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Climate and land-use change impacts in the São Francisco Basin (SFB), Brazil

2015 International SWAT Conference

24./26.06.2015, Santa Margherita di Pula (CA), Sardinia/Italy

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SWIM vs. SWAT

Are there many differences?

There are some, but… (SWIM is based on SWAT'93 & MATSALU)

- **Same model structure**
- **Basic assumptions and equations comparable**

Some specific functionalities are different:

- **Wetlands**
- **Dams and reservoirs**
- **Agriculture (Irrigation, crop rotations,…)**

…

SWAT more user-friendly… (interfaces etc.)

SWIM rather "pure" scientific tool…

Overview

- Introduction
- Calibration and validation
- Results:
  - Climate scenarios
  - Land-use scenario
  - Water management scenario
- Summary

Figura 1. Bacia hidrográfica do rio São Francisco dividida e suas principais usinas hidrelétricas e postos fluviométricos. **ANA (2004)**

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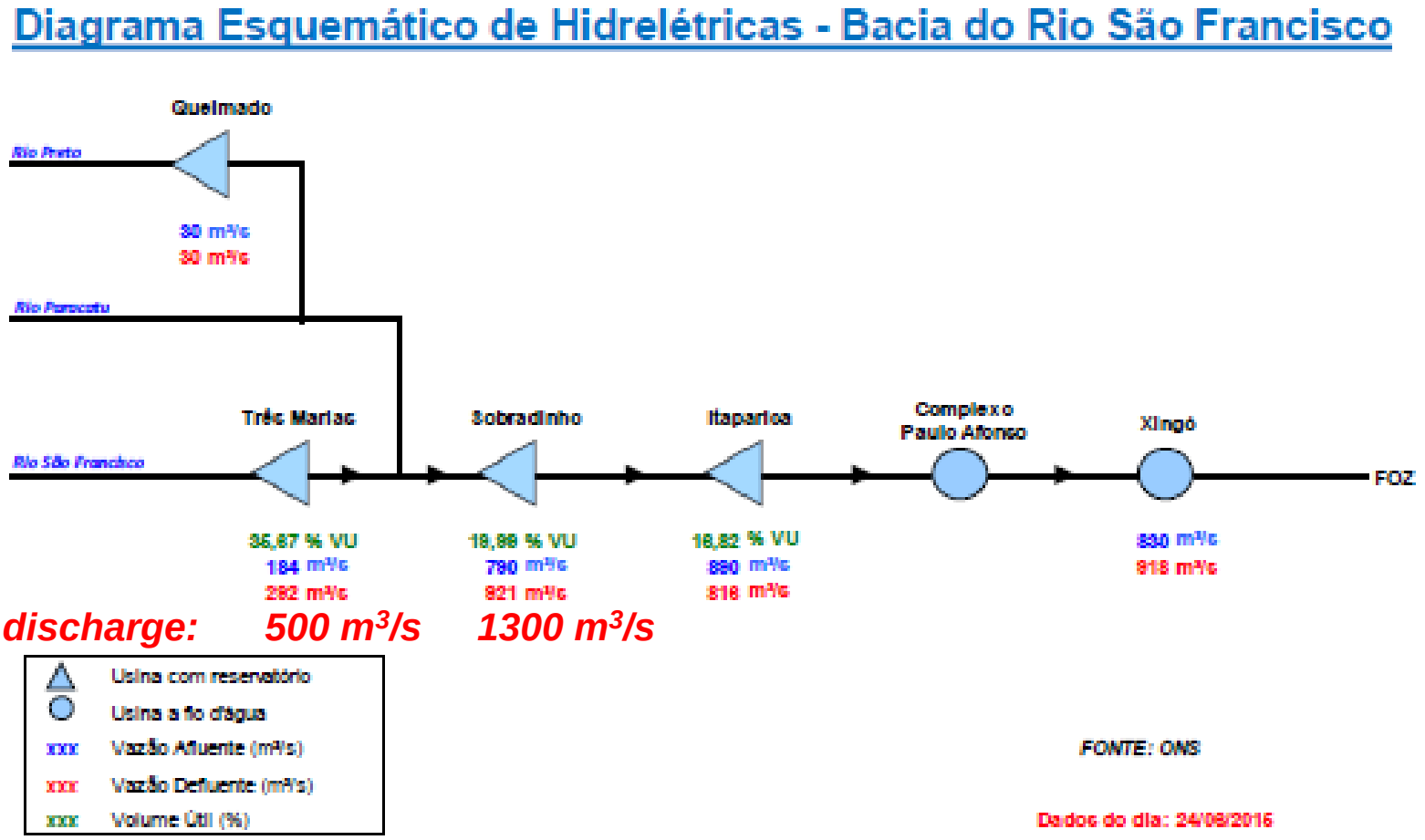
Figura 1. Bacia hidrográfica do rio São Francisco dividida e suas principais usinas hidrelétricas e postos fluviométricos. **ANA (2004)**

INNOVATE: INterplay among multiple uses of water reservoirs via inNOVative coupling of substance cycles in Aquatic and Terrestrial Ecosystems ⇒ Focus area: Itaparica Reservoir, Brasil

Overview

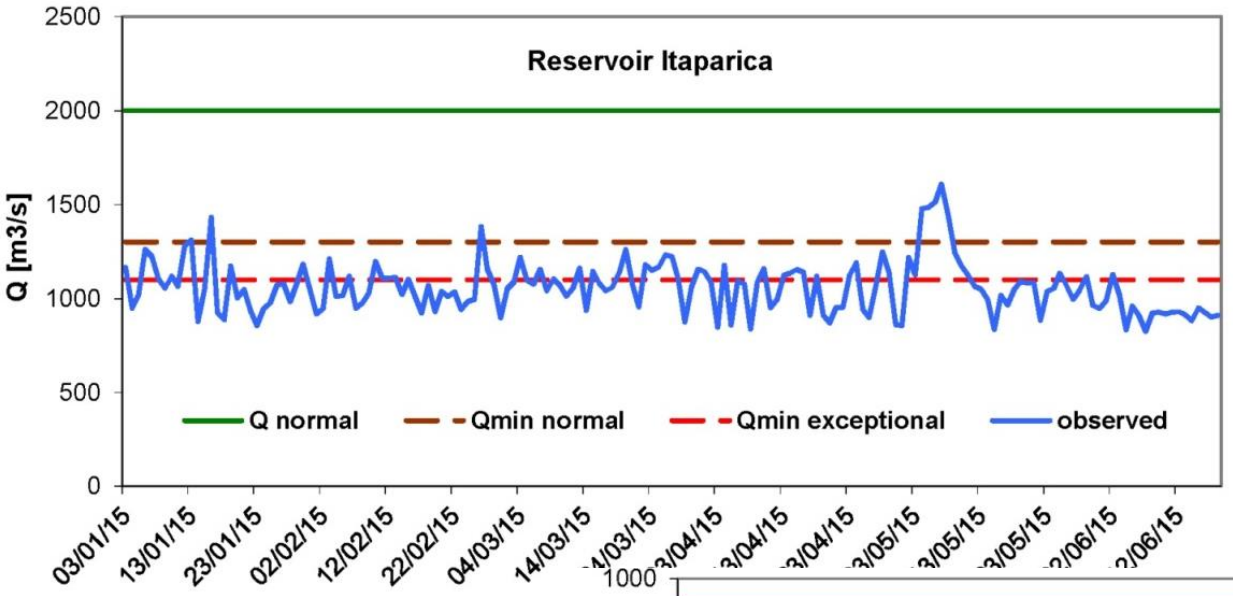
Drougth in the São Francisco river basin (SFB), lasting for more than 3 years …



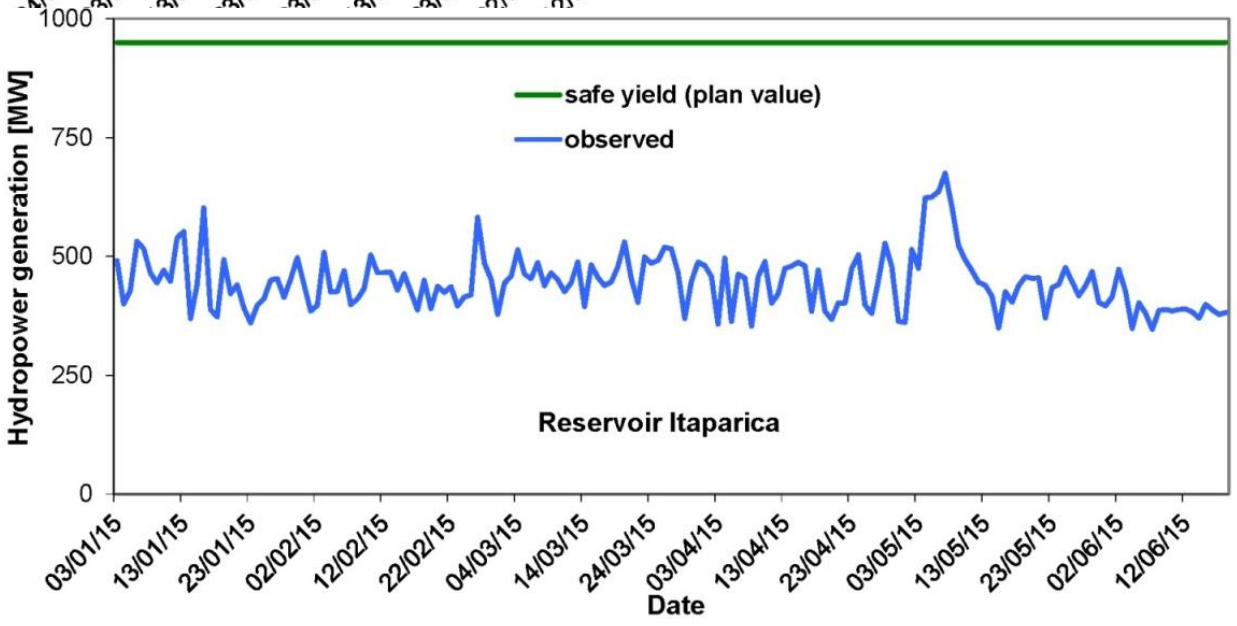
Minimum discharge: 500 m³/s 1300 m³/s

Source: Agência Nacional de Águas (ANA): SALA DE SITUAÇÃO; http://arquivos.ana.gov.br/saladesituacao/BoletinsDiarios/SF_25-6-2015.pdf

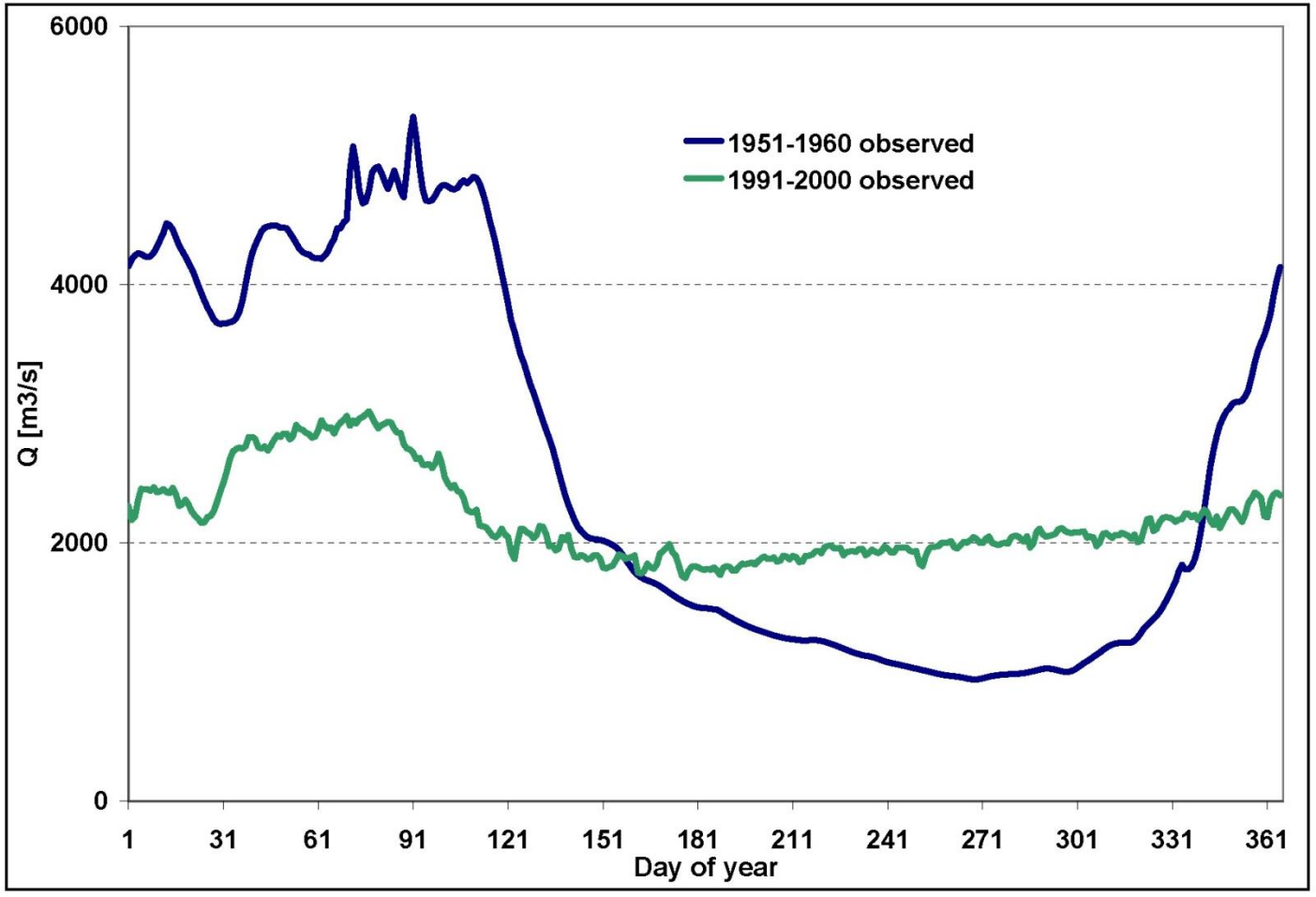
Overview



Dec. – Apr.: rainy season!!!



Introduction: observed discharge at gauge Traipu / São Francisco



data: ONS (http://www.ons.org.br/)

