Carleton University

Permafrost in rock walls of western Canada

PermafrostNet
NSERC | CRSNG

Presented by Emilie Stewart-Jones
Supervisor: Stephan Gruber

Introduction

Rising air temperatures cause the rock and ice filling its cracks and crevices to warm, **rendering some rock walls unstable**. When they fail, thousands or millions of cubic metres of rock can slide down the mountain, posing a risk to infrastructure, wildlife habitats and human life.

To assess the potential **hazard of rock falls** in an area, we need to know where permafrost exists and how it is changing, something that is unknown for the greater part of the mountainous regions of western Canada.

The presence of permafrost depends on topography and climate which dictate the amount of solar radiation received. This relationship between permafrost and its environment is normally evaluated with **rock temperature measurements**.

Due to difficult access and high expense, there are few such observations in rock walls of permafrost environements of western Canada, making it difficult to detect patterns in this highly variable environment.

The study presented here makes use of **modelling,** as it allows us to surpass these difficulties by extrapolating observations to a larger spatial and temporal context.

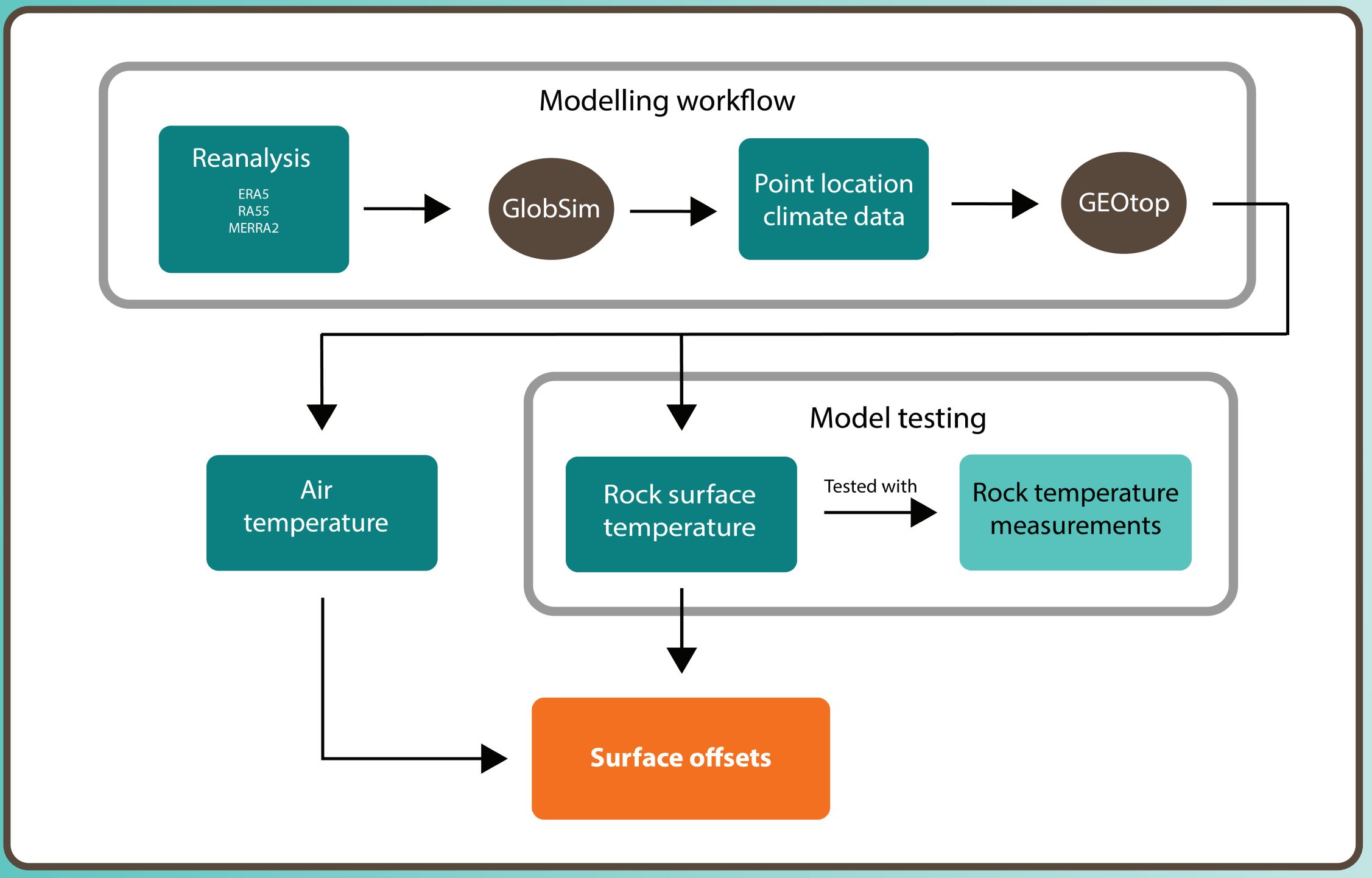
Methods

① First, investigate the differences between mountainous permafrost regions of western Canada and those in Scandinavia and Europe by conducting a spatial analysis of various climate variables.

