International Permafrost Association

GTN-P

Global Terrestrial Network for Permafrost

STRATEGY AND IMPLEMENTATION PLAN 2016 - 2020

For the Global Terrestrial Network for Permafrost (GTN-P)

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WMO

United Nations Educational, Scientific and Cultural Organization
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Table of Contents

SUMMARY

Permafrost is recognized as Essential Climate Variable (ECV) within the Global Climate Observing System of UN and ICSU organisations. The Global Terrestrial Network for Permafrost (GTN-P) is the primary international programme concerned with long-term monitoring of permafrost. The core mission of the GTN-P is sustained comprehensive long-term monitoring network, in order to provide consistent, representative and high quality standardized long-term data series of selected permafrost parameters at key sites and to assess their state and changes over time. The Strategy and Implementation Plan 2016-2020 outlines recent progress and future challenges facing the network. It describes the governance and management structure of GTN-P, linkages to regional and global observing systems, management process and reporting strategies. It presents measurement methods and protocols used in field data collection and state of the art data management system, which was recently designed and implemented to process, analyse, and visualize permafrost data. It concludes with the outlook of the future developments of the network in order to sustain and succeed its core mission of providing long-term observations and maintain the availability of data collected.



ACKNOWLEDGEMENTS

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1.1 Introduction

Permafrost is recognized as Essential Climate Variable (ECV) within the Global Climate Observing System of UN and ICSU organisations.

The Global Terrestrial Network for Permafrost (GTN-P) is the primary international programme concerned with sustained long-term monitoring of permafrost. Permafrost is soil, rock, and any other subsurface earth material that exists at or below 0°C throughout at least two consecutive years, usually for decades up to tens and hundreds of millennia. Permafrost conditions can affect depths of tens of meters up to more than a kilometre and affect many natural processes and human activities in cold regions at high latitudes and high altitudes (Figure 1). Overlying the permafrost is the active layer, which thaws during the summer and refreezes the following winter. Thermal conditions and active layer processes are robust indicators of the state of the permafrost system under climate change.

The main purpose of the GTN-P is to **operate a sustained comprehensive long-term monitoring network, in order to provide consistent, representative and high quality standardized long-term data series of selected permafrost parameters at key sites and to assess their state and changes over time**.

The data collected within the GTN-P provide essential information to help understanding the ecosystem processes, including potential release of GHGs from permafrost, to develop and validate numerical models, to produce maps of present permafrost extent, and to develop scenarios of its evolution over time. These data are also used to validate permafrost modules in Earth System Models, and help to refine the adaptation and mitigation strategies of the UNFCCC.

GTN-P also aims provide answers to socio-economical issues relevant to the populations living in permafrost areas and beyond, through the provision of key information for land management and planning decisions including those related to resource development and development of strategies to adapt and mitigate climate change in permafrost areas.

The Strategy and Implementation Plan 2020 (SIP 2020) briefly outlines the historical developments, the current status and future directions of the GTN-P. This document replaces the SIP 2012-2016 (GTN-P, 2012).

The specific objectives of the present plan are:

- To provide a comprehensive strategy and vision for the role, mandate and mission of GTN-P until 2020 and beyond.
- To ensure that the adequate governance and capacity is in place in order to implement this strategy.

1.2 Historical Development

GTN-P was developed in the 1990s by the Terrestrial Observation Panel for Climate (TOPC) and implemented by the International Permafrost Association (IPA) under the Global Terrestrial Observing System (GTOS) as part of the Global Climate Observing System (GCOS) in support of UNFCCC, with the long-term goal of obtaining a comprehensive view of the spatial structure, trends, and variability of changes in permafrost conditions worldwide (Brown *et al.*, 2000; Burgess *et al.*, 2000). Presently, the two major components of GTN-P are: (a) long-term monitoring of the thermal state of permafrost in an extensive borehole network, the **Thermal State of Permafrost - TSP**; and (b) monitoring of the **Active-layer thickness and dynamics - ALT**. These components have been implemented through partial networks coordinated by the International Permafrost Association (IPA) since their establishment.

The TSP database was originally hosted at the Geological Survey of Canada (GSC) in Ottawa. The TSP observatories in the United States and Russia have been supported by the US National Science Foundation and managed by the Permafrost Laboratory at the University of Alaska Fairbanks. Program description, measurement protocols and data are available at the TSP website www.permafrostwatch.org. The Circumpolar Active Layer Monitoring (CALM) programme, the largest international programme concerned with monitoring of ALT, was established in 1991 and initially affiliated with the International Tundra Experiment (ITEX). Through US NSF funding CALM has had operational bases at Rutgers University (1991-94), the State University of New York (1994-97) the University of Cincinnati (1998-2003), the University of Delaware (2003-09), and is currently headquartered at the George Washington University. Long-term support for data collection in Alaska and Russia has been provided by the U.S. National Science Foundation, and data from all CALM sites are available through a dedicated CALM web site (www.gwu.edu/~calm). Data from TSP and CALM are partially available from the National Snow and Ice Data Center in Boulder, Colorado (NSIDC), and Advanced Cooperative Arctic Data and Information Service (ACADIS), and NSF Arctic Data Center, reflecting NSF efforts to provide data archival, preservation and access for all projects funded by NSF's Arctic Science Program. U.S. Geological Survey (USGS) has established an array of climate-monitoring stations in Arctic Alaska as part of the U.S. Department of the Interior/Global Terrestrial Network for Permafrost (DOI/GTN-P) Observing System in 1998 (Urban and Clow, 2017) and continues temperature monitoring of the DOI/GTN-P Deep Borehole Array with some sites dating back to 1973 (Clow, 2014). From the very beginning, efforts had been made within the IPA to include permafrost in rugged mountain topography at lower latitudes/higher altitudes (Haeberli et al. 1993, 1998). Particularly, the EU-PACE project, systematically established a series of 100 m deep boreholes for long-term observation of permafrost thermal conditions along a continental-scale longitudinal transect from Svalbard through Scandinavia and the Aps to the Sierra Nevada in Spain (Harris et al. 2001, 2003).

During the International Polar Year 2007-08 (IPY) the IPA coordinated and strengthened the collection of standardized permafrost temperature data in the TSP project focussing on obtaining a first global snapshot. A borehole inventory of mean annual ground temperatures for 600 boreholes (snapshot) from all permafrost areas, including high-altitude locations outside the polar regions, became available online in ISO-compliant format at the National Snow and Ice Data Center (NSIDC). Synthesis papers were published at the end of the International Polar Year (IPY) in a special issue of the journal *Permafrost and Periglacial Processes* (e.g. Smith et al. 2010, Romanovsky et al. 2010 a, b, Christiansen et al. 2010, Vieira et al. 2010, and Brown, 2010); followed by an IPY legacy permafrost observatory report (Brown and Christiansen, 2011). The progress of the CALM program is summarised in Shiklomanov et al. (2008, 2012) and CALM special issues in *Polar Geography* in 2000 (Brown et al., 2000) and *Permafrost and Periglacial Processes* in 2004 (e.g. Nelson et al, 2004) with another special issue in progress for publication in *Polar Geography* in 2018.

The continued involvement of individual permafrost scientists and relevant stakeholders is assured through their participation in **GTN-P meetings and workshops.** The first of these workshops was held in the Fall of 2011 and was followed by three technical workshops in February, September and November 2012**.** The workshops, partially funded by the PAGE21 project, helped summarize the needs and technical requirements of GTN-P data providers and users. These include field scientists, modellers, ecologists, engineers, other scientific communities, observing networks, lecturers, students, the general public, and policy-makers. The first workshop focussed on the technical needs required for scientists and modellers to form the scientific basis for the data portal, which will offer outlets for the general public and policy-makers.

The First GTN-P Strategy and Implementation Plan was produced in 2012 (GTN-P, 2012). The document outlined the governance structure of the network, defined roles and responsibilities of the National Correspondents (NC), Executive Committee (later renamed to Steering Committee, SC) and Advisory Board (AB). The governance structure was put in place in the Spring 2013. The first meeting of the NCs was held at the WMO Headquarters in Geneva in early May 2013. Of the 25 countries formally included in the GTN-P, 18 countries were represented. The second meeting took place in Quebec in September 2015 and largely focused on developing data standards and protocols and was attended by 28 participants from 16 countries (Lewkowicz et al., 2016). Major progress was made to establish the GTN-P Secretariat, to improve the data management system, data policy and standards, and to increase sustainability of the GTN-P network by introducing Young National Correspondents (YNC). The YNC were formally elected during the GTN-P meeting held at the Eleventh International Conference on Permafrost (ICOP) in Potsdam Germany in June 2016. During the ICOP meeting the call for a new Strategy and Implementation Plan (SIP2020) to outline the directions of the GTN-P development over the next four years was announced. By the time of the GTN-P meeting at ICOP2016, the Data Management System (DMS) had 1357 boreholes with metadata, 485 with complete time series and 250 active layer monitoring sites with metadata and 102 with continuous annual time series (Figure 1).

