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NORPERM, the Norwegian Permafrost Database – a TSP NORWAY IPY legacy

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Abstract

NORPERM – The Norwegian Permafrost Database was developed at the Geological Survey of Norway during the International Polar Year (IPY) 2007–2009 as the main data legacy of the IPY research project *Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost in Norway and Svalbard* (TSP NORWAY). This paper describes the structural and technical design of NORPERM. NORPERM follows the IPY data policy of open, free, full and timely release of IPY data, and the borehole metadata description follows the Global Terrestrial Network for Permafrost (GTN-P) standard. The ground temperature data infrastructure in Norway and Svalbard is also presented, focussing on the TSP NORWAY permafrost observatory installations in the *North Scandinavian Permafrost Observatory* and *Nordenskiöld Land Permafrost Observatory*, as the data providers for NORPERM. Further developments of the database, possibly towards a regional database for the Nordic area, are also discussed.

The purpose of NORPERM is to store ground temperature data safely and in a standard format for use in future research. NORPERM stores temperature time series from various depths in boreholes and from the air, snow cover, ground-surface or upper ground layer recorded by miniature temperature data-loggers, and temperature profiles with depth in boreholes obtained by occasional manual logging. It contains all the temperature data from the TSP NORWAY research project, totalling 32 boreholes and 98 sites with miniature temperature data-loggers for continuous monitoring of micrometeorological conditions, and 6 temperature depth profiles obtained by manual borehole logging. The amount of data in the database will gradually increase as data from older, previous projects are added. NORPERM also provides links to near real-time permafrost temperatures obtained by GSM data transfer.

1 Introduction

Permafrost is ground (soil or rock and included ice and organic material) that remains at or below 0 °C for at least two consecutive years (van Everdingen, 1998). Permafrost underlies about 25% of the Earth's land mass (Brown et al., 2001), and its temperature serves as a useful indicator of climate change and has been identified as one of six cryospheric indicators of climate change by the Global Climate Observing System (GCOS) through the Global Terrestrial Observation System (GTOS) (Burgess et al., 2000). The Global Terrestrial Network for Permafrost (GTN-P) of the GCOS/GTOS is responsible for the international coordination and management of permafrost temperature data and active layer depths (Burgess et al., 2000).

In the last three to four decades, permafrost temperatures have increased in large areas of the Arctic (Pavlov, 1994; Osterkamp and Romanovsky, 1999; Smith et al., 2005; Jorgenson et al., 2006; Osterkamp, 2007; Isaksen et al., 2007; Harris et al., 2009). The number of instrumented sites however is few, and a need for a global permafrost temperature monitoring network was realized by the International Permafrost Association (IPA), who coordinated the International Polar Year (IPY) 2007–2009 research project *Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost* (TSP). The main aims of the TSP project were to obtain a spatially distributed snapshot of permafrost temperatures during IPY covering the world's permafrost regions, and to significantly expand the network of boreholes for improved detection of future changes in the permafrost thermal state (Brown and Christiansen, 2006). In the national TSP projects, permafrost observatories were established with ground temperature recordings in boreholes, either as occasional logging or continuous monitoring, and with temperature monitoring in the air, snow cover, at the ground surface and/or in the upper ground to resolve climate-permafrost relationships. Recordings of the active layer thickness for the Circumpolar Active Layer Monitoring (CALM) network (Brown et al., 2000) were also included. It is the goal to keep the observatories running also after IPY, as International Network of Permafrost Observatories, to provide long-term

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data series. These series will contribute to global observation programmes such as the Sustaining Arctic Observing Networks (SAON) and the Pan-Antarctic Observing System (PantOS).

The Norwegian contribution to TSP, the *Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost in Norway and Svalbard* (TSP NORWAY), has established permafrost observatories in the two northernmost counties of Troms and Finnmark in Norway and in central and western Svalbard (Christiansen et al., 2010). These contain 32 boreholes and 98 sites with miniature temperature data-loggers (MTDs) for continuous monitoring of micrometeorological conditions (see Table 1). The considerable amount of data acquired are handled according to the IPY data policy (International Polar Year Data and Information Service – IPYDIS, http://ipydis.org), stating that data collected under the auspices of IPY-projects should be stored in secure repositories and made openly, freely and fully available on the shortest feasible timescale (http://ipydis.org). The GTN-P holds only metadata and summaries (Burgess et al., 2000) and is thus not fulfilling these criteria, but acts as the international TSP metadatabase. National TSP projects therefore either had to use existing database systems such as e.g. the Cooperative Arctic Data and Information Service (CADIS) database of the Arctic Observing Network (AON-CADIS) used by the US-Russian TSP project (http://www.aoncadis.org/projects), or develop a database to accommodate all the ground thermal data collected, such as done in the TSP NORWAY project by establishing the Norwegian Permafrost Database (NORPERM). NORPERM was technically developed by the Geological Survey of Norway (NGU) in cooperation with the TSP NORWAY scientists. It forms part of the national borehole database at the Geological Survey of Norway, and is an important part of the TSP NORWAY research infrastructure.

The aim of this paper is to present the main data legacy of the TSP NORWAY project; the NORPERM database and its structural and technical design. We also give an overview of the pre-IPY and the IPY permafrost data infrastructure in Norway and Svalbard, with focus on the two TSP NORWAY permafrost observatories which formed the basis for NORPERM. Potential future developments of NORPERM are discussed towards the end of the paper.

2 Infrastructure of permafrost temperature data in Norway and Svalbard

While permafrost in Svalbard is continuous except beneath large glaciers, permafrost in Norway is restricted to the mountain areas (Brown et al., 2001; Etzelmüller et al., 2003; Humlum et al., 2003; Harris et al., 2009). Christiansen et al. (2010) gives an overview of the thermal state of permafrost in the Nordic region during IPY, showing that the temperature in the upper part of the permafrost in the Norwegian mountains is above −1 °C except in the highest-lying locations, while in Svalbard it is in the range −2 to −6 °C.

