GFZ
Helmholtz Centre
Potsdam

Helmholtz Centre Potsdam
GFZ German Research Centre
for Geosciences

Markus J. Schwab, Mirosław Błaszkiewicz,
Thomas Raab, Martin Wilmking,
Achim Brauer (eds.)

ICLEA Final Symposium 2017

Climate Change, Human Impact and Landscape Evolution in the Southern Baltic Lowlands

Abstract Volume & Excursion Guide

Scientific Technical Report STR17/03

www.gfz-potsdam.de

Helmholtz Association

Recommended citation:

Schwab, M. J., Błaszkiewicz, M., Raab, T., Wilmking, M., Brauer, A. (Eds.) (2017),
ICLEA Final Symposium 2017: Abstract Volume & Excursion Guide.
Scientific Technical Report STR 17/03, GFZ German Research Centre for Geosciences.
DOI: http://doi.org/10.2312/GFZ.b103-17037.

Imprint

Helmholtz Centre Potsdam
GFZ German Research Centre
for Geosciences

Telegrafenberg
D-14473 Potsdam

Published in Potsdam, Germany
June 2017

ISSN 2190-7110

DOI: http://doi.org/10.2312/GFZ.b103-17037
URN: urn:nbn:de:kobv:b103-17037

This work is published in the GFZ series
Scientific Technical Report (STR)
and electronically available at GFZ website
www.gfz-potsdam.de

Markus J. Schwab, Mirosław Błaszkiewicz,
Thomas Raab, Martin Wilmking,
Achim Brauer (eds.)

ICLEA Final Symposium 2017

Climate Change, Human Impact and Landscape Evolution in the Southern Baltic Lowlands

Abstract Volume & Excursion Guide

Scientific Technical Report STR17/03

Virtual Institute of Integrated Climate and Landscape Evolution Analyses

-ICLEA-

A Virtual Institute within the Helmholtz Association

Deutsches GeoForschungsZentrum GFZ
Ernst Moritz Arndt Universität Greifswald
Polnische Akademie der Wissenschaften (PAN)
Brandenburgische Technische Universität Cottbus (BTU)

ICLEA Final Symposium 2017

Climate Change, Human Impact and Landscape Evolution in the Southern Baltic Lowlands

Abstract Volume & Excursion Guide

Edited by
Markus J. Schwab, Mirosław Błaszkiewicz, Thomas Raab, Martin Wilmking, Achim Brauer

7-9 June 2017, GFZ German Research Centre for Geosciences, Potsdam, Germany

Table of Contents

ICLEA after five varves –

5 years of interdisciplinary German – Polish research

We cordially welcome the ICLEA community and the scientific advisory board as well as our external partners and guests to the final symposium of our Virtual Institute ICLEA (*Integrated Climate and Landscape Evolution Analyses*) in Potsdam, the same place where we have started our collaboration five years ago. Five years is a long period for project-funded research and non-palaeolimnologists may forgive me when I first recognize the fact that additional five varves (annual laminations) and tree rings have accumulated during the project time extending our geoarchives of landscape change. Obviously, our Virtual Institute is documented not only in our publications, PhD theses, outreach and other commonly used evaluation parameters, but and measurable also in our archives. These five varves and tree rings probably are amongst the best studied and we made significant steps forward in understanding how they formed and how environmental signals were transferred into our archives. We are gathering here to present our main achievements and share them with the scientific community, but we also want to make use of this symposium to address new challenges for our research and discuss novel approaches and methodologies to address these challenges.

The overarching goal of landscape research is to better anticipate regional impacts of future global change in order to create intelligent adaptation strategies to limit negative consequences of such changes for our societies. However, landscape evolution is the result of complex coupled processes working at different time scales. Anticipating future developments will not be possible by simply extrapolating trends of the last few decades because of inherent legacies and landscape controlling mechanisms that function on longer time scales. We, therefore, need to integrate information from the past in a holistic and time-integrating approach. However, the concept of learning from the past is easy to be claimed, but its realization in detail still is challenging and not straightforward to accomplish. Information from the past is recorded in different natural archives including lake sediments, tree rings, palaeo-soils and geomorphological features. All of them have been intensively studied within ICLEA. Each of these archives contains information about different environmental aspects at different time resolution and a comprehensive picture about past landscape evolution and its driving mechanisms requires integrating all available information. In order to be able to achieve this, we first must know how to reliably interpret the data from our archives in terms of past changes.

Proxy data are for geoscientists like hieroglyphs for archaeologists for which a dictionary is lacking. In ICLEA, we implemented the task to write such dictionary for our proxy data. We made good progress in proxy calibration as this will be presented during our symposium. However, we also disclose some fundamental challenges that we would like to discuss in the next three days. One of these concerns is the question of a non-analogue situation today due to the comprehensive human impact that might not allow the transfer of observed climate – environment – proxy relations far back in time. Even without human impact the proxy responses to climate and environment changes might not always have been stationary on longer time scales. In ICLEA, we have demonstrated that

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

we have to seriously consider these limitations in proxy calibration, but that there are potential solutions to deal with these limitations in a differentiated way and, ultimately, minimize them.

In ICLEA our focus particularly is on terrestrial geoarchives, because they have the advantage over marine and ice cores of providing regional climate and environment information directly from the human habitat. As above mentioned, this advantage implies the problem of possible direct and indirect human-induced modifications of proxy signals in these archives. On the other hand, this can provide new windows into the way of life of pre-historic societies which did not deliver written documents. Exploiting our archives with respect to past human activities is a major chance especially for palaeolimnological research in the next decade. The main objective and challenge will be to disentangle human and natural signals in these archives. In contrast to the progress in climate and environment proxies, we still have a great demand in developing proxies for human activity like, for example, specific fire proxies and human biomarkers. Some first attempts in this direction have been developed in ICLEA that will presented during this symposium.

We will present our main results in an integrated way according to the main themes of relevance rather than following the classical work package ordering based on archive type and disciplines. The order of sessions partly reflect the development of research in ICLEA during course of the project. We started with a strong focus on deciphering the role of natural variability and its driving mechanisms and increasingly considered man – climate – environment interactions as a highly intriguing topic not only for the industrialization period, but even for the prehistoric period.

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial
Session 2: Recent change and instrumental observations
Session 3: Integrating time-scales and regional synchronization
Session 4: Man - climate - environment interactions

We have invited international experts for each of these themes to give keynote presentations and further stimulate our discussions. In addition to the oral sessions, we give room for detailed discussions in front of posters as in our previous workshops. Finally, we keep a good ICLEA tradition to discuss new results not only in lecture rooms but also in front of the objects that we are investigating, *i.e.* during field excursions. Some of you may remember that one of our previous field excursions led us to Lake Gościąż in central Poland, a European key site for reconstructing past climate and environmental change. Our Polish colleagues were successful in achieving funding from the Polish Science Foundation for a new project on this important archive, demonstrating the usefulness of such field excursions for giving birth to new ideas. The field excursion during this symposium, organized by our colleagues from BTU Cottbus, will bring us to Lusatia, a region known not only for its long human impact, but it is also one of the landscapes in Germany with the strongest human interference due to intensive lignite mining. Thereby, we want to emphasize the particular role of human – nature interferences. One of the key results in ICLEA was the evidence that in this region earlier human impact, as documented by hundreds or even thousands of charcoal kilns, was much more intensive than thought before.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Coming back to the beginning of ICLEA five years ago, the problem of a major lake level decline in many northeastern German lakes was a specific motivation for our research. At that time it was claimed in media that this phenomenon is caused by global warming and only the beginning of a dramatic and unprecedented regional aridification. During the duration time of ICLEA we first observed a period of rapid lake level increase and subsequently another decline. We learned that lake level variations are not simply following a general trend but appear to be highly dynamic. Their driving mechanisms are more complex than assumed including not only climate but also natural and anthropogenic vegetation changes and man-made hydrological change since several centuries. From our lake and tree archives we further learned that the amplitude of changes observed in the last decades are still below the amplitudes at Holocene time scales reaching several meters depending on the location. Obviously, this is not an argument to underestimate present-day change, but rather is a strong sign for the variability and sensitivity of our landscape environment and that stability is a matter of time scales.

This is only one concrete example how ICLEA research lead to a more differentiated view on landscape evolution and shed light on the complexity of underlying mechanisms and processes. More examples will be shown during this symposium. Besides these scientific results, many of them already published in international peer-review journals, some still in review or preparation, ICLEA was a nucleus for a number of follow-up projects that have been successfully initiated. Not all of them can be named here, but some will be presented during the symposium. One is the new project on Lake Gościąż by our Polish colleagues. New cores have been taken by a joint Polish-German team and are presently investigated with cutting-edge methodologies. Recently, 'BaltRap' (The Baltic Sea and its southern Lowlands: proxy – environment interactions in times of Rapid change) lead by IOW (Leibniz Institute for Baltic Sea Research) in Warnemünde received funding by the Leibniz Association. Here, we will investigate the interrelationship of landscape evolution using ICLEA results with the development of the Baltic Sea in postglacial times. Last, but not least, a series of new projects got funding by the German Science Foundation (DFG) and German Federal Environment Foundation (DBU) related to spatial and temporal dimension of historical charcoal burning in Lusatia and its implication for cultural landscape development.

However, the final appraisal of ICLEA should not only be based on publications and follow-up projects. We made very good progress in bringing together different disciplines with their own specific languages and research philosophies. This value cannot be estimated high enough since it requires a clear objective and endurance to understand each other and, thereby, learn from each other. We made a step forward, but there is still some way to go. In general, networking and collaboration was the solid base for our research but, in addition, personal friendships grew in ICLEA that will continue beyond this research program. A large number of students and early career scientist got the chance to work in a fascinating and inspiring team forming a truly *Virtual Institute*. At this point, it needs to be emphasized that we overcame the traditional view on landscapes based on state borders. We established a trustful bilateral collaboration based on mutual scientific interests and attitudes with our partners from the Polish Academy of Sciences that will be further continued and even extended beyond the program.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The ICLEA community wants to express special thanks to our scientific advisory board! We very much appreciated your support, suggestions and discussions that helped to further develop our research and adjust our goals during the course of the project. Finally, we are grateful to the Helmholtz Association for the generous funding! Without that, our scientific achievements and personal experiences and appreciations would not have become possible.

We thank all participants for their inspiring contributions and results summarized in this Volume and wish all of us fruitful discussions, new ideas and collaborations, an exciting day in the field and an enjoyable time in Potsdam.

Achim Brauer (speaker), Markus Schwab (coordination)

Chapter I: Program Overview

Venue: GFZ German Research Centre for Geosciences
Address: Albert Einstein Science Park, Telegrafenberg Haus H, Potsdam (Germany)

Wednesday June 7, 2017	
8:15 – 8:45 **Registration, Poster Installation & Welcome Coffee**	
8:45 – 9:00	**Opening / Welcome Notes**
8:45 – 8:50	**Michael Kühn** Chair of the Scientific Council, GFZ German Research Centre for Geosciences
8:50 – 8:55	**Paweł Rowiński** Vice-President, Polish Academy of Sciences (PAS)
8:55 – 9:00	**Marek Degórski** Director Institute of Geography and Spatial Organization (IGSO PAS)
9:00 – 9:05	**Andreas Schulze** Initiative and Networking Fund, Helmholtz Association
9:05 – 9:50	**Introduction Talks**
9:05 – 9:30	**Achim Brauer** (GFZ) ICLEA after five varves - 5 years of interdisciplinary German – Polish research
9:30 – 9:50	**Mirosław Błaszkiewicz** (IGSO PAS) Timing of formation of postglacial lakes within the limit of the Last Glaciation in Poland
9:50 –10:40	**Session 1 *Abrupt and High Frequency Climate Variability since the Last Glaciation***
9:50 – 10:15	**Kurt Nicolussi** (University Innsbruck) Tree-ring analyses on Holocene climate variability in the Alps – from single years to millennia
10:15 – 10:40	**Celia Martín-Puertas** (Royal Holloway, University of London) Learning what varves tell us about Abrupt Holocene Climate Change
10:40 – 11:00 **Coffee Break**	
11:00 – 11:20	**Leszek Marks** (University of Warszaw) Last Glacial maximum and the following deglaciation in central Europe
11:20 – 11:40	**Nadine Dräger & Florian Ott** (GFZ / MPI SHH Jena) A high resolution comparison of varve formation and preservation in Lakes Tiefer See and J. Czechowskie during the last 6000 years
11:40 – 13:00	**Poster Session for all Sessions** Authors **Session 1** and **Session 2** in Attendance
13:00 - 14:00 **Lunch break**	
14:00 – 15:50	**Session 2 *Recent change and instrumental observations***
14:00 – 14:25	**Mark Gessner** (IGB Leibniz-Institute of Freshwater Ecology and Inland Fisheries) Observational and experimental evidence revealing strong protracted consequences of extreme weather events on lakes
14:25 – 15:00	**Nadav Lensky** (GSI Geological Survey of Israel) Seasonality and depth control over halite deposition: In situ observations from the Dead Sea and implications to the formation of thick halite sequences
15:00 – 15:20	**Iris Heine** (GFZ) Monitoring of Calcite Precipitation in Hardwater Lakes with Multi-Spectral Remote Sensing Archives
15:20 – 15:40	**Theresa Blume & Ingo Heinrich** (GFZ) Soil water availability, tree water uptake and information storage in tree rings

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

15:40 – 16:30	**Poster Session for all Sessions** Authors **Session 3** and **Session 4** in Attendance
16:30 – 18:20	**Session 3: *Integrating time-scales and regional synchronisation***
16:30 – 16:55	**Wojciech Tylmann** (University of Gdańsk) Combining limnology and paleolimnology to track the variability of modern and past sediment fluxes: A perspective from varved lakes in northeastern Poland
16:55 – 17:20	**Jérôme Kaiser** (Leibniz Institute for Baltic Sea Research – Warnemünde IOW) BaltRap – from environmental monitoring to paleoenvironmental reconstructions
17:20 – 17:40	**Sabine Wulf** (GFZ / University Heidelberg) Tephrostratigraphies of ICLEA varved lake records from NE Germany and N central Poland: an overview
17:40 – 18:00	**Florian Ott & Nadine Dräger** (MPI SHH Jena / GFZ) Deciphering varve formation in Lake Czechowskie (N Poland) and Lake Tiefer See (NE Germany) through comprehensive lake monitoring
18:00 – 18:20	**Allan Buras** (TU München) Tree-growth divergence – a global phenomenon?
19:15 – 22:30	**Ice breaker**
Thursday June 8, 2017	
8:00-22:00	**Day Excursion by Bus to Lusatia including Evening Get Together in the Spreewald region**
Friday June 9, 2017	
8:15 – 8:30	**Registration & Welcome Coffee**
8:30 – 8:50	**Leszek Starkel** (Polish Academy of Sciences) The Polish – German cooperation in the palaeogeographic studies of the Holocene
8:50 – 10:30	**Poster Session for all Sessions** **Authors in attendance**
10:30 – 13:30	**Session 4: *Man - environment - climate interactions***
10:30 – 11:10	**Philip Gibbard** (University of Cambridge) The Anthropocene; a formal stratigraphical unit, an informal concept, or an interval of Holocene time?
11:10 – 11:35	**Jed O. Kaplan** (University of Lausanne) Modeling global human-environment interactions in the preindustrial late Quaternary: What have we learned and what is the way forward?
11:35 – 11:55	**Martin Theuerkauf** (University Greifswald) Holocene Lake level fluctuations in NE-Germany – disentangling climate, vegetation and human drivers
11:55 – 12:15	**Anna Schneider** (BTU Cottbus-Senftenberg) Assessing the legacies of historical charcoal production in Brandenburg
12:15 – 12:35	**Elisabeth Dietze** (GFZ) Holocene fire regimes of the central European lowlands: man-vegetation-climate feedbacks
12:35 – 12:55	**Michał Słowiński** (IGSO PAS) Impact of Medieval road construction on landscape transformation during the last 700 years in N Poland
12:55 – 13:30	**Final discussion & Closing remarks**
13:30	**Lunch**

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Chapter II: Abstracts - *Overview in alphabetical order*

Overview in alphabetical order		
47	**Dietze, Elisabeth**; Słowiński, Michał; Zawiska, Izabela; Veh, Georg & Brauer, Achim: Holocene lake level changes related to multiple driving mechanisms at Fürstenseer See, NE-Germany	Poster
49	**Dietze, Elisabeth**; Theuerkauf, Martin; Słowiński, Michał; Brauer, Achim & the CEL fire synthesis team: Holocene fire regimes of the central European lowlands: man-vegetation-climate feedbacks	Oral
52	**Dobrowolski, Radosław**; Bałaga, Krystyna; Buczek, Alicja; Alexandrowicz, Witold Paweł; Mazurek, Małgorzata; Hałas, Stanisław & Piotrowska, Natalia: Holocene climate fluctuations of Volhynia Upland recorded in spring-fed fen deposits from Komarów site (SE Poland)	Poster
53	**Dobrowolski, Radosław**; Rodzik, Jan; Mroczek, Przemysław; Zagórski, Piotr; Pidek, Irena Agnieszka; Bałaga, Krystyna; Wołoszyn, Marcin; Dzieńkowski, Tomasz & Hajdas, Irka: Climate changes and human impact during middle ages in the light of geoarchaeological studies in the Hrubieszów Basin (Volhynia Upland, eastern Poland)	Poster
54	**Dräger, Nadine**; Ott, Florian; Wulf, Sabine; Theuerkauf, Martin; Obremska, Milena; Plessen, Birgit; Słowiński, Michał; Tjallingii, Rik; Kienel, Ulrike; Błaskiewicz, Mirosław & Brauer, Achim: A high resolution comparison of varve formation and preservation in Lakes Tiefer See and J. Czechowskie during the last 6000 years	Oral
57	**Dräger, Nadine**; Theuerkauf, Martin; Szeroczyńska, Krystyna; Wulf, Sabine; Tjallingii, Rik; Plessen, Birgit; Kienel, Ulrike & Brauer, Achim: Varve microfacies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany)	Poster
61	**Dreibrodt, Stefan**; Bork, Hans-Rudolf; Feeser, Ingo & Dörfler, Walter: Sediment transfer in German lowland lake catchments - Erosion on the slopes and input into annually laminated lake sediments	Poster
61	**Dreibrodt, Stefan**; Feeser, Ingo & Dörfler, Walter: Disentangling paleolimnological processes by microfacies analysis of synchronously deposited annually lake sediments in northern central Europe	Poster
62	Dreibrodt, Janek; Hopp, Luisa; Germer, Sonja; Morgner, Markus; Güntner, Andreas & **Blume, Theresa**: Throughfall and stemflow dynamics of different tree species and their implications for groundwater recharge	Poster
64	**Feeser, Ingo**; Dreibrodt, Stefan & Dörfler, Walter: Climate or men? Identifying drivers of multidecadal to centennial palaeolimnological processes during the Neolithic in Northern Germany	Poster
65	**Fojutowski, Michał**; Gierszewski, Piotr; Brykała, Dariusz; Bartczak, Arkadiusz; Plessen, Birgit; Pinkerneil, Sylvia; Błaszkiewicz, Mirosław & Brauer, Achim: Environmental monitoring of the catchment area in the context of contemporary sedimentation in Lake Gościąż, Poland	Poster
67	Giling, Darren P.; Kasprzak, Peter; Nejstgaard, Jens C.; Berger, Stella A.; Shatwell, Tom; Gonsiorczyk, Thomas; Kirillin, Georgiy; Grossart, Hans-Peter; Selmeczy, Géza; Padisák, Judit; Engelhardt, Christof; Penske, Armin; Lentz, Maren; Casper, Peter; Sareyka, Jörg & **Gessner, Mark O.**: Observational and experimental evidence revealing strong protracted consequences of extreme weather events on lakes	Oral

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overview in alphabetical order		
70	**Gibbard, Philip**: The Anthropocene; a formal stratigraphical unit, an informal concept, or an interval of Holocene time?	Oral
71	**Gierszewski, Piotr**; Brykała, Dariusz; Kaszubski, Michał & Fojutowski, Michał: Paleolakes as an element modifying water and matter circulation in young-glacial river-lake systems	Poster
74	**Heine, Iris**; Brauer, Achim; Heim, Birgit; Itzerott, Sibylle; Kasprzak, Peter; Kienel, Ulrike & Kleinschmit, Birgit: Monitoring of Calcite Precipitation in Hardwater Lakes with Multi-Spectral Remote Sensing Archives	Oral
77	**Helle, Gerhard**; Freund, Mandy; Heinrich, Ingo; Balting, Daniel; Navabzadeh, Nadia & Riedel, Frank: The ICLEA region in the context of a 400-year spatial reconstruction of European summer drought from a network of tree ring stable isotopes	Poster
79	**Hirsch, Florian**; Schneider, Anna; Raab, Alexandra; Raab, Thomas; Ouimet, Will & Dethier, David: Late Holocene biochar enrichment in soils - implications of an anthropogenic legacy for ecosystems	Poster
82	**Hoelzmann, Philipp**; Brauer, Achim; Dräger, Nadine; Kienel, Ulrike & Ott, Florian: Heavy Metal Enrichment in laminated lake sediments from N-Germany and N-Poland: Geochemical background and enrichment history	Poster
84	**Kaiser, Jérôme**; Arz, Helge; Dellwig, Olaf & BaltRap members: BaltRap – from environmental monitoring to paleoenvironmental reconstructions	Oral
86	**Kaiser, Knut**; Keller, Nora; Brande, Arthur; Dalitz, Stefan; Hensel, Nicola; Heußner, Karl-Uwe; Kappler, Christoph; Michas, Uwe; Müller, Joachim; Schwalbe, Grit; Weiße, Roland & Bens, Oliver: A large-scale medieval dam-lake cascade in central Europe: water level dynamics of river Havel, Berlin-Brandenburg region, Germany	Poster
89	**Kaiser, Knut**; Oldorff, Silke; Breitbach, Carsten; Kappler, Christoph; Theuerkauf, Martin; Scharnweber, Tobias; Schult, Manuela; Küster, Mathias; Engelhardt, Christof; Heinrich, Ingo; Hupfer, Michael & Bens, Oliver: A submerged pine forest from the early Holocene in the Mecklenburg Lake District, NE Germany	Poster
91	**Kaplan, Jed O**.: Modeling global human-environment interactions in the preindustrial late Quaternary: What have we learned and what is the way forward?	Oral
93	**Kappler, Christoph**; Kaiser, Knut; Tanski, Phillipp; Klos, Friederike; Fülling, Alexander; Mrotzek, Almut; Sommer, Michael & Bens, Oliver: Stratigraphy and age of colluvial deposits indicating Late Holocene soil erosion in northeastern Germany	Poster
94	**Kienel, Ulrike**; Lami, Andrea; Plessen, Birgit; Kirillin, Georgiy; Brademann, Brian; Pinkerneil, Sylvia; Gerli, Stefano; Dräger, Nadine & Brauer, Achim: Summer blooms of cyanobacteria in Lake Tiefer See (NE Germany) - Increased nutrient input can overrule shallow lake mixing as driver	Poster
97	**Kienel, Ulrike**; Plessen, Birgit; Brademann, Brian; Pinkerneil, Sylvia & Brauer, Achim: d^{18}O signatures of calcite precipitation in Lake Tiefer See (NE Germany) – from monitoring to understanding the subannually laminated deposition since 1924 AD	Poster

Overview in alphabetical order		
101	**Kramkowski, Mateusz**; Filbrandt-Czaja, Anna; Kotrys, Bartosz; Zawisza, Edyta; Rzodkiewicz, Monika; Słowiński, Michał; Tjallingii, Rik; Błaszkiewicz, Mirosław & Brauer, Achim: Early Holocene in light of the high-resolution multiproxy analyses - laminated sediments of Lake Jelonek, Poland	Poster
103	Jonczak, Jerzy; Florek, Wacław; **Kruczkowska, Bogusława**; Niska, Monika & Gadziszewska, Joanna: Multi-proxy reconstruction of the polycyclic pedocomplex development in Dębina, central Polish Baltic coast	Poster
105	**Lauterbach, Stefan**; Andersen, Nils; Erlenkeuser, Helmut; Danielopol, Dan L.; Namiotko, Tadeusz; Hüls, Matthias; Belmecheri, Soumaya; Nantke, Carla; Meyer, Hanno; Chapligin, Bernhard; von Grafenstein, Uli & Brauer, Achim: Excess warming in Central Europe after the 8.2 ka cold event: evidence from a varve-dated ostracod δ18O record from Mondsee (Austria)	Poster
108	**Lauterbach, Stefan**; Strasser, Michael; Tjallingii, Rik; Spötl, Christoph & Brauer, Achim: Historic mass movements recorded in the sediments of Hallstätter See (Upper Austria) – natural hazards at a UNESCO World Cultural Heritage Site	Poster
110	**Lensky, Nadav**; Sirota, Ido; Arnon, Ali & Enzel, Yehouda: Seasonality and depth control over halite deposition: In situ observations from the Dead Sea and implications to the formation of thick halite sequences	Oral
113	**Lindemann, Christin**; Ott, Florian; Tjallingii, Rik; Słowiński, Michał; Schwab, Markus J.; Błaszkiewicz, Mirosław & Brauer, Achim: Climate and environment changes between 250 B.C. and 1000 A.D. reconstructed from varved lake sediments of Lake Głęboczek (N Poland)	Poster
116	**Lischeid, Gunnar**; Kaiser, Knut; Stüve, Peter; Nützmann, Gunnar; Steidl, Jörg & Dannowski, Ralf: Spurious water level trends out of nothing? Taking the Hurst phenomenon seriously	Poster
118	**Marks, Leszek**: Last Glacial maximum and the following deglaciation in central Europe	Oral
121	**Martín-Puertas, Celia**; Brauer, Achim; Tjallingii, Rik; Muscheler, Raimund; Blockley, Simon; Palmer, Adrian; Schwab, Markus J. & Giralt, Santiago: Learning what varves tell us about Abrupt Holocene Climate Change	Oral
124	**Nicolussi, Kurt**; Leuenberger, Markus; Schlüchter, Christian; Weber, Georg & Ziehmer, Malin M.: Tree-ring analyses on Holocene climate variability in the Alps – from single years to millennia	Oral
127	**Noryśkiewicz, Agnieszka M.;** Kordowski, Jarosław; Kramkowski, Mateusz; Obremska, Milena; Rzodkiewicz, Monika; Słowiński, Michał; Zawiska, Izabela; Błaszkiewicz, Mirosław & Brauer, Achim: Helianthemum pollen representation in the area of Czechowo during the Younger Dryas – A climate or an environmental indicator?	Poster
130	**Obremska, Milena**; Ott, Florian; Słowiński, Michał; Błaszkiewicz, Mirosław & Brauer, Achim: From the Bronze Age to the Migration Period – human activity recorded in the lake sediments of Lake Czechowskie (Northern Poland)	Poster
132	**Ott, Florian**; Dräger, Nadine; Brykała, Dariusz; Kienel, Ulrike; Gierszewski, Piotr; Plessen, Birgit; Schwab, Markus J.; Brademann, Brian; Pinkerneil, Sylvia; Słowiński, Michał; Błaskiewicz, Mirosław & Brauer, Achim: Deciphering varve formation in Lake Czechowskie (N Poland) and Lake Tiefer See (NE Germany) through comprehensive lake monitoring	Oral

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overview in alphabetical order		
135	**Pinkerneil, Sylvia**; Kienel, Ulrike; Brademann, Brian; Dräger, Nadine; Plessen, Birgit & Brauer, Achim: Monitoring water isotope composition of Lake Tiefer See Klocksin (NE Germany) to understand our paleoclimate archives	Poster
137	**Plessen, Birgit**; Kienel, Ulrike; Dräger, Nadine; Pinkerneil, Sylvia & Brauer, Achim: The history of increasing anthropogenic nutrient loading into the Lake Tiefer See (NE Germany) - from monitoring to the sedimentary record	Poster
139	**Płóciennik, Mateusz**; Kotrys, Bartosz; Heiri, Oliver; Antczak, Olga; Jakiel, Aleksandra; Baradyn, Daria; Tosik, Kamila & Brooks, Stephen: Chironomidae-inferred summer temperatures from Poland based on the Swiss-Norwegian & Swiss-Norwegian-Polish training set	Poster
142	**Ramisch, Arne**; Tjallingii, Rik; Hartmann, Kai & Brauer, Achim: Dynamical proxy responses to climate transitions recorded in lake sediments on the Tibetan Plateau	Poster
144	**Rzodkiewicz, Monika**; Hübener, Thomas; Ott, Florian; Zawiska, Izabela; Brykała, Dariusz; Gierszewski, Piotr; Kaszubski, Michał; Obremska, Milena; Słowiński, Michał; Błaszkiewicz, Mirosław & Brauer, Achim: Changes in the trophic state of Czechowskie Lake during the last 2000 years	Poster
148	**Scharnweber, Tobias**; Heußner, Karl-Uwe; Smiljanic, Marko; Heinrich, Ingo; Buras, Allan & Wilmking, Martin: How global change fakes medieval hydroclimate- a tree ring based millennium long drought reconstruction for NE-Europe	Poster
150	**Schneider, Anna**; Hirsch, Florian; Raab, Alexandra & Raab, Thomas: Dye tracer visualization of infiltration patterns in soils on historic charcoal hearth sites	Poster
152	**Schneider, Anna**; Hirsch, Florian; Wechler, Klaus-Peter; Raab, Alexandra & Raab, Thomas: Mapping a palaeosurface and archaeological site location in an anthropogenic drift sand area	Poster
155	**Schneider, Anna**; Raab, Alexandra; Hirsch, Florian; Bonhage, Alexander & Raab, Thomas: Assessing the legacies of historical charcoal production in Brandenburg	Oral
157	**Słowiński, Michał**; Ott, Florian; Obremska, Milena; Theuerkauf, Martin; Czaja, Roman; Wulf, Sabine; Błaszkiewicz, Mirosław & Brauer, Achim: Impact of Medieval road construction on landscape transformation during the last 700 years in N Poland	Oral
159	**Stivrins, Normunds**; Aakala, Tuomas; Kuuluvainen, Timo; Pasanen, Leena; Ilvonen, Liisa; Holmström, Lasse & Seppä, Heikki: Long-term boreal forest dynamics and disturbances: a multi-proxy approach	Poster
161	Tecklenburg, Christina & **Blume, Theresa**: Spatial patterns of lacustrine groundwater discharge: can we predict them and do they vary in time?	Poster
163	**Theuerkauf, Martin**; Couwenberg, John & Mrotzek, Almut: DISQOVER the landcover - New tools in quantitative vegetation reconstruction	Poster
166	**Theuerkauf, Martin**; Dietze, Elisabeth; Küster, Matthias; Lorenz, Sebastian; Schult, Manuela & Blume; Theresa: Holocene Lake level fluctuations in NE-Germany – disentangling climate, vegetation and human drivers	Oral
169	**Tjallingii, Rik**; Martín-Puertas, Celia & Brauer, Achim: Multivariate analyses of XRF core scanning and µ-XRF data for Early Holocene environmental reconstructions of lake Meerfelder Maar	Poster

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overview in alphabetical order		
171	**Tylmann, Wojciech**: Combining limnology and paleolimnology to track the variability of modern and past sediment fluxes: A perspective from varved lakes in northeastern Poland	Oral
173	**Tyszkowski, Sebastian**; Słowiński, Michał; Obremska, Milena; Theuerkauf, Martin; Ott, Florian; Dietze, Elisabeth; Kaczmarek, Halina & Brauer, Achim: 800 years of forest transformation in northern Poland recorded in varved lake sediments and cartographical data	Poster
175	**Unger, Andrea;** Dräger, Nadine; Ott, Florian; Sips, Mike; Lehmann, Dirk J.: Visual Analytics for microfacies data from lake sediment cores	Poster
178	Wilke, Henriette; Thoss, Heiko; Güntner, Andreas & **Blume, Theresa:** Hydrogeology of a young moraine area in NE Germany: Subsurface structures and groundwater modeling	Poster
180	**Wulf, Sabine**; Dräger, Nadine; Ott, Florian; Serb, Johanna; Appelt, Oona; Słowiński, Michał; Błaszkiewicz, Mirosław; Schwab, Markus J. & Brauer, Achim: Tephrostratigraphies of ICLEA varved lake records from NE Germany and N central Poland: an overview	Oral

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Abstracts - *Overview in thematic order*

Page		
	Introduction talks	
29	**Błaszkiewicz, Mirosław**; Brauer, Achim; Kordowski, Jarosław & Słowiński, Michał: Timing of formation of postglacial lakes within the limit of the Last Glaciation in Poland	Oral
3	**Brauer, Achim:** ICLEA after five varves - 5 years of interdisciplinary German – Polish research	Oral

	Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial	
22	**Aichner, Bernhard**; Słowiński, Michał; Ott, Florian; Noryśkiewicz, Agnieszka M.; Brauer, Achim & Sachse, Dirk: Ecological and hydrological changes in Northern Poland during the Younger Dryas from the organic geochemical perspective	Poster
24	**Balanzategui, Daniel**; Heußner, Karl-Uwe; Wazny, Tomasz; Helle, Gerdhard; Peters, Richard L.; Hurley, Alexander & Heinrich, Ingo: Wood anatomical from lowland European oak and Scots pine for climate reconstruction	Poster
52	**Dobrowolski, Radosław**; Bałaga, Krystyna; Buczek, Alicja; Alexandrowicz, Witold Paweł; Mazurek, Małgorzata; Hałas, Stanisław & Piotrowska, Natalia: Holocene climate fluctuations of Volhynia Upland recorded in spring-fed fen deposits from Komarów site (SE Poland)	Poster
54	**Dräger, Nadine**; Ott, Florian; Wulf, Sabine; Theuerkauf, Martin; Obremska, Milena; Plessen, Birgit; Słowiński, Michał; Tjallingii, Rik; Kienel, Ulrike; Błaskiewicz, Mirosław & Brauer, Achim: A high resolution comparison of varve formation and preservation in Lakes Tiefer See and J. Czechowskie during the last 6000 years	Oral
61	**Dreibrodt, Stefan**; Feeser, Ingo & Dörfler, Walter: Disentangling paleolimnological processes by microfacies analysis of synchronously deposited annually lake sediments in northern central Europe	Poster
77	**Helle, Gerhard**; Freund, Mandy; Heinrich, Ingo; Balting, Daniel; Navabzadeh, Nadia & Riedel, Frank: The ICLEA region in the context of a 400-year spatial reconstruction of European summer drought from a network of tree ring stable isotopes	Poster
105	**Lauterbach, Stefan**; Andersen, Nils; Erlenkeuser, Helmut; Danielopol, Dan L.; Namiotko, Tadeusz; Hüls, Matthias; Belmecheri, Soumaya; Nantke, Carla; Meyer, Hanno; Chapligin, Bernhard; von Grafenstein, Uli & Brauer, Achim: Excess warming in Central Europe after the 8.2 ka cold event: evidence from a varve-dated ostracod $\delta^{18}O$ record from Mondsee (Austria)	Poster

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overview in thematic order		
113	**Lindemann, Christin**; Ott, Florian; Tjallingii, Rik; Słowiński, Michał; Schwab, Markus J.; Błaszkiewicz, Mirosław & Brauer, Achim: Climate and environment changes between 250 B.C. and 1000 A.D. reconstructed from varved lake sediments of Lake Głęboczek (N Poland)	Poster
118	**Marks, Leszek**: Last Glacial maximum and the following deglaciation in central Europe	Oral
121	**Martín-Puertas, Celia**; Brauer, Achim; Tjallingii, Rik; Muscheler, Raimund; Blockley, Simon; Palmer, Adrian; Schwab, Markus J. & Giralt, Santiago: Learning what varves tell us about Abrupt Holocene Climate Change	Oral
124	**Nicolussi, Kurt**; Leuenberger, Markus; Schlüchter, Christian; Weber, Georg & Ziehmer, Malin M.: Tree-ring analyses on Holocene climate variability in the Alps – from single years to millennia	Oral
127	**Noryśkiewicz, Agnieszka M.;** Kordowski, Jarosław; Kramkowski, Mateusz; Obremska, Milena; Rzodkiewicz, Monika; Słowiński, Michał; Zawiska, Izabela; Błaszkiewicz, Mirosław & Brauer, Achim: Helianthemum pollen representation in the area of Czechowo during the Younger Dryas – A climate or an environmental indicator?	Poster
139	**Płóciennik, Mateusz**; Kotrys, Bartosz; Heiri, Oliver; Antczak, Olga; Jakiel, Aleksandra; Baradyn, Daria; Tosik, Kamila & Brooks, Stephen: Chironomidae-inferred summer temperatures from Poland based on the Swiss-Norwegian & Swiss-Norwegian-Polish training set	Poster
169	**Tjallingii, Rik**; Martín-Puertas, Celia & Brauer, Achim: Multivariate analyses of XRF core scanning and µ-XRF data for Early Holocene environmental reconstructions of lake Meerfelder Maar	Poster
175	**Unger, Andrea;** Dräger, Nadine; Ott, Florian; Sips, Mike; Lehmann, Dirk J.: Visual Analytics for microfacies data from lake sediment cores	Poster

Session 2: Recent change and instrumental observations		
25	**Balanzategui, Daniel**; Knorr, Antje; Heußner, Karl Uwe; Wazny, Tomasz; Beck, Wolfgang; Słowiński, Michał; Helle, Gerdhard; Buras, Allan; Wilmking, Martin; van der Maaten, Ernst; Scharnweber, Tobias; Dorado Liñán, Isabel & Heinrich, Ingo: 810-year history of cold-season temperature variability for northern Poland	Poster
26	**Bartczak, Arkadiusz** & Krzemiński, Michał: The Application of the Standardised Precipitation Index (SPI) for the Evaluation of Intensity of Dry and Wet Periods in the Vicinity of Czechowskie Lake	Poster
32	**Blume, Theresa**; Heidbüchel, Ingo; Simard, Sonia; Güntner, Andreas **& Heinrich, Ingo**: Dry spells and the tree-water feedback loop: how does limited water availability affect different tree species and how do different tree species affect water availability?	Oral
34	**Blume, Theresa**; Heidbüchel, Ingo; Simard, Sonia; Güntner, Andreas & Heinrich, Ingo: Soil water availability, tree water uptake and information storage in tree rings	Poster
62	Dreibrodt, Janek; Hopp, Luisa; Germer, Sonja; Morgner, Markus; Güntner, Andreas & **Blume, Theresa**: Throughfall and stemflow dynamics of different tree species and their implications for groundwater recharge	Poster

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

	Overview in thematic order	
65	**Fojutowski, Michał**; Gierszewski, Piotr; Brykała, Dariusz; Bartczak, Arkadiusz; Plessen, Birgit; Pinkerneil, Sylvia; Błaszkiewicz, Mirosław & Brauer, Achim: Environmental monitoring of the catchment area in the context of contemporary sedimentation in Lake Gościąż, Poland	Poster
67	Giling, Darren P.; Kasprzak, Peter; Nejstgaard, Jens C.; Berger, Stella A.; Shatwell, Tom; Gonsiorczyk, Thomas; Kirillin, Georgiy; Grossart, Hans-Peter; Selmeczy, Géza; Padisák, Judit; Engelhardt, Christof; Penske, Armin; Lentz, Maren; Casper, Peter; Sareyka, Jörg & **Gessner, Mark O.**: Observational and experimental evidence revealing strong protracted consequences of extreme weather events on lakes	Oral
71	**Gierszewski, Piotr**; Brykała, Dariusz; Kaszubski, Michał & Fojutowski, Michał: Paleolakes as an element modifying water and matter circulation in young-glacial river-lake systems	Poster
74	**Heine, Iris**; Brauer, Achim; Heim, Birgit; Itzerott, Sibylle; Kasprzak, Peter; Kienel, Ulrike & Kleinschmit, Birgit: Monitoring of Calcite Precipitation in Hardwater Lakes with Multi-Spectral Remote Sensing Archives	Oral
94	**Kienel, Ulrike**; Lami, Andrea; Plessen, Birgit; Kirillin, Georgiy; Brademann, Brian; Pinkerneil, Sylvia; Gerli, Stefano; Dräger, Nadine & Brauer, Achim: Summer blooms of cyanobacteria in Lake Tiefer See (NE Germany) - Increased nutrient input can overrule shallow lake mixing as driver	Poster
97	**Kienel, Ulrike**; Plessen, Birgit; Brademann, Brian; Pinkerneil, Sylvia & Brauer, Achim: $d^{18}O$ signatures of calcite precipitation in Lake Tiefer See (NE Germany) – from monitoring to understanding the subannually laminated deposition since 1924 AD	Poster
110	**Lensky, Nadav**; Sirota, Ido; Arnon, Ali & Enzel, Yehouda: Seasonality and depth control over halite deposition: In situ observations from the Dead Sea and implications to the formation of thick halite sequences	Oral
116	**Lischeid, Gunnar**; Kaiser, Knut; Stüve, Peter; Nützmann, Gunnar; Steidl, Jörg & Dannowski, Ralf: Spurious water level trends out of nothing? Taking the Hurst phenomenon seriously	Poster
135	**Pinkerneil, Sylvia**; Kienel, Ulrike; Brademann, Brian; Dräger, Nadine; Plessen, Birgit & Brauer, Achim: Monitoring water isotope composition of Lake Tiefer See Klocksin (NE Germany) to understand our paleoclimate archives	Poster
161	Tecklenburg, Christina & **Blume, Theresa**: Spatial patterns of lacustrine groundwater discharge: can we predict them and do they vary in time?	Poster
178	Wilke, Henriette; Thoss, Heiko; Güntner, Andreas & **Blume, Theresa:** Hydrogeology of a young moraine area in NE Germany: Subsurface structures and groundwater modeling	Poster

	Session 3: Integrating time-scales and regional synchronization	
36	**Bonk, Alicja**; Błaszkiewicz, Mirosław; Brauer, Achim; Kramkowski, Mateusz; Schwab, Markus J. & Tjallingii, Rik: The new insights into Lake Gościąż annually laminated sediments – preliminary results	Poster

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overview in thematic order		
38	**Börner, Andreas**; Lorenz, Sebastian; Theuerkauf, Martin; Słowinski, Michał; Zawiska, Izabela; Fülling, Alexander; Meng, Stefan & Niessner, Dominique: The development of Dobbin basin and Mildenitz river from Weichselian deglaciation to Early Holocene (Mecklenburg-Vorpommern, NE Germany)	Poster
43	**Buras, Allan**; Sass-Klaassen, Ute & Wilmking, Martin: Tree-growth divergence – a global phenomenon?	Oral
44	**Czymzik, Markus**; Muscheler, Raimund; Adolphi, Florian; Mekhaldi, Florian; Dräger, Nadine; Ott, Florian; Błaszkiewicz, Mirosław; Słowiński, Michał; Aldahan, Ala; Possnert, Göran & Brauer, Achim: Synchronizing the time-scales of the varved Lakes Tiefer See/Czechowskie sediment records to IntCal13 using the common cosmogenic radionuclide variations	Poster
47	**Dietze, Elisabeth**; Słowiński, Michał; Zawiska, Izabela; Veh, Georg & Brauer, Achim: Holocene lake level changes related to multiple driving mechanisms at Fürstenseer See, NE-Germany	Poster
57	**Dräger, Nadine**; Theuerkauf, Martin; Szeroczyńska, Krystyna; Wulf, Sabine; Tjallingii, Rik; Plessen, Birgit; Kienel, Ulrike & Brauer, Achim: Varve microfacies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany)	Poster
64	**Feeser, Ingo**; Dreibrodt, Stefan & Dörfler, Walter: Climate or men? Identifying drivers of multidecadal to centennial palaeolimnological processes during the Neolithic in Northern Germany	Poster
84	**Kaiser, Jérôme**; Arz, Helge; Dellwig, Olaf & BaltRap members: BaltRap – from environmental monitoring to paleoenvironmental reconstructions	Oral
101	**Kramkowski, Mateusz**; Filbrandt-Czaja, Anna; Kotrys, Bartosz; Zawisza, Edyta; Rzodkiewicz, Monika; Słowiński, Michał; Tjallingii, Rik; Błaszkiewicz, Mirosław & Brauer, Achim: Early Holocene in light of the high-resolution multiproxy analyses - laminated sediments of Lake Jelonek, Poland	Poster
132	**Ott, Florian**; Dräger, Nadine; Brykała, Dariusz; Kienel, Ulrike; Gierszewski, Piotr; Plessen, Birgit; Schwab, Markus J.; Brademann, Brian; Pinkerneil, Sylvia; Słowiński, Michał; Błaskiewicz, Mirosław & Brauer, Achim: Deciphering varve formation in Lake Czechowskie (N Poland) and Lake Tiefer See (NE Germany) through comprehensive lake monitoring	Oral
142	**Ramisch, Arne**; Tjallingii, Rik; Hartmann, Kai & Brauer, Achim: Dynamical proxy responses to climate transitions recorded in lake sediments on the Tibetan Plateau	Poster
171	**Tylmann, Wojciech**: Combining limnology and paleolimnology to track the variability of modern and past sediment fluxes: A perspective from varved lakes in northeastern Poland	Oral
180	**Wulf, Sabine**; Dräger, Nadine; Ott, Florian; Serb, Johanna; Appelt, Oona; Słowiński, Michał; Błaszkiewicz, Mirosław; Schwab, Markus J. & Brauer, Achim: Tephrostratigraphies of ICLEA varved lake records from NE Germany and N central Poland: an overview	Oral

Session 4: Man - climate - environment interactions		
41	**Brykała, Dariusz**; Dziembowski, Michał; Masloch, Katarzyna; Siudek, Wojciech; Tomczak, Sandra; Lamparski, Piotr; Majerska, Marta; Kujawa, Przemysław; Baniewska, Anna; Skorupka, Barbara & Borkowski, Sławomir: Using historical encyclopedic works in geospatial reconstruction of hydraulic structures in the rivers of Central and Eastern Europe	Poster
49	**Dietze, Elisabeth**; Theuerkauf, Martin; Słowiński, Michał; Brauer, Achim & the CEL fire synthesis team: Holocene fire regimes of the central European lowlands: man-vegetation-climate feedbacks	Oral
53	**Dobrowolski, Radosław**; Rodzik, Jan; Mroczek, Przemysław; Zagórski, Piotr; Pidek, Irena Agnieszka; Bałaga, Krystyna; Wołoszyn, Marcin; Dzieńkowski, Tomasz & Hajdas, Irka: Climate changes and human impact during middle ages in the light of geoarchaeological studies in the Hrubieszów Basin (Volhynia Upland, eastern Poland)	Poster
61	**Dreibrodt, Stefan**; Bork, Hans-Rudolf; Feeser, Ingo & Dörfler, Walter: Sediment transfer in German lowland lake catchments - Erosion on the slopes and input into annually laminated lake sediments	Poster
70	**Gibbard, Philip**: The Anthropocene; a formal stratigraphical unit, an informal concept, or an interval of Holocene time?	Oral
79	**Hirsch, Florian**; Schneider, Anna; Raab, Alexandra; Raab, Thomas; Ouimet, Will & Dethier, David: Late Holocene biochar enrichment in soils - implications of an anthropogenic legacy for ecosystems	Poster
82	**Hoelzmann, Philipp**; Brauer, Achim; Dräger, Nadine; Kienel, Ulrike & Ott, Florian: Heavy Metal Enrichment in laminated lake sediments from N-Germany and N-Poland: Geochemical background and enrichment history	Poster
103	Jonczak, Jerzy; Florek, Wacław; **Kruczkowska, Bogusława**; Niska, Monika & Gadziszewska, Joanna: Multi-proxy reconstruction of the polycyclic pedocomplex development in Dębina, central Polish Baltic coast	Poster
86	**Kaiser, Knut**; Keller, Nora; Brande, Arthur; Dalitz, Stefan; Hensel, Nicola; Heußner, Karl-Uwe; Kappler, Christoph; Michas, Uwe; Müller, Joachim; Schwalbe, Grit; Weiße, Roland & Bens, Oliver: A large-scale medieval dam-lake cascade in central Europe: water level dynamics of river Havel, Berlin-Brandenburg region, Germany	Poster
89	**Kaiser, Knut**; Oldorff, Silke; Breitbach, Carsten; Kappler, Christoph; Theuerkauf, Martin; Scharnweber, Tobias; Schult, Manuela; Küster, Mathias; Engelhardt, Christof; Heinrich, Ingo; Hupfer, Michael & Bens, Oliver: A submerged pine forest from the early Holocene in the Mecklenburg Lake District, NE Germany	Poster
91	**Kaplan, Jed O.**: Modeling global human-environment interactions in the preindustrial late Quaternary: What have we learned and what is the way forward?	Oral

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overview in thematic order		
93	**Kappler, Christoph**; Kaiser, Knut; Tanski, Phillipp; Klos, Friederike; Fülling, Alexander; Mrotzek, Almut; Sommer, Michael & Bens, Oliver: Stratigraphy and age of colluvial deposits indicating Late Holocene soil erosion in northeastern Germany	Poster
108	**Lauterbach, Stefan**; Strasser, Michael; Tjallingii, Rik; Spötl, Christoph & Brauer, Achim: Historic mass movements recorded in the sediments of Hallstätter See (Upper Austria) – natural hazards at a UNESCO World Cultural Heritage Site	Poster
130	**Obremska, Milena**; Ott, Florian; Słowiński, Michał; Błaszkiewicz, Mirosław & Brauer, Achim: From the Bronze Age to the Migration Period – human activity recorded in the lake sediments of Lake Czechowskie (Northern Poland)	Poster
137	**Plessen, Birgit**; Kienel, Ulrike; Dräger, Nadine; Pinkerneil, Sylvia & Brauer, Achim: The history of increasing anthropogenic nutrient loading into the Lake Tiefer See (NE Germany) - from monitoring to the sedimentary record	Poster
144	**Rzodkiewicz, Monika**; Hübener, Thomas; Ott, Florian; Zawiska, Izabela; Brykała, Dariusz; Gierszewski, Piotr; Kaszubski, Michał; Obremska, Milena; Słowiński, Michał; Błaszkiewicz, Mirosław & Brauer, Achim: Changes in the trophic state of Czechowskie Lake during the last 2000 years	Poster
148	**Scharnweber, Tobias**; Heußner, Karl-Uwe; Smiljanic, Marko; Heinrich, Ingo; Buras, Allan & Wilmking, Martin: How global change fakes medieval hydroclimate- a tree ring based millennium long drought reconstruction for NE-Europe	Poster
150	**Schneider, Anna**; Hirsch, Florian; Raab, Alexandra & Raab, Thomas: Dye tracer visualization of infiltration patterns in soils on historic charcoal hearth sites	Poster
152	**Schneider, Anna**; Hirsch, Florian; Wechler, Klaus-Peter; Raab, Alexandra & Raab, Thomas: Mapping a palaeosurface and archaeological site location in an anthropogenic drift sand area	Poster
155	**Schneider, Anna**; Raab, Alexandra; Hirsch, Florian; Bonhage, Alexander & Raab, Thomas: Assessing the legacies of historical charcoal production in Brandenburg	Oral
157	**Słowiński, Michał**; Ott, Florian; Obremska, Milena; Theuerkauf, Martin; Czaja, Roman; Wulf, Sabine; Błaszkiewicz, Mirosław & Brauer, Achim: Impact of Medieval road construction on landscape transformation during the last 700 years in N Poland	Oral
159	**Stivrins, Normunds**; Aakala, Tuomas; Kuuluvainen, Timo; Pasanen, Leena; Ilvonen, Liisa; Holmström, Lasse & Seppä, Heikki: Long-term boreal forest dynamics and disturbances: a multi-proxy approach	Poster
166	**Theuerkauf, Martin**; Dietze, Elisabeth; Küster, Matthias; Lorenz, Sebastian; Schult, Manuela & Blume; Theresa: Holocene Lake level fluctuations in NE-Germany – disentangling climate, vegetation and human drivers	Oral
163	**Theuerkauf, Martin**; Couwenberg, John & Mrotzek, Almut: DISQOVER the landcover - New tools in quantitative vegetation reconstruction	Poster
173	**Tyszkowski, Sebastian**; Słowiński, Michał; Obremska, Milena; Theuerkauf, Martin; Ott, Florian; Dietze, Elisabeth; Kaczmarek, Halina & Brauer, Achim: 800 years of forest transformation in northern Poland recorded in varved lake sediments and cartographical data	Poster

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Abstracts

In alphabetical order

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Ecological and hydrological changes in Northern Poland during the Younger Dryas from the organic geochemical perspective

Aichner, Bernhard[1,2]*; Słowiński, Michał[3,4]; Ott, Florian[3]; Noryśkiewicz, Agnieszka[5]; Brauer, Achim[3] & Sachse, Dirk[1,2]

[1] GFZ - German Research Centre for Geosciences, Section 5.1 Geomorphology, Organic Surface Geochemistry Lab, Potsdam, Germany

[2] University of Potsdam, Institute of Earth and Environmental Sciences, Potsdam, Germany

[3] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[4] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organisation, Toruń, Poland

[5] Nicholas Copernicus University, Institute of Archaeology, Toruń, Poland

* Corresponding author: baichner@uni-potsdam.de

Annually laminated (varved) sediments with defined event-based age anchor points such as tephra layers enable the establishment of precise chronologies in lacustrine climate archives. To decipher the drivers of ecological changes across the Younger Dryas (YD) in central Europe, we analyzed concentrations of aliphatic leaf wax biomarkers from Trzechowskie paleolake in northern Poland. Samples were taken in 10 years intervals from ca. 13,300 to ca. 10,000 yrs BP with the Laacher See (12,880±40 yrs BP) and the Askja-S tephra (11,228±226 yrs BP) as anchor points for age-calibration. Further, we applied compound specific hydrogen isotope analysis to infer past hydrological changes, in comparison to results from the well-dated Meerfelder Maar record located up 900 km to the southwest (Rach et al., 2014). Between 12,750 and 12,600 yrs BP, an increase of average chain length (ACL) of *n*-alkanes indicate a transition from a tree-dominated lake catchment (*Pinus*, *Betula*) to an environment mainly covered by *Juniperus* and grasses, which is in agreement with decadally resolved palynological data (Słowiński et al., 2017). A rapid reversal of ACL was observed between 12,690 and 11,600 yrs BP, triggered by a strong decrease of *n*-C_{27}-alkanes, which is in phase with expansion of tree palynomorphs. Decreasing δD values of *n*-alkanes indicate a rapid cooling and/or a change of moisture source together with a slight aridification between 12,680 and 12,600 yrs BP. This is synchronous to a rapid and strong aridification inferred for the beginning of the YD at Meerfelder Maar (western Germany) (Rach et al., 2014) but ca. 170 yrs after the inferred onset of cooling at both Meerfelder Maar and the NGRIP ice core at 12,850 yrs BP. Based on paired δD values of aquatic and terrestrial compounds, we infer that hydrological changes at the end of the YD started ca. 11,760 yrs BP at Lake Trzechowskie, i.e. ca. 80 yrs before ecological responses took place within the catchment. This highlights a different temporal succession of hydrological triggers and ecological responses. Further it illustrates variability in spatial impact of climatic changes in eastern compared to western Europe. The observations could potentially be related to the stronger influence of the Fennoscandian icesheets and/or the Siberian High on atmospheric circulation patterns in the more continental climate influenced parts of Eastern Europe.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association and the Helmholtz Climate Initiative REKLIM Topic 8 "Rapid climate change derived from proxy data".

References

Rach, O., Brauer, A., Wilkes, H., Sachse, D., 2014. Delayed hydrological response to Greenland cooling at the onset of the Younger Dryas in Western Europe. Nature Geoscience 7, 109–112.

Słowiński, M., Zawiska, I., Ott, F., Noryśkiewicz, A., Plessen, B., Apolinarska, K., Rzodkiewicz, M., Michczyńska, D., Wulf, S., Skubala, P., Kordowski, J., Błaszkiewicz, M., Brauer, A., 2017. Differential proxy responses to late Allerød and early Younger Dryas climatic change recorded in varved sediments of the Trzechowskie palaeolake in Northern Poland. Quaternary Science Reviews 158, 94-106.

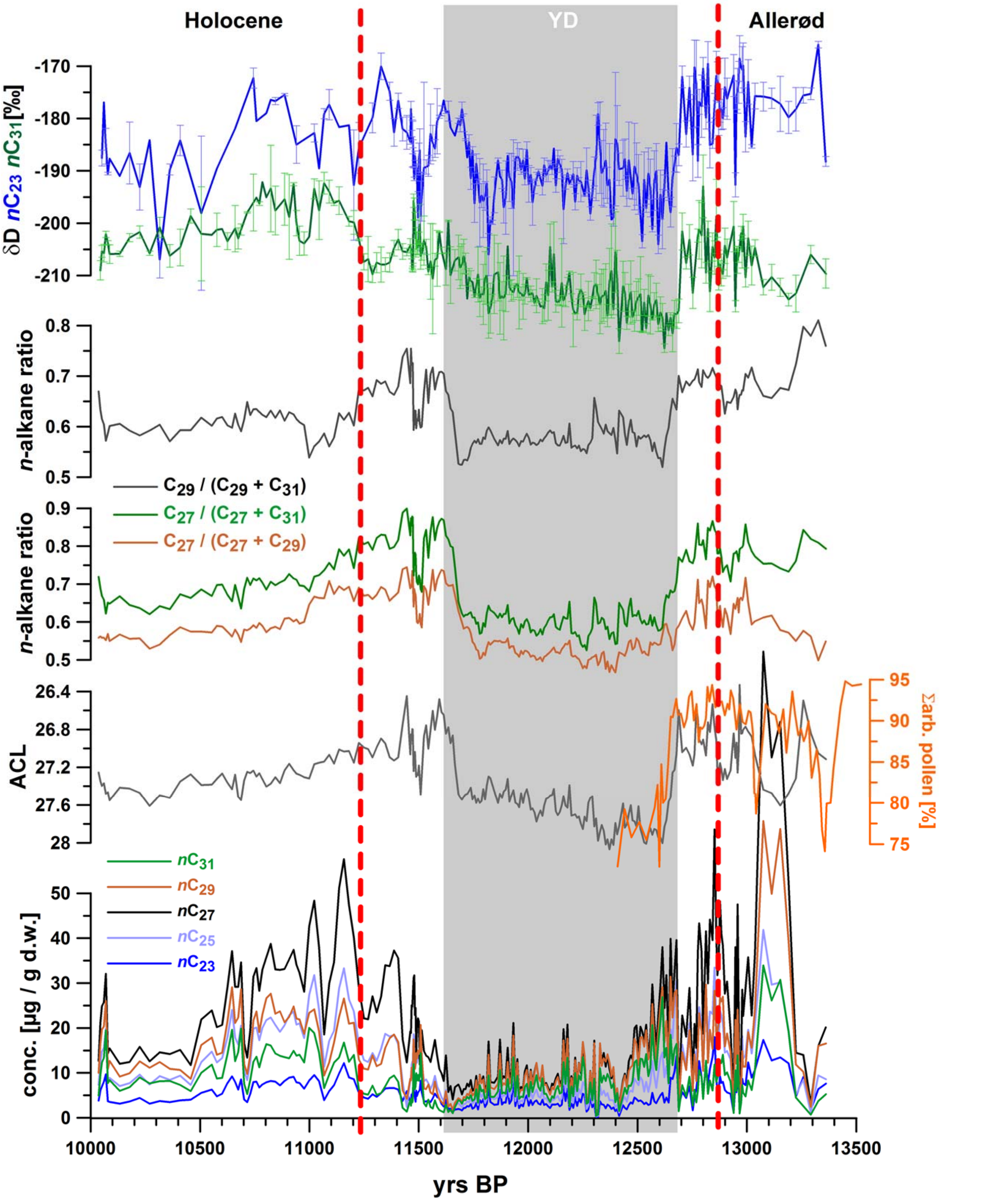


Fig. 1: *Concentrations and δD values of n-alkanes in the sampled core section of Trzechowskie paleolake. ACL: average chain length. YD: Younger Dryas. Dashed lines mark the Askja-S (early Holocene) and Lacher See (Allerød) tephra layers. ΣArboreal pollen from Słowiński et al. (2017) (Słowiński et al., 2017).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Wood anatomical parameters from lowland European oak and Scots pine for climate reconstruction

Balanzategui, Daniel[1]**; Heußner, Karl-Uwe[2]; Wazny, Tomasz[3]; Helle, Gerdhard[1]; Peters, Richard L.[4]; Hurley, Alexander[5] & Heinrich, Ingo[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[2] Deutsches Archäologisches Institut, Scientific Department of the Head Office, Berlin, Germany

[3] University of Arizona, Tree-Ring Laboratory, Arizona, United States

[4] Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland

[5] University of Birmingham, School of Geography, Earth and Environmental Sciences, Edgbaston, Birmingham, United Kingdom

* Corresponding author: dan@gfz-potsdam.de

Tree-ring based climate reconstructions from temperate lowlands are largely missing due to diffuse climate signals found in traditional tree ring-width and maximum latewood density studies. Developments in quantitative wood anatomy indicate that cell anatomical features may carry additional environmental information that could assist climate reconstruction. This motivated us to analyse wood anatomy in two tree species, the European oak (*Quercus robur L.*) and Scots pine (*Pinus silvestris L.*), as they are widely distributed across European temperate lowlands, and their common use in building materials over past centuries could possibly assist in extending the chronologies further into the past

We combined material from living trees with historical building timber from temperate lowland forests in northern Germany and Poland covering the period AD 1300 to 2016. Approximately 46,000 earlywood oak vessels from 64 trees, and 1.2 million pine tracheid cells from 41 trees, were measured using flatbed scanner (oak vessels), confocal laser scanning microscope (pine tracheids) and image analysis tools (ROXAS).

Results indicate that both oak earlywood vessel (e.g., mean area of five largest vessels) and pine tracheid anatomical proxies (e.g., early- and latewood radial diameter) contain climate signals that are different and stronger than those of corresponding tree ring-width chronologies. Additionally, by using only raw values, or applying very little detrending to the chronologies, it may be possible to preserve low- frequency climate signals.

Our analysis confirms that new anatomical proxies and their relation to climate provide additional climate proxy information within wood structure, however, these are yet to be fully explored. This information will be crucial in extending climate reconstruction records into largely unexplored geographic regions.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association.

Session 2: Recent change and instrumental observations

810-year history of cold-season temperature variability for northern Poland

Balanzategui, Daniel[1]*; Knorr, Antje[1]; Heußner, Karl Uwe[2]; Wazny, Tomasz[3]; Beck, Wolfgang[4]; Słowiński, Michał[5]; Helle, Gerdhard[1]; Buras, Allan[6]; Wilmking, Martin[7]; van der Maaten, Ernst[7]; Scharnweber, Tobias[7]; Dorado Liñán, Isabel[8] & Heinrich, Ingo[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[2] Deutsches Archäologisches Institut, Scientific Department of the Head Office, Berlin, Germany

[3] University of Arizona, Tree-Ring Laboratory, Arizona, United States

[4] Johann Heinrich von Thünen Institute, Forest Ecology and Forest Inventory, Eberswalde, Germany

[5] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organisation, Toruń, Poland

[6] Department of Ecology and Ecosystem Management, Technische Universität München, Freising, Germany; Institute of Botany and Landscape Ecology, Ernst-Moritz-Arndt-Universität, Greifswald, Germany

[7] University of Greifswald, Landscape Ecology, Greifswald, Germany

[8] CIFOR-INIA, Departamento de Silvicultura y Gestión de los Sistemas Forestales, Madrid, Spain

* Corresponding author: dan@gfz-potsdam.de

Pinus sylvestris is a commonly used species in European dendroclimatology due to its wide distribution across much of the continent. Almost all studies find radial growth strongly related to summer temperature, a result attributed to site selection at high latitude/altitude environments where trees grow at their ecophysiological limits. Due to the amount of attention spent on these sites there is a geographical and seasonal bias in temperature reconstructions among tree-ring proxies in Europe. To overcome the limited availability of tree-ring proxies within the European temperate lowlands, we present a northern Poland ring-width chronology developed from living and historical *P. sylvestris* that shows a strong and robust common growth signal back to AD 1200. Investigations into the climate- growth relationship find year-to-year ring-width variability to be more strongly correlated to winter and early-spring temperature (T_{ndJFMA}) than summer temperature. The reconstruction statistics suggest that the regression model used to estimate temperature back in time has good predictive skill with reduction of error and coefficient of efficiency of 0.389 and 0.164, respectively. Reconstructed T_{ndJFMA} reveals 1198, 1199 and 1949 as the warmest and 1868 the coolest T_{ndJFMA} on record. The low-frequency reconstruction indicates that warm- and cool phases last from 50 to 100 years with the coolest period occurring from 1830 to 1910 and the warmest period from 1910 to 2010. Comparisons with other recently published temperature reconstructions from tree-rings, ice-cores, and instrumental and observation data yielded similarities and differences in the low-frequency variability most likely attributed to the proxy used and the reconstruction target period.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association.

Session 2: Recent change and instrumental observations

The Application of the Standardised Precipitation Index (SPI) for the Evaluation of Intensity of Dry and Wet Periods in the Vicinity of Czechowskie Lake

Bartczak, Arkadiusz[1]* & Krzemiński, Michał[2]

[1] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organisation, Toruń, Poland
[2] Gdańsk University of Technology, Faculty of Applied Physics and Mathematics, Department of Probability and Biomathematics, Gdańsk, Poland
* Corresponding author: arekbartczak@gazeta.pl

Dry and wet periods, as well as their intensity, are detected and evaluated with a number of indices, one of which is the Standardised Precipitation Index (SPI) developed and applied by McKee et al. (1993). The creators of the index point at its possible application for other characteristics e.g. river discharges, snow cover, soil moisture, groundwater level, etc. In Poland, the SPI has been used since 2000 (Łabędzki, 2004) and it comes recommended by the Polish hydrological and meteorological service as one of the indices for monitoring atmospheric drought events (posucha.imgw.pl).

For this paper, the SPI was calculated on the basis of data series obtained from four precipitation stations located in the area surrounding Czechowskie lake (Fig. 1). The time span for three of them – Starogard Gdański, Chojnice and Śliwice – covered the period 1952-2014 whereas that for the Kościerzyna station was 1952-2014. The data was provided by the Institute of Meteorology and Water Management (IMGW) in Warsaw and all the calculations were performed for the hydrological year (November – October).

Fig. 1: *Research area and precipitation station used for the study.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The SPI calculation is based on the long-term precipitation data which is transformed into a normal distribution by the Box – Cox method (Box G.E.P, Cox D.R., 1964, 1982) with the following formula:

$$y^{(\lambda)} = \begin{cases} \dfrac{y^{\lambda} - 1}{\lambda} & (\lambda \neq 0) \\ \log y & (\lambda = 0) \end{cases}$$

This power transformation attempts to transform a set of data to a normal distribution by finding the value of power parameter λ that minimizes the variation. To check that the transformation produces a normal distribution we used Shapiro-Wilk test (a p-value>0.05 indicates the distribution does not differ significantly from the standard normal distribution).

Finally, we classified the calculated standardised indices according to the scheme suggested by Guttman (1999) (Tab. 1). The classification is based on determination of equal intervals whose limits are a multiple of the standard deviation from the mean value.

***Tab. 1**: SPI values.*

Classification period	SPI
Extremely wet	2.00 or more
Very wet	1.50 ÷ 1.99
Moderately wet	1.00 ÷ 1.49
Normal	0.99 ÷ -0.99
Moderately dry	-1.00 ÷ -1.49
Severely dry	-1.50 ÷ -1.99
Extremely dry	-2.00 and less

Source: Guttman, 1999.

The applied procedure made it possible to identify and evaluate the intensity (the SPI value) of both wet periods (precipitation above the mean value) and dry periods (precipitation below the mean value). Fig. 2 presents the calculated values of the SPI for the summer half-year (V-X) in the investigated period.

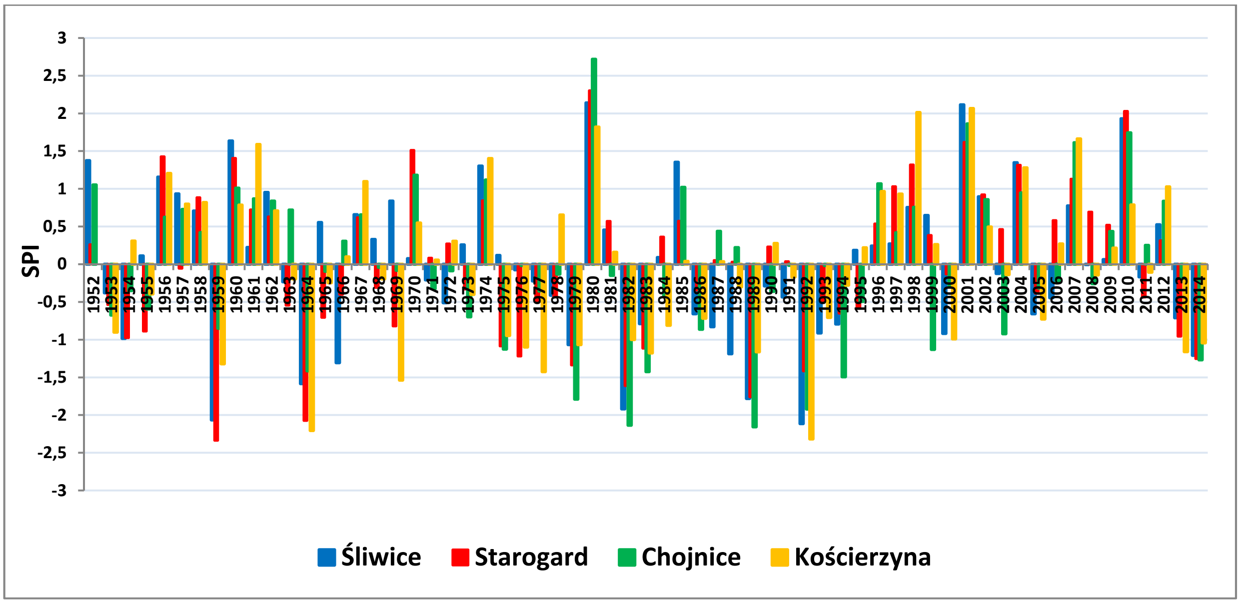


***Fig. 2:** Values of SPI (Standardised Precipitation Index) in the summer half-year period 1952-2014; Source: Own elaboration.*

References

Box G.E.P., Cox D.R., 1964. An Analysis of Transformations, Journal of the Royal Statistical Society, Series B, Vol. 26, No. 2, p. 211-252.

Box G.E.P., Cox D.R., 1982. An Analysis of Transformations Revisited, Rebutted, Journal of the Royal Statistical Association, Vol. 77, No. 377, p. 209-210.

Guttman N.B., 1999. Accepting the Standardized Precipitation Index: A Calculation Algoritm, Journal of the American Water Resources Association, Vol. 35, No. 2, p. 311-322.

Łabędzki L., 2004. Problematyka susz w Polsce [Drought Problems in Poland], Woda-Środowisko-Obszary Wiejskie [Water-Environment-Rural Areas], t. 4, z. 1(10), p. 47-66.

McKee T.B., Doesken N.J., Kleist J., 1993. The Relationship of Drought Frequency and Duration to Time Scale, Eight Conference on Applied Climatology, 17-22 January 1993, Anheim, California, p. 179-184.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overall presentation

Timing of formation of postglacial lakes within the limit of the Last Glaciation in Poland

Błaszkiewicz, Mirosław[1]*; Brauer, Achim[2]; Kordowski, Jarosław[1] & Słowiński, Michał[1]

[1] Polish Academy of Sciences, Institute of Geography and Spatial Organization, Department of Environmental Resources and Geohazards, Toruń, Poland

[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

* Corresponding author: mirek@geopan.torun.pl

A distinct time gap exists between the creation of the young glacial basins which developed during the final phase of the last glaciation and the appearance of the lakes in these environments. Detailed geomorphological studies of a large number of lake basins has provided a wealth of arguments for the hypothesis that the fundamental cause of this time gap was a long-term preservation of the lake basins by dead-ice, which, at least initially, took place under periglacial conditions. In the case of certain depressions in northern Poland, the time gap is more than a thousand years and independent of major climatic changes including rapid warming that occurred during this time. Most lakes appeared in the Bølling-Allerød complex, but some older lakes had already formed before the Allerød, whereas other lakes came into being only at the end of the Preboreal. The main reason for the difference in the formation of the lakes is the local diversity of melt-out processes of the buried dead-ice blocks (Fig. 1). The melting intensity differed after the ice-sheet retreat and lasted in a few depressions even until the end of the Preboreal. Particularly important for the preservation of blocks of dead-ice were the drainage processes of the depressions, which might have been gradual and constant or interrupted. On one hand, depressions in the vicinity of a water flows that underwent prominent downward erosion during the Late Glacial (Fig. 2). On the other hand, local morphological conditions favored longer preservation of stagnant water so that the thermal effect of water above the dead-ice led to rapid melting and to an early establishing of a water-filled lake already at the beginning of the Late Glacial. The melt-out of buried dead-ice blocks under thermokarst conditions was very fast regardless of the duration of the dead-ice preservation (Fig. 1). The long-term preservation of some lake basins as a consequence of the presence of buried dead-ice blocks not only indicates the presence of Late Glacial permafrost after the ice retreat, but also provides evidence for the timing of its ultimate disappearance. The probable age of the final degradation of permafrost in the study area is the end of the Preboreal – beginning of the Boreal (Błaszkiewicz, 2011).

This study is a contribution to scientific project financed by the National Science Centre, Poland – No. UMO-2015/19/B/ST10/03039 and to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association.

References

Błaszkiewicz, M., 2011. Timing of the final disappearance of permafrost in the central European Lowland, as reconstructed from the evolution of lakes in N Poland. Geological Quarterly, 55, 4, 361-374.

Błaszkiewicz M., Piotrowski J., Brauer A., Gierszewski P., Kordowski J., Kramkowski M., Lamparski P., Lorenz S., Noryśkiewicz A., Ott F., Słowiński M., Tyszkowski S., 2015. Climatic and morphological controls on diachronous postglacial lake and river valley evolution in the area of Last Glaciation, northern Poland. Quaternary Science Reviews 20, 109, 13-27.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

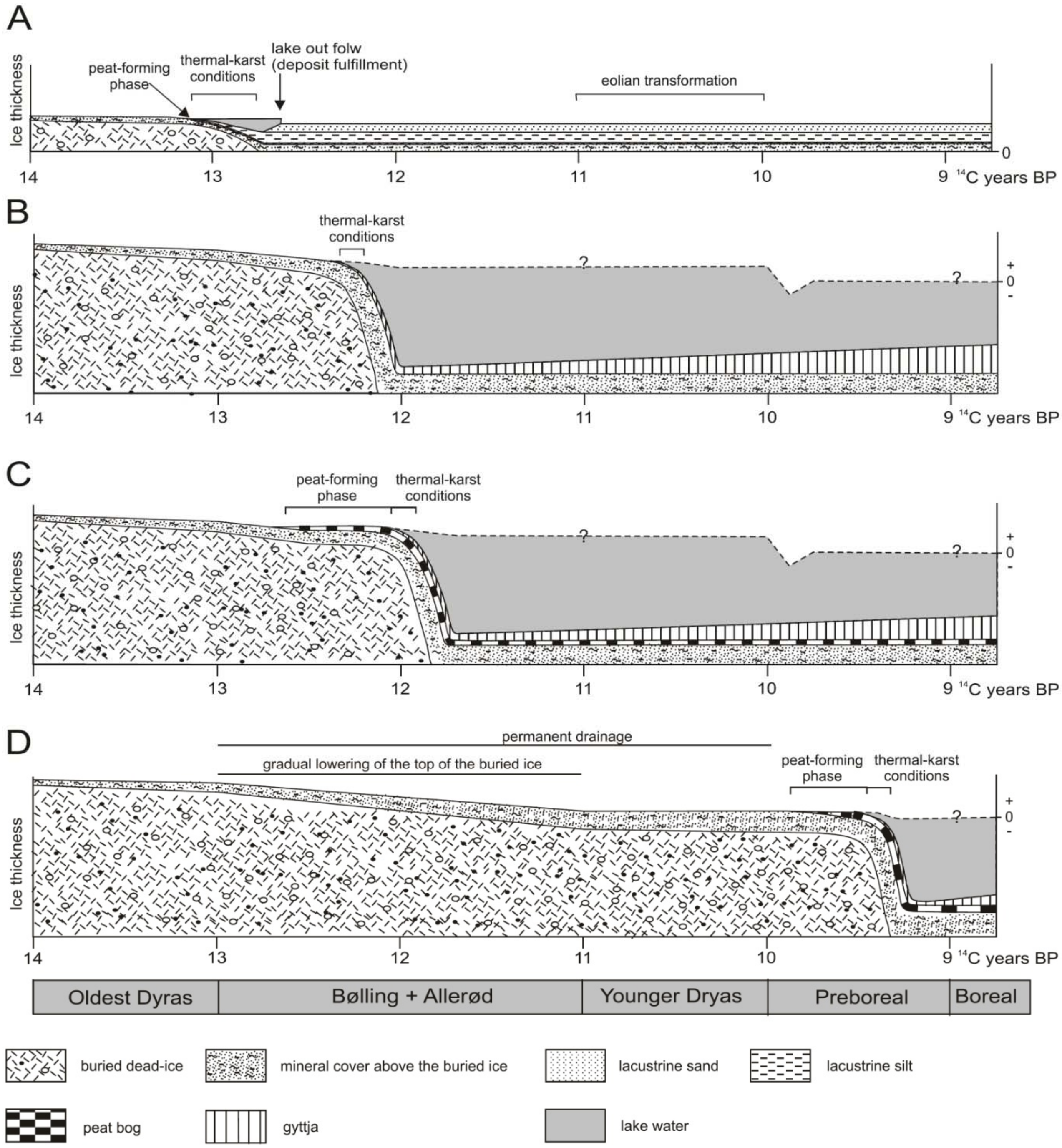


Fig. 1: *Melt-out development of the buried dead-ice and related lake development in the Late Glacial and early Holocene (Błaszkiewicz, 2011). A – pre-Allerød lakes; B – lakes of the Bølling-Allerød interval; C – lakes of the Bølling-Allerød interval with basal peat bog; D – early Holocene lakes; 0 – level of contemporary lakes or peat bog plains.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

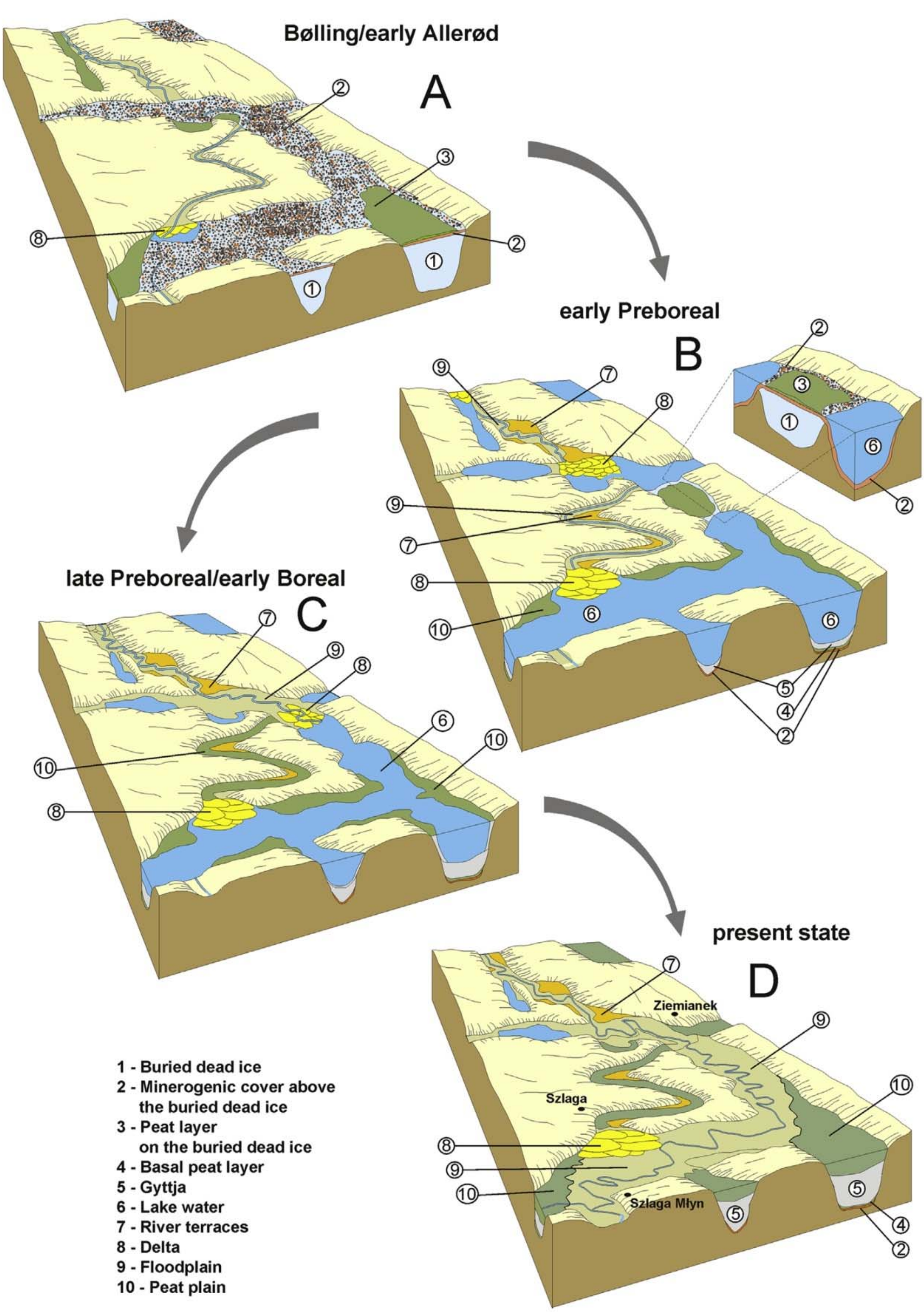


Fig. 2: *Cartoon showing the main development stages reconstructed in the middle section of the Wda River valley during the Lateglacial and Holocene (Błaszkiewicz et al., 2015).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Soil water availability, tree water uptake and information storage in tree rings

Blume, Theresa[1]*; Heidbüchel, Ingo[1,2]; Simard, Sonia[3]; Güntner, Andreas[1] & Heinrich, Ingo[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.4, Hydrology, Potsdam, Germany
[2] Helmholtz Centre for Environmental Research UFZ, Department of Hydrogeology, Leipzig, Germany
[3] GFZ - German Research Centre for Geosciences, Section 5.2, Climate Dynamics and Landscape Evolution, Potsdam, Germany
* Corresponding author: blume@gfz-potsdam.de

The interrelationships between soil water availability, tree water uptake and information storage in tree rings are studied at the TERENO Northeastern German lowland observatory within the Serrahn section of the Müritz National Park, specifically in the forests around Lake Hinnensee. The observatory is located in a glacial outwash plane and thus soils are sandy with high hydraulic conductivities and little water holding capacity. Soils are relatively uniform across the observatory. This has the advantage that forest stand specific responses including their effects on water storage and percolation can be identified more easily as differences are not masked by differences in soil physical characteristics. The here presented poster gives an overview of the joint work of dendrochronologists and hydrologists and provides a first integration of the various data sets.

Soil water availability, soil water patterns and dynamics are studied with 450 soil moisture sensors which are installed at 14 sites covering beech, pine and oak forest stands. These sensors are arranged in five profiles per site, reaching down to a depth of 200 cm. At six of these sites 24 sapflow sensors and 30 dendrometers were installed to investigate tree responses directly. As these variables are measured at high temporal resolution it is not only possible to compare years or seasons, but also daily responses to both weather conditions and water availability. This allows us to compare soil water availability (Fig. 1) with tree water uptake, tree water deficit and tree growth. Tree water deficit and tree growth as well as diurnal fluctuations in tree diameter can be obtained from the dendrometer time series. Tree water uptake, on the other hand, is monitored using two different methods: a) directly within the tree by measuring sap velocities and converting them to fluxes and b) by converting diurnal soil moisture changes to root water uptake rates. The sapflow data set furthermore shows different responses of the three tree species to variations in daily water vapor pressure deficit (Fig. 2).

The experimental sites cover both upslope sites (which are generally drier) and downslope sites, which are located close to the lake, where groundwater tables are generally less than 3 m below ground. Thanks to this experimental design, we were also able to investigate the effects of spatially differing water availability, while the trees are subject to basically the same climatic forcing and to compare these effects among tree species. At the downslope sites diurnal signals of root water uptake were not only observed in the soil moisture time series but also in shallow groundwater levels. These same sites have also been the focus of dendrochronological tree coring campaigns, resulting in long tree-ring chronologies used for reconstructed time series. The climate-growth relationships statistically derived from the dendro-archive time series were compared with those found during the monitoring period itself. Oak tree ring analyses could be used to reconstruct past groundwater level fluctuations. With the same data set it was possible to identify several regime shifts in the last 240 years, where sometimes upslope and sometimes downslope sites were more advantageous for oak growth as a result of strongly fluctuating water availability.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

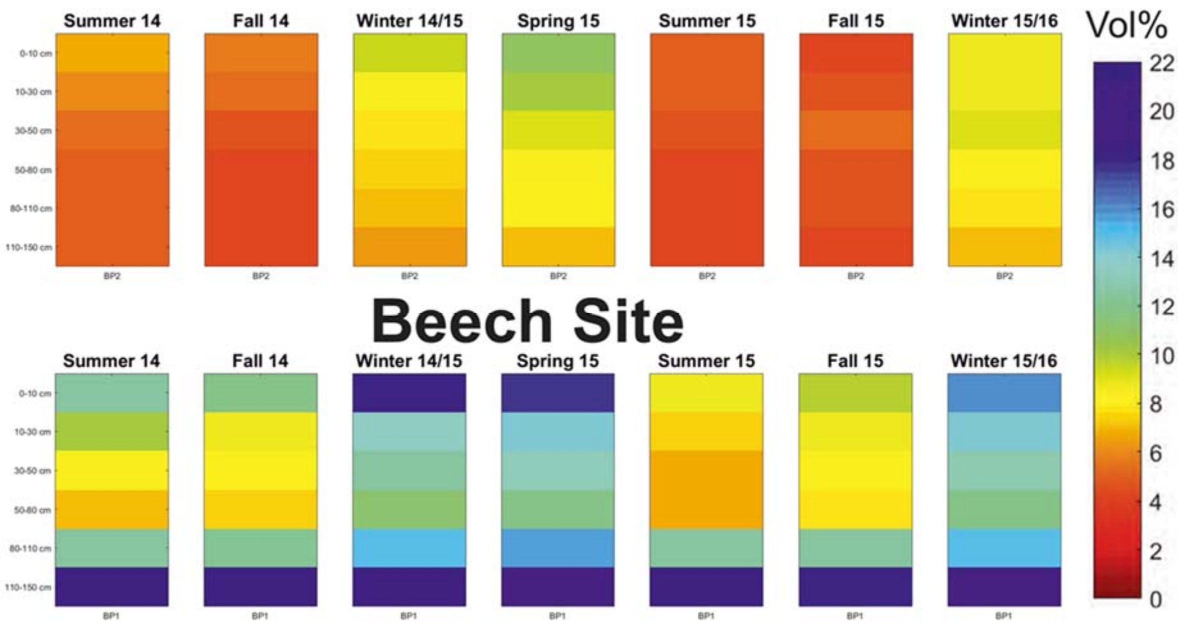


***Fig. 1**: Soil moisture across seasons at the beech upslope site (top) and the beech downslope site (bottom).*

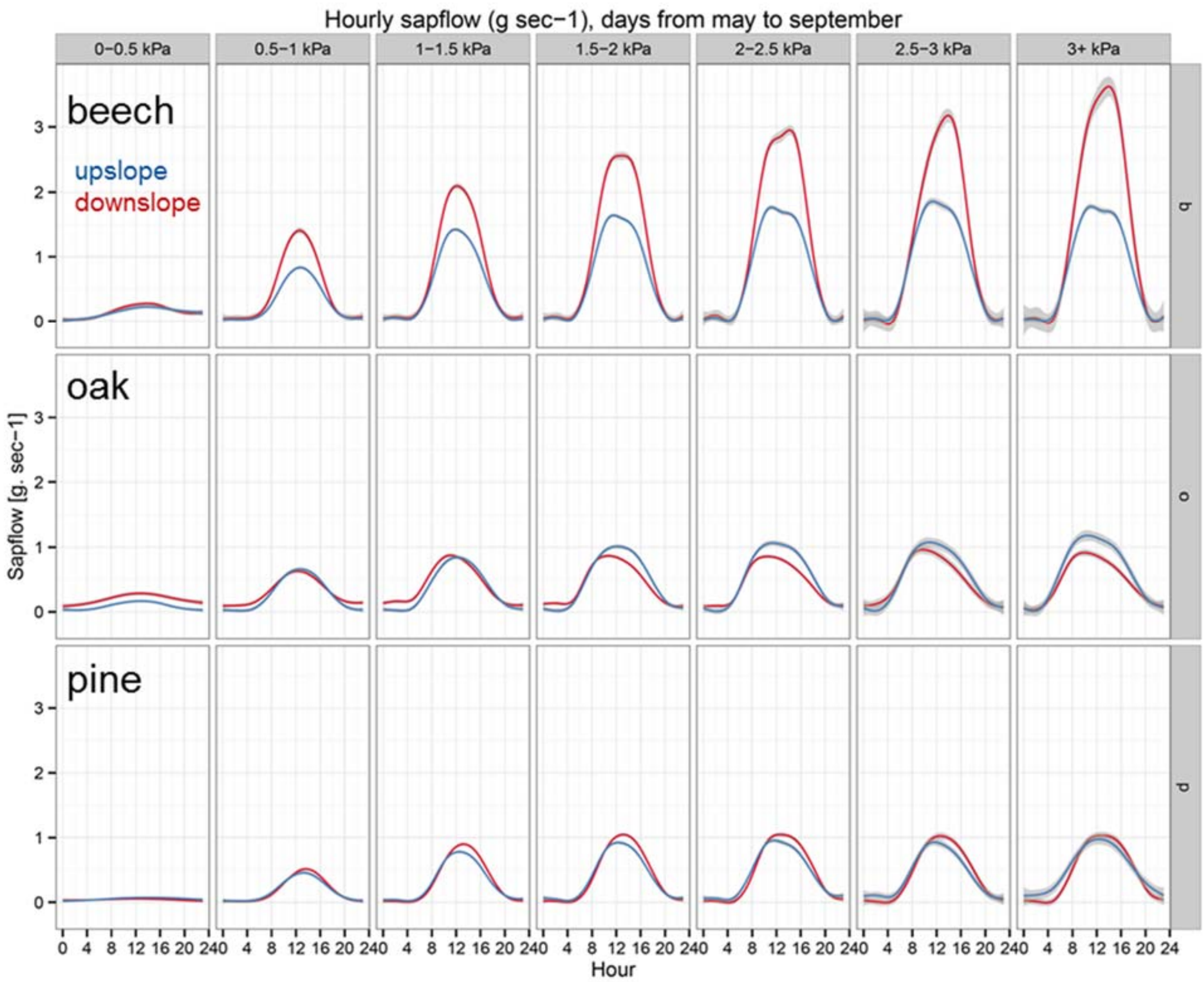


***Fig. 2**: Average sapflow for three tree species: comparing upslope and downslope responses to different water vapor pressure deficit.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Dry spells and the tree-water feedback loop: how does limited water availability affect different tree species and how do different tree species affect water availability?

