Combination of CP & CSA

D2.9- Research and Monitoring at INTERACT sites

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Author: Elmer Topp Jørgensen and Morten Rasch

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

Table of Contents

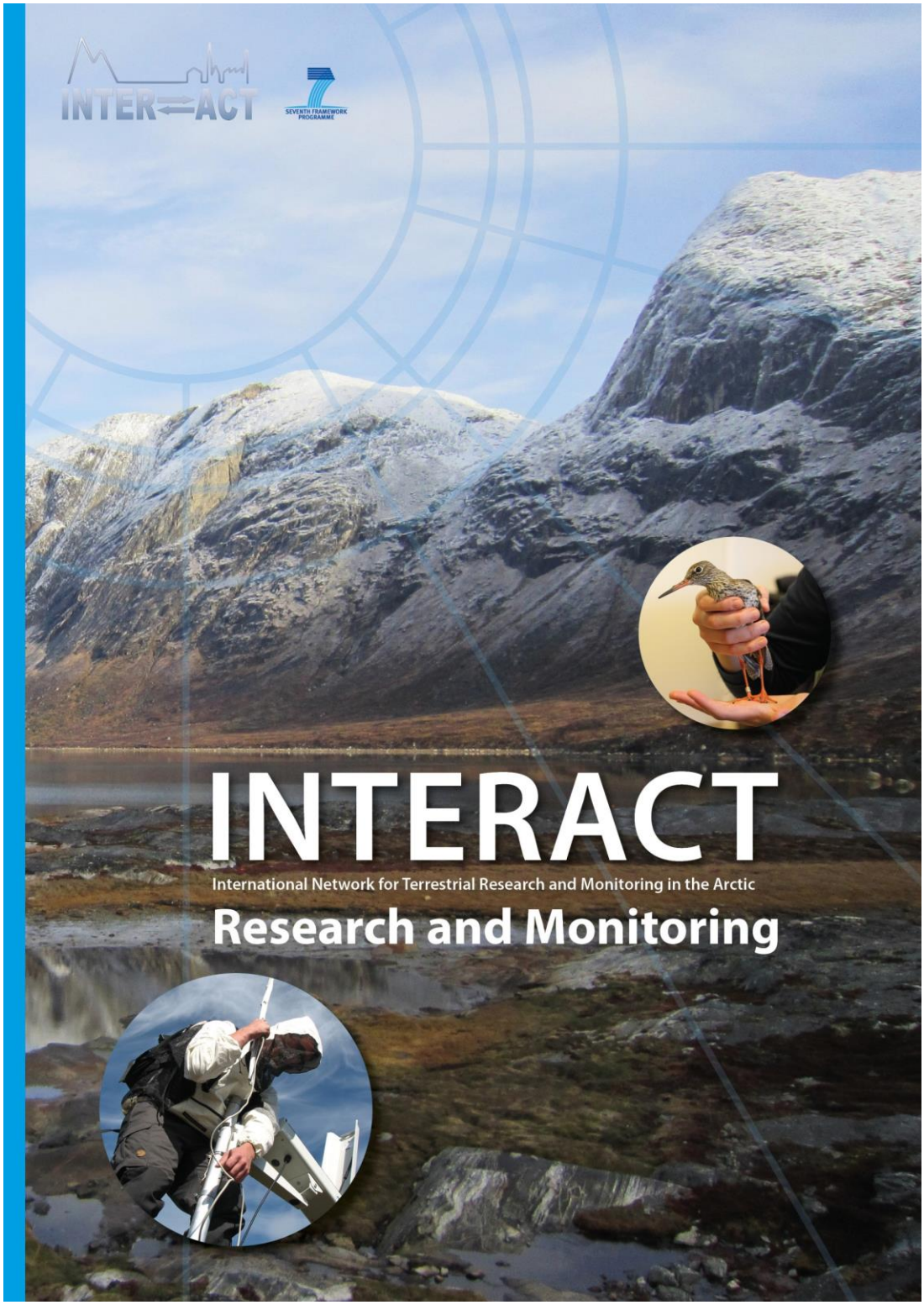
Publishable Executive Summary

INTERACT station managers have produced this report on research and monitoring activities that take place at INTERACT stations. The report is the third publication in the series of INTERACT publications produced by the Station Managers' Forum. It presents a summary of the scientific achievements of the INTERACT stations since the year 2000 by documenting the research and monitoring activities that have been carried out since then at the stations. It present recommendations for an INTERACT Minimum Monitoring Programme and provides descriptions of best practices for monitoring of selected parameters from protocols of scientific networks and programmes.

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

www.eu-interact.org

1. INTERACT Research and Monitoring report



INTERACT Research and Monitoring

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The report is available in PDF from the INTERACT website 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 2011-14 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), the International Study of Arctic Change (ISAC) and the World Wildlife Foundation (WWF).

The printing of this report has been made possible by means provided by INTERACT, The European Commission and Aarhus University (Denmark).

Preface

The Arctic Council's Arctic Monitoring Assessment Programme (AMAP) and the Conservation of Arctic Flora and Fauna (CAFF) through its Circumpolar Biodiversity Monitoring Programme (CBMP) have followed the transformation of INTERACT from its origins of just nine research stations around the North Atlantic into a true circum-arctic network of more than 70 research stations across the Arctic and northern alpine areas of Europe, Russia and North America.

Climate change, contamination, biodiversity loss and changes to the Arctic's 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, while 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 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 Network in response to the recognised need to enhance arctic monitoring.

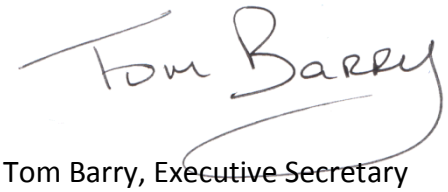
A significant part of the experimental research and long-term monitoring of climate change effects on arctic terrestrial ecosystems takes place on research stations. Accordingly, arctic research stations are important nodes in the gathering of knowledge about the status and trends of arctic environments 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 report and 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 report also provides recommendations for an 'INTERACT Minimum Monitoring System' that can help station managers prioritise in-house monitoring programmes and it 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

Contents

About INTERACT

The International Network for Terrestrial Research and Monitoring in the Arctic, INTERACT, is a network of more than 70 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, manufacturers of scientific instruments/equipment).

INTERACT is a one stop shop providing information that allows researchers to identify one or more stations that comply with their specific research needs both in relation to environmental and climatic conditions, and in relation to facilities and services offered at the individual stations.

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

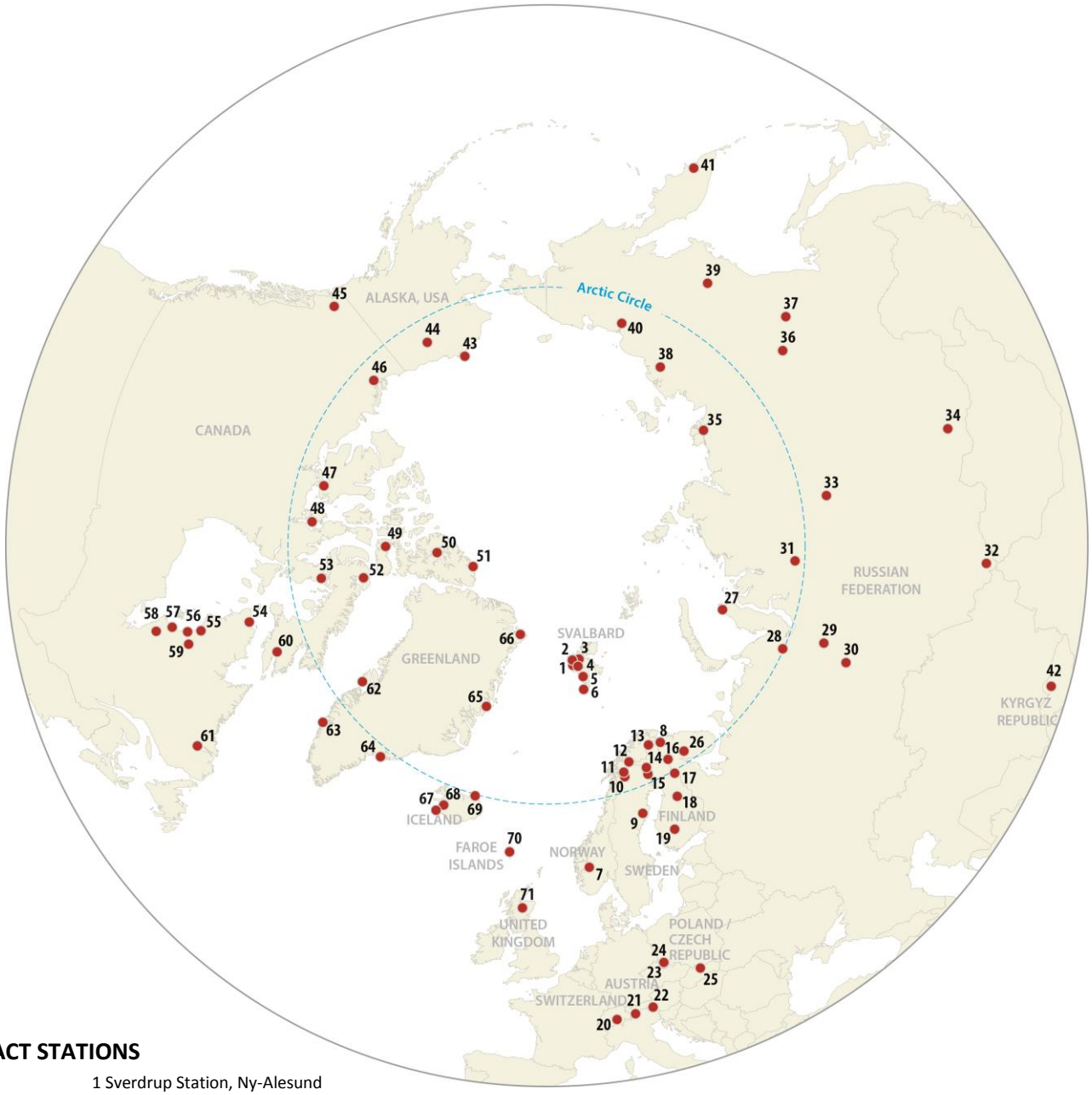
Since 2011, INTERACT has focused on developing the network so far by describing its individual facilities (the research stations) in an INTERACT Station Catalogue and by publishing a book on how to manage research infrastructures located in remote and harsh arctic and alpine environments.

The current report is the third publication in the series of INTERACT publications produced by the Station Managers' Forum. It presents a summary of the scientific achievements of the INTERACT stations since year 2000 by documenting the research and monitoring activities that have been carried out since then at the stations.

This report 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 report.

INTERACT Partner Stations and Observer Stations

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



INTERACT STATIONS

SVALBARD	1 Sverdrup Station, Ny-Alesund
	2 Netherlands' Arctic Station
	3 NERC Arctic Research Station
	4 Italian Arctic Station – Dirigibile Italia
	5 Czech Arctic Research Station, incl. Petuniabukta
	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 Research Station
	16 Kolari Research Unit
	17 Oulanka Research Station
	18 Kainuu Fisheries Research Station
	19 Hyytiälä Forestry Research Station (SMEAR II)
SWITZERLAND	20 ALPFOR Furka Pass
AUSTRIA	21 Hintereisferner Research Station
	22 Sonnblick Observatory
CZECH REPUBLIC	23 Krkonoše Mountains National Park
POLAND	24 Karkonosze National Park
	25 M&M Kłapa Research Station
RUSSIAN FEDERATION	26 Khibiny Educational and Scientific Station
	27 Beliy Island Research Station
	28 Labytnangi Ecological Research Station
	29 Numto Park Station
	30 Mukhrino Field Station
	31 Igarka Geocryology Laboratory
	32 Aktru Research Station
	33 Evenkian Field Station, Tura
	34 Baikal Istomino Field Station
	35 Samoylov Research Station
	36 Spasskaya Pad Scientific Forest Station
	37 Elgeeii Forest station
	38 Chokurdakh Scientific Tundra Station
	39 Orotuk Field Station
	40 Northeast Science Station, Cherskii
	41 Avachinsky Volcanoe Field Station
KYRGYZ REPUBLIC	42 Adygine Research Station
ALASKA, USA	43 Barrow Arctic research Center/ Barrow Environmental Observatory
	44 Toolik Field Station
CANADA	45 Kluane Lake Research Station
	46 Western Arctic Research Centre (WARC)
	47 Canadian High Arctic Research Station
	48 M'Clintock Channel Polar Research Cabins
	49 Mars Arctic Research Station
	50 Polar Environment Atmospheric Research Laboratory (PEARL)
	51 CEN Ward Hunt Island Field Station
	52 CEN Bylot Island Field Station
	53 Igloolik Research Center
	54 CEN Salluit Research Station
	55 CEN Boniface River Field Station
	56 CEN Umiujaq Research Station
	57 CEN Whapmagoostui-Kuujjuarapik Station
	58 CEN Radisson Station
	59 CEN Clearwater Lake Station
	60 Nunavut Research Institute
	61 Labrador Institute Research Station
GREENLAND	62 Arctic Station
	63 Greenland Institute of Natural Resources
	64 Sermilik Research Station
	65 Zackenberg Research Station
	66 Villum Research Station, Station Nord
ICELAND	67 Sudurnes Science and Learning Center
	68 Litla Skard
	69 RIF Field Station
FAROE ISLANDS	70 Faroe Islands Nature Investigation (FINI)
UNITED KINGDOM	71 Cairngorms

Structure of the report and how to use it

In this report, we present an overview of the research and monitoring activities that is made possible by the research infrastructures included in the INTERACT network. A searchable database will virtually accompany the report 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.

The report itself presents an outline of the research and monitoring activities that take place at INTERACT stations, including:

- INTERACT research and monitoring activities
  - INTERACT observational capacity
  - Scientific networks in which INTERACT station staff is represented
- Overview of scientific disciplines and parameter groups sampled at INTERACT stations since year 2000
- Best practices for long-term monitoring
  - INTERACT Minimum Monitoring Programme
  - Scientific networks and programmes with best practices sampling protocols.

How to use the report

The report can be used by both station managers and the scientific community.

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

- Consulting the recommended INTERACT Minimum Monitoring Programme (Chapter 3)
- Identifying gaps in disciplines or parameter group coverage at the station (Chapter 2)
- Looking through the descriptions of scientific networks and programmes and follow relevant leads to best practice sampling protocols (Chapter 4)

The scientific community can use the report to:

- Identify stations that conduct science (disciplines/monitored parameter groups) relevant to their field (Chapter 2)
- Identify potential new study sites by searching out gaps in the geographical coverage of relevant disciplines/monitored parameter groups (Chapter 2)

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 the maps (Chapter 2). Details of the individual research and monitoring projects can be found in a database being released together with this report (Chapter 2 and www.eu-interact.org).

The INTERACT Station Catalogue (can be downloaded from www.eu-interact.org) can be used to assess whether a knowledge gap in disciplines or monitored parameter group coverage at a station is caused by

the lack of the specific environmental feature in the area or a lack of scientific activity within this field. When potential new sites have been identified, it is always recommended that scientists consult the website of the research station or contact the station manager to enquire about the specific conditions and discuss the feasibility of the proposed activities.

The INTERACT Metadata Database
In the INTERACT Metadata Database, 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 Appendix 1, Tables 1-2). The database 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).

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 Appendix 1). 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.

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

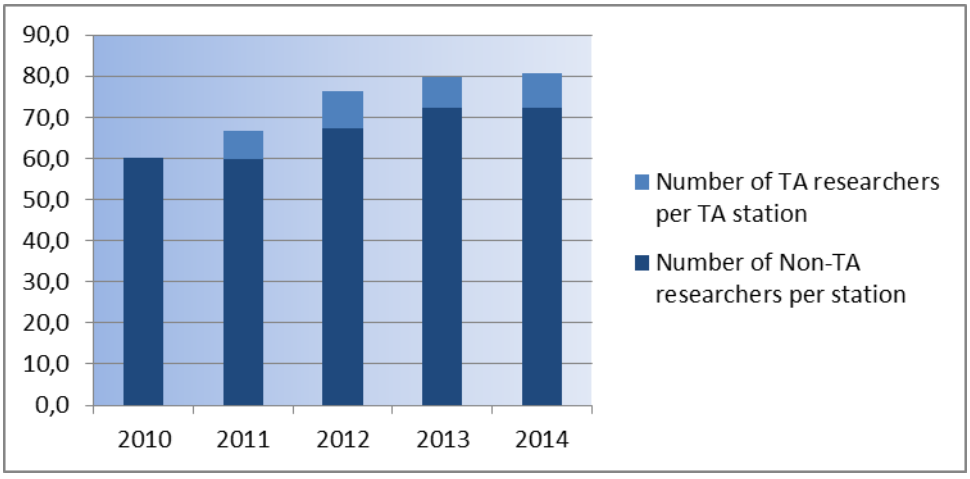
Data quality
The data included in the database has been provided by the station managers using the archiving system available at their station. Data management practices vary significantly between sites and the information available for each station therefore depends on the systems in place for tracking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

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 discipline, and as monitored parameter groups are related to specific monitoring projects, this will allow scientists to at least identify a PI name, which should enable the user to contact this person and ask for further details.

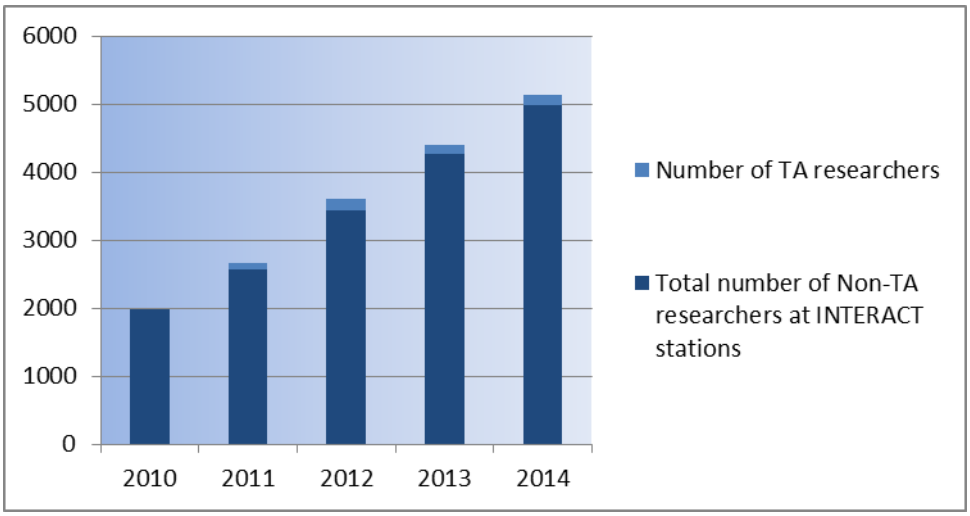
Summary of INTERACT research and monitoring activities

1.1 INTERACT observing capacity

The research stations within the INTERACT network offer access for researchers and other stakeholders (authorities, donors, artists, etc.). The past decades has seen increased focus on the Arctic as a showcase for Climate Change and the induced impacts on the environment. This increased focus is also reflected in the statistics from the four year period in which the INTERACT project has been in operation (2011-2014). The average number of researchers per station has increased by 20% (from 60 to 73 visitors per station in 2010 and 2014 respectively). Some INTERACT stations have also offered Transnational Access (see Deliverable D4.4) which added even further to the increase of the average number of researchers per station and brought it up by 25 % (from 60 in 2010 to just over 80 visitors per station in 2014).



The average number of visitors per station in INTERACT from 2010 to 2014. The dark blue colour shows the number of visitors without INTERACT Transnational Access funding while the light blue colour shows added visitors per station for stations offering Transnational Access.



The growth of the observational capacity of INTERACT from 2010 to 2014. The dark blue colour shows the total number of visitors per year with no INTERACT Transnational Access funding while the light blue colour shows the total number of visitors funded by Transnational Access.

The total number of researchers hosted at INTERACT stations grew from around 2000 in the year 2010 to over 5000 in 2014, an increase of 150 %. The increase is explained by the rapid expansion of the network from 33 stations in 2011 to more than 70 stations in 2014. The average number of researchers per station, however, also increased during this period (see diagram above).

1.2 Scientific networks, programmes and organisations with INTERACT representation

INTERACT stations host and participate in a multitude of scientific networks, programmes and organisations. A survey conducted in 2014 showed that INTERACT associated staff participates in over 75 different scientific networks, programmes and organisations. These range from scientific single disciplinary networks, over circum-arctic monitoring programmes to regional and global organisations. The list covers different fields of focus from improved scientific understanding over improved data management to providing management advice and setting research and monitoring agendas. The initiatives range from national single discipline scientific networks and programmes to large regional and global multidisciplinary organisations.

The list below is a snapshot of the networks, programmes and organisation in which INTERACT station associated staff was represented in 2014. Note that the list of networks is not static and new may be added and some disappear from the list with changes in station staff or changes in the networks, programmes and organisations.

Scientific Networks, programmes and organisation in which INTERACT station staff was represented (2014)

ACTRIS - Aerosols, Clouds, and Trace gases Research Infrastructure Network (Europe), www.actris.net
ADAPT - Arctic Development and Adaptation to Permafrost in Transition (Canada), www.cen.ulaval.ca/adapt
AERONET - Aerosol Robotic Network (global), http://aeronet.gsfc.nasa.gov
AMAP - Arctic Monitoring and Assessment Programme (Arctic), www.amap.no
AnaEE - Analysis and Experimentation on Ecosystems (Europe), www.anaee.com
AON - Arctic Observing Network (Arctic), www.arcus.org/search-program/aon
APECS - Association of Polar Early Career Scientists (Arctic and Antarctic), www.apecs.is
AQUAEXCEL - Aquaculture infrastructures for excellence in European Fish Research (Europe), www.aquaexcel.eu
Arctic WOLVES – Arctic Wildlife Observations Linking Vulnerable EcoSystems (Canada), www.cen.ulaval.ca/arcticwolves/index.html
ASP - Arctic Science Partnership (Canada, Greenland and Denmark), www.asp-net.org
ATBI - All Taxa Biodiversity Inventory (USA), www.dlia.org/atbi
ATNEA - Analysis of Aerosol Transport Patterns from Northern Europe (Europe), http://cordis.europa.eu/project/rcn/103908_en.html
BSRN - Baseline Surface Radiation Network (global), www.bsrn.awi.de
CAFF/C-Bird - Conservation of Arctic Flora and Fauna/Circumarctic Seabird Expert Group (Arctic), www.caff.is/seabirds-cbird
CAFF/CBMP - Conservation of Arctic Flora and Fauna/Circumpolar Biodiversity Monitoring Programme (Arctic), www.caff.is/cbmp
CAFF/Flora group - Conservation of Arctic Flora and Fauna/ Flora Expert Group (Arctic), www.caff.is/flora-cfg
CALM - Circumpolar Active Layer Monitoring Programme (global), www.gwu.edu/~calm
CALON - Lakes Observing Network (Arctic), www.arcticlakes.org
CARMA - Circumarctic Rangifer Monitoring and Assessment Network (Arctic), http://carma.caff.is
CNNRO - anadian Network of Northern Research Operators (Canada), http://cnnro.org/CNNRO.html
DEFROST - Depicting ecosystem-climate feedbacks from permafrost, snow and ice (Arctic), www.ncoe-defrost.org
EARLINET - A European Aerosol Research Lidar Network (Europe), www.earlinet.org
ENVRI - Common Operations of Environmental Research Infrastructures (Europe), http://envri.eu
ExpeER - Experimentation in Ecosystem Research (Europe), www.expeeronline.eu
FARO - Forum of Arctic Research Operators (Arctic), http://faro-arctic.org
FITFISH - Swimming of fish and implications for migration and aquaculture (Europe), (website under construction)
FLUXNET - Terrestrial Carbon Flux Network (global), www.fluxnet.ornl.gov
GEM - Greenland Ecosystem Monitoring (Greenland), http://g-e-m.dk/
GEO/GEOSS - Group on Earth Observation/Group on Earth Observation System of Systems (global), www.earthobservations.org

GLIMS - Global Land Ice Measurements from Space (global), www.glims.org
GLISN - Greenland Ice Sheet Seismic Network (Greenland), www.iris.edu/hq/programs/glisn
GLORIA - Global Observation Research Initiative in Alpine Environments (global), www.gloria.ac.at
GTN-G - Global Terrestrial Network Glaciers (global), www.gtn-g.org
GTN-P - Global Terrestrial Network on Permafrost (global), http://gtnp.arcticportal.org
IAGA - International Association of Geomagnetism and Aeronomy (global), www.iugg.org/IAGA
IASC - International Arctic Science Committee (Arctic), www.iasc.info
IACS (IUGG) - International Association for Cryospheric Science (global), www.cryosphericsciences.org
ICES - International Council for the Exploration of the Sea (global), www.ices.dk
ICOS - Integrated Carbon Observing System (Europe), www.icos-infrastructure.eu
IGS - International Glaciological Society (global), www.igsoc.org
IMAGE - International Monitoring for Auroral Geomagnetic Effects (global), http://space.fmi.fi/image
INCREASE - Integrated Network on Climate Research Activities on Shrubland Ecosystems (Europe), http://increase.ku.dk
InGOS - Integrated non-CO_2 Greenhouse gas Observing System (Europe), www.ingos-infrastructure.eu
INTERMAGNET - International Real-time Magnetic Observatory Network (global), www.intermagnet.org
ILTER - International Long Term Ecological Research (global), www.ilternet.edu
IPA - International Permafrost Association (global), http://ipa.arcticportal.org
ISAC - International Study of Arctic Change (Arctic), www.arcticchange.org
ITEX - International Tundra Experiment (Arctic), http://ibis.geog.ubc.ca/itex
LCC - Landscape Conservation Cooperative (USA), http://lccnetwork.org
LifeWatch - European e-Science Infrastructure for Biodiversity and Ecosystem Research (Europe), www.lifewatch.com
LTER Europe - Long Term Ecological Research (Europe), www.lter-europe.net
LTER US - Long Term Ecological Research (USA), www.ilternet.edu/member-networks/north-america/usa
LTREB - Long term Research in Environmental Biology (USA), www.nsf.gov/funding/pgm_summ.jsp?pims_id=13544
MACC - Monitoring of Atmospheric Composition and Climate (Europe), www.gmes-atmosphere.eu
MRI - Mountain Research Initiative (global), http://mri.scnatweb.ch/en
NAFO - Northwest Atlantic Fisheries Organisation (Atlantic), www.nafo.int
NAMMCO - North Atlantic Marine Mammal Commission (Atlantic), www.nammco.no
NDACC - Network for the Detection of Atmospheric Climate Change (global) www.ndsc.ncep.noaa.gov
NEON - National Ecological Observatory Network (USA), www.neoninc.org
NGEE - Next Generation Ecosystem Experiment (Arctic), http://ngee-arctic.ornl.gov
NNSI - North Slope Science Initiative (USA), www.northslope.org
OBFS - Organisation of Biological Field Stations (USA), www.obfs.org
PAGE21 - Changing Permafrost in the Arctic and its Global Effects in the 21st Century (Arctic), www.page21.eu
PAN - Polar Archaeology Network (Polar), www.iasc.info/home/networks/pan
PEEX - Pan-Eurasian Experiment (Finland, Russia and China), www.atm.helsinki.fi/peex
S4C Science Network - Science for the Carpathians and Mountains Research Network (Europe), www.forumcarpaticum.org/FC-main/Main_S4C.html
SAON - Sustained Arctic Observing Network (Arctic), www.arcticobserving.org
SEDIBUD - Sediment Budgets in Cold Environments (global), www.geomorph.org/wg/wgsb.html
SIOS - Svalbard Integrated Arctic Earth Observing System (Svalbard), www.sios-svalbard.org/prognett-sios/Home_page/1234130481072
SITES - Swedish Infrastructure of Ecosystem Science (Sweden), www.fieldsites.se/en
SMEAR - SMEAR Station Network (Finland, Estonia, China and South Africa), www.atm.helsinki.fi/SMEAR
SNPN - Swedish National Phenology Network (Sweden), www.slu.se/svenskafenologinatverket
TCN - Tundra Conservation Network (Arctic), http://peregrinefund.org/subsites/tcn
Uarctic - University of the Arctic (Arctic), www.uarctic.org
WGMS - World Glacier Monitoring Service (global), www.wgms.ch
WMO/GAW- World Meteorological Organisation/Global Atmosphere Watch (global), http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html
WMO/GCW - World Meteorological Organisation/Global Cryosphere Watch (global), http://globalcryospherewatch.org

2. Research and monitoring projects carried out at INTERACT stations

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 Research and Monitoring Database, the chapter is intended to be a tool for station managers, researchers, donors, scientific networks, programmes and 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 sources and data 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 until May 2014. The survey was split into three components:

- Scientific disciplines at the station.
- Metadata on research and monitoring projects (project name, start/end, PI, location, publications, etc.).
- Metadata on monitored parameter groups (season start/season end, frequency, methodology, etc.).

69 stations have provided information on which scientific disciplines they support at their station, while 42 stations contributed with standardised metadata for all research and monitoring projects and monitored parameter groups. The metadata template that INTERACT station managers agreed to follow and recommend for implementation at all stations is given in Appendices 2.1 and 2.2.

The data presented in this report (and the associated data repository) are based on the contributions from station managers or associated staff. In some cases station managers have been unable to provide all required metadata or parameter information. For all projects and dataseries given in the report and the repository it is, however, possible to find the principal investigator who can be contacted for more information.

How to use this chapter:

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

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

[1] This report 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 INTERACT.

The maps can be used for identifying relevant stations and projects of interest.

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

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.

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 Research and Monitoring Database (www.eu-interact.org) can be used to identify geographical gaps or identify stations that host projects that can serve as a base for your further research.

- 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 Research and Monitoring Database (www.eu-interact.org) where you search out more detailed information on projects related to the specific discipline or parameter group. If you have a need more detailed information than is included in the project metadata, you need to contact the Principal Investigator whose name is listed for all registered projects (in some cases, the station manager should be contacted).
- If looking for gaps, you should remember that there are stations and projects that are not part of INTERACT and hence are not covered by this report. When you have identified a gap, you can read about the specific station(s) in the INTERACT Station Catalogue[2] 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[3]).

Are you a researcher looking for publications or data?

If you are looking for publications or data (e.g. for a larger assessment, comparisons or references), you can use maps and the associated INTERACT Research and Monitoring Database (www.eu-interact.org) to identify stations that host projects related to the desired discipline or parameter group.

- When looking for publications or data related to the desired discipline or parameter group, you can use the map to identify the relevant station(s). You should then go to the INTERACT Research and Monitoring Database (www.eu-interact.org) 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.

[2] http://www.eu-interact.org/fileadmin/user_upload/pdf/Downloads/INTERACT_Station_Catalogue.pdf
[3] www.eu-interact.org/field-sites

Are you a station manager looking for knowledge and/or data gaps in your monitoring programme?
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 what scientific disciplines or parameter groups that are not monitored at or near you station. 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 Research and Monitoring Database (www.eu-interact.org).