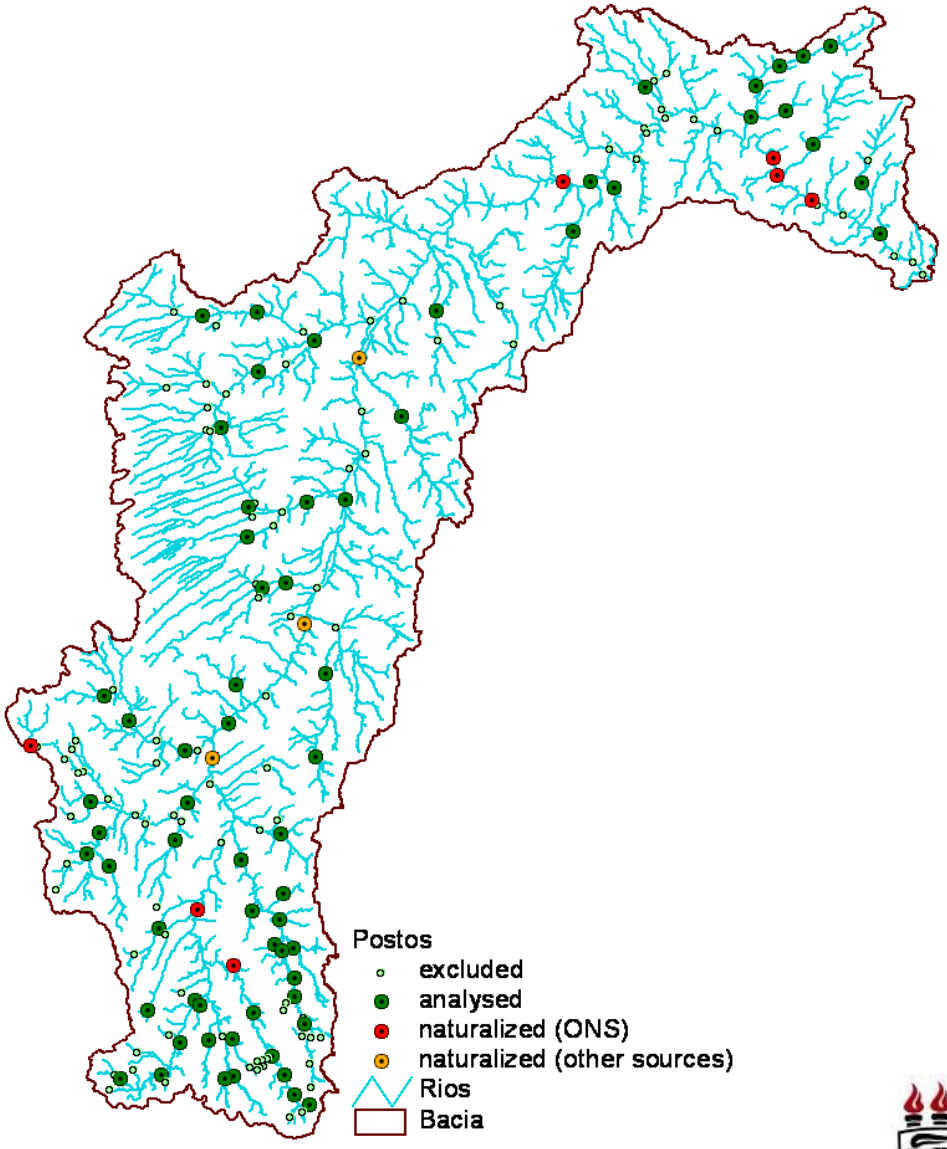
Introduction: observed discharges

São Francisco River basin: 640,000 km^2

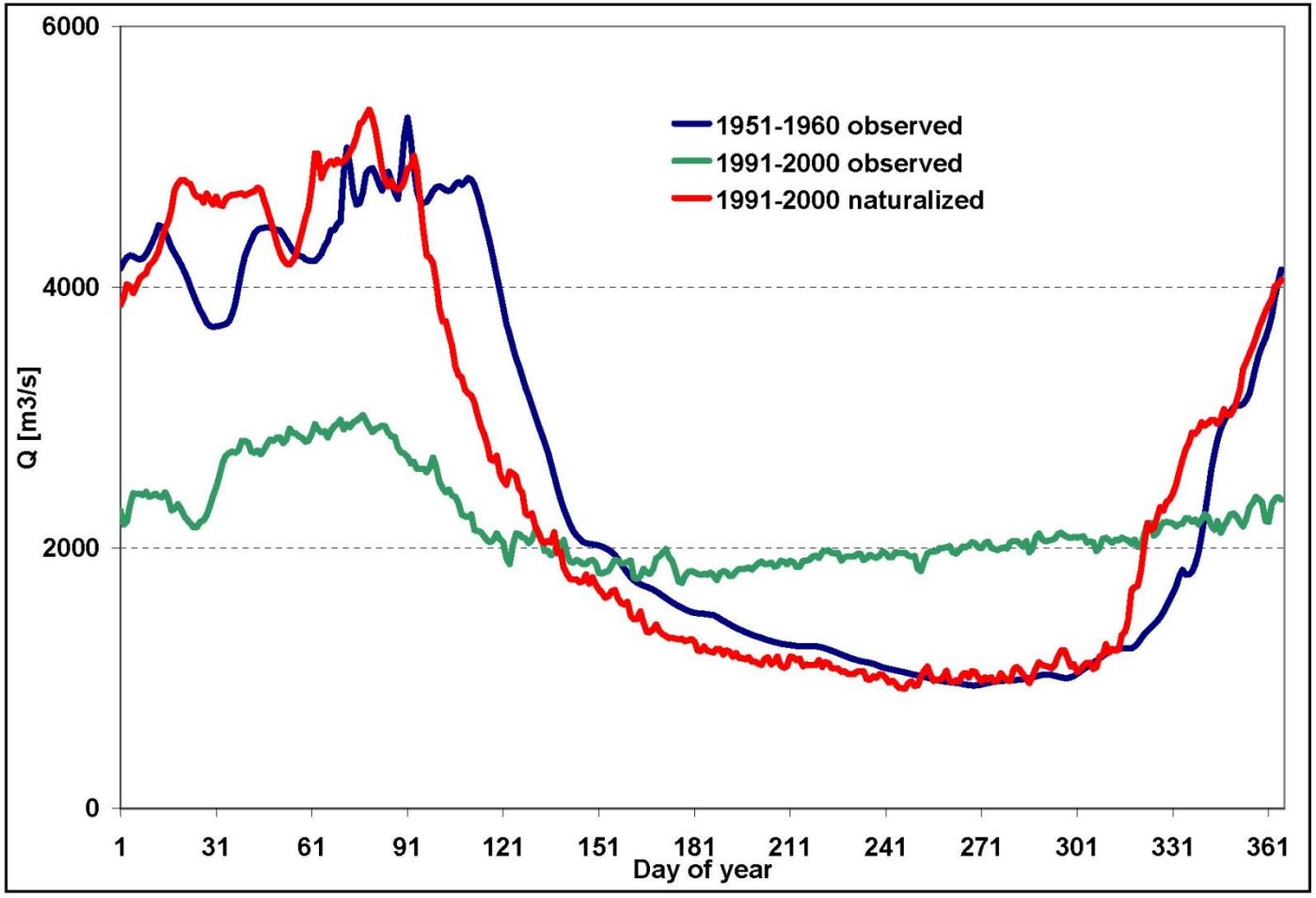
Discharge measurements from 175 gauges (ANA - *Agência Nacional de Águas*)

Criteria for selection: catchment area, time series length, no large gaps in time series
$\Rightarrow$ 65 gauges selected

For some gauges **naturalized** discharges (calculated by subtracting reservoir effects & water uses from measured discharges) are available from ONS (*Operador Nacional do Sistema Elétrico*) and other sources



Introduction: discharge at gauge Traipu / São Francisco

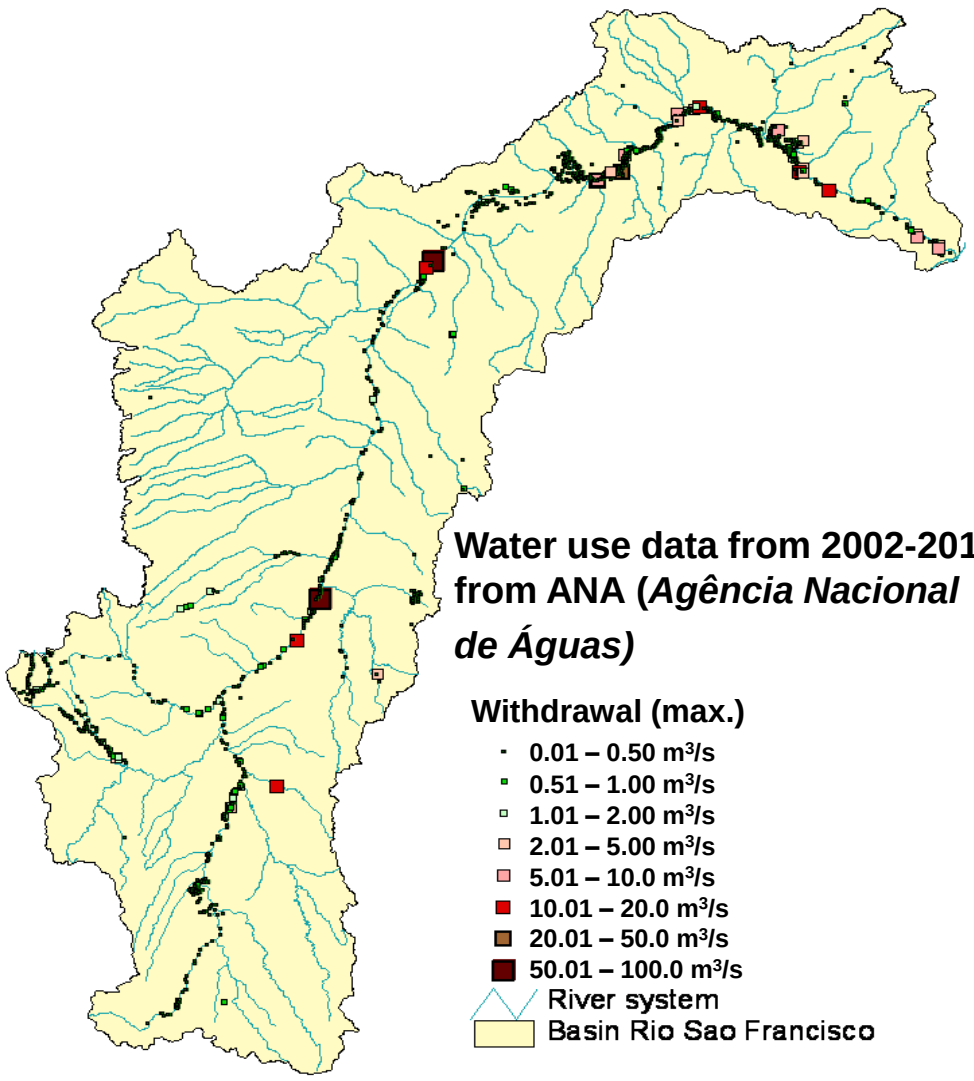


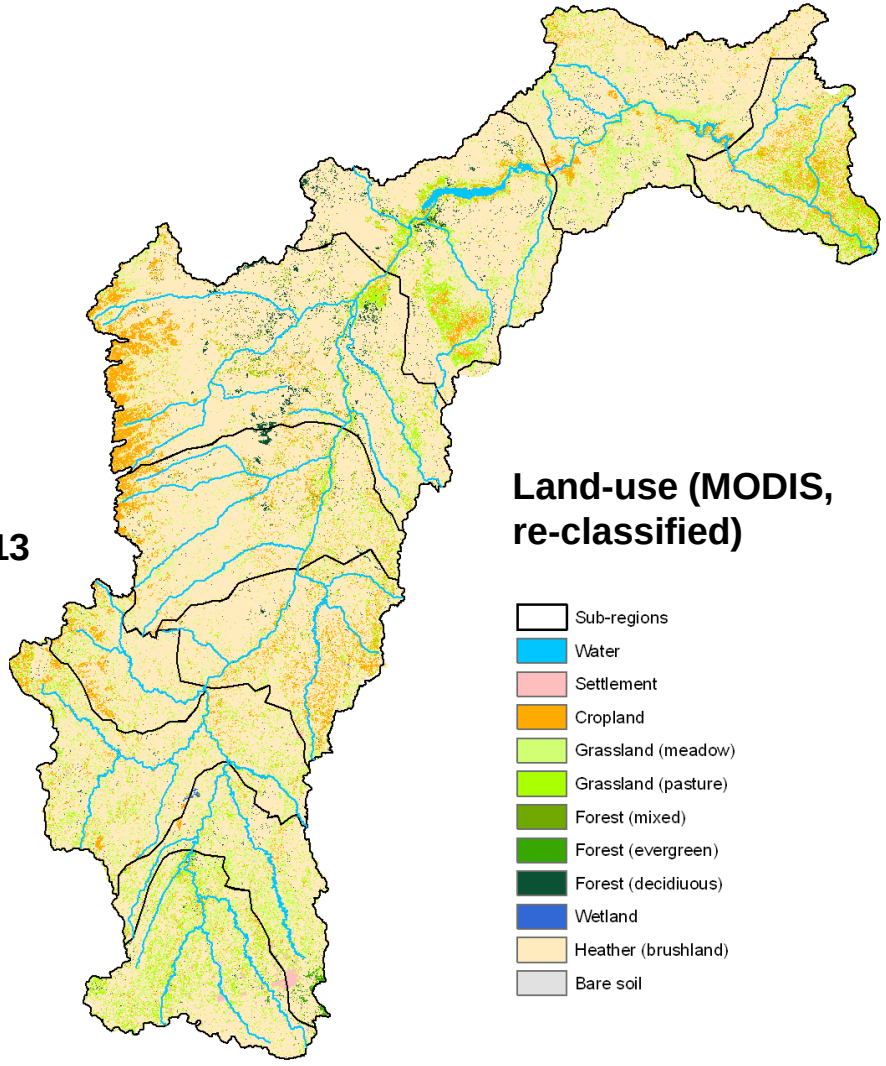
data: ONS (http://www.ons.org.br/)

Introduction: data used

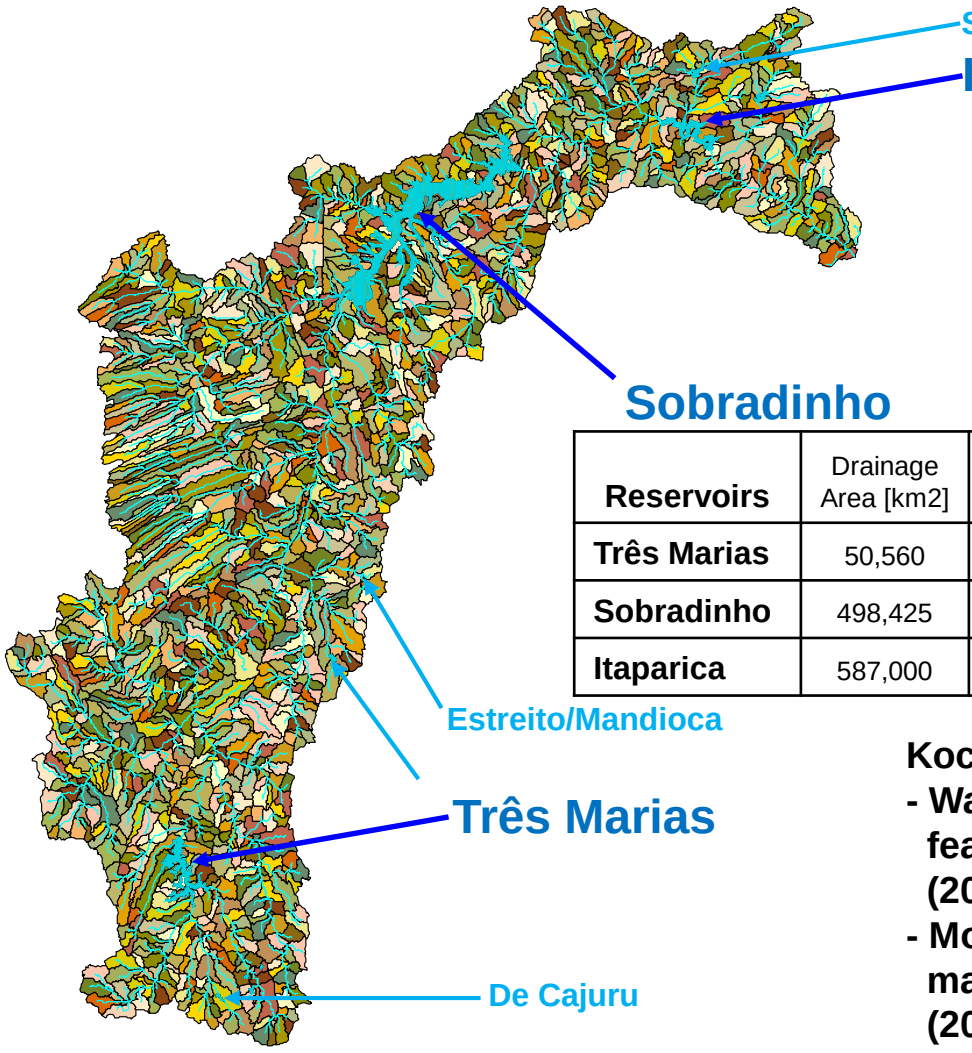
- **SRTM-Digital Elevation Model**
- **Soil data: EMBRAPA (Brazilian Enterprise for Agricultural Research)**
- **Land-use: MODIS2001 & 2010; adapted to land use classes in SWIM**
- **Climate: daily (re-analysis data; e.g. Tmax, Tmean, Tmin, precipitation, solar radiation) from WATCH-project (http://www.eu-watch.org/) grid cells of 0.5° (approx. 50x50km)**

Introduction: data used





Introduction: SWIM; delineation of Sub-basins (1627)



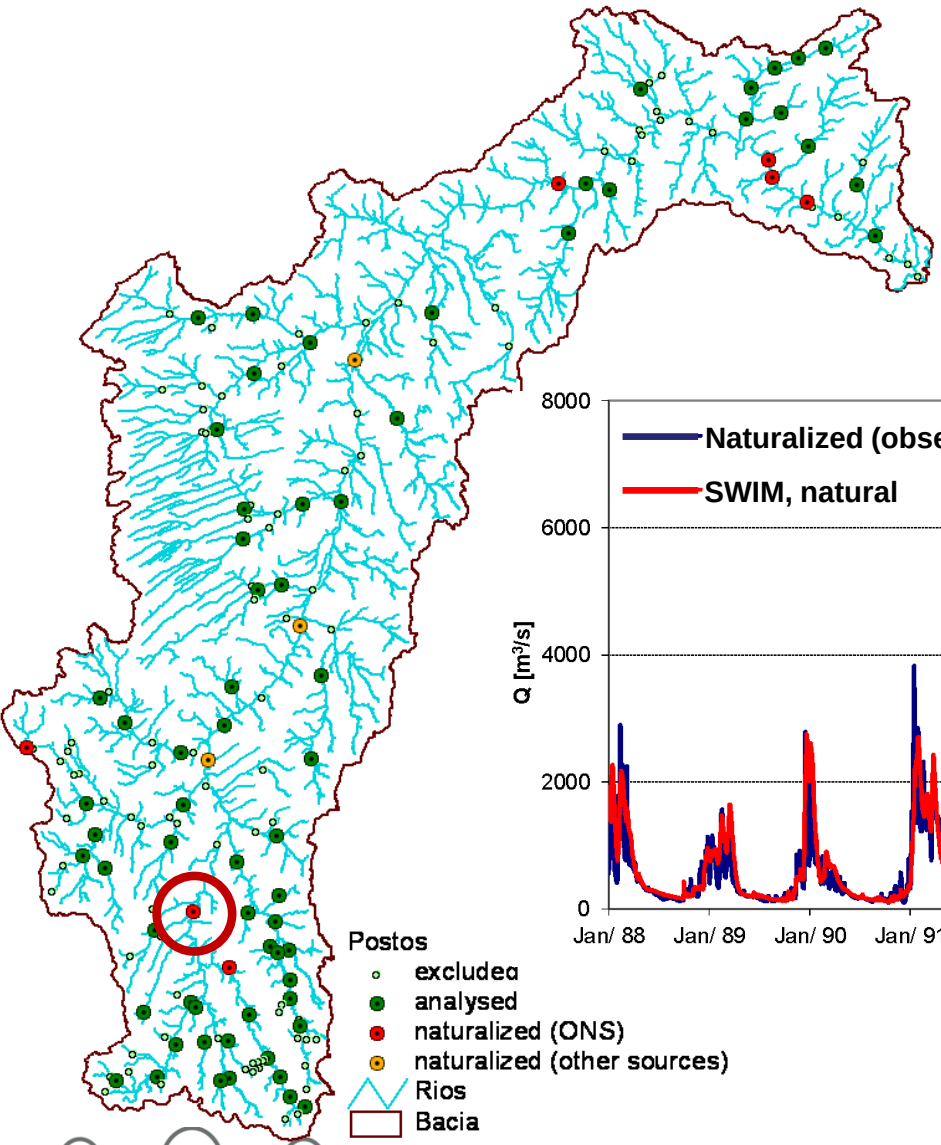
23 Sub-catchments with different parameter sets

