ASSESSMENT OF UNCERTAINTY IN FLOOD FLOWS UNDER CLIMATE CHANGE

THE UPPER THAMES RIVER BASIN (ONTARIO, CANADA)

Slobodan P. Simonović
Professor
Civil and Environmental Engineering
The University of Western Ontario
London, Ontario, Canada

Main messages

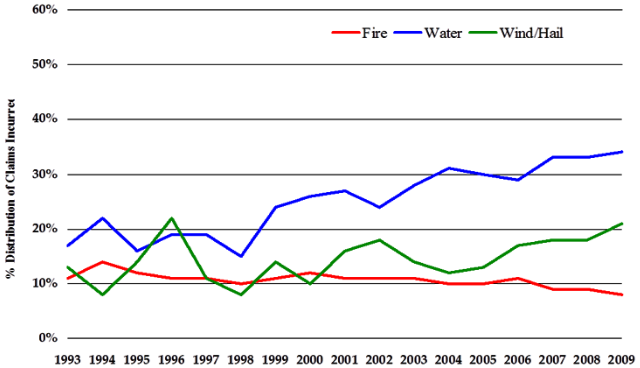
- A large uncertainty exists in all the projected future design floods.
- Use of probabilistic approach assists to better outline the uncertainty linked to future climate.
- For the purpose of engineering practice in the Upper Thames River Basin, the design extreme floods established from observed data should be increased for at least 30% to account for climate change.

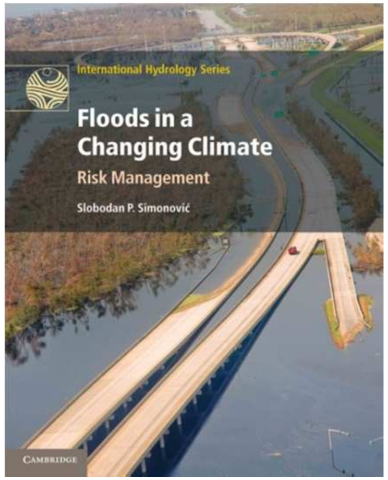
Outline

- Introduction
- Methodology
  - Climate change and flood flows
  - Uncertainty assessment
- The Upper Thames case study
- Conclusions

Introduction

- Flood management may be significantly affected by climate change
  - Magnitude
  - Frequency
  - High level of uncertainty
- Need for an appropriate methodology




