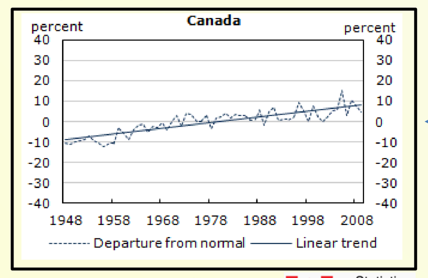
Assessing Nonstationarity in Rainfall Extremes and Changes in Future Design Rainfall in NA-CORDEX Regional Climate Models across Southern Ontario

Poulomi Ganguli*[1,2], Paulin Coulibaly[1]

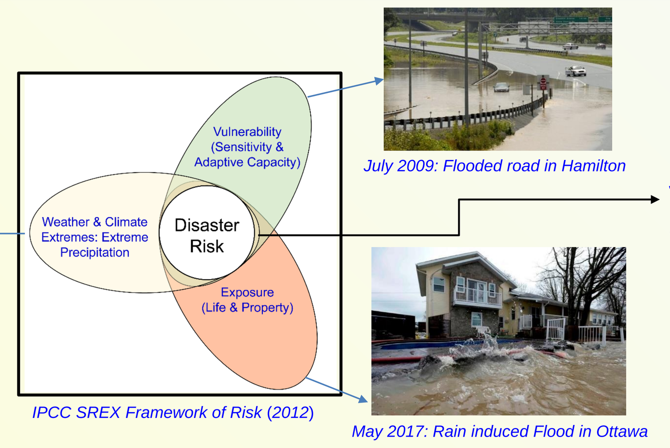
[1]Department of Civil Engineering, McMaster University, Hamilton, Ontario, Canada, [2]Helmholtz-Center Potsdam – GFZ German Research Center for Geosciences