Blume, Theresa[1]*; Heidbüchel, Ingo[2]; Simard, Sonia[3]; Güntner, Andreas[1] **& Heinrich, Ingo[1,3]***

[1] GFZ - German Research Centre for Geosciences, Section 5.4, Hydrology, Potsdam, Germany
[2] Helmholtz Centre for Environmental Research UFZ, Department of Hydrogeology, Leipzig, Germany
[3] GFZ - German Research Centre for Geosciences, Section 5.2, Climate Dynamics and Landscape Evolution, Potsdam, Germany
* Corresponding authors: blume@gfz-potsdam.de, heinrich@gfz-potsdam.de

Evapotranspiration exerts a strong influence on the terrestrial water budget and influences water availability, flow and transport in the unsaturated zone as well as groundwater recharge. In forested environments, evapotranspiration is to a large part controlled by trees. When water becomes scarce, different tree species can show diverse responses. In this ongoing study we investigate (1) if and how much trees control their own living environment (water availability and water distribution in the subsurface) under these circumstances, (2) how, in turn, this affects them in both water uptake and growth, and (3) how these signals are recorded in the tree-ring archive.

The tree-water feedback loop is investigated using a multi-method approach in various forest stands in the northeastern German lowlands. This approach combines sapflow and dendrometer measurements as well as tree-ring analyses with the analysis of soil moisture patterns in space and time including root water uptake rates derived from soil moisture. The latter method translates the daily decrease of soil water content monitored with in-situ sensors during days without rainfall into root water uptake. It has the advantage that it provides depth distributions of species specific root water uptake and thus additional information allowing for a more detailed analysis of the relationship between water availability and water uptake. High resolution climatic data makes it possible to investigate the site specific interplay between atmospheric demand and water availability on the one hand and tree response and adaptation on the other hand. The comparison of spatio-temporal patterns of these responses with concurrent tree growth as well as tree-ring analyses enables a first matching of actual and “archived” patterns and thus an estimate of how much of this information is stored in tree rings.

The study site is the TERENO Northeastern German lowland observatory within the Serrahn section of the Müritz National Park, specifically the forests around Lake Hinnensee. This site is of particular interest in the context of short and long term climatic signals, as the lake is known to show strong variations in water levels (Fig. 1). However, only parts of these dynamics can be explained by the variability of precipitation in the region. The site of the observatory is located in a glacial outwash plane and thus soils are sandy with high hydraulic conductivities and little water holding capacity. 450 soil moisture sensors were installed at 14 sub-sites covering beech, pine and oak forest stands (Fig. 2). These sensors are arranged in five profiles per site, reaching down to a depth of 200cm. At six of these sites 24 sapflow sensors and 30 dendrometers were installed to investigate tree responses directly. These same sites have also been the focus of dendrochronological tree coring campaigns, resulting in long tree-ring chronologies used for reconstructed time series. The climate-growth relationships statistically derived from the dendro-archive time series were compared with those found during the monitoring period itself.

The first full vegetation period was monitored in 2014. While 2014 was still a relatively wet year, the following two years became successively drier which lead to both a strong decline in soil moisture contents as well as a decline in groundwater and lake levels (Fig. 3 and Fig. 1). Soil moisture dynamics clearly are largest in the uppermost soil layers. Nevertheless, also the deeper soil horizons at 130 and 200 cm are characterized by a decrease of soil water content in particular during dry summer spells where near-surface moisture is largely depleted. Thus, during dry conditions, root water uptake by trees can be shown to take place at these larger depths. This data set thus provides an excellent basis to study both the effect and the response of different tree species to gradually declining water availability.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

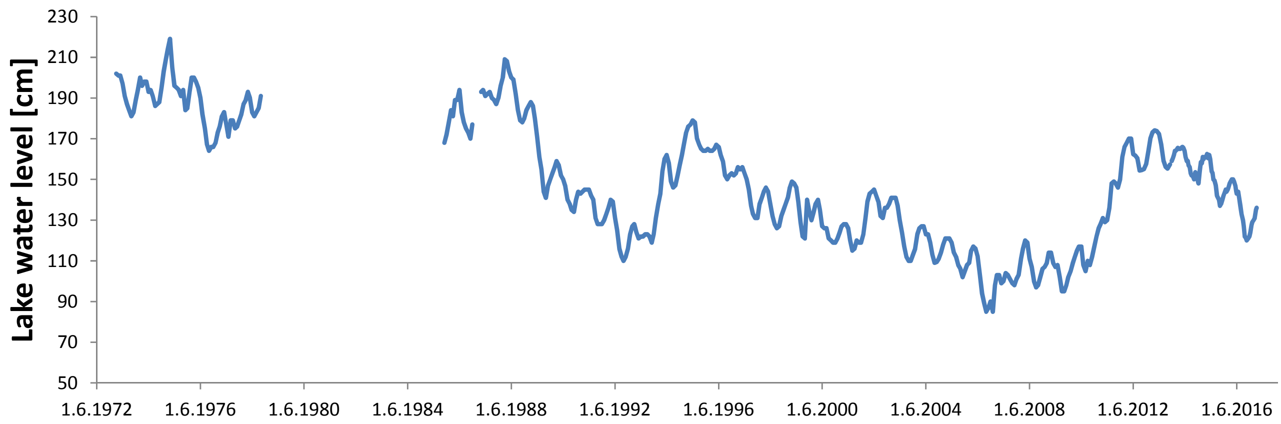
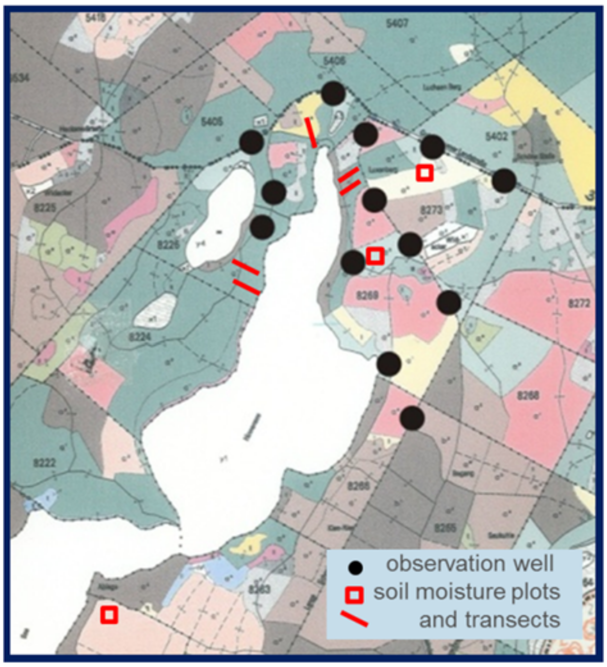


***Fig. 1**: Water level fluctuations at Lake Hinnensee.*



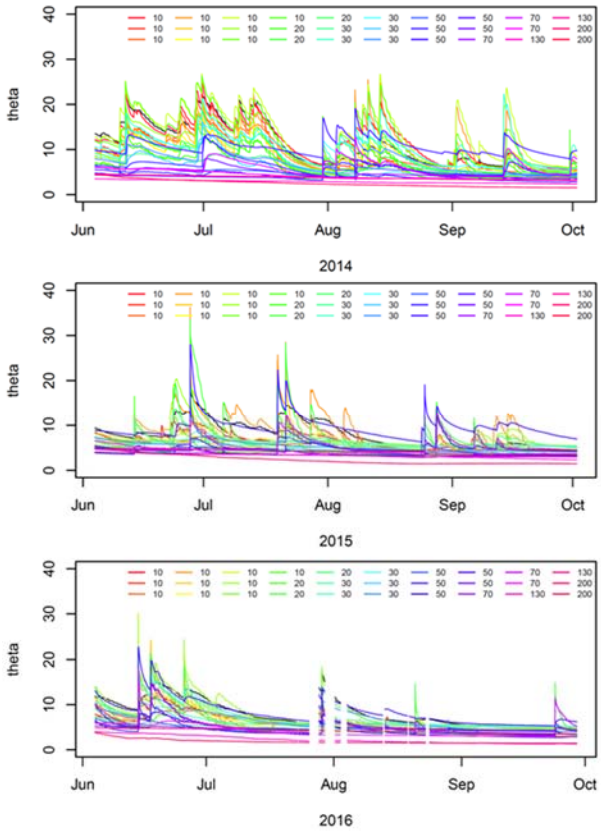


***Fig. 2**: The field site and its intrumentation. The three northernmost soil moisture transects are also instrumented with sapflow sensors and dendrometers. Basic climate parameters are measured at all sites and are complemented by two climate stations just north of the lake.*

***Fig. 3**: Soil moisture dynamics for three consecutive years at one of the mixed pine-beech forest stands. Red and orange lines are near-surface dynamics, while purple lines show the dynamics at greater depths.*

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

Session 3: Integrating time-scales and regional synchronization

The new insights into Lake Gościąż annually laminated sediments – preliminary results

Bonk, Alicja[1]*; Błaszkiewicz, Mirosław[1]; Brauer, Achim[2]; Kramkowski, Mateusz[1]; Schwab, Markus J.[2] & Tjallingii, Rik[2]

[1] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland

[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam

* Corresponding author: a.bonk@twarda.pan.pl

Lake Gościąż (52°35'N, 19°21'E) is the study site of a project that aims at use of laminated sediments to the emerging paleoclimatic and paleoenvironmental transect across Europe along the W-E axis (lakes Meerfelder maar - Rehwiese - Tiefer - Czechowskie) through the use of modern high-resolution research techniques and on a detailed analysis of the response of natural environments of varying degrees of continentalism to global climate impulses.

The lake is located in a Gostynińskie Lake District (central Poland) that was formed in the marginal part of the Scandinavian ice sheet at 64.3 m a.s.l.. The lake belongs to a complex of four connected lakes called Na Jazach lake system. Lake Gościąż has a small area (41.7 h) and it is drained by the Ruda River, which today discharges to the Wocławek Reservoir. Lake Gościąż consist of two basins: a smaller, in the northern part (Tobyłka Bay) and the main basin. The maximum depth (24 m) of the lake is located in the central part of the main basin (Fig. 1).

Lake Gościąż is an iconic record for paleoclimate and paleoenvironmental reconstructions. In 1985 AD the laminated sediments of Lake Gościąż were discovered and examined in detail. The results of this study became an important component of our understanding of climate and environmental changes over the last 13,000 years. Since that time new methods have been developed and advanced. Here, we present the new composite sediment profile and some preliminary results of micro-facies analysis combined with µXRF scanning results.

A set of cores collected from the deepest part of the lake indicate that the sediment record, except of the topmost part, contains a continuous sequence of varved deposits down to glacial sands (Fig. 2B). The composite sediment profile was obtained by stratigraphic correlation based on macro- and microscopic comparison of well-preserved laminations and diagnostic horizons. The entire profile was subsampled continuously for thin sections. Fresh sediment blocks were collected using aluminum foil trays, frozen in liquid nitrogen, freeze-dried and impregnated with an epoxy resin following the procedure described by Lotter and Lemcke (1999). Cutting and slab-polishing to the thickness of 25–30 µm was done by MK Factory (Germany). Then, thin sections were scanned with 2400 dpi resolution between two polarizing foils on a flatbed scanner equipped with a transparency unit. Thin sections were microscopically analyzed at 20× to 1000× magnification (Fig. 2A) and different varve microfacies were recognized and described. Varves were counted by two persons on high-resolution images using the CooRecorder software. Basing on independent counting the preliminary chronology and its uncertainty was estimated using following procedure: 1) varves identified in both countings were added to the chronology without increasing the uncertainty; 2) varves missed in one counting were not added to the chronology but the uncertainty was increased by a half year in both directions. The varve thickness was calculated as mean value from a three measurements to account for horizontal variability within one varve. We also determined Varve Quality Index (VQI) to evaluate the quality of varve preservation following three classes suggested by Bonk et al. (2015). In order to measure the element composition and confirm the annual character of the varves, the fresh core were scanned using ITRAX corescanner (Cox Analytical Systems) at GFZ Potsdam, Germany (Fig. 2b, c). The scanning was performed at a spatial resolution of 200 micrones.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The future work will focus on further, detailed analysis of thin section and obtaining radiocarbon dates in order to develop a refined age-depth model for entire Holocene and Lateglacial record. Since the topmost part of the sediment consists of homogenous gyttya, tephrochronololgy and radionuclides dating (Cs-137) will to be applied to anchor the floating varve chronology.

This study is a contribution to scientific project financed by the National Science Centre, Poland – No. UMO-2015/19/B/ST10/03039.

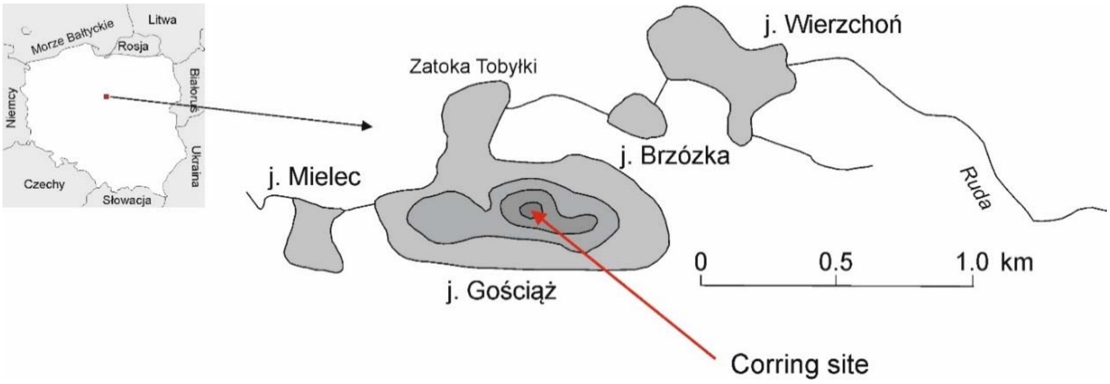


Fig. 1*: Location of Lake Gościąż with the basin bathymetry & coring site (modified from Gierszewski, 2000).*

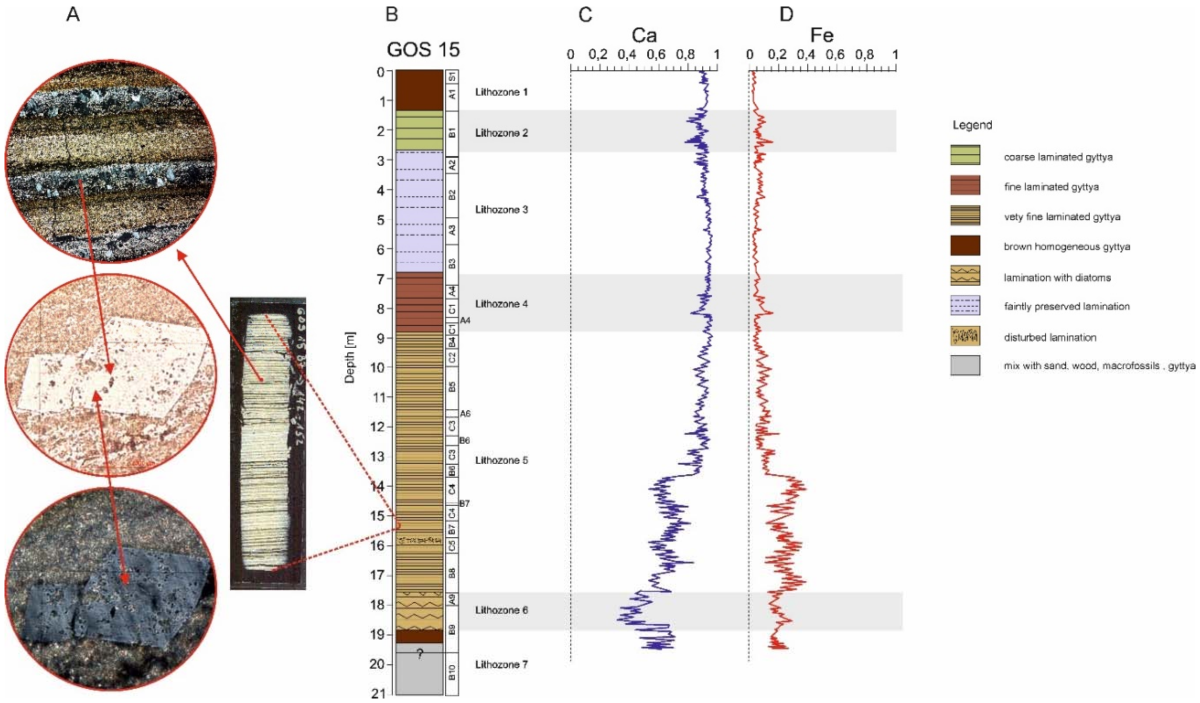


Fig. 2*: Composite profile of the Lake Gościąż sediments: an example of single varved composition (A); lithology of the composite profile (B); XRF scanning results – Ca (C) and Fe (D).*

References

Bonk, Alicja, Wojciech Tylmann, Tomasz Goslar, Agnieszka Wacnik, and Martin Grosjean. "Comparing Varve Counting and 14c-Ams Chronologies in the Sediments of Lake Żabińskie, Northeastern Poland: Implications for Accurate 14c Dating of Lake Sediments." Geochronometria 42, no. 1 (2015). http://dx.doi.org/10.1515/geochr-2015-0019.

Gierszewski, Piotr. Charakterystyka Środowiska Hydrochemicznego Wód Powierzchniowych Zachodniej Części Kotliny Kłodzkiej. Prace Geograficzne. Warszawa: Conlinuo 2000.

Lotter, A. F. and G. Lemcke. "Methods for Preparing and Counting Biochemical Varves." Boreas 28 (1999): 243-52.

Ralska-Jasiewiczowa, M., T. Goslar, T. Madeyska, and L. Starkel. Lake Gościąż, Central Poland a Monographic Study. Kraków: W. Szafer Institute of Botany Polish Academy of Sciences, 1998.

Session 3: Integrating time-scales and regional synchronization

The development of Dobbin basin and Mildenitz river from Weichselian deglaciation to Early Holocene (Mecklenburg-Vorpommern, NE Germany)

Börner, Andreas[1]*; Lorenz, Sebastian[2]; Theuerkauf, Martin[2]; Słowiński, Michał[3]; Zawiska, Izabela[3]; Fülling, Alexander[4]; Meng, Stefan[2] & Niessner, Dominique[2]

[1] State Agency of Environment, Nature Conservation and Geology, State Geological Survey, Güstrow, Germany
[2] Greifswald University, Institute of Geography and Geology, Greifswald, Germany
[3] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
[4] Humboldt-University Berlin, Faculty of Mathematics and Natural Sciences, Geography Department, dating laboratory, Berlin, Germany
* Corresponding author: andreas.boerner@lung.mv-regierung.de

In central Mecklenburg-Vorpommern, several glacio-lacustrine basins are embedded in the outwash plains of the Pomeranian Phase (W2) of the Weichselian glaciation. Construction of the NEL gas pipeline in 2012 allowed to study of these basins, the Dobbin basin, in the framework of a detailed geological mapping project. Several sites across the basin were sampled for sedimentological (carbon content, grainsize distribution) and palaeoecological analysis (pollen, plant macrofossils, Cladocera) as well as for dating by ^{14}C and OSL. Sediments cover the Weichselian glacial/periglacial to Holocene period. Results indicate that during deglaciation of the Frankfurt-Phase (W1F, cf. Litt et al., 2007), a river system and local ice-dammed lake existed in the glacigenic 'Dobbiner Plage' depression. The glaciofluvial phase of W1F-deglaciation is represented by cross bedded gravel and sand deposits; it has been OSL dated to ~21-20 ka (Fig. 1). On top of the glaciofluvial sequence, periglacial structures like meso-scale frost cracks and largescale frost wedge casts with a maximum of 2 m depth were detected (Fig. 2). The OSL dates suggest that cover sands (mainly aeolian) filling the ice wedges were deposited between 19.5 – 17.3 ka. The timing of periglacial encroachment with opening and filling of ice wedge polygons therefore well correlates with colder period of Pomeranian ice transgression phase (W2) and the beginning deglaciation.

The lacustrine sedimentation and bog development during late glacial period is well preserved in numerous depressions with diameters of 30-100 m. The depressions are separated by W1F till ridges or glaciofluvial sediments, but were once part of a large lake basin. The sediment sequence starts with glaciofluvial deposits. During the beginning late-glacial around ~14.5 ka the melting of buried dead ice reshaped the lake basin morphology by new depressions, in- and outlets. Radiocarbon dates indicate that peat formation started soon after the start of the Weichselian late-glacial period (Meiendorf-Interstadial acc. to Litt et al., 2007). High resolution analysis of a basal peat layer indicates that initial organic and lacustrine sedimentation started in shallow ponding mires, evolving from buried dead ice sinks in the glaciofluvial sequence, in which telmatic plants (*Carex aquatilis*, *Schoenoplectus lacustris*) dominated. *Chydorus sphaericus*, the only cladocera species recorded, is ubiquitous and can survive in almost all reservoir types in very harsh conditions. Findings of *Characeae* than point at the formation of shallow lakes (*Chara spec.*, *Nitella oognia*). The expansion of rich fen communities, including *Scorpidium scorpoides* demonstrate the aggradation of the shallow basin. The appearance of *Alona costata* points at a lowering of pH values in that process. A tree trunk of arctic dwarf birch *Betula nana* with C^{14}-dating 14.2 ka cal. BP shows that first dwarf tree vegetation established during this first telmatic period. At this position in the basin, the basal peat layer is covered by minerogenic sediments, which points at a period of increasing water levels and fluvial dynamics possibly related to a cold period with permafrost formation (Oldest/Older Dryas?). The following warmer period affected the melting out of buried dead ice blocks as well as the deepening of basin depressions. During this period, an extended paleolake developed. Its maximum water level is indicated by lake terraces at 51 m and 43 m a.s.l.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

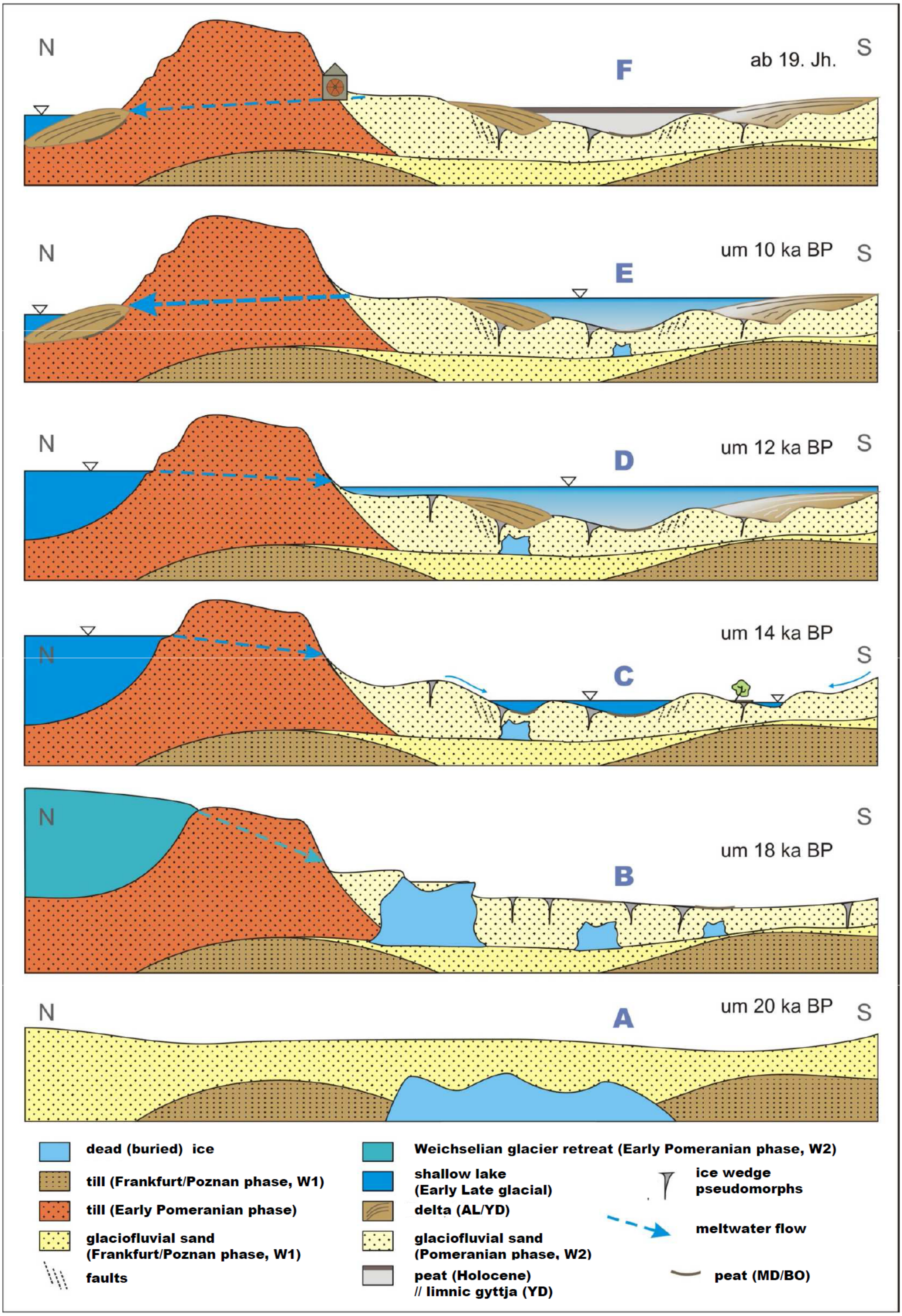


***Fig. 1**: Dobbertin basin - a time/genesis model after deglaciation of Frankfurt/Poznan Phase (Lorenz et al., 2015). (MD/BO - Meiendorf/Bölling interstadial, AL/YD - Alleröd/Younger Dryas)*

In deeper basin depressions, the glaciofluvial sequence and the locally observed basal peat layer are covered by calcareous and silicate gyttias of an interstadial phase (Meiendorf-Interstadial acc. to Litt et al., 2007). In the lower calcarous organic silt layer, fragments of Lymnaidae*,* Unionidae, *Valvata aff. Piscinalis, Radix sp., Anodonta sp., Pisidium casertanum, P. obtusale* and *P. sp.* were detected. At the same time frame we expect the onset of the fluvio-lacustrine filling from a 'Paleo-Mildenitz' river flowing generally from N to S. Several delta cones in lake sediments give evidence of a still considerable fluvial influx which filled up the Dobbertin basin fringes with fluviolacustrine deposits. The marginal delta cone deposits are interlocked with calcarous limnic layers (Fig. 3).

***Fig. 2**: Glaciolacustrine sequence of deglaciation of Frankfurt Phase in Dobbertin basin, which is penetrated by large ice wedge casts (profile hight 2.5 m). Above ice wedge filling and glaciofluvial sands horizontally bedded sands of fluviolacustrine deposition during Late glacial period are visible.*

***Fig. 3**: Interlocked sequence of fluvio-lacustrine deposition at the edge of delta cone and lake basin. The upper sequence of the former basin centre is filled by horizontally bedded calcareous gyttja (grey) and in uppermost part by Holocene peat (pict.: A. Börner).*

The main fluvio-lacustrine phase is dated to Allerød interstadial. Towards the end of this period the lake level decreased and fluvial delta interlocked with limnic deposits filled the deeper basin zone. Its sedimentation history is well recorded in several profiles of calcareous and silicate gyttjas, whereas sedimentary units derived from organic and inorganic carbon content as well as grain size distribution allows a stratigraphical comparison of different profiles. The lake phase with high lake levels ended during Younger Dryas/Preboreal transition, when the Dobbin basin was drained by the formation of the river Mildenitz transverse valley. Delta cones in Lake 'Schwarzer See', NW situated (Fig. 1) and the incision into the 5 m river terrace within the so called 'Mildenitz-Durchbruchstal' indicate the flow reversal of river Mildenitz from southern to northern direction (Baltic sea basin). The uppermost sediment sequence in the Dobbertin basin is represented by a pattern of decomposed Holocene peat.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis --ICLEA-- of the Helmholtz Association.

References

Litt, T., Behre, K.-E., Meyer, K.-D., Stephan, H.-J. & Wansa, S., 2007. Stratigraphische Begriffe für das Quartär des norddeutschen Vereisungsgebietes. – Eiszeitalter u. Gegenwart, 56: 7-65; Hannover.

Lorenz, S., Börner, A., Niessner, D., Słowiński, M., Zawiska, I., Theuerkauf, M., Fülling, A., Schult, M. & Lampe, R., 2015. Das Paläoseebecken nördlich von Dobbertin. – In: Börner et al. (Red.): Tagungsband 79. Tagung der Arbeitsgemeinschaft Norddeutscher Geologen. LUNG-Heft 1/2015: 273-281, Güstrow.

DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Using historical encyclopedic works in geospatial reconstruction of hydraulic structures in the rivers of Central and Eastern Europe

Brykała, Dariusz[1]*; Dziembowski, Michał[1]; Masloch, Katarzyna[2]; Siudek, Wojciech[2]; Tomczak, Sandra[2]; Lamparski, Piotr[1]; Majerska, Marta[3]; Kujawa, Przemysław[3]; Baniewska, Anna[3]; Skorupka, Barbara[3] & Borkowski, Sławomir[3]

[1] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
[2] Nicolaus Copernicus University, Faculty of History, Toruń, Poland
[3] Nicolaus Copernicus University, Faculty of Earth Sciences, Poland
*Corresponding author: darek@geopan.torun.pl

Among the many types of data sources for research on the reconstruction of changes in the geographical environment, descriptive and statistical sources play an important role in characterising the extent of anthropopression in the studied area. Such sources include the first monographs of cities and regions as well as encyclopedic works. The first studies of this type in Europe were created already in the ancient times. Over the centuries, they became increasingly detailed and included smaller and smaller administrative units.

One example of such work is the *"Słownik geograficzny Królestwa Polskiego i innych krajów słowiańskich"* (in English: *"Geographical Dictionary of the Kingdom of Poland and other Slavic countries"*) published in the years 1880-1895. The "*Słownik*" was supposed to be informative and describe the territories of the Commonwealth of Two Nations within pre-1772 borders (currently: Poland, Lithuania, Latvia, Estonia, Russia, Belarus, Ukraine, Moldova). In practice, it covered not only the above terrain, but also extensive neighbouring areas (e.g. the European part of Russia, the Czech Republic, Romania, Germany – see Fig. 1).

The 15 volumes of the "Dictionary" have a total of about 15,000 pages and contain about 200,000 entries. They concern regions, towns, villages and economic settlements, as well as rivers, lakes, ponds and mountain peaks. These entries are very diverse in terms of content and detail because they were based on the materials sent by correspondents with different background and knowledge of the region. As many as 685 people helped with the editorial work of the "*Słownik*", and about 150 people authored the entries.

The reason for the creation of the "*Słownik*" was connected with the fact that by the second half of the nineteenth century there was no detailed, comprehensive and up-to-date geographical analysis of the Polish lands. The particular value of the "*Słownik*" is evidenced by the fact that many sources on which the entries were based, were lost or destroyed. This applies mainly to smaller towns and factory settlements. Hence, this work is an important source of geographical, historical, economic, demographic and biographical information. The information contained in the "*Słownik*" presents the situation of changes in the use of hydroelectric power shortly after the industrial revolution of the mid-nineteenth century.

In the first stage of the research, a database of all watermills and other water-using plants listed in the "*Słownik*" was created. The following types of facilities were taken into account: stationary watermills (grain mills), floating mills, sawmills, fulling mills and paper mills. The database covers about 25,000 references of about 70,000 such objects. The database has also been expanded to include information on all artificial water bodies (breeding ponds, mill ponds, eel ponds, pools) as they show the degree of change in the natural fluvial conditions of river systems.

The "*Słownik*" contains information both on individual objects and groups of them. For this reason, it was decided to include this division when creating the database and visualising the results. Assigning geographic coordinates (UTM) to individual hydroelectric plants listed in the "*Słownik*" proved to be a very time consuming step. Determination of the location for 90% of all objects was successful.

By using the Geographic Information Systems tools, the distribution of objects from the database was visualised. This allowed a thorough spatial analysis and correlation between the morphological and economic factors influencing the location of the hydrotechnical objects in question.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

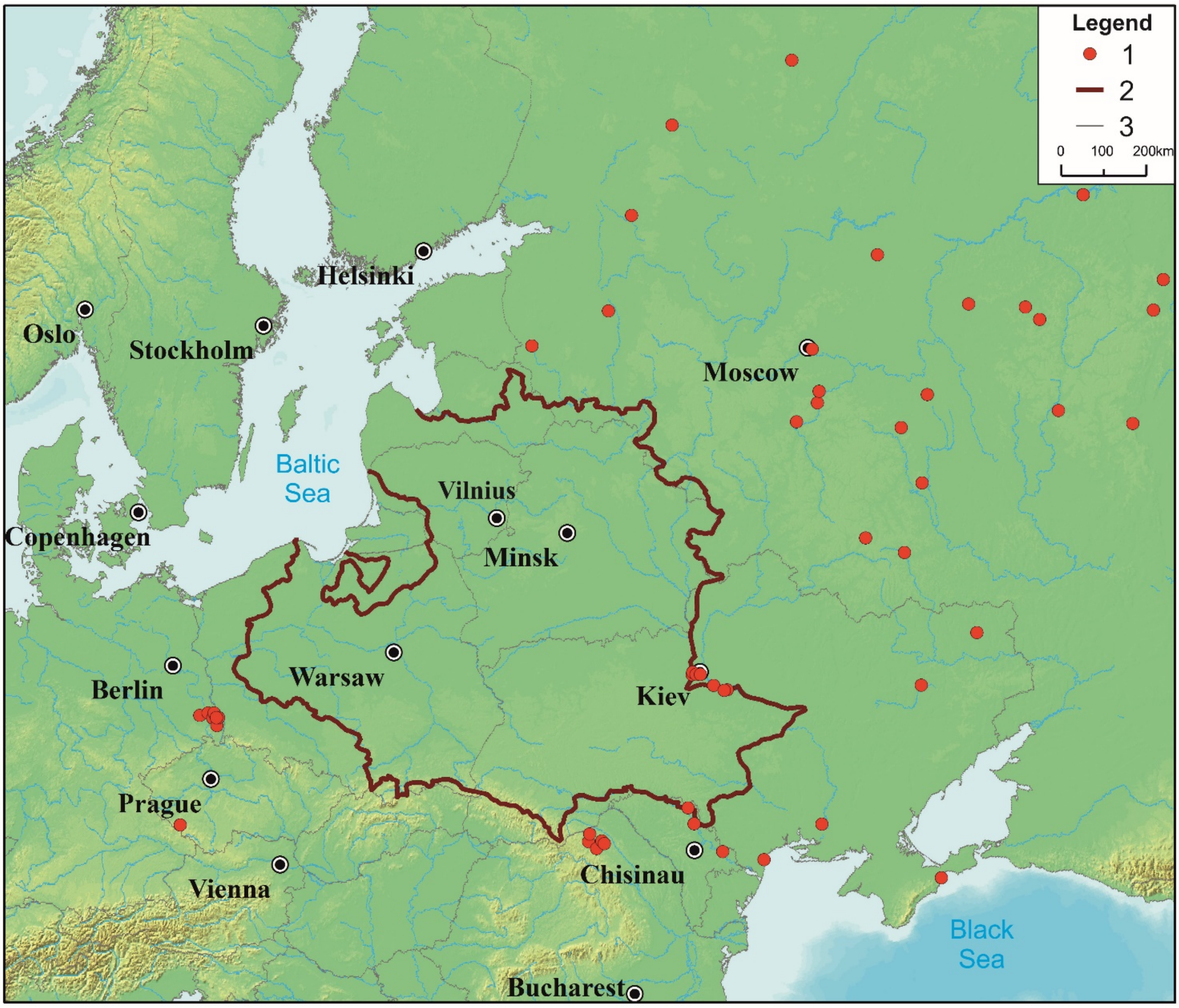


***Fig. 1**: The spatial coverage of the information about water management included to "Słownik". 1 – examples of watermills recorded outside the borders of pre-1772 Poland; 2 – border of pre-1772 Poland; 3 – recent borders of states.*

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and the National Science Centre, Poland (grant No. DEC-2011/03/D/HS3/03631).

References

Callier, E., 1882. Uwagi krytyczne nad Słownikiem Geograficznym Królestwa Polskiego, Poznań.

Czarnecki, S., 1934. Dawny i nowy słownik geograficzny ziem polskich, Warszawa.

Parucki, Z., 1955. Słownik Geograficzny Królestwa Polskiego jako źródło do badań rozmieszczenia sił wytwórczych kapitalizmu w Polsce, [in:] Dokumentacja Geograficzna, 5, Warszawa.

Siniarska-Czaplicka, J., 1966. Papiernictwo na ziemiach środkowej Polski w latach 1750-1850, [in:] Studia z Dziejów Rzemiosła i Przemysłu, vol. VI, p. 123-232.

Słownik geograficzny Królestwa Polskiego i innych krajów słowiańskich (eds. F. Sulimierski, W. Walewski, J. Krzywicki & B. Chlebowski), 1880-1904. Vol. 1-15, Warszawa.

Targowski, M., 2000. „Słownik geograficzny Królestwa Polskiego i innych krajów słowiańskich" jako źródło informacji o archiwach, [in:] Pamiętnik III Ogólnopolskiego Zjazdu Studentów Archiwistyki w Lublinie (ed. J. Łosowski), Lublin, p. 173-187.

Session 3: Integrating time-scales and regional synchronization

Tree-growth divergence – a global phenomenon?

Buras, Allan[1]*; Sass-Klaassen, Ute[2] & Wilmking, Martin[3]

[1] Technische Universität München, Ecoclimatology, Freising, Germany
[2] Wageningen University and Research, Forest Ecology and Forest Management, Wageningen, Netherlands
[3] Greifswald University, Landscape Ecology and Ecosystem Dynamics, Greifswald, Germany
* Corresponding author: allan@buras.eu

Tree-ring data are considered an essential cornerstone of paleoclimatology and a valuable tool for predicting climate change impacts on and carbon dynamics of forest ecosystems. However, a growing body of literature indicates, that the standard dendrochronological approach to evaluate tree-ring data may too rigorously neglect individualistic tree-growth: Trees of the same species sampled at one site often express different long-term growth patterns and therefore differing climate-growth relationships. This phenomenon is commonly termed growth divergence (GD) and might weaken our ability to correctly estimate past climatic extremes and variability, project future forest growth and benchmark mechanistic models. Yet, there is a complete lack of detailed information on the frequency, magnitude and severity of GD occurrence.

Here, we present results from a global GD assessment covering 135 data-sets from 50 tree species distributed over 116 sites across 22 countries. GD is assessed using the Principal Component Gradient analysis (PCGA, Buras et al., 2016) – a multivariate technique which was specifically designed to identify multiple signals in time-series populations such as tree-ring data. Moreover we analysed whether and if so how the consideration of GD impacts tree-ring based climate reconstruction. That is, we compared transfer functions based on standard master chronologies with transfer functions based on PCGA-responder chronologies with respect to their predictive power (r^2) and temporal stability using the bootstrapped transfer function stability test (BTFS, Buras et al., 2017). Finally, to get a deeper understanding of GD drivers, we performed a multiple linear regression to explain GD magnitude which we expressed using the correlation between the extreme responder chronologies.

We found clear signs of GD in 85 percent of all data-sets distributed over all investigated sites (Fig. 1).

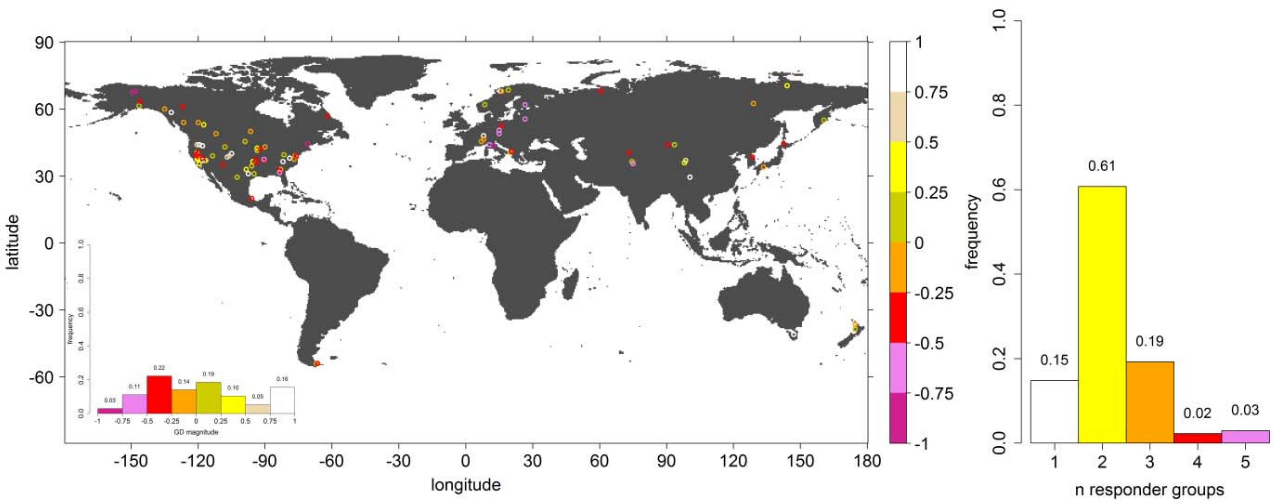


Fig. 1*: Distribution and magnitude of growth divergence expressed by extreme responder chronology correlation (left, the lower the correlation and the more violet the colour the stronger the growth divergence) and frequency distribution of the number of identified responder groups (right).*

When accounting for GD, stability of climate-growth relationships and explained variance of climate transfer functions increased remarkably. A multiple linear regression based on sample size, latitude, and climatic water balance was significant and able to explain 34 percent of global GD variations. These results advocate for an incorporation of GD assessments into dendrochronology to increase the precision of tree-ring based climate reconstructions as well as the prediction of forest ecosystem responses to global change. Since GD appears to be a global phenomenon, the driving mechanisms behind it need to be identified. Based on three case studies from Southern Bavaria, Franconia, and Poland which are presented it appears that light exposition as well as air pollution may trigger GD.

References

Buras, A., van der Maaten-Theunissen, M., van der Maaten, E., Ahlgrimm, S., Hermann, P., Simard, S., Heinrich, I., Helle, G., Unterseher, M., Schnittler, M., Eusemann, P., Wilmking, M., 2016. Tuning the Voices of a Choir: Detecting Ecological Gradients in Time-Series Populations. *PLOS ONE* 11, e0158346.

Buras, A., Zang, C., and Menzel, A., 2017. Testing the stability of transfer functions. Dendrochronologia 42, 56-62.

Session 3: Integrating time-scales and regional synchronization

Synchronizing the time-scales of the varved Lakes Tiefer See/Czechowskie sediment records to IntCal13 using the common cosmogenic radionuclide variations

Czymzik, Markus[1,2]*; Muscheler, Raimund[2]; Adolphi, Florian[2]; Mekhaldi, Florian[2]; Dräger, Nadine[1]; Ott, Florian[1]; Błaszkiewicz, Mirosław[3]; Słowiński, Michał[3]; Aldahan, Ala[4]; Possnert, Göran[5] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[2] Lund University, Department of Geology, Lund, Sweden
[3] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
[4] United Arab Emirates University, Department of Geology, Al Ain, United Arab Emirates
[5] Uppsala University, Tandem Laboratory, Uppsala, Sweden
* Corresponding author: mczymzik@gfz-potsdam.de

Paleoclimate archives provide unique insights into the dynamics of the climate system under varying forcing conditions. Particularly the timing and spatial patterns of climate variations can provide valuable information about the driving mechanisms. However, time-scale uncertainties between different paleoclimate/paleoforcing records often inhibit a detailed investigation of such climate variations.

Cosmogenic radionuclides like ^{10}Be and ^{14}C are produced in the upper atmosphere through a cascade of nuclear reactions by incident high energy galactic cosmic rays. The flux of these galactic cosmic rays towards Earth's atmosphere is modulated by changes in helio- and geomagnetic field strength (Lal and Peters, 1967). Detecting and aligning the externally forced and globally uniform cosmogenic radionuclide production signal provides a tool for synchronizing natural environmental archives around the globe (Muscheler et al., 2014).

To date, such synchronization studies are limited to ^{10}Be records from polar ice cores and ^{14}C time-series from trees. Here, we apply this approach for synchronizing ^{10}Be records from varved sediments of Lakes Tiefer See and Czechowskie around the grand solar minima 250 a BP (Maunder Minimum), 2700 a BP (Homeric Minimum) and 5500 a BP to ^{14}C production rates inferred from the IntCal13 calibration curve (Reimer et al., 2013; Muscheler et al., 2014).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

^{10}Be concentrations were measured in sediment samples from Lakes Tiefer See and Czechowskie using accelerator mass spectrometry. In an attempt for correct for possible environmental influences on ^{10}Be deposition, multiple regression analyses were applied integrating proxy time-series from the same archive. Since this procedure can also reduce solar production variability in the ^{10}Be records as imprinted by possible Sun-climate linkages in the proxy time-series, ^{10}Be composites were calculated by averaging the original ^{10}Be concentration and environment-corrected ^{10}Be records. Best fits between the ^{10}Be composites from Lakes Tiefer See and Czechowskie with ^{14}C production rates from the IntCal13 calibration curve were determined using windowed cross-correlation. Significances of the correlations were calculated using 10000 iterations of a non-parametric random phase test (Ebisuzaki, 1997).

^{10}Be concentrations in Lakes Tiefer See and Czechowskie sediments show multi-decadal to centennial variability (Fig. 1). ^{10}Be concentrations vary between 1.1 and 7.1 x 10^8 atoms g^{-1} in Lake Tiefer See sediments and 0.9 and 3.8 x 10^8 atoms g^{-1} in Lake Czechowskie sediments. Correcting for possible environmental influences on ^{10}Be deposition mainly modifies amplitudes, but does not distinctly change multi-decadal excursions in the ^{10}Be concentration records, providing confidence in the detected ^{10}Be signals (Fig. 1).

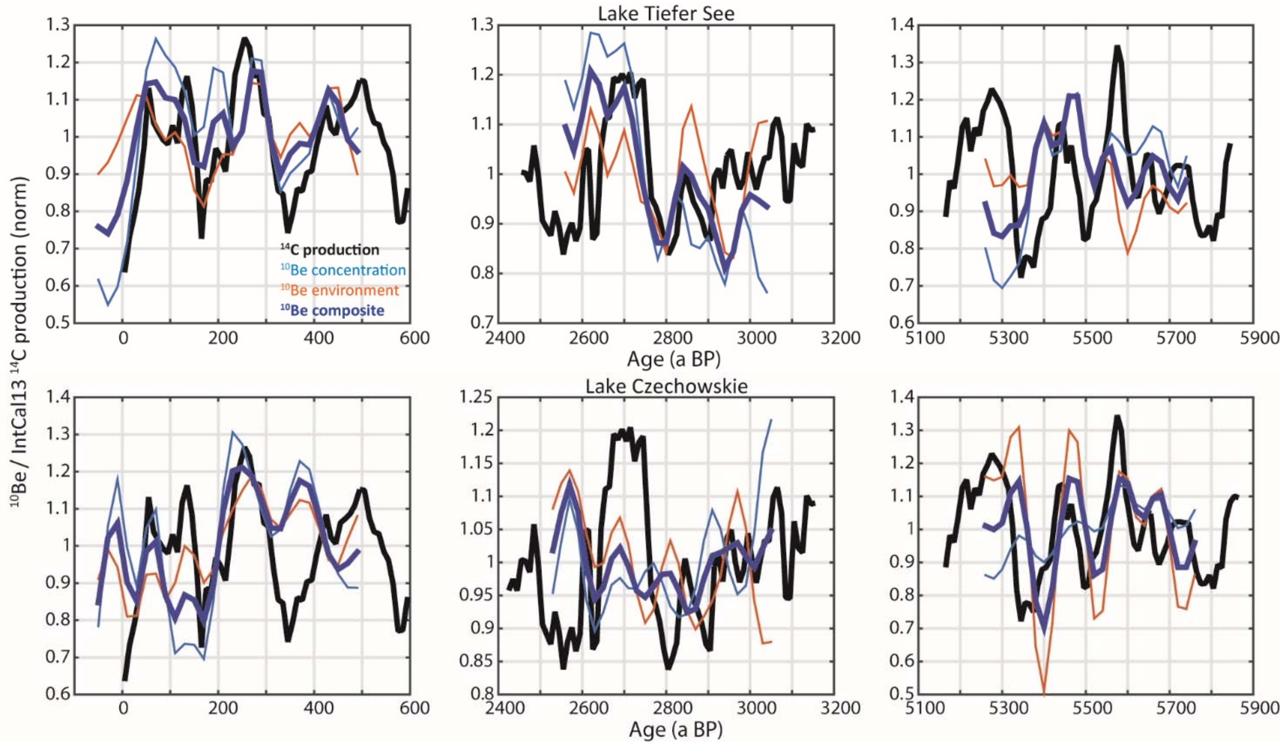


Fig. 1: *^{10}Be concentrations, environment-corrected ^{10}Be and ^{10}Be composites from varved Lakes Tiefer See and Czechowskie sediments compared with ^{14}C production rates inferred from the IntCal13 calibration curve. All ^{10}Be records are 75-year low-pass filtered, to reduce noise.*

Synchronizing the ^{10}Be composites to IntCal13 ^{14}C production rates by means of windowed cross correlation provided significant correlations during the Maunder-, Homeric- and 5500 a BP grand solar minimum for Lake Tiefer See and during the 5500 a BP grand solar minimum for Lake Czechowskie. Highest significant correlations occur, when the ^{10}Be composites from Lake Tiefer See are shifted for 1 (Maunder Minimum), 39 (Homeric Minimum) and 80 (grand solar minimum 5500 a BP) years into the past. The best fits are within varve counting uncertainties for the Maunder- and Homeric Minimum, and 6 years outside the given varve counting uncertainty of ±74 years for the 5500 a BP grand solar minimum. The highest significant correlation between the ^{10}Be composite from Lake Czechowskie during the 5500 a BP grand solar minimum and IntCal13 ^{14}C production rates occurs when the ^{10}Be record is shifted for 30 years towards younger times (within varve counting uncertainties). No significant correlations with IntCal13 ^{14}C production rates were detected for the ^{10}Be composites from Lake Czechowskie around the Maunder- and Homeric Minimum. The discrepancies

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

between the cosmogenic radionuclide records might be explained by redepositon of ‘old’ ^{10}Be in the relatively large catchment of Lake Czechowskie and/or inhomogeneous ^{10}Be deposition related to changing atmospheric circulation and precipitation.

We use the synchronous IntCal13 ^{14}C production (solar activity) and paleoclimate records from Lake Tiefer See around the Maunder-, Homeric- and 5500 a BP grand solar minimum for preliminary investigations of possible Sun-climate connections. Significant correlations between solar activity and varve thickness point to a solar influence on climate at Lake Tiefer See during the Maunder- and Homeric Minimum, whereas both variables are not significantly correlated during the 5500 a BP grand solar minimum. Varve thickness reductions during the Maunder- and Homeric Minimum in Lake Tiefer See sediments are mainly caused by decreased sedimentary diatom abundances. Previous studies on lake sediments from north-eastern Germany suggest that reductions in diatom abundances are caused by shorter mixing periods during colder climate states (Dreßler et al., 2011). Presumably, colder conditions during the Maunder- and Homeric Minimum also led to the observed reduction in diatom productivity in Lake Tiefer See. The absence of a clear linkage between solar activity and varve thickness during the grand solar minimum 5500 a BP might be explained by warmer temperatures during the Holocene Thermal Optimum, potentially overprinting solar induced cooling effects on diatom productivity.

Synchronizing ^{10}Be records from Lake Tiefer See sediments during the Maunder-, Homeric- and 5500 a BP grand solar minimum as well as from Lake Czechowskie sediments during the 5500 a BP grand solar minimum to IntCal13 ^{14}C production rates provided novel time-markers for improving the connected varve chronologies. However, a lack of co-varying changes between IntCal13 ^{14}C production rates and ^{10}Be records from Lake Czechowskie during the Maunder- and Homeric Minimum also point to the importance of transport and catchment processes on ^{10}Be deposition. Investigating Sun-climate linkages based on synchronized cosmogenic radionuclide and paleoclimate records from Lake Tiefer See allowed us robust studies of Sun-climate connections, with negligible time-scale uncertainties between the solar activity and paleoclimate record.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA) of the Helmholtz Association.

References

Dreßler, M., A. Schwarz, T. Hübener, S. Adler, and B. W. Scharf, 2011. Use of sedimentary diatoms from multiple lakes to distinguish between past changes in trophic state and climate: Evidence for climate change in northern Germany during the past 5,000 years, *J. Paleolimnol.*, *45*, 223–241.

Ebisuzaki, W., 1997. A method to estimate the statistical significance of a correlation when the data are serially correlated, *J. Clim.*, *10*, 2147–2153.

Lal, D., and B. Peters, 1967. Cosmic ray produced radioactivity on the Earth, in *Handbuch der Physik*, edited by S. Flügge, pp. 551–612, Springer, Berlin.

Muscheler, R., F. Adolphi, and M. F. Knudsen, 2014. Assessing the differences between the IntCal and Greenland ice-core time scales for the last 14,000 years via the common cosmogenic radionuclide variations, *Quat. Sci. Rev.*, *106*, 81–87.

Reimer, P. J. et al., 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP, *Radiocarbon*, *55*, 1869–1887.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 3: Integrating time-scales and regional synchronization

Holocene lake level changes related to multiple driving mechanisms at Fürstenseer See, NE-Germany

Dietze, Elisabeth[1]*; Słowiński, Michał[2]; Zawiska, Izabela[3]; Veh, Georg[4] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[2] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland

[3] Polish Academy of Sciences, Department of Geoecology and Climatology, Institute of Geography and Spatial Organization, Warsaw, Poland

[4] University of Potsdam, Institute for Earth and Environmental Sciences, Potsdam, Germany

* Corresponding author: edietze@gfz-potsdam.de

The Fürstenseer See-Hinnensee is a complex lake basin that formed during and after meltdown of the Weichselian ice sheet. The lake sediments consist of alternating organic and carbonate-rich muds that accumulated on top of glaciofluvial sands (Dietze et al., 2016).

To reconstruct Holocene lake level changes, an acoustic sub-bottom profile across the deepest sub-basin was compared with sediment facies and lake sediment properties along a transect of five sediment cores. Shifts in the boundary between sand and mud deposition allowed reconstructing minimum and maximum lake extents. These have been linked with continuous carbonate deposition in the deep basin. During low lake levels, high amounts of carbonate have deposited and preserved due to the isolation of sub-basins, whereas carbonate was lacking in organic-rich muds that accumulated during high lake stands (Dietze et al., 2016).

In the early Holocene (>9700 cal. yrs BP), lake levels were rather high probably due to final melting of subsurface remains of permafrost and dead-ice in the sandy areas of the northern central European lowlands (Błaszkiewicz et al., 2015). When pine (-birch-oak) forests established on sandy soils generally lower, but fluctuating lake levels (3-4 m below modern) were reconstructed for the period between 9700 and 6400 cal. yrs BP. This type of forest could efficiently consume water (Guswa and Spence 2012), especially under warmer conditions. The transition towards a cooler and wetter late Holocene could explain the subsequent trend towards increasing lake levels that reached a short-term high-stand of 4 m above modern at around 5000 cal. yrs BP (Dietze et al., 2016). Forests were dominated by beech and oak that route much more water towards the ground than pine stands and, hence, contributed to positive groundwater recharge (Guswa and Spence, 2012). Lake levels remained high between 3800 and 800 cal. a BP, when also initial human impact started to open the landscape (initiation of forest clearance, forest grazing, Küster et al., 2014). This could sustain the high water level, but the lake sediments did not record further short-term fluctuations during this period. Lake level changes were recorded again after 800 cal. yrs BP, when humans profoundly affected the lake by altering the drainage system, regional land cover and lake trophy. This led to locally diverse hydrological changes. At Lake Fürstenseer See, lower lake stands were recorded during the 12th and 15th/16th century AD, while during the 13th and 14th century AD a 3 m higher lake stand was recorded also by onshore morphological and sedimentological evidence (Kaiser et al., 2014). With the forest management shift towards conservation during the 18th century (Messner, 2009), the water levels reached the modern state, but lake sediments did not record the fluctuations of 1.3 m observed during the measurement period (1973-2010).

Hence, the lake sediments of Fürstenseer See indicated that Holocene lake level amplitudes clearly exceeded the observed modern lake level fluctuations. An absolute range of +/- 4 m shift in lake level compared to today was reconstructed for the Early-Mid-Holocene between 10000 and 4000 cal. yrs BP. Within a few millennia the lake area dropped by half or has increased threefold compared to today's extent (Fig. 1), in a time when human impact on the drainage system was negligible. Rather, local and regional vegetation cover after the glacial period affected ground- and lake water level changes in interaction with insolation-driven climatic change (Dietze et al., 2016).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The feedbacks between past climate change, catchment configuration, vegetation history and human impact, that explain local Holocene water level changes, imply that future regional forest and water management under a warming world could a) face much stronger water level shifts than measured so far and b) needs more time-scale dependent process-understanding of the close interaction of the hydrological system with climate and land cover change in this water-dominated landscape.

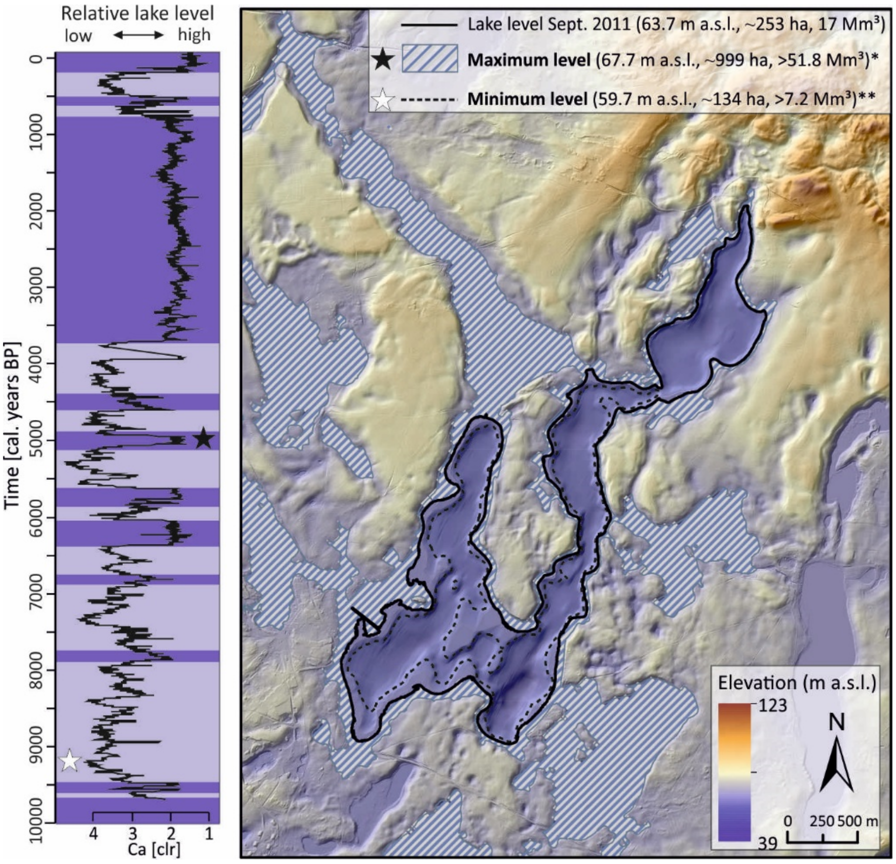


***Fig. 1**: Holocene lake level changes at Lake Fürstenseer See-Hinnensee. Left, relative fluctuations have been reconstructed by the Ca-deposition for the last 10000 years with dark (light) blue bars representing periods of relatively higher (lower) lake levels. Black (white) star indicates the reconstructed absolute maximum (minimum) lake extensions that are shown in the map (right). Figures after Dietze et al. (2016).*

References

Błaszkiewicz, M., Piotrowski, J. A., Brauer, A., Gierszewski, P., Kordowski, J., Kramkowski, M., Lamparski, P., Lorenz, S., Noryśkiewicz, A. M., Ott, F., Słowiński, M. & Tyszkowski, S., 2015. Climatic and morphological controls on diachronous postglacial lake and river valley evolution in the area of Last Glaciation, northern Poland. Quaternary Science Reviews 109, 13-27.

Dietze, E., Słowiński, M., Zawiska, I., Veh, G. & Brauer, A., 2016. Multiple drivers of Holocene lake level changes at a lowland lake in northeastern Germany. Boreas 45, 828-845.

Guswa, A. J. & Spence, M., 2012. Effect of throughfall variability on recharge: application to hemlock and deciduous forests in western Massachusetts. Ecohydrology 5, 563-574.

Kaiser, K., Küster, M., Fülling, A., Theuerkauf, M., Dietze, E., Graventein, H., Koch, P. J., Bens, O. & Brauer, A., 2014b. Littoral landforms and pedosedimentary sequences indicating late Holocene lake-level changes in northern central Europe — A case study from northeastern Germany. Geomorphology 216, 58-78.

Küster, M., Fülling, A., Kaiser, K. & Ulrich, J., 2014. Aeolian sands and buried soils in the Mecklenburg Lake District, NE Germany: Holocene land-use history and pedo-geomorphic response. Geomorphology 211, 64-76.

Messner, G., 2009. Geschichte der Müritz-Nationalparkregion. 208 pp. Förderverein Müritz-Nationalpark e.V., Neubrandenburg.

DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Holocene fire regimes of the central European lowlands: man-vegetation-climate feedbacks

Dietze, Elisabeth[1]*; Theuerkauf, Martin[2]; Słowiński, Michał[3]; Brauer, Achim[1] & the CEL fire synthesis team[4]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[2] University of Greifswald, Institute of Geography and Geology, Greifswald, Germany

[3] Polish Academy of Sciences, Stanisław Leszczycki Institute of Geography and Spatial Organization, Warsaw, Poland

[4] *CEL fire synthesis team*: A. Feurdean, M. Stančikaitė, S. Veski, A. Poska, N. Stivrins, J. Vassiljev, M. Obremska, M. Lamentowicz, M. Latałowa, A. Pędziszewska, A. Wacnik, M. Szal, D. Weisbrodt, J. Swieta-Musznicka, J. Gadziszewska, K. Bloom, K. Marcisz, P. Kołaczek, S. Lauterbach, W. Dörfler, I. Feeser, N. Dräger, F. Ott, T. Giesecke, S. Jahns, M. Wieckowska-Lüth & J. Wiethold

* Corresponding author: edietze@gfz-potsdam.de

The central European lowlands (CEL), south of the Baltic Sea, are characterized by clear gradients in modern climate (temperature, precipitation; Metzger et al., 2005). In particular, a more continental climate prevails in northern Poland compared to northern Germany and the Baltic states. The CEL share a similar geological history because the Scandinavian Ice Sheet covered this area during the last glaciation. Its retreat left a diverse geomorphological and pedological setting that provided the scene for the migration of natural vegetation during the late Glacial and early Holocene. This setting also influenced human settlement history during the Holocene, as not all soil types were equally suitable for land use (Kaplan et al., 2009). Accordingly, Holocene land cover history shows a complex regional pattern as evidenced by regional palynological records (Nielsen et al., 2012). Many questions, for example about the intensity of past human land use and the interaction with natural climate and vegetation change, are still open. One way to disentangle these interactions is the study of multiple palaeoecological and sedimentological proxies in lake and peatland archives that recorded past environmental conditions.

A rarely interpreted proxy in this region is sedimentary charcoal, a proxy for past fire activity. Natural forest fires in the region are today largely restricted to pine forest as temperate deciduous forests are not fire-prone, yet little is known about natural fire activity in the different climate of the early and mid-Holocene. Furthermore, today's forest fires are largely suppressed by forest management, whereas human activity in the past could be responsible for extensive biomass burning. Fire has been used, for example, as tool to clear forests, to fertilize agricultural land or to drive technological advances. However, little is known about past interactions of human activity, climate, fire and vegetation in this region.

We will present a first synthesis of Holocene fire history along a spatial gradient from northern Germany to the Baltic countries, north of the maximum extent of the last glaciation (Fig. 1). The synthesis is based on c. 60 sedimentary charcoal records of different time resolution and spatial coverage (Fig. 2), from lakes and peat archives. Sites have been grouped according to modern environmental parameters (Metzger et al., 2005, EEA, 2006) and political boundaries. By comparing charcoal composites of several regional and climatic clusters (composite over all sites: Fig. 2), we discuss a) potential climatic drivers (e.g. temperature vs. precipitation that affect the burning potential of the fuel) and b) the impact of different human land use histories. By a comparison with quantitative vegetation reconstructions (REVEALS transformed pollen records of well-dated key sites), the relationship of land cover, land use, fire and climate will be discussed. The results show that after the early Holocene decline in pine forests, charcoal records are predominantly related to human land use histories.

Hence, paleofire reconstruction have a high potential to help disentangling the past human-climate interaction. In an outlook, a new multi-fire proxy approach that combines classical proxies (macrocharcoal of size classes) with new molecular markers (levoglucosan, mannosan and galactosan) is illustrated by the example of varved, northern Polish lake Czechowskie. This approach will allow far more specific paleofire regime reconstructions in the future.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

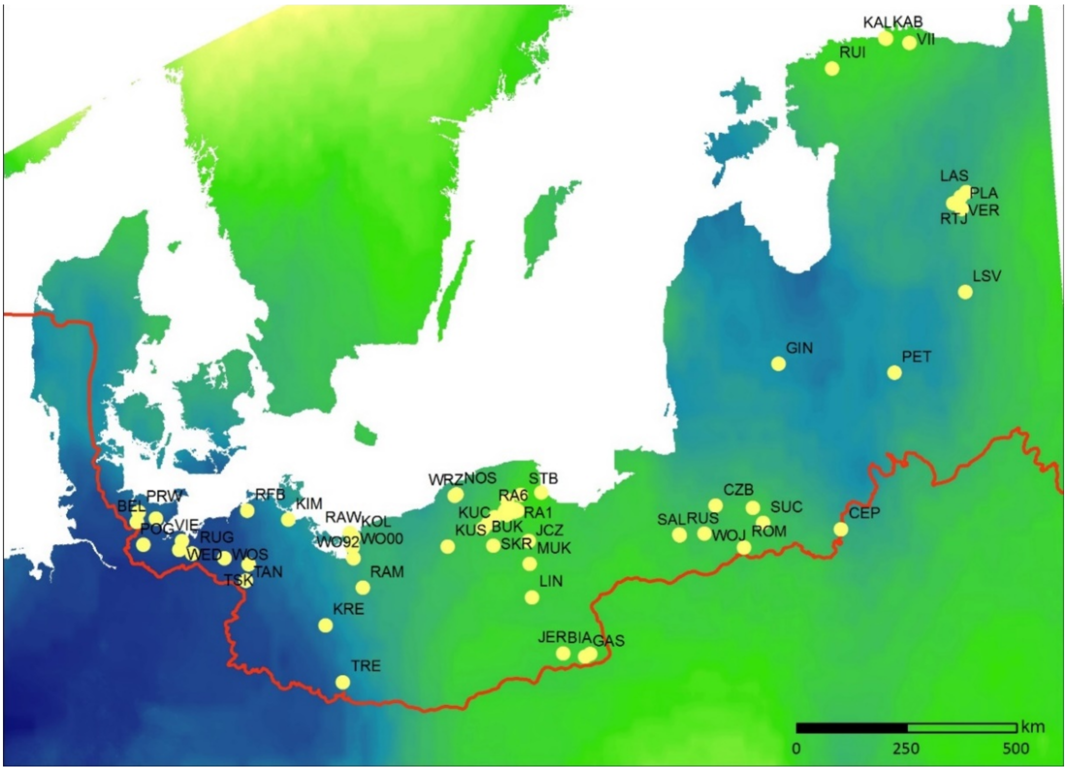


***Fig. 1**: Sites with charcoal records in the central European lowlands. Map background: continentality gradients (from high to low = light green to dark blue, Metzger et al., 2005). Red lines marks last maximum extent of the Scandinavian Ice Sheet (Hardt and Böse, 2017).*

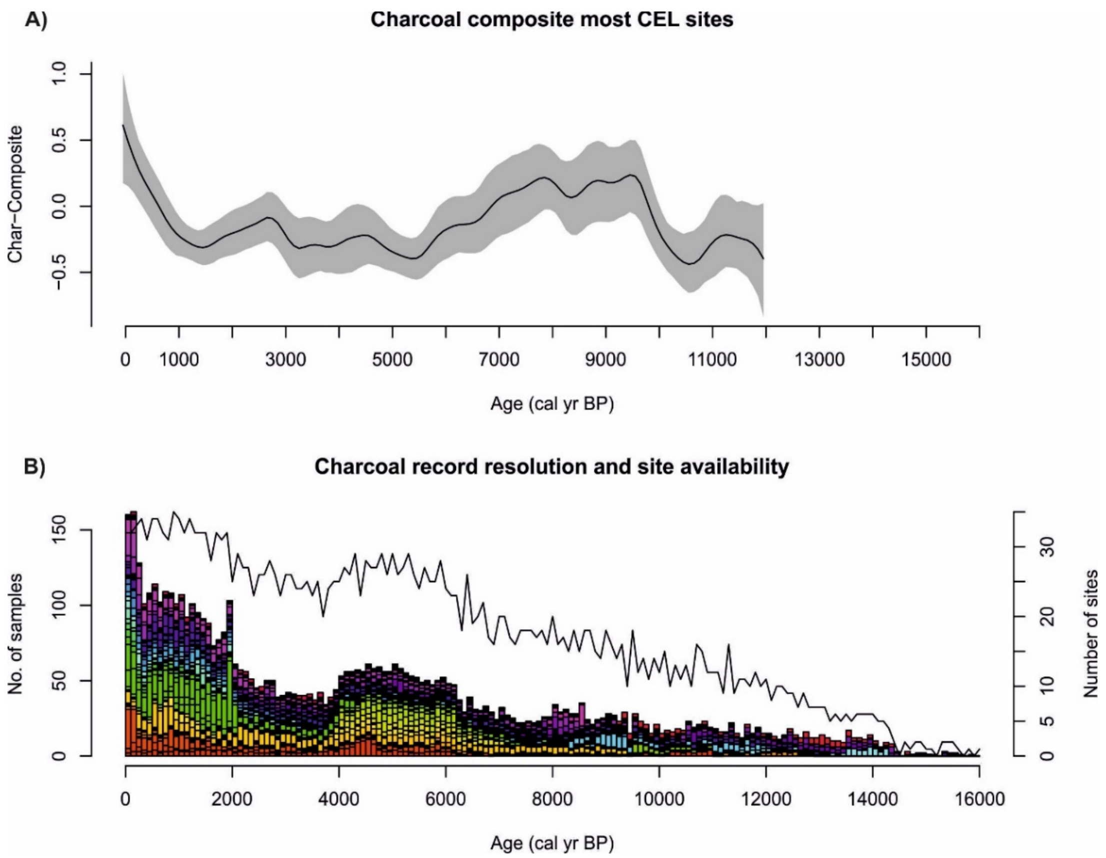


***Fig. 2**: A: Charcoal composite of 53 CEL sites that have been available until mid April 2017 calculated using the R paleofire package (Blarquez et al., 2014). B: Sample resolution in 100 year bins for each site and site availability during the Holocene that are the base for the charcoal composite in A.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

References

Blarquez, O., Vannière, B., Marlon, J.R., Daniau, A.-L., Power, M.J., Brewer, S., Bartlein, P.J., 2014. paleofire: An R package to analyse sedimentary charcoal records from the Global Charcoal Database to reconstruct past biomass burning. Computers & Geosciences 72, 255-261.

EEA (European Environment Agency), 2006. CORINE land cover data. http://land.copernicus.eu/pan-european/corine-land-cover/clc-2006

Hardt, J., Böse, M., 2016. The timing of the Weichselian Pomeranian ice marginal position south of the Baltic Sea: A critical review of morphological and geochronological results, Quaternary International, http://dx.doi.org/10.1016/j.quaint.2016.07.044

Kaplan, J.O., Krumhardt, K.M., Zimmermann, N., 2009. The prehistoric and preindustrial deforestation of Europe. Quaternary Science Reviews 28, 3016-3034.

Metzger, M.J., Bunce, R.G.H., Jongman, R.H.G., Mucher, C.A., Watkins, J.W., 2005. A climatic stratification of the environment of Europe. Global Ecology and Biogeography 14, 549–563.

Nielsen, A.B., Giesecke, T., Theuerkauf, M., Feeser, I., Behre, K.-E., Beug, H.-J., Chen, S.-H., Christiansen, J., Dörfler, W., Endtmann, E., Jahns, S., de Klerk, P., Kühl, N., Latałowa, M., Odgaard, B.V., Rasmussen, P., Stockholm, J.R., Voigt, R., Wiethold, J., Wolters, S., 2012. Quantitative reconstructions of changes in regional openness in north-central Europe reveal new insights into old questions. Quaternary Science Reviews 47, 131-149.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Holocene climate fluctuations of Volhynia Upland recorded in spring-fed fen deposits from Komarów site (SE Poland)

Dobrowolski, Radosław[1]*; Bałaga, Krystyna[1]; Buczek, Alicja[2]; Alexandrowicz, Witold Paweł[3]; Mazurek, Małgorzata[4]; Hałas, Stanisław[5] & Piotrowska, Natalia[6]

[1] Maria Curie-Skłodowska University, Faculty of Earth Sciences and Spatial Managements, Lublin, Poland;
[2] University of Life Sciences, Faculty of Horticulture, Lublin, Poland
[3] University of Science and Technology, Faculty of Geology, Geophysics and Environment Protection, Krakow, Poland
[4] Adam Mickiewicz University, Institute of Geoecology and Geoinformation, Poznań, Poland
[5] Maria Curie-Skłodowska University, Institute of Physics, Lublin, Poland
[6] Silesian University of Technology, Institute of Physics, Gliwice, Poland
* Corresponding author: radoslaw.dobrowolski@umcs.pl

Spring-fed fens are a special group of palaeoenvironmental data archives. They belong to the rare group of soligenous mires supplied with ascending groundwater outflow. They cover small areas and form cupolas, which occur mostly within larger mire complexes with different natures of supply. Besides the specific vegetation composition and morphology, spring-fed fens are distinguished by a special lithology of deposits, i.e. the alternating occurrence of peat and calcareous tufa layers (Succow, 1988; Dobrowolski, 2011), stratigraphically representing often the whole Holocene. Due to the continuous record of biogenic-carbonate deposition such fens are highly suitable for detailed palaeoenvironmental studies, including palaeoclimatic. As the course of carbonate deposition is closely connected with the surrounding environment, the tufa layers can be an important indicator of humidity-temperature changes in the Holocene.

The Komarów spring-fed fen in the Volhynia Upland (SE Poland) is the first peatland of this type in the eastern part of Europe for which multi-proxy data have been gathered to reconstruct past ecological changes. Radiocarbon-dated spring-fed fen deposits, with its multi-proxy data (macrofossils, molluscs, geochemistry, pollen, stable isotopes of oxygen and carbon) enable us: (1) to distinguish four main stages of fen evolution, which reflected a distinct variability of water supply conditions, and (2) to reconstruct the Holocene humidity-temperature changes. The beginning of peat-tufa deposition took place in a Boreal phase, after a significant cool fluctuation of climate occurring *ca.* 9.4 ka cal BP. We suggest that climate was the most important factor conditioning the development of the spring-fed fen. Permafrost degradation, and then wet periods, intensified the activity of ascending springs. Autogenic development of deposit succession in the studied fen was definitely conditioned by hydrological changes induced by climate. Based on the multi-proxy data, 12 cold events of different rank were identified. They are also recorded in other Polish and European sites. A record of distinct variability of depositional conditions at *ca.* 9.4, 8.2, 5.9, 4.6, 2.8, 1.4, and 0.55 ka cal BP corresponds to quasi-periodical global climate changes in the Holocene named the Bond events. The majority of the cold events recorded in $\delta^{13}C$ and $\delta^{18}O$ of carbonates can be correlated to the Greenland oxygen isotope curve.

References

Dobrowolski, R., 2011. Problemy klasyfikacyjne osadów torfowisk źródliskowych (Problems with classification of deposits of spring-fed fens). *Studia Limnologica et Telmatologica* 5, 1: 3-12.

Succow, M., 1988. Landschaftsökologische Moorkunde. Gebrüder Borntraeger Berlin-Stuttgart: 1-340.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Climate changes and human impact during middle ages in the light of geoarchaeological studies in the Hrubieszów Basin (Volhynia Upland, eastern Poland)

Dobrowolski, Radosław[1]*; Rodzik, Jan[1]; Mroczek, Przemysław[1]; Zagórski, Piotr[1]; Pidek, Irena Agnieszka[1]; Bałaga, Krystyna[1]; Wołoszyn, Marcin[2]; Dzieńkowski, Tomasz[3] & Hajdas, Irka[4]

[1] Maria Curie-Skłodowska University, Faculty of Earth Sciences and Spatial Managements, Lublin, Poland
[2] Maria Curie-Skłodowska University, Institute of Archaeology, Lublin, Poland
[3] University of Rzeszów, Institute of Archaeology, Rzeszów, Poland
[4] ETH Zürich, Laboratory of Ion Beam Physics, Zürich, Switzerland
* Corresponding author: radoslaw.dobrowolski@umcs.pl

Hrubieszów Basin (Volhynia Upland) in the eastern Poland was, during the early medieval period, one of the central areas of the Polish-Rus border zone (so called Cherven Towns), separating the territory controlled by the Piasts (Polish kings dynasty) and by the Riurikids (Ruthenian dynasty). Two main settlement complexes in that area – Czermno site (=historical capital of the Cherven Towns) and Gródek site (=identified with medieval Volhyn stronghold) was studied by interdisciplinary, geoarchaeological research team.

Main aims of our investigation was: (1) reconstruction of structural and functional plans of settlement complexes and (2) detailed reconstruction of the environmental changes in the vicinity of the both sites (palaeogeomorphology, palaeohydrology, vegetation cover) during Middle Ages, with particular emphasis on phases of human impacts.

Results of our studies suggest that: (1) the beginning of the development of space in the both sites for settlement and defense purposes was chronostratigraphically dated to the 7th-8th centuries; climate was relatively cold and dry in that period; (2) intensive transformations of the landscape (=adaptation for settlement) were carried out on a large scale, for the next five centuries (land levelling, reorganization of drainage connected with the construction of moats, construction of banks and dams), (3) main stages of human impact (with well-done multi-proxy data) are connected with the half of the 9th, the turn of the 10th and 11th centuries and second half of the 12th century, (4) all these anthropogenic stages were connected with relatively warm and humid climate.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

A high resolution comparison of varve formation and preservation in Lakes Tiefer See and J. Czechowskie during the last 6000 years

Dräger, Nadine[1*]; Ott, Florian[1,2]; Wulf, Sabine[1,3,4]; Theuerkauf, Martin[5]; Obremska, Milena[6]; Plessen, Birgit[1]; Słowiński, Michał[7]; Tjallingii, Rik[1]; Kienel, Ulrike[1]; Błaskiewicz, Mirosław[7] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[2] Max Planck Institute for the Science of Human History, Department of Archaeology, Jena
[3] GFZ - German Research Centre for Geosciences, Section 5.1 Geomorphology, Potsdam, Germany
[4] Heidelberg University, Institute of Earth Science, Heidelberg, Germany
[5] University Greifswald, Institute for Geography and Geology, Greifswald, Germany
[6] Polish Academy of Sciences, Institute of Geological Sciences, Warsaw, Poland
[7] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
* Corresponding author: ndraeger@gfz-potsdam.de

Annually laminated (varved) lake sediments are unique archives to reconstruct past climate and environment changes beyond instrumental datasets, as they allow accurate dating and multi-proxy analyses at an unprecedented level of temporal resolution and accuracy. The key objective of the ICLEA virtual institute is to understand processes of climate and landscape evolution in the southern Baltic lowlands during the Holocene epoch. To that end, we aim at elucidating the impact and interaction of different landscape forming processes (i.e. climate and land use by humans) using varved sediment archives.

Following this objective, the varved sediment records of two lakes located on a W-E transect, Lake Tiefer See (TSK; NE Germany) and Lake Czechowkie (JC; N Poland), are compared. While local changes may only be recorded in individual records, regional climatic changes should be traceable as a common signal in both records. In particular, the design of the investigation in ICLEA enables a high resolution comparison of both records: (1) an accurate and precise chronology was independently established for each sediment profile, using varve counting, AMS 14C dates and identification of tephra layers (Ott et al., 2016; Wulf et al., 2016), and (2) both sediment profiles were analysed with an identical analytical protocol.

TSK and JC are located in a distance of ca. 400 km in a similar geomorphologic position within the Pomeranian terminal moraine belt of the Weichselian glaciation. While the size of both lakes is similar (~75 ha), TSK is twice as deep as JC (62 and 33 m, respectively). We present multi-proxy data at interannual to sub-decadal resolution for the uppermost 7.7 m (TSK) and 9.3 m (JC) of the sediment profiles spanning the last ~6000 years (Czymzik et al., 2015; Dräger et al., 2017; Dräger et al., submitted; Kienel et al., 2013; Ott et al., submitted; Ott et al., prep; Theuerkauf et al., 2015).

The main difference between both records is the varve preservation: while the JC record is almost continuously varved over the last ~6000 years, about 45% of the TSK sediments are poorly or even partially non-varved. These phases of poorly- and non-preserved varves in the TSK record occur extended and more frequently since ~4000 cal. a BP (Fig. 1) and probably reflect strengthened circulation in the water column of TSK. In contrast, intervals of predominantly well-varved sediment reflect reduced lake circulation promoting the formation of anoxic conditions and the preservation of varves. The strengthened lake circulation in TSK since ~4000 cal. a BP has been linked to gradual changes in the northern hemisphere orbital forcing, leading to cooler and windier conditions in Central Europe. Superimposed decadal- to centennial scale variability of the lake circulation regime is likely the result of additional human-induced changes of the catchment vegetation (Dräger et al., 2017).

At JC the most pronounced sedimentological change is observed in the sedimentation rate, which is mainly related to the deposition of diatoms and re-suspended sediments. Monitoring observations suggest that both layer types are deposited in the autumn season. Phases of increased sedimentation rates occur more frequently during the last ~2800 years (Fig. 1) and are interpreted to reflect increased nutrient supply, which

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

is presumably caused by intensified lake circulation in JC and the related intensified resuspension of sediment. The strengthened lake circulation in JC since ~2800 cal. a BP has been linked to intensified impact of the westerly wind system in this region causing increased water column mixing in particular during the autumn and winter (Ott et al., prep).

In summary, both lake sediment records have been sensitive to the strength of lake circulation during the last 6000 years, but the response differs. In TSK strengthened lake circulation impacted on the entire deposition pattern (i.e. no varve preservation). In JC, in contrast, strengthened lake circulation affected sedimentation rates by increased diatom growth and resuspension of sediment. Both lakes reveal common phases of increased lake circulation (Fig. 1): 2800–2100 cal. a BP, 1650–1550 cal. a BP (300–400 AD) and since 1200 cal. a BP (AD 750). The coincidence of these phases suggests external forcing mechanisms related to regional climate change. In addition, these three phases coincide with known periods of generally cooler, wetter and windier climate corresponding to the 2.8 ka event (e.g. Martín-Puertas et al., 2012), the 'Dark Ages cold period' and 'Little Ice Age' (e.g. Büntgen et al., 2011). Intervals of only increased lake circulation in TSK might reflect a predominantly local forcing signal by human-land use and/or a relevance of the continental gradient during these phases.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

References

Büntgen U, Tegel W, Nicolussi K, McCormick M, Frank D, Trouet V, Kaplan JO, Herzig F, Heussner KU, Wanner H, Luterbach J (2011) 2500 Years of European Climate. Science 331: 578–582.

Czymzik M, Muscheler R, Brauer A, Adolphi F, Ott F, Kienel U, Dräger N, Słowiński M, Aldahan A, Possnert G (2015) Solar cycles and depositional processes in annual 10Be from two varved lake sediment records. Earth and Planetary Science Letters 428: 44–51.

Dräger N, Brauer A, Theuerkauf M, Szeroczyńska K, Tjallingii R, Plessen B, Kienel U, Brauer A (2017) A varve micro-facies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany). The Holocene 27: 450–464.

Dräger N, Plessen B, Kienel U, Słowiński M, Ramisch A, Brauer A (submitted) Relation between varve preservation and δ13C of sedimentary organic matter in the Lake Tiefer See sediment record. Quaternary Science Reviews

Kienel U, Dulski P, Ott F, Lorenz S, Brauer A (2013) Recently induced anoxia leading to the preservation of seasonal laminae in two NE-German lakes. Journal of paleolimnology 50(4): 535–544.

Martín-Puertas C, Matthes K, Brauer A, Muscheler R, Hansen F, Petrick C, Aldahan A, Possnert G, van Geel B (2012) Regional atmospheric circulation shifts induced by a grand solar minimum. Nature Geoscience 5(6): 397–401.

Ott F, Wulf S, Serb J, Słowiński M, Obremska M, Tjallingii R, Błaszkiewicz M, Brauer A (2016) Constraining the time span between the early Holocene Hässeldalen and Askja-S Tephras through varve counting in the Lake Czechowskie sediment record , Poland. Journal of Quaternary Science 31: 103–113.

Ott F, Kramkowski M, Wulf S, Plessen B, Serb J, Tjallingii R, Schwab M, Słowiński M, Brykała D, Tyskowski S, Putyrskaya V, Appelt O, Błaszkiewicz M, Brauer A (submitted). Site-specific sediment responses to climate change during the last 140 years in three varved lakes in Northern Poland. The Holocene submitted

Ott F et al. (in prep.). Stepwise mid-Holocene evolution in North Atlantic influence in the southern Baltic realm recorded in varved sediments of Lake Czechowskie (Poland). In preparation

Theuerkauf M, Dräger N, Kienel U, Kuparinen A, Brauer A (2015) Effects of changes in land management practices on pollen productivity of open vegetation during the last century derived from varved lake sediments. The Holocene 25(5): 733–744.

Wulf S, Dräger N, Ott F, Serb J, Appelt O, Guðmundsdóttir E, van den Bogaard C, Słowiński M , Błaszkiewicz M, Brauer A (2016) Holocene tephrostratigraphy of varved sediment records from Lakes Tiefer See (NE Germany) and Czechowskie (N Poland). Quaternary Science Reviews 132: 1–14.

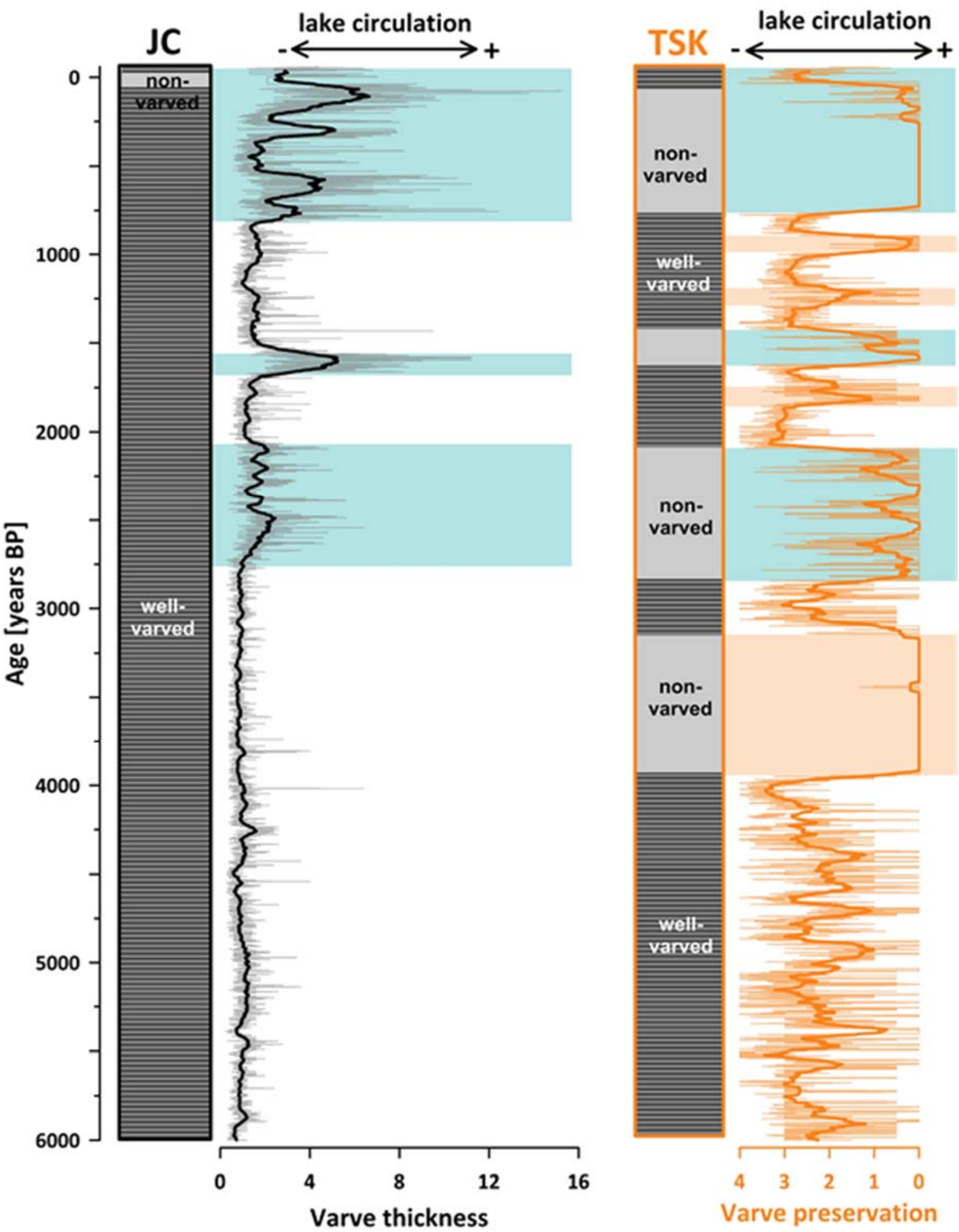


***Fig. 1**: Comparison of the varve thickness of Lake Czechowskie (JC) and the varve preservation record of Lake Tiefer See (TSK) including lithological profiles. Both records are indicator for the strength in lake circulation in the respective lake. Green shaded intervals highlight coinciding phases of increased lake circulation in both lakes (2800–2100 cal. a BP, 1650–1550 cal. a BP (300–400 AD) and since 1200 cal. a BP (AD 750). Orange shaded intervals in TSK highlight phases of only increased lake circulation in TSK.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 3: Integrating time-scales and regional synchronization

Varve microfacies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany)

Dräger, Nadine[1]*; Theuerkauf, Martin[2]; Szeroczyńska, Krystyna[3]; Wulf, Sabine[1,4,5]; Tjallingii, Rik[1]; Plessen, Birgit[1]; Kienel, Ulrike[1] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2: Climate Dynamics and Landscape Evolution, Germany
[2] University Greifswald, Institute for Geography and Geology, Greifswald, Germany
[3] Polish Academy of Sciences, Institute of Geological Sciences, Research Centre Warsaw, Poland
[4] GFZ - German Research Centre for Geosciences, Section 5.1: Geomorphology, Potsdam, Germany
[5] Heidelberg University, Institute of Earth Science, Heidelberg, Germany
* Corresponding author: ndraeger@gfz-potsdam.de

The future of the Earth's climate system is one of the greatest problems faced by society today. Predicting the future of the Earth's climate and the consequences for landscape development, however, is complex and controversial, which is in particular because the role of natural climate variability on regional scales induced by, for example, solar activity, volcanic eruptions and orbital forcing on future climate development is still uncertain. This study therefore aimed to reconstruct the natural climate and environmental changes during the last 6000 years in NE Germany, by conducting detailed sedimentological and geochemical analyses on the annually laminated (varved) lake sediment archive of Lake Tiefer See (Czymzik et al., 2016; Dräger et al., 2017; Kienel et al., 2016, 2013; Theuerkauf et al., 2015). Varved lake sediments represent unique archives on continents in the human habitat providing both, precise chronologies and high resolution proxy data. Reconstructing environmental conditions from lake sediments, however, requires a detailed understanding of all environmental drivers. Especially during the late Holocene, human impact caused striking changes of landscapes and ecosystems. Disentangling influences caused by humans from those induced by climate change on lake sedimentation is a major challenge for palaeolimnologists dealing with climate reconstructions for the late Holocene. In this respect, two research questions were addresses in this study: which factors control sediment variability at Lake Tiefer See and can we differentiate the impact of climate change and human impact on sediment variability?

