Effects of Snow and Surface Material on the Thermal Regime of Steep Slopes

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Motivation

Snow and soil are heterogeneous in mountain environments, impacting spatial distribution of permafrost on a very localized level. Other considerations for permafrost distribution in mountains include elevation, aspect, and slope. Additionally, Canada's western mountains range latitudinally, with strong differences in climate.

This poster presents some findings of the impacts ground and snow have on surface offset at different elevations, aspects, and slopes at three latitudinally-distinct sites in Western Canada (Fig 2.).

Figure 1: Joffre Peak, BC. Landslide occurred May 2019 on the north side of the slope. Heterogeneity of mountain environments can be seen, with bare rockfaces, snow, and vegetation (photo credit: Civil Engineering Canada)

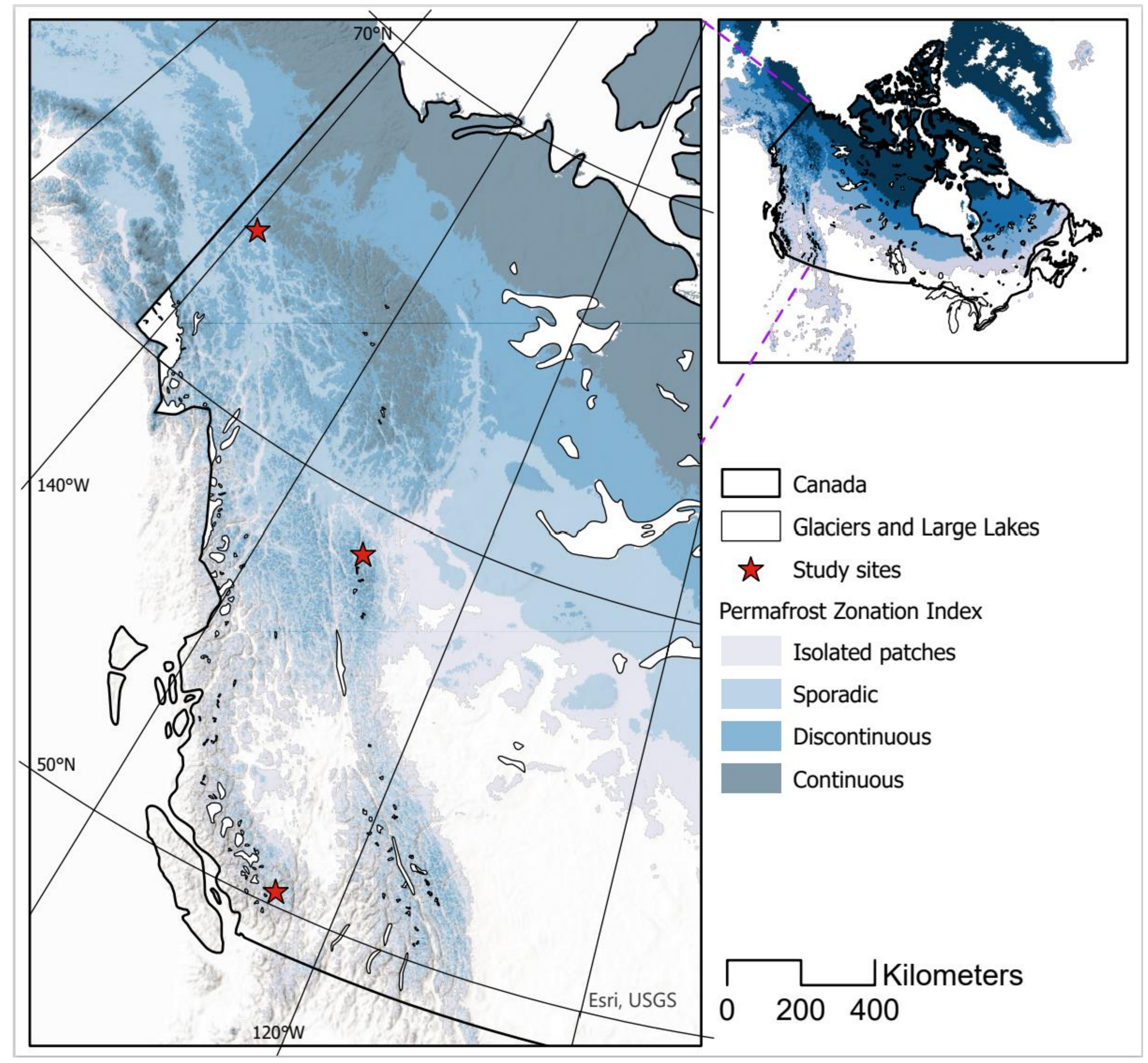

Figure 2: Study sites (South: Joffre Peak BC, Central: Toad River BC, North: Dawson City YT) where observational data is being collected. Permafrost Zonation Index[1] translated roughly to established zones.