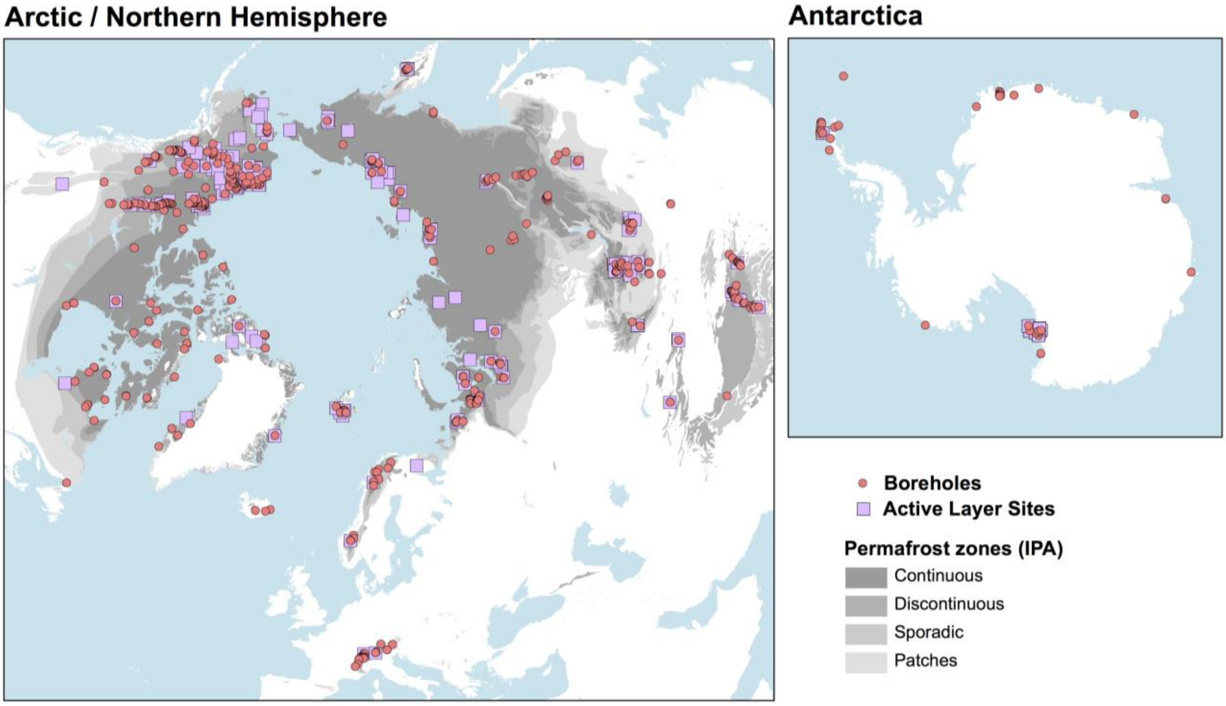


Figure 1. Location of the GTN-P monitoring sites and permafrost distribution

1.3 Current State of the Network

The GTN-P made a considerable progress from a grass roots organization towards a structured and operational GCOS entity. The GTN-P core group that formed during the EU project PAGE21 (2011-2015) was able to successfully establish a governance structure and establish a functional body that provided the current baseline network of people for the Permafrost as an Essential Climate Variable (ECV). It is critically important to capitalize on the previous accomplishments and to secure the future and sustainability of the GTN-P network. The establishment of national or regional permafrost centres to collect, analyse and process data is critical for the continued success of the GTN-P network.

Presently, GTN-P consists of a network of 38 NCs and 17 Young NCs representing 26 partner countries. The GTN-P Secretariat, hosted by the Alfred Wegener Institute (AWI, Germany) coordinates the network activities. The Arctic Portal (AP, Iceland), maintains data management system (gtnp.arcticportal.org) and coordinates data management and dissemination. The GTN-P Data Management System (DMS) is based on open source code and can be mirrored in other organizations/countries to provide a language friendly interface and to comply with the country-specific data policies and regulations. The first DMS mirror was opened in Germany in June 2017. Presently, permafrost monitoring sites registered within the GTN-P Database include about 1360 boreholes and 250 active layer measurement sites, describing over 5 million individual data units (Figure 2). The GTN-P Database including a comprehensive description and metadata statistics was published by Biskaborn et al. (2015b). An empirical assessment of potential quality indices of the GTN-P data was carried out by Biskaborn et al. (2015a) based on the IPA action group program "Quality Control and Assurance of active layer thickness and permafrost temperature variables in the GTN -P Database".

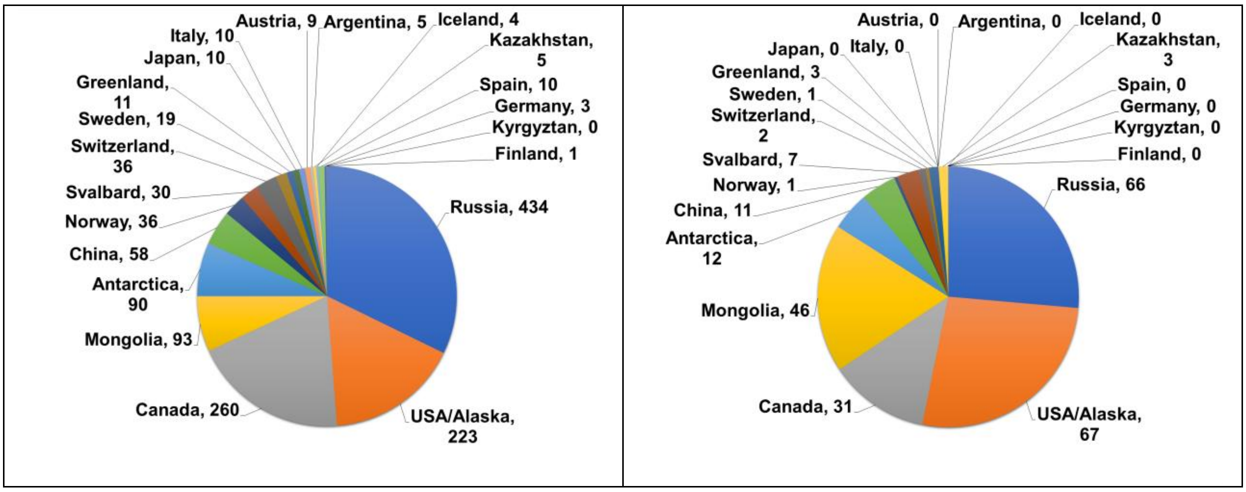


Figure 2. Number of TSP and ALT sites registered within GTN-P by participating country

1.4 Major Challenges

GTN-P *in situ* data acquisition operates on a largely voluntary basis with partial funding through private, national and internationally-sponsored programmes. National projects support local networks and observatories, such as the US Geological Survey Alaskan deep borehole network and the US National Science Foundation-supported CALM and TSP sites in Alaska and Russia, the EU PAGE21 and PACE projects, the German ESKP Program, the Russian Academy of Sciences “Evolution of Cryosphere” Program, Canadian transects supported under the Geological Survey of Canada, the Swiss Permafrost Monitoring Network PERMOS, the French Cryosphere observation network CRYOBS-CLIM, the Norwegian NORPERM data base and GEF in Mongolia, the international ANTPAS network in Antarctica, among others. **Sustaining observations requires dedicated long-term funding both on national and international level.** The establishment of national or regional permafrost centres to compile and analyse data is needed to preserve the observations in the future.

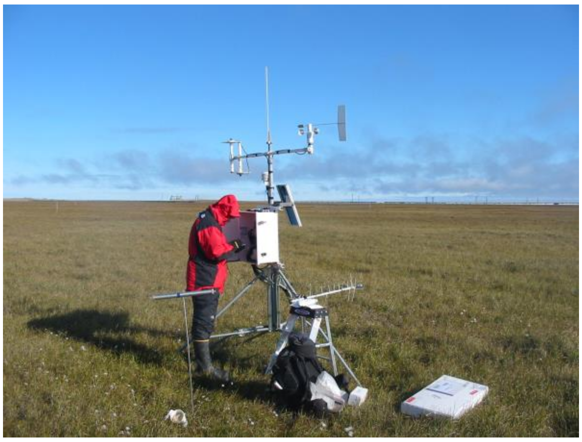
Measurement and reporting standards require further development and compliance with the international best practices, guidelines and standards, the development of which are currently being coordinated by WMO’s Global Cryosphere Watch. Upscaling techniques for research sites and permafrost networks, initially based on upgraded reference sites, are required to complement active layer and thermal observations with monitoring of active geomorphological surface processes (e.g., slope movements, thermokarst and lake development, coastal dynamics, and terrain instability).

