Ranking ground surface temperature simulations in the Northwest Territories tundra.

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INRODUCTION / BACKGROUND

Modelling can be used to predict ground temperatures at different points in time, given known surface conditions. Models differ in their bias and performance at the same location due to the way they choose to represent physical phenomena. So, how can we establish which models or datasets are best at representing locations of interest? Consistency in implementing and reporting model evaluation allows for a well-defined measure of improvement. The focus of this project is to develop a quantitative approach to model evaluation that allows for meaningful interpretation of summary statistics across a range of spatial and temporal testing conditions.

The scope of this project is constrained to one permafrost variable: **ground surface temperature (GST)** at roughly 10 cm depth. Temperature is the sole criteria permafrost is defined by, making it of particular interest when modelling the subsurface periglacial environment.

METHODOLOGY

Simulations This project will involve two permafrost models, GEOtop[2] and CLASSIC each forced with JRA55, MERRA-2, and ERA5 reanalysis data.

Observations Observational ground temperature data from the NWT is collected from Carleton permafrost database (COLDASS) and NSERC PermafrostNet ERDDAP.

Accomatic The python package used to partition simulation and observational datasets and produce a suite of summary statistics used to generate model rankings is called **accomatic**[3]. Each simulation will be tested against a range of accordance measures, then split by season and terrain type. The resulting multi-variate summary statistics table is used to establish model rankings.

STUDY SITES

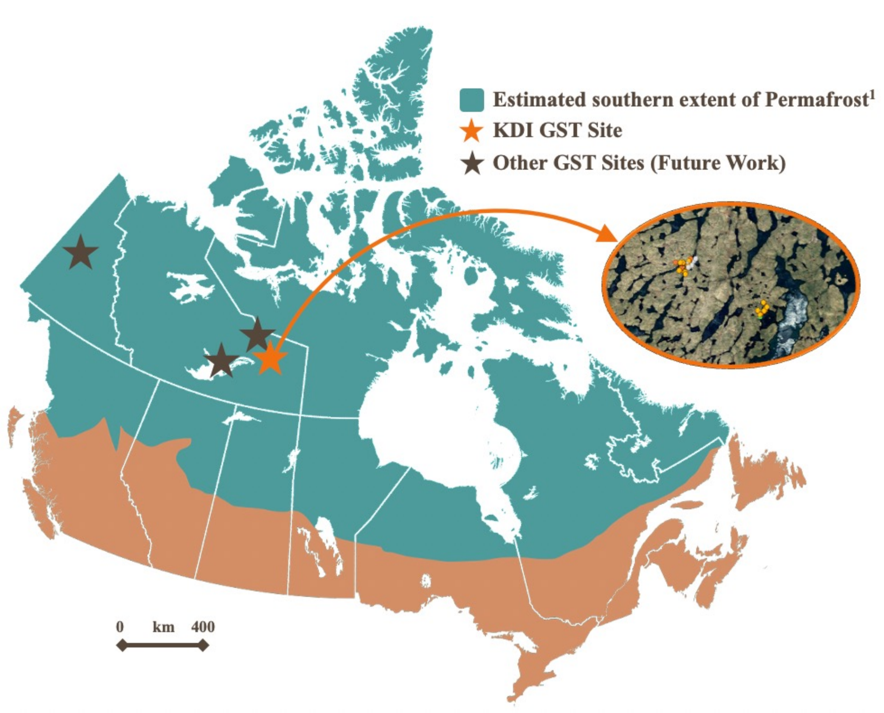


Figure 1: Ground Surface Temperature Clusters across Canada

GROUND SURFACE TEMPERATURE (GST)

GST is measured roughly 10 cm below the ground surface. This variable is representative the difference between air temperature at the surface and the temperature of the ground. It allows us to understand the insulating (or, conductive) properties of things like surface albedo, snow cover and vegetation.

Mini loggers that are used to measure GST.

Relative to other permafrost variables (active layer thickness, depth of permafrost, etc.) GST is inexpensive to measure**.** This variable is highly representative of the underlying thermal regime, and there are tons of accessible GST datasets across Canada to be used for model validation.

