Design procedure to mitigate the effect of snow accumulation along embankment built on permafrost

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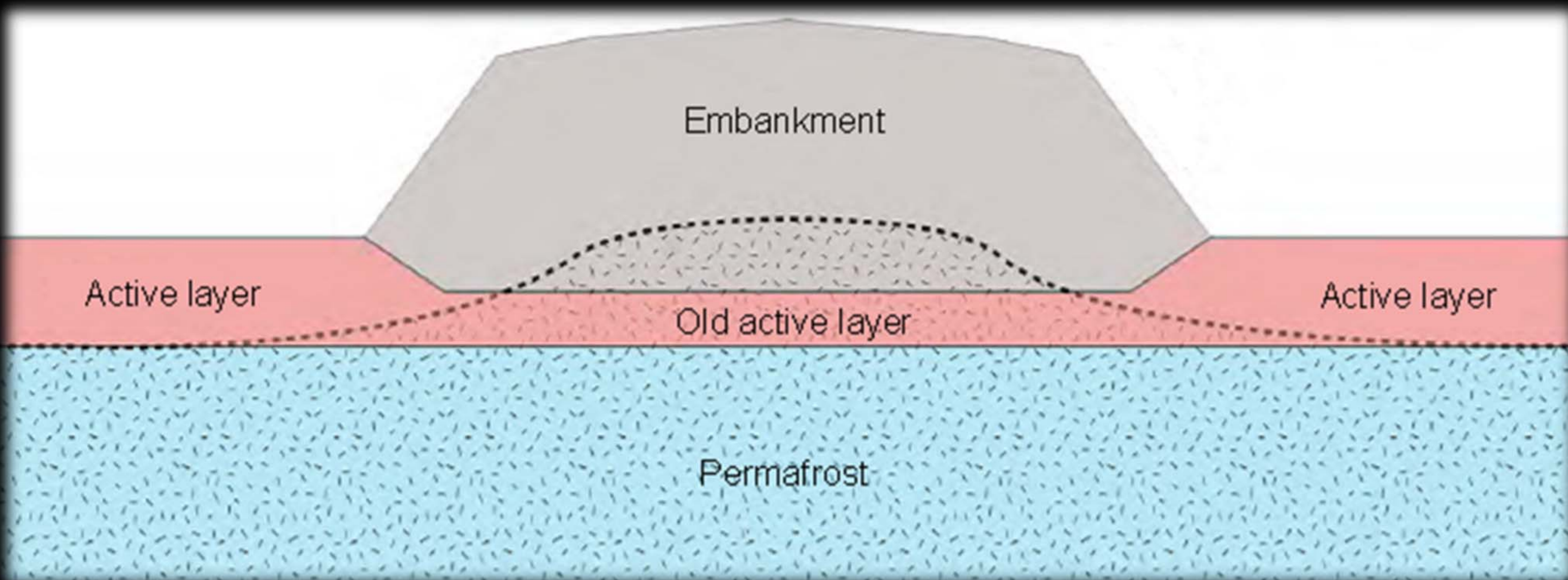
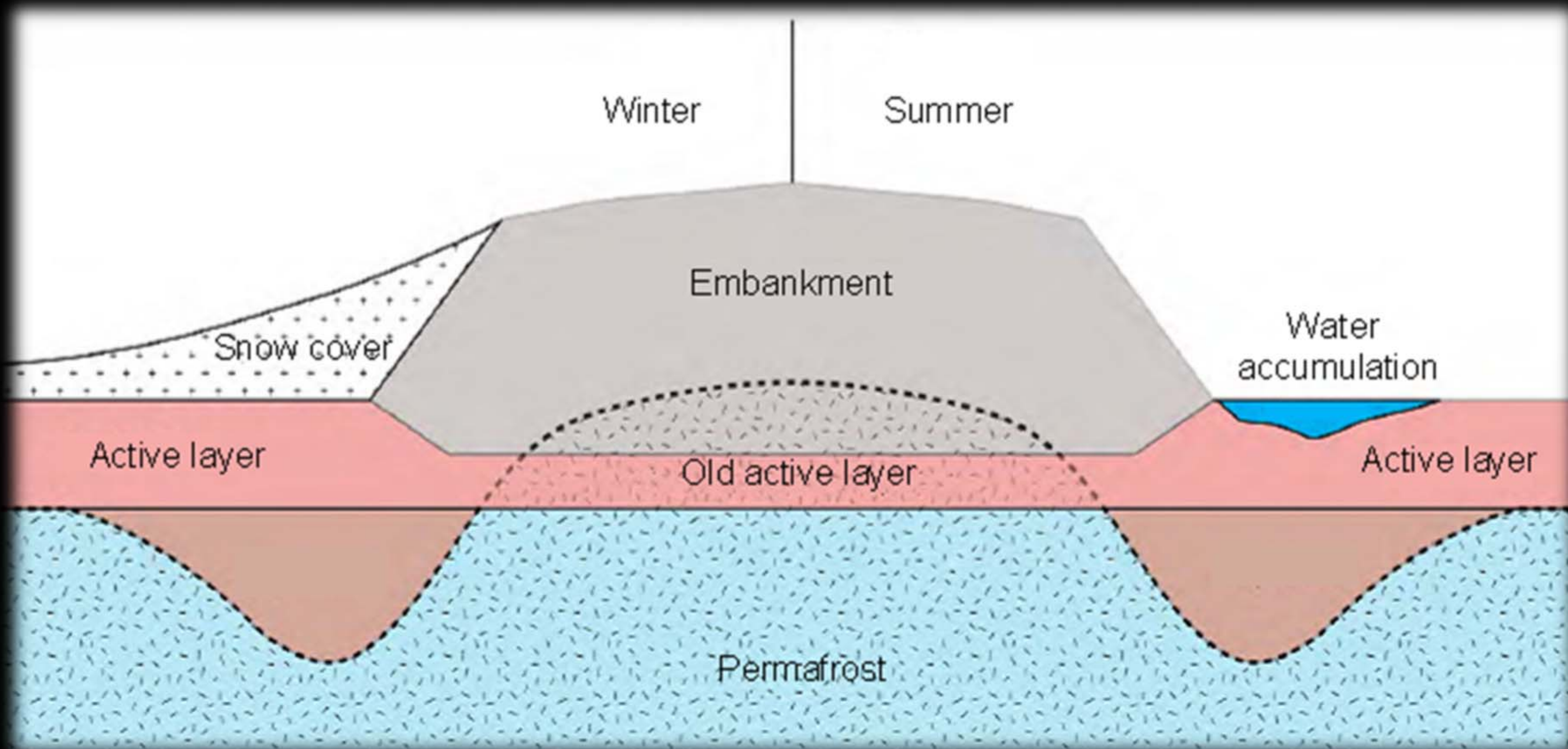
ARQULUK SYMPOSIUM Whitehorse, February 21st, 2018