2.1 Pre-IPY permafrost data

Before the IPY 2007–2009, direct thermal monitoring of permafrost existed only at Juvvasshøe and Dovrefjell in southern Norway, two sites in Troms, northern Norway, and Janssonhaugen and Adventdalen in central Svalbard (Christiansen et al., 2010). The Permafrost and Climate in Europe (PACE) project significantly contributed by establishing thermal monitoring in Juvvasshøe and Janssonhaugen from 1998–2000 down to 129 and 100 m depth (Isaksen et al., 2001; Harris et al., 2009). Ground temperature has been monitored since 2001 in an altitudinal transect of 11 shallow boreholes (9–10 m) across the permafrost transition zone in Dovrefjell, southern Norway (Sollid et al., 2003). A long-term monitoring programme of permafrost and climate and its potential influence on unstable rock slopes was initiated in 2001 with one borehole at Dalsnibba in southern Norway and two in northern Norway at Guolasjavri and Trolltinden (Isaksen et al., 2004), the latter two being continued as part of TSP NORWAY. In addition, numerous near-ground-surface temperature series exists from local permafrost mapping projects (e.g. Isaksen et al., 2002; Heggem et al., 2005; Juliussen and Humlum, 2007; Farbrot et al., 2008; Isaksen et al., 2008) and periglacial process studies (e.g. Christiansen, 2005).

The focus had thus until IPY been on the mountains of southern Norway, and relatively little was known of the distribution of permafrost and its thermal state in northern Norway and Svalbard (Christiansen et al., 2010).

2.2 Permafrost observatory design

During the IPY the TSP NORWAY project established two permafrost observatories; the North Scandinavian Permafrost Observatory, in Norway covering the counties of Troms and Finnmark (Fig. 1), and the Nordenskiöld Land Permafrost Observatory in central Svalbard (Fig. 2). Within the observatories, ground temperature recording takes place in 16 so-called permafrost areas in Northern Norway, and seven in Svalbard (Table 1). The west coasts of northern Norway and Svalbard experience a maritime climate. Further inland however, towards Finnmarksvidda in northern Norway and Adventdalen in central Svalbard, the climate is moderately continental. The distribution of NORPERM permafrost areas have been selected to represent these gradients, but also microclimatic gradients such as differences in snow cover or ground-surface material. In northern Norway, the Kistefjellet mountain in the west and the Iškoras mountain in continental Finnmarksvidda in the east represent the range in continentality (Fig. 1). In Svalbard, the continentality range is represented by Kapp Linnè at the most martime part of the west coast to the Advent- and Longyeardalen area in Svalbard (Fig. 2).

2.3 IPY ground thermal instrumentation

The measurements include monitoring of ground temperatures in boreholes, occasional manual temperature logging in boreholes and micrometeorological monitoring in the air, snow cover, at the ground surface or in the upper ground layer using miniature temperature data-loggers (MTDs) (Fig. 3). Eight holes were drilled and instrumented for temperature monitoring in Northern Norway in autumn 2007, and additional five

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holes were established in 2008 (Table 2). In addition, two existing boreholes (Isaksen et al., 2004) were re-instrumented for continuous monitoring (Table 2). Thus, there were in total 15 TSP boreholes with temperature monitoring in Northern Norway during IPY (Table 1).

In Svalbard, 12 holes were drilled in spring 2008 and instrumented in summer and autumn 2008 (Tables 1, 2). Two existing holes with thermal monitoring (Kristensen et al., 2008) are included into the Nordenskiöld Land Permafrost Observatory (Table 2). Three additional holes were drilled in 2009, two of which were drilled by the local coal-mining company Store Norske Spitsbergen Grubekompani and instrumented in cooperation with TSP NORWAY (Table 2). This gives a total of 17 TSP boreholes with temperature monitoring in Svalbard (Table 1). The boreholes cover the elevation range from 492 to 990 m a.s.l. in northern Norway and from 5 to 901 m a.s.l. in Svalbard (Table 2).

The depth of the boreholes range from 2.2 to 90 m, although most are 10 to 15 m deep (Table 2). This gives a total of 570.2 m of TSP boreholes with ground temperature monitoring in northern Norway and Svalbard, distributed evenly at the two observatories (281.4 m in northern Norway and 288.8 m in Svalbard, Table 2).

Two of the boreholes in Svalbard and one borehole in northern Norway were established in collaboration with the PYRN-TSP project (Table 2), which have established boreholes also in northern Sweden (five holes) and northern Finland (one hole) (Juliussen et al., 2008; Christiansen et al., 2010). NORPERM will be the main database also for the PYRN-TSP project, although the map service of the public interface so far only covers Norway and Svalbard.

Two types of instrumentation are used; miniature temperature data-loggers and thermistor-strings connected to Campbell dataloggers (Table 2). Miniature temperature data-loggers (GeoPrecision, Tinytag, Hobo U22 and U23, UTL-1) generally have lower accuracies (0.2 to 0.27 °C) than the Campbell-logger set-ups (<0.05 °C), but allow more widespread use of this less expensive instrumentation. The equipment has been calibrated at 0 °C in an ice-bath prior to installation. Two of the boreholes (the

19 m deep Endalen hole and the 5 m deep Gruvefjellet hole) have been additionally instrumented for near real-time data transfer via GSM, and the latest data can be accessed and directly downloaded via an URL-address provided in NORPERM. This has proven to be innovative in TSP NORWAY research, education and outreach efforts. The temperature recording interval is 1–6 h, but 24 h for the deepest hole (Table 2). The time series covers at present one to two hydrological years, i.e. the IPY period (Table 2). The monitoring continues after the IPY for future assessment of long-term trends in permafrost temperatures.

Manual temperature logging has been made in cooperation with the Geological Survey of Norway in three holes drilled in 2007 and 2009 as part of the research project *Longyearbyen* CO_2 *Lab* (http://co2-ccs.unis.no/) and in three old exploration boreholes in Northern Norway (Table 1). The holes in Svalbard were logged to 440 to 900 m (Table 2) using two types of probes measuring geophysical parameters. The first probe, the TCN-probe, measures temperature with an accuracy of 0.5 °C, electrical conductivity and natural gamma radiation. The water quality probe (SWQS) measures temperature with a very high accuracy of 0.02 °C, electrical conductivity, pressure, degree of saturation, Ph, redox potential and nitrogen content. For both probes the measurements are reliable only in liquid water, so the measurements were made immediately after drilling before the drilling water froze. Thus, these probes give data that are not strictly reflecting the temperature in the permafrost. For the old holes in Northern Norway it was not possible to use these probes, so they were logged to only 22m with a thermistor-string that was read with a multimeter (Table 2).