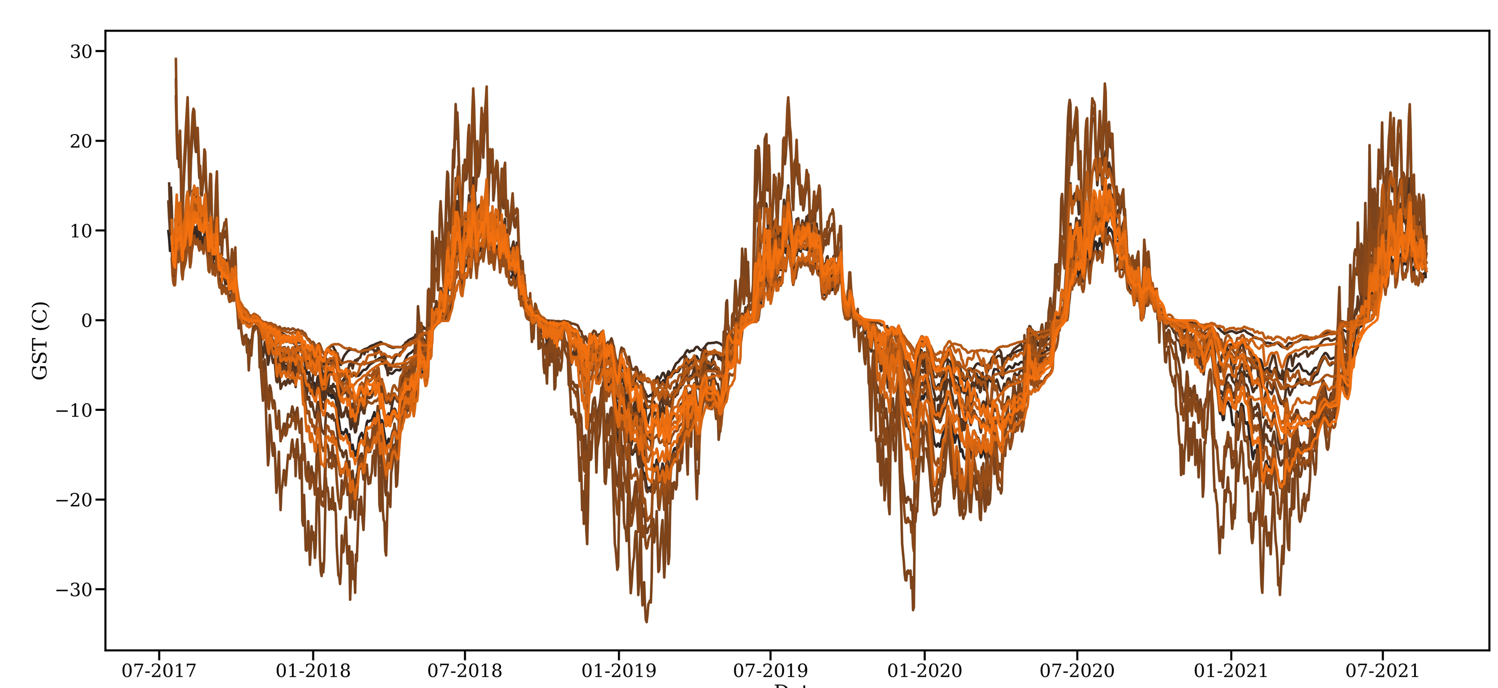
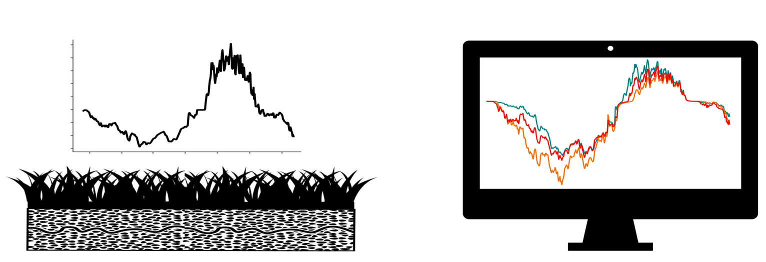


