UNIVERSITY OF SASKATCHEWAN
Global Water Futures
GLOBAL INSTITUTE FOR WATER SECURITY
GWF.USASK.CA

CANADA FIRST RESEARCH EXCELLENCE FUND | APOGÉE CANADA FONDS D'EXCELLENCE EN RECHERCHE

Hydrologic-land surface modelling of the Canadian sporadic-discontinuous permafrost: initialization and uncertainty quantification

Mohamed S. Abdelhamed[1,2,*] , Mohamed E. Elshamy[1], Howard S. Wheater[1,2,3] , Saman Razavi[1,2,3]

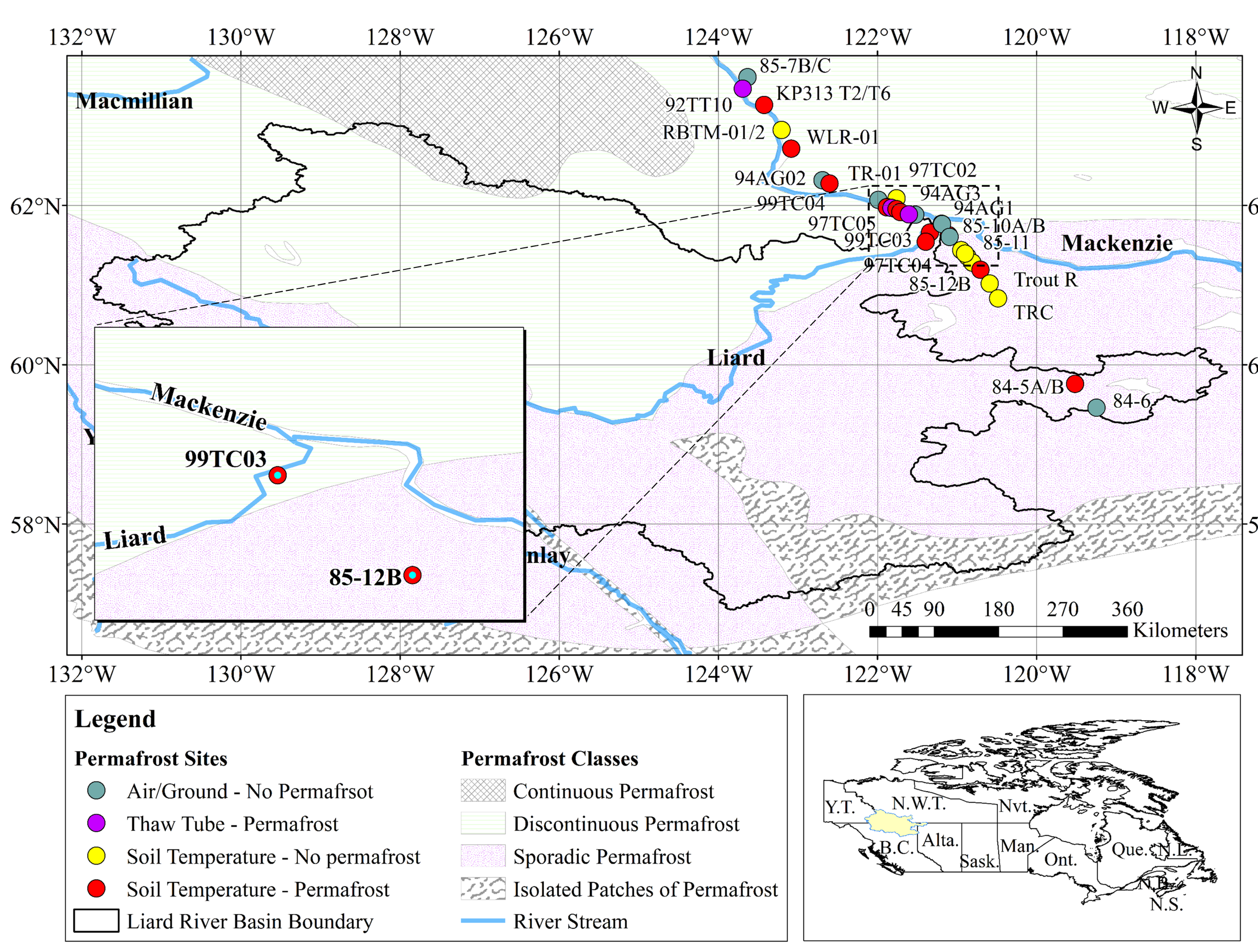
[1]Global Institute for Water Security, University of Saskatchewan, [2]Department of Civil and Geological Engineering, University of Saskatchewan, [3]School of Environment and Sustainability, University of Saskatchewan

