UQÀM
Université du Québec à Montréal

CENTRE ESCER
POUR L'ÉTUDE ET LA SIMULATION DU CLIMAT
À L'ÉCHELLE RÉGIONALE

Environnement et Lutte contre les changements climatiques
Québec

Ouranos

RIISQ
Réseau Inondations InterSectoriel du Québec

Assessing the added value of convection-permitting climate model simulations in simulating floods over southern Quebec watersheds

Behmard Sabzipour
Postdoctoral fellow, UQAM

Supervisor
Philippe Lucas-Picher
UQAM

Co-supervisor
Richard Turcotte
MELCCFP

SYMPOSIUM OURANOS 2025

Motivation and context

- An increase in the frequency and intensity of climate hazards (e.g., **floods**, **heavy precipitation**) [Martel et al., 2021; Guerreiro et al., 2018; Moustakis et al., 2021]

- Floods caused by heavy precipitation during the summer-fall period, primarily due to convective storms

- Debby (Aug. 2024) **158** mm at YUL (<24 hr); previous record **93** mm (Nov. 1996)

Motivation and context

General Circulation Models (GCMs)
~ 500-100 km

→

Regional Climate Models (RCMs)
~ 50 -10 km

→

Convection-Permitting Model (CPM) or (CPRCMs)
~ < 4 km

Deep convection explicitly simulated

Under-estimation of sub-daily RAINFALL EXTREMES
>>>
Deep convection parameterization scheme
(Prein et al., 2016; Ban et al., 2021)

+ Added value for simulation of sub-daily i.e. HOURLY rainfall extremes
(Prein et al., 2015; Ban et al., 2021; Poncet et al., 2024)

Transferability of this added-value to flood simulation ??

Objectives

- Evaluating the capacity of CPMs to simulate precipitation extremes and assess their added value

- Verifying whether the added value of CPMs improves flood simulation

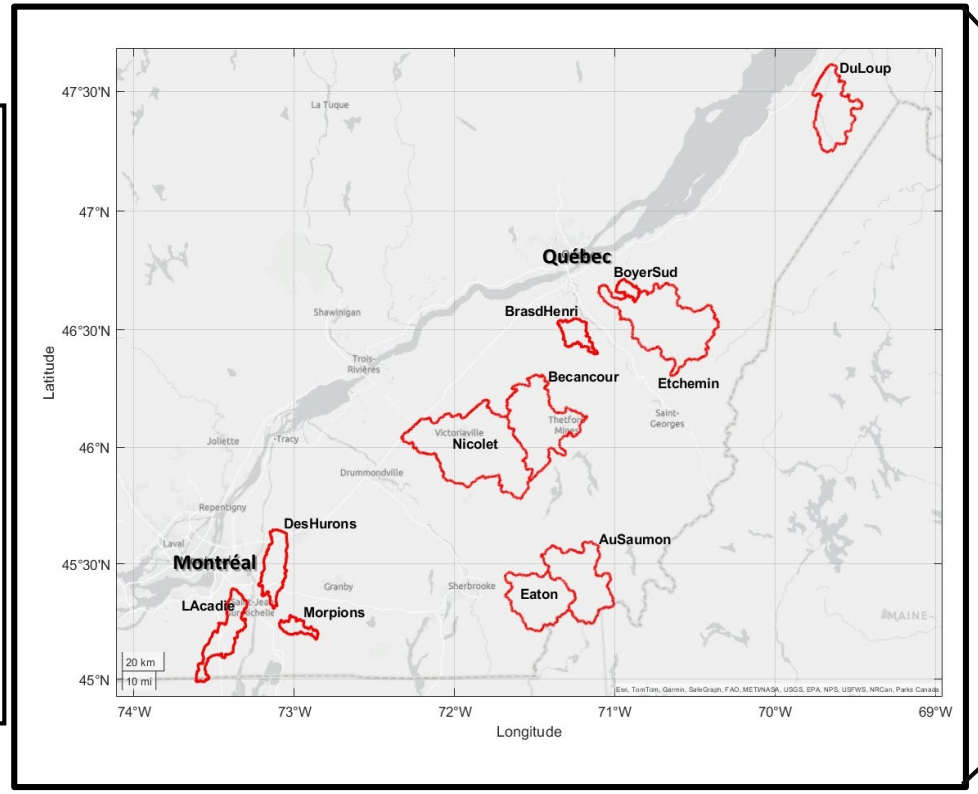
Data sets and Domain

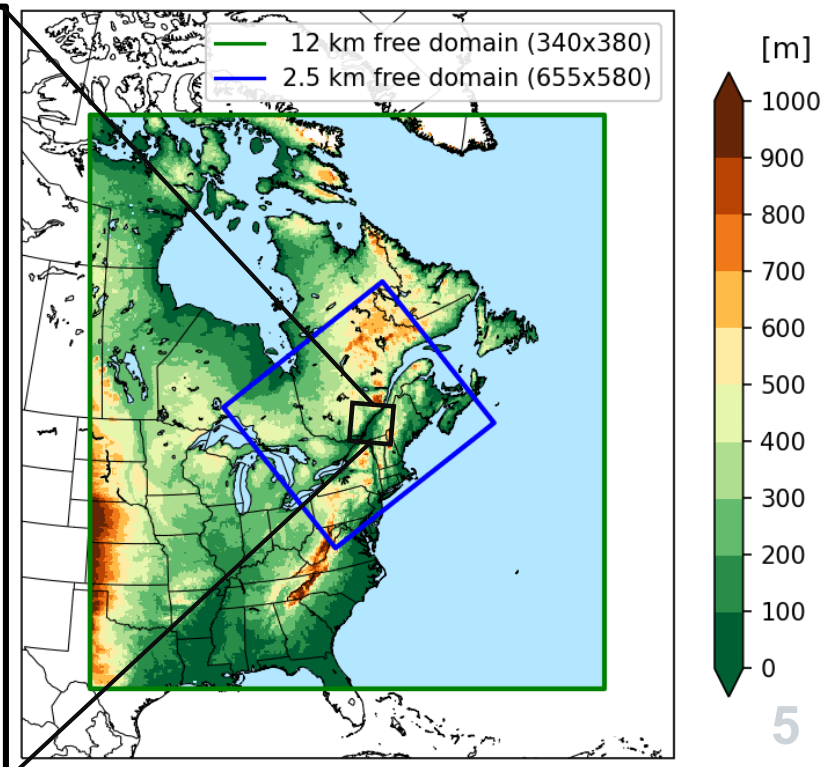
Source of data	Type of data	Spatial resolution	Temporal resolution	Variable	Period of coverage
CRCM6 (Canadian Regional Climate Models version6) 12km Driven by ERA5 reanalysis	Climate simulations	12 km	1 h	2-m air Temperature Precipitation amount	1999 – 2021
CRCM6 (Canadian Regional Climate Models version6) 2.5km Driven by CRCM6 12KM	Climate simulations	2.5 km	1 h	2-m air Temperature Precipitation amount	1999 – 2021

(Roberge et al., 2024)

11 basins

- Emphasize on small basins
- Populated regions
- Availability of hourly discharge (20 years)
- Inside climate model domain





Data sets and Domain

Source of data	Type of data	Spatial resolution	Temporal resolution	Variable	Period of coverage
Environment and Climate Change Canada (ECCC)	Weather Stations	-	1 h	**Precipitation amount**	2014-2023(hourly) 2000-2023(daily)
Centre d'expertise hydrique du Québec (CEHQ)	Discharge Stations	-	15 MINUTES	**River discharge**	1997 – 2022
RDRS (Regional Deterministic Reforecast System) = **CaSR** (Canadian Surface Reanalysis) **(ECCC)**	Reanalysis	~10 km	1 h	**Precipitation amount**	2000 – 2018
ERA5-Land (ECMWF)	Reanalysis	~9 km	1 h	**2-m air Temperature** Precipitation amount	1999 – 2022
IMERG (Integrated Multi-satellitE Retrievals for GPM (Global Precipitation Measurement)) **V6 (NASA)**	Satellite	~10 km	30 MINUTES	Precipitation amount	2000 – 2021

→ Assess the added value of CPM (i.e. Extreme Precipitation)

Calibrate hydrological model ←

Methodology

Objective 1: Evaluating the capacity of CPMs to simulate precipitation extremes and assess their added value

Added value ← **Most reliable observation** ← **Data Analysis** CRCM6-12,2.5 KM

Objective 2: Verifying if the added value brought by CPMs leads to improvement of flood simulation using hydrological models

Run GR5Dt with Calibrated Parameter set
Inputs (**P**; **T**)
SET1(RDRS; ERA5-LAND) SET2(IMERG; ERA5-LAND)
SET3(CRCM6-2.5KM) **SET4(CRCM6-12KM)**

Simulated Streamflow timeseries (2001-2018)

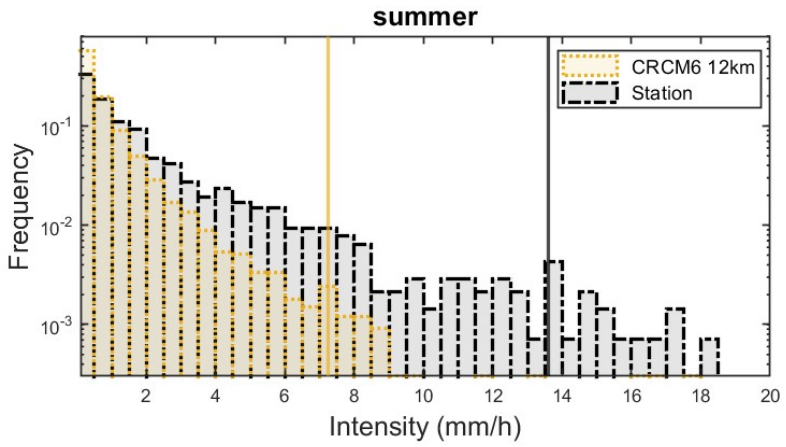
Peak (SUMMER-FALL) flow analysis
Peak (i.e. biggest value per year)

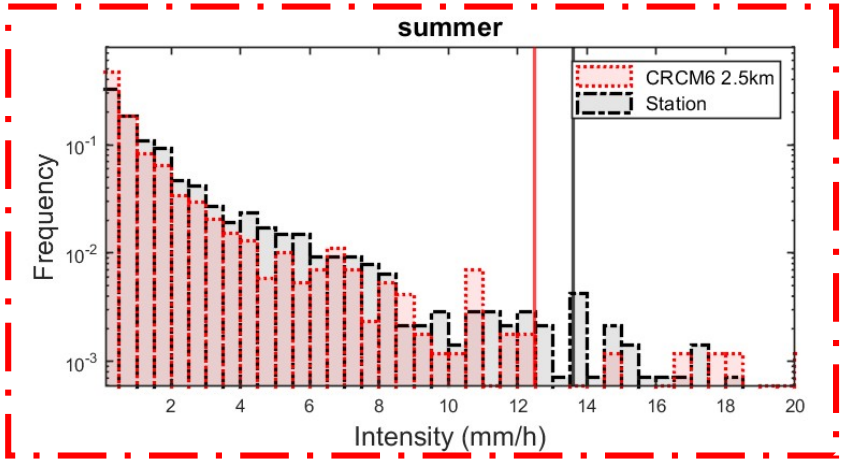
Calibrate GLOBAL Hydrological model (GR5Dt) at HOULRY time step (2001-2018)
7 Parameters
SCE-UA algorithm
Observed streamflow (11 basins)
Model input (**P**recipitation) : RDRS
Model input (2-m **T**emperature) : ERA5-LAND