Some of the currently inactive sites could potentially be reactivated, and measurements of soil vertical displacement and permafrost temperatures should systematically become integrative parts of active layer monitoring. GTN-P has also identified new monitoring sites needed to obtain representative coverage in the Europe/Nordic region, within the Russian Federation and within Central Asia (Mongolia, Kazakhstan, and China); in the Southern Hemisphere (South America, New Zealand, Antarctica); and in North American mountain ranges and lowlands.

While the GTN-P network is delivering products that are more and more widely used, **its capacity to secure long-term funding to sustain network activities and coordination has**

not evolved to meet research and societal needs and still largely relies on the voluntary contribution of individuals and short-term funded national research projects. At the same time expectations of monitoring, reporting, development and maintaining of standardized geospatial datasets in commonly used formats require a continuing effort for data management. The growing need for the permanent secretariat and data management personnel is essential in order to maintain the operational capacity of the network.
It is the goal of this document to outline the strategy needed to answer the needs of the community for robust long-term observations of permafrost and to propose changes to the management structure and capacity of GTN-P to complete these tasks.

2.1 Towards a permanent permafrost observing network



The role of permafrost in the Earth System and its impact on climate, infrastructure and land management has dramatically increased the awareness of the scientific community and the general public of permafrost and permafrost science. The degradation of permafrost, the resulting release of additional greenhouse gases or the long-term destabilization of icy mountain peaks worldwide are arguably among the most prominent issues in the discussion about climate change impacts. Concurrently, economic development of the Arctic and high altitude areas affected by the presence of permafrost raises critical issues related to the terrain instability and the potential natural hazards resulting from the warming and thawing of ice-rich permafrost. To assess the risks associated with changes in the thermal state of permafrost a robust permafrost observing network is needed. In recent years, several countries initiated national coordination networks for monitoring of permafrost temperatures such as the PERMOS network in Switzerland (Vonder Muehll et al. 2008, PERMOS 2016). However, most observations are still part of academic research projects and depend on the involvement and voluntary work of individual researchers (See the following selected references: Clow 2008; Etzelmuller et al. 2008; Midttomme et al. 2008; Osterkamp 2008; Romanovsky et al. 2008 a, b, 2010 a, b; Sharkhuu et al. 2008; Smith et al., 2008, 2010; Vonder Muehll et al., 2008; Zhao et al., 2010; Christiansen et al 2010, 2012; Vieira et al. 2010, Brown and Christiansen, 2011). Current activities and recent results were reported at the International Conferences on Permafrost, a special IPY issue of Permafrost and Periglacial Processes and routinely presented in “State of the Climate” report published by the American Meteorological Society (Streletskiy et al., 2017; Romanovsky et al., 2017).

The role of the GTN-P is to regularly provide information to the scientific community, policy makers, and to society on the extent, state, and evolution of permafrost, relying on its extensive and geographically representative networks of instrumented field sites and on the established well-defined measurement protocols. To do so, the GTN-P is delivering timely products relevant to the permafrost research community, to the scientific community at large, to the wider public and to policy-makers. These products include global datasets of the temperature of permafrost, active layer dynamics, and archived temperature data, with the potential to add more permafrost related data.

GTN-P shall focus on its core products and distribute them through an easily accessible and frequently updated data information system. GTN-P shall remain open to include additional permafrost related data (such as terrain deformation, changes in ice content, GHG fluxes). Also, the possibilities offered by new technologies have to be assessed and integrated when considered robust and productive.

The specific tasks of GTN-P, building on past accomplishments, shall be:

- to compile standardized data of permafrost thermal conditions and active layer evolution and to regularly publish an assessment report on these variables,
- to maintain and support a publicly available and easy to use data portal,
- to prepare a report of permafrost temperatures and active layer evolution at selected reference sites to serve national and international climate assessment reports,
- to coordinate and promote observations under the current GTN-P network,
- to stimulate the integration of new methods and new observations of permafrost, through numerical modelling, field and remote sensing methods,
- to periodically assess changes, and contribute to relevant assessments on the state of permafrost based upon its data management system.

Finally, GTN-P should be strengthened by **creating partnerships with services monitoring other ECV components** (e.g. glaciers, snow, meteorology, soils, hydrology, ecology) to co-locate monitoring sites and expand existing networks at reduced cost (e.g. as part of the CryoNet sites of the Global Cryosphere Watch). GTN-P should continue its effort to promote the **systematic permafrost monitoring,** which can be accomplished by its integration as part of official meteorological, hydrometeorological or climate stations located in permafrost regions, establishing private-governmental partnerships in key resource development areas, securing long-term research funds, and building in-situ network capacity. Concurrently, GTN-P should use these synergies to improve the representativeness of its network and seek to establish monitoring sites in under-represented ecological environments.

To address the growing needs for permafrost observations, **GTN-P shall continue to develop an effective and sustainable governance structure.** An independent supervision should involve key players in global observing, including the sponsors of GTN-P, but also international players such as SCAR, GCW, IASC and IACS. To coordinate the day-to-day operations of GTN-P, a coordinating entity shall be created and funded to the extent possible, that is, through the provision of at least **one position for the coordination** of the network (the GTN-P Secretariat) and **one position for the related data management**.

The GTN-P shall continue to rely on a **bottom-up approach associated with data submission**, through the involvement of national and young national correspondents, closely associated with the community that manages these observatories. When possible, these NCs should be closely associated with the ones of major observing systems and UN agencies (e.g. WMO). The NCs should form the backbone of the reporting process, and be closely associated with the decision-making at the GTN-P coordination level.

2.2 Governance and management structure

In order to succeed in its mission, GTN-P has established a robust governance structure capable of directing, coordinating, monitoring and reporting on the network activities (Figure 3). This structure ensures external review of activities, rapid decision-making, efficient and frequent reporting as well as an effective information flow.

The GTN-P present structure is outlined in the text and diagram below (Figure 3). The structure includes a Steering Committee, Advisory Board, a Secretariat, and National and Young National Correspondents.

Steering Committee

The Steering Committee (SC) is the governing body of the GTN-P. It meets on a regular basis via frequent online meeting conferences and in person during international and regional conferences on permafrost. The SC reviews the activities of the network, sets the directions for the future and leads the initiative for new activities in the network. The Steering Committee ensures that connections to other international bodies are well established and frequent. The SC is responsible for the coordination with the sponsors of GTN-P. The SC's decisions and performance should be reviewed and audited regularly by the Advisory Board.

The **members of the Steering Committee are chosen by the scientific community, preferably, but not necessarily, among the GTN-P NC, country members of the IPA, and the sponsors of the network,** based on a nomination process engaging the science community. Any member of the permafrost community at large can be nominated to the SC. The entire voting process can be made using online voting tools.

The Steering Committee itself shall choose the chair among its members. Members should be chosen for a four-year term, and can be re-elected for an additional term. The Steering Committee shall be made of **six members** representing a wide range of specialties involved in permafrost observations as well as specialists in data management. The presence of a young researcher, through the involvement of the Permafrost Young Researchers Network (PYRN) is a requirement. The young researcher is elected from the YNCs.

The SC shall ensure that the overarching goals of GTN-P are being pursued. It shall, annually **report on the strategy, decisions, actions and reporting of GTN-P as a whole** and in collaboration with the Secretariat communicate its report to the sponsors of the network and the IPA through the relevant publications (Permafrost and Periglacial Processes, Frozen Ground, etc.) and updates on the GTN-P webpage. The SC should compile a more comprehensive review of the GTN-P activities and structure every four years, together with the report on global permafrost state and evolution.