Introduction and Background

Annual Mean Precipitation Departure wrt 1961-1990



Source: Statistics Canada

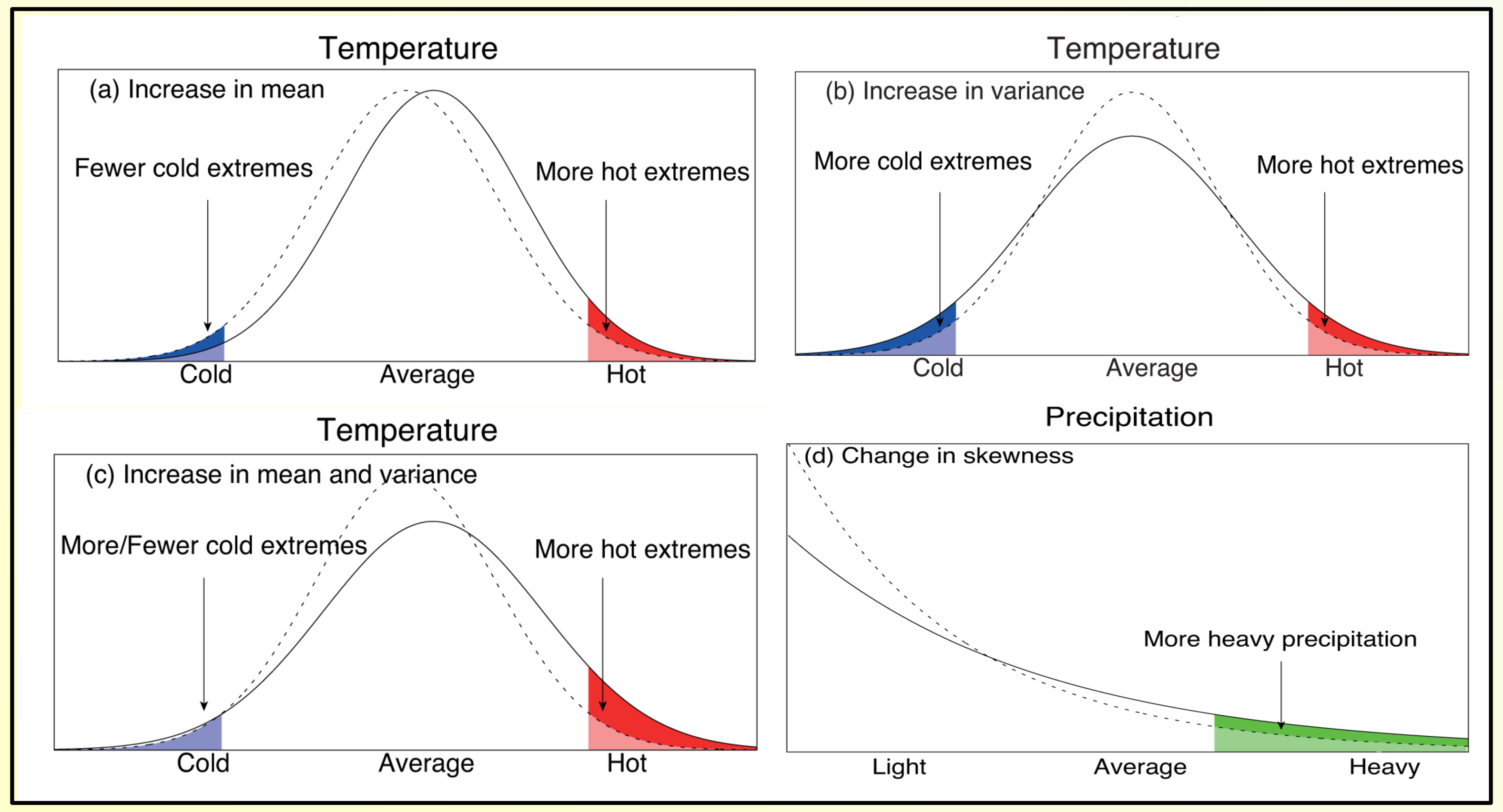


IPCC SREX Framework of Risk (2012)

July 2013 GTA: US $850 million
May 2017 Quebec & ON: US $1 billion

Source: Canadian Underwriter

- A relatively small perturbation in climate can result into a substantial changes into the frequency of extremes: Changes in mean, variability, and skewness can complicate the process



Source: IPCC AR5 Chapter **1** (Fig. **1.8**), Page *134*

Study Area and Data

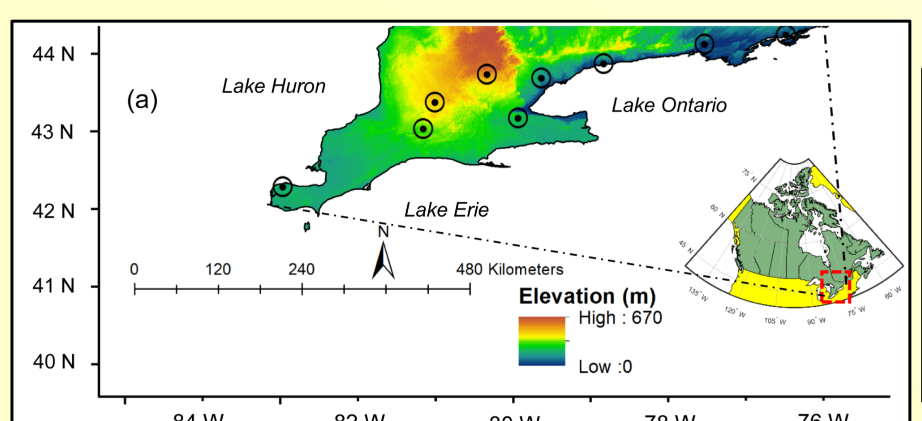
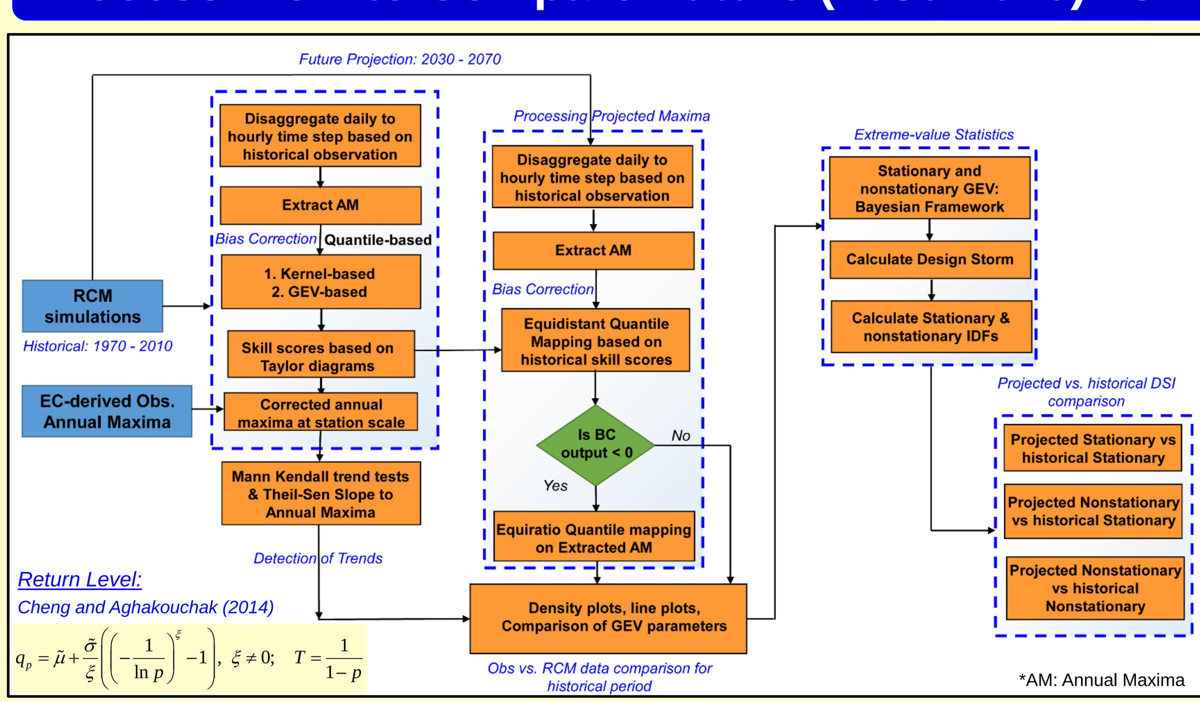