International Hydrology Series

Floods in a Changing Climate

Risk Management

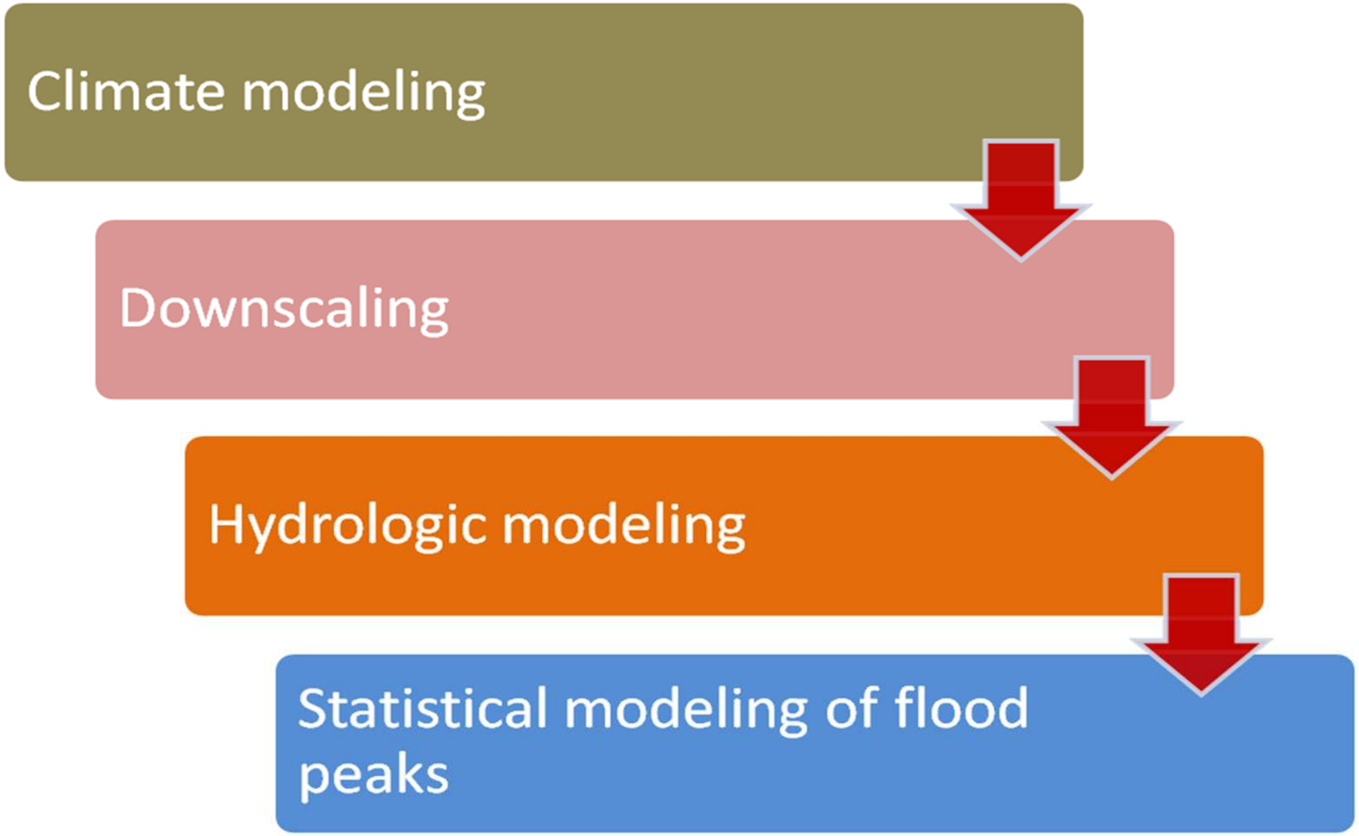
Slobodan P. Simonović

CAMBRIDGE

Introduction

- Traditional approach
  - Climate scenarios from selected GCMs
  - Hydrologic modeling
  - Analysis of peak flows using a flood frequency approach
- Problems
  - GCM structure
  - Choice of future emission scenarios
  - Climate variability
  - Course spatial and temporal scales
  - Choice of simulated hydrologic regime (future land use, hydrologic model structure, model parameters,…)

Methodology



Climate modeling

Downscaling

Hydrologic modeling

Statistical modeling of flood peaks

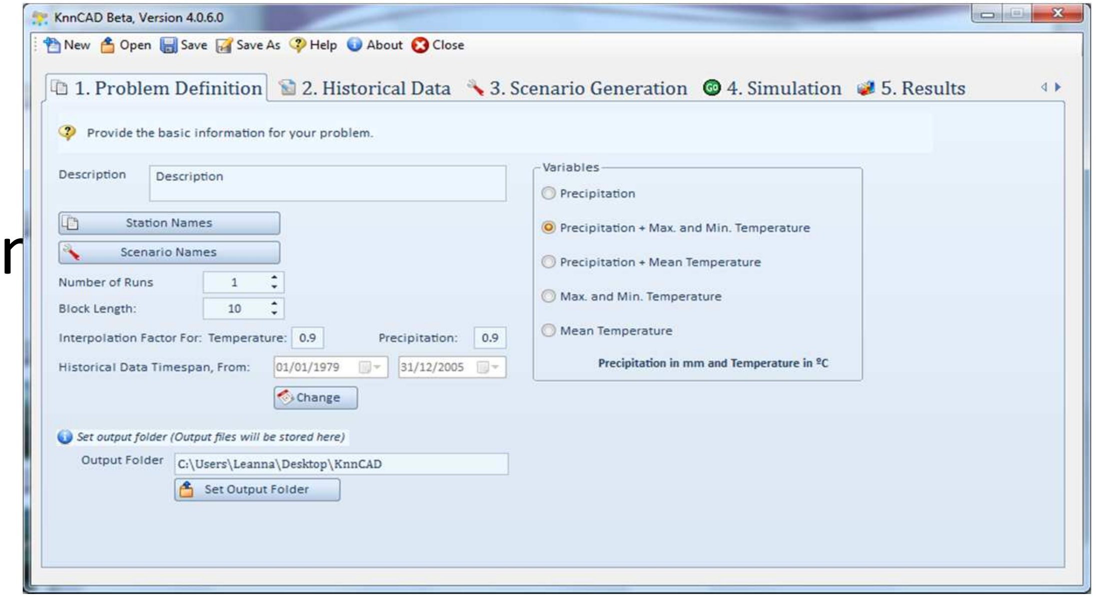
Methodology

- Climate modeling
  - Six GCMs
  - Three emission scenarios
  - 15 projections
  - Three time slices 2020, 2050, 2080