Context



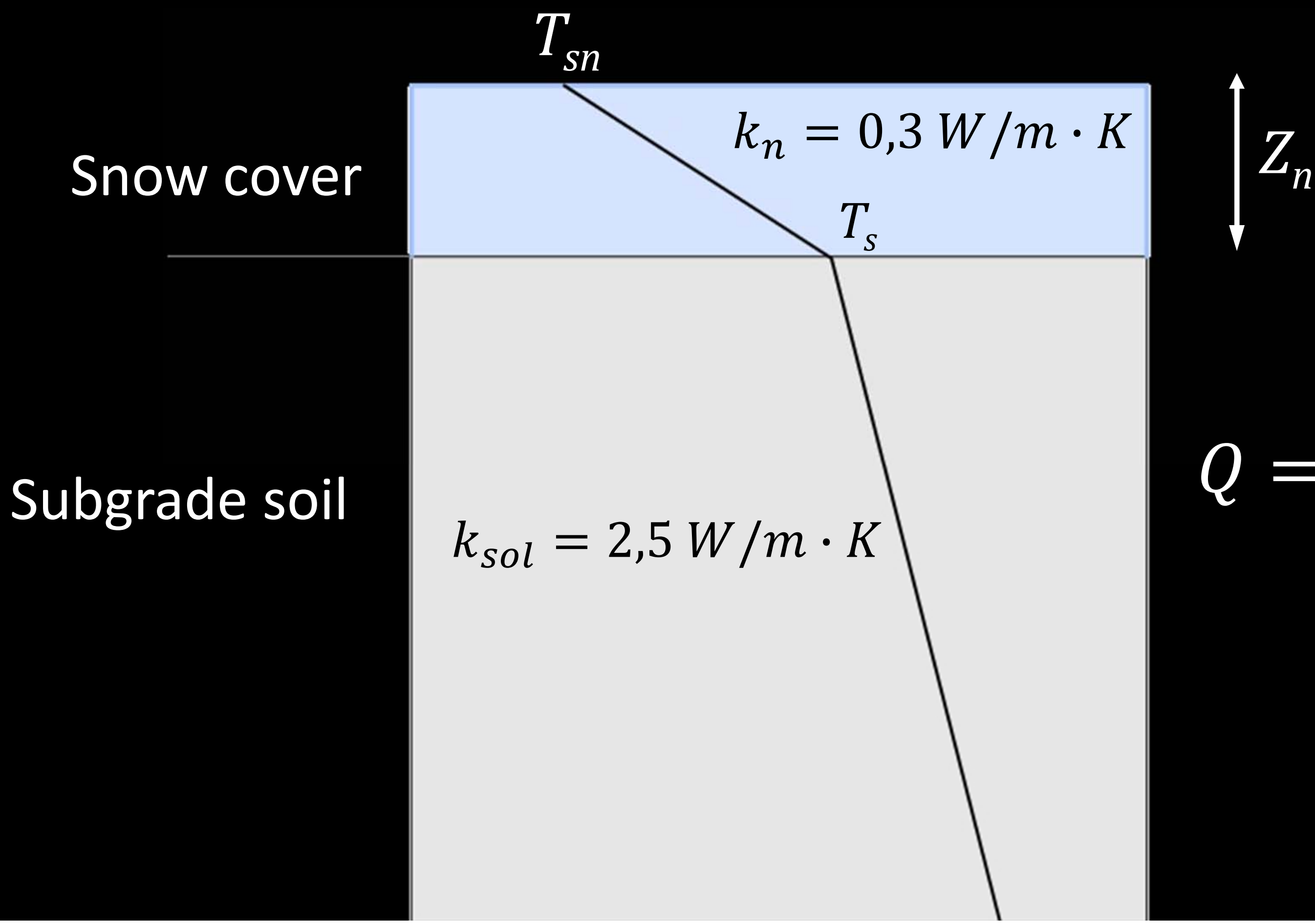
modified from L'Hérault et al., 2012

Context



modified from L'Hérault et al., 2012

Heat transfer



$$Q = k_n \frac{T_{sn} - T_s}{Z_n}$$

Embankment geometry

Embankment thickness

Slope angle

Use of berms

Objective and Methodology

Develop an engineering tool for optimization of embankment geometry to minimize negative effects of snow accumulation on embankment slopes