Table. Available daily and sub-daily rainfall record

Stations	Hourly	Daily
Hamilton	1971 - 2003	1960 - 2011
Oshawa	1970 - 1999	1970 - 2015
Toronto Person Intl. Airport	1960 - 2012	1940 - 2012
Windsor	1960 - 2007	1940 - 2014
Kingston	1961 - 2003	1960 - 2007
London	1961 - 2001	1940 - 2015

Process Flow to Compare Future (2030-2070) vs Present-Day (1970-2010) IDF

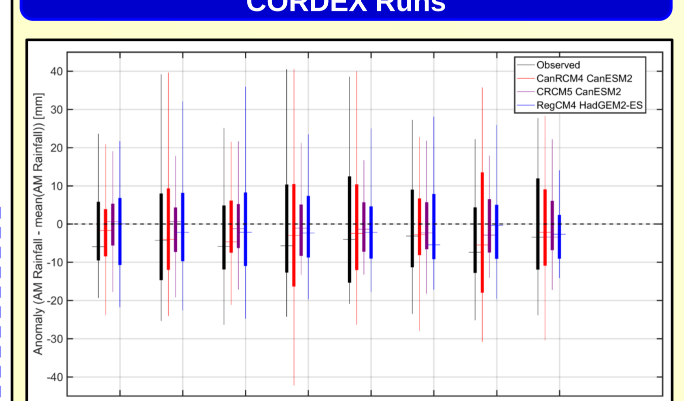


$$q_p = \tilde{\mu} + \frac{\tilde{\sigma}}{\xi}\left(\left(-\frac{1}{\ln p}\right)^{\xi} - 1\right),\ \xi \neq 0;\quad T = \frac{1}{1-p}$$

For future IDF: GEV model with time varying location parameter:

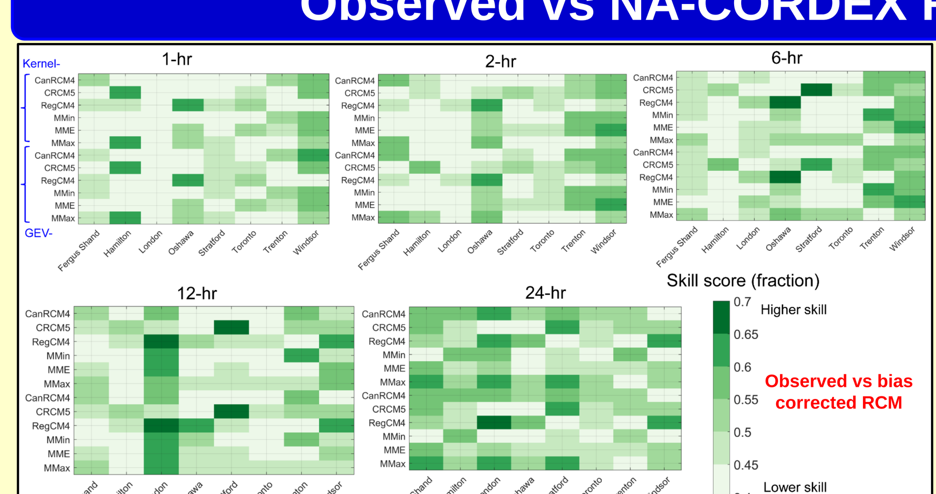
$$\tilde{\mu}(t) = \mu_0 + \mu_1 t$$

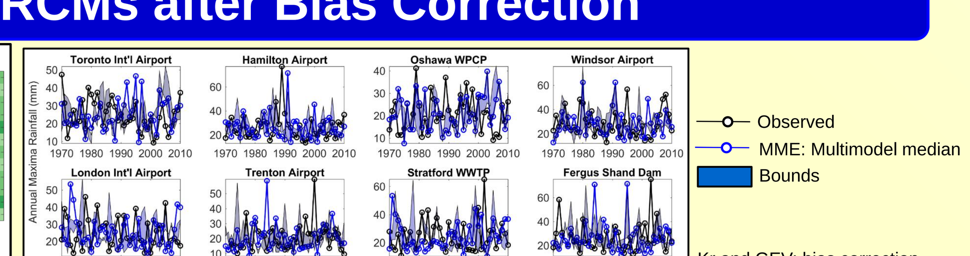
Distribution of AM Precipitation in NA-CORDEX Runs