The near ground-surface temperatures are monitored in the air, snow cover, at the ground surface and/or in the upper layer of the ground (<2 m) to study the effect of meteorological and micro-meteorological factors on the ground temperature. There are 52 such set-ups in Svalbard, including mainly pre-IPY sites that have been included into the Nordenskiöld Permafrost Observatory, and 46 sites established during IPY in Northern Norway. Different types of miniature temperature data-loggers have been used (Tinytag, GeoPrecision M-Log, HOBO U22 and U23, UTL-1), with accuracies of

0.2 to 0.27 °C. The temperature recording interval is 1–2 h. Temperatures are obtained either on relatively snow-free sites to achieve a good relationship to air temperature, or below thick snow covers to obtain values on the Bottom Temperature of the winter Snow cover (BTS) (Haeberli, 1973).

Ground temperature data are also being monitored by three high-schools in southern Norway through the TSP NORWAY education and outreach module "TSP-fryseboksen"; the "TSP-freezer". The TSP-freezer is a box with a frost tube and a 1.0 m long thermistor string with three thermistors connected to a GeoPrecision miniature data-logger. The schools bought the box from TSP NORWAY and installed the frost tube and thermistor-string to monitor depth of seasonal frost in their schoolyards, or on nearby mountain tops where permafrost is expected. The Longyearbyen school borehole in Svalbard is also part of the education and outreach module, and is also part of the *Permafrost Health Outreach Program* of the University of Alaska, Fairbanks (http://www.uaf.edu/water/projects/permafrost/top.htm).

Also the research project *Permafrost and seasonal frost in southern Norway: Understanding and modeling the atmosphere-ground temperature* (CRYOLINK) (Etzelmüller et al., 2009) started during the IPY, however, focusing geographically in southern Norway. CRYOLINK collects permafrost and seasonal frozen ground temperature data from altitudinal transects in the areas of the mountains Juvvasshøe (6 boreholes), Jetta (3 boreholes) and Tron (3 boreholes), to delineate the local altitudinal limit and thermal state of permafrost.

3 The design of NORPERM

On 26 February 2009 the NORPERM database was officially launched as the main data legacy of the TSP NORWAY IPY-project. Before this date, all data on permafrost temperature was stored only locally on the individual permafrost scientists' computers. NORPERM fulfils the criteria set by the IPY data policy by providing open, free and full access to all temperature data acquired by the project and gradually also to other data on ground temperature in Norway.

The Geological Survey of Norway (NGU) is the managing institution for geological data in Norway, and is therefore the natural institution to host a Norwegian database on ground temperature. NORPERM was developed as part of the larger NGU borehole database system. The database was designed in close collaboration between NGU IT-technicians and TSP NORWAY scientists, with a TSP NORWAY post doc scientist acting as database administrator during the development and first operational phase. The technical programming was made by several IT-technicians at NGU, each specialized on different parts of the system.

The design process started with defining the data types to be included in the database; NORPERM should hold temperature data series acquired in the air, snow cover, near ground surface or boreholes by monitoring set-ups, but also temperature profiles with depth acquired by occasional manual borehole logging (cf. Fig. 3). NGU has temperature logs from deep boreholes (<1000 m) from projects on crustal heat generation and heat flow (Pascal et al., 2008; Slagstad et al., 2009) that also should be included. These are, however, not from permafrost areas. NORPERM should also hold metadata and photographs for detailed site description.

The next step was to define important criteria and to find a suitable structure for the database, before the technical development commenced. NORPERM should be easy to use by the different scientists despite large amounts of data in different formats and being measured with different instruments, and it should have a map-based interface. Another criterion was that proper citation of the datasets when used by other scientists should be ensured. This was facilitated through a citation template, following the IPYDIS policy on citation of IPY datasets. This template can be found under the *Information about the data* tag in NORPERM. The design process lasted two years, from the start of IPY in March 2007 until the launch at the end of the IPY in February 2009.

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3.1 Structural design

The NORPERM database is structured into four levels with decreasing spatial scale (Fig. 4). At the uppermost level are the entire land areas of Norway and Svalbard, as the database shall be able to contain data from all parts of the entire geographical area of the Norwegian Kingdom. Practically, mainly because of differences in available background maps, but also because of the distance between the two land areas, the database has separate interfaces for Norway and Svalbard (www.ngu/no/norperm). The second level is the permafrost observatories (Figs. 1, 2) followed by the permafrost areas at the third level, and finally the individual measurement sites at the finest level of detail (Fig. 4).

The permafrost observatories are at the regional scale, with the Nordenskiöld Land Permafrost Observatory in Svalbard covering 5000 km^2, and the North Scandinavian Permafrost Observatory covering 75 000 km^2 in Northern Norway. At this scale the map service of the database gives the position of the permafrost areas in point format (Fig. 4).

A permafrost area represents a geographically limited area where one or more measurement sites are clustered (Fig. 4). Spatially a permafrost area is typically at the scale of a mountain or a valley. The permafrost areas vary in geographical extent from, in the case of only one measurement site, the immediate surroundings of the site, to 30 km or more in length as for the Advent- and Longyeardalen permafrost area in Svalbard with 13 boreholes and 42 miniature temperature data-loggers (Table 1). Metadata describing the permafrost area, such as climate, large-scale geomorphology and geology, is given in fact sheets for each area. The fact sheet appears when clicking the permafrost areas in the map. The metadata are complemented with overview photographs and sketch maps in standard JPEG-format.

