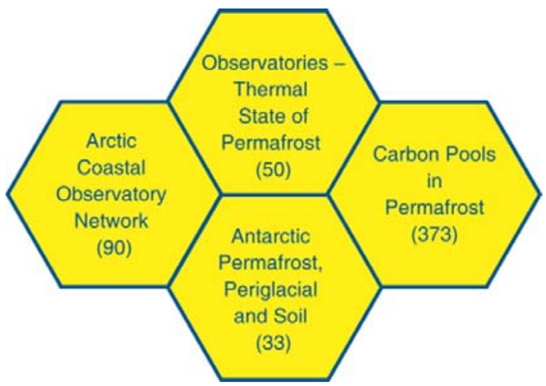
MANUAL FOR MONITORING AND REPORTING PERMAFROST MEASUREMENTS

PART 1: PERMAFROST BOREHOLE TEMPERATURES
Thermal State of Permafrost (TSP)

PART II: ACTIVE LAYER
Circumpolar Active Layer Monitoring (CALM)



International Permafrost Association

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MONITORING AND REPORTING DATA ON PERMAFROST BOREHOLE TEMPERATURES AND ACTIVE LAYER THICKNESS

INTRODUCTION

This document is intended as a guide for measurements and reporting of data on permafrost thermal state and active layer properties during the International Polar Year (IPY). It contains procedures and information developed over the past 15 years. Details on these methods and metadata and data submission formats are available on websites:

- GTN-P Website (www.gtnp.org)
- CALM website (www.udel.edu/Geography/calm)

Four core IPY coordination projects endorsed by the IPY Joint Committee are the focus of the IPY Permafrost Program under the coordination of the International Permafrost Association:

- Project 50: Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost (TSP) – Jerry Brown and Hanne Christiansen
- Project 33: Antarctic and sub-Antarctic Permafrost, Periglacial and Soil Environments (ANTPAS) –James Bockheim and Mauro Guglielmin
- Project 90: Arctic Circumpolar Coastal Observatory Network (ACCO-Net) – Paul Overduin and Nicole Couture
- Project 373: Carbon Pools in Permafrost Regions (CAPP) – Peter Kuhry and Eva-Maria Pfeiffer

Recent results of these programs were report in the Proceedings of the Ninth International Permafrost Conference (NICOP) in summer 2008. Other projects, both approved by IPY and non IPY projects, plan to contribute sites and data.

Our ultimate goals are:

- A sustainable database system
- The establishment of International Network of Permafrost Observatories (INPO).

The same procedures and standards are proposed for the Global Observing Systems for Climate in support of Essential Climate Variables (ECV) required by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC).

Part I: BOREHOLE PERMAFROST TEMPERATURES
(Thermal State of Permafrost-TSP)

The following guidelines are intended to serve existing and new projects and in principle represent a minimum requirement for data collection and submission.

1. BOREHOLE SELECTION AND TYPE MEASUREMENTS

Several criteria are recommended for the designation of boreholes to be included in the long-term International Network of Permafrost Observatories (INPO).

1. Boreholes with long-term records of prior observations in order to establish recent trends (ideally several decades or more).
2. New boreholes in undisturbed areas that can be protected and can be available for continuing observations.

Two measurement strategies are proposed (see several illustrations of types of observatory instrumentation including a remote climate station):

Type 1: Long-term, high-frequency (hourly to daily) continuous observations in a limited number of key boreholes, which are representative of a given regions (note: these more frequent observations are desirable to depths of at least 15-20 meters);

Type 2: Occasional or periodical measurements in the other available and deeper boreholes (if possible annual or more frequently).

2. EQUIPMENT REQUIREMENTS.

- Type 1 observations require dataloggers. A variety of data logging systems are available, and the choice is dependent on national programs and their funding. As a minimum, and based primarily on cost considerations for the IPY-TSP program, the HOBO U12 4-External Channel Data Logger (www.hobologgers.com) with temperature sensors TMC-HD. Additional sensors can be added by using additional multiple point loggers. Operating times can be extended by adding larger capacity batteries (details of calibration and logger modifications can be provided by Vladimir Romanovsky ffver@uaf.edu or the TSP US-Russia website (www.gi.alaska.edu/snowice/Permafrost-lab/projects/projects_active/proj_tsp.html)

Individual participants can employ other types of loggers and/or thermal cables (chains) with similar sensor characteristics for both Type 1 and 2 observations. Several examples are available within national programs as illustrated PERMOS in Switzerland (www.permos.ch)

3. MEASUREMENT FREQUENCY

Type 1: The minimum requirement is three, 8-hour observations per day year round. Four daily observations at 6-hours intervals are recommended.

