SEVENTH FRAMEWORK PROGRAMME

INTERACT

International Network for Terrestrial Research and Monitoring in the Arctic

Research and Monitoring

INTERACT is a circumarctic network of terrestrial field bases in Arctic, alpine and neighbouring forested areas. The network is funded for 2011-2015 by EU's Seventh Framework Programme as "Integrating Activity" under the theme "Research Infrastructures for Polar Research".

INTERACT has an overarching concept of strategically sampling the great environmental variation throughout northern areas. This concept is illustrated in the graphic below which shows the location of the **INTERACT** Stations within environmental space, defined by temperature and precipitation ranges.

INTERACT Stations

SVALBARD
1 Sverdrup Research Station
2 Netherlands' Arctic Station
3 UK Arctic Research Station
4 CNR Arctic Station "Dirigibile Italia"
5 Czech Arctic Research Station of Josef Svoboda
6 Polish Polar Station Hornsund

NORWAY
7 Finse Alpine Research Centre
8 Bioforsk Svanhovd Research Station

SWEDEN
9 Svartberget Research Station
10 Tarfala Research Station
11 Abisko Scientific Research Station

FINLAND
12 Kilpisjärvi Biological Station
13 Kevo Subarctic Research Station
14 Värriö Subarctic Research Station
15 Pallas-Sodankylä Stations
16 Kolari Research Unit
17 Oulanka Research Station
18 Kainuu Fisheries Research Station
19 Hyytiälä Forestry Research Station (SMEAR II)

SWITZERLAND
20 Alpine Research and Education Station Furka

AUSTRIA
21 Station Hintereis
22 Sonnblick Observatory

CHECH REPUBLIC
23 Krkonoše Mountains National Park

POLAND
24 Karkonosze National Park
25 M&M Klapa Research Station

RUSSIA
26 Khibiny Educational and Scientific Station
27 Mukhrino Field Station
28 Numto Park Station
29 Labytnangi Ecological Research Station
30 Beliy Island Research Station
31 Willem Barents Biological Station
32 Khanymey Research Station
33 Kajbasovo Research Station
34 Aktru Research Station
35 Igarka Geocryology Laboratory
36 Evenkian Field Station
37 International Ecological Educational Center "Istomino"
38 Research Station Samoylov Island
39 Spasskaya Pad Scientific Forest Station
40 Elgeeii Scientific Forest Station
41 Chokurdakh Scientific Tundra Station
42 Orotuk Field Station
43 North-East Science Station
44 Avachinsky Volcano Field Station
45 Meinypil'gyno Community Based Biological Station

KYRGYZ REPUBLIC
46 Adygine Research Station

USA
47 Barrow Arctic Research Center/ Barrow Environmental Observatory
48 Toolik Field Station

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51 Canadian High Arctic Research Station
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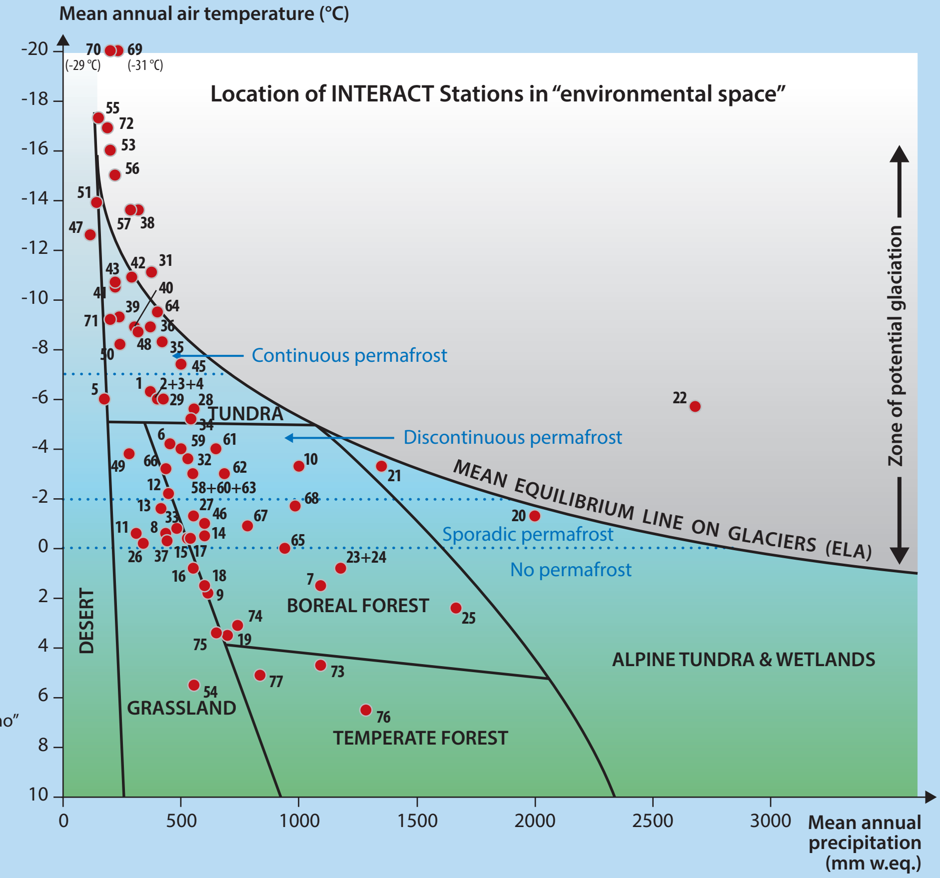

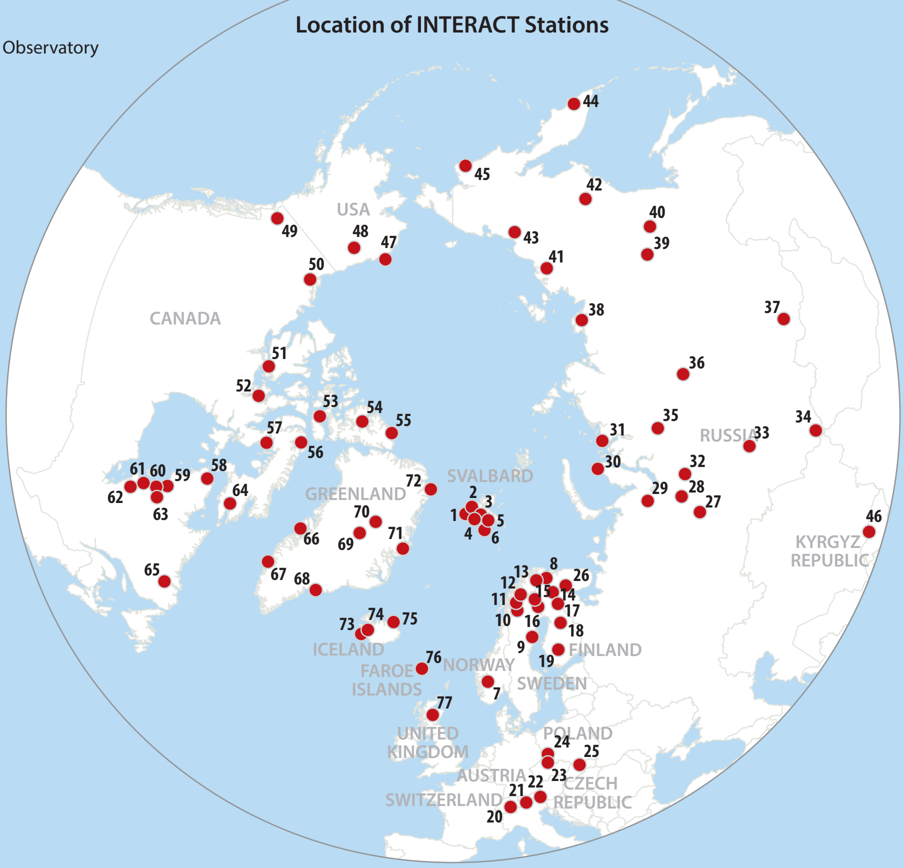

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INTERACT
Research and Monitoring

Editors:
Elmer Topp-Jørgensen
Zhanna Tairova
Morten Rasch
Jannik Hansen

INTERACT Research and Monitoring

Editors: Elmer Topp-Jørgensen[1], Zhanna Tairova[1], Morten Rasch[2] and Jannik Hansen[1]

Contributors: Chapter 1: Henrik Skov[3] and Niels Martin Schmidt[1]. Chapter 2 and 3: Managers of INTERACT Research Stations

[1] Department of Bioscience, Aarhus University, Denmark
[2] Department of Geoscience and Natural Resource Management, University of Copenhagen, Denmark
[3] Department of Environmental Science, Aarhus University, Denmark

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www.eu-interact.org

INTERACT is a network of terrestrial field bases in arctic and alpine areas of the Northern Hemisphere. The network is funded for 2011-15 by EU's Seventh Framework Programme as an 'Integrating Activity' under the theme 'Research Infrastructures for Polar Research'.

The network has been endorsed by the International Arctic Science Committee (IASC), the Arctic Monitoring and Assessment Programme (AMAP), the Circumpolar Biodiversity Monitoring Program (CBMP), the Sustaining Arctic Observing Networks (SAON), Forum of Arctic Research Operators (FARO), the International Study of Arctic Change (ISAC) and the World Wildlife Foundation (WWF).

The printing of this book has been made possible by means provided by INTERACT and The European Commission.

Khibiny Research Station, Russia (Sven Fuchs).

Preface

The Arctic Council's Arctic Monitoring Assessment Programme (AMAP) and the Conservation of Arctic Flora and Fauna (CAFF) through its Circumpolar Biodiversity Monitoring Program (CBMP) have followed the transformation of INTERACT from its origin as a network of just nine research stations around the North Atlantic region into a true circumarctic network of more than 75 research stations across the Arctic and northern alpine areas of Europe, Russia and North America.

Climate Change, contamination, biodiversity loss and changes in the arctic environment have serious impacts, both inside and outside the Arctic. Trends indicate that these effects will become more severe in the near future, subjecting arctic countries and their peoples to new environmental, economic and societal challenges. But these changes will not only affect local residents; global activities affect the Arctic and changes in the Arctic environment have global consequences. The global community must improve arctic monitoring to better understand the changes and their effects. To understand this, more comprehensive observations of environmental, social and economic issues need to be included in arctic monitoring.

The need for comprehensive, sustained and interdisciplinary arctic observations and data management has been recognized by the Arctic Council, and emphasised in reports such as the Arctic Climate Impact Assessment (ACIA) and the report of the International Conference on Arctic Research Planning (ICARP II). In 2009, the Arctic Council launched the Sustaining Arctic Observing Networks in response to the recognised need to enhance arctic monitoring.

A significant part of the experimental research and long-term monitoring of Climate Change effects on arctic terrestrial ecosystems takes place on research stations. Accordingly, arctic research stations are important nodes in the gathering of knowledge about the status and trends of arctic environments now and in the future. The central role of arctic research stations is reflected in recent AMAP, CAFF and the Intergovernmental Panel on Climate

Change (IPCC) assessments, e.g., Arctic Climate Impact Assessment (AMAP, CAFF, IASC), Snow, Water, Ice and Permafrost in the Arctic (AMAP), Arctic Biodiversity Assessment (CAFF) and IPCC Fifth Assessment Report.

INTERACT has gathered information on research and monitoring activities at stations included in the network. This book and the associated database present information on the scientific disciplines and monitored parameters covered by the individual stations. It is a knowledge source that can help identify gaps and find studies to build on or include in assessments. The book also provides recommendations for an 'INTERACT Minimum Monitoring System' that can help station managers prioritise in-house monitoring programmes. Finally, the book seeks to facilitate the implementation of common practices by describing selected scientific networks with standard protocols (including AMAP and CBMP).

Such information is extremely valuable for the development and implementation of Arctic Council monitoring programmes, for scientists, station managers and other stakeholders, and we therefore strongly welcome the effort made by INTERACT to coordinate and harmonise research and monitoring efforts that will greatly contribute to our knowledge and understanding of changes occurring in the arctic environment.

Lars Otto Reiersen, Executive Secretary
Arctic Monitoring and Assessment Programme

Tom Barry, Executive Secretary
Conservation of Arctic Flora and Fauna

Villum Research Station, Greenland (Stephan Bernberg).

Content

About INTERACT

The International Network for Terrestrial Research and Monitoring in the Arctic, INTERACT, is a network of more than 75 research stations located throughout arctic and northern alpine areas. The network aims to build capacity for identifying, understanding, predicting and responding to environmental change. This is achieved by sharing knowledge and facilitating the development of state of the art facilities and services offered to visiting scientists and other stakeholders from all over the Globe.

The network acts as a platform for sharing of knowledge between station managers in the network and between the network, the scientific community (through international organisations and thematic networks and programmes) and other stakeholders (e.g. local communities, authorities and intergovernmental fora).

The stations included in INTERACT cover a multitude of environmental habitats, gradients and ecological thresholds and thus provide a unique platform for studying ecosystem functioning and Climate Change impacts.

The network has been endorsed by the International Arctic Science Committee (IASC), the Arctic Monitoring and Assessment Programme (AMAP), the Circumpolar Biodiversity Monitoring Program (CBMP), the Sustained Arctic Observing Networks (SAON), Forum of Arctic Research Operators (FARO), the International Study of Arctic Change (ISAC) and the World Wildlife Foundation (WWF) and cooperation agreements have been signed with numerous other international organisations and networks.

Since 2011, the INTERACT Station Managers' Forum has focused on developing the network by describing its individual facilities (the research stations) in an INTERACT Station Catalogue and by publishing a book on how to manage research infrastructures located in remote and harsh arctic and alpine environments.

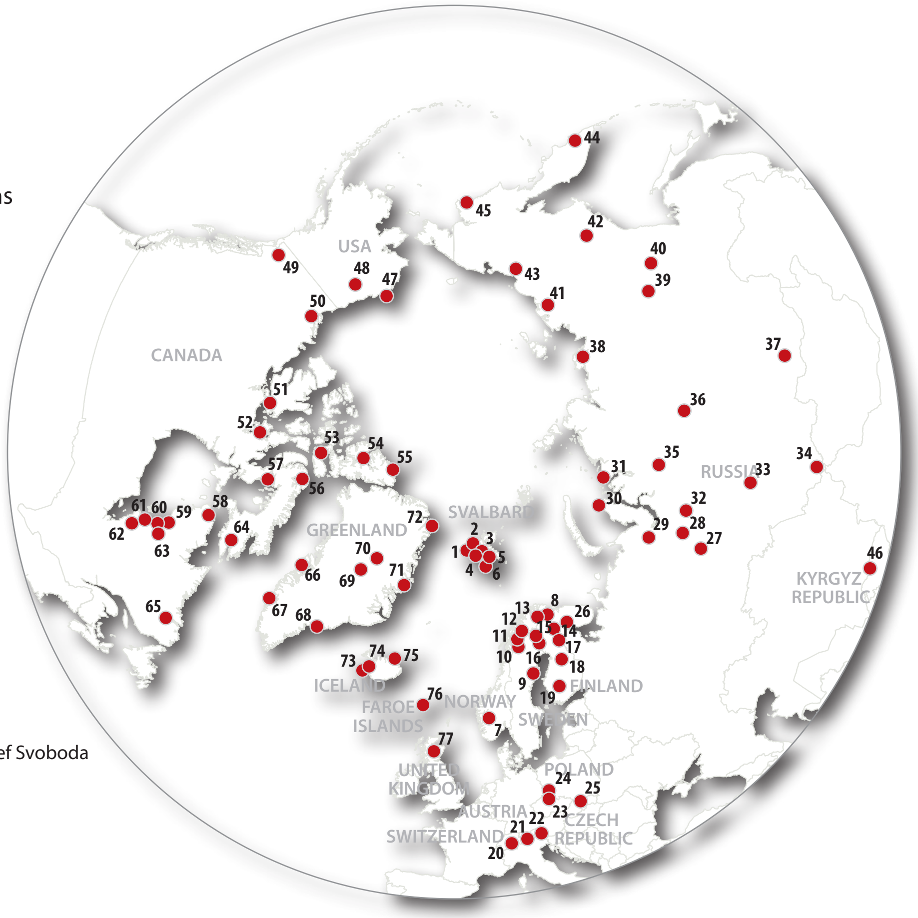
This book is the third publication in the series of INTERACT publications produced by the Station Managers' Forum. It presents a recommended minimum monitoring programme for terrestrial field stations, describes key scientific networks and provides an overview of the scientific activities undertaken at INTERACT stations since year 2000.

The book is published together with a searchable metadata database allowing scientists and other stakeholders to search out details on the different research and monitoring projects which have taken place at INTERACT stations.

www.eu-interact.org

INTERACT stations

Numbers assigned to the stations are continuously updated as the network expands and may therefore not follow the numbering in other INTERACT publications.



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Structure of the book and how to use it

This book presents recommendations for an 'INTERACT Minimum Monitoring Programme' for research stations, and describes selected long-term monitoring themes through descriptions of existing scientific networks and programmes.

The book also presents an overview of the scientific disciplines and parameter groups sampled at INTERACT stations since the year 2000. A searchable database will virtually accompany the book allowing researchers and other stakeholders to identify projects of relevance to their work and to search out details of the individual projects, including project name, monitored parameters, PI name and contact details, publications, etc. This database can be accessed via the INTERACT website (www.eu-interact.org).

77 stations contributed with information concerning scientific disciplines covered at the stations, while 42 stations contributed with metadata on research and monitoring projects, and on parameter groups monitored at the stations.

How to use the book

INTERACT Minimum Monitoring Programme (Chapter 1)

The 'INTERACT Minimum Monitoring Programme' can be used by research station managers developing research and monitoring strategies for their station. The section describes key parameters for nine themes that should be considered part of monitoring programmes at terrestrial field stations.

Where possible, links are provided to relevant scientific networks and programmes. This allow station managers or scientific leaders to identify described best practices sampling protocols, thus providing an opportunity for improved standardisation of data collection.

The following themes are included:

- Climate monitoring.
- Spatial background information.
- Hydrological monitoring.
- Physical landscape monitoring.
- Vegetation monitoring.
- Fauna monitoring.
- Bio-geochemical monitoring.
- Atmospheric chemistry and pollution monitoring.
- Land-use monitoring.

Selected best practices (Chapter 2)

Station managers and scientific leaders of terrestrial field stations can in this chapter find inspiration for implementation of standardised monitoring sampling protocols developed by scientific networks and programmes. The individual descriptions of networks and programmes include description of purpose, suitable sites, parameters monitored, methodology, how to become involved and geographical coverage.

Networks described in chapter 2.

No.	Abbreviation	Name	Field
2.1	WMO	World Meteorological Organisation	Climate
2.2	AMAP	Arctic Monitoring and Assessment Programme	Climate, ecosystems and stressors
2.3	CBMP (CAFF)	Circumpolar Biodiversity Monitoring Program (Conservation of Arctic Flora and Fauna)	Ecosystems and biodiversity
2.4	ENV-Europe/ ILTER	ENV-Europe/ International Long Term Ecological Research	Ecosystems and biodiversity
2.5	GLORIA	Global Observation Research Initiative In Alpine Environments	Mountain ecosystems and biodiversity
2.6	ITEX	International Tundra Experiment	Ecosystem functioning and Climate Change experiments
2.7	EXPEER/ AnaEE/ INCREASE	Experimentation in Ecosystem Research / Analysis and Experimentation on Ecosystems/ An Integrated Network on Climate Research Activities on Shrubland Ecosystems	Ecosystem functioning and Climate Change experiments
2.8	ShrubHub	Network investigating changes in woody vegetation in arctic and alpine tundra ecosystems	Arctic and Alpine tundra ecosystems
2.9	ICOS	Integrated Carbon Observing System	Climate Change, CO_2 fluxes
2.10	InGOS	Integrated non-CO_2 Greenhouse gas Observing System	Climate Change, Non-CO_2 carbon fluxes
2.11	CALM (IPA/GTN-P)	Circumpolar Active Layer Monitoring (International Permafrost Association/ Global Terrestrial Network for Permafrost)	Permafrost and active layer monitoring
2.12	TSP (IPA/GTN-P)	Thermal State of Permafrost (International Permafrost Association/ Global Terrestrial Network for Permafrost)	Permafrost temperatures
2.13	GTN-G	Global Terrestrial Network for Glaciers	Glaciers

Research and monitoring activities at INTERACT stations (Chapter 3)

The chapter can be used by both station managers and representatives from the scientific community.

Station managers can use the chapter to find inspiration for developing or revising the monitoring programme at their station, by:

- Identifying gaps in the monitoring programme at their station.
- Comparing their monitoring programme to stations located in similar environments.

The representatives from the scientific community can use the chapter to:

- Identify stations that conduct science relevant to their field of interest.
- Identify potential new study sites by searching out gaps in geographical coverage.

To enable the identification of relevant research and monitoring projects or gaps in the scientific knowledge, the geographical coverage of the different scientific disciplines and monitored parameter groups is presented on maps (Chapter 3).

Details of the individual research and monitoring projects can be found in the INTERACT GIS metadata database being released together with this book.

The maps presented in chapter 3 show stations where:

- A specific parameter group is being monitored or a specific scientific discipline is undertaken (**red colour dots**).
- A specific parameter group is not being monitored or a specific scientific discipline is not undertaken (**orange colour dots**).
- No information was provided (**grey colour dots**).

The dots on the maps are numbered. To relate the number to a specific station, simply flip out the flap of the front cover. This reveals a list of stations that allows you to relate the number of the station on the relevant map to the name of the station.

In the INTERACT Station Catalogue (www.eu-interact.org) you find detailed descriptions of the individual stations, which can be used to assess whether a knowledge gap in discipline or monitored parameter group coverage at a station is caused by lack of the specific environmental feature in the area or a lack of the specific scientific activity within this field. Note that station numbers in the catalogue differ from the numbers used in this publication.

References in the text are given as a [number] that is referring to the reference list on page 136.

1 INTERACT Minimum Monitoring Programme

Authors: Morten Rasch, Henrik Skov, Niels Martin Schmidt and Elmer Topp-Jørgensen

Tarfala Research Station, Sweden (Gunhild Rosqvist).

1.1 Designing an 'INTERACT Minimum Monitoring Programme'

View from Arctic Station, Greenland, over Disko Bugt dotted with icebergs from the Sermeq Kujalleq glacier. A simple monitoring programme was able to document significant changes in ice cover period (Louise K. Berg).

In the early 1990's, the management board of the INTERACT station 'Arctic Station' in Qeqertarssuaq in West Greenland decided to ask their scientific leader to register the sea-ice cover on the sea outside his office, the large embayment called Disko Bugt, each day at noon. The observations should be made visually and registered in increments of 10 %, i.e. either 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 or 100%. This was the start of a very simple and inexpensive monitoring programme, and it has been maintained and still is by the changing staff at the station. From the beginning, the monitoring programme was criticized for not being scientific due to the qualitative character of the observations and due to the fact that the observations over the years were made by many different scientific leaders, i.e. due to the fact that the station, as part of its general staff policy only make contracts of three years or less with their scientific leaders. However, during the winter 1995-96, the environmental conditions changed dramatically in Disko Bugt, and after several decades of more or less permanent ice cover of the sea during wither and spring months, the entire embayment experienced much more unstable sea-ice conditions and many winters with almost no or only scattered sea-ice during winter. This had great influence on the community in which Arctic Station is situated, it was the result of a significant change in the climatic/oceanographic conditions, and it led to milder and shorter winters and resulting changes in both the marine and the terrestrial compartments of the ecosystem. As a result, the time series of sea-ice cover that initially was criticized for not being scientific therefore turned out to be widely cited in many research papers, and from the information being registered in the time series it was actually possible to extract more objective information like the day of first sea-ice cover, the last day with sea-ice cover, and a characterization of the sea-ice cover into categories like 'no sea-ice', discontinuous sea-ice' and 'continuous sea-ice'.

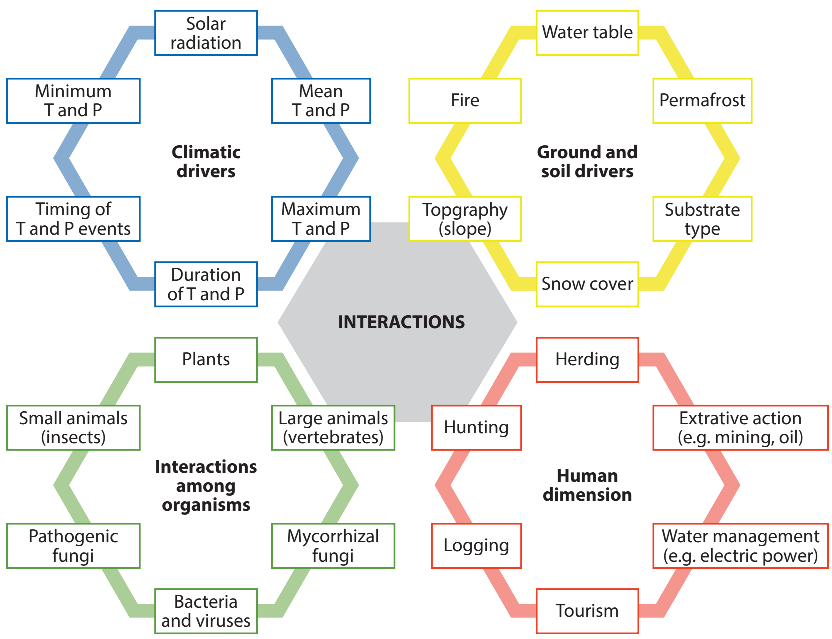
This case illustrates many of the dilemmas being involved in establishing monitoring programmes. When we initiate monitoring we do not exactly know when and where the changes that we might want to observe will occur and as such we cannot foresee the exact value of the parameter that we decide to measure again and again. As a result, many funding agencies prioritize to give money to experimental research instead of long-term monitoring. This generally has an influence on the money and time that can be allocated to long-term monitoring, and as such, generally an influence on how advanced a monitoring programme we can design. Further, by monitoring only a few environmental features we might be able to see some change but at the same time we might not be able to explain what the cause of the change was or how the change will affect other parts of the environment. For this purpose we need much more extensive monitoring programmes looking at entire ecosystems and normally with at least several hundred parameters being measured. To maintain such more extensive monitoring programmes, permanent staff (not necessarily at the station all year) with different skills and scientific backgrounds is needed, and accordingly the costs will rise and so will the vulnerability in relation to the chance of long-term financing. It is therefore not trivial to design a monitoring programme, and an early consideration should be on how much money it will be realistic to have allocated for the monitoring on a longer term (>10 years).

There are only a few arctic examples of very extensive monitoring programmes allowing for studies of natural changes to entire ecosystems as a result of e.g. environmental changes like Global Warming. The best known is probably the Greenland Ecosystem Monitoring programme (GEM) which has two study sites in Greenland at which a total of 3,500 ecosystem parameters are being measured at each site and at regular intervals. The costs for running GEM are close to three million euro per year, and as such it is way beyond the opportunity for many research stations to implement such a monitoring programme.

However, monitoring programmes being less extensive than GEM are of course much easier to have financed and could still provide information being of great importance and provide valuable information for circumarctic/regional assessments to the research community visiting the station and to the local community. The challenge is to design a monitoring programme being of relevance to most stakeholders within the budget being allocated, and at the same time being possible to maintain over a longer period (>10 years).

It is recommended for any research station to be able to provide some kind of baseline information to visiting scientists – and the community. Without such information, the visiting scientists will first of all, during the experiment design, have difficulties in deciding on whether the station is applicable for their research, and later they will have difficulties in placing the results of their research in a temporal, spatial and environmental context. Without at least a minimum knowledge of climate variability in space and time most environmental science does not make sense. Accordingly, all research stations need some kind of monitoring either being carried out as an in-house activity or with data being collected from external sources, for example a national network of weather stations.

Monitoring programmes should provide background information that can be used to analyse other types of research and monitoring data. Here an example of influences on arctic wildlife, of which several could be covered by a monitoring programme [1].



Toolik Field Station, USA, is hosting one of the most comprehensive monitoring programmes in the Arctic
(Syndonia Bret-Harte).

Most research stations maintain some kind of long-term monitoring as part of the normal run of the station. The amount of parameters being monitored does however vary a lot between stations. While some stations only maintain a climate station with a few sensors, other stations run inter-disciplinary long-term monitoring of entire ecosystems (like Greenland Ecosystem Monitoring) with several hundred or even thousands of different parameters being measured as an integrated part of the station operation.

There are also large differences in how the monitoring is being funded and for what purpose the results are being produced. At some stations, a base line monitoring is being maintained on a more or less volunteer basis by scientists working at the station. Such monitoring programmes are often characterized as being focused on very specific scientific subjects depending on the personal interest of the scientists maintaining the programme. At other research stations the monitoring is carried out mainly by the station as a service for visiting scientists and to provide data being relevant for many scientists, for example climate measurements. Such monitoring programmes are usually financed through the running budget of the station. Finally, some stations host long-term monitoring/research programmes that vary in extent, level of inter-disciplinarity and coordination, being funded by external sources with the purpose of producing knowledge on the state of the environment for different stakeholders, i.e. typically the scientific community, the political administrative system and other decision makers, and the local community.

The INTERACT Station Managers Forum consists of leaders of very different arctic and northern alpine research stations varying from small stations being manned by only one part-time person to larger research stations being permanently staffed with more than ten people to take care of station operation and long-term in-house monitoring. Further, the group consists of people having very different scientific background within the fields of biology, physical geography and atmospheric chemistry or having an administrative/technical background. As such the group is considered to include relevant expertise on prospects and consequences in relation to development and run of long-term environmental monitoring in the Arctic and in northern alpine regions. Accordingly, it was decided to have the group giving recommendations on how to establish a sustainable long-term monitoring programme – a so called 'INTERACT Minimum Monitoring Programme'.

Most research stations operate or provide access to data from a nearby climate station, and as such most research stations could claim that they carry out a minimum monitoring programme. However, with the discussions of a general design for an 'INTERACT Minimum Monitoring Programme' in the INTERACT Station Managers Forum we wanted to proceed a bit beyond the pure registration of climate. It is the experience in the group that at least the visiting scientists and surrounding community need and can make use of a bit more information like e.g. snow distribution, water and energy balance, plant community distribution and phenology, fauna distribution and phenology, bio-geochemistry (especially in relation to carbon balance), air quality and land-use. As a result the group of INTERACT station managers decided to design an 'INTERACT Minimum Monitoring Programme' focusing on the following subjects:

- Climate monitoring.
- Spatial background information.
- Hydrological monitoring.
- Physical landscape monitoring.
- Vegetation monitoring.
- Fauna monitoring.
- Bio-geochemical monitoring.
- Atmospheric chemistry and pollution monitoring.
- Land-use monitoring.

The sections below will for each subject describe the recommendations given by the INTERACT Station Managers Forum, and the chapter will conclude with a section describing the 'INTERACT Minimum Monitoring Programme'. Most of the subjects of relevance to establishing long-term monitoring relates to establishing long time series on different ecosystem parameters. However, spatial information, like e.g. topographic maps and maps of geology, soils, vegetation, snow cover and permafrost, is also part of the information that could be important for visiting scientists and the community, and accordingly the section 'Spatial information' will address what kind of spatial information should as a minimum be made available by the research station.

Bringing in external experts can help stations develop monitoring programmes building on international standards and best practices. Here at Zackenberg Research Station, Greenland (Morten Rasch).

1

Climate monitoring

Most landscape and ecosystem function and processes are in some way related to climate/weather. The only way to provide climate data from a specific area is by operating a climate station for a longer period. This is only rarely possible for scientists visiting a research station on a project basis, and it is therefore absolutely mandatory for a research station to be able to provide climate and weather data to the visiting scientists either from one or more climate stations operated by the research station or by providing data from a nearby climate station operated by others (e.g. national weather service). Climate stations operated by national weather services do normally only register climate parameters being relevant for weather forecasting. Consequently, it is desirable that the research station operates its own climate station to allow for the most relevant sensor configuration. A climate station operated by INTERACT research stations should at least have the following sensors at 2 m above terrain:

- Air temperature.
- Air humidity.
- Wind velocity.
- Wind direction.
- Air pressure.
- Precipitation.
- Short wave incoming radiation.
- Short wave outgoing radiation.
- Net radiation.
- UV-B radiation.

It is recommended to duplicate at least the air temperature, air humidity, wind velocity and wind direction sensors to reduce the chance of missing data due to sensor failure. It could further be considered to supplement the measurements at 2 m above terrain with measurements of at least air temperature, air humidity, wind velocity and wind direction at a higher elevation above terrain (7.5 or 10 m above terrain).

Climate monitoring tower at Station Hintereis, Austria (Christin Wild).

It could further be considered to supplement the sensors listed above with sensors for:

- Snow depth.
- Soil temperature (at different depths).
- Soil humidity (at different depths).

Climate stations with a configuration as suggested above are provided commercially by different companies. They are normally easy to install even without experience. It is however still recommended to acquire technical assistance when installing the equipment. Further, it is recommended to carefully consider and, if necessary, seek advice on where to place the climate station (in relation to buildings, local weather conditions, etc.).

The INTERACT-ICOS Energy Balance Station at Zackenberg Research Station, Greenland (Christian Stiegler).

'The INTERACT-ICOS Energy Balance Station'
INTERACT has in cooperation with the Integrated Carbon Observation System (ICOS) and by recommendation from the international climate modeller community developed a climate station suitable for measurements of energy balance, i.e. 'The INTERACT-ICOS Energy Balance Station'. This type of climate station is now installed at ten localities in the Arctic and as such it is considered a standard for energy balance measurements. The INTERACT-ICOS Energy Balance Station is a bit more expensive than the more normal climate stations mentioned above mainly due to a more expensive wind velocity and direction sensor (a so-called sonic anemometer). However, by using this system for climate measurements, research stations will be able to provide exactly the data needed by the climate modeller community, and the research stations will further secure a direct comparability between the data they are measuring and data being provided by other research stations with a similar climate station. Further, the station can relatively easy be upgraded to also measure the exchange of different gasses, for example CO_2 and CH_4, between the ground and the atmosphere, so-called eddy co-variance measurements (see section on *Bio-geochemical monitoring*). This kind of climate station is, with or without the suggested extra sensors, the ideal climate station for INTERACT research stations. However, due to the more advanced configuration compared to other climate stations, it is a more expensive solution, it demands a more experienced staff for the operation, and it is more sensitive in relation to sensor failure. Further information and specifications concerning the INTERACT-ICOS Energy Balance Station and contacts can be found on the INTERACT website (www.eu-interact.org/joint-research-activities/feedback-mechanisms).

Spatial background information

Good maps or other spatial information is absolutely necessary for most scientists visiting a research station. While some maps need to be updated at regular intervals due to changes of the spatial distribution of the features being the theme of the maps, other maps does not need such maintenance. Update of maps showing themes being subject to changing spatial distribution can be considered monitoring. For example, an update of a vegetation map at regular intervals will allow for long-term research on e.g. vegetation adaptation to Climate Change.

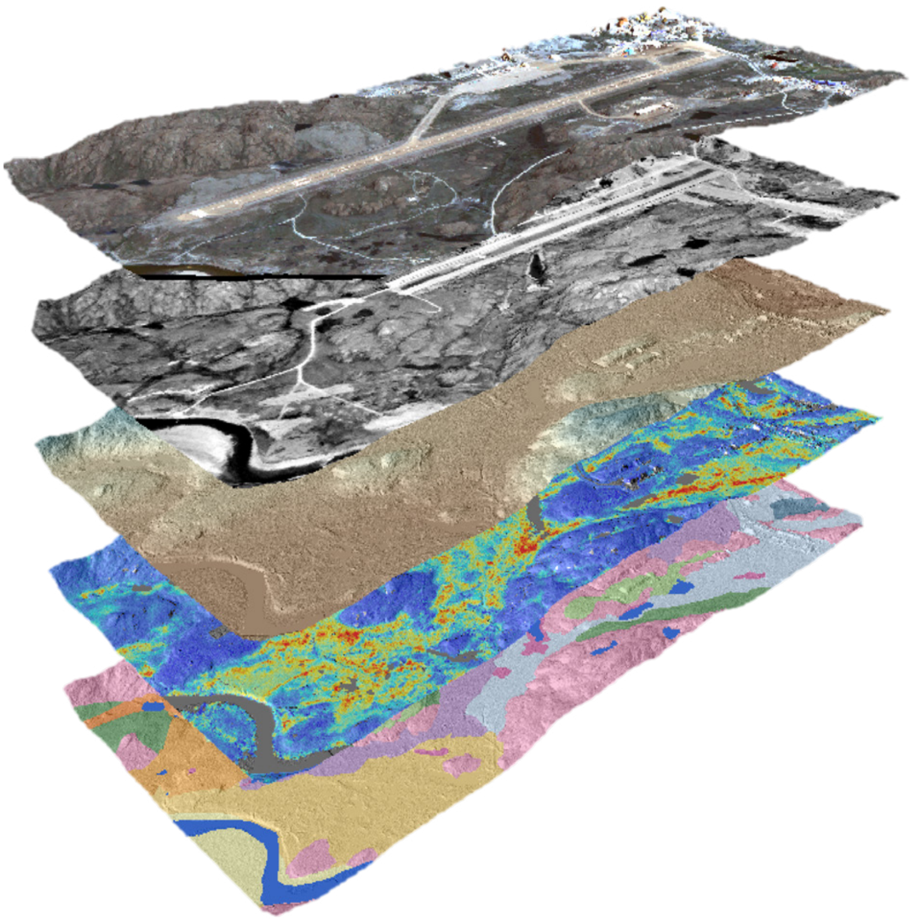
The following spatial information for the study area should as a minimum be made available for scientists visiting the station:

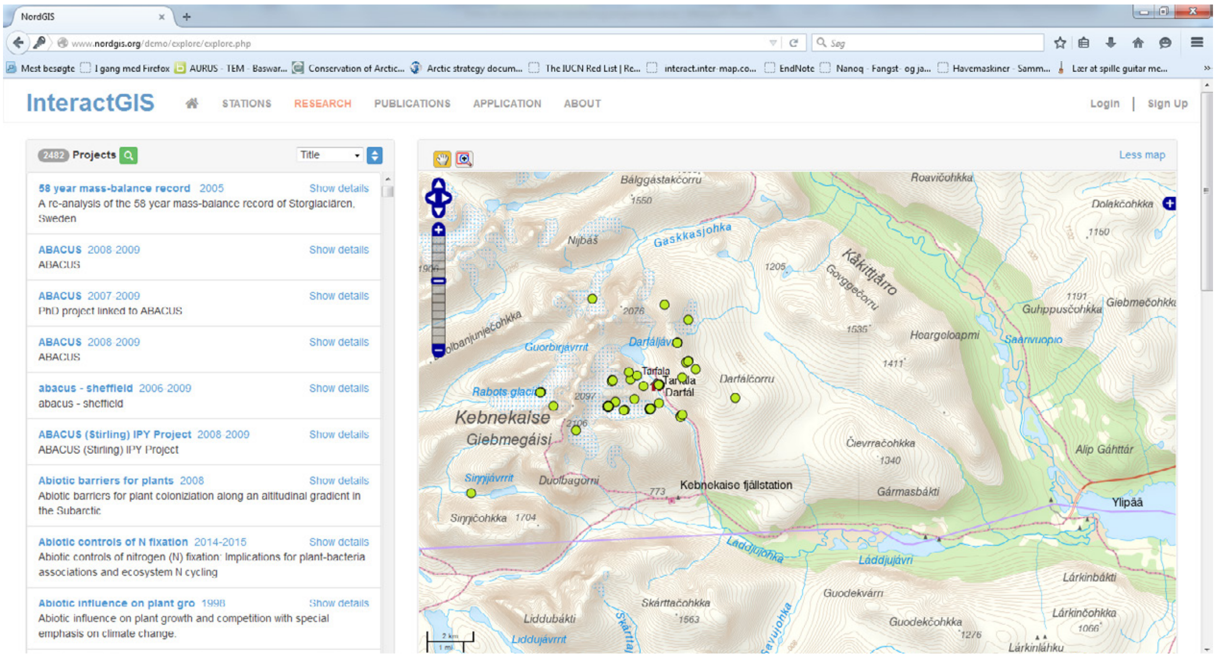
- A digital elevation model, with at least topography, infrastructure and waterbodies as themes.
- Most recent topographic maps or a collection of maps being made over the years.
- Geological maps.
- Most recent satellite images, aerial photographs or ortho-photos.

Further it is recommended that the research station if possible can provide the following spatial information:

- A vegetation map or a collection of vegetation maps being made over the years.
- A soil map or a collection of soil maps being made over the year.
- False-colour aerial photographs and/or multispectral satellite images.

Example of geoscience mapping used to create detailed maps with information on geology, slope, drainage, etc. of the area around the CEN Salluit Research Station, Canada (Emannuel L'Hérault).





Online access to georeferenced background maps can be used in research planning, for landscape monitoring purposes and analysis of other data. Here elevation map around Tarfala Research Station also showing lakes, rivers and glaciers, as well as the location of research activities.

Hydrological monitoring

Much of the research addressing issues on a 'landscape scale' use drainage basins as the landscape unit being investigated. This is due to the fact, that river drainage basins are relatively confined systems allowing for establishment of 'balances' of what comes in and what goes out, e.g. water balance and carbon balance. If a research station is situated near a river it is therefore recommended that a relevant drainage basin is selected as study area for landscape scale research, and that the research station install relevant instrumentation that is needed for long-term monitoring of the drainage basin.

As a minimum, the drainage basin should be instrumented with either automatic sensors or manual measurements of:

- Precipitation.
- River water discharge.
- pH and conductivity.

The basic measurements mentioned above can all be made with automatic instrumentation, though manual measurements of river water discharge are needed to establish a so-called Q/h relation between river water level ('h', normally being the parameter being measured automatically), and river water discharge ('Q'). Hydrological stations with a configuration as suggested above are provided commercially by different companies.

Such, hydrological stations are relatively easy to install. However, before installation due consideration should be made concerning the most appropriate site for installation of the hydrological station. Preferably, the hydrological station should be placed down-stream of an appropriate drainage basin which should be neither too large (making it difficult to get around and make ground measurements being representative for the system) nor too small (not being representative for the

Hydrological monitoring at Avachinsky Volcano Field Station, Russia
(Georg Romanescu).

landscape diversity in the area under investigation). For practical reasons, it will often be desirable to locate the hydrological station near a bridge to allow for easy installation of sensors (e.g. mounting them on the bridge) and to allow for easy access to the hydrological station (for maintenance, data download, etc.).

It could further be considered to supplement the hydrological monitoring suggested above with monitoring of:

- Suspended sediment transport.
- Organic matter transport.
- Solute transport.

Suspended sediment transport can be measured semi-automatically with different sensors, though manual laboratory measurements from selected water samples will give more precise results. For measurements of organic matter transport and solute transport, laboratory analysis on water samples are recommended but also very time consuming.

Physical landscape monitoring

Physical landscape monitoring is the monitoring of landscape features (geomorphology) and processes, and the monitoring of physical features, like snow cover, and its spatial distribution. It includes monitoring of snow cover, periglacial geomorphology, glacial geomorphology, fluvial geomorphology and coastal geomorphology.

Change of geomorphology is generally a slow process, and as such most geomorphological monitoring demands a long time scale for observation of change. However, landscape changes can and will occasionally occur faster than what has

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Ground penetrating radar can be used to investigate snow depthi. Here applied at Tarfala Research Station, Sweden (Gunhild Rosqvist).

Snow cover monitoring at Research Station Samoylov Island, Russia (Thomas Opel).

been the norm (in the future probably more often due to Climate Change and due to the resulting larger probability of so-called extreme events). Examples of such very fast geomorphological changes could be (i) coastal cliff recession due to increased wave exposure resulting from melt of sea-ice, (ii) changes of glacial landscapes due to fast glacier recession resulting from warming, (iii) changes of river bed configuration due to extreme flooding events or (iv) melting permafrost. It is important that station staff is aware of such fast changes in geomorphology and register them once they happen. Even very limited information, like recurrent photographs taken during the events, might be of great value to geomorphologists not being able to be on site continuously.

To design a full monitoring set-up for the physical landscape is a huge task, and for most research stations this would not make sense. However, it is recommended to monitor the following:

- Active layer depth.
- Snow cover.
- Fast landscape changes – when they occur.

Measurements of active layer depth, i.e. the thickness of the soil layer thawing each summer, has been standardized by International Permafrost Association in the so called CALM programme (Circumpolar Active Layer Monitoring). Normally, measurements are carried out in 100 X 100 m grids with a distance of ten meters between each measuring point (which gives a total of 121 measuring points). Measurements can either be made at regular intervals during the summer to establish a time series of the seasonal

Active layer monitoring at Abisko Scientific Research Station, Sweden
(Jonas Åkerman).

thawing, or it can be limited to one measurement per year of the so-called Maximum Active Layer Depth, i.e. the depth of the active layer just before the mean daily air temperature passes below freezing point. Manuals for the CALM measurements are available on the homepage of International Permafrost Association (www.gwu.edu/~calm/research/measurements.html).

Snow cover controls much of the functioning of arctic ecosystems. However, it is not an easy task to monitor snow cover. It can be done by automatic processing of either recurrent satellite images or recurrent normal digital photographs being taken with cameras situated in the research area. However, before the registration of the snow cover can occur, this type of pictures needs to be transferred into ortho-photos, and then advanced software will be needed to identify what is snow covered surfaces and what is snow free surfaces. An automatic system for carrying out such processing has been developed at Zackenberg Research Station for digital photographs taken by cameras situated at high altitudes within the study area (typically on mountain tops or along mountain sides). Further information about this type of snow cover monitoring is available in the GeoBasis manual on the website for Zackenberg Research Station (www.zackenberg.dk).

For research stations not having the staff and resources to implement the very sophisticated snow cover monitoring described above, a simpler monitoring of snow cover could be chosen. A very simple snow cover monitoring, still having some value for visiting scientists and community, could be to make daily visual observations of snow cover in a well-defined area and using e.g. the categories 'No snow', 'Discontinuous snow cover' and 'Continuous snow cover'.

Vegetation monitoring

In relation to climate warming it is important to have base-line studies of vegetation at different scales, from landscape scale and down to plot or even species scale. While plot scale studies can reveal changes in the phenology at species and vegetation zone scale, studies at a landscape scale can reveal changes in vegetation zoning. Both issues are important for the understanding of vegetation as a component in ecosystems under change. It is recommended that research stations as a minimum carry out the following monitoring on vegetation:

- Phenology of characteristic species in relevant characteristic vegetation zones.
- Recurrent photography of vegetation on both plot scale and landscape scale using either conventional digital cameras, special 'false colour' cameras or satellite images
- Mapping of vegetation zones at regular intervals either in vegetation maps or along altitudinal transects

It is further recommended that research stations maintain lists of plant species occurring in its nearest vicinity with some kind of indication of abundance. Such lists should be kept updated at regular intervals to also include new and potentially invasive species.

If the station staff includes botanists, it could further be considered to supplement the very simple monitoring suggested above with:

- The ITEX long-term manipulation programme, http://ibis.geog.ubc.ca/itex.
- The GLORIA vegetation monitoring programme, www.gloria.ac.at.
- Monitoring of grazing or browsing effects on vegetation.
- Dendrochronological studies on trees and shrubs, e.g. Shrub Hub, http://shrubhub.biology.ualberta.ca.

Further information on vegetation monitoring is available for the very extensive biological monitoring sub-programme BioBasis under Greenland Ecosystem Monitoring. Manuals for the BioBasis monitoring sub-programme are available on www.zackenberg.dk. The ITEX and the GLORIA vegetation monitoring programmes are described in details on the web-pages of the two organisations on respectively http://ibis.geog.ubc.ca/itex and www.gloria.ac.at.

Vegetation monitoring at Kluane Lake Research Station, Canada (David Hik).

Vegetation monitoring at Alpine Research and Education Station Furka, Switzerland (Christian Körner).

Mapping of vegetation and development and maintenance of species list require skilled staff and so does establishment of long-term botanical monitoring programmes – like the ITEX programme and the GLORIA programme. However, once established, the monitoring can be maintained by less experienced staff, like e.g. biology students or locals with a general interest in botany. If even such staff is not available at the research stations, it will still be worth as a minimum to establish vegetation plots and to do recurrent photography of these for later use as a mean for phenology studies.

Fauna monitoring

Monitoring of fauna generally requires skilled staff with zoological competences, and making observations of e.g. species phenology and distribution is generally very time consuming and dependent on many hours of field work. However, a few observations can be made pretty easily by staff being less specialised. Many research stations also maintain lists of casual fauna observations made by staff and visiting scientists during their time in the field. This is a good and very inexpensive mean for procuring lists of species being typical for the area. Observations should include the following information: 'Species', 'Number', 'Time' (day and time), 'Position' (GPS coordinates), 'Observer' (name).

The following minimum of observations is suggested:

- Species lists for mammals, birds and other taxonomic groups that can be identified by station staff or visiting scientists.
- First observation during the season of different bird species regularly migrating to or through the area.
- First observation during the season of regularly occurring breeding species (if any).

If the station staff includes zoologists, it could further be considered to supplement the very simple monitoring suggested above with:

- Track transects for counting of mammal and bird species characteristic to the area.
- Trapping of arthropods to allow for establishing lists of occurrence at different taxonomic levels.

Field observation of the resident fauna at Zackenberg Research Station, Greenland (Lars Holst Hansen).

Monitoring of freshwater fauna at Oulanka Research Station, Finland (Pirkko Siikamäki).

Barnacle goose monitoring at Netherlands' Arctic Station, Svalbard (Maarten Loonen).

Extensive descriptions on how to monitor fauna are given in the manual for the Greenland Ecosystem Monitoring BioBasis programme at Zackenberg being available on www.zackenberg.dk.

Bio-geochemical monitoring

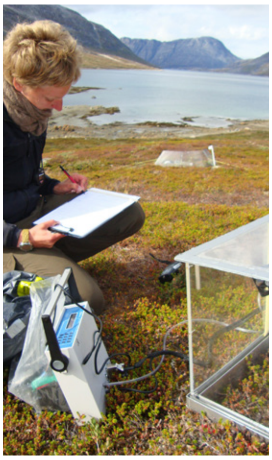
Maintaining a bio-geochemistry monitoring programme is not an easy task. It demands specialized instrumentation which is generally not trivial to operate, and it demands advanced data processing and at least some kind of laboratory work. However, the understanding of carbon balance and the mechanisms controlling carbon balance are important tasks in international polar research, and there is a general lack, at least in some parts of the Arctic, of long time series of especially CO_2, CH_4 and N_2O exchange between the tundra and the atmosphere. It is therefore recommended that INTERACT stations having the relevant staff and means prioritize at least some kind of bio-geochemical monitoring. Highest priority should be given to monitoring of:

- General nutrient levels in soils.
- Carbon balance/flux.

Monitoring of the general level of nutrients in soils should cover different vegetation zones being representative for the area in which the research station is situated, and the monitoring should be carried out at regular intervals. A more thorough description of how to establish and maintain monitoring of nutrient levels in soils is given in the manual for the GeoBasis sub-programme of Greenland Ecosystem Monitoring on www.zackenberg.dk.

Many different means for measuring the exchange of greenhouse gasses between the tundra and the atmosphere exist, either on plot scale or landscape scale. For a minimum monitoring programme it is recommended to carry out measurements

Bio-geochemical flux-measurements in the Kobbefjord area near Greenland Institute of Natural Resources, Greenland (Bula Larsen).



on a landscape scale of the CO_2 balance based on the so-called eddy co-variance technique. The instrumentation consists of a small climate station equipped with a few climate sensors, including a sonic anemometer for measurements of turbulence, and a so-called a Li-COR instrument for measurements of CO_2 concentrations. The system is described in details in the manual for the GeoBasis sub-programme of Greenland Ecosystem Monitoring on www.zackenberg.dk. It is strongly recommended to consult with people having experience with this kind of measurements before deciding on instrumentation, study site, etc. The instrumentation used for eddy co-variance measurements of the CO_2 balance can easily be attached to the 'INTERACT-ICOS Energy Balance Station' described in the section on Climate Monitoring. Before doing so, it should however be considered, if the energy balance station is situated in an area being feasible for measurements of CO_2 balance on a landscape scale – CO_2 balance measurements with the eddy co-variance method should be made in a relatively horizontal area with homogenous vegetation and a distance to infrastructure and other vegetation zones of at least 500 meters.

More information can also be found on the websites for the Integrated Carbon Observing System (ICOS), www.icos-infrastructure.eu and the Integrated non-Carbon Greenhouse gas Observing System (InGOS), www.ingos-infrastructure.eu.

Atmospheric chemistry and pollution monitoring

The ecosystem surfaces are at all times in exchange with the atmosphere. Compounds are deposited and emitted. These processes determine the load of pollutants and the geochemical cycle. Deposition can proceed either via dry deposition of gasses and particles or via wet deposition via wash out compounds by precipitation. It is a large challenge to determine these processes especially in the Arctic. Dry deposition can however be determined by micrometeorological methods (eddy correlation or gradient methods) but it demand a lot of man power. Alternatively, the atmospheric concentrations can be measured and the load to the surface calculated based on simple considerations of deposition velocities and mixing layer height etc. The load to the surface can thereafter be checked by collection of samples.

A flux station measuring greenhouse gas and energy exchange between land and atmosphere near Abisko Scientific Research Station, Sweden (Mathilde Jammet).

Advanced atmospheric measuring station, Pallas-Sodankylä Research Station, Finland
(Riika Ylitalo).

It is recommended to make a prioritised programme with low cost activities being most highly prioritized. Such a prioritised list of air-quality measurements is suggested to include:

- Black carbon.
- Heavy metals and nutrient salts.
- Old Persistent Organic Pollutants.
- Heavy metals in snow.
- Persistent Organic Pollutants in snow.
- Elemental mercury in air.
- Carbon monoxide.
- NOx.
- Ozone.