2D thermal modeling of embankments on natural grounds considering the effect of snow accumulation

Calibrate the model using field data collected during the winter of 2014-2015 at Tasiujaq test site

Quantify the effect of key parameters related to embankment geometry

Test site

Tasiujaq airstrip

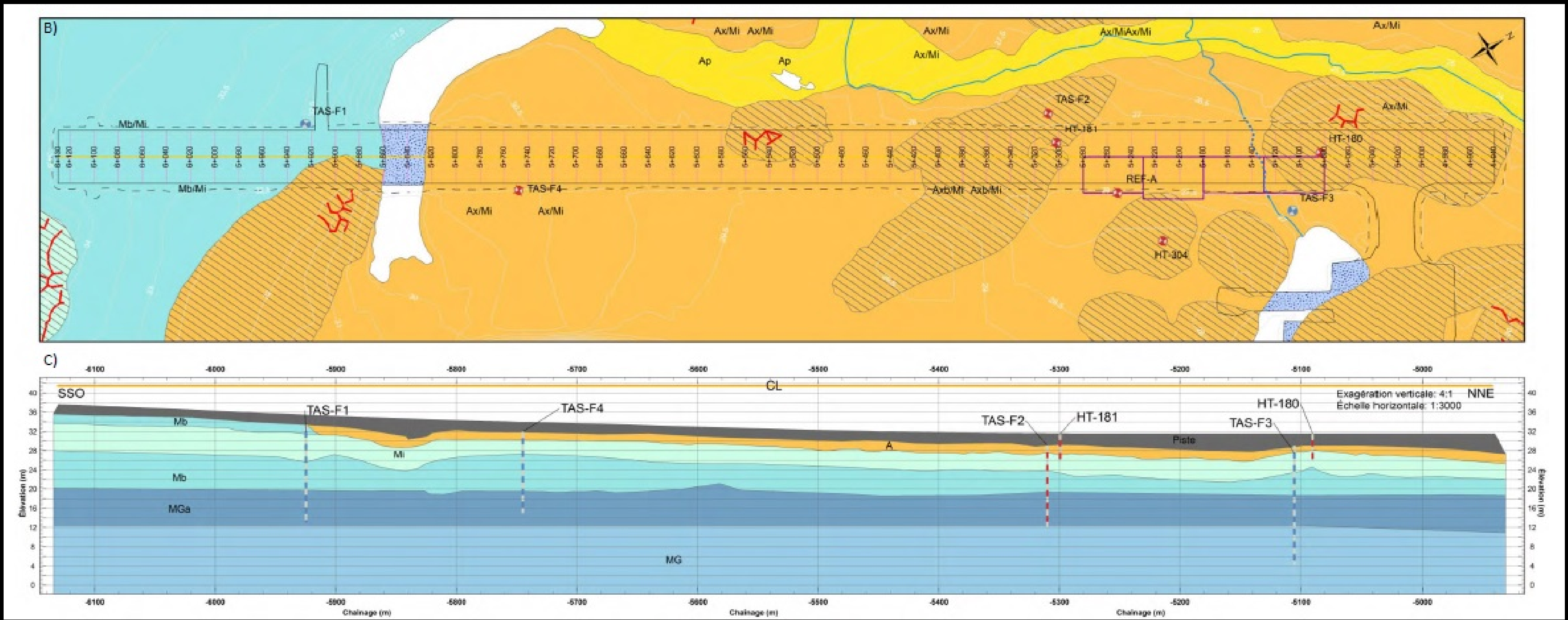
Discontinuous permafrost