Calibrated Parameter set

Results – Objective 1

Frequency Intensity Histogram Summer (JJA)

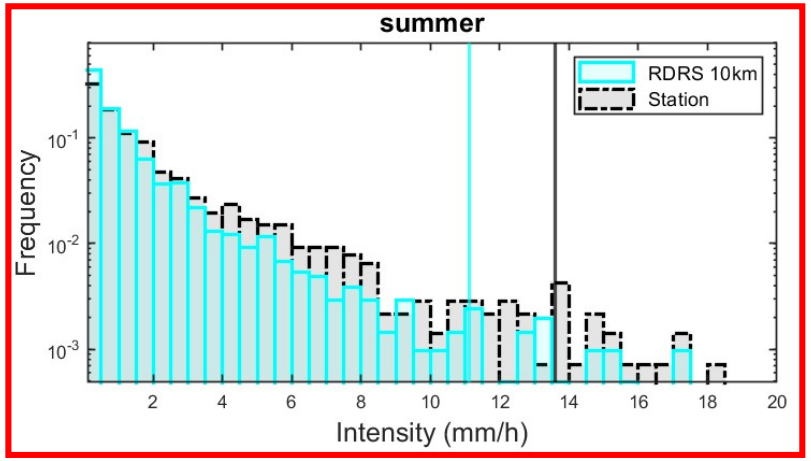


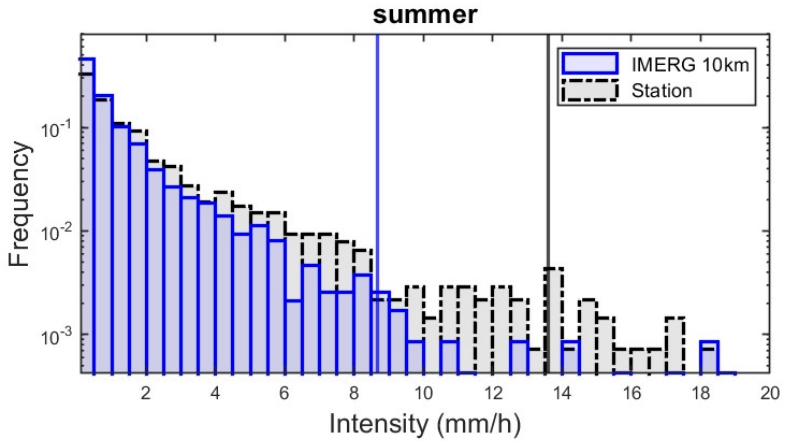


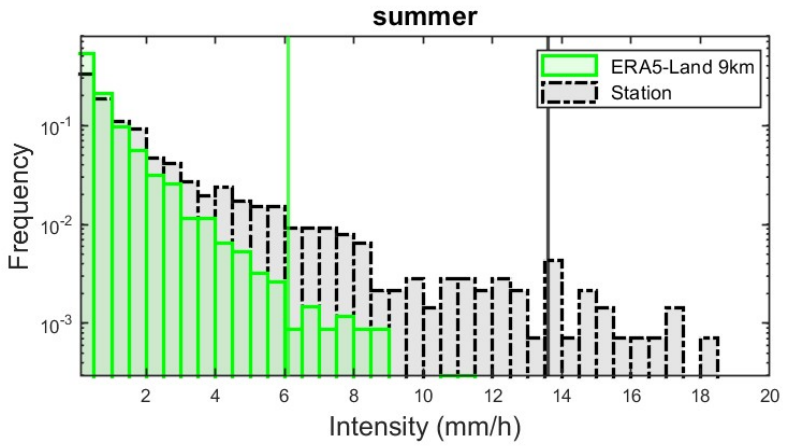
Station: MONTRÉAL
PIERRE ELLIOTT TRUDEAU INTL

	Periods
Station	2014-2023
CRCM6s	2011-2020
IMERG	2011-2020
ERA5-LAND	2011-2020
RDRS	2009-2018

Vertical line shows 99.9th percentile



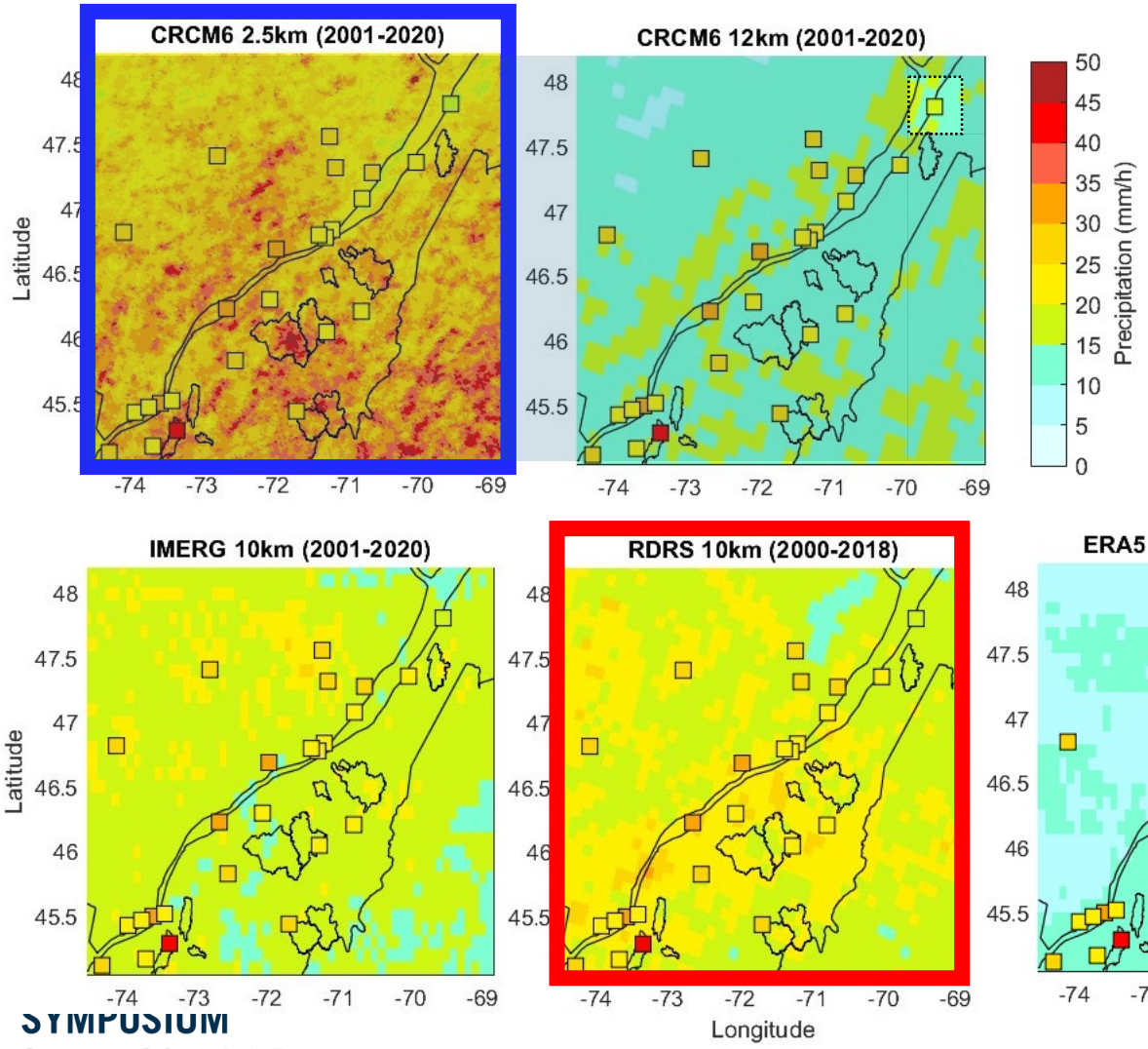




Results – Objective 1

99.99th percentile
Hourly precipitation
Summer (JJA)

Station data (2014-2023) > 60% availability



- Added value of CRCM6-2.5 km in simulating extreme precipitation compared to CRCM6-12km
  - Result are consistent for Fall (SON)
- Reanalysis (RDRS): Best observation data for calibrating the hydrological model; aligns with station data for the 99.99th percentile

