International
Permafrost
Association

GTN-P
Global Terrestrial
Network for
Permafrost

Global Terrestrial Network on Permafrost (GTN-P)

STRATEGY AND IMPLEMENTATION PLAN 2012-2016

Strategy and Implementation Plan for the Global Terrestrial Network on Permafrost (GTN-P) presented by the International Permafrost Association (IPA) to the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System (GTOS).

November 2012

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This Strategy and Implementation Plan was prepared by the Global Terrestrial Network for Permafrost Task Force, chaired by Dr. H. H. Christiansen and reviewed by two anonymous reviewers and by the GTN-P Executive Committee

1. Rationale and objectives

1.1 Background

The Global Terrestrial Network for Permafrost (GTN-P) is the primary international programme concerned with monitoring permafrost parameters. GTN-P was developed in the 1990s by the International Permafrost Association (IPA) under the Global Climate Observing System (GCOS) and the Global Terrestrial Observing Network (GTOS), with the long-term goal of obtaining a comprehensive view of the spatial structure, trends, and variability of changes in the active layer thickness and permafrost temperature (Brown *et al.*, 2000; Burgess *et al.*, 2000). The latter are also acknowledged as Essential Climate Variables (ECVs) by GCOS and GTOS. The two related international monitoring networks 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, the **Circumpolar Active Layer Monitoring-CALM**. These networks have been coordinated by the International Permafrost Association (IPA) since their establishment. TSP was originally based at the Geological Survey of Canada in Ottawa (GSC), Canada. The TSP observatories in the United States and Russia have been supported by the US National Science Foundation and managed by the University of Alaska Fairbanks. Permafrost temperature data from these observatories are freely available from a dedicated US-Russia TSP website <www.permafrostwatch.org> and from the Advanced Cooperative Arctic Data and Information Service (ACADIS) which is a joint effort by the National Snow and Ice Data Center (NSIDC), the University Corporation for Atmospheric Research (UCAR), UNIDATA, and the National Center for Atmospheric Research (NCAR) to provide data archival, preservation and access for all projects funded by NSF's Arctic Science Program. The CALM program, established in 1991, was initially affiliated with and supported by the International Tundra Experiment (ITEX). 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 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 <http://www.gwu.edu/~calm/> and the National Snow and Ice Data Center in Boulder, Colorado.

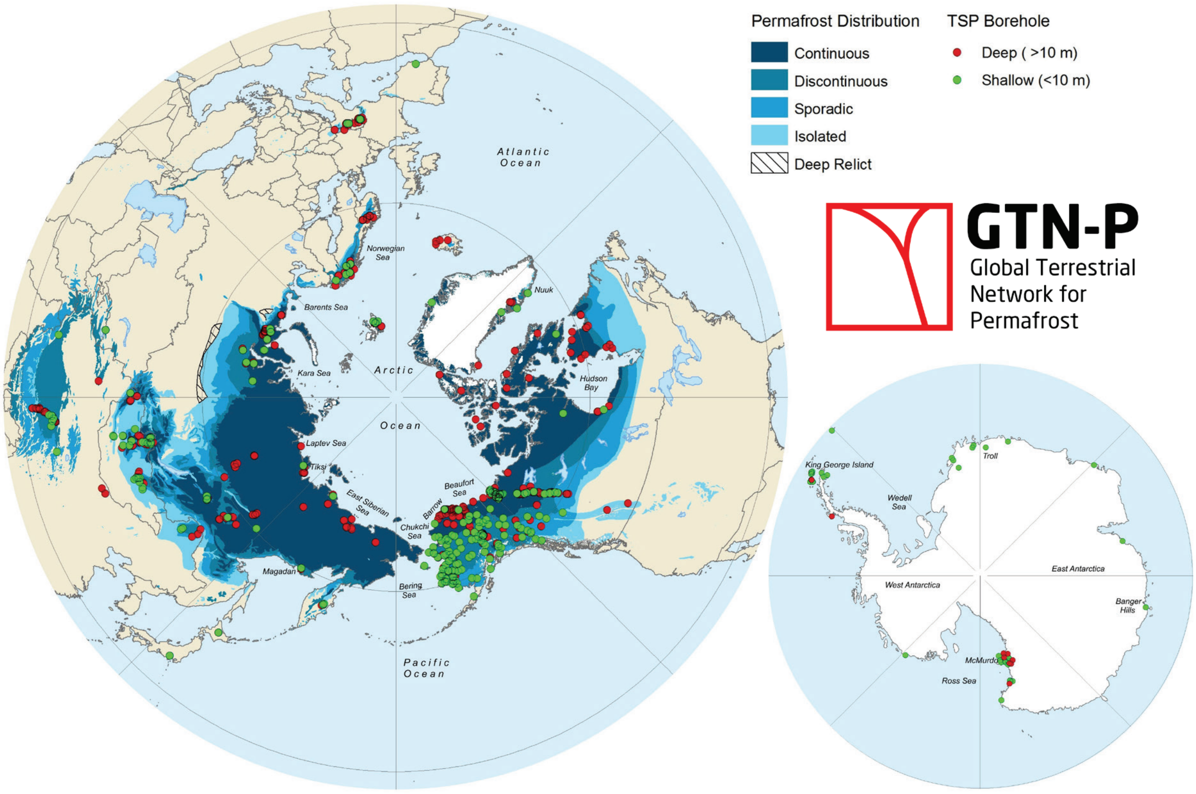


Figure 1 - Location of long-term monitoring sites of the Thermal State of Permafrost (TSP) in GTN-P.

