Permafrost Temperature

Based on

GCW Permafrost - Guide on Best Practices. Work in Progress by the Permafrost Task Team of the GCW Advisory Group. It will be included in the WMO Guide for Instruments and Methods of Observation (WMO No.-8), Volume II, Measurement of Cryosphere Variables.

Isaksen, K., Lutz, J., Sørensen, A. M., Godøy, Ø., Ferrighi, L., Eastwood, S., & Aaboe, S. (2022). Advances in operational permafrost monitoring on Svalbard and in Norway. Environmental Research Letters, 17(9), 095012. DOI: 10.1088/1748-9326/ac8e1c

Streletskiy, D., Noetzli, J., Smith, S.L., Vieira, G., Schoeneich, P., Hrbacek, F. and A.M. Irrgang (2022): Measurement Recommendations and Guidelines for the Global Terrestrial Network for Permafrost (GTN-P). DOI: 10.5281/zenodo.5973079

Definition and background

Permafrost: Subsurface material that remains continuously at or below 0 °C for at least two consecutive years.

The observation of permafrost relies on in-situ measurements.

Temperature measurement in boreholes is the only direct and quantitative thermal observation and the primary method for long-term climate-related permafrost monitoring.

Permafrost was selected as one of the essential climate variables (ECVs) of the Global Climate Observing System (GCOS).

ECV Permafrost Products and Units of Measure to comply with the WMO definitions and best practices

Definitions

Permafrost temperature:

- The ground temperature measured in the permafrost at specific depths.
- It is the primary and direct variable to observe permafrost and its changes.
- Permafrost temperature is measured in degrees Celsius (°C).
- Measured typically along a vertical profile in a borehole.
- The typical depth of boreholes varies from less than 10 m to 100 m or more.

Measurement methods

Permafrost temperatures are commonly measured in a drilled borehole. The two most often used methods are

(1) permanent installation of a temperature sensor string in the borehole for continuous measurements often by a data logger, or

(2) temporary lowering of a portable temperature sensor into the borehole to measure the temperature at different depths.

Measurement methods (continuous temperature reading)

- Data loggers are utilized for measurements typically every 1 to 24 hours and provide a continuous record of ground temperatures
- Accessed remotely for (near) realtime data (if remote access is not available, periodic visits are required to acquire data from loggers).

Measurement methods (manual temperature reading)

- 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, depending on the depth and corresponding temperature variability.
- At depths below the penetration of the annual temperature wave (i.e., the Depth of Zero Annual Amplitude, DZAA), and up to depths of about 50 m, annual temperature measurements are sufficient.
- At greater depths (>50 m) where temperatures change slowly, biennial or less frequent (5–10 years) measurements are sufficient to capture long-term changes in permafrost temperature.
- With increasing permafrost warming and degradation, more advective processes may become relevant, which cannot be captured with measurements of low temporal resolution.
- In light of increasing permafrost temperatures at the majority of measuring sites it is recommended to increase the frequency of permafrost temperature measurements.

Depth below land surface

- The standard depths for permafrost temperature measurements defined by the *Global Terrestrial Network for Permafrost* (GTN-P) are 5, 10, 20 m below the surface.
- Spacing of sensors generally increases with depth due to the decreasing temporal variability in the ground temperatures.
- For example, in the uppermost 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 below the Depth of the Zero Annual Amplitude (DZAA).
- The minimum desirable sensor levels for continuous measurements using data loggers for boreholes less than 15 m deep are: 3, 5, 10 meters and at the bottom of the borehole.
- Within the EU Project PACE a standard for a 100 m borehole was defined (Harris et al. 2001): 0.2, 0.4, 0.8, 1.2, 1.6, 2, 2.5, 3, 3.5, 4, 5, 7, 9, 10, 11, 13, 15, 20, 25, 30, 40, 50, 60, 70, 80, 85, 90, 95, 97.5 and 100 m depth below land surface
- Measurements at the DZAA as well as at 10 and 20 m depth were established for reporting in national and international assessments.

