Modelling of water availability and water management for the São Francisco Basin, Brazil

(Modelização da disponibilidade e do manejo da água na bacia hidrográfica do Rio São Francisco)

2014 International SWAT Conference

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Overview

- Introduction
- SWIM model
- Problems (calibration and validation) and solutions
- Results / Scenarios
- Outlook

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

Introduction: SWIM vs. SWAT

Are there (m)any differences?

There are some, but… (SWIM is based on SWAT'94 & MATSALU)

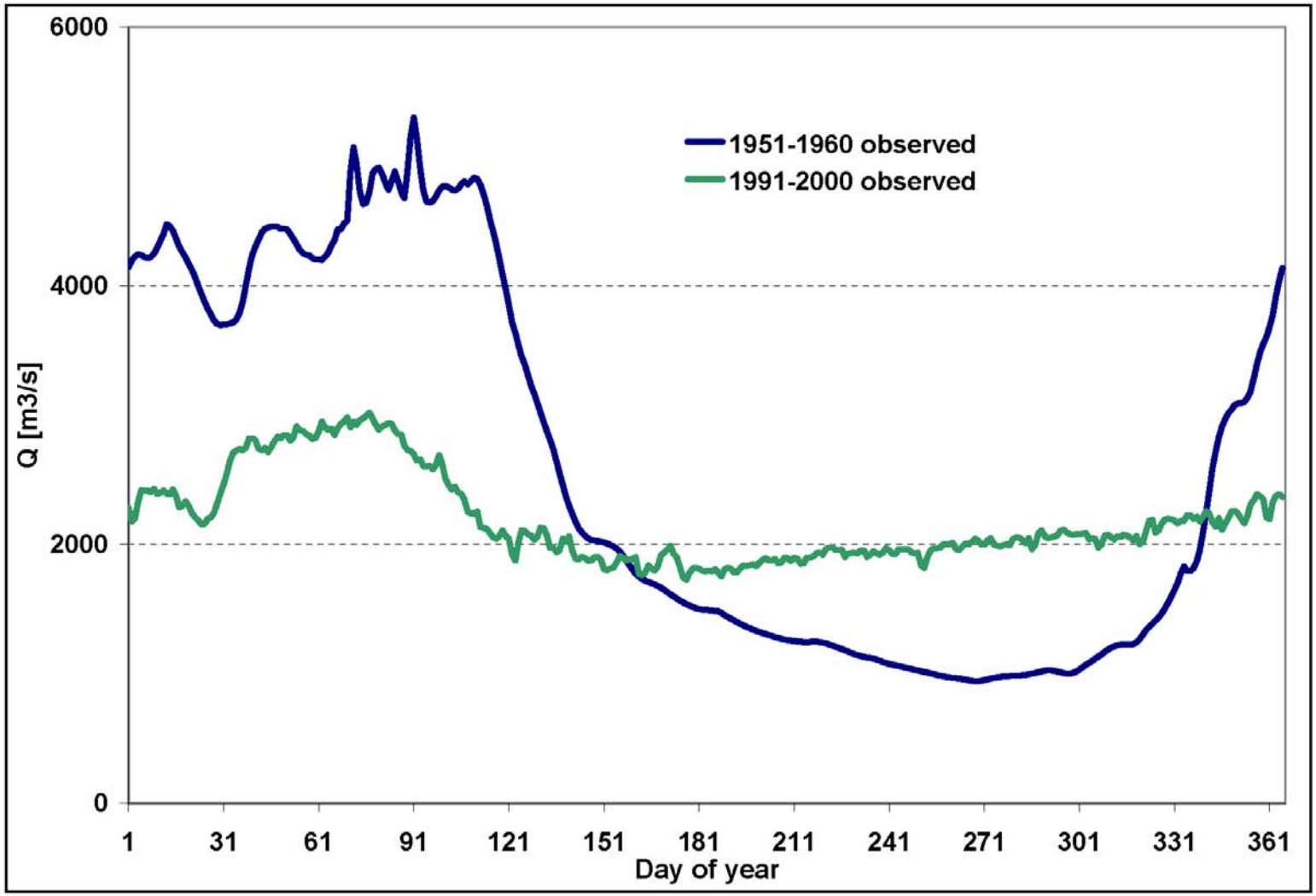
- **Same model structure**
- **Basic assumptions and equations similar**

Some specific functionalities

- **Wetlands**
- **Dams and reservoirs**
- **Agriculture (Irrigation)**
- **...**

SWAT: more user-friendly

Introduction: Discharge at gauge Traipu / São Francisco



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

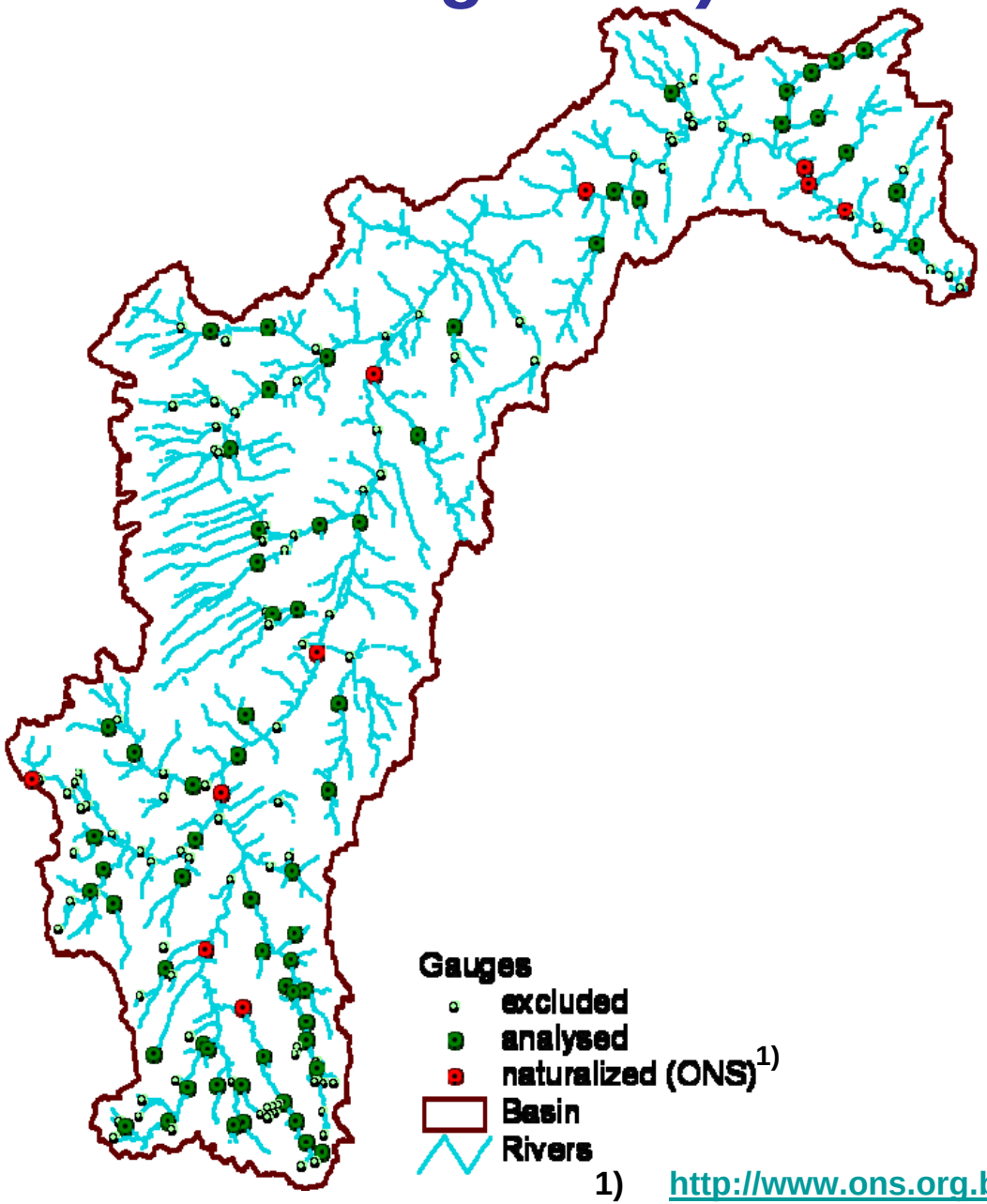
Introduction: Discharge measurements – ANA (http://portalsnirh.ana.gov.br/)

São Francisco River basin: 640,000 km^2

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

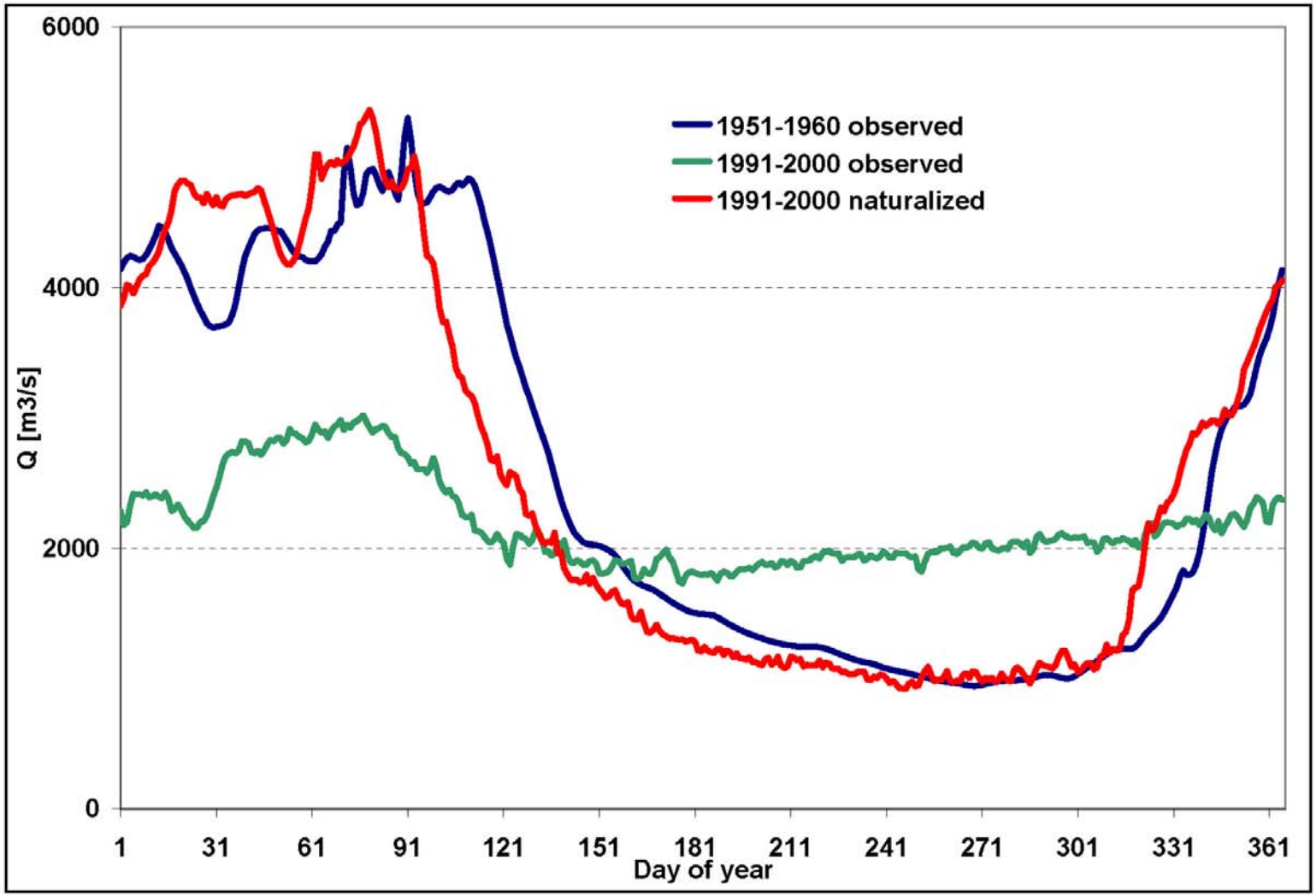
Criteria for selection: catchment area, time series length, no large gaps in time series
⇒ 65 gauges selected

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



1) http://www.ons.org.br/

Introduction: Discharge at gauge Traipu / São Francisco



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

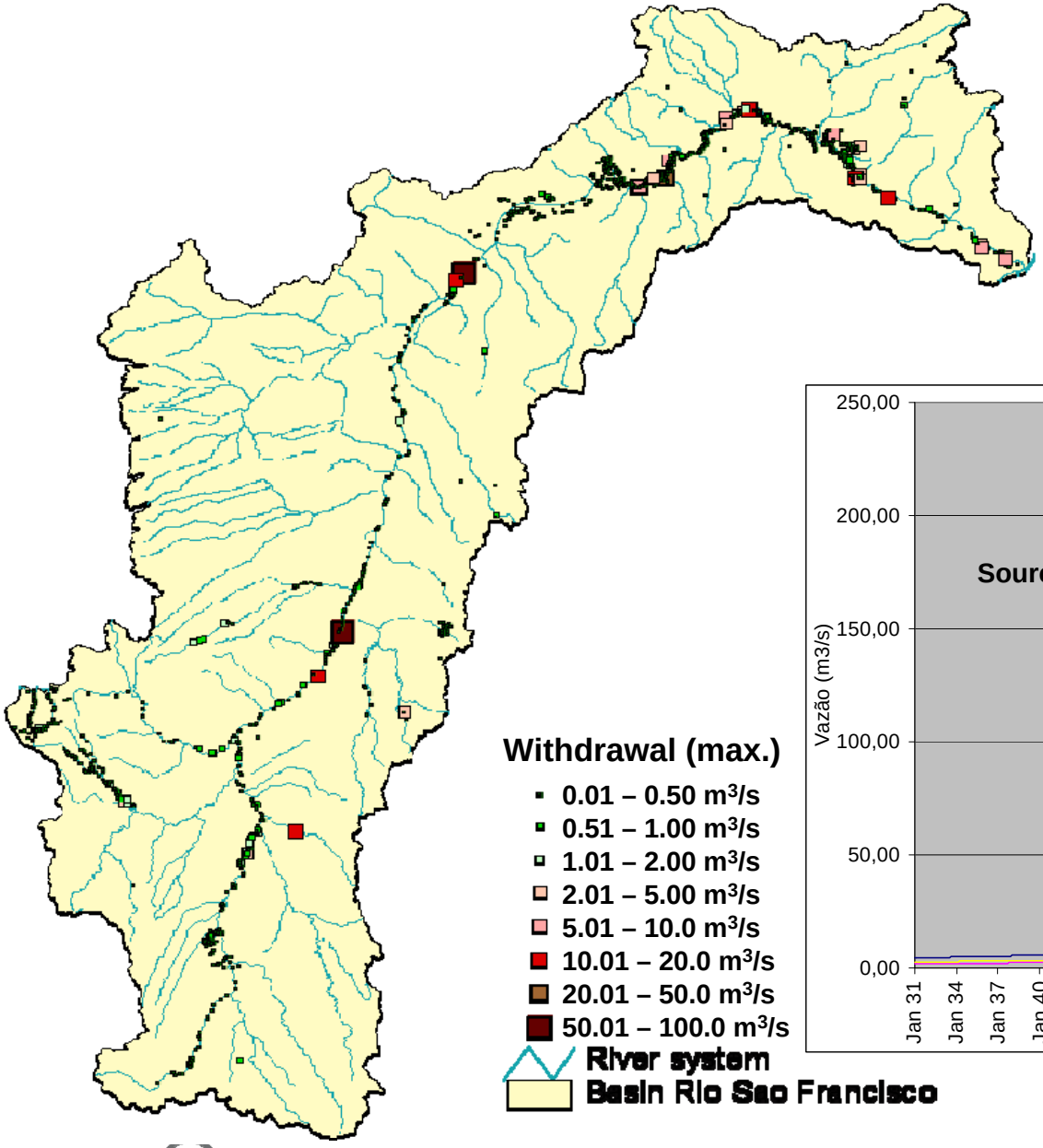
Introduction: Naturalization of discharge (ONS)

ONS: http://www.ons.org.br/operacao/vazoes_naturais.aspx

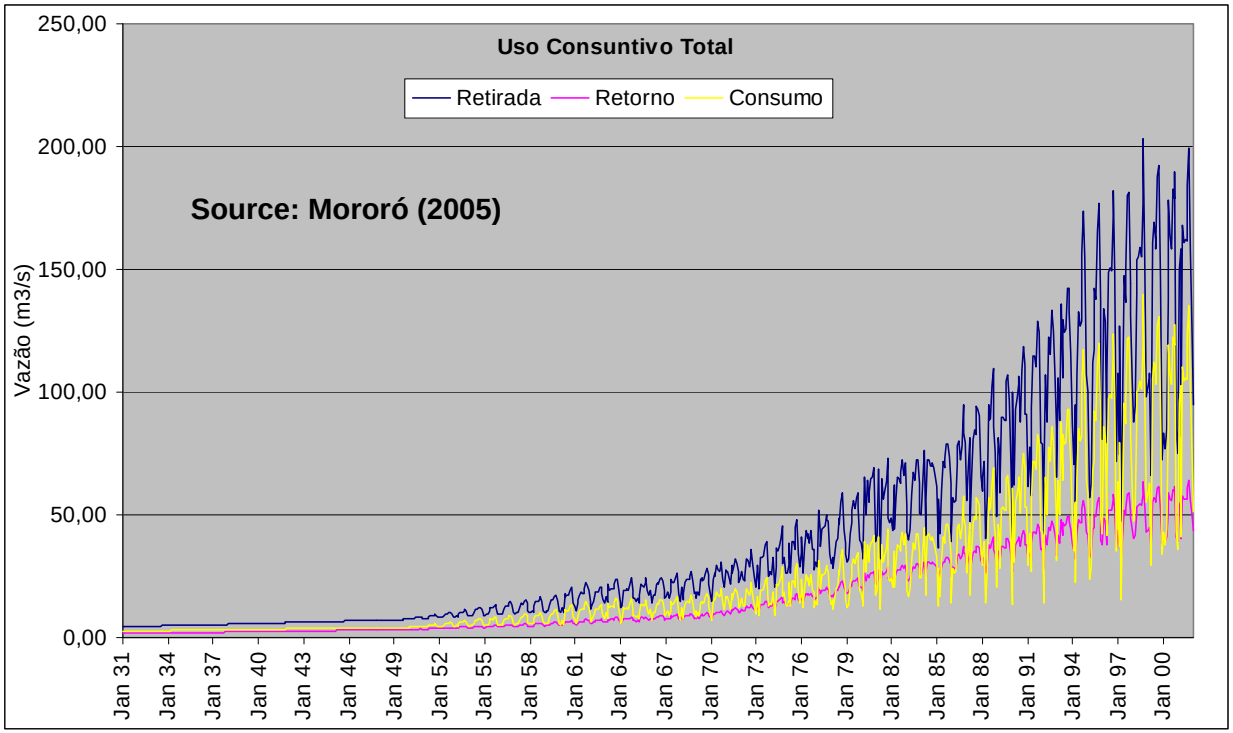
Microsoft Excel - Tempos de viagem.xls

	A	B	C	D	E	F	G
2		MODELAGEM DA BASE DE DADOS TÉCNICA			TEMPO VIAGEM EM CONDIÇÕES NATURAIS (HORA)		TEMPO VIAGEM EM CONDIÇÕES DE RESERVATÓRIO
3	RES_ID	NOME	RES_ID jusante	NOME jusante	TVN		TVR
52	PPCNO1	CANOAS I	PPCAPI	CAPIVARA	17,2		5
53	PPCAPI	CAPIVARA	PPTAQU	TAQUARUÇU	9,3		4
54	PPTAQU	TAQUARUÇU	PPROSA	ROSANA	13,9		4
55	PPROSA	ROSANA	PNITAI	ITAIPU	56		48
56	PNITAI	ITAIPU					
57	IGSCL	SANTA CLARA-PR	IGFND	FUNDÃO	2		2
58	IGFND	FUNDÃO	JDJORD	JORDÃO	1,8		1,8
59	JDJORD	JORDÃO	IGSSAN	SALTO SANTIAGO	9,6		1
60	JDDJOR	DESVIO DE JORDÃO	IGSEGR	SEGREDO	0		0
61	IGGBMU	G.B.MUNHOZ	IGSEGR	SEGREDO	12,7		1
62	IGSEGR	SEGREDO	IGSSAN	SALTO SANTIAGO	11,7		1
63	IGSSAN	SALTO SANTIAGO	IGSOSO	SALTO OSÓRIO	10		1
64	IGSOSO	SALTO OSÓRIO	IGSCAX	SALTO CAXIAS	9,4		1
65	TOSMES	SERRA DA MESA	TOUHCB	CANA BRAVA	10		10
66	TOUHCB	CANA BRAVA	TOUHPA	PEIXE ANGICAL	32		32
67	TOUHPA	PEIXE ANGICAL	TOLAJ	LAJEADO	64		64
68	TOLAJ	LAJEADO	TOTUCU	TUCURUI	144		144
69	TOTUCU	TUCURUI					
70	SFTMAR	TRÉS MARIAS	SFSOBR	SOBRADINHO			
71	SFQMDO	QUEIMADO	SFSOBR	SOBRADINHO			
72	SFSOBR	SOBRADINHO	SFGON	LUIZ GONZAGA			
73	SFGON	LUIZ GONZAGA	SFMOXO	MOXOTÓ			
74	SFMOXO	MOXOTÓ	SFPAF4	PAULO AFONSO 4			
75	SFPAF4	PAULO AFONSO 4	SFXING	XINGÓ			
76	SFXING	XINGÓ					
77	SFMOXO	MOXOTÓ	SFP123	PAULO AFONSO 1,2,3			
78	SFP123	PAULO AFONSO 1,2,3	ISFXING	XINGÓ			
79	PIBESP	BOA ESPERANÇA					
80	AMUGUA	GUAPORÉ					
81	CRCURU	CURUÁ-UNA					
82	PGUCV	PEDRA DO CAVALO					
83	JEIRAP	IRAPÉ	JEUITP	ITAPEBI	60		60
84	JEUITP	ITAPEBI					