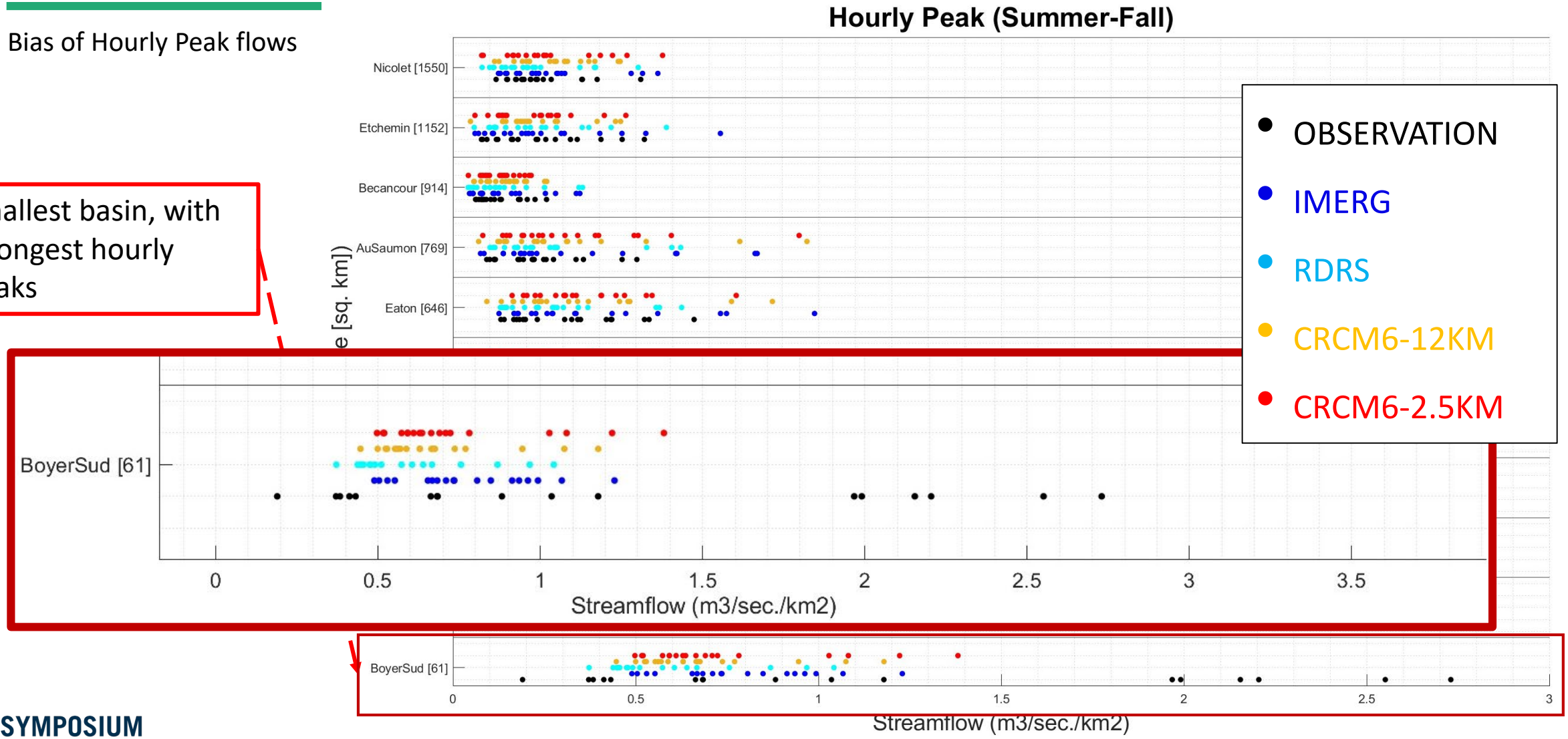
Results – Objective 2

Bias of Hourly Peak flows

Results – Objective 2

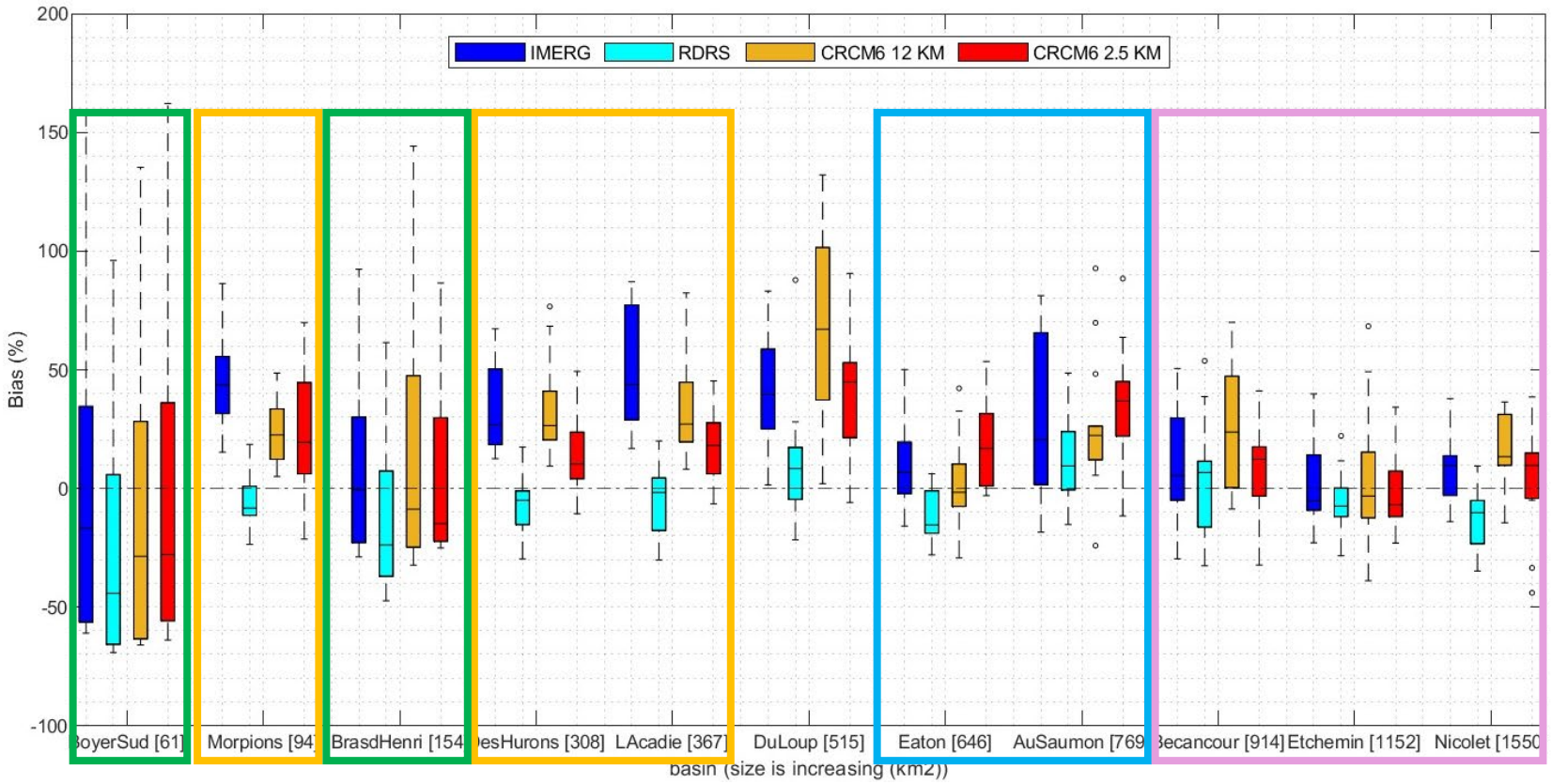
Bias of Hourly Peak flows

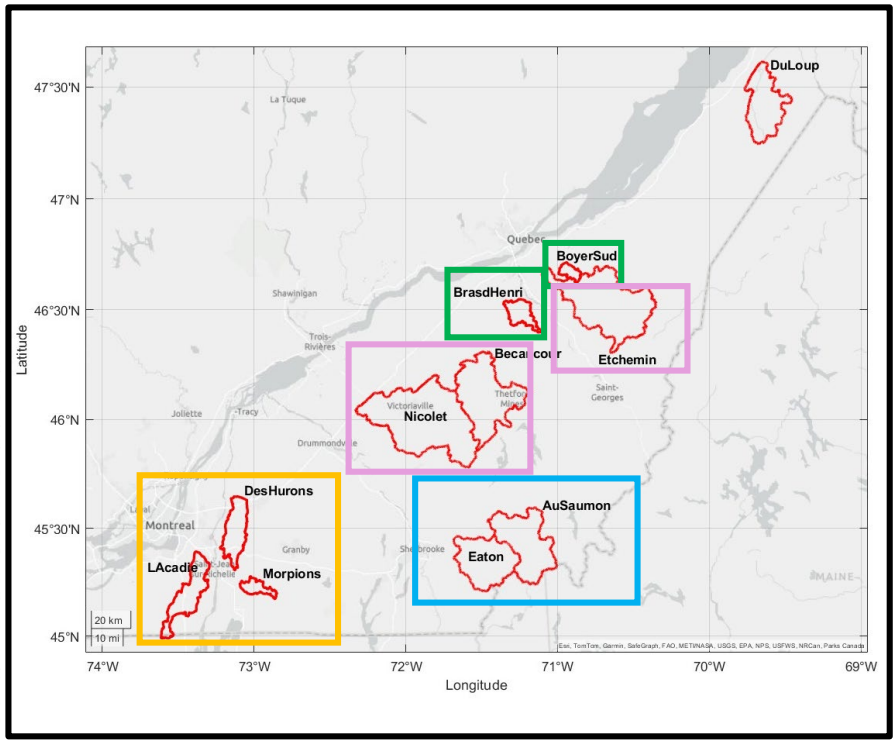
Smallest basin, with strongest hourly peaks



Results – Objective 2

Bias of Hourly Peak flows



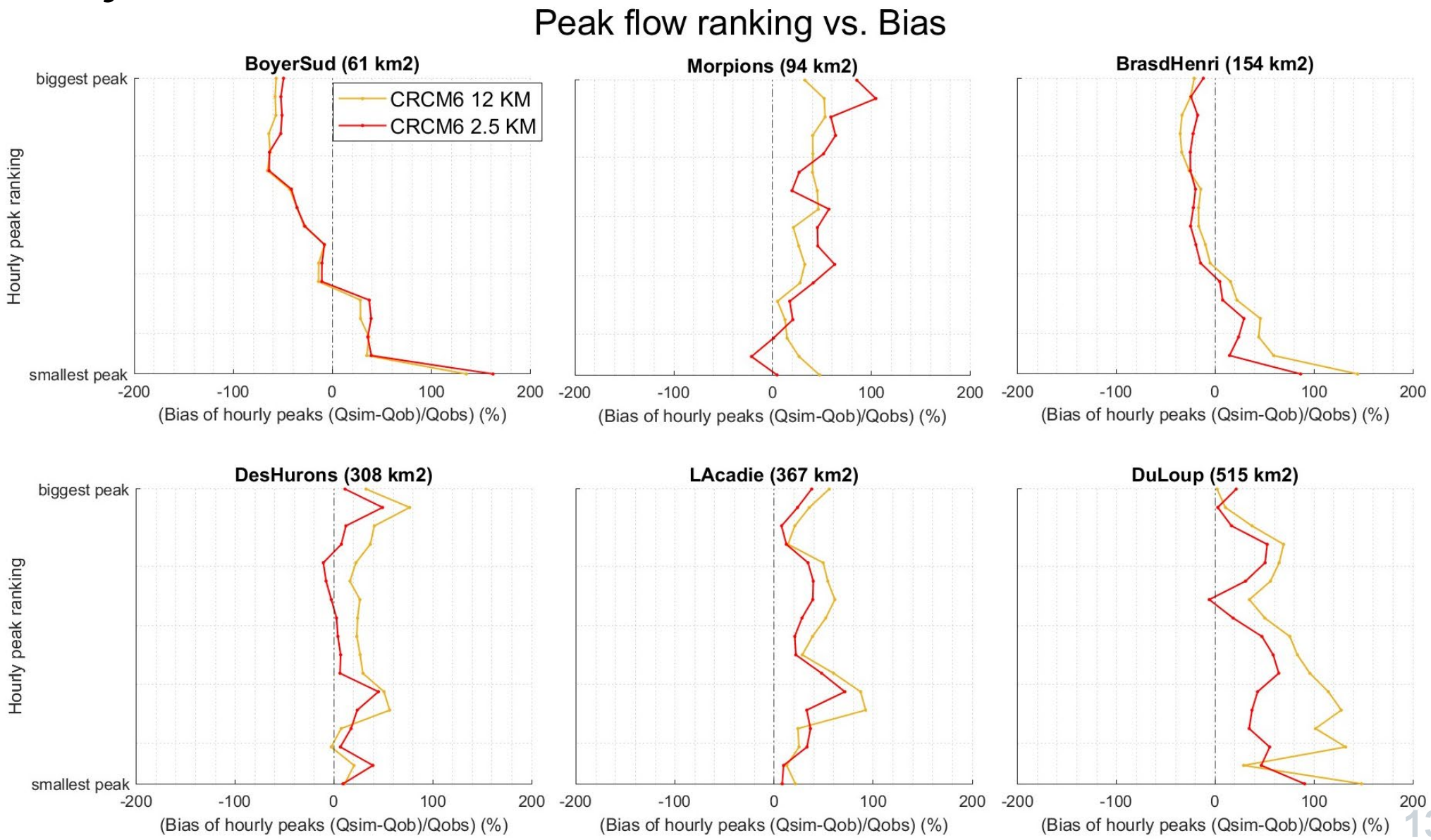


- Lower bias for RDRS – underestimation of peaks

- **Better** performance (smaller biases and narrower dispersion of biases) for CRCM6-2.5km
- Results from basins with similar size and location show similar signature (i.e. size of box, direction of biases(+/-))

Results – Objective 2

Lower biases for CRCM6-2.5KM



Conclusion – Take Home Message

- **Added value**; Can we say that CRCM6-2.5km performs better than CRCM6-12km in simulating Extreme hourly precipitation? Yes
  Histogram (Frequency-Intensity)
  99.99th percentile maps

- Does this advantage persist when CRCM6 outputs are used as input for hydrological modeling to simulate floods?