GCM models	Sponsors, Country	Emission Scenarios	Atmospheric Resolution	
			Lat	Long
CGCM3T47, 2005	Canadian Centre for Climate Modelling	A1B, B1, A2	3.75°	3.75°
CGCM3T63, 2005		A1B, B1, A2	2.81°	2.81°
CSIROMK3.5, 2001	Commonwealth Scientific and Industrial Research Organization (CISRO) Atmospheric	B1, A2	1.875°	1.875°
GISSAOM, 2004	National Aeronautics and Space Administration (NASA)/ Goddard Institute for Space Studies (GISS)	A1B, B1	3°	4°
MIROC3.2HIRES, 2004	Centre for Climate System Research , National Institute for Environmental Studies, and Frontier Research Centre for Global Change (JAMSTEC), Japan	A1B, B1	1.125°	1.125°
MIROC3.2MEDRES, 2004		A1B, B1, A2	2.8°	2.8°

Methodology

- Downscaling
  - KnnCAD weather generator
  - Integration of local ar global data (change factor)
  - Reshuffling and perturbing



Provide the basic information for your problem.

Description: Description

Number of Runs: 1

Block Length: 10

Interpolation Factor For: Temperature: 0.9 Precipitation: 0.9

Historical Data Timespan, From: 01/01/1979 31/12/2005

Variables

○ Precipitation

● Precipitation + Max. and Min. Temperature

○ Precipitation + Mean Temperature

○ Max. and Min. Temperature

○ Mean Temperature

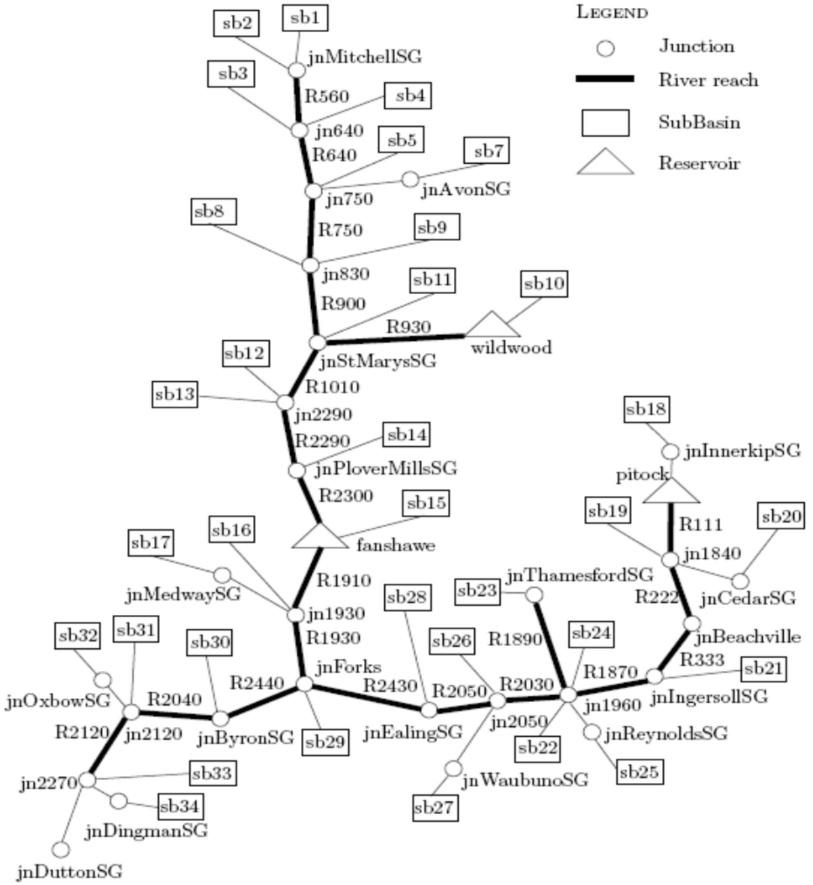
Precipitation in mm and Temperature in ºC