Introduction: Water use in the São Francisco basin



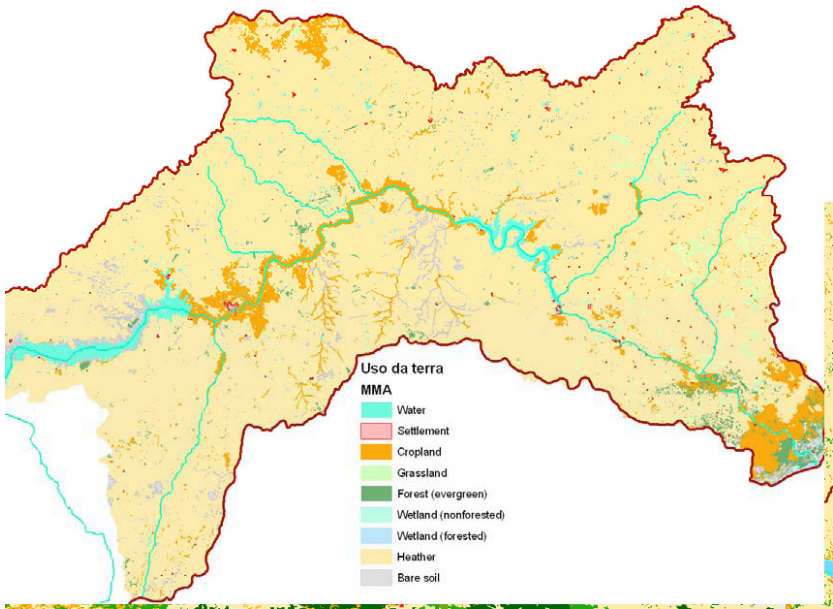
Water use data from 2002-2013
from ANA (*Agência Nacional de Águas)*

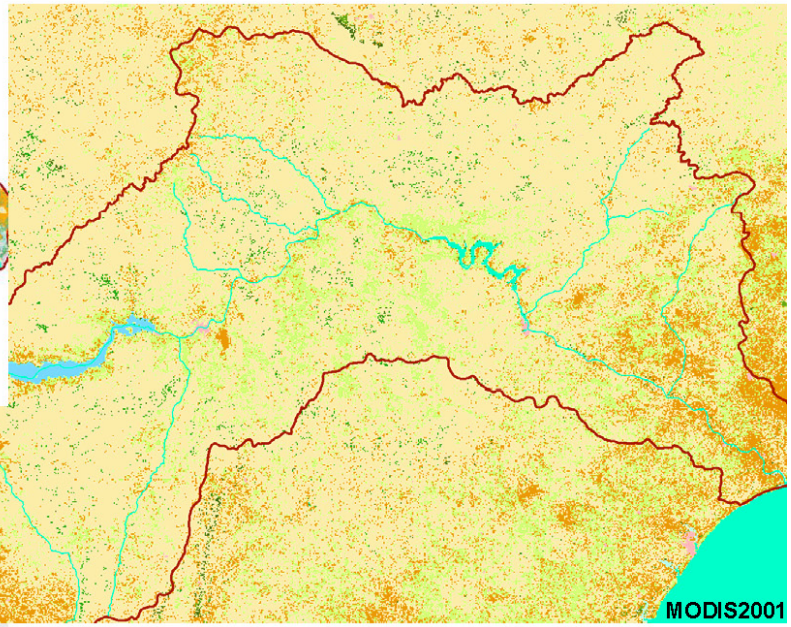


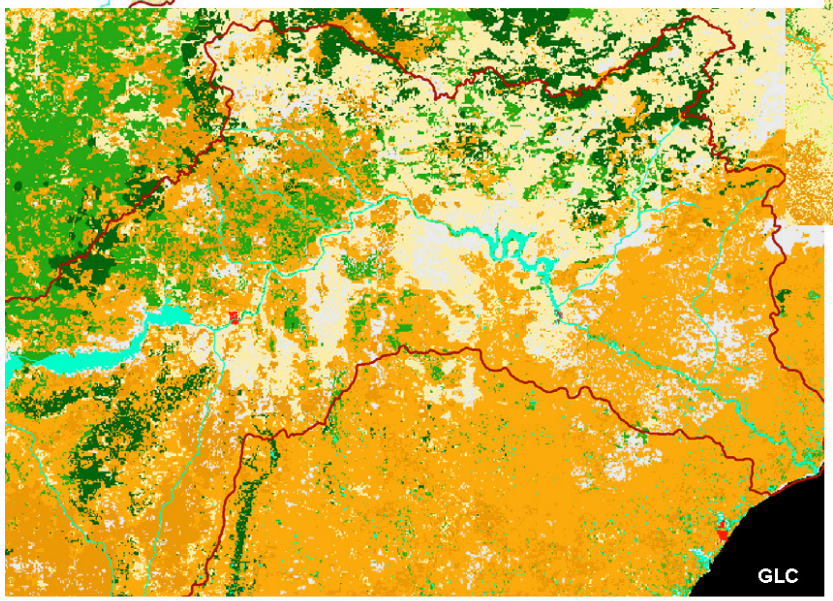
SWIM: Approach in this study

1. **Collection/controlling of data**
2. **SWIM calibration/validation on naturalized discharges**
3. **SWIM simulation including water management**
4. **SWIM simulations for climate scenarios**
5. **SWIM simulations for land-use scenarios**

SWIM: Land-use data





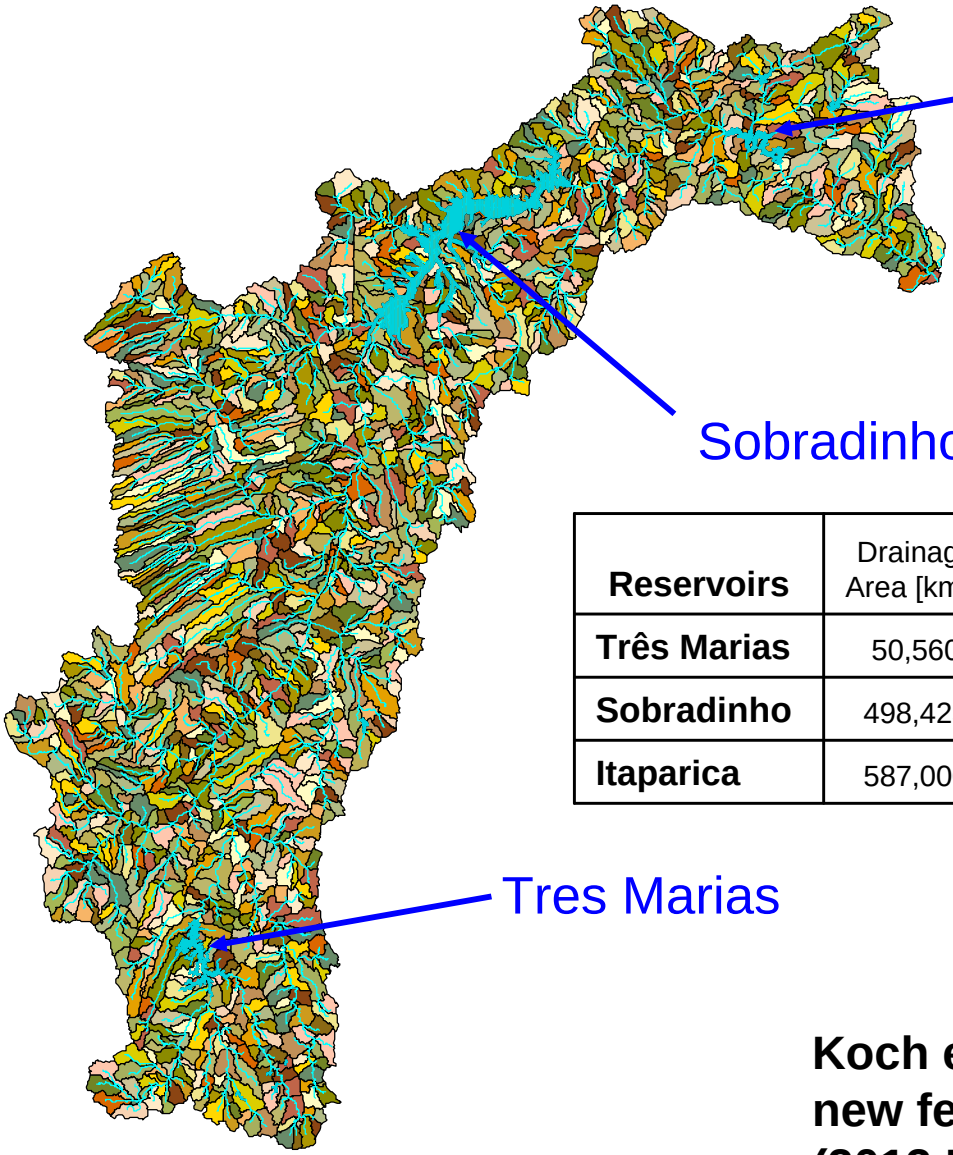


- **SRTM-Digital Elevation Model**
- **Soil data: EMBRAPA - Brazilian Enterprise for Agricultural Research)**

Land use maps according to *Ministério do Meio Ambiente* (Uso da terra), Global Land Cover-Project (GLC), and MODIS2001;

land use data adapted to land use classes in SWIM

SWIM: Delineation of Sub-basins (1627)



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	430	1,300
Itaparica	587,000	10,782	7,233	1,500	700	1,300

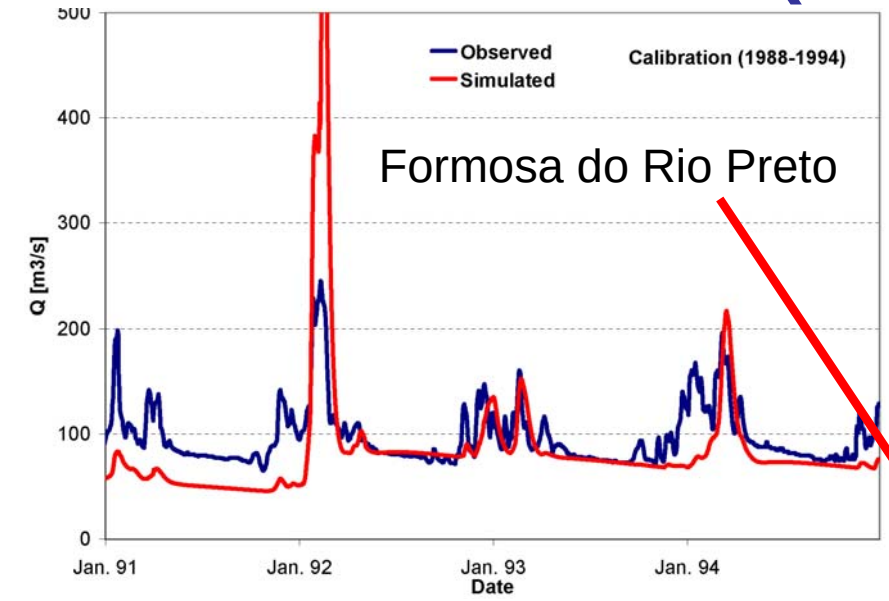
Koch et al.: Water management modeling in SWIM: new features and applications (2013 International SWAT Conference, Toulouse)

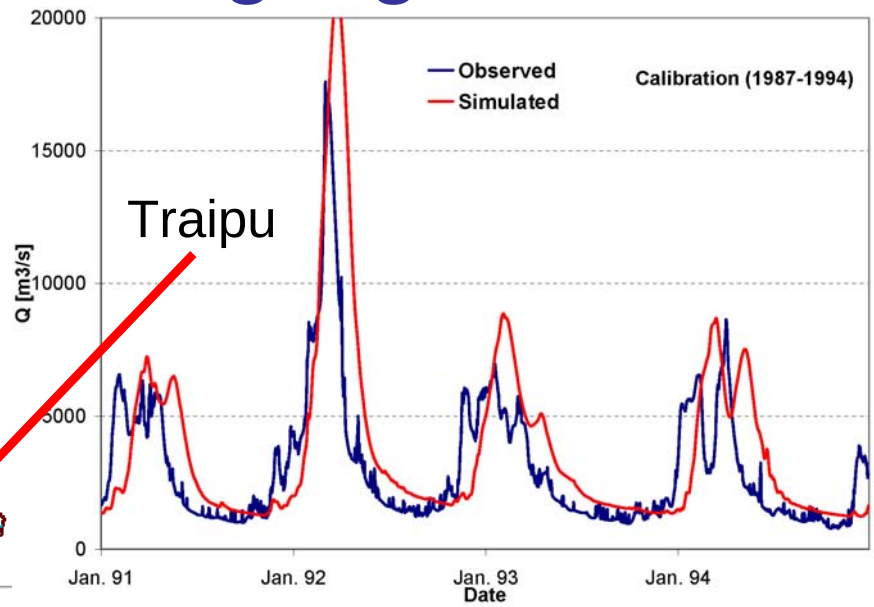
SWIM: Climate data for calibration / validation

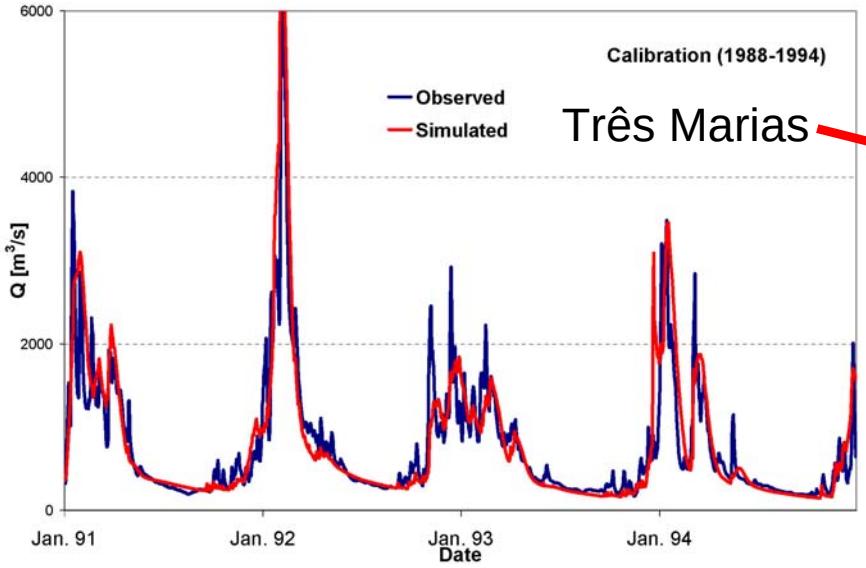
- daily climate data (re-analysis data corrected by using monthly observations; e.g. Tmax, Tmean, Tmin, precipitation, solar radiation) from the WATCH-project (http://www.eu-watch.org/)

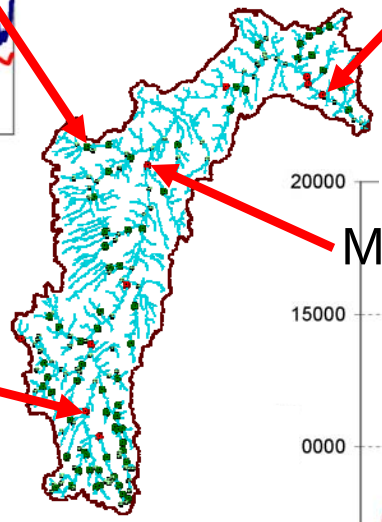
- grid cells of 0.5° (approx. 50x50km)

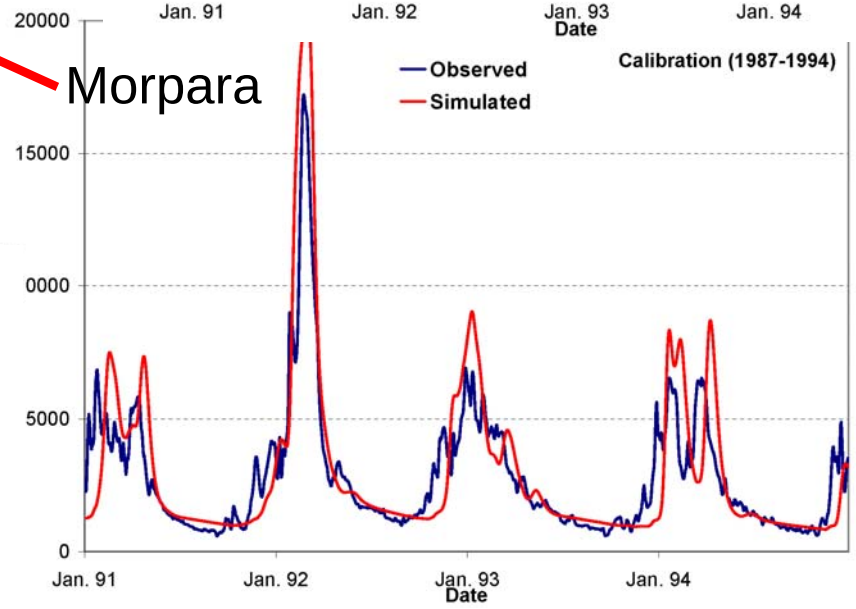
SWIM: Calibration (1988-1994) and validation (1995-2001) at 23 gauges











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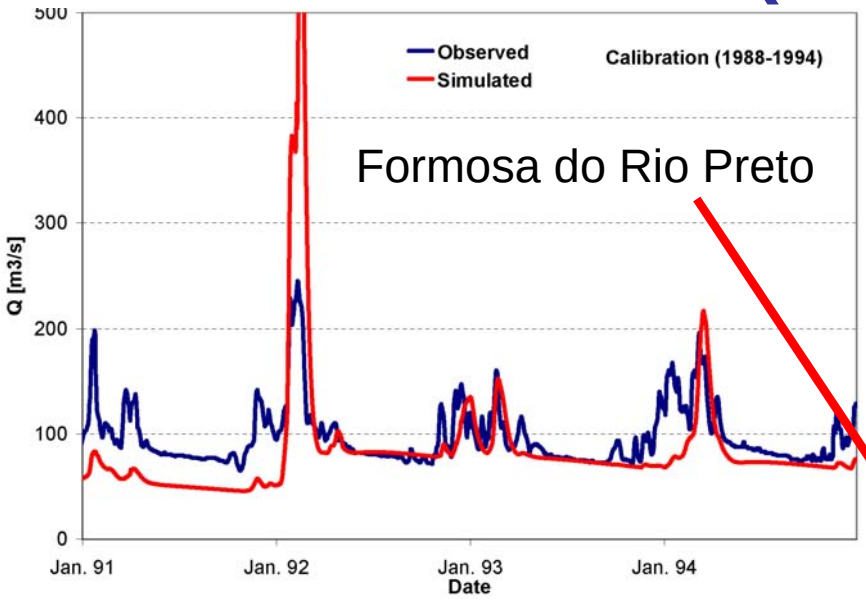
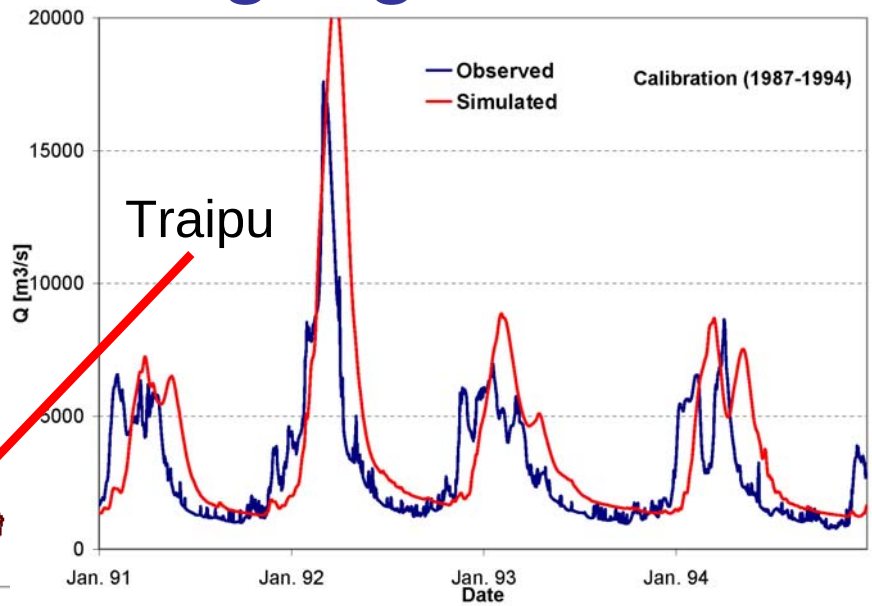
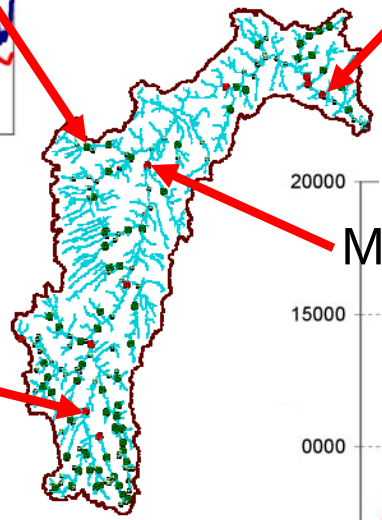
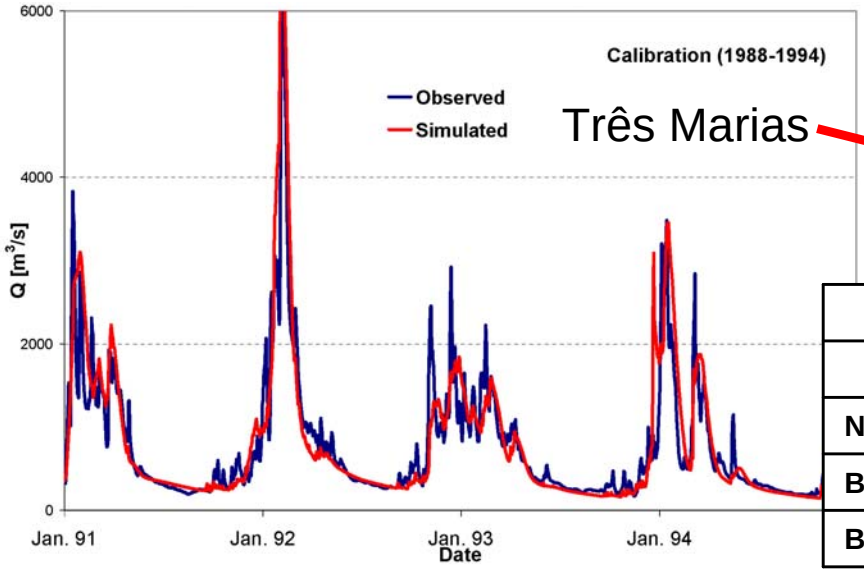
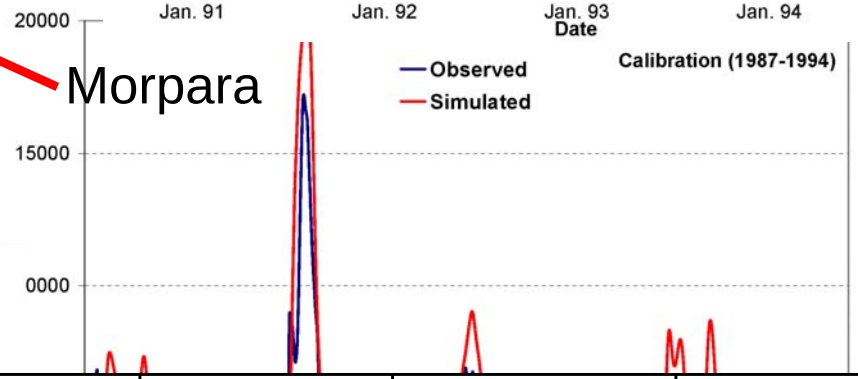




