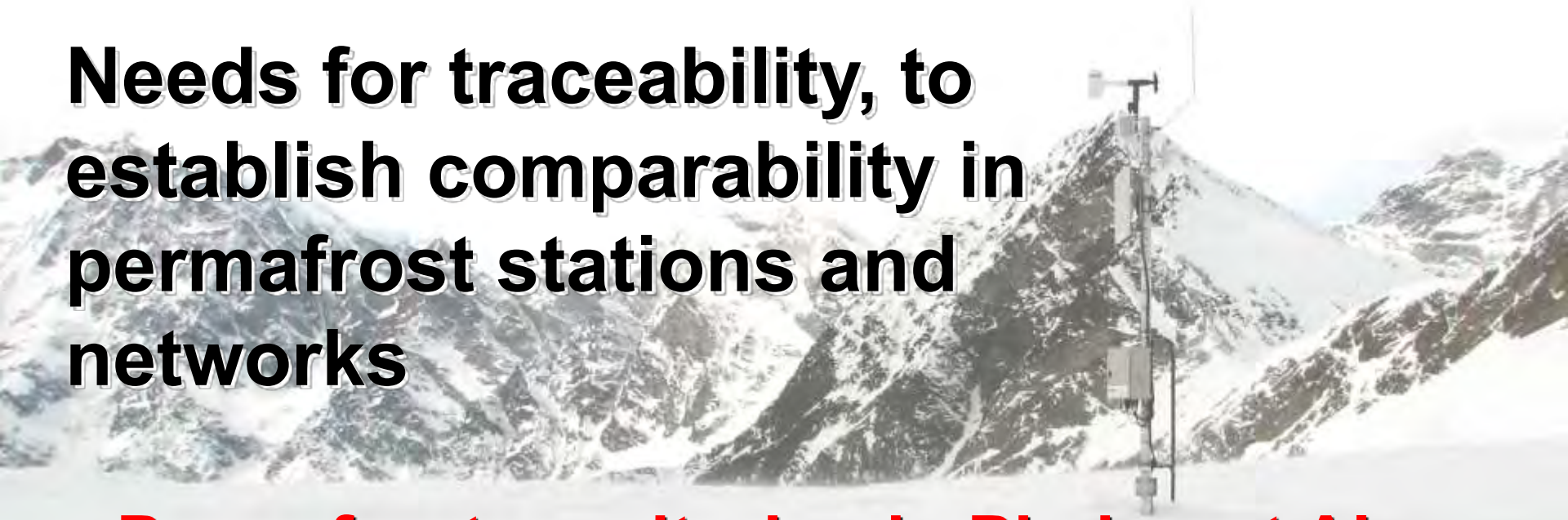
METEOMET
Metrology for Meteorology

MeteoMet International Workshop

Metrology for High Mountains Climate Observational Issues

Moncalieri, 15th Feb. 2017

Needs for traceability, to establish comparability in permafrost stations and networks



Permafrost monitoring in Piedmont Alps

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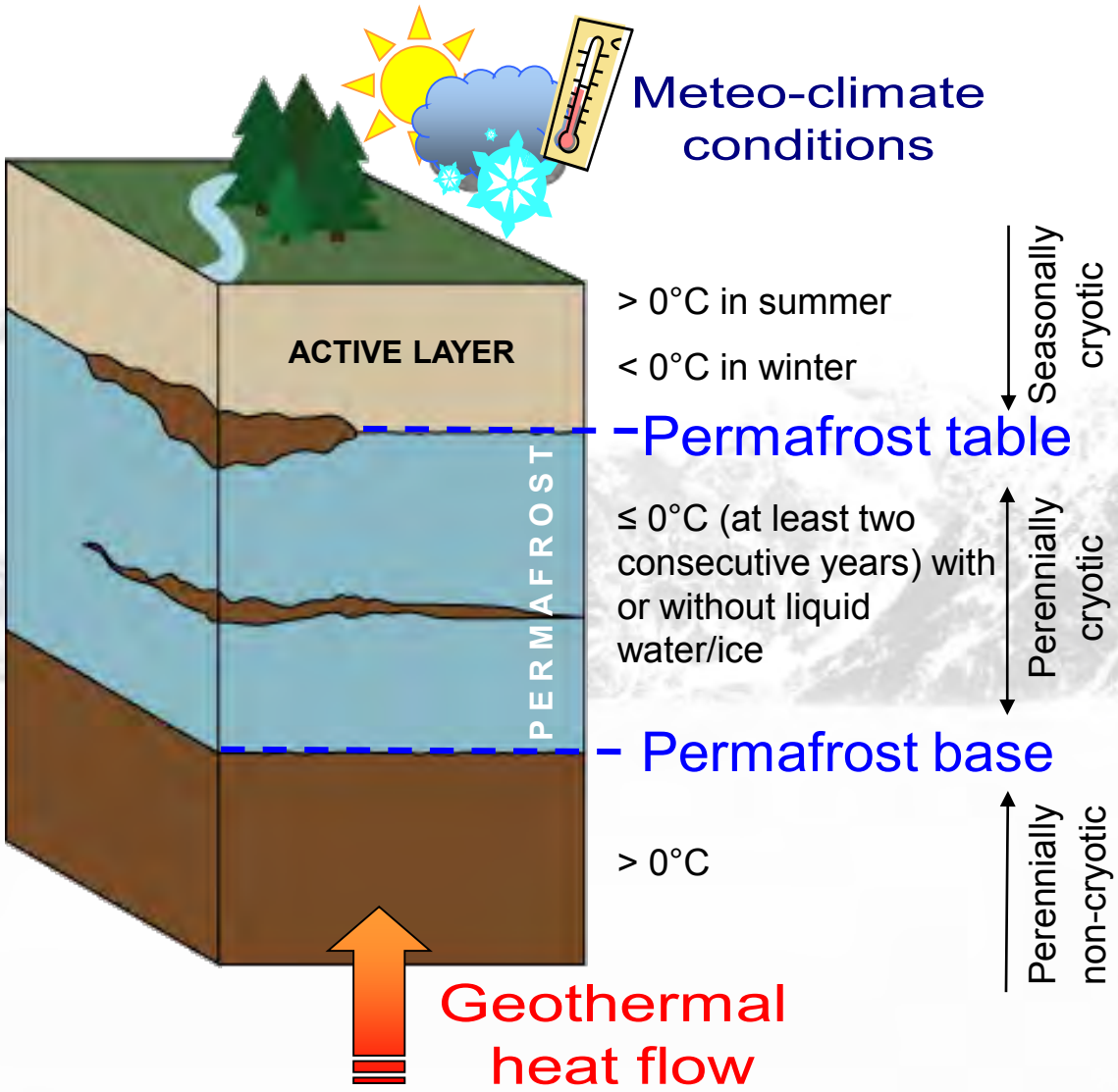
PIEMONTE Arpa Agenzia Regionale per la Protezione Ambientale

What is PERMAFROST ?



Permafrost (*perennially frozen ground*) is lithospheric material (rocks, soil, debris, …) with temperatures ≤ 0°C for at least two consecutive years, independently of its water/ice content.

Temperature conditions:
- "Cryotic" and "non-cryotic"

State conditions:
- "unfrozen", "partially-frozen", "frozen" or "dry"

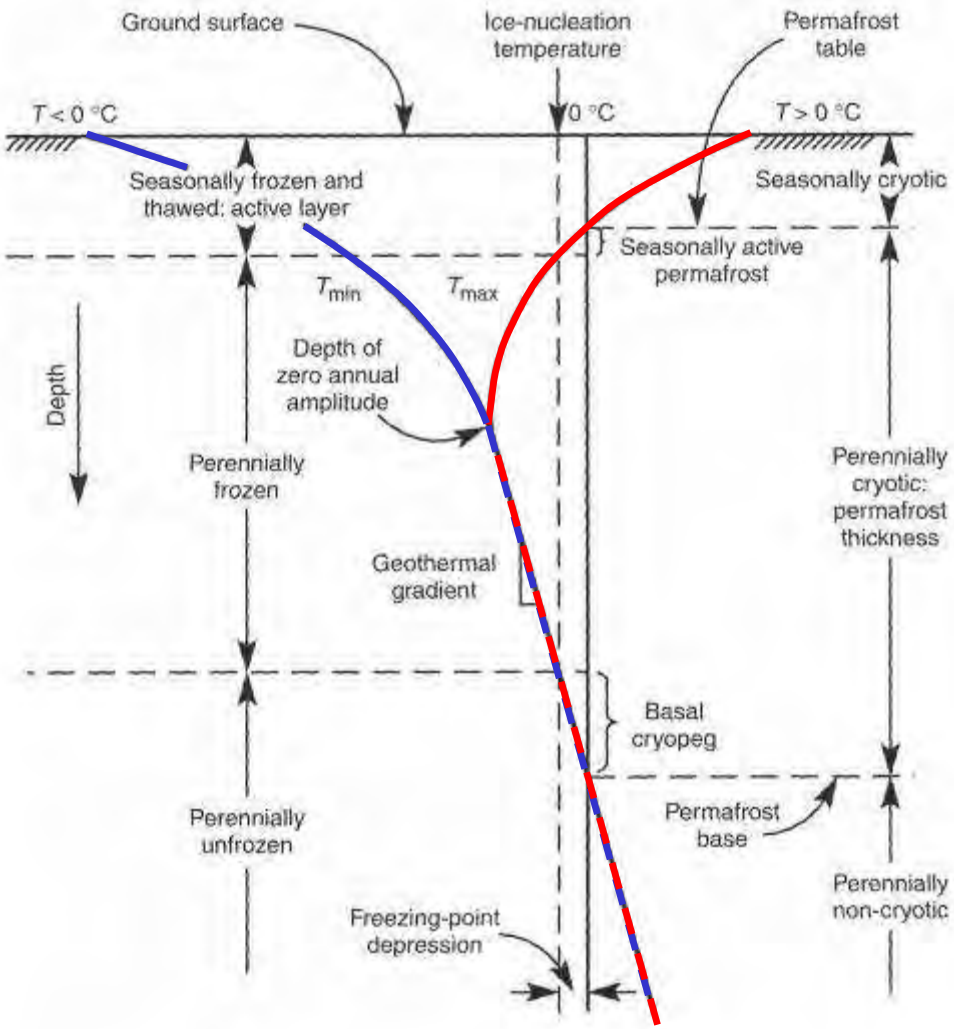
The growth of permafrost reflects a <u>negative heat balance</u> at the surface of the earth

What is PERMAFROST ?

Typical ground-thermal regime indicating **maximum** and **minimum** temperatures.

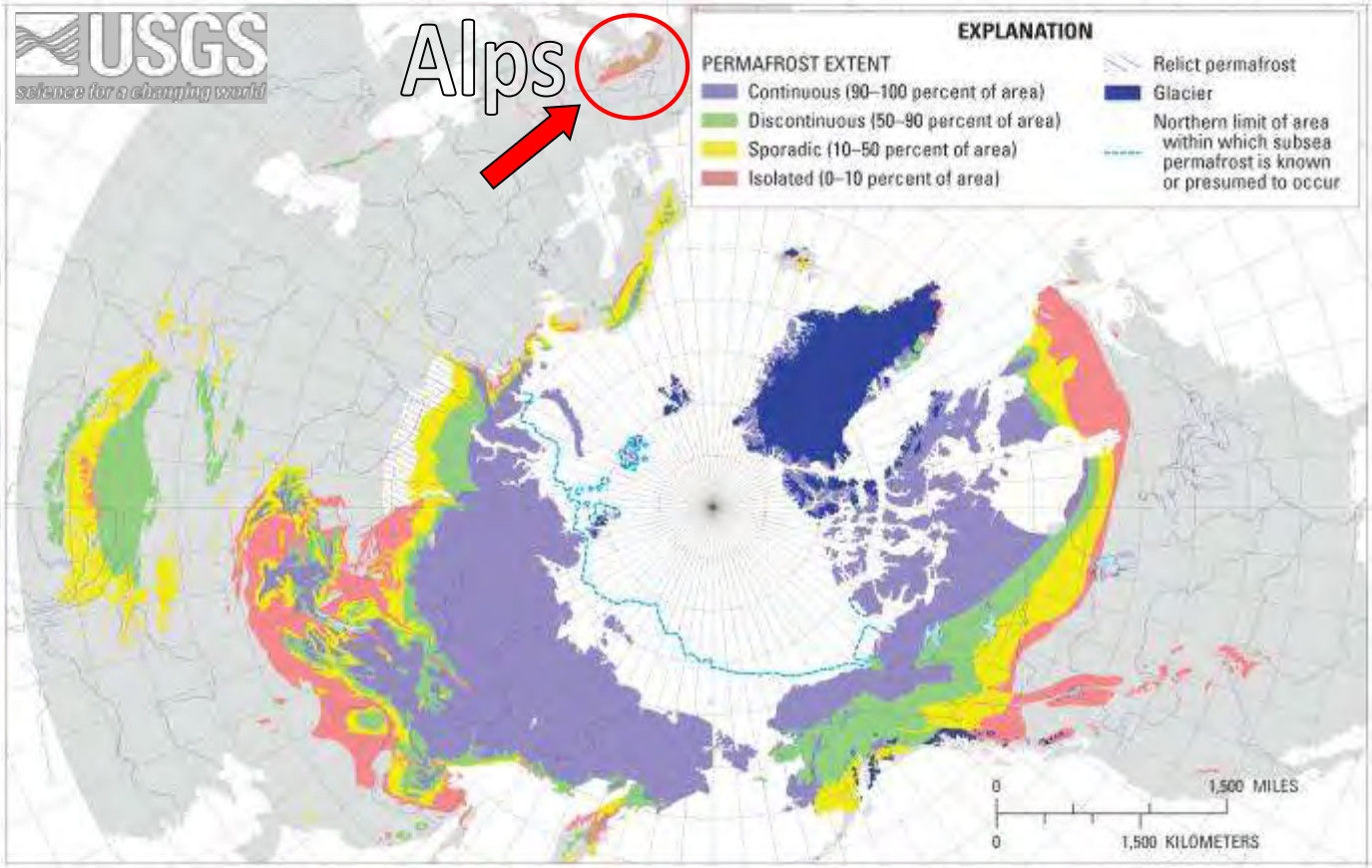
Main elements:

- **Thickness of active layer** or **depth of permafrost table** (m)
- **Depth of Zero Annual Amplitude** (ZAA), point where summer and winter temperatures converge (no seasonal influence) (m)
- **Depth of permafrost base** (m)



PERMAFROST distribution (Northern hemisphere)

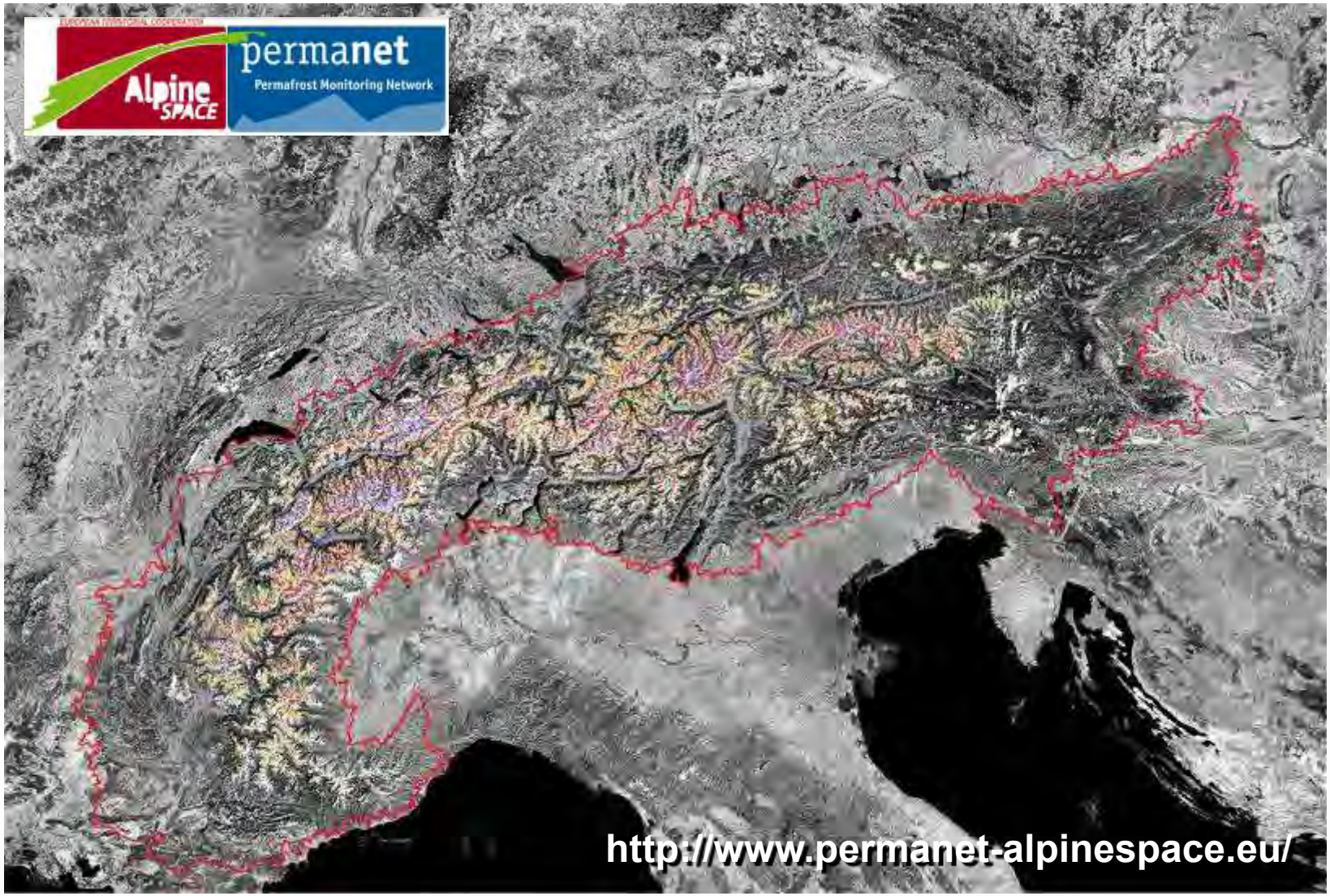
Permafrost is the most extended component of th cryosphere in the world and it occurs in two contrasting but sometimes overlapping geographic regions: **high latitudes** (polar) and **high altitudes** (alpine)



More than 20% of the world's land area is underlain permafost (almost in the Northern hemisphere): 80% Alaska, 50% of Russia and Canada, ~100% Tibet plateau, ~20% Alps.

Brown et al., 1997; figure prepared by Dmitri Sergeev, Permafrost Laboratory, Geophysical Institute, University of Alaska Fairbanks

PERMAFROST distribution (the Alps)

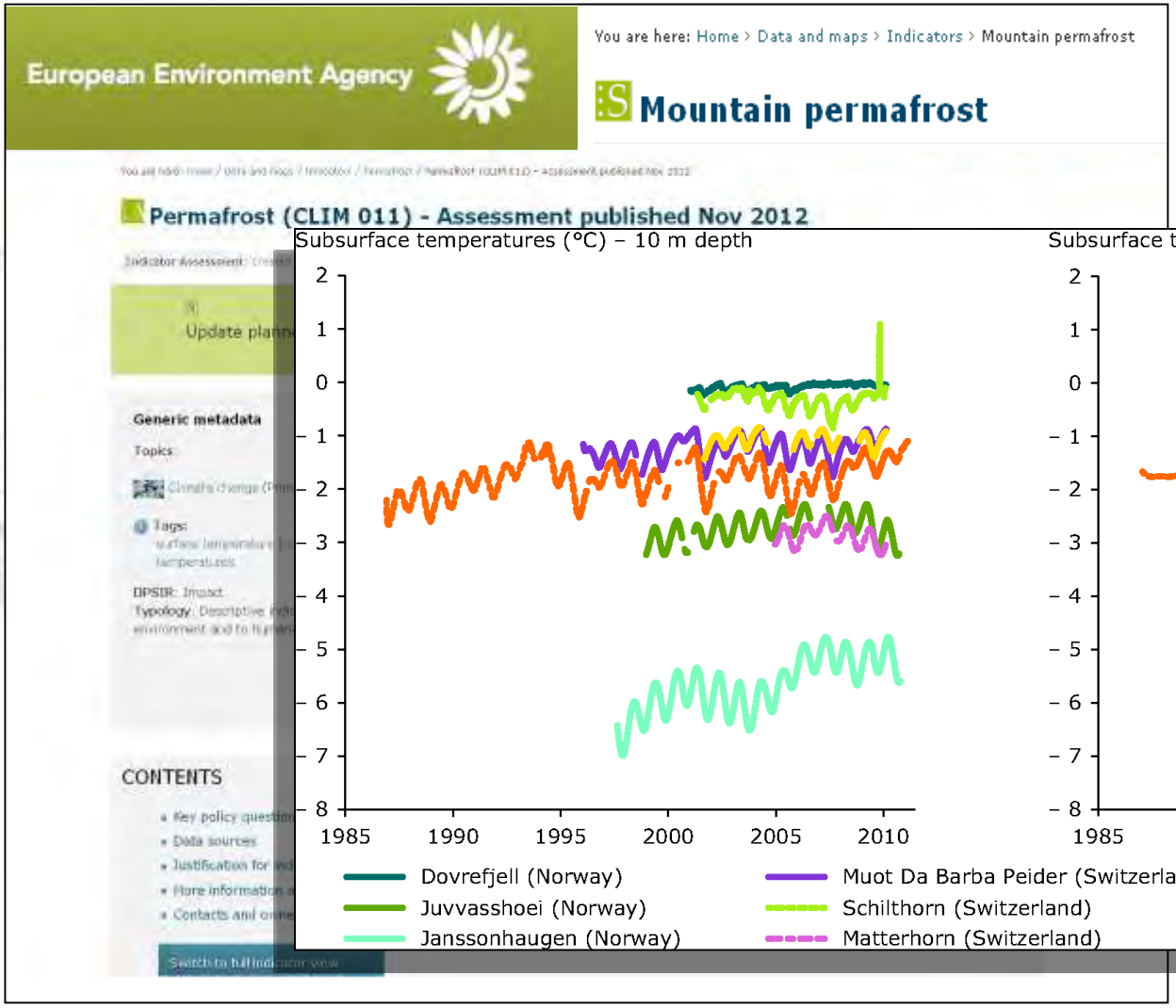


Alpine (mountain) PERMAFROST distribution

Distribution of alpine permafrost is not unlike that of high-latitude (polar) permafrost but in this case the driving factors are: **irregular morphology**, **altitude** and **aspect of the slopes** and **distribution** and **duration of the snow**.