Figure 1 shows the location of TSP monitoring sites and Figure 2 the location of CALM monitoring sites. Both TSP and CALM have regional components for the Southern Hemisphere, mainly the Antarctic, in cooperation with the International Permafrost Association (IPA) and the Scientific Committee for Antarctic Research (SCAR).

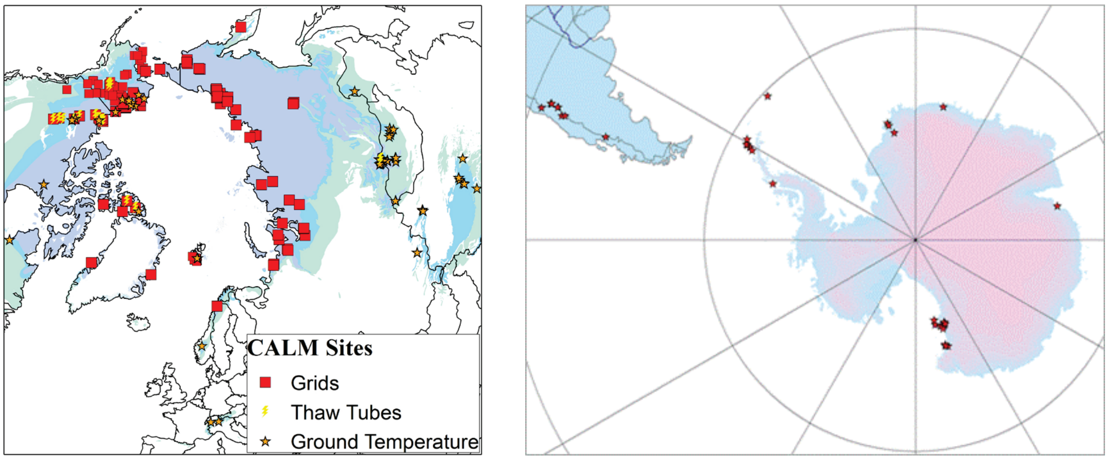


Figure 2 - Location of long-term monitoring sites of the Circumpolar Active Layer Monitoring (CALM) network in GTN-P.

The main purpose of the GTN-P is to operate a strong monitoring network, in order to **provide consistent long-term data series** of selected permafrost parameters and to assess their state and changes based on actual field measurements over time. The data generated from the GTN-P can then be utilized to **develop and validate models,** to produce regional maps of current permafrost conditions, and also to predict future permafrost extent (see for example Anisimov and Reneva, 2006; Riseborough *et al.*, 2008; Romanovsky *et al.*, 2007; Sazonova and Romanovsky, 2003; Sazonova *et al.*, 2004). These outputs can be used to validate permafrost modules in Global Climate Models (GCMs), and help to **refine the stabilisation scenarios of the Intergovernmental Panel on Climate change** (IPCC). GTN-P products are also meant to provide answers to socio-economical issues directly relevant to the populations living in permafrost areas and beyond, through the provision of key information for land management decisions including those related to resource development and development of strategies to adapt to climate change in permafrost areas.

1.2 Achievements

During the International Polar Year (IPY) the IPA coordinated and strengthened the collection of standardized permafrost temperature data (snapshot) in the TSP project focussing on obtaining a first circumpolar snapshot. The current network consists of more than **860 boreholes in both hemispheres** with more than 25 participating countries. The vast majority of sites are equipped for long-term permafrost temperature observations. A borehole inventory of mean annual ground temperatures for 600 boreholes (snapshot) from all permafrost areas, including locations outside the polar areas, is available online in ISO-compliant format at the National Snow and Ice Data Center (NSIDC). At present, the network of active layer thickness and shallow temperature observations amounts to **over 200 active-layer monitoring sites** in both hemispheres. Most of these sites are re-visited on an annual basis.

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. 2010a,b, Christiansen et al. 2010). The papers highlight the spatial variability of ground temperatures and the sensitivity of the system to climate variability. Through other activities coordinated by the IPA, such as the Carbon Pools in Permafrost Regions (CAPP) project, a systematic comparison of ground temperature evolution data with recently created maps of soil carbon and a first estimation of permafrost carbon sensitivity to temperature increase is now possible.

As a result of two decades of leadership, the IPA, through GTN-P, has facilitated development of the following products:

- ► A network of 860 boreholes to monitor permafrost temperature in both hemispheres (http://nsidc.org/data/g02190.html).