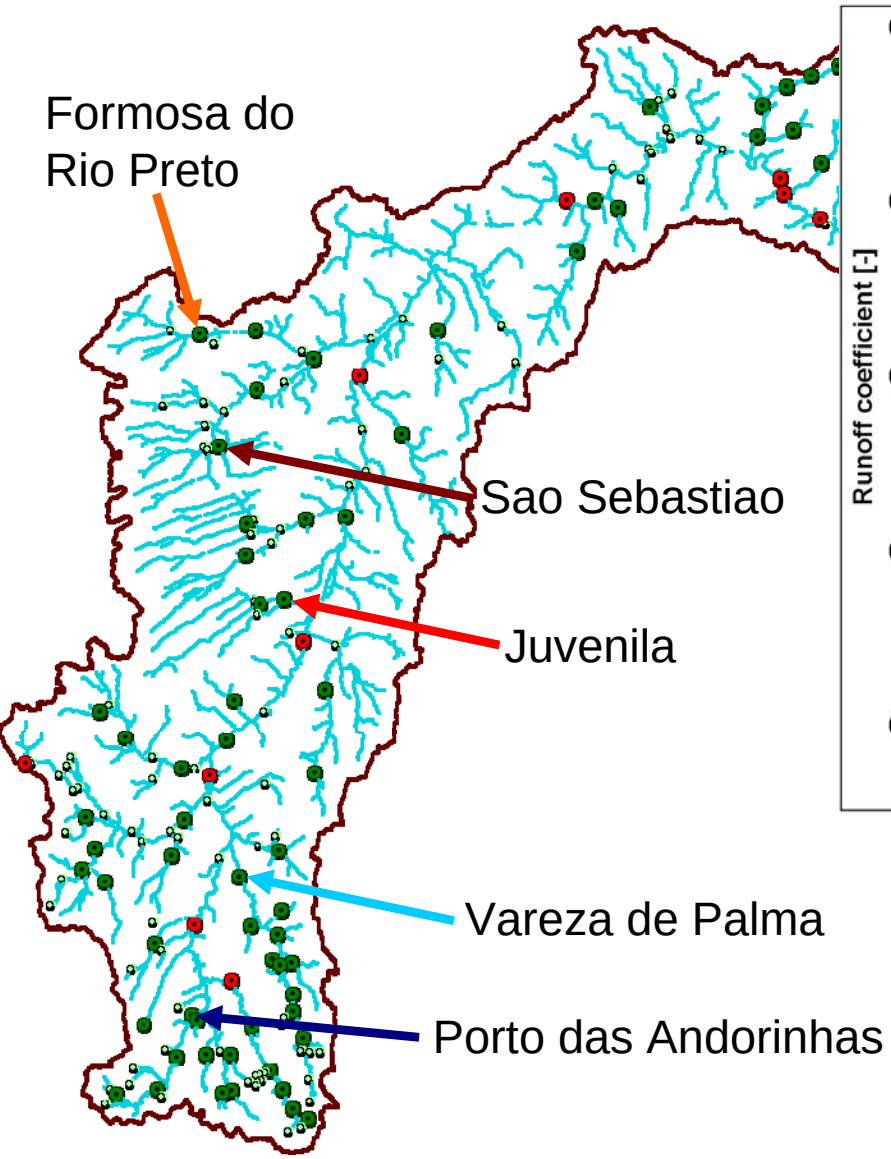


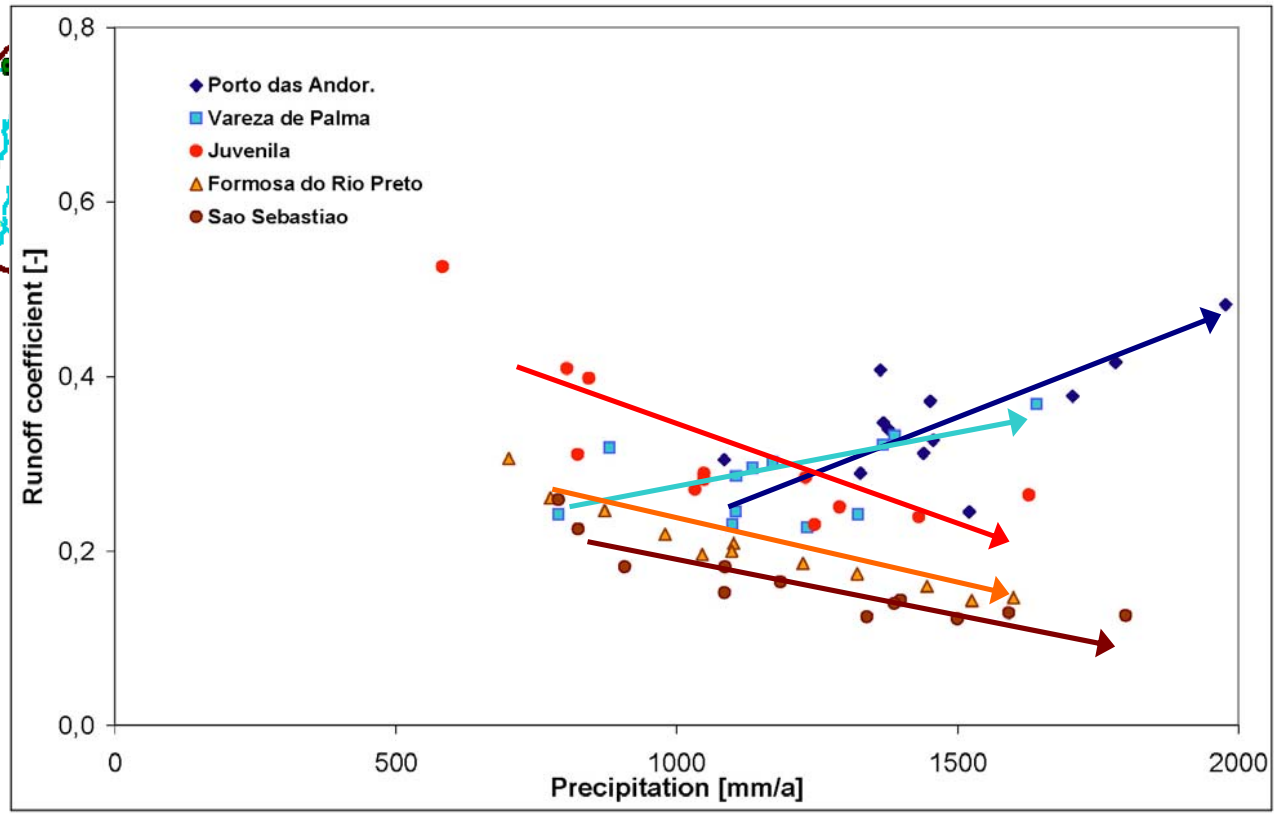




	Tres Marias		Morpara		Form. d. R. Preto		Traipu	
	cal.	val.	cal.	val.	cal.	val.	cal.	val.
NSE	0,74	0,73	0,65	0,46	0,17	0,18	0,28	0,25
BIAS [m³/s]	57,9	28,2	303	60	-20,6	-4,3	757	532
BIAS	12%	2%	13%	3%	-17%	-5%	27%	19%

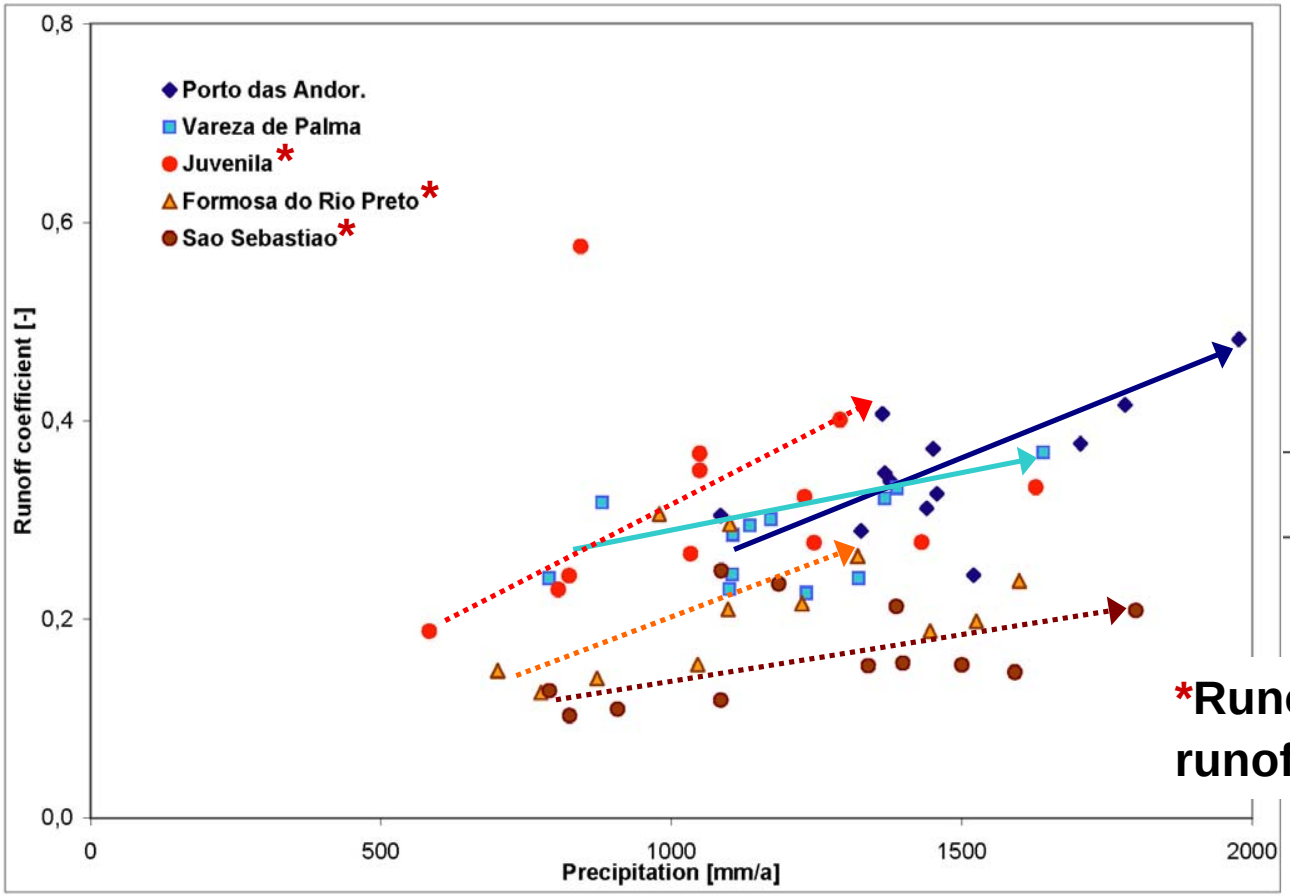
Problems: Runoff coefficient for different rivers

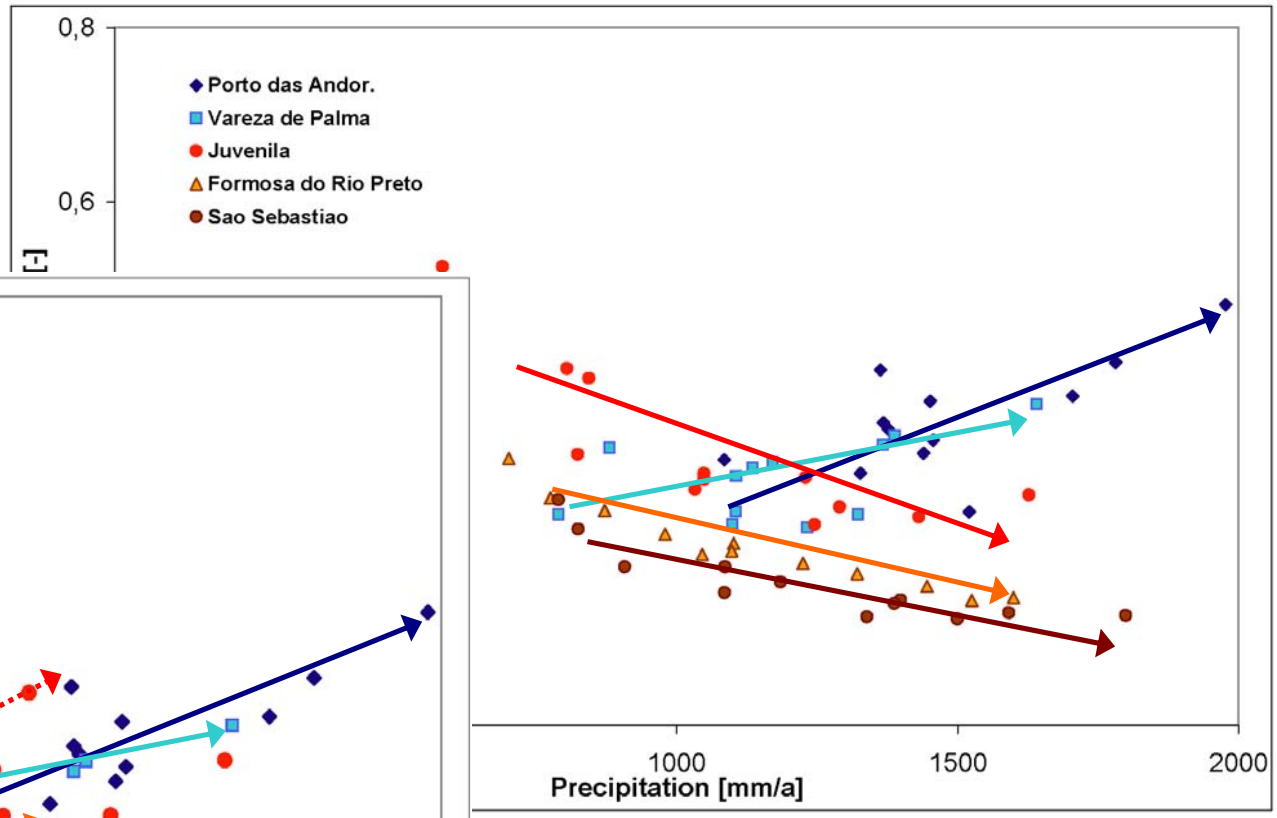




Runoff coefficient:
runoff [mm/a] / precipitation [mm/a]

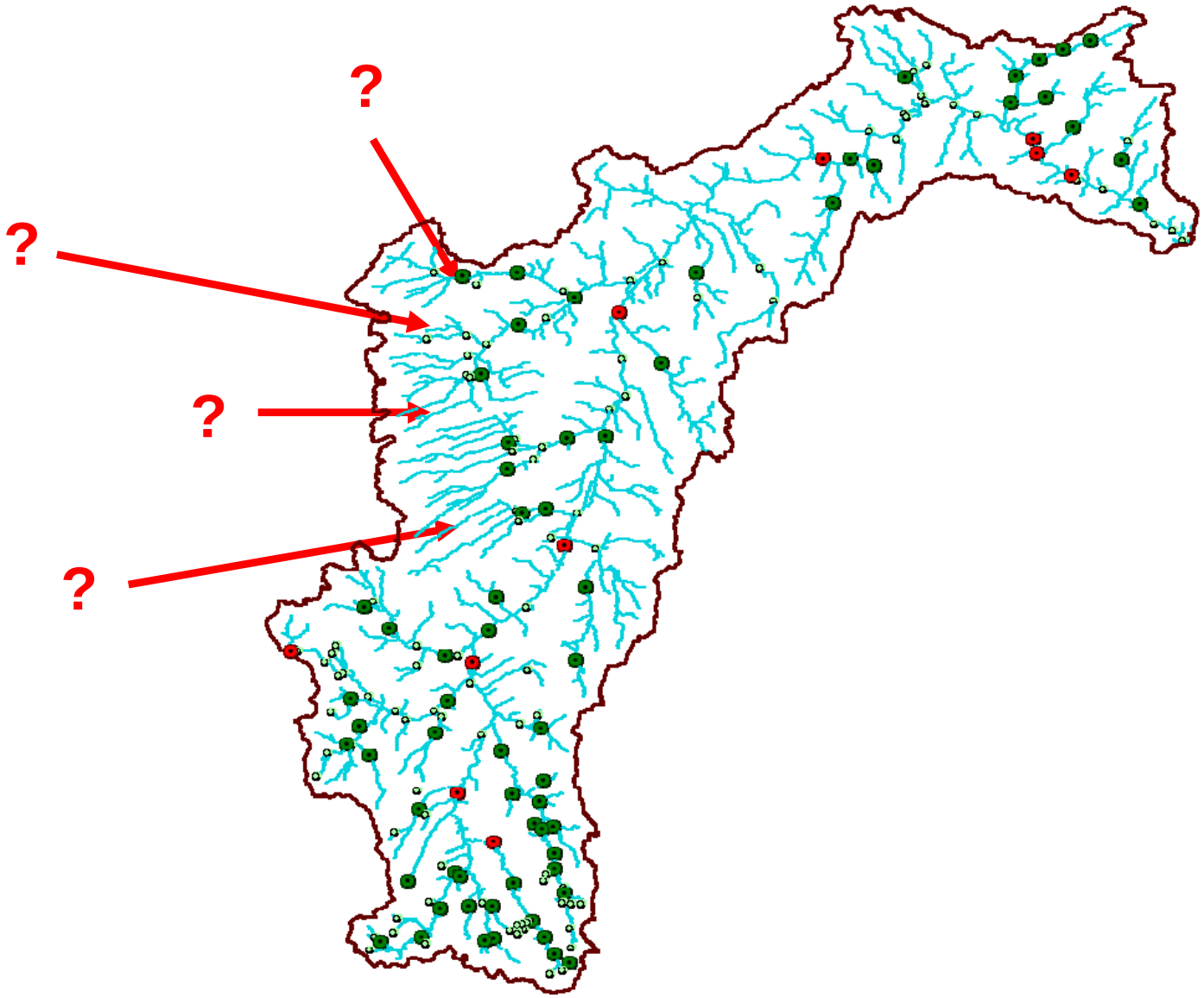
Problems: Runoff coefficient for different rivers