Airstrip alignment favoring snow accumulation

Surficial geology known

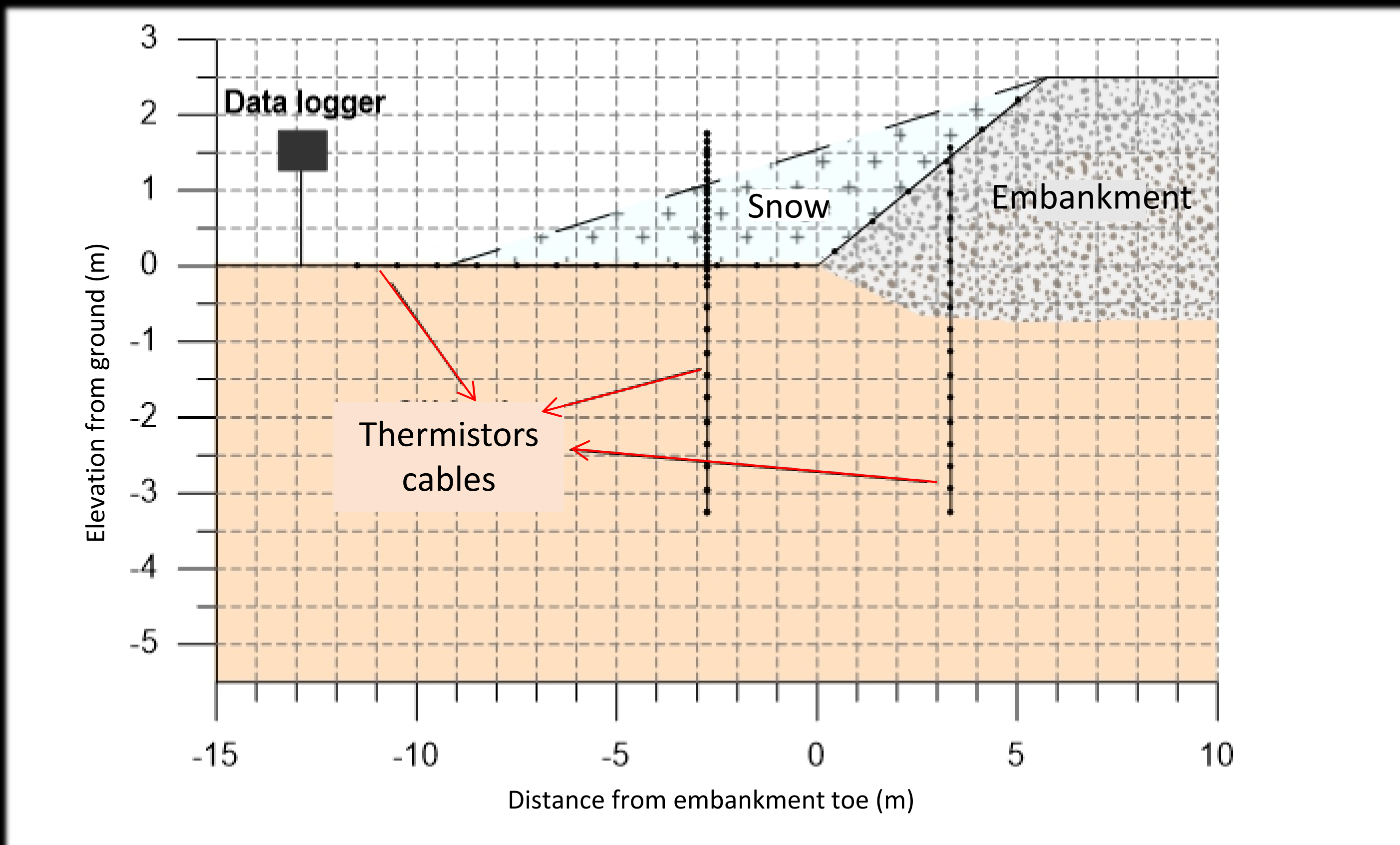
L'Hérault et al., 2012

Test site

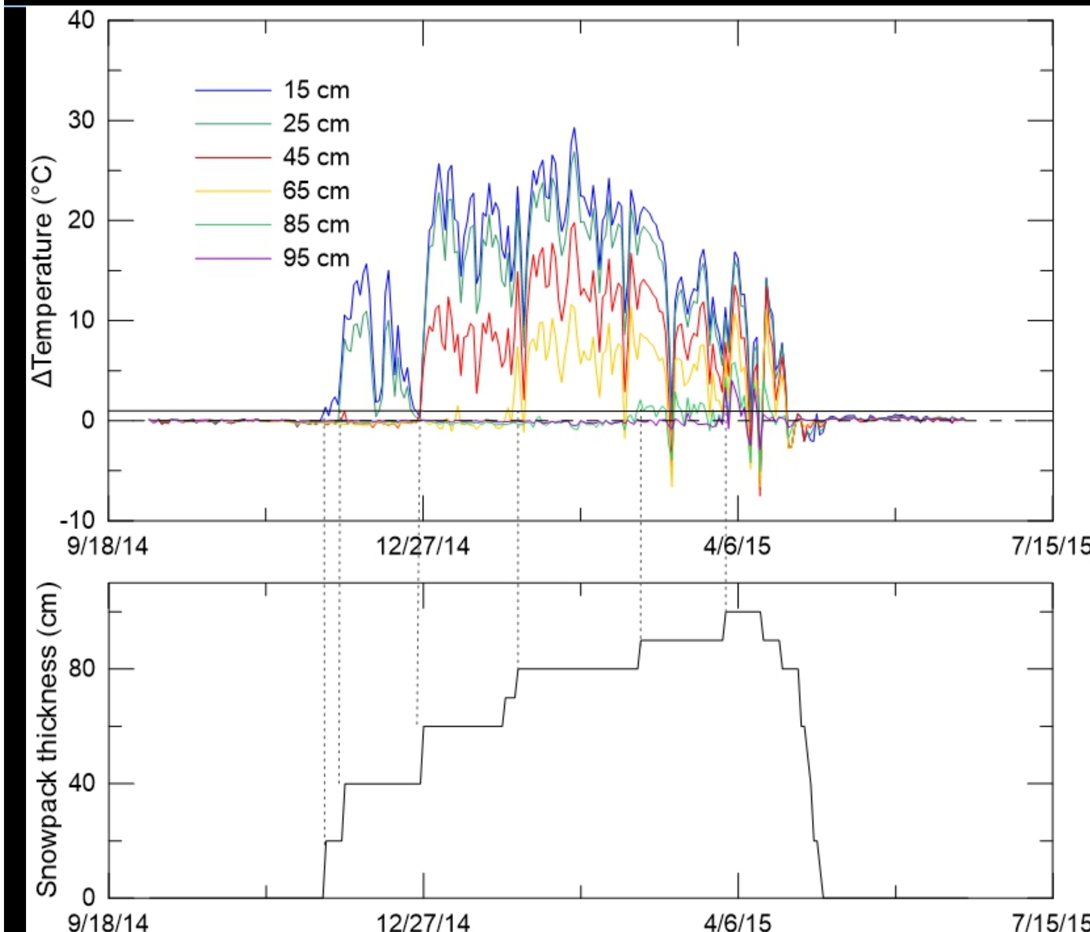


L'Hérault et al., 2012

Monitoring


Data logger
Snow
Embankment
Thermistors cables
Elevation from ground (m)
Distance from embankment toe (m)
3
2
1
0
-1
-2
-3
-4
-5
-15
-10
-5
0
5
10