Set output folder (Output files will be stored here)

Output Folder: C:\Users\Leanna\Desktop\KnnCAD

Methodology

- Hydrologic modeling
  - HEC-HMS continuous model
  - Precipitation, temperature and potential evapotranspiration – inputs
  - Flows - output



Methodology

- Flood flow frequency
  - Peak-over-threshold
  - Generalized Pareto Distribution (GPD) with Poisson arrival rate
  - L-moments method of fitting
  - L-moment ratio diagrams for testing the suitability of GPD and Poisson process

$$F(q) = P(Q < q / q > q_0) = 1 - \left[1 - \frac{k}{\beta}(q - q_0)\right]^{\frac{1}{k}}$$

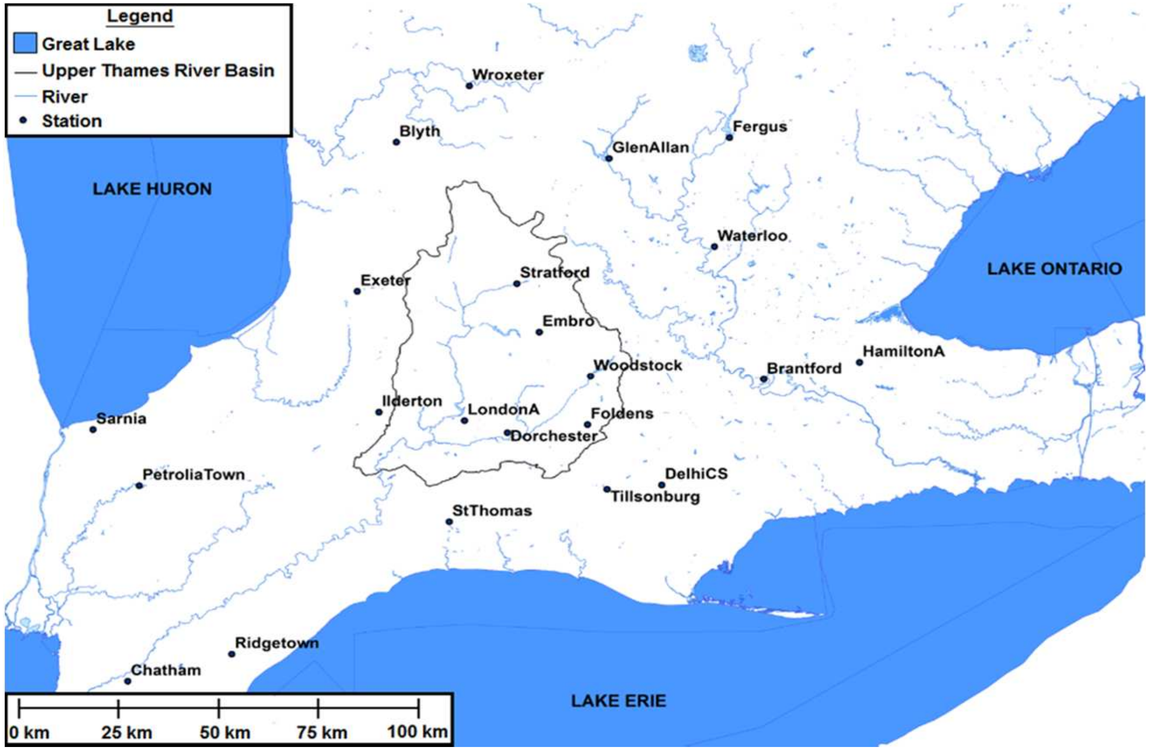
$$F(q) = 1 - \exp\left[-\frac{1}{\beta}(q - q_0)\right]$$

$$q(F) = q_0 + \frac{\beta}{k}\left[1 - (1 - F)^k\right] \quad , k \neq 0$$

$$q(F) = q_0 - \beta \ln[1 - F] \quad , k = 0$$

Case study

- UTRB
  - Area: 3,450 km^2
  - 33 sub-basins
  - 17 streamflow
  - 22 precipitation stations
  - 3 reservoirs



