

# SWAT Hourly Calibration using SWAT-CUP for a Large Watershed in Southeast Brazil and Flooding Applications

Danielle A. Bressiani<sup>1,\*</sup>, R. Srinivasan<sup>2</sup>, E. M. Mendiondo<sup>1,3</sup>  
& K. C. Abbaspour<sup>4</sup>

<sup>1</sup> Engineering School of São Carlos, University of São Paulo

<sup>2</sup> Spatial Science Laboratory, Texas A&M University

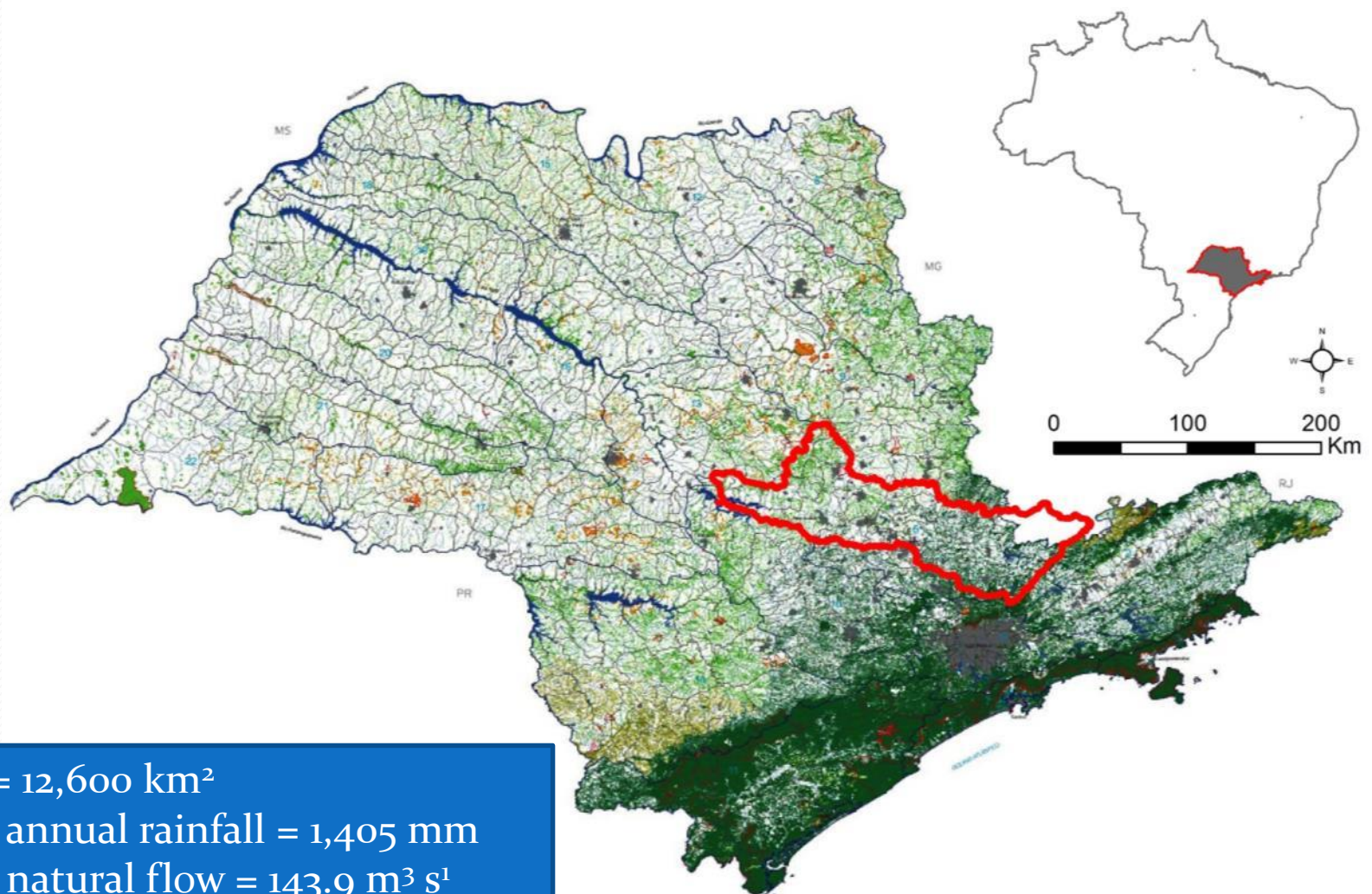
<sup>3</sup> Brazilian Center of Monitoring and Early Warning of Natural Disasters

<sup>4</sup> Eawag, Swiss Federal Institute of Aquatic Science and Technology

# Background

- Application of hydrological models to watersheds at a **sub-daily time step** is very important for **better understanding of flow and water quality dynamics**;
- The urgency of such applications and developments has **increased in recent years** due to increased urbanization, and **higher frequency of extreme hydro-meteorological events**;
- Climate change impact and accelerated landuse change due to population growth can **exasperate the situation in the coming years**;
- A new component to allow **hourly calibration** has been incorporated in the **SWAT-CUP** software package;
- This study presents the application results of an **hourly SWAT model using SWAT-CUP** (SUFI-2 algorithm) for calibration.