2.1 Research and monitoring disciplines

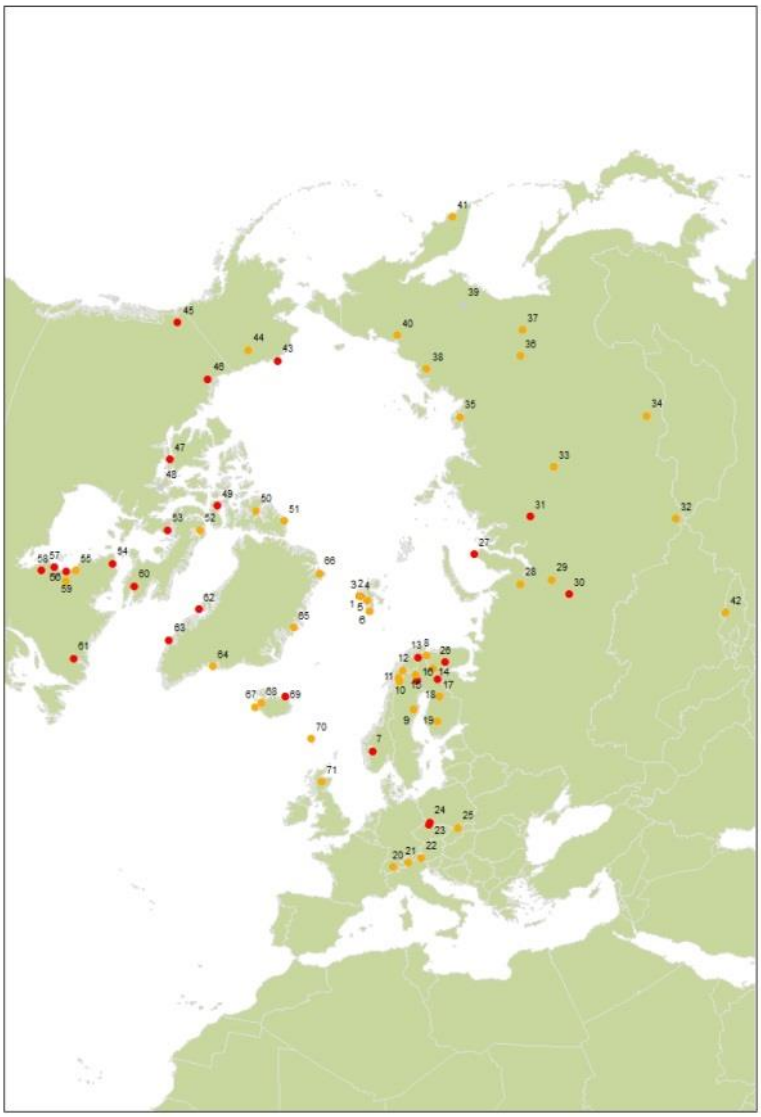
In this section, the reader will be introduced to science disciplines that are covered by research and monitoring projects at INTERACT stations. General descriptions of science disciplines are followed by maps depicting field stations that have hosted or are hosting research or monitoring projects within the presented disciplines since year 2000.
Disciplines covered by research and monitoring projects at INTERACT field stations are listed in Table 2.1.1, where some of the individual disciplines were grouped together.

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	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

Table 2.1.1. List over scientific disciplines included in the INTERACT Research and Monitoring database.

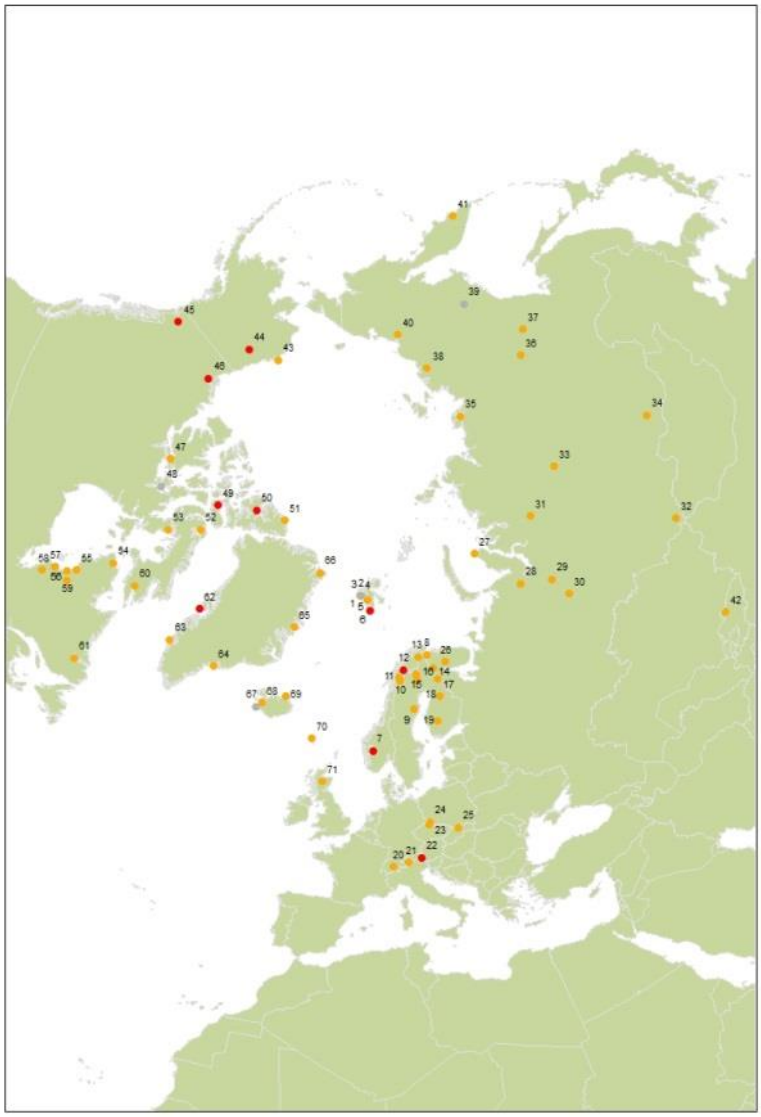
Anthropology, Archaeology and Sociology – are three branches within the social science and humanities academic disciplines.
Anthropology is "the science of humanity", which studies human beings in aspects ranging from the biology and evolutionary history of *Homo sapiens* to the features of human society and culture (1).
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 (1).
Sociology is a social science discipline that studies human societies, their interactions, and the processes that preserve and change them (1).

Geographical distribution of INTERACT stations covering the disciplines: *Anthropology, Archaeology and Sociology*.
Red: Yes; Orange: No;
Grey: N/A.



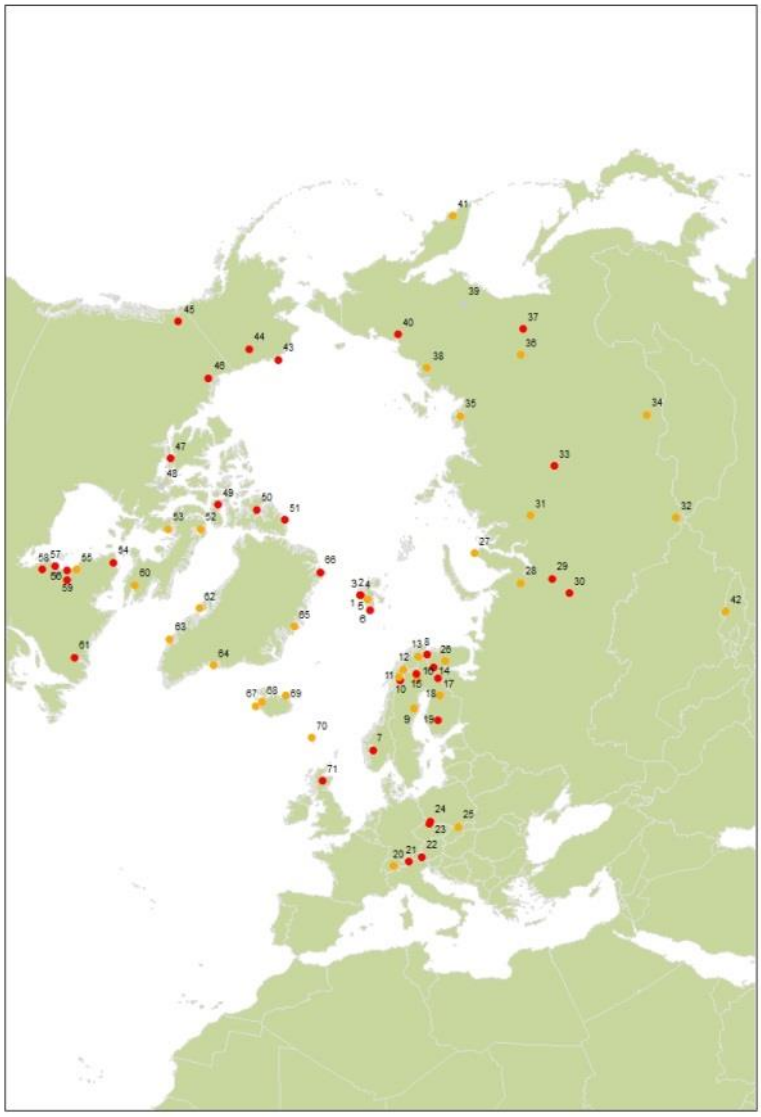
Astrophysics is a branch of astronomy dealing primarily with the behavior, physical properties, and dynamic processes of celestial objects and phenomena in outer space (2).

Geographical distribution of INTERACT stations covering the discipline: *Astrophysics*.
Red: Yes; Orange: No; Grey: N/A.



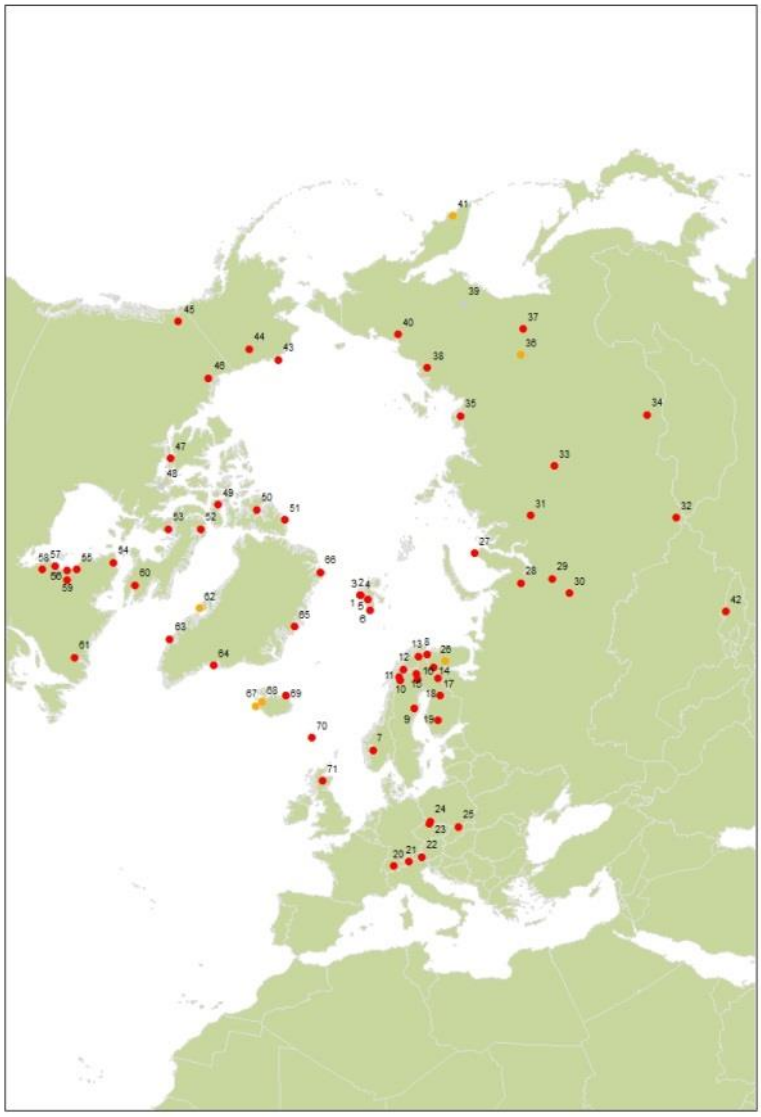
Atmospheric chemistry and physics are branches of atmospheric sciences. *Atmospheric Chemistry* studies the chemical composition of the natural atmosphere, the way gases, liquids and solids in the atmosphere interact with each other and with the earth's surface and associated biota, and how human activities 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 modeling, oceanography, geology and volcanology and other disciplines. Research is increasingly connected with other areas of study such as climatology (3,4). *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 the 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) (3).

Geographical distribution of INTERACT stations covering the disciplines: *Atmospheric chemistry* and *physics*.
Red: Yes; Orange: No; Grey: N/A.



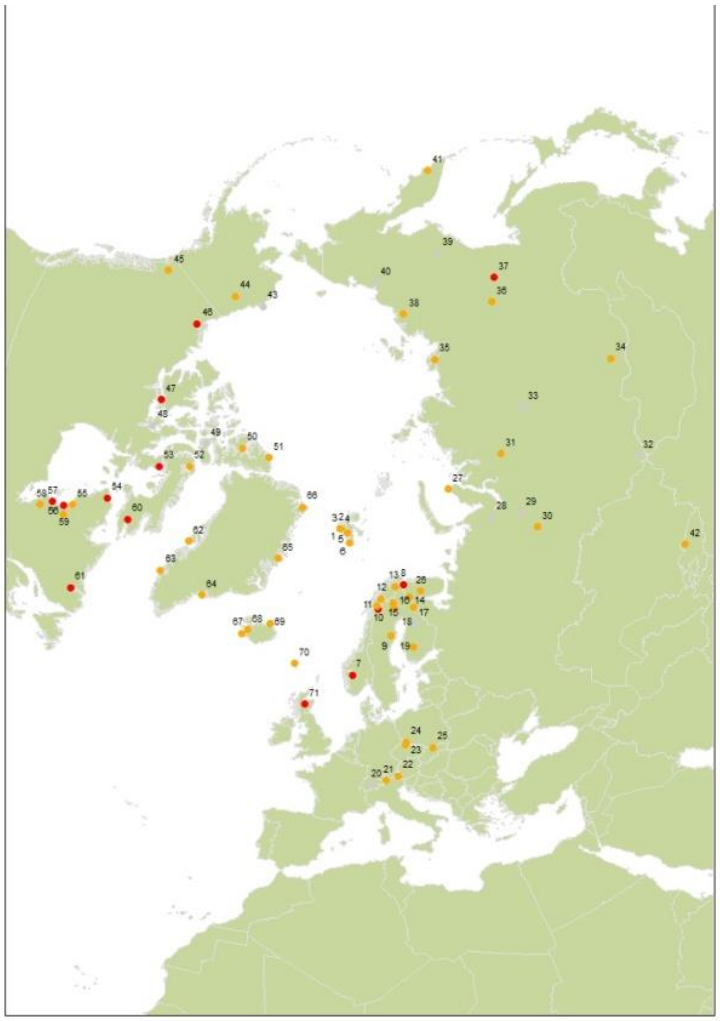
Climatology is a branch of the atmospheric sciences concerned with both the description of climate and the analysis of the causes of climatic differences and changes and their practical consequences. Climatology treats the same atmospheric processes as meteorology, but it seeks as well to identify the 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 (1).

Geographical distribution of the INTERACT stations covering the discipline: *Climatology*.
Red: Yes; Orange: No; Grey: N/A.



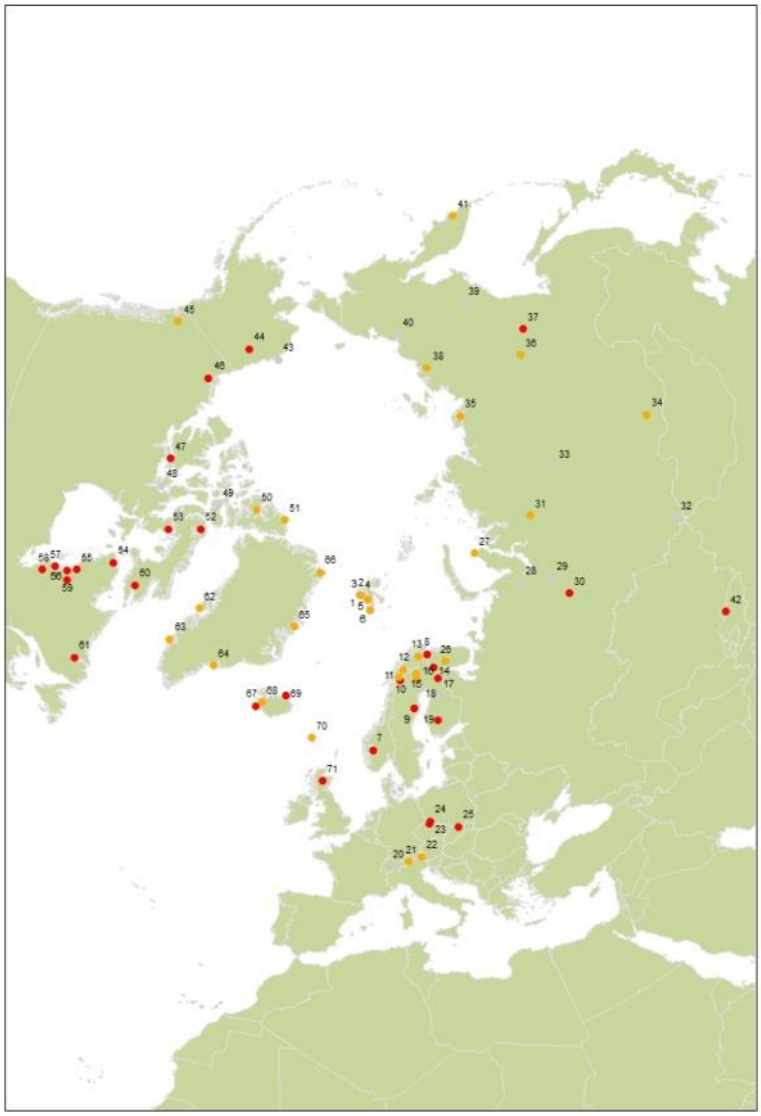
Citizen Science and Community-based Monitoring concerns the engagement of the public in research and monitoring. Citizen Science is scientific research conducted, in whole or in part, by amateur or nonprofessional scientists. Formally, citizen science has been defined as "the systematic collection and 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. **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 (3).

Geographical distribution of INTERACT stations covering the disciplines: *Citizen Science and Community-based Monitoring (CBM)*. Red: Yes; Orange: No; Grey: N/A.



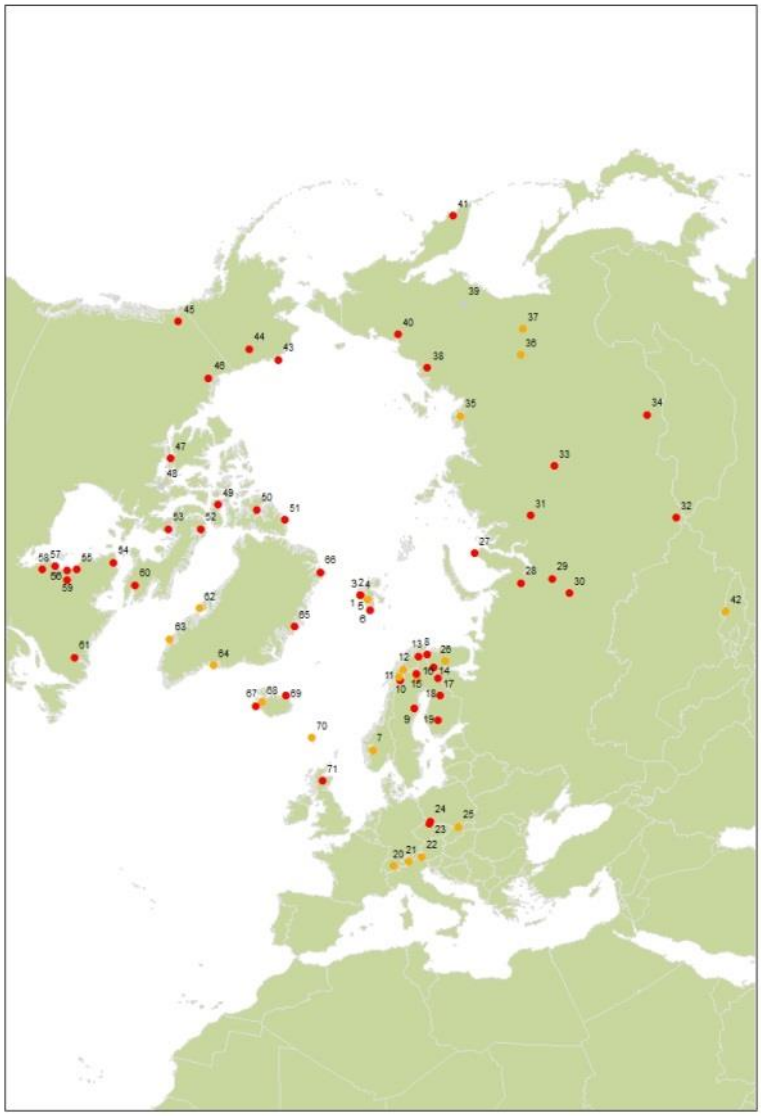
Ecosystem services is an evolving scientific discipline that describes collective benefits for the humankind from ecosystems. Ecosystem services include physical services in the form of natural resources, water, climate, etc. to non-physical services like appreciation of biodiversity, landscape and natural 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 (3).

Geographical distribution of INTERACT stations covering the discipline: *Ecosystem services*.
Red: Yes; Orange: No; Grey: N/A.



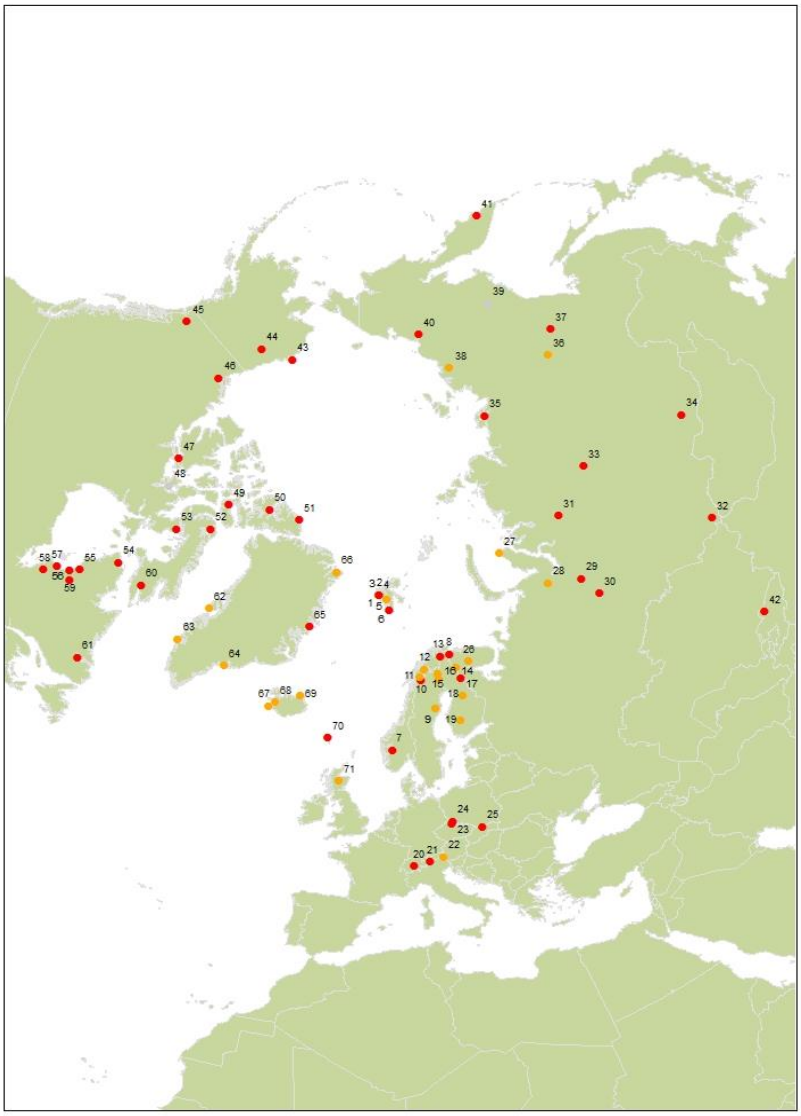
Environmental science - Pollution is the interdisciplinary scientific study of the environment and environmental problems, e.g. pollution, which is the presence or introduction into the environment (especially as a result of human activity) of harmful or poisonous substances, or excessive levels of light, noise, organic waste, etc. (5).

Geographical distribution of INTERACT stations covering the discipline: *Environmental sciences, Pollution.*
Red: Yes; Orange: No; Grey: N/A.



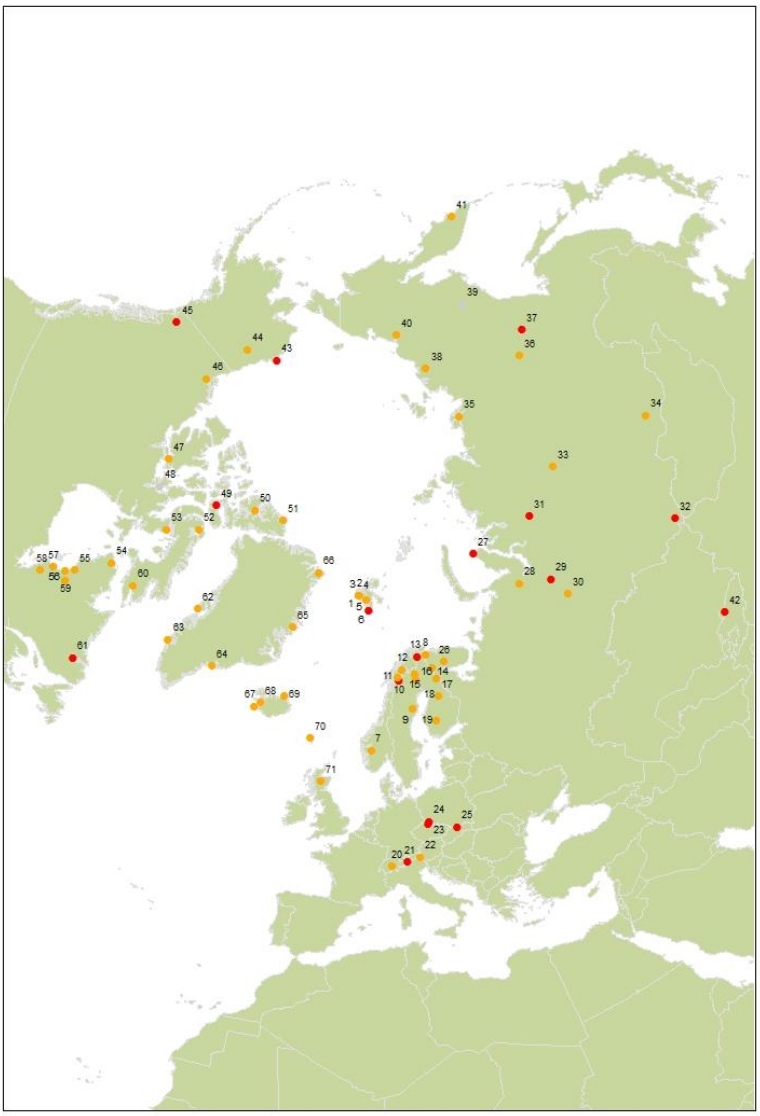
Geocryology is the study of frozen rock, soils, and ground. It deals with (i) the origin, historical development and conditions of existence of frozen strata in the earth's crust, (ii) the processes and phenomena that occur in freezing, frozen, and thawing rock, soils, and ground, as well as their structure, 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 (6).
Geomorphology is the scientific study of the land-forms on the Earth's surface and of the processes that have fashioned them. Recently an extraterrestrial aspect has developed, resulting from studies of lunar and planetary surfaces (7).

Geographical distribution of INTERACT stations covering the disciplines: *Geocryology and Geomorphology.*
Red: Yes; Orange: No; Grey: N/A.



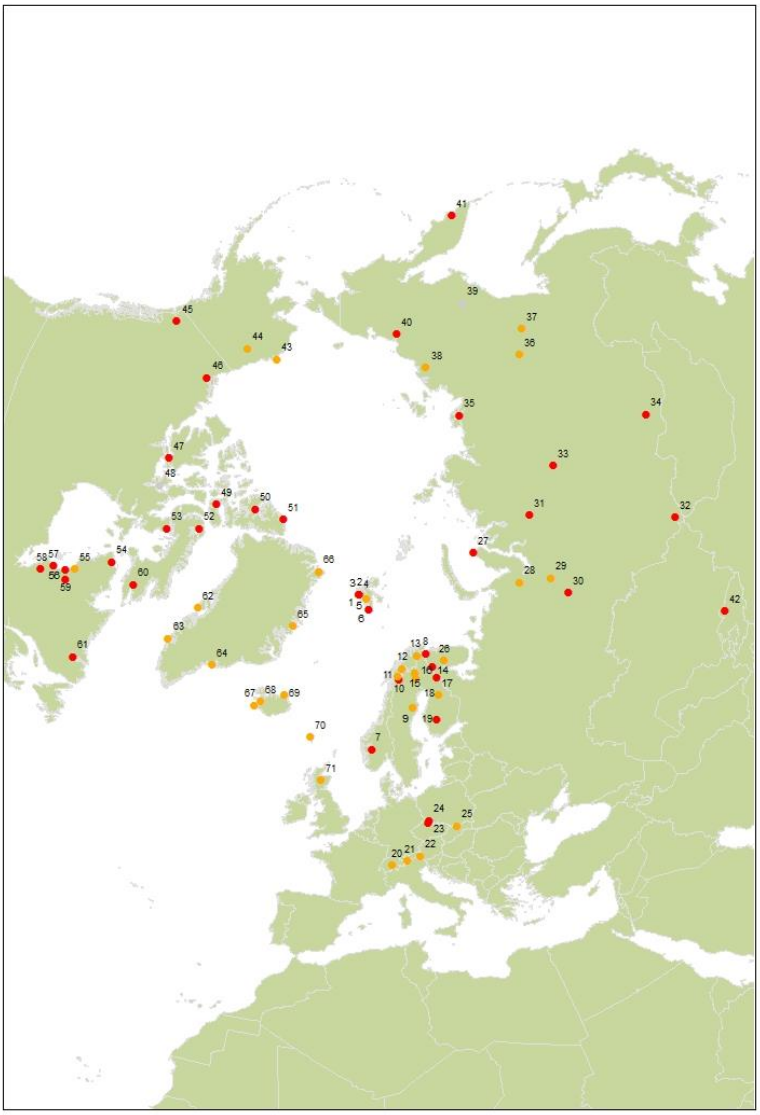
Geodesy is the science of measurement of the shape or figure of the Earth and its gravitational field. This science has expanded from topographic and astronomic surveying with the advent of satellite positioning systems, e.g. GPS and SPS (7).

Geographical distribution of INTERACT stations covering the discipline: *Geodesy.*
Red: Yes; Orange: No; Grey: N/A.



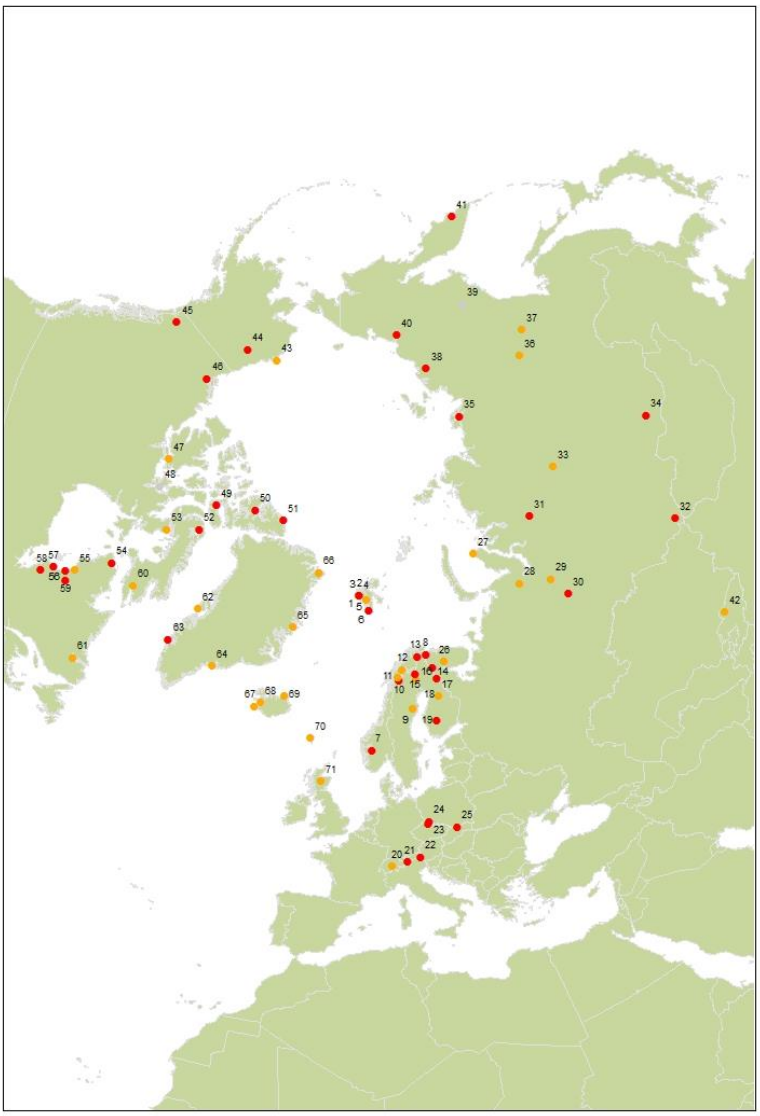
Geology is the scientific study of the composition, structure, and history of the Earth (7).
Sedimentology is the scientific study, interpretation, and classification of sediments, sedimentary processes and sedimentary rocks (7).