Modelling

These simulations were run using GEOtop and ERA5 reanalysis climate data for Joffre Peak BC, Toad River BC, and Dawson City YT, over 40 years from 1980 to 2022. Temperatures were modelled at 10cm depth, representing ground surface temperature.

Modelling of snow variability and soil:

1. Snow of the same volume deposited on a horizontal and sloped surface will vary in thickness.
2. Additionally, snow does not adhere to steep slopes (>55°-60°)[2,3] and needs to be further reduced to parameterise avalanches and wind effects. Snow depth can be adjusted using a snow correction factor (SCF) (Fig 4).
3. High and low SCFs of 1.2 and 0.7 were also chosen to simulate cases of wind-distributed snow and avalanching.

Soil was modelled using a 10-cm layer of loam with a volumetric water content of 25%.

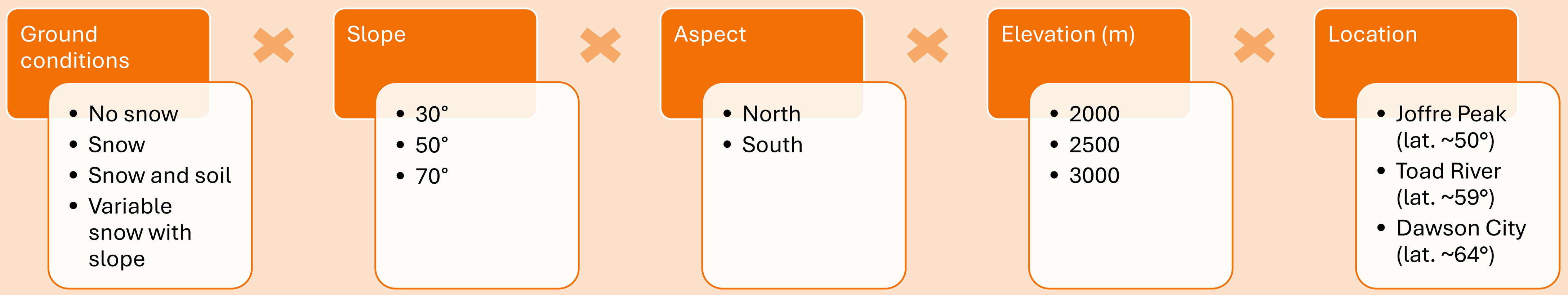

Figure 3: Five factors explore variability. For each factor, the different modelled conditions are shown.

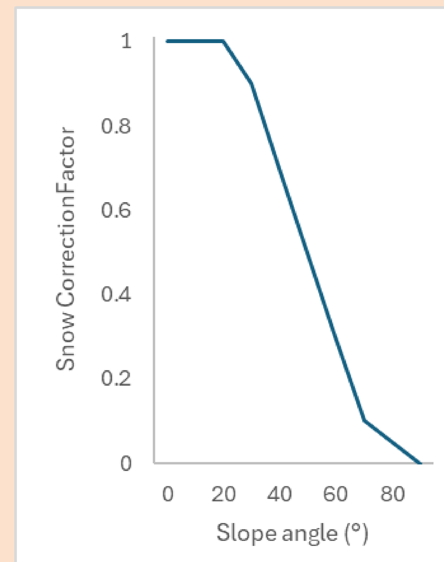

Figure 4: Snow correction are adjusted as a function of slope angle. Slopes between 30-80° are affected by the snow correction factor.[4]