# Study Area – Piracicaba Watershed



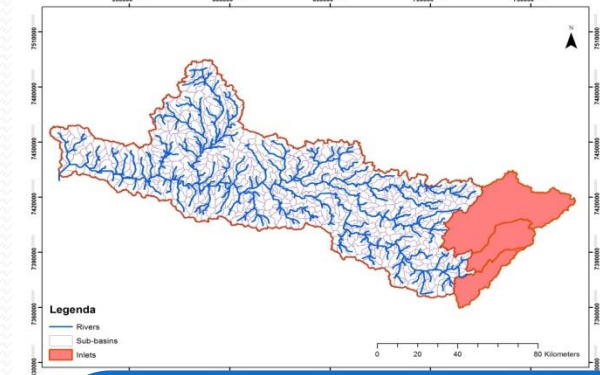
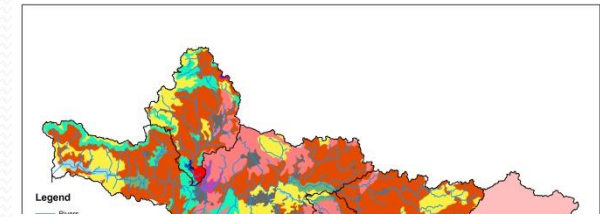
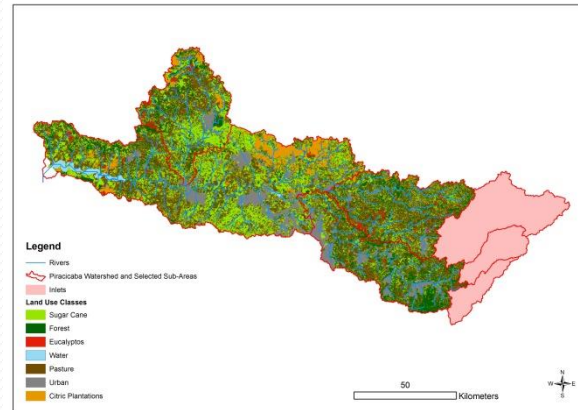
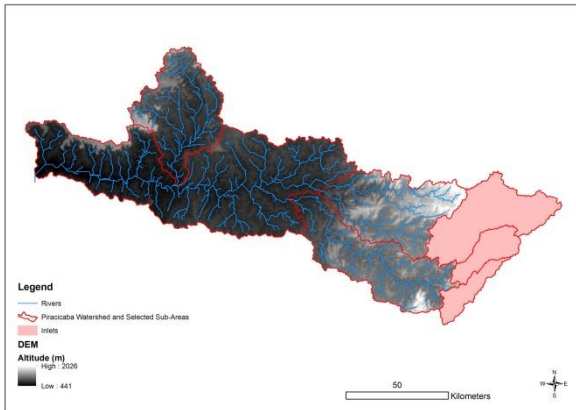
- Area = 12,600 km<sup>2</sup>
- Mean annual rainfall = 1,405 mm
- Mean natural flow = 143.9 m<sup>3</sup> s<sup>-1</sup>
- Population = 3.5 million people
- Pop density = 272 hab/km<sup>2</sup>

The region is prone to severe **flooding and droughts**.



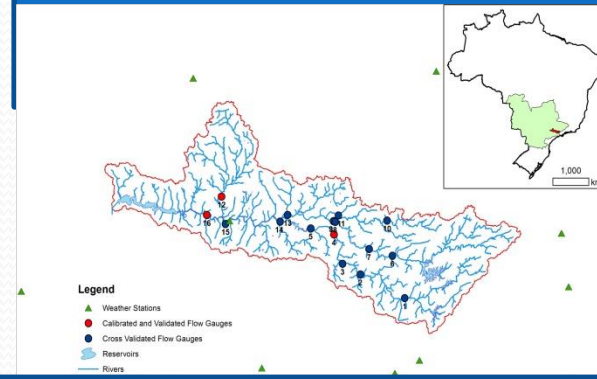
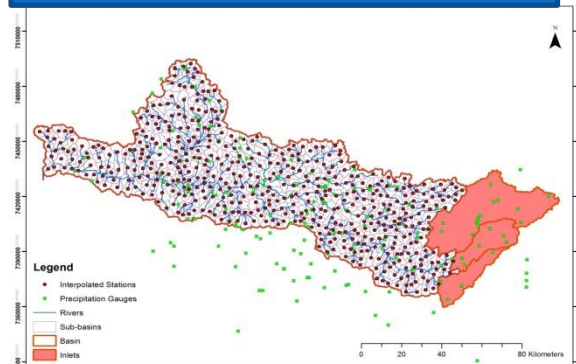
# Model Set Up

- The Piracicaba Watershed ArcSWAT project was built using freely available data on the web, or provided by Government agencies and Research institutions.



ASTER 30 meter resolution

Landsat 5 TM, supervised



Precip: Interpolated from 189 stations for daily (ANA, DAEE)

9 Weather Stations (INMET & USP)  
16 flow gauges (ANA, DAEE)

523 sub-basins were delimited in SWAT, with an average area of 20Km<sup>2</sup>, the modeled watershed area is of 10,454 Km<sup>2</sup>

# Calibration and Validation

- Sensitivity Analysis (Global and One at a Time)
- Manual and automated calibration using SUFI-2 (SWAT - CUP) and validation were performed:

Using Daily Climate Datasets:

Yearly Average Values



Monthly Time Step



Daily Time Step

Using Hourly Rainfall Data:

Hourly Time Step

# Hourly Calibration in SWAT-CUP

- A new component to allow hourly calibration has been incorporated in the SWAT-CUP software package, using SUFI-2.
- The hourly results for determined sub-basin is extracted in SWAT, using the fig.fig file;

The screenshot displays the SWAT-CUP software interface. The title bar reads "Danielle.Sufi2 - SWAT-CUP". The ribbon includes tabs for "Home", "Parallel Processing", "Utility Programs", and "Layout". The ribbon contains various icons for file operations (Cut, Copy, Paste, Undo, Redo, Find, Replace, Select All), editing (Next/Previous Bookmark, Clear Bookmarks, Save, Save All), calibration (Calibrate...), iteration management (Save Iteration, Validate...), printing (Print Preview, Advanced Writing, Print), window management (Close All), and help (Help, About, License and Activation). The Project Explorer on the left shows a tree view with folders for "Danielle", "Calibration Inputs", "Executable Files", "Calibration Outputs", "Sensitivity analysis", "Maps", "Utility Programs", and "Iteration History". The main window displays the "Sufi2\_Extract.bat" batch file configuration. Below the title bar, several tabs are open: "Iter2\_2\_CN\_test - Best\_Sim.txt", "Iter2\_2\_CN\_test - Goal.txt", "Iter2\_2\_CN\_test - New\_pars.txt", "Sufi2\_Extract.bat", "Sufi2\_post.bat", "Sufi2\_run.bat", and "Sufi2\_pre.bat". The "Sufi2\_Extract.bat" window shows a table with columns "File Name / Command" and "Execute".