Case study

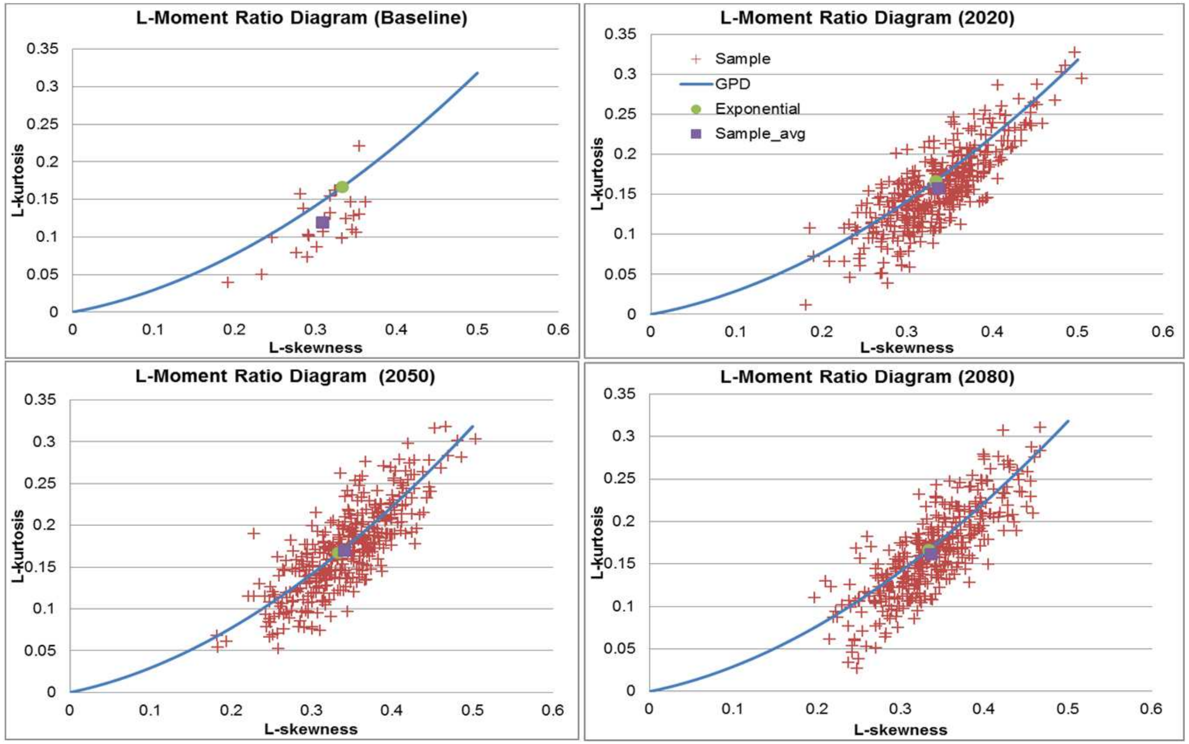
- Data
  - Daily weather data (precipitation, max t and min t) for 1979 – 2005 for 22 stations
  - Climate data (min t, max t, precipitation, specific humidity, northward wind, southward wind and mean sea level pressure) for nearest grid points surrounding UTRB for four time slices: 1961-1990, 2011-2040, 2041-2070 and 2071-2100
  - Interpolation to each station
  - Calculation of change factors
  - Modified historic data used with KnnCAD weather generator (each case is simulated 25 times)
  - Generated series used with the hydrologic model
  - Peaks extracted from the flow series

Case study

- Peak flows
  - POT series for 2020, 2050, and 2080 plus baseline (1979-2005) (15 GCMsx25 runs=375 POT series)
  - Variable results for various GCMs and time slices:
    - Max increase 44% (CGCM3T63-A1B for 2080)
    - Max decrease 8% (MICROC3HIRES for 2050)