- ► A network of over 200 sites to monitor active layer thickness (http://www.gwu.edu/~calm/).
- ► Maps and databases of current permafrost temperature that can be utilized for modelling and other efforts.
- ► Records/time series of permafrost temperatures and active layer thickness that can be used to determine changes in permafrost conditions over the last two to three decades.
- ► Synthesis papers describing current conditions and recent changes.

1.3 Challenges

Presently, GTN-P *in situ* data acquisition operates on a voluntary basis (often with no dedicated long-term funding), through individual national and regionally-sponsored research projects and different programmes. The strong development of these national programmes has superimposed national technological and methodological requirements, which become increasingly difficult to standardize globally. In addition, **the level of national and regional activity has developed faster than the GTN-P management capacity**.

The leadership of the IPA has largely contributed to the success of TSP and CALM, in that its national networks and perceived leadership in the field of permafrost research have concurrently acted to foster an integrative and international approach. **This widely perceived authority acts positively on the frequent production of outputs for the network** by ensuring rapid communication between the different actors involved in permafrost monitoring, and via the links of the IPA to global organizations such as the World Meteorological Organization (WMO). The IPA is contributing its expertise to the upcoming Sustaining Arctic Observing Networks (SAON), coordinated by the International Arctic Science Committee (IASC), and to the Panel on Polar Observations Research and Services of the Executive Committee of WMO (EC-PORS). The latter, as well as SAON, recommended using the permafrost networks as pilot projects in their starting observing activities. However, none of these initiatives provide support/funding for actual observations or data management.

The efficient stewardship of the IPA is limited by its capacity to coordinate its observing activities. While the networks are reaching a quasi-operational level, and delivering products more widely used everyday, **its capacity to coordinate has not evolved and relies largely of the voluntary contribution of a few individuals**. Expectations have also grown with time, and live reporting of data, standardized geospatial datasets or production of searchable time series are common requests, which pre-supposes skills in data management. The growing reporting duties and the increasingly complex technical requirements associated with the publishing of outputs, requires a set of competences that goes beyond the good will of a few individuals and needs a structured management, endorsed at the highest level, with the appropriate resources to complete the tasks it is assigned with.

It is the goal of this document to outline the strategy needed to answer the needs of the community for robust long-term observing of permafrost and to propose changes to the management structure and capacity of GTN-P to complete these tasks.

1.4 Objectives

The present document, presented by the IPA to GCOS and GTOS, aims at providing a new strategy and implementation plan for the GTN-P, building on the well established existing TSP and CALM networks and addressing the needs of the scientific community and society at large in the twenty-first century.

The specific objectives of the present plan are:

- To provide a clear strategy and vision for the role, mandate and mission of GTN-P for the period 2012-2016 and beyond.
- To suggest a set of changes to the governance and structure of GTN-P to implement this strategy.
- To suggest a set of improvements to the data management setup of GTN-P to implement the strategy.

2. The Strategy

2.1 A permanent permafrost observing network

The role of permafrost in the Earth system and its growing impact on infrastructure and land management has dramatically increased the awareness of the scientific community and the general public for permafrost science. The thawing of permafrost and the resulting release of greenhouse gases is arguably one of the most prominent issues in today's global climate science. Concurrently, economic development of the Arctic and high altitude areas affected by the presence of permafrost raises critical issues related to the stability of the subsurface and the potential natural hazards resulting from the thawing of permafrost. To comprehensively and precisely assess the risks associated with changes in the thermal state of permafrost a robust benchmark is needed. The IPA sees the GTN-P as the cornerstone of permafrost observation and the instrument needed to answer scientific and societal needs related to the evolution of permafrost.

The role of the GTN-P is to provide timely information to the scientific community and to society on the state of permafrost, relying on its extensive and geographically representative instrumented field networks using well-defined measurement protocols. To do so, the GTN-P should aim at 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 should include global datasets on the temperature of permafrost, active layer thickness and dynamics, and archive temperature data, with the potential to add more permafrost related data if feasible at a later stage.

GTN-P shall focus on its core products, that is, the monitoring of the ECVs and distribute these products through an easily accessible and frequently updated, and for some sites, online web interface. Once a robust framework is established to coordinate and standardize the collection, processing and dissemination of the field data, GTN-P should also aim to include data on seasonally frozen ground, to better integrate ancillary environmental data, to produce outreach products and to rationalize its network by collaborating with other ECV-monitoring capable networks (e.g. soil moisture or glaciers).

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

- to collect standardized data on permafrost temperature and active layer thickness evolution and to publish a report on those every 4 years,
- to prepare a report of permafrost temperatures and active layer thickness at selected reference sites at 2 year intervals,
- to coordinate and upgrade the existing TSP and CALM networks,
- to stimulate the integration of new methods and new observations of permafrost, through 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 further developed by **creating partnerships with those monitoring other cryospheric ECV components** (e.g. snow, meteorology, soils) to co-locate monitoring sites and expand existing networks at reduced cost. Eventually, GTN-P should promote the systematic integration of permafrost temperature monitoring at all official meteorological stations located in all types of permafrost and seasonal frozen ground areas. 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. Partnerships with industry can help to establish monitoring sites in key resource development areas.

