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4th Annual ICLEA Workshop 2015

Dynamics of Climate and Landscape Evolution of Cultural Landscapes in the Northern Central European Lowlands since the Last Ice Age

Abstract Volume & Excursion Guide

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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)

4th Annual ICLEA Workshop 2015

Dynamics of Climate and Landscape Evolution of Cultural Landscapes in the Northern Central European Lowlands since the Last Ice Age

Abstract Volume & Excursion Guide

Edited by
Markus J. Schwab, Achim Brauer, Dariusz Brykała, Piotr Gierszewski, Piotr Lamparski & Mirosław Błaszkiewicz

23-26 June 2015, Słubice (Masovian Voivodeship), Poland

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Welcome note

We cordially welcome the ICLEA community and the scientific advisory board as well as our external partners and guests to our 4th annual assembly, which will be held again in Poland. Our venue this year is the newly established conference resort near the village of Słubice (Masovian Voivodeship; Województwo Mazowieckie) close to the banks of Vistula River (Wisła; Weichsel) in the vicinity of the town of Płock. Although we have a comprehensive scientific programme, we again save sufficient time for a field excursion to learn about the geomorphological and geological history of this part of Poland but also about measures of water management and construction. The tradition to discuss new results not only in lecture rooms but also in front of the objects, which we are investigating, is an important part of our culture. Without giving away too much, we can already mention at this point that our excursion will lead us this time also to the famous Lake Gościąż, a European key site for reconstructing past climate and environmental change.

The most important event in the past year was our mid-term evaluation almost exactly one year ago in the headquarters of the Helmholtz Association in Berlin, which was very successful and guaranteed full funding until the end of 2016. This great success was made possible by the inspiring and curiosity-driven scientific work of the entire ICLEA community including all our partners. At this point we want to especially thank our very motivated young scientists for their enthusiastic work. We are grateful also to our scientific advisory board for their support and discussions.

After the first three years of our virtual institute, we are still rapidly growing and a multiplicity of fascinating results is emerging. This holds the challenge to further ensure integration of the individual outcomes within the Work Packages and disciplines. Therefore, after the first step of having one session of integrating talks at the Greifswald workshop, we now do the next step and change the workshop format from a Work Package-based one to five thematic sessions. Each of these sessions will start with a multi-authored incentive talk followed by extended poster sessions for discussions. Overlaps of disciplines and Work Packages are explicitly desired.

We are grateful to the Helmholtz Association for funding ICLEA within the Initiative and Networking Fund, which enables us not only to come together for this workshop but beyond that provides major benefits for our scientific perspectives and initiates new personal contacts and friendships. Even if we will still have this funds available for 1.5 more years, it is now time to think about the future of ICLEA and this workshop is a good occasion to start this discussion.

We want to thank all participants for their inspiring contributions and results summarized in this volume and wish all of us fruitful discussions, new ideas and collaborations, good weather for the field day and an enjoyable time in Poland.

Achim Brauer (ICLEA Spokesman), Markus Schwab (ICLEA Coordinator)

Mirosław Błaszkiewicz & Piotr Lamparski (Toruń Organization Committee)

Chapter I: Program Overview

Venue: Hotel Kawallo
Address: Leonów 7A, 09-533 Słubice, Poland

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	10:15-10:30 Coffee Break
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Theme C High resolution climate reconstruction / WP4

Decadal resolved leaf wax records reveal spatial patterns of hydrological and climatic changes during the onset of the Younger Dryas in western and eastern Europe

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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. This is especially useful to study subtle temporal differences in the consequences of mechanisms and feedbacks during abrupt climatic changes such as the Younger Dryas over larger spatial areas.

To decipher the drivers of ecological change across the Allerød/Younger Dryas transition in Europe, we analyzed leaf wax biomarkers from Trzechowskie paleolake [TRZ; northern Poland] and Meerfelder Maar [MFM; western Germany, Rach et al., 2014], covering in total a ca. 800 km east-west gradient. Samples were taken in 10 year intervals across the onset of the Younger Dryas, with the Laacher See Tephra (12,880 yrs BP) as a common anchor point for age-calibration.

In TRZ, between 12,750 and 12,600 yrs BP, changes in the ratio of terrestrial *n*-alkanes indicate a gradual transition from a tree-dominated lake catchment (*Pinus*, *Betula*) to an environment mainly covered by *Juniperus* and grasses, which is in agreement with palynological data (Fig. 1). δD values of *n*-alkanes indicate a rapid cooling and/or a change of moisture source together with a slight aridification (change of $\varepsilon_{terr-aq}$: ca. 10‰) between 12,680 and 12,600 yrs BP. This is synchronous to a more rapid and strong aridification (change of $\varepsilon_{terr-aq}$: ca. 25‰) inferred for the beginning of the Younger Dryas at MFM [Rach et al., 2014], but ca. 170 yrs after the inferred onset of cooling at MFM and the NGRIP ice core at 12,850 yrs BP [Rasmussen et al., 2006].

We infer that hydrological changes at the onset of the YD were strongest and most abrupt in western Europe, where we find a substantial increase in aridity occurring over just 80 years, resulting in widespread environmental changes. Further to the east the increase of aridity is less pronounced and a cooling signal and/or change of moisture source (drop of δD) is observed later. The different temporal succession and impact of hydrological and climatic changes in eastern Europe could be related to the influence of the Fennoscandian ice sheets 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) and the Helmholtz Climate Initiative REKLIM Topic 8 "Rapid climate change derived from proxy data" of the Helmholtz Association.

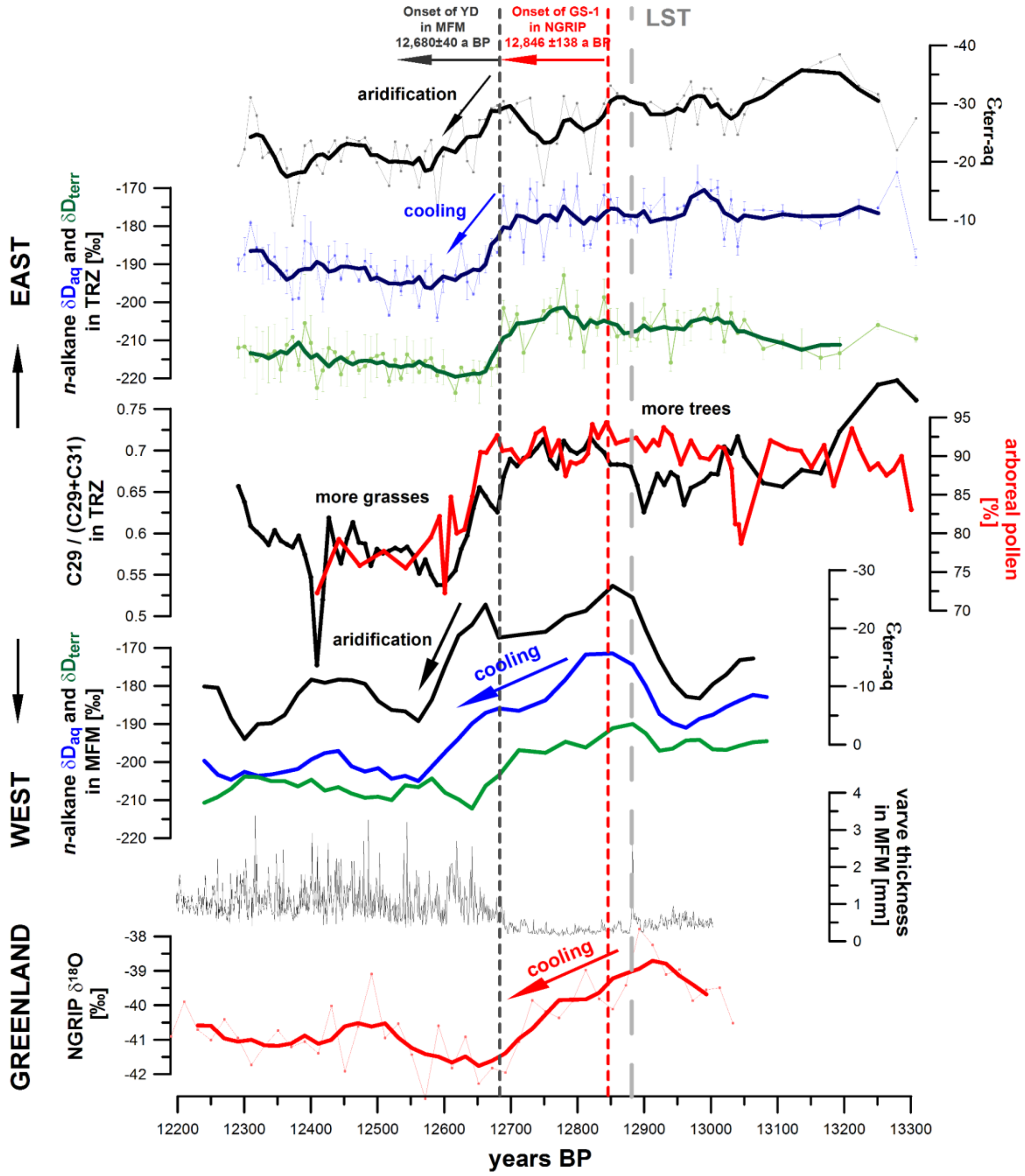

Fig. 1: Proxy data comparison between Trzechowskie Paleolake (TRZ), Meerfelder Maar (MFM) and Greenland icecores (NGRIP).

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Theme A Monitoring / WP5

The Late Glacial effect on the Dnieper River Valley formation

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The structure of the Dnieper River valley near Orsha City (in the East of Belarus) was in some extent reflected in investigations by a number of researchers of Belarus (Goreckij, 1970; Isachenkov, 1964; Kvasov, 1975 etc.). However, some questions concerning genesis, age and evolution of the Dnieper River valley still remain controversial.

At the studied area the Late Glacial maximum (Orshanskaya Stage) was located on the right bank of the Dnieper River. The Middle Quaternary sediments with a height about 200 m a.s.l. are located on the left bank. The Late Glacial didn't overcome this barrier. Along the edge of the glacial barrier, an extensive area of melt water streams was formed, situated in the area of the present day Dnieper River. This area was a part of the marginal flow along the entire edge of the Late Glacial. Fluvioglacial sediments (sandurs / outwash plains, fans, deltaic sediments etc.) are accumulated (Fig. 1). Their maximal elevation is about 200 m a.s.l. After the glacial retreating there has happened a restructuring of the hydrographic regime in this region. Proglacial Lake Luchosinskoje and Lake Surozskoje were formed in lowlands to the north of Orsha City. Their maximal altitude was less than 185 m a.s.l. (Ilin, 1967). Additionally, by runoff hollows connected lakes were formed in the East (Dokuchaev, 1878; Isachenkov, 1964). With a further glacial retreat to the Braslavskaya stage the proglacial Lake Polockoje was formed. This lake was wildly developed, with a maximal elevation of less than 165 m a.s.l., in the north of Belarus.

Proglacial sedimentary, fluvial and tectonic conditions are reflected in the morphology of the Dnieper valley and structure of the alluvial sediments. Fluvioglacial sediments (200 m a.s.l.) are genetically and morphologically conjugated with the terrace 2 of the Dnieper River. This deposition corresponds to the time of the Late Glacial Maximum and the beginning of the deglaciation (about 22 000 – 18 000 BP), confirmed by absolute dating (Zimenkov, 1989). Alluvial and fluvioglacial sediments, corresponding to the second terrace development, are limited in the forms of narrow strips (Fig. 1). With the lowering of lake levels there is likely a decrease of the erosion basis. This, together with glacio isostatic raising led to the eroding of Dnieper River and formed the terrace 1. According to absolute dating the lower part of terrace 1 has an age of about 17 150 BP (Zimenkov, 1989).

After the disappearance of the proglacial 180 m and 160 m lakes the hydrographic pattern on the studied area gradually acquired a modern shape. The water systems of the Western Dvina River and Niemen River were evolved and from the system of the Dnieper River separated. Finally, the modern eastern river flow in the valley of the Dnieper River was established. The channel has eroded and the flood plain about 7 m was formed. Geographically, there was a turn of the Dnieper River to the south near Orsha City.

Studies have shown that latitudinal part of the Dnieper River (to the east of Orsha City), owes its origin, morphology and structure of the alluvium to the Late Glacial. The existence of the studied valley of the Dnieper River at the Middle Quaternary is debatable.

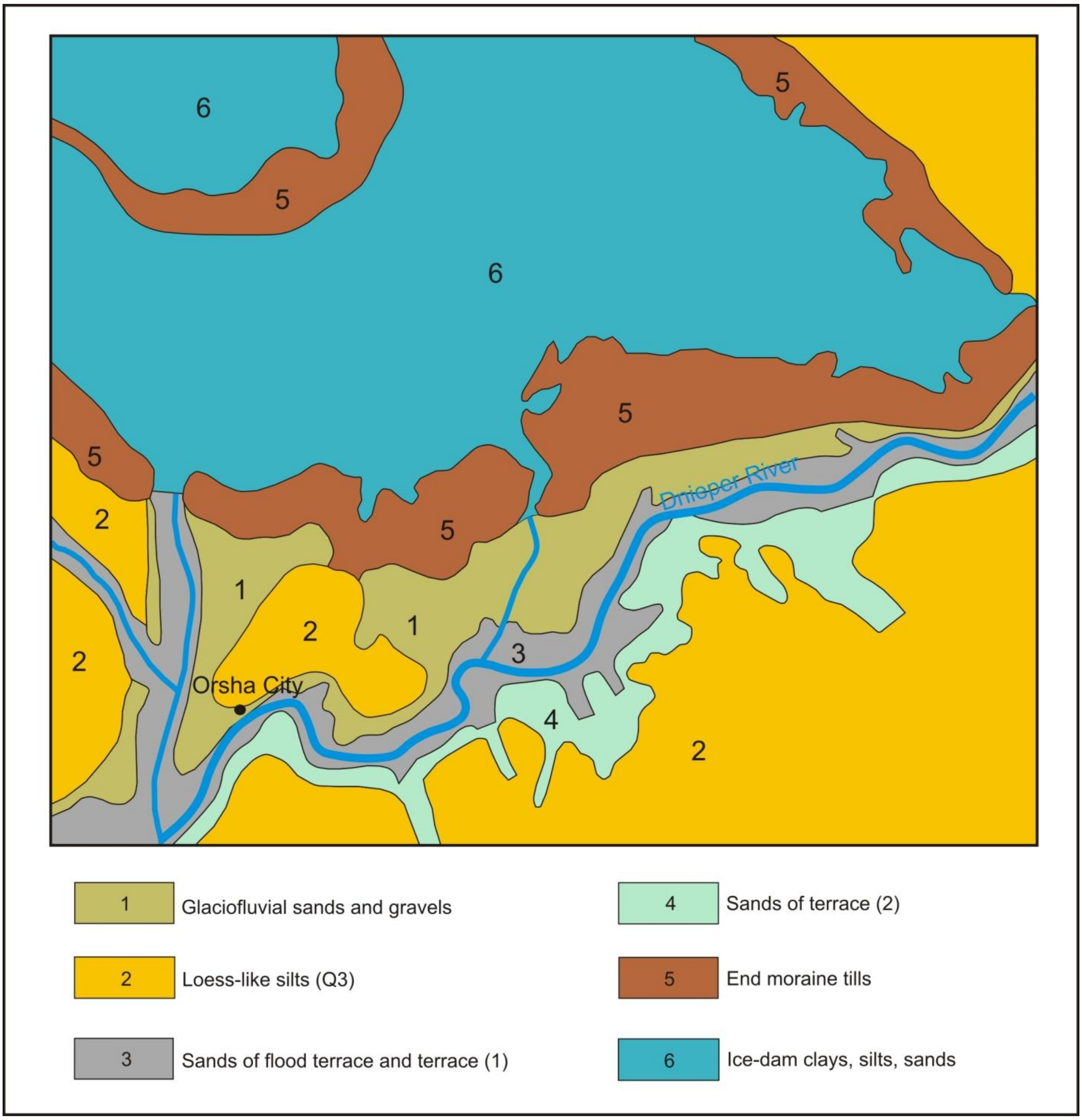

Fig. 1: Geological scheme of the Valley of Dnieper River near Orsha City (scale appr.: 1:100 000).

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Theme B Present and Palaeohydrology / WP1

The annual maximum daily rainfall in the vicinity of Czechowskie Lake

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With this work the author sets to determine the variability of the annual maximum daily rainfall, as well as to calculate its probable values with certain exceedance probability. The calculations are based on data series obtained from five precipitation stations located in the vicinity of Lake Czechowskie (Fig. 1). The time span concerned embraced the period of 1952 – 2014 (for the Czarna Woda station the data covered the periods 1961 – 1972 and 1983 – 2014, and for the Kościerzyna station it was 1953 – 2014). All the data used for the following calculations were provided by the Institute of Meteorology and Water Management in Warsaw, Poland.

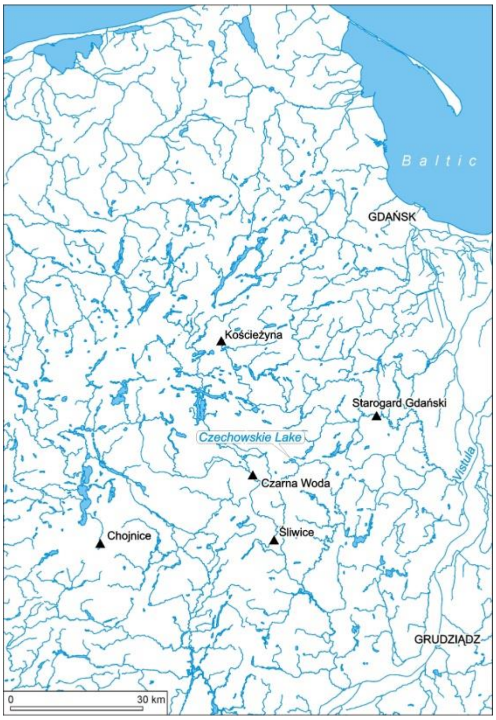

Fig. 1: Research area and precipitation station used for the study.

Rainfall variability. The mean value of the annual maximum rainfall for the analysed period ranged between 34.9 mm in Czarna Woda and 37.4 mm in Starogard Gdański. The lowest values were, to a large extent, similar to one another and ranged from 14.7 mm in Śliwice to 17.5 mm in Starogard Gdański (Fig. 2). At the same time, the highest values of the maximum daily rainfall and the time of their occurrence varied significantly. The highest values of the annual maximum daily rainfall in the examined period were observed in Kościerzyna on June 6, 1998 and stood at 100.8 mm, in Śliwice on June 20, 1969 – 89.1 mm, in Chojnice on July 19, 1974 – 84.6 mm, in Starogard Gdański on July 9, 2001 – 78.1 mm and the same day in Czarna Woda – 73.6 mm.

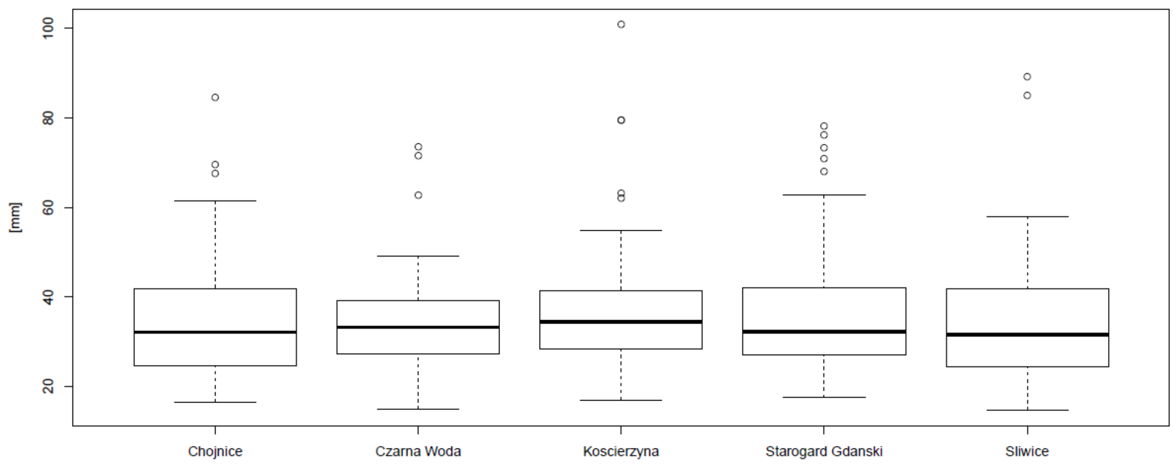

Fig. 2: Box plot for the data distribution of the annual maximum daily rainfall in the analysed precipitation stations.

As regards the yearly cycles, it was from April to October that the highest daily rainfall occurred, although it also happened in November, December, or even January (Chojnice). Most frequently, however, it was observed in the months of June, July and August (Fig. 3).

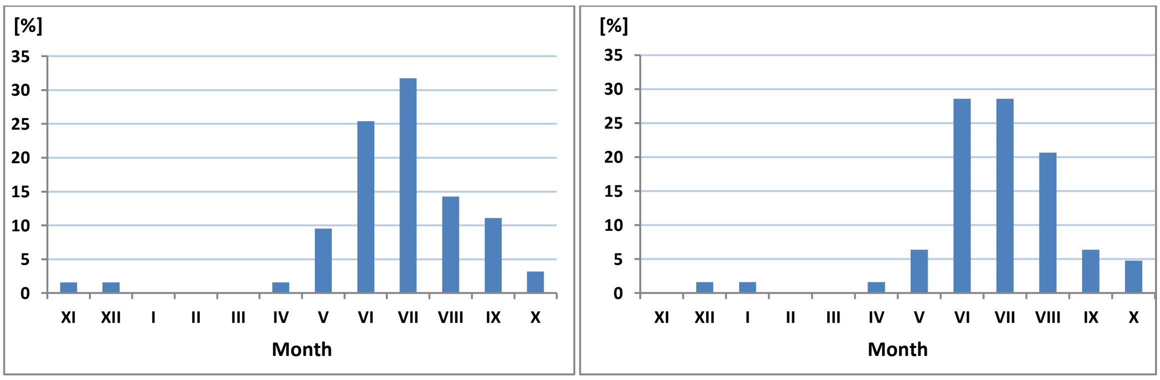

Fig 3. Frequency of occurrence [%] of the annual maximum daily rainfall in particular months of the hydrological year in Śliwice (on the left) and in Chojnice (on the right).

Quantiles of the maximum rainfall. The following procedure to determine the quantiles of the annual maximum daily rainfall was applied. First, the empirical distribution for the series of data from each station was determined. Next, the analysed series of precipitation were tested for the theoretical probability distribution matching the empirical distribution. It was assumed that the random properties of the maximum values can be represented by the following types of probability distributions: log-gamma, gamma, log-normal, Weibull (Krężałek K., et al., 2013). The best fit of the theoretical probability distributions to the empirical distributions for the series from each station was determined with the use of Akaike Information Criterion (AIC) (Mitosek H.T., 1993). The obtained AIC results point at the log-gamma distribution to be the best fitting to the empirical one, the finding which is true for each analysed precipitation station. The values of 50%, 10%, 5% and 1% quantiles are given in the table 1. The values of quantiles determined on the basis of the log-gamma theoretical distribution are characterised by high levels of similarity in all investigated stations but one in Czarna Woda, which might be a consequence of the sample size i.e. a shorter period accepted for the analysis.

Tab. 1. Maximum, minimum, mean and probable with a particular exceedance probability annual maximum daily rainfall.

Precipitation Station	Annual maximum daily rainfall [mm]			Annual maximum daily rainfall [mm] for a specific exceedance probability			
	min	max	mean	50%	10%	5%	1%
Chojnice	16.5	84.6	35.1	32.4	52.3	60.3	79.6
Kościerzyna	17.0	100.8	37.2	34.3	55.7	64.4	85.3
Starogard Gdański	17.5	78.1	37.4	34.4	56.0	64.8	86.1
Śliwice	14.7	89.1	35.3	32.4	53.6	62.3	83.6
Czarna Woda	14.9	73.6	34.9	32.9	49.6	56.0	70.8

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Theme D Late Glacial landscape change / WP5

Periglacial conditions as a factor of relief transformation in the area of the Last Glaciation, northern Poland

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For a long time the author has been conducting geomorphological research in Eastern Pomerania, which was entirely covered by the Late Weichselian ice sheet. In the central part of this area a distinct marginal zone associated with the Pomeranian Phase developed during the ice sheet recession. In the course of this research, a lot of evidence was gathered pointing to the development of permafrost after the ice sheet disappeared from the described area. The most important of them include thermal contraction cracks, frost-related transformation of soil, oriented kettle-holes on the outwash plains and long-term preservation of basins by blocks of buried dead ice.

Oriented kettle-holes were documented in the vicinity of Starogard Gdański on the outwash plain associated with the Pomeranian Phase of the Last Glaciation. These forms are composed of specific riverbend basins stretching over nearly five km, concordant with the direction of meltwater runoff. The deepest parts of depressions are filled with lacustrine deposits and peat of thicknesses of up to 6 m. Oriented kettle-holes were preserved by ice of the icing type, and are an important morphological indicator of the permafrost occurrence.

A similar paleogeographical meaning, documenting the long-term presence of icing, is also expressed by post-sedimentation deformations occurring in the sediments filling the braided paleo-channel developed within a low outwash level, at the mouth of the valley of the Wierzyca. Deformation structures found there, mainly in the form of a network of antithetic faults, occur only in the sandy-gravel deposits filling the paleo-channel, without the continuation in the sediments in which the channel was formed. These deformations were created as a result of melting of icing, covered by fluvioglacial deposits.

Another evidence of permafrost presence are periglacially transformed soil profiles within the topmost part of sediments of the proximal part of the high outwash level near Stara Kiszewa, associated with the maximum range of the ice sheet of the Pomeranian Phase. What is documented there is a well-developed sequence of polygenetic frost transformation, with characteristics of periglacial aggradation and degradation forming a clearly marked perstruction zone. They are treated as a relic of the permafrost active layer.

An important argument informing about the development of permafrost are also thermal contraction cracks. In the research area they were found e.g. in the area of Błędno (foreground of the Pomeranian Phase). There they are developed in the outwash area, where aeolian phenomena took place in the Younger Dryas.

In addition to the above indicative periglacial phenomena documenting long-term permafrost, a particularly important argument informing on one side of its presence, and on the other on the time of its disappearance, is the long-term preservation of lake basins with buried blocks of ice. Documented preservation of dead ice blocks, in some basins lasting up to the Preboreal, leads to the conclusion that the ultimate disappearance of permafrost in the research area was only at the beginning of the Holocene

The research in the area of Northern Poland clearly indicates permafrost encroachment over the areas uncovered by the ice sheet during its recession. Traces of periglacial transformation occur both in the immediate foreland and in hinterland of the Pomeranian Phase. Very deep permafrost coverage of up to at least 100 m, as indicated by the presence of ice buried in deep subglacial channels, as well as the long-term preservation of buried dead ice blocks, reaching in some cases up to 5 000 years, suggest that in the area of the Last Glaciation the relics of the permafrost deriving from the anaglacial phase of the ice sheet development might have merged with the encroaching permafrost from the recession phase. In the light of the research, in such a model one should also take into account a very important role of buried dead ice blocks in the morphogenesis of the Last Glaciation areas. The rate of permafrost degradation, in addition to the obvious global climatic factors, largely depended on local conditions and, above all, on the hydrogeological conditions.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367).

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).

Invited talk

The archaeological landscape of Lake Czechowskie region

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For archaeologists, analyses of a human activity dynamic, recorded in varved sediments are of great importance, because they serve as certain references to reconstructions made on relics of human culture. Lake Czechowskie varved sediments are such a reference (Obremska at al.). The lake is located in Northern Poland in Pomerania in Tuchola Forest. The sediments were examined in regard to a human factor from 50 BC to 550 AD.

To define the density of a settlement in Lake Czechowskie region from younger pre-Roman period to Migration period (i.e. from 2nd century BC to the middle of 6th century AD), a query of archaeological sources was carried out in archives and literature. After an initial recognition, it was decided to map the ancient settlement in a radius of about 35 km from the lake of our interest. The map of the area in question show an uneven distribution of the settlement (Fig. 1). Such distribution derives from two main factors: the lack of systematic archaeological surface surveys and the influence of contemporary environment, in particular, a forestation for the availability of archaeological sources.

Lake Czechowskie and its immediate vicinity, by currently available, partial archaeological data, are located in the area almost completely devoid of traces of settlement in the period under consideration. The lake is located almost exactly in the middle between two large clusters of settlement which there are about 30 km away from each other. In the west, Czersk (Fig. 1: 6) and Brusy (Fig. 1: 3) “islands” form the first cluster with such well-known sites as Odry (Fig. 1: 7) and Leśno (Fig. 1: 3). The eastern cluster is in Skarszewy (Fig. 1: 9) and Starogard Gdański (Fig. 1: 10) regions (Grabarczyk 1997; Walenta 2009).

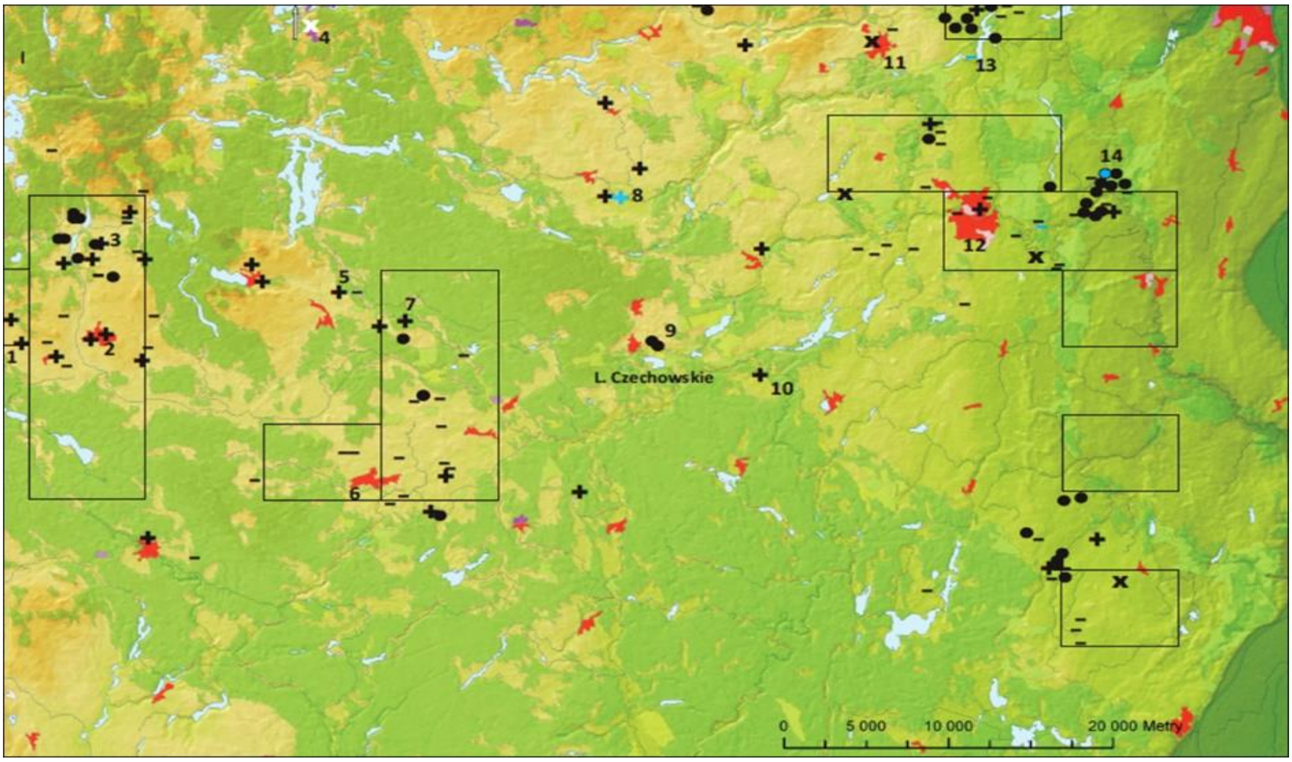
Within about 13 km radius from Lake Czechowskie there are three archaeological sites dating from 50 BC after 550 AD, i.e. from the time interval analyzed on laminated sediments of the lake. One of the sites - in Osowo Leśne (Fig. 1: 9) is a poorly examined cemetery that cannot be dated earlier than from the middle of the 2nd century AD to the beginning of 3rd century. The last two sites (settlements from Roman period) have been lately discovered in Iwiczno (Fig. 1: 10).

The earliest finds from the mapped area (within the currently accepted time frame for the study of varved sediments, i.e. from 50 BC to 550 AD) are known only from three sites: Chwarzno (Fig. 1: 8), Brzeźno Wielkie (Fig. 1: 14) and Obozin (Fig. 1: 13). The sites provided a few remains of Oksywie culture - only small amount of pottery that can be dated generally to the last 2 centuries BC. Next archaeological objects cannot be dated earlier than to the last quarter of the 1st century AD (Walenta 2009, p. 77-78, 87). The appearance of the settlement here at the time is usually related to the influx of people of Scandinavian origin - Goths, identified with the Wielbark culture (Kokowski 2007, p. 51). The widest range and the highest density Wielbark culture settlement reached in a mapped area in the 2nd half the 2nd century AD to the first decades of the 3rd century (Grabarczyk 1997; Walenta 2009). In this region there is much less sites that can be dated to the period from about 230 to about 300 AD. These include cemeteries in Cisewie (Fig. 1: 5), Odry and Wielkie Chełmy (Fig. 1: 1). Probably from the last quarter of the 3rd century AD up to half of the 6th century AD, i.e. to the end of the Migration Period, traces of human activity in mentioned area, apart from sporadic cases like stray find in Cisewie and treasure from Łubiana (Fig. 1: 4; Mączyńska 2006), cannot be distinguished on the grounds of cultural objects.

Partially contradictory conclusions from archaeological and pollen data result from incomplete archaeological sources. In this case, the results of palynological analysis of exactly dated sediments from varved lakes give an invaluable help for the reconstruction of the image of settlement in prehistory.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367)

Fig. 1: Settlement distribution in Lake Czechowskie region from 50 BC to 550 AD.



- stray find (younger pre-Roman period); - stray find (Roman period); ● - settlement (younger pre-Roman period); ● - settlement (Roman period); + - grave (younger pre-Roman period); + - cemetery (Roman period); x - hoard (Roman period); x (white mark) - hoard (Migration period); Rectangles mark areas of systematic archaeological prospection.

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Theme E Human impact / WP5

The role of the 19th century encyclopedic works as sources for the study on the reconstruction of the range of hydraulic structures' development of rivers in Poland

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Among the many types of data sources for the reconstruction of the changes of the environment a very important role is played by the descriptive and statistical sources, showing the extent of human impact on the study area. Such sources include the first monographic studies of towns and regions, as well as reference works. The first such studies were created in Europe in ancient times. Over the centuries, they became more and more detailed and included smaller settlement units.

"*Słownik geograficzny Królestwa Polskiego i innych krajów słowiańskich*" in the form of monthly brochures was published in the Polish language in Warsaw in the years 1880-1895 (supplementary volume in 1900-1904). The chief editor and originator of the *Słownik* was Filip Sulimierski. The idea was to prepare a dictionary of the information and tourism character and describe the areas formerly included in the Republic of Poland in the pre-1772 borders, i.e. before the partitions of Poland. In practice, it referred not only to these areas, but also to the neighboring areas.

The 15 volumes of the *Słownik* contain approx. 15,000 pages and 200,000 entries (Parucki, 1955). They refer to regions, towns, villages and hamlets, as well as rivers, lakes, ponds and mountains. These entries are very diverse in terms of the content and details, as they were developed on the basis of the materials sent by correspondents of different backgrounds, academic preparation and knowledge of the region. The editorial work of the *Słownik* was assisted by 685 people, and the entries were written by about 150 people (Konarski, 1995).

The reason for the preparation of the *Słownik* was the lack of a detailed, comprehensive and current geographical description of the Polish lands until the second half of the nineteenth century. The specific value of the *Słownik* is the fact that many sources on the basis of which its entries were formed were later lost or destroyed. This applies mainly to smaller towns and industrial settlements. Documents relating to the editing process of the *Słownik*, stored by the Polish Tourism Society in Warsaw, were burned in September 1939, at the beginning of World War II. Hence, this work is an important source of geographical, historical, economic, demographic and biographical information (Targowski, 2000).

The *Słownik* is often the first and almost mandatory source of information for a geographer conducting spatial analyses in Poland in a historical perspective. Particularly valuable is the information relating to the level of economic development of individual settlements. Probably all production facilities, together with the information on the energy source, type and number of devices as well as the production volume are included.

The *Słownik* was used as an important source of information in the research on the reconstruction of the management of the Polish rivers. It shows the changes in the hydropower use of rivers immediately after the industrial revolution (the invention of the water turbine and steam engine). The first stage was the preparation of a database of all the water mills and other factories that used the energy of flowing water listed in the *Słownik*. It includes about 12,800 references to about 20,000 objects of this type (Fig. 1). Furthermore, the database was expanded to include information on all artificial reservoirs (fish ponds, mill ponds, other ponds, eel traps), which provide the insight into the changes in the natural fluvial conditions of river systems. In the subsequent stages of the research, all the repetitions will be removed and the comparative analysis with the data based on other sources, mainly mapping, will be carried out.

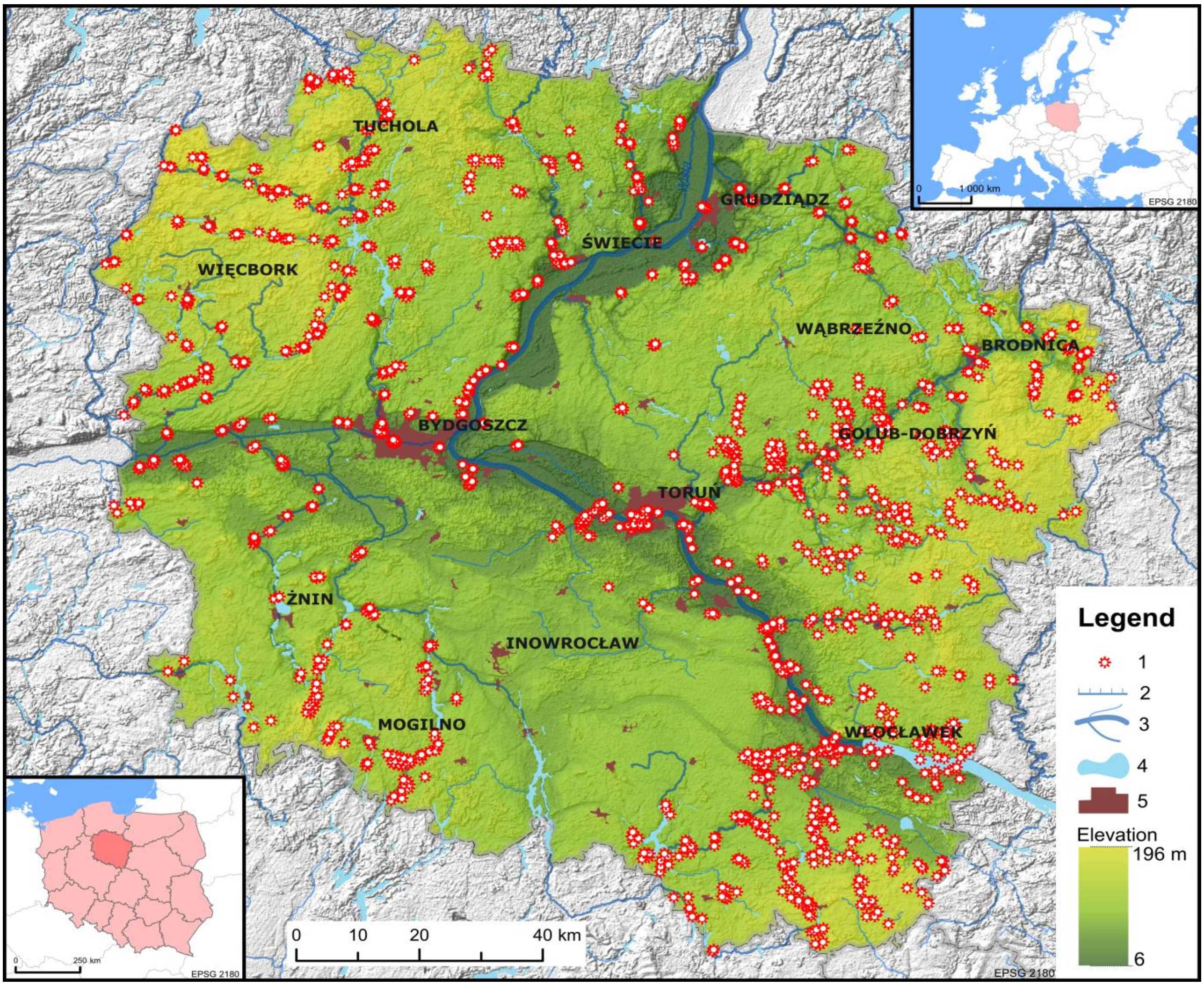

Fig. 1: Distribution of watermills within the Kujawsko-Pomorskie region before the Industrial Revolution.

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).

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Theme E Human impact / WP5

For understanding former cultural landscape - preserved windmills and watermills in open-air museums in Poland

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For centuries watermills and windmills were an important part of the economy of Europe. They were also a very important element of the landscape. In the 1920s the historical value of mills was noted, and thus the actions to preserve them were undertaken (Prarat, in press).

To date, these monuments have not been fully recognized. What remains unknown is the number of preserved buildings. Therefore, the aim of this presentation is to present the main issues related to the protection of mills, mainly in open-air museums. These activities are to be shown against the history of milling in the area of northern Poland, with a focus on the greatest period of their development, i.e. the nineteenth century.

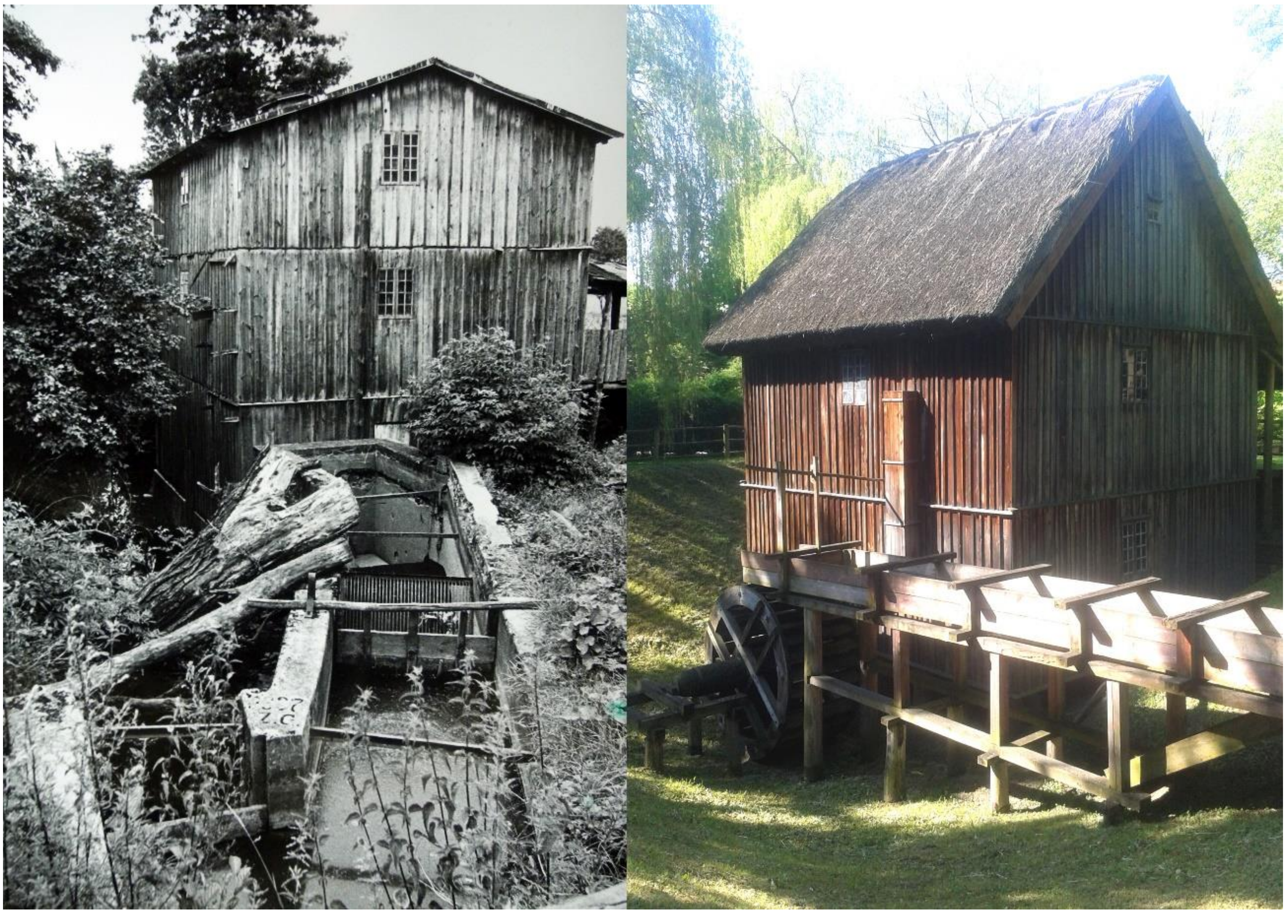

Fig. 1: Watermill from Strzygi with: turbine (left - 1960s) and waterwheel (right - 2014). At the moment in the Ethnographic Museum in Toruń (photos: Archive MET, sign. I-1306-90; K. Kopczyński, 2014).

After World War II, there was a total collapse of mills in Poland. Single small objects functioned until the 1960s (Fig. 1). Since the late 1980s the individual owners of old mills began to redevelop small hydropower plants (Brykała, 2009; Jagiełło, 2014). To date, windmills situated outside the museums are already in ruins.

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Preserved mills account for about 15% of the stock of the late nineteenth and early twentieth century. We have in Poland over 70 open-air museums and ethnographic parks (skanseny.net), in which only 23 windmills and 6 watermills are located. They are in a relatively good technical condition, but very few objects are fully technically operational (Prarat, 2014).

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).

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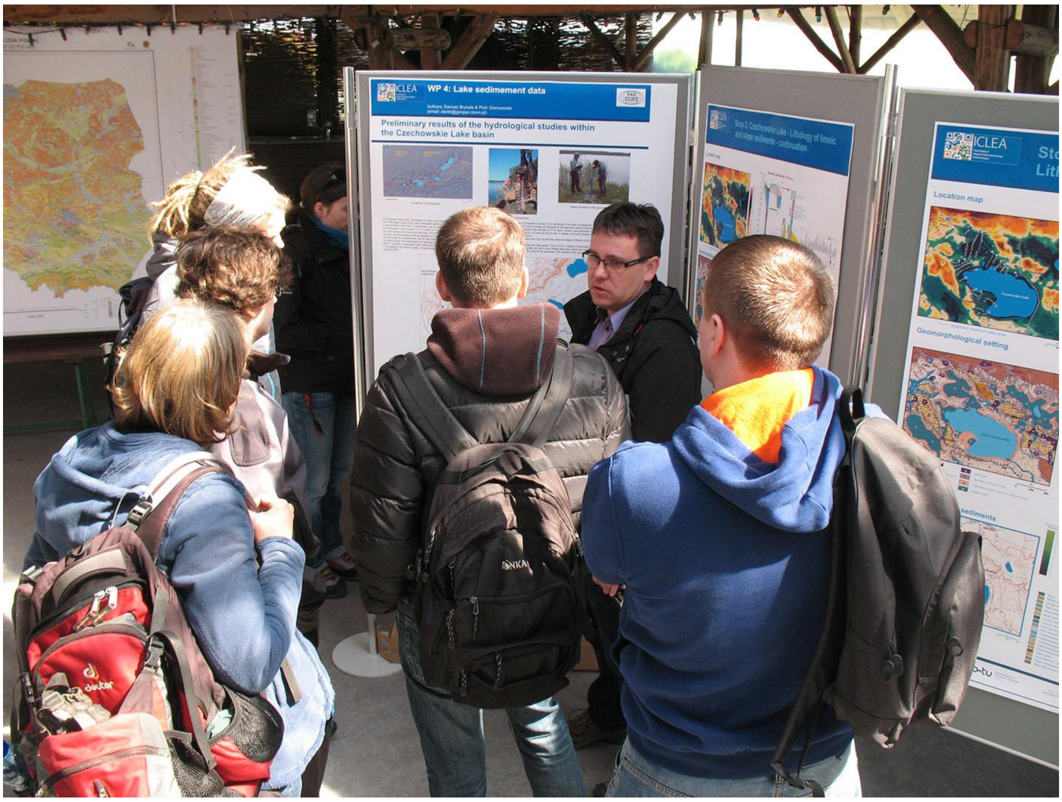

Discussion of results during the poster session at Lake Czechowskie, 2nd Annual ICLEA Workshop 2013 in Stara Kiszewa, Poland (photo Lamparski, PAS).

Theme E Human impact / WP3 & WP5

Charcoal kiln relicts – a favorable site for tree growth?

Buras, Allan[1,*]; Hirsch, Florian[2]; Cruz Garcia, Roberto[1]; van der Maaten, Ernst[1]; Takla, Melanie[3]; Räbiger, Christin[1]; Schneider, Anna[2]; Simard, Sonia[4]; Heinrich, Ingo[4]; Helle, Gerd[4]; Raab, Alexandra[3]; Raab, Thomas[2] & Wilmking, Martin[1]

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Soils with incompletely combusted organic material (aka 'black carbon') are considered fertile for plant growth. Considerable enrichment of soils with black carbon is known from Chernozems, from anthropogenic induced altering of soils like the 'Terra Preta' in South America (e.g. Glaser, 2001), and from charcoal kiln relicts. Recent studies have reported a high spatial frequency of charcoal kiln relicts in the Northeastern German lowlands (Raab et al., 2015), which today are often overgrown by forest plantations. In this context the question arises whether these sites are favorable for tree growth.

Here we compare the performance of 22 *Pinus sylvestris* individuals – a commonly used tree species in forestry – growing on charcoal kiln relicts with 22 control trees. Growth performance (height growth and diameter growth) of the trees was determined using dendrochronological techniques, i.e. standard ring–width measurements were undertaken on each two cores per tree and tree height was measured in the field. Other wood properties such as annual wood density and wood chemistry were analyzed.

Our results (see Fig. 1) indicate that trees growing on charcoal kiln relicts grow significantly less and have a significantly lower wood density in comparison with control trees. Specific chemical components such as Manganese were significantly higher in kiln trees.

These results highlight that tree growth on charcoal kiln relicts is actually hampered instead of enhanced. Possibly this is a combined effect of differing physical soil properties which alter soil water accessibility for plants and differing chemical soil properties which may negatively affect tree growth either if toxic limits are surpassed or if soil nutrient availability is decreased. Additional soil analyses with respect to soil texture and soil chemistry shall reveal further insight into this hypothesis. Given the frequent distribution of charcoal kiln relicts in the German lowlands (e.g. Raab et al., 2015) and their potentially adverse effects on tree growth, these findings elucidate a yet unknown impact of past human activities on recent biological processes. Detailed studies of wood-anatomy and stable isotopes shall help to better understand the observed kiln-specific reactions of pines. To test whether other tree species also are affected, we recently sampled each 15 *Quercus rubra* specimen using a similar design.

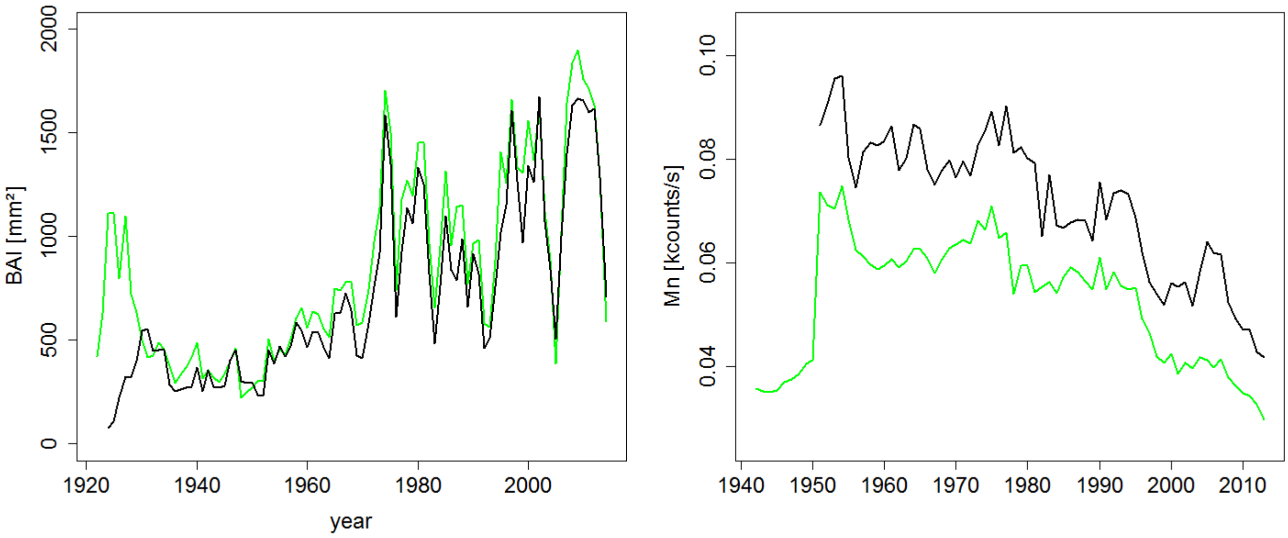

Fig. 1: Left: Basal area increments (BAI) of kiln trees (black line) are significantly lower than BAI of control trees (green). The average BAI of kiln trees is only 86 percent of control trees' BAI. Right: In contrast Mn concentrations of kiln trees are significantly higher in comparison to control trees (on average 31 percent higher concentrations).

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367).

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Theme C High resolution climate reconstruction / WP3

Tuning the voices of a choir: Introducing a new tool to enhance the signals that are stored in tree-ring archives

Buras, Allan[1,*]; van der Maaten, Ernst[1]; Scharnweber, Tobias[1]; Simard, Sonia[2]; Heinrich, Ingo[2]; Helle, Gerd[2]; van der Maaten-Theunissen, Marieke[1]; Eusemann, Pascal[1]; Schnittler, Martin[1] & Wilmking, Martin[1]

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Tree-ring based archives, such as ring-width or density, are frequently used proxies for the reconstruction of past environmental parameters at annual resolution (e.g. Fritts, 1976). In terms of tree-ring width based reconstructions, ring-width measurements are usually acquired from several (often at least 20) trees growing under similar conditions (the 'choir') which are then averaged to a so-called master chronology (the 'voice'). Theoretically, this averaging evens out the individual-specific noises that act upon single trees. A statistical measure which frequently has been assumed to reflect the quality of tree-ring based reconstructions is the so-called expressed population signal (EPS, Wigley et al., 1984). Investigators have often sought to maximize EPS independent of individual tree reactions, but rather aiming at large sample sizes, which increase the value of EPS. Although studies have shown that the environmental signal of master chronologies may be enhanced in comparison with single trees (e.g. Carrer, 2011), ecological theory suggests that depending on particular site conditions (e.g. dry vs. wet sites) different trees within populations may react on different environmental drivers, i.e. a gradient of responses exists within the population. Detecting and accounting for these gradients in respective groups may help to lower the noise in the resulting averaged chronologies and therefore potentially enhance their strength as a proxy in terms of transfer functions.

As a contribution to this particular topic, we present a new methodological approach - the Principal Component Gradient Analysis (PCGA), designed to identify variable growth responses in tree populations. To test its performance, we applied PCGA to various datasets which express different gradients of individual growth responses. Among these datasets were pseudo-populations, i.e. artificially generated dendro-data for which population gradients are known. Pseudo-populations help to estimate whether a statistical approach successfully detects population gradients. PCGA performance was compared to other statistical approaches which have earlier been used in this context.

For all tested datasets PCGA resulted in a continuum of tree growth responses and was thus able to identify individual growth responses. To allow for a definition of groups based upon PCGA, we calculated expected EPS using subsampling within Monte Carlo simulations, which allows for predicting the EPS of a population subsample. If individual growth responses existed, EPS of PCGA defined subsamples was higher as expected from the Monte Carlo prediction. PCGA detected population gradients where other approaches failed (Fig. 1).

Average chronologies of groups defined by PCGA expressed stronger responses to particular environmental parameters and thus a higher potential for environmental reconstruction in comparison with the overall, site based, master chronology. Based on our analyses we conclude that PCGA allows for a more precise tuning of tree-ring based reconstructions and therefore is able to enhance the precision of estimates on past environmental conditions. In contrast, a rigorous maximization of EPS as frequently undertaken in many studies may even decrease the quality of environmental reconstructions if individual growth responses exist. As a consequence we suggest the application of PCGA prior to tree-ring based reconstructions to maximize the precision of paleo-environment reconstructions.

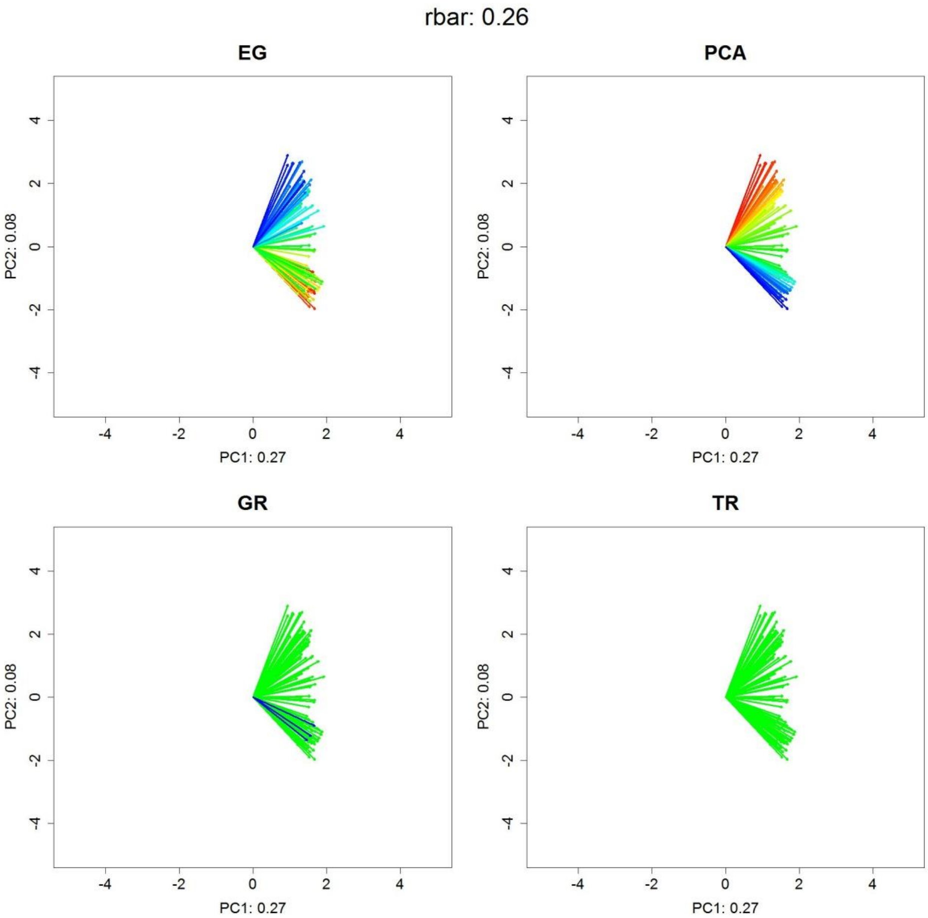

Fig. 1: Comparison of PCGA (top right), GR (bottom left), and TR (bottom right) approaches for detecting population gradients within a pseudo-population (mean inter-series correlation aka rbar: 0.26). The top-left panel (EG) shows the known population gradient. Rainbow colors indicate the spectrum of the population gradient. I.e. PCGA is able to detect the population gradient as shown in EG (the inversion of color arrangement in comparison to EG is not meaningful) whereas GR and TR fail.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367).

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Theme C High resolution climate reconstruction / WP4

Solar cycles and depositional processes in annual ^{10}Be from two varved lake sediment records

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The potential of Beryllium 10 (^{10}Be) in annually laminated (varved) lake sediments for solar activity reconstruction is, to date, largely unexplored. It is hypothesized that ^{10}Be contents in sediments from well-chosen lakes reflect the solar modulated atmospheric radionuclide production signal. However, so far solar activity reconstruction from ^{10}Be in varved lake sediments is hampered due to a lack of detailed knowledge about the process chain from production in the atmosphere to deposition on the lake floor.

^{10}Be concentrations ($^{10}Be_{con}$) were measured at annual resolution from varved sediment cores of Lakes Tiefer See (TSK) and Czechowskie (JC) for the period 1983-2009 (~solar cycles 22 and 23). Calibrating the $^{10}Be_{con}$ time-series against complementing proxy records from the same archive as well as local precipitation and neutron monitor data, indicating changes in atmospheric radionuclide production, allowed (i) identifying the main depositional processes and (ii) evaluating the potential for solar activity reconstruction.

$^{10}Be_{con}$ in TSK and JC sediments are significantly correlated to varying neutron monitor counts (TSK: r=0.5, p=0.05, n=16; JC: r=0.46, p=0.03, n=22) (Figure). However, the further correlations with changes in organic carbon contents in TSK as well as varying organic carbon and detrital matter contents in JC point to catchment specific biases in the $^{10}Be_{con}$ time-series. In an attempt to correct for these biases multiple regression analysis was applied to extract an atmospheric ^{10}Be production signal ($^{10}Be_{atmosphere}$) (Figure). To increase the signal to noise ratio a ^{10}Be composite record ($^{10}Be_{composite}$) was calculated from the TSK and JC $^{10}Be_{atmosphere}$ time-series. $^{10}Be_{composite}$ is significantly correlated to variations in the neutron monitor record (r=0.49, p=0.01, n=27) and matches the expected amplitude changes in ^{10}Be production between solar cycle minima and maxima of about 35% (Fig. 1).

This calibration study underlines the large potential of ^{10}Be in varved lake sediments for tracking the atmospheric radionuclide production signal. However, our data also point to, partly site-specific, limitations stressing the importance of well-chosen lake/catchment settings for solar activity reconstruction.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367).

