A Characterization of Point-Scale CTSM Performance in the Canadian Arctic

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Introduction & Context

The Arctic has warmed at roughly three times the global average rate since 1979, driving changes in snow cover, permafrost, and terrestrial water storage (TWS). Predicting how the Arctic land surface will continue to respond requires land surface models that can accurately represent frozen-ground and snow processes. This project is currently evaluating how well the Community Terrestrial Systems Model (CTSM), reproduces observed snow, soil moisture, and soil temperature behaviour at a number of Canadian Arctic sites using a collection of reanalysis and observational datasets.

Study Sites & Current CTSM Configuration

Compset: IHistClm50Sp, 1995–2014 historical run
Land cover: Satellite phenology (prescribed plant functional types)
Forcing: GSWP3 reanalysis-derived, 3-hourly

Table 1. Observational sites selected for comparison.

Site Name (Abbrev.)	Latitude	Longitude	Elevation (m)	Permafrost
Iqaluit Tundra (IT)	63.75	-68.43	197	Continuous
Trail Valley Creek (TVC)	68.75	-133.50	85	Continuous
Havikpak Creek (HC)	68.32	-133.52	80	Continuous
Smith Creek (SC)	63.15	-123.25	150	Discontinuous
Baker Creek (BC)	62.72	-114.57	266	Discontinuous

Sites were chosen primarily on data availability as observational records are notoriously sparse in the Arctic. Sites still aim to span a range of vegetation cover, longitude, and permafrost zone.

Figure 1. Map of sites across the Canadian arctic. Green stars indicate discontinuous permafrost and purple indicates continuous permafrost.

Results: Snow Depth

Observed snow depths exceed the physically expected range (e.g. >1 m in summer), likely reflecting sensor error rather than true accumulation. Because of this ERA5 data is included to validate the model. CTSM systematically underestimates snow depth when compared to ERA5 (e.g. Trail Valley Creek, Fig. 2).