Background and Objectives

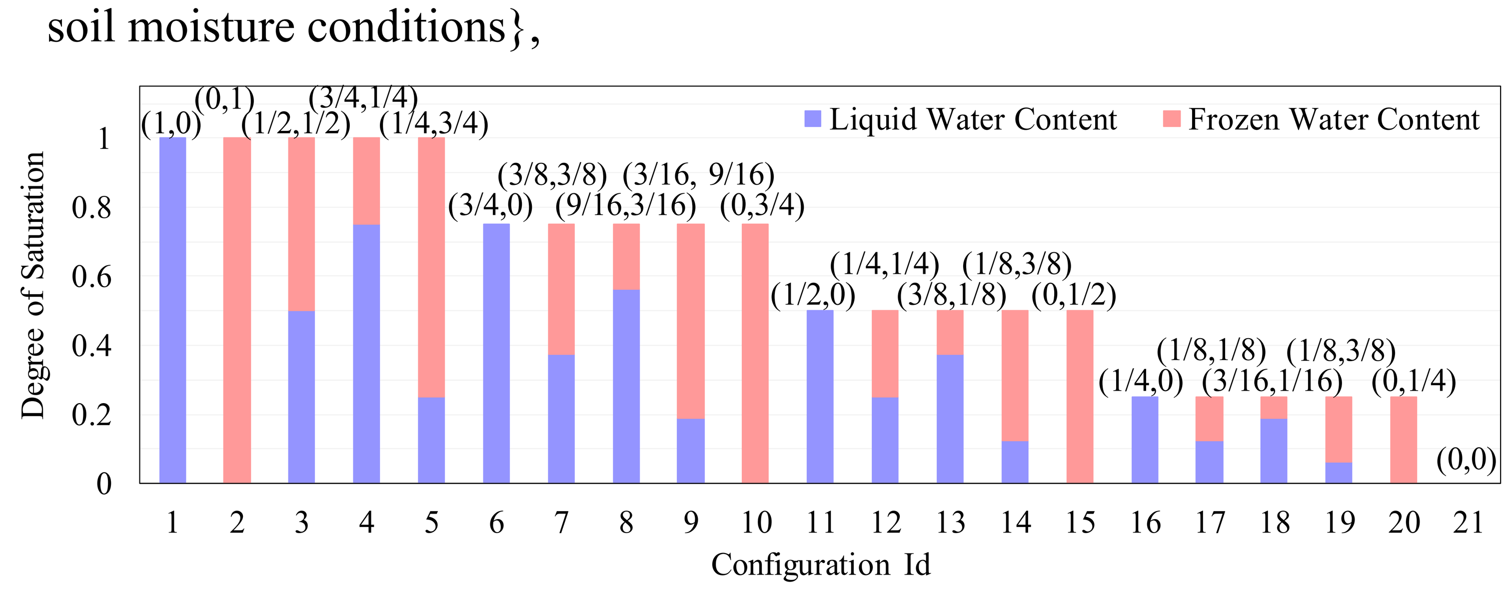
- ❑ Permafrost thaw has been observed in recent decades in the Northern Hemisphere and is expected to accelerate with global warming,
- ❑ Predicting the future of permafrost requires proper representation of the interrelated surface/subsurface thermal and hydrologic regimes,
- ❑ Hydrologic-Land surface models (H-LSMs) are well suited for such predictions, as they couple heat and water interactions across soil-vegetation-atmosphere interfaces and can be applied over large scales,
- ❑ However, H-LSMs are challenged by the long-term thermal and hydraulic memories of permafrost and the paucity of historical records to represent permafrost dynamics under transient climate conditions,
- ❑ The challenge of H-LSMs initialization is addressed by characterizing the impact of initial climate conditions and initial soil frozen and liquid water contents on the simulation length required to reach equilibrium,
- ❑ Further, we quantify how the uncertainty in model initialization propagates to simulated permafrost dynamics.

