Investigating Techniques for Flood Quantile Estimation in Canada

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Outline of Presentation

1. Introduction
2. Flood Frequency Analysis
3. Regional FFA
4. Seasonality Measure
5. Region of Influence
6. Study area & Dataset
7. Regional Models

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Introduction

- Floods are a damaging form of natural disaster
- Effects have been experienced around the world
- Most common natural hazard in Canada

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Introduction

- Effective mitigation requires reliable flood estimation
- Accurate estimation of probability of exceedance
- Requirement for design of flood protection infrastructure

Flood Frequency Analysis

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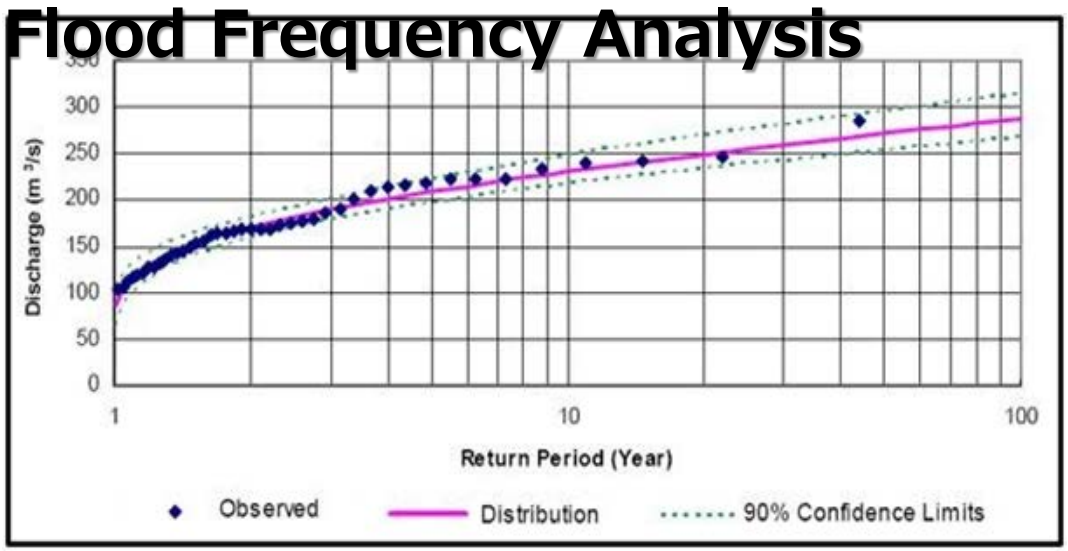
Flood Frequency Analysis

- Studying the past events
- Determine the probability of future occurrences
- Theoretical frequency distribution



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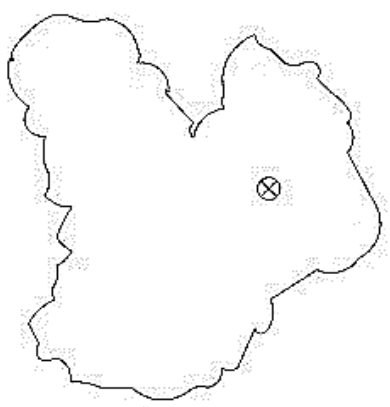
Flood Frequency Analysis

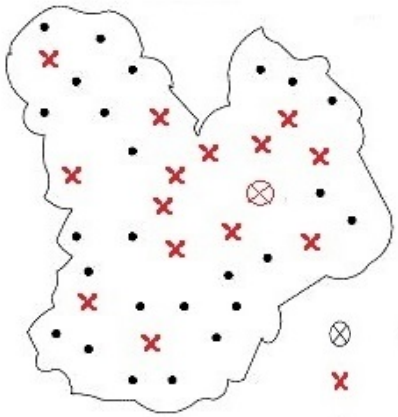
- At-site flood frequency analysis
- Reliable for sufficiently long flow records
- Insufficient gauging network/data record



40
station year

Resolution: Trading space for time

Regional Frequency Analysis



500
station years

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Regional Flood Frequency Analysis

- Screening for gross error
- Checking IID assumption

- Selecting the best fit distribution
- Goodness-of-fit test

- Constructing confidence intervals

- Constructing homogeneous regions
- Similarity measures
- Pooling techniques

- Quantile flood estimation for different sites within the region

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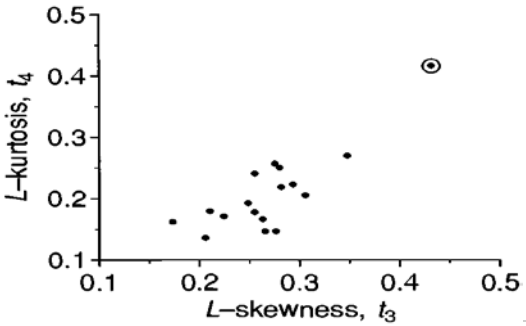
Regional Flood Frequency Analysis

- **Data Screening**
- Regionalization
- Fitting Frequency Distribution
- Flow Estimate
- Uncertainty Estimate

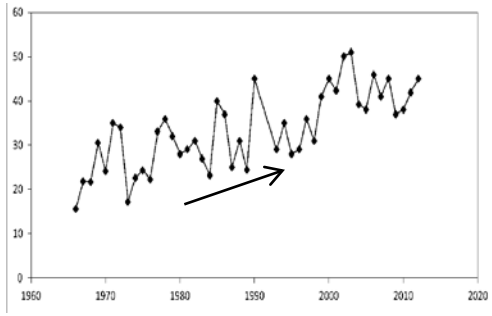
Checking for gross errors

- Incorrect data values
- Outliers



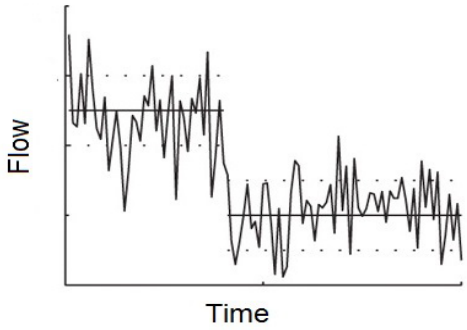
Temporal trend analysis: Mann-Kendall test