② Next, the modelling workflow used to simulate rock wall temperatures is tested with rock wall temperature observations from BC and Yukon to assess accuracy and plausibility of predictions.

③ Finally, model simulations are run to investigate the effects of topography on SOs in areas with different latitudes and continentality within permafrost regions of western Canada.

Climate reanalysis data is downscaled to point location using the software Globsim. Rock surface temperatures are modelled using the physically-based model GEOtop, forced with the reanalysis data.


Modelling workflow

Reanalysis (ERA5, RA55, MERRA2) → GlobSim → Point location climate data → GEOtop → Air temperature; Rock surface temperature

Model testing

Rock surface temperature — Tested with → Rock temperature measurements

Air temperature → Surface offsets

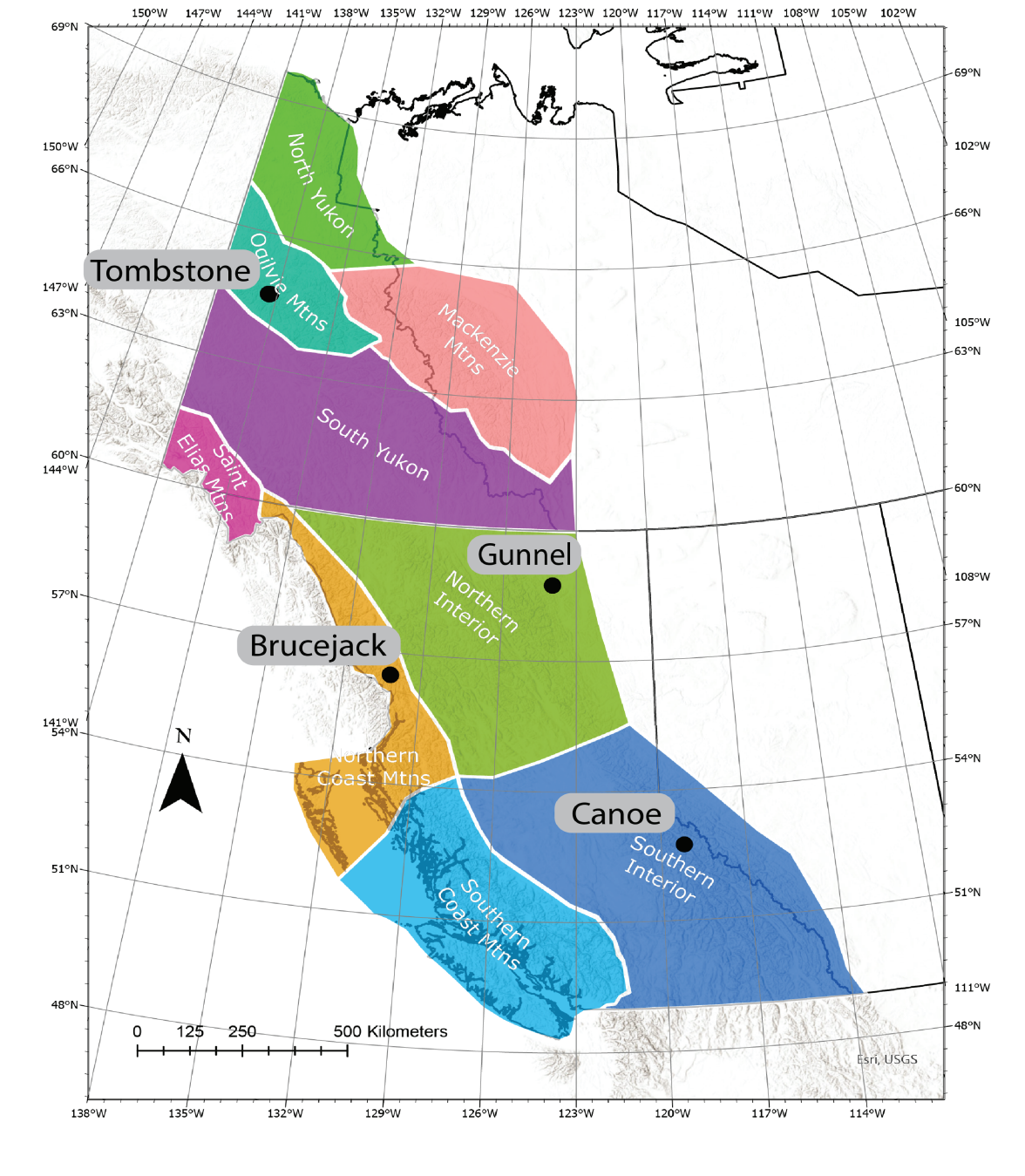
Rock surface temperature → Surface offsets