Model, study area, datasets, and methods

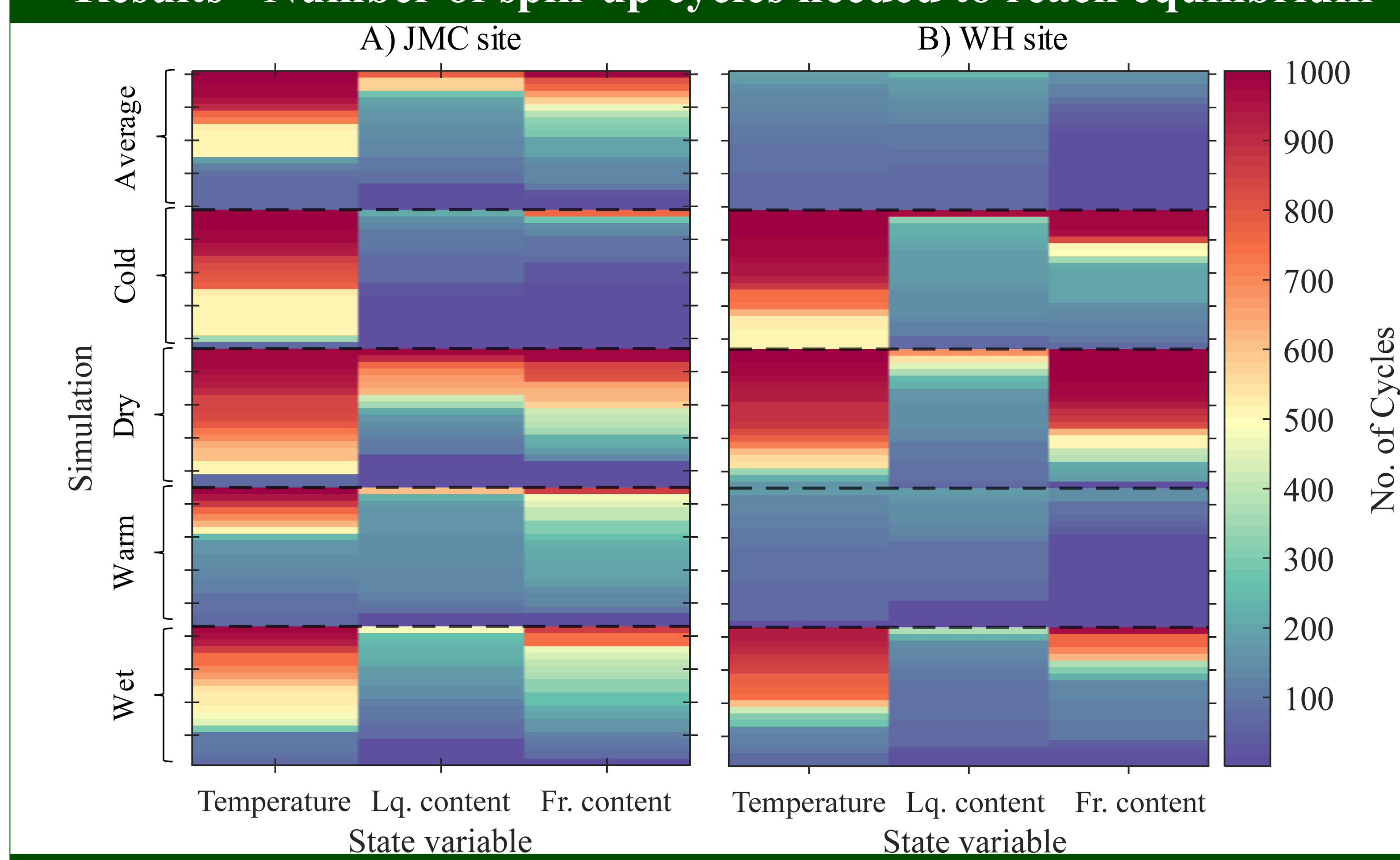
- ❑ Point-mode setups using MESH model with deep soil profile (51.24m),
- ❑ Jean Marie Creek (JMC: site 85-12B) underlain by sporadic permafrost, and Wrigley Highway (WH: site 99TC03) underlain by discontinuous permafrost,



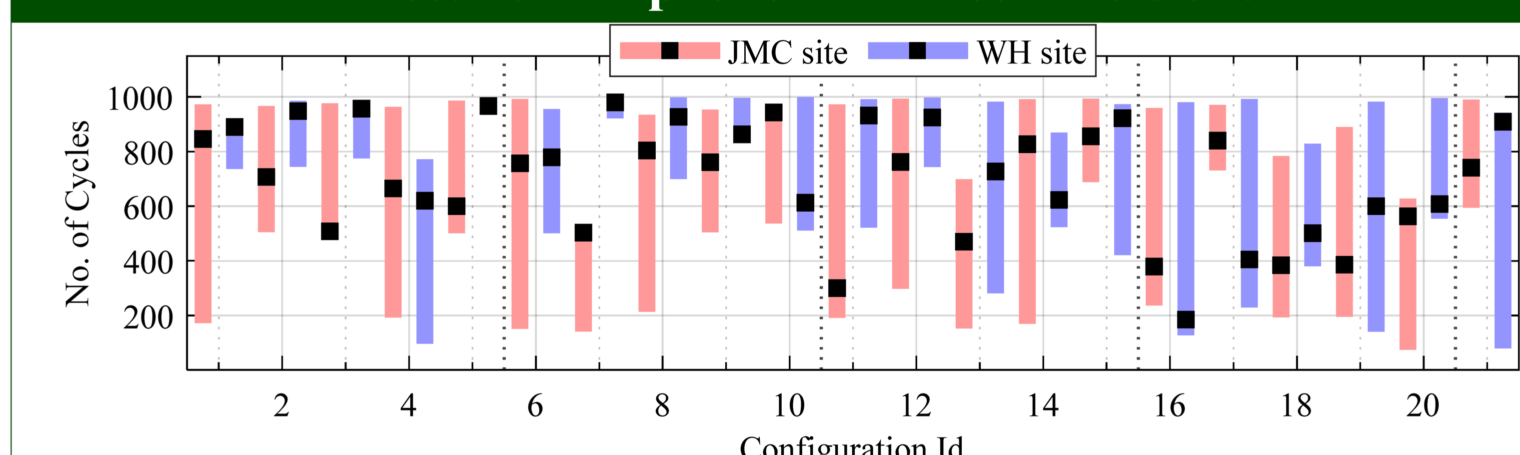
- ❑ WFDEI (WATCH Forcing Data with the ERA-Interim analysis) covering the period 1979-2016,
- ❑ Permafrost data compiled from several Geological Survey of Canada reports,
- ❑ A single-year spinning method for 2000 cycles is utilized for initialization,
- ❑ Each site has a total of 105 initialization scenarios {5 climate conditions x 21 soil moisture conditions},



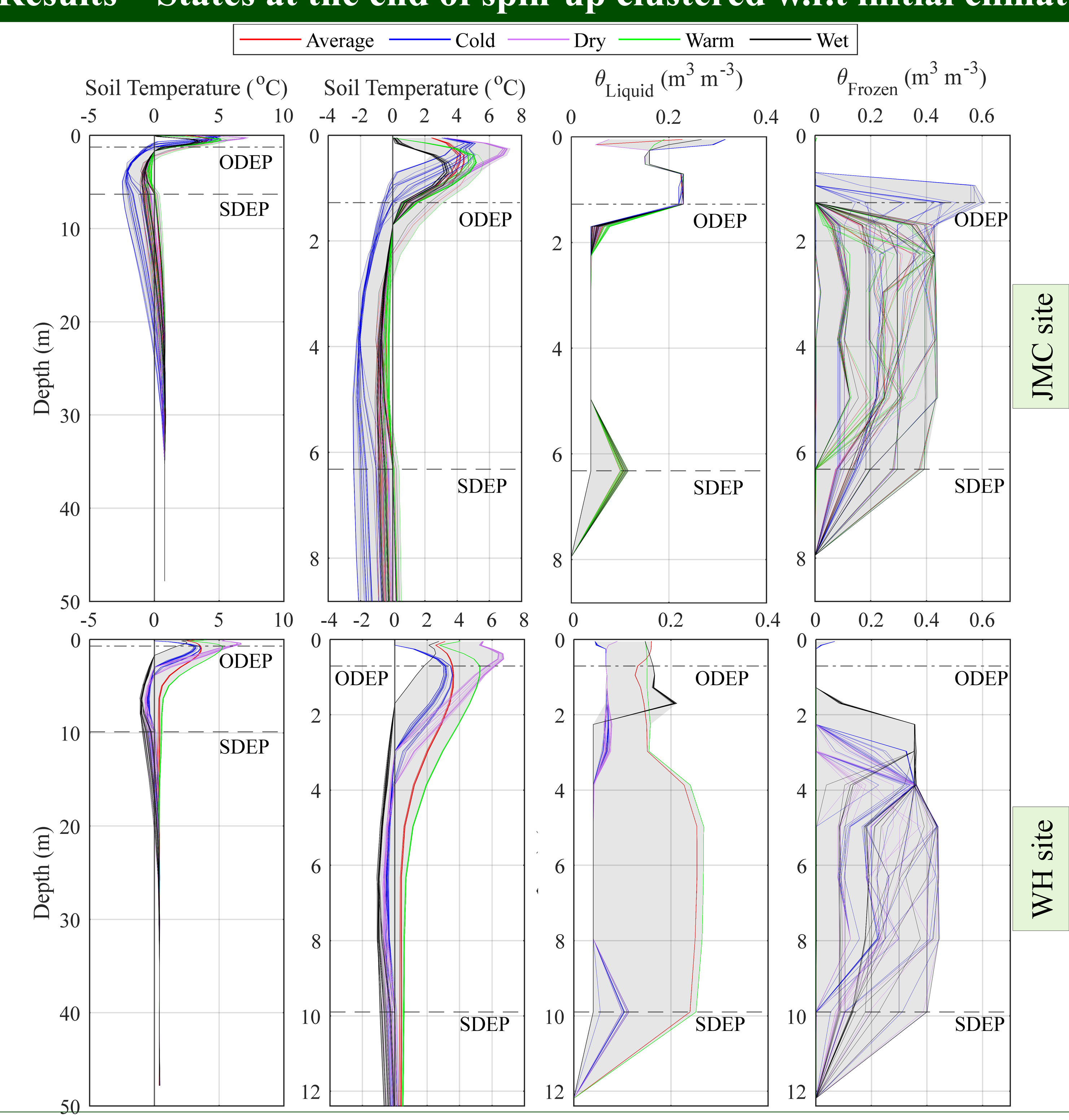
Results - Number of spin-up cycles needed to reach equilibrium