Reservoirs	Drainage Area [km2]	Capacity [Hm3]	Dead storage [Hm3]	HPP, inst. [MW]	HPP, yield [MW]	Qmin. [m3/s]
Três Marias	50,560	19,528	4,250	396	250	500
Sobradinho	498,425	34,117	5,448	1,050	510	1,300
Itaparica	587,000	10,782	7,233	1,500	900	1,300

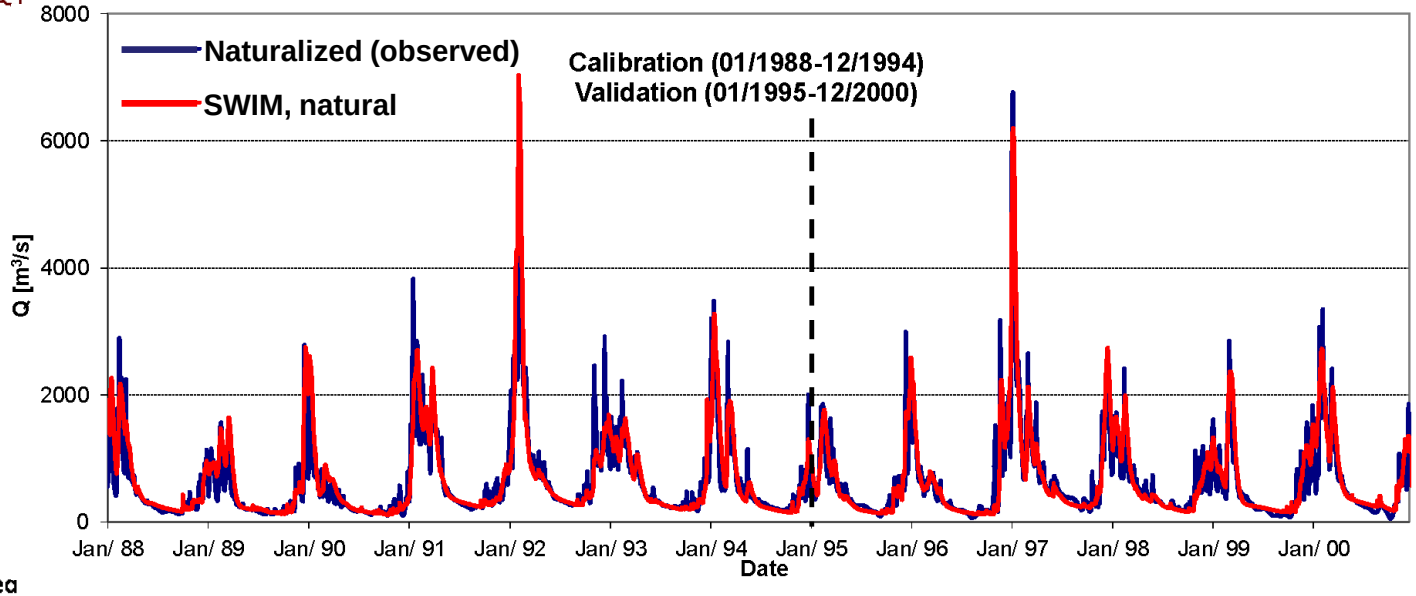
Koch et al.:

- **Water management modeling in SWIM: new features and applications (2013 International SWAT Conference, Toulouse)**
- **Modelling of water availability and water management for the São Francisco Basin, Brazil (2014 International SWAT Conference, Porto de Galinhas/Brazil)**

SWIM: Calibration & validation for natural discharge



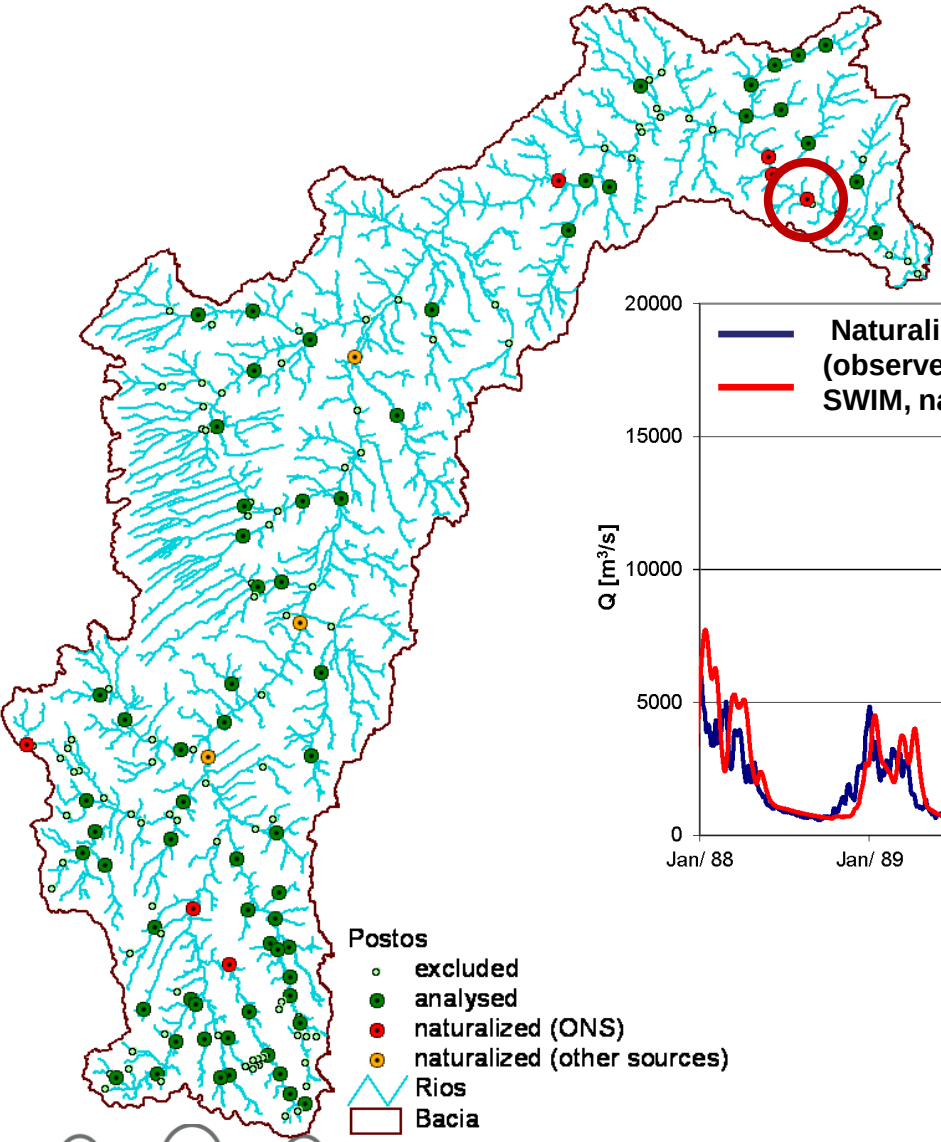
reservoir Três Marias



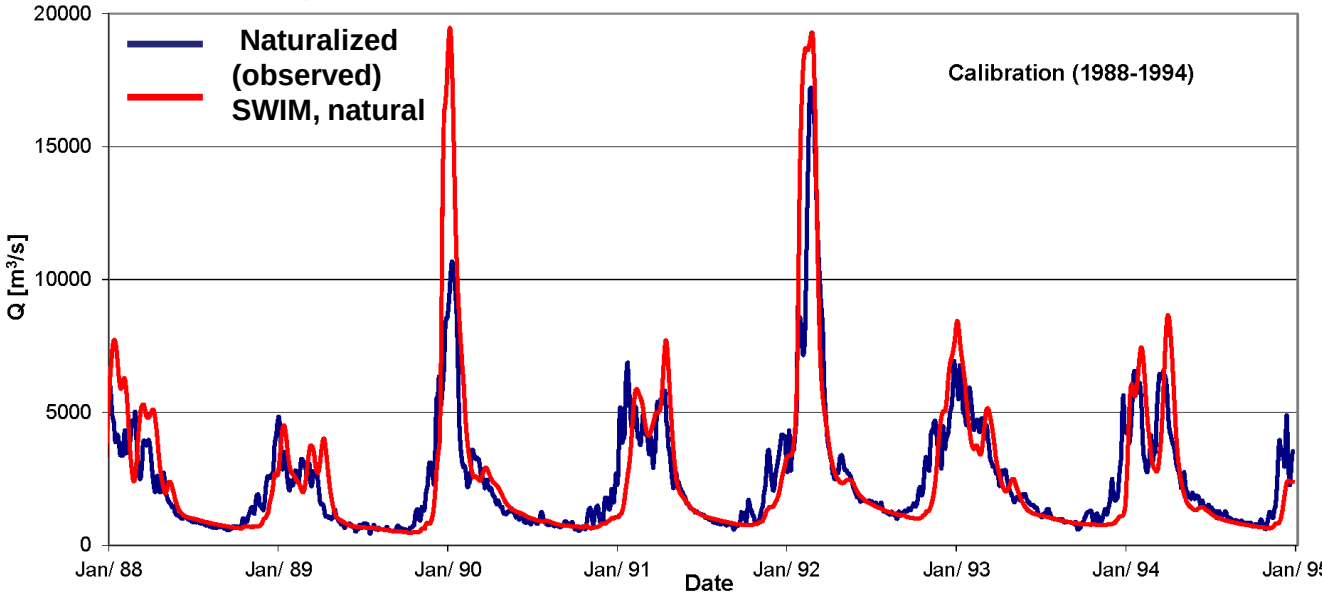
NSE 0.77 **NSE 0.76**

PBIAS 16% **PBIAS 14%**

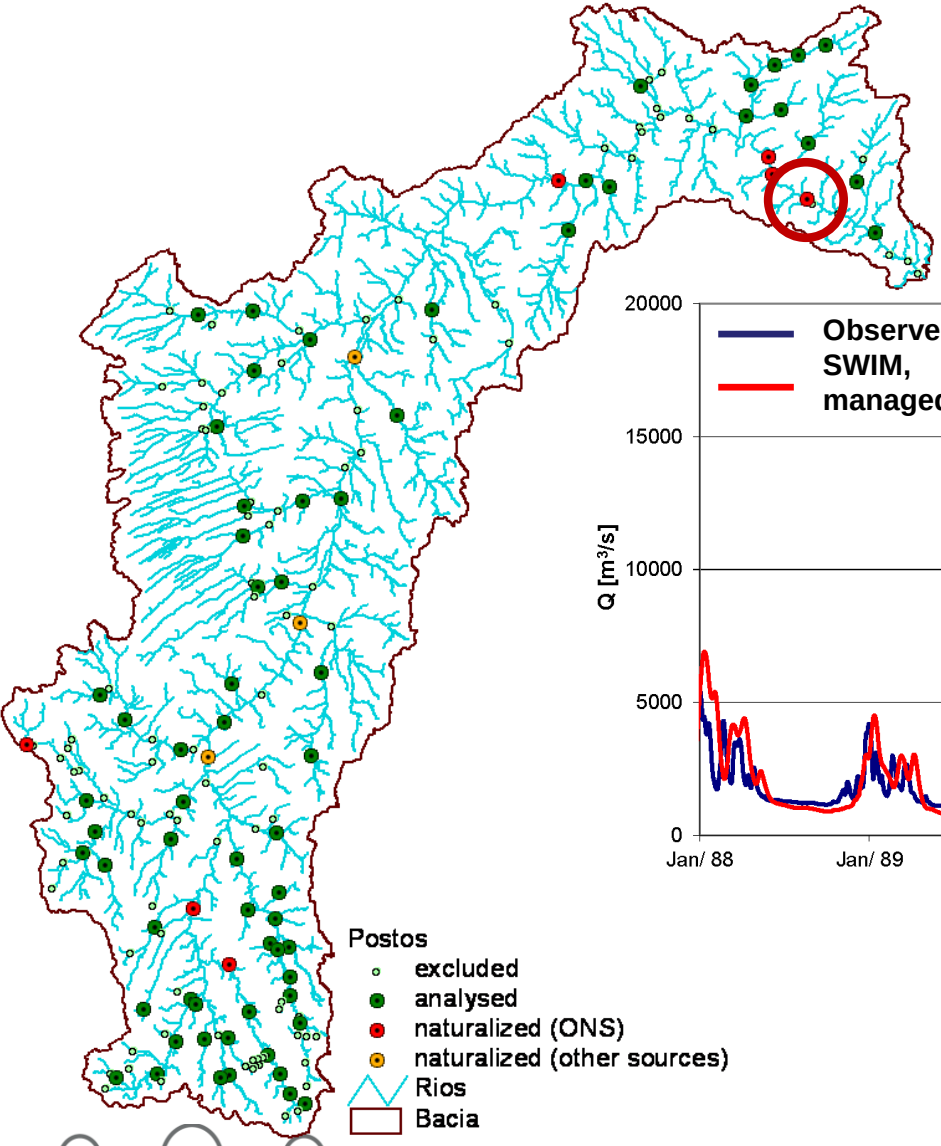
SWIM: Calibration for natural & managed discharge