Results

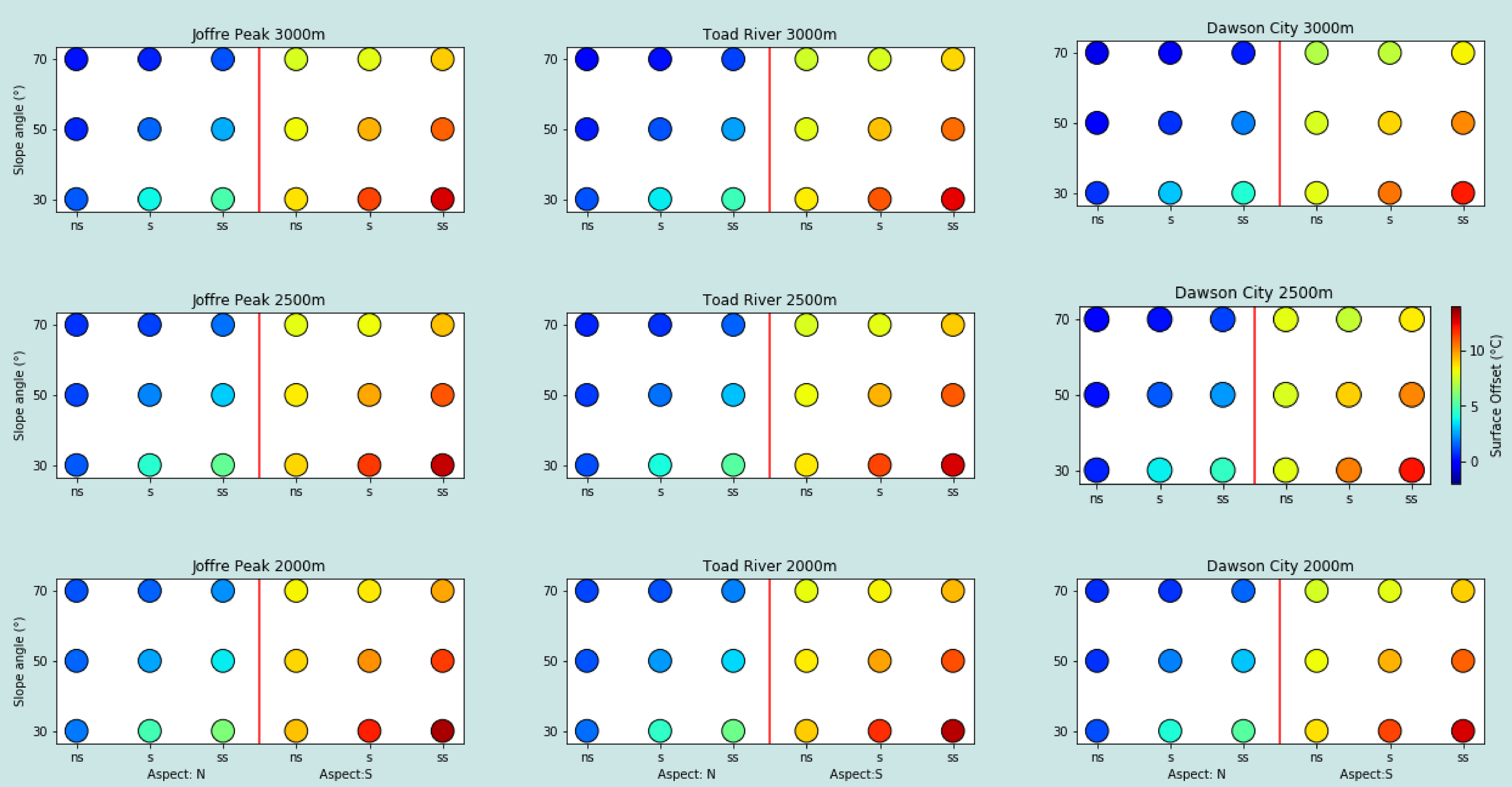

Figure 5: Surface offsets for 3 locations at 3 elevations, 3 slope angles, 2 aspects for conditions of no snow (ns), snow (s), and snow and soil (ss).