Figure 2: Ground Surface Temperature at 23 GST Sites in KDI

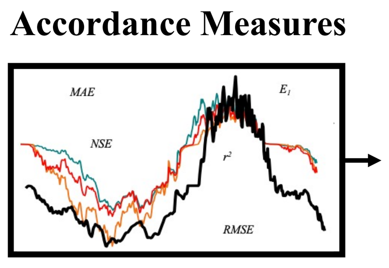
TESTING CONDITIONS



Observations

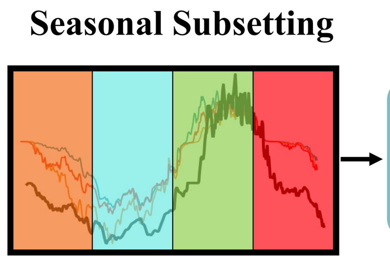
Simulations

Accordance Measures



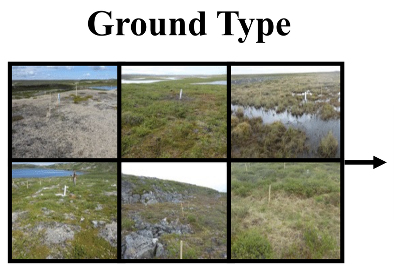
Measure how models perform across a range of **accordance statistics.**

Seasonal Subsetting



Measure how **seasonality** influences model performance.

Ground Type



Evaluate how models perform in **different terrains.**

PARAMATERIZING TERRAIN TYPES IN GEOTOP

One of the most challenging aspects of environmental simulation work, is **parameterizing** models. That is, developing numerical values to represent real life phenomena. When modelling GST, important characteristics to represent include:

(1) Topography

(2) Ground type *i.e.* subsurface materials and processes

(3) Surface vegetation

Ground type will dictate thermal properties of the ground such as thermal capacity or conductivity in both unfrozen and frozen states. Figure 3 shows five simulations run for the same site. Assigning different ground material (clay, peat, *etc.*) can drastically influence how GST is predicted.

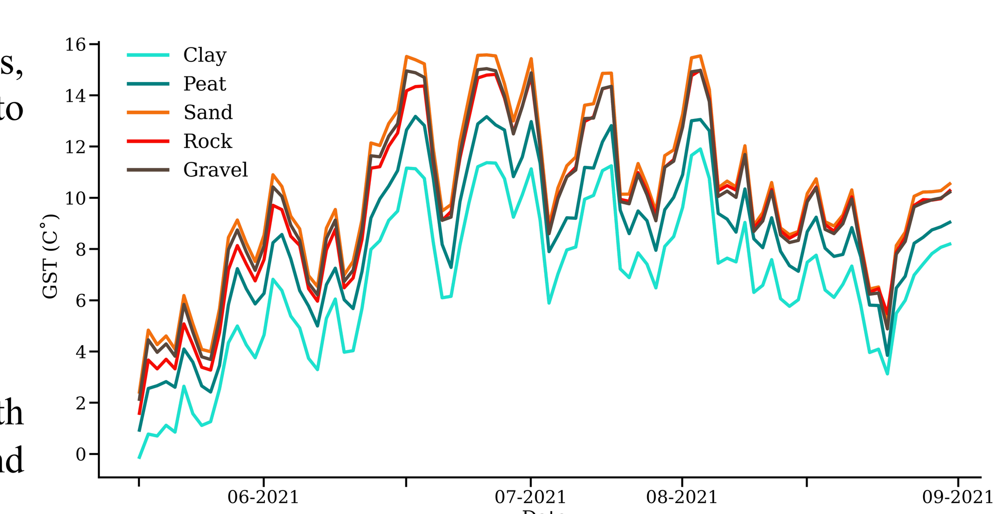


Figure 3: Different terrain types influencing simulation output.

MODEL RANKING

Simulations are ranked 1st, 2nd, and 3rd based on root-mean-square-error (*RMSE*), mean-absolute-error (*MAE*) and coefficient of determination (r^2) values. These three accordance measures are a small subset of statistical measures that will be used in future work. As we can see in Figure 4, the overall rankings for ERA5, MERRA and JRA-55 driven models are consistent across all three accordance measures.

