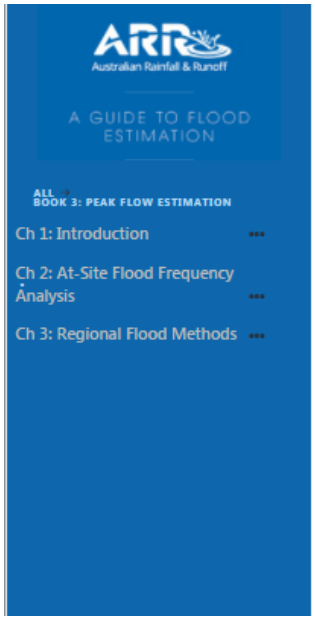
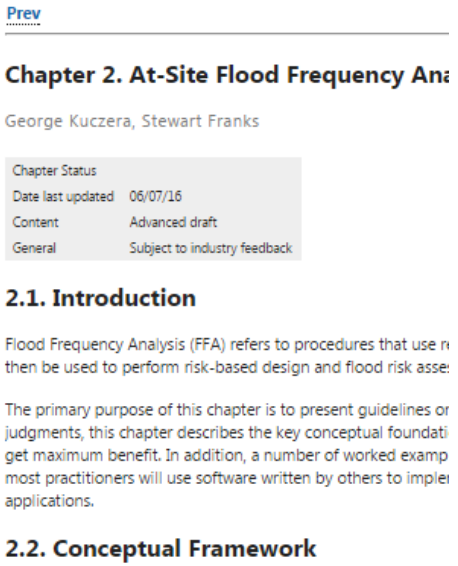
Theme 1-6: Development of new flood estimation manual for Canada.

Martin Durocher and
Donald Burn

Reference Manual

- Other countries
  - Australian Rainfall runoff (http://arr.ga.gov.au/arr-guideline)
  - Flood Estimation Handbook (UK)
  - Bulletin 17B (USA)
- Manual
  - Online documentation* (+pdf)
  - Multiple author contributions
  - Update and feedback
- Content
  - Detailed description of the methodologies with references
  - Adaptation of the methodologies for Canada
  - Floods and extreme rainfalls
  - Regional and ungauged analysis

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Chapter 2. At-Site Flood Frequency Ana

George Kuczera, Stewart Franks

Chapter Status	
Date last updated	06/07/16
Content	Advanced draft
General	Subject to industry feedback

2.1. Introduction

Flood Frequency Analysis (FFA) refers to procedures that use r
then be used to perform risk-based design and flood risk asse

The primary purpose of this chapter is to present guidelines or
judgments, this chapter describes the key conceptual foundati
get maximum benefit. In addition, a number of worked examp
most practitioners will use software written by others to imple
applications.

2.2. Conceptual Framework

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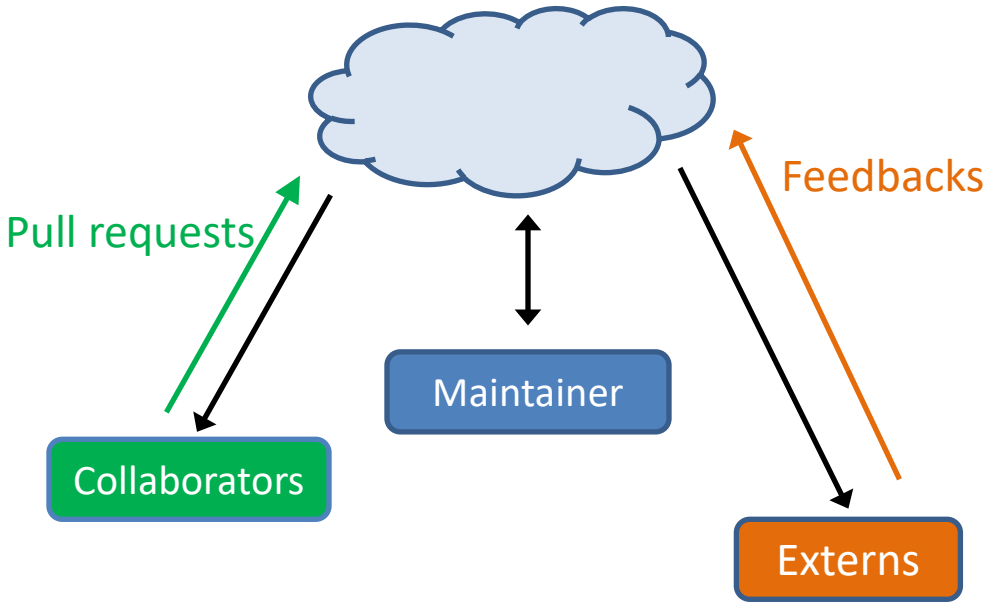
Software