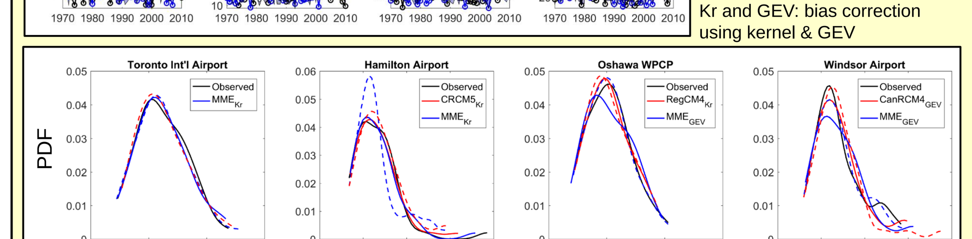
*AM: Annual Maxima

Observed vs NA-CORDEX RCMs after Bias Correction



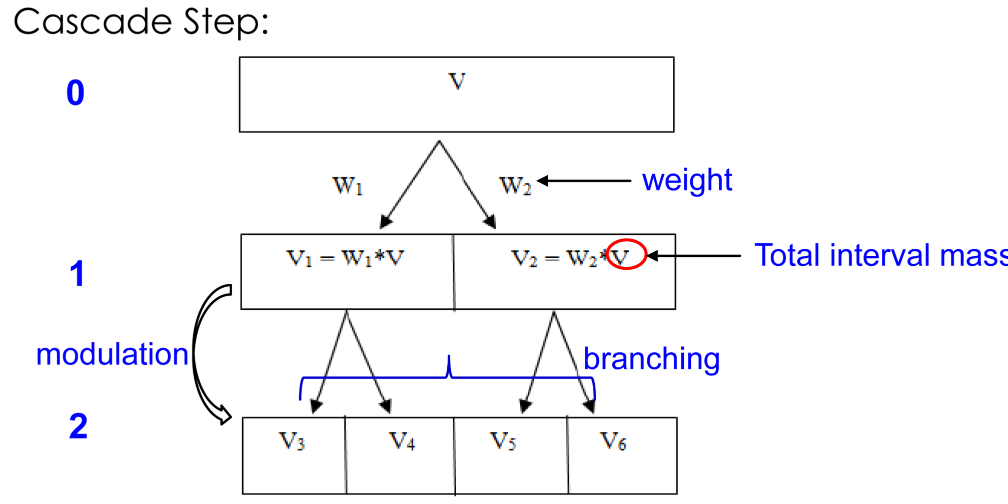


Kr and GEV: bias correction using kernel & GEV



Multiplicative Random Cascade (MRC) for Rainfall Disaggregation

Cascade Step:



$$W_1, W_2 = \begin{cases} 0 \ and \ 1 & with\ probability\ P(0/1) \\ 1 \ and \ 0 & with\ probability\ P(1/0) \\ W_{x/x} \ and \ 1 - W_{x/x} & with\ probability\ P(X/X) \end{cases}$$

where, $0 < Wx/x < 1$

Volume = $V = V_1 + V_2 + V_3 + V_4 + V_5$

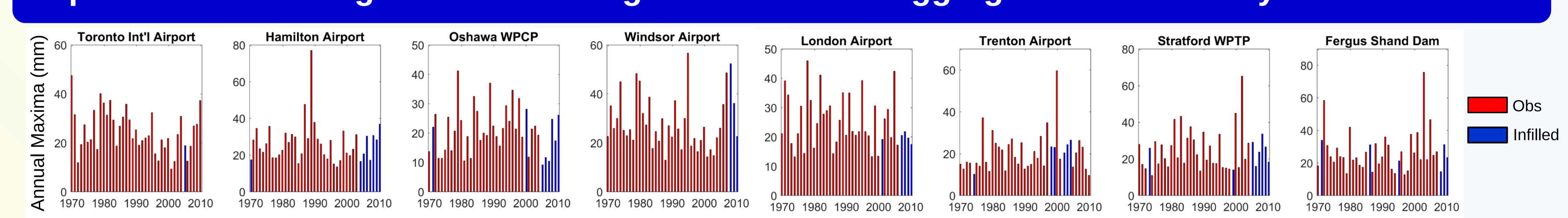
$P(0/1) + P(1/0) + P(x/x) = 1$

Assumptions: Probabilities P and $W_{x/x}$ distributions are scale invariant.