PERMAFROST and Climate Change

Mountain permafrost is considered (e.g. EEA) a **main indicator of Climate Change** since its existence and distribution are directly linked to climate conditions.



PERMAFROST and Climate Change

It is *very likely* that NH snow cover will reduce as global temperatures rise over the coming century. A retreat of permafrost extent with rising global temperatures is *virtually certain*.

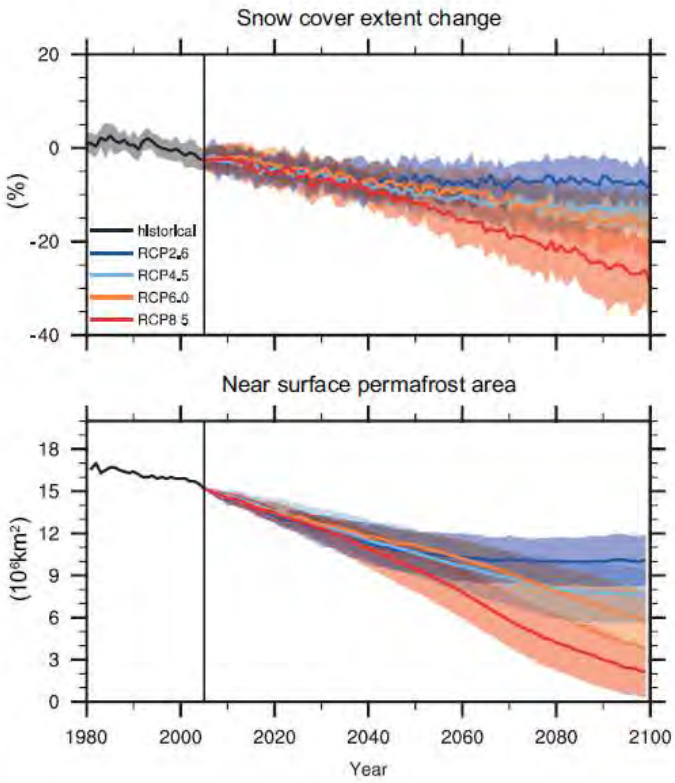


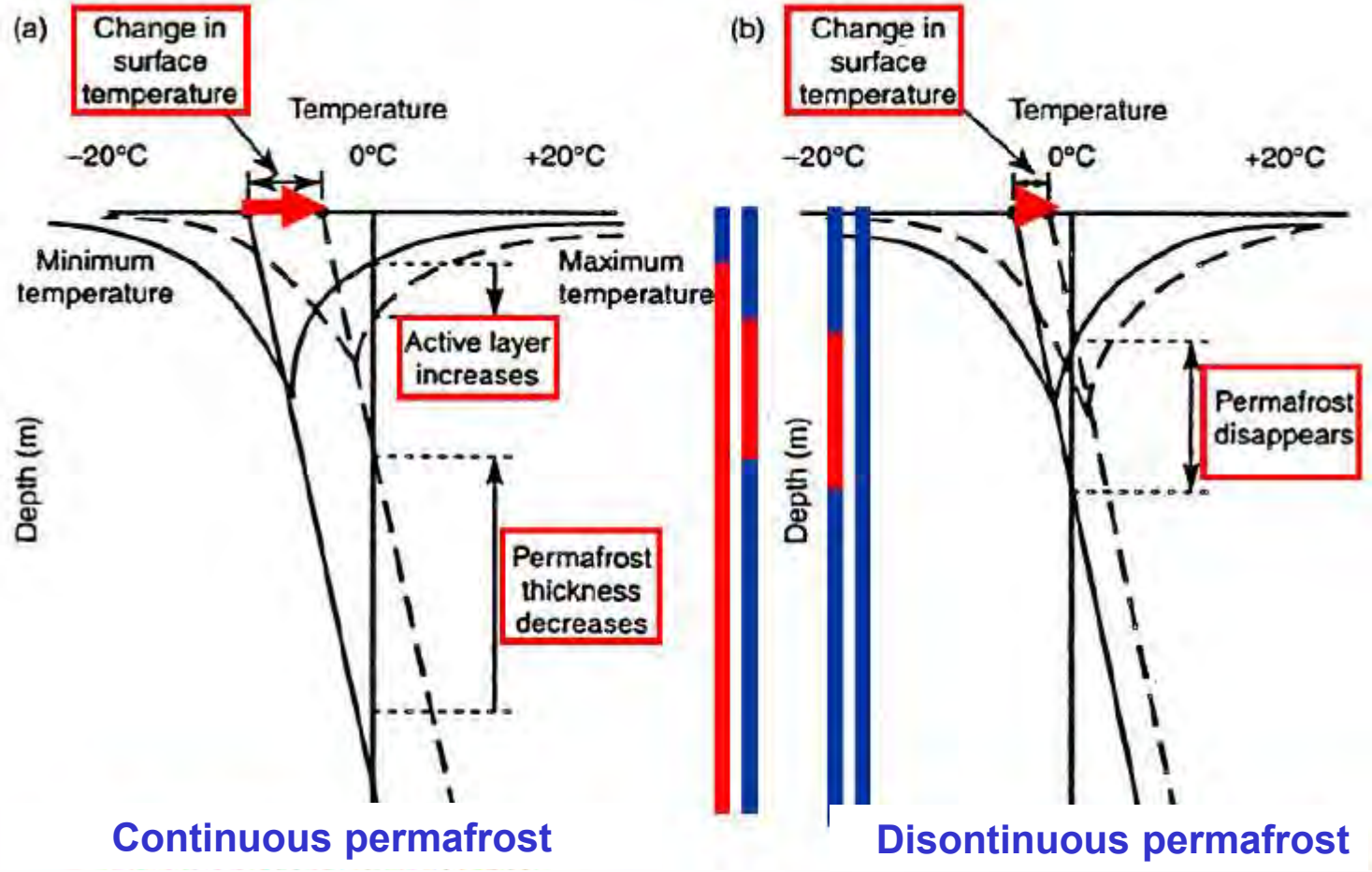
Figure TS.18 | (Top) Northern Hemisphere (NH) spring (March to April average) relative snow-covered area (RSCA) in CMIP5, obtained by dividing the simulated 5-year box smoothed spring snow-covered area (SCA) by the simulated average spring SCA of 1986–2005 reference period. (Bottom) NH diagnosed near-surface permafrost area in CMIP5, using 20-year average monthly surface air temperatures and snow depths. Lines indicate the multi model average, shading indicates the inter-model spread (one standard deviation). {Figures 12.32, 12.33}

- 37%

- 81%

PERMAFROST and Climate Change

Change in the climatic conditions at the ground surface, the thickness of the permafrost will change accordingly (e.g. an increase in mean surface temperature will result in a decrease in permafrost thickness).



Continuous permafrost

Disontinuous permafrost

PERMAFROST degradation and relative RISKS

In mountain areas, the active layer increasing and degradation of permafrost cause slope instability (landslides and acceleration of rock glaciers) and ground ice loss.

Rock fall scar with ice (Carrel hut, 3830 m, Mt. Cervino).

Photo: L. Trucco, 2003

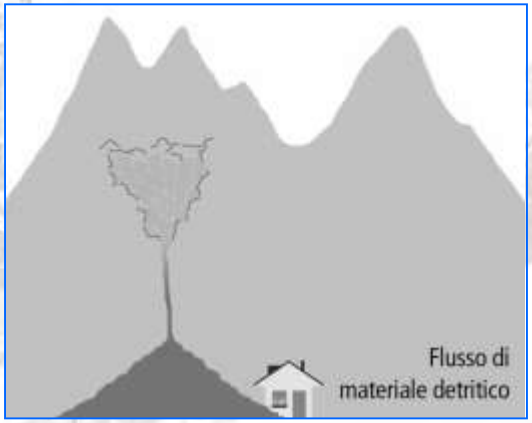
Rock avalanche over 2 millions m^3 (Punta Thurwieser, Gruppo Ortles), September 2004

PERMAFROST degradation and relative RISKS

PERMAFROST degradation and relative RISKS

Debris flow started in high mountain area that reached the valley floor involving road and railway (Switzerland, 2006)

Fig. 21 Treno deragliato in seguito alla lava torrentizia del Durnand il 25 luglio 2006.



PERMAFROST degradation and relative RISKS

Slope instability in high mountain area causes instability of structures and infrastructures

Cable way damaged by permafrost ice melt (Switzerland)

Arpa Piemonte activities

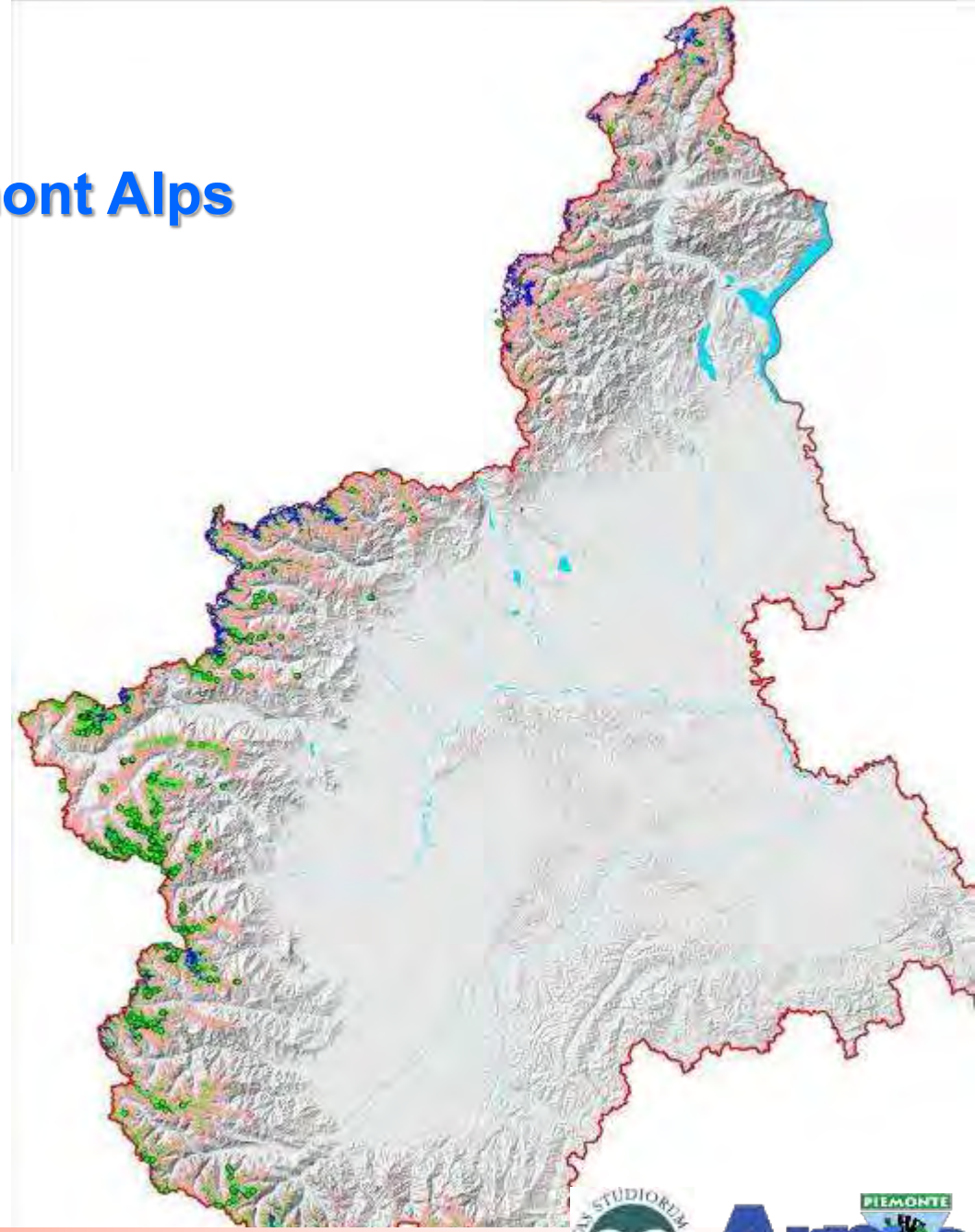
- Activities on “permafrost and periglacial environment” started in **2006** and in 2008÷2011 received a great contribution from European project “**PermaNet, Permafrost long-term monitoring Network**” (Alpine Space Program), with the collaboration of Insubria University (Prof. M. Guglielmin).

- PermaNet highly improves knowledge on mountain permafrost in Piedmont Alps: a first **Cryosphere Map** of the region has been realized and a first Regional **Permafrost Monitoring Network** has been established.

- PermaNet was a start-up project and at its end (2011) Arpa Piemonte established a new institutional service (**B3.19 - “Monitoraggio del permafrost”**) in order to follow-up the activities on permafrost at regional scale (in charge to the Dept. “Geology and Natural Hazards”).

Arpa Piemonte activities

Cryosphere Map of Piedmont Alps



Geoitalia 2009
VII Forum Italiano di Scienze della Terra
Rimini, 9 - 11 settembre 2009

First Cryosphere Map of Piedmont Alps

(Guglielmin & Paro, 2009)

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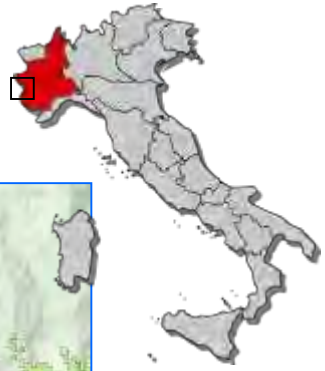
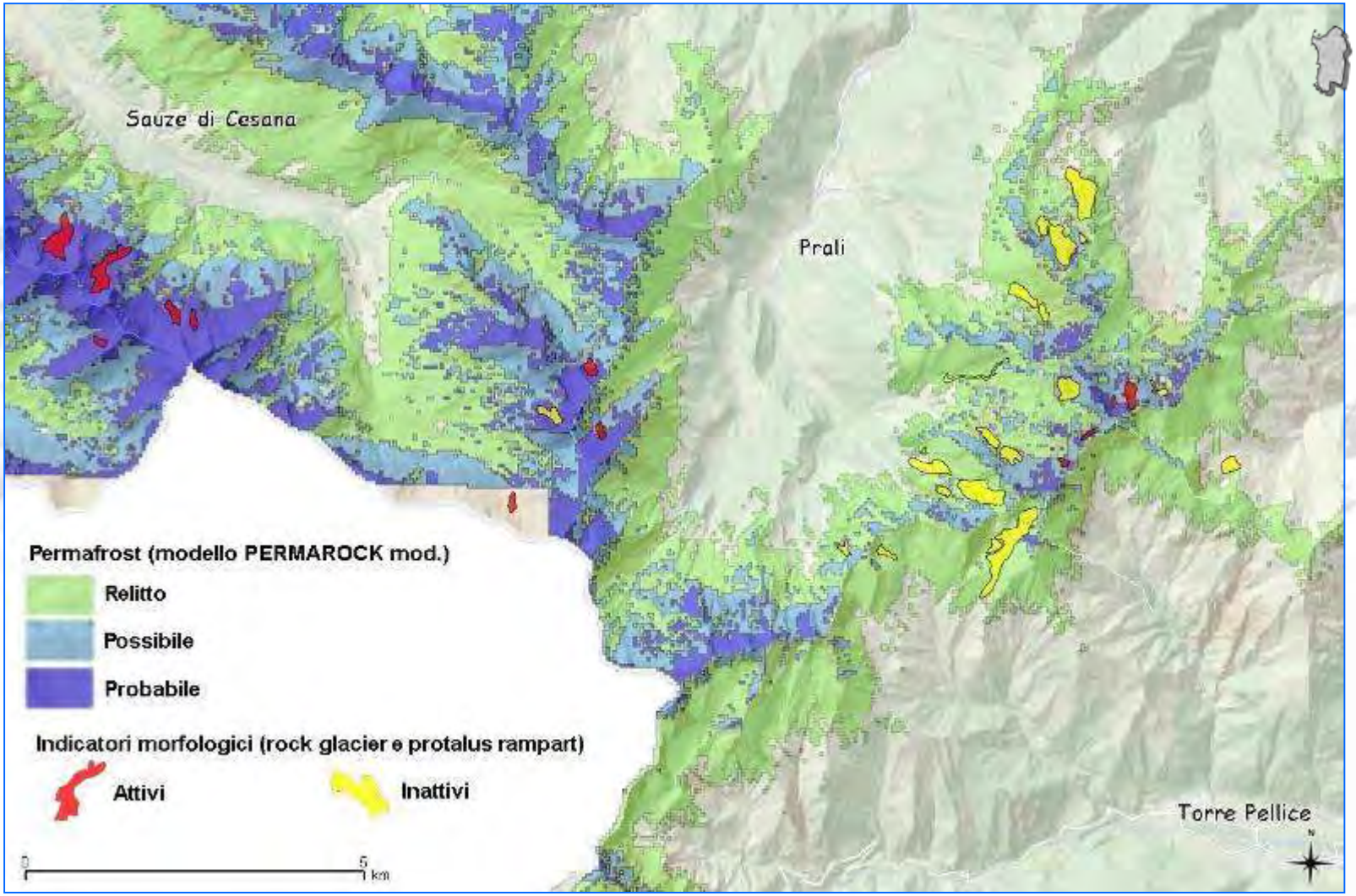
Arpa Piemonte activities