Permaforst Temperature sensors

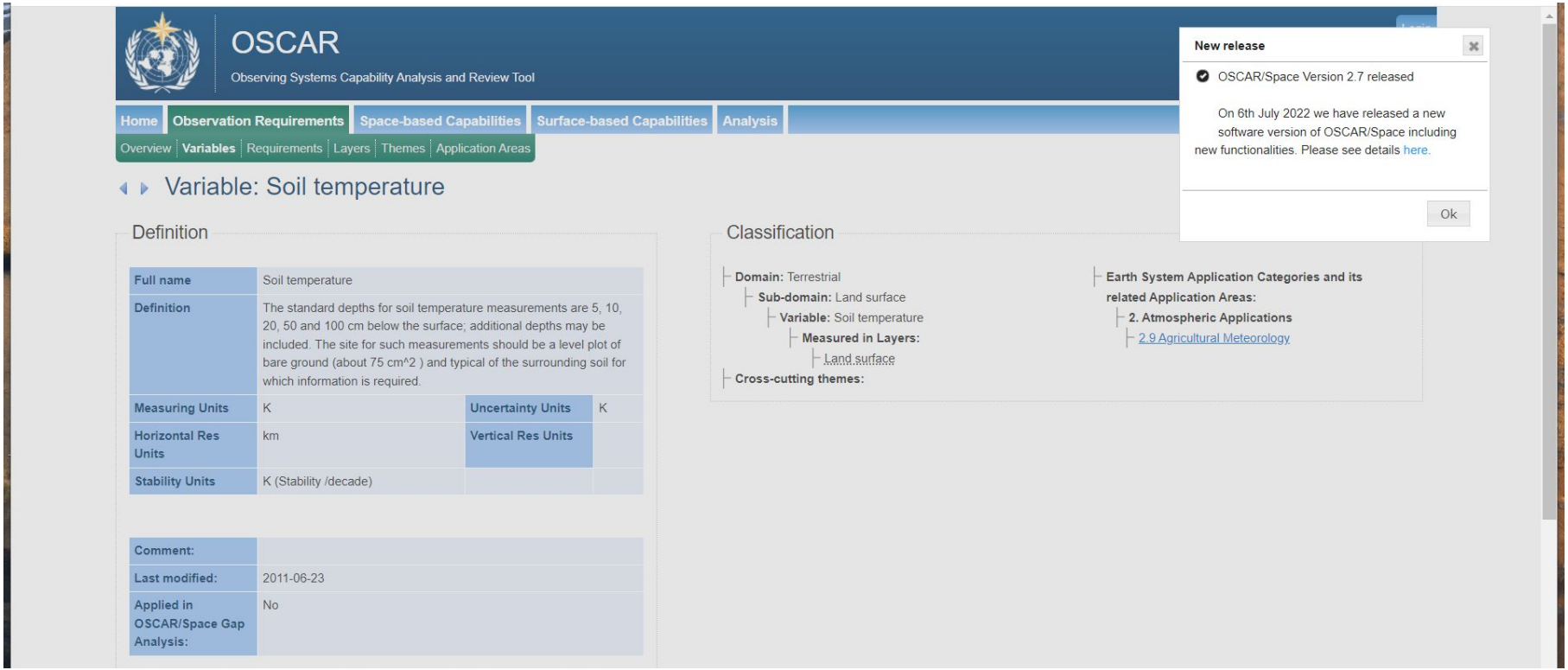
Thermistors and Resistance Temperature Detectors

Thermocouples

Fiber optic (Distributed Temperature Sensing (DTS))

Silicon based digital temperature sensors

Soil temperature (WMO)



Soil temperature (WMO CIMO Guide 2014)

2.2.2.3 Measuring soil temperatures

- The standard depths for soil temperature measurements are 5, 10, 20, 50 and 100 cm below the surface; additional depths may be included.
- The site for such measurements should be a level plot of bare ground (about 75 cm^2) and typical of the surrounding soil for which information is required.
- If the surface is not representative of the general surroundings, its extent should not be less than 100 m^2.