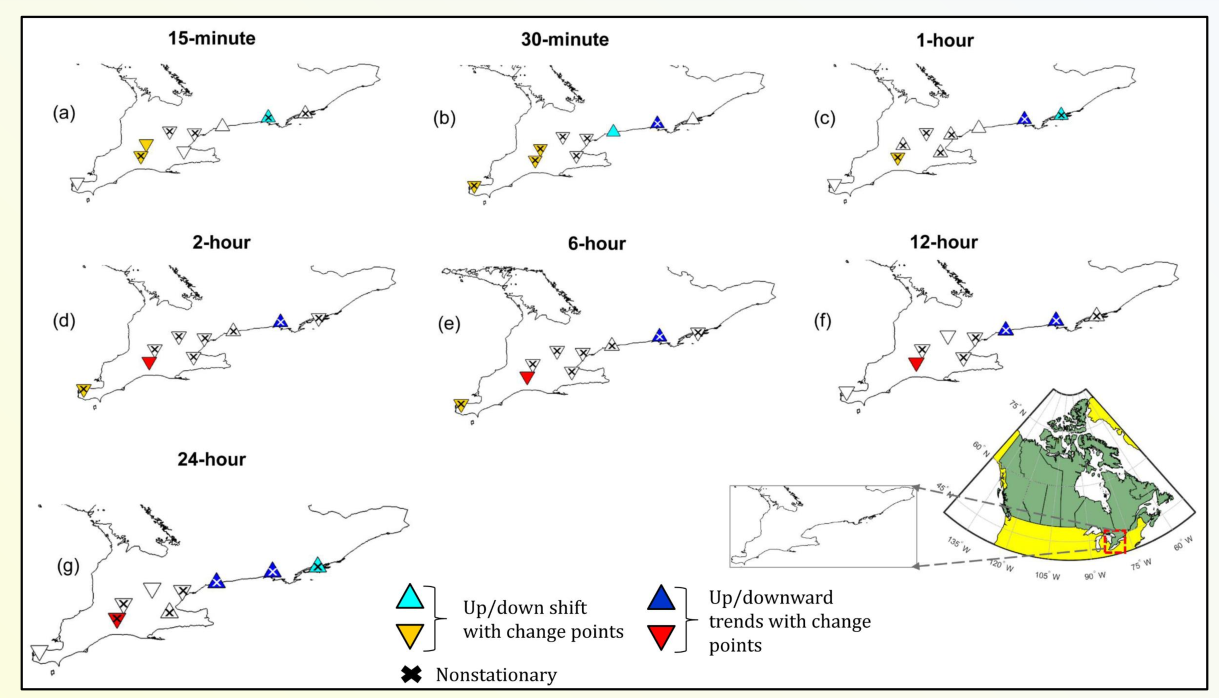
Volume Classes *Olsson (1998)*

- **Starting box**: Period in the beginning of sequence, proceeded by a dry period and succeeded by a rainy period
- **Enclosed box**: Period within a sequence, preceded and succeeded by rainy period
- **Ending box**: Period in the end of sequence, preceded by a rainy period and succeeded by a dry period
- **Isolated box**: Proceeded and succeeded by dry period

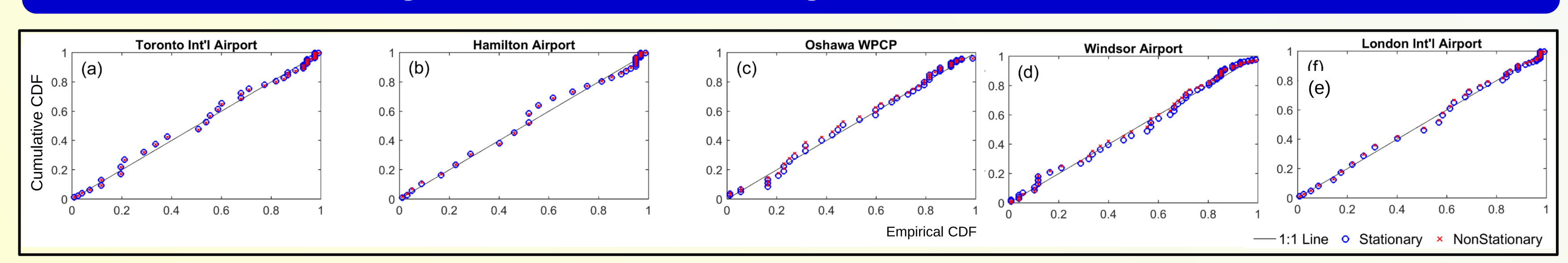
Imputation of Missing AM Series using MRC-based disaggregation followed by Bias Correction