Geographical distribution of INTERACT stations covering the disciplines: *Geology and Sedimentology.*
Red: Yes; Orange: No; Grey: N/A.



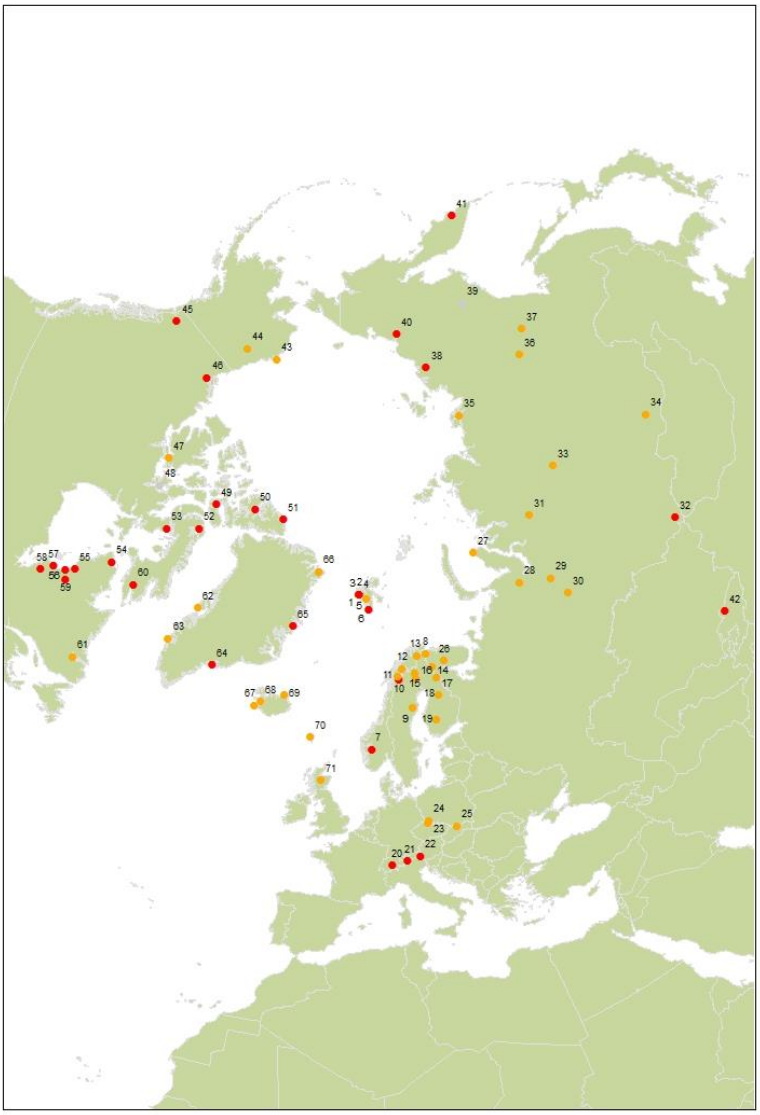
Geophysics is the science concerned with all aspects of the physical properties and processes of the Earth and planetary bodies and their interpretation, including, for example, seismology, gravity, magnetism, heat flow, and geochronology (7).

Geographical distribution of INTERACT stations covering the discipline: *Geophysics.*
Red: Yes; Orange: No; Grey: N/A.



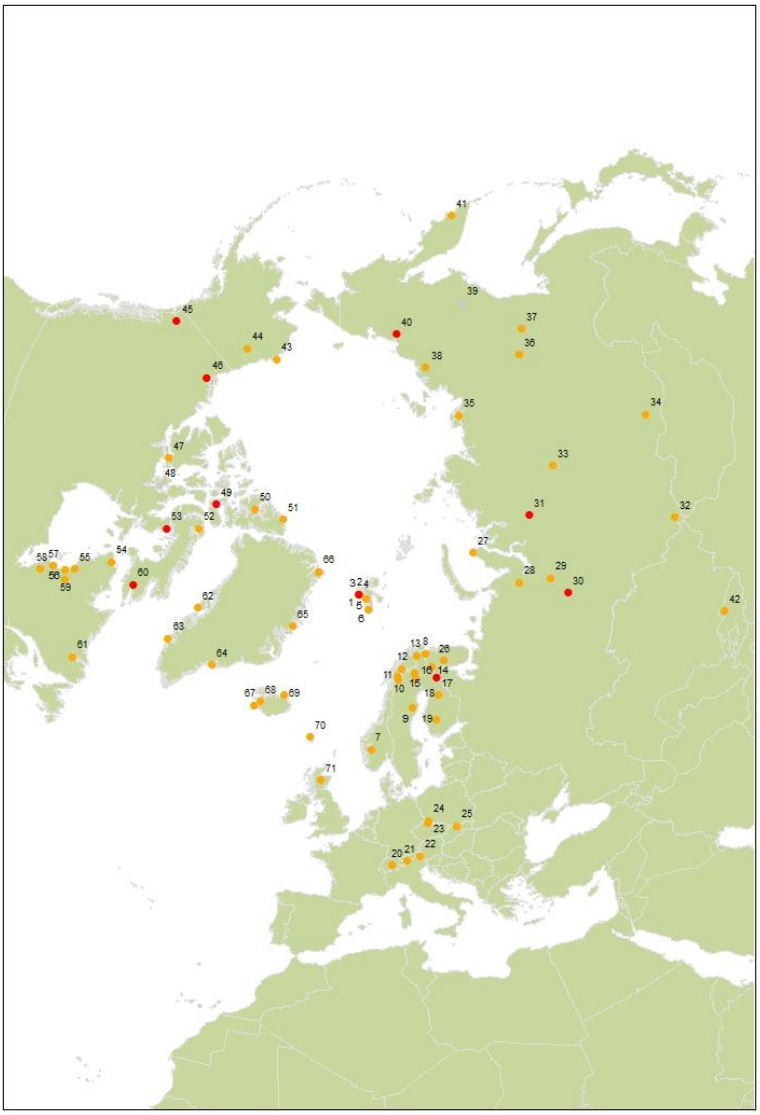
Glaciology is the scientific study of ice in all its forms. It therefore includes the study of ice in the atmosphere, in lakes, rivers, and oceans, and on and beneath the ground. Commonly, however, it is the study of glaciers (7).

Geographical distribution of INTERACT stations covering the discipline: *Glaciology*.
Red: Yes; Orange: No; Grey: N/A.



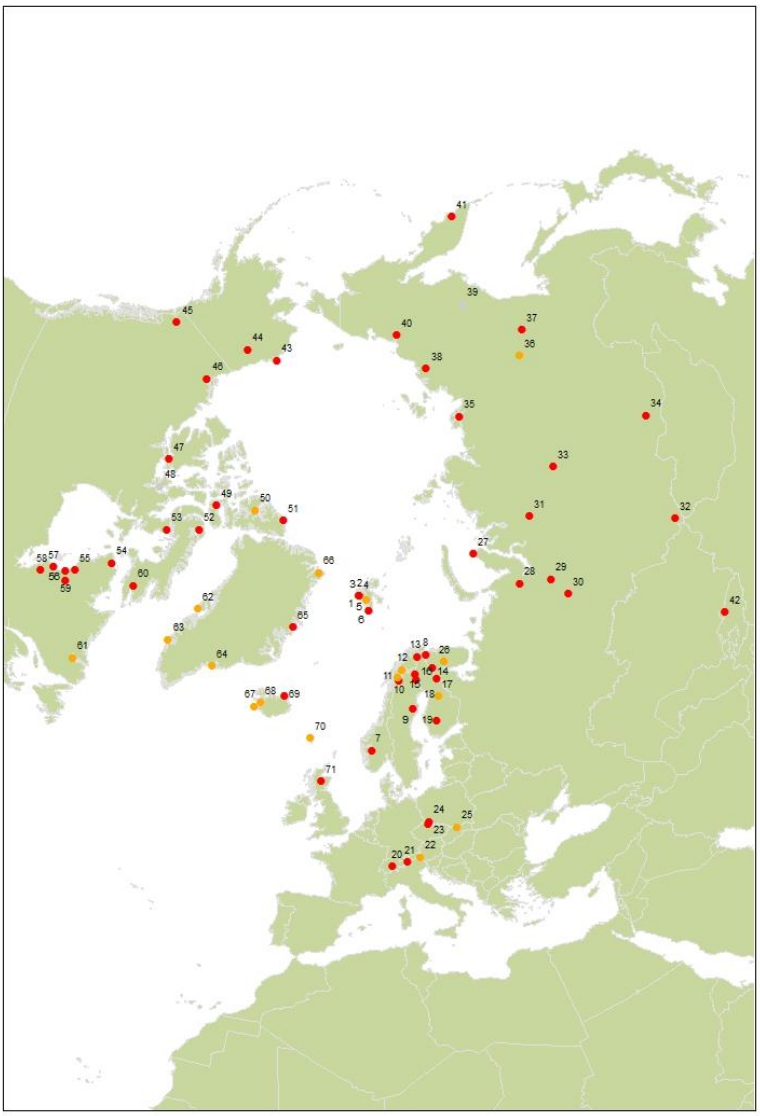
Human biology, Medicine. Human biology is the branch of science concerned with the development and functioning of the human organism and aspects of the life of human populations such as their ecology, genetics and epidemiology. **Medicine** is the science or practice of the diagnosis, treatment and prevention of disease (5).

Geographical distribution of INTERACT stations covering the disciplines: *Human biology and Medicine.*
Red: Yes; Orange: No; Grey: N/A.



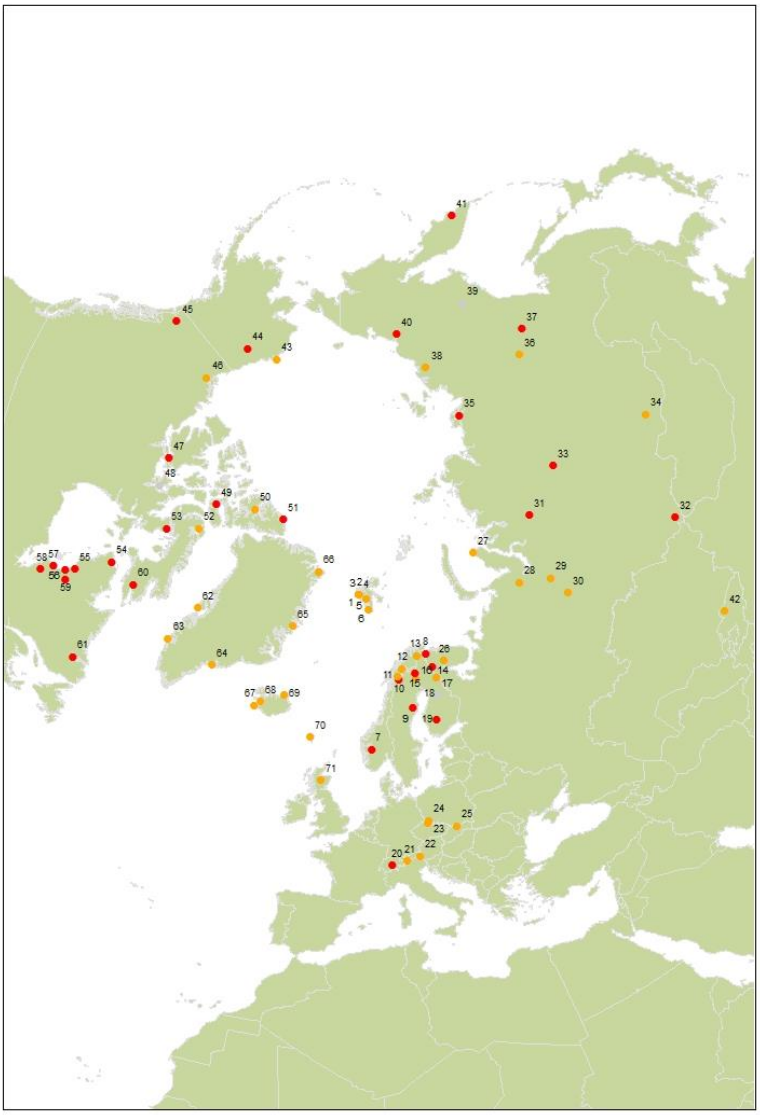
Hydrology is the study of the hydrologic (water) cycle. While it involves aspects of geology, oceanography and meteorology, it emphasizes the study of bodies of surface water on land and how they change with time (7).

Geographical distribution of INTERACT stations covering the discipline: *Hydrology.*
Red: Yes; Orange: No; Grey: N/A.



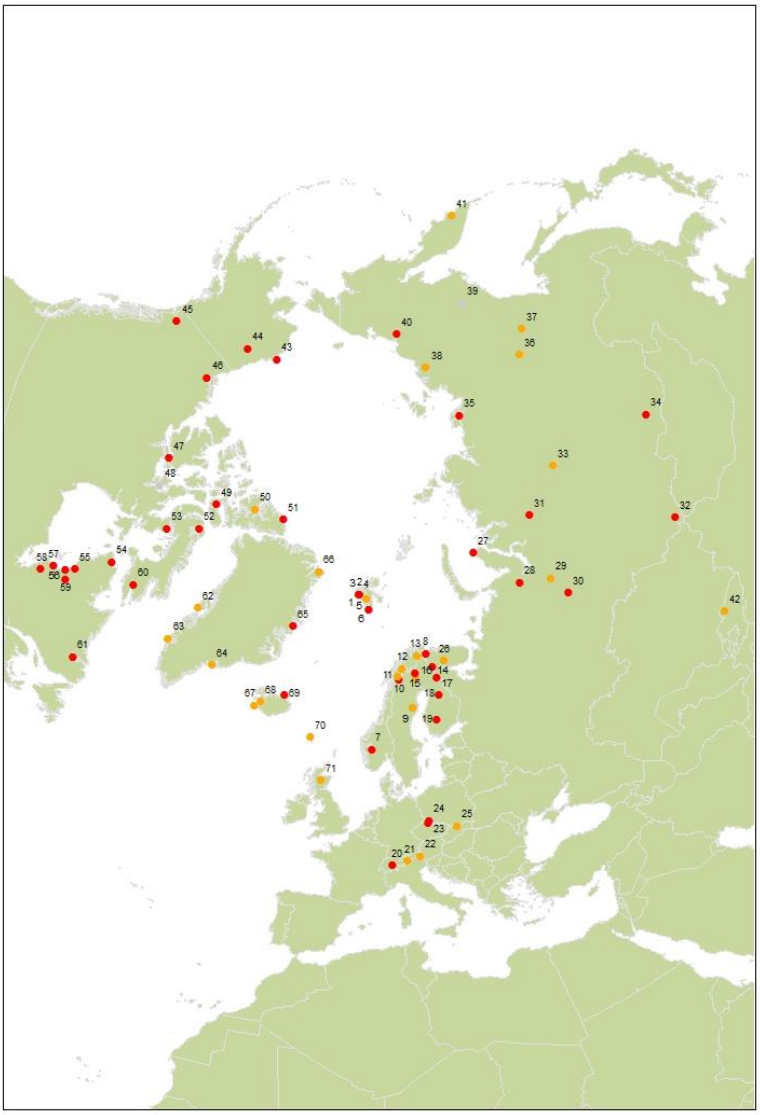
Isotopic chemistry is a study of the abundance ratios of isotopes (both stable and radioactive) of major and trace elements (e.g. Rb/Sr, Pb/U, etc.), to elucidate a number of inorganic, organic, environmental, biogeochemistry and biochemical reaction mechanisms and other processes (7).

Geographical distribution of INTERACT stations covering the discipline: *Isotopic chemistry.*
Red: Yes; Orange: No; Grey: N/A.



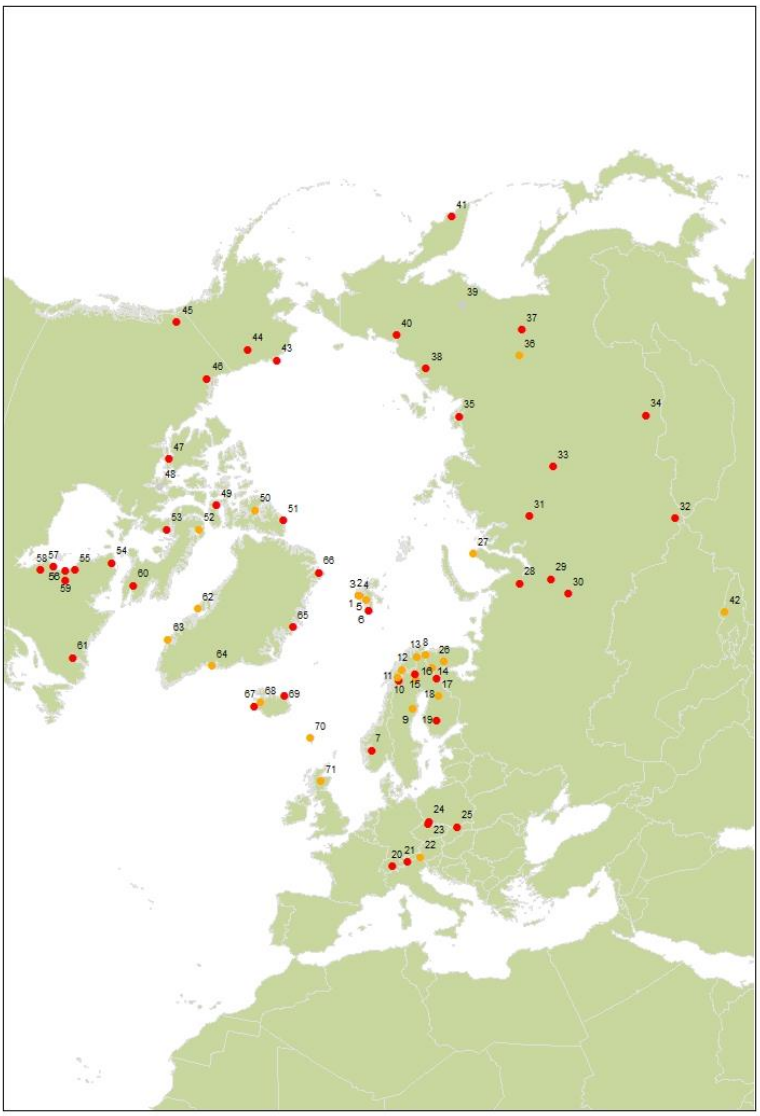
Limnology is a subsystem of hydrology that deals with the scientific study of fresh waters, specifically those found in lakes, ponds, rivers and streams. The discipline also includes the biological, physical and chemical aspects of the occurrence of freshwater bodies (1).

Geographical distribution of INTERACT stations covering the discipline: *Limnology.*
Red: Yes; Orange: No; Grey: N/A.



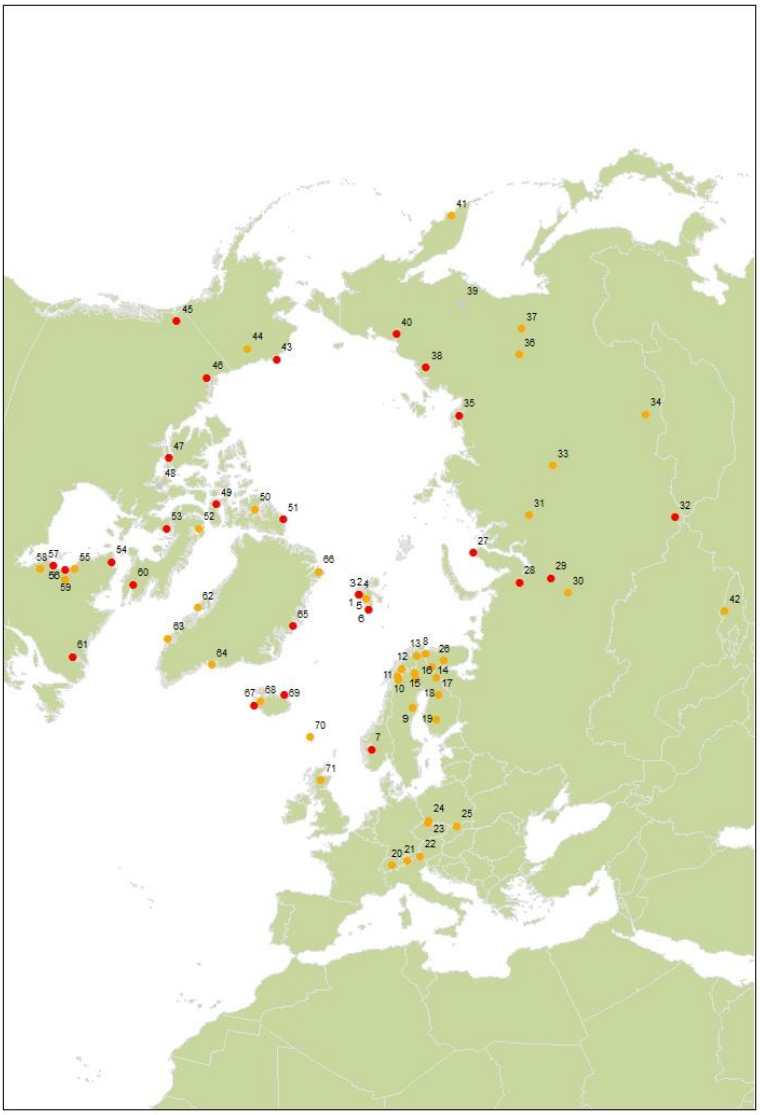
Mapping is the drawing, making or provision of a map or maps (5). **GIS** - Geographic (also Geographical) Information System, is a computer based systems specially designed and implemented for two subtle but interrelated purposes: managing geospatial data and using these data to solve spatial problems (8).

Geographical distribution of INTERACT stations covering the disciplines: *Mapping and GIS.*
Red: Yes; Orange: No; Grey: N/A.



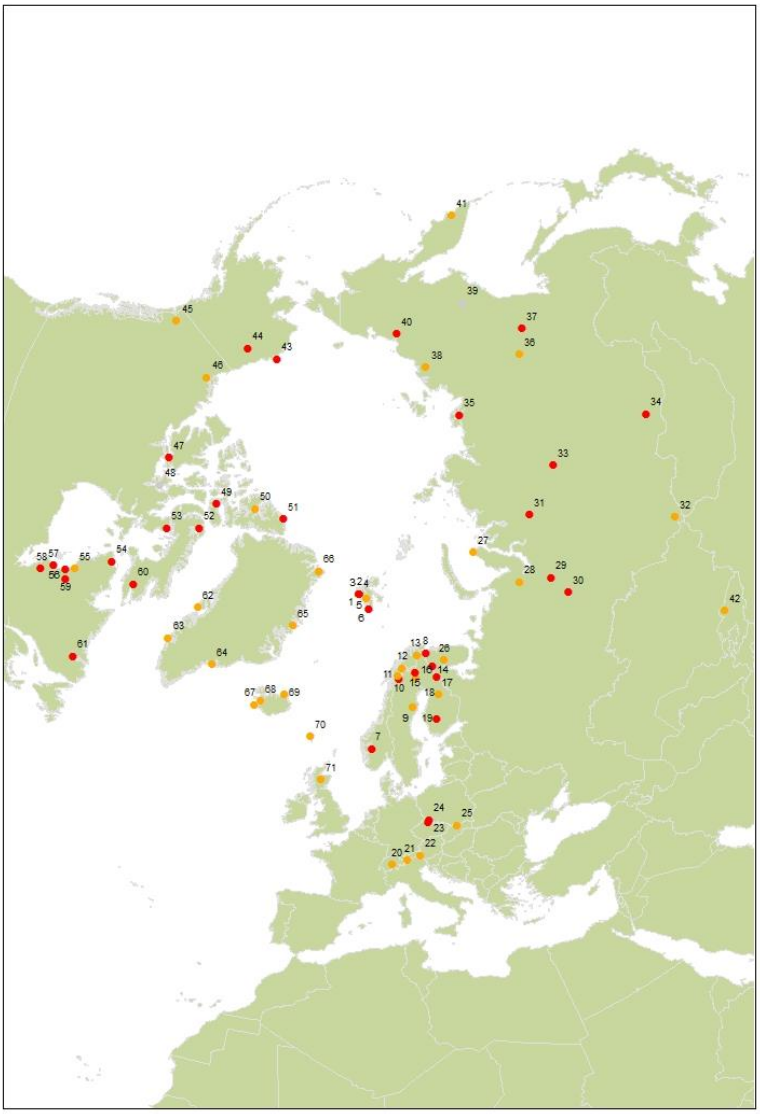
Marine biology/ecology is the scientific study of organisms in the ocean or other marine or brackish bodies of water. Given that in biology many phyla, families and genera have some species that live in the sea and others that live on land, marine biology classifies species based on the environment rather 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 (3).

Geographical distribution of INTERACT stations covering the discipline: *Marine biology.*
Red: Yes; Orange: No; Grey: N/A.



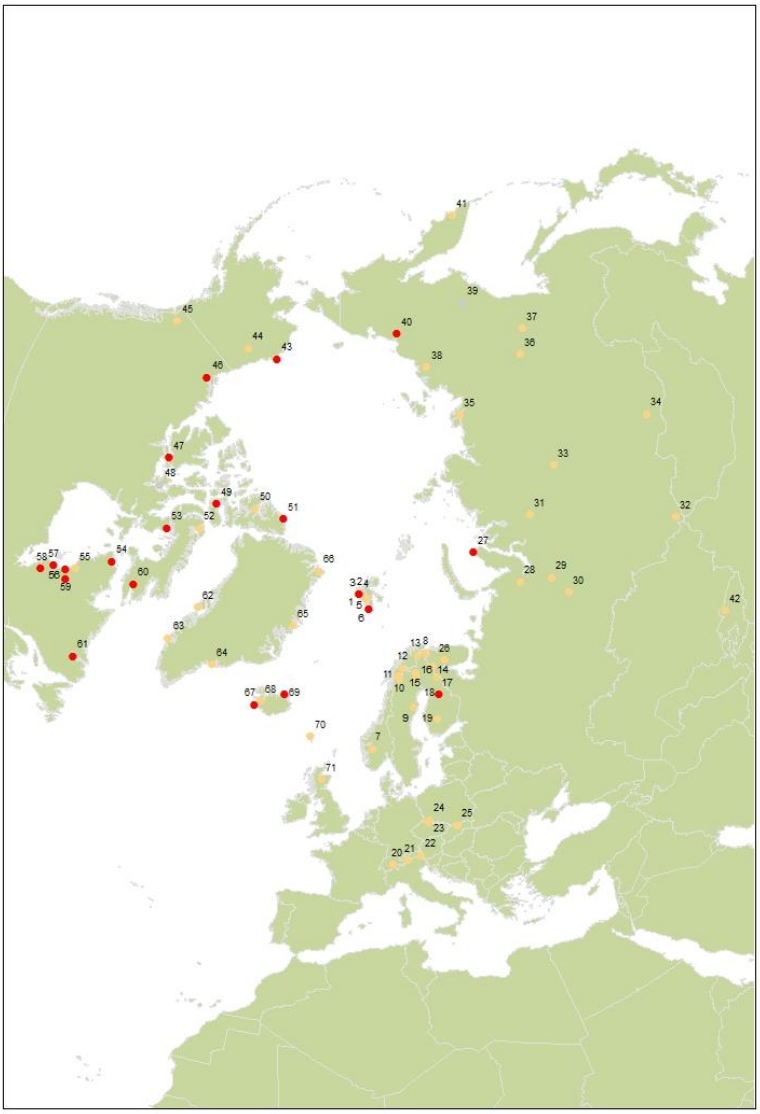
Microbiology is the study of microorganisms or microbes, a diverse group of minute, simple life forms that include bacteria, archaea, algae, fungi, protozoa, and viruses. The field is concerned with the structure, function and classification of such organisms and with ways of both exploiting and controlling their activities (1).

Geographical distribution of INTERACT stations covering the discipline: *Microbiology.*
Red: Yes; Orange: No; Grey: N/A.



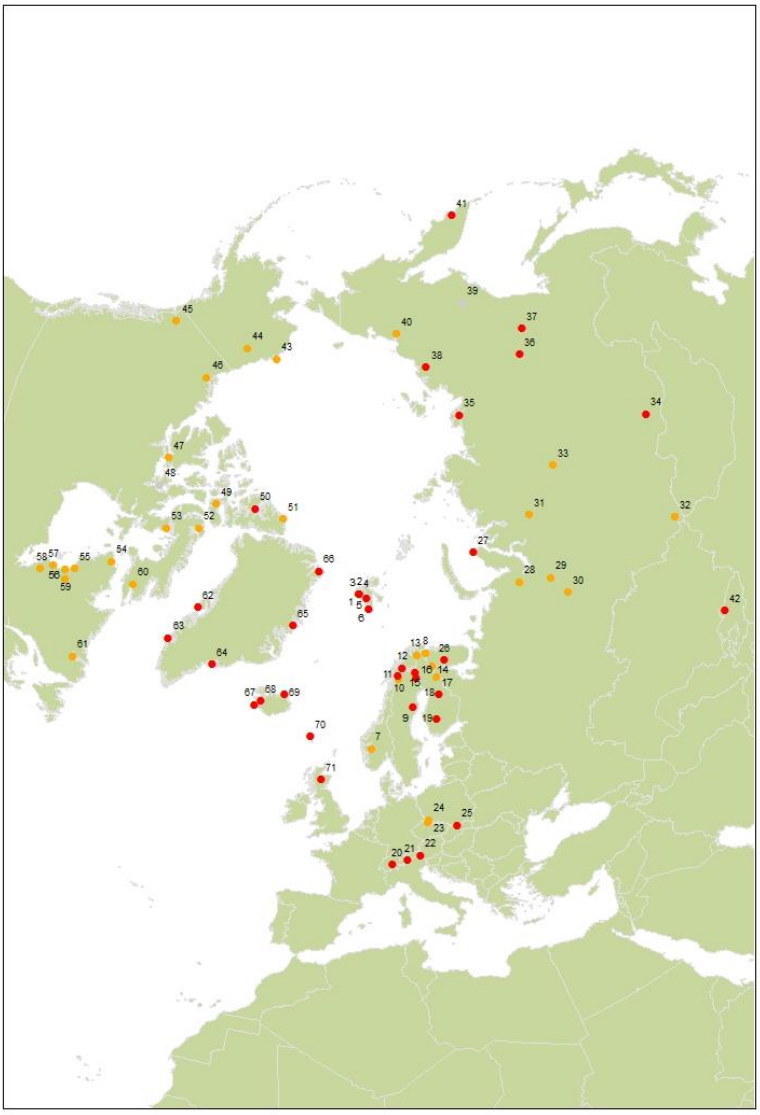
Oceanography, Fishing. Oceanography is the scientific discipline concerned with all aspects of the world's oceans and seas, including their physical and chemical properties, their origin and geologic framework, and the life forms that inhabit the marine environment. **Fishing** is the business, occupation, or industry of catching fish or of taking other products from the sea, lakes or rivers (1,5).

Geographical distribution of INTERACT stations covering the disciplines: *Oceanography and Fishery.*
Red: Yes; Orange: No; Grey: N/A.