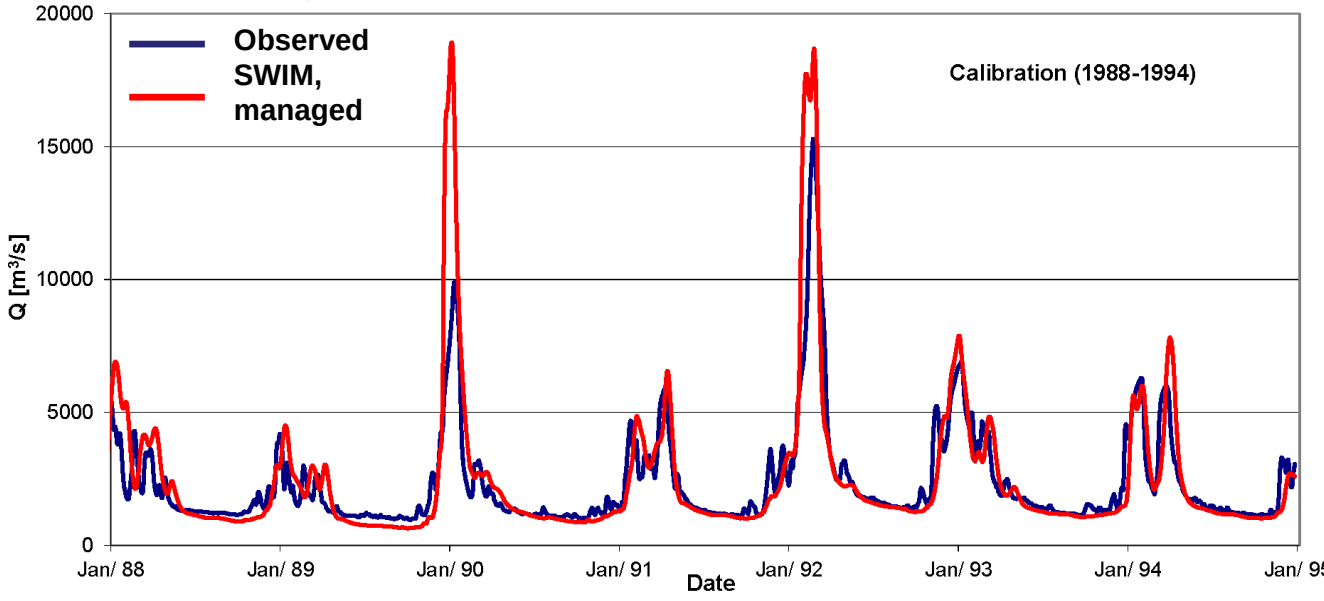
Gauge Traipu



SWIM: Calibration for natural & managed discharge

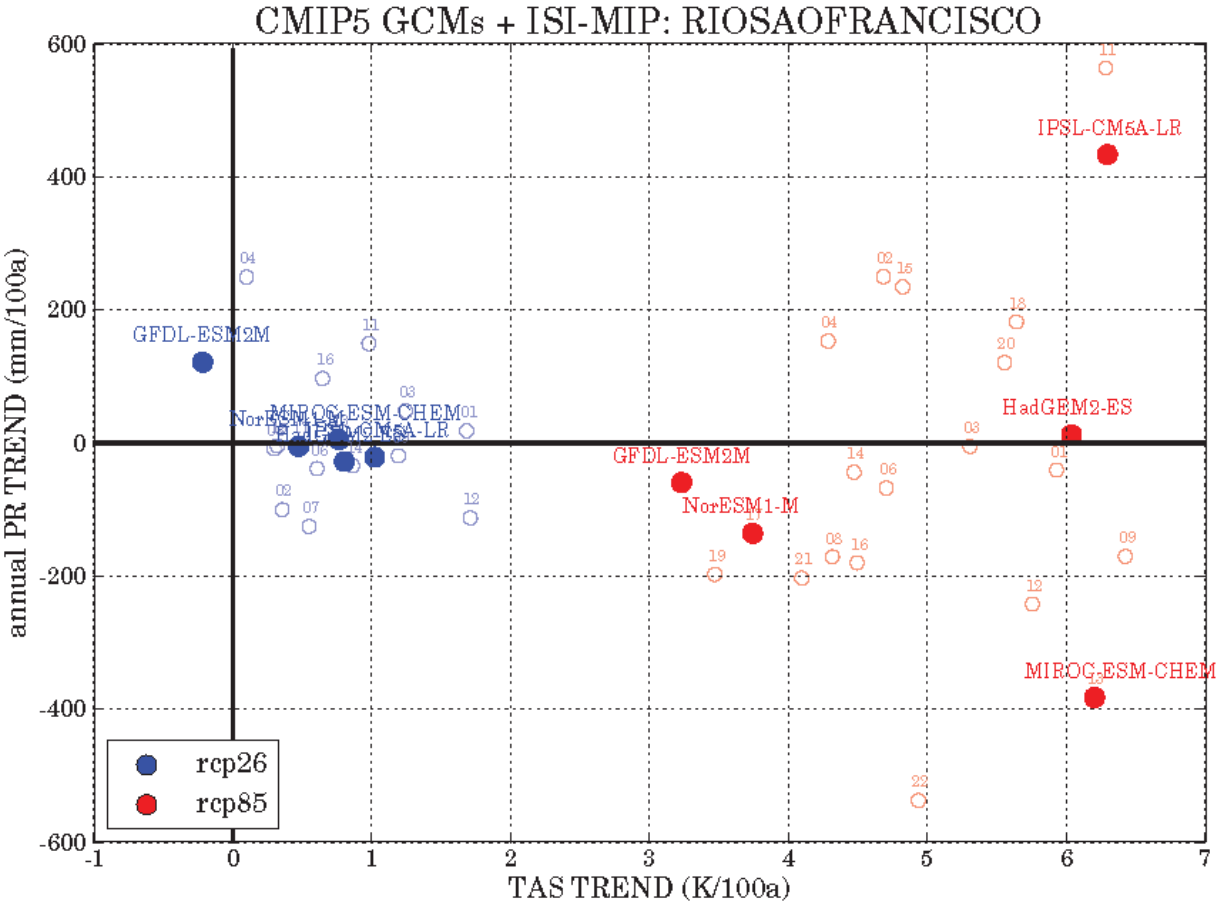


Gauge Traipu

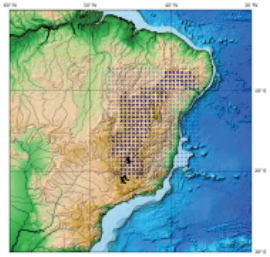


Scenarios: Climate (RCP: Representative Concentration Pathway)

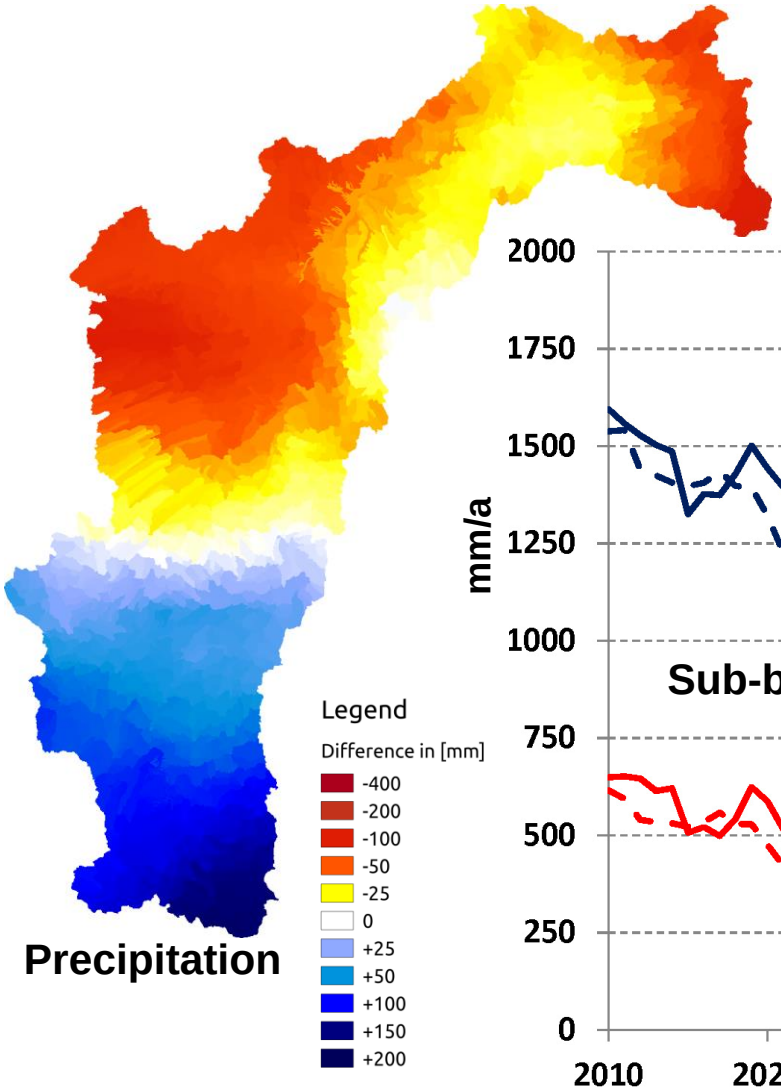
Climate projections of five CMIP5 ESMs (http://cmip-pcmdi.llnl.gov/cmip5/); bias-corrected (Hempel et al., 2013)



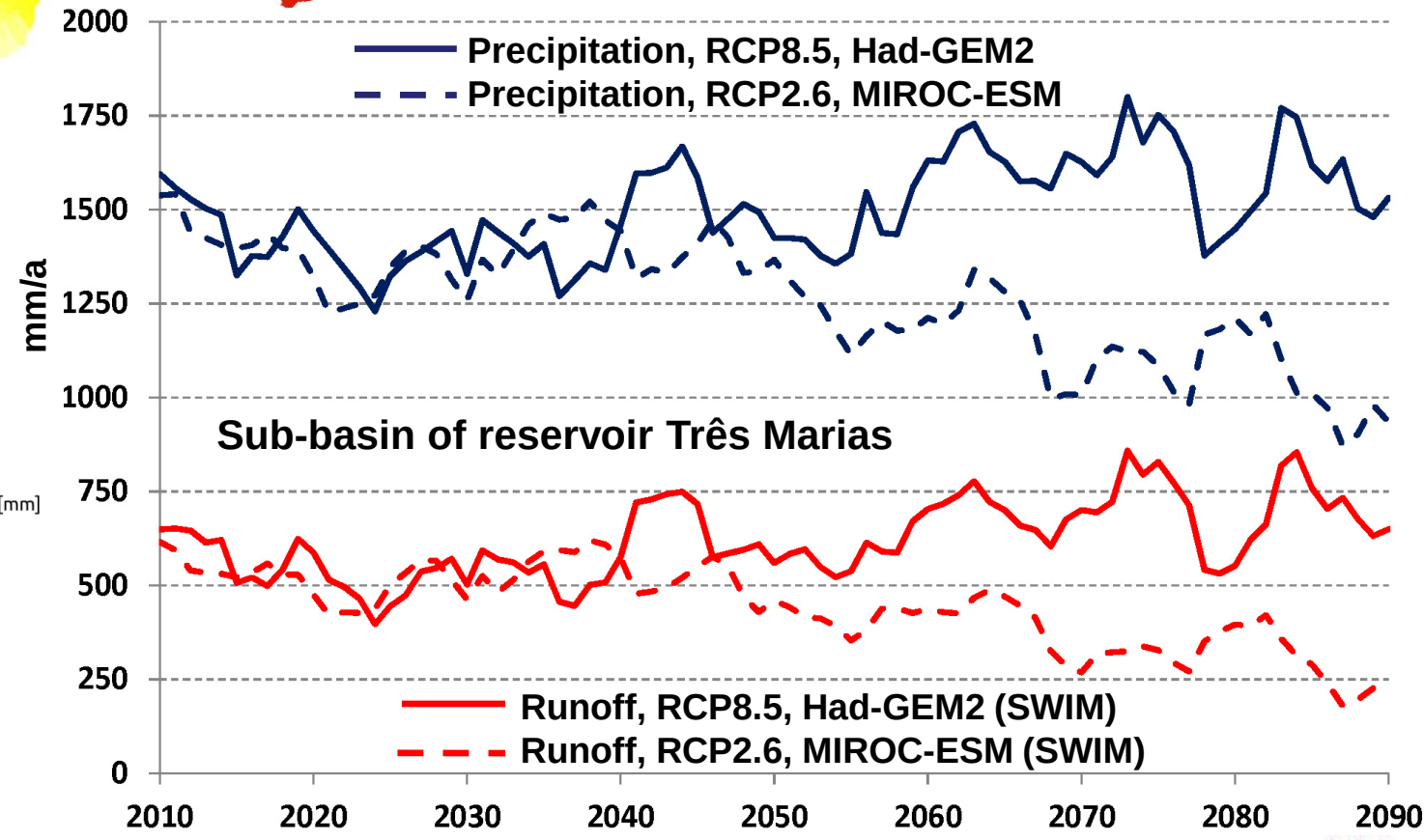
01 CSIRO-Mk3-6-0
02 MPI-ESM-MR
03 CESM1-CAM5
04 FIO-ESM
05 HadGEM2-AO
06 BNU-ESM
07 bcc-csm1-1-m
08 CCSM4
09 CanESM2
10 FGOALS-s2
11 IPSL-CM5A-MR
12 MIROC-ESM
13 MIROC-ESM-CHEM
14 MIROC5
15 MPI-ESM-LR
16 MRI-CGCM3
17 NorESM1-M
18 ACCESS1-0
19 inmcm4
20 ACCESS1-3
21 CESM1-BGC
22 IPSL-CM5B-LR
23 IPSL-CM5A-LR



Scenarios: Climate

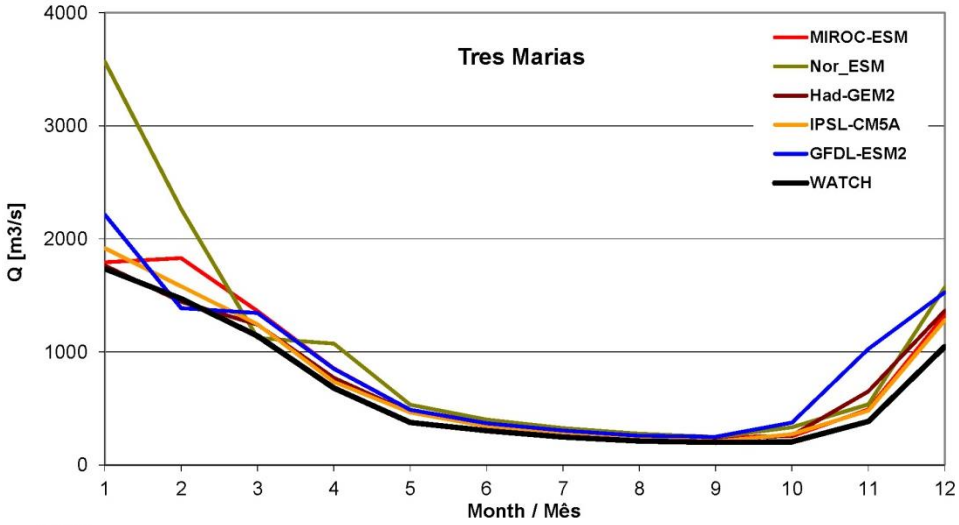


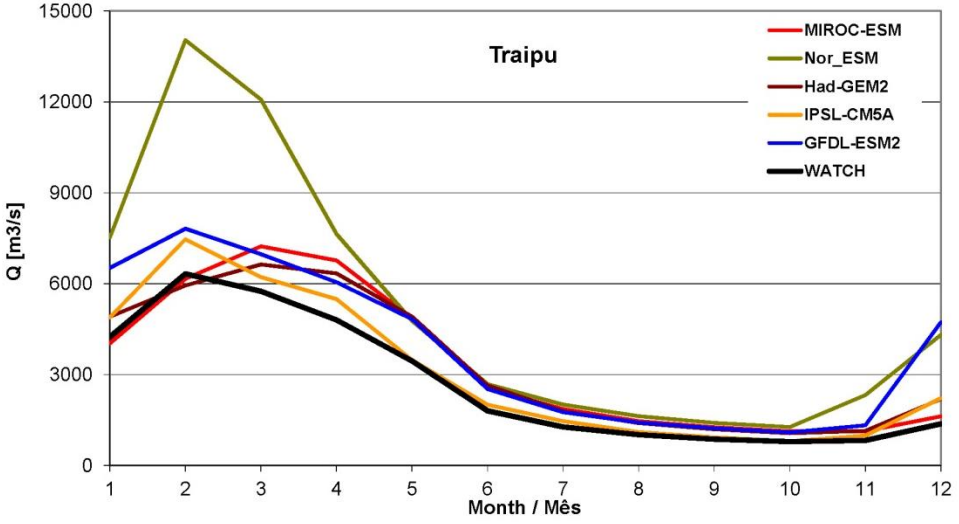
Precipitation



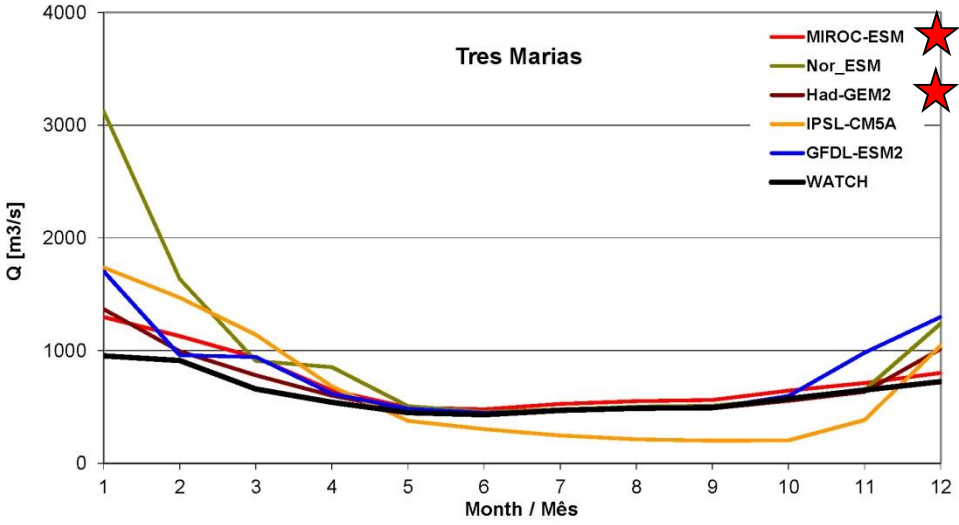
Results: SWIM, historical runs (1981-2000)