Type 2: At least one annual temperature logging of a cased borehole is recommended. Early to late Fall measurements coincide with the maximum active layer depth. However, in most cases availability of logistics will determine the actual time of measurement.

4. SPACING OF SENSORS (Type1)

Spacing intervals of sensors depend on depth of holes and number of sensors; shallow holes and relatively undisturbed holes require closer spacing near the surface. CALM soil temperature sites located near a borehole may replace the need for sensors at less than 2 m, (i.e. at surface, 0.3, 1.0, and 2.0m. (see Part II).

Two types of thermistor spacing are proposed as a minimum when using a minimum of four-point logger system:

1. For boreholes less than 15 m deep: 3m, 5m, 10m, and at the bottom of the hole.
2. For boreholes deeper than 15 m: 5m, 10m, 15m and the maximum depth of the borehole.

Additional measurements at other depths using a cable (thermal chain) with or without loggers are welcome, but should be carefully documented in a standard table form (depth vs temperature at different times; see **Data Processing**).

5. DATA PROCESSING AND REPORTING

5.1. Metadata file

Each borehole and active layer site requires an individual metadata form. During the IPY period and in preparation for the CAPS 3.0 CD ROM, a universal coding system is proposed for each site. For boreholes, follow the GTN-P instruction (www.gtnp.org). It is recommended that each borehole provide, as available, a gallery of images (general landscape view, view of drilling site, detail view of borehole and air or space images).

The following designation is recommended for newly assigned boreholes: a unique number (***borehole ID***) and a responsible individual in the following format:

National team ID (2 letters_2 digits)_Number of the borehole (4 digits).

Example: for Russia, ***RU_01_0003*** (Borehole No. 3 of the Russian research team leader 01). The responsible national data manager (see list below) will assign the team ID and borehole numbers upon receipt of the draft metadata form. Approved forms will be forwarded to the GTN-P.

5.2. Data reporting

Data from the boreholes should be reported at least once per year starting in 2007. Individuals are responsible for quality control unless other arrangements have been agreed to with national or regional coordinators. The goal is two fold: (1) to obtain a consistent snapshot of permafrost temperatures during the IPY period (2007-2009) and (2) to provide a database for archiving and production of future data products such as CAPS 3.0. "Snapshot" or summary data will be submitted annually for posting on the GTN-P. Processed archival data will be submitted through national coordinators for archiving locally and at the National Snow and Ice Data Center (NSIDC). Additional policies and methods of data submission are under development.

5.3. Data file

An example of data submission is provided for boreholes equipped with U12-4 dataloggers (reporting by individual projects may differ):

1. The original data spreadsheet (electronic) with the measurements per day during the year.
2. Averaged daily temperatures. Software for averaging available from the U.S. coordinators.

The data will be stored in the database with the following proposed structure.

For Type 1 measurements using a 6-hour observational period:

Borehole ID	Depth (m)			
Time	3.0	5.0	10.0	15.0
27.10.2006 0:00	-5.573	-8.396	-10.092	-9.439
27.10.2006 6:00	-5.573	-8.396	-10.092	-9.439
27.10.2006 12:00	-5.573	-8.396	-10.092	-9.439
27.10.2006 18:00	-5.573	-8.396	-10.092	-9.405
…	…	…	…	…
dd.mm.yyyy hh:mm	t.ttt (^{o}C)	t.ttt (^{o}C)	t.ttt (^{o}C)	t.ttt (^{o}C)

- For average daily temperatures

Borehole ID	Depth (m)			
Time	3.0	5.0	10.0	15.0
27.10.2006	-5.573	-8.396	-10.092	-9.431
28.10.2006	-5.573	-8.396	-10.092	-9.439
…	…	…	…	…
dd.mm.yyyy	t.ttt (^{o}C)	t.ttt (^{o}C)	t.ttt (^{o}C)	t.ttt (^{o}C)

For Type 2 Measurements:

Borehole ID	Depth, m			
Time	x.x	x.x	…	x.x
dd.mm.yyyy	-5.573	-8.363	…	-10.057

- All data should be presented in a MS Excel files entitled: ***Boreholes ID_year_6h.xls*** (for files with 6 hourly measurements) and ***Boreholes ID_year_d.xls*** (for files with averaged daily temperatures).