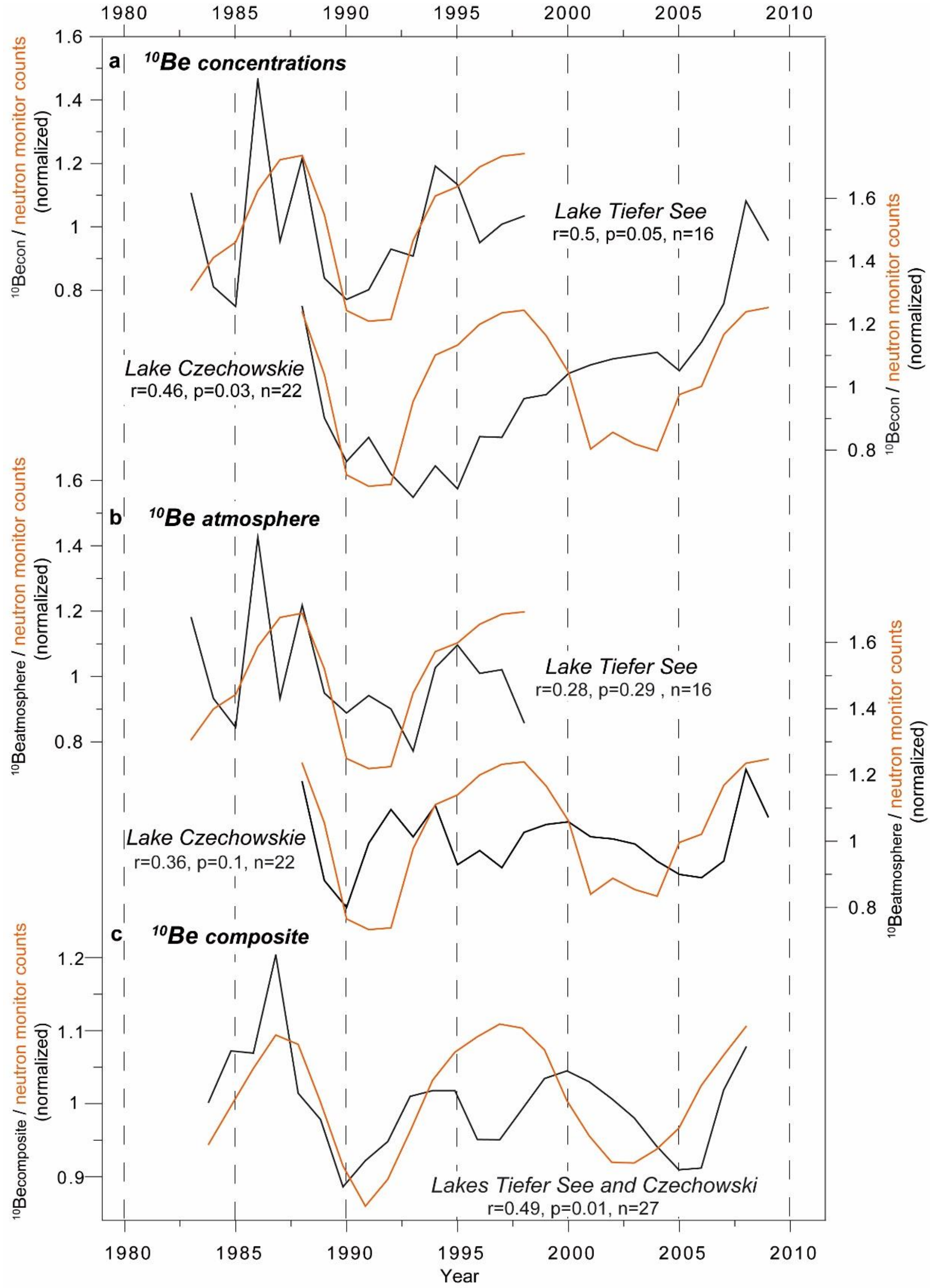

Fig.1: (a) ^{10}Be concentrations ($^{10}Be_{con}$) and (b) calculated ^{10}Be atmosphere ($^{10}Be_{atmosphere}$) from Lakes Tiefer See and Czechowskie compared to neutron monitor counts. (c) ^{10}Be composite record ($^{10}Be_{composite}$) from Lakes Tiefer See and Czechowskie $^{10}Be_{atmosphere}$ overlain by neutron monitor counts. Amplitude variations of the neutron monitor data were scaled to match the expected changes in atmospheric ^{10}Be production of about 35%. Neutron monitor data were shifted one year into the future to account for the atmospheric residence time of ^{10}Be. All data-series were divided by the mean for normalization. Before calculating correlations, the datasets were resampled to annual resolution by linear interpolation. $^{10}Be_{composite}$ is filtered with a 3-year running mean to reduce noise.

Invited talk

Soil indicators of pedogenic processes development as a tool for interpreting the evolution of the environment during the late Pleistocene and Holocene

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Soil as an integral component of geo-ecosystems is formed and shaped by other elements of the natural environment, affecting at the same time properties of many of them, such as the flora, fauna, water management, etc. Therefore, it can be regarded, as a kind of the mirror of a number of natural processes occurring in the system of geographical environment, plus due to its versatility in the system, also as an indicator of human pressure on the environment. It has become more common in recent years, to use soil studies to interpret paleo-environments and evolution of the natural environment landform, especially in the reconstructions of the development of the geographical environment of the Pleistocene and Holocene. Such studies utilize physical and chemical properties of soil, since they serve as good indicators of specified litho-morphological processes and natural-climate conditions, by which the soil was formed. Soil characteristics, that are most commonly used as indicators, include the content of macro and microelements, or quantitative and qualitative content of humus, as well as many others, for determination of which, the specialized interdisciplinary knowledge is required. Among them, the geochemical indicators of the content of individual forms of iron and aluminum in soil and their mutual relations are of significant importance when it comes to interpretation of the changes in the geographical environment. Similarly, for the interpretation of the development of paleo-environments, it is very helpful to utilize the ultramorphoscopic analysis. The basis of this analysis are classified physical and chemical characteristics of weathering, and morphological characteristics of the relief, shape and surface matting of the sand grains visible in the micrographs of scanning electron microscopy (SEM). Obtained results are used to determine the sequence of changing geomorphological environments of the development of studied soils, in terms of contemporary and ancient landscapes.

The aim of this study is to present the possibilities of utilizing the results of analyses of the content of particular forms of iron and aluminum in soil, as well as of SEM to interpret the evolution of paleographical environment conditions, in which the podzols of two model areas were developed, namely in the Karkonosze Mountains and Meghalaya Upland in India.

Theme C High resolution climate reconstruction / WP4

Holocene climate variability and human impact recorded in annually laminated sediments of Lake Tiefer See (NE Germany)

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The annually laminated (varved) sediment record of Lake Tiefer See offers the possibility to study climate and environmental changes with a precise chronology and up to seasonal resolution. Multi-proxy studies of the past 1200 years demonstrated that the appearance of poorly and non-varved intervals are related to phases of enhanced circulation in Lake Tiefer See caused by both, climate change and human impact (Dräger et al., in prep.). Hence, variations in the sedimentation pattern in the Holocene lake record suggest a great potential for identifying past climate and environmental changes.

Lake Tiefer See is located within the Pomeranian terminal moraine belt of the Weichselian glaciation and is part of the Klocksin Lake Chain which acted as a sub-glacial gully system. A total of 7 parallel sediment cores were collected in 2011 (A, B, C) and 2013 (D, E, F, G) from the deepest part of Lake Tiefer See using an UWITEC piston corer. Three cores reached glacial sand deposits at the base (D, E, F). A composite profile was constructed by correlating macroscopic well distinguishable marker layers in all profiles. The chronology of the core sequence is based on varve counting, AMS 14C dating of terrestrial plant remains and identification of cryptotephras (e.g. the AD 1875 Askja eruption). Tephra layers of Eifel- and Icelandic provenance in the lowermost part of the core sequence suggest an onset of lake sedimentation in the late Allerød at about 13 000 years BP and an onset of varve preservation at the beginning of the Holocene.

A combined approach of microfacies analyses using thin sections, µ-XRF analyses on split sediment cores, geochemical analyses of bulk samples and pollen analyses has been carried out. The most prominent change occurs at ca. 5300 BP. After that date, sediments are more variable in terms of geochemical composition and varve preservation on centennial time scales. Changes of geochemical composition include variations of the calcite, rhodochrosite, diatom and organic matter content. Furthermore, phases of poor varve preservation are accompanied by an increase of detrital matter into the lake and, at least partly, by forest clearance due to farming in the catchment.

In this study we are aiming at testing the applicability of the appearance of poorly and non-varved intervals as a proxy for enhanced lake circulation in Lake Tiefer See sediments for the Holocene period and discuss reasons for the changes happening since ca. 5300 BP. The overarching goal within the ICLEA objective is to compare the sediment records from Lake Tiefer See and Lake Czechowskie (N-central Poland) which provides an almost continuously varved sequence. Further investigations include a detailed multi-proxy comparison of both lake records of the Holocene period in order to figure out why varve preservations ceased during certain periods in Lake Tiefer See and not in Lake Czechowskie. We discuss possible local influences such as variations of the lake size, lake level and anthropogenic disturbances on the vegetation in the lake catchment. Regional variations are related with the influences of the North Atlantic and the East European continental climate changes that cause variations in atmospheric circulation, precipitation and wind strength.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and Terrestrial Environmental Observatory (TERENO) of the Helmholtz Association.

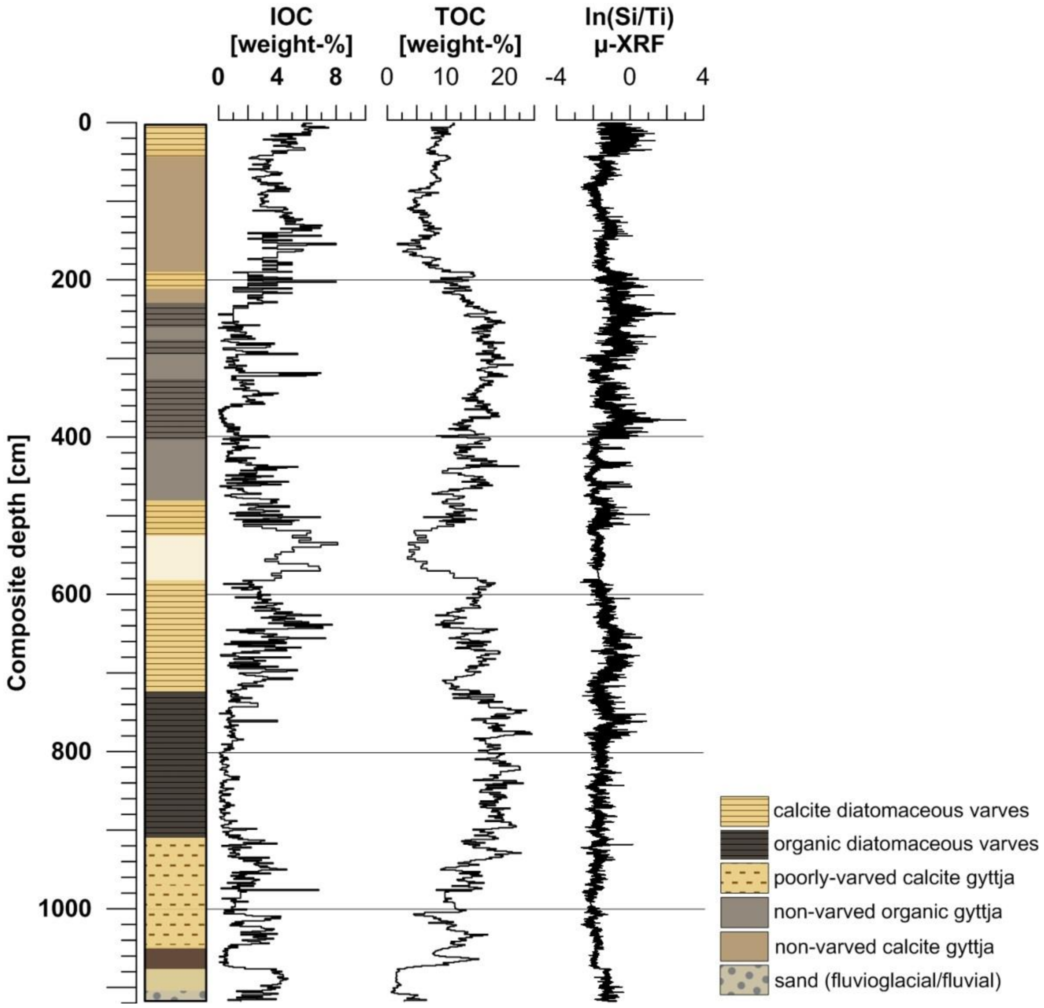

Fig. 1: Holocene sediment record of Lake Tiefer See: lithological profile, inorganic carbon content (IOC), organic carbon content (TOC) and µ-XRF Si/Ti ratio.

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Dräger N., Theuerkauf M., Słowiński M., Hübener T., Szeroczynska K., Plessen B., Tjallingii R., Kienel U., Lorenz S., Brauer A. in prep. Climatic control and human impact on varve preservation during the last 1400 years in Lake Tiefer See (NE Germany).

Theme A Monitoring / WP1

Species specific temporal patterns of throughfall and stemflow in deciduous and coniferous forests with implications for unsaturated zone and groundwater recharge processes

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The extent of rainfall redistribution by forest canopies and resulting spatial patterns vary for different tree species and can play an important role for soil moisture distribution and subsequently for groundwater recharge. A thorough understanding of these relationships will improve our ability to predict future impacts of climate and forest structural changes on the water balance of forest stands. Therefore we quantified the fractions of throughfall and stemflow per gross rainfall for different forest types and for different meteorological conditions and rainfall characteristics.

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. Within 2000m²-plots situated in the Müritz-Nationalpark (north-eastern Germany), trough-based throughfall monitoring systems with a total collecting area of 6.6m² per site, and soil moisture, leaf wetness and sapflow sensors were installed. Stemflow was measured for 5-10 trees per site with a temporal resolution of 1min.

Canopy structure is likely to have a major influence on the throughfall distribution. Therefore, the forest structure was characterized by a detailed mapping of tree species, stem positions and stem diameters. Seasonal variations of leaf coverage were monitored by ground-based leaf-area index (LAI) measurements. Evaporation from the canopy is the sum of evaporation during rainfall events and of precipitation stored in the canopy that is evaporated after rainfall ceased. We estimated the storage capacity of the canopy based on the cumulative precipitation between the onset of rainfall and the onset of throughfall. The influence of rainfall intensity and leaf wetness before the onset of rainfall events on canopy storage was also assessed.

The data set was used to parameterize and run the soil hydrological model HYDRUS-2D at various spatial scales to assess the effect of stemflow and throughfall patterns on the dynamics and distribution of soil moisture and groundwater recharge.

First results highlight the importance of concentrated water input by stemflow (Fig. 1), subsequent high infiltration rates around beech stems and the resulting local soil saturation for rapid groundwater recharge (Fig. 2). For the other tree species stemflow plays a minor role and rainfall redistribution patterns are more determined by canopy gaps or ground vegetation. However in large rainfall events soil saturation and enhanced groundwater recharge could occur below pine and oak trees as well.

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 is supported by TERENO infrastructure of the Helmholtz Association.

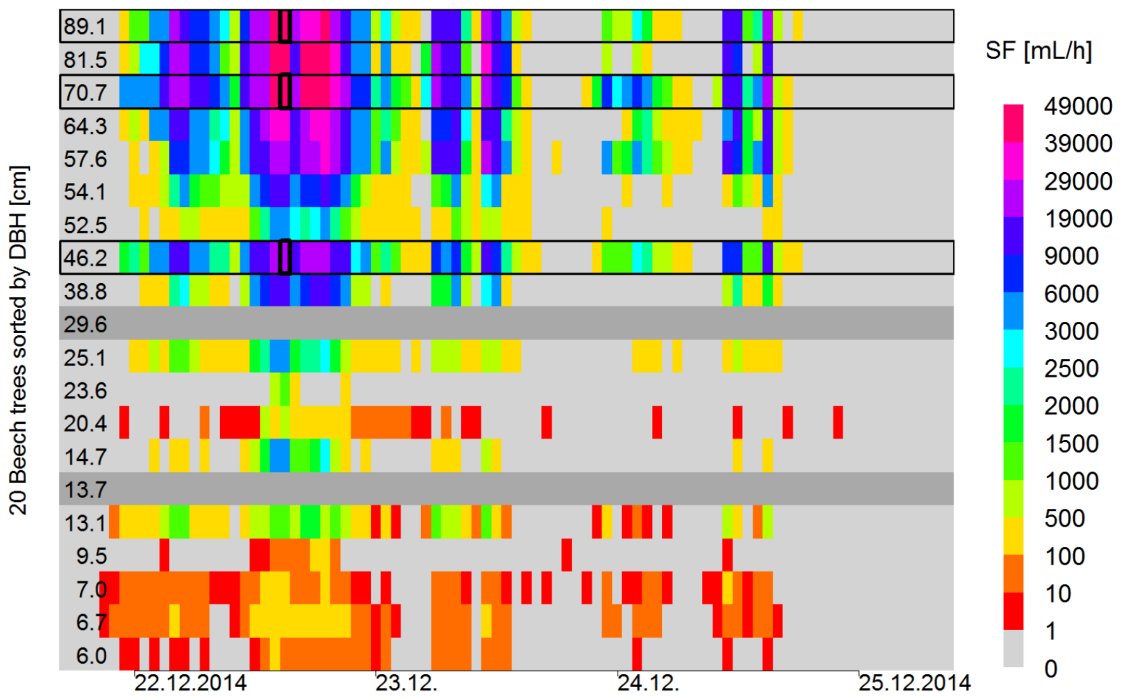

Fig.1: Stemflow time series for a large winter rain event: Trees sorted by diameter at breast height DBH (dark grey=NA, black frames indicate data used for modeling).

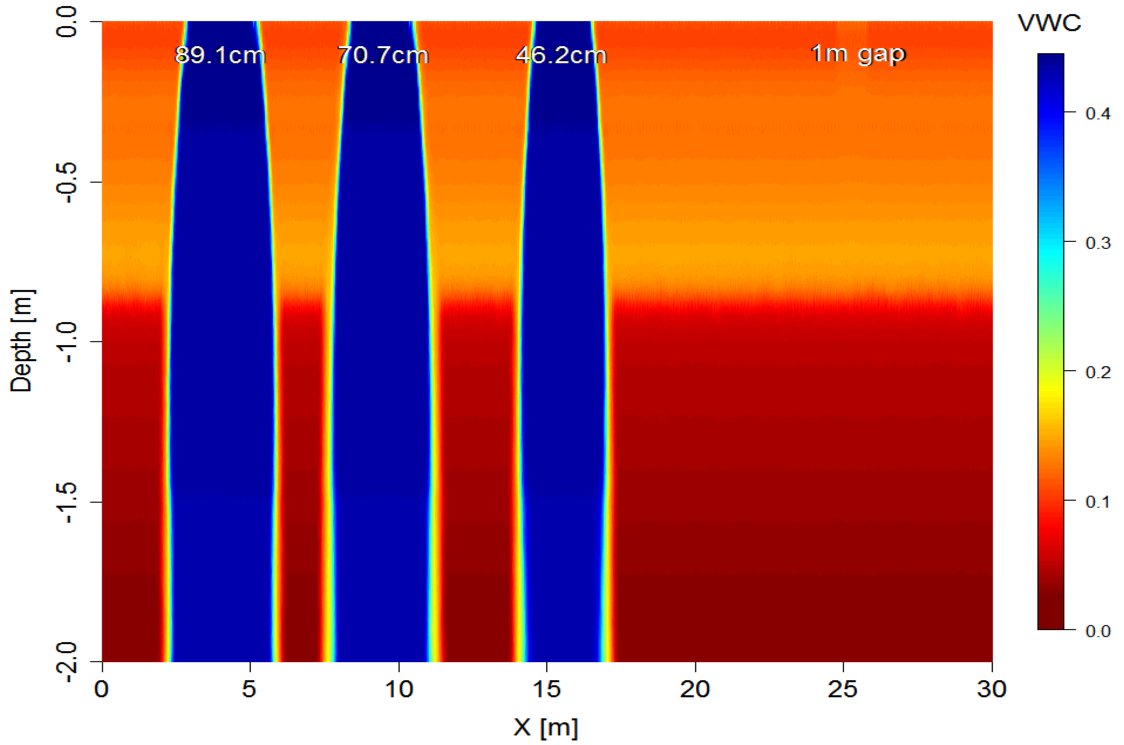

Fig. 2: Stemflow infiltration patterns of 3 beech trees and a canopy gap simulated with HYDRUS (blue: volumetric water content (VWC) close to saturation, red: close to field capacity), throughfall infiltration visible as homogeneous background pattern, macropore flow is not considered.

Theme A Monitoring / WP4

Thermal and hydrochemical structure of Lake Czechowskie - monitoring results

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The aim of the study of the thermal and chemical structure of Lake Czechowskie is the extent and nature of the temporal variability of water stratification and, consequently, the hydrodynamics of the lake. Since the beginning of May 2013 water temperature has been recorded in the deepest part of the lake. The temperature sensors are located at 14 levels and the data recording is done every two hours, and since the autumn of 2014 - every half an hour. The measurement results show that after a short period of the spring homothermous conditions, the lake becomes strongly thermally stratified. It includes a thin epilimnion layer (approx. 6 m at the end of the summer), a strongly developed thermocline with a temperature gradient of 3.5°C per 1 m, and a hypolimnion layer comprising up to 48% of the lake capacity. The nature of stratification and the conditions of its formation allow classifying Lake Czechowskie as a lake of bradymictic characteristics.

Detailed analysis of the temperature distribution at various depths showed very large daily temperature amplitudes. They extend to a depth of 9 m and range from 2 to 3.5°C. Deeper they are smaller and do not exceed 1°C (Fig. 1). Depth of the individual isotherms changes significantly during the day. This is mainly observed in more windy days. Changes in the position of the isotherms, especially in the metalimnion layer, are more than 1 m. High rate of change of temperature can prove the existence of internal waves in the lake. They are generated even in the case of a small wind velocity (approx. 2-3 m·s^{-1}). The presence of seiche water movements was confirmed by the results of measurements of the speed and direction of water currents.

Fig. 1: Average and maximum value of daily amplitude of water temperature in Lake Czechowskie (between April 2013 and April 2014).

In October 2014 a systematic study was started on the diversification of the chemical properties of the water in the vertical profile of Lake Czechowskie. The measurement column is located in the deep part of the lake, where once a month the following indicators are measured at 1 m intervals: pH, REDOX potential, dissolved oxygen, specific electrical conductance, turbidity and water temperature. In addition, in five horizons water samples are collected for chemical analyses. These include the determination of salinity, concentration of nutrients (nitrogen and phosphorus) as well as organic and inorganic carbon. Preliminary results of the analyses show the presence of a well-developed chemical stratification. The chemocline is observed in relation to the various parameters of the water quality. Its presence is detected even during the spring water circulation.

The research of the lake water oxygenation showed a positive heterograde distribution of oxygen concentration during the summer thermal stratification. Under the conditions of spring water mixing a system developed where the surface layer of the water showed the lowest oxygenation (approx. 5 $mg \cdot dm^{-3}$), then grew and at a depth of 6 m stabilized at about 20 $mg \cdot dm^{-3}$.

Theme A Monitoring / WP5

Effect of beaver dams' failures on valley modification and implications for palaeoenvironmental reconstructions – preliminary results

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Large beaver activity was observed along the outlet of Lake Głęboczek. It expresses in relief transformation of the valley bottom and its slopes. Created by beaver's small ponds functioning as local sediment traps. Periodically the dams were failed. This led to rapid water drainage. The effects of such an event were observed in December 2014 and May 2015. Studying the effects of contemporary beaver activity may be helpful for palaeoenvironmental interpretations. On the poster will be presented preliminary results of the observation and measurement of the effects of beaver dam's failure.

Fig. 1: Beaver dam before (A) and after (B) failure.

Theme A Monitoring / WP4

Monitoring climate signal transfer into the varved lake sediments of Lake Czechowskie, Poland

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In 2012 we started a monitoring program at Lake Czechowskie, Poland, because the lake comprises a long Holocene time series of calcite varves until recent times. The aim of the program is to understand how environmental and climatic conditions influence the hydrological conditions and, ultimately, the sediment deposition processes of the lake

Two different types of sediment traps provide sediment samples with monthly resolution from different water depths (12 m, 26 m). In addition, hydrological data including water temperature in different depths, water inflow, throughflow and outflow and the depth of visibility are measured. These data allow to describe strength and duration of lake mixing in spring and autumn and its influence on sedimentation. The sediment samples were analyzed with respect to their dry weight (used to calculate mean daily sediment flux), their inorganic and organic carbon contents, the stable C- and O-isotopes of organic matter and calcite as well as N-isotopes of organic matter. For selected samples dominant diatom taxa are determined.

Our first results demonstrate the strong influence of the long winter with ice cover until April in 2013 on the sedimentation. A rapid warming in only 9 days starting on April 9th 2013 from -0.3 °C to 15.2 °C resulted in fast ice break-up and a short lake mixing. Additionally the wind occurs during this period mainly and strongly from southerly directions. This wind direction seems to reduce vertical circulation of the lake (Fig.1).

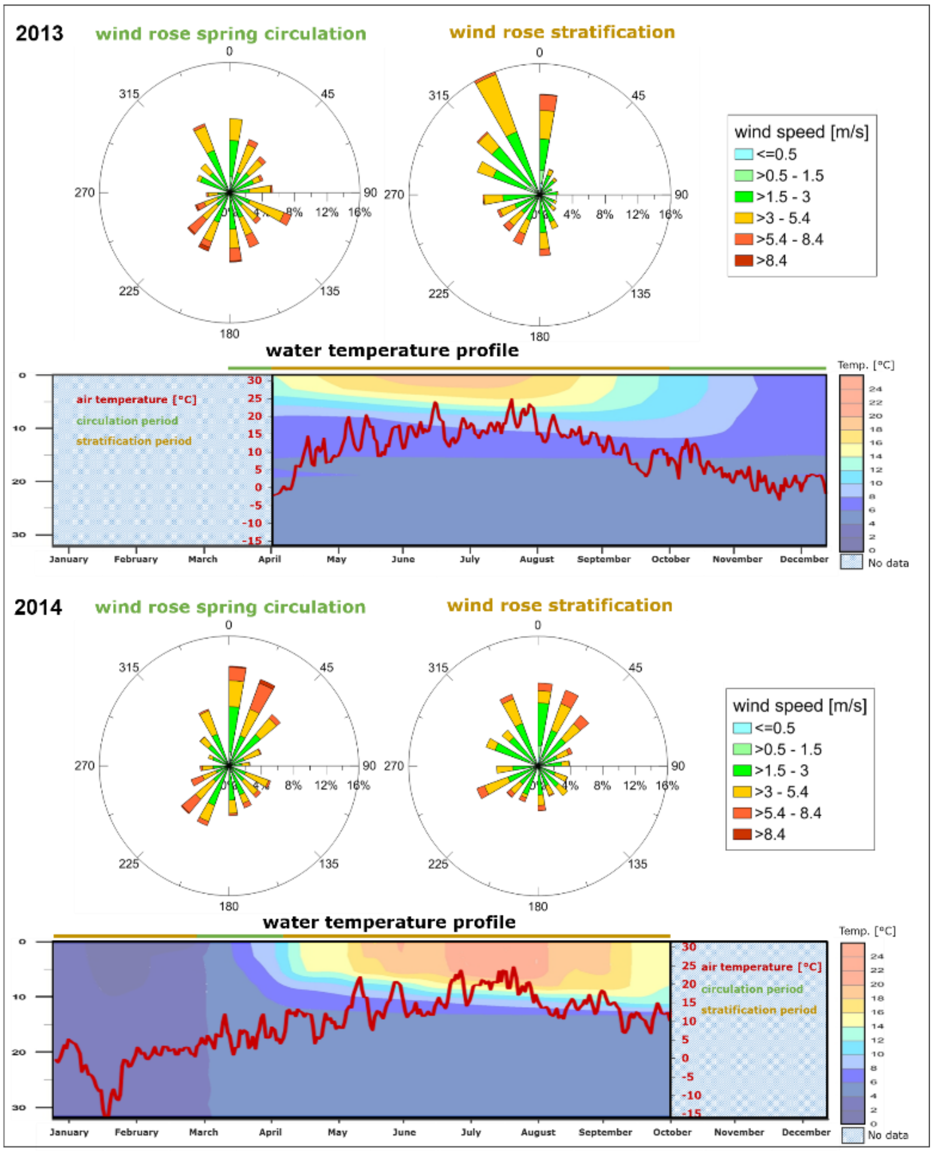

Fig. 1: Environmental conditions April 2013 – October 2014.

In consequence of this short and minor mixing period, a minor algal bloom especially of *Fragilaria sp.* and *Crysophycea sp*. starts in April with a maximum in May. A strong algae induced biogenic calcite precipitation was observed in May which leads to the monthly maximum in calcite deposition of 1.16 [g/m²d] (65.23 % of the total trapped sediments). Caused by weak algae bloom the $\delta^{13}C_{carb}$ signal increased despite the strong calcite precipitation lightly. 2013 was a year with a weak summer stratification, with strong northerly winds. Through these conditions a *Phacotus* sp. bloom was inhibited. During the summer stratification in 2013 the $\delta^{13}C_{carb}$ signal increased continuously caused by carbonate consumption through algae bloom and calcite precipitation. In contrast the sedimentation pattern in 2014 differs. Triggered by a long spring circulation period and strong northerly winds, an intense algae bloom, mostly of *Fragilaria* sp. and *Crysphychea* sp. took place. This strong bloom is responsible for a missing of the expected decrease of $\delta^{13}C_{carb}$ signal because of upwelling nutrients. Calcite precipitation was 2014 inhabited until July. In July the calcite amount was nearly the same than in May of 2013 (1.14 [g/m²d]; 65% of total trapped sediments). A distinct summer stratification and less wind led to distinct *Phacotus* sp. bloom in July. The vital effect of *Phacotus* sp. influenced the $\delta^{13}C_{carb}$ signal. Hereby there is only a minor increase of the $\delta^{13}C_{carb}$ signal despite an increasing calcite precipitation visible. The ratio of organic matter reaches the maximum in both years in late summer and autumn, with peaks in September 2013 (0.28 [g/m²d]; 41.18% of the sediments) and August 2014 (0.28 [g/m²d]; 35.12% of the sediments) (Fig. 2).

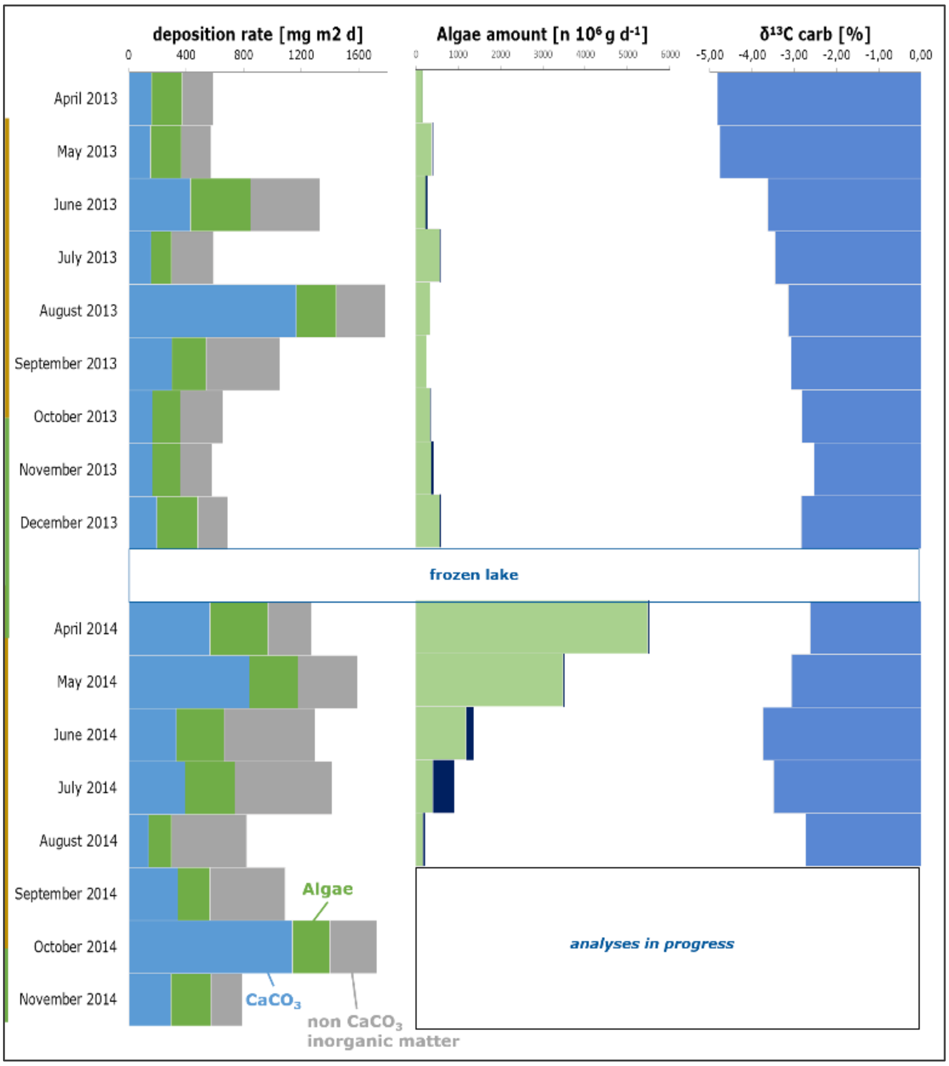

Fig. 2: Sedimentation pattern 4C trap April 2013 – November 2014.

These results are related to the seasonal deposition as revealed by micro-facies analyses of sub-recent sediments in the varve model. The ultimate goal of a comprehensive understanding of seasonal deposition in the lake and the underlying controlling mechanisms is an improved interpretation of long time series of varve sublayers in the sediment record.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA – of the Helmholtz Association and National Science Centre, Poland (grant No. VH-VI-415). These ICLEA studies are supported by TERENO infrastructure of the Helmholtz Association.

Theme C High resolution climate reconstruction / WP4

High resolution investigation of Last Glacial to early Holocene varved sediments of Lake Głęboczek (Tuchola Pinewoods) – preliminary results

Haas, Christoph[1,*]; Mollath, Richard[1,*]; Ott, Florian[1]; Plessen, Birgit[1]; Schwab, Markus J.[1]; Tjallingii, Rik[1]; Wulf, Sabine[1,2]; Błaszkiewicz, Mirosław[3] & Brauer, Achim[1]

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Lake Głęboczek, located 2 km W of Lake Czechowskie, has recently been added as a study site within the ICLEA frame as its predominantly finely laminated sediments suggests an annual nature (varves). These well preserved varves are the key for a detailed reconstruction of changes in the paleoclimate and environmental features. In 2014 two series of parallel and overlapping sediment cores have been recovered from Lake Głęboczek (53°52’11.7” N, 18°12’23.1” E) at 18 m water depth with a modified Livingstone corer (Więckowski, K., 1959). With an undisturbed surface sediment core obtained in 2013 (Ghilardi corer) a composite profile with the total length of 8.44 m was established by correlating unambiguous marker layers (Fig. 1). Preliminary micro-facies investigations in the top and lower part of the sediment record revealed varved sediments and highlights the lakes potential to be a viable archive for past environmental and climatic changes.

The focus of this study is the interval from 7.46 - 6.42 m, for which we assume, in comparison with the Lake Czechowskie sediment record, to cover the Last Glacial-Interglacial transition. Detailed investigations comprise micro-facies analyses including varve and sublayer thickness measurements and the evaluation of changes in the sublayer structure and composition including the examination of representative samples with the scanning electron microscope. Geochemical analyses (µ-XRF element scanning, TOC, C/N, $\delta^{13}C$, $\delta^{18}O$, $\delta^{15}N$) will give additional insights to sedimentation processes and to track any potential change in climate or the lake’s vicinity. Independent age information will be gathered by (i) AMS ^{14}C dating on 31 selected, terrestrial plant macro remains of which 17 samples are distributed within the study interval, (ii) varve counting of a 1.10 m sediment section and (iii) tephrochronology.

With this research we hope to (1) pinpoint a possible transition from the Last Glacial to early Holocene and (2) get an insight into any abrupt changes in the sediment, which might be evidence for an adaptation of the environment to a changing climate. In the end we will compare our findings on a local scale with those of Lake Czechowskie and on a regional extent with the work done at Lake Tiefer See Klocksin, situated 378 km further west in northern Germany, to track any climatic and environmental changes along a W-E transect 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 Centre, Poland (grant No. 2011/01/B/ST10/07367).

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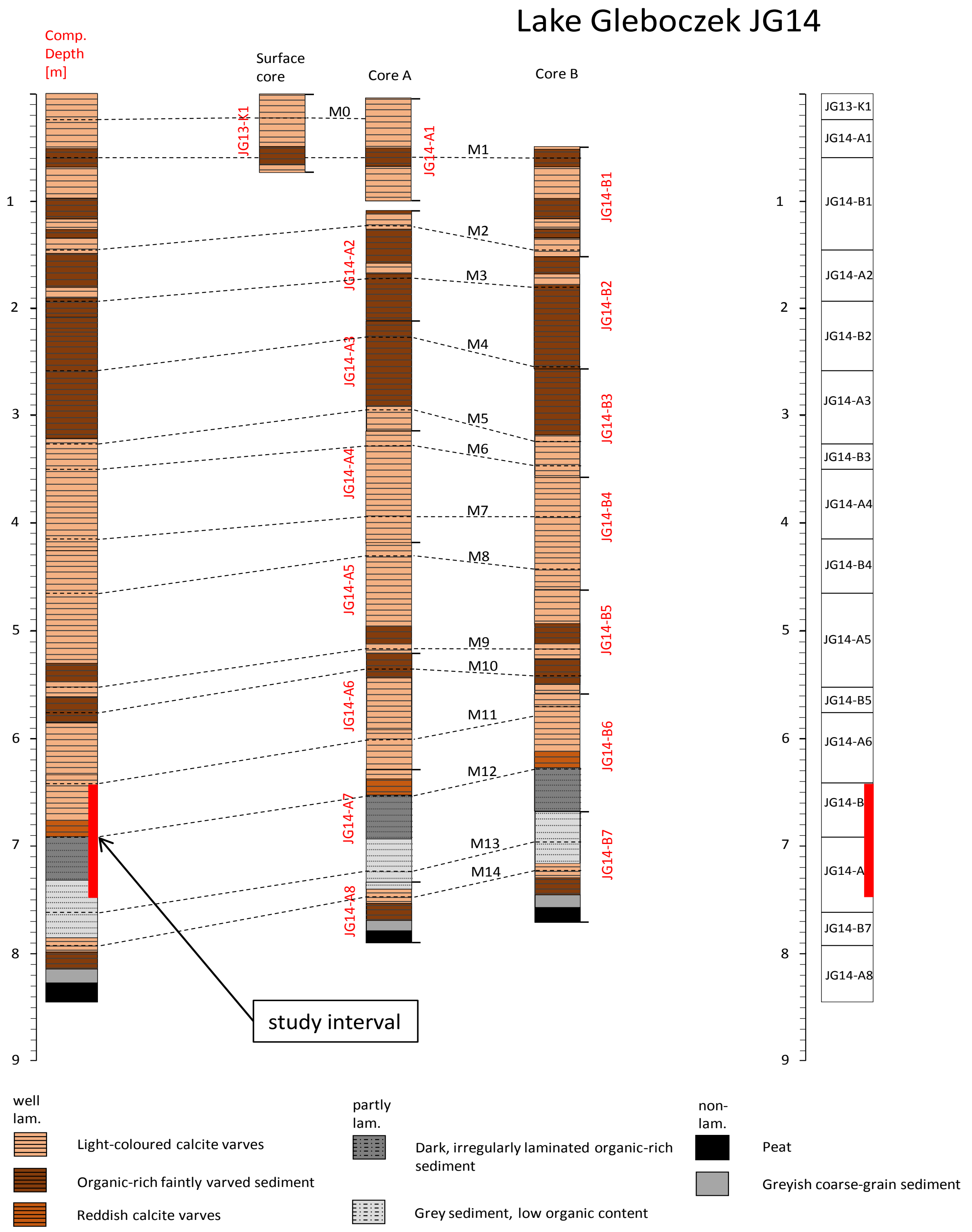

Fig. 1: Composite Profile for sediments of Lake Głęboczek obtained from cores JG14 A and B as well as the surface core by correlating marker layers M0-M14. The in red highlighted section is showing the interval, which was studied in high resolution.

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Theme A Monitoring / WP1

Monitoring soil moisture with cosmic ray neutrons: a recommendation for sensor calibration in forests and other low-count environments

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Cosmic ray neutron sensors present a promising new way to measure soil moisture at intermediate (i.e. hillslope) scales. A calibrated function allows for the conversion of neutron counts to volumetric soil moisture within the sensor's footprint (a circle with a diameter of 300 m and 10 to 40 cm down into the soil – depending on current soil moisture conditions). We installed one cosmic ray neutron sensor in a mixed forest in the low-land of north eastern Germany and calibrated it 10 ten times throughout one calendar year (tab. 1).

Tab. 1 Measured soil moisture in upper 30 cm (ϑ_{30cm}), depth-weighted measured soil moisture (ϑ_{depthW}), depth-weighted measured soil moisture and lattice water (ϑ+LW_{depthW}), soil physical parameters (bulk density (ρ_{bd30cm}) and lattice water content (LW_{30cm})), mean soil moisture derived from calibrated neutron sensor measurements (ϑ_{mod}) as well as neutron count calibration parameters (N_0) for the ten calibrations.

Calibration	θ_{30cm} (m³/m³)	θ_{depthW} (m³/m³)	$\theta+LW_{depthW}$ (m³/m³)	ρ_{bd30cm} (g/cm³)	LW_{30cm} (m³/m³)	θ_{mod} (m³/m³)	N_0 (counts/h)
WINTER	0.163	0.230	0.264	1.218	0.0420	0.134	833.1
SPRING1	0.153	0.201	0.236	1.218	0.0420	0.137	836.2
SPRING2	0.150	0.186	0.219	1.160	0.0400	0.129	827.1
SPRING3	0.140	0.176	0.210	1.189	0.0410	0.136	835.4
SPRING4	0.139	0.172	0.205	1.162	0.0401	0.137	836.5
SUMMER	0.073	0.081	0.118	1.182	0.0408	0.154	855.8
FALL1	0.112	0.138	0.173	1.184	0.0408	0.179	882.8
FALL2	0.140	0.175	0.209	1.166	0.0402	0.137	835.9
FALL3	0.119	0.151	0.186	1.185	0.0409	0.162	864.3
FALL4	0.126	0.151	0.185	1.179	0.0407	0.149	850.4
Mean	**0.131**	**0.166**	**0.200**	**1.184**	**0.0409**	**0.146**	**845.8**
SD	**0.024**	**0.038**	**0.037**	**0.020**	**0.0007**	**0.015**	**16.5**

We found that a single calibration was not able to satisfactorily define the shape of the calibration function because the soil moisture time series derived from the neutron sensor did not match independent in-situ soil moisture measurements from distributed time domain transmissivity sensors. Our 10 calibrations suggested that the shape of the calibration function is flatter than the one given by the standard calibration function (Fig. 1, left panel). We excluded the annual cycle of tree foliation and defoliation as a possible reason for the differences between the individual calibrations since the variable hydrogen mass in the deciduous trees' leaves was small compared to changes in hydrogen mass in the soils caused by soil moisture variations. Possible reasons for the difference in the shape of the calibration function include moisture dynamics in the litter layer and the low neutron count location we are working in. We tested whether a two point calibration is sufficient to define the shape of the calibration function (Fig. 1, right panel) and concluded that it is indeed sufficient if one of the calibrations is conducted during very dry soil moisture conditions and the second one during wet conditions (covering at least 50% of the total range of soil moisture).

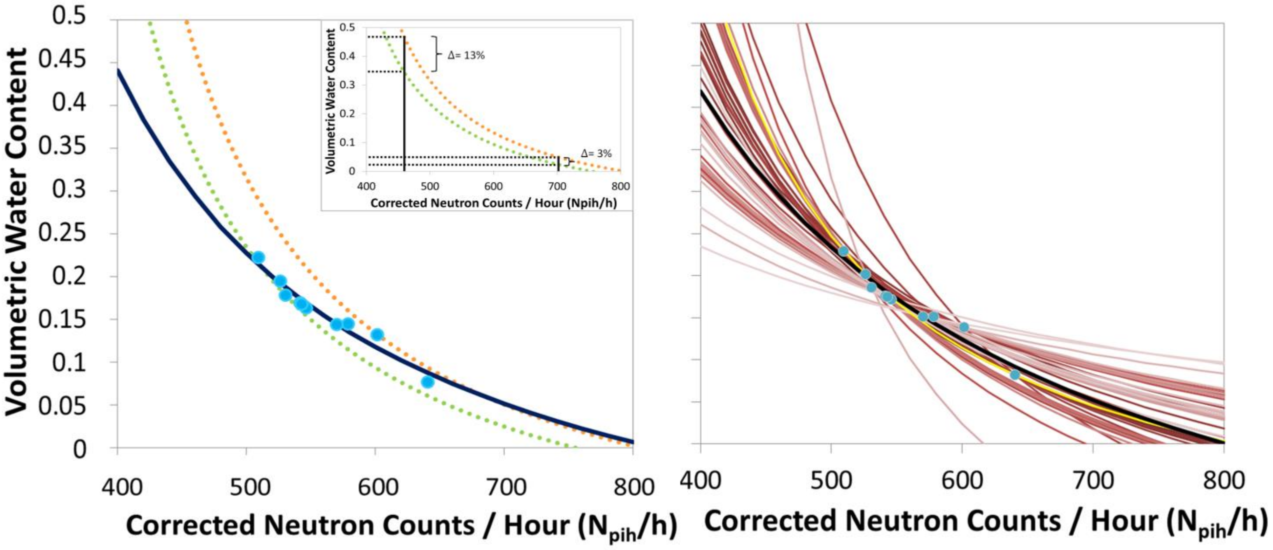

Fig. 1: Left: Calibration points for 10 calibration dates (blue dots) are better captured by a flatter calibration function (solid line) with different calibration parameters than by the calibration functions suggested by the standard calibration (Desilets et al., 2010) (dotted lines). The inset shows that differences in soil moisture between the individual calibrations are larger when soil moisture is high. Right: Best-fit calibration functions (red-brown colored lines) for all combinations of two-point calibrations (blue dots). Best-fit calibration function for ten-point calibration (black line). Best-fit two-point calibration function derived from calibration points with highest and lowest volumetric water content (yellow line).

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367). These ICLEA studies are supported by TERENO infrastructure of the Helmholtz Association.

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Theme A Monitoring / WP2

Reconstruction of Lake Level Changes of Groundwater-fed Lakes in Northeastern Germany using RapidEye Time Series

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Groundwater-fed lakes in northeastern Germany are characterized by significant lake level changes, but only few lakes have in situ level measurements. In this study we test the potential of RapidEye (RE) satellite images for the indirect reconstruction of small natural lake level changes. Based on our test site Lake Fürstenseer See (FS), we define requirements and limitations for the method. The lake level reconstruction is based on the combination of extracted water-land-borders from RE images (2009-2014) with high-resolution topography data. The water-land-borders of 37 RE images were extracted automatically using Otsu's threshold (Otsu, 1979) for the NIR band and for the normalized difference water index (NDWI) (McFeeters, 1996). The lake level reconstruction is performed with the more accurate NIR results. For a precise reconstruction of the lake level a very shallow shoreline subset (ca. 3% slope) with only little vegetation is needed. Vegetation as dense reed and overhanging trees cover the water surface area and hinder the acquisition of the water-land-border via satellite. At Lake FS, the reconstructed absolute lake levels are underestimated between 0 and 20 cm, but the method proofs an accurate reconstruction of relative lake level changes (RSME= 6 cm). For low lake levels with a sandy beach the accuracy is very high (RSME= 3 cm), with rising lake levels and a flooding of the sandy area the accuracy decreases (RSME= 6-8 cm). For the automatic extraction of the water-land-border (NIR) the transition of water to surrounding high vegetation is challenging. The results were evaluated with DGPS measurements, in situ lake level records, and a GIS analysis.

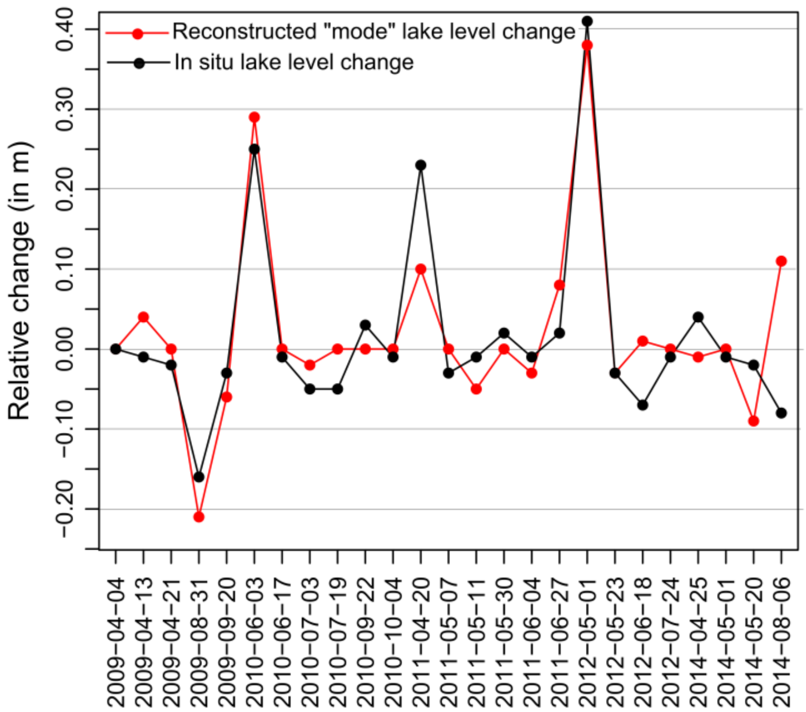

Fig. 1: Comparison of the in situ and reconstructed relative lake level changes; relative level change $\Delta h = h(t) - h(t+1)$. The black line shows the relative changes $\Delta h(in\ situ)$ of the in situ lake level. The red line, are the relative changes $\Delta h(reconstructed)$ of the reconstructed "mode" levels. Twelve dates were removed because of misclassifications of the water-land-border due to low sun elevation angles.

This study is funded by the Helmholtz Association of German Research Centres Initiative Networking Fund for funding a Helmholtz Virtual Institute VH VI 415. Satellite imagery is provided by ESA (proposal nr. 14611) and BlackBridge (RESA Projekt ID A1274).

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Break during the excursion at Lake Czechowskie, 2nd Annual ICLEA Workshop 2013 (photo I. Heine, GFZ)

Theme C High resolution climate reconstruction / WP3

Climate reconstructions from tree-ring widths for the last 850 years in Northern Poland

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The conifer *Pinus sylvestris* is a prominent species for temperature reconstructions based on long tree-ring chronologies in areas located near the latitudinal and altitudinal limits of the species' distribution (e.g., in Scandinavia and Siberia). Such reconstructions form the major part of the palaeo data base used for the IPCC reports. Tree-ring chronologies of *Quercus robur*, on the other hand, have mainly been used to reconstruct precipitation. However, long temperature reconstructions derived from temperate lowland trees growing well within their distributional limits in central Europe, as is the case in northern Poland, do not exist and thus are not part of the IPCC report, which is an essential gap in the European palaeoclimate data base. Dendroclimatological analysis at temperate lowland sites was so far difficult to perform mainly because there was little evidence of a clear climate signal in the chronologies.

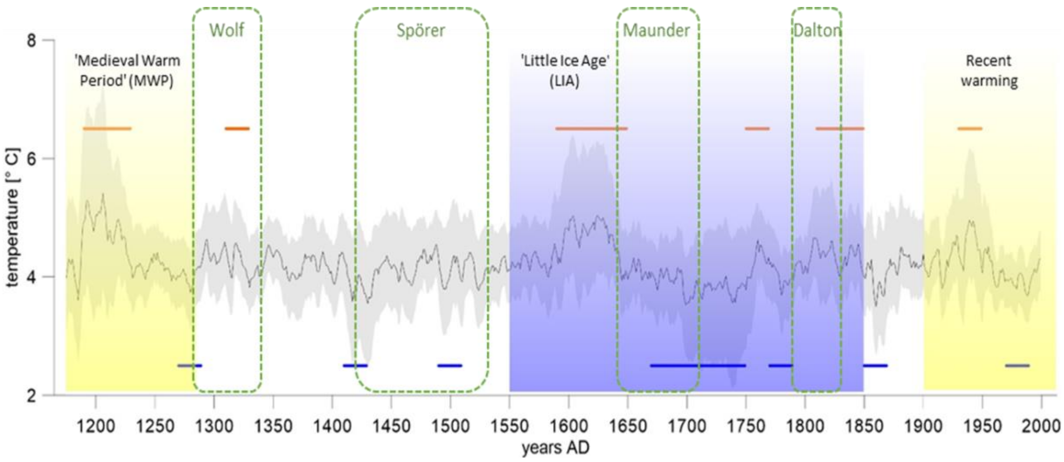

Fig. 1: Reconstructed max Feb-to-Mar temperatures (black line: average reconstruction based on 4 possible temperature reconstructions; grey area: spread between highest and lowest reconstructed values for each year). Yellow and blue boxes define known warm and cold phases. Red and blue lines represent warmest and coldest reconstructed intervals, respectively; green boxes indicate periods of solar minima.

Here, we present two robust multi-centennial reconstructions of winter temperature and summer precipitation based on pine and oak tree-ring widths chronologies from northern Poland, where so far no long tree-ring based reconstructions were available (Fig. 1). A comparison of our new records with global, hemispherical and regional reconstructions reveals partial agreements between them. The disagreements may have several reasons: different climate parameters are compared, e.g. mean annual versus max winter temperatures. Besides our reconstructions are only based on tree rings while the others also include other proxies, and the spatial coverage of our reconstructions is more local to regional in contrast to hemispherical reconstructions. Furthermore, our chronologies may have experienced an overly strong loss of low-frequency signals due to the short length of the sample segments. When using short segments the so-called segment length curse becomes a problem. It means that a mean chronology comprised of individual series of relatively short segment length, which need to be detrended and standardized before averaging them into one mean site chronology, can only reconstruct climate on frequencies that are at maximum the length of the average segment lengths. This may explain why the winter temperatures of our reconstruction do not indicate any modern warming, nor does the summer precipitation reconstruction suggest any modern 20th century changes.

In addition, we present chronologies of measured cell structures such as cell wall thickness and cell lumen area of *P. sylvestris* and *Q. robur*. We used our new method (Liang et al. 2013a, b) applying confocal laser scanning microscopy to increment core surfaces for efficient histometric analyses (Fig. 2).

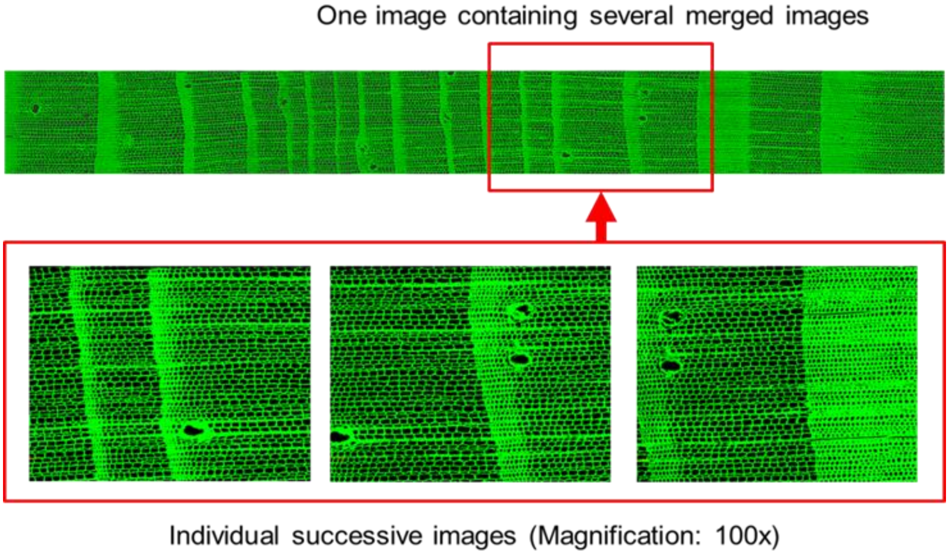

Fig. 2: Example of cell structures visible on a simple increment core surface by means of the Olympus FluoView FV300 confocal laser scanning microscope (CLSM).

We demonstrate that the correlations with climate data are strong and different from those found for tree-ring widths (e.g., the N-Poland oak-vessel-lumen-area-chronology correlates well with the previous November-to-January minimum temperature, r = 0.56 and N-Poland pine-tracheid-lumen-area-chronology with max Feb-to-June temperature, r = -0.66). The potential to develop long-term reconstructions is moreover substantiated by the fact that we can simply use raw values and thus low-frequency signals can be sustained in the chronologies. First comparisons with other temperature reconstructions corroborate the results.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367).

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Theme C High resolution climate reconstruction / WP3

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

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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 within the framework of the EU project ISONET in the early 2000s. None of the ISONET sites was located in the ICLEA region apparently leaving a gap in spatial coverage. In this study we will present a spatial reconstruction of European summer drought from the ISONET network and assess its representativeness for the ICLEA region by comparison with a composite tree ring stable isotope chronology from NE Germany. Furthermore, the spatial homogeneity of seasonal climate signals in tree ring width and tree ring stable isotope records was tested by seasonal correlation analysis. The example in Figure 1 displays the highest seasonal correlation (at 95% significance level) of tree ring oxygen isotopes with gridded precipitation GPCC (within 60km) from 1901 to 1998. Only sites with significant correlations are shown. The analysis revealed that the tree-ring oxygen isotopes 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 seasonality. However, figure 1 indicates that tree growth of the ICLEA regions and further to the east is strongly influenced by winter precipitation.

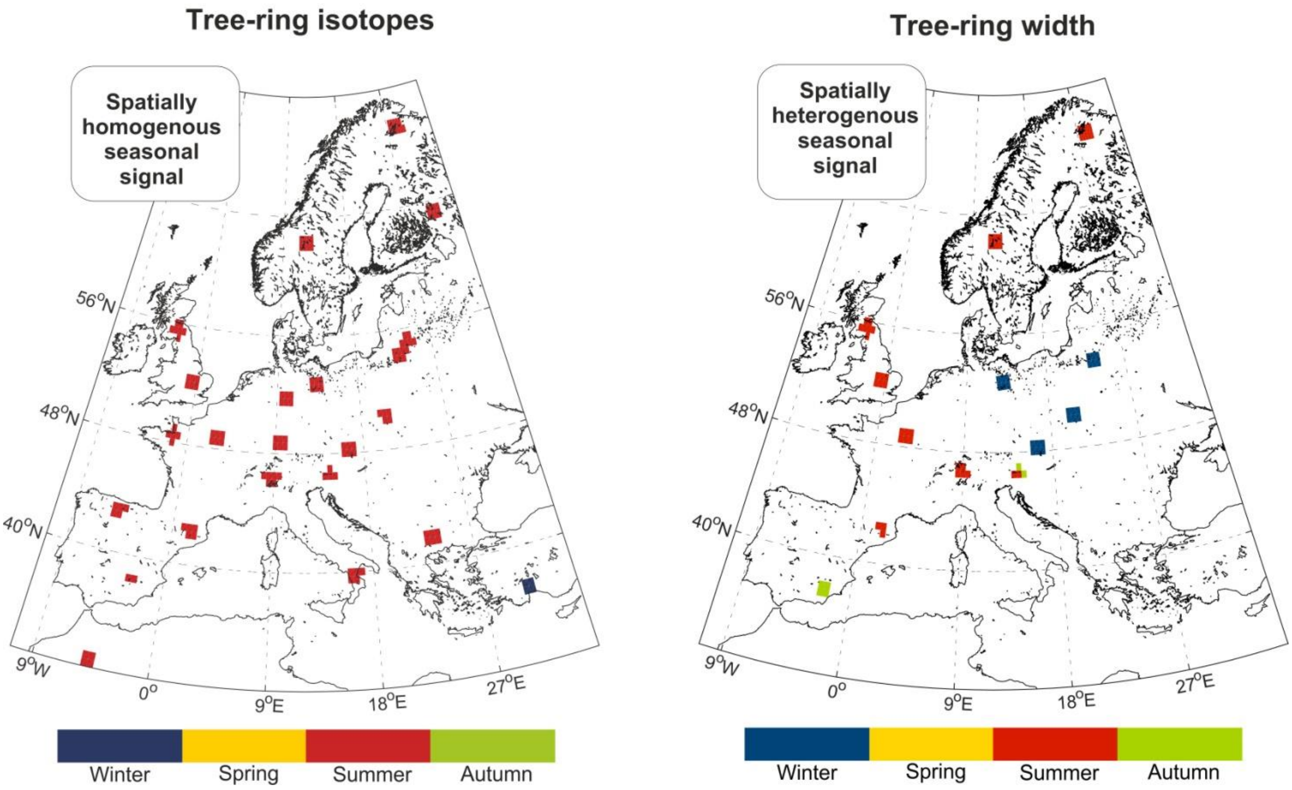

Fig. 1: Seasonal correlation analysis of tree-ring stable isotopes (left) and tree ring width (right) across Europe.

Based on the results from the spatially resolved seasonal correlation analysis tree ring oxygen isotope data series were used for setting up a 400 year temporal reconstruction (Fig. 2) and spatial maps of European summer drought. Figure 3 gives two examples showing the years 1888 AD with the wettest summer reconstructed for Central Europe and 1842 AD which was reconstructed as the driest summer for whole Europe, except for the SE Mediterranean.

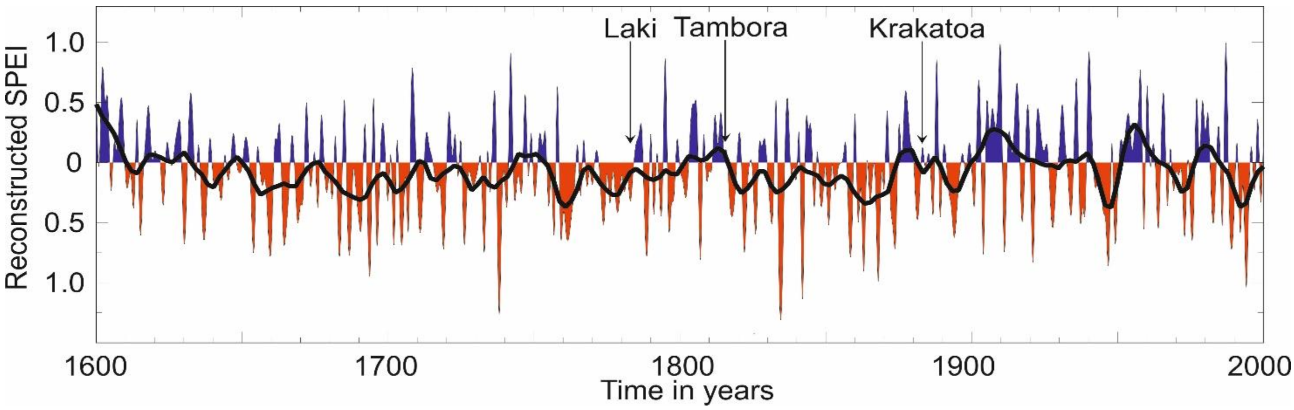

Fig. 2: Temporal variability of European summer drought ($SPEI_{JA}$) averaged over the whole continent. Blue shaded areas: positive SPEI values associated with generally wet conditions; red shaded areas: dry conditions coordinating to negative SPEI values. A smoothed LOESS low-pass filter is given as a black line. Major volcanic eruptions are pointed by arrows for 1783 Laki (Iceland), 1815 Tambora (Indonesia) and 1883 Krakatoa (Indonesia).

