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Hydrological modelling of the Nelson Churchill River Basin using HYPE

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01. Introduction

- Meteorological data such as precipitation and temperature are the major driving inputs to understand the hydrological behaviour of any catchment (Hong et al., 2006).
- Hydrological modeling is a necessary tool for studying the impacts of climate change on water resources, which is essential in analyzing and projection of potential impacts due to change in future climate scenarios (Praskievicz and Chang, 2009).

Objectives:

- To simulate the impact of climate change on the hydrological behavior of NCRB;
- To evaluate the impact of selection of meteorological product on hydrological uncertainty;
- To evaluate the cold region processes in HYPE, such as frozen soil algorithm.

02. Study Area

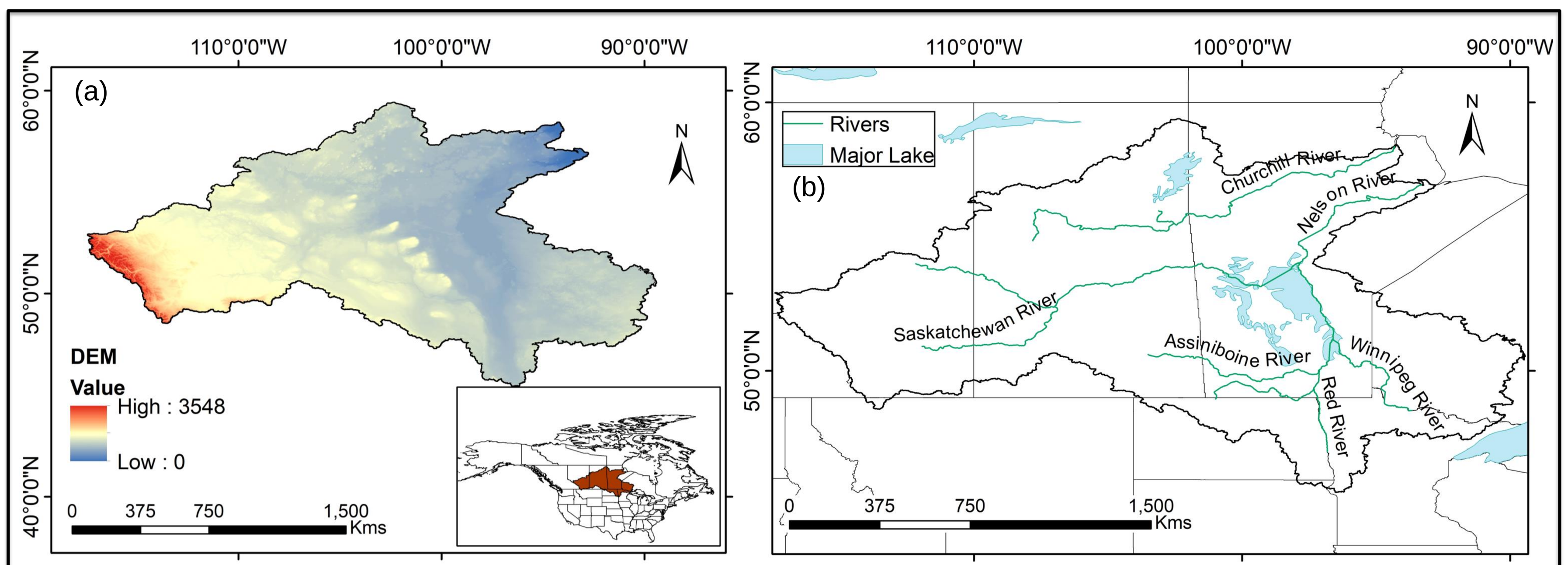


Figure 1 Location map and DEM of Nelson Churchill River Basin

The Nelson Churchill River Basin (NCRB) is the third largest catchment in North America with drainage area of 1.4 million sq. kilometres. The NCRB basin extends from Rocky Mountains in the west to the Lake Superior in the east. The Nelson and Churchill Rivers with respective catchment areas of 1.07 million sq. km and 0.28 million sq. km are the two major river systems of the basin, draining the entire catchment to the outlet in the Hudson Bay to the North (Figure 1b). Generally, the annual average temperature ranges, north to south, from -6.5 °C to +6.1 °C; and total annual precipitation ranges from 320 mm to 800 mm (Figure 2). The mountain region receives the highest precipitation and the prairies are the driest region.

03. Input Forcing Data used for HYPE

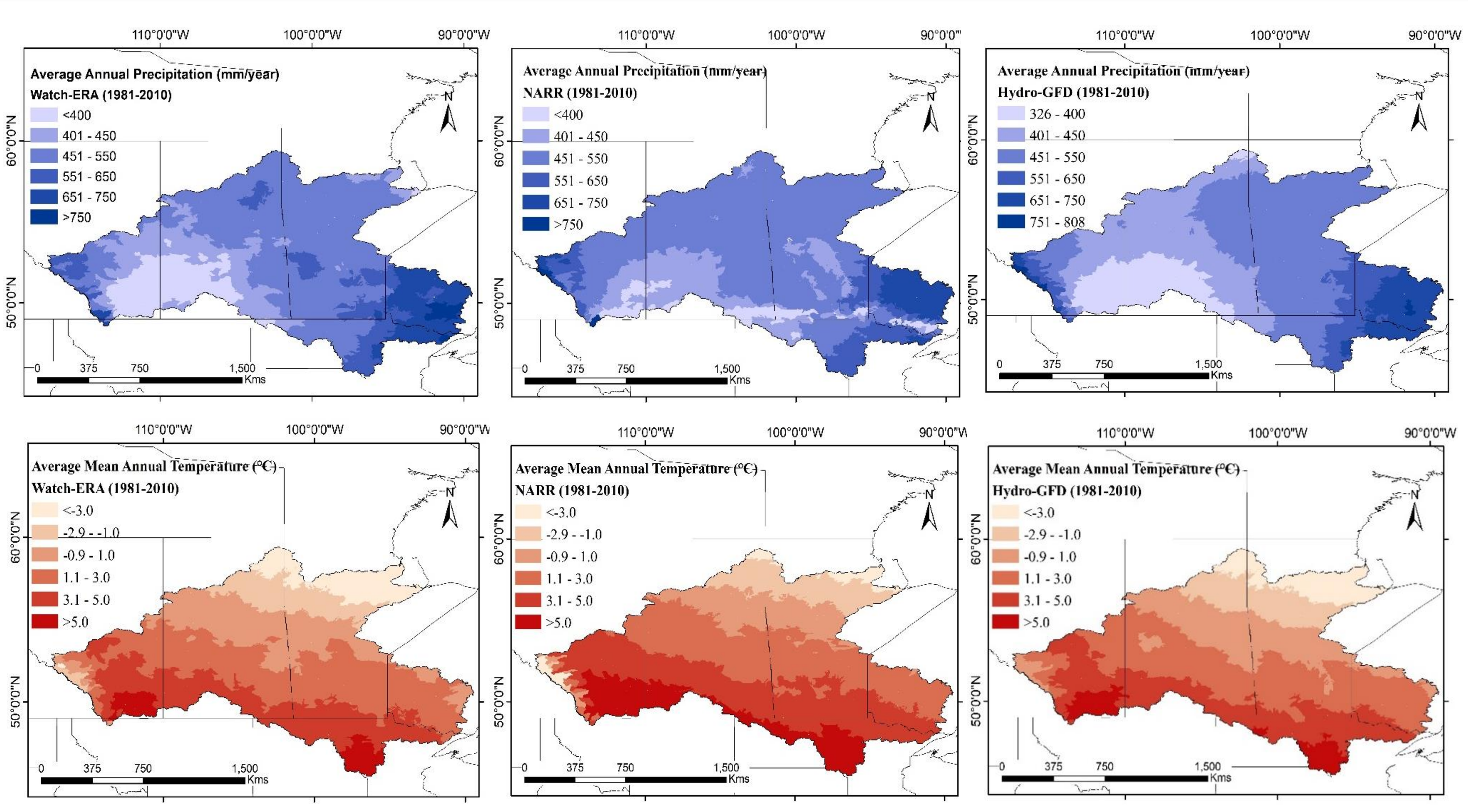


Figure 2 Average Annual precipitation and average annual mean temperature map of NCRB for Watch-ERA, NARR and Hydro-GFD dataset.

04. Sensitivity Analysis and Calibration of HYPE Parameters

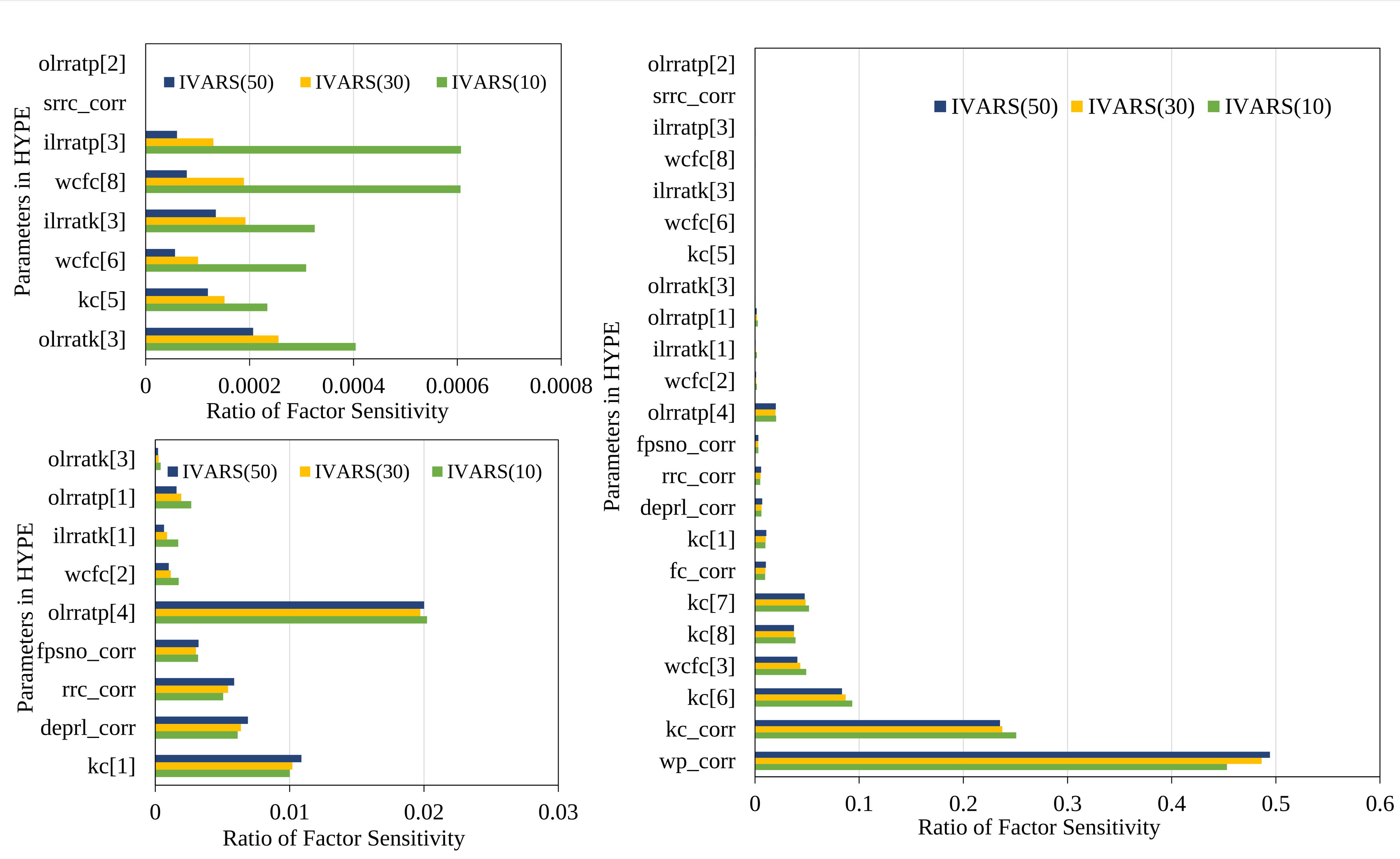
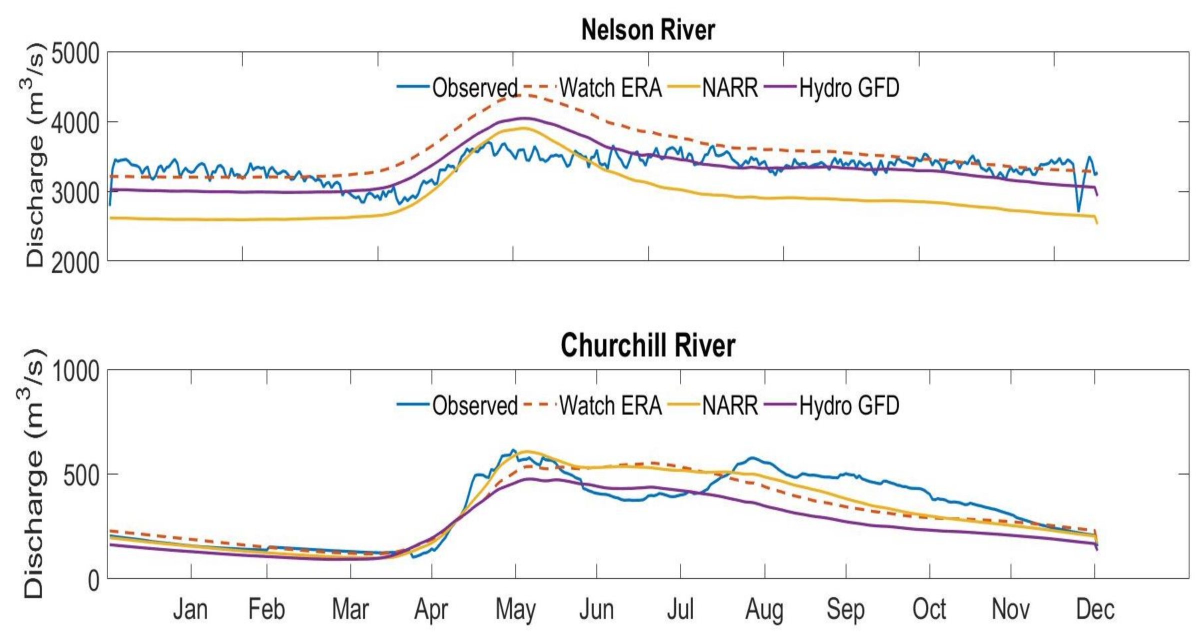