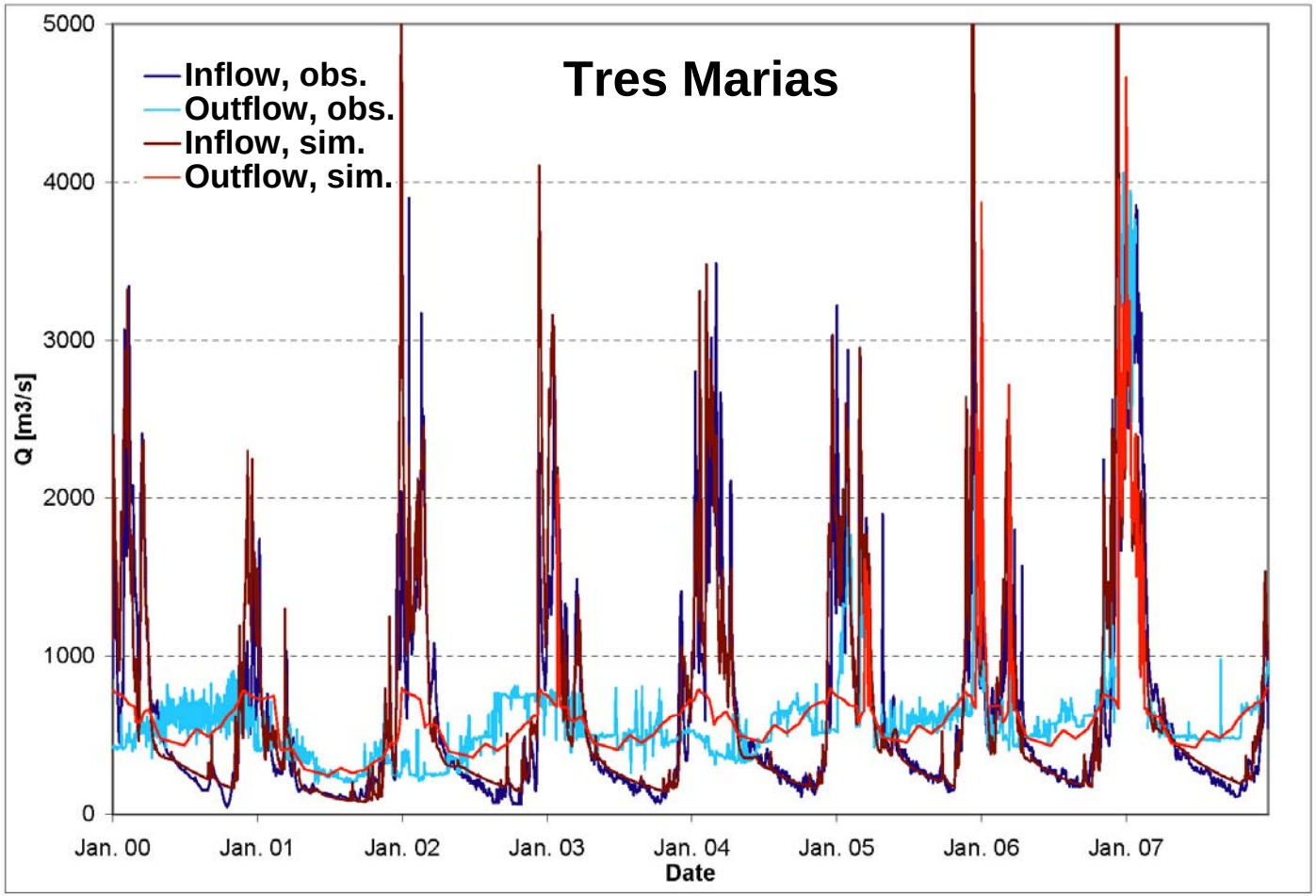


***Runoff coefficient:**
runoff [mm/a] / precipitation [mm/a-1]

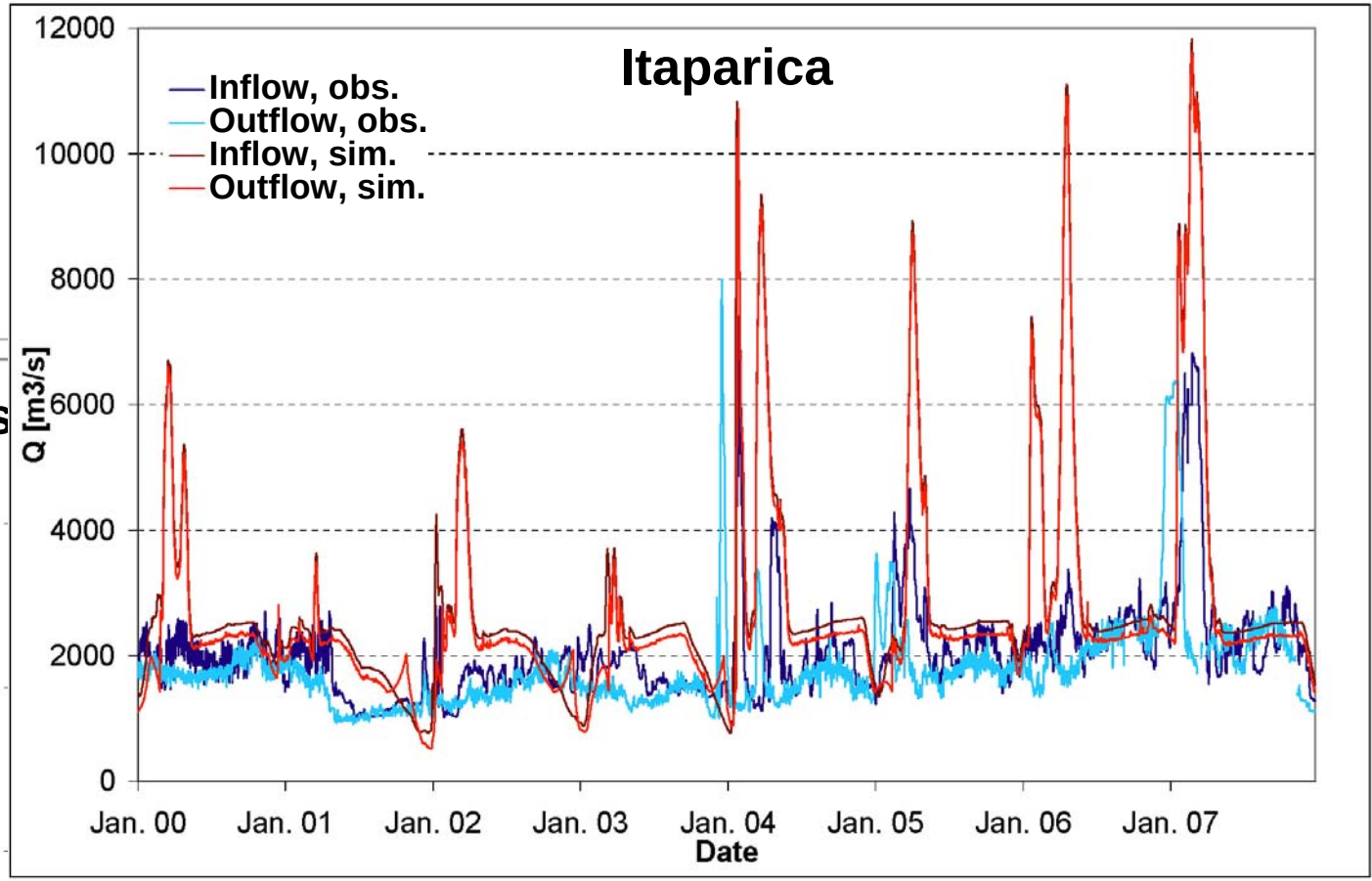
Problems: Slow reaction of baseflow or groundwater inflow from other (sub-)basins?

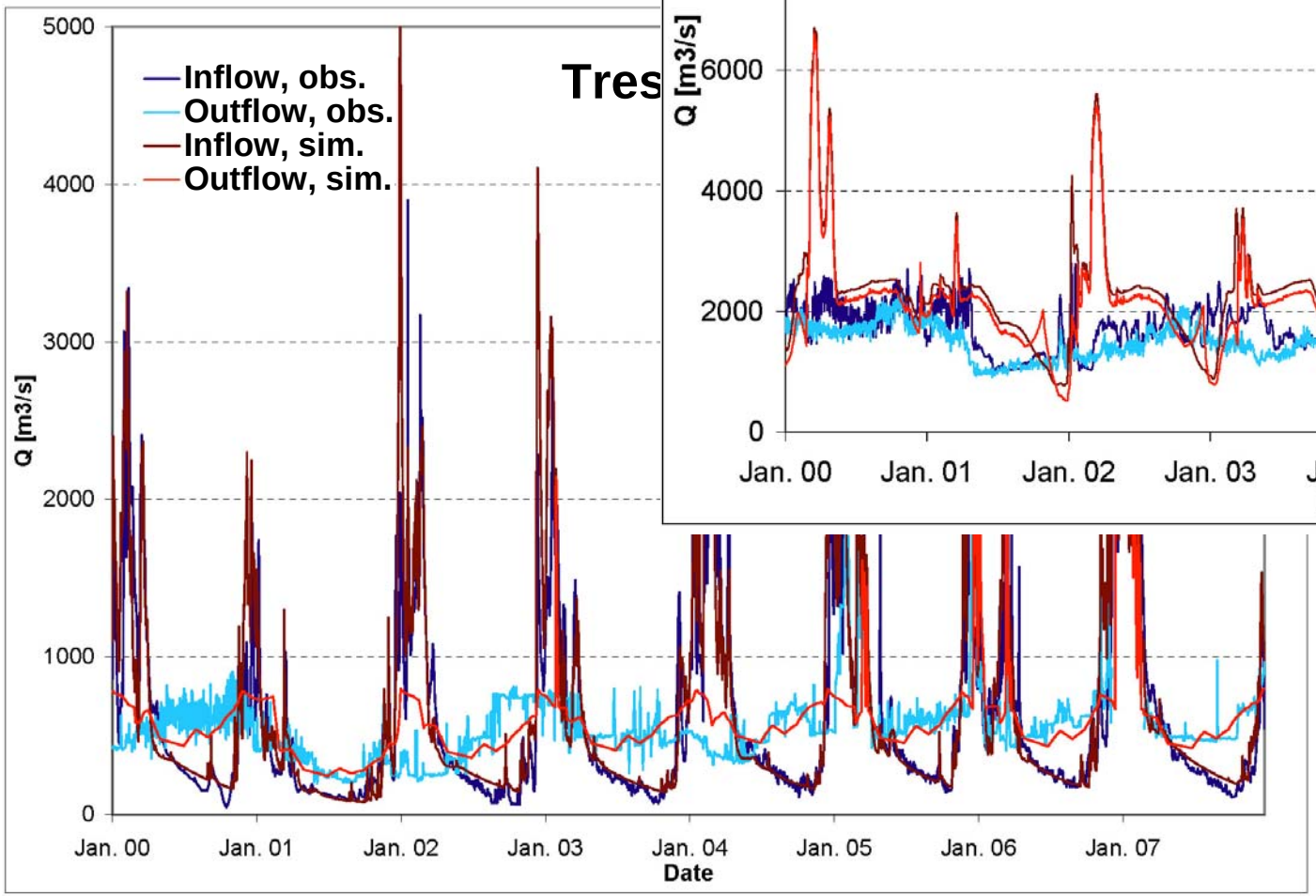


Results: managed discharges



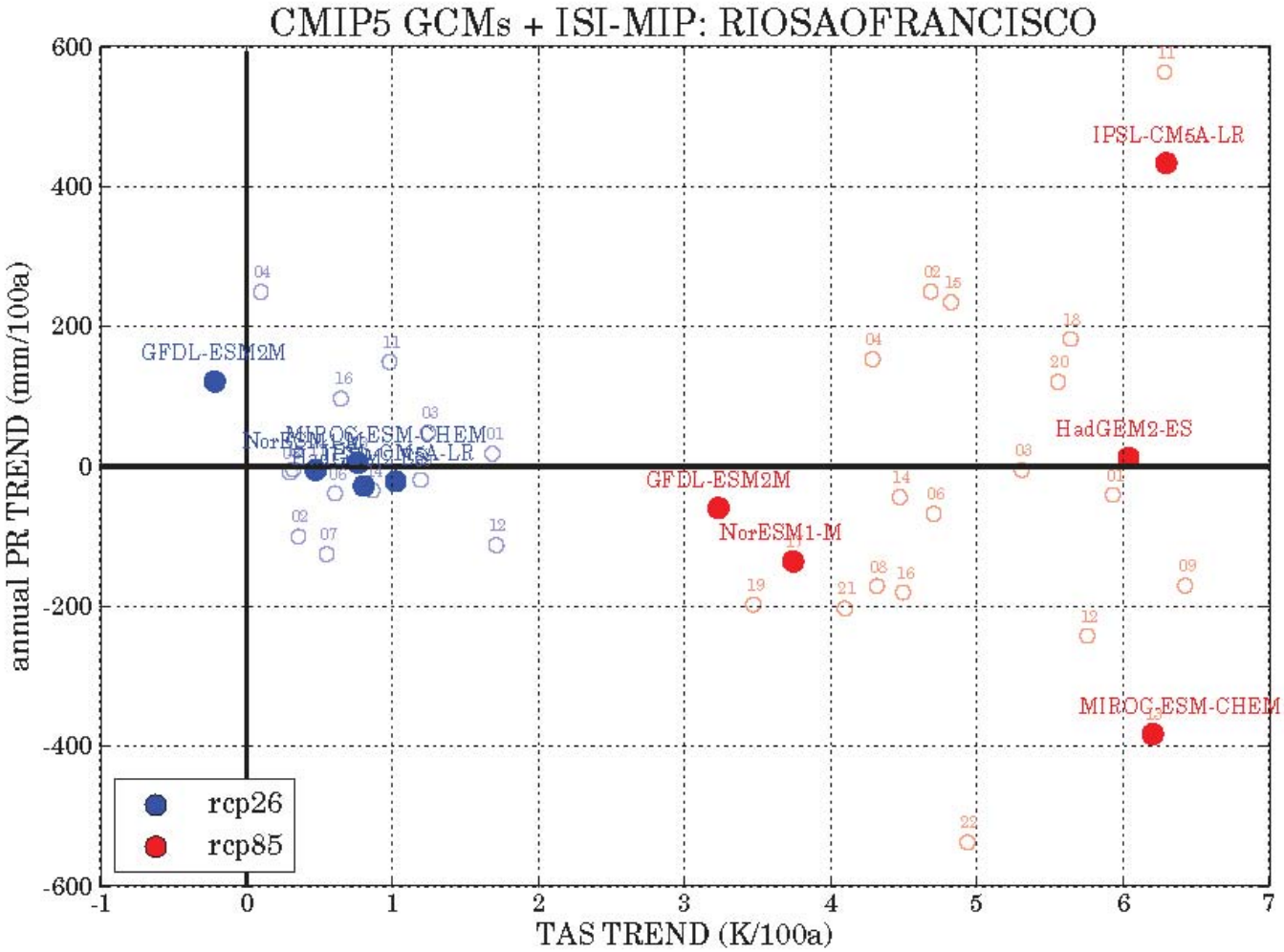
Results: managed discharges





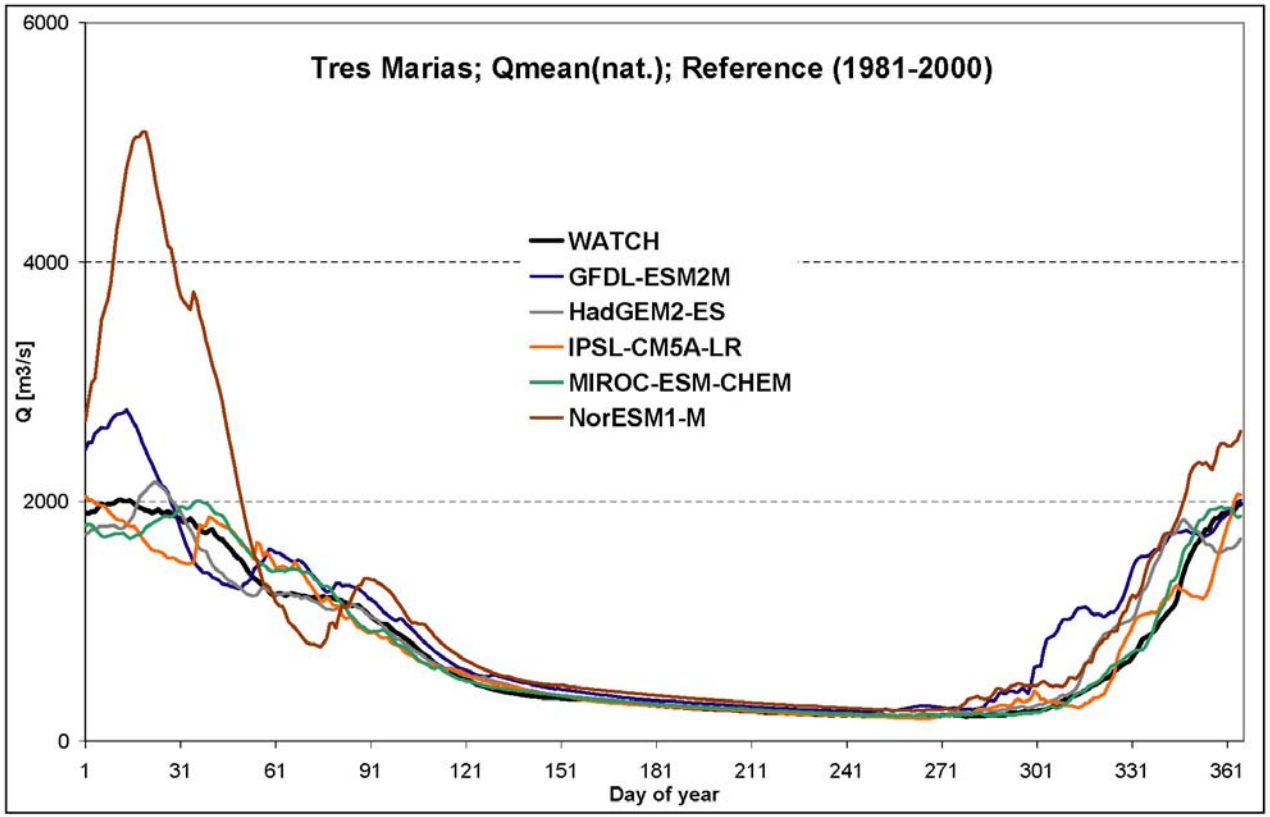
Scenarios: Climate scenarios (RCP: Representative Concentration Pathway)

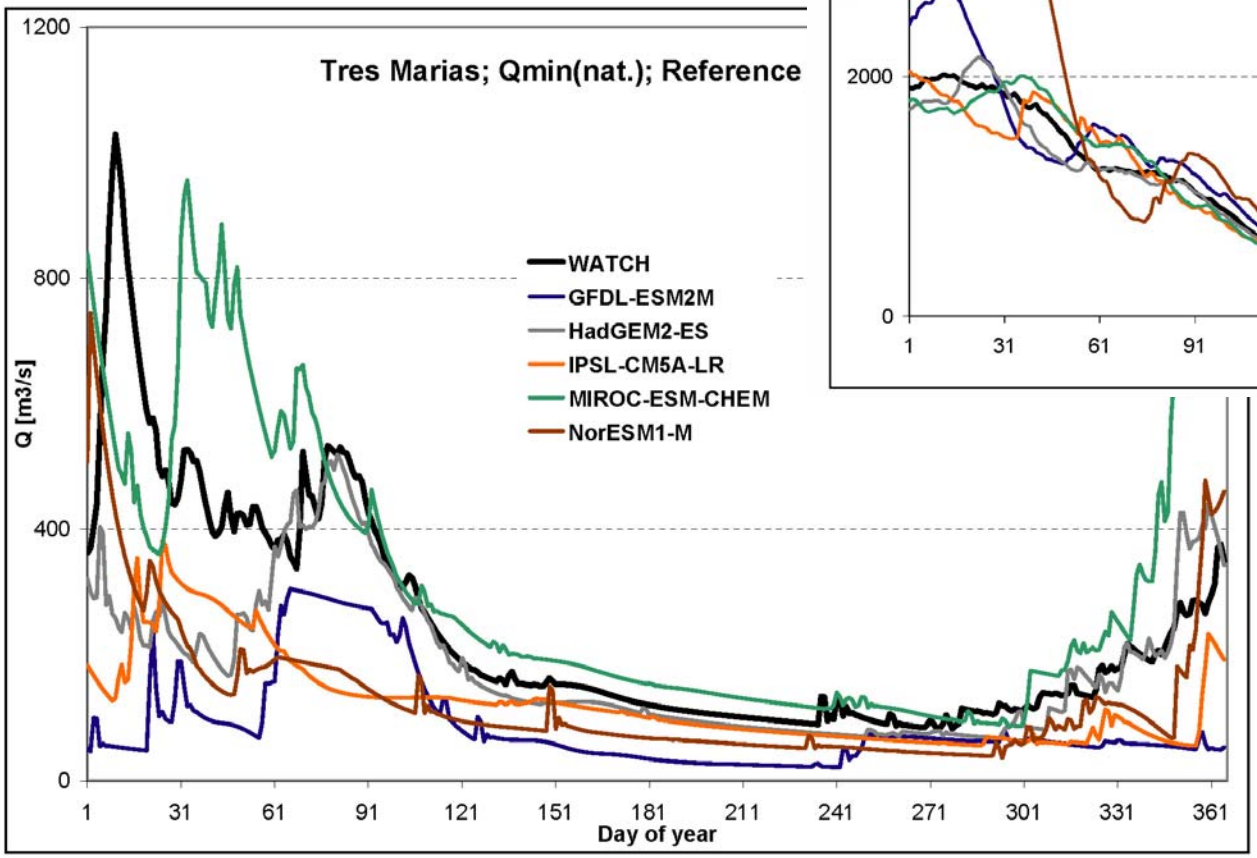
Climate projections of five CMIP5 ESMs (http://cmip-pcmdi.llnl.gov/cmip5/); bias-corrected (Hempel et al., 2013)



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

Results: Climate models (reference, natural Q)