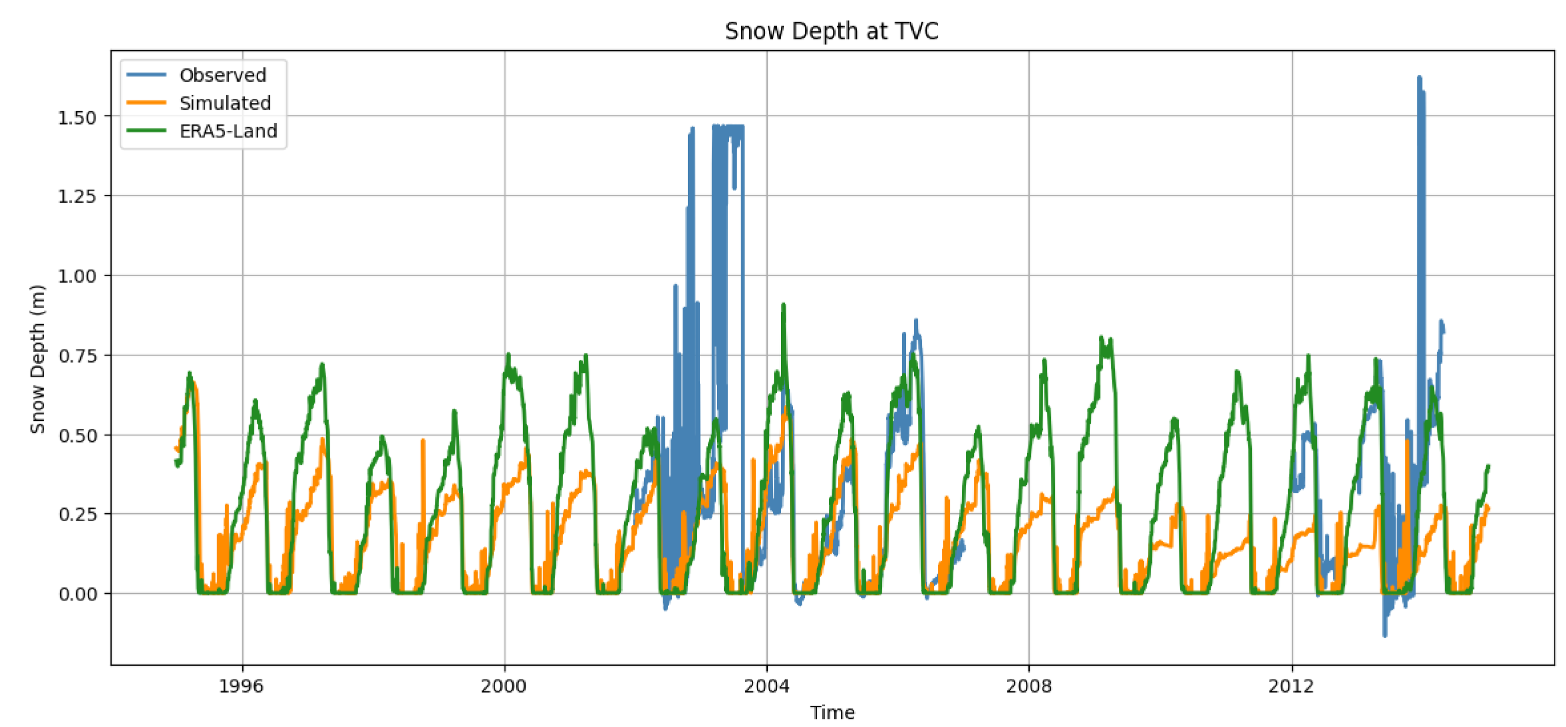

Figure 2. Observed vs. ERA5 vs. CTSM snow depth at Trail Valley Creek. Colours distinguish different data sources.

Results: Soil Moisture

Observed soil moisture data averaged over months appears to be almost anti-correlated. Substantial RMSE differences exist between Winter/Spring and Fall/Summer data, likely implying that observational data is again error prone due to freezing soil temperatures.

	Full Year	Fall	Winter	Spring	Summer
RMSE	0.508	0.362	0.620	0.634	0.288

When examining the time series data, the observational soil moisture drops close to zero, which further supports this claim if the soil moisture sensor cannot read moisture in frozen soil.

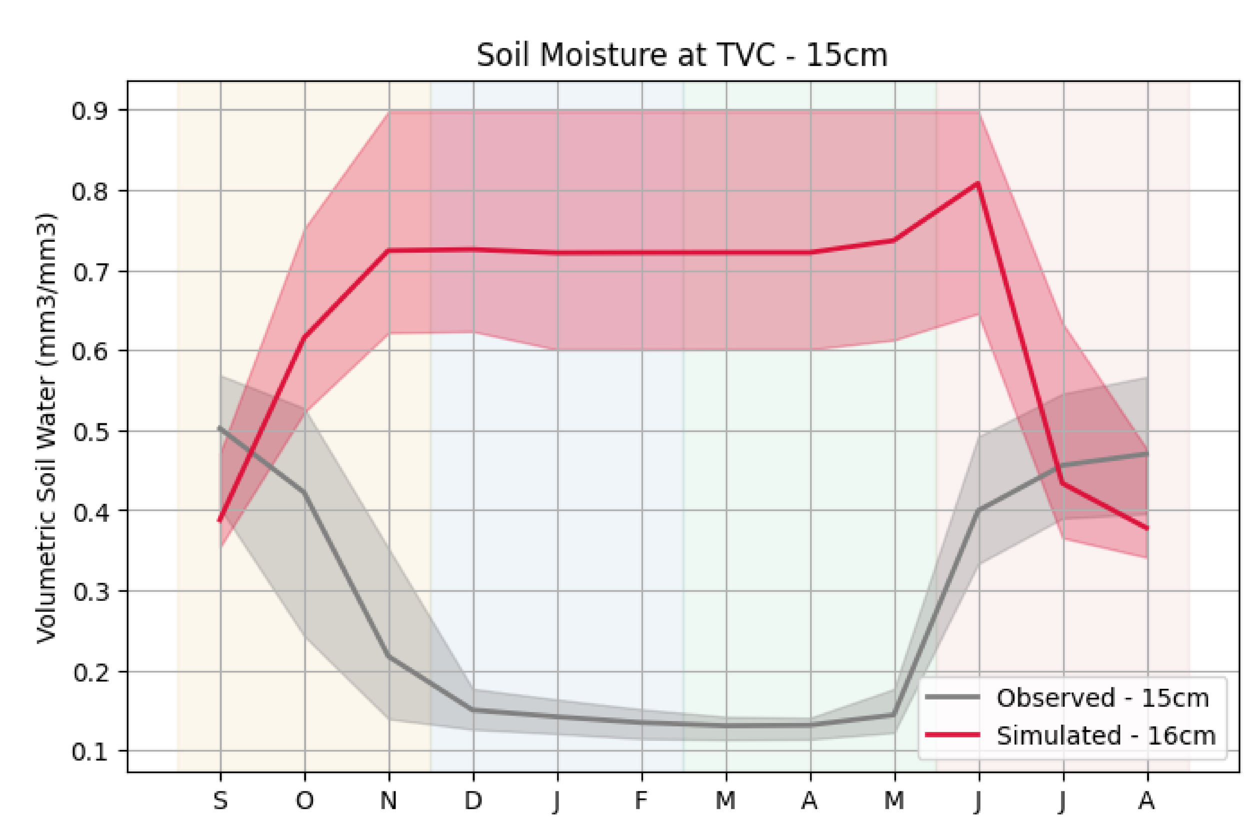

Figure 3. Seasonal soil moisture plot at Trail Valley Creek. Observational data is taken at 15cm and CTSM simulates a depth of 16cm.