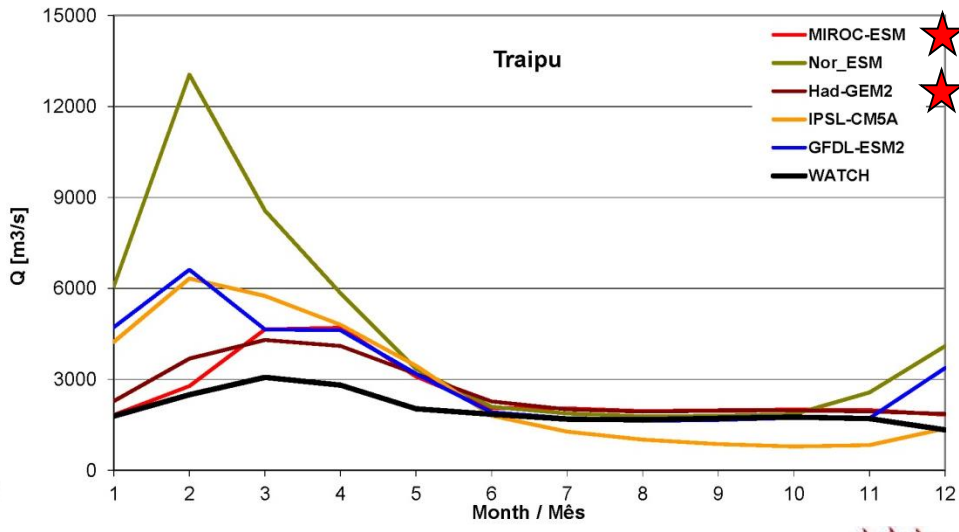
Q natural





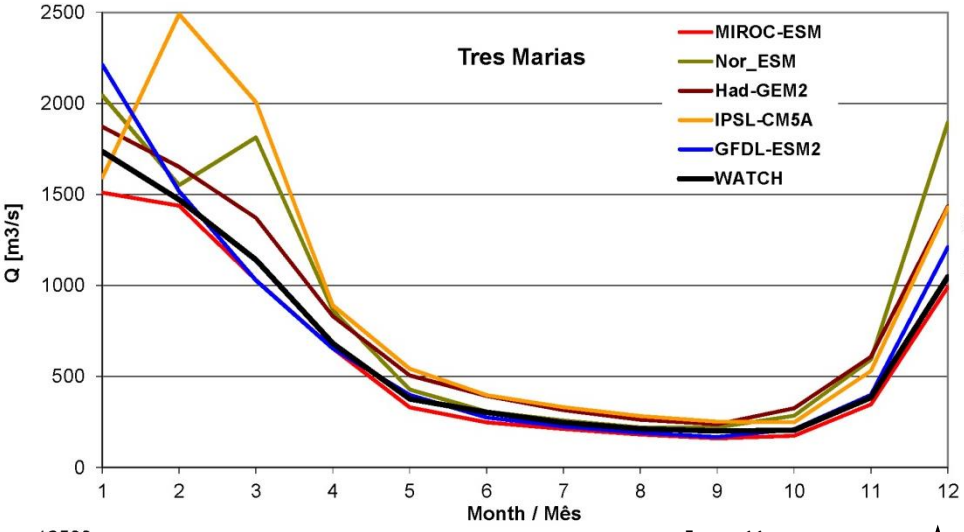
Q managed

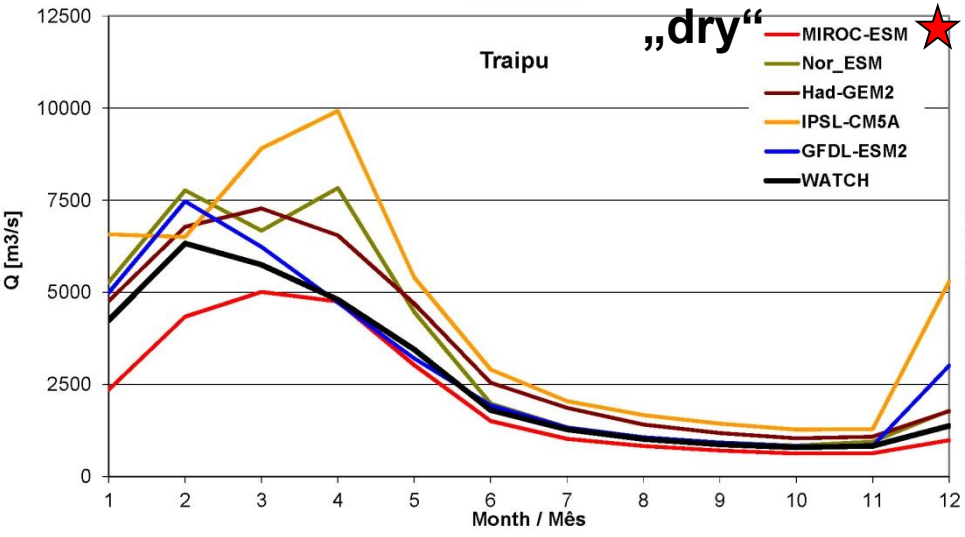




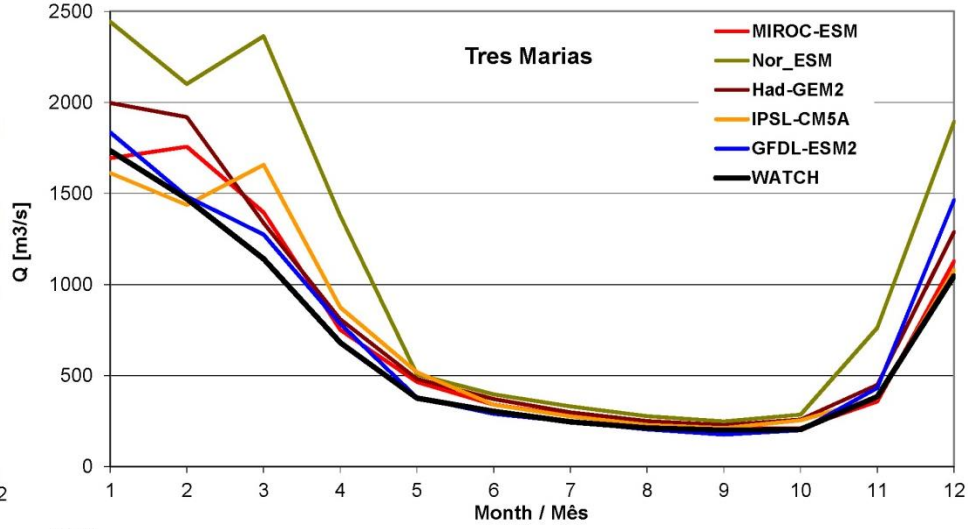
Results: SWIM, climate scenarios (2021-2050)

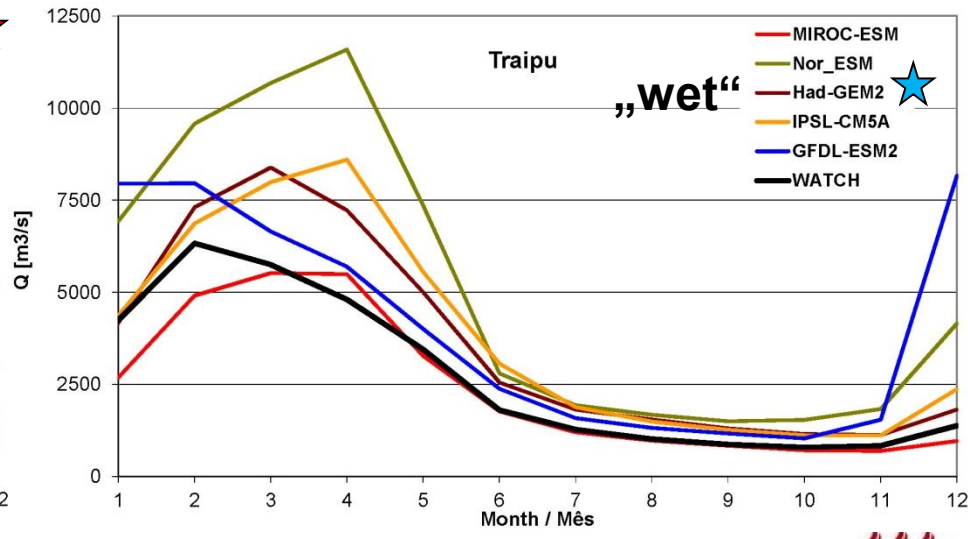
Q natural, RCP2.6





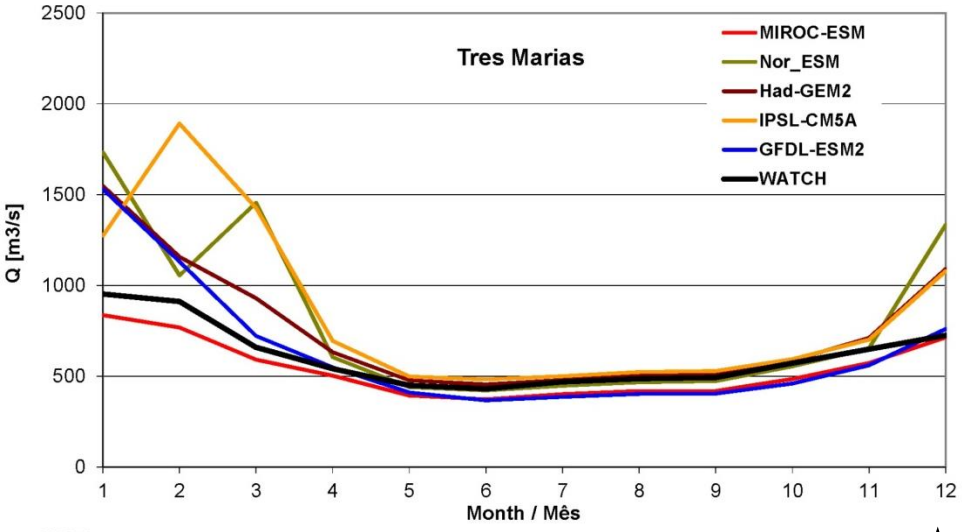
Q natural, RCP8.5

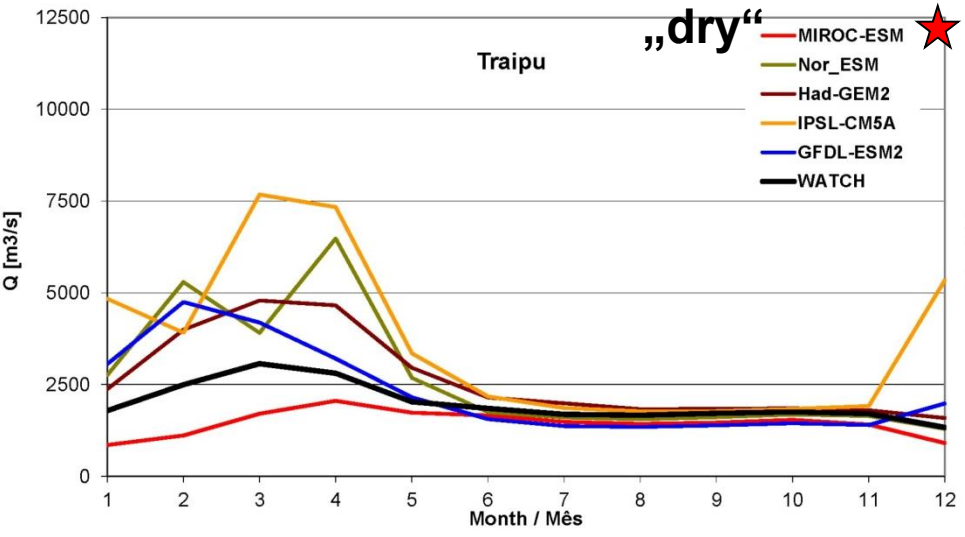




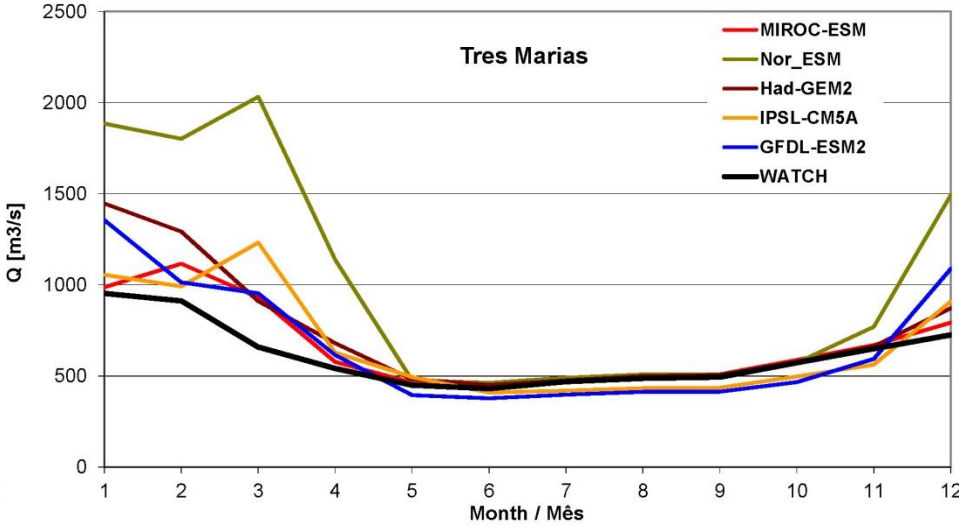
Results: SWIM, climate scenarios (2021-2050)

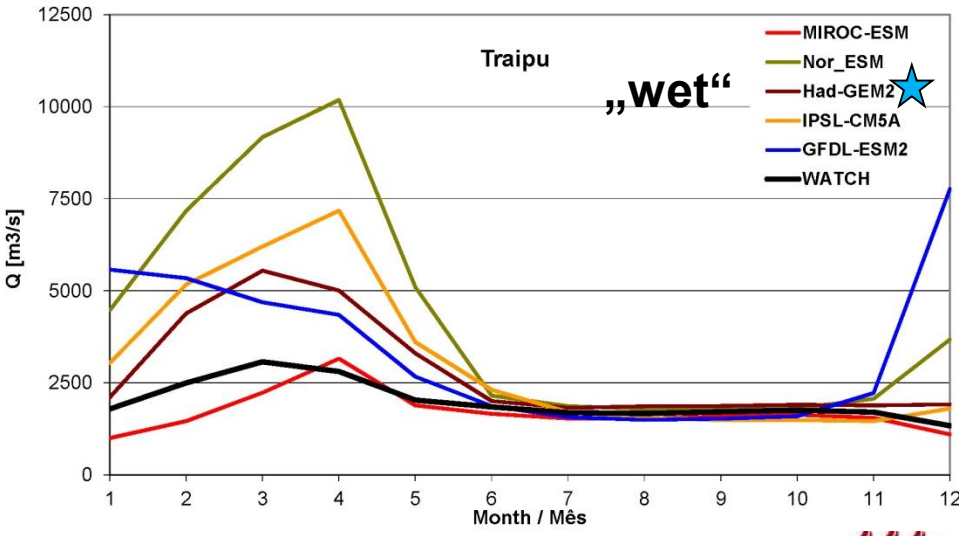
Q managed, RCP2.6





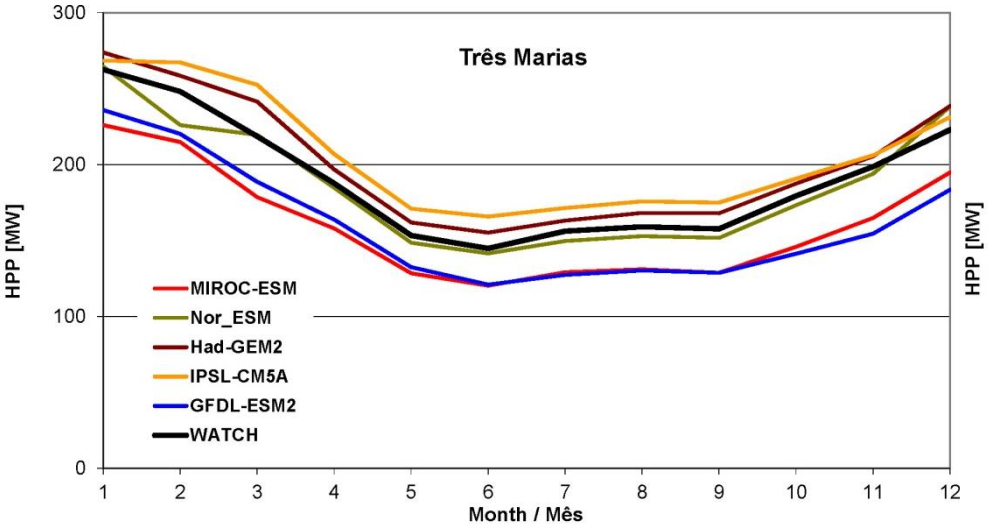
Q managed, RCP8.5

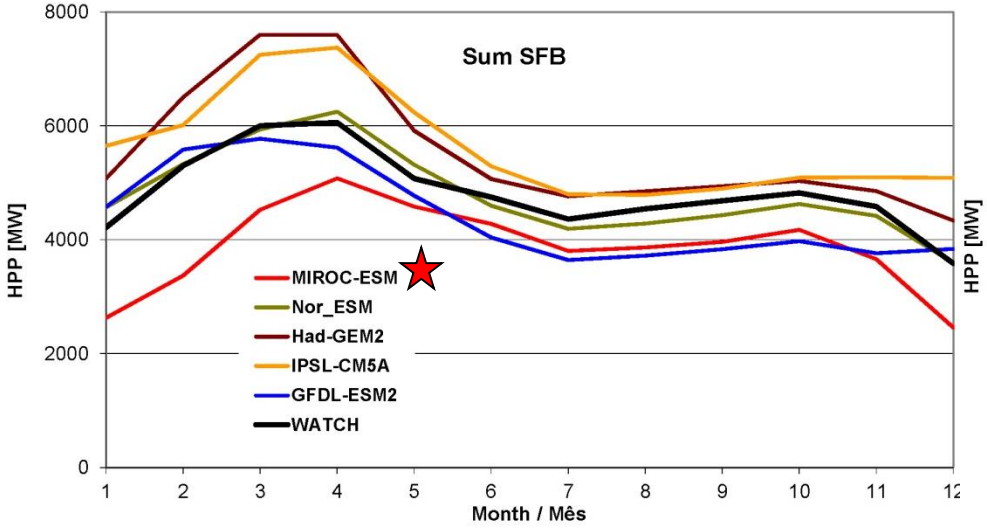




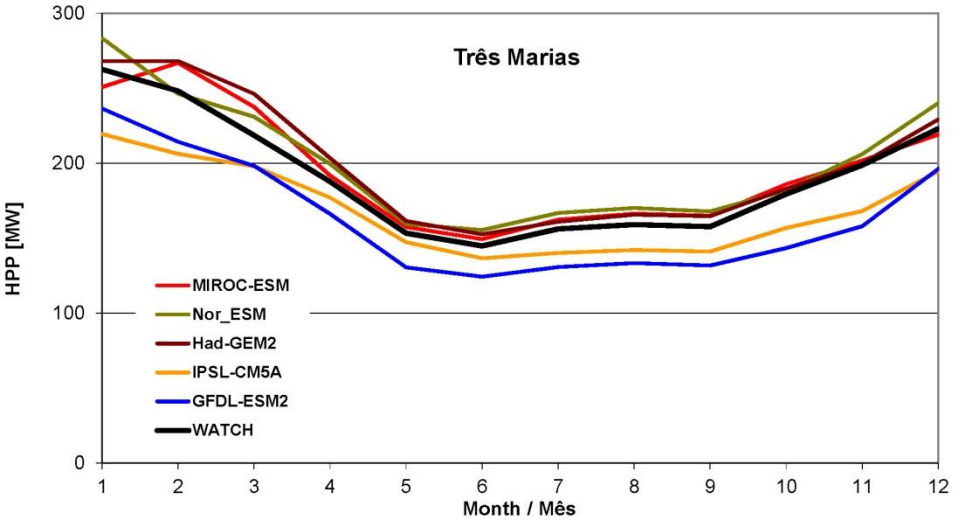
Results: SWIM, climate scenarios (2021-2050)

