Guide lines for monitoring

BTS
Bottom temperature of snow cover

Definition

The Bottom Temperature of Snow cover (BTS) is defined as the temperature measured at the snow/ground interface (Haeberli 1973).

BTS has to be distinguished from Ground Surface Temperature (GST), which is measured in the ground (soil or rock) slightly below the surface. BTS measurement probes do not penetrate the ground and measure therefore the temperature of the lowermost snow rather than that of the ground.

Relevant parameters

The scope of BTS measurements is to assess the Winter Equilibrium Temperature (WEqT). Thus, measurement campaigns are usually made during the late winter, when a sufficient snow cover is established since at least one month (typically March, or even early April), but before onset of snow melt.

The WEqT will depend i) on the presence/absence of permafrost, and ii) on the history of the snow pack on the measurement location.

In presence of permafrost, the negative heat flux coming up from the cold frozen subsurface will lead to strongly negative WEqT (typically less than -2 °C), whereas on non frozen soil, the WEqT will be close to 0 °C or moderately negative (Haeberli 1973). Thus the WEqT can be a good indicator of permafrost occurrence and can help to discriminate permafrost from non-permafrost areas, provided that the snow cover developped early in the winter and remained sufficient to isolate the soil surface from atmospheric influence.

Classically, the following typical threshold values of WEqT were used as indicators :
- GST > 2 °C : permafrost unlikely.
- GST 2-3 °C : permafrost possible, uncertainty range.
- GST < 3 °C : permafrost probable.

However, the WEqT is strongly influenced by the snow height and duration. It is usually admitted that a snow depth of 80 to 100 cm is necessary to provide a sufficient insulation against air temperature variations. Thus WEqT is not reached every year, neither at every location. In addition, the snow cover must be established since the beginning of the winter. If a sufficient snow cover is lacking, especially during the cold days of November-December, the soil will cool down drastically, leading to deep seasonal frost, and very negative values of WEqT can be measured even in non-permafrost areas.

As a result, WEqT at a given location may vary by 2-3 °C from one winter to the other, depending on snow cover history. Thus the threshold values have been abandonned, and the discrimination of permafrost/non-permafrsot areas relies on the contrasts of WEqT, usually well marked if WEqT is reached.

Correction equations have been proposed and used in order to correct the influence of snow thickness and homogenize the data. The interest of such a correction is limited, due to the high temporal and spatial variability of BTS, and statistical analyses have shown the absence of correlation between snow depth and BTS at a given date. Thus the use of snow depth corrections has been adandonned.

Measurement techniques

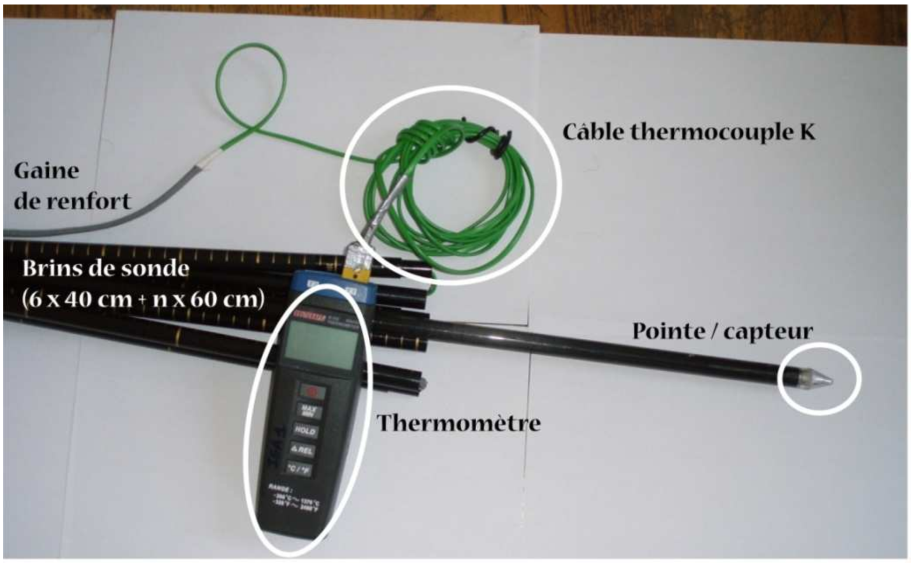
BTS is measured in winter through the snow cover with special probes. The following devices are used :

- Glass fiber sticks, equipped with a sealed thermistor probe, distributed by Markasub AG (Switzerland). The resitance values are read on a multimeter, and converted to temperatures by a formula depending on the thermistor type. This commercial device can be assembled to a length up to 4 meters, with 1 m pieces. Price : ca 1500 €, only on special ordering.
- A light device has been developped by GIPSA-lab and IGA-PACTE, using a standard carbon fiber avalanche probe of 3 m equipped with a thermocouple, with direct reading of temperature. Price : ca 100 € of material, with self construction.
- A new model using the same carbon fiber avalanche probe, was equipped with a Pt 100 thermistor probe. Resistance values are read on a multimeter, and converted to temperatures by a formula depending on the thermistor type. Price : ca 250 €, including installation and calibration.

