SHORT- AND LONG-TERM FLOW FORECASTING IN RIO GRANDE WATERSHED

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