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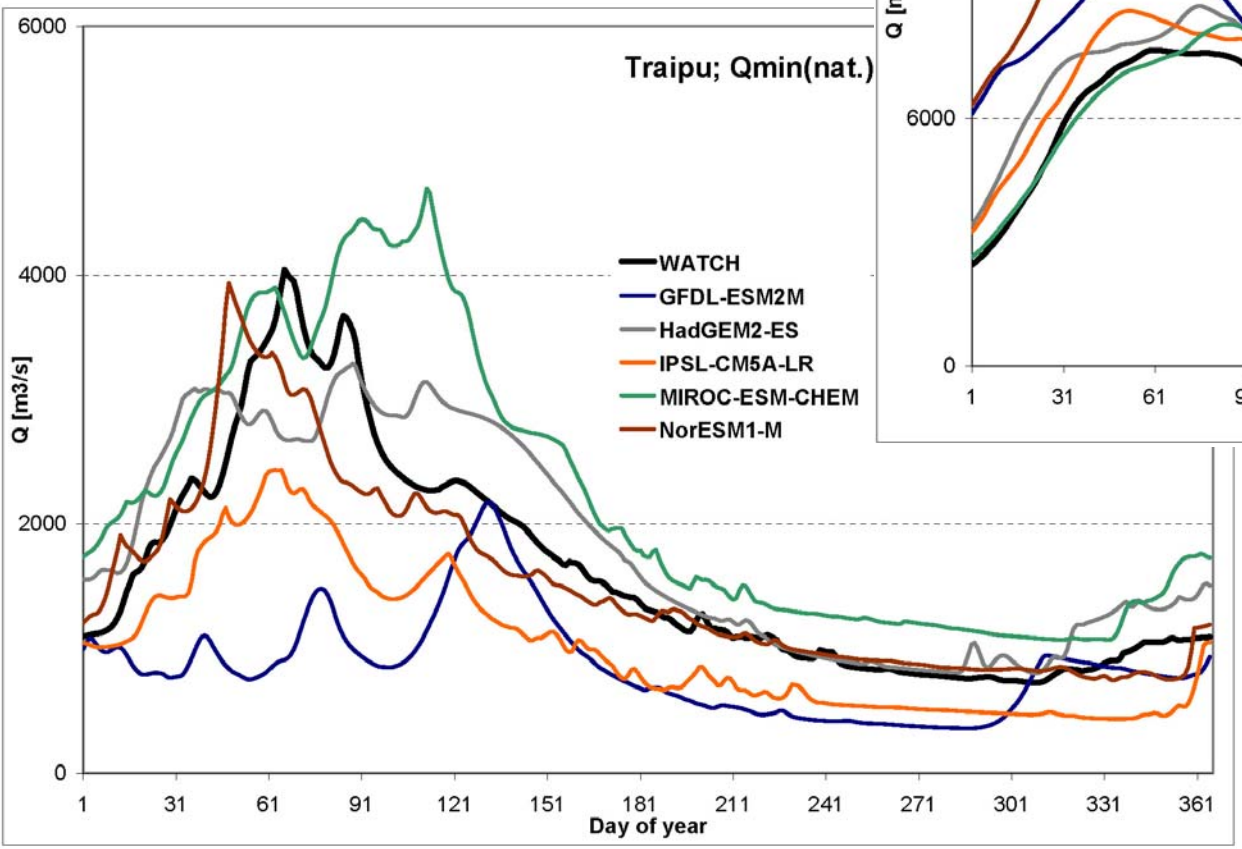
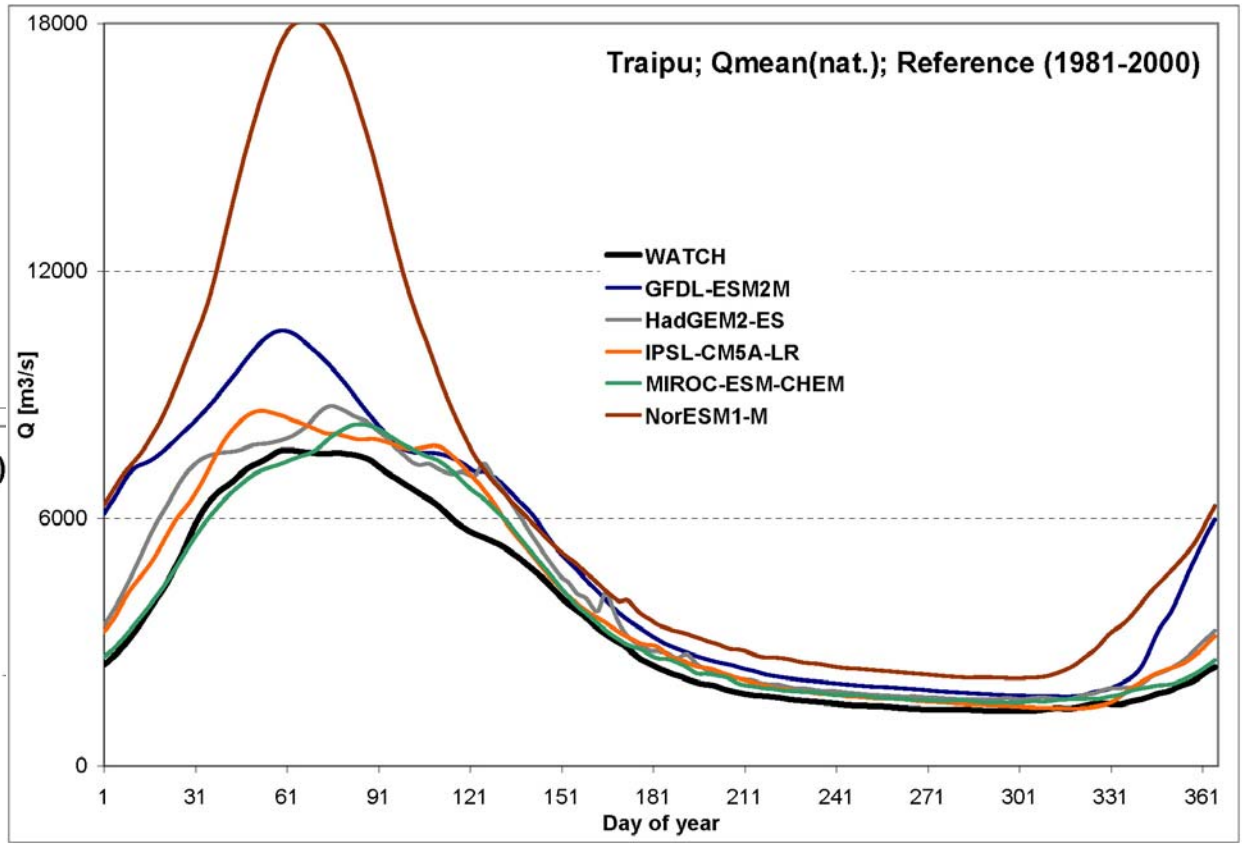
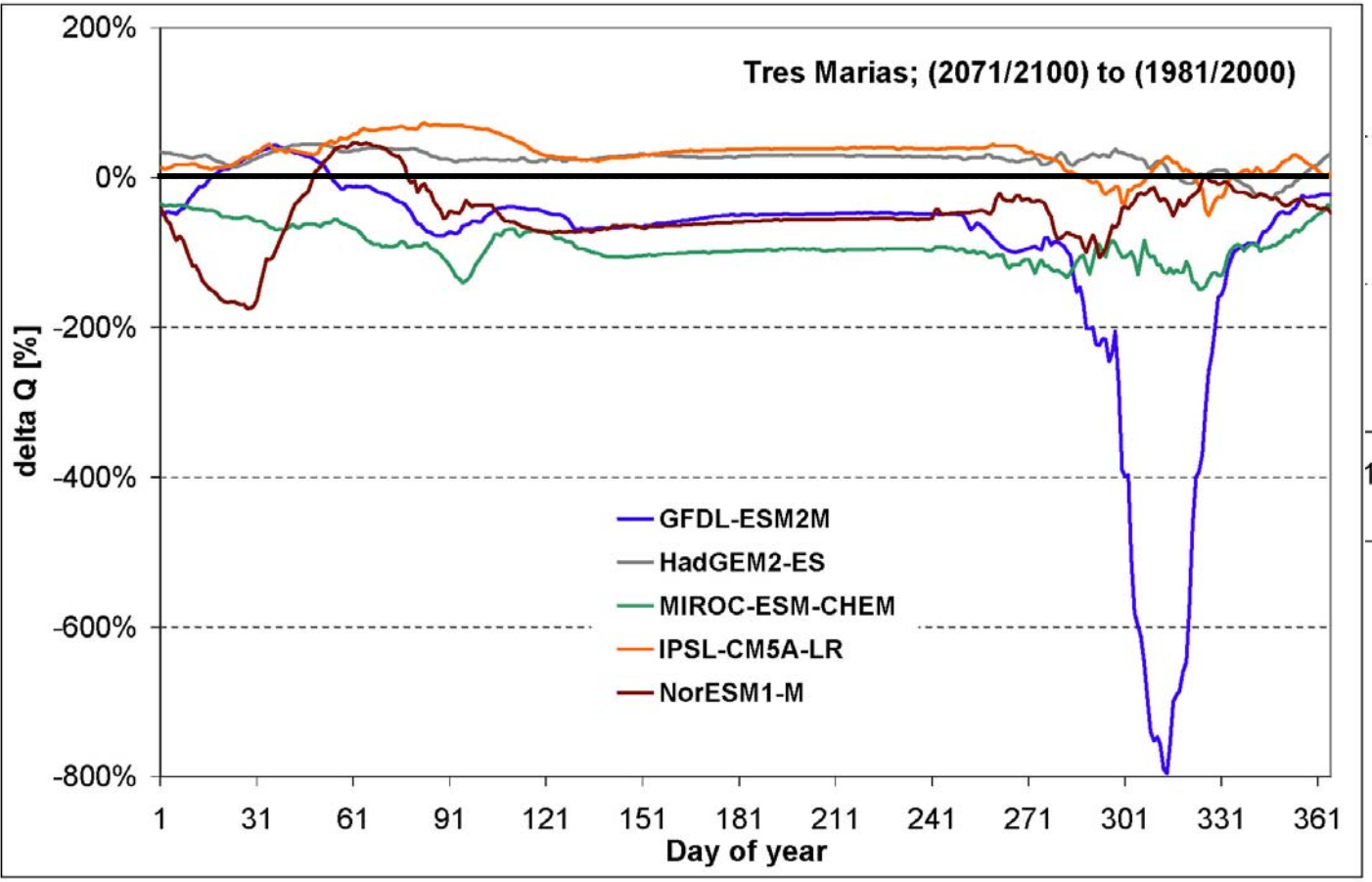
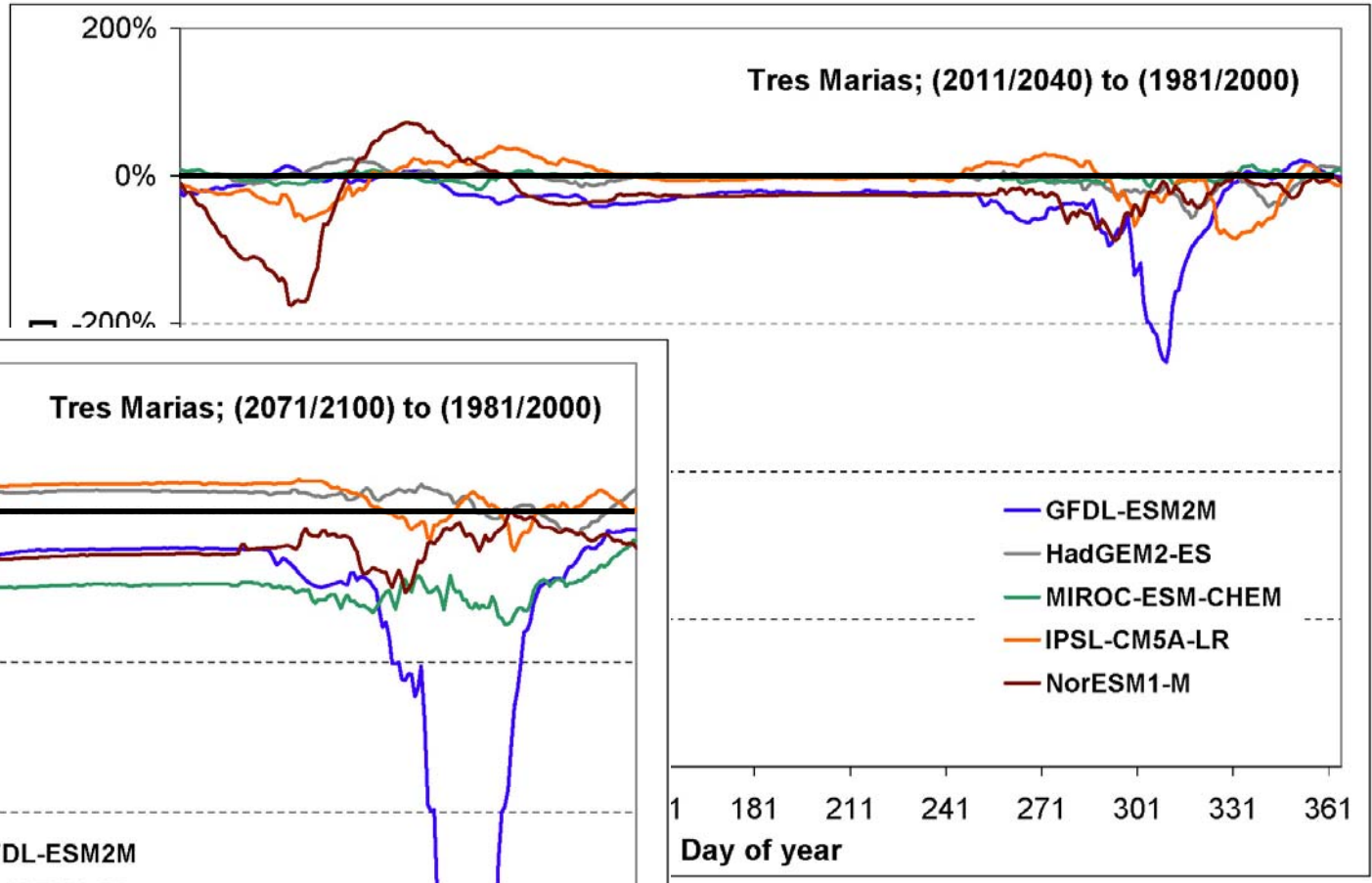




Scenario RCP8.5: Changes natural Q





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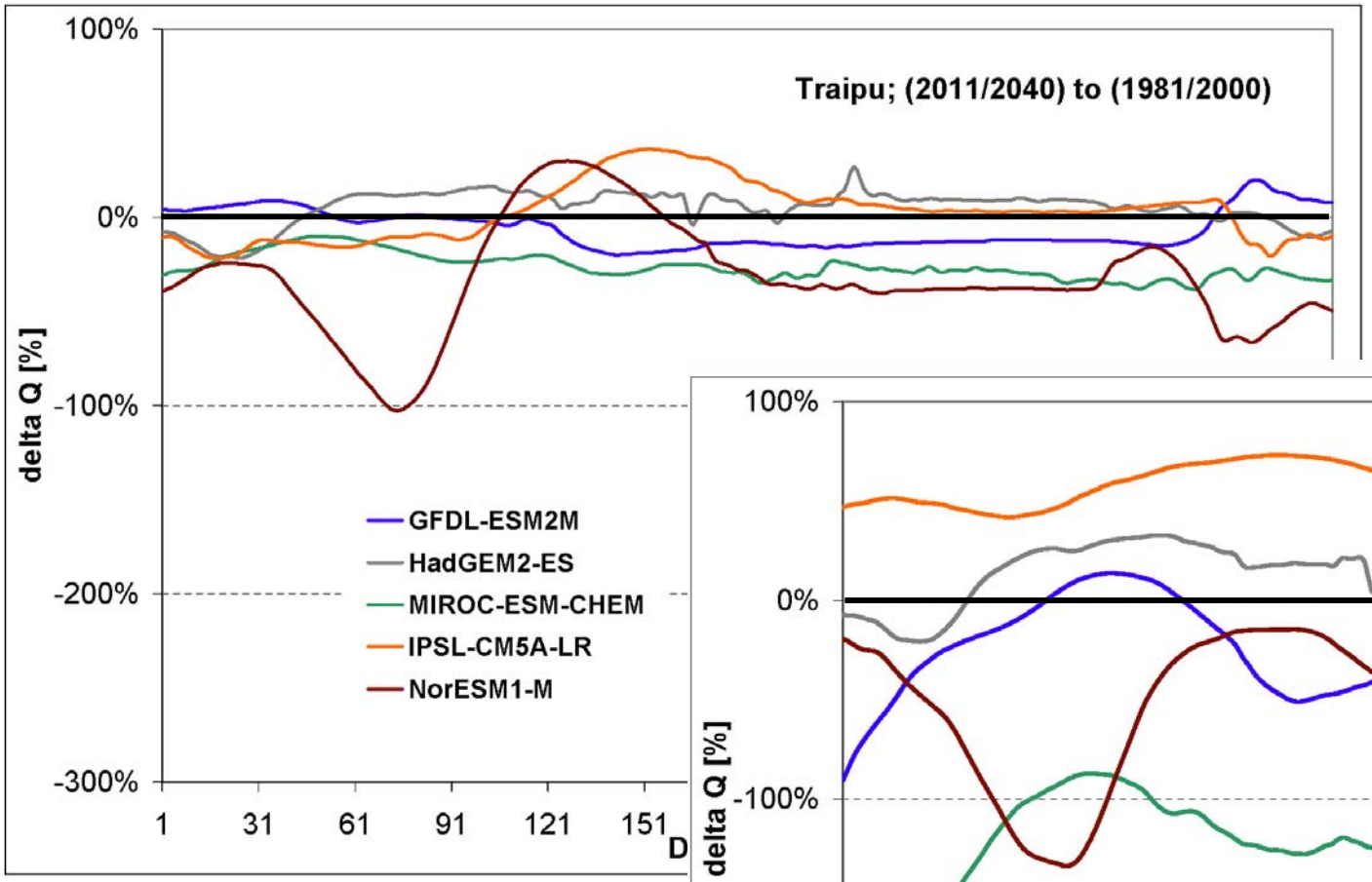
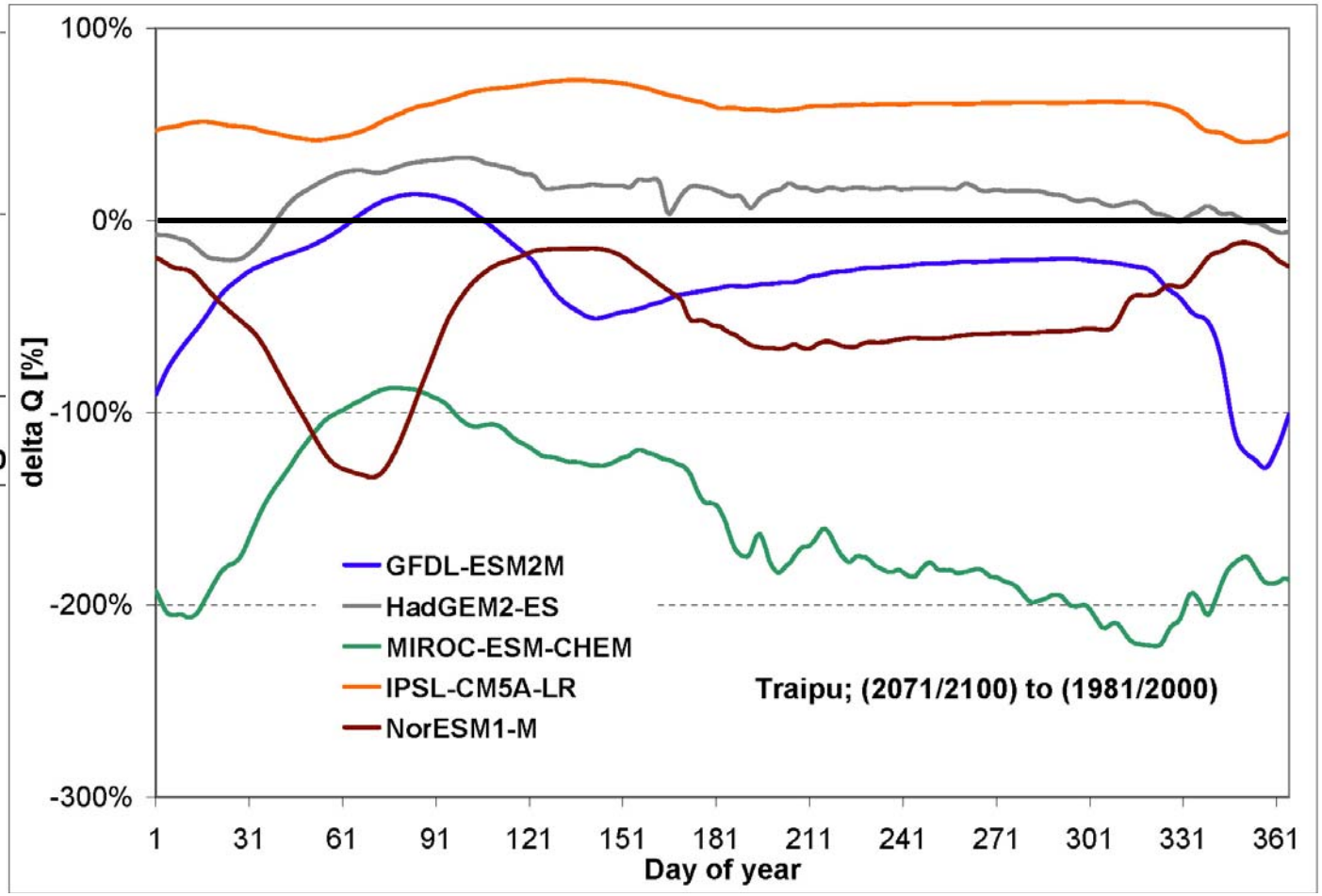
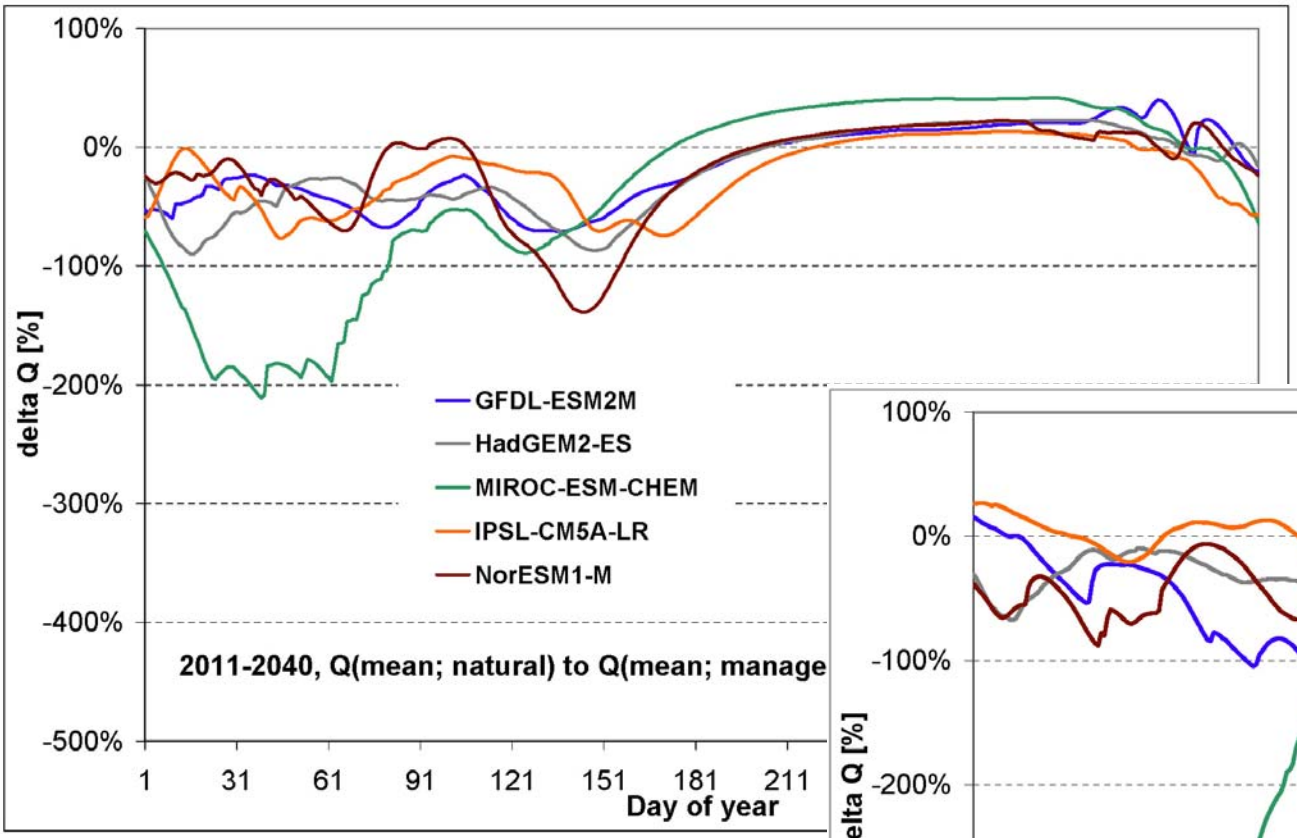
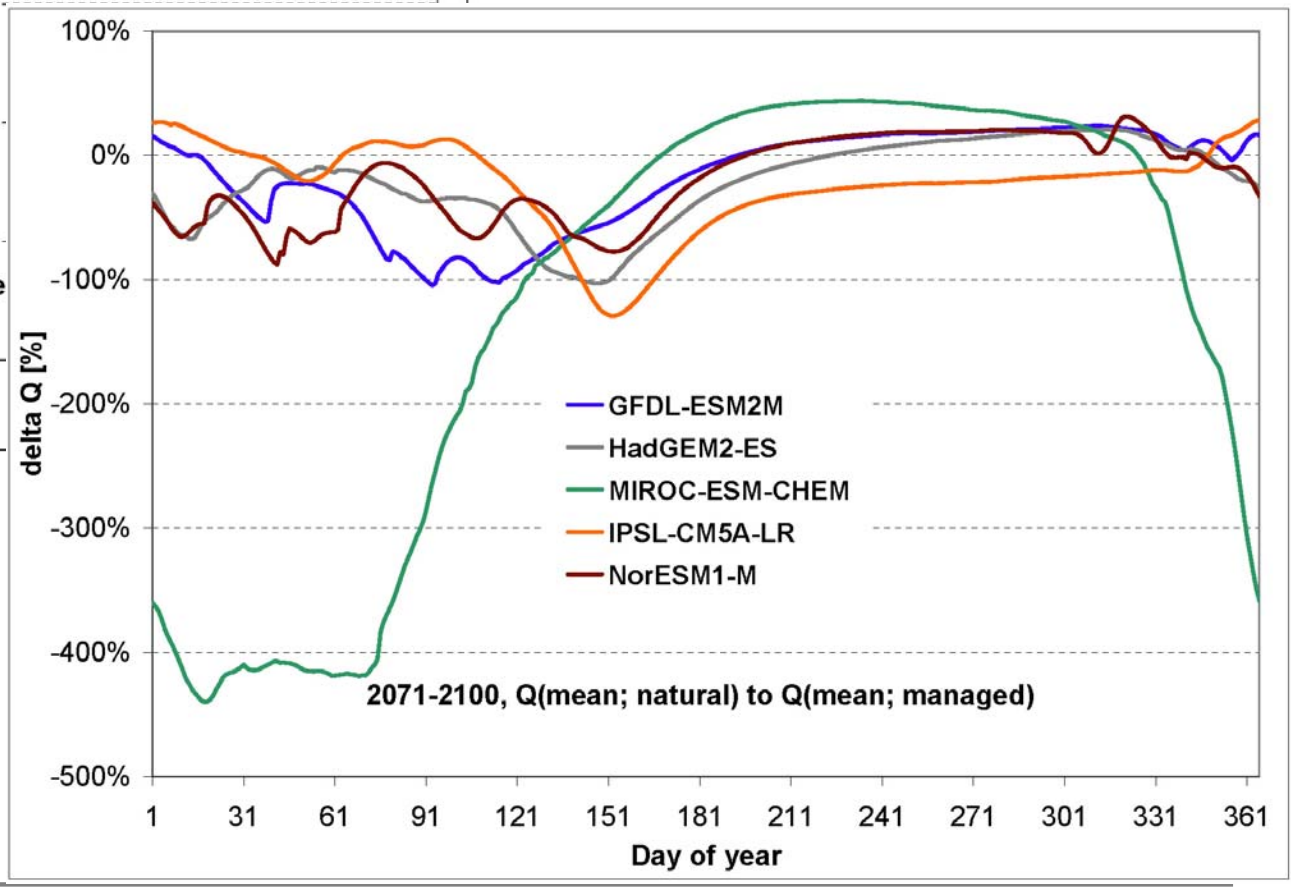


