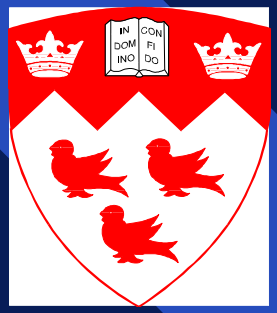


McGill

ON STATISTICAL MODELING OF EXTREME RAINFALL PROCESSES FOR URBAN WATER INFRASTRUCTURE DESIGN IN THE CONTEXT OF CLIMATE CHANGE

Van-Thanh-Van Nguyen
and
Others (Students and Collaborators)

OUTLINE

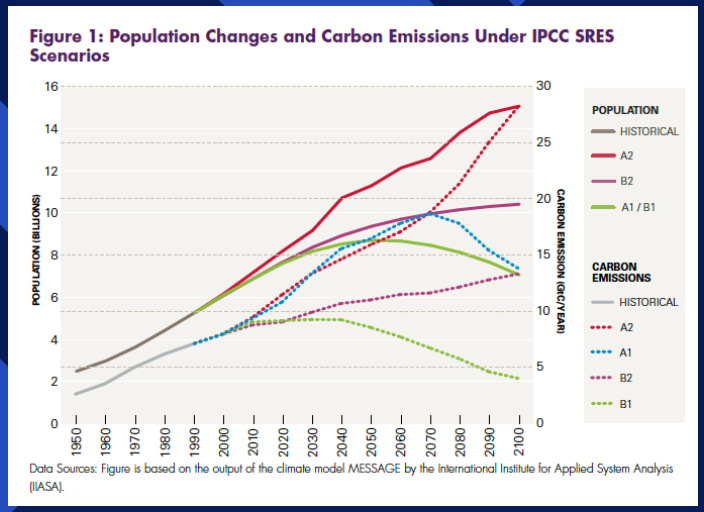
- Urban Water Management - Challenges and Issues?
- Climate Variability and Climate Change - Scale Mismatch?
- Objective: Modeling of Extreme Rainfall Processes in the Climate Change Context
- Methods and Practical Tools
  - Decision-Support Tool
  - Technical Guideline
- Conclusions

Urban Environmental Challenges and Issues

- **Population Growth:** Water Stress
- **Urbanization:** Land-use Change Impacts
- **Climate Change** Impacts:
  - **Water Quantity Issues**: floods, droughts, water supply, etc.
  - **Water Quality Issues**: water pollution, water treatment, etc.
  - **Public Health:** heat-related mortality, spreading of infectious diseases, etc.
  - **Transportation:** road maintenance, etc.
  - **Infrastructure:** durability of materials, etc.

HOW TO ASSESS THESE IMPACTS ON HYDROLOGIC PROCESSES AT THE CATCHMENT SCALE (e.g., "SMALL" URBAN AREAS)?

➡ **The SPATIAL and TIME SCALE Issues?**



Climate Variability and Climate Change

- **How to Quantify Climate Change?**

  General Circulation Models (GCMs):

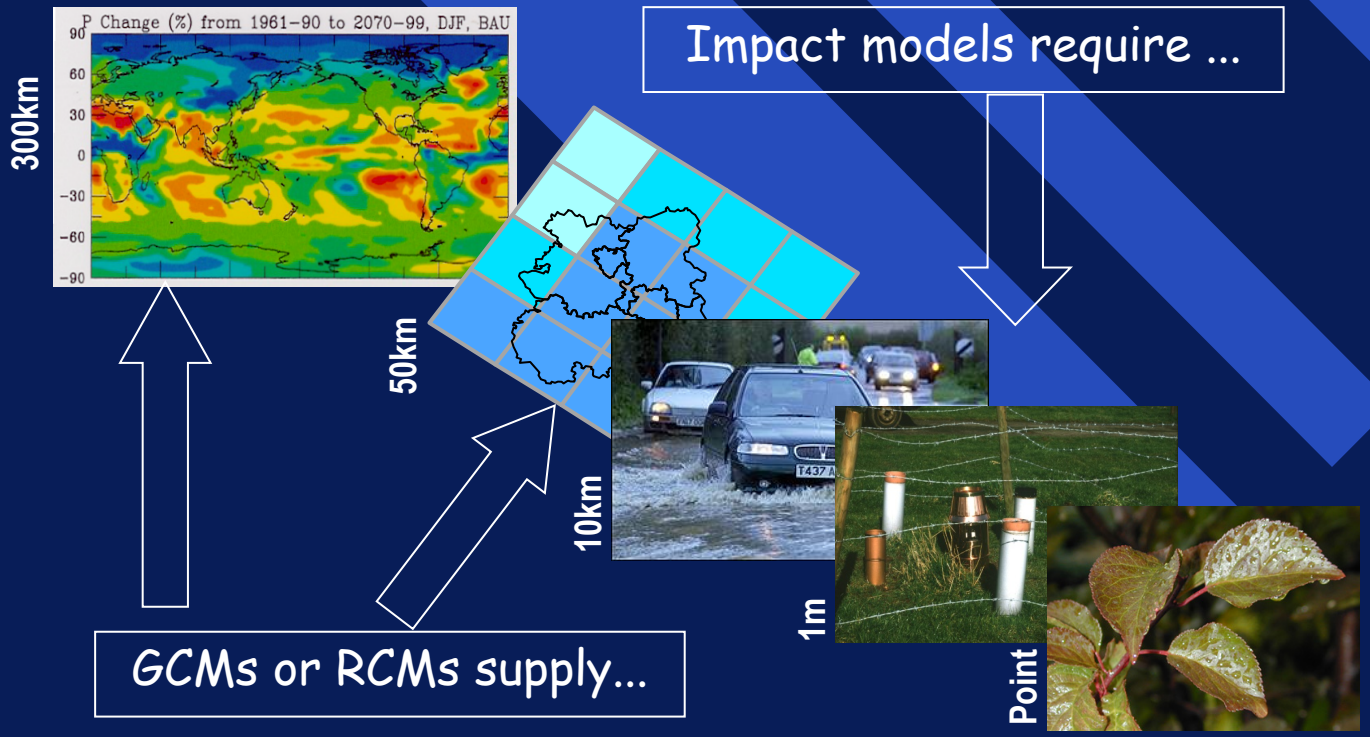
  - A credible simulation of the "average" "large-scale" seasonal distribution of atmospheric pressure, temperature, and circulation.
  - Climate change simulations from GCMs are "inadequate" for impact studies on regional scales:
    - Spatial resolution ~ 50,000 km^2
    - Temporal resolution ~ daily, month, seasonal
    - Reliability of some GCM output variables (such as cloudiness ➔precipitation)?