When zooming to a scale finer than 1:1 000 000, the map view changes to show point symbols for the individual measurement sites (Fig. 4). A measurement site may be a borehole with temperature monitoring or a manual temperature log, or measurements

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of air-, snow-, and near ground-surface temperatures from miniature temperature dataloggers (MTDs). Each site has been given ID according to if it is a borehole or MTD site. For example, for the site IS-B-1 the -B- indicates that this is a borehole, and the prefix IS is an abbreviation for the site name, in this case Iškoras. Similarly, the -M- in RW-M-1 indicates that this is a miniature temperature datalogger. The two data types are displayed with different symbols in the map (Fig. 4). Each measurement site has a fact sheet with metadata following the GTN-P standard (Burgess et al., 2000) along with information on instrument type and calibration (Fig. 5). Photographs showing site details are provided at this level. All the temperature data series from the respective measurement sites are available through links in the fact sheet. All data series must be homogenous, i.e. recorded with the same instrument and have the same recording interval throughout. If one or both of these are changed, or if there is a significant period without data coverage, the data are stored as separate series. One measurement site may thus have several data series, and there is a link for each of the data series. The fact sheet also gives a link to an automatically generated graphical overview plot for each of the data series.

3.2 Technical design

Some technical modules from existing NGU databases have been reused, such as login routines, part of the borehole metadata description and handling of photographs. Other modules, such as import of temperature data from diverse formats have been developed especially for NORPERM.

The database is built on the Oracle database system (Oracle RDBSM) and Oracle development tools (Oracle Forms, Oracle Reports, PL/SQL etc), and ArcSDE geodatabase and Web Map Service (WMS, www.isotc211.org) technology for the public map interface (Fig. 6). Oracle maintenance strategies are followed and technical maintenance including back-up every night is performed by the IT-section at NGU, securing all the data in a professional way.

NORPERM has two separate user interfaces; one for data handling and one public. The Oracle interface for data import and maintenance is web-based and password-restricted, enabling external data administration by the different permafrost scientists collecting data. The administrator, who is a permafrost scientist, can sit outside NGU and create or delete NORPERM user profiles for data providers, and grant access privileges to/from the users through the NGU database system. The users can be given reading, writing or administration privileges depending on their different roles.

The data are carefully quality checked by the scientist responsible for the individual measurement sites before being imported into NORPERM (Fig. 6). The administrator is responsible for the overall data quality and to ensure that all TSP NORWAY data and other relevant data are included in NORPERM. The data comes in two fundamentally different formats; the time series of temperatures from various depths and the temperature profiles from manual borehole logging with depth (cf. Fig. 3). The two types of data must be handled differently in the database, with different routines for import, export and storage. In addition, the use of different instruments and data-logger software has resulted in a wide variety of data formats (in particular date formats) that has to be handled by the import routine. The export function, however, gives a standard text-file that can be read by most spread sheets.

To provide a map-based public interface for the different users of the database, NORPERM is georeferenced and made available on the internet using a WMS server (Fig. 6). WMS also makes it possible to combine geographic information seamlessly from various sources in Norway, and share it between many users and applications. In practice, the map services (layers) from different service providers comprise the whole map, and are overlaid in an ordered succession on the screen (Fig. 7). Transparency can be set by the user for the individual map services to obtain the desired map view. Map services used in NORPERM are topography, orthophotos and superficial deposits, the latter only for mainland Norway, allowing a study of controlling factors such as ground material characteristics before selecting which site to download temperature data from. These are shared through the public national co-operation on digital data, Norge Digital (Norway Digital, www.norgedigitalt.no). Map service providers are The Norwegian Mapping Authority, the Norwegian Polar Institute and NGU. The public user interfaces for the Norwegian mainland and Svalbard differ in background map layout, due to different map service providers, and some functions such as geographical search is missing in the Svalbard interface. The applications include standard facilities such as zooming and panoraming.

4 NORPERM metadata exports

Annual metadata reporting to the GTN-P, the international TSP metadatabase, is handled with an export routine that automatically fills out the GTN-P metadata form on the administrator's request (Fig. 6) and stores it in digital format. The temperature at the depth of the zero annual amplitude or lower thermistor is automatically extracted and included in the GTN-P form. The form is sent by e-mail to the GTN-P office at the Geological Survey of Canada. Further, borehole metadata have been made available for the Svalbard Science Forum *Research in Svalbard* metadatabase for cross-disciplinary IPY metadata search.

5 Possible future NORPERM developments

To increase the scientific value of NORPERM, we will work to include also all relevant permafrost temperature data from Norway and Svalbard collected before IPY. Much of such data is at the moment being imported into the database, but it does require an effort also in the post-IPY future to ensure that all relevant data is included.

In its present state, the public interface of NORPERM has somewhat reduced functionality on search functions. At present it is possible to make geographical searches (place names, municipality and county) in the mainland Norway application. We hope to be able to develop search functions also on permafrost areas, measurement site

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names and IDs and metadata describing the sites. A metadata search option would enable a search for all sites with a specific parameter value, e.g. boreholes in bedrock. A search option on temperature summaries at standard levels (annual temperature in the air, at the ground surface and at a specified depth in the ground, in particular at the depth of the zero annual temperature amplitude) would also be feasible.

A possibility for improved visualization through introducing 3-D view has been discussed for the entire NGU database system, and NORPERM will follow this possible upgrade.

We have had increased Nordic permafrost collaboration during IPY, and particularly with the PYRN-TSP project collecting permafrost borehole temperatures in Finland, Norway and Sweden. Therefore it would be natural to expand the NORPERM database to cover the entire Nordic area, thus further developing it to become a regional Nordic permafrost database, still to be abbreviated NORPERM. This Nordic Permafrost Database will provide a much better permafrost data overview and basis for collaboration than has ever existed in the Nordic area. Most likely this would be the first regional permafrost database providing completely open and free access to all permafrost data from an entire region, and with access to near real-time data from selected boreholes.

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Table 1. All NORPERM permafrost areas in the North Scandinavian and Nordenskiöld Land Permafrost Observatories, including the number of boreholes and miniature temperature data-loggers (MTDs). Boreholes with continuous temperature monitoring and boreholes with manual temperature logging are listed separately.