- Examples: ***RU_01_0003_2007_6h.xls*** or ***RU_01_0003_2007_d.xls***
- Format of depth record: in meters, one position after decimal point: *x.x*. Format of the date of a record: *dd.mm.yyyy*
- ATTENTION! In all types of data **dot symbol (.), NOT comma** (,) should be used as a decimal point!!!

6. Equipment Documentation

For Type 2 measurements description of equipment is required. In this file, the following information is required:

1. Type of the sensor(s)
2. Operating range and precision
3. Method of measurements (multi-sensor cable/thermal chain or single sensor)
4. Description of the measuring instrument or data logger used for measurements.
5. Protocol of sensors calibration at 0ºC in the table format temperature vs time. Calibration should be done using the ice-bath method twice per year (at the beginning and end of season of measurements) for the mobile measuring system or at least once before installation for the permanently installed cables/loggers.

7. National and/or Regional Coordinator

Canada and international metadata coordinator: Sharon Smith < ssmith@nrcan.gc.ca >

United States, Russia and Asia (Mongolia, Kazakhstan): Vladimir Romanovsky <ffver@uaf.edu> and Alexander (Sasha) Kholodov < akholodov@gi.alaska.edu >

Nordic: Hanne Christiansen <hanne@unis.no>

Europe: Switzerland: Daniel VonderMuehll <daniel.vondermuehll@systemsx.ch>

Antarctic: Mauro Guglielmin <mauro.guglielmin@uninsubria.it>

China: Lin ZHAO linzhao@lzb.ac.cn

Japan: TBN

PART II: ACTIVE LAYER THICKNESS
Circumpolar Active Layer Monitoring (CALM)

INTRODUCTION

Active-layer thickness (ALT) is the maximum development of the seasonally thawed layer, reached at the end of the summer or early fall. Thaw depth is the thickness of the thawed layer at any time during its development in summer. Active-layer thickness can vary substantially both spatially and on an interannual basis. In general, it is greater in years with warmer summers and thinner in those with cooler temperatures. Both thaw depth and ALT display large spatial variability over short lateral distances in response to the properties of surface and subsurface materials.

The CALM network currently consists of more than 165 active sites in both hemispheres. In addition to soil thaw, soil and air temperature, soil moisture content, and vertical movement are also measured at many sites. Recommended protocols for establishing sites, measuring active-layer, soil temperatures and moisture, and vertical displacement and reporting data are found on the CALM and related web sites and reporting data:

- http://www.udel.edu/Geography/calm/
- http://www.unis.no/RESEARCH/GEOLOGY/Geo_research/Ole/PeriglacialHandbook/ActiveLayerThicknessMethods.htm

The following is a summary of CALM requirements and procedures. Users are referred to web sites for details or contact the CALM data coordinator:
Kolia Shiklomanov <shiklom@UDel.Edu>

1. ACTIVE LAYER

Measurements along transects or on grids provide data on annual thaw patterns, provide data for volumetric estimates, and identify the factors responsible for active-layer variability. The length of transects or the dimensions of grids depend on the scale of local variability. Grids are typically 10, 100 and 1000 m on a side, with grid nodes spaced evenly at 1, 10, or 100 m, respectively (Appendix B). Probing of the active layer is performed mechanically with a graduated metal rod (see website for details).

2. SOIL AND AIR TEMPERATURES

Soil and shielded air temperatures are recorded using dataloggers at one or more points on the grid. Temperature sensors (usually thermistors) are inserted into the active layer and upper permafrost in a vertical array. The temperature sensor may be individual probes or a series of thermistors embedded in a small-diameter acrylic cylinder place in the soil and permafrost, and connected to data loggers (see Part 1). Depths vary based on local conditions. A minimal, single site array includes sensors at 1.5m above the surface in a radiation shield, ground surface, 0.5, 1.0, 1,5, 2.0m depths. Data are recorded at recommended, two-hour intervals, year round. ALT is interpolated from these daily records.

