Future Evolution of Hydrological Processes in Southern Ontario

Example of the Big Creek Watershed

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Introduction

- **Focus on Southern Ontario:**

√ High occurrence of flood disasters

√ Highly **populated and industrialized urban area** surrounded by **agricultural lands**

√ Projected **increase of temperatures and rainfall extremes** in the region

- **Past and future evolution of streamflow well studied:**

√ Shift toward the early winter in many watersheds

- **Areas of improvement:**

× Difficult comparisons between watersheds (Different hydrological models)

× Processes generating high flows barely studied

× Uncertainties of the method not always assessed

Main Objectives

(1) Evaluate the **future evolution of peak flows in Southern Ontario using a coupled hydrological model (GSFLOW)** in three watersheds:

(i) Urban (ii) Semi-urban (iii) Rural

(2) Understand the **hydro-meteorological processes** associated with the extreme events and peak flows

(3) Assess the **uncertainties** associated with the use of **global climate models** projections

Methods

- GSFLOW coupled hydrological model:

- ➢ **PRMS** Surface conceptual semi-distributed model
- ➢ **MODFLOW:** 3 dimensional groundwater model

- **Calibration** of model parameters thanks to past observations

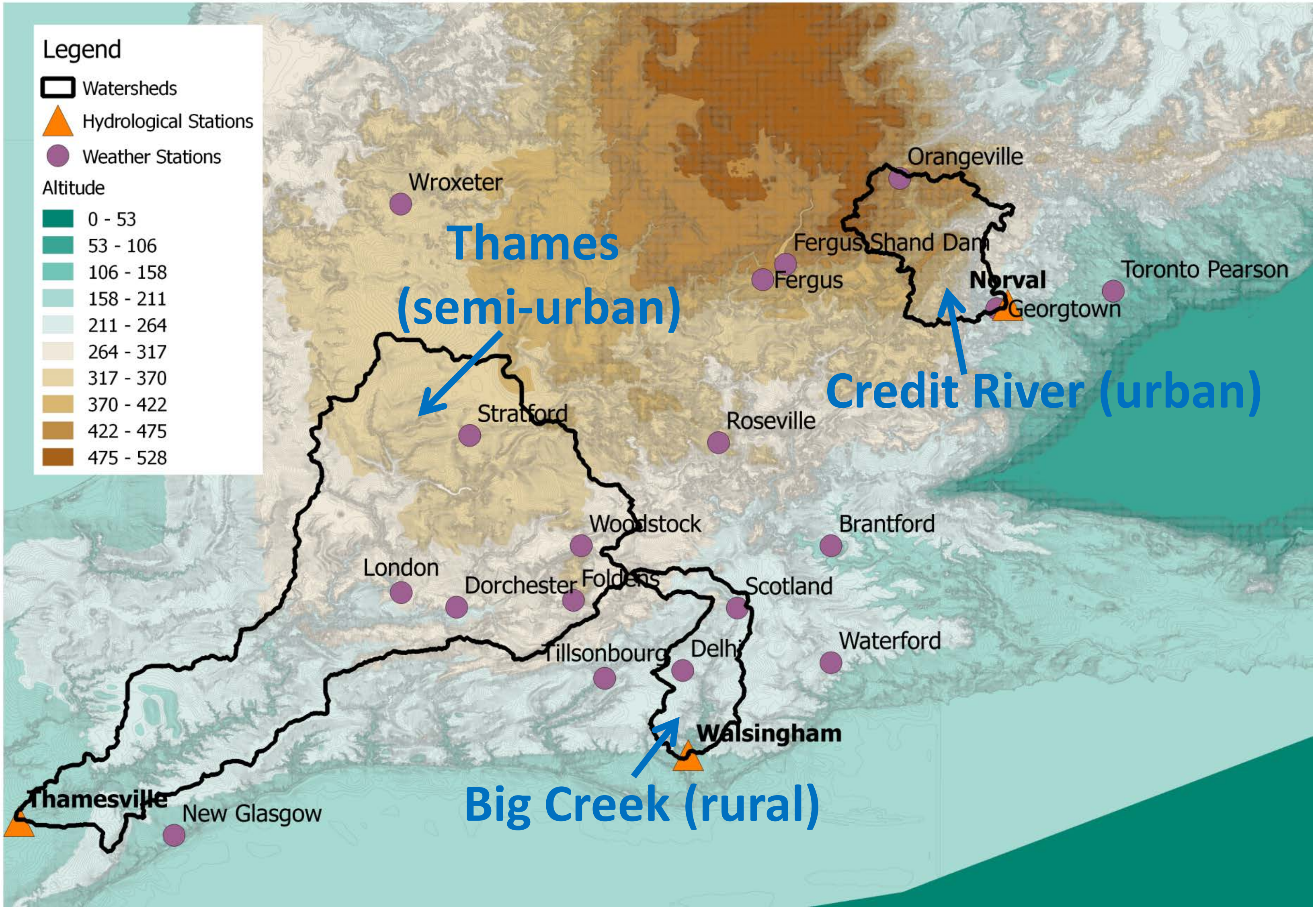
Input: Temperatures, Precipitations

Observed variables: Solar Radiation, Streamflow

- **Simulation of the future streamflow** thanks to the **calibrated set of parameters**

Input: Downscaled **Temperatures and Precipitations** from **11 CMIP5** models with **RCP 4.5** and **8.5** scenarios.

