Extreme Rainfall Nonstationary Investigation and Evaluation of Nonstationary-based Intensity-Duration-Frequency (IDF) Curves for Southern Ontario Region in a Changing Climate

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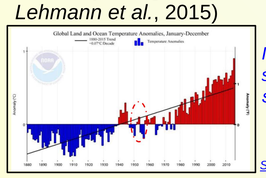
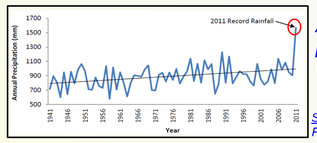
Introduction and Background

- Global hydrological cycle is expected to intensify in a warming climate (*Donat et al.,* 2016; *Lehmann et al.*, 2015)



Increase in land-surface temp. anomaly since 1880s'

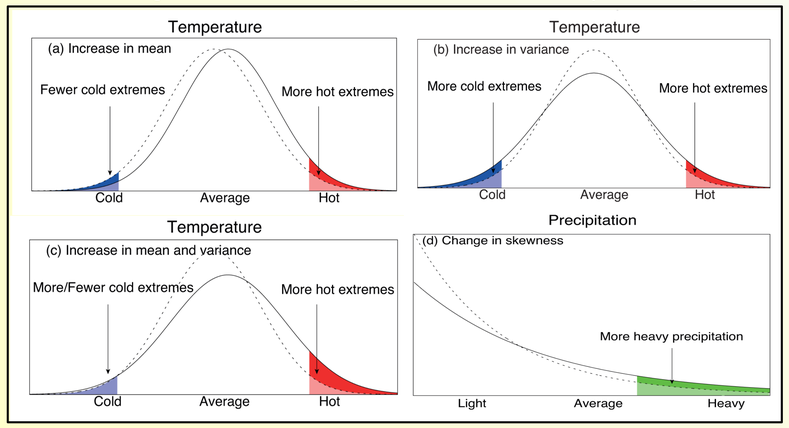
Source: https://www.ncdc.noaa.gov/



Annual average precipitation in Windsor (1941-2011)

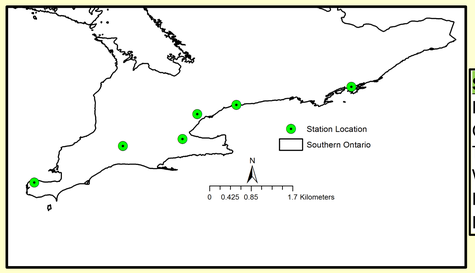
Source: Climate Change Action Plan: The City of Windsor'2012

- 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



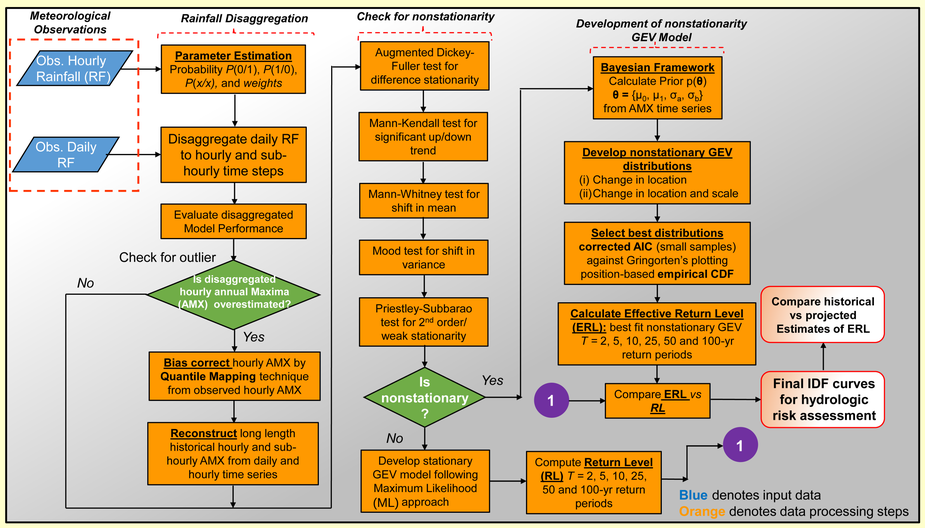
Source: IPCC AR5 Chapter **1** (Fig. **1.8**), Page *134*