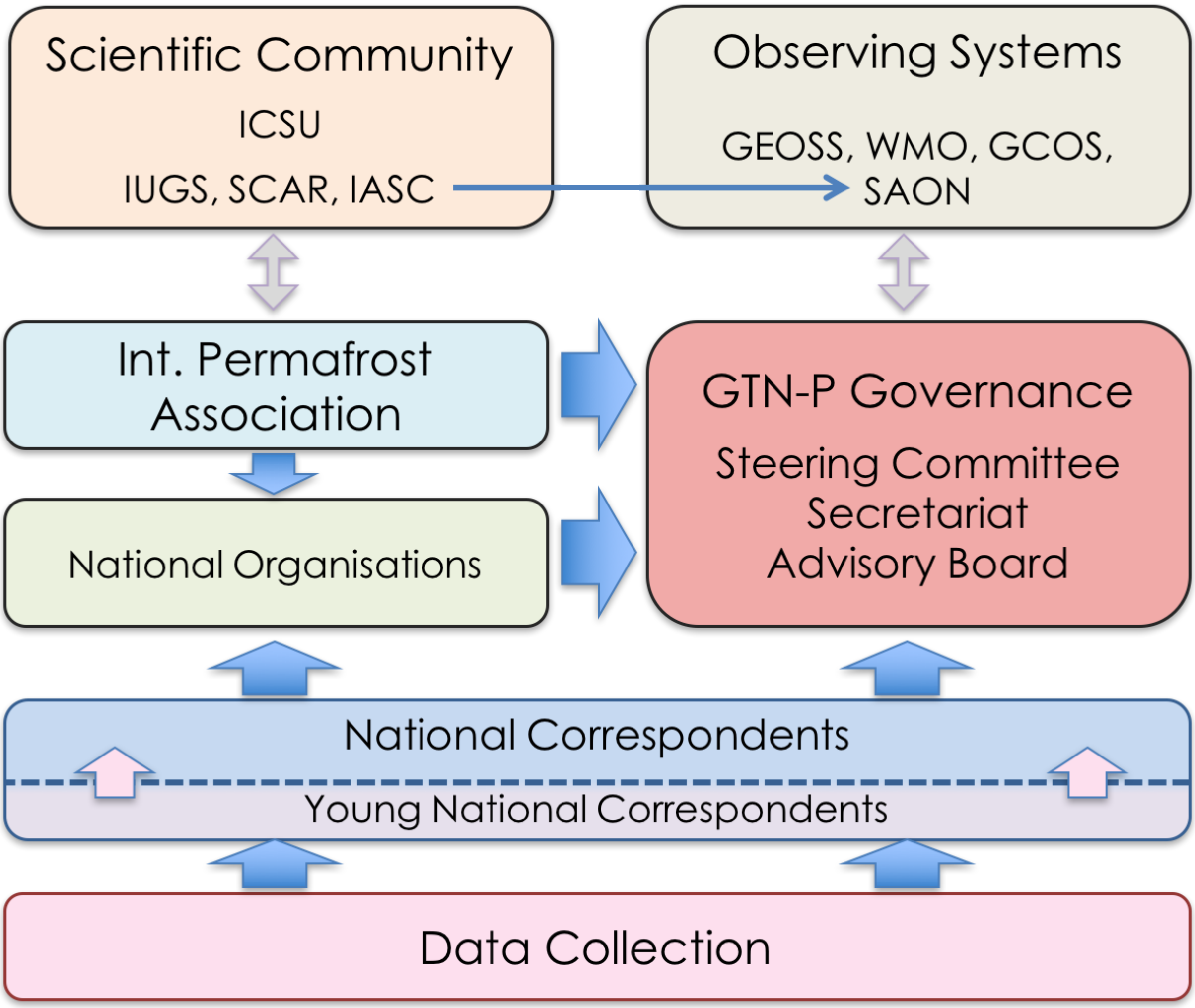


Figure 3. Governance structure and information flow for GTN-P

National and Young National Correspondents

National Correspondents (NC) shall be selected to coordinate and compile permafrost data in their own country, to interact with national institutions and funding agencies, and to build on the IPA network. In ad-hoc situations, national correspondents may also manage data outside of their own borders.

NC shall be proposed by the country, either through the IPA national Adhering Body, or through a process better adapted to the national context. In general, the nomination should be based on a consensus among the investigators involved in GTN-P activities in the country. When a structure is already in place, it should be used to nominate the correspondent. The position shall be reviewed after two years by the GTN-P Steering Committee and measures taken if replacement is deemed necessary.

NC shall foster the implementation of the GTN-P strategy in their country. This may include the building and improving structure of a national network, as well as the coordination of monitoring activity and data submission in the country.

NC shall be responsible for stimulating and coordinating the compilation of data and reporting by the individual investigators to the Data Management System of the GTN-P. NC can take added responsibility and directly report the data in their country. Their major responsibility is providing updates on monitoring data at least once a year.

NC shall maintain close contacts with relevant institutions and funding agencies in their country and the IPA, and national focal points of related international entities (IASC, GCOS, GCW etc.). These contacts will enable the emergence of an operational framework for the collection and reporting of permafrost data in the country (in the way e.g. PERMOS is operational in Switzerland) and help in reaching out to the whole community of permafrost researchers in that country.

Young National Correspondents shall be nominated by the NC after the review of all the candidates and approved by the SC. YNC should be members of PYRN at the time of nomination. YNC should work closely with the NC to promote GTN-P on the national level, inform peers about the network and be actively involved in the data collection and submission to the GTN-P DMS. GTN-P YNC is expected to attend GTN-P workshops and events closely related to the GTN-P mission, such as national and international conferences on permafrost, and contribute to GTN-P reports and publications. It is expected that GTN-P YNC at the time of appointment attend a higher education institute or work at an organization located in the corresponding country represented, and be closely familiar with GTN-P activities within the corresponding country.

GTN-P Advisory Board

The Advisory Board (AB) is the body that provides non-binding strategic advice and scientific expertise to the management of GTN-P. The SC, the IPA Steering Committee and the GTN-P Secretariat jointly nominate representatives to the AB. It will serve for four-year renewable terms, and will normally communicate electronically. The AB advises the GTN-P, GCOS and IPA initiatives concerning present practice and future developments on the monitoring of permafrost, and on the delivery of datasets to the wider permafrost community. It evaluates the work of the SC the Secretariat on approximately four-year intervals. The Chair of SC is responsible for insuring that assessment is taking place in transparent and timely manner and ensures that appropriate actions are taken to improve GTN-P operations based on AB recommendations.

GTN-P Secretariat

The **GTN-P Secretariat** shall be responsible to conduct, under the general direction of the SC, the current business of the GTN-P, the data management including, the collection and redistribution of data, the periodic reporting and release of products for GTN-P, the coordination with other organizations, education and outreach activities.

The Secretariat of GTN-P shall be staffed with at least one position (Scientist-level position), and shall be reviewed on a four-year basis by the SC. It shall handle **the financial management of GTN-P** and anticipate funding cycles by conducting an active fundraising strategy. The Secretariat shall support the data management efforts of GTN-P by providing a **central platform for communication**, acting as a focal point of contact for national organizations and national contacts and maintaining strong ties to the IPA. The current secretariat was originally funded by the PAGE21 EU project in 2012 and is based in the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Germany. AWI is committed to support the Secretariat till 2018. Further support is needed to expand and strengthen the network and move forward with the dissemination strategy after May 2018.

The Secretariat is responsible for the integration, standardization, formatting, archiving and publishing of the GTN-P data. The technical and structural implementation of the Data Management framework is described in detail in the following section.

The Secretariat shall report as a minimum annually on GTN-P activities and produce policy-relevant bulletins on GTN-P outputs under the leadership and in close communication with the SC and key experts. It shall foster the network by **publicizing its efforts and outputs widely to all kind of audiences** including the scientific community, the general public, funding agencies and policy-makers at national and international levels.

The Secretariat shall ensure that GTN-P is embedded in existing observing activities at the international and national levels and aligns its processes with their activities and frameworks. The Secretariat shall also **pursue active linkages with relevant international organisations.** This includes seeking the future inclusion of GTN-P observing activities in WMO.

The GTN-P representatives are shown on the diagram below (Figure 4). The full list of national and young national correspondents is available in Appendix.