Measurements of air quality generally demands advanced instrumentation and skilled staff, and monitoring of air quality is generally a bit beyond the scope of INTERACT, being a network mainly focusing on terrestrial ecosystems. However, the INTERACT secretariat can help putting researchers and research stations in contact with specialists to advice on air quality monitoring if needed (see the section 'Further information').

Additional information can be found on the website of Arctic Monitoring and Assessment Programme, www.amap.no.

Land-use monitoring

Most arctic research stations are situated in rather remote arctic areas with limited commercial use of the land. However, use of land for forestry, agriculture and pasture occur in the more boreal situated research stations, and near some research stations the land is also used for hunting and different industry and mining activities. It is considered beyond the scope of the research stations to monitor the use of land and changes in land-use outside the study area. This use of land is normally being overseen by different public institutions, and research stations should at least know about the relevant institutions to contact for information and should at least hold all relevant maps as part of the spatial information being available for visiting scientists.

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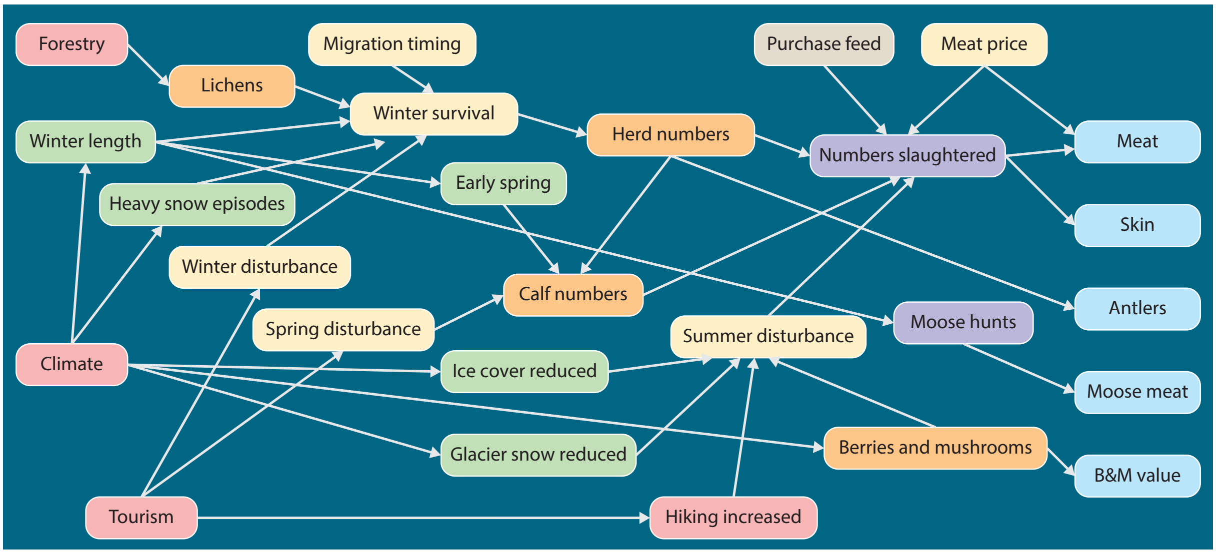
It is, however, essential that stations monitor their own land-use, to have historic records of activities. Especially important are records of reference areas or manipulative/extractive studies that may affect future research and monitoring efforts. Information on historic projects is also relevant for scientist when looking for geographical gaps or existing studies to build on. INTERACT has developed 'The INTERACT GIS', which is an online project management tool for research stations that allows capture of project metadata with spatial information on project activities (see www.eu-interact.org for more details and contact person).

It is recommended that INTERACT stations adopt the INTERACT GIS tool to monitor land-use within the station study area. An INTERACT minimum monitoring system should therefore include:

- Land-use and land-use changes of e.g. station facilities, infrastructure, instrumentation, projects, and where relevant local resource use.

Land-use mapping with local residents at CEN Salluit Research Station, Canada (Valérie Gratton).

Example of an ecosystem service assessment related to reindeer herding using a Bayesian Belief Network, Abisko Scientific Research Station, Sweden (Ron Smith).



1.2 The 'INTERACT Minimum Monitoring Programme'

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Based on the information given above INTERACT recommends that all research stations being part of INTERACT should strive towards having a monitoring programme with at least the following being observed and provided to station users (i.e. the scientific community and other stakeholders):

Climate monitoring

Sonnblick Observatory, Austria (Gernot Weyss).

The following parameters should be a part of the climate monitoring:

- Air temperature.
- Air humidity.
- Wind velocity.
- Wind direction.
- Air pressure.
- Precipitation.
- Short wave incoming radiation.
- Short wave outgoing radiation.
- Net radiation.
- UV-B radiation.

It should further be considered to measure the following parameters:

- Snow depth.
- Soil temperature (at different depths).
- Soil humidity (at different depths).

Ideally, INTERACT stations should operate an 'INTERACT-ICOS Energy Balance Station' either as a supplement to the stations main climate station or as its main climate station.

Spatial background information

CEN Whapmagoostui-Kuujjuarapik Research Station, Canada (Warvick F. Vincent).

The following spatial information for the study area should as a minimum be made available for scientists visiting the station:

- A digital elevation model, with at least topography, infrastructure and rivers as themes.
- Most recent topographic maps or a collection of maps being made over the years.
- Geological maps.
- Most recent satellite images, aerial photographs or ortho-photos.

It is further recommended that the following spatial information can be provided:

- A vegetation map or a collection of vegetation maps being made over the years.
- A soil map or a collection of soil maps being made over the year.
- False-colour aerial photographs and/or multispectral satellite images.

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Recurrent mapping of landscape features being subject to change in spatial distribution over time, e.g. vegetation, can be used as an integrated part of the stations monitoring programme.

Hydrological monitoring

Czech Arctic Research Station of Josef Svoboda, Svalbard (Jan Kavan).

If rivers occur in the vicinity of the station a well defined drainage system should be selected for monitoring (either with automatic sensors or manual measurements) of the following parameters:

- Precipitation.
- River water discharge.
- pH and conductivity.

It should further considered to measure the following parameters:

- Suspended sediment transport.
- Organic matter transport.
- Solute transport.

Physical landscape monitoring

International Ecological Educational Center "Istomino", Russia (Eduard Batotsyrenov).

The following physical landscape features should be included in the research station monitoring:

- Active layer depth.
- Snow cover.
- Fast landscape changes – when they occur.

Snow cover can be monitored at different levels of sophistication. However, a simple daily visual monitoring of the snow cover into the following categories: 'No snow', 'Discontinuous snow cover' and 'Continuous snow cover' should be possible to maintain at any research station.

Vegetation monitoring

Meinypil'gyno Community Based Biological Station, Russia (Anastasia Yakusheva).

It is recommended that research stations as a minimum carry out the following monitoring on vegetation:

- Phenology of characteristic species in characteristic vegetation zones, e.g. by maintaining monitoring of a few so-called 'ITEX control plots'.
- Recurrent photography of vegetation on both plot scale and landscape scale using either conventional digital cameras, special 'false colour' cameras or satellite images.
- Mapping of vegetation zones at regular intervals either in vegetation maps or along altitudinal transects.

It is further recommended that research stations maintain lists of plant species (including recurrent updates including new invasive species).

The monitoring suggested above could be supplemented with:

- The ITEX long-term manipulation programme.
- The GLORIA vegetation monitoring programme.
- Monitoring of grazing or browsing effects on vegetation.
- Dendrochronological studies on trees and shrubs.

Fauna monitoring

RIF Field Station, Iceland (Yann Kolbeinsson).

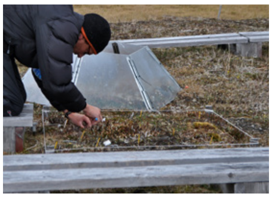
The following minimum of fauna monitoring is recommended:

- Species lists for mammals, birds and other taxonomic groups that can be identified by station staff or visiting scientists.
- First observation during the season of different bird species regularly migrating through the area.
- First observation during the season of regularly occurring breeding species (if any).

If the station staff includes zoologists, it could further be considered to supplement the monitoring with:

- Track transects for counting of mammal and bird species being normal in the area.
- Trapping of arthropods to allow for establishing lists of occurrence at different taxonomic levels.

Bio-geochemical monitoring



Barrow Arctic Research Center/ Barrow Environ-mental Observatory, USA (Jakub Hruška).

Bio-geochemical monitoring is not an easy task but requires trained staff, advanced instrumentation and laboratory facilities. However, if bio-geochemical monitoring is considered to be a realistic part of the station monitoring, priority should be given to monitoring of:

- General nutrient levels in soils.
- Carbon balance/flux.

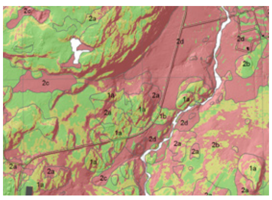
Atmospheric chemistry and pollution monitoring

Villum Research Station, Greenland (Morten Rasch).

Air quality monitoring is generally expensive and demands skilled staff. It is therefore recommended to make a prioritised programme with low cost activities being most highly prioritized. Such a prioritised list of air-quality measurements is suggested to include:

- Black carbon.
- Heavy metals and nutrient salts.
- Old Persistent Organic Pollutants.
- Heavy metals in snow.
- Persistent Organic Pollutants in snow.
- Elemental mercury in air.
- Carbon monoxide.
- NOx.
- Ozone.

Land-use monitoring



CEN Salluit Research Station, Canada [2].

Stations should at least keep track of land-use within their study area. The minimum INTERACT monitoring of land-use therefore includes:

- Monitor land-use in the study area by mapping e.g. station facilities, infrastructure, instrumentation, projects, and where relevant local resource use.

Research stations should also know about the relevant institutions to contact for information on land-use and should hold all relevant land-use maps as part of the spatial information being available for visiting scientists.

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Further information

The monitoring mentioned above is already in operation at many INTERACT research stations, and these stations will be willing to share their monitoring manuals with others. Accordingly, much information about sensors and methods can be found on the home pages of the different research stations.

Since Greenland Ecosystem Monitoring (GEM) is by far the most extensive ecosystem monitoring programme in the Arctic, it is strongly recommended to consult the GEM monitoring manuals before deciding on own instrumentation and methodologies. GEM is divided into five different sub-programmes, i.e. ClimateBasis, GeoBasis, BioBasis, MarineBasis and GlacioBasis, each having their own manuals. Updated versions of the manuals for the most extensive GEM monitoring site, i.e. Zackenberg Research Station in Northeast Greenland, are available on www.zackenberg.dk.

Circumarctic monitoring networks, like ITEX, IPA-CALM, GLORIA, etc., provide manuals on their respective websites (see also Chapter 2) for short descriptions of selected scientific networks with standardised monitoring protocols). You may also find relevant information on the INTERACT website in relation to Joint Research Activities, e.g. the INTERACT-ICOS Energy Balance Station and the INTERACT GIS.

The INTERACT Secretariat can provide advice on who to contact on specific issues and up to date contact information is available on www.eu-interact.org.

2 Best pratice for monitoring

– a description of existing scientific networks with best practices

Toolik Field Station, USA (Elmer Topp-Jørgensen).

2

This section presents a selection of best practice descriptions for monitoring the natural environment (both biotic and abiotic parameters) and anthropogenic stressors. It is meant as inspiration for station managers developing or revising existing long-term monitoring programmes at their station.

The scientific networks described in this section were selected by INTERACT station managers based on discussions of criteria for selection and desired scientific fields. The networks represent disciplines within the bio-science, geo-science, climate related sciences and glaciological science.

While the networks, programmes and projects we describe here have been selected to cover many scientific disciplines, there are undoubtedly additional relevant initiatives, as well as a number of regional/national monitoring activities that can be inspiring for stations managers. We therefore recommend that station managers also explore science agendas of the many other entities involved in arctic research and monitoring, e.g.: ICARP, IASC, ISAC, GEOSS, SAON as well as regional and national initiatives.

Many INTERACT stations also make their monitoring protocols available on their websites. Websites and contact information for INTERACT stations can be found on the INTERACT website www.eu-interact.org/field-sites.

The networks' descriptions include:

Disciplines:	The disciplines covered by the network.
Keywords:	Selected keywords describing the network.
Description:	A brief description of the network and its objectives.
Suitable sites:	Describing ecosystem types or features that are required for implementing network protocols.
Parameters:	Listing parameters or parameter groups that are monitored by the network.
Methodology:	Brief description of applied methodologies and instrumentation and/or link to protocols.
How to become involved:	Describing how to get involved and/or the contact information where one can get additional information on how to join the network.
Geographical coverage:	Describing or showing on a map the general geographical coverage of the network.

2

Polish Polar Station Hornsund, Svalbard (Marek Szymocha).

2.1 WMO

World Meteorological Organisation

Website: www.wmo.int
Contact address: www.wmo.int/pages/contact/form_en.php

Disciplines: Climatology and Climate Change, Hydrology.

Keywords: Weather, Climate Change, Atmosphere.

2

Description: The World Meteorological Organization (WMO) is a specialized agency of the United Nations. It is the UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources. WMO has a number of observing programmes centered around weather, climate and hydrology, e.g.:

Climate measuring station at Mukhrino Field Station, Russia (Nina Filippova).

World Weather Watch (WWW)

The World Weather Watch – the core of the WMO Programmes – combines observing systems, telecommunication facilities, and data-processing and forecasting centres – operated by Members – to make available meteorological and related environmental information needed to provide efficient services in all countries.
See: www.wmo.int/pages/prog/www/index_en.html.

Hydrology and Water Resource Programme (HWRP)

The Hydrology and Water Resources Programme (HWRP) is concerned with the assessment of the quantity and quality of water resources, both surface and groundwater, in order to meet the needs of society, to permit mitigation of water-related hazards, and to maintain or enhance the condition of the global environment.
See: www.wmo.int/pages/prog/hwrp/index_en.php.

World Climate Programme (WCP)

The scope of WCP is to determine the physical basis of the climate system that would allow increasingly skillful climate predictions and projections, develop operational structures to provide climate services and to develop and maintain an essential global observing system fully capable of meeting the climate information needs.
See: www.wmo.int/pages/prog/wcp/index_en.html.

WMO conducts or are involved in many other programmes and projects (e.g. World Climate research Programmes, www.wcrp-climate.org).
For a complete list see, www.wmo.int/pages/summary/progs_struct_en.html.

Suitable sites: All ecosystems.

Parameters: Monitored parameters depend on programme, but they are mostly centered around weather, climate and hydrology, see links above.

Methodology: Instrumentation and methodologies can be found under the individual programmes, see links above.

How to become involved: Identify relevant contact persons of the individual programmes, see links above.

Geographical coverage: Global.

2

Climate measurements from Polish Polar Station Hornsund, Svalbard (Adam Nawrot).

2.2 AMAP

Arctic Monitoring and Assessment Programme

2

Website: www.amap.no

Contact address: amap@amap.no

Disciplines: Climatology and Climate Change, Environmental Sciences – Pollution, Human biology, Terrestrial biology – Biodiversity.

Keywords: Integrated assessments, climate, pollution, human health, effects and impacts, status and trends of Arctic ecosystems, adaptation.

Description: AMAP is one of six working groups of the Arctic Council. AMAP is conceived as a process integrating both monitoring and assessment activities, in order to:

- Produce integrated assessment reports on the pollution and climate status and trends of the conditions of Arctic ecosystems.
- Identify possible causes for changing conditions.
- Detect emerging problems, their possible causes and the potential risk to Arctic ecosystems including indigenous peoples and other Arctic residents.
- Recommend actions required to reduce risks to Arctic ecosystems.

To prepare its assessments, AMAP:

- Designed and implemented a coordinated monitoring programme to monitor the levels of pollutants and climate variables and assess the effects of pollution in all compartments of the Arctic environment (the atmospheric, terrestrial, freshwater and marine environments and human populations). AMAP monitoring activities are based, to the greatest extent possible, on ongoing national and international monitoring and research; aiming to harmonize this work and where necessary, promote new activities to fill identified gaps in order to meet the AMAP objectives.
- Instituted an assessment process to produce assessment reports and other products. The AMAP assessments are performed according to agreed guidelines and are based on: (i) data and information already published in scientific literature, (ii) data and information obtained from AMAP's monitoring programme, and (iii) traditional knowledge.

Climate measuring station at Arctic Station, Greenland (Thomas Holst).

The AMAP Trends and Effects Monitoring Programme (ATEMP) is a harmonized programme for monitoring the status, trends and effects of contaminants, Climate Change and its impacts, and human health across the circumarctic region.

ATEMP is based largely on ongoing national and international monitoring and research activities and AMAP national implementation plans (NIPs). ATEMP is coordinated with and complements the Circumpolar Biodiversity Monitoring Program (CBMP), and both of these programmes contribute to the Sustaining Arctic Observing Networks (SAON) initiative.

The ATEMP is currently being updated and will include new recommended monitoring protocols.

AMAP conducts larger targeted assessments together with other major international organisations, e.g.:

- Adaptation Actions for a Changing Arctic (www.amap.no/adaptation-actions-for-a-changing-arctic-part-c).
- Trends in Stockholm Persistent Organic Pollutants (POPs) in Arctic Air, Human media and Biota (www.amap.no/documents/doc/Trends-in-Stockholm-Convention-Persistent-Organic-Pollutants-POPs-in-Arctic-Air-Human-media-and-Biota/1081).
- Arctic Ocean Acidification (www.amap.no/documents/doc/Arctic-Ocean-Acidification-2013-An-Overview/1061).
- Arctic Health Risks: Impacts on health in the Arctic and Europe owing to climate-induced changes in contaminant cycling, (www.arcrisk.eu).
- Snow, Water, Ice and Permafrost in the Arctic (SWIPA) (www.amap.no/swipa);
- Arctic Climate Impact Assessment (ACIA) (www.amap.no/arctic-climate-impact-assessment-acia).

Suitable sites: All stations within the AMAP focus area.

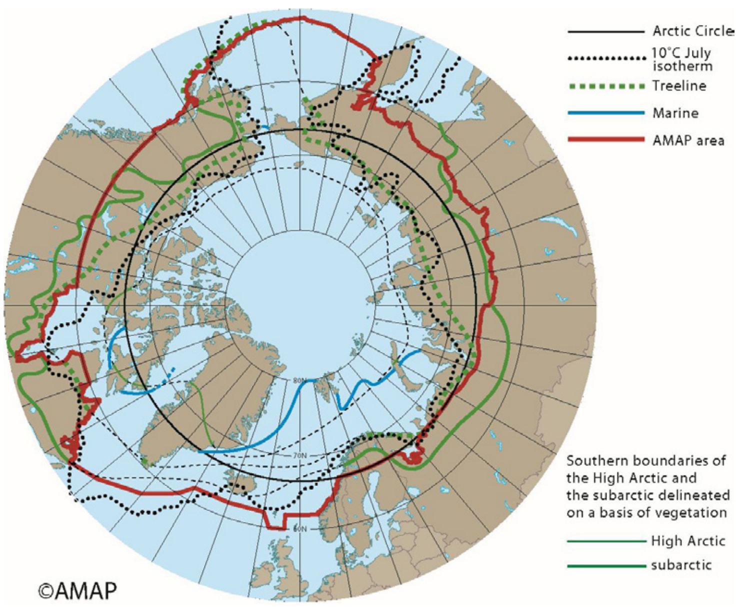
Parameters: A list of parameters to be monitored is under development. Parameters included in assessments depend on the subject, but generally, AMAP sample parameters related to pollution, environmental impact, human health and Climate Change.

Methodology: Detailed specifications of the recommended monitoring elements under the various sub-programmes of the ATEMP will be available soon, www.amap.no/about/the-amap-programme/amaps-monitoring-programme.

AMAP produces guidelines for laboratories providing input to AMAP assessments. An example is 'Guidelines for laboratories producing data for AMAP Human Health Studies' (www.amap.no/documents/doc/guidelines-for-laboratories-producing-data-for-amap-human-health-studies/1027).

How to become involved: Contact relevant national focal points through www.amap.no/contacts/search.

Geographical coverage: Arctic. Activities in all eight arctic countries.



The AMAP geographical boundary (AMAP).

2.3 CBMP

Circumpolar Biodiversity Monitoring Program

Website: www.caff.is/monitoring
Contact address: caff@caff.is

Disciplines: Terrestrial biology – Biodiversity,
Terrestrial biology – Ecosystem function.

Keywords: Biodiversity, Climate Change, Anthropogenic stressors, conservation, management.

Description: The Circumpolar Biodiversity Monitoring Program (CBMP) is the cornerstone programme of the Conservation of Arctic Flora and Fauna (CAFF), the Arctic Council's biodiversity working group. The CBMP is an international network of scientists, government agencies, indigenous organizations and conservation groups working together to harmonize and integrate efforts to monitor Arctic biodiversity and ecosystems.

The goal is to facilitate more rapid detection, communication and response to the significant biodiversity-related trends and pressures affecting the circumpolar world.

CBMP organizes its efforts around the major ecosystems of the Arctic. It coordinates marine, freshwater, terrestrial and coastal monitoring activities while establishing international linkages to global biodiversity initiatives. The CBMP emphasizes data management, capacity building, reporting, coordination and integration of Arctic monitoring, and communication, education and outreach.

CBMP ecosystem expert groups have developed Arctic Biodiversity Monitoring Plans as a framework to guide coordinated long-term monitoring across the Arctic's major ecosystems.

Suitable sites: Stations located within the CBMP arctic boundary (and associated catchment areas). The individual plans describe criteria for selection of sites.

The CAFF geographical boundary (CAFF).

Arctic Terrestrial Biodiversity Monitoring Plan

CBMP's Arctic Terrestrial Biodiversity Monitoring Plan is designed to provide a framework for the harmonization of existing Arctic monitoring data and coordination of future, long-term terrestrial ecosystem-based biodiversity monitoring.

The CBMP-Terrestrial Plan aims to address these priority management questions:

- What are the status, distribution, and conditions of terrestrial focal species, populations, communities, and landscapes/ecosystems and key processes/ functions occurring in the Arctic?
- How and where are these terrestrial focal species, populations, communities, and landscapes/ecosystems and key processes/functions changing?
- What and how are the primary environmental and anthropogenic drivers influencing changes in biodiversity and ecosystem function?
- Where are the areas of high ecological importance including, for example, resilient and vulnerable areas (related to the (related to the Focal Ecosystem Components (FECs)) and where are drivers having the greatest impact?

2

Parameters:

The Plan is structured around a set of FECs which are the targets of the monitoring effort, and their related attributes (characteristics) that serve as indicators of terrestrial biodiversity status and trends.

Four main terrestrial biotic groups were selected for systematic monitoring:

- Vegetation (including fungi).
- Invertebrates (including some arthropods with life stages in aquatic environments).
- Birds (resident and migratory).
- Mammals (resident and migratory).

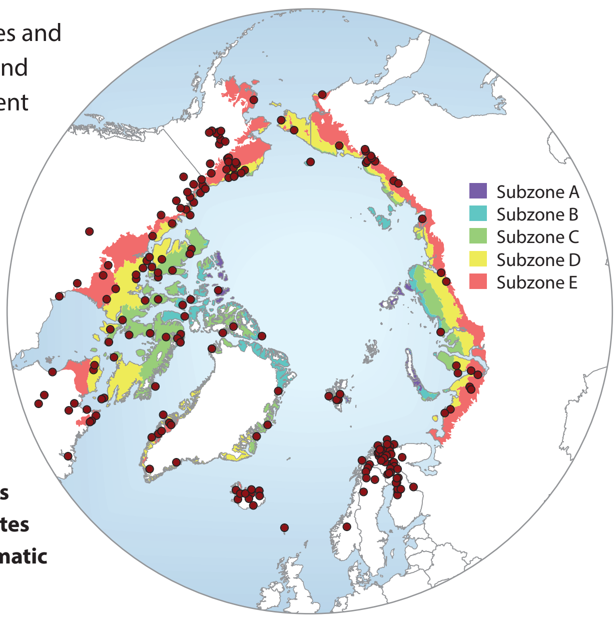
Methodology:

The framework of the CBMP-Terrestrial Plan was developed collaboratively by international participants with taxonomic, scientific, traditional knowledge and community-based expertise and related stakeholders and was focused around three consensus-based workshops. Best practices in monitoring design were used to develop a strategy that is efficient, practical and allows for participation along a range of capacity and across varying ecological conditions.

See the monitoring plan for further details: www.caff.is/publications/view_document/256-arctic-terrestrial-biodiversity-monitoring-plan.

Geographical coverage:

The plan includes terrestrial species and habitats in the Arctic, sub-Arctic, and high latitude alpine regions adjacent to and continuous to these environments.



Location of terrestrial long-term monitoring sites, programmes and infrastructure that can contribute to monitoring capacity as part of the CBMP-Terrestrial Plan. Sites are shown on a map of Arctic bioclimatic subzones (CAFF).

The Circumpolar Biodiversity Monitoring Program develop monitoring plans for terrestrial, freshwater, marine and coastal ecosystems (Christian Körner, Øivind Tøien, William Callaghan, José Gérin-Lajoie, Nikolay Yakushev, Christian Körner).

Arctic Freshwater Biodiversity Monitoring Plan

CBMP's Arctic Freshwater Biodiversity Monitoring Plan details the rationale and framework for improvements related to the monitoring of freshwaters of the circumpolar Arctic, including ponds, lakes, rivers and their tributaries and associated wetlands.

The primary objectives of the CBMP Freshwater Plan include:

- Identify relevant freshwater ecosystem components and indicators for freshwater ecosystems that are suitable for monitoring and assessment at the circumpolar level.
- Identify abiotic parameters that are relevant to freshwater biodiversity and need ongoing monitoring.
- Articulate detailed impact hypotheses that describe protocols and optimal sampling strategies for monitoring arctic freshwaters that draws on existing protocols and activities.
- Create a strategy for organisation of existing research and information (scientific, community-based and Traditional Ecological Knowledge) to evaluate current status and trends.
- Develop a process for undertaking periodic assessments of arctic freshwaters.
- Identify the financial support and institutional arrangements required to undertake such a programme.
- Give input to assessment of baselines and ecological change in Artic freshwaters.

Parameters:

The Freshwater Plan provides a recommended suite of Focal Ecosystem Components (FECs) and attributes for assessing the status and trends in biodiversity of Arctic lakes and rivers. FECs are biotic or abiotic elements, such as taxa or key abiotic processes, which are ecologically pivotal, charismatic and/or sensitive to changes in biodiversity. The CBMP Freshwater Plan describes criteria to select the parameters and indicators and includes aspects related to the following FECs:

- Fish (lakes and rivers).
- Benthic invertebrates (lakes and rivers).
- Zooplankton (lakes).
- Benthic algae (lakes and rivers).
- Phytoplankton (lakes).
- Macrophytes (lakes).

- Riparian vegetation (rivers).
- Water temperature regime (lakes and rivers).
- Hydrologic and ice regimes (lakes and rivers).
- Water quality (lakes and rivers).
- Climatic regime (lakes and rivers).
- Permafrost (lakes and rivers).

Methodology: The Freshwater Plan was developed collaboratively by freshwater experts from all participating countries and members of the Freshwater Expert Monitoring Group. It was based on a ranking of FECs in relation to ecosystem function and sensitivity to stressors, sampling feasibility and data availability.

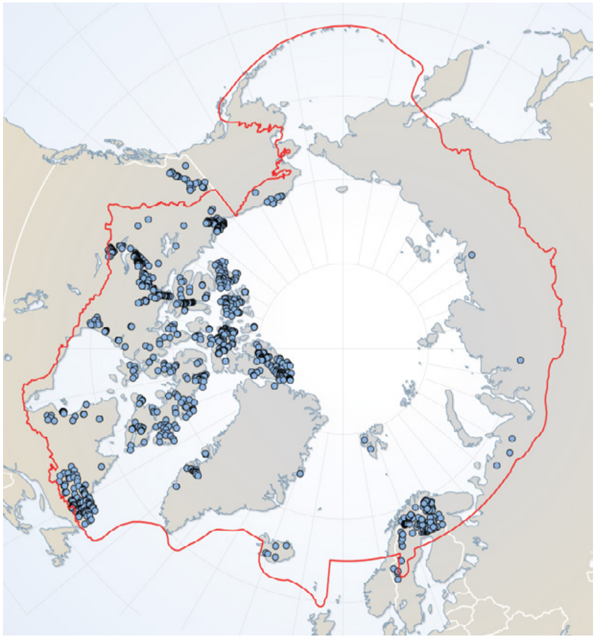
See the monitoring plan for further details: http://caff.is/monitoring-series/196-arctic-freshwater-biodiversity-monitoring-plan.

How to become involved: The Freshwater Plan identifies a set of criteria for the selection of preferable monitoring sites, namely, (i) sites with high-quality and long-term data sets, (ii) biodiversity hotspots, i.e., areas with high species richness or unique species composition (e.g. rare species) and high conservation value, (iii) medium to small river catchments and lakes to ensure effective sampling effort and representative species collection, and (iv) sites of high significance to local communities.

To become involved in CAFF's CBMP, please contact the applicable national representative from the Freshwater and/or Terrestrial Steering Groups. They can be found on the CBMP website: www.caff.is/monitoring. Alternatively, the CAFF Secretariat can help answer any questions and identify relevant national points of contact, caff@caff.is.

Geographical coverage: Arctic. Activities in all eight arctic countries.

Sites of existing river biotic and abiotic data in the CAFF designated zone. Points on the maps may represent more than one location (CAFF).



Sites of existing lake/pond biotic and abiotic data in the CAFF designated zone. Points on the maps may represent more than one location (CAFF).

2.4 ENV-Europe/ILTER

(International Long Term Ecological Research)

2

Website: www.enveurope.eu and www.ilternet.edu

Contact address: www.enveurope.eu/contacts

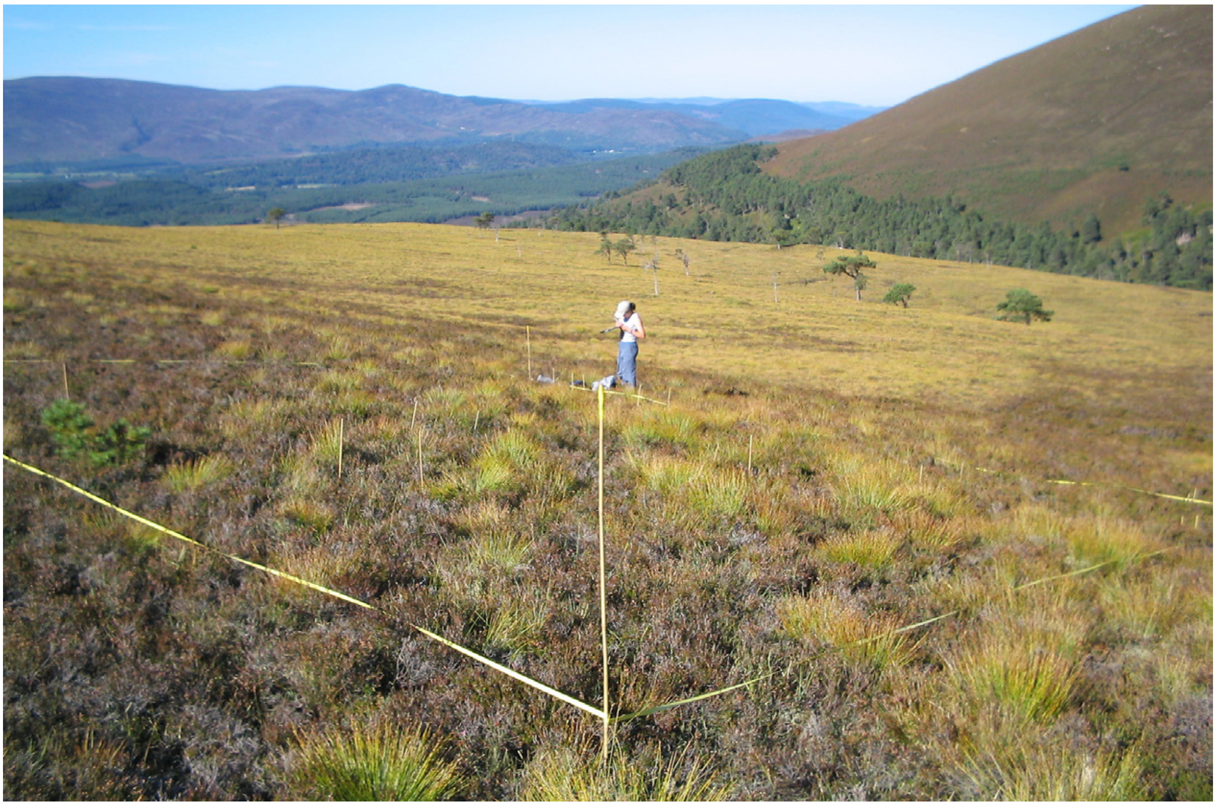
Disciplines: Climatology and Climate Change, Marine biology, Terrestrial biology – Biodiversity, Terrestrial biology – Ecosystem function.

Keywords: LTER, ecology, ecosystem, Climate Change.

Description: EnvEurope is a scheme for ecological research and monitoring based at the distributed network of LTER-Europe sites (Long Term Ecological Research – Europe). The key principles of the project are scientific knowledge, common information management and harmonization of parameters and methods at a European scale through a cross-domain approach.

The International Long Term Ecological Research (ILTER) is a global network of scientists engaged in long-term, site-based ecological and socio-economic research. The ILTER is composed of regional LTER networks, which again are divided into national LTER networks. Increased appreciation of the importance of long-term research in assessing and resolving complex environmental issues has led to a rapid expansion of the network that now includes more than 40 member networks.

LTER site at ECN Cairngorms, Scotland, UK (Jan Dick).



Suitable sites: Terrestrial, freshwater and marine ecosystems.

Parameters (EnvEurope)**:** Parameters have been selected to be:

- Biologically relevant (maintaining balanced communities).
- Providing univocal information.
- Broadly applicable to many sites and stressors.
- Integrative (biotic indicators).
- Interpretable: distinguishing "good from bad" states.
- Cost-effective: maximum information per unit effort.

Terrestrial sites

Vascular plants (incl. species/life form, abundance, structure and population dynamics), mosses (species and abundance), lichens (species and abundance), forest (dead wood, forest distribution, structure and demographics), birds (breeding and nesting), butterflies (species and abundance), soils (classification, density, composition, chemistry, temperature, moisture), atmosphere (air temperature, moisture, pressure, wind speed, atmospheric composition and radiation), biomass production, energy balance, fluxes, harvest volume and water (depth, level and runoff).

Rivers

Macrophytes and phytobenthos (abundance), macroinvertebrates (abundance), fish (species and abundance), invasive species (species and abundance), sediments (structure and composition), water (flow, temperature, conductivity, turbidity and chemistry), atmosphere (air temperature, moisture, pressure, wind speed), habitat (diversity and coverage), hydromorphology, Land-use (cover and change), biomass, energy balance and nutrients.

Lakes

Macrophytes (abundance and cover), phytoplankton (abundance), fauna (abundance), invasive species (species and abundance), sediments (structure, composition), water (temperature gradient, chemistry level and flow) nutrients, secchi depth, atmosphere (air temperature, moisture, pressure, wind speed), habitat (type and cover), land-use (cover and change), phytoplankton, chlorophyll, radiation, fluxes, nutrients, biomass, harvest level and primary production. For details, see methodology below.

Methodology (EnvEurope)**:** The manual presents harmonised methods for environmental indicators across different ecosystems. References for methodological descriptions are provided in the manual, www.enveurope.eu/misc/PD_A2.1.2ab_Frenzel_et_al-ManualHarmonisedMethods_Rev2_0.pdf

How to become involved: EnvEurope: Contact EnvEurope, www.enveurope.eu/contacts , or national sites (terrestrial, www.enveurope.eu/freshwater-sites/terrestrial-site or freshwater, www.enveurope.eu/terrestrial-site/freshwater-sites).

ILTER: Through national focal points. Criteria and procedures are described here, www.ilternet.edu/contacts.

Geographical coverage: ILTER: Global. 781 research sites. EnvEurope encompasses 67 LTER-Europe sites in 11 european countries.

2.5 GLORIA

Global Observation Research Initiative In Alpine Environments

Website: www.gloria.ac.at
Contact address: office@gloria.ac.at

Disciplines: Climatology and Climate Change, Terrestrial biology – Biodiversity, Terrestrial biology – Ecosystem function.

Keywords: Ecosystems, terrestrial biology, species diversity, vegetation, temperature, Climate Change.

Description: The aim of GLORIA's Multi-Summit approach is to establish and maintain a long-term observation network to obtain standardised data on alpine biodiversity and vegetation patterns on a global scale. Its purpose is to assess risks of biodiversity losses and the vulnerability of high mountain ecosystems under Climate Change pressures.

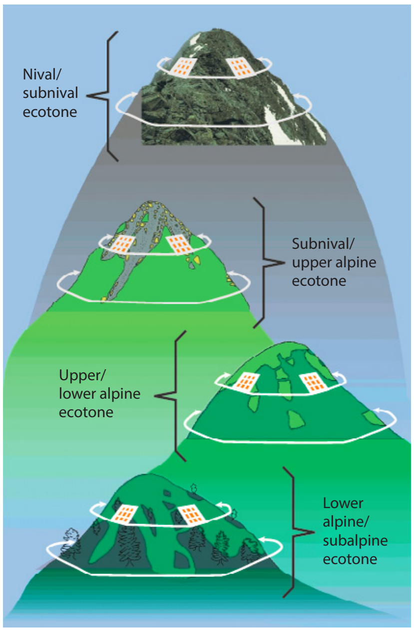
Therefore, the GLORIA Multi-Summit approach aims to:

- Provide standardised, quantitative data on (i) the altitudinal differences in species richness, (ii) species composition, (iii) vegetation cover, (iv) soil temperature and (v) snow cover period in mountain systems world-wide.
- Assess the potential risks for biodiversity losses due to Climate Change by comparing the current distribution patterns of species, vegetation and environmental factors along vertical and horizontal (biogeographical) gradients.
- Provide a baseline for the long-term monitoring and observation of species and vegetation to detect climate-induced changes of vegetation cover, species composition and species migration (at observation intervals of 5 to 10 years or even longer, if appropriate).
- Quantify the temporal changes of biodiversity and vegetation patterns for providing a substantial input to data-based scenarios on risks for biodiversity losses and on risks for ecosystem instability.

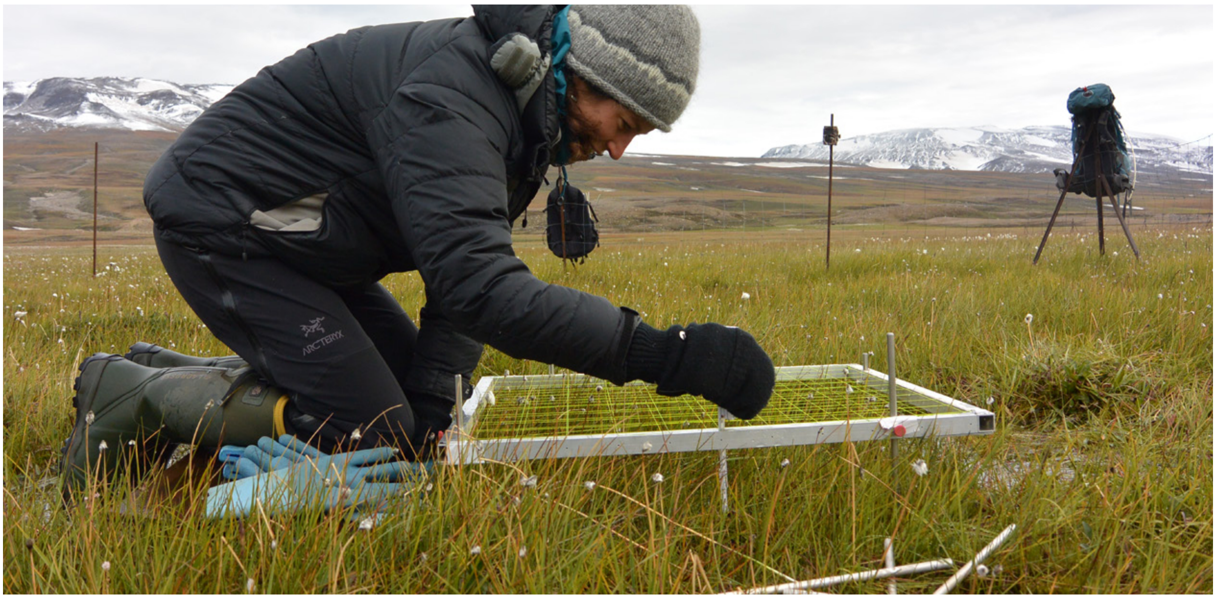
Suitable sites: A GLORIA target region (GLORIA multi-summit sites) should comprise a suite of at least four summits which represent an elevation gradient from the natural treeline ecotone (where applicable) up to the limits of (vascular) plant life, or in regions where these limits are not reached, up to the uppermost vegetation zone.

Sites should thus be in alpine environments with multiple summits. Summits need not be more that 20 elevation meters from surrounding landscape. Very steep summits and plateau like mountains are not applicable.

Site selection is described in detail in the Gloria Field manual – Multi-summit approach, www.gloria.ac.at/?a=10.



The Gloria Multi-Summit approach (Gloria).



Plant community composition studies at Zackenberg Research Station, Greenland (Christian Bay).

2

Parameters:

Mandatory activities:

- Species (vascular plants) recording in 16 1m × 1m quadrats:
  - Visual cover estimation.
  - Point framing (100 points per quadrat as a new application).
- Species recording in eight summit area sections, abundance estimation defined on an ordinal scale.
- A careful photo documentation of plots and summit set-up.
- Continuous soil temperature measurements (4 points per summit site).

Optional activities (in addition to the mandatory activities):

- Bryophytes and lichens recording.
- Subplot-frequency of species in 1 m × 1 m quadrats (previously this was a standard method).
- Increase of 1 m × 1 m quadrats up to 32 per summit site.
- Estimation of species cover in summit area sections.
- Line-pointing in 10 m squares (4 per summit).

Methodology:

The Gloria field manual provides the basic guidelines for a standardised field application of the state of the art GLORIA monitoring method. It was designed to be universally applicable in the world-wide range of alpine environments from polar to tropical latitudes. It is recommended that you contact the Gloria Coordination Office to ensure proper site selection and methodologies.

Gloria Field manual – Multi-summit approach: www.gloria.ac.at/?a=10.

Forms and guidelines: www.gloria.ac.at/?a=51.

How to become involved:

The implementation process from study design to data management is described on the website: www.gloria.ac.at/?a=10. New sites should be registered before starting field work. The Gloria Coordination Office can be contacted at any time and asked for advice: office.gloria@univie.ac.at.

Geographical coverage:

Global. Mountain areas: 121 active research sites.

2.6 ITEX

International Tundra Experiment

Website: http://ibis.geog.ubc.ca/itex

Contact address: ghenry@geog.ubc.ca or see website

Disciplines: Climatology and Climate Change, Terrestrial biology – Biodiversity, Terrestrial biology – Ecosystem function.

Keywords: Ecosystem, Climate Change, tundra, manipulation, open-top chambers.

2

Description: The International Tundra Experiment is a network of researchers examining the impacts of warming on tundra ecosystems. ITEX seeks to examine the response of circumpolar cold adapted plant species and tundra ecosystems to environmental change, specifically to an increase in summer temperature. Empirical knowledge based on experiments coupled with available evolutionary history, ecology and genetics was chosen as the best way to predict species response to Climate Change.

The ITEX research model combines long-term and short-term experimentation with monitoring and has the elegance and simplicity called for to understand ecosystem response and vulnerability to change. The experiment is designed to examine the effects of temperature change by (i) maximizing geographic representation, (ii) minimizing technical and equipment requirements, (iii) being long-term, (iv) focusing primarily on species and, if resources permit, (v) allowing for genetic and system level studies.

Collectively the ITEX network is able to pool its data sets to examine vegetation response at varying levels, for example genetics (from ecotype to functional type), across space (from habitats to ecosystems) and over time.

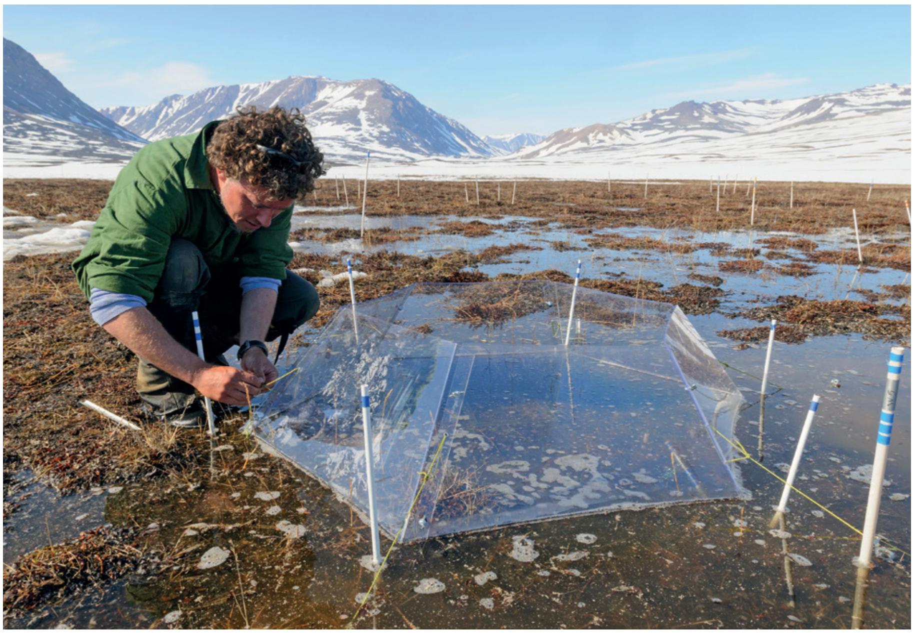
Suitable sites: Sites with tundra ecosystems where tree growth is hindered by low temperatures and short growing seasons.

Parameters: Participation may be at several levels of complexity and sophistication depending on interests and available funding support. Every ITEX site operates some form of warming experiment.

Monitored parameter groups include: Climate (simple/advanced), snow and ice, active layer, temperature enhancement experiments, plant response variables, insects, plant community measurements (cover composition, etc.), seed rain and germination and evolutionary response.

ITEX chambers installed at Mukhrino Field Station, Russia (Nina Filippova).

Setting up the ITEX hexagon for temperature manipulation at Zackenberg Research Station, Greenland
(Lars Holst Hansen).



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Methodology:

Each ITEX study site is expected to collect similar data following established protocols provided in the ITEX Manual. Most sites use open-top chambers to warm the tundra. These passive chambers affect plant growth and phenological development in a variety of ways.

Experimental Design

Number of species: Species are listed in different priority classes according to value as a target species for studying Climate Change effects. The number of species monitored can vary from site to site. Species selection is described in the ITEX manual.

Siting: Treatment sites should be placed in areas with uniform soil, plant cover (vegetation), slope angle, and slope exposure.

Treatment period: Treatments should begin at the date of release from snow and continue until late August or the inception of the winter snow period, whichever comes first.

Extent of Experiment: A five-year commitment to an experimental site is suggested as a minimum. Sites with on-going long-term programs and personnel, such as field stations, reserves, and long-term ecological research sites, are considered optimum, to secure that the experiment may be expected to continue.

Details of the recommended methodology are presented in the ITEX manual, http://ibis.geog.ubc.ca/itex/library/index.php.

How to become involved: To contact ITEX, see website and contact info above. Join the ITEX list-server by sending an email to listproc@lists.colorado.edu with the message: "SUBSCRIBE ITEX [add your name here]". No subject line is necessary.

Geographical coverage: Global. Tundra and tundra-like ecosystems.

2.7 EXPEER

Experimentation in Ecosystem Research

Website: www.expeeronline.eu
Contact address: www.expeeronline.eu/index.php/contact

AnaEE

Analysis and Experimentation on Ecosystems

2

Website: www.anaee.com
Contact address: info@anaee.com

INCREASE

An Integrated Network on Climate Research Activities on Shrubland Ecosystems

Website: www.increase.ku.dk
Contact address: iks@ign.ku.dk

Disciplines: Climatology and Climate Change, Ecosystem services, Terrestrial biology – Biodiversity, Terrestrial biology – Ecosystem function.

Keywords: Ecosystem, manipulation, experimental design, Climate Change.

Description: There are a number of projects related to experimental and manipulative research on ecosystems.

Ecosystems are increasingly impacted by human activities to a point that some boundaries for the sustainability of ecosystem services are or will be transgressed. It is then urgent to develop a thorough understanding of the mechanisms behind ecosystem services and their controls in order to better predict rates of future changes and to develop mitigation or adaptation scenarios.

ExpeER (Experimentation in Ecosystem Research) is a European project which aims to bring together, for the first time, the major observational, experimental, analytical and modelling facilities in ecosystem science in Europe.

AnaEE is a research infrastructure for experimental manipulation of managed and unmanaged terrestrial and aquatic ecosystems. It will strongly support scientists in their analysis, assessment and forecasting of the impact of climate and other global changes on the services that ecosystems provide to society.

INCREASE is an EU-funded infrastructure of six large-scale Climate Change experiments and one phytotron designed to study Climate Change effects on shrublands. The experiments combine two different approaches to study climate effects on ecosystems, the "space for time" substitution by investigating ecosystems along a precipitation and temperature gradient in Europe and by ecosystem manipulations.

EXPEER site at Hyytiälä Forest Research Station, Finland, with prescribed burning of pine forest (Juho Aalto).

2

The goals of these projects include:

- Develop and test new methods to overcome current limitations in understanding ecosystem processes.
- Develop improved environmental control techniques and new experimental approaches.
- Develop ecosystem models and provision of a model toolkit.
- Develop upscaling and data interpretations methods of bio-geochemical and ecological processes.

Suitable sites: EXPEER/AnaEE: Vegetated areas, natural or managed. INCREASE: Shrubland.

Parameters: A core set of parameters has been chosen on the basis of the range of ecological integrity and priority given by the scientific communities of the individual programmes. Biotic parameters overlap to some extent between the three programmes and include control of a number of abiotic parameters related to Climate Change, land-use change, loss of biological diversity, bio-geochemical nitrogen cycle and phosphorus cycles, global fresh water use, chemical pollution, atmospheric aerosol loading, ocean acidification and stratospheric ozone.

Methodology: Manipulative studies (e.g. adding/removing nutrients, stressors, shade/light, water, species, etc.).

ExpeER aims to harmonise measurement and sampling methods for a core set of environmental and ecosystem variables. See more details on their website, www.expeeronline.eu/accomplishments.html.

AnaEE aims to provide expertise in planning, constructing and maintaining ecosystem experiments as well as generating new ideas for experiments at multiple scales. Contact AnaEE to find out more.

INCREASE experimental approach and link to method papers, www.increase.ku.dk/experimental_approach.

How to become involved: Contact project manager or relevant work package leader, www.expeeronline.eu/index.php/contact.

Geographical coverage: Europe. Ca. 300 observational sites and 18 experimental sites.

2.8 ShrubHub

Changes in woody vegetation in arctic and alpine tundra ecosystems

Website: http://shrubhub.biology.ualberta.ca
Contact address: isla.myers-smith@ed.ac.uk

2

Discipline: Climatology and Climate Change, Terrestrial biology – Biodiversity, Terrestrial biology – Ecosystem function.

Keywords: Dendrochronology, fixed-point photography, woody vegetation, tundra vegetation, Climate Change.

Description: ShrubHub is a network of researchers investigating changes in woody vegetation in arctic and alpine tundra ecosystems. The network was established to foster communication between researchers working in tundra ecosystems around the Arctic and to promote data synthesis.

Suitable sites: Sites with woody vegetation.

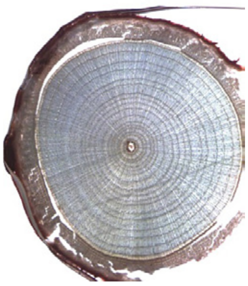
Parameters: Stem growth (ring width and elongation) shrub-cover and abiotic parameters.

Methodology: The network arranged a workshop to compare growth ring, stem elongation or other shrub growth data from arctic and alpine tundra sites. Methodologies are discussed in the workshop report, http://shrubhub.biology.ualberta.ca/shrub-synthesis-workshop.

Methods include dendrochronology boreholes in stems and fixed point photography of shrub cover.

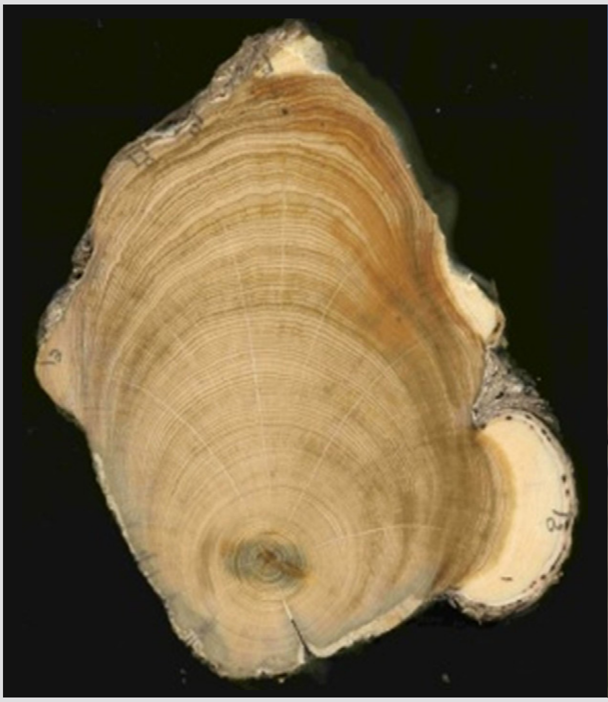
How to become involved: Contact network coordinator.