  Cautiously Yes
  Bias of peak streamflow

- Next steps:
  - Use a distributed hydrological model
  - Estimate the evolution of floods in future

Merci pour votre attention

SYMPOSIUM
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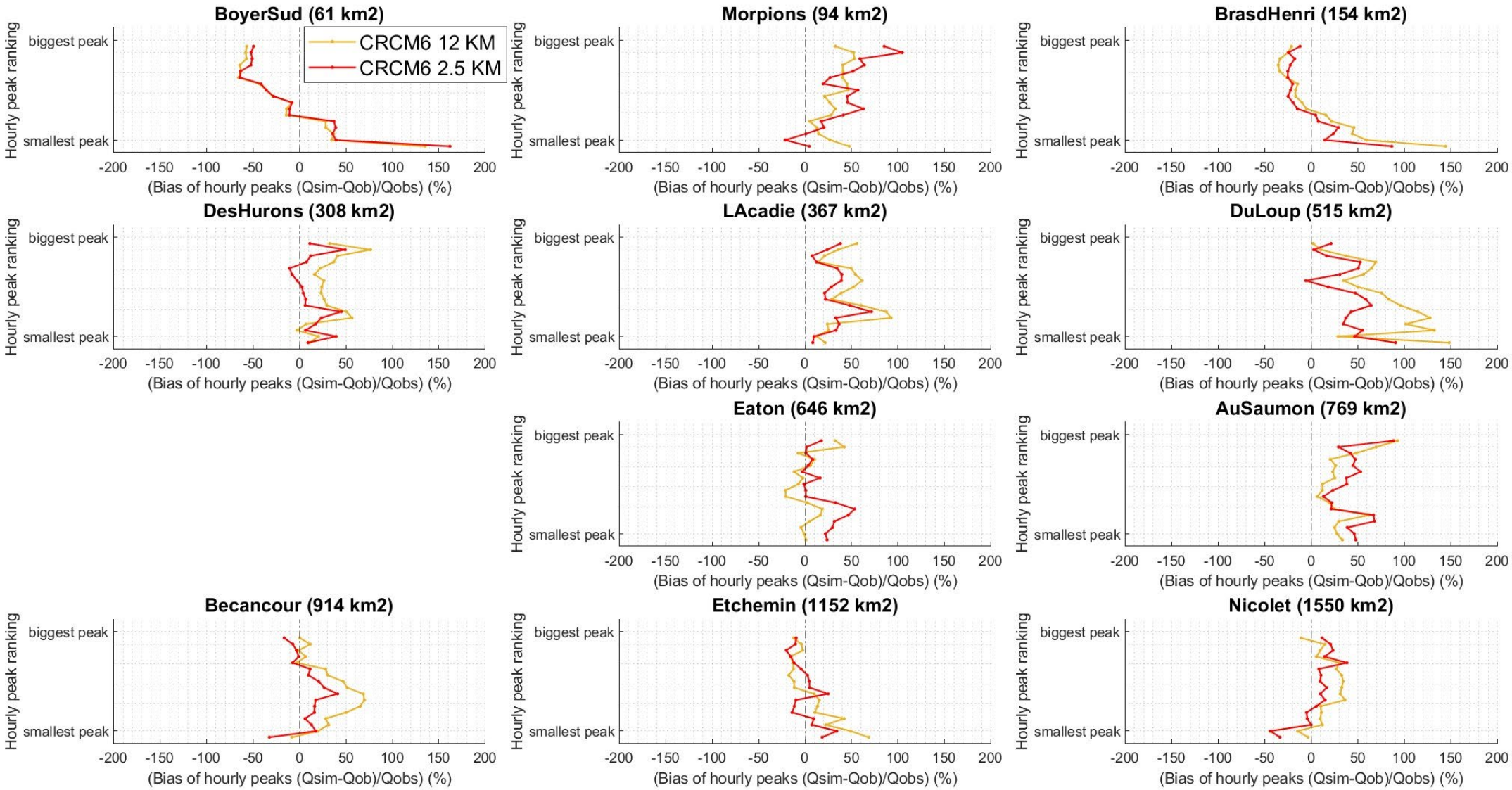
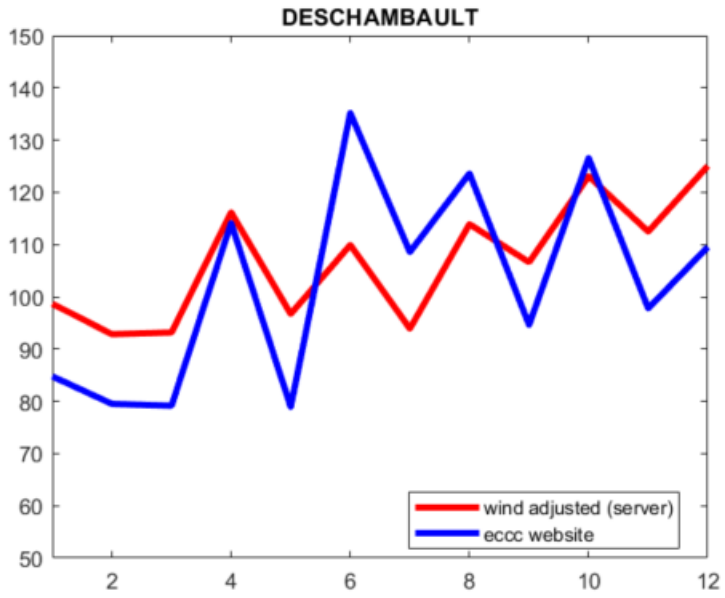
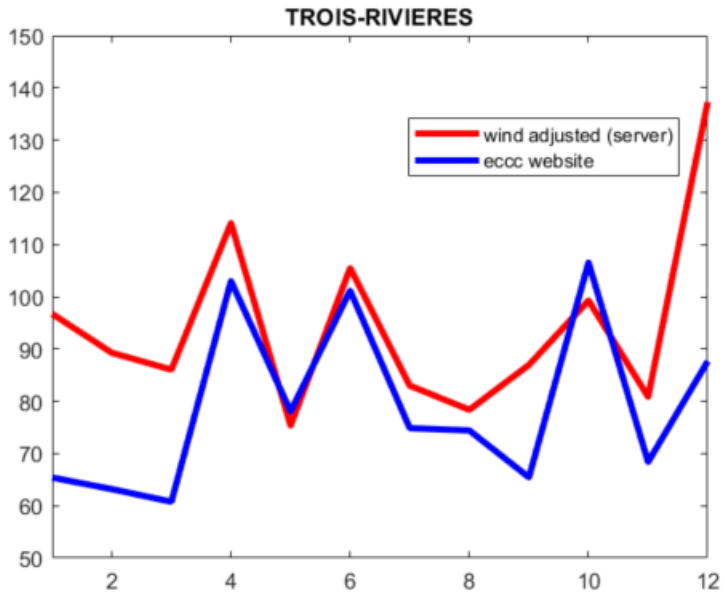
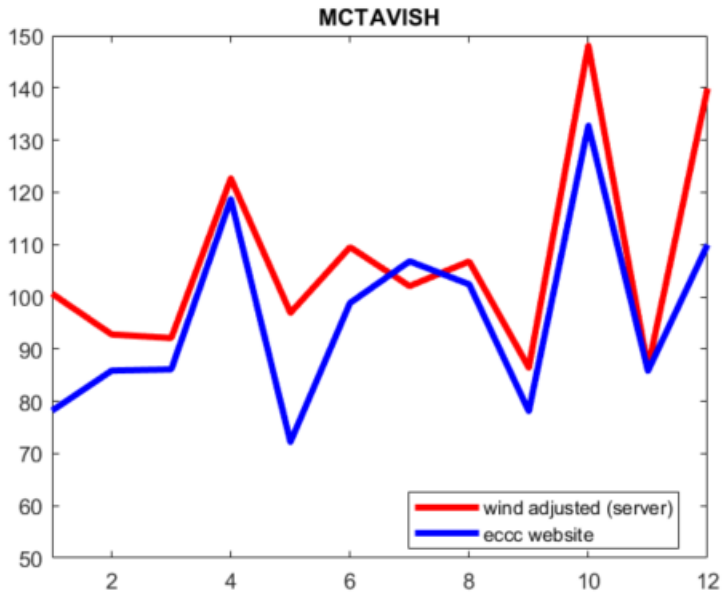
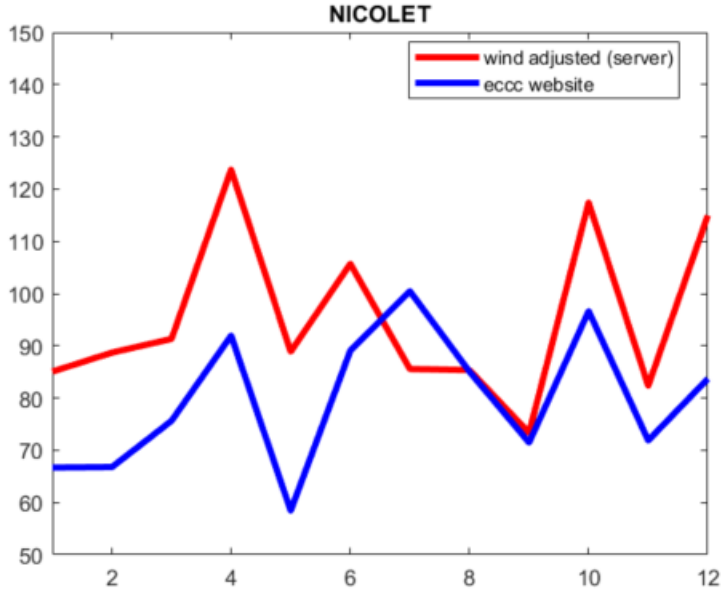
Cumulative Frequency of Hourly Peaks

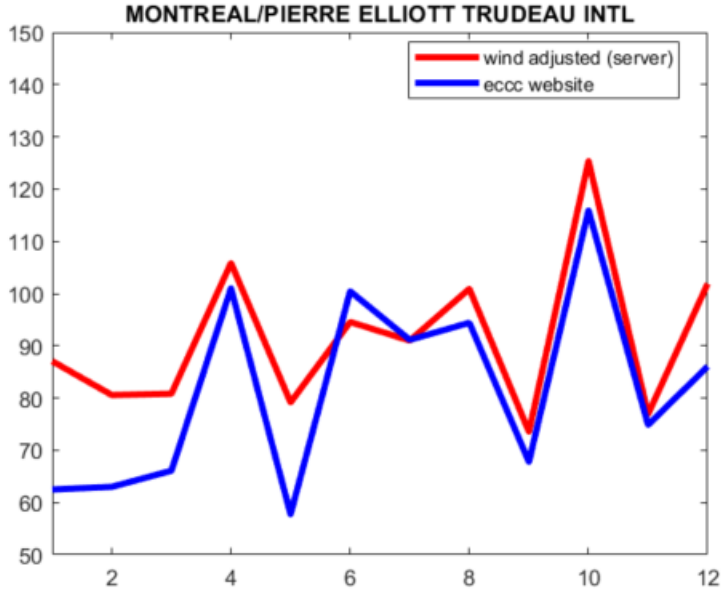












Comparing mean annual precipitation extracted from hourly precipitation from weather stations