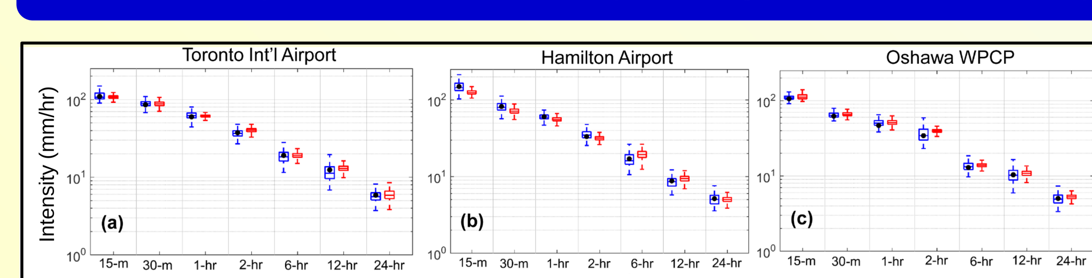
Detection of Nonstationary Trends



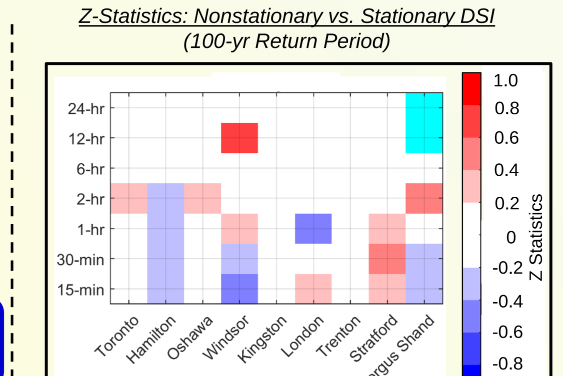
Stationary vs Nonstationary GEV Fit: Observed Data



Stationary vs Nonstationary Design Storm Intensity (DSI): 100-year Return Period



Z-Statistics: Nonstationary vs. Stationary DSI (100-yr Return Period)

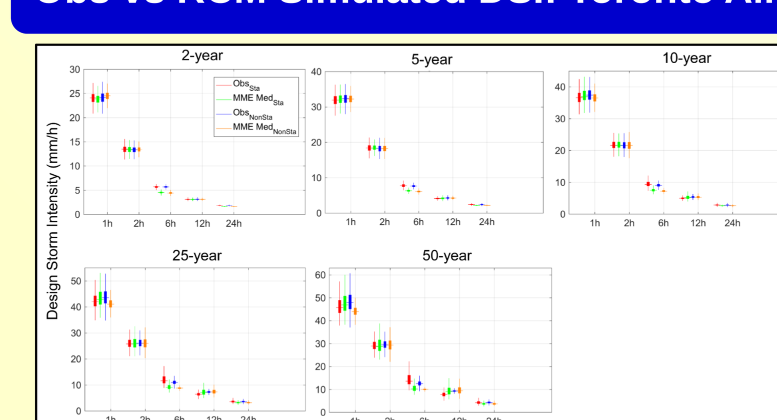


- For station-based observed IDF: Nonstationarity is assumed for both location, $\tilde{\mu}$ & scale parameter, $\tilde{\sigma}$ due to longer record availability.
- Z-statistics:

$$z = \frac{\hat{z}_T^{NonSta} - \hat{z}_T^{Sta}}{\sqrt{0.5\left(var\{\hat{z}_T^{NonSta}\} + var\{\hat{z}_T^{Sta}\}\right)}}$$

$var\{\hat{z}_T^{NonSta}\}$ = Estimated variance of *T*-year event estimate and associated confidence interval [5th and 95th percentile quantile].

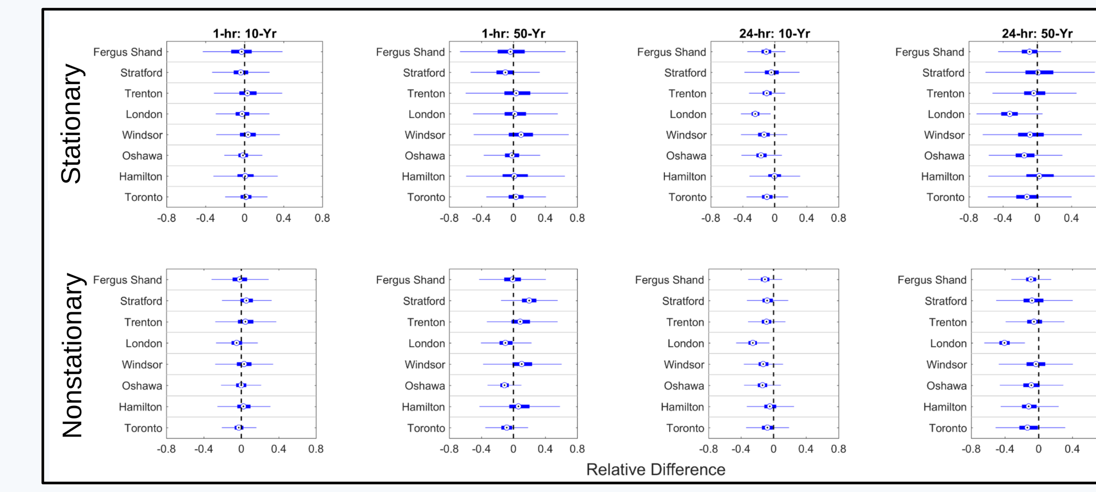
Obs vs RCM Simulated DSI: Toronto Airport, 1970 - 2010