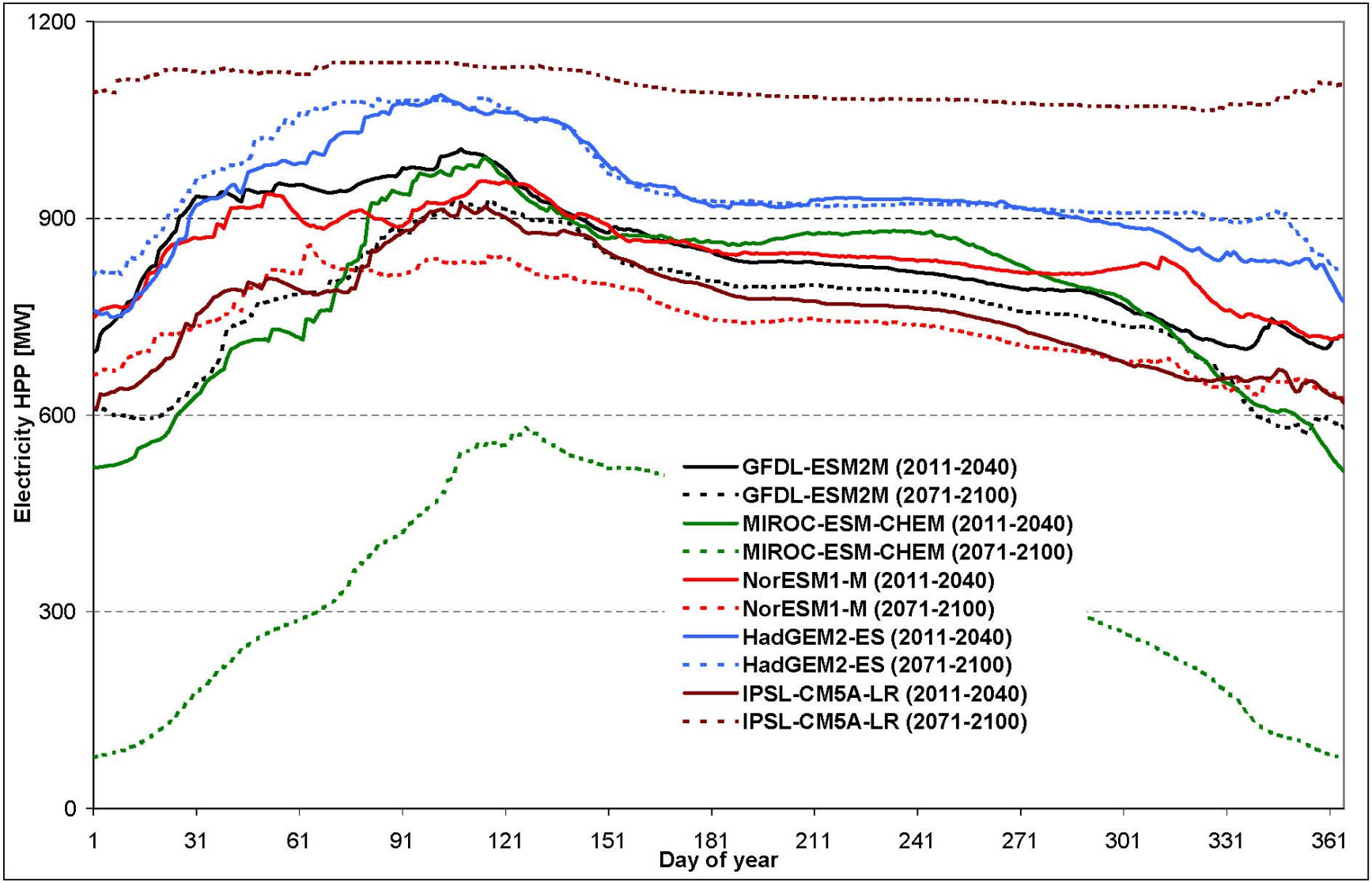


Scenario RCP8.5: Changes in mean daily outflow reservoir Itaparica (natural to managed)





Results: Scenario RCP8.5, mean daily electricity generation Itaparica

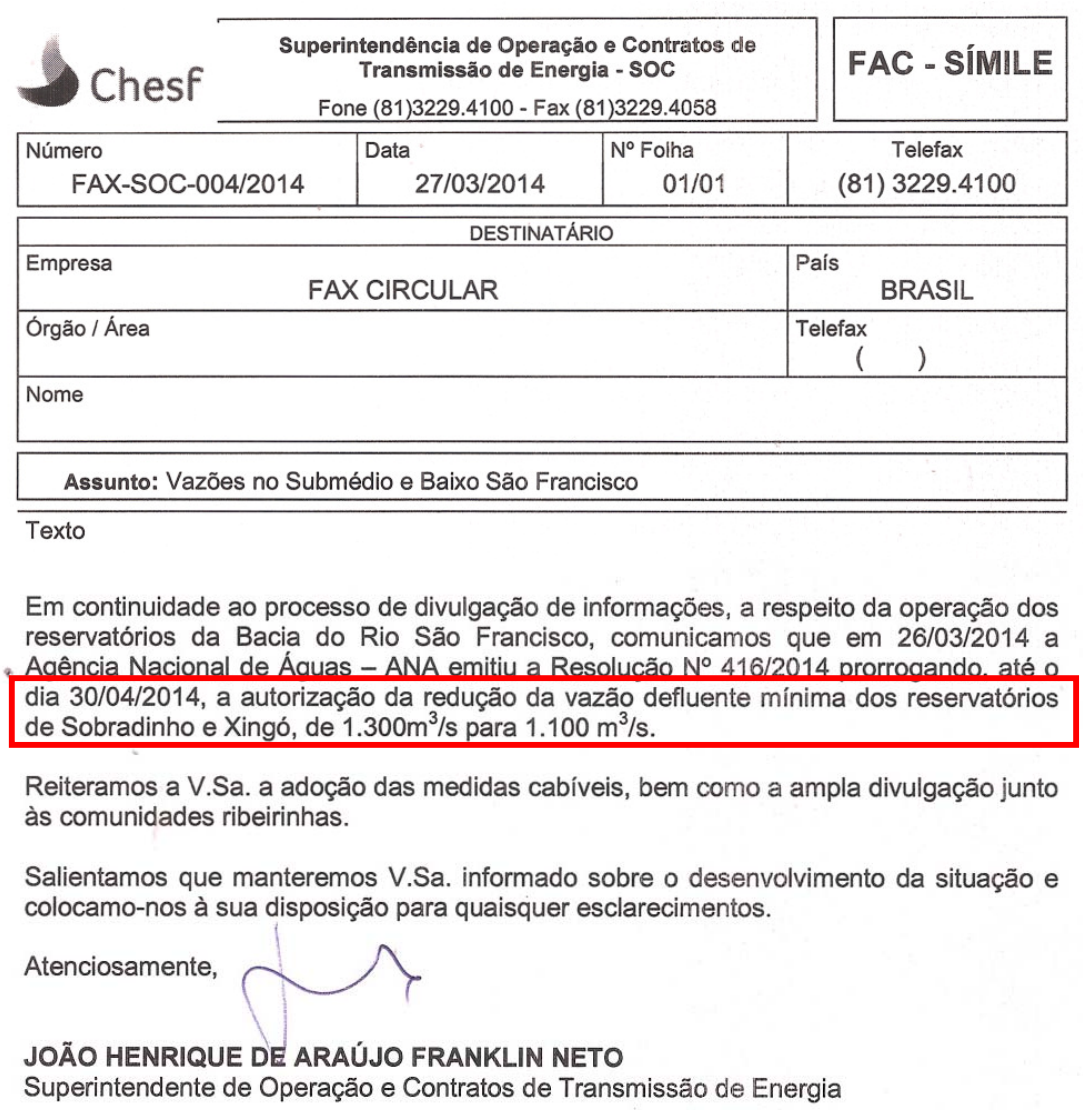


Outlook

Presentation of scenarios and results to stakeholder:

1. **Recife (04.08.2014)**
2. **Belo Horizonte (06.08.2014)**
3. **Petrolandia (08.08.2014)**

Discussion, e.g.:
change reservoir management (especially for drought conditions)?!



Chesf

Superintendência de Operação e Contratos de Transmissão de Energia - SOC
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FAC - SÍMILE

Número	Data	Nº Folha	Telefax
FAX-SOC-004/2014	27/03/2014	01/01	(81) 3229.4100

DESTINATÁRIO

Empresa	País
FAX CIRCULAR	BRASIL
Órgão / Área	Telefax ( )
Nome	

Assunto: Vazões no Submédio e Baixo São Francisco

Texto

Em continuidade ao processo de divulgação de informações, a respeito da operação dos reservatórios da Bacia do Rio São Francisco, comunicamos que em 26/03/2014 a Agência Nacional de Águas – ANA emitiu a Resolução Nº 416/2014 prorrogando, até o dia 30/04/2014, a autorização da redução da vazão defluente mínima dos reservatórios de Sobradinho e Xingó, de 1.300m^3/s para 1.100 m^3/s.

Reiteramos a V.Sa. a adoção das medidas cabíveis, bem como a ampla divulgação junto às comunidades ribeirinhas.

Salientamos que manteremos V.Sa. informado sobre o desenvolvimento da situação e colocamo-nos à sua disposição para quaisquer esclarecimentos.

Atenciosamente,

JOÃO HENRIQUE DE ARAÚJO FRANKLIN NETO
Superintendente de Operação e Contratos de Transmissão de Energia

Outlook: “better” climate scenarios?

Summary

- **Data availability for the São Francisco River basin is very good**
- **SWIM was modified to fit south American conditions**
- **A number of problems (calibration/validation) could be solved**
- **Some problems remain (e.g. groundwater inflow from other basins, reliability of naturalized discharges, applicability of climate scenarios?)**
- **Open question: include channel losses (especially for main river)?**

- **Approach applied:**

- **SWIM calibration/validation on naturalized discharges**
- **SWIM simulation including water management**
- **SWIM simulations for climate scenarios**
- **SWIM simulations for land-use scenarios**

… seems to be promising

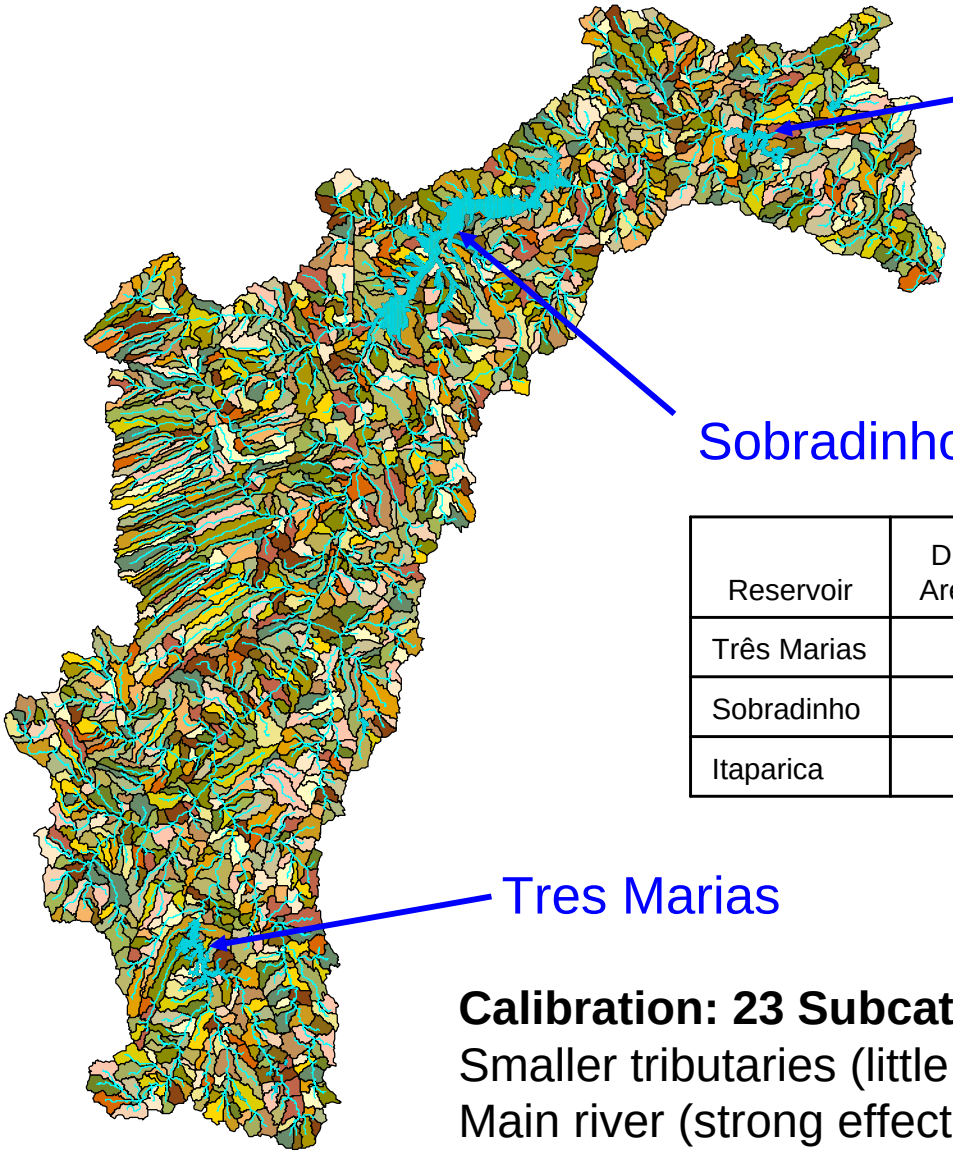
Isso é tudo

OBRIGADO PELA ATENÇÃO!

THANK YOU!

Vielen Dank für Ihre Aufmerksamkeit!

SWIM: Delineation of Sub-basins (1627)



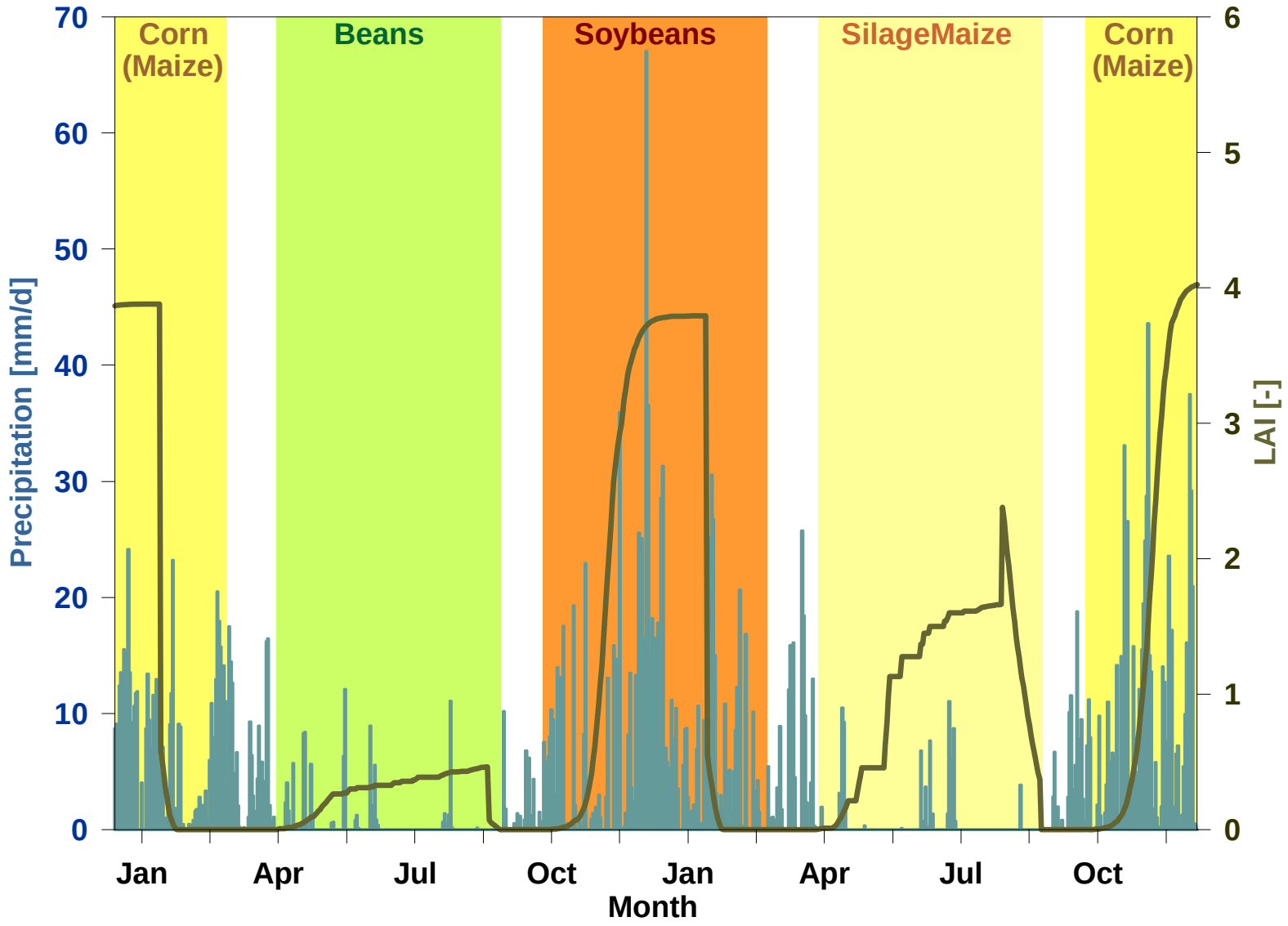
Reservoir	Drainage Area [km2]	Capacity [hm3]	Dead storage [hm3]	HPP, inst. [MW]	HPP, yield [MW]	Qmin. [m3/s]
Três Marias	50,560	19,528	4,250	396	250	500
Sobradinho	498,425	34,117	5,448	1,050	430	1,300
Itaparica	587,000	10,782	7,233	1,500	700	1,300