Geographical coverage: Northern hemisphere. Arctic and alpine tundra ecosystems. Ca. 40 research sites.



Dendrology (http://shrubhub.biology.ualberta.ca).

Heather sampled to investigate the influence of climate on shrub growth, Faroe Islands Nature Investigation, Faroe Islands (Iilka Bell).



Annual growth rings contain information on past climatic conditions. Here a cross section of a 180 year old juniper (DendroGreif laboratory).

Larvae herbivory affect growth patterns especially in outbreak years. Here in the Kobbefjord area near the Greenland Institute of Natural Resources, Greenland (Katrine Raundrup).

ShrubHub investigates growth patterns of shrubs in arctic and alpine environments, Western Arctic Research Centre, Canada (Aurora Research Institute).

2.9 ICOS

Integrated Carbon Observing System

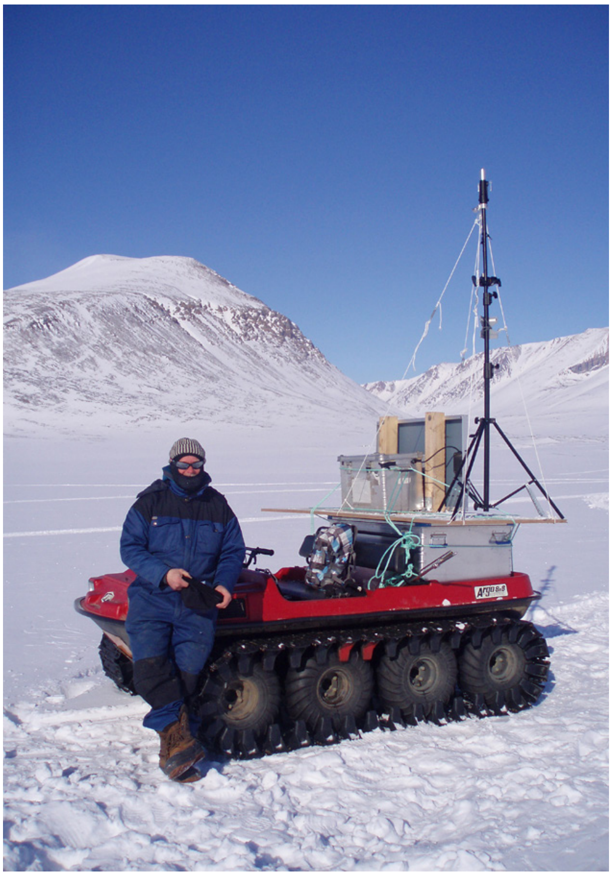
Website: www.icos-ri.eu
Contact: icos-admin@helsinki.fi

Disciplines: Atmospheric chemistry and physics, Climatology and Climate Change, Limnology, Oceanography, Soil Science, Terrestrial biology – Ecosystem function.

Keywords: Greenhouse gas, carbon cycle, Climate Change, flux measurements.

Description: ICOS is a European research infrastructure dedicated to high precision observations of greenhouse gas concentrations and fluxes. ICOS infrastructures provide the long-term observations required to understand the present state and predict future behaviour of the global carbon cycle and greenhouse gas emissions. ICOS tracks carbon fluxes in Europe and adjacent regions by monitoring the ecosystems, the atmosphere and the oceans through integrated networks. The measurements allow the scientific community and intergovernmental organisations to monitor and assess the effectiveness of carbon sequestration and/or greenhouse gases emission reduction activities on global atmospheric composition levels, including attribution of sources and sinks by region and sector.

Suitable sites: All types of environments, natural or managed.



Mobile energy measuring tower, Zackenberg Research Station, Greenland (Christian Stiegler).

Parameters:

- Atmospheric greenhouse gas concentrations of CO_2, CH_4, CO and radiocarbon-CO_2 to quantify the fossil fuel component.
- Ecosystem fluxes of CO_2, CH_4, H_2O, along with climate variables (e.g. radiation, temperature, precipitation/snow, etc.) and ecosystem variables needed to understand processes.
- Ocean-air flux observations.

See www.eco.kt.dtu.dk/Research/Research-Projects/Projects-within-Carbon-storage-greenhouse-gas-exchange-and-atmospheric-feedback-for-ecosystems/ICOS for detailed list of variables for each environmental compartment.

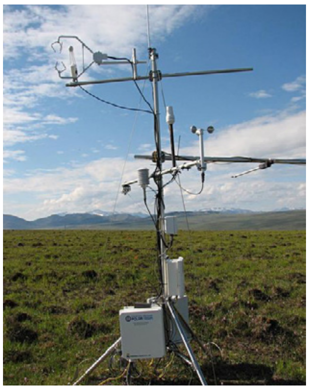
Methodology: ICOS recommends specific gas analyser and eddy covariance flux measurement sensors to measure GHG fluxes, while several meteorological sensors comply with ICOS requirements. Protocols for ancillary measurements are under discussion. See ICOS Stakeholder Handbook 2013 for details, www.eco.kt.dtu.dk//-/media/Centre/ECO/Research/Carbon storage/Stakeholders Handbook 2013.ashx.

How to become involved: ICOS is based on national membership. Participation is a two-fold process where the GHG research and observing community in a country needs to organize and find a person recognized by the community to be the main communication point (focal point) towards ICOS. Each country willing to join in ICOS can also nominate a representative of the country in the ICOS Stakeholders' Interim Council (General Assembly in the ICOS ERIC).

ICOS recently (November 2015) re-organised to form a legal entity, ICOS ERIC (Integrated Carbon Observation System European Research Infrastructure Consortium) centered around national networks. Find information about how to join on their webiste, www.icos-ri.eu/about-us/our-aims/join-us.

Geographical coverage: Europe. Ca. 95 measuring stations in eight countries.

CO_2 analyser in Greenland (Christian More/Our Polar Heritage).



Small tower at Toolik Field Station, USA (Syndonia Bret-Harte).

High tower at Hyytiälä Forest Research Station, Finland (Juho Aalto).

2.10 InGOS

Integrated non-CO_2 Greenhouse gas Observing System

2

Website: www.ingos-infrastructure.eu
Contact address: management@ingos-infrastructure.eu

Disciplines: Atmospheric chemistry and physics, Climatology and Climate Change, Limnology, Oceanography, Soil Science, Terrestrial biology – Ecosystem function.

Keywords: Greenhouse gas exchange, climate feedbacks, Climate Change, Non-CO_2 greenhouse gases.

Description: InGOS is an EU funded Integrating Activity (IA) project, supporting the integration of and access to existing national research infrastructures, targeted at improving and extending the European observation capacity for non-CO_2 greenhouse gases. As such it complements ICOS which focuses on carbon.

There is a big need to support and integrate the observing capacity of Europe for non-CO_2 greenhouse gases. The emissions of these gases are very uncertain and it is unknown how future Climate Change will feedback into these (mainly land-use coupled) emissions.

InGOS aims for harmonization, exchange and dissemination of measured data on the EU greenhouse gas budget. InGOS will establish a data centre and modelling framework to provide policy relevant information.

Suitable sites: Terrestrial and aquatic ecosystems.

Parameters: Non-carbon greenhouse gases and related abiotic parameters.

Methodology: InGOS is in the process of developing standardized methods.

How to become involved: Contact management@ingos-infrastructure.eu or subscribe to mailing list, www.ingos-infrastructure.eu/?page_id=426.

Geographical coverage: Europe. Ca. 22 atmospheric observing stations.

InGOS (and ICOS) research infrastructure, Abisko Scientific Research Station, Sweden (Robert Holden).

The SMAER II mast at Hyytiälä Forest Research Station, Finland, monitors CO_2, H_2O, CO, O_3, SO_2, NO, NO_2, temperature and wind speed profiles, properties of solar and thermal radiation of the stand and fluxes of CO_2, H_2O, O_3, aerosols, and several volatile organic compounds (Juhu Aalto).

2.11 CALM

Circumpolar Active Layer Monitoring (IPA/GTN-P)

Website: www.gwu.edu/~calm

Contact address: www.gwu.edu/~calm/about/admins.html

Discipline: Climatology and Climate Change, Geocryology.

Keywords: Permafrost, active layer, thaw depth.

Description: The active layer is a layer of earth materials between the ground surface and permafrost that freezes and thaws on an annual basis. The active layer is extremely important in many of Earth's cold regions because permafrost can form an impermeable layer at depth that restricts the majority of geomorphic, hydrologic, and bio-geochemical processes to this relatively thin layer.

CALM (Circumpolar Active Layer Monitoring) program was established in the early 1990s. CALM's goals include monitoring the thickness of the active layer, the temperature in the near-surface layers of the permafrost regions, and surface movements attributable to frost heave and thaw settlement. The broader impacts of this project are derived from the hypothesis that widespread, systematic changes in the thickness of the active layer could have profound effects on the flux of greenhouse gases, on the human infrastructure in cold regions, and on landscape processes.

Together with its sister programme, the International Permafrost Association's Thermal State of Permafrost programme, CALM comprises the Global Terrestrial Network for Permafrost (GTN-P), itself a component of the Global Terrestrial Observation System and the Global Climate Observation System (GTOS/GCOS).

Suitable sites: Stations with access to areas with permafrost soils.

Parameters: CALM investigators measure the seasonal depth of thaw at plots of various dimensions. Soil and air temperature, soil moisture content, and vertical movement are also measured at many sites. These measurements, combined with site-specific information about soils, landscape and vegetation, can be used to "scale up" assessments of the stability and projected changes to regional and circumpolar scales.

Active layer on top of permafrost, Chokurdakh Scientific Tundra Station, Rusia (Frans-Jan Parmentier).

Methodology: CALM investigators measure the seasonal depth of thaw at plots of various dimensions using a standard protocol. CALM data are made freely available.

Measurement protocols:

www.gwu.edu/~calm/research/measurements.html.

Methods for measuring active layer thickness:

www.unis.no/35_staff/staff_webpages/geology/ole_humlum/PeriglacialHandbook/ActiveLayerThicknessMethods.htm.

Forms:

www.gwu.edu/~calm/research/forms.html.

Installation instructions:

www.gwu.edu/~calm/research/install.html.

Equipment vendors:

www.gwu.edu/~calm/about/vendors.html.

How to become involved: Contact CALM programme administrators, www.gwu.edu/~calm/about/admins.html.

Geographical coverage: Global. Permafrost regions. More than 200 sites.

Active layer depth measurement at Zacenberg Research Station, Greenland (Morten Rasch).

2

2.12 TSP

Thermal State of Permafrost (IPA/GTN-P)

2

Website: http://ipa.arcticportal.org/activities?catid=0&id=15

Contact address: contact@ipa-permafrost.org

Discipline: Climatology and Climate Change, Geocryology.

Keywords: Permafrost temperature, Climate Change, thaw, climate feedbacks.

Description: The Thermal State of Permafrost programme measure permafrost temperatures to address questions related to climate warming and the attendant environmental and societal issues in the cold regions of Planet Earth. The TSP data set will serve as a baseline for the assessment of the rate of change of permafrost temperatures and permafrost distribution, to validate climate model scenarios and to support process research in order to improve our understanding of permafrost dynamics.

Together with its sister programme, the International Permafrost Association's Circumpolar Active Layer Monitoring programme, TSP comprises GTN-P, the Global Terrestrial Network for Permafrost, itself a component of the Global Terrestrial Observation System and the Global Climate Observation System (GTOS/GCOS).

Suitable sites: Stations located in areas with permafrost. TSP welcomes:

- Boreholes with long-term records of prior observations in order to establish recent trends.
- New boreholes in undisturbed areas that can be protected and can be available for continuing observations.

Parameters: Permafrost borehole temperatures and associated abiotic parameters.

Borehole drilling to initiate monitoring of permafrost temperatures at Abisko Scientific Research Station, Sweden (Jonas Åkerman).

Methodology: Two measurement strategies are proposed:

Type 1:

Long-term, high frequency (minimum 3 times/day, 4 recommended) continuous observations in a limited number of key boreholes, which are representative of a given region. Borehole depth should be at least 15-20 meters.

Type 2:

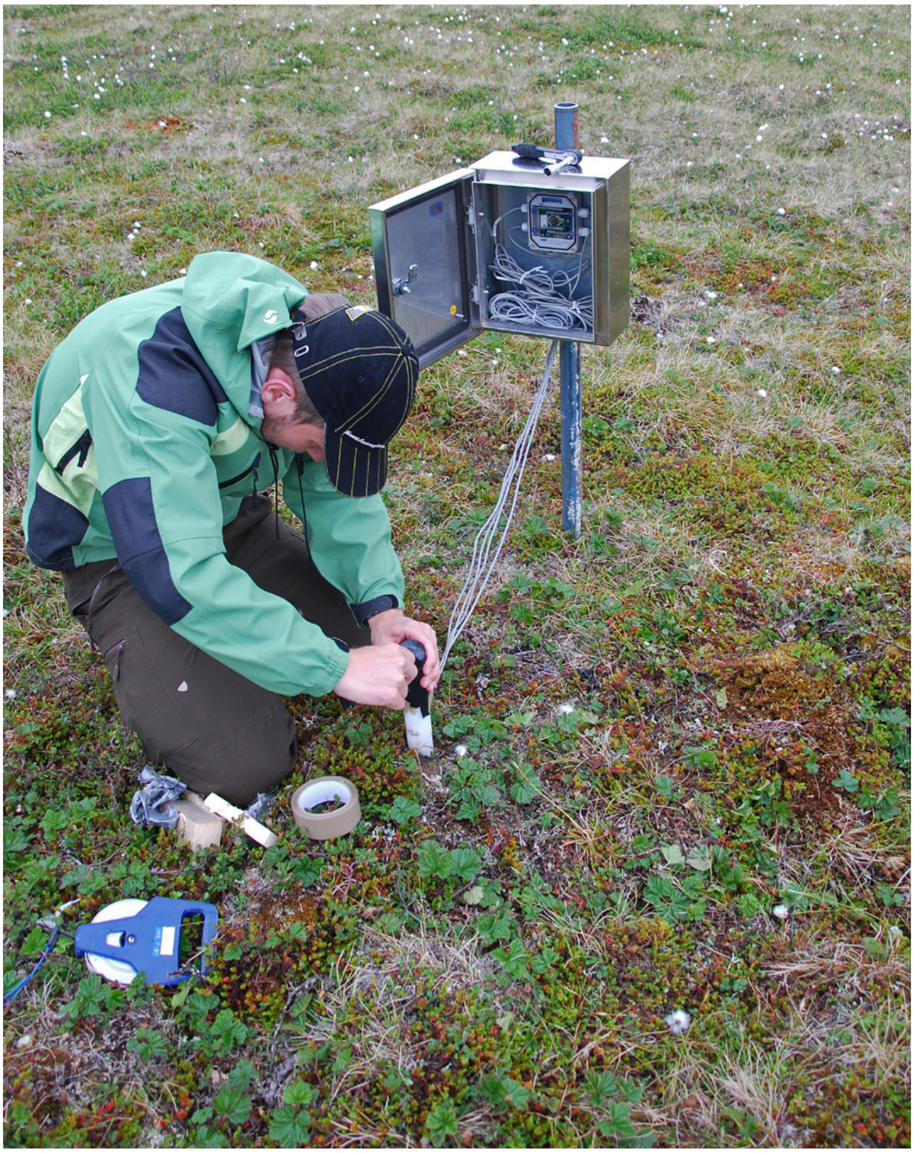
Occasional or periodical measurements (at least annually or more frequently) in deeper boreholes.

Observations require data-loggers. A variety of data logging systems are available, and the choice depends on their funding. See manual for methodologies and required equipment or contact TSP to enquire about newest recommendations, http://ipa.arcticportal.org/images/stories/tsp_manual.pdf.

How to become involved: See list of national/regional coordinators in the manual or contact IPA (contact@ipa-permafrost.org).

Geographical coverage: Global. Permafrost regions. More than 1000 boreholes.

Thermal State of Permafrost measuring station, Abisko Scientific Research Station, Sweden (Margareta Johansson).



2.13 GTN-G

GTN-G

Global Terrestrial Network for Glaciers

Website: www.gtn-g.org

Contact address: mail@gtn-g.org or www.gtn-g.org/contact.html

Disciplines: Climatology and Climate Change, Glaciology.

Keywords: Glacier, Climate Change, mass balance, energy balance.

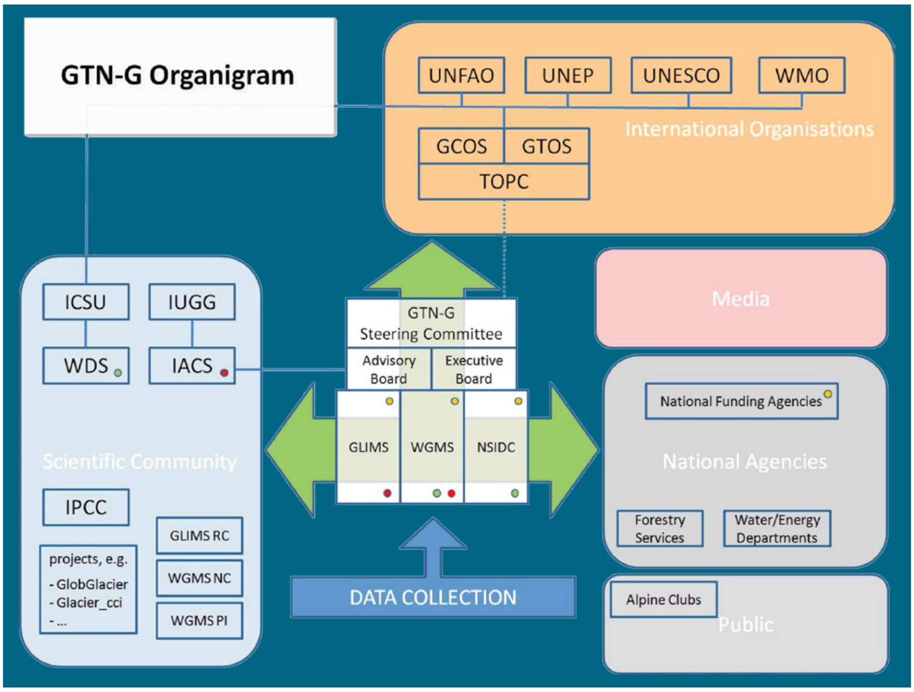
Description: The Global Terrestrial Network for Glaciers (GTN-G) is the framework for the internationally coordinated monitoring of glaciers and ice caps in support of the United Nations Framework Convention on Climate Change (UNFCC).

The network, authorized under the Global Climate/Terrestrial Observing System (GCOS, GTOS), is jointly run by the World Glacier Monitoring Service (WGMS), the U.S. National Snow and Ice Data Center (NSIDC), and the Global Land Ice Measurements from Space initiative (GLIMS).

Amongst these three bodies, key expertise for in-situ measurements has traditionally been located at World Glacier Monitoring Service (WGMS), whereas GLIMS and NSIDC have mainly focused on remote sensing and data management in relation to glaciers. WGMS is therefore the most relevant starting point for stations seeking information on standard field methodologies.

The WGMS collects standardised observations on changes in mass, volume, area and length of glaciers with time (glacier fluctuations), as well as statistical information on the distribution of perennial surface ice in space (glacier inventories). Such glacier fluctuation and inventory data are high priority key variables in climate system monitoring; they form a basis for hydrological modelling with respect to possible effects of atmospheric warming, and provide fundamental information in glaciology, glacial geomorphology and Quaternary geology.

Organisation of GTN-G
(www.gtn-g.org/pics/GTN-G_Organigramm_v2.pdf).



Glacier work at Kluane Lake Research Station, Canada (Lance Goodwin).

Suitable sites: Stations with access to glaciated environments.

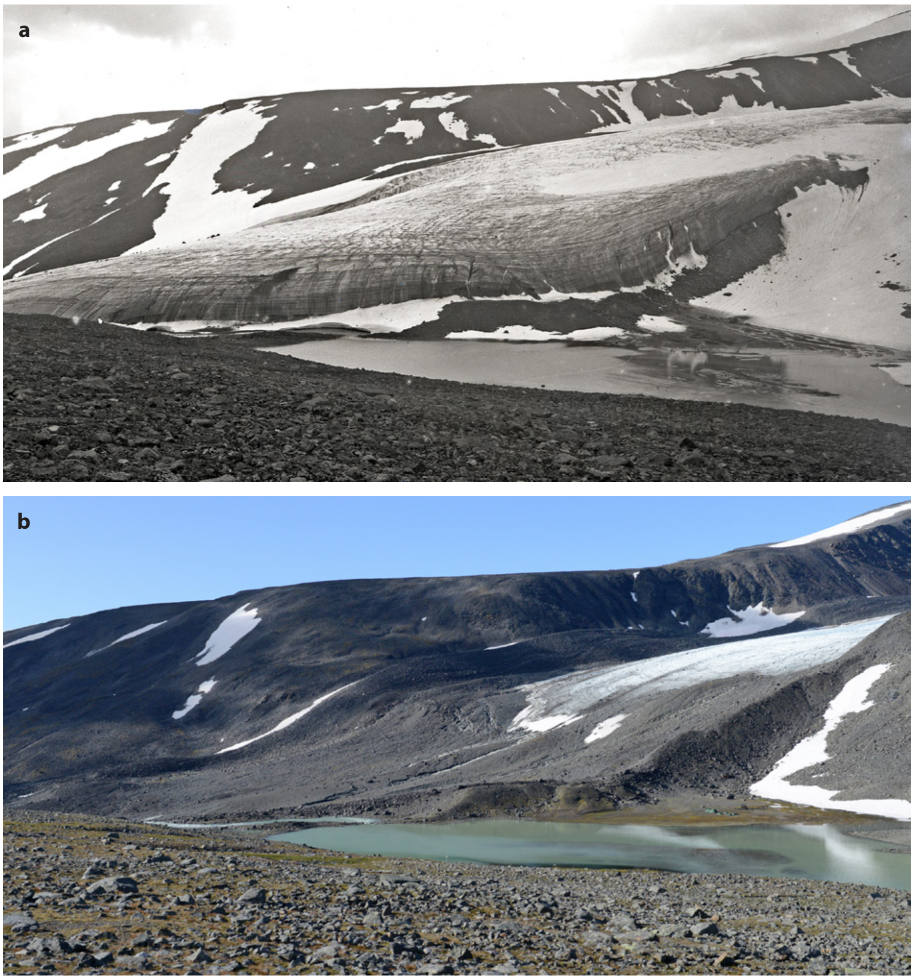
Parameters: Energy balance, mass balance, flow dynamics and extent.

Methodology: Within the Global Terrestrial Network for Glaciers (GTN-G), the following guidelines and standards have been established regarding glacier fluctuations, www.gtn-g.org/literature.

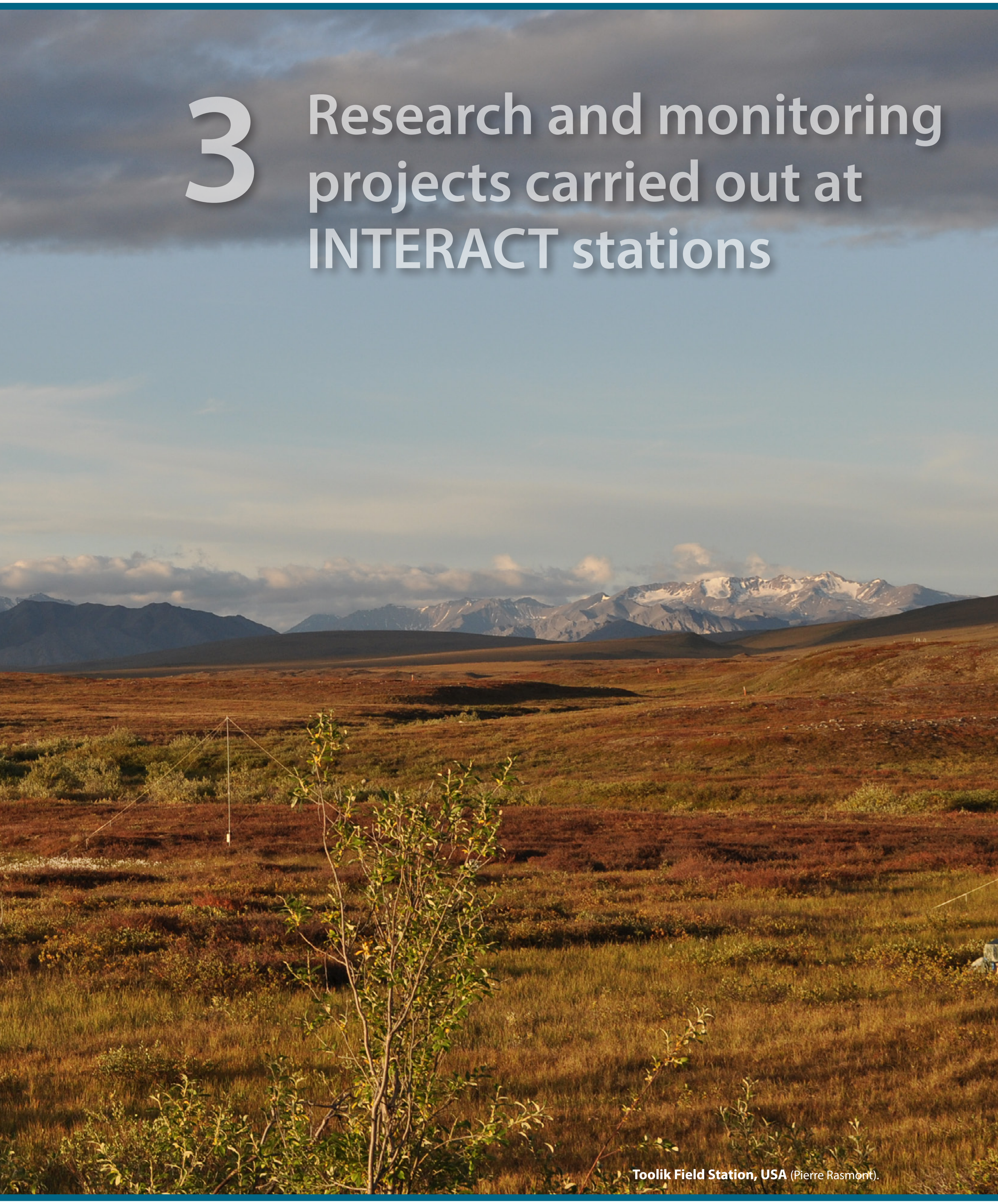
How to become involved: See website, www.gtn-g.org/contact.html or enquire via e-mail (mail@gtn-g.org).

Geographical coverage: Global. Glaciated environments. Activities in more than 30 countries.

Change in the extent of Storglacieren, Tarfala Research Station, Sweden, between 1910 (a) and 2013 (b) (Fredrik Enquist (a), Per Holmlund (b)).



3 Research and monitoring projects carried out at INTERACT stations



Toolik Field Station, USA (Pierre Rasmont).

This chapter presents information on the geographical distribution of the scientific disciplines and monitored environmental parameters within the INTERACT network of research stations.

Coupled to the INTERACT GIS system (that includes a research and monitoring project metadata database), the chapter is intended to be a tool for station managers, researchers, donors, scientific networks, programmes, organisations, etc. to:

- Select the most appropriate station or stations for a specific research or monitoring project (e.g. by identifying geographical gaps in disciplines and parameters or by identifying relevant knowledge and data sources to build on)[1].
- Identify historic metadata and data sources for application in assessments and publications.

The chapter is based on a survey of all research and monitoring projects undertaken at INTERACT stations since the start of the year 2000 and until May 2014. The survey was split into three components:

- Scientific disciplines covered within the research/monitoring work at the station.
- Metadata on research and monitoring projects.
- Metadata on monitored parameter groups.

Results are presented on maps showing the geographical distribution of disciplines and parameter groups covered by INTEACT stations. Appendices 1 and 2 present overview tables for all disciplines and monitored parameter groups.

3

The survey

Timespan

The database includes all research and monitoring projects undertaken since the year 2000 and until May 2014. For monitoring projects, some stations also provided data from before 2000.

Number of participating stations

77 stations have provided information on which scientific disciplines they cover within the research/monitoring projects at their station. Of these, 42 stations also contributed with standardised metadata for all research and monitoring projects and monitored parameter groups.

Template

In order to assemble uniform datasets from all INTERACT stations, the managers developed a metadata template to be used for gathering the relevant project metadata (see Appendices 3 and 4). As no resources were set aside for providing these data, it was agreed that a relatively simple template should be applied when looking back at historic data, while a more comprehensive template should be used for all ongoing and new research and monitoring projects.

Data quality

The data included in the database has been provided by the station managers using the archiving system available at their station. Data management practices vary significantly between sites and the information available for each station therefore depends on the systems in place for tracking research and monitoring activities at the station.

1 This book only presents data from INTERACT stations. When seeking to identify geographical gaps, the reader should be aware that there may be research stations, and research and monitoring projects that are not part of the INTERACT network.

All data sets have been quality assured. Many incomplete metadata data sets have been submitted and in many cases the station manager has not been able to provide further information. All projects included in the database do, however, have a project title, a PI name and a discipline, and as monitored parameter groups are related to specific monitoring projects, this will allow users to at least identify a Principal Investigator (PI) name, which should enable the users to contact this person and ask for further details.

The INTERACT GIS – research and monitoring project metadata database

The INTERACT GIS system includes a research and monitoring project metadata database. Here interested scientists and other stakeholders can explore detailed information about individual research and monitoring projects undertaken at INTERACT stations since the year 2000 (see metadata template in Appendices 3 and 4). INTERACT GIS holds project metadata for all research and monitoring projects (PI name and contact information, start/end dates, location, etc.) and also for parameter groups being monitored by the individual monitoring projects (including e.g. start/end date, sampling frequency, study location, etc.).

A search function allows users to search out specific disciplines, PI names, locations, keywords, parameters, etc. Search results will allow users to identify a relevant PI that can be contacted for more information about the specific project (in some cases links to publications and data are also provided in the database).

3

How to use this chapter

The geographical coverage of scientific disciplines and monitored parameter groups are presented on maps highlighting stations that:

To identify a station, simply find the number on the discipline (parameter group map) and use the flap on the inside of the cover to identify the station name.

- Covers a specific discipline or monitor the parameter group in question (**red colour**).
- Do not study the specific discipline or monitor the parameter group in question (**orange colour**).
- Station for which we have no information (**grey colour**).

The maps can be used for identifying relevant stations and projects of interest. Dots on the maps are numbered. To relate a number to a specific station, simply flip out the flap of the inside front cover. This reveals a list of stations that allows you to relate the number of the station on the discipline or parameter group map to the name of the station.

More detailed information on specific projects and monitored parameter groups can be retrieved using the INTERACT GIS system. The use of this repository is described in detail at the INTERACT website (www.eu-interact.org).

Are you a researcher looking for one or more suitable research stations?

If looking for one or more stations to be the site for your research or monitoring project, the maps and associated INTERACT GIS system can be used to identify geographical gaps, or to identify existing projects or data essential for desired research or monitoring initiatives.

- When looking for stations that host projects related to the discipline or parameter group of interest, you can use the map to identify relevant stations. You should then go to the INTERACT GIS where you search out more detailed information on projects related to the specific discipline or parameter group. If you need more detailed information than is included in the project metadata, you may contact the Principal Investigator (PI) whose name is listed for all registered projects (in some cases, the station manager should be contacted).
- When looking for knowledge gaps, you should remember that there are stations and projects that are not part of INTERACT and hence are not covered in this book. When you have identified a gap, you can read about the specific station(s) in the INTERACT Station Catalogue or you can contact the relevant station manager to enquire about the suitability of the station in relation to your intended study (contact details can be found on the INTERACT website.

Are you a researcher looking for data or publications?

If you are looking for data (e.g. for a larger assessment, comparisons or references) or publications , you can use the maps and the associated INTERACT GIS system to identify stations that host projects related to the desired discipline or parameter group.

3

- When looking for publications or data related to the discipline or parameter group of interest, you can use the map to identify the relevant station(s). You should then go to the INTERACT GIS system where you can search for more detailed information on projects related to the specific discipline or parameter group. If interested in receiving publications or data, the PI that is listed in the metadata for the specific project should be contacted. Note, that there is no guarantee that you can access the data, as this is the decision of the specific PI. INTERACT, however, strongly encourages stations to provide free access to their data and to data collected by scientists using their stations.

Are you a station manager looking for knowledge and/or data gaps in your monitoring programme?

Identify gaps
If you are involved in the design of monitoring programmes at research stations in the arctic and northern alpine areas, you can use the maps to see what scientific disciplines or parameter groups that are not monitored at or near your station.

Identify protocols
You can use it to identify stations that have implemented protocols of your interest and e.g. ask them for advice on instrumentation, implementation, maintenance and data management. If it is an external part that is responsible for the project, you can find contact details in the INTERACT GIS system.

Compare monitoring efforts to stations in similar environments
Through the INTERACT Station Catalogue you can identify stations similar in natural environment, Climate Change impacts, size of operations, etc. This enables you to compare your monitoring programme with other similar stations and allow you to find inspiration for developing the monitoring programme at your station.

3.1 Research and monitoring disciplines

In this section, the reader will be introduced to the science disciplines that are covered by research and monitoring projects at INTERACT stations. General descriptions of science disciplines are followed by maps depicting field stations that have hosted or are hosting research or monitoring projects within the presented disciplines since the year 2000.

Disciplines covered by research and monitoring projects at INTERACT field stations are listed in Table 3.1.1, where some of the individual disciplines were grouped together.

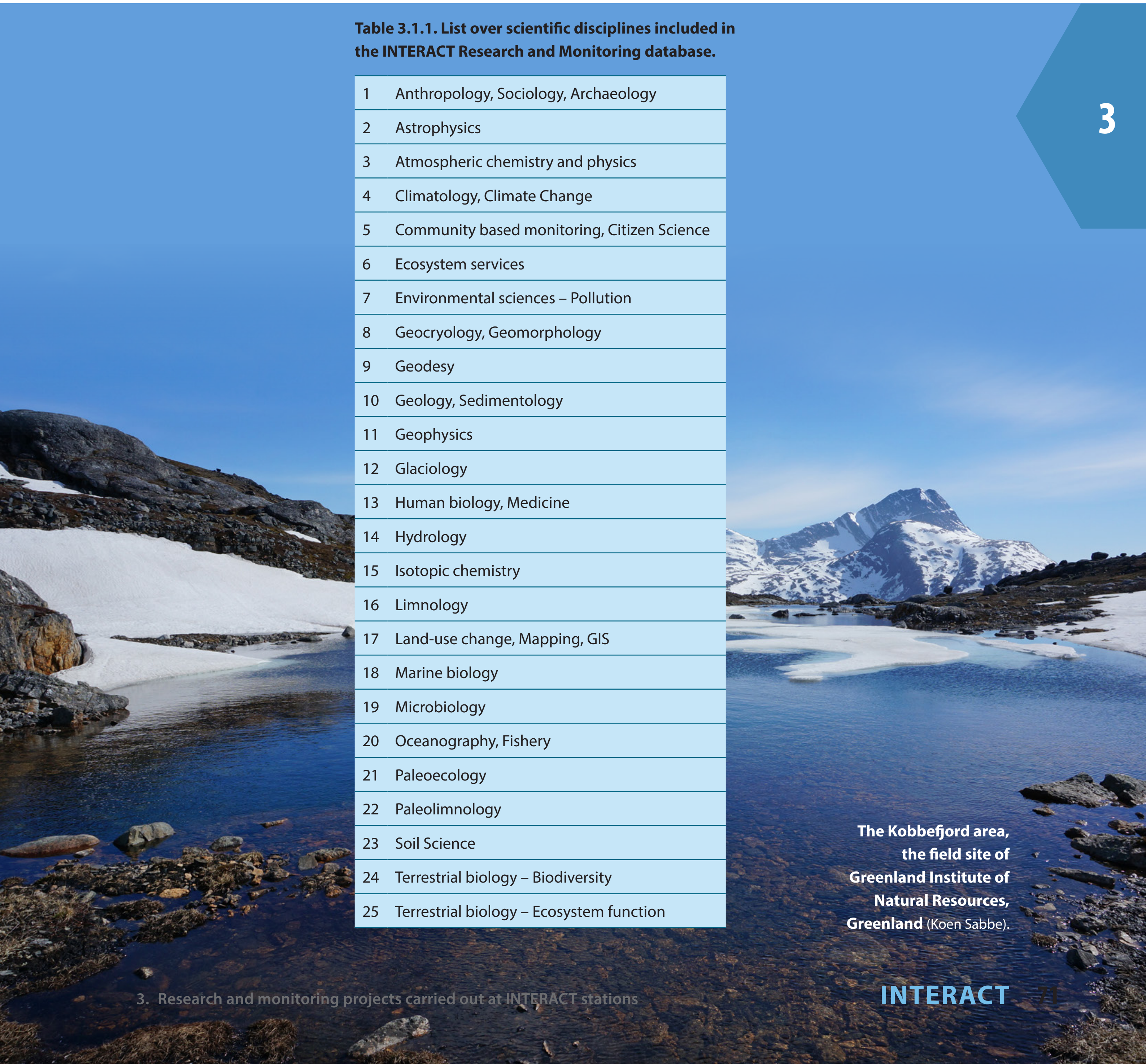
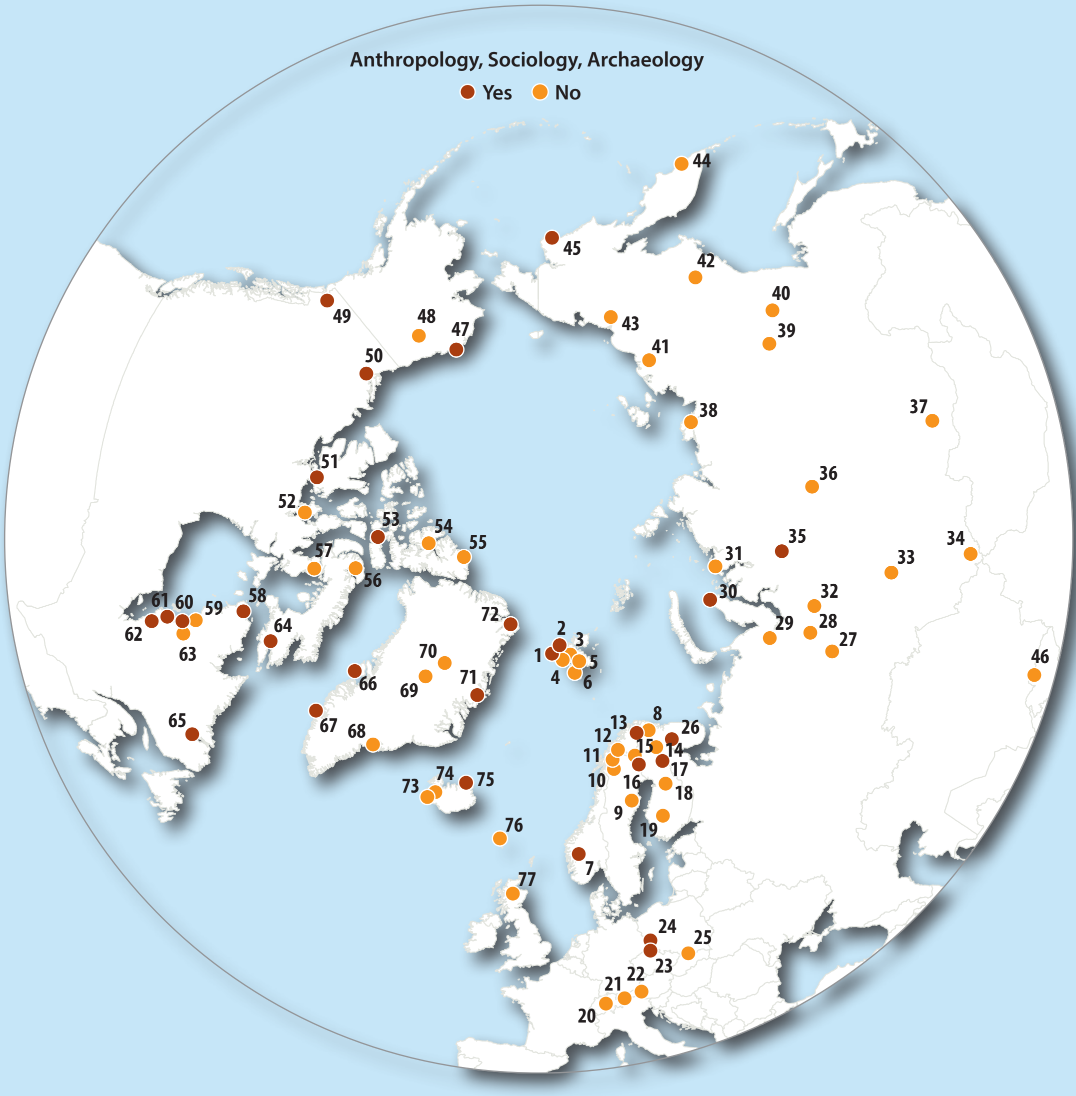


Table 3.1.1. List over scientific disciplines included in the INTERACT Research and Monitoring database.

1	Anthropology, Sociology, Archaeology
2	Astrophysics
3	Atmospheric chemistry and physics
4	Climatology, Climate Change
5	Community based monitoring, Citizen Science
6	Ecosystem services
7	Environmental sciences – Pollution
8	Geocryology, Geomorphology
9	Geodesy
10	Geology, Sedimentology
11	Geophysics
12	Glaciology
13	Human biology, Medicine
14	Hydrology
15	Isotopic chemistry
16	Limnology
17	Land-use change, Mapping, GIS
18	Marine biology
19	Microbiology
20	Oceanography, Fishery
21	Paleoecology
22	Paleolimnology
23	Soil Science
24	Terrestrial biology – Biodiversity
25	Terrestrial biology – Ecosystem function

The Kobbefjord area, the field site of Greenland Institute of Natural Resources, Greenland (Koen Sabbe).



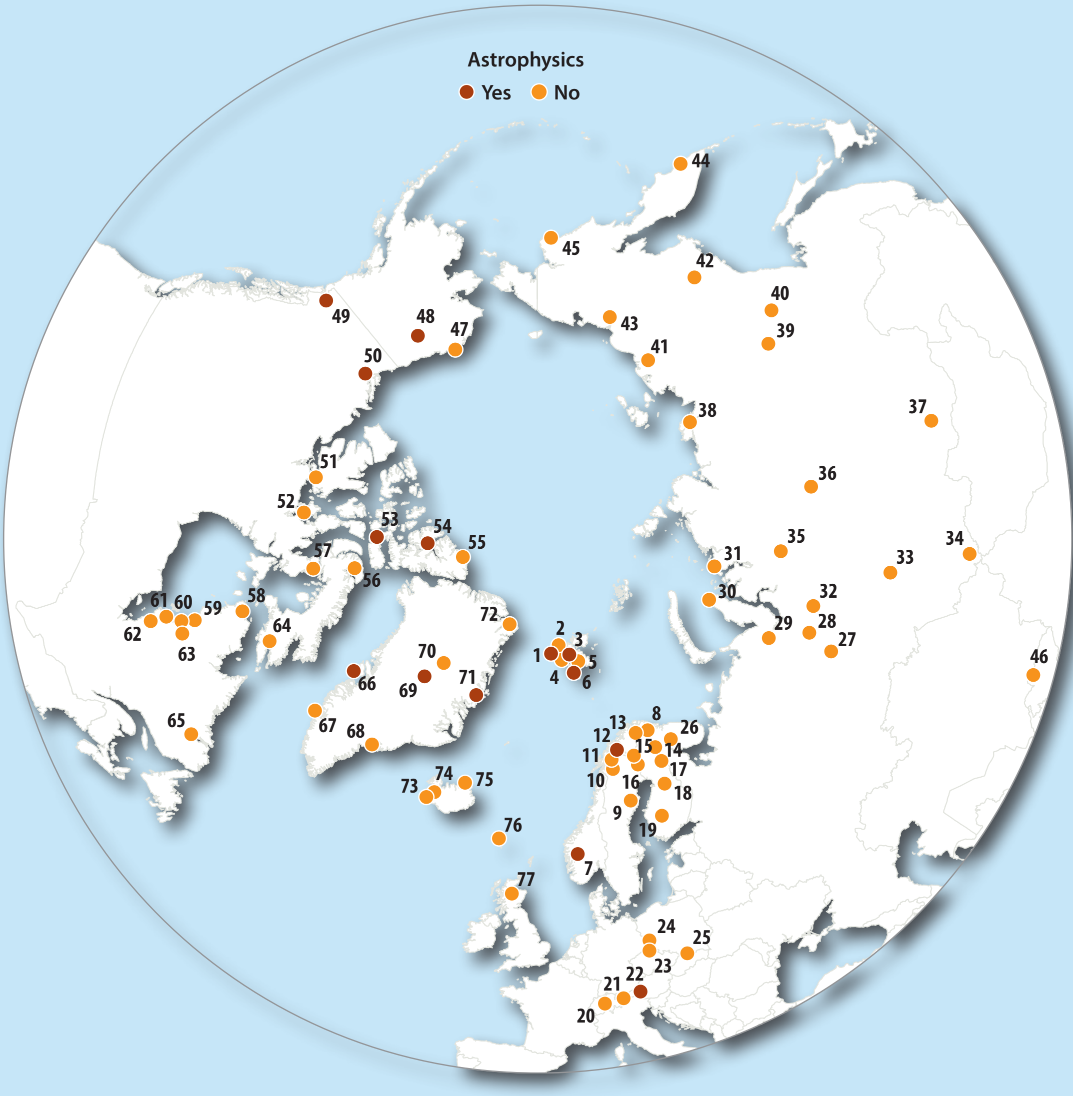
3.1.1 Anthropology, Sociology, Archaeology

are the three branches within the social science and humanities academic disciplines.

Anthropology is "the science of humanity", which studies human beings in aspects ranging from the biology and evolutionary history of *Homo sapiens* to the features of human society and culture [3].

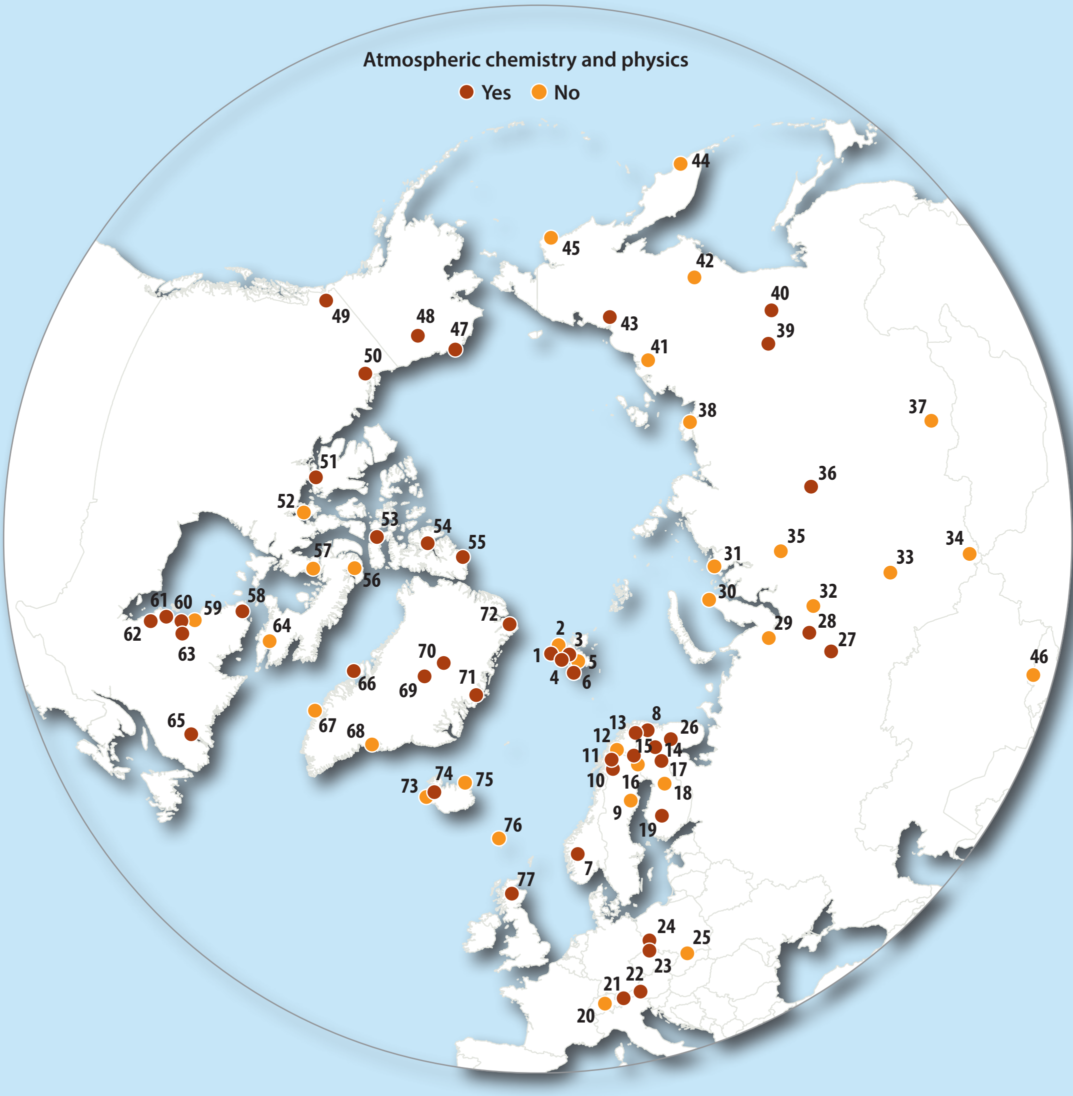
Sociology is a social science discipline that studies human societies, their interactions, and the processes that preserve and change them [3].

Archaeology is the scientific study of the material remains of past human life and activities. These include human artifacts from the very earliest stone tools to the man-made objects that are buried or thrown away in the present days. Archaeology has long been an integral part of Anthropology [3].



3.1.2 Astrophysics

is a branch of astronomy dealing primarily with the behaviour, physical properties, and dynamic processes of celestial objects and phenomena in outer space [4].

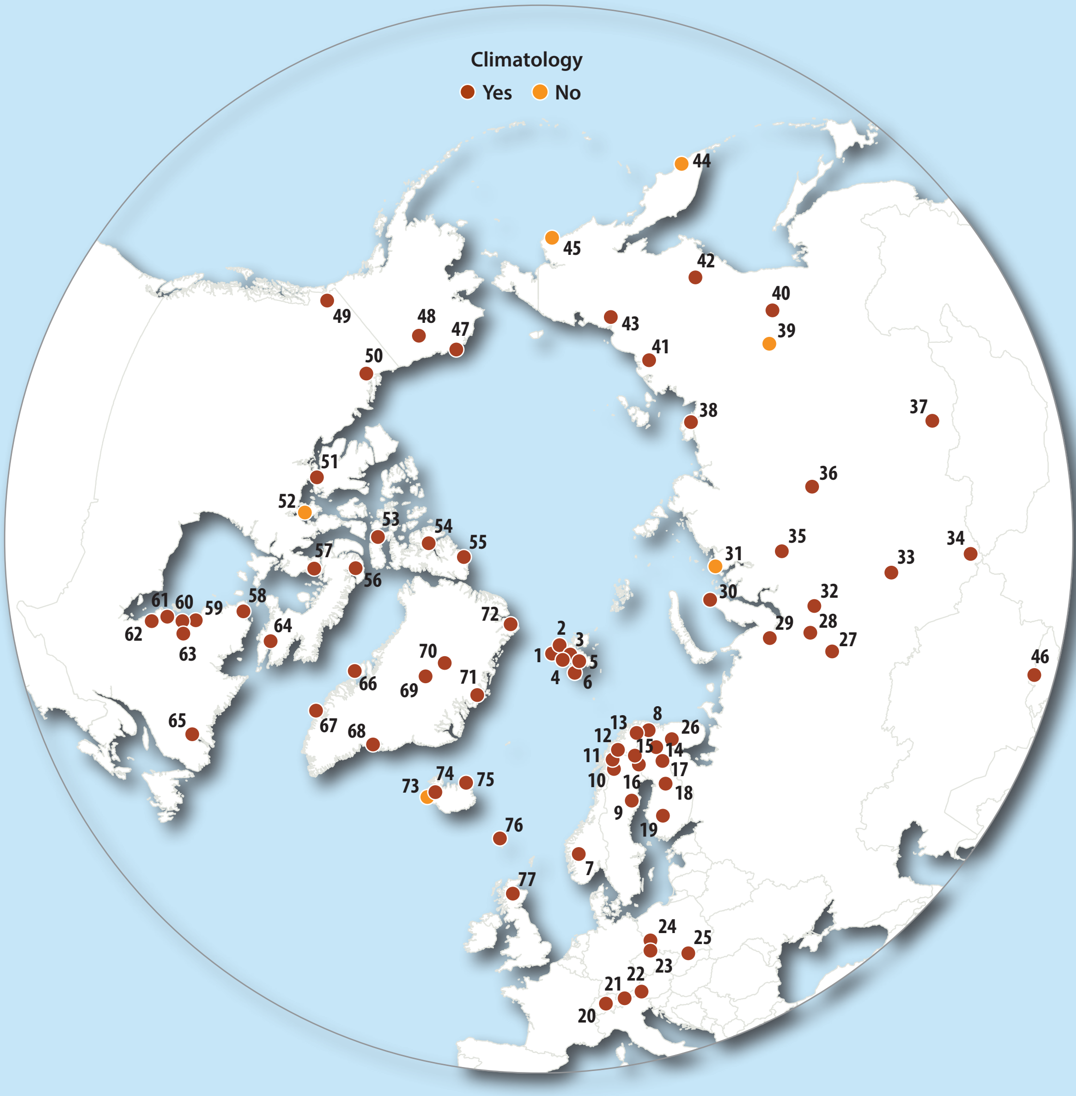


3.1.3 Atmospheric chemistry and physics

are branches of atmospheric sciences.