3. FROST TUBE

Thaw/frost tubes are devices extending from above the ground surface through the active layer into the underlying the permafrost. They provide an inexpensive annual record of active-layer thickness and are especially useful in areas where thaw is too deep to monitor by probing, and in stony, fine-textured, or saline substrates in which probing is not feasible. Because the device is embedded in permafrost, the outer tube serves as a stable reference to determine if thaw subsidence or heave has occurred.

4. SOIL MOISTURE CONTENT

Methods include both destructive (gravimetric) and non-destructive The soil moisture content has an important effect on soil thermal properties, soil heat flow, and vegetation and is a critical parameter in analyzing the magnitude and variability of summer thaw. If possible, all measurements should be made at a depth of 15-20 cm with a known volume of soil collected. It is useful to sample throughout the summer at about 6-10 sites over the grid. If this is not feasible, end-of-summer measurements are most useful at time of ALT probing. The location should be marked with a stake, and samples collected from near (0.5 m) the same site each year.

Non-destructive measurements applies to digital measurements collected and recorded at a single or multiple sites, and refer especially to TDR and similar sensors. Metadata should include the site location (see CALM map form), type and model of instrument, soil type and texture, depth of reading(s), and temporal frequency of measurements. The time and date should be included with the time series of soil moisture content.

5. VERTICAL DISPLACEMENT (update in progress based on the CALM June 2008 NICOP workshop)

Thaw subsidence (thaw settlement) refers to downward displacement of the ground surface occurring when ice-rich permafrost thaws. This consolidation may not be apparent in ALT records obtained exclusively by mechanical probing. Frost defended benchmarks or other methods of tracking changes in surface and permafrost elevations are currently in use. See the following for an example of a simple device use to observe vertical displacement: http://www.udel.edu/Geography/calm/research/vertical_gauge.html

6. DATA REPORTING

Each site requires a completed metadata form (Appendix C). An optional soils description form is available. Annual data are submitted to the CALM data coordinator in the recommend formats. ALT are posted in a multi-year format on the CALM web site. Soil temperature and other data files for each site are posted as individual files on the web. In the case of U. S. funded sites all data are submitted annually to the National Snow and Ice Data Center for archiving and inclusion on the CAPS CDs.

Appendix A. GTN-P Metadata Form (rev. 03/2007)

BOREHOLE NAME (see new nomenclature rules)

COUNTRY (select recommended country code and name for new metadata forms)
AR ARGENTINA
AU AUSTRIA
CA CANADA
CN CHINA
DK DENAMARK
IS ICELAND
IT ITALY
JP JAPAN
KZ KAZAKHSTAN
MN MONGOLIA
NZ NEW ZEALAND
NO NORWAY
PL POLAND
PT PORTUGAL
RU RUSSIA
ES SPAIN
CH SWITZERLAND
UK UNITED KINGDOM
US UNITED STATES

LATITUDE AND LONGITUDE (degrees, minutes, seconds if available)

BOREHOLE DEPTH (m) AND MEASUREMENT INTERVAL IF DIFFERENT FROM DEPTH

YEAR DRILLED

METHOD OF DRILLING

DURATION OF DRILLING (hours/days)

TYPE OF AND DISTANCE FROM HEAT SOURCES (surface disturbance, m)
Natural [ ] no disturbance [ ] lake [ ] river [ ] other natural disturbance (describe)
[ ] anthropogenic (describe type of disturbance; pipeline, storage area, reservoir, etc.)

PERIOD OF PRIOR MEASUREMENTS AND FREQUENCY (starting date; annually, monthly, weekly, or daily etc.)

METHOD OF TEMPERATURE MEASUREMENT (thermistor probe, permanent cable [provide number of sensors and nominal depth], fluid filled hole and its level, diameter and type of casing , depth of casing, etc.)