BUFR - WMO observation templates

6.1 WMO AWS (automatic and manned station) template, one hour period (Dragosavac, ECMWF 2008)
DATA DESCRIPTORS EXPANDED

24	002189	CAPABILITY TO DISCRIMINATE LIGHTNING STRIKES
25	010004	PRESSURE
26	010051	PRESSURE REDUCED TO MEAN SEA LEVEL
27	010061	3-HOUR PRESSURE CHANGE
28	010063	CHARACTERISTIC OF PRESSURE TENDENCY
29	007004	PRESSURE
30	010009	GEOPOTENTIAL HEIGHT
31	007032	HEIGHT OF SENSOR ABOVE LOCAL GROUND (OR DECK OF MARINE PLATFORM)
32	007033	HEIGHT OF SENSOR ABOVE WATER SURFACE (SEE NOTE 6)
33	012101	TEMPERATURE/DRY-BULB TEMPERATURE
34	012103	DEW-POINT TEMPERATURE
35	013003	RELATIVE HUMIDITY
36	007061	DEPTH BELOW LAND SURFACE
37	012130	SOIL TEMPERATURE
38	007061	DEPTH BELOW LAND SURFACE
39	012130	SOIL TEMPERATURE
40	007061	DEPTH BELOW LAND SURFACE
41	012130	SOIL TEMPERATURE
42	007061	DEPTH BELOW LAND SURFACE
43	012130	SOIL TEMPERATURE
44	007061	DEPTH BELOW LAND SURFACE
45	012130	SOIL TEMPERATURE
46	007032	HEIGHT OF SENSOR ABOVE LOCAL GROUND (OR DECK OF MARINE PLATFORM)
47	007033	HEIGHT OF SENSOR ABOVE WATER SURFACE (SEE NOTE 6)
48	033041	ATTRIBUTE OF FOLLOWING VALUE
49	020001	HORIZONTAL VISIBILITY
50	007032	HEIGHT OF SENSOR ABOVE LOCAL GROUND (OR DECK OF MARINE PLATFORM)
51	007033	HEIGHT OF SENSOR ABOVE WATER SURFACE (SEE NOTE 6)
52	020031	ICE DEPOSIT (THICKNESS)
53	020032	RATE OF ICE ACCRETION

35	RELATIVE HUMIDI	0.7800000000E+02	%
36	DEPTH BELOW LAN	0.5000000000E-01	M
37	SOIL TEMPERATUR	0.2896500000E+03	K
38	DEPTH BELOW LAN	0.1000000000E+00	M
39	SOIL TEMPERATUR	0.2893500000E+03	K
40	DEPTH BELOW LAN	0.2000000000E+00	M
41	SOIL TEMPERATUR	0.2892500000E+03	K
42	DEPTH BELOW LAN	0.5000000000E+00	M
43	SOIL TEMPERATUR	0.2883500000E+03	K
44	DEPTH BELOW LAN	0.1000000000E+01	M
45	SOIL TEMPERATUR	0.2850500000E+03	K
46	HEIGHT OF SENSO	0.2000000000E+01	M
47	HEIGHT OF SENSO	MISSING	M
48	ATTRIBUTE OF FO	0.0000000000E+00	CODE TABLE 33041
49	HORIZONTAL VISI	0.1200000000E+05	M
50	HEIGHT OF SENSO	MISSING	M
51	HEIGHT OF SENSO	MISSING	M
52	ICE DEPOSIT (TH	MISSING	M
53	RATE OF ICE ACC	MISSING	CODE TABLE 20032

Possible points to discuss

- What changes ought to be made in BUFR tables for reporting permafrost temperature?
  - New element descriptor 'Permafrost Temperature', - or is 0 12 130 *Soil Temperature* sufficient?
- Extending code table 0 02 096 *Type of temperature sensor*?
- New sequence descriptor(s) for including permafrost temperature?
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