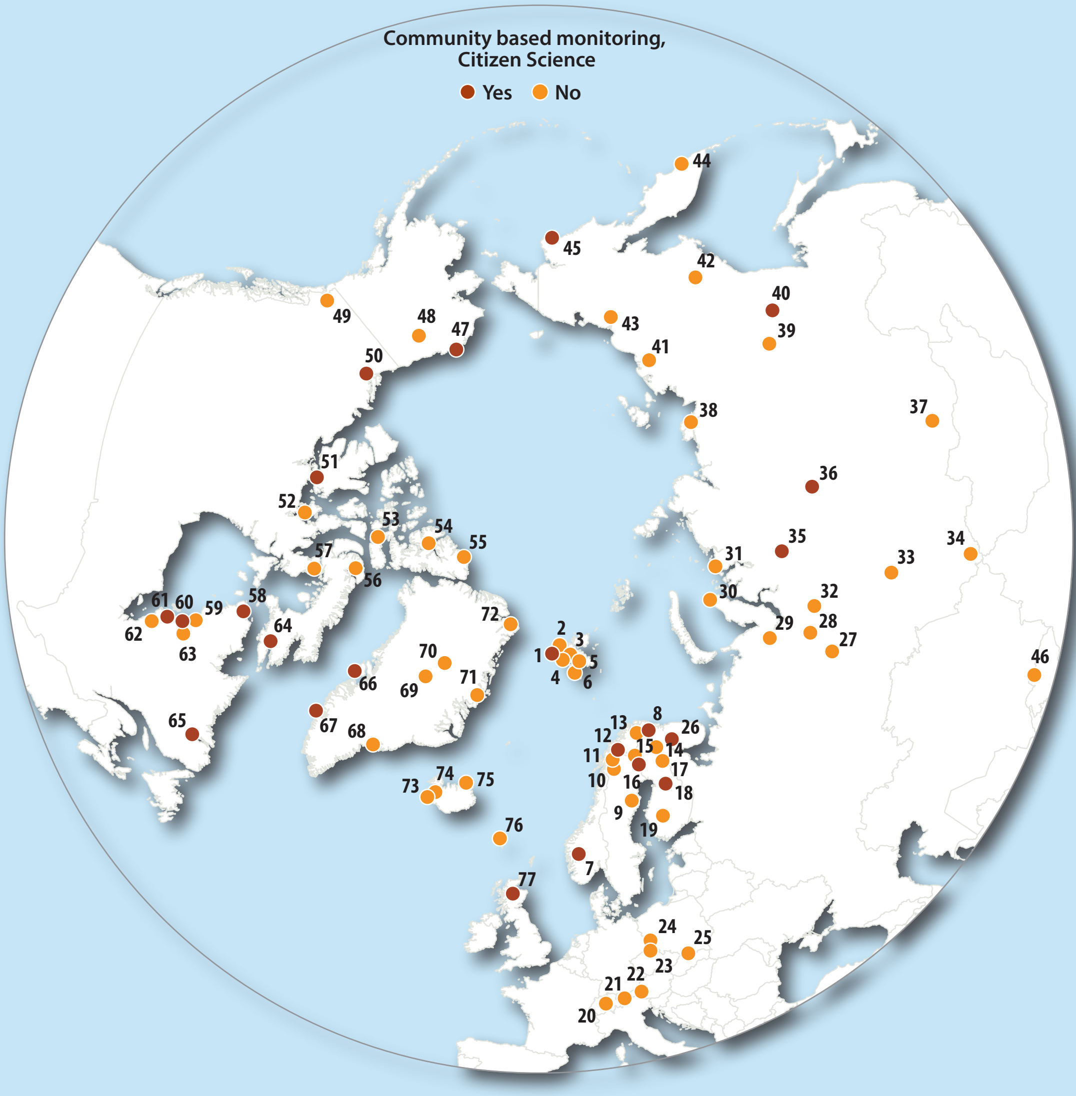
Atmospheric chemistry studies the chemical composition of the natural atmosphere, the way gases, liquids and solids in the atmosphere interact with each other and with the earth's surface and associated biota, and how human activities may be changing the chemical and physical characteristics of the atmosphere. It is a multidisciplinary field of research and draws on environmental chemistry, physics, meteorology, computer modelling, oceanography, geology and volcanology and other disciplines. Research is increasingly connected with other areas of study such as climatology (5, 6).

Atmospheric physics is the application of physics to the study of the atmosphere. Atmospheric physicists attempt to model Earth's atmosphere and the atmospheres of other planets using fluid flow equations, chemical models, radiation balancing and energy transfer processes in the atmosphere (as well as how these tie into other systems such as the oceans) [5].



3.1.4 Climatology, Climate Change

is a branch of the atmospheric sciences concerned with both the description of climate and the analysis of the causes of climatic differences and changes and their practical consequences. Climatology treats the same atmospheric processes as meteorology, but it seeks as well to identify the slower-acting influences and longer-term changes of import, including the circulation of the oceans and the small yet measurable variations in the intensity of solar radiation [3].

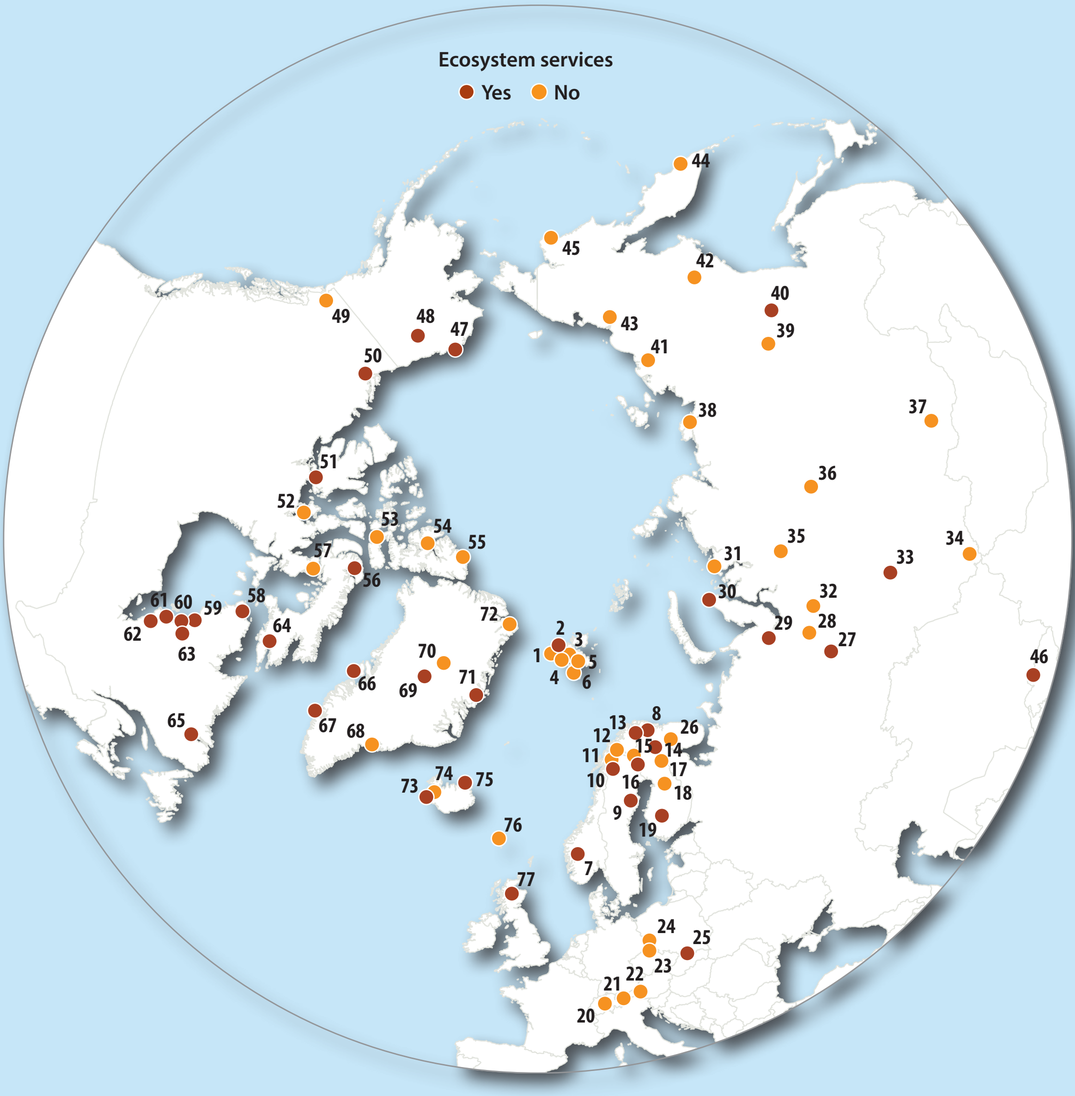


3.1.5 Community based monitoring, Citizen Science

concerns the engagement of the public in research and monitoring.

Citizen Science is scientific research conducted, in whole or in part, by amateur or non-professional scientists. Formally, citizen science has been defined as "the systematic collection and analysis of data; development of technology; testing of natural phenomena; and the dissemination of these activities by researchers on a primarily avocational basis." The collection (and possibly analysis) of data, is typically a part of a collaborative project with professional scientists/organisations [5].

Community based Monitoring (CBM) is a form of public oversight, ideally driven by local information needs and community values, to contribute to the management of ecological resources (natural resources and ecosystem services). Within the CBM framework, members of a community affected by environmental change generate demands, suggestions, critiques and data that they then feed back to the organization implementing the program or managing the environmental change [5].



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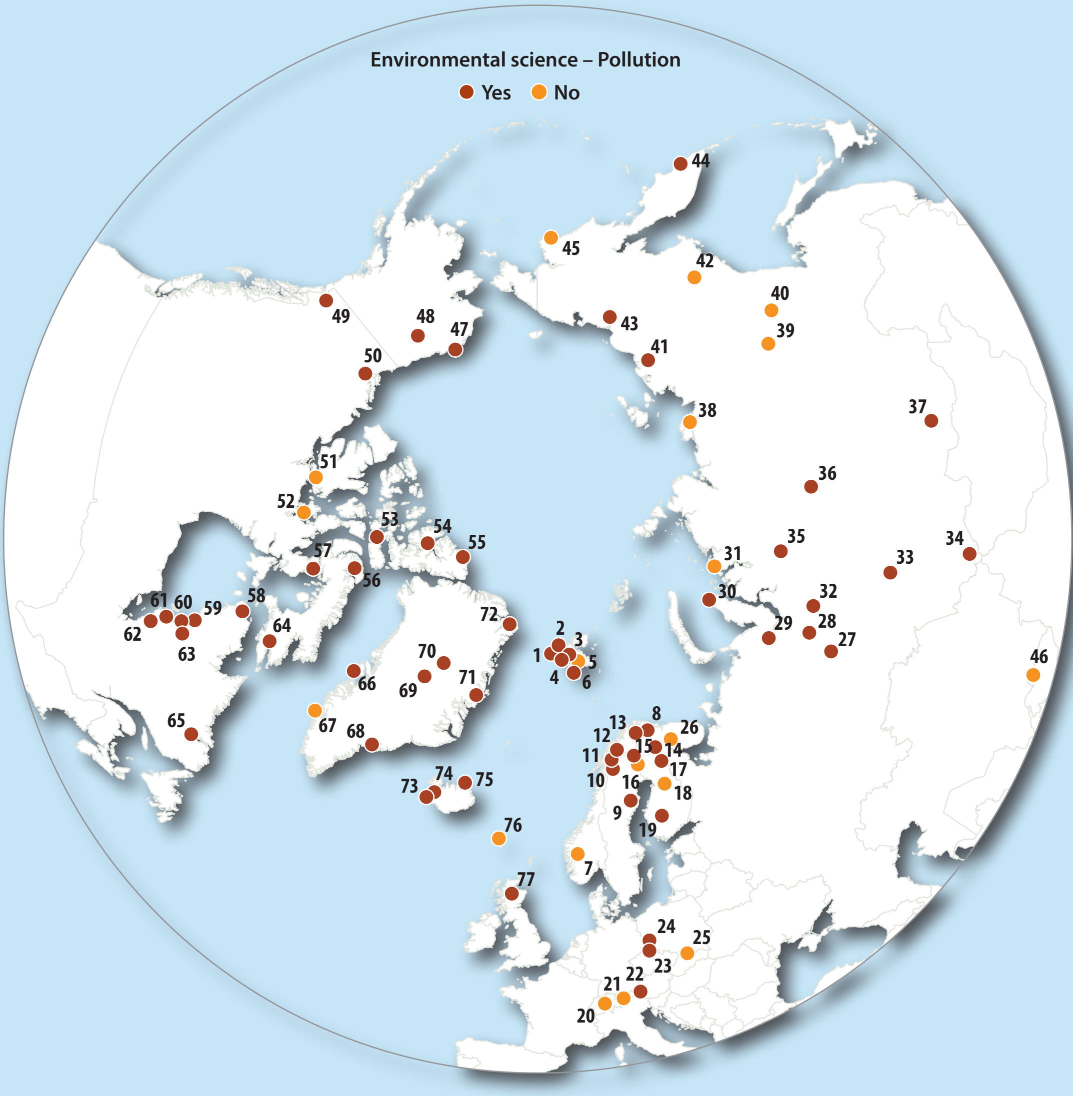
3.1.6 Ecosystem services

is an evolving scientific discipline that describes collective benefits for the humankind from ecosystems. Ecosystem services include physical services in the form of natural resources, water, climate, etc. to non-physical services like appreciation of biodiversity, landscape and natural features. Ecosystem service assessments and monitoring investigate how people use, benefit from, or alter the ecosystem services, even if just for the maintenance of ecosystem function [5].



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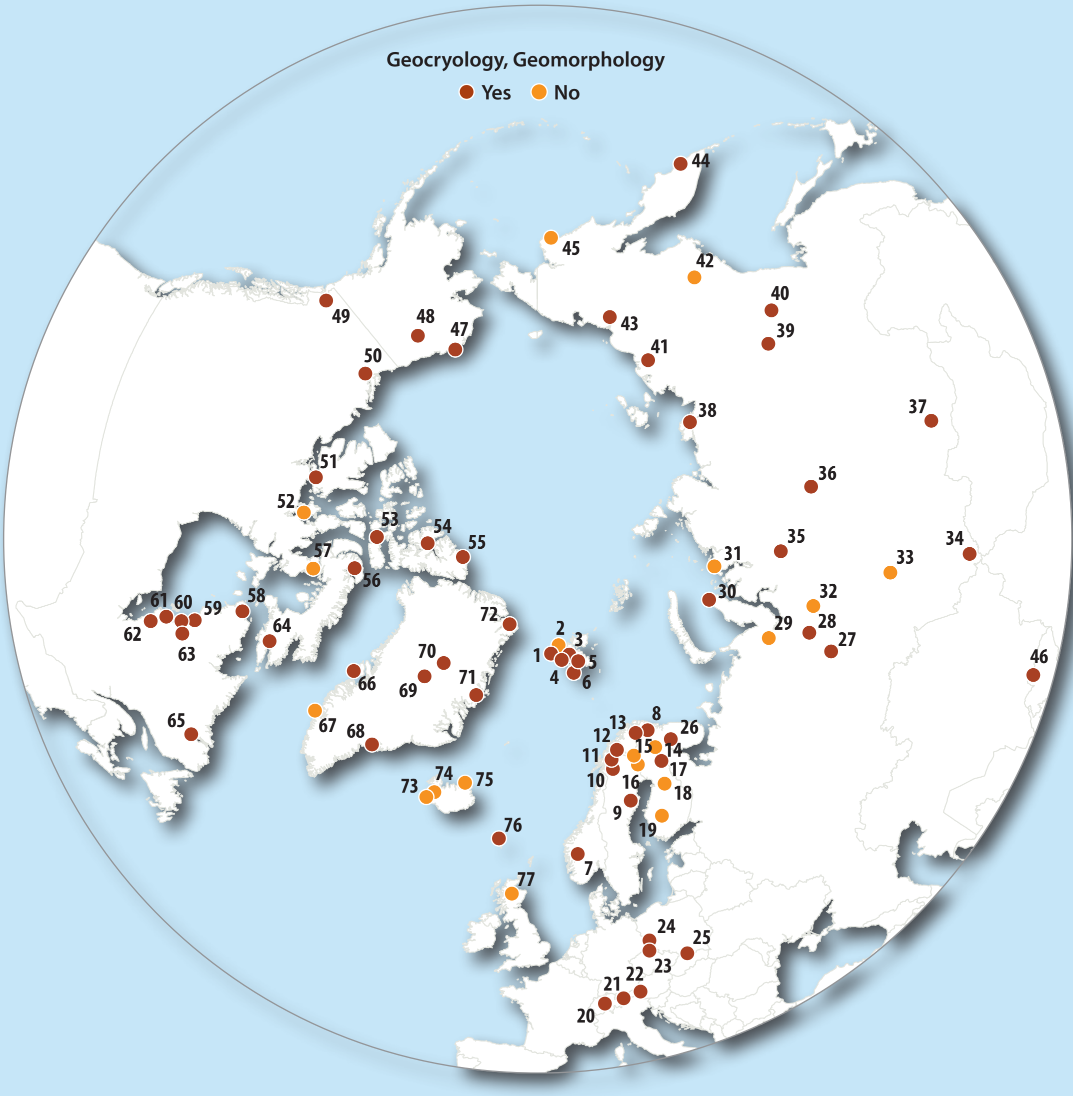
3.1.7 Environmental sciences – Pollution

is the interdisciplinary scientific study of the environment and environmental problems, e.g. pollution, which is the presence or introduction into the environment (especially as a result of human activity) of harmful or poisonous substances, or excessive levels of light, noise, organic waste, etc. [7].



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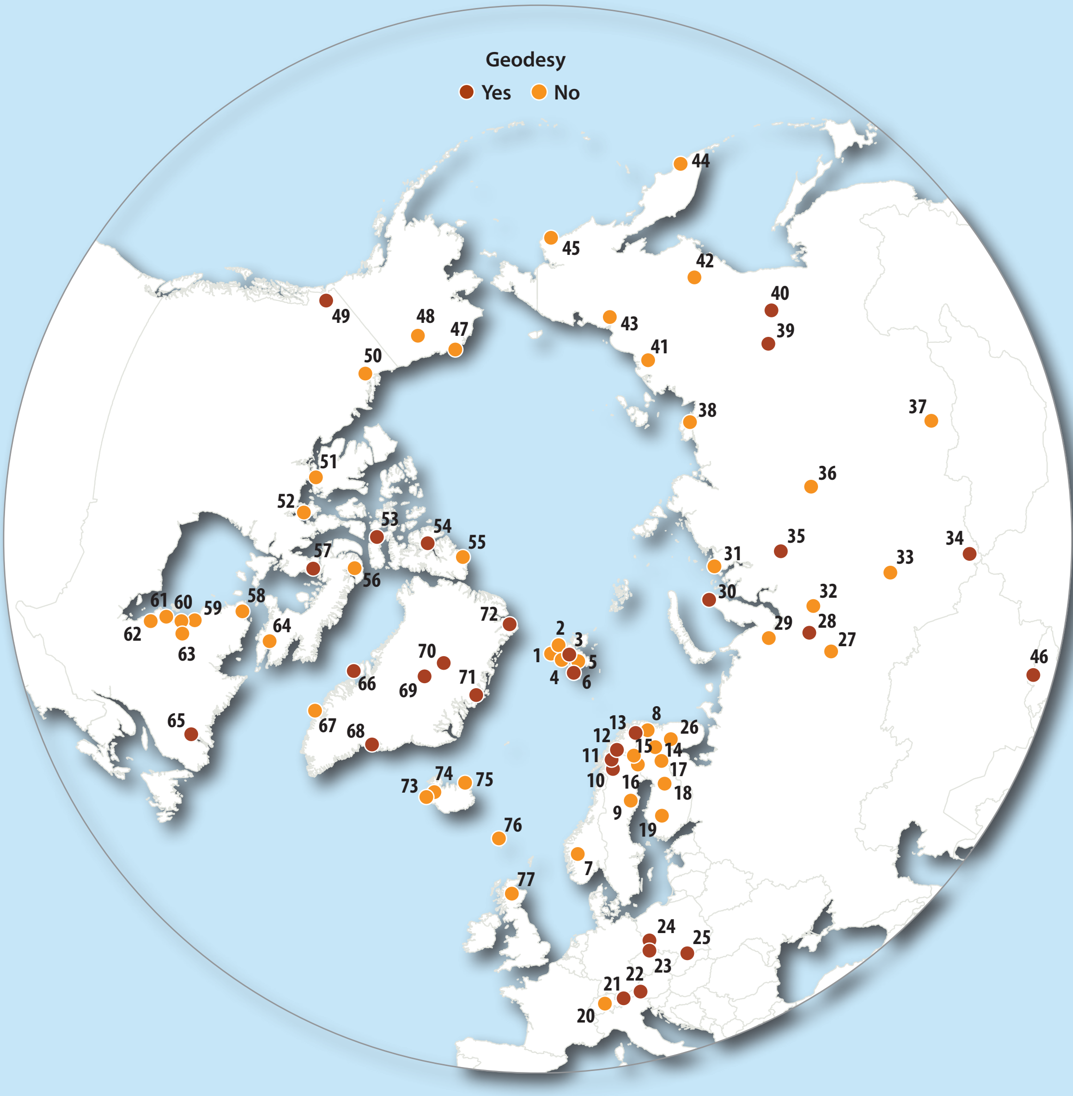
3.1.8 Geocryology, Geomorphology

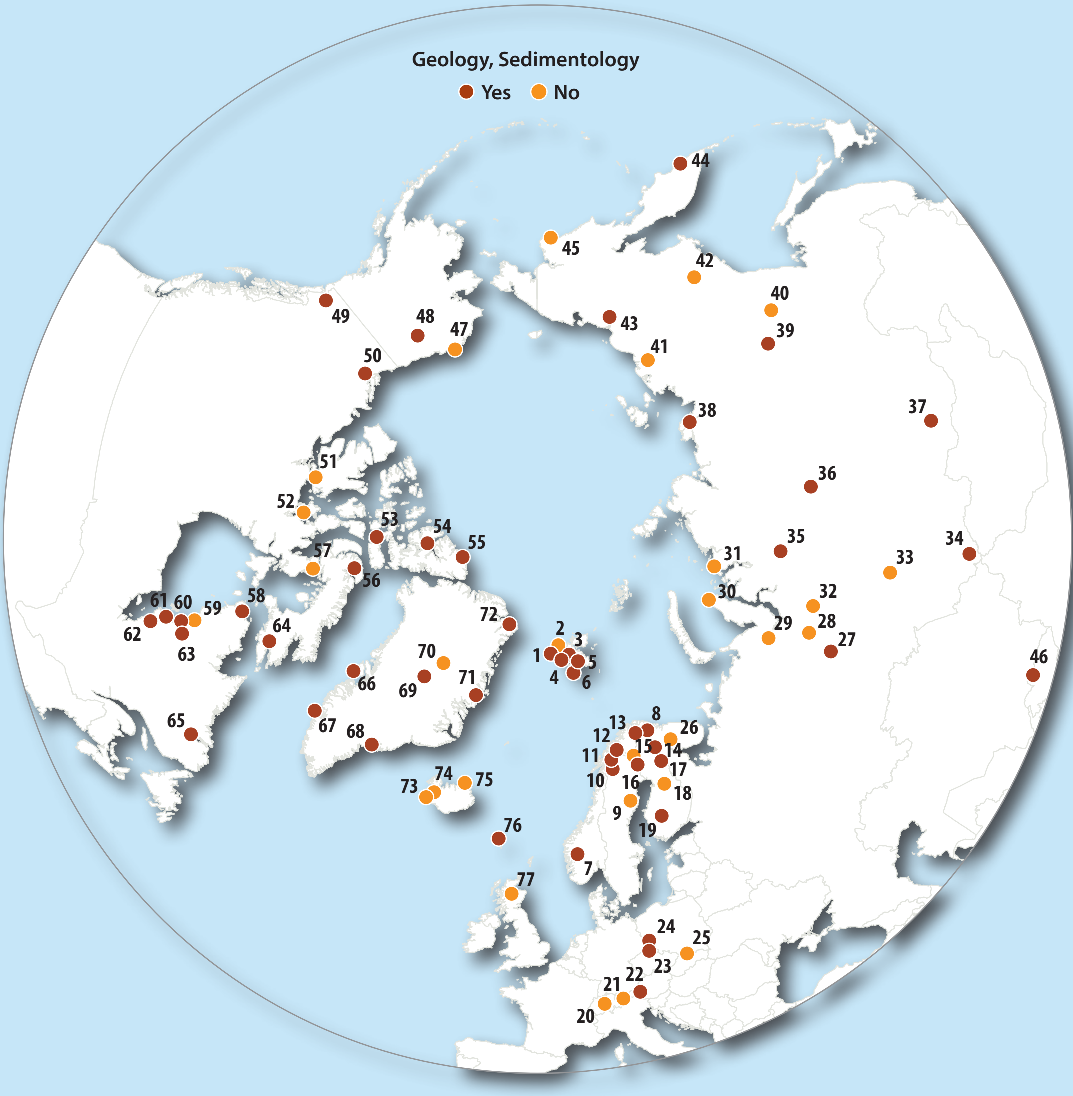
Geocryology is the study of frozen rock, soils, and ground. It deals with (i) the origin, historical development and conditions of existence of frozen strata in the earth's crust, (ii) the processes and phenomena that occur in freezing, frozen, and thawing rock, soils, and ground, as well as their structure, composition, and properties, and (iii) the geophysical, physicogeological, geomorphological, and hydrogeological phenomena related to the processes of the freezing, thawing, and diagenesis of frozen strata. In addition to developing the theory of such processes, geocryology deals with the development of methods of influencing processes of freezing in the interests of construction, transportation, agriculture and other activities. In this connection, two main directions or branches are developing –general geocryology and engineering geocryology [8].

Geomorphology is the scientific study of the land-forms on the Earth's surface and of the processes that have fashioned them [9].



3.1.9 Geodesy

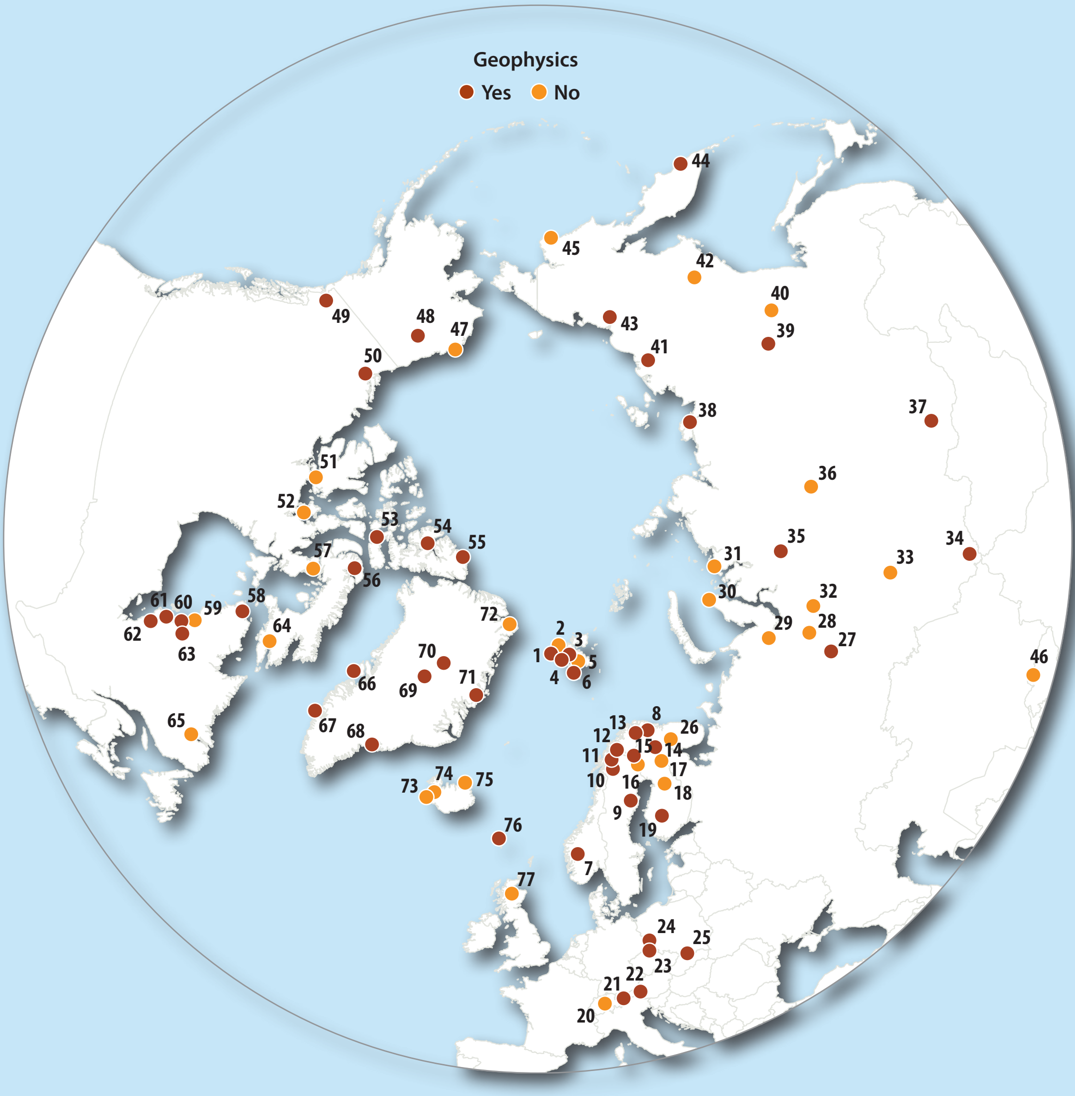
is the science of measurement of the shape or figure of the Earth and its gravitational field. This science has expanded from topographic and astronomic surveying with the advent of satellite positioning systems, e.g. GPS and SPS [9].



3.1.10 Geology, Sedimentology

Geology is the scientific study of the composition, structure, and history of the Earth [9].

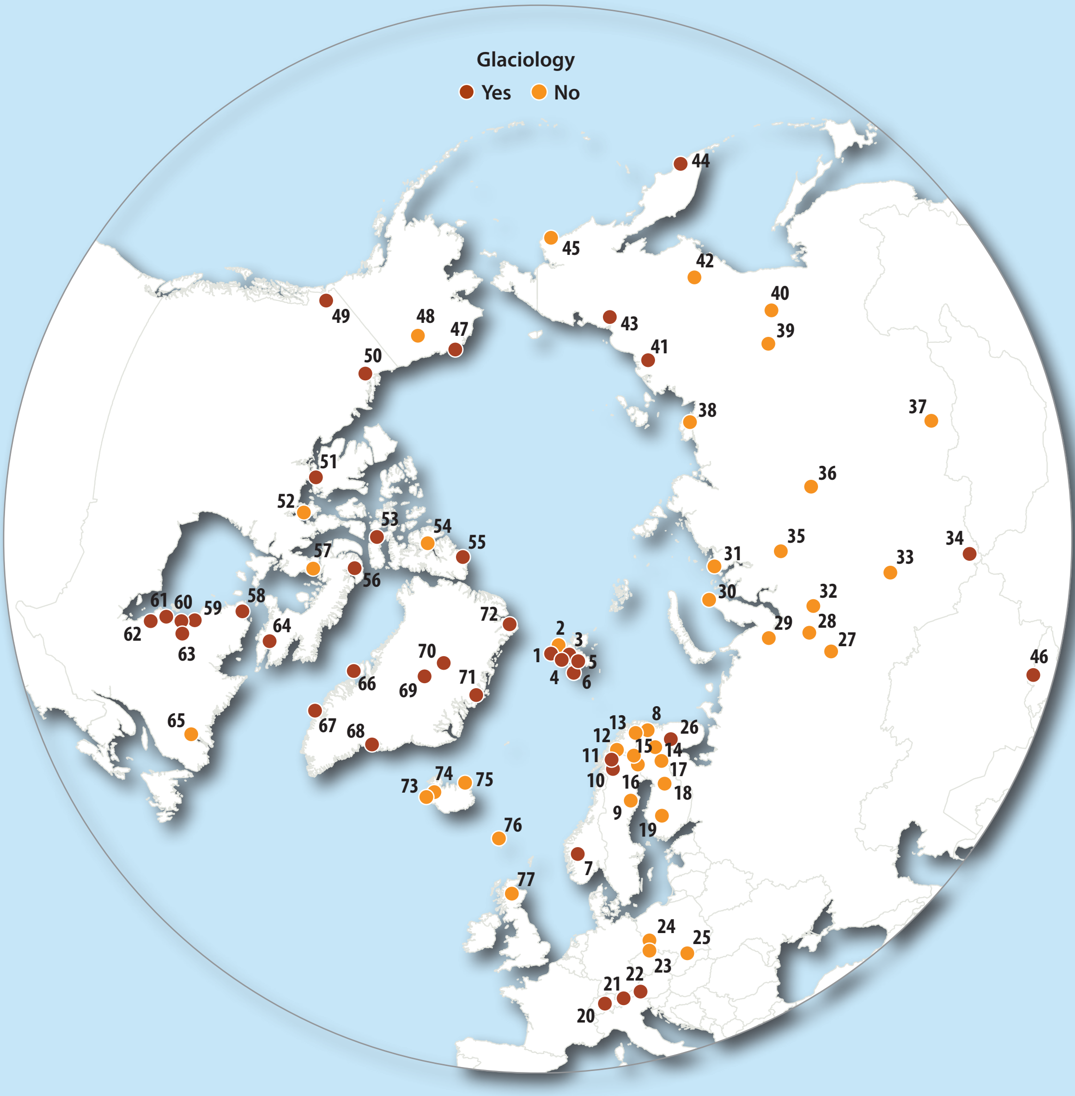
Sedimentology is the scientific study, interpretation, and classification of sediments, sedimentary processes and sedimentary rocks [9].



3

3.1.11 Geophysics

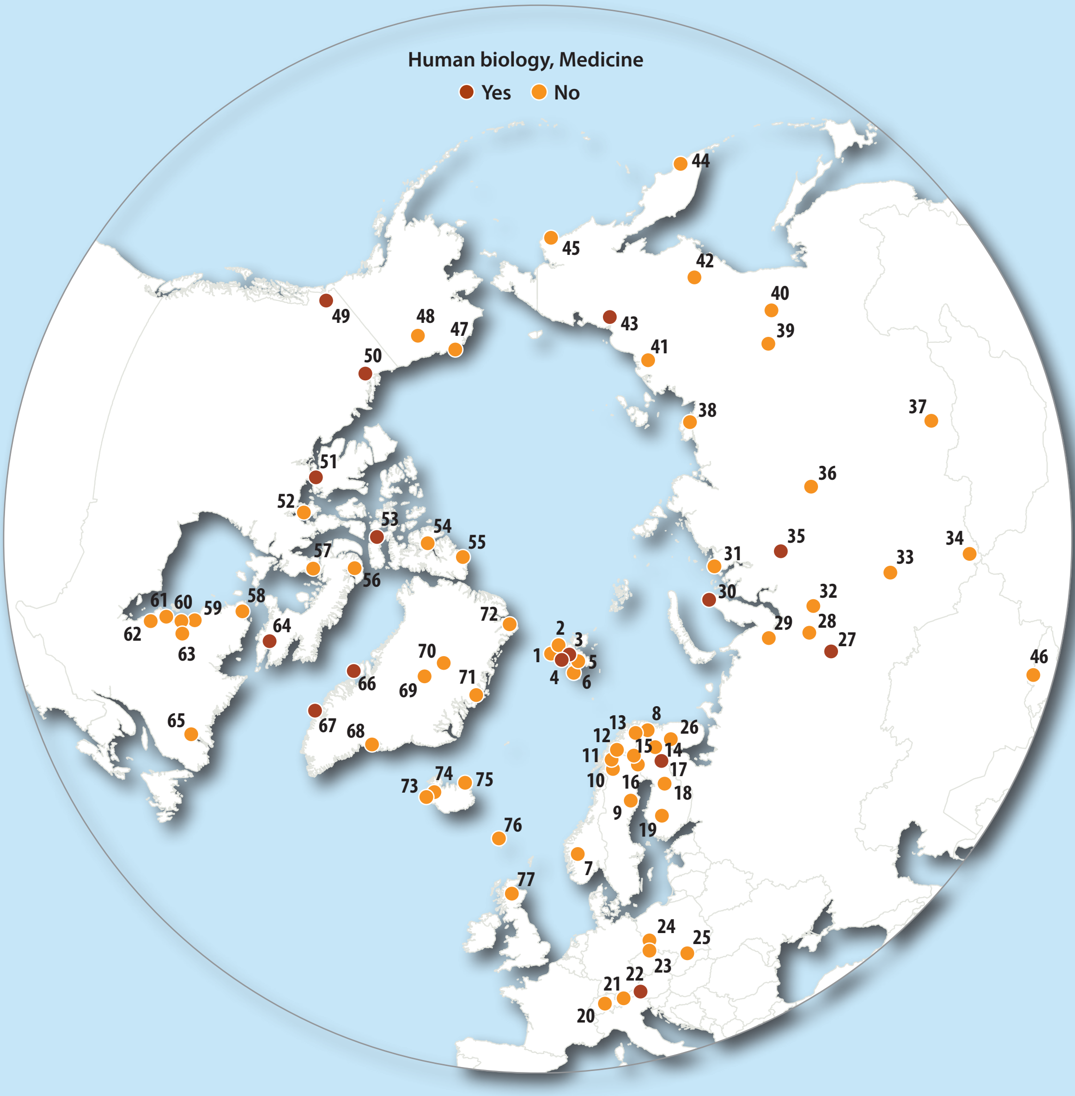
is the science concerned with all aspects of the physical properties and processes of the Earth and planetary bodies and their interpretation, including, for example, seismology, gravity, magnetism, heat flow, and geochronology [9].



3

3.1.12 Glaciology

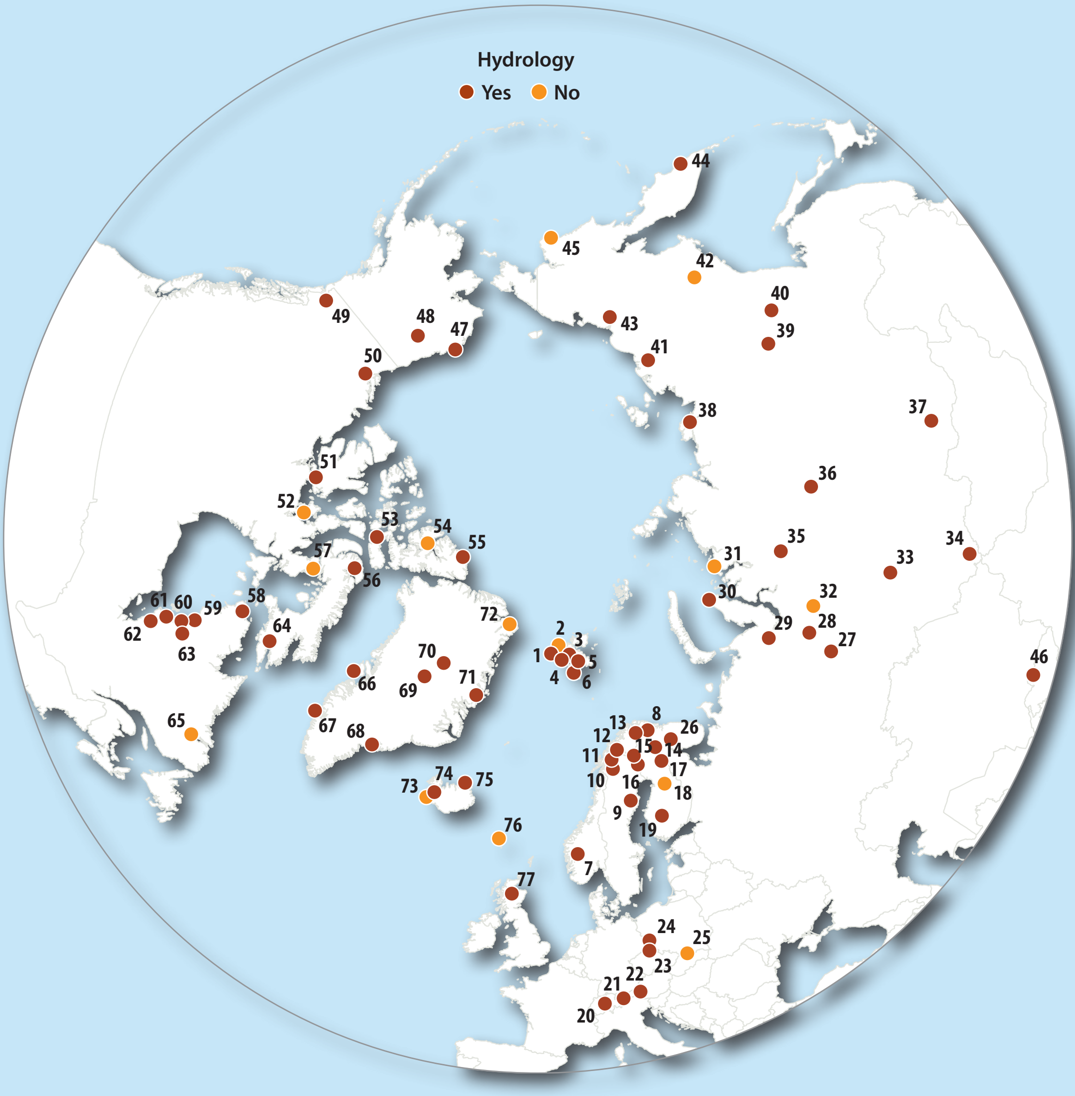
is the scientific study of ice in all its forms. It therefore includes the study of ice in the atmosphere, in lakes, rivers, and oceans, and on and beneath the ground. Commonly, however, it is the study of glaciers [9].



3.1.13 Human biology, Medicine

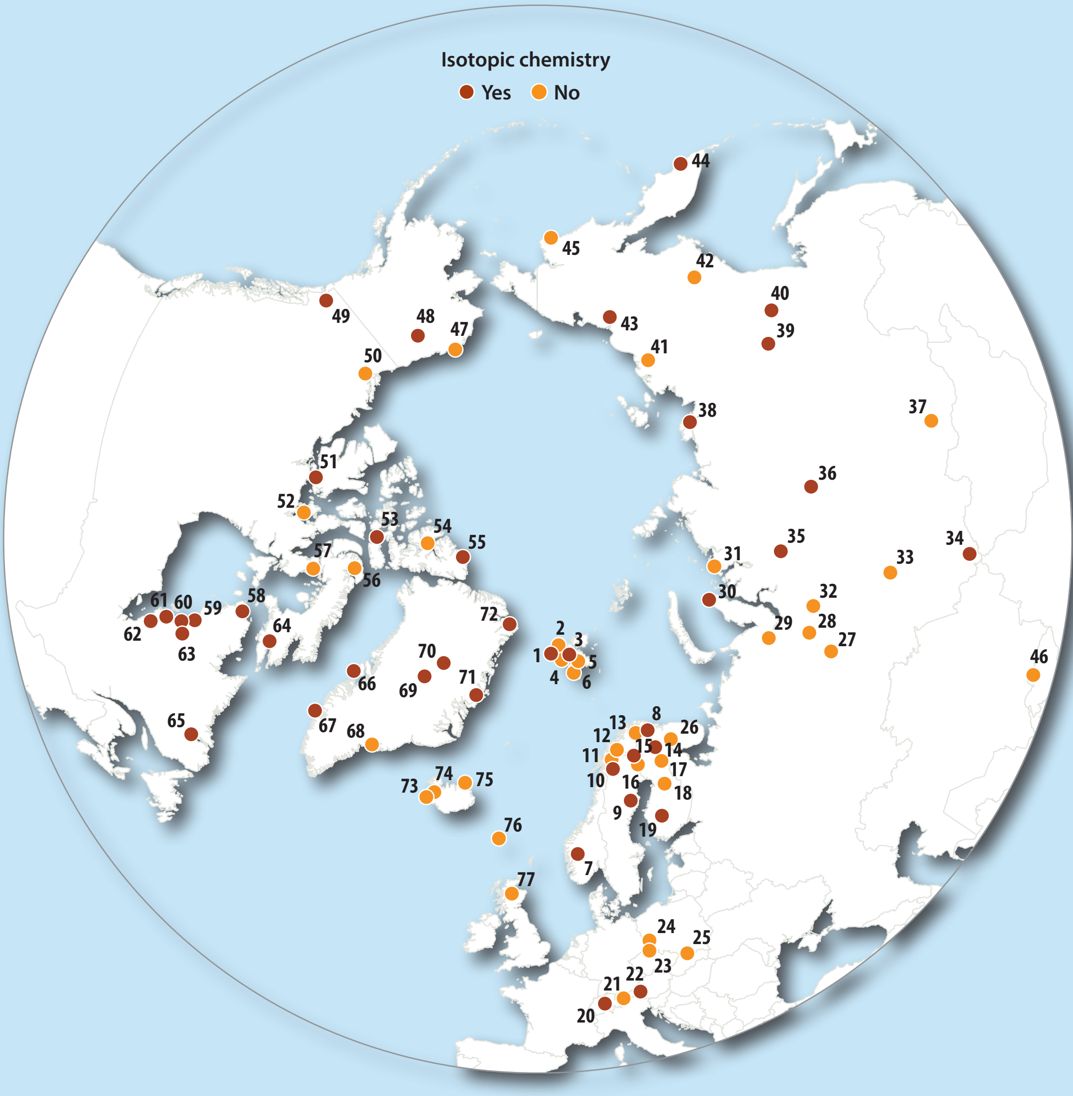
Human biology is the branch of science concerned with the development and functioning of the human organism and aspects of the life of human populations such as their ecology, genetics and epidemiology [10].

Medicine is the science or practice of the diagnosis, treatment and prevention of disease [10].



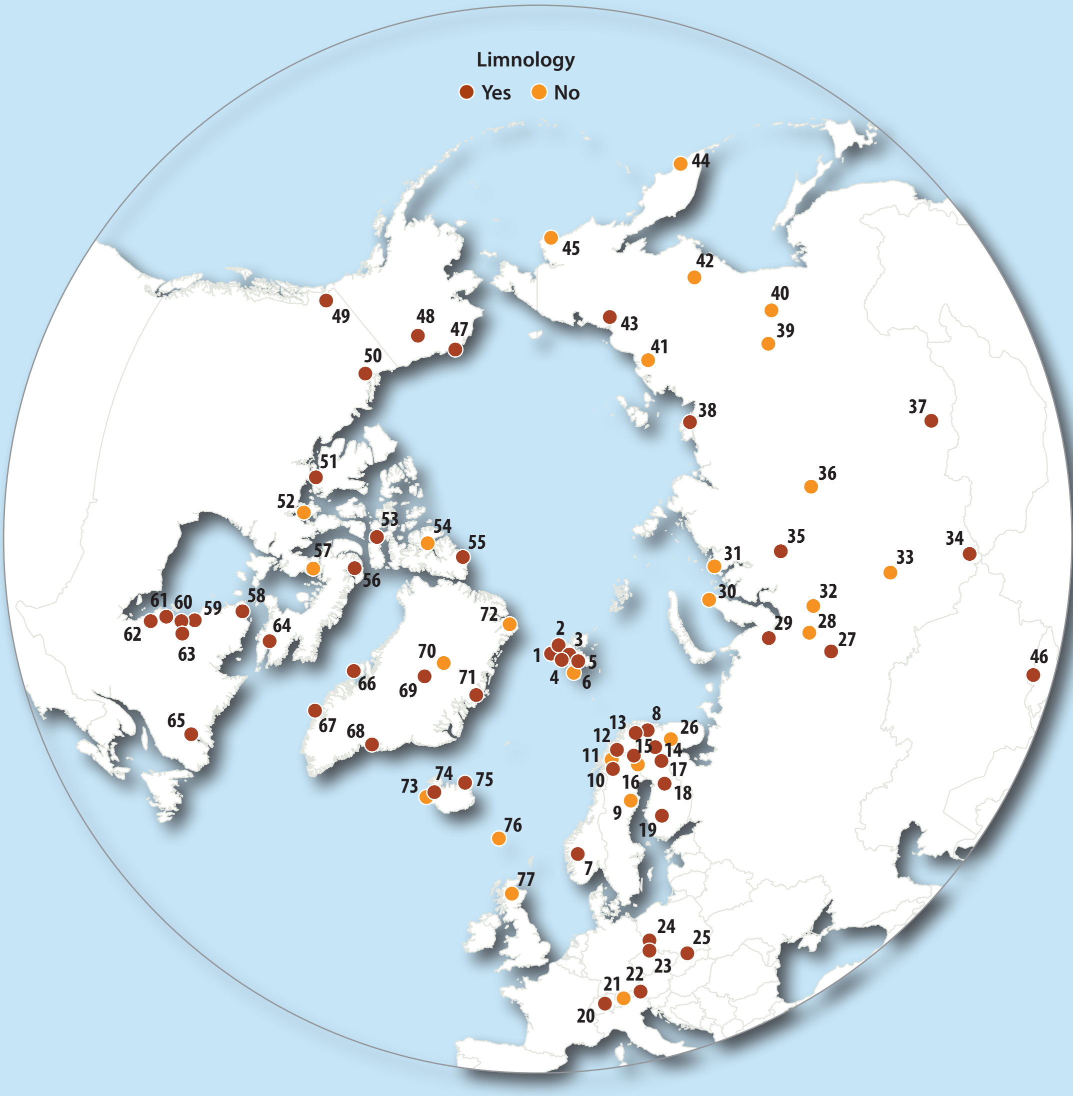
3.1.14 Hydrology

is the study of the hydrologic (water) cycle. While it involves aspects of geology, oceanography and meteorology, it emphasizes the study of bodies of surface water on land and how they change with time [9].



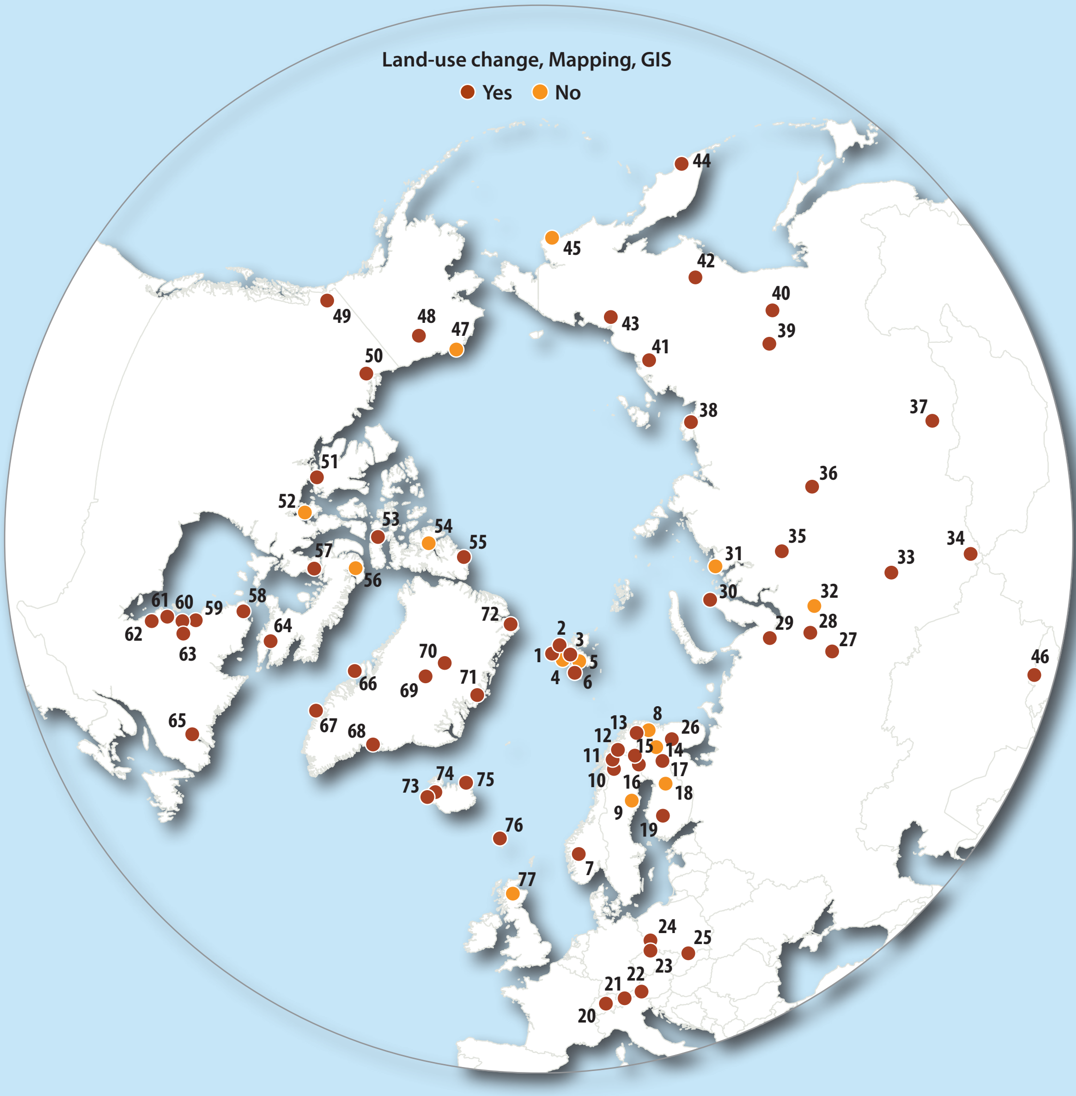
3.1.15 Isotopic chemistry

is a study of the abundance ratios of isotopes (both stable and radioactive) of major and trace elements (e.g. Rb/Sr, Pb/U, etc.), to elucidate a number of inorganic, organic, environmental, bio-geochemistry and biochemical reaction mechanisms and other processes [9].