In a first step, a reliable and independent chronology was performed for the 7.7 m long sediment profile by using a multiple-dating concept, which provides a valuable base for detailed comparison and synchronization of the Lake Tiefer See data set with other climate records. Varve counting and findings of three volcanic crypto-ash layers (tephra; Wulf et al., 2016) in the sediments form the chronological framework for the last ~6000 years. The good agreement with independent radiocarbon dates of terrestrial plant remains verifies the accuracy of the age model (Fig. 1).

The most pronounced feature of the of the Lake Tiefer See sediment record is the alternation between well-varved and non-varved (nearly homogenous) sediment intervals, which is related to changes in varve preservation in Lake Tiefer See (Fig. 2). In order to examine the environmental factors controlling the preservation of varves, different proxies for palaeoenvironmental conditions were applied (Fig.2): $\delta^{13}C_{OM}$ (stable carbon isotopes of the organic matter fraction), TOC (total amount of organic matter), ln(Ti/Si) ratio (from µ-XRF element scanning data; relative variation of redeposited sediment from shallower water depths) and microfossil data (Cladocera and diatom assemblages; Szeroczyńska, 2016). Analyses reveal that well-varved sediments were deposited under anoxic bottom water conditions in the lake, which were caused by reduced circulation of the water column in the lake. Instead, non-varved intervals indicate increased water circulation in Lake Tiefer See, leading to more oxygenated conditions at the lake ground. An exception is the well-varved sediment deposited since AD1924, which is mainly influenced by human-induced lake eutrophication (Kienel et al., 2016, 2013). Based on these findings, the trend of increasing occurrence of non-varved intervals in the sediment record since ~4000 years ago suggests an increasing trend of lake circulation at Lake Tiefer See in this time. The consistency of the results across Central Europe is shown by detailed comparison to other palaeoclimate records (Fig. 3). This comparison suggests that the long-term trend is

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

probably related to gradual changes in Northern Hemisphere orbital forcing, which induced colder and windier conditions in Central Europe during the late Holocene and, therefore, reinforced lake circulation. The trend of increasing lake circulation in Lake Tiefer See additionally is superimposed by decadal to centennial scale variability of the lake circulation intensity. Comparison of this variability to pollen data from the same sediment record indicates a relation between decadal to centennial scale periods of increased lake circulation with settlement phases of human at Lake Tiefer See. The underlying mechanism behind that is probably related to deforestation activities, which reduced the wind shelter of the lake and, hence, increased the sensitivity of lake circulation to wind stress. However, results of this thesis also suggest that several of these decadal to millennial phases are additionally reinforced by climate changes. A first indication is provided by the comparison to the Baltic Sea record, which shows striking correspondence between major non-varved intervals at Lake Tiefer See and bioturbated sediments in the Baltic Sea (Fig. 3). Furthermore, a preliminary comparison to the ICLEA study site Lake Czechowskie (N central Poland) shows a coincidence of at least three phases of increased lake circulation in both lakes, which concur with periods of known climate changes (2.8 ka event, 'Migration Period' and 'Little Ice Age'). These results suggest an additional over-regional climate forcing also on short-term increase of lake circulation in Lake Tiefer See.

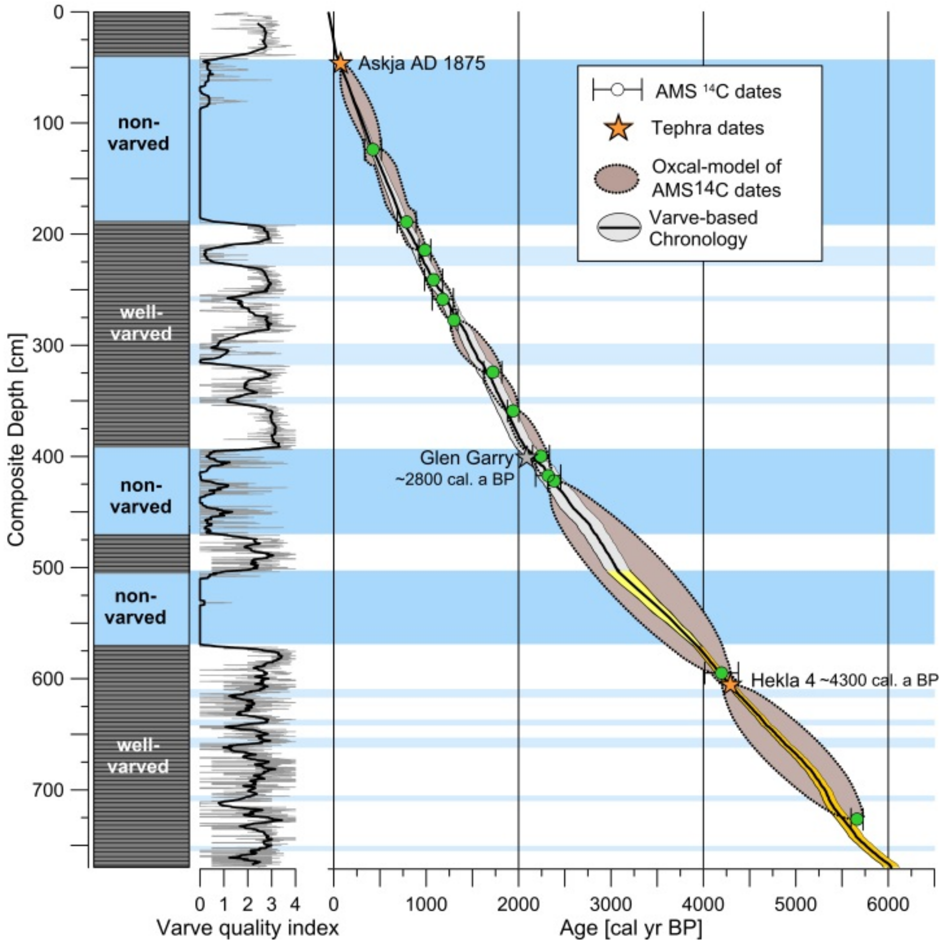


***Fig. 1**: Age-depth model of the Lake Tiefer See composite profile: solid black line shows varve counts and varve-based interpolation; light grey and orange shading illustrates the accumulated counting error of the varve chronologies; green dots show AMS 14C dates; orange stars indicate positions of cryptotephras; the black dotted line highlights upper and lower ranges of the AMS 14C P_Sequence depositional model (variable k- parameter) conducted with OxCal 4.2; blue shaded areas reflect non-varved and poorly varved intervals.*

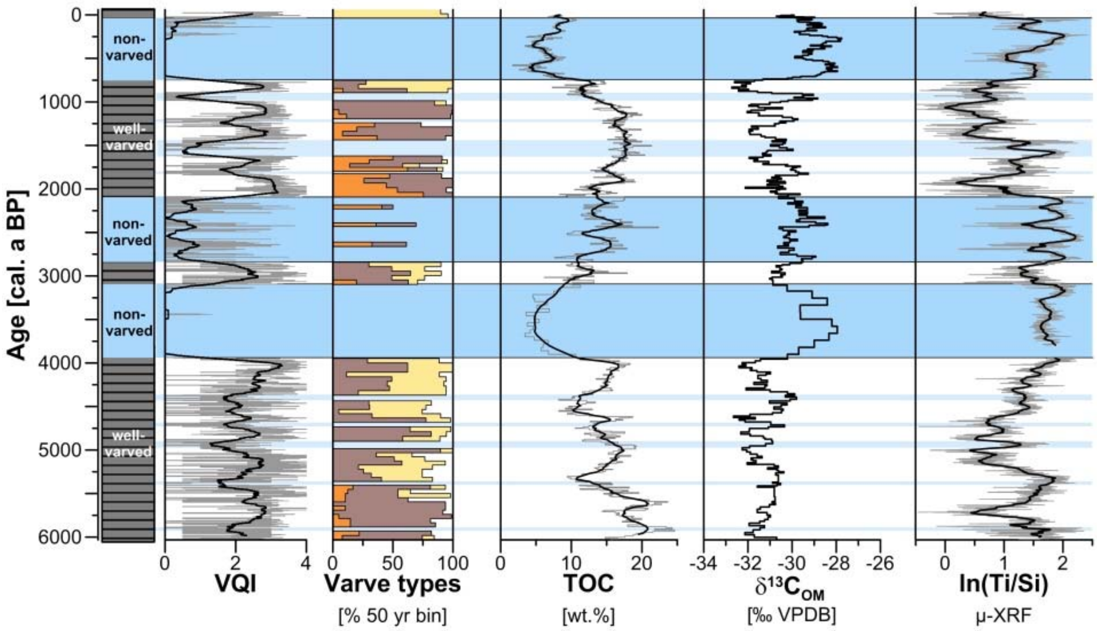


***Fig. 2**: Sediment profile with main sedimentological parameters. Sediment column with well-varved (striped dark grey) and non- varved (light blue) sections. Results of sedimentological analysis: varve quality index (VQI), occurrence of varve types (yellow=calcite varves; orange=Ca-rhodochrosite varves; brown=organic varves). Results of geochemical analysis: TOC content $\delta^{13}C_{OM}$ and log-ratios of Ti and Si (ln(Ti/Si)) obtained from µ-XRF element scanning. Black lines indicate the 51-year running mean of the data plots. Blue shaded areas reflect non-varved and poorly varved intervals.*

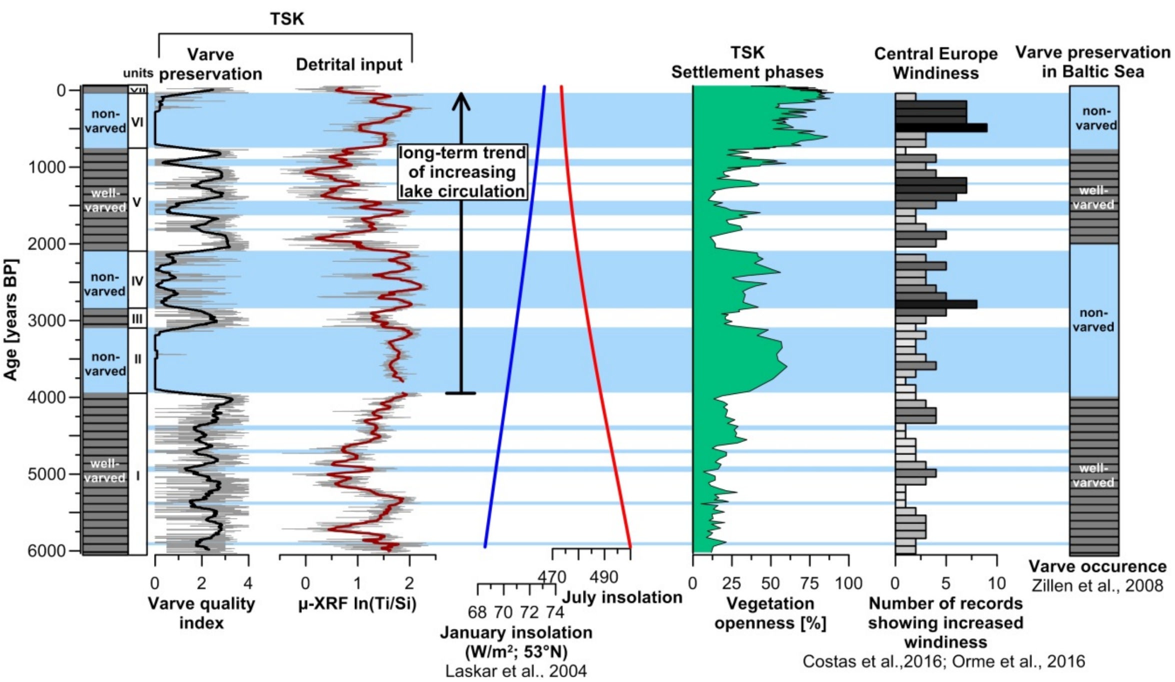


***Fig. 3**: Overview of the main results in comparison with Central European windiness and varved (striped dark grey) and bioturbated (light blue) sections in Baltic Sea basins. Dark and blue shaded areas reflect non-varved and poorly varved intervals, respectively. Central European windiness reflects the state of research in 100-year windows from wind reconstructions from different archives.*

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

References

Czymzik, M., Adolphi, F., Muscheler, R., Mekhaldi, F., Martín-Puertas, C., Aldahan, A., Possnert, G., Brauer, A., 2016. A varved lake sediment record of the 10Be solar activity proxy for the Lateglacial-Holocene transition. Quat. Sci. Rev. 153, 31–39. doi:10.1016/j.quascirev.2016.10.007

Dräger, N., Theuerkauf, M., Szeroczyńska, K., Wulf, S., Tjallingii, R., Plessen, B., Kienel, U., Brauer, A., 2017. A varve micro-facies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany). The Holocene 27, 450–464. doi:10.1177/0959683616660173

Kienel, U., Dulski, P., Ott, F., Lorenz, S., Brauer, A., 2013. Recently induced anoxia leading to the preservation of seasonal laminae in two NE-German lakes. J. Paleolimnol. 50, 535–544.

Kienel, U., Kirillin, G., Brademann, B., Plessen, B., Lampe, R., Brauer, A., 2016. Effects of spring warming and mixing duration on diatom deposition in deep Tiefer See, NE Germany. J. Paleolimnol. 57, 1–13. doi:10.1007/s10933-016-9925-z

Szeroczyńska, K., 2016. Long term subfossil Cladocera record from the partly varved sediment of Lake Tiefer See (NE Germany). Adv. Oceanogr. Limnol. 7, 184–196. doi:10.4081/aiol.2016.6297

Theuerkauf, M., Dräger, N., Kienel, U., Kuparinen, A., Brauer, A., 2015. Effects of changes in land management practices on pollen productivity of open vegetation during the last century derived from varved lake sediments. The Holocene 25, 733–744. doi:10.1177/0959683614567881

Wulf, S., Dräger, N., Ott, F., Serb, J., Appelt, O., Guðmundsdóttir, E., van den Bogaard, C., Słowiński, M., Błaszkiewicz, M., Brauer, A., 2016. Holocene tephrostratigraphy of varved sediment records from Lakes Tiefer See (NE Germany) and Czechowskie (N Poland). Quat. Sci. Rev. 132, 1–14. doi:10.1016/j.quascirev.2015.11.007

Session 4: Man - climate - environment interactions

Sediment transfer in German lowland lake catchments - Erosion on the slopes and input into annually laminated lake sediments

Dreibrodt, Stefan[1]*; Bork, Hans-Rudolf[1]; Feeser, Ingo[2] & Dörfler, Walter[3]

[1] Christian-Albrechts-University, Institute for Ecosystem Research, Ecosystem Research and Geoarchaeology, Kiel, Germany
[2] Christian-Albrechts-University, Institute of Pre- and Protohistoric Archaeology, Kiel, Germany
* Corresponding author: sdreibrodt@ecology.uni-kiel.de

Holocene annually laminated lake sediments are perfect archives of soil erosion history in their catchments. A comparison of quantitative data of erosion (truncated soils, gullies) and sedimentation on the slopes (colluvial layers, gully fills) on the slopes with the input of detrital components into the lake enables the establishment of an inventory of sediment delivery into the different sediment stores in space and time. Furthermore, high-energy events that cross thresholds of connectivity between the different stores are detectable and precisely datable.

The Holocene hydro-sedimentary connectivity was found to be very slow (< 10 % of eroded material reach the lake) at the investigated lakes and thus questioning data reported from other archives (namely alluvial systems). Extraordinary high-energy runoff events in the central European lowlands were detected during the 18th and 14th century as well as at ca. 200 cal BC. The potential of the reconstruction of high-resolution chronologies of extreme precipitation events (recurrence intervals) as well as the reconstruction of representative data for the central European lowlands and the estimation of thresholds of hydro-sedimentary systems are discussed.

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Disentangling paleolimnological processes by microfacies analysis of synchronously deposited annually lake sediments in northern central Europe

Dreibrodt, Stefan[1]*; Feeser, Ingo[2] & Dörfler, Walter[2]

[1] Christian-Albrechts-University, Institute for Ecosystem Research, Ecosystem Research and Geoarchaeology, Kiel, Germany
[2] Christian-Albrechts-University, Institute of Pre- and Protohistoric Archaeology, Kiel, Germany
* Corresponding author: sdreibrodt@ecology.uni-kiel.de

Microfacies analysis of annually laminated lake sediments enables a precise reconstruction of limnological processes during the Holocene. This could be fostered by comparative analysis of synchronously deposited varve sequences from different lakes. This design allows the distinction of events and phases that were in action in a set of compared lakes at the same time and thus have a regional trigger probably (probably climate) from processes that are only reflected in a single record (local human activity within the lake catchment or lake internal processes). If the compared lakes differ in their dimension (size, depth, volume) the kind of trigger processes might be inferred from different but synchronous limno-sedimentological response due to varying thresholds.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Throughfall and stemflow dynamics of different tree species and their implications for groundwater recharge

Dreibrodt, Janek[1]*; Hopp, Luisa[2]; Germer, Sonja[3]; Morgner, Markus[1]; Güntner, Andreas[1] & **Blume, Theresa[1]**

[1] GFZ - German Research Centre for Geosciences, Section 5.4 Hydrology, Potsdam, Germany
[2] University of Bayreuth, Department of Hydrology, Bayreuth, Germany
[3] Max-Planck Institut für Biogeochemie, Jena, Germany
* Corresponding author: ja3br@posteo.de, Janek.Dreibrodt@MLUL.Brandenburg.de

Rainfall redistribution by forest canopies varies for different tree species and can play an important role for soil moisture patterns and groundwater recharge. The forest canopy can lead to considerably less rainfall input to the forest floor, as, under certain conditions, incoming precipitation is captured and evaporated without reaching the ground. On the other hand, redistribution processes lead to increased spatial variability of rainfall input to the forest floor, as certain "drip points" can receive higher input amounts and intensities than measured above the canopy, while other locations are so well shielded that they remain dry. Especially stemflow can be a major conduit of water to the soil and into the subsurface, as these fluxes are strongly channeled and input intensities can be very high. These high input intensities at the base of trees can lead to preferential water flow to greater depths and could possibly even create hotspots of groundwater recharge. However, the amount of stemflow strongly depends on tree physical characteristics, for example a funnel-like arrangement of the tree branches or a smooth tree bark. A thorough understanding of these relationships will improve our ability to predict future impacts on the water balance of forest stands as a result of climate on the one hand and forest structural changes on the other hand.

In the context of decreasing groundwater levels in north-eastern Germany, the influence of forests on groundwater recharge is of considerable interest and is one of the focus areas of the TERENO Observatory in this region. Experimental efforts were concentrated on the forests around Lake Hinnensee, which are part of the Müritz National Park. Throughfall was continuously measured at 7 sites with different dominant tree species and ages: young and old beech, young oak, and young and old pine. At each site trough-based throughfall monitoring systems were installed on 2000 m^2-plots. The total collecting area of these trough systems amounted to 6.6 m^2 per site. The large collecting area is necessary to ensure the reliable determination of average amounts, as throughfall is highly variable in space. Stemflow was measured with tipping buckets at 5-10 trees per site with a temporal resolution of 1 min.

To date more than one year of high temporal resolution data has been collected for each investigated site. This has allowed for deeper insights into the dynamics of throughfall and stemflow and their dependencies on tree species, age, season and other rainfall and forest characteristics.

The data set was used to parameterize and run the soil hydrological model HYDRUS-2D from single tree to forest stand scale to assess the effect of stemflow and throughfall patterns of different forest types on the dynamics and patterns of soil moisture. The spatial distribution of root water uptake turned out to be a critical point in the model set up with regard to the ability of the model to simulate observed soil moisture dynamics.

Results highlight the importance of concentrated water input by stemflow in beech stands, subsequent high infiltration rates around beech stems and the resulting high soil moisture contents for rapid groundwater recharge. For the other tree species stemflow plays a minor role and rainfall redistribution patterns are more determined by canopy gaps or ground vegetation.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

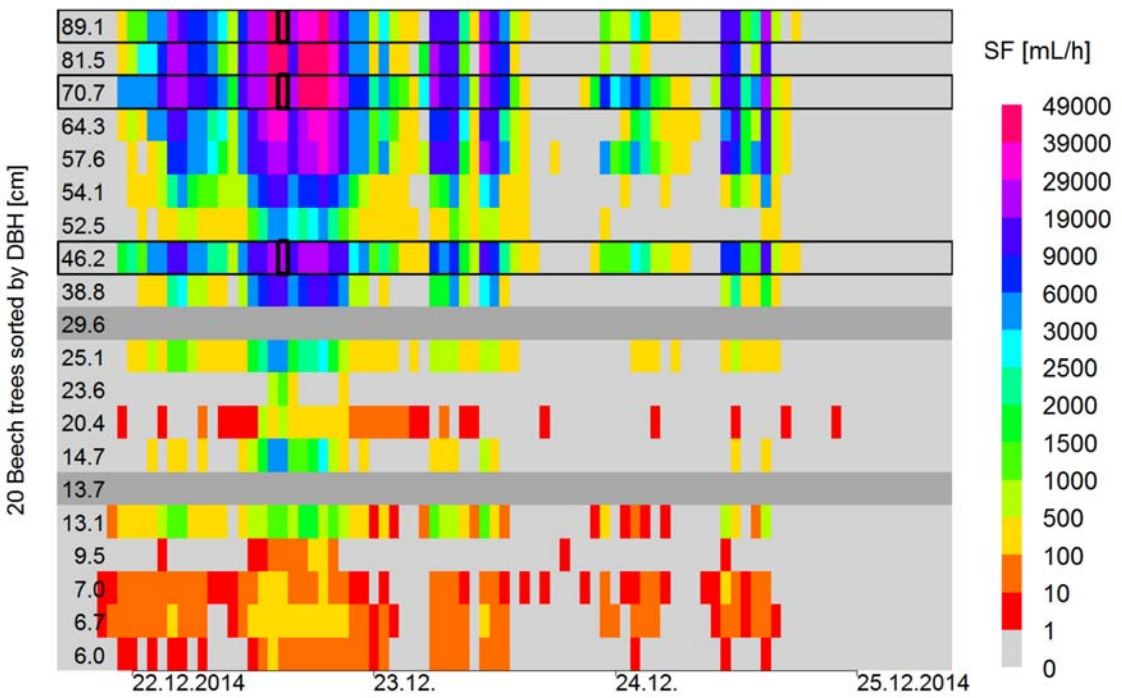


***Fig. 1**: Stemflow time series for a large winter rainfall event: Trees sorted by diameter at breast height DBH (darkgrey=NA, black frames indicate data used for modeling).*

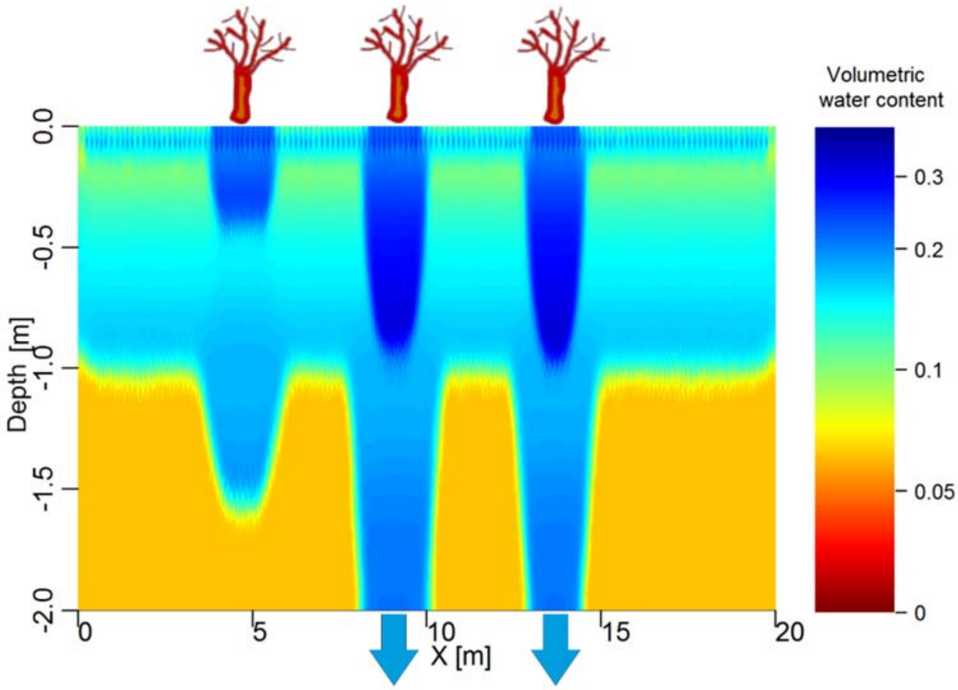


***Fig. 2**: Model-based assessment of groundwater recharge. Simulated soil water content 40 h after rainfall event. Diameter at breast height of beech trees (left to right in cm): 89,1; 70,7; 46,2 areas with high soil moisture(dark blue) influenced by concentrated stemflow infiltration; high water contents at free drainage boundary of model domain indiciate groundwater recharge (blue arrows).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 3: Integrating time-scales and regional synchronization

Climate or men? Identifying drivers of multidecadal to centennial palaeolimnological processes during the Neolithic in Northern Germany

Feeser, Ingo[1]*; Dreibrodt, Stefan[2] & Dörfler, Walter[1]

[1] Christian-Albrechts-University, Institute of Pre- and Protohistoric Archaeology, Kiel, Germany
[2] Christian-Albrechts-University, Institute for Ecosystem Research, Ecosystem Research and Geoarchaeology, Kiel, Germany
* Corresponding author: ifeeser@ufg.uni-kiel.de

When interpreting palaeolimnological data from a single site, it remains often difficult to distinguish regional from local signals or natural from anthropogenic impact, respectively. An insight into the nature of processes evoking these signals, identifying their source and their spatial significance can only be achieved by a comparison of multiple records within a region. In doing so it is possible to single out similar synchronous developments that indicate developments on the regional scale. In contrast, signals not found in other sites are likely to reflect local phenomena. The potential for the comparison of processes of different temporal scales and rhythms, i.e. long-term vs. short-term processes, is thereby constrained by sampling resolution and dating uncertainties of the records. Increasingly detailed archaeological chronologies, e.g. often reflecting short-term centennial or multidecadal developments, raise the demand for appropriate palaeoenvironmental records. In this context especially annually laminated lake sediments offer the possibility for high resolution multiproxy studies on a well constraint time scale.

We present examples for such an approach by comparing data spanning the Neolithic period (4500-2000 cal. BC) from a series of palynological lake records from the young moraine area of Northern Germany with special emphases on Lake Woserin and Lake Belau, two sites with annually laminated sediments. For these sites we combine different signals from the palynological, micro-morphological, and geochemical records and identify climate or human activities as drivers for short-term lake internal processes.

Session 2: Recent change and instrumental observations

Environmental monitoring of the catchment area in the context of contemporary sedimentation in Lake Gościąż, Poland

Fojutowski, Michał[1]*; Gierszewski, Piotr[1]; Brykała, Dariusz[1]; Bartczak, Arkadiusz[1]; Plessen, Birgit[2]; Pinkerneil, Sylvia[2]; Błaszkiewicz, Mirosław[1] & Brauer, Achim[2]

[1] Polish Academy of Sciences, Institute of Geography, Department of Environmental Resources and Geohazard, Torun, Poland
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
* Corresponding author: mfojutowski@wp.pl

Lake Gościąż (52°34'58"N, 19°20'25"E) is located in central Poland, in the Gostynin-Włocławek Landscape Park. The characteristic feature of this water body is the occurrence of annually laminated sediments which record climate changes and related environmental impacts. In the 1980s Lake Gościąż was subject of a multidisciplinary study that led to the discovery of annualy laminated deposits. Since then, novel and advanced high-resolution methodologies have been developed providing the unique chance to re-investigate this key record in European paleoclimate research. Therefore a new project has been launched under the title 'Environmental Record of Climate Change in the last 15 000 years along the European W-E transect line'. It has been conducted in cooperation with the GeoForschungZentrum in Potsdam.

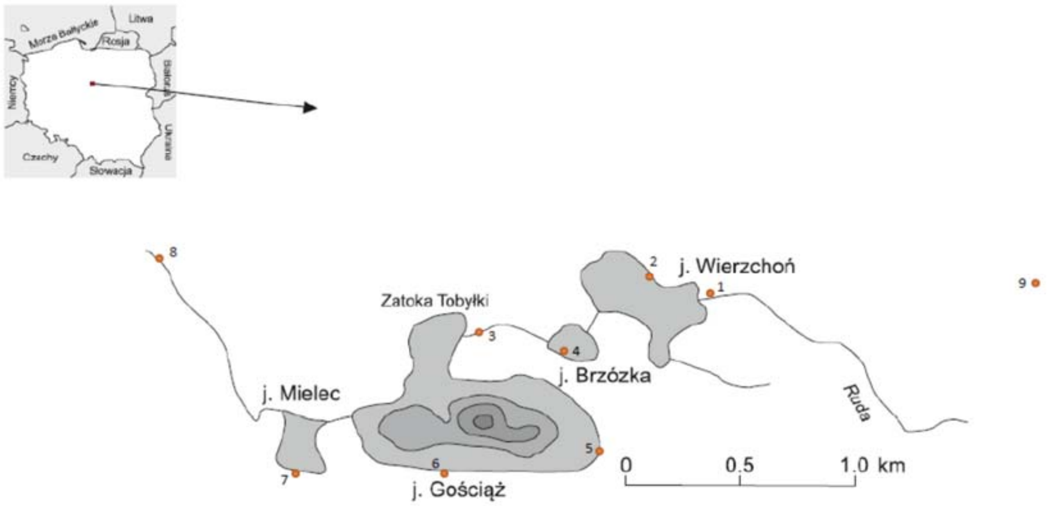
The main objective of the project is to use the laminated sediments of Lake Gościąż for the emerging European paleoclimatic-paleoenvironmental WE transect (lakes MeerfelderMaar - Rehwiese - Tiefer See-Czechowskie) by applying modern high resolution research techniques refine climate and environmental reconstructions in order to better resolve regional aspects of past climate change.

In 2015, 29 cores of laminated sediments foming three parallel and overlapping sediment profiles were collected from the lake. The composite profile of about 21 meters in length presents changes in the natural environment since Lateglacial until today. Annual lamination, as well as tephrochronological, isotopic and palynological analyses, as µXRF scanning, will allow to identify even decadal-scale climatic variations over the past several thousand years.

Another crucial approach of current research is the observation and analysis of the present day sedimentation in a lake monitoring approach. For this purpose, sediment traps with monthly sampling intervals have been installed in the lake. To complement the monitoring approach (Fig. 1), two meteorological stations have been installed on the lake and in the catchment area to measure meteorological data including - temperature, wind speed and direction, precipitation, atmospheric pressure and humidity - with hourly frequency (Fig. 1). In addition, measurements of physicochemical properties of water and flow volumes are systematically carried out in the catchment area (Fig. 1). Correlation of the entire data set enable to distinguish relationships between sedimentation processes and climatic and human factors.

The poster presents the methodology and the first results of the monitoring data conducted since November 2016. This project (2015/19/B/ST10/03039) financed by NCS (National Centrum of Science).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037



1. Inflow to Wierzchoń lake GOS1
2. Wierzchoń lake GOS 2
3. Inflow to Tobyłka bay GOS 3
4. Brzózka lake GOS 4
5. Gościąż lake - beach GOS 5
6. Gościąż lake - the flow of groundwater GOS 6
7. Niche headwaters - Mielec GOS 7
8. Ruda - threshold correction GOS8
9. Rain collector GOS 9

Fig. 1*: Map of measuring points in the Lake Gościąż catchment.*

Fig. 2*: Meteorological station near Gościąż lake.*

Session 2: Recent change and instrumental observations

Observational and experimental evidence revealing strong protracted consequences of extreme weather events on lakes

Giling, Darren P.[1]; Kasprzak, Peter[1]; Nejstgaard, Jens C.[1]; Berger, Stella A.[1]; Shatwell, Tom[2]; Gonsiorczyk, Thomas[1]; Kirillin, Georgiy[3]; Grossart, Hans-Peter[1,4]; Selmeczy, Géza[1,5]; Padisák, Judit[5,6]; Engelhardt, Christof[4]; Penske, Armin[1]; Lentz, Maren[1]; Casper, Peter[1]; Sareyka, Jörg[1] & **Gessner, Mark O.[1,7]***

[1] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Department of Experimental Limnology, Stechlin, Germany
[2] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Department of Ecosystem Research, Berlin, Germany
[3] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Department of Ecohydrology, Berlin, Germany
[4] University of Potsdam, Institute of Biochemistry and Biology, Potsdam, Germany
[5] MTA-PE Limnoecology Research Group, Veszprem, Hungary
[6] University of Pannonia, Department of Limnology, Veszprem, Hungary
[7] Berlin Institute of Technology (TU Berlin), Department of Ecology, Berlin, Germany
* Corresponding author: gessner@igb-berlin.de

Climate change scenarios project an increase in extreme weather events in many parts of the world. Of particular importance to lakes are storms that disrupt the vertical thermal stratification of the water column and redistribute mineral resources, organic matter and plankton communities. We combined data from routine monitoring and a large-scale enclosure experiment to assess consequences of extreme summer storms on lake ecosystems. Data from biweekly samples collected in a clear-water lake indicate that upwelling of deep water in response to a storm-induced extreme inclination of the thermocline entrained a deep layer of phytoplankton (filamentous cyanobacteria) into the surface water where release from light limitation boosted primary production (Fig. 1). This caused massive calcite precipitation that rapidly shifted the clear lake into a turbid state. A signal of this shift is expected to be preserved in the sediment record. The sequence of events derived from these observational data could be largely reproduced by simulating a

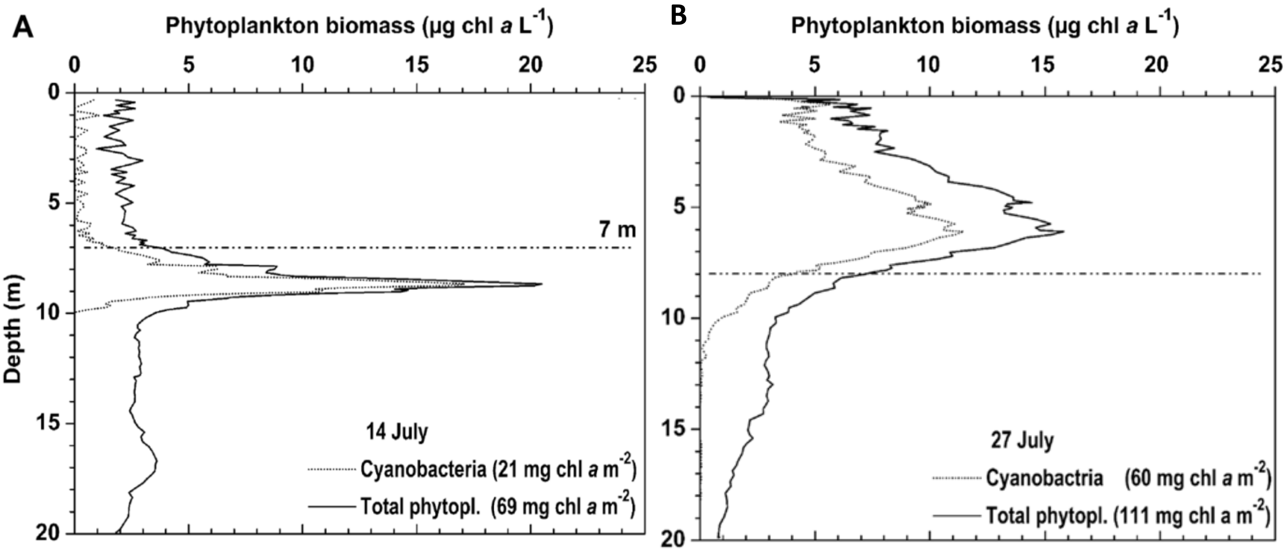


Fig. 1: *Vertical profiles and areal quantity of chlorophyll a (chl a) as well as areal concentration of total phytoplankton and cyanobacteria on 14 and 27 July 2011, recorded with a group-selective in-situ fluoroprobe (From Kasprzak et al. 2017).*

wind-induced disruption of summer stratification in an experimental facility consisting of large replicated enclosures established in a lake. Experimentally lowering the thermocline in these enclosures (Fig. 2) mixed nutrients and deep-water phytoplankton into the surface waters, reflecting the processes indicated by the lake monitoring data. High frequency-measurements of oxygen concentrations along the entire depth profile

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

in the enclosures and calculatations of depth-integrated rates of gross primary production (GPP) and ecosystem respiration (ER) showed that GPP in the surface water was stimulated by an average of 76% above controls over a period of 4 weeks (Fig. 3). ER increased by an average of 71%. Although GPP and ER remained tightly coupled, the entire water column became substantially more autotrophic for more than 3 weeks. This should result in increased sedimentation of organic and possibly also of mineral matter. As in the observational study, these responses were driven by a bloom of filamentous cyanobacteria that were carried from a thin deep-water layer to the surface water. Overall our observational and experimental results consistently show that short single mixing events induced by extreme storms can induce prolonged changes in ecosystem processes, independent of external inputs of nutrients and organic matter. Consequently, changes in the frequency, severity and timing of extreme events projected under future climate conditions might be strong enough to outweigh the influence of gradual trends of global environmental change on lake ecosystems.

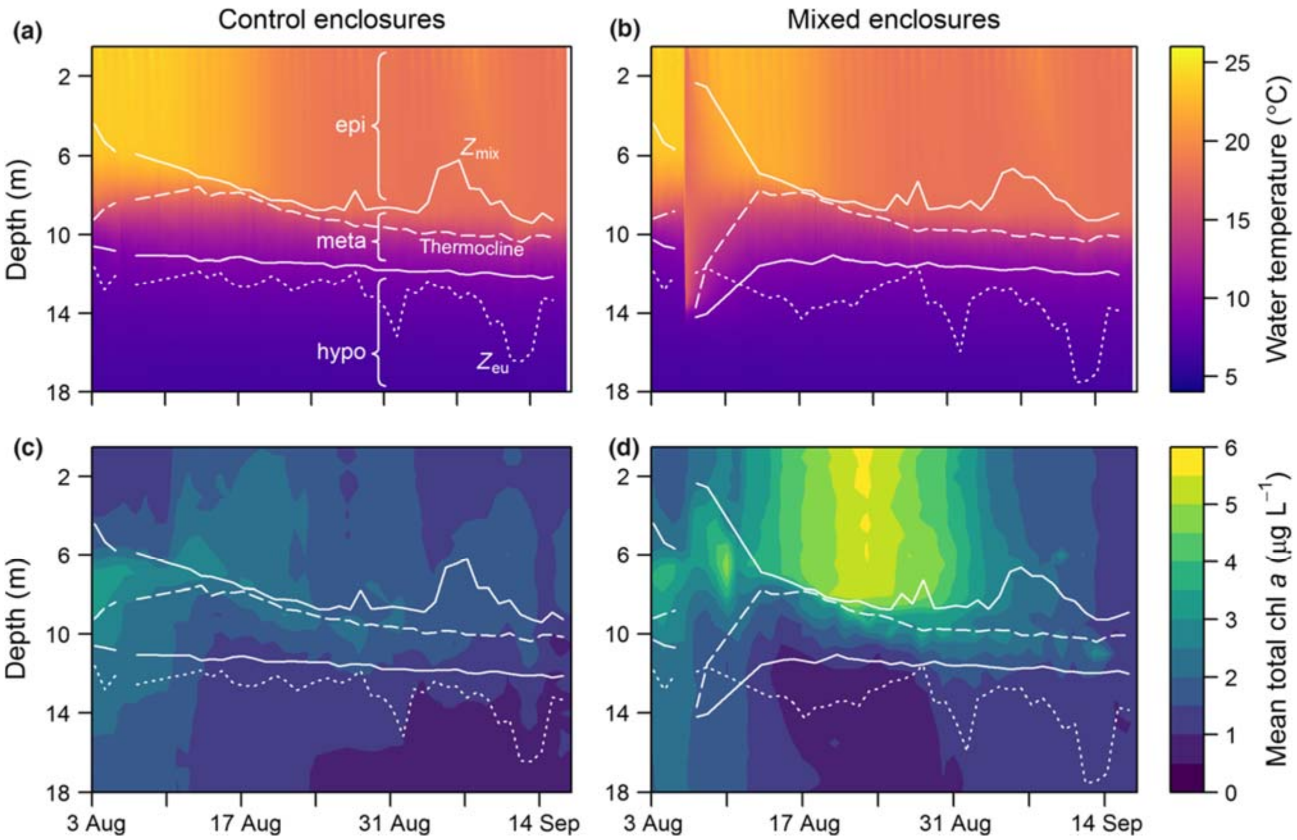


***Fig. 2:** Contour plots showing water temperature (a, b) and chlorophyll-a concentration (c, d) of continuously recorded vertical profiles of control (left) and mixed (right) enclosures over the experimental period (44 days). Chlorophyll-a plots display daily mean values from control (n = 4) and mixed (n = 4) enclosures. Temperature plots show example enclosures. Solid white lines indicate the mean daily metalimnion boundaries (the upper line indicating the mixed-layer depth, Z_{mix}), and the dashed white line represents the mean daily thermocline depth (i.e. the plane of the steepest density gradient). The dotted line indicates the mean daily photic depth (Z_{eu}). Mean daily stratification depths are not indicated for the day of mixing (August 6) because of high variation. Periods of missing data (notably August 9–11) are linearly interpolated (From Gilling et al. 2017)*

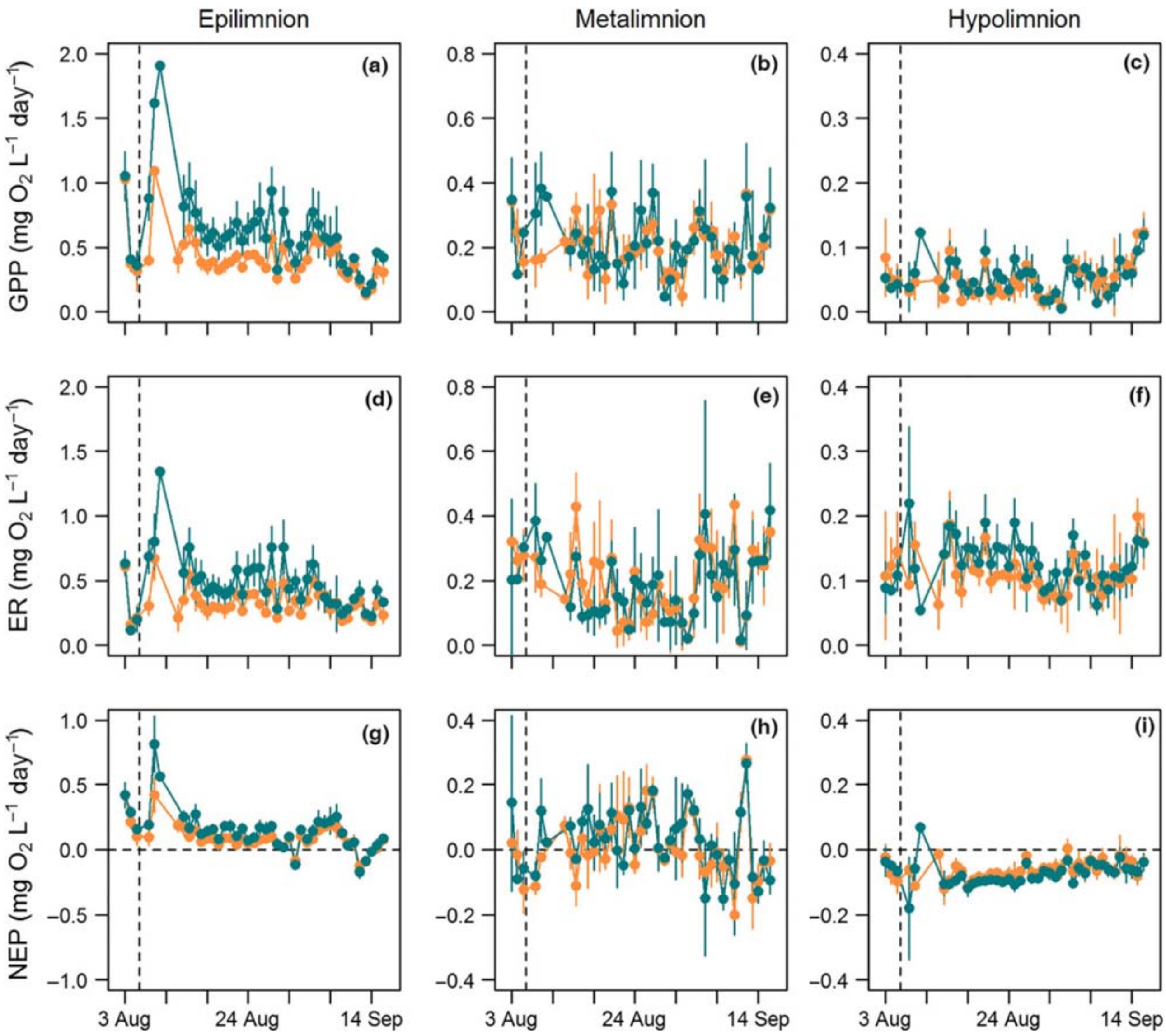


Fig. 3*: Volumetric rates (mean ± SD) of depth-integrated metabolism in control (bright orange) and mixed (dark turquoise) enclosures. Responses are mean volumetric rates of gross primary production (GPP; a–c), ecosystem respiration (ER; d–f) and net ecosystem production (NEP; g, h, f) for the epilimnion, metalimnion and hypolimnion, respectively. Vertical dashed lines indicate experimental mixing on 6 August 2014 (From Gilling et al. 2017).*

References

Kasprzak P., T. Shatwell, M.O. Gessner, T. Gonsiorczyk, G. Kirillin, G. Selmeczy, J. Padisák, and C. Engelhardt. 2017. Extreme weather event triggers cascade towards extreme turbidity in a clear-water lake. Ecosystems (DOI: 10.1007/s10021-017-0121-4).

Giling D.P., J.C. Nejstgaard, S.A. Berger, H.-P. Grossart, G. Kirillin, A. Penske, M. Lentz, P. Casper, Jörg Sareyka, and Mark O. Gessner. 2017. Thermocline deepening boosts ecosystem metabolism: evidence from a large-scale lake enclosure experiment simulating a summer storm. Global Change Biology 23, 1448–1462.

Session 4: Man - climate - environment interactions

The Anthropocene; a formal stratigraphical unit, an informal concept, or an interval of Holocene time?

Gibbard, Philip*

University of Cambridge, Cambridge Quaternary, Department of Geography, and Scott Polar Research Institute, Cambridge CB2 3EN, England, UK.

* Corresponding author: plg1@cam.ac.uk

In recent years 'Anthropocene' has been proposed as an informal stratigraphic term to denote the current interval of anthropogenic global environmental change. A case is also been made for its consideration as a formal series/epoch, based on the recognition of a suitable marker horizon or event, such as the start of the Industrial Revolution in northern Europe. In order for the Anthropocene to merit designation as a formal stratigraphic unit, however, such an event would need to leave a global signature consistently distinct from that of the Holocene or of previous interglacials of the Pleistocene, and be marked by novel biotic (i.e. biostratigraphical), sedimentary and geochemical change. Although there is clear evidence in recent geological records of anthropogenic effects on the natural environment (atmospheric trace gas increase, sea-level rise, accelerated erosion, etc), it is far from certain that the stratigraphic signature of these trends is sufficiently distinct, consistent and adequately dated at the global scale, for the proposal for a Holocene/Anthropocene boundary to be substantiated on stratigraphic grounds. As a consequence, there is a view within the Earth-science community that, if the term is to be employed, it should remain an informal label. Here the Anthropocene will be considered in the context of the formal definition of geological time-scale units, particularly of the requirement for relating such units to unequivocal Global Stratigraphic Section and Point ('golden spike') localities, and that adoption of the term 'Anthropocene' will ultimately depend on whether such an event layer or horizon can be identified globally. In the absence of such a marker, it will be concluded that there is no justification for decoupling the Anthropocene from the Holocene, and that if the term Anthropocene is deemed to have utility, it should be as an informal historical designation rather than a formally-defined stratigraphic unit (of whatever status) within the Geological Time Scale.

References

Gibbard, P.L. & Walker, M.J.C. 2014. The term 'Anthropocene' in the context of formal geological classification. In: Waters, C., Zalasiewicz, J., Williams, M., Ellis, M., Snelling, A. (eds.) A stratigraphic basis for the Anthropocene. Geological Society, London, Special Publications, first published 25 October, 2013; doi 10.1144/SP395.1.

Walker, M., Gibbard, P., Lowe, J. 2015. Comment on "When did the Anthropocene begin? A mid-twentieth century boundary is stratigraphically optimal" by Jan Zalasiewicz et al. (2015), Quaternary International, 383, 204-207.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Paleolakes as an element modifying water and matter circulation in young-glacial river-lake systems

Gierszewski, Piotr*; Brykała, Dariusz; Kaszubski, Michał & Fojutowski, Michał

Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
* Corresponding author: piotrg@geopan.torun.pl

The influence of lakes on the size and variability of river discharge, as well as their role in transforming the chemical properties of water coming from lake basins, have already been described (e.g. Hillbricht-Ilkowska 1999, Bajkiewicz-Grabowska 2002). However, when concentrating on the changes taking place in modern lakes, the influence of basins of the paleolakes which are now filled up with organic-mineral sediments is often neglected. Determining their role in the water and matter circulation has been the aim of hydrological and hydrochemical monitoring carried out in the catchment of Lake Czechowskie since mid-2012.

The hydrographic system of Lake Czechowskie consists of several river and lake segments. Lake sections are not only modern lakes (Głęboczek and Czechowskie), but also paleolakes basins, which have now the form of biogenic plains. Lake parts of the system are connected by short valley sections, most often of a gap nature. The size and variability of water runoff from the catchment is mainly depended by groundwater supply and evaporation size. The share of underground supply in the Struga Czechowska discharge is approximately 85 %. Such a structure of the catchment water balance ensures stability of the river discharge even during periods of significant precipitation deficit.

The groundwater fluctuations ranged from 0.17 m to 2.14 m. The lowest ones were recorded by the piezometers located in watershed zones, where the groundwater table is located at the depths from 8 to 18 m. The greatest dynamics of fluctuations of the groundwater table was found in the shallow-lying groundwater of the lake terraces. As a result of the high stability of the deeper underground waters, which are the main source of supply for Lake Czechowskie, there are only slight fluctuations in water levels in this lake. In the analysed period they were 0.44 m.

The main supply area of the catchment is located in its NW section. This is where a complex of paleolakes is located (Kordowski et al. 2014). The surface of this area is cut by a system of drainage ditches, which strongly drains this part of the catchment. Groundwater outflows are located at the foot of the northern slopes of the paleolakes. The Struga Czechowska flows through the central part of this paleolakes. This section shows the greatest increase in the water flow rate. The fact that there are significant water resources in this part of the drainage basin is testified by the specific discharge value of 14.44 $dm^3s^{-1}km^{-2}$. The measurements showed that the average discharge in the outlet from Lake Czechowskie in the analysed period was 85 dm^3s^{-1} and was significantly, i.e. one third higher than the sum of the size of water inflow to the lake via watercourses. Hydrochemical studies have shown that the examined waters, both surface and underground, represent the same hydrocarbon-calcium-sulphate hydrochemical type. Compared to homogeneous ionic composition, the salinity diversity is very high. It is indicated by the electrolytic conductivity values that ranged from 74-1806 $\mu S \cdot cm^{-1}$ in the study period. The stream waters moving in the organic-carbonate deposits of paleolakes and shallow groundwater in these areas are most highly mineralised (>700 $\mu S \cdot cm^{-1}$). The lowest mineralisation (<100 $\mu S \cdot cm^{-1}$) is recorded in groundwater circulating in sandy sediments of outwash plains. Mineralisation of the water of Lake Czechowskie of about 350 $\mu S \cdot cm^{-1}$ is a result of the supply from both sources as well as the effect of biogeochemical processes therein.

The variation of water chemistry in the longitudinal profile of the studied river-lake system indicated that contemporary and already non-existent lakes play a key role in shaping the chemical characteristics of water in young-glacial basins. In the waters of the watercourses flowing through paleolakes a sudden increase in salinity was recorded (by about 80-100 $\mu S \cdot cm^{-1}$). In contrast, in the outflow from Lake Czechowskie, it clearly dropped.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

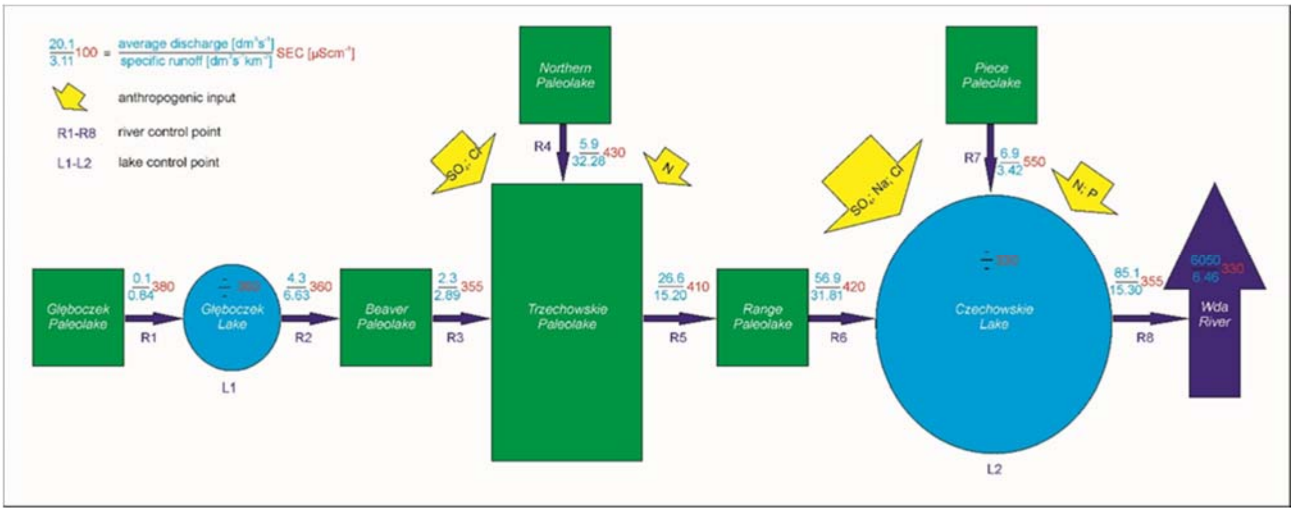


***Fig. 1**: Model of the transformation of hydrochemical properties and runoff in the longitudinal profile of the Czechowska stream.*

These changes are primarily due to the concentration of bicarbonate anion and calcium cation, the delivery of which is associated with carbonate gytia which occur shallow beneath the surface. There was also a significant increase in sulphate anion concentration in the paleolake areas.

The properties of the water of Lake Czechowskie are highly influenced by surface and underground water supply flowing from the north. The moraine plateau extending there is built of deposits rich in carbonates. At the same time, these areas are intensively utilised in agriculture, which is reflected in higher concentrations of chlorides and sodium in the waters of Lake Czechowskie and the rivers that feed the lake from the north. Agricultural activities also result in high concentrations of nitrogen and total phosphorus in waters flowing from this direction.

Hydrochemical studies showed that the zones of water enrichment in salts are associated with paleolakes basins filled with the organic-carbonate sediment, while the salt precipitation zones with the modern lakes.

The lakes and paleolakes forming a cascade system of interconnected pools are the most important elements shaping the conditions of water and matter circulation in lowland young-glacial basins. The research has shown that paleolakes, similarly to modern lakes, influence the runoff from the catchment area and transform the chemical properties of the water circulating in it.

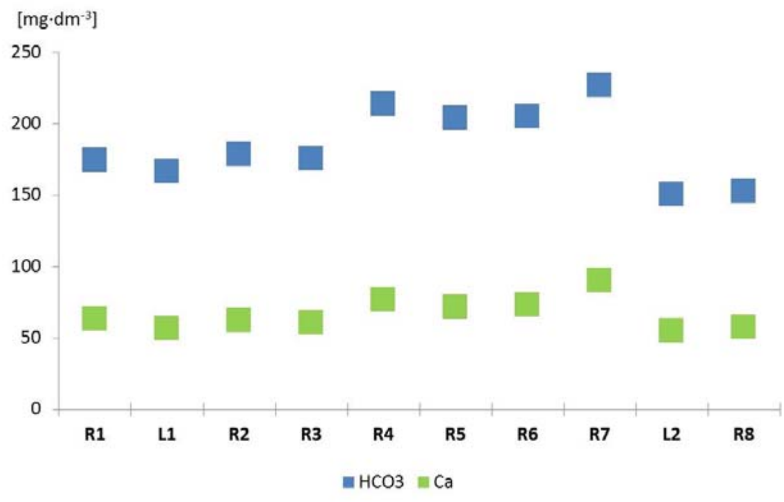


***Fig. 2**: The changeability of bicarbonates and calcium iones in the longitudinal profile of the Czechowska stream (sections of stream the same like on the Fig. 1).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analyses (ICLEA), grant number VH-VI-415.

References

Bajkiewicz-Grabowska, E. 2002. Obieg materii w systemach rzeczno-jeziornych, Warsaw University, Warszawa.

Hillbricht-Ilkowska, A. 1999. Shallow lakes in lowland river systems: Role in transport and transformations of nutrients and in biological diversity, Hydrobiologia, 408-409, 349-358.

Kordowski, J., Błaszkiewicz, M., Kramkowski, M., Słowiński, M., Tyszkowski, S., Brauer, A., Brykała, D., Gierszewski, P., Lamparski, P., Lutyńska, M., Mirosław-Grabowska, J., Noryśkiewicz, A.M., Obremska, M., Ott, F., Wulff, S. & Zawiska, I. 2014. Charakterystyka środowisk depozycyjnych Jeziora Czechowskiego i jego otoczenia. Landform Analysis, 25, 55-75.

Session 2: Recent change and instrumental observations

Monitoring of Calcite Precipitation in Hardwater Lakes with Multi-Spectral Remote Sensing Archives

Heine, Iris[1]*, Brauer, Achim [2], Heim, Birgit[3], Itzerott, Sibylle [1], Kasprzak, Peter [4], Kienel, Ulrike[2,5] & Kleinschmit, Birgit [6]

[1] GFZ - German Research Centre for Geosciences, Section 1.4 Remote Sensing, Potsdam, Germany
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] Alfred Wegener Helmholtz Center for Polar and Marine Research, Research Unit Potsdam, Germany
[4] Leibniz-Institute of Freshwater Ecology & Inland Fisheries, Department of Experimental Limnology, Neuglobsow/ Stechlin, Germany;
[5] University Greifswald, Institute for Geography and Geology, Greifswald, Germany
[6] Technische Universität Berlin, Geoinformation in Environmental Planning Lab, Berlin, Germany
* Corresponding author: iheine@gfz-potsdam.de

Calcite precipitation is a bio-geochemical process that induces the precipitation of calcium carbonate particles due to a shift in the carbonate equilibria in the open water of hardwater lakes. The precipitation dyes the lake a water milky turquoise (Koschel et al. 1987; Kelts & Hsü 1978; Strong & Eadie 1978) until the calcite particles settle and are deposited in the lake sediment (Fig. 1). Thus, calcite precipitations are also described as "whiting", "milky water phenomenon" or "seasonal clouding" (Koschel et al. 1987; Strong & Eadie 1978; Thiemann & Koschel 2001). Calcite precipitation reduces the nutrient concentration and phytoplankton productivity and therefore is a natural protection mechanism of hardwater lakes against eutrophication (Proft 1984, Koschel et al. 1997). Additionally, it has a high climate relevance as the sedimentation process represents a carbon sink (Proft 1984; Koschel et al 1997).

The Northeast German Plain is a region dominated by many hardwater lakes (Koschel et al. 1987) (Fig. 2), but only few lakes are regularly monitored and the number and spatial distribution of affected lakes are unknown. This paper presents a remote sensing based method to observe calcite precipitation over large areas, which are an important prerequisite for a systematic monitoring. We use globally archived satellite remote sensing data for a retrospective systematic assessment of past multi-temporal calcite precipitation events. The database of this study consists of 205 data sets that comprise freely available Landsat and Sentinel 2 data acquired between 1998 and 2015 covering the Northeast German Plain.

The water milky turquoise color of lakes during calcite precipitation comes along with a decrease in Secchi depth and an increase of the reflectance between blue and near-infrared (Thiemann & Koschel 2001; Weidemann et al. 1985). In the Landsat imagery, the reflectance in green shows the strongest increase and has the maximum reflectance values. Thus, our automatic classification is based on the metric BGR area, the triangular area between the blue, green and red reflectance value. The classification results are evaluated using field measurements of $CaCO_3$ concentrations at three selected lakes in the Feldberg Lake District (Fig. 1) and sediment core data at one lake in the Klocksin Lake Chain.The classification accuracy (0.88) is highest for calcite concentrations ≥0.7 mg/L. False negative results are caused by the choice of a conservative classification threshold. False positive results can be explained by already increased calcite concentrations. After the evaluation, we successfully transferred the developed method to 21 other hardwater lakes in Northeast Germany.

Our study shows that 15 of the 24 lakes covering a total area of approximately 17 km^2 have at least one calcite precipitation event in the observation period. The frequency of calcite precipitation events varies between one detection and regular detections nearly every year. The durations of calcite precipitation events also vary between the lakes, but are for the three lakes with regular calcite precipitation in average 37 days. At two lakes the effects of lake trophy restoration measures on calcite precipitation can be monitored.

The high number of missed calcite precipitation events, together with gaps in Landsat time series, reduces the accuracy of frequency and duration monitoring. For example, the comparison with sediment data at TS shows that calcite precipitation events have been missed in some years due to low image density in the critical time periods (May to September). In future the image density will increase by acquisitions of Sentinel-

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

2a and coming Sentinel-2b. Therefore, we tested successfully the application of the BGR area classification method on two Sentinel-2 images.
Our results emphasized the variety of the lakes and the need to monitor each lake individually. This is due to the complex processes of calcite precipitation, which are influenced by a number of factors including lake trophic state, algae composition and activity, human measures and climate. For the monitoring calcite precipitation in lakes in the entire Northeast German Plain using the large Landsat archive and Sentinel-2 imagery a new method is provided. This is an essential prerequisite, in combination with geochemical analyzes, to investigate the role of permanent CO_2 storage in form of calcite in this region.
This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

Further information: *Heine, I., Brauer, A., Heim, B., Itzerott, S., Kasprzak, P., Kienel, U., & Kleinschmit, B. (2017). Monitoring of Calcite Precipitation in Hardwater Lakes with Multi-Spectral Remote Sensing Archives. Water, 9(1), 15. http://doi.org/10.3390/w9010015.*

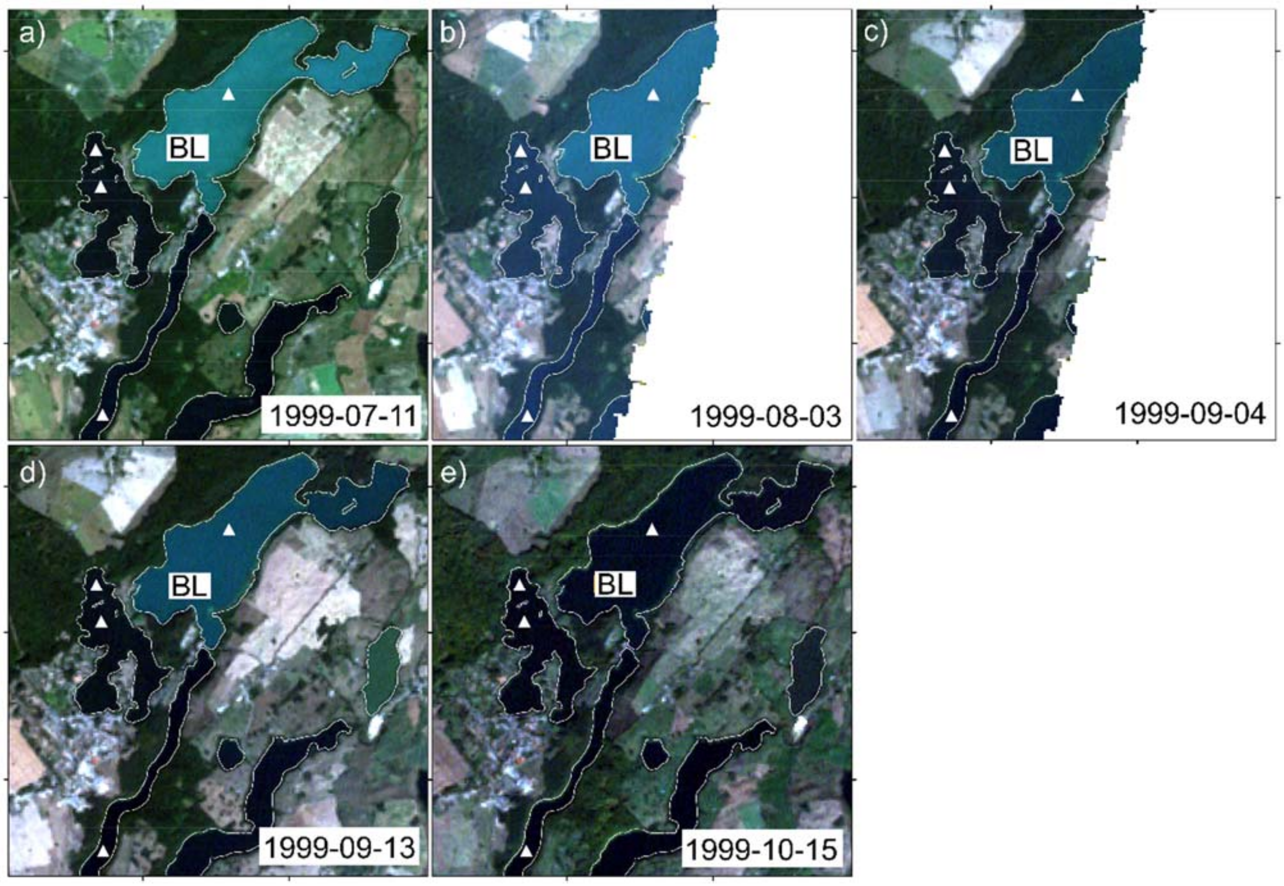


***Fig 1:** Quasi-true color RGB Landsat 7 images of the Feldberg Lake District. All lakes are framed with lines and the positions of in situ measurements are marked with white triangles. Breiter Luzin (BL) is turquoise colored on 11 July 1999 **(a)** due to calcite precipitation. In the following, calcite precipitation diminishes from 3 August 1999 to 13 September 1999 **(b–d)**, and on 15 October 1999 **(e)** BL appears dark again.*

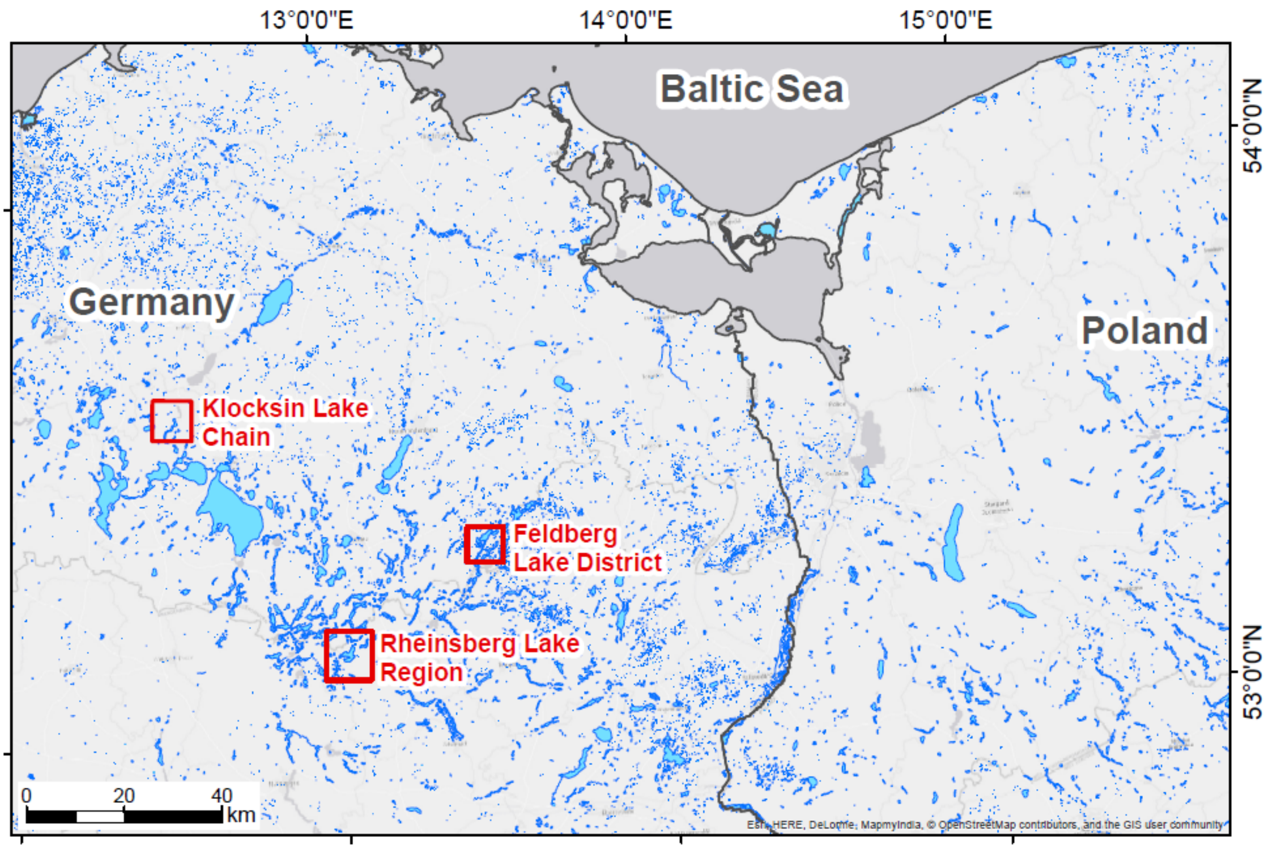


Fig. 2: *The Northeast German Plain with the three study areas: Feldberg Lake District, Klocksin Lake Chain and Rheinsberg Lake Region.*

References

Kelts, K. & Hsü, K., "Chapter 9: Freshwater carbonate sedimentation," in Lakes - Chemistry Geology Physics, 1978, pp. 295–323.

Koschel, R., P. Kasprzak & A. Schreiber, "Kalzitfällung und Nahrungskettenmanipulation," Laufener Semin., vol. 3/97, no. 3, pp. 61–76, 1997.

Koschel, R.; G. Proft & H. Raidt, "Autochthone Kalkfällung in Hartwasserseen der Mecklenburger Seenplatte," Limnol., vol. 18, no. 2, pp. 317–338, 1987.

Proft, G.,"Die pelagische Calcitfällung und der Carbonatgehalt von Sedimenten pleistozäner Seen," Acta Hydrochim. Hydrobiol., vol. 12, no. 1984, pp. 321–326, 1984.

Strong, A. & B. J. Eadie, "Satellite observations of calcium carbonate precipitations in the Great Lakes," Limnol. Oceanogr., vol. 23, no. 5, pp. 877–887, 1978.

Thiemann, S. & R. Koschel, "Erfassung des räumlichen Verteilungsmusters von Kalkfällung mit Fernerkundungsdaten," Wasser und Boden, vol. 53, no. 10, pp. 25–28, 2001.

Weidemann, A. D., T. T. Bannister, S. W. Effler & D. L. Johnson, "Particulate and optical properties during CaCO3 precipitation in Otisco Lake," Limnol. Oceanogr., vol. 30, no. 5, pp. 1078–1083, 1985.

DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

The ICLEA region in the context of a 400-year spatial reconstruction of European summer drought from a network of tree ring stable isotopes

Helle, Gerhard[1]*; Freund, Mandy[1,2]; Heinrich, Ingo[1]; Balting, Daniel[1]; Navabzadeh, Nadia[2] & Riedel, Frank[2]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[2] Freie Universität Berlin, Berlin, Germany

* Corresponding author: ghelle@gfz-potsdam.de

ICLEA is aiming at merging data across various time and spatial scales. With respect to time scales the realization of this demand is built upon on the integration of instrumental data and proxy data. With concern to spatial scales and focusing on climate it is of interest how the ICLEA region has evolved. Instrumental climate data have revealed that the annual sum of precipitation in the region has not changed over the last 100 years. However, seasonality has significantly changed with increased precipitation during winter and decreased rainfall in summer. It has become evident, that Europe's vulnerability is not restricted to the Mediterranean or the Middle East. Over central Europe extreme drought events occur even more frequent (Lloyd Hughes & Saunders, 2002). Although climate projections remain uncertainties about intensity and duration, a strong increase in drought frequency is predicted (Blenkinsop & Fowler, 2007). ICLEA particularly addresses the need for long-term data sets to better understand the spatial complexity of the large scale European hydroclimatic system. Such a long-term perspective is essential both for validation of climate models and comparison with other proxy, historical, and archaeological data.

Trees are a fundamental part of European ecosystems and they are acting as an important interface between atmosphere, biosphere, pedosphere and human environment. The precise annual dating differs considerably from other proxy data like corals, ice cores or sedimentary depositions.

A spatially resolved tree ring proxy data set of stable isotopes (carbon and oxygen) back to 1600AD has been derived from tree-ring chronologies of a network of European tree sites. Here, we will present and discuss a roughly 400year record of hydroclimate variability for the ICLEA region of NE-Germany based on a with a composite tree ring stable isotope record (stable carbon and oxygen isotopes) from pine and oak tree rings in the context of a spatial reconstruction of European summer drought from a European tree-ring isotope network (ISONET).

First, the significance and seasonal representation of climate signals in the tree ring stable isotope records was tested and compared with corresponding signals in tree ring widths by seasonal correlation analysis with gridded precipitation GPCC (within 60km) from 1901 to 1998. The analysis revealed that the tree-ring oxygen isotopes of all sites show a spatially homogenous seasonal signal responding to summer only (one exception: Turkey). In contrast, the strongest precipitation signal in tree ring width is highly variable across Europe in terms of seasonal response. However, studies indicate that tree growth of the ICLEA region and further to the east is strongly influenced by winter temperature (Balanzategui et al. 2017).

Based on our results from the spatially resolved seasonal correlation analysis tree ring oxygen isotope data series were used for setting up 400 year temporal reconstructions (Fig. 1) that allow for spatial maps of European summer drought and regional comparison. Lake Hinnensee data is derived from a single site only, hence, the SPEI-2 reconstruction shows higher variability than the regional reconstructions. The overall spatial hydroclimatic patterns across Europe reveal two dominate atmospheric circulation modes, closely linked to the Summer North Atlantic oscillation. Altogether, past summer conditions are spatially diverse, but also show similarities between regions. For example, summer hydroclimate in Fennoscandia was characterized by rather dry conditions during ca. 1630 to 1900AD. NE-Germany, as reflected by Lake Hinnensee data, experienced similar dry periods between ca. 1630 to 1700 and ca.1850 to 1900AD, but contrastingly rather wet summer conditions between ca. 1700 to 1850AD.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

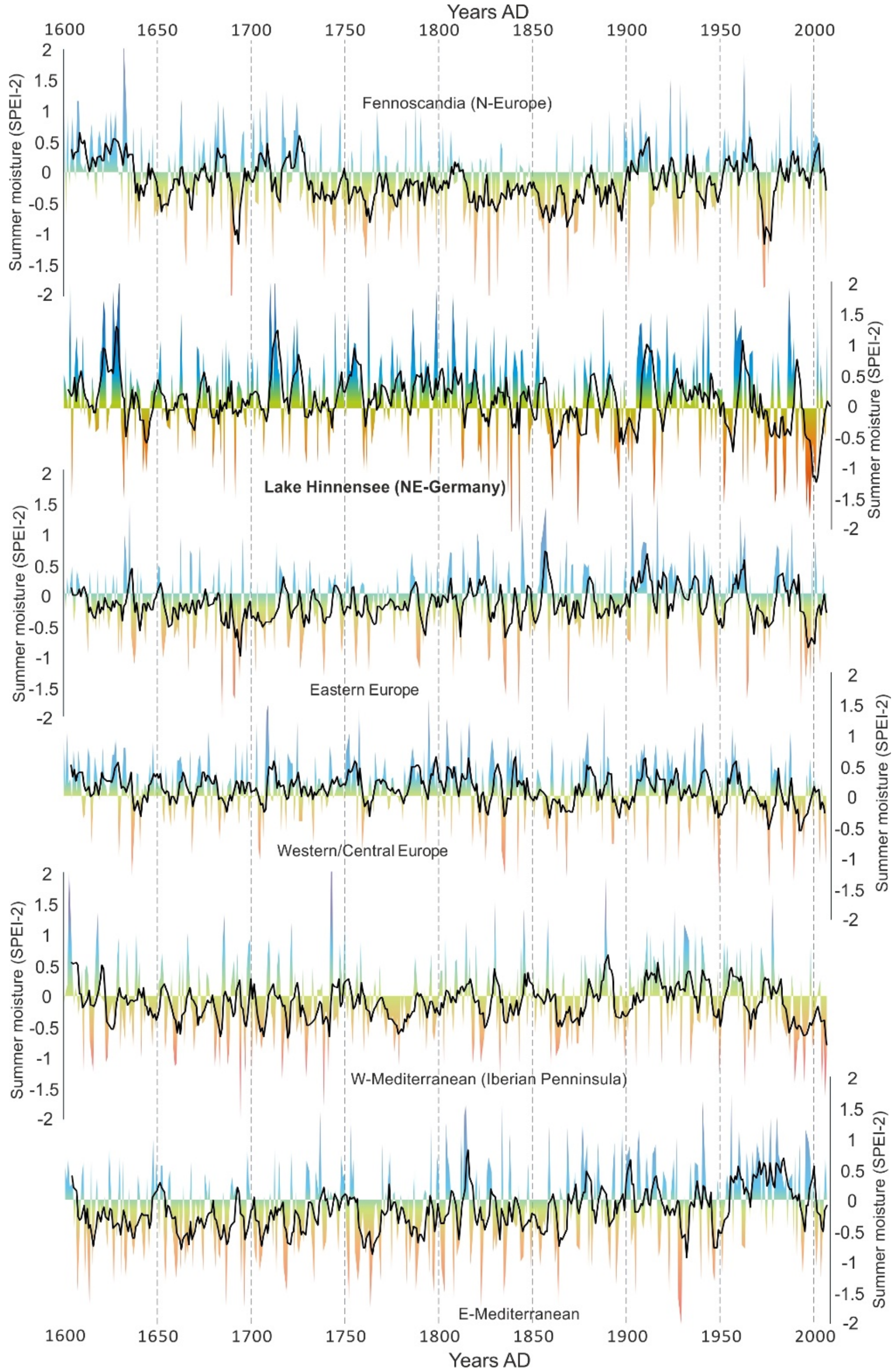


Fig. 1*: Regional reconstructions of European summer moisture variability (SPEI-2, Jul/Aug) since 1600AD and reconstruction of SPEI-2 from Lake Hinnensee (NE-Germany).*

References

Balanzategui, Knorr, A., D., Heußner, K.-U., Beck, W., Helle, G., Wazny, T., Buras, A., Wilmking, M., Heinrich, I. (2017) 800-year palaeohistory of cold-season temperature variability for northern Poland. BOREAS, accepted

Blenkinsop S., Fowler, H. 2007. Changes in European drought characteristics projected by the PRUDENCE regional climate models. International Journal of Climatology 27/12: 1595–1610

Lloyd Hughes, B., Saunders, M.A, 2002. A drought climatology for Europe. Int. J of Climatology 22/13: 1571–1592

Session 4: Man - climate - environment interactions

Late Holocene biochar enrichment in soils - implications of an anthropogenic legacy for ecosystems

Hirsch, Florian[1]*; Schneider, Anna[1]; Raab, Alexandra[2]; Raab, Thomas[1]; Ouimet, Will[3] & Dethier, David[4]

[1] BTU Cottbus-Senftenberg, Geopedology and Landscape Development, Cottbus, Germany
[2] BTU Cottbus-Senftenberg, Research Center Landscape Development and Mining Landscapes, Cottbus, Germany
[3] University of Connecticut, Department of Geography and Center for Integrative Geosciences, Connecticut, USA
[4] Williams College, Center for Environmental Studies, Williamstown, Massachusetts, USA
* Corresponding author: florian.hirsch@b-tu.de

Historical relicts of charcoal hearths (RCHs) provide an excellent setup to study long-term effects of biochar on soil development and plant growth. In pre-industrial times, large-quantities of charcoal were necessary for high-energy demand industries like ironworks. Hence numerous relicts of charcoal hearths can be found in ancient woodlands nearby historical ironworks both in Europe and in the Eastern United States. Within the scope of our study we elaborate the importance of relict charcoal hearths for the soils and the landscape development in the North German Lowland (Raab et al. 2015) and verify the transferability of our findings to a representative area with historical charcoal production in Litchfield County, Connecticut, USA (Raab et al. 2017).

In Lower Lusatia (NE Brandenburg, Germany), a large charcoal burning field was detected by archaeological research and mapping of RCHs on shaded-relief maps (SRMs). The charcoal was produced for the Peitz ironworks (operation time: 1554 – 1858) nearby. More than 300 years of charring wood in circular upright charcoal hearths left behind a remarkable amount of relicts in the forests northeast of Cottbus. The diameters of the ground plans of the RCHs vary strongly from 4 to 30,5 m. Charcoal burning resulted in a diverse soil landscape which is mainly characterized by hot spots of sites with a normally 30 cm thick heterogeneous charcoal bearing substrates on the former charcoal hearth platforms. In consequence, the soils on the relict charcoal hearths have experienced a considerable enrichment with biochar having an age between about 430 to 130 years. A further legacy effect seems to concern soil mineralogy, because soil color and magnetic susceptibility measurements strongly suggest that the substrate of the charcoal hearths and the buried soil was affected by thermal induced transformation processes of iron(hydr-)oxides.

In Litchfield County (Connecticut, northeastern United States) and surrounding regions, the iron industry dominated the economy and the landscape throughout the 19th century, peaking around 1850. Thus, the large number of charcoal hearths in this region is a relict of the more than 150 years long widespread iron production. In contrast to our study area in Lower Lusatia, which is characterized by a flat topography, the charcoal hearths in Litchfield County have a different architecture because the colliers erected the charcoal hearths on man-made terraces on the hillslopes. We also find that many charcoal hearths have been stabilized with boulders on the downslope side during construction and repeated use. In conclusion, the RCHs in Litchfield County are similar to those in the European low mountain ranges with respect to soil stratigraphy, size (e.g., average inner diameters of 9.5 m) and the construction of platforms on hillslopes. In Litchfield County, the black topsoils on the charcoal hearths containing residual charcoal are on average 2.6 times thicker than adjacent Cambisols. Frequently, the charcoal hearths display two or more black, charcoal-rich strata separated by layers of reddish-brown soil with minor charcoal contents indicating multiple use of the site. The presence of residual products from charcoal production classifies the soils as Anthropic Udorthents (US Soil Taxonomy) or Spolic Technosols (Humic) according to the World Reference Base for Soil Resources.

Although architecture and soil stratigraphy are basically comparable to charcoal burning areas in European low mountain ranges, completely different time frames and land use histories for European and northeastern United States must be considered. In the case of Europe, within the supra-regional centres of the medieval ore mining industry, intensive mining activities related with the production of large quantities of charcoal for ore processing resulted in the deforestation of large woodland areas and caused far-reaching landscape changes. Moreover, European land use history is long and complex. Most mining areas in Europe may have seen different and multiple usages (mainly farming and forestry) before and after the mining periods. In contrast, the landscape of the northeast United States was subject to very different types of land use by

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

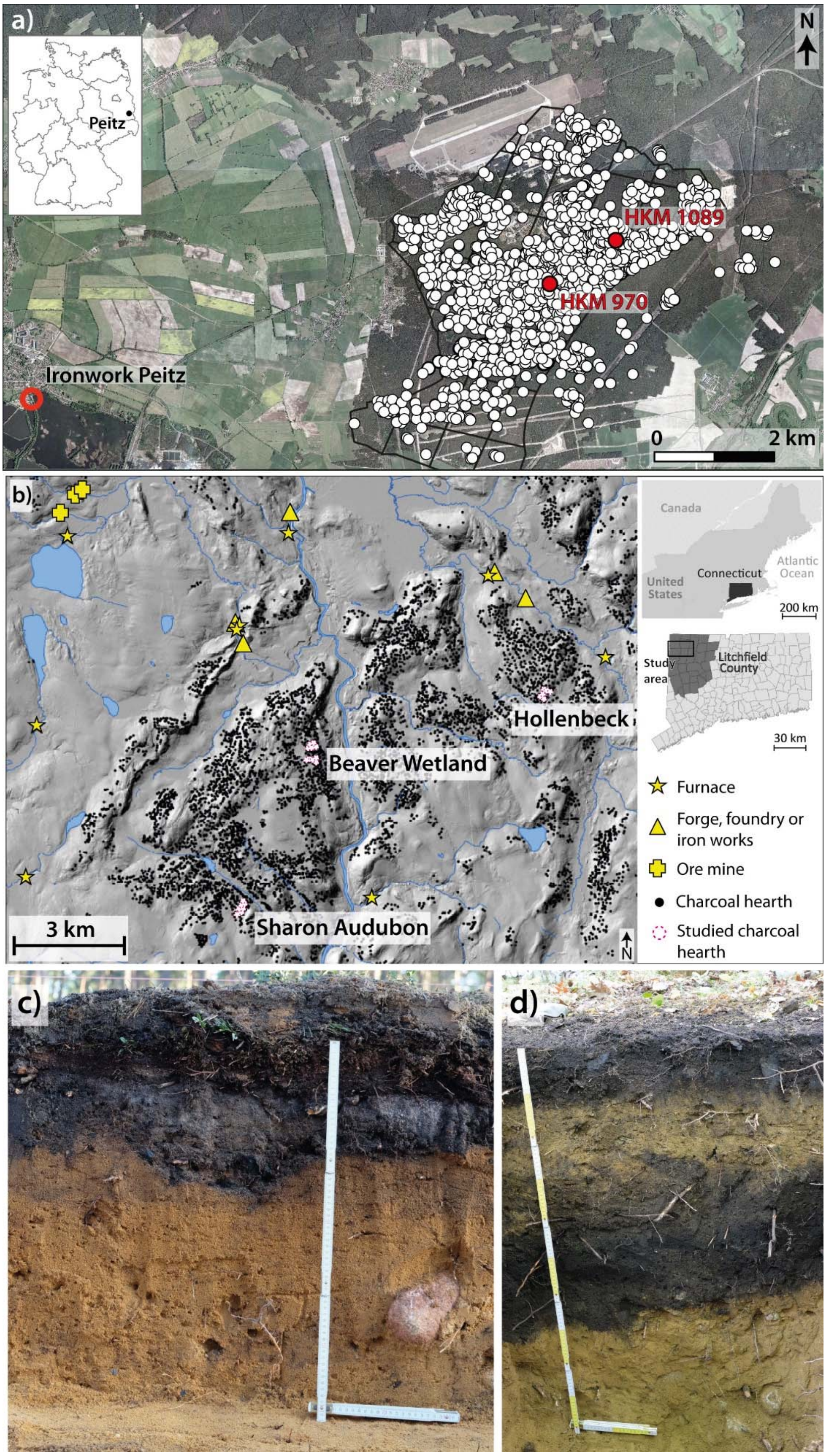


Fig. 1*: a) relict charcoal hearths (white dots, mapping stand 2016) in the historic forest plots (black grids) east of the village of Peitz, and b) in Litchfield County, Connecticut, USA; c) soil in the center of RCH No. 1089, Germany, d) multilayered soil profile of a relict charcoal hearth in Litchfield County.*

DOI: 10.2312/GFZb103-17037

Native American groups who had inhabited the region for thousands of years. The colonization of the region by Europeans in the 17th century brought drastically different types of land use, including charcoal production, European agricultural practices, and different forms of resource extraction. It is remarkable that present landscapes are densely forested and remains of former charcoal production, although only 125 years old, are barely visible at the surface, yet they have left a distinct pedogenic imprint. Geoarchaeological research on charcoal hearths is an emerging field that can significantly enhance our understanding of the environmental impact of historical charcoal production on our soil landscapes. Because European colonists brought knowledge of iron-working and charcoal production to New England, comparative studies between Europe and North America may allow us to quantify the “legacy effect” of this past land use on our modern ecosystems. The widespread occurrence of charcoal hearth remains and their high spatial density in different ecosystems underlines their importance for further pedological research.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association.

References

Raab, A., Takla, M., Raab, T., Nicolay, A., Schneider, A., Rösler, H., Heußner, K. U., and Bönisch, E. (2015): Pre-industrial charcoal production in Lower Lusatia (Brandenburg, Germany): Detection and evaluation of a large charcoal-burning field by combining archaeological studies, GIS-based analyses of shaded-relief maps and dendrochronological age determination. Quaternary International 367, 111-122.