Snowpack Evolution



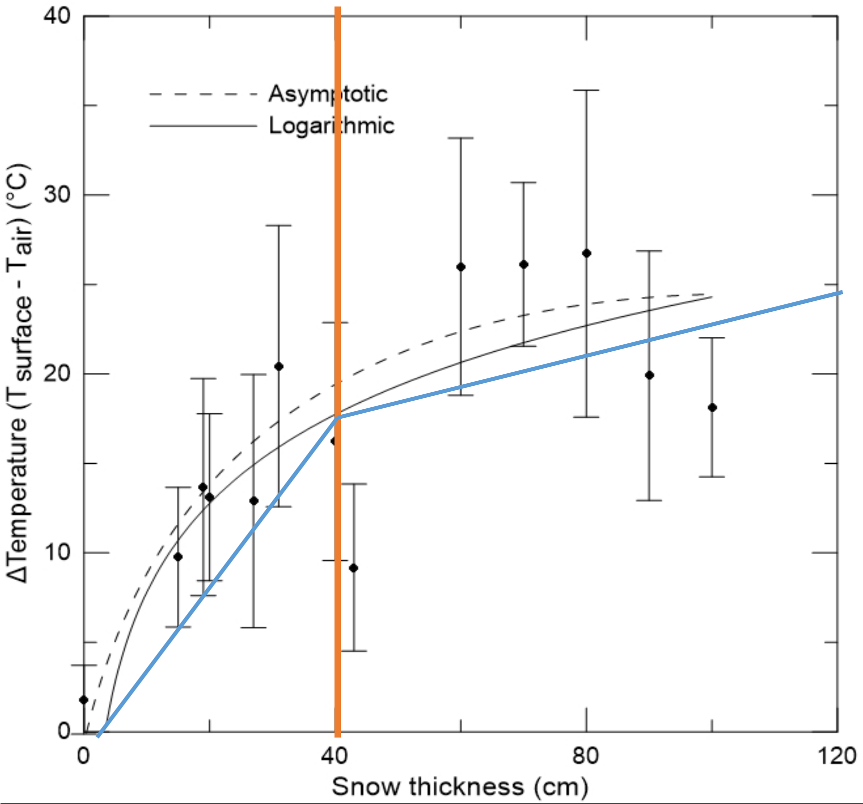
Accuracy : ± 5 cm

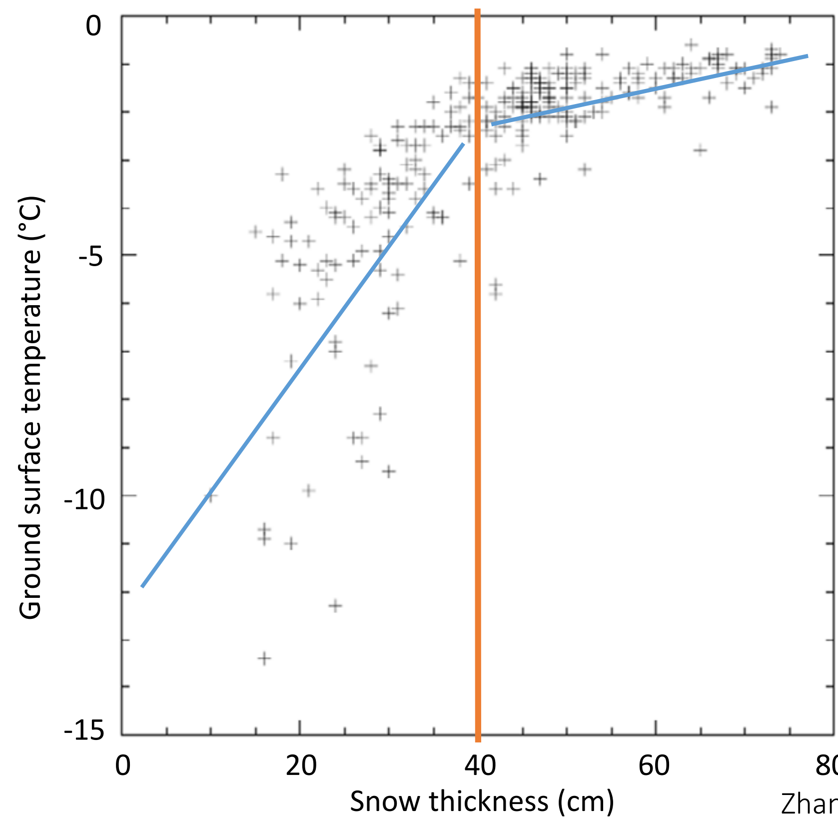
Snowpack accumulation began at the end of November

Maximum snow depth : 90 cm (on March 31st)