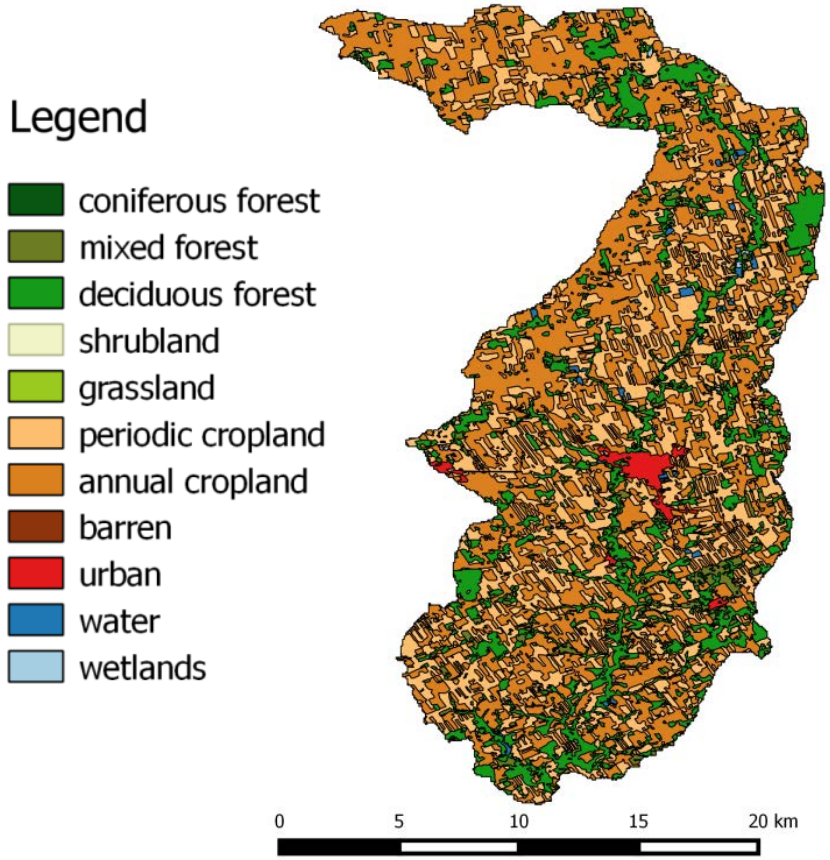
Study Area



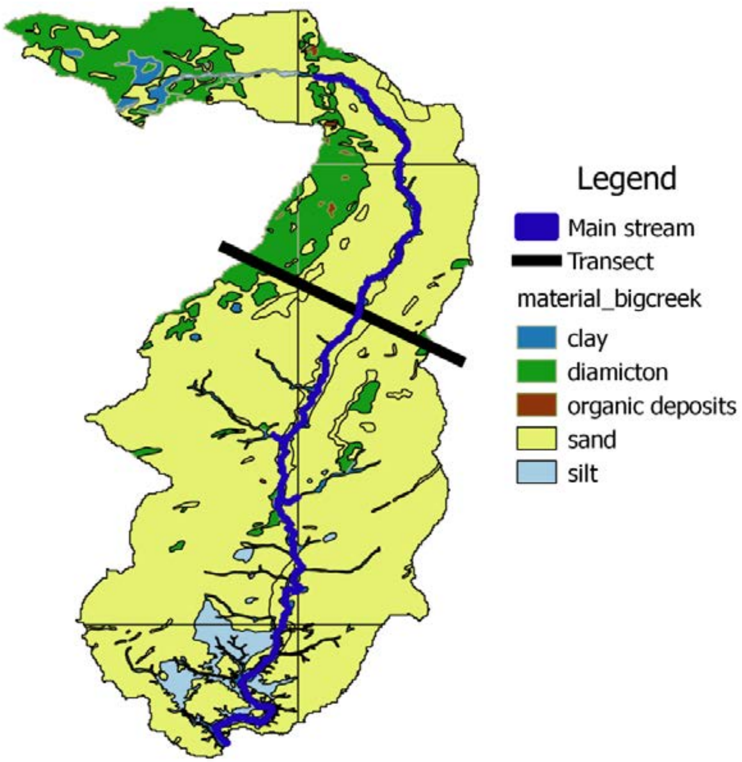
Legend
Watersheds
Hydrological Stations
Weather Stations
Altitude
0 - 53
53 - 106
106 - 158
158 - 211
211 - 264
264 - 317
317 - 370
370 - 422
422 - 475
475 - 528
Thames (semi-urban)
Credit River (urban)
Big Creek (rural)
Orangeville
Wroxeter
Fergus Shand Dam
Fergus
Norval
Georgtown
Toronto Pearson
Stratford
Roseville
Woodstock
Brantford
London
Dorchester
Foldens
Scotland
Tillsonbourg
Delhi
Waterford
Walsingham
Thamesville
New Glasgow

Big Creek Watershed Characteristics

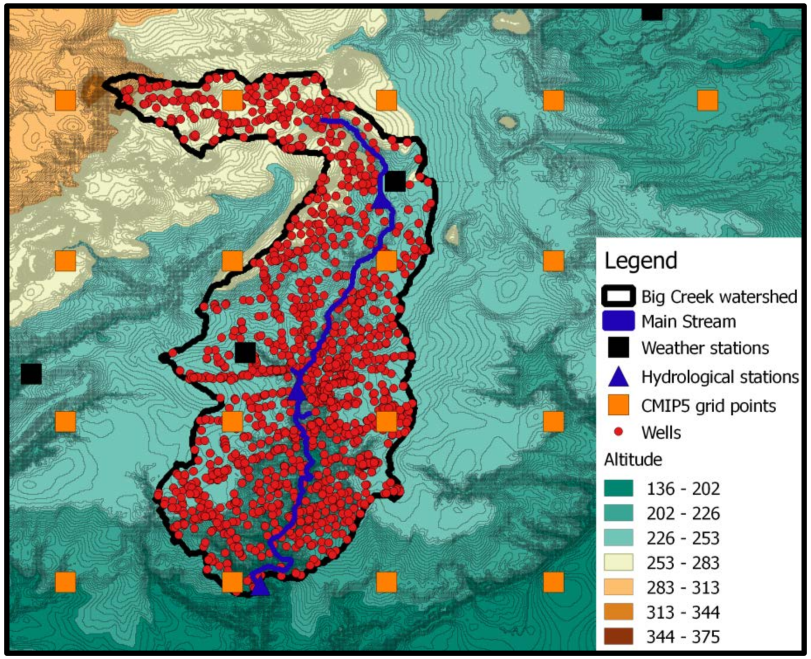
Land Use



Geology



Big Creek River Simulations: GS FLOW Input Data



- Past: **Temperatures and Precipitations in Delhi and other stations**
- Future: **Bias Correction of CMIP5 datasets** (Closest point from Delhi)