1- wind-adjusted data from our server (red)

2- directly downloaded from ECCC website (blue)

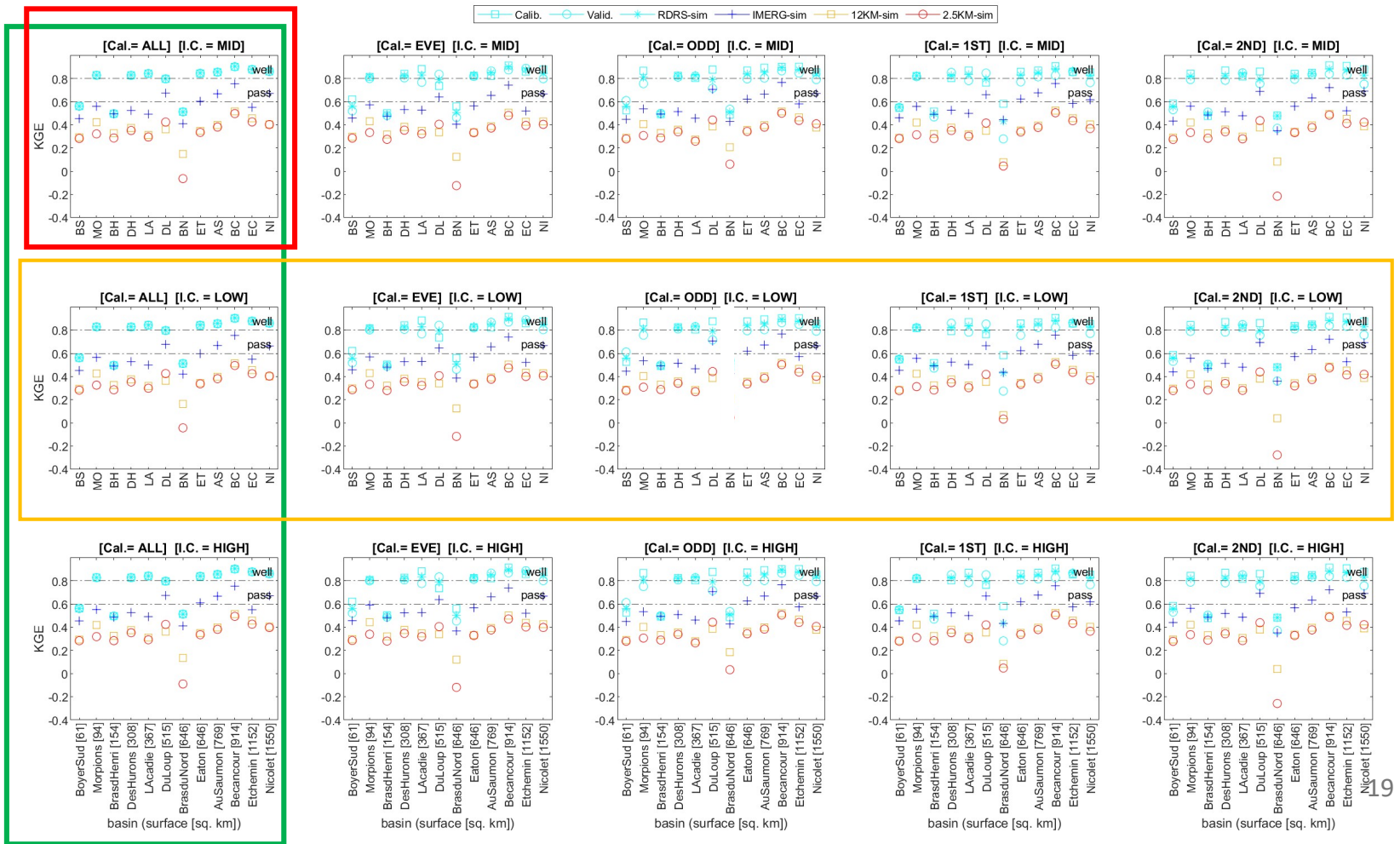
Hydrological Model Calibration

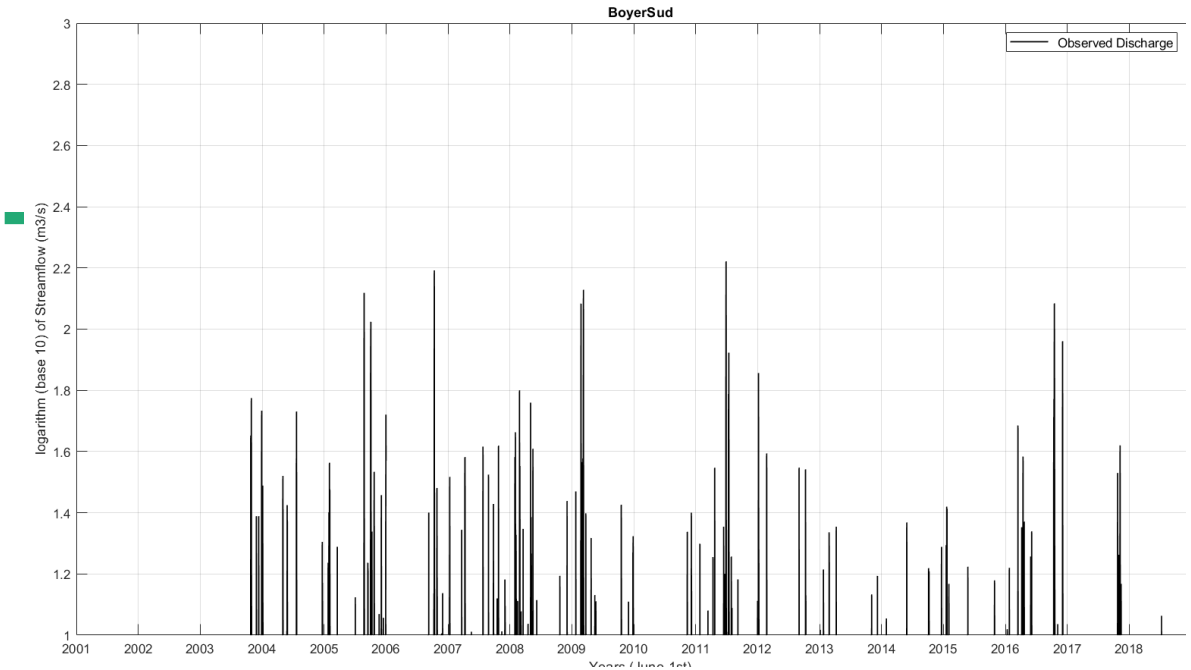
Calibration performance

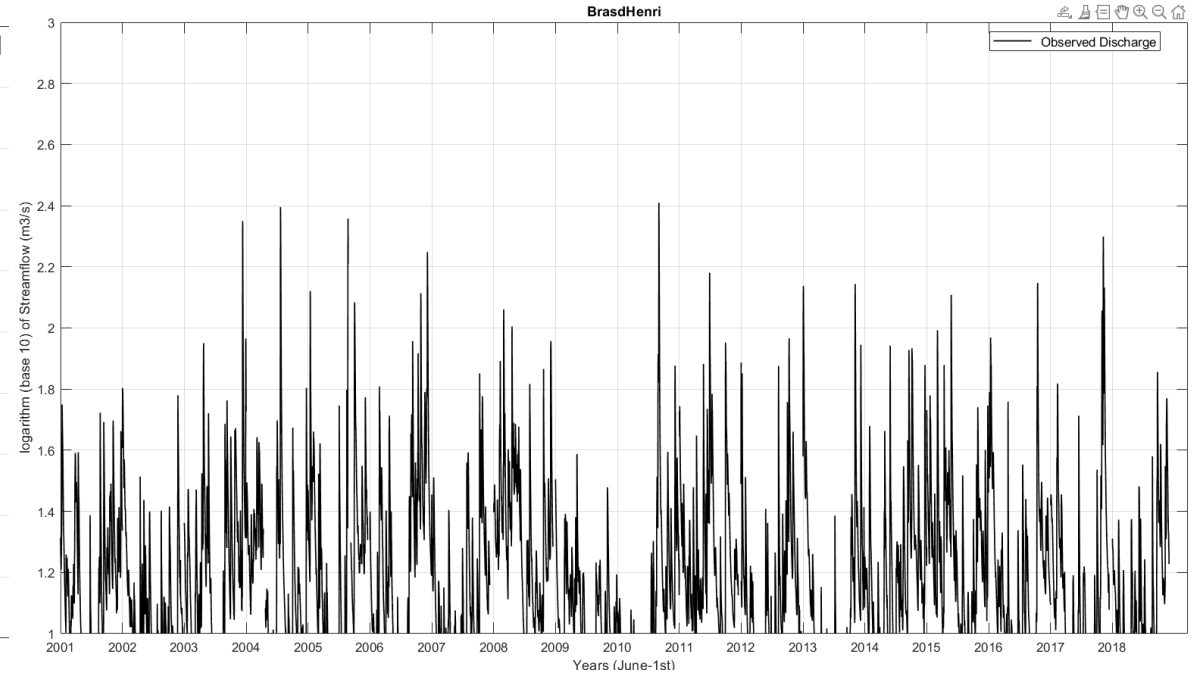
Different CALIBRATION SETTING to show that parameter sets from multiple recipe of calibration does not affect calibration performance (i.e. KGE)