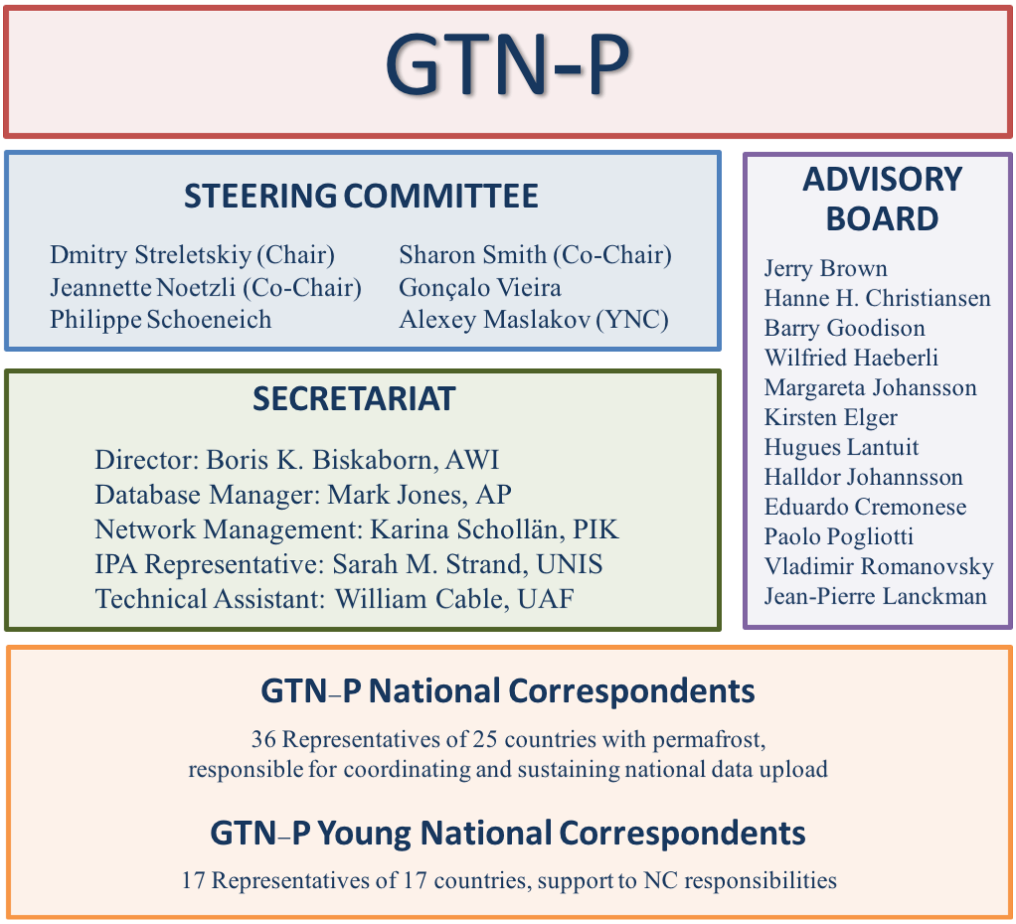


Figure 4. Governance structure of the network as of September 2017.

2.3 Linkages to regional and global observing systems

Global Observing Systems

GTN-P shall act in close collaboration with GCOS to ensure that the framework proposed in this document is implemented and is being carefully embedded in existing observational strategies and systems. In particular, GTN-P shall coordinate, whenever possible, the location of its sites close to the ones of existing global systems and follow the Global Hierarchical Observing Strategy (GHOST) and the Integrated Global Observing Strategy (IGOS) recommendations in order to bridge the gap between detailed local investigations and representative global coverage (e.g. Harris et all. 2001).

Regional and thematic observing systems

GTN-P shall acknowledge the very specific nature of its focus on the cryosphere and cooperate actively with the existing initiatives in this realm, such as GTN-G. In particular, GTN-P should seek to encourage the efforts of the Global Cryosphere Watch Initiative (GCW) of WMO and the Sustaining Arctic Observing Networks (SAON) initiative of the International Arctic Science Committee (IASC). GTN-P shall seek to become a founding partner of these networks and systems, and adapt its efforts to feed its data products to these activities. GTN-P strongly encourages the national or regional coordination of permafrost monitoring activities through the networking of its national correspondents and/or the building of regional, national and international structures (e.g. ANTPAS, PERMOS).

2.4 Process Management and Reporting

The timely reporting of permafrost data in GTN-P is based on an efficient information flow, relying on the input of field investigators through the activities of the NV and YNC. The overall information flow, encompassing both data collection and reporting is described in the organogram shown in Figure 4, Section 2.2.

NC are requested by the SC to inform national colleagues of the standards, protocols and reporting formats associated with the submission of data. **They will annually ensure that local collaborators submit their data** either (1) into a national/regional database when applicable, (2) to the NC or (3) directly to the GTN-P DMS. To do so, National Correspondents will be provided by the Secretariat with documents describing the protocols and reporting formats supported by GTN-P.

GTN-P shall conduct a proactive publication strategy, including **the regular publication of standardized data on permafrost temperature and active layer evolution for selected sites.** This publication shall characterize the spatial and temporal variability of these variables. The data used in this publication shall also feed into periodic international reports such the BAMS State of the Climate annual report (Streletskiy et al., 2017; Romanovsky et al., 2017), the Arctic Report Card (http://www.arctic.noaa.gov/reportcard/), and major global or regional climate assessments.

Although GTN-P's primary audience is the scientific community, it shall strive to make its science understandable to the public and to interact on a regular basis with the media and the public. To do so, it shall publish its regular bulletins in a short, illustrated and understandable format and distribute them widely. The goal of GTN-P will be to deliver relevant, and understandable products to a wide range of stakeholders. The GTN-P Secretariat shall also strive to publicize the network through presentations and involvements in outreach events. Finally, the data shall be continued to be accessible online through the GTN-P DMS in a user-friendly interface, ensuring compliance with scientific and technical standards, by putting the accessibility of the site for the general public at the forefront.

2.5 Measurement methods, protocols and standards

Permafrost has been identified by GCOS as an Essential Climate Variable (ECV). The following section is largely based on the Assessment of the status of the development of the standards for the Terrestrial Essential Climate Variables - T7 - Permafrost and seasonally frozen ground (Smith and Brown, 2009). It gives a summary of existing and most used standards.

Definitions:

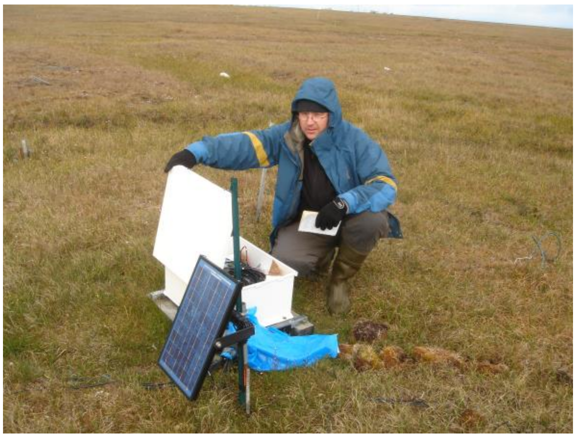
Permafrost: Permafrost is subsurface earth materials that remain continuously at or below 0°C throughout at least two consecutive years, usually for extended time periods up to many millennia.

Active Layer: The surface layer of the ground, subject to annual thawing and freezing in areas underlain by permafrost.

Variables and Units of Measure

Thermal State of Permafrost (TSP) - Ground temperatures measured at specified depths (°C).
Active Layer Thickness and Dynamics (ALT) - Thickness of seasonally thawed soils measured in (cm), surface displacements measured in (cm).

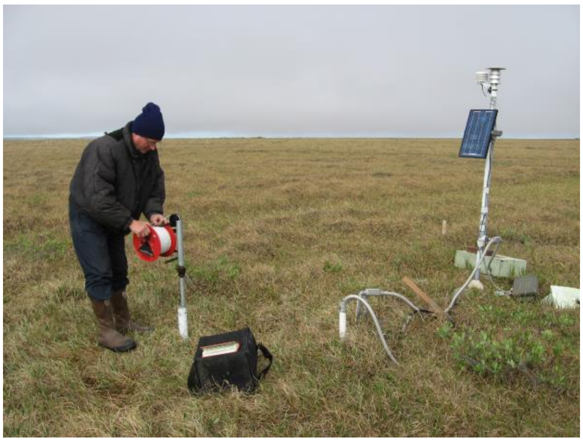
Thermal State of Permafrost (TSP)



Permafrost temperatures define the thermal state of permafrost and are obtained in boreholes. The depth of boreholes varies from less than 10 m to greater than 100 m. It is advisable to drill permafrost boreholes with air cooling in order to have least disturbance of the ground ice, and to install a casing and a covering structure at the surface to limit the air convection. Temperature measurements in boreholes may be recorded manually with a portable temperature logging system or continuously by data loggers. The accuracy and resolution of the sensors and measurement varies but it is advisable for accuracy to be ±0.1°C or better. Thermistor strings should be periodically retrieved from the boreholes for recalibration and essential maintenance.

At shallower depths, generally less than 15 m, ground temperatures experience an annual temperature cycle and it is desirable to have several measurements throughout the year, at a minimum spring and fall. At depths below the penetration of the annual temperature wave (depth of zero annual amplitude), and up to depths of about 50 m, annual temperature measurements are sufficient. At greater depths where temperatures change slowly, biennial or less frequent (5-10 years) measurements are sufficient. Data loggers may be utilized for repetitive hourly measurements. They reduce the number of site visits, provide a continuous record of ground temperatures and can be accessed remotely for (near) real time data. Spacing of sensors on thermistor chains (or the spacing of measurements if single sensor used) generally increases with depth. For example, in the upper 5 to 10 m, sensor spacing of 0.5 to 1 m can adequately define the shallow thermal regime while spacing may increase to 5 to 10 m or more at depths greater than 20 m. Within the EU Project PACE a standard for the thermistor spacing for a 100 m borehole was defined (Harris et al. 2001): 0.2, 0.4, 0.8, 1.2, 1.6, 2, 2.5, 3, 3.5, 4, 5, 7, 9, 10, 11, 13, 15, 20, 25, 30, 40, 50, 60, 70, 80, 85, 90, 95, 97.5 and 100 m. Adaptation to site specific characteristics may however be required when knowledge

on the subsurface characteristics is available. In coarse blocky surfaces (rock glaciers) measurements above ca. 1 m depth may not be useful due to the often unclear definition of the actual surface. The minimum desirable thermistor spacing for continuous data measurements using data loggers (e.g. 4-hourly measurements) for boreholes less than 15 m deep: 3,5,10 m and at the bottom of the borehole. For boreholes deeper that 15 m: 5, 10, 15 m and the maximum depth of borehole. In the absence of data loggers, the maximum and minimum annual temperature at each depth above the level of zero amplitude can be utilized to characterize the ground thermal regime. Other derived parameters that are determined are the mean ground temperature at each depth and the depth of zero annual amplitude. Where deeper temperatures are available, the base of the permafrost can also be determined. This may be done through interpolation between sensors if temperatures are measured below the base of permafrost. For a detailed discussion of high precision temperature measurements, the reader is directed to Clow (2008). In mountain permafrost the distortion of the profile due to complex topography commonly requires modelling below the deepest sensor in order to determine permafrost base.