File Name / Command	Execute
SUFi2_extract_rch_hrly.exe	<input checked="" type="checkbox"/> (Optional)
SUFi2_extract_rch.exe	<input type="checkbox"/> (Optional)
SUFi2_extract_hru.exe	<input type="checkbox"/> (Optional)
SUFi2_extract_sub.exe	<input type="checkbox"/> (Optional)
SUFi2_extract_res.exe	<input type="checkbox"/> (Optional)
SUFi2_extract_mgt_Cropyield.exe	<input type="checkbox"/> (Optional)
extract_rch_No_Chr.exe	<input type="checkbox"/> (Optional)

# Most Sensible in the Global Sensitive Analysis

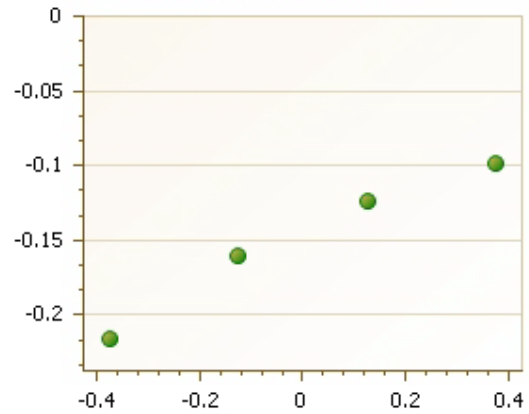
- Monthly:
  - GW\_Delay ; CN<sub>2</sub>
- Daily:
  - CN<sub>2</sub>, CNCOEF, ESCO, Surlag
- Hourly:
  - CN<sub>2</sub>, CNCOEF, LAT\_TIME, ALPHA\_BF, ESCO, CH\_N<sub>2</sub>, SLSUBBSN, Surlag....

# One at a Time Sensitivity Analysis

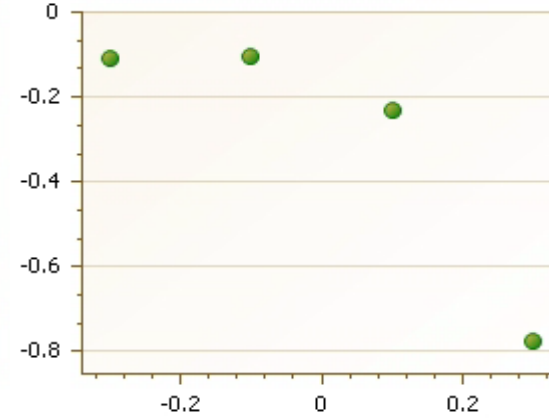
- A One at a Time, sensitivity Analysis was conducted for the **hourly time step, with 4 simulations for each parameter**. With several parameters:

- r
- v
- a
- v
- v
- r
- r
- r
- v
- r\_\_SLSUBBSN.hru
- v\_\_RCHRG\_DP.gw
- v\_\_CANMX.hru\_\_\_\_\_FRS
- r\_\_CH\_L1.sub
- r\_\_CH\_N1.sub
- r\_\_ALPHA\_BF.gw
- r\_\_CH\_k1.sub
- a\_\_GWQMN.gw
- r\_\_HRU\_SLP.hru
- a\_\_REVAPMN.gw
- v\_\_GW\_REVAP.gw