Raab, T., Hirsch, F., Ouimet, W., Johnson, K. M., Dethier, D., and Raab, A. (2017): Architecture of Relict Charcoal Hearths (RCHs) in Northwestern Connecticut, USA. Geoarchaeology.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Heavy Metal Enrichment in laminated lake sediments from N-Germany and N-Poland: Geochemical background and enrichment history

Hoelzmann, Philipp[1]*, Brauer, Achim[2]; Dräger, Nadine[1]; Kienel, Ulrike[1,3]; Ott, Florian[1,4]

[1] Freie Universität Berlin, Institute of Geographical Sciences, Physical Geography, Berlin, Germany
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] University Greifswald, Institute for Geography and Geology, Greifswald, Germany
[4] Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany
* Corresponding author: phoe@zedat.fu-berlin.de

For two annually laminated lake sediment records, situated in rural environments in NE-Germany (Lake Tiefer See) and N-Poland (Lake Czechowskie), we present a detailed heavy metal enrichment history with sub-decadal resolution for the last 200 years. We determine the local and specific geogenic background values on the base of heavy-metal analysis of pre-industrial sediments and different sediment types (e.g. calcareous gyttja, organic gyttja etc.) and relate these to the global geochemical background value (GGBV) for shales determined by Turekian and Wedepohl (1961). These results provide means to calculate and quantify anthropogenic heavy metal accumulations and enrichment factors as well as to define regional measures for a state of reference, reflecting natural conditions without human impact.

Sediment analyses were performed using an aqua regia solution and an inductively-coupled plasma optical emission spectrometer (ICP-OES) according to DIN EN 1346 (Anonymous, 2001) to determine the heavy metals Cd, Co, Cr, Ni, Pb, and Zn. The dry bulk density of the sediments (g/cm³) together with the age models of the sediment records were used to calculate mass accumulation rates (MAR; g / cm² / a) for the period 1800 to 2010 AD. MAR are used to quantify and to differentiate between heavy metal concentrations of the sediments itself and the heavy metal input to the lakes.

All three lakes show a similar pattern of relatively low heavy metal concentrations. Co, Cr, and Ni show values well below the GGBV and only Cd, Pb, and Zn exhibit heavy metal enrichments that exeed the GGBV slightly (Figure 1). Preindustrial values of Cd, Pb, and Zn are low and lie within or only slightly above the detection limits (0.3 µg Cd / g dry weight; 5 µg Pb / g dry weight; 12 µg Zn / g dry weight). In Lake Tiefer See the heavy metal concentrations begin to rise around 1860 whereas in Lake Czechowskie a ca. 20 year later rise is notable. Highest heavy metal concentrations in the sediments of lake Tiefer See and Lake Czechowskie are reached by 1960 AD and thereafter these show a clear decline towards the top of the cores (2010 AD) where the values are within the GGBV for Cd and Pb, whereas Zn shows values below the GGBV. The setting of the lakes - no direct inflow or connection to larger settlements – and the relatively clear concentration signal for Pb suggest a mainly atmospheric source for the heavy metal concentrations due to increasing industrialization within the framework of the Industrial Revolution.

The three lakes show an individual pattern of MAR that result from various processes within the lakes itself and their catchments. Authigenic components (e.g. calcite, diatoms etc.) and especially anthropogenic processes related to historical events or development measures may influence the MAR and thus the heavy metal concentration of the sediments.

At Lake Tiefer See the MAR does not show large changes throughout the last 200 years and the heavy metal input runs almost parallel to the Cd, Pb, and Zn concentration of the sediments. In contrast, the MAR at Lake Czechowskie changes dramatically between 1830 to 1880 to more than twofold values of the average of the last 200 years, probably due to railway installation in the vicinity. During this period the heavy metal input (kg/a of Cd, Pb, and Zn) reached values similar to the input around 1960 when Cd, Pb and Zn concentrations were highest. This points out that determination of MAR is necessary to evaluate heavy metal deposition in the lakes.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

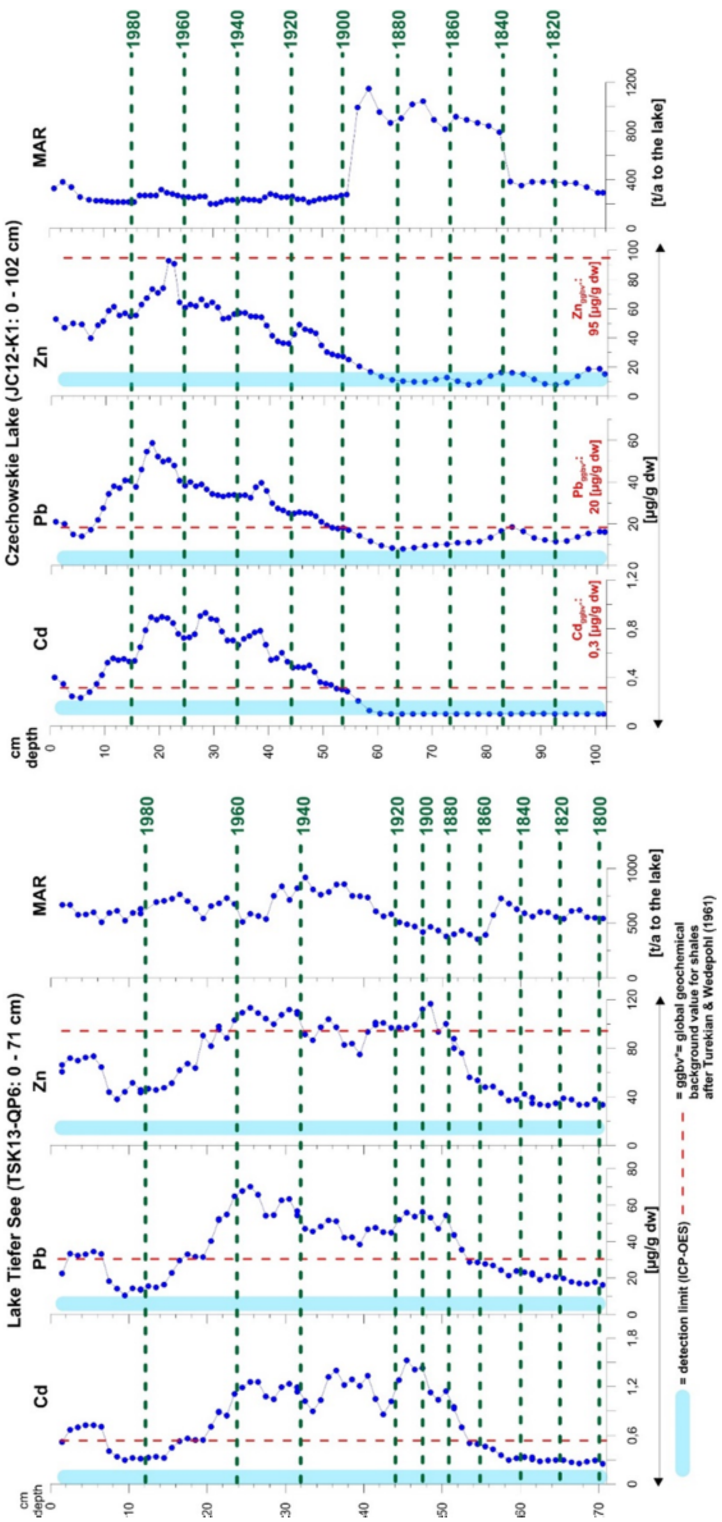


***Fig. 1**: Cd, Pb, and Zn concentrations (µg/g dry weight) and mass accumulation rate (MAR in t/a to the lake) for Czechowskie Lake and Lake Tiefer See.*

References

Anonymous (2001): Charakterisierung von Schlämmen - Bestimmung von Spurenelementen und Phosphor - Extraktionsverfahren mit Königswasser; Deutsche Fassung EN 13346: 2000, Beuth Verlag (Ed.).

Turekian, K. and Wedepohl, K. (1961): Distribution of the elements in some major units of the earth`s crust. Bull. Geol. Soc. Am., 72:175-192.

Session 3: Integrating time-scales and regional synchronization

BaltRap – from environmental monitoring to paleoenvironmental reconstructions

Kaiser, Jérôme[1]*; Arz, Helge[1]; Dellwig, Olaf[1] & BaltRap members

[1] Leibniz Institute for Baltic Sea Research – Warnemünde (IOW), Marine Geology, Seestrasse 15, 18119 Rostock-Warnemünde, Germany
* Corresponding author: jerome.kaiser@io-warnemuende.de

The new national BaltRap network ("The Baltic Sea and its southern Lowlands: proxy – environment interactions in times of Rapid change"; https://www.io-warnemuende.de/geo-projekte-baltrap.html) aims to comprehensively understand the impact of rapid climate change in the southern Baltic Sea region during the Holocene by integrating high-resolution marine (sediments) and terrestrial (lake sediments and tree rings) proxy archives (Fig. 1). As a prerequisite for the interpretation of proxy time series is a profound knowledge of the actual natural systems and the processes leading to proxy formation. Instrumental time series, archive monitoring, and a thorough proxy development are required to trace seasonal to decadal-scale responses of the brackish/marine and terrestrial/limnic environments to climate variability. Existing instrumental time series of climate parameters will be compared with on-going monitoring protocols in all BaltRap archives to elucidate the formation, calibration, and application of complementary bio- and geo-based proxies.

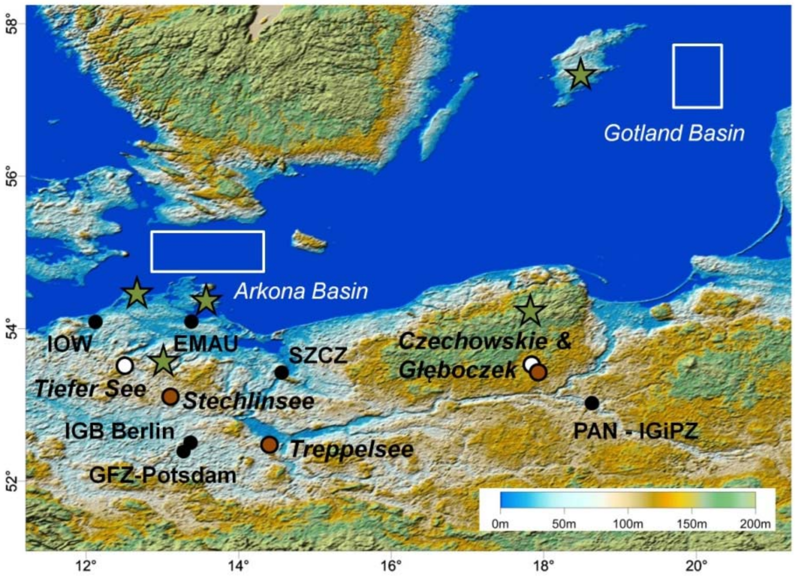


Fig. 1: *Location of BaltRap study sites: tree rings (green stars), Baltic Sea (white rectangles) and lakes (white circles: lake sediment records available and studied within ICLEA; orange circles: lakes to be studied within BaltRap). Black circles: partner institutions involved in the network.*

The terrestrial monitoring part will build on ongoing lake and tree monitoring established by the Virtual Institute ICLEA. For the Baltic Sea, available instrumental observations are reaching back into the 19th century, but a comprehensive ecosystem monitoring by means of coastal stations, research vessels, moorings, permanent stations, and satellites was developed stepwise after the Second World War and significantly intensified after founding of the HELCOM (Helsinki Commission; www.helcom.fi) in 1975 for protecting the Baltic marine environment against anthropogenic influences. However, despite the vast amount of instrumental data, calibration of paleoenvironmental proxies is often complicated due to weakly constraint chronologies of these young sediments. In many cases sedimentation is not continuous and sediments are subject to erosion, re-suspension, lateral transport, and focusing due to intense wind driven waves and current activity. Therefore, a direct link of sedimentary proxies with instrumental water column observations is not always straightforward and generally not well established. Recently developed event stratigraphic and radionuclide based chronologies in some restricted Baltic Sea areas like the central Baltic deeps form now a

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

solid base for the in depth proxy development and validation with instrumental time series (Kabel et al., 2012; Moros et al., 2016).

Among others, promising results come from organic biomarkers in recent/sub-recent sediments. Using surface sediments from the entire Baltic Sea, Kaiser and Arz (2016) and Kaiser et al., (2016) have tested and calibrated some biomarkers and organic proxies for e.g. primary production, terrestrial inputs, freshwater environments, water temperature and surface water inflow from the North Sea. In a previous study, Kabel et al., (2012) calibrated the TEX_{86} water temperature proxy for the Baltic Sea using surface sediments, and further applied this proxy on well-dated short sediment core from the central Baltic Sea (eastern Gotland Basin) (Fig. 2). The TEX_{86} temperature record reflects instrumental sea surface temperatures over the last 40 years, attesting the robustness of the proxy and allowing its use to reconstruct temperature back in time beyond instrumental data. Most recently, a TEX_{86} temperature record has been produced together with a reconstruction of surface salinity over the last 2000 years by means of a short sediment core from the central Baltic Sea (Landsort Deep). These records are closely related to temperature and rainfall fluctuations known in Europe and Scandinavia, highlighting the huge potential of such organic proxies for Holocene paleoenvironmental reconstructions in the Baltic Sea realm.

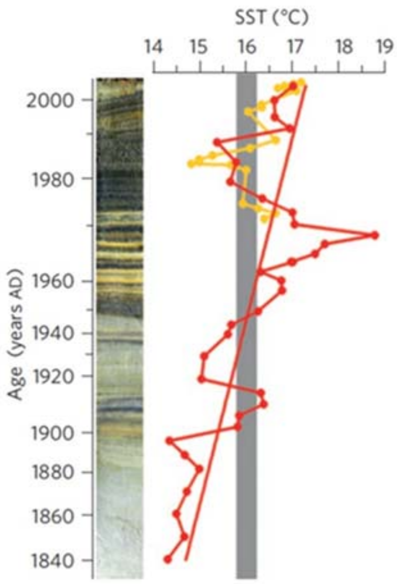


Fig. 2: *Proxy-based (TEX^{L}_{86}) sea surface temperature estimates based on a short sediment core from the eastern Gotland Basin (red line with dots, straight line shows the main trend) compared to instrumental sea surface temperatures (yellow line with dots). The vertical gray bar represents the minimum temperature for cyanobacterial blooms in the Baltic Sea (modified after Kabel et al., 2012).*

The synchronization of the terrestrial and marine archives in order to decipher between local (anthropogenic) and regional (climatic) signals will be a key issue for the ultimate phase of BaltRap. Beyond independent age models based on radionuclides and radiocarbon dating, event stratigraphy (using e.g. atmospheric pollutants and trace metals), tephrochronology and proxies registering climate variability at a (sub)regional scale (such as temperature and humidity) will be used tentatively for synchronization.

References

Kabel, K., Moros, M., Porsche, C., Neumann, T., Adolphi, F., Andersen, T.J., , Siegel, H., Gerth, M., Leipe, T., Jansen, E., Sinninghe Damsté, J.S., 2012. Impact of climate change on the Baltic Sea ecosystem over the past 1,000 years. Nature Climate Change 2, 871–874.

Kaiser, J., Arz, H.W., 2016. Sources of sedimentary biomarkers and proxies with potential paleoenvironmental significance for the Baltic Sea. Continental Shelf Research 122, 102-119.

Kaiser, J., Belt, S.T., Tomczak, M., Brown, T.A., Wasmund, N., Arz, H.W., 2016a. C25 highly branched isoprenoid alkenes in the Baltic Sea produced by the marine planktonic diatom Pseudosolenia calcar-avis. Organic Geochem. 93, 51-58.

Moros, M., Andersen, T. J., Schulz-Bull, D., Häusler, K., Bunke, D., Snowball, I., Kotilainen, A., Zillen, L., Jensen, J. B., Kabel, K., Hand, I., Leipe, T., Lougheed, B. C., Wagner, B., Arz, H. W., 2017. Towards an event stratigraphy for Baltic Sea sediments deposited since AD 1900: approaches and challenges. Boreas 46, 129-142.

DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

A large-scale medieval dam-lake cascade in central Europe: water level dynamics of river Havel, Berlin-Brandenburg region, Germany

Kaiser, Knut[1]*; Keller, Nora[2]; Brande, Arthur[3]; Dalitz, Stefan[4]; Hensel, Nicola[5]; Heußner, Karl-Uwe[6]; Kappler, Christoph[1,7]; Michas, Uwe[8]; Müller, Joachim[4]; Schwalbe, Grit[1]; Weiße, Roland[9] & Bens, Oliver[1]

[1] GFZ - German Research Centre for Geosciences, Germany
[2] University of Marburg, Department of Geography, Germany
[3] Technische Universität Berlin, Department of Ecology, Ecosystem Science and Plant Ecology, Germany
[4] Municipal Office Brandenburg/Havel, Heritage Conservation, Germany
[5] Archäologie Manufaktur GmbH, Germany
[6] DAI - German Archaeological Institute, Germany
[7] Brandenburg University of Technology Cottbus-Senftenberg, Chair of Soil Protection and Recultivation, Germany
[8] Berlin Monument Authority, Germany
[9] Auf dem Kiewitt 27/41, D-14471 Potsdam, Germany
* Corresponding author: kaiserk@gfz-potsdam.de

Understanding the historical water level dynamics helps to comprehend how waterscapes in northern central Europe and beyond were anthropogenically transformed, and which pre-modern hydro-ecological reference status can be presumed. It was occasionally hypothesized by different scientific disciplines that the present-day hydrography of the metropolitan area of Berlin and its surrounding is a product of medieval and modern human transformation of the drainage system, modified to meet the needs for energy and food supply (milling, fishing), urbanization and inland navigation (e.g. Brande, 1996; Nützmann et al., 2011; Kaiser et al., 2012).

An interdisciplinary study was carried out to trace the hydrological changes of the river Havel over the course of the last c. 2000 years (Kaiser et al., 2017). The river system forms a series of dammed lakes and river sections which were greatly altered through hydraulic engineering in the past. Along the middle course of the Havel, sixteen sedimentary sequences available for geoarchaeological and paleoecological research were analysed in order to reconstruct regional water level dynamics. Chronological control was ensured through a multitude of palynological, dendrochronological, archaeological, and radiocarbon data.

The sections upriver from the Brandenburg/H. and Spandau weirs, representing sites with historic watermills (undershot type), reveal substantial water level changes during the late Holocene. Generally, lower water levels before and higher levels during the medieval German colonization of that area (c. A.D. 1180/1250) can be inferred (Fig. 1). This water level increase, which is primarily attributed to dams constructed for watermills and secondarily due to a multitude of fish weirs, took place rapidly and amounted to a relative height of c. 1.5 m. It enlarged the river's cross-sections and increased the size of existing lakes or initiated secondary lake developments when already aggraded, and thus caused a flooding of large parts of land. The rising water level even influenced the settlement topography to a large degree. Several medieval rural settlements were abandoned due to flooding.

In total a c. 150 km-long dammed lake cascade was formed, which is one of the largest anthropogenic dam-lake structures in historic times globally. Thereof, the c. 70 km-long middle river course between Brandenburg/H. and Spandau is the largest medieval dam lake in central Europe known thus far, considerably enlarging existing glacial lakes along river Havel.

From a general perspective, the hydraulic effects of medieval to modern watermills in northern central Europe can be classified by the impoundment effect: besides numerous small-scale dammings of streams and minor rivers which often form chains of small dam impoundments, there is also a large-scale effect, comprising dam lakes with a longitudinal range of up to some tens of kilometers. Several larger river valleys in the lowlands were drowned in this way, representing a legacy of hydraulic energy production in medieval and modern Europe.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

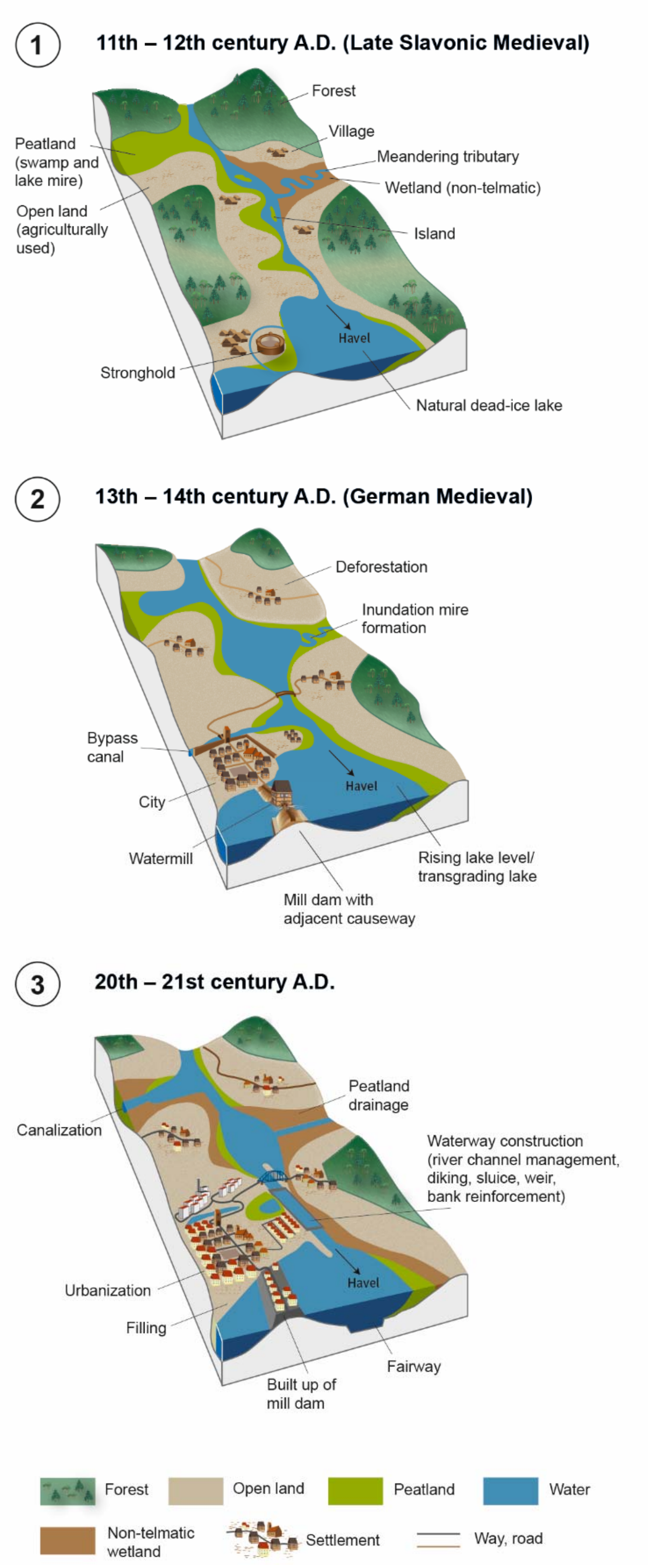


Fig. 1: *Conceptual model showing selected hydrological, sedimentological, ecological and settlement changes in the middle river Havel valley caused by anthropogenic impoundment (mill damming).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

References

Brande, A., 1996. Type region D-s, Berlin. In: Berglund, B.E., Birks, H.J.B., Ralska-Jasiewiczowa, M., Wright, H.E. (Eds.), Palaeoecological events during the last 15000 years. Regional syntheses of palaeoecological studies of lakes and mires in Europe. John Wiley & Sons, Chichester, pp. 518-523.

Kaiser, K., Lorenz, S., Germer, S., Juschus, O., Küster, M., Libra, J., Bens, O., Hüttl, R.F., 2012. Late Quaternary evolution of rivers, lakes and peatlands in northeast Germany reflecting past climatic and human impact – an overview. E&G Quaternary Science Journal 61, 103-132.

Kaiser, K., Keller, N., Brande, A., Dalitz, S., Hensel, N., Heußner, K.-U., Kappler, C., Michas, U., Müller, J., Schwalbe, G., Weiße, R., Bens, O., 2017. A large-scale medieval dam-lake cascade in central Europe: water level dynamics of river Havel, Berlin-Brandenburg region, Germany. Geoarchaeology – An International Journal, in press.

Nützmann, G., Wolter, C., Venohr, M., Pusch, M., 2011. Historical patterns of anthropogenic impacts on freshwaters in the Berlin-Brandenburg region. Die Erde 142, 41-64.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

A submerged pine forest from the early Holocene in the Mecklenburg Lake District, NE Germany

Kaiser, Knut[1]*; Oldorff, Silke[2]; Breitbach, Carsten[3]; Kappler, Christoph[1,4]; Theuerkauf, Martin[5]; Scharnweber, Tobias[6]; Schult, Manuela[5]; Küster, Mathias[7]; Engelhardt, Christof[8]; Heinrich, Ingo[1]; Hupfer, Michael[8] & Bens, Oliver[1]

[1] GFZ - German Research Centre for Geosciences, Germany
[2] Nature Park Stechlin-Ruppiner Land, Germany
[3] University of Potsdam, Institute of Earth- and Environmental Science, Germany
[4] Brandenburg University of Technology Cottbus-Senftenberg, Chair of Soil Protection and Recultivation, Germany
[5] University of Greifswald, Institute of Geography and Geology, Germany
[6] University of Greifswald, Institute of Botany and Landscape Ecology, Germany
[7] Müritzeum Waren (Müritz), Germany
[8] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Germany
* Corresponding author: kaiserk@gfz-potsdam.de

Subaquatic tree stumps and trunks were discovered at Lake Giesenschlagsee (Fig. 1) at a water-depth interval between 2 to 5 m using scuba diving, sidescan sonar and a remotely operating vehicle (ROV). Several upright standing stumps (diameters: 8-50 cm, heights above ground: 7-45 cm), fixed by roots in the ground, indicate an *in situ* record.

Botanical determination revealed Scots pine (*Pinus sylvestris*) with an individual age of up to 92 years. Being older than the regional reference chronology for pine, the trees could not be dated by dendrochronology. Radiocarbon ages from the wood range from 10361 ± 76 to 10887 ± 148 cal BP which is equivalent to the late Boreal to mid Preboreal biozones.

The rooting ground of the trees was a sedge peat, dating palynostratigraphically shortly before the early Holocene expansion of hazel in the region between 10500 and 10800 cal BP. Tilting of the peat bed by 4 m indicates subsidence of the forest floor due to local dead ice melting, causing drowning and preservation of the trees for millennia.

For the first time a submerged pine forest from the early Holocene could be documented in a lake of central Europe. Together with further recently detected Lateglacial *in situ* tree occurrences in nearby lakes it represents a new and very promising type of geobio-archive in that region. Initial dendrochronological analyses reveal a great potential of the well-preserved wood in terms of environmental and climatological information stored in the tree ring characteristics. A systematic screening for more subfossil wood preserved in regional lakes might lead to longer and continuous tree chronologies covering larger parts of the late Quaternary.

Comparable *in situ* pine occurrences occur at some terrestrial (buried setting) and marine sites (drowned setting) in northern central Europe and beyond but partly differ in age. In general, they document shifts of the zonal boreal forest ecosystem during the late Quaternary. As the vegetation history, topography and lake forming processes in the formerly glaciated (Weichselian) areas of central Europe are widely similar, further drowned forests can be expected at least in some of the thousands of glacial lakes in this region.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

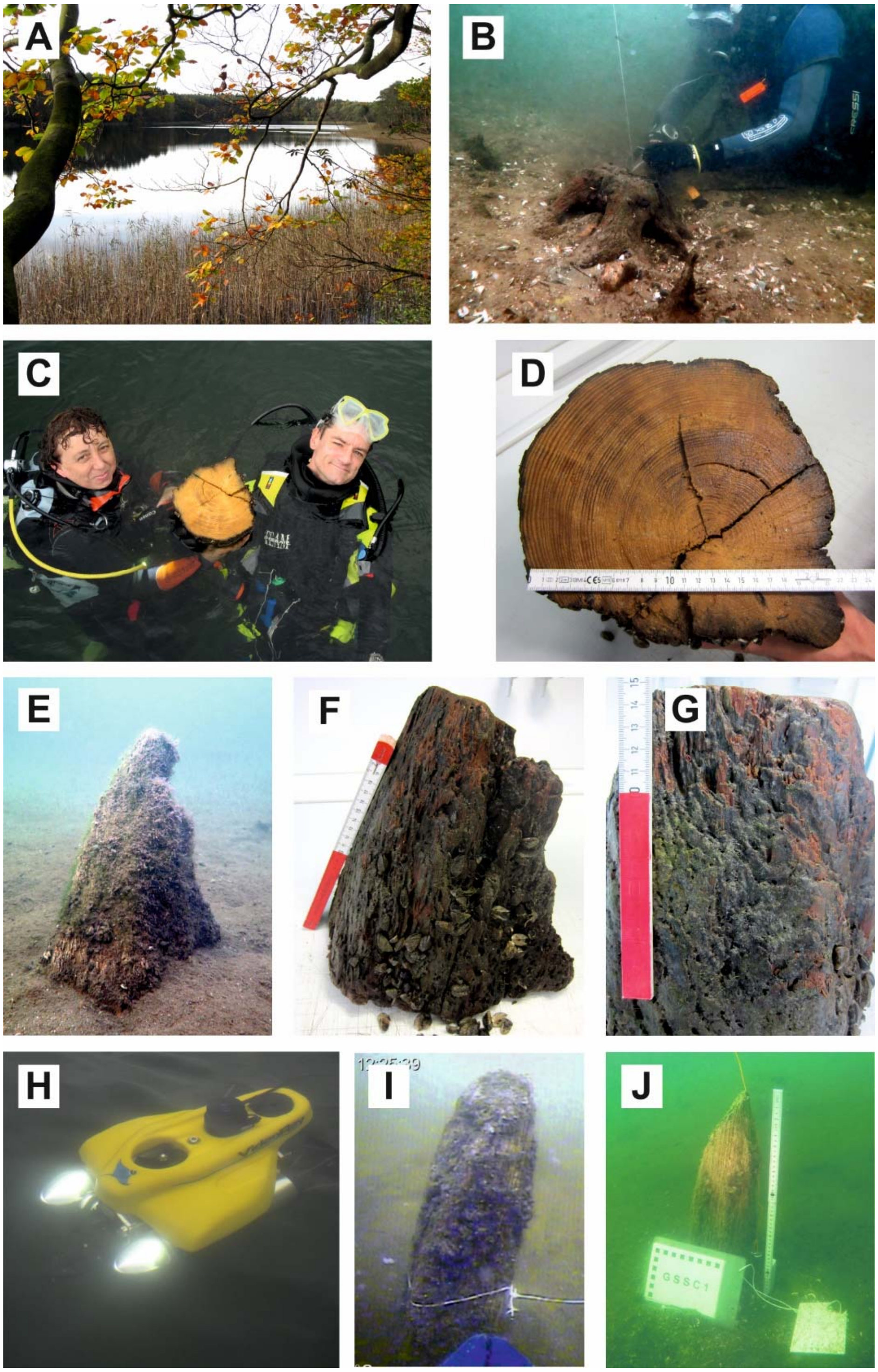


Fig. 1: *Photographs of the Lake Giesenschlagsee record. A: Northern part of the lake. B: Diver sampling tree stump GSSC5 (10674 ± 63 cal BP). C: Divers with a sample (cross section) of tree stump GSSC3 (10887 ± 148 cal BP). D: Cross section of tree stump GSSC3 in the lab (diameter: c. 22 cm). E: Tree stump GSSC3 found in situ (height: c. 50 cm) with coatings of algae and molluscs (Dreissena polymorpha). F: Outside appearance of tree stump GSSC3 in the lab (total view) with coating of molluscs (Dreissena polymorpha) and small cavity-like feeding traces (upper part). G: Outside appearance of tree stump GSSC3 in the lab (detail view). H: Operating ROV. I: Photograph of tree stump GSSC1 (height: c. 45 cm) taken by the ROV. J: Photograph of tree stump GSSC1 (height: c. 45 cm) taken by diver during documentation and sampling (photographs: A, C, D, F-H: K. Kaiser; B, E: S. Oldorff; I: C. Engelhardt; J: C. Breitbach).*

Session 4: Man - climate - environment interactions

Modeling global human-environment interactions in the preindustrial late Quaternary: What have we learned and what is the way forward?

Kaplan, Jed O.[1,2]*

[1] Institute of Earth Surface Dynamics, University of Lausanne, Switzerland
[2] ARVE Research Sàrl, Switzerland
* Corresponding author: jed.kaplan@arve-research.com

The expansion and dispersal of modern humans across the world during the Late Pleistocene and Holocene is one of the most important periods in the evolution of the earth system. Niche construction, combined with megafauna extinctions and rapid climate change, set the stage for the development of agriculture, urbanization and the emergence of complex civilizations. From the first domestication of plants and animals more than 10,000 years ago to the emergence of empires in the Iron Age, a series of agricultural and technological developments further revolutionized land use by societies worldwide. The spread of crop plants across the continents, the adoption of animal traction, the invention of the plow and the wheel, of metal agricultural implements, and the application of organic fertilizers all led to the intensification land use for crop and animal production. This intensification allowed both growing human populations to be supported by a stable land base, and opened up new frontiers for agriculture that were previously undesirable for cultivation. In some cases, growing populations further developed macro-levels of social organization that facilitated collective undertakings that influenced land use, such as irrigation and terracing. All of these phenomena occurred heterogeneously in space and time, and while their importance for climate and the carbon cycle over the late Quaternary is strongly debated, at local to regional scales it is generally acknowledged that landscape history has an important anthropogenic component.

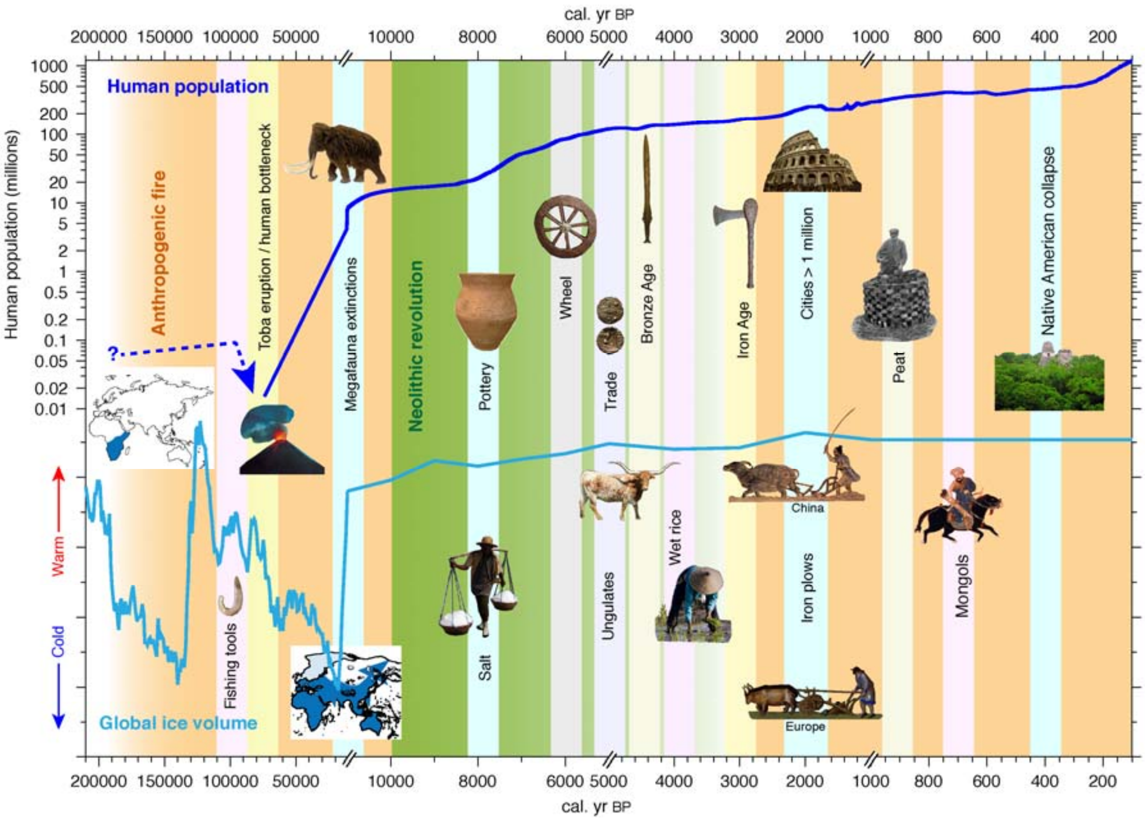


Fig. 1: *Major developments in human-environment history over the late Quaternary.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Thus, understanding human-environment interactions and anthropogenic influences on the earth system in the past is essential for assessing the current state of ecosystems and the services they provide to humanity. This is particularly true for the terrestrial biosphere, but marine and freshwater ecosystems, and even regional and global climate, were likely modified by human activities centuries to millennia ago. Studying linked environmental and human history also gives us insight into times when societies were either resilient or vulnerable in the face of exogenous environmental change, such as extended drought, cold, heat and other aspects of climate variability. Direct observations are however very sparse in space and time, especially as one considers prehistory. Numerical models are therefore essential to produce a continuous picture of human-environment interactions in the past. Agent-based approaches, while widely applied to quantifying human influence on the environment in localized studies, are unsuitable for global spatial domains and late Quaternary timescales because of computational demands and large parameter uncertainty.

Here I outline a new paradigm for the quantitative modeling of human-environment interactions in preindustrial time that is adapted to the global late Quaternary. Rather than attempting to simulate agency directly, my model is informed by a suite of characteristics describing those things about society that cannot be predicted on the basis of environment, e.g., diet, presence of agriculture, or range of animals exploited. These categorical data are combined with the properties of the physical environment in coupled human-environment model. The model is, at its core, a dynamic global vegetation model with modules for simulating the human use of fire for landscape management, and for simulating crop growth that is adapted for preindustrial agriculture. The former module simulates the way in which climate and other properties of the physical environment affected suitability for hunter-gatherer populations, while at the same time allowing humans to modify their local environment, i.e., niche construction, through the controlled application of wildland fire. The latter module allows me to simulate yield and calories for feeding both humans and their domesticated animals. Using both modules, I calculate a basic carrying capacity and couple this with a simple demographic model to calculate potential population, and, constrained by labor requirements and land limitations, we create scenarios of land use and land cover on a moderate-resolution grid. We further implement a feedback loop where anthropogenic activities lead to changes in the properties of the physical environment, e.g., through soil erosion.

I provide an overview of the current state of the art in modeling human-environment interactions and give three examples of my latest modeling experiments. First, I will show how humans could have had a substantial influence on the landscapes of Europe during the Last Glacial Maximum, selectively using fire to promote more open and heterogeneous landscapes. This anthropogenic modification of the land surface facilitated further dispersal and increases in population, a positive feedback that ultimately accelerates the growth and spread of humans across the planet. Second, I will demonstrate how the arrival of the Maori in New Zealand at about 1280 CE led to rapid, widespread changes in flora and fauna, including deforestation and extinction of many endemic species. My simulations show that small numbers of highly forager-horticulturalists, using fire to improve their mobility and hunting and foraging opportunities, caused both an initial peak in fire for deforestation and a small increase in background fire frequency that prevented forest vegetation from regenerating because of changes in the structure of the vegetation; mainly an increase in herbaceous fuels. Finally, I will demonstrate the “way forward” in modeling Holocene land use change caused by agricultural societies with a case study from West Africa, where we have performed an extensive synthesis of archaeological data to map changing subsistence livelihoods over the Iron Age transition. This transition was a key period for the development of contemporary African environments, and the role of humans versus climate change are highly debated. Together, these examples provide an illustration of the importance of human action for the Earth System over the late Quaternary and the way in which models may help provide a quantitative, spatially continuous picture of environmental change.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Stratigraphy and age of colluvial deposits indicating Late Holocene soil erosion in northeastern Germany

Kappler, Christoph[1,2]*; Kaiser, Knut[1]; Tanski, Phillipp[3]; Klos, Friederike[4]; Fülling, Alexander[5]; Mrotzek, Almut[6]; Sommer, Michael[7] & Bens, Oliver[1]

[1] GFZ - German Research Centre for Geosciences, Potsdam, Germany
[2] Brandenburg University of Technology Cottbus-Senftenberg, Chair of Geopedology and Landscape Development, Cottbus, Germany
[3] Freie Universität Berlin, Institute of Geographical Sciences, Berlin, Germany
[4] Technical University Bergakademie Freiberg, Institute of Geology, Freiberg, Germany
[5] Humboldt University of Berlin, Institute of Geography, Berlin, Germany
[6] University of Greifswald, Institute of Botany and Landscape Ecology, Greifswald, Germany
[7] Leibniz Center for Agricultural Landscape Research (ZALF) e.V., Institute of Soil Landscape Research, Müncheberg, Germany
* Corresponding author: kappler@gfz-potsdam.de

The mesoscale Quillow river catchment, located in an agriculturally used hummocky glacial landscape, bears sedimentary sections with colluvial sediments. These sediments were analysed to explore the pedosedimentary geoarchive potential of different landforms. Based on these findings we seek to establish a local chronology of late Holocene soil erosion. Sections from lower slopes were found to contain a simple stratigraphy mostly with one topping colluvial layer. With a thickness of up to 1 m it mostly buries a palaeosol. By contrast glacial kettle holes preserve more complex sequences, partly containing several colluvial layers of up to 30 cm thickness with intercalating palaeosols. The most complex stratigraphy is associated with a kettle hole serving as the ultimate sediment trap for a dendritic gully system. This kettle hole is bound to produce a sequence of 4 m of alternating peat and colluvial layers. Thirty-one OSL ages and 13 radiocarbon ages were used to reconstruct phases of enhanced soil erosion.

Soil erosion, potentially human induced as corroborated by local archaeological and palynological data, can be traced back to the last c. 4000 years. Hence, the earliest colluvial deposits are chronologically linked to the Late Bronze Age. Most ages, however, cluster within the last 600 years with a peak in the last 200 years, ascribing the main phase of local soil erosion to the recent past. Thus, although several settlements are proven in the catchment since the Neolithic, prominent human impact by agricultural soil erosion does not occur before the last millennium. According to their OSL chronologies, other regions in central Europe show a more complex erosion history exhibiting a pronounced two- or three-phased age-distribution from colluvial sediments dating into the last c. 5000 years.

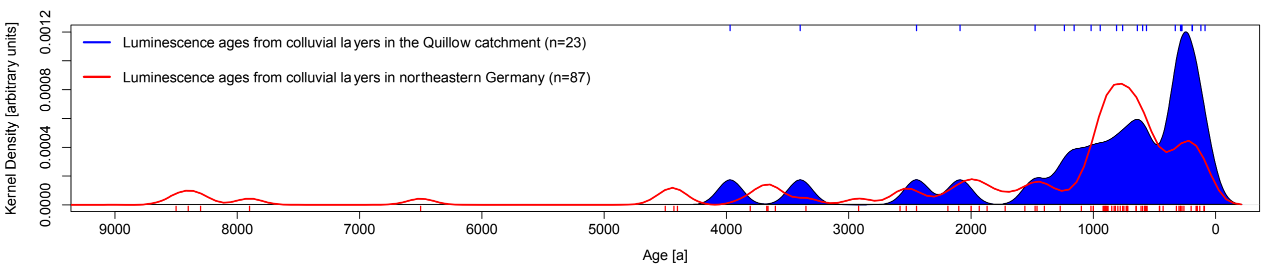


Fig. 1: *Kernel density estimates of dated colluvial layers (luminescence ages) indicating historical soil erosion in the Quillow catchment (blue curve) and in the total area of Northeast Germany (red curve).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Summer blooms of cyanobacteria in Lake Tiefer See (NE Germany) - Increased nutrient input can overrule shallow lake mixing as driver

Kienel, Ulrike[1]*; Lami, Andrea[2]; Plessen, Birgit[1]; Kirillin, Georgiy[3]; Brademann, Brian[1]; Pinkerneil, Sylvia[1]; Gerli, Stefano[2]; Dräger, Nadine[1] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[2] ISE CNR-Institute for Ecosystem Studies, Paleolimnology, Verbania Pallanza, Italy

[3] Leibniz-Insitute of Freshwater Ecology and Inland Fisheries IGB, Berlin, Germany

***** Corresponding author: ukienel@gfz-potsdam.de

Lake monitoring of deep Lake Tiefer See during four successive, but meteorologically different summer seasons 2012 to 2015 revealed a strong impact of the duration of constantly warm, shallow-mixing periods in summer on the outcome of cyanobacteria blooms. Sediment trapped in 12 and 50m water depth yielded the highest concentrations of pigments related to cyanobacteria (echinenone, zeaxanthin, and myxoxanthophyll with accentuation on the latter indicative for colonial forms) during the longest period of shallow lake mixing (< 4m water depth) in summer 2014 (Fig. 1).

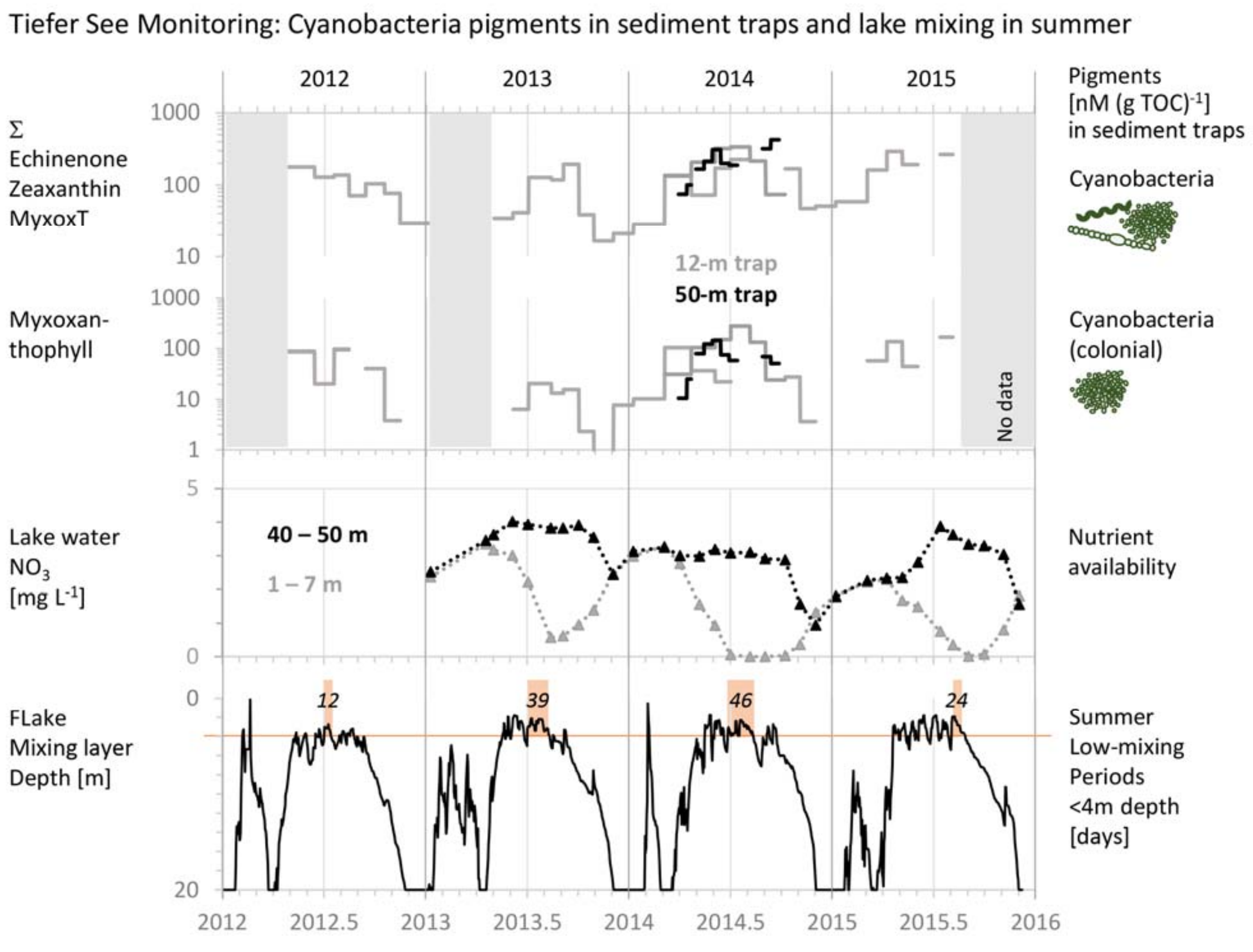


Fig. 1: *Tiefer See monitoring: Concentrations of pigments related to cyanobacteria were highest during the longest summer period of of reduced lake mixing in summer 2014 (modelled using the lake-temperature model FLake (Kirillin 2010; Mironov 2008)). The strong bloom used up the epilimnetic nitrate pool already at the end of June, causing cyanobacteria to move into the metalimnion (8 – 10m water depth).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

In the recent, varved sediment record of Tiefer See since 1920 (Kienel et al., 2013), annually resolved cyanobacteria concentrations varied strongest, forming the first principal component (PC1 47%) of phytoplankton development. Spring-blooming diatoms were less variable (PC2 22%) with peaks and trend opposite to cyanobacteria. Cryptophytes, chlorophytes and phototrophic bacteria gained importance after 1984 (PC3 12%) (Fig. 2).

As indicated during monitoring, cyanobacteria concentrations increase during constantly warm summer periods 1929-1934 (consecutive days >15°C) and along with shallow mixing (<4m water depth) during the periods 1953-1959 and 1965-1971. The peak development from 1976–1984 however, followed an increase of nutrient input to the lake while warm, low-mixing periods were comparatively short.

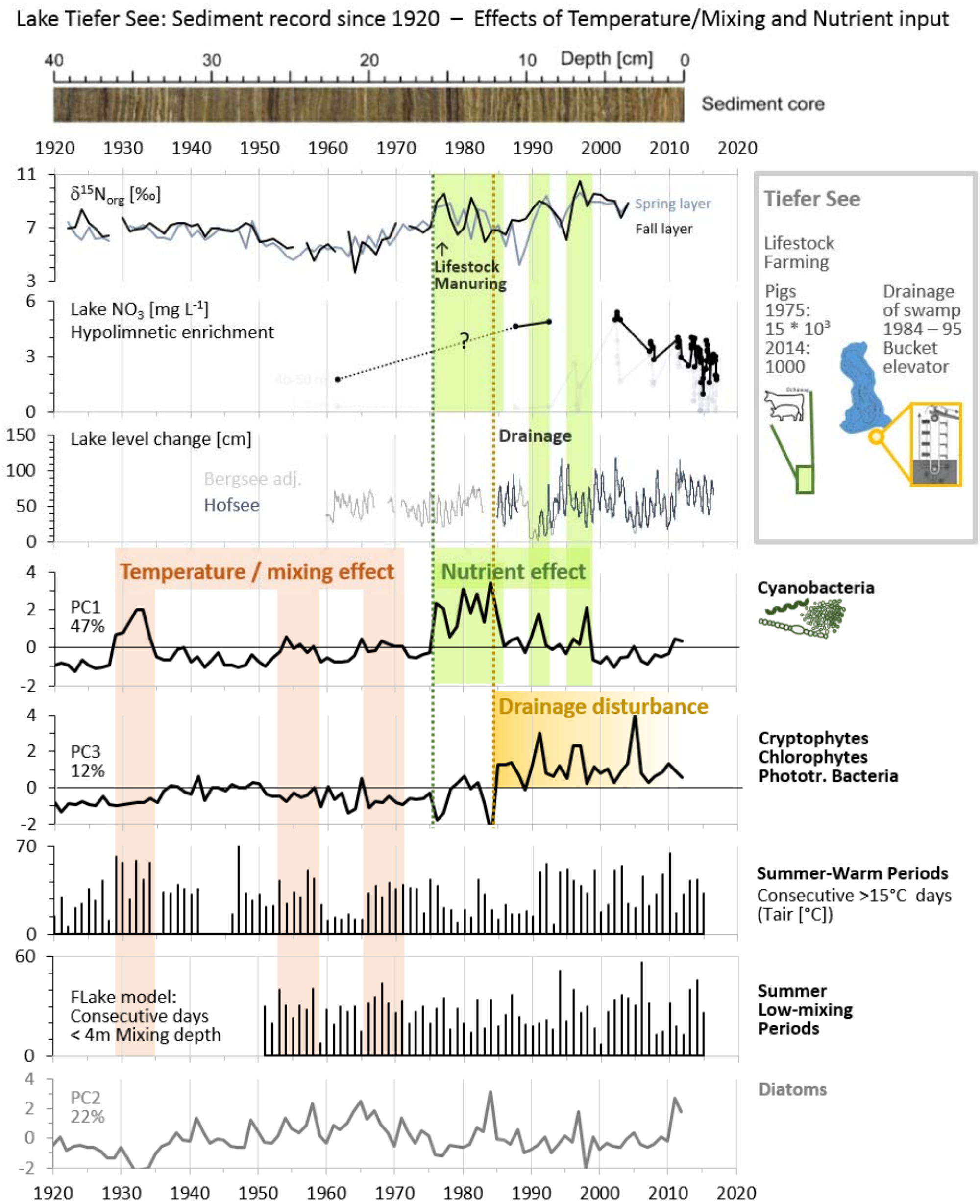


Fig. 2: *Tiefer See sediment record including the principal components of specific pigment concentrations and stable nitrate isotope ratios of organic matter. Nitrate concentration in the lake water co-indicates the nutrient availability, which increased with lifestock farming. Episodic drainage of the swamp area decreased the lake level. Consecutive 15°C days describe warm summer periods and low-mixing periods are consecutive days of lake mixing depth < 4m.*

This nutrient input relates to an abrupt increase in lifestock farming in the mid-1970s with the dung used to fertilize the fields in the catchment. Nutrient enrichment is tracked as an increase in 15-N of organic matter (especially related to increased pig numbers) and later on also as hypolimnetic NO_3 enrichment[1]. Until 1998, cyanobacteria still contributed to the phytoplankton assemblage, but cryptophytes, chlorophytes and photosynthetic bacteria[2] became dominant synchronous with episodic drainage of the swamp area in the SE of the lake (1984 – 95). Although nutrient input decreased in the mid-2000s, it was only after 2010, that diatoms regained the importance they had between 1945 and 1975 (Kienel et al., 2017). While cryptophytes, chlorophytes and photosynthetic bacteria remained important, cyanobacteria tend to increase in importance.

Our study shows that bummer-blooming cyanobacteria benefit from an increased stability of the water column in warm summers (Jöhnk et al., 2008; Wagner and Adrian, 2009). Increased nutrient concentrations increase the susceptibility of lakes to these effects (Posch et al., 2012) and can even overrule them as driver of cyanobacteria blooms as indicated for the period 1976 – 1984 in Tiefer See.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

References

Jöhnk K.D., Huisman J.E.F., Sharples J., Sommeijer B.E.N., Visser P.M., Stroom J.M. (2008) Summer heatwaves promote blooms of harmful cyanobacteria. Glob Change Biol 14:495-512

Kienel U., Dulski P., Ott F., Lorenz S., Brauer A. (2013) Recently induced anoxia leading to the preservation of seasonal laminae in two NE-German lakes. J Paleolimnol 50:535-544

Kienel U., Kirillin G., Brademann B., Plessen B., Lampe R., Brauer A. (2017) Effects of the spring warming and mixing duration on diatom deposition in the deep Tiefer See, NE Germany J Paleolimnol 57:37-49

Kirillin G. (2010) Modeling the impact of global warming on water temperature and seasonal mixing regimes in small temperate lakes. Boreal Environ Res 15:279-293

Mironov D.V. (2008) Parameterization of lakes in numerical weather prediction. Description of a lake model. COSMO Technical Report, Deutscher Wetterdienst 11:1-41

Posch T., Koster O., Salcher M.M., Pernthaler J. (2012) Harmful filamentous cyanobacteria favoured by reduced water turnover with lake warming. Nature Clim Change 2:809-813

Wagner C., Adrian R. (2009) Cyanobacteria dominance: Quantifying the effects of climate change. Limnol Oceanogr 54:2460-2468

Züllig H. (1986) Carotenoids from plankton and photosynthetic bacteria in sediments as indicators of trophic changes in Lake Lobsigen during the last 14000 years. Hydrobiologia 143:315-319

[1] Data from Ministry for Agriculture and Environment Mecklenburg Vorpommern, Schwerin

[2] *Rhodobacter sphaeroides*, indicative of anoxic conditions reaching further up in the in water column (Züllig 1986)

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

$\delta^{18}O$ signatures of calcite precipitation in Lake Tiefer See (NE Germany) – from monitoring to understanding the subannually laminated deposition since 1924 AD

Kienel, Ulrike[1]*; Plessen, Birgit[1]; Brademann, Brian[1]; Pinkerneil, Sylvia[1] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
*Corresponding author: ukienel@gfz-potsdam.de

Monitoring of particle formation and deposition in the deep, oligo-mesotrophic, hardwater lake Tiefer See was set up in 2012 with the motivation to study how co-monitored weather and lake conditions influence the characteristics of the subannual laminae in the biogenic calcite varve deposits. Here we discuss processes that determine the stable oxygen isotope signature of the calcite precipitates as observed during the monitored period 2012 – 2015 along with temperatures and isotope composition of lake water and precipitation. To evaluate how the signals observed are transferred to the varved sediment record deposited since 1924 (Kienel et al., 2013), we analysed the oxygen isotope signature of the annual calcite sublamiae and discuss the results in relation with additional instrumental and proxy data.

In temperate freshwater lakes, calcite precipitation is induced when phytoplankton blooms develop with the temperature increase and lake stratification in spring, when photosynthesis consumes CO_2, and the saturation constant of calcite decreases (Kelts and Hsü, 1978). In the case of equilibrium precipitation, the $\delta^{18}O$ composition of the calcite is controlled only by the temperature and the isotope composition of the ambient water resulting in a specific fractionation of approximately - 0.24 ‰ per °C (e.g. Kim and O'Neil 1997). Important additional influences are amount and isotopic composition of precipitation (+0.6 ‰ per °C), evaporation, and the rate of calcite precipitation (Clark and Fritz, 1997; Leng and Marshall, 2004).

In Lake Tiefer See, $\delta^{18}O$ values of the mixed water column around -4.5‰ SMOW document an evaporation trend relative to an average value of -9‰ SMOW in precipitation (Pinkerneil et al., this volume). An increase of the $\delta^{18}O$ of epilimnion water to -3.5‰ SMOW documents an evaporation trend of +1‰ during lake stratification from May to September (Fig. 1). The calcite precipitates trapped in the epilimnion during this period show ^{18}O depletion with increasing temperature of the ambient water with a range between -3 and -6.5‰ PDB (Fig. 1). Especially temperatures in May and June determined their $\delta^{18}O$ signature as substantiated by the similarity of the measured values with those calculated for calcite precipitation in equilibrium with temperature according to Kim and O'Neil (1997). In addition we observed a trend towards ^{18}O enrichment over the monitored period.

The up to 2-millimetre thick calcite sublaminae in the sediment record cover a slightly narrower range of $\delta^{18}O$ between -4.5 and -6.3‰ PDB (Fig. 2). To test for the temperature coupling as observed for the epilimnion precipitates, we compared them to the longest, regional air temperature series from the station Schwerin. We find significant, negative correlations of the $\delta^{18}O_{calcite}$ with the May/June average of air temperature throughout the record, indicating that the temperature variability in May/June primarily determined the variability of the $\delta^{18}O$ values of the calcite precipitated in the way that higher temperatures led to the precipitation of calcite with lower $\delta^{18}O$ values.

Lower than average values were measured for the period 1981 – 1995, although the May/June temperatures did no increase proportionally. Additional data document increased nutrient input to the lake from manuring and drainage activities in the catchment, which caused increases in phytoplankton production (Kienel et al., 2017, Kienel et al., this volume) and precipitation of the thickest calcite sublaminae on record. In this case, the increased rate of precipitation caused further ^{18}O depletion of the calcite (Teranes et al., 1999; Fronval et al., 1995).

A tendency towards ^{18}O enrichment after 2004 would indicate cooler May/June temperatures than recorded. Here, lower relative lake levels support evaporation as superimposed effect on the $\delta^{18}O$ signature of the calcite (Clark and Fritz, 1997).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Our study shows that the variations in the $\delta^{18}O$ values of the calcite precipitated correspond to the variations in the average air temperature in May/June with lighter $\delta^{18}O_{calcite}$ related to higher temperatures. The absolute $\delta^{18}O$ values were however affected by human activities (manuring, drainage) that increased lake production and calcite precipitation rate leading to ^{18}O depletion during the period 1981 - 1995 and by evaporation causing ^{18}O enrichment after 2004. This clearly suggests important implications from the stable oxygen isotope ratio of calcite precipitation in paleolimnological studies but also shows that a multiproxy approach is required to achieve reliable information.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

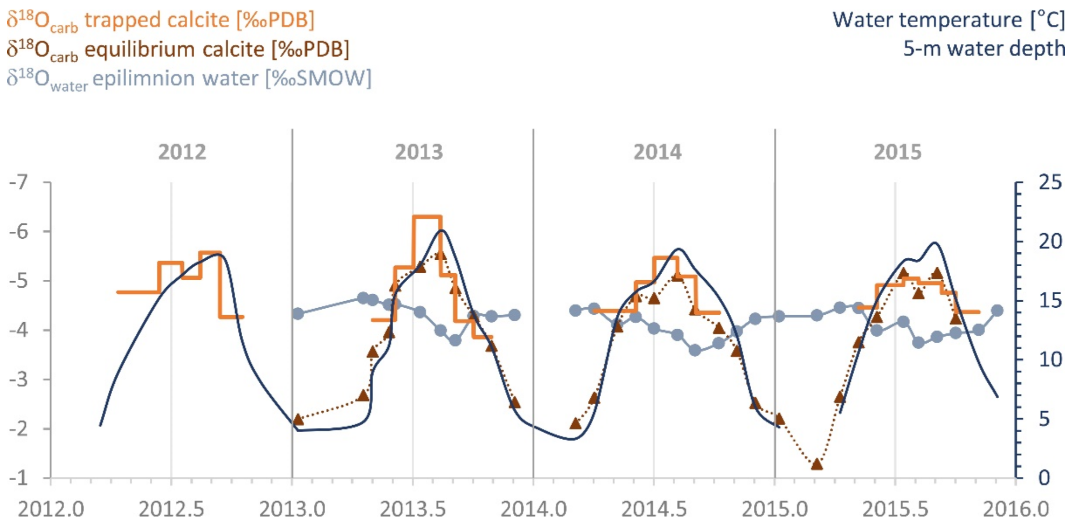


Fig. 1: *Lake Tiefer See monitoring: $\delta^{18}O$ [‰PDB] of calcite precipitated in the epilimnion (5m water depth) compared to the $\delta^{18}O$ signature of calcite precipitation in equilibrium with water temperature. These values are calculated according to Kim and O'Neil (1997) using the water temperature (trapping period average) and the water $\delta^{18}O$ [‰SMOW] (values from 5 m water depth). Calcite preciptated in May and June showed $\delta^{18}O$ values close to those of calculated equilibrium precipitation. A tendency to increased $\delta^{18}O$ values over the monitored period hints at increasing evaporation.*

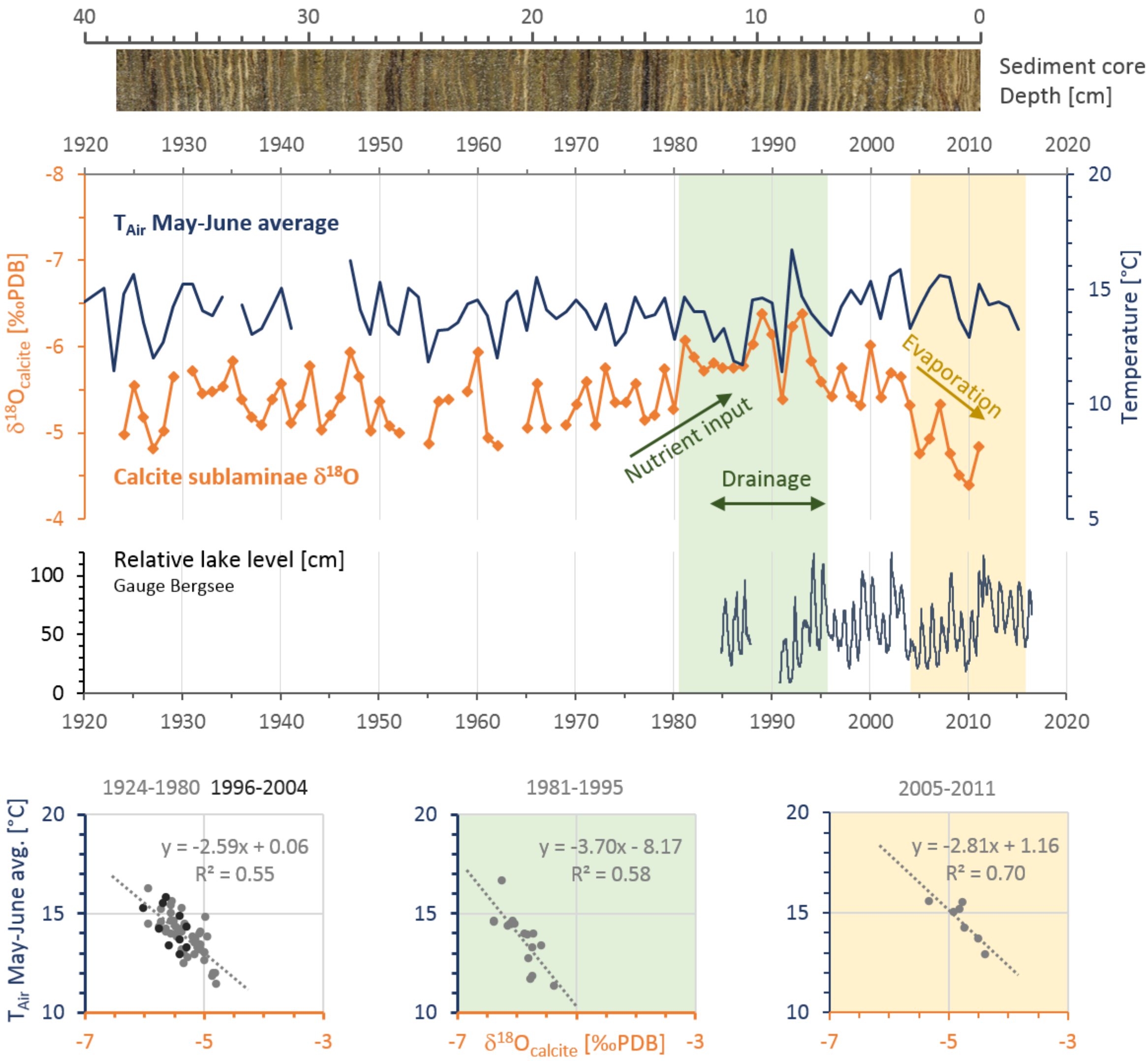


Fig. 2: *Lake Tiefer See sediment record: δ^{18}O [‰PDB] of calcite sublaminae in the varved sediment record (1924 – 2011) compared with the air temperatures (May to June average) and the relative lake level.*
The variability of air temperature during the main phase of calcite precipitation (May to June) determines the variability of the δ^{18}O values of precipitated calcite throughout the record. They are shifted towards lighter values during the period 1981-1995 when calcite precipitation intensified related to increased lake production following nutrient input to the lake (manuring, drainage of the swamp area SE of the lake). After 2004, the heaviest δ^{18}O values on record hint at evaporation along with lowered lake levels and as indicated over the monitored period (Fig.1).

References

Clark I., Fritz P. (1997) Environmental isotopes in hydrogeology. Lewis Publishers, Boca Raton, New York, 328 pp

Fronval T., Bo Jensen N., Buchardt B. (1995) Oxygen isotope disequilibrium precipitation of calcite in Lake Arresø, Denmark. Geology 23:463-466

Kelts K., Hsü K. (1978) Freshwater Carbonate Sedimentation. In: Lerman A (ed), Lakes: Chemistry, Geology and Physics. Springer, Berlin, pp. 295–323

Kienel U., Dulski P., Ott F., Lorenz S., Brauer A. (2013) Recently induced anoxia leading to the preservation of seasonal laminae in two NE-German lakes. J Paleolimnol 50: 535-544

Kienel U., Kirillin G., Brademann B., Plessen B., Lampe R., Brauer A. (2017) Effects of the spring warming and mixing duration on diatom deposition in the deep Tiefer See, NE Germany J Paleolimnol 57:37-49

Kienel U., Lami A., Plessen B., Kirillin G., Brademann B., Pinkerneil S., Gerli S., Dräger N., Brauer A. (this volume) Summer blooms of cyanobacteria in Lake Tiefer See (NE Germany) - Increased nutrient input can overrule shallow lake mixing as driver

Kim S.-T., O'Neil J.R. (1997) Equilibrium and nonequilibrium oxygen isotope effects in synthetic carbonates. Geochim Cosmochim Acta 61:3461-3475

Leng M.J., Marshall J.D. (2004) Palaeoclimate interpretation of stable isotope data from lake sediment archives. Quat Sci Rev 23:811-831

Pinkerneil S., Kienel U., Plessen B., Dräger N., Brauer A. (this volume) Monitoring water isotope composition of Lake Tiefer See Klocksin (NE Germany) to understand our paleoclimate archives

Teranes J.L., McKenzie J.A., Lotter A.F., Sturm M. (1999) Stable isotope response to lake eutrophication: Calibration of a high-resolution lacustrine sequence from Baldeggersee, Switzerland. Limnol Oceanogr 44:320-333

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 3: Integrating time-scales and regional synchronization

Early Holocene in light of the high-resolution multiproxy analyses - laminated sediments of Lake Jelonek, Poland

Kramkowski, Mateusz[1*]; Filbrandt-Czaja, Anna[3]; Kotrys, Bartosz[6]; Zawisza, Edyta[4]; Rzodkiewicz, Monika[5]; Słowiński, Michał[1]; Tjallingii, Rik[2]; Błaszkiewicz, Mirosław[1] & Brauer, Achim[2]

[1] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] Nicolaus Copernicus University, Chair of Geobotany and Landscape Plannig, Faculty of Biology and Environmental Protection, Toruń, Poland
[4] Polish Academy of Sciences, Institute of Geological Sciences Warsaw, Poland
[5] Adam Mickiewicz University, Institute of Geoecology and Geoinformation, Poznań
[6] Polish Geological Institute – National Research Institute, Pomeranian Branch, Szczecin, Poland
* Corresponding author: mateusz_k@tlen.pl

Lake Jelonek is located in Northern Poland (53°45'58N, 18°23'30E) in the Tuchola Forest (Fig. 1). Annually laminated (varved) lake deposits are important natural archives for past climatic and environmental changes at seasonal resolution (Fig. 2). Here, we present a new project focusing on high-resolution analyses of early Holocene sediments. Ott et al. (2016) have shown that only a minor signal of the Preboreal Oscillation (PBO) appears in the proxies of the Lake Czechowskie sediment record. PBO, together with 8.2 ka oscillations, are two the most known events of the Early Holocene. However, probably due to small number of long sediment records, there are much less evidences for PBO in the Central and East Europe Thus, we want to test if we find a PBO signal in the nearby Lake Jelonek record in ca. 15 km distance of Lake Czechowskie. This project has three main research goals: (1) to determine the response of the natural environment including the ecosystem of the lake and its catchment to the short-term Preboreal climate oscillation (PBO), which was caused by a sudden drainage of freshwater from glacial Lake Agassiz to the Atlantic Ocean at ~11,300 cal yr., (2) to determine possible leads and lags of different proxy responses to the PBO cooling and, (3) to test for synchroneity of the PBO in different parts of Europe. In order to determine the pace of biotic and abiotic environmental change to the PBO, we will apply a range of paleoecological and geochemical analyses: the succession of changes will be dated by varve chronology (calcite varve) and tephrochronology from the volcanic eruptions Hässeldalen – 11,380 ± 216 cal yr BP and Askja-S – 11,228 ± 226 cal yr BP (Ott et al., 2016); the chronology will be further supported by AMS ^{14}C dating; the summer temperature reconstruction will be based on Diptera Chironomidae, using calibration data from Europe and Asia; pH and eutrophication reconstruction (TP - Total Phosphorus) will be based on diatoms and subfossil Cladocera using the European Diatom Database (EDDI, Battarbee et. al., 2000), calibration data from lakes of Central Europe (Blanco et al., 2014) and calibration data from Finland; sedimentological (micro-facies) and geochemical analyses, such as µXRF element scanning and stable isotopes of $^{18}O/^{16}O$ and $^{13}C/^{12}C$; vegetation reconstructions will provide information of changes in the lake's catchment (Fig. 3). The use of modern research equipment and high resolution analyses in conjunction with precise chronology will expand our knowledge about the course and response of the natural environment to a climatic impact of the Preboreal Oscillation recorded in laminated sediments of Lake Jelonek in the Tuchola Forests.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association; grant number VH-VI-415 and National Science Centre, Poland grant 2015/19/N/ST10/02655.

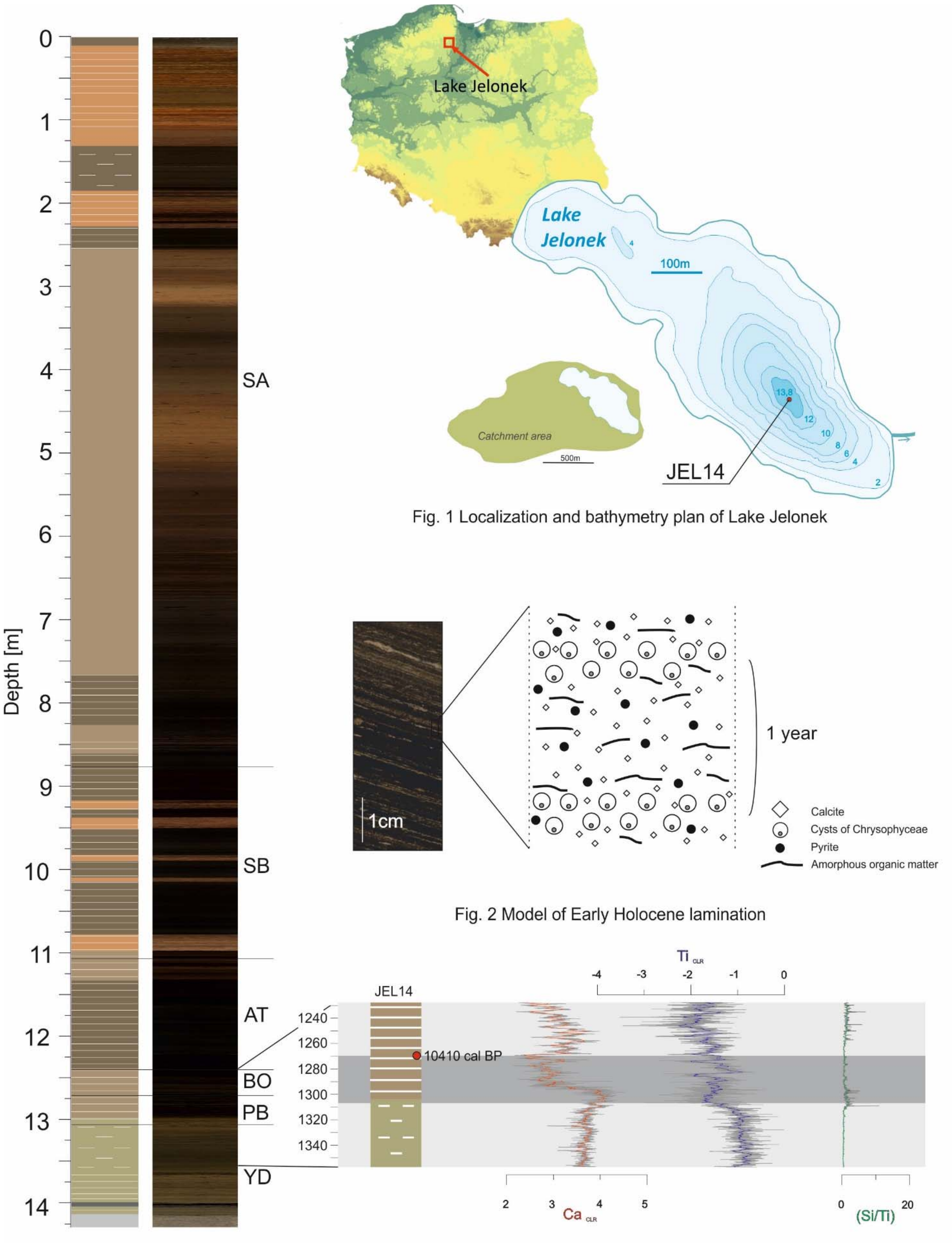


Fig. 1 Localization and bathymetry plan of Lake Jelonek

Fig. 2 Model of Early Holocene lamination

***Fig. 3**: Composite profile of Lake Jelonek and µXRF data of Early Holocene.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

References

Battarbee, R. W., Juggins S., Gasse F., Anderson N. J., Bennion H., Cameron N. G., 2000. European Diatom Database (EDDI). An information system for paleoenvironmental reconstruction. European Climate Science Conference, European Commission, Vienna, Austria 1998, 1–10.

Blanco, S., Cejudo-Figueiras, C., Álvarez-Blanco, I., van Donk, E., Gross, E.M., Hansson, L.-A., Irvine, K., Jeppesen, E., Kairesalo, T., Moss, B., Nõges, T., Bécares, E., 2014. Epiphytic Diatoms along Environmental Gradients in Western European Shallow Lakes. CLEAN – Soil, Air, Water 42, 229-235.

Ott, F., Wulf, S., Serb, J., Słowiński, M., Obremska, M., Tjallingii, R., Błaszkiewicz, M., Brauer, A., 2016. Constraining the time span between the Early Holocene Hässeldalen and Askja-S Tephras through varve counting in the Lake Czechowskie sediment record, Poland. Journal of Quaternary Science 31, 103-113.

Session 4: Man - climate - environment interactions

Multi-proxy reconstruction of the polycyclic pedocomplex development in Dębina, central Polish Baltic coast

Jonczak, Jerzy[1]; Florek, Wacław[2]; **Kruczkowska, Bogusława[3]***; Niska, Monika[2] & Gadziszewska, Joanna[2]

[1] Warsaw University of Life Sciences, Department of Soil Environment Sciences, Warsaw, Poland
[2] Pomeranian University in Słupsk, Institute of Geography and Regional Studies, Słupsk, Poland
[3] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
* Corresponding author: b.przewozna@twarda.pan.pl

Based on palynological, fossil Cladocera, radiocarbon dating, physical and chemical analysis we reconstructed major phases of development of the polycyclic pedocomplex in the cliff near Dębina, central part of the Polish Baltic coast. The investigated stand covers a section of coastal cliff between 221.3 and 221.4 km of the Polish Baltic coast, near the village of Dębina (54°38,642'N, 17°00,701'E), in the central part of the Słowińskie Coast mesoregion (Fig. 1).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

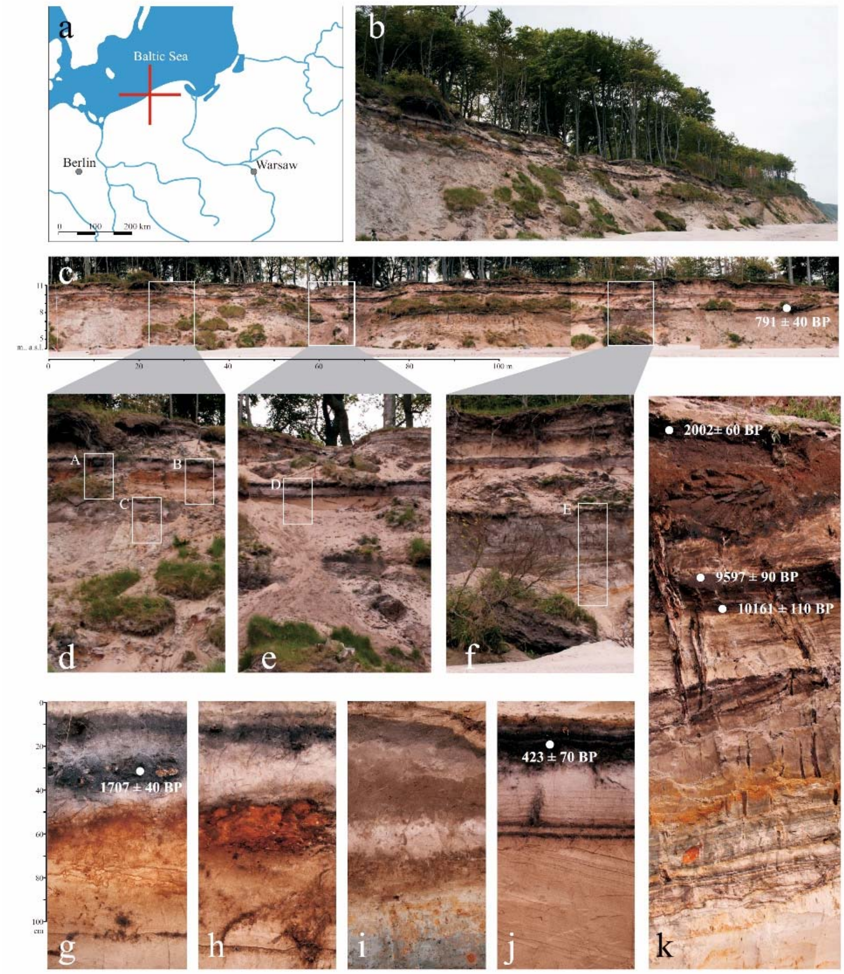


Fig. 1: *Stand location (a), morphology of the cliff (b), locations of soil profiles within the cliff (c, d, e, f) and morphology of the soils in profiles A (g), B (h), C (i), D (j) and E (k).*

The studied pedocomplex covered soils developed from the Late Glacial to the modern times. During the Late Glacial, a small proglacial oligotrophic lake has developed on the bottom of which stratified lacustrine sediments have been accumulated. Lake catchment constituted a hilly moraine landscape built up form glacial till, the roof of which was eroded by water, leading to the formation of erosional pavement and thin covers of poorly sorted fluvial deposits. Soils development within was initialized in a result of vegetation explosion in warm episodes of the Late Glacial. Within the lake basin developed poor in nitrogen and phosphorus and enriched in free iron oxides Dystric Stagnic Fluvisol Humic whereas in lake catchment Stagnic Podzols with some features typical for periglacial environments, including the presence of cryoilluvial horizon. These soils were buried in the Early Subatlantic due to intensification of aeolian processes. Within the cover of aeolian sands, Ortsteinic Podzols developed. A fossil fireplace preserved in these soils constitutes a record of human activity dating back to almost 2,000 years. The complex of Ortsteinic Podzols is dissected by a dry valley developed as a result of a fluvial episode. Than it was filled with aeolian sands, and Dystric Arenosol Aeolic developed within them. About 500 years ago, Ortsteinic Podzols and Dystric Arenosol Aeolic were buried. The reconstructed major phases of litho-morpho-pedogenic processes are well inscribed in temporal dynamics of these processes, which has also been established by other authors for this area.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Excess warming in Central Europe after the 8.2 ka cold event: evidence from a varve-dated ostracod $\delta^{18}O$ record from Mondsee (Austria)

Lauterbach, Stefan[1,2]*; Andersen, Nils[3]; Erlenkeuser, Helmut[3]; Danielopol, Dan L.[4]; Namiotko, Tadeusz[5]; Hüls, Matthias[3]; Belmecheri, Soumaya[6,7]; Nantke, Carla[1,8]; Meyer, Hanno[9]; Chapligin, Bernhard[9]; von Grafenstein, Uli[6] & Brauer, Achim[2]

[1] University of Innsbruck, Institute of Geology, Innsbruck, Austria
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] University of Kiel, Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, Kiel, Germany
[4] University of Graz, Institute of Earth Sciences (Geology & Palaeontology), Graz, Austria (formerly at: Austrian Academy of Sciences, Institute for Limnology, Mondsee, Austria)
[5] University of Gdańsk, Faculty of Biology, Department of Genetics, Laboratory of Limnozoology, Gdańsk, Poland
[6] Laboratoire des Sciences du Climat et de l'Environnement, UMR CEA-CNRS, 91191 Gif-sur-Yvette, France
[7] now at: University of Arizona, Laboratory of Tree-Ring Research, Tucson, USA
[8] now at: Lund University, Department of Geology, Lund, Sweden
[9] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Research Unit Potsdam, Potsdam, Germany
* Corresponding author: stefan.lauterbach@uibk.ac.at

The Holocene warm period has been punctuated by several short-term climate perturbations (Mayewski et al., 2004). Among these, the so-called 8.2 ka event represents a particularly prominent cold climate anomaly (e.g. Alley & Ágústsdóttir, 2005). This cold episode is generally considered as having been triggered by the catastrophic drainage of the Laurentide proglacial lakes Agassiz and Ojibway (Barber et al., 1999; Teller et al., 2002; von Grafenstein et al., 1998). The associated sudden input of a large amount of freshwater into the North Atlantic caused a salinity/density reduction of the ocean surface waters and consequently a transient slowdown of the Atlantic meridional overturning circulation (AMOC) (e.g. Ellison et al., 2006; Kleiven et al., 2008). This resulted in reduced northward heat transport, leading to a cooling in the North Atlantic realm (e.g. Alley & Ágústsdóttir, 2005; Rohling & Pälike, 2005), which is also evident in climate model simulations (e.g. Bauer et al., 2004; Morrill et al., 2013; Wiersma et al., 2011). So far, several proxy-based studies have addressed the causal mechanisms, absolute dating, duration, amplitude, spatio-temporal characteristics and environmental consequences of the 8.2 ka event (e.g. Alley & Ágústsdóttir, 2005; Alley et al., 1997; Barber et al., 1999; Boch et al., 2009; Daley et al., 2011; Ellison et al., 2006; Kleiven et al., 2008; Kobashi et al., 2007; Marshall et al., 2007; Nicolussi & Schlüchter, 2012; Rasmussen et al., 2007; Rohling & Pälike, 2005; Teller et al., 2002; Thomas et al., 2007; Veski et al., 2004; von Grafenstein et al., 1998). Nevertheless, only little attention has been given to climate recovery at the demise of the cold event, neither by proxy-based nor modeling studies, although this is essential for understanding the dynamics and regional peculiarities of rapid climate warming. Hence, many uncertainties concerning the amplitude and pattern of the AMOC slowdown during the 8.2 ka event and its subsequent recovery as well as regarding the associated climatic changes remain. Here we present a new sub-decadally resolved and precisely dated oxygen isotope ($\delta^{18}O$) record for the interval between 7.7 and 8.7 ka BP derived from benthic ostracods preserved in the varved lake sediments of pre-Alpine Mondsee (Upper Austria), providing new insights into climate development around the 8.2 ka cold event in Central Europe. The high-resolution Mondsee $\delta^{18}O_{ostracods}$ record reveals a pronounced phase of relatively low $\delta^{18}O$ values (~0.8 ‰ below the 8.7–8.3 ka BP mean) around 8.2 ka BP (Fig. 1), whose total duration (151 years; central cold period of 80 years) and absolute dating (8231–8080 varve years BP, i.e. calendar years before AD 1950) closely agree with results from other precisely dated Northern Hemisphere palaeoclimate archives, e.g. the Greenland ice cores (Kobashi et al., 2007; Rasmussen et al., 2007; Thomas et al., 2007) and which is consequently interpreted as the 8.2 ka cold event. Recent monitoring revealed that Mondsee is a hydrologically highly sensitive lake and that the isotopic composition of the lake water ($\delta^{18}O_{lake}$) closely mirrors that of the long-term average of local precipitation ($\delta^{18}O_{precip}$), the latter being at present mainly controlled by air temperature variability (Różański et al., 1992). Although also

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

other factors than air temperature might have influenced $\delta^{18}O_{precip}$ in the past (e.g. changes in precipitation seasonality and/or source), the Mondsee $\delta^{18}O_{ostracods}$ record can therefore be regarded in first approximation as a proxy for past air temperature variability. This assumption is corroborated by the close agreement of the $\delta^{18}O_{ostracods}$-inferred temperature drop during the 8.2 ka event (~1.5–2.0°C) with independent, pollen-based air temperature reconstructions (e.g. Veski et al., 2004). In addition to the clear reflection of the 8.2 ka cold event, the Mondsee data set provides evidence for a prominent 75-year-long $\delta^{18}O$ overshoot by 0.3–0.4 ‰ (Fig. 1) directly after the 8.2 ka event (between 8080 and 8005 varve years BP). Considering air temperature as the main influence of the Mondsee $\delta^{18}O_{ostracods}$ record, this overshoot can be interpreted as a period of excess warming (about 0.5–0.6°C above the pre-8.2 ka event level) in Central Europe. Though so far not been explicitly described elsewhere, this observation is consistent with evidence from other proxy records in the North Atlantic realm (e.g. Boch et al., 2009; Kobashi et al., 2007; Marshall et al., 2007; Rasmussen et al., 2007; Thomas et al., 2007; von Grafenstein et al., 1998), therefore likely reflecting a hemispheric-scale signal rather than a local phenomenon. As a possible trigger we suggest an enhanced resumption of the AMOC, supporting assumptions from climate model simulations (e.g. Renssen et al., 2007; Wiersma et al., 2011).

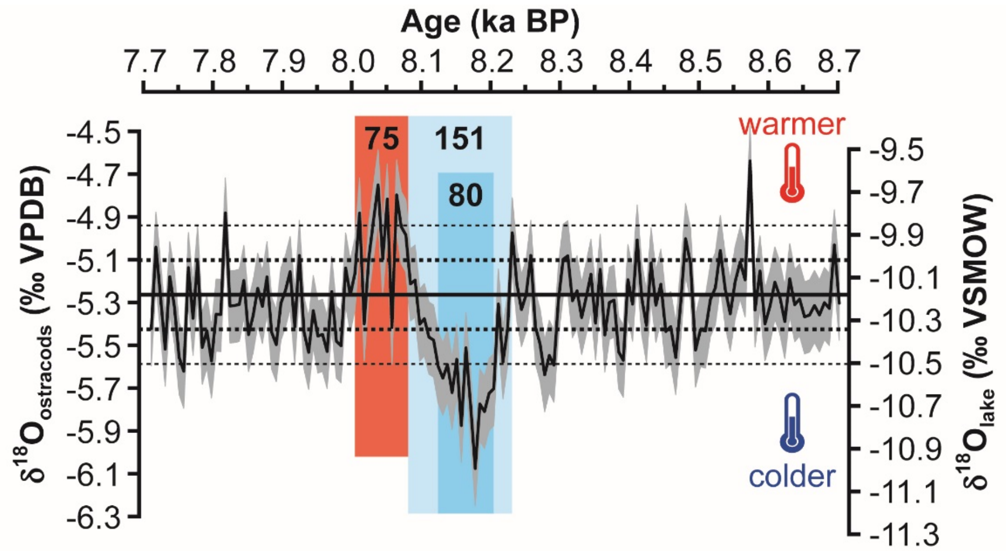


Fig. 1: *Measured $\delta^{18}O$ of juvenile Candona neglecta valves ($\delta^{18}O_{ostracods}$) preserved in the Mondsee sediments and calculated $\delta^{18}O$ of the lake water ($\delta^{18}O_{lake}$) for the interval 7.7–8.7 ka BP. The grey shading indicates the absolute error of ± 0.17 ‰. The solid horizontal line represents the mean $\delta^{18}O$ of the interval before the 8.2 ka event (8.7–8.3 ka BP), the thick and thin dashed lines represent ±1σ and ±2σ, respectively. The light and dark blue bars mark the entire 8.2 ka event and the central cold period, respectively. The red bar indicates the subsequent $\delta^{18}O$ overshoot (all durations given in years).*

References

Alley, R. B. & Ágústsdóttir, A. M., 2005. The 8k event: cause and consequences of a major Holocene abrupt climate change. Quaternary Science Reviews 24, 1123–1149.