2.2 Efficient governance and management

To address the growing needs for permafrost observations, **GTN-P shall develop a governance structure adapted to the challenges of the 21st century.** An independent supervision should involve key players in global observing, including the sponsors of GTN-P, but also regional players such as SCAR, 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 one position for the coordination of the network (the GTN-P Secretariat) and one position for the related data management.

CALM and TSP should be brought closer together in GTN-P to maximize synergies between the present two networks. Based on new funding, the management of both networks should be coordinated with the new GTN-P central management structure, although the identity of the networks shall be retained. This process shall be dealt with in a progressive manner.

The new organisation of GTN-P shall also **clearly articulate and define the bottom-up approach associated with data reporting**, through the involvement of national correspondents. When possible, these national correspondents should be tightly associated with the ones of major observing systems and UN agencies (e.g. WMO). The national correspondents should form the backbone of the reporting process, and be closely associated with the decision-making at the GTN-P coordination level.

The individuals making up the structure shall be chosen in cooperation between GCOS, GTOS and the IPA through a clearly defined process handled primarily by the central management of GTN-P.

2.3 A robust data management framework

The data management framework proposed for GTN-P shall rely on a centrally coordinated data management system, dividing its activities in three main pillars:

- Field data collection archival and storage
- Data dissemination and visualisation
- Advisory input to the science community and policy-makers

To do so, GTN-P shall build on the legacy of the Frozen Ground Data Center (FGDC), as initially located at the National Snow and Ice Data Center (NSIDC), on the existing AON ACADIS data portal, and on the expertise of the Arctic Portal for web data publication and design to create a new system, embedded in the system of the current EU project PAGE21.

The data management system of the GTN-P should be centrally coordinated and should oversee data submission, archival (complying with national metadata and data requirements), storage (centrally or by connecting to regional/national databases), and dissemination. GTN-P should be outfitted with a data management coordinating body responsible for overseeing its data management framework.

Datasets produced by GTN-P are archived at the Arctic Portal and at a data storage facility part of the World Data System. The PANGAEA Earth Data Publisher is a solid candidate to take on that role, as it is part of the new ICSU World Data System, which holds the expertise for archiving and storing datasets produced by GTN-P. GTN-P should work towards **strengthening the role of the Arctic Portal and PANGAEA as repository of permafrost data**. It should also create or strengthen links between its archival role and the other components of the GTN-P data management framework.

At a later stage, 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 and 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.

GTN-P should work towards **building a robust, yet 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.

3. Governance and Structure

3.1 A new management structure

To implement its strategy, GTN-P needs to be upgraded with a structure and an executive management capable of directing, coordinating, monitoring and reporting on the network activities. This structure needs to be divided in several entities to ensure external review of activities, rapid decision-making, efficient and frequent reporting as well as a structured information flow.

The new structure proposed by the IPA is outlined in the text and diagram below.

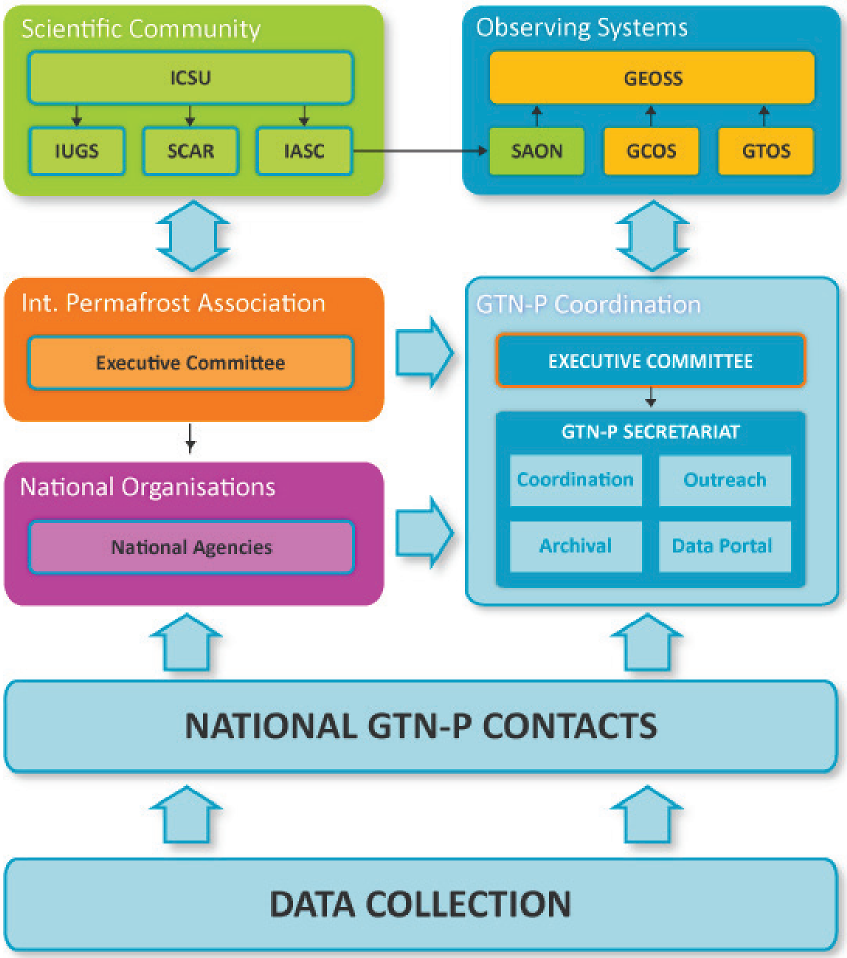


Figure 3 - Proposed governance structure and information flow for GTN-P

The main new component in the proposed structure is the strengthened central coordination component encompassing governance, management and data management. The new structure includes an Executive Committee, a secretariat and national correspondents.