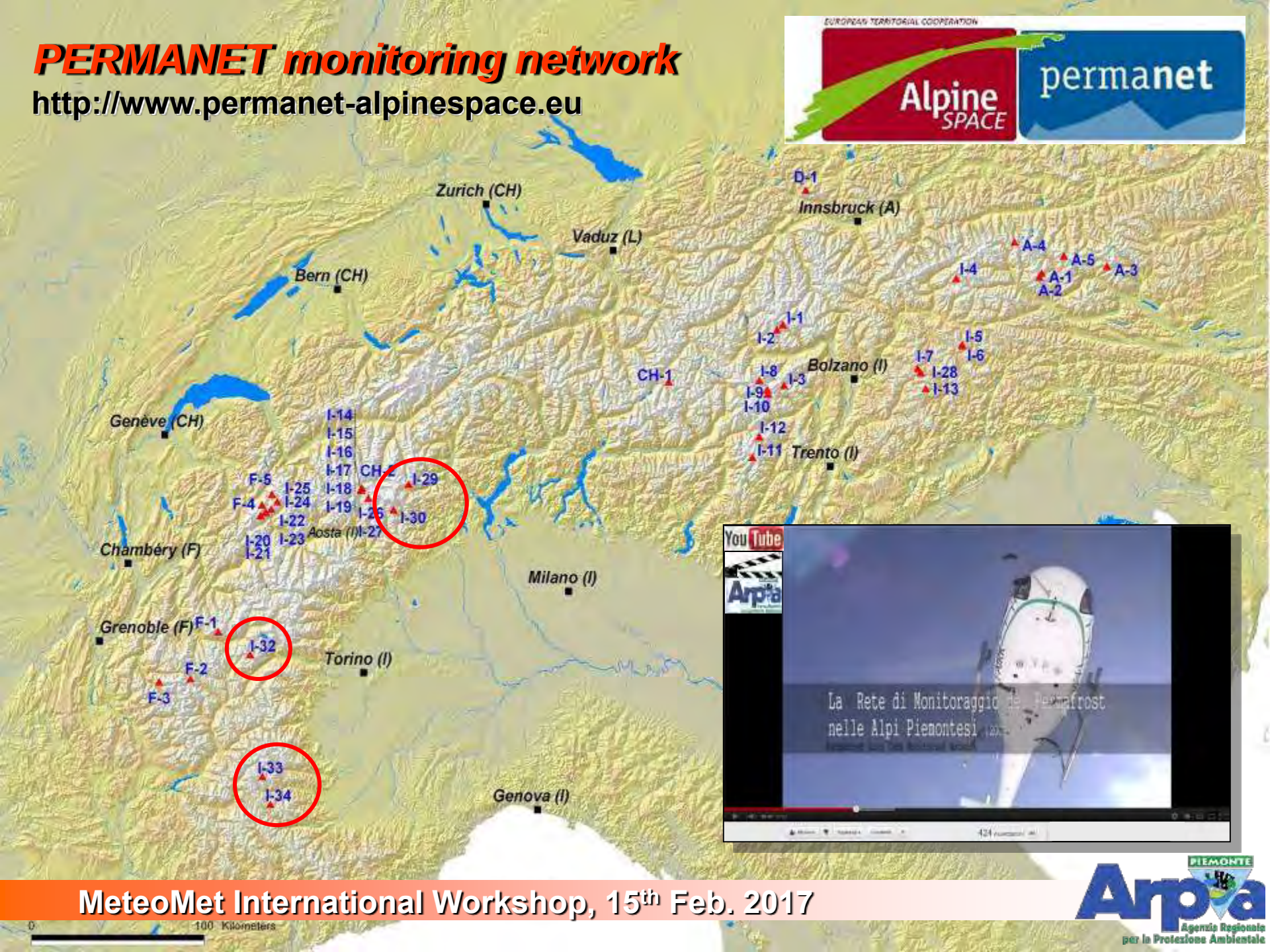
Cryosphere Map of Piedmont Alps





PERMANET monitoring network

http://www.permanet-alpinespace.eu



Arpa Piemonte activities

Regional Network for Permafrost Monitoring

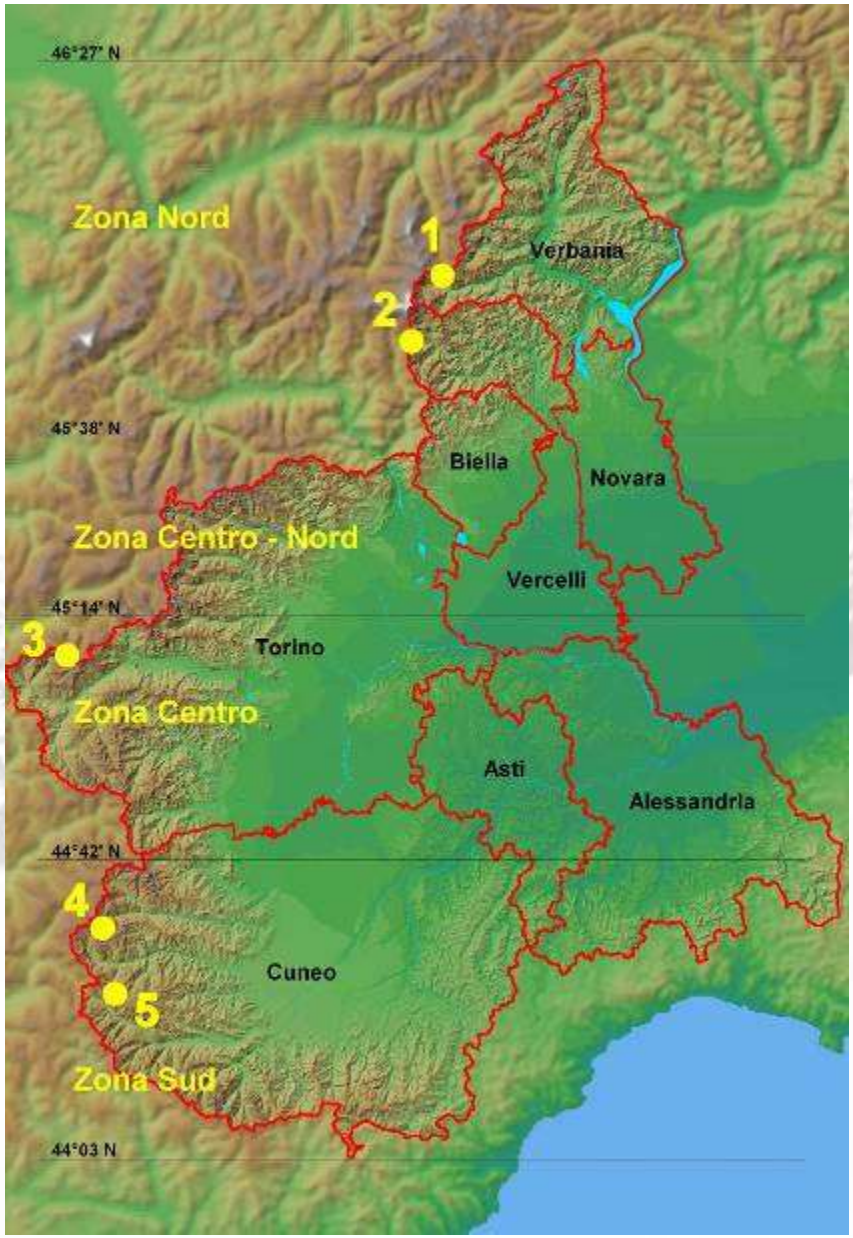
1 – Mt. Moro Pass (Macugnaga, VB), altitude 2870 m (borehole 30 m deep)

2 – Salati Pass (Alagna Valsesia, VC), altitude 2890 m and **3020** m (boreholes 5 m and 30 m deep respectively)

3 – Sommeiller Pass (Bardonecchia, TO), altitude 2990 m (three boreholes 5, 10, 100 m deep) – **KEY SITE**

4 – La Colletta Pass (Bellino, CN), altitude 2840 m (borehole 30 m deep)

5 – Gardetta Pass (Canosio, CN), altitude **2500** m (borehole 30 m deep)



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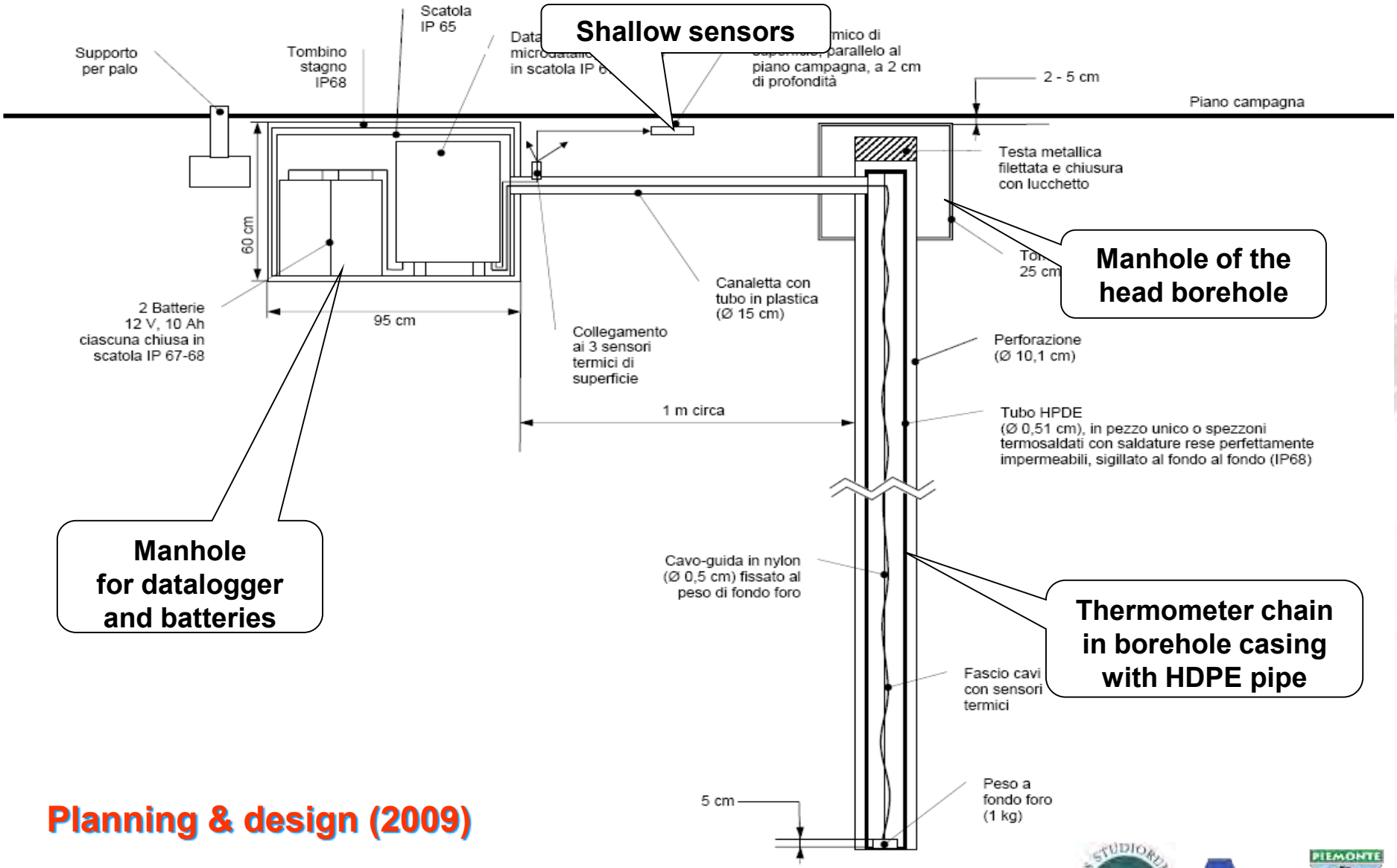
Arpa Piemonte activities Regional Permafrost Monitoring



Planning & design (2009)

Arpa Piemonte activities Regional Permafrost Monitoring

Drilling phase

Sommeiller Pass (Bardonecchia, TO), 2990 m – Key Site

Depth:

1 borehole (100 m)
casing: HDPE and steel pipes

1 borehole (10 m)
casing: HDPE pipe

1 borehole (5 m)
no casing

Instruments:

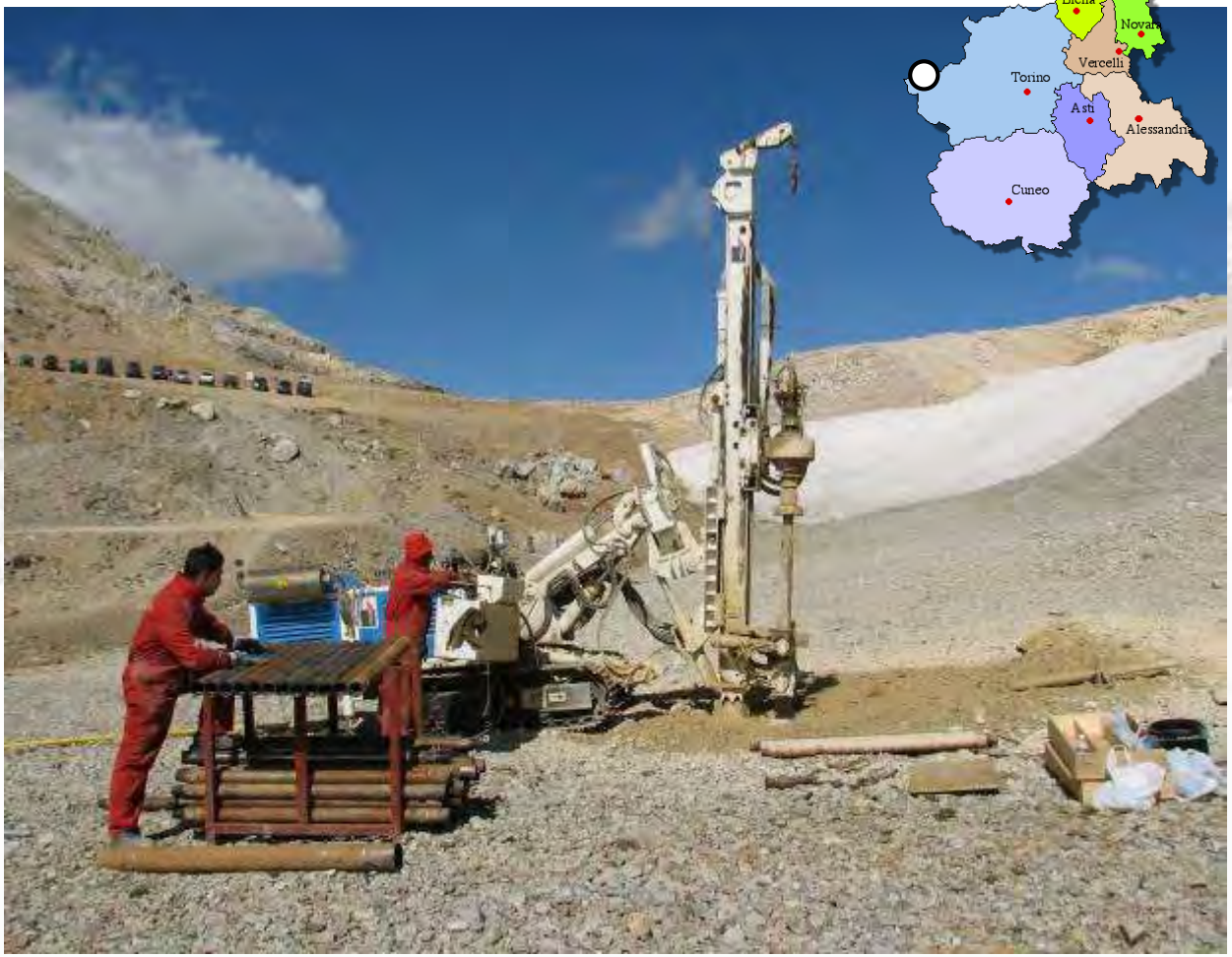
34 thermistors

1 datalogger

1 weather station

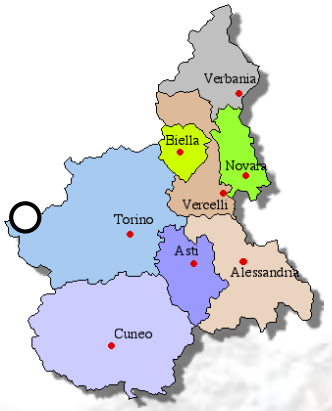
Logistic:

Dirt road (4WD vehicles)



Arpa Piemonte activities Regional Permafrost Monitoring

Installation phase - Weather station



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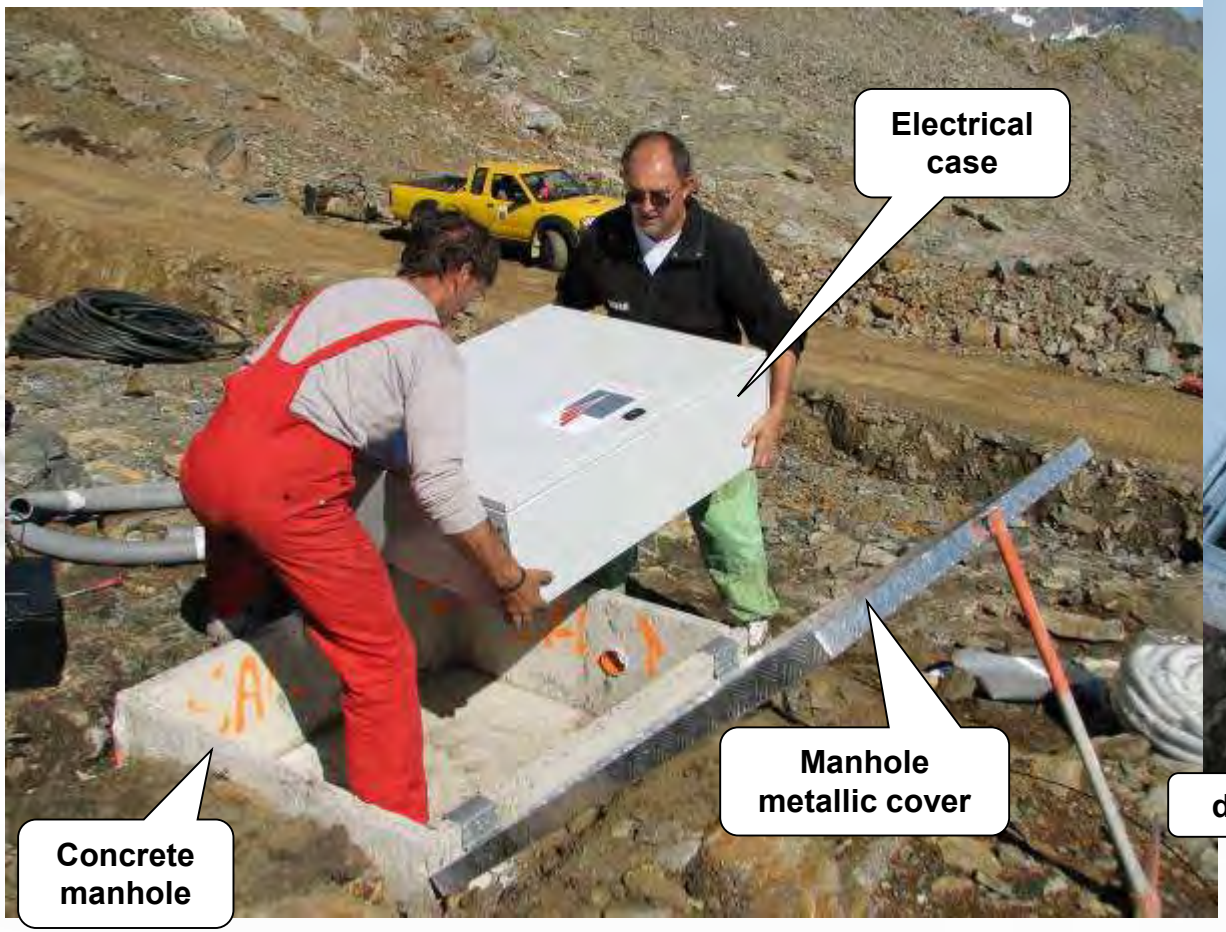
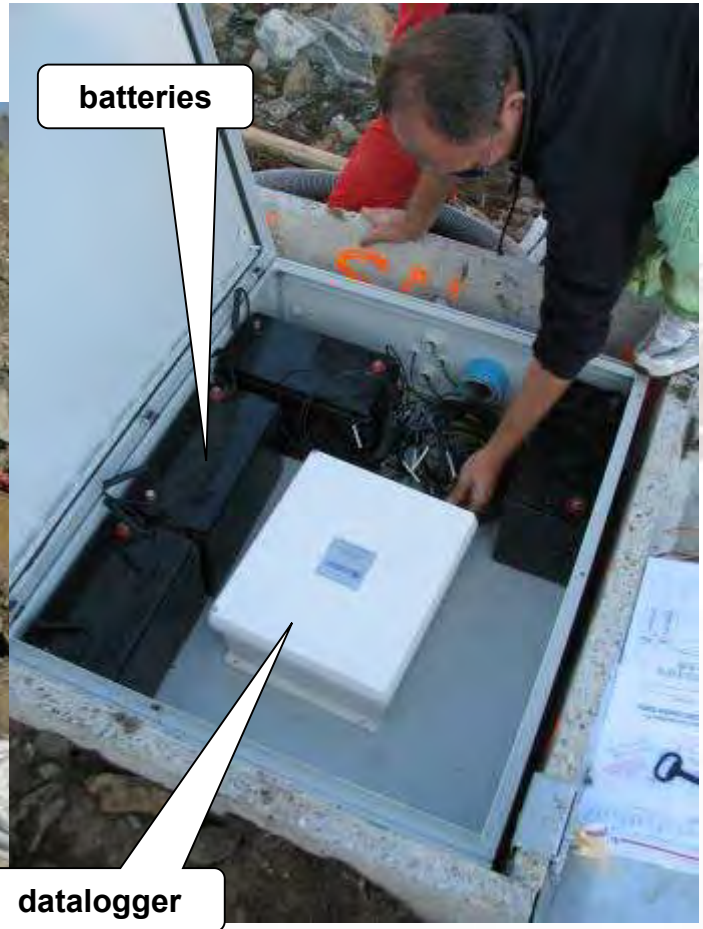
Arpa Piemonte activities Regional Permafrost Monitoring

Installation phase – Sensors and dataloggers

Manholes for datalogger and batteries





Arpa Piemonte activities Regional Permafrost Monitoring

Damages due to water infiltration (2010)