- Software
  - Desktop application
  - Webpage*
  - R-package* vs MATLAB
- Basic users
  - Manual analysis with simple GUI
  - Access database (analyzed sites)
  - Input of their data
    - Station Name
    - Flow data, Coordinates
    - Descriptors: Area, slope, Stream length, waterbody, elevation, coordinate, Mean annual precipitation.
- Advanced users
  - Modification and improvement of the guidelines
  - Batch analysis and scripting

- Available on Github
  - Free code hosting service
  - Easy consultation and collaboration.



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Ungauged sites analysis

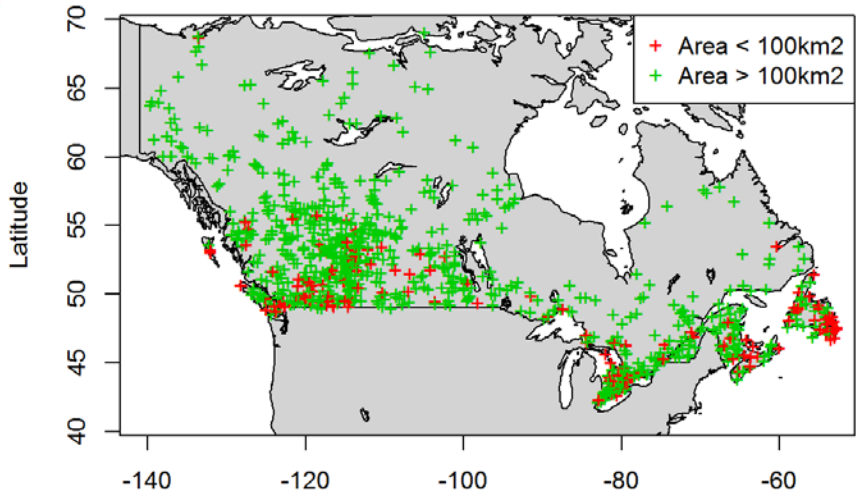
- Objective: Prediction of flood risks based on catchment descriptors

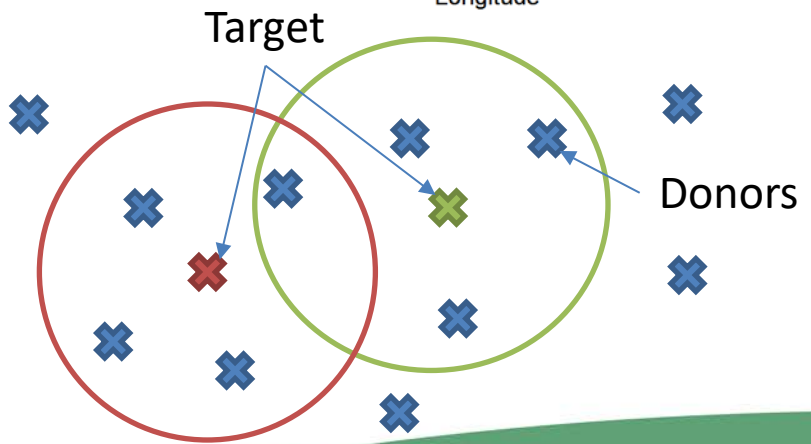
- Initial considerations
  - Guidelines from the other themes 1.X
    - Choice of the distributions
    - Quality and nature of the output
  - Adaption to the diversity of Canada
  - Literature review