Results – Impact of initial soil moisture

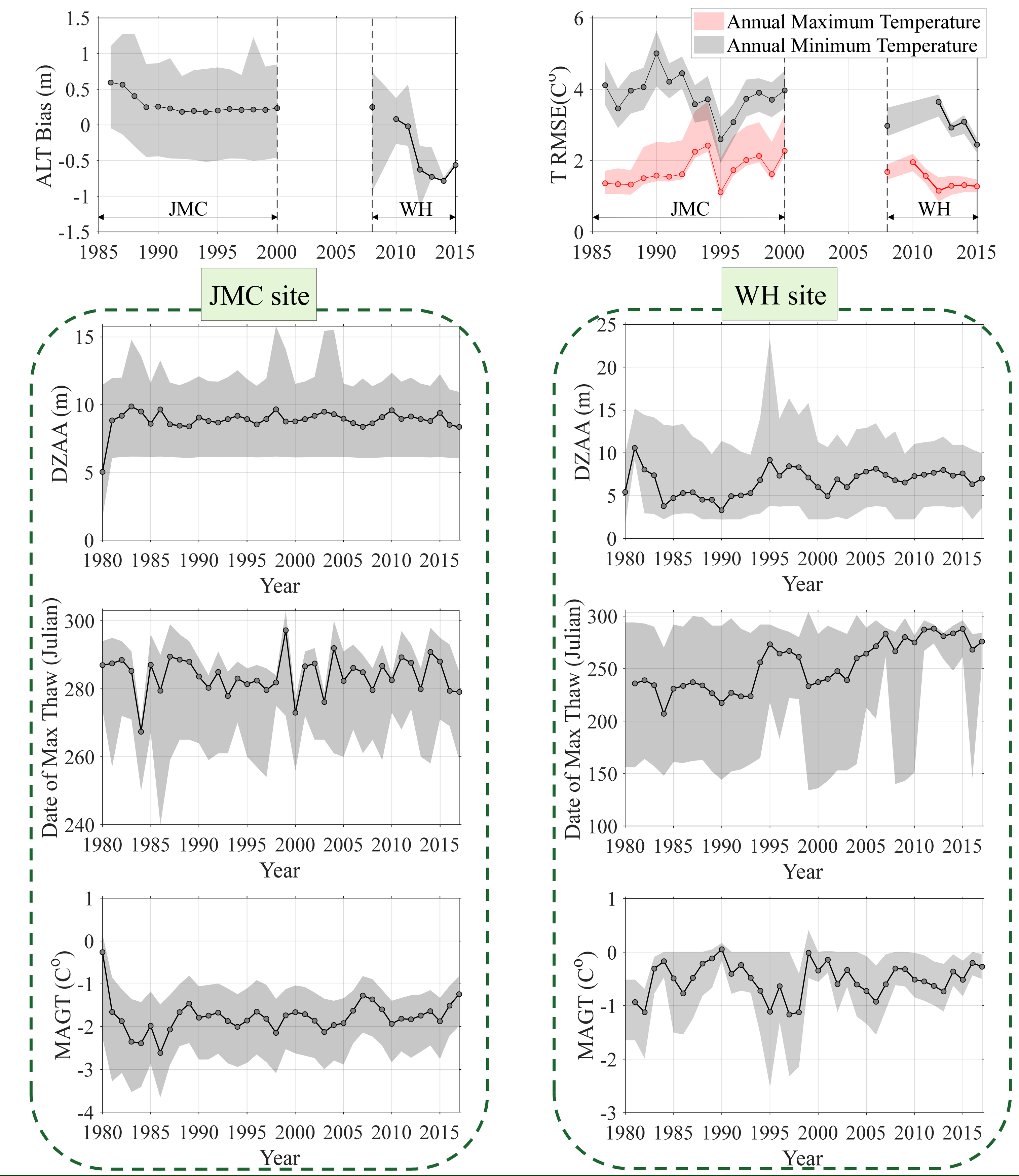


Results – States at the end of spin-up clustered w.r.t initial climate



ODEP: the depth of organic soil & SDEP: the soil permeable depth.

Results – Uncertainty propagation to simulated permafrost



Concluding remarks

- Model spin-up based on a repetition of 200-1000 annual cycles could be appropriate for initializing soil temperature and water content profiles under different climate and moisture conditions and model configurations,
- Initializing the soil column with a wet condition (25% saturation) required minimal spin-up length under different spin-up climates,
- The bias in simulated active layer thickness (ALT) showed a systematic error in the range of ±1 m observed at the two sites; the RMSE of maximum and minimum annual temperature envelopes varied by ~1.5 °C and ~ 0.75°, respectively, as a function of initial climate and moisture conditions,
- The depth of the zero-annual temperature amplitude (DZAA) had a magnitude of variability of three- to four-fold among all the numerical experiments,
- Examining the temporal evolution of freezing/thawing cycles highlighted the high variability of the date of maximum thaw (ALT-DOY) with initial conditions, shifting by up to four weeks between August and October; the mean annual ground temperature (MAGT) showed a stronger response to the driving climate than initial soil moisture, ranging between 2-3 °C annually,
- The study raises a fundamental issue of attempting to initialize models to a steady state while the real system is transient, which as yet has no simple resolution.

* Contact: Mohamed.Abdelhamed@usask.ca

SCAN ME