How to develop Climate Change scenarios for impacts studies in hydrology?

- Spatial scale ~ a few km² to several 1000 km²
- Temporal scale ~ minutes to years

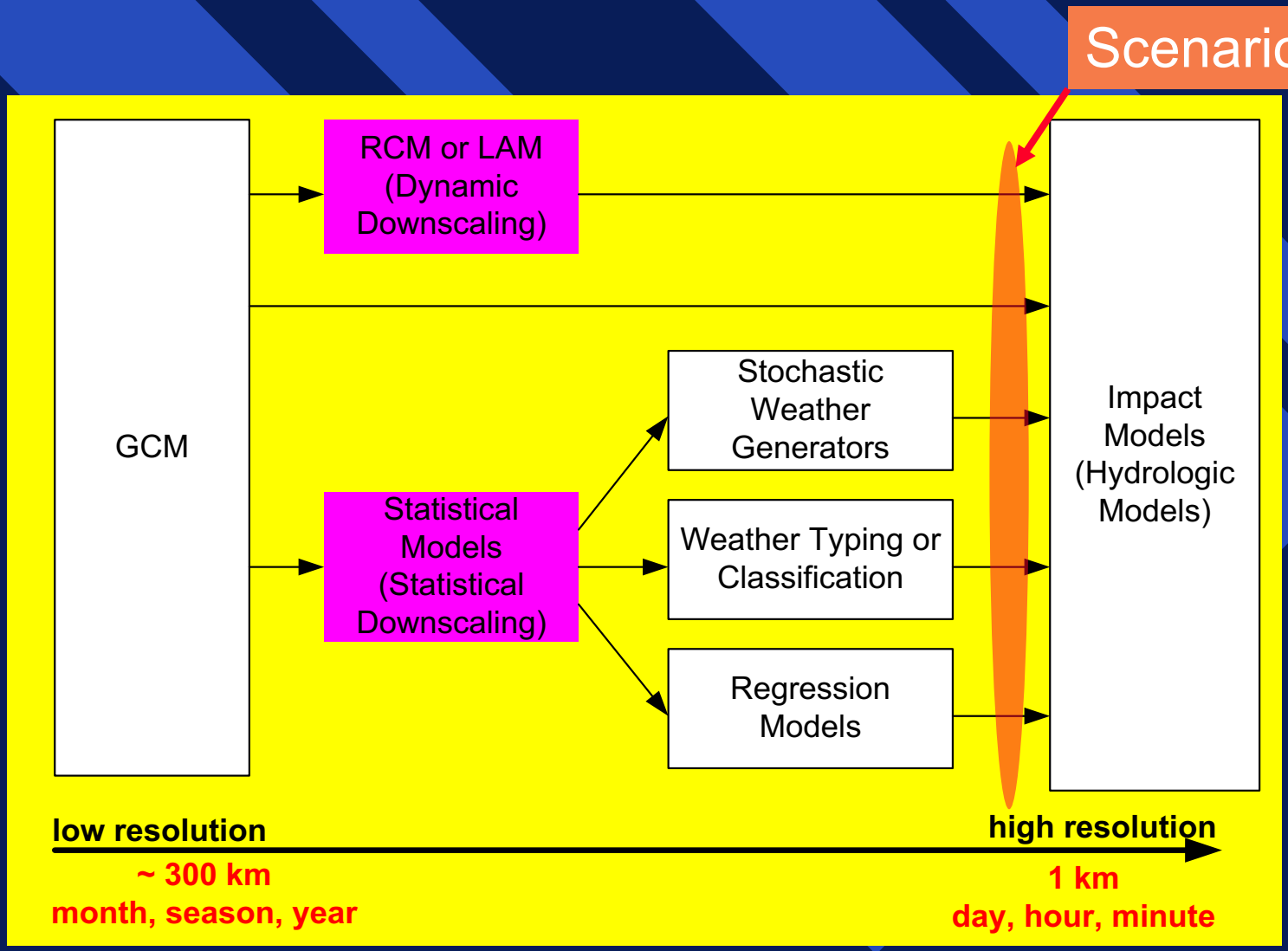
➡ A scale mismatch between the information that GCM can confidently provide and the scales required by impacts studies.