MME Med_{Sta}: Multimodel median RCM with stationary model

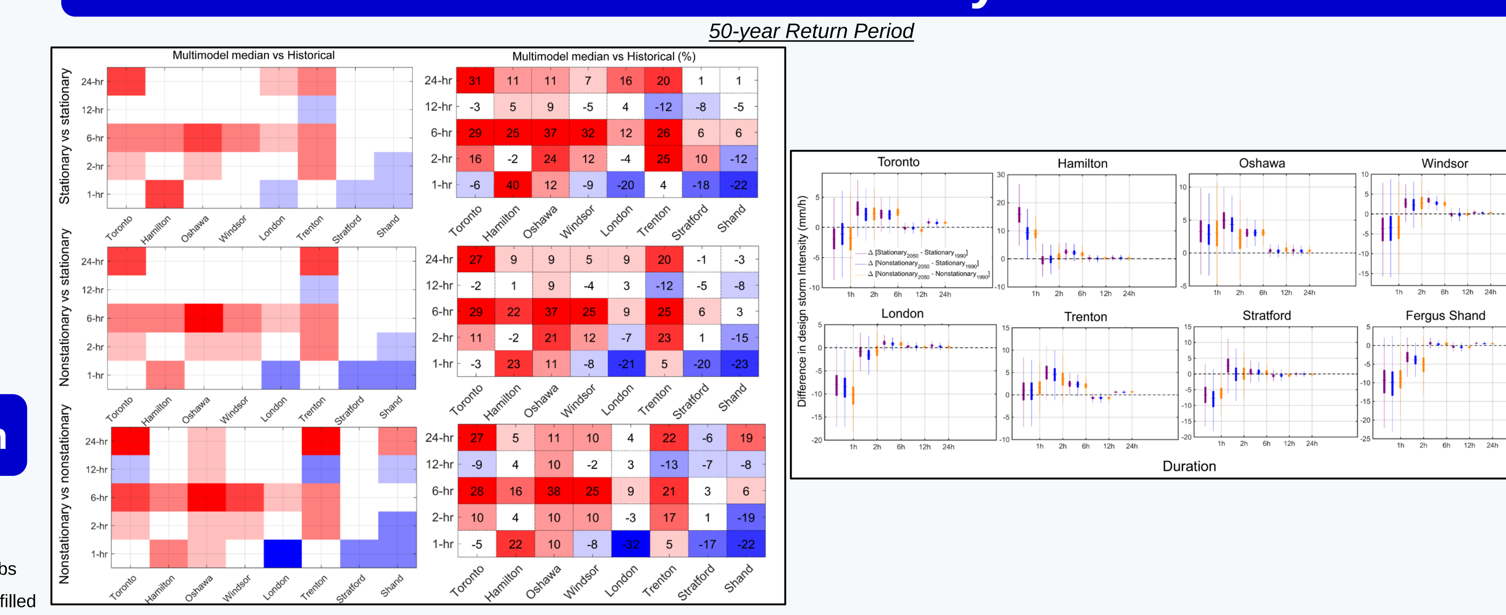
MME Med_{NonSta}: Multimodel median RCM with nonstationary model

Obs. Vs. RCM Simulated DSI: Relative Differences (1970-2010)