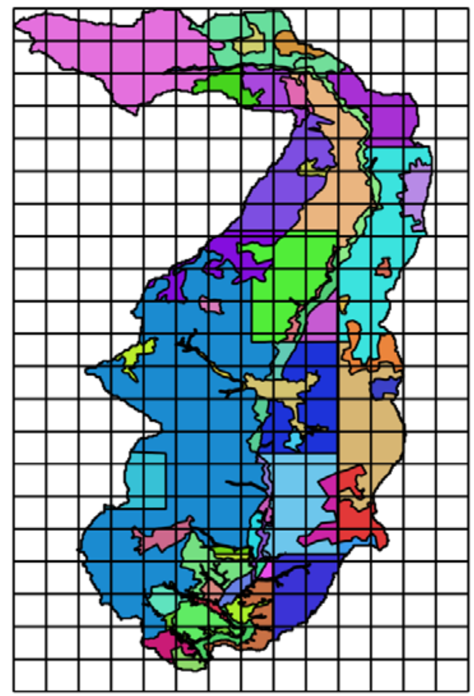
- Delineation of **hydrological response units (HRU)** and **construction of the 3D grid (21 Rows / 14 Columns / 2 Layers)**

- **Calibration**: Trial and error approach

✓ **Initialization:** 1986 - 1987

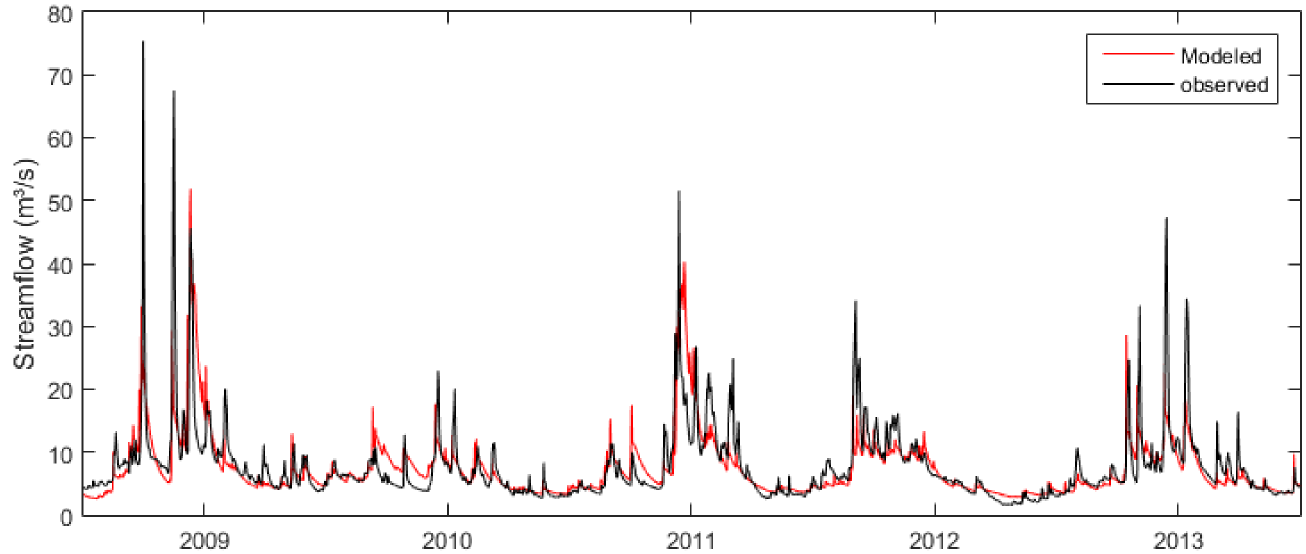
✓ **Calibration:** 1987 - 2007

✓ **Validation:** 2008 - 2013

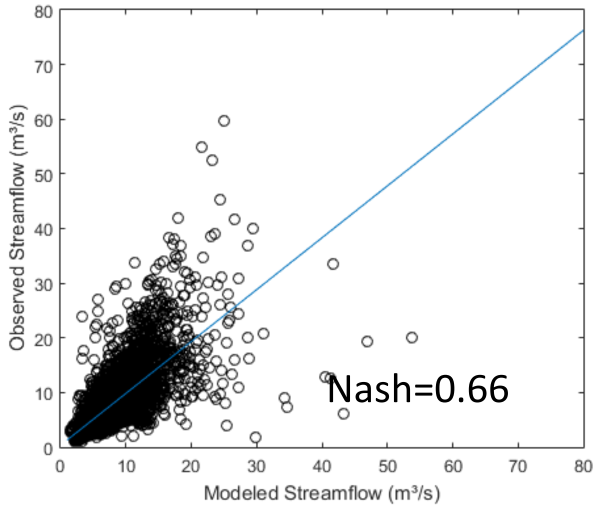


Big Creek River HRUs and Grid

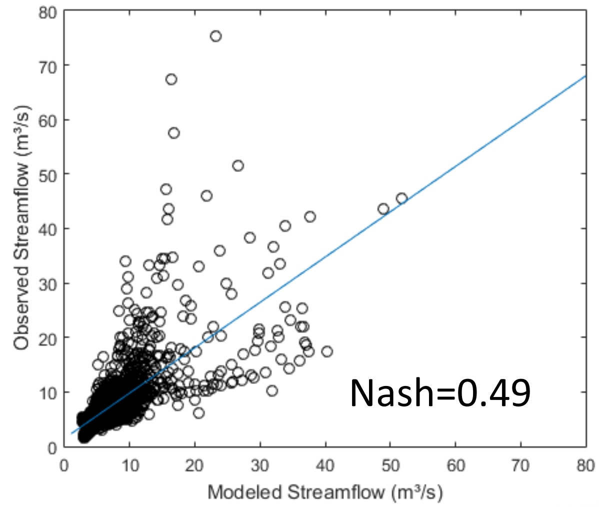
Results: Modeled and Observed Streamflow