Active Layer Thickness and Dynamics (ALT)

At most active layer monitoring sites, the maximum thaw depth (thickness of the active layer) is determined. However seasonal progression of the active layer may also be monitored at sites of intensive investigations for process understanding. Several traditional methods reviewed by Nelson and Hinkel (2003) are used to determine the seasonal and long-term changes in thickness of the active layer: mechanical probing once annually, frost (or thaw) tubes and interpolation of ground temperatures obtained by data loggers. The Circumpolar Active Layer Monitoring CALM program's flexibility with respect to sampling design has led to significant insights into active-layer behaviour through formal field experiments (e.g, Nelson et al., 1999; Mazhitova and Kaverin, 2007). See website for more details and measurement protocols (http://www.gwu.edu/~calm/).

Mechanical Probing

The minimum observation required is a late season measurement of the thickness of the active layer. However, additional observations on soil, vegetation and climate parameters are encouraged. Time of probing varies with location, ranging from mid-August to mid-September in the Northern Hemisphere, when thaw depths are near their end-of-season maximum. Probing utilizes a graduated metal (e.g. stainless steel) rod, with a tapered point and handle, typically 1 cm in diameter and about 1 m long. Longer probes may be used where active layers are thicker (e.g. 1-3 m) although difficulties may arise when probing to greater depth. The probe rod is inserted into the ground to the point of resistance which is associated with a distinctive sound and contact that is apparent when ice-rich, frozen ground is encountered. All measurements are made relative to the surface; in standing water, both thaw depth and water depth are recorded. Typically, two measurements are made at each location and the average reported. If a standard spacing is maintained between the two sampling points, probing is performed within one meter of each other.

A gridded sampling design or transect allows for analysis of intra- and inter-site spatial variability (Nelson et al., 1998, 1999; Burgess et al., 2000). The size of the plots or grid and length of the transects vary depending on site geometry and design; grids range between 10, 100, and 1000 m on a side, with nodes distributed evenly at 1, 10, or 100 m spacing, respectively. The method accuracy is within 1 cm, but thaw settlement may result in underestimation of the active layer thickness by mechanical probing in regions underlain by ice-rich permafrost by (Shiklomanov et al., 2013; Streletskiy et al., 2016).

Frost/thaw tubes

When read periodically, frost tubes provide information about seasonal progression of thaw and maximum seasonal thaw. The exact vertical position of a single frost tube should be determined at the end of the first summer of active layer measurements by selecting a point representative of the mean active layer depth for the entire grid. Thaw/frost tubes are devices extending from above the ground surface through the active layer into the underlying permafrost. They are used extensively in Canada. Construction materials, design specifications, and installation instructions are available for several variants of the basic principle (Rickard and Brown, 1972; Mackay, 1973; Nixon, 2000). A rigid outer tube is anchored in permafrost, and serves as a vertically stable reference; an inner, flexible tube is filled with water or sand containing dye. The approximate position of the thawed active layer is indicated by the presence of ice in the tube, or by the boundary of the colourless sand that corresponds to the adjacent frozen soil. Each summer the thaw depth, surface level, and maximum heave or subsidence is measured relative to the immobile outer tube. These measurements are used to derive two values for the preceding summer: (1) the maximum thaw penetration, independent of the ground surface and corrected to a standard height above the ground established during installation; and (2) the active layer thickness, assumed to coincide with maximum surface subsidence. With modifications, the accuracy of the measurements is about 2 cm.

Ground temperature profiles

Ground and air temperature are recorded as basic information at many sites, especially with the increasing availability of inexpensive, reliable temperature data loggers. Temperature sensors (usually thermistors) are inserted into the active layer and upper permafrost as a vertical array. Several installations currently use an array of thermistors embedded in a small-diameter acrylic cylinder and connected to a high-capacity data logger. Soil temperature should be recorded at approximately one - to three-hour intervals, measured at a sensor interval of 15 cm, and on a seasonal basis to determine maximum thaw penetration or additionally on an annual basis to establish mean annual soil temperatures.

Temperature records from a vertical array of sensors can be used to determine active-layer thickness at a point location, e.g. boreholes (see TSP above). For mountain areas, where permafrost is typically found in coarse blocky areas or bedrock, this is the only applicable method to determine ALT. The thickness of the active layer is estimated using the highest temperatures recorded at the uppermost thermistor in the permafrost and the lowermost thermistor in the active layer. The temperature records from the two sensors are interpolated to estimate maximum thaw depth (0°C) during any given year. For this reason, the probe spacing, data collection interval, and interpolation method are crucial parameters in assessing the accuracy and precision of the estimate (Riseborough, 2008). The uncertainty of the modern ground temperature measurements can be as low as 0.02–0.05 °C, so probe spacing becomes more critical in interpolation process. Freeze-thaw processes periodically act to "jack" the instrument vertically out of its original position, which may result in biases over the long-term periods (Urban and Clow, 2017).

Metadata and Ancillary Data

Metadata describing the observation sites are an important part of the GTN-P and should be based on existing ISO geospatial standards (ISO19115) in addition to collecting (when feasible) information on the surrounding environment such vegetation, soil type, stratigraphy, geomorphology and geology.

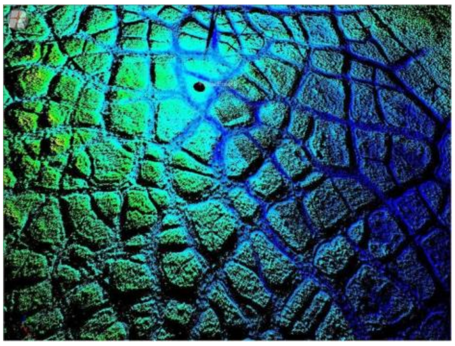
Other data may be collected at monitoring sites to support the interpretation of active layer and permafrost temperature data and to characterize the relationship between permafrost conditions and climate or local factors. Air temperature and snow depth are often measured at monitoring sites as well as other climatic data in order to better characterize microclimate. Soil moisture content may also be measured as it is an important factor determining the thermal behaviour of the ground and is a recognised ECV. Changes in ice content are detectable by geophysical methods (Hilbich et al. 2008, Hauck et al. 2011). Variability of thermal conditions in boreholes due to variable surface cover and topography can be captured using distributed miniature temperature loggers in the area of a borehole, which helps to assess representativeness (Vonder Mühll et al. 2008). In most cases, off-the-shelf instrumentation can be utilized to make these measurements automatically and relatively inexpensively. Presently, data are typically recorded on a data logger that can be downloaded during annual (or less frequent) visits to the site.

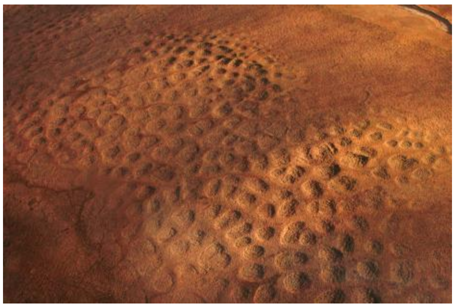
2.6. Data Management System

"Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems." This is one of the main climate monitoring principles published by GCOS. The GTN-P data management system should be centrally coordinated by the GTN-P Secretariat, which should oversee data submission, archival (complying with national metadata and data requirements), storage (centrally or by connecting to regional/national databases), and

dissemination. The GTN-P Secretariat should be the data management coordinating body responsible for overseeing its data management framework.