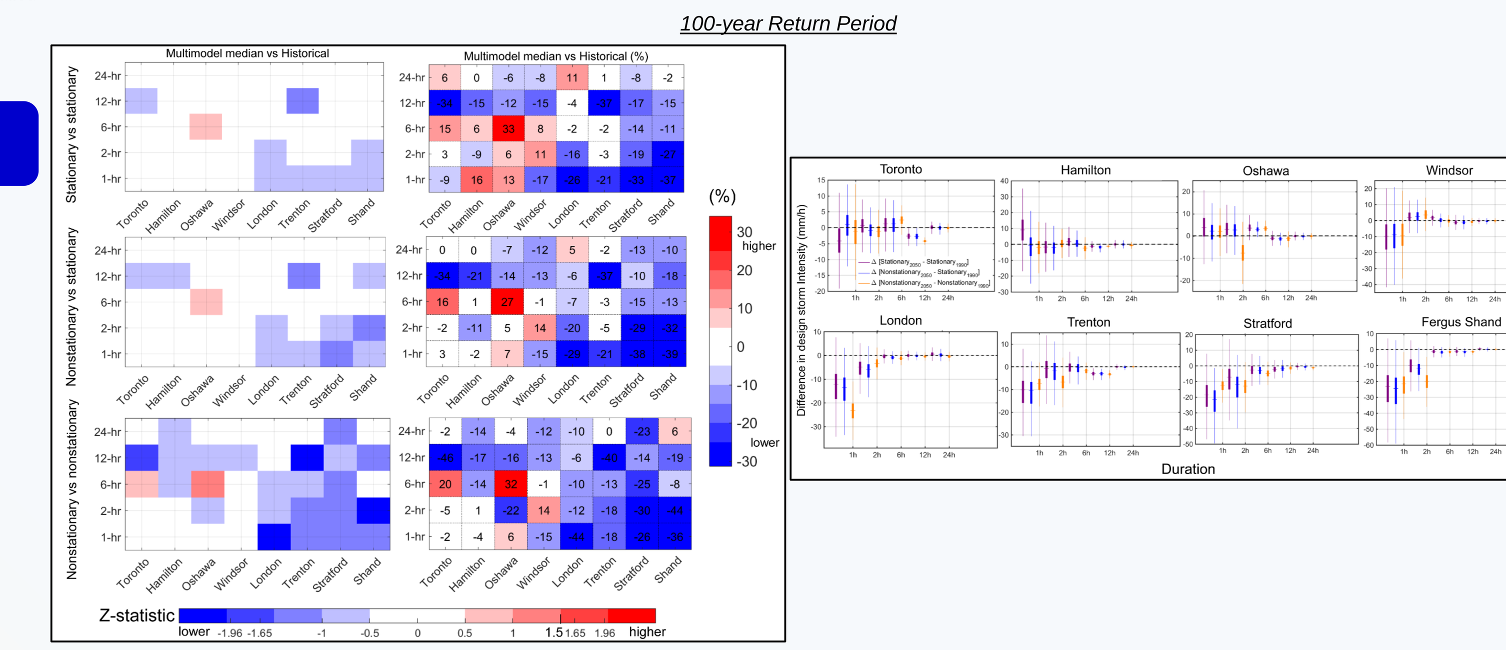


Future vs Baseline IDF: 10- & 50- year Return Periods

50-year Return Period



100-year Return Period



Conclusions

Station-based observation: Nonstationary vs Stationary IDF

- Nonstationary trends are prominent in short-duration rainfall extremes
- The stationary versus nonstationary models do not exhibit any statistically significant differences in the design storm intensity

Future Scenario: RCP8.5

- Nonstationary projected IDF curves are developed using high-resolution RCMs archived at NA-CORDEX domain
- In near future, storm intensities are expected to intensify at less than 25-year events while opposite trend is noticed for larger return period events

Related Publications

- Ganguli, P and Coulibaly, P. Does nonstationary in rainfall requires nonstationary Intensity-Duration-Frequency curves? Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-325 (in review)
- Ganguli, P and Coulibaly, P. Assessment of future changes in intensity-duration-frequency curves for Southern Ontario using North American (NA) – CORDEX models with nonstationary methods. arXiv:1706.00122.

References

- T.F. Stocker et al. IPCC AR5 Working Group I: Phys. Sci. Basis, **1535** (2013).
- C.B. Field et al. IPCC SREX Managing the risk of extreme events and disasters to advance climate change adaptation, **582** (2012).
- J. Olsson, *Hydrol. Earth Syst. Sci. Discuss.* **2**, 19–30 (1998).
- L. Cheng, A. AghaKouchak, *Sci. Rep.* **4** (2014), doi: 10.1038/srep07093.

Acknowledgement

- Primary Funding Source: NSERC Canadian FloodNet
- Special thanks to Toronto Region Conservation Authority (TRCA) and Essex Region Conservation Authority (ERCA) for sharing hourly rainfall data.
- The daily rainfall data and design rainfall volume is downloaded from Environment Canada Historical (http://climate.weather.gc.ca/) and Engineering (ftp://ftp.tor.ec.gc.ca/Pub/Engineering_Climate_Dataset/IDF/) database respectively .

[1] McMaster Water Resources and Hydrologic Modeling Lab, McMaster University, http://www.hydrology.mcmaster.ca/

*Contact Information: gangulip@mcmaster.ca