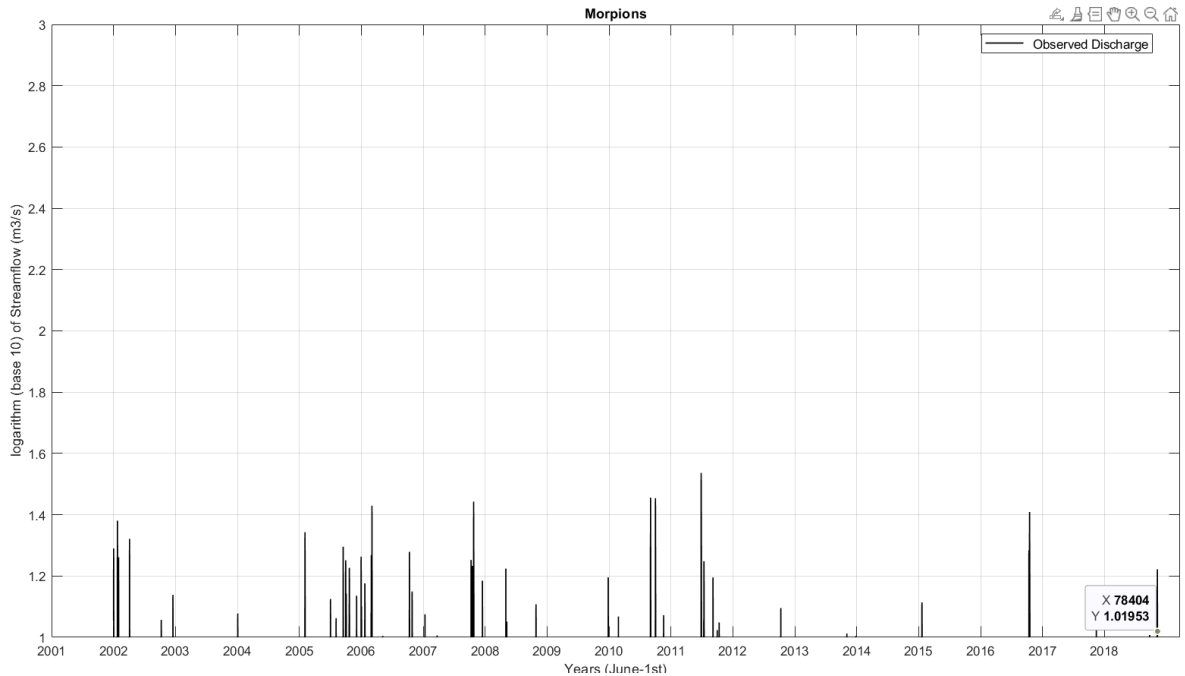
Using RDRS as precipitation input

- Calibration performance is less sensitive to variations in the initial seeds (vertical direction of the plots)
- Calibration performance is more sensitive to changes in the calibration-validation periods (horizontal direction of the plots)



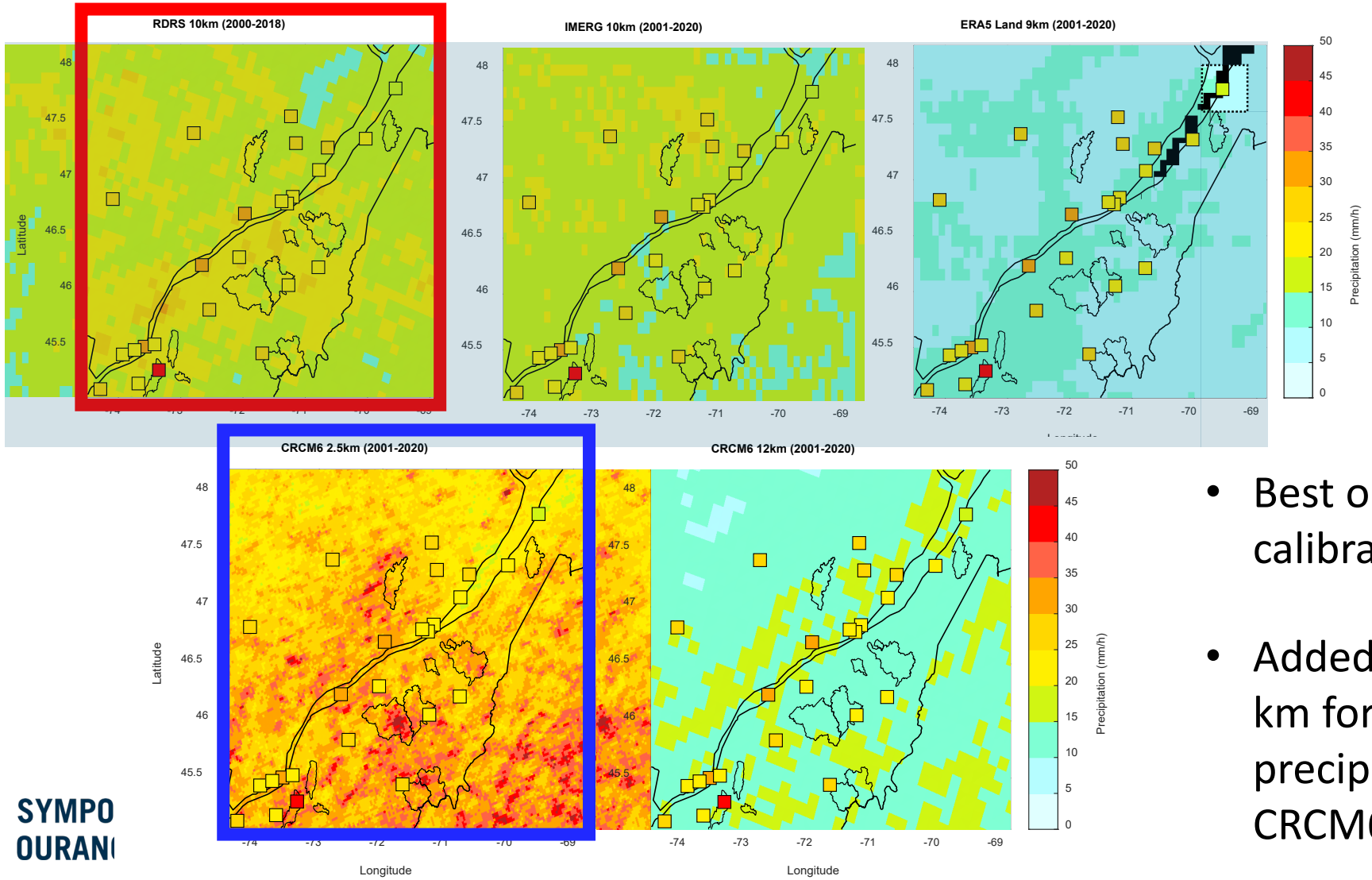

BoyerSud
Observed Discharge
logarithm (base 10) of Streamflow (m3/s)
Years (June-1st)


BrasdHenri
Observed Discharge
logarithm (base 10) of Streamflow (m3/s)
Years (June-1st)


Morpions
Observed Discharge
logarithm (base 10) of Streamflow (m3/s)
Years (June-1st)
X 78404
Y 1.01953