Flooding of dataloggers and data loss

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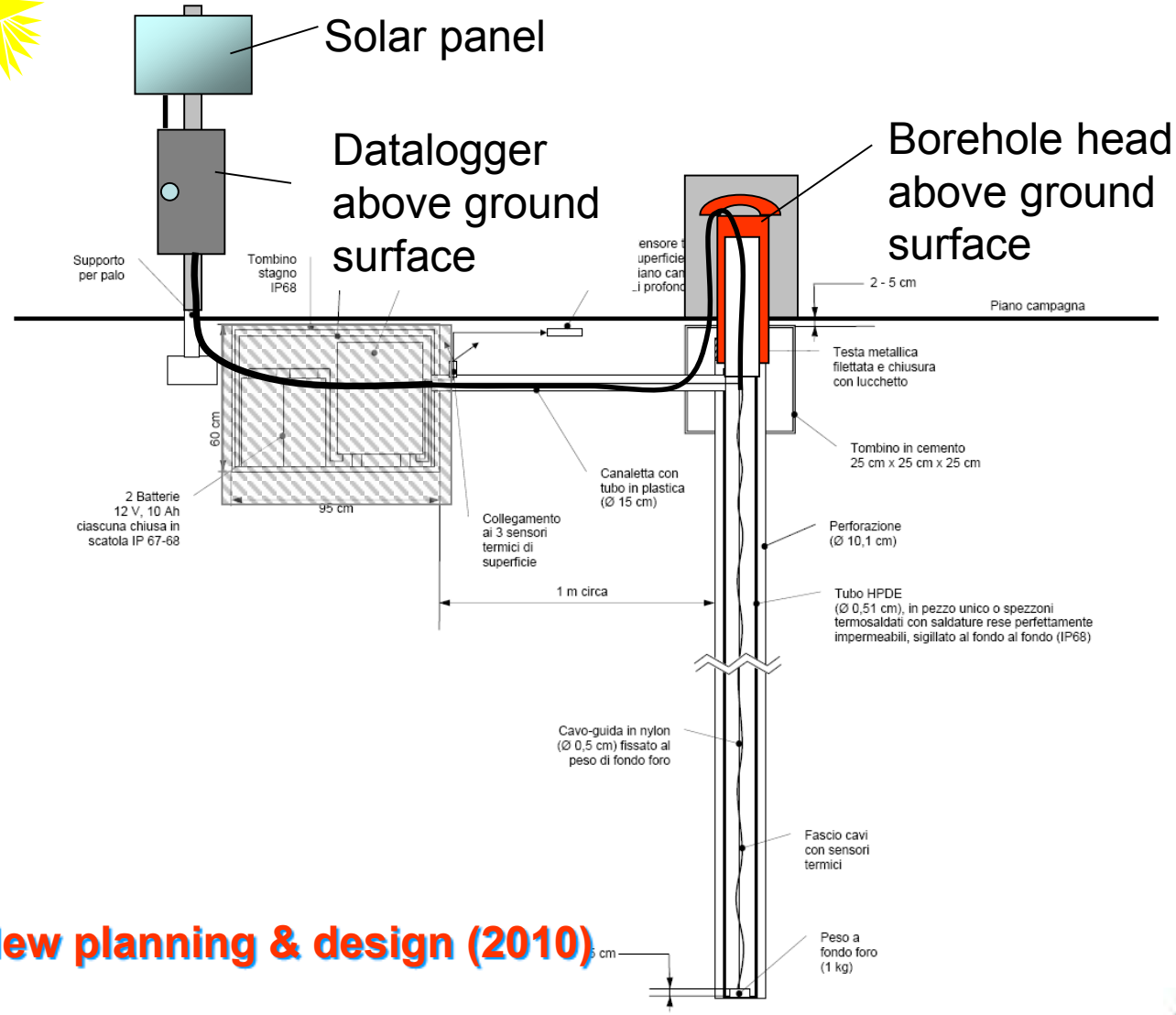
Damages due to water infiltration (2010)

Water in the boreholes and thermistors chain trapped in the ice

Arpa Piemonte activities Regional Permafrost Monitoring



New planning & design (2010)

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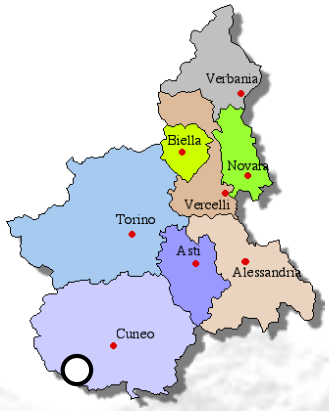
Borehole restoration (2010÷2012)

De-icing and water emptying of boreholes and thermistor chains

(La Colletta, Dec. 2011)

Arpa Piemonte activities Regional Permafrost Monitoring



New datalogger installed above ground surface

(Gardetta Pass)

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Station restoration (2011÷2012)

Datalogger and borehole head installed above ground surface; installation of solar panels

(Sommeiller Pass, Oct. 2012)

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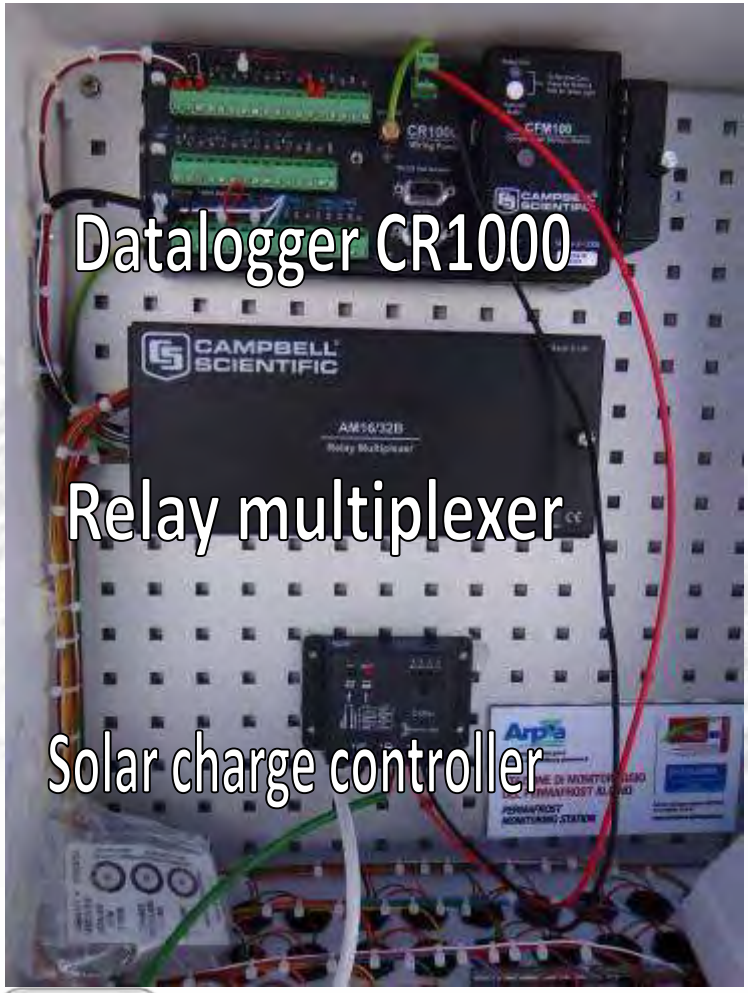
Protection box for underground batteries

Arpa Piemonte activities Regional Permafrost Monitoring



Sensor:	BetaTherm 100K6A Thermistor
Temperature Measurement Range:	-35° to +50°C
Thermistor Inter-changeability Error:	±0.10°C over 0° to 50°C; ±0.4 @ -30°C
Thermistor Survival Range:	-50° to +100°C
Steinhart-Hart Equation Error:	≤±0.01°C over -35° to +50°C (CRBasic dataloggers only)

CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

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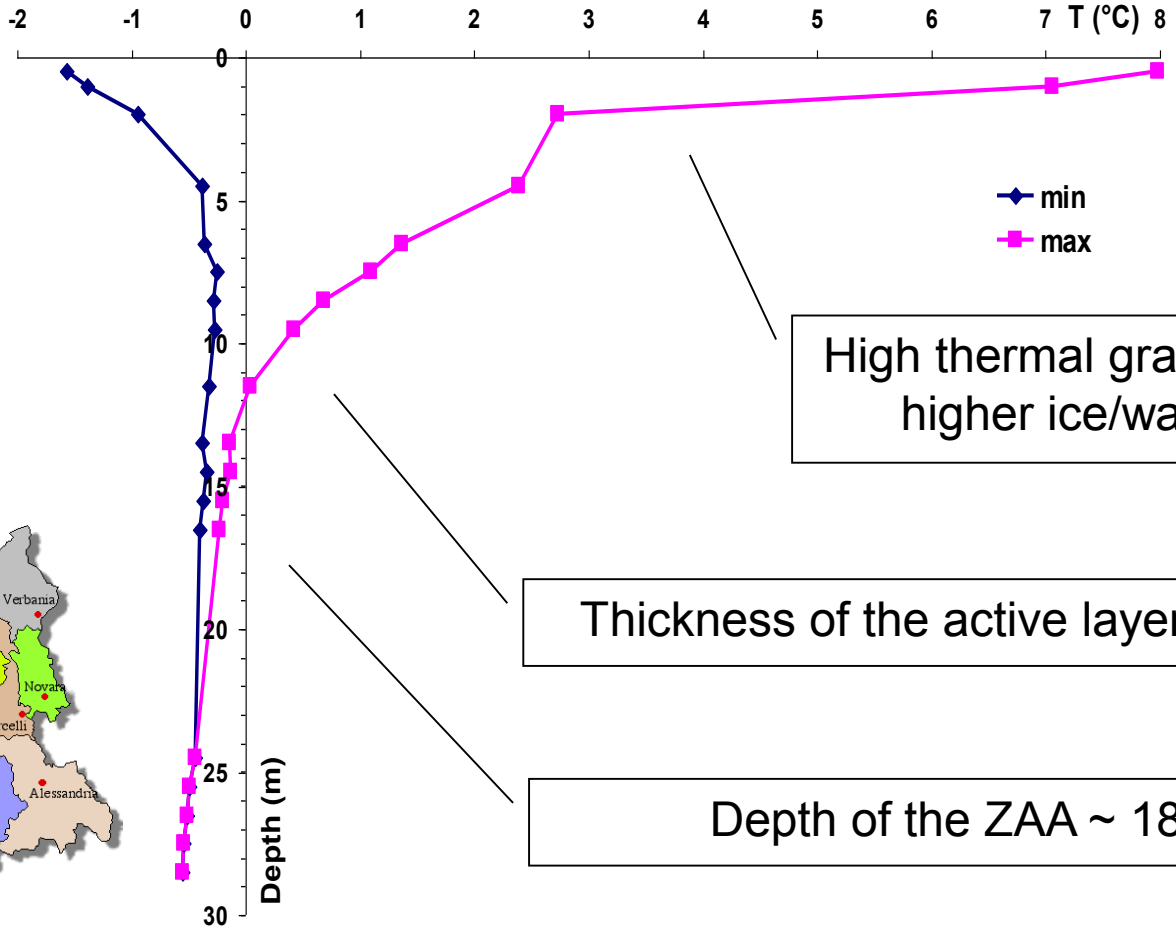
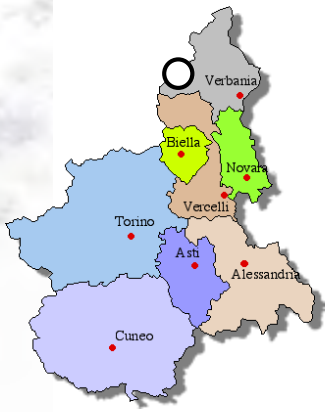
Preliminary results: Mt. Moro Pass (Macugnaga, VB) – 2870 m





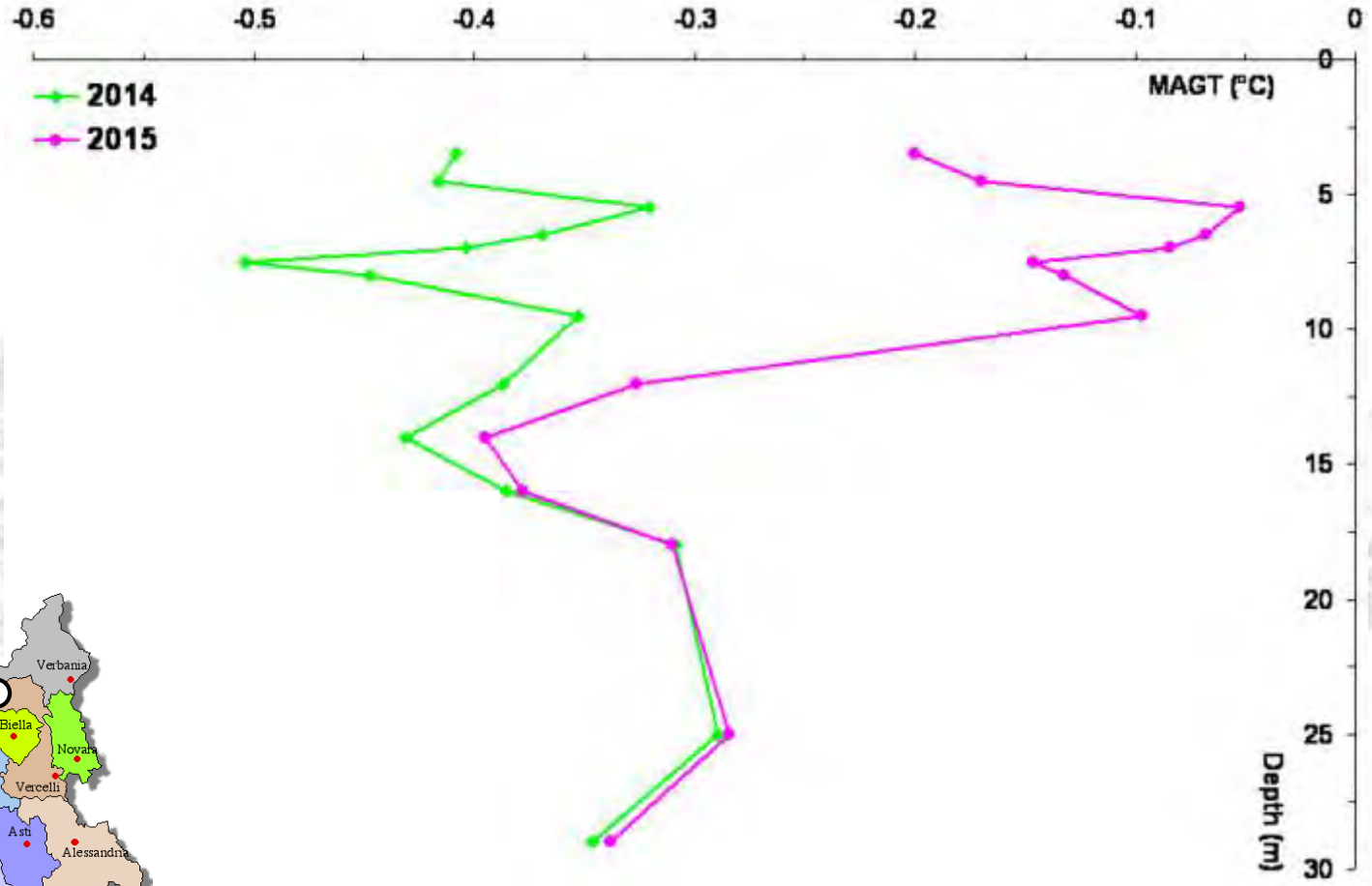
High thermal gradient (2.6°C/m): higher ice/water content?

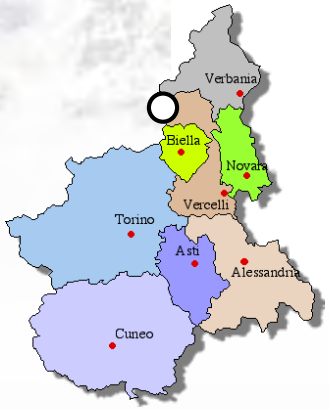
Thickness of the active layer 11.5 m

Depth of the ZAA ~ 18 m

Exemple of thermal profile of the M.t Moro Pass permafrost station obtained from the maximum and minimum values of the average daily temperatures.

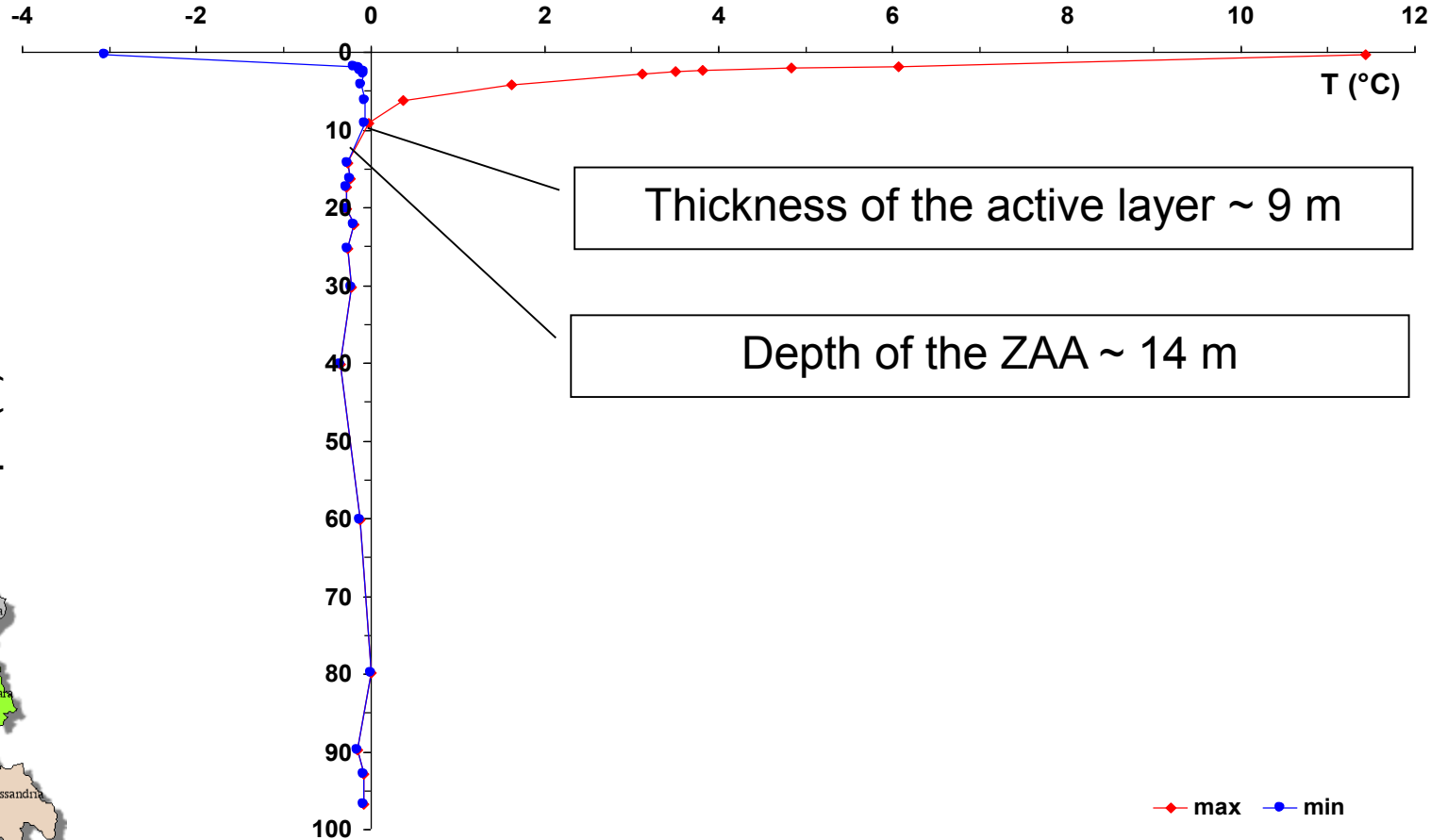
Preliminary results : Salati Pass – Corno Camosci (Alagna Valsesia, VC) – 3020 m