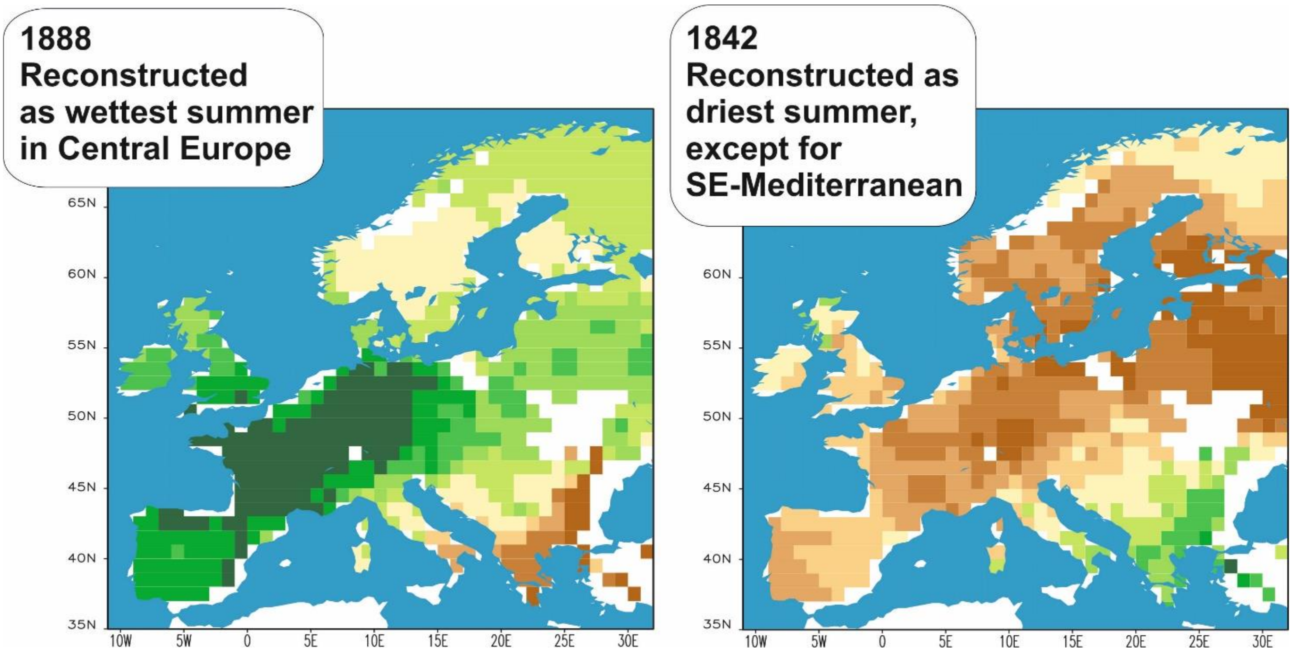

Fig.3. The wettest (1888 AD) and the driest (1842 AD) summer in Europe of the last 400 years. Reconstructed from tree ring oxygen stable isotopes.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis ICLEA of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367). These ICLEA studies are supported by TERENO infrastructure of the Helmholtz Association.

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Theme E Human impact / WP5

Late Quaternary landscape development at Lake Trzechowskie in Northern Poland from terrestrial archives

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Late Pleistocene landscape development in Northern Poland is mainly characterized by glacial and periglacial conditions due to glacial advances from the Scandinavian Ice Sheet at the Last Glacial Maximum (LGM). With the meliorating climate at the end of the Late Pleistocene and the establishing vegetation the geomorphologic activity diminished. In the stabilized landscape soil formation is initiated and on the sandy substrate podsolization and brunification are the dominating pedogenic processes. During the Late Holocene anthropogenic induced soil erosion causes locally a reshaping of the landscape (Hirsch et al., 2015). The recently reported finding of the Laacher See Tephra in the varved sediments of the palaeolake Trzechowskie (Wulf et al., 2013), bears the potential to connect a well dated chronological marker to the surrounding landscape for paleoenvironmental studies. Because the paleolake Trzechowskie experienced a striking drop of the lake level, the recent lake Trzechowskie is smaller and former nearshore lacustrine sediments are now terrestrial environments.

We therefore used a pedological-sedimentological approach with soil mapping along a transect to characterize the landscape development from the present-day lakeshore to the surrounding hills (Fig. 1d). Findings from drillings and soil pits were extrapolated by a survey with ground penetrating radar (GPR).

Our findings from the soil survey and the preliminary laboratory analysis indicate, that soil development on the lower lake terrace is only weak. The topsoil is rich in organic material and still contains calcium carbonate (Fig. 1a). In about 100 m distance from the recent lakeshore a 30 cm thick layer of lacustrine carbonate precipitation below the topsoil can be traced several hundred meters along the lake terrace (Fig. 1e). Within the lacustrine carbonate deposit brownish mottles along earthworm tubes hint on redoximorphic processes after the lowering of the lake level. Below the carbonate layer glaciolacustrine sediments build the base of the lake terrace and strong mottling is caused by the near groundwater table. The glaciolacustrine sediments contain loamy intraclasts and water escape structures. Shear zones in the glaciolacustrine sediments hint on post-sedimentary settlement due to the melting of buried dead ice (Fig 1b, c).

On the slopes south of the lake terrace, the sediments are free of carbonates and podsolization and brunification prevail (Fig. 1f, g). In the soil pit on the upper slope the sandy substrate is interlayered with loamy bands (Fig. 1g, h). Since clay coatings are absent we associate the loamy bands with sedimentary processes during the deposition of the substrate during the Late Pleistocene.

The ongoing research reveals that the terrestrial archives span from the Late Pleistocene to the Late Holocene. Further micromorphological studies on the translocation of iron and calcium carbonate will replenish the findings from the field soon.

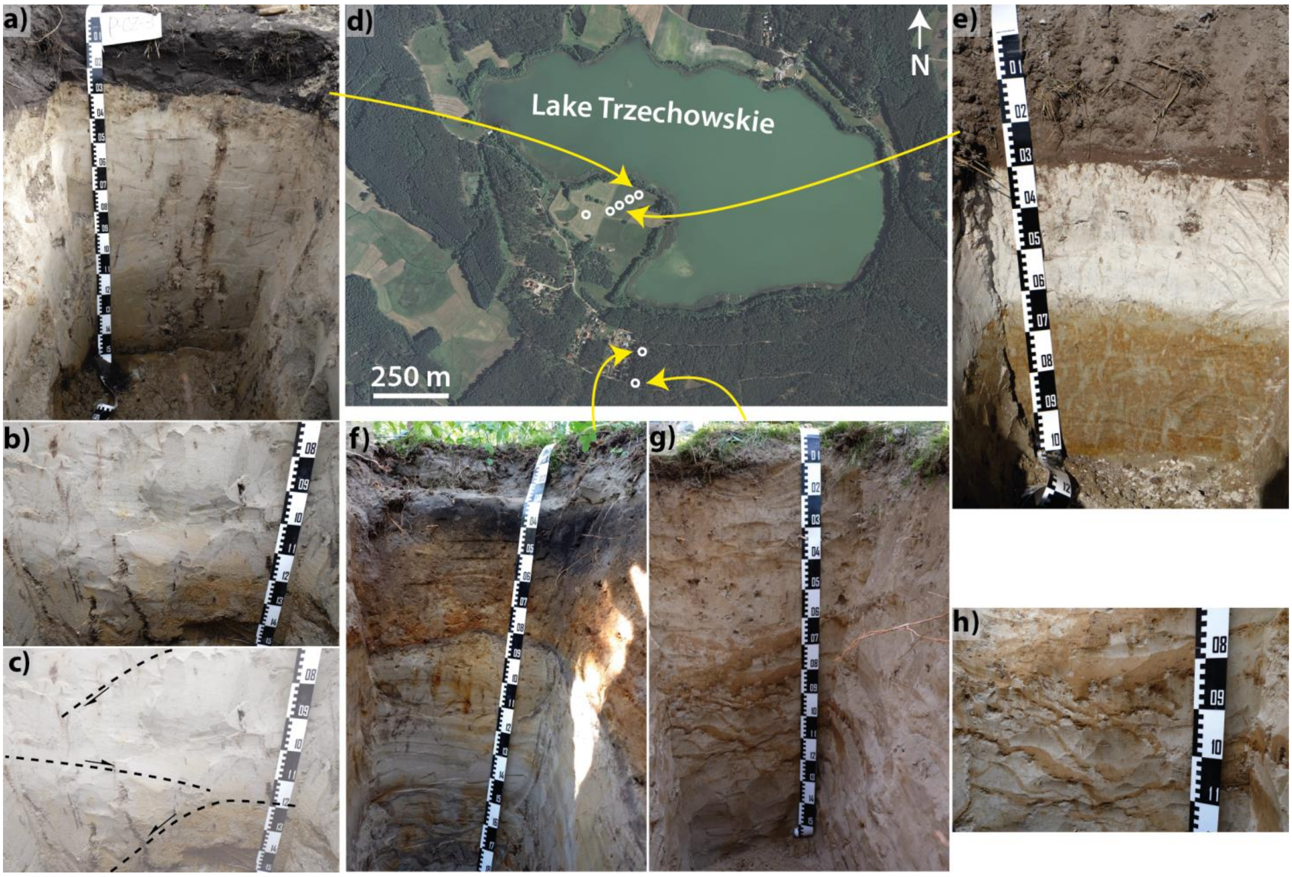

Fig. 1: a) Soil pit near the lake shore with a dark plowing horizon and bright glacilacustrine sediments below; b) and c) shear zones in the glacilacustrine sediments; d) study site with the soil pits; e) white lacustrine carbonate precipitation fossilized below plowing horizon, the lacustrine chalk is covering the glaciolacustrine sediments showing redoximorphic features; f) Podzol at the toe slope; g) and h) plowing horizon on the upper slope above sandy substrate interlayered with loamy bands.

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Theme E Human impact / WP5

Effects of historical charcoal burning on soil properties

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In Northeastern Germany the production of ironware between the 16th and 19th centuries left behind a remarkable amount of charcoal kiln remains (CKRs) in the forests north of Cottbus (Raab et al. 2015).

Archaeological studies supplemented by remote sensing surveys, show that charcoal was produced around Cottbus from several thousand charcoal kilns, which had internal diameters of up to 20 m (Schneider et al. 2015). The CKRs are only up to 100 m distant from each other. Hence, for the 35 km^2 large study area, the till now prospected total ground area of the CKRs is about 0.5 km^2. On the flat surface the round charcoal kiln remains are smooth platforms elevated up to 40 cm higher than the surrounding area. They consist of an at maximum 40 cm thick sandy sediment layer containing residues of the charcoal production processes (charcoal fragments, ash and other organic materials). Because of the high density and their large number, CKRs are a remarkable pool for carbon accumulation on the sandy parent material. Therefore we aim to characterize the pyrolysis, the enrichment of carbon and the changes in soil hydraulic properties induced by charcoal production.

Field work was carried out in summer 2014 during archaeological rescue excavations on a CKR with about 15 m in diameter and a test site outside of the CKR (Fig. 1b). We drained 150 l of Brilliant Blue solution on 1 m^2 large test plots and afterwards trenched horizontal and vertical profiles for recording the staining patterns (Fig. 1d). Undisturbed soil samples for soil micromorphology and further undisturbed samples for characterizing mechanical and hydraulic properties were taken.

On the flat surface of the glaciofluvial deposits of the last glaciation *Rubic Albic Brunic Arenosols (Protospodic)* respectively *Podsol-Braunerden* (Ae/Bs/Bv/II Cv) developed (Fig. 1a). The lower boundary of the topsoil is sharp and horizontal, indicating former plowing. The soil solution of the mineral topsoil is strongly acidic (pH 3.8), and below the surface a pale white fringe indicates podzolic bleaching. With increasing soil profile depth the soil solution increases to pH 4.4. The podzolisation is associated with the modern use of the site for pine growth following the former agricultural use. While the 3 cm thick litter (L horizon) was stained blue, almost no dye precipitated into the organic topsoil (Oh horizon) indicating strong preferential flow. Within the mineral topsoil (Ae horizon) the dye penetrated vertically into the soil indicating preferential flow along roots or former root channels (Fig. 1a, g).

On the CKR the dye penetrated the 23 cm thick residual layer of the CKR only on local spots, horizontal displacement of the dye is negligible (Fig. 1e). Below the residual layer within the buried mineral horizon, a sharp and horizontal color change indicates again the lower limit of a plowing horizon. The top of the fossilized plowing horizon has on the uppermost 2 cm a pale reddish-white color, hinting on an alteration of minerals due to pyrolysis during charcoal burning. Within the plowing horizon the dye penetrated also vertically forming cones along roots or root channels into the soil (Fig. 1h). Below the plowing horizon the distribution of the dye is more blurry (Fig. 1e), a feature which has also been observed at the site outside of the CKR (Fig. 1f). The soil solution within the residual layer varies between pH 3.5 to 4.3, in the fossilzed soil below, the pH ranges from 4.5 to 5.4. The soil is classified as *Spolic Technosol over a Rubic Brunic Arensol*, respectively as *Podsol-Regosol above a fossilized Braunerde* (Ahe/Bhs-ilCv/II fAp/II Bv/Cv).

Preliminary laboratory analyses underline the findings from the field and indicate that the carbon rich sediments have a higher field capacity than the surrounding soils. The matrix potential of the carbon rich sediment is high and the water drop penetration time tests show high water repellency. Our findings suggest that the charcoal production led to an enrichment of carbon to the landscape and that the hydraulic properties of the ash layer can negatively affect plant performance on the CKRs which we investigate in another study.

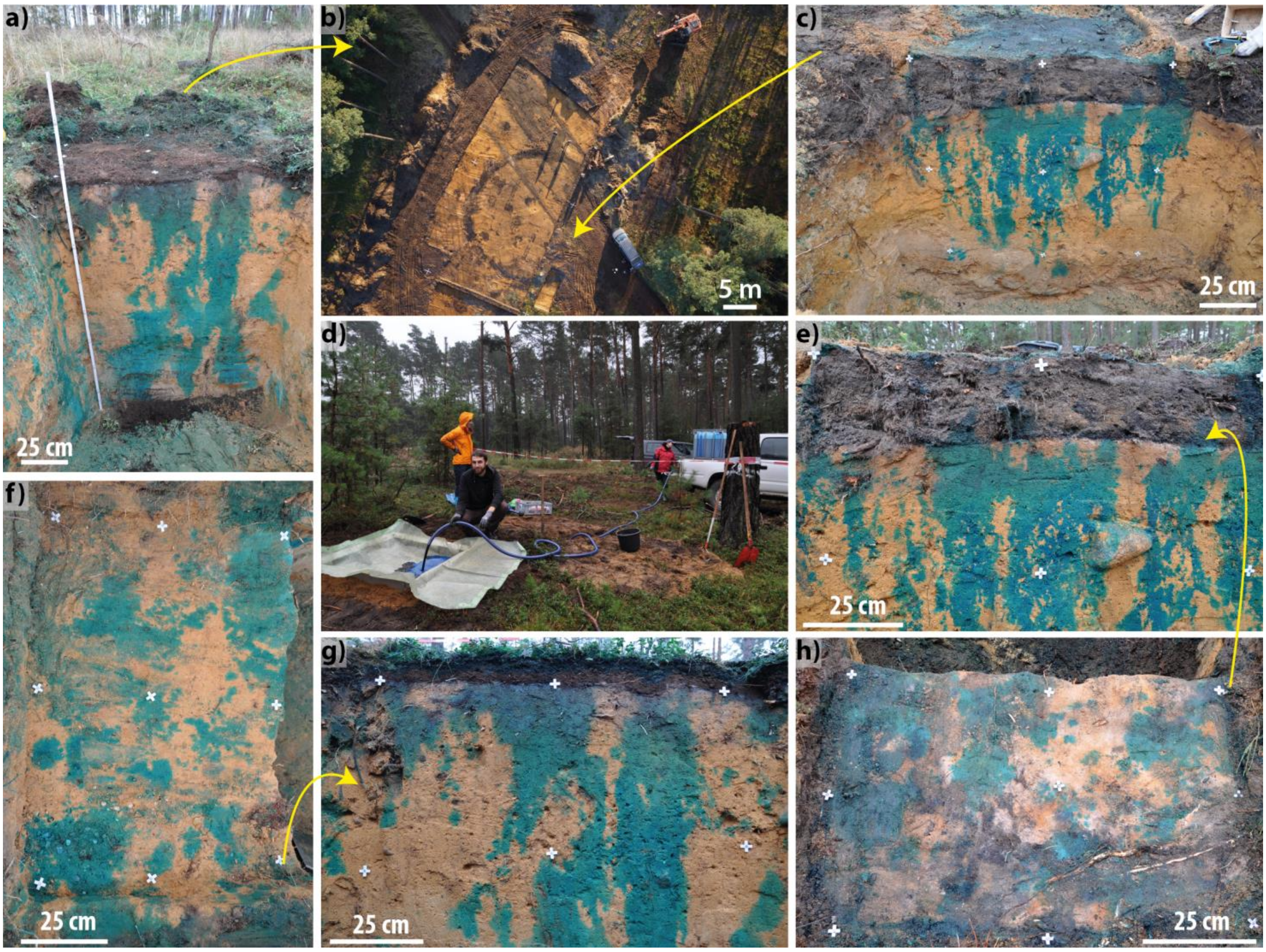

Fig. 1: a) Soil outside of the CKR; b) Ground plan of a CKR. The outer ring of the CKR is transversely crossed by a younger forest track and plow marks; c) soil on the CKR with the residual layer containing sand, ash and charcoal; d) application of the Brilliant Blue; e) at the base of the residual layer the underlying sediment has on the uppermost 2 cm a pale reddish-white color. Below and above the stone (right of the center) no dye precipitated; f) horizontal section 30 cm below the surface outside of the CKR; g) almost no dye is precipitated in the organic topsoil (Oh) below the litter; h) horizontal section at the base of the residual layer of the CKR.

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Theme E Human impact / WP4

The heavy metal enrichment History in Lake Tiefer See and Lake Czechowskie

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Lake Tiefer See (N-Germany) and Lake Czechowskie (N-Poland) are two lakes of comparable size (~ 76.5 ha) that are both located in rural environments of young glacial landscapes. For both lakes long sediment cores exist that reach the sandy late Pleistocene base. For Lake Tiefer See these sediments comprise ~11 m and the period 1800 to 2010 AD is represented in the uppermost ~70 cm of the sedimentary record. For Lake Czechowskie the sedimentary record is 13.30 m long and the last c. 200 years are represented by the uppermost 100 cm. As both lakes exhibit annually laminated sediments a precise age-control can be applied to the samples. The aim of this study is to present a detailed heavy metal enrichment history for the last two hundred years at a decadal to subdecadal resolution for both lakes and to identify influences of land-use changes within the sedimentary record. On the base of heavy-metal analysis of pre-industrial sediments and different sediment types (e.g. calcareous gyttja, organic gyttja etc.) the local and specific geogenic background values are determined. These results provide means to calculate and quantify with sub-decadal resolution anthropogenic heavy metal accumulations and enrichment factors (EF) as well as to define regional measures for a state of reference, reflecting natural conditions without human impact.

The 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).

Both lakes show a similar pattern of relatively low heavy metal concentrations if compared to the so-called index of geoaccumulation (Müller 1979), which is based on the average global metal content in shales (global geogenic background values = ggbv; Turekian and Wedepohl, 1961). Only Pb, Zn and Cd show a clear parallel pattern of enrichment in both lakes starting around 1850-1860 AD according to mainly atmospheric input due to increasing industrialization within the framework of the Industrial Revolution. Highest concentrations are reached around 1960 AD and thereafter the Cd, Pb, and Zn concentration show a clear decline to reach at the top of both records values near the ggbv (Figs. 1 and 2).

The dry bulk density of the sediments (g/cm^3) together with the age model were used to calculate mass accumulation rates (MAR; $g/cm^2/a$). From MAR and heavy metal concentrations of the sediment deposition of Cd, Pb, and Zn (k/a) for both lakes were calculated for the period 1800 to 2010 AD. Opposite to the similar concentration pattern of Cd, Pb, and Zn for both lakes, the MAR shows a diverse distribution for the last two hundred years (Figs. 1 and 2):

- Lake Czechowskie shows a moderate MAR (~200-400 t/a) between 1800-1820 AD but between 1820-1880 AD it increases to ~800-1100 t/a. Thereafter the MAR drops sharply and remains until present on a constant level (~225 t/a).
- Lake Tiefer See shows MAR values between 340 to 920 t/a that reach maximum values around 1940 AD. MAR for Cd, Pb, and Zn run parallel and start to increase ~1860 AD. After maximum values that were reached around 1940-1950 AD the heavy metal depositon declines until 1980 AD.

Interestingly, highest MAR values for Cd, Pb, and Zn not necessarily coincide with periods of highest heavy metal concentration (e.g. Lake Czechowskie between 1820-1860 AD). This reflects the relevance to determine MAR to evaluate heavy metal deposition in the lakes.

As authigenic components (e.g. calcite, pyrite, diatoms, total organic carbon content etc.) influence the heavy metal concentration of the sediments, different sediment types exhibit varying geogenic background values.

The heavy metal EF for Cd, Pb, and Zn vary in both lakes between 2 to 8.7 and exhibit slightly higher but comparable values to NE polish lakes (Tylmann et al. 2011).

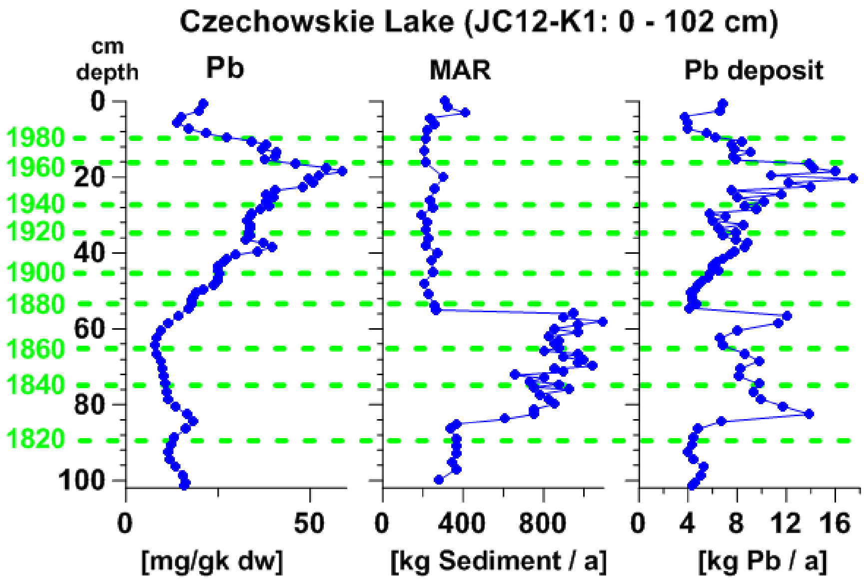

Fig. 1: Pb concentration (mg/kg dw), MAR (kg/a) and Pb deposition in the sediments of Lake Czechowskie between 1800 to 2010 AD.

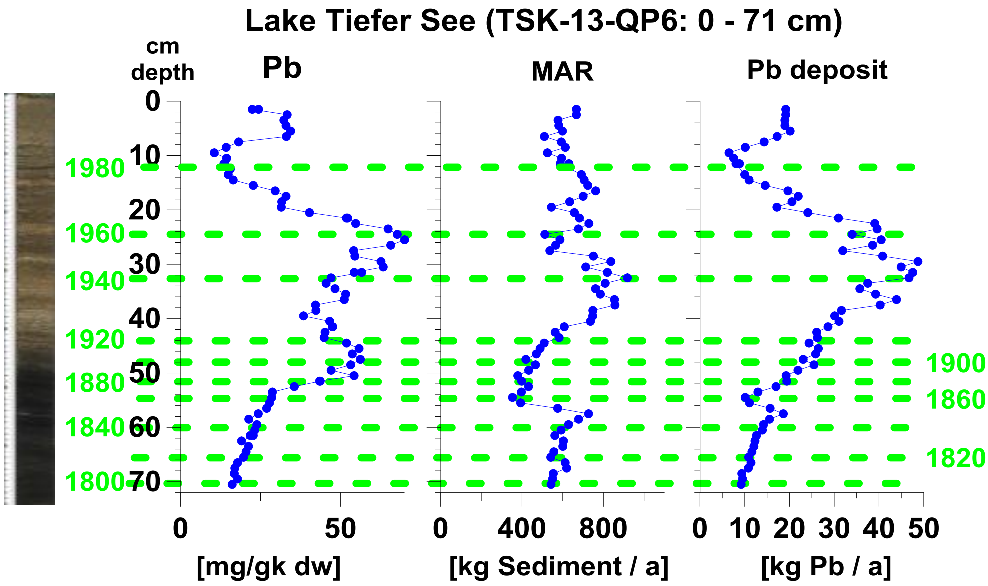

Fig. 2: Pb concentration (mg/kg dw), MAR (kg/a) and Pb deposition in the sediments of Lake Tiefer See between 1800 to 2010 AD.

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Theme A Monitoring / WP4

Estimation of coastal erosion rate on water reservoir

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The research of the transformation of the shore zone of artificial water reservoirs are long-term monitoring studies, often covering the entire length of the shoreline of the tested basin. Extremely valuable sources of data in such studies are variously dated cartographic materials: large-scale maps and surveying plans as well as aerial photographs. In recent years, the materials derived from the airborne laser scanning, i.e. light detection and ranging (LiDAR) which are among the most accurate terrain data, gained importance.

The possibility of using different type of data in the studies of the transformation of the shore zone of a water reservoir will be presented on the example of the Jeziorsko Reservoir on the Warta River (Central Poland). The reservoir was created in the years 1986-1992. It is a typical retention reservoir with large, nearly 5-m, water level changes in a yearly cycle. Its total surface area, depending on the water level, is between 19.6 km^2 and 242.3 km^2. The total length of the shore is 44.3 km, of which 14.2 km (32.1%) are embanked. Nearly 40% of the non-embanked shore is still active, and its development is the result of the processes of shoreline erosion, mass movements and accumulation. Most problems are caused by the abrasive shores which represent 27% of the non-embanked shoreline. The height of the accompanying cliff varies from a few cm to 12.5 m. Banks builds Quaternary glacial sediments (tills, sands and clays), and in few places Pliocene clays.

The paper aims at presenting contemporary research methods based on Geographical Information Systems, which may be used for estimation of coastal erosion rate on water reservoir.

The following cartographic and photogrammetric materials were used: topographic maps at a scale of 1:5000, 1:10000, aerial photographs taken in 1986, 1991, 2004 and an orthophotomap from 2005 and at scale 1:5000. Ground photogrammetry was use for current processes recording in coastal zone like mass movements (topples, landslides) and banks erosion. Other data from field studies were collected with the use of the GPS (the Global Positioning System).

In the years 1991-2009 the shoreline of the reservoir retreated by 6.9 to 18.7 m in the northern part of the reservoir (the cliff of 1-12.2 m) and by 9 to 29.6 m in its southern part (the cliff of 2.0-8.5 m). The cliff recession pace with the development of the shore zone significantly decreased; in the northern part of the reservoir the cliff recession dropped from 1.5 m/y in 1991-2004 to 0.5 m/y in 2004-2009, while in the southern part - from 0.7-2.22 m/y in 1991-2004 to 0-1.12 m/y in 2004-2009 (Fig. 1a).

The study used the airborne LiDAR data from the years 2009 and 2011 in the ALS formats, the raster with a resolution of 0.5 m and the point cloud of the resolution of min. 4 points per m^2. Their compilation with the materials previously used in the study, such as surveying, the DGP measurements of the upper edge of the cliff (2009), aerial photographs and orthophotomap made it possible to determine the rate and direction of the transformation of the shore of the Jeziorsko Reservoir since its construction until 2011 (Fig. 1b).

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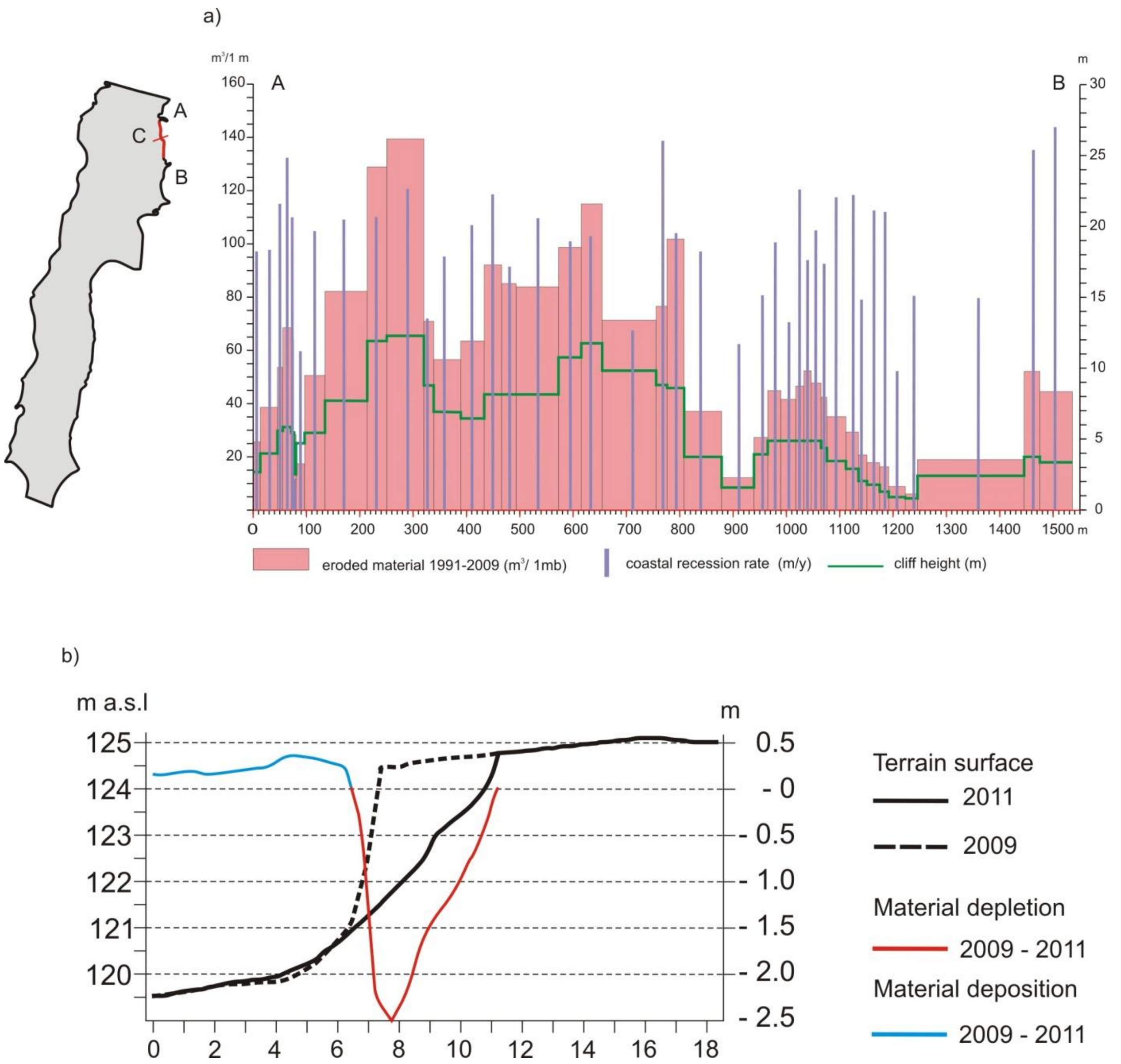

Fig. 1: Coastal erosion a) from 1991 to 2009 base aerial and ground photogrammetric materials, b) from 2009 to 2011 base airborne LiDAR data - cross section.

This study was supported by the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA) of the Helmholtz Association.

Theme B Present and Palaeohydrology / WP5

Multi-decadal lake-level dynamics in north-eastern Germany as derived by a combination of gauging, proxy-data and modelling

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In the glacially formed landscape of north-eastern Germany pronounced hydrological changes have been detected in recent decades (e.g. Kaiser et al., 2014, 2015), leading to the general question how lake levels and related groundwater levels perform in a long-term perspective, i.e. during the last c. 100 years. But long-term lake-level records are rare; most observations do not start before the late 20th century. Therefore, the potential of historic hydrological data, comprising drowned trees (as a geo-/bioarchive) and aerial as well as map imagery (as a document archive) was tested in order to derive discrete-time lake-level stands. These data are contrasted with lake-level simulations, obtaining a continuous-time series.

Two small glacial lakes without connection to the stream network (i.e. closed lakes) were investigated in the Schorfheide area, c. 70 km north of Berlin. Both are dominantly fed by groundwater and precipitation but differ in their hydrogeological and catchment characteristics. For one lake a c. 40 year-long gauging record is available, showing high lake levels in the 1980s followed by a lowering of c. 3 m till the mid-2000s. In both lakes submerged in situ tree remains were discovered and dated by dendrochronology, revealing low lake levels during the first half of the 20th century. One lake was almost completely dry until c. 1960. Aerial photos provided data on lake levels since the 1930s which are corroborated by evidence of topographic mapping. Combining the empiric data with retrograde lake-level modelling, a well-proven lake-level record can be established for one lake that covers the last c. 90 years (Fig. 1). The same general lake-level dynamics could be reconstructed by means of proxy data for the other lake. In both cases weather/climate has been the dominant driver of lake-level dynamics. Comparisons with other multi-decadal lake-level records from the region show that these differ, depending on the hydrological lake type which modifies water feeding and water level. The results clearly showed that lake levels exhibited substantial long-term changes that should be taken into account in future hydroclimatic and hydrological studies.

Ongoing work in the surroundings of the lakes examined aims, on the one hand, to realise a detailed study of structures (landforms, soils, vegetation) along shorelines that have been affected by water-level changes over the last decades. On the other hand, an analysis of sub-littoral sediment cores is under way for the adjacent lakes (Warnitzsee, Briesensee), and this aims to generate millennial-scale lake-level records. Combining all evidence, i.e. monitoring data, proxy-data analysis and further modelling efforts, we aspire to establish a long-term lake-level history for the region, covering the whole Holocene.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analyses - ICLEA-, grant number VH-VI-415. These ICLEA studies are supported by TERENO infrastructure of the Helmholtz Association. Some research had already been carried out within the NEWAL-NET project funded by the German Ministry of Education and Research (Grant No. 0330562A).

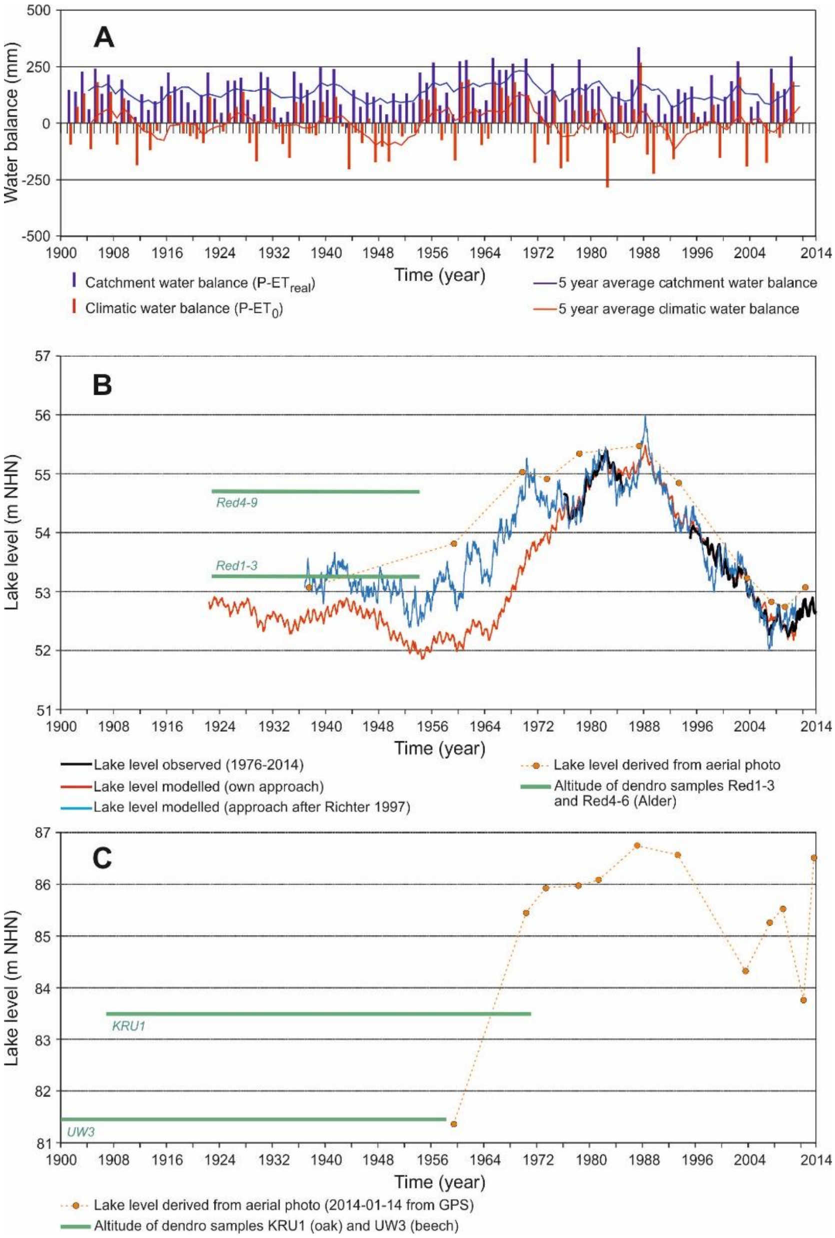

Fig. 1: Synoptic overview on multi-decadal climatic and lake-level dynamics in the study area.
A – Catchment water balance und climatic water balance for Lake Rednerswalder See and Angermünde meteorological station, respectively.
B – Lake-level dynamics of Lake Redernswalder See according to different evidence.
C – Lake-level dynamics of Lake Krummer See according to different evidence.

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Theme B Present and Palaeohydrology / WP5

Discovery of a drowned forest from the early Holocene in the Mecklenburg Lake District, north-eastern Germany

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In 2014 subaquatic tree remains were discovered by scuba divers some metres below the present level of Lake Giesenschlagsee (north of Rheinsberg/Mark). This 32 ha large glacial lake (max. 23 m in depth) is embedded in an outwash plain and dominantly fed by groundwater and stream water inflow. For the period 1972-2014 lake-level monitoring at this lake revealed a maximum amplitude of 50 cm. According to growth properties (upright position, roots) eight tree stumps were found in situ so far (Fig. 1). Research on the properties of the tree remains and their geological-geomorphological setting (e.g. character of the former land surface bearing the stumps) has recently begun.

The stumps occur in a water depth interval of c. 2.5 to 5 m. The largest diameter and height of a stump observed is c. 40 cm and 70 cm, respectively. The cut surface of one of the stumps showed c. 80 year rings. Four stumps were botanically determined revealing pine (*Pinus* sp.; 2x) and undiff. conifer (2x). Radiocarbon dating of three stumps yielded an age interval of 9190 ± 50 to 9520 ± 50 BP (9140-8293 cal BC), corresponding with the early Holocene. Dendrochronological dating of the terminal piece of one stump (c. 50 tree rings) yielded an unlikely age (1954 AD).

To our knowledge, the 'drowned forest' at Lake Giesenschlagsee is the only one in situ assemblage of old (prehistoric) subfossil trees on the bottom of an inland lake in north-eastern Germany detected thus far. By contrast, very young (historic) in situ tree remains of beech, oak and alder (period 1895-1979 AD) were discovered below the water levels and along the shorelines of two lakes in the Schorfheide area, north of Berlin (Kaiser et al. 2015). Old (i.e. early to late Holocene) submarine tree remains of different species (e.g. in situ stems and stumps of oak), however, were discovered along the Baltic Sea coast, partly forming well-investigated geo-/bioarchives (e.g. Lampe 2005; Uścinowicz et al. 2011).

The tree remains recently discovered in Lake Giesenschlagsee offer an exceptional opportunity to examine ecological and site conditions during the early Holocene with special focus on forest structure, tree growth dynamics and the climate proxy potential of tree rings/wood. Furthermore, as the tree remains and the related land surface prove an early Holocene lowstand of the lake level, they substantially contribute to the palaeohydrologic history of Lake Giesenschlagsee. Ongoing research (prospection phase) aims at the discovery and mapping of further tree remains at this lake using scuba divers and imaging both of a remotely operated vehicle (ROV) and a side scan sonar. Furthermore, by means of a sediment penetrating sonar the lake bottom stratigraphy shall be explored, preparing for core drillings in order to characterise the former terrestrial surface (soil cover) in which the trees grew. At the end a complex sampling and analysis procedure is planned (analysis phase) focussing on local sedimentology/geomorphology, palaeopedology, palaeohydrology and vegetation history including dendrochronology/-ecology.

Fig. 1: In situ tree stump of pine (Pinus spec.) found in Lake Giesenschlagsee in a water depth of c. 4 m with a maximum diameter of c. 40 cm and a height over the lake bottom of c. 70 cm (Photograph: S. Oldorff). The stump yielded a radiocarbon age of 9520 ± 50 BP (9140-8710 cal BC).

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analyses - ICLEA-, grant number VH-VI-415. These ICLEA studies are supported by TERENO infrastructure of the Helmholtz Association. Financial support was further provided by the project Diving for Environmental Conservation of the Naturschutzbund Deutschland (NABU).

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Theme E Human impact / WP5

Rapid assessment of dating of terrestrial geoarchives using a portable OSL reader

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Recent soil and topographic patterns in the young morainic area of northeastern Germany are mainly caused by human-induced (pre-) historical processes, e.g. deforestation or soil erosion, that are mainly linked to agrarian land use. Ongoing research in the Uckermark region aims at the chronostratigraphical potential of terrestrial archives like slopes, floodplains or alluvial fans. Dating of specific sediment layers/soil horizons by means of optical stimulated luminescence is time-consuming and expensive. Therefore, information about depositional dynamics before detailed sampling would be a major advantage to develop a well-adapted site-specific strategy.

A novel approach has been established for rapid assessment of terrestrial archives (e.g. Munyikwa and Brown 2014; Sanderson and Murphy 2010). A portable OSL reader from the Scottish Universities Environmental Research Center (SUERC) was used for high-resolution measurements of sediments (depth interval = 10 cm). This method enables the measurement of the natural luminescence signal of quartz (OSL) and feldspar (IRSL) grains in untreated samples in a very cost- and time-efficient manner. The luminescence profiles obtained give an insight into the depositional dynamics of the profiles, e.g. revealing macroscopically non-distinguishable hiatus in the sequence ("crypto-stratigraphy", e.g. Fig.1, C ~ 130 cm depth) or showing disturbances in the sedimentary structure. Another benefit is the potential to identify insufficiently bleached sediments, consequently avoiding false burial ages (e.g. Fig.1, B).

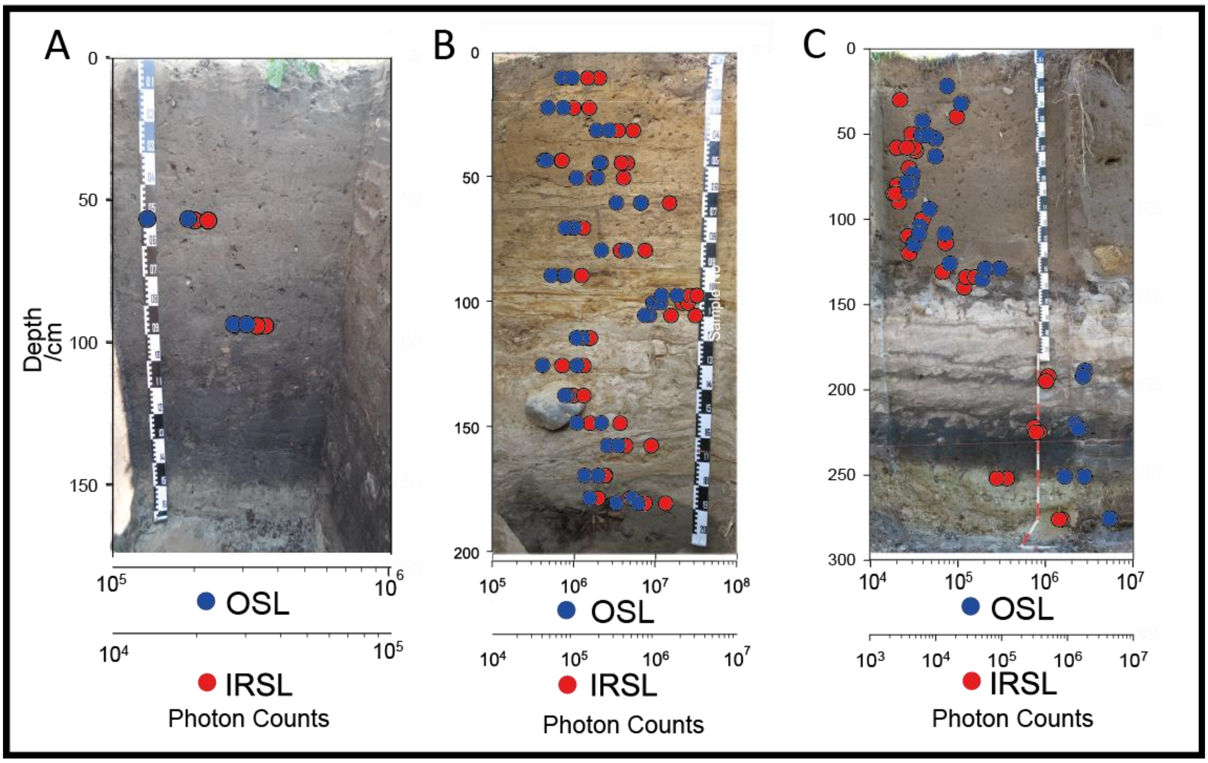

Fig. 1: Exemplary soil profiles of the Quillow-Catchment, Uckermark, NW Brandenburg with plotted luminescence intensities of OSL & IRSL [total photon counts].

As a perspective, there is the possibility to construct "pseudo-luminescence ages" within these sequences if at least two or three conventional OSL-ages are available and the environmental dose rate is nearly constant over the profile. The suitability of this approach for constructing high-resolution age-profiles in terrestrial archives is subject of further research.

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

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What can we learn from soil? Excursion to Lake Fürstenseer See catchment (Müritz National Park) during the 1st Annual ICLEA Workshop 2012 in Templin, Germany (photo M. Schwab, GFZ).

Theme A Monitoring / WP4

The role of lakes and palaeolakes in shaping the runoff and chemical properties of water in the young-glacial catchments – example of Lake Czechowskie

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The impact of lakes on the size and variability of river discharge as well as their role in the transformation of the chemical properties of the outflow from the lake catchment have been addressed in the scientific literature for a long time (e.g. Hillbricht-Ilkowska, 1999; Bajkiewicz-Grabowska, 2002). Focusing on the existing lakes, researchers generally ignored the effect of fossil lake basins filled up with organic mineral deposits. Defining their role and importance in the water and matter cycles is one of the objectives of the hydrological and hydrochemical monitoring, which has been run in the catchment of Lake Czechowskie from mid-2012.

The axis of the Lake Czechowskie catchment is a hydrographical system made of river and lake sections. Lake sections are not only present-day lakes (Głęboczek and Czechowskie), but also basins of the lakes operating in the past, which are now biogenic plains. Lake sections of the system are connected by short valley sections, mostly of a gap character. The size and variability of surface water runoff from the basin is mainly affected by groundwater and the size of evaporation. Stable groundwater table provides stability of the river discharge, even during the periods of significant precipitation deficit.

Groundwater fluctuation ranges registered during the period from May 2012 to February 2015 were between 0.17 and 1.25 m. The smallest were in the deepest piezometers located in watershed areas, and the largest in the shallow groundwater of lake terraces. The small dynamics of the groundwater states is reflected by slight fluctuations of water levels in Lake Czechowskie, which in the analyzed period amounted 0.40 cm.

The surface of palaeolake Trzechowskie, cut by a system of drainage ditches, is the area where an essential part of the surface runoff from the monitored catchment is formed. Large water resources in this part of the catchment are evidenced by the specific runoff value, which amounts to 25 $dm^3s^{-1}km^2$. It is much larger than the whole basin specific runoff which reaches 11 $dm^3s^{-1}km^2$. The measurements showed that the average surface runoff from Lake Czechowskie in the analyzed period was 0,065 m^3s^{-1} and was similar to the size of the water influx via watercourses supplying the lake. On the basis of this value it was calculated that the theoretical time to replace the water in Lake Czechowskie is 2.8 years.

The hydrochemical study showed that the studied ground- and surface waters represent the same bicarbonate-calcium-sulphate hydrochemical type. Against the background of a homogeneous ionic composition, the spatial variation of their overall salinity is very large. This is reflected by the values of electrolytic conductivity, which in the study period ranged from 76 to 1218 $\mu S \cdot cm^{-1}$. The most mineralized (700-800 $\mu S \cdot cm^{-1}$) are the waters of streams migrating in the organic-carbonate formations of the palaeolakes and shallow groundwater in these areas (Fig. 1). The lowest mineralization is showed by the groundwater circulating in sandy sediments of outwash plains. Mineralization of the Lake Czechowskie water of approx. 340 $\mu S \cdot cm^{-1}$ is a result of supplying the lake from both sources and the effect of biogeochemical processes occurring in the lake (Fig. 1). The hydrochemical monitoring results showed that the zones of water enrichment in salts are associated with palaeolake basins filled with the organic-carbonate sediment, while the salt precipitation zones with lakes.

The results of the study of matter flow in the basin of Lake Czechowskie showed that palaeolakes equally affect the runoff volume and the transformation of the chemical properties of the water circulating in the basin as the lakes functioning today. The modern lakes and palaeolakes create a cascade system of

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interconnected basins. Depending on the place they occupy in the cascade, their effect on the water circulation and transformation of matter is different.

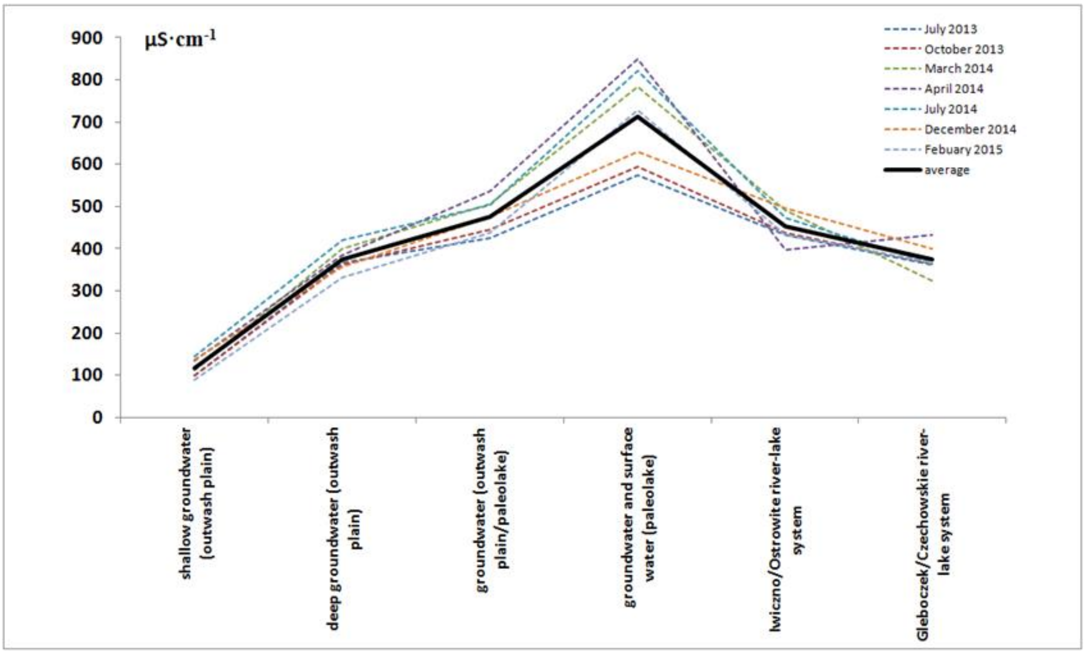

Fig. 1: Average value of the electrolytic conductivity of water in the specific groups of ground- and surface waters.

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Theme A Monitoring / WP4

Nutrient input and spring temperature development have interfering effects on algal development in Lake Tiefer See

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Monitoring of deep Lake Tiefer See showed a much larger deposition of diatoms following ice out and a rapid spring stratification in mid-April 2013 compared to that following the gradual warming and stratification in mid-April 2012. The manifold of diatom individuals in 2013 compared to 2012 amounted to calculated 2.0 compared to 0.15 g silica per square meter and day during the spring maximum. The striking difference was the two orders of magnitude larger number of *Stephanodiscus* sp. in 2013, which were only a minor component in 2012.

The monitored weather and lake conditions suggest the 2013-spring bloom was boosted by a quick succession of ice breakup, spring turnover, and stratification leading to nutrient recycling and rapidly improved light conditions. The comparatively longer mixing in spring 2012, calculated using the lake-temperature model FLake (Kirillin 2010; Mironov 2008), in contrast, caused population losses that impeded bloom development.

To verify the exemplified inverse relation of diatom deposition and mixing duration in spring we use the subannually laminated, recent sediment record of Lake Tiefer See (AD 1924 – 2008) (Kienel et al. 2013), the instrumental series from the meteorological station in Schwerin, and model simulations of the spring mixing. The mixing duration was calculated as the period between water temperatures of 4°C and a mixing depth of 6 m were reached for the period 1951 – 2008. To cover the full sediment record a simple estimate of the mixing period was calculated from mean temperatures, i.e. the temperature duration from the first 5°C-day to the first of ≥5°C days.

The annual diatom deposition was calculated as the annual average µXRF-counts of Si in the sediment record (AD 1924-2008), based on negligible amounts of detrital Si, low deposition of inorganic matter during winter, and a striking balance of IM deposition and Si deposition calculated from the diatom frustules deposited.

We find support for the linear and inverse relation of diatom silica deposition with the duration of spring mixing using the modelled mixing duration with 32% explained variability and with 20% using the temperature relation, respectively. The explanation increases to 52%, respectively 55% when the period AD1980-2005 is removed from the data set. The lack of diatom response during this period is supposed to relate to the primary influence of nutrients from intensive manuring and drainage in the catchment on the algal development at that time (Kienel et al. in review).

This influence of nutrients is supported by nitrogen isotope values measured in organic matter subsampled annually along the sediment record (AD 1924 – 2008). The $\delta^{15}N_{org}$ values increase from a recent background of 5 to 7 ‰ $\delta^{15}N_{org}$ to 9 ‰ in 1978 synchronously with an increase of lifestock farming in the lake catchment. These values are similar to the average $\delta^{15}N_{org}$ measured in trap material. Along with $\delta^{15}N_{NO3}$ values up to 12 ‰ measured in the epilimnion water of the lake this indicates manure as the source of the nitrate.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analyses -ICLEA-, grant number VH-VI-415. The monitoring equipment used was funded by the Terrestrial Environmental Observatory Infrastructure initiative of the Helmholtz Association (TERENO Observatory NE

Germany). Financial support was further provided by the project "TSK Link" (BR 2208/11-1; LA 1029/6-1) funded by the "Deutsche Forschungsgemeinschaft" (DFG).

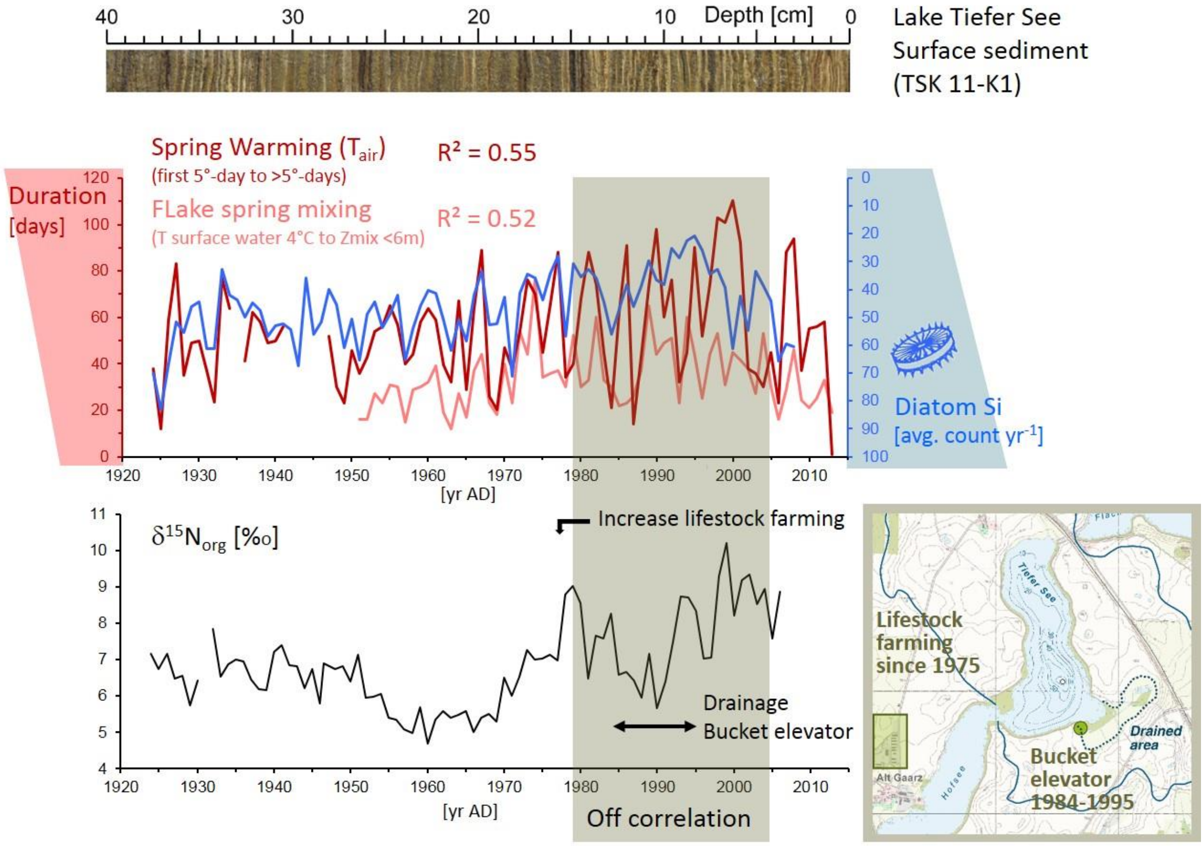

Fig. 1: Inverse correlations of the durations of spring warming and FLake spring mixing with the diatom Si along the varved, recent sediment record of Lake Tiefer See, estimated after the period of increased nutrient input from manure is taken off the data set. Insert: positions of stables for lifestock farming and bucket elevator in the catchment of the lake.

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Theme B Present and Palaeohydrology / WP1 & WP5

Progress on the reconstruction of sedimentary evolution of Czechowskie Lake and its hypothetic past water level fluctuations

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Czechowskie Lake is located in north-central Poland in Tuchola Forest, about 100 kilometers SW away from Gdańsk. In the deepest parts of the lake there are preserved laminated sediments with a unique, excellent Holocene climatic record. The lake has the area of 76.6 ha. Actual water level is at 109.9 m a.s.l. The average depth is 9.59 m, maximal 32 m. The maximum infilling with the limnic and telmatic sediments reaches over 12 m. In the terrestrialised part of the lake and in its litoral zone there have been made numerous boreholes crossing limnic and slope sediments. They have been analysed in respect to lithology and structure. Some of them were also investigated palynologically which along with radiocarbon datings allowed to reconstruct major phases of the water level fluctuations.

The lake has a history dating back to Pomeranian phase of the Upper Vistulian glaciation which is proved by an analysis of sedimentary successions in the vicinity of present-day water body. Primarily it come to existence as an spatially very variable ice dammed lake with varying lake levels and glacilimnic clays deposition but after dead ice and permafrost disintegration it changed deposition style towards a lake with gyttjas deposition which are very differentiated. The earliest change in favor of this type of deposition was recorded at about 12 800 radiocarbon years ago. Until the onset of Holocene there is marked also intensive process of turbidites deposition.

First approximations of water lake fluctuations indicate highest water stand at ca 12 800 radiocarbon years ago reaching about 113.5 m a.s.l. The lowest water level occurred most probably about 10 000 – 7 000 years ago going down to about 101 m a.s.l (about 8 m below preset level). The total water level fluctuations may have also had a range of about 12-13 m. The detailed course of fluctuations is still matter of ongoing debate but it is clear that about 500 years ago come to a rise of the water of about 1 m over present-day level due to construction of watermills on the outflow watercourse from the lake. The water level reached present level about 200-300 years ago due to intensive melioration of that area. It is consistent with the beginning of peat cover sedentation which starts in most cases also 200-300 years ago. Final terrestrialization of the north western part of the lake came only 200-300 years ago and is caused anthropogenically.

In the bottom of the lake there is a marked presence of many overdeepenings with the diameter of dozen or several dozen meters and the depth of up to 10 m with numerous, distinct troughs between them. They favored the preservation of the lamination in the deepest parts of the lake due to waves hampering and stopping of the density circulation in the lake water body. The analysis of limnic sediments revealed considerable spatial and temporal variability mainly in dependence of the area of the water body and water level in time of deposition. In the lake are recorded three distinct phases of lake level decrease. The sedimentary evolution in the isolated minor lake basins showed gradual decrease of mineral and organic deposition in favor for carbonate one although in places separated by transient increase of organic sedimentation. Increased deposition of colluvial deposits took place in Late Glacial and again about 200 years ago due to transient deforestation of the lake vicinity.