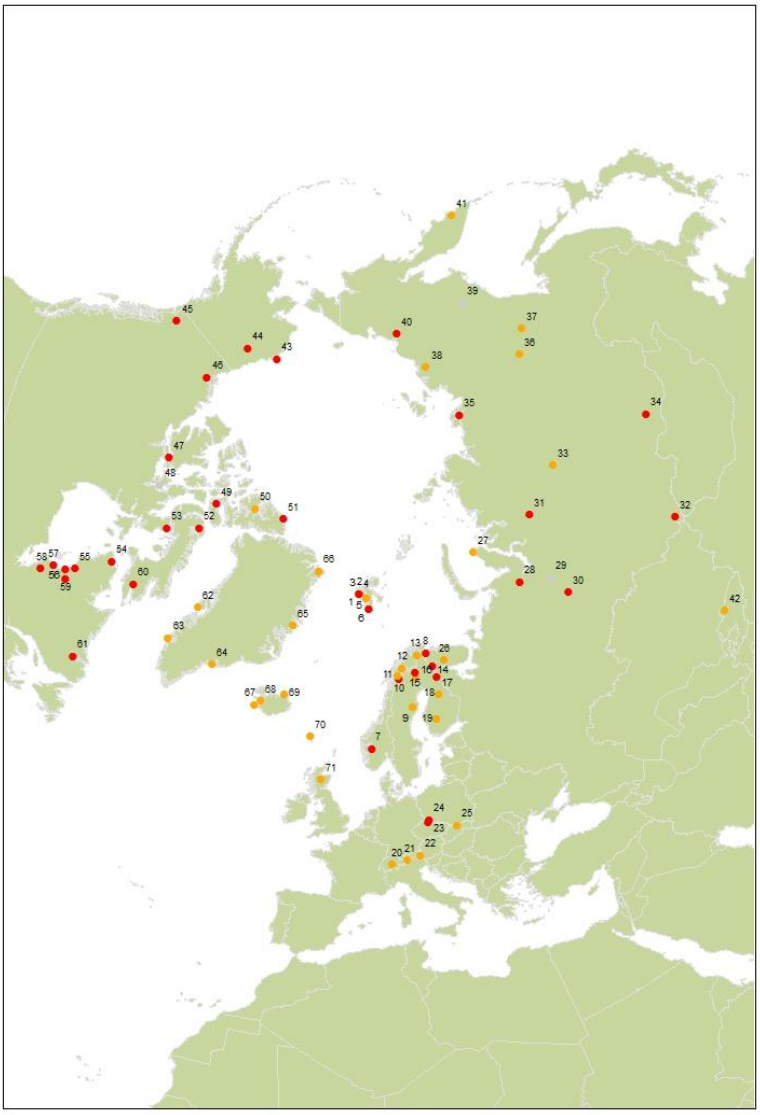
Paleoecology is a branch of ecology that deals with extinct and fossil plants and animals (5).

Geographical distribution of INTERACT stations covering the discipline: *Paleoecology.*
Red: Yes; Orange: No; Grey: N/A.



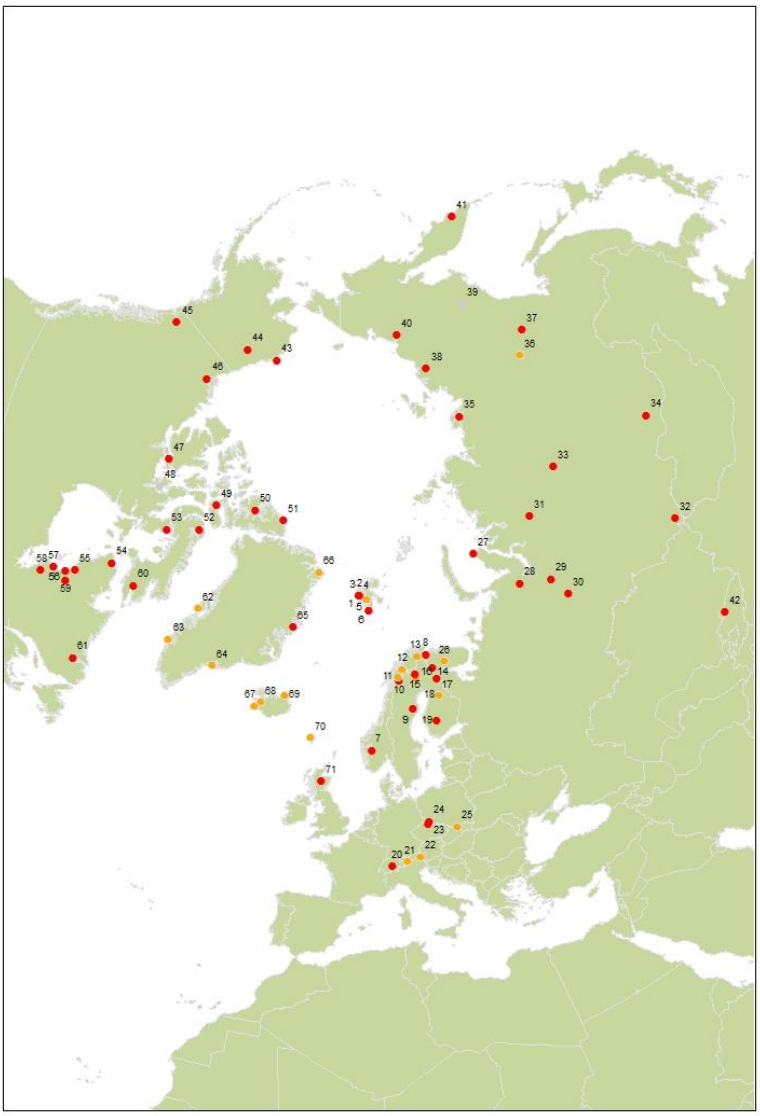
Paleolimnology is the study of the conditions and processes occurring in lakes in the geological past (5).

Geographical distribution of INTERACT stations covering the discipline: *Paleolimnology.*
Red: Yes; Orange: No; Grey: N/A.



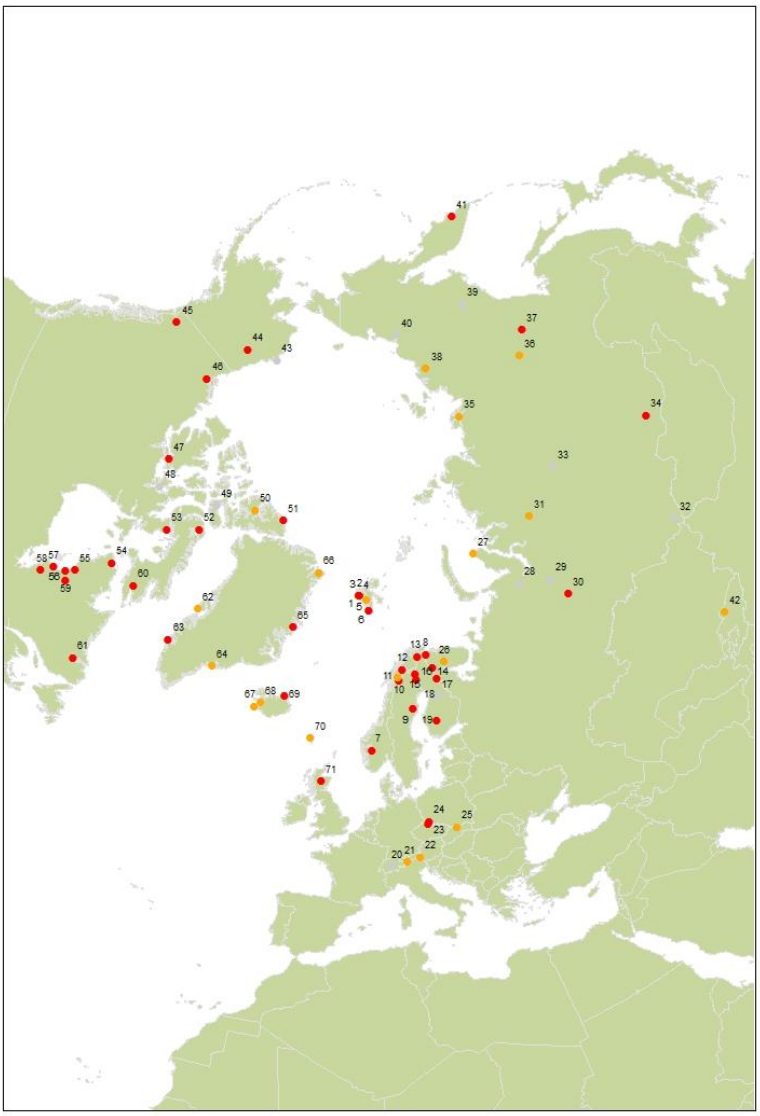
Soil science is the study dealing with soils as a natural resource on the surface of the earth including (i) soil formation, classification and mapping, (ii) physical, chemical, biological, and fertility properties of soils per se and (iii) these properties in relation to the use and management of soils (9).

Geographical distribution of INTERACT stations covering the discipline: *Soil science.*
Red: Yes; Orange: No; Grey: N/A.



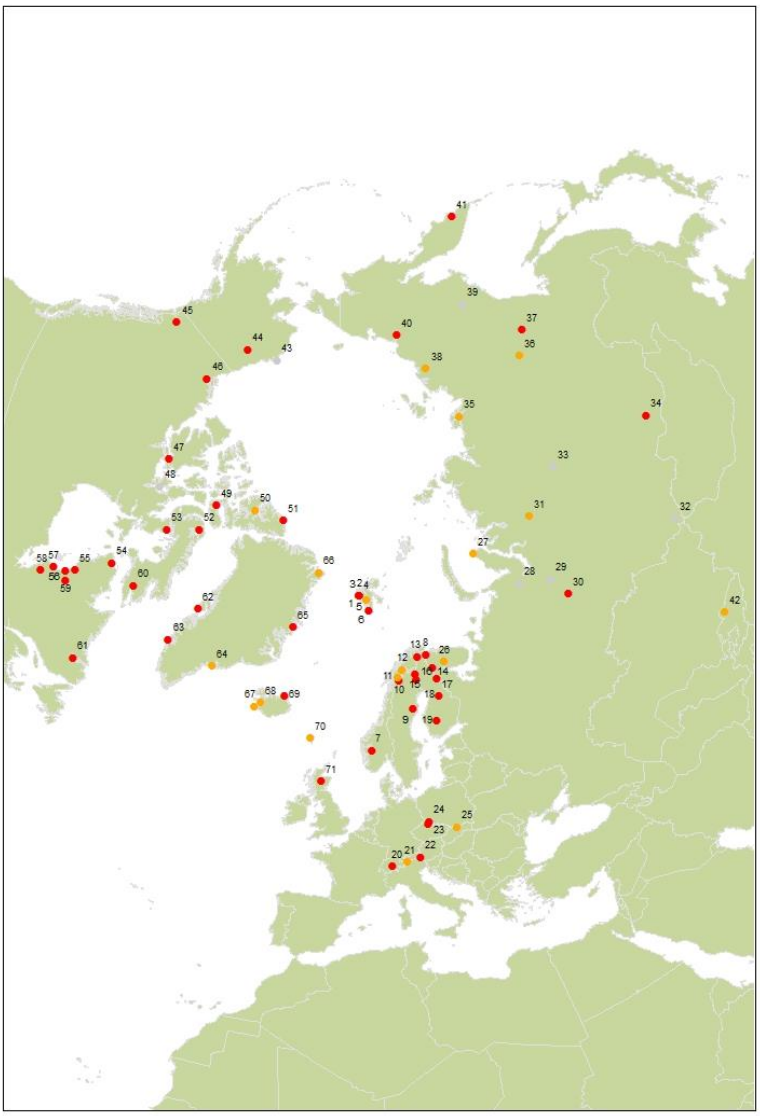
Terrestrial biology - Biodiversity is the study of the diversity and variability among living organisms and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems (10).

Geographical distribution of INTERACT stations covering discipline: *Terrestrial biology/biodiversity.*
Red: Yes; Orange: No; Grey: N/A.



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 (11).

Geographical distribution of INTERACT stations covering discipline: *Terrestrial biology/ecosystem function.*
Red: Yes; Orange: No; Grey: N/A.



2.2 Monitored environmental parameters

In this section, the reader will be 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 xx. 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).

Climate parameters grouped into the relevant categories are presented in Appendices 2.3-2.6.

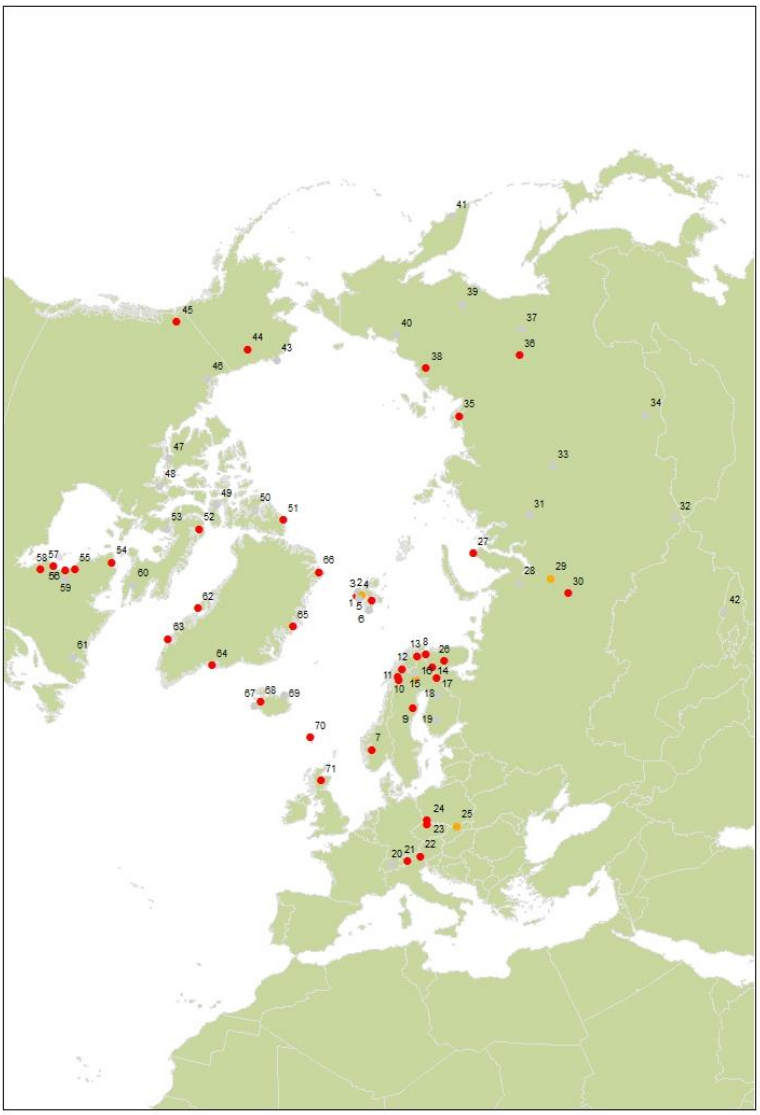
Table 2.2.1. Overview of the categories included into the each theme.

Climate	Geo	Glacier	Bio
Meteorology - atmosphere	Geology/Geomorphology	Glacier characteristis	Vegetation
Radiation	Geophysics and Geodesy	Mass balance	Arthropods
Energy balance	Sub-surface characteristics	Climate	Birds
Precipitation	Snow characteristics	Glacier hydrology	Mammals
Soil	Atmospheric composition	Biogeochemistry of snow, ice and water *	Lake ecology
	Greenhouse gas exchange	Microbiology of snow, ice and water *	Microbiology
	Energy budget	Particles and aerosols *	Genetics
	Hydrology/Limnology	Pollutants e.g. POPs and heavy metals, in snow, ice and water *	Pollution
	Pollution	Isotope chemistry of snow, ice and water *	Diseases
			Parasites
			Socio-ecological issues (disturbance)

* parameters under the category “Other” within the “Glacier” theme.

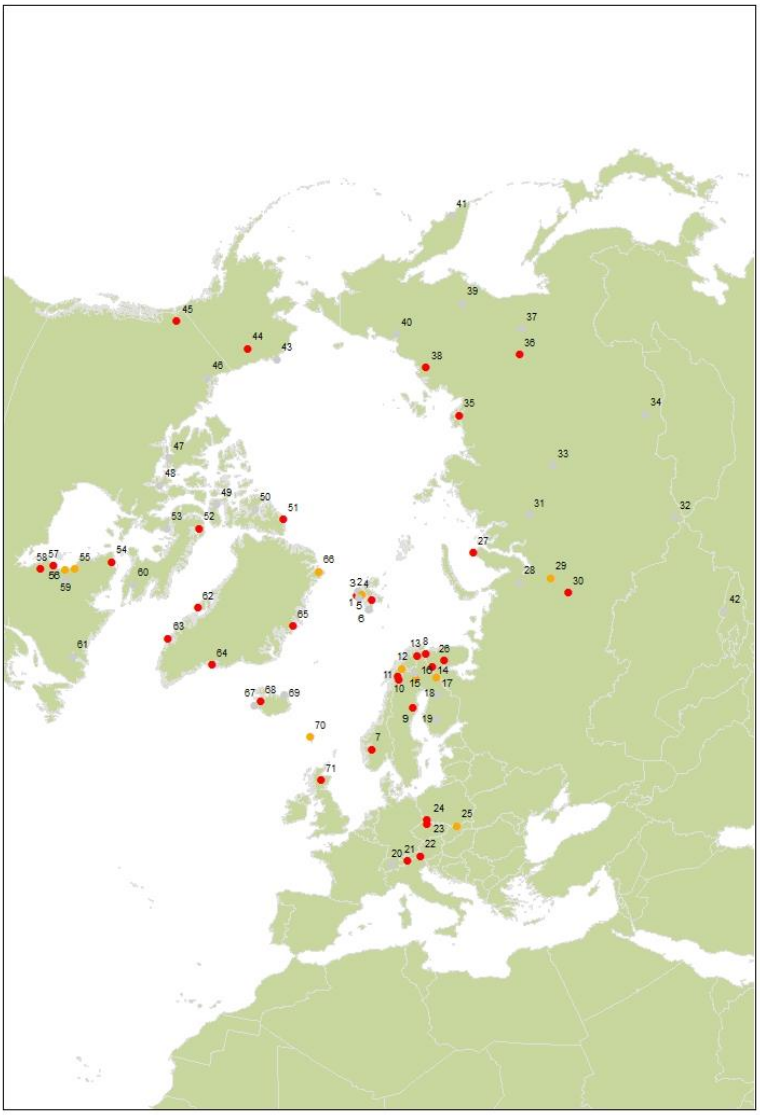
"Climate" parameters

Geographical distribution of INTERACT stations covering a parameters category "Meteorology – atmosphere" within the "Climate" theme. Red: Yes; Orange: No; Grey: N/A.



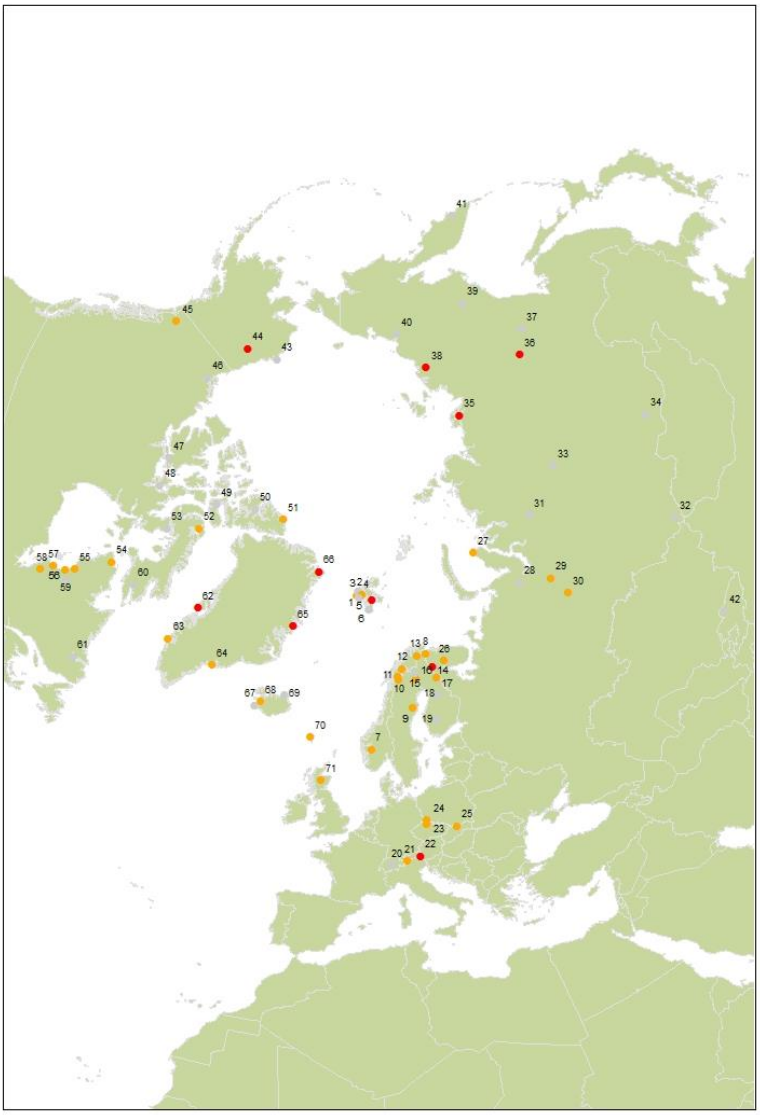
Category	Parameters
Meteorology – atmosphere	Air temperature
	Air humidity
	Air pressure
	Wind velocity
	Wind direction
	Precipitation

Geographical distribution of INTERACT stations covering a parameters category “Radiation” within the “Climate” theme. Red: Yes; Orange: No; Grey: N/A.



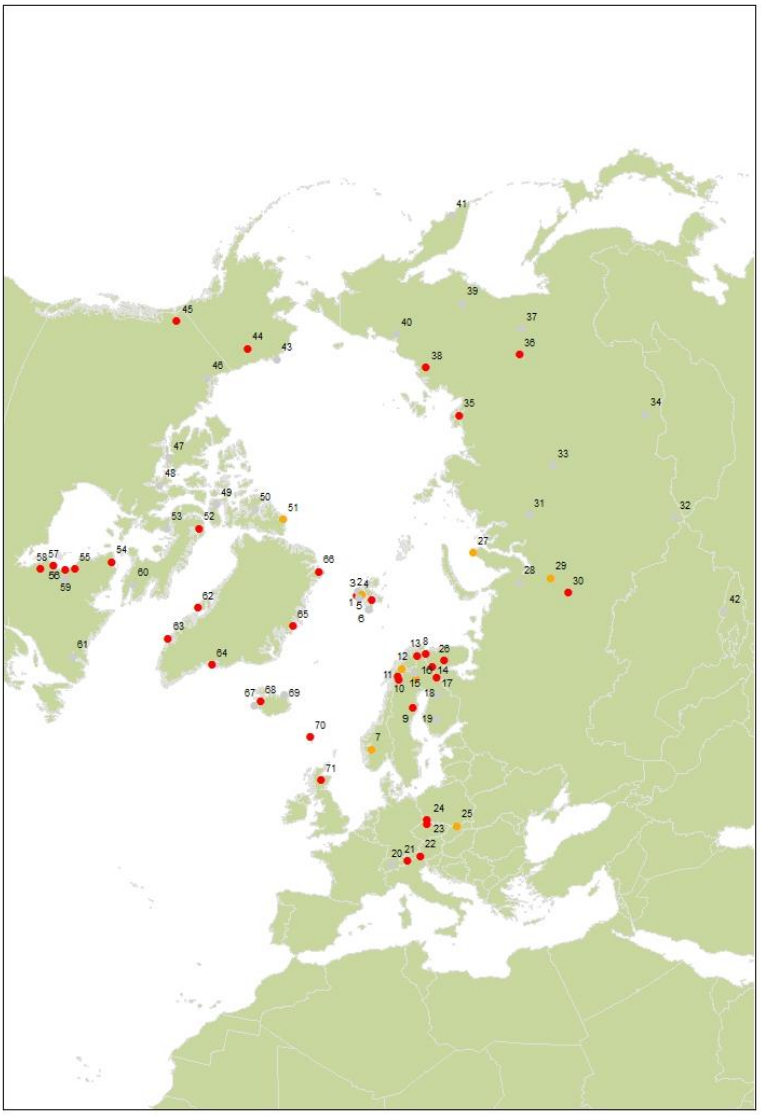
Category	Parameters
Radiation	Short wave incoming
	Short wave outgoing
	Long wave outgoing
	Long wave incoming
	Net radiaton
	UV-B
	Multi-spectral
	Cloud cover/hours of sunshine

Geographical distribution of INTERACT stations covering a parameters category “Energy balance” within the “Climate” theme. Red: Yes; Orange: No; Grey: N/A.



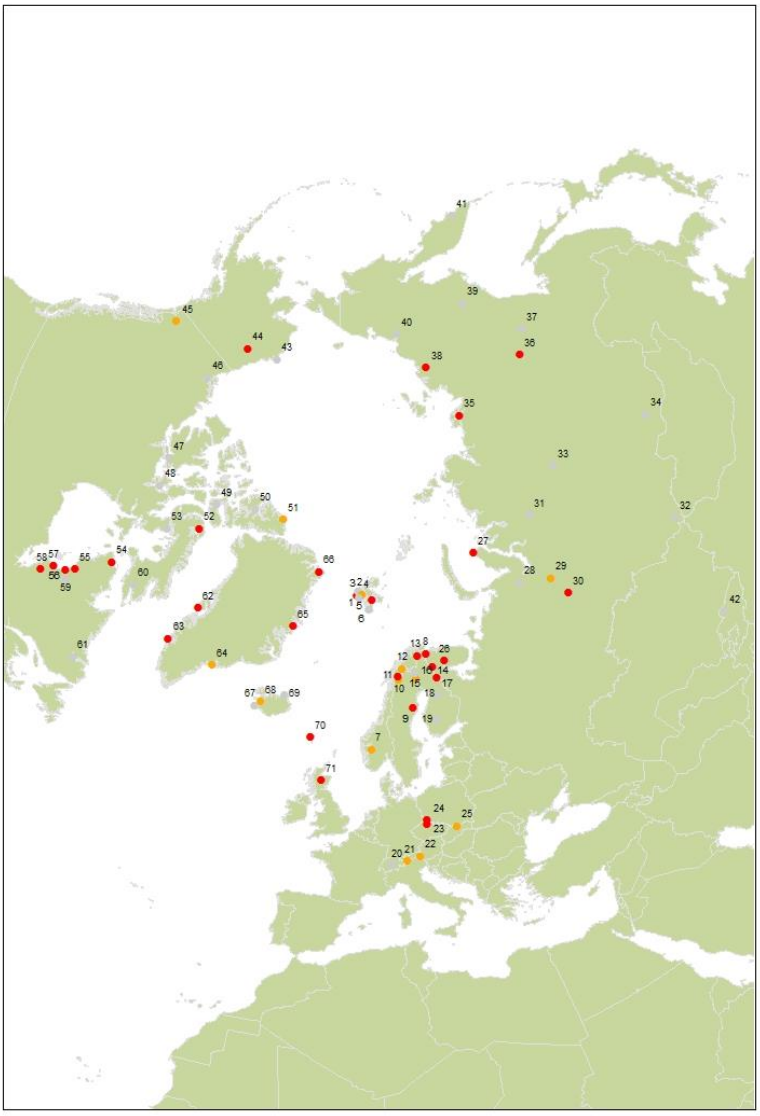
Category	Parameters
Energy balance	Energy balance

Geographical distribution of INTERACT stations covering a parameters category “Precipitation” within the “Climate” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
Precipitation	Rain precipitation
	Rain intensity
	Snow precipitation
	Snow intensity

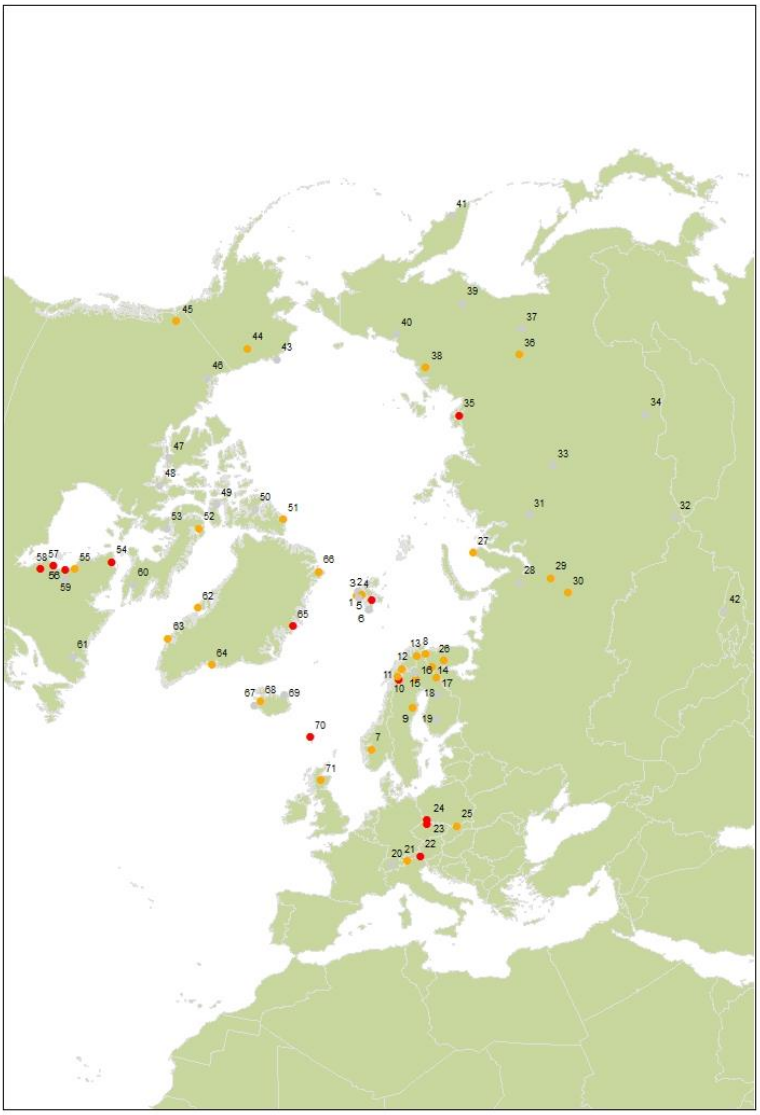
Geographical distribution of INTERACT stations covering a parameters category “Soil” within the “Climate” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
Soil	Soil temperature
	Soil humidity (TDR)

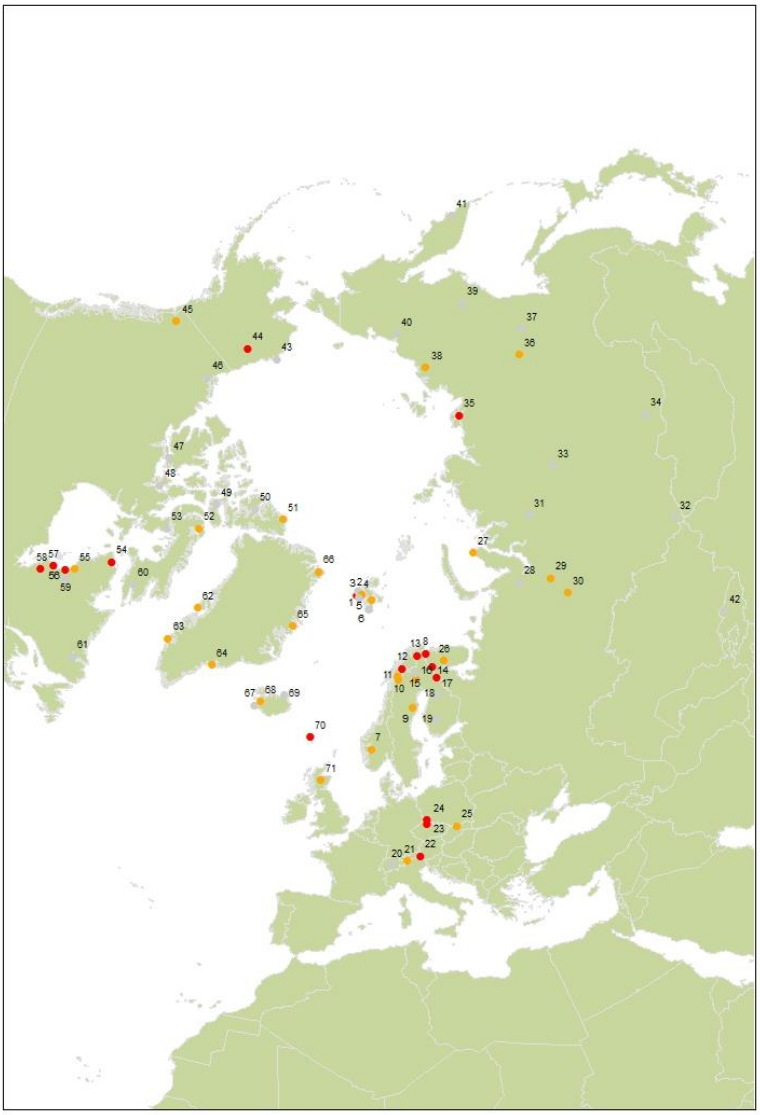
"Geo" parameters

Geographical distribution of INTERACT stations covering a parameters category "Geology/Geomorphology" within the "Geo" theme. Red: Yes; Orange: No; Grey: N/A.