- Nonparametric rank-based test
- Significance of monotonic trend
- False trend detection in case of positive correlation
- Block bootstrap test/ resample data in block



Change-point detection

- Nonparametric rank-based test
- Sudden shift in the mean of data



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Regional Flood Frequency Analysis

Data Screening

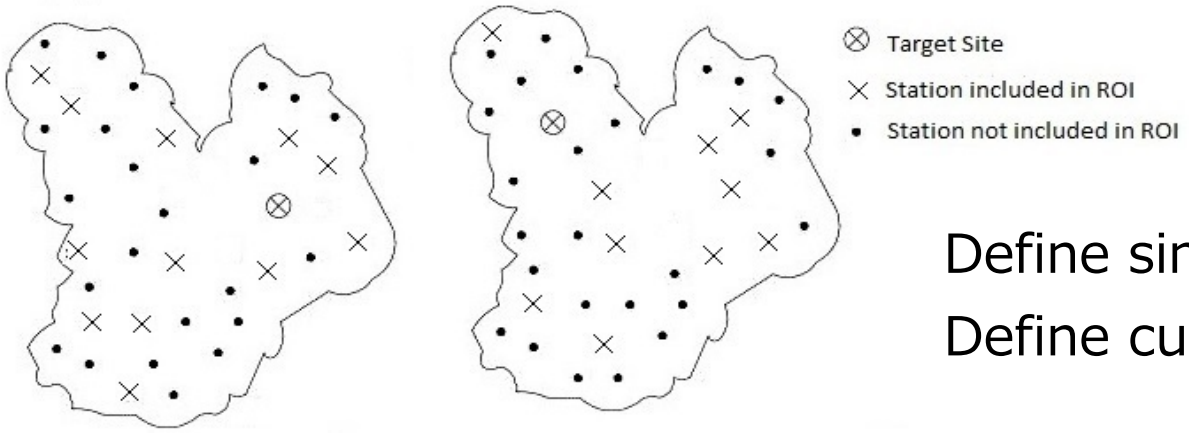
Regionalization

Fitting Frequency Distribution

Flow Estimate

Uncertainty Estimate

- Regionalization approaches
- Formation of homogenous regions
- Based on site focused approach
- Region of Influence approach (ROI)



Define similarity

Define cut-off point

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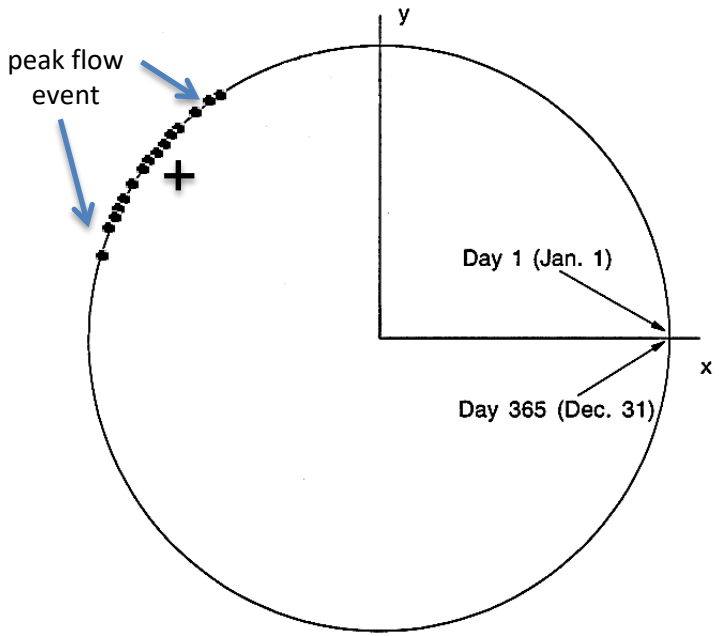
Regional Flood Frequency Analysis

- Data Screening
- **Regionalization**
- Fitting Frequency Distribution
- Flow Estimate
- Uncertainty Estimate

Similarity measure:
- Physiographic characteristics
- Flood statistics
- **Flood seasonality**

Seasonality measure:
- Julian date of peak flow events
- Converted to angular value



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Regional Flood Frequency Analysis

- Data Screening
- Regionalization
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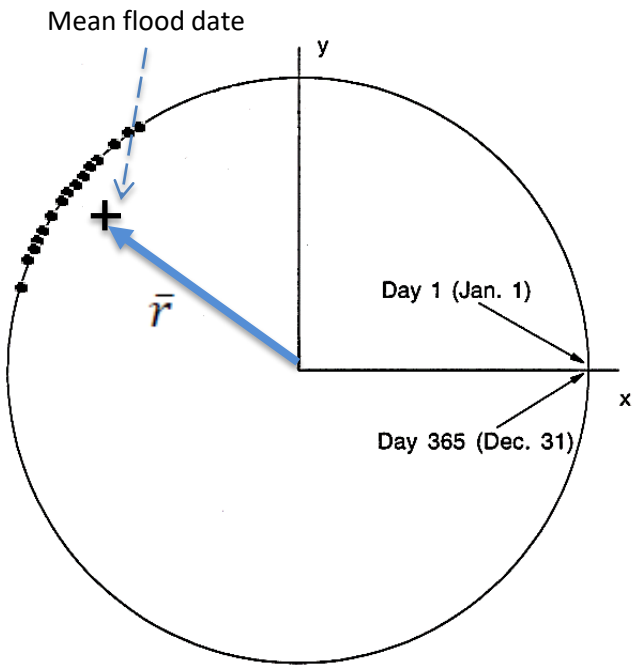
Seasonality measure:

$$\theta_i = (Julian\ Date)_i \frac{2\pi}{365}$$

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} \cos(\theta_i) \qquad \bar{y} = \frac{1}{n}\sum_{i=1}^{n} \sin(\theta_i)$$

$$MD = tan^{-1}\left(\frac{\bar{y}}{\bar{x}}\right)\frac{365}{2\pi}$$

$$\bar{r} = \sqrt{\bar{x}^2 + \bar{y}^2}$$



Flow magnitude as weights:

$$\bar{x}' = \frac{\sum_{i=1}^{n} q_i cos(\theta_i)}{\sum_{i=1}^{n} q_i} \qquad \bar{y}' = \frac{\sum_{i=1}^{n} q_i sin(\theta_i)}{\sum_{i=1}^{n} q_i}$$