3.1.16 Limnology

is a subsystem of hydrology that deals with the scientific study of fresh waters, specifically those found in lakes, ponds, rivers and streams. The discipline also includes the biological, physical and chemical aspects of the occurrence of freshwater bodies [3].



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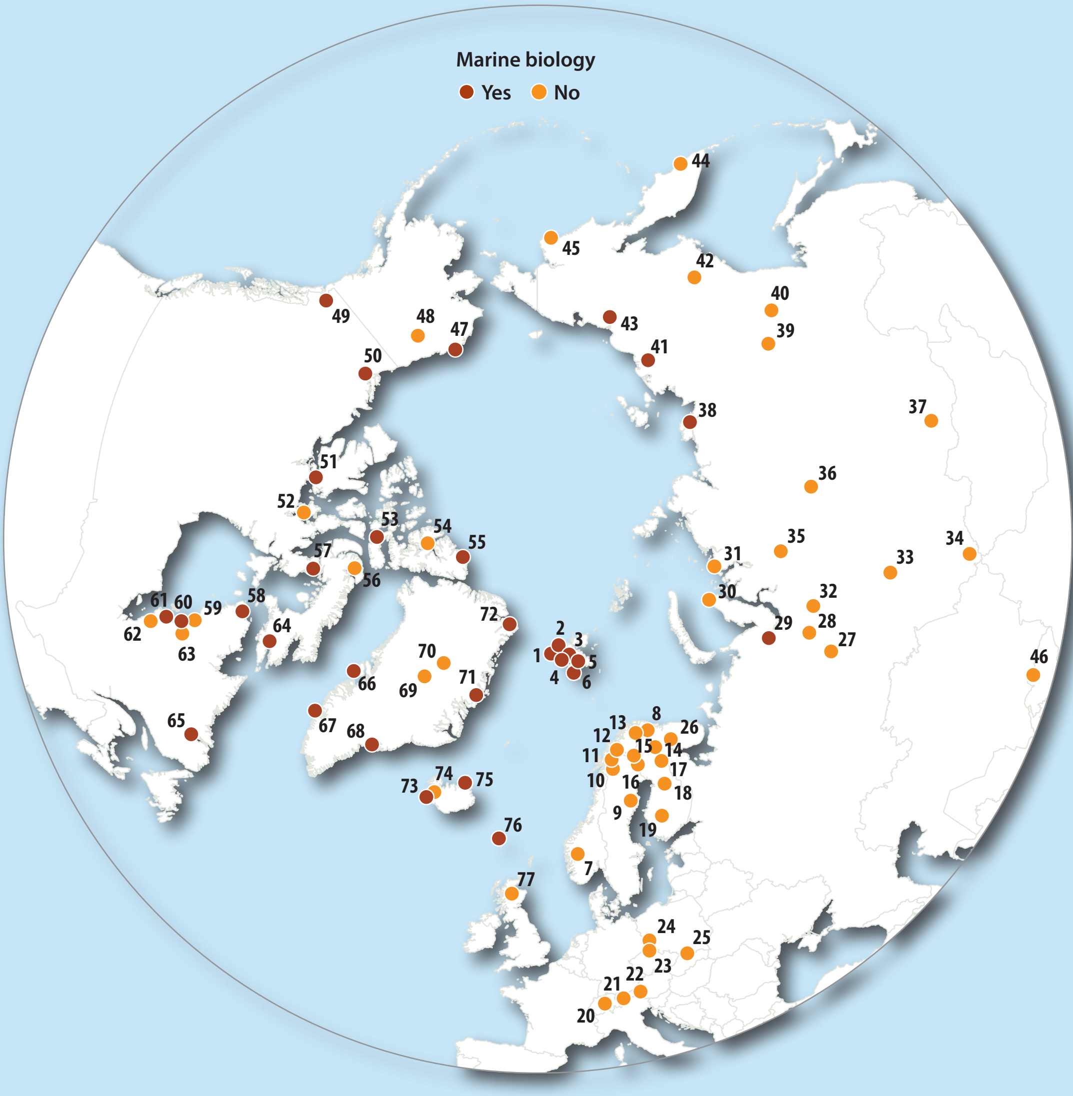
3.1.17 Land-use change, Mapping, GIS

Land-use change is the mapping of changes in the management, modification (e.g. infrastructure) and use of an area (e.g. science, resource use, tourism, etc.) [5].

Mapping is the drawing, making or provision of a map or maps [8].

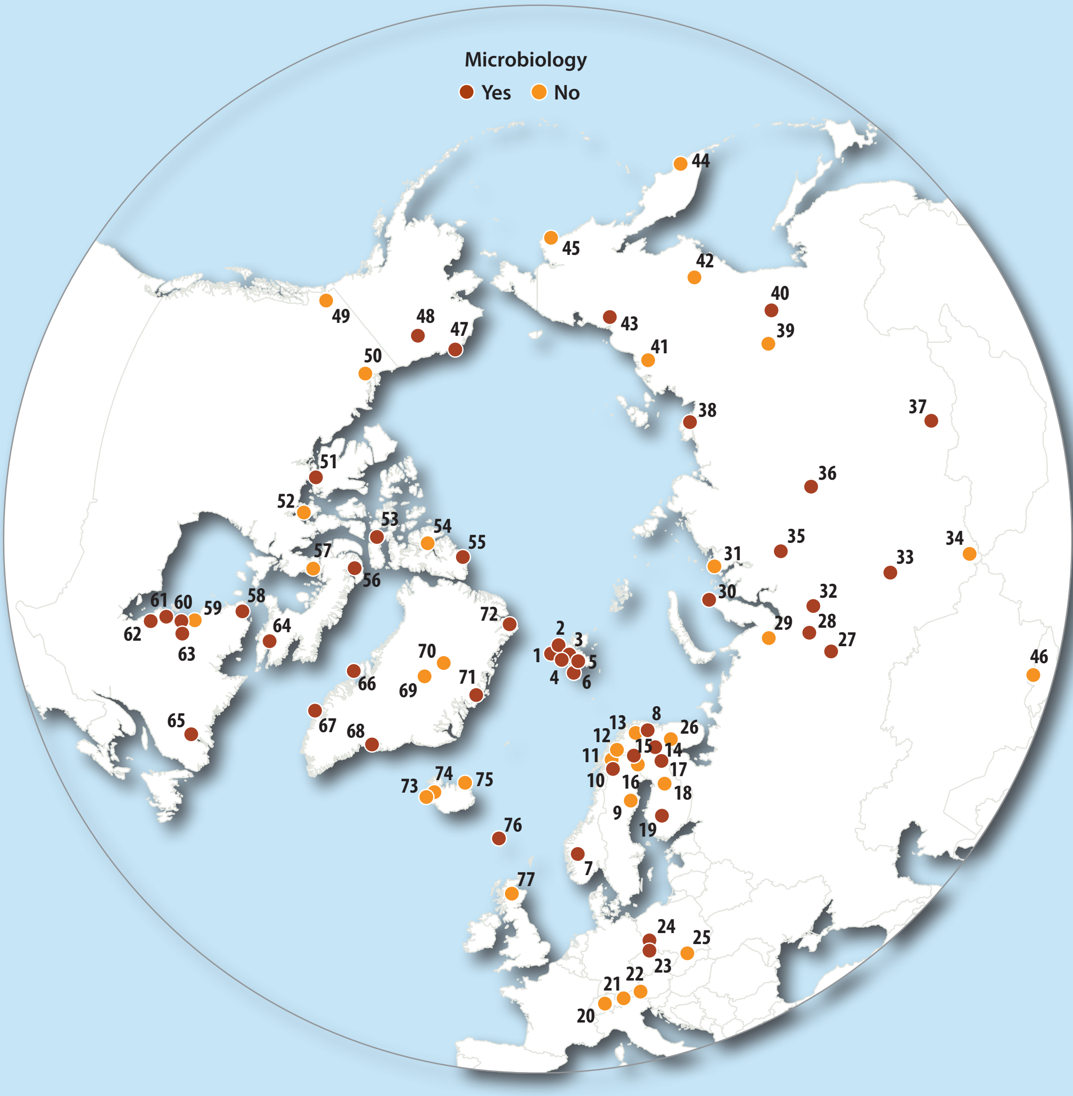
GIS – Geographic (also Geographical) Information System, is a computer based system specially designed and implemented for two subtle but interrelated purposes: managing geospatial data and using these data to solve spatial problems [11].



3

3.1.18 Marine biology

is the scientific study of organisms in the ocean or other marine or brackish bodies of water. Given that in biology many phyla, families and genera have some species that live in the sea and others that live on land, marine biology classifies species based on the environment rather than on taxonomy. Marine biology differs from marine ecology as it is the study of the organisms themselves, whereas marine ecology is focused on how organisms interact with each other and the environment [5].



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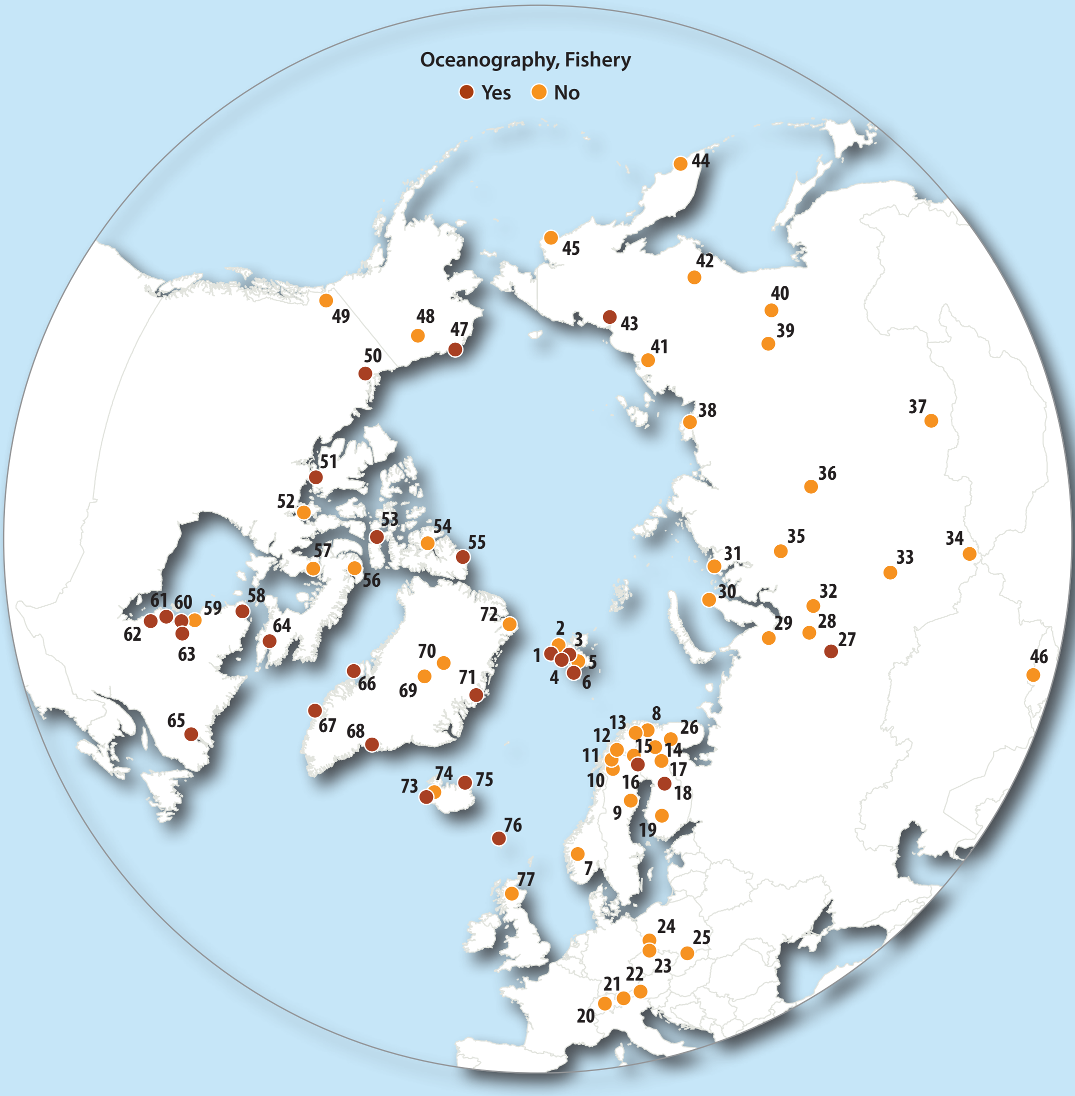
3.1.19 Microbiology

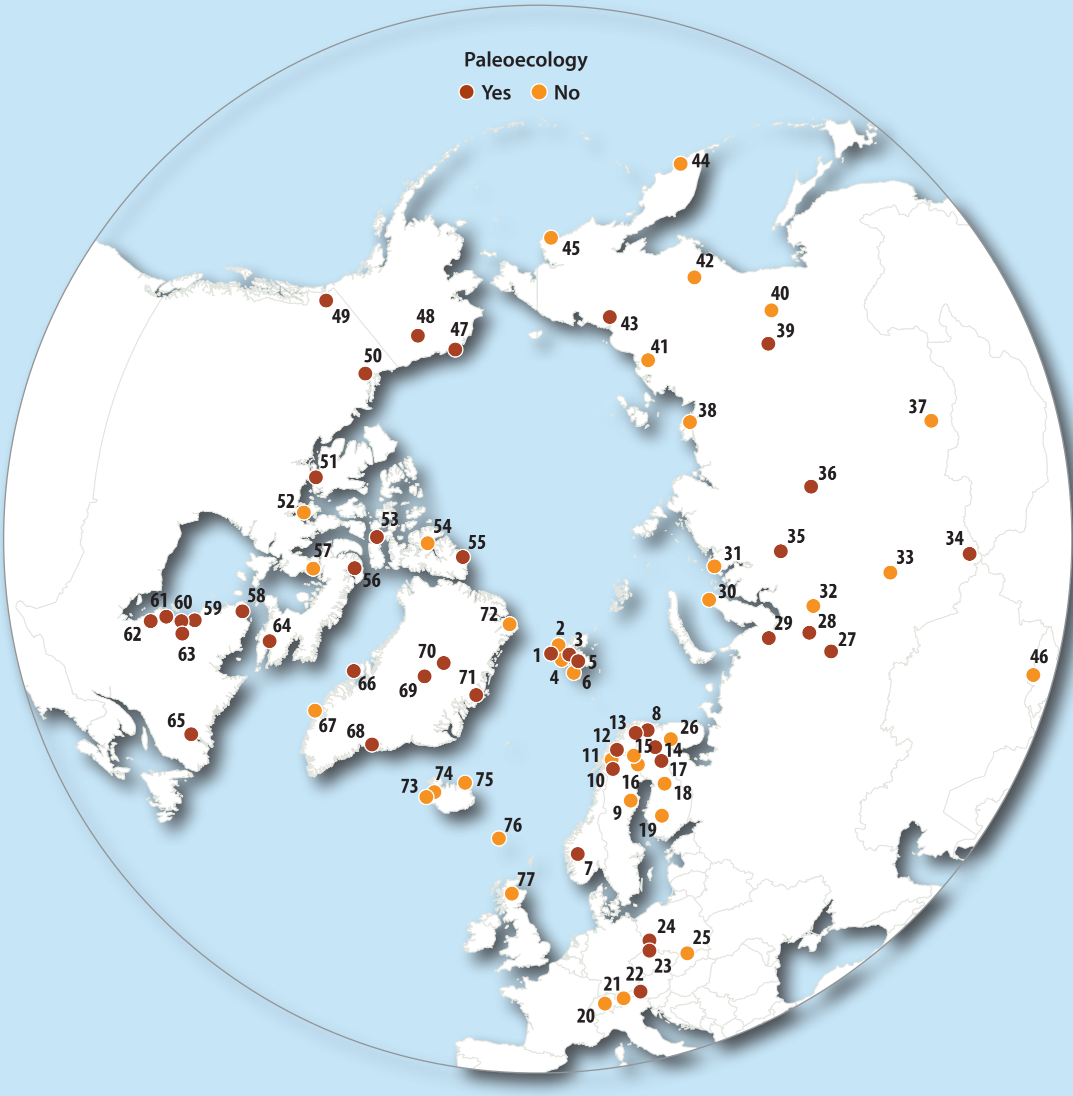
is the study of microorganisms or microbes, a diverse group of minute, simple life forms that include bacteria, archaea, algae, fungi, protozoa and viruses. The field is concerned with the structure, function and classification of such organisms and with ways of both exploiting and controlling their activities [3].



3.1.20 Oceanography, Fishery

Oceanography is the scientific discipline concerned with all aspects of the world's oceans and seas, including their physical and chemical properties, their origin and geologic framework, and the life forms that inhabit the marine environment [3].

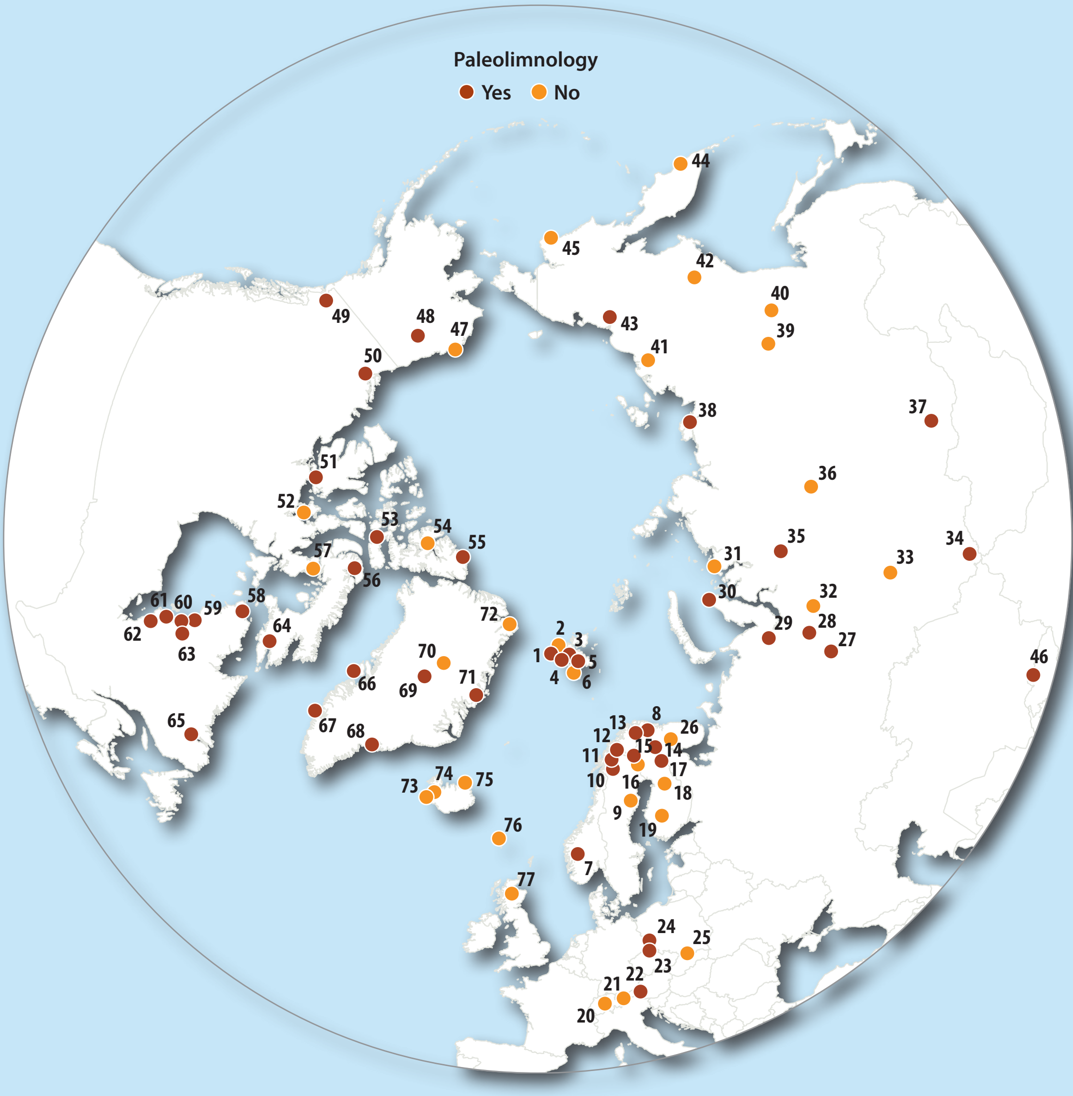
Fishery is the business, occupation, or industry of catching fish or of taking other products from the sea, lakes or rivers [10].



3

3.1.21 Paleoecology

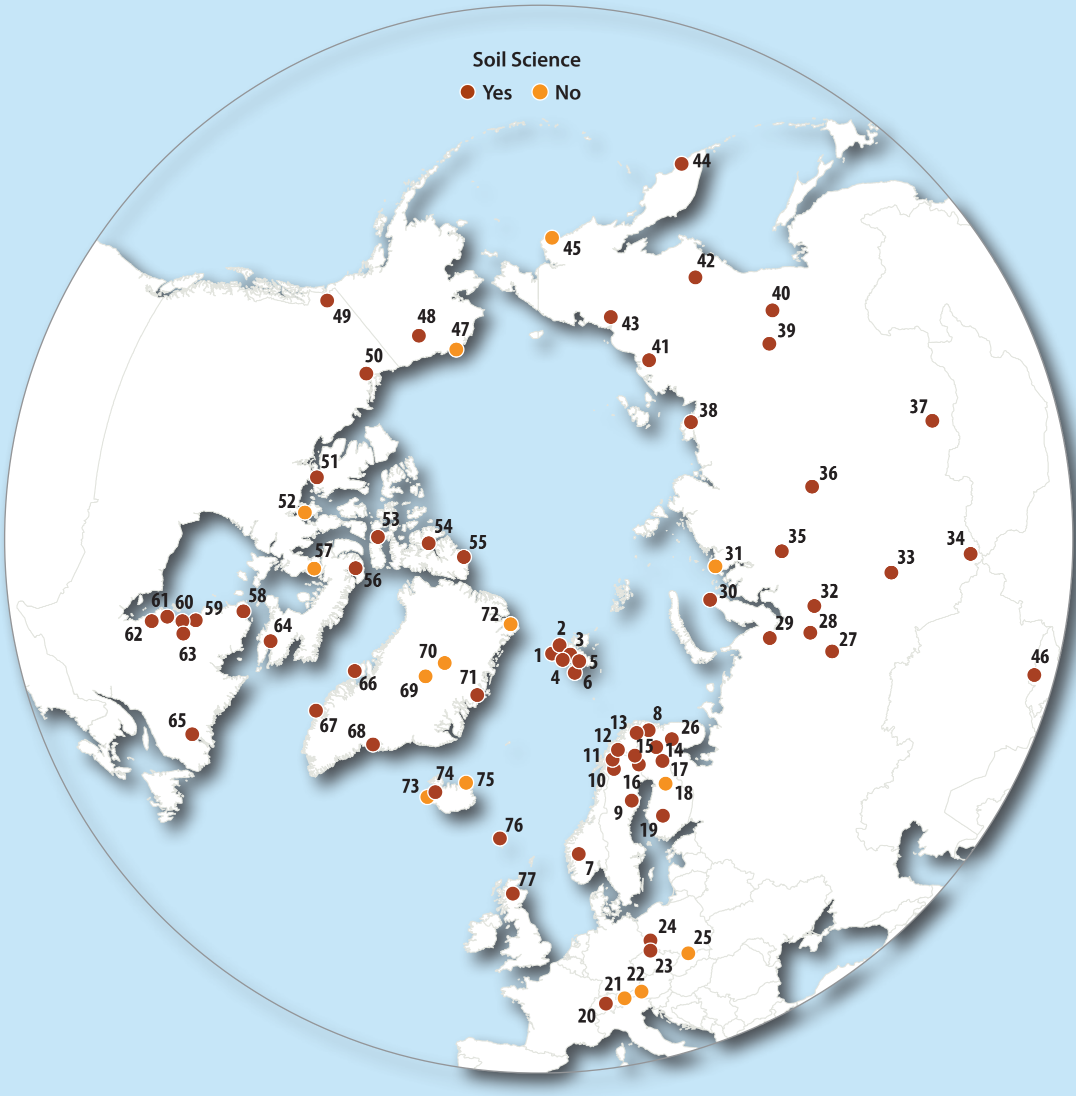
is a branch of ecology that deals with extinct and fossil plants and animals [10].



3

3.1.22 Paleolimnology

is the study of the conditions and processes occurring in lakes in the geological past [10].



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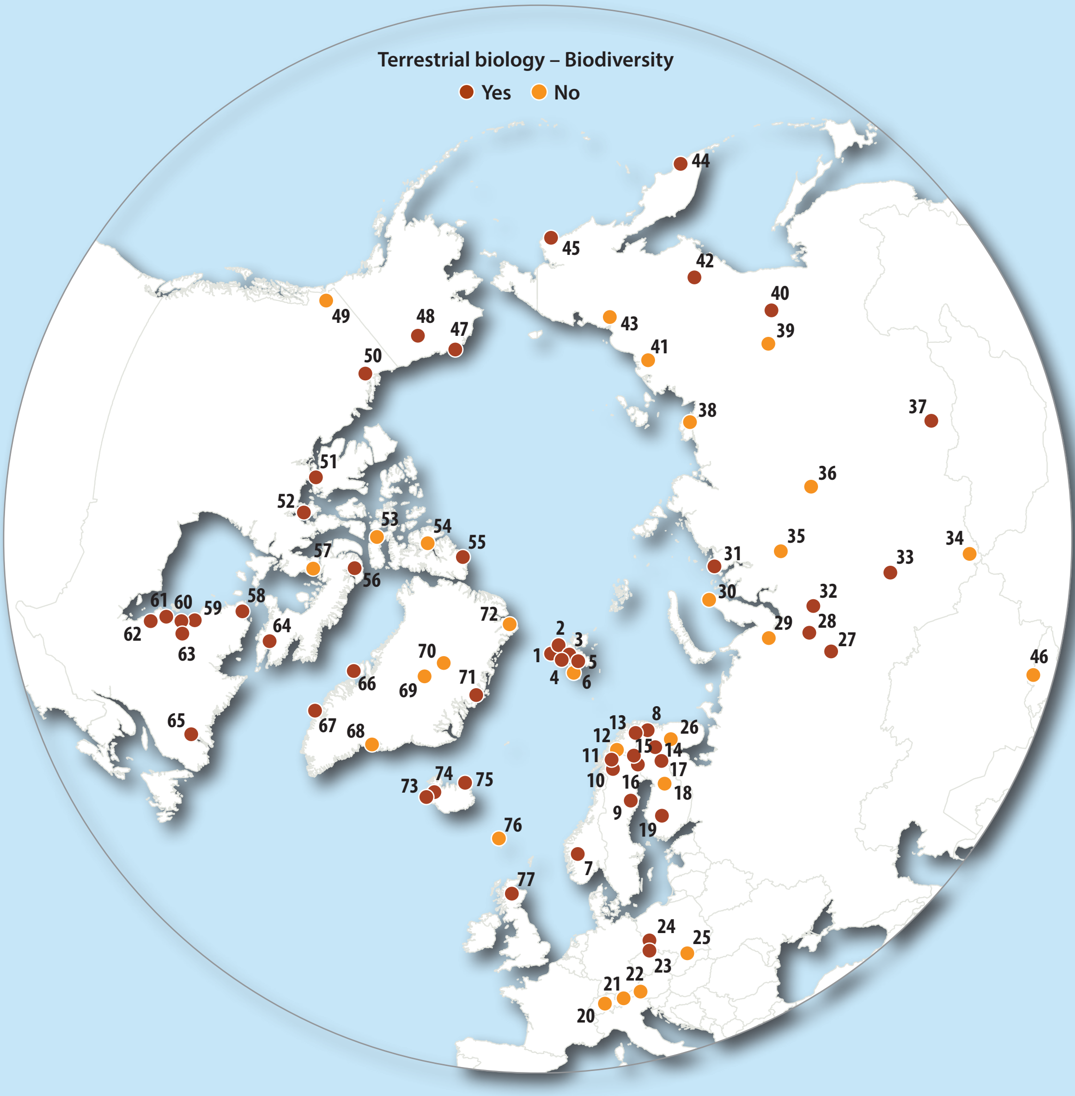
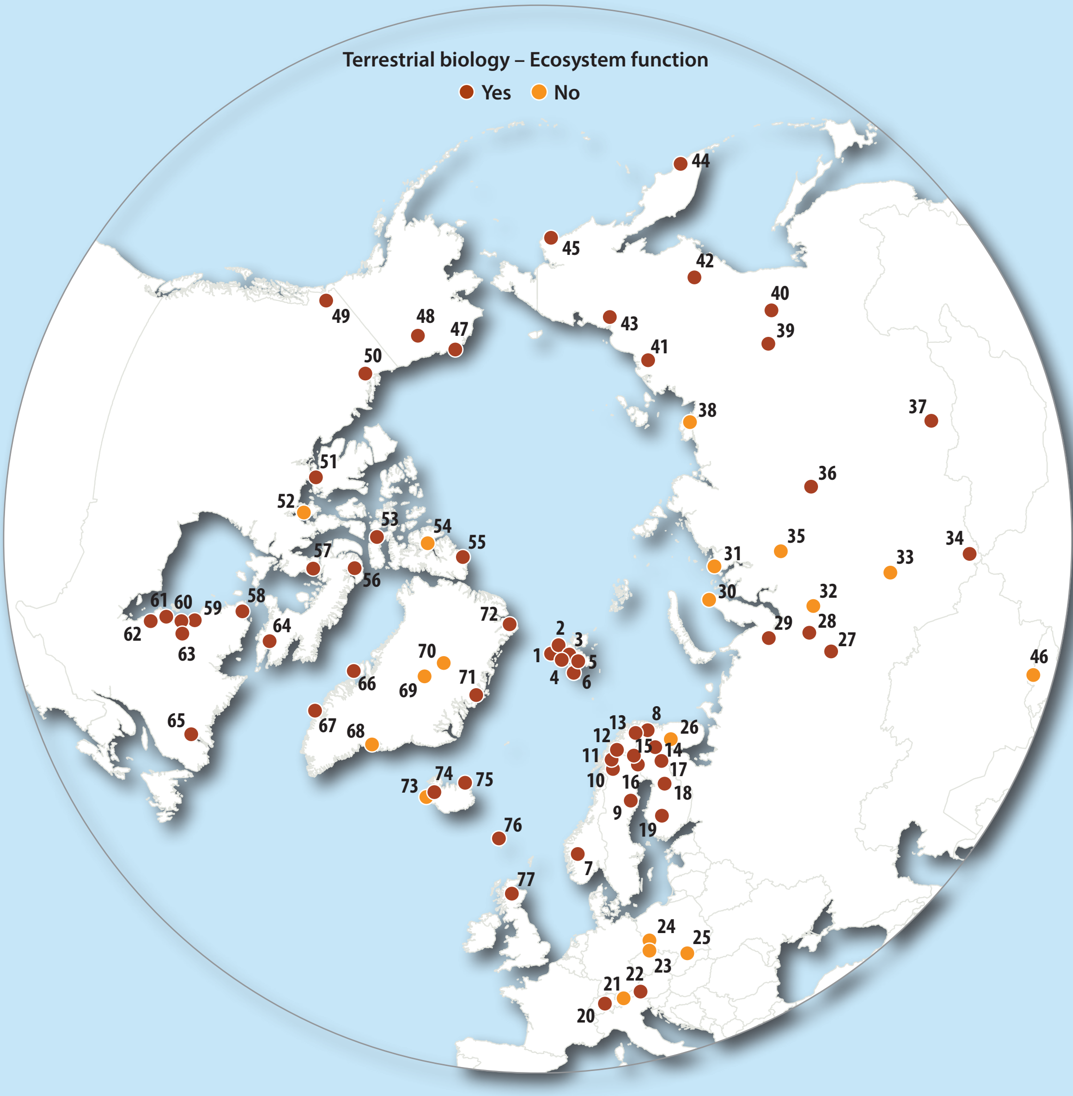
3.1.23 Soil Science

is the study dealing with soils as a natural resource on the surface of the Earth including (i) soil formation, classification and mapping, (ii) physical, chemical, biological and fertility properties of soils per se, and (iii) these properties in relation to the use and management of soils [12].



3.1.24 Terrestrial biology – Biodiversity

is the study of the diversity and variability among living organisms and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems [13].



3

3.1.25 Terrestrial biology – Ecosystem function

is an intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy [14].

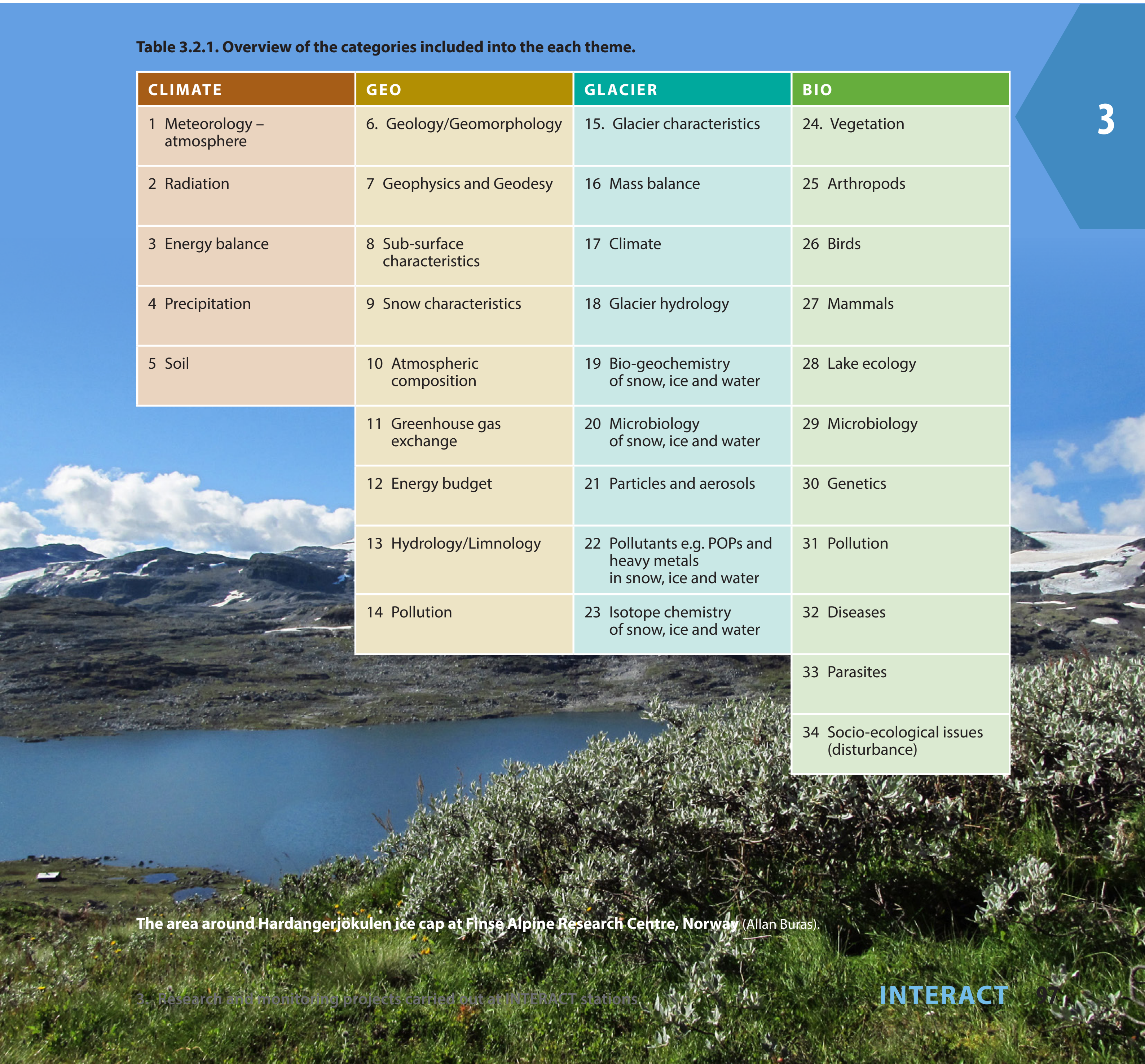
3.2 Monitored environmental parameter groups

In this section, the reader is introduced to the environmental parameters monitored at the INTERACT stations. In order to make the practical application of this chapter less laborious, the parameters were grouped into broader categories belonging to the four themes CLIMATE, GEO, GLACIER and BIO. The categories for each theme are presented in Table 3.2.1. Maps illustrate the geographical distribution of INTERACT stations that monitor at least one parameter in a parameter group. Hence, to learn which specific parameter is being monitored, you need to explore the INTERACT Research and Monitoring Database (www.eu-interact.org).

The parameters included in the different categories under each theme are presented in tables 3.2.2-3.2.5.

Table 3.2.1. Overview of the categories included into the each theme.

CLIMATE	GEO	GLACIER	BIO
1 Meteorology – atmosphere	6. Geology/Geomorphology	15. Glacier characteristics	24. Vegetation
2 Radiation	7 Geophysics and Geodesy	16 Mass balance	25 Arthropods
3 Energy balance	8 Sub-surface characteristics	17 Climate	26 Birds
4 Precipitation	9 Snow characteristics	18 Glacier hydrology	27 Mammals
5 Soil	10 Atmospheric composition	19 Bio-geochemistry of snow, ice and water	28 Lake ecology
	11 Greenhouse gas exchange	20 Microbiology of snow, ice and water	29 Microbiology
	12 Energy budget	21 Particles and aerosols	30 Genetics
	13 Hydrology/Limnology	22 Pollutants e.g. POPs and heavy metals in snow, ice and water	31 Pollution
	14 Pollution	23 Isotope chemistry of snow, ice and water	32 Diseases
			33 Parasites
			34 Socio-ecological issues (disturbance)

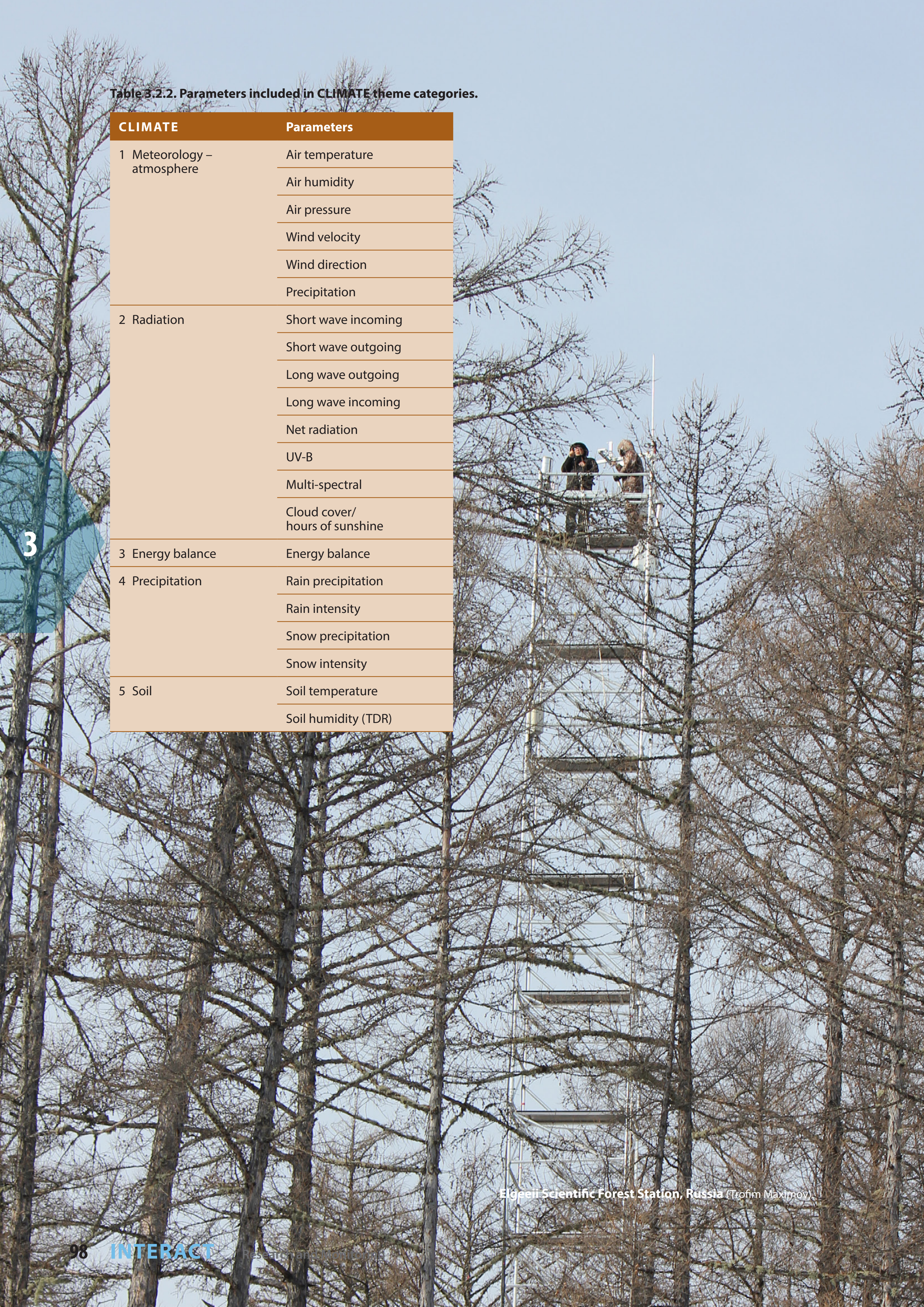


The area around Hardangerjökulen ice cap at Finse Alpine Research Centre, Norway (Allan Buras).

Table 3.2.2. Parameters included in CLIMATE theme categories.

CLIMATE	Parameters
1 Meteorology – atmosphere	Air temperature
	Air humidity
	Air pressure
	Wind velocity
	Wind direction
	Precipitation
2 Radiation	Short wave incoming
	Short wave outgoing
	Long wave outgoing
	Long wave incoming
	Net radiation
	UV-B
	Multi-spectral
	Cloud cover/ hours of sunshine
3 Energy balance	Energy balance
4 Precipitation	Rain precipitation
	Rain intensity
	Snow precipitation
	Snow intensity
5 Soil	Soil temperature
	Soil humidity (TDR)

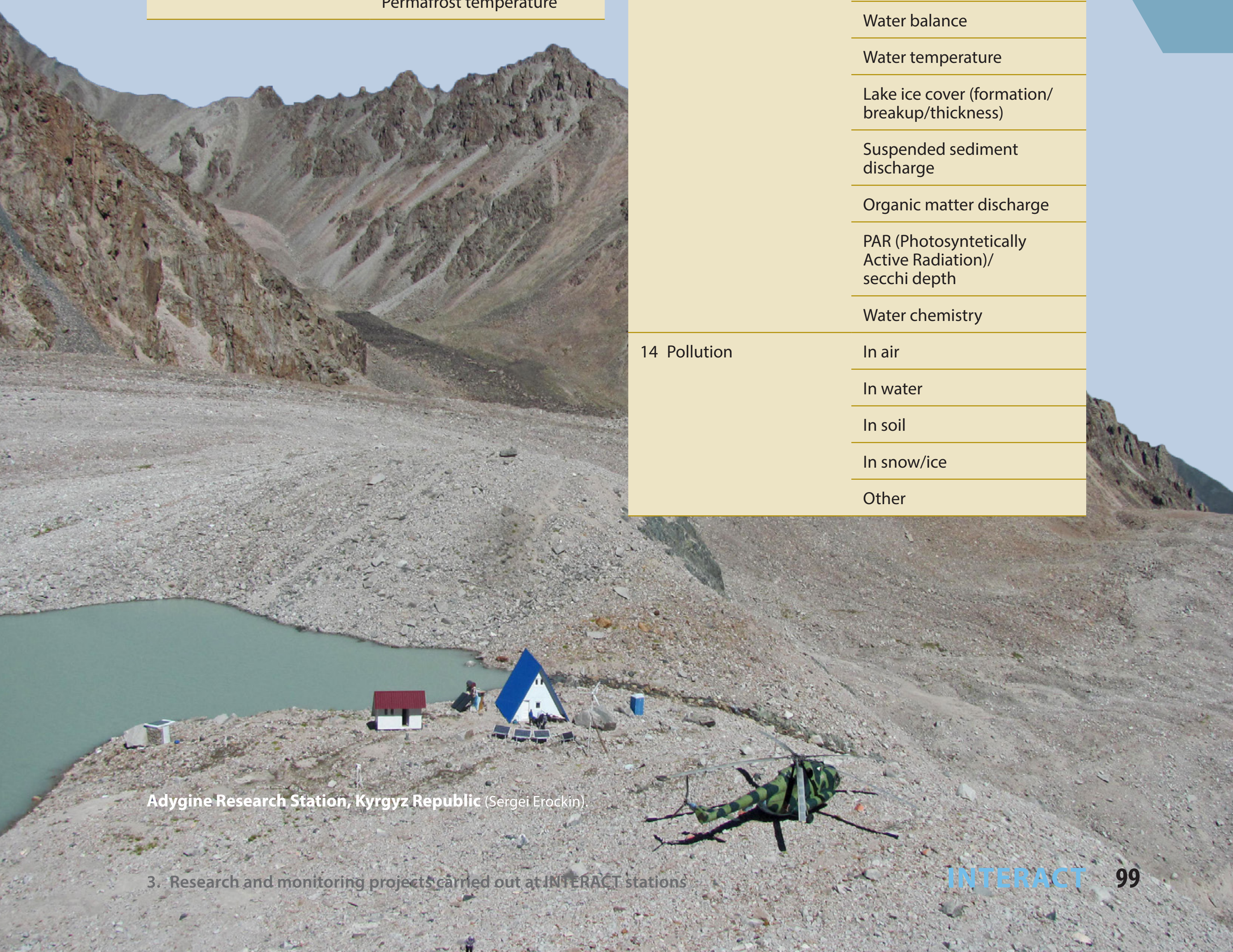
3



Elgeeii Scientific Forest Station, Russia (Trofim Maximov)

Table 3.2.3. Parameters included in GEO theme categories.

GEO	Parameter
6 Geology/ Geomorphology	Quaternary geology
	Sedimentology
	Bedrock geology
	Erosion
7 Geophysics and Geodesy	Gravity
	Magnetic field
	Aurora
	Seismic activity
8 Sub-surface characteristics	Ground surface temperature
	Ground/soil temperature
	Soil moisture content
	Ground water table
	Soil water chemistry
	Active layer depth
	Permafrost distribution
	Permafrost thickness
	Permafrost temperature
9 Snow characteristics	Snow depth
	Snow cover
	Snow density
	Snow temperature
10 Atmospheric composition	CO_2 concentration
	CH_4 concentration
11 Greenhouse gas exchange	CO_2 exchange
	CH_4 exchange
	N_2O exchange
12 Energy budget	Net radiation
	Sensible heat flux
	Latent heat flux
	Soil heat flux
13 Hydrology/Limnology	Precipitation
	River water discharge/ water level
	Lake water level
	Water balance
	Water temperature
	Lake ice cover (formation/ breakup/thickness)
	Suspended sediment discharge
	Organic matter discharge
	PAR (Photosyntetically Active Radiation)/ secchi depth
	Water chemistry
14 Pollution	In air
	In water
	In soil
	In snow/ice
	Other



Adygine Research Station, Kyrgyz Republic (Sergei Erockin)

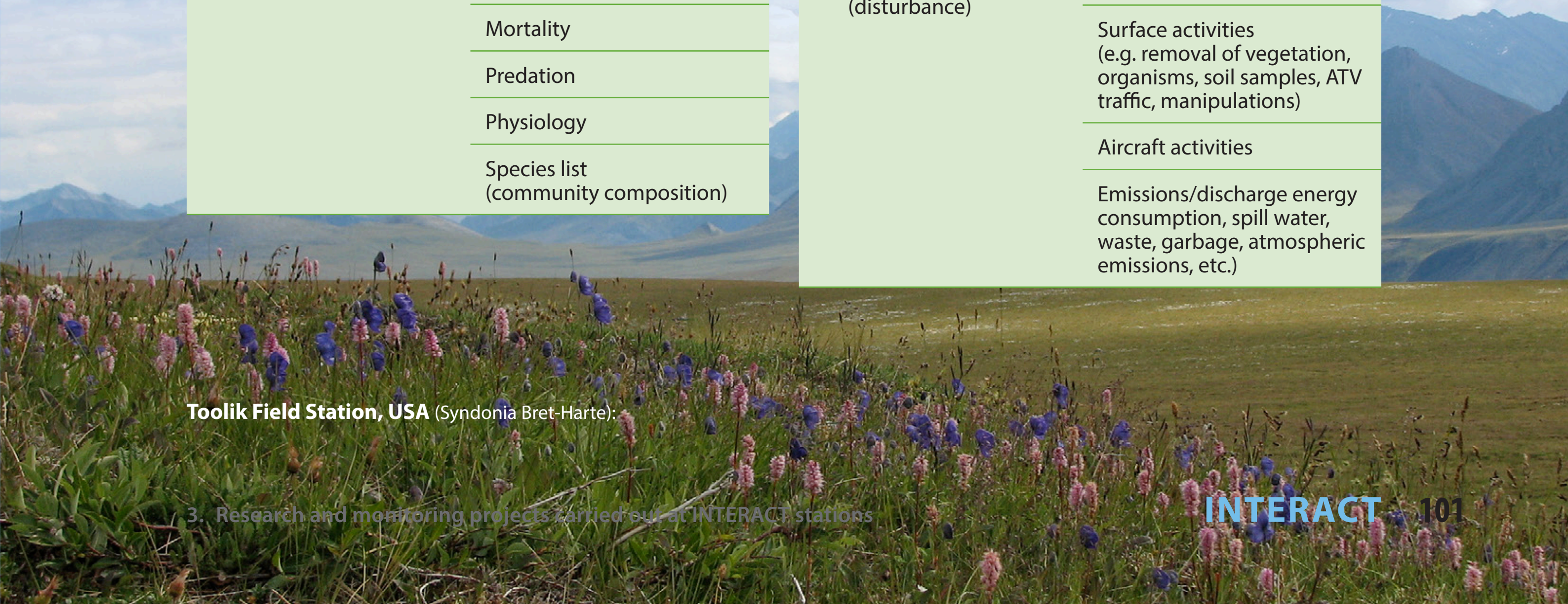
Table 3.2.4. Parameters included in GLACIER theme categories.

GLACIER	Parameters
15 Glacier characteristics	Glacier area
	Topography
	Elevation change
	Terminus position
	Ice velocity
	Ice thickness
	Debris cover
	Surface albedo/ reflexion coefficient
16 Mass balance	Mass balance
	Snow water equivalent
	Snowcover stratigraphy
	Equilibrium Line Altitude
	Duration of snow cover
	Calving flux
17 Climate	Climate measurements
	Energy balance
18 Glacier hydrology	Run-off
	Supra-, en- and subglacial drainage system
	Meltwater retention
	Glacial lake outburst floods
19 Bio-geochemistry of snow, ice and water	Bio-geochemistry of snow, ice and water
20 Microbiology of snow, ice and water	Microbiology of snow, ice and water
21 Particles and aerosols	Particles and aerosols
22 Pollutants e.g. POPs and heavy metals in snow, ice and water	Pollutants e.g. POPs and heavy metals in snow, ice and water
23 Isotope chemistry of snow, ice and water	Isotope chemistry of snow, ice and water

Kluane Lake Research Station, Canada (Lance Goodwin).

Table 3.2.5. Parameters included in BIO theme categories.