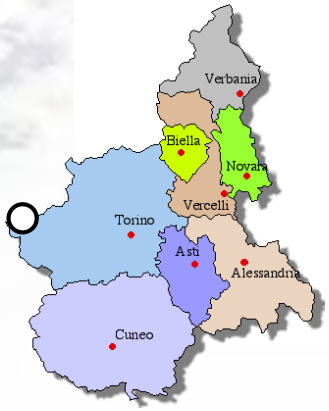




Thermal profile of mean annual temperatures in 2014 and 2015

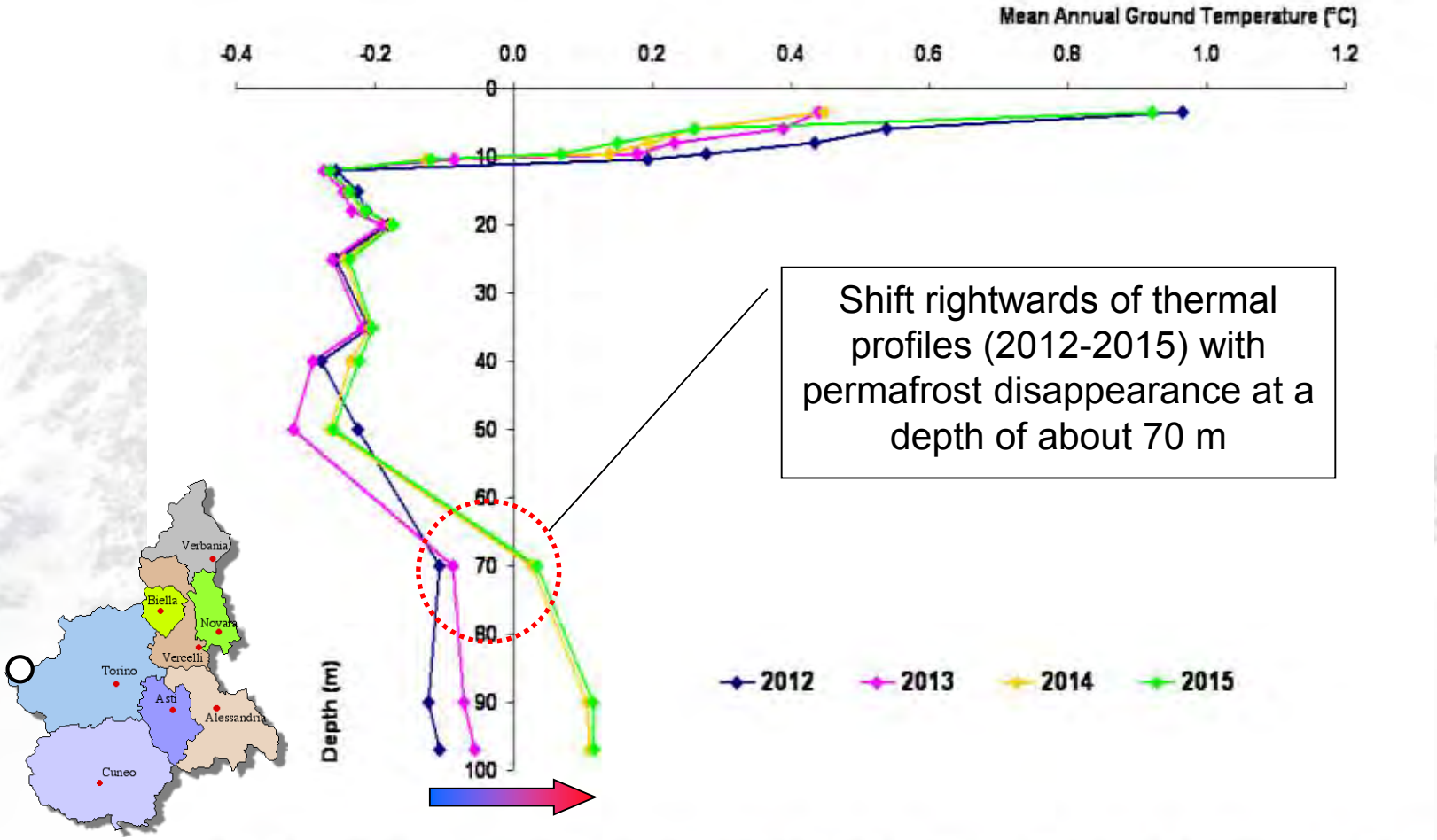
Preliminary results : Sommeiller Pass (Bardonecchia, TO) – 2980 m





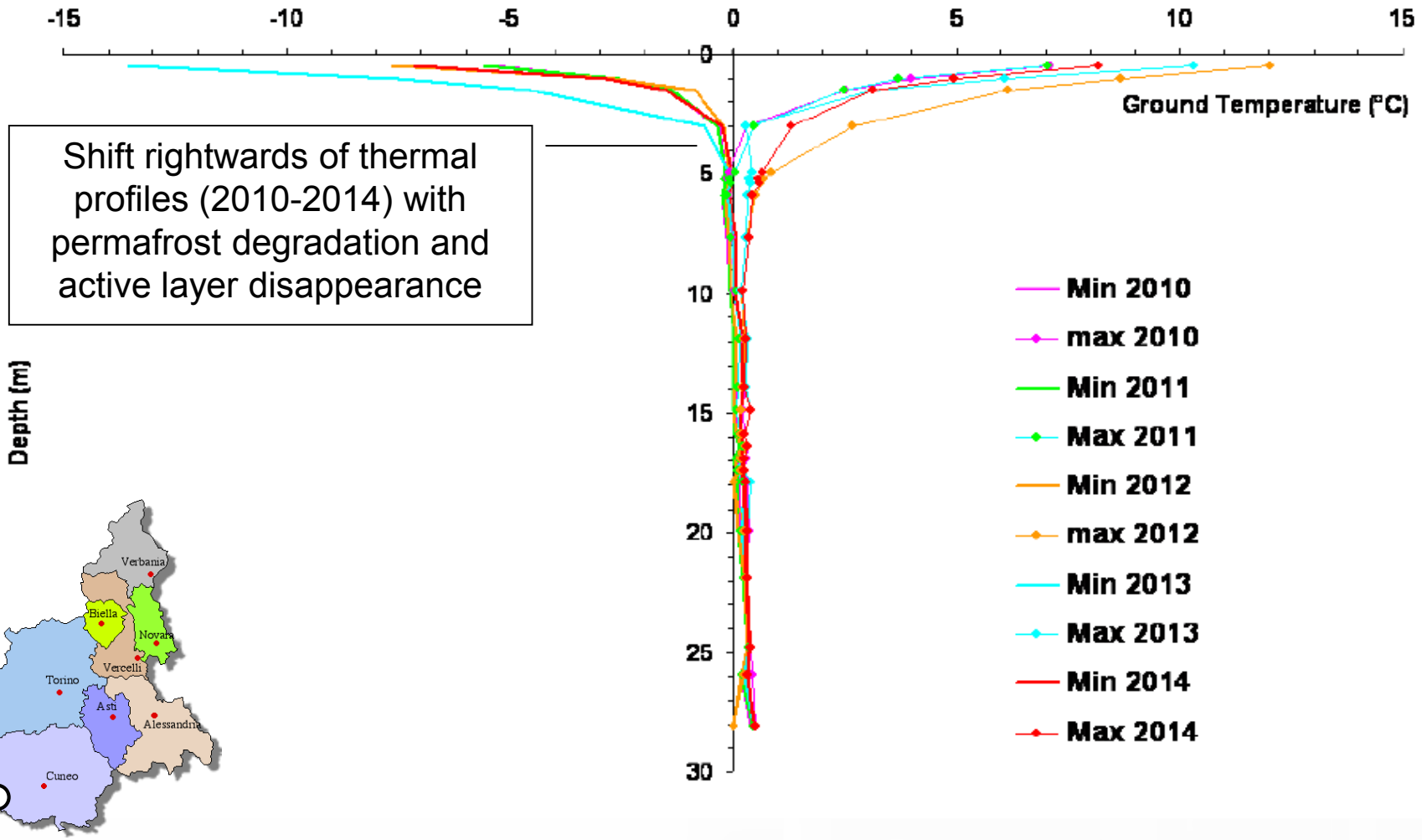
Exemple of thermal profile of the Sommeiller Pass permafrost station obtained from the maximum and minimum values of the average daily temperatures (**2012**).

Preliminary results : Sommeiller Pass (Bardonecchia, TO) – 2980 m



Thermal profile of mean annual temperatures (**2012 to 2015**)

Preliminary results : La Colletta Pass (Bellino, CN) – 2870 m



Shift rightwards of thermal profiles (2010-2014) with permafrost degradation and active layer disappearance

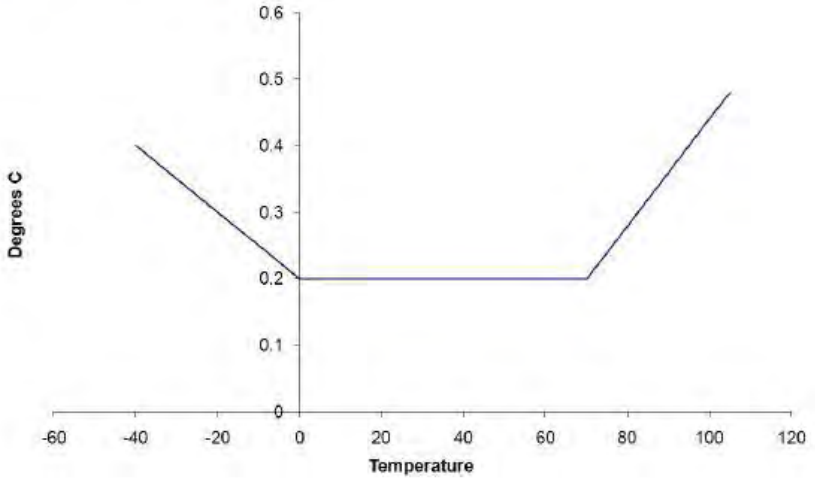
Thermal profile of the La Colletta Pass permafrost station obtained from the maximum and minimum values of the average daily temperatures (**2010 to 2014**).

Arpa Piemonte activities Ground Surface Temperature (GST)

Sensor Specification

Measuring Range	-40 to +105°C (-40 to +221°F)
Sensor Type	10K NTC Thermistor

Sensor Accuracy



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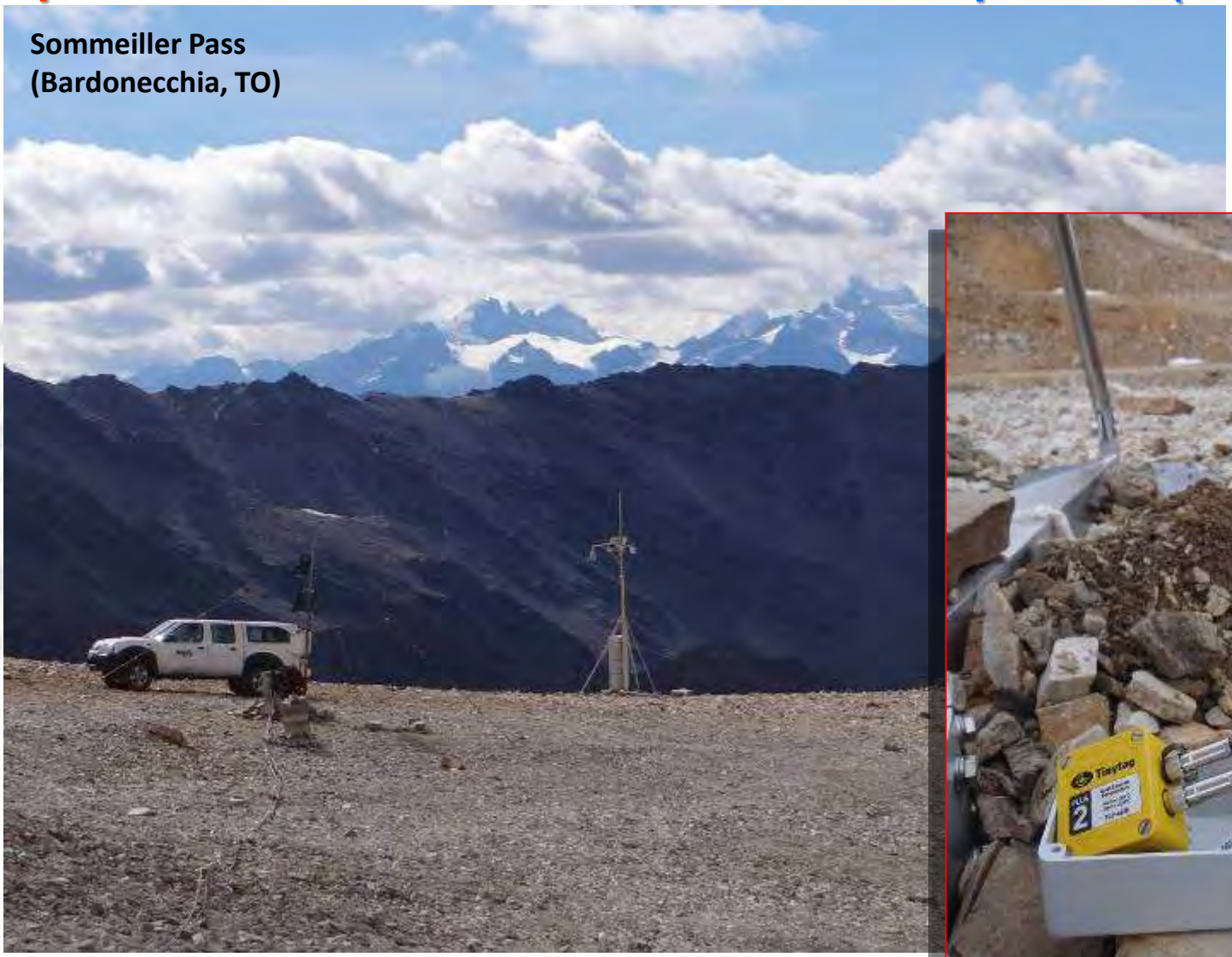
Arpa Piemonte activities Ground Surface Temperature (GST)

Sommeiller Pass
(Bardonecchia, TO)



2 sensors installed under nivometer

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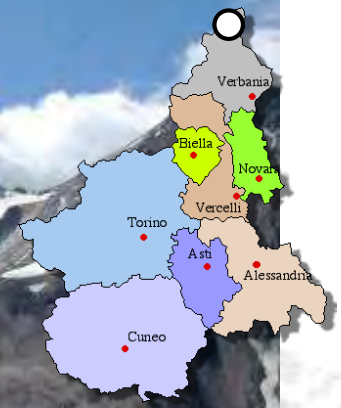
Arpa Piemonte activities Ground Surface Temperature (GST)

Sabbione reservoir
(Formazza, VB)



16 thermistors in recently deglaciated area

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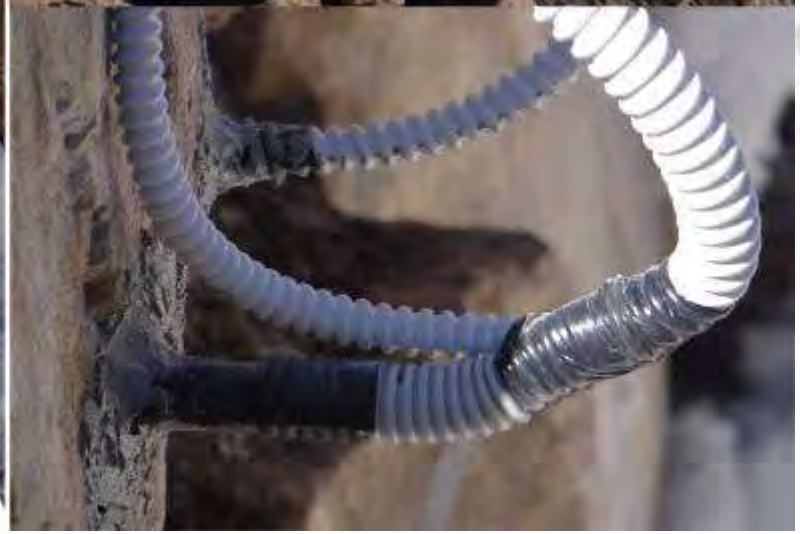
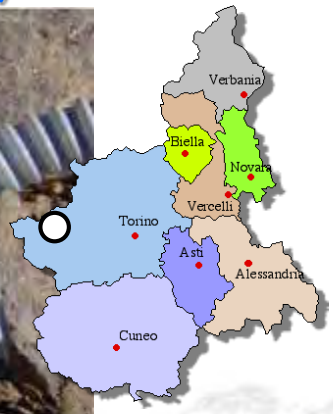
Arpa Piemonte activities Ground Surface Temperature (GST)

Mt. Rocciamelone
(Novalesa, TO)





6 thermistors installed in bedrock close to rockfall scars

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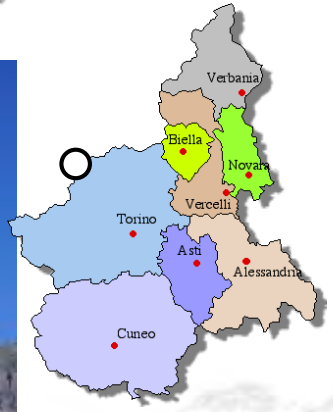
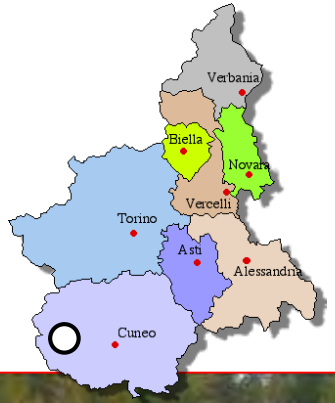
Arpa Piemonte activities Ground Surface Temperature (GST)

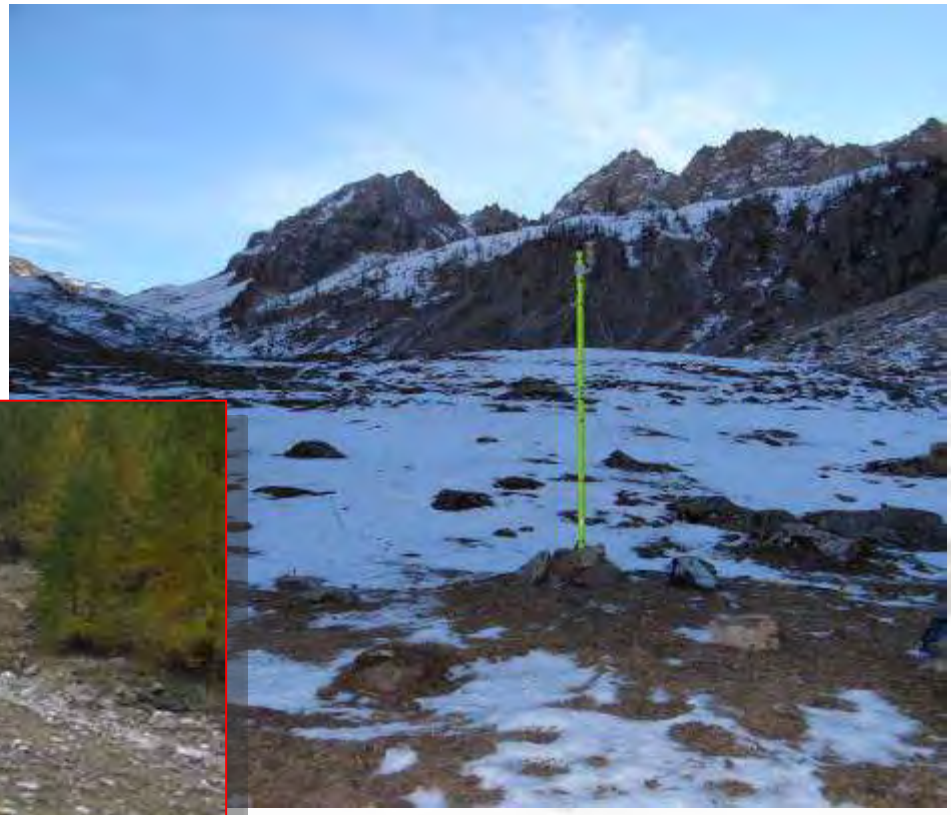
Serrù reservoir (Ceresole Reale, TO)



Sensor installation in debris covers (rock glacier, moraine, talus, …)

Arpa Piemonte activities Ground Surface Temperature (GST)

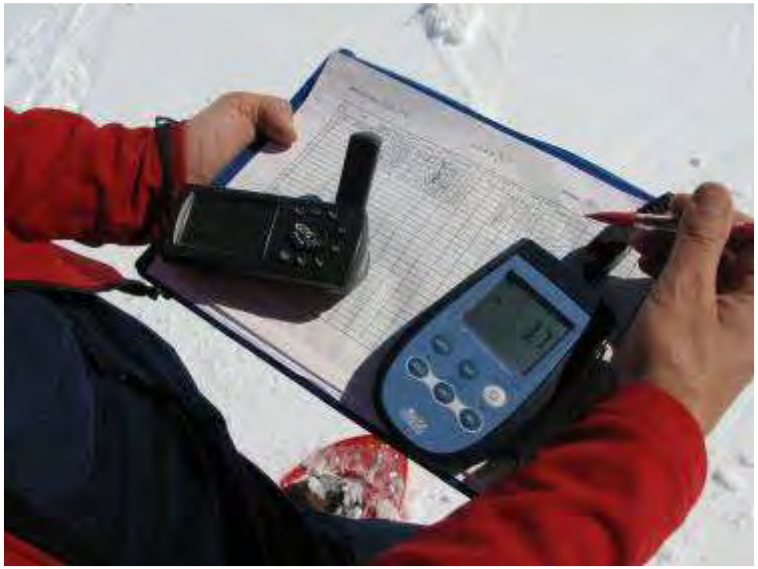




Thermistors installation in relation to monitoring cold spring waters

Arpa Piemonte activities Bottom Temperature of the Snow (BTS)