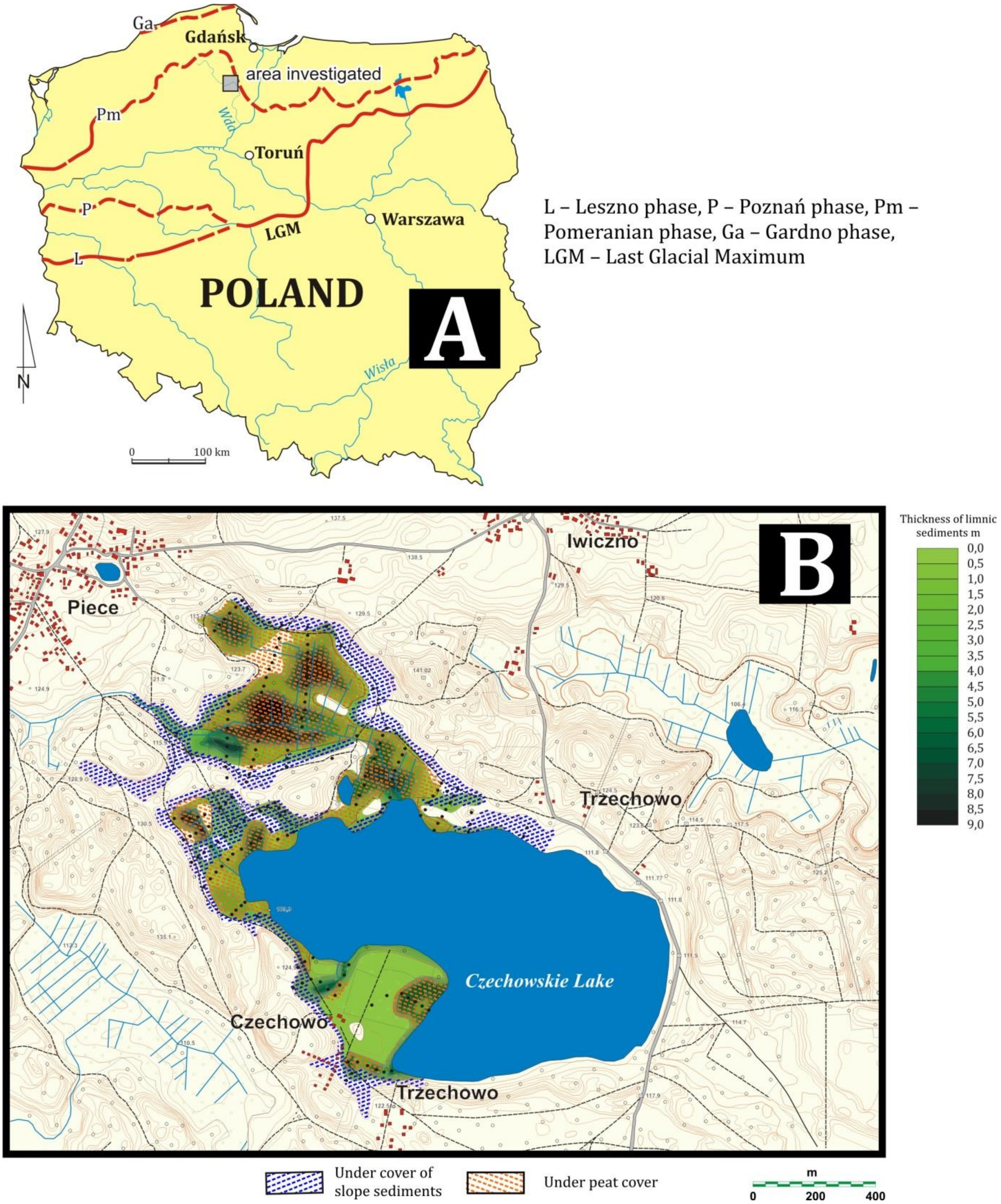

Fig. 1: A) Location of an area investigated; B) Reconstructed filling thickness with limnic sediments in the terrestrialised part of the lake.

Theme A Monitoring / WP1 & WP 5

Relevance of river lakes in circulation of water and sediments on the floodplain of the lower Vistula valley

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Regarding the outflow the Vistula River is the largest river in the Baltic catchment. In its lower course it has developed an anastomosing channel pattern modified strongly by intensive human hydro-technical activity and by the regulation which have intensified about 200 years ago. Channel regulation apart from already existing lakes have left many new artificially created much smaller than the preexisting ones.

This activity has also altered the hydrological and sedimentary regime of riverine lakes. It turned out that only the small portion of the lakes infilled rapidly but the majority has persisted to present day almost unchanged in spite of regulation.

The reason of this resistance to silting is connected with specific interaction of sediment removing during high flood water episodes and strong groundwater circulation in former river arms transformed in present-day lakes located close to main river channel.

The main object of investigations with an intensive groundwater exchange rate with the main Vistula channel and supposed Quaternary and Tertiary aquifers was the Old Vistula lake (Stara Wisła) near Grudziądz town. It has got an area of 50 ha, mean depth 1,73 m, maximum depth 8 m, length about 4 km and medium width about 100 m. In the years 2011-2015 on the water surface layer there were conducted cyclic, two weekly field measurements which included following parameters: temperature, pH, Eh, suspended matter amount, total and carbonaceous mineralization. For discrimination of water types which play significant role in water circulation on the Vistula valley floor similar measurements were also conducted in other fluvial lakes and Vistula tributaries. To find the differences in valley setting processes and the morainic areas outside it some measurements were also carried on the Chełmżyńskie Lake, 30 km from the valley edge. Hydrological data were supplemented by geological investigations of floodplain sediments cover which has important impact on the rate of groundwater migration and circulation.

Investigations carried proved that there exists distinct gradient of carbonaceous mineralization from small values in the Vistula channel to high values at the valley edges. PH and Eh parameters in the Old Vistula lake were different than in all other surveyed sites what leads to conclusion that it is fed by deeper ground-waters than in the case of other fluvial lakes and Vistula tributaries, particularly in low water stand times. This is because it has not continuous flood sediments cover on its floor. The sediments accumulated during the low stands of water are removed from fluvial lakes while high stands by flood waters. Temporarily deposited sediment is also removed due to high groundwater "exchange" rate when the fluvial lake has a sufficient hydrological connectivity to the main Vistula channel.

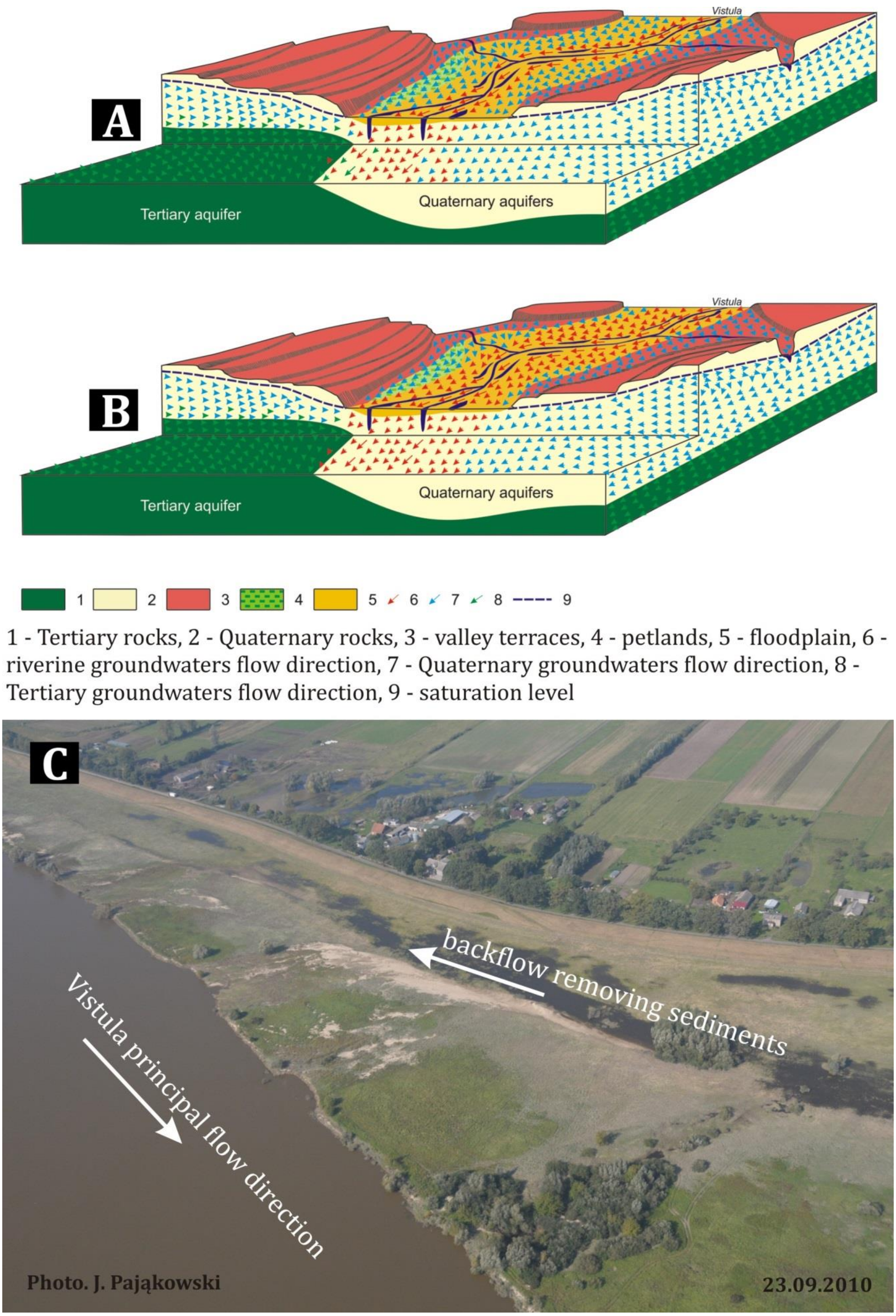

Fig 1. A, B – conceptual model of water circulation in the lower Vistula River valley for low (A) and high water stages (B). C – Photography illustrating the process of removing of sediments due to flood in May 2010.

Theme C High resolution climate reconstruction / WP4

Lake Jelonek (North Poland) – preliminary results of microfacies analysis and high resolution µ-XRF element scanning

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Lake Jelonek is located in Northern Poland (53°45'58N, 18°23'30E). In 2013 and 2014 a Polish-German team recovered three overlapping series of sediment records JEL14-A-(1445 cm), JEL14-B-(1430 cm), JEL14-C-(1435 cm) and seven 1 m cores JEL13 (K1-K7) from the deepest part of Lake Jelonek (13.8 m)(Fig.1).

The cores were split in half, lithologically described, photographed and correlated with each other by 28 marker layers to construct a composite profile covering 1426 cm (Fig.2). The entire profile was sub-sampled for continuous series of overlapping thin sections.

Here we present detailed varve micro-facies for different sediment intervals and the preliminary chronology based on AMS ^{14}C dating of 10 terrestrial macro remains samples and the Askja AD-1875 tephra. Additional analyses, so far, comprise µ-XRF element scanning which will be used to infer sediment changes reflecting internal and external processes. Furthermore, previous pollen investigations by A. Filbrandt-Czaja (2009) will be implemented into the recent study and continued by pollen analyses of continuously taken (1 cm increments) samples.

The main goal is to synchronize the sediment record from Lake Jelonek with records from Lake Czechowskie and paleolake Trzechowskie, located 15 km north-east, to achieve a comprehensive knowledge of landscape forming processes and to distinguish between local and regional impacts during the past.

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. These ICLEA studies are supported by TERENO infrastructure of the Helmholtz Association.

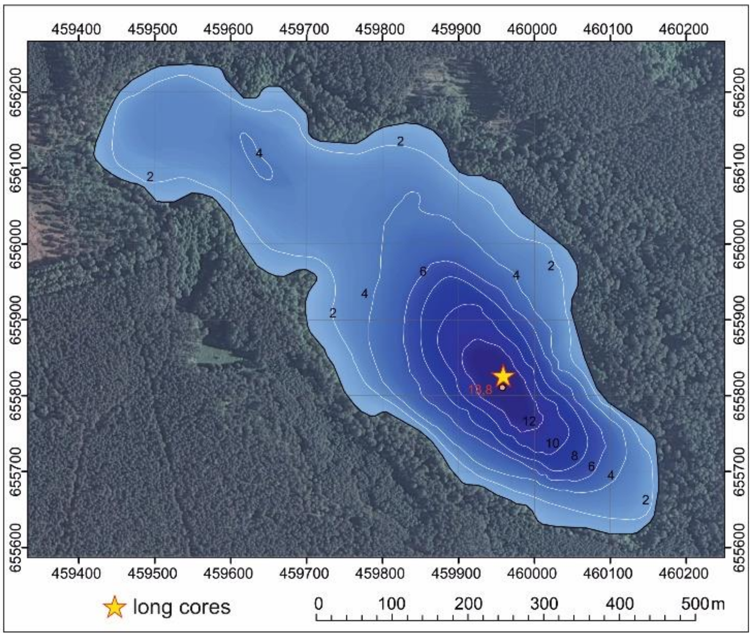

Fig. 1: Bathymetric map of Lake Jelonek.

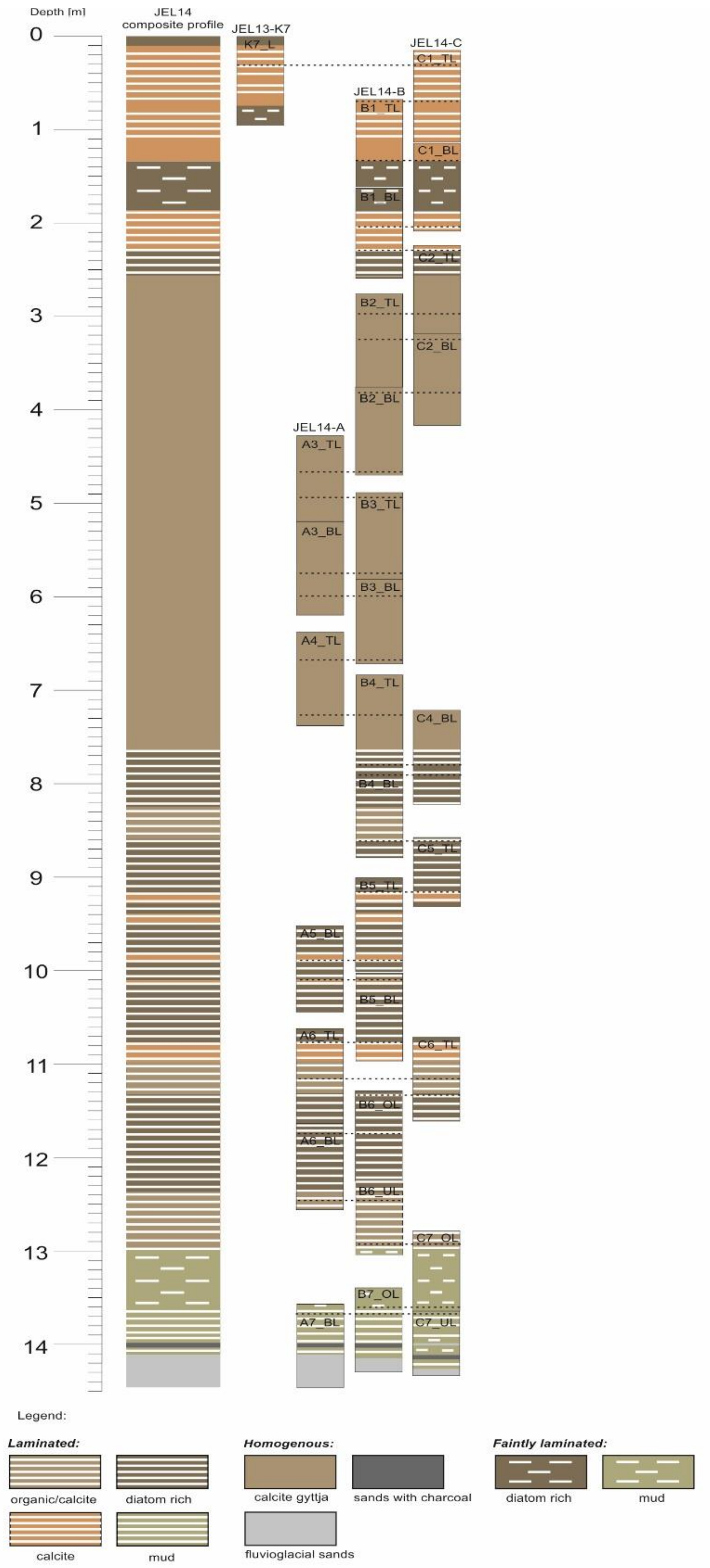

Fig. 2: JEL14 composite profile.

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Theme D Late Glacial landscape change / WP5

Soil memory in environmental and archaeological reconstructions – capabilities, benefits, restrictions

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Soil as a natural habitat of plants, animals and human is one of the most important elements of natural environment, subjected to continuous impact of external factors. As a result, internal soil system can be disturbed, often irreversibly. Soils are reservoirs of knowledge about past and contemporary processes in view of their persistent pedogenic soild-phase characteristics (Targulian and Sokolova 1996; Targulian and Goryachkin 2004, 2008). Soil-based reconstructions can be performed on poorly or moderately transformed areas. Strongly modified regions, (especially brownfields or build-up areas) aren't good research objects in view of significant damage of soils and lack of changed and natural study areas comparisons possibilities. Contemporary soil cover is the sum of natural pedogenic processes and their transformations occurring in the course of history. From the beggining of human activity, signs of natural and anthropogenic processes have been saved in soils. Depending on soil type (mineral, organic), these transformations are different and concern to other characteristics. Knowing the benchmark characteristics of each soil types and their changes it is possible to reconstruct natural environmental conditions. The most visible are changes of soil morphology, which depending on type of causative factor. Natural system of horizons is very important to proper soil functioning. Interference in this sequence can lead to basic soil functions disruption and finally to its degradation. Soil profiles truncation is a common dangerous problem, especially on undulated tilled areas (Świtoniak 2014). Reduction of soil thickness can be treated as an indicator of human impact intensity. These and other anthropogenic activity signs can be saved in soils for a long time. Soil morphology changes in combination with interference in soil physical and chemical properties allows to make environmental and archaeological reconstructions. Soils are linked to topography, human impact and every process occurs at the soil surface.

Based on Targulian and Goryachkin (2004, 2011) observations, soil memory has „in situ" character, what makes it the perfect tool for the reconstructions on the local scale. Furthemore, soil as a complex, unconsolidated mixture of inorganic, organic and living material is characterized by unique properties, which are much more useful for landscape restorations than informations included in sediments. Individual soil units created with a comibination of factors, like microclimate, microrelief, plant cover, etc., constitute a record of the soil-forming processes and local environmental and anthropogenic conditions. Actually natural soil chemistry and morphology in comibination with the study of human-transformed soils are probably the best-known applications of soil science in archaeological research (Holliday 2004).

Each sediments deposited at the earth's surface are subjected to transformations as a consequence of natural and anthropogenic proceses. Soil-forming processes convert these deposits into soils, which are characterized by unquotable properties and horizons sequences. Furthemore, soil as a complex, unconsolidated mixture of inorganic, organic and living material is characterized by unique properties, which are much more useful for landscape restorations than informations included in sediments.

The study area is located within the Drawsko Lakeland, which is a part of the West Pomeranian Lakeland in northwestern Poland. The research was conducted within two differently used keetle holes (meadow, arable land) (Fig. 1).

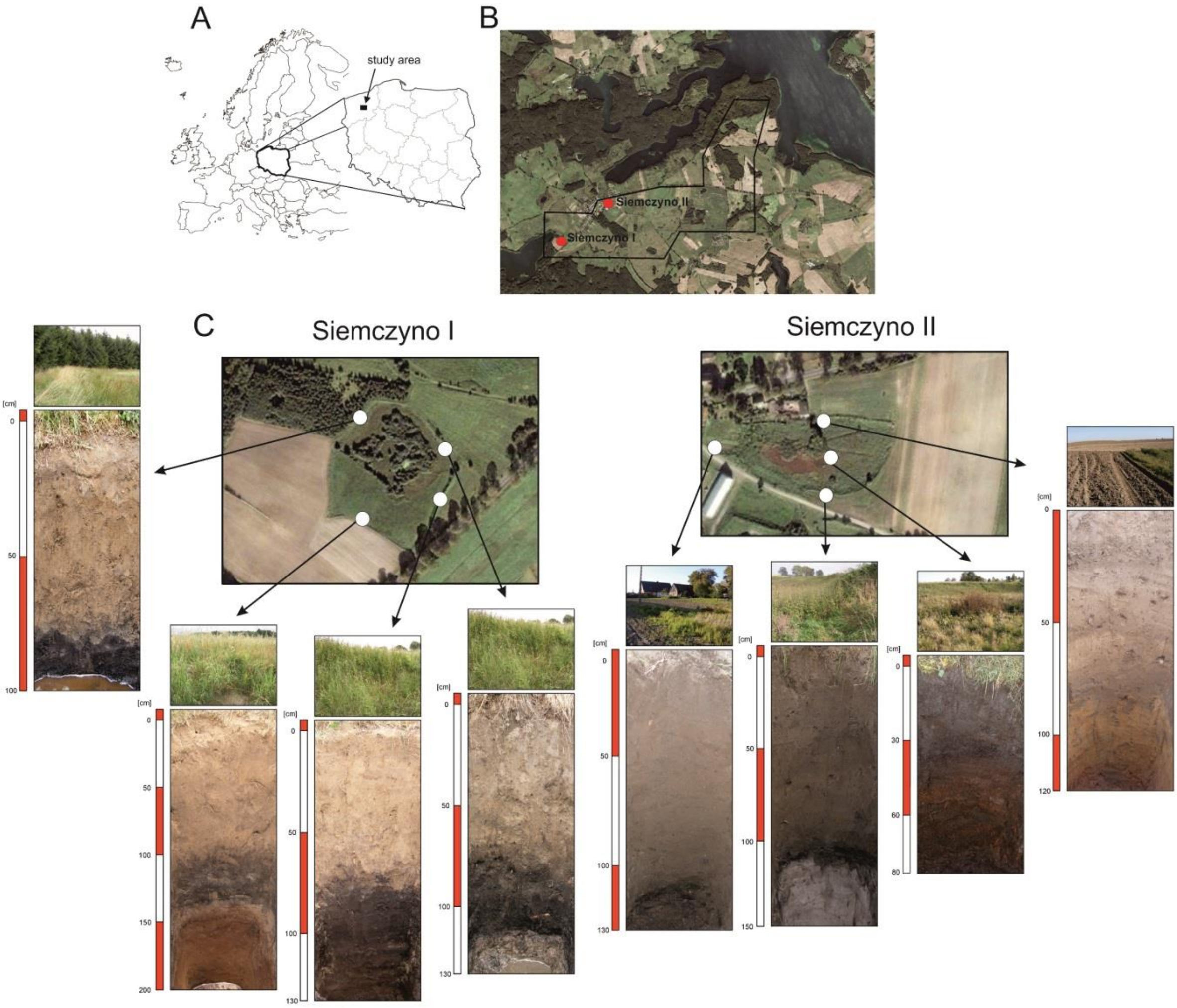

Fig. 1: The research area: A – location, B – study area ortophotomap, C – selected soil profiles on Siemczyno I and Siemczyno II.

This paper presents results obtained as part of the project "Changes of properties of basins without outlets in the young glacial landscape as a result of anthropogenic denudation and erosion." This project has been supported by the Polish Ministry of Science and Higher Education (Research Project No. N N305056240).

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Theme D Late Glacial landscape change / WP5

Ground penetrating radar soundings of an abandoned Wda river valley

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The paper present the results of the research, which have made on a former branch of the Wda river valley, in the area covered by Quaternary (Vistulian) deposits in the northern part of Poland. Now this branch of the valley is dry, inactive, and all former channels are filled up with biogenic sediments (peat and gyttja).

The research took place on about 3.5 km long section of the former meandering river valley around the Szlaga forester's lodge. Thickness of the biogenic sediments was measured by GPR method. GPR studies were supported by detailed geologic data from hand drillings (up to 2.5 m). Twelve hand drillings cross-sections have been made.

To the GPR research was chosen the high resolution 400 MHz central frequency antenna with GSS'I SIR SYSTEM-2000™ georadar. Horizontal scaling was made by survey wheel device. The range of radar penetration was adjusted to 150 ns (10^{-9} s) two way time (TWT), what is an equivalent of 3 meters in depth of peat sediment with assumed dielectric constant about 55 (Fig. 1).

Overall, 34 radar cross-sections was made all in all more than 1500 meters crosswise of the valley (including the 5 calibration ones – not marked on the map) in selected locations at intervals of 50-150 m from each other (Fig. 2). On most ground penetrating radar cross-sections, the organic sediments up to a depth of about 2-2.5 meters have been recognized (Lamparski 2009, Błaszkiewicz et al. 2015). The ground penetrating radar profiling method (GPR) was used also to recognition an internal structure of the biogenic sediments. Some geophysical anomalies representing boundaries between peat and gyttja have been identified.

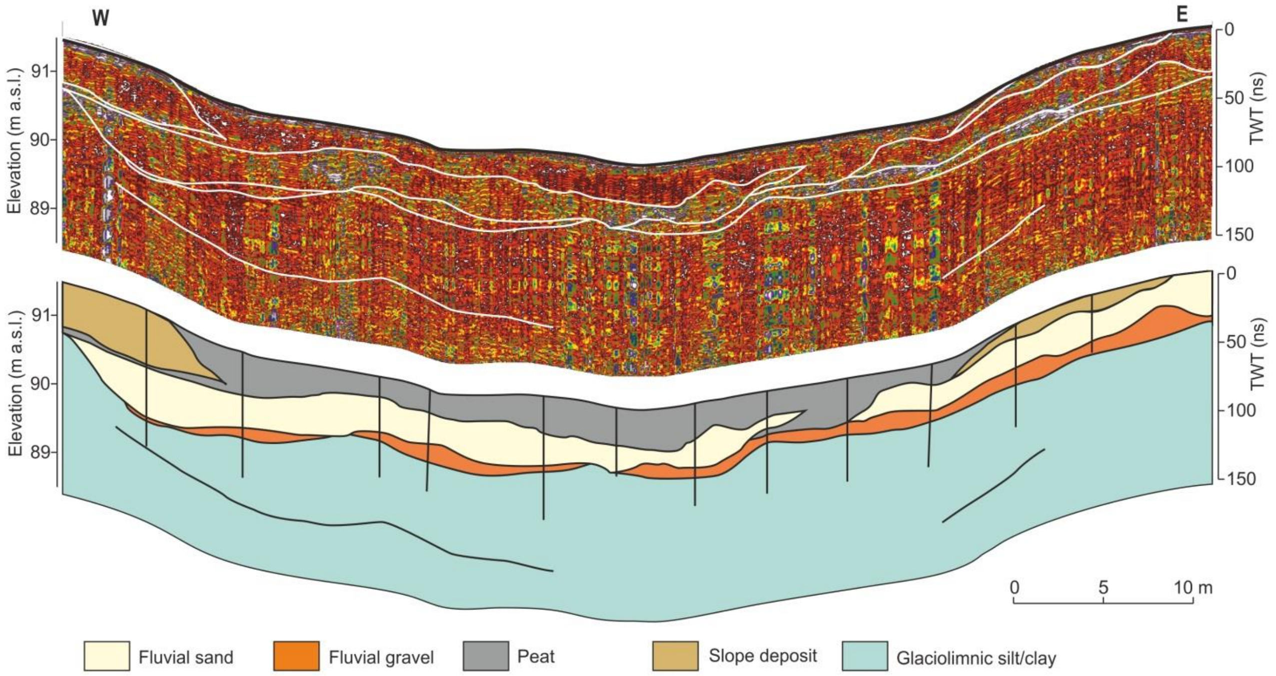

Fig. 1: Interpreted GPR profile (PSD1) through the northern part of the abandoned Wda river valley (top) and geological cross-section based on GPR and drilling data (bottom). Locations in Fig. 2.

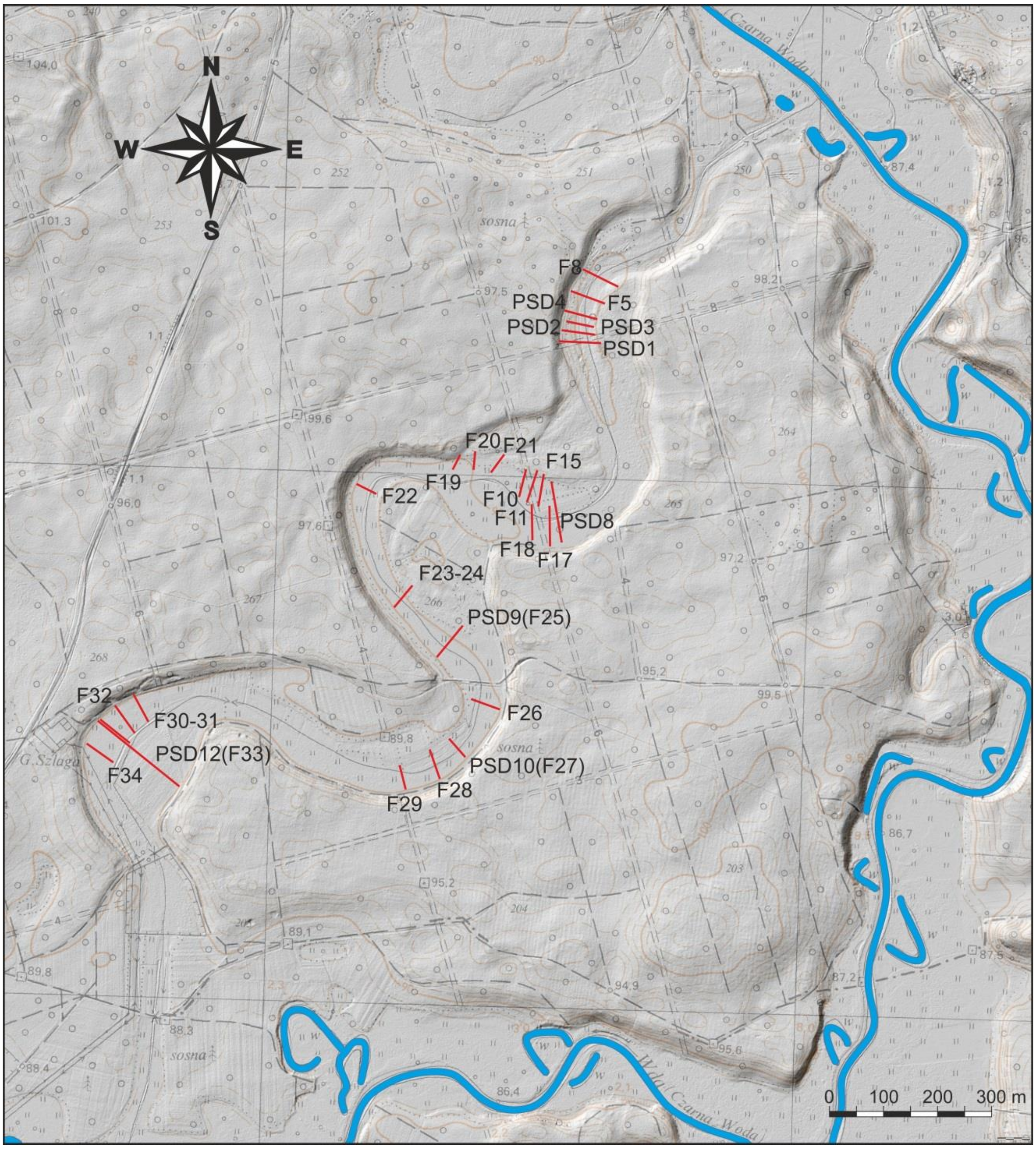

Fig. 2: Location map of the GPR profiles.

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

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Theme D Late Glacial landscape change / WP4

From Weichselian deglaciation to Late-glacial and Early Holocene lake basin and river valley formation – the Dobbertin basin (Mecklenburg-Vorpommern, NE Germany)

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In central Mecklenburg-Vorpommern vast areas between the terminal moraine belts of the Frankfurt Phase (W1F) and Pomeranian Phase (W2) were covered by glacio-lacustrine basins embedded in the outwash plains. We study late-glacial to early Holocene basin and landscape development using cores collected along a pipeline trench crossing the Dobbertin basin in Mecklenburg. Core analyses include sedimentological (carbon content, grain size distribution) and palaeoecological proxies (pollen, plant macrofossils, Cladocera) as well as absolute datings by ^{14}C and OSL.

With deglaciation of the Frankfurt Phase the depression north to the villages Dobbertin and Dobbin ("Dobbiner Plage") were covered by a glaciofluvial river system in combination with local ice-dammed lake basins. The early glaciofluvial phase of W1-deglaciation is represented by cross bedded gravel and sand deposits. This glaciofluvial sequence has been dated by OSL in several profiles around 20 ka BP. On top of the glaciofluvial sequence numerous periglacial structures like meso-scale frost cracks up to large scale frost wedge casts with a maximum of 2 m depth were to found (Fig. 1). The first uncalibrated OSL data of re-deposited cover sand (aeolian?) from ice wedge filling give varying ages between 19.5 – 17.3 ka BP. This timing of periglacial encroachment perfectly correlate with glacial transgression period during colder climatic conditions of Pomeranian ice transgression phase (W2).

The lacustrine sedimentation and bog development during late glacial period is well preserved in numerous depressions with diameters of 30-100 m, which are separated by W1F till ridges or glaciofluvial sediments, but once formed one large lake basin. The sediment sequence starts with glaciofluvial deposits. During the late-glacial around ~14 ka BP 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. 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* sp., *Nitella oognia*). The expansion of rich fen communities, including *Scorpidium scorpoides*, and a decline in Cladocera diversity show that these lakes soon again terrestrialised with peat formation. The appearance of *Alona costata* points at a lowering of pH values in that process. A tree trunk of birch (14.2 ka cal. BP) shows that first trees 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 warming period affected the melting out of buried dead ice blocks as well as the deepening of basin depressions. During this period a big paleolake came into being, which uppermost lake levels are indicated by lake terraces at 51 m and 43 m a.s.l. In deeper basin depressions, the glaciofluvial sequence and the locally observed basal peat layer are covered by calcareous

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and silicate gyttjas of a warmer interstadial phase. At the same time we expect the onset of the fluvio-lacustrine filling from 'Paleo-Mildenitz' river system originating in ice-marginal areas flowing from north to south. Several delta cones in lake sediments give evidence of a still considerable fluvial influx caused by the 'Paleo Mildenitz' river system which filled up the Dobbertin basin fringes with fluvial deposits. The delta deposits are interlocked with lacustrine layers (Fig. 2).

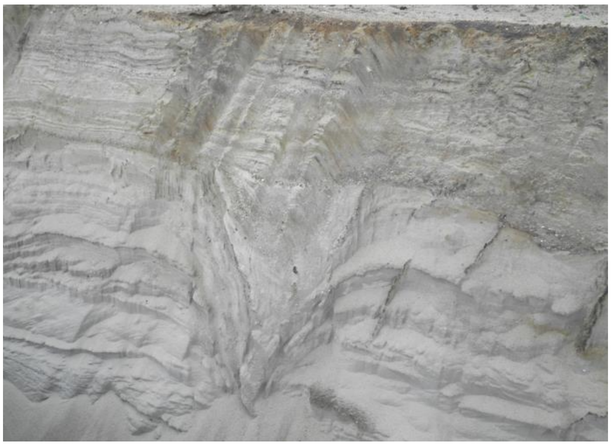

Fig. 1: Glaciolacustrine sequence of deglaciation of Frankfurt Phase in Dobbertin basin, which is penetrated by large ice wedge casts (profile length 2.5 m). Above ice wedge filling and glaciofluvial sands horizontally bedded sands of fluviolacustrine deposition during Late glacial period are visible.

Fig. 2: 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 (photos: A. Börner).

The main fluvio-lacustrine phase is reliably dated by pollen analysis to Allerød interstadial and additionally by a ^{14}C date of an embedded pine tree trunk (12.8 ka cal. BP). At the latest from this period a large lake filled the Dobbertin basin. 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 Dobbertin basin was drained by the formation of the River Mildenitz transverse valley. The level of the late glacial 5 m river terrace corresponds to the second lake terrace. Delta cones in Lake Schwarzer See and the incision into the 5 m river terrace indicate the flow reversal of River Mildenitz from southern to northern direction. The uppermost sediment sequence in the Dobbertin basin is represented by a pattern of strongly decomposed peat (Fig. 2).

Theme C High resolution climate reconstruction & D Late Glacial landscape change / WP4

Younger Dryas cooling in the Czechowo Region - climate or local environmental conditions

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Pollen, non-pollen palynomorphs, Diatomae, Cladocera, isotopes, macrofossils, and geochemistry (Tab.1) of biogenic sediments were used to reconstruct the environmental changes in Czechowo Region during the Younger Dryas cooling. The results come from seven cores located in different topographic positions in the Czechowo Region (Fig. 1, Tab.1).

Tab. 1. List of the analyses for each profile

No	Site	Symbol	Analyses
1	Lake Czechowskie small basin	JC-12-s	Pollen, Cladocera, Diatomae, , geochemistry
2	Lake Czechowskie the deepest basin	JC	Pollen, Cladocera, Diatomae, geochemistry
3	Lake Czechowskie terrace	TK	Pollen, geochemistry
4	Lake Czechowskie vicinity	„Oko”	Pollen, Cladocera, Diatomae isotopes
5	Trzechowskie palaeolake	T/trz	Pollen, macrofossils, Cladocera, Diatomae, geochemistry
6	Valley between Trzechowskie palaeolake and Lake Czechowskie	DTCZ-4	Pollen, geochemistry
7	Lake Czechowskie vicinity	Cz/80	Pollen, Cladocera, macrofossils, Diatomae, isotopes

The beginning of the Younger Dryas in all profiles coincides with the rise of *Juniperus* and NAP curve including Poaceae, Cyperaceae and heliophilous taxa such an *Artemisia*, *Helianthemum* and Chenopodiaceae.

The results of the analyses (pollen, macrofossils, *Cladocera*, *Diatomae*, isotopes and sediment type) suggest the climate fluctuations within the Younger Dryas cooling. The local factors such as slope, exposure, water access (e.g water table depth) had an influence on the paleoenvironment. This is reflected in the different participation of plant species among sites as well as in the different sediment type and sedimentation rate. Accumulation of mineral matters and carbonate was very important factor in the process of sedimentation during the Younger Dryas. Decreases in the pollen concentration coincide with an increase in thickness of sediment.

The thickness and type of the sediment accumulated differ significantly between the sites (Tab. 2). In the profiles with a full sequence of the Younger Dryas (JC-12-s, JC, TK, „Oko”, T/trz, DTCZ-4) the thickest sediment is in TK (Tab. 2). Topography around the TK profile was characterized by the presence of unstable slopes, from which the sand was exposed to wind and water erosion and accumulated in below. Therefore in this profile the fast sedimentation rate was due to a large supply of mineral substance. The thinness of the Younger Dryas sediment is in the profile from the Czechowskie Lake small basin JC-12-s (48 cm). In Cz/80 profile the biogenic sedimentation stopped at the beginning of this cool period

During the Younger Dryas sedimentation rate varied among sites but pollen concentration were generally lower then during the Allerød in all studied sites.

The reduction of *Pinus* and *Betula* population is distinctly reflected by low concentrations of pollen. This reduction of woods coincident with spread of grasslands.

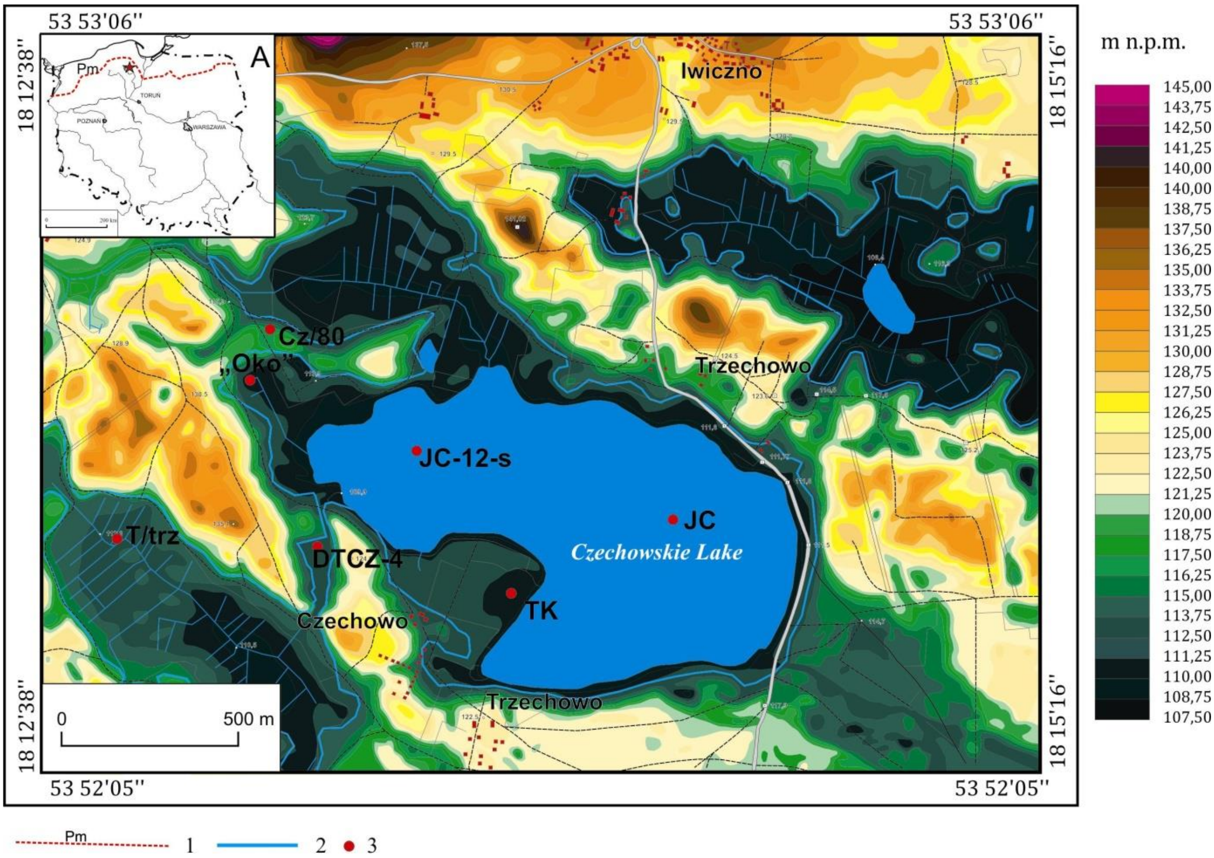

Fig. 1: Location of the study area and investigated profiles; 1 – course of the Pomeranian phase, 2 – the estimated maximum lake level, 3 - profiles; Symbols according to table 1.

Tab. 2. Thickness of sediment belongs to the Younger Dryas

No	Symbol	Thickness of sediment
1	JC-12-s	48 cm
2	JC	70 cm
3	TK	166 cm
4	„Oko"	118 cm
5	T/trz	61 cm
6	DTCZ-4	50 cm

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367).

Theme E Human impact / WP4

Wielbark culture tribes activity recorded in the varved sediments of Lake Czechowskie (northern Poland)

Obremska, Milena[1,*]; Noryśkiewicz, Agnieszka Maria[2]; Ott, Florian[3]; Bokiniec, Ewa[2,4]; Słowiński, Michał[5]; Błaszkiewicz, Mirosław[5] & Brauer, Achim[3]

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We present a record from the annually laminated (varved) sediments of Lake Czechowskie, located in northern Poland (north-east part of Tuchola Forest) covering the period 50 BC-650 AD. We used high-resolution pollen analysis, sedimentological (varve and sublayer thickness variations) and geochemical (µ-XRF data) proxies to reconstruct the environmental changes within a time of increasing human activity and fluctuating climatic conditions. The chronology was established by varve counting and confirmed by AMS ^{14}C dating, ^{137}Cs activity measurement and a tephra layer (Askja AD-1875). Sampling and measuring increments of our proxy data varying between subseasonal (µ-XRF), annual (varves) and 1-16 varve year resolution (biotic) allows to trace even short lasting local and regional changes. In relation to the archaeological data from the region we focused on the progress of human activity from the 50 BC up to 550 AD. According to the archaeological chronology this period corresponds with the Late pre-Roman Age, Roman Age and Migration Period. About the end of I century on the Tuchola Forest the Wielbark culture tribes appeared. Wielbark culture is identified with the inflow of people of Scandinavian origin – Goths. Archaeological research demonstrated that during the Late pre-Roman Age till about 70 AD there was generally lack of traces of human activity in the region. The highest development of local community occurred between 150–250 AD. Our results display phases of human activity and their influence on the environment in the vicinity of Lake Czechowskie (Fig. 1).

The visible deforestation and changes in the forest composition due to human pressure took place between 80–360 AD. The first changes (80–150 yr. AD) caused by appearing of human tribes showed the development of ruderal and meadow and pastures plant communities. In the second half of the 2nd century the settlements were in completely. Between 150–360 AD the share of human indicators, e.g. grazing, pasturing and crop cultivation, were highest. An intensification of lake productivity (expressed as an increase of varve thickness) started after 250 AD. The rapid decline of human indicators about 360 years AD at the transition to the migration period might be related to cooler conditions forcing the people to give up their settlement and move.

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).

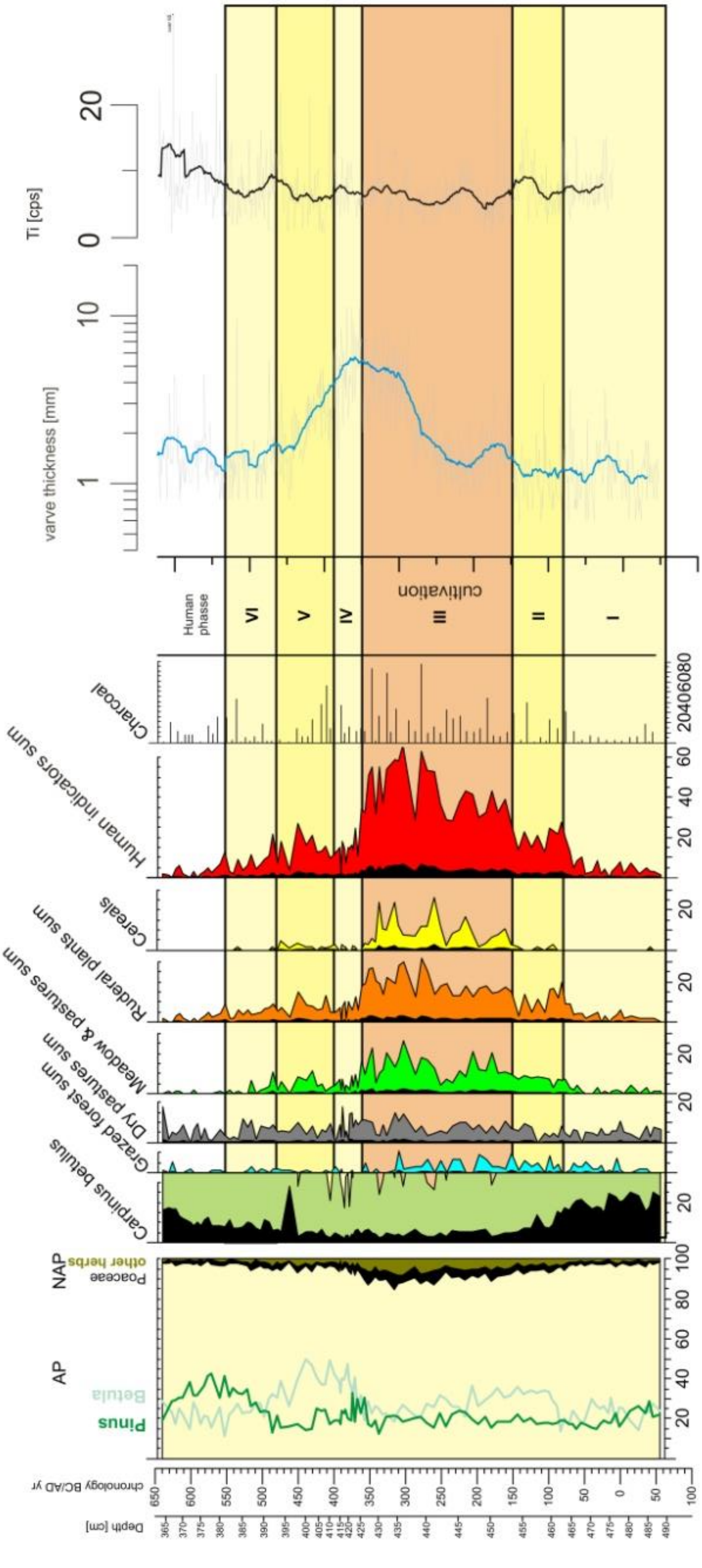

Fig. 1 Pollen diagram - main treesand summary curves of human indicators; varve thikness.

Theme C High resolution climate reconstruction / WP4

The Czechowskie Lake Sediment Record: Highlights and Potentials

Ott, Florian[1,*]; Brauer, Achim[1]; Słowiński, Michał[1, 2]; Wulf, Sabine[1,3]; Serb, Johanna[1]; Putyrskaya, Victoria[4]; Plessen, Birgit[1]; Obremska, Milena[5]; Kordowski, Jarosław[2] & Błaszkiewicz, Miroslaw[2]

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The Lake Czechowskie, located in north-central Poland, is one of the key study sites within the ICLEA project, which aims to investigate the mechanisms, responses and paces of past landscape scale changes within the northern and central European Lowlands (Błaszkiewicz et al., 2015; Wulf et al., 2013). In order to determine Holocene inter-annual and decadal-scale variability and to establish a precise time scale we investigated the predominantly varved sediments of Lake Czechowskie. The chronology has been established by a multiple dating approach comprising varve counting, AMS ^{14}C dating, ^{137}Cs activity concentration measurements and tephrochronology. The combination of independent dating techniques revealed a well-constrained age model even for phases lacking annual laminations. The identification of three distinct tephra layers within Lake Czechowskie and their counterparts in NE Germany Lake Tiefer See, allows reliable high-resolution archive synchronization within the ICLEA frame. Furthermore, the occurrence of Early Holocene tephras with Icelandic provenance (Hässeldalen and Askja-S tephras) within a varved interval enabled for the first time the precise determination of the time span between both tephras through annual layer counting (differential dating).

Varve parameters such as varve thickness and sublayers structure variations as well as geochemical composition (carbon and nitrogen analyses, µ-XRF element scanning) allow a comprehensive reconstruction of the Holocene climatic and environmental evolution in Northern Poland. Thereby, six major changes in lake sedimentation have been identified, encompassing (i) transitions from varved to non-varved sediments and *vice versa* at 11, 500; 10,500 and 7,300 cal yrs BP, respectively, (ii) changes in varve micro-facies pattern at 6,500 and 4,200 varve yrs BP and (iii) a distinct increase in varve thickness and inter-annual variability since 2,800 varve yrs BP. These changes reflect large-scale reorganization of the climate system throughout the Holocene with increasing influences of the North Atlantic climate system in Poland. Moreover, the observed changes suggest different thresholds and trigger mechanisms over the investigated time period

Ongoing investigations comprises unambiguous identification/dating of additional Early Holocene/Late Glacial tephra layers, the comparison of local vs. regional sedimentation pattern of three nearby lakes (Czechowskie, Głęboczek, Jelonek) for the last ca. 150 years and detailed synchronization with Lake Tiefer See for their lakes entire record.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367). These ICLEA studies are supported by TERENO infrastructure of the Helmholtz Association.

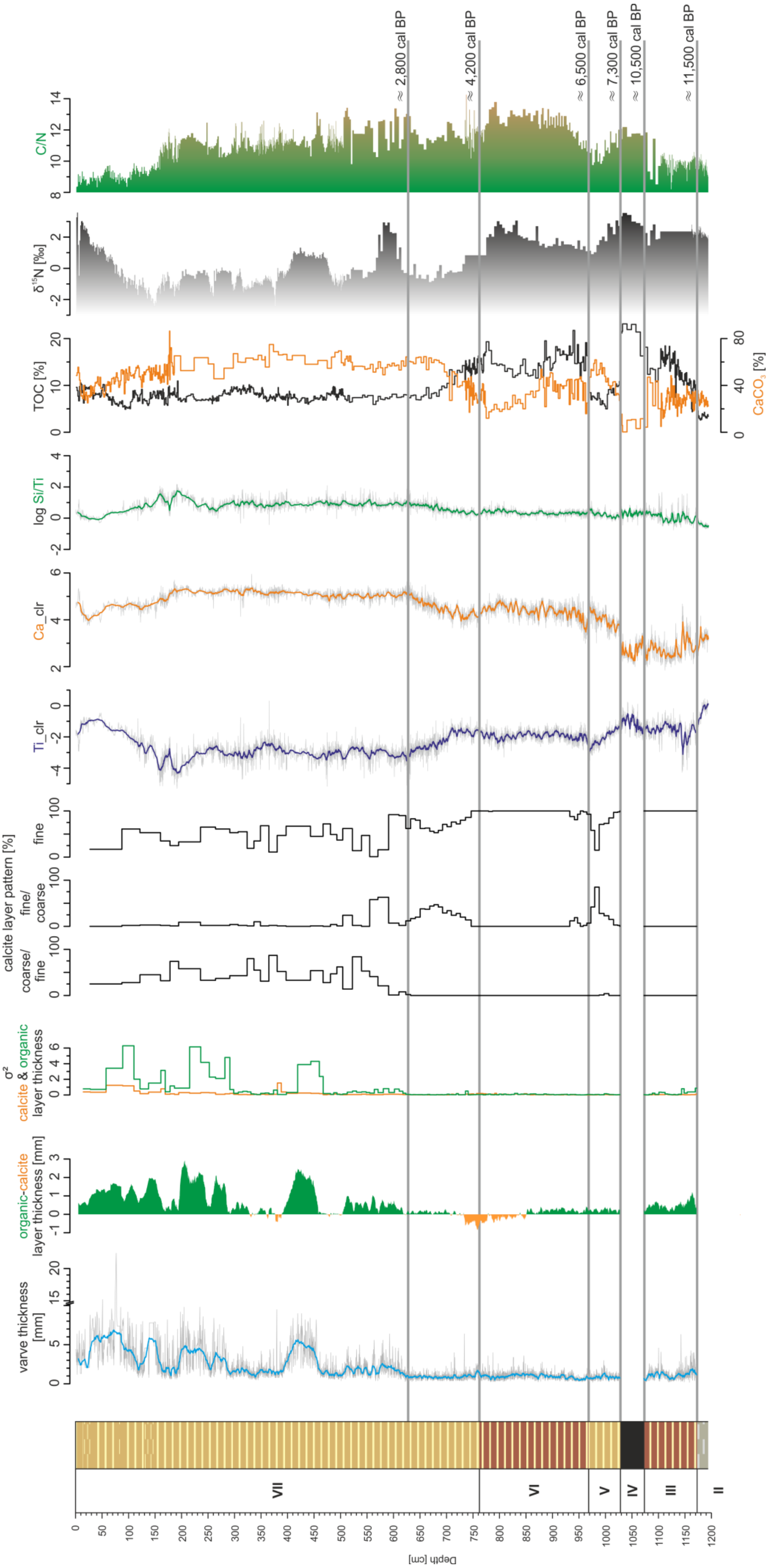

Fig. 1: Lithological profile of Lake Czechowskie and its quantitative (varve and sublayer thickness plot, variance of sublayers) and qualitative varve parameters (structure of calcite sublayer). The geochemical composition is shown by data derived from µ-XRF element scanning, carbon and nitrogen analyses. In order to account for variations in sample geometry and physical properties (water or organic matter content) single elements are expressed as centre-log ratio values and element ratios as log ratio of count rates (Weltje and Tjallingii, 2008).

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Piston coring with UWITEC drilling equipment at Lake Czechowskie, Poland (photo M. Slowinski, PAS)

Theme C High resolution climate reconstruction / WP4

Regional and local sedimentation signatures in varved sediments of the last 150 years in three lakes in northern central Poland

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Beyond instrumental data and historical documents, annually laminated (varved) lake sediments are suitable high-resolution recorders of past climatic and environmental changes. Lacustrine sediments offer a unique opportunity to decipher natural variability and human impacts on environmental systems especially during the last two centuries when the latter became increasingly important. An essential factor in this respect, are processes controlled by local catchment and lake basin characteristics.

In this study we present results from three varved lakes located in a close proximity to each other in northern central Poland (Lake Czechowskie, JC; Lake Głęboczek, JG; Lake Jelonek, JEL) for the last 150 years. All lakes have been independently dated combining annual layer counting, in one case (JC) supported by 137Cs dating, and a tephra marker layer (Askja AD1875 tephra) as a tie point. Our proxy data includes micro-facies (seasonal layer composition and thickness) and geochemical analyses (µXRF scanning at 200 µm step size, carbon and nitrogen analyses at 2-6 varve year resolution).

A common signature of all lake records are periods of increased varve thickness caused by particularly thick layers of pennate diatoms which occurred contemporaneously but with different durations. An interval of enhanced varve thickness occurs from AD 1860-1912 in JC, AD 1860-1900 in JG and AD 1870 to 1895 in JEL. In addition, intervals with less good varve preservation along with enhanced supply of detrital matter also occur in all lakes, but are shorter in the smaller lakes JG and JEL compared to JC (AD 1912-1952 and AD 1969-1985 in JC, AD 1960-1979 in JG and AD 1990-recent sediment surface in JEL). Here, we will discuss causes for differences and similarities in varve responses including lake-catchment size relations, local basin morphology, afforestation and agriculture, and climate (precipitation, seasonality). Finally, we will compare our results with published data from a varved lake in NE Germany (Tiefer See) located ca. 400 km to the West.

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.

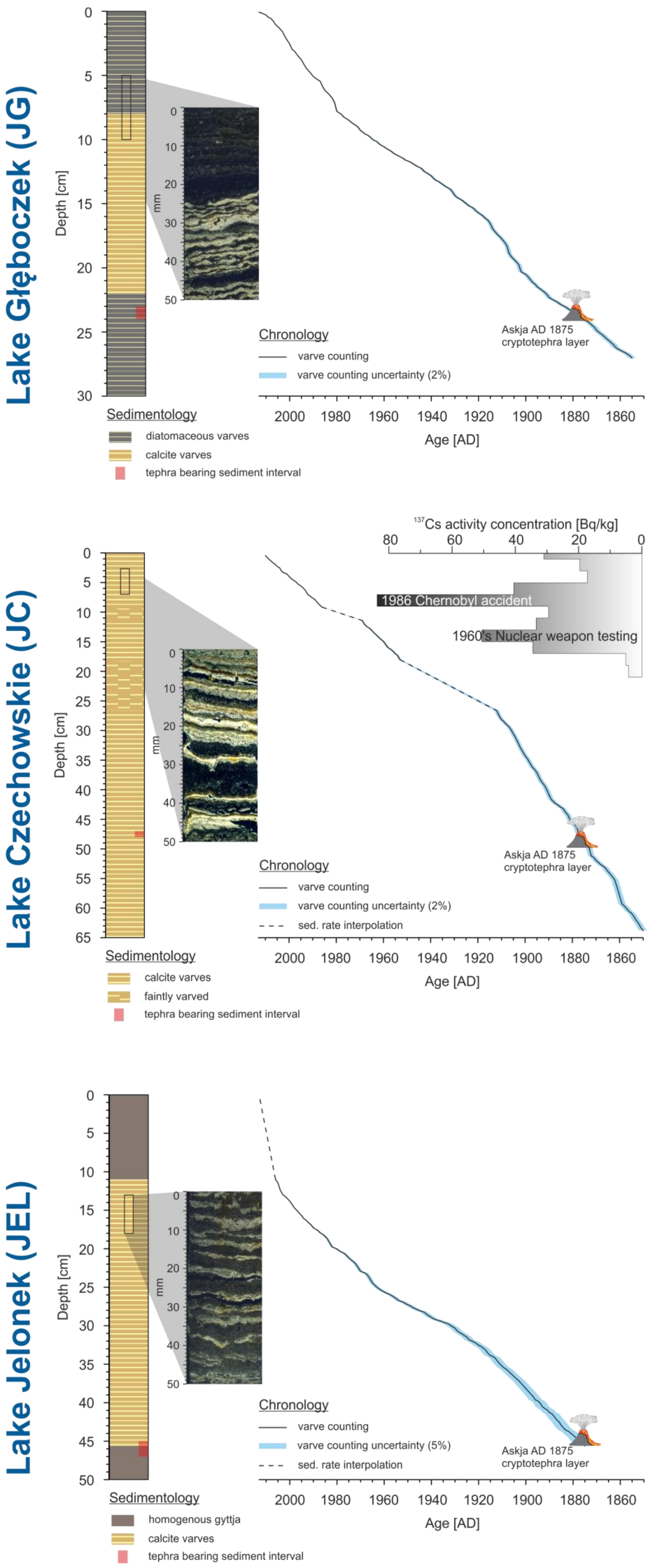

Fig.1. Lithological profiles of surface sediments of Lake Głęboczek (JG13_K1; down to 30 cm), Lake Czechowskie (JC10_7, down to 65 cm) and Lake Jelonek (JEL13_K7, down to 50 cm), their varve chronologies and ^{137}Cs activity concentration measurements (only JC). Varve chronologies reach back to AD 1850 (JG, JC) and AD 1875 (JEL), respectively, and are anchored to the Askja AD 1875 cryptotephra layer (all three records) and the top of the sediments (JC: 2010; JG: 2013). Grey shadings display position of representative thin section images with its corresponding varve types.

Theme C High resolution climate reconstruction / WP4

Sedimentary record of Morasko meteorite impact in lake sediments from the region of Poznań - preliminary results of interdisciplinary study

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About 5 – 6 ka BP a largest iron meteorite shower in Central Europe took place nearby contemporary Morasko, Poznań, Poland (Fig. 1). The so far documented evidences of the impact include thousands of iron meteorites distributed over an area of approximately 3 x 1 km and at least 7 impact craters with maximum diameter of about 100 m. Previous studies mainly focused on the meteorites properties. The aim of the current project is to reconstruct physical and environmental consequences of the event using sedimentary records preserved in lake sediments.

Morasko crater field is located in Poznań Lake District. In its close vicinity (< 8 km) there are few lakes from which three were selected for investigations, namely: Glinnowieckie Lake, Strzeszyńskie Lake and Kierskie Lake (Fig. 1). Each of these is of glacial origin and was formed after Poznań (Frankfurt) phase of the last glaciation (~18.5 ka BP). The analyses of the lake sediments are focused on middle Holocene (ca. 4.5 – 6.5 ka BP), i.e. in a range of supposed impact age. From each lake from 2 to 4 sediment cores up to 14 m long were collected. Selected cores were analyzed in terms of their sedimentology (grain size distribution, sedimentary structures), magnetic susceptibility, geochemistry (XRF scanning, TC, TOC, $_{total}N$, $\delta^{15}N$, $\delta^{13}C$) and micropaleontology (pollen, diatom and cladocera assemblages). The age control was by AMS ^{14}C dating.

Preliminary results from analysis of Strzeszyńskie Lake sediments cores indicate large scale soil erosion in catchment of the lake around 6 ka BP (Fig. 2). This is expressed as event layer enriched in coarser grained sediments, characterised by reversal of time-depth relationships dates and higher content of isotopically light carbon which could originate from terrestrial plant detritus. The latter interpretation is strengthened by the subsequent eutrophication expressed in preserved lamination of overlaying sediments. At the same interval pollen analysis shows significant shift in plant composition, namely increase content of pioneering birch (*Betula*) and decrease in deciduous forest component, oak (*Quercus*). Moreover distinct peak in nitrogen was found and was interpreted as the possible effect of the atmosphere disturbance resulting in post-impact acid rains. Nonetheless further analysis have to be performed to be able to state that the aforementioned disturbances was triggered by Morasko meteorite impact event as well as to obtain more precise data about duration of its effects and, based on sedimentary record from other lakes, their spatial extent.