➡ "Downscaling methods" are necessary!!!



(P. Gachon)

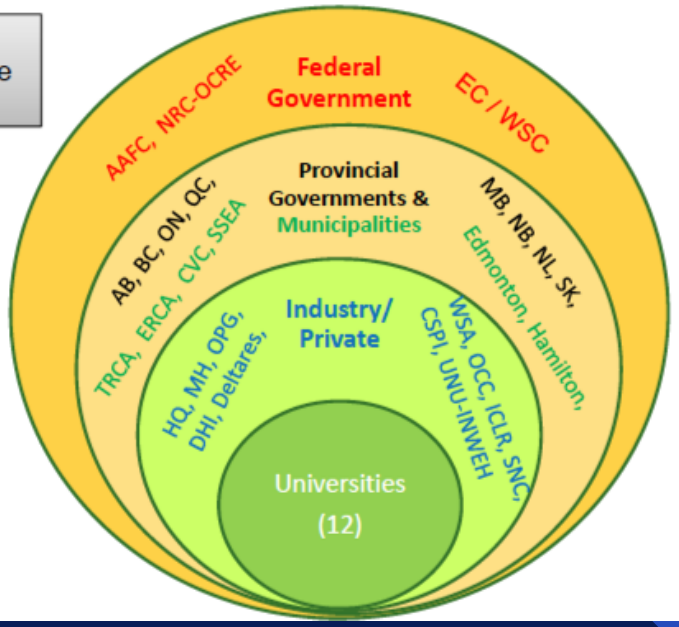
DOWNSCALING METHODS



FLOODNET - NSERC Canadian Strategic Network (2014-2020)

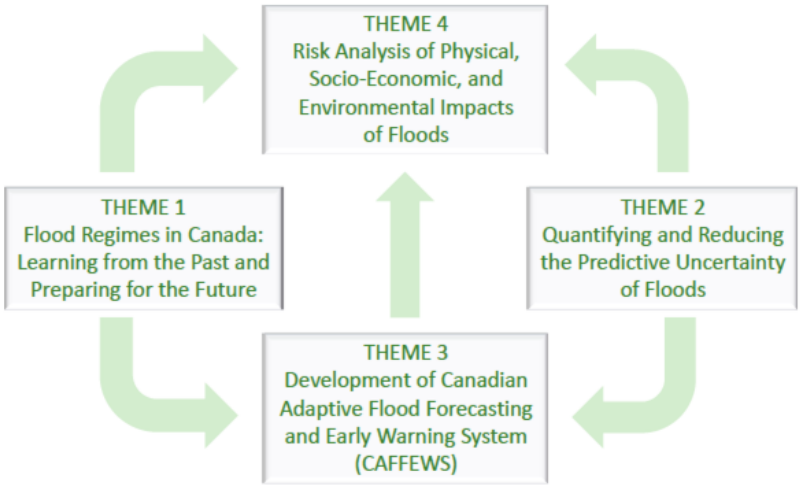
3. FloodNet Team

30 public/private partners



(P. Coulibaly, McMaster University)

4. Research Program: Themes/Projects



4. Research Program: Outcomes

Theme	Examples of outcomes
Theme 1	• Manual and statistical tools for flood frequency analysis in Canada. • New guidelines and procedures for updating IDF curves.
Theme 2	• New optimization framework for multi-reservoirs operation. • Forecast system evaluation tool and guidelines for the use of ensemble forecasts in operational flood forecasting.
Theme 3	• Data estimation tool for addressing the common issue of the paucity of monitoring networks. • Canadian adaptive flood forecasting and early warning system (CAFFEWS).
Theme 4	• Integrated flood vulnerability indicators for planning and decision making. • New knowledge for enhanced understanding of flood impacts on agricultural lands and aquatic ecosystems.

PROJECT OBJECTIVE AND KEY CHALLENGES

OBJECTIVE:

Evaluate climate change impacts on Intensity-Duration-Frequency (IDF) curves and develop new regional IDF curves for selected cities in Canada.

KEY CHALLENGES:

- **Climate Change Impacts:**
  - **Downscaling Approaches**
  - **Non-stationarity Process**
- **Single-Site and Regional Rainfall Modeling:**
  - **Multi-site Modeling Methods**
  - **Regionalization Methods (Ungaged Sites)**

CANADIAN STANDARDS ASSOCIATION - TECHNICAL GUIDE

Bookmarks

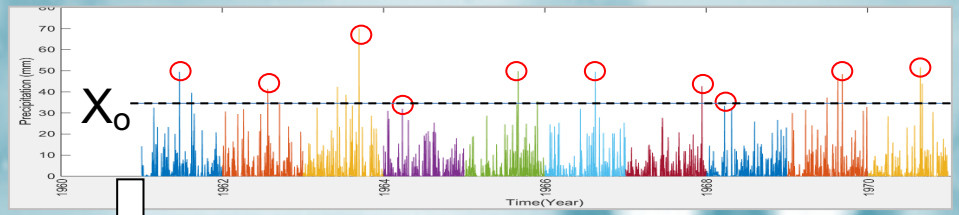
CSA GROUP™

CSA PLUS 4013:19

TECHNICAL GUIDE
Development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resources practitioners