Executive Committee

The Executive Committee shall become the **governing body of the GTN-P**. It should meet on an annual basis, review the activities of the network, set the directions for the future and give the impulse for new activities in the network. The Executive Committee should also ensure that connections to other international bodies are solid and frequent. The Executive Committee should be directly responsible to the sponsors of GTN-P. The Executive Committee's decisions and performance should be reviewed and audited regularly by the Advisory Board.

The **members of the Executive Committee shall be chosen by the scientific community, preferably among the country members of the IPA, the IPA governing bodies and the sponsors of the network,** based on a nomination process engaging the science community. A chair of the Executive Committee shall be chosen among its members by the committee itself and be approved by the network sponsors and the IPA. Members should be chosen for two years, with the objective to renew half of the Executive Committee every two years. The Executive Committee shall be made of six members. The members shall represent a wide range of specialties involved in permafrost observations as well as specialists of data management. The founding Executive Committee consisted of individuals from the permafrost temperature and active layer measurements communities to focus on the strengthening of these activities. The sponsors of the network as well as the IPA EC shall be represented as Ex-Officio on the Executive Committee in addition to these six individuals. The presence of young researchers, through the involvement of the Permafrost Young Researchers Network (PYRN) is a requirement. The Executive Committee shall ensure that the overarching goals of GTN-P are being pursued. It shall, in a short annual report, **report on the strategy, decisions, actions and reporting of GTN-P as a whole** and communicate its report to the sponsors of the network and the IPA. The Executive Committee should compile a more comprehensive review of the GTN-P activities and structure every four years, together with the report on permafrost temperature and ALT.

GTN-P Secretariat

The GTN-P Secretariat shall be responsible to conduct, under the general direction of the Executive Committee, **the current business of the GTN-P**, the data management, the collection and redistribution of data, the periodic reporting and release of products for GTN-P, and the dialogue and linkages with other organizations.

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 Executive Committee. 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 central point of contact for national organizations and national contacts and maintaining strong ties to the IPA. The Secretariat will be funded for the period 2012-2016 to a large extent through the PAGE21 permafrost project funded by the European Union.

The Secretariat will be 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 section 6.

The Secretariat shall report as a minimum annually on GTN-P activities and produce attractive policy-relevant bulletins on GTN-P outputs. 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** and seek the future inclusion of its observing activities in WMO.

National Correspondents and local collaborators

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

National Correspondents 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. They shall hold the position for a period of four years. The position shall be reviewed after two years and measures taken by the GTN-P Executive Committee if replacement is deemed necessary.

National Correspondents 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.

National Correspondents shall be responsible for stimulating and coordinating the collection of data and reporting by the individual investigators to the Data Management or the GTN-P Secretariat office to be fed into the GTN-P information system. National Correspondents can take added responsibility and directly report the data in their country. Their major responsibility, however, will be mainly directed to providing data updates at least once a year.

National Correspondents shall maintain close contacts with relevant institutions and funding agencies in their country and the IPA national Adhering Bodies. These contacts will enable the emergence of an operational framework for the collection and reporting of permafrost data in the country (e.g. PERMOS in Switzerland) and help in reaching out to the whole community of permafrost researchers in the country.

3.2 Linkages to regional and global observing systems

Global Observing Systems

GTN-P shall act in close collaboration with its two sponsors (GCOS and GTOS) 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 organize the location of its sites close to the ones of existing global systems and follow closely the Global Hierarchical Observing Strategy (GHOST) and the Integrated Global Observing Strategy (IGOS) recommendations.

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 become a founding partner of these networks and systems, and adapt its efforts to feed its data products to these efforts. When appropriate, GTN-P shall encourage the regional coordination of permafrost monitoring activities through the networking of its national correspondents and/or the building of regional or supranational structures (e.g. ANTPAS, PermaNet).