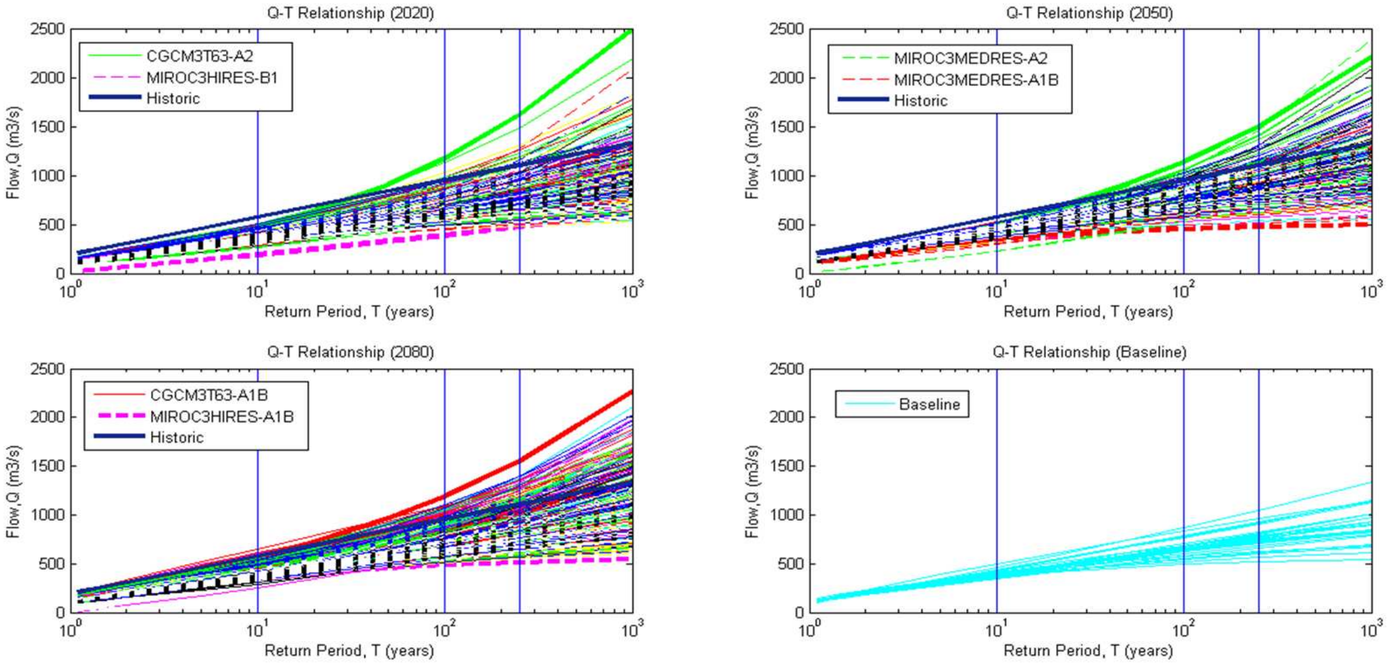
Case study

- Evaluation of POT modeling (L-moment ratio diagrams)
  - GPD shape parameter k=0
  - Dispersion index D rejected Poisson about 50%