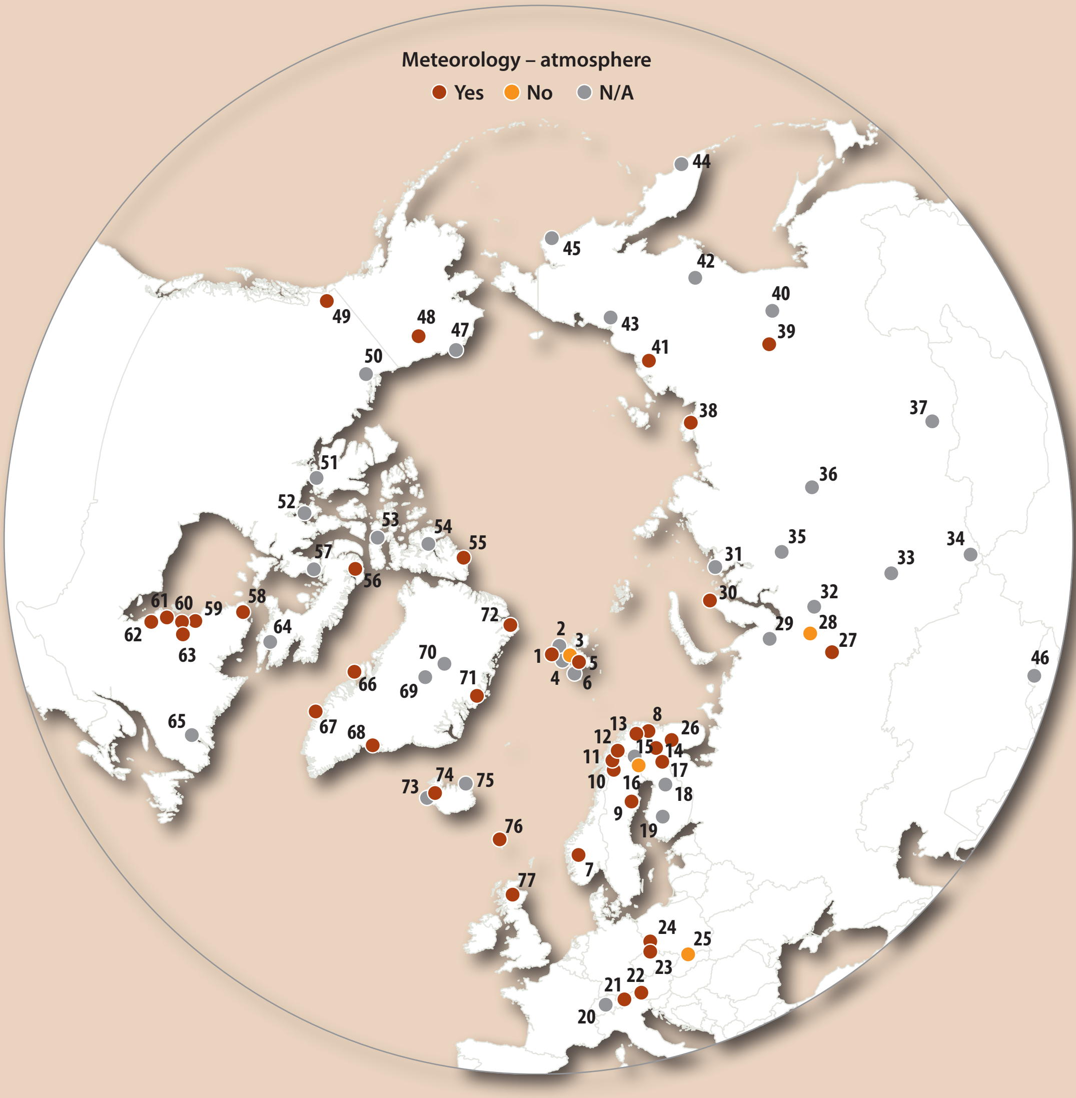
BIO	Parameters
24 Vegetation	Flowering phenology
	Amount of flowering
	NDVI (plot/transect)
	Landscape NDVI (from satellite images)
	Vascular plant community composition
	Bryophyte community composition
	Lichen community composition
	Fungi community composition
	Berry production
	Aerobiological monitoring (pollen, spores, etc.)
	Species list (community composition)
25 Arthropods	Abundance
	Emergence phenology
	Insect herbivory
	Species list (community composition)
26 Birds	Abundance
	Distribution
	Phenology
	Breeding birds
	Nest initiation phenology
	Nest predation rates
	Species list (community composition)
27 Mammals	Mammal abundance
	Mammal distribution
	Mammal reproduction
	Mortality
	Predation
	Physiology
	Species list (community composition)
28 Lake ecology	Phytoplankton (chlorophyll?)
	Zooplankton
	Vegetation
	Fish
	Invertebrates
	Species list (community composition)
29 Microbiology	Interstitial fauna
	Species list (community composition)
30 Genetics	Collection of animal tissue
31 Pollution	Pollution measurements in vegetation
	Pollution measurements in water
	Pollution measurements in mammals (body burdens, biomarkers)
	Pollution measurements in birds (body burdens, biomarkers on both adults and offspring e.g. egg shell thinning, macro plastic in nests/in body)
32 Diseases	Mammals
	Birds
	Fish
	Vegetation
	Other
33 Parasites	Mammals
	Birds
	Fish
	Vegetation
	Other
34 Socio-ecological issues (disturbance)	Number of visitors
	Surface activities (e.g. removal of vegetation, organisms, soil samples, ATV traffic, manipulations)
	Aircraft activities
	Emissions/discharge energy consumption, spill water, waste, garbage, atmospheric emissions, etc.)



Toolik Field Station, USA (Syndonia Bret-Harte).

3.2.1 Meteorology – atmosphere

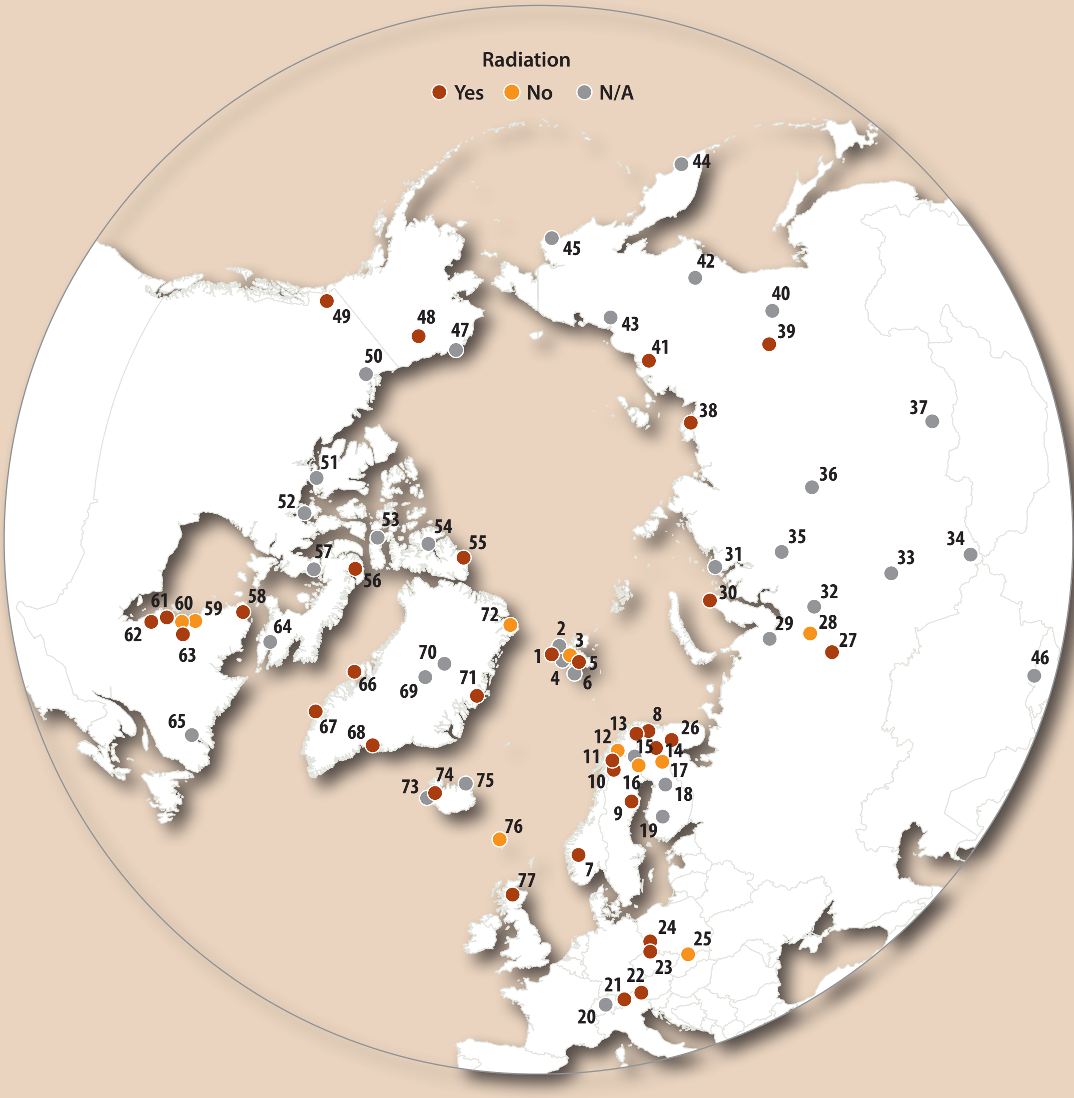
- Air temperature
- Air humidity
- Air pressure
- Wind velocity
- Wind direction
- Precipitation



CLIMATE

3.2.2 Radiation

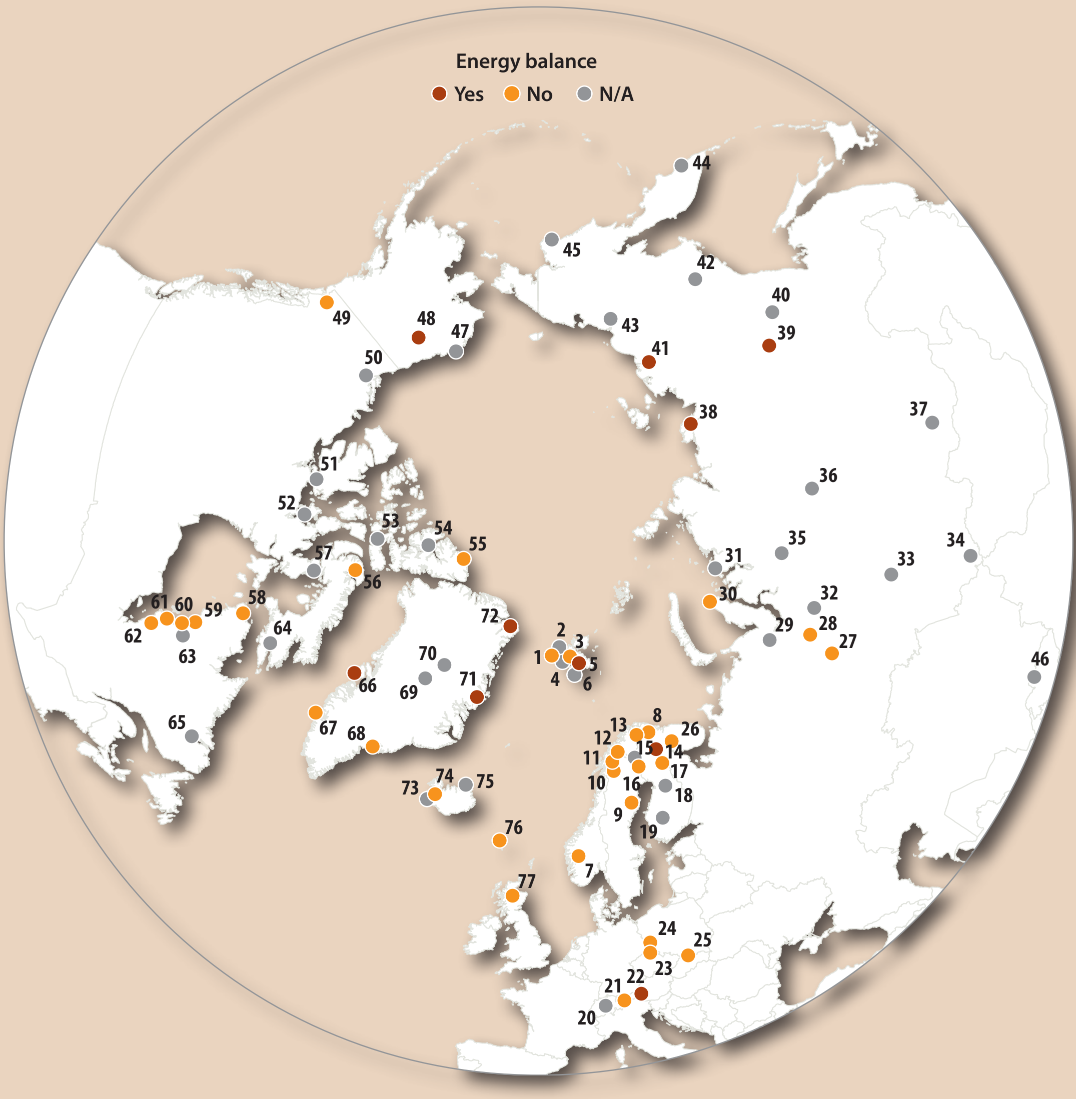
- Short wave incoming
- Short wave outgoing
- Long wave outgoing
- Long wave incoming
- Net radiaton
- UV-B
- Multi-spectral
- Cloud cover/hours of sunshine



CLIMATE

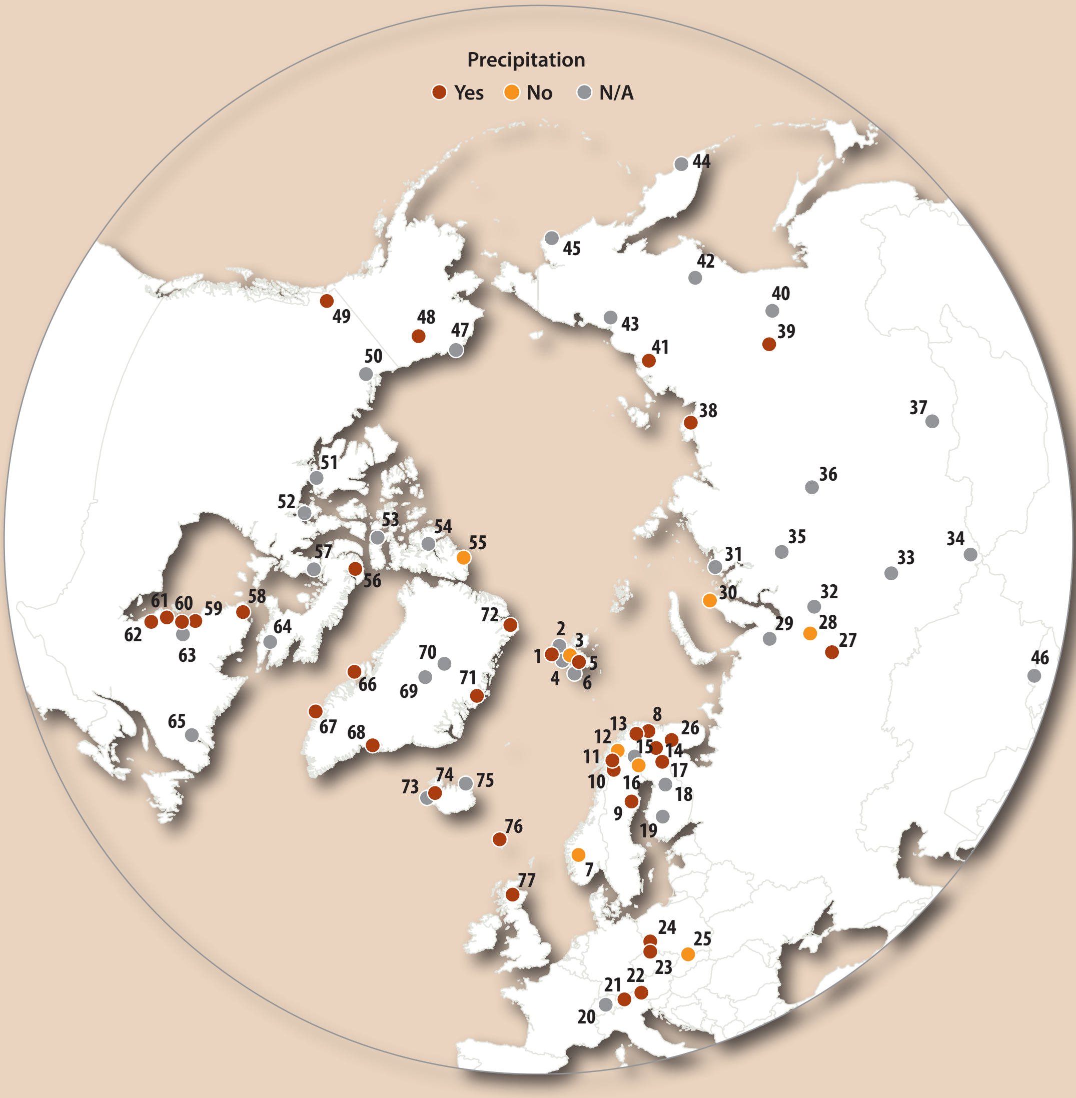
3.2.3 Energy balance

- Energy balance



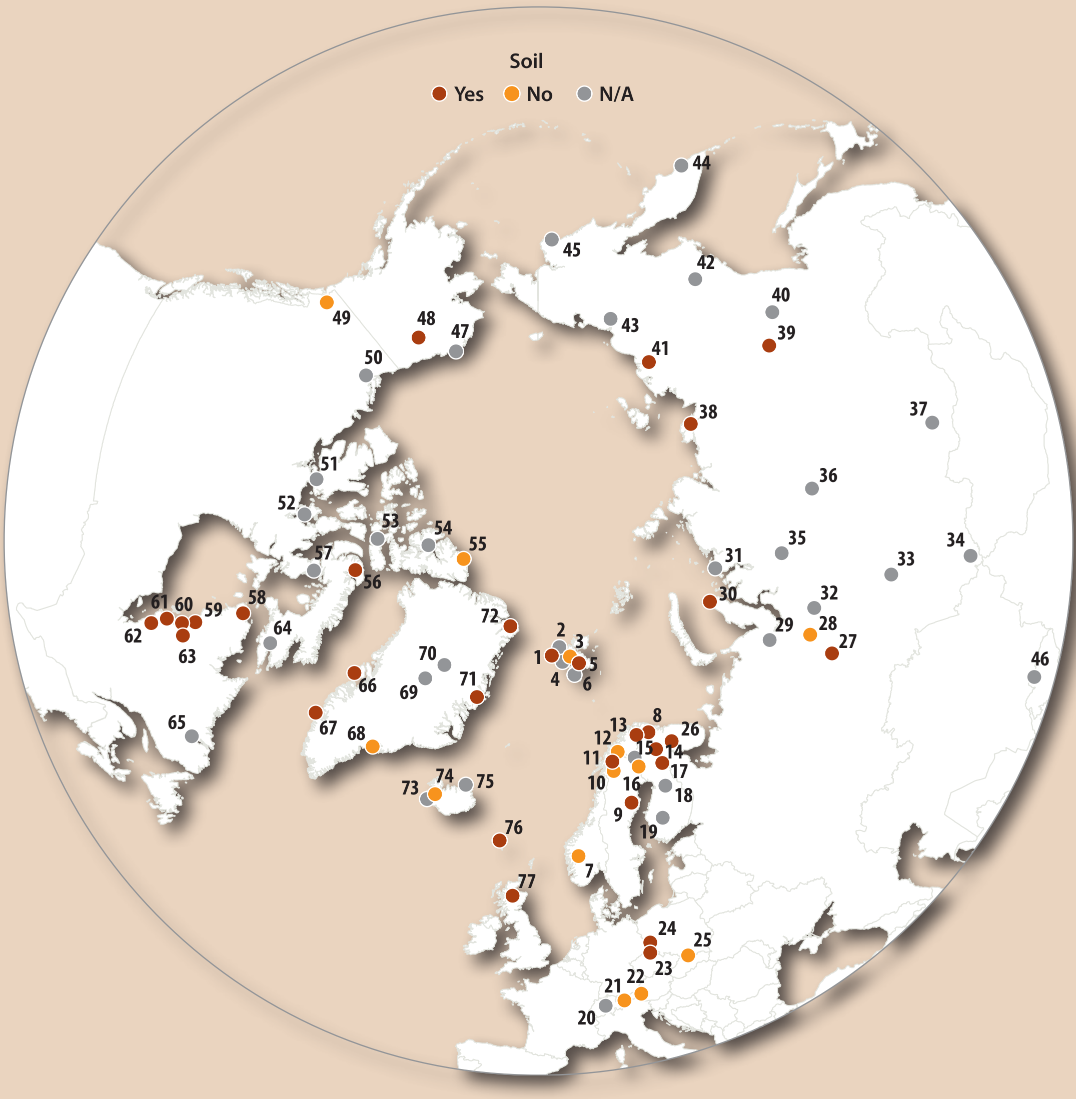
3.3.4 Precipitation

- Rain precipitation
- Rain intensity
- Snow precipitation
- Snow intensity



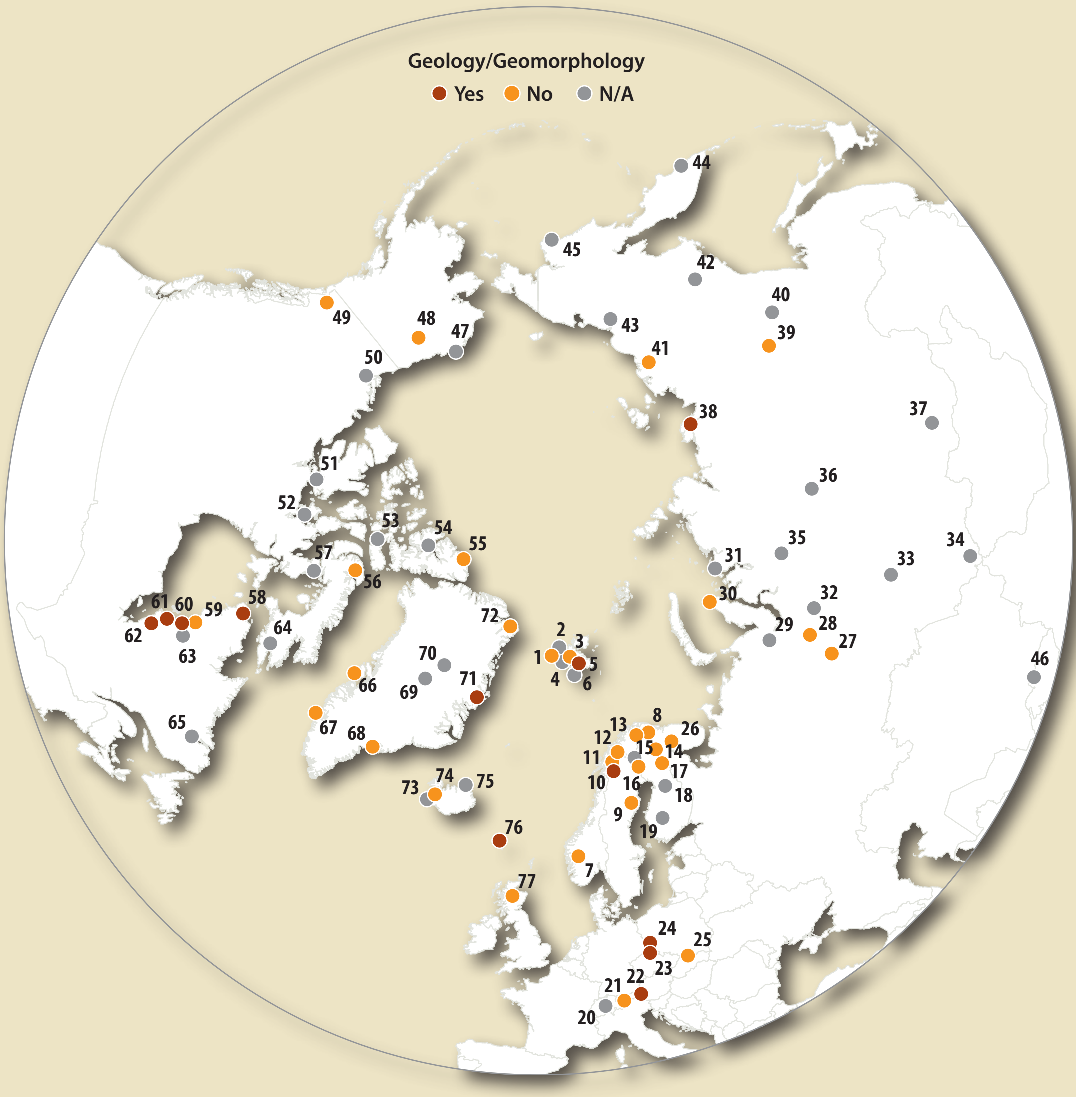
3.2.5 Soil

- Soil temperature
- Soil humidity (TDR)



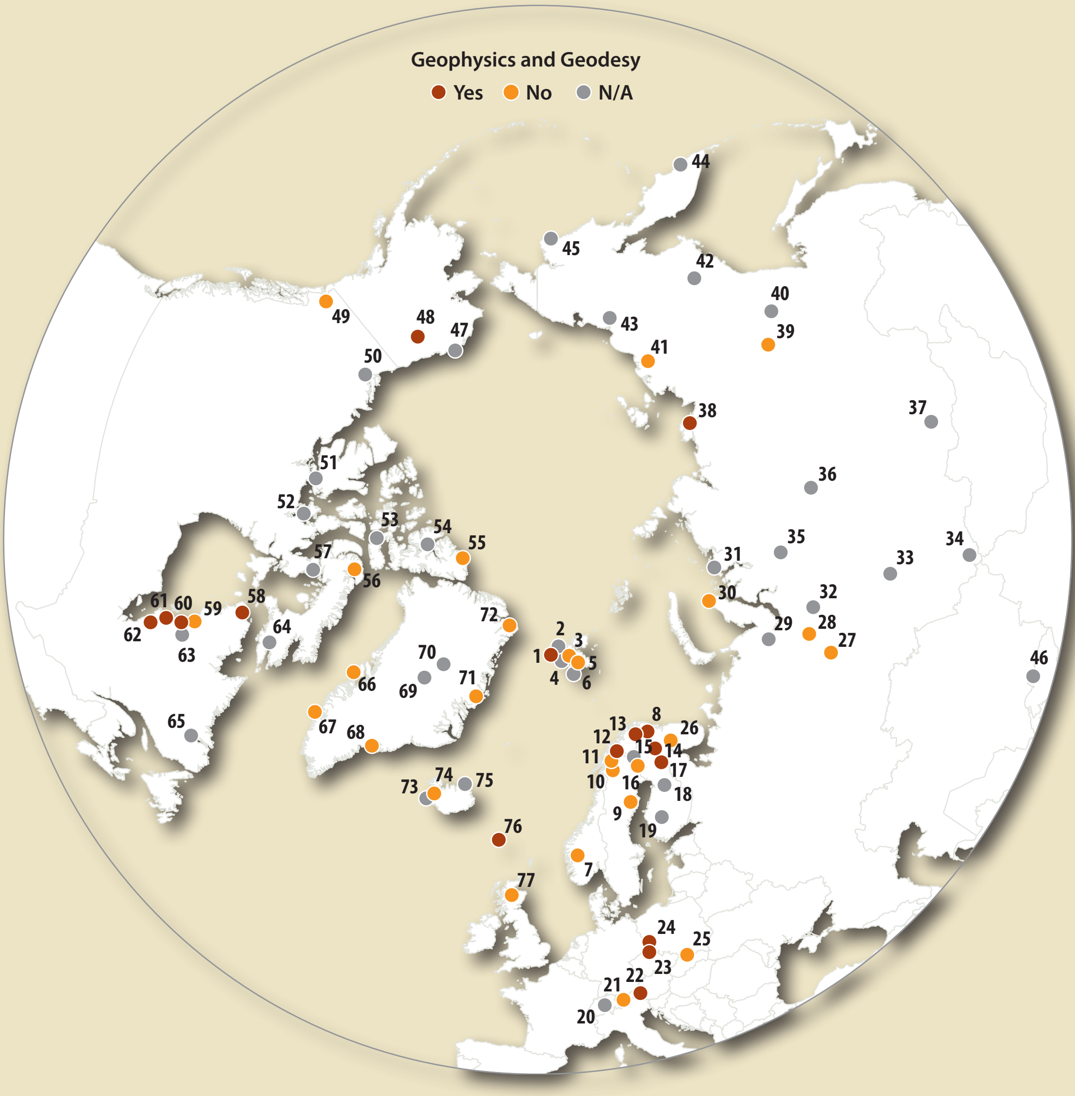
3.2.6 Geology/Geomorphology

- Quaternary geology
- Sedimentology
- Bedrock geology
- Erosion



3.2.7 Geophysics and Geodesy

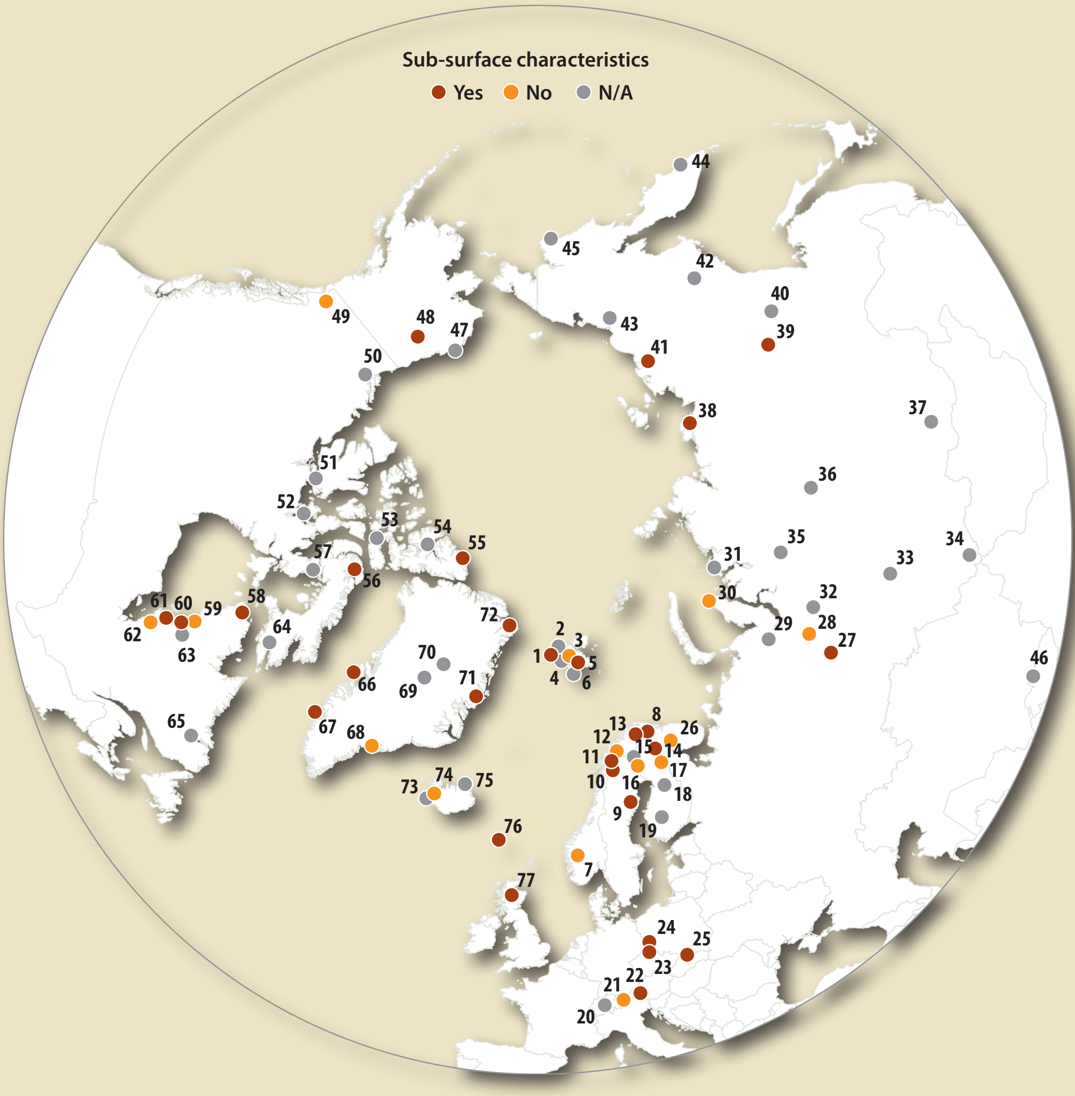
- Gravity
- Magnetic field
- Aurora
- Seismic activity



GEO

3.2.8 Sub-surface characteristics

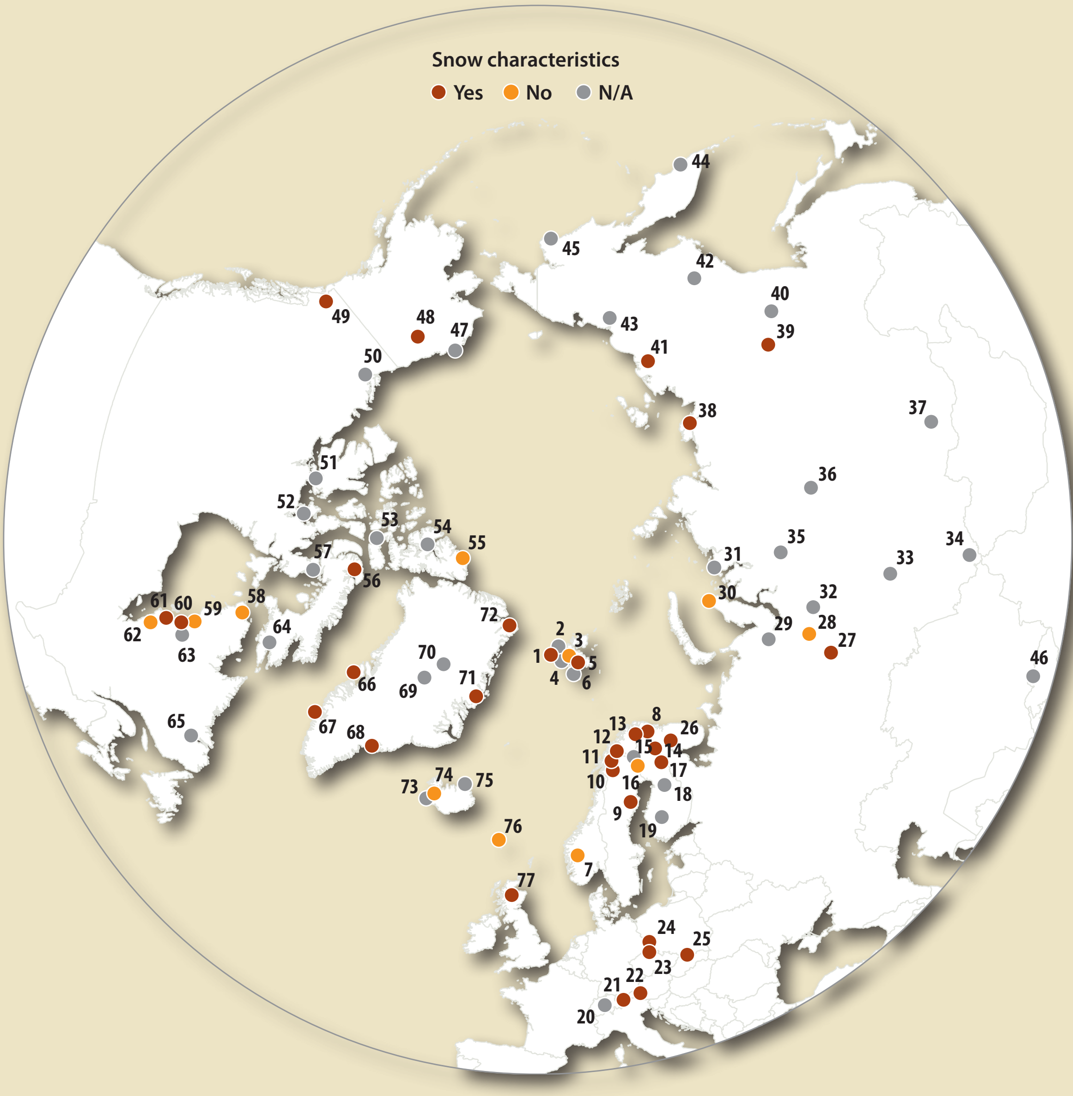
- Ground surface temperature
- Ground/soil temperature
- Soil moisture content
- Ground water table
- Soil water chemistry
- Active layer depth
- Permafrost distribution
- Permafrost thickness
- Permafrost temperature



GEO

3.2.9 Snow characteristics

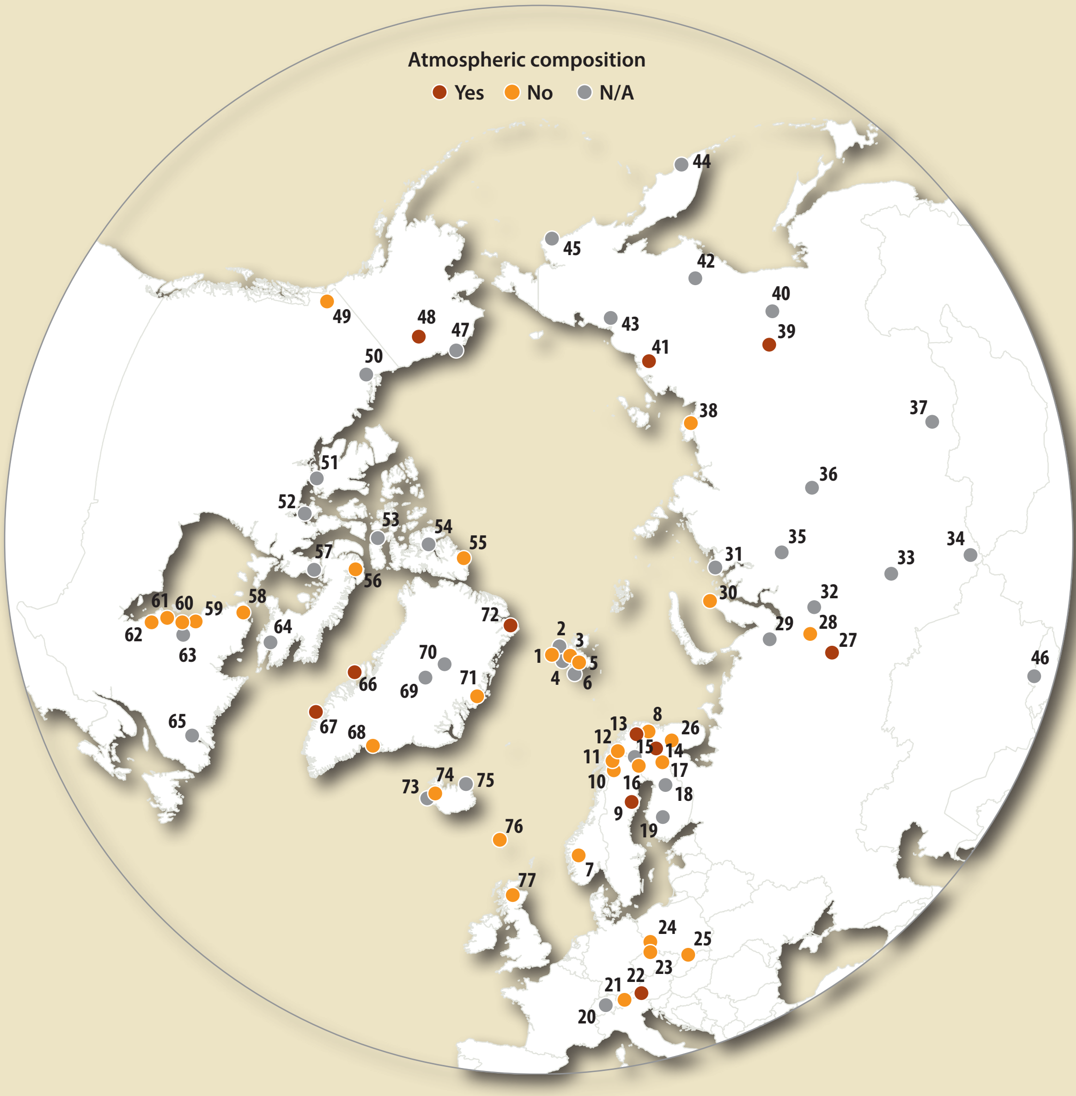
- Snow depth
- Snow cover
- Snow density
- Snow temperature



GEO

3.2.10 Atmospheric composition

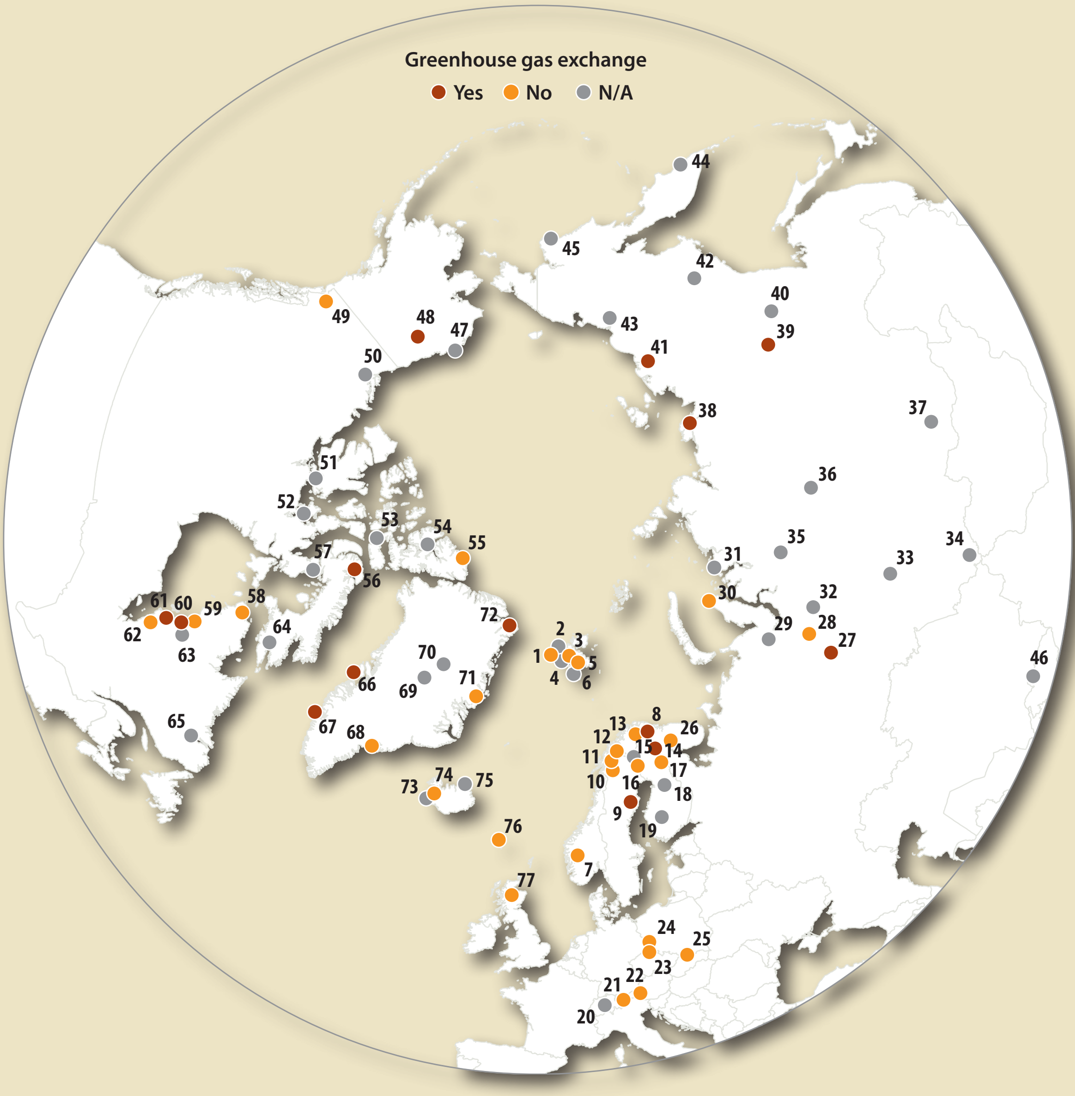
- CO_2 concentration
- CH_4 concentration



GEO

3.2.11 Greenhouse gas exchange

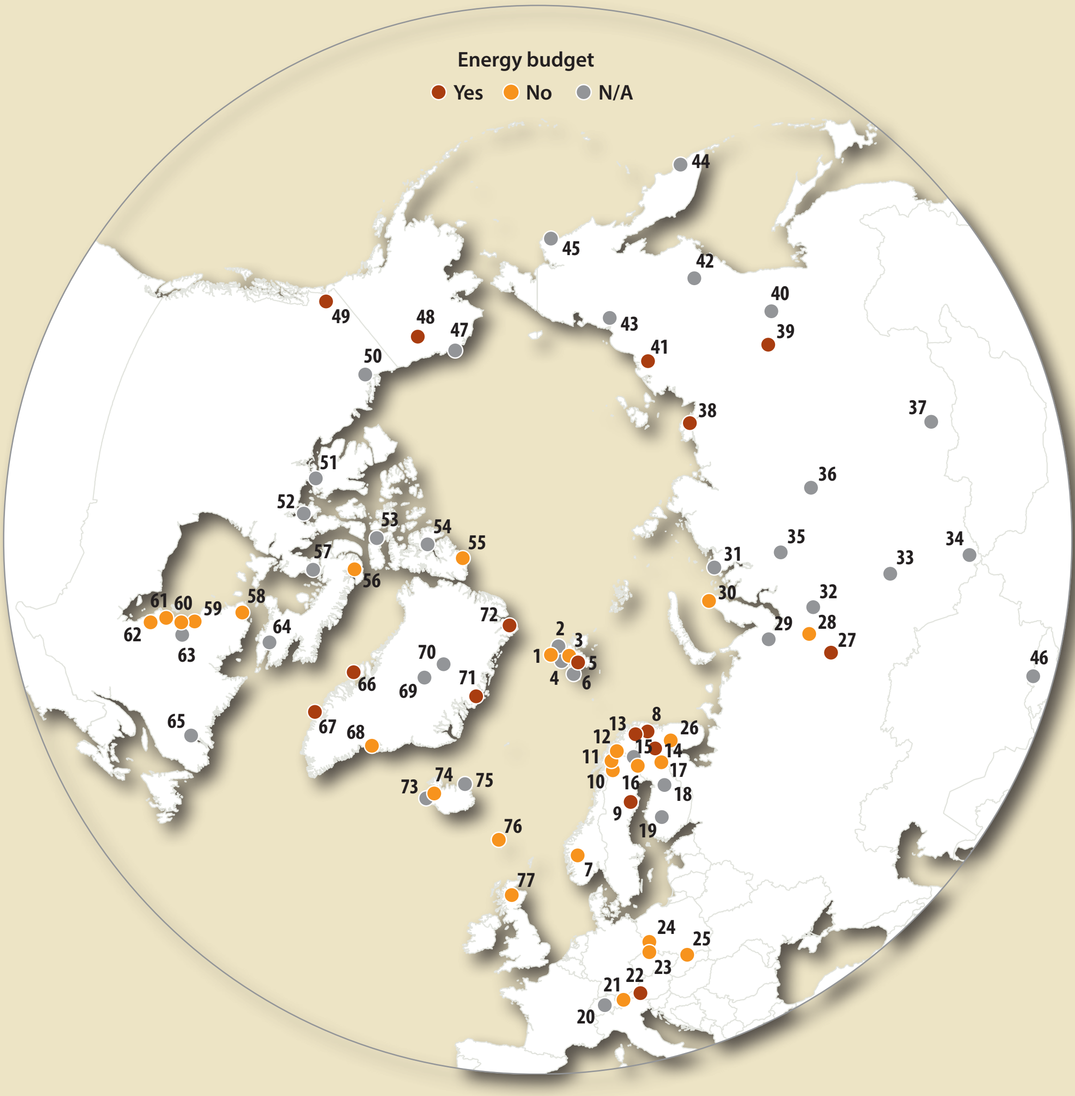
- CO_2 exchange
- CH_4 exchange
- N_2O exchange



GEO

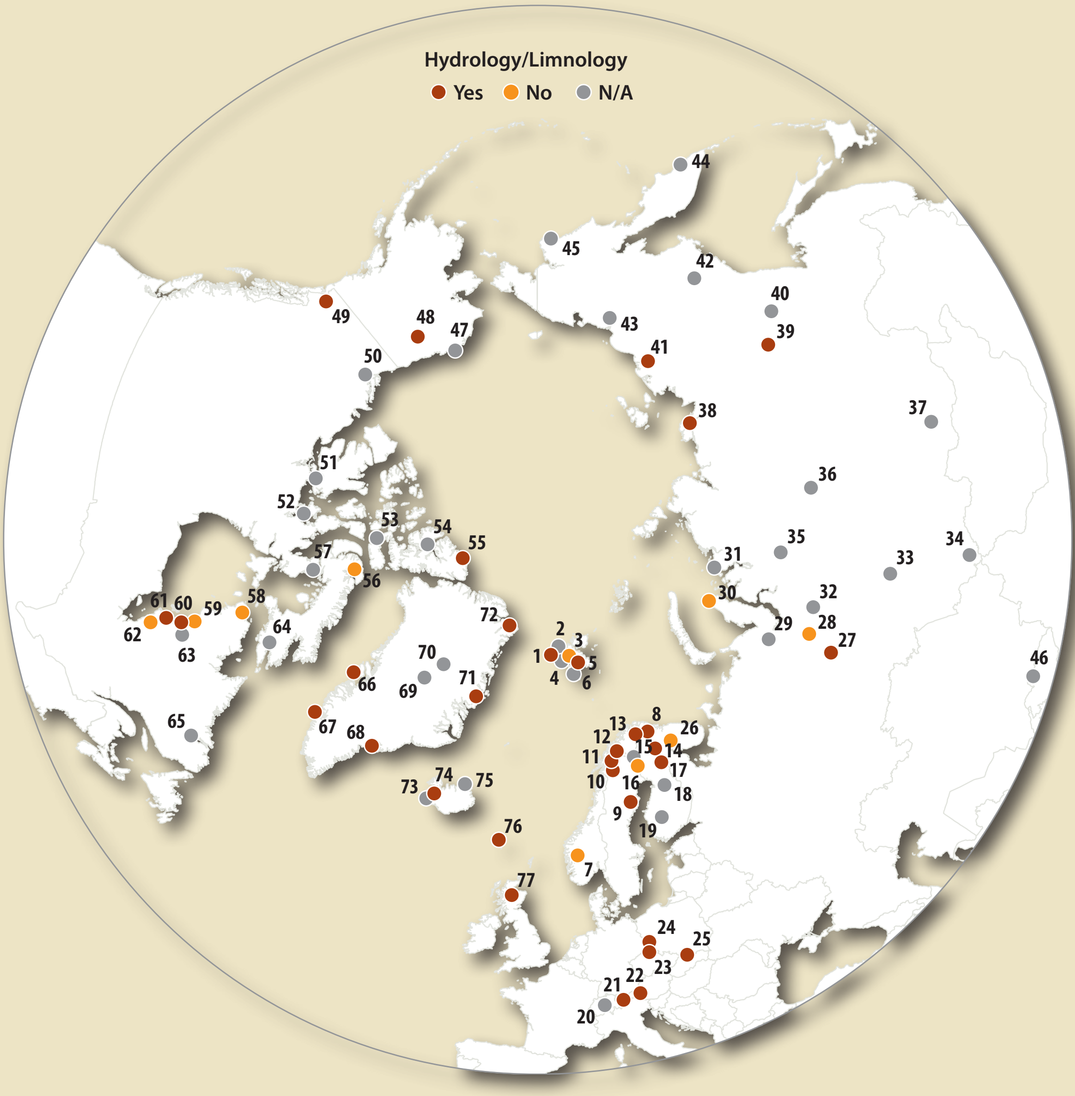
3.2.12 Energy budget

- Net radiation
- Sensible heat flux
- Latent heat flux
- Soil heat flux



3.2.13 Hydrology/Limnology

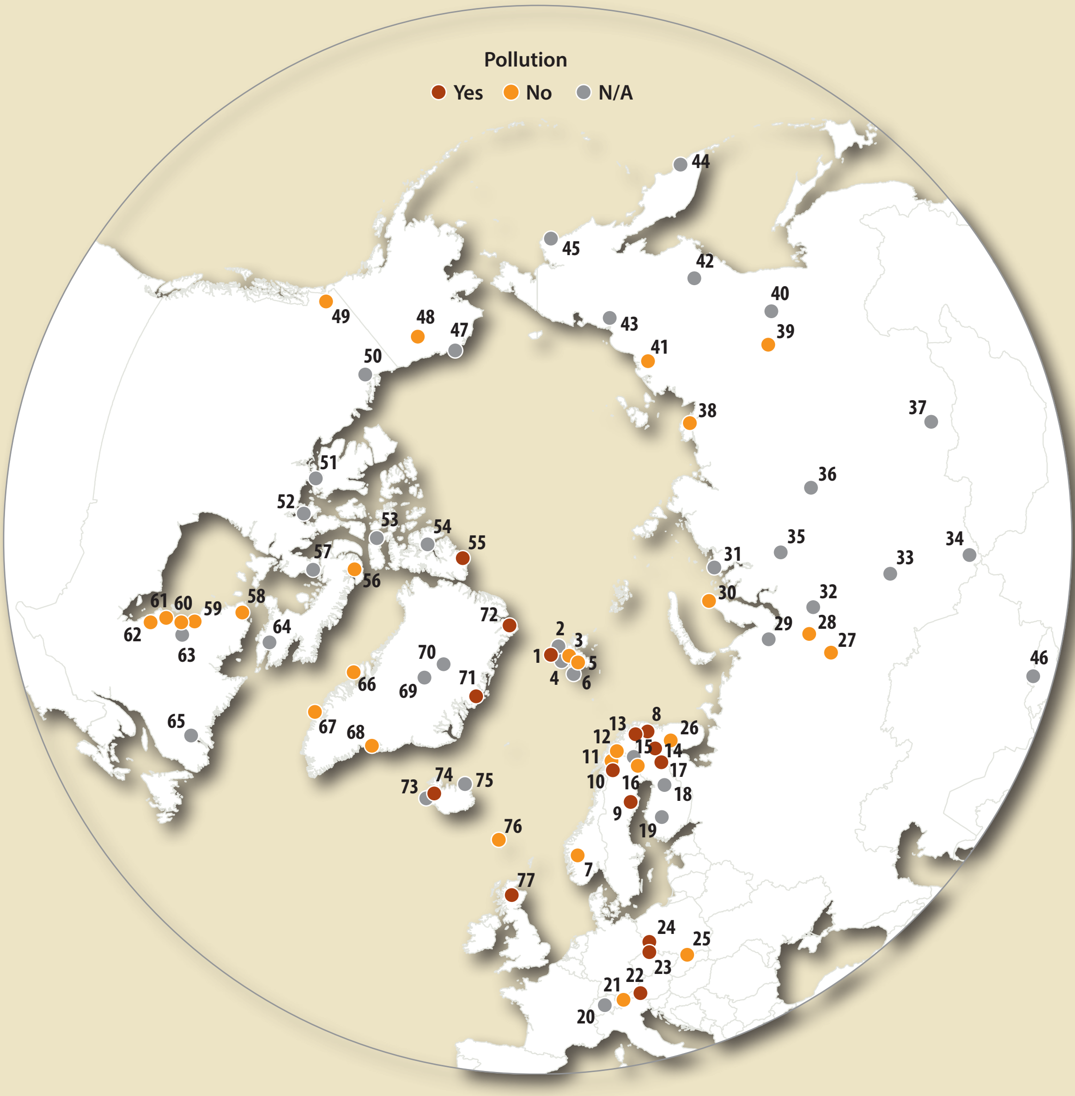
- Precipitation
- River water discharge/water level
- Lake water level
- Water balance
- Water temperature
- Lake ice cover (formation/breakup/thickness)
- Suspended sediment discharge
- Organic matter discharge
- PAR (Photosyntetically Active Radiation)/secchi depth
- Water chemistry