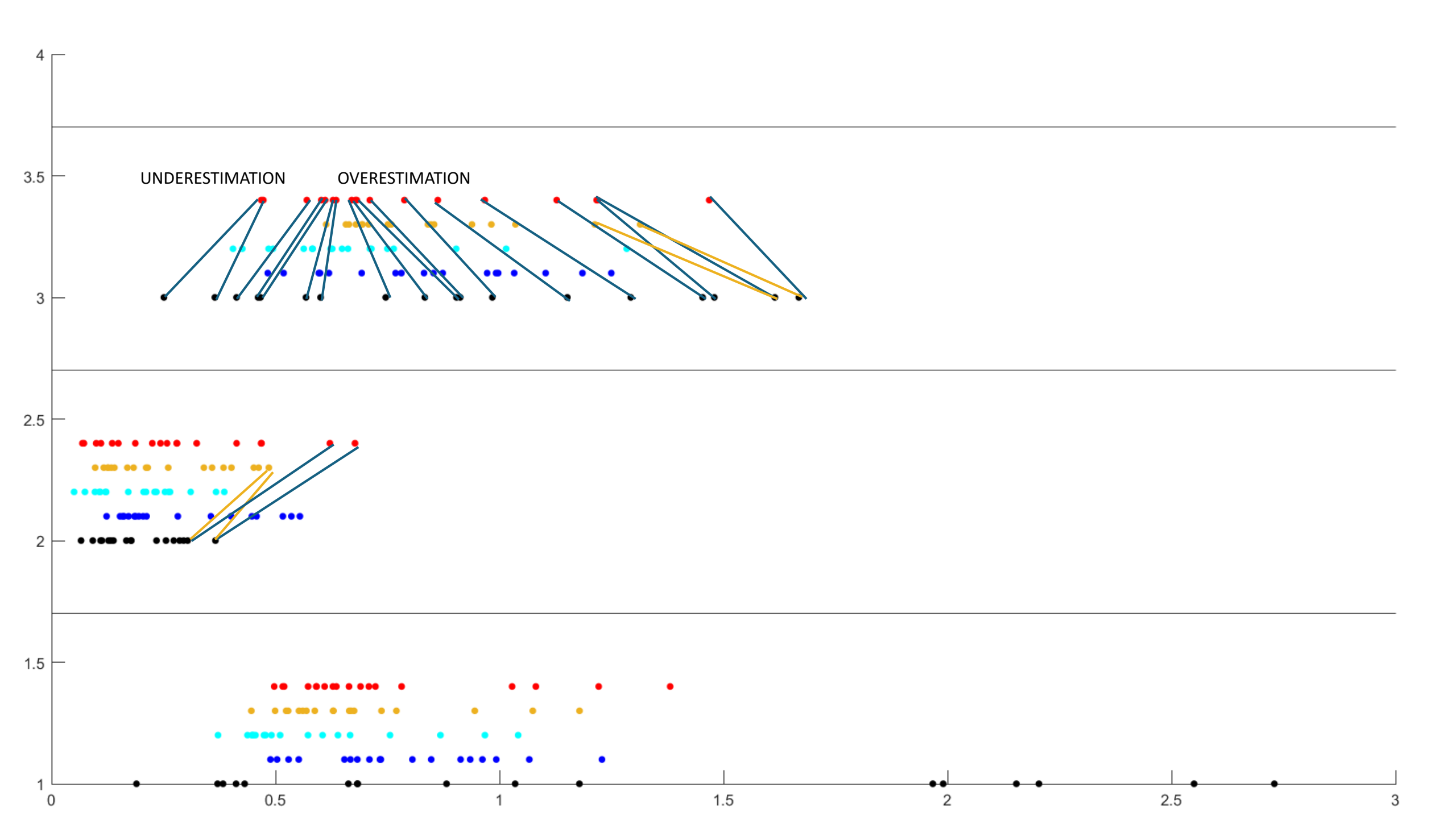
Results – Objective 1

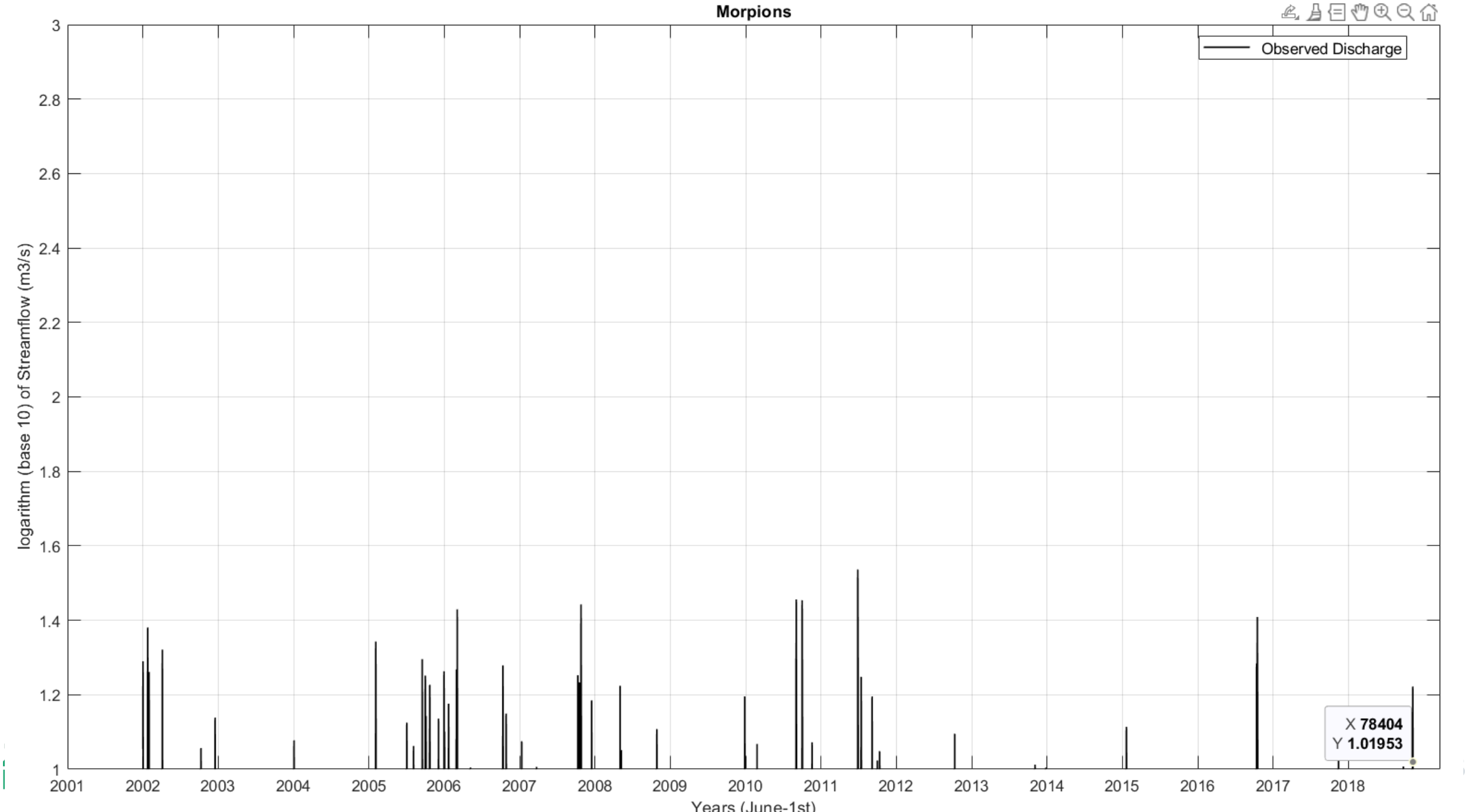
99.99th percentile
Hourly precipitation
Summer (JJA)

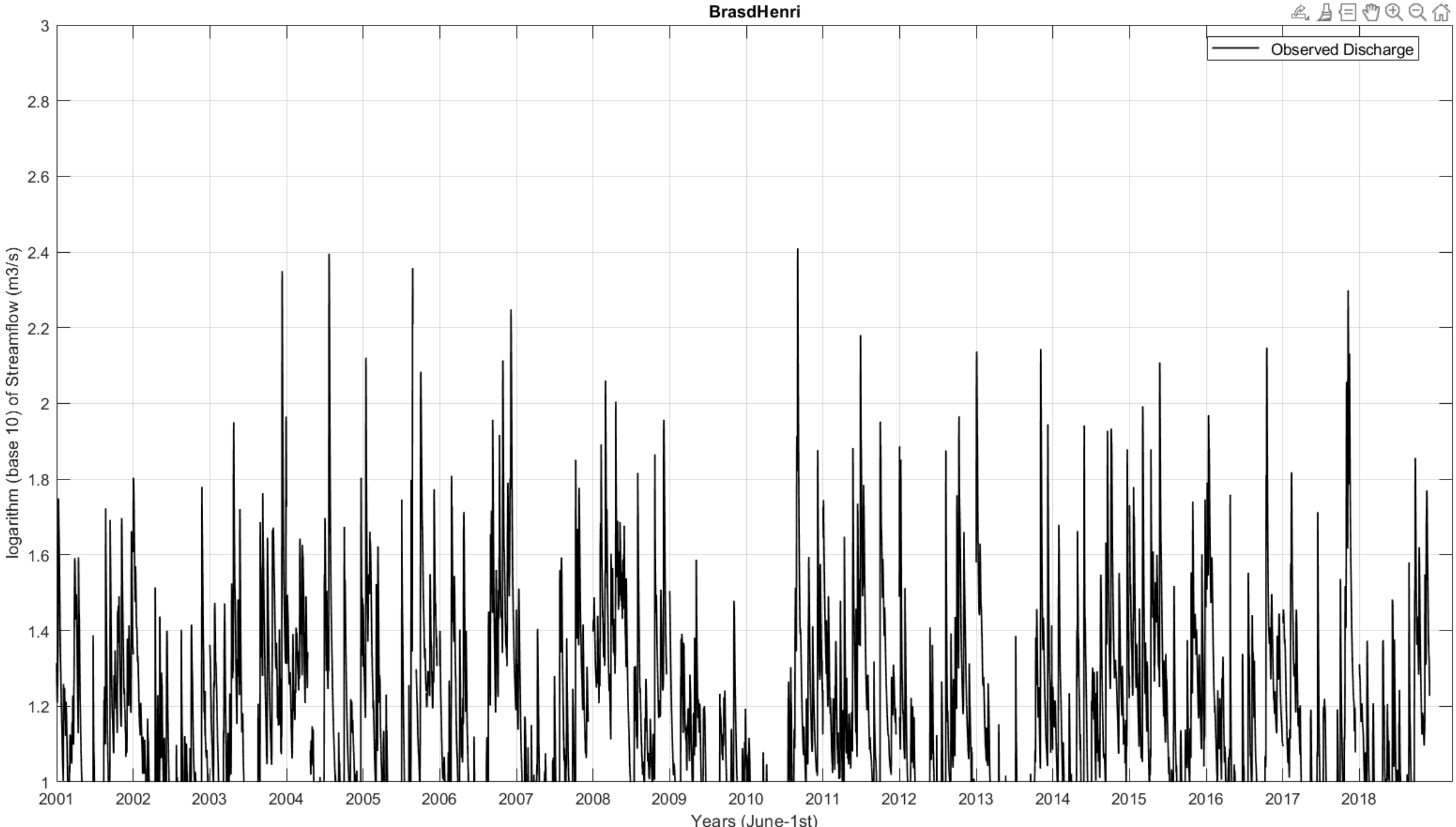


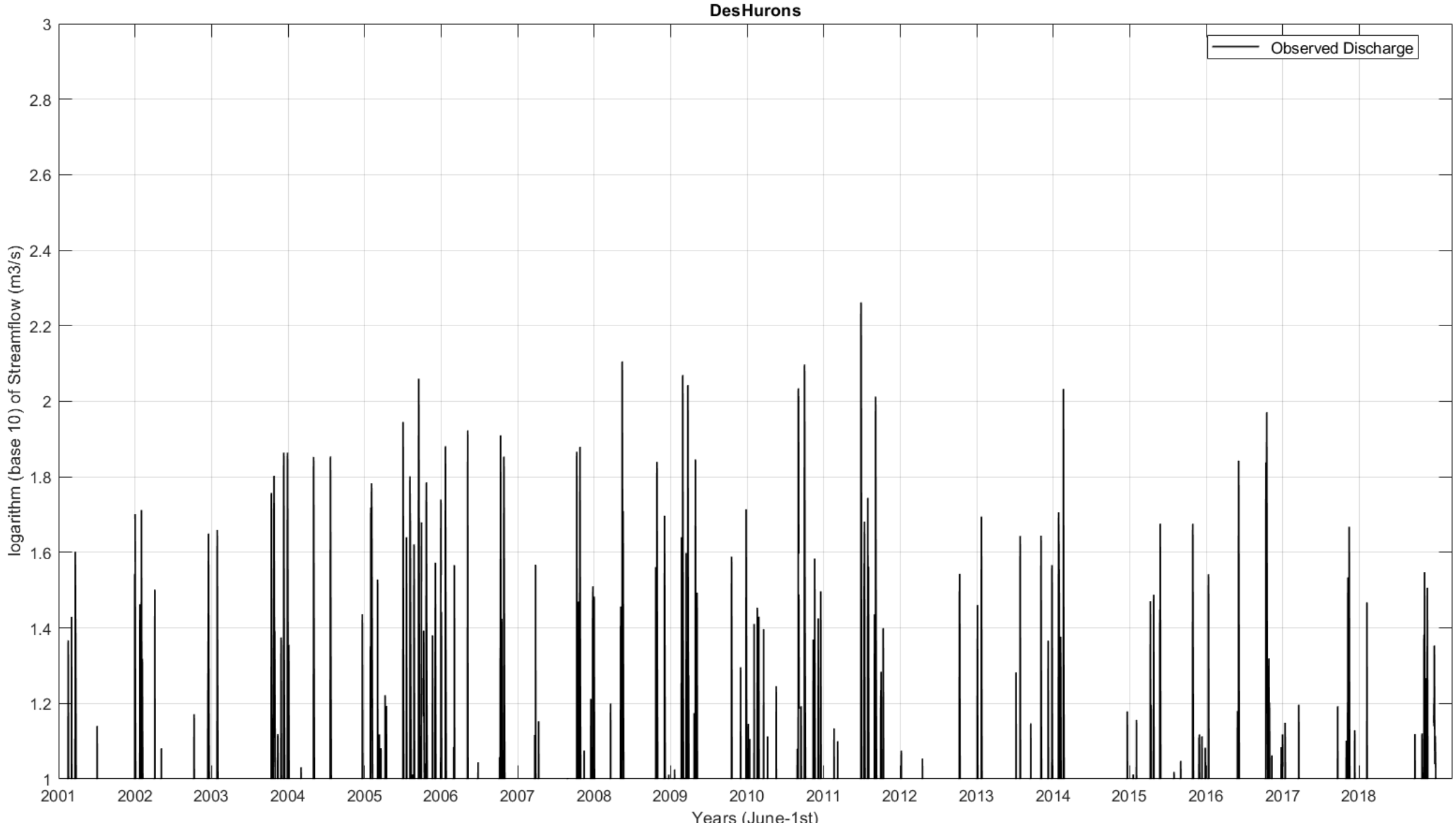
Station data (2014-2023)
60% non-missing