- Methodology
  - Region of influence (ROI)
  - Generalized least-squares (GLS)
  - Copula framework (intersite)

Region of influence

- Data
  - 1346 sites (RFA)
    - 918 with descriptors
- Calibration of the ROI
  - Metric
    - Geographical
    - Euclidean distance
  - Number of donors
    - Independent
    - Fixed by provinces
  - Descriptors
    - Equations by provinces
    - Shrinking methods





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Generalized least squares

- Better representation of the uncertainty
- GLS Regression
  - Regression equation

$$\log(\mathbf{y}) = \mathbf{X}\boldsymbol{\beta} + \underbrace{\boldsymbol{\eta}}_{\text{model}} + \underbrace{\boldsymbol{\varepsilon}}_{\text{sample}}, \quad \Lambda = \sigma_\eta^2 \mathbf{I} + \underbrace{\boldsymbol{\Sigma}}_{\text{model}} = \sigma_\eta^2 G(\sigma_\eta^2)$$

ω = Total

  - Estimation by iterative least squares
  - Input from regional frequency analysis
    - Minimizing sampling error
  - Flood quantiles model
    - Mixing families of distributions

- Other possibilities
  - Input from at-site analysis or combine information
  - Quantile-based vs Parameter-based

Sampling covariance

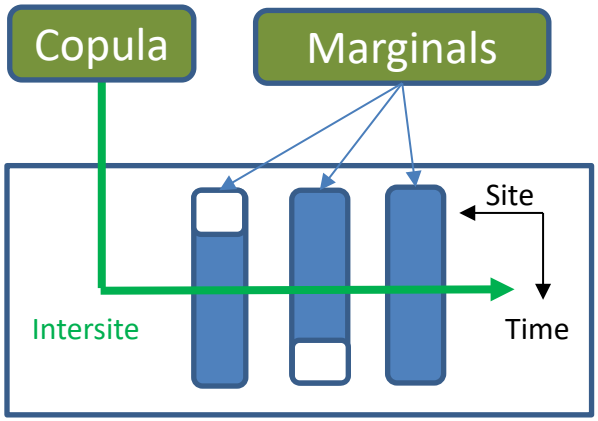
- Intersite correlation
  - Affect uncertainty in regional analysis
  - Effect of large meteorological cells
  - Widespread snowmelt
  - Nesting sites

- Copula framework
  - Multivariate copula

$$F(\mathbf{x}) = C\left(\underbrace{F_1^{-1}(x_1)}_{U_1}, \ldots, \underbrace{F_d^{-1}(x_d)}_{U_d}\right), \quad \text{with} \quad \mathbf{x} = (x_1, \ldots, x_d), \; U_i \in [0,1]$$

  - Estimation independent of the marginals.
  - Nonparametric modelling of the pairwise dependence

- Monte-Carlo Simulations
  1. Simulate from the Normal copula
  2. Compute the output variables
  - Repeating steps 1-2, several times
  - Evaluating the covariance matrix



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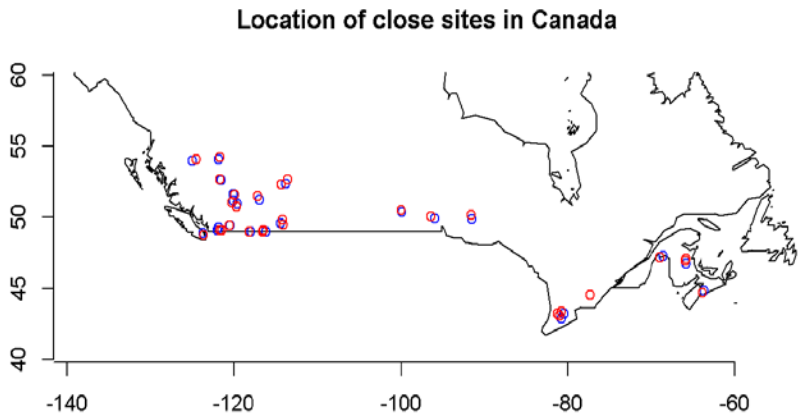
Validation of the Normal copula