GEO

3.2.14 Pollution

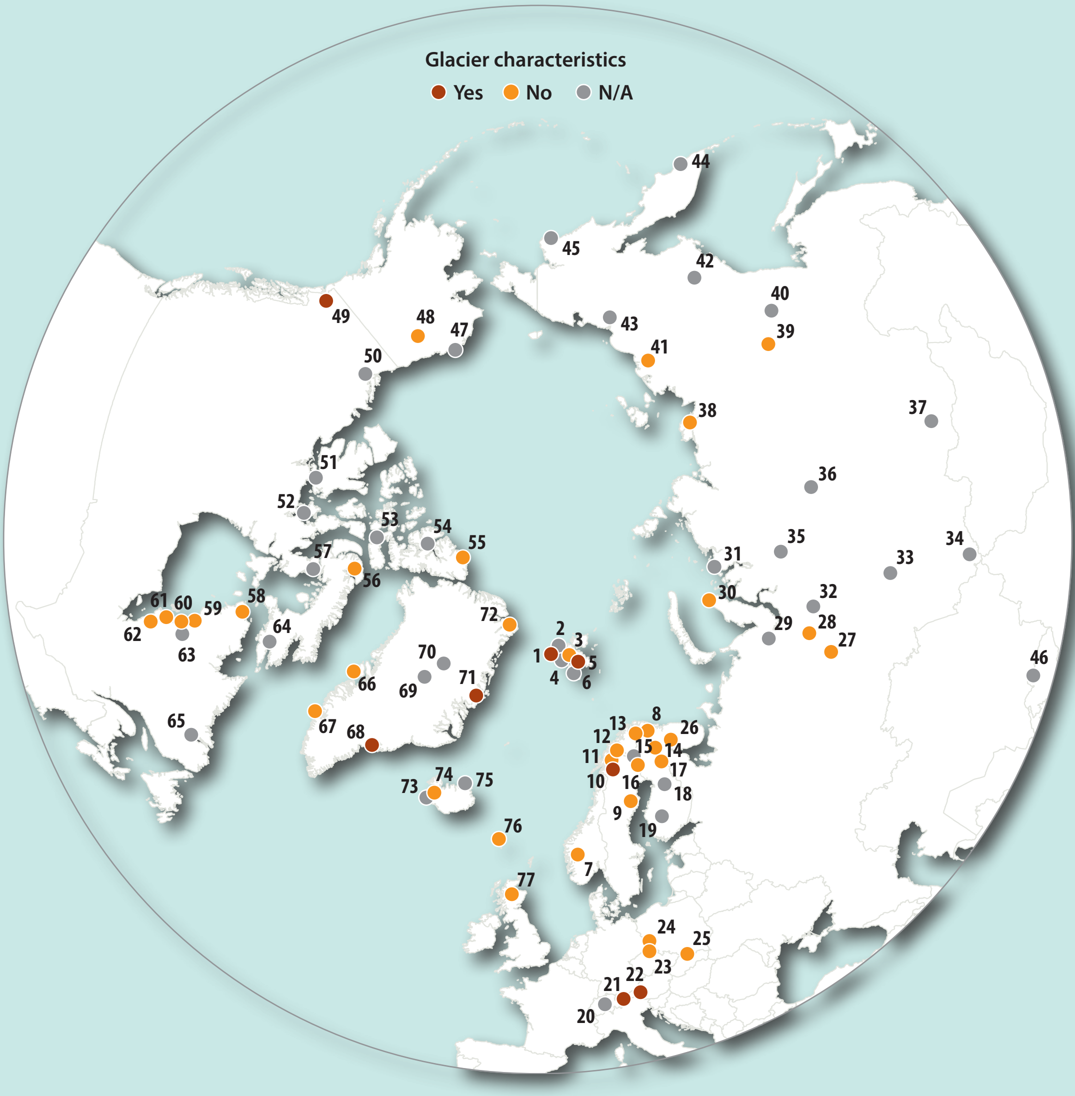
- In air
- In water
- In soil
- In snow/ice
- Other



GEO

3.2.15 Glacier characteristics

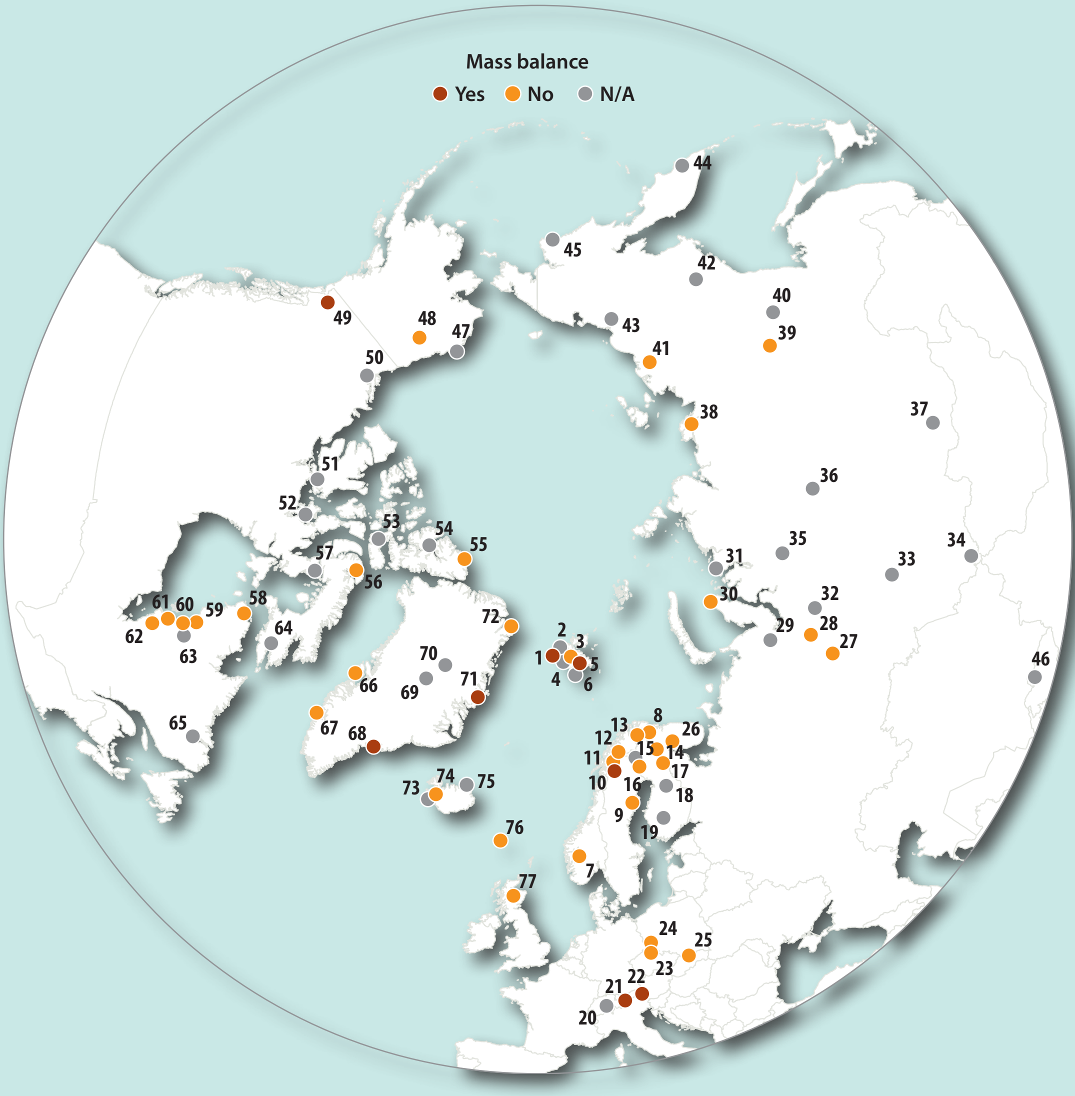
- Glacier area
- Topography
- Elevation change
- Terminus position
- Ice velocity
- Ice thickness
- Debris cover
- Surface albedo/reflexion coefficient



GLACIER

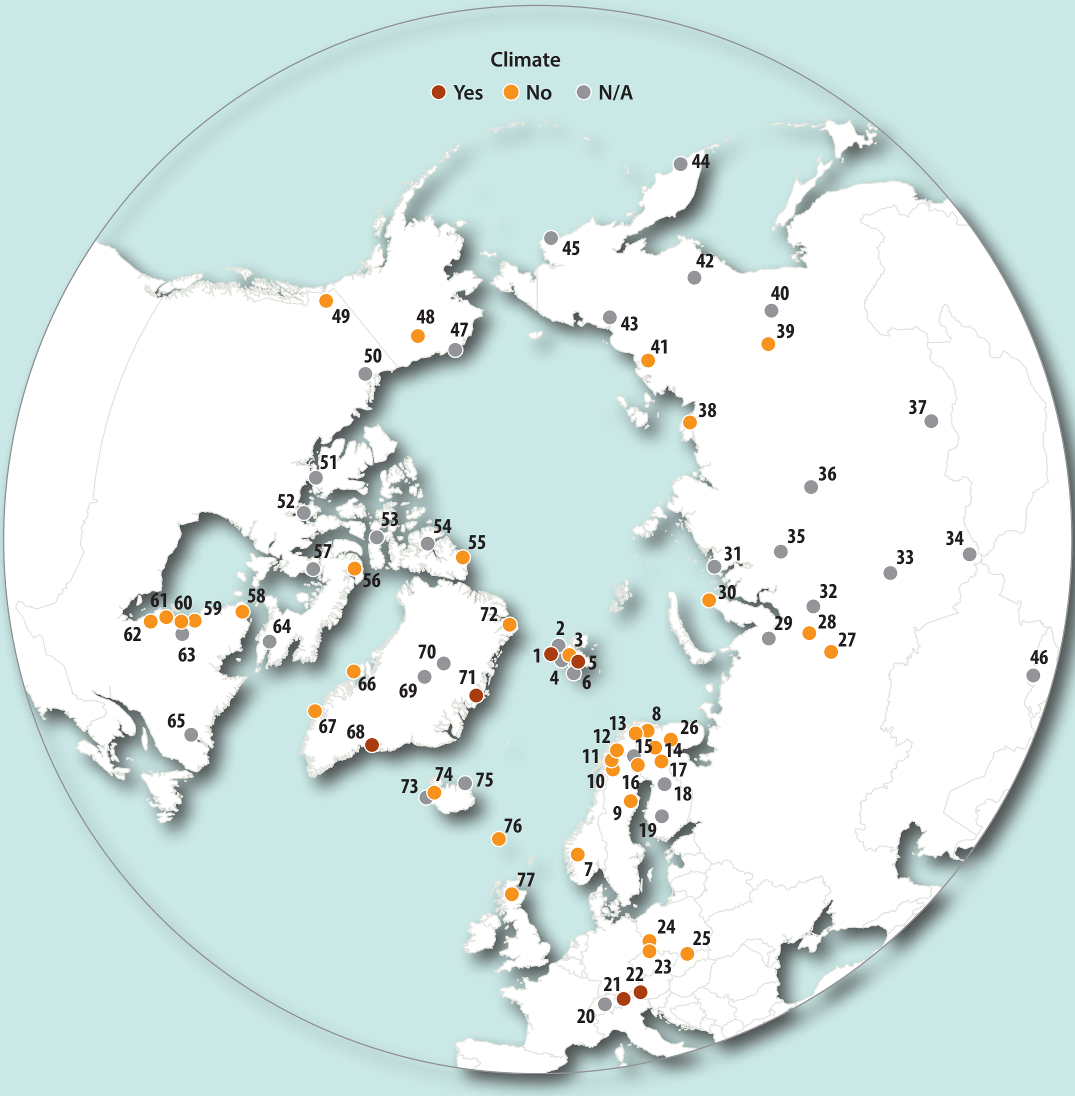
3.2.16 Mass balance

- Mass balance
- Snow water equivalent
- Snowcover stratigraphy
- Equilibrium Line Altitude
- Duration of snow cover
- Calving flux



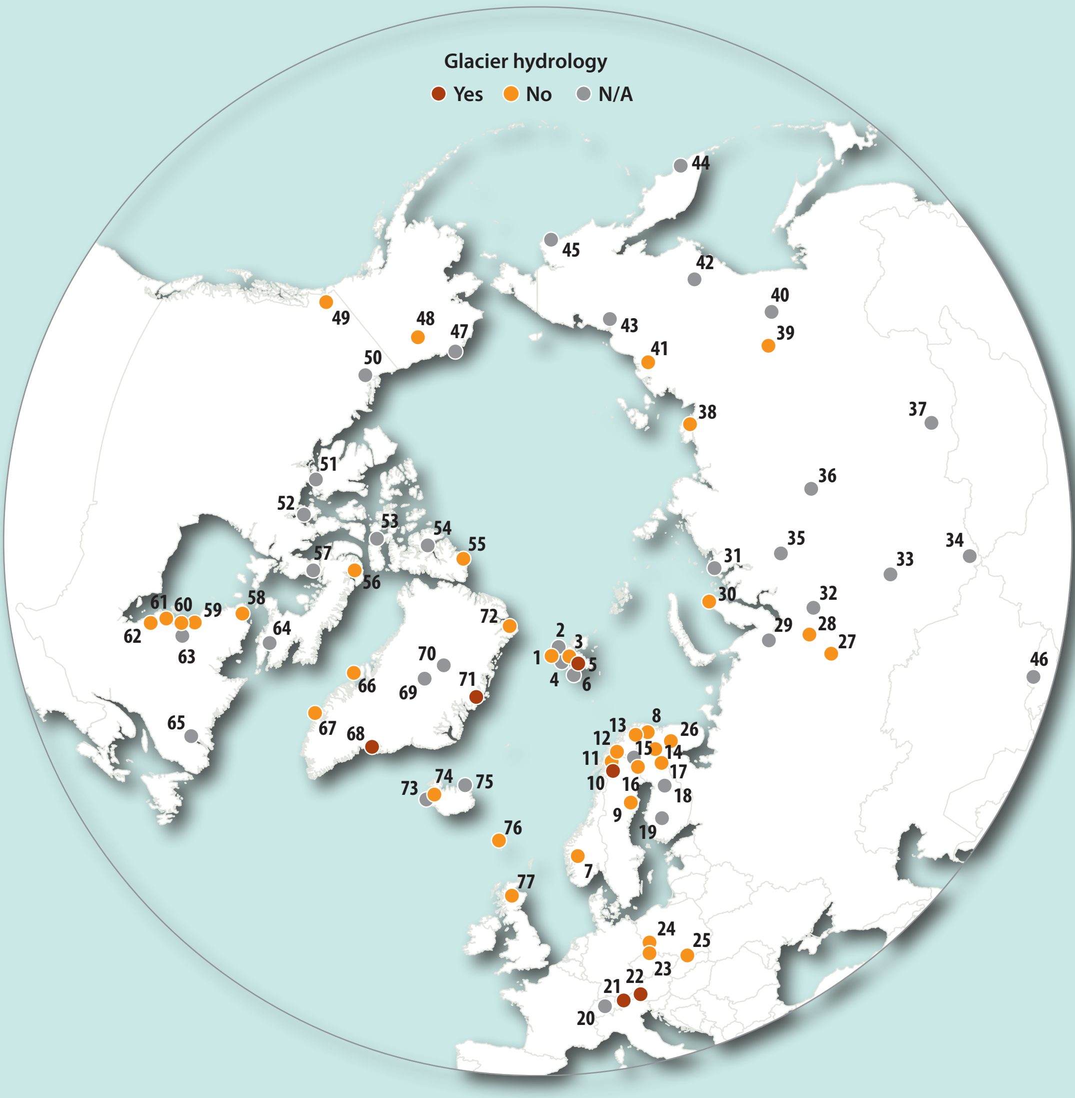
3.2.17 Climate

- Climate measurements
- Energy balance



3.2.18 Glacier hydrology

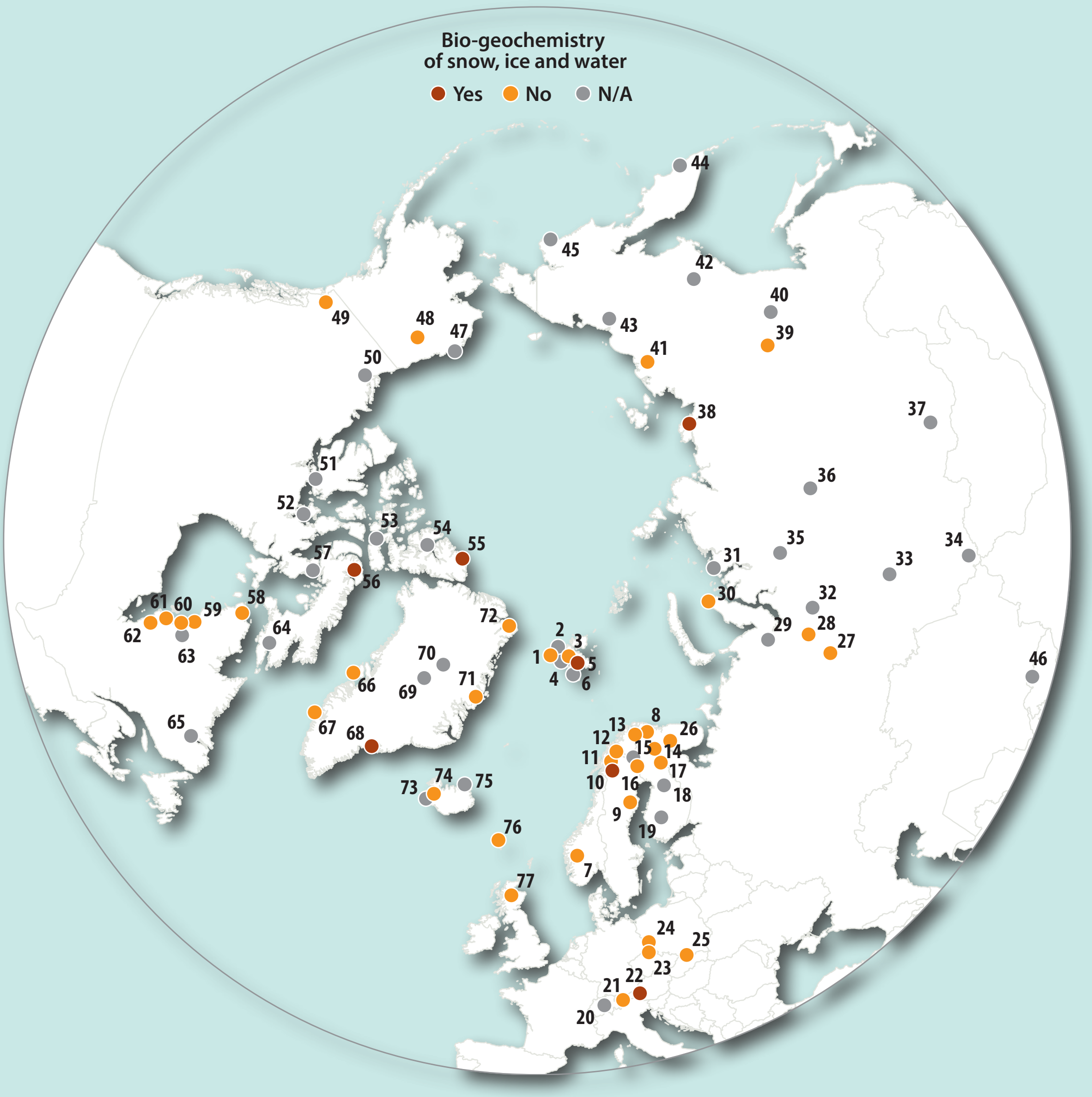
- Run-off
- Supra-, en- and subglacial drainage system
- Meltwater retention
- Glacial lake outburst floods



GLACIER

3.2.19 Bio-geochemistry of snow, ice and water

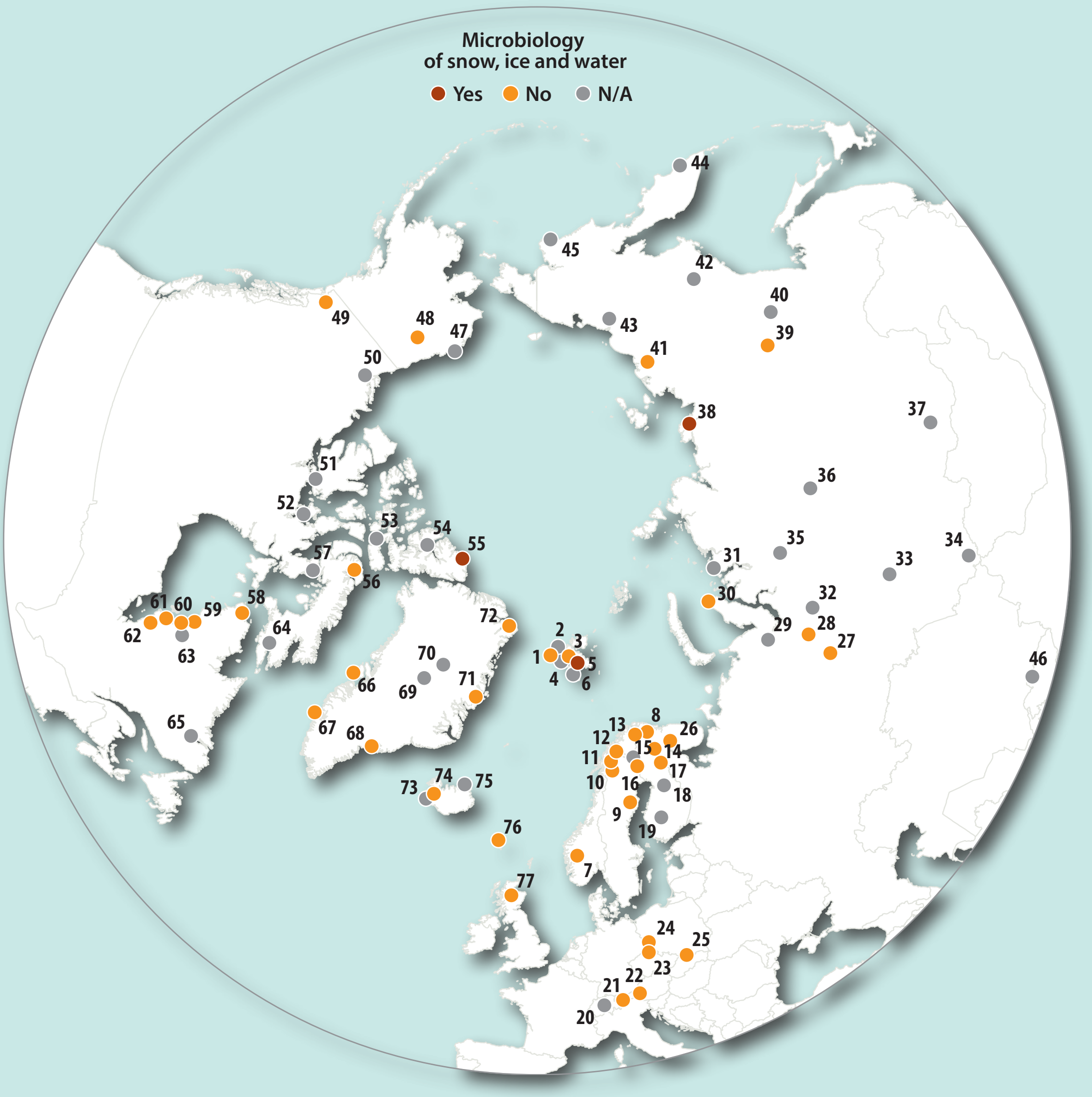
■ Bio-geochemistry of snow, ice and water



GLACIER

3.2.20 Microbiology of snow, ice and water

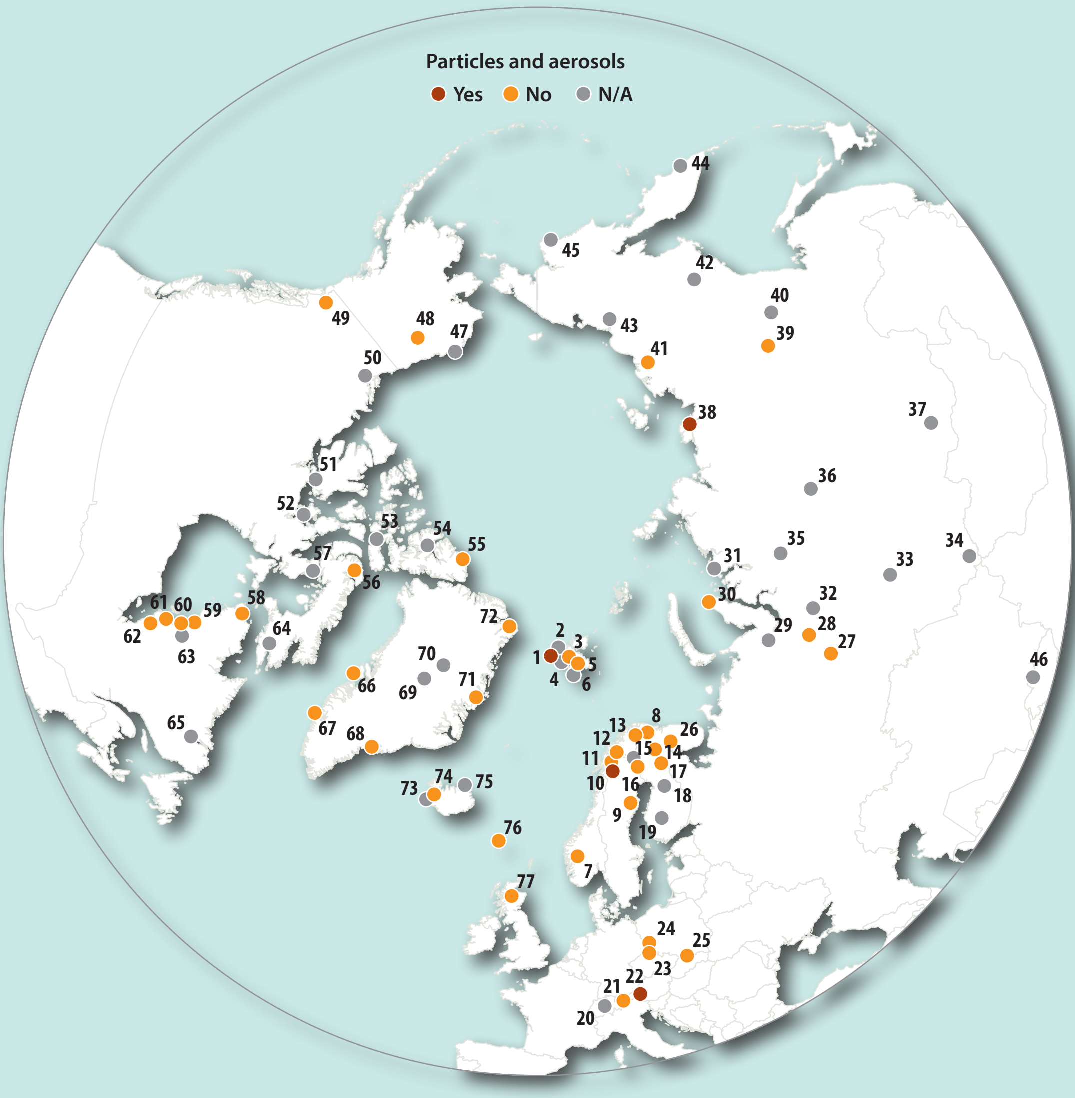
■ Microbiology of snow, ice and water



GLACIER

3.2.21 Particles and aerosols

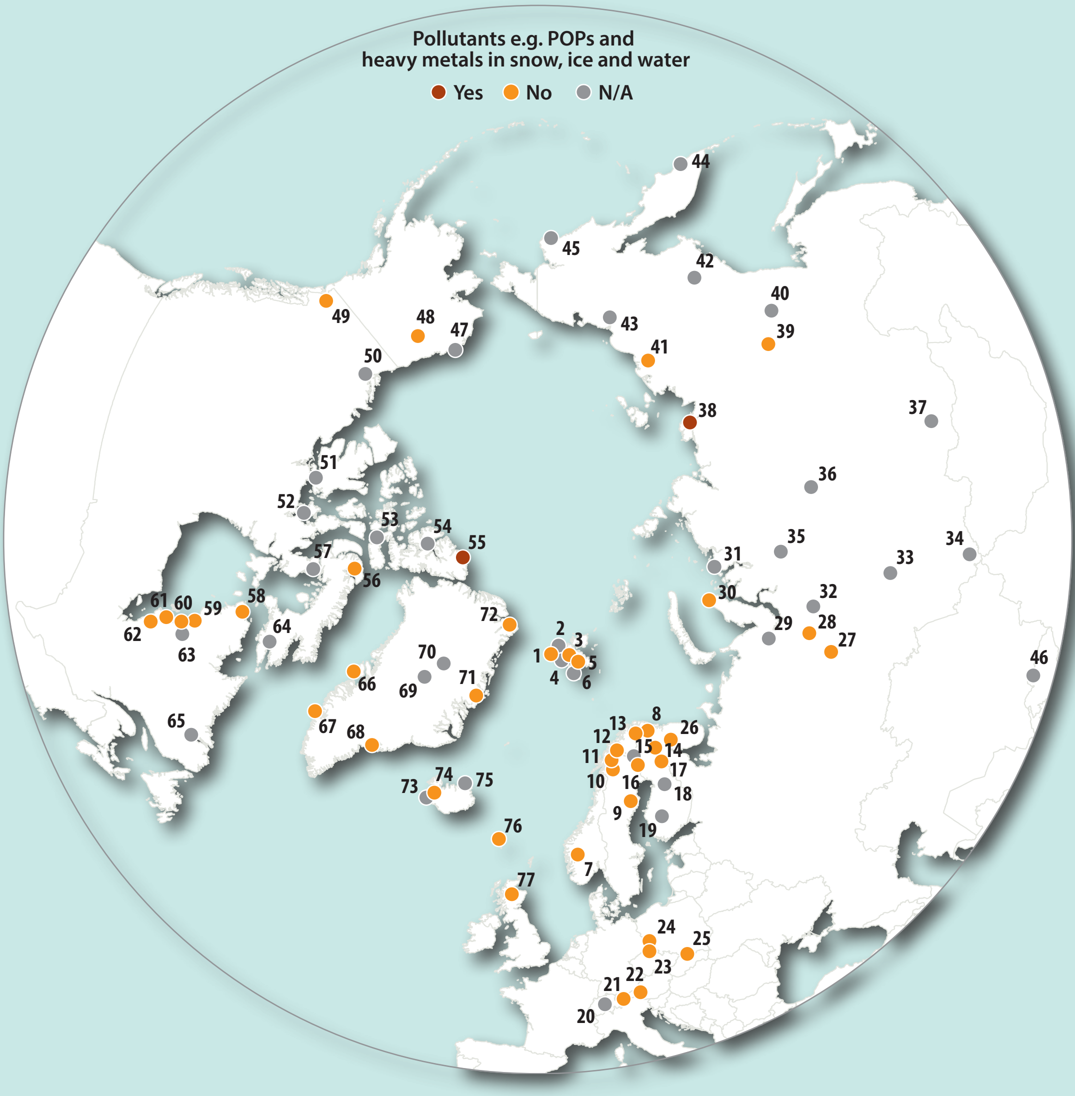
■ Particles and aerosols



GLACIER

3.2.22 Pollutants e.g. POPs and heavy metals in snow, ice and water

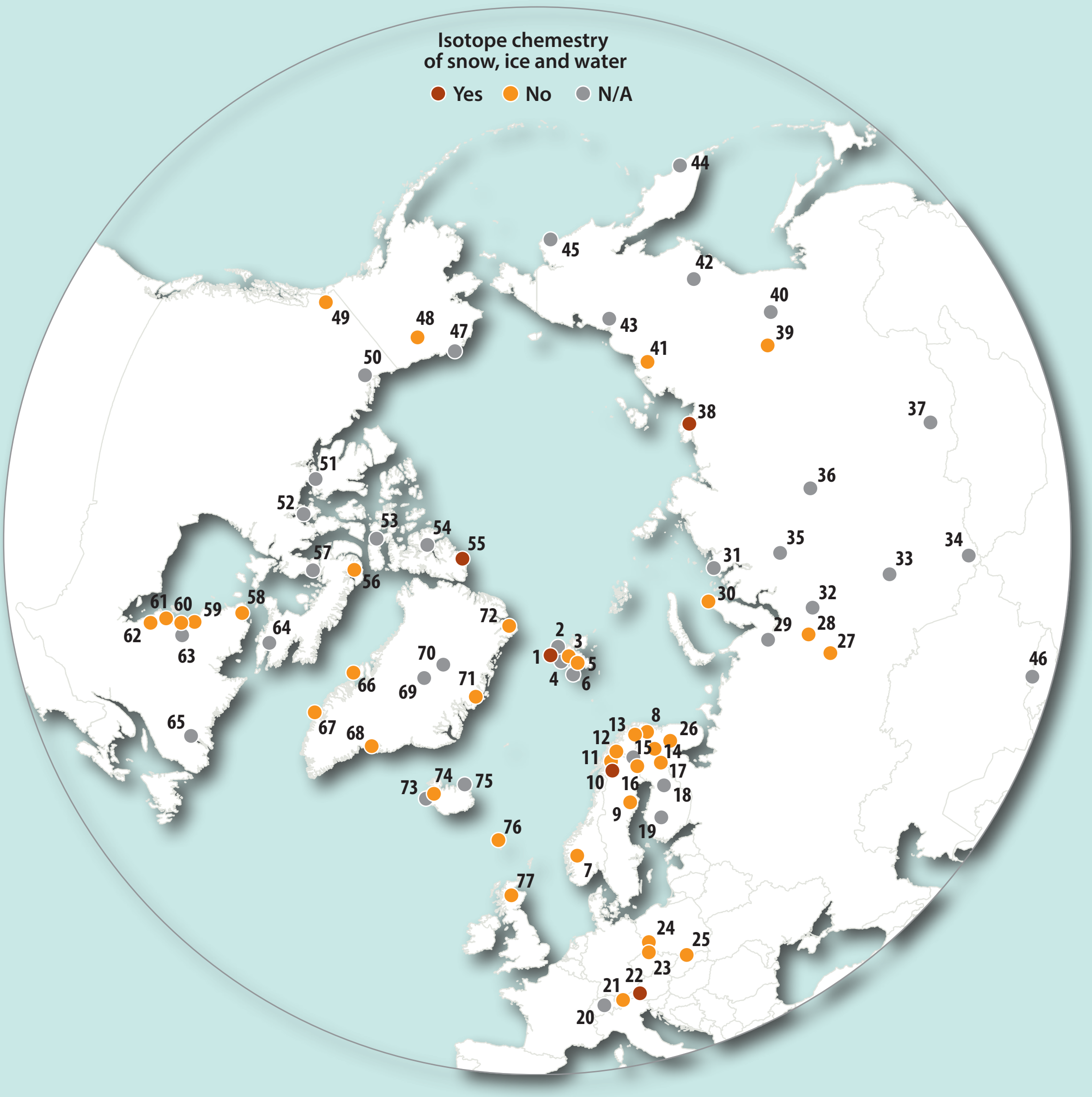
- Pollutants e.g. POPs and heavy metals in snow, ice and water



GLACIER

3.2.23 Isotope chemistry of snow, ice and water

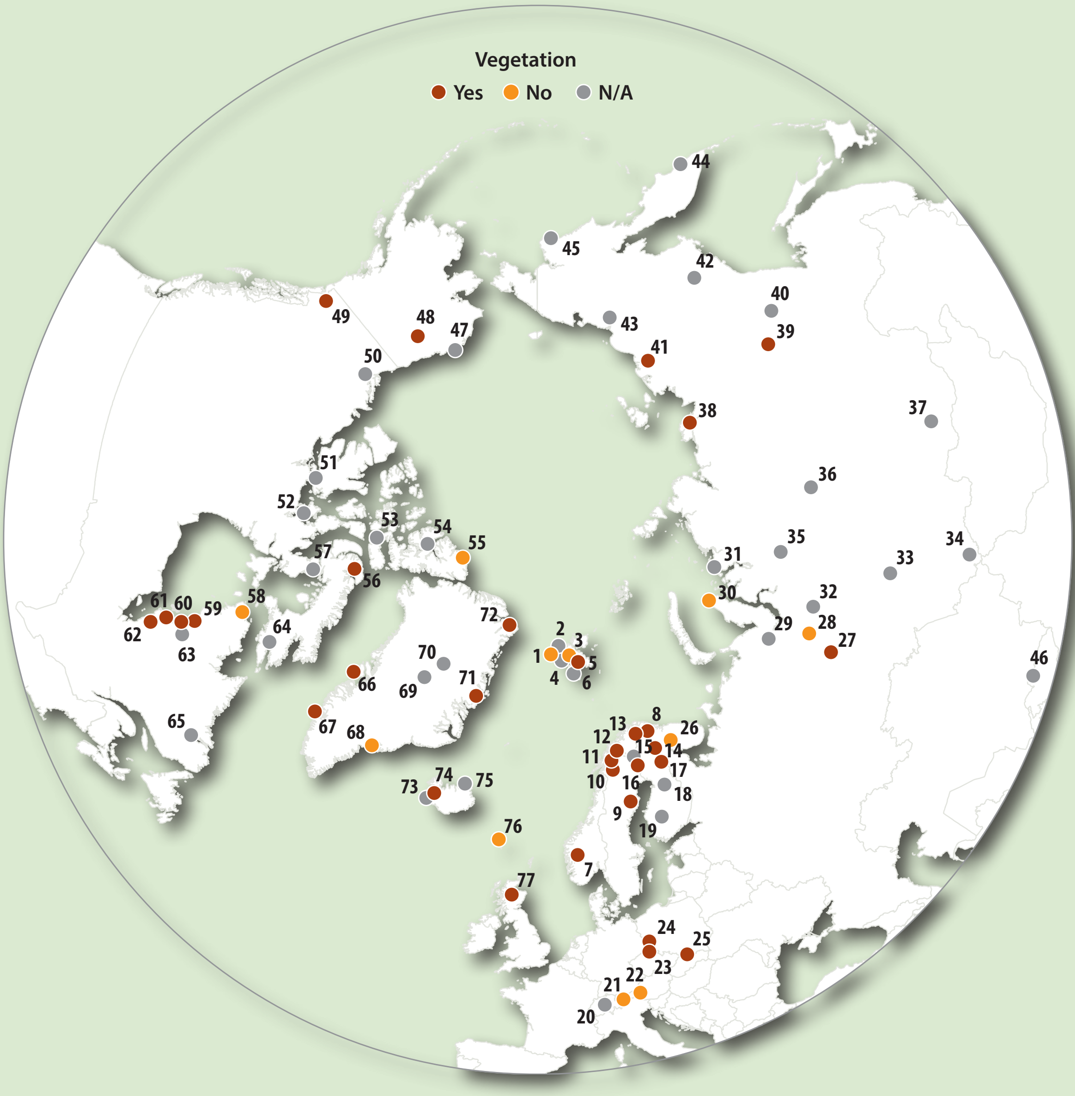
- Isotope chemistry of snow, ice and water



GLACIER

3.2.24 Vegetation

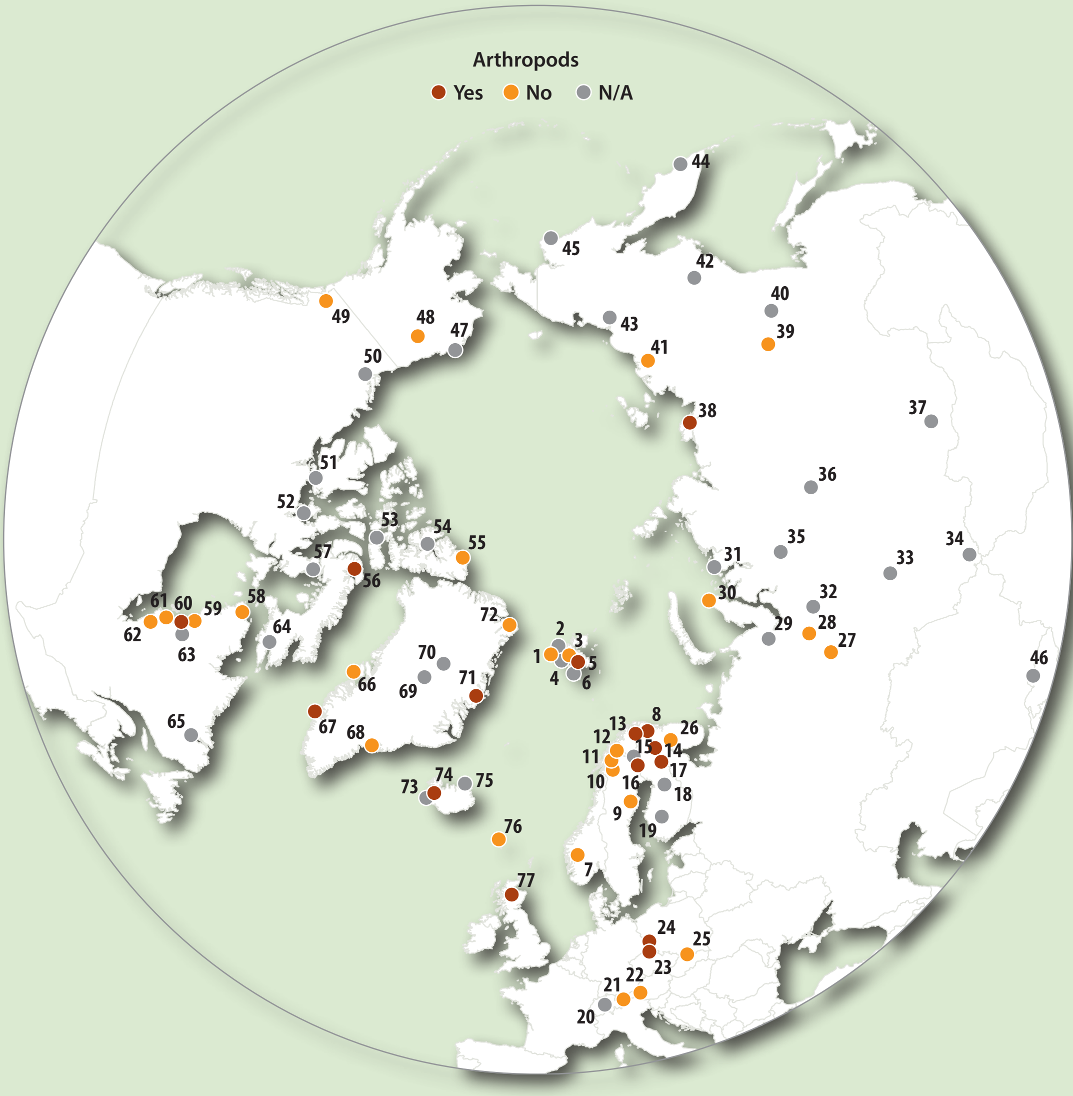
- Flowering phenology
- Amount of flowering
- NDVI (plot/transect)
- Landscape NDVI (from satellite images)
- Vascular plant community composition
- Bryophyte community composition
- Lichen community composition
- Fungi community composition
- Berry production
- Aerobiological monitoring (pollen, spores, etc.)
- Species list (community composition)



BIO

3.2.25 Arthropods

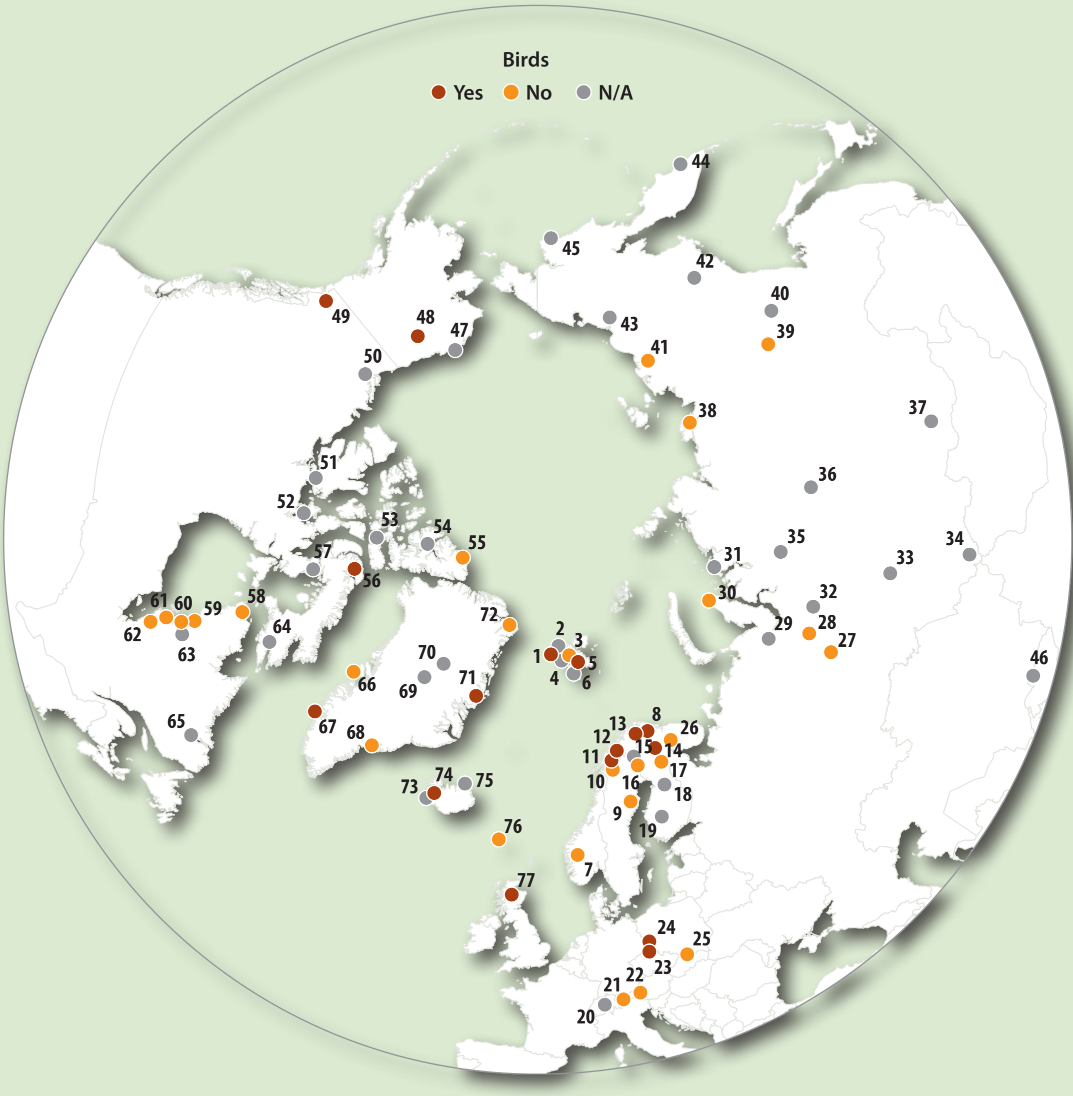
- Abundance
- Emergence phenology
- Insect herbivory
- Species list (community composition)



BIO

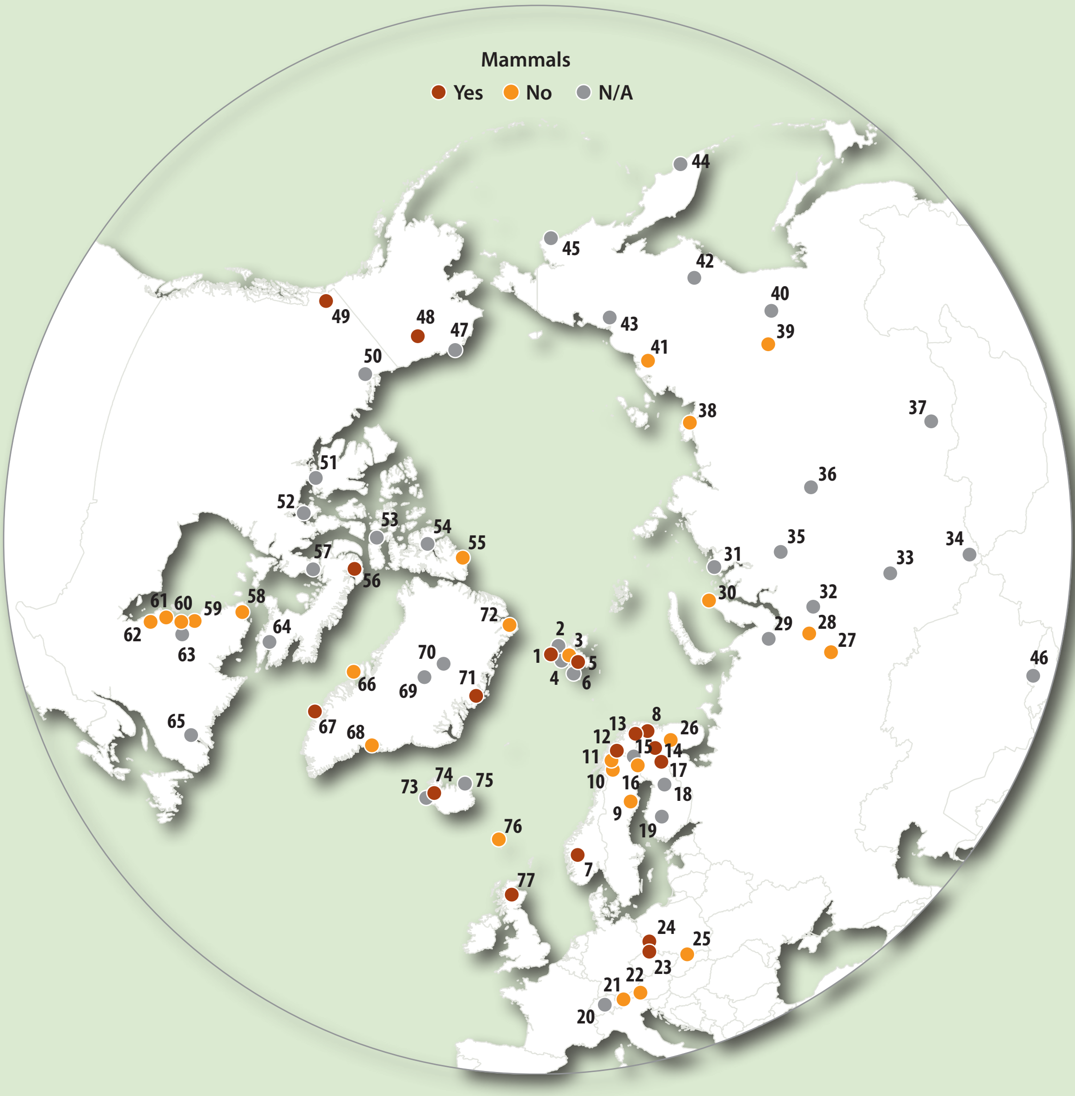
3.2.26 Birds

- Abundance
- Distribution
- Phenology
- Breeding birds
- Nest initiation phenology
- Nest predation rates
- Species list (community composition)