Calibration: 23 Subcatchments with different parameter sets

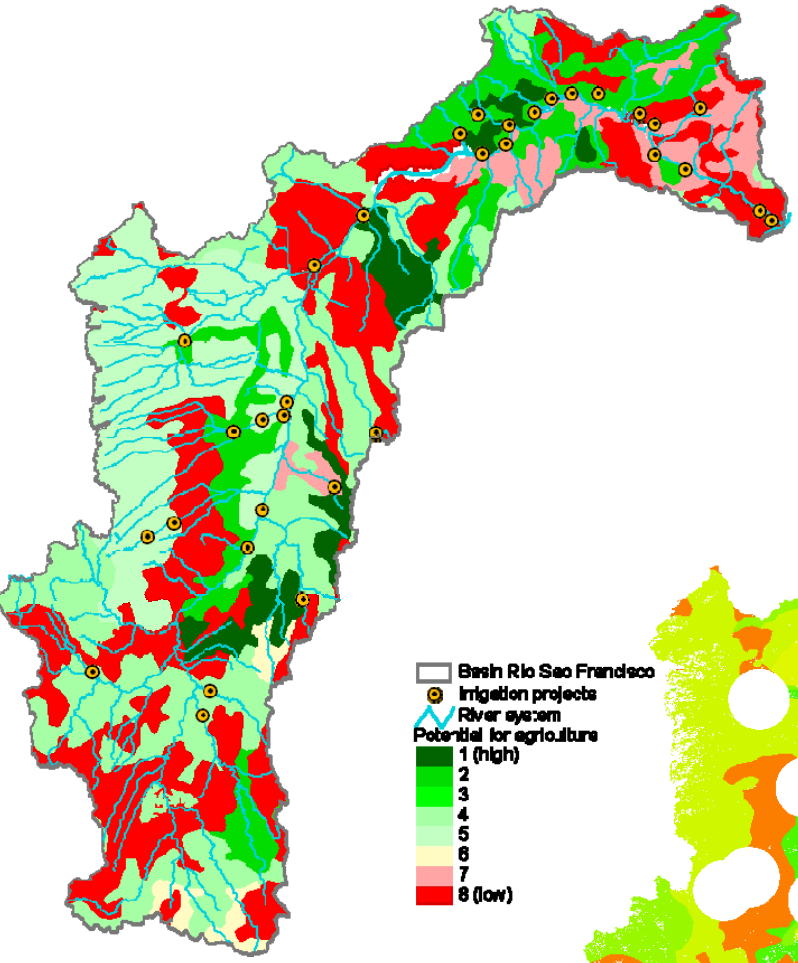
Smaller tributaries (little effect of water management) => measured discharges

Main river (strong effects of water management) => naturalized discharges

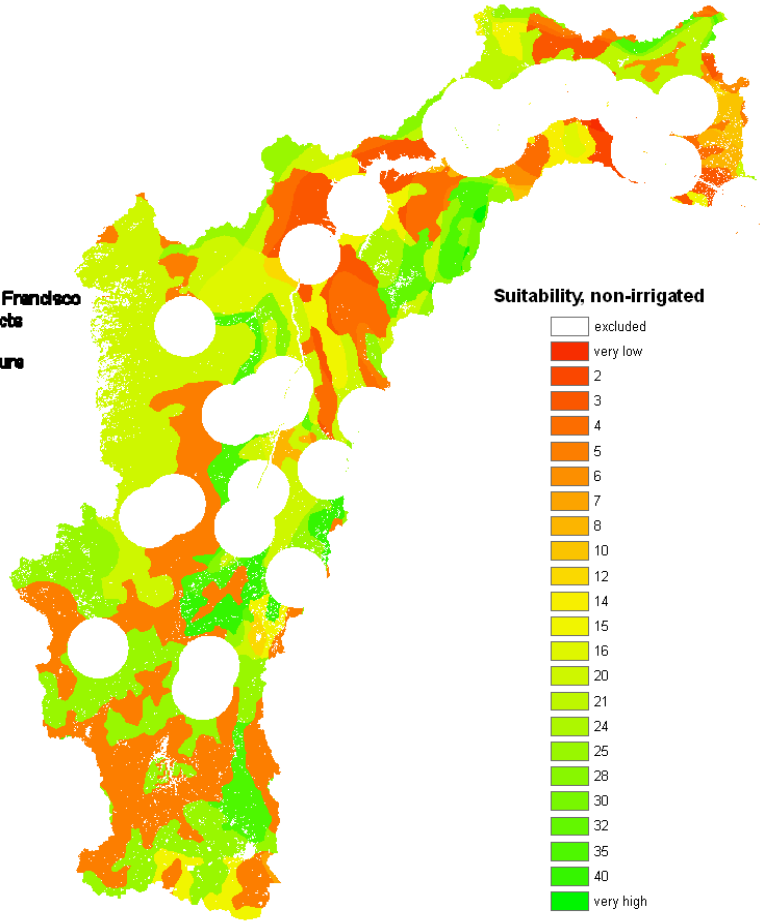
SWIM: Crop rotation including two harvests per year

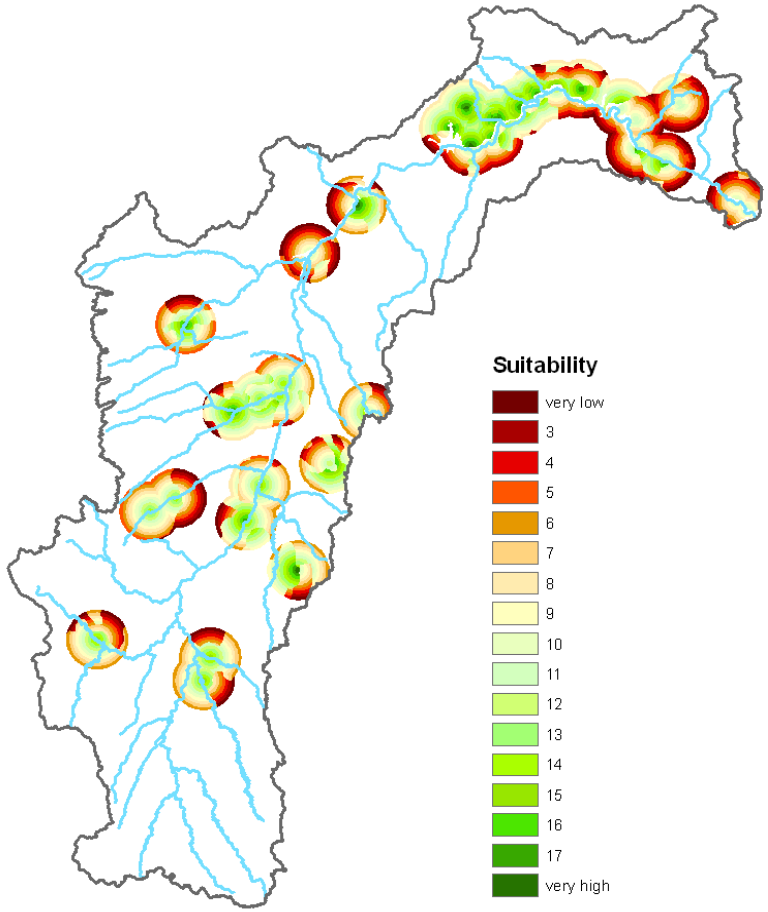


Outlook



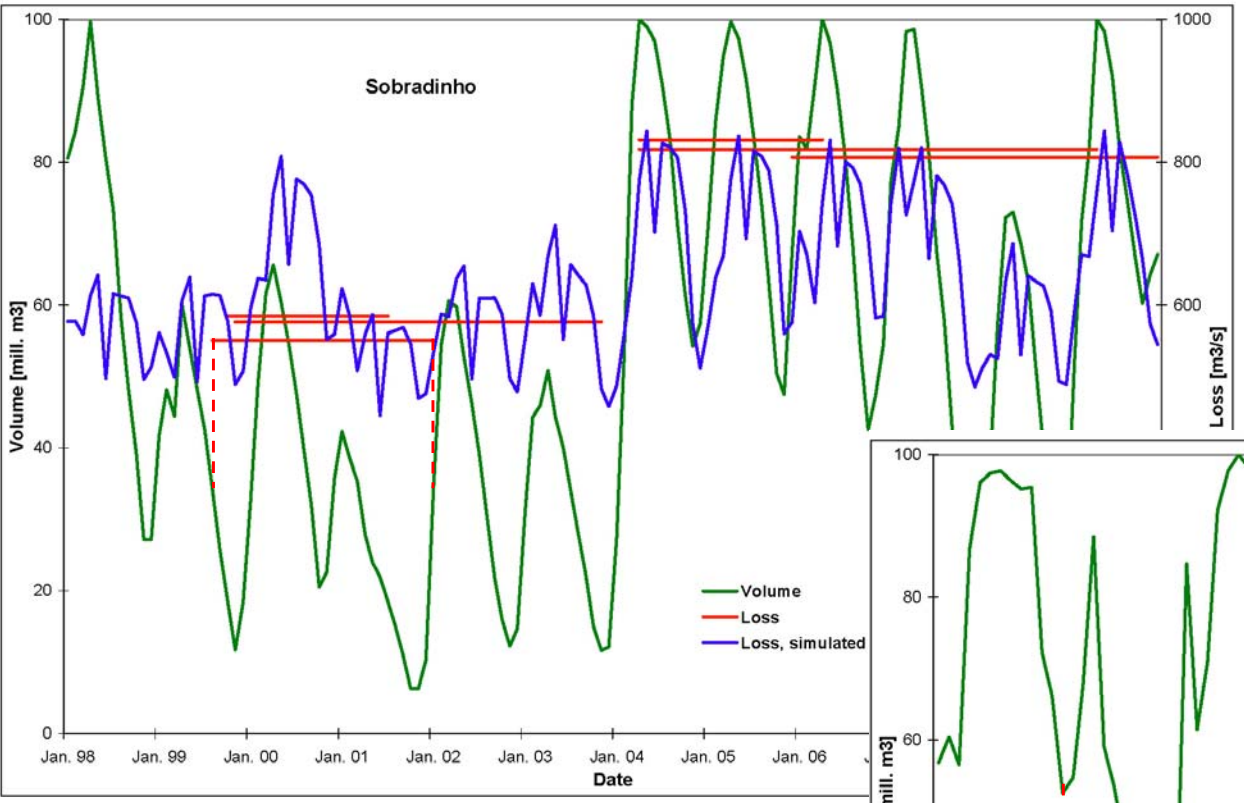
Potential for agriculture according to IBGE



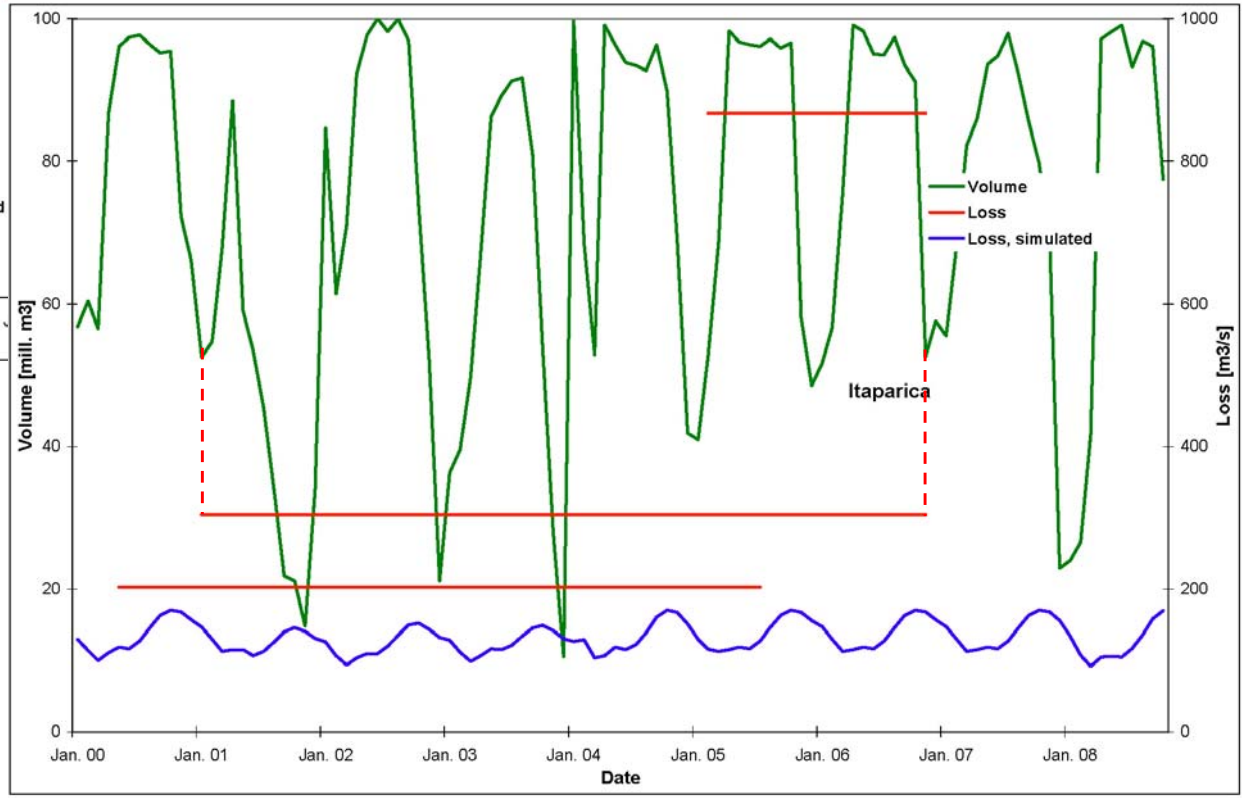


Scenarios with changed land-use; e.g. [non-]irrigated agriculture

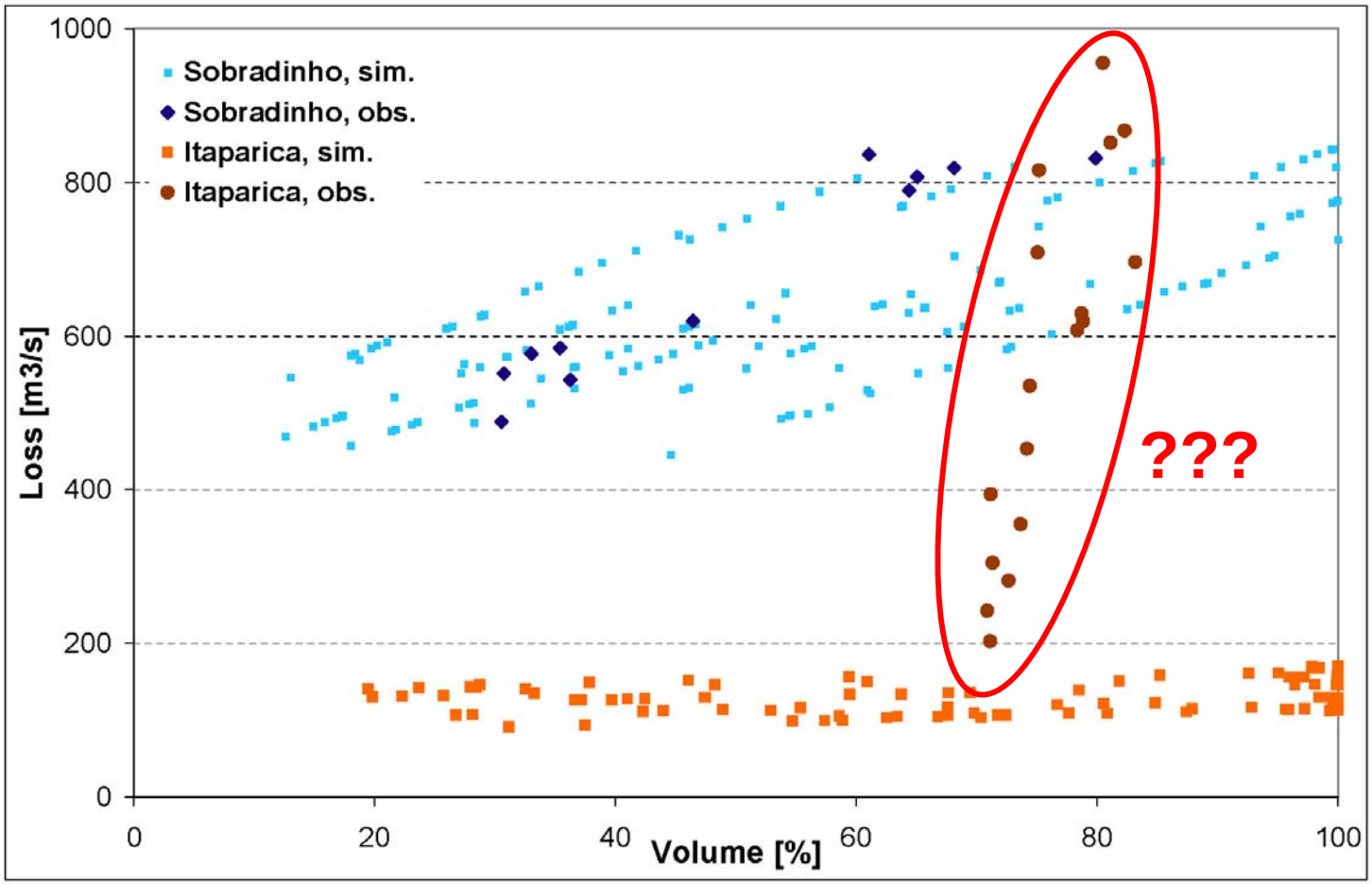
Losses (seepage, CWB, withdrawals) from reservoirs



Loss: difference between sum of inflow and sum of outflow for same volume at different times

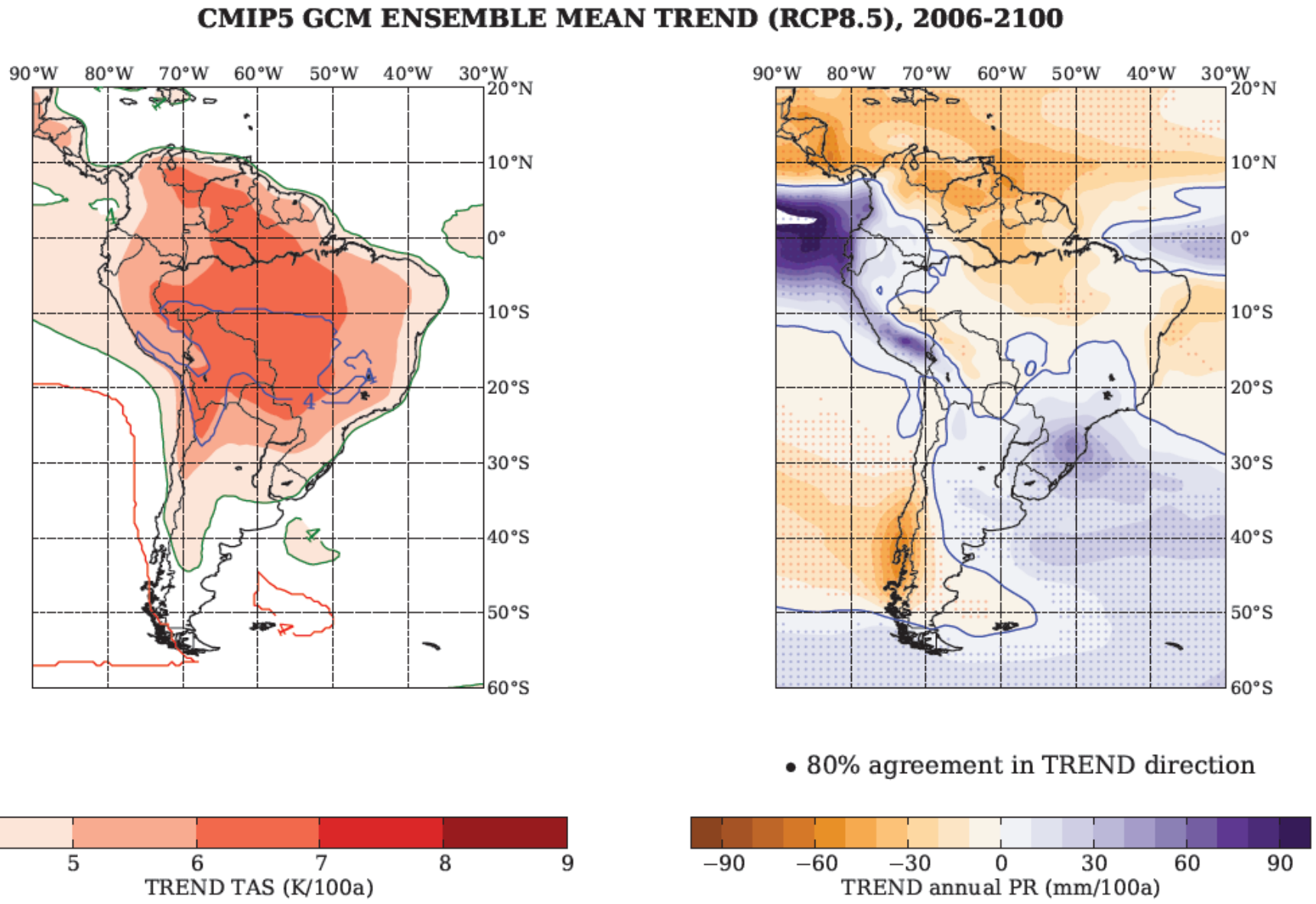


Losses (seepage, CWB, withdrawals) from reservoirs

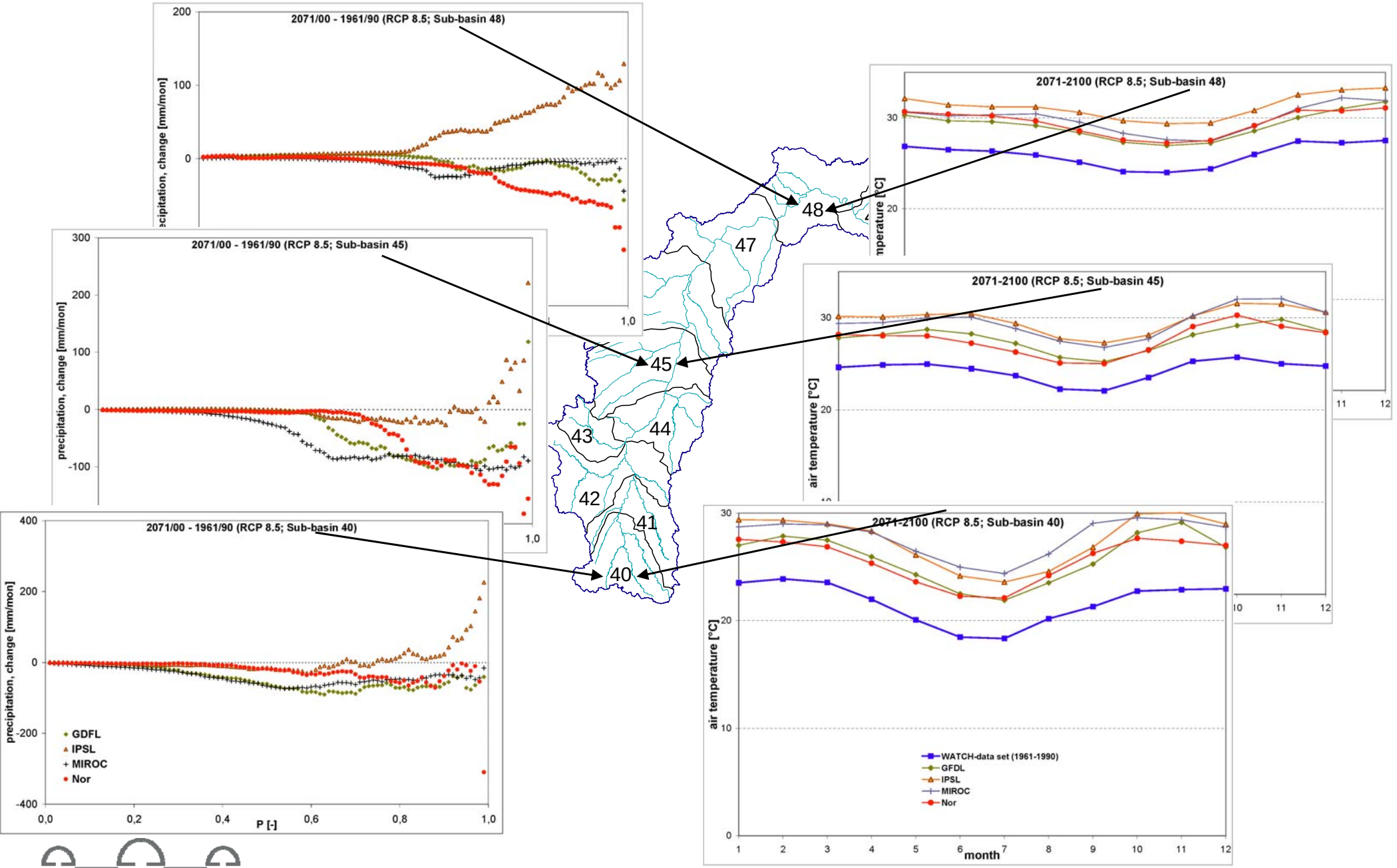


Sobradinho: 34,117 Hm^3
Itaparica: 10,782 Hm^3

XXXX


CMIP5 GCM ENSEMBLE MEAN TREND (RCP8.5), 2006-2100
90°W 80°W 70°W 60°W 50°W 40°W 30°W
20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S
• 80% agreement in TREND direction
4 5 6 7 8 9
TREND TAS (K/100a)
−90 −60 −30 0 30 60 90
TREND annual PR (mm/100a)

Climate scenario (RCP8.5)



CONCLIMA
Conferência Nacional de Mudanças Climáticas

Our Challenge:

- ***To build an Earth System Model in Brazil, from state of the art component models in the nation and abroad:***

1. To incorporate expert knowledge (e.g. the LBA program) about ocean-ice-atmosphere-biosphere interactions of relevance to Brazil;
2. To provide the scientific foundations of global climate change scenarios for mitigation and adaptation policies to climate change in Brazil;
3. To contribute to form a new generation of modeling-capable earth system scientists in the nation.