The Markasub probe is the most used and the only commercially available. It has a good precision, but proved to be fragile and very sensitive to schocks. The measurement point can easily be damaged and has then to be replaced (cost of 250-300 €). The price is high, considering that efficient survey campaigns need several probes.

The home made thermocouple probe had a lower precision and needed to be calibrated. There may be offsets between different probes, so that a series of common measures has to be made in order to calculate a correction function for each probe. In addition, the stability of measurement proved to be vairable, due to the fact that thermocouple measurements are influenced by the temperature of the connection to the electronic thermometer. Thermocouple must therefore be considered as unsuitable for measurements in winter conditions.

The avalanche probes were thus transformed and equipped with Pt 100 thermistors. Once calibrated, these are very stable and reliable. Such devices are very suitable, and have many advantages compared to the Markasub probe : low cost, light weight, easy to carry in a back pack, good penetration in snow. The only disadvantage is the limited length. It is important ot use a carbon and not an aluminium avalanche probe, in order to avoid heat conduction along the probe.



+ Corps de sonde en carbone (isolant, léger)
+ Pointe en aluminium (conducteur, léger)
+ Connectique limitée

- Thermocouple K : précision +/- 0,5°C
- Electronique sensible au froid

Fig. 1 – Home made BTS probe based on a 3 m long commercial carbon fiber avalanche probe and a K thermocouple inserted in the aluminum point. Direct temperature reading on an eletronic thermometer.

Several problems may occur during measurement due to the internal structure of the snow cover :

- The probe must reach the ground. On rocky material, the sound usually allows a confident control, but on soft ground it may be difficult to be sure that the probe really touches the ground.
- The presence of icy freezing levels in the snow pack may hinder the penetration of the probe.
- Even without ice layers, the penetration can be difficult, depending on the snow quality.
- The limited length of the probes doesn't allow measurements on deep snow accumulation areas.

For the Markasub probe, the use of an extra stick for making the hollow is necessary, because of the fragility of the measurement point of the probe. The much thinner avalanche probe has a much easier penetration capacity and can be used directly.

Measurement strategies

BTS measurement is used for mapping of the spatial distribution of ground temperatures.

The usual method is based on a grid sampling, and interpolation of the temperature distribution. Several works have been made on the ideal sampling interval. An interval in the order of 15 to 30 m is recommended, depending on the heterogeneity of the micro-topography and the extent of the area to map. The most efficient way is to use a rope of fixed length for the interval and to measure parallel lines. As each measure needs a stabilization time of 20-15 minutes, a survey needs several probes.

Another sampling strategy is to measure along transects, if possible on at least 2 parallel lines.

As the interpretation bases more on the interpolated temperature distribution than on single point values, the exact localisation of every point is not crucial (precision of ± 2-3 m is sufficient).

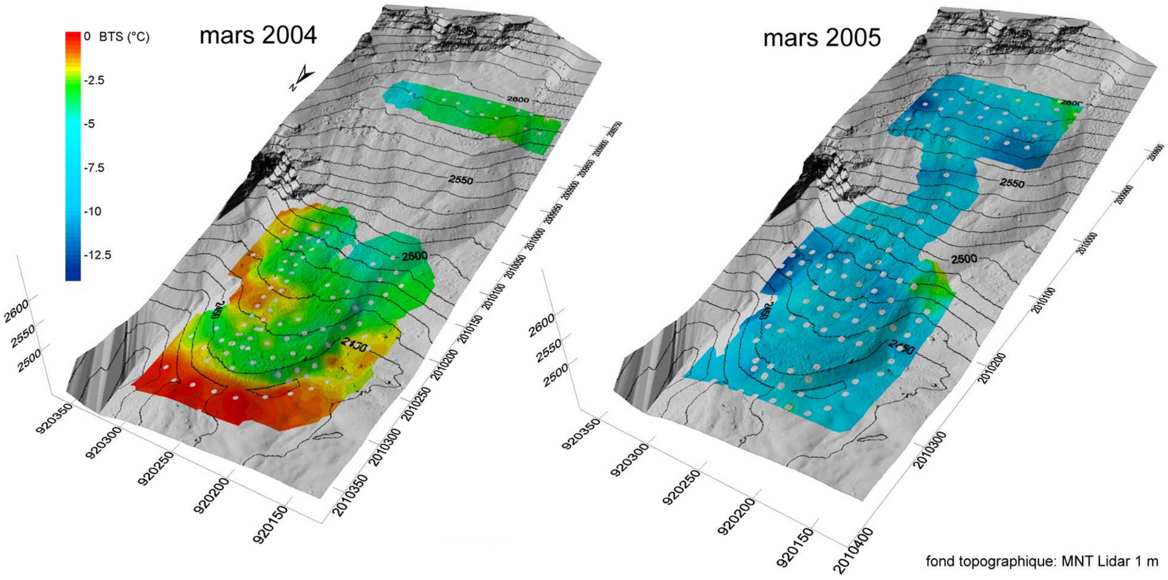
Positionning can be made either through DGPS or through anchoring on fixed land-marks (e.g. rising blocks, poles, …). The use of a regular grid spacing facilitates the positionning on a limited number of anchor points.