3.2.27 Mammals

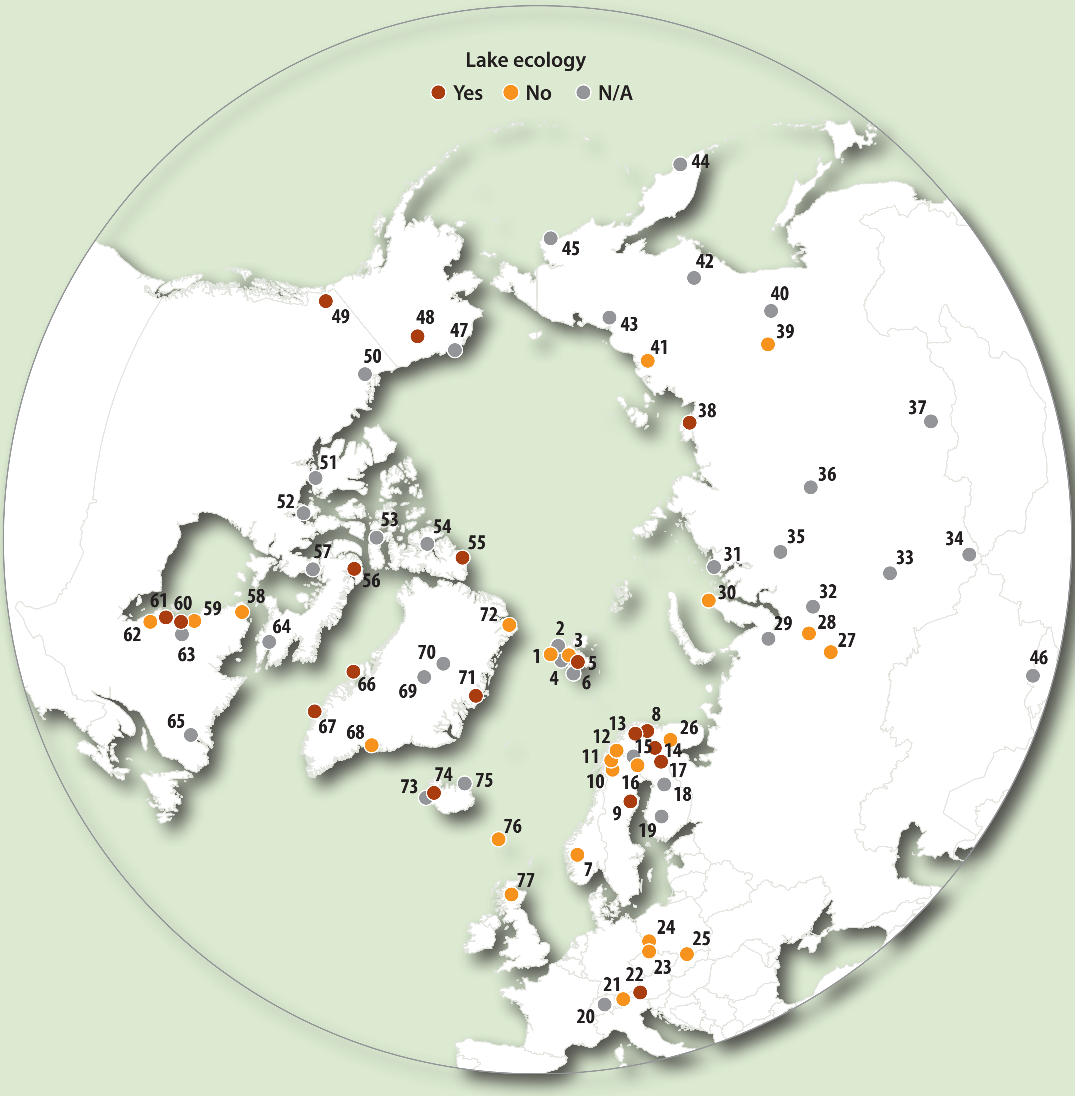
- Mammal abundance
- Mammal distribution
- Mammal reproduction
- Mortality
- Predation
- Physiology
- Species list (community composition)



BIO

3.2.28 Lake ecology

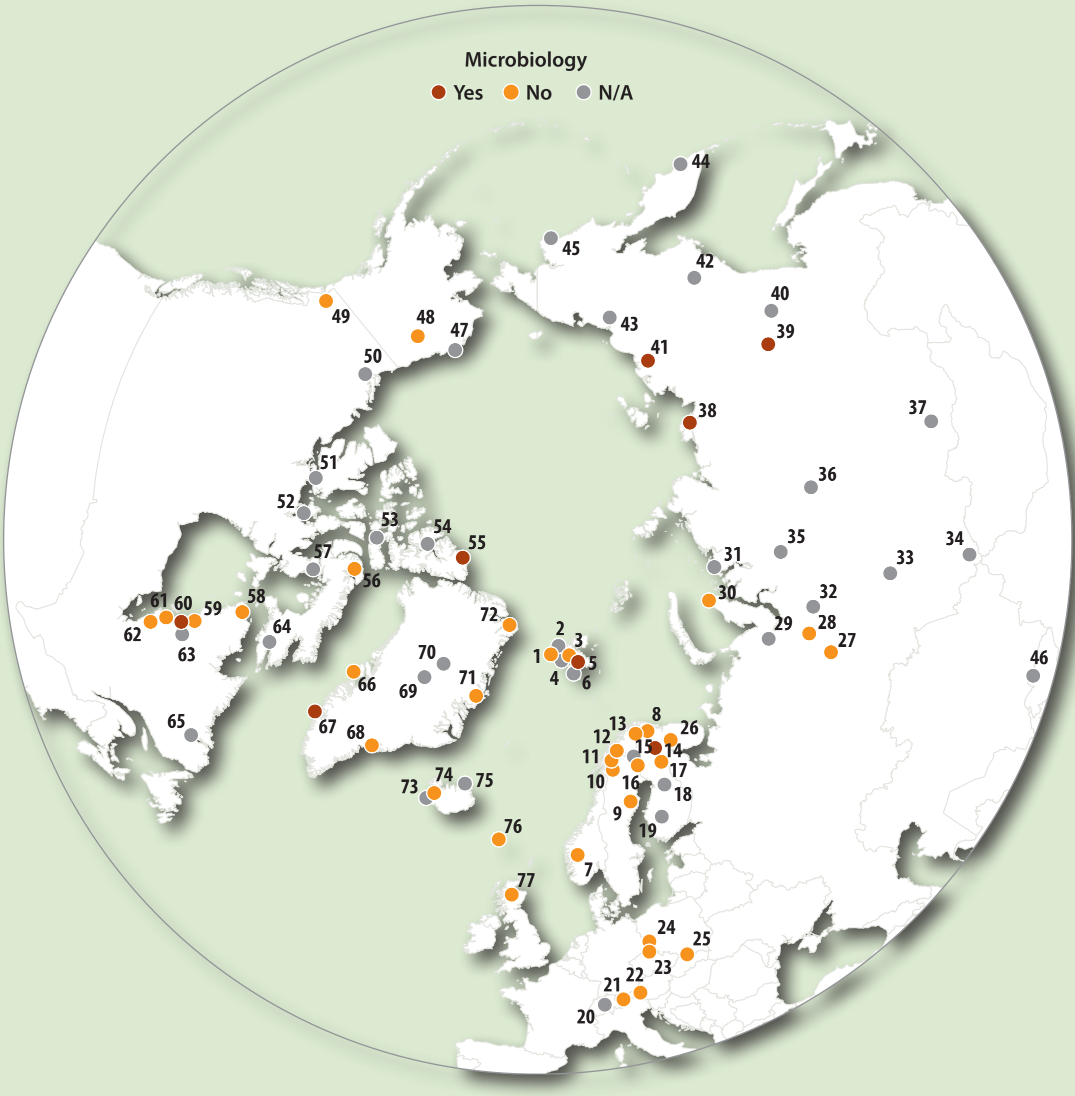
- Phytoplankton (chlorophyll)
- Zooplankton
- Vegetation
- Fish
- Invertebrates
- Species list (community composition)



BIO

3.2.29 Microbiology

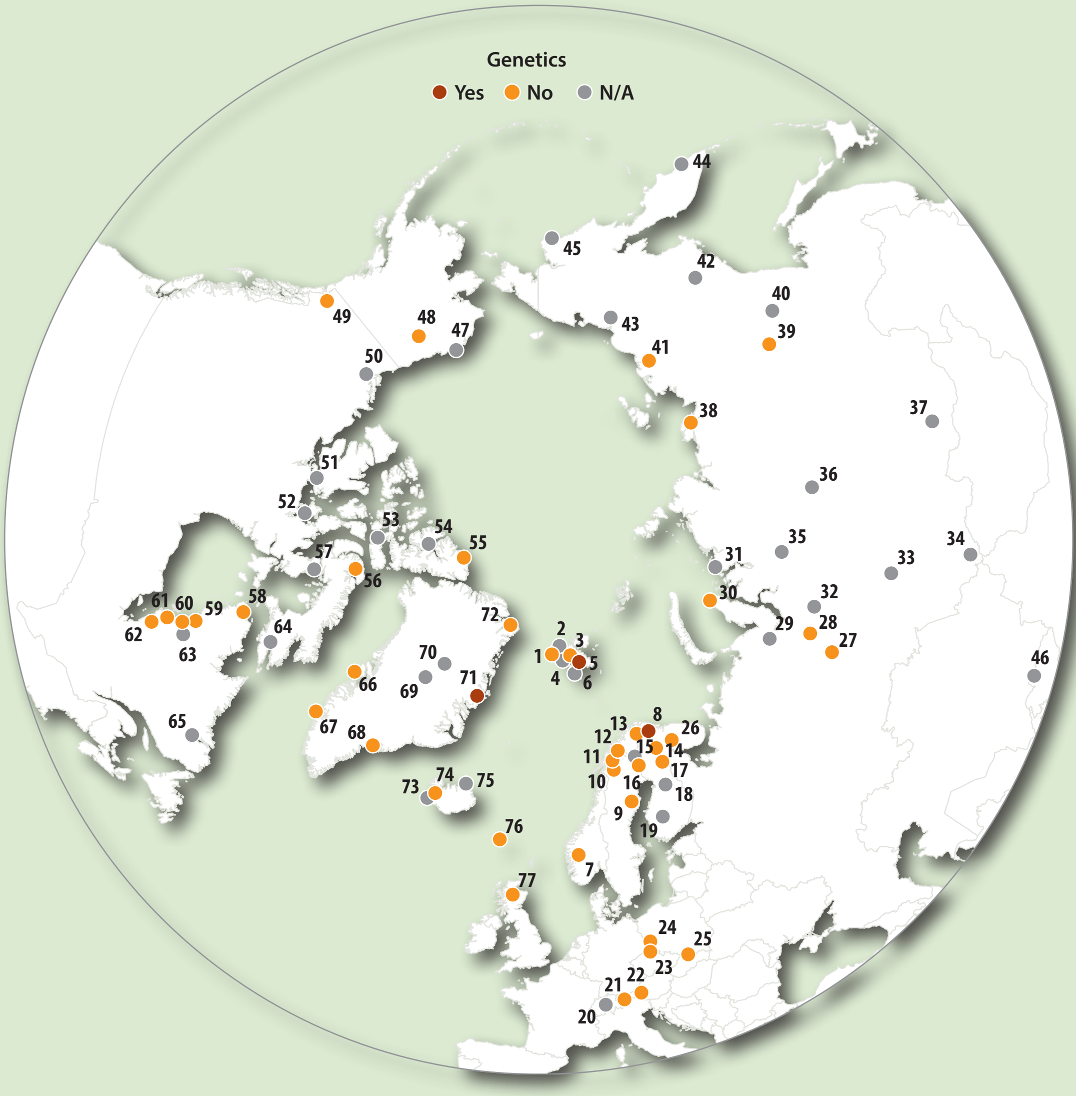
- Interstitial fauna
- Species list (community composition)



BIO

3.2.30 Genetics

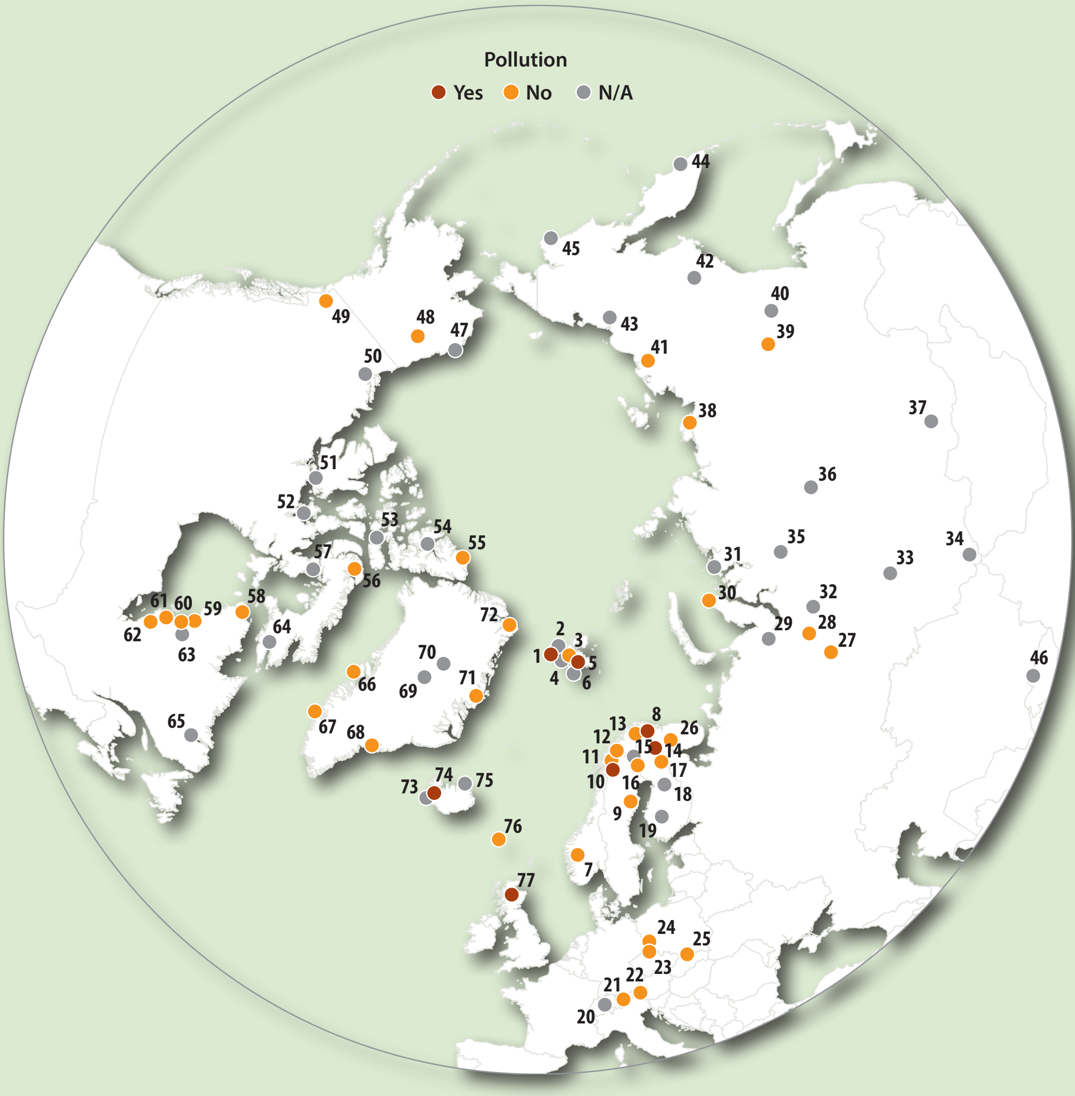
- Collection of animal tissue



BIO

3.2.31 Pollution

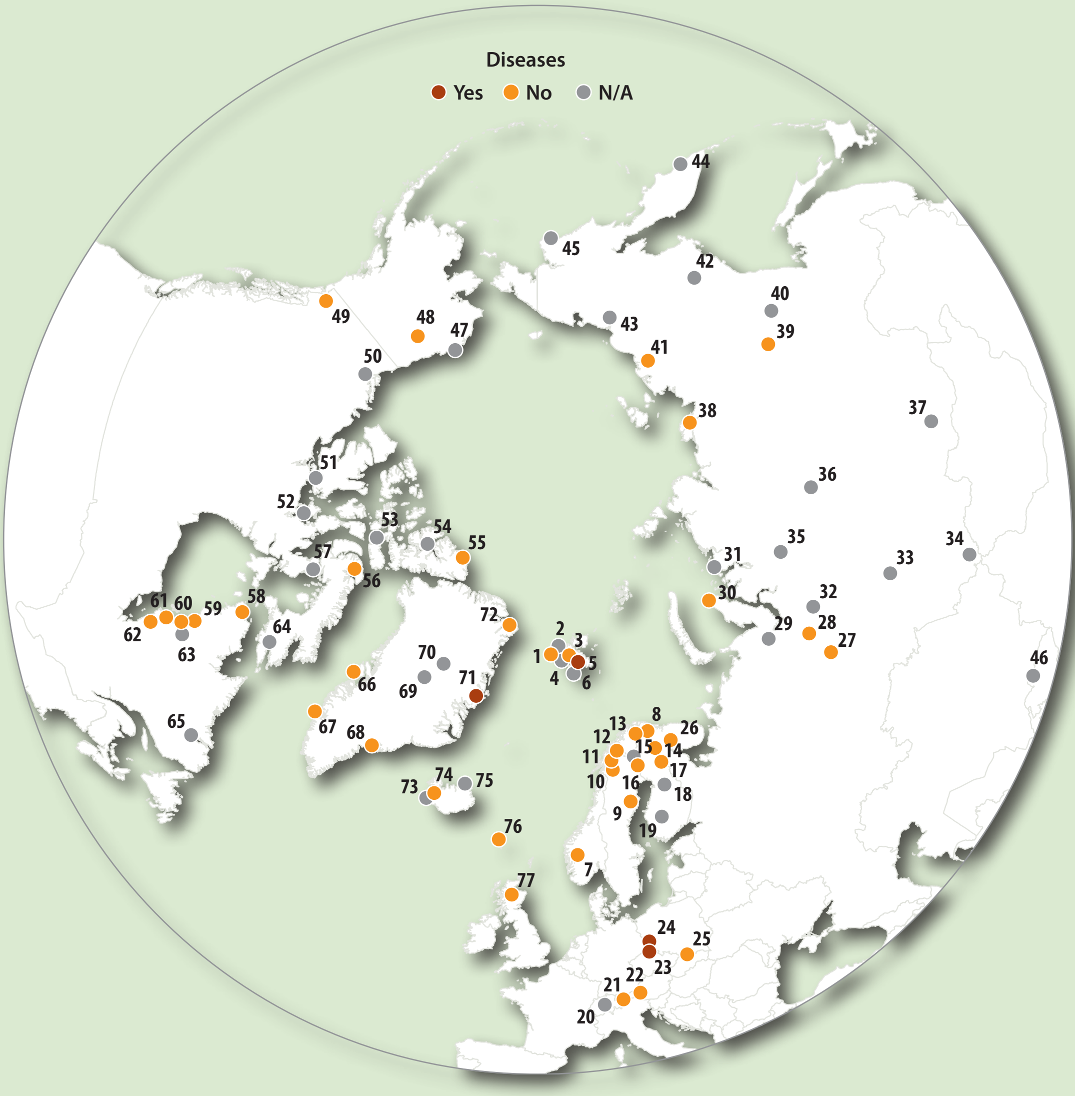
- Pollution measurements in vegetation
- Pollution measurements in water
- Pollution measurements in mammals (body burdens, biomarkers)
- Pollution measurements in birds (body burdens, biomarkers on both adults and offspring e.g. egg shell thinning, macro plastic in nests/in body)



BIO

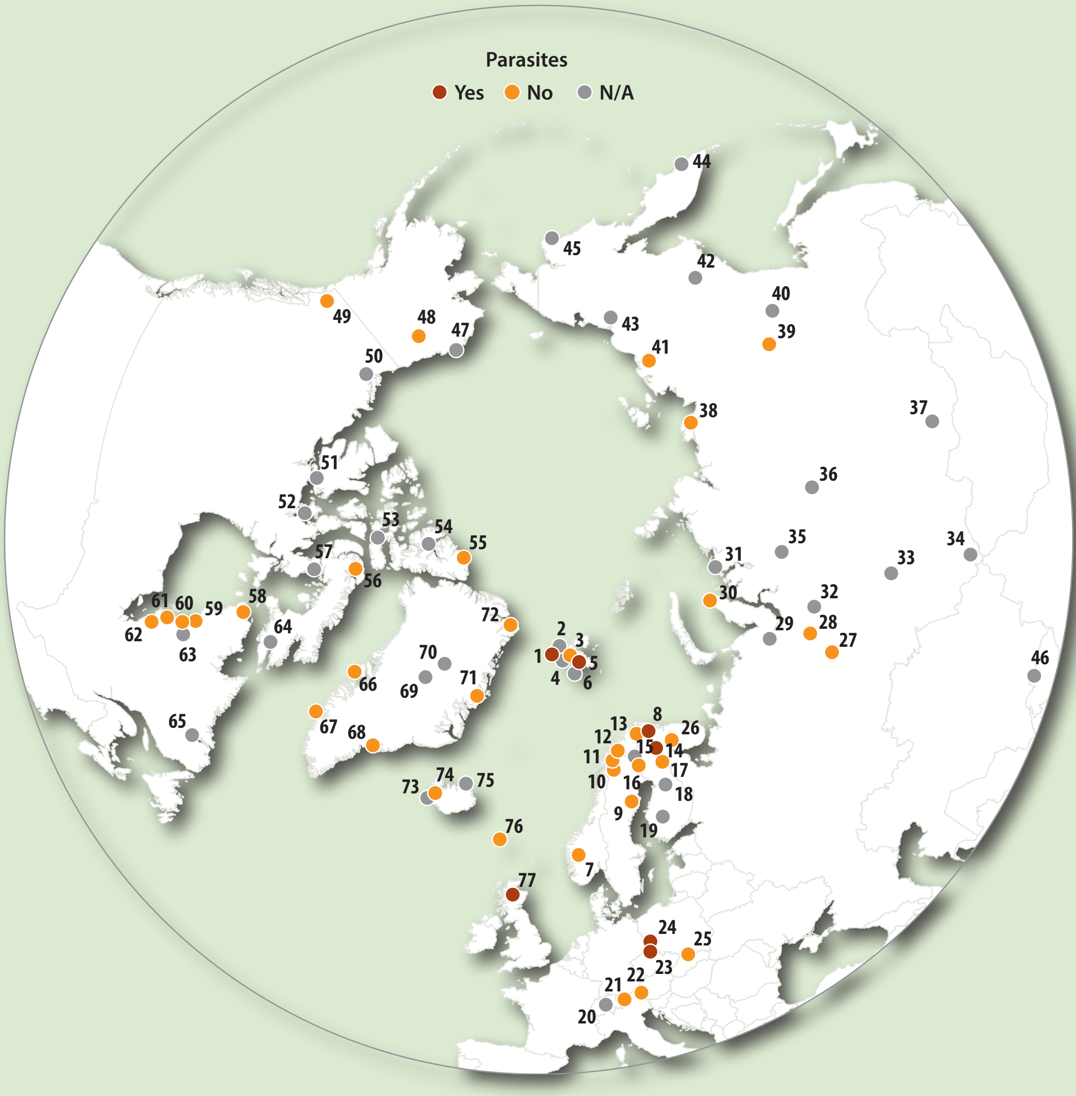
3.2.32 Diseases

- Mammals
- Birds
- Fish
- Vegetation
- Other



3.2.33 Parasites

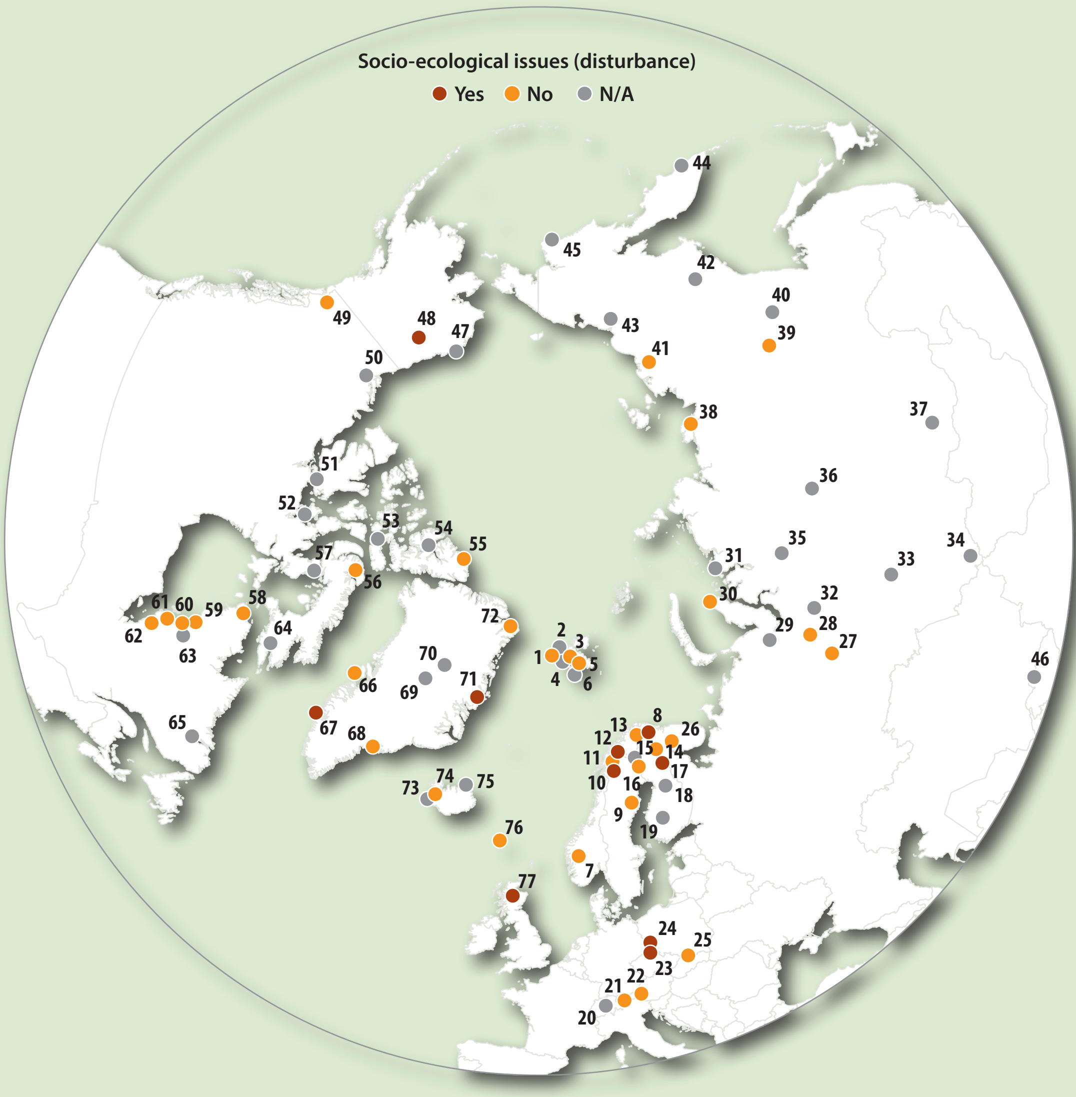
- Mammals
- Birds
- Fish
- Vegetation
- Other



BIO

3.2.34 Socio-ecological issues (disturbance)

- Number of visitors
- Surface activities (e.g. removal of vegetation, organisms, soil samples, ATV traffic, manipulations)
- Aircraft activities
- Emissions/discharge energy consumption, spill water, waste, garbage, atmospheric emissions, etc.



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Appendices

CEN Bylot Island Field Station, Canada (Gilles Gauthier).

Appendix 1
Overview of disciplinary coverage

● Yes ● No

Station name	Anthropology, Sociology, Archaeology	Astrophysics	Atmospheric chemistry and physics	Climatology, Climate Change	Community based monitoring, Citizen Science	Ecosystem services	Environmental sciences – Pollution	Geocryology, Geomorphology	Geodesy
1 Sverdrup Research Station	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
2 Netherlands' Arctic Station	Yes	No	No	Yes	No	Yes	Yes	No	No
3 UK Arctic Research Station	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
4 CNR Arctic Station "Dirigibile Italia"	No	No	Yes	Yes	No	No	Yes	Yes	No
5 Czech Arctic Research Station of Josef Svoboda	No	No	No	Yes	No	No	No	Yes	No
6 Polish Polar Station Hornsund	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
7 Finse Alpine Research Centre	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
8 Bioforsk Svanhovd Research Station	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
9 Svartberget Research Station	No	No	No	Yes	No	Yes	Yes	Yes	No
10 Tarfala Research Station	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes
11 Abisko Scientific Research Station	No	No	Yes	Yes	No	No	Yes	Yes	Yes
12 Kilpisjärvi Biological Station	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes
13 Kevo Subarctic Research Station	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes
14 Värriö Subarctic Research Station	No	No	Yes	Yes	No	Yes	Yes	No	No
15 Pallas-Sodankylä Stations	No	No	Yes	Yes	No	No	Yes	No	No
16 Kolari Research Unit	Yes	No	No	Yes	Yes	Yes	No	No	No
17 Oulanka Research Station	Yes	No	Yes	Yes	No	No	Yes	Yes	No
18 Kainuu Fisheries Research Station	No	No	No	Yes	Yes	No	No	No	No
19 Hyytiälä Forestry Research Station (SMEAR II)	No	No	Yes	Yes	No	Yes	Yes	No	No
20 Alpine Research and Education Station Furka	No	No	No	Yes	No	No	No	Yes	No
21 Station Hintereis	No	No	Yes	Yes	No	No	No	Yes	Yes
22 Sonnblick Observatory	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
23 Krkonoše Mountains National Park	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
24 Karkonosze National Park	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
25 M&M Kłapa Research Station	No	No	No	Yes	No	Yes	No	Yes	Yes
26 Khibiny Educational and Scientific Station	Yes	No	Yes	Yes	Yes	No	No	Yes	No
27 Mukhrino Field Station	No	No	Yes	Yes	No	Yes	Yes	Yes	No
28 Numto Park Station	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
29 Labytnangi Ecological Research Station	No	No	No	Yes	No	No	Yes	No	No
30 Beliy Island Research Station	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes
31 Willem Barents Biological Station	No	No	No	No	No	No	No	No	No
32 Khanymey Research Station	No	No	No	Yes	No	No	Yes	No	No
33 Kajbasovo Research Station	No	No	No	Yes	No	Yes	Yes	No	No
34 Aktru Research Station	No	No	No	Yes	No	No	Yes	Yes	Yes
35 Igarka Geocryology Laboratory	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes
36 Evenkian Field Station	No	No	Yes	Yes	No	No	Yes	Yes	No
37 International Ecological Educational Center "Istomino"	No	No	No	Yes	No	No	Yes	Yes	No
38 Research Station Samoylov Island	No	No	No	Yes	No	No	No	Yes	No

Geology, Sedimentology	Geophysics	Glaciology	Human biology, Medicine	Hydrology	Isotopic chemistry	Limnology	Land-use change, Mapping, GIS	Marine biology	Microbiology	Oceanography, Fishery	Paleoecology	Paleolimnology	Soil Science	Terrestrial biology – Biodiversity	Terrestrial biology – Ecosystem function
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(Continues)

Appendix 1
Overview of disciplinary coverage

● Yes ● No

Station name	Anthropology, Sociology, Archaeology	Astrophysics	Atmospheric chemistry and physics	Climatology, Climate Change	Community based monitoring, Citizen Science	Ecosystem services	Environmental sciences – Pollution	Geocryology, Geomorphology	Geodesy
39 Spasskaya Pad Scientific Forest Station	No	No	Yes	No	No	No	No	Yes	Yes
40 Elgeeii Scientific Forest Station	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
41 Chokurdakh Scientific Tundra Station	No	No	No	Yes	No	No	Yes	Yes	No
42 Orotuk Field Station	No	No	No	Yes	No	No	No	No	No
43 North-East Science Station	No	No	Yes	Yes	No	No	Yes	Yes	No
44 Avachinsky Volcano Field Station	No	No	No	No	No	No	Yes	Yes	No
45 Meinypil'gyno Community Based Biological Station	Yes	No	No	No	Yes	No	No	No	No
46 Adygine Research Station	No	No	No	Yes	No	Yes	No	Yes	Yes
47 Barrow Arctic Research Center/ Barrow Environmental Observatory	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
48 Toolik Field Station	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No
49 Kluane Lake Research Station	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
50 Western Arctic Research Centre	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
51 Canadian High Arctic Research Station	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No
52 M'Clintock Channel Polar Research Cabins	No	No	No	No	No	No	No	No	No
53 Flashline Mars Arctic Research Station	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
54 Polar Environment Atmospheric Research Laboratory	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
55 CEN Ward Hunt Island Research Station	No	No	Yes	Yes	No	No	Yes	Yes	No
56 CEN Bylot Island Field Station	No	No	No	Yes	No	Yes	Yes	Yes	No
57 Igloolik Research Center	No	No	No	Yes	No	No	Yes	No	Yes
58 CEN Salluit Research Station	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
59 CEN Boniface River Field Station	No	No	No	Yes	No	Yes	Yes	Yes	No
60 CEN Umiujaq Research Station	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
61 CEN Whapmagoostui-Kuujjuarapik Research Station	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
62 CEN Radisson Ecological Research Station	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
63 CEN Clearwater Lake Research Station	No	No	Yes	Yes	No	Yes	Yes	Yes	No
64 Nunavut Research Institute	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No
65 Labrador Institute Research Station	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
66 Arctic Station	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
67 Greenland Institute of Natural Resources	Yes	No	No	Yes	Yes	Yes	No	No	No
68 Sermilik Research Station	No	No	No	Yes	No	No	Yes	Yes	Yes
69 Summit Station	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
70 EGRIP Field Station	No	No	Yes	Yes	No	No	Yes	Yes	Yes
71 Zackenberg Research Station	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
72 Villum Research Station	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
73 Sudurnes Science and Learning Center	No	No	No	No	No	Yes	Yes	No	No
74 Litla-Skard	No	No	Yes	Yes	No	No	Yes	No	No
75 RIF Field Station	Yes	No	No	Yes	No	Yes	Yes	No	No
76 Faroe Islands Nature Investigation	No	No	No	Yes	No	No	No	Yes	No
77 ECN Cairngorms	No	No	Yes	Yes	Yes	Yes	Yes	No	No

Geology, Sedimentology	Geophysics	Glaciology	Human biology, Medicine	Hydrology	Isotopic chemistry	Limnology	Land-use change, Mapping, GIS	Marine biology	Microbiology	Oceanography, Fishery	Paleoecology	Paleolimnology	Soil Science	Terrestrial biology – Biodiversity	Terrestrial biology – Ecosystem function
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Appendix 2
Overview of monitored parameter groups

● Yes ● No ● N/A

Station name	CLIMATE					GEO								
	Meteorology – atmosphere	Radiation	Energy balance	Precipitation	Soil	Geology/Geomorphology	Geophysics and Geodesy	Sub-surface charachteristics	Snow characteristics	Atmospheric composition	Greenhouse gas exchange	Energy budget	Hydrology/Limnology	Pollution
1 Sverdrup Research Station	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Yes	Yes
2 Netherlands' Arctic Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 UK Arctic Research Station	No	No	No	No	No	No	No	No	No	No	No	No	No	No
4 CNR Arctic Station "Dirigibile Italia"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5 Czech Arctic Research Station of Josef Svoboda	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No
6 Polish Polar Station Hornsund	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7 Finse Alpine Research Centre	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
8 Bioforsk Svanhovd Research Station	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
9 Svartberget Research Station	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10 Tarfala Research Station	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	No	No	No	Yes	Yes
11 Abisko Scientific Research Station	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes	No
12 Kilpisjärvi Biological Station	Yes	No	No	No	No	No	Yes	No	Yes	No	No	No	Yes	No
13 Kevo Subarctic Research Station	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
14 Värriö Subarctic Research Station	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15 Pallas-Sodankylä Stations	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16 Kolari Research Unit	No	No	No	No	No	No	No	No	No	No	No	No	No	No
17 Oulanka Research Station	Yes	No	No	Yes	Yes	No	Yes	No	Yes	No	No	No	Yes	Yes
18 Kainuu Fisheries Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
19 Hyytiälä Forestry Research Station (SMEAR II)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20 Alpine Research and Education Station Furka	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21 Station Hintereis	Yes	Yes	No	Yes	No	No	No	No	Yes	No	No	No	Yes	No
22 Sonnblick Observatory	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
23 Krkonoše Mountains National Park	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
24 Karkonosze National Park	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
25 M&M Kłapa Research Station	No	No	No	No	No	No	No	Yes	Yes	No	No	No	Yes	No
26 Khibiny Educational and Scientific Station	Yes	Yes	No	Yes	Yes	No	No	No	Yes	No	No	No	No	No
27 Mukhrino Field Station	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
28 Numto Park Station	No	No	No	No	No	No	No	No	No	No	No	No	No	No
29 Labytnangi Ecological Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30 Beliy Island Research Station	Yes	Yes	No	No	Yes	No	No	No	No	No	No	No	No	No
31 Willem Barents Biological Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
32 Khanymey Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
33 Kajbasovo Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
34 Aktru Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35 Igarka Geocryology Laboratory	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36 Evenkian Field Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37 International Ecological Educational Center "Istomino"	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
38 Research Station Samoylov Island	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No

GLACIER									BIO											
Glacier characteristics	Mass balance	Climate	Glacier hydrology	Bio-geochemistry of snow, ice and water	Microbiology of snow, ice and water	Particles and aerosols	Pollutants e.g. POPs and heavy metals in snow, ice, water	Isotope chemistry of snow, ice and water	Vegetation	Arthropods	Birds	Mammals	Lake ecology	Microbiology	Genetics	Pollution	Diseases	Parasites	Socio-ecological issues (disturbance)
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(Continues)

Appendix 2
Overview of monitored parameter groups

● Yes ● No ● N/A

Station name	CLIMATE: Meteorology – atmosphere	CLIMATE: Radiation	CLIMATE: Energy balance	CLIMATE: Precipitation	CLIMATE: Soil	GEO: Geology/Geomorphology	GEO: Geophysics and Geodesy	GEO: Sub-surface charachteristics	GEO: Snow characteristics	GEO: Atmospheric composition	GEO: Greenhouse gas exchange	GEO: Energy budget	GEO: Hydrology/Limnology	GEO: Pollution
39 Spasskaya Pad Scientific Forest Station	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
40 Elgeeii Scientific Forest Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
41 Chokurdakh Scientific Tundra Station	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
42 Orotuk Field Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
43 North-East Science Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
44 Avachinsky Volcano Field Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
45 Meinypil'gyno Community Based Biological Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
46 Adygine Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
47 Barrow Arctic Research Center/ Barrow Environmental Observatory	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48 Toolik Field Station	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
49 Kluane Lake Research Station	Yes	Yes	No	Yes	No	No	No	No	Yes	No	No	Yes	Yes	No
50 Western Arctic Research Centre	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
51 Canadian High Arctic Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
52 M'Clintock Channel Polar Research Cabins	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
53 Flashline Mars Arctic Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
54 Polar Environment Atmospheric Research Laboratory	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
55 CEN Ward Hunt Island Research Station	Yes	Yes	No	No	No	No	No	Yes	No	No	No	No	Yes	Yes
56 CEN Bylot Island Field Station	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No	No	No
57 Igloolik Research Center	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
58 CEN Salluit Research Station	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
59 CEN Boniface River Field Station	Yes	No	No	Yes	Yes	No	No	No	No	No	No	No	No	No
60 CEN Umiujaq Research Station	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
61 CEN Whapmagoostui-Kuujjuarapik Research Station	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
62 CEN Radisson Ecological Research Station	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
63 CEN Clearwater Lake Research Station	Yes	Yes	N/A	N/A	Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
64 Nunavut Research Institute	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
65 Labrador Institute Research Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
66 Arctic Station	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
67 Greenland Institute of Natural Resources	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
68 Sermilik Research Station	Yes	Yes	No	Yes	No	No	No	No	Yes	No	No	No	Yes	No
69 Summit Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
70 EGRIP Field Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
71 Zackenberg Research Station	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
72 Villum Research Station	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
73 Sudurnes Science and Learning Center	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
74 Litla-Skard	Yes	Yes	No	Yes	No	No	No	No	No	No	No	No	Yes	Yes
75 RIF Field Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
76 Faroe Islands Nature Investigation	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No
77 ECN Cairngorms	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes	Yes

GLACIER									BIO											
Glacier characteristics	Mass balance	Climate	Glacier hydrology	Bio-geochemistry of snow, ice and water	Microbiology of snow, ice and water	Particles and aerosols	Pollutants e.g. POPs and heavy metals in snow, ice, water	Isotope chemistry of snow, ice and water	Vegetation	Arthropods	Birds	Mammals	Lake ecology	Microbiology	Genetics	Pollution	Diseases	Parasites	Socio-ecological issues (disturbance)
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Appendix 3 INTERACT Project metadata template

The metadata template for both research and monitoring projects, that INTERACT station managers agreed to follow and recommend for implementation at all stations.

Column title	Information required
Station name	Scroll down list: Station name (full name, spelled out).
Project #	Project number assigned by INTERACT. Enter one project per line.
Project title	The project title (full name, spelled out).
Optional: Project short title	Short title of the project.
Project start (yyyy-mm-dd)	Start of the project in the format "yyyy-mm-dd". If dd is unknown, state yyyy-mm-01. If mm-dd is unknown, state yyyy-01-01.
Project end (yyyy-mm-dd)	End of the project in the format "yyyy-mm-dd". If dd is unknown, state yyyy-mm-01. If mm-dd is unknown, state yyyy-01-01.
PI full name	Full name of the Principal Investigator (PI). Must include first name and surname spelled out.
PI home institution	Full name of the institution.
PI home institution country	Scroll down list: Full name of the country. Arctic states are followed by European states and then the rest of the world.
PI contact e-mail address	PI contact e-mail address.
Discipline1	Scroll down list: Choose the primary discipline of the project.
Optional: Discipline2	Scroll down list: Choose the secondary discipline of the project.
Study location (WGS84) decimal degrees – Latitude	The N/S location should be given in decimal degrees using World Geodetic System – WGS84 (number of decimals is optional, but at least two is recommended). This is not ideal for multiple plot/transect surveys. Where plots/transects are located nearby one another, you may write the coordinates of a central plot. Where plots and transects are distributed widely, you may enter the coordinates of the station. It is recommended that INTERACT stations collect spatial GIS information of all plots and transects for present and future projects.
Study location (WGS84) decimal degrees – Longitude	The W/E location should be given in decimal degrees using World Geodetic System – WGS84 (number of decimals is optional, but at least two is recommended). This is not ideal for multiple plot/transect surveys. Where plots/transects are located nearby one another, you may write the coordinates of a central plot. Where plots and transects are distributed widely, you may enter the coordinates of the station. It is recommended that INTERACT stations collect GIS information of all plots and transects for present and future projects.

Column title	Information required
Optional: Study location (local site name)	The local name of the study site (if known) and if relevant the description of how to find it.
Optional: Keywords	Write selected keywords, separate with comma. Keywords are intended for use in search functions. A list of standardised keywords for inspiration is found on separate sheet. Instructions of how to use that sheet are in the text following this table. It is recommended that INTERACT stations use these standardised keywords for present and future projects.
Optional: Comments	Comments can include additional information, e.g. additional contact info, major changes to programmes, location info, other disciplines, etc.
Optional: Project web-link	Project web link (if more than one link: separate by comma).
Optional: Project members	Project members names, separate by comma.
Optional: Short project description	Short description/link to the description of the project.
Optional: Research methodology	Short description of research methodology and instrumentation.
Optional: Publications	Reference information and/or link to the publications (if more than one link: separate by comma).
Optional: Web link to the raw data file	Links to raw data files (if more than one link: separate by comma).
Optional: Funding agency/ donor	Full name of the funding agency/private donor (if more than one: separate by comma).
Optional: Grant number/ID	Grant number/ID (if more than one: separate by comma).
Optional: Institution project ID	The project ID used at the research institution (if more than one: separate by comma).

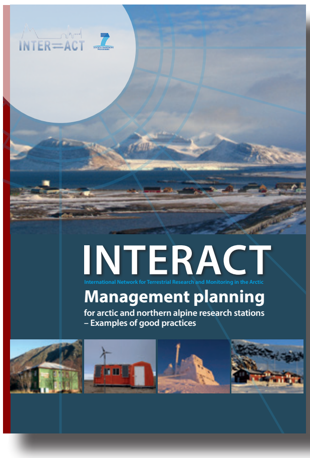
Appendix 4 INTERACT template for monitored parameter groups

Categories and environmental parameters template for monitoring projects, that INTERACT station managers agreed to follow and recommend for implementation at all stations.

Column title	Information required	
Category	General category/grouping of variables – predefined by INTERACT.	
Parameter	Measured variables – predefined by INTERACT.	
Check Box	Choose: 1 – for YES; 0 – for NO	
Season Start	Scroll down list: Choose the month number. Season "Start" and "End" months may vary between years – thus the extreme values should be included, meaning the earliest month and the latest month.	
Season End	Scroll down list: Choose the month number. Season "Start" and "End" months may vary between years – thus the extreme values should be included, meaning the earliest month and the latest month.	
Frequency	Frequency (select from scroll down list).	
	Hourly	X < 1 hour
	Daily	1 hour < X < 1 day (24 hours)
	Weekly	1 day < X < 7 days
	Every 2 weeks	7 days < X < 15 days
	Monthly	15 days < X < 1 month (28-31 days)
	Every 1-6 months	1 month (28-31 days) < X < 6 months
	Yearly	6 months < X < 1 year (12 months)
	Every 1-5 years	1 year < X < 5 years (60 months)
Optional: Special info (MAX 20 words)	Additional information may be provided, e.g. methodology used, scale (transect, plot, census area, landscape) or other.	
Project title as in MetaData table	Select from scroll down list the title of relevant project that monitor the specific parameter group (title will be added when you enter these in the metadata sheet for monitoring projects). If more than one monitoring project monitors a parameter group, please use the additional columns.	

INTERACT Products

INTERACT Management planning for Arctic and northern alpine research stations



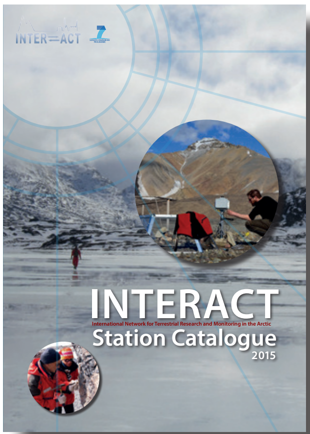
Many scientists studying the Arctic and alpine areas of the Northern Hemisphere rely on research stations for conducting their research and monitoring projects. These stations should provide an efficient and safe platform allowing scientists to focus on their field of interest.

In this highly illustrated book, INTERACT station managers share their combined knowledge and experiences gained from managing a set of very different research stations located in very different environmental and climatic settings. The book describes and identifies key aspects of station management in chapters on management planning, policies, staff, visitors, permit issues, health and safety, environmental impact, outreach and marketing, research and monitoring, training and education, and knowledge capture and data management.

The target audience for the book is mainly managers of research stations in Arctic and alpine areas, but it may also be a useful tool for all others involved in science coordination and logistics.

The book can be downloaded freely at www.eu-interact.org

INTERACT Station Catalogue – 2015



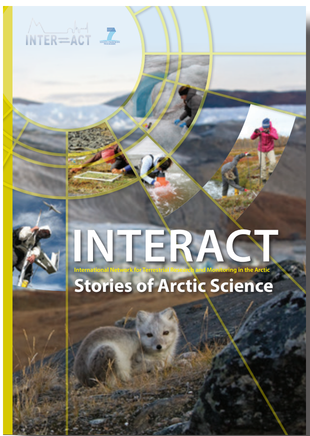
The INTERACT research stations provide a circumarctic platform for research and monitoring in Arctic and alpine areas, and adjacent forest environments. INTERACT stations are located in all major environmental envelopes of the Arctic providing an ideal platform for studying Climate Change and its impact on the environment and local communities.

To help guide scientists to their ideal platform, INTERACT has produced a catalogue of research stations that can help researchers and other stakeholders to identify research stations that suit their specific needs. In this highly illustrated "travel guide" for researchers, station managers describe their station and share facts about the local climate and surrounding environment.

The target audiences for this catalogue are scientists, scientific networks, organisations, managers of research and monitoring programmes, and others who are looking for relevant field sites for implementation of their research and monitoring agendas.

The catalogue can be downloaded freely at www.eu.interact.org

INTERACT Stories of Arctic Science



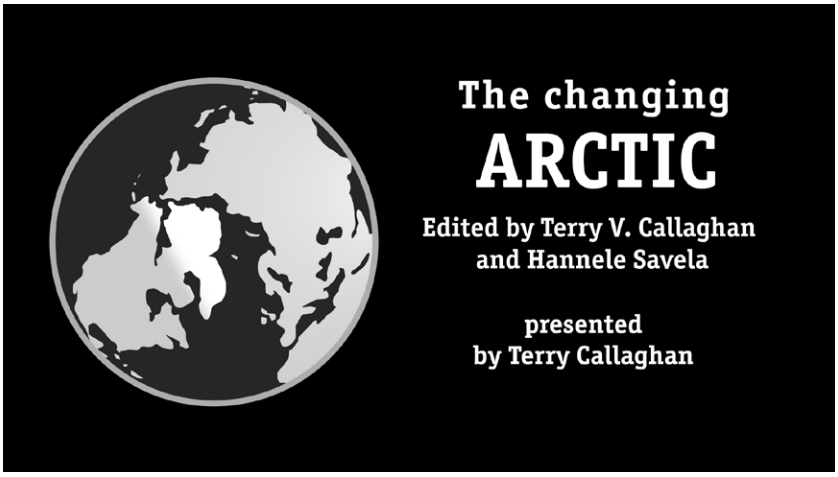
INTERACT stations host many thousands of scientists from around the world working in multiple disciplines and INTERACT collaborates with numerous research consortia and international research and monitoring networks. Through a Transnational Access funding mechanism, INTERACT has offered access for scientists to more than 20 of our stations. Based on these, INTERACT has produced a highly illustrated popular science book that contains many science stories of cutting-edge Arctic research from topics as diverse as Landscape-forming Processes to the Peoples of the Arctic, as told by the scientists themselves.

The book is intended for anyone with an interest in arctic science or a natural curiosity to explore adventurous and fascinating arctic science stories of global importance.

The book can be downloaded freely at www.eu-interact.org

Other INTERACT Products

On-line course and video lectures: The Changing Arctic



The book, "INTERACT Stories of Arctic Science", forms the basis of an on-line course with a series of video lectures arranged by Lektorium of St. Petersburg and Tomsk State University, Russia, together with the University of the Arctic.

The course "The Changing Arctic" presents a range of topics from the forefront of Arctic science including landscape formation, permafrost dynamics, glaciology, land-atmosphere links, and ecology on land and in freshwaters. The final lectures discuss the implications of change for the People of the North and the global community and summarise INTERACT's contributions to studying these issues.

No prior knowledge is needed for taking the course or for viewing the lectures; all that is required is natural curiosity and willingness to invest time in understanding these environmental issues of global concern.

The course is edited by Terry V. Callaghan and Hannele Savela, and presented by Terry V. Callaghan. The course material can be used either as a resource for education to gain a course certificate, or for viewing out of general interest.

Register for the course or view the on-line video lectures and other material at:

Coursera on-line learning platform, **www.coursera.org/learn/the-changing-arctic**

Lektorium: www.lektorium.tv

National research Tomsk state university

Tomsk State University: http://tsu.ru/english/

INTER=ACT

INTERACT: www.eu-interact.org

UArctic

University of the Arctic: www.uarctic.org

ORGANISATIONS WORKING WITH INTERACT

The International Arctic Science Committee (IASC) is a non-governmental, international scientific organization. The IASC mission is to encourage and facilitate cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic region.
www.iasc.org

Arctic Monitoring and Assessment Programme (AMAP) is an Arctic Council initiative with the objective of providing reliable and sufficient information on the status of, and threats to, the Arctic environment, and providing scientific advice on actions to be taken in order to support Arctic governments in their efforts to take remedial and preventive actions relating to contaminants.
www.amap.no

The Circumpolar Biodiversity Monitoring Program (CBMP) is an Arctic Council initiative supporting an international network of scientists, governments, indigenous organizations and conservation groups working to harmonize and integrate efforts to monitor the Arctic's living resources.
www.caff.is/monitoring

Sustaining Arctic Observing Networks (SAON) is an Arctic Council initiative that supports and strengthens the development of multinational engagement for sustained and coordinated pan-Arctic observing and data sharing systems that serve societal needs, particularly related to environmental, social, economic and cultural issues.
www.arcticobserving.org

International Study of Arctic Change (ISAC) is a program that provides a scientific and organizational framework focused around its key science questions for pan-Arctic research including long-term planning and priority setting. ISAC establishes new and enhances existing synergies among scientists and stakeholders engaged in Arctic environmental research and governance.
www.arcticchange.org

The WWF Global Arctic Programme has coordinated WWF's work in the Arctic since 1992. WWF works through offices in six Arctic countries, with experts in circumpolar issues like governance, climate change, resilience, fisheries, oil and gas, and polar bears.
www.wwf.org

INTERACT STATION MANAGERS' FORUM

The Station Managers' Forum under INTERACT provides a platform for exchange of information between research station managers and disseminates this information to the network, associated partners, local communities and other interested stakeholders.

The Station Managers' Forum produces a number of deliverables related to ecosystem research and monitoring, as well as station management and administration. This catalogue is a deliverable of the forum and upcoming products include reports on station management and administration, and research and monitoring undertaken at INTERACT stations.

Managers exchange and share information through biannual meetings, provide input to reports and can ask other managers for advice through a web-initiated dialogue forum. The Station Managers' Forum meetings are open to external partners (non-consortium members) and will be used to provide information from the different infrastructures to other managers and INTERACT work package deliverables.

www.eu-interact.org

INTERACT

International Network for Terrestrial Research and Monitoring in the Arctic

INTERACT is a one-stop shop for access to research infrastructures in the Arctic and in alpine areas of the Northern Hemisphere.

The main objective of INTERACT is to build capacity for identifying, understanding, predicting and responding to changes throughout the wide environmental and land-use envelopes of the Arctic and alpine areas of the Northern Hemisphere.

The INTERACT network of field stations provides a unique platform for terrestrial sciences and the network hosts and operates top level research and monitoring projects and programmes within a wide range of scientific disciplines.

This book is about the research and monitoring activities that are carried out at arctic and northern alpine research stations in the INTERACT network. It provides recommendations for a minimum monitoring programme and describes best practices for monitoring selected parameters through established scientific networks and programmes. The book also presents an overview of scientific activities at the individual research stations through a graphical presentation of monitored parameter groups and scientific disciplines.

The book is published together with a searchable metadata database allowing scientists and other stakeholders to search out details on the different research and monitoring projects which have taken place at the INTERACT stations providing data for the book.

Let's INTERACT !

www.eu-interact.org

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