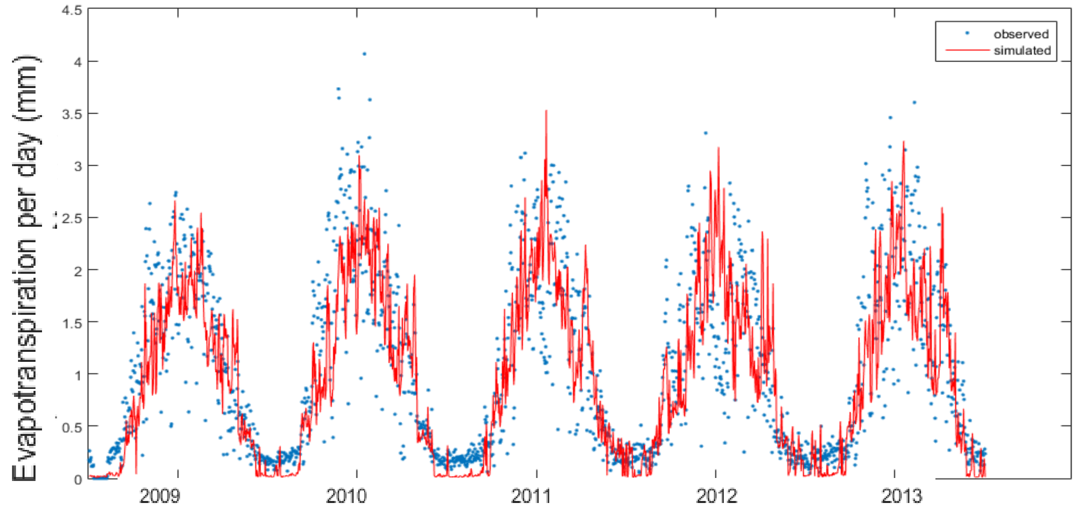
Calibration (1987-2007)

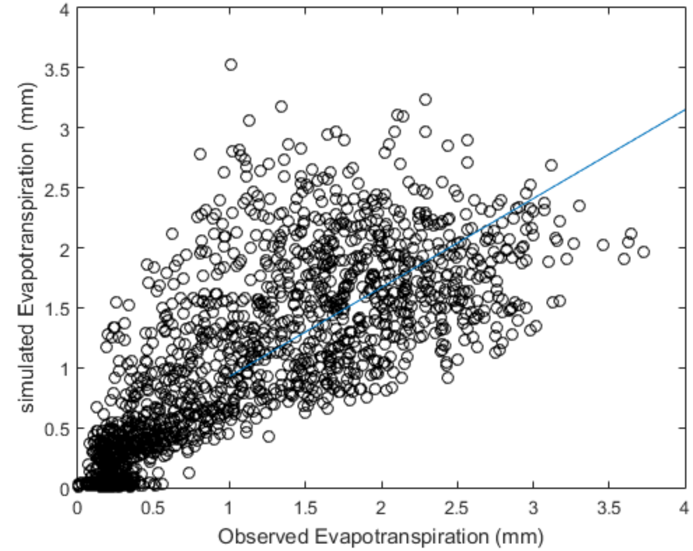


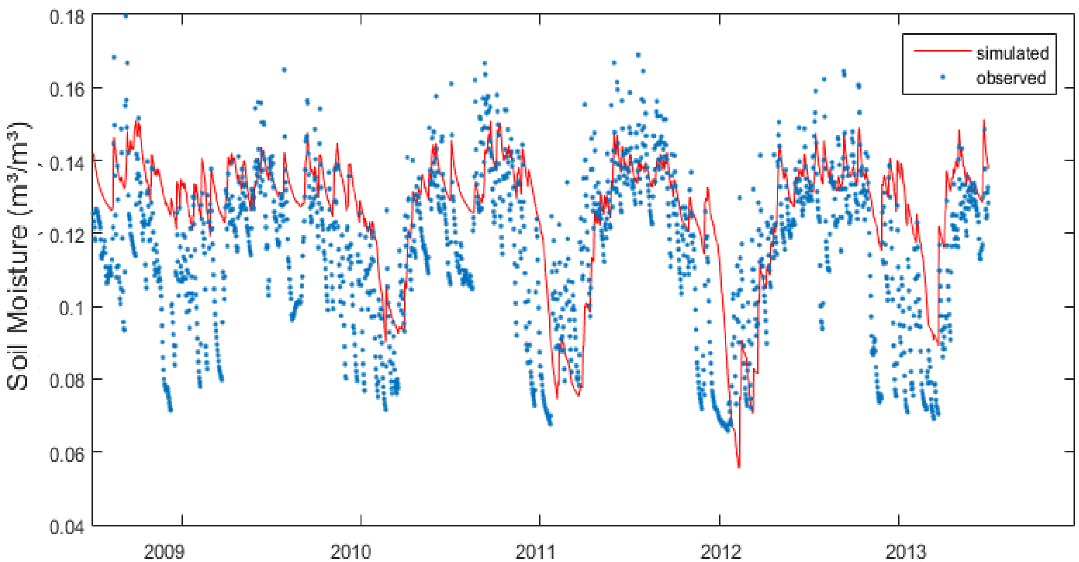
Validation (2008-2013)