Permafrost Areas	No. of boreholes with monitoring	No. of boreholes with logging	MTDs
North Scandinavian Permafrost Observatory			
Kistefjellet	1	–	2
Njunis	–	–	4
Lavkavagge	3	–	–
Nordnes	3	–	18
Kåfjord-Ryodasvarri	–	–	4
Guolasjavri	3	–	–
Trolltinden	1	–	–
Abojavri	2	–	1
Bidjovagge	–	2	1
Kautokeino	–	–	1
Suolovuopmi	–	–	1
Sihccajavri	–	–	1
Cuovdattmohkki	–	–	3
Karasjok/Iškoras	2	–	7
Tana/Rustefjelbma	–	1	2
Karlebotn	–	–	1
TOTAL	15	3	46

Table 1. Continued.

Permafrost Areas	No. of boreholes with monitoring	No. of boreholes with logging	MTDs
Nordenskiöld Land Permafrost Observatory			
Kapp Linnè	4	–	10
Advent- and Longyeardalen	10	3	42
Ny-Ålesund	1	–	–
Reindalen-Lunckefjell	1	–	–
Svea	1	–	–
TOTAL	17	3	52
Southern Norway (school module)			
Åsvang	–	–	1
Malvik	–	–	1
Gausdal	–	–	1
TOTAL	–	–	3
TOTAL, both observatories	32	6	98

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Table 2. All NORPERM TSP NORWAY borehole measurement sites, with location, borehole length with temperature data, information whether the temperature in the borehole is monitored or manually logged, the start date of monitoring or alternatively the data for manual logging, recording interval in the case of monitoring and type of instrument used. The accuracy of the different instrument types are as follows: YSI-thermistors connected to a Campbell data-logger +/−0.05 °C, GeoPrecision M-Log7 +/−0.2 °C, HOBO U22 +/−0.2 °C, Tinytag +/−0.2 °C, EBA thermistor-string connected to Lakewood data-logger +/−0.2 °C. The TCN- and SWQS-probes have accuracies of +/−0.5 and +/−0.02 °C, respectively. The accuracy of the manual readings with multimeter is assumed to be +/−0.1 °C.

Measurement site (Borehole name)	Borehole ID	Permafrost area	Longitude	Latitude	Elevation (m a.s.l.)	Borehole length (m) with temperature recording	Start date/ Log date	Recording interval (hr)	Instrument type
Northern Norway									
Kistefjellet	Ki-B-1	Kistefjellet	18°07′49″ E	69°17′27″ N	990	24.8	26-Sep-07	6	YSI therm., Campbell log.
Nordnes 1	No-B-1	Nordnes	20°24′33″ E	69°33′21″ N	624	2.3	17-Sep-08	1	GeoPrecision M-Log7
Nordnes 2	No-B-2	Nordnes	20°25′11″E	69°33′21″ N	797	2.3	17-Sep-08	1	GeoPrecision M-Log7
Nordnes 3	No-B-3	Nordnes	20°26′02″ E	69°33′26″ N	908	2.2	17-Sep-08	1	GeoPrecision M-Log7
Lavkavagge 1	La-B-1	Lavkavagge	20°26′44″ E	69°14′57″ N	766	14	08-Sep-07	6	YSI therm., Campbell log.
Lavkavagge 2	La-B-2	Lavkavagge	20°29′34″ E	69°14′20″ N	600	30.5	16-Aug-07	2	HOBO U22
Lavkavagge 3	La-B-3	Lavkavagge	20°34′47″ E	69°13′26″ N	492	15.8	16-Aug-07	2	HOBO U22
Guolasjavri 1*	Gu-B-1	Guolasjavri	21°12′38″ E	69°21′13″ N	786	32.3	06-Sep-07	4–6	GeoPrecision M-Log7
Guolasjavri 2	Gu-B-2	Guolasjavri	21°10′05″ E	69°21′56″ N	814	10.5	17-Aug-07	2	HOBO U22
Guolasjavri 3	Gu-B-3	Guolasjavri	21°03′39″ E	69°21′20″ N	780	10.5	17-Aug-07	2	HOBO U22
Iškoras 1	Is-B-1	Karasjok/Iškoras	25°20′11″ E	69°18′08″ N	585	10.7	04-Mar-08	6	YSI therm., Campbell log.
Iškoras 2**	Is-B-2	Karasjok/Iškoras	25°20′45″ E	69°18′02″ N	600	58.5	26-Sep-08	6	YSI therm., Campbell log.
Abojavri 1	Ab-B-1	Abojavri	22°11′38″ E	69°38′33″ N	761	6.6	19-Aug-07	2	HOBO U22
Abojavri 2	Ab-B-2	Abojavri	22°07′33″ E	69°40′51″ N	570	30.3	19-Aug-07	2	HOBO U22
Trolltinden*	Tr-B-1	Trolltinden	20°25′54″ E	70°04′30″ N	848	29.4	Logger failure	–	GeoPrecision M-Log7
Bidjovagge[−]	Bh-S188A	Bidjovagge	22°29′54″ E	69°16′23″ N	607	22.0	Aug-07	–	therm., multimeter
Bidjovagge 6[−]	Dh-06	Bidjovagge	22°28′50″ E	69°17′59″ N	732	22.0	Aug-07	–	therm., multimeter
Tana Gruber[−]	GA01-04	Tana/Rustefjelbma	28°31′49″ E	70°28′37″ N	370	22.0	Aug-07	–	therm., multimeter
			Total length with monitoring			281.4			
			Total length with manual logging			66.0			
Svalbard									
Kapp Linnè 1	KL-B-1	Kapp Linnè	13°38′05″ E	78°03′21″ N	20	29	22-Sep-08	6	YSI therm., Campbell log.
Kapp Linnè 2	KL-B-2	Kapp Linnè	13°38′13″ E	78°03′15″ N	20	38	22-Sep-08	6	YSI therm., Campbell log.
Kapp Linnè 3	KL-B-3	Kapp Linnè	13°38′23″ E	78°03′11″ N	20	4	19-Aug-08	1	GeoPrecision M-Log7
Kapp Linnè snow drift	KL-B-4	Kapp Linnè	13°44′27″ E	78°03′26″ N	44	2.8	08-Aug-09	1	Tinytag, Gemini data-loggers
Ny-Ålesund	NA-B-1	Ny-Ålesund	11°55′54″ E	78°55′19″ N	46	9.9	06-Aug-08	1	GeoPrecision M-Log7
Gruvefjellet***	GF-B-1	Advent- and Longyeardalen	15°37′55″ E	78°11′48″ N	464	5	03-Mar-08	1	YSI therm., Campbell log.
Endalen**, ***	EN-B-1	Advent- and Longyeardalen	15°46′54″ E	78°11′26″ N	53	19	16-Sep-08	6	YSI therm., Campbell log.
Old Auroral Station 1*	AS-B-1	Advent- and Longyeardalen	15°50′05″ E	78°12′05″ N	9	9.5	23-Feb-04	1	Tinytag, Gemini data-loggers
Old Auroral Station 2**	AS-B-2	Advent- and Longyeardalen	15°50′05″ E	78°12′05″ N	9	9.9	16-Sep-08	1	GeoPrecision M-Log7
Snow drift 1	SN-B-1	Advent- and Longyeardalen	15°54′48″ E	78°11′15″ N	10	9.7	30-Jul-08	1	GeoPrecision M-Log7
Snow drift 2	SN-B-2	Advent- and Longyeardalen	15°54′48″ E	78°11′15″ N	10	5	02-Dec-08	1	GeoPrecision M-Log7
Innerhytte pingo	IP-B-1	Advent- and Longyeardalen	16°20′39″ E	78°11′20″ N	84	19	03-May-08	1	GeoPrecision M-Log7
Longyearbyen school	SK-B-1	Advent- and Longyeardalen	15°36′23″ E	78°12′32″ N	68	9	29-Feb-08	1	GeoPrecision M-Log7
Larsbreen	LB-B-1	Advent- and Longyeardalen	15°35′54″ E	78°11′33″ N	208	11	08-May-08	1	GeoPrecision M-Log7
Breinosa****	E-2009	Advent- and Longyeardalen	16°04′01″ E	78°08′35″ N	677	10	10-Mar-09	1	GeoPrecision M-Log7
Lunckefjell****	20-2009	Lunckefjell	16°46′09″ E	78°01′16″ N	901	90	22-Jun-09	24	YSI therm., Campbell log.
Svea 5	Sv-B-5	Svea	16°47′42″ E	77°52′54″ N	20	8	03-Apr-05	2–6	EBA therm., Lakewood log.
Dh1-CO2-07[−−,] *****	Dh1-CO2-07	Advent- and Longyeardalen	15°32′48″ E	78°14′10″ N	5	440.0	06-Dec-07	–	SWQS water quality probe
Dh2-CO2-07[−−,] *****	Dh2-CO2-07	Advent- and Longyeardalen	15°32′44″ E	78°14′10″ N	5	440.2	04-Dec-07	–	SWQS water quality probe
Dh4-CO2-09[−−−,] *****	Dh4-CO2-07	Advent- and Longyeardalen	15°49′25″ E	78°12′09″ N	9	900.5	02-Dec-09	–	TCN-probe
			Total length with monitoring			288.8			
			Total length with manual logging			1780.7			