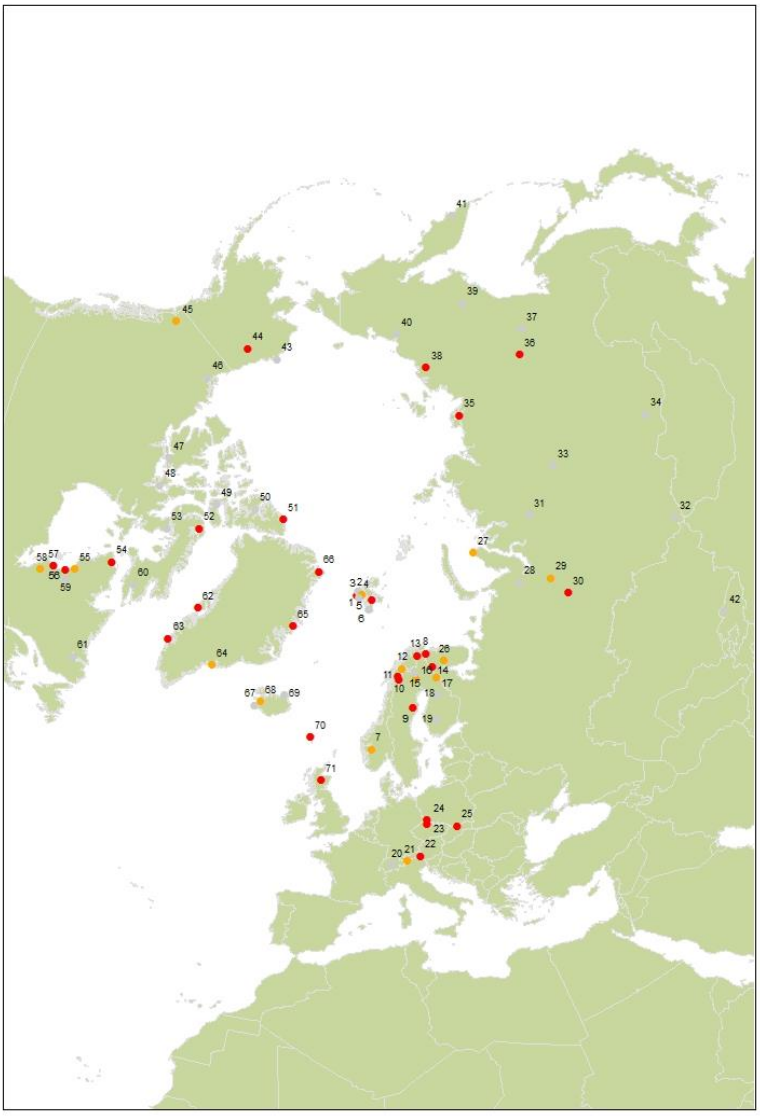
Category	Parameters
Geology/geomorphology	Quaternary geology
	Sedimentology
	Bedrock geology
	Erosion

Geographical distribution of INTERACT stations covering a parameters category “Geophysics and Geodesy” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



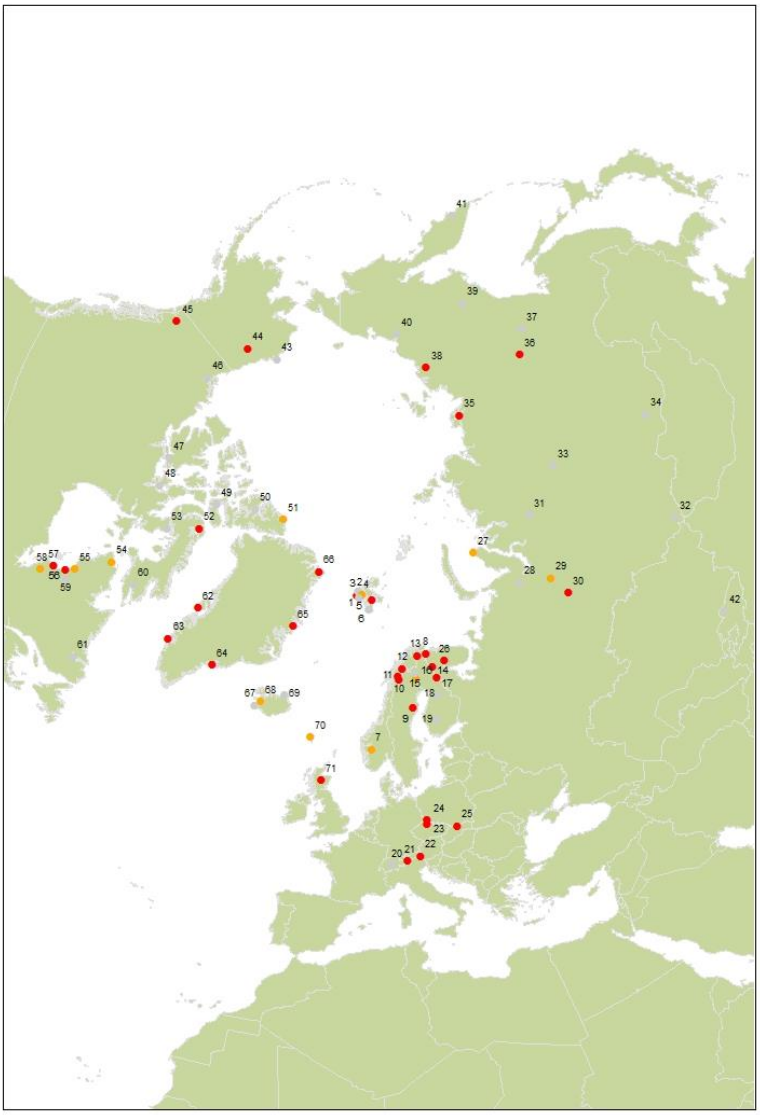
Category	Parameters
Geophysics and geodesy	Gravity
	Magnetic field
	Aurora
	Seismic activity

Geographical distribution of INTERACT stations covering a parameters category “Sub-surface characteristics” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



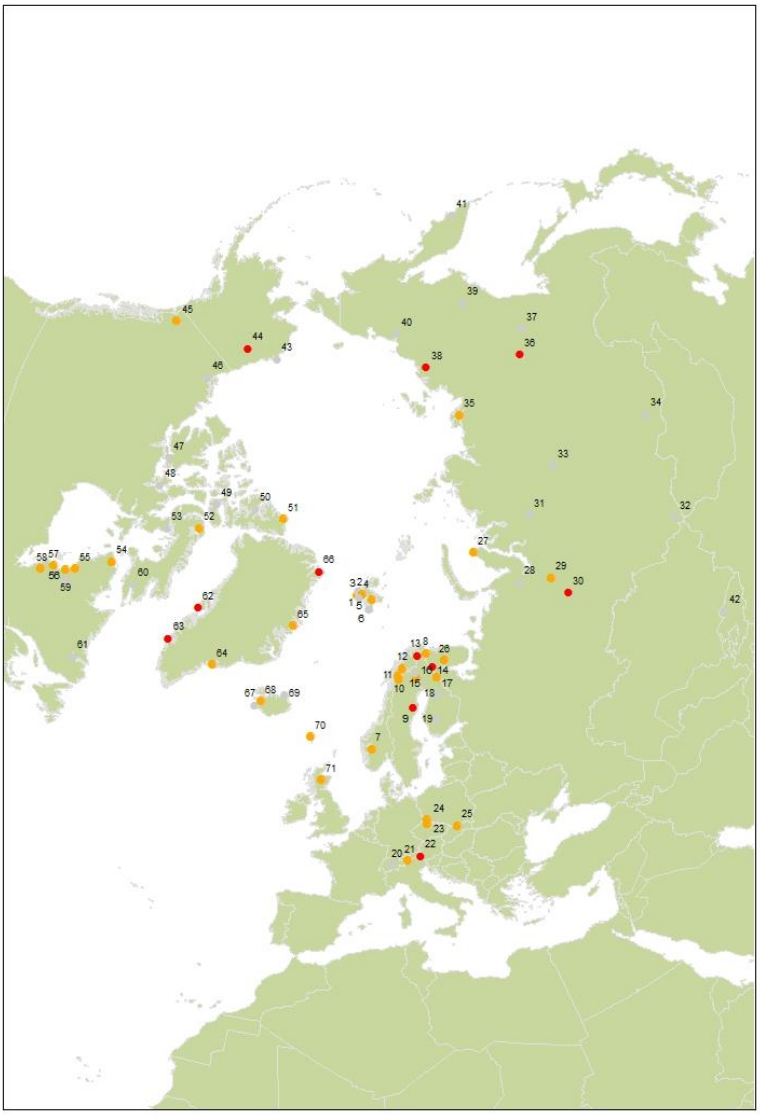
Category	Parameters
Sub-surface characteristics	Ground surface temperature
	Ground/soil temperature
	Soil moisture content
	Ground water table
	Soil water chemistry
	Active layer depth
	Permafrost distribution
	Permafrost thickness
	Permafrost temperature

Geographical distribution of INTERACT stations covering a parameters category “Snow characteristics” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



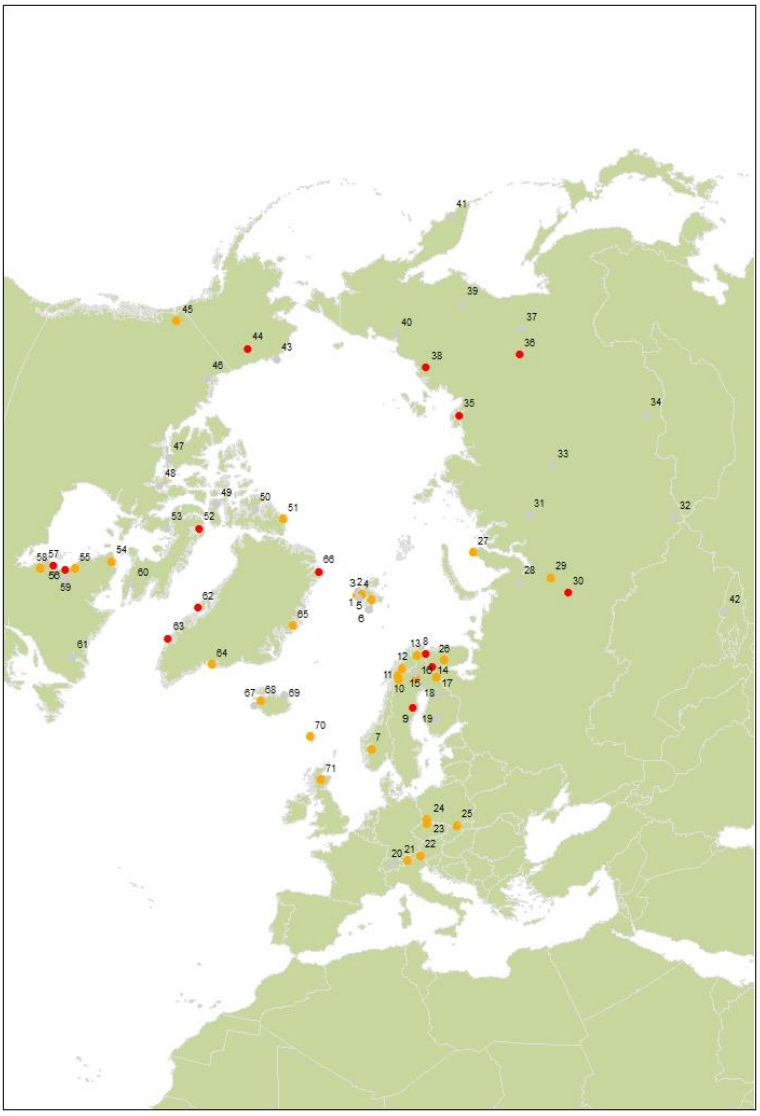
Category	Parameters
Snow characteristics	Snow depth
	Snow cover
	Snow density
	Snow temperature

Geographical distribution of INTERACT stations covering a parameters category “Atmospheric composition” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



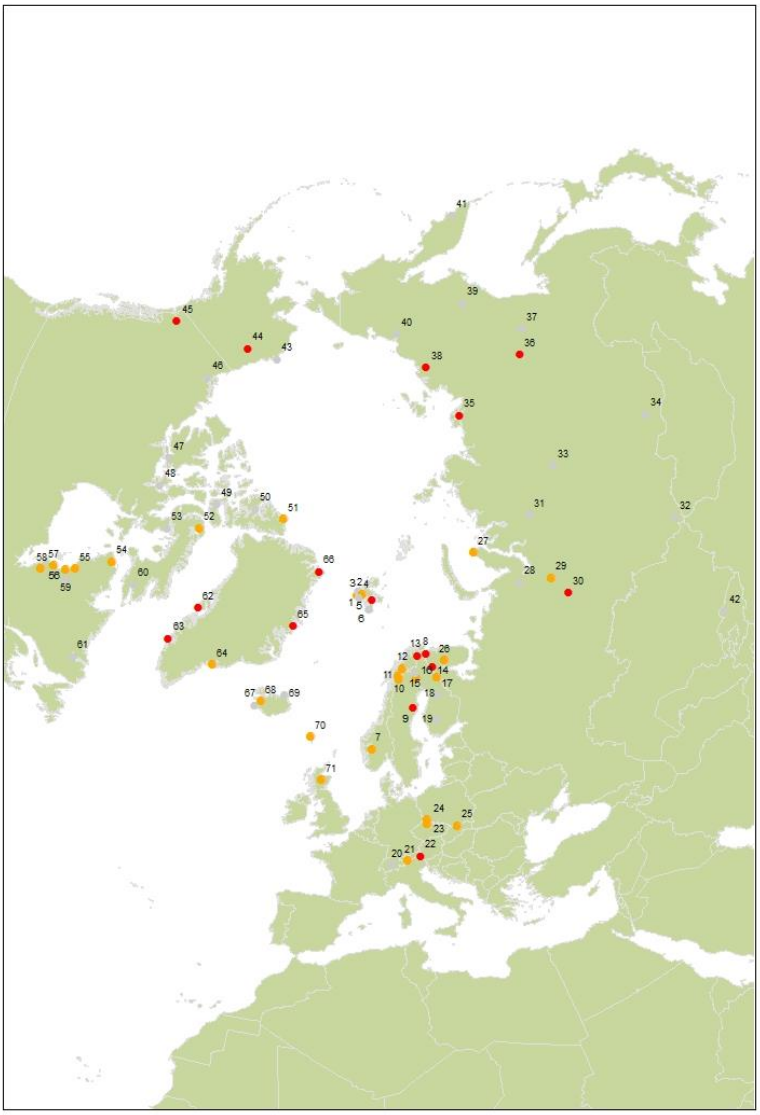
Category	Parameters
Atmospheric composition	CO_2 concentration
	CH_4 concentration

Geographical distribution of INTERACT stations covering a parameters category “Greenhouse gas exchange” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



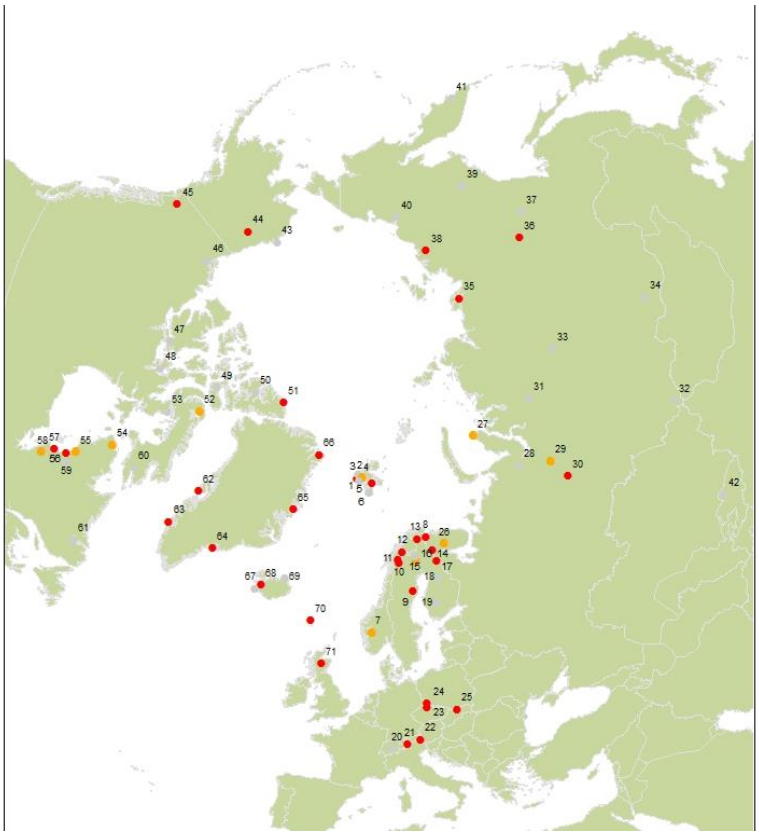
Category	Parameters
Greenhouse gas exchange	CO_2 exchange
	CH_4 exchange
	N_2O exchange

Geographical distribution of INTERACT stations covering a parameters category “Energy budget” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



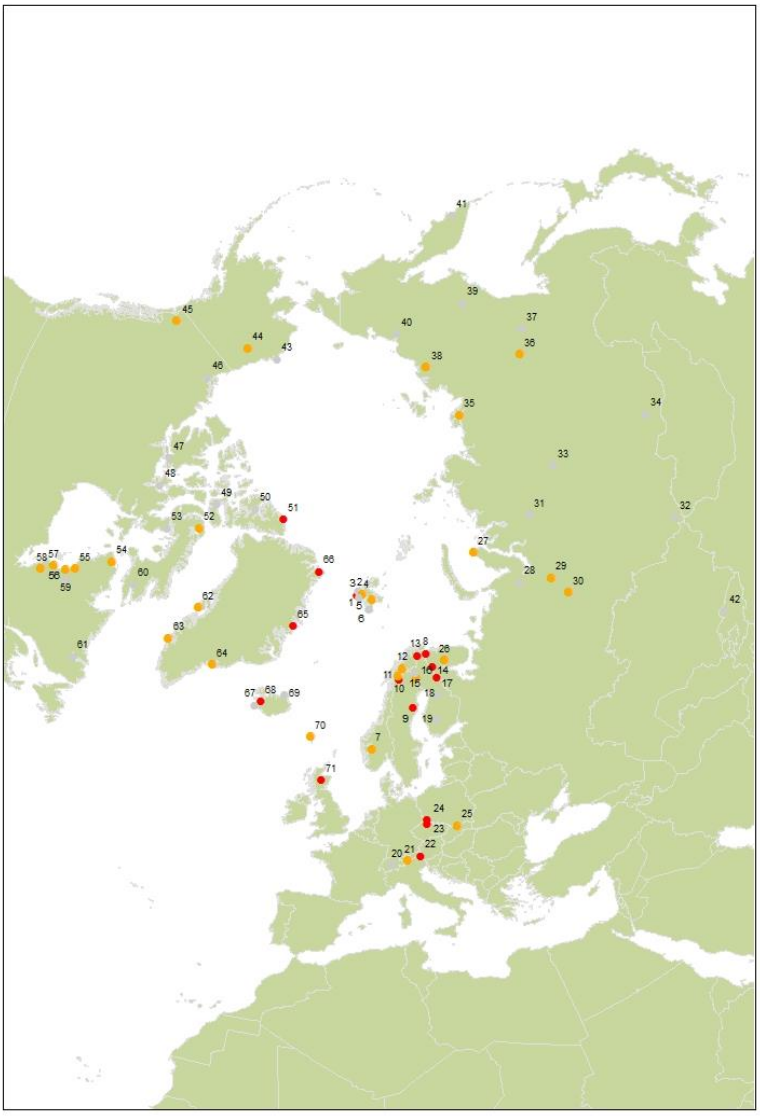
Category	Parameters
Energy budget	Net radiation
	Sensible heat flux
	Latent heat flux
	Soil heat flux

Geographical distribution of INTERACT stations covering a parameters category “Hydrology/Limnology” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
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

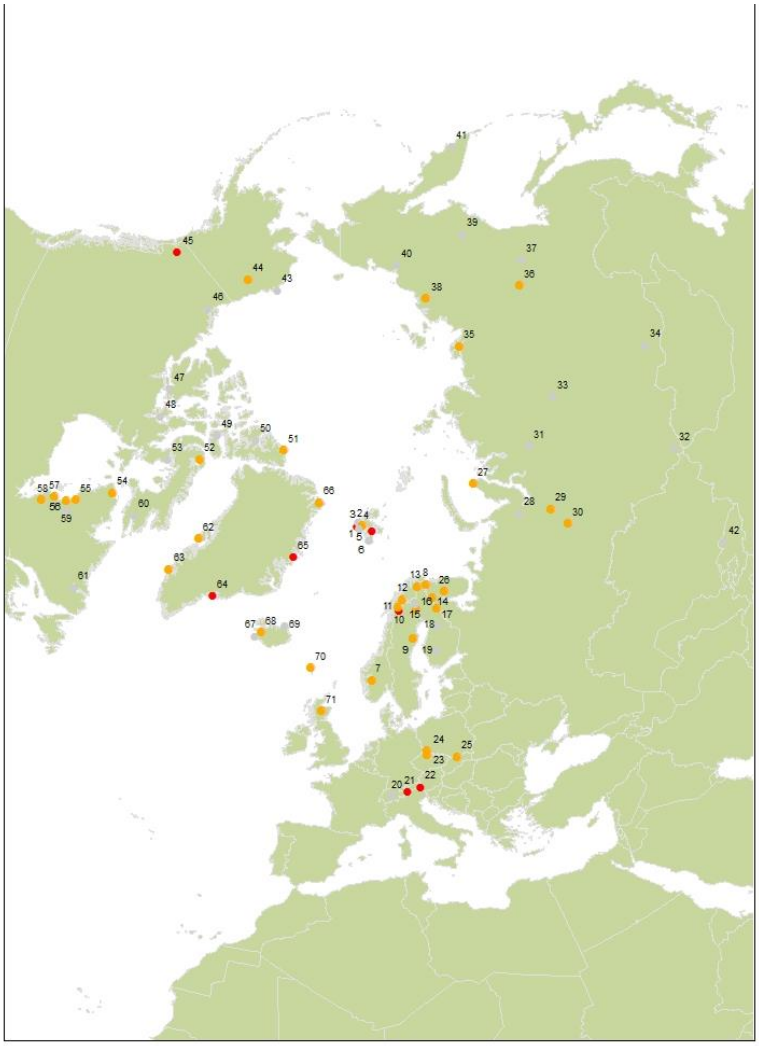
Geographical distribution of INTERACT stations covering a parameters category “Pollution” within the “Geo” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
Pollution	In air
	In water
	In soil
	In snow/ice
	Other

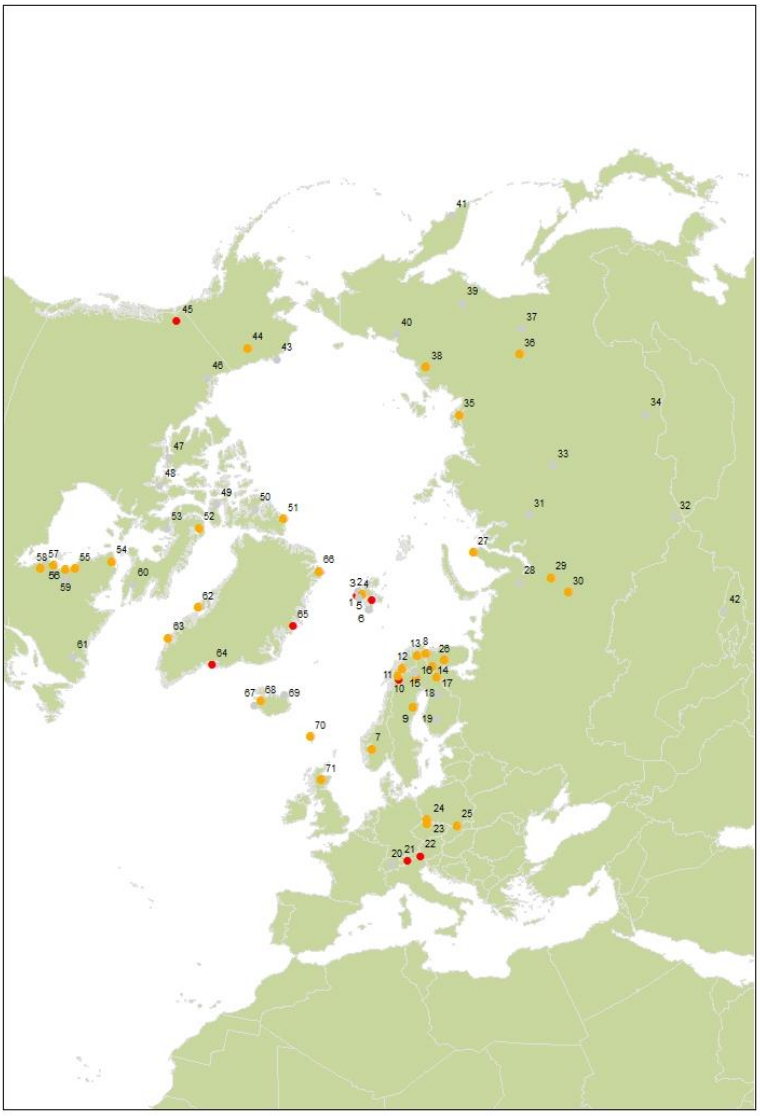
"Glacier" parameters

Geographical distribution of INTERACT stations covering a parameters category "Glacier characteristics" within the "Glacier" theme. Red: Yes; Orange: No; Grey: N/A.



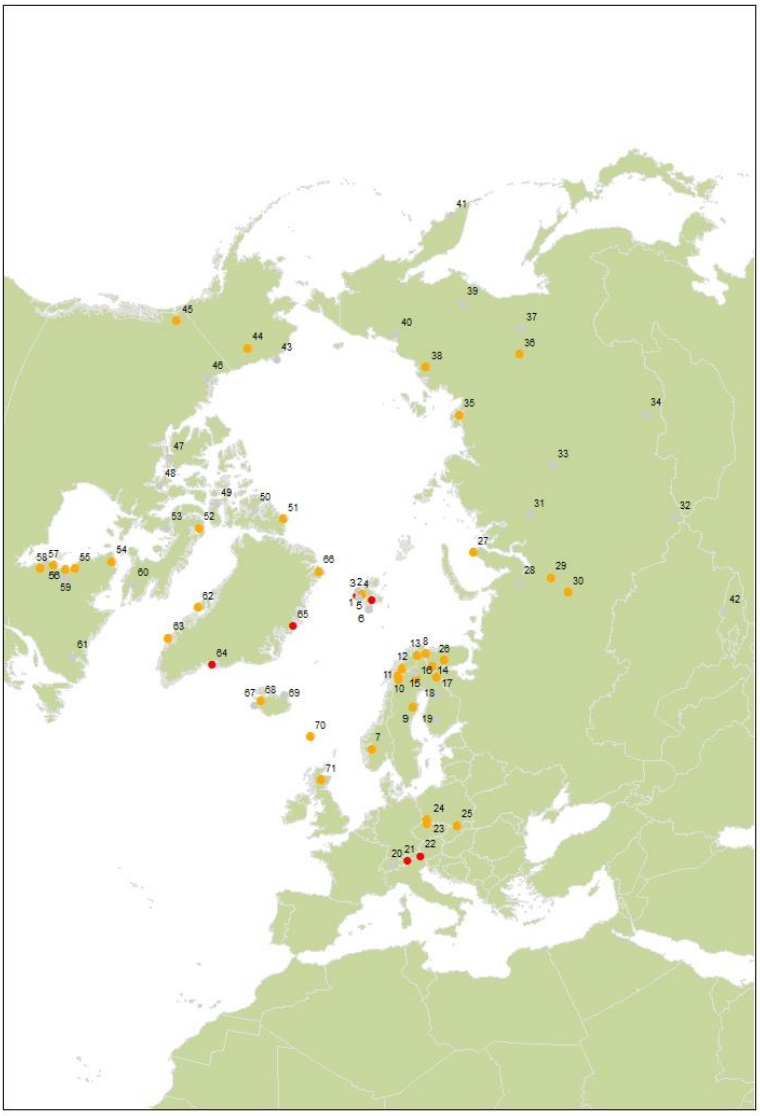
Category	Parameters
Glacier characteristis	Glacier area
	Topography
	Elevation change
	Terminus position
	Ice velocity
	Ice thickness
	Debris cover
	Surface albedo/reflexion coefficient

Geographical distribution of INTERACT stations covering a parameters category “Mass balance” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



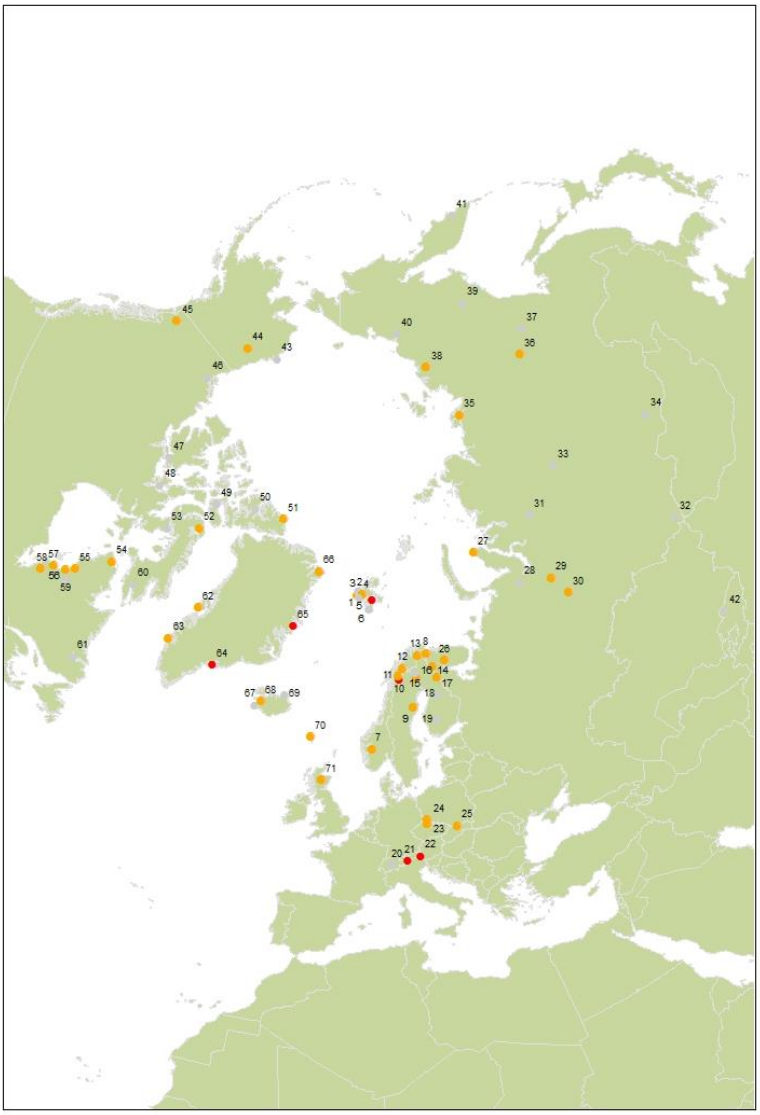
Category	Parameters
Mass balance	Mass balance
	Snow water equivalent
	Snowcover stratigraphy
	Equilibrium Line Altitude
	Duration of snow cover
	Calving flux