Study Area and Data

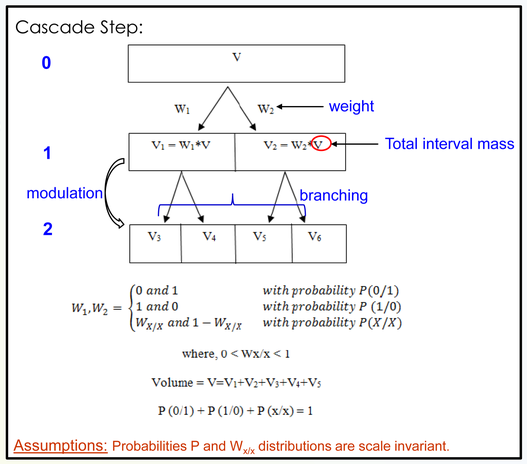


Stations	Hourly	Daily
Hamilton	1971 - 2003	1960 - 2011
Oshawa	1970 - 1999	1970 - 2015
Toronto Person Intl. Airport	1960 - 2012	1940 - 2012
Windsor	1960 - 2007	1940 - 2014
Kingston	1961 - 2003	1960 - 2007
London	1961 - 2001	1940 - 2015

Process Flow to Develop Nonstationary IDF



Multiplicative Random Cascade (MRC) for Rainfall Disaggregation



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

Volume Classes *Olsson (1998)*

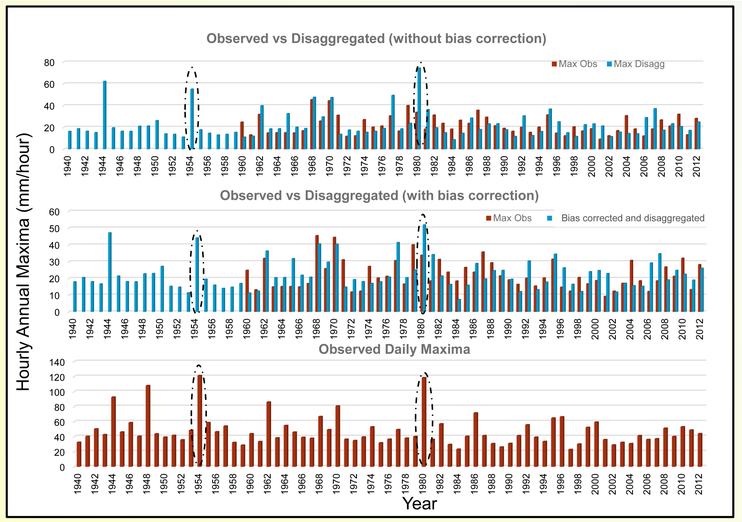
- **Starting box**: Period in the beginning of sequence, proceeded by a dry period and succeeded by a rainy period
- **Enclosed box**: Period within a sequence, preceded and succeeded by rainy period
- **Ending box**: Period in the end of sequence, preceded by a rainy period and succeeded by a dry period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

Performance Evaluation of MRC: A. McMaster Weather Station Data

Table: Model performance for daily to hourly and daily to sub-hourly rainfall disaggregation (2010 – 2013)

Time	Metrics	Observed	Simulated
Hourly	Zero values (%)	91.92	91.50
	# of extremes (> 25mm)	5	6
	Individual RF volume (μ ± σ) mm	1.60 ± 2.95	1.45 ± 2.89
	Event volume (μ ± σ) mm	4.52 ± 10.40	4.50 ± 8.82
	Event Duration (μ ± σ) hour	2.83 ± 3.51	3.09 ± 2.69
	Mean Interarrival time between event, hour	36.82 ± 64.70	37.33 ± 65.10
	Mean Annual Maxima (μ ± σ) mm	39.97 ± 21.42	32.97 ± 12.33
Minute (15-min)	Zero values (%)	94.43	95.35
	Individual RF volume (μ ± σ) mm	0.032 ± 1.20	0.031 ± 1.28
	Event volume (μ ± σ) mm	1.87 ± 6.28	1.96 ± 4.64
	Event Duration (μ ± σ) min	3.15 ± 5.77	2.94 ± 3.47
	Mean Interarrival time between event, min	59.54 ± 177.33	64.12 ± 182.01
	Mean Annual Maxima (μ ± σ) mm	20.4 ± 10.22	23.4 ± 12.70