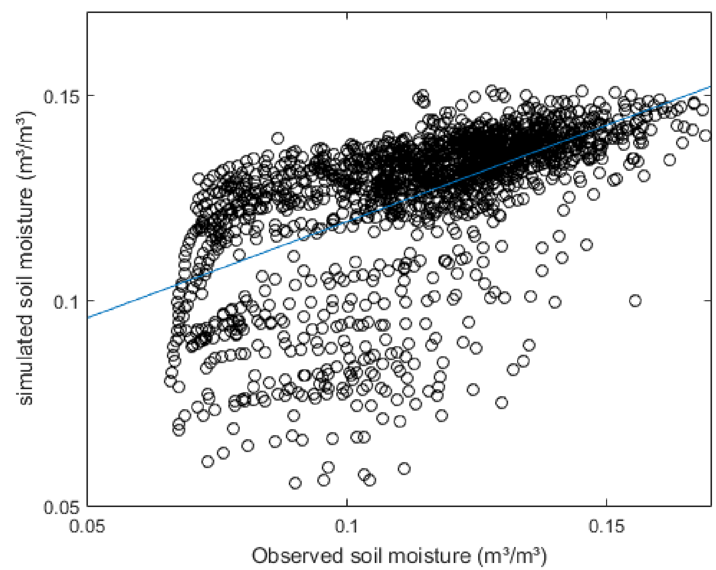


Validation of Evapotranspiration and Soil Moisture



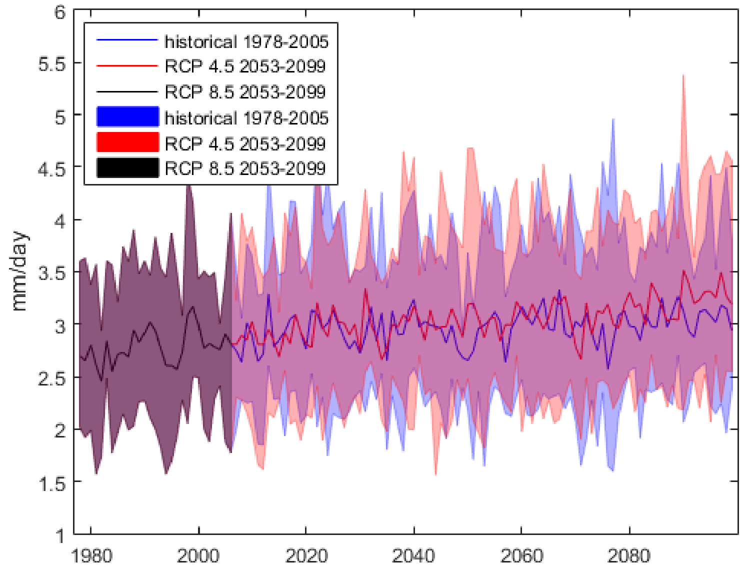




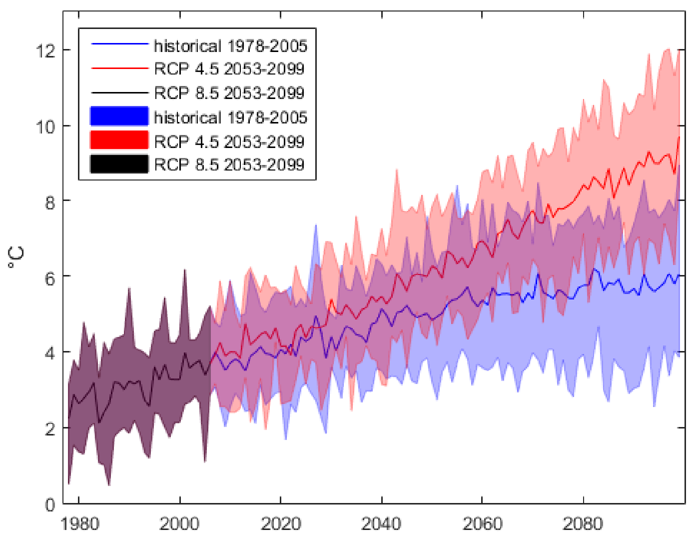


GCM Simulated Future Climate Data

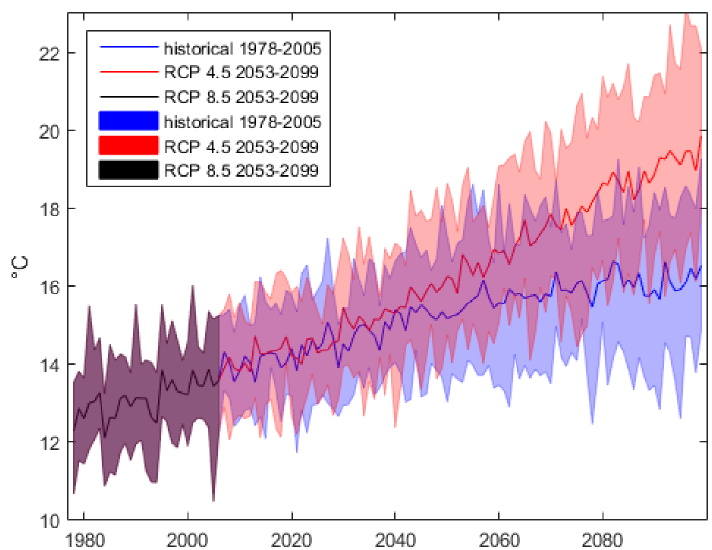
(IPCC CMIP5 Data from 11 GCMs)