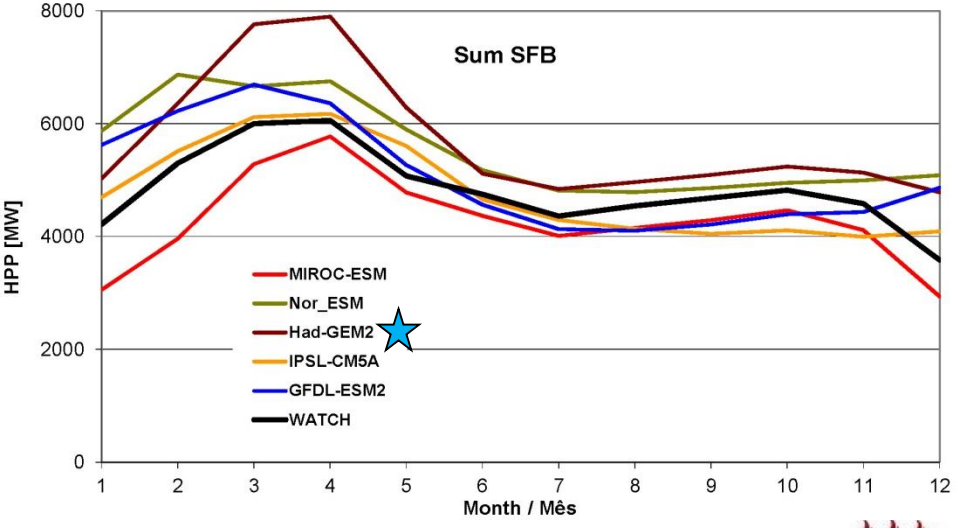
Hydro-power generation, RCP2.6





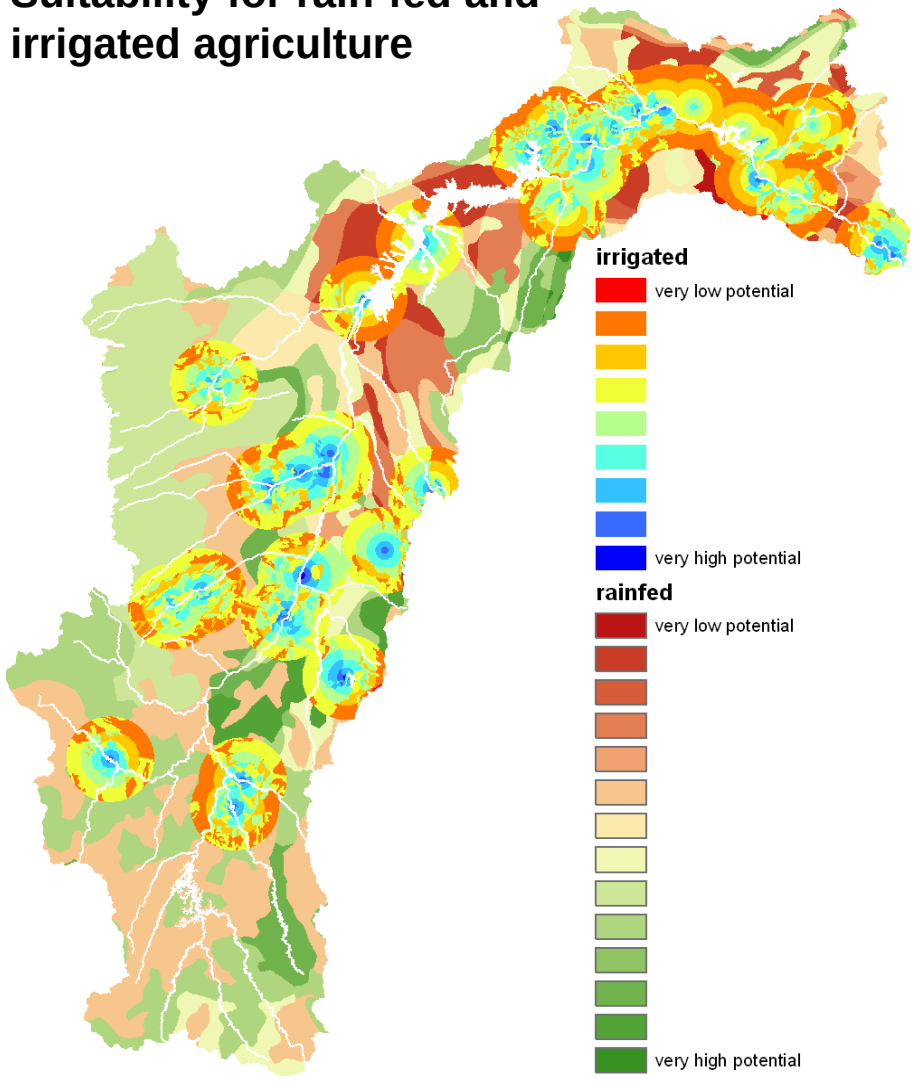
Hydro-power generation, RCP8.5



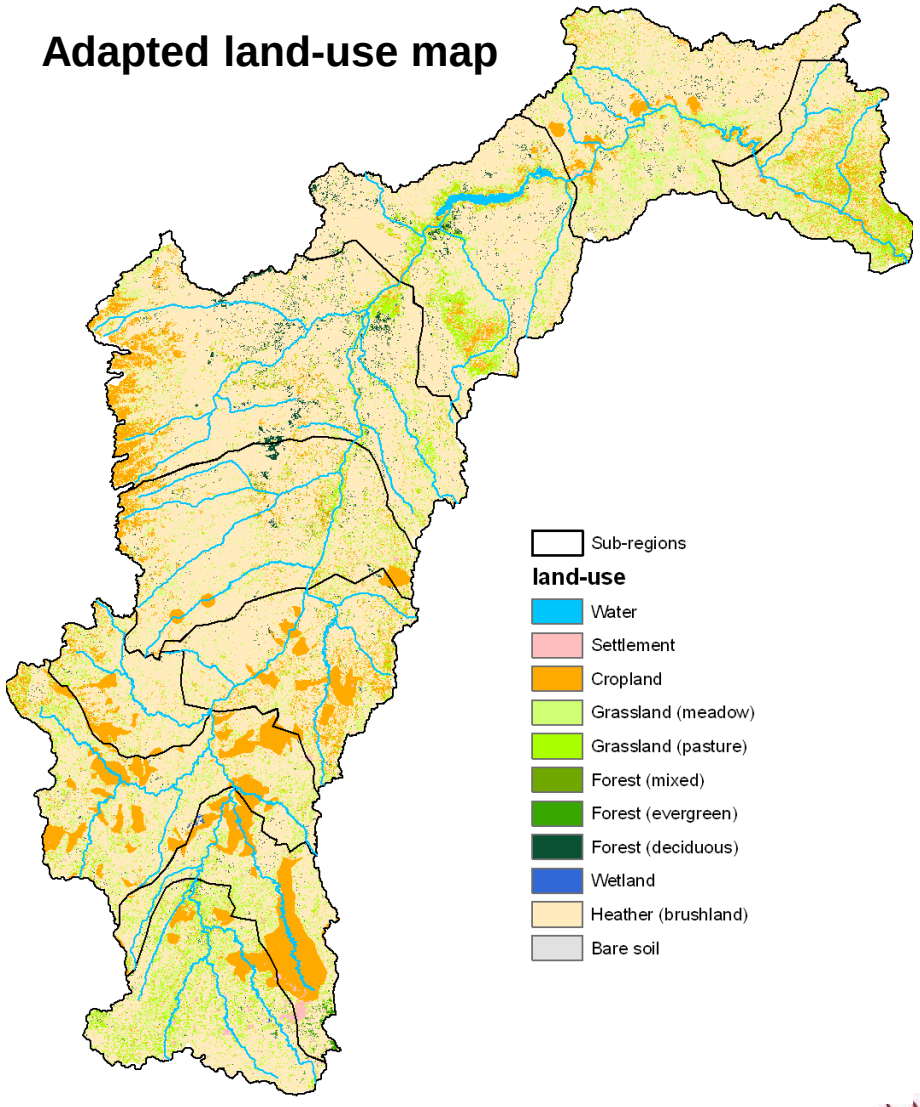


Land-use scenario: increase in agricultural land-use

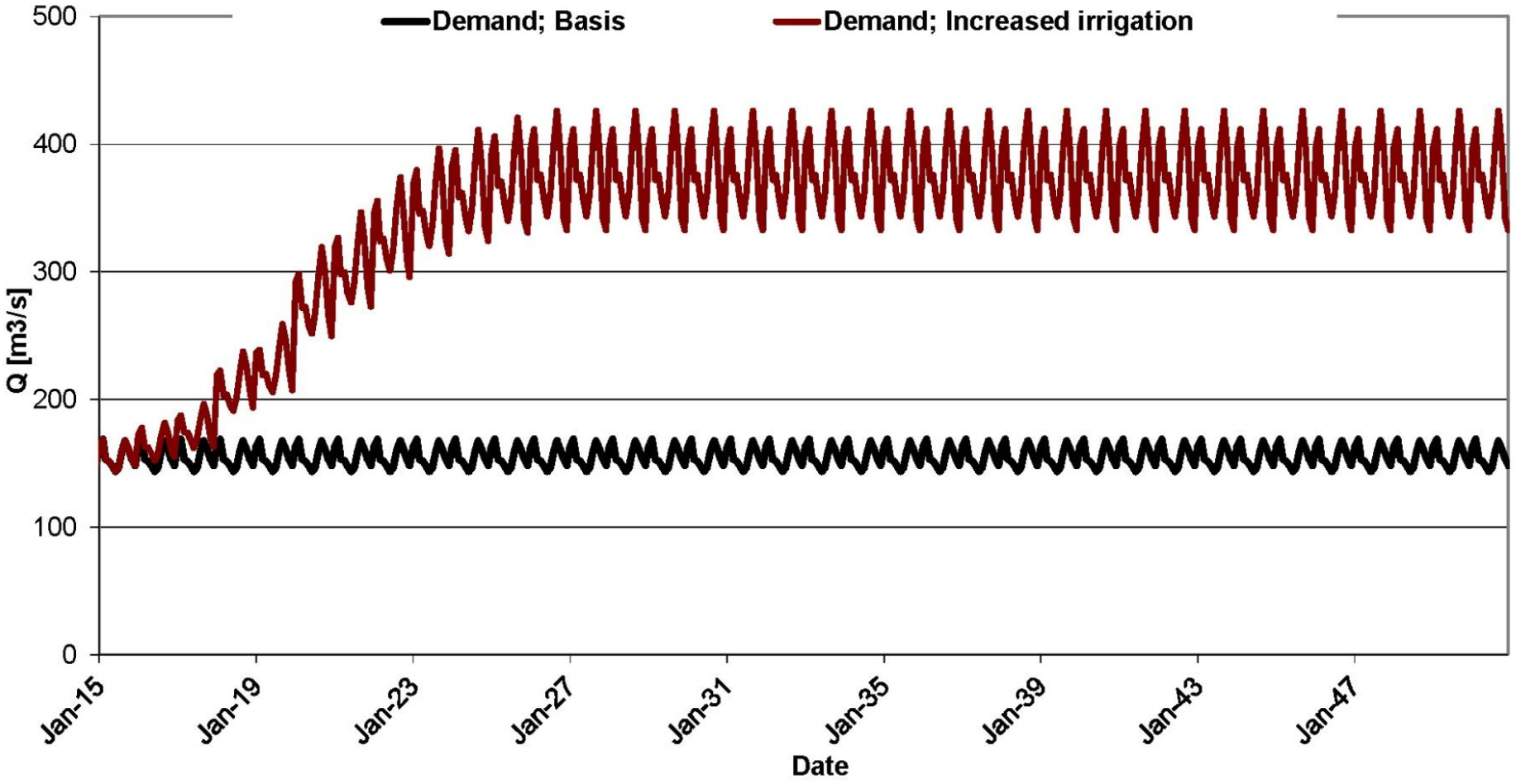
Suitability for rain-fed and irrigated agriculture