* Pre-IPY data available. ** Partly or fully sponsored by the PYRN-TSP project. *** Near real-time data access **** Made in cooperation with Store Norske Spitsbergen Grubekompani. ***** Logging made by the Longyearbyen CO_2 Lab research project and data made available for TSP NORWAY. [−] Only manual logging, recorded with thermistor-string and multimeter. [−−] Only manual logging, recorded with SWQS-probe. [−−−] Only manual logging, recorded with TCN-probe.

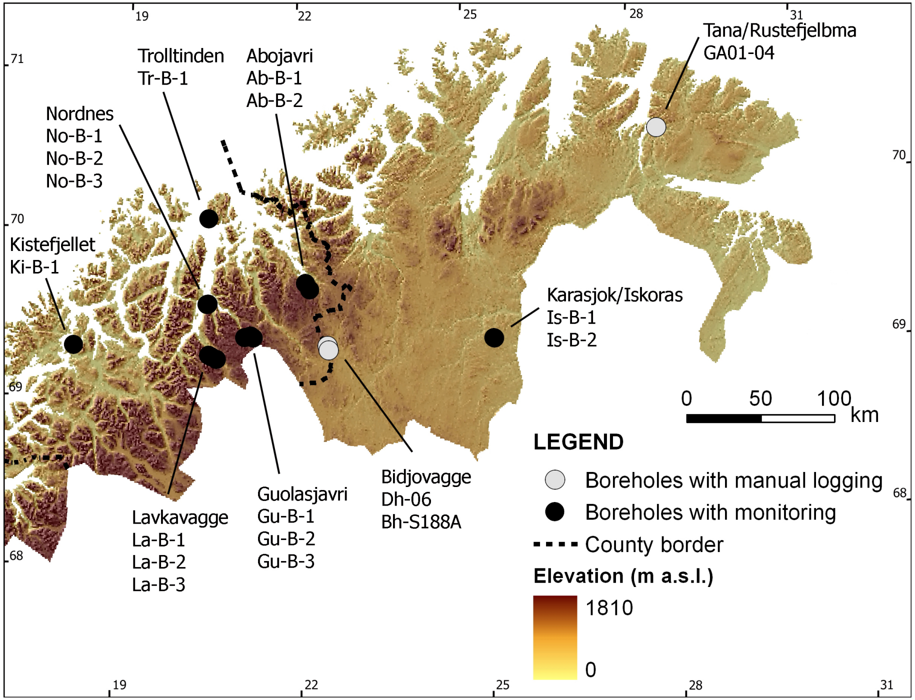

Fig. 1. The North Scandinavian Permafrost Observatory with the position of the boreholes indicated. The borehole IDs refer to Table 2.