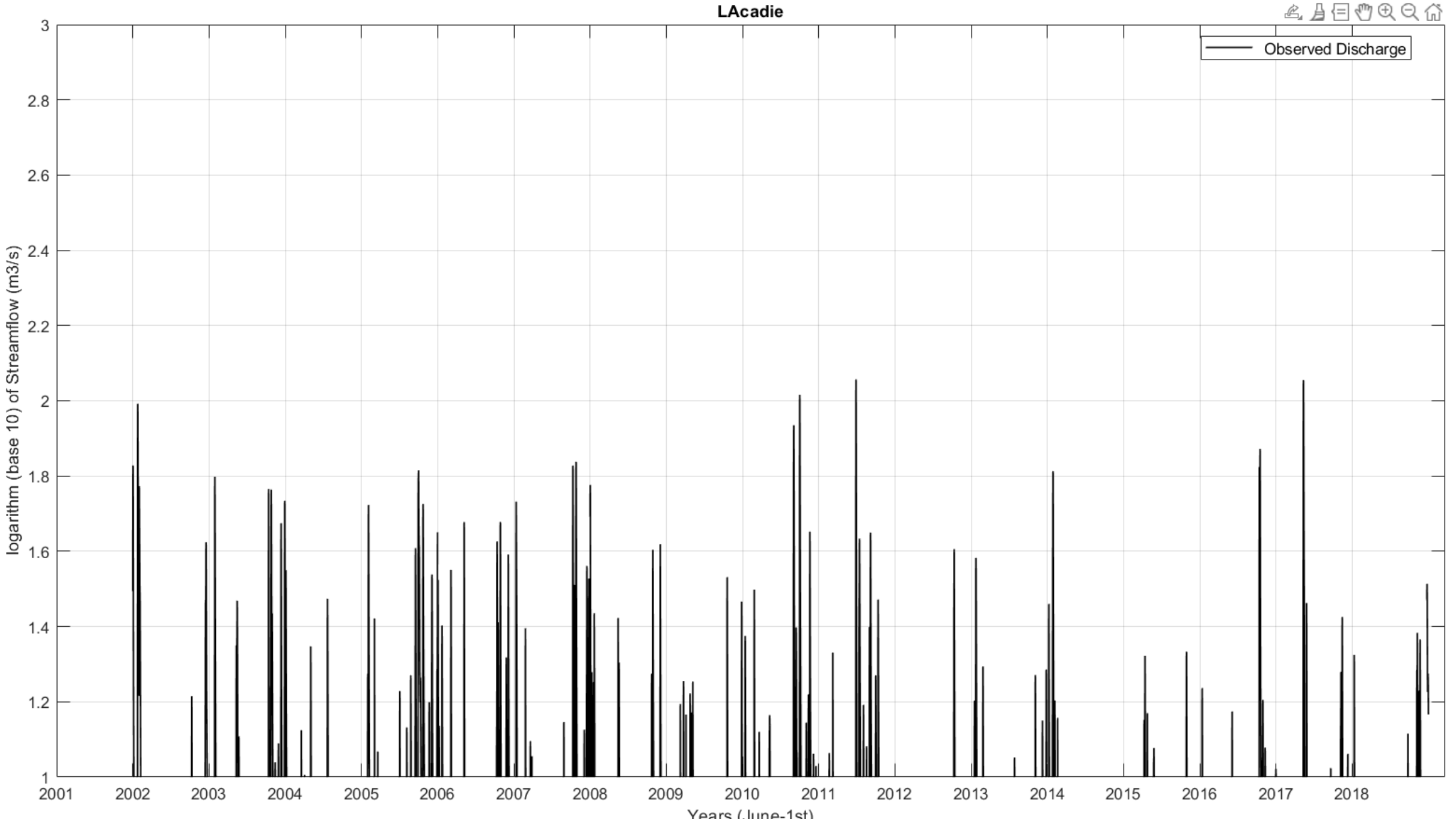
- Best observation to be used for calibrating hydrological model
- Added value of using CRCM6-2.5 km for presenting extreme precipitation compared to CRCM6-12km

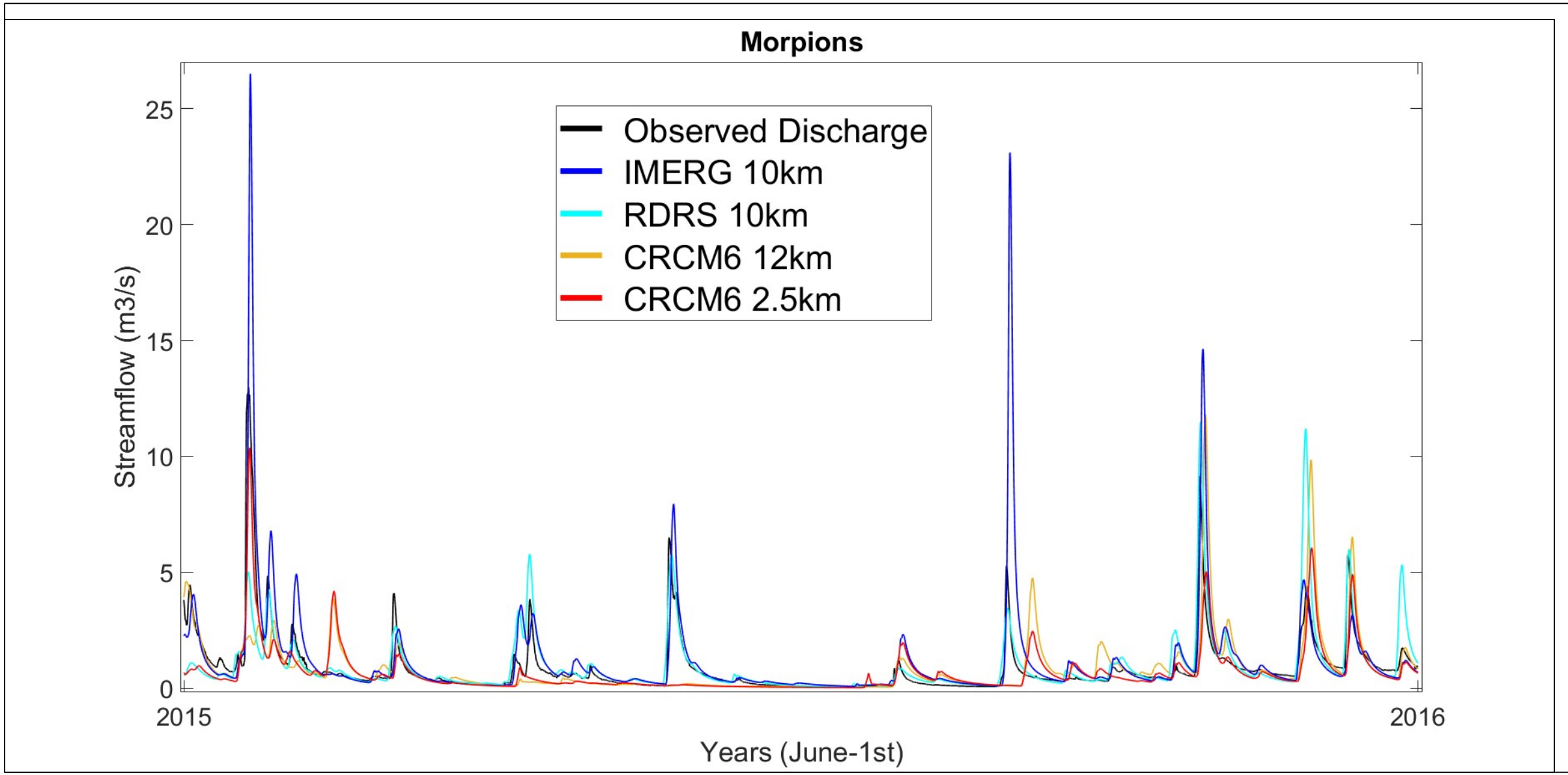

UNDERESTIMATION
OVERESTIMATION
4
3.5
3
2.5
2
1.5
1
0
0.5
1
1.5
2
2.5
3


Morpions
Observed Discharge
logarithm (base 10) of Streamflow (m3/s)
Years (June-1st)
X 78404
Y 1.01953
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

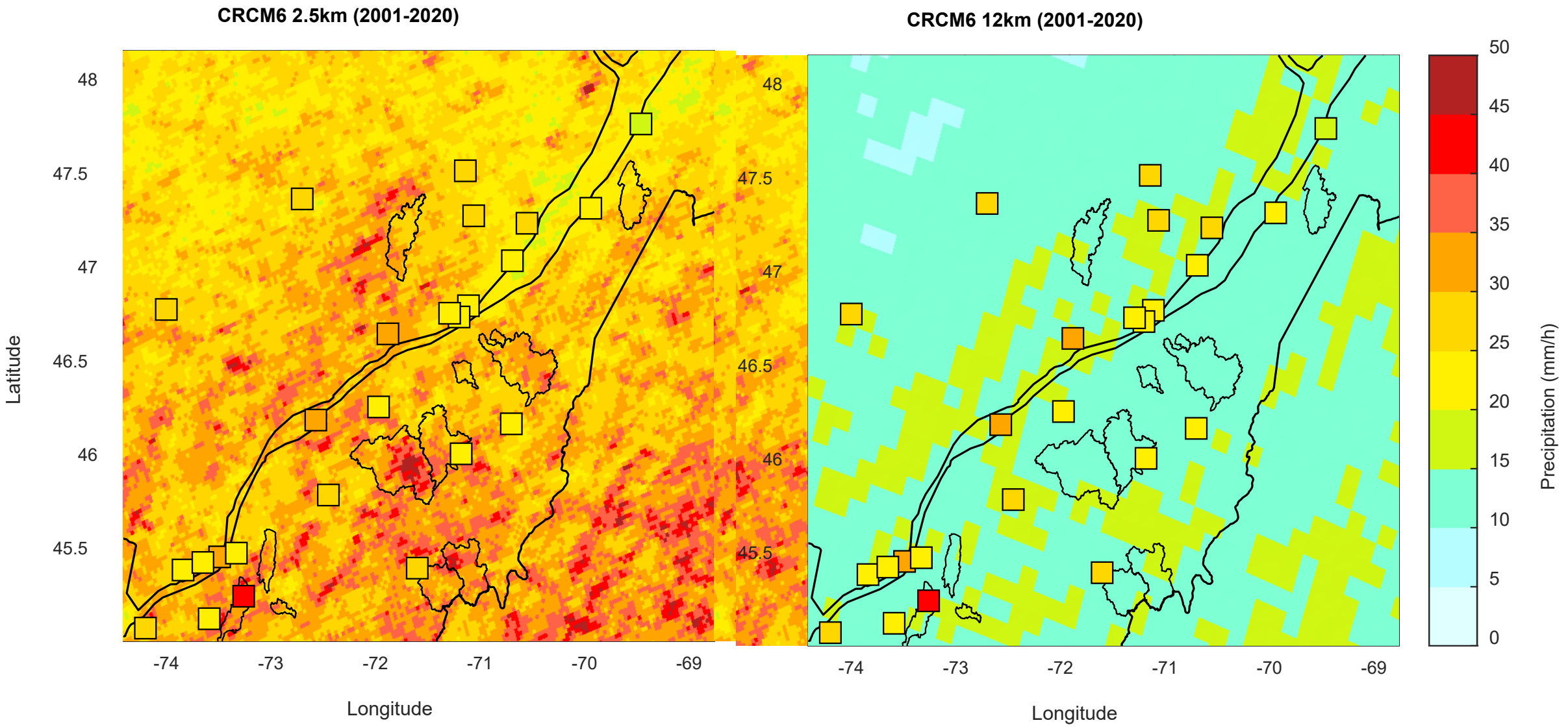

BrasdHenri
Observed Discharge
logarithm (base 10) of Streamflow (m3/s)
Years (June-1st)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


DesHurons
Observed Discharge
logarithm (base 10) of Streamflow (m3/s)
Years (June-1st)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


LAcadie
Observed Discharge
logarithm (base 10) of Streamflow (m3/s)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Years (June-1st)


Morpions
Observed Discharge
IMERG 10km
RDRS 10km
CRCM6 12km
CRCM6 2.5km
Streamflow (m3/s)
0
5
10
15
20
25
2015
2016
Years (June-1st)

Results – Objective 2



Fall – 99.99th percentile hourly precipitation