Study region

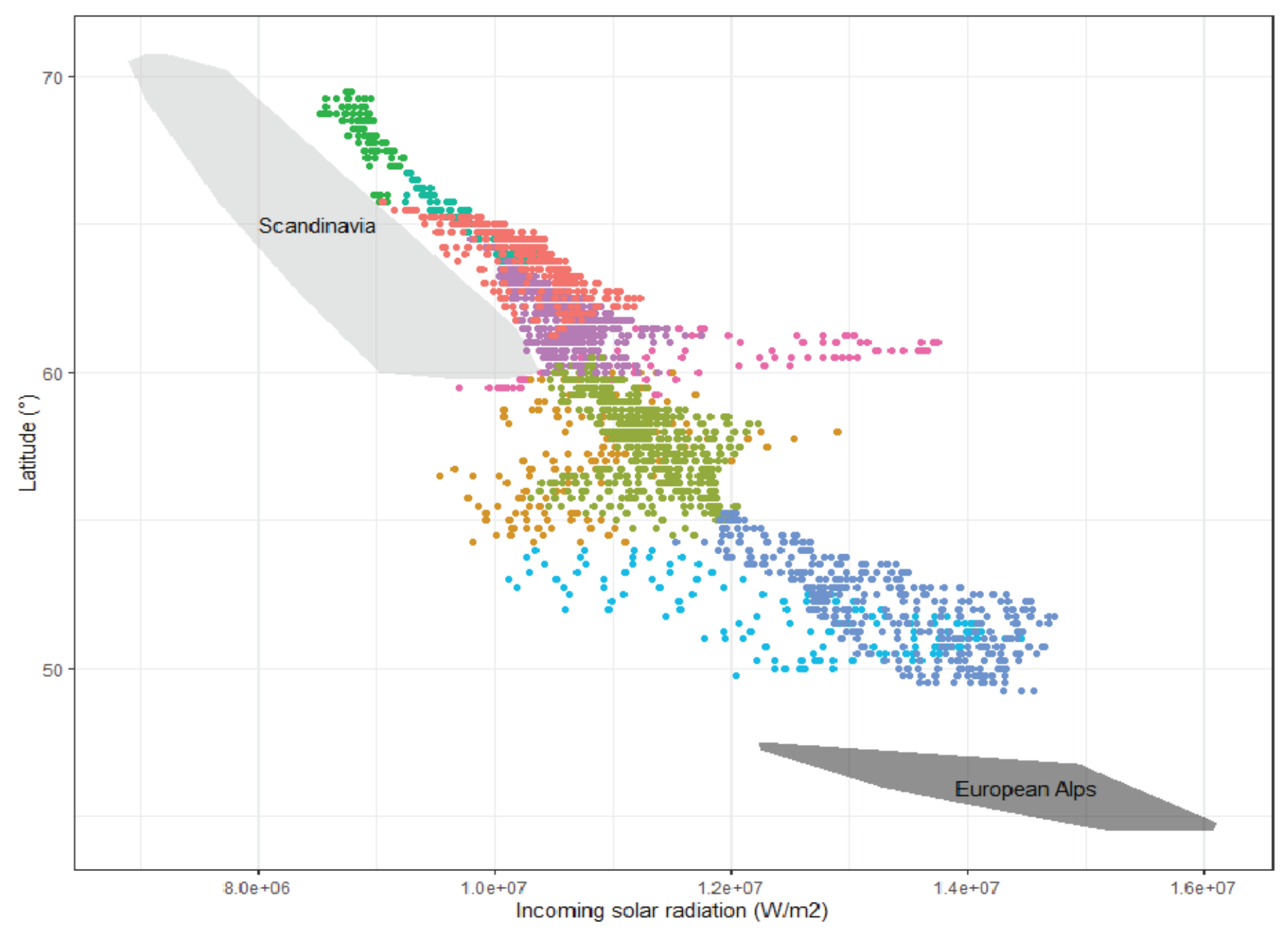
The study area is subdivided into **9 sub-regions** based on topo-climatic conditions

Climate in these sub-regions is compared with Scandinavian and European mountain permafrost regions.