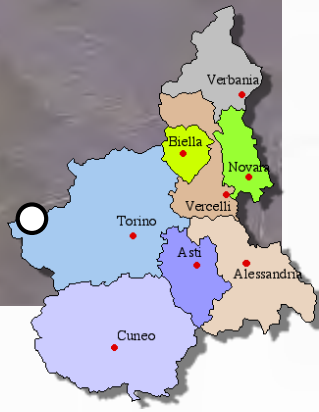
BTS: ground surface temperature measured under snow cover at the end of the winter period, before starting snow melt



Year	Site	BTS point
2009	6	176
2010	4	113
2011	3	142
2012	3	246
2013	5	273
2014	3	440
2015	4	211
totale		1601

Arpa Piemonte activities Bottom Temperature of the Snow (BTS)

Sommeiller Pass, 20th Feb. 2014
(Bardonecchia, TO)



BTS measurement at the grid knots (10 m x 10 m)

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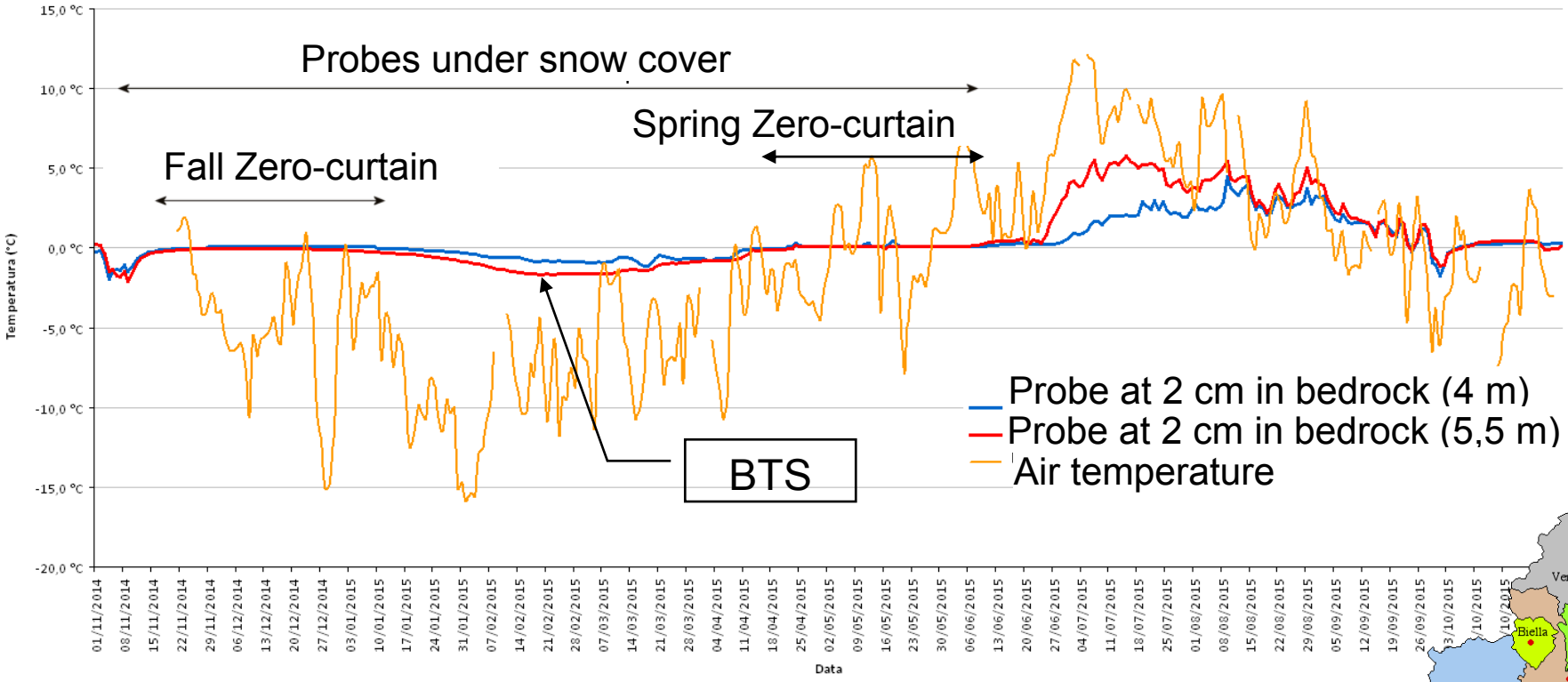
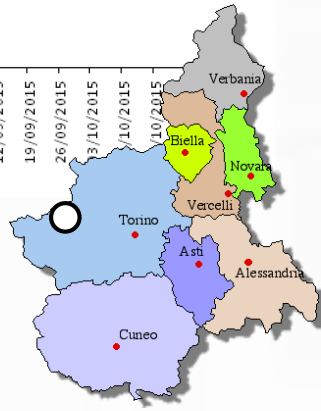
Arpa Piemonte activities Ground Surface Temperature (GST)

Example of thermal effect of the snow cover on the bedrock

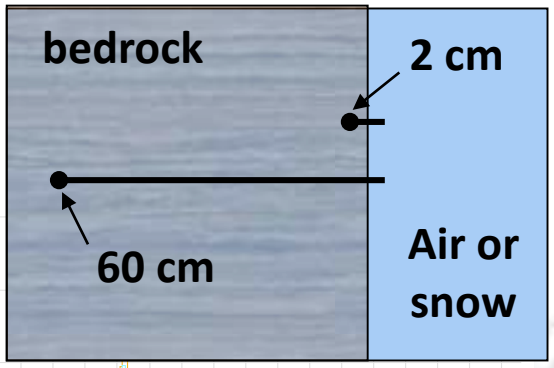




Mt. Rocciamelone (Novalesa, TO) – 3200 m

Arpa Piemonte activities Ground Surface Temperature (GST)

Example of thermal wave propagation in the bedrock



Mt. Rocciamelone (Novalesa, TO) – 3000 m

Arpa Piemonte activities

Permafrost (?) and landslide

Installation of a multiparametric column at 3150 m a.s.l. on the South ridge of Mt. Rocciamelone, near the landslide scar of the 2006

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Haute Montagne

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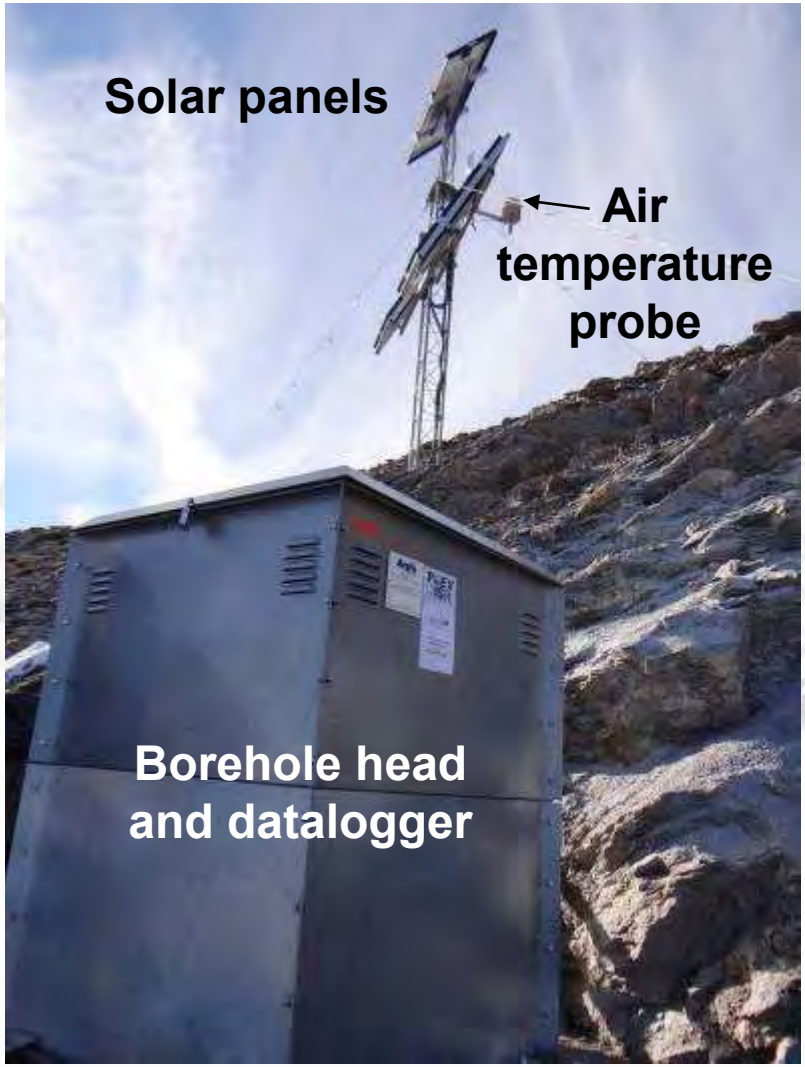
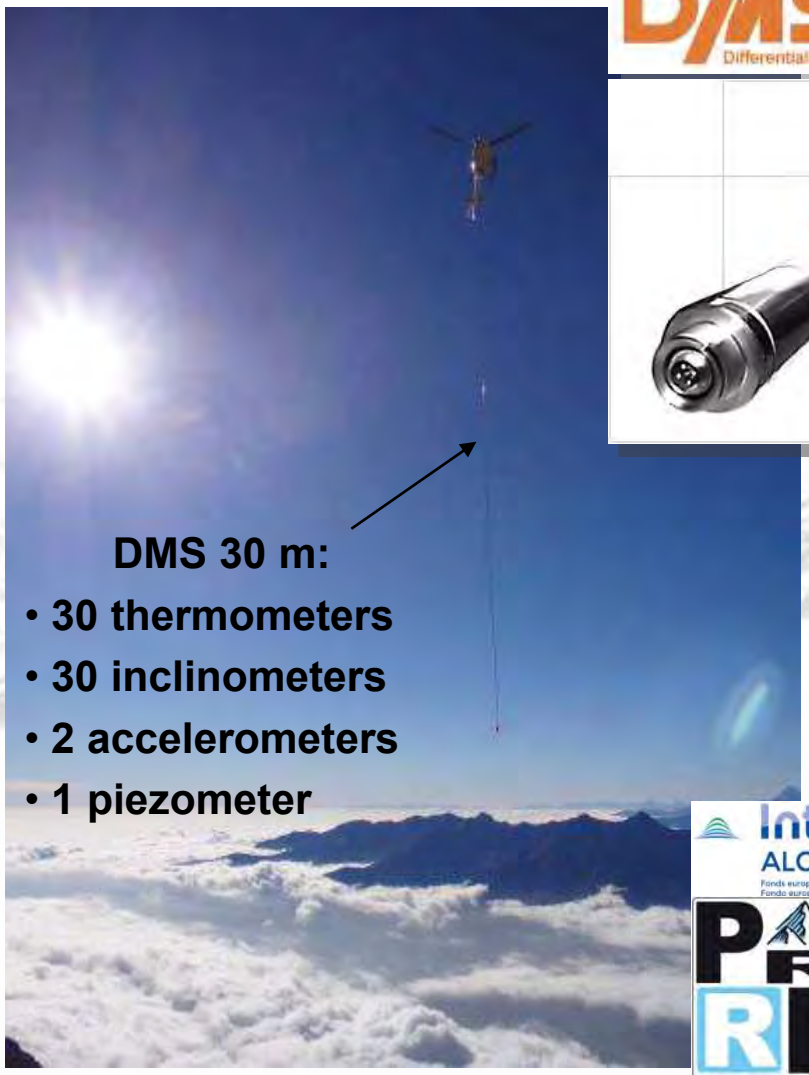
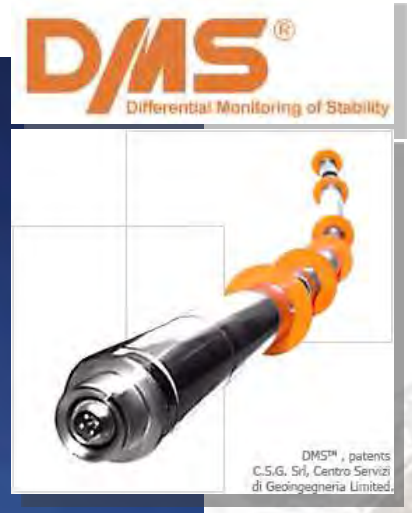
Arpa Piemonte activities Permafrost (?) and landslide







Mt. Rocciamelone, 3150 m a.s.l. (Oct. 2016)

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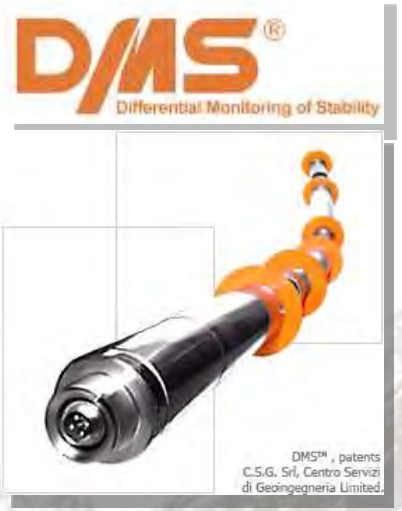
Arpa Piemonte activities Permafrost (?) and landslide

Air temperature transducer

TEMPERATURE SENSOR	
Type	PT100 – Platinum resistance
Tolerance class	Class 1/3 (DIN 43760) ±0.1°C
Range [°C]	-30°/+60°C
Resistance [Ω]	100@0°C
Resolution [°C]	0.1



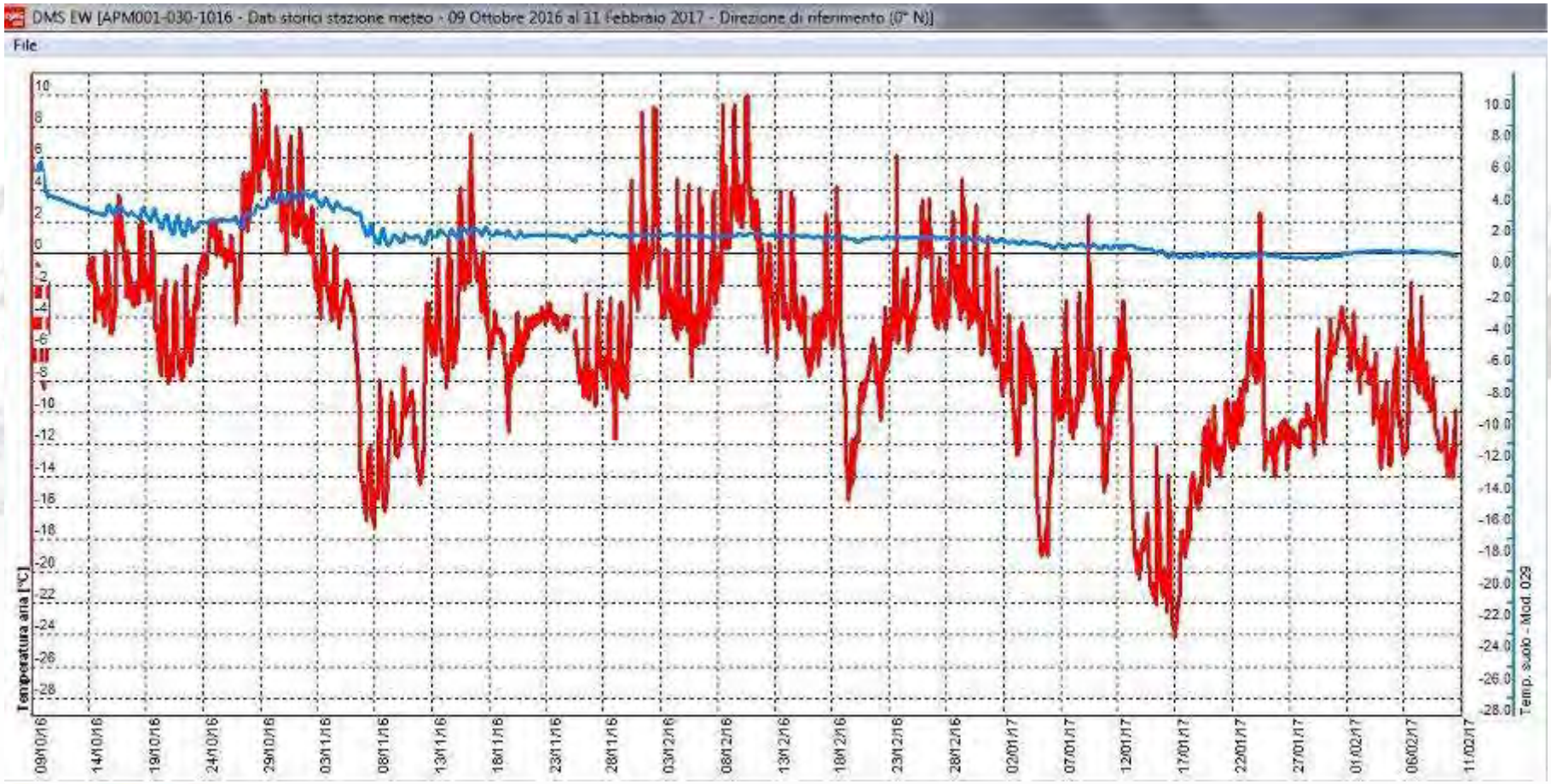
DMS temperature transducer

TEMPERATURE SENSOR	
Type	PT1000 – Platinum resistance
Tolerance class	Class A (DIN 60751/95) ±(0.15+0.002|t|*
Range [°C]	-20°/+70°C
Resistance [Ω]	1000@0°C
Resolution [°C]	0.1
Linearity [%FS]	±0.2

* Where t is the absolute value of the temperature.