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Regional Flood Frequency Analysis

Data Screening

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Fitting Frequency Distribution

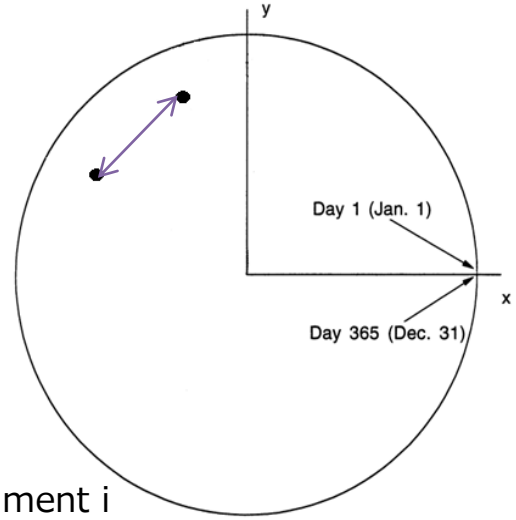
Flow Estimate

Uncertainty Estimate

Similarity measure:

- Distance metric (Euclidian distance)
- Defining closeness of each station to every other
- Seasonality measure is employed in defining similarity between sites

$$D_{ij} = \left[\sum_{m=1}^{M} \left(x_m^i - x_m^j\right)\right]^{1/2}$$



D_{ij} is the dissimilarity between catchment i and j

x_m^i are the coordinated of the mean flood date for catchment i

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Regional Flood Frequency Analysis

Data Screening

Regionalization

Fitting Frequency Distribution

Flow Estimate

Uncertainty Estimate

Based on L-moment theory of Hosking and Wallis (1997):

- Construct L-moments
- Regional weighted average
- Testing homogeneity of pooling groups
- Compares variability of L-moment ratios to expected value

$$H = \frac{(V - \mu_V)}{\sigma_V}$$

If H<1 acceptably homogeneous region
If 1≤H<2 Possibly Heterogeneous region
If H≥2 definitely Heterogeneous region

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Regional Flood Frequency Analysis

Data Screening

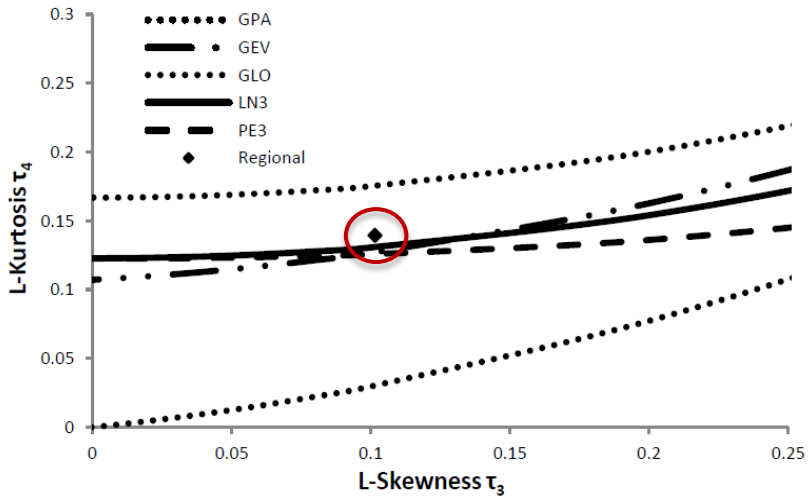
Regionalization

Fitting Frequency Distribution

Flow Estimate

Uncertainty Estimate

- Using the L-moments approach
- Check goodness-of-fit test
- Compare fit of different distributions to regional average
- Select best fitted regional distribution



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Regional Flood Frequency Analysis

Data Screening

Regionalization

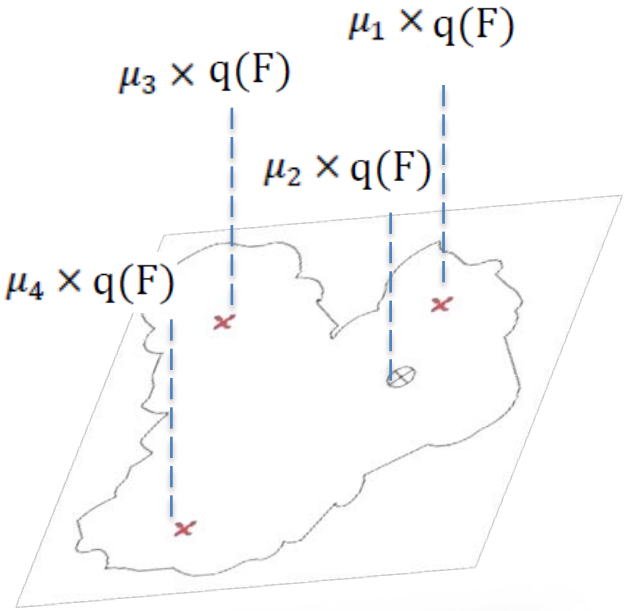
Fitting Frequency Distribution

Flow Estimate

Uncertainty Estimate

- Approach based on index-flood
- Flow quantile at each site
- Product of pooled quantile and index flow

$$Q_i(F) = \mu_i q(F)$$



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Regional Flood Frequency Analysis