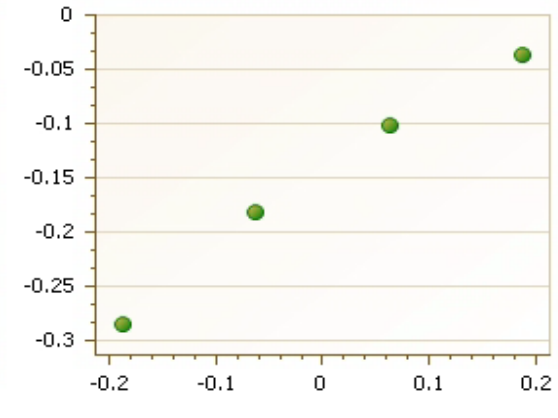
1:R\_SOL\_K(..).sol



1:R\_CN2.mgt

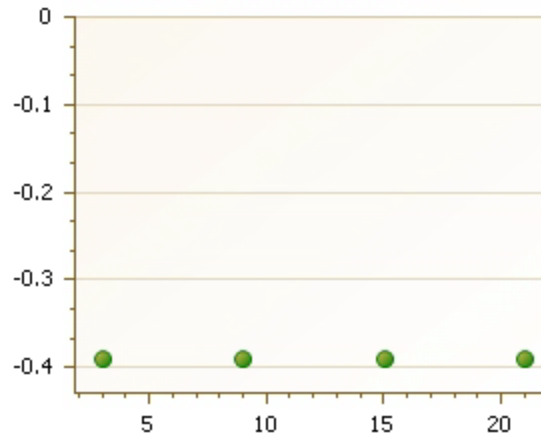


1:R\_CH\_N2.rtc



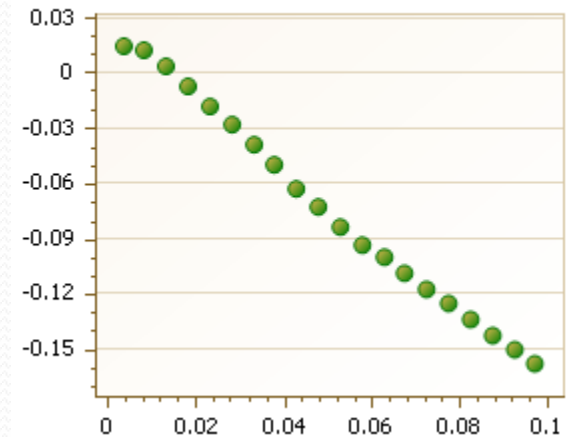
0.05 24.0

1:V\_SURLAG.bsn



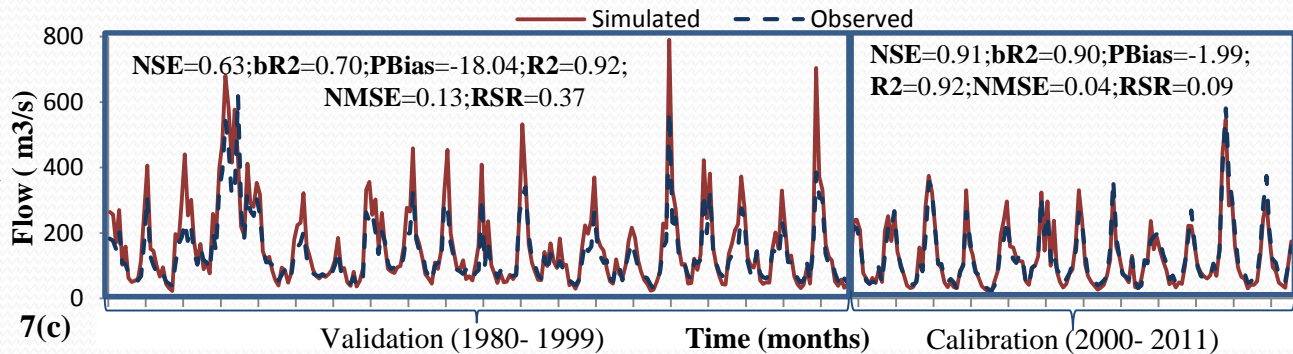
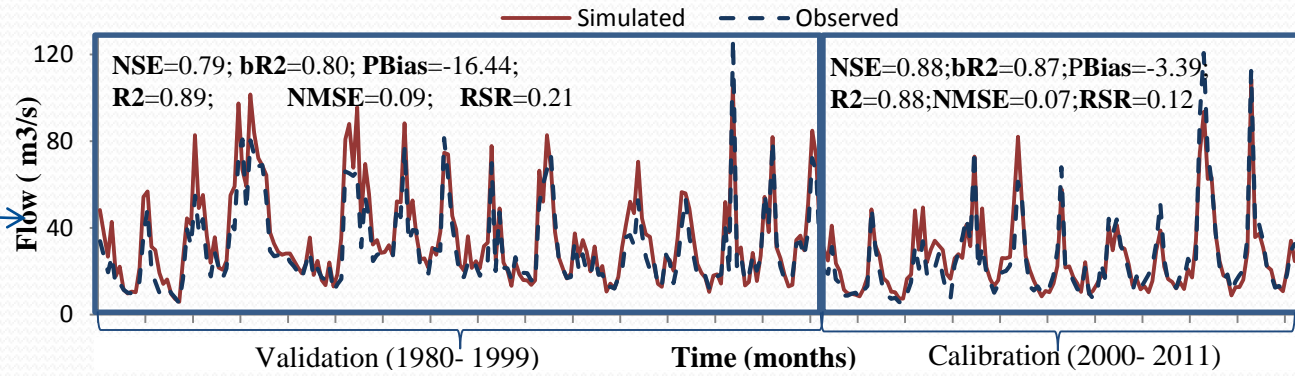
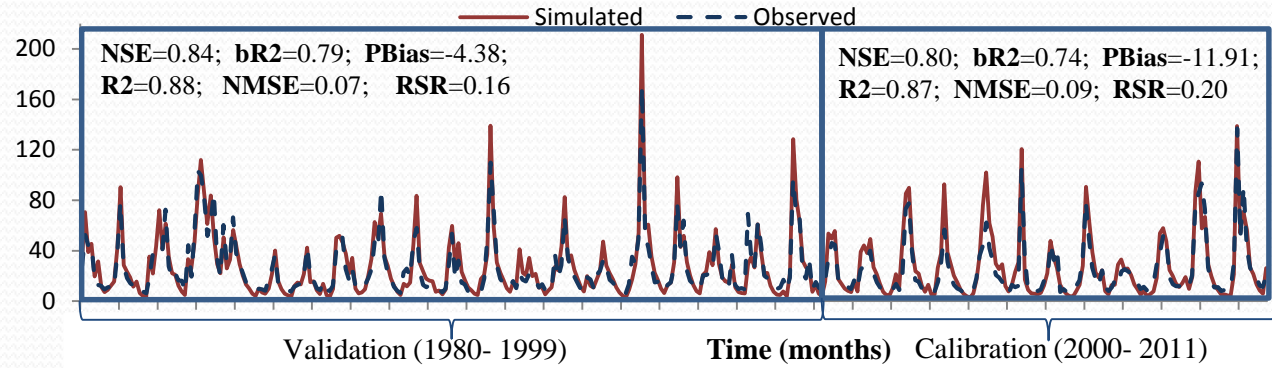
0.02 0.09