These results were obtained within a project funded by National Science Center (Poland) grant No. 2013/09/B/ST10/01666. The authors kindly thank to all the persons involved in the project for help during the fieldwork and fruitful discussions.

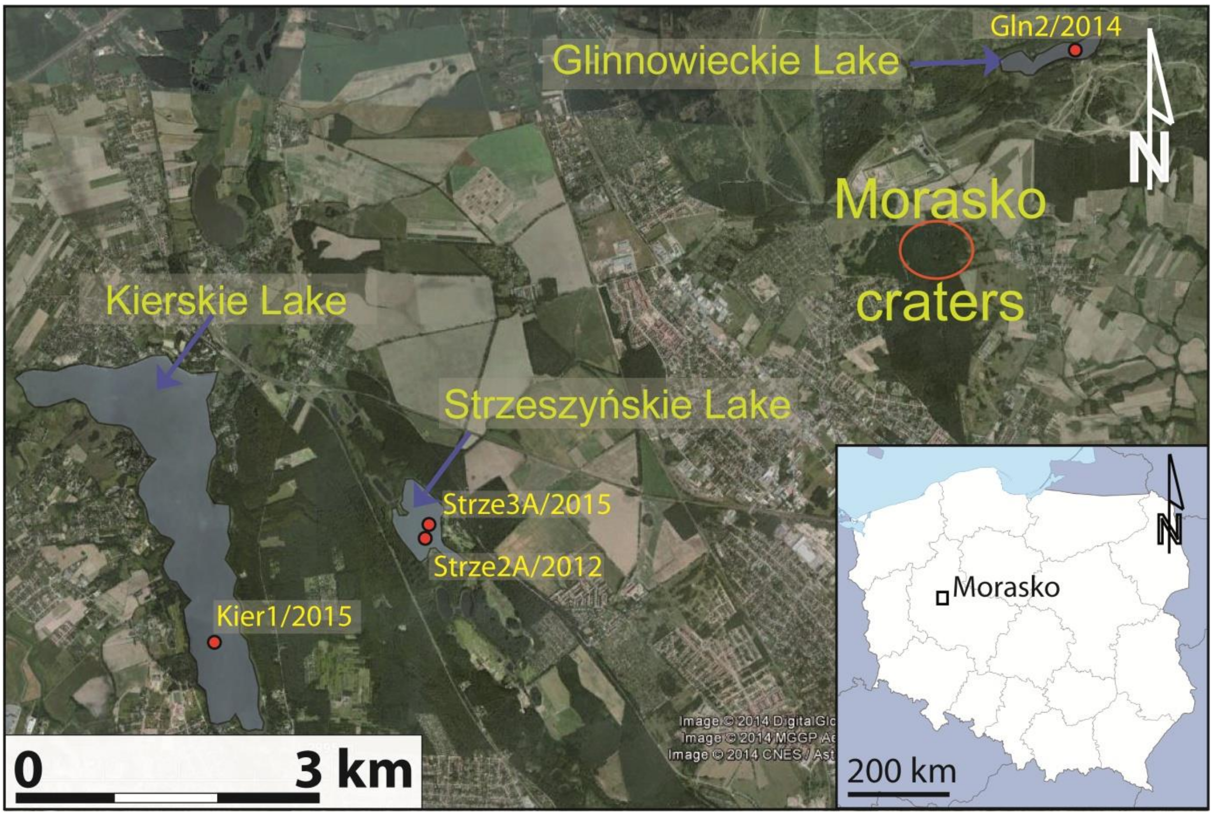

Fig. 1: Location of the study area with marked investigated lakes. Red dots relate to coring positions.

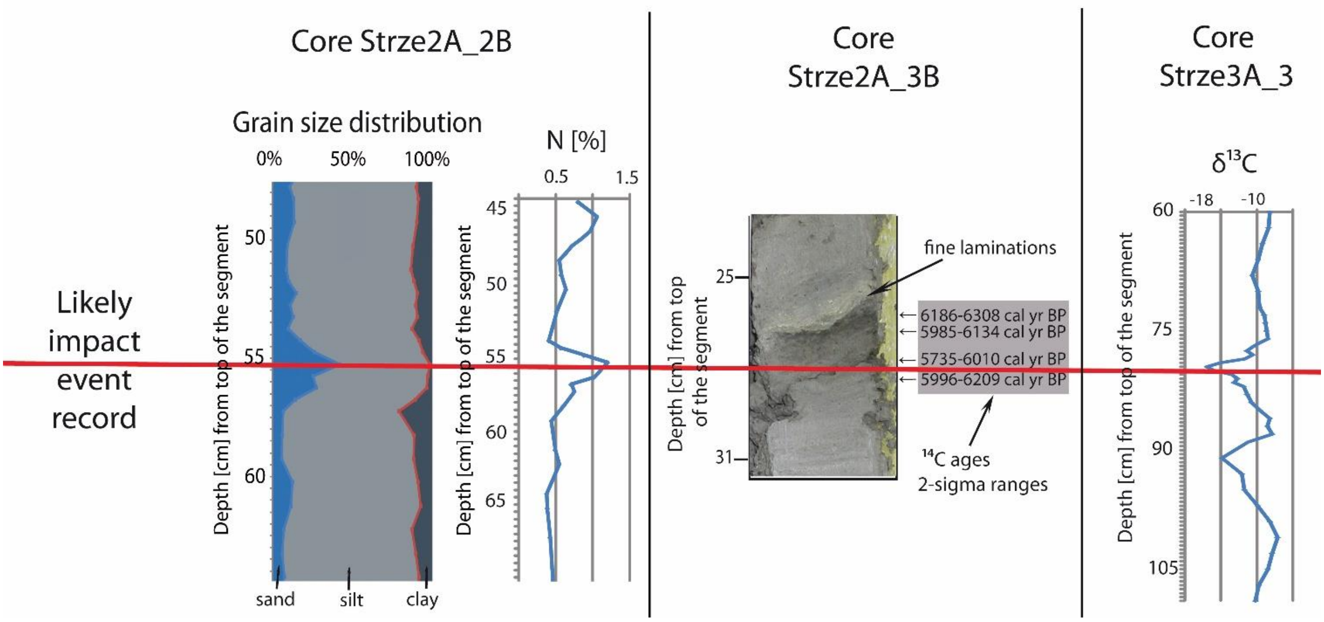

Fig. 2: Preliminary results from analysis of related cores from Strzeszyńskie Lake. Possible record of Morasko meteorite impact event marked by red line.

Theme A Monitoring & Theme C High resolution climate reconstruction / WP4

Nitrogen isotopes in present and past lake sediments (Tiefer See, NE Germany) and there potential for palaeoenvironmental and human impact reconstruction

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Stable isotope ratios of nitrogen can be widely used to reconstruct past palaeoenvironmental conditions, agricultural landscape development, and industrial pollution. They may reflect human impact by extensive land use, manure or sewage input, and atmospheric nitrogen. To understand the lake nitrogen cycle in relation to natural variability and anthropogenic forcing, we study the sediment record of Lake Tiefer See (Mecklenburg/N-Germany) together with the recent input and productivity, biweekly to monthly monitored in sediment traps in the hypo-, meta- and epilimnion. Lake Tiefer See was formed as part of the Klocksin-Lake-Chain, a subglacial gully system in the morainic terrain of the N-German-Polish Basin (Kienel et al., 2013).

Monitoring of the dimictic to monomictic Lake Tiefer See (62.5 m water depth) over the last three years clearly shows high $\delta^{15}N$ (+7 to +14‰) values for trapped material, mainly corresponding with internal organic productivity driven by nutrient loading and the development of anoxia in the hypolimnion. Compared to that, surface soil and terrestrial plant materials are characterised by lower $\delta^{15}N$ (+3 to +6‰) values (Fig. 1). The NH_4^+ composition of lake water is lower than 1 ppm with $\delta^{15}N_{NH4}$+ ~ 0‰. High $\delta^{15}N$ of +15‰ was found in nitrate of lake water. The high $\delta^{15}N_{NO3}$- values in epilimnion water together with low $\delta^{18}O$ < +10‰ reflect nitrogen input from manure, used to fertilize the surrounding fields and the isotope fractionation due to physical and biochemical processes.

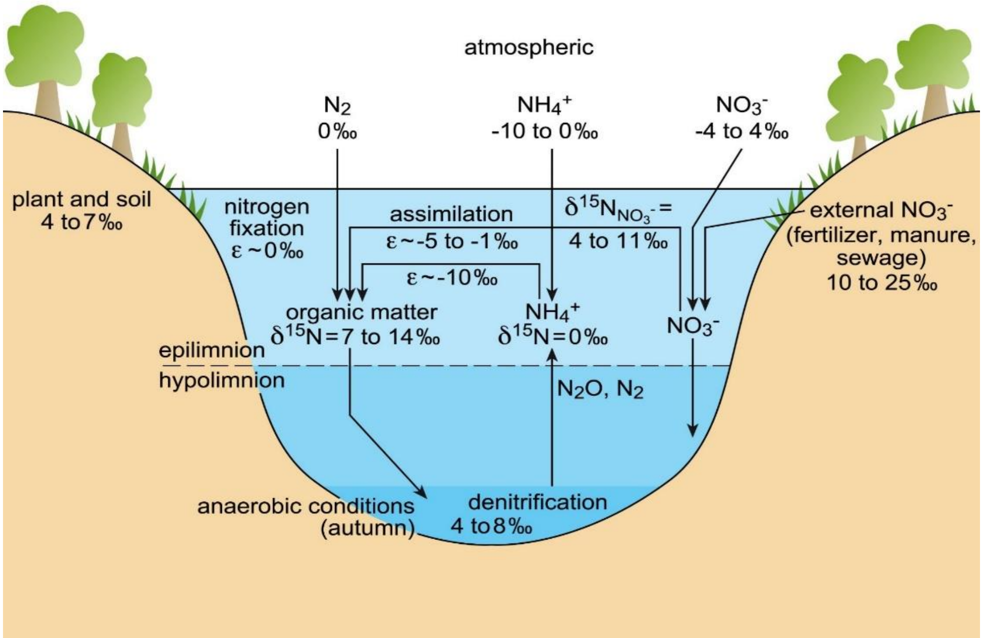

Fig. 1: Nitrogen cycle in Lake Tiefer See. Source characterization in the lake nitrogen cycle according to Teranes and Bernasconi (2000) and Kendall (1998).

The $\delta^{15}N$ values of annual sediment laminae (AD 1924-2006) show a recent increase to +10‰, similar to the mean value measured in sediment trap material. Over the last 400 years, the sediment record shows a continuous increase in $\delta^{15}N$ values from +3 to +8‰, interrupted by short term phases of decreasing ^{15}N

enrichment that can be related to historical development. The recent high $\delta^{15}N$ values of phytoplankton reflect assimilation of dissolved nitrogen components enriched in ^{15}N.

With continued studies we attempt to further understand the nitrogen cycle in Lake Tiefer See in relation with changing anthropogenic nitrogen sources. Increases in $\delta^{15}N$ in lake sediments since 1800 AD, for example, are related to changes in agriculture with societal background. According to Theuerkauf et al. (2015), the fallow periods in the crop rotation system were replaced by the production of fodder plants and grass. This in turn increased livestock numbers, manure production and the input of nitrogen enriched in ^{15}N.

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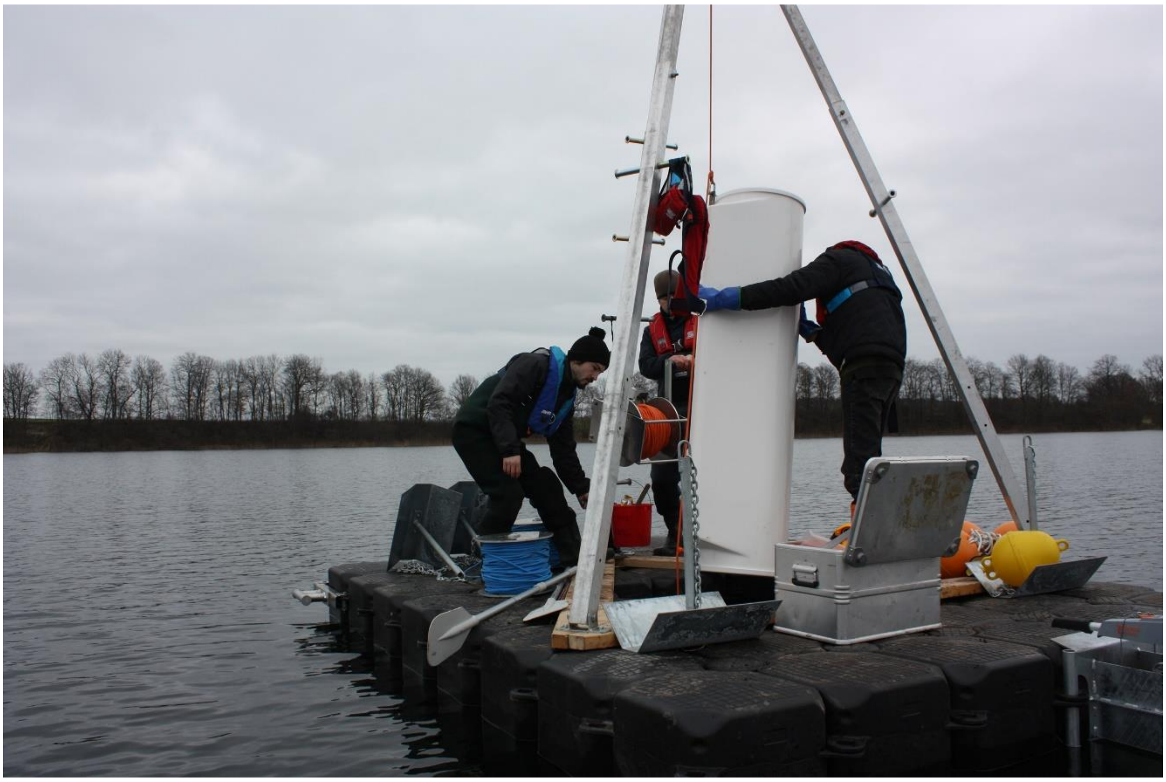

Installation of monitoring equipment (sequential sediment trap) in March 2012 at Lake Tiefer See, Germany (photo J. Mingram, GFZ).

Theme C High resolution climate reconstruction / WP4

Trophic gradients in Czechowskie Lake during the last 2000 years inferred from diatoms assemblages

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Lakes systems respond physically, chemically and biologically to environmental changes and these reactions are registered in various ways in lake sediment records.

One of the most used bio-proxy for such lake development in the past are subfossil diatoms. Variations in the species composition of the diatom flora are often used to reconstruct changes in the environmental conditions that occurred after the period of deglaciation.

Tucholskie Forests is one of the biggest Polish complex of forests that covers approximately 4500 km^2. This area is rich in both hilly terrain covered by pine forests (approx. 77%) and lakes that encompass almost 5% of forest area. There are numerous subglacial channels across the region, from north to south and from east to west. The area is also rich in other kinds of lakes, such as post-glacial potholes and small ponds as well as flat lakes. The lakes of Tucholskie Forests are characterised by different levels of trophy and water purity (Gwoździński, Kilarczyk 2009).

In our study we analysed the sediments of Lake Czechowskie, which is located in the northern part of the Tuchola Forest region (Northern Poland). Lacustrine sediments of this lake are laminated and therefore are unique archive to reconstruct climate and environmental changes in Northern Polish Lowland. In this research we focused on the last 2000 years and with high resolution analyzed diatoms, pollen, cladocera and sediment geochemistry. The core chronology is based varve counting, 14C AMS dating of terrestrial macro remains, 137Cs activity measurement.

This poster presents the diatom record in Lake Czechowskie during the last 2000 years. The next step will be the comparison with human and climate influence to the changes in diatom record.

The DI-TP reconstruction showed, basic diatom associations (505 – 381.8 cm, about 450 AD), dominated by *Cyclotella comensis* and *Fragilaria nanana*, suggest oligo to mesotrophic DI-TP mean values of 15.1 µg/l with single values between 8.5 to 20 µg/l. There are only five isolated single outlier up to 26 µg/l, caused by single peaks of eutrophent taxa (*Stephanodiscus parvus* or *Aulacoseira granulata*).

This development had been interrupted by a short shift in diatom associations between 376.9 – 370.3 cm (469-512 AD). This short event of rising DI-TP values were supported by the increasing amount of TP significant taxa: *S.parvus* reached up to 54-80%, before decreasing down to 2.4 - 0% (364 - 357 cm, 556-596 AD).

Afterwards (367.3 – 342.1cm, 537-696 AD) the diatoms returned back to the former community-structure with basic DI-TP values.

Between 335 and 260cm (715-1193 AD) the smooth of the DI-TP values shows a longer period of increasing TP-values, up to mean values of 30 µg/l. But the single data fluctuating very strong, there are values between oligotrophic (10.9 µg/l) at 276 cm (1139 AD) and meso- to eutrophic values (44 µg/l) at a sediment depth of 279 cm. The DI-TP increases are supported by an amount of TP-significant taxa of more then 95%.

At core sequenz of 258.8 cm (1231 AD) the mean DI-TP values turned back to mesotrophic values. This phase includes a long periode until the beginning of the 19th century (76 cm, 1837 AD). Contrary to the previous period the DI-TP values are relatively stable, only between 179cm (1444 AD) and 161cm (1551 AD) there are remarkable TP-fluctuations. Otherwise, the sum of TP-significant taxa does not support these TP fluctuations.

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).

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Lake monitoring: Exchange of a sequential sediment trap in April 2015 at Lake Czechowskie, Poland (photo A. Brauer, GFZ).

Theme A Monitoring / WP2

Modification of the binning method for cartographic imagery of visual landscape attractiveness

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The poster shows the possibility of using the modified binning method to determine the visual landscape attractiveness (VLA) in the young-glacial area in Northern Poland. The sources of the data included a V-Map Level 2 and orthophotomap. Most commonly, the binning method is used in chemistry, biology, medicine, and raster graphics. The proposed modification of the method consists of adding and subtracting thematic binning matrices. The landscape quantifying stage considers both natural as well as the cultural elements of the landscape. Cultural components are classified into two groups, i.e. those increasing and those decreasing the VLA. As a result of using the method the total assessment of the individual elements of the landscape are obtained in the form of a map of the visual landscape attractiveness of the research area.

The advantage of the presented method is the ease of use, while a disadvantage the requirement for expertise at the stage of the landscape quantifying. The poster also shows examples of errors that can occur when using this method.

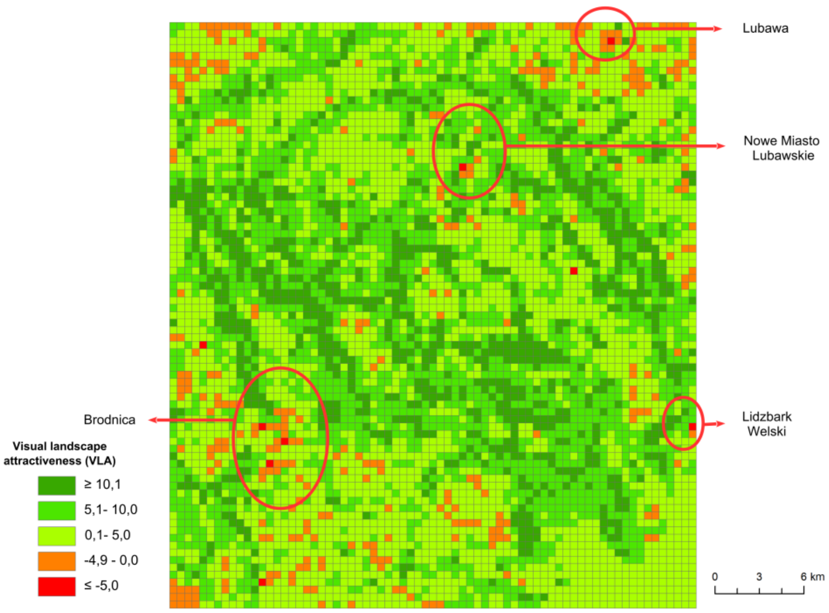

Fig. 1: Map of visual landscape attractiveness (VLA), taking into account natural and cultural components of landscape.

Part of presented results was established through the implementation of research grant funded by N. Copernicus University - Grant No 1699-G/2013 “Role of land-cover in 3D modelling processes of viewshed in young-glacial landscape”. 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.

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http://www.gislounge.com/binning-gis/

Theme C High resolution climate reconstruction / WP3

Is one sample enough? Differences and similarities in element concentrations of tree rings in dependence of sampling direction and height along the stem

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Dendrochemistry, i.e. the chronological analysis of element concentrations in the rings of living trees and archaeological wood is an evolving field. Attempts have been made to attribute trends, peaks or depletion of certain metal elements to volcanic eruptions, atmospheric pollution and other abrupt and gradual environmental or climatic changes (e.g. Padilla and Anderson, 2002; Pearson et al., 2009; Watmough, 1999). Once scientifically successfully established, the relationship between environmental drivers (the contemporary growth environment) and element concentrations in tree rings may offer great annually or even intra-annually resolved proxy potential as trees or archaeological/subfossil wood are widely available.

Current challenges to dendrochemistry are mainly due to: 1) Possible radial or vertical translocation processes of elements in the wood (active during heartwood formation or passive) that might blur or obscure any dendrochemical signal and hamper precise dating of events. 2) Labour and time intensive methods (e.g. atomic absorption spectrometry (AAS) or inductively coupled plasma mass spectroscopy (ICP-MS)) that normally require sample digestion or solvent extraction and limit the amount of samples which can be processed. This leads to usually small sample sizes (<10) in dendrochemical studies, with mostly only one sample (core) per individual analyzed.

X-ray fluorescence (µXRF) provides a non-destructive, high resolution and timesaving alternative and offers the opportunity to increase sample size, but needs to be methodologically tested to ensure scientific accuracy. In our study we systematically compare count-rates of certain elements (Al, Si, P, S, Cl, K, Ca, Cr, Mn, Fe, Ni) between three different expositions (N, S and W) and three different heights (base, middle and top) along the stems of mature deciduous (*Castanea sativa* Mill.) and coniferous (*Pinus sylvestris* L.) trees. Measurements are conducted with an ITRAX Multiscanner equipped with a Cu X-ray beam on 1.2 mm thick wooden laths with a resolution of 50 µm, averaged within annual ring boundaries and normalized for comparison.

First results point to both differences and similarities in count-rates of the analyzed elements along stem radii and stem heights. Namely, clear but non-systematic differences were observed at high frequency (interannual) resolution, whereas longer term (decadal) trends were rather similar (see Fig.1 as an example). This holds true for nutrients, non-nutrients as well as their ratios that for example could serve as indicators for changes in soil acidity. To enhance the desired common environmental signal and to average out physiologically controlled differences in element distribution in the xylem, we propose to analyze more than one sample per tree and to develop specific chronology building procedures also in dendrochemical studies. Meeting these initial challenges promises a host of new opportunities in dendrochemistry and all its scientific and practical applications.

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

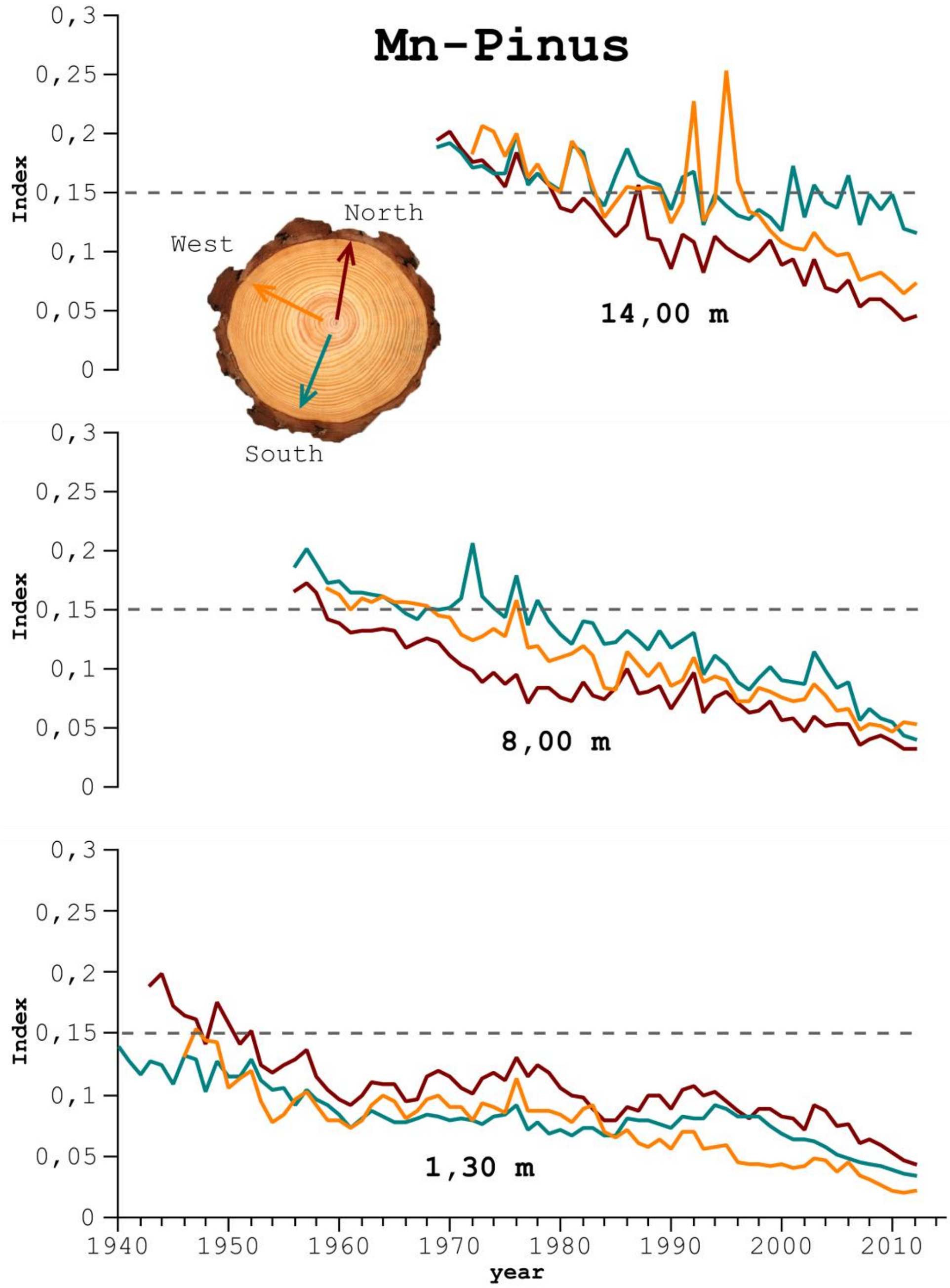

Fig. 1: Count rates of Manganese averaged within ring boundaries for three different directions and three different heights along the stem of one pine-tree, indicating similar low frequency trends but some differences in high frequency variations. Values are divided by coherent scatter to account for matrix effects.

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Theme E Human impact / WP5

Towards an inventory of historic charcoal production fields in Brandenburg, Germany

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The historic production of charcoal is an important component of the late Holocene fire history for many landscapes. In ongoing archaeological excavations in the charcoal production field in the forefield of the open-cast mine Jänschwalde, more than 1000 historic charcoal kiln sites have been documented so far. A detailed manual mapping of kiln sites from Shaded Relief Maps (SRMs), derived from digital elevation models (DEMs), revealed similar kiln site densities in surrounding forest areas (Raab et al. 2015). Although charcoal consumption in the area north of Cottbus was probably exceptionally large because of the operation of the Peitz ironworks, intensive forest use for charcoal production can also be assumed for other areas in the Northern European Lowland.

The aim of this study therefore is to detect and map other large occurrences of charcoal kiln remains in the state of Brandenburg, based on the results from the exceptionally well-described charcoal production fields north of Cottbus. We present the first results of two approaches used in order to achieve a large-scale inventory of charcoal production fields:

1) Automated mapping based on template matching (Schneider et al. 2015) was used to detect kiln sites for a 1000 km^2 area, spanning from the sandur and terminal moraine areas north of Cottbus to the Berlin Ice Marginal Valley around Müllrose. Templates representing the characteristic geometry of kiln sites with diameters between 10 and 28 m were used to search for sites in LIDAR-based DEMs with a spatial resolution of 2 m. For the areas north of Peitz, results of the automated approach could be compared with the results of the manual mapping from the 1 m DEM.

2) A GIS-based analysis of environmental and historic data was used to identify potential areas of large-scale charcoal production in Brandenburg. The analysis was based on the hypothesis that large charcoal kiln fields can be found in areas that i) are close to historic industrial sites with a high charcoal consumption, ii) are close to occurrences of bog iron ore which is smeltered using large amounts of charcoal, and iii) have been continuously covered by forest during the last centuries. Information on these parameters was gathered in an archive and literature study and from historic and recent maps. Areas with a high probability of kiln site occurrence were then determined using a binary additive model. In the last step, SRMs were visually checked for clearly visible kiln sites and soil properties were analysed in the determined areas.

The comparison of automated and manual mapping results reveals that the automated approach can describe the spatial distribution patterns of kiln sites, although not all kiln sites could be detected. Results of automated mapping show the large charcoal production field north of Peitz and another area with a considerably high kiln site density in the Berlin Ice Marginal Valley. However, kiln sites in this area appear to have considerably lower diameters as compared with the exceptionally large kiln sites detected around Peitz. In other relatively high-relief regions of the study area, only a few relatively small kiln sites are detected. Based on the GIS-analyses, eight areas with a high probability of kiln site occurrence are identified. By visual interpretation of SRMs, high kiln site densities in these areas are confirmed. The analysis of soil maps shows that kiln fields are predominantly located on sandy soils with a low yield potential. Although further parameters and study areas need to be considered in the model in order to explain the spatial distribution patterns of charcoal production, results indicate correlations between the location of bog iron ore deposits, historic ironworks and charcoal kiln fields.

All in all, the results show that large charcoal kiln fields occur in several regions within Brandenburg and thus further affirm that charcoal production is a so far underestimated component of the land use history in many parts of the Northern European Lowlands.

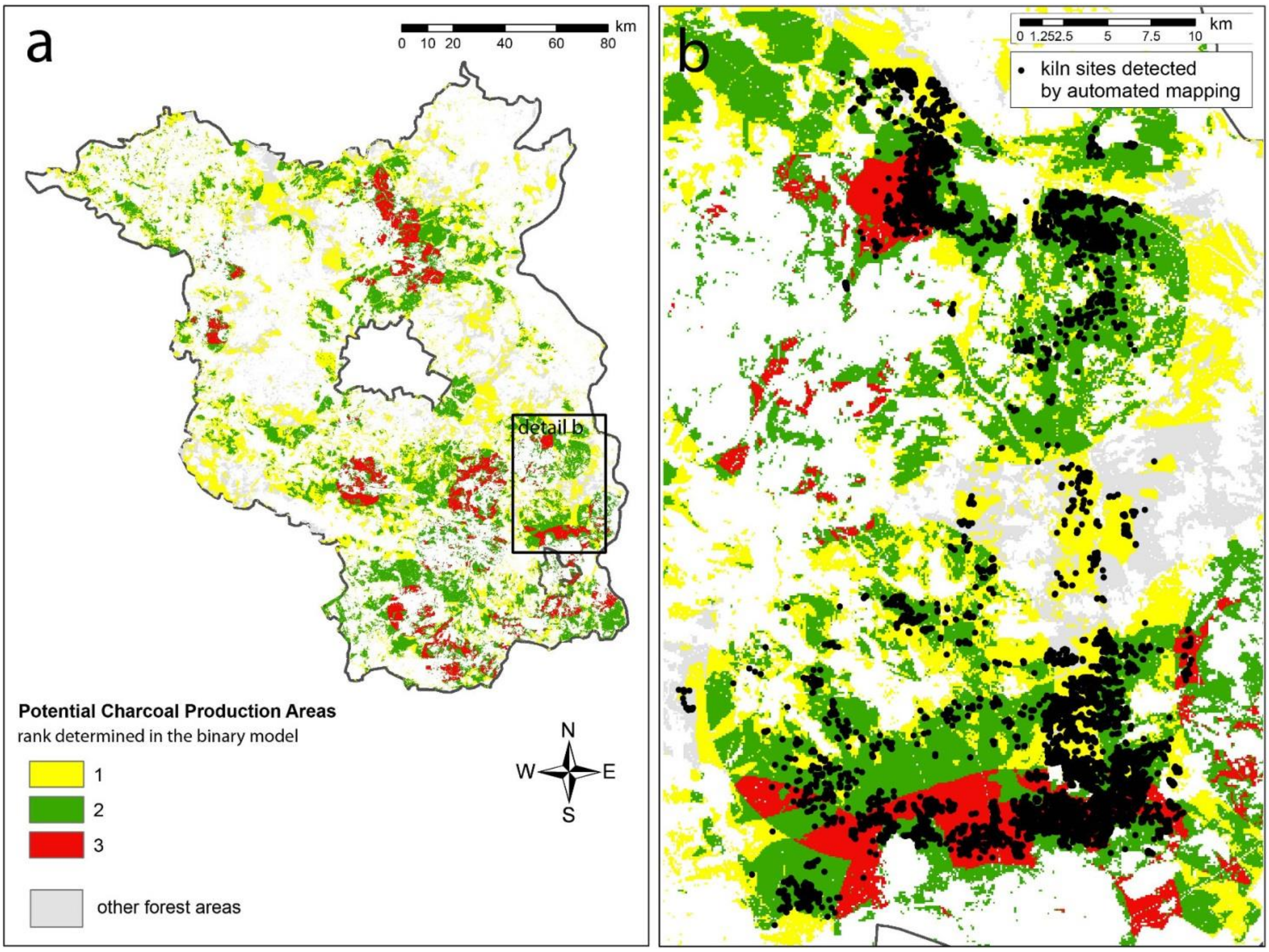

Fig. 1: a) Location of the potential charcoal production areas in Brandenburg identified with the binary additive model; b) charcoal kiln relicts mapped with the automated approach in comparison to the results of the binary model for the area marked on the left. Considerably high kiln densities occur in areas with a high rank assigned by the binary model, however, kiln relicts were also mapped in areas with lower ranks.

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

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Theme B Present and Palaeohydrology / WP4

Littoral vegetation changes as indicators of Late Glacial and Holocene lake-level changes in Lake Tiefer See

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Lake Tiefer See (N 53.59°, E 12.53°) is one of the rare lakes with a long sequence of annually laminated Holocene sediments in northern Central Europe. The lake has no superficial drainage so that its water level fluctuates; at present by about 1 m. In the past, lake level fluctuations may have even been stronger and could have affected varve formation. The aim of our investigations is to reveal Late Glacial and Holocene lake level changes using sediment cores from the lake shore.

Present poster focuses two long peat sequences from the south-eastern bay (TS2, TS3) and one such sequence from the western shore (TS17) of Lake Tiefer See (Fig. 1). TS2 is located in *Phragmites* reed vegetation, TS3 in an alder carr in about 100 m distance. TS17 is also located in an Alder carr. Microfossils analysis reveals that these peat sections represent several periods of high and low water levels. For example, layers with high concentrations of *Thelypteris palustris* spores and wood cells indicate the presence of forest vegetation at the site and thus low water levels while layers rich in *Pediastrum* algae point at higher water levels.

To reveal water level fluctuations in more detail we additionally apply macrofossil analysis. The macrofossil diagrams of TS2 and TS3 show a basal layer peat (dated to the mid-Allerød period) rich in tree remains such as *Betula* nutlets and female catkin bracts, *Pinus* and *Populus* budscales, suggesting that this basal peat layer was formed in - or in the vicinity of - woodlands rich in birch, pine and poplar. Both sites then drowned still during the Late Glacial, possibly following dead ice melting. During that process, temporarily reed vegetation with *Menyanthes trifoliata*, *Carex rostrata* and mosses established at both sites.

Around 9000 cal BP, the presence of e.g. *Typha* seeds indicates the establishment of reed vegetation and thus of now decreasing water level in Lake Tiefer See. The absence of sediments from the mid-Holocene (9000-6000 cal. BP) suggests that lake level has been mostly low during this period. A similar hiatus is observed in TS 17, but not in TS3. At this sites macrofossil data for this period indicate the transition from aquatic vegetation (with *Chara* and *Typha*) to fen vegetation dominated by sedges (*Carex paniculata/appropinquata*) and ferns (*Thelypteris palustris*). The following zone is characterized by *Cladium mariscus*, which is adapted to a fluctuating water level from 1m (Fig. 2). We assume that wetter conditions prevailed at TS3 because this site is possibly separated from the main lake basin. Possibly at 6000 cal. BP, peat formation again started also at TS 2 and TS 17, suggesting that the water level of Lake Tiefer See has increased. Macrofossil data in the following indicate recurrent shifts between forested to open vegetation at TS2, representing some fluctuation in the lake level. By comparing with TS 3 we finally aim to detect shifts of alder carr, reed, floating-leaved and submerged vegetation along the lake shore (cf. Gaillard & Digerfeldt 1991).

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

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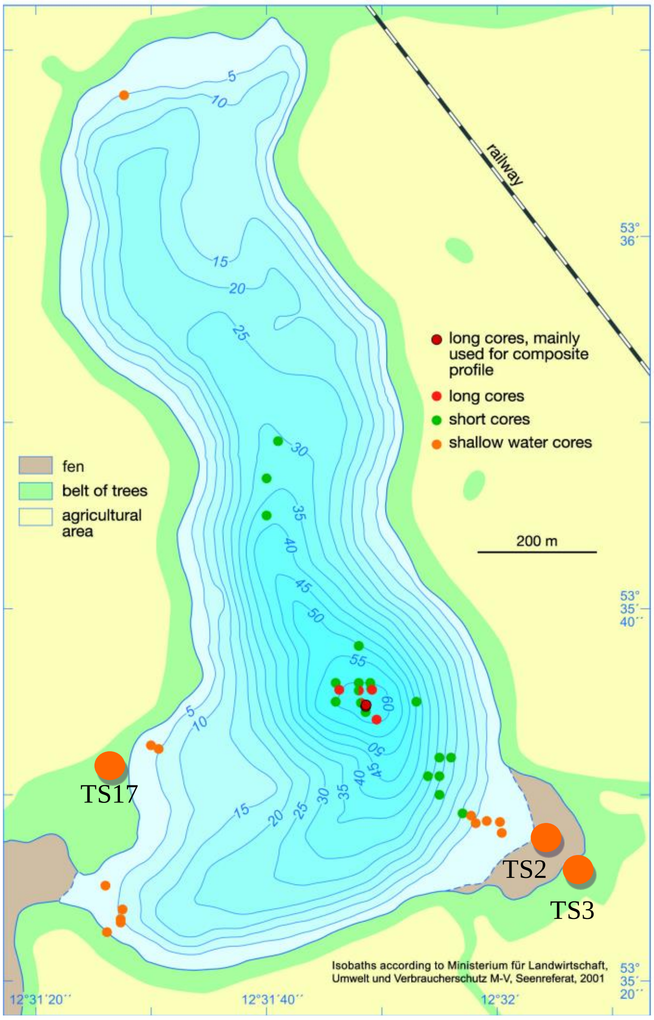

Fig. 1: Location of the investigated profiles TS2, TS3 and TS17.

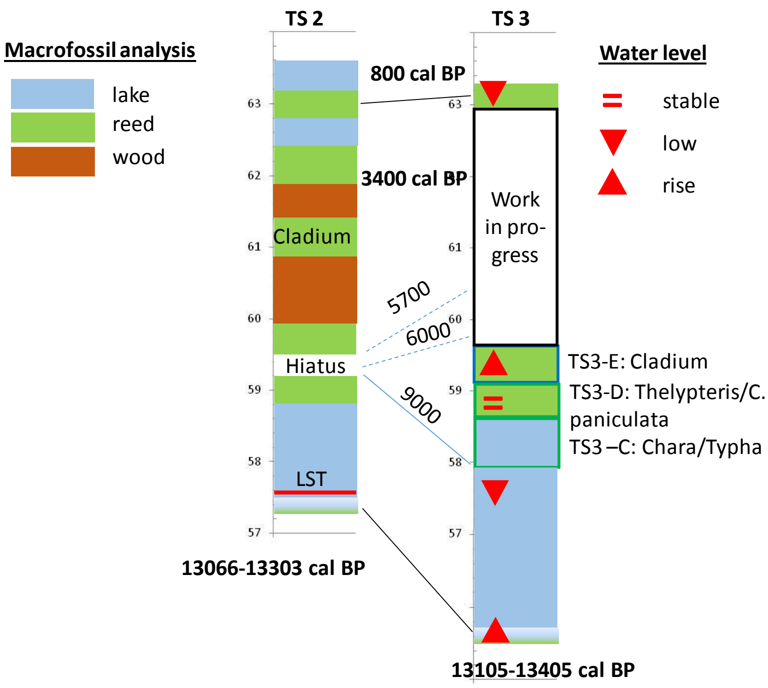

Fig. 2: Comparison of macrofossil zones of the core TS2 and TS3.

The Virtual Institute of Integrated Climate and Landscape Evolution Analyses - ICLEA

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Understanding causes and effects of present-day climate change on landscapes and the human habitat faces two main challenges, (i) too short time series of instrumental observation that do not cover the full range of variability since mechanisms of climate change and landscape evolution work on different time scales, which often not susceptible to human perception, and, (ii) distinct regional differences due to the location with respect to oceanic/continental climatic influences, the geological underground, and the history and intensity of anthropogenic land-use. Both challenges are central for the ICLEA research strategy and demand a high degree of interdisciplinary. In particular, the need to link observations and measurements of ongoing changes with information from the past taken from natural archives requires joint work of scientists with very different time perspectives. On the one hand, scientists that work at geological time scales of thousands and more years and, on the other hand, those observing and investigating recent processes at short time scales.

The GFZ, Greifswald University and the Brandenburg University of Technology together with their partner the Polish Academy of Sciences strive for focusing their research capacities and expertise in ICLEA. ICLEA offers young researchers an interdisciplinary and structured education and promote their early independence through coaching and mentoring. Postdoctoral rotation positions at the ICLEA partner institutions ensure mobility of young researchers and promote dissemination of information and expertise between disciplines. Training, Research and Analytical workshops between research partners of the ICLEA virtual institute are another important measure to qualify young researchers.

The long-term mission of the Virtual Institute is to provide a substantiated data basis for sustained environmental maintenance based on a profound process understanding at all relevant time scales. Aim is to explore processes of climate and landscape evolution in an historical cultural landscape extending from northeastern Germany into northwestern Poland. The northern-central European lowlands will be facilitated as a natural laboratory providing an ideal case for utilizing a systematic and holistic approach.

In ICLEA five complementary work packages (WP) are established according to the key research aspects. WP 1 focus on monitoring mainly hydrology and soil moisture as well as meteorological parameters. WP 2 is linking present day and future monitoring data with the most recent past through analysing satellite images. This WP will further provide larger spatial scales. WP 3-5 focus on different natural archives to obtain a broad variety of high quality proxy data. Tree rings provide sub-seasonal data for the last centuries up to few millennia, varved lake sediments cover the entire research time interval at seasonal to decadal resolution and palaeosoils and geomorphological features also cover the entire period but not continuously and with lower resolution. Complementary information, like climate, tree ecophysiological and limnological data etc., are provided by cooperation with associated partners.

Further information about ICLEA: www.iclea.de

Theme A Monitoring / WP3

Response of xylem sapflux density to VPD of temperate species growing on sites with contrasting soil water content

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Soil water availability is a major driver of plant productivity and a limiting factor in several environments (Patataki et al. 1998). Besides soil moisture content, several key factors such as atmospheric water content (vapour pressure deficit, VPD), solar radiation and tree size influence tree water use (expressed as volume flux here) (O'Grady et al. 1999).

A natural experimental design was set up in NE Germany in a temperate lake ecosystem where major shifts in groundwater and lake levels have been observed in the last decades. The location is characterized by a precipitation regime below 600 mm annually. Soil moisture profiles, matrix potential, piezometers, dendrometers and sapflow sensors, as well as standard climate stations providing high temporal resolution information were installed in sites with different soil water content, i.e. close to the lakeshore and up on the surrounding slope around lake Hinnensee. The dynamics of water use of three important European tree species (*Pinus sylvestris, Quercus petraea* and *Fagus sylvatica*) and its impact on forest productivity are the main focus here.

Physiological differences between species and locations

All species show a considerable physiological plasticity adapting their behaviour to environmental differences. The average diurnal sapflux density (J_s) of pine, oak and beech located at the lakeshore and up on the hill was calculated over the growing season (01.06-30.09.2014) (Fig. 1). Increased sapflux density and hence tree water use with increasing VPD along the day was observed in all species located at the downhill sites. Maximum J_s was reached between 12:00 and 13:00 hours and could be maintained for a few hours longer despite higher VPD values. Only pines sustained higher J_s after 16:00 hours whereas both deciduous species saw their water use rapidly declining. Pines and beeches located downhill displayed very similar J_s whereas oaks from the same location had the highest water use of all species and locations. As opposed to the downhill sites, the three species J_s declined with increasing evaporative demand of the atmosphere indicating a certain level of tree water stress forcing the stomata to close early, and followed a reverse pattern at the end of the afternoon when VPD decreased again. Pines and beeches display a very different overnight-early morning J_s between locations, sapflux density being close to zero overnight whereas water flux from uphill trees is higher than at midday. One possible explanation might be a higher rehydration rate of uphill trees during that period compared to the downhill ones, as seen on Fig. 2a) suggesting a decoupling between sapflux density and stomatal conductance during some part of the diurnal cycle. The different water use strategies of species at both locations did not result in different wood biomass production as expressed by stem radial growth, except for pines located at the lakeshore which showed reduced growth in 2014 (Fig. 2b).

Hysteresis is observed in all species from all location at varying degrees. It occurs when the response in a dependant variable, *y*, for the same value of an independent variable, *x*, vary over time. Little is known on the causes of hysteresis in the response of water use to VPD. The contribution of stored water in the tree stem, different stomatal sensitivity to VPD during the day or changes in soil-to-leaf hydraulic conductivity might partly explain this phenomenon (O'Grady et al. 1999). Clearly, a better understanding on the degree of hysteresis, as well as on changes in the direction of loop rotation (clockwise vs. counter clockwise) between species and locations is of crucial importance if a more complete understanding of tree function and water use, and site/catchment hydrology is wanted (Zeppel et al. 2004). Models estimating water use rarely consider the occurrence of hysteresis.

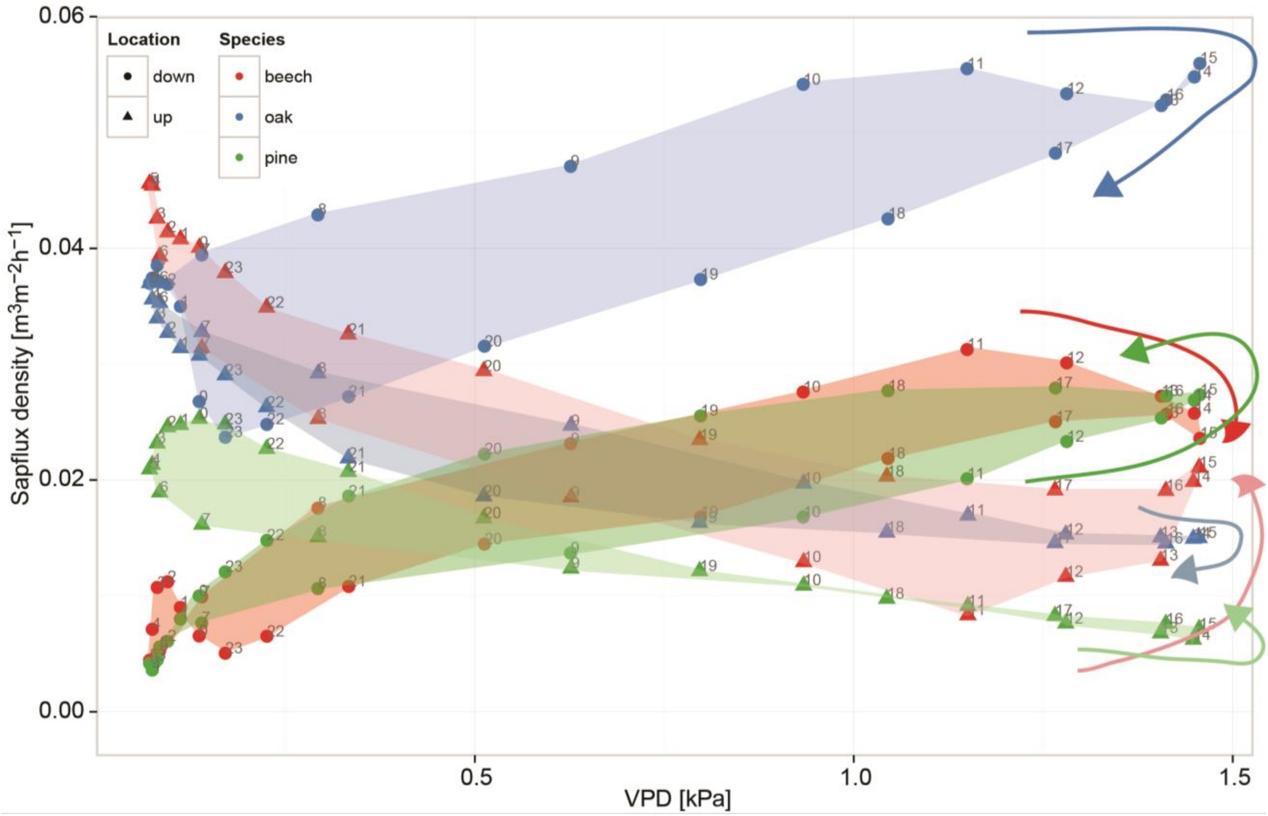

Fig. 1: The relationship between vapour pressure deficit (VPD; kPa) and sapflux density ($m^3m^{-2}h^{-1}$). The data represent the average of four trees over 24h in the growing season 2014 (June 1st – September 30th). Numbers from 1 to 23 besides symbols indicate the hour of the day.

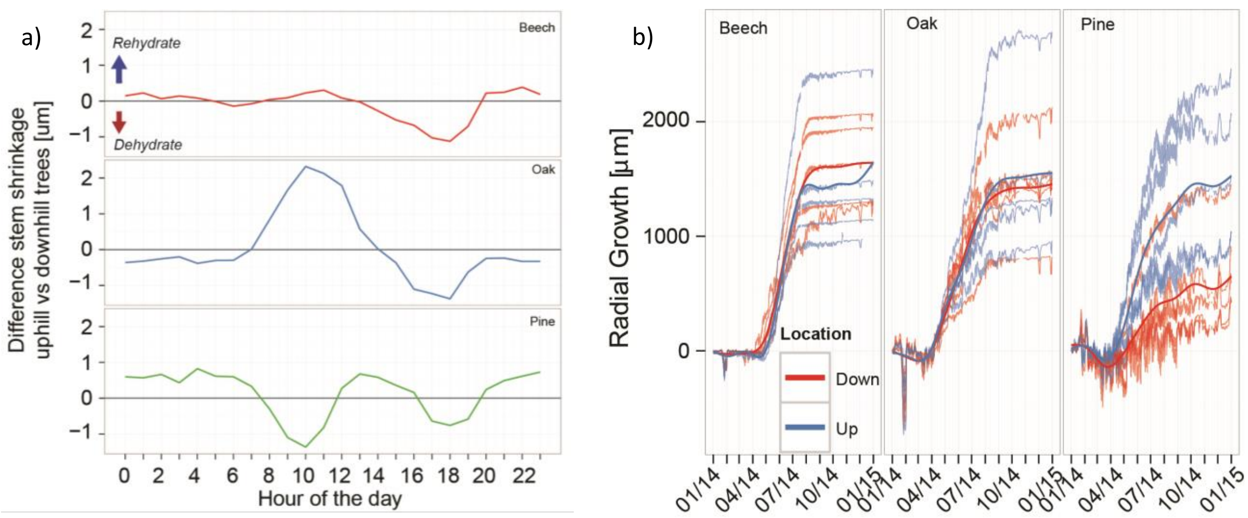

Fig. 2: a) Differences between hourly stem diameter (µm) variations from uphill compared to downhill trees. Values above and below zero indicate higher and lower rehydration of uphill trees compared to downhill ones, respectively. The data represent the average of four trees over 24h in the growing season 2014 (June 1st – September 30th), b) half-hourly stem diameter variation measured on individual trees using electronic point dendrometer. Bold lines indicate average radial growth (µm) by location.

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, supported by TERENO infrastructure of the Helmholtz Association.

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ICLEA / TERENO monitoring site for tree ring and hydrological research at Lake Hinnensee (Fürstenseer See), Müritz National Park, Germany (photo S. Simard, GFZ).

Theme C High resolution climate reconstruction / WP4

How route construction influenced landscape transformation during the last 700 years in NE Poland

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From way back, connecting pathways (routes in a wider sense) play an essential role in human life and are fundamental for cultural and economic exchange. However, routes also had negative impacts on nearby settlements since they became important during war times for troop transports and may even have fostered the spread of epidemic diseases. In any case, routes are important cornerstones in the development of human settlement and landscape evolution. Commonly, historians investigate the role of routes for cultural developments, whereas environmental consequences of historical route construction so far had attained less attention.

Here, we present, for the first time, 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 built in the early 13th century and it initially led from today’s territory of Germany (Brandenburg) through capital of Neumark (Myślibórz, 1298 AD) to the Castle of the Teutonic Order in Malbork (Poland, 1286 AD). In the first few centuries this track developed and became the key migratory route during the Middle Ages on the territory of Pomerania. 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’s catchment. Such environmental changes are recorded in the sediments and can be traced with novel high resolution analytical methods.

Based on a 1-16 varve year resolution pollen record combined with sub-annual resolving µ-XRF element scanning and precise varve dating five phases of significantly lower human activity interrupted by phases of stronger human impact were distinguished. Comparing these data with historical sources revealed a clear impact of wars and deployment through armed forces in this region. The strongest declines in anthropogenic pressure on the landscape are clearly related to periods of war and subsequent regeneration in the periods between wars. Hence, it was the construction of the Via Marchionis that indirectly influenced the development of Pomeranian landscape mainly due to its role as pathway for armed forces.

This research was funded by the National Science Centre grants No. NN306085037. This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA) of the Helmholtz Association. It is a contribution to the climate initiative REKLIM Topic 8 ‘Abrupt climate change derived from proxy data’ of the Helmholtz Association.

Themes A Monitoring & B Present and Palaeohydrology / WP4 Lake sediments

Micro-refuges as unique synergies of the environment – a case study of *Betula nana* glacial relicts from a *Sphagnum* mire (Northern Poland)

Słowiński, Michał[1,2*]; Słowińska, Sandra[3,4,]; Noryśkiewicz, Agnieszka M.[5]; Lamentowicz, Mariusz[4,6] & Kołaczek, Piotr[4]

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Peatlands are "hydrogenic islands", which are characterized by specific vegetation, hydrological conditions and an orographic modified local climate, are very valuable areas for the local flora and fauna. In the last decade, much effort was made at better understanding of microrefugia and their important role in post-glacial migration of various plant species.

The aim of this study is to explain a long-term persistence of the glacial relict Betula nana in a Sphagnum peatland in northern Poland far from the southern range of its natural distribution. The study site, Linje mire, is located in northern Poland (Central European lowlands - 91 m a.s.l.; 53°11'15"N, 18°18'34"E). It is a unique floristic nature reserve, where the arctic-boreal species *Betula nana* is protected.

We suppose that the persistence of Betula nana is driven by a) the morphology and geology of the catchment, b) the maintenance of open vegetation on the peatland surface and c) exceptional microclimatic and hydrological conditions.

A detailed research was carried out on the peat profile using pollen analysis, to reconstruct the presence of open habitat on the mire during the Holocene. Furthermore, detailed monitoring of local climate, hydrology of the peatland and the surrounding area was conducted. The pollen analysis revealed a continuous presence of Betula nana in the postglacial history of the peatland. The results of local climate monitoring indicated that the mire possesses a typical microclimate, with air temperature amplitude much higher in relation to the open area, in particular during the growing season. This, in combination with the hydrology, which depends on the geology of the surrounding area, affects Betula nana population. Linje mire is a unique microrefugium sustained by local factors such as microclimate, geology, local relief and hydrology. However, it is still challenging to explain the intriguing case why this species still occurs within the study site.

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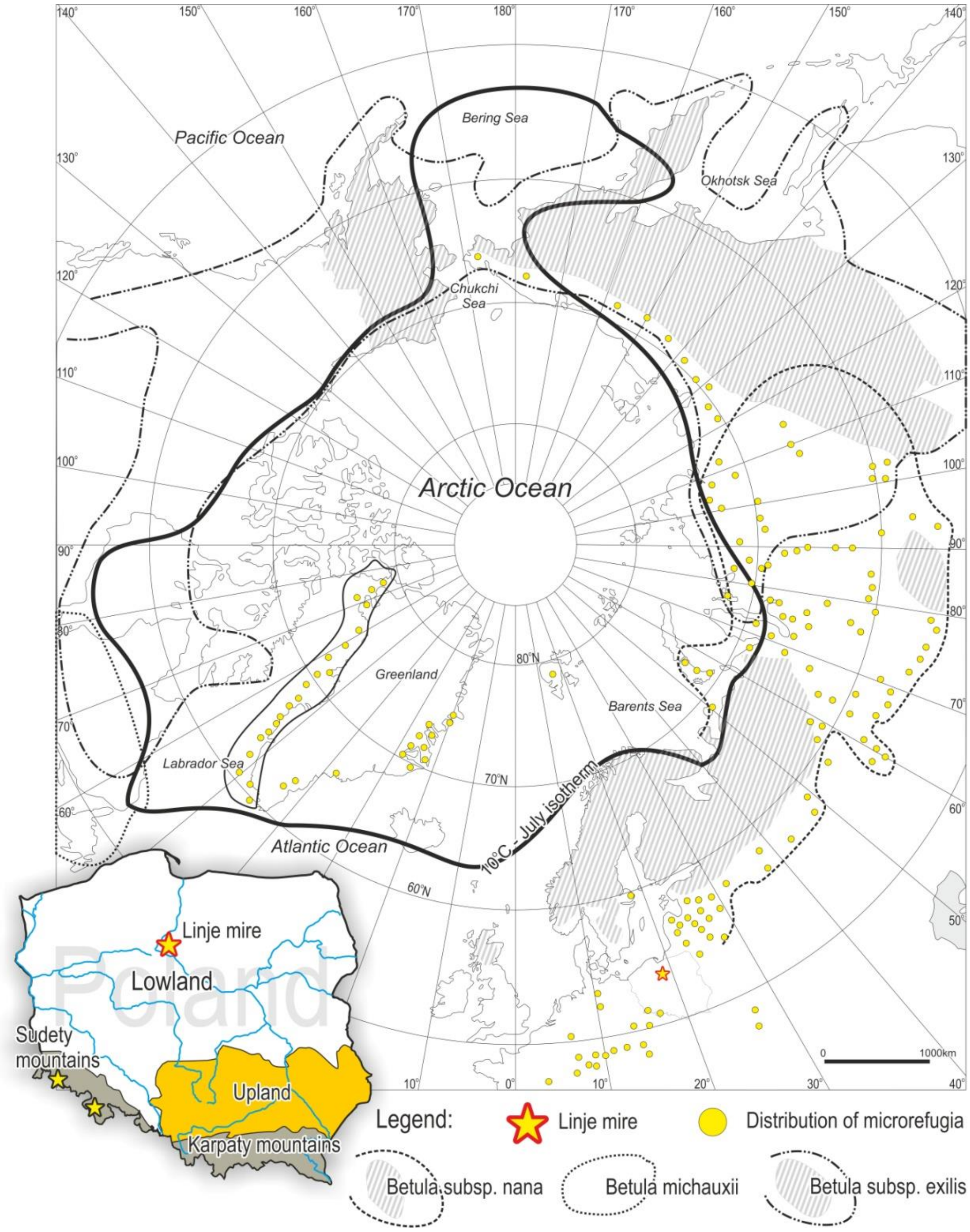

*Fig. 1: Present range of occurrence **Betula nana** (subsp. **nana** and subsp. **exilis**) and **Betula michauxii** on the northern hemisphere and in Poland (based on data from Swedish Museum of Natural History).*

This work is part of a larger project "Influence of biotic and abiotic factors on the functioning of "Linje" mire - the implication for palaeoclimatic studies" was funded by the National Science Centre grants No. NN306060940 and Polish-Swiss Research Programme No. PSPB-013/2010. This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution (ICLEA) of the Helmholtz Association.

Theme C High resolution climate reconstruction / WP4

Last 800 years history of human activity recording in laminated lake sediment - palaeolimnological vs. archival data (Lake Czechowskie, northern Poland)

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It has been almost 100 years since the first palynological analysis results regarding the history of Swedish bogs were announced by Leonard von Post in 1916. From that moment the palynological analysis is indispensable, enabling to evaluate changes in the natural environment. Palynological analysis results provide information on the history of vegetation under the influence of climate change, as well as human activity.

The aim of this study is to combine the great potential of the palynological analysis with the cartographic materials (maps) and historical information, which perfectly complement the knowledge of human activity and its impact on the transformation of the natural environment in the study area.

The aim of the study was to reconstruct human development in the Tuchola Pinewoods (Lake Czechowskie, Northern Poland) during the last 800 years based on the pollen analysis of the annually laminated lake sediments, and on the detailed historical maps and documents. The chronology was based on the annual laminations supported by the AMS 14C dates, 210Pb and 137Cs dating, as well as with the use of the tephra AD 1875 Askja.

Based on the *Principal Component Analysis* (*PCA*), the pollen data was divided into four statistically significant groups, which reflect the general transformation of the landscape. In the first phase, i.e. between AD 1200 and 1412 (p1), the Lake Czechowskie area was generally forested with *Quercus*, *Carpinus* and *Pinus* forests. Archival data also confirm the largest forest cover at the time (archival materials from the twelfth and fifteenth century). In the next phase p2 (1412-1776) a greater human activity was observed. It is visible through the gradual opening of the landscape and increased share of crops (i.e. cereals). The maximum openness of the landscape was in the p3 phase between 1776 and 1905; the same results are revealed in the historical maps from end of XVIII century (Karte von Ost-Preussen nebst Preussisch Litthauen und West-Preussen, called Schroetter Map). We can also observe the transformation of the forest dominated by Scots pine (forestry). The period associated with the phase p4 between 1909 and 2010, shows an increase in the forest cover (closing the landscape) with dominance of the Scots pine in the stand.

The analysis of human development and the transformation of the landscape of the Lake Czechowskie area indicate four landscape and social phases, which show rapid changes in the openness and closeness of the landscape, with simultaneous vegetation type change. The results show a high potential of the pollen results combined with historical maps and data analysis in the reconstruction of human development in the past.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. 2011/01/B/ST10/07367).