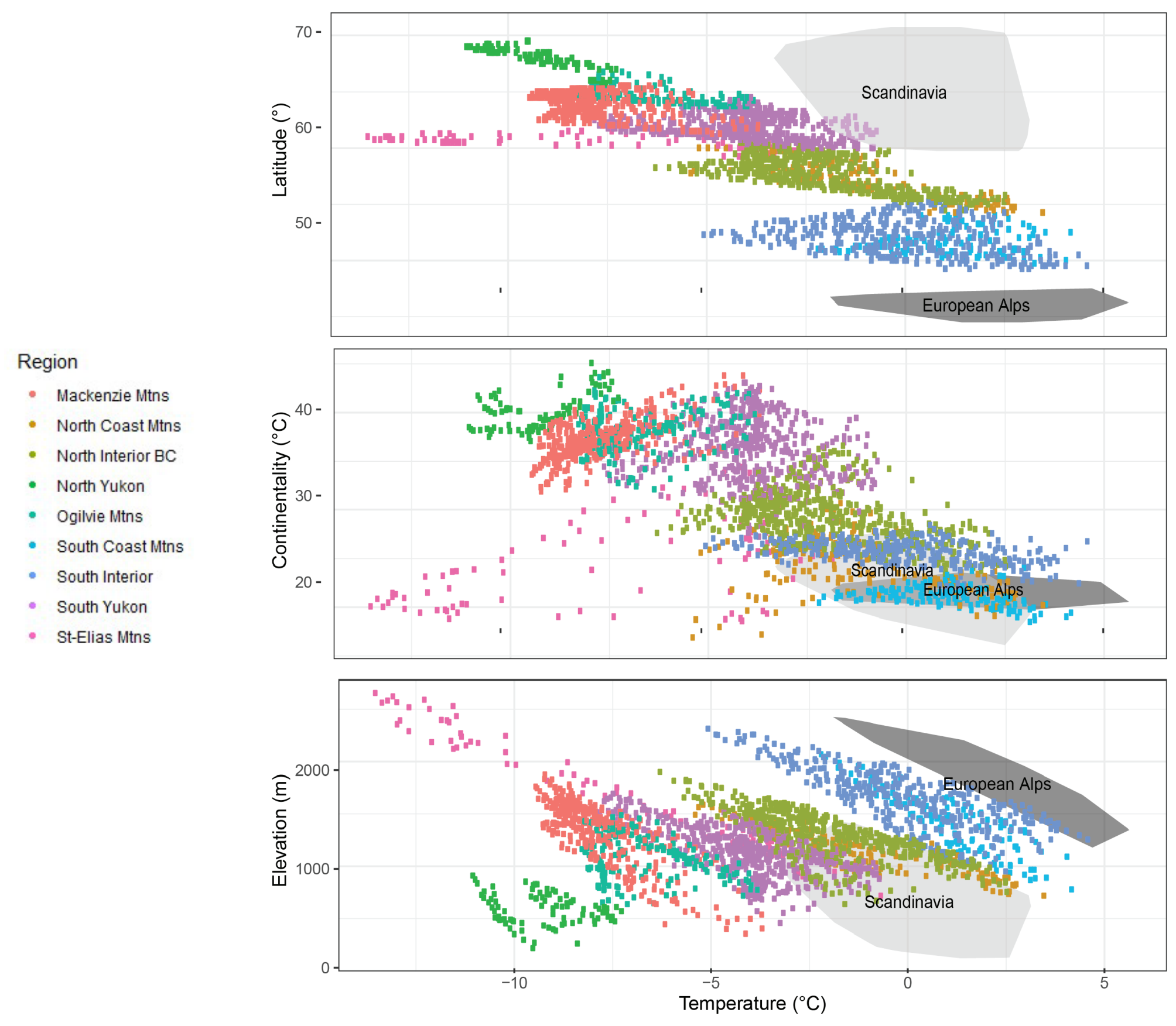
The model is evaluated with observations from four locations: Tombstone, Mount Gunnel, Brucejack mine, and Canoe Mountain.



1 What are the differences between permafrost regions in the mountains of Europe, Scandinavia and western Canada?



Incoming solar radiation affects surface offsets and the difference in temperature between north and south facing rock walls.