1:V\_SURLAG.bsn





# Monthly Results



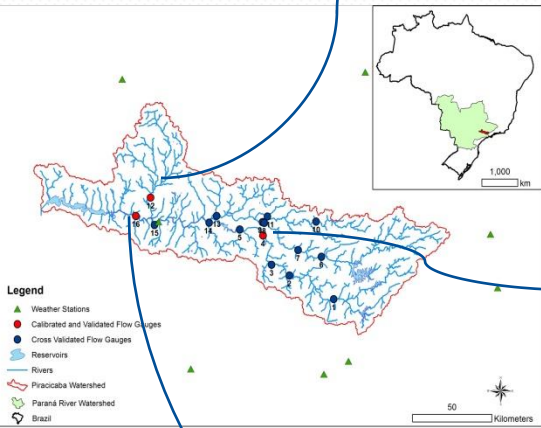
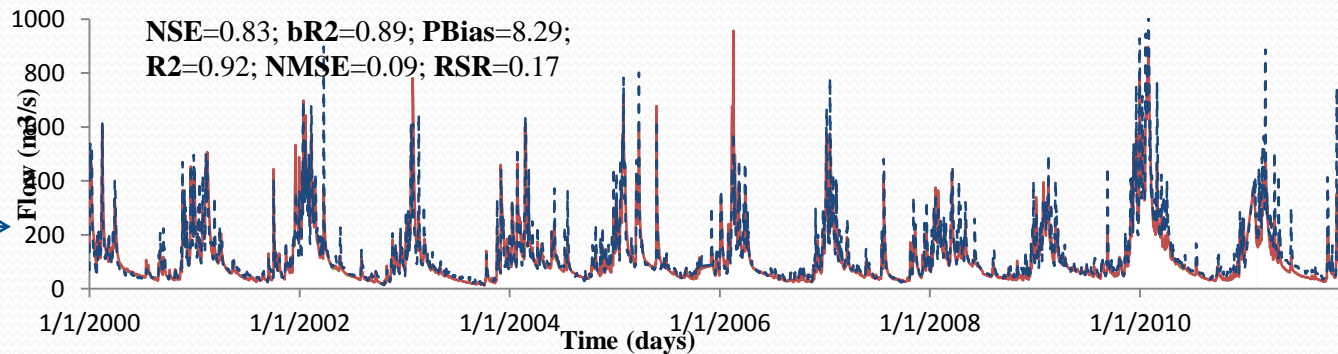
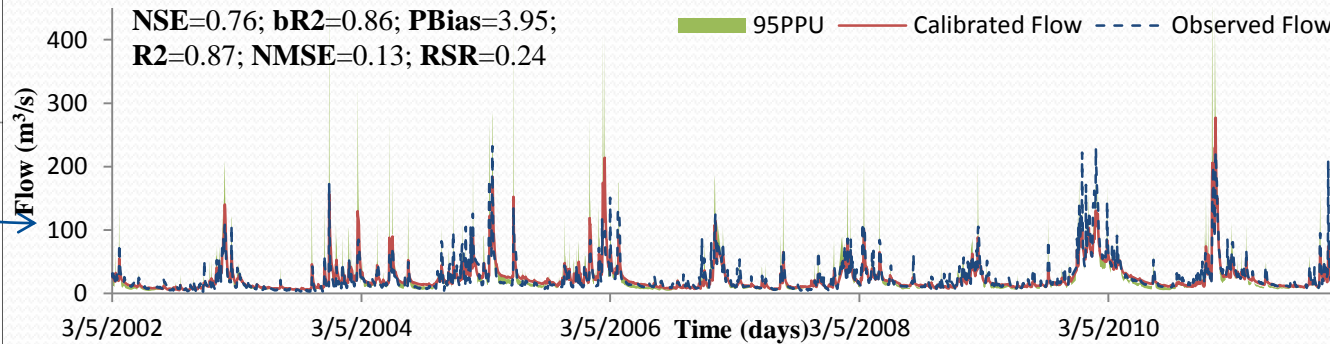
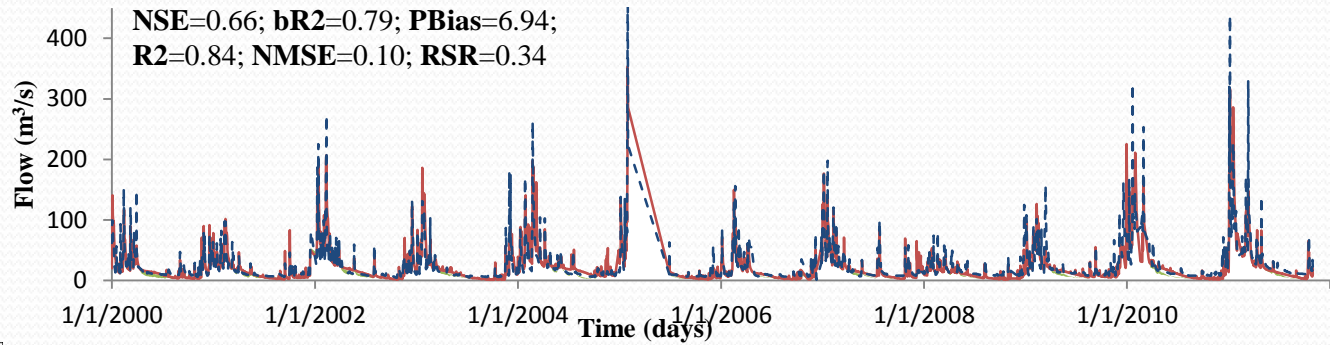
**Legend**

- ▲ Weather Stations
- Calibrated and Validated Flow Gauges
- Cross Validated Flow Gauges
- Reservoirs
- Rivers
- ▭ Piracicaba Watershed
- ▭ Paraná River Watershed
- 🇧🇷 Brazil



7(c)

# Daily Calibrated Flow Results



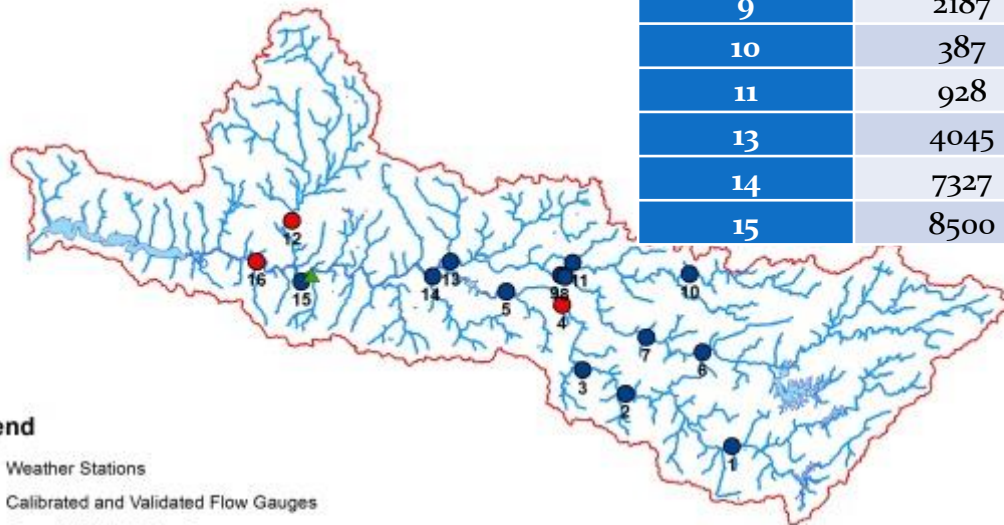
# Daily Validation and Cross Validation Results

Gauge station	Drainage area (km <sup>2</sup> )	NSE	bR <sub>2</sub>	PBias
4	2,308	0.80	0.82	-7.57
12	1,581	0.70	0.81	5.75
16	11,040	0.67	0.73	-12.80

Validation for the Red Gauge Stations

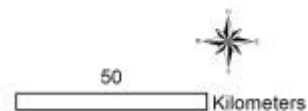
Gauge station	Drainage area (km <sup>2</sup> )	NSE	bR <sub>2</sub>	PBias
1	1143	0.65	0.79	15.81
2	1920	0.80	0.88	5.49
3	2152	0.75	0.86	9.58
5	1950	0.79	0.85	1.94
6	1140	0.75	0.82	-1.65
7	1950	0.78	0.86	4.82
8	2180	0.69	0.83	-3.52
9	2187	0.86	0.69	-2.34
10	387	0.66	0.76	-0.65
11	928	0.72	0.78	-1.88
13	4045	0.79	0.83	1.36
14	7327	0.83	0.88	8.61
15	8500	0.83	0.86	14.61