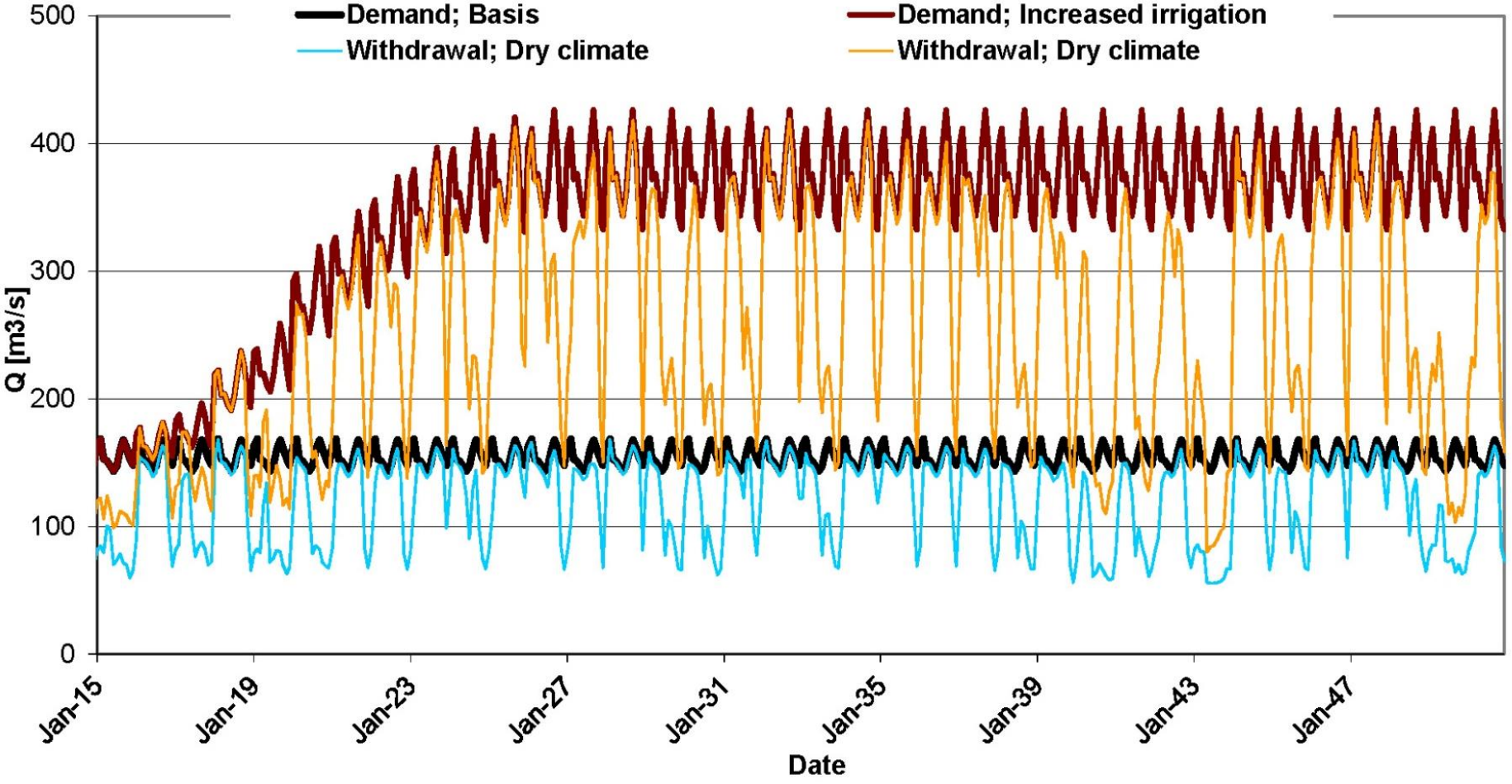
Adapted land-use map



Land-use scenario: increase in agricultural land-use

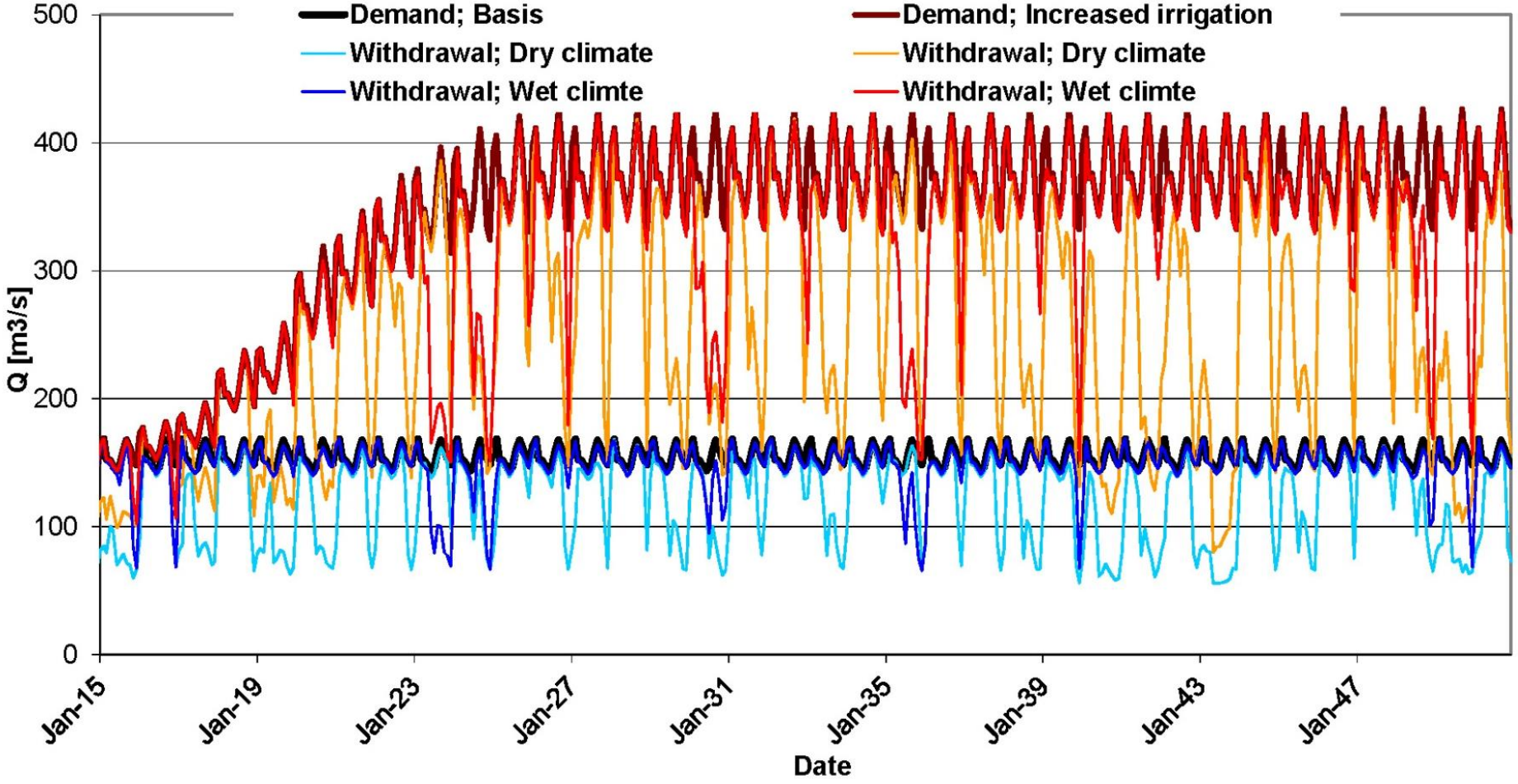


Land-use scenario: increase in agricultural land-use



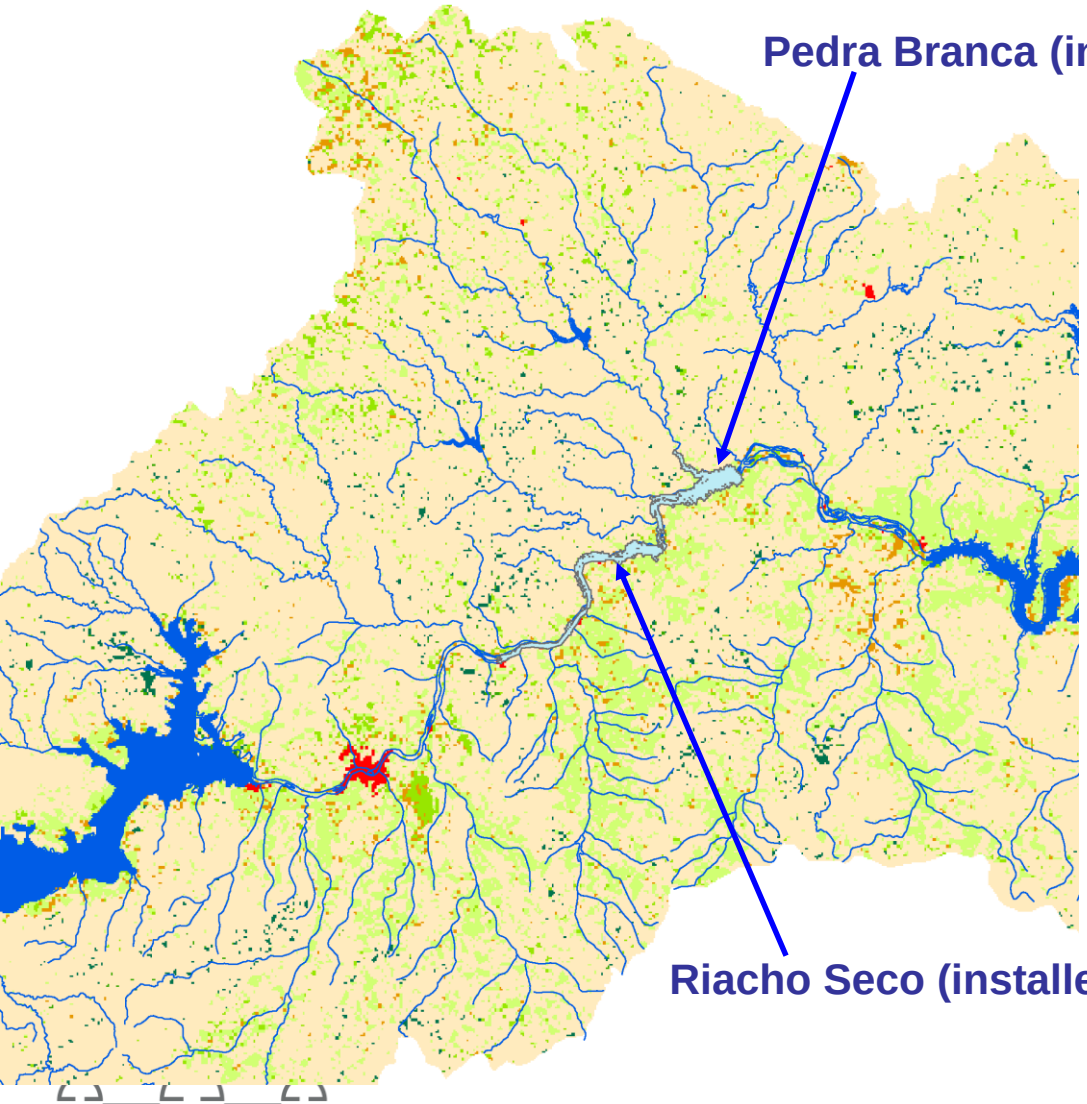
Assumption: strict observation of minimum discharges

Land-use scenario: increase in agricultural land-use



Assumption: strict observation of minimum discharges

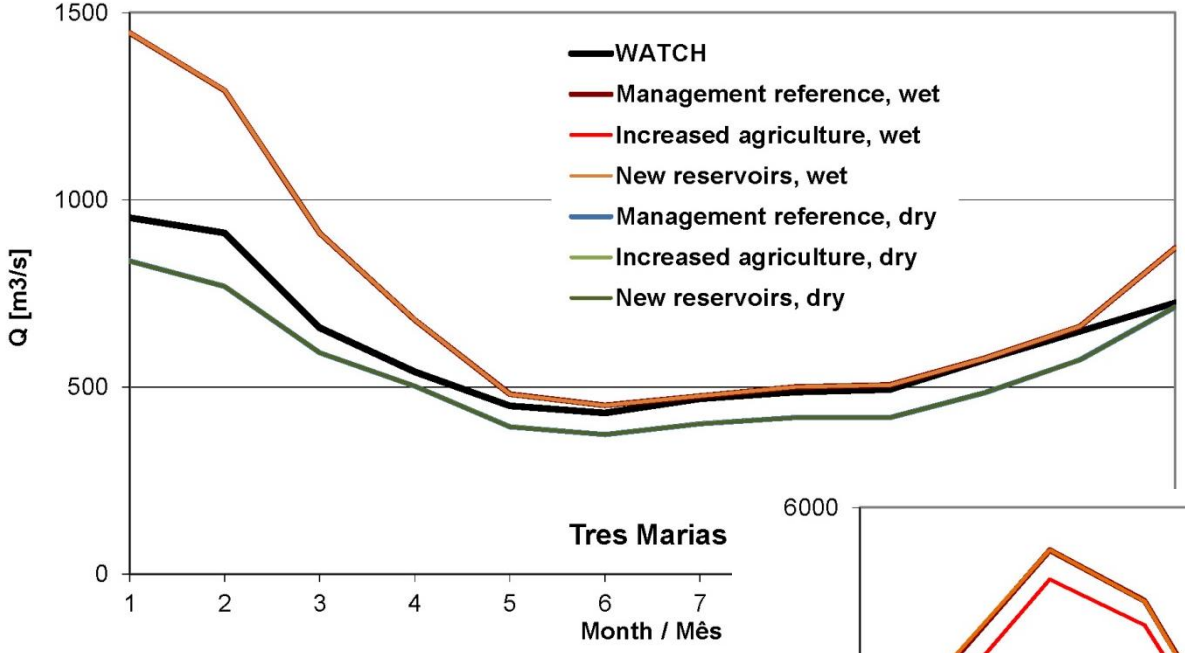
Water management scenario: new reservoirs (hydro-power generation)

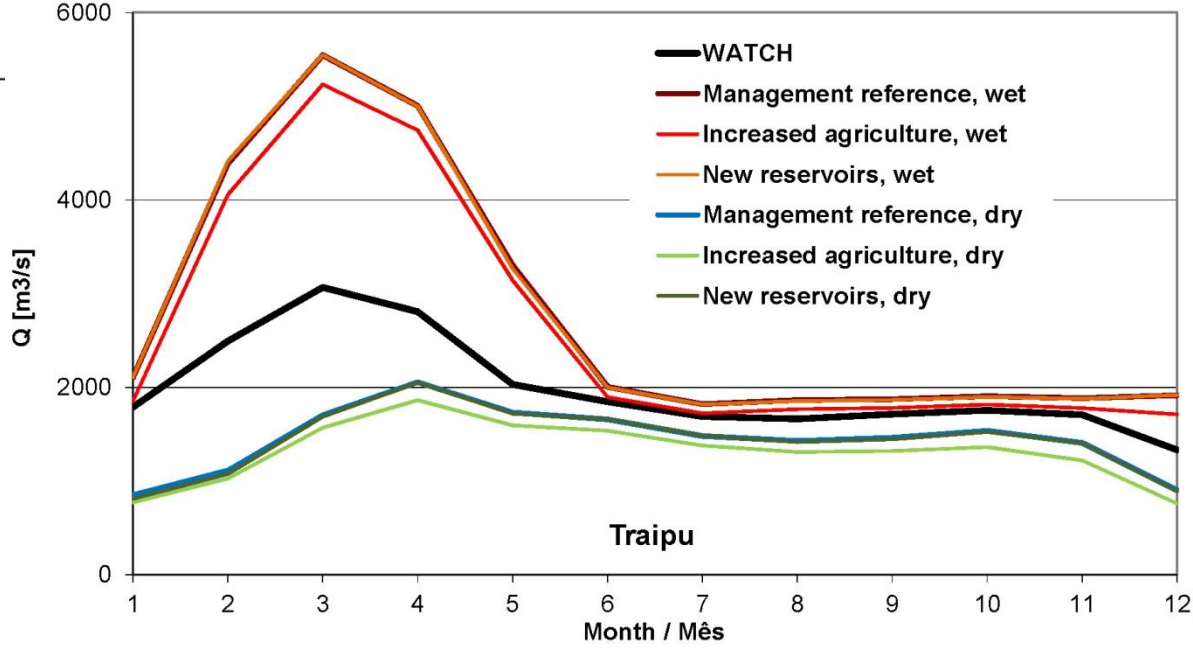


Pedra Branca (installed: 320MW; firm energy: 195MW)

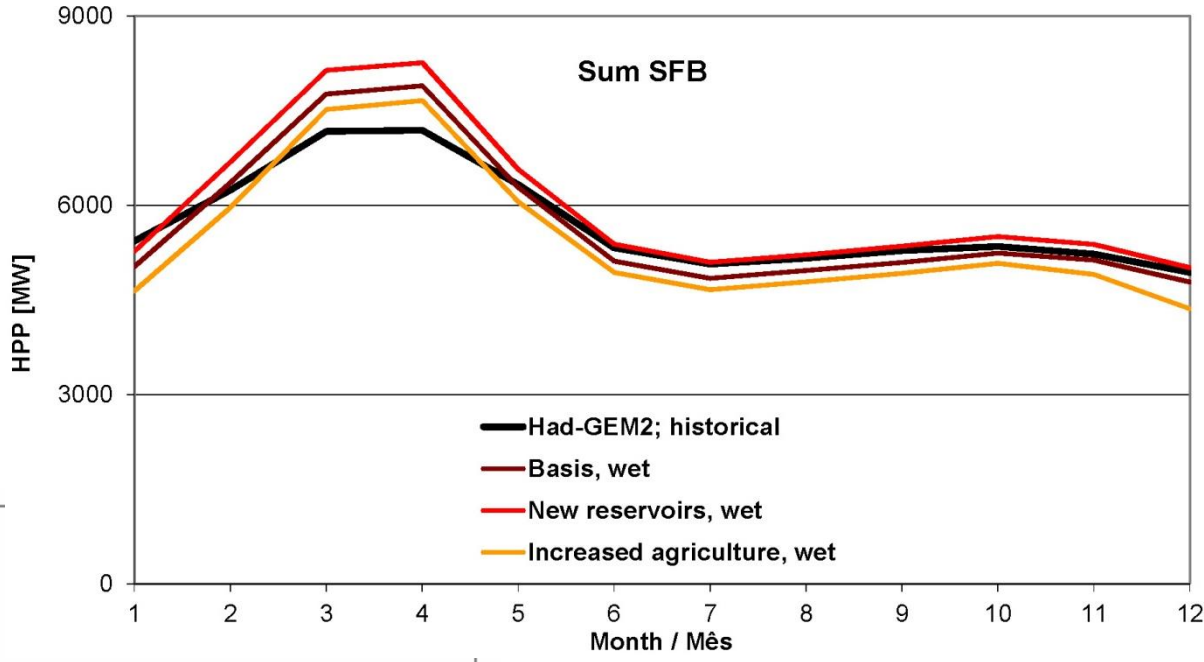
Riacho Seco (installed : 240MW; firm energy: 145MW)

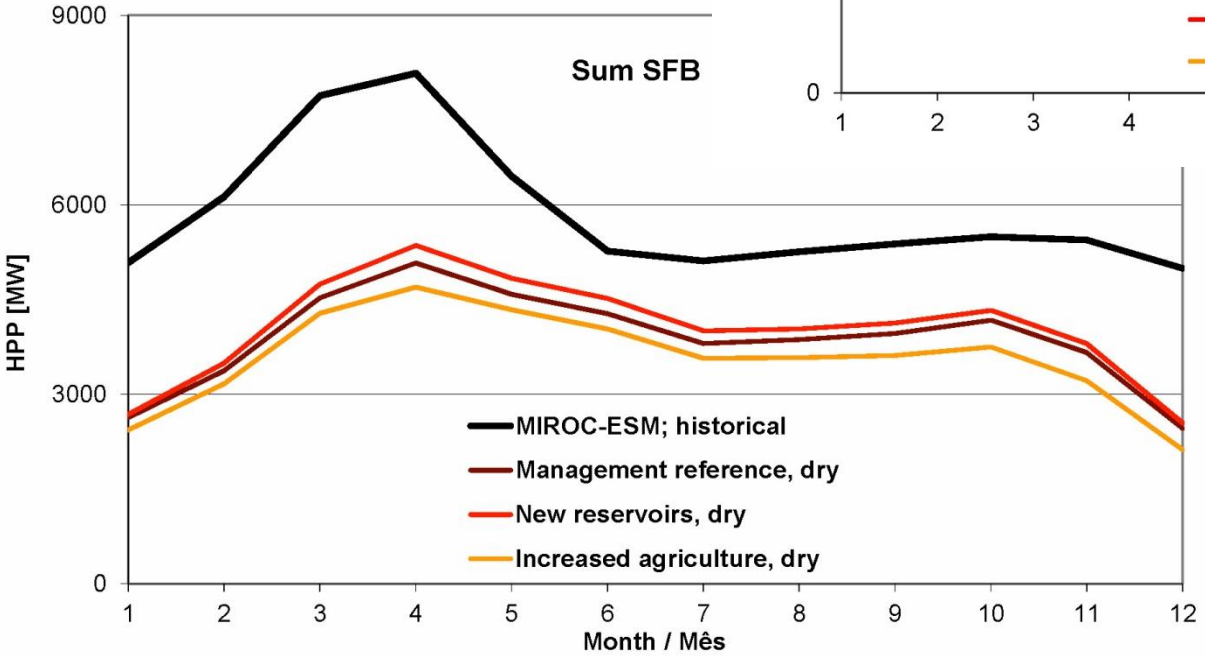
Results: SWIM, discharge (2021-2050)





Results: SWIM, hydro-power generation (2021-2050)





Summary

- Climate change simulations using a selection of climate models and climate scenarios (RCPs) were carried out

- Effects of climate change on runoff (⇒ water availability, hydro-power generation) depend maily on selected climate model (⇒ different directions: drier or wetter future!!!)