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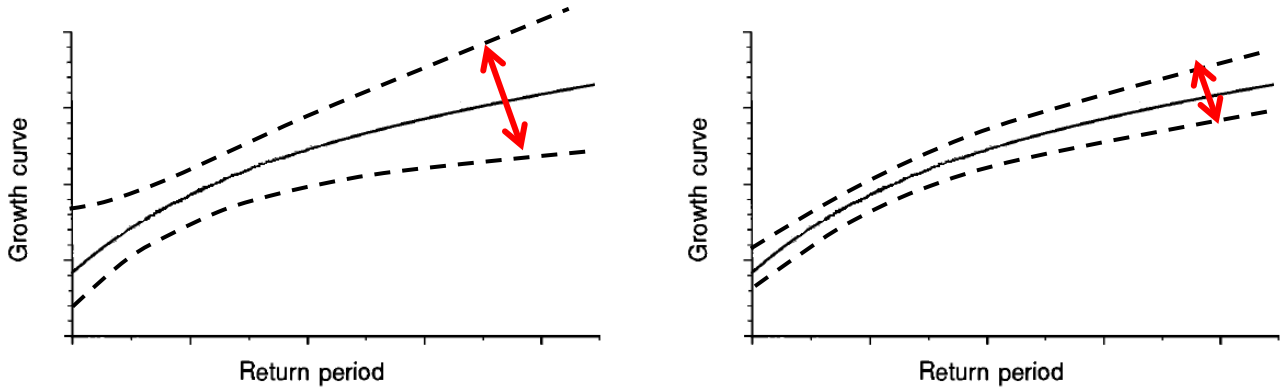
Uncertainty Estimate

Estimating quantile uncertainty:

- Based on confidence interval for quantile estimates
- Bootstrap approach was used
- For both at-site and pooled quantiles
- Narrower CI, lower uncertainty



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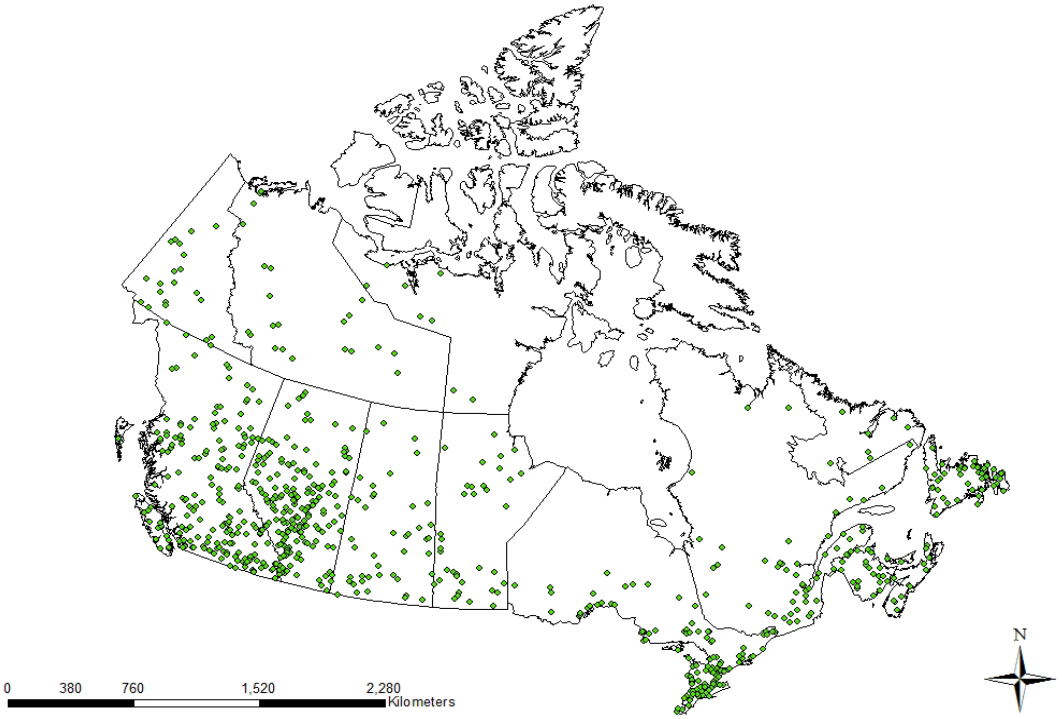
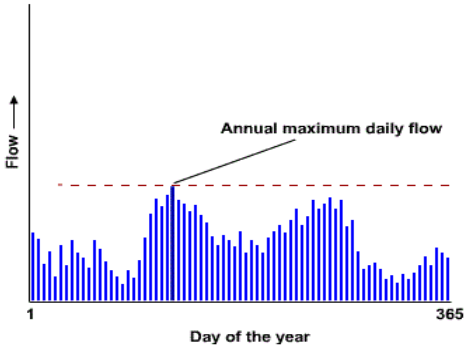
Regional Models

- 771 Hydrometric stations
- Minimum 20 years of recorded flows
- 20 to 111 years range of stationary records