Geographical distribution of INTERACT stations covering a parameters category “Climate” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



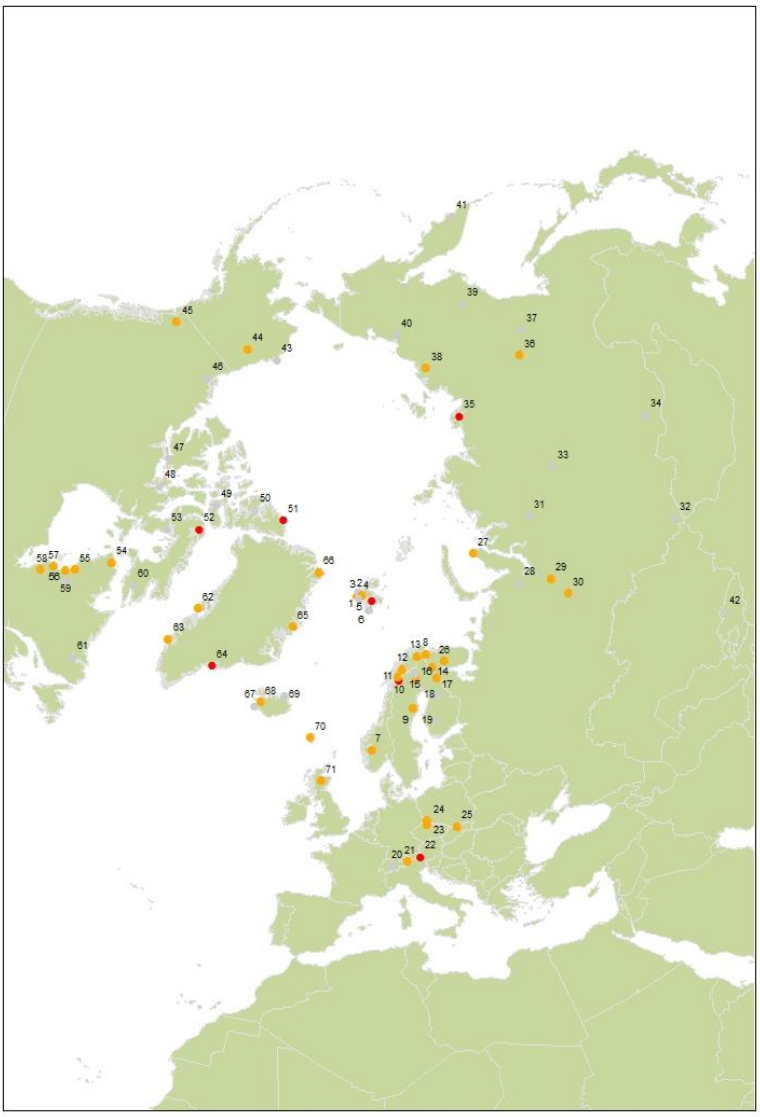
Category	Parameters
Climate	Climate measurements
	Energy balance

Geographical distribution of INTERACT stations covering a parameters category “Glacier hydrology” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



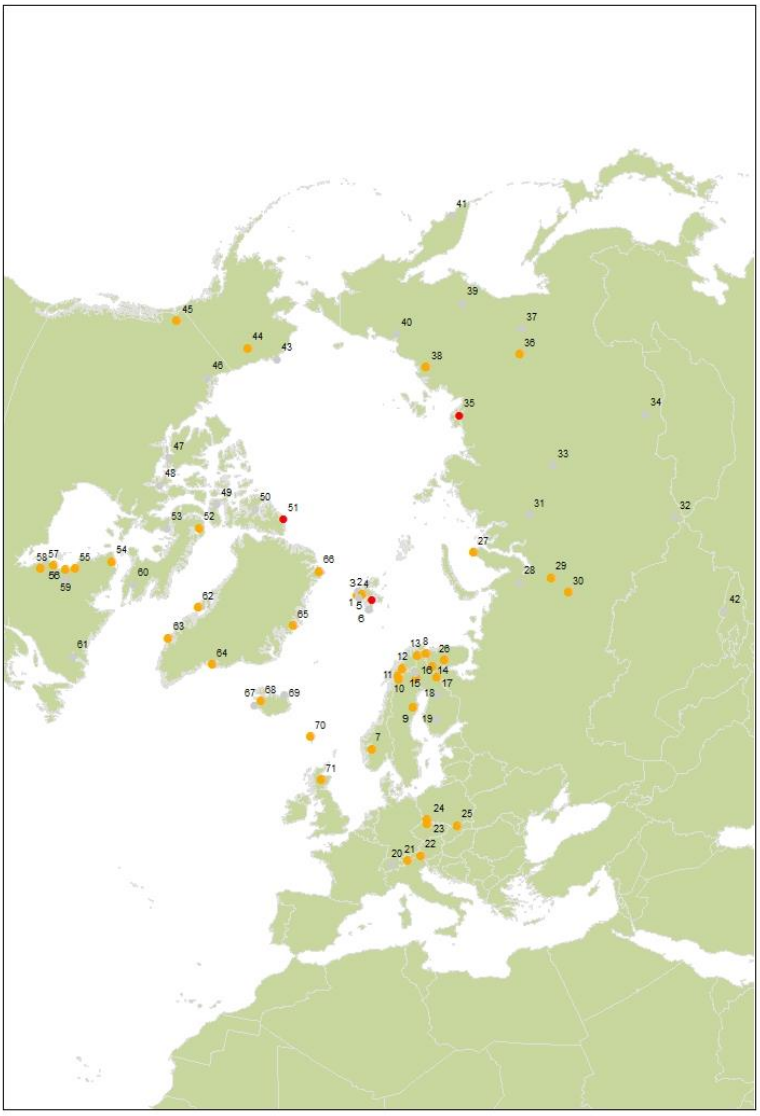
Category	Parameters
Glacier hydrology	Run-off
	Supra-, en- and subglacial drainage system
	Meltwater retention
	Glacial lake outburst floods

Geographical distribution of INTERACT stations covering parameter “Biogeochemistry of snow, ice and water” under the category “Other” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



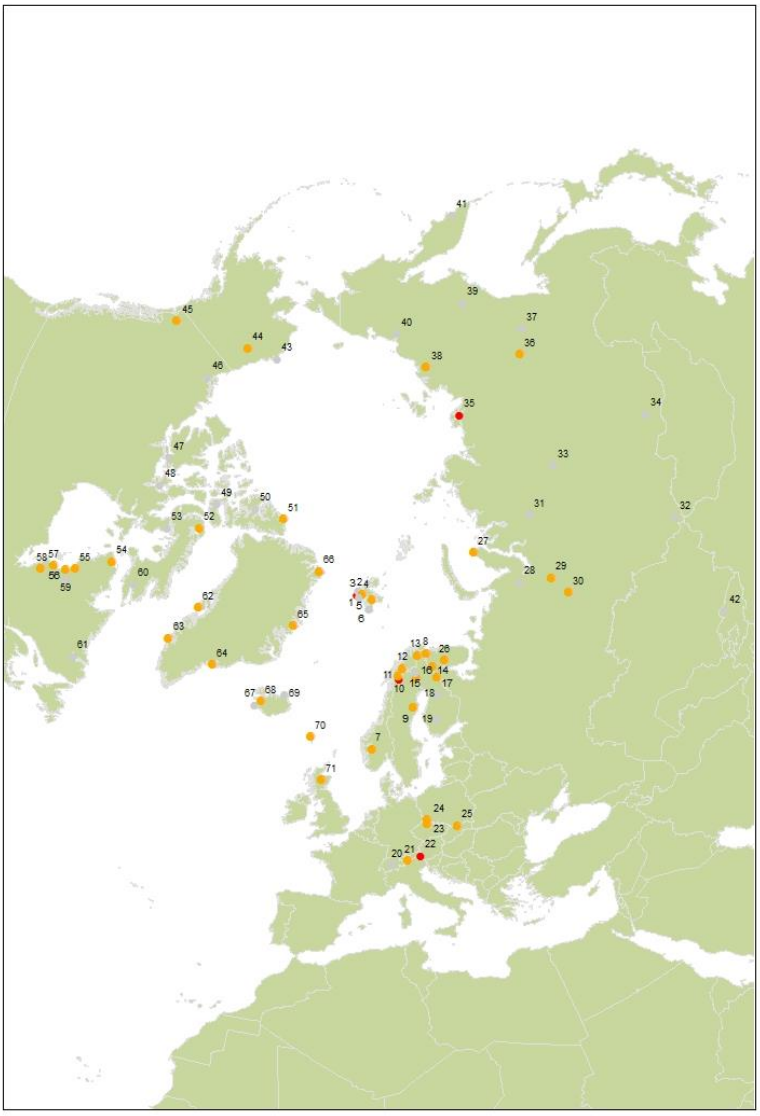
Category	Parameters
Other	Biogeochemistry of snow, ice and water
	Microbiology of snow, ice and water
	Particles and aerosols
	Pollutants e.g. POPs and heavy metals, in snow, ice and water
	Isotope chemistry of snow, ice and water

Geographical distribution of INTERACT stations covering parameter “Microbiology of snow, ice and water” under the category “Other” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



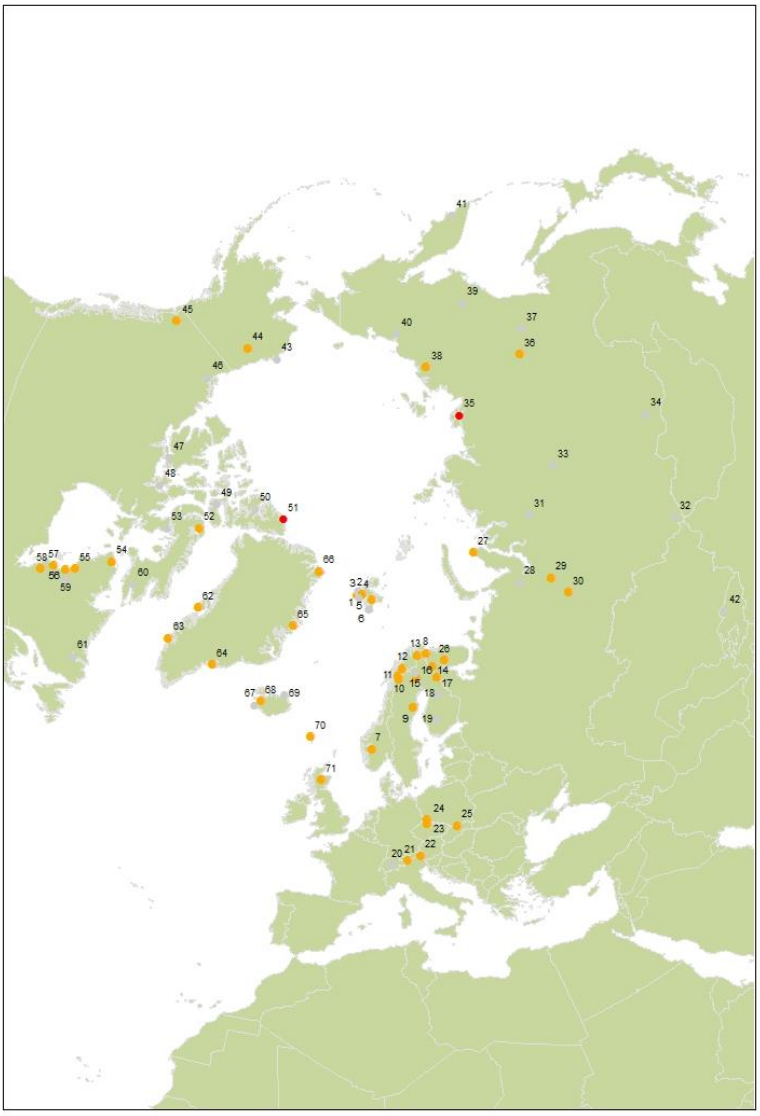
Category	Parameters
Other	Biogeochemistry of snow, ice and water
	Microbiology of snow, ice and water
	Particles and aerosols
	Pollutants e.g. POPs and heavy metals, in snow, ice and water
	Isotope chemistry of snow, ice and water

Geographical distribution of INTERACT stations covering parameter “Particles and aerosols” under the category “Other” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



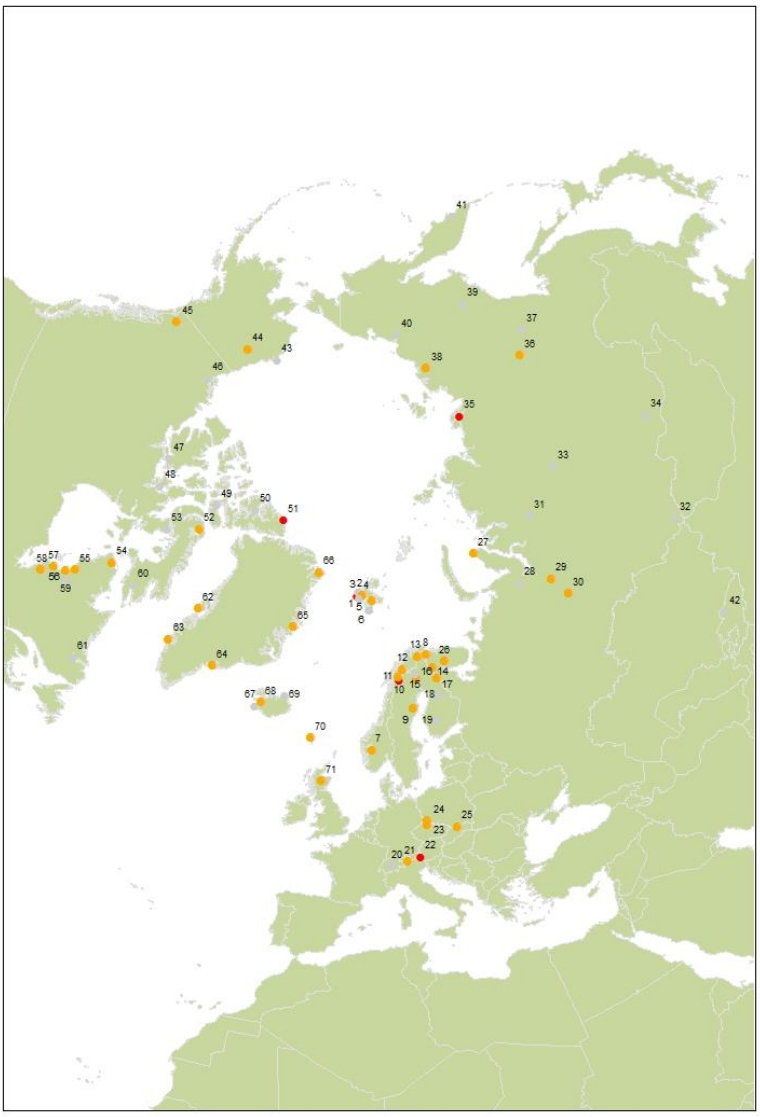
Category	Parameters
Other	Biogeochemistry of snow, ice and water
	Microbiology of snow, ice and water
	Particles and aerosols
	Pollutants e.g. POPs and heavy metals, in snow, ice and water
	Isotope chemistry of snow, ice and water

Geographical distribution of INTERACT stations covering parameter “Pollutants e.g. POPs and heavy metals, in snow, ice and water” under the category “Other” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
Other	Biogeochemistry of snow, ice and water
	Microbiology of snow, ice and water
	Particles and aerosols
	Pollutants e.g. POPs and heavy metals, in snow, ice and water
	Isotope chemistry of snow, ice and water

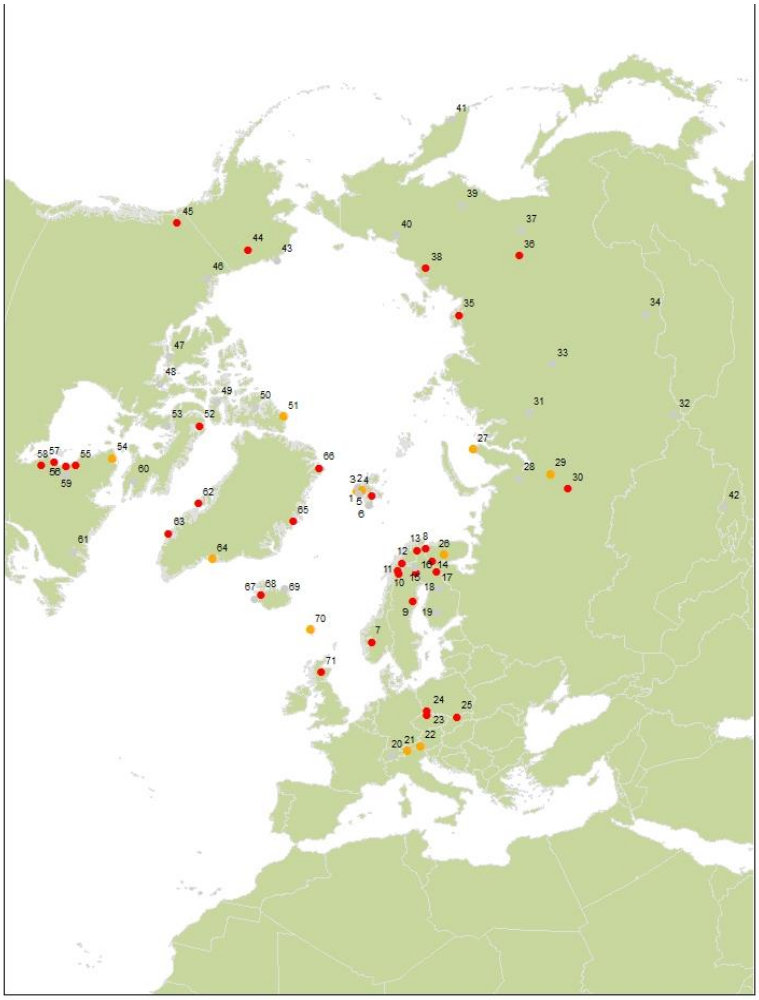
Geographical distribution of INTERACT stations covering parameter “Isotope chemistry of snow, ice and water” under the category “Other” within the “Glacier” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
Other	Biogeochemistry of snow, ice and water
	Microbiology of snow, ice and water
	Particles and aerosols
	Pollutants e.g. POPs and heavy metals, in snow, ice and water
	Isotope chemistry of snow, ice and water

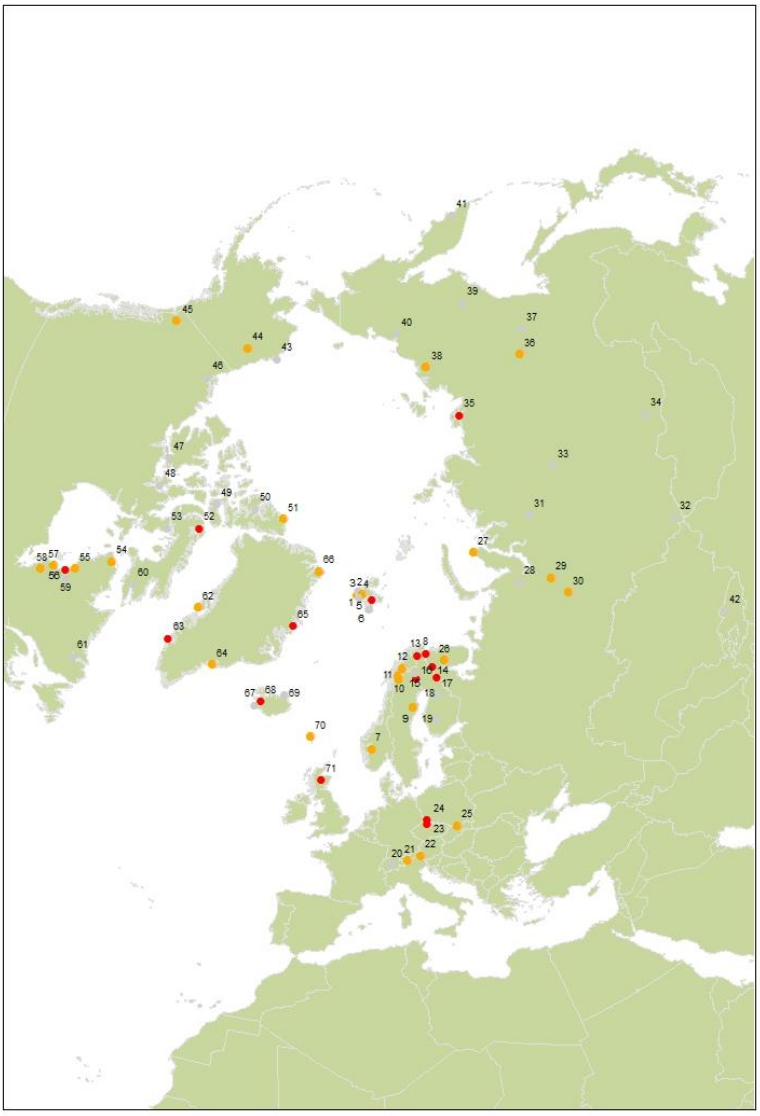
"Bio" Parameters

Geographical distribution of INTERACT stations covering a parameters category "Vegetation" within the "Bio" theme.
Red: Yes; Orange: No; Grey: N/A.



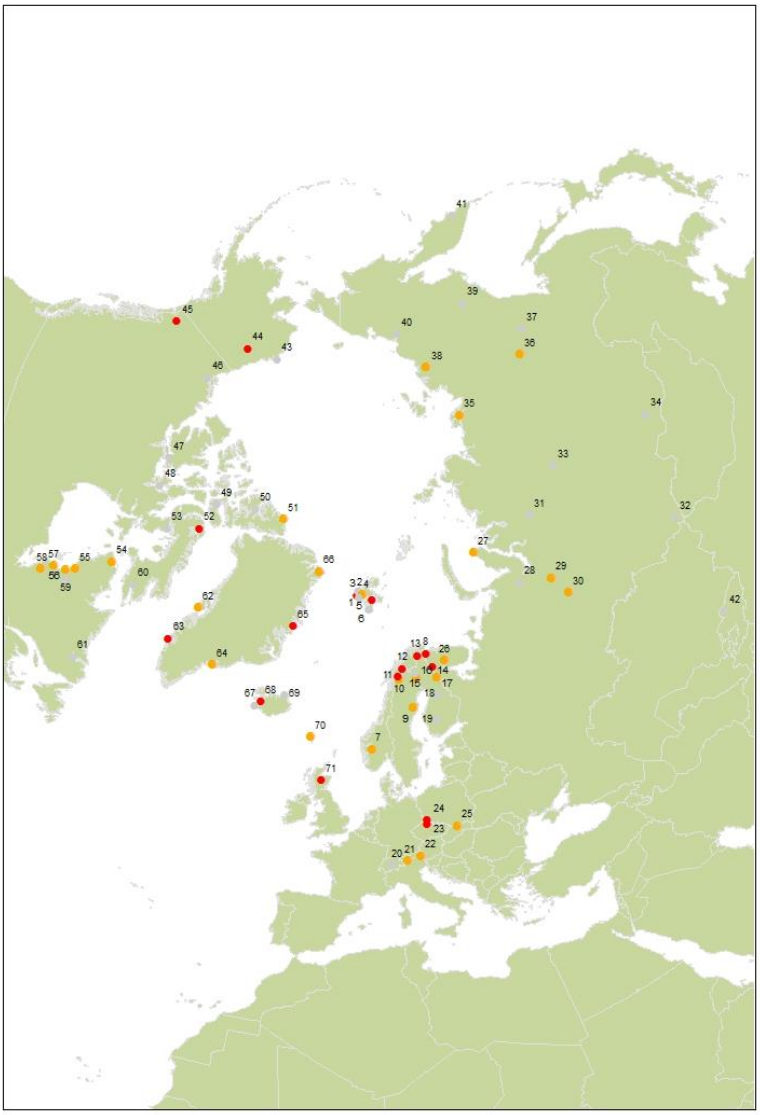
Category	Parameters
Vegetation	Flowering phenology
	Amount of flowering
	NDVI (plot/transect)
	Landscape NDVI (from satellite images)
	Vascular plant community composition
	Bryophyte community composition
	Lichen community composition
	Fungi community composition
	Berry production
	Aerobiological monitoring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

Geographical distribution of INTERACT stations covering a parameters category “Arthropods” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



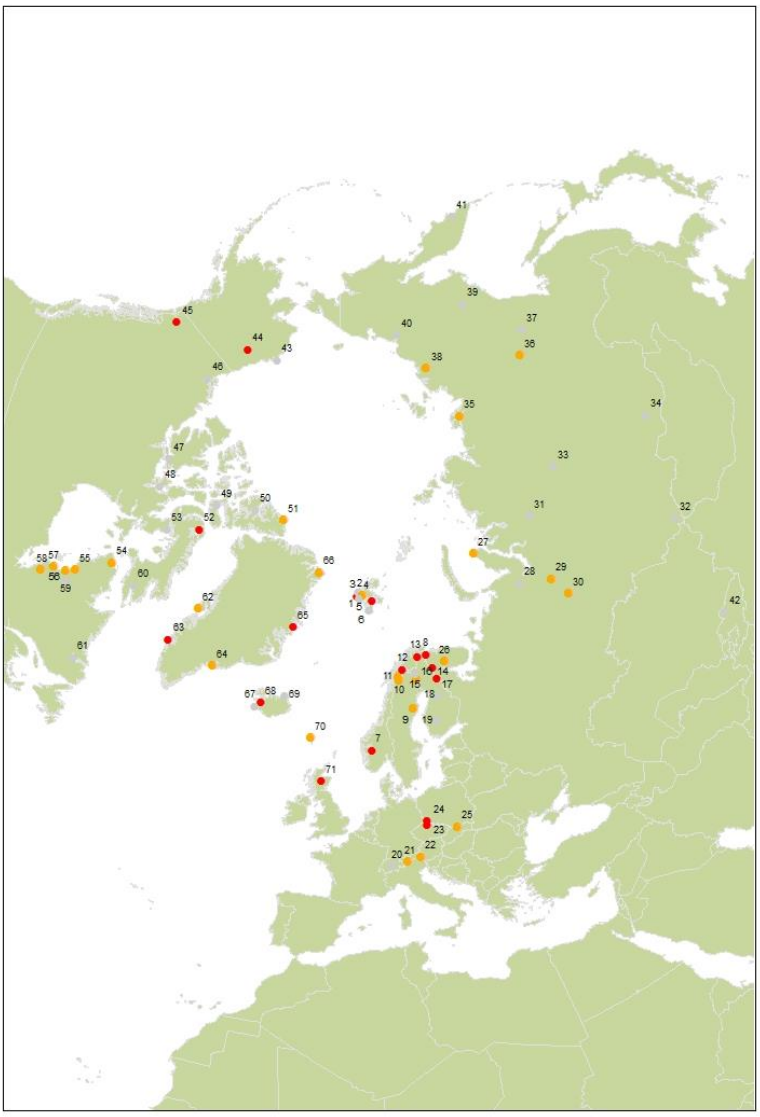
Category	Parameters
Arthropods	Abundance
	Emergence phenology
	Insect herbivory
	Species list (community composition)

Geographical distribution of INTERACT stations covering a parameters category “Birds” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



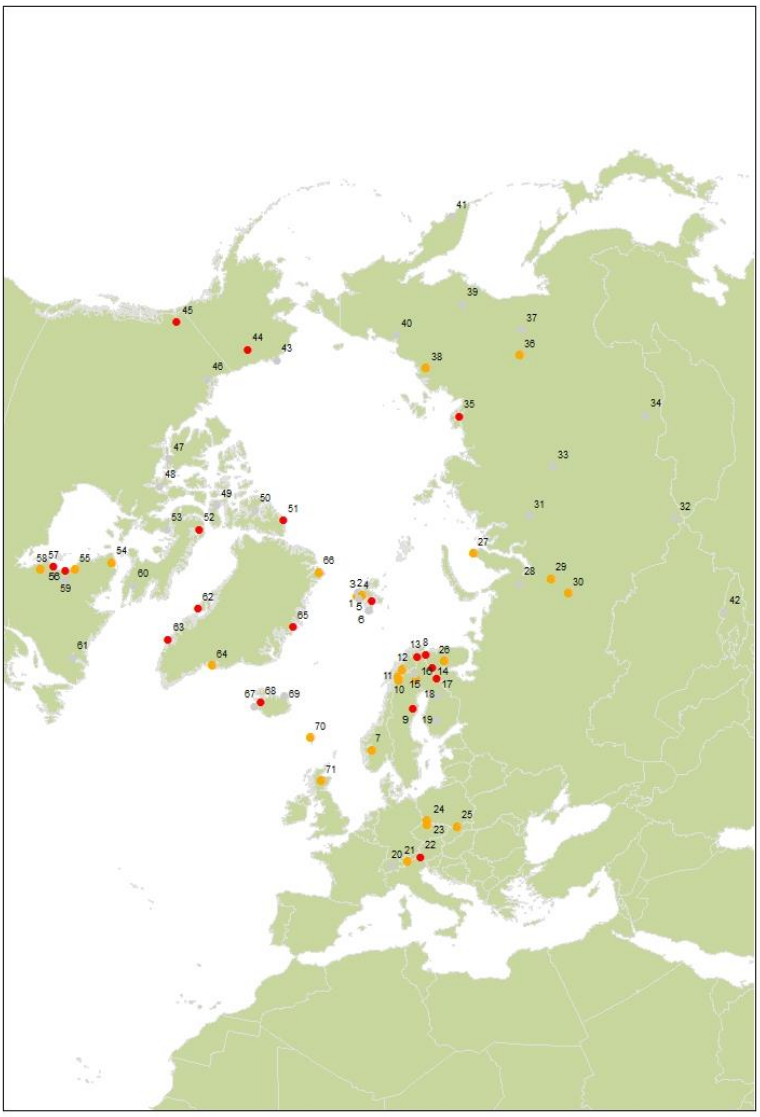
Category	Parameters
Birds	Abundance
	Distribution
	Phenology
	Breeding birds
	Nest initiation phenology
	Nest predation rates
	Species list (community composition)

Geographical distribution of INTERACT stations covering a parameters category “Mammals” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