Alley, R. B., Mayewski, P. A., Sowers, T., Stuiver, M., Taylor, K. C. & Clark, P. U., 1997. Holocene climatic instability: A prominent, widespread event 8200 yr ago. Geology 25, 483–486.

Barber, D. C., Dyke, A., Hillaire-Marcel, C., Jennings, A. E., Andrews, J. T., Kerwin, M. W., Bilodeau, G., McNeely, R., Southon, J., Morehead, M. D. & Gagnon, J. M., 1999. Forcing of the cold event of 8,200 years ago by catastrophic drainage of Laurentide lakes. Nature 400, 344–348.

Bauer, E., Ganopolski, A. & Montoya, M., 2004. Simulation of the cold climate event 8200 years ago by meltwater outburst from Lake Agassiz. Paleoceanography 19, PA3014.

Boch, R., Spötl, C. & Kramers, J., 2009. High-resolution isotope records of early Holocene rapid climate change from two coeval stalagmites of Katerloch Cave, Austria. Quaternary Science Reviews 28, 2527–2538.

DOI: 10.2312/GFZb103-17037

Daley, T. J., Thomas, E. R., Holmes, J. A., Street-Perrott, F. A., Chapman, M. R., Tindall, J. C., Valdes, P. J., Loader, N. J., Marshall, J. D., Wolff, E. W., Hopley, P. J., Atkinson, T., Barber, K. E., Fisher, E. H., Robertson, I., Hughes, P. D. M. & Roberts, C. N., 2011. The 8200 a yr BP cold event in stable isotope records from the North Atlantic region. Global and Planetary Change 79, 288–302.

Ellison, C. R. W., Chapman, M. R. & Hall, I. R., 2006. Surface and deep ocean interactions during the cold climate event 8200 years ago. Science 312, 1929–1932.

Kleiven, H. F., Kissel, C., Laj, C., Ninnemann, U. S., Richter, T. O. & Cortijo, E., 2008. Reduced North Atlantic Deep Water coeval with the Glacial Lake Agassiz freshwater outburst. Science 319, 60–64.

Kobashi, T., Severinghaus, J. P., Brook, E. J., Barnola, J. M. & Grachev, A. M., 2007. Precise timing and characterization of abrupt climate change 8200 years ago from air trapped in polar ice. Quaternary Science Reviews 26, 1212–1222.

Marshall, J. D., Lang, B., Crowley, S. F., Weedon, G. P., van Calsteren, P., Fisher, E. H., Holme, R., Holmes, J. A., Jones, R. T., Bedford, A., Brooks, S. J., Bloemendal, J., Kiriakoulakis, K. & Ball, J. D., 2007. Terrestrial impact of abrupt changes in the North Atlantic thermohaline circulation: Early Holocene, UK. Geology 35, 639–642.

Mayewski, P. A., Rohling, E. E., Stager, C. J., Karlen, W., Maasch, K. A., Meeker, L. D., Meyerson, E. A., Gasse, F., van Kreveld, S., Holmgren, K., Lee-Thorp, J., Rosqvist, G., Rack, F., Staubwasser, M., Schneider, R. R. & Steig, E. J., 2004. Holocene climate variability. Quaternary Research 62, 243–255.

Morrill, C., LeGrande, A. N., Renssen, H., Bakker, P. & Otto-Bliesner, B. L., 2013. Model sensitivity to North Atlantic freshwater forcing at 8.2 ka. Climate of the Past 9, 955–968.

Nicolussi, K. & Schlüchter, C., 2012. The 8.2 ka event – Calendar-dated glacier response in the Alps. Geology 40, 819–822.

Rasmussen, S. O., Vinther, B. M., Clausen, H. B. & Andersen, K. K., 2007. Early Holocene climate oscillations recorded in three Greenland ice cores. Quaternary Science Reviews 26, 1907–1914.

Renssen, H., Goosse, H. & Fichefet, T., 2007. Simulation of Holocene cooling events in a coupled climate model. Quaternary Science Reviews 26, 2019–2029.

Rohling, E. J. & Pälike, H., 2005. Centennial-scale climate cooling with a sudden cold event around 8,200 years ago. Nature 434, 975–979.

Różański, K., Araguas-Araguas, L. & Gonfiantini, R., 1992. Relation between long-term trends of oxygen-18 isotope composition of precipitation and climate. Science 258, 981–985.

Teller, J. T., Leverington, D. W. & Mann, J. D., 2002. Freshwater outbursts to the oceans from glacial Lake Agassiz and their role in climate change during the last deglaciation. Quaternary Science Reviews 21, 879–887.

Thomas, E. R., Wolff, E. C., Mulvaney, R., Steffensen, J. P., Johnsen, S. J., Arrowsmith, C., White, J. W. C., Vaughn, B. & Popp, T., 2007. The 8.2 ka event from Greenland ice cores. Quaternary Science Reviews 26, 70–81.

Veski, S., Seppä, H. & Ojala, A. E. K., 2004. Cold event at 8200 yr BP recorded in annually laminated lake sediments in eastern Europe. Geology 32, 681–684.

von Grafenstein, U., Erlenkeuser, H., Müller, J., Jouzel, J. & Johnsen, S. J., 1998. The cold event 8200 years ago documented in oxygen isotope records of precipitation in Europe and Greenland. Climate Dynamics 14, 73–81.

Wiersma, A. P., Roche, D. M. & Renssen, H., 2011. Fingerprinting the 8.2 ka event climate response in a coupled climate model. Journal of Quaternary Science 26, 118–127.

Session 4: Man - climate - environment interactions

Historic mass movements recorded in the sediments of Hallstätter See (Upper Austria) – natural hazards at a UNESCO World Cultural Heritage Site

Lauterbach, Stefan[1]*; Strasser, Michael[1]; Tjallingii, Rik[2]; Spötl, Christoph[1] & Brauer, Achim[2]

[1] University of Innsbruck, Institute of Geology, Innsbruck, Austria

[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

* Corresponding author: stefan.lauterbach@uibk.ac.at

Human activity associated with salt mining in Hallstatt (Upper Austria) can be traced back to the Neolithic and underground salt mining in the area is documented since the Middle Bronze Age (Kern et al., 2009). The cultural and economic importance of this salt mining and the wealth of associated archaeological artefacts – particularly from the epoch of the Early Iron Age, for which Hallstatt became the eponym – has been recognized already 20 years ago by assigning the status of a UNESCO World Cultural Heritage Site to the Hallstatt area. Underground mining activity is well documented for prehistoric times and known to have been repeatedly affected by large mass movements, destroying mining facilities, for example, at the end of the Bronze Age and during the Late Iron Age. In contrast, evidence of mining activity in the Common Era between the 5th and late 13th century AD is relatively scarce, which could be related to socio-economic changes as well as to continued mass movement activity, possibly biasing the archaeological record. Within the frame of a project aiming at reconstructing past flood activity of the Traun River, a major tributary of the Danube, a suite of sediment cores has been obtained from the deepest part of Hallstätter See. These cores have been used to construct a continuous, 15.63-m-long composite sediment core, which has been investigated within the present study with respect to the occurrence of large-scale mass movement deposits. Most of the composite core sediments consist of sub-mm- to cm-scale laminated pelagic carbonate mud with frequently intercalated small-scale turbidites, reflecting seasonally variable detrital input by the Traun River and the smaller tributaries. However, an outstanding feature of the Hallstätter See sediment record are two large-scale event layers. The upper one consists of a ~2.45 m thick complex basal mass transport deposit (revealing disturbed and folded laminated pelagic lake sediments, homogenized sediments with liquefaction structures and large stones of up to 4 cm in diameter) and an overlying, 1.45 m thick co-genetic turbidite (Fig. 1). The lower event layer at the base of the composite sediment core comprises the uppermost 1.49 m of another large-scale turbidite, whose base was not reached during coring. However, it appears reasonable that this turbidite is also underlain by a large mass transport deposit. Besides their clearly visible sedimentological features, the two large-scale event layers are to some extent also reflected in geophysical and geochemical core scanning data. While the mass transport deposit below the upper turbidite is characterized by pronounced variability in magnetic susceptibility (χ) and the µ-XRF log(Ca/Ti) ratio and therefore not clearly distinguishable from the regular laminated pelagic carbonate mud, most probably due to the still partly preserved primary sediment structure, the turbidite deposits reveal both a clearly reduced variability in the scanning data, reflecting the homogeneous sediments. Based on the sedimentological characteristics, the upper event layer as well as the second turbidite are interpreted as the subaqueous continuation of large-scale mass movements (i.e. landslides, rock falls) that most likely originated from the steep-sloped rock walls at the western lake shore where also the Hallstatt salt mining area is located. According to AMS ^{14}C dating of terrestrial plant macro remains (mainly *Fagus* leaf fragments) that have been obtained from the sediment cores, the sediment succession recovered in the 15.63-m-long composite sediment core covers the last ~2300 years with the two large-scale mass movement deposits dating to ca. 1050 and 2300 cal. years BP. Particularly the dating of the lower mass movement deposit shows a good temporal agreement with the occurrence of a large-scale mass movement in the Hallstatt high valley that destroyed the Late Iron Age mining facilities (Kern et al., 2009). However, a direct spatial relation and also the exact synchronicity between both events cannot be proven at present and needs to be further investigated. Moreover, the dating of the younger mass movement deposit indicates that such events occurred in the area not only during prehistoric times but also

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

during the Common Era, which could possibly explain the lack of archaeological evidence for mining activity between the 5th and late 13th century AD.

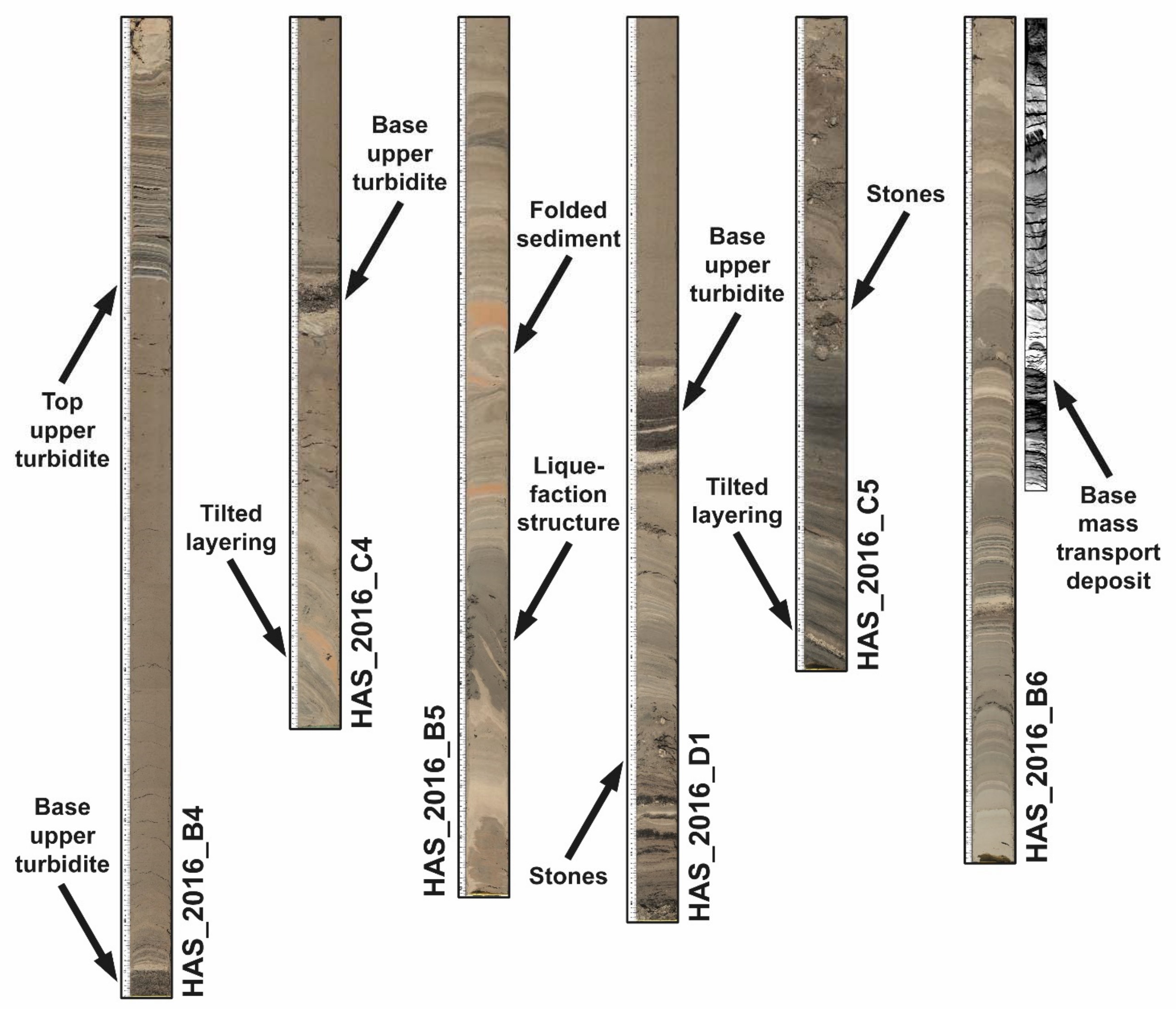


Fig. 1: *Pictures of core segments from the Hallstätter See composite sediment core that contain the upper large-scale mass movement deposit. Visible are the overlying co-genetic turbidite (core HAS_2016_B4) and the basal mass transport deposit with tilted/folded layering (cores HAS_2016_C4 & HAS_2016_B5), liquefaction structures (core HAS_2016_B5) and large stones (cores HAS_2016_C5 & HAS_2016_D1), as well as the transition to the underlying undisturbed pelagic carbonate mud (core HAS_2016_B6; the computer tomography scan clearly depicts the base of the disturbed sediments in the mass transport deposit).*

References

Kern, A., Kowarik, K., Rausch, A. W. & Reschreiter, H. (Eds.), 2009. Kingdom of salt – 7000 years of Hallstatt. Natural History Museum, Vienna.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Seasonality and depth control over halite deposition: In situ observations from the Dead Sea and implications to the formation of thick halite sequences

Lensky, Nadav[1]*; Sirota, Ido[1,2]; Arnon, Ali[1,3] & Enzel, Yehouda[1,2]

[1] Geological Survey of Israel, Jerusalem, Israel.
[2] The Institute of Earth Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel.
[3] Department of Geography and Environment, Bar Ilan University, Ramat-Gan, Israel.
* Corresponging author: nadavl@gsi.gov.il

Layered halite sequences are found in deep basins throughout the geological record. However, analogs for such sequences are commonly studied in shallow environments. Here, we studied active precipitation of halite layers from the only modern analog for deep, halite-precipitating basins, the hypersaline Dead Sea. In situ observations in the Dead Sea link seasonal thermohaline stratification (Arnon et al., 2016), halite saturation (Sirota et al., 2016), and the characteristics of the actively forming halite layers (Sirota et al., 2017). The spatiotemporal evolution of halite precipitation in the Dead Sea was characterized by means of monthly observations of (1) lake thermohaline stratification (temperature, salinity, and density), (2) degree of halite saturation (Fig. 1), and (3) textural evolution of the active halite deposits (Fig. 2). We present the observed relationships between the textural characteristics of layered halite deposits (i.e., grain size, consolidation, and roughness) and the degree of saturation, which in turn reflects the limnology and hydroclimatology. The lake floor is divided into two principal environments: a deep, hypolimnetic lake floor and a shallow, epilimnetic lake floor. In the deeper hypolimnetic lake floor, halite continuously precipitates with seasonal variations: (1) During summer, consolidated coarse halite crystals form rough surfaces under slight supersaturation. (2) During winter, unconsolidated, fine halite crystals form smooth lake floor deposits under high supersaturation (Fig. 3). These observations support interpretations of the seasonal alternation of halite crystallization mechanisms. The shallow epilimnetic lake floor is highly influenced by the seasonal temperature variations, and by intensive summer dissolution of part of the previous year's halite deposit, which results in thin sequences with annual unconformities. This emphasizes the control of temperature seasonality on the characteristics of the precipitated halite layers. In addition, precipitation of halite on the hypolimnetic floor, at the expense of the dissolution of the epilimnetic floor, results in lateral focusing and thickening of halite deposits in the deeper part of the basin and thinning of the deposits in shallow marginal basins.

References

Arnon, A., Selker, J.S. and Lensky, N.G. (2016) Thermohaline stratification and double diffusion diapycnal fluxes in the hypersaline Dead Sea. *Limnol. Oceanogr.* 61, 1214–1231. doi:10.1002/lno.10285.

Sirota, I., Arnon, A. and Lensky, N.G. (2016), Seasonal variations of halite saturation in the Dead Sea. *Water Resour. Res.*, 52, doi:10.1002/2016WR018974.

Sirota, I., Enzel, Y. and Lensky, N.G. (2017) Temperature seasonality control on modern halite layers in the Dead Sea: In situ observations. *GSA Bulletin*. doi:10.1130/B31661.1.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

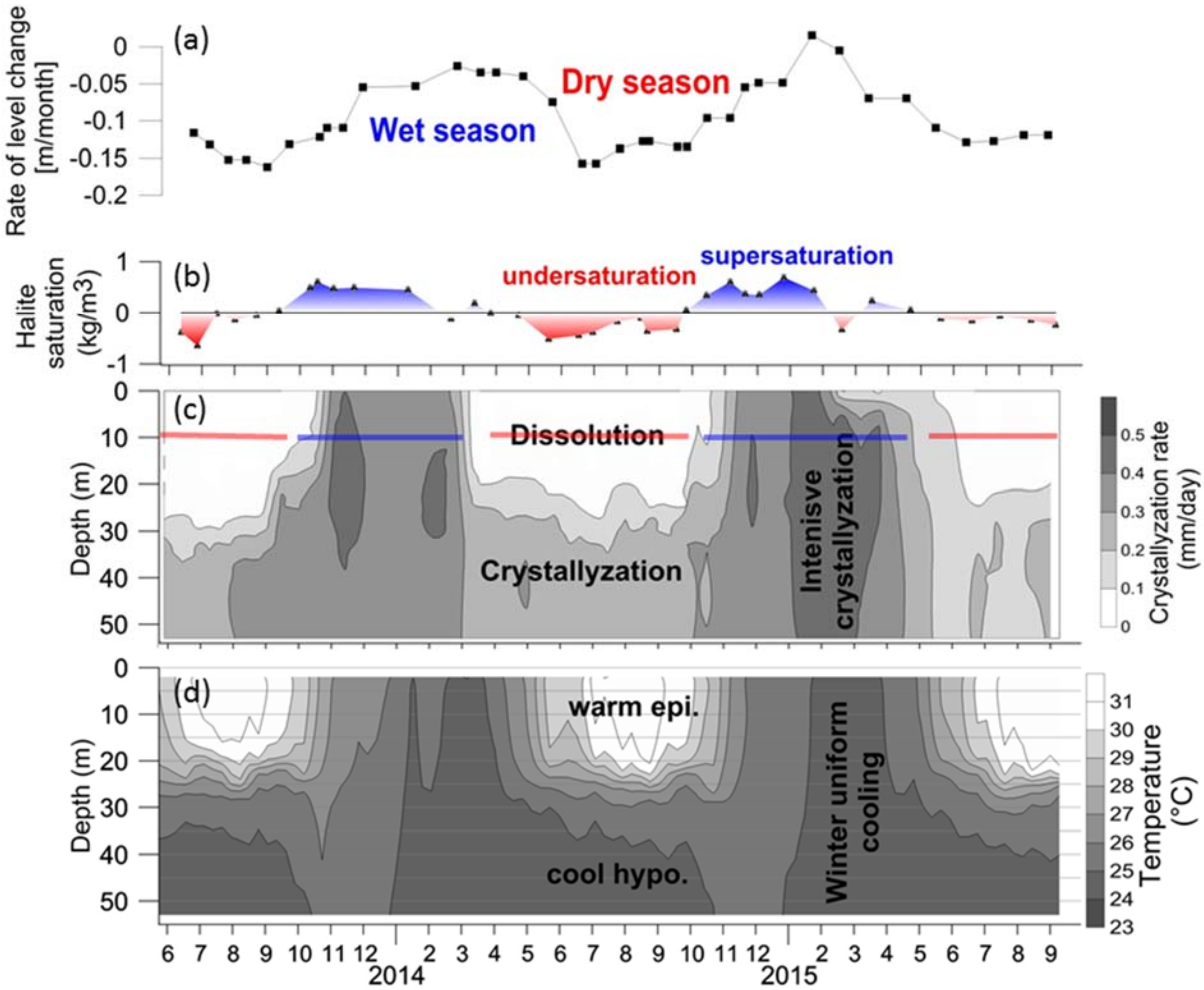


Fig. 1: *Time series of (a) rate of lake level change, (b) degree of halite saturation, (c) and (d) depth-time diagram halite precipitation rates, based on cable measurements and temperature, respectively. Scale bars in the right (modified after Sirota et al., 2016).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

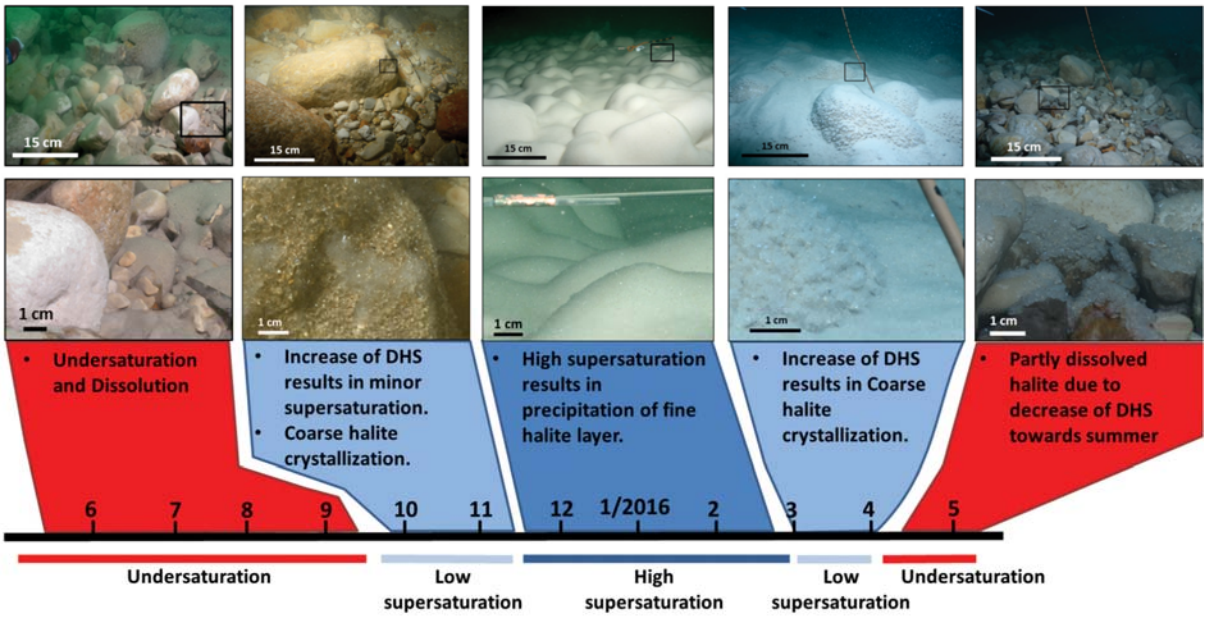


Fig. 2: *Annual halite precipitation cycle on the shallow lake floor (~10 m) coupled with the annual empirical degree of halite saturation (DHS) variations (modified after Sirota et al., 2017).*

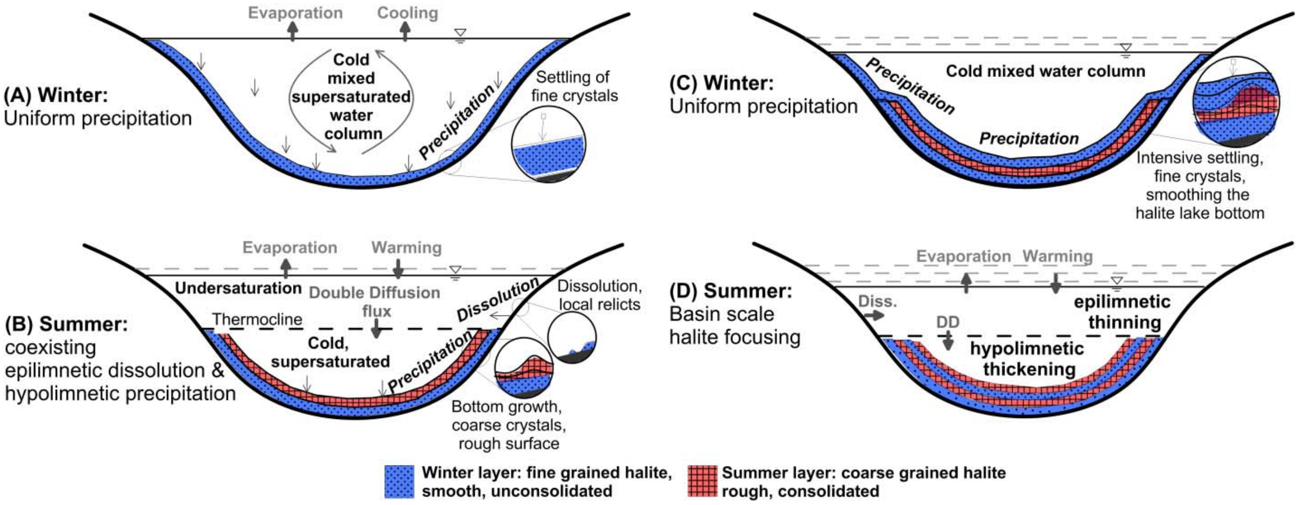


Fig. 3: *Conceptual model of the evolution of a deep hypersaline waterbody depositing halite sequence. Two different, depth-dependent environments result in (1) a clastic sequence (devoid of halite) on the shallow lake floor (above the thermocline) and (2) a continuous, well-bedded halite sequence on the deep lake floor (below the thermocline) composed of seasonal halite layers. DD—Double-Diffusion flux (modified after Sirota et al., 2017).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Climate and environment changes between 250 B.C. and 1000 A.D. reconstructed from varved lake sediments of Lake Głęboczek (N Poland)

Lindemann, Christin[1]*; Ott, Florian[1, 2]; Tjallingii, Rick[1]; Słowiński, Michał[3]; Schwab, Markus J.[1], Błaszkiewicz, Mirosław[3] & Brauer, Achim[1]

[1] GFZ - German Research Center for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[2] now at: Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany

[3] Polish Academy of Sciences, Institute of Geography and Spatial Organization, Toruń, Poland

* Corresponding author: christin@gfz-potsdam.de

Lake Głęboczek is located in the Tuchola Pinewoods (Polish: Bory Tucholskie) in northern Poland (53° 52' 11.7'' N; 18° 12' 23.1'' E). The lake basin is formed by glacial hydrodynamic processes and fills a kettle hole and is located on a glacial outwash plane (Błaszkiewicz, 2011). This lake is part of a cascade like lake system including two lakes and one paleolake (Fig. 1). The varved sediments from Lake Głęboczek will allow reconstructing paleoclimatic and paleoenvironmental variability at decadal to seasonal time resolution and provide a complementary record to the one from neighbouring Lake Czechowskie at the lower end of the lake cascade.

In addition to a surface core obtained in 2013, two series of parallel, overlapping sediment cores have been recovered in 2014 from Lake Głęboczek at a water depth of 18 m with a modified Livingstone corer (Wieckowskie, 1959). The resulting 8.44 m composite profile has been constructed by correlating marker layers. This profile consists of 9 facies units including sandy and clayish, partly laminated lake sediments (8.44 m to 6.99 m sediment depth; facies units I to VI) followed by a faintly laminated facies unit VII (6.99 m to 6.78 m sediment depth). The overlying facies units VIII and IX (above 6.78 m sediment depth) are composed of organic rich, predominantly well- varved sediment (Fig. 2). The early Holocene part of the Lake Głęboczek cores were investigated by Haas (2015) and Mollath (2016).

Here, we focus on the interval of 1.89 m to 0.86 m composite depth (Fig. 2). In this interval the two facies units VIII and IX are identified. Unit VIII consists of finely laminated, dark brownish, sediment consisting of a diatom sublayer and a sublayer with amorphous organic material. These laminations are interpreted as organic diatom varves. In some intervals varves are only poorly preserved. Characteristic for facies unit IX are distinct beige-yellowish fine laminations consisting of a light calcite sublayer and a dark diatom-organic sublayer (Fig. 2). These laminates represent typical biochemical calcite varves.

Microfacies analyses including scanning electron microscopy and measuring of the varve- and sublayer thickness and defining varve boundaries based on the composition of the sublayers were conducted during this study. The resulting floating varve chronology has been anchored to the absolute time scale by two AMS radiocarbon dating of terrestrial macro fossils (OxCal model output of two ^{14}C dates) (Fig. 2). Additional µ-XRF core scanning provides high resolution elemental variations for the studied core interval.

The studied interval corresponds to the time- span of 250 B.C. to 1000 A.D including the later part of the Roman Warm Period, the Dark Age Cold Period and the beginning of the Medieval Warm Period. Changes in varve thickness appear to reflect the main climate variations during this period. Warm phases are commonly reflected by higher varve thickness and low interannual variability, while thin varves and enhanced interannual variability can be associated with cold phases.

We further observe poor varve preservation and even missing lamination in the time interval of 50 B.C to 100 A.D., followed by an increase in detrital input during the time interval A.D. 250 to 300 in the Lake Głęboczek sediments. Since it has been shown in the sediment record of neighbouring Lake Czechowskie that the area was inhibited by the Wielbark culture (Obremska, et al., 2014; Urbanczyk, 1998), we speculate that theses sediment changes might be related to human impact. The chronology constructed in this study provides the basis for further high-resolution pollen and faecal biomarker analysis to obtain a set of proxy data to verify the interpretation of a human impact on the sediment record.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

In the frame of the new BaltRap Project (funded by the Leibniz Association) a varve model and a chronology of the entire Holocene and Lateglacial sediment record will be established. Integrated geochemical and microfacial analyses will be implemented to reconstruct the palaeoclimatic and paleoenvironmental evolution of the Holocene. Detailed comparison with Lake Czechowskie is envisaged to distinguish local from regional controls of the lake sedimentation further comparison with sediment records from the Baltic Sea within the BaltRap project will provide a better understanding of land-sea relation in the southern Baltic realm.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis (ICLEA) of the Helmholtz Association and National Science Center, Poland.

References

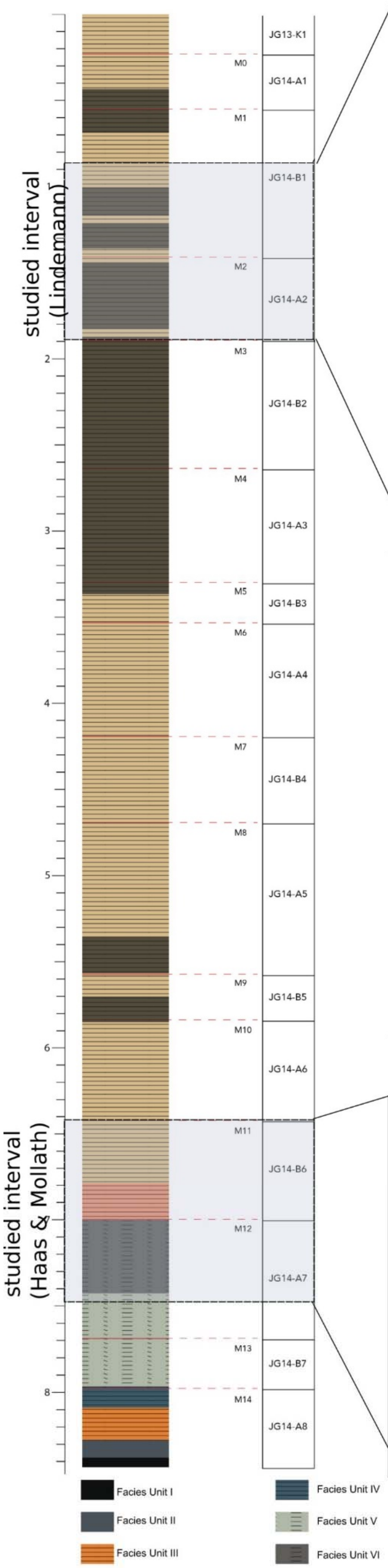
Błaszkiewicz, M. (2011). Timing of the final disappearance of permafrost in the central European Lowland, as reconstructed from the evolution of lakes in N Poland. Geological Quarterly, 55(4), 361–374.

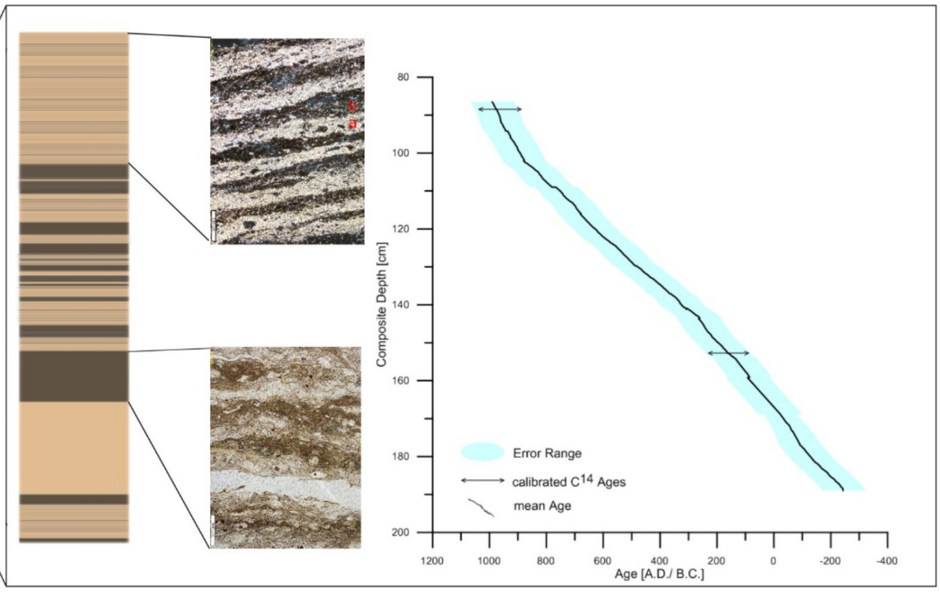
Haas, C. (2015). Rekonstruktion frühholozäner Klima- und Landschaftsentwicklung anhand von Seesedimenten des Głęboczek Sees, Polen. Masterthesis, Rheinische Friedrich-Wilhelms-Universität Bonn.

Urbanczyk, P. (1998). The Goths in Poland --Where Did They Come from and When did They Leave? European Journal of Archaeology, 1(3), 397–415.

Więckowski, K. (1959). Pierwsze próby z sondą rdzeniowa do pobierania monolitów osadów dennych jezior. Przegląd Geograficzny, 31, 361–366.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037





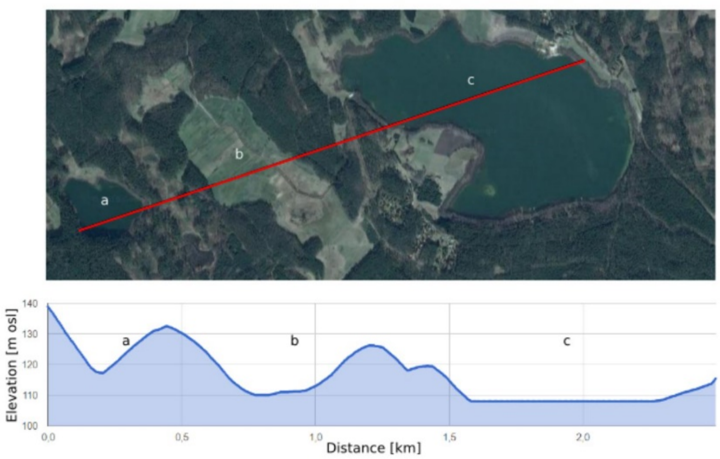


***Fig 1**: Overview about the cascade like lake system*

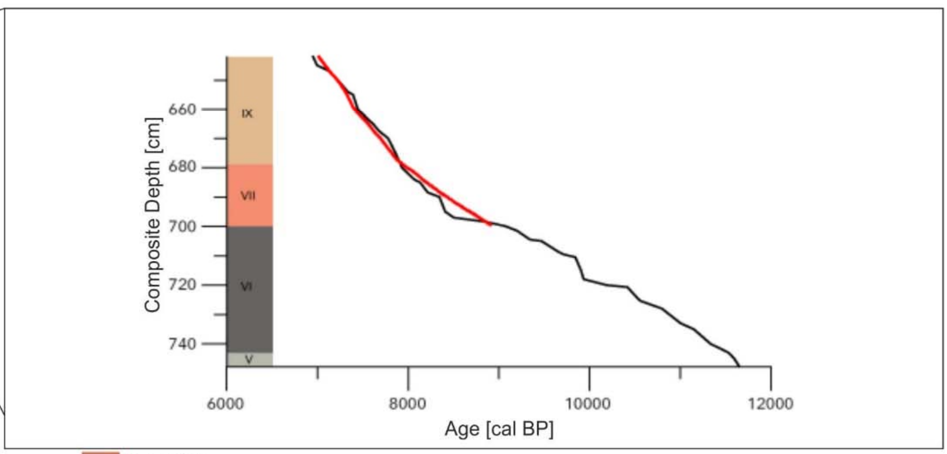


***Fig. 2:** Composite Profile with marked studied intervals and Age Depth Models.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Spurious water level trends out of nothing? Taking the Hurst phenomenon seriously

Lischeid, Gunnar[1]*; Kaiser, Knut[2]; Stüve, Peter[3]; Nützmann, Gunnar[4]; Steidl, Jörg[1] & Dannowski, Ralf[1]

[1] Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg & University of Potsdam, Germany
[2] GFZ - German Research Centre for Geosciences, Potsdam, Germany
[3] Staatliches Amt für Landwirtschaft und Umwelt Mecklenburgische Seenplatte StALUMS, Neubrandenburg, Germany
[4] Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Germany
* Corresponging author: lischeid@zalf.de

Trend analysis is widely used to check for effects of climate change on hydrological systems. For Northeast Germany a long-term decrease of water availability has been predicted (Holsten et al., 2009, Wegehenkel and Kersebaum 2009, Huang et al., 2010). In fact, significantly decreasing trends of groundwater head and lake water level have been observed during the last three decades (Germer et al., 2011, Kaiser et al., 2014).

However, opposing trends have been observed in this region as well (Kaiser et al., 2014). The same applies to lake water level studied in 32 lakes in an adjacent region in North Poland (Wrzesiński and Ptak 2016). Inconsistent trends have often been interpreted as deviations from a general regional trend due to local natural or anthropogenic effects (Germer et al., 2011, Wrzesiński and Ptak 2016).

On the other hand apparently inconsistent trends might be due to long-term persistence (Hurst phenomenon). Therefore, apparent linear trends can result from low-frequency oscillations that are inherent to natural systems irrespective of human impacts (Koutsoyiannis 2006). This study aimed at testing which of these effects might better explain the observed discrepancies.

Local effects were subtracted from time series of lake water level (n=23) and groundwater head (n=17) observations during a 28 years period (monthly values 1985-2013) in Northeast Germany. To that end a principal component analysis was performed following the approach by Lischeid et al., (2010). The residuals were checked for trends to be compared with those of precipitation and potential evapotranspiration (cf. Thomas et al., 2012, Hohenbrink et al., 2016). We found numerous significant trends for lake water level and groundwater head, although with opposing signs, depending on the degree of damping of the input signal. In contrast, there were no consistent trends for the respective meteorological variables.

Instead, trends of the former were primarily due to low-pass filtering of the groundwater recharge signal: The more high-frequency oscillations were attenuated during seepage flux in the vadose zone, the more minor long-term oscillations in the input signal became visible, resulting in apparent linear trends. These empirical results are in line with postulated effects of the Hurst phenomenon (Hurst 1951, Mandelbrot and van Ness 1968, Koutsoyiannis and Montanari 2007) and nicely confirm the findings of a numerical experiment by Koutsoyiannis (2006). Thus caution is advised when trend analysis is applied in a naïve way.

References

Germer, S., Kaiser, K., Bens, O., Hüttl, R.F. (2011): Water balance changes and responses of ecosystems and society in the Berlin-Brandenburg region – a review. Die Erde 142: 65-95

Hohenbrink, T.L., Lischeid, G., Schindler, U., Hufnagel. J. (2016): Disentangling the effects of land management and soil heterogeneity on soil moisture dynamics. Vadose Zone Journal 15(, DOI: 10.2136/vzj2015.07.0107

Holsten, A., Vetter, T., Vohland, K., Krysanova, V. (2009): Impact of climate change on soil moisture dynamics in Brandenburg with a focus on nature conservation areas. Ecological Modelling 220: 2076-2087

Huang, S., Krysanova, V., Österle, H., Hattermann, F.F. (2010): Simulation of spatiotemporal dynamics of water fluxes in Germany under climate change. Hydrological Processes 24: 3289-3306

Hurst, H.E. (1951): Long term storage capacities of reservoirs. Transactions of the American Society of Civil Engineers 116: 776-808

Kaiser, K., Koch, P., Mauersberger, R., Stüve, P., Dreibrodt, J., Bens, O. (2014): Detection and attribution of lake-level dynamics in north-eastern central Europe in recent decades. Regional Environmental Change 14: 1587-1600

Koutsoyiannis, D. (2006): A toy model of climatic variability with scaling behaviour. Journal of Hydrology 322, 25-48

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Koutsoyiannis, D., Montanari, A. (2007): Statistical analysis of hydroclimatic time series: Uncertainty and insights. Water Resources Research 43: W05429

Lischeid, G., Natkhin, M., Steidl, J., Dietrich, O., Dannowski, R., Merz, C. (2010): Assessing coupling between lakes and layered aquifers in a complex Pleistocene landscape based on water level dynamics. Advances in Water Resources 33: 1331-1339

Mandelbrot, B. B., van Ness, J.W. (1968): Fractional Brownian motion, fractional noises and applications. SIAM Review 10: 422-437

Thomas, B., Lischeid, G., Steidl, J., Dannowski, R. (2012): Regional catchment classification with respect to low flow risk in a Pleistocene landscape. Journal of Hydrology 475: 392-402

Wegehenkel, M., Kersebaum, K.C. (2009): An assessment of the impact of climate change on evapotranspiration, groundwater recharge, and low-flow conditions in a mesoscale catchment in Northeast Germany. Journal of Plant Nutrition and Soil Science 172: 737-744

Wrzesiński, D., Ptak, M. (2016): Water level changes in Polish lakes during 1976–2010. Journal of Geographical Sciences 26: 83-101

DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Last Glacial maximum and the following deglaciation in central Europe

Marks, Leszek*

Polish Geological Institute – National Research Institute, Warsaw and University of Warsaw, Faculty of Geology, Poland
* Corresponging author: leszek.marks@pgi.gov.pl, leszek.marks@uw.edu.pl

The area of Poland is a stratotype region for the Weichselian Glaciation, in which dynamics and limits of the last Scandinavian Ice Sheet (SIS) were determined. The ice sheet was most widespread to the south in eastern Germany and in western Poland, territories of which acted as the main tracks for the ice that passed across the Baltic Basin. Ice sheet dynamics in this area was highly dependent on land relief, reflected presumably in a stream-like pattern of the ice sheet body (Marks, 2002).

Ice sheet limits were determined based on analysis and compilation of cartographic data, particularly of orientation of linear landforms and clasts in tills (Marks, 2012, 2015). They were indicated by ice-marginal formations including end moraines, ice-marginal fans and outwash plains (Marks et al., 2006). A chronology of the ice sheet limits was established based on OSL, cosmogenic isotope and radiocarbon datings (e.g. Rinterknecht et al., 2005, 2006a, b; Dzierżek and Zreda, 2007; Lüthgens, Böse, 2011; Wysota et al., 2011; Houmark-Nielsen, 2012; Marks, 2012).

The Late Weichselian ice sheet advance was presumably preceded by an ice sheet advance around 30-35 ka BP that was examined in western and southern peripheries of the Baltic Basin (Houmark-Nielsen, 2010; Marks, 2012; Piotrowski, *personal communication*). During the initial part of the Late Weichselian glaciation, the SIS advanced straight from the north to Denmark and from northeast to Germany and Poland. Presumably, in the same time another part of the SIS ice moved along the Baltic Sea depression but due to longer distance, it reached considerably later the central and mid-eastern part of Europe from the east and northeast. The maximum ice sheet limit of the Late Weichselian Glaciation in Poland (at present roughly connected with the LGM – for discussion see Clark et al., 2009) was diachronic and occurred at 24-19 ka BP, being younger in the east. In western Poland this limit was commonly correlated with the Leszno Phase, whereas in central and eastern Poland usually with the Poznań Phase (Fig. 1). It seems therefore possible that different palaeo-ice streams were activated at different time to the south of the Baltic Basin during the Weichselian (Punkari, 1997). The southernmost extent of the ice sheet in western Poland occurred during the Leszno Phase at 24-22 cal kyrs BP and corresponded to the Main Ice Advance in Denmark and the Brandenburg Phase in Germany. Then, during the followsing Late Weichselian deglaciation there were numerous readvances (preceded by recessions) and standstills of the ice sheet margin. The first deglacial phase was the Poznań Phase (20-19 cal kyrs BP) that was represented by the ice margin standstill after 50-70 km distance retreat in western Poland. It was undoubtedly a transgressive glacial episode and indicated maximum ice sheet limit in central and eastern Poland, were a distinct lobe occurred in the Middle Vistula valley (Molewski, 2007; Wysota et al., 2009; Marks, 2012). The Poznań Phase corresponded to the Frankfurt Phase in Germany, the Orsha Phase in Belarus, the Grūda Phase in Lithuania and the Ostashkov Phase in Russia. This phase was followed by ice sheet advance during the Pomeranian Phase (17-16 cal kyrs BP) when several glacial lobes at the ice margin were formed. The Gardno Phase was a transgressive event, expressed by prominent push moraines in central part of the Polish seashore and it was dated at 16.8-16.6 cal kyrs BP. Two younger ice sheet limits were distinguished in the southern Baltic Sea Basin to the north of the present Polish coastline (Fig. 1). They were in turn the Słupsk Bank Phase, dated at 16.2-15.8 cal kyrs BP and the Southern Middle Bank Phase, dated at 15.4-15.0 cal kyrs BP (Uścinowicz, 1999). The former could be correlated with the Central Skåne Phase (16-15 kyrs BP) in Sweden (Houmark-Nielsen, 2010). However, a scarcity of data, no exact dates and problematic correlation with the neighbouring areas due to lack of synchronicity of main ice sheet limits in Europe during the Late Weichselian, made their detailed correlation extremely difficult (Marks, 2002).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Both during the maximum and the most deglacial phases the glacial limits indicated lobate patterns of marginal formations, reflecting outlets of palaeo-ice streams within the southern and southeastern fringe of the Scandinavian Ice Sheet to the south of the Baltic Basin. During deglaciation numerous readvances and standstills of the ice sheet margin occurred but due to diversified structure of the ice sheet body, its peripheries behaved differently, even in neighbouring regions.

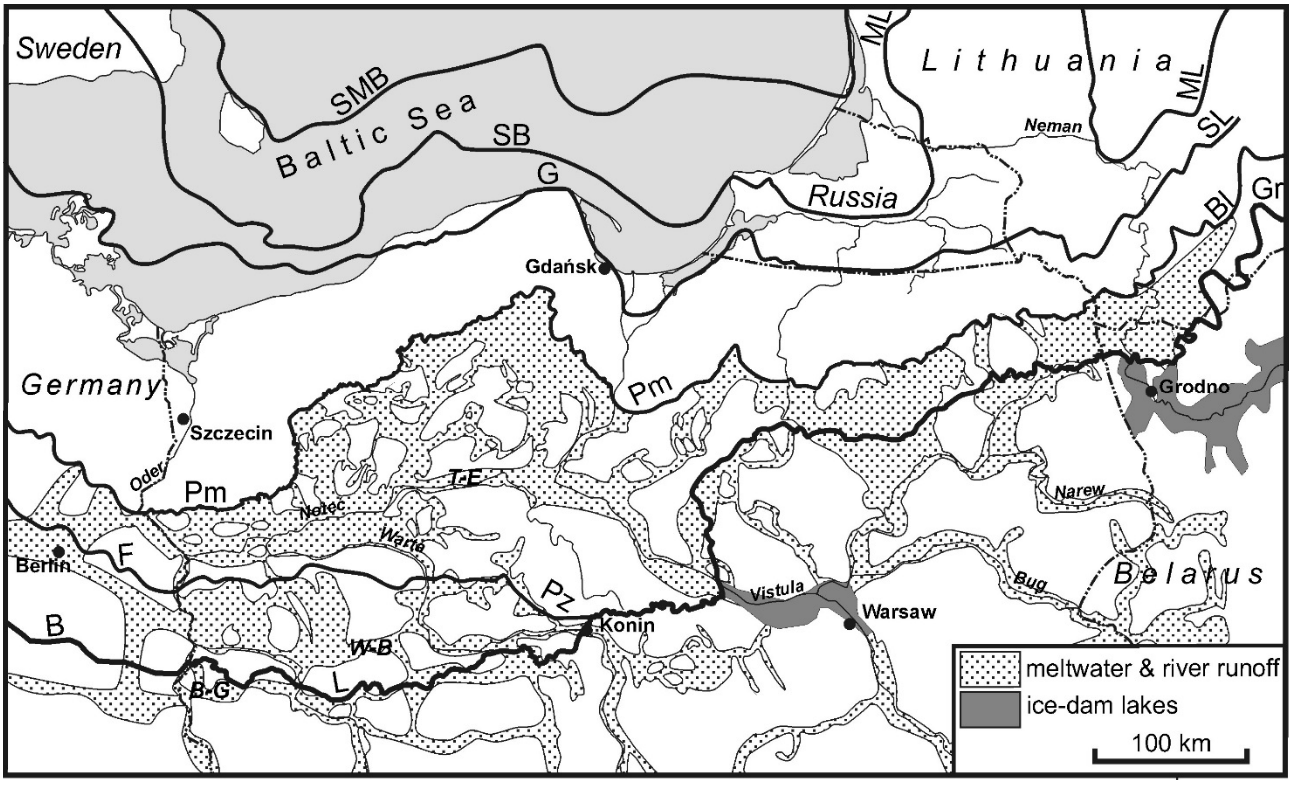


Fig. 1: Location sketch of the study area with limits of the major glacial phases during Late Weichselian in Poland and neighbouring areas: B – Brandenburg, Bl – Baltija, F – Frankfurt, G – Gardno, Gr – Grūda, L – Leszno, ML – Middle Lithuanian; Pm – Pomeranian, Pz – Poznań, SB – Słupsk Bank, SL – South Lithuanian, SMB – Southern Middle Bank; indicated are main ice-marginal streamways (B-G – Baruth-Głogów, W-B – Warsaw-Berlin, T-E – Toruń-Eberswalde), sandurs and river valleys; after Marks (2012), modified.

References

Clark, P.U., Dyke, A.S., Shakun, J.D., Carlson, A.E., Clark, J., Wohlfarth, B., Mitrovica, J.X., Hostetler, S.W., McCabe, A.M. 2009, The Last Glacial Maximum: Science 325, 710-714.

Dzierżek, J., Zreda, M. 2007. Timing and style of deglaciation of northeastern Poland from cosmogenic ^{36}Cl dating of glacial and glaciofluvial deposits. Geological Quarterly 51 (2): 203-216.

Houmark-Nielsen, M. 2010. Extent, age and dynamics of Marine Isotope Stage 3 glaciations in the southwestern Baltic Basin. Boreas 39 (2): 343-359.

Houmark-Nielsen, M. 2012. Cosmogenic surface exposure dating the last deglaciation in Denmark: Discrepancies with independent age constraints suggest delayed periglacial landform stabilization. Quaternary Geochronology 13: 1-17, doi.org/10.1016/j.quageo.2012.08.006

Lüthgens, C., Böse, M. 2011. Chronology of Weichselian main ice marginal positions in north-east Germany. Quaternary Science Journal 60 (2-3), 236-247, doi 10.3285/eg.60.2-3.02

Marks, L. 2002. Last Glacial Maximum in Poland. Quaternary Science Reviews 21 (1): 103-110.

Marks, L. 2012. Timing of the Late Vistulian (Weichselian) glacial phases in Poland. Quaternary Science Reviews 44, 81-88, doi:10.1016/j.quascirev.2010.08.008

Marks, L. 2015. Last deglaciation of northern continental Europe. Cuadernos de Investigación Geográfica 41 (2): 279-293, doi: 10.18172/cig.2698

Marks, L., Ber, A., Gogołek, W., Piotrowska, K. (eds.) 2006. Mapa geologiczna Polski 1 : 500 000, z tekstem objaśniającym. Państwowy Instytut Geologiczny, Warszawa.

Molewski, P. 2007. Neotectonic and glacidynamic conditions for the formation of the Pleistocene of the Kujawy Moraine Plateau. Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, Toruń, 1-140.

Punkari, M., 1997. Glacial and glaciofluvial deposits in the interlobate areas of the Scandinavian Ice Sheet. Quaternary Science Reviews 16, 741-753.

Rinterknecht, V.R., Clark, P.U., Raisbeck, G.M., Yiou, F., Bitinas, A., Brook, E.J., Marks, L., Zelčs, V., Lunkka, J.-P., Pavlovskaya, I.E., Piotrowski, J.A., Raukas, A. 2006a. The last deglaciation of the southeastern sector of Scandinavian Ice Sheet. Science 311: 1449-1452.

Rinterknecht, V.R., Marks, L., Piotrowski, J.A., Raisbeck, G.M., Yiou, F., Brook, E.J., Clark, P.U. 2005. Cosmogenic 10Be ages on the Pomeranian Moraine, Poland. Boreas 34: 186-191.

Rinterknecht, V.R., Marks, L., Piotrowski, J.A., Raisbeck, G.M., Yiou, F., Brook, E.J., Clark, P.U. 2006b. 'Cosmogenic dating of the Pomeranian Moraine: adding a regional perspective': Reply to comments. Boreas 35 (3), 605-606.

Uścinowicz, S. 1999. Southern Baltic area during the last glaciation. Geological Quarterly 43 (2), 137-148.

Wysota, W., Molewski, P., Sokołowski, R.J. 2009. Record of the Vistula ice lobe advances in the Late Weichselian glacial sequence in north-central Poland. Quaternary International 207 (1-2), 26-41.

Wysota, W., Molewski, P., Piotrowski, J.A., Murray, A.S., Bateman, M.D. 2011. Stratygrafia nasunięć ostatniego lądolodu w centralnej Polsce na podstawie datowania luminescencyjnego. XVIII Konferencja *Stratygrafia plejstocenu Polski*, Stara Kiszewa 5-9-09-2011. PIG-PIB, Warszawa: 119.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Learning what varves tell us about Abrupt Holocene Climate Change

Martín-Puertas, Celia[1]*; Brauer, Achim[2]; Tjallingii, Rik[2]; Muscheler, Raimund[3]; Blockley, Simon[1]; Palmer, Adrian[1]; Schwab, Markus J.[2] & Giralt, Santiago[4]

[1] Royal Holloway, University of London, Department of Geography, Centre of Quaternary Research, Egham, UK
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Germany
[3] Lund University, Department of Earth and Ecosystem Sciences, Lund, Sweden
[4] Institute of Earth Sciences Jaume Almera (ICTJA-CSIC) Lluis Sole i Sabaris s/n, Barcelona, Spain.
* Corresponding author: celia.martinpuertas@rhul.ac.uk

Our investigations focus on the understating of how rapid and unexpected changes in the Earth's climate system influenced European environmental conditions in the Holocene and may do so in the future. Annually-laminated (varved) lake sediments have the advantage of storing past environmental and climate changes that have occurred in Europe in less than a decade. We reconstruct climate variability from sedimentological and chemical features kept in the varves, and work with climate modellers to formulate and test hypothesis about rapid climate change that arise from our empirical data. We are interested in abrupt climate change because the way humans live, our activities and needs are causing the Earth to enter in a new mode, which might move the climate system across a threshold and potentially trigger abrupt climate change. As a similar situation has never been recorded by instrumental data, high-quality records of past climate are crucial to help plan for the future.

Here we show a summary of recent studies of the Meerfelder Maar (MFM) record, a varved lake in Germany that provides environmental and climatic information at annual resolution. We put special emphasis on the lake response to the climatic amelioration and rapid climate changes that occurred during the early Holocene (11,700 to 9,000 a BP), as well as to the significant solar-induced abrupt climate change in the Late Holocene 2,800 years ago. And we present the ongoing work that includes new sites.

Change during the Early Holocene

Early Holocene climate in Europe were characterized by large climatic re-organizations. The Greenland $\delta^{18}O$ isotope record shows an initial abrupt warming followed by a gradual multi-centennial temperature increase superimposed by short-lived isotope oscillations at 11.4, 10.3 and 9.3 ka b2k (Rasmussen et al., 2014). These oscillations have been related to cool pulses in the North Atlantic (NA) realm, i.e. the so-called 'Preboreal Oscillation' (PBO), 'Boreal Oscillation' (BO) and the '9.3 ka event' (Björck et al., 1997; McDermott et al., 2001). In central Europe, re-forestation through a plant succession was the consequence of the rising temperature and encouraged by re-immigration of species from their glacial refugia in southern Europe as well as soil formation (Theuerkauf et al., 2014). Short-term interruptions of forest development coincided with the rapid cold oscillations (Björck et al., 1997).

As the pollen record from MFM does not reflect the short-term fluctuations (Litt et al., 2009), we investigated to what extent changes in sediment deposition respond to either the long-term changes of the surface conditions in the catchment and/or short-term climatic oscillations (Martín-Puertas et al., 2017). For this study we applied a novel methodological approach based on advanced clustering for the total micro X-ray Fluorescence (micro-XRF) core scanning data as a suitable tool to better depict environmental and climatic changes in the geochemical record. Our main results showed that the lake was sensitive to changes in the winter minerogenic influx during the Early Holocene and that the long-term vegetation reorganization and evolution of the lake's catchment played a predominant role for sediment deposition, especially at the Preboreal/Boreal biostratigraphical boundaries. We did not observe clear signals corresponding to known short-term climatic oscillations described in the NA region. A possible explanation might be the strong increase in tree pollen at the onset of the Holocene that might have superimposed environmental impacts of the PBO, as well as the stable phases at MFM with dense Corylus cover in the catchment during the Boreal period probably made the lake system resilient to the climate oscillations at 10.3 and 9.3 ka BP (Martín-Puertas et al., 2017).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Solar-induced abrupt climate change in the Late Holocene

A major climate shift during the Late Holocene was evidenced as a cooling and increased humidity in the NA-European region 2,800 years ago coinciding with the Subboreal-Subatlantic biostratigraphic transition, and associated with low solar radiation (van Geel et al., 1999). A less active Sun implies high cosmogenic radionuclide production rates in the atmosphere related to weaker shielding against galactic cosmic ray fluxes; thus, both the steep increase in ^{14}C content of the atmosphere from 2,800 to 2,650 a BP and the rise in ^{10}Be flux archived in Greenland ice cores point to a centennial-scale solar minimum between 2,750-2,550 a BP known as the Homeric minimum (Reimer et al., 2009; Vonmoos et al., 2006). Large changes in solar ultraviolet radiation can indirectly affect climate through the so-called `top-down' mechanisms that connect changes in stratospheric circulation to the Arctic Oscillation/North Atlantic Oscillation (NAO) and affect European winter variability (Ineson et al., 2011). Examining palaeoclimate variability for signs of `top-down' mechanisms involved in the Homeric Minimum requires accurate climate reconstructions with accurate dating to reduce uncertainties of solar-climate phasing and highly resolved palaeoclimate proxies not only for past temperatures and precipitation but also for other climate parameters such as wind strength (Martín-Puertas et al., 2012). To match this challenge, we analysed the MFM wind-sensitive varve record to derive variations in wind strength and the rate of ^{10}Be accumulation, a proxy for solar activity, both linked to the same varve chronology; and also combined proxy data with long-term climate model simulations. We found a sharp and parallel increase in both windiness and cosmogenic 10Be deposition 2,760 aBP and a reduction in both entities 199 years later. We infer that the atmospheric circulation reacted abruptly and in phase with the solar minimum, which is broadly consistent with atmospheric circulation patterns in long-term climate model simulations, and in reanalysis data that assimilate observations from recent solar minima into a climate model. We conclude that a solar-induced negative mode of the NAO caused abrupt climate change 2,760 years ago (Martín-Puertas et al., 2012).

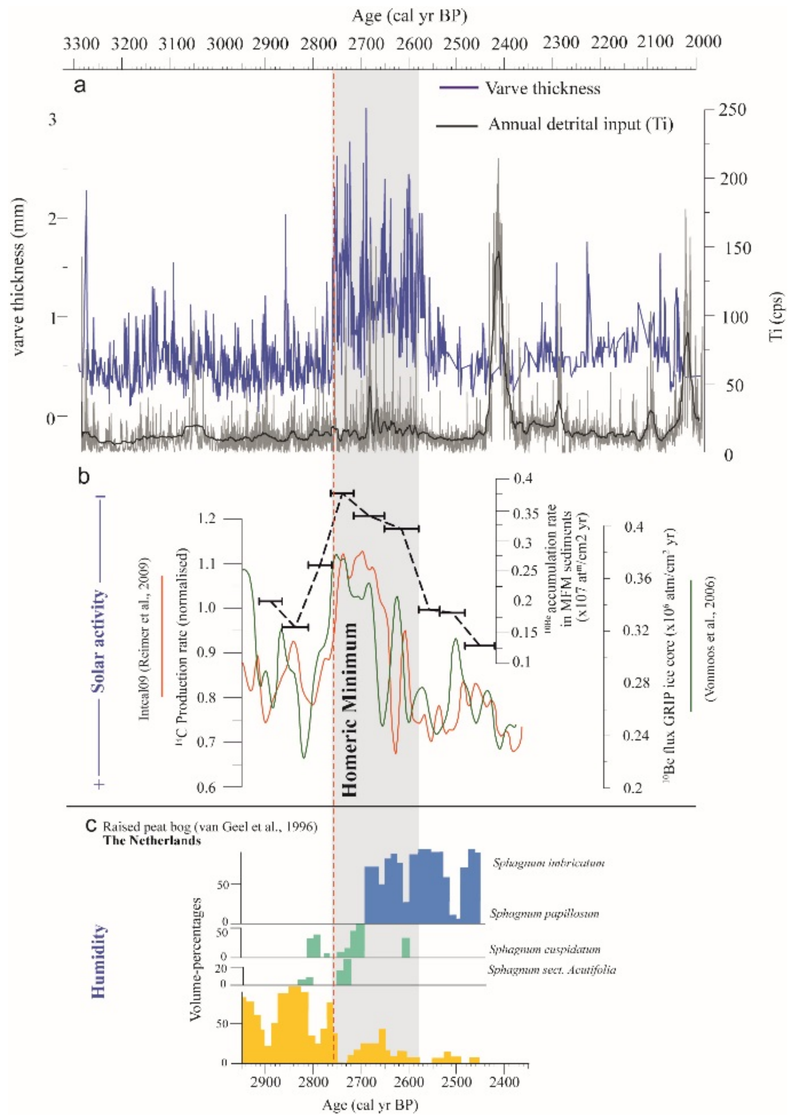


***Fig. 1**: Abrupt Climate Change 2.8 ka (Martín-Puertas et al., 2012). a: MFM varve thickness variability (blue) and detrital input (Ti) variability (grey) from 3,300 to 2,000 cal yr BP; the dark grey line indicates smoothing by 100-data running average. b: Proxies for solar activity: ^{10}Be accumulation rate in MFM sediments expressed in flux units (black); normalized ^{14}C production rate (red); and^{10}Be flux from the GRIP ice core (green). c, Raised bog-based humidity proxy for the Netherlands interpreted showing evidence for the 'Homeric climate oscillation' in western Europe.*

As concluding remark, it should be pointed out the proxy response in the early Holocene (runoff-sensitive

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

proxy record) is different from that in the late Holocene, when the lake was rather susceptible to wind speed and rapid climate oscillations were well reflected. The relationship between palaeolimnological proxy data and climate conditions throughout the Holocene in MFM (Martín-Puertas et al., 2012) shows a long-term change in the proxy sensitivity at 5000 a BP, likely influenced by either a long-term change in the lake and/or climate system. Based on our findings, we believe that the climate-proxy relationship established by calibration between proxy data and instrumental series might not remain constant in time during longer climate periods shifting the interpretation of the archive (Martín-Puertas et al., 2012).

Ongoing work

A future grand solar minimum is projected by 2050 AD, which is predicted to interrupt the current trend of global warming for several decades. However, the impact on regional atmospheric circulations, which control flooding, droughts or hurricanes, may be seriously underestimated by climate models (Ineson et al., 2015). Our study in MFM established a suitable approach to investigate the role of the Sun in past climate change, but is limited to one site and to one grand solar minimum. Thus, our goal now is to integrate studies at the regional level rather than local examples during several solar minima, which will allow evaluating the spatial distribution of the NAO and the dimensions of its effect on European climate. We are analysing Holocene varved records from the UK, France, Germany and Azores and using tephrochronology for validation of the chronologies and synchronisation.

References

Björck, S., Rundgren, M., Ingolfsson, O and Funder, S. (1997). The Preboreal oscillation around the Nordic Seas: terrestrial and lacustrine responses. Journal of Quaternary Science 12: 455-465.

Ineson, S. et al. (2011). Solar forcing of winter climate variability in the Northern Hemisphere. Nature Geosci. 4, 753–757.

Ineson S., Amanda C. Maycock, Lesley J. Gray, et al. (2015). Regional climate impacts of a possible future grand solar minimum, Nature Communications 6. doi: 10.1038/ncomms8535.

Litt, T., Schölzel, C., Kühl, N. & Brauer, A. (2009): Vegetation and climate history in the Westeifel Volcanic Field (Germany) during the last 11,000 years based on annually laminated lacustrine maar sediments. Boreas 38: 679-690.

Martín-Puertas, C., Matthes, K., Brauer, A. et al. (2012): Regional atmospheric circulation shifts induced by a grand solar minimum. - Nature Geoscience, 5, p. 397-401.

Martín-Puertas, C., Brauer, A., Dulski, P., Brademann, B. (2012): Testing climate–proxy stationarity throughout the Holocene: an example from the varved sediments of Lake Meerfelder Maar (Germany). - Quaternary Science Reviews, 58, p. 56-65.

Martín-Puertas, C., Tjallingii, R., Bloemsma, M. and Brauer, A. (2017), Varved sediment responses to early Holocene climate and environmental changes in Lake Meerfelder Maar (Germany) obtained from multivariate analyses of micro X-ray fluorescence core scanning data. J. Quaternary Sci., 32: 427–436.

McDermott, F.; Mattey, D. P.; Hawkesworth, C. (2001). Centennial Scale Holocene Climate Variability Revealed by a High-Resolution Speleothem [delta]18O Record from SW Ireland. Science 294: 1328-1331

Rasmussen et al., 2014. A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: refining and extending the INTIMATE event stratigraphy, Quaternary Science Reviews 106: 14-28.

Reimer, P J; M G L Baillie, E Bard et al. (2009). Intcal09 and Marine09 radiocarbon age calibration curves, Radiocarbon 51, 1111-1150.

Theuerkauf, M., Bos, J.A.A., Jahns, S., Janke, W., Kuparinen, A., Stebich, M., Joosten, H. (2014): Corylus expansion and persistent openness in the early Holocene vegetation of northern central Europe, Quaternary Science Reviews 90: 183-198.

van Geel, B., Raspopov, O.M., Renssen, H., van der Plicht, J.,Dergachev, V.A., Maijer, H.A.J. (1999). The role of solar forcing upon climate change. Quaternary Science Reviews 18, 331–338

Vonmoos, M. , Beer, J. and Muscheler, R. (2006): Large variations in Holocene solar activity — constraints from 10Be in the GRIP ice core . Journal of Geophysical Research 111, A10105 , doi:10.1029/ 2005JA011500.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Tree-ring analyses on Holocene climate variability in the Alps – from single years to millennia

Nicolussi, Kurt[1]*; Leuenberger, Markus[2,3]; Schlüchter, Christian[3,4]; Weber, Georg[1] & Ziehmer, Malin M.[2,3]

[1] University of Innsbruck, Alpine Tree-Ring Group, Institute of Geography, Innsbruck, Austria
[2] University of Bern, Climate and Environmental Physics, Physics Institute, Bern, Switzerland
[3] University of Bern, Oeschger Center for Climate Change Research, Bern, Switzerland
[4] University of Bern, Institute of Geological Sciences, Bern, Switzerland
* Corresponding author: Kurt.Nicolussi@uibk.ac.at

Tree rings from treeline sites of the mid and high latitudes are known as efficient climate archive for past summer temperature variability. The proxy tree-ring width is usually used for the analysis and reconstruction of climate variability, however, wood density, i.e. maximum density values of conifers established by classical radiodensitometric as well as novel Blue Intensity analyses (e.g. Wilson et al., 2014), and stable isotope data (e.g. Kress et al., 2014) are increasingly utilized, too. Tree rings as climate archive have several advantages, i.e. accurate dating even over millennia into the past and seasonal resolution of the time series. These advantages easily allow the establishment of transfer functions between tree-ring and instrumental climate data and thereby the quantified reconstructions of past climate variability. Because tree-ring based climate reconstructions are based on averaged individual tree-ring series as well as on transfer functions of instrumental climate data, the statistical strength of the reconstructions can be examined. The accurate dating of tree-ring chronologies enables the recognition of wide-spread, even hemispheric climatic events, e.g. caused by major volcanic eruptions, and subsequently estimates of the climatic consequences of such events (e.g. Sigl et al., 2015).

However, there are several challenges regarding the usage of tree rings for accurate climate reconstructions, i.e. age related growth variability of individual trees, partly smoothed climatic sensitivity of tree rings from evergreen species, effects of sampling height at trees, impact of elevation on tree-growth in mountainous areas and the availability of samples necessary for the establishment of multi-millennial reconstructions.

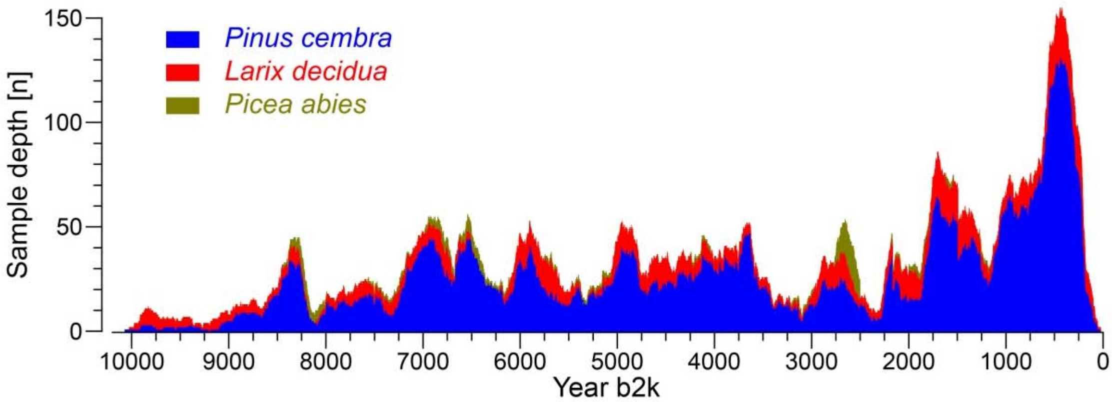


Fig. 1: *Sample-depth record of the continuous Eastern Alpine Conifer Chronology (EACC). The record shown is based on more than 1600 subfossil and try-dead samples from high-elevated sites in the Alps (Nicolussi et al., 2015).*

A specific strength of tree-ring data is the reconstruction of high- to mid-frequency climate variability up to multi-decadal periods, i.e. by applying individual age-detrending of tree-ring series which results in satisfying statistical outcomes even with relatively low replications. The tree-ring based reconstruction of long-term climate fluctuations needs different approaches to overcome limitations regarding individual series length (Cook et al., 1995). The usage of empirical growth models, i.e. Regional Curve Standardisation, for the requisite age-detrending of tree-ring series has been established as an approach to overcome such

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

limitations (Briffa and Melvin, 2011). However, this approach is sensitive to sampling strategies and needs higher sample depths for statistically acceptable reconstructions.

The Alps provide exceptional preconditions for dendroclimatic reconstructions, i.e. multi-centennial instrumental climate records to analyse climate – tree-ring relationships and a plethora of other climate proxy records for comparisons. Tree-ring research to build up long records started already in the mid-20th century, however, only in recent years a Holocene tree-ring record, the Eastern Alpine Conifer Chronology (EACC), was constructed (Nicolussi et al., 2009). The EACC was established from samples originating at treeline or treeline-near sites, i.e. ca. 2000 to 2400 m a.s.l., mainly in the eastern Alps. The exploited sites are glacier forefields, peat bogs and small lakes where samples of the typical central-Alpine species cembran pine (*Pinus cembra*) and larch (*Larix decidua*) and occasionally also spruce (*Picea abies*) were collected. The EACC tree-ring width record continuously spans the last ca. 10,000 years up to the present day and was established from above 1600 subfossil and dry-dead samples as well as from more than 300 cores from living trees (Nicolussi et al., 2009, 2015). The chronology has served as the basis to analyse the Holocene environmental history, i.e. glacier and treeline variability as well as snow avalanche activity in the Alps (e.g. Nicolussi et al., 2005; Nicolussi et al., 2007; Nicolussi and Schlüchter, 2012), but also for dating of archaeological material (e.g. Pichler et al., 2009).

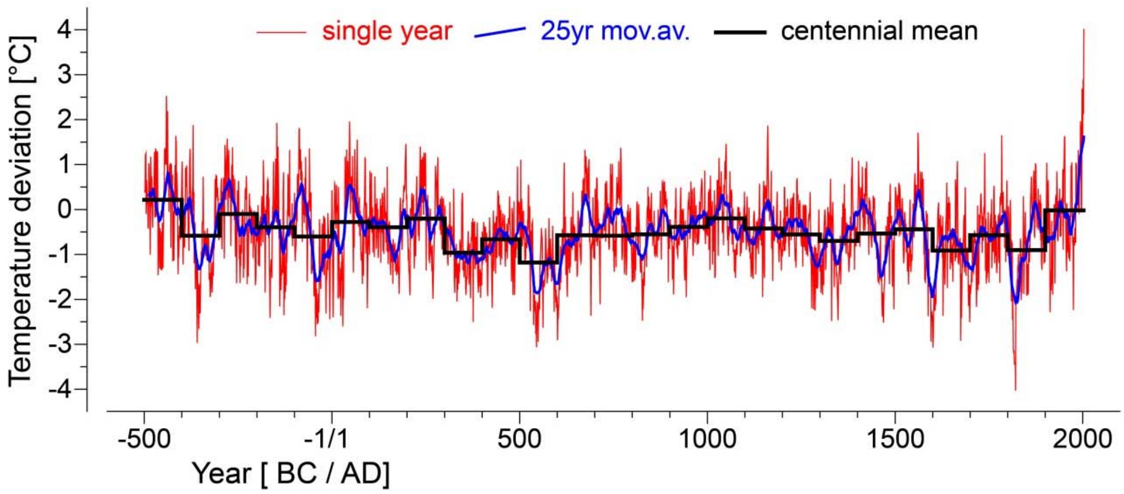


Fig. 2: *Reconstructed summer (June-July-August) temperature variability of the last 2500 years in Alps. The temperature values are given as anomalies with respect to the 1901–2000 period (Büntgen et al., 2011).*

The tree-ring width data itself were utilized for multi-centennial to multi-millennial summer temperature reconstructions for central Europe (Büntgen et al., 2011, Nicolussi et al., 2013). Dated wood material of the EACC has also been used to establish multi-centennial regional radiocarbon data (Dellinger et al., 2004) as well as multi-millennial stable isotope records (Ziehmer et al., in prep.). The tree-ring width based summer temperature reconstruction for central Europe covering the last ca. 2500 years shows a long-term cooling until the Little Ice Age and subsequently the modern warming (Fig. 2). A mid-Holocene temperature reconstruction, covering the period 4400 to 3400 BC, indicates the onset of the mid- to late-Holocene cooling with a first temperature minimum around 4350, a multi-centennial warm period around 4100 and a subsequent cooling until the mid of 4th millennium BC (Nicolussi et al., 2013)

These reconstructions display not only long-term climatic trends but also several abrupt short-term changes, i.e. cooling events that lasted from a single year up to a decade. Some major cooling events, e.g. ca. 540, ca. 1601 or ca. 1816 AD, can directly be related to large volcanic eruptions that caused climatic disturbances (e.g. Sigl et al., 2015). Detailed analyses of historically well documented eruptions indirectly displayed in different Alpine tree-ring data, i.e. tree-ring width and maximum density data of the same year, can possibly be used

DOI: 10.2312/GFZb103-17037

for a sub-seasonal reconstruction of the climatic impact. E.g., the temperature drop caused by the Novarupta eruption in June 1912 is not displayed in the width data but in the maximum wood density data of that year due to different growth periods within the summer half year. However, such analyses require not only tree-ring width but multi-proxy data for the same year, which remains, in respect to the Holocene, a challenge for the future.

References

Briffa, K.R. and Melvin, T.M. (2011): A closer look at Regional Curve Standardization of tree-ring records: Justification of the need, a warning of some pitfalls, and suggested improvements of its application. In: Hughes, M,K., Diaz, H.F., Swetnam, T.W. (eds.): Dendroclimatology: Progress and Prospects. Berlin, Springer Verlag, 113–145.

Büntgen, U., Tegel, W., Nicolussi, K., McCormick, M., Frank, D., Trouet, V., Kaplan, J.O., Herzig, F., Heussner, K.-U., Wanner, H., Luterbacher, J., Esper, J. (2011): 2500 Years of European Climate Variability and Human Susceptibility. Science 331: 578-582.

Cook, E.R., Briffa, K.R., Meko, D.M., Graybill, D.A., Funkhouser, G. (1995): "The'segment length curse'in long tree-ring chronology development for palaeoclimatic studies." The Holocene 5, 229-237.

Dellinger, F., Kutschera, W., Nicolussi, K., Schießling, P., Steier, P., Wild, E.M. (2004): A ^{14}C calibration with AMS from 3500 to 3000 BC, derived from a new high-elevation stone-pine tree-ring chronology. Radiocarbon 46/2, 969-978.

Kress, A., Hangartner, S., Bugmann, H., Büntgen, U., Frank, D.C., Leuenberger, M., Siegwolf, R.T.W., Saurer, M. (2014): Swiss tree-rings reveal warm and wet summers during medieval times. Geophysical Research Letters 41, 1732–1737.

Nicolussi, K., Kaufmann, M., Patzelt, G., van der Plicht,J., Thurner, A. (2005): Holocene tree-line variability in the Kauner Valley, Central Eastern Alps, indicated by dendrochronological analysis of living trees and subfossil logs. Vegetation History and Archaeobotany 14: 221-234.

Nicolussi, K., Pindur, P., Schießling, P., Kaufmann, M., Thurner, A., Luzian, R. (2007): Waldzerstörende Lawinenereignisse während der letzten 9000 Jahre im oberen Zemmgrund, Zillertaler Alpen, Tirol. In: Luzian R., Pindur P. (Eds.): Prähistorische Lawinen - Nachweis und Analyse holozäner Lawinenereignisse in den Zillertaler Alpen, Österreich. BFW-Berichte 141 / Mitt. d. Kommission für Quartärforschung d. Österr. Akademie der Wissenschaften, Wien, 16: 157-176.

Nicolussi, K., Kaufmann, M., Melvin, T.M., van der Plicht, J., Schießling, P., Thurner, A. (2009): A 9111 year long conifer tree-ring chronology for the European Alps - a base for environmental and climatic investigations. The Holocene 19, 909-920.

Nicolussi, K., Schlüchter, C. (2012): The 8.2 ka event - Calendar-dated glacier response in the Alps. Geology 40: 819-822.

Nicolussi, K., Matuschik, I., Tegel, W. (2013): Klimavariabilität und Siedlungsdynamik am Beispiel der Feuchtbodensiedlungen im Raum Oberschwaben, Bodensee und Nordostschweiz 4400–3400 BC. In: Bleicher, N., Schlichtherle, H., Gassmann, P., Martinelli, N. (eds.). Dendro - Chronologie -Typologie - Ökologie. Festschrift André Billamboz. Freiburg i. Br., 61–77.

Nicolussi, K., Weber, G., Patzelt, G., Thurner, A. (2015): A question of time: extension of the Eastern Alpine Conifer Chronology back to 10 071 b2k. In: Wilson R., Helle G., Gärtner H. (eds.), TRACE – Tree Rings in Archaeology, Climatology and Ecology 13, 69-73. Scientific Technical Report 15/06, GFZ German Research Centre for Geosciences.

Pichler, T., Nicolussi, K., Goldenberg, G. (2009): Dendrochronological analysis and dating of wooden artefacts from the prehistoric copper mine Kelchalm/Kitzbühel (Austria). Dendrochronologia 27: 87-94.

Sigl, M., Winstrup, M., McConnell, J.R., Welten, K.C., Plunkett, G., Ludlow, F., Büntgen, U., Caffee, M., Chellman, N., Dahl-Jensen, D., Fischer, H., Kipfstuhl, S., Kostick, C., Maselli, O.J., Mekhaldi, F., Mulvaney, R., Muscheler, R., Pasteris, D.R., Pilcher, J.R., Salzer, M., Schüpbach, S., Steffensen, J.P., Vinther, B.M., Woodruff, T.E., (2015): Timing and climate forcing of volcanic eruptions for the past 2,500 years. Nature 523, 543–549.

Wilson, R., Rao, R., Rydval, M., Wood, C., Larsson, L-Å., Luckman, B.H. (2014): Blue intensity for dendroclimatology: the BC blues: a case study from British Columbia, Canada. The Holocene 24, 1428-1438.

Ziehmer, M.M., Nicolussi, K., Schlüchter, C., Leuenberger, M. (in prep.): A novel high-resolution insight into Holocene climate variability provided by triple isotope records from Alpine tree-rings.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Helianthemum pollen representation in the area of Czechowo during the Younger Dryas

Noryśkiewicz, Agnieszka M.[1]*; Kordowski, Jarosław[2]; Kramkowski, Mateusz[2]; Obremska, Milena[2]; Rzodkiewicz, Monika[3]; Słowiński, Michał[2]; Zawiska, Izabela[2]; Błaszkiewicz, Mirosław[2] & Brauer, Achim[4]

[1] Nicolaus Copernicus University, Toruń
[2] Polish Academy of Science, Warszawa, Toruń
[3] Adam Mickiewicz University, Poznań
[4] German Research Centre for Geosciences, Potsdam
* Corresponding author: agnieszka.noryskiewicz@umk.pl

The project ICLEA focused our palynological research in the northeastern part of the Tuchola Pinewoods. More than nine pollen profiles (Hirsch et al., 2015; Noryśkiewicz et al., 2015) and a number of samples as palynological expertise were made. The profiles presented in this work were collected along a W-E transect from a Głęboczek Lake to a Czechowskie Lake and were located in different topographic and morphological positions (Fig. 1).

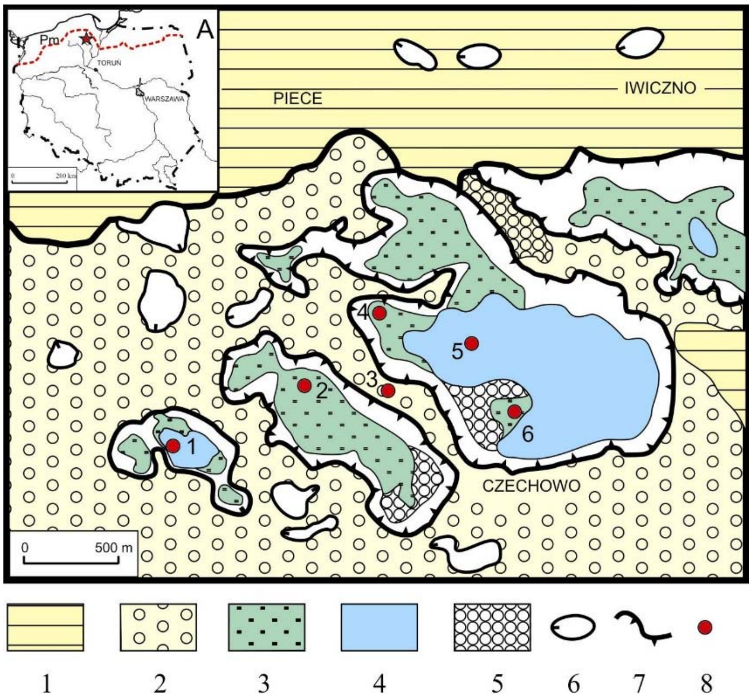


***Fig. 1:** Geomorphology in the area of Czechowo 1 - morainic plateau, 2 - outwash, 3 - biogenic plains, 4 - lakes, 5 - kames, 6 - kettle holes, 7 - edges of subglacial channels, 8 - location of the palynological profiles discussed in the text: 1 - JG (Głęboczek Lake), 2 - T/trz (Palaeolake Trzechowo), 3 - DTCZ (Valley between Trzechowo and Czechowo), 4 - „Oko" (Palaeolake Czechowo), 5 - JC-12-s (Lake Czechowo), 6 - TK (Palaeolake Czechowo kame terrace).*

Based on these profiles, we provide a detailed description of all major vegetation types that developed since the last deglaciation. Particular attention was paid to the presence and representation of rock-rose (*Helianthemum*) pollen in late glacial sediments. Species of the genus *Helianthemum* belong to the Cistaceae family and are mostly dwarf shrubs or herbaceous plants. Currently, the main area of occurrence of the *Helianthemum* species is in the Mediterranean region (Noryśkiewicz 2004). In northern Europe only a few species of the *Helianthemum* (e.g. *H. nummularium* and *H. arcticum*) are widespread (Hjelle and Koff 2015). All Helianthemum species are heliophilous and grow on dry to slightly moist soils (Noryśkiewicz et al., 2004). Commonly, *Helianthemum* species are considered as indicator species for calcareous grassland, but they can

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

grow as well in more acidic habitats (Noryśkiewicz et al., 2004; Hjelle and Koff, 2013). *Helianthemum* species are a constituent of a dwarf shrub tundra, which occurred also in unshaded areas within the open lateglacial forests and parklands and are often considered as a steppe component of tundra (e.g. Heikkilä et al., 2009; Pędziszewska et al., 2015).

Helianthemum pollen is a common and characteristic constituent of the lateglacial pollen floras not only from Poland but as well from the other parts of Europe. Generally, in Europe the pollen of this genus is represented during all lateglacial subdivisions (mostly colder periods) but in the lateglacial pollen diagrams from Czechowo area *Helianthemum* pollen show a great variability (Fig. 2). In all studied profiles high amounts of *Helianthemum* were found in the younger part of the Younger Dryas (maximum in profile 1 - 4.9%, 2 – 2.7%, 3 – 1.2%, 4 – 3.2%, 5 – 1.9%, 6 – 2% basic pollen sum - Fig. 2). This confirms other data from Bory Tucholskie (Tuchola Pineforest) (e.g. Hjelmroos-Ericsson, 1981; Miotk-Szpiganowicz, 1992; Noryśkiewicz, 2006; Filbrandt-Czaja, 2009; Hirsch et al., 2015) as well as in Kashubian Lake District (Pędziszewska et al., 2015). In contrast, *Helianthemum* pollen records from Wielkopolska, Lower Silesia and Kielce-Sandomierz upland (Noryśkiewicz 2004) show lower abundances. It still remains unclear why these parts of the country have been less suited to the expansion of grasslands supporting the *Helianthemum*.

Possible explanations for the spread of *Helianthemum* in the study area during the younger part of Younger Dryas might not only be climate but the habitat as well. A poor, sandy habitat (outwash/sandur plains – fig. 1) rich in a carbonate, probably in combination with a continental climate might have caused the development of these steppe species.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA – of the Helmholtz Association.

References

Filbrandt-Czaja A. 2009. Studia nad historią szaty roślinnej i krajobrazu Borów Tucholskich. Wyd. UMK. Toruń.

Heikkilä M., Fontana S.L., Seppä H. 2009. Rapid Lateglacial tree population dynamics and ecosystem changes in the eastern Baltic region. JQS 24(7): 802–815.

Hirsch F., Schneider A., Nicolay A., Błaszkiewicz M., Kordowski J. Noryśkiewicz A.M., Tyszkowski S., Raab A., Raab T. 2015. Late Quaternary landscape development at the margin of the Pomeranian phase (MIS 2) near the Wygonin (Northern Poland). Catena 124. 28–44.

Hjelle K.L., Koff T. 2013. *Helianthemum* pollen representation in moss samples from calcareous meadows in Estonia, in. *Pollen Monitoring Programme, 9th International meeting, 26.-30. August, Prague, Czech Republic.* Ed. P. Kuneš, V. Abraham, P. Bobek, H. Svobodova-Svitavska, Charles University in Prague, Faculty of Science, Department of Botany: 18−19.

Hjelmroos-Ericsson M.1981. Holocene development of Lake area, northwestern Poland. Thesis 10, Lund.

Miotk-Szpiganowicz G. 1992. The history of the vegetation of Bory Tucholskie and the role of man in the light of palynological investigation. Acta Palaeobotanica 32 (1): 39–122.

Noryśkiewicz A.M. 2006. Historia cisa w okolicy Wierzchlasu w świetle analizy pyłkowej. Wyd. UMK, Toruń.

Noryśkiewicz. A.M., Zawiska I., Rzodkiewicz M., Mirosław-Grabowska J., Obremska M., Kordowski J., Kramkowski M., Słowiński M., Ott F., Błaszkiewicz M., Brauer A., 2015. Younger Dryas cooling in Czechowo Region-climate or local environmental conditions. 4th Annual ICLEA Workshop 2015: Abstract Volume & Excursion Guide (pp 89-90). Scientific Technical Raport 15/05, GFZ German Research Centre Geosciences.

Noryśkiewicz B., Filbrandt-Czaja A., Noryśkiewicz A.M., Nalepka D. 2004. *Helianthemum* Mill. – Rock-rose, [in] Late Glacial and Holocene history of vegetation in Poland based on isopollen maps ed. M. Ralska-Jasiewiczowa et al., W. Szafer Institute of Botany, PAS. Kraków: 315–318.

Pędziszewska A., Tylman W., Witak M., Piotrowska N., Maciejewska E., Latałowa M. 2015. Holocene environmental changes reflected by pollen, diatoms, and geochemistry of annually laminated sediments of Lake Suminko in the Kashubian Lake District (N Poland). Review of Palaeobotany and Palynogy 216: 55–76.