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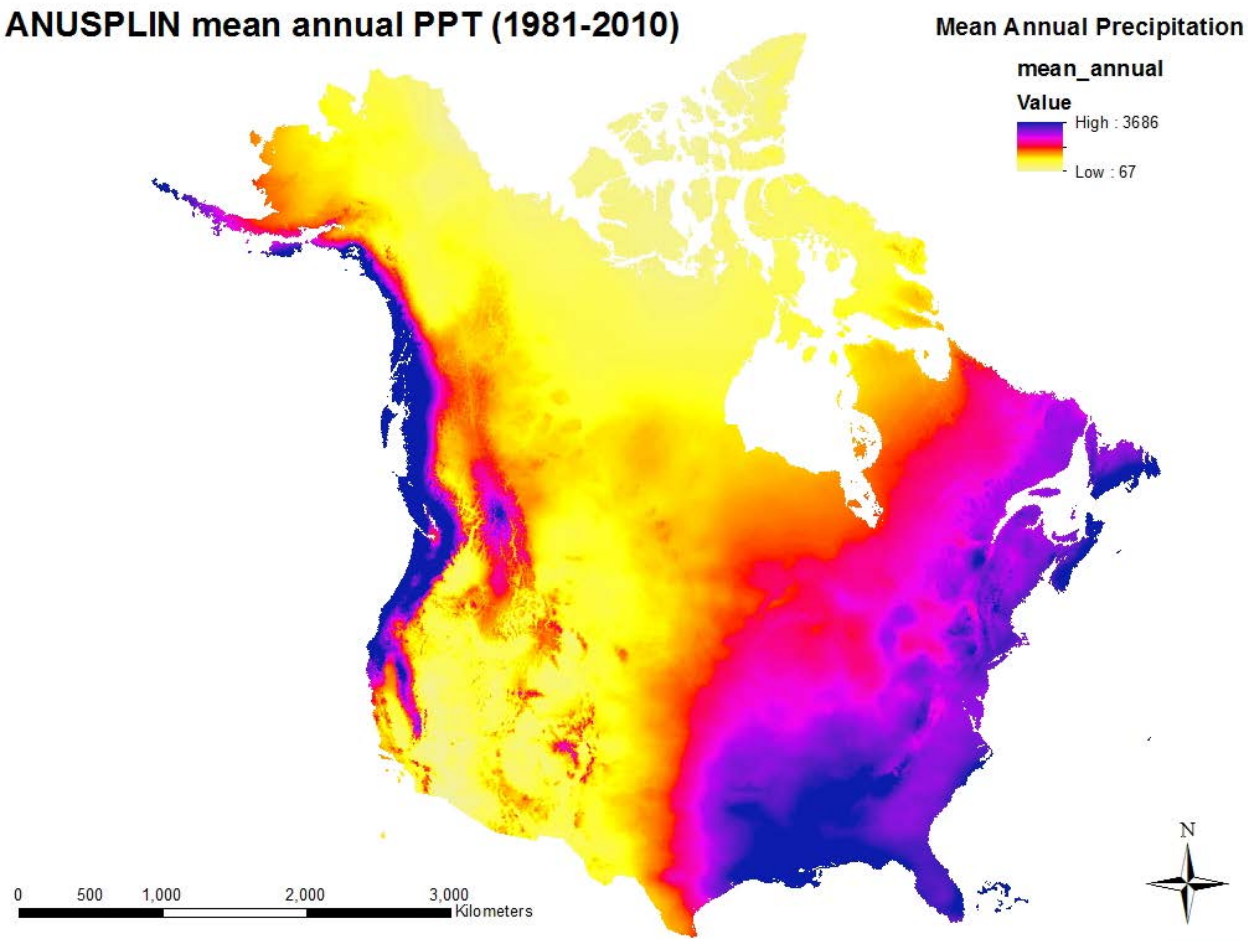
Regional Models



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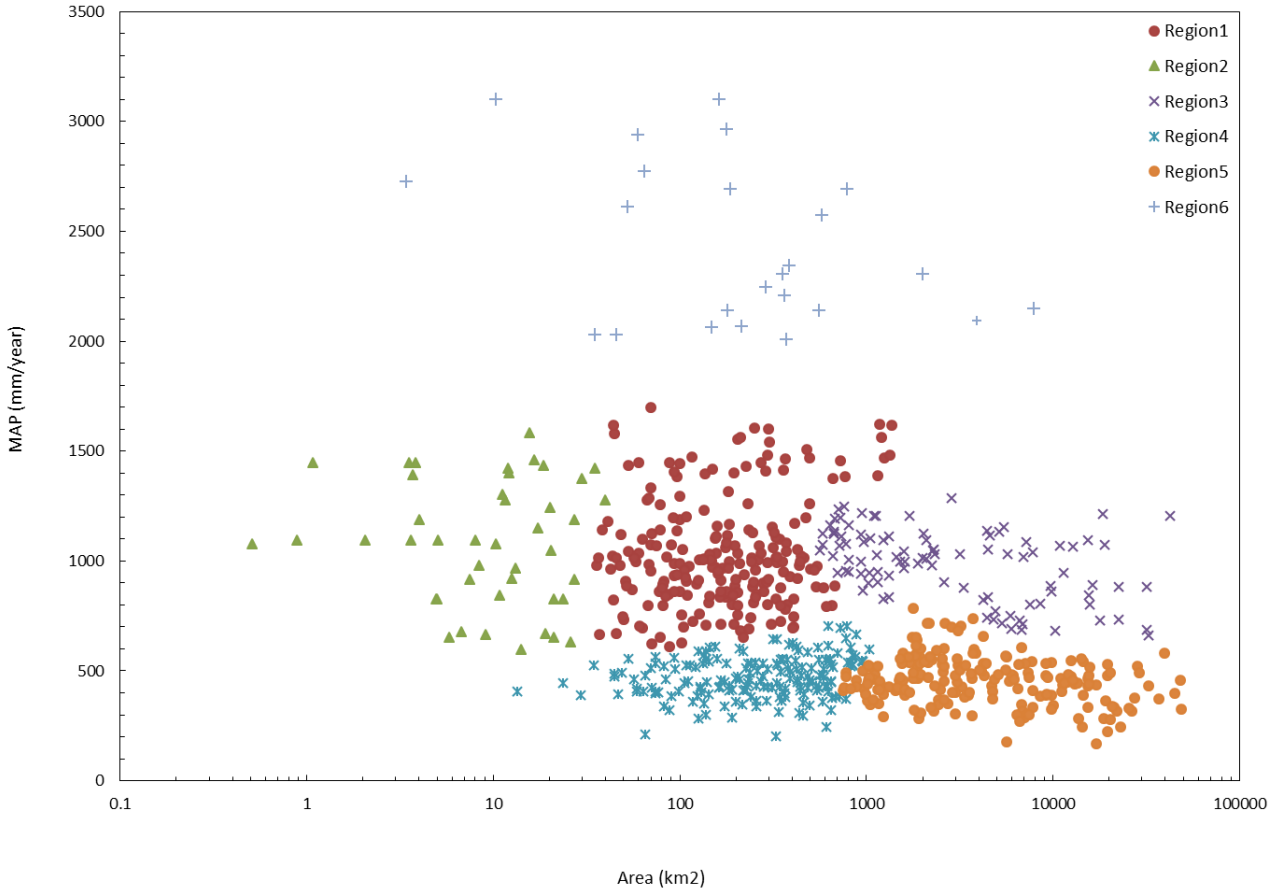
Regional Models



Super regions?