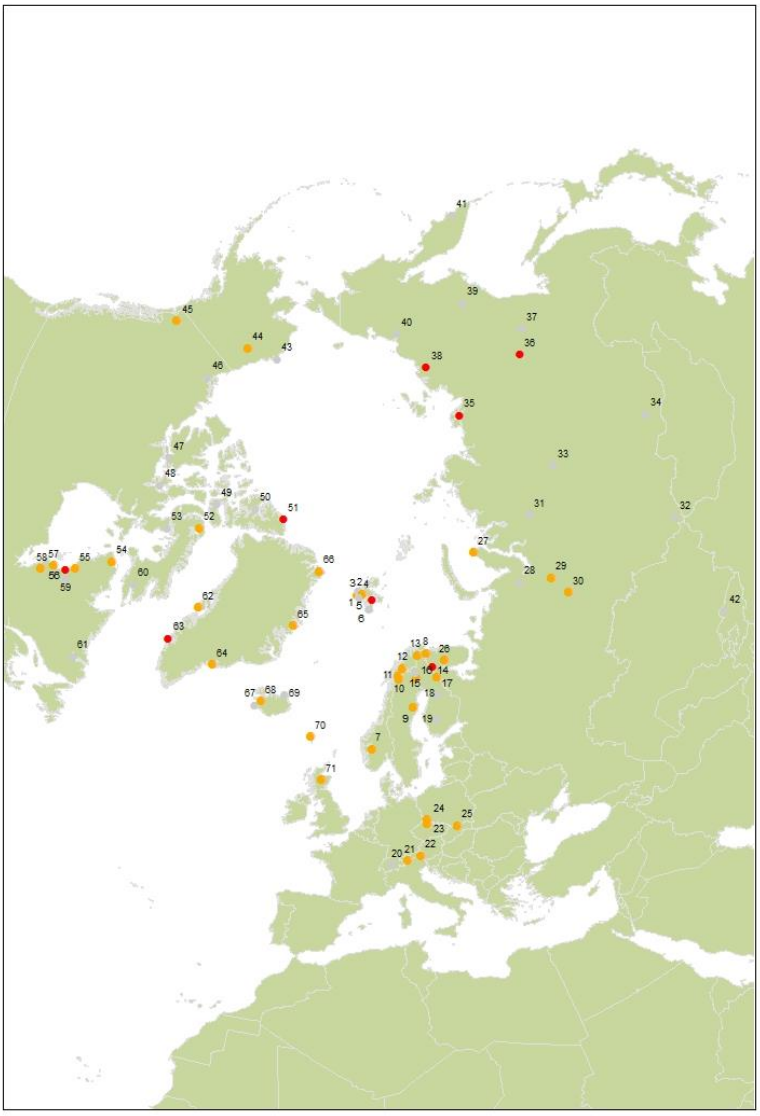
Category	Parameters
Mammals	Mammal abundance
	Mammal distribution
	Mammal reproduction
	Mortality
	Predation
	Physiology
	Species list (community composition)

Geographical distribution of INTERACT stations covering a parameters category “Lake ecology” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



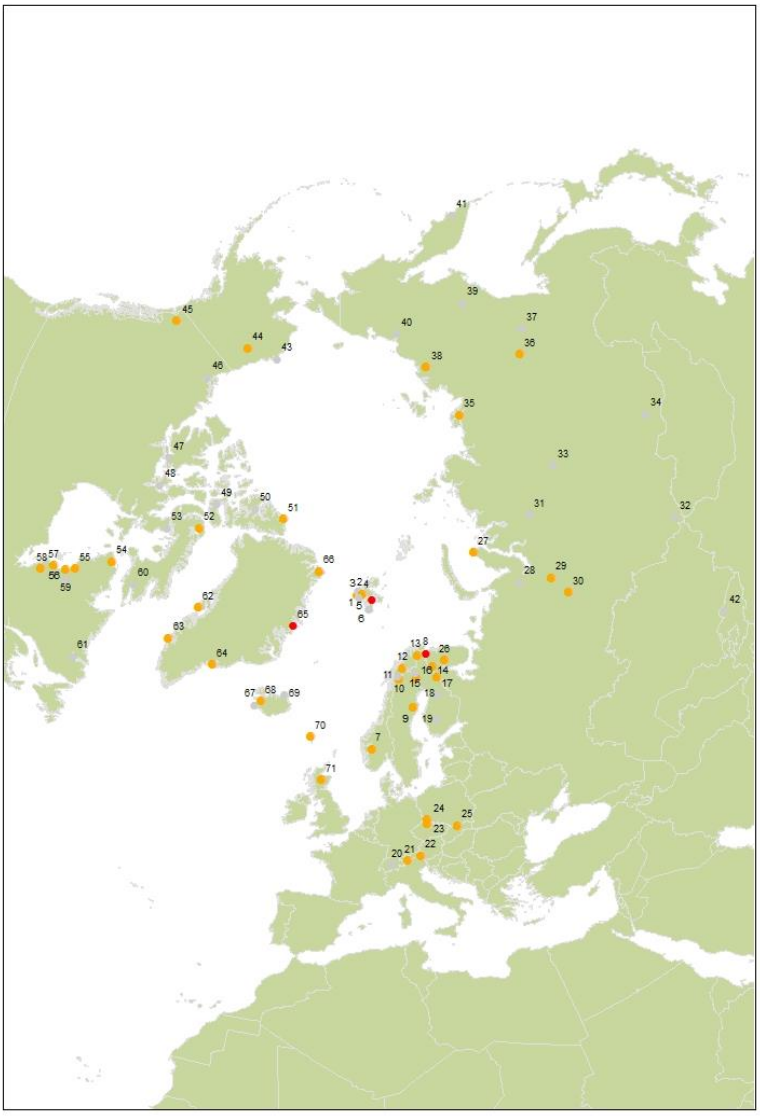
Category	Parameters
Lake ecology	Phytoplankton (chlorophyll)
	Zooplankton
	Vegetation
	Fish
	Invertebrates
	Species list (community composition)

Geographical distribution of INTERACT stations covering a parameters category “Microbiology” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



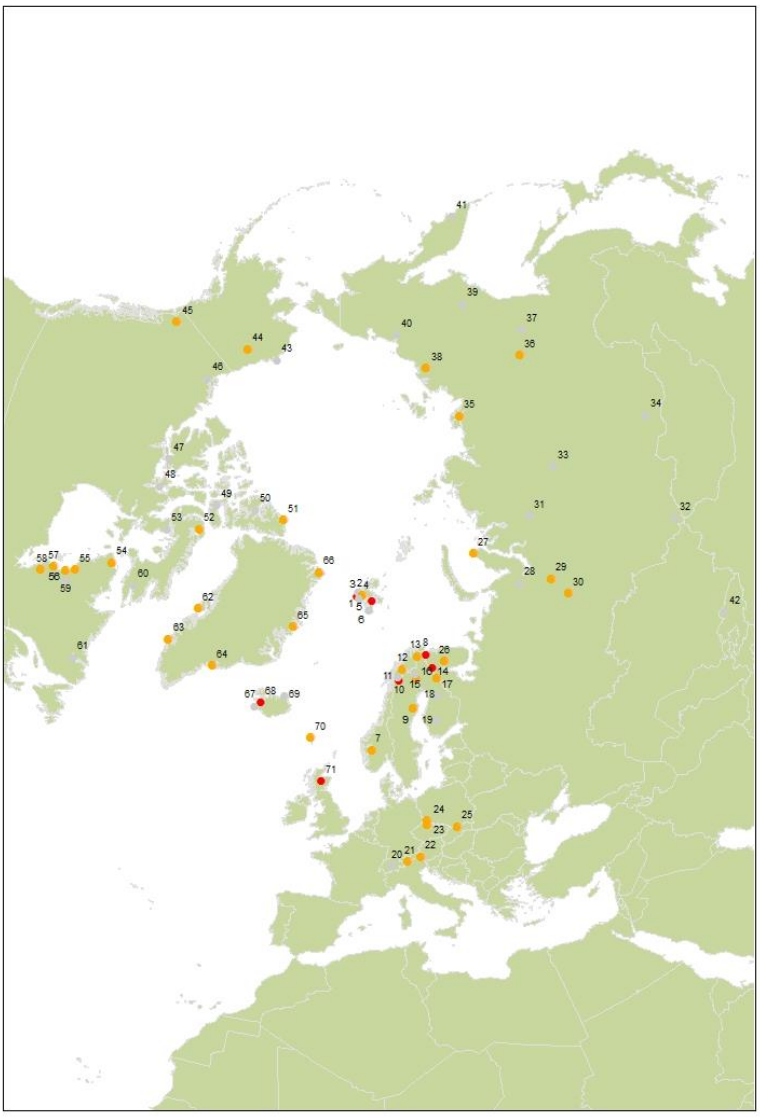
Category	Parameters
Microbiology	Interstitial fauna
	Species list (community composition)

Geographical distribution of INTERACT stations covering a parameters category “Genetics” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



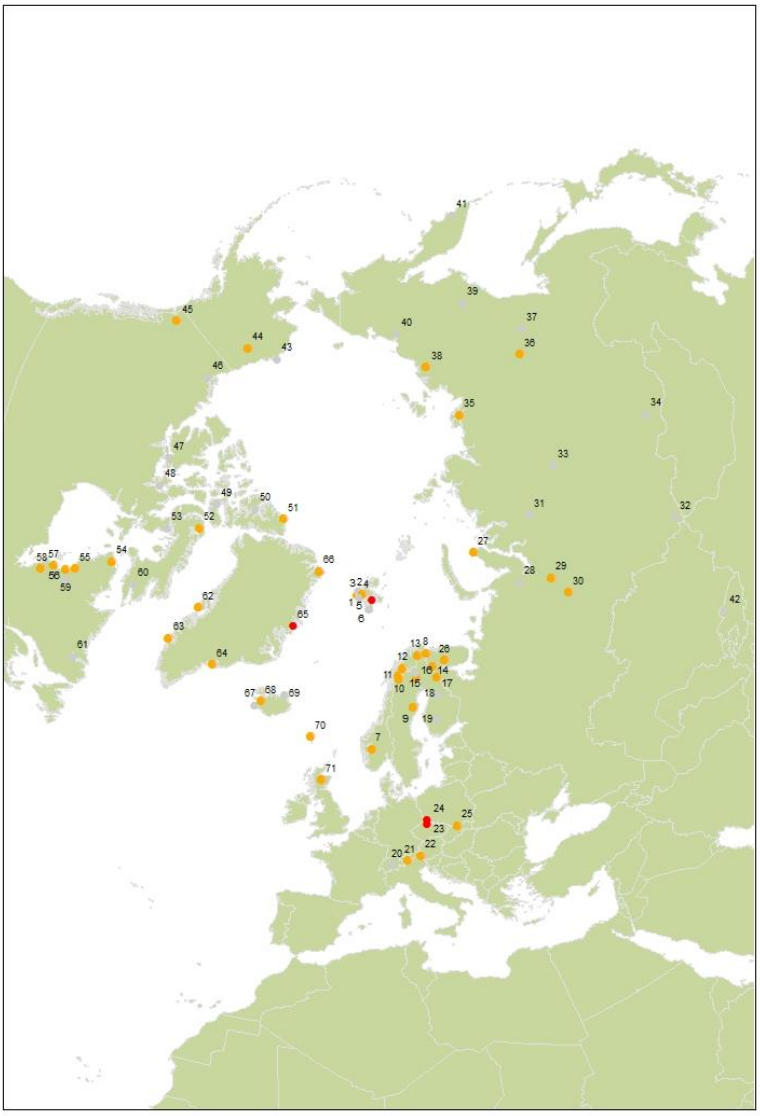
Category	Parameters
Genetics	Collection of animal tissue

Geographical distribution of INTERACT stations covering a parameters category “Pollution” within the “Bio” theme.
Red: Yes; Orange: No; Grey: N/A.



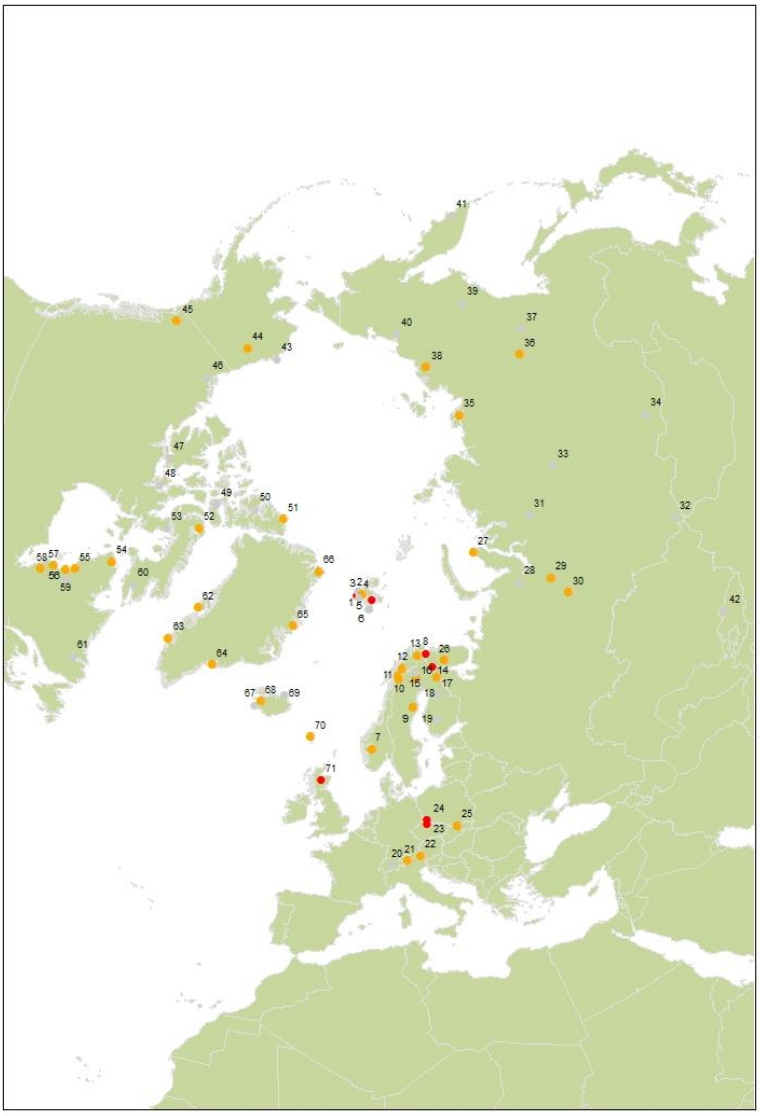
Category	Parameters
Pollution	Pollution measurements in vegetation
	Pollution measurements in water
	Pollution measurements in mammals (body burdens, biomarkers)
	Pollution measurements in birds (body burdens, biomarkers on both adults and offspring e.g. egg shell thinning, macro plastic in nests/in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

Geographical distribution of INTERACT stations covering a parameters category “Diseases” within the “Bio” theme.
Red: Yes; Orange: No; Grey: N/A.



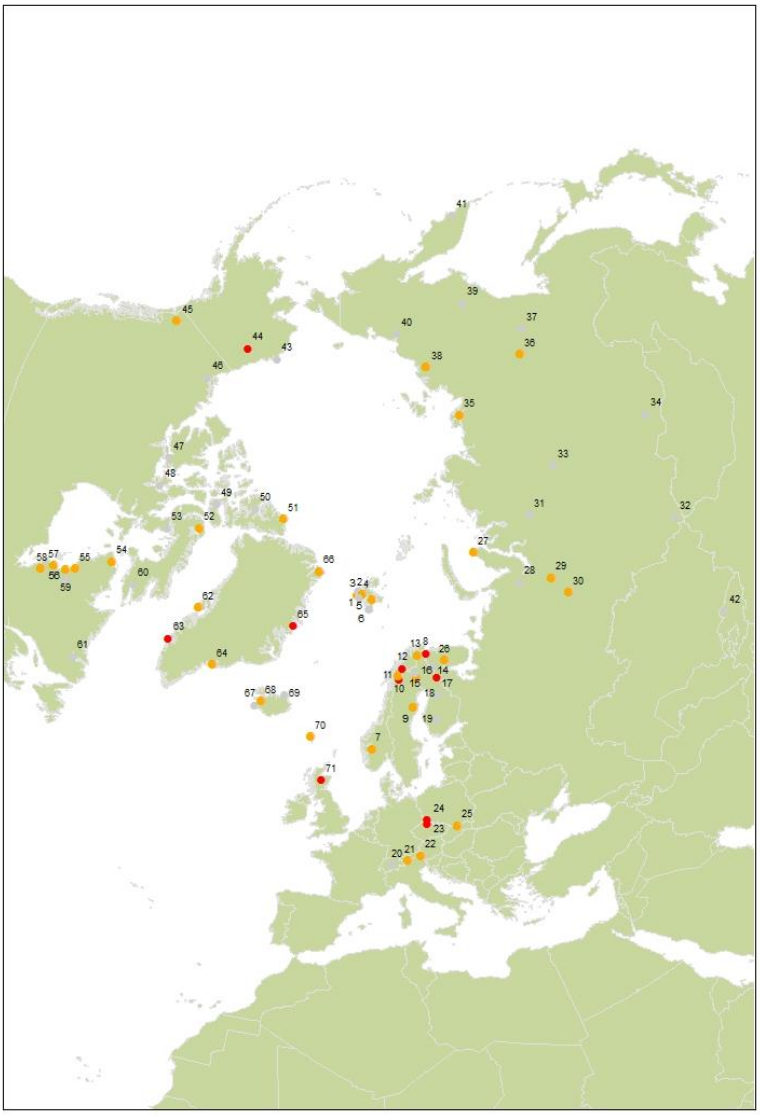
Category	Parameters
Diseases	Mammals
	Birds
	Fish
	Vegetation
	Other

Geographical distribution of INTERACT stations covering a parameters category “Parasites” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
Parasites	Mammals
	Birds
	Fish
	Vegetation
	Other

Geographical distribution of INTERACT stations covering a parameters category “Socio-ecological issues (disturbance)” within the “Bio” theme. Red: Yes; Orange: No; Grey: N/A.



Category	Parameters
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.)

3. INTERACT Minimum Monitoring Programme

3.1 Designing an 'INTERACT Minimum monitoring Programme'

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 a 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 circum-arctic/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.

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 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, biogeochemistry (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 information.
- Hydrological monitoring.
- Physical landscape monitoring.
- Vegetation monitoring.
- Fauna monitoring.
- Biogeochemical 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.

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 other (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).

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'
INTERACT has in cooperation with the Integrated Carbon Observation System (ICOS) and by recommendation from the international climate modeler 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 modeler 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 needs 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 or a collection of the both being made over the years.

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.

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 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 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 the 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 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 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.ipa.arcticportal.org).

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 otho-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 is 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.

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.

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 general lack, at least in some parts of the Arctic, of long time series of especially CO_2, CH_4 and NO 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 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 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

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.

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
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.

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 (or similar system) to monitor land use within the station study area. An INTERACT minimum monitoring system should therefore include:

- Land use and land use changes of station facilities, infrastructure, instrumentation and projects.

3.2 The 'INTERACT Minimum Monitoring Programme'

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
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 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
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 or a collection of the both being made over the years.

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.

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
If rivers occur in the nearest vicinity of the station a well-defined drainage basin should be selected and monitoring (either with either automatic sensors or manual measurements) of the following parameters should be carried out:

- 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
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
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
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.

Biogeochemical monitoring
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.

Air quality monitoring
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
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 land use (research and monitoring projects, housing, roads, research infrastructure, etc.).

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.

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.

Circum-arctic monitoring networks, like ITEX, IPA-CALM, GLORIA, etc., provide manuals on their respective websites (see also Chapter 4) 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.

4. Best practice for monitoring – a description of existing scientific networks with best practices

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.

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.

The networks' descriptions include:

Discipline: 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.

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.

CBMP - Circumpolar Biodiversity Monitoring Programme

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

Disciplines: Terrestrial Biology - Ecosystem function, Terrestrial Biology - Biodiversity

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

Description:
The Circumpolar Biodiversity Monitoring Program (CBMP) is the cornerstone program 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. Our goal is to facilitate more rapid detection, communication, and response to the significant biodiversity-related trends and pressures affecting the circumpolar world.

The 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 communications, education and outreach.

Arctic ecosystems are under increasing pressure from: climate change, habitat fragmentation, resource development, contaminants, urbanization, increased agriculture, invasive species and competition from the movement of more southerly species. The composition of Arctic biodiversity is highly related to temperature, and with the Arctic warming at twice the global rate this causes major concern for Arctic biodiversity. Temperature can affect ecosystems through thawing permafrost, snowmelt, drought, fires, changes in phenology (with subsequent implications on the food web), encroachment of invasive species, pest outbreaks and disease transmissions, etc. For some species that feed and reproduce in the short Arctic summer, longer growing seasons may be an advantage, but specialized Arctic wildlife are predicted to be negatively affected by climate change.

Exactly how these pressures - alone and in combination - affect Arctic species and ecosystems is unknown because the Arctic´s complexity and size make it difficult to detect and attribute changes. In addition, existing terrestrial monitoring efforts are often uncoordinated, limiting the ability to efficiently make effective management decisions, despite increasing urgency and pressure to act.

In response, 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.

www.caff.is

Arctic Terrestrial Biodiversity Monitoring Plan

The 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 FECs) and where are drivers having the greatest impact?

Parameters:

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

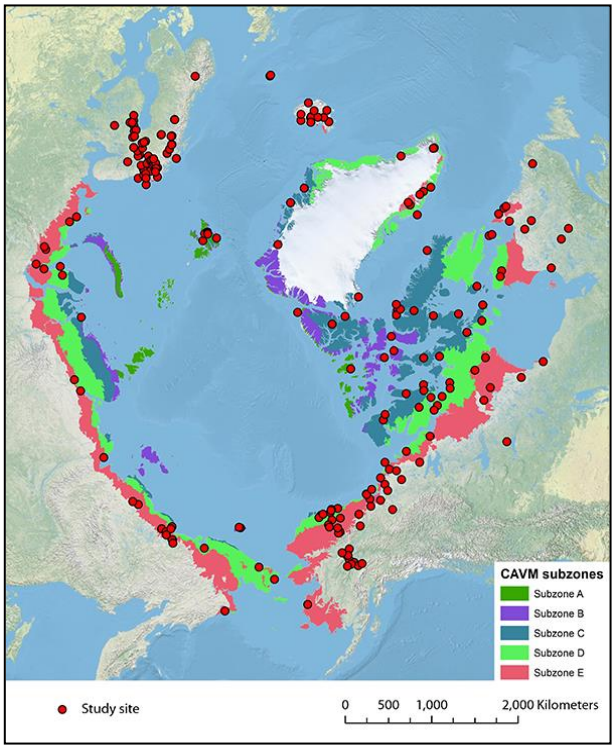
Four main terrestrial biotic groups were selected for systematic monitoring:

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

The CBMP-Terrestrial Plan describes a nested, multi-scale framework to determine baseline conditions and evaluate changes with respect to the long-term integrity of Arctic ecosystems and biodiversity. Methods and strategies for monitoring range from site-based focal studies to pan-Arctic



Circumpolar Arctic bioclimate subzones and location of long-term monitoring sites, programs and infrastructure that can contribute to monitoring capacity as part of the CBMP-Terrestrial Plan. This map includes all biotic groups (CAFF).

remote sensing and global modeling approaches, and incorporate data-gathering through scientific analyses, Traditional Knowledge (TK) and community-based monitoring (CBM). The CBMP-Terrestrial Plan recommends building on robust standardized techniques that are feasible and already in use across circumpolar regions where possible, and suggests additional techniques (e.g., genetic analyses, stable isotope signature analyses, satellite-based or other technology-based tracking and telemetry systems, and remote sensing) where infrastructure and capacity exists.

See the monitoring plan for further details: http://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. The TEMG closely follows the definitions, geographic boundaries, species and ecosystem coverage as outlined by the CAFF Arctic Biodiversity Assessment (CAFF ABA 2013). The CBMP-Terrestrial Plan scope includes high and low Arctic consistent with the Circumpolar Arctic Vegetation Map's subzones A-E (CAVM Team 2003 and alpine sub-Arctic regions in proximity of the Arctic proper).

Arctic Freshwater Biodiversity Monitoring Plan

The 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. This "umbrella plan" for monitoring the Arctic freshwater environment identifies existing capacity to facilitate improved cost effective monitoring through enhanced integration and coordination. This will allow for earlier detection of disturbances and provide for faster information transfer, leading to more effective and efficient policy and management response.

The primary objectives of the CBMP Freshwater Plan include:

- Identify of 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 is founded on ideas forwarded in a framework document and work undertaken during two workshops. In addition to the Freshwater EMG Steering Group members, both workshops included freshwater experts with a broad range of expertise, and contributors from all participating countries.

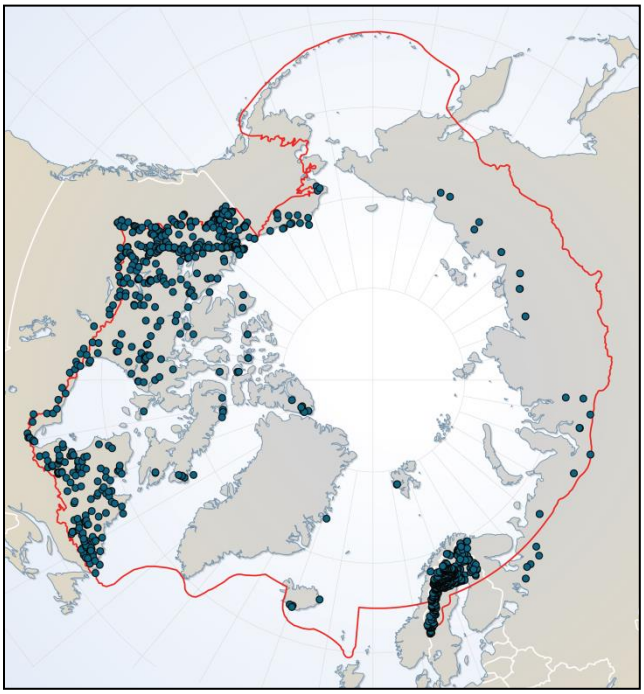
In the first workshop, participants identified the important elements (stressors, FECs, parameters and indicators) of a pan-Arctic Freshwater monitoring plan. Each of the FECs and indicators was given arank of high, medium or low based on importance to ecosystem function and sensitivity to stressors, sampling feasibility, and data availability. The mechanistic link between environmental or anthropogenic stressors and FECs was identified through "Impact Hypotheses". These statements outline the potential ways that various stressors might impact structural and functional aspects of biotic communities. Information on available freshwater data for the focal elements was also summarized during this workshop, and will be an important basis for the first assessment of Arctic freshwaters. Information on existing data will also help in selecting future monitoring sites.

During the second workshop, participants refined the lists of FECs, parameters and indices to produce lists of freshwater elements to be considered for monitoring and assessment. This workshop was primarily focused on developing a draft Freshwater Plan to be reviewed and completed by the Freshwater EMG Steering Group.

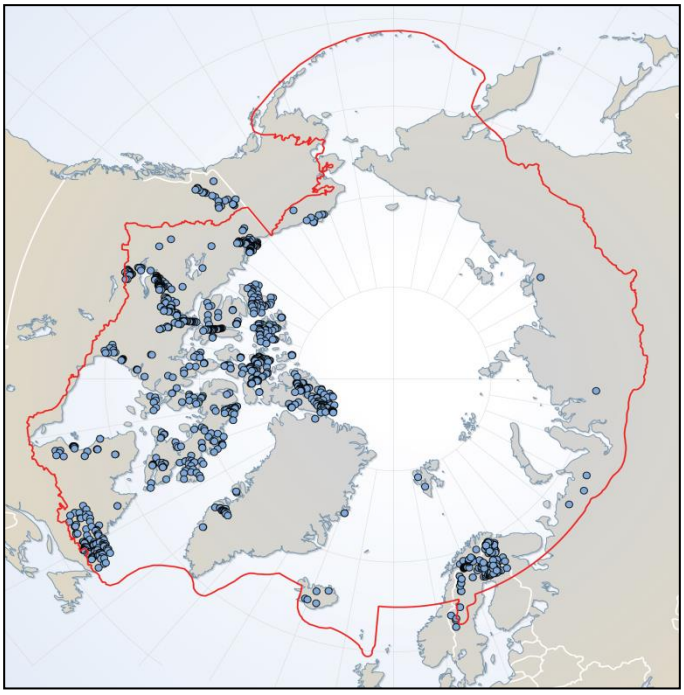
How to become involved:
To become involved in CAFF's CBMP, please contact the applicable national representative from the Freshwater and/or Terrestrial Steering Groups. They can be found on the CBMP website: www.caff.is/monitoring. Alternatively, the CAFF Secretariat can help answer any questions and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

Geographical coverage:
The Arctic regions considered include those areas covered by the Arctic Biodiversity Assessment (ABA) and CAFF boundaries, whichever is more inclusive for a particular area. In addition, the sub-region division developed for the ABA was adopted as an appropriate means of sub-dividing Arctic freshwaters. This schema divides the Arctic into three sub-regions: high Arctic, low Arctic and sub-Arctic. Delineation of sub-regions is based on a set of several biogeographical features like vegetation types, including the northern limit of the timber and treeline, duration of the biologically productive season and mean annual temperature.

The Freshwater Plan identifies a set of criteria for the selection of preferable monitoring sites, namely, (1) sites with high-quality and long-term data sets, (2) biodiversity hotspots, i.e., areas with high species richness or unique species composition (e.g., rare species) and high conservation value, (3) medium to small river catchments and lakes to ensure effective sampling effort and representative species collection, and (4) sites of high significance to local communities.
Additional variables for consideration during the selection of sites may include water source (e.g., glacial vs. non-glacial water bodies), presence or absence of fish, and geomorphic characteristics (e.g., mean stream width, mean lake depth).



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



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

ENV-Europe/ILTER (International Long Term Ecological Research)

Website: www.enveurope.eu and www.ilternet.edu
Contact address: www.enveurope.eu/contacts

Discipline: Terrestrial biology – Ecosystem function, Terrestrial biology – Biodiversity, Climatology

Keywords: LTER, ecology, ecosystem, Climate Change

Description:
EnvEurope is a scheme ecological research and monitoring based on 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 networks 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.

Suitable sites:
Terrestrial and freshwater 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), soil (classification, density, composition, chemistry, temperature, moisture), atmosphere (air temperature, moisture, pressure, wind speed, atmospheric composition and radiation), biomass production, energy balance, fluxes, harvest volume, 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, 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/about/membership.

Geographical coverage:

EnvEurope encompass 67 LTER-Europe sites in terrestrial, continental waters, wetlands and marine ecosystems from 11 countries.

LTER networks that are members of ILTER. Green markers indicate networks being members of ILTER (the International Long-Term Ecological Research Network). Red markers indicate networks which are under development, and are not yet formal members of ILTER (www.ilternet.edu/member-networks).

GLORIA - Global Observation Research Initiative In Alpine Environments

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

Disciplines: Terrestrial Biology – Ecosystem function, Terrestrial Biology - Biodiversity

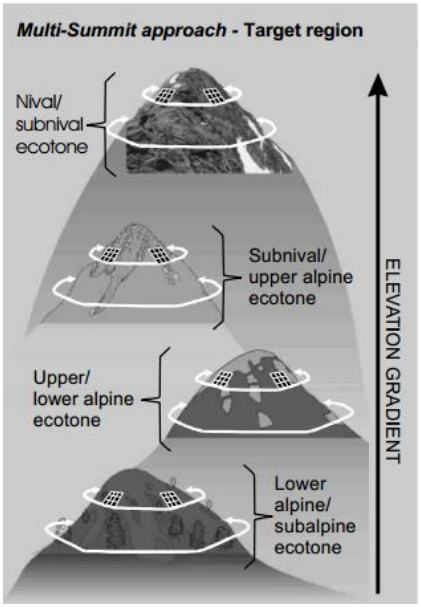
Keywords: Ecosystems, terrestrial biology, species diversity, vegetation, temperature, Climate Change

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.

Parameters

Mandatory activities:

- Species (vascular plants) recording in 16 1m x 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 ('r!': very rare; 'r': rare; 's': scattered; 'c': common; 'd': dominant).
- 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 x 1 m quadrats (previously this was a standard method).
- Increase of 1 m x 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).

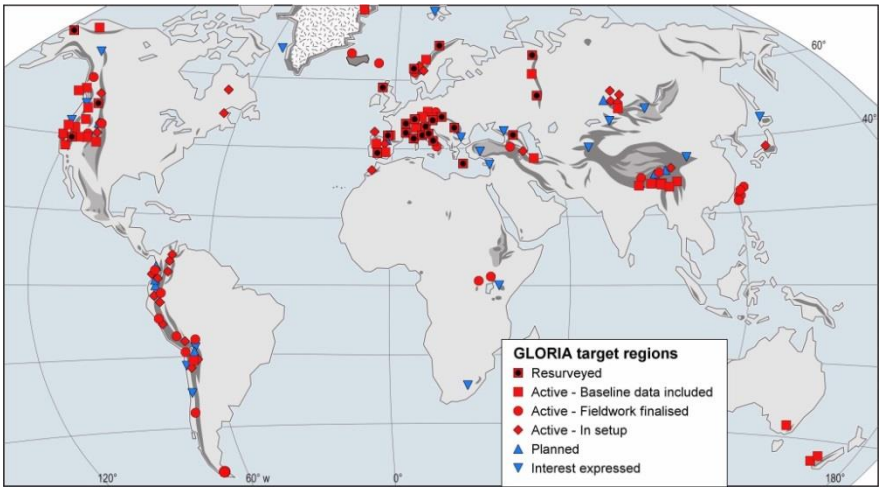
Ordesa, Pyrenees, Spain (2500m) (Harald Pauli/GLORIA).