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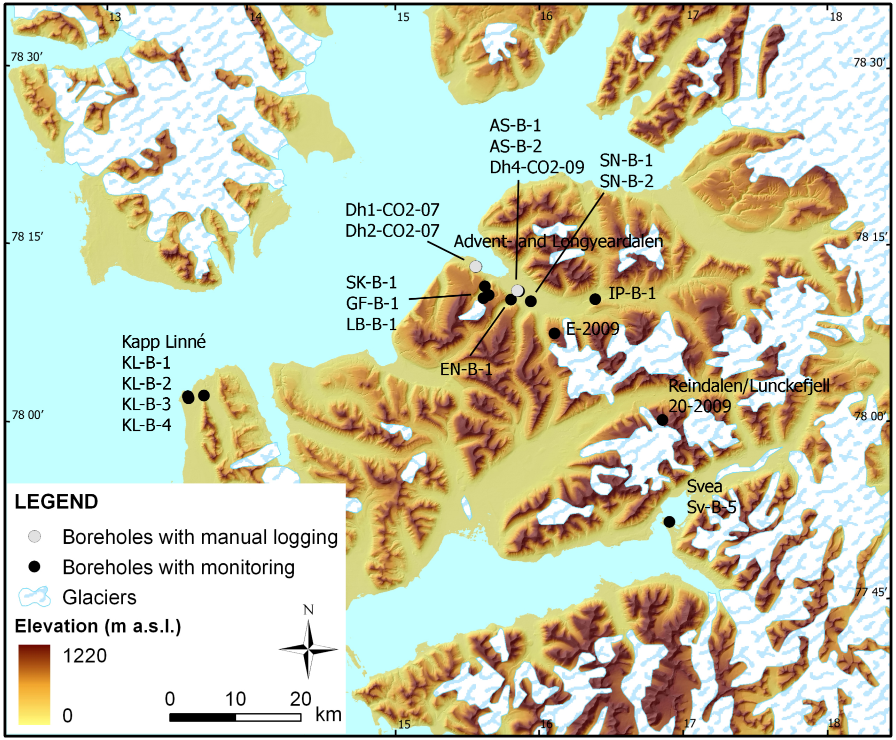

Fig. 2. The Nordenskjöld Land Permafrost Observatory in Svalbard with the position of the boreholes indicated. The Ny-Ålesund borehole is located outside the map. The borehole IDs refer to Table 2.

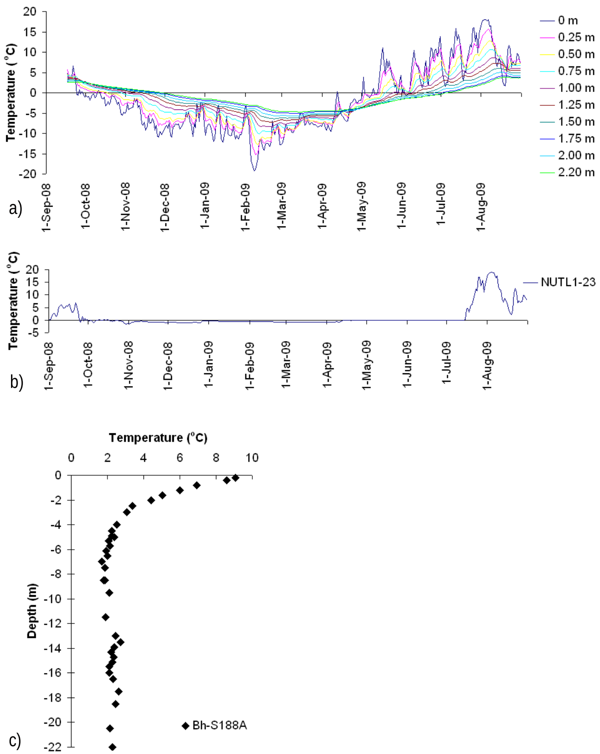

Fig. 3. Examples of the three different data types collected as part of the TSP NORWAY research project, all collected in the North Scandinavian Permafrost Observatory. **(a)** temperature time-series from monitoring in the borehole NO-B-3 in the Nordnes permafrost area, **(b)** temperature time-series from micrometeorological monitoring at the site NUTL1-23 (surface temperature time series illustrating the effect of a thick long-lasting snow cover) in the Nordnes permafrost area, and **(c)** temperature-depth profile from manual borehole logging of the Bh-S188A borehole in the Bidjovagge permafrost area.

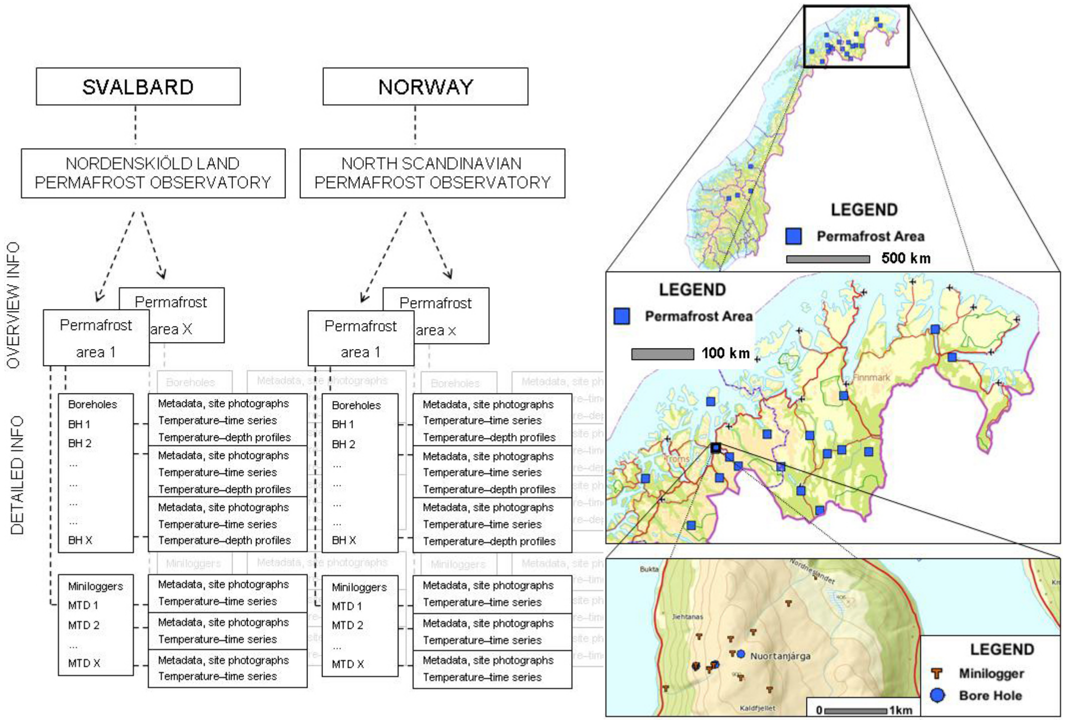

Fig. 4. Overview of the structure of NORPERM. The database is structured into four levels with decreasing spatial scale, represented by the entire land areas of Svalbard and Norway at the coarsest scale, the two permafrost areas at the regional scale followed by the permafrost areas and finally the measurement sites at the finest level of detail. The insert maps shows how this is displayed in the map, with to the upper right the entire Norwegian land area with permafrost areas shown as point symbols, in the middle right the North Scandinavian Permafrost Observatory with permafrost areas also here shown as point symbols, and to the lower right the Nordnes permafrost area with the measurement sites shown as point symbols.