Precipitation

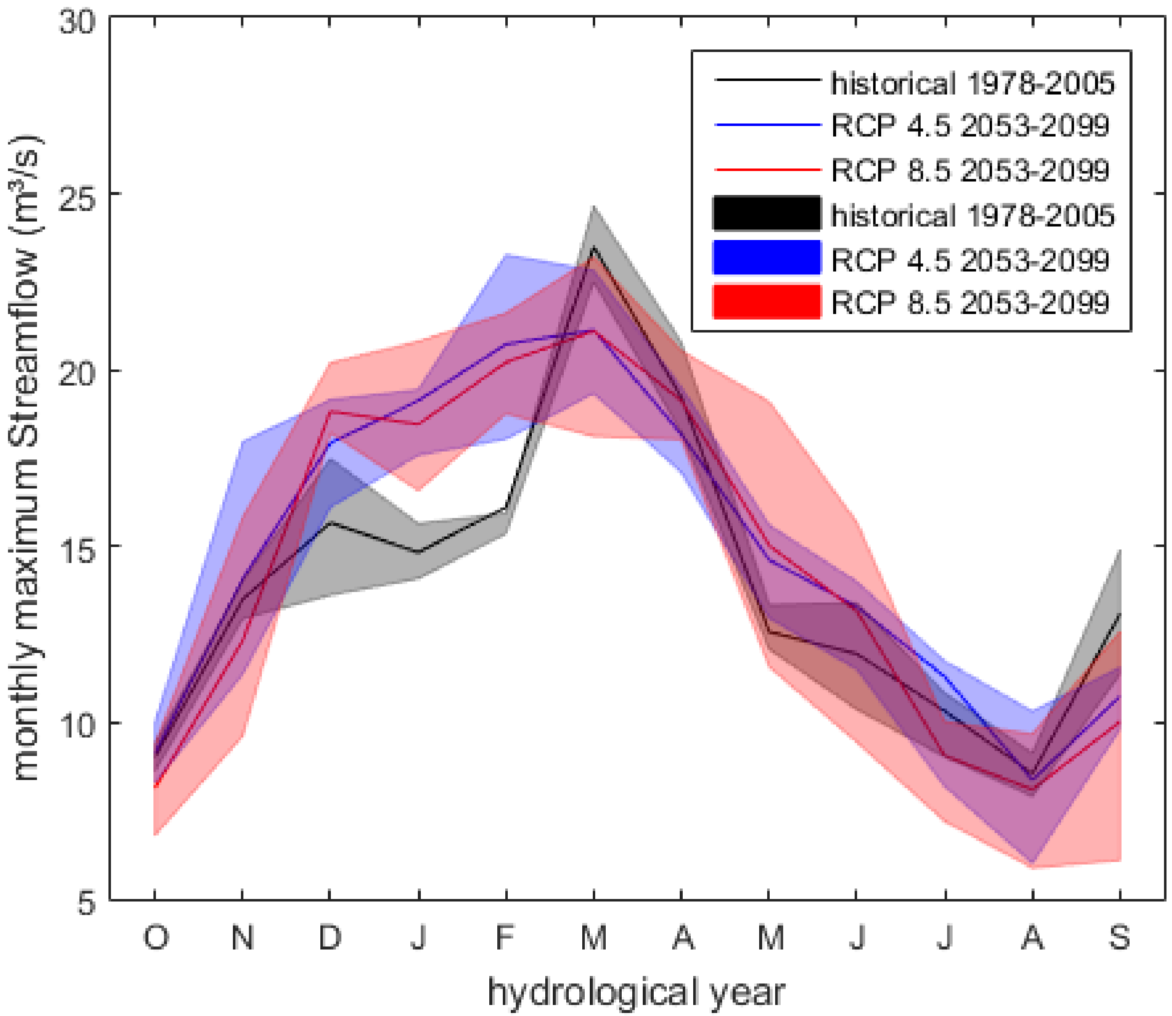


Tmin



Tmax

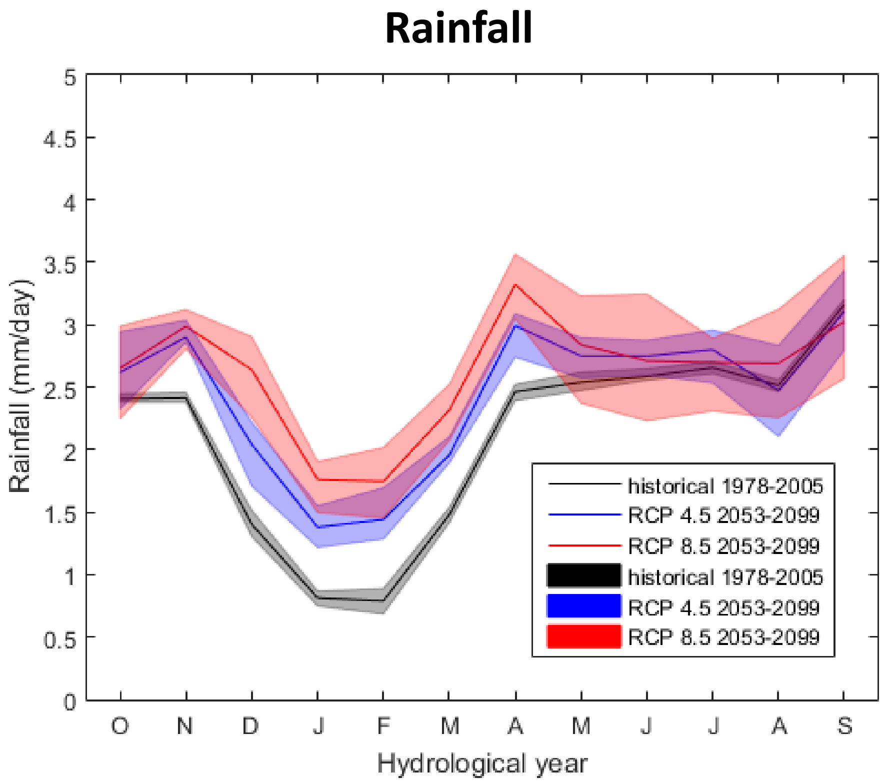
Simulation of Peak Flows

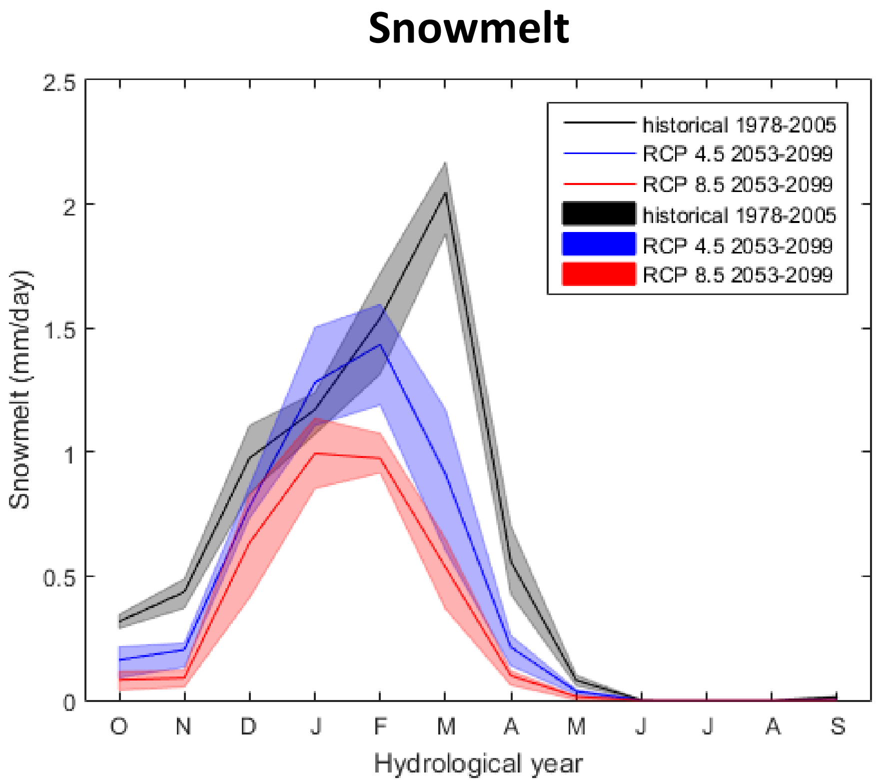


- Future **change in streamflow during winter** months (Dec-Mar)
- Large **uncertainties for the other months** mostly with **RCP 8.5**.

What is the contribution of temperatures and precipitations in this peak flow shift?