Arpa Piemonte activities Permafrost (?) and landslide

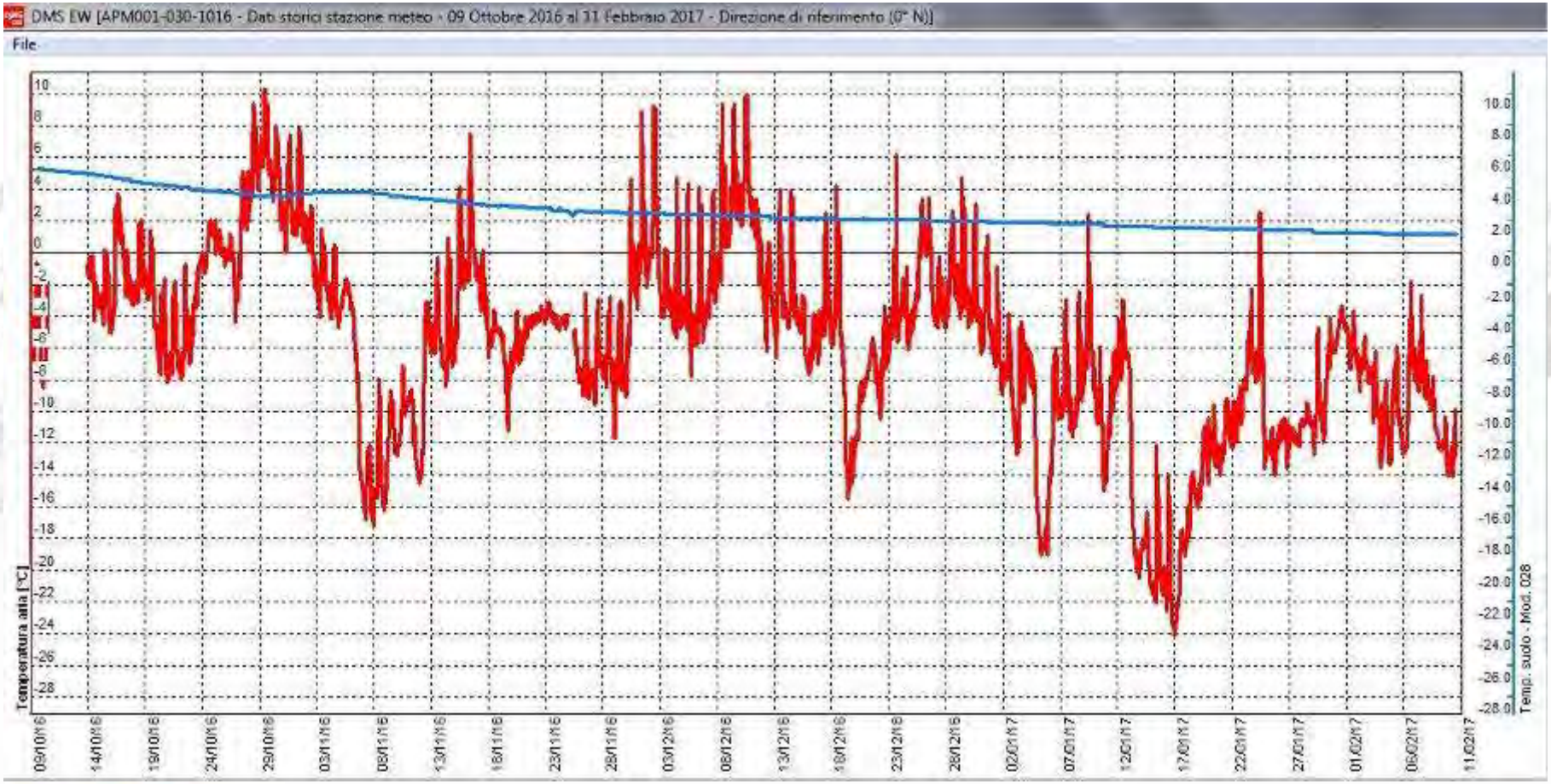
Air temperature – underground temperature (-1 m),10/2016-02/2017



DMS® Differential Monitoring of Stability

Arpa Piemonte activities Permafrost (?) and landslide

Air temperature – underground temperature (-2 m),10/2016-02/2017

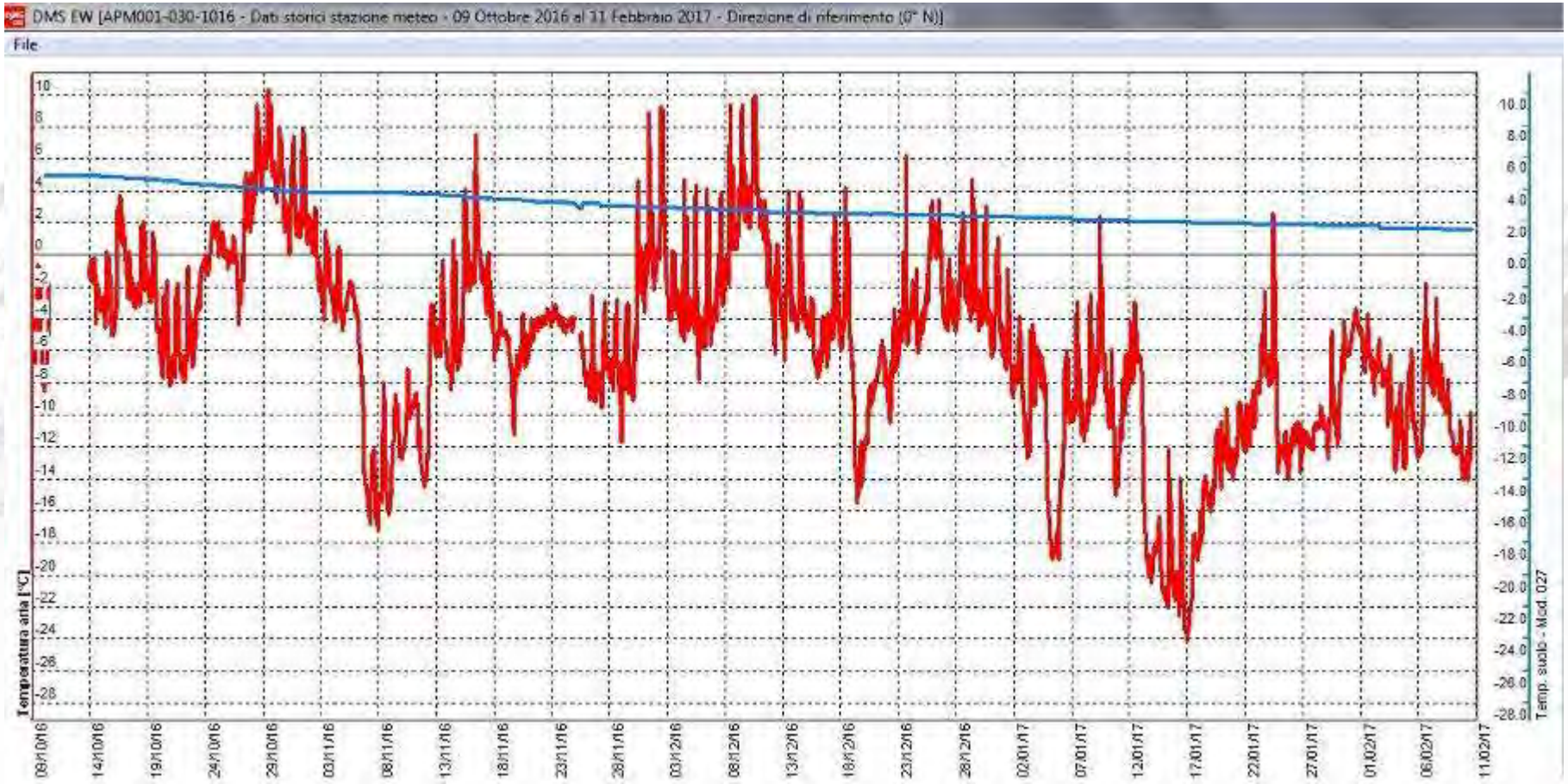


DMS® Differential Monitoring of Stability

MeteoMet International Workshop, 15th Feb. 2017

Arpa Piemonte activities Permafrost (?) and landslide

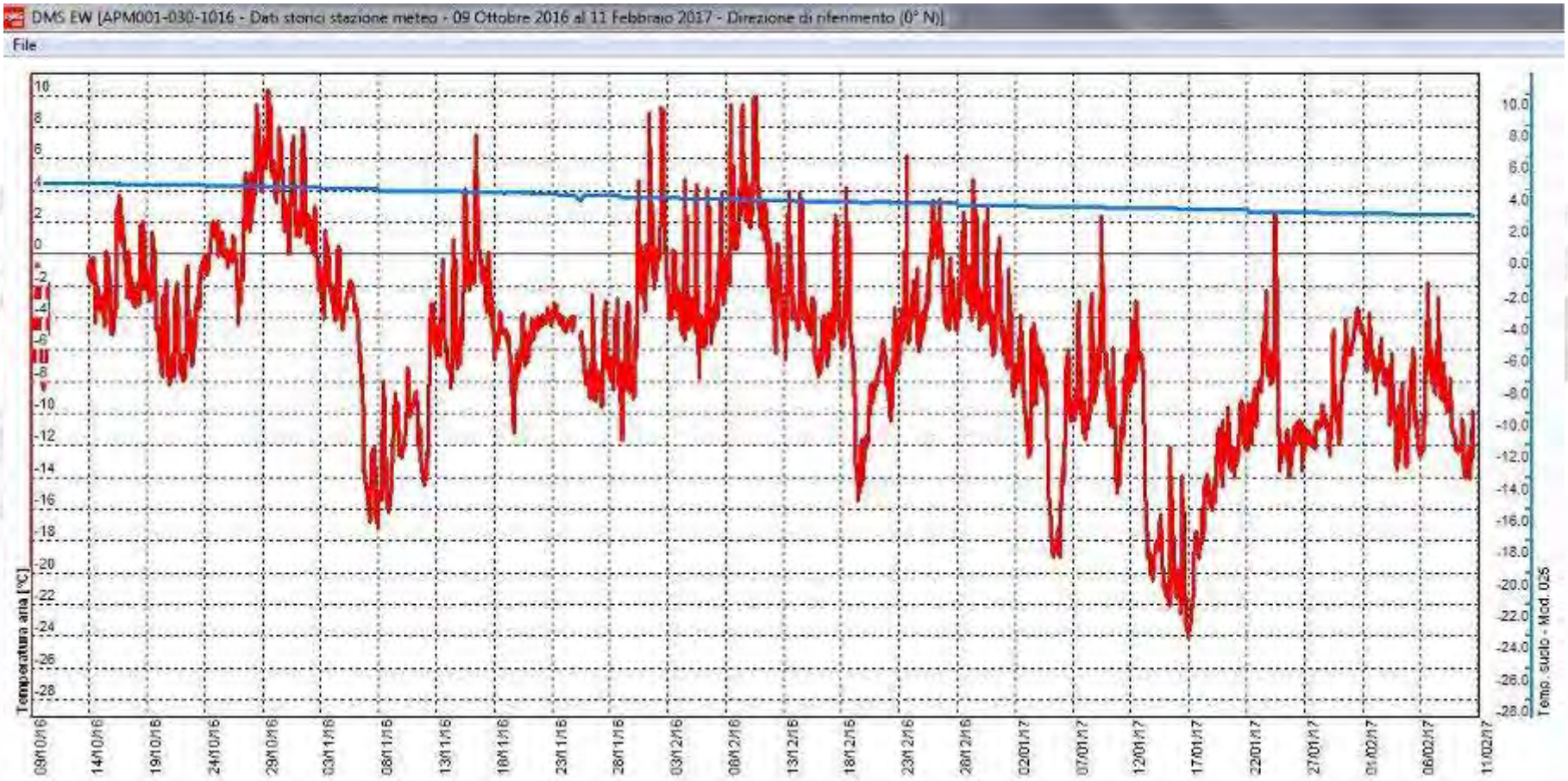
Air temperature – underground temperature (-3 m),10/2016-02/2017



DMS® Differential Monitoring of Stability

Arpa Piemonte activities Permafrost (?) and landslide

Air temperature – underground temperature (-5 m),10/2016-02/2017



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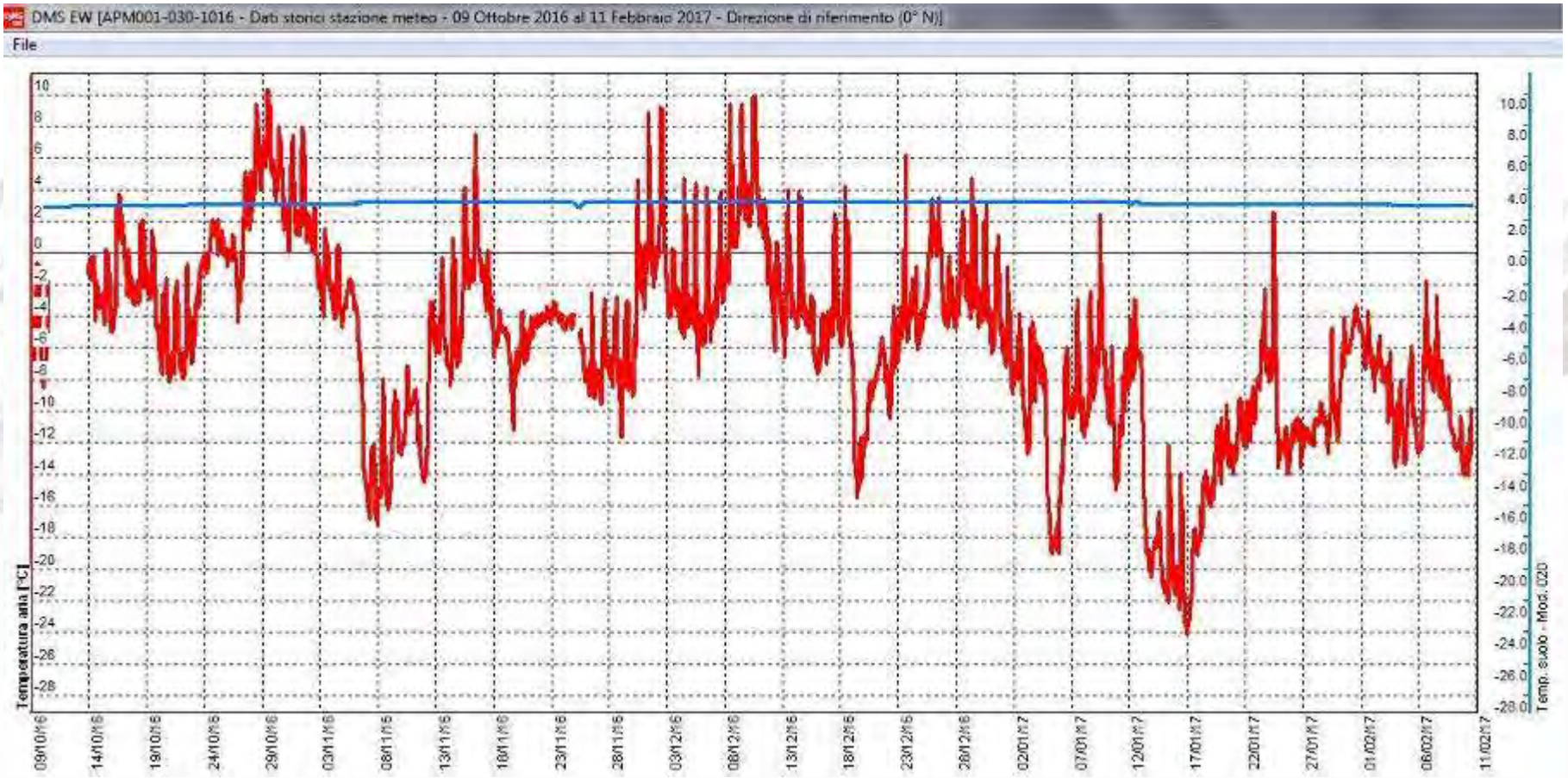
Arpa Piemonte Agenzia Regionale per la Protezione Ambientale

Arpa Piemonte activities Permafrost (?) and landslide

Air temperature – underground temperature (-10 m),10/2016-02/2017



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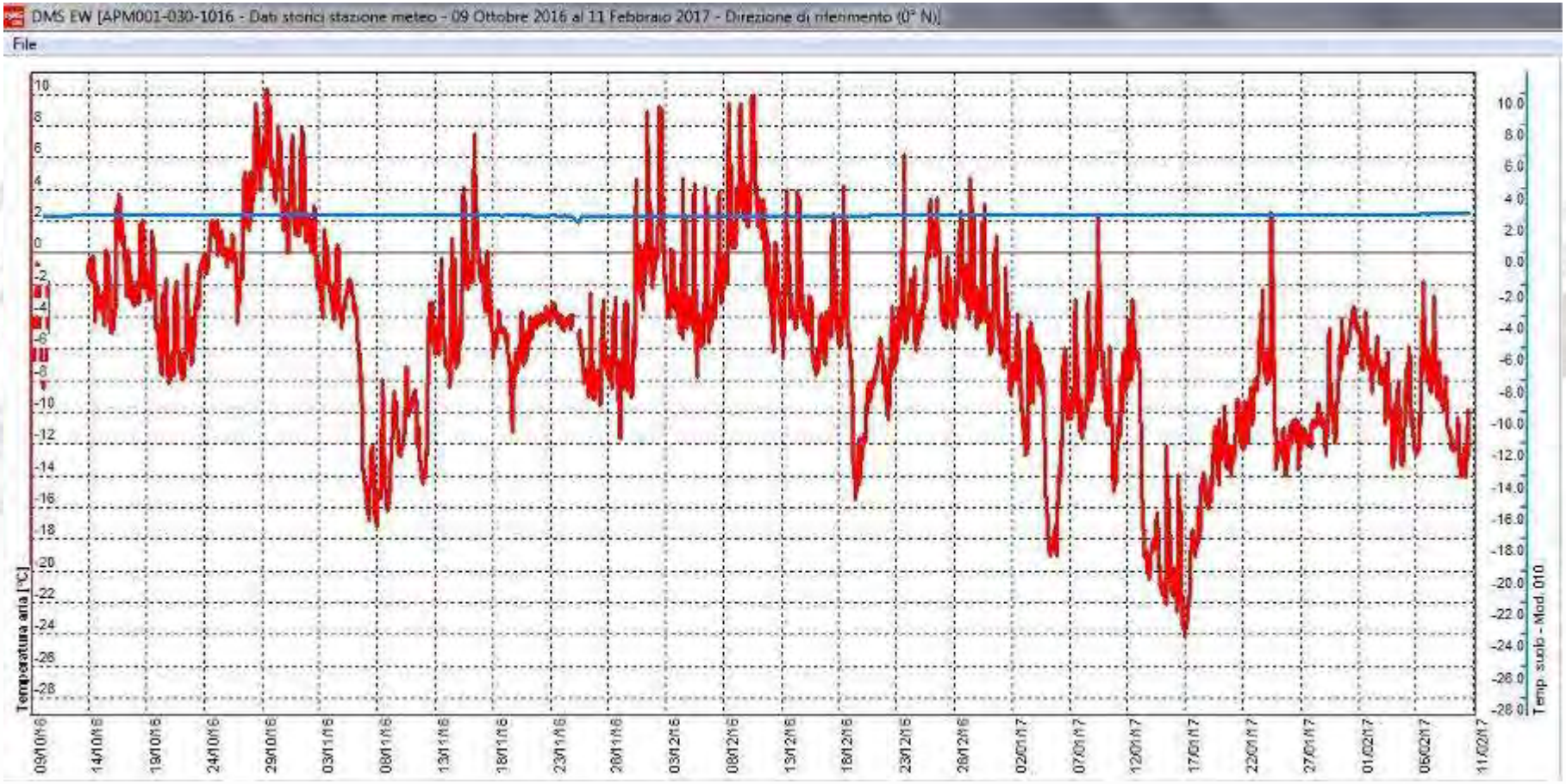
Arpa Piemonte activities Permafrost (?) and landslide

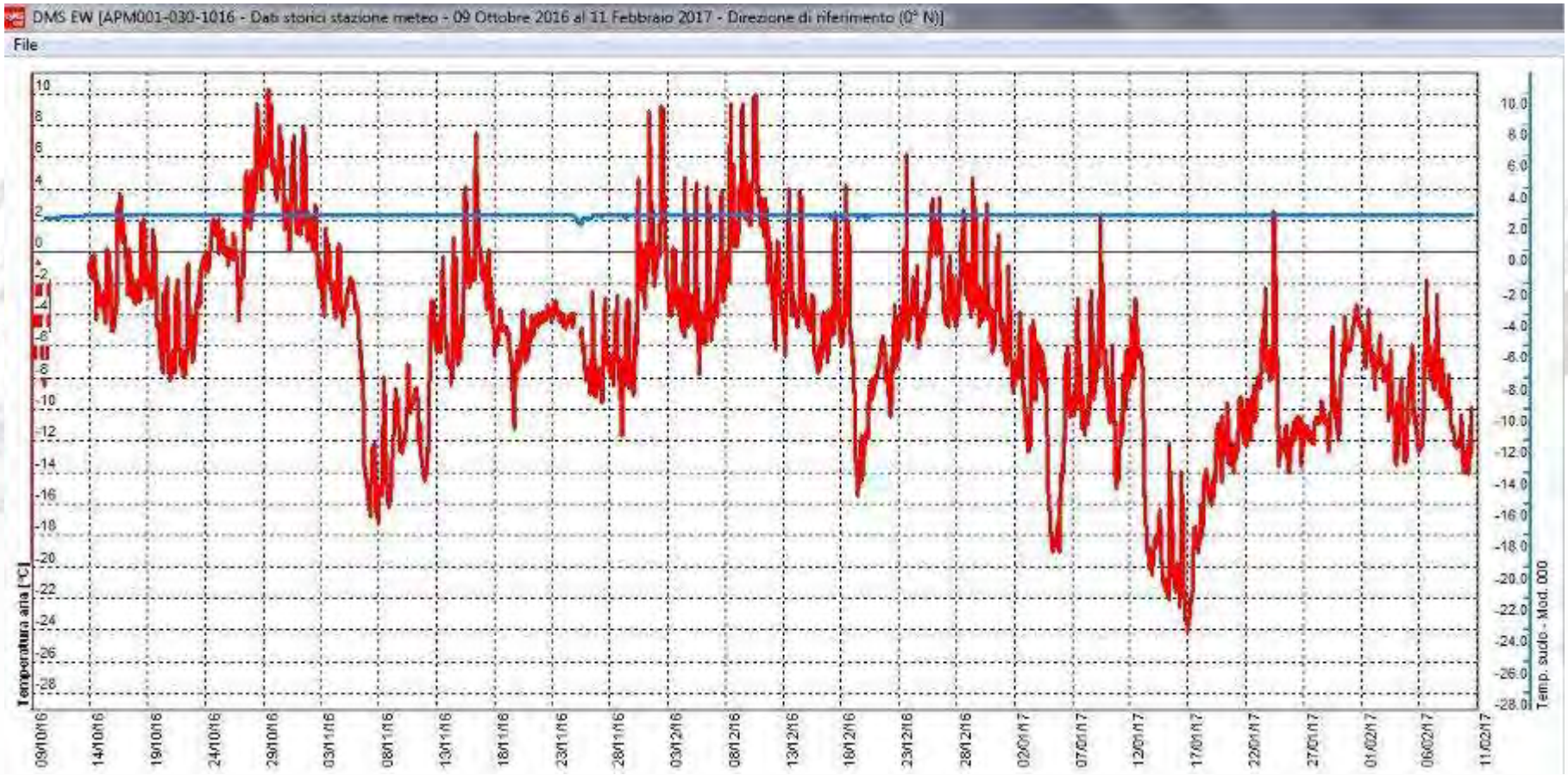
Air temperature – underground temperature (-20 m),10/2016-02/2017