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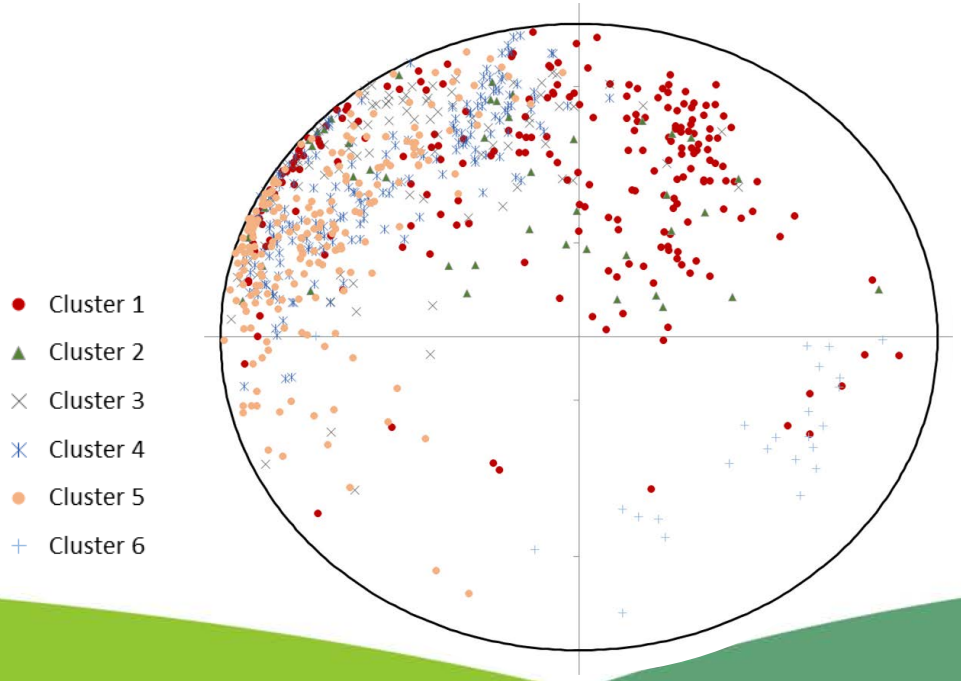
Regional Models

Steps in the analysis:

- ✓ 6 super regions were considered
- ✓ 4 different combination of seasonality measures
- ✓ Seasonality measures estimated for each site
- ✓ Euclidian distance to define dissimilarity
- ✓ Sites were arranged in descending similarity order



Seasonality space representation of the gauging stations

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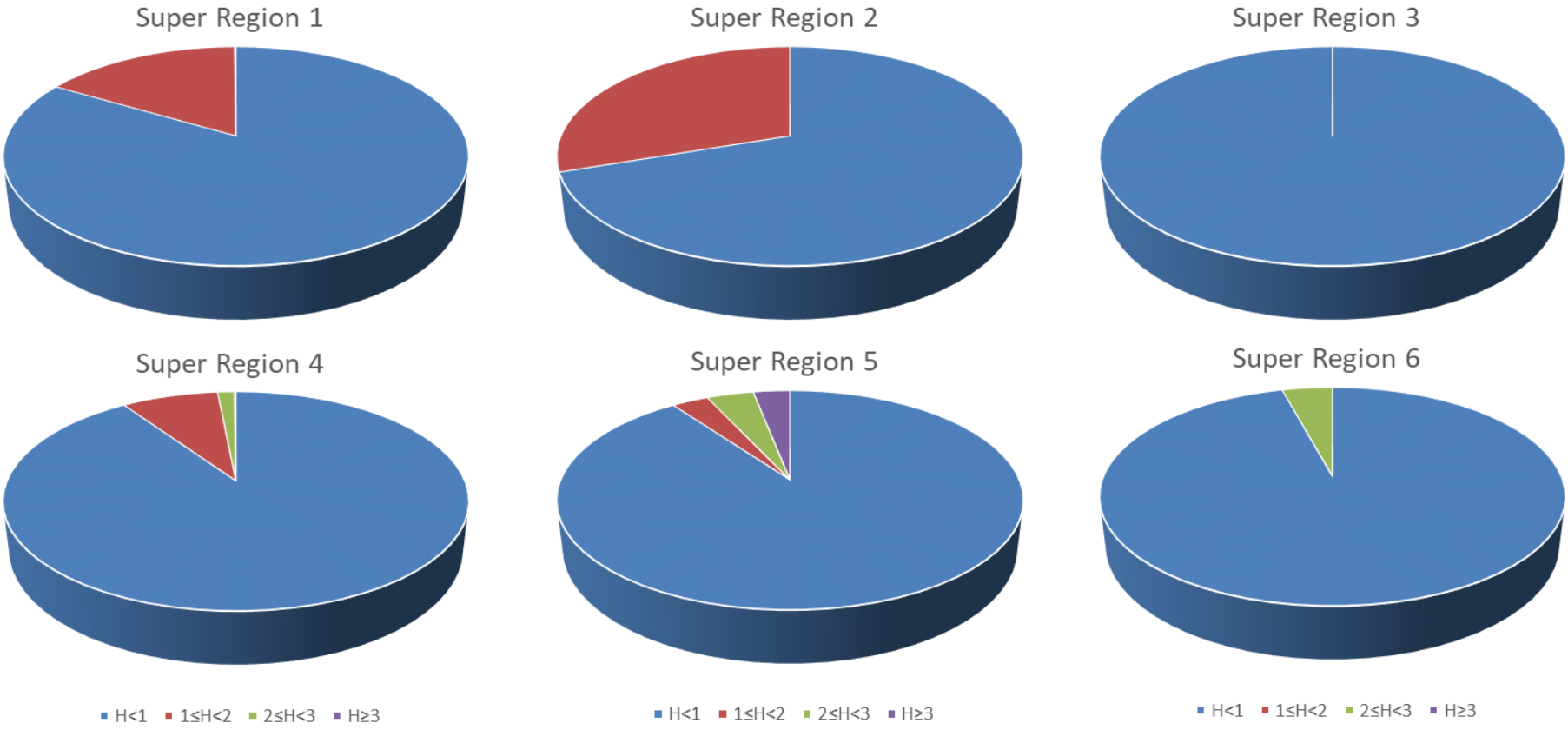
Regional Models