IDF RELATIONS

Observed Rainfall Data – Complete Time Series

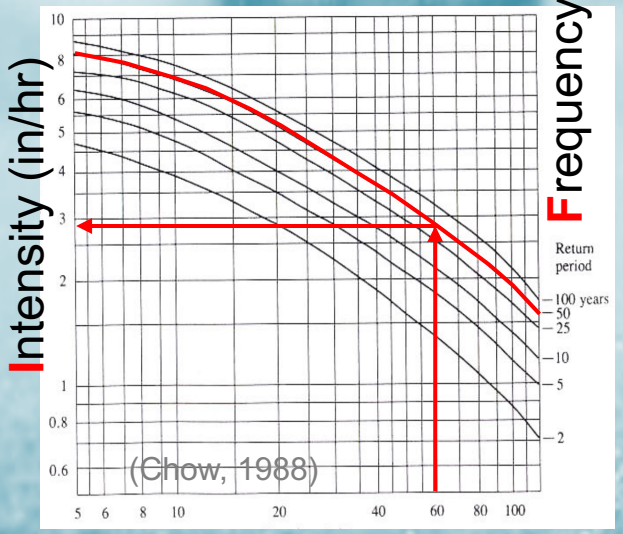


Extreme Rainfall Series

Rainfall Frequency Analysis

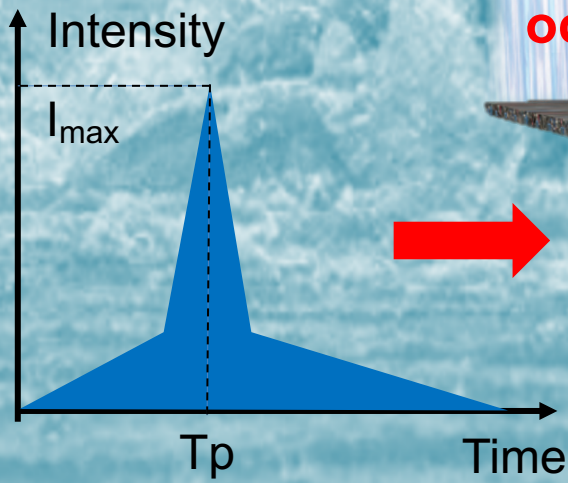
IDF Curves

Design Storm

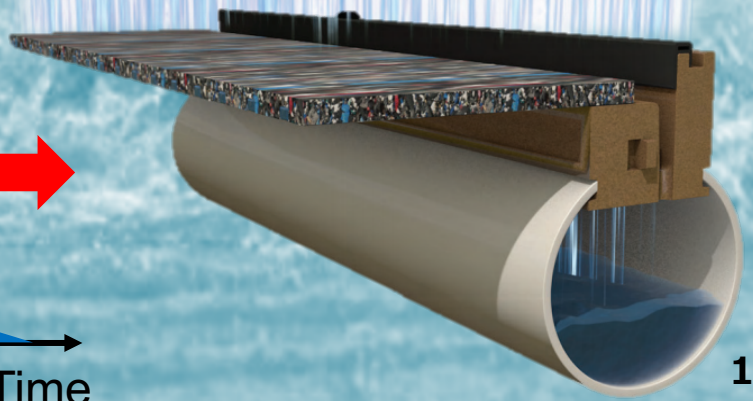


ISSUES:

- To analyze a large amount of data for different time scales and for different stations.
- To select a suitable probability distribution for a given site or region.
- To develop IDF relations for the current climate.
- To assess the climate change impacts on IDF relations.