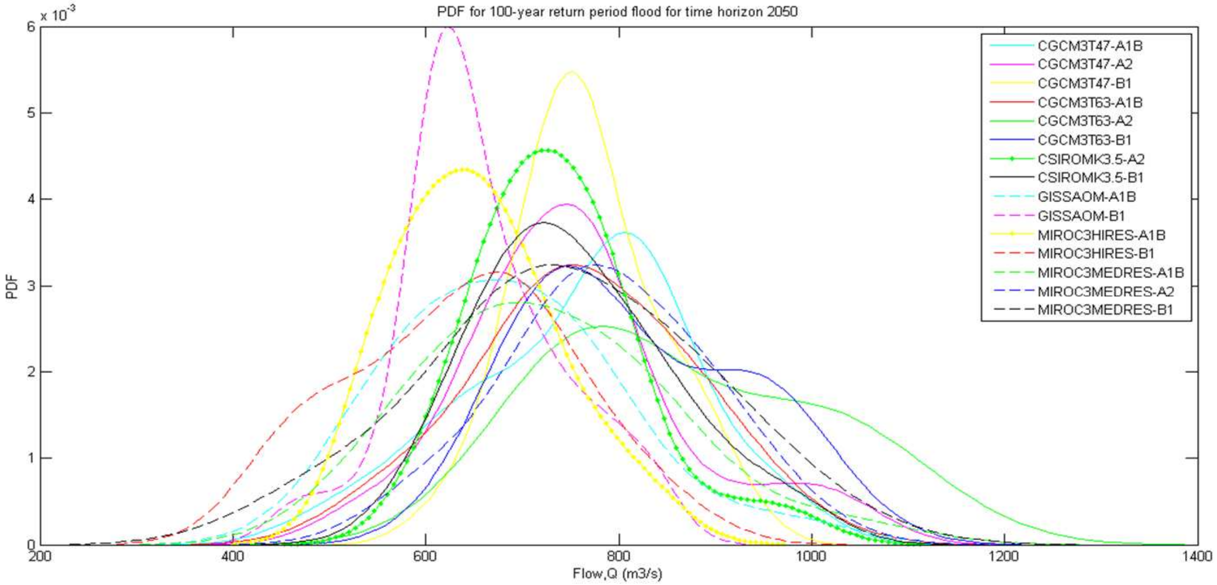
Case study

- Flood magnitude-return period curves



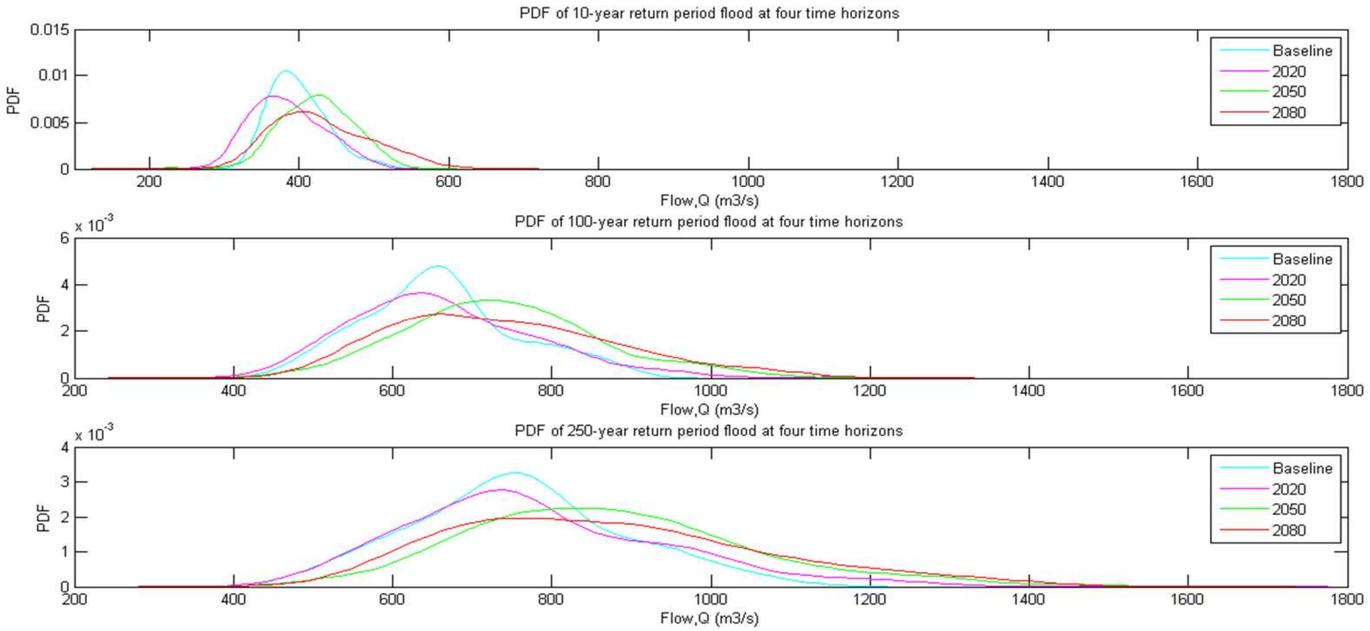
Case study

- Uncertainty measure
  - Non-parametric normal kernel function
  - Example of 100 year return period for 2050



Case study

- Uncertainty measure
    - Summary for return periods T=10, 200 and 250 years
    - Four time horizons



Conclusions

- POT modelling with GPD using k = 0 (i.e. Exponential distribution) should be used for flood frequency analysis at the Byron gauging station in the Upper Thames River basin.
- A large uncertainty exists in all the projected future design floods. Use of probabilistic approach assists to better outline the uncertainty linked to future climate.
- Based on the study results, it is rational to believe that the hydrologic behaviour of the Upper Thames River basin would be changed over the next century. While it is impossible to predict the future floods accurately, the recommendation of this study is to include the uncertainty associated with future design floods into engineering and management practices. Based on the comparison made with the baseline period it is recommended, for engineering practice that design extreme floods established from observed data should be increased for at least 30% to account for climate change.

Resources

www.slobodansimonovic.com

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