CONCLIMA
Conferência Nacional de Mudanças Climáticas

Concluding Remarks

- BESM-OA model has been completed, allowing Brazil to inaugurate its participation in the CMIP5/IPCC AR5 global climate change scenarios.
- BESM-Ibis/Inland is under construction with first runs showing promising results.
- Next steps: Full ESM with dynamical vegetation, continental hydrology and the incorporation of the Atmos Chemistry component.

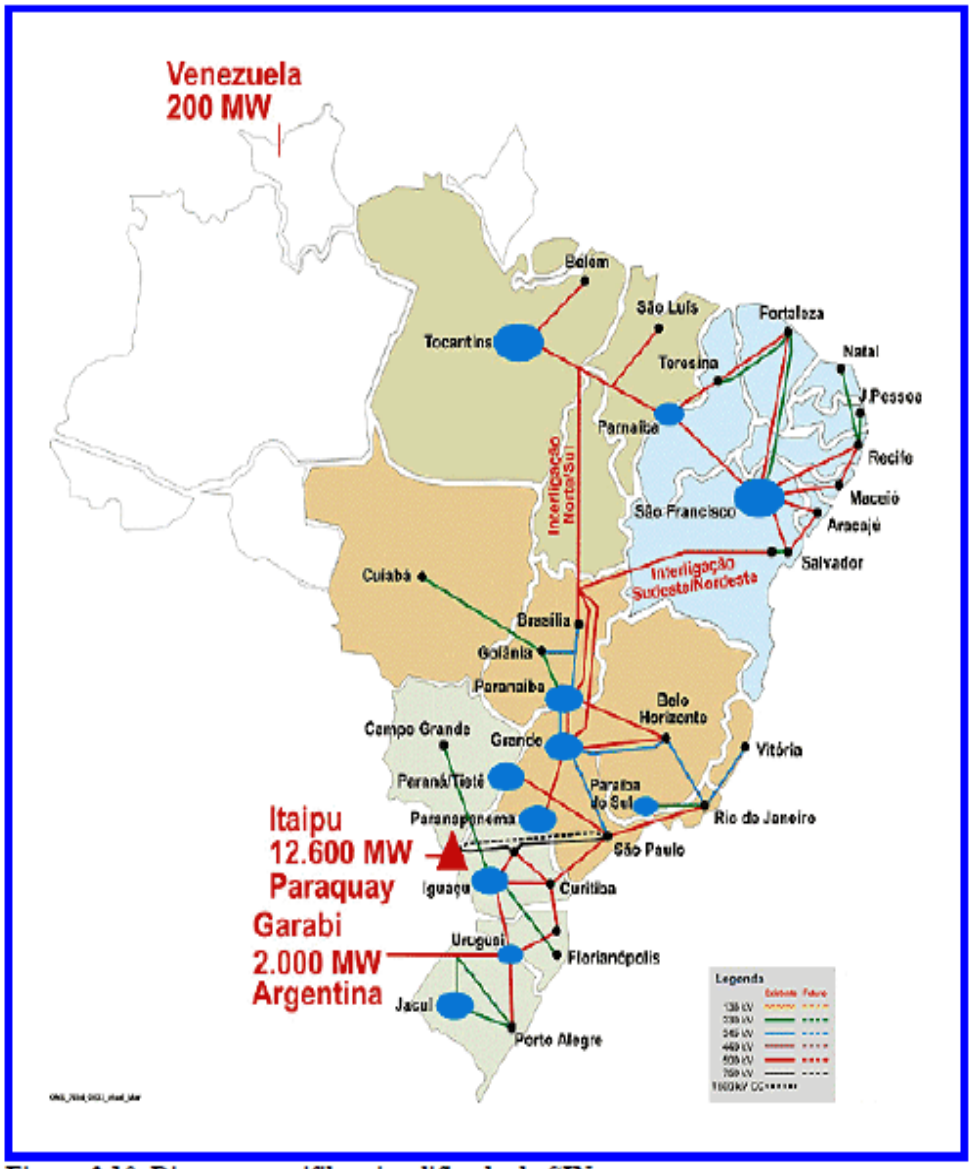
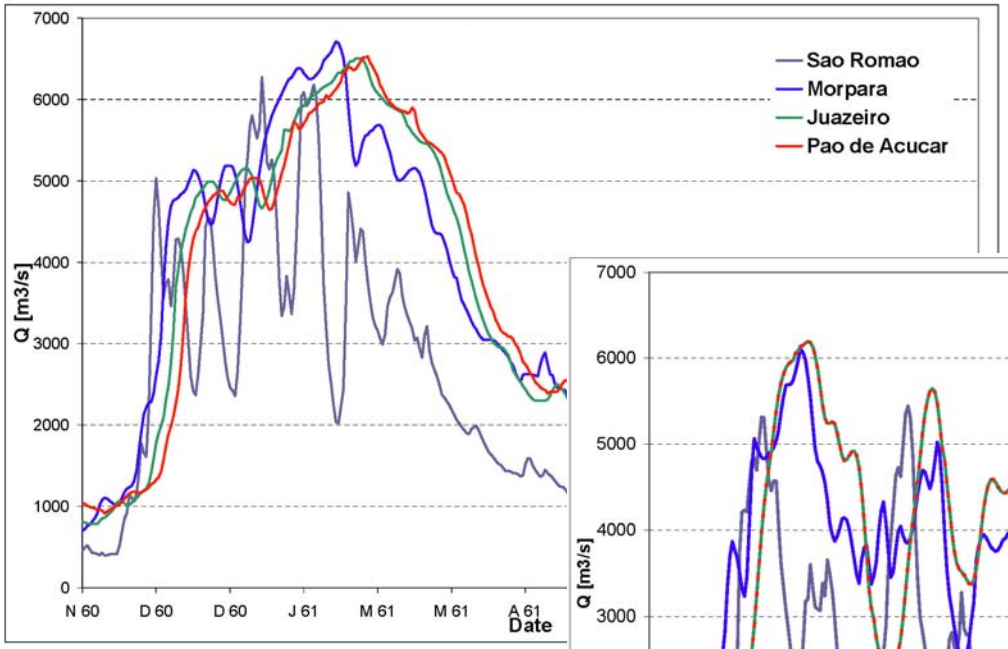
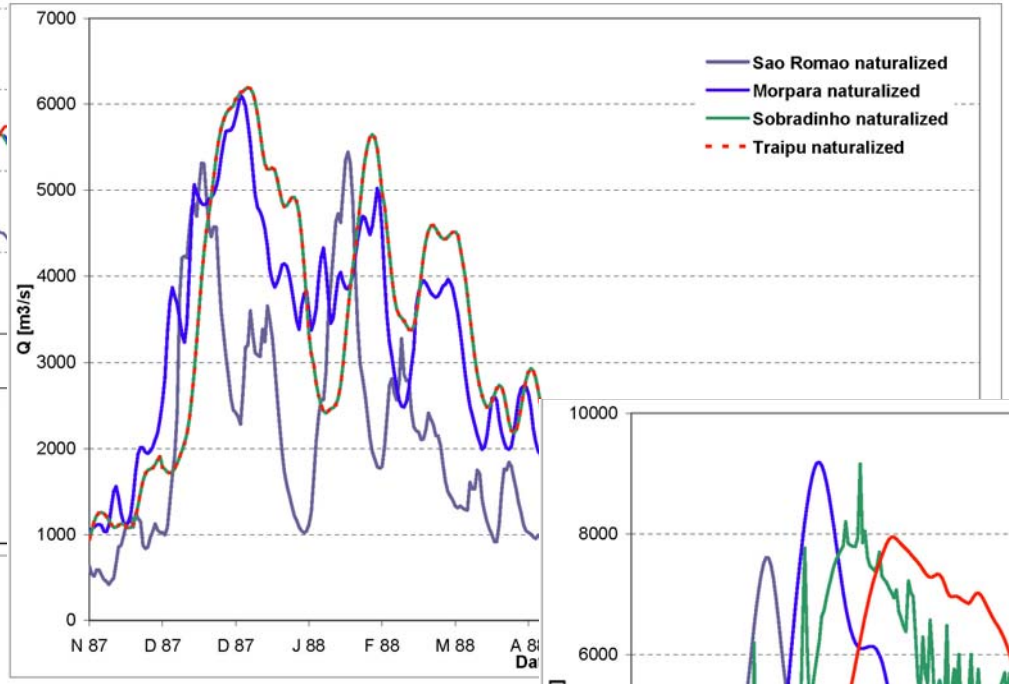


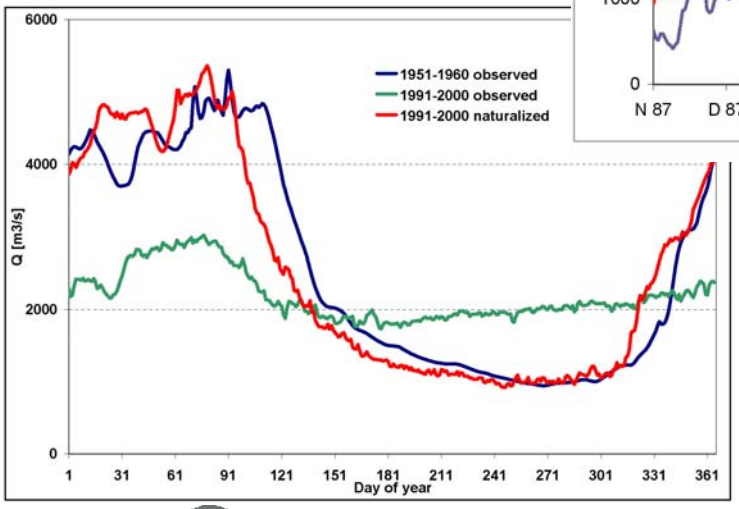
Figura 3.10. Diagrama unifilar simplificado do SIN

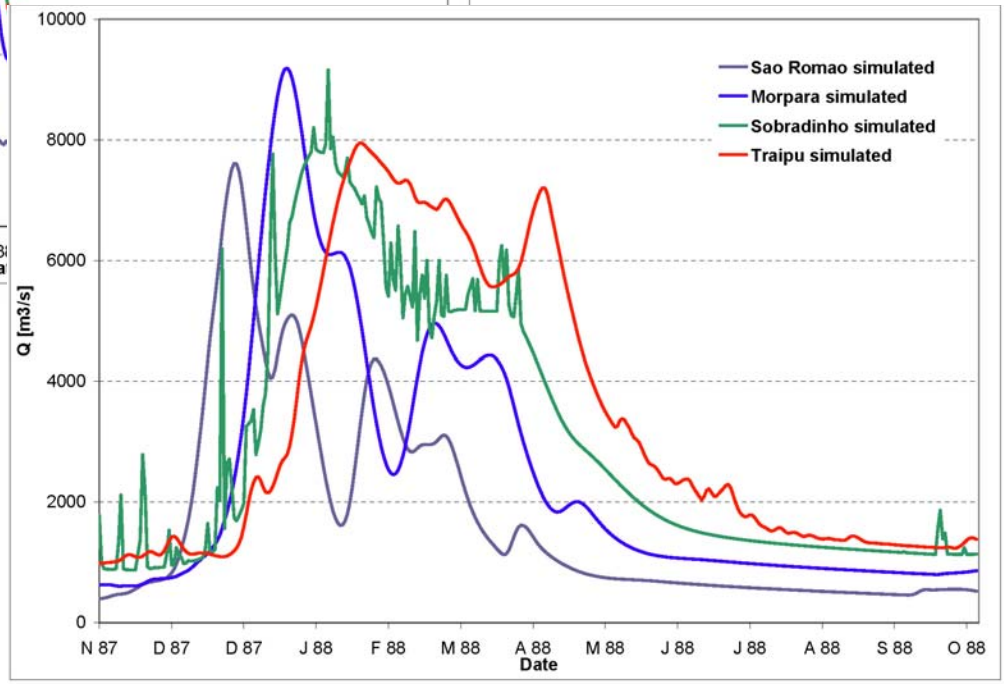
SIN: *Sistema Interligado Nacional* (National Transmission Grid)
(Figures from *Agência Nacional de Águas*)

Natural conditions?

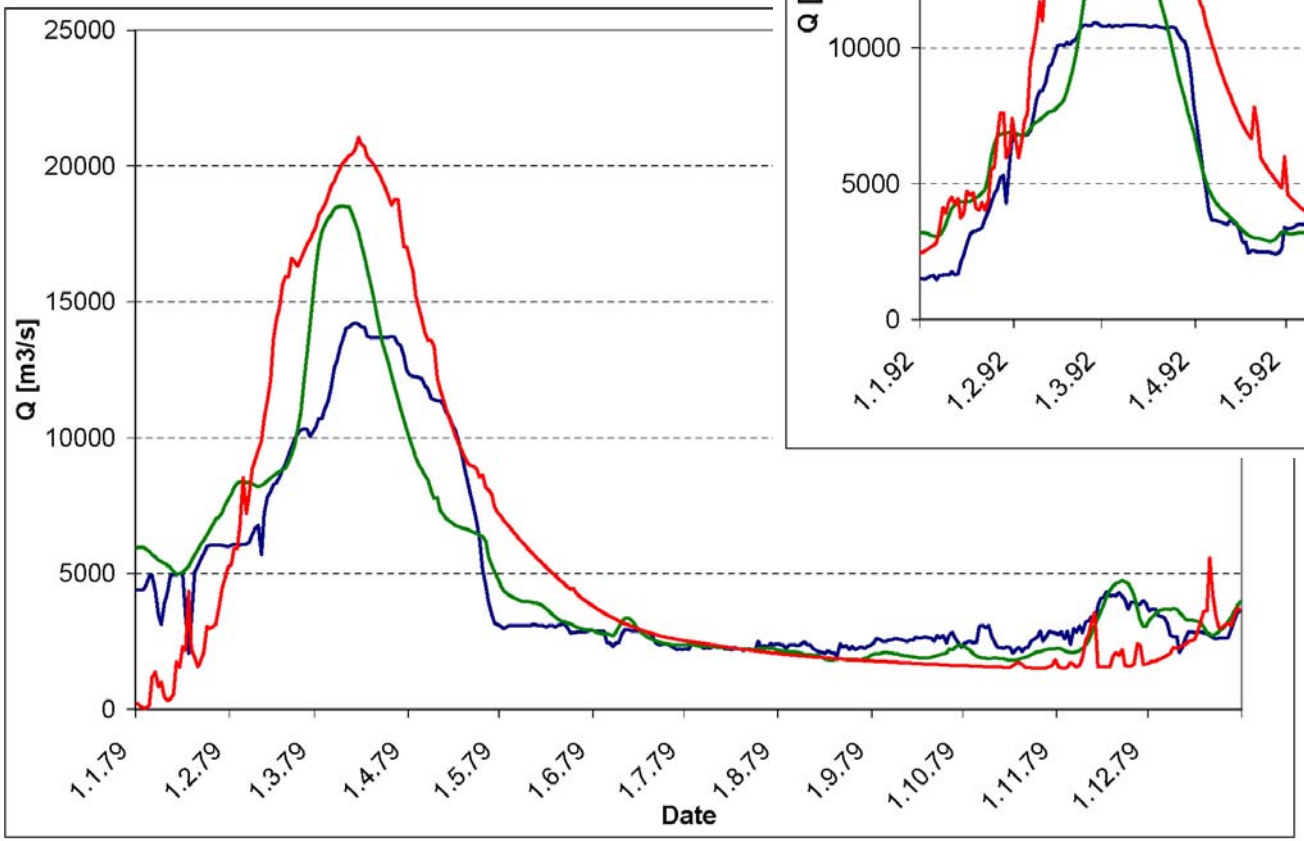


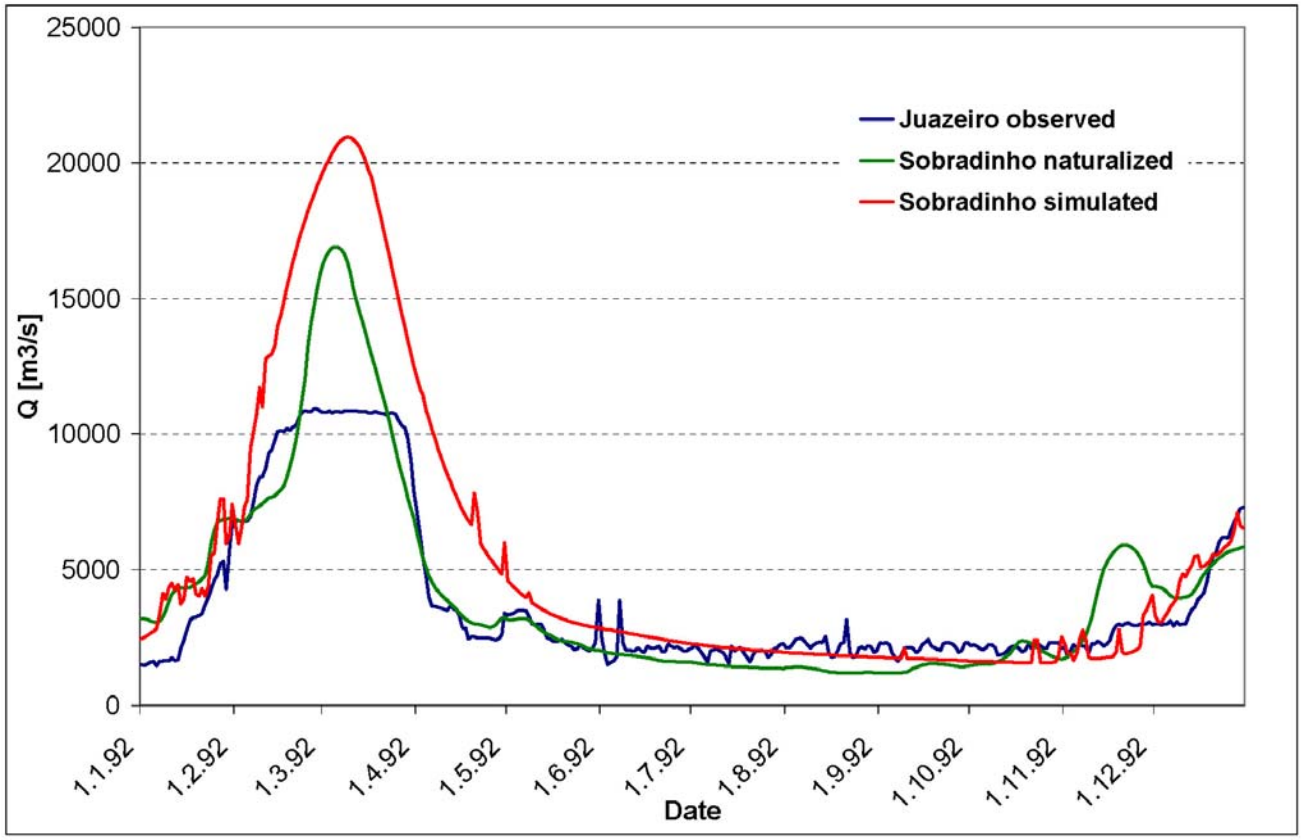






SWIM: Simulation of major floods





Questions: how reliable are
- observed discharges?
- naturalized discharges?
- climate input data?
- simulation results (SWIM parameter sets)?

Scenario RCP8.5: mean daily discharge reservoir Itaparica