4. Process management and reporting

4.1 Process management

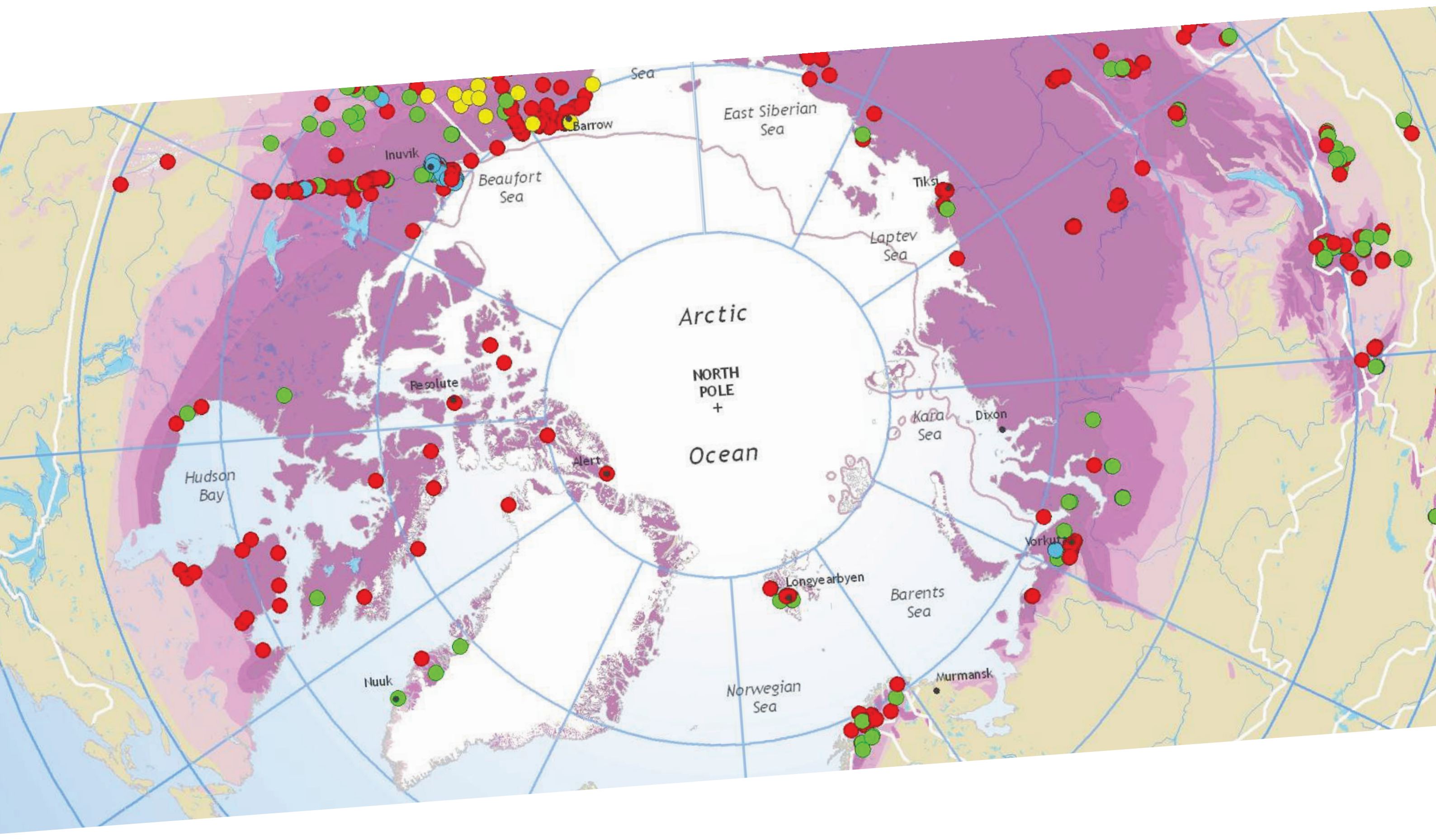
The timely reporting of permafrost data in GTN-P will have to rely on an efficient information flow, relying on the input of field investigators through the commitment of the National Correspondents. The overall information flow, encompassing both data collection and reporting is described in the organogram shown in figure 4, section 3.

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

4.2 Reporting

GTN-P shall conduct a proactive publication strategy, including the **publication of standardized data on permafrost temperature evolution and active layer thickness and dynamics every two years for reference sites.** This publication shall emphasize the spatial and temporal variability in trends. The data used in this publication shall also feed into existing reports such as the Global Outlook on Ice and Snow (e.g. Romanovsky et al., 2007), the BAMS State of the Climate annual report (Christiansen et al., 2012; Romanovsky et al., 2012), the Arctic Report Card (http://www.arctic.noaa.gov/reportcard/), or major global or regional climate assessments.

Although GTN-P's primary audience is the scientific community, it shall strive to make its science understandable and to interact on a regular basis with the media and the public. To do so, it shall publish its bulletins every two years for reference sites and every four years for all sites in a short, illustrated and understandable format and distribute them widely. The goal of GTN-P will be to deliver feasible, relevant, and understandable products to a wide range of stakeholders. The Secretariat shall also strive to publicize the network through presentations and involvements in outreach events. Finally, the data shall be accessible online 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.



5. Technical standards

5.1 Definition and units of measure

Permafrost: Permafrost is sub-surface earth materials that remain continuously at or below 0°C for two or more consecutive years.

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

Variable	Unit of measure
Permafrost – Thermal State of Permafrost (TSP)	*Ground temperatures measured at specified depths (°C).*
Active Layer thickness	*Thickness measured in (cm)*

5.2 Measurement methods, protocols and standards

The following section is 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.