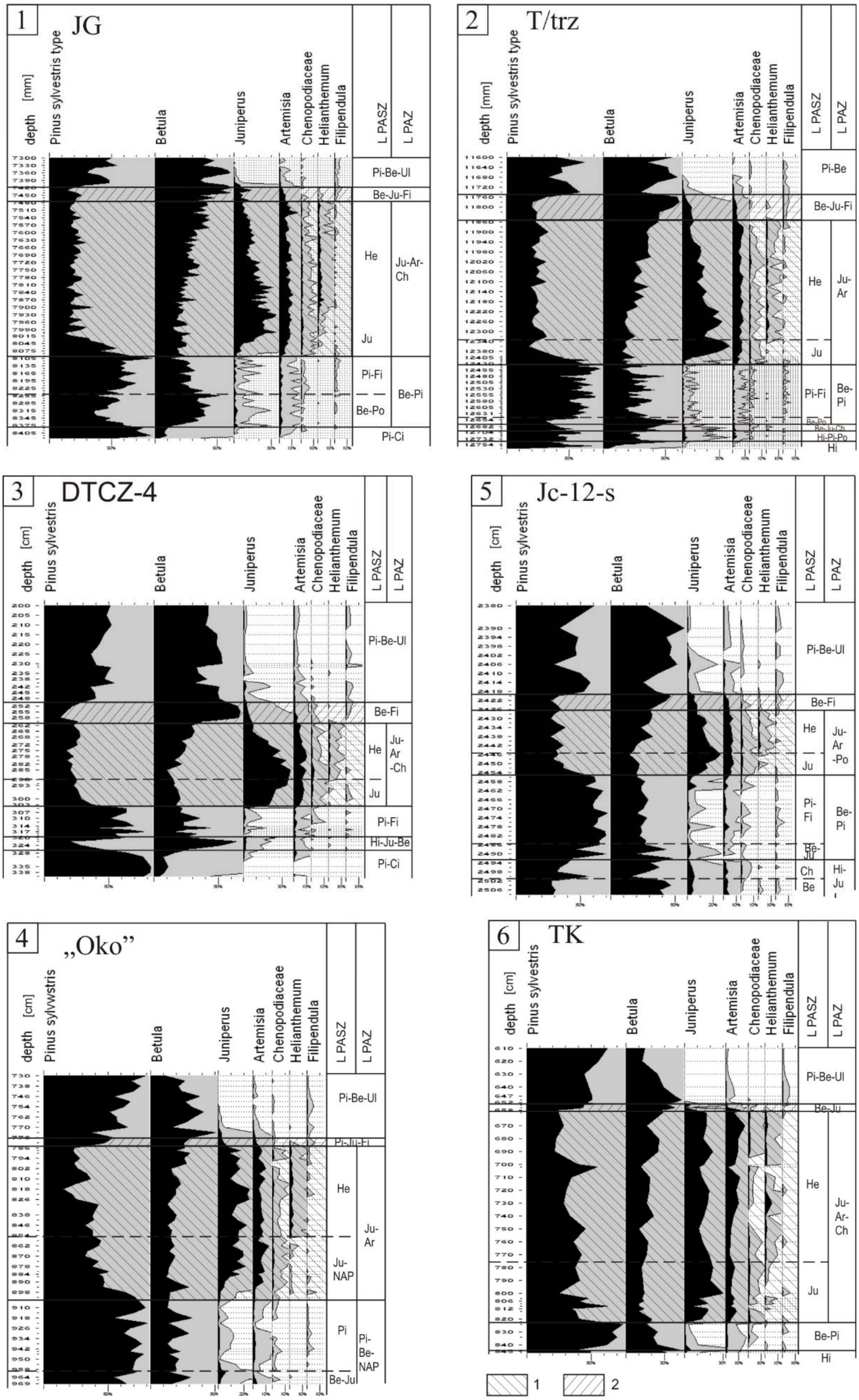


Fig. 2: *Czechowo area, percentage pollen diagram of selected taxa; 1 – Younger Dryas, 2 – Yanger Dryas/Preboreal transition; Numbers 1–6 according to Fig. 1.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

From the Bronze Age to the Migration Period – human activity recorded in the lake sediments of Lake Czechowskie, (Northern Poland)

Obremska, Milena[1]*; Ott, Florian[2,3]; Słowiński, Michał[4]; Błaszkiewicz, Mirosław[4] & Brauer, Achim[2]

[1] Polish Academy of Sciences, Institute of Geological Sciences, Research Centre in Warsaw, Poland
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany
[4] Polish Academy of Sciences, Institute of Geography, Department of Environmental Resources and Geohazards, Warsaw, Poland,
* Corresponding author: mobremska@twarda.pan.pl

Human activity has strong impact on the landscape transformation. These environmental responses are well expressed in palaeoecological records, for example, obtained from lake sediments. A precise age control is crucial for the evaluation and interpretation of biotic proxies. In this respect, the annually laminated (varved) sediment record from Lake Czechowskie in northern Poland is an excellent archive for a high-resolution reconstruction of human impact on landscape evolution.

We present continuous pollen dataat 5-year resolution from the Lake Czechowskie sediments that comprise a time interval of 2600 varve years (3600-1000 cal yr BP). The chronology was established by varve counting and is confirmed by AMS ^{14}C dating, ^{137}Cs activity measurement and a tephra layer (Askja, 1875). We used high-resolution pollen and green algae analysis to reconstruct the vegetation history within a time of increasing human activity and fluctuating climatic conditions activity in the northern part of the Tuchola Forest, the location of Lake Czechowskie.

Our results (Fig. 1) display clear differences between periods of different human pressure on the landscape in this area. Between 3600-3000 cal yr BP (archeological determination for Poland as the middle to the late Bronze Age (Kaczanowski and Kozłowski, 1998) the pollen record shows low presence of humans in this region. After 3000 cal yr BP (in transition to Early Iron Age) human activity gradually increased and at about 2650 cal yr BP the percentage value of human indicator pollen grains shows a rapid increase. The maximum of this phase occurred about 2550 yr BP but high values of human indicators remained until ca 2100 cal yr BP. This period of human activity in the area is associated with the Pomeranian culture.

In addition to the significant presence of human indicator pollen grains human impact is clearly visible also in deforestation (Fig. 1). A decline of human activity in the Lake Czechowskie region occurred after 2100 cal yr BP and lasted to the end of Ist century BC. This phase is significantly marked by an increasing contribution of arboreal pollen (AP), especially percentages of *Carpinus* (hornbeam) pollen grains. During the following 400 years settlements of the Wielbark culture (*Obremska et al* in prep.) developed closed to the lake area. The development of settlements and agriculture took place at expense of surrounding hornbeam forests. The rapid decline of human indicators plants (cereals, ruderal, grazed) at about 1400 cal yr BP (550 BC) reflects the transition to the Migration period and might be related to cooler climate conditions forcing people to give up their settlements.

This study is a contribution to the Virtual Institute ICLEA (Integrated Climate and Landscape Evolution Analysis) funded by the Helmholtz Association. The research was supported by the National Science Centre Poland (grant NCN 2011/01/B/ST10/07367).

References

Kaczanowski P. and Kozłowski J.K., 1998. Wielka historia Polski Tom 1 Najdawniejsze dzieje ziem polskich (do VII w.). FOGRA Kraków

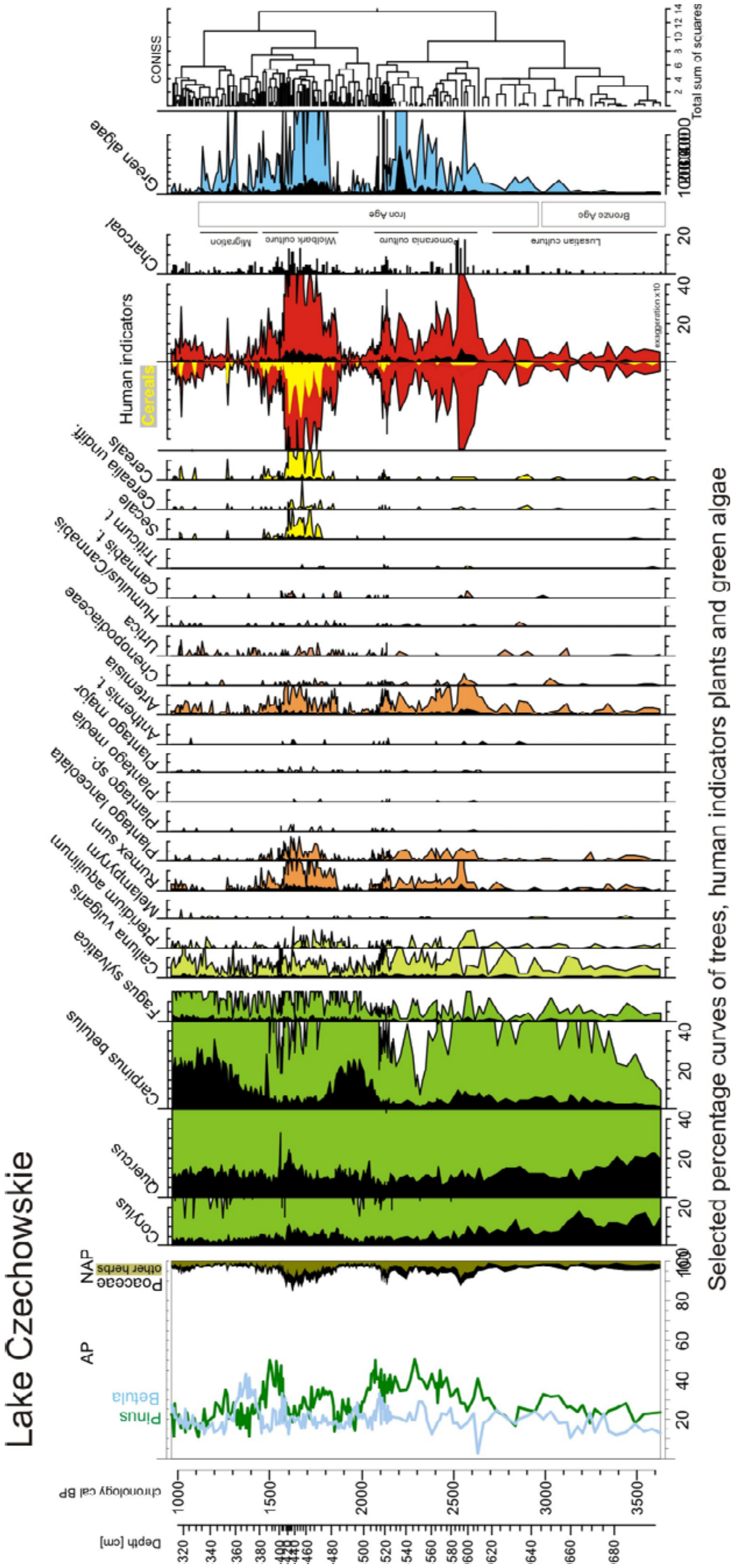


***Fig. 1:** Selected percentage curves of trees, human indicator plants and green algae.*

Session 3: Integrating time-scales and regional synchronization

Deciphering varve formation in Lake Czechowskie (N Poland) and Lake Tiefer See (NE Germany) through comprehensive lake monitoring

Ott, Florian[1,2]*; Dräger, Nadine[1]; Brykała, Dariusz[3]; Kienel, Ulrike[1]; Gierszewski, Piotr[3]; Plessen, Birgit[1]; Schwab, Markus J.[1]; Brademann, Brian[1]; Pinkerneil, Sylvia[1]; Słowiński, Michał[3]; Błaskiewicz, Mirosław[3] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate dynamics and landscape evolution, Potsdam, Germany
[2] Max Planck Institute for the Science of Human History, Department of Archaeology, Jena
[3] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization Toruń, Poland
* Corresponding author: ottflo@gfz-potsdam.de

Monitoring of lake sedimentation, limnological, hydrological and climate parameters combine measurements and observations. Those natural experiments on lacustrine systems are conducted to (i) understand the current link between in- and external processes and their effects on lake sedimentation as well as (ii) to verify the interpretation of sediment records. The ICLEA project aims at integrating natural archives (such as lake records) with seasonal time resolution and calibrating their proxy time series by comprehensive on-site monitoring. The lake monitoring has been realized for the Lake Tiefer See (TSK), located in NE Germany, and Lake Czechowskie (JC), located in N Poland, since 2012. The general setup is comparable, i.e. sediment trap sampling intervals are identical (automatic sequential traps) or at least similar (4-cylinder traps). Additional limnological (water temperature, pH, electrical conductivity, oxygen saturation) as well as climatological parameters (air temperature, precipitation, wind speed/direction) are measured simultaneously at both sites and help to better understand externally driven changes on e.g. sedimentation changes.

As a result, Lake Tiefer See exhibits one major sediment formation pulse lasting from early spring to the end of the summer period comprising diatom blooms and biogenic calcite precipitation. This observation is in phase with varve characteristics of the last century as revealed by recent studies (Dräger et al., 2016; Kienel et al., 2017, 2013). Earlier varve formation was highly variable and different from modern day varves (Dräger et al., 2016). Validation of seasonal sedimentation processes is therefore only possible for the last app. 120 years and remains challenging at TSK for older periods. However, one of the significant sedimentological changes observed throughout the Holocene record is the total cease of varved intervals. The latter has been linked to a combination of climate changes and human induced deforestation (Dräger et al., 2016). An interesting result from the sediment trap studies are the different carbonate fluxes between epi- (high flux) and hypolimnion (low flux) during the summer months in at least two consecutive years (Fig. 1). This might imply carbonate dissolution processes throughout the water column, which is one explanation for the absence of calcite varves in older intervals of the TSK record and will be further analyzed. Novel approaches testing the cyanobacteria-nutrient load relation yield the opportunity for millennial long quantitative proxy reconstructions (Kienel et al., 2017).

In contrast, Lake Czechowskie exhibits two sediment deposition pulses. As in TSK, sedimentation starts in early spring and lasts until summer and is characterized by biogenic precipitated calcite and planktonic diatoms, both indicative of bioproductivity. In contrast to TSK, a second deposition pulse occurs from late autumn throughout the winter season with a succession of planktonic (pennate) diatoms (bioproductivity) and a subsequent deposition of littoral (periphytic) diatoms and littoral calcite. The latter is a clear sediment re-deposition feature (Czymzik et al., 2015), which is further corroborated by the exclusive occurrence in the hypolimnion traps. The sediment trap results from JC yield identical sublayers as deposited during the last app. 2800 years (Ott et al., 2016, 2014, submitted), indicating a less sensitive sedimentary system to externally forced changes than TSK. The onset of this particular varve type at JC has been linked to the gradual intensification of westerly air masses since about that time. This resulted in enhanced productivity due to

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

wind induced nutrient upwelling and littoral sediment re-deposition. Both, intensified productivity as well as littoral sediment reworking has been observed during two consecutive years of the monitoring and are subject of recent investigations.

Both monitoring studies show that TSK and JC are equally controlled by spring/summer productivity, which in case of TSK, is controlled by the timing and duration of thermal mixing in spring (Kienel et al., 2017). The results further revealed the impact of wind-driven re-suspension which is exclusively observed at JC. In comparison with their Holocene sediment records, monitoring results can be used for a much longer validation period than in TSK (2800 vs. 120 years).

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analyses (ICLEA), grant number VH-VI-415, the climate initiative REKLIM Topic 8 'Abrupt climate change derived from proxy data' of the Helmholtz Association, the National Science Centre (Poland), grant number 2011/01/B/ST10/07367 and uses infrastructure of the Terrestrial Environmental Observatory (TERENO).

References

Czymzik, M., Muscheler, R., Brauer, A., Adolphi, F., Ott, F., Kienel, U., Dräger, N., Słowiński, M., Aldahan, A., Possnert, G., 2015. Solar cycles and depositional processes in annual 10Be from two varved lake sediment records. Earth Planet. Sci. Lett. 428, 44–51.

Dräger, N., Brauer, A., Theuerkauf, M., Szeroczyńska, K., Tjallingii, R., Plessen, B., Kienel, U., Lorenz, S., 2016. A varve micro-facies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany). The Holocene. 27:3, 450-464

Dräger, N., Kienel, U., Plessen, B., Ott, F., Brademann, B., Pinkerneil, S., Brauer, A. (in prep.). Linking varve-formation processes to climate and lake conditions at Tiefer See (NE Germany)

Kienel, U., Dulski, P., Ott, F., Lorenz, S., Brauer, A., 2013. Recently induced anoxia leading to the preservation of seasonal laminae in two NE-German lakes. J. Paleolimnol. 50, 535–544. Kienel, U., Kirillin, G., Brademann, B., Plessen, B., Lampe, R., Brauer, A., 2017. Effects of spring warming and mixing duration on diatom deposition in deep Tiefer See, NE Germany. J. Paleolimnol. 57, 37–49.

Kienel, U., Kirillin, G., Brademann, B., Plessen, B., Lampe, R., Brauer, A. 2017: Effects of spring warming and mixing duration on diatom deposition in deep Tiefer See, NE Germany. - Journal of Paleolimnology, 57, 1, p. 37-49.

Ott, F., Brauer, A., Słowiński, M., Wulf, S., Putyrskaya, V., Błaszkiewicz, M., 2014. Constructing a precise and robust chronology for the varved sediment record of Lake Czechowskie (Poland), in: Geophysical Research Abstracts.

Ott, F., Wulf, S., Serb, J., Słowiński, M., Obremska, M., Tjallingii, R., Błaszkiewicz, M., Brauer, A., 2016. Constraining the time span between the Early Holocene Hässeldalen and Askja-S Tephras through varve counting in the Lake Czechowskie sediment record, Poland. J. Quat. Sci. 31, 103–113.

Ott, F., Kramkowski, M., Wulf, S., Plessen, B., Serb, J., Tjallingii, R., Schwab, M., Słowiński, M., Brykała, D., Tyskowski, S., Putyrskaya, V., Appelt, O., Błaszkiewicz, M., Brauer, A., (submitted). Site-specific sediment responses to climate change during the last 140 years in three varved lakes in Northern Poland. The Holocene

Ott, F., Brykała, D., Gierszewski, P., Schwab, M., Brademann, B., Dräger, N., Kienel, U., Pinkerneil, S., Plessen, B., Słowiński, M., Błaszkiewicz, M., Brauer, A. (in prep.). Processes of seasonal layer formation in varve Lake Czechowskie (N Poland): Linking monitoring and sediment core data

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

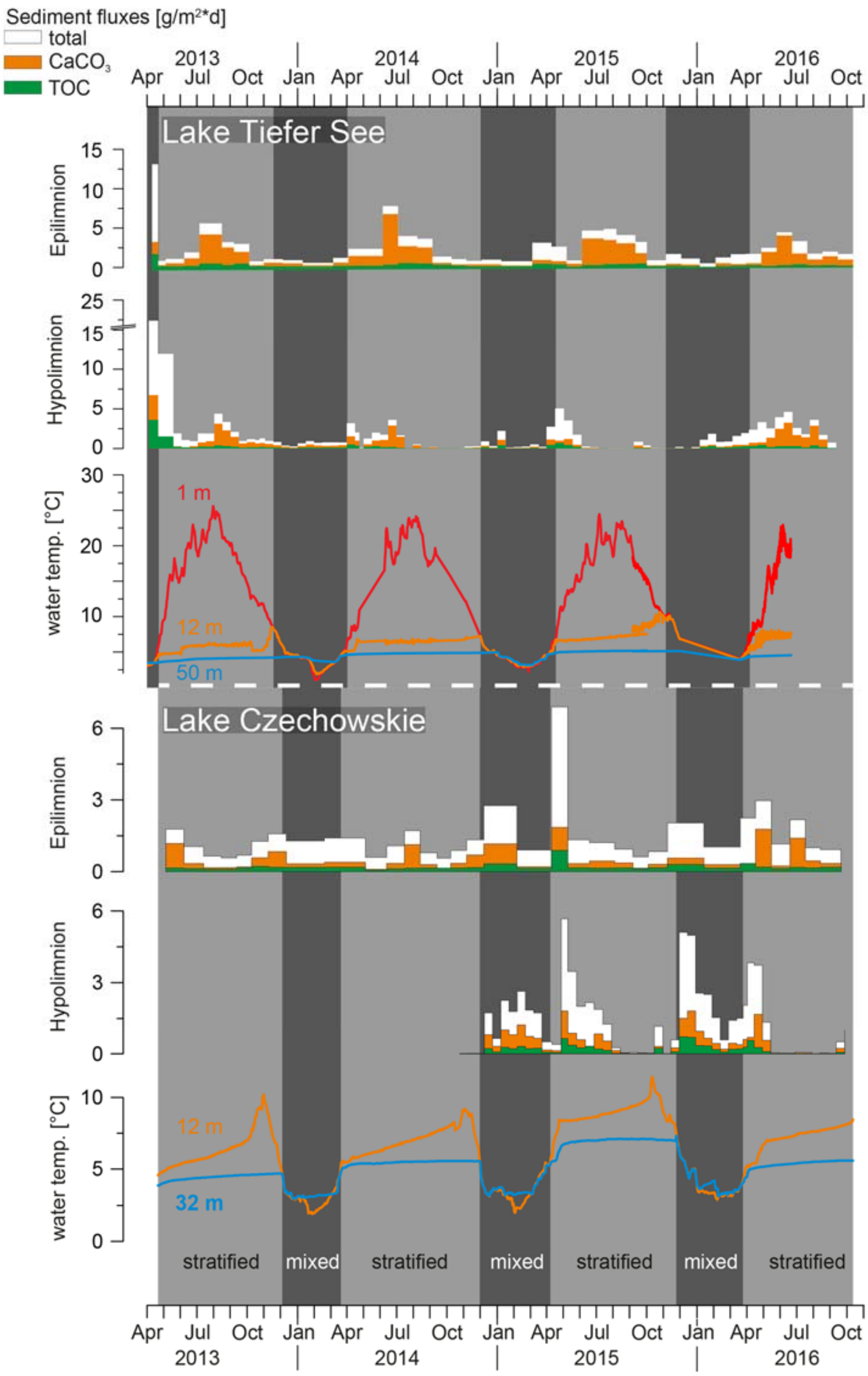


***Fig. 1:** Comparison of lake monitoring for Lake Tiefer See and Lake Czechowskie. Sediment traps comprise 4-cylinder (epilimnion, monthly sampling intervals) and automatic sequential sediment traps (hypolimnion, biweekly sampling intervals), respectively. Lake mixing (dark grey bars) and stratification (light grey bars) periods have been determined by the convergence (thermal mixing) and divergence (thermal stratification) of water temperature logger data.*

Session 2: Recent change and instrumental observations

Monitoring water isotope composition of Lake Tiefer See Klocksin (NE Germany) to understand our paleoclimate archives

Pinkerneil, Sylvia*; Kienel, Ulrike; Brademann, Brian; Dräger, Nadine; Plessen, Birgit & Brauer, Achim

GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

* Corresponding author: sylvia.pinkerneil@gfz-potsdam.de

Introduction

The $\delta^{18}O$ values of carbonates precipitated in lakes are of increasing interest in paleoclimate research. To understand the variation of $\delta^{18}O$ in carbonates deposited in lake sediment records, a long-term monitoring started in March 2012 at Lake Tiefer See in NE Germany. The study of modern controls of the lake $\delta^{18}O$ system can be used to calibrate the $\delta^{18}O$ variability in carbonate $\delta^{18}O$ proxies (Jones et al., 2016 a+b). Lake water was sampled monthly in water depths of 1, 3, 5, 7, 10, 20, 40, 45, and 50m. Rain water was collected also in monthly increments since December 2016 from a rain water sampler installed on a platform in the center of the lake. The water temperature was measured using temperature loggers installed in 1m-spacing down to 15m water depth and 5m-spacing down to 55m depth below. Meteorological data measured on site in 10 min-intervals include temperature, relative humidity, solar radiation, rainfall and wind speed. In addition, we use the $\delta^{18}O$ values from the nearby GNIP station in Neubrandenburg (ca. 50 km E from Lake Tiefer See, period 1997-2002).

Analytical method

Aliquots of filtered lake and rain water (1.8 ml) were filled into glass vials capped with silicone Teflon septa and analyzed using a Cavity Ring-Down Spectrometer from PICARRO. The stable isotope ratios ($\delta^{18}O$ and δD) were measured with an L2130-i and L2120-i analyzer, equipped with an A0211 vaporizer and V1102-i respectively in the water isotope laboratory of section 5.2 at the German Research Centre for Geosciences in Potsdam.

All samples were measured 2 to 4 times in high precision mode with nitrogen as carrier gas. The data correction was performed offline following the procedure described by van Geldern and Barth (2012). To reduce the memory effect, only the last 6 of 10 measurements of each sample were used. The isotopic ratios are reported using the delta notation in per mil (‰) relative to the international SMOW standard and are calibrated using the VSMOW2, VSLAP2 and two laboratory reference standards. The analytical precision is <0.02‰ for $\delta^{18}O$ and <0.3‰ for δD.

Results

The precipitation in NE Germany shows annual ranges from -13‰ to -4‰ $\delta^{18}O$ and from -95‰ to -30‰ δD, depending on season and temperature. The isotopic composition of the rain water is slightly different from the Global Meteoric Water Line (GMWL, y=8*x+10) with a shift to more positive $\delta^{18}O$ values resulting in a Local Meteoric Water Line (LMWL) of y=7.5*x+3.6 for the GNIP station Neubrandenburg. The $\delta^{18}O$ values in rain samples collected in 2016 at Lake Tiefer See show comparable values.

The $\delta^{18}O$ values of the epilimnion water of Lake Tiefer See range from -5 to -3.5‰ with continuously increasing values during summer stratification. The seasonal variation and changes between winter/spring and summer/autumn are similar except for the year 2013 when $\delta^{18}O$ values were generally lower. Assuming ground water $\delta^{18}O$ values around -9‰, the lake shows a significant evaporative loss of water and with this an enrichment in $\delta^{18}O$. A simple calculation of Rayleigh fractionation results in an evaporative loss of lake water of about 30 to 40 %. The relatively similarity of the annual evaporative trend in the monitored years allows a calculation of precipitation temperature of the lake carbonate record (Kienel et al., in prep.).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

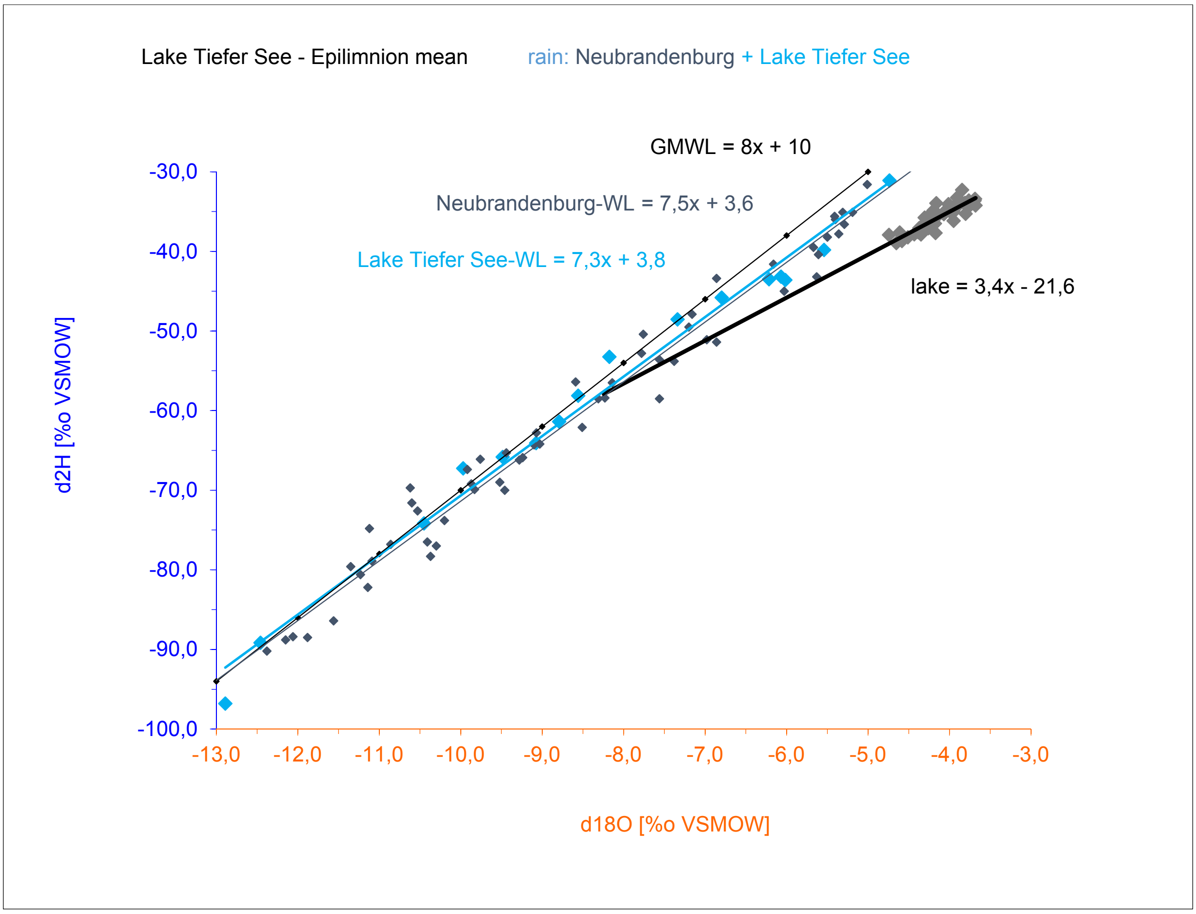


Fig.1: *Global Meteoric Water Line (GMWL), Local Meteoric Water Line (LMWL from Neubrandenburg) and measured $\delta^{18}O$ and δD values of local precipitation (Lake Tiefer See-WL) and lake water (epilimnion mean). Slopes between the LMWL and the lake water indicate the evaporation trend.*

References

van Geldern, R., Barth, J.A.C. (2012) Optimization of instrument setup and post-run corrections for oxygen and hydrogen stable isotope measurements of water by isotope ratio infrared spectroscopy (IRIS). Limnology and Oceanography: Methods 10, 1024-1036.

Jones et al., (2016a) Water isotopic systematics: Improving our paleoclimate interpretations. Quaternary Science Reviews 131, 243-249.

Jones et al., (2016b) Comparisons of observed and modelled lake δ18O variability. Quaternary Science Reviews 131, 329-340.

DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

The history of increasing anthropogenic nutrient loading into the Lake Tiefer See (NE Germany) - from monitoring to the sedimentary record

Plessen, Birgit*; Kienel, Ulrike; Dräger, Nadine; Pinkerneil, Sylvia & Brauer, Achim

GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

* Corresponding author: birgit.plessen@gfz-potsdam.de

Nitrogen content and isotopic composition (d^{15}N) of lake sediments are controlled by external and internal sources and processes and can be used to detect environmental changes (Kendall, 1998; Teranes & Bernasconi, 2000). External sources like plant and soil material, with moderately positive d^{15}N values, can be distinguished from nitrate introduced with manure or sewage with values up to +25‰ and from nitrate fertilizer or recent atmospheric reactive nitrogen with values around 0‰. Internal processes such as nitrate utilisation during phytoplankton production cause a positive shift in d^{15}N whereas an increase in the biomass of cyanobacteria which fix nitrogen from the air results in a depletion in ^{15}N (Fig. 1).

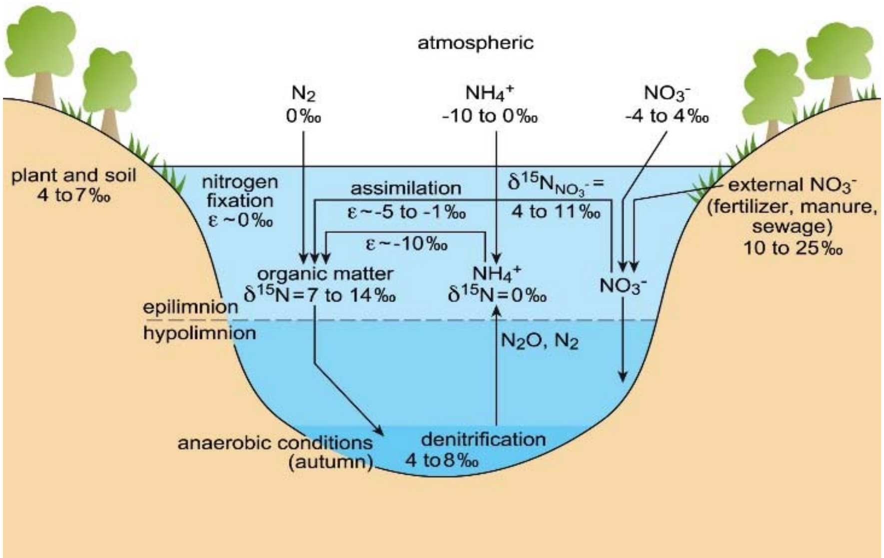


Fig. 1: *Nitrogen cycle in Lake Tiefer See. Sources according to Teranes and Bernasconi (2000) and Kendall (1998).*

Lake Tiefer See (Mecklenburg/Germany) is a deep (~63 m) oligo-mesotrophic hard-water lake with pronounced summer stratification (Kienel et al., 2013). The lake is part of a NS directed lake chain that formed in a subglacial channel system. The Holocene record of lake sediments at the deepest part of the lake is characterized by well-varved and non-varved intervals (Dräger et al., 2017). To understand the interaction of lake productivity and nitrogen cycle and the influence of natural (climate) variability and anthropogenic forcing, we integrate (1) the recent input and lake production, monitored in lake water and sediment traps since 2012 with (2) the annually laminated (varved) sediment record of the last 100 years and (3) the sediments deposited during the last 2000 years.

Monitored data suggest that seasonal variations in d^{15}N are related to lake productivity. This is indicated by the correspondence between increases of lake production (phytoplankton blooms) and d^{15}N of organic matter from +7 to +14‰. The synchronous decrease in the concentration of dissolved nitrate (NO_3^-) while ^{15}N becomes enriched from +8 to +12‰ suggests that nitrate utilization causes the enrichment in ^{15}N (Teranes & Bernasconi, 2000). The d^{15}N signature further clearly hints at manure as the source of the dissolved nitrate.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Compared to the $d^{15}N$ signature of the trapped material, the lake sediments of the last 100 years show less ^{15}N enrichment with maximum values of +10‰. This difference may reflect decomposition of organic material and denitrification processes at the lake bottom.

Variations of nitrogen contents and isotope values in the sediment record of the last 2000 years are related to anthropogenic nutrient loading, which increased with the intensity of land use (agriculture, lifestock farming, manuring) in the lake catchment. Until 1800 AD, the $d^{15}N$ values of the lake sediments are relatively low and vary little between +2 to +4‰. This range is similar to that in the worldwide compilation of lacustrine records (McLauchlan et al., 2013). The variations mainly reflect changes in lake productivity influenced by climatic changes and/or enhanced population and land use. Nutrient loading to the lake intensified in the late 18th century when the regional human impact increased. From AD 1800 to 1900 a shift in $d^{15}N$ from +4 to +7‰ gives evidence for important changes in agriculture with societal background. The 3-field crop system was replaced by an intensive agriculture with enhanced production of fodder plants for lifestock farming (Theuerkauf, 2015). This required fertilizer containing nitrogen, phosphorous, potassium, magnesium and sulphur as identified by Liebig in 1840 in the well-known “Law of the Minimum”. The consequences were imports of guano (initiated by Humboldt around 1800), later on followed by imports of saltpeter, as well as English salts. Further, the recovery of potassium salts in Germany and the use of manure led to immense improvements and yields of agriculture during the period 1870 to 1900.

The significant increase of $d^{15}N$ at the beginning of the 19th century is a strong indication for manuring with guano during that time because of the naturally high $d^{15}N$ signature of seabird guano (+10 to +25‰). A further increase in $d^{15}N$ to +7‰ is synchronous with the preservation of varved sediments after 1924, which was promoted by the coupled increases of nutrient input, lake production and oxygen consumption during decomposition. An expansion of lifestock farming around AD 1975 caused $d^{15}N$ values to increase further to +9‰, which can be related to the application of pig manure. After a short decline in $d^{15}N$ during the years of turn, the most recent values around +10‰ reflect the strong influence of nutrient input linked with increasing lake productivity.

References

Dräger, N., Theuerkauf, M., Szeroczynska, K., Wulf, S., Tjallingii, R., Plessen, B., Kienel, U., Brauer, A. (2017) Varve microfacies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany). The Holocene, 27, 450-464.

McLauchlan, Williams, J.J., Craine, J.M., Jeffers, E.S. (2013) Changes in global nitrogen cycling during the Holocene epoch. Nature 495.

Kendal, C. (1998) Tracing nitrogen sources and cycling in catchments. P. 519-576. In: Kendal, C. & McDonell, J.J. (eds.) Isotope tracers in catchment hydrology, Elsevier.

Kienel, U., Dulski, P., Ott, F., Lorenz, S., Brauer, A. (2013) Recently induced anoxia leading to the preservation of seasonal laminae in two NE-German lakes. Journal of Paleolimnology, 50, 4, p. 535-544.

Teranes, J.L. and Bernasconi, St.M. (2000) The record of nitrate utilization and productivity limitation provided by d15N values in lake organic matter – A study of sediment trap and core sediments from Baldeggersee, Switzerland. Limnology and Oceanography, 45, 801-813.

Theuerkauf, M., Dräger, N., Kienel, U., Kuparinen, A. and Brauer, A. (2015) Effects of changes in land management practices on pollen productivity of open vegetation during the last century derived from varved lake sediments. Holocene. 25, 5, 733-744.

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Chironomidae-inferred summer temperatures from Poland based on the Swiss-Norwegian & Swiss-Norwegian-Polish training set

Płóciennik, Mateusz[1]*; Kotrys, Bartosz[2]; Heiri, Oliver[3]; Antczak, Olga[1]; Jakiel, Aleksandra[1]; Baradyn, Daria[1]; Tosik, Kamila & Brooks, Stephen[4]

[1] University of Lodz, Department of Invertebrate Zoology and Hydrobiology, Lodz, Poland
[2] Polish Geological Institute – National Research Institute, Pomeranian Branch, Szczecin, Poland
[3] Aquatic Palaeoecology Institute of Plant Sciences and Oeschger Centre for Climate Change Research, Bern, Switzerland
[4] Natural History Museum, Department of Life Sciences, London, UK
* Corresponding author: mplociennik10@outlook.com

The Polish Plain is an important region for a palaeoclimatic reconstruction of the Late Glacial and Holocene, being under influence of continental and Atlantic air masses. Whereas the north of the country remained glaciated, Central and Southern Poland were under periglacial conditions during the Weichselian glaciation. Due to a lack of natural lakes which still exist today, Chironomidae-inferred climatic reconstructions are based on palaeolake, oxbow and fen sequences. The main study site in Poland is the Żabieniec kettle hole with a 16 m continuous Late Glacial and Holocene sequence. The other accessory sites in Central Poland are Rąbień Bog, Koźmin Fen, Pawłowa, Ługi and Grabica palaeoxbows to the west, and Bęczkowice Fen to the south, as well as Stubno and Łuka oxbows which were analysed in the Carpathian foothills in Poland and Ukraine. Generally, the results of reconstructions indicate much warmer Late Glacial than in North-Western Europe (Brooks and Langdon 2014). It is unclear if Central Poland experienced a distinctive summer temperature decrease during the Younger Dryas (YD). Sites where *Corynocera ambigua* was not dominant indicate no clear cooling period during the YD. The Holocene temperatures, estimated mainly from the Żabieniec assemblages, reveal mild climatic conditions close to the present. Two sites from the East Carpathian foothills indicate warmer Early Holocene conditions than current temperatures.

The Swiss-Norwegian inference model (Heiri et al., 2011) was used for reconstructions from the above-mentioned sites. As it combines reference sites from Norway and the Swiss Alps, it lacks representative localities from the Central European plains belt. This is a very important gap that complicates reconstructions from temperate European latitudes. To expand the Swiss-Norwegian model, a Polish training set (TS) was developed. As many as 102 lakes, mainly from Pomerania and the Masurian Lakelands, as well as the Polish Plain, the Sudetes and the Carpathian Mountains, were included. After merging the Polish and Swiss-Norwegian TS, a Swiss-Norwegian-Polish TS, which includes 376 lakes and 134 chironomid morphotypes (Fig. 1), was developed and has a mean July temperature range of 3.5°C to 20°C. The R^2 and RMSEP of transfer functions developed from this TS, based on ANN and WA-PLS, were 0.96 and 1.35°C, respectively.

The Swiss-Norwegian-Polish TS was applied to the Żabieniec Lake sequence (Central Poland) using ANN and WA-PLS transfer functions. Both reconstructions reveal higher Late Glacial and similar Holocene summer temperatures than the Swiss-Norwegian model (Tab. 1).

References

Brooks, S.J., Langdon, P.G. 2014. Summer temperature gradients in northwest Europe during the Lateglacial to early Holocene transition (15–8 ka BP) inferred from chironomid assemblages. Quaternary International 341, 80-90.

Heiri, O., Brooks, S.J., Birks, H.J.B., Lotter, A.F., 2011. A 274-lake calibration data-set and inference model for chironomid-based summer air temperature reconstruction in Europe. Quaternary Science Reviews 30, 3445-3456.

Płóciennik, M., Self, A., Birks, H.J.B., Brooks, S.J., 2011. Chironomidae (Insecta: Diptera) succession in the Żabieniec bog and its palaeo-lake (Central Poland) through the Late Weichselian and Holocene. Palaeogeography Palaeoclimatology Palaeoecology 307, 150-167.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

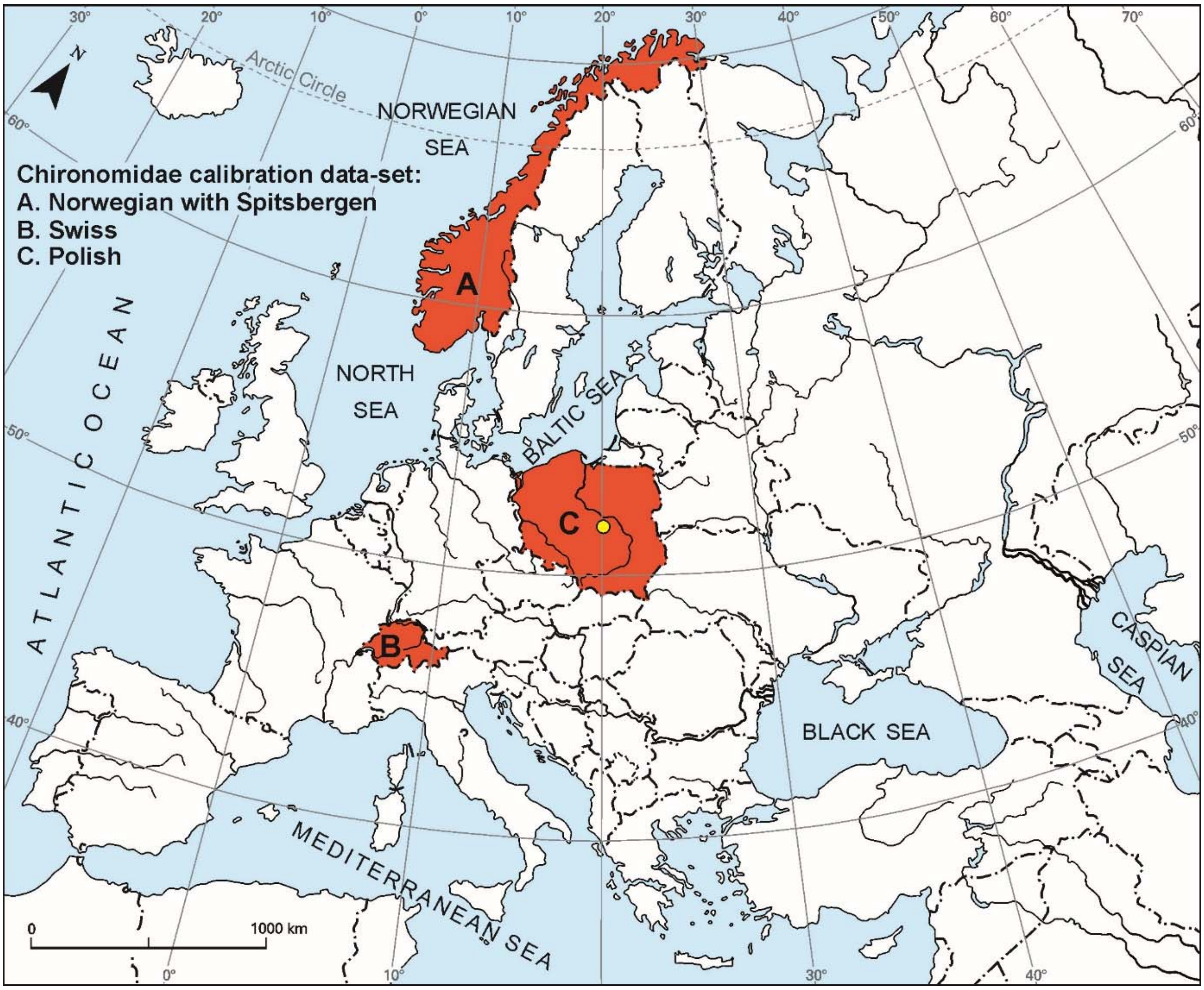


Fig. 1: *The Swiss-Norwegian-Polish training set location. Yellow dot – Żabieniec Lake location.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Period	Żabieniec core depth	Dates	Żabieniec	
			Swiss- Norw-Pol TS ANN	Norw-Swiss WA-PLS
		Żabieniec age	Swiss-Norw-Pol TS WA-PLS	Russian WA-PLS (Płóciennik et al., 2011)
Plenivistulian/Oldest Dryas	1604-1241 cm	>22 ky BP - 16.3 ky cal. BP*	7.25-15.3 °C	9-12.4°C
			11.2-16.4°C	10.3-13.7°C
Bølling	1241-1081 cm	16.3-14.3 ky cal. BP*	16.7-18.8°C	14.2-16°C
			17.1-19.7°C	13.8-16.3°C
Older Dryas - Allerød	1081-981 cm	14.3-12.9 ky cal. BP	13.3-18.1°C	13.7-14.6°C
			14.8-18.1°C	14.9-16.6°C
Younger Dryas	981-891 cm	12.87-11.42 ky cal. BP	14.1-18°C	13.5-16.5°C
			15.8-19.1°C	14.7-16.4°C
Preboreal Period	891-781 cm	11.42-9.9 ky cal. BP	16.2-17.7°C	14-17.2°C
			15.85-18.7°C	14.6-16.2°C
Boreal Period	781-681 cm	9.9-8.8 ky cal. BP	14.8-16.1°C	15.5-17.7°C
			17-18.6°C	13.8-15.8°C
Atlantic Period	681-411 cm	8.8-4.8 ky cal. BP	11.7-18°C	14.4-17.4°C
			16-20°C	9.5-16.8°C
Subboreal Period	411-251 cm	4.8-2.8 ky cal. BP	14.2-18°C	15-18.8°C
			16.5-19.6°C	13.7-16°C
Subatlantic Period	251-1 cm	2.8 ky cal. BP-present	13.2-17.5°C	15.2-19.2°C
			13.3-19.6°C	8.9-15.8°C
Modern Times	last 2 samples	second half of XX c.	16.5°C	16.5-16.9°C
			17.6-18°C	13.5-14.3°C

Tab. 1: *Results of mean July air temperature reconstructions from Żabieniec palaeolake – unpublished ones, based on the Norwegian-Swiss TS and the Swiss-Norwegian-Polish TS, and previously published ones, based on the Russian TS (Płóciennik et al., 2011). * Ages in the Żabieniec record older than Older Dryas are older than expected based on the pollen stratgraphy and should be interpreted with caution.*

Session 3: Integrating time-scales and regional synchronization

Dynamical proxy responses to climate transitions recorded in lake sediments on the Tibetan Plateau

Ramisch, Arne[1]*; Tjallingii, Rik[1]; Hartmann, Kai[2] & Brauer, Achim[1]

[1] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[2] Free University of Berlin, Institute of Geographical Science, Berlin, Germany
* Corresponding author: aramisch@gfz-potsdam.de

Lakes are among the most reliable archives of paleoenvironmental change in terrestrial settings, especially on long time scales. Environmental change (as e.g. climatic variability) affects numerous lake internal and external processes and triggers variations in sedimentological variables which are subsequently deposited in the sedimentary record of a lake as proxies. The signal propagation model between environmental forcing as input and the proxy record as output is often assumed to be linear (see Fig. 1, left side). The assumption states, that a sensor within the lake (e.g. sediment grains or ostracods) stores a scaled and noisy version of the environmental forcing signal (e.g. variations in precipitation or temperature). However, landscape evolution models (Armitage et al., 2011) and field investigations (Hajek et al., 2012) indicate an important role of autogenic dynamics of the sedimentary routing system in the formation of sedimentary records on long (>10^3 years) time scales. Dynamical system responses to environmental forcing (see Fig. 1b, right side), in turn, may overprint climatic signals and impede a linear inference of paleoclimatic input functions from sedimentary proxy records.

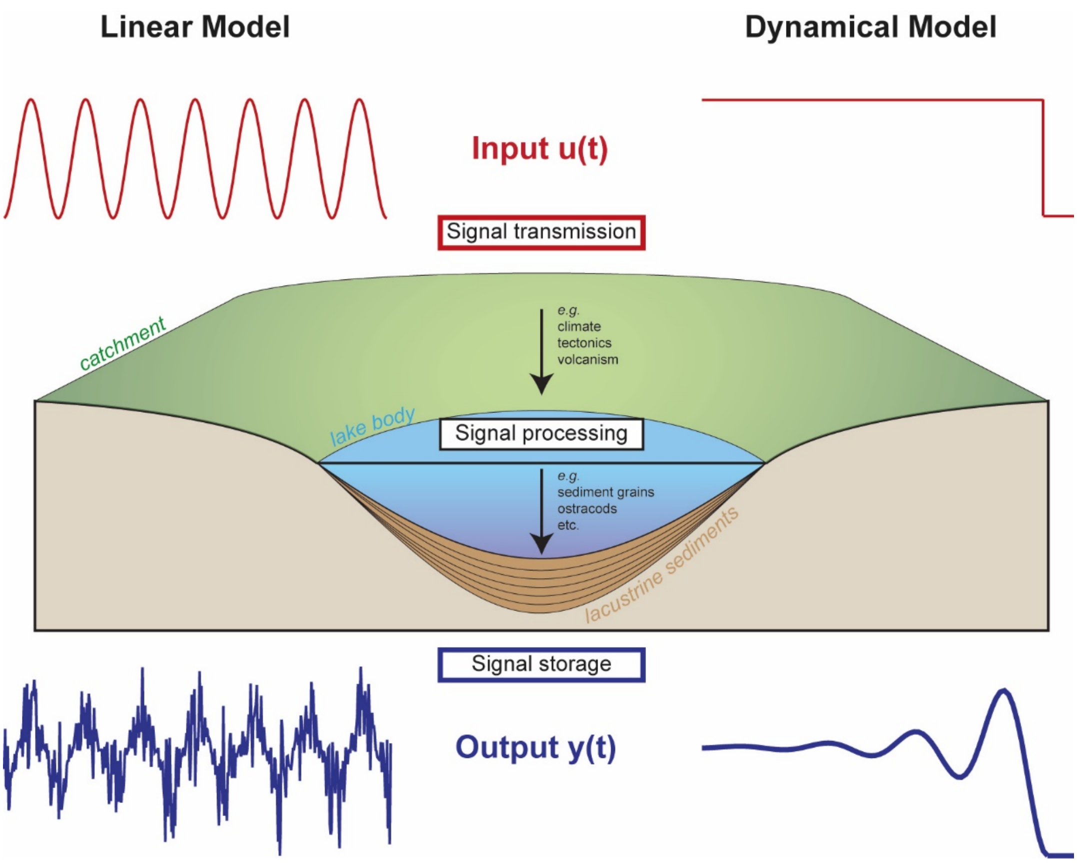


Fig. 1: *Conceptual model of climate-signal propagation in lake systems: Linear vs. dynamic proxy responses.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

To analyze a potential influence of autogenic sedimentary dynamics on lacustrine proxy records, we re-evaluate the geochemical composition from three lakes located on the Tibetan Plateau measured by non-destructive XRF scans, previously published by Doberschütz et al., (2014) and Ahlborn et al., (2016). Non-destructive XRF scans provide high-resolution records of relative element concentrations that are commonly related to past environmental change. Paleoenvironmental change on the Tibetan Plateau is mainly influenced by the evolution of the Asian Summer Monsoon circulation, which is believed to have decreased in intensity during the past 12 ka throughout monsoonal Asia (Herzschuh, 2006), synchronous to decreasing boreal summer insolation. In contrast, the variations in element concentrations of the three lake records indicate asynchronous variations of similar geochemical proxies since the Late Glacial. The variations are characterized by harmonic oscillations in relative elements concentrations, differing in frequency and magnitude in between the lakes.

Here we argue, that the oscillatory behavior is a result of a feedback mechanism in between the dissolution of mineral phases and the removal of particulate matter within the drainage basins of each lake. The asynchronous evolution of the records is explained by catchment specific responses to climate transitions resulting from different morphological configurations of the lakes drainage basins. Further, we introduce a numerical model, which simulates the feedback mechanism and reproduces major Holocene variations in element concentrations of the three lake systems. Our findings hold important implications for the reconstruction of environmental signals from lake sediments predominantly influenced by terrestrial processes.

References

Ahlborn, M., Haberzettl, T., Wang, J., Henkel, K., Kasper, T., Daut, G., Zhu, L., Mäusbacher, R., 2016. Synchronous pattern of moisture availability on the southern Tibetan Plateau since 17.5 cal. ka BP - the Tangra Yumco lake sediment record. Boreas. doi:10.1111/bor.12204

Armitage, J.J., Duller, R. a., Whittaker, A.C., Allen, P. a., 2011. Transformation of tectonic and climatic signals from source to sedimentary archive. Nat. Geosci. 4, 231–235. doi:10.1038/ngeo1087

Doberschütz, S., Frenzel, P., Haberzettl, T., Kasper, T., Wang, J., Zhu, L., Daut, G., Schwalb, A., Mäusbacher, R., 2014. Monsoonal forcing of Holocene paleoenvironmental change on the central Tibetan Plateau inferred using a sediment record from Lake Nam Co (Xizang, China). J. Paleolimnol. 51, 253–266. doi:10.1007/s10933-013-9702-1

Hajek, E.A., Heller, P.L., Schur, E.L., 2012. Field test of autogenic control on alluvial stratigraphy (Ferris Formation, Upper Cretaceous-Paleogene, Wyoming). Bull. Geol. Soc. Am. 124, 1898–1912. doi:10.1130/B30526.1

Herzschuh, U., 2006. Palaeo-moisture evolution in monsoonal Central Asia during the last 50,000 years. Quat. Sci. Rev. 25, 163–178. doi:10.1016/j.quascirev.2005.02.006

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Changes in the trophic state of Czechowskie Lake during the last 2000 years

Rzodkiewicz, Monika[1]*; Hübener, Thomas[2]; Ott, Florian[3]; Zawiska, Izabela[4]; Brykała, Dariusz[5]; Gierszewski, Piotr[5]; Kaszubski, Michał[5]; Obremska, Milena[6]; Słowiński, Michał[5]; Błaszkiewicz, Mirosław[5] & Brauer, Achim[3]

[1] Adam Mickiewicz University Poznań, Department of Quaternary Geology and Palaeogeography, Institute of Geoecology and Geoinformation, Poznań, Poland
[2] University of Rostock, Institute of Bioscience, Rostock, Germany
[3] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[4] Polish Academy of Sciences, Department of Geoecology and Climatology, Warsaw, Poland
[5] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Torun, Poland
[6] Polish Academy of Sciences, Research Centre in Warsaw, Institute of Geological Sciences, Warsaw, Poland
* Corresponding author: lutynska@amu.edu.pl

Lakes systems respond physically, chemically and biologically to climate and environmental changes and these reactions are registered in various ways in lake sediment records.

Tucholskie Forests is one of the largest Polish forest area that covers approximately 4500 km^2. This area is is characterized by a hilly terrain and numerous subglacial North-South and East-West orientated sub-glacial channels (Gwoździński and Kilarczyk, 2009). In this study we analysed the sediments of Lake Czechowskie.

Lake Czechowskie is situated in the eastern part of the Pomeranian Lakeland in the Tuchola Pinewoods, 60km south-west of Gdańsk, Poland (53°52.2'N, 18°14.1'E, 108 m a.s.l.), in a subglacial channel formed during the Weichselian Glaciation, between 17 and 16 cal ka BP (Błaszkiewicz et al., 2015; Marks, 2012) (Fig. 1).

Lake Czechowskie (JC) is located in the northern central European Lowlands in the foreland of the terminal moraine of the Pomeranian ice advance of the last glaciation, which is dated at 15.6±0.6 ^{10}Be ka (Rinterknechta et al., 2014). This lake has a melt genesis, namely lake basins formed by the melting of buried ice blocks (Błaszkiewicz, 2011; Błaszkiewicz et al., 2015; Kaiser et al., 2012; Loon et al., 2012; Słowiński, 2010; Słowiński et al., 2015; Wulf et al., 2016).

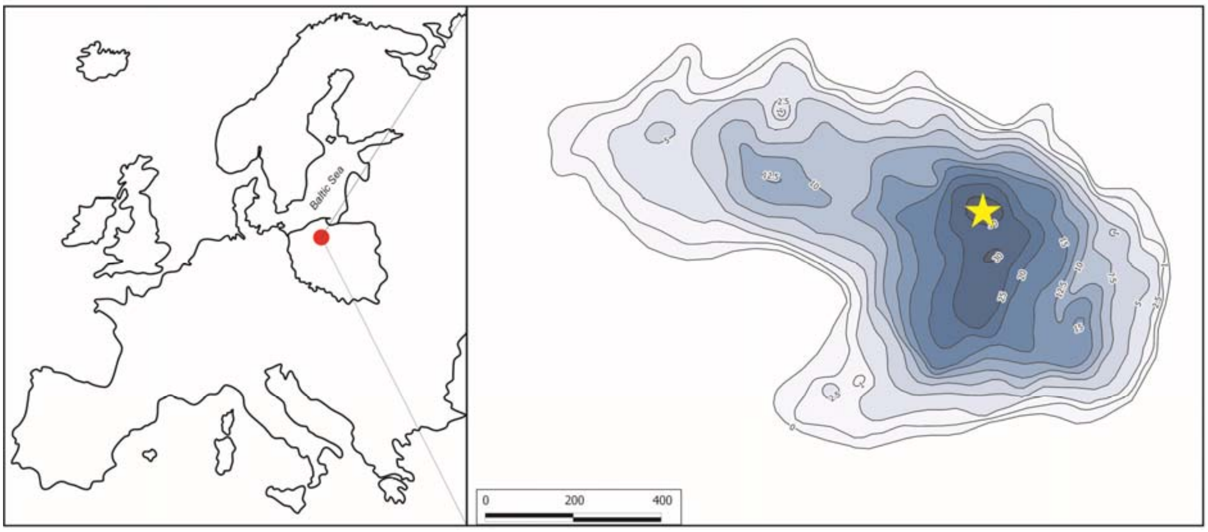


Fig. 1: *Location of the study site and the main core of Lake Czechowskie.*

Four parallel and overlapping sediment sequences as well as several short cores were retrieved between 2009 and 2012 from the deepest parts of the lake (Fig. 1) using an UWITEC piston corer and a Ghilardi Gravity Corer (KGH 94). A continuous composite profile of 1346 cm length has been constructed by defining unambiguous correlation layers (Ott et al., 2016; Wulf et al., 2016). Lacustrine sediments of this lake are annually laminated and, therefore, represent a unique archive to reconstruct climate and environmental changes in Northern Polish Lowland.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The age-depth model is based on (1) varve counting and thickness measurements in the well-laminated sediment unit, (2) AMS ^{14}C dating of terrestrial plant macro remains, (3) radionuclide ^{137}Cs dating (4) tephrochronology, and (5) biostratigraphy.

This poster presents the diatom, Cladocera and pollen records of Lake Czechowskie for the last 2000 years. One of the most common bio-proxies for lake development are subfossil diatoms. Variations in the species composition of the diatom flora is used to reconstruct changes in the environmental conditions triggered by either changing climate and/or human impact on the lake ecosystem.

Diatom-inferred total phosphorous (DI-TP) levels of the euphotic zone were calculated based on a merged European diatom training set consisting on a local data set from 84 lakes in northern Germany (Adler & Hübener, http://www.biologie.uni-rostock.de/abt/botanik/AG-Phykologie/index.htm) and the European Diatom Database Initiative data set (EDDI, Battarbee et al., 2000; current data at http://craticula.nc.ac.uk/eddi/jsp/).

The DI-TP reconstruction (Fig. 2) showed that, diatom associations at 0 AD to 450 AD (505.0 - 381.8 cm), dominated by *Lindavia comensis* and *Fragilaria nanana*, suggest oligo to mesotrophic DI-TP mean values of 15 µg l^{-1} with individual values between 9 to 20 µg l^{-1}. There are only five isolated single outliers up to 26 µg l^{-1}, caused by peaks of eutrophent taxa (*Stephanodiscus parvus* or *Aulacoseira granulata*).

A first rapid shift in diatom associations towards more trophic conditions occurred between 470 - 510 AD (376.9–370.3 cm) mainly caused by rising *S. parvus* reaching up to 54-80%. The abundance of this taxa decreased again to 2.4-0.0% between 560 - 600 AD (364-357 cm).

Between 715 - 1190 AD (335 - 260cm) DI-TP values showed an increasing trend up to mean values of 30 µg l^{-1}. Hovever, the individual data strongly fluctuated between oligotrophic (11 µg l^{-1}) at 1140 AD and meso- to eutrophic values (46 µg l^{-1}) at 1000 AD. Main increases in DI-TP are caused by abundances of TP-indicator taxa of more then 95%.

At 1230 AD the mean DI-TP values turned back to mesotrophic values. This phase includes a long periode until the 19th century (1840 AD). Contrary to the previous period the DI-TP values remained relatively stable between 1140 and 1830 AD, when DI-TP values was between 5 µg l^{-1} to 27 µg l^{-1}.

In relation to the archaeological data from the region we focused on the progress of human activity from the 50 BC up to 2000 AD. The visible deforestation and changes in the forest composition due to human pressure took place between 150 - 2000 AD. The first changes (150 - 380 AD) caused by appearing of human tribes showed the development of ruderal and meadow and pastures plant communities. Between 1580–1760 AD increase of human indicators, e.g. cereals, grazing, pasturing and crop cultivation. Palinological data showed the rapid increase of deforestation and human indicators about 1800 to 2000 years.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association.

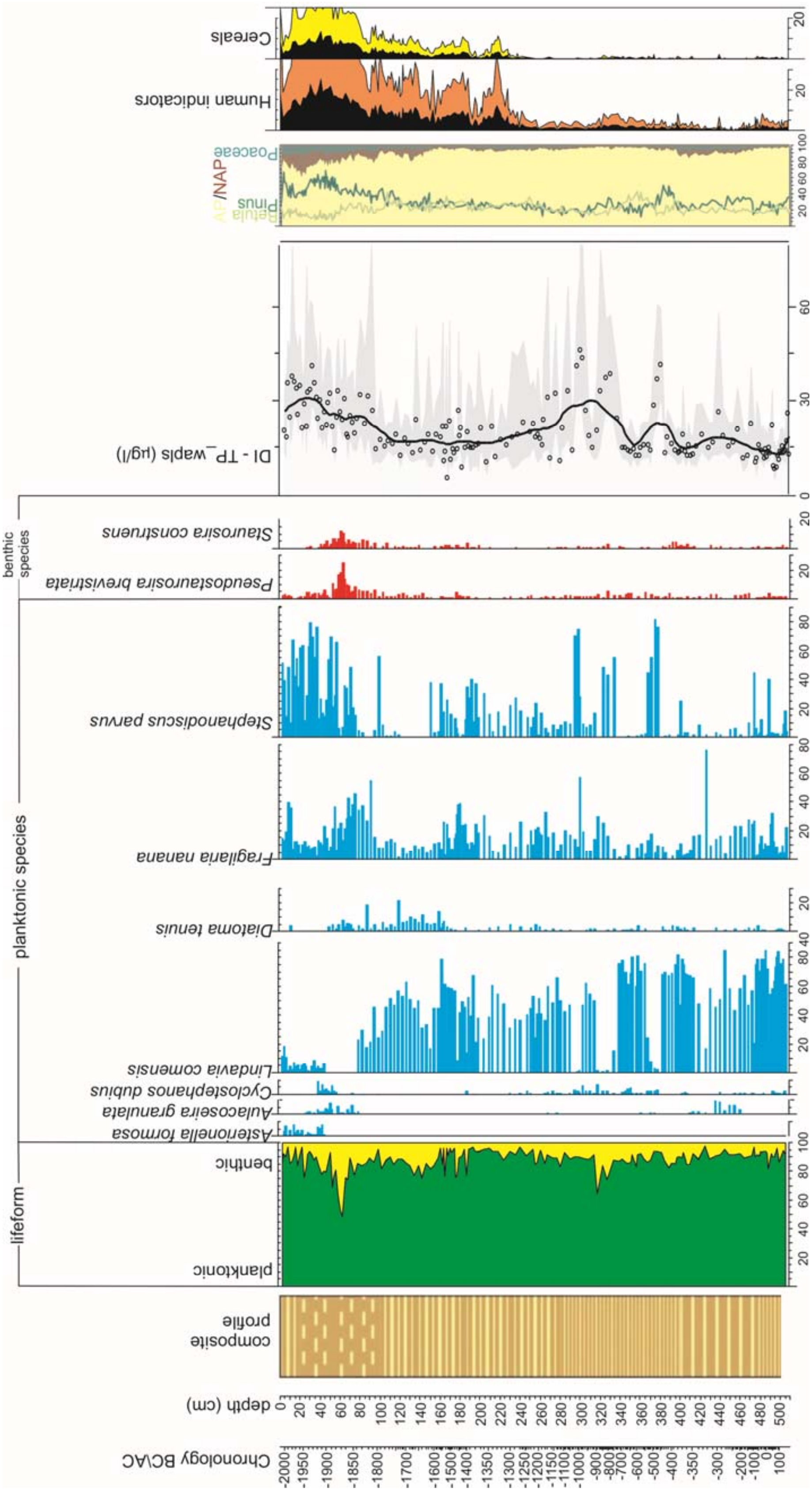


***Fig. 2:** Relative abundance diatom dominant species in laminated sediments of Lake Czechowskie (species with values >2%), DI-TP reconstruction and human indicators during the last 2000 years.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

References

Battarbee, R. W., Juggins, S., Gasse, F., Anderson, N. J., Bennion, H., Cameron, N. G., 2000. European Diatom Database (EDDI). An information system for paleoenvironmental reconstruction. European Climate Science Conference, European Commission, Vienna, Austria 1998, 110

Błaszkiewicz, M., 2011. Timing of the final disappearance of permafrost in the central European Lowland, as reconstructed from the evolution of lakes in N Poland. Geological Quarterly 55, 361–374.

Błaszkiewicz, M., Piotrowski, J.A., Brauer, A., Gierszewski, P., Kordowski, J., Kramkowski, M., Lamparski, P., Lorenz, S., Noryśkiewicz, A.M., Ott, F., Słowiński, M., Tyszkowski, S., 2015. Climatic and morphological controls on diachronous postglacial lake and river valley evolution in the area of Last Glaciation, northern Poland. Quaternary Science Reviews 109, 13–27. doi:10.1016/j.quascirev.2014.11.023

Gwoździński, K., and Kilarczyk, E., 2009. Purity of water in chosen lakes in the north-eastern part of Tucholskie Forests. Teka Kom. Ochr. Kszt. Środ. Przyr. OL PAN, 6, 84-92

Kaiser, K., Lorenz, S., Germer, S., Juschus, O., Küster, M., Libra, J., Bens, O., Hüttl, R.F., 2012. Late Quaternary evolution of rivers, lakes and peatlands in northeast Germany reflecting past climatic and human impact – an overview. Quaternary Science Journal 61, 103–132. doi:10.3285/eg.61.2.01

Loon, A.J. van, Błaszkiewicz, M., Degórski, M., 2012. The role of permafrost in shaping the Late Glacial relief of northern Poland. Netherlands Journal of Geosciences 91, 223–231.

Marks, L., 2012. Timing of the Late Vistulian (Weichselian) glacial phases in Poland. Quaternary Science Reviews 44, 81–88.

Ott, F., Wulf, S., Serb, J., Słowiński, M., Obremska, M., Tjallingii, R., Błaszkiewicz, M., Brauer, A., 2016. Constraining the time span between the Early Holocene Hässeldalen and Askja-S Tephras through varve counting in the Lake Czechowskie sediment record, Poland. Journal of Quaternary Science 31, 103–113. doi:10.1002/jqs.2844

Rinterknechta, V., Börner, A., Bourlès, D., Braucher, R., 2014. Cosmogenic 10Be dating of ice sheet marginal belts in Mecklenburg-Vorpommern, Western Pomerania (northeast Germany). Quaternary Geochronology 19, 42–51. doi:10.1016/j.quageo.2013.05.003

Słowiński, M., 2010. Macrofossil reconstruction of preboreal wetland formed on dead ice block e a case study of the Borzechowo mire in East Pomerania, Poland. Studia Quaternaria 27, 3–10.

Słowiński, M., Błaszkiewicz, M., Brauer, A., Noryśkiewicz, B., Ott, F., Tyszkowski, S., 2015. The role of melting dead ice on landscape transformation in the early Holocene in Tuchola Pinewoods, North Poland. Quaternary International 388, 64–75.

Wulf, S., Dräger, N., Ott, F., Serb, J., Appelt, O., Gudmundsdóttir, E., van den Bogaard, C., Słowiński, M., Błaszkiewicz, M., Brauer, A., 2016. Holocene tephrostratigraphy of varved sediment records from Lakes Tiefer See (NE Germany) and Czechowskie (N Poland). Quaternary Science Reviews 132, 1–14. doi:10.1016/j.quascirev.2015.11.007

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

How global change fakes medieval hydroclimate- a tree ring based millennium long drought reconstruction for NE-Europe

Scharnweber, Tobias[1]*; Heußner, Karl-Uwe[2]; Smiljanic, Marko[1]; Heinrich, Ingo[3]; Buras, Allan[4] & Wilmking, Martin[1]

[1] University of Greifswald, Greifswald, Germany
[2] German Archaeological Institute (DAI), Berlin, Germany
[3] GFZ - German Research Centre for Geosciences, Section 5.4 Hydrology, Potsdam, Germany
[4] Technical University Munich (TUM), Munich, Germany
* Corresponding author: tobias.scharnweber@uni-greifswald.de

Using tree-ring width of drought sensitive tree species to reconstruct hydroclimate relies on the simple relationship of good growth (broad RW) during years of good water supply and growth depressions (narrow RW) as a result of water shortage. Since the beginning of industrialization Nitrogen and CO_2 fertilization effects have markedly influenced growth rates of trees (Pretzsch et al., 2014). Therefore using long term (decadal to centennial) trends of tree growth to reconstruct climatic trends of the same time frequency is strongly biased by this non-climatically induced growth stimulation. It is therefore necessary to distinguish the relative influence of climate from other non-climatic factors (e.g. age, competition, growth-enhancement by CO_2 and N-depositions) and to either remove their relative influence or to make sure that their effect was stable over time.

In our study we use a millennial long dataset of tree ring width (TRW) from beech wood stemming from living trees and historical construction wood from NE-Germany to reconstruct regional summer drought. Beech was preferred over oak in this reconstruction as it offers different advantages. Irrespective of site conditions (wet/dry; often unknown for historical wood) beech with its rather superficial root system shows a consistent and temporally stable drought signal over the period of instrumental data in its ring width pattern ($r>0.6$ with summer drought index, PDSI; Scharnweber et al., 2013). In addition it can be assumed that in contrast to oak or other species frequently used as timber, beech wood was available locally and not traded long distances. Its ring-width pattern found in archaeological wood thus shows a locally defined signal making this species the better for reconstructing regional summer moisture conditions.

To enable direct comparison of the modern period with the similarly high replicated medieval times, we developed a data adaptive method to identify and detrend the recent non-climatically induced growth trends caused by fertilization (Fig. 1). This allowed us to use one common regional growth curve standardization (RCS) for standardizing both wood sources (living and historical) and in turn facilitates a direct comparison of today's summer hydroclimate with the conditions 1000 years ago by retaining much of the low frequency information in the TRW-data. This is in contrast to many other reconstructions that either use two or more different RCS curves for the living and historical tree ring data or use individual detrending which limits the low frequency information in the resulting chronology to the lengths of the series (tree ages).

Our results based on this new method revealed considerably drier conditions during the medieval climate anomaly (MCA) compared with standard reconstruction methods and other existing reconstructions (Fig. 2). It adds to the discussion whether the MCA was rather warm and dry or warm and wet (Kress et al., 2014). Although most strongly in highly industrialized and/or agricultural regions of Central-Europe, the effect of growth stimulation by atmospheric nitrogen deposition and/or higher CO_2 concentrations might also be apparent in more remote boreal regions and potentially impact TRW-based temperature reconstructions from this area.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

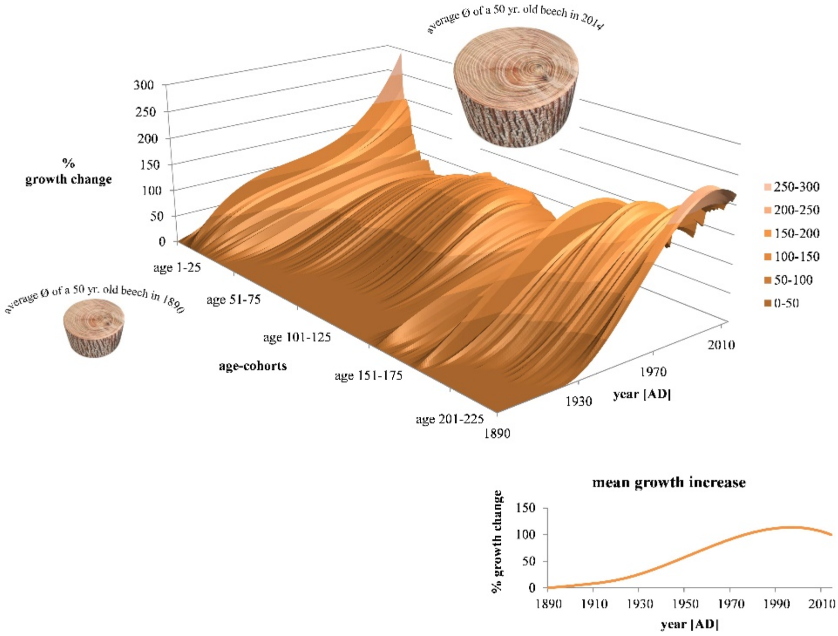


Fig. 1: *Mean percentage growth change of 25 year-long age cohorts of beech over the last century; curves are polynomial regressions of RW – trends for cambial age aligned TRW data rearranged by calendar year (for example the average RW of a tree at age 51-75 was 1.2 mm in 1890 and 2.3 mm in 2014 which equals a growth change of +91.67%). The mean curve of all age cohorts (inset) was used to detrend the raw RW-data before any further analysis.*

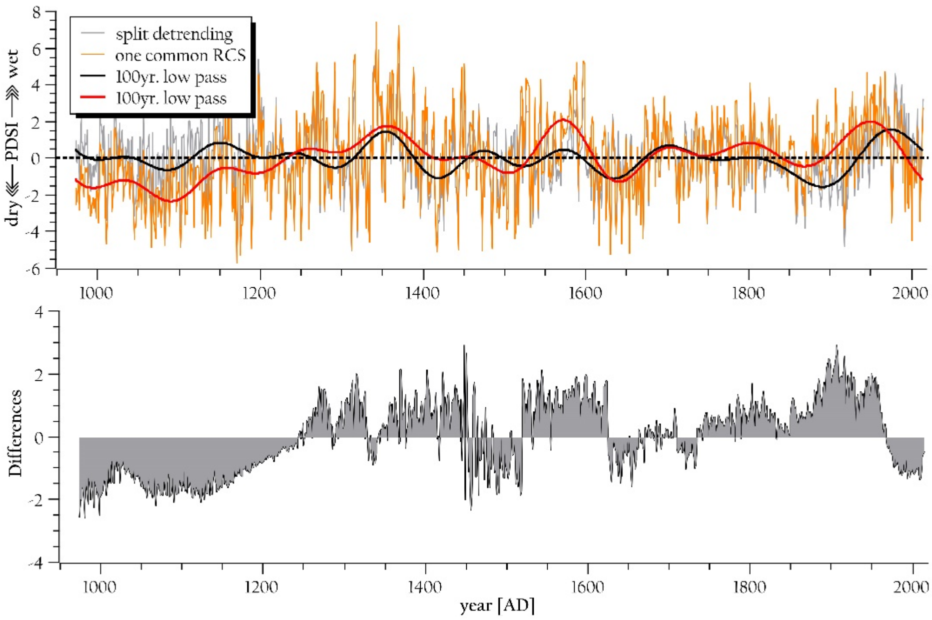


Fig. 2: *Comparison of our reconstruction (linear regression) of summer drought index (PDSI) using one common regional curve for the dataset of living and historical wood after pre-detrending for the fertilization effect (orange and red curves) and the classical, split-detrending approach (grey and black curves). The lower panel shows the differences between the two approaches. Especially the medieval climate anomaly (MCA) ~1000-1200 appears much drier in the one RCS-reconstruction.*

References

Kress, A., Hangartner, S., Bugmann, H., Büntgen, U., Frank, D. C., Leuenberger, M., & Saurer, M., 2014. Swiss tree rings reveal warm and wet summers during medieval times. *Geophysical Research Letters*, *41*(5), 1732-1737.

Pretzsch, H., Biber, P., Schütze, G., Uhl, E., & Rötzer, T., 2014. Forest stand growth dynamics in Central Europe have accelerated since 1870. *Nature communications*, *5*.

Scharnweber, T., Manthey, M., & Wilmking, M., 2013. Differential radial growth patterns between beech (Fagus sylvatica L.) and oak (Quercus robur L.) on periodically waterlogged soils. *Tree Physiol*, *33*, 425-437.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Dye tracer visualization of infiltration patterns in soils on historic charcoal hearth sites

Schneider, Anna[1]*; Hirsch, Florian[1]; Raab, Alexandra[2] & Raab, Thomas[1]

[1] BTU Cottbus-Senftenberg, Geopedology and Landscape Development, Cottbus, Germany
[2] BTU Cottbus-Senftenberg, Research Center Landscape Development and Mining Landscapes, Cottbus, Germany
* Corresponding author: anna.schneider@b-tu.de

The production of charcoal in hearths, pits, or kilns was an important component of historic forest use in Europe and Northern America. Even today, charcoal produced in hearths represents a significant contribution to the energy supply in many regions of the World. The remains of charcoal hearths (RCHs) are therefore a widespread legacy of land use in forest areas. Several studies have characterized the effects of RCHs on plant colonization, growth and cover composition. However, only a few studies have attempted to characterize the soil properties of such sites. Especially the soil hydraulic characteristics of RCHs have received little attention in previous studies.

The aim of our study was to characterize the spatial patterns of infiltration and soil wetness on historic charcoal hearth sites compared with undisturbed sandy forest soils by describing the preferential pathways for water flow. Therefore, infiltration experiments with a dye tracer solution were conducted, and soil profiles were described and analysed. Two sites, located north of Cottbus (Brandenburg, Germany), covered by pine (*Pinus sylvestris L.*) and oak (*Quercus rubra L.*) forest were studied, and two plots located on the RCHs and the surrounding forest soils were examined at each site. The hydraulic conductivity of the undisturbed surfaces of the RCHs and the forest soils was characterized in the field by measurements with a hood infiltrometer before the tracer experiments were performed. For the infiltration experiments, 150 l of a solution with the tracer Brilliant Blue FCF were poured on delimited plots. Several horizontal and vertical profiles were excavated for each plot, and dye tracer distribution was recorded and analyzed by orthorectified photographs and image analysis. The penetration resistance of the soil horizons was measured with a pocket penetrometer. The soil organic matter content and soil pH were determined from bulk samples; and undisturbed samples were taken to characterize bulk density, saturated hydraulic conductivity and hydrophobicity by water drop penetration time (wdpt) tests.

Except for the technogenic deposits that were present at the RCHs, the studied soil profiles are similar in terms of their stratigraphy. The Weichselian glaciofluvial sediments at the bases of the profiles are covered by periglacial coversands containing two stone layers with occasional ventifacts. The undisturbed forest soil is a Brunic Arenosol (Protospodic) with incipient podzolic eluviation in the topmost few centimeters of the topsoil. The subsoil horizons were characterized by weathering and brunification. At the RCH sites, relatively thin organic horizons (L+Of layers) and thin topsoil horizons (Ah horizons) are developed above the technogenic deposit remaining from the charcoal hearths. The remains of the hearth operation are dark gray, relatively loose sediment layers with a thickness of up to 40 cm, which are rich in charcoal fragments. The lower boundary of each charcoal-rich layer is quite distinct and even and is marked by thin black and white bands that represent accumulations of fine charcoal fragments. The topsoil horizons buried below these layers have quite distinct and clear upper boundaries, indicating that the profiles were truncated during site preparation. The upper 2 to 4 cm of these topsoils have a slightly more reddish color that presumably resulted from the thermal oxidation of iron below the charcoal hearths. Moreover, these horizons are slightly more consolidated than the horizons outside of the RCHs. The charcoal-rich technogenic deposits have high contents of soil organic matter and low bulk densities. The bulk density of the mineral topsoil is higher under the RCHs than for the reference profiles at both sites. The hood infiltrometer measurements indicate that the saturated hydraulic conductivity is highly variable for both sites, but the average measured conductivity values were higher on the RCH platforms than for the surrounding forest soils. The wdpt tests revealed extremely high hydrophobicity, but also wettable conditions for all the profiles, and wdpt values measured do not indicate increased hydrophobicity due to heating of the soil.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The results of the dye tracer experiments performed in our study reflect differences in infiltration behavior between forest soils and RCH soils (Fig. 1). Greater degrees of preferential flow and therefore increased heterogeneity of soil wetness were noted at hearth sites. Detailed analyses of tracer distributions in vertical and horizontal profiles revealed that infiltration in the charcoal-rich deposits on RCHs is limited to a few preferential flow paths, presumably because of the high heterogeneity of grain and pore sizes and the extremely high hydrophobicity of the deposits. Infiltration was also highly concentrated within preferential flow paths in the organic horizons of natural forest soils, and infiltration patterns in the mineral topsoils are similar for the RCH and forest soil profiles. The infiltration patterns characteristic of the RCHs originated at the boundary between the buried topsoil and the subsoil horizons below the hearth remains. The relatively high variability in bulk density and hydrophobicity noted for the RCH soils may contribute to the evolution of these infiltration patterns.

The results of our study suggest that soil moisture distribution below RCHs can be affected by characteristic infiltration behavior in the technogenic deposits of such sites, although the basic soil physical and chemical parameters assessed in our study can not fully explain the characteristic flow patterns seen in RCH soils. The results confirm that soil properties can be affected by historic land use, even in areas with continuous forest cover, and that land use legacy effects need to be considered in soil mapping and the assessment of ecological site conditions.

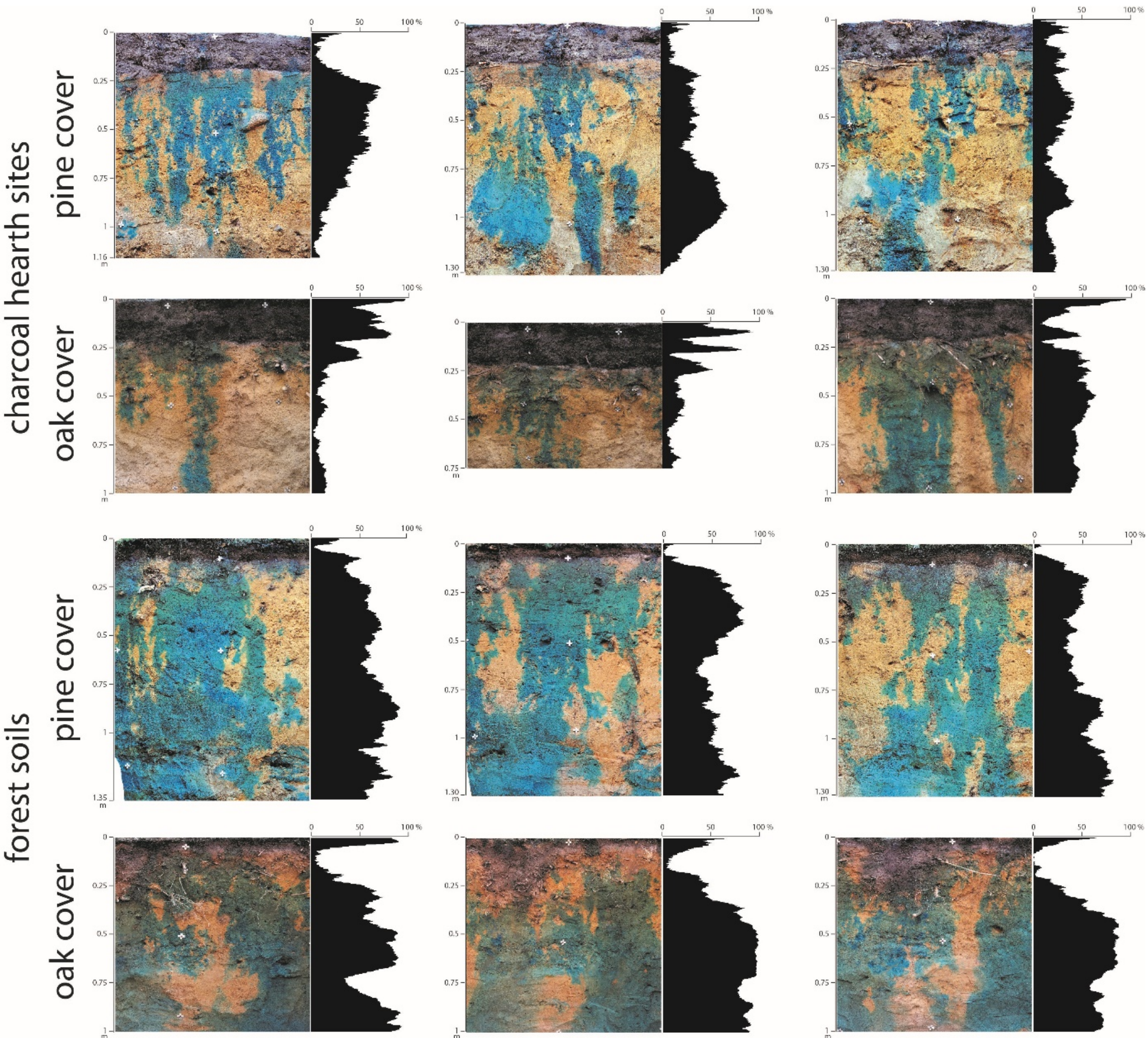


Fig. 1: *Dye tracer stain patterns in profile photos and plots of horizontally integrated one-dimensional vertical values of relative dye coverage vs. depth for vertical soil profiles on the four experimental plots.*

Session 4: Man - climate - environment interactions

Mapping a palaeosurface and archaeological site location in an anthropogenic drift sand area

Schneider, Anna[1]*; Hirsch, Florian[1]; Welcher, Klaus-Peter[2]; Raab, Alexandra[3] & Raab, Thomas[1]

[1] BTU Cottbus-Senftenberg, Geopedology and Landscape Development, Cottbus, Germany
[2] Brandenburgisches Landesamt für Denkmalpflege und Archäologisches Landesmuseum (BLDAM), Zossen, Germany
[3] BTU Cottbus-Senftenberg, Research Center Landscape Development and Mining Landscapes, Cottbus, Germany
* Corresponding author: anna.schneider@b-tu.de

The human occupation of landscapes is often related to ecological and geomorphological structures. Because archaeological remains are consequently often concentrated at specific positions in topography, using models of morphology in the form of topographic maps or digital elevation models (DEMs) is a well-established method in archaeological survey and analysis. However, geomorphological processes in prehistoric and even historic times, often induced by human land use, can have caused a reshaping of local morphology, especially in areas that are prone to sediment erosion and relocation. Consequently, the recent morphology of landscapes prone to sediment relocation can considerably differ from the local relief at phases of prehistoric settlement and land use. Information on the relief at phases of human landscape occupation is therefore necessary in order to make successful predictions of potential archaeological hot spots and to make reasonable interpretations of the archaeological record of a site.

In this study (Schneider et al., 2017), we reconstructed a buried surface for an archaeological excavation area in an inland dune field in Brandenburg, Germany. Archaeological rescue excavations were carried out in the area in preparation for mining, and they revealed multilayered sediment sequences with fossilized soils and sediments from the Late Pleistocene to the Late Holocene (Raab et al., 2015). The morphology is characterized by a homogeneous morphology in sheet sand areas and relatively high topographic variations on a small scale around inland dunes. The landscape is prone to a distinct reshaping of morphology because of the high erodibility of the sandy substrate, as documented for other areas with sandy substrate in the Northern European Lowland. Remains from hunter-gatherer camps, dating to the older Mesolithic (11 to 9 ka BP) were documented in archaeological excavations and were found to be associated with a buried soil horizon.

To gather information on the relief of the buried soil surface, we used a combination of sedimentological and pedological profile descriptions along archaeological survey trenches and geophysical prospection with ground penetrating radar supplemented with microdrone photography and photogrammetry, GPS surveys, and analysis of LIDAR-based elevation models. A digital elevation model of the buried surface was created by combining point data from these sources. The buried surface morphology and the position of the archeological remains within the reconstructed landscape were analyzed in GIS.

Soil and sedimentological description of profiles along the excavation trenches showed that the topmost sediment complex in the study area consists of relatively well-sorted sands of aeolian origin, intersected by several thin and discontinuous humic horizons which are most likely the remains of former organic topsoils and therefore indicate repeated sediment relocation after relatively short phases of surface stability. Soil genesis sediment complex is weak, with only thin Brunic Arenosols (Regosol) developed on the surface. A well-developed buried soil was recorded below the aeolian sand layer for large areas of the study site. The buried soil is mainly developed as a Rustic Podzol (Eisenpodsol) or a Carbic Ortsteinic Podzol (Humuspodsol), with varying thicknesses of eluvial and illuvial horizons and varying degrees of organic compound and sesquioxide accumulation. Horizontal transitions from a Rustic Podzol to a Carbic Ortsteinic Podzol were observed in several trenches. The buried topsoil layer showed varying humus contents and was considerably compact and rich in organic matter in some profiles with Carbic Ortsteinic Podzols. In two trenches towards the lower area in the southern part of the study site, a transition from Carbic Ortsteinic Podzols to Histosols was observed. Below the buried soil or the erosional truncation, a fossilized pedogenic layer with lighter-coloured, and well-sorted, presumably aeolian sand was found over most parts of the trenches. Charcoal fragments and organic residues were found within this horizon but were less frequent than in the upper sand

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

layer. This fossilized horizon shows similar characteristics as the so-called Usselo soil that is often described for Late Pleistocene aeolian deposits in the Northern European Lowlands (Kaiser et al., 2009; Vandenberghe et al., 2013) and associated with a short phase of soil formation before the Younger Dryas.

Sediment profiles could be recorded up to a depth of several metres by GPR because of the high penetration depth in the dry and predominantly sandy substrate. The strong contrast of dielectric properties of the aeolian sand and the fossil soils allowed for a clear identification of the buried soil surface as a strong and continuous signal over large parts of the radargrams. The favourable conditions at the site, with the well-preserved palaeosols, the closely spaced trenches of the archaeological excavations and a good quality GPR signal for the buried surface layer, made it possible to reconstruct the morphology of the surface before Holocene relief modifications.