Datasets collected by GTN-P are primarily archived at the Arctic Portal (Iceland) and the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (Germany) as co-hosting institutions. Quality checked (and partly aggregated) data products will be regularly uploaded to a data storage facility that is a part of the ICSU World Data System. The PANGAEA Earth Data Publisher is a solid candidate to take on that role, as it is a part of the new ICSU World Data System, and hosts already the metadata on boreholes and active layer sites. Their relational database system enables it to link data author ID's to GTN-P borehole ID's and related datasets. **GTN-P should work towards strengthening the role of the Arctic Portal, the Alfred Wegener Institute and PANGAEA as technical database designer, scientific data manager, and international repository of permafrost data**. GTN-P shall continue to build on the legacy of the Frozen Ground Data Center (FGDC), as initially located at the National Snow and Ice Data Center (NSIDC) to continue to improve the GTN-P data management strategies.





GTN-P should work actively towards the **integration of Earth observation data**, as space agencies increasingly develop concepts geared towards observation of permafrost. These new initiatives should be integrated at an early stage into GTN-P and the GTN-P data management coordination. Central coordination should ensure that synergies between the data information systems of these initiatives and the one of GTN-P are implemented early in the development process. GTN-P should also strive to provide an outlet for Earth observation data produced by space agencies for permafrost purposes by ensuring that the appropriate standards are used, but also that the wide range of audiences interested in permafrost products get access to these outputs. For example, GTN-P was deeply involved in the PERMAFROST project. PERMAFROST was funded by the European Space Agency (ESA) Data User Element (DUE) program, which is a component of the Earth Observation Envelope Program (Elger et al., 2012). Currently, GTN-P is providing validation data for the GlobPermafrost Initiative.

GTN-P should continue to work towards **sustaining a robust, and accessible information system for permafrost data**, compliant with existing international data standards, following open-access policies in line with the IPY data policy (IPY, 2008), capable of delivering data to permafrost scientists and modellers, but also to the scientific community at large, to policy-makers and the general public. This effort should be clearly articulated in existing observing initiatives to ensure that datasets are fed in a seamless manner to partner observing data information systems.

GTN-P Database Development

The GTN-P Database (GTN-P, 2015) is accessible online at http://gtnpdatabase.org or through the GTN-P website at http://www.gtnp.org. The Data Management System (DMS) was developed within the PAGE21 EU project in cooperation between the Alfred Wegener Institute (Germany) and the Arctic Portal (Iceland). The existing data portals of TSP and ALT/CALM are subdued into the new system. The GTN-P Database structure and statistics on available metadata are published in Biskaborn et al. (2015a).

The GTN-P DMS brings into global use a new range of standardization and interoperability for the *in situ* permafrost temperature and active layer data and metadata. The software uses open source technologies and is modular. Independent parts can be improved according to scientific, strategic and socio-economic user requirements.

The general framework of the GTN-P DMS is based on open source technologies following an object-oriented data model implemented with CakePHP and the database PostGIS, the spatial version of PostgreSQL. GTN-P DMS is hosted at the Arctic Portal in Akureyri, Iceland. The database distinguishes between permafrost temperatures and active layer thickness. To ensure interoperability and enable inter-database searching, metadata field names are based on a controlled vocabulary registry. The documentation of the DMS is available and regularly updated on gtnp.org (ISSN 2410-2385).

The online interface of the GTN-P Database was developed to maximize usability both for the data provider and user. Data users can access the database without an account and password and have access to (i) permafrost temperatures, (ii) annual thaw depths (ALT) and (iii) help sections. While administrators have full access, data providers cannot modify or delete data of third parties. Data not marked as “published” by the data providers are not accessible to third parties or the public. The help section provides tutorials and template files for upload and download of borehole temperature and active layer grid data as well as GTN-P maps and fact sheets.

GTN-P follows an open-access policy in line with the IPY data policy and the GEO (Group on Earth Observations) data-sharing principles. The GTN-P Steering Committee decided on a general embargo period of one year. This means that e.g. data from 2015 will be available at the earliest in 2016 in order to allow investigators the first opportunity to publish their data. For special cases, e.g., doctoral dissertations, this embargo may be extended on request. The data will be made freely available to the public and the scientific community with the belief that their wide dissemination will lead to greater understanding and new scientific insights. Before being able to download published data, users must accept the terms and conditions of the data use policy. Therein, the user is asked to contact the site PI’s prior to publication to prevent potential misuse or misinterpretation of the data.

The GTN-P Database features both (i) basic search and (ii) custom search functions. The goal of these functions is to narrow down the number of data records based on a set of criteria. While the basic search is a simple filter by manual character input, the advanced custom search allows the use of multiple search criteria to retrieve a defined list of data records from the repository. The data and metadata associated with the search results can be downloaded by the data user as compressed file packages containing standardized metadata forms in text and XML (Extensible Markup Language) and the corresponding data in CSV format. GTN-P develops tools for data analysis, processing and quality assurance, through the data model definition and a set of internal database triggers, functions and a SQL-to-NetCDF (Network Common Data Form) Python converter. Measurement frequencies and methods, sampling profiles, values and null values count, time series first and last date, time gaps, total and annual minimum, maximum, average, standard deviation and variance are systematically retrieved during the data upload. TSP data sets will be linearly interpolated at consistent 0, 1, 2, 3, 5, and 10 m borehole depths. All eligible data sets are aggregated into a NetCDF file. Conventions for CF 1.6 metadata are being designed to promote the processing and sharing of files created with the NetCDF Application Programmer Interface and provides a definitive description of the spatial and temporal properties of the data. The resulting NetCDF files will represent (i) a TSP data set in a multidimensional array representation of annual time series profiles of ground temperature, orthogonal along vertical and orthogonal along time, and (ii) a CALM data set in an orthogonal multidimensional array representation of annual times series of active layer thickness.

Standardization and interoperability of the system and its data may be accomplished at the highest level making the GTN-P DMS a perfect terrestrial network candidate for a case with GCW, ADC. Numerous improvements must be made to the DMS for establishing its full robustness and sustainability. The data submission mechanism is still heavy to maintain and not enough methodological consensus have been implemented to reach its best efficiency. Furthermore, the definition and adoption of global datasets products, quality parameters, web services and their structure are still difficult to achieve. Indeed, data science is a multidisciplinary field involving new actors in the permafrost community with an unprecedented degree of integration needed between all stakeholders at global and local level ranging from science and global systems to industries and to governmental agencies for decision making.

Outlined below is a comprehensive list of tasks and initiatives that the Data Management team should consider in the next phase.

Data Management System Infrastructure and Data Submission

The implementation of an IT infrastructure responding to increasingly complex user demands (such as ingesting and serving data efficiently, on-the-fly data processing and analytics, visualisation and web services interoperable within international data infrastructures and standards) requires constant efforts of enhancing stability, robustness, efficiency, modularity, and maintainability.

The GTN-P DMS and its staff are based at the Arctic Portal in Iceland. In order to sustain the development of the DMS a long-term cooperation with Icelandic research fund should be established. The software uses open source technologies and is modular. Independent parts can be improved according to scientific and socio-economic user requirements in order to enhance users experience and lowering maintenance. To assure sustainability and scientific usage mirroring the entire system in multiple locations is recommended, as well as maintaining of a detailed DMS documentation.

To sustain the regular and continuous data acquisition, two different submission mechanisms should be envisaged:

- Data acquisition from TSP and ALT/CALM annual monitoring campaigns, coordinated by National Correspondents.
- Data rescue from other data repositories in cooperation with the NSIDC and other data archives.

Online data submission mechanisms and data validation rules should regularly be improved as guided by user experiences and requirements.

Standards and Quality Control

The definition and adoption of a common international standard for permafrost data is a demanding process. The next GTN-P meetings and participation in international data management proposals must build a momentum for achieving interoperability of the database within GEOSS, WMO, GCW, ADC. Participation in different joining efforts (INTERACT, CODATA, ICSU, RDA) with initiatives on data integration must be a growing concern. The following keywords describe targeted topics for the following years:

- Web Services deployment and standard implementation (WIGOS versus ISO19115-3)
- Data quality and uncertainty assessment
- Products for modellers Climate and Forecast convention (CF1.7)
- Structured Technologies and Permafrost Ontologies

Datasets and Products

The GTN-P DMS encompasses the workflow of a modern monitoring network from raw data submission to distribution of data products. Due to their great heterogeneity and spatial variability, *in situ* terrestrial data are difficult to distribute on a gridded basis. As a consequence, methodological consensus and metadata standards must be continuously implemented for their management within GTN-P in order to facilitate data integration into climate research and global modelling programs. The following identify targeted topics for the next four years:

- Regular analysis and report on metadata
- Next global report on permafrost temperature change
- Potential effect of permafrost degradation on permafrost region’s infrastructure (GTN-P as the early warning system for permafrost thaw)
- NetCDF products for Earth System modelling community

3.1. Network Outlook and Long-term Sustainability

The GTN-P success would not have been possible without the substantial monetary investments and work of a large number of motivated people and critical organizations. The network was created essentially as a bottom-up structure, reflecting the needs in observations conducted by members of the permafrost community. It is now at a mature stage, with a developed governance structure, an established and active secretariat and a sophisticated, international data management system. The success of GTN-P is acknowledged by other terrestrial networks, WMO and members of other scientific communities. In order to succeed in the future, GTN-P should continue to be an exceptional model within the observational community and to build on the previous successes of the network. The GTN-P should also rely on experiences and lessons learned from other networks, communities and associations, and in close collaboration with other members of observational community, such as GTN-G and GCW. To sustain and improve its network management, the GTN-P should intend to link data management processes, structures and technologies to existing elaborated networks in the marine and atmospheric science branches. To become a one-stop service for permafrost variables, the network can improve the integration of remotely sensed data (surface soil moisture and surface temperature) in the GTN-P data management system, and work towards a collaboration with the networks on organic carbon (i.e. The Northern Circumpolar Soil Carbon Database). However, GTN-P must continue to focus on its primary mission and not to be diminished by the growing number of other initiatives by WMO, GCOS and others.