DMS® Differential Monitoring of Stability

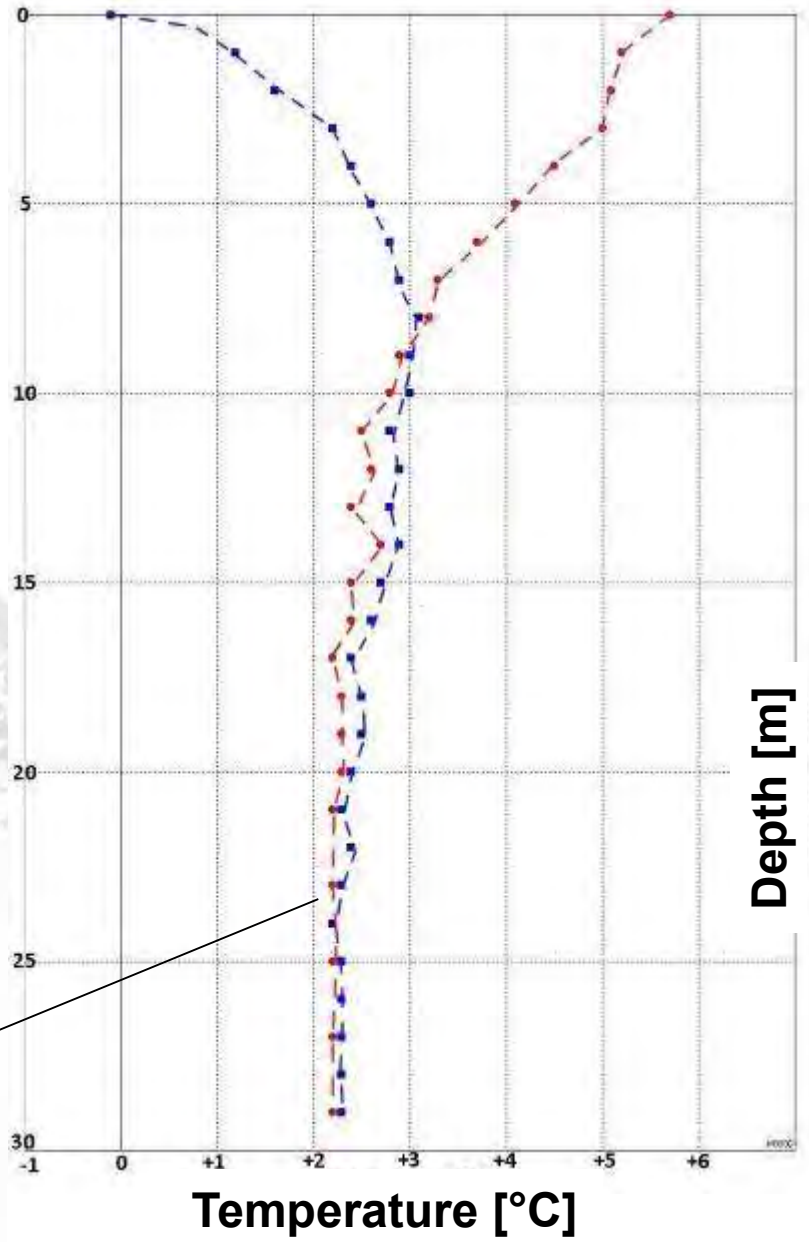
Arpa Piemonte activities Permafrost (?) and landslide

Air temperature – underground temperature (-30 m),10/2016-02/2017



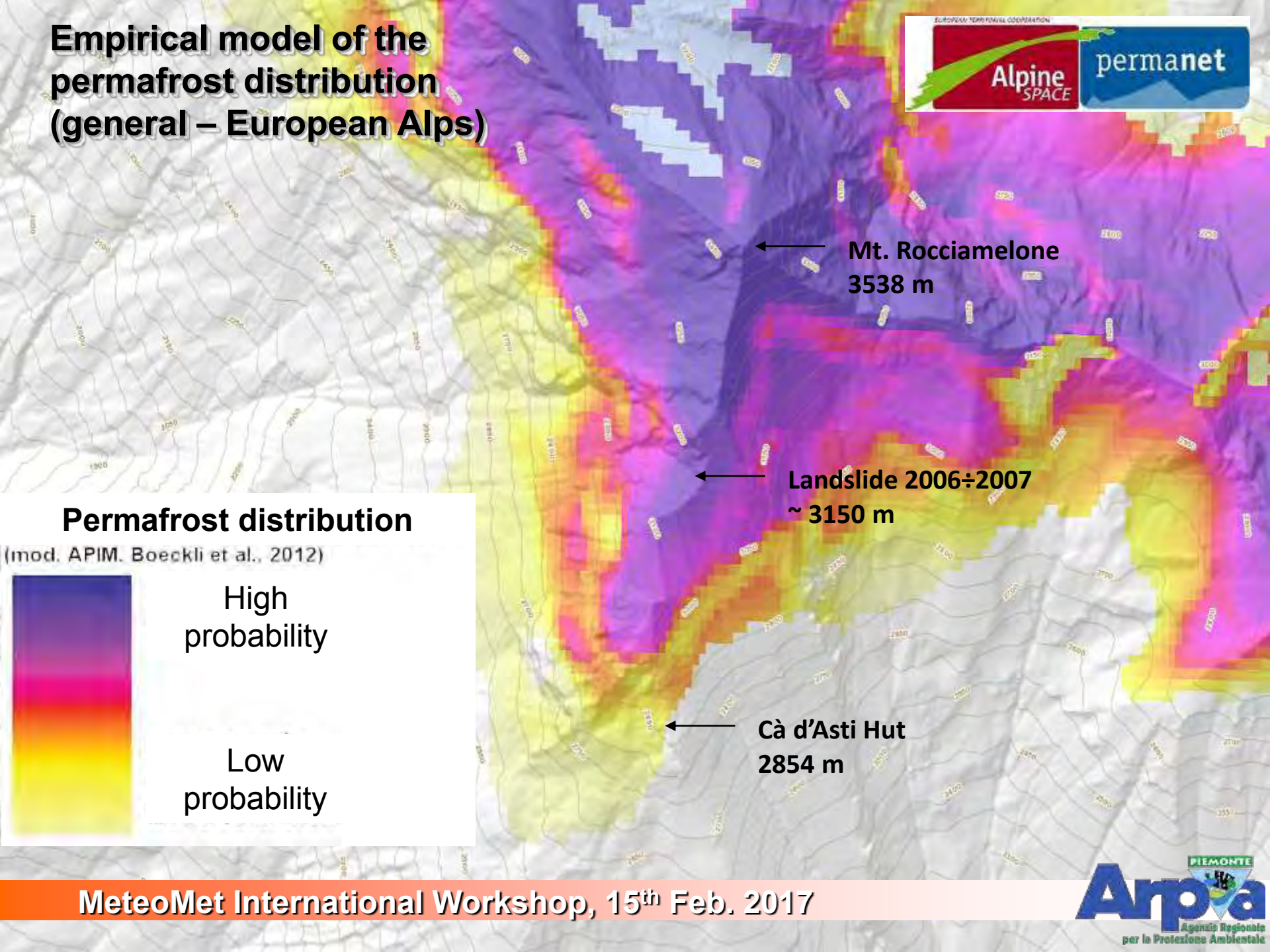
Arpa Piemonte activities
Permafrost (?) and landslide

Underground temperature variation
Oct. 2016 to Feb. 2017



At the moment, no cryotic conditions

Empirical model of the permafrost distribution (general – European Alps)



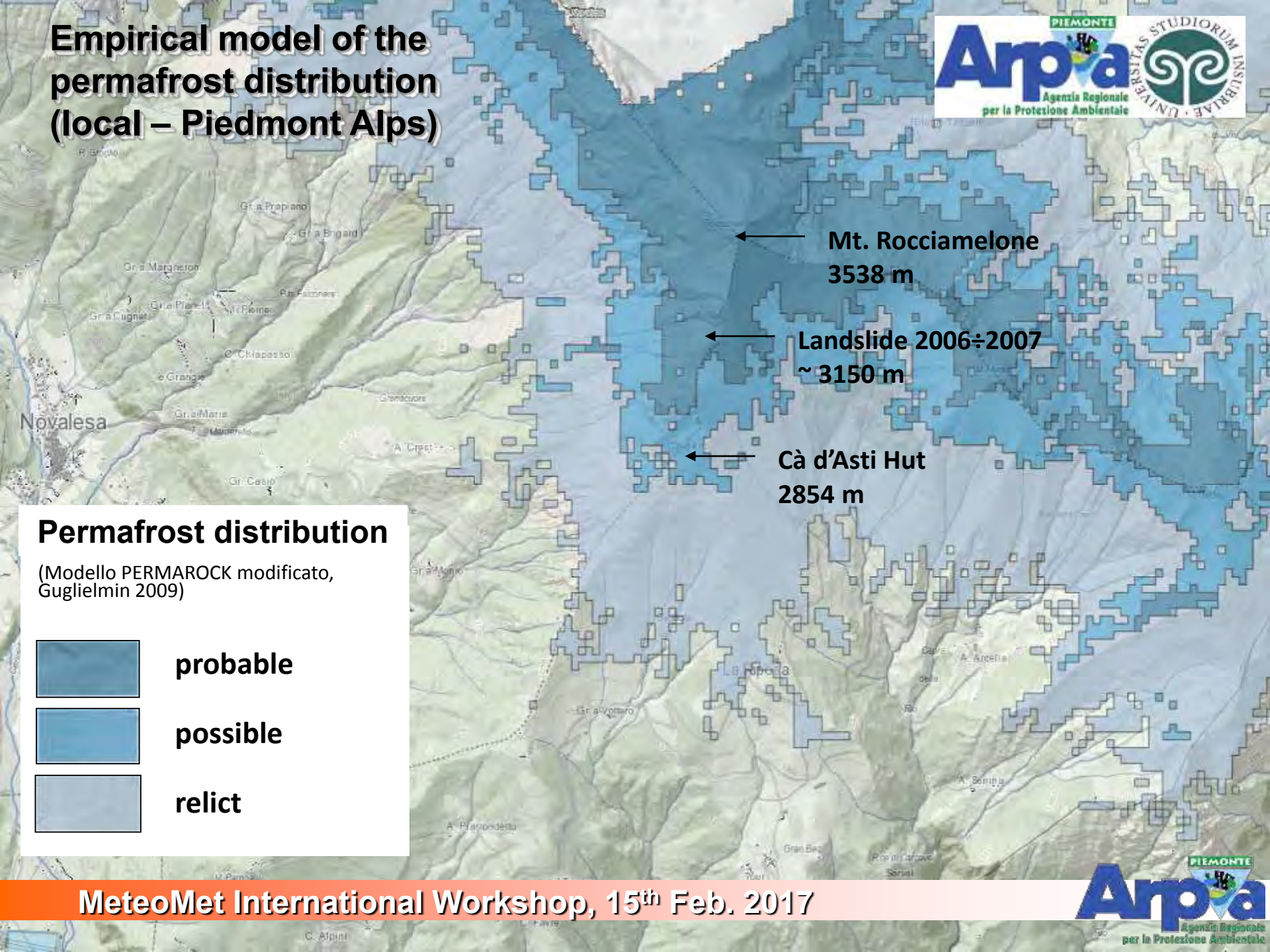
Permafrost distribution

(mod. APIM. Boeckli et al., 2012)

High probability

Low probability

Empirical model of the permafrost distribution (local – Piedmont Alps)

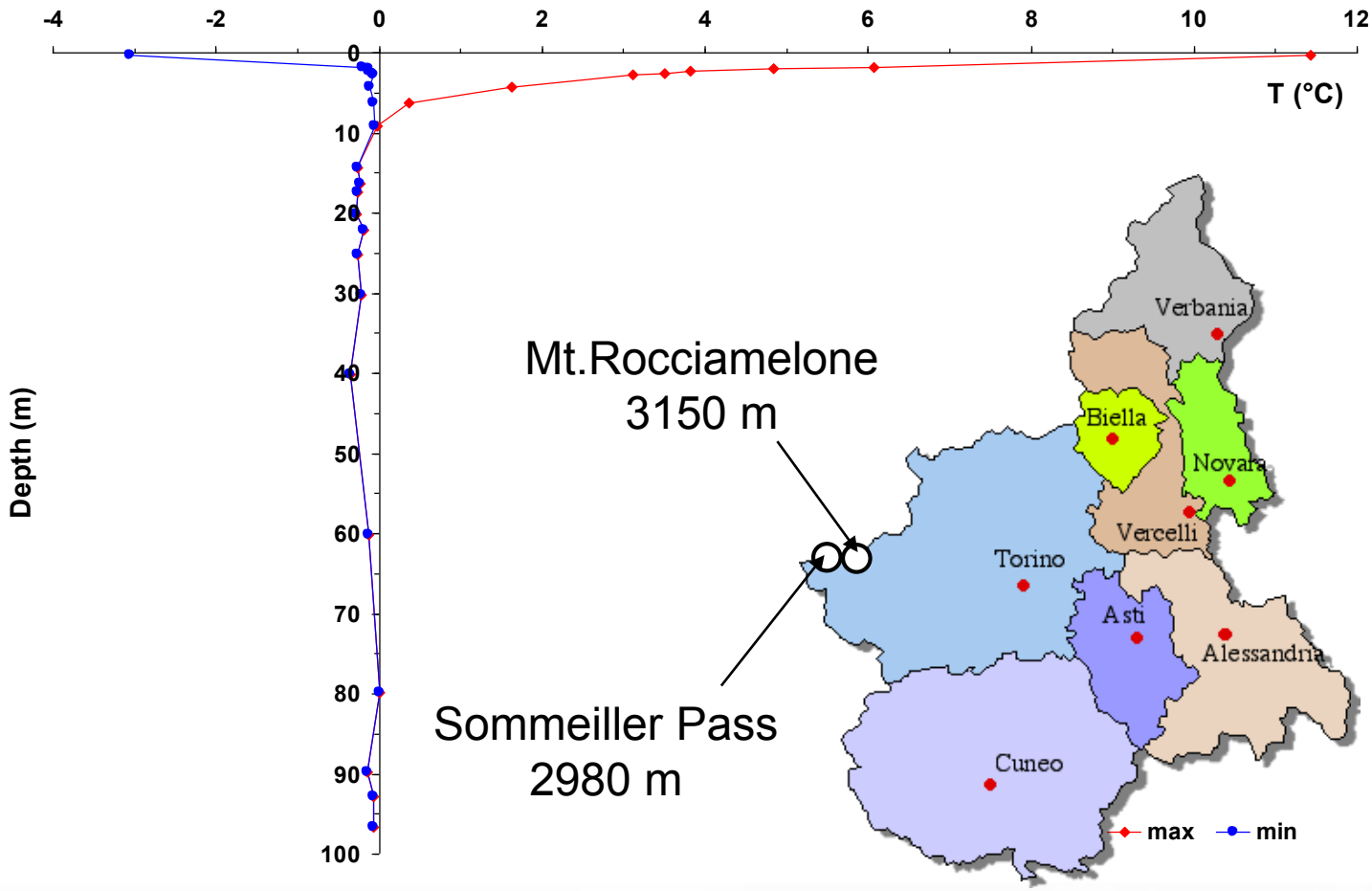


Permafrost distribution

(Modello PERMAROCK modificato, Guglielmin 2009)

- probable
- possible
- relict

Preliminary results : Sommeiller Pass (Bardonecchia, TO) – 2980 m



Exemple of thermal profile of the Sommeiller Pass permafrost station obtained from the maximum and minimum values of the average daily temperatures (**2012**).

Arpa Piemonte activities Permafrost (?) and landslide

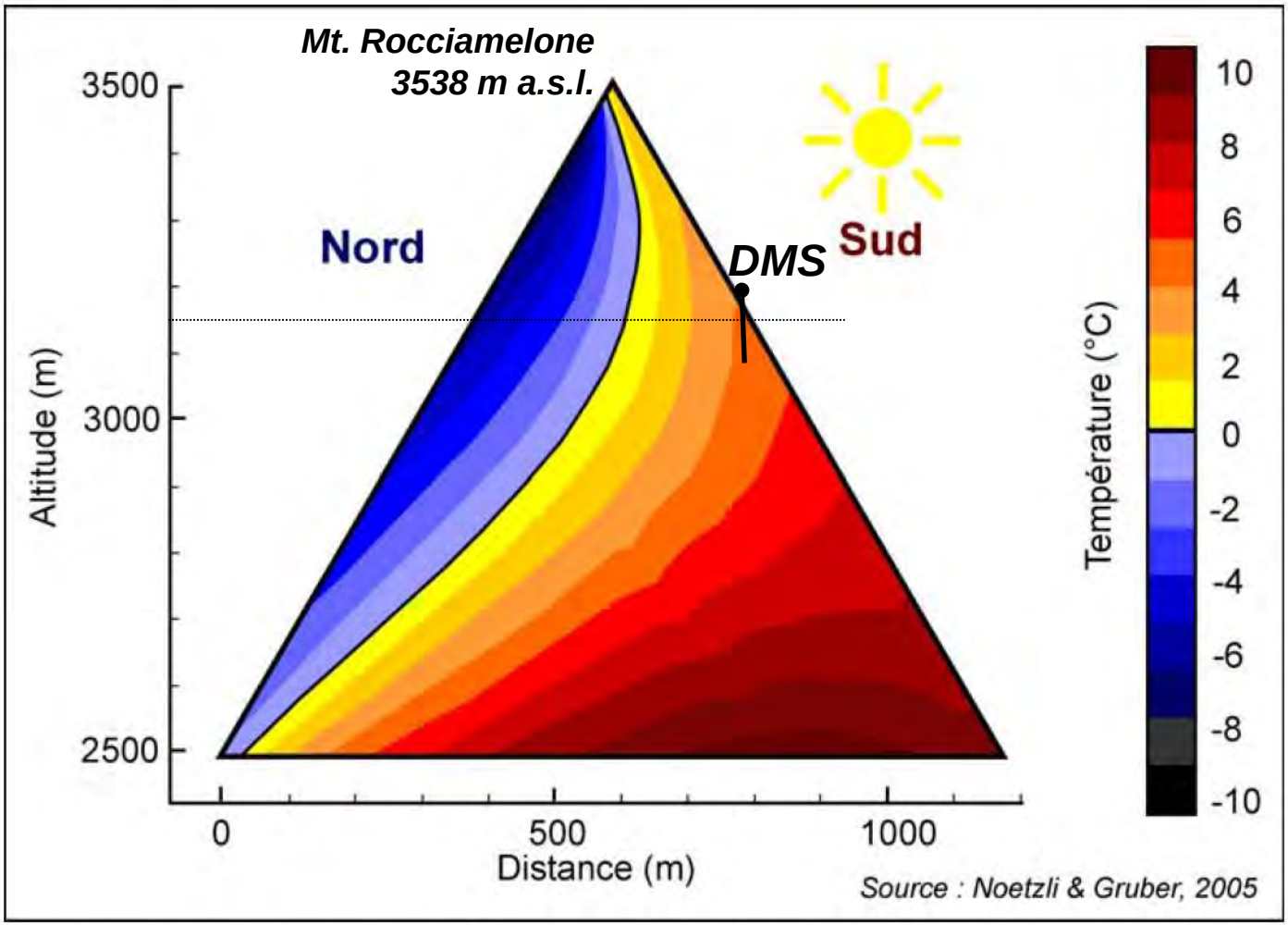


Fig. 2 – Modélisation du champ thermique à l'intérieur d'une montagne en fonction des conditions de surface (dépendantes de l'altitude et de l'orientation) (adapté de Noetzli & Gruber, 2005).

Arpa Piemonte activities Cave cryosphere

With the collaboration of Prof. Vigna (Polithecnic University of Turin)

GST monitoring in caves with ice and glacier (Ligurian Alps)

Conclusions (according to Beninston et al., 2017)

1. Quality-controlled data with high spatial and temporal resolution are essential for both the detection of past changes and the development and validation of numerical models that project future evolution.

2. Understanding the interplays between environmental mechanisms (air temperatures, micro-climate, soil properties, onset and duration of snow, etc.) and going beyond temperature-based projections will be a key for increase the reliability of future projections.

3. A big problem is represented by lack of meteo-climate data in high mountain area (very few weather station in high and very high altitude).

4. On-site measurement in high mountain areas are intrinsically affected by uncertainties (more or less great) and it is important to distinguish between “uncertainty” and “error”.

5. Permafrost is the hidden part of the cryosphere and cryologists strongly need a correct measures and data in order to know this element and to build reliable models and scenarios usefull to communicate permafrost changes to administrators, risk managers and people.

Thank you for your kind attention

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Arpa Piemonte

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S.S. Monitoraggi e Studi Geologici

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