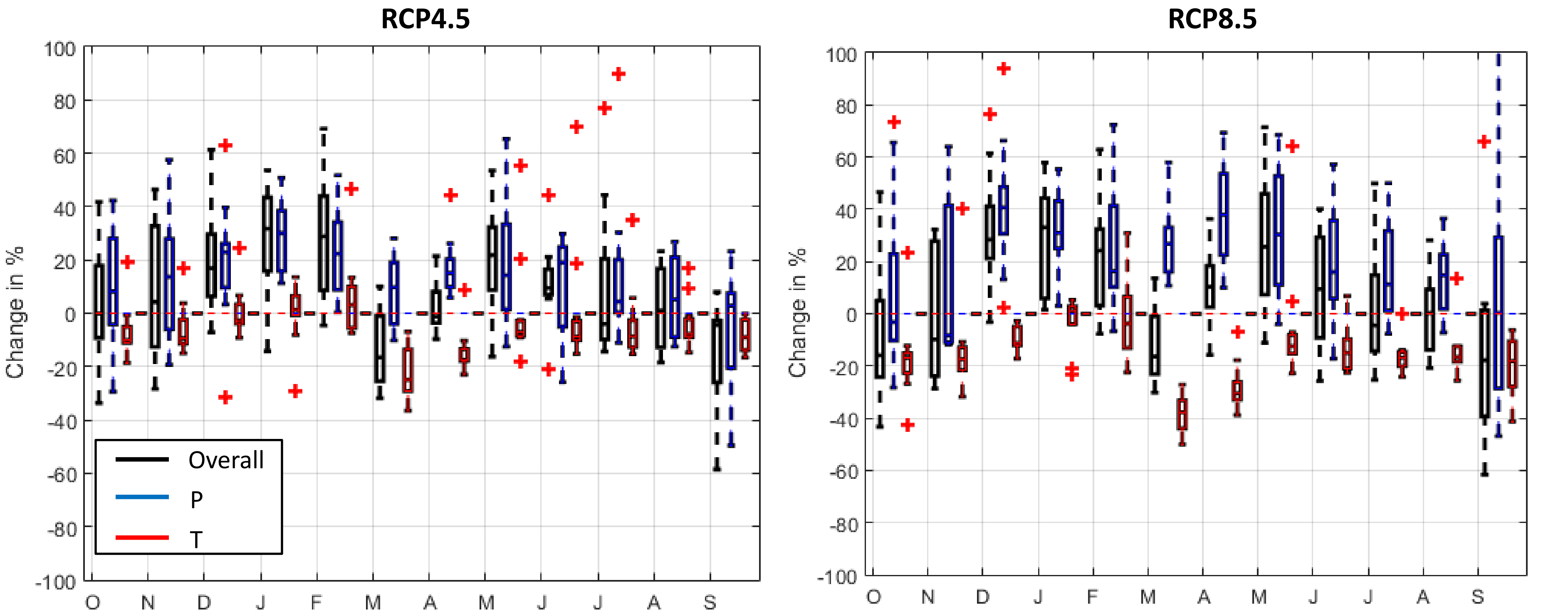
Simulation of Rainfall and Snowmelt





- **Increase in winter rainfall**
- **Snowmelt peak period shifted from March to February.**
- **RCP 8.5 scenario** predicted **higher increase in winter rainfall and larger decrease in snowmelt**
- Larger **uncertainty in rainfall in summer** for **RCP 8.5 scenario.**