PERMAFROST ZONE Continuous [ ] Discontinuous [ ] Sporadic [ ]
Isolated [ ] Mountain [ ]

PERMAFROST [ ] PRESENT [ ] ABSENT

PERMAFROST THICKNESS (if known, m)

MEAN ANNUAL GROUND TEMPERATURE AT OR NEAR DEPTH OF ZERO ANNUAL AMPLITUDE (within 0.1°C) – report value for most recent year or 12 month interval

Depth of zero annual amplitude (or depth of measurement reported above) (m)

Year or 12 month interval for mean reported above

Range (if applicable) of mean annual ground temperature over observation period (°C)

ELEVATION (above sea level , m)

SITE SLOPE (angle, aspect)

SITE TOPOGRAPHY AND LOCAL RELIEF [ ]Valley [ ]Top of hill or ridge [ ]Plain
Local relief (m)

LANDFORM OR GEOMORPHOLOGICAL DESCRIPTION AND HISTORY OF SITE (age)

GEOLOGY (brief description of bedrock, sediments, including types and estimate of ice content volume [high, medium, low])

DOMINANT SITE VEGETATION
[ ] Polar desert [ ]Tundra [ ] Shrub Tundra [ ] Forest Tundra [ ]Coniferous Forest
[ ] Deciduous Forest [ ] Grassland [ ] Other (describe)

AIR TEMPERATURE AND SNOW COVER THICKNESS/DENSITY MEASUREMENTS AT THE BOREHOLE SITE (indicate frequency of observations):
Air temperature: Yes [ ] No [ ] Snow thickness: Yes[ ] No[ ] Density: Yes [ ] No[ ]

ACCESSIBILITY OF THE BOREHOLE
Mode of transportation (helicopter, road, offroad vehicle, river, etc.)

Distance from road access (km)

NAME AND LOCATION OF CLOSEST CLIMATE STATION (latitude, longitude, and distance from borehole, km) – provide (if available) mean monthly air temperature and snow depth of reporting interval for mean annual ground temperature

RESPONSIBLE INDIVIDUAL(S) AND ORGANIZATION FOR DATA COLLECTION (complete mailing address, email and fax addresses)

RELEVANT PUBLICATIONS (complete citation, use additional space)

OTHER COMMENTS: (use additional space)

APPENDIX B: SAMPLING POINTS OF A CALM GRID

SITE:______________________ **DATE: _______**

Northing: __________

Northing

1	2	3	4	5	6	7	8	9	10	11
12	13	14	15	16	17	18	19	20	21	22
23	24	25	26	27	28	29	30	31	32	33
34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63	64	65	66
67	68	69	70	71	72	73	74	75	76	77
78	79	80	81	82	83	84	85	86	87	88
89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120	121

Easting

Northing: __________

Easting: ___________

Easting: ___________

Sum: ________ **Max: _______** **Min: ______**

N: **Mean:** **Std. Dev:**

APPPENDIX C: CALM SITE METADATA FORM (rev. 03-24-07)

SITE NAME: ____

COUNTRY: (USE OR MODIFY LIST INDER GTN-P METADATA FORM)

PRIMARY RESEARCHERS:____
____

SITE LATITUDE/LONGITUDE: ____

SITE ELEVATION (mean elevation above sea level, meters): ______________________

SITE SLOPE AND ASPECT: ____

GEOMORPHOLOGICAL (landform) DESCRIPTION OF AREA CONTAINING SITE:
____
____
____
____
____

SOIL DESCRIPTION (see soil form page 1 and 2 for more detail:
< http://www.udel.edu/Geography/calm/research/forms/soil_page1.html>;
or simply indicate predominant texture, i.e., ‘sand’, ‘gravel’, ‘peat’, etc.):_________
____

PERMANENT TEMPERATURE AND/OR MOISTURE INSTALLATIONS (probes, recorders, sensors, etc.); INCLUDE ANNUAL AVERAGE VALUES/RANGES WHEN POSSIBLE: ____
____
____

CLOSEST CLIMATE STATION (name, lat./long.); INCLUDE MONTHLY AIR TEMP. AND SNOW DEPTH FOR YEARS OF CALM MEASUREMENTS: _______________
____
____

ADDITIONAL COMMENTS: