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Understanding Extreme Precipitation Characteristics over Western Canada

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Abstract

This study investigated the observed characteristics of extreme precipitation over western Canada using multiple statistical techniques and explores the impacts of climate change on future extreme precipitation by comparing the Pseudo Global Warming (PGW) projection against retrospective simulation (CTL) generated using the Weather Research Forecasting (WRF) model at convection permitting scale (model's horizontal grid spacing = 4km). Preliminary analysis of the observed station data shows a heterogeneous pattern of precipitation change over western Canada. The PGW simulations show increased total precipitation compared to CTL simulations. For the dynamical model study, the Weather Research and Forecasting (WRF) model simulates a high intensity 50 and 100-year precipitation events for current climate conditions than by the end of this century.

Background

Canada is warming at twice the global average. Increased atmospheric moisture due to global warming may increase the likelihood of extreme precipitation (Trenberth et al., 2003) which is highly variable both in space and time. Many extreme precipitation events are caused by mesoscale convective systems (MCSs). In southern Canada, Alberta and South Saskatchewan, MCSs are projected to increase under pseudo global warming projection (Li et al., 2017; Liu et al., 2017; Prein et al., 2017). Intensive agricultural activities over the Canadian Prairies may augment precipitation intensity locally (Betts et al., 2013). It is yet to be understood whether summer convection will enhance or suppress over Prairies under warmer and moister climatic conditions from mid-to-late 21st century (Stewart et al., 2019).

Objective of the study

The effect of climate change on extreme precipitation events in the Canadian Prairies remain uncertain. Therefore, our goal is to better understand the spatio-temporal variability of extreme precipitation events on the Canadian Prairies under present and future climate conditions.

Research Question?

1. How have the properties of extreme rainfall events changed in the Prairie Provinces in recent decades?
2. What is the trend in extreme precipitation events over different seasons and regions?
3. What characteristics of extreme precipitation under the Pseudo-Global warming (PGW) approach relative to current climate will change?
4. How does PGW dynamical downscaling approach impact 50/100 years return period precipitation?

Experimental Configuration

Simulation period:
Current Climate (WRF-CTL): 2001-2015
Future Climate (WRF-PGW): 2086-2100
Horizontal resolution: 4 km (convection permitting)
Vertical layer: 37 (Sigma)
Cumulus schemes: No cumulus scheme
PBL schemes: YSU
Microphysics schemes: Thompson

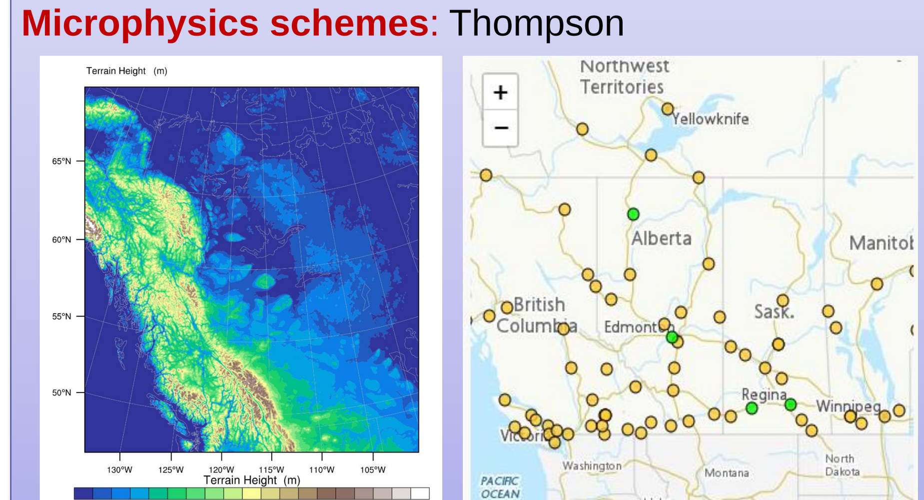


Fig. 1: WRF model domain (left) and location of station observations (right) used in this study

Data and Methodology

Data:

1. WRF-CTL simulations were compared against WRF-PGW simulations
2. Observed Precipitation from Env. And Climate Change Canada (station locations are illustrated in Figure 1)

Statistical Analyses:

1. Non-parametric Mann-Kendall test and Theil-Sen's slope analyses for trend and rate analyses
2. Generalized Extreme Value (GEV) distribution analysis for return period calculation

The sampling distribution of the largest of m values converges to the GEV distribution, with the probability density function (pdf):

$$f(x)=1/\alpha\ \ [1-(\kappa\,(x-\xi))/\alpha]^{(-1+1/\kappa)}\ \exp\{-[1-(\kappa\,(x-\xi))/\alpha]^{(1/\kappa)}\} \qquad 1-\kappa(x-\xi)/\alpha>0$$

Where, α, ξ, and κ are the location (or shift), scale, and shape parameters, respectively. When κ approaches to zero, the GEV distribution converges to Gumbel distribution whose PDF is given by:

$$f(x)=1/\alpha\ \ \exp\{-\exp[-((x-\xi))/\alpha]-((x-\xi))/\alpha\}$$

The CDF is given by:

$$F(x)= \exp\{-\exp[-((x-\xi))/\alpha]\}$$

The return period T associated with quantile x is interpreted as the average time between occurrences of events of that magnitude or greater.

$$T= 1/[1-F(x)]$$

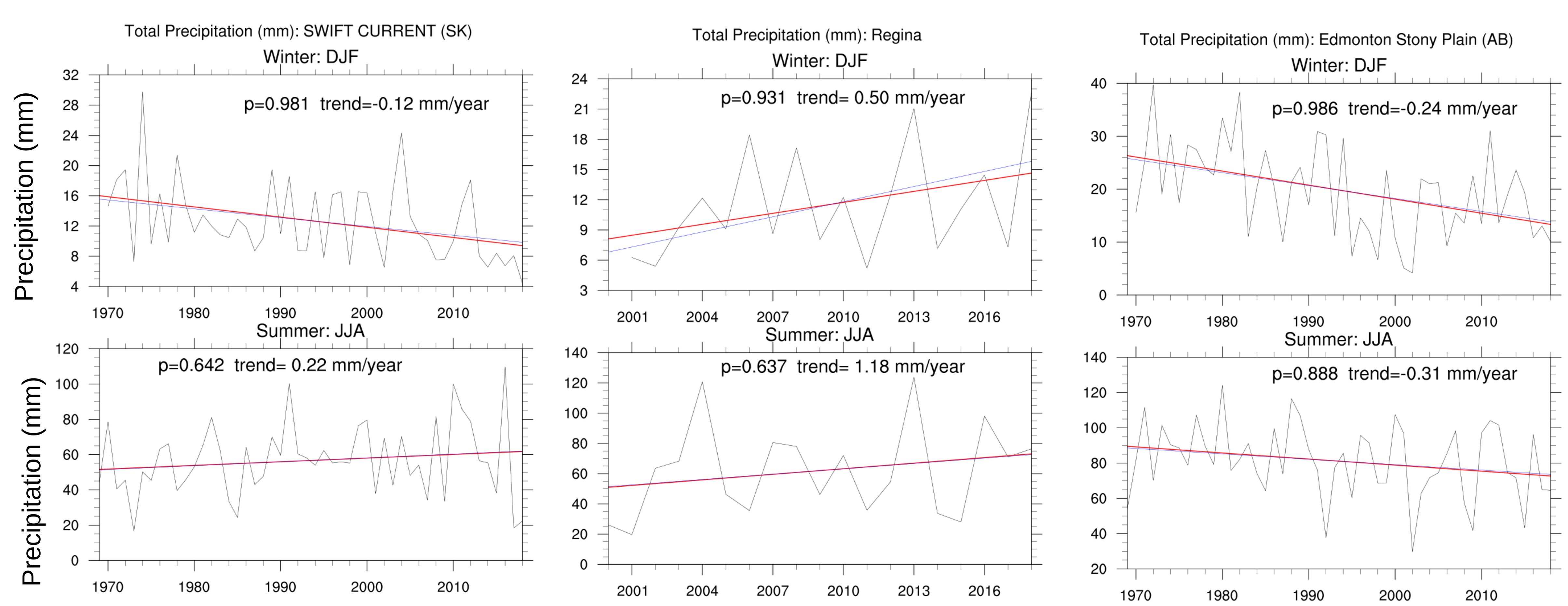


Fig. 2: Seasonal precipitation trend using Mann-Kendall test for different stations across the Canadian Prairies.