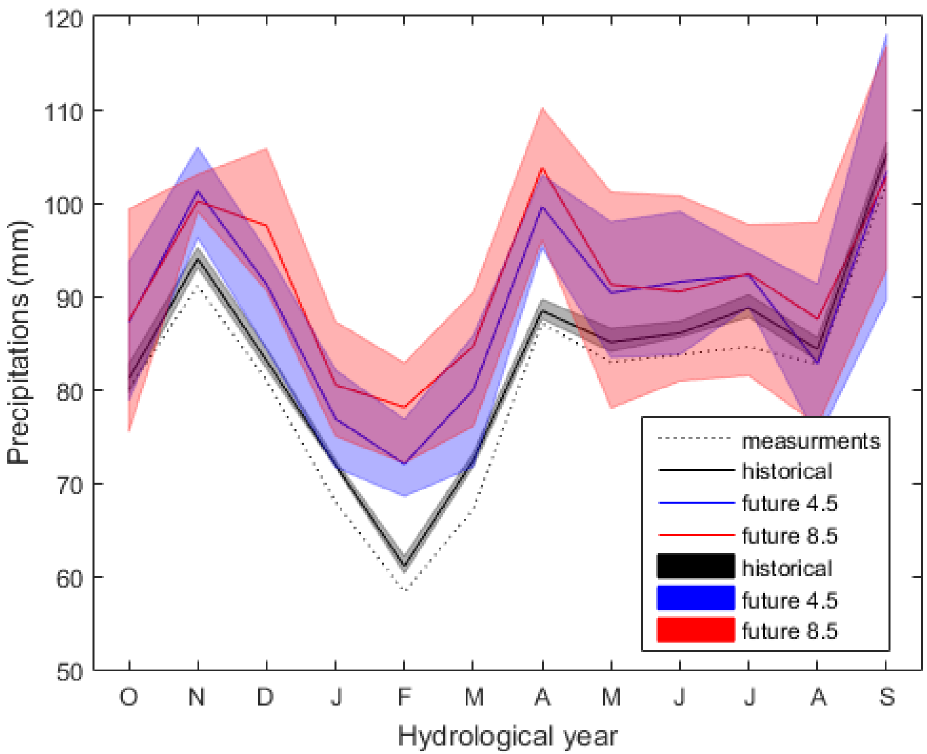
Streamflow Simulations After Removing Temperature Trends



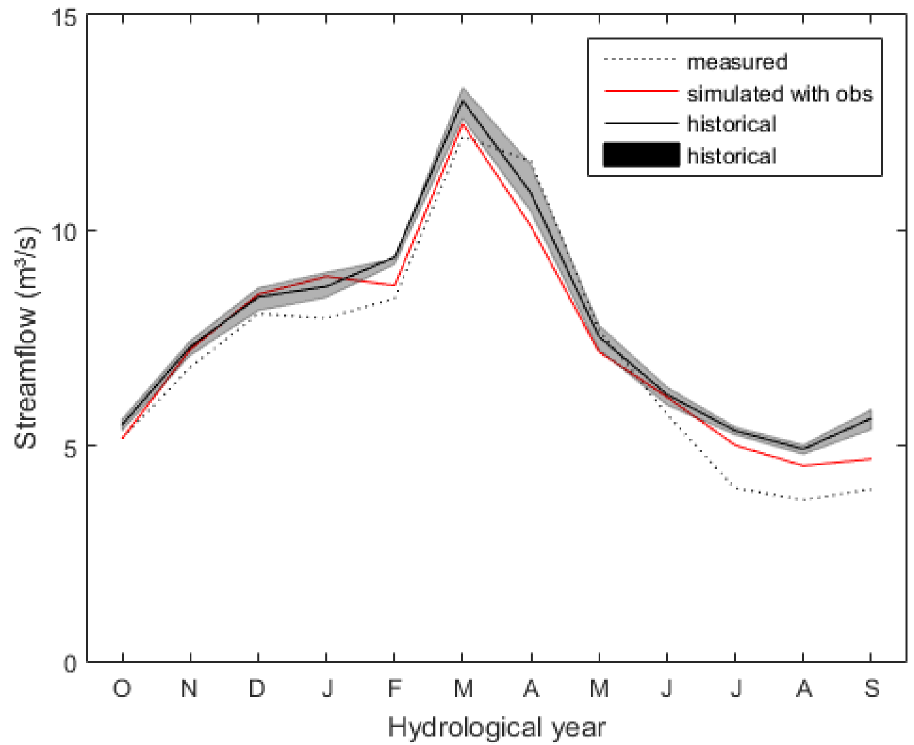
- **Increase of winter streamflow (December-February) due to precipitation increase.**
- **Decrease of streamflow in March** due to **increase of temperatures (Less snowmelt)**
- In **summer no clear result**: **increase of precipitations ≠ increase of temperatures** (ETP)
- **RCP 8.5 scenario enhanced the role of temperature** (less snowmelt in winter, more ETP in summer) but **increase in uncertainties**

Discussion: Cascade of Uncertainty in Simulations

✓ **From Climate Models**



✓ **From GSFLOW Model**



The parametrization of the hydrological and climate models should be improved

Conclusions

- GSFLOW model is able to simulate streamflow reasonably well in **Big Creek catchment**
- The **projected streamflow using input data from** 11 global climate models and 2 scenarios (**RCP 4.5 and 8.5)** show:
  - ✓ A **shift in extreme hydrological events towards early winte**r due to **increase in temperature and precipitation**
- **Uncertainties from different GCM mainly in summer and with RCP 8.5**
- This study can **help society prepare** for the future **evolution of peak flows**

Future work

- **Improve the calibration process** by using **local data availability** (evapotranspiration, soil moisture etc.) and a high-flow based likelihood function.

- Use a **finer grid in MODFLOW** (200m X 200m)

- Create a **seasonal extreme indice (Rainfall in winter)** to understand **the evolution of high flow generated by rainstorm**

- **Compare** the results between **different watersheds** in the region.

Thank You

Questions?

Acknowledgments:

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Province of Ontario