Figure 3 Sensitivity Analysis of HYPE parameters using VARS

- Hydrological Predictions for the Environment (HYPE) model was used for hydrological modelling in the NCRB because it is a continental-scale, semi-distributed, cold regions model
- The NCRB is a setup within A-HYPE, which is a regional implementation of the HYPE hydrological model (Lindström et al., 2010) , developed by the Swedish Meteorological and Hydrological Institute (SMHI).
- Sensitivity Analysis of Model parameters was carried out using Variogram Analysis of Response Surfaces (VARS) (Razavi and Gupta, 2016) (Figure 3).
- HYPE was forced with different input data and re-calibrated using a split-sample approach from 1981-1985, 1991-1995 and 2001-2005. The remaining years, through 2013, were used for validation. (Figure 4).
- Automatic calibration of the most sensitive model parameters based on Markov Chain Differential Evolution Adaptive Metropolis (DREAM) algorithm is on-going.

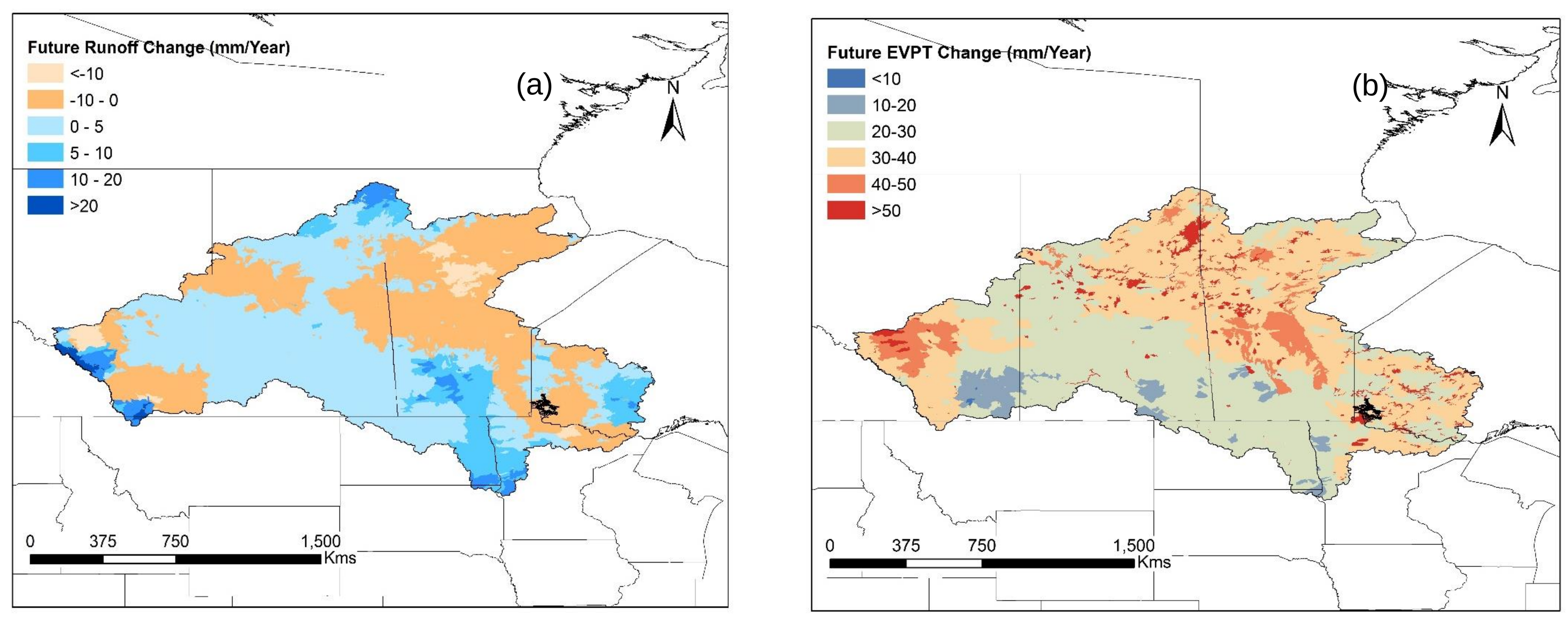


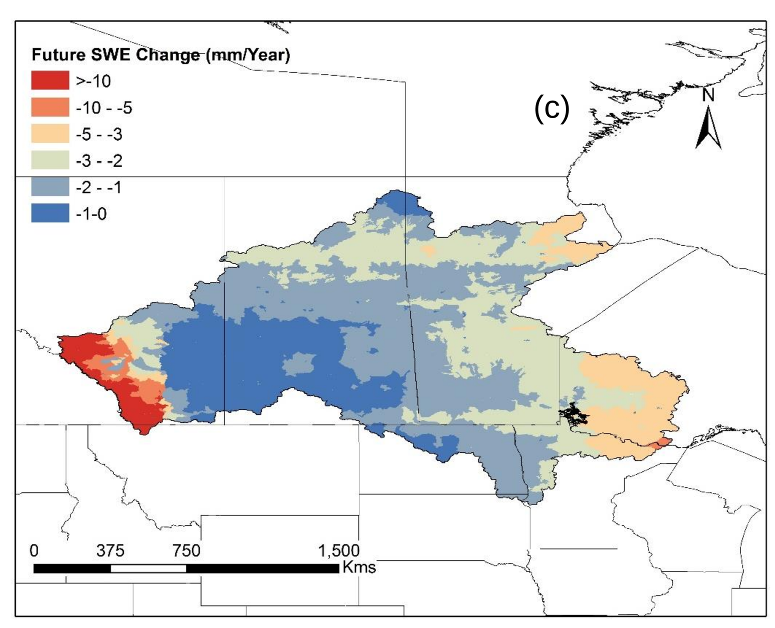
Dataset	NSE	KGE
Watch-ERA	0.44	0.58
NARR	0.27	0.56
Hydro-GFD	0.2	0.46

Dataset	NSE	KGE
Watch-ERA	0.56	0.64
NARR	0.53	0.65
Hydro-GFD	0.50	0.52

Figure 4 Comparison of daily averaged annual hydrograph for baseline period (1981-2010) Nelson and Churchill River for different datasets.

05. HYPE Projections





- 19 GCMs from CMIP5 used for future projection (>87% of the variability from 154 GCMs)
- Figures 5a-5c show the projected changes in hydrology for the future (2021-2050)
- Runoff is projected to increase up to 40% within parts of the basin.
- Evapotranspiration loss is increasing (+15%) and most is most significant in open-water dominated areas.
- SWE is observed to be decreasing (up to 25%) for all sub-basins

Figure 5 Future absolute changes (mm/year) in Water balance components (2021-2050) compared to baseline period (1981-2010) analyzed with WATCH-ERA dataset.

06. Discussion and Conclusions

- Current calibration of HYPE model with WATCH-ERA dataset shows better performance compared to NARR and Hydro-GFD.
- HYPE correction factors and land use parameters are more sensitive based on VARS analysis.
- Future projections shows mostly increasing runoff (up to ~40%); increasing evapotranspiration (up to 15%) in the lake areas (i.e., Lake Winnipeg and Lake Manitoba); and decreasing SWE with increasing temperatures.
- Impact of climate change is most visible on SWE in the Rocky mountains (up to 25% decrease).
- The next step of the study is to quantify the uncertainty associated with the selection of different meteorological forcing, including resolution of forcing (i.e., comparison to WRF), and to validate frozen soil algorithm using field-based measurements.

References & Acknowledgements

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