Ensemble modelling as a step towards permafrost climate services

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Context

Permafrost thaw describes the progression of ice loss in the ground, commonly as a result of rising air temperatures. Ice loss in the ground impacts permafrost landscapes by causing ground subsidence, along with changes in hydrology and biogeochemistry.
In response to a rapidly changing climate, the impacts of permafrost thaw will intensify, putting infrastructure, communities, and ecosystems at risk. To address these risks, permafrost climate services are needed – permafrost information that supports decisions for adaptation to future permafrost thaw.

Objectives

The goal of my research is to develop a prototype for a simulation-based component of permafrost climate services. This component aims to complement the observation-based component of a climate service by

- Generating data for locations and times at which no observations are available,
- Simulating metrics that are hard to measure in the field, and
- Capturing and propagating uncertainties related to imperfect representation of ground conditions and uncertainties in driving climate.

Methodology

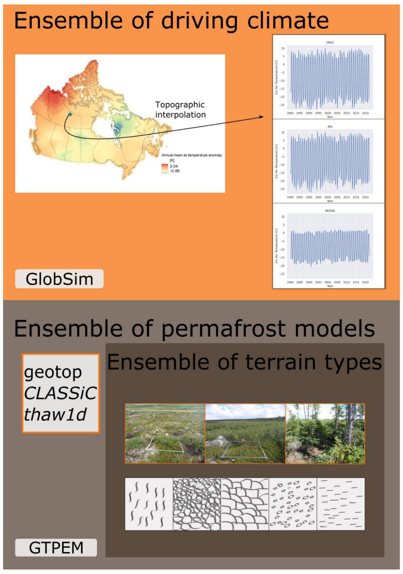

Figure 1: Simulation methodology; an ensemble of permafrost models is driven with an ensemble of terrain type descriptions (vegetation, subsurface characteristics) using the *GTPEM* toolbox and ensembles of driving climate, derived with *GlobSim*

Metrics

and why they are relevant

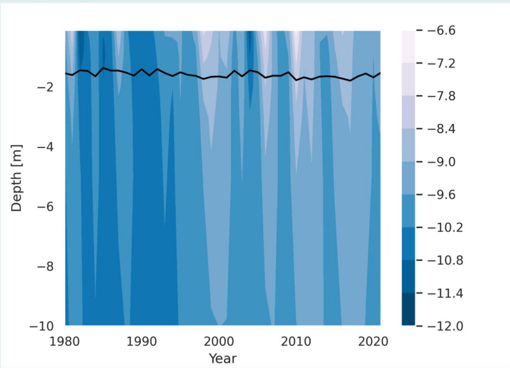

Figure 2: Ensemble means of annual mean ground temperature and active layer thickness at one site

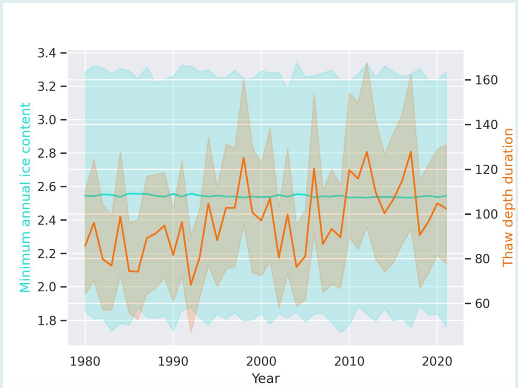

Figure 3: Ensemble means and (25,75) percentiles of annual minimum ice content and thaw depth duration

Ground Temperature – standard metric for monitoring the annual and long-term thermal state of the soil column, also identified as Essential Climate Variable

Active Layer Thickness – a thickening active layer is a sign for permafrost degradation whereas thinning of the active layer is a sign for permafrost aggradation, identified as Essential Climate Variable

Ice Content – characterizes permafrost thaw when it reaches a minimum after the summer thaw; indicator for stability of the ground and the hydrological impact of permafrost warming

Annual thaw depth duration – soil in the soil column warmer than 0°C, integrated over both depth and time; indicator for susceptibility to landslides and degradation of organic material

Conclusions

1. Ensemble simulations are capable of capturing, quantifying, and propagating uncertainties in driving climate and ground conditions

2. As different metrics are relevant for a different use cases (e.g., terrain type and time scale), a suite of metrics must be simulated

3. Magnitudes of change (anomalies) aid the identification of trends and regions susceptible to (future) thaw

Next steps

Identification and parameterization of suitable terrain types, including vegetation

Extension of timescales to include future climate scenarios (via de-biased climate models)

Improvement of ensemble output by comparison with field observations

References

Cao, Bin et al. 2019. “GlobSim (v1.0): Deriving Meteorological Time Series for Point Locations from Multiple Global Reanalyses.” Geoscientific Model Development 12(11): 4661–79.

Harp, D. R. et al.: Effect of soil property uncertainties on permafrost thaw projections: A calibration-constrained analysis, Cryosphere, 10, 341–358, doi:10.5194/ tc-10-341-2016, 2016.

GTPEM,Grid Toolkit for Permafrost Ensemble Modelling, https://gitlab.com/permafrostnet/gtpem

Acknowledgements

- Nick Brown, (PermafrostNet): GTPEM, GlobSim, and overall technical support
- Hannah Macdonell, GlobSim support
- Permafrost lab group at CarletonU, general support
- Digital Research Alliance of Canada, providing access to supercomputer
- westgrid, providing cloud virtual machine through a research platforms and portals grant (RPP)

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