The comparison of the recent surface and the reconstructed buried surface model (Fig. 1) shows a considerable reshaping of the relief, affirming the relevance of Late Holocene, anthropogenically induced aeolian activity in coversand and inland dune areas. A map of elevation differences between the recent surface and the palaeosurface model reflects a maximum thickness of sand cover of approximately 5.7 m above the buried surface.

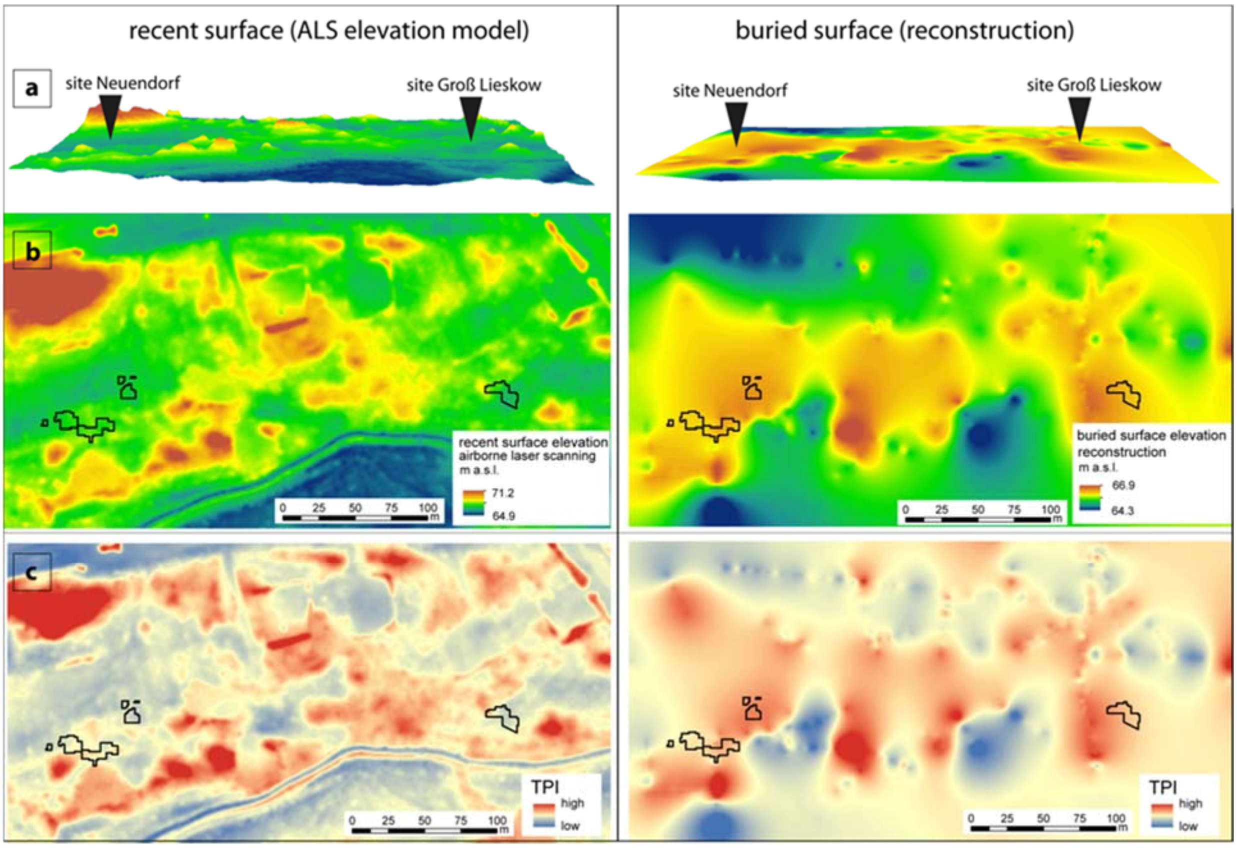


Fig. 1: *Elevation model of the recent surface of the study area, based on ALS (left), and the reconstructed model of the buried surface (right), in 3D (a) and planar view (b); and maps of the Topographic Position Index derived from the models (c). The location of the archaeological excavation sites is marked by arrows in (a) and outlined in (b) and (c). Schneider et al., 2017.*

The topographic position of the documented archaeological remains in the recent surface clearly differs from their position in the palaeolandscape: Whereas the main artefact clusters seem to be located in a low position between inland dunes in relation to the recent morphology, the palaeosurface model shows that the sites were actually located in relatively prominent and exposed positions at the slopes of dunes. Results of a viewshed analysis further show the consequences of the differing relief positions: Only small visible areas

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

around the excavation sites were determined based on the recent surface model because the view towards lower parts of the area is obstructed by ridges of small dunes. Based on the reconstructed surface model, however, considerably larger visible areas around the Mesolithic sites were determined.

Similar modifications of the relief around archaeological sites as observed for our study site are to be expected in other areas with high sediment erodibility and small-scale relief variations. Our results show that a reconstruction of buried surfaces, along with a chronological classification of the sediment stratigraphy, can considerably improve archaeological surveys and interpretation of sites in morphologically active areas.

References

Kaiser, K., Hilgers, A., Schlaak, N., Jankowski, M., Kühn, P., Bussemer, S., Przegietka, K., 2009. Palaeopedological marker horizons in northern central Europe: characteristics of Lateglacial Usselo and Finow soils. *Boreas* 38(3): 591-609. DOI: 10.1111/j.1502-3885.2008.00076.x

Raab, T., Raab, A., Nicolay, A., Takla, M., Hirsch, F., Rösler, H., Bauriegel, A., 2015. Opencast mines in South Brandenburg (Germany)—archives of Late Quaternary landscape development and human-induced land use changes. *Archaeological and Anthropological Sciences* 8 (3): 453-466. DOI: 10.1007/s12520-015-0227-6

Schneider, A., Hirsch, F., Wechler, K.-P., Raab, A., Raab, T. (2017): Reconstruction of a Palaeosurface and Archaeological Site Location in an Anthropogenic Drift Sand Area. *Archaeological Prospection*, in press, available online. DOI: 10.1002/arp.1571

Vandenberghe, D.A.G., Derese, C., Kasse, C., van den Haute, P., 2013. Late Weichselian (fluvio-)aeolian sediments and Holocene drift-sands of the classic type locality in Twente (E Netherlands): a high-resolution dating study using optically stimulated luminescence. *Quaternary Science Reviews* 68: 96-113. DOI: 10.1016/j.quascirev.2013.02.009

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - climate - environment interactions

Assessing the legacies of historical charcoal production in Brandenburg

Schneider, Anna[1]*; Raab, Alexandra[2]; Hirsch, Florian[1]; Bonhage, Alexander[1] & Raab, Thomas[1]

[1] BTU Cottbus-Senftenberg, Geopedology and Landscape Development, Cottbus, Germany
[2] BTU Cottbus-Senftenberg, Research Center Landscape Development and Mining Landscapes, Cottbus, Germany
* Corresponding author: anna.schneider@b-tu.de

Relicts of historical charcoal hearth or kiln sites are characterized by anthropogenic small scale relief-features with special substrate properties. They are valuable archives of land use history. In addition, these legacies of historical charcoal production affect current soils and ecosystems. Despite numerous studies on relict charcoal hearths (RCHs) in Central Europe, essential questions regarding the relevance of charcoal production as a part of forest use history and its effects on soil properties are still unsolved. Mapping and analysis of RCH distribution for continuous areas was hardly attempted, and the characterization of effects on soils and ecosystems is therefore mainly limited to single sites. These knowledge gaps are particularly evident in the Northern European Lowland, where studies on the spatial dimension of historical charcoal production are still sparse. The detailed studies in the probably largest archaeologically excavated historical charcoal hearth field in the open-cast mine Jänschwalde (north of Cottbus, Germany) indicate a considerable underestimation of the relevance of historical charcoal production as a part of the land use system, of the number of charcoal production areas and hearth sites, and therefore also of the relevance of their effects on soil on a landscape scale, especially for this region. Our project therefore aims at describing and assessing the spatial dimensions of historical charcoal production and relevant effects on soil hydraulic properties for the area of the state of Brandenburg, as a part of the Northern European Lowland.

Archaeological rescue excavations in the forefield of the active open-cast lignite mine Jänschwalde have revealed a large charcoal production field, with 1,200 excavated RCHs so far (as of July 2016). Motivated by these findings, the spatial and temporal dimensions of charcoal production in the area were studied by mapping and analyzing RCHs and historical landscape structures. Manual mapping of RCHs was carried out based on Shaded Relief Maps (SRMs) derived from Digital Elevation Models (DEMs), and results were validated against archaeological excavations and results of forest site mapping. The spatial distribution of RCHs was analysed in GIS with descriptive and spatial statistics. Additionally, tree-ring datings of charcoal fragments from selected RCHs were used to study the temporal relation between RCHs. In order to identify further areas of extensive charcoal production in Brandenburg, we used a GIS analysis of environmental and historical data. The analysis is based on the assumption that RCHs can be found in areas that have been continuously covered by forest during the last centuries. Information on historic forest areas and industrial sites as large consumers of charcoal are gathered in GIS based on historical maps, archive and literature studies. In areas continuously covered by forest, SRMs were visually checked for the occurrence of RCHs in a 1 km^2 grid, at a mapping scale of 1:4,000.

The mapping of RCHs for the forest areas around Peitz resulted in a dataset of almost 6,000 sites mapped over an area of 109 km^2 (Fig. 1). The validation of the mapping from SRM against archaeological excavations and forest site mapping showed that about one third of the RCHs found in excavations or forest mapping could not be detected from the SRMs, most probably because of the various anthropogenic surface disturbances in our study area. The diameters of the mapped RCH ground plans range between 4.0 and 30.5 m, indicating that charcoal hearths in the regions were considerably large, as compared with previously described sites and the specifications made in historic forest regulations. The analysis of the spatial distribution of RCHs suggests that the transport distance or proximity of villages to charcoal production sites is the most important factor influencing the location of hearth sites. Results of mapping from SRM further show that up to 3 % of the soil surface in the study area are covered by hearth remains. Furthermore, the visual inspection of the LIDAR-based 1 m DGM for areas covered by forest in historical maps shows that such high densities of RCHs are not unique in the study area around Peitz, but that high numbers of RCHs occur in

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

many large forest areas in Brandenburg. The distribution of the charcoal production in relation to former industrial sites fields affirms that historical iron- and glassworks were important charcoal consumers.

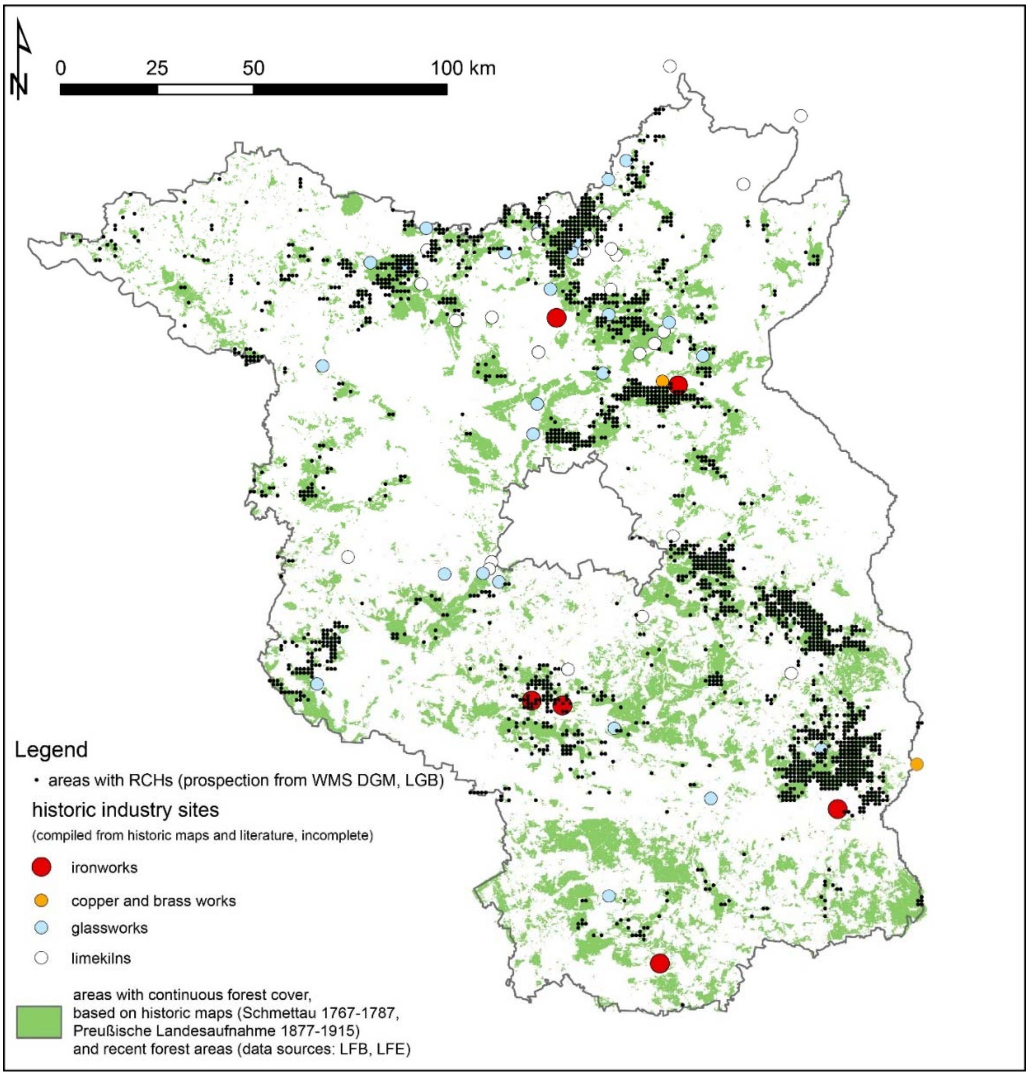


Fig. 1: *Preliminary results of a visual inspection of Digital Elevation Models for the occurrence of RHCs in Brandenburg, compared with the location of former industrial sites as large potential charcoal consumers. Black dots mark areas with RCHs visible in Shaded Relief Maps, assessed in a 1 km^2 grid. Areas not covered by Schmettau maps are not yet included in the analysis. The distribution of RCHs indicates a concentration of charcoal production in forest areas in the vicinity of historic iron- and glassworks.*

To assess the effects of RCHs on the soil water conditions, infiltration experiments with a dye tracer solution were conducted, and soil profiles were described and analysed. The infiltration experiments were carried out on three locations so far, comparing plots on the RCH platform and the undisturbed forest soil outside of the RCH for each location. In addition to the recording and analysis of tracer stain patterns, bulk and undisturbed samples were taken from several depths in the plots to characterize basic soil chemical and physical properties. For a continuous monitoring of the soil water regime, a sensor transect equipped with soil moisture probes and pF-meters was recently installed at the experimental plots on one RCH. The results of infiltration experiments and RCH soil characterization indicate differences in the infiltration characteristics of hearth site soils and undisturbed forest soils: Hood infiltrometer measurements show a very high spatial variability of hydraulic conductivity for hearth site soils, and water-drop-penetration-time tests reflect extremely high hydrophobicity of the technogenic layer on the hearth sites. Results of dye tracer experiment show considerably strong preferential flow and therefore a higher spatial variability of soil wetness below the hearth remains.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Overall, the outcomes of our research show that the spatial organisation and operation of charcoal production in the Northern European Lowland can differ in many respects from charcoal production in low mountain ranges, e.g., concerning forest management, size of charcoal burning platforms and used tree species. Our results furthermore indicate that RCHs are widespread in forest areas in Northeastern Germany, and that the legacy effects of historical charcoal production might significantly affect overall site conditions in forest areas with a high density of hearth remains.

Session 4: Man - climate - environment interactions

Impact of Medieval road construction on landscape transformation during the last 700 years in N Poland

Słowiński, Michał[1]*; Ott, Florian[2,3]; Obremska, Milena[4]; Theuerkauf, Martin[5]; Czaja, Roman[6]; Wulf, Sabine[2,7,8]; Błaszkiewicz, Mirosław[9] & Brauer, Achim[2]

[1] Polish Academy of Sciences, Institute of Geography, Department of Environmental Resources and Geohazards, Warsaw, Poland
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany
[4] Polish Academy of Sciences, Institute of Geological Sciences, Warsaw, Poland
[5] University Greifswald, Institute for Geography and Geology, Greifswald, Germany
[6] Nicolaus Copernicus University, Department of Medieval History, Institute of History and Archival Sciences, Toruń, Poland
[7] GFZ - German Research Centre for Geosciences, Section 5.1 Geomorphology, Potsdam, Germany
[8] Heidelberg University, Institute of Earth Sciences, Heidelberg, Germany
[9] Polish Academy of Sciences, Institute of Geography, Department of Environmental Resources and Geohazards, Toruń, Poland
* Corresponding author: michal.Słowiński@geopan.torun.pl

Here, we present a high-resolution reconstruction of the impact of the construction of the trade route “Via Marchionis” on landscape evolution in Northern Poland since more than 700 years. This reconstruction is based on exploiting the annually laminated (varved) sediment record of the nearby located Lake Czechowskie. The track “Via Marchionis” was established in the early 13th century and initially led from the Mark Brandenburg (Germany) through the capital of Neumark (Myślibórz, 1298 AD) to The Castle of the Teutonic Order in Malbork (Poland, 1286 AD). It was one of the first main West-East connections in northern central Europe and functions as a road until today. In the following centuries, this track became a key migration route during the Middle Ages in the territory of Pomeralia. Frequently recurring wars over the last millennium had great impact on the historical and environmental development of the southern Baltic territory. Moving armed forces often expended and devastated the region and caused changes in sovereignty and population density, all of which resulted in changes in regional vegetation and erosion processes in the lake catchment. Such environmental changes are recorded in the sediments and can be traced with novel

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

high resolution analytical methods. We established a high-resolution palaeoenvironmental reconstruction based on a pollen record at 5-year resolution combined with sub-annual resolving µ-XRF element data of sediments and precise varve dating. As a result, five phases of significantly lower human pressure interrupted by phases of intensified human impact were distinguished. A comparison of these data with historical sources revealed a clear relation of vegetation changes and wars and deployment through armed forces in this region. The strongest declines in anthropogenic pressure on the landscape occurred during periods of war and the subsequent decades of regeneration. Our results suggest that moving of armed forces devastated the region and caused changes in sovereignty and population density, which in turn resulted in changes in regional vegetation and erosion processes in the lake's catchment. Therefore, we conclude that the construction of Via Marchionis was an important factor for the development of the Pomeralia landscape since the 14th century.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA) of the Helmholtz Association. This research was funded by the National Science Centre grants NCN UMO-2015/17/B/ST10/03430. It is a contribution to the climate initiative REKLIM Topic 8 'Abrupt climate change derived from proxy data' of the Helmholtz Association.

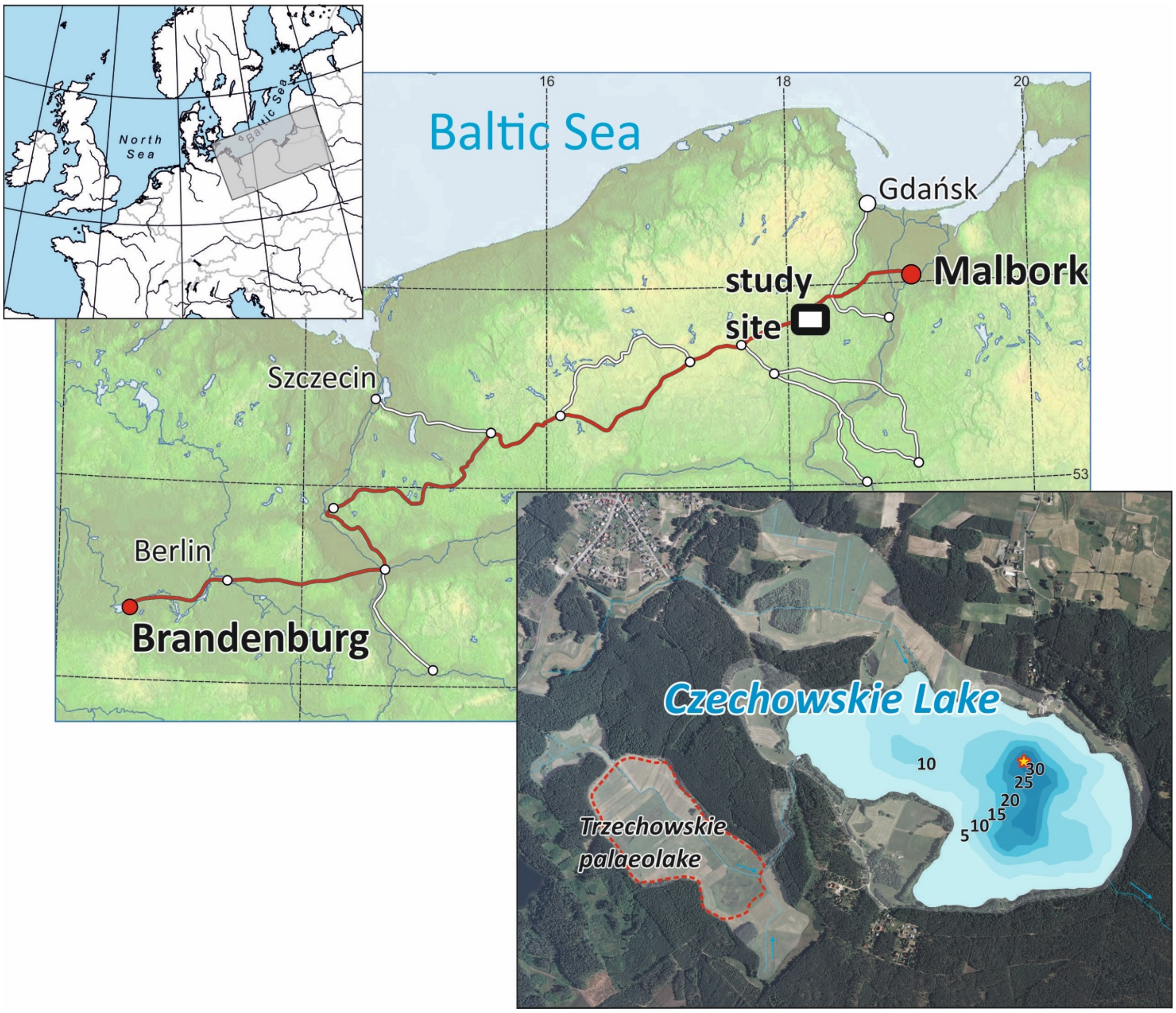


Fig. 1: *Location of the study site (Czechowskie lake) and the course of the "Via Marchionis" track by Central Europe.*

Session 4: Man - climate - environment interactions

Long-term boreal forest dynamics and disturbances: a multi-proxy approach

Stivrins, Normunds[1*]; Aakala, Tuomas[2]; Kuuluvainen, Timo[2]; Pasanen, Leena[3]; Ilvonen, Liisa[3]; Holmström, Lasse[3] & Seppä, Heikki[1]

[1] University of Helsinki, Department of Geosciences and Geography, Helsinki, Finland
[2] University of Helsinki, Department of Forest Sciences, Helsinki, Finland
[3] University of Oulu, Department of Mathematical Sciences, Oulu, Finland
* Corresponding author: normunds.stivrins@helsinki.fi

The boreal forest provides a variety of ecosystem services that are threatened under the ongoing climate change. In the past, fire has been perhaps the most important disturbance shaping the dynamics of the European boreal forest, and the predicted changes in temperature, precipitation and consequently droughts may change fire occurrence and behaviour in the future. Forest ecosystems, like climates, are not static entities, but vary in space and time. Along with the climate, there are several factors (fire, human-impact, pathogens), which influence boreal forest dynamics. Palaeoecological data, such as pollen, stomata, and macroscopic charcoal preserved in sediment layers, and tree-rings in living and dead trees, provide a uniquely rich natural long-term archive. These archives make it possible to investigate major changes in the distribution, composition, and extent of the boreal ecosystems over time, primarily in response to Holocene climate changes at millennial and centennial scales. During the late Holocene, they also make is possible to study the changes in land-use and human impact. Combination of short and long-term studies allowing complex assessment of forest response to natural abiotic and biotic stress factors. Such understanding is necessary for sustainable management of the boreal forest now and in the future. The ongoing EBOR (Ecological history and long-term dynamics of the boreal forest ecosystem) project integrates forest ecological and palaeoecological approaches to study boreal forest dynamics and disturbances.

Using pollen, non-pollen palynomorphs, micro- and macrocharcoal, tree rings and fire-scars, we analysed forest dynamics at stand-scale by sampling small forest hollows (small paludified depressions), small lake, and the surrounding forest stands in Finland and western Russia (Fig. 1). Consecutive 1 cm samples were analysed from Kämmekkä (125 cm), Naava (127 cm), Polttiais (142 cm) and Pine (380 cm) hollows, and 0.5 cm samples from lake Valkea-Kotinen (37 cm). Chronology for all sites were based on AMS dates done in Poznan, Poland. In addition, ^{210}Pb measurements were used to establish the modern age of the top of the lake sediment core. Although, two shards of microtephra were found in Pine forest hollow, which possibly could belong to Askja-1875 eruption, due to the lack of geochemical analyses and limited amount of shards, we did not include this marker-horizon in age-depth modelling. All ^{14}C dates were calibrated using the IntCal13 calibration dataset, and age-depth models created using the Clam 2.2 programme deposition model with a linear interpolation at 2 σ (95.4%) confidence level.

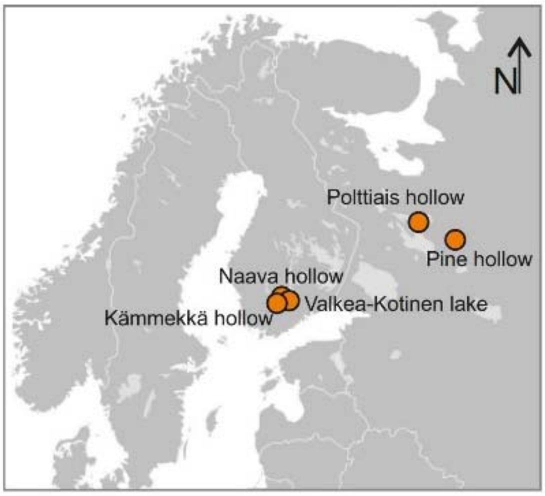


Fig. 1: *EBOR project study sites in Finland and western Russia.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Charcoal analysis of sediment sequence provides information on past fire activity but, charcoal-based fire reconstructions often lack spatial characteristic of a specific fire regime. We analysed macrocharcoal particles >150 µm that are usually not transported far from fires, and are likely suitable for reconstructing local fire events. Based on specific fire-prone fungi spore findings and tree-ring (fire-scar) data we were able to separate low- from high-intensity fire episodes. The *Neurospora* ascospores do not germinate under ordinary cultural conditions but grow readily after having been subjected to moist heat at 65–70 °C for a few minutes. Often *Neurospora* are absent in the charred layers. Meanwhile *Gelasinospora* have an excellent value as a marker of past surface fire episodes and can often be found in charcoal layers.

Using macrocharcoal data, we estimated a mean fire return interval of 450 to 840 years for the Russian and 760 years for the Finnish sites. Fungi *Neurospora* growing on charred tree bark after a low-intensity fire was identified both in Russian and Finnish sites (Fig. 2). More frequent findings of fungi *Gelasinospora* indicate that surface fires were common at the study sites. As fire events left scarred trees alive, tree fire-scar data revealed several surface fires also in the recent past, i.e. over the last 300 years.

In addition, our findings indicate a negative relationship between *Picea* and fungi *Lasiosphaeria caudata* (Fuckel) Sacc. belonging to *Hilberina*. Although this fungi tend to prefer well decayed angiosperm wood over gymnosperms, they are known also to form a host-parasite relationship between *Picea*.

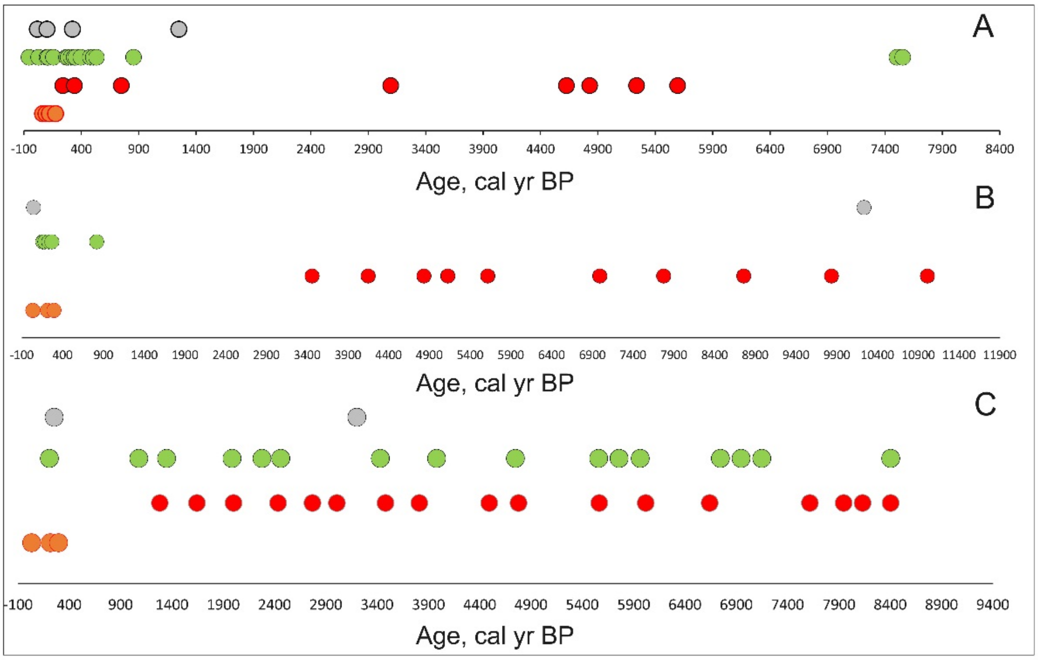


Fig. 2: *Low intensity fire events (gray circles) based on findings of Neurospora and surface fires (green circle) according to finds of Gelasinospora, fire events (red circles) based on macrocharcoal data and Char analysis and fire events (orange circles) based on tree fire-scars at (A) Naava, (B) Polttiais and (C) Pine forest hollow.*

Overall, the results of our EBOR project demonstrate how two types of fire-archive sources can be integrated to achieve better understanding of fire dynamics in the boreal forest. Based on the fungi spore findings in sediment sequences and tree fire-scar data we were able to distinguish low-(surface) and high-intensity fire events. Negative relationship between *Picea* and fungi *Lasiosphaeria caudata* possibly suggests that fungi positive and negative influences on tree species could be a significant but understudied factor shaping boreal forest over the time.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Spatial patterns of lacustrine groundwater discharge: can we predict them and do they vary in time?

Tecklenburg, Christina* & **Blume, Theresa**

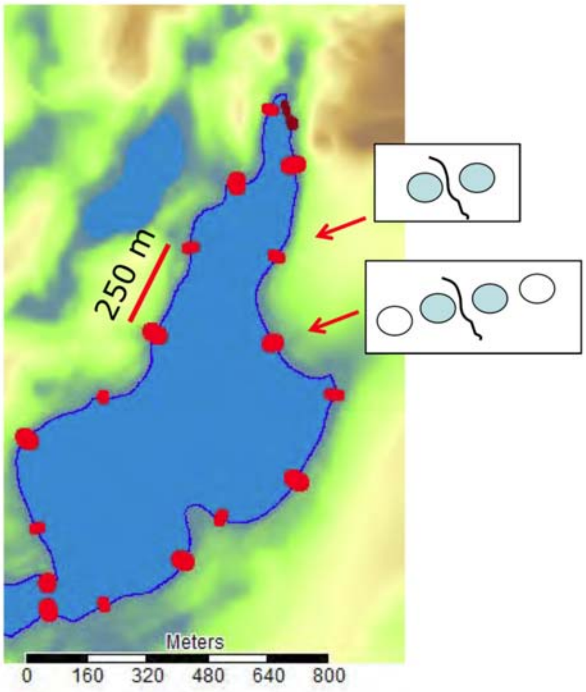
GFZ - German Research Centre for Geosciences, Section 5.4 Hydrology, Potsdam, Germany
* Corresponding author: christina.tecklenburg@gfz-potsdam.de

The vulnerability of a groundwater-lake system to changes in climate or landuse depends on various factors, such as the size of the groundwater storage, the rates of both groundwater recharge and lacustrine groundwater discharge and then also the temporal stability of the groundwater flow paths. Lake Fürstenseer See / Hinnensee, a lake that is purely groundwater fed, has shown large water table fluctuations in recent decades. These strong fluctuations are a sign of groundwater system sensitivity to changes in boundary conditions. A better understanding of the underlying controls of these observed responses might help us to estimate the potential vulnerability not only of this specific groundwater-lake system, but also in the context of regional observations of declining groundwater levels. Such an endeavour requires detailed and extensive measurements and monitoring data, not only of groundwater fluctuations, but also of lacustrine groundwater discharge, its spatial patterns, its overall amount and its temporal variability.

Lacustrine groundwater discharge (LGD) can significantly affect lake water balances and lake water quality. However, quantifying LGD and its spatial patterns is challenging because groundwater discharge locations cannot be identified as easily as surface inflows. On the one hand because groundwater discharge usually occurs not as visible springs, but as seepage below the water line, and on the other hand because of the large spatial extent of the aquifer-lake interface. As the spatial variability of LGD is usually high, it is necessary to cover this large area in sufficient detail in order to truly capture its patterns.

This is the first study to specifically study larger scale patterns of LGD with sufficient spatial resolution to systematically investigate how landscape and local characteristics affect the spatial variability of groundwater discharge into a lake. We manually measured vertical temperature profiles around the 0.49km² Lake Hinnensee in north-eastern Germany with a needle-thermistor. This method has the advantage that it allows for high spatial coverage and resolution. Groundwater inflow rates were estimated from the temperature profiles using the heat transport equation. The near-shore LGD rates were complemented with sediment temperature measurements with a fibre-optic cable installed along 6 transects across the lake bed and radon measurements of lake water samples taken just above the sediment as qualitative indicators of presence or absence of LGD in the off-shore area of the lake. In addition to the temperature based estimation of groundwater inflow rates, over 60 piezometers were installed around the lake (Fig. 1) and equipped with pressure sensors to capture the temporal dynamics of inflows at high temporal resolution. As the hydrogeology of the catchment is sufficiently homogeneous (sandy sediments of a glacial outwash plain, no bedrock control) to avoid patterns being dominated by geological discontinuities, we were able to test the common assumptions that spatial patterns of LGD are controlled by sediment characteristics, topography, and the gradients of the groundwater flow field. The high-spatial resolution data set allowed for these tests to consider both small and large scale variability in LGD. We found that large scale groundwater inflow patterns were correlated with topography and the groundwater flow field while small scale patterns correlated with grainsize distributions of the lake sediment (*Tecklenburg and Blume, HESSD 2016*). These findings confirm results and assumptions of theoretical and modelling studies more systematically than was previously possible with coarser sampling designs. However, we also found that a significant fraction of the variance in LGD could not be explained by these controls alone and that additional processes will need to be considered. While regression models using these controls as explanatory variables had limited power to predict LGD rates, the results nevertheless encourage the use of topographic indices and sediment heterogeneity as an aid for targeted future studies of groundwater inflow in lake systems.
We found that LGD was concentrated in the near shore area, but there was also a large along-shore variability, including specific regions of higher rates and higher spatial variability (Fig. 2).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037



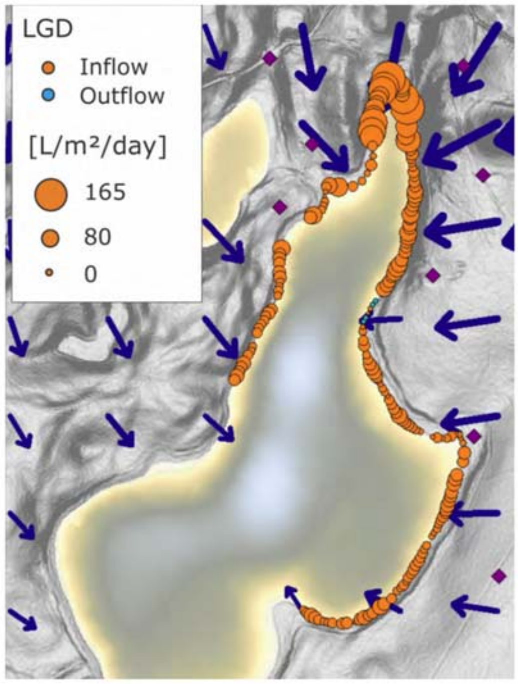


***Fig. 1:** Experimental design for piezometric monitoring network, consisting of both short and long piezometer transects. Short transects are comprised of two piezometers, one in the lake sediment and one on shore, long transects have two lake sediment and two on-shore piezometers.*

***Fig. 2:** Lacustrine groundwater discharge rates (LGD) at Lake Hinnensee. LGD rates were estimated from manually measured sediment temperature profiles. LGD rates are higher and more spatially variable in the northern section of the lake.*

Offshore LGD was generally negligible. Spatial patterns of LGD were observed to be stable on the seasonal or year-to-year scale (Fig. 3), but the response to rainfall events differed between locations. This indicates that groundwater flow paths have remained temporally stable during most of the observation period, despite declining groundwater levels. However, the monitoring period is still too short to extrapolate these findings into the future and both continued observations as well as computer simulations as presented by Wilke at al. (this issue) are necessary to get a better estimate of system vulnerability to change.

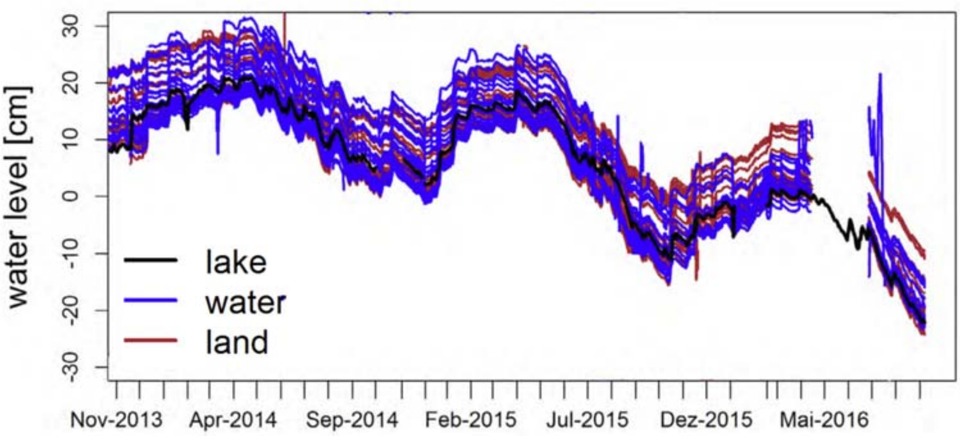


***Fig. 3:** Seasonal dynamics of water levels in the lake (black), in the piezometers installed in the lake sediment (blue) and on-shore (red). All water levels show similar dynamics at this temporal scale.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

References

Tecklenburg, C. and Blume T.: Identifying, characterizing and predicting spatial patterns of lacustrine groundwater discharge. Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-634, 2016 (in review for HESS)

Wilke H., Thoss, H., Güntner A. and Blume T.: Hydrogeology of a young moraine area in NE Germany: Subsurface structures and groundwater modeling *(this abstract volume)*

Session 4: Man - climate - environment interactions

DISQOVER the landcover - New tools in quantitative vegetation reconstruction

Theuerkauf, Martin*; Couwenberg, John & Mrotzek, Almut

University of Greifswald, Institute of Botany and Landscape Ecology, Greifswald, Germany
* Corresponding author: martin.theuerkauf@uni-greifswald.de

The landcover is a key element of the earth system. It interacts with atmosphere and climate, with soils and with the water cycle. Therefore, landcover reconstructions are essential for a better understanding of how the earth system responds to e.g. climate variations or human activity.

Pollen based reconstructions are the most powerful and widely used tool for landcover reconstructions. Although the field of palynology established already 100 years ago, landcover reconstructions until recently suffered from three major biases in pollen data: First, plant taxa produce pollen in very different amounts. Secondly, various pollen types are dispersed differently. Thirdly, a pollen sample from a lake or peatland represents the surrounding landcover in a distance weighted manner, i.e. plants growing in some distance from the site have less influence on the pollen signal than plants growing nearby.

The first widely recognised approach to reduce the bias in pollen data is the Landscape Reconstruction Algorithm (LRA). It combines the REVEALS model and the LOVE model (Sugita, 2007a, b). REVEALS is designed to translate pollen deposition from large lakes into regional vegetation composition. LOVE employs REVEALS output to translate pollen deposition from very small lakes or mires into local vegetation composition. The LRA requires extensive parameters calibration, i.e. calculation of pollen productivity estimates (PPEs) from surface pollen data.

The LRA is now increasingly applied, although several underlying assumptions and parameters have rarely been tested. To validate the approach, we tested sensitivity with respect to pollen dispersal and homogeneity of the landcover. The tests show that the underlying dispersal model is a crucial parameter in the LRA. REVEALS applications with the often applied Gaussian plume model tend to produce unrealistic results. We propose to instead apply REVEALS with a state-of-the-art Langrangian stochastic model (LSM) on pollen dispersal and deposition. To that end we implemented REVEALS in the R environment for statistical computing with various dispersal model options and the LSM as the default model (Theuerkauf et al., 2016).

Tests have furthermore shown that the REVEALS model only produces realistic results under the assumption that regional vegetation is homogenous, i.e. shows no pattern across the region. In reality, however, vegetation will often be arranged in a pattern related to e.g. the pattern of soils and relief, namely in divers

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

landscapes like that of Central Europe. REVEALS is not suited to reconstruct such regional vegetation pattern, even if applied on numerous pollen records from that region. We therefore alternatively suggest the extended downscaling approach (EDA). The EDA searches for the most probable vegetation composition within different landscape units, which are defined by e.g. the robust, present day pattern of soils and relief. To that end, the EDA employs iterative forward modelling; it fits vegetation composition to the robust landscape patterns by comparing simulated with actually observed pollen deposition. Tests using synthetic data have shown that the EDA has the potential to reconstruct fine scaled vegetation patterns with high accuracy (Theuerkauf and Couwenberg, 2016). The approach requires pollen data from a minimum of 5, ideally 20 sites. The EDA has also been implemented in the R environment for statistical computing.

LOVE as the second component of the LRA is designed to reconstruct vegetation composition on a local scale, which means within several 10^{th} of meters around a site. As such, LOVE potentially allows stand scale reconstructions of forest dynamics. However, as implemented so far also the LOVE model relies on the Gaussian plume model, which has been shown inappropriate in a number of tests. Mrotzek et al. (2016) alternatively present the Marco Polo model. In contrast to LOVE, Marco Polo relies on manipulations of the pollen sum alone is therefore not susceptible to the pitfalls of an unsuitable dispersal model. Test applications have shown similar or even better performance than LOVE (Mrotzek et al., 2016). Also Marco Polo has been implemented in the R environment for statistical computing.

All the quantitative methods discussed here rely on pollen productivity estimates (PPEs) as a key parameter. PPE calibration is a difficult and time consuming task. For Europe, PPEs have so far been estimated in 13 studies – yet the results differ substantially. The reasons for these discrepancies are still poorly understood. They may either represent true differences in pollen productivity, e.g. in response to differential climate or soil conditions. More probably the discrepancies related to unsuitable methods or data sets used in PPE calibration. Furthermore, the use of PPEs calibrated with surface samples in quantitative approaches relies on the assumption that pollen productivity of plants has not changed in the past. Instead, high resolution pollen analysis from Lake Tiefer See has shown that pollen productivity of grasses is strongly influenced by land management (Theuerkauf et al., 2015).

On the poster we present ROPES, a new method that allows to 1) apply REVEALS without a priory calibrated PPEs and 2) produces PPEs within the method. The approach is based on the fact that past vegetation change should be similarly expressed in pollen accumulation rate data (PAR) and REVEALS reconstruction. That means that for each taxon of a given pollen record, the ratio of PAR values and REVEALS reconstructed cover should be constant. We illustrate the approach using artificial and empiric pollen data from Lake Tiefer See.

The methods presented have largely been developed within the ICLEA virtual institute and on the basis of high resolution pollen data from Lake Tiefer See. All the methods are, or soon will be, publicly available in the R package DISQOVER (**http://disqover.botanik.uni-greifswald.de/**).

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA; www.iclea.de) of the Helmholtz Association (Grant Number VH-VI-415) and is supported by Helmholtz infrastructure of the Terrestrial Environmental Observatory (TERENO) North-eastern Germany.

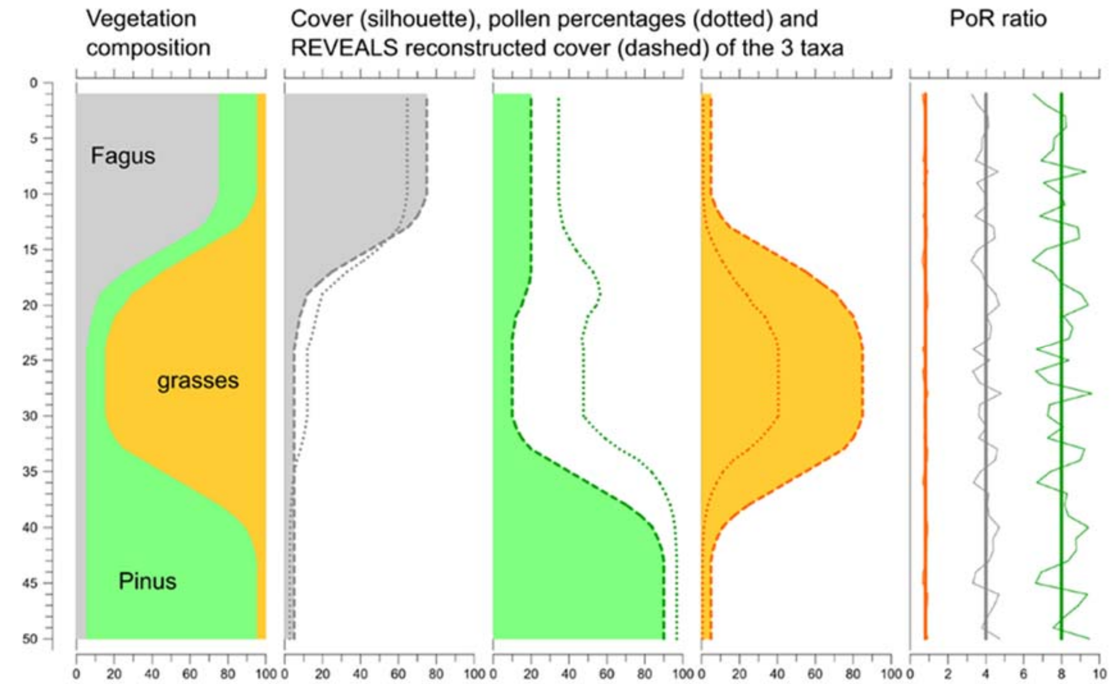


Fig. 1: *Principles of the ROPES approach. With a given vegetation composition (left), the PAR over REVEALS ratio (PoR, right) is constant along a pollen record if REVEALS is applied with PPEs that represent true pollen productivity of all taxa.*

References

Sugita, S., 2007a. Theory of quantitative reconstruction of vegetation I: Pollen from large sites REVEALS regional vegetation composition. The Holocene 2: 229–242.

Sugita, S., 2007b. Theory of quantitative reconstruction of vegetation II: All you need is LOVE. The Holocene 2: 243–258.

Theuerkauf, M., Dräger, N., Kienel, U., Kuparinen, A., Brauer, A., 2015. Effects of changes in land management practices on pollen productivity of open vegetation during the last century derived from varved lake sediments. Holocene 25:733–744 (DOI:10.1177/0959683614567881).

Theuerkauf, M., Couwenberg, J., Kuparinen, A., Liebscher, V., 2016. A matter of dispersal: REVEALSinR introduces state-of-the-art dispersal models to quantitative vegetation reconstruction. Vegetation History and Archaeobotany 25:541–553 (DOI 10.1007/s00334-016-0572-0).

Theuerkauf, M., Couwenberg, J., 2016. The extended downscaling approach: A new R-tool for pollen-based reconstruction of vegetation patterns. The Holocene OnlineFirst (DOI: 10.1177/0959683616683256).

Session 4: Man - climate - environment interactions

Holocene Lake level fluctuations in NE-Germany – disentangling climate, vegetation and human drivers

Theuerkauf, Martin[1]*; Dietze, Elisabeth[2]; Küster, Matthias[3]; Lorenz, Sebastian[4]; Schult, Manuela[3] & Blume, Theresa[5]

[1] University of Greifswald, Institute of Botany and Landscape Ecology, Greifswald, Germany
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] Müritzeum – Naturhistorische Landessammlung für Mecklenburg-Vorpommern, Waren
[4] Institute of Geography and Geology, University of Greifswald, Greifswald, Germany
[5] GFZ - German Research Centre for Geosciences, Section 5.4 Hydrology, Potsdam, Germany
* Corresponding author: martin.theuerkauf@uni-greifswald.de

Lake level fluctuations represent changes in the lake's water budget. Changes in the water budget are obviously related to climate parameters, namely precipitation and evapotranspiration. However, evapotranspiration and with that the water budget are also influenced by landcover; transpiration, for example, is higher in forests than in open arable land. Also human activity may influence a lake's water budget either directly through drainage or damming, or indirectly through changes in landcover and with that in evapotranspiration. Although lake levels may be influenced by various factors, Holocene lake level fluctuations are still often interpreted in terms of climate variations alone. Magny (2004) argues that regionally synchronous lake level fluctuations can be assumed to be climate driven.

To validate this view, we here explore the impact of climate versus other factors on Holocene lake level fluctuations in NE Germany. The key site is Lake Tiefer See (N 53.59, E 12.53), one of the rare lakes with long sequences of annually laminated Holocene sediments in northern Germany. Positioned between laminated lakes in the Eifel region and in Central Poland, the lake provides great potential to study past climate, vegetation and human land use along a climate gradient of increasing continentality.To reconstruct Holocene lake level fluctuations of Lake Tiefer See, we collected 20 cores at the lake margin and in surrounding peatlands (Fig. 1).

Analysis includes geochemical parameters as well as macrofossils and pollen. Dating is based on radiocarbon dates and on pollen stratigraphies, which were correlated to the well dated long core from the centre of the lake. Based on the analysis, past water level at each sample site and level is estimated in three categories. Results from all cores were combined to determine the most probably range of the lake level during the Holocene. The results suggest that the lake level of Tiefer See fluctuated by at least 6 m during the Holocene. The highest lake levels were found just after the onset of the Holocene and over the past 4000 years whereas the lowest lake levels prevailed from 9000 to 6000 cal. BP.

Fig. 1: *Coring sites at Lake Tiefer See.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

To explore the causes of lake level fluctuations we first compare the results with REVEALS based landcover reconstructions. The REVEALS model translates pollen deposition from large lakes into regional vegetation composition. We applied the model through the REVEALSinR function from the R package DISQOVER, with the Lagrangian stochastic model on pollen dispersal and pollen productivity estimates calibrated in the study area (Theuerkauf et al., 2016). Comparison shows that variations in the lake level curve partly correspond with changes in landcover. For example, the increase of the lake level after 4000 cal. BP corresponds with the widespread expansion of agriculture in the Bronze Age while subsequent drops in the lake level correspond to periods of reduced land use activity and increasing forest cover, e.g. during the migration period. However, other changes in the lake level do not appear to be related to changes in landcover, for example mid Holocene lake level fluctuations.

To evaluate whether landcover changes could indeed explain the observed lake level fluctuations, we tested the sensitivity of the lake level to landcover changes using hydrological modelling. In a first step, vegetation composition in the catchment area of the lake is reconstructed for selected time slices with the extended downscaling approach (EDA; Theuerkauf and Couwenberg, 2016). The EDA combines pollen data from several sites with robust landscape patterns to reconstruct vegetation composition within that landscape pattern. From that we estimated cumulative transpiration and ultimately groundwater recharge. Differences in groundwater recharge are likely to cause fluctuations in groundwater levels and consequently also in lake levels, as Lake Tiefer See is largely groundwater fed. The modelled lake level fluctuations have a similar magnitude as the reconstructed lake level fluctuations. While only rough estimates, these hydrological estimates support our hypotheses that vegetation dynamics, besides climate variations, are an important control on ground- and lake water level fluctuations. For purposes of comparison we present lake level reconstruction from further lakes in the region.

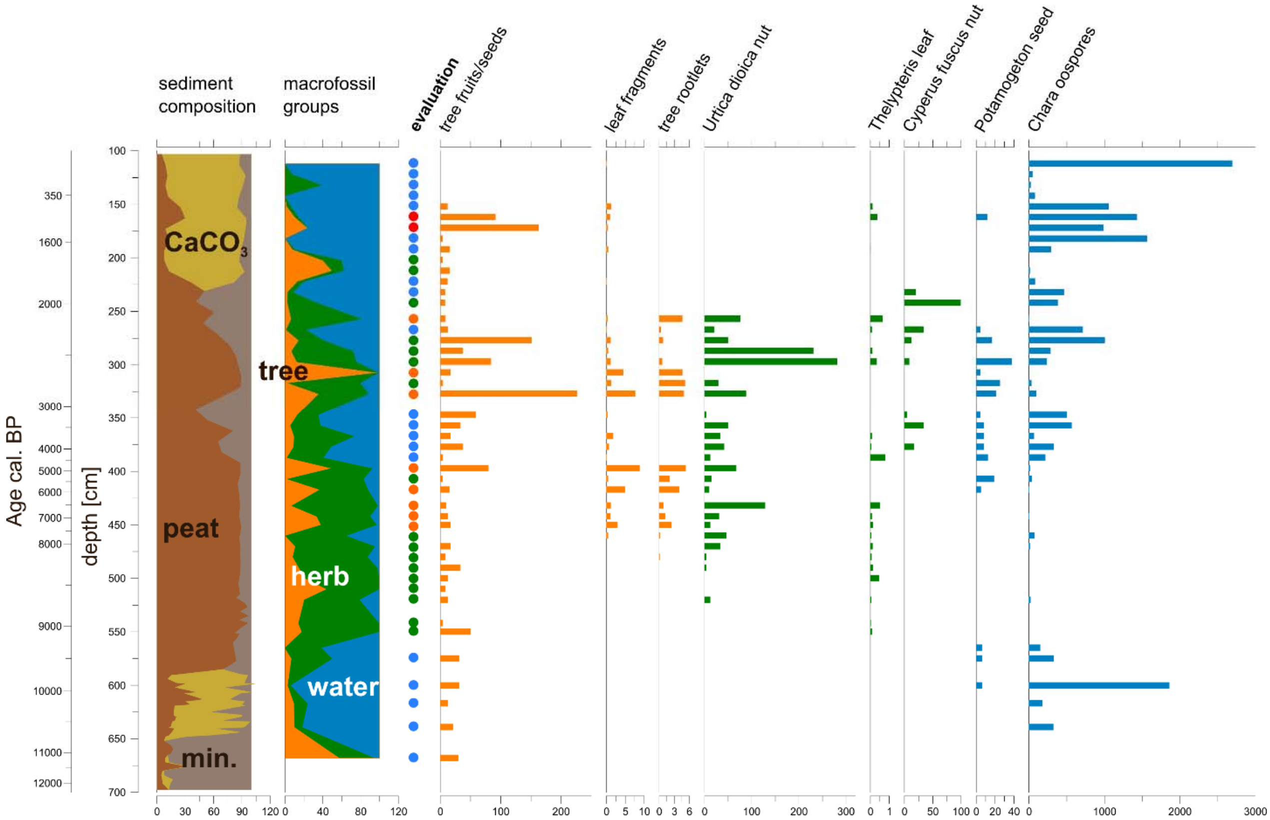


Fig. 2: *Selected results of geochemical, pollen and macrofossil analysis at core TS2 as an example of data analysis.*

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA; www.iclea.de) of the Helmholtz Association (Grant Number VH-VI-415) and is supported by Helmholtz infrastructure of the Terrestrial Environmental Observatory (TERENO) North-eastern Germany.

References

Magny, M., 2004. Holocene climate variability as reflected by mid-European lake-level fluctuations and its probable impact on prehistoric human settlements. Quaternary International 113: 65–79 (DOI:10.1016/S1040-6182(03)00080-6).

Theuerkauf, M., Couwenberg, J., Kuparinen, A., Liebscher, V., 2016. A matter of dispersal: REVEALSinR introduces state-of-the-art dispersal models to quantitative vegetation reconstruction. Vegetation History and Archaeobotany 25:541–553 (DOI 10.1007/s00334-016-0572-0).

Theuerkauf, M., Couwenberg, J., 2016. The extended downscaling approach: A new R-tool for pollen-based reconstruction of vegetation patterns. The Holocene OnlineFirst (DOI: 10.1177/0959683616683256).

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Multivariate analyses of XRF core scanning and µ-XRF data for Early Holocene environmental reconstructions of lake Meerfelder Maar

Tjallingii, Rik*; Martín-Puertas, Celia & Brauer, Achim

GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

* Corresponding author: rik.tjallingii@gfz-potsdam.de

The development of the log-ratio calibration model has provided a linear solution for calibrating X-ray fluorescence (XRF) core scanning records. This model demonstrates that log-ratios of XRF intensities are linearly related to log-ratios of geochemical element concentrations and allow quantification of relative matrix effects. Consequently, log-ratios of element intensities provide reliable records of relative changes in chemical composition. However, sediment heterogeneity and changing mineral associations often inhibits robust interpretation of individual elements in terms of climatic and environmental proxies. Log-ratio transformation of element intensities provides normally distributed data allowing for meaningful application of multivariate statistical analyses. Contrary to the common use of single geochemical elements or element ratios, multivariate statistical analyses contemplates the simultaneous variation of all elements measured.

In combination with the well-constrained age of varved records and detailed micro-facies analyses, the use of multivariate analyses of XRF core scanning data has great potential for reconstructing climatic- and local environmental changes. Multivariate statistical results of annually laminated lake sediments allow in-depth interpretation on depositional changes. The sediment record of lake Meerfelder Maar (Germany) presented here covers the early-Holocene period when vegetation strongly changes in the lake's catchment. The Meerfelder Maar record reveals a mixture of both climate forced and lake internal variations during this period. The multivariate statistical results allow linking depositional processes with geochemical elements and reveal additional compositional variations in the first millennium after the Younger Dryas-Holocene transition. These variations are not apparent form single geochemical elements or element ratios and seem to be related to the division between seasonal sub-layers of the varves. However, there is no clear link between these variations and short-term climatic oscillations described in the North Atlantic region like the Preboreal Oscillation.

In addition to multivariate analyses applied on ITRAX (200 µm) core scanning results, we present the outcome similar multivariate analyses obtained from sediment bocks measured by the EAGLE micro-XRF (50 µm). These results are used to investigate the effects of different sample resolutions on the out come of these statistical analyses. The higher resolution of the EAGLE micro-XRF ensures measuring of single varves or sub-layers, whereas the measurements acquired by the ITRAX core scanner can include overlapping of varves and sub-layers. Such a comparison helps to reveal potential mixing effects that can arise form variations in varve thickness, which is common in the varved sediments of Meerfelder Maar.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

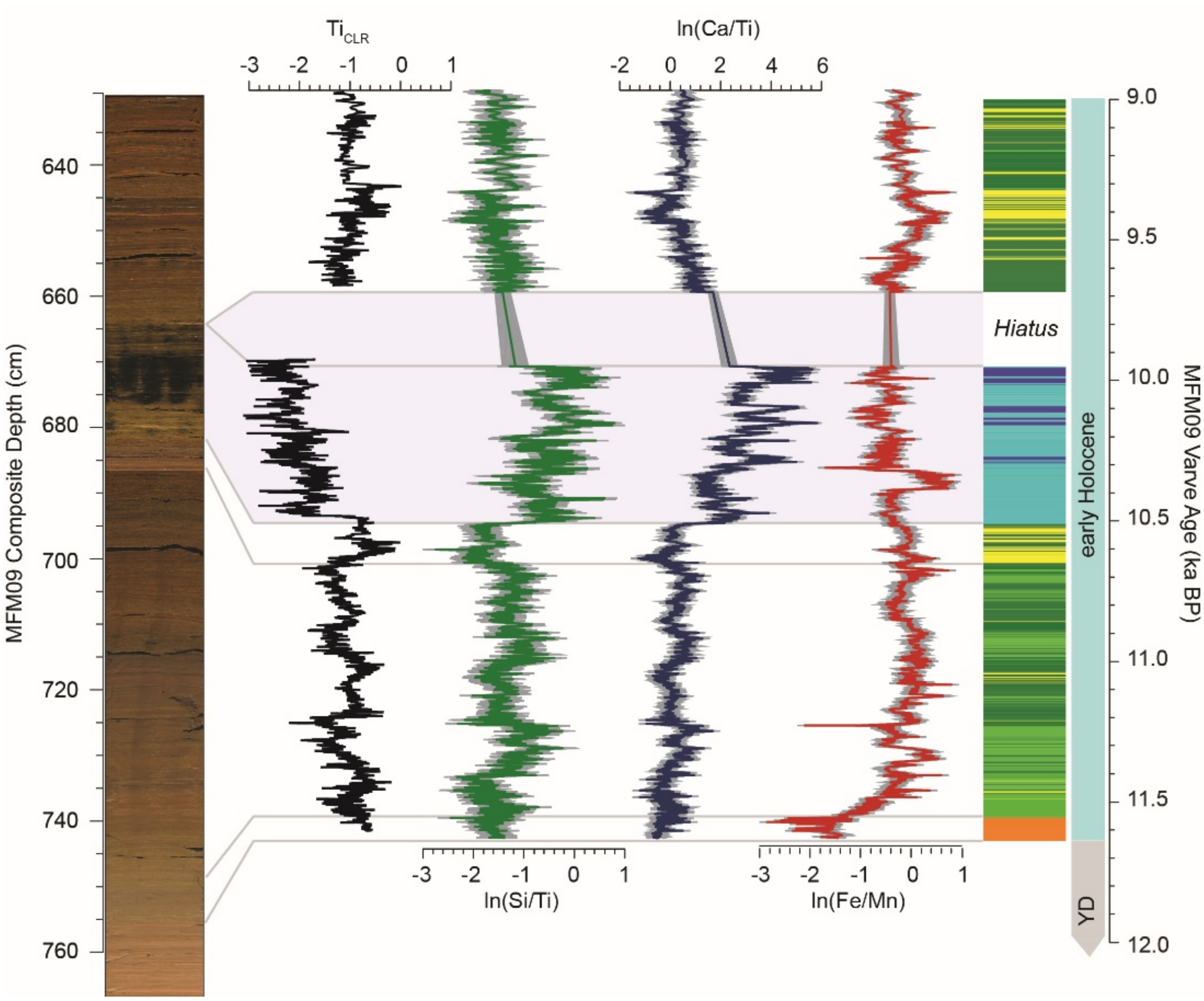


***Fig. 1:** Early Holocene sediments and XRF core scanning records of Lake Meerfelder Maar. Element-ratios include analytical confidence (95%) and were selected after biplot correlation. XRF-element records reveal detailed information about main sedimentological variations. Multivariate characterization using clustering provides additional information on compositional changes, which are not obvious from conventional element records.*

Session 3: Integrating time-scales and regional synchronization

Combining limnology and paleolimnology to track the variability of modern and past sediment fluxes: A perspective from varved lakes in northeastern Poland

Tylmann, Wojciech*

University of Gdansk, Faculty of Oceanography and Geography, Environmental Change Reconstruction Laboratory, Gdansk, Poland

* Corresponding author: wojciech.tylmann@ug.edu.pl

The study of varved sediments is progressing quickly towards analyses at annual and seasonal resolution. This progress is supported by dynamic development of non-destructive scanning techniques, such as element count-rates analyzed by micro-XRF scanning (Croudace and Rothwell, 2015) or hyperspectral imaging used to identify organic components and minerals on the basis of their diagnostic light absorption (Butz et al., 2015). Ultra-high resolution scanning techniques are able to provide up to several dozens of analytical data points within one varve. However, reconstruction of paleoclimatic and paleoenvironmental information from such high-resolution data series demands a thorough knowledge of the processes affecting the sediment archive from which this information is extracted. Moreover, atmosphere-catchment-lake relationships and related processes are individual for every lake, therefore also the sedimentary effect is likely individual for every site. Therefore, of crucial importance is the understanding of sediment-formation processes which may only be achieved by integrated process studies. Data derived in this way provide an opportunity to improve substantially the interpretation of proxy data. However, observational data sets that could explain the specific processes leading to sediment formation and environmental signal preservation of sufficient temporal resolution are still scarce.

Modern lake research, particularly when dealing with seasonally to annually resolved varved sediments, combines limnological monitoring, sediment trapping and analysis of recent sediments. This approach can be successfully applied to recognize the mechanism of biogenic varves formation which is usually very complex and includes interactions of physical, chemical and biological processes (e.g. Bonk et al., 2015). With numerous lakes where biogenic varves were identified (Tylmann et al., 2013), northeastern Poland is ideal for investigating these processes. As a case study, we present results from Lake Żabińskie located in the Masurian Lakeland with the aim to understand the mechanisms behind seasonal variability of sediment fluxes. A five-year long observation was conducted covering limnological conditions within the water column (water temperature, oxygen concentrations and chlorophyll-a concentrations) as well as sediment fluxes. Sediment samples collected in different seasons were also analyzed for their elemental composition including contents of total organic carbon (TOC), total inorganic carbon (TIC), total nitrogen (TN) and total sulphur (TS). The results show that different mixing patterns (dimictic to meromictic) may occur in Lake Żabińskie, depending on the meteorological conditions during individual years. The measurement data indicates that the length and intensity of spring and fall mixing of the water column may have significant implications for photosynthetic primary production and sedimentation processes. The sediment fluxes varied substantially during the observation period and were largely dependent on the water column mixing. Most characteristic spring (April-June) maxima appear every year. Spring deposition is related to intense calcite precipitation and can constitute >50% of the total annual flux. Depending on meteorological conditions during late fall (November-December), a second maxima in the sediment flux may also occur when fall overturn is completed. Considerable variability was also observed for the elemental fluxes of TOC, TN and TS. The effects of these complex relationships between water column dynamics, in-lake production and sedimentation can be recognized in different structures of varves deposited on the lake bottom. Despite different seasonal variability, total annual sediment fluxes (mass accumulation rates) in different years were comparable. Also comparison of sediment fluxes registered in the sediment trap with mass accumulation rates estimated from the sediment core shows good agreement.

The results from Lake Żabińskie laid the foundations for a new project aiming at further investigations of climate signal preservation in biogenic varves in northern Poland. We selected three lakes (Lake Żabińskie,

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Lake Łazduny and Lake Rzęśniki) of highest potential for process studies. The lakes are located in the central part of the Masurian Lakeland, therefore overall climatic conditions are the same. They are small, relatively deep and in all of them biogenic varves are excellently preserved. However, they are different in terms of trophic status, catchment size and catchment land-use. This project creates a unique opportunity to conduct 4-year long and high-resolution monitoring of different elements of the lake systems. It will provide a comprehensive dataset not only explaining relationships between meteorological conditions and biogenic varve formation in the investigated lakes, but also demonstrating possibilities and limitations of tracking short-term weather-scale atmospheric phenomena in lake sediments. Additionally, comparison with similar studies which are currently ongoing in north-central Poland (ICLEA sites – Lake Czechowskie, Lake Jelonek and Lake Głębokie), can help in disentangling the role of local and regional conditions in sedimentation processes.

References

Bonk A., Tylmann W., Amann B., Enters D., Grosjean M., 2015. Modern limnology and varve-formation processes in Lake Żabińskie, northeastern Poland: comprehensive process studies as a key to understand the sediment record, Journal of Limnology 74(2): 358-370.

Butz C., Grosjean M., Fischer D., Wunderle S., Tylmann W., Rein B., 2015. Hyperspectral imaging spectroscopy: a promising method for the biogeochemical analysis of lake sediments, Journal of Applied Remote Sensing 9: 096031-1-20.

Croudace I. W. and Rothwell R. G., 2015. Micro-XRF Studies of Sediment Cores. Applications of a Non-destructive Tool for the Environmental Studies, Developments in Paleoenvironmental Research 17, Springer-Verlag: 656 pp.

Tylmann W., Zolitschka B., Enters D., Ohlendorf C., 2013. Laminated lake sediments in northeast Poland: distribution, preconditions for formation and potential for paleoenvironmental investigation, Journal of Paleolimnology, 50: 487-503.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Session 4: Man - environment - climate interactions

800 years of forest transformation in northern Poland recorded in varved lake sediments and cartographical data

Tyszkowski, Sebastian[1]*; Słowiński, Michał[2]; Obremska, Milena[3]; Theuerkauf, Martin[4]; Ott, Florian[5,6]; Dietze, Elisabeth[5]; Kaczmarek, Halina[1] & Brauer, Achim[5]

[1] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Toruń, Poland
[2] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography and Spatial Organization, Warszawa, Poland
[3] Polish Academy of Sciences, Research Centre in Warsaw, Institute of Geological Sciences, Warsaw, Poland
[4] University Greifswald, Institute for Geography and Geology, Greifswald, Germany,
[5] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[6] Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany
* Corresponding author: sebtys@wp.pl

Today, Northern Poland and in particular the Tuchola Pinewoods is an area of high afforestation, but an increasing number of reports show that the structure and type of vegetation has been strongly transformed in the past with consequences for the ecosystems (Berglund and Miotk-Szpiganowicz, 1992; Lamentowicz et al., 2008; Milecka and Szeroczyńska, 2005).

The aim of the study was to reconstruct human impact on landscape development in the Tuchola Pinewoods (Northern Poland) during the last 800 years. We applied an approach that combined historical maps and documents with pollen data from varve-dated lake sediments.

The analysis of geographical environment changes involved an application of various maps, including: map of Ślaski (including changes in afforestation from Middle Ages), maps of F.L. Schrötter (1796–1802) in a scale of 1: 50000, Topographische Karte (Meßtischblatt) maps from end of XIX century, in scale of 1:25000 and contemporary topographic maps 1: 50000 and aerial photographs.

Pollen data were obtained from Lake Czechowskie varved lake sediments at a resolution of 5 varves (= years). The chronology of the sediment record was based on varve counting, AMS 14C dating, 137Cs activity concentration measurements and tephrochronology (presence of Askja AD 1875). We applied the REVEALS model to translate pollen percentage data into regional plant abundances. The interpretation of the pollen record was further based on pollen accumulation rate data. The pollen record and historic documents showed similar trends in vegetation development. From AD 1200 to AD 1412 the Lake Czechowskie area was largely forested with Quercus, Carpinus and Pinus forests. Vegetation became more open between AD 1412 and 1776 and reached a maximum openness from AD 1776 to 1905. Furthermore, intensified forest management led to the transformation from mixed to pine dominated forests. Since the early 20th century the forest cover increased again with a dominance of the Scots pine. While pollen and historic data show similar trends, they differ substantially in the degree of openness during the four phases (Fig. 1). Pollen data commonly suggest more open conditions. We discuss potential causes for this discrepancy including unsuitable parameters settings in REVEALS and unknown changes in the forest structure. Using pollen accumulation data as proxy we aim to identify the most probable causes for the apparent difference. Finally, we discuss the observed vegetation change in relation to the socio-economic development of the area.

The high time resolution of five years combined with precise age determination allowed for detailed reconstruction of human activity in the Tuchola Pinewoods over the last 800 years. The results of paleoecological analysis combined with archival cartographic materials and documents give a unique insight into the human development in the Tuchola Pinewoods and its impact on the landscape, and the ecosystem of Lake Czechowskie.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

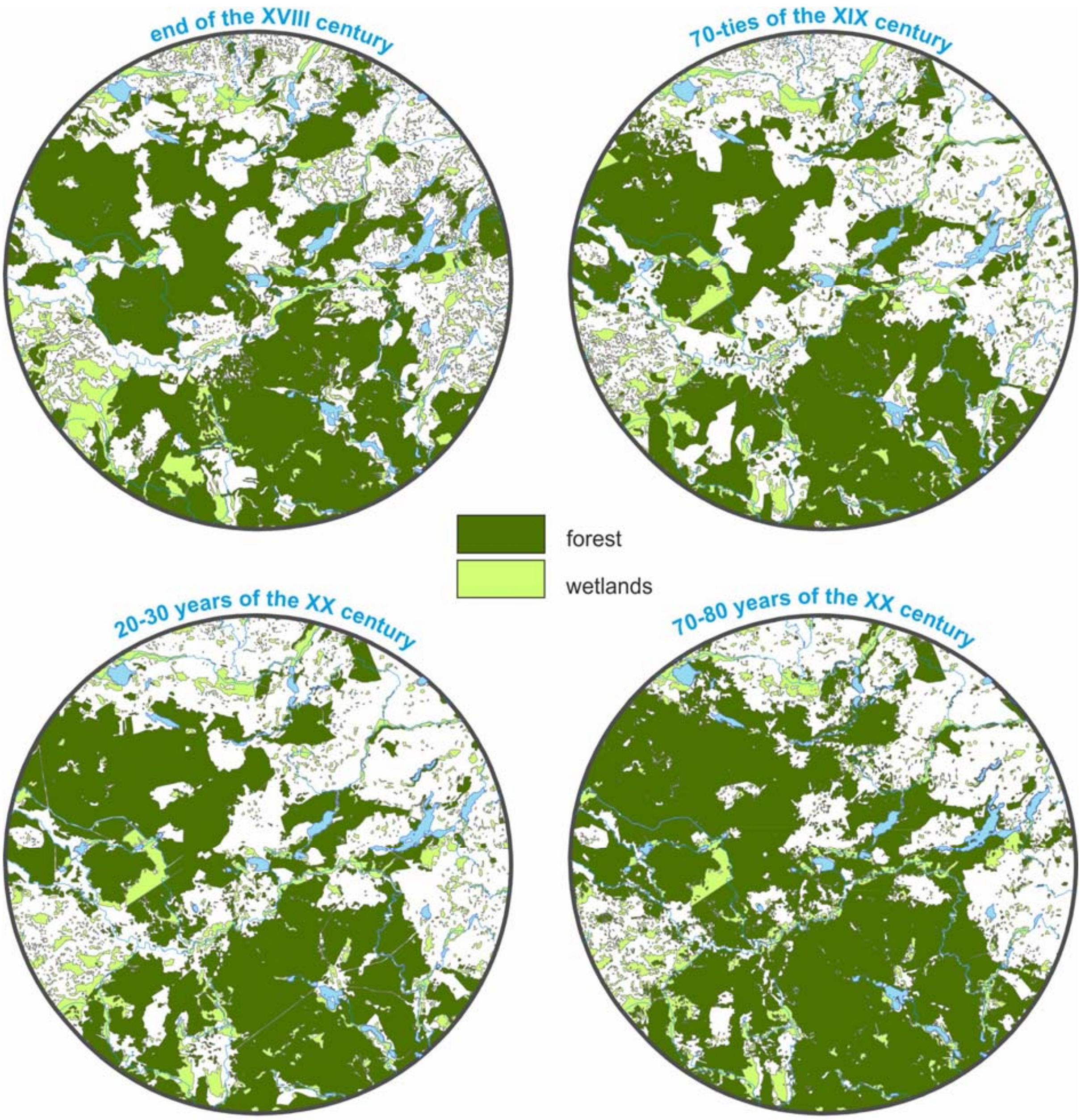


Fig. 1: *Forests and wetlands around Czechowskie lake (15 km from lake).*

References

Berglund, B. E. and G. Miotk-Szpiganowicz, 1992. Human impact on the vegetation of Bory Tucholskie on the basis of palynological investigations. Folia Archaeologica 16(258-264).

Lamentowicz, M., M. Obremska and E. Mitchell, 2008. Autogenic succession, land-use change, and climatic influences on the Holocene development of a kettle-hole mire in Northern Poland. Review of Palaeobotany and Palynology 151(1-2): 21-40.

Lamentowicz, M., M. Obremska and E. A. D. Mitchell, 2008. Autogenic succession, land-use change, and climatic influences on the Holocene development of a kettle-hole mire in Northern Poland. Review of Palaeobotany and Palynology 151(1-2): 21-40.

Milecka, K. and K. Szeroczyńska, 2005. Changes in macrophytic flora and planktonic organisms in Lake Ostrowite, Poland, as a response to climatic and trophic fluctuations. The Holocene 15(1): 74-84.

Session 1: Abrupt and High Frequency Climate Variability since the Late Glacial

Visual Analytics for microfacies data from lake sediment cores

Unger, Andrea[1]*; Dräger, Nadine[2]; Ott ,Florian[2,3]; Sips, Mike[1] & Lehmann, Dirk J.[4,5]

[1] GFZ - German Research Centre for Geosciences, Section 1.5 Geoinformatics, Potsdam, Germany

[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany

[3] Max Planck Institute for Human History, Jena, Germany

[4] Otto-von-Guericke University, Magdeburg Germany

[5] University Rey Juan Carlos, Madrid, Spain

* Corresponding author: andrea.unger@gfz-potsdam.de

Annually laminated lake sediments reveal unprecedented details of past climate and environmental characteristics (Brauer et al., 2008; Martín-Puertas et al., 2012). Microscopy of the annual layers (microfacies analysis) is one approach to extract this information (Brauer et al., 2009). To fully understand the rich information provided by microfacies data, suitable analysis methods are required. So far, the analysis of microfacies data relied on a set of standard methods. They support two main analysis approaches: First, The annual sequences of layers (varves) are inspected step-wise over limited time frames. This is time consuming and highly demanding for the analyst. Understanding the temporal development of varves over thousands of years becomes very challenging if the microfacies data comprises a high number of different layer sequences. The second approach is to inspect temporal developments of derived variables at annual resolution. Examples for variables derived from varves are the number of layers, the thickness of layers, or the appearance of specific layers during the years. Investigating derive data requires tedious data processing and comes with the drawback that conclusions are drawn from abstract and possibly oversimplified data.

We introduce a novel analytical method that considers the annual layer sequences over the complete time span. Specifically, our goal is to support the generation of hypotheses from microfacies data addressing two questions: (A) Which climate and environmental conditions appeared in the past and what was the response of the landscape? (B) What was the temporal extent of climate and environmental conditions and when did transitions happen? To our knowledge, our method is the first to systematically support this goal. It is based on the visual analytics methodology. It combines automated data analysis with visualization, which enables human assessment during analysis, and interaction, which enables users to steer the analysis process according their demands. In our method, the central instruments for hypotheses generation are the construction and exploration of groups of varves. Each group subsumes varves that indicate similar climate and environmental conditions. Grouping varves supports the generation of hypotheses as follows: (A) Climate and environmental conditions as well as the landscape responses are indicated by the layer sequences that appear in grouped varves. (B) The temporal extent of conditions as well as transition points become apparent from the temporal distribution of groups.

As an initial step, our tool provides an overview of the microfacies data (Fig. 1). The left view shows the layer sequences in each year over the complete time span, possibly comprising thousands of years. To reveal the variability of lake responses in the microfacies data, the visualization on the right shows the automatically extracted set of unique layer sequences that appear over time. The interactive linking of both views supports the exploration which varves exhibit the same layer sequences.

Using the overview as the basis, the main step is to generate groups of varves that indicate similar conditions. To this end, our visual interface offers convenient means to generate, adapt, and store groups of varves. We make use of the basic assumption that identical layer sequences in different years indicate the same climate and environmental conditions: Adding a layer sequence to a group automatically comprises all years with that same layer sequence. We know about microfacies data that similar conditions may also lead to different layer sequences. We therefore support the task to identify which varves indicate similar conditions even though the layer sequences differ. Two important aspects need to be concurrently considered in this regard: First, the indicative meaning of different varves is assessed based on domain knowledge and compared.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Second, it is inspected whether varves appear in the same temporal context. Note that relevant time spans are not known a-priori and are therefore subject to human assessment. Our visual interface (Fig. 2 and 3) supports the concurrent assessment of both aspects by composing views for the inspection and comparison of layer sequences and views for the temporal distribution of varves. In addition, our method specifically addresses the challenge to build groups from microfacies data with highly diverse varves. Our tool automatically recommends varves that potentially indicate similar conditions based on a computational measure that quantifies the similarity of layer sequences.

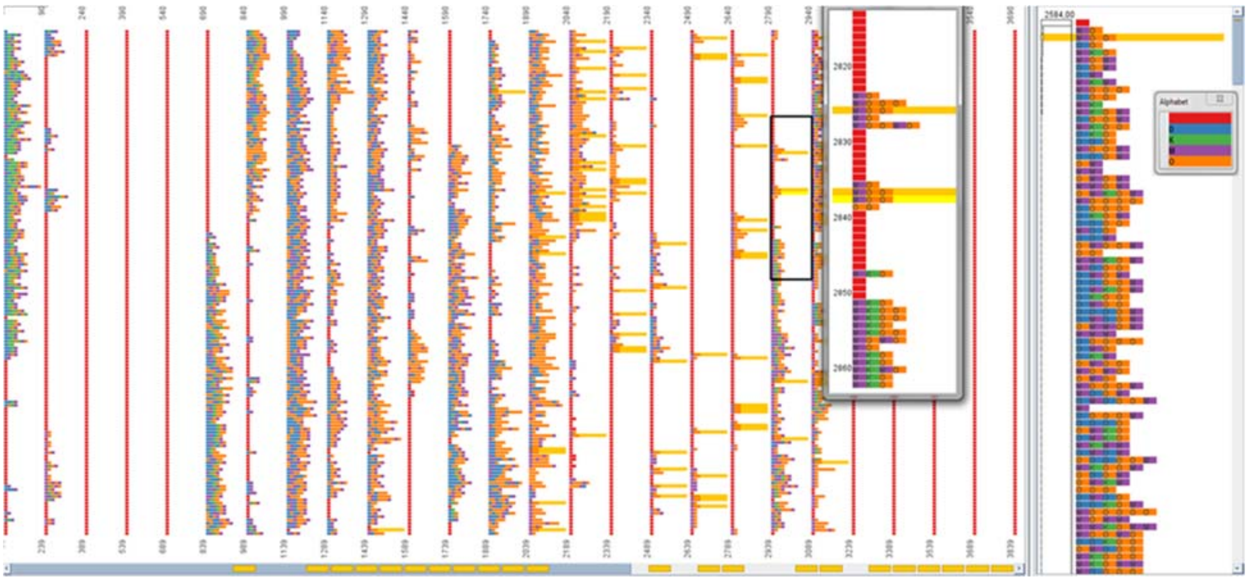


***Fig. 1:** Overview of microfacies data from Tiefer See (Dräger et al., 2017). Left: Visualization of annual layer sequences over thousands of years. The overall time sequence is split into multiple columns aligned side by side. Each column shows a time interval of years from top to bottom. A row in a column depicts the corresponding annual layer sequence by colored blocks. A selected time interval (black border) can be magnified on demand (on top of the view) Right: Visualization of the set of unique layer sequences as a list, sorted by decreasing frequency from top to bottom. Each row shows on unique layer sequence.*

We have used our tool to investigate microfacies data from Tiefer See (Dräger et al., 2017) (Fig. 1 and 2) and Lake Czechowskie (Ott et al., 2015) (Fig. 3). For both lakes, time periods of similar climate and environmental conditions known from other studies could be confirmed with noticeably little analytical effort. Further, novel hypotheses were generated. With regard to Tiefer See, the two time periods 6,000 to 5,000 and 2,000 to 1,000 cal. a B.P. were found to comprise similar varves (light red group in Fig. 2), even though different behaviors were expected in these time spans. Concerning Lake Czechowskie, the temporal distributions of groups pointed to novel transition points and periods, which we depict in Fig. 3.

Our tool fills an important methodological gap in the analysis of microfacies data. It enables investigations that were not carried out before due to high analytical efforts. Our initial use cases have shown that our prototype effectively facilitates the generation of hypotheses about climate and environmental conditions and their temporal extent in the past.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association.

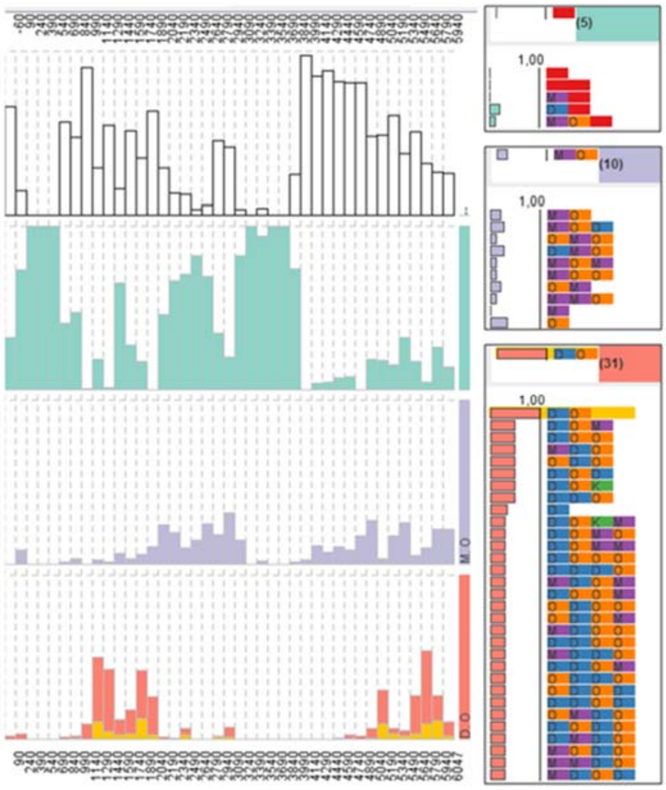


Fig. 2: *Visual exploration of groups of similar varves at Tiefer See (Dräger et al., 2017). Three groups have been generated (in turquoise, purple, and light red). The left view shows a histogram over time for each group (white histograms shows ungrouped varves). The right view shows the distinct annual layer sequences that are subsumed in the groups.*

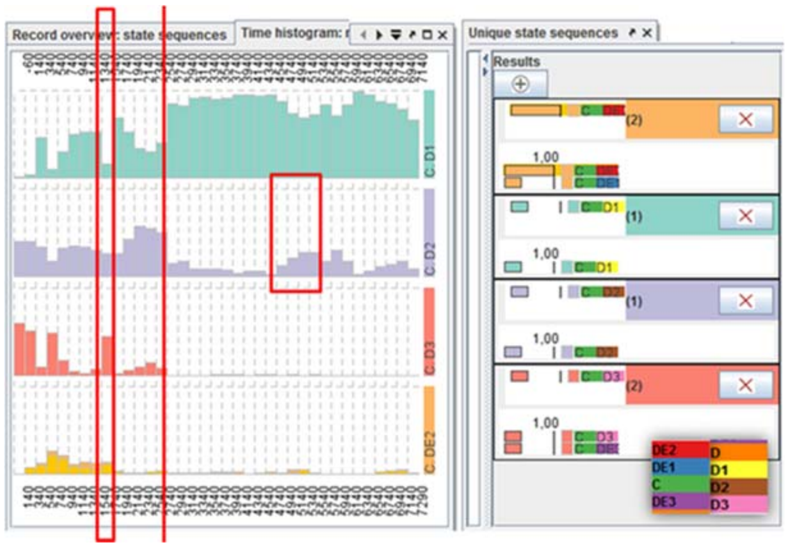


Fig. 3: *Visual exploration of groups of similar varves at Lake Czechowskie (Ott et al., 2015).*

The groups' temporal distributions are shown in separate time histograms. The red lines markers highlight interesting findings: An abrupt change around 1,500 cal. a B.P., a transition point at 2,000 cal. a B.P, and gradual changes in the time period 4,700 to 5,300 cal. a B.P.

References

Brauer, A.; Mangili, C.; Moscariello, A. & Witt, A., 2008. Palaeoclimatic implications from micro-facies data of a 5900 varve time series from the Piànico interglacial sediment record, southern Alps. Palaeogeography, Palaeoclimatology, Palaeoecology, 259, 121-135.

Martín-Puertas, C.; Matthes, K.; Brauer, A.; Muscheler, R.; Hansen, F.; Petrick, C.; Aldahan, A.; Possnert, G. & van Geel, B., 2012. Regional atmospheric circulation shifts induced by a grand solar minimum. Nature Geoscience, 5, 397-401.

Brauer, A.; Dulski, P.; Mangili, C.; Mingram, J. & Liu, J., 2009. The potential of varves in high-resolution paleolimnological studies. PAGES news, 17, 96-98.

Dräger, N.; Theuerkauf, M.; Szeroczynska, K.; Wulf, S.; Tjallingii, R.; Plessen, B.; Kienel, U. & Brauer, A., 2017. Varve microfacies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer See (NE Germany). The Holocene, 27, 450-464.

Ott, F.; Brauer, A.; Słowiński, M.; Wulf, S.; Putyrskaya, V.; Plessen, B.; Błaszkiewicz, M., 2015. Varved sediments from Lake Czechowskie (Poland) reveal gradual increase in Atlantic influence during the Holocene. Geophysical Research Abstracts, 17, EGU201.

DOI: 10.2312/GFZb103-17037

Session 2: Recent change and instrumental observations

Hydrogeology of a young moraine area in NE Germany: Subsurface structures and groundwater modeling

Wilke, Henriette*; Thoss, Heiko; Güntner, Andreas & **Blume, Theresa**

GFZ - German Research Centre for Geosciences, Section 5.4 Hydrology, Potsdam, Germany
* Corresponding author: wilke@gfz-potsdam.de

The vulnerability of a groundwater system to changes in climate or landuse depends on various factors, such as the size of the groundwater storage, the rate of groundwater recharge and the temporal stability of the groundwater flow paths. Lake Fürstenseer See, a lake that is purely groundwater fed, has shown large water table fluctuations in recent decades. These strong fluctuations are a sign of groundwater system sensitivity to changes in boundary conditions and therefore a better understanding of the underlying controls might help us to estimate the potential vulnerability not only of this specific groundwater-lake system, but also in the context of regional observations of declining groundwater levels. Such an endeavor requires detailed and extensive measurements and monitoring data on the one hand and a physically based model as a tool for data synthesis and hypothesis testing on the other hand.

The focus area of this study is the region of Lake Fürstenseer See, which is located in a young moraine area in the terminal moraine and outwash plain area of the last glacial maximum (Pomeranian) in Mecklenburg-Vorpommern, north-eastern Germany. A number of glacial channel valleys from the Weichselian cross the area in a mainly NNE – SSW direction (Börner, 2015).

Investigating groundwater-relevant subsurface structures and properties of young moraine areas is a challenging task due to the heterogeneity of the subsurface combined with limited possibilities of outcrop characterization. To overcome this challenge we implemented a multi-method approach that merges a variety of geophysical, hydrochemical and hydrogeological monitoring data with a model of groundwater dynamics.