Results: Soil Temperature

Soil temperature shows the strongest model to observation agreement (Fig. 4). Qualitatively the trend-line of simulation vs observational data seems much more agreeable.

	Full Year	Fall	Winter	Spring	Summer
RMSE	7.401	5.290	11.272	6.857	3.208

RMSE still appears to be higher in Winter/Spring. In combination with soil moisture RMSE, further scrutiny of how CTSM's freezing and thawing times could be warranted.

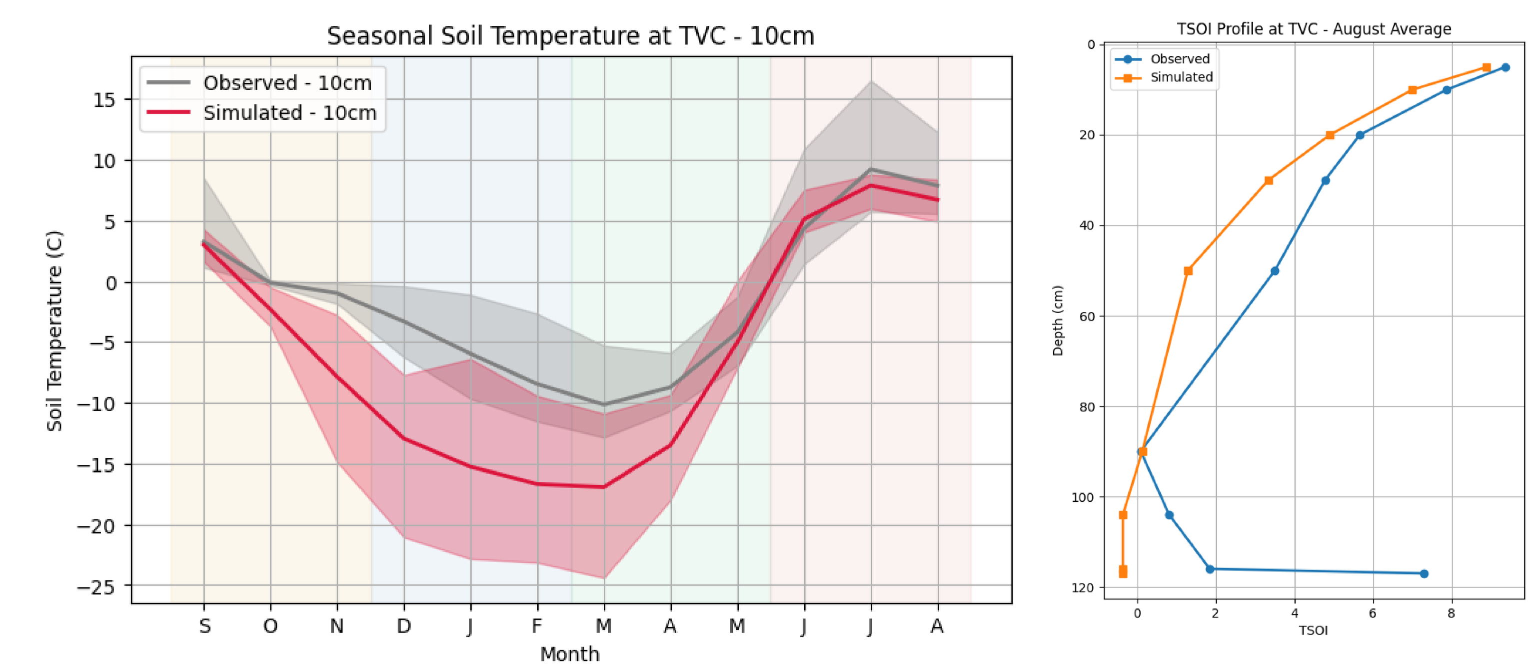

Figure 4. Seasonal average of soil temperature at Trail Valley Creek for 10cm depth.

Conclusions & Next Steps

Initial CTSM runs show promise in soil temperature simulation. Issues currently arise in validation of soil moisture due to likely-unreliable frozen-season observations. Reliance of internal group data products like bias corrected soil moisture values will likely be necessary for full validation. Future work also includes:

- Examining more variables such as vegetation cover and other related values.
- Use of different resolutions of CTSM runs such as 1km.
- Extending simulation time scale for more site validation (i.e. 2015-Present Day);
- Using other data products for further evaluation (bias corrected soil moisture/temperature values, GRACE TWS, and other satellite data products);

References

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