More than absolute temperatures, the interest of BTS mapping is to show the spatial distribution of temperatures. The method is well suited to investigate the spatial permafrost limits. So it is best used in transition areas between permafrost and non-pemafrost, i.e rock glacier fronts, or for mapping of temperature contrasts, i.e. on cold scree slopes.

The method provides a temperature map on a given date. As such it is complementary to GST monitoring at fixed points, giving the temperature evolution over time. Thus the best strategy is an association of GST loggers with BTS mapping.

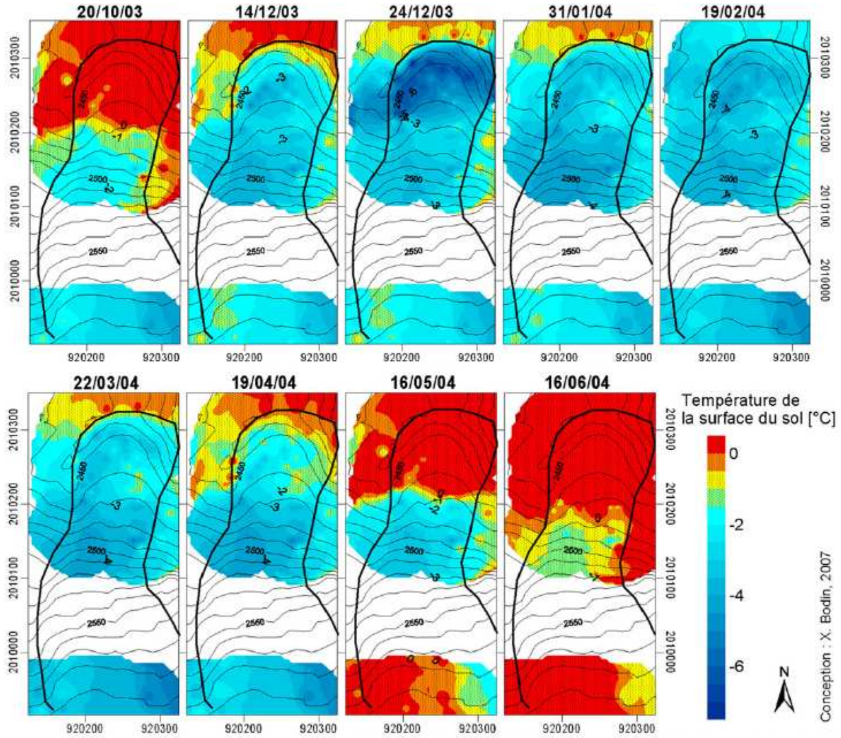
BTS mapping can be used once on a site, in order to assess the permafrost limits (provided that the winter is suitable for a good contrast), or repeated during successive winters for assessment of temperature distribution pattern changes (fig. 2).

The use of a well distributed set of GST monitoring points and repeated BTS mappings at different dates during the same season allows to model the development of the temperature field over the whole winter (fig. 3).



fond topographique: MNT Lidar 1 m

Fig. 2 – BTS mapping of the same area (rock glacier) in two successive winters (from Bodin 2005). The images illustrate the temporal variation due to snow cover history (same color scale). In winter 2004, the thick snow cover provided a good insulation, and distinct temperature contrasts (of 2-3 °C) developed between the permafrost area on the rock glacier, and non frozen areas in front of it, allowing an accurate mapping of the lower permafrost limit. In winter 2005, the lack of snow cover induced a general cooling and deep seasonal freezing of the ground, and no contrast was visible.



Trait noir épais : limite de RGL1 - Fond topographique : MNA 10m, coord. Lambert 2

Fig. 3 – Evolution of the surface temperature distribution reconstructed from i) BTS surveys in November 2003 and March 2004 and ii) a set of 5 MTD distributed over the surface. Zones considered as homogeneous in terms of temperature evolution are defined around each MTD on the base of the BTS surveys. The temperature at every BTS point is then supposed to evolve in a similar way as the GST recorded at the corresponding MTD (after Bodin 2005, 2007).

References

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