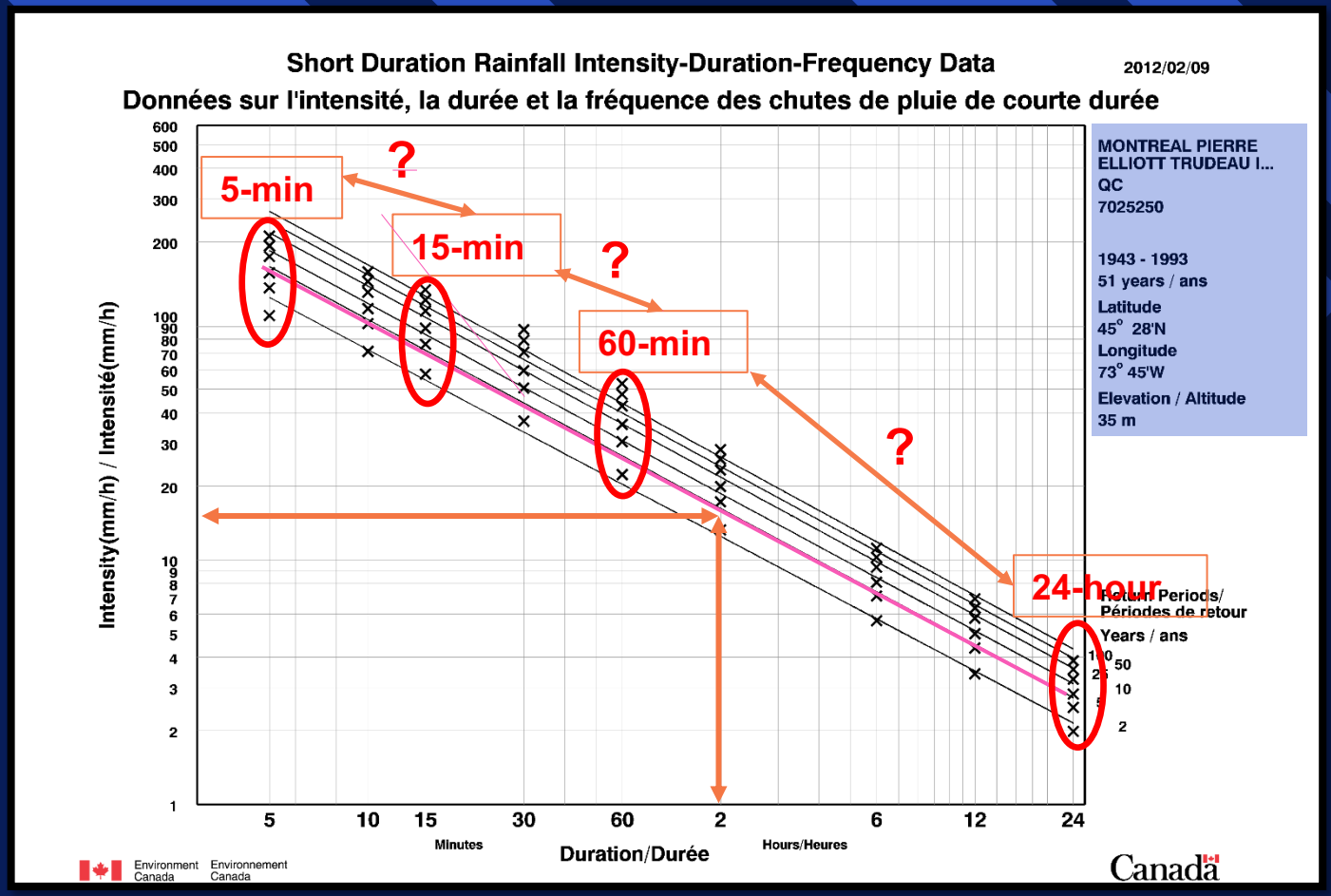


Probability of extreme rainfall occurrence & amount ???



Extreme rainfall estimation

Design Rainfall = to estimate **maximum amount** of rainfall at a given site for a ***specific duration*** and ***return period*** ⇒ ***Intensity-Duration-Frequency (IDF) curves***



Statistical Downscaling – Single Site

GCM Climate Predictors

↓ Is it feasible?

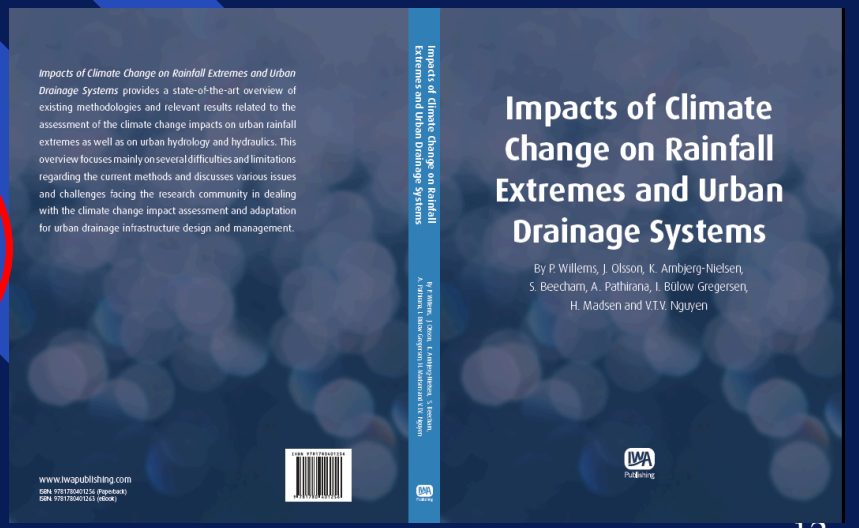
Local Daily Precipitation Series

↓ Is it feasible?