THE BOREHOLE DATABASE
at Norwegian Geological Survey.

Norges geologiske undersøkelse
Geological Survey of Norway

Norsk versjon

Fact Sheet for borehole

Name on Borehole : Kistefjellet; **Borehole ID :** Ki-B-1
Area : Kistefjell
Climatic zone : Nordland og Troms **Land :**Norway

Location

Marking point: **Longitude:** 18.1303662 **Latitude:** 69.2907292
UTM-Zone 34 - EUREF89/WGS84
X-coord: 386784 m. **Y-coord:** 7689433 m.
The coordinates is NOT verified.
Kommune: Lenvik (1931)
Kartblad: Lenvik (1433-1)

Drilling stand

Type of stand: Ground surface **Hight above sea:** 990 m.

Borehole

Length: 25 m. **Depth to rock:** 0 m.
Diameter: 45 mm **Angle/Direction:** 83/ 160 degrees

Casing

Length: **Diameter:**

The Drilling **The year of drilling:** 2007
Purpose: Permafrost Observatory Project TSP Norway
Drilling method: Core drilling
Drilling company: NGU
Project: TSP Norway

Comments

Information from the Permafrost database

Duration of drilling: 1.0 days. **Accessibility to the borehole:** Road
Measurements at borehole site of: - **air temperature?:**Yes ; - **snow thickness?:**Yes
Topography: Slope **Local relief:** 1 m.
Site slope: 5 degrees **Site aspect:** 180 degrees
Vegetation: Lichen
Surface material: Rock
Thickness on organic horizon : 0 cm.
Type of heat source: No heat sources **Distance:**
Description of heat source(s):
Permafrost observed: No
Snow condition: Large snow thickness (greater than 80 cm)

Images from the borehole and/or the borehole area:

Photo no. 1 showing Kistefjellet"

Logging of temperature over time.

Data logger name: Alpug logger system
Install. method : Drilling Install. date: 07.09.2007
Measuring place: In borehole
Measuring date: Start :07.09.2007 Stop :09.09.2009
Measur. interval: 6 Hour
Precision: +/- 0.02 degrees.
No of reg. in time: 2933 Show measuring values. Show graph.

Fig. 5. Example of a borehole fact sheet for the Kistefjellet (KI-B-1) borehole.

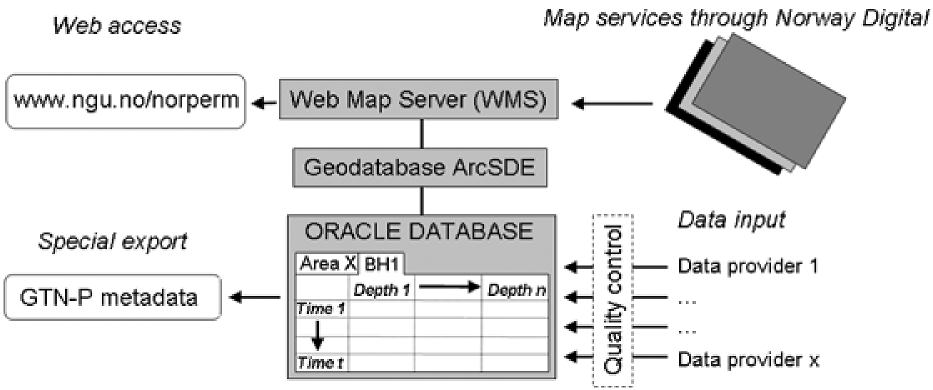

Fig. 6. NORPERM data management structure. Data is entered and stored in an Oracle database (RDBSM) module. The GTN-P metadata export is also developed in Oracle. The map-based public interface builds on georeferencing through an ArcSDE geodatabase and a WMS server for online web access. Digital map layers for the background map are available through Norway Digital.

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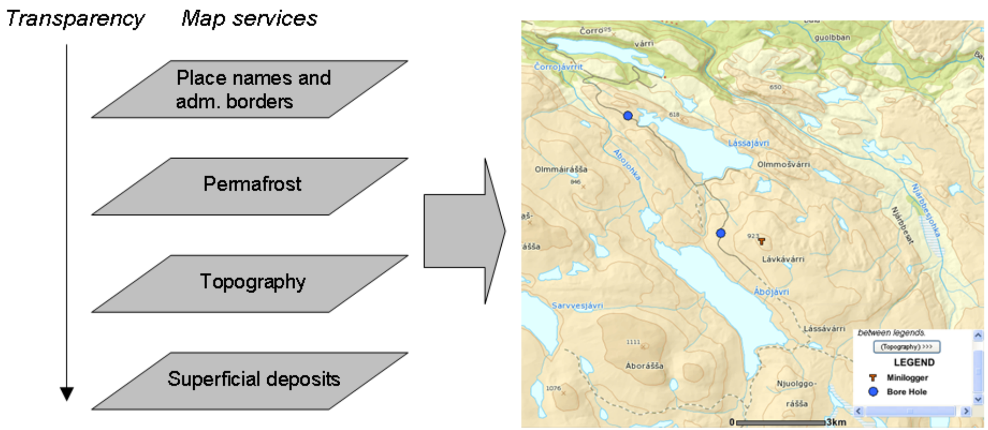

Fig. 7. Compilation of different map layers from different vendors into a composite map. Transparency can be set by the user for the individual map services. The permafrost Map service is the georeferenced data from the Oracle module. The map shows the Abojavri permafrost area with topography and place names.