Cross-Validation for the Blue Gauge Stations



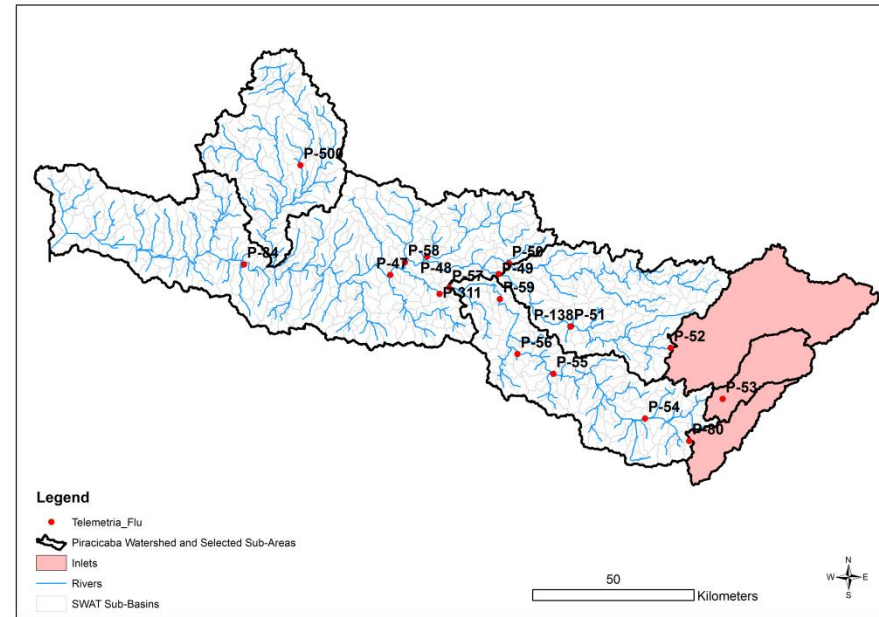
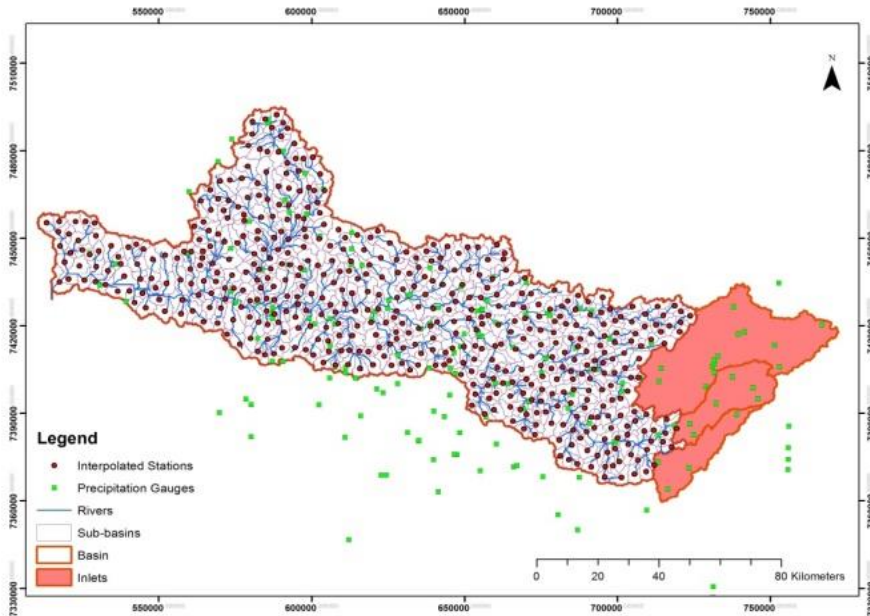
## Legend

- ▲ Weather Stations
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# Piracicaba Hourly Calibration

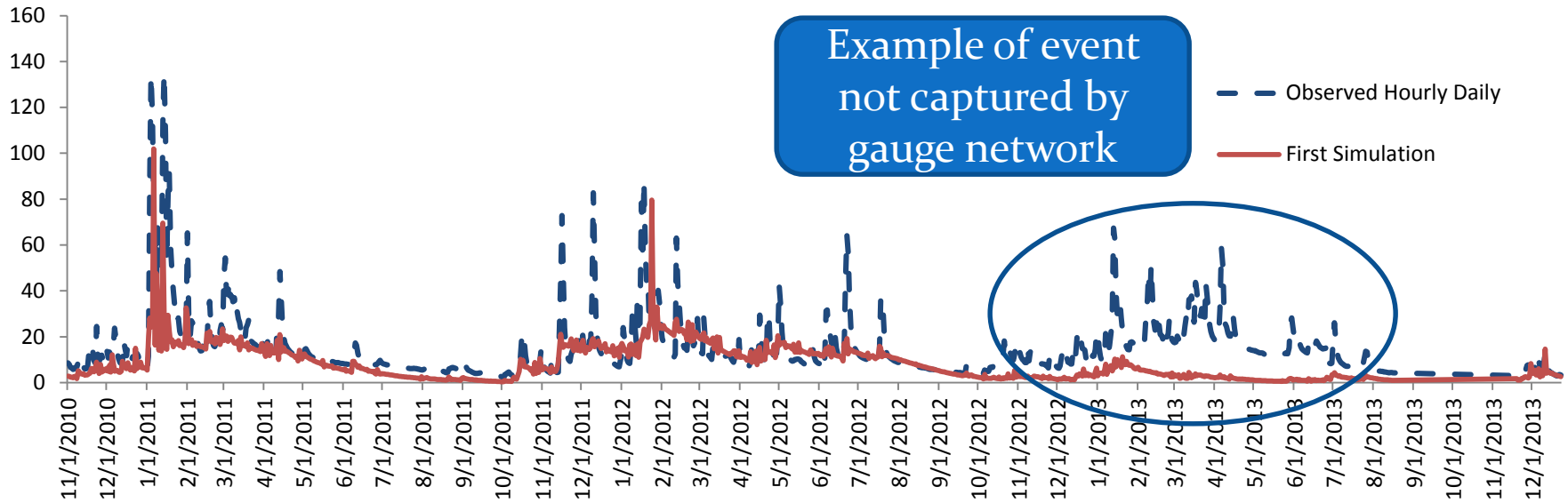
- Precipitation Data Limitation:



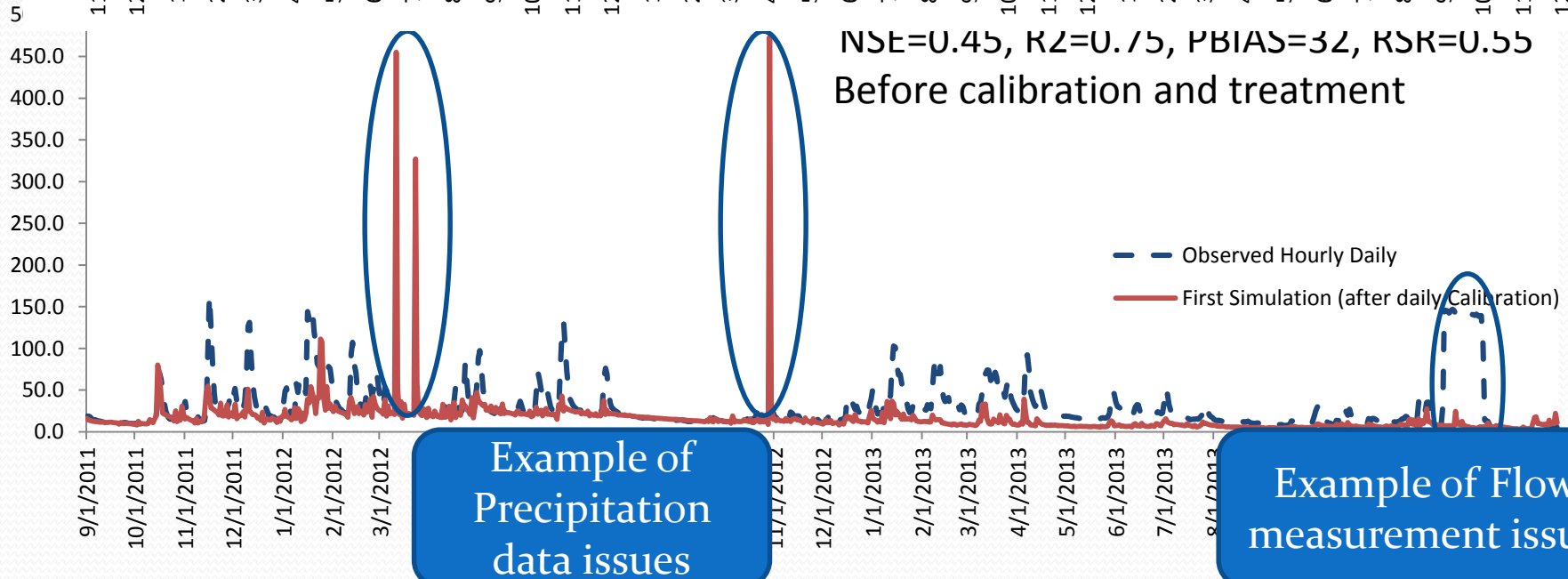
Daily: ~200 gauge stations,  
interpolated for each sub-basin.  
Sufficient data for 30 years

Hourly: 16 gauge stations, not with the  
best spatial distribution.  
Reasonable Data for 1 to 7 years  
depending on the station  
Also a lot of data problems were found  
on the hourly precipitation data.

# Data Issues



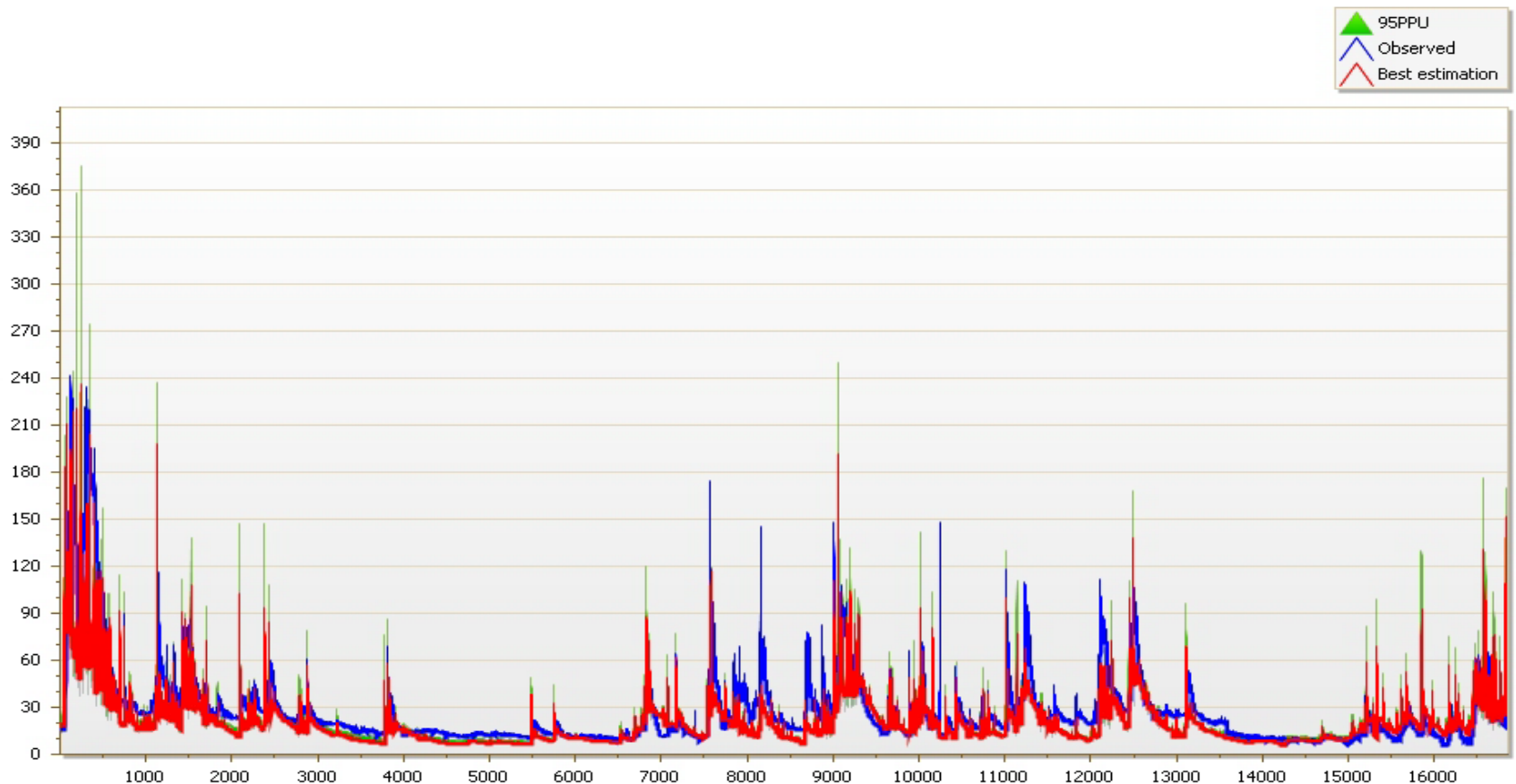
$NSE=0.45$ ,  $R^2=0.75$ ,  $PBIAS=32$ ,  $RSR=0.55$   
Before calibration and treatment