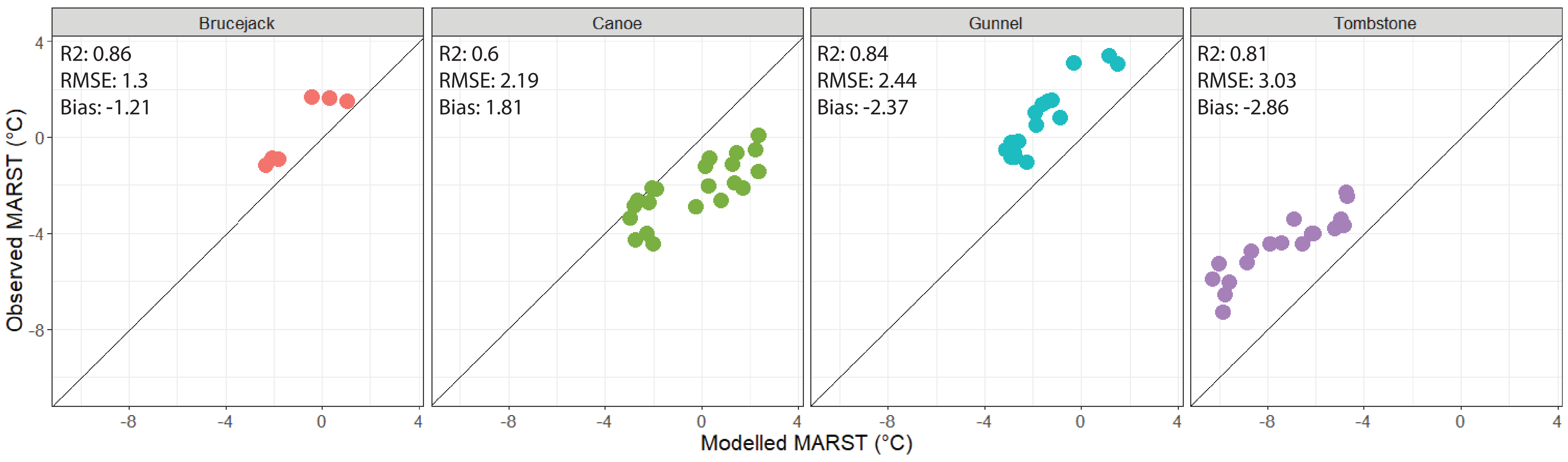


Air temperature (along with incoming solar radiation) affect MARST

Resulting hypotheses

1. Areas of southern BC and Alberta (South Interior and Southern Coast Mtns) have similar MARST to the Alps because of overlapping radiation and air temperature.
2. The most northern regions (North Yukon, Ogilvie Mtns) and coastal regions (Northern Coast Mtns) of western Canada have similar north-south MARST differences (1.5 – 3.5 °C) and SOs to the Scandes because of overlapping radiation.
3. Southern Interior BC and Alberta and parts of the Southern Coast Mtns regions have similar north-south MARST differences (7 – 8 °C) and SOs to the Alps because of overlapping radiation.
4. In western Canadian regions north of 60° N and parts of Northern BC, the effect of altitude on MARST is less than the Scandes and Alps because of greater continentality.

2 How strong are the model predictive capabilities?



Observed versus modelled MARST for each of the four testing locations. Every point represents an average of the three reanalyses for a single site and year.

Interpretation

1. Within a single model testing location, there are strong correlations between modelled and observed MARST (R2). This strong relationship demonstrates that the model is capable of simulating fine-scale variability, that is, how the local conditions alter the effect of the climate forcing. This study is focused on surface offsets, which are a measurement of the effect of local conditions on rock temperatures. As such, the modelling workflow is well suited for generating surface offsets.
2. The bias between the modelled and oberved MARST indicates that the modelling workflow does not accurately predict MARST. This points to a systematic bias dependant on location. A possible explanation are the known biasses in climate reanalysis data.

Next steps

③ Apply model to a location in every western Canadian sub-region, with three different climate forcings (reanalyses) and varying topography.

9 locations X 3 reanalyses X 3 slope angles X 10 elevations X 4 aspects

Definitions

Surface offsets (SO): The difference between the mean annual air temperature and the mean annual ground surface temperature.
Continentality: Increases with distance from the ocean or large bodies of water. Here it is expressed as the annual amplitude in air temperature.
MARST: Mean annual rock surface temperature.

Digital Research Alliance of Canada | Alliance de recherche numérique du Canada

Acknowledgements:
- Nick Brown (technincal support)
- Marten Geertsema (advisory committee)
- Compute Ontario (www.computeontario.ca/)
- westgrid (www.westgrid.ca)
- Digital Research Alliance of Canada (alliancecan.ca)
- Carleton Permafrost lab group

Contact:
Emilie Stewart-Jones
Carleton University
emiliestewartjones@cmail.carleton.ca