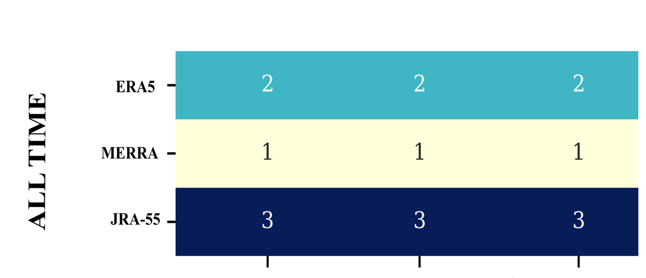


Figure 4: Rankings of three model configurations for GST temperatures at KDI (n = 23).

Model rankings begin to shift after seasonal subsetting. Figure 5 shows that while GST simulated in the Summer months (JJA) perform best when forced with ERA5 data, this model pairing performs poorest in the Spring.

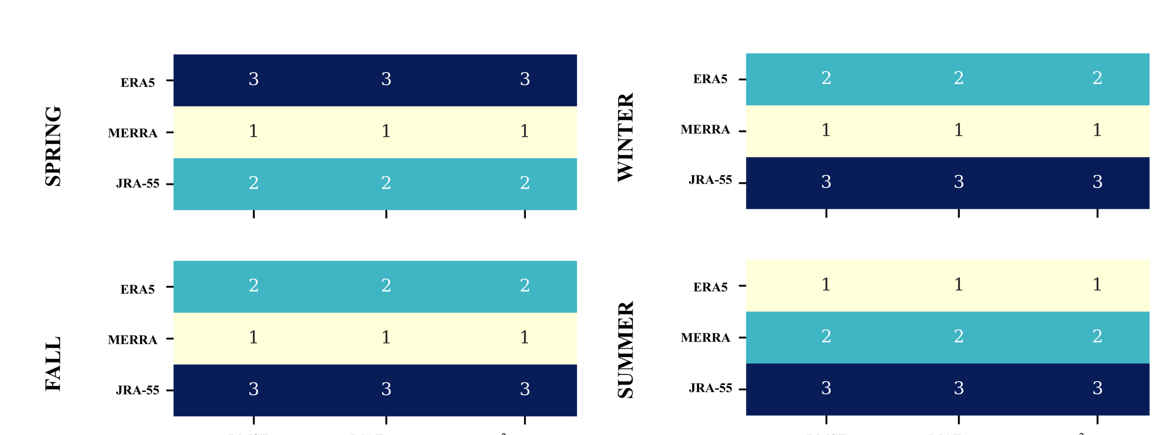


Figure 5: Rankings of three model configurations for GST temperatures at KDI (n = 23), subset by seasons: (DJF, MAM, JJA, SON)

SUMARY / NEXT STEPS

Key Findings Overall, the **best performing model** was the MERRA-2 forced GEOtop pairing. In addition to ranking first for each accordance measure, these simulations also consistently ranked first across Fall, Spring and Winter seasons. JRA-55 forced GEOtop simulations **ranked lowest** apart from Spring months (MAM). An analysis of terrain type subsetting did not produce meaningful results, likely due to the insufficient number of sites (and subsequently, terrain types)

Future Work This poster summarizes the findings of only the first iteration of using *accomatic* to evaluate model simulations and uses only a small subset of GST data. Future work includes:

1. Larger amount of GST data to allow for meaningful terrain type analysis (shown in "Study Sites" figure).
2. More rigorous parameterization of individual sites in GEOtop.
3. Addition of CLASSIC model, driven by all three reanalysis datasets.
4. More in depth description of terrain type subsetting and classification metrics.
5. Additional analysis of seasonality (How do we define a season?)

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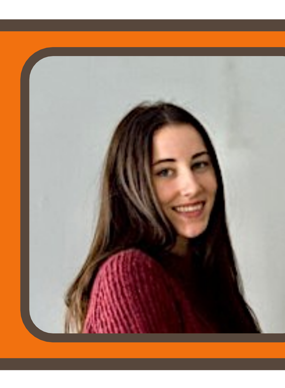

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