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.



(www.gloria.ac.at/?a=10)

ITEX - International Tundra Experiment

Website: http://ibis.geog.ubc.ca/itex
Contact address: ghenry@geog.ubc.ca or see website

Disciplines: Terrestrial biology - Ecosystem, Climatology

Key words: Ecosystem, Climate Change, tundra, manipulation, open-top chambers

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.

(http://ibis.geog.ubc.ca/itex/library/index.php)

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.

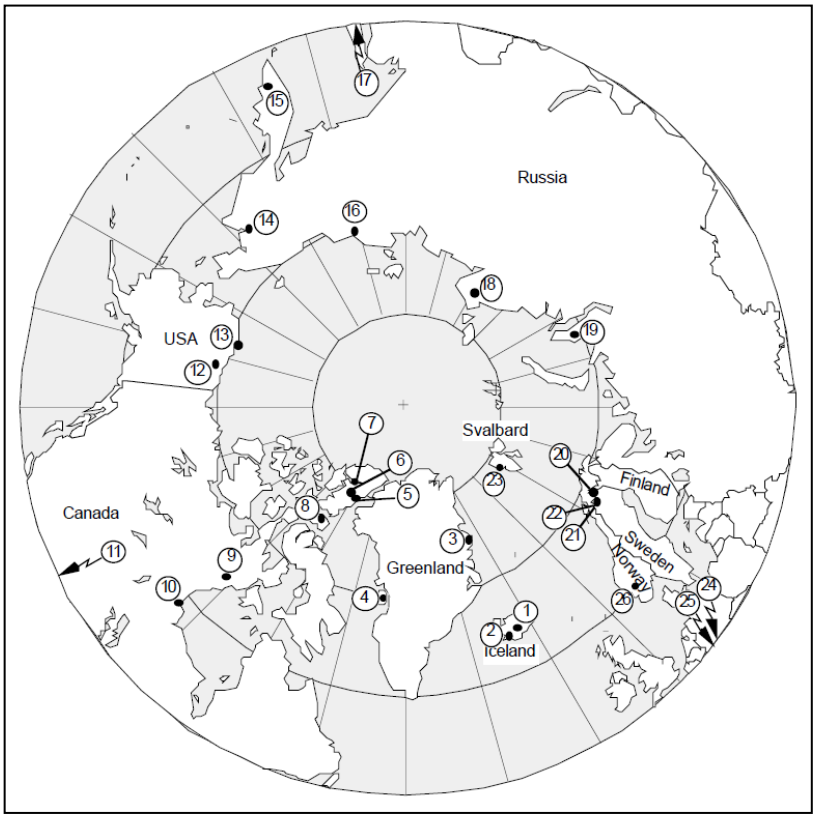
Extent of Experiment: A five-year commitment to an experimental site is suggested as a minimum. Sites with on-going long-term programs and personnel, such as field stations, reserves, and long-term ecological research sites, are considered optimum, to secure that the experiment may be expected to continue.

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 listserver 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:



(http://ibis.geog.ubc.ca/itex)

ITEX sites

1 Hveravellir, Iceland
2 Mt. sSkálafell, Iceland
3 Zackenberg, Greenland
4 Disko Island, Greenland
5 Alexandra Fjord, Canada
6 Sverdrup Pass, Canada
7 Hot Weather Creek, Canada
8 Baker Lake, Canada
9 Baker Lake, Canada
10 Churchill, Canada
11 Niwot Ridge, USA
12 Toolik Lake, USA
13 Barrow, USA
14 Anadyr, Russia
15 Petropavlovsk, Russia
16 Lower Kolyma, Russia
17 Taisetsu Mts., Japan
18 Taimyr, Russia
19 Yamal, Russia
20 Kilpisjärvi, Finland
21 Abisko, Sweden
22 Latnjajaure, Sweden
23 Ny-Ålesund, Svalbard
24 Val Bercla, Switzerland
25 Furka Pass, Switzerland
26 Finse, Norway

EXPEER - Experimentation in Ecosystem Research

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

AnaEE - Analysis and Experimentation on Ecosystems

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: Terrestrial biology – Ecosystem function, Ecosystem services

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 (2010-2014) 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 shrub lands. 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.

The goals of these projects include:

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

Suitable sites:
Vegetated areas, natural or managed (INCREASE: shrub lands).

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, biogeochemical 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/index.php/accomplishments/expeer-protocols.
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, but applicable in all areas.

Shrub Hub – network investigating changes in woody vegetation in arctic and alpine tundra ecosystems

Website: http://shrubhub.biology.ualberta.ca/
Contact address: imyerssmith@ualberta.ca

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

Discipline: Terrestrial biology – Ecosystem function

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

Description:
Shrub Hub 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.

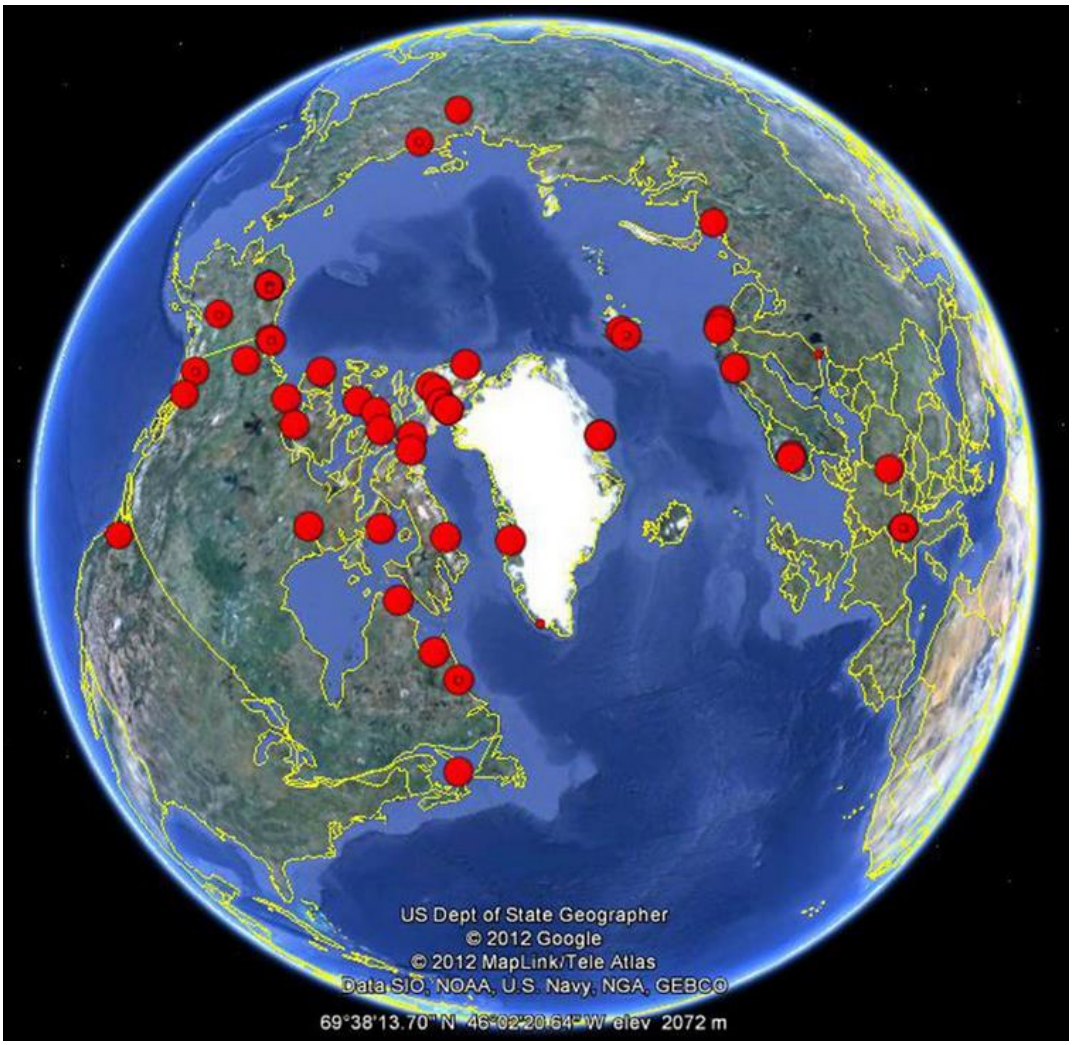
Methods include dendrochronology boreholes in stems and fixed point photography of shrub cover.

How to become involved:
Contact network coordinator (see above).

Repeat photography 1970 – 2009 from the IPY project Back to the Future (Terry Callaghan/Sheffield University and Torben R. Christensen/Lund University).

Geographical coverage:

Arctic and alpine areas of the northern hemisphere (http://shrubhub.biology.ualberta.ca).



AMAP – Arctic Monitoring and Assessment Programme

Website: www.amap.no
Contact address: www.amap.no/contacts

Discipline: Environmental science - Pollution, Climatology

Keywords: Pollution, contaminants, Climate Change, adaptation, environmental assessments

Description:
AMAP is one of six working groups of the Arctic Council. The AMAP Trends and Effects Monitoring Programme (ATEMP) is a harmonized programme for monitoring the trends and effects of contaminants and climate change across the circum-arctic 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 Programme (CBMP) and both of these programmes contribute to the Sustaining Arctic Observing Systems (SAON) initiative.

The AMAP Trends and Effects Monitoring Programme is currently being updated and will include new recommended monitoring protocols.

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

- Snow, Water, Ice and Permafrost in the Arctic (SWIPA), www.amap.no/swipa.
- Arctic Health Risks: Impacts on health in the Arctic and Europe owing to climate-induced changes in contaminant cycling, www.arcrisk.eu.
- Adaptation Actions for a Changing Arctic, www.amap.no/adaptation-actions-for-a-changing-arctic-part-c.

Suitable sites:
All stations within the AMAP focus area.

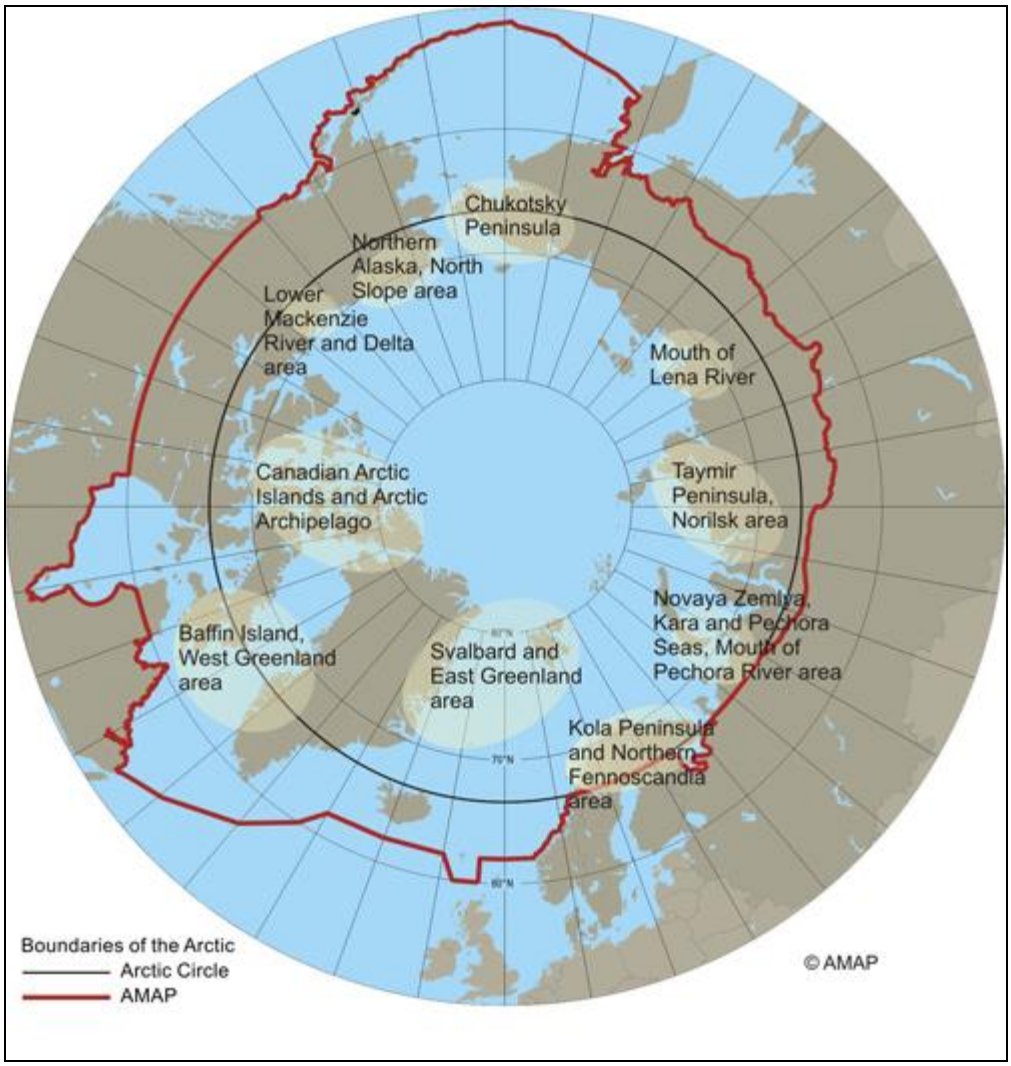
Parameters:
A list of parameters to be monitored is under development. Parameters included in assessments depend on the subject, but generally, AMAP sample parameters related to pollution, environmental impact, human health and Climate Change.

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 .

Guidelines for laboratories providing input to AMAP assessments, 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:



The AMAP boundary (www.amap.no).

WMO - World Meteorological Organisation

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

Discipline: Meteorology, Climatology, Hydrology

Keywords: Weather, Climate Change, atmosphere

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.:

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.

ICOS – Integrated Carbon Observing System

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

Disciplines: Climatology, Atmospheric chemistry, Soil science, Terrestrial biology – Ecosystem function, Limnology, Oceanography

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 behavior 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.

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

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

ICOS infrastructures; gas-flux chambers, small tower and high tower (Lars Holst Hansen/Aarhus University; Donie Bret Harte/Toolik Research Station; Andrej Sogachev/Technical University of Denmark).

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.

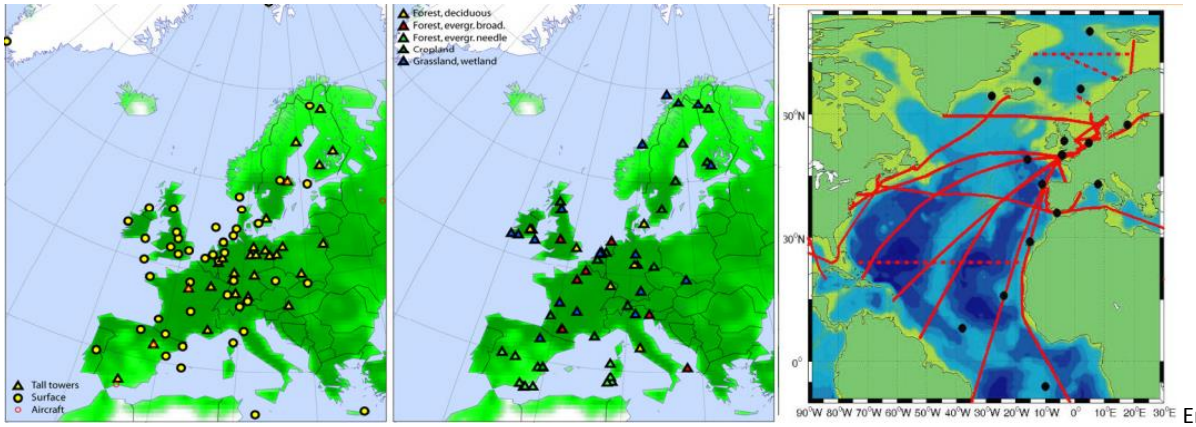
See, www.atm.helsinki.fi/icoseu/fra/docs/pub/Stakeholder_Handbook_201303.pdf for detailed list of variables for each environmental compartment.

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.atm.helsinki.fi/icoseu/fra/docs/pub/Stakeholder_Handbook_201303.pdf.

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 is currently in the transition and construction phase. An ICOS ERIC legal entity will be in place in 2014. When ICOS ERIC is operative, the practice on how to join ICOS RI may slightly change. Follow the website for updated information on how to join, www.icos-infrastructure.eu/node/10.

Geographical coverage:



Envisioned ICOS infrastructure network for atmospheric (left), terrestrial (central) and marine (right) environments (www.icos-infrastructure.eu).

InGOS - Integrated non-CO2 Greenhouse gas Observing System

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

Discipline: Terrestrial biology – Ecosystem function, Soil science, Climatology

Keywords: Greenhouse gas exchange, climate feedbacks, Climate Change, Non-CO2 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 date centre and modeling 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:
European focus, but applicable in all countries.

InGOS research infrastructure (www.ingos-infrastructure.eu/?page_id=203).

Distribution of InGOS research infrastructures (www.ingos-infrastructure.eu/?page_id=203).

CALM – Circumarctic Active Layer Monitoring (IPA/GTN-P)

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

Discipline: 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 biogeochemical 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 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 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.

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

Active layer measurement using probe (Hanne H Christiansen/UNIS)

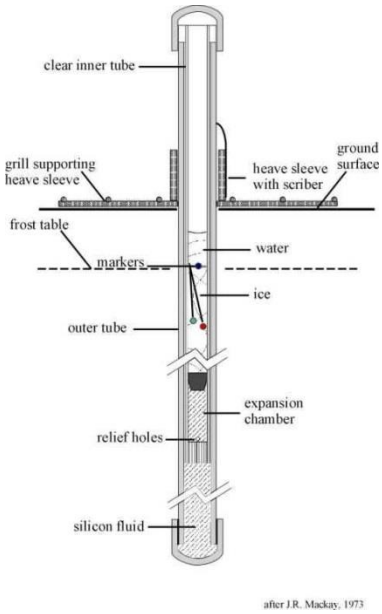
Methods for measuring active layer thickness,
www.unis.no/35_staff/staff_webpages/geology/ole_humlum/PeriglacialHandbook/ActiveLayerThicknessMethods.htm

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

Installation instructions,
www.gwu.edu/~calm/research/install.html.

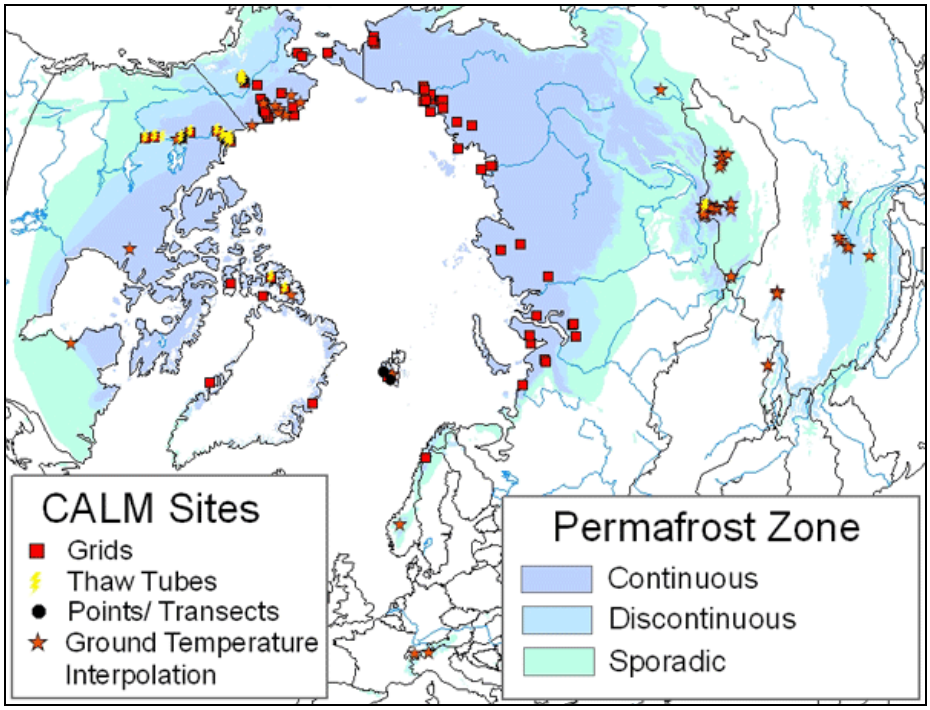
Equipment vendors,
www.gwu.edu/~calm/about/vendors.html.

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



Thaw/frost tubes are devices extending from above the ground surface through the active layer into the underlying the permafrost (www.gwu.edu/~calm).

Geographical coverage:
The CALM observational network, established in the 1990s, observes the long-term response of the active layer and near-surface permafrost to changes and variations in climate at more than 200 sites in both hemispheres. The Southern Hemisphere component (CALM-South) currently includes sites in Antarctic and South America.



CALM sites on the northern hemisphere (www.gwu.edu/~calm).

Thermal State of Permafrost (IPA/GTN-P)

Website: ipa.arcticportal.org/activities/gtn-p/tsp/15-tsp.html
Contact address: contact@ipa-permafrost.org

Discipline: 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 Circumarctic 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:

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

Borehole drilling, East Greenland (Hanne H. Christiansen/UNIS).

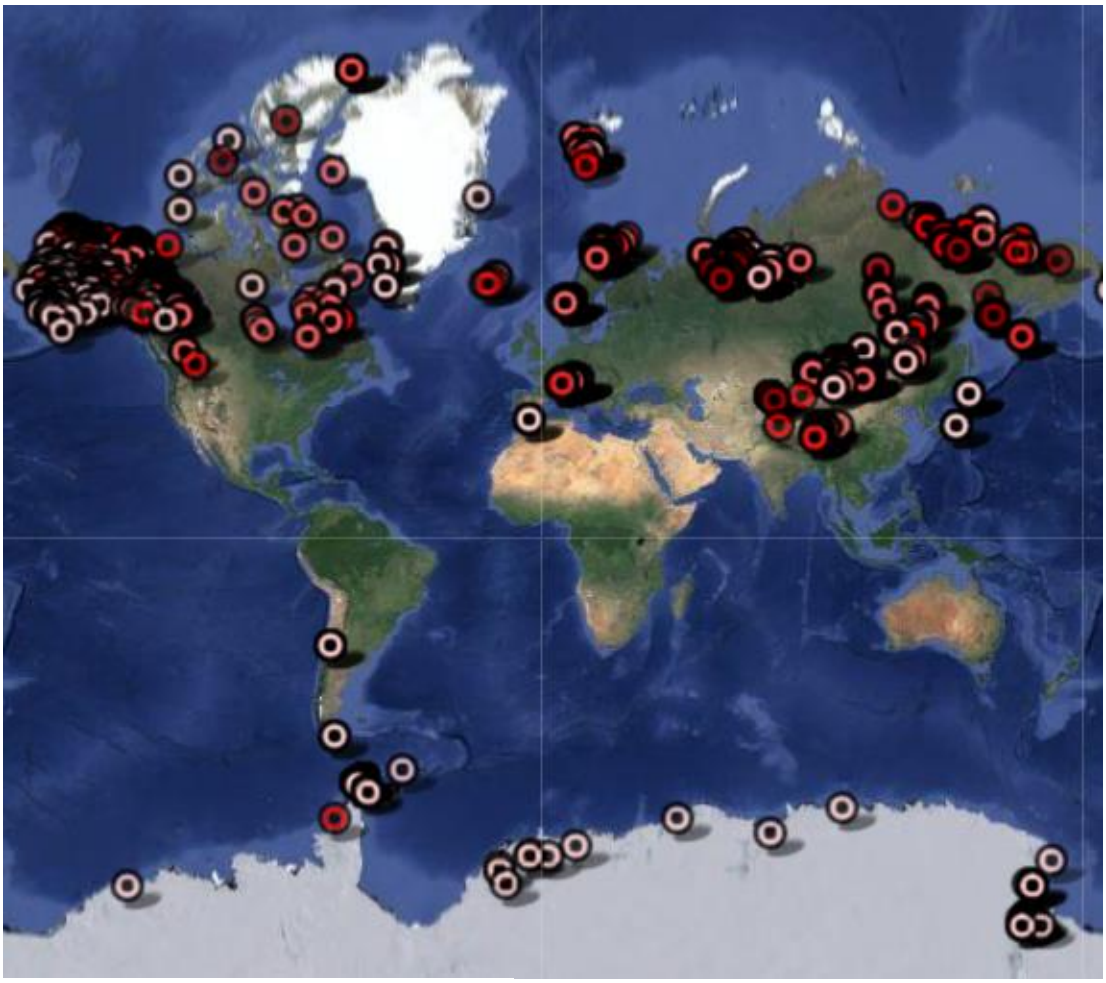
Parameters:
Permafrost borehole temperatures and associated abiotic parameters.

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:



(www.gtnpdatabase.org/pages/global-map)

GTN-G – Global Terrestrial Network for Glaciers

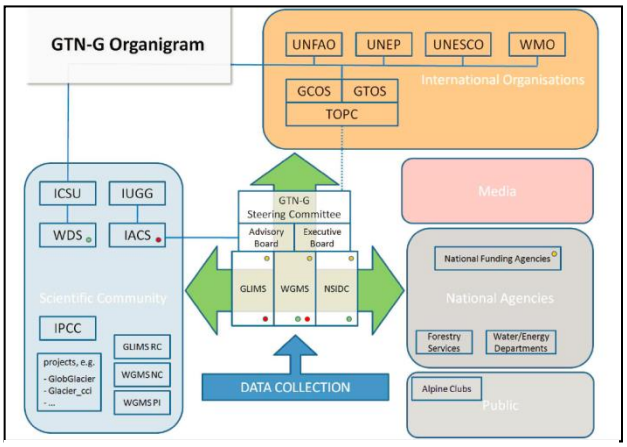
Website: www.gtn-g.org/index.html
Contact address: mail@gtn-g.org or http://www.gtn-g.org/contact.html

Discipline: Glaciology, Climatology

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).



Organisation of GTN-G (www.gtn-g.org/index.html).

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 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 World Glacier Monitoring Service (WGMS) collects standardized 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.


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

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.wgms.ch/guidelines.html.

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

Geographical coverage:
WGMS annually collects glacier data through its scientific collaboration network that is active in more than 30 countries. The highest information density is found for the Alps and Scandinavia, where long and uninterrupted records are available.

Glacier near Sermilik Research Station, Greenland (Lea Hansen/University of Copenhagen).

Glacier near CEN Bylot Island Field Station (Gilles Gauthier/CEN).

References

1) Britannica Online Encyclopedia, retrieved on November 03, 2014. http://global.britannica.com

2) Merriam-Webster, Incorporated, retrieved on November 03, 2014. http://www.merriam-webster.com/dictionary

3) Wikipedia the free encyclopedia, retrieved 03 November 2014. http://en.wikipedia.org/wiki

4) University of Waterloo, Faculty of Science, retrieved 03 November, 2014. http://www.science.uwaterloo.ca/~cchieh/cact/applychem/atmosphere.html

5) Oxford English Dictionary Online. Oxford University Press. Retrieved 9 November 2014. http://www.oed.com

6) The Free dictionary, by Farlex, retrieved 09 November 2014. http://encyclopedia2.thefreedictionary.com

7) A Dictionary of Earth Sciences. 3rd Edition (2008). Ed. Allaby, M. OXFORD University Press.

8) Lo, C.P. and Yeung, A.K.W., "Concepts and techniques of Geographic Information Systems". 2nd edition. PH Series in Geographic Information Science. Pearson Education Inc. 2007.

9) Soil Science Society of America, retrieved 11 December 2014. www.soils.org

10) Convention on Biological Diversity, retrieved 11 December 2014. www.cbd.int/convention/articles/default.shtml?a=cbd-02

11) United Nations Environment Programme, retrieved 11 December 2014. http://www.unep.org

Appendices

Appendix 2.1. 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	Optional info: the project short title
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)	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.
PI* full name	Full name of 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	Optional info: 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 - WGS 84 (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.

Continuation of Appendix 2.1. The metadata template for both research and monitoring projects, that INTERACT station managers agreed to follow and recommend for implementation at all stations.

Study location (WGS84) decimal degrees - Longitude	The W/E location should be given in decimal degrees using World Geodetic System - WGS 84 (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.
Optional: Study location (local site name)	Optional info: 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 ",". 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 spread 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	Optional info: project web link (if more than one link: separate by ",").
Optional: Project members	Optional info: project members names, separate by ",".
Optional: Short project description	Optional info: short description/link to the description of the project.
Optional: Research methodology	Optional info: short description of research methodology and instrumentation.
Optional: Publications	Optional info: reference information and/or link to the publications (if more than one link: separate by ",").
Optional: Web link to the raw data file	Optional info: links to raw data files (if more than one link: separate by ",").
Optional: Funding agency/ donor	Optional info: full name of the funding agency/private donor (if more than one: separate by ",").
Optional: Grant number/ID	Optional info: grant number/ID (if more than one: separate by ",").
Optional: Institution project ID	Optional info: the project ID used at the research institution (if more than one: separate by ",").

*** PI = Principal Investigator**

Appendix 2.2. INTERACT template for monitored paramaters

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 INTEACT.	
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 scrol 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 meatadata sheet for monitoring projects). If more than one monitoring project monitor a parameter group, please use the additional columns.

Appendix 2.3. Parameters for the "*Climate*" discipline.

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

Appendix 2.4. Parameters for the "*Geo*" discipline.

Category	Parameter
Geology/geomorphology	Quaternary geology
	Sedimentology
	Bedrock geology
	Erosion
Geophysics and geodesy	Gravity
	Magnetic field
	Aurora
	Seismic activity
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
Snow characteristics	Snow depth
	Snow cover
	Snow density
	Snow temperature
Atmospheric composition	CO_2 concentration
	CH_4 concentration
Greenhouse gas exchange	CO_2 exchange
	CH_4 exchange
	N_2O exchange
Energy budget	Net radiation
	Sensible heat flux
	Latent heat flux
	Soil heat flux
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
Pollution	In air
	In water
	In soil
	In snow/ice
	Other

Appendix 2.5. Parameters for the "*Glacier*" discipline.

Category	Variable
Glacier characteristis	Glacier area
	Topography
	Elevation change
	Terminus position
	Ice velocity
	Ice thickness
	Debris cover
	Surface albedo/reflexion coefficient
Mass balance	Mass balance
	Snow water equivalent
	Snowcover stratigraphy
	Equilibrium Line Altitude
	Duration of snow cover
	Calving flux
Climate	Climate measurements
	Energy balance
Glacier hydrology	Run-off
	Supra-, en- and subglacial drainage system
	Meltwater retention
	Glacial lake outburst floods
Other	Biogeochemistry of snow, ice and water
	Microbiology of snow, ice and water
	Particles and aerosols
	Pollutants e.g. POPs and heavy metals, in snow, ice and water
	Isotope chemistry of snow, ice and water

Appendix 2.6. Parameters for the "*Bio*" discipline.

Category	Parameters
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)
Arthropods	Abundance
	Emergence phenology
	Insect herbivory
	Species list (community composition)
Birds	Abundance
	Distribution
	Phenology
	Breeding birds
	Nest initiation phenology
	Nest predation rates
	Species list (community composition)
Mammals	Mammal abundance
	Mammal distribution
	Mammal reproduction
	Mortality
	Predation
	Physiology
	Species list (community composition)
Lake ecology	Phytoplankton (chlorophyll?)
	Zooplankton
	Vegetation
	Fish
	Invertebrates
	Species list (community composition)
Microbiology	Interstitial fauna
	Species list (community composition)
Genetics	Collection of animal tissue
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)
Diseases	Mammals
	Birds

	Fish
	Vegetation
	Other
Parasites	Mammals
	Birds
	Fish
	Vegetation
	Other
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.)

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 presents an overview of scientific disciplines and monitored parameter groups, provides recommendations for a minimum monitoring programme and describes best practices for monitoring selected parameters through established scientific networks and programmes.

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