- Multivariate Normal distribution
  - Closed analytical form
  - Easy to simulate
- Data: 32 sites
  - Dist < 40 km, rho > 0.7, n > 50 years
- Alternative copula
  - Extreme: Husler-Reiss, Gumbel
  - Asymmetrical : Clayton
  - Tail dep.: T-copula
- GOF tests are inconclusive
- Normal copula generally the best fit



% of site where AIC better than Normal copula

T	HR	GUMB	CLT
16	19	16	16

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Spearman rho

- Empirical vs model-based
- Additive models

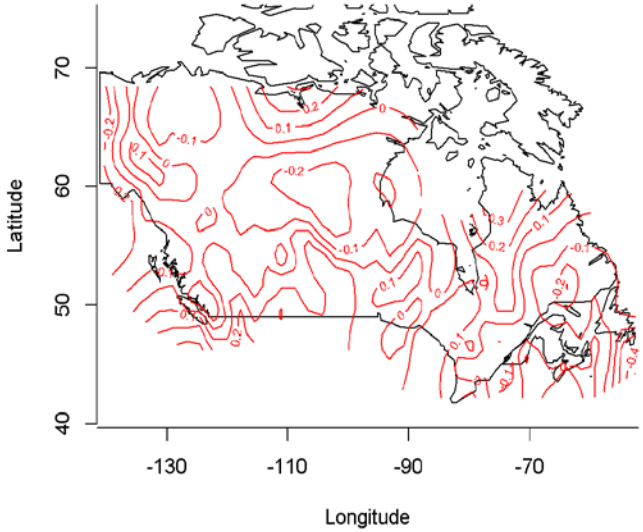
$$g(\rho_{ij}) = f_1(h_{ij}) + f_2(\bar{A}_{ij}) + f(\bar{x}_{ij}, \bar{y}_{ij}) + \varepsilon_{ij}$$

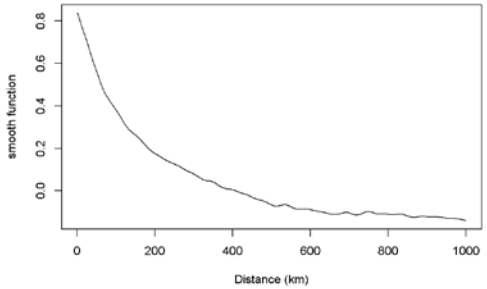
  - Fisher z-transform
  - Thin plate splines
  - Variance explained 50%
  - Anisotropy
  - Pairs < 1000km

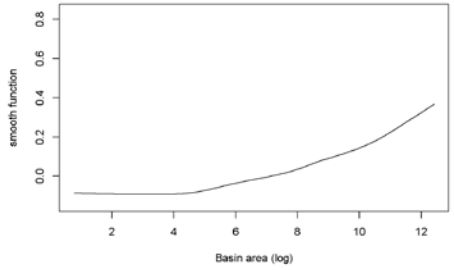
- Relation with correlation coefficients

$$\theta_{ij} = 2\sin\left(\frac{\pi}{6}\rho_{ij}\right)$$

  - Correction for positive–definite matrix







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Future work

- Software and manual
  - Determining the medium
  - Github: R-package
  - mduroche@uwaterloo.ca
- Ungauged analysis
  - Providing guidelines for calibrating the ROI/GLS model
  - Simplified intersite model
  - Alternative predictive methods