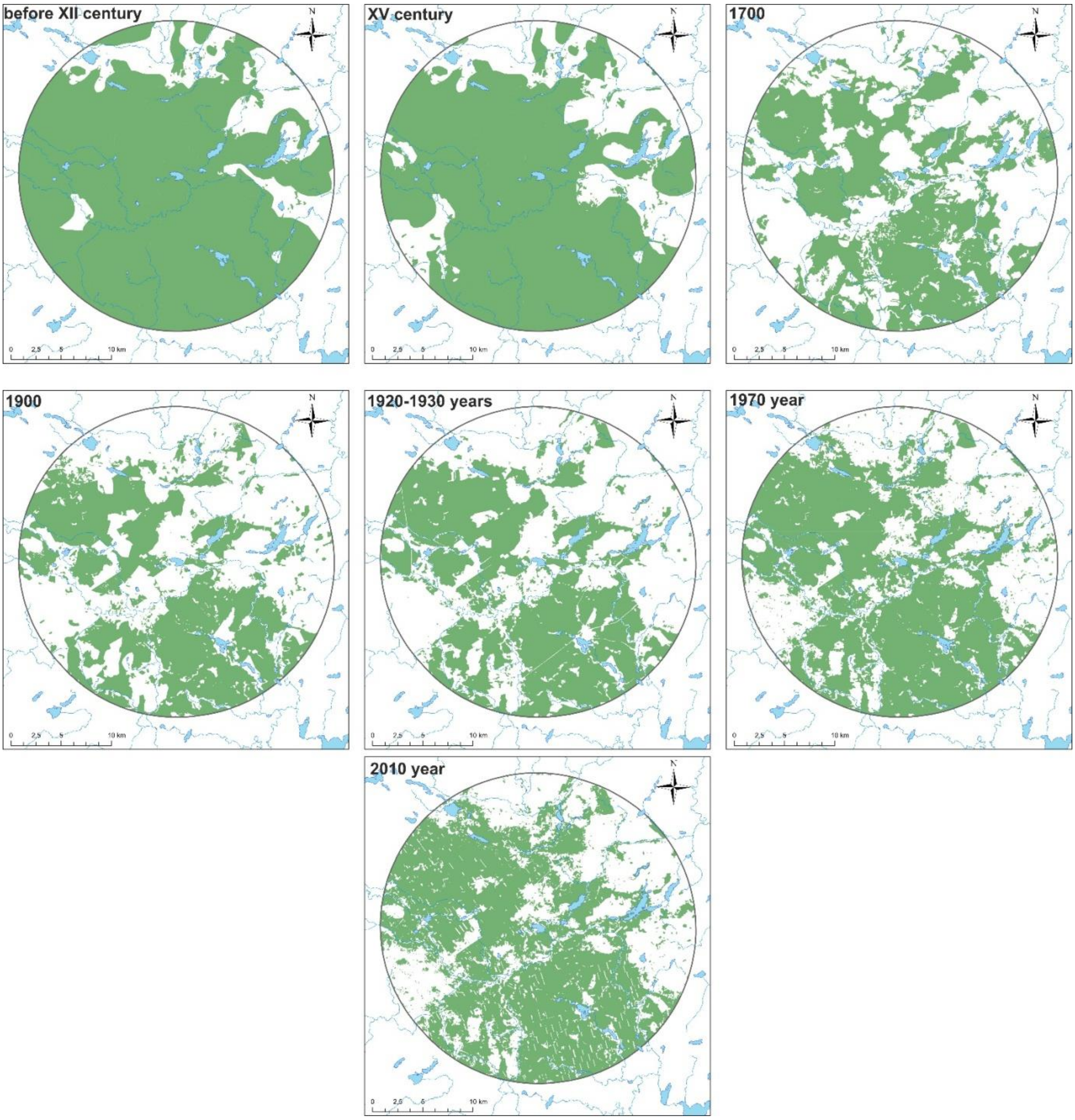

Fig. 1: Forest cover changes inside a 15-km radius around the Czechowskie Lake from XII century until today.

Theme C High resolution climate reconstruction / WP4

Differential proxy response of lake systems during late Allerød and early Younger Dryas climatic fluctuations in Northern Poland (Trzechowskie paleolake)

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The transition from the warmer Allerød to the cooler Younger Dryas period is well understood to represent sudden and extreme climate changes during the end of the last glaciation. Thus, lake sediment studies within paleoclimatic and paleoecological research on this transition are ideal to enhance the knowledge about “lead and lags” of lake system responses to abrupt climate changes through applying multi-proxy sediment analyses.

In this study, we present the results of high-resolution studies on varved late glacial sediments from the Trzechowskie paleolake, located in the northern Poland (center Europe).

High-resolution bio-proxies (pollen, macrofossils, Cladocera and diatoms), geochemical analyses (µ-XRF data, TOC, C/N ratios, $\delta^{18}O_{carb}$ and $\delta^{13}C_{org}$ stable isotopes) and a robust chronology based on varve counting, AMS ^{14}C dating and tephrochronology were used to reconstruct the lake system responses to rapid climatic and environmental changes of Trzechowskie paleolake during the late Allerød - Younger Dryas transition. Paleoecological and geochemical analyses, which were carried out in a 4 to 16 years temporal sample resolution, allowed to defining short-termed shifts of the ecosystem that were triggered by abrupt climate changes (Fig. 1).

The rapid and pronounced cooling at the beginning of the Younger Dryas had a major impact on the lake and its catchment as clearly reflected by not synchronous changes of both, biotic and geochemical proxies. The results of high-resolution analysis indicate (a) increase of soil erosion in the catchment during the Allerød-YD transition, (b) a delayed response of the vegetation compared to the lake depositional system at the YD onset of 20 years, and (c) a non-synchronicity of vegetation responses between Western (Lake Meerfelder Maar) and Eastern European sites (Trzechowskie palaeolake) at the YD onset.

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 (grants No. NN 306085037 and NCN 2011/01/B/ST10/07367).

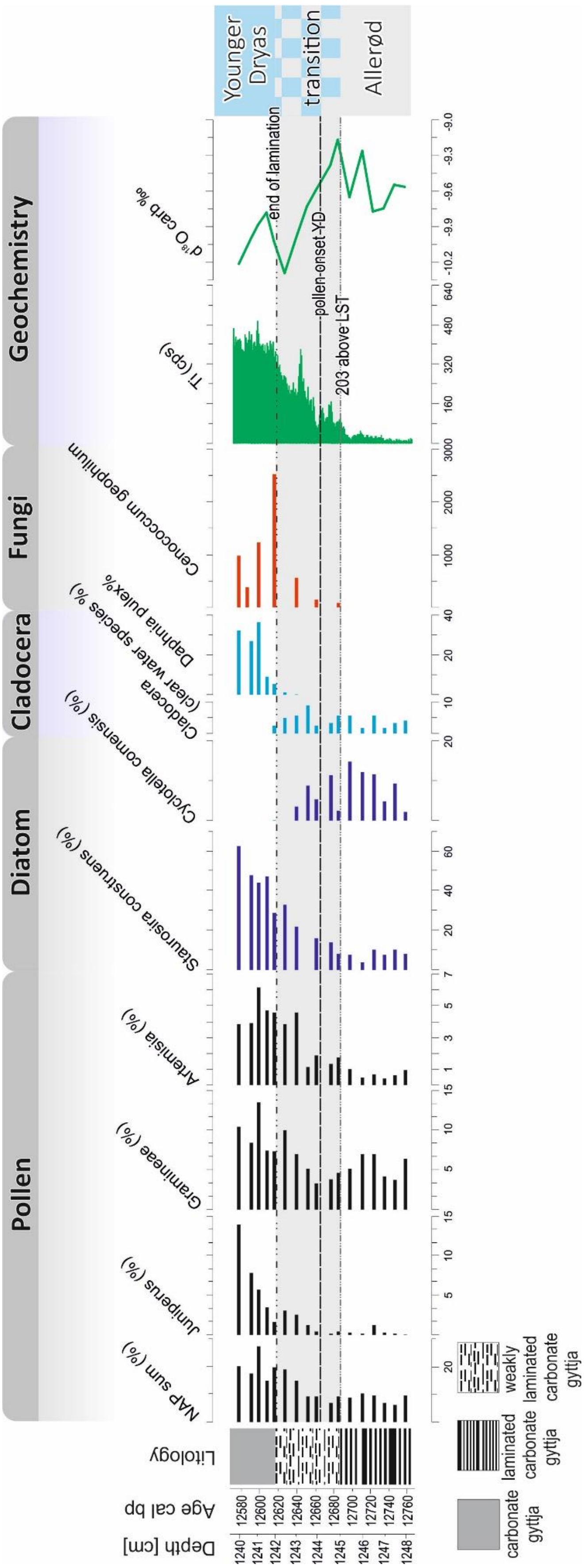

Fig. 1: Summary of Trzechowskie palaeolake proxy data.

Invited talk

The reflection of hydrological regime in fluvial and lake systems during Younger Dryas and Early Holocene on territory of Poland

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The Younger Dryas was characterized by cooling and retreat of boreal forest but also by preservation of large meanders. Only in selected reaches the ice–jam floods caused the return to braiding tendency. The lowering of upper tree line in the mountains increased sediment load reflected in Subcarpathian Basins in formation of blanket in silty overbank sediments covering Allerød bogs as well transformation of channel bars in sandy dunes.

Rapid expansion of forest vegetation about 11500 years BP reduced the river discharges several times expressed in formation of meandering channels 3-5 fold smaller, as well extension of peat bogs over floodplains flooded during summer rains. Between 9500 and 8500 years BP together with activisation of westerlies (after decay of Laurentide ice sheet) increased frequency of heavy downpours and continuous rains causing agradation, avulsions of river channels and formation of thick alluvial fans even at the outlets of small tributaries. One of them in about 6 meters contained 100 rainy events. At that time many big landslides were recorded in the Flysch Carpathians and debris avalanches in high Tatra Mts. This phase is also well marked in limestone areas and in glaciated Alps. In several peat bogs we fin the intercalations of sandy or silky alluvia.

The lakes developed after melting of buried ice before Younger Dryas or during that phase and gradually were incorporated in new fluvial systems. During first early Holocene humid phase followed a distinct rise of water level observed both in closed depressions as well in transfluent lakes incorporated to developing fluvial systems. It was frequent case this caused outflow and rapid lowering of water level – expressed even in statistical analyses of lakes in zone of Vistulian glaciations (Michczyńska et al. 2013). During that phase followed also a mixture of overland lake waters and rising level of deeper groundwater, what has been documented in rapid change of chemical composition (of 180) in water of lake Gościąż (Ralska-Jasiewiczowa et al. 1998). The problem of relations between transformation of surface lake storage and formation of groundwater storage needs farther studies.

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Theme E Human impact / WP4

Reconstructing vegetation openness from the pollen record – an example from Lake Tiefer See (NE Germany)

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Since the mid-Holocene, humans have transformed the largely forested landscape of central Europe into an open, agricultural landscape. That transformation has possible influenced the climate but also lakes in various ways. As the vegetation cover influences evapotranspiration and thus groundwater recharge, that transformation may have for example affected the water level of groundwater fed lakes such as Lake Tiefer See. Changes in vegetation openness may thus help to understand the sediment record of this lake. Various approaches to reconstruct past openness have been recently presented, yet the reliability and accuracy of these approaches is largely unknown.

Pollen data is the best proxy available to reconstruct the vegetation cover of terrestrial sites. Reconstructing openness is hampered, however, by the fact that herbs and grasses produce far less pollen than the dominant tree species. Even in largely open landscapes the pollen record is thus dominated by tree pollen, i.e. open vegetation is strongly underrepresented. Past openness may still be reconstructed from the pollen record by using correction factor approaches. Such approaches rely on pollen productivity estimates, which describe relative pollen productivity of plant species in relation to a reference taxon. Still pollen productivity of plants is not only difficult to measure, it may also respond to changes in climate or land use practices (Theuerkauf et al. 2015). Grasses, for examples, produce more pollen when fertilized but less pollen when often mown. As the magnitude of these effects are still poorly understand, the reconstruction of past vegetation openness by correction factor approaches introduces unknown errors.

Vegetation openness may alternatively be reconstructed using pollen accumulation rate data. Pollen accumulation rates represent abundances of each taxon separately and thus potentially allow sharper reconstruction of past openness. Yet pollen accumulation data is rarely applied because pollen accumulation in a lake may be strongly altered by sediment focusing and re-deposition. Pollen accumulation rate data may still be useful in lakes where these processes are known to be limitedly important, e.g. in Lake Tiefer See. Also in the application of pollen accumulation data, the reference period has great impact in the results (Fig. 1).

As a tree near a lake contributes far more pollen to that lake than a tree in some kilometer distance, pollen data represent vegetation composition in a distance weighted way. This implies that a specific proportion of indicators for open vegetation in the pollen record may represent a rather small patch of open vegetation just at the lake or extended areas of open vegetation in some greater distance from the lake. When using pollen data from just one site (percentage or accumulation rate data) we thus cannot reliably estimate vegetation openness in a region. One approach to solve this problem is the extended downscaling approach (Theuerkauf et al. 2014). This approach combines pollen data from numerous sites in a region with the pattern of soils and relief to arrive at most the probable vegetation composition (including openness) on different site types in a region.

We here apply all three approaches to reconstruct vegetation openness in the Lake Tiefer See area. By comparing the results we aim to explore the reliability of the three approaches and to arrive at realistic error estimates.

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, supported by TERENO infrastructure of the Helmholtz Association.

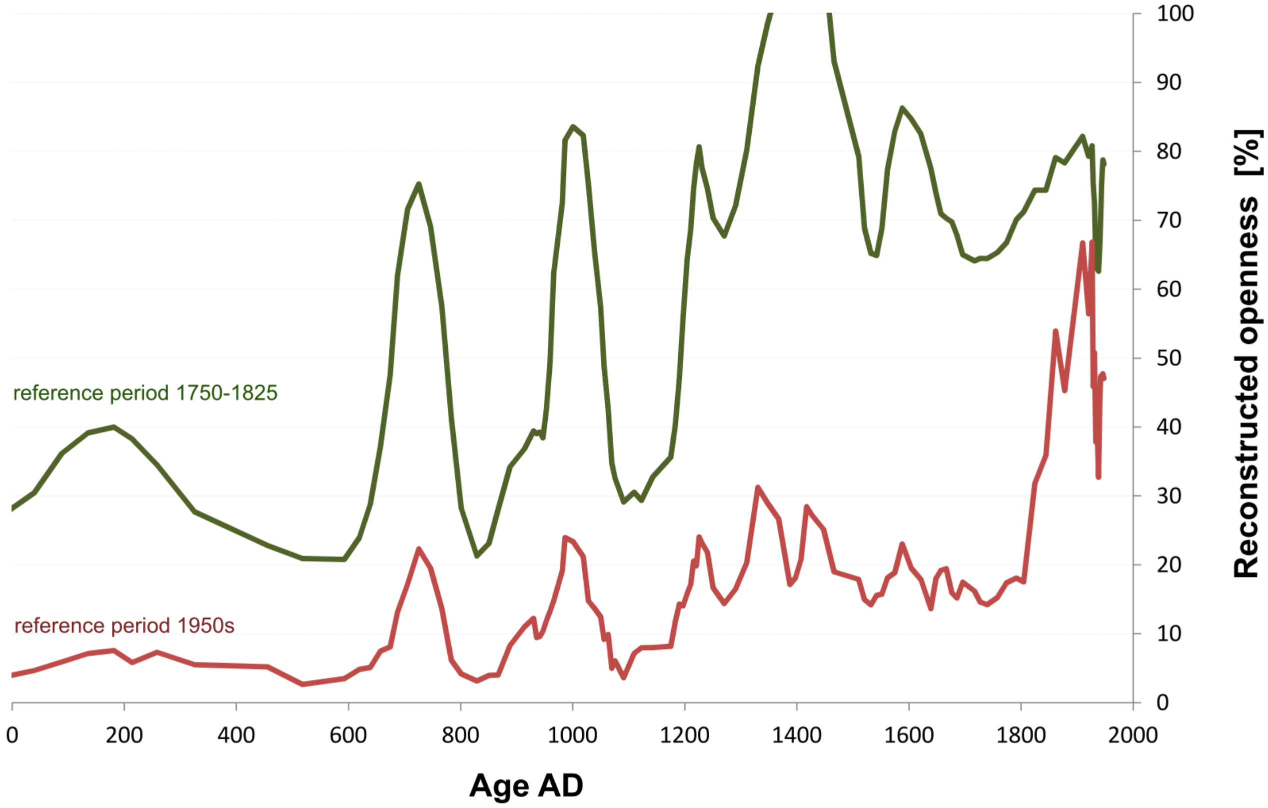

Fig. 1: Reconstruction of vegetation openness in the Lake Tiefer See area based on the pollen accumulation rate approach. Using two different reference periods (1950s and 1750-1825) produces very different results because pollen productivity of herbs and grasses in the 1950s has been much higher than between 1750 and 1825 AD.

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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.

Theme B Present and Palaeohydrology / WP4 & WP5

Holocene lake-level changes in the Schorfheide region (Lake Warnitzsee and Lake Briesensee, NE Germany) – The current state of research

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Several lakes in the Schorfheide area (ca. 50 km north of Berlin) fluctuated by 3 m or more over the last decades (Kaiser et al. 2015) – and possible also did in the past. These lakes are thus potentially well suited to reconstruct long term Holocene lake level changes. During a coring campaign in August 2013 we explored whether sediments reflecting past lake level changes are preserved. This campaign focused on Lake Warnitzsee, where seven cores were taken along two transects. All cores show several alternations of peat and gyttja layers, with a maximum of seven peat layers in core WAR2 and WAR5. Geochemical analysis (all cores) and radiocarbon dating (two cores) has been completed, pollen analysis is in progress. Pollen analysis will be used to correlate the sediment cores and to verify whether water level fluctuations are related to vegetation change in the region.

The results so far indicate that beside short-lived fluctuations, the water level in Lake Warnitzsee follows a long-term trend of high water levels in the early Holocene, low water levels between 8000 and 6000 cal. BP and a stepwise increase since approx. 5000 cal. BP towards the modern level.

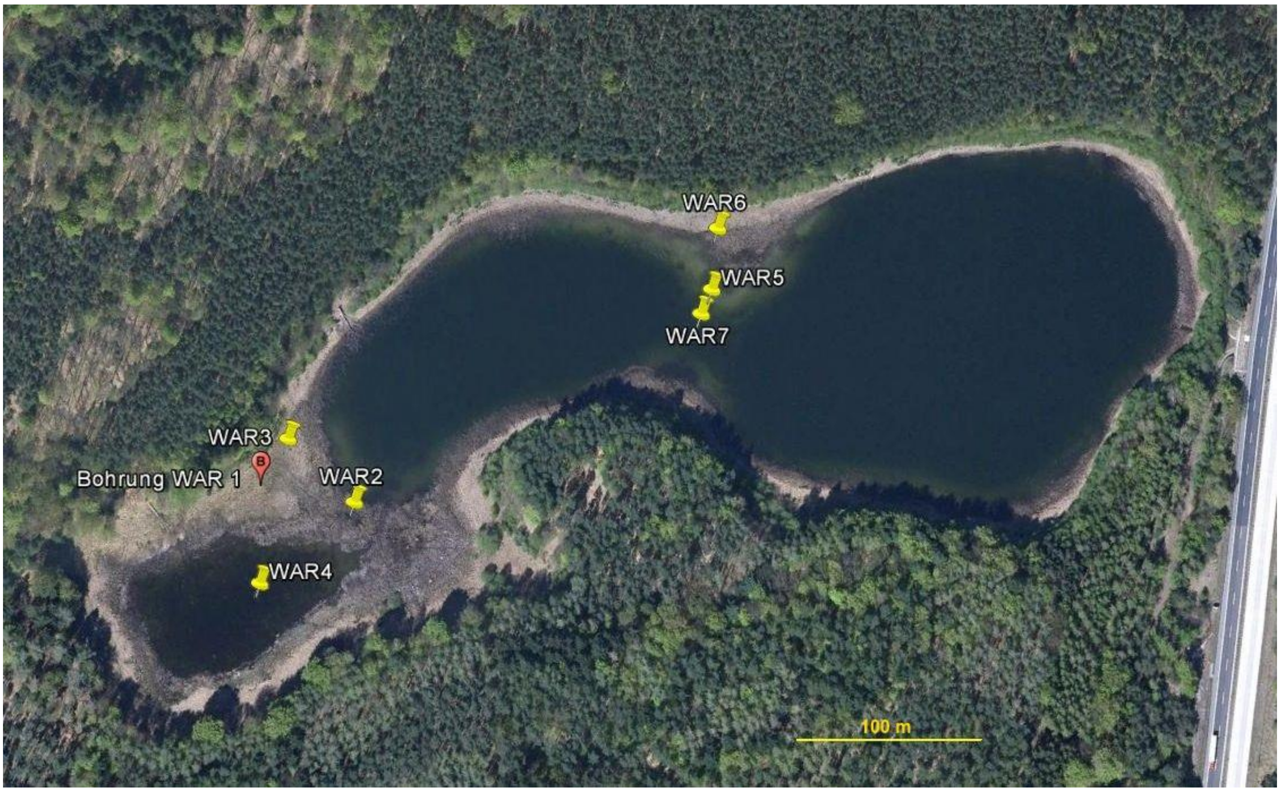

Fig. 1: Coring sites in Lake Warnitzsee (Schorfheide, NE Germany).

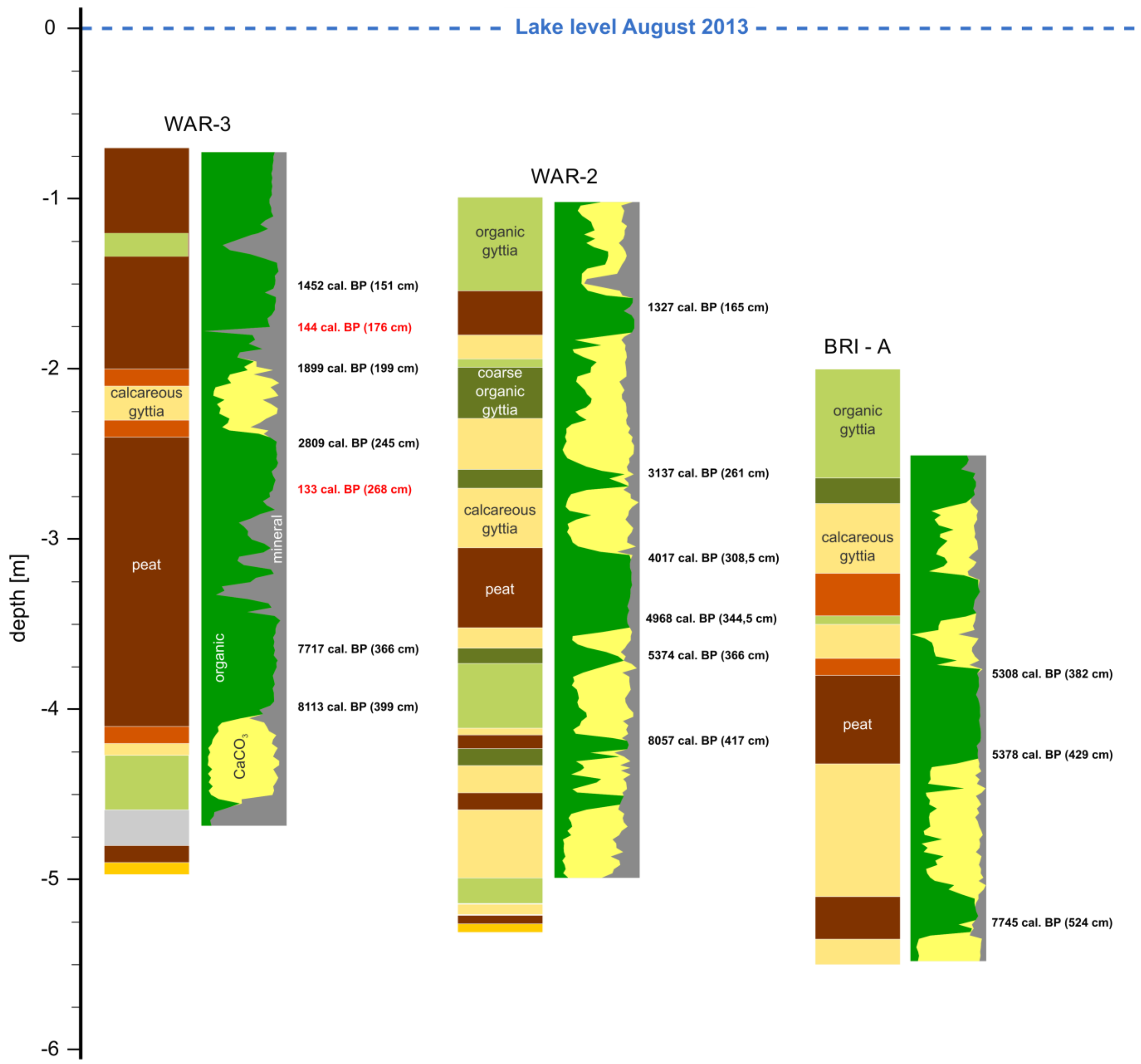

Fig. 2: Stratigraphy and sediment composition of cores from Warnitzsee and Briesensee (Schorfheide, NE Germany).

By comparing with further lake level records in the region we finally aim at exploring major drivers of Holocene lake level variability in the area.

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.

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Kaiser, K., Heinrich, I., Heine, I., Natkhin, M., Dannowski, R., Lischeid, G., Schneider, T., Henkel, J., Küster, M., Heussner, K.-U., Bens, O., Chmieleski, J., 2015. Multi-decadal lake-level dynamics in north-eastern Germany as derived by a combination of gauging, proxy-data and modelling. Journal of Hydrology (in press).

Theme B Present and Palaeohydrology / WP4

Holocene lake level fluctuations of Lake Tiefer See (NE Germany)

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Lake levels fluctuate in response to global (climatic) or local (vegetation, drainage) change. Lake level changes in turn may alter depositional processes in a lake and thus the character of the newly forming sediments. To refine the interpretation of the varved sediments of Lake Tiefer See (NE-Germany) we thus study past lake level changes of this lake. The study focuses on the following questions:

- How did the lake level fluctuate throughout the Holocene?
- What caused these changes?
- Are these changes represented in the varved sediments?

The study is based on 19 sediment cores (Fig. 1) from the margin of Lake Tiefer See, including surrounding peatlands. In all cores, we analysed sediment composition and grain sizes of mineral matter. In peat sections, also macrofossil composition was analysed. Dating is provided by radiocarbon dating (mainly basal sediments) and pollen analyses. Pollen stratigraphic events could be correlated to pollen data from the well dated long core from the centre of Tiefer See. Information on the past lake level is derived from the presence of gyttja (lake level above that point) and peat layers (lake level at about this point).

The presence of calcareous gyttja layers from the early Holocene at the very margin of the lake indicates that the lake level periodically has been about as high as today. However, peat layers in deeper positions also show that the lake level sharply dropped for a short period before 11,000 cal. BP.

In all our sediment cores, sediments from the period ~6000-9000 cal. BP are absent. It thus appears that that the lake level has been constantly low during this period, possibly 8 m lower than today.

Sedimentation in the marginal cores proceeds at ~5000 cal. BP, suggesting that the lake level increased back to present levels within about 1000 years. With some fluctuations, the lake level has been high since then.

To detect whether these lake level fluctuations represent changes in climate or changes in the catchment of the lake itself, we compare the lake level record with climate proxies as well as proxies of vegetation composition and land use. We hypothesize that the long-term trend primarily results from changes in vegetation openness, i.e. high lake levels in the early and late Holocene correspond to periods of open vegetation and thus increased groundwater formation. Short-lived lake level fluctuations (e.g. around 11.000 cal. BP) instead possibly represent periods of exceptional climatic conditions. To underline the interpretation we use sensitivity calculations to test, how much changes in land cover or climate might affect the lake level of Tiefer See.

We then outline whether and how these changes have affected sediment formation in Lake Tiefer See. Varve formation is not continuous but characterized by repeated changes in varve composition. For several periods, varve formation is also interrupted.

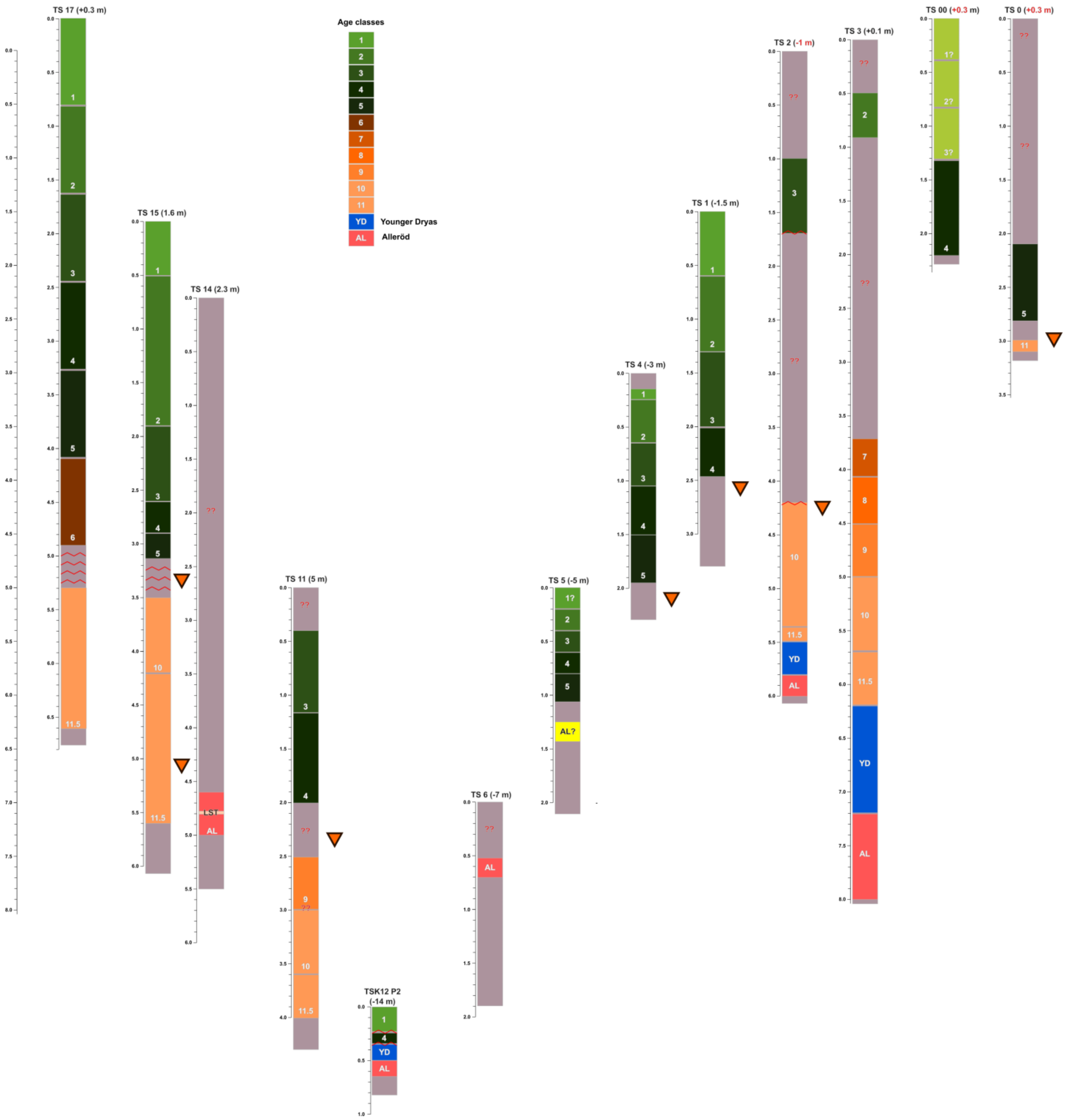

Fig. 1: Preliminary dating (in millennia bins) of selected sediment cores from the margin and surrounding peatlands of Lake Tiefer See. Dating is based on radiocarbon dating and biostratigraphic correlation with a core from the lake centre by pollen analysis.

Finally, by comparing with further lake level records from the region we explore common trends in Holocene lake level changes, which may help to detect the main drivers of Holocene lake level changes.

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.

Theme C High resolution climate reconstruction / WP4

Identifying local and regional changes in lake sediments of the ICLEA project using XRF scanning data

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The ICLEA project includes several lake records of the northern Polish and German lowlands for detailed climatic and environmental reconstructions. The use of XRF core scanning plays a central role in the reconstruction of past sedimentological changes and has great potential for correlating the changes of the individual lakes. Especially finely laminated and varved sediments provide detailed archives of sedimentological changes that can be linked to both local environmental changes and regional climatic changes. Here we present a statistical concept for XRF core scanning data to evaluate the most prominent sedimentological changes of individual sediment cores of the lakes Gleboczek, Jelonek, and Tiefer See. The main requirement for rigorous statistical results is the availability of replicate XRF scanning measurements obtained at representative parts of the sediment core. A similar approach applied on early Holocene sediments of Lake Meerfelder Maar allowed linking of chemical elements to both autochthonous and allochthonous sedimentological processes (Martin-Puertas et al., in prep; Fig. 1 and 2).

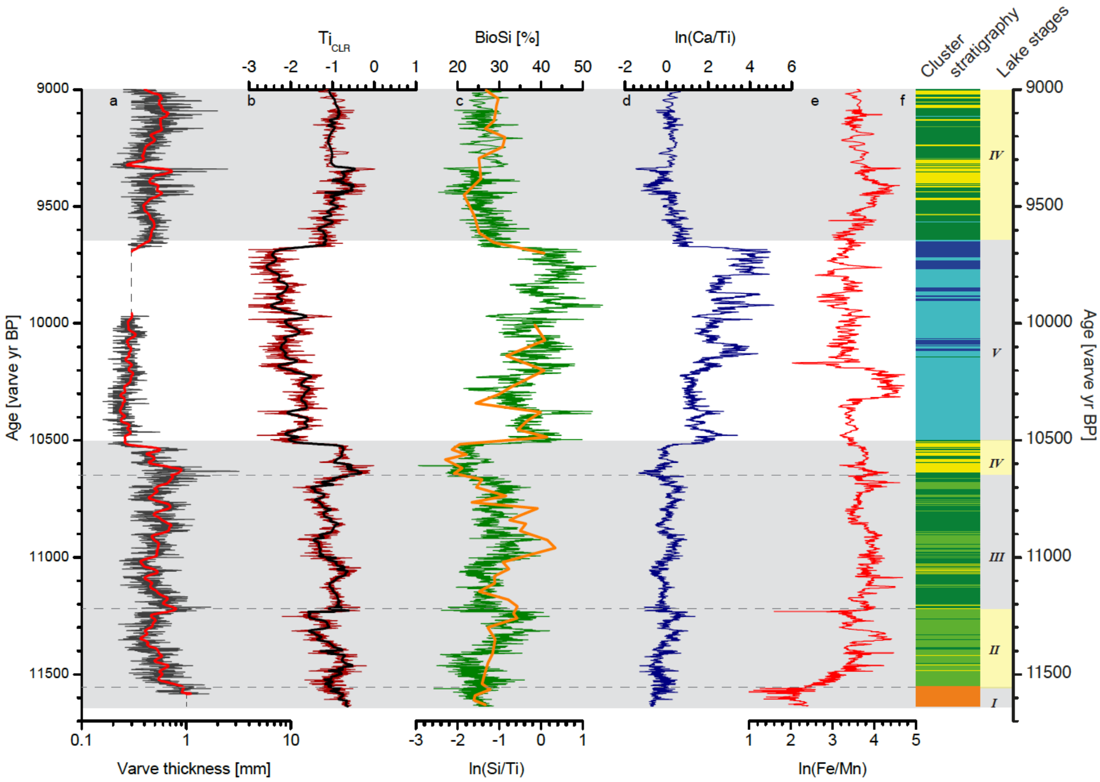

Fig. 1: Early Holocene XRF stratigraphy, varve thickness, and biogenic silica of Lake Meerfelder Maar (Martin-Puertas et al., in prep). The most prominent sedimentological variations were identified based on a) varve thickness and changes in the relative elemental changes of b) Ti, c) Si/Ti, d) Ca/Ti, e) and Fe/Mn, which represent changes of detrital matter, biogenic silica, calcite, and redox sensitive elements, respectively. f) Statistical clusters of the XRF data provide objective stratigraphical results on the compositional changes (see also Fig. 2). These results provide detailed information on allochthonous climatic variations during the Preboreal and Boreal transition, and autochthonous a environmental changes between 9655 and 10500 yrs BP.

For lakes Gleboczek, Jelonek, and Tiefer See, we focus on the mid-Holocene changes of the individual records in all three lakes. Comparison of these lake records can potentially differentiate between locally forced changes and regional climatic trends.

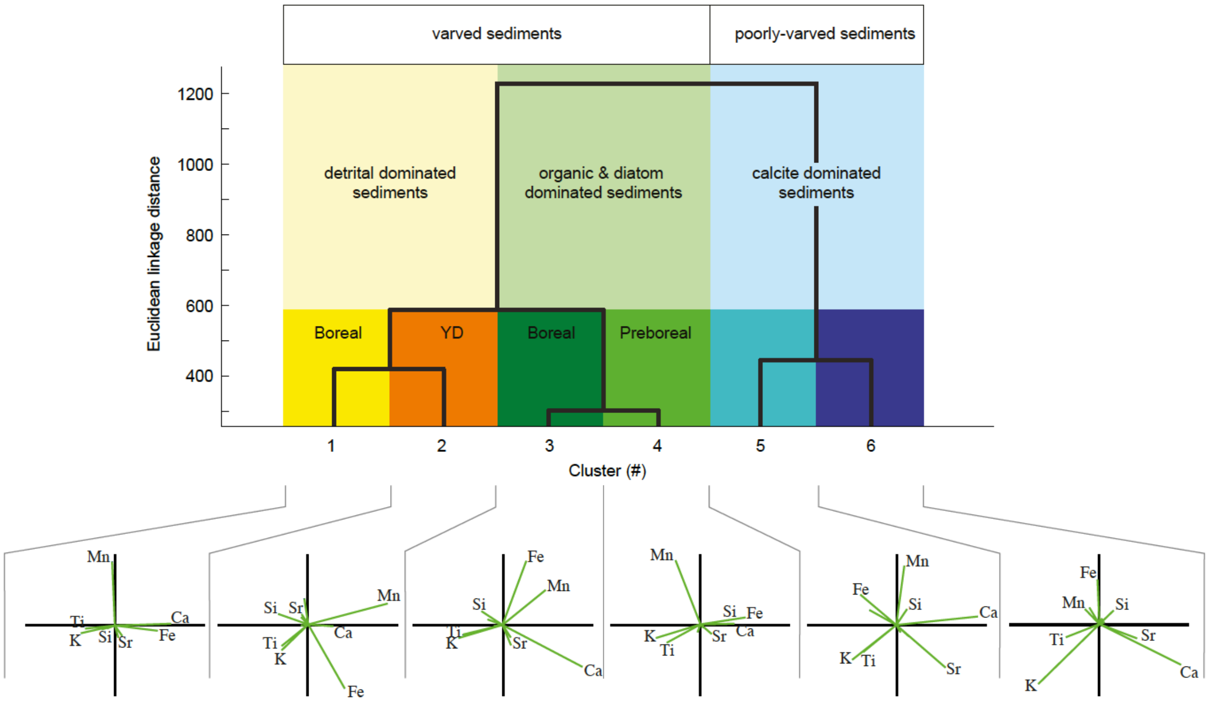

Fig. 2: Hierarchical dendrogram and compositional changes of the individual clusters obtained for the XRF data of Lake Meerfelder Maar. a) The individual clusters represent the average composition of the corresponding sediment core. b) Biplots of the first 2 principal components provide detailed information on the correlation of all elements measured for each of the clusters. Elements situated next to each other correlate well (e.g. Ti and K), whereas elements situated opposite of each other reveal an anti-correlation (e.g. Ti and Ca in cluster 1). For example, Si correlates with the detrital elements in cluster 1, but reveal an anti-correlation in cluster 4. This can be explained by the lack of well-defined diatom layers in cluster 1.

References:

Celia Martin-Puertas, Rik Tjallingii, Menno Bloemsma, Achim Brauer (*in prep.*). Early Holocene climate and environmental response of Lake Meerfelder Maar (Germany) using µ-XRF core scanning data.

Invited talk

The CLIMPOL project: toward quantitative paleoclimate reconstructions from lake sediments in northeastern Poland

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The project CLIMPOL (Climate of northern Poland during the last 1000 years: Constraining the future with the past) aims at a quantitative reconstruction of climate change based on varved sediments from Lake Żabińskie in northeastern Poland. The lake is located in the Masurian Lakeland (54°07'54."N; 21°59'01.1"E) and presents features typical for kettle-hole lakes, i.e. small surface area (41.6 ha) and considerable depth (44.4 m). The reconstructions are based on high-resolution analyses using precise chronology and biological, sedimentological and geochemical proxies. The results are calibrated with a modern training set of lakes (transfer function) and calibration-in-time approach, and validated with early instrumental and documentary data available.

During a three-year long observation period we investigated limnological and hydrochemical conditions within the water column as well as recent sediment fluxes to understand the relationship between the lake water properties and the sediment formation processes. These observations indicated considerable seasonal variability in the fluxes of total organic carbon, biogenic silica and calcite. The annual sedimentation model was established based on the sediment composition variability and used for the interpretation of laminations preserved in the sediment record. Microscopic investigations of thin sections proved the annual character of these laminations. Three varve microfacies were distinguished along the sediment profile showing a different number of calcite laminae interbedded with diatoms, organic detritus and minerogenic admixtures. The chemical composition inferred from high-resolution XRF measurements allowed for the recognition of individual seasons within one varve. The varve chronology for the last millennium had very small uncertainty (1-2%) and was validated with independent dating methods, i.e. the ^{137}Cs activity peaks, the Askja tephra horizon and 32 AMS ^{14}C dates of terrestrial macrofossils distributed along the sediment profile. Overall, the whole dataset is consistent and highlights the reliability of the chronology with the accuracy of a decade.

The Polish training set for biological proxies (chironomids, chrysophytes, diatoms, pollen) consists of sediment trap and surface sediment samples from 50 lakes in northern Poland. Multivariate statistical analyses revealed the most important variables for the chironomid and chrysophyte assemblages. Transfer functions were developed and applied to an annually-varved sediment core from Lake Żabińskie for the period AD 1000-2010. As a reliability test, we reconstructed mean August temperatures since AD 1886 and compared the reconstruction with instrumental data for the Masurian Lakeland. This showed that inferences obtained with the training set were accurate at near-annual resolution and over decadal scales. The transfer function was then applied to the chironomid assemblages downcore to reconstruct the variations in temperature over the past millennium and key periods of climate change were reconstructed (MCA, LIA and 20C). Furthermore, statistical analysis of the chrysophyte data set revealed that the number of days with water temperature below 4°C (DB4°C) in the epilimnion, which is related to cold-season air temperature, is the most important variable for the chrysophyte assemblages. Striking correspondence between the DB4°C reconstruction and the combined volcanic and solar forcing prior to the 20th century suggests that winter climate in Poland responds mostly to natural forced variability. Very strong volcanic eruptions lead to particularly long winters while variability in Total Solar Irradiance plays a minor role.

Theme E Human impact / WP5

Mass movements of lowland areas in long range TLS and ALS monitoring

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The development of geodynamic processes in lowland areas remains an interesting issue for geomorphology and geology as well as civil engineering. Landslides, slumps, slope washes, rills and gully erosion are considered both geomorphological processes and natural hazards. In order to know precisely their origin and development, it is crucial to determine the rate and direction of their change. Previously such studies used geodesy and photogrammetry but the recent progress in the LiDAR technology allows collecting the data in a wider range and comparable or higher precision than most of geodetic methods. Airborne Laser Scanning (ALS) is also a good tool, but high costs and low frequency of the surveys make it difficult to trace the dynamics of the studied phenomena and processes. Nevertheless, this method enables gathering information from large areas, which is useful for the preliminary identification of the research issues and nomination of the areas for subsequent case studies. It is, however, more common to use Terrestrial Laser Scanning (TLS) for the detailed studies of morphology and its change. This method provides mobility and high accuracy, and enables frequent measurements. The problem in the analysis of many geoprocesses lies in the limited range of this method.

This study concerns the Lower Vistula Valley located in northern Poland. It presents the results of measurements of landslides located in the escarpment zone of a big river valley. The object of the studies is mass movements developing within the quaternary deposits on the valley slopes. These processes were monitored in previous years with the traditional survey methods, mainly based on the geodesy field observations (benchmark) as well as the analyses of historical maps and archives. The ALS method used during the study enabled gathering the data on the valley with the density of 8 points per sq m, which provided the background for the consecutive monitoring study. In the surveys a terrestrial scanner Riegl VZ-4000 was applied. This TLS scanner has a very long range of up to 4000 m. The TLS scan positions were located from 0.5 km to 2-3 km from the research objects (depending on the position), on the opposite river bank or valley side. A point cloud of three to four scan positions was made for each landslide. The scans were performed at a maximum resolution of 0.002. During the merging of each point cloud the Riegl Multi Station Adjustment tool was used for the automatic fine adjustment and alignment. The scan positions and georeferences were registered using the global coordinates with an integrated RTK GPS receiver. After three campaigns based on the collected data from the ALS and TLS scanning and previous filtration a digital terrain model was created. The obtained model was compared in the GIS software in order to assess the changes in the terrain morphology resulting from the geodynamic processes.

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

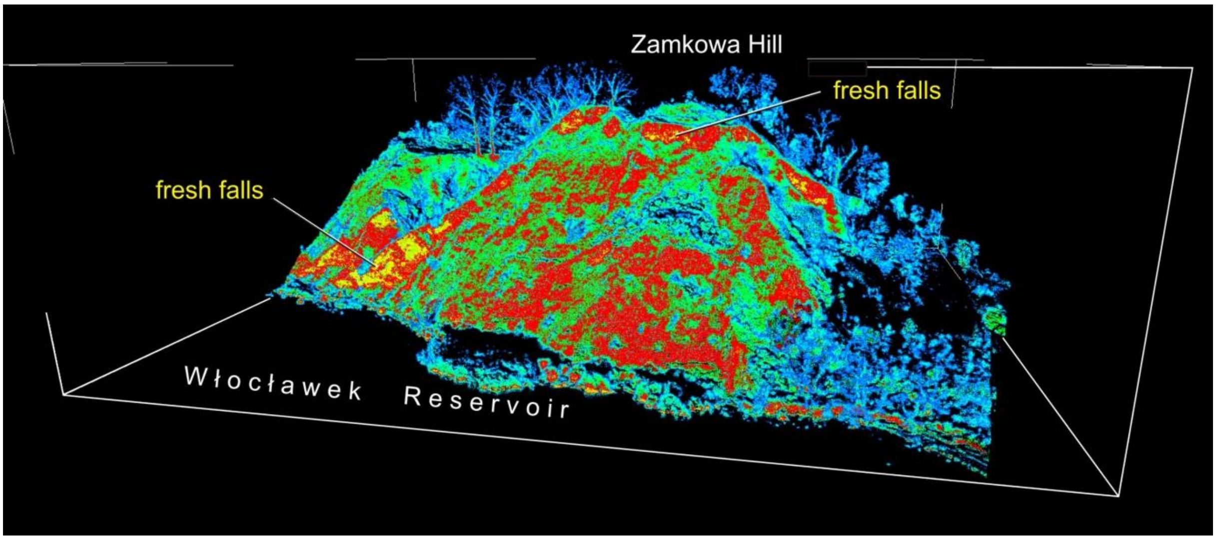

Fig. 1: Point cloud of Zamkowa Hill (scan form 2500 m, fresh falls in red and yellow color).

Hydrological monitoring at Lake Hinnensee (Müritz National Park), Germany (photo M. Morgner, GFZ).

Theme A Monitoring / WP4

Transformation of wetlands in the NE part of the Tuchola Pinewoods over the last 200 years on the basis of cartographic data

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Transformation of wetlands is conditioned by climatic, geological, hydrological and biotic as well as anthropogenic factors. Dynamic changes in lake and river systems in Northern Poland occurred at the time of the dead ice blocks melting and permafrost decay. Over the following periods of time, these changes tended to be more evolutionary. The disappearance of lakes and formation of wetlands occurred in the process of slow shallowing by filling lake basins with biogenic sediments. Only in the last few hundred years the process has been disturbed and significantly remodelled by human activity. A particularly important role was played by reclamation which led to the drainage of many wetlands and disappearance of lakes. Draining of wetlands has led to an increase in the participation of birch, oak, maple and hornbeam in the stands which in turn might have lead to a change in sedimentation in water bodies. Furthermore, due to mineralisation of peat some micro- and macroelements have become available to plants and incorporated back into circulation in the ecosystem. The goal of the research is to determine the direction and rate of change of wetlands over the last 200 years in the selected test area around Lake Czechowskie in the Tuchola Pinewoods. The study area is located in northern Poland, within the Weichselian glaciation. From earlier studies it is known that in this area over the last 200 years the biggest changes resulted from massive tree felling between the end of the eighteenth century and mid-nineteenth century. At the same time since the mid-eighteenth century, in this area very intensive reclamation works were carried out whose main objective was to convert peatlands into meadows. The biggest changes caused by land reclamation took place between mid-nineteenth and early twentieth century. At the same time, this area was abundant in dams and water mills. This study is based on historical and contemporary maps, including the following: Schrötter-Engelhart, Karte von Ost-Preussen nebst Preussisch Litthauen und West-Preussen nebst dem Netzdistrict, 1:50 000, 1796-1802; Messtischblatt, 1:25 000, (mapping conducted in 1874), the WIG map, 1:25 000 (Military Geographical Institute), 1931-33; topographic map from 1970; aerial photos at 1964, 1969; 1987; 1997; aerial orthophotomap, 1:5000, 2010. The obtained results can be used to correlate sedimentological changes in lacustrine sediments with the trends in landscape changes over the past 200 years (Tab. 1, Fig. 1).

Tab. 1. Wetlands area

	Wetlands area			
Distance form Lake Czechowskie	end of XVIII century	70y of XIX century	20/30y of XX century	70/80y of XX century
0-15 km	11,8%	11,4%	9,8%	9,0%
0-5 km	6,1 %	7,9%	7,5%	7,0%

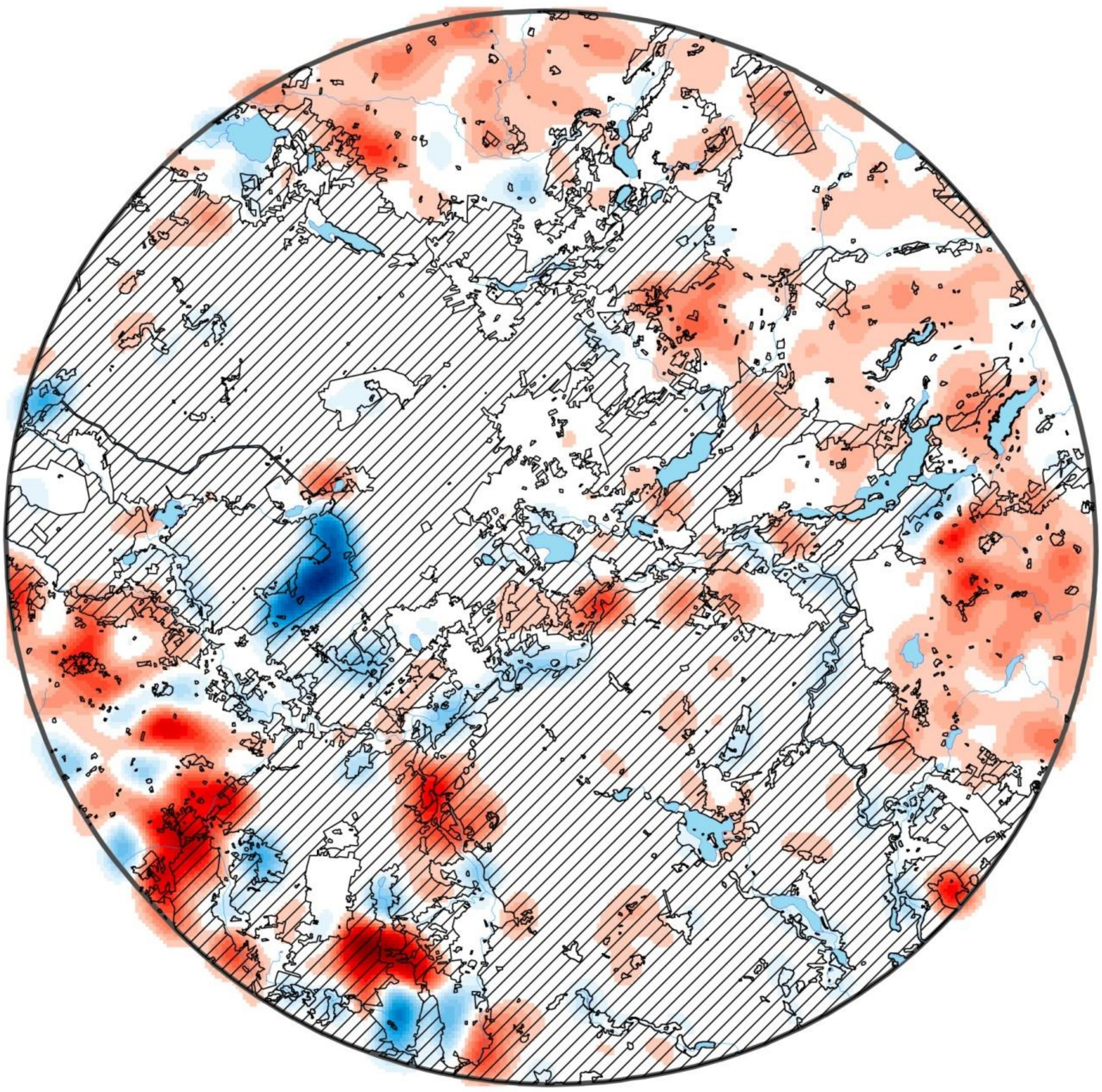

Fig. 1: Wetlands density differences between end of the XVIII century and 70-80 years of XX century (within a radius of 15 km from Czechowskie Lake; red - decrease of density of wetlands, blue - increase of density of wetlands, cross lines - current forests cover).

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.

Invited contribution WP1 – WP5

Geo Visual Analytics for Integrated Data Analysis of Heterogeneous Data Sets

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Various data are constantly gathered within ICLEA. Understanding climate and landscape evolution requires an integrated analysis of all relevant data. This demands new methods for data analysis and interpretation. A promising methodology in this regard is Visual Analytics. The interdisciplinary field combines visualization, human computer interaction, and automated data analysis methods. Geo Visual Analytics specifically addresses analysis problems that involve spatial and temporal data. This is my area of research.

Benefits of Geo Visual Analytics

Previous research results have shown various benefits of Visual Analytics: It is a valuable aid in creating a mental model of the data, steering the analysis process, and understanding analysis results. By supporting the exploration of data, Visual Analytics enables the generation of new hypotheses. This expands the common approach of testing known hypotheses. It reduces time spent on data handling and gives more time for scientific reasoning, as relevant data and analysis methods are instantly available and linked with each other. Further, Visual Analytics has the ability to broaden the scope of analysis because all available data can be considered, instead of being limited to aggregations or small subsets of the data.

My approach: User and application centered

My approach to develop Geo Visual Analytics methods puts the demands of geoscientists in focus. As a starting point, I investigate the specific application context, the analysis goals, and the sequence of analysis steps. Potential improvements are identified by examining the methods and tools that are already in use. The improvements are realized in a new Geo Visual Analytics tool. It is iteratively developed: New ideas are implemented in a prototype. This is instantly tested by geoscientists. Their feedback leads to improvements and extensions. These are again implemented and tested until the tool is well-adapted to the analysis goals.

Results of previous research

My research group has developed new analysis methods for various geoscientific applications.

- Our collaboration with Earth system modelers at GFZ addressed the assessment of geoscientific simulation models. The integration of uncertain, irregularly sampled observation data with simulation results significantly improved model validation (Figure 1). Other methods supported the detection of prominent geophysical processes in spatio-temporal simulation data. Compared to existing methods, we achieved a faster, more objective, and more reliable identification of relevant patterns.
- Our cooperation with researchers from Potsdam Institute of Climate Impact Research resulted in novel analysis methods for large time series. It included the multi-scale exploration of time series with irregular sampling (Figure 2), the detection of recurring events, and the analysis of correlations among ensembles of time series.

Goals of Geo Visual Analytics research in ICLEA

In ICLEA, a main analytical challenge arises from the heterogeneity of data sets. Data sets differ in measurement quantities and value ranges; they have different spatial and temporal coverage, resolution, and sampling. As a consequence, suitable analysis methods need to include more than measured data values. The integrated analysis of heterogeneous data sets requires an explicit understanding of context information, which comprises, i.e., acquisition method, spatial and temporal reference frame, measurement quantities, their value ranges, and data quality.

The goal of my research is to develop Geo Visual Analytics methods that are able to “understand” this context information and thus enable geoscientists to a) quickly identify and assess all information that is relevant for the current analysis task and b) perform an integrated data analysis that covers all relevant information.

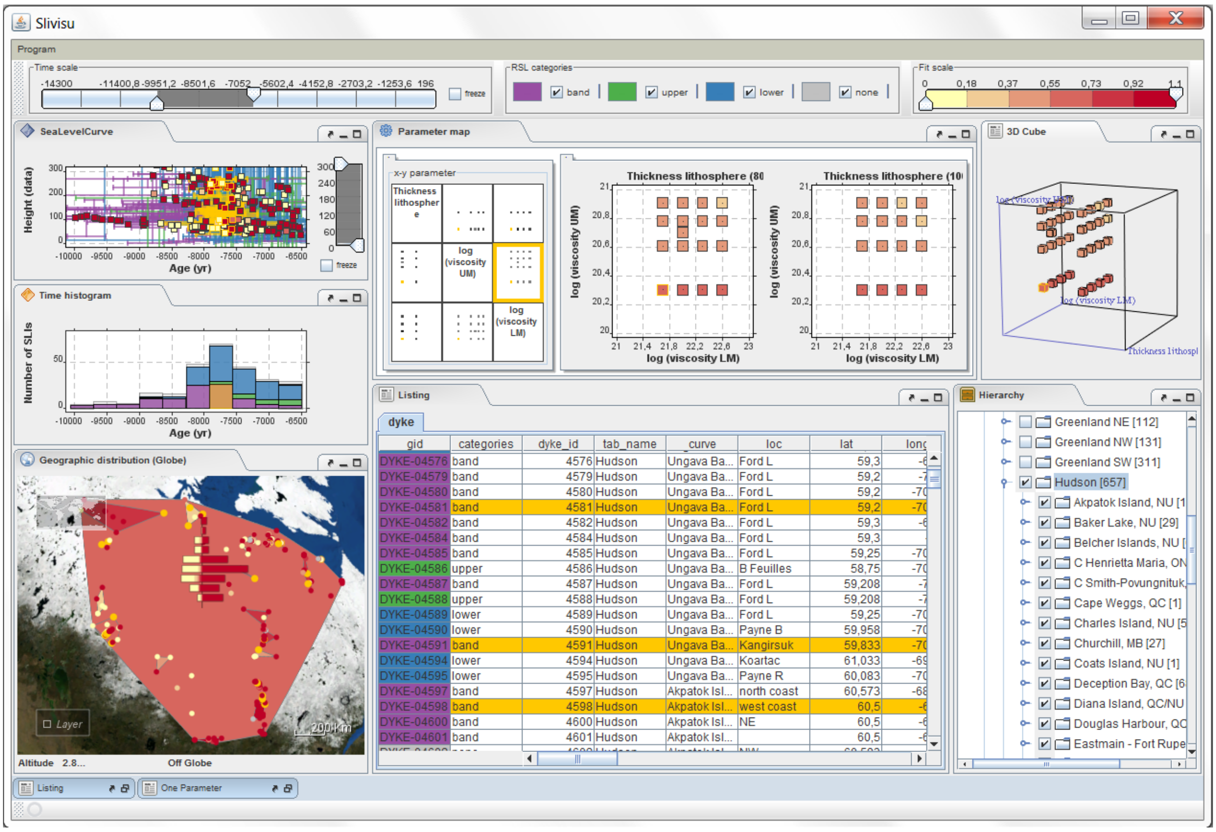

Fig. 1: The user interface of Slivisu, a Geo Visual Analytics tool to validate geoscientific simulation models. The tool integrates irregularly sampled observation data and simulation results. The various data facets are shown by a combination of linked views.

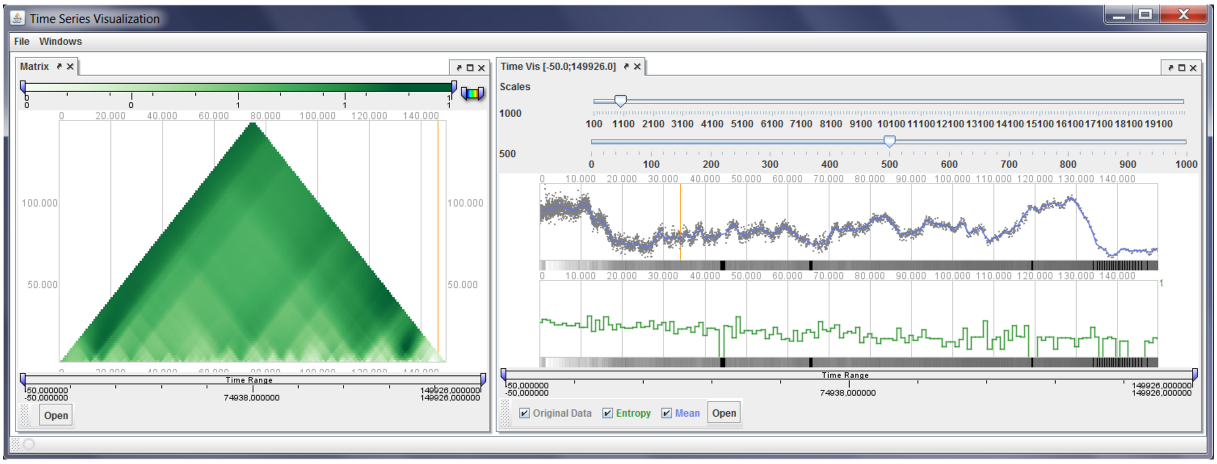

Fig. 2: The visual interface of Pinus, a tool for exploring large time series on multiple scales. The view on the left shows the time series on numerous scales; the views on the right depict details on one selected scale.

Theme A Monitoring / WP1

Hydrogeology of a young moraine area in NE Germany: Subsurface structures and groundwater modeling

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Investigating 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 suggest a multi-method approach that merges a variety of geophysical, hydrochemical and hydrogeological monitoring data with iterative hypothesis-based modeling of groundwater dynamics.

The focus area of this study is the region of Lake Fürstenseer See (one of the TERENO field sites of the Helmholtz Association), 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 buried subglacial valleys from the Weichselian cross the area in a mainly NNE – SSW direction (Fig. 1) (Börner 2015).