Performance Evaluation of MRC: B. Hourly Annual Maxima of Pearson International Airport, Toronto



References

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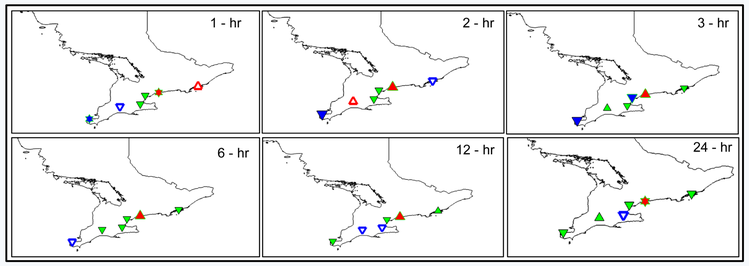
Detection of Nonstationary Trends



Development of Nonstationary IDF

- Nonstationary GEV (*Cheng et al., 2014*)

$$G(x) = \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right\} \quad -\infty < \mu,\ \xi < \infty,\ \sigma > 0$$

- Model **I**: Nonstationary in location $\mu(t) = \mu_0 + \mu_1 t$
- Model **II**: Nonstationary in location and scale

$\tilde{\mu}(t) = \mu_0 + \mu_1 t,\ \tilde{\sigma}(t) = \exp(\sigma_0 + \sigma_1 t),\ \xi(t) = \xi$

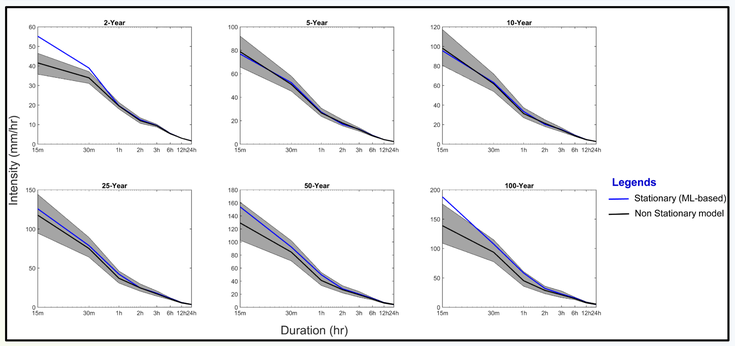
- Return level estimate $q_p = \tilde{\mu} + \frac{\tilde{\sigma}}{\xi}\left(\left(-\frac{1}{\ln p}\right)^{\xi} - 1\right),\ \xi \neq 0; \quad T = \frac{1}{1-p}$

Selection of Best Model for IDF Development

Table: Selection of best fitted GEV distribution for **2-hour** annual maximum rainfall

Models	ξ	σ_1	σ_2	μ_1	μ_0	AIC_c
Stationary (ML-based)	-0.10	2.94			10.15	-85.53
Model I (50th percentile)	-0.21	6.46		0.09	6.84	**-101.79**
Model II (50th percentile)	0.05	-0.0017	1.29	-0.01	11.54	-86.24

IDF Curves for Toronto International Airport (1950-2012)



Conclusions and Future Work

Conclusions

- Nonstationary trends are prominent in hourly annual maxima rainfall
- Nonstationary GEV models simulate extremes better than stationary models
- Significant difference in return levels for 2-, 50-, and 100-year return periods

Future Work

- Develop IDF using nonstationary method for current and projected time period
- Compare difference in return level estimates in stationary and nonstationary models during current and projected time periods

Acknowledgement

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