Currently, no detailed knowledge about subsurface structures and groundwater dynamics is available for the lake Fürstenseer See region. However, as we are looking at a purely groundwater controlled lake system (no natural surface inflows or outflows), this information is essential for a better understanding of the lake water table dynamics and the related processes. The establishment of 17 observation wells, a groundwater level monitoring system and the investigation of subsurface characteristics with standard methods such as grain size analyses, permeameter tests and porosity measurements on disturbed and undisturbed samples supplied important first insights. They showed characteristics typical for outwash plains consisting of mainly medium sands with porosities with a mean value of 32.6 % and hydraulic conductivities mainly in the range of $1*10^{-4}$ m/s for the vertical as well as horizontal direction. In order to obtain more detailed information on the subsurface structures and characteristics, geophysical methods were used. Electric resistivity tomography (ERT) surveys along different transects of up to 1400 m length (Fig. 1) were carried out to detect the boundary between aquifer and aquiclude as well as the lateral extent of the glacial channel valleys. . From analyses of the stable isotopes oxygen-18 and deuterium and the radioactive radon as well as from physico-chemical parameters, spatial patterns of different groundwater regions can be determined. These regions may indicate areas of different groundwater origin and residence time, which amongst others are determined by subsurface properties, structures and boundaries. The stable isotope data, for instance, showed evaporation influences in the groundwater of four of the 17 observation wells. This might be an indicator that the groundwater at these locations still shows the influence of lake-water seepage from the nearby lakes (Fig. 2), as lakes usually show a much stronger evaporation signal than groundwater. The electrical conductivity of the groundwater varies considerably around Lake Hinnensee, which also suggests different water origins or flow paths. Very low values can point at higher diffuse recharge. The groundwater level observations show highest water levels in April and May and lowest in October and November. The

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

spatial variability of these dynamics can also be used as an indicator for spatial structural and compositional differences in the subsurface. In general, the hydrographs of the seventeen observation wells are relatively similar in their seasonal dynamics. However, they show slightly different trends, which again indicates different residence times and flow paths.

The structural information gained from field campaigns and lab analyses, such as hydraulic conductivities or the base of the aquifer were then used to set up a groundwater flow model with the software Visual MODFLOW Pro. While groundwater dynamics can be evaluated directly by comparison with the observed dynamics at the observation wells, groundwater flow paths are evaluated based on hydrochemical data from the observation wells with their observed spatial patterns. First results show a relatively good agreement between model results and measured data. However, one needs to take into account that measured hydrochemical and geophysical data provide a much more detailed picture of subsurface properties than is possible to realize in a groundwater model, where complexity needs to be reduced to the dominant features.

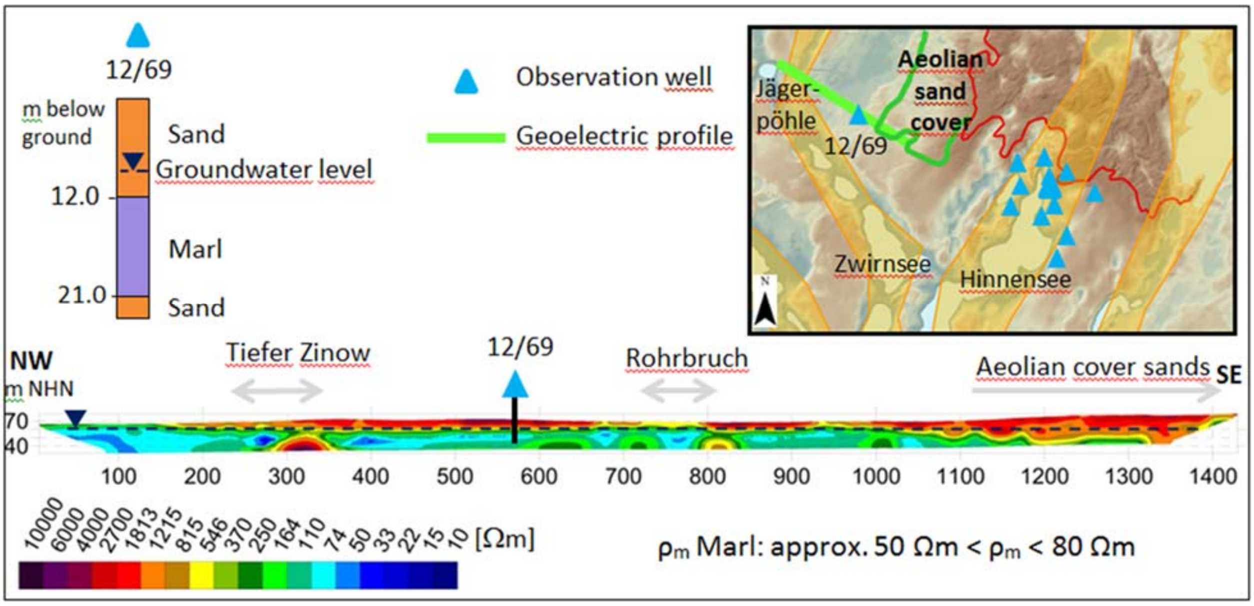


Fig. 1: *Geoelectrical profile NW of Lake Hinnensee.*

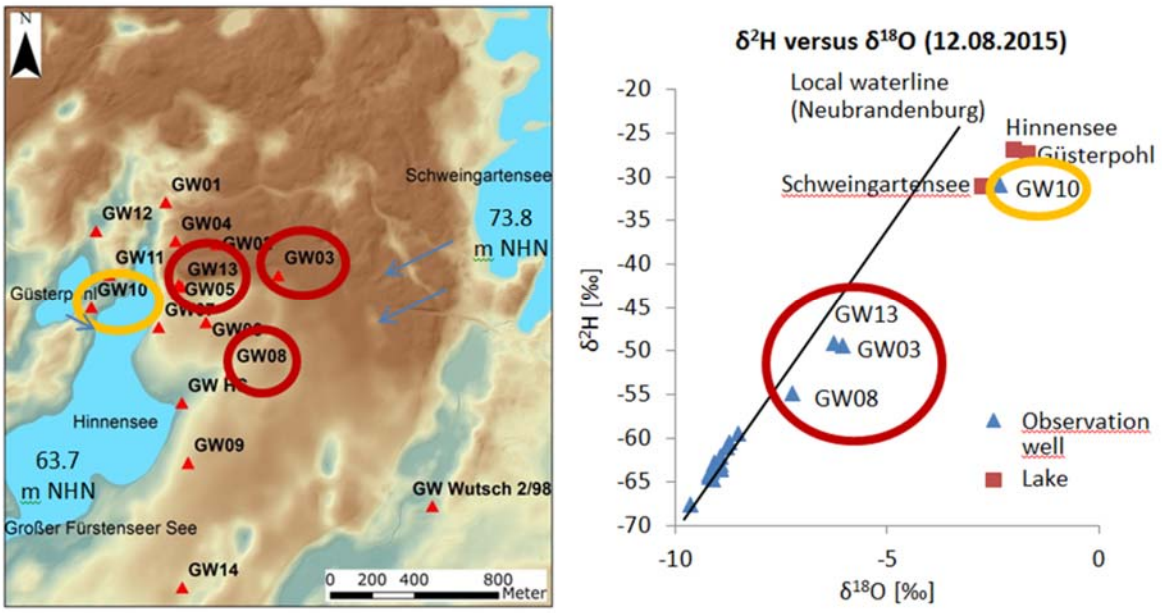


Fig. 2: *Lakewater influence in groundwater observation wells.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution –ICLEA– of the Helmholtz Association supported by TERENO infrastructure of the Helmholtz Association.

References

Börner, A., 2015. Geologische Entwicklung des Gebietes um den Großen Fürstenseer See. – In: Kaiser, K., Kobel, J., Küster, M., Schwabe, M. (ed.): Neue Beiträge zum Naturraum und zur Landschaftsgeschichte im Teilgebiet Serrahn des Müritz-Nationalparks (Mecklenburg). Forschung und Monitoring, 4; Berlin (Geozon Science Media). in print

Session 3: Integrating time-scales and regional synchronization

Tephrostratigraphies of ICLEA varved lake records from NE Germany and N central Poland: an overview

Wulf, Sabine[1,2,3]*****; Dräger, Nadine[2]; Ott, Florian[2,4]; Serb, Johanna[2]; Appelt, Oona[5]; Słowiński, Michał[6]; Błaszkiewicz, Mirosław[6]; Schwab, Markus[2] & Brauer, Achim[2]

[1] GFZ - German Research Centre for Geosciences, Section 5.1 Geomorphology, Potsdam, Germany
[2] GFZ - German Research Centre for Geosciences, Section 5.2 Climate Dynamics and Landscape Evolution, Potsdam, Germany
[3] Heidelberg University, Institute of Earth Sciences, Germany
[4] Max Planck Institute for the Science of Human History, Department of Archaeology, Jena
[5] GFZ- German Research Centre for Geosciences, Section 4.3 Chemistry and Physics of Earth Materials, Germany
[6] Polish Academy of Sciences, Department of Environmental Resources and Geohazards, Institute of Geography, Warszawa, Poland
* Corresponding author: sabine.wulf@gfz-potsdam.de

We present the tephrochronological results of annually laminated lake records from NE Germany (Tiefer See) and N central Poland (Lake Czechowskie, Trzechowskie palaeolake), which have been acquired during the ICLEA programme.

A total of eight and six Holocene cryptotephras from mainly Icelandic and subordinately Eifel and Italian volcanic sources have been identified in Tiefer See and Lake Czechowskie, respectively. Ages of six distinct eruptive events were applied to verify the varve chronologies. In this context, a revised tephra age for the early Holocene Askja-S tephra, which forms an important isochron at the end of the Preboreal Oscillation, was estimated from the Czechowskie varve chronology at 11,228 ± 226 cal yr BP (Ott et al., 2016).

Three cryptotephra layers (Askja AD1875, Askja-S and Hässeldalen) provide ideal synchronisation markers for both high-resolution palaeoclimate records (Wulf et al., 2016). The Askja AD1875 tephra, for example, enabled the detailed comparison of historical proxy data that allows the reconstruction of anthropogenic environmental changes (Słowiński et al., 2017a) and regional inter-lacustrine comparisons (Ott et al., 2017).

In addition to the Holocene tephras, we also identified the Lateglacial Laacher See Tephra (LST, Eifel Volcanic Field, 12,880 varve yr BP) as visible layer at the base of lacustrine sediments in Tiefer See (Dräger et al., 2017) and as cryptotephra in the laminated section of Trzechowskie palaeolake (Wulf et al., 2013). The LST was used to constrain temporal and spatial phase relationships of environmental and vegetation responses to abrupt climate changes during the Allerød/Younger Dryas transition in three varved lake records over a 900-km central European transect (Wulf et al., 2013; Słowiński et al., 2017b).

Overall, results of tephra studies provide the foundation of a detailed Holocene and Lateglacial tephrostratigraphy especially in northern-central Poland and contribute to the understanding of both palaeoenvironmental key questions and natural hazard assessments.

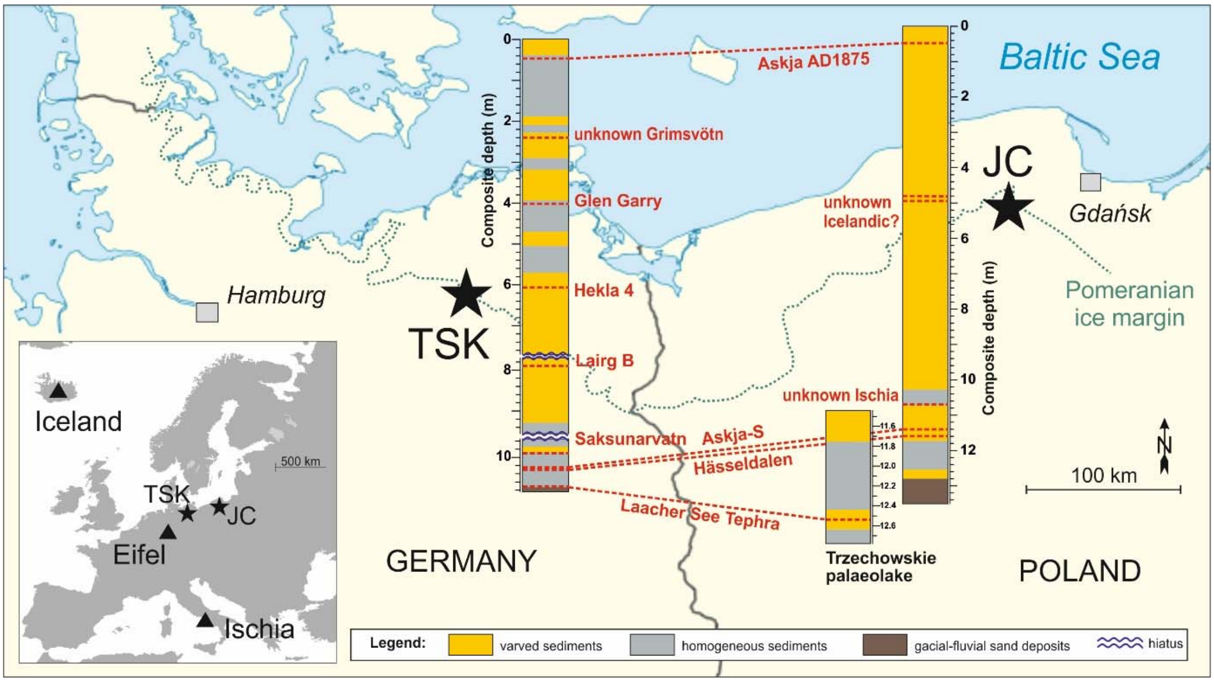


***Fig. 1:** Schematic map of N Germany and N central Poland with the position of lakes Tiefer See (TSK) and Czechowskie/Trzechowskie palaeolake (JC), their lithological profiles and cryptotephra layers identified within varved and non-varved sediments. Inlet map additionally indicates the location of tephra sources (Iceland, Eifel, Ischia).*

References

Dräger, N., Theuerkauf, M., Szeroczynska, K, Wulf, S., Tjallingii, R., Plessen, B., Kienel, U., Brauer, A., 2017. Varve microfacies and varve preservation record of climate change and human impact for the last 6000 years at Lake Tiefer see (NE Germany). The Holocene 27, 450-464.

Ott, F., Wulf, S., Serb, J., Słowiński, M., Obremska, M., Błaszkiewicz, M., Brauer, A., 2016. Constraining the time span between the early Holocene Hässeldalen and Askja-S tephras through varve counting in the Lake Czechowskie sediment record, Poland. Journal of Quaternary Science 31, 103-113.

Ott, F., Kramkowski, M., Wulf, S., Plessen, B., Serb, J., Tjallingii, R., Schwab, M., Słowiński, M., Brykała, D., Tyszkowski, S., Putyrskaya, V., Appelt, O., Błaszkiewicz, M., Brauer, A., 2017. Site-dependent proxy response to climate change during the last 140 years observed in varved lake sediments in Northern Poland. Abstract EGU2017-8274, European Geosciences Union General Assembly, Vienna, Austria, 23–28 April 2017.

Słowiński, M., Ott, F., Obremska, M., Theuerkauf, M., Czaja, R., Wulf, S., Błaszkiewicz, M., Brauer, A., 2017a. Impact of Medieval road construction on landscape transformation during the last 700 years in N Poland. Abstract EGU2017-9969, European Geosciences Union General Assembly, Vienna, Austria, 23–28 April 2017.

Słowiński, M., Zawiska, I., Ott, F., Noryśkiewicz, A.M., Plessen, B., Apolinarska, K., Rzodkiewicz, M., Michczyńska, D.J., Wulf, S., Skubała, P., Kordowski, J., Błaszkiewicz, M., Brauer, A., 2017b. Differential proxy responses to late Allerød and early Younger Dryas climatic change recorded in varved sediments of the Trzechowskie palaeolake in Northern Poland. Quaternary Science Reviews 158, 94-106.

Wulf, S., Ott, F., Słowiński, M., Noryśkiewicz, A.M., Dräger, N., Martín-Puertas, C., Czymzik, M., Neugebauer, I., Dulski, P., Bourne, A., Błaszkiewicz, M., Brauer, A., 2013. Tracing the Laacher See Tephra in the varved sediment record of the Trzechowskie palaeolake in central Northern Poland. Quaternary Science Reviews 76, 129-139.

Wulf, S., Dräger, N., Ott, F., Sern, J., Appelt, O., Guðmundsdóttir, E., van den Bogaard, C., Słowiński, M., Błaszkiewicz, M., Brauer, A., 2016. Holocene tephrostratigraphy of varved sediment records from Lakes Tiefer See (NE Germany) and Czechowskie (N Poland). Quaternary Science Reviews 132, 1-14.

DOI: 10.2312/GFZb103-17037

Chapter III: Excursion and fieldtrip guide 2017

Late Quaternary landscape development and legacies of human-induced land use changes in Lower Lusatia, South Brandenburg, Germany

Raab, Thomas[1]; Raab, Alexandra[2]; Hirsch, Florian[1];
Schneider, Anna[1] & Bonhage, Alexander[1]

[1] Brandenburgische Technische Universität Cottbus-Senftenberg, Chair of Geopedology and Landscape Development, Cottbus, Germany
[2] Brandenburgische Technische Universität Cottbus-Senftenberg, Research Center Landscape Development and Mining Landscapes, Cottbus, Germany

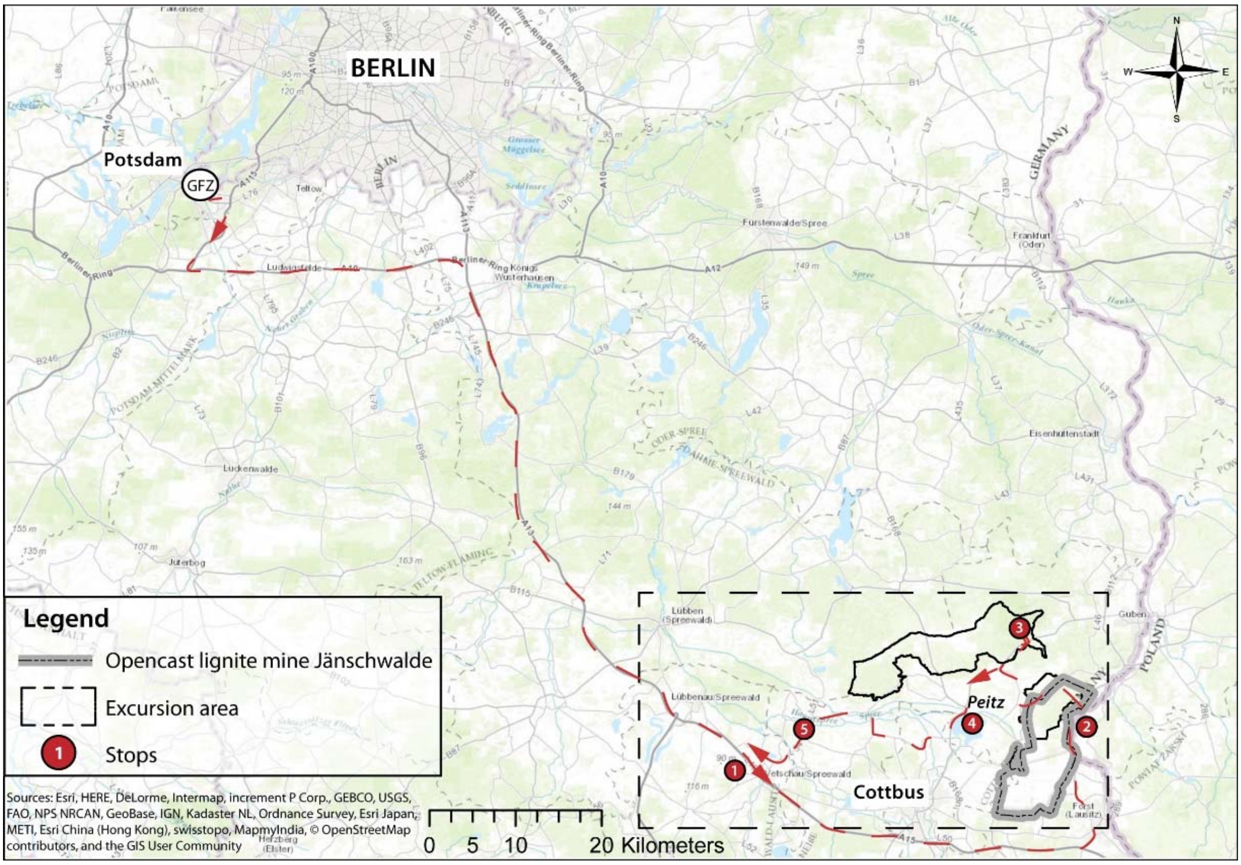


***Fig. 1**: Topographic map of Southeast Brandenburg (Overview map and travel route).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

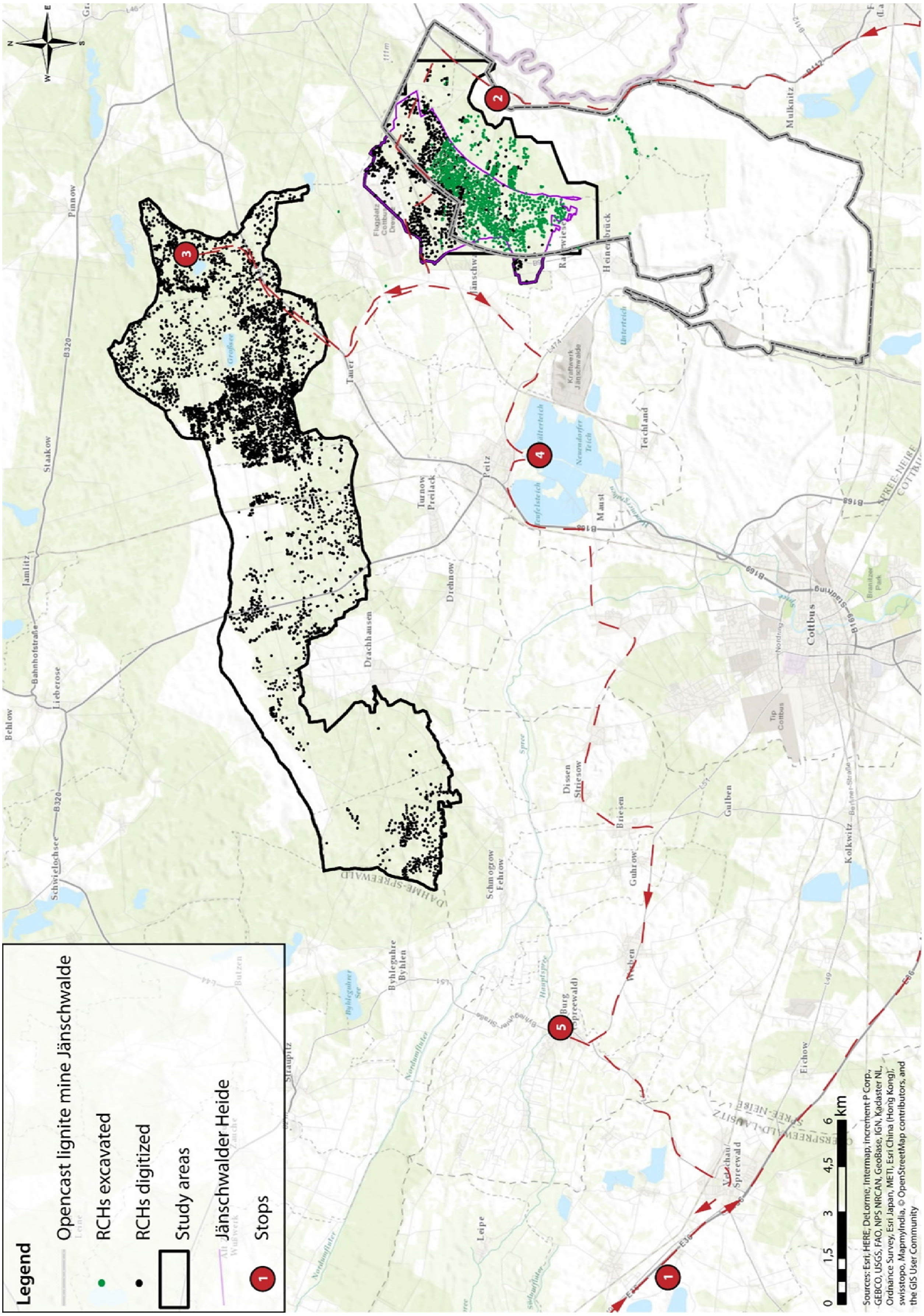


***Fig.2:** Topographic map of the Cottbus-Jänschwalde region showing the excursion route including stops.*

Introduction

Since 2010, earth scientists at the *Brandenburg University of Technology Cottbus-Senftenberg* (BTU) have cooperated with archaeologists of the *Brandenburgische Landesamt für Denkmalpflege und Archäologisches Landesmuseum* (BLDAM) and soil scientists of the *Landesamt für Bergbau, Geologie und Rohstoffe* (LBGR) to study the impact of past land uses, i.e., changes in vegetation, landforms and soils induced by agriculture or forestry. A common objective is to distinguish natural versus anthropogenic forcings and processes. During this excursion, we present selected results providing novel insights into both Late Quaternary landscape dynamics and human-induced environmental changes in Lower Lusatia.

Brandenburg is located in the central part of the North European Lowland (NEL), which is a zone of extensive plains ranging from the North Sea and the Baltic Sea to the foothills of the low mountain ranges of Central Europe in the south and in from the Netherlands in the west to the eastern parts of Poland (Fig. 3a). The plains reach a maximum elevation of 200 m a.s.l. The NEL was mainly shaped by glacial and periglacial processes in the Quaternary (Liedtke and Marcinek 1995). In the study area, the Last Glacial Maximum (LGM) corresponding to the Brandenburger Stadium is dated between 24 and 20 kyr BP, according to Böse et al. (2012).

Because of sparse or absent vegetation cover and aeolian activity, the formation of dunes and coversand was a major geomorphological process in the periglacial areas of the NEL during the LGM (Zeeberg 1998, Schirmer 1999, Kasse 2002, Hirsch et al. 2015, Hirsch et al. 2017). With the climatic and environmental changes at the end of the Pleistocene, the landscape stabilized and soils developed. Late glacial soils, referred to as Usselo and Finow soils, are widespread in the NEL (e.g., Kaiser et al. 2009, Hirsch et al. 2017). Depending on the texture and chemical composition of the parent material, clay translocation and brunification were the prevailing pedogenic processes in the transition from the Late Pleistocene to the Holocene (Kühn 2003).

During the Holocene, podzolization occurred on sandy substrates (Vandenberghe et al. 2013), and it was likely intensified by human activities, such as the afforestation of pine trees (Reiß et al. 2009).

Some of the soils in South Brandenburg are suitable for intensive agriculture and crop production, particularly on loamy till substrates. However, sandy substrates are most prevalent. The Cambisols and Retisols in the area have considerably lower ratings than soils in other districts of the NEL, such as the highly productive Chernozems or Luvisols in the loess belts (Bauriegel et al. 2001; Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg 2010). Hence, land use in South Brandenburg consists of a mixture of agriculture, forestry and pasture that is mainly determined by local edaphic conditions. This land use mosaic is also characteristic of the region where the study sites are located (Fig. 3b, c).

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

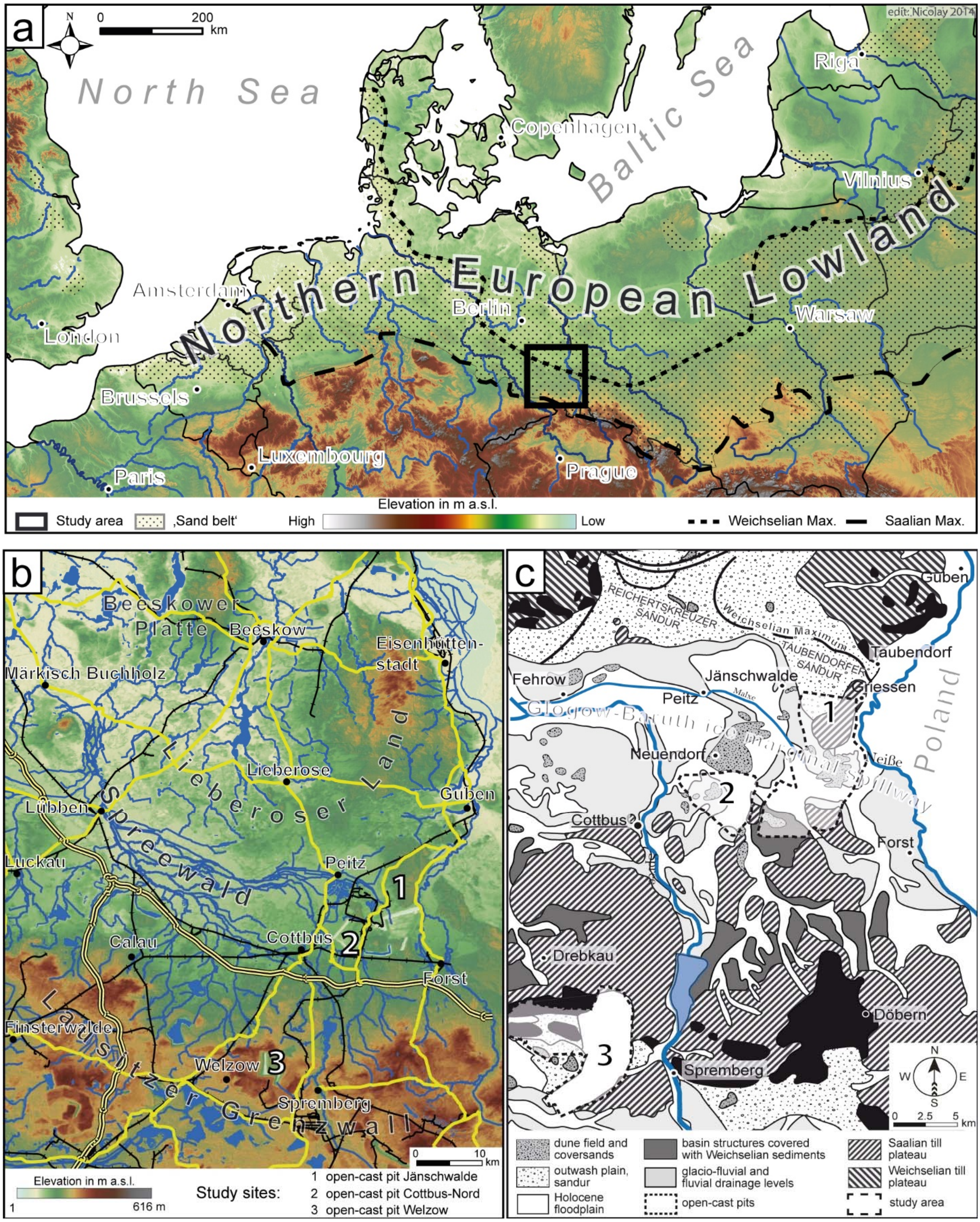


***Fig. 3:** Geographic location of the study area. a) Location of the study area within the Northern European Lowland, displayed on a relief map. b) Detailed relief map of the study area showing the location of the opencast mines of Jänschwalde, Cottbus-Nord and Welzow-Süd. Database for a) and b): Jarvis et al. (2008). c) Geomorphological map of the study area (adapted from Nowel (1992) and Cepek et al. (1994) and modified according to Lippstreu and Sonntag (2003) and Noack (1965)). – Figure from Raab, T. et al. (2015).*

DOI: 10.2312/GFZb103-17037

Stop 1 – Slavic Fort of Raddusch – Archaeology in Lower Lusatia

From the beginning of the 1990s onwards an adaptation of the Slavic fort of Raddusch was constructed as project of the Brandenburgisches Landesamtes für Denkmalpflege und Archäologisches Landesmuseum (BLDAM). The adaption of the fort, which was built by the Slavic tribe of the Lusizi in the late 9th/early 10th century, was constructed at the excavated original site of the district Raddusch on the edge of the Spreewald between Vetschau and Lübbenau.

The construction houses the 600 square meter permanent exhibition *Archaeology in Lower Lusatia*, regularly changing traveling exhibitions, and several other attractions such as a walkway through 12.000 years of regional landscape change, a restaurant, picnic areas, and a playground.

Fig. 4: *Slavonic Fort of Raddusch.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Stop 2 – Opencast lignite mine Jänschwalde (Viewpoint Grießen)

Opencast mining in Germany and Lusatia – basic facts

Germany is by far the leading lignite-producing country worldwide, producing 185 Mio tons in 2012 (Bundesanstalt für Geologie und Rohstoffe 2013: 84), followed by China (145 Mio t) and Russia (78 Mio t). Lignite is the only fossil energy feedstock exploited in Germany in significant amounts. In 2012, 25.7 % of Germany's electricity was generated by lignite-fired power plants (DEBRIV 2013: 11). Although Germany is striving to restructure the energy market to achieve a 100 % alternative energy supply by reducing the combustion of fossil fuels and strengthening alternative energies, lignite mining will be an important issue in Germany for many years to come. This matter concerns not only reclamation (Krümmelbein et al. 2012) and ecological research (Raab et al. 2012) but also the challenge of studying archaeological remains prior to their destruction.

The Lusatian lignite mining district, a region in Southeast Brandenburg and northern Saxony (Figs. 3, 5), is the second largest lignite producer among the four German mining districts (62 Mio t lignite in 2012). Since mining was initiated, the total demand for mining land in Lusatia has reached 861 km^2 (DEBRIV 2013: 21). Currently, two active mines exist in South Brandenburg (Jänschwalde and Welzow-Süd) and two exist in Saxony (Nochten and Reichwalde) (Fig. 5).

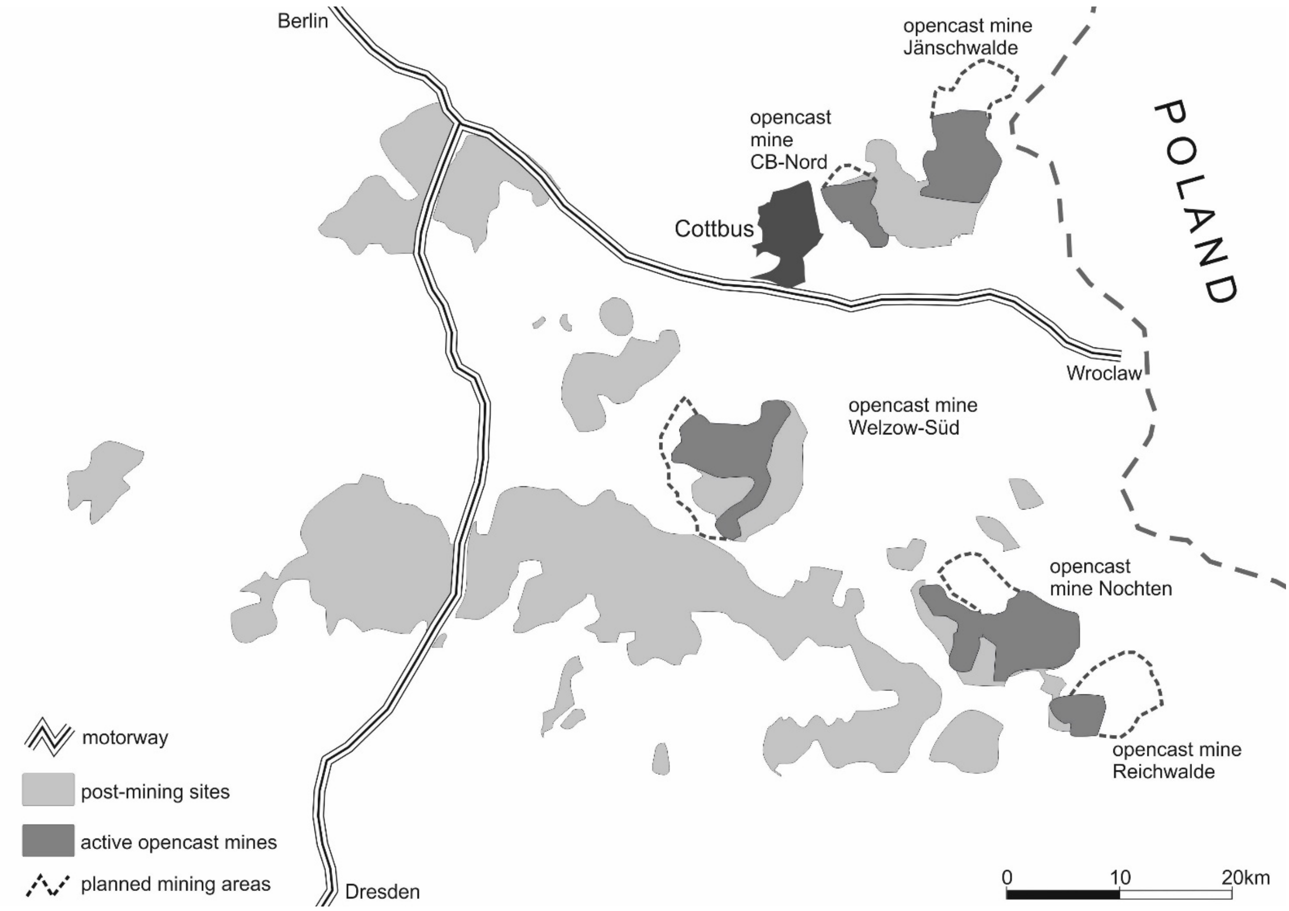


Fig. 5: *Sketch map of the Lower Lusatian lignite mine district (post-mining sites, active opencast lignite mines and planned mining areas). – Figure from Raab, T. et al. (2015).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Opencast mining in Lusatia – technology and implications for geoarchaeological research

In Lusatia, lignite is exploited entirely from opencast mines using the strip mining approach. This approach basically involves three main operational areas or units: the forefield, the lignite trench and the dumping site or reclamation area. Strip mining in Lusatia is performed via the conveyor bridge technique, which allows for a relatively continuous and predictable succession of archaeological excavations in the forefield of the lignite trench. In the opencast pit of Jänschwalde, the velocity of the conveyer bridge is 500 m yr^{-1} on average, and the mine is as wide as 5,000 m (Fig. 6). Figure 7 shows the distribution of post-mining soils in the Brandenburg part of the Lusation lignite mining district.

Fig. 6: *View of the opencast lignite mine of Jänschwalde, with the overburden conveyer bridge. The view is to the east (photo: H. Rösler). – Figure from Raab, T. et al. (2015).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

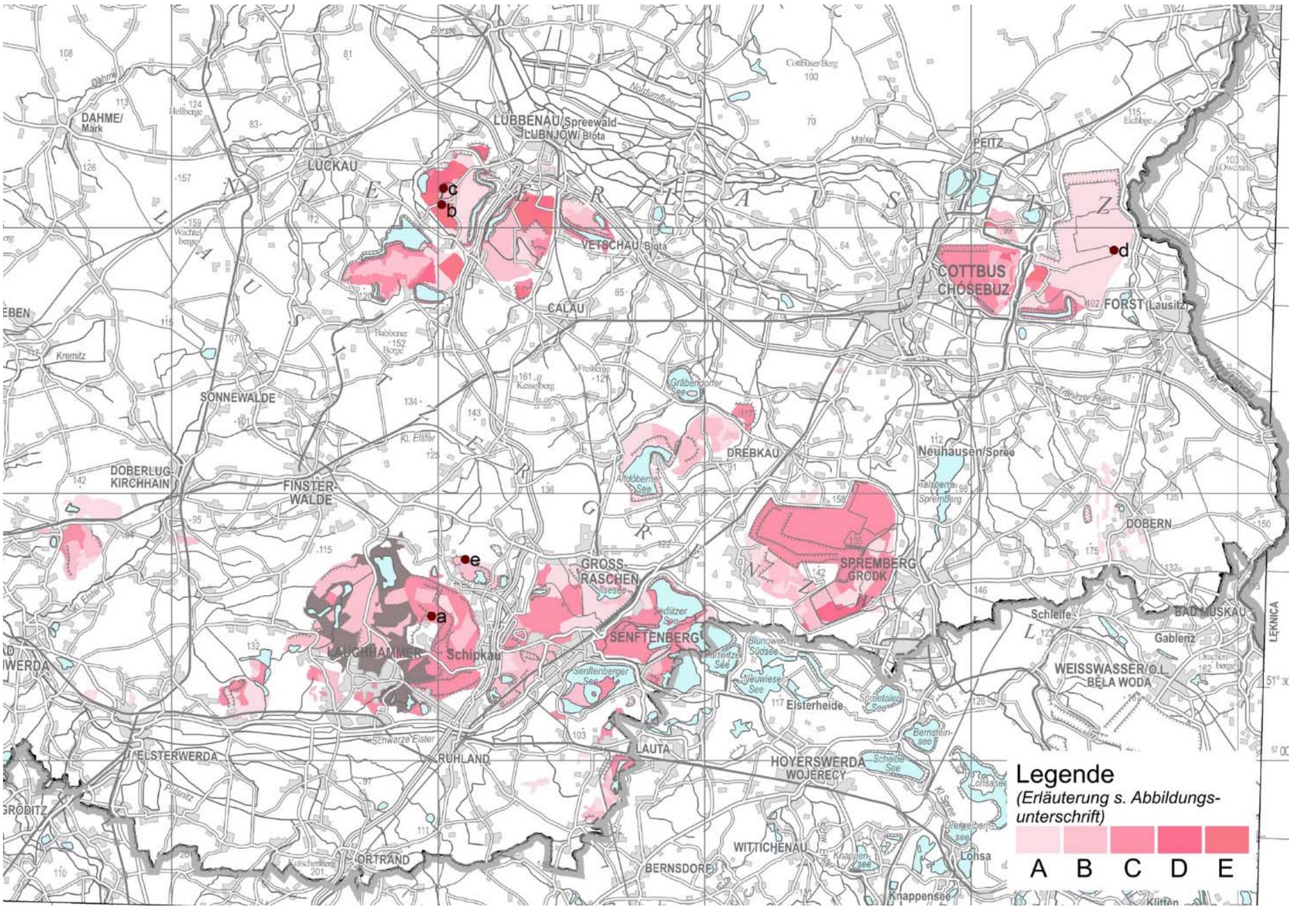


Fig. 7: *Occurrence of post-mining soils in the Brandenburg part of the Lusatian lignite mining district; [legend (english soil types according to WRB): A – mainly Regosol (Arenosols) and Lockersyrosem (Arenic Regosols) from dumped sandy substrate; B – Regosol (Arenosols) and Lockersyrosem (Arenic Regosols) mainly from dumped sandy substrate containing lignite, Lockersyrosem (Calcaric Regosols) and Pararendzina (Calcaric Regosols) from calcareous dumped sandy substrate; C – Regosol (Arenosols) and Lockersyrosem (Calcaric Regosols) from dumped sandy substrate containing loamy fragments, frequently Pararendzina (Calcaric Regosols) from dumped calcareous sandy-loamy substrate; D – Regosol (Arenosols) and Lockersyrosem (Arenic Regosols) from dumped loamy substrate with sandy material, sealed surfaces; E – frequently Regosol (Anthrosols) from flushed ashes fom lignite power plants) [source: extract from Bodengeologische Übersichtskarte 1 : 300 000 (BÜK 300)]. – Figure from Gerwin et al. (2015).*

According to the regulations of the *Brandenburgisches Denkmalschutzgesetz* (BbgDschG, effective date 20.05.2004), archaeological excavations must be conducted in advance of lignite extraction. In southern Brandenburg, approximately 5% of the total area of opencast mines is fully examined by digging archaeological trenches or excavating the area (Fig. 5). In comparison with the total area of the state of Brandenburg, the density of archaeological excavations in opencast mines is unique. Furthermore, the total mining area is available for archaeological excavations, as opposed to the rather small-scale excavation sites outside the mining area. Although lignite mining causes total destruction of the landscape, the potential for conducting geoarchaeological research in the Lusatian Mining District is promising.

Fig. 8: *Aerial photograph of systematic archaeological test trenches in the Jänschwalde opencast mine, including the archaeological planes of the ground plans (black circles) of former upright circular charcoal kilns. Photo: H. Rösler 2008. – Figure from Raab, T. et al. (2015).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Stop 3 – Tauer Forest (Waldschule Kleinsee)

Historic charcoal production in the Tauer Forest

At the stop at Lake Kleinsee in the Tauer Forest, we will present results of our work on the spatial distribution and pedological properties of relict charcoal hearths (RCHs) and show a characteristic RCH soil profile.

The woodland area Tauerscher Forst is characterised by a flat topography with minor altitude differences (63 – 87 m a.s.l.) (Fig. 9). Quaternary glaciations from the Scandinavian ice-sheet affected the study area, thus glacigenic sediments and landforms are widely distributed (mainly tills of ground moraines and glacio-fluvial to fluvial sands of sandurs and ice marginal valleys). The sandy substrates, normally free from carbonates and rich in quartz and some feldspar, are the parent material for the nutrient-poor, and often acidic soils (Lippstreu et al., 1994, Gerwin et al. 2015). According to Hofmann and Pommer (2005) the potential natural vegetation would be pine – sessile oak forests (Kiefern-Traubeneichenwald) on locations with loamy substrates. On sandy soils (sandurs) pine woods would occur and on lowland areas (floodplains of the rivers Neiße, Spree and Malxe) bird cherry – ash woods and floodplain forests (Traubenkirschen – Eschenwald) would be present.

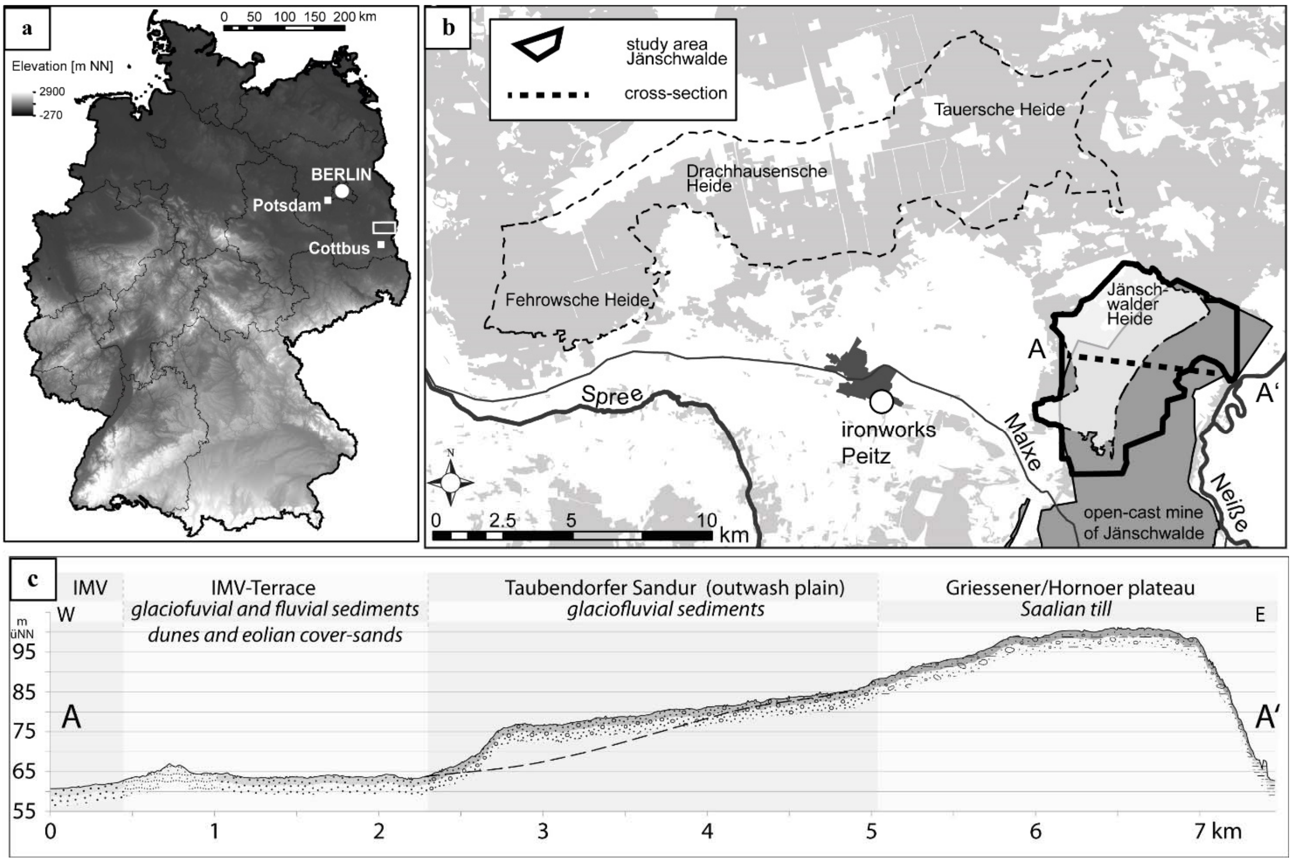


Fig. 9: *Study area. (a) Location map, (b) Forest cover and forestry districts in the vicinity of the study area according to ATKIS-Basis-DLM (Landesvermessung und Geobasisinformation Brandenburg) and Preußische Urmeßtischblätter 1845 (districts) (c) Elevation cross-section showing main geomorphological units and Quaternary substrates. - Figure from Raab A. et al. (2015).*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The Tauerscher Forst lies N and E of the village Peitz. At large, it represents the area of the former royal forest district Tauer (*Königlich Tauersches Forstrevier*). The forest district surrounds the Peitzer Lowland, which is part of the Glogau-Baruth ice marginal valley. The Peitzer Lowland was originally wooded and had been successively deforested for meadows and pasture until the end of the 18th century (Krausch, 2008). The investigation area of our studies is divided into two parts: the study areas Jänschwalde and Tauer (Fig. 6). The study area Jänschwalde (c. 32 km^2) lies E of Peitz and comprises the historical Jänschwalder Heide (18 km^2). Actually, it stretches for the most part over the territory of the active opencast lignite mine Jänschwalde, which gradually proceeds in northward direction. The study area Tauer (c. 96 km^2) is situated N of Peitz. Formerly, it was subdivided into three historical forests, called Heiden: the Fehrower Heide, the Drachhausener Heide and the Tauersche Heide. Two small lakes, typical hollow moulds, are present in the Tauersche Heide, the lakes Großsee and Kleinsee. Today, the Tauerscher Forst, is mainly characterised by forestry with pine monoculture. But, large areas are heavily disturbed by modern anthropogenic uses like a meanwhile abandoned military training area and a solar power plant. Today, some parts of the Tauersche Heide are protected areas. In the village Peitz, an ironwork was established presumably before 1554 and was operated until 1858. Through most of the operation time, the ironwork was under Prussian administration, except from 1807 to 1813/15 when it was led under Saxon administration. The ironwork processed bog iron ore from the broader surroundings in the Peitzer Lowland (Müller, 2017). The energy supply was fulfilled with charcoal. The entire former royal forest district Tauer was available as wood resource (Müller, 2017). The possession history of this forest district is complex, but since 1701 it was in royal Prussian possession (Takla et al., 2013). During the course of time, forest administration and forest divisions changed several times. Under Friedrich II., in 1764, the forest district was subdivided into forest plots (called Jagen). From this time on the forest management has changed by Royal Orders. Selection forest should be replaced by systematic tree cutting, afforestation by natural regeneration should be abandoned, and seeding and plantations of pine trees should be introduced (Müller, 2014). In 1779, another Royal Order became effective in Prussia, which regulated charcoal production by detailed indications (Friedrich II., 1779).

As legacies of the historic charcoal production, relict charcoal hearths occur widespread in the Tauer Forest. The RCHs were first detected by field surveys for archaeological rescue excavations in the forefield of the Jänschwalde mine. In contrast with the charcoal-burning sites on slopes in mountainous regions, where RCH platforms were prepared on small terraces (e.g., Ludemann, 2003), the levelling of circular areas across the flat landscape required less effort. Thus, the RCH platforms are considerably less marked than the RCHs in the mountainous regions. Nevertheless, the RCHs in our study area emerged as microtopographic surface features (Fig. 10). Furthermore, charcoal pieces may suggest the existence of RCHs. Following the archaeological excavation of the surface, the RCHs are evident in the light-coloured sands as distinct, black circles (Fig. 11) that resulted from the construction of circular upright charcoal hearth (*Platzmeiler*). After building the wood stacks, the charcoal hearths were sealed with brushwood and soil. To prevent forest fires, ditches that were approximately 40 cm deep were dug around the wood stacks. The soil material from the ditch was probably used to seal the stack. Following the pyrolysis process, the charcoal

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

was raked out and the ditches were filled with charcoal-rich substrate from the platforms. The large-scale systematic archaeological excavations carried out by archaeologists from the BLDAM in the forefield of the mine have revealed more than 1,200 RCHs so far (as of July 2016). Mapping of RCHs was extended to forest areas beyond the mine forefield based on shaded relief maps derived from digital elevation models. The results revealed the presence of about 6,000 sites over an area of 109 km^2 in the Tauer Forest (Fig. 12). The diameters of the mapped RCH ground plans range between 4.0 and 30.5 m, indicating that charcoal hearths in the regions were considerably large, as compared with previously described sites and the specifications made in historic forest regulations. The analysis of the spatial distribution of RCHs suggests that the transport distance or proximity of villages to charcoal production sites is the most important factor influencing the location of hearth sites.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

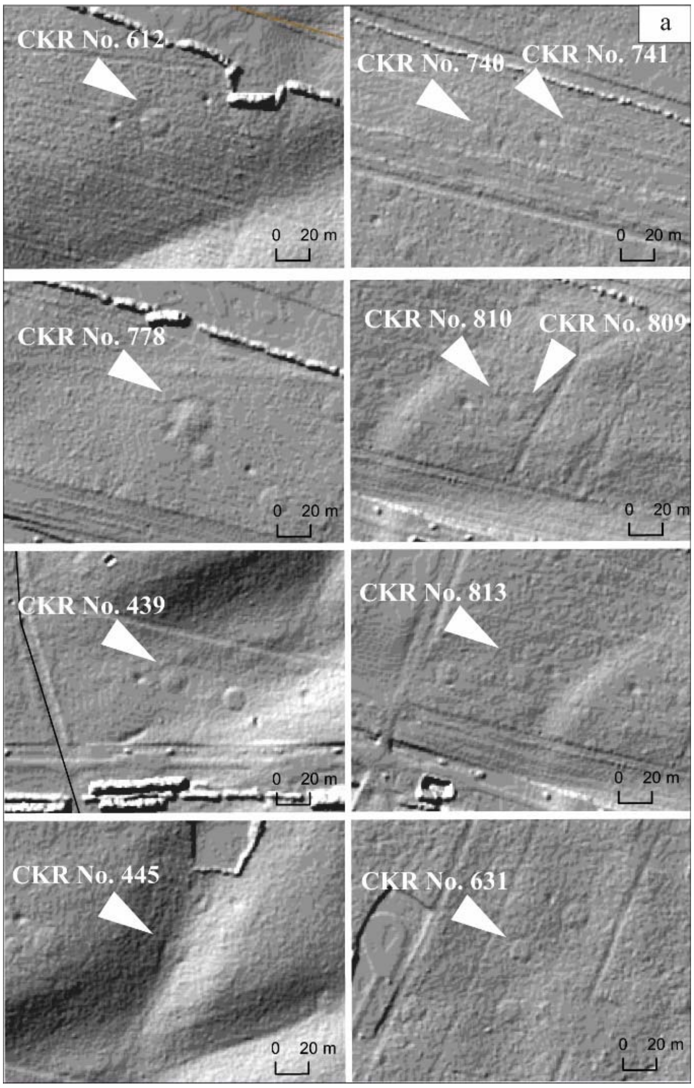


Fig. 10 a): *GIS-analyses of relict charcoal hearths (RCHs). (a) Examples of RCHs visible on the SRM.*

ALS-data copyright Vattenfall Europe Mining AG, Markscheiderei.

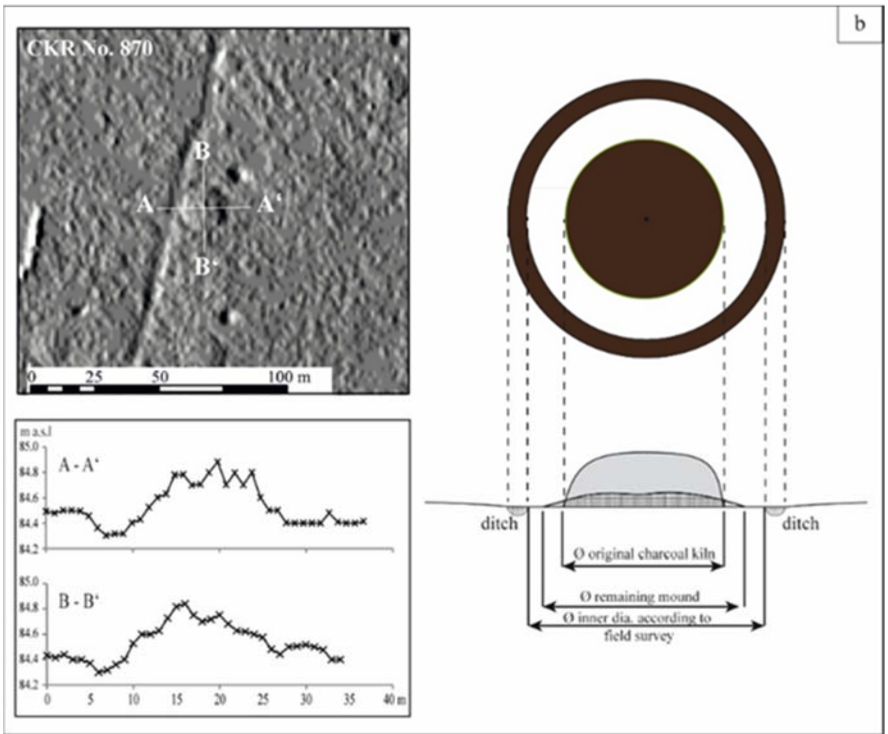


Fig. 10 b): *GIS-analyses of relict charcoal hearths (RCHs). (b) Shaded-relief map (SRM) and elevation cross-sections through the remaining mound of a charcoal hearth and graphics showing the features detectable. – Figure from Raab A. et al. (2015).*

DOI: 10.2312/GFZb103-17037

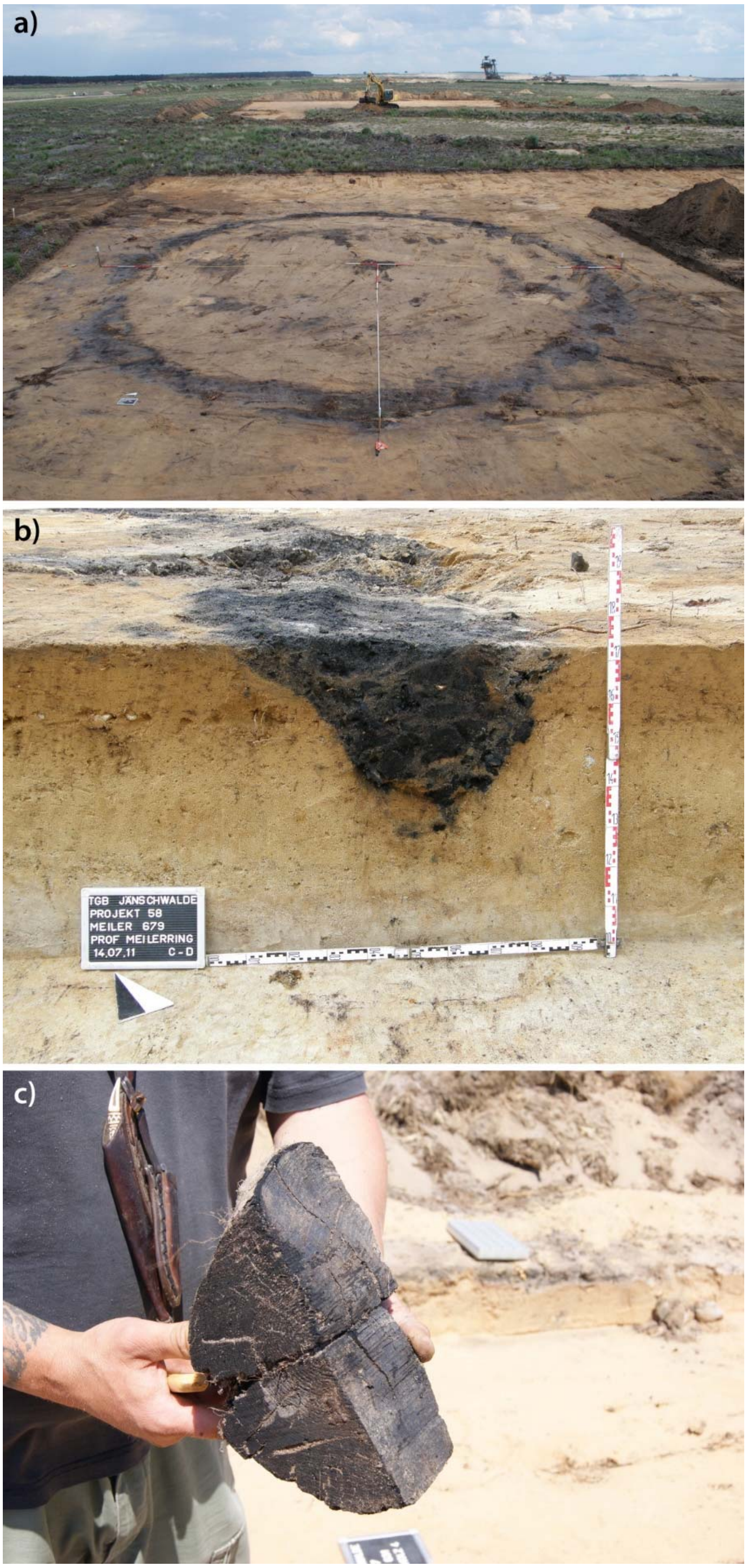


***Fig. 11:** Photographs from RCH excavations: (a) view on the planum of RCH no. 629 (A. Troppa), (b) view on a profile in the ditch of charcoal RCH no. 679 (H. Blumenstein), (c) charcoal chunk from RCH no. 631 (H. Blumenstein). - Figure from Raab A. et al. (2015).*

DOI: 10.2312/GFZb103-17037

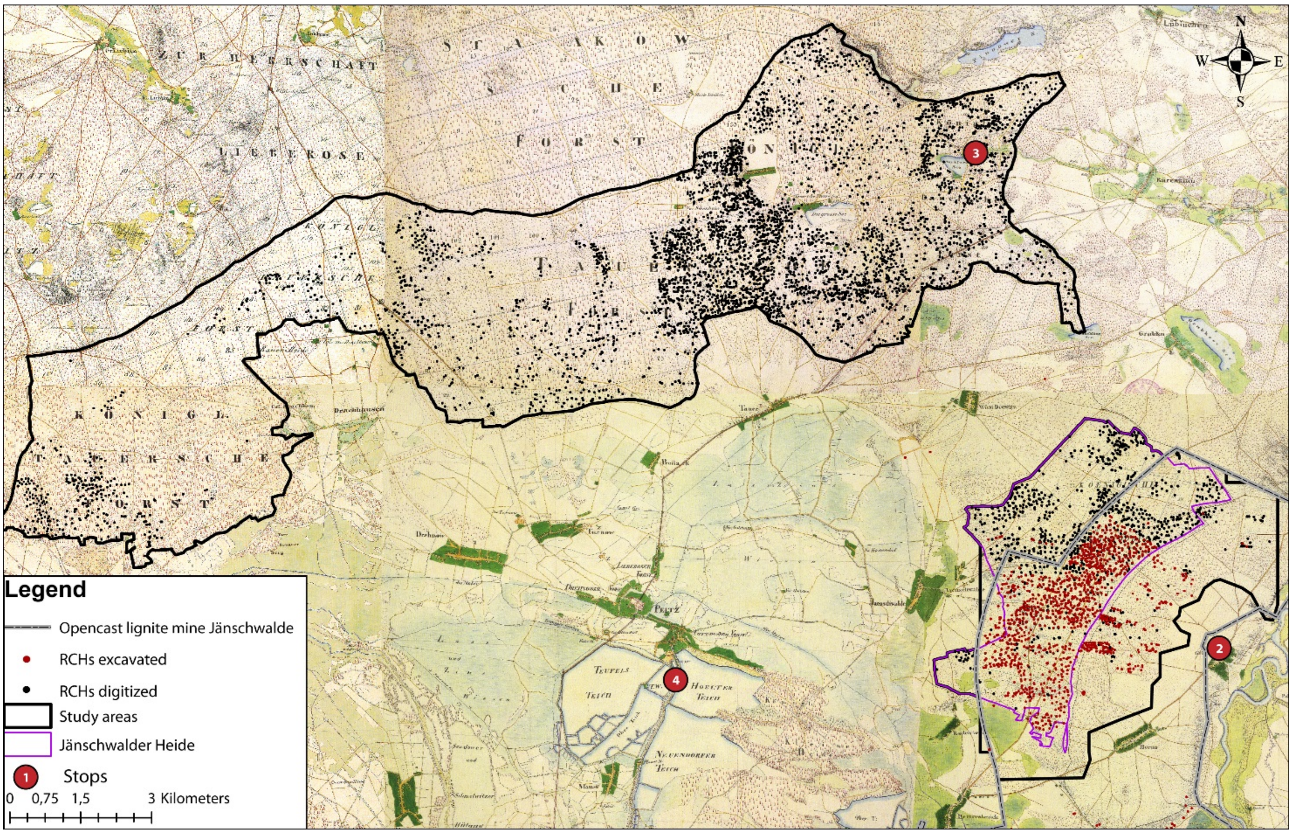


***Fig. 12:** Former royal forest district Tauer displayed on the Prussian ordnance survey map from 1845-1846 (4052 Jamlitz, 4053 Pinnow, 4151 Werben, 4051 Lieberose, 4153 Groß Gastrose, 4252 Peitz) showing RCH site.*

The pedological characteristics of RCHs were studied on several sites, comparing the RCH soils to the forest soils in the vicinity of the sites. The stratigraphy of RCHs (Fig. 9) is, in general, characterized by a technogenic layer on top of the natural soil profile, consisting of relatively small charcoal fragments remaining at the hearth site after charcoal harvesting. Relatively thin organic horizons (L+Of horizon) and thin topsoil horizons (Ah horizons) are developed above the technogenic deposit remaining from the charcoal hearths. Soils on the RCH are classified as Spolic Technosols over Brunic Arensols.

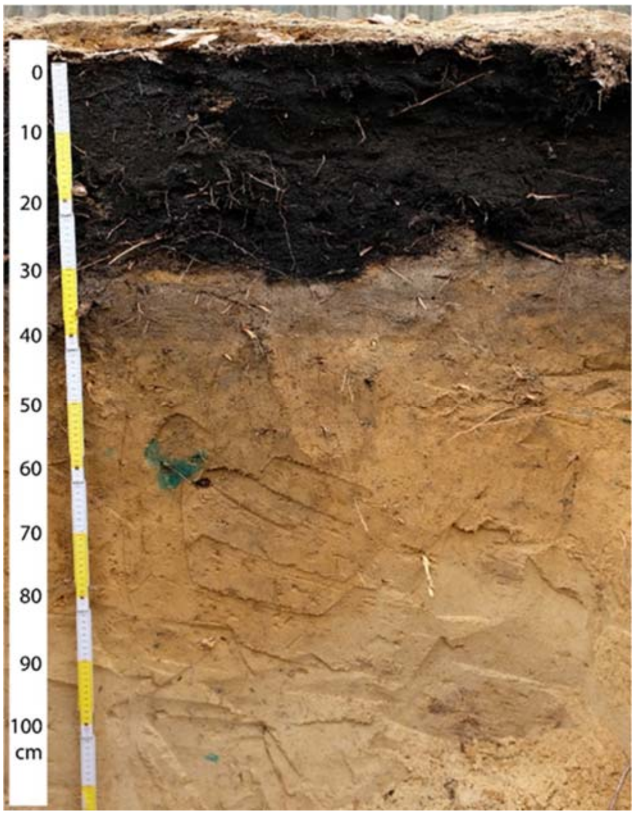


***Fig. 13:** Soil profile in the central part of an RCH platform with a 30 cm layer of charcoal-rich technogenic deposit.*

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

The remains of the hearth operation are dark grey, relatively loose sediment layers, rich in charcoal fragments, with a thickness of up to 40 cm in central parts of the hearth sites. The lower boundary of the charcoal-rich layers is often considerably distinct and even, and is marked by thin black and white bands with an accumulation of fine charcoal fragments and ash. Topsoil horizons buried below this layer show similar color, grain size distribution and root density as topsoil horizons in undisturbed soil profiles. However, the upper 2 to 4 cm of these topsoils often have a slightly more reddish color, presumably resulting from a thermal oxidation of iron below the charcoal hearths; and the horizons are generally slightly more consolidated than the horizons outside of the RCHs.

Stop 4 – Peitz Ironworks

The history of the Peitz ironworks (operation time: c. 1544 – 1856) is comprehensively described by Müller (2017). Until the end of the 17th century, the Peitz ironwork was the only ironwork in the Mark Brandenburg. One reason for the founding of the ironwork was the wealth of commodities in the surrounding of the Peitz location. The existence of large woodlands and bog iron ore deposits in the direct vicinity were certainly decisive criterions to build up the facility at Peitz. Further, Peitz is situated on an important trade route linking Saxony (via Bautzen and Spremberg) to Cottbus and to Frankfurt/Oder. The first product of the ironwork was cast-iron munitions, most probably for the fortress Peitz which was build up from 1559 onwards. Table 1 gives an overview of selected operation history data of the ironwork Peitz.

Fig. 14: *Blast furnace building of the Peitz ironworks.*

DOI: 10.2312/GFZb103-17037

***Table 1:** Selected operation history data of the ironwork Peitz (1554-1858).*
According to data from Müller (2017)

1554-1701	**Margravial-electoral administration**
Prior to 1554	Founding of the ironwork Peitz
1616-1648	30-years war
1631	Destruction of the ironwork
1643	Ironwork almost completely destroyed by fire
1691	A large part of the ironwork burnt down
1701-1807	**Royal Prussian administration**
1756-1763	7-years war
26 August 1759 –27	Downtime of the ironwork
1768	Founding of the *Berg- und Hüttendepartment* within the reorganization of the
1778	Founding of the *Hüttenamt Peitz* (ironworks office)
14 June 1779	Official handover of the ironwork Peitz to the royal *Hauptbergwerks- und*
8 July 1806	Napoleonic war > Treaty of Tilsit > ironwork in Saxon possession
1807-1813/15	**Royal Saxon administration**
1813/15-1858	**Prussian administration**

References

Bauriegel A, Kühn D, Schmidt R, Hering J, Hannemann J (2001): Bodenübersichtskarte des Landes Brandenburg 1:300.000. Kleinmachnow, Potsdam.

Bundesanstalt für Geowissenschaften und Rohstoffe (2013) Energiestudie 2013. Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen 17.

http://www.bgr.bund.de/DE/Themen/Energie/Downloads/Energiestudie_2013. Accessed 25 February 2014.

Böse M, Lüthgens C, Lee JR, Rose J (2012): Quaternary glaciations of northern Europe. Quaternary Science Reviews 44:1–25.

Cepek AG, Hellwig D, Nowel W (1994): Die Gliederung des Saale-Komplexes im Niederlausitzer Braunkohlenrevier. Brandenburg Geowissenschaftliche Beiträge 1(1):43-83.

DEBRIV (2013): Braunkohle in Deutschland 2013 - Profil eines Industriezweiges.

http://www.braunkohle.de/pages/publikation php?page=144. Accessed 25 February 2014

Friedrich II., Preußen, König (1779) Verordnung, wie es mit dem Holzschlag zu Kohlen und Köhlereyen bei den königlichen Eisen= Blech= Kupfer= und auch anderen Hütten= undHammerwerken gehalten werden soll. De Dato Berlin, den 18. Januar 1779. Quelle: Brandenburgisches Landeshauptarchiv, Pr. Br. Rep. 2A III F Regierung Potsdam, Nr. 487 Generalia. Holzkohlen-S. Kohlenschwelen in den kgl. Forsten und Holzschlag für Köhlereien bei den kgl. Hütten- und Hammerwerken (1738-1849), F.5-12.

Gerwin W, Raab T, Bauriegel A, Nicolay A (2015): Junge Böden der Niederlausitz. Brandenburgische Geowissenschaftliche Beiträge 22: 137-148.

Grünewald U, Schoenheinz D (2014): Berbaubedingte Gewässerversauerung in der Niederlausitz – Ursachen, Ausmaß und Minderungskonzepte. Hydrologie und Wasserbewirtschaftung 58(5):274 – 285. http://www.hywa-online.de/hefte/2014/HyWa_2014,5_2.pdf

Hirsch F, Schneider A, Nicolay A, Błaszkiewicz M, Kordowski J, Noryskiewicz AM, Tyszkowski S, Raab A, Raab T (2015): Late Quaternary landscape development at the margin of the Pomeranian phase (MIS 2) near Lake Wygonin (Northern Poland). Catena 124:28-44. doi:10.1016/j.catena.2014.08.018

Hirsch, F., Spröte, R., Fischer, T., Forman, S.L., Raab, T., Bens, O., Schneider, A., Hüttl, R.F., 2017. Late Quaternary aeolian dynamics and soil stratigraphy (pedogenesis/soil development) in the North European Lowlands - new findings from the Baruther ice-marginal valley. Die Erde 148, 58-73.

Hofmann G, Pommer U (2005): Potentielle Natürliche Vegetation von Brandenburg und Berlin mit Karte im Maßstab 1: 200 000. Eberswalder Forstliche Schriftenreihe.

Jarvis A, Reuter HI, Nelson A, Guevara E (2008): Hole-filled SRTM for the globe version 4. Consultative Group on International Agricultural Research, Washington. http://srtm.csi.cgiar.org

Kaiser K, Hilgers A, Schlaak N, Jankowski M, Kühn P, Bussemer S, Przegietka K (2009): Palaeopedological marker horizons in northern central Europe: characteristics of Lateglacial Usselo and Finow soils. Boreas 38(3):591–609.

Kasse C (2002): Sandy aeolian deposits and environments and their relation to climate during the Last Glacial Maximum and Lateglacial in northwest and central Europe. Progress in Physical Geography 26(4):507–532

Krausch H.-D. (2008): Beiträge zur Wald-, Forst, und Landschaftsgeschichte Brandenburgs. Verlag Kessel.

Krümmelbein J, Bens O, Raab T, Naeth MA (2012): A history of lignite coal mining and reclamation practices in Lusatia, eastern Germany. Canadian Journal of Soil Science 92:53-66. doi:10.4141/cjss2010-063

Kühn P (2003): Micromorphology and Late Glacial/Holocene genesis of Luvisols in Mecklenburg–Vorpommern (NE-Germany). Catena 54 (3):537–555. doi:10.1016/S0341-8162(03)00129-2.

Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg (2010): Atlas zur Geologie von Brandenburg. Landesvermessung und Geobasisinformation, Cottbus.

Liedtke H, Marcinek J (eds) (1995): Physische Geographie Deutschlands. Perthes Geographie Kolleg, 2nd edn. Justus Perthes, Gotha.

Lippstreu L, Sonntag A (2003): Geologische Übersichtskarte Cottbus 1:200.000, Blatt CC4750 Cottbus. Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover.

Müller, F (2014): Erzwungene Nachhaltigkeit? Die Peitzer Amtsheiden unter dem Einfluss des örtlichen Hüttenwerkes. Jahrbuch für Regionalgeschichte 32:55-72.

Müller F (2017): Der Wandel der Kulturlandschaft im Raum Peitz infolge des mehrhundertjährigen Betriebes des dortigen Eisenhüttenwerkes (Mitte 16. bis 19. Jahrhundert). - Geopedology and Landscape Development Research Series Vol. 6, 428 S. http://www-docs.b-tu.de/fg-geopedologie/public/GeoRS/GeoRS_Vol6_Frank_Mueller.pdf

Ludemann T (2003): Large-scale reconstruction of ancient forest vegetation by anthracology - a contribution from the Black Forest Phytocoenologia 33:645-666.

Noack S (1965): Geomorphologische Kartierung der Binnendünen des Südostraumes der DDR. Dissertation, Martin-Luther-Universität Halle-Wittenberg.

Nowel W (1992): Geologische Übersichtskarte des Niederlausitzer Braunkohlenreviers im Maßstab 1:200.000. Lausitzer Braunkohlen AG, Senftenberg.

Preußische Urmeßtischblätter (1845-1846), Blatt 4051 Lieberose, Blatt 4052 Jamlitz, Blatt 4053 Pinnow, Blatt 4151 Werben, Blatt 4152 Peitz (1845), Blatt 4153 Groß Gastrose (1845). Quelle: Staatsbibliothek zu Berlin - Preußischer Kulturbesitz (originals), Landesvermessung und Geobasisinformation Brandenburg (reprints).

Raab, A., Takla, M., Raab, T., Nicolay, A., Schneider, A., Rösler, H., Heußner, K. U., Bönisch, E. (2015): Pre-industrial charcoal production in Lower Lusatia (Brandenburg, Germany): Detection and evaluation of a large charcoal-burning field by combining archaeological studies, GIS-based analyses of shaded-relief maps and dendrochronological age determination. Quaternary Intational 367:111-222.

Raab, T., Raab, A., Nicolay, A., Takla, M., Hirsch, F., Rösler, H., Bauriegel, A. (2015): Opencast mines in South Brandenburg (Germany) - archives of Late Quaternary landscape development and human-induced land use changes. Archaeological and Anthropological Sciences 8:453-466.

Raab T, Krümmelbein J, Schneider A, Gerwin W, Maurer T, Naeth MA (2012): Initial ecosystem processes as key factors of landscape development — a review. Physical Geography 33(4):305-343. doi:10.2747/0272-3646.33.4.305

Reiß S, Dreibrodt S, Lubos CCM, Bork H-R (2009): Land use history and historical soil erosion at Albersdorf (northern Germany)—ceasedagricultural land use after the pre-historical period. Catena 77(2):107–118.

Schirmer W (1999): Definitions concerning coversand, fossil soil and paleosol. In: Schirmer W (ed) Dunes and fossil soils, GeoArcheoRhein 3: 187–190.

Takla, M., Raab, T., Raab, A., 2013. Standort 4 – Eisenhüttenwerk Peitz . Die frühindustrielle Köhlerei in der Jänschwalder Heide (Niederlausitz) – Eine GIS-basierte Rekonstruktion des Wald- und Landschaftszustandes mithilfe historischer Karten ab dem 18. Jahrhundert, in: Raab, T., Hirsch, F., Raab, A., Schopper, F., Freytag, F. (Eds.), Arbeitskreis Geoarchäologie – Jahrestagung 2013, 2.-4.5.2013 BTU Cottbus, Tagungsband und Exkursionsführer, Cottbus:89-97. https://opus4.kobv.de/opus4-btu/frontdoor/index/index/docId/4061

Vandenberghe DAG, Derese C, Kasse C, Van den Haute P (2013): Late Weichselian (fluvio-)aeolian sediments and Holocene drift-sands of the classic type locality in Twente (E Netherlands): a high-resolution dating study using optically stimulated luminescence. Quaternary Science Reviews 68:96–113. doi:10.1016/j.quascirev.2013.02.009

Zeeberg J (1998): The European sand belt in eastern Europe and comparison of Late Glacial dune orientation with GCM simulation results. Boreas 27(2):127–139.

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

Acknowledgements

The ICLEA Final Symposium 2017 is the 5th international ICLEA workshop and is financed by the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA) of the Helmholtz Association, supported by the GFZ German Research Centre for Geosciences and BTU Brandenburg University of Technology Cottbus-Senftenberg.

Participants of the 1st Annual ICLEA Workshop 2012 in Templin (Federal State of Mecklenburg-Vorpommern, Germany) (photo Schwab, GFZ).

Participants of the 2nd Annual ICLEA Workshop 2013 in Stara Kiszewa (Pomeranian Voivodeship, Poland) at Lake Czechowskie (photo Lamparski, PAS).

DOI: 10.2312/GFZb103-17037

Participants of the 3rd Annual ICLEA Workshop 2014 in Greisfswald-Wieck (photo S. Lorenz, Uni Greifswald)

Participants of the 4th Annual ICLEA Workshop 2015 in Słubice (Masovian Voivodeship) (photo ICLEA)

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

List of participants –ICLEA Final Symposium 2017

Abbreviations of institutions

AMU Poznań = *Adam Mickiewicz University Poznań; Institute of Geoecology and Geoinformation, Poland*
BTU *= Brandenburg University of Technology, Cottbus, Germany*
Geopedology *Chair of Geopedology and Landscape Development*
FZLB *Research Center Landscape Development and Mining Landscapes*
CAU Kiel *= Christian-Albrechts-Universität University of Kiel, Germany*
PPA *Institute of Prehistoric and Protohistoric Archaeology*
IER *Institute for Ecosystem Research*
GFZ *= Helmholtz Centre Potsdam - German Research Centre for Geosciences, Potsdam, Germany;*
Section 1.4 *Remote Sensing;* ***Section 1.5*** *Geoinformatics;* ***Section 3.3*** *Earth Surface Geochemistry;*
Section 5.2 *Climate Dynamics and Landscape Evolution;* ***Section 5.4*** *Hydrology*
IGB *= Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany*
IGSO PAS *= Polish Academy of Sciences, Institute of Geography and Spatial Organization,*
Department of Environmental Resources and Geohazards Toruń, Poland
Department of Geoecology and Climatology Warsaw, Poland
Department of Geoenvironmental Research Krakow, Poland
IGS PAS *= Institute of Geological Sciences, Polish Academy of Sciences, Warsaw, Poland*
IOW *= Leibniz Institute for Baltic Sea Research – Warnemünde, Germany*
LUNG M-V *= State Office for Environment Nature protection and Geology of Mecklenburg – Western Pomerania, Güstrow, Germany*
MPI SHH *= Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany*
PGI - NRI *Polish Geological Institute – National Research Institute, Warsaw, Poland*
RHUL = *Royal Holloway, University of London*
TUM *= Technische Universität München, Professorship Ecoclimatology*
U Aarhus = *Aarhus University, Department of Geoscience, Aarhus, Denmark*
U Innsbruck Geog = *University of Innsbruck, Institute of Geography*
U Innsbruck Geol = *University of Innsbruck, Institute of Geology*
UMCS *= Maria Curie-Skłodowska University, Lublin, Poland*
University Greifswald, *Germany*
IBL *= Institute of Botany and Landscape Ecology,* ***IGG*** *= Institute for Geography and Geology*
ZALF *= Leibniz Centre for Agricultural Landscape Research*

	Name, Surname	**Institution**	**Email**
Dr.	Aichner, Bernhard	University of Potsdam	baichner@uni-potsdam.de
	Balanzategui, Daniel	GFZ Sect. 5.2	dan@gfz-potsdam.de
Dr.	Bartczak, Arkadiusz	IGSO PAS Toruń	arekbartczak@gazeta.pl
	Becker, Felix	GFZ Sect. 5.2	felixb@gfz-potsdam.de
Prof.	Błaszkiewicz, Mirosław	IGSO PAS Toruń	mirek@twarda.pan.pl
Dr.	Blume, Theresa	GFZ Sect. 5.4	blume@gfz-potsdam.de
	Bonhage, Alexander	BTU, Geopedology, Cottbus	Alexander.Bonhage@b-tu.de
Dr.	Bonk, Alicja	IGSO PAS Toruń	a.bonk@twarda.pan.pl
Dr.	Börner, Andreas	LUNG M-V	andreas.boerner@lung.mv-regierung.de
	Brademann, Brian	GFZ Sect. 5.2	brademan@gfz-potsdam.de
Prof.	Brauer, Achim	GFZ Sect. 5.2	brau@gfz-potsdam.de
Dr.	Brykała, Dariusz	IGSO PAS Toruń	darek@geopan.torun.pl
Dr.	Buras, Allan	TUM	allan@buras.eu
Dr.	Czymzik, Markus	GFZ & Lund University	mczymzik@gfz-potsdam.de
Prof.	Degórski, Marek	IGSO PAS Warsaw	m.degor@twarda.pan.pl

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

	Name, Surname	Institution	Email
Dr.	Dietze, Elisabeth	GFZ Sect. 5.2	edietze@gfz-potsdam.de
Prof.	Dobrowolski, Radoslaw	UMCS Lublin	rdobro@poczta.umcs.lublin.pl
Dr.	Dörfler, Walter	CAU Kiel, PPA	wdoerfler@ufg.uni-kiel.de
Dr.	Dräger, Nadine	GFZ Sect. 5.2	ndraeger@gfz-potsdam.de
Dr.	Dreibrodt, Stefan	CAU Kiel, IER	sdreibrodt@ecology.uni-kiel.de
	Durstewitz, Luca	FU Berlin	l.durstewitz@posteo.de
	Dziembowski, Michał	IGSO PAS	michaldziembowski@wp.pl
Dr.	Feeser, Ingo	CAU Kiel, PPA	ifeeser@ufg.uni-kiel.de
	Fojutowski, Michał	IGSO PAS Toruń	mfojutowski@wp.pl
	Fritsch, Simone	BTU, Geopedology, Cottbus	fritsch@b-tu.de
	Gerschke, Christine	GFZ Sect. 5.2	gerschke@gfz-potsdam.de
Prof.	Gessner, Mark	IGB	gessner@igb-berlin.de
Prof.	Gibbard, Philip	University of Cambridge	plg1@cam.ac.uk
Dr.	Gierszewski, Piotr	IGSO PAS Toruń	piotrg@geopan.torun.pl
	Heine, Iris	GFZ Sect. 1.4	iris.heine@gfz-potsdam.de
Dr.	Heinrich, Ingo	GFZ Sect. 5.4	heinrich@gfz-potsdam.de
Dr.	Helle, Gerhard	GFZ Sect. 5.2	ghelle@gfz-potsdam.de
Dr.	Hirsch, Florian	BTU, Geopedology, Cottbus	Florian.Hirsch@b-tu.de
Dr.	Hoelzmann, Philipp	FU Berlin	philipp.hoelzmann@fu-berlin.de
Dr.	Kaczmarek, Halina	IGSO PAS Toruń	halina@geopan.torun.pl
Dr.	Kaiser, Jérôme	IOW	jerome.kaiser@io-warnemuende.de
Dr.	Kaiser, Knut	GFZ	knut.kaiser@gfz-potsdam.de
	Kalanke, Julia	GFZ Sect. 5.2	juliak@gfz-potsdam.de
Prof.	Kaplan, Jed O.	University of Lausanne	jed.kaplan@unil.ch
	Kappler, Christoph	BTU Cottbus & GFZ	kappler@gfz-potsdam.de
Dr.	Kienel, Ulrike	GFZ Sect. 5.2	ukienel@gfz-potsdam.de
	Köppl, Matthias	GFZ Sect. 5.2	mkoeppl@gfz-potsdam.de
Dr.	Kramkowski, Mateusz	IGSO PAS Toruń	mkramkowski@twarda.pan.pl
Dr.	Kruczkowska, Bogusława	IGSO PAS Warsaw	b.przewozna@twarda.pan.pl
Prof.	Kühn, Michael	GFZ, Chair of the Scientific Council and Dept. Director	mkuehn@gfz-potsdam.de
Dr.	Lamparski, Piotr	IGSO PAS Toruń	piotr@geopan.torun.pl
Dr.	Lauterbach, Stefan	U Innsbruck, Geol,	stefan.lauterbach@uibk.ac.at
Dr.	Lensky, Nadav	Geological Survey of Israel (GSI)	nadavl@gsi.gov.il
	Lindemann, Christin	GFZ Sect. 5.2	christin@gfz-potsdam.de
Prof.	Lischeid, Gunnar	ZALF Müncheberg	lischeid@zalf.de
Prof.	Marks, Leszek	PGI - NRI Warsaw	leszek.marks@uw.edu.pl
Dr.	Martín-Puertas, Celia	RHUL, London	celia.martinpuertas@rhul.ac.uk
	Müller, Daniela	GFZ Sect. 5.2	danielam@gfz-potsdam.de
Prof.	Negendank, Jörg F.W.	University of Potsdam	neg@gfz-potsdam.de
Prof.	Nicolussi,Kurt	U Innsbruck, Geog,	kurt.nicolussi@uibk.ac.at
Dr.	Noryśkiewicz, Agnieszka M.	University of Toruń	agnieszka.noryskiewicz@umk.pl
Dr.	Obremska, Milena	IGS PAS Warsaw	mobremska@twarda.pan.pl
	Ott, Florian	MPI SHH, Jena	ott@shh.mpg.de
	Pauly, Maren	GFZ Sect. 5.2	mpauly@gfz-potsdam.de
	Pinkerneil, Sylvia	GFZ Sect. 5.2	sytopi@gfz-potsdam.de
Prof.	Piotrowski, Jan A.	University of Aarhus	jan.piotrowski@geo.au.dk
Dr.	Plessen, Birgit	GFZ Sect. 5.2	birgit@gfz-potsdam.de

STR 17/03. GFZ German Research Centre for Geosciences.
DOI: 10.2312/GFZb103-17037

	Name, Surname	**Institution**	**Email**
	Płóciennik, Mateusz	University of Lodz	mplociennik10@outlook.com
Dr.	Raab, Alexandra	BTU, FZLB, Cottbus	araabalex@b-tu.de
Prof.	Raab, Thomas	BTU, Geopedology, Cottbus	raab@b-tu.de
Dr.	Ramisch, Arne	GFZ Sect. 5.2	aramisch@gfz-potsdam.de
Prof.	Rowiński, Paweł	Polish Academy of Sciences, Vice-President	katarzyna.kordonska@pan.pl
Dr.	Rzodkiewicz, Monika	AMU Poznań	lutynska@amu.edu.pl
Dr.	Scharnweber, Tobias	University Greifswald, IBL	tobias.scharnweber@uni-greifswald.de
Dr.	Schneider, Anna	BTU, Geopedology, Cottbus	anna.schneider@b-tu.de
	Schulze, Andreas	Helmholtz Association	andreas.schulze@helmholtz.de
Dr.	Schwab, Markus J.	GFZ Sect. 5.2	mschwab@gfz-potsdam.de
Dr.	Schwank, Mike	Swiss Federal Institute WSL	mike.schwank@wsl.ch
Dr.	Słowiński, Michał	IGSO PAS Warsaw	michal.slowinski@geopan.torun.pl
Prof.	Starkel, Leszek	IGSO PAS Krakow	starkel@zg.pan.krakow.pl
Dr.	Stivrins, Normunds	University of Helsinki	normunds.stivrins@helsinki.fi
Prof.	Szupryczyński, Jan	IGSO PAS Toruń	jan.szupryczynski@geopan.torun.pl
Dr.	Tesmer, Maja	GFZ Sect. 3.3	tesmer@gfz-potsdam.de
Dr.	Theuerkauf, Martin	University of Greifswald, IBL	martin.theuerkauf@uni-greifswald.de
Dr.	Tjallingii, Rik	GFZ Sect. 5.2	rik.tjallingii@gfz-potsdam.de
Prof.	Tylmann, Wojciech	University of Gdańsk	wojciech.tylmann@ug.edu.pl
Dr.	Tyszkowski, Sebastian	IGSO PAS Toruń	sebtys@wp.pl
Dr.	Unger, Andrea	GFZ Sect. 1.5	unger@gfz-potsdam.de
	Wacker, Lisa	GFZ Sect. 5.2	lisaw@gfz-potsdam.de
Dr.	Wulf, Sabine	GFZ Sect. 5.2 & U Heidelberg	sabine.wulf@geow.uni-heidelberg.de
	Zhao, Xueru	GFZ Sect. 5.2	amyzhao@gfz-potsdam.de

(last update May 22, 2017)

ISSN 2190-7110