- New reservoirs, mainly used for hydropower generation, and new irrigation schemes were included in the scenario analysis

- Wet scenario: high safety of water supply (also for increased water demand)
- Dry scenario: even for the reference scenario high deficits

- Impacts of irrigation water requirement on hydropower generation low compared to climate impacts (strict observation of minimum discharges assumed in the simulations)

Grazie!

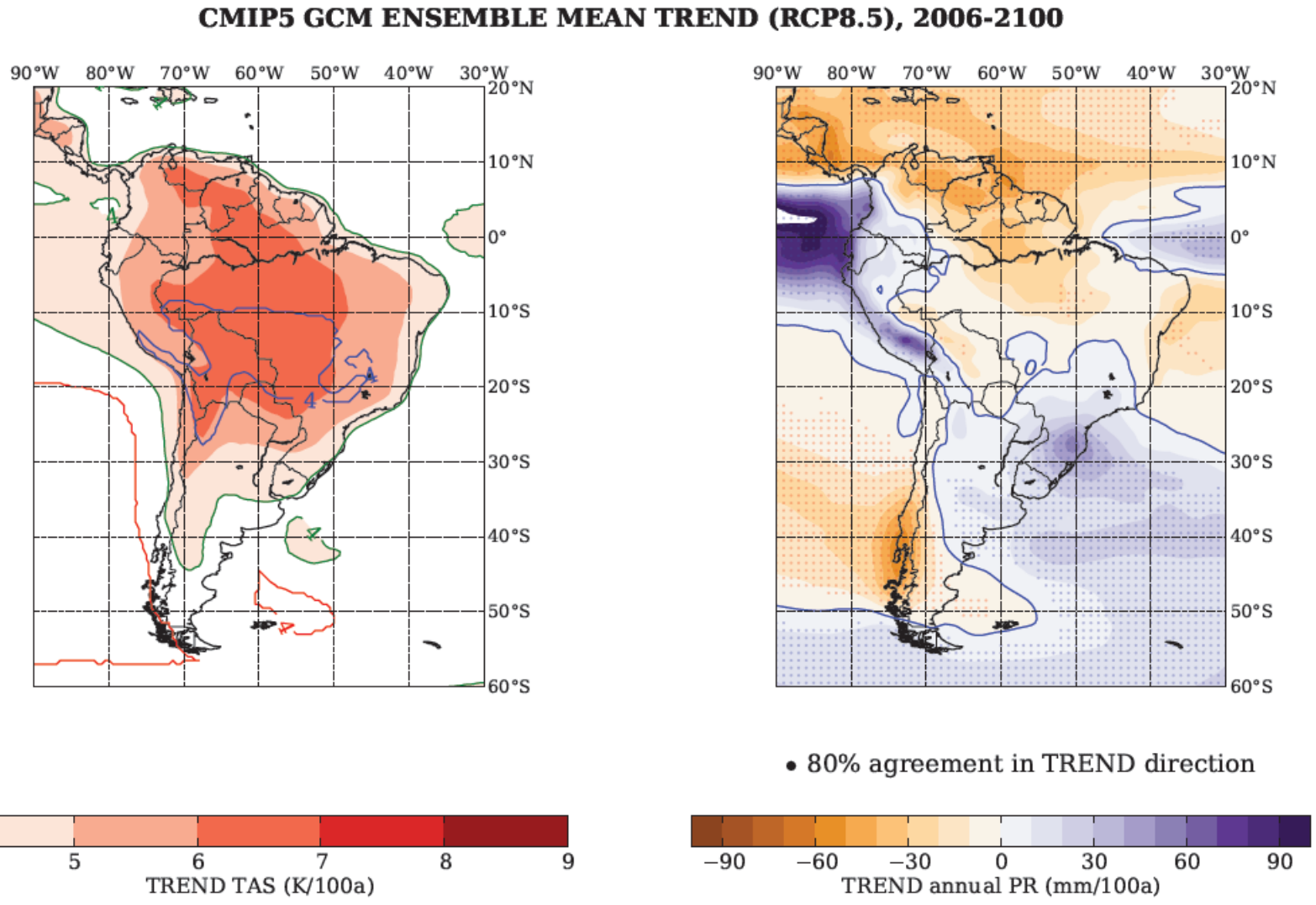
OBRIGADO!

Thank you!

Vielen Dank!

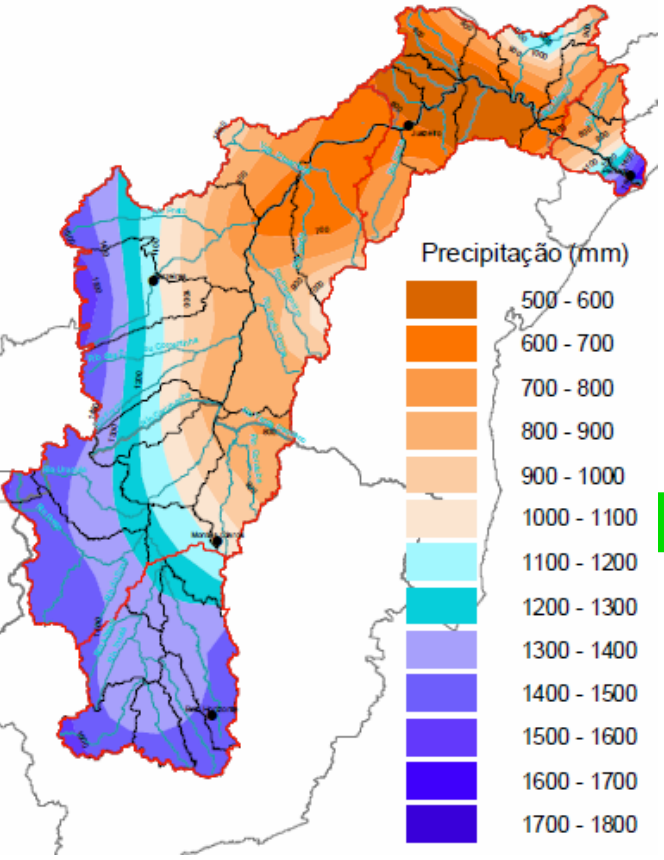
Hagen.Koch(at)pik-potsdam.de

Scenarios: Climate scenarios (RCP: Representative Concentration Pathway)

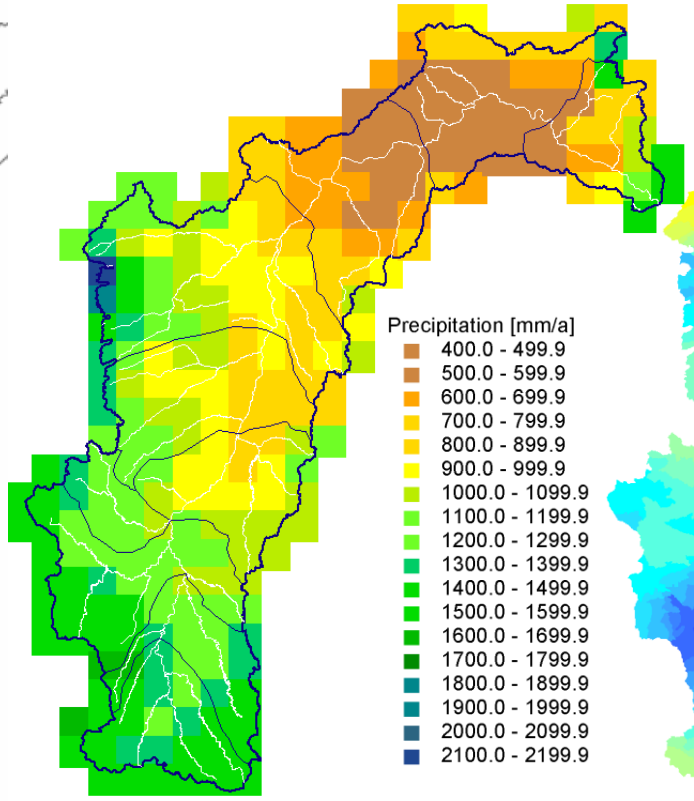


Scenarios: Climate (extreme floods)

Annual precipitation

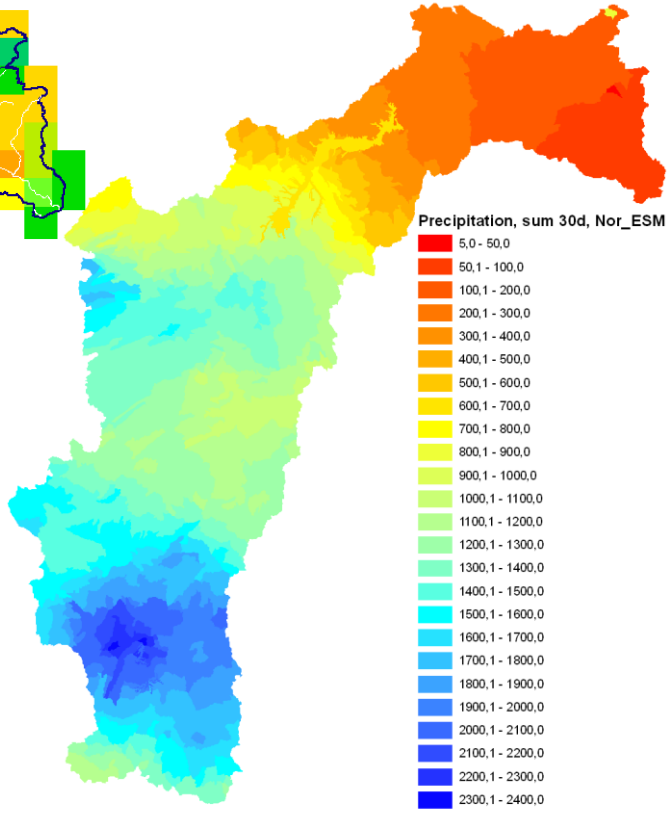


1961-1990; *Agência Nacional de Águas* (ANA), 2004



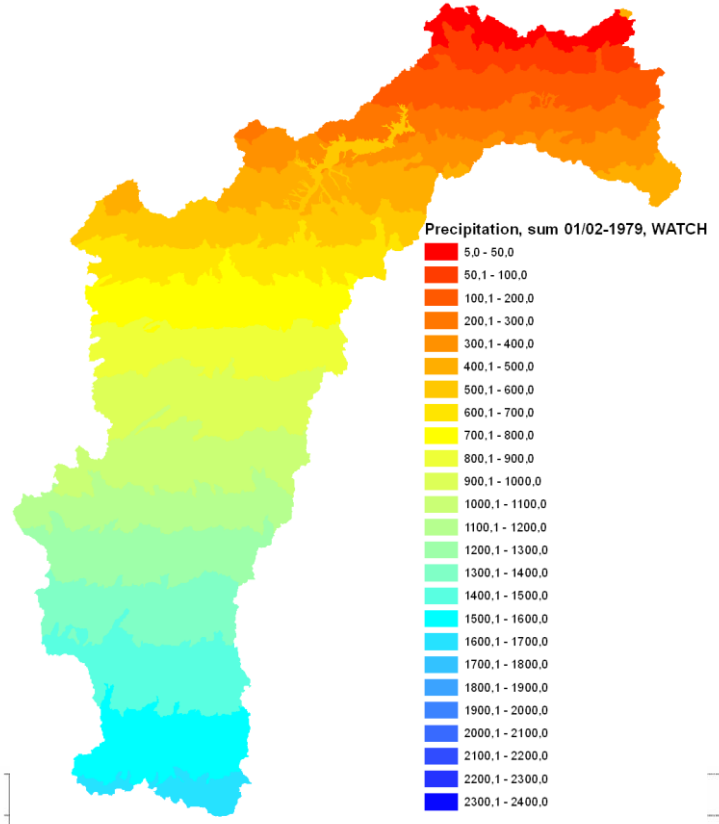
1961-1999; WATCH-data set

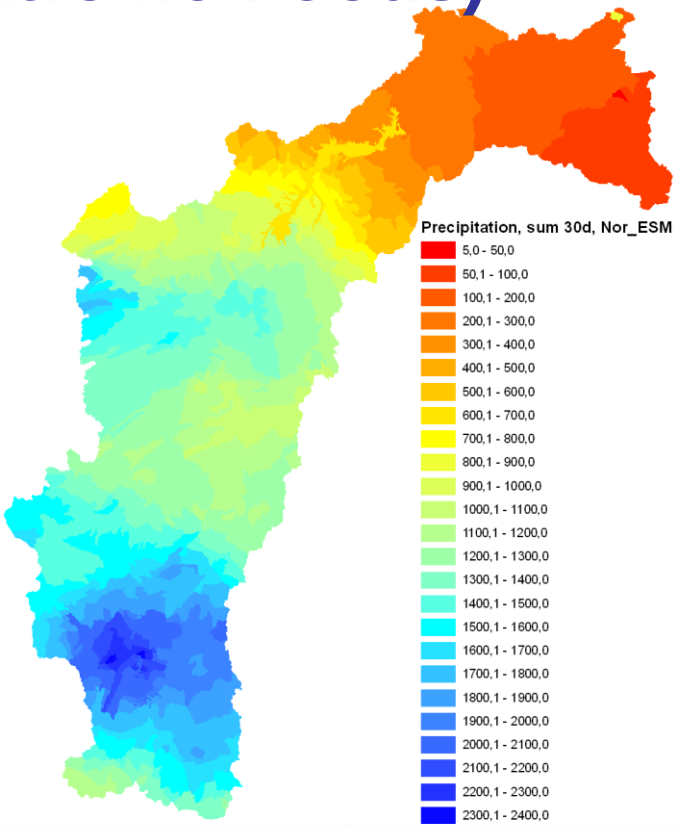
Precipitation causing extreme flood in climate scenario (example)

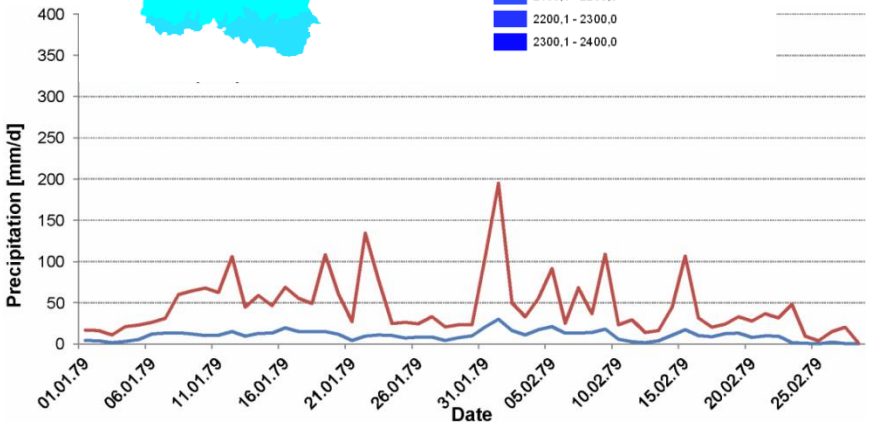


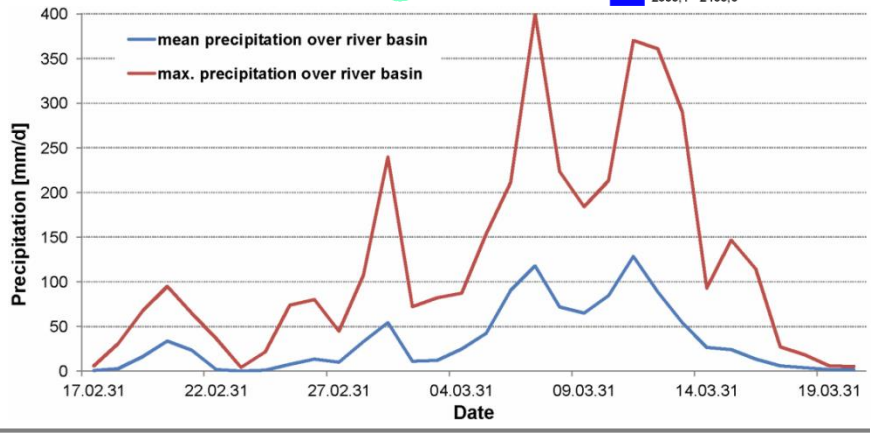
Precipitation sum 30d [mm] (17.02.-19.03.2031), Nor_ESM, RCP 8.5

Scenarios: Climate (extreme floods)









SWIM: Climate data for calibration / validation

- daily climate data (re-analysis data corrected by using monthly observations; e.g. Tmax, Tmean, Tmin, precipitation, solar radiation) from the WATCH-project (http://www.eu-watch.org/)

- grid cells of 0.5° (approx. 50x50km)

SWIM: simulated runoff (mean 1981-2010)