5.2.1 *In situ* measurement

Permafrost temperatures

Permafrost temperatures define the thermal state of permafrost and are obtained by lowering a calibrated thermistor into a borehole, or recording temperature from multi-sensor cables permanently or temporarily installed in the borehole. Measurements may be recorded manually with a portable temperature logging system or by data loggers. Less frequent site visits are required if data loggers are utilized. The accuracy and resolution of the thermistors and measurement varies but it is desirable for accuracy to be ±0.1°C or better. The depth of boreholes varies from less than 10 m to greater than 100 m. 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 but ideally monthly. Data loggers may be utilized for daily measurement of shallow temperatures to reduce the number of site visits and provide a continuous record of ground temperatures.

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 required. Spacing of sensors on cables (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.

The maximum and minimum annual temperature at each depth above the level of zero amplitude defines the annual temperature envelope and can be utilized to characterize the ground thermal regime. The collection of data on a monthly or more frequent basis will facilitate the determination of the temperature envelope. Other derived parameters that are often 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 may also be determined. This may be done through interpolation between sensors if temperatures are measured below the base of permafrost or through extrapolation below the deepest sensor.

Monitoring of permafrost temperature is undertaken by some national programmes, but in general many observations are part of academic research projects. Current activities and recent results were reported at the Ninth International Conference on Permafrost and a special IPY issue of Permafrost and Periglacial Processes. See the following references: Clow 2008; Etzelmuller et al. 2008; Midttomme et al. 2008; Osterkamp 2008; Romanovsky et al. 2008a,b, 2010a,b; Sharkhuu et al. 2008; Smith et al., 2008a, 2010;

Vonder Muehll et al., 2008; Zhao et al. 2008; 2010; Christiansen et al 2010; Viera et al. 2010). For a detailed discussion of high precision temperature measurements, the reader is directed to Clow (2008).

Active Layer Thickness (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 soil temperatures obtained by data loggers. The 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 under the Circumpolar Active Layer Monitoring (CALM) protocol 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 of greater diameter may be used where active layers are thicker (e.g. 1-3 m) although difficulties 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.

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 the 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 colorless 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.

Soil temperature profiles

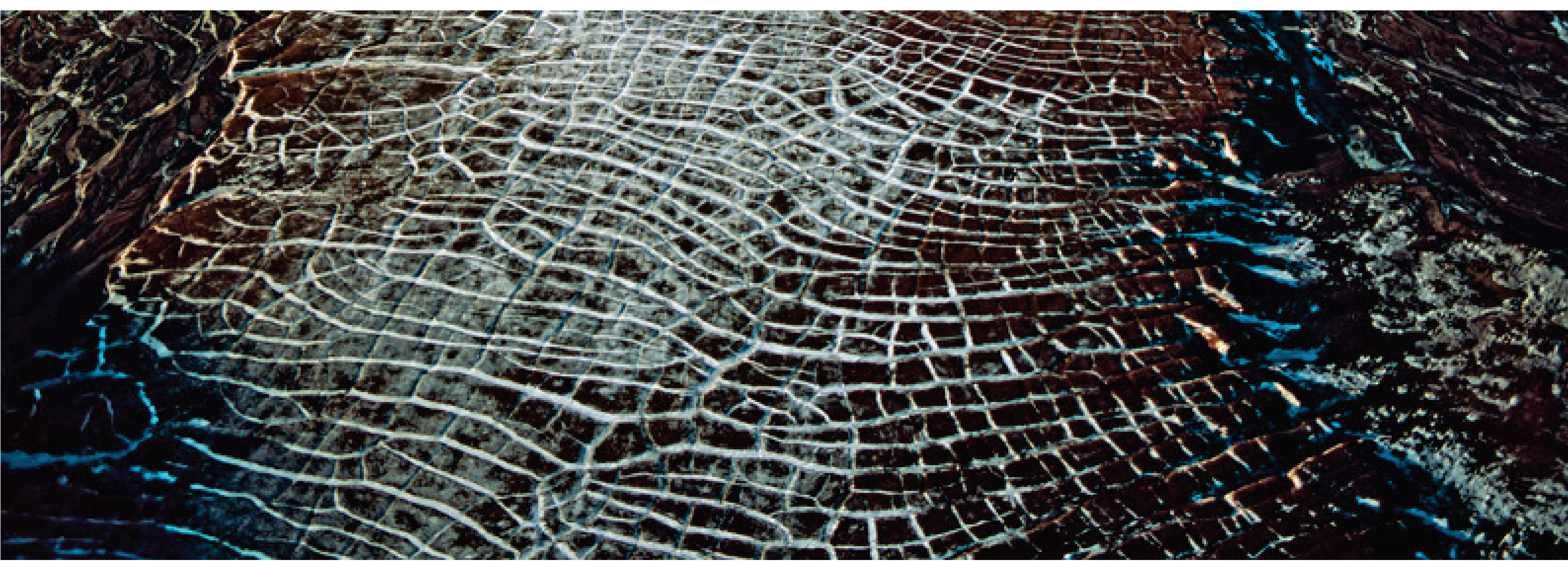
Soil and air temperature are recorded as basic information at many CALM sites, especially with the increasing availability of inexpensive, reliable temperature data loggers. Temperature sensors (usually thermistors) are inserted into the active layer and upper permafrost as a vertical array. Several CALM 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. The thickness of the active layer is estimated using the warmest 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).