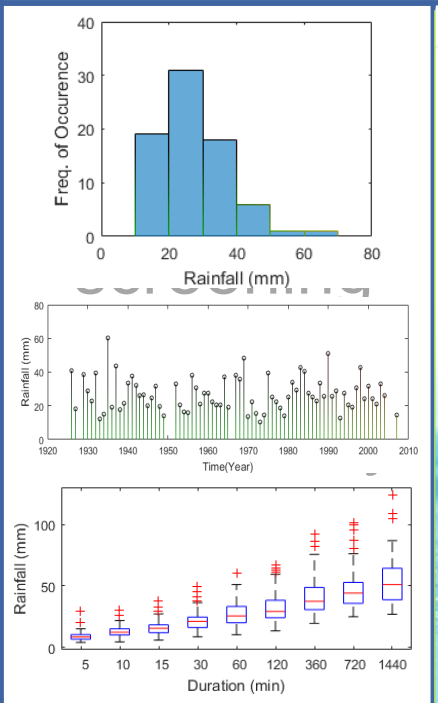
Daily Extreme Precipitations

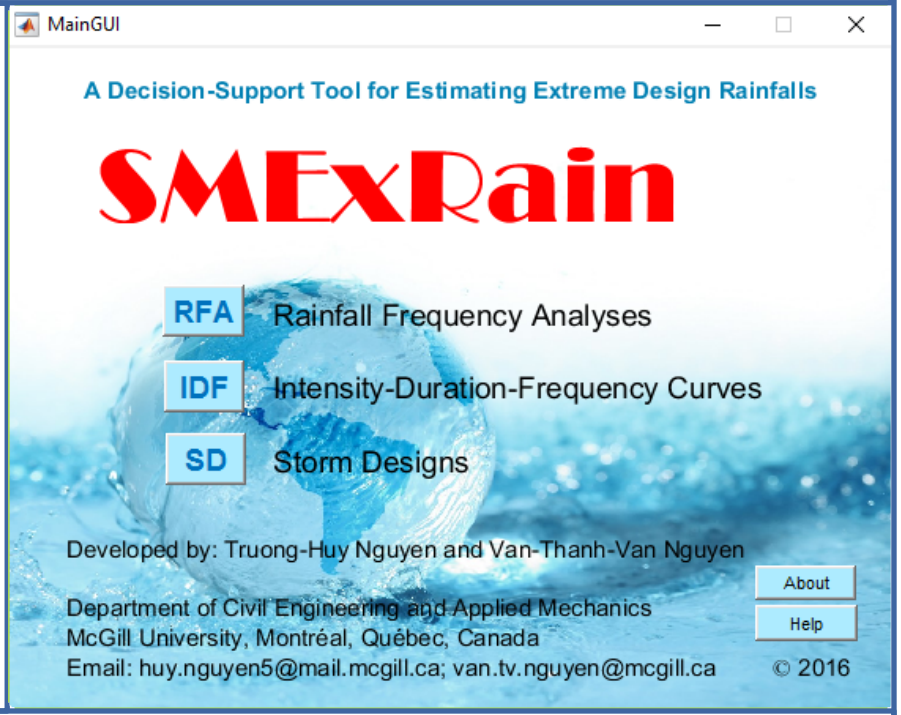
↓ Is it feasible?