Steps in the analysis:

- ✓ for each target site the first 25 similar sites were identified
- ✓ Initial ROI for the target site
- ✓ Homogeneity of ROI was checked
- ✓ Heterogeneous ROIs were revised
- ✓ Site with maximum improvement in ROI homogeneity sequentially removed
- ✓ Homogeneity of ROI was reevaluated

Regional Models

Identified ROIs for each catchment:



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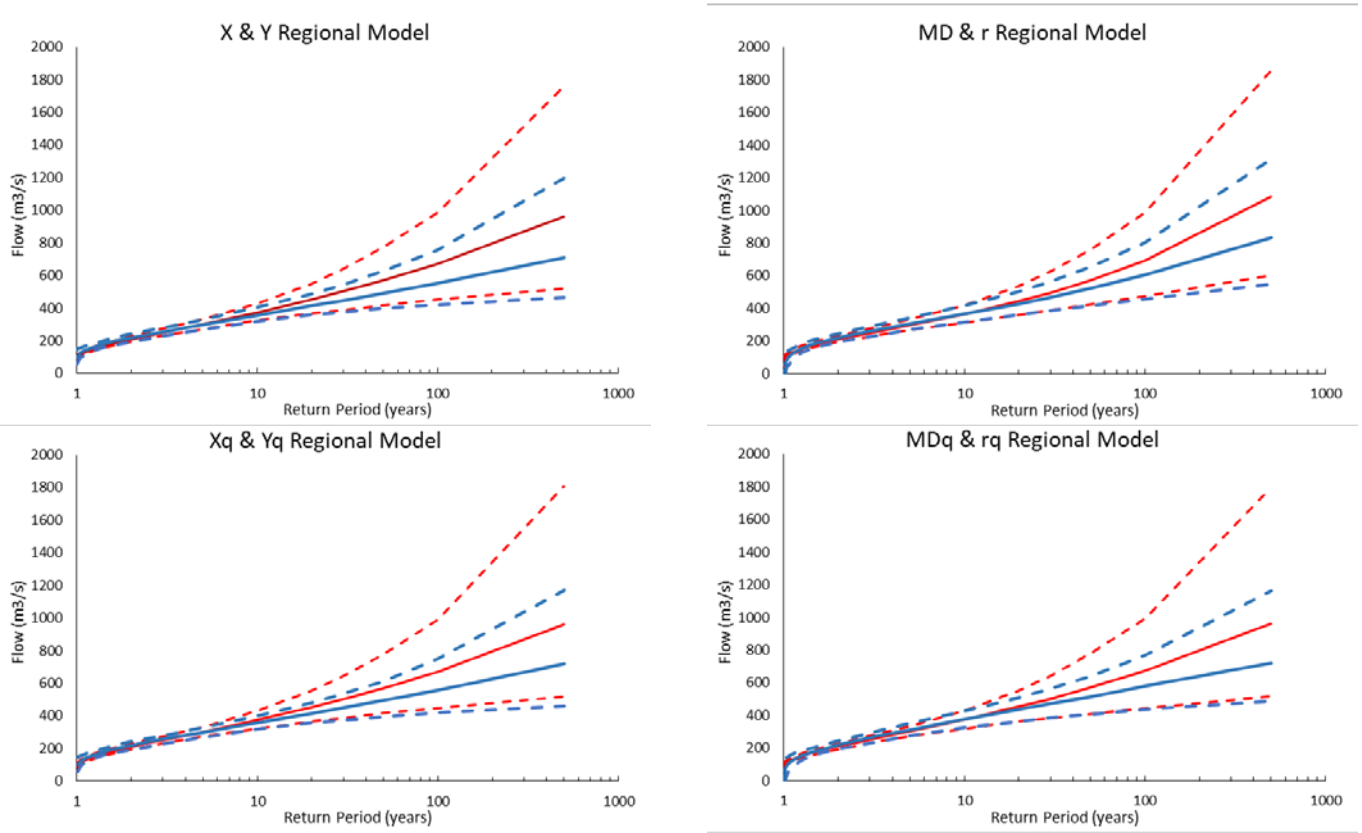
Regional Models