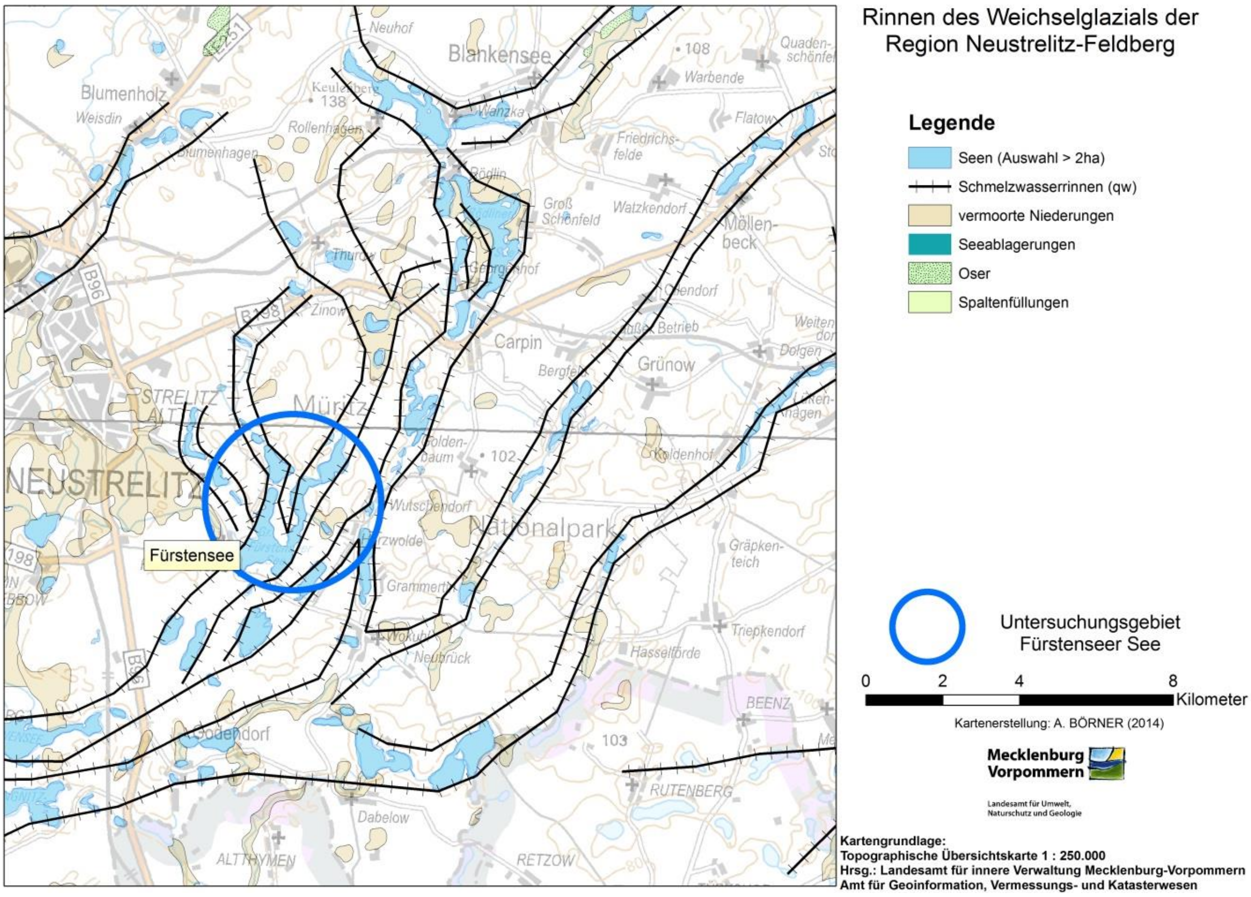

Fig. 1: Location of the buried valleys in the study area (Börner 2015).

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 ongoing processes of groundwater-lake interactions. The assumed main control on groundwater flow paths of the uppermost aquifer in this region is the depth and the "topography" of the first aquiclude. Additionally, the buried valleys and the terminal moraine are likely to influence the groundwater flow. In order to obtain more detailed information on the subsurface structures and characteristics geophysical methods are used. Electric resistivity tomography (ERT) surveys along 6 different transects of up to 1000 m length are performed to detect the boundary between aquifer and aquiclude and the lateral extent of the buried valleys (Fig. 2). The measured specific electrical resistances provide the chance to infer information on the valley filling.

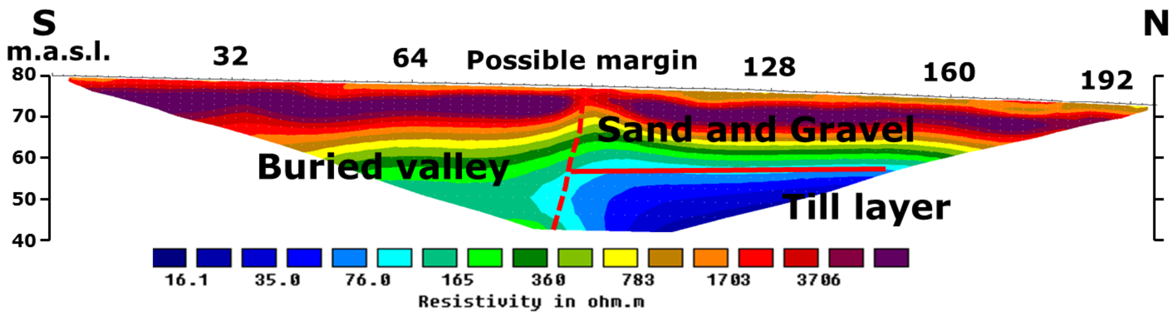

Fig. 2: Possible margin of a buried valley from ERT measurement northwest of Lake Hinnensee.

The groundwater flow model Visual MODFLOW Pro was parameterized based on average hydraulic properties determined from core samples taken during observation well drilling. Data from a nearby climate station was used as input, while well water level dynamics in 23 observation wells and lake water level dynamics were used for validation. In a first hypothesis the depth of the aquiclude was assumed to be uniform over the entire region. In a second iteration, the depth of the aquiclude which was identified at 20 of the wells was interpolated over the area. The resulting groundwater flow paths and dynamics were re-evaluated. In a final step, data from the ERT investigations along several transects throughout the area as well as the information on the buried valleys by Börner (2015) (Fig. 1) were also included in the interpolation of the depth of the aquiclude. 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 and the observed spatial patterns of groundwater inflow into the lake.

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 is supported by TERENO infrastructure of the Helmholtz Association.

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Theme C High resolution climate reconstruction / WP4

Lateglacial and Holocene tephrostratigraphy of the Northern central European lowlands – constraints from the varved sediment records of lakes Tiefer See and Czechowskie

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Tephra layers (volcanic fallout deposits) are important stratigraphic isochrones that allow the dating and direct comparison of palaeoclimate and palaeoenvironmental data among sedimentary archives and thus the determination of potential temporal and spatial offsets of palaeoclimate signals.

A detailed tephrostratigraphic framework has been developed for two continuous, mostly varved lake sediment sequences from NE Germany (Lake Tiefer See, TSK) and central N Poland (Lake Czechowskie, JC) for the last 14,000 years. A total of eleven distinct cryptotephras (non-visible tephras) were detected so far and chemically fingerprinted in order to define correlatives and to integrate known tephra ages into the sediment chronologies. The major element compositions of volcanic glass shards of cryptotephras indicate a major source from Icelandic (2150-2400 km), subordinately Eifel (Germany, 500-840 km) and probably Campanian/Italian volcanoes (1420-1480 km).

In detail, Lake Tiefer See exhibited eight tephras of which three are also recorded in Lake Czechowskie sediments. These tephras are rhyolitic in composition and encompass the historical Askja-AD1875, and the early Holocene Askja-S and Hässeldalen tephras. Askja-S and Hässeldalen are dated at ca 10,810±240 cal yr BP and 11,380±216 cal yr BP, respectively (Wohlfarth et al., 2006), and thus represent ideal synchronization markers for the detailed study of the Preboreal Oscillation (PBO).

The phonolitic Laacher See Tephra from the Eifel Volcanic Field (LST; 12,880±40 varve yr BP; Brauer et al., 1999) at the base of the TSK sediment sequence, the basaltic Saksunarvatn Ash (10,210±35 cal yr BP; Lohne et al., 2013) as well as the Late Holocene rhyolitic Hekla-4 (4,218±65 cal yr BP; Dugmore et al., 1995) and Glen Garry tephras (2088±122 cal yr BP; Barber et al., 2008) in Lake Tiefer See are further important anchor points for the comparison with other rare high-resolution palaeoclimate records in Central and Northern Europe. An unknown basaltic cryptotephra of Grimsvötn provenance has been newly detected in Lake Tiefer See and dated by the varve and sedimentation rate chronology at ca 1100 cal yr BP.

Lake Czechowskie sediments surprisingly revealed two K-alkaline cryptotephras of Italian origin. The uppermost cryptotephra is dispersed in early Holocene sediments (ca 10,000 cal yr BP) and shows a trachytic composition that is typical for Ischia tephras. Its dated correlative, however, has not been assigned yet. The second cryptotephra is located in the lowermost Lateglacial part of the JC sequence and is characterized by a phonolitic glass chemistry, which can be roughly correlated with the Neapolitan Yellow Tuff (14,194±172 cal yr BP; Bronk Ramsey et al., 2015). It is synchronously deposited with an Icelandic rhyolitic cryptotephra that most likely relates to the Penifiler tephra (13,939±66 cal yr BP; Bronk Ramsey et al., 2015). Therewith, Lake Czechowskie is one of the very exceptional archives in Europe that exhibits tephras from both northern and southern European volcanoes.

In summary, the tephra results from Lake Tiefer See and Lake Czechowskie greatly contribute to an improvement of sediment chronologies and lead to an extension of the Central European tephrostratigraphic framework.

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and National Science Centre, Poland (grant No. NN306085037 and 2011/01/B/ST10/07367).

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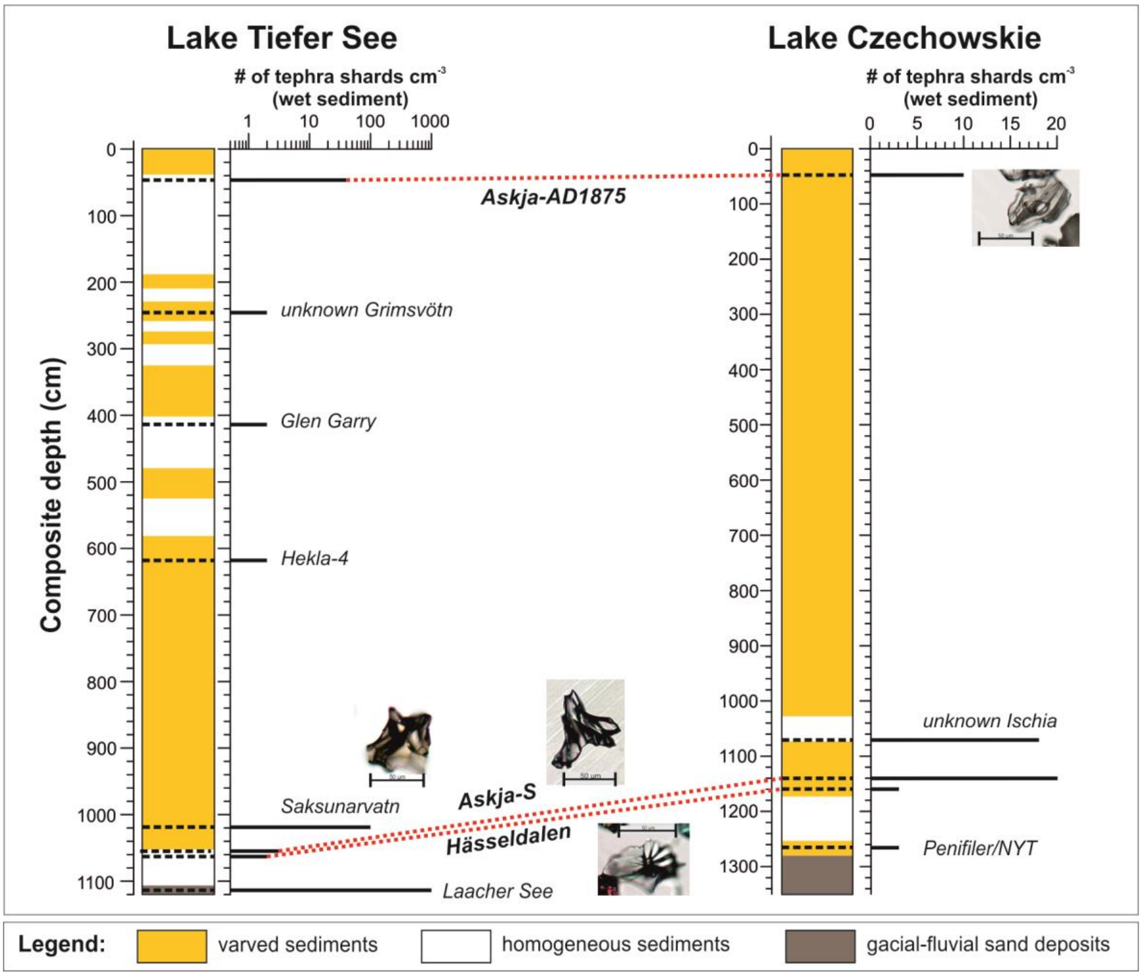

Fig. 1: Tephrostratigraphies of lakes Tiefer See and Czechowskie with selected images of volcanic glass shards.

Theme C High resolution climate reconstruction / WP4

Late glacial and early Holocene climate changes revealed by multi-proxy research on lake sediments from Tuchola Forest region (Poland)

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The study of the past climate is one of the most investigated topic in paleolimnology and to reveal climate changes lake sediment are used. They are known to be great source of information of the past as they are functioning as natural archives preserving animal and plants remains. The analysis of species composition, chemical properties of the sediments allow to reason about how functioned the environment in the past. In this study we investigated biogenic sediments from paleolake Trzechowskie, located in Tuchola Forest (Northern Poland). We made Cladocera, diatom, pollen, macrofossil, XRF analysis, the chronology was determined by varve counting, Laacher See Tephra (12,880 yrs BP) and 14C dating. We aimed to reconstruct climate changes from pre- Allerød until Atlantic period. The regional changes were revealed by pollen analysis, Cladocera, diatom, analysis allowed to find out how lake environment adapted to those changes. We were interested in similarities and differences between the reaction of different proxies to climatic events (Fig. 1).

The preliminary results revealed that Cladocera, diatoms and plants communities were sensitive to climatic changes and it is well shown in the results of PCA ordination method (Fig. 1). However in the results of Cladocera and diatoms analysis, which reflect well lake environment conditions, the grates shift in the species composition was noted in the beginning of Allerød, Younger Dryas and Boreal period. The Late Glacial climate fluctuations caused more abrupt lake environment changes than those that happened in the Holocene. The Preboreal warming came gradually and recorded less pronouncedly. Due to the results of diatoms analysis water level increased at that time. The important environment change occurred at the beginning of Boreal period. Cladocera results might suggest lake level drop and the lack of diatoms remains may be an evidence of drastic change of water chemical properties as the diatoms do not preserve well in acid waters. This environmental change is likely to be connected with an event of regional range. At that time in other archives recorded increase of fluvial erosion and landslides in the river valleys.

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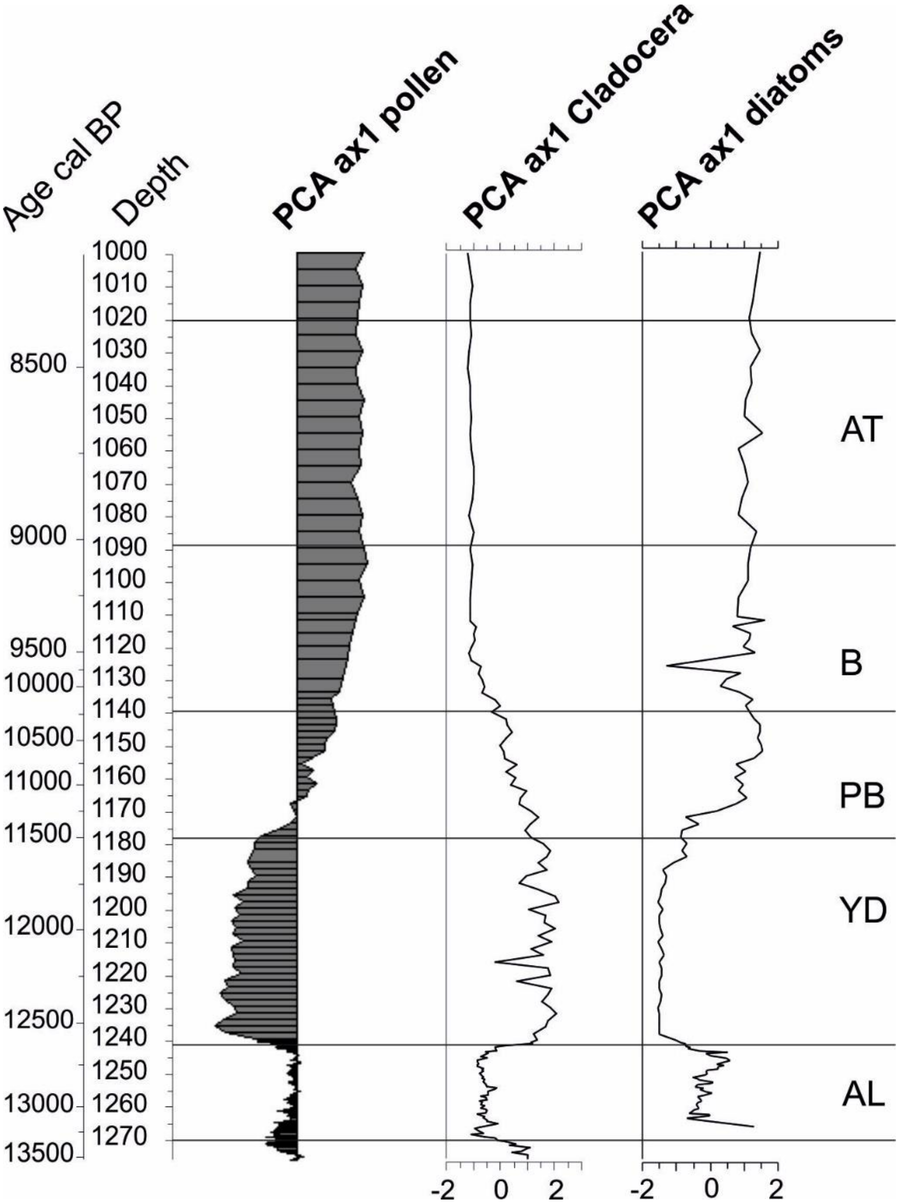

Fig. 1: The results of Principal Component Analysis (PCA) for pollen, Cladocera and Diatoms assemblages from paleoloake Trzechowskie, located in Tuchola Forest (Northern Poland).

Chapter III: Excursion and fieldtrip guide 2015

Late Glacial and Holocene transformation of the relief and surface waters in the Płock Basin and its surroundings

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Introduction

The Płock Basin is a valley widening of the largest Polish river - the Vistula, on whose western and eastern edges two major cities developed: Płock and Włocławek (both have more than 100,000 inhabitants). This area is located in central Poland (Fig. 1), on the border between the voivodeships of Kujawsko-Pomorskie and Mazowieckie. J. Kondracki (1994) distinguished the Płock Basin as a separate physico-geographical mesoregion. To the south-west the Basin borders the Kujawy Lakeland, and to the south the Kutno Plain; to the north-east, on the right bank of the Vistula, it is adjacent to the Dobrzyń Lakeland and Płońsk Morainic Plateau.

The central part of the Płock Basin is occupied by the Gostynin-Włocławek Landscape Park (G-WLP), which is one of the oldest landscape parks in Poland. It was created in 1979 to protect the geomorphological values of the area, which are a complex of inland dunes, subglacial channels, numerous lakes as well as wetlands and swampy areas. The Park covers an area of 389.50 km^2, and its buffer zone covers 141.95 km^2. Forests account for 62% of its surface, lakes - 3.5%, while other areas, mainly used for agriculture, occupy 1/3 of the G-WLP area.

The Park is an important element of the ecological corridor connecting the Kampinos National Park (MAB Biosphere Reserve) with the Bydgoszcz Forest and beyond - with the Tuchola Pinewood Forest (also the MAB Biosphere Reserve). The G-WLP is also included in the European ecological network Natura 2000 via two special bird protection areas: Błota Rakutowskie (PLB040001) and Żwirownia Skoki (PLB040005), and a special area of habitats protection - Uroczyska Łąckie (PLH220053). In the Park there are 14 nature reserves, including the global phenomenon of the Gościąż geomorphological reserve, protecting the laminated lake sediments of the last 13,000 years. Other nature reserves are mainly of the floral, forest, bog and ornithological character. In total, legal protection in the form of nature reserves refers to 4.7% of the Park area. In its borders there are 77 natural monuments; they are mostly native dendrological specimens – single, in groups and four tree avenues. In historical times the area was covered with forest communities known as the Gostynin Forest. Within the forest communities, due to the poor, mostly sandy substrate, pine and mixed forests dominate. In the rivers valleys and around the lakes are riparian forests and alder swamps.

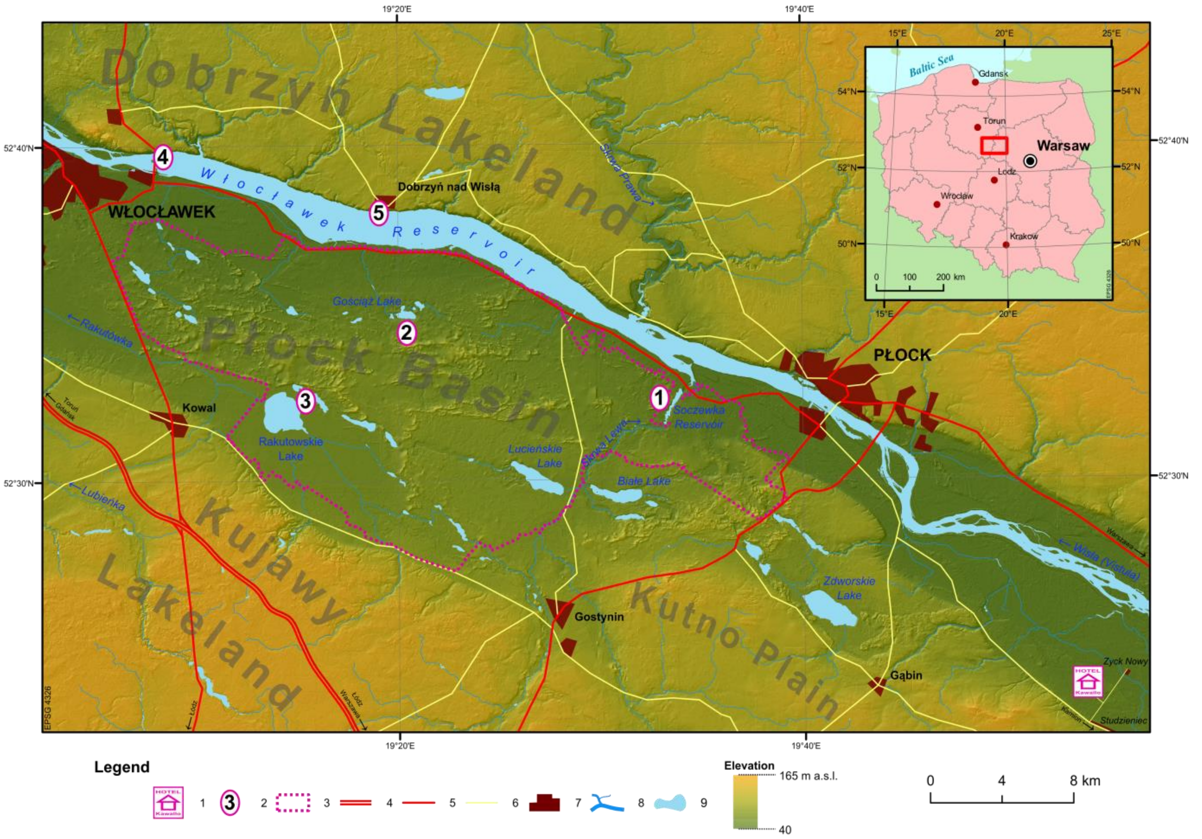

Fig. 1: Location of the Fieldtrip Stops during the 4th ICLEA Workshop in the Płock Basin.

Explanation: 1 – workshop venue, 2 – fieldtrip stop, 3 – border of the G-WLP, 4 – highway, 5 – main road, 6 – local road, 7 – town, 8 – river, 9 – lake or reservoir.

Geological structure

The Płock Basin area and its surroundings lie within the two structural units distinguished in the Cenozoic substratum. They are the Kujawy Swell, extending to NW-SE and covering the south-western periphery of the region, and the Płock Trough, located east of the Gostynin-Włocławek line. Those regional structures are built of the Mesozoic and Upper Permian (Zechstein) sedimentary rocks.

The Cenozoic is disconcordant with the underlying Mesozoic strata. It forms a continuous sedimentary cover of varying thickness, composed of Paleogene, Neogene and the Quaternary. The Paleogene is consists mainly of sands with gravel interbeddings and glauconitic sands (Oligocene), while Neogene is represented by sands, carbonaceous sands, silts, clays and brown coal (Miocene) as well as variegated clays (Miocene/Pliocene).

The Neogene is exposed in the high edge of the Vistula valley between Płock, through Dobrzyń to the Włocławek area (Baraniecka & Skompski 1978). Its course is irregular, associated with glaciotectonic elevations formed by the oldest Pleistocene ice sheets occupying the Płock Basin area.

The Quaternary has an average thickness of 40-55 m, but it locally varies widely from 2 to 154.5 m. Rapid changes in the thickness are associated with glaciotectonic deformations zones and deep valleys cuts in the Quaternary substratum (Fig. 2).

The Pleistocene is best development in the morainic plateau surrounding the Płock Basin. There it is mostly built of tills, usually two to four, rarely five to six seams, as well as of the deposits separating them i.e. glaciofluvial sands and gravels, glaciolacustrine silts and clays and seldom river sands or gravels. However mineral and organic lake-bog sediments are also occasionally noted. On the other hand, in the Płock Basin area the Pleistocene sedimentary succession is dominated by fluvial and glaciofluvial deposits as well as of ice-dammed lake sediments, while tills occur sporadically (Fig. 2).The oldest Pleistocene sediments are preglacial (Pretiglian-Waalian) fluvial sands and gravels, exposed in the southern slope of the Płock Basin at Baruchowo (Roman 2010a) and also in the right Vistula edge nearby Murzynowo (Skompski 1969). Younger fluvial series fill a deep, buried valley cut into the Quaternary substratum during the Augustów Interglacial (Bavelian). In the Płock Basin area, NW of Gostynin, the bottom of that river valley is placed at the sea level (Roman 2011) (Fig. 2). However, the deepest incisions of the sub-Quaternary surface (up to 40 m below sea level) appear nearby Włocławek, and were formed by subglacial waters during the first ice sheet advances in the area i.e. South Polish Glaciations (Cromerian-Elsterian). The evidence of those advances are two tills, preserved fragmentarily, and also glaciotectonites. The most intense deformations of sub-Quaternary sediments, especially Neogene, have arisen during that period. They are expressed as large scale folds, thrust folds and shears with amplitudes of up to 100 m (Różański, Włodek 2009). The glaciotectonic structures are exposed in the high right edge of the Vistula between Płock and Włocławek.

The Mazovian Interglacial (Holsteinian) was crucial for the coming into being of a vast depression in the Płock Basin. Its origin was supported by significant vertical tectonic movements that intensified sedimentation-incision cycles in the main transit river, running SE-NW, concordant with the axis of the sub-Cenozoic structures (Baraniecka 1979, Roman 2003, 2010b). Moreover, a broad valley formed during the Mazovian Interglacial has posed a convenient location for the subsequent younger erosion and accumulation cycles, associated with the outflow of glacial, river-glacial and, finally, river waters, as well as has fostered the formation of vast ice-dammed lakes.

Sediments of the Middle Polish Glaciations (Saalian) constitute a significant part of the Quaternary cover in the plateau areas. We speak of tills (one to three beds) and glaciofluvial series as well as ice-dammed lake deposits. Glaciotectonic disturbances are also related with Saalian tills. Neogene sediments are rarely involved in those structures and their amplitudes reach a maximum of 30-40 m.

The Eemian sediments in the Płock Basin area are river sands and gravels of one cycle, but in the morainic plateau they are residual pavements, as well as lake sediments and peat (Domosławska-Baraniecka 1965, Roman, Balwierz 2010). The incision of the main Eemian river in the Płock Basin has not exceeded the depth of the valleys from the Mazovian Interglacial, i.e. 40-50 m.

The Vistulian (Weichselian) Glaciation was initially marked in lacustrine deposits and peat (Early and Middle Weichselian), followed by glacial, glaciofluvial and river-glacial sediments (Late Weichselian). During the Poznań (Frankfurt) Phase (Skompski 1969) of about 20.9-18.7 OSL ka BP, the Płock Basin and the adjacent morainic plateaus were occupied by the Płock ice-lobe (Roman 2010b, 2013).

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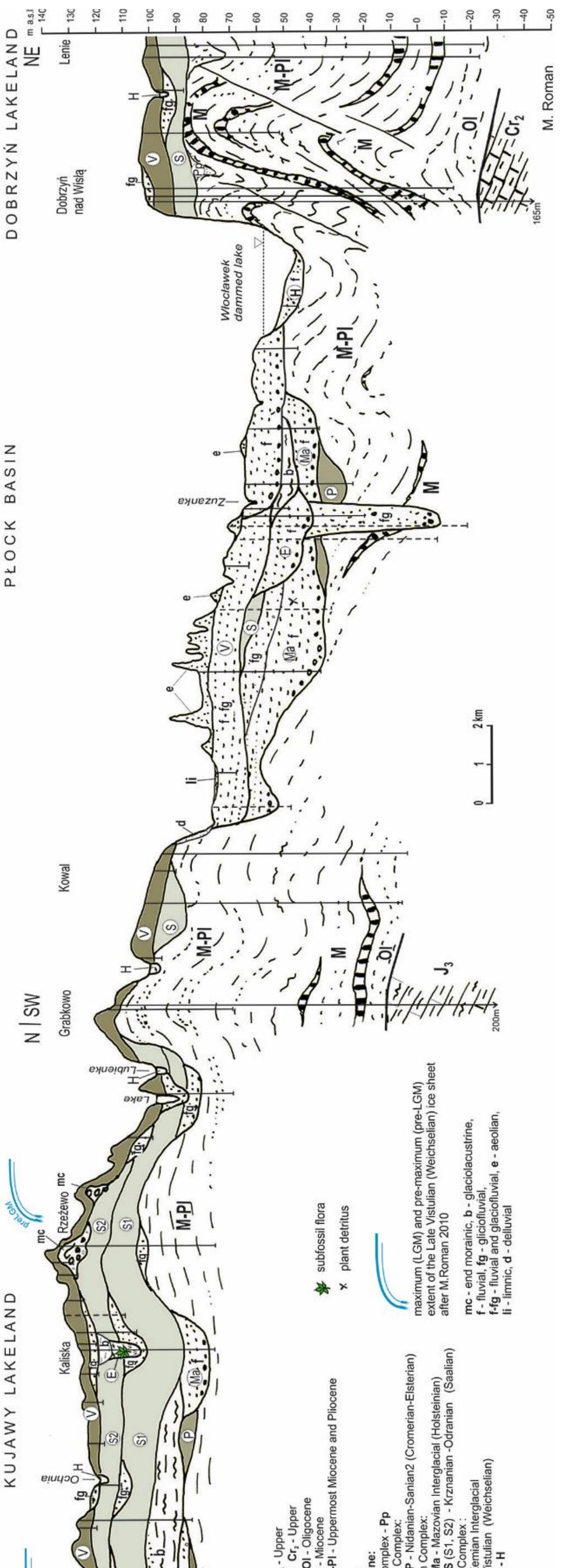

Fig. 2: Geological cross-section of the Płock Basin and surrounding morainic plateaus, after M. Roman 2010, completed.

The advance of the ice sheet was preceded by the accumulation of thick clay-silt series (up to 15 m), deposited in an extensive reservoir reaching the Warsaw Basin. The series were cut by broad channels filled with glaciofluvial sandy-gravel deposits of a thickness of 20 m.

Within the Płock ice-lobe area there is only a one till, which, at the Kaliska, was found above the Eemian Interglacial lake-bog deposits (Domosławska-Baraniecka 1965, Baraniecka & Skompski 1978) (Fig. 2). The till builds the morainic plateau of the Kujawy and Dobrzyń Lakelands and the surface of the Ciechomice level in the Płock Basin. Glaciotectonic disturbances associated with the youngest till do not exceed 15 m in the depth. Their occurrence is restricted to overridden end moraines and glaciomarginal forms delineating the extent of the last ice sheet maximum. Moreover, from that period also known are sandy deposits which build outwash plains and crevasse forms (eskers, kames). Fluvial-glacial deposits building extensive levels of ice marginal valleys are particularly widespread in the said Płock Basin area.

The late Pleistocene sediments are mainly alluvial deposits that build higher terraces, delluvia and aeolian sands forming covers, single parabolic dunes and vast dune fields. Dunes diversify the surface of ice marginal valley levels as well as the higher Vistula terraces in the Płock Basin. Lacustrine sediments and peat filling melt-out depressions are also known to have come from the late Pleistocene.

The Holocene in the area discussed is mainly represented by river sediments (floodplains), as well as aeolian, delluvial and lake-bog sediments.

Relief development in the Pleistocene and early Holocene

The relief of the Płock Basin and its surroundings was shaped primarily during the last Scandinavian ice sheet advance, and in the Holocene. The relief of the southernmost and north-easternmost regions surrounding the Basin developed during the earlier glaciation, i.e. the Odra (Saalian) Glaciation.

About 25,000 years ago, in the Late (Weichselian) Vistulian, the ice sheet advanced onto the Polish territory and in the Leszno (Brandenburg) Phase, about 22-20,000 years ago, it reached the Inowrocław Plain (west of the Płock Basin) (Wysota et al. 2009, Roman 2010b).

Only during the next phase, the Poznań (Frankfurt) Phase, about 19-18,000 years ago, the ice sheet advanced onto the area in question with the Płock Lobe. In the depression of the basin the ice sheet moved towards the south-east, according to the axis of the cavity, and then entered the area of the plateaus spreading outside in the fan-shaped form (Roman 2010b). The ice sheet transgression on the plateau area took place in stages. About 18,500 years ago, the advancing ice sheet formed its front north of Lubień Kujawski and north-west of Gąbin (Roman 2010b, Lisicki 2014, Fig. 3a). At that time, glaciomarginal fans developed, and in the basin an extensive ice-dammed lake formed. Meltwater flowed out via snouts of glacier and accumulated sandy-gravel deposits of outwash plains.

Further transgression of the ice sheet resulted in transgressing glaciomarginal forms and disturbing the deposits that build them. The results were the so-called push and transgressed moraines (Roman 2010b, 2013). The advancing ice sheet and its subglacial waters continued forming subglacial channels. The maximum range of the ice sheet in the area of the Płock Basin occurred about 18,000 years ago (Fig. 3b). The front of the ice sheet stopped south of Gostynin and in the vicinity of Gąbin, as well as in the Vistula valley about 10 km south-east of Płock. The rate of the ice sheet transgression in the valley was calculated at about 400 m/year. At the maximum ice sheet range, the ice thickness was estimated from about 150 m in the eastern part of the Płock Basin to more than 300 m in its western part (Roman 2010b).

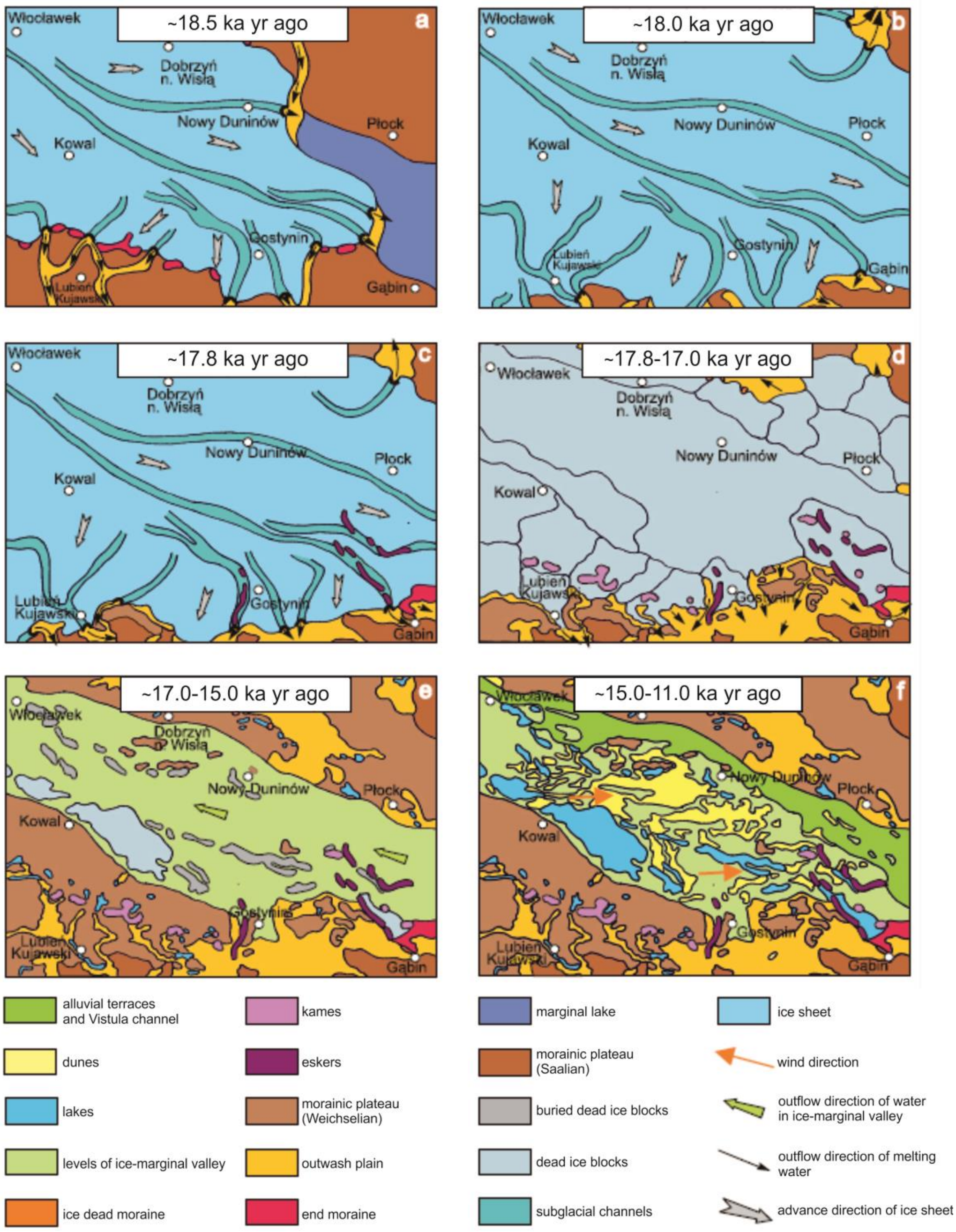

Fig. 3. Paleogeomorphological sketch of the Płock Basin and its surroundings (Lisicki, 2014).

Explanation: a - ice sheet advance, b - maximum ice sheet range, c - frontal deglaciation, d - areal deglaciation, e - formation of ice-marginal valley, f - formation of dunes.

During the ice sheet disappearance, about 17,800 years ago (Fig. 3c), the ice sheet front retreated and stabilised just north of Gąbin. A marginal zone was established there. Within it meltwater formed a large glaciomarginal fan (recession frontal moraine). Along the subglacial channels ice tunnels developed. In them the sediments of future eskers were accumulated - Łąck-Zdwórz of the NW-SE course, Dobrzykowo of the W-E course and Gostynin of the N-S course (Roman 2003).

During the further deglaciation, from about 17,800 to 17,000 years ago (Fig. 3d), meltwater deposited fluvioglacial sands and gravels. In the stagnant ice sheet clefts formed, in which accumulation of sands, silts and gravel of the future kames took place (also superimposing the earlier transgressed glaciomarginal forms).

Further deglaciation led to the disintegration of the ice sheet into smaller patches and then dead ice blocks. Between them and in their foreland sands and gravels of dead ice moraines were accumulated.

During the Pomeranian Phase, about 17,000 years ago, the ice sheet front formed far to the north of the basin area. About 15,000 years ago, blocks of dead ice continued melting away. In the area of the glacial plateau, in the places where blocks of dead ice melted, lakes developed. In the Płock Basin single ice blocks were partially covered with sands of the ice-marginal valleys (Fig. 3e). These sands were accumulated over river-glacial water of the Pra-Vistula, flowing to the west and north-west. Sands of the ice-marginal valley build five glacial-river levels.

At the end of the Pleistocene meadow terraces of the Vistula River and its tributaries developed. Most of the dead ice blocks melted about 15-11,000 years ago, and in the depressions lakes formed (Fig. 3f). The largest melt-out lake formed in the area of the current Lake Rakutowskie and had an area of almost 50 km^2. Best developed melting area occurs around Lake Zdworskie, north-west of Gąbin, in the hinterland of the end moraines. At the turn of the Pleistocene and Holocene aeolian processes occurred on the vast fluvial-glacial levels. In the periglacial climate and at the presence of permafrost the aeolian transport from the west resulted in the formation of wind-blown plains. Under the conditions of the dwarf shrub tundra, at a smaller range of permafrost, large parabolic, transverse and irregular dunes developed.

In the Holocene tundra area was transformed into a forest-tundra, and then into taiga. The range of lakes decreased, and in the climate optimum the Płock Basin and its surroundings were mostly overgrown with deciduous forests. After climate cooling, the forest environment was transformed into mixed and coniferous forests.

Geomorphology of the Płock Basin

The Płock Basin is a polygenetic form, which developed as a result of successive processes of glacial, fluvioglacial and fluvial: erosion and accumulation. In the majority of works devoted to the morphogenesis of the Płock Valley the researchers emphasize its earlier structure, which refers to at least the last stage of the Middle-Polish (Riss) glaciation (Mojski 1970, Skompski 1969). The Basin is surrounded by morainic plateaus, which are built predominantly of glacial tills, locally covered with sandy-gravel sediments. The morainic plateaus surfaces occur at the altitudes of about 90-135 m south of the Płock Basin and about 90-110 m to the north of it.

The dominant element in the bottom of the Płock Basin are extensive morphological levels at 98-95 m, 92-90 m and 82-80 m above sea level associated with the outflow and partial blocking of the meltwaters of the disappearing ice sheet, which lasted from the end of the Poznań Phase until the beginning of the Pomeranian Phase. Below there is a system of river terraces with the elevations descending according to the course of the Vistula, down to the floodplain, currently flooded by the Włocławek reservoir.

The levels of ice-marginal valley are dissected by subglacial channels, which are the geomorphological hallmarks of the Gostynin Lakeland. They form complex of some systems with the length exceeding 20 km. At such significant lengths subglacial channels are relatively narrow forms, of an average width of about 300-500 m and at the same time very deep, up to 50 m from the ice-marginal valley surface which they dissect. Glacial channels in the Płock Basin were formed during the last ice sheet presence (Poznań Phase) as a result of subglacial flow of meltwater under hydrostatic pressure. Immediately after their creation they were preserved by blocks of dead ice, over which the flowing water formed the levels of ice-marginal valley. Subsequent melting of the ice (mainly in Allerød) led to the preparation of the forms and the creation of lakes in them. The presence of subglacial channels in the Płock Basin within the ice-marginal valley levels, clearly younger in relation to them, is an important geomorphological evidence pointing to the fact that the subglacial channels were preserved by the blocks of dead ice.

The surface of ice-marginal valley is also diversified by a number of dune forms. The first aeolian phases in the area took place already in the Oldest and Older Dryas. At that time, in the periglacial conditions and at the presence of permafrost, wind-blown sand plains formed with numerous ventifacts. However, the main dune-forming period in the Płock Basin occurred in the Younger Dryas. Then, in the conditions of the withdrawal of vegetation (dwarf bush tundra), but with lower spread of permafrost, which contributed to the greater availability of sandy material for blowing, large dune forms of the heights of up to 20 m were developed. Generally, they form large dune fields consisting of parabolic, transverse and irregular dunes.

Hydrographic network

The hydrographic specificity of the Płock Basin is based on postglacial lakes located in the area of the ice-marginal valley. They occupy deep sections of glacial channels and are arranged in two series (north and south) intersecting the Płock Basin from the north-west to the south-east. The largest of these is Lake Rakutowskie (5.51 km^2) and Lake Lucieńskie (2.03 km^2), while the deepest - over 30 m - is Lake Białe (1.5 km^2); the other lakes are: Wikaryjskie (0.66 km^2), Goreńskie (0.55 km^2), Gościąż (0.47 km^2) and Przytomne (0.37 km^2).

The Płock Basin is drained by three hydrographic networks. The first one drains the eastern part of the G-WLP – it is the catchment of the Skrwa Lewa (43 km long), which is a left tributary of the Vistula. The sources and upper reaches of the Skrwa Lewa are located outside the bottom of the Vistula valley (Kutno Plain). Its average specific discharge at the mouth section is approx. 2 $m^3 \cdot s^{-1}$. It flows perpendicular towards the Vistula including in its drain two of the three largest lakes in the Park (Lucieńskie and Białe). In the lower reaches it is dammed by a barrage Soczewka and creates an artificial reservoir with an area of 46 hectares.

The second hydrographic network is the Rakutówka, a tributary of the Zgłowiączka, which drains the southern and western parts of the Płock Basin. It flows in a north-easterly direction, parallel to the edge of the Kuyavian Plateau and flows into Lubieńka (right tributary of the Zgłowiączka). The Rakutówka's discharges are very diverse - the highest in spring when snow melts - up to 4 $m^3 \cdot s^{-1}$, and the lowest reaches only 0.01 $m^3 \cdot s^{-1}$ at the end of the summer (data obtained in 2010-2013 by Bartczak A., Tyszkowski S., Glazik R., unpublished material). In dry years, below the outflow of the river from Lake Rakutowskie the discharge in the river disappears.

The third hydrographic network of the dune area in the central part of the Płock Basin is composed of the catchments of small watercourses: Ruda, Zuzanka and Rybnica, of a length of less than 10 km. They flow out from the lakes in the Park and flow perpendicular to the Vistula. Their lower reaches are now flooded with the waters of the dam reservoir on the Vistula (Włocławek reservoir). The discharge of these rivers is small: 0.05-0.1 $m^3 \cdot s^{-1}$ but very stable, which indicates a high retention capacity of their catchments.

Along the northern border of the Płock Basin is the Włocławek reservoir, which is a key element in the hydrographic network of the area. This reservoir was built in 1970 by damming up the Vistula with the barrage in Włocławek.

Water cycle conditions

Water circulation in the Płock Basin was recognised and described by R. Glazik (1978) and then modified by P. Gierszewski (2000) on the basis of the hydro-chemical characteristics of surface waters. The predominant form of water supply in the southern part of the Basin - in the edge zone of the plateau, is lateral surface runoff of rainwater or snowmelt from the plateau, as well as groundwater of the shallow Quaternary aquifers. The central part of the Basin is dominated by the groundwater supply from deep Quaternary aquifers, as well as with Tertiary (Miocene) waters through a hydrogeological window. Locally, in the central part of the research area, on dune-covered terrain, precipitation is of great importance in water supply. The northern part of the Basin is dominated by the ground water supply and local infiltration from the Włocławek reservoir.

The study area (eastern part of the Kuyavian Region) is characterised by unfavourable structure of the water balance. Some of the lowest total precipitation and discharge in Poland is recorded in this area (Bartczak, 2007). The lowest annual precipitation totals, not exceeding 500 mm, are not recorded throughout the entire area, but in patches. One of these patches is adjacent to the study area on the southern side (Brześć Kujawski). In Baruchowo in the Płock Basin the average annual precipitation total for the period 1951-2000 was 521 mm, and the extreme values of annual precipitation ranged from 377 mm in 1989 to 735 mm in 1996. The summer half-year precipitation dominated, i.e. from May to October (Fig. 4). It accounted for 63% of the average annual precipitation. The winter half-year precipitation, i.e. from November to April, accounted for 37% of the average annual precipitation. Although precipitation in this half-year was lower than in the summer half-year, it played a more important role because it was retained as snow. The abundance of water stored in the snow cover and the rate of snow melting in the spring influences groundwater recharge as well as the occurrence of floods in rivers. The maximum monthly precipitation was recorded in June 1980 and was 213 mm in Baruchowo.

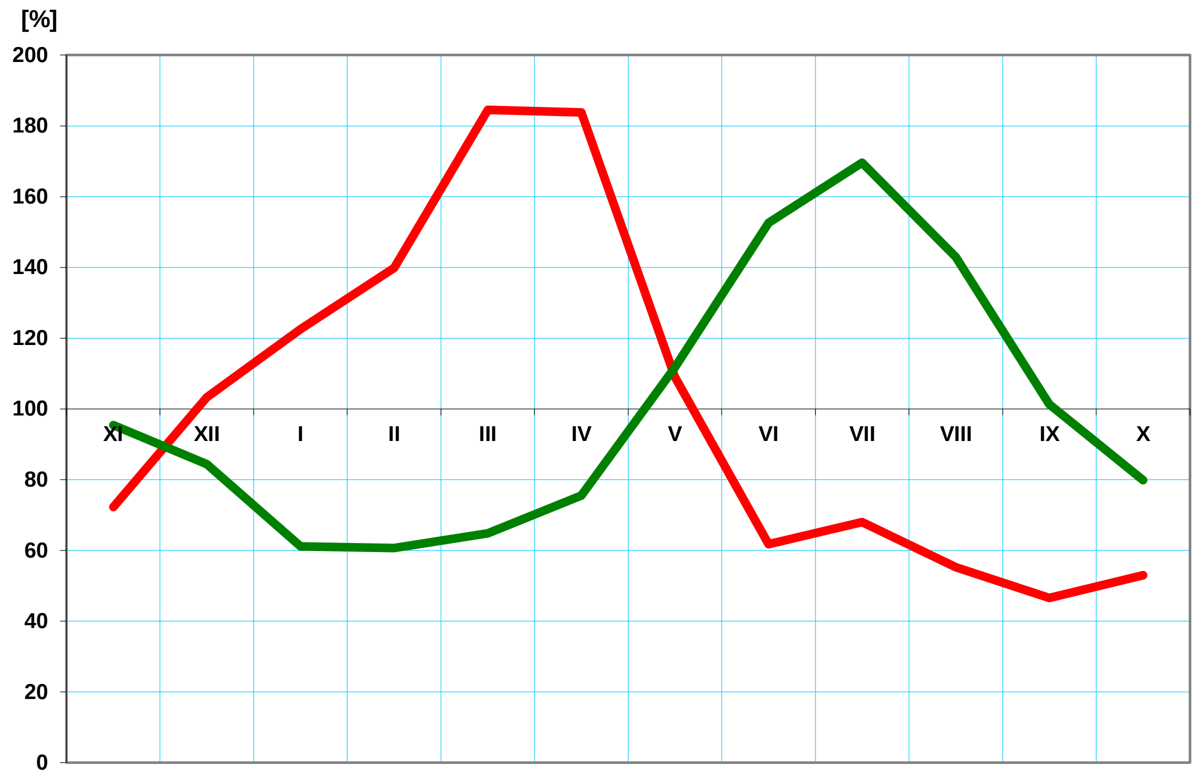

Fig. 4. Seasonal distribution of river outflow (red line) and precipitation (green line) in the Zgłowiączka catchment.

In the multi-year period 1976-2005, the average specific discharge was from 2.65 $dm^3s^{-1}km^{-2}$ (Zgłowiączka catchment) to 2.97 $dm^3s^{-1}km^{-2}$ (Skrwa Lewa catchment) to 3.08 $dm^3s^{-1}km^{-2}$ (Lubieńka catchment) (Bartczak, 2007; Brykała, 2009). During the hydrological drought that occurred in 1989-1993 the average specific discharge was 0.94 $dm^3s^{-1}km^{-2}$ (Zgłowiączka catchment) and 1.42 $dm^3s^{-1}km^{-2}$ (Skrwa Lewa catchment). The field research conducted in this specific period by P. Gierszewski (2000) shows that the highest average specific discharge was for the catchment of the Zuzanka - 2.19 $dm^3s^{-1}km^{-2}$, while the lowest for the catchment of the Rybnica - 0.38 $dm^3s^{-1}km^{-2}$. On the other hand, in the extremely humid period (1976-1982) the average specific discharge exceeded 4 $dm^3s^{-1}km^{-2}$ (Zgłowiączka, Lubieńka and Skrwa Lewa catchments).

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Fieldtrip Stops

Stop 1: Watermills in the Skrwa Lewa catchment and Soczewka reservoir

Until Middle Ages human activity over the Polish land had influenced the changes in river patterns and the conditions of the runoff in an insignificant way. When agricultural techniques developed well, the area of plough land increased at the expense of forests. As a result, grain crops went up contributing to searching new ways of flour-milling. At the turn of the 11th and the 12th centuries, watermills appeared all over the Polish land (Baranowski, 1977). Quite often watermills existed for hundreds of years in the same locations (Podgórski, 2004, Brykała, 2005). Until the beginning of the 20th century, they were the main elements of small rivers' water storage.

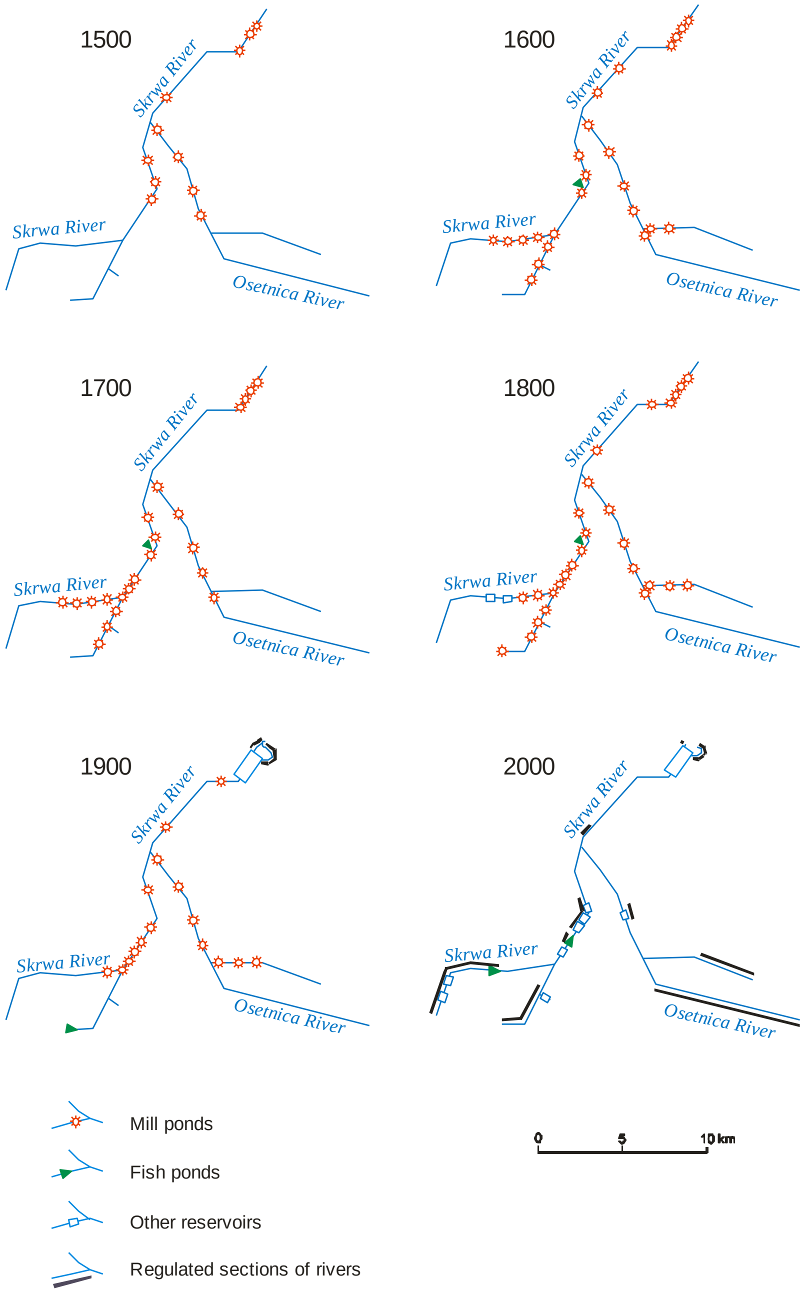

Fig. 5. Reconstruction of hydraulic structures development in valleys of the Skrwa Lewa and Osetnica from 15th to 20th century (Brykała, 2005).

The first information about watermills in the Skrwa Lewa catchment date back to the half of the 14th century. At those times the area of the Skrwa Lewa catchment was not densely populated. Number of mills increased very quickly. During the 1st half of the 16th century number of watermills was doubled (Fig. 5). That process of watermills' increasing was slowed down by a difficult situation caused by Swedish Wars in the 17th century. Back then, nearly all the watermills existing within the discussed area were destroyed. In the 18th century milling industry redeveloped in these areas. In many places, mills were rebuilt on the previously dammed waters. From the mid-19th century to the break of World War I, the number of the watermills within the Skrwa Lewa catchment decreased. More and more often watermills bankrupted not being able to resist competition of big motor or electric mills. World War II and the period of the People's Republic of Poland brought about a fast disappearance of the water milling industry.

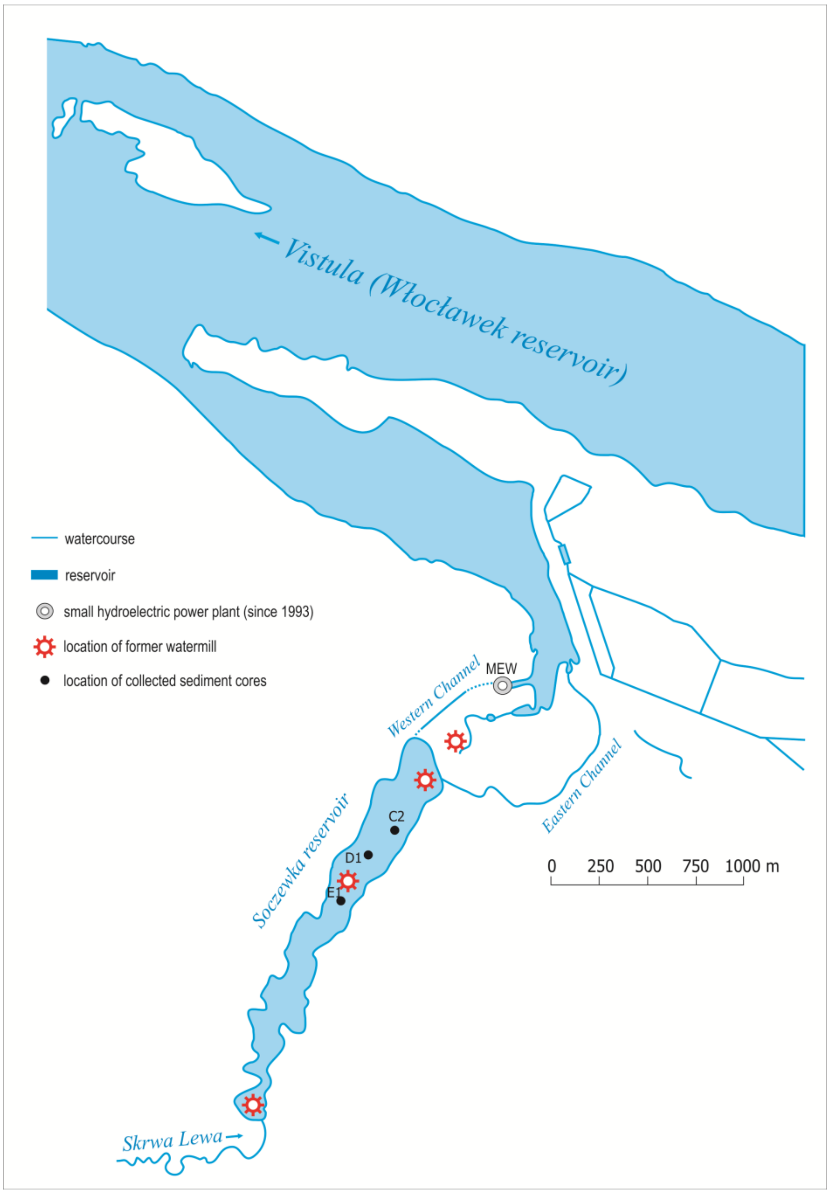

Fig. 6. Location of collected sediment cores from the Soczewka reservoir (Brykała, 2007).

The Soczewka is an artificial reservoir damming water from the Skrwa Lewa river for over 160 years. The Skrwa Lewa (length: 48.5 km, average slope: 1.53 ‰, catchment: 390.94 km^2) is a left tributary of the Vistula. The river flows into the Włocławek reservoir with two channels (Western and Eastern). In the past, on this section of river some watermills operated: Moździerz, Sapa, Soczewka and Socha (Fig. 6). Their hydraulic structures dammed the water to a height of approx. 3 m. These mills existed for almost 500 years (Brykała, 2007). In the years 1848-1853 the mills and the associated ponds were combined into one water body. The new dam was based on the Sapa Mill dike and gave the height of 7 m. The resulting reservoir has a total capacity of 1.222 Mio m^3, maximum depth of 7.0 m, average depth of 2.6 m, maximum length of 2.22 km and maximum width of 0.35 km. Soczewka reservoir plays an important role in the transformation of the river runoff from the catchment of the Skrwa Lewa. The amount of water stored is 4.3% of disposable water resources of the catchment (Brykała 2009).

In order to identify the bottom sediments accumulated in the Soczewka reservoir, 12 cores of intact structure were collected. The following facies of an average thickness of several tens of centimetres can be delimited (Fig. 7): (1) variously-grained sands with gravel, washed, fluvioglacial, (2) fine-grained medium sands with an admixture of vegetable detritus, (3) coarse-detritus gyttjas, mainly with alder wood fragments from the mill reservoirs on the river bed, (4) silt gyttjas with small amount of organic matter and carbonates, on average of approx. 20%, (5) fine-grained and variously-grained sands deposited as a result of abrasion fluvioglacial, fluvial or aeolian materials.

The content of heavy metals Hg, Co, Cr, Cu, Ni, Pb, Zn, Cd was determined in two sediment cores (C2, E1) (Fig. 7). In the majority of the samples, the concentrations are in the range of the geochemical background. In few cores the content of certain metals (Hg, Cr, Cu, Cd, Zn) slightly exceeded the limit values for water purity class 1 according to the classification of the PGI (Bojakowska, Sokołowska 1998). The variability of the metals concentration in the analysed sediment cores does not show a clear differentiation. Basically, the deposits more polluted with metals, expressed by the sum of their content in the sediment, occurred in the top of layer. Relatively high concentrations of metals were also recorded in the sediments accumulated in the old mill ponds. A higher concentration of metals in these deposits is associated with the sorption properties of organic matter.