While GTN-P has not yet developed the capacity to independently maintain and support the observations, it has developed the capacity to connect those involved in the observational community, and to provide platforms for meetings, discussions, and dissemination of data. Integration of individuals within the GTN-P permafrost observational community empowered those connected within the network by allowing their work to be exposed to a much larger scientific community and Society at large.

The progress of GTN-P, from organizing workshops to developing a data management system, was sponsored by numerous organizations. The EU project PAGE21 contributed significantly to creating the new governance structure and the GTN-P Database. PAGE21 allowed the building of the present network capacity. Unfortunately, it did not provide a way of sustaining this capacity. Keeping the secretariat and data management system, both of which are vital components of GTN-P, requires significant human and monetary resources. Maintaining the network after PAGE21 on a voluntary basis took significant effort which otherwise could have been invested in fulfilling the GTN-P mission, i.e. by publishing the planned four-year scientific report. Several projects that proposed funding for the data activities in GTN-P were submitted (EU, German-Russian, German). AWI, IPA, ESKP, IASC and

GWU provided much needed funding to keep the network at the established capacity during this transition period.

While short-term human and monetary investments can enhance the network and significantly contribute to its various functions (workshops, data management, publication and dissemination of materials and knowledge transfer), they do not solve the overall need for sustained long-term investment. Research or governmental organizations are subject to budget cuts and changes in priorities. As an independent, international programme, in addition to short-term research project' support, the GTN-P shall develop its own capacity in order to support secretariat, data management system, to organize workshops and meetings, to design and publish educational and outreach materials, and to support young scientists. This can be achieved through the re-established governance structure in order to make a legal entity. Creating a non-profit organization or NGO would allow for institutionalizing GTN-P and to develop larger membership structures, create an ability to seek individual and corporate sponsors, as well as to apply for grants directly. The IPA should be more proactive as the parent organization.

To create a legal entity, the GTN-P needs to work towards:

- An operational budget of minimum of 100K USD per year;
- Specified memberships, both free (i.e. academia, personal use), voluntarily (non-commercial organizations) and mandatory (commercial sector, such as exploration companies, commercial weather forecast systems);
- Specify data and data management system policy;
- Actively promote permafrost beyond the research community, community engagement, and fundraising.



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S.1. GTN-P Timeline 2010 - 2020

April 2010

- Submission of an IPA Strategy Preparation Document to the Council of the IPA, outlining the need to overhaul GTN-P and the initiative to form a task force to compile a strategy and implementation plan.

May 2010

- Formation of the GTN-P task force by the Executive Committee of the IPA, following the recommendation of the IPA Strategy Preparation Document.

June 2010

- Validation of the IPA Strategy Preparation Document during the twentieth IPA Council and subsequent validation of the recommendations to strengthen and to make GTN-P operational under the IPA leadership.
- First Meeting of the GTN-P Task force during the Third European Conference on Permafrost and decision on the timeline for the compilation of the strategy and implementation plan.

November 2010

- Compilation of a first draft of the Strategy and Implementation Plan and internal editing process (circulation in the GTN-P Task Force).

April 2011

- Finalization of the first draft of the Strategy and Implementation Plan.
- Strategy and Implementation Plan sent to IPA Executive Committee, TSP and CALM leaders for review.
- Strategy and Implementation Plan sent for review to targeted reviewers.

September 2011

- Integration of reviews and editing of Strategy and Implementation Plan.

November 2011

- Data Management GTN-P Workshop for data providers and users, including potential national correspondents.
- Establishment of GTN-P Interim Executive Committee.
- Establishment of a writing team for the GTN-P Information System user and technical requirements based on the outputs of the stakeholder workshop.

December 2011

- Establishment of GTN-P Secretariat in Potsdam, Germany.
- Finalization of user and technical requirement document for GTN-P Information System.

February 2012

- First PAGE21/GTN-P technical workshop on DMS held in Copenhagen, Denmark.

March 2012

- Initiation of GTN-P Information System design.
- Preparation of inventory of existing datasets.

June 2012

- Finalization of GTN-P Information System.
- First GTN-P Executive Committee appointed and met during the Tenth International Conference on Permafrost.

September 2012

- Second PAGE21/GTN-P technical workshop on DMS held in Akureyri, Iceland.

November 2012

- Third PAGE21/GTN-P technical workshop on DMS held in Hamburg, Germany.
- GTN-P EC meeting to revise the GTN-P Strategy and Implementation plan.

December 2012

- Designation of GTN-P National Correspondents by the corresponding countries.

January 2013

- Strategy and Implementation Plan sent to GCOS and GTOS for review and endorsement.

March 2013

- Feedback from GCOS and GTOS.
- First call for data reporting.
- Announcement of the launch of the GTN-P DMS Beta version.

May 2013

- Second GTN-P workshop at WMO in Geneva.

June 2014

GTN-P Meeting in Evora, Portugal during 4th EUCOP.

February 2014

- GTN-P Workshop in Akureyri.

September 2015

- Official release of the GTN-P DMS.
- GTN-P in the report of GCOS.
- ESSD GTN-P Metadata publication.

October 2015

- Third GTN-P Workshop, Quebec, Canada.

- Announcement of the launch of the GTN-P DMS.
- Change in governance structure, introduction of YNC positions.

December 2015

- Nomination of Young National Correspondents

June 2016

- GTN-P Meeting and Session at ICOP2016, Potsdam, Germany.
- GTN-P contribution to GCOS Implementation Plan.
- Compilation of the first GTN-P data report/snapshot using DMS.

September 2016

- Nomination of representative of YNC to SC.
- Final call for data submission to be used in Snapshot.
- Integration of NSIDC datasets into GTN-P DMS.

December 2016

- GTN-P Data report

June 2017

- Compilation of the Strategy and Implementation Plan: 2016-2020, editing and external review process.
- Opening of the GTN-P Mirror and establishing AWI (Germany) as co-host partner of Arctic Portal (Iceland).

December 2017

- Publication of monitoring standards.

July 2018

- GTN-P meeting during IPA Regional Conference at the Fifth European Conference on Permafrost (EUCOP5), Chamonix, France.
- Planning of GTN-P Mirror in Russia (with interface in Russian language) and China

July 2020

- GTN-P workshop during ICOP2020, Lanzhou, China
- Opening of the GTN-P Mirror in Russia and China
- Second GTN-P Data Report

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S.3. List of Acronyms

ALT	Active Layer Thickness
ANTPAS	Antarctic Permafrost, Soils and Periglacial Environments
CALM	Circumpolar Active Layer Monitoring
DMS	Data Management System
DUE	Data User Element
ECV	Essential Climate Variable
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
FGDC	Frozen Ground Data Center
GCM	Global Climate Model
GCOS	Global Climate Observing System
GCW	Global Cryosphere Watch
GEO	Intergovernmental Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GHOST	Global Hierarchical Observing Strategy
GSC	Geological Survey of Canada
GTN-G	Global Terrestrial Network for Glaciers
GTN-P	Global Terrestrial Network for Permafrost
GTOS	Global Terrestrial Observing System
GWU	George Washington University
IACS	International Association of Cryospheric Sciences
IASC	International Arctic Science Committee
ICSU	International Council for Science
IGOS	Integrated Global Observing Strategy
IPA	International Permafrost Association
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
IUGS	International Union of Geological Sciences
NSIDC	National Snow and Ice Data Center
PAGE21	Changing Permafrost in the Arctic and its Global Effects in the 21st Century
PYRN	Permafrost Young Researchers Network
SAON	Sustaining Arctic Observing Networks
SCAR	Scientific Committee for Antarctic Research
SCDMO	IPA Standing Committee on Data Management and Observing
SFG	Seasonal Frozen Ground

TSP	Thermal State of Permafrost
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WDC	World Data Centre
WMO	World Meteorological Organization

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Strategy and Implementation Plan 2016-2020
For the Global Terrestrial Network for Permafrost (GTN-P)

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