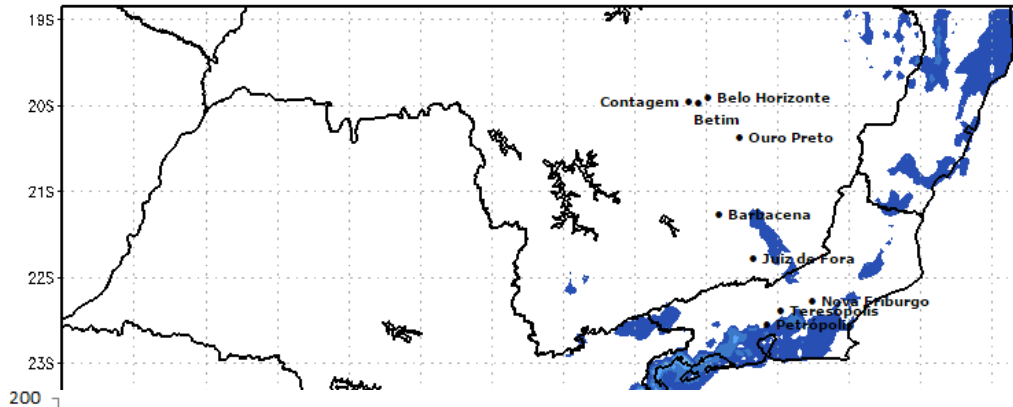
# Hourly Calibration

- $R_2 = 0.61$ ,  $NSE = 0.57$ ,  $PBIAS = 19.3$
- The other calibrated location, and cross-validated ones, have similar results, with  $NSE > 0.5$

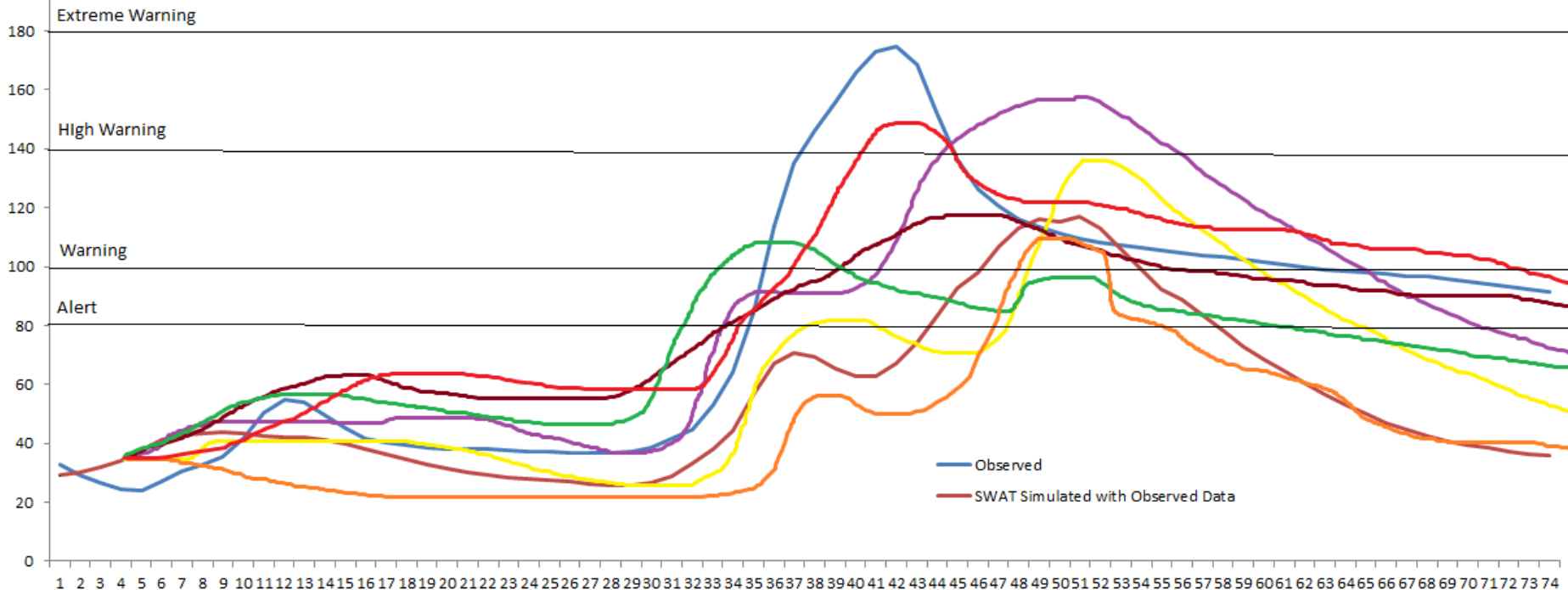


# Flood Modeling for Forecasting

CPTEC/INPE/MCT – MODELO Meso Eta 05 km  
Previsao 2015062300+000072h, valida para 26/06/2015, 00UTC  
Precipitacao Total acumulada em 3 dias (mm)



State-of-the-art  
research and operational  
CPTEC-INPE (Center for  
Space Research/ Brazilian



# Final Remarks

- SWAT can now be automatically calibrated using **SWAT-CUP for hourly** time-step;
- The Piracicaba SWAT Model was calibrated for hourly time steps (with limited data);
- Calibration of this model resulted in **satisfactory and reasonable agreements** between observed and modeled;
- The aim is to have an application of the SWAT hourly Piracicaba model for **flood forecasting**;
- **Still road ahead:** Improvements in the calibration and on using the ensembles is necessary;
- This developed method **foresees future applications** which can help the real time operational decision making for **disaster risk reduction of hydrological extremes** at strategic river basins

# ACKNOWLEDGMENTS



Comitês PCJ



**TEXAS A&M**  
UNIVERSITY®

**eawag**  
aquatic research ooo



# Thank you very much!

For further information:

- [\*danielle.bressiani@usp.br\*](mailto:danielle.bressiani@usp.br) (*Danielle Bressiani*)
- [\*daniebressiani@gmail.com\*](mailto:daniebressiani@gmail.com)