In the profile of the sediments collected in the lower, deeper part of the reservoir, the contents of 9 compounds of the PAHs was determined (Fig. 7, profile D1). The sum of the marked compounds clearly decreases down in the bottom sediment profile from 943 ppb to 69 ppb (Banach, 1993). In the mineral sediments deposited prior to reservoir sedimentation, it is only 30 ppb (limit value for the content of PAH compounds of uncontaminated sediments is 200 ppb - Bojakowska et al. 2000). In the case of the studied reservoir, it is exceeded only in the upper 90 cm layer of the sediment. The lowest content and variability in the vertical profile is shown by rather unstable tricyclic aromatic hydrocarbons, whose concentration is significantly higher only in the upper 20 cm layer of the sediment. Greater content and greater variability in the vertical profile is recorded for the tetra cyclic aromatic hydrocarbons (negatively affecting the animals), and five and six cyclic aromatic hydrocarbons (carcinogenic). Their highest concentrations occur in the upper part of sediments (70-220 ppb). Then, their content is reduced gradually and in a layer at a depth of 1 m it reaches 69-21 ppb. Below this layer to the mineral substrate, concentrations of the analysed compounds of these two groups PAH do not change, reaching values of 10-3 ppb in the bottom of sediment.

The analysis of the total mineral oils, marked in the profile E1 (Fig. 7) showed no clear tendency of change in their contents in the sediment profile. Their concentration is high both in the top of layer and in the deeper parts of the sedimentary profile. In the reservoir sediments their concentrations ranged from approx. 97 to 384 $mg \cdot kg^{-1}$, and in the mineral deposits of the substrate <10 $mg \cdot kg^{-1}$.

The research conducted within the coastal zone indicates that currently a shore of the reservoir is mainly erosional. It represents 58% of the total length of the shore, and excluding the artificial shore - as much as 67%. This shore is accompanied by active cliffs of up to 1.2 m. However, cliffs of up to 0.5-0.7 m dominate (45% of the length of the abrasive shore). Accumulative shore makes up 7% and biogenic shore 24%. Noteworthy is the presence of secondary accumulation shore (accumulative shore accompanied by the old, currently inactive cliffs). Their height ranges from 0.2 to 0.8 m. This type accounts for 16% of the length of the accumulative shore.

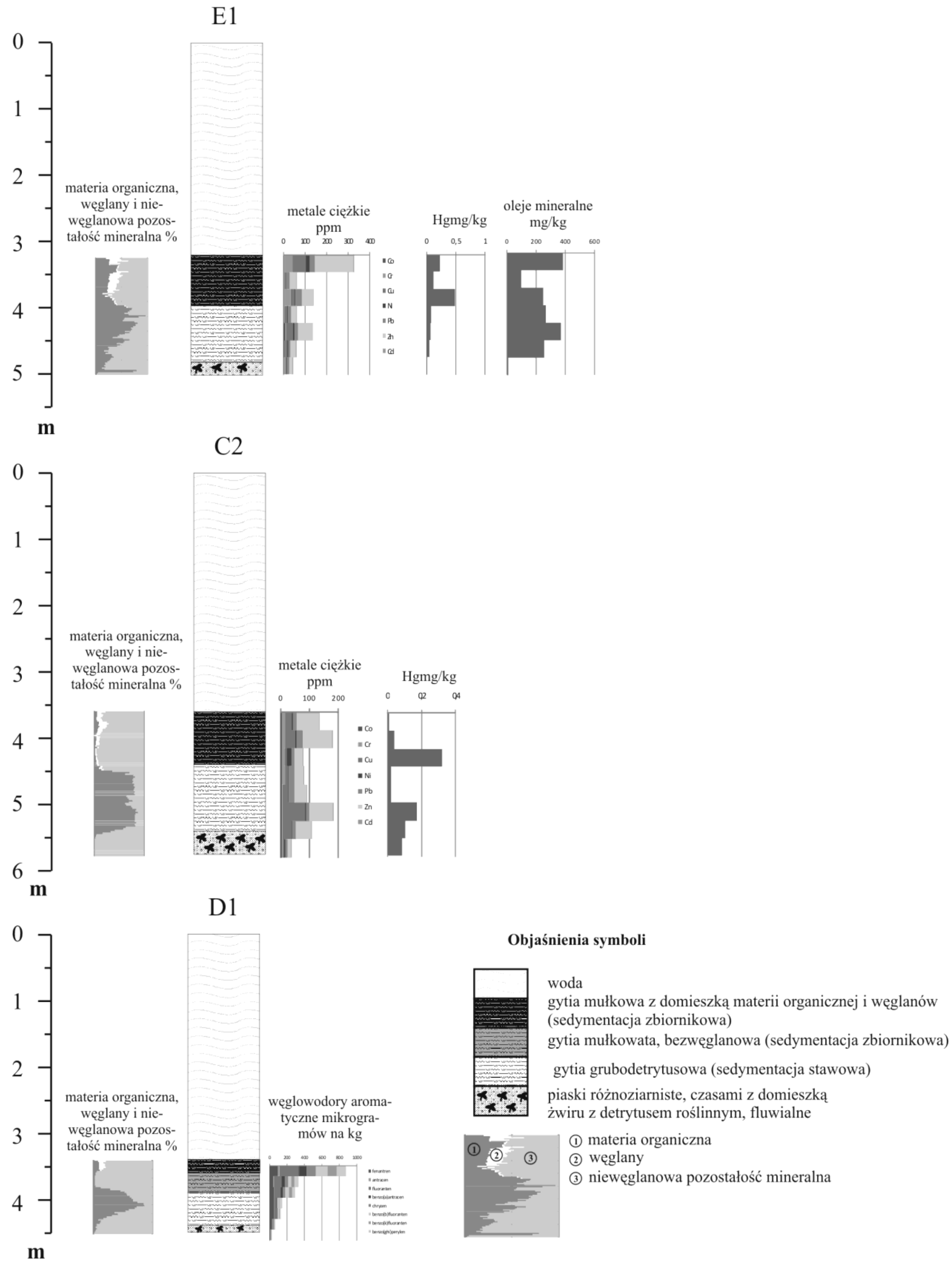

Fig. 7. Summary of geochemical analyses for the selected cores of the bottom sediments from the Soczewka reservoir.

Stop 2: Lake Gościąż

The northern part of the Płock Basin, covered by dune forms, is drained by short streams flowing directly into the Vistula. They usually flow out from lakes or springs located within the subglacial channel lakes. Such a system is also represented by the catchment of the Ruda stream, where a group of lakes "Na Jazach" is located. Water from the catchment of the area of 56 km^2 is discharged directly to the Vistula via a stream of the length of 9 km. Along a considerable distance it runs in the bottom of the subglacial channel, including into drainage four lakes: Wierzchoń, Brzózka, Gościąż and Mielec. In the middle reach, below the lakes, a weir functioning in the location of the former, at least 350-year-old mill dike, dammed the river to approx. 3 meters. In its mouth section the Ruda is within the backwater reach of the Włocławek reservoir. In 1990-1994 the Ruda's discharge downstream of the lakes averaged 78.4 $dm^3 \cdot s^{-1}$, which corresponds to an average specific discharge of 1.47 $dm^3 \cdot s^{-1} \cdot km^{-2}$. It should be noted, however, that the period of 1990-1993 was one of the more severe hydrological droughts in Poland in the twentieth century. In the years of average precipitation totals (2004), the average Ruda's discharge was approx. 30% higher and amounted to 111 $dm^3 \cdot s^{-1}$ ($q = 2.09\ dm^3 \cdot s^{-1} \cdot km^{-2}$). In both periods the summer half-year discharge was about 40% lower than that of the winter half-year. The values of the relative discharge amplitude of 1.49 (hydrological drought years) and 1.53 (average years) indicate small fluctuations of the discharge.

The discharge of the watercourse is essentially formed by groundwater supplying the Lake Gościąż channel. Their outflows in the form of descending springs are visible at the foot of the southern slope of the channel lake. The yield of single springs is small and ranges from 0.05 to 0.37 $dm^3 \cdot s^{-1}$. The total supply of the lake by groundwater outflows on the southern shore of the lake was 9.8 $dm^3 \cdot s^{-1}$ in May 2004, and 7.5 $dm^3 \cdot s^{-1}$ in October. As a result of such supply, the discharge of the Ruda at the outlet from Lake Gościąż is almost six times higher than at the inlet. The hydrological regime of the Ruda characterized by aligned discharge is the result of a large proportion (80-90%) of groundwater in the total outflow and a high retention capacity of the catchment (permeable substrate, large forest cover, presence of lakes).

Surface waters of the Ruda catchment represent the bicarbonate-calcium-sulphate type and are characterised by low mineralisation, which in the years 1990-1994 was about 190 $mg \cdot dm^{-3}$. Groundwater supplying the watercourse is only slightly more mineralised (220 $mg \cdot dm^{-3}$). Low mineralisation of the water in the catchment area is conditioned by the type of sediment (leached fluvioglacial and fluvial sands) and the presence of large forest areas (80%), which have the ability to store and recycle large amounts of mineral salts. Hydroclimatic conditions prevailing in a given year (dry year, average year) have not had a significant impact on the diversity of the chemical properties of water in the catchment of the Ruda. High homogeneity and stability of the chemical properties of water in the basin is the result of a small spatial differentiation of the characteristics of the natural environment (incl. lithology, land use) of the catchment and its large retention capacity.

The highest impact on hydrochemical characteristics of the Ruda's water is exerted by lakes. They affect the reduction of the total mineralisation of water, mainly by the decrease in the concentrations of ions HCO_3^- and Ca^{+2}. This is due to carbonate unbalance in the lake waters, as a result of which there occurs the precipitation of authigenic carbonates. Biogeochemical processes under reducing conditions in the deeper parts of the lakes also affect a decline in the sulphate concentration in the water flowing from the lakes.

Lake Gościąż is famous mostly because of the annual lamination of its sediments (Fig. 8), covering ca. 13,000 years, with almost 10,000 extremely regular varves from between late Allerød and late Subboreal.

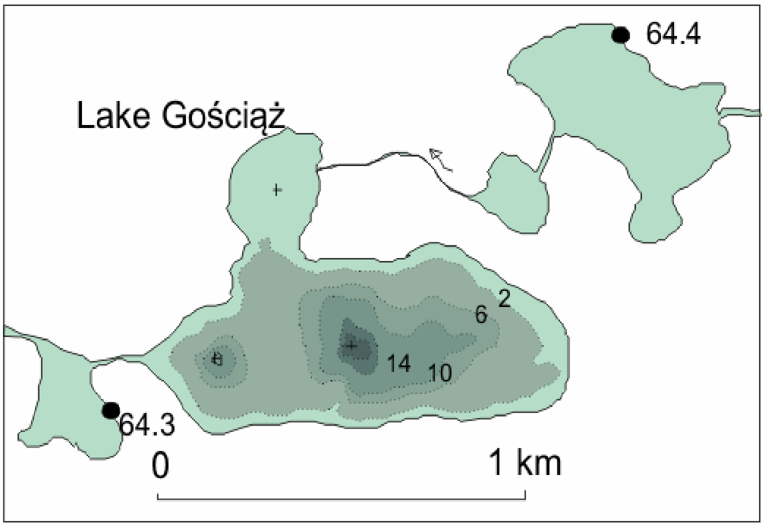

Fig. 8. Left: Lake Gościąż in the system of the "Na Jazach" lakes. Right: photo of lamination in the Atlantic section of the Lake Gościąż sediments (average varve thickness: 1 mm) (T. Goslar).

Due to that, the site was a subject of multidisciplinary research, held in the 80-ties and 90-ties of 20th century under the direction of M. Ralska-Jasiewiczowa (Ralska-Jasiewiczowa, Goslar, Madeyska, Starkel (eds), 1998). The research encompassed recognition of recent environment of Lake Gościąż and connected lakes (including geological structure, hydrology, chemistry, hydrobiology and isotopic composition), and reconstruction of the natural environmental evolution since the late glacial, and of human impact on natural environment since Mesolithic till today. Due to the lamination, reconstructions of past environment could be made with chronological accuracy and time resolution rarely met in palaeostudies.

The basin of Lake Gościąż, together with the other basins of the "Na Jazach" lake system (Fig. 8), formed close to the margin of the Vistulian ice-sheet, most probably in course of dead ice melting, that caused collapse of original depressions (wet hollows, infilled in Bölling with peat-like deposits). In the Allerød, the lake depth gradually increased, partly due to the collapse of its bottom, and partly because of the rise of water level, causing that all separate depressions became connected in one lake system. The ultimate end of meltout processes enabled the formation of laminated sediments, which commenced almost simultaneously, ca. 300-200 years before the end of Allerød.

The climatic change at the transition between Allerød and Younger Dryas (ca. 12,800 years ago) was clearly evidenced in all types of records available (oxygen isotopic composition, pollen, green algae, diatoms, *Cladocera*), and according to varve counting, it was completed within 150 years. The recession of forests facilitated slumping processes, enhanced erosion through the whole YD and intensified spring floods. In the later part of YD, the climate warmed gradually, and its humidity increased, that caused increase of lake trophy.

The transition between Younger Dryas and Holocene (ca. 11,600 years ago), was marked by abrupt warming (by more than 5°C in 70 years), causing blooms of green algae in the lake vegetation, and triggering development of forests and soils. These changes inhibited input of detrital matter to the lake, and resulted in temporary lowering of water level.

^{14}C dating of series of plant macrofossils collected from varved sediments documented that the boundaries of Younger Dryas were marked also by distinct changes of ^{14}C concentration in the atmosphere, presumably caused by joint action of changes of vertical oceanic circulation and of solar activity (Goslar et al. 1995, 2000). Preservation of varves allowed also for high-resolution reconstruction of ecological and climatic changes at the YD/PB boundary, including recognition of ca. 30-yr long period with more winter/less summer precipitation prior to the onset of the major warming, followed by 20-yr long period of rapid winter warming and less winter precipitation and then ca. 40 years of rapidly warming humid climate (Ralska-Jasiewiczowa et al. 2003).

During Preboreal (ca. 11,600-10,100 years ago) the enhanced flow of groundwater supplied maximum amount of carbonate ions into the lake, strengthening thermal stratification and causing e.g. maximum content of iron in the sediments. On land, *Betula* and *Populus* trees were expanding first (with somewhat delayed appearance of *Ulmus*) and in the later stage *Pinus* became dominant and *Corylus* did appear. The Boreal (ca. 10,000-9,000 years BP) was characterised by maximum pollen influx (partly due to still open canopies), and maximum July temperature already exceeding 17°C (is indicated by *Viscum*).

In the Atlantic (ca 9,000 – 5,800 years BP), the water level still decreased, ultimately dividing the "Na Jazach" system into individual lakes, and temporarily causing emergence of threshold between the main body of Lake Gościąż and its northern bay. In was the time of high lake trophy, which in spite of a lower content of carbonate ions, stimulated formation of wide calcite laminae. The whole Atlantic period was a time of maximum development of mixed deciduous forests, with dominance of *Ulmus*, *Fraxinus* and *Quercus*.

Archaeological recognition in the Lake Gościąż region documented sites of Mesolithic tribes (from between 8,000 and 6,600 years BP), their activity being reflected by some pollen indicators of disturbance of the structure of forests. From 6,400 years BP on, Neolithic populations started to settle the region, represented first by the Funnel Beaker Culture. However, records of their influence in the lake sediment are rather vague.

The onset of Subboreal period (ca. 6,000 years BP) is marked by the abrupt extinction of *Ulmus* trees that, although caused by factors other than man, stimulated intensification of settlement processes by forest opening. The humans (of the Comb-Pitted Pottery and/or Epibeaker Cultures) caused probably local spread of *Taxus* on abandoned pastures around 4,900 years BP, and increase of lake trophy that lasted long after the decline of Neolithic settlement. Around 4,100 years BP, tribes of Bronze Age cultures appeared. The pollen record of the earliest Trzciniec Culture activity is rather weak, but the spread of *Betula* after ca. 3,800 years BP and expansion of *Carpinus*, with simultaneous reduction of *Corylus* and decrease of *Quercus* might have been stimulated by this culture. Around 3,400 years BP, the hornbeam forests were for the first time destroyed by the tribes of Lusatian Culture, which could also be responsible for lake eutrophication around between 3,200 and 2,800 years BP.

Around 3,400 years BP, the first disturbances of laminae started to appear, bringing the first serious break of continuous lamination at 3,200 years BP. This perturbation was the effect of hypolimnion oxidation in the shallowing lake basin, partly counterbalanced by the human-induced eutrophication. Indeed, the heaviest disturbances of lamination occurred only after the decline of Lusatian Culture and lowering of lake trophy.

The first centuries of the Subboreal period (after 2,600 years ago), were marked by expansion of birch and regeneration of hornbeam forests enabled by the retreat of the Lusatian settlement. This expansion was coincident with the rise of water table, peaking in the highest water level of Lake Gościąż during the whole Holocene (ca. 1 m above the present day water surface).

In the period of Roman influences, the human impact intensified again. Between ca. 2,000-1,700 years BP, large areas for were deforested for agricultural purpose by the populations of the Przeworska cultures, and *Secale cereale* and *Cannabis sativa* were introduced into common cultivation. Re-expansion of *Carpinus* woods and post-farming *Betula* copses was enabled in the Migration period (400 – 1000 AD), when human population was distinctly reduced. At that time, water level was gradually lowering leading to very low water stands after ca. 700 AD.

The new intensification of human settlement accompanied the formation of the Polish state in the 10th century. This led to gradual extinction of deciduous forests, with only pine and mixed pine woods remaining. Then, an intensified input of clastic material to the lake was noted after 1100 AD, and a slight gradual increase of phosphorus over centuries, reflected slowly increasing eutrophication stimulated by agriculture.

The next intensification of human impact occurred at the end of 18th century, when several new villages were formed few kilometres away of the "na Jazach" complex by the settlers of the so-called "Hollandii" colonization (1770-1863 AD). The villages consisted of individual farms grouped in the mixed pine woods, where oak was probably locally abundant (Dąb = oak) This caused destruction of still remained *Carpinus* and *Corylus* stands, led to depletion of biogenic CO_2 in groundwater, weaker dissolution of carbonate rocks and drop of input of calcium and other relevant ions to the lake. However, increasing frequency of cereals (*Secale*) in the pollen spectra is visible only after ca. 1820 AD. Roughly at the same time, improvement of lamination quality in sediments is noted, probably due to gradual eutrophication of the lake, suggested by the increasing content of iron (bound in form of sulphides), increasing frequency of *Bosmina longirostris* and *Pediastrum.* The increasing potassium content at the same time, seems to correspond with the cultivation of potatoes (indicated by pollen of *Solanum nigrum* appearing after 1820 AD).

After 1864 AD, a German colonisation supported by the Russians ruling this territory, formed the village of Dąb Borowy, with its farms located around the lakes. Human activity of this village had direct influence on the lake ecosystems and sediment chemistry, causing rapid increase of lake trophy from ca. 1880 AD on. However, significant development of agriculture commenced about 1910 AD only (as reflected by pollen record of many cereals, potatoes, *Fagopyrum* etc.). The progress of agriculture is also connected with the maximum content of phosphorus in 1925 AD, though the highest crops are suggested by the maximum frequencies of *Secale* pollen between 1934-1941 only.

By the end of Second World War (in 1944 AD) the villages around the "Na Jazach" lakes were abandoned and from this time on, the area was subject to gradual reforestation. However, until 1954-1956, when the lake shore itself was afforested, the open land was still used by inhabitants of neighbouring villages. This history is reflected in pollen data, showing significant decrease in frequencies of cultivated plants and accompanying weeds from 1953 AD. The gradual extinction of farming activity coincides with surprisingly abrupt changes in lake ecosystem around 1950 AD, including decrease of sedimentation rate, decrease of Cyanobacteria and Chlorophyceae, extinction of vivianite in 1946, drop of Cu/Zn ratio in 1949, drop decline of phosphorus in sediments after 1950, drop of Fe content after 1950 followed by its gradual decline through ca. 15 years, and drop of Araphidinae diatoms after 1960. Some of these indicators reflected increasing oxidation of lake hypolimnion, that affected preservation of laminae in sediments, which became less distinct after ca. 1945 and almost completely disappeared after 1966.

Stop 3: Lake Rakutowskie

The peated area of the Błota Rakutowskie and Błota Kłócieńskie is one of the largest wetland ecosystems in the Gostynin Lakeland. In the central part of the Błota Rakutowskie there is a shallow (maximum depth of ~ 2.5 m) eutrophic Lake Rakutowskie surrounded by a belt of floodplain sedge meadows.

In 1982 the fauna reserve of Lake Rakutowskie was created to protect the lake and its characteristic aquatic and wetland vegetation. In 2004 and 2009, the area of Lake Rakutowskie was covered by the Nature 2000 program - initially Birds Directive (Błota Rakutowskie) to protect numerous birds nesting on the wetland, such as the common crane, black tern, bluethroat, bean goose, greylag goose, teal and shoveler, then Habitats Directive (Błota Kłócieńskie) in order to protect both aquatic vegetation, including pondweed meadows (*Charales*), and terrestrial habitats, including moor grass meadows (*Molinia*) and wet ash-alder forests.

Lake Rakutowskie is a remnant of the once much larger water body (Glazik 1978). Its basin is a large and shallow depression of long, gentle slopes. It is surrounded by vast plains with a thin (up to 2 m) peat cover. The lake basin is concentric. Height differences within a kilometre from the lake, between the lowest point in the central part (71.5 m) and the highest (73.9 m) to the north-west is 2.4 m. In the rest of the area the height difference does not exceed 1 m.

In order to analyse changes in the environment - topographic maps, aerial photographs and orthophotomap were used. The oldest source material used is Topographic Map of the Kingdom of Poland made in 1843. Furthermore, the following maps were used: maps Reymann's Specialkarte published in the mid-nineteenth century, General Maps of Central Europe of 1902, and Karte des Westlichen Russlands of 1911. Other maps used included: the Operational Map of Poland of the Military Geographical Institute (WIG) of 1922, WIG maps of 1930, German Topographische Karte (Meßtischblatt) issued in 1941 and 1944, and a topographical map of 1983 (Fig. 9). The authors also made use of the aerial photographs from 1961, 1980, 1996 and 2009.

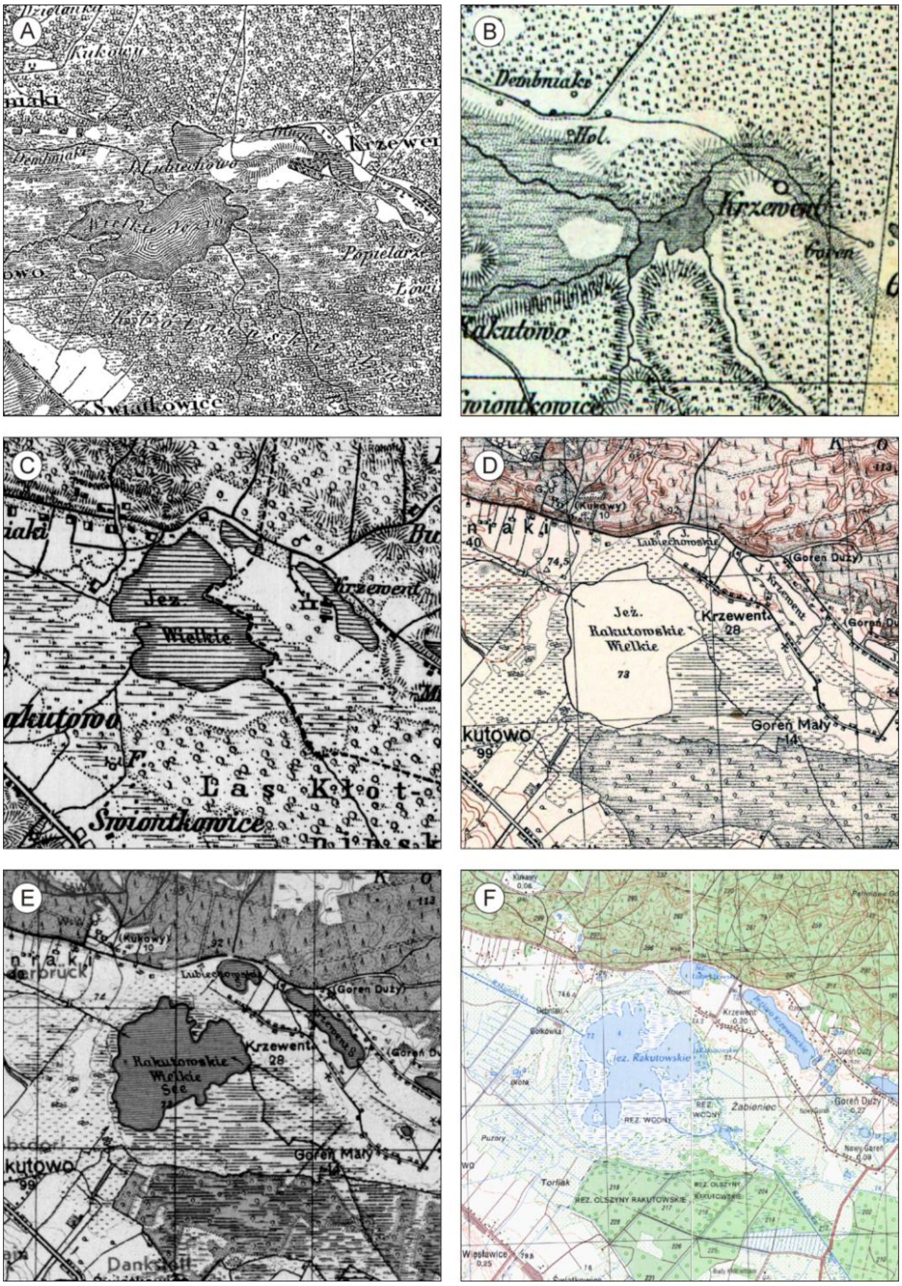

Fig. 9. Surroundings of Lake Rakutowskie on archive maps (Kramkowski et al., 2014).
A -Topograficzna Karta Królestwa Polskiego (Mapa Kwatermistrzostwa) (1843), B - Reymann's topographische Special-Karte von Central Europa (1845), C - Wojskowy Instytut Geograficzny – Topographic map (1922), D - Topographische Karte (Meßtischblatt) (1944), E - Karte des Deutschen Reiches - Großblatt/Einheitsblatt (1945), F - current topographic map.

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The maps from the years 1902-1911 show that Lake Rakutowskie had an area of 307 ha and was supplied by 3 watercourses from the southern and western directions. In the period between 1911 and 1930, in the immediate vicinity of the lake, a complex of draining ditches appeared. There are also traces of peat extraction. This map also shows the largest documented lake range of 329.3 ha, which represents an increase by 7% compared with the previous period. At that time, the shoreline in the south shifted by about 400 m. The cartographic material from the year 1945 presents another major change in the surface of the lake. It decreases by 31%, to 226.8 ha. From that time until 1961, it reduced its area by 50.8 ha. An extensive drainage network was developed around the lake, and thus the water flowing into the lake from the north and south were captured by the ditches and discharged directly to the Rakutówka below the lake. The aerial photos of 1980 show further, but not so intense changes within the bay near the village Krzewent, where its shoreline retreated by about 250 to 400 m (Fig. 10). Between 1980 and 1996 reed thickets and willow clumps encroach into the area, reaching a diameter of 50-80 m, and the surface area of the lake is reduced by 31%. In 2009, the bay is a terrestrial area overgrown with dense vegetation. At the same time, the area taken by reedbeds and rushes increases, and floating marshy peat mat expands. Within 13 years along all the shores and around islets vegetation moved into the water by approx. 40 m, thereby reducing the area of open water from 119.5 ha in 1996 to 101.8 ha.

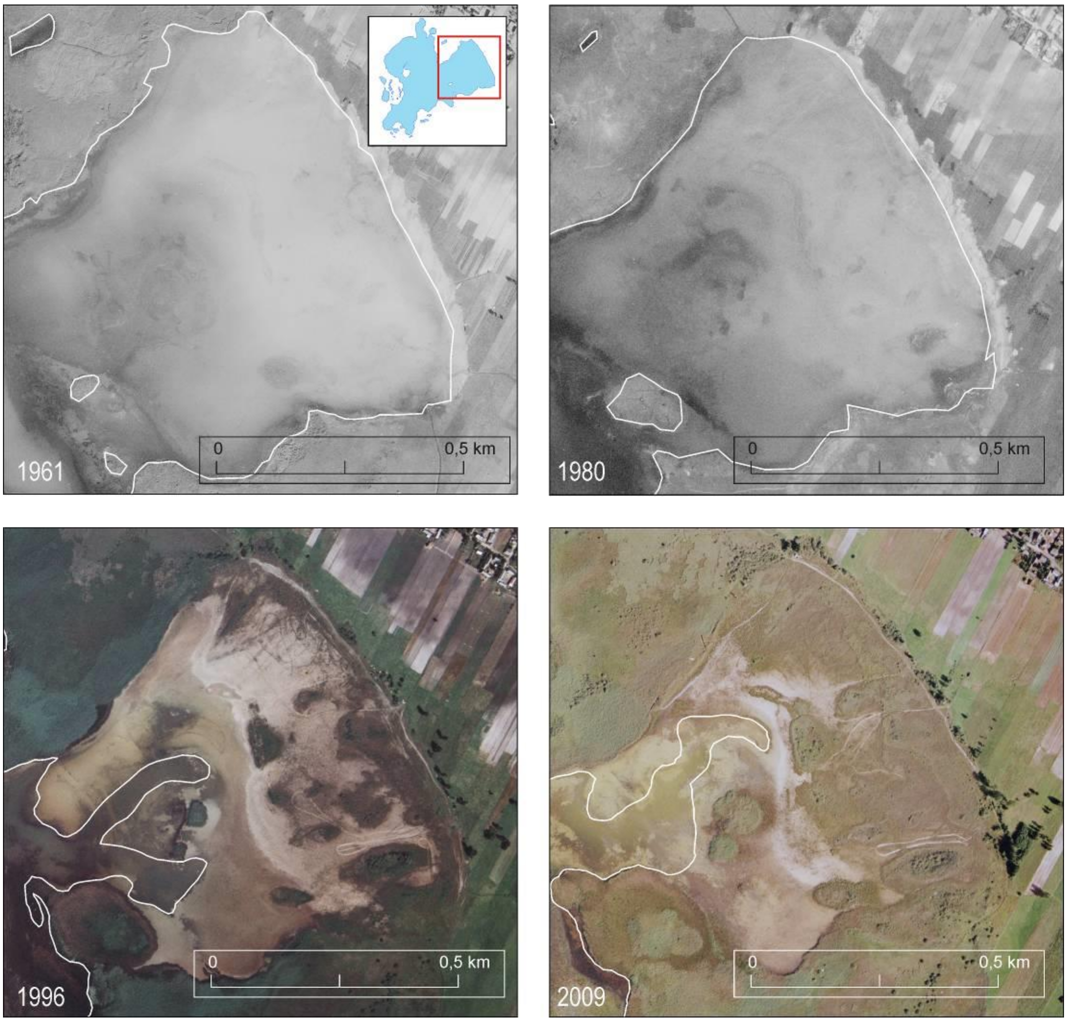

Fig. 10. Northeastern bay on aerial photographs (Kramkowski et al., 2014).

Lake Rakutowskie is primarily supplied by small streams flowing from the Kuyavian Plateau. In the precipitation deficit years, such as in 2014, their discharges are small, averaging from 7 to 40 $dm^3 \cdot s^{-1}$. The very diverse seasonal discharge of these watercourses consists of a short, maximum two months' over-average discharge, and a long-term summer-autumn low flow period. In the watercourses whose sources are located within the ice-marginal valley, the outflow completely disappears at this time. As a result, the supply of the lake is also periodic. In the autumn and winter months, the lake water resources are gradually restored. At this time, the outflow from the lake is lower than the inflow. The situation changes from April, when the outflow from the lake is largest. In 2014 it was 0.51 $m^3 \cdot s^{-1}$. The size of the outflow from the lake decreases rapidly until to lack of outflow in late June and early July. A similar regime of the supply of Lake Rakutowskie and the size of the outflow (0.3 $m^3 \cdot s^{-1}$) was observed in 1992-1994 covering the period of a hydrological drought. For comparison, in the multi-annual period (1966-1975) the average discharge at the outlet of the river from the lake was 0.77 $m^3 \cdot s^{-1}$ (q - 2.9 $dm^3 \cdot s^{-1} \cdot km^{-2}$). In the unusually wet 2011 it reached a value of 1.25 $m^3 \cdot s^{-1}$, which translates into a specific discharge of 5.5 $dm^3 \cdot s^{-1} \cdot km^{-2}$ (Bartczak et al. 2014).

The water feeding Lake Rakutowskie is characterised by a great diversity of salinity (SEC from approx. 350 $\mu S \cdot cm^{-1}$ to 1000 $\mu S \cdot cm^{-1}$). Most mineralised water is in the watercourses flowing from the Kuyavian Plateau and least mineralised in the watercourses whose source areas are located within the bottom of the ice-marginal valley. The catchment is dominated by the water HCO_3-Ca and HCO_3-Ca-Mg, typical of the late-glacial environment. Less important are the waters of the structure of HCO_3-SO_4-Ca, HCO_3-SO_4-Ca-Mg and HCO_3-Cl-SO_4-Ca, which may indicate their anthropogenic transformation. Although the nature of the catchment area is agricultural, the supply of nutrients to the lakes is moderate. Concentrations exceeding the background values mainly concerned N-NO_2 and N-NH_4. Concentrations of N-NO_3, especially P-PO_4, were typically lower than the background values. The largest supply of biogenic nitrogen and phosphorus salts comes from the morainic plateau intensively used for agriculture.

On the basis of the spatial variation of chemical properties of water and water circulation conditions in the catchment of the Rakutówka, four spatial units of hydrogeochemical facies, were identified (Fig. 11).

The first facies (A) is the HCO_3-Ca water of the watercourses flowing from the Kuyavian Plateau. Mineral-rich substrate is the cause of their high mineralisation. Within this hydrochemical facies it is possible to delimit two smaller units. The area located in the eastern part of the catchment (facies A') is characterised by a change in the type of water into HCO_3-Cl-SO_4-Ca during the spring runoff. It indicates a greater impact of the surface component of runoff on the water chemistry. In the western part of the plateau edge zone (facies A''), in addition to the dominant type of HCO_3-Ca water type, of great importance is also HCO_3-Ca-Mg water. In this area, water receives the biggest load of nutrients in the form of nitrate and orthophosphate. More intensive agriculture on better quality soils also contributes to an increase in the total concentration of ions, and used fertilisation is responsible for the higher concentrations of nutrients in the waters of rivers fed directly from the plateau.

Facies B is the water of the watercourses flowing in the ice-marginal valley nearby the plateau, in the bottoms of peaty subglacial channels. They supply the basin of Lake Rakutowskie with less mineralised water of the type HCO_3-Ca and, periodically, HCO_3-SO_4-Ca. Water of the facies C is found in the depression in the bottom of which Lake Rakutowskie is. They show high mineralisation and the structure of the Ca-HCO_3 type. The waters of Lake Rakutowskie and the Rakutówka below the lake have the most diverse ionic composition. However, the dominant water is HCO_3-Ca-Mg with periodically increased importance of sulphates (facies D). Mineralisation of water in this area is lower than mineralisation of the plateau water supplying the lake and is about 600-550 $\mu S \cdot cm^{-1}$.

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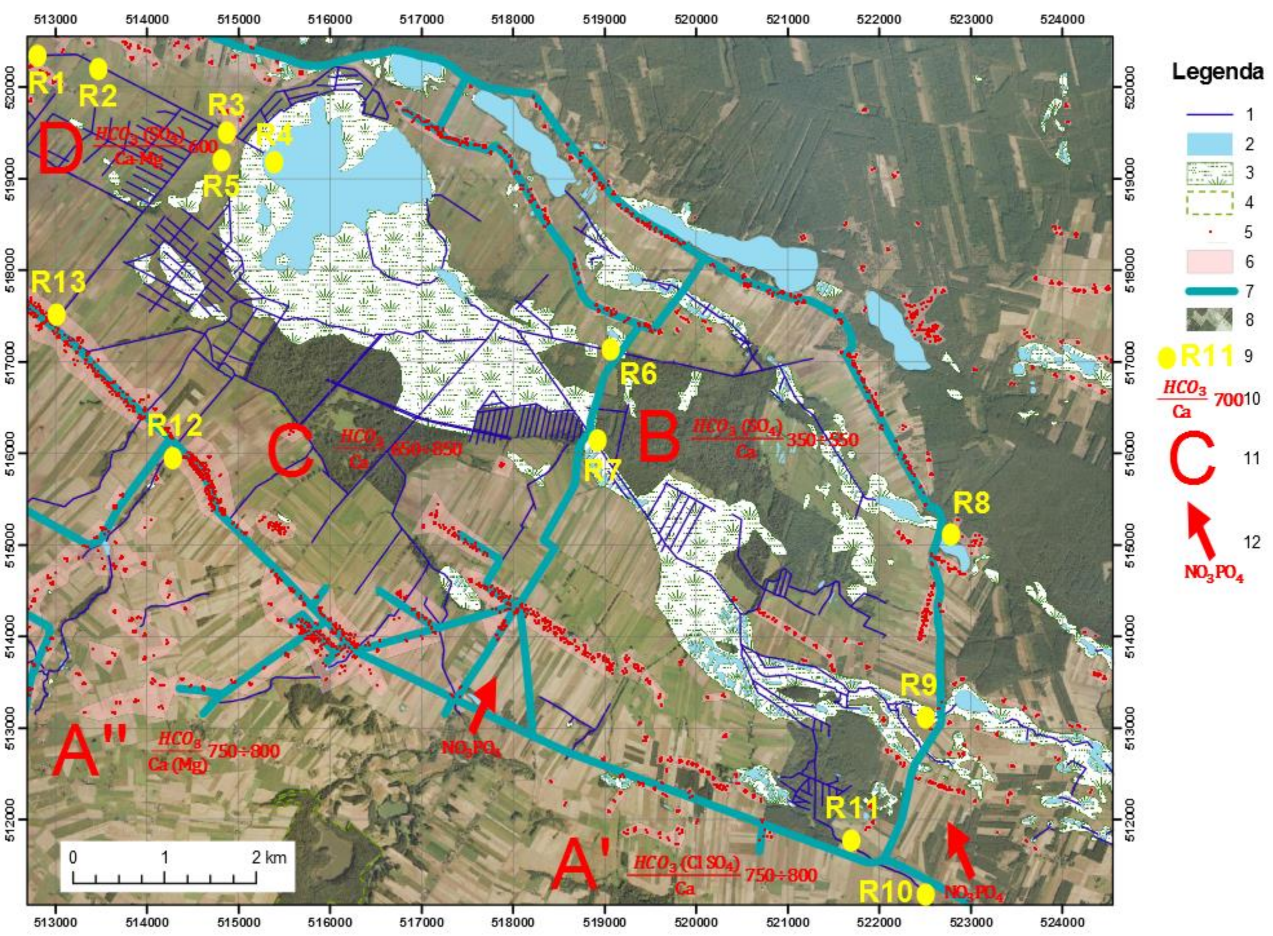

Fig. 11. Hydrochemical characteristics of the Rakutowskie Lake surroundings and potential sources of water pollution. Explanations:

1 – watercourses,
2 – lakes,
3 – wetlands,
4 – nature reserve borders,
5 – buildings,
6 – potential sources of supply of wastewaters from rural buildings,
7 – potential sources of supply of pollution from roads,
8 – diffuse pollution from agricultural sources,
9 – monitoring points,
10 – hydrochemical water type, in numerator – dominant anions, in denominator - dominant cations, on the right - value of electrolytic conductivity in μS·cm^{-1},
11 – symbol of hydrochemical facies,
12 – the directions of supply biogenic pollutants, and their main types.

Stop 4: Włocławek reservoir

The Włocławek barrage was put into operation in 1970. In the design, the Włocławek dam was to be the first of eight in the cascade of the lower Vistula. The project has not been completed, and the operation of the barrage in isolation causes a number of problems. The Włocławek barrage is 1,200 m long and consists of five structures: earth front dam, weir, water power plant of 160 MW, fish ladders and shipping locks. As a result of damming the Vistula by about 14 m, the largest - in terms of an area - dam reservoir in Poland formed (75 km^2). The length of the reservoir is 57 km, average width - 1.2 km, average depth - 5.5 m and maximum depth - approx. 15 m. The current storage capacity is estimated at 370 Mio m^3 (second place in Poland).

The functioning of the Włocławek barrage is one of the main factors affecting the continuity of fluvial processes taking place in the Vistula riverbed. Significant transformation refers to the conditions of the clastic sediment transport. Water flow decreases towards the dam - at an average discharge of the Vistula of approx. 900 $m^3 \cdot s^{-1}$, it amounts to 50-70 $cm \cdot s^{-1}$ on the border of backwater and 8-6 $cm \cdot s^{-1}$ at the dam. This causes all the dragged and rolled bedload of the Vistula is accumulated at the upper part of the reservoir in the form of a sand and gravel alluvial fan (Fig 12). In shallow areas of the reservoir (to a depth of approx. 6 m), where the bottom is impacted by waves, sand deposits may occur.

The reservoir retains about 25-40%, and in certain hydrological situations even 70% of suspended load, which when falling creates loamy-clay sediments in the lower, limnic part of the reservoir (Fig. 12). The wide variation in the concentration of total suspended solids was also noticed in individual cross sections of the reservoir. In the upper part of the reservoir (Płock profile) they reached up to 74% (Kaszubski 2014). Research on the suspension concentration variation in the cross sections showed that the role of the former Vistula channel as a route of preferential flow and supply of clastic material into the reservoir, reaches the area located about 20 km upstream of the dam.

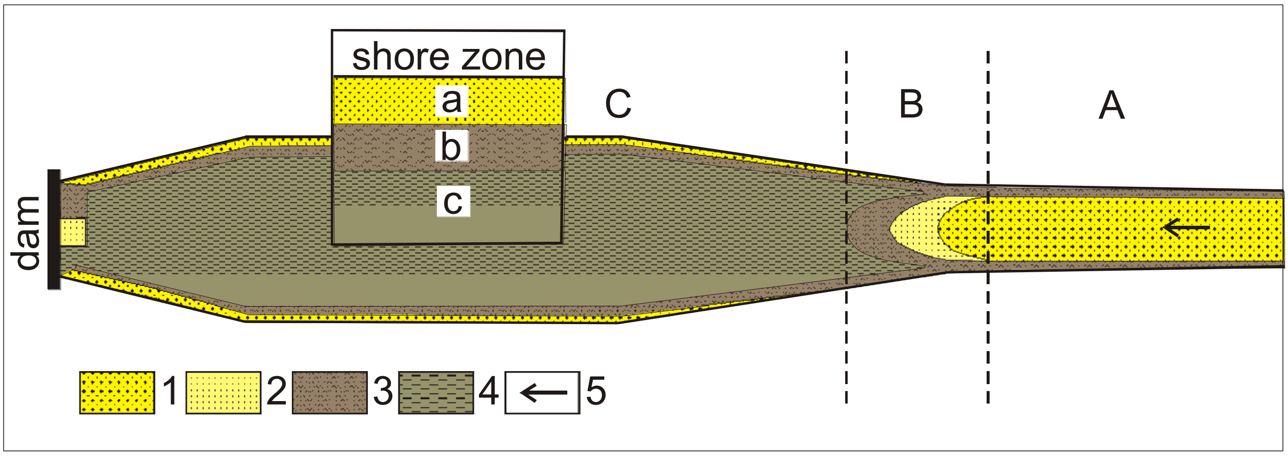

Fig. 12. Model of deposits accumulation in a lowland, valley and overflow reservoir on the example of the Wloclawek Reservoir (after Banach 1994, modified): 1 – coarse-grained sands, 2 – fine-grained sands, 3 - silty sands, 4 – silts and clays, 5 – direction of water flow. Hydro- and lithodynamic zones in the reservoir: A – river accumulation zone, B – delta accumulation zone, C – lake accumulation zone, a – water bank platform (lithoral) zone, b – water bank platform slope (sub-lithoral) zone, c – deep-water accumulation (profoundal) zone.

Reservoirs with small depths and rapid exchange of water, such as the Włocławek Reservoir, show a very wide diversity of sedimentary environments. In their case, the higher water dynamic caused by waves and wind circulation is the cause resuspension and redeposition of sediments accumulated earlier. The sediments of the Włocławek Reservoir are primarily loamy and loamy-sandy material (72%). Sandy sediments make up approx. 24% and clay only 4% of the total. Overall, the distribution of sediment types reflects the division into fluvial and limnic accumulation zones observed in the reservoirs (Fig. 12) The depth of the reservoir, its bottom morphology and complex systems of currents of different origins affect large spatial variations of bottom sediments types. Lithodynamic interpretation of the accumulation condition of bottom sediments showed that the Włocławek Reservoir lacks the conditions for sustained accumulation of sediment. Predominating conditions are typical for environments where there is movement (transport) of deposits. This is confirmed by the results of model calculations, which showed that in adverse weather conditions (wind speed of 15 $m \cdot s^{-1}$) sediment down to a depth of even 8 m is subjected to resuspension. This means that redeposition refers to loamy-sandy sediments of approx. 40% of the bottom of the reservoir.

Large dynamics of the sedimentary complex affects the diversification of sediment accumulation. Studies of the thickness of sediment filling the limnic section of the reservoir showed that the average thickness of deposits in subsequent cross sections is clearly different. It ranged from 0.65 m to 2.3 m. In the same profile there were places of 4.2 m of the sediment and places entirely devoid of loamy and clayey sediment. The average rate of loamy and loamy-sandy sediment accumulation in the limnic part of the reservoir is 4 $cm \cdot yr^{-1}$.

Clastic sediment deficit and high energy of the water flowing from the reservoir are the causes of severe erosion of the Vistula riverbed below the dam (Fig. 13). Its effect is the increase in the average depth of the channel by more than 3.5 m over a distance of 10 km below the barrage and 2.1 m on another 10 km stretch (Habel 2013). After 20 years of the barrage operation, the front of the erosion zone was located about 30 km below the dam. Intense erosion of the channel below the barrage in Włocławek is also the effect of the operation regime of the hydropower plant. Until 2002 it was a regime showing large diurnal changes in water flow (450-1,600 $m^3 \cdot s^{-1}$), which resulted in instantaneous increases in the water flow (Babiński 1992). The manifestation of the riverbed erosion at the stretch extending up to 30 km downstream of the barrage is almost completely devoid of sandy bars. In the bottom of the channel there are also, hard to wash out, gravely-stony Quaternary residuum and clay Pliocene sediments. These surfaces form underwater thresholds, the presence of which reduces erosion of the bottom of the riverbed, while easing its lateral migration and unblocking side channels (Gierszewski et al. 2015). Below the erosion sections there extends a section of accumulation of eroded alluvia (Fig. 13). The spatial extent of the erosion section and the beginning of the zone of predominating accumulation gradually moves downstream.

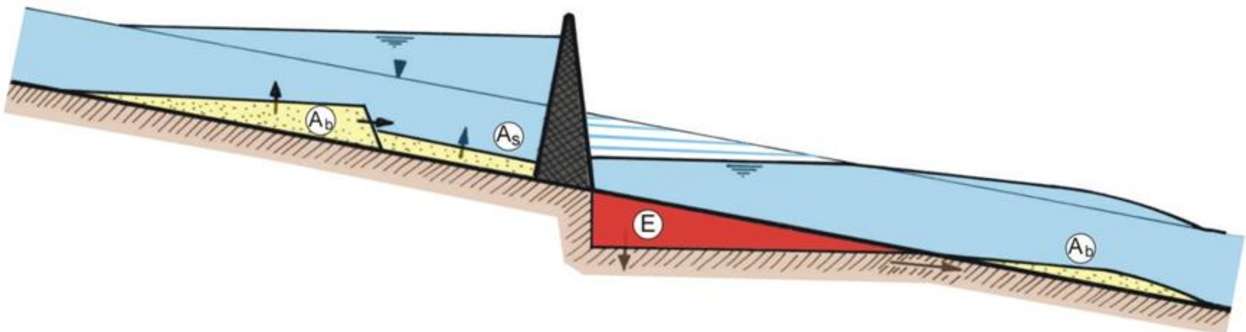

Fig. 13. Downstream and upstream effects of dams on alluvial/lowland river (acc. Babiński 2002):
Ab – bed load deposition zone, As – suspended load deposition zone, E – erosion zone; vectors indicate the directions of channel processes development.

Stop 5: Castle Hill and central landslide in Dobrzyń nad Wisłą

The right bank escarpment of the Vistula River between Płock and Włocławek reaches from 20 to 40m over the mean water level in the Włocławek reservoir and is continuously subjected to surface mass movement. A specific geological structure facilitates the development of that phenomenon (Fig. 14). The scarp consists of two main complexes diversified by lithology, structure and age i.e. Neogene and Pleistocene. In the Płock-Włocławek zone the younger complex overlies discordantly distorted Neogene sediments. Beyond that area, the two complexes are usually concordant, divided only by an erosional confine (Roman 2010, 2013).

The Neogene complex contains glaciotectonically disturbed Miocene sands as well as loams and sands with brown coal, and Mio-Pliocene clays, so-called variegated clays. That complex also includes early Pleistocene pre-glacial deposits, which together with the Neogene, participate in the said deformations. The Neogene complex builds a vast elevation running along the right edge of the Vistula valley (Skompski 1969, 1995), and its ceiling appears up to 25 m above the water level of the current Włocławek Reservoir. Neogene here is strongly deformed and features various folds, thrust folds and overlaps accompanied by small scale normal and reversed faults and sheares.

Amplitude of thrust-fold structures is approx. 100 m south of Płock (Różański, Włodek 2009), whereas at Dobrzyń it reaching 40-90 m (Skompski 1968, Banach et al. 2013). The axis orientation and vergence of the structures suggest that they arose as a result of glacitectonic compression towards NE (Brykczyński 1982). The age of those structures is associated with the first ice sheets entering the Vistula paleo-valley, i.e. the South Polish glaciations (Cromerian and Elsterian).

The Pleistocene complex includes 2-4 tills, locally divided by glaciofluvial sands or glaciolacustrine silts. These almost horizontal deposits (Fig. 14), are visible in the upper part of the right edge of the Vistula River over the older Neogene disturbed complex.

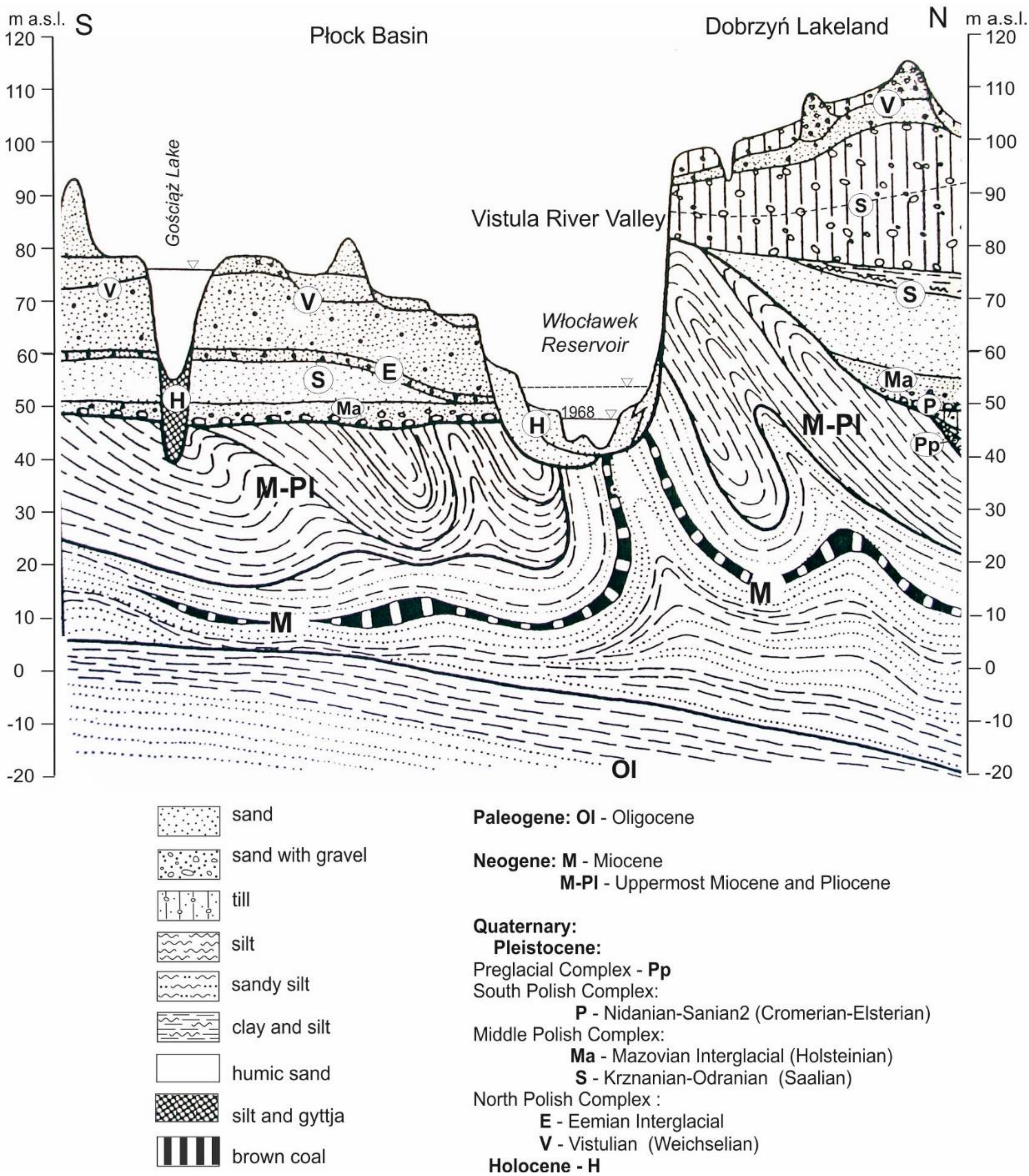

Fig. 14. Geological cross-section across the Vistula valley near Dobrzyń-on-the-Vistula (Dobrzyń nad Wisłą) by Skompski (1995), as amended.

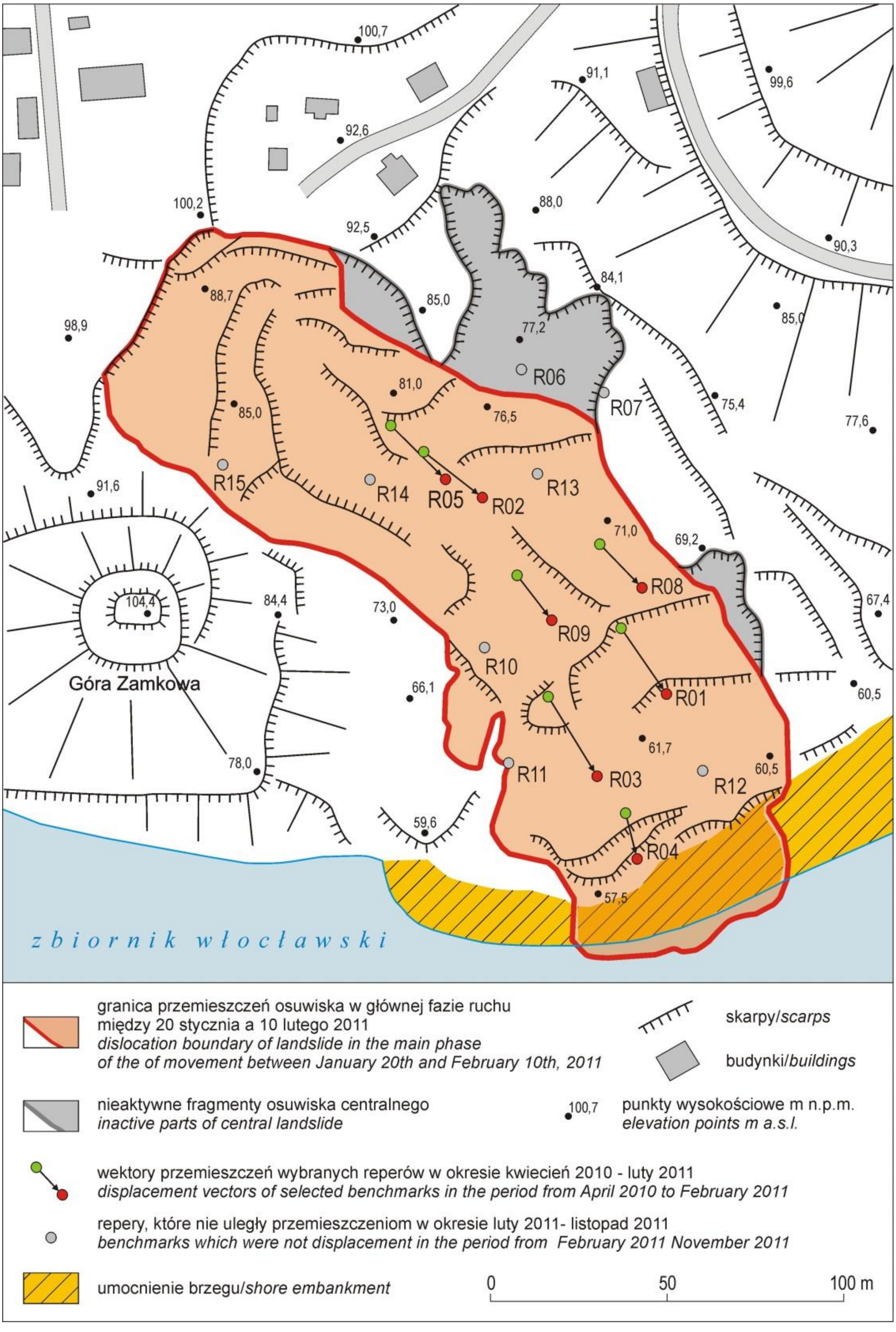

Fig. 15. Sketch of the central landslide at Dobrzyń-on-the-Vistula (Dobrzyń nad Wisłą) (Banach et al., 2013).

This type of the geological structure of the NE margin of the Włocławek reservoir implies the development of landslides. As a result of vertical fractures involving the Pleistocene complex in the edge area, migration of rainwater to the Neogene complex is facilitated. As a result, the Mio-Pliocene clays in the bottom part of the slope get plastic, initiating the development of sliding surfaces and landslide processes. What is important is the orientation of the sliding surface relative to deformation structures in the Neogene complex. Particularly susceptible to activation are the surfaces consistent with the main elements of the structures.

Before the creation of the reservoir the above slope was formed by landslide processes. The landslides occurring in the area are located in the syncline axes, in places where Pliocene clays are above the water of the reservoir. Nearly 32% of the total length of the right bank of the reservoir, i.e. 14.5 kilometers, experiences mass movements (Banach, Spanila 2000).

One of the biggest, active landslides within the shore zone of the Włocławek reservoir is the central landslide in Dobrzyń-on-the-Vistula. Monitoring studies of this form have been conducted since 1969, i.e. the period of the river impoundment. These include geodetic monitoring of displacements and geomorphological mapping within the landslide.

The central landslide is an old rotational landslide, active before creating the Włocławek reservoir. This form is 220 m long, 60 to 90 m wide, and its area is about 2 ha (Fig. 15). The upper part of the landslide crown is developed in the Quaternary deposits (two beds of glacial till separated by sandy deposits) of a thickness of about 20 m, overlying the Pliocene clays. In the landslide, on the basis of the inclinometer measurements at three sites (Madej 1981), the occurrence of the slip surface was recorded at the depths of 7, 9 and 16 m.

As a result of the changes of the morphodynamic and hydrogeological conditions related to the creation of the Włocławek reservoir in 1970, there was a significant increase in the activity of this form lasting until 1984. The pre-damming movements (1959-1970), determined on the basis of photogrammetric measurements, amounted to 2.6 $m \cdot yr^{-1}$, while in the period 1970-1984, the average yearly movements were as follows: 1.4 m in the upper part of the landslide, 2.4 m in the middle and 3.2 m in its lower part. The main scarp of the landslide in this period retreated by 30 m. In the 1980s and 1990s the landslide dynamics clearly dropped to 1.0-1.7 $m \cdot yr^{-1}$, i.e. to the size from the period before damming of the river, and stayed at this level until 2002 when, as a result of heavy rainfall, there was a strong, short-term activation of this form. In the period from December 2002 to early 2010 the central landslide was displacing at the rate similar to that before the river damming, i.e. 1-2 $m \cdot yr^{-1}$. A sharp increase in the rate of displacement occurred in 2010. During a period of 10 months, i.e. from April 2010 to February 2011, the displacement within the central landslide reached 13.2-23.1 m, with a maximum displacement in its central part. During its most intense period, from December 2010 to February 2011, the horizontal displacements within the landslide were 10.0-19.4 m. These are very large values, not recorded in the 40-year period of monitoring the dynamics of this form. In the period 2010-2011 the main scarp of the landslide retreated from 3 to 5 m. Such large transformation was probably the result of the alignment of the unusually high and prolonged rainfall during the summer and autumn of 2010 with the snow thaw and adverse air temperature changes at the turn of 2010 and 2011 (Banach et al. 2013). Since February 2011 clear central landslide stabilisation has been observed.

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Fieldwork in ICLEA to document archeological sites of charcoal production (charcoal kiln sites), open cast mine Jänschwalde, Lusatia (photo T. Raab, BTU)

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Participants of the 3rd Annual ICLEA Workshop 2014 in Greisfswald-Wieck (photo S. Lorenz, Uni Greifswald)

List of participants – 4th Annual ICLEA-Workshop 2015

Abbreviations of institutions

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
GFZ *= Helmholtz Centre Potsdam - German Research Centre for Geosciences, Potsdam, Germany;*
Section 1.4 *Remote Sensing;* ***Section 1.5*** *Geoinformatics;* ***Section 5.1*** *Geomorphology;*
Section 5.2 *Climate Dynamics and Landscape Evolution;* ***Section 5.4*** *Hydrology;* ***CZP*** *Critical Zone Platform*
BTU Cottbus-Senftenberg *= Brandenburg University of Technology, Chair of Geopedology and Landscape Development, Cottbus, Germany*
University of Greifswald, *Germany*
IBL *= Institute of Botany and Landscape Ecology,* ***IGG*** *= Institute for Geography and Geology*
IGS PAS *= Institute of Geological Sciences, Polish Academy of Sciences, Warsaw, Poland*
LUNG MV *= State Office for Environment Nature protection and Geology of Mecklenburg-Western Pomerania, Güstrow, Germany*
NAS Belarus = *National Academy of Sciences of Belarus, Minsk, Belarus*
Department of Geodynamics and Paleogeography, Institute for Nature Management
PIG-PIB Warsaw *= Geological Museum at the Polish Geological Institute - National Research Institute, Warsaw, Poland*
WSL *= Swiss Federal Institute for Forest, Snow and Landscape Research, Zürich, Switzerland*
GAMMA *= GAMMA Remote Sensing Research and Consulting Ltd., Gümligen, Switzerland*

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