Quantile estimation and confidence interval comparison- site 01EF001



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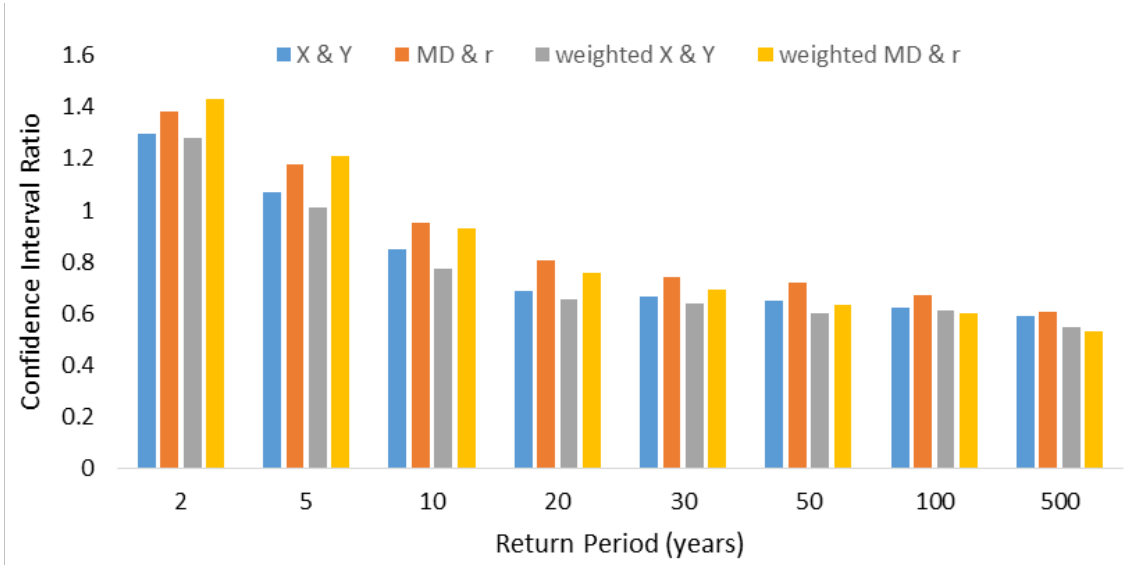
Regional Models

Confidence interval comparison for different return periods:



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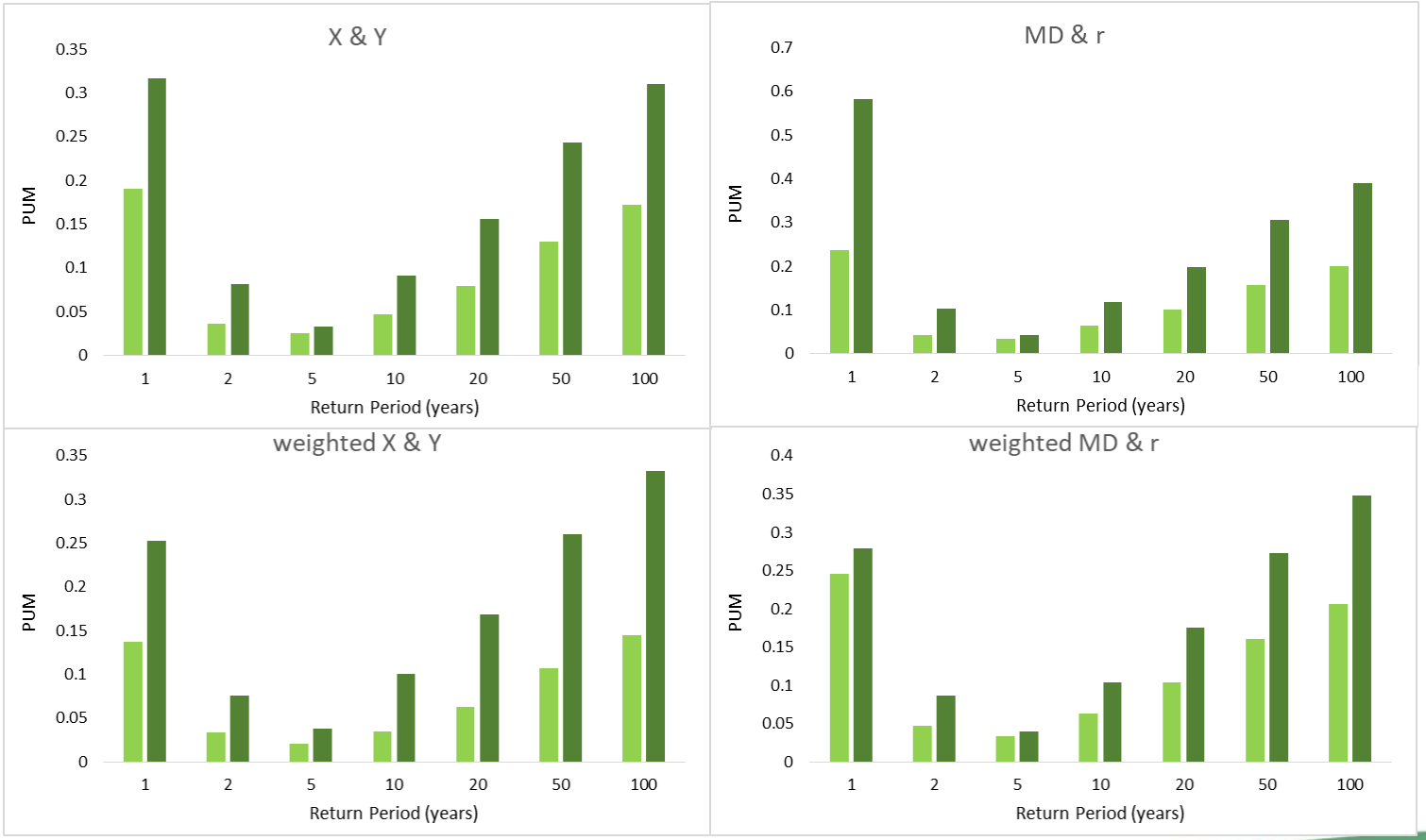
Regional Models

Pooled Uncertainty Measure (PUM):



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Conclusion

Summary of results:

- ✓ Hydrometric stations across Canada
- ✓ Pooled flood frequency analysis
- ✓ Region of Influence (ROI) approach
- ✓ In the context of super regions
- ✓ Homogeneous regions successfully constructed
- ✓ Quantile estimates obtained for longer return periods
- ✓ Employing super regions improved quantile estimation

Questions

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