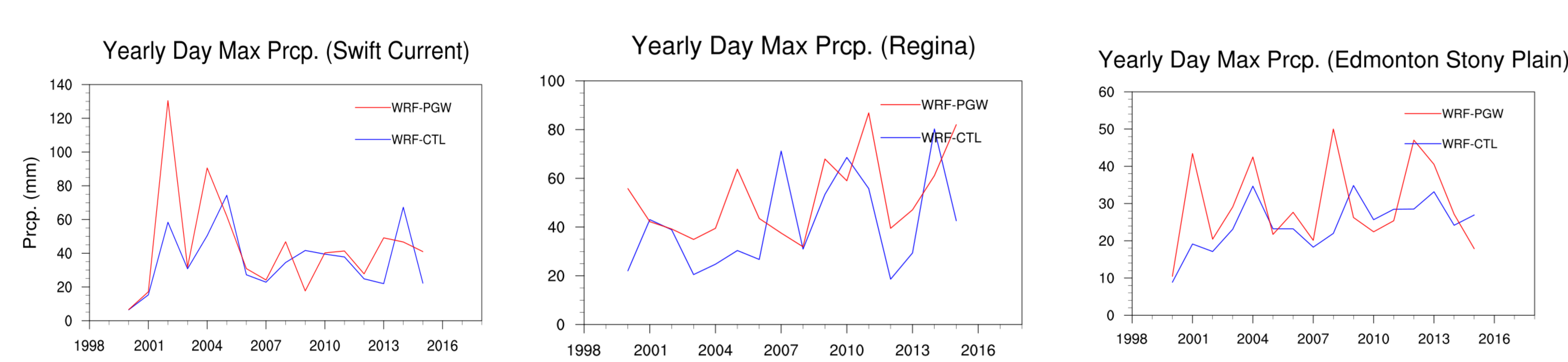
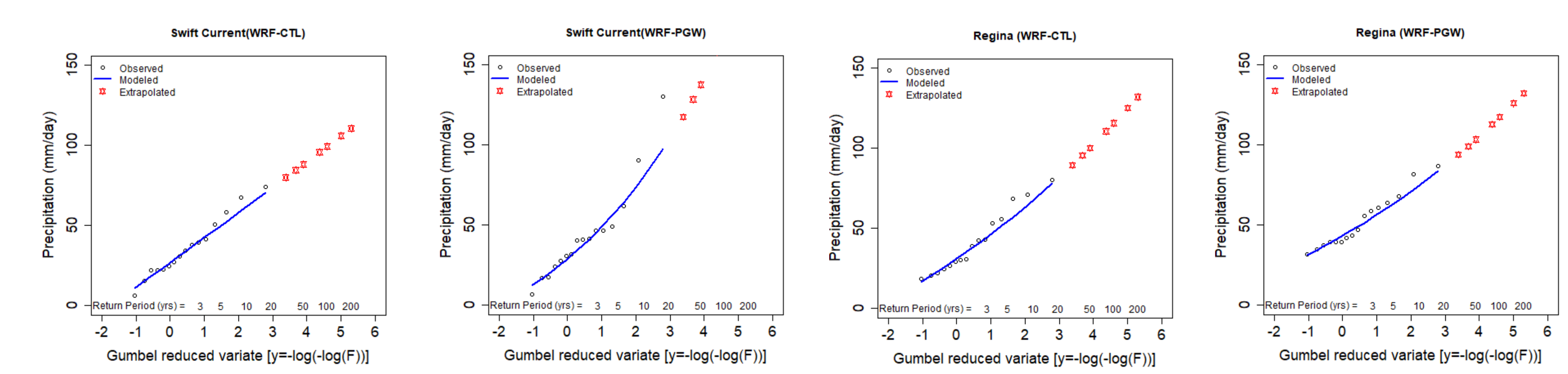


Fig. 3. Comparison of annual maximum daily precipitation (for the wettest of the 365 days) trend simulated by the convection permitting Weather Research and Forecasting (WRF) Control (WRF-CTL) and Pseudo–Global Warming (WRF-PGD) simulations.

Preliminary Results and Discussion

- Prairie Precipitation shows high spatial and temporal variability
- The same station shows an opposing trend of precipitation in summer and winter
- Magnitude of domain-averaged daily maximum precipitation was higher in case of WRF-PGW than WRF-CTL simulations
- The magnitude of 50 and 100-year return period precipitation is higher in WRF-CTL than WRF-PGW simulation
- Under PGW scenario, magnitude of 50- and 100-year return period precipitation show less sensitivity



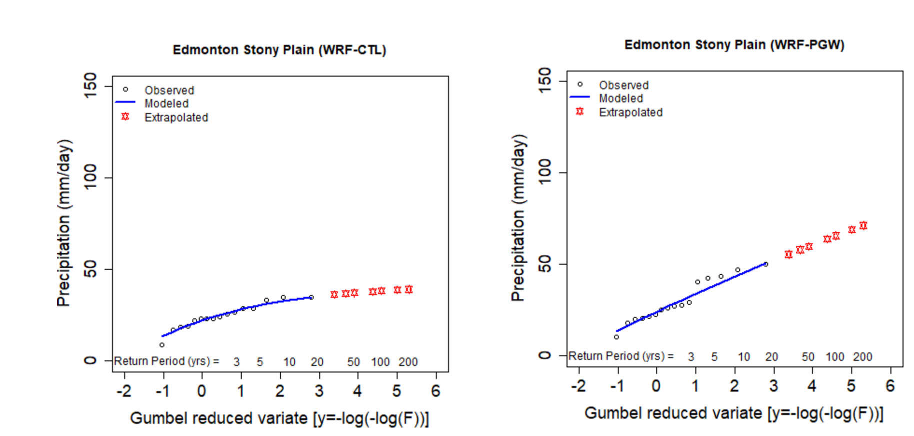


Fig. 4: Comparison of return period precipitation at different stations for WRF-CTL and WRF-PGW simulations

Limitations/Future Work

Statistical analysis of climate data alone cannot, in principle, reveal the physical cause of any changes in extreme precipitation events. Dynamical modelling studies may help us infer the physical cause of an extreme event.

Future Work

Local and regional precipitation characteristics depend on large-scale atmospheric circulation patterns (e.g., El Nino, North Atlantic Oscillation). Thus, to identify cause and effect relationship a joint analysis of many time series is required. We wish to extend our current work to analyze multiple variables including (but not limited to): Geopotential Height, Potential Vorticity, Mean Sea-level pressure. Further, an ensemble of numerical modelling simulations from Coupled Model Intercomparison Project 5 (CMIP5) models and Convection-Permitting Pseudo–Global Warming Simulation will be analyzed

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