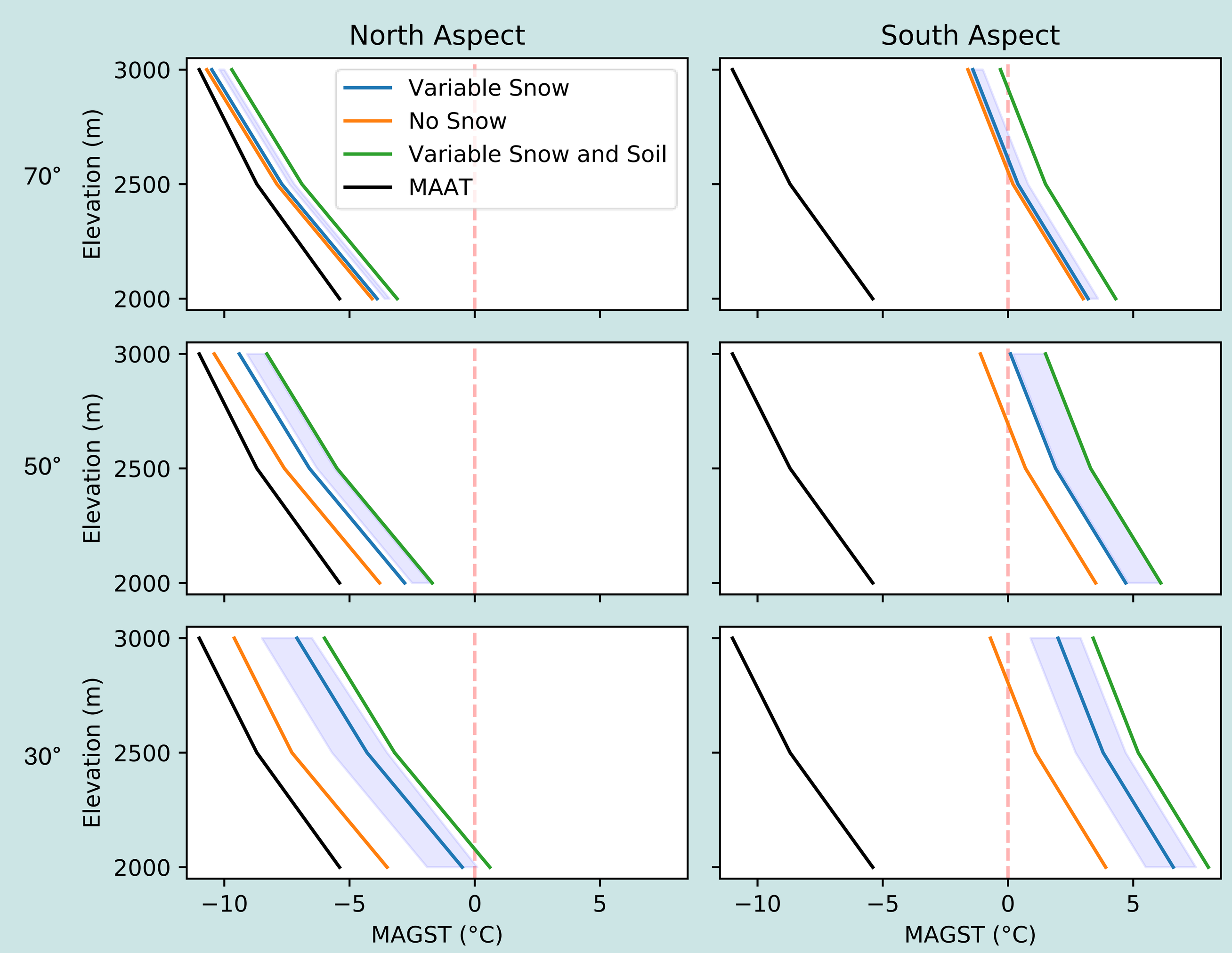

Figure 6: Mean Annual Ground Surface Temperature for different aspects, elevation, slope angles, and ground covers, simulated for Joffre Peak BC. Mean Annual Air Temperature (MAAT) is shown for reference. Blue regions represent the temperature spread between low and high SCFs.

Takeaways

- Surface Offsets (SO) are greatest on southern aspects, and smallest on northern aspects, with the largest SOs occurring at lower latitudes and where snow and soil are combined (Fig 5).
- Soil increases the warming effect of snow, even as a thin layer. In the absence of snow and soil, SO only decreases slightly with slope angle.
- On northern aspects SO decreases with increasing steepness and decreasing snow cover.
- With increasing slope angle and snow present, Mean Annual Ground Surface Temperature (MAGST) approaches Mean Annual Air Temperature (MAAT) lines in northern aspects (Fig 6).
- MAGSTs encompassed by the low and high SCFs center on variable snow MAGSTs at lower slope angles and move towards variable snow and soil cover with increasing slope angles. This shows how snow accumulating in concave sections of topography may impact the ground thermal regime.

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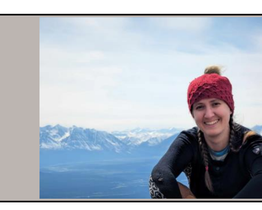

References and Acknowledgements

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4. Pogliotti, P., Influence of snow cover on MAGST over complex morphologies in mountain permafrost regions. PhD Thesis. 2011

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