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 as carbon content, grain size, stratigraphy, geomorphology and geology.

Other data may be collected at monitoring sites to aid in 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 a recognised ECV. 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.



6. Data Management

GTN-P aims at **building a robust, yet accessible information system for permafrost data**, compliant with existing international ISO-compliant standards, following open-access policies in line with the IPY data policy, capable of delivering archive and real-time data when feasible 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. The network should be outfitted with a proprietary data policy at an early stage of the proposed implementation plan.

6.1 Coordination and participation of permafrost scientists and relevant stakeholders

The data management framework of GTN-P shall be established as a permanent GTN-P Data and Information System and shall be coordinated by the GTN-P Secretariat. The Information System shall divide its activities in two main areas: field data archival and storage, and data dissemination and visualisation. It shall build its structure based on technical requirements set by stakeholder participation through large consultation.

Individual permafrost scientists and relevant stakeholder involvement will be assured in their participation in **GTN-P 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 will help summarize the needs and technical requirements of GTN-P data providers and users. Potential data providers and users will 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 upon which the data portal will build to offer outlets for the general public and policy-makers. The defined technical requirements will be used to form a plan for the elaboration of the data portal to be finished by end of 2012 in close collaboration with PAGE21. The second of these workshops is scheduled for May 2013.

6.2 Data archival and storage

Datasets included in GTN-P will be archived centrally in a master database to be constructed in 2012, using the data management system from the EU PAGE21 project. GTN-P will include storing datasets from additional locations to take advantage of existing systems (e.g. NORPERM, AON ACADIS, CALM, PERMOST), depending on national requirements and on the technical setup. However, the emphasis of GTN-P will be to ensure the commitment of the managers of additional databases to make available data to the central GTN-P data management system. Datasets will be stored and processed in a wide variety of formats to facilitate the extraction of stakeholder-relevant datasets. The structure of the database should accommodate existing systems (e.g. DUE Permafrost) and take advantage of existing nomenclature.

The first step in the implementation of the **data submission** process will be the creation of an online form to submit annual data updates. This form should be as intuitive and easy to use as possible. While much of the data submission process will be left to individual investigators, a data quality check will take place, under the coordination of the secretariat. The data submission tool should be designed to minimize the occurrence of errors, for instance by displaying data graphically upon submission.

6.3 Data portal

The Data Portal of GTN-P will be the main outlet for the data to be collected and distributed by GTN-P. It will be a major improvement to the existing data portals of TSP (gtnp.org) and CALM (gwu.edu/~calm), which will be subdued into the new system, and use the latest technology to make datasets easily searchable and accessible in an online fashion. The Data Portal will be organized along two main axes. First, the organization of the database itself, and second the online interface (including data submission).

The database will be object-oriented and will store or have direct links to most of the datasets and make them available online. Datasets will be stored in the formats determined during the GTN-P workshops and constantly updated. These will include tables, maps, but also readily downloadable shapefiles and KML layers (Google Earth), as well as to provide datasets directly useable in models, including in upcoming permafrost modules of Global Climate Models

The online interface will consist of a web page (portal) to submit, search and access datasets. It will build on the interface of the upcoming EU PAGE21 permafrost data management system to provide a tool useable by all potential users. A special emphasis will be put on the rapid access to geographically targeted data: Modellers will for instance be provided with a direct link to relevant datasets made available online in the format compatible with their models. The interface will include a map and a text-driven search interface as well as an online mapping service. The latter will be specifically built to be easily understandable by the general public and to feature intuitive controls to the display of datasets as well as immediate export to mapping software. These will include the production of illustrations on the state and evolution of permafrost. That aspect will be strengthened by the delivery of accurate and verified metadata. The burden to the data management system will be offset by the careful selection of a small number of formats to be delivered.

7. Implementation history and future actions

The implementation plan outlined above includes certain steps that were taken already and the rest of them will be progressively put in place throughout 2013, to reach a fully functional framework by the end of 2014. The following period (2013-2016) will be used to feed the system with data and evaluate the structure and process management put in place, through annual GTN-P workshops for the National correspondents and the GTN-P leadership.

7.1 2010-2011

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 Council meeting of the IPA 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 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.
- Finalization of user and technical requirement document for GTN-P Information System.

7.2 2012-2016

February 2012

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

March 2012

- Start the construction of the GTN-P Information System
- 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

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 Information System

May 2013

- Second GTN-P workshop at WMO in Geneva

October 2013

- Compilation of first GTN-P data bulletin

Appendices

A - List of Acronyms

ALT	Active Layer Thickness
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-P	Global Terrestrial Network for Permafrost
GTOS	Global Terrestrial Observing System
GWU	George Washington University
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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