Sub-Daily Extreme Precipitations

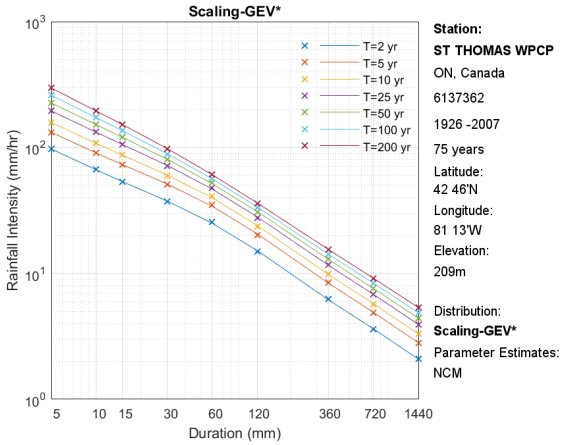


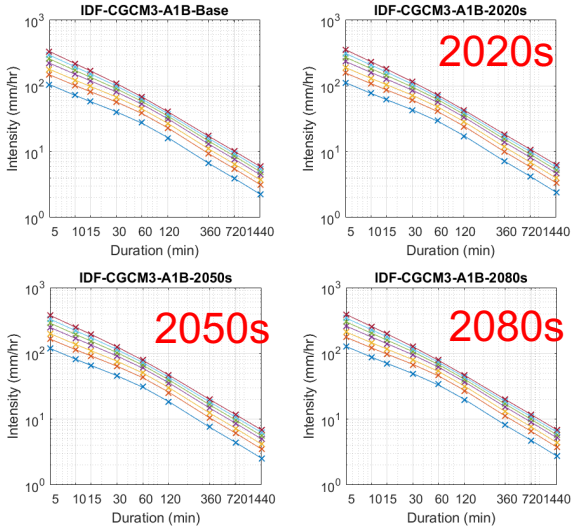
Software Description

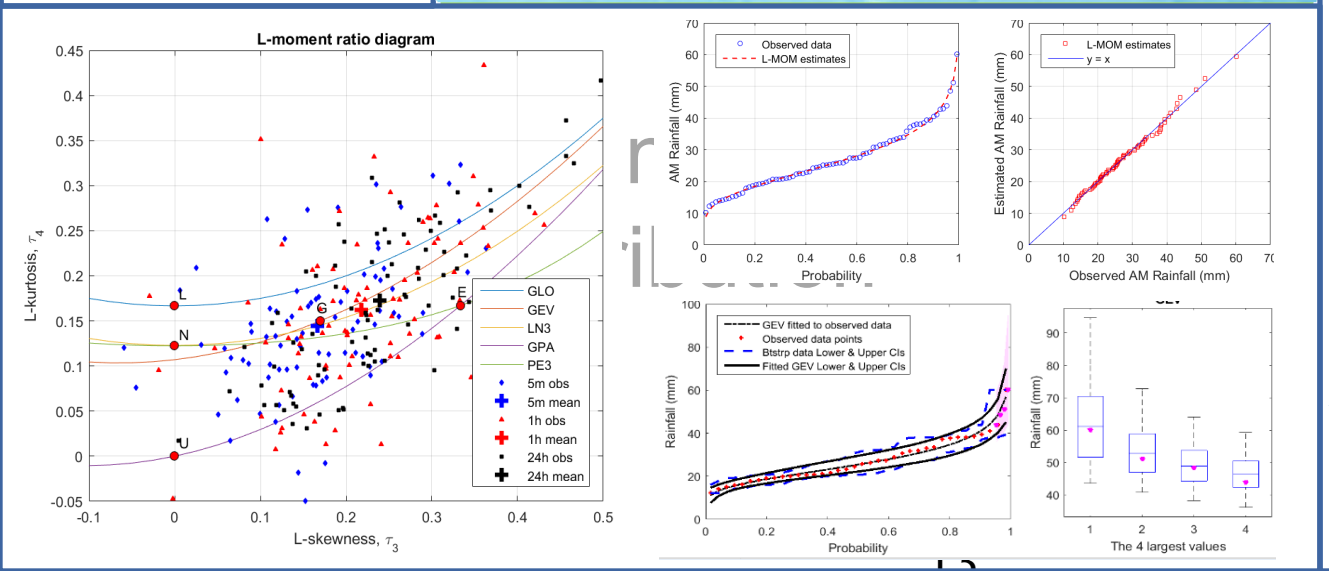




IDF Relations

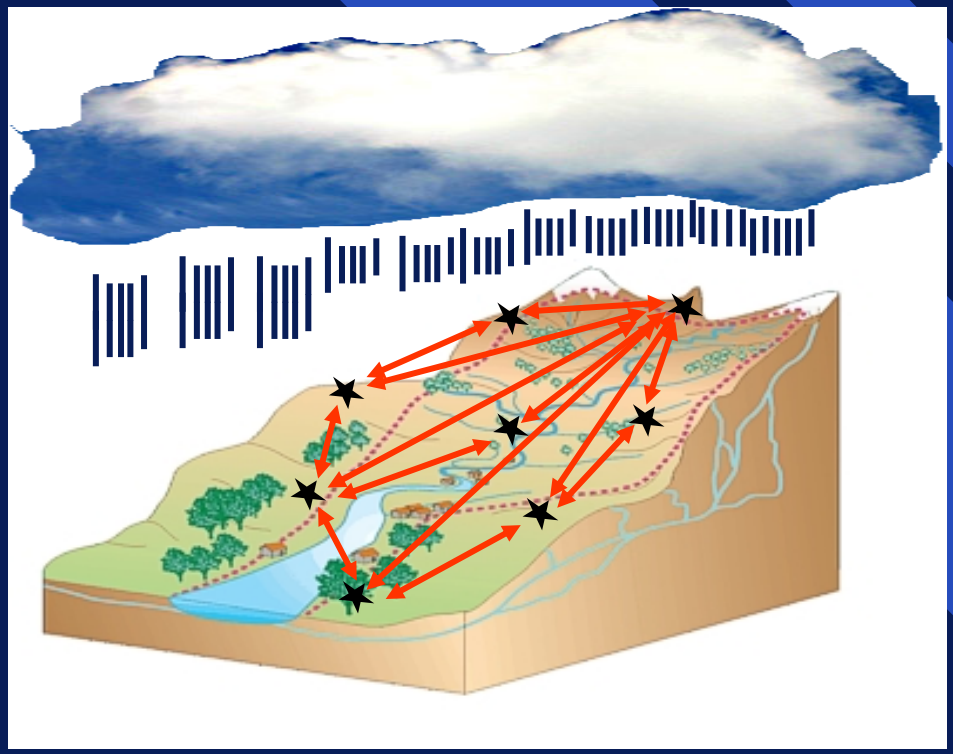






Multisite and Multivariate Statistical Downscaling Approach

- Spatial (between-site) correlation
- Temporal (at-site) correlation
- Correlation between Tmax and Tmin



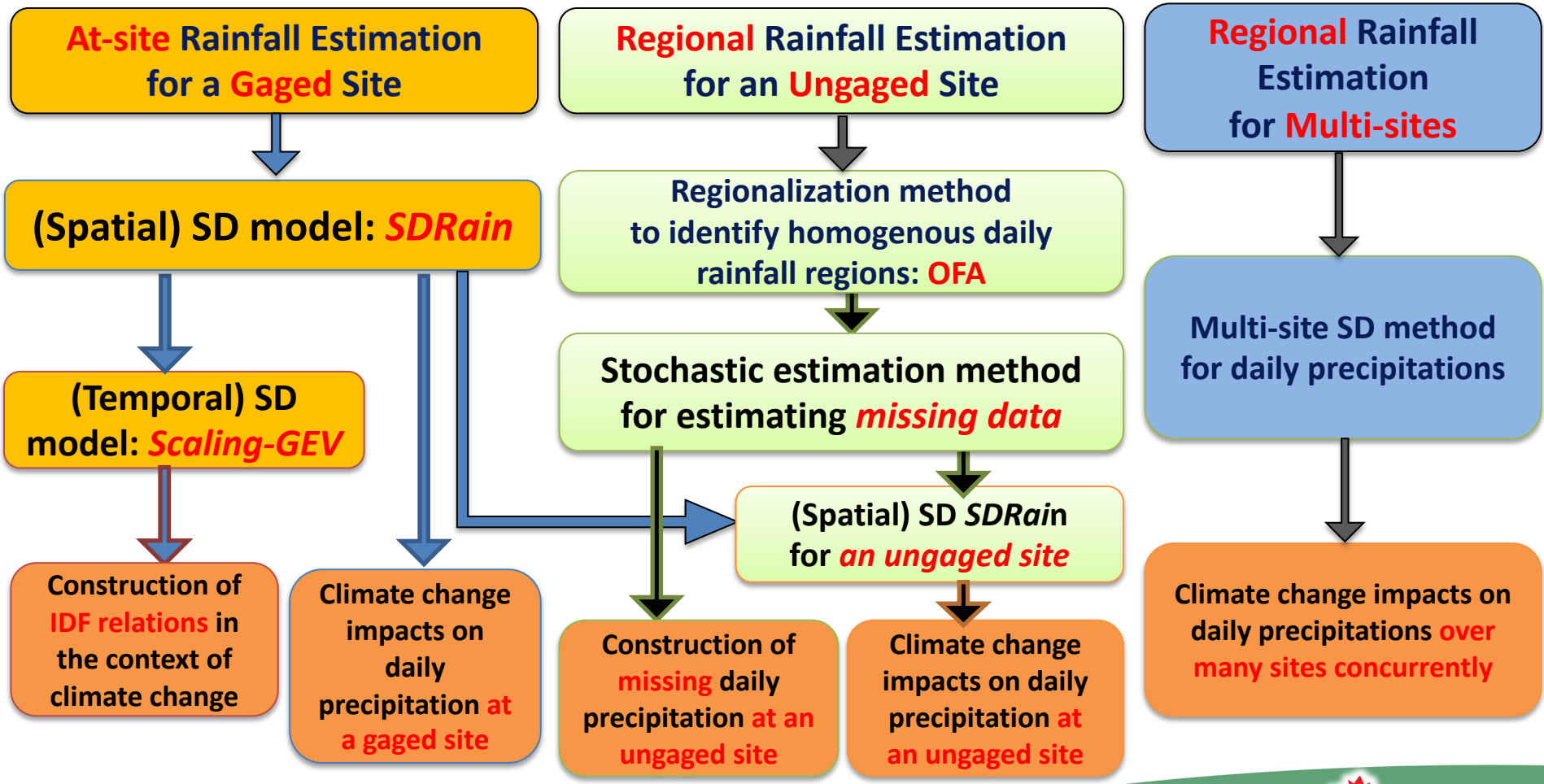
Daily Extreme Temperatures:

- Khalili et al., Int. J. Climatology, 2011
- Khalili and Nguyen, ASCE J. of Hydrologic Eng., 2018.

Daily Precipitation Series:

- Khalili and Nguyen, Climate Dynamics, 2017
- Khalili and Nguyen, Stoch. Env. Res. and Risk Ass., 2018

SUMMARY OF RESEARCH PROGRESS: Climate Change Impacts on Extreme Rainfalls - SDExRain



CONCLUSIONS

- Significant advances have been achieved regarding the global climate modeling. However, GCM/RCM outputs are still not appropriate for assessing climate change impacts at the regional or local scales.
- Downscaling methods provide useful tools for this assessment.
- In general, statistical downscaling models could provide "good" but "biased" estimates of the observed statistical properties of the daily precipitation and extreme temperature processes at a local site. Hence, bias-correction methods are required.
- It is feasible to assess the impacts of climate change on runoff at small watershed scales using the proposed precipitation downscaling methods for gaged and ungaged sites.

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1. Herath, S.M., Sarukkalige, P.R., and Nguyen, V-T-V. (2016), A spatial temporal downscaling approach to development of IDF relations for Perth airport region in the context of climate change, ***Hydrological Sciences Journal***, 61:11, 2061-2070, DOI:10.1080/02626667.2015.1083103.
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3. Khalili, M. and Nguyen, V-T-V. (2017), An efficient statistical approach to multi-site downscaling of daily precipitation series in the context of climate change, ***Climate Dynamics***, DOI: 10.1007/s00382-016-3443-6.
4. Nguyen, T-H., El Outayek, S.; Lim, S-H., and Nguyen, V-T-V. (2017), A Systematic Approach to Selecting the Best Probability Models for Annual Maximum Rainfalls – A Case Study Using Data in Ontario (Canada), ***Journal of Hydrology,***553, pp. 49-58 http://dx.doi.org/10.1016/j.jhydrol.2017.07.052
5. Khalili, M. and Nguyen, V-T-V. (2018), Efficient Statistical Approach to Multisite Downscaling of Extreme Temperature Series Using Singular Value Decomposition Technique, ***ASCE Journal of Hydrologic Engineering.*** 23(6), DOI:10.1061/(ASCE)HE.1943-5584.0001662.
6. Khalili, M. and Nguyen, V-T-V. (2018), A Perfect Prognosis Approach for Daily Precipitation Series in Consideration of Space-Time Correlation Structure, ***Stochastic Environmental Research and Risk Assessment,*** DOI:10.1007/s00477-018-1625-y.

PUBLICATIONS

7. Nguyen, T-H. and Nguyen, V-T-V. (2019), A Decision Support Tool for Constructing Robust IDF Relations in Consideration of Model Uncertainty, ***ASCE Journal of Hydrologic Engineering,*** 24(7), DOI:10.1061/(ASCE)HE.1943-5584.0001802.
8. Hassanzadeh, E., Nazemi, A., Adamowski, J., Nguyen, T-H., and Nguyen, V-T-V. (2019), Quantile-based downscaling of rainfall extremes: Notes on methodological functionality, associated uncertainty and application in practice, ***Advances in Water Resources,*** 131, 13 pages, https://doi.org/10.1016/j.advwatres.2019.07.001.
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10. Nguyen, T-H., and Nguyen, V-T-V. (2020). Linking climate change to urban storm drainage system design: An innovative approach to modelling of extreme rainfall processes over different spatial and temporal scales**, *Journal of Hydro-environment Research,*** *29: 80-95.DOI:10.1016/j.jher.2020.01.006*.
11. Yeo, M-H, Nguyen, V-T-V., and Kponodu, T. A. (2020). Characterizing extreme rainfalls and constructing confidence intervals for IDF curves using scaling-GEV distribution model, ***International Journal of Climatology*** (in press).

Thank you for your attention!

Van-Thanh-Van Nguyen
Email: van.tv.nguyen@mcgill.ca
http://www.mcgill.ca/civil/