Snowmelt began on April 15th

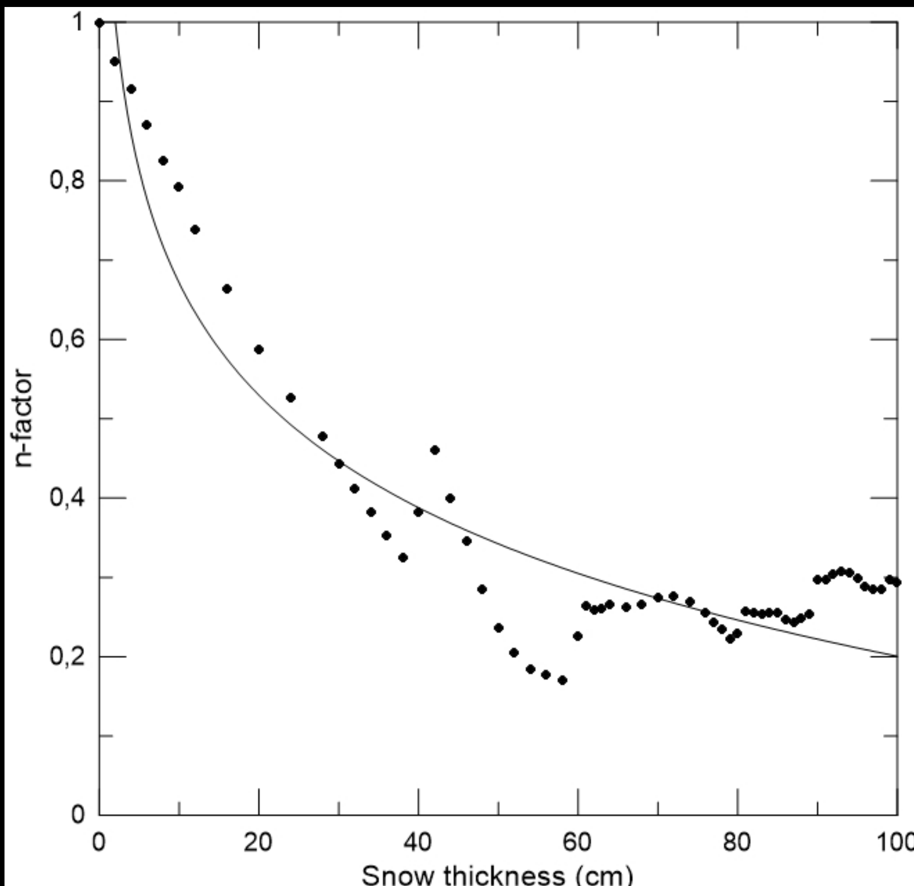
Snow depth effects on ground surface temperature





Zhang, 2005

Ground surface temperature – n factor



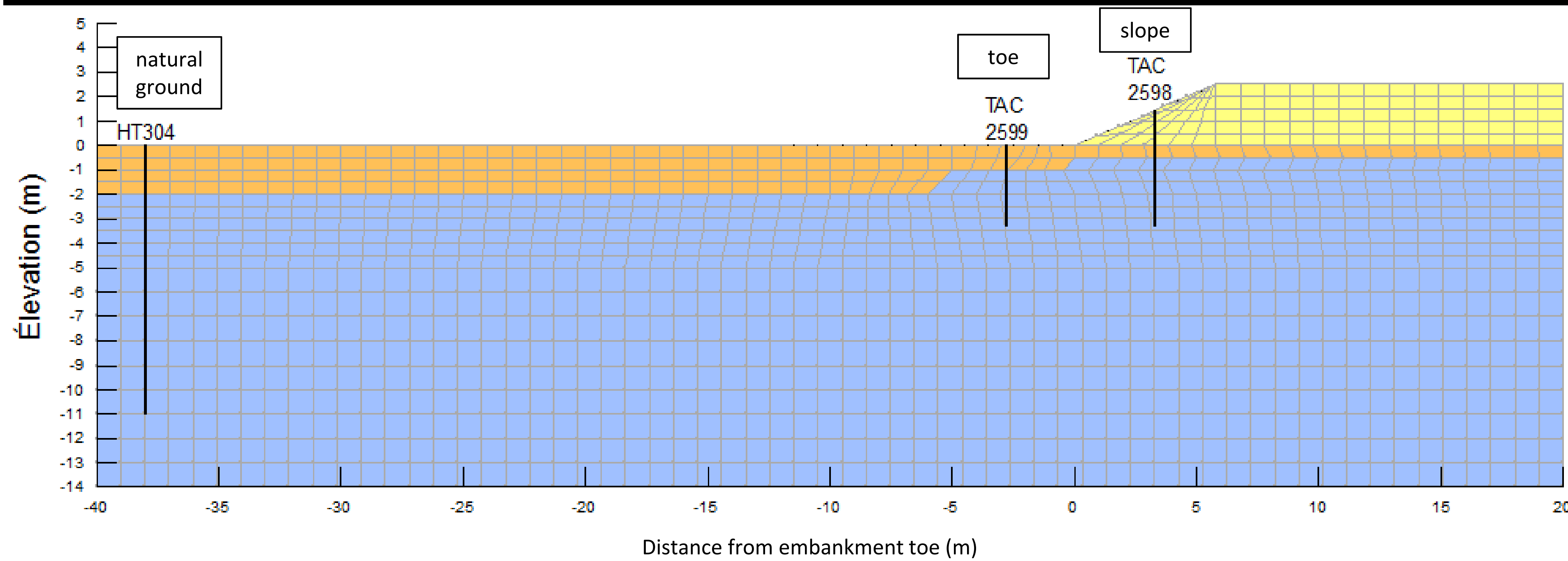
$n_f = T_{surface}/T_{air}$

Snow depth becomes an important factor when > 40 cm

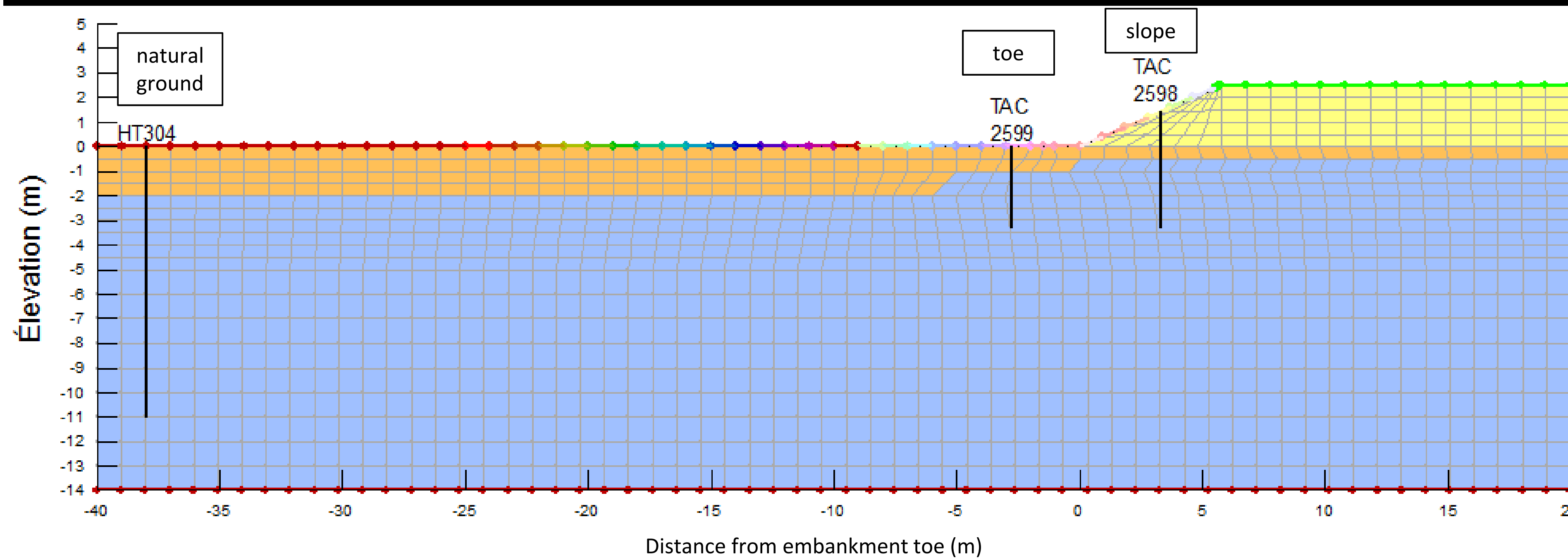
Logarithmic relationship between snow thickness and n factor at the slope/soil surface :

$$n_f = -0.204 \times \ln(z_s) + 1.142$$

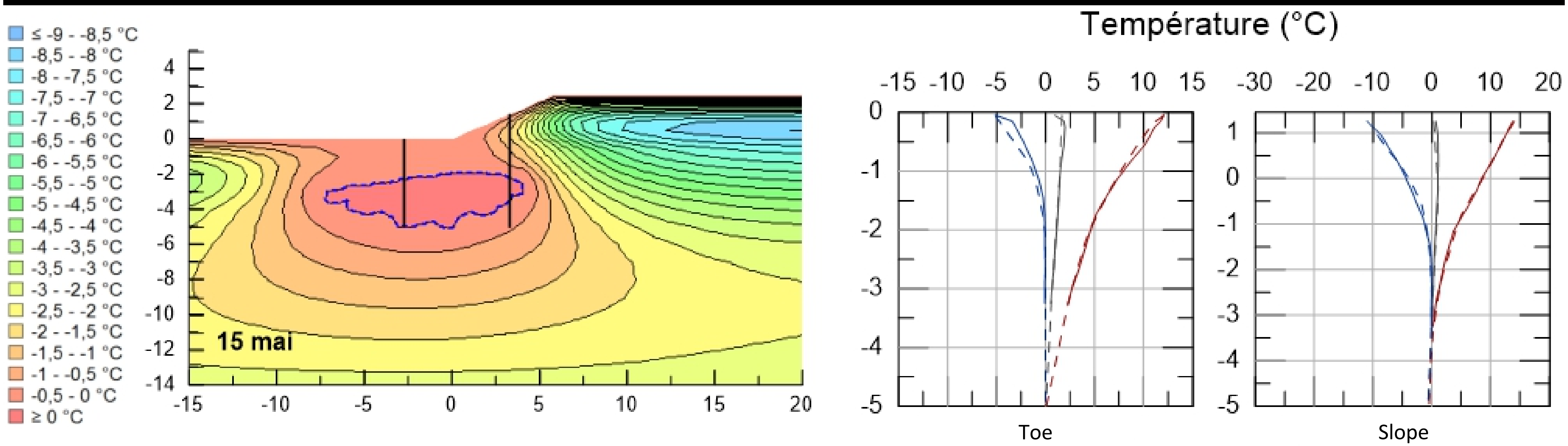
Geothermal model – Geometry



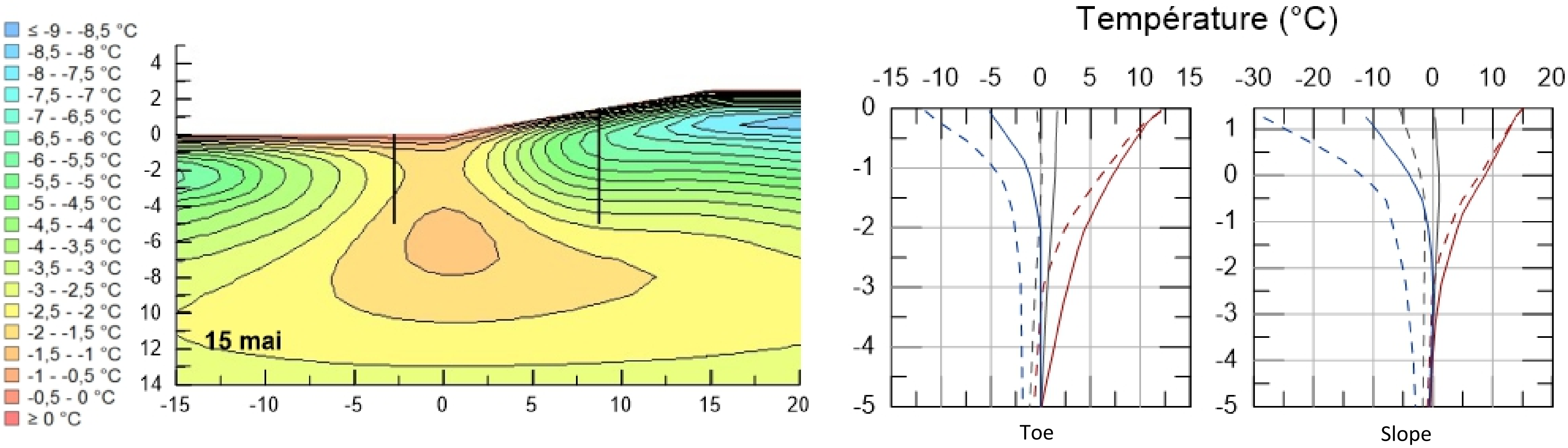
Geothermal model – Limit conditions



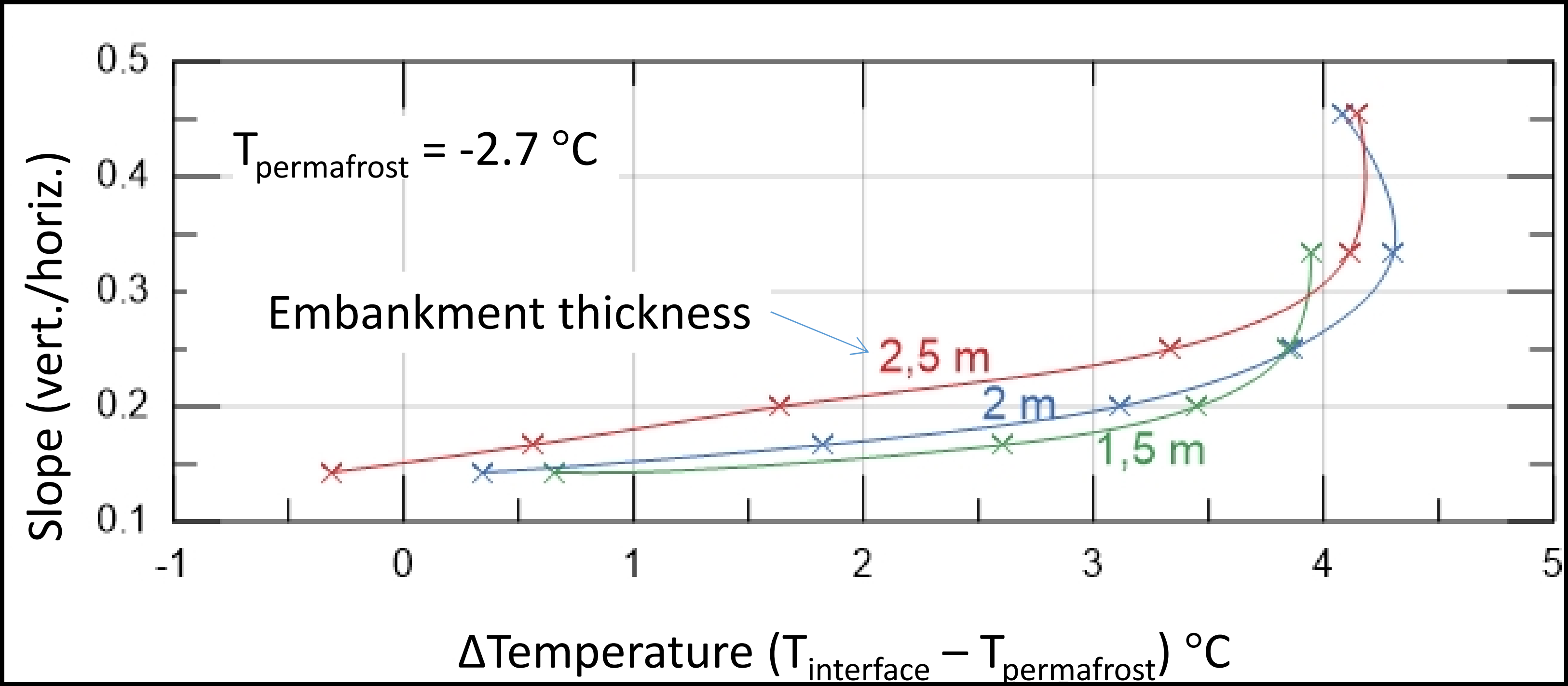
Geothermal model – Calibration



Geothermal modeled – Gentle slope



Design chart



non final chart

Conclusion

- The relationship between the n-factor and snow thickness can be represented using a logarithmic function.
- The design procedure is applicable for embankments where wind conditions and embankment alignment cause important snow accumulation.
- The thickness of the embankment needs to be considered in the design since gentle slopes are more effective for thick embankments.

Benefits

New design chart enables to mitigate the impact of snow accumulation (insulation) along embankments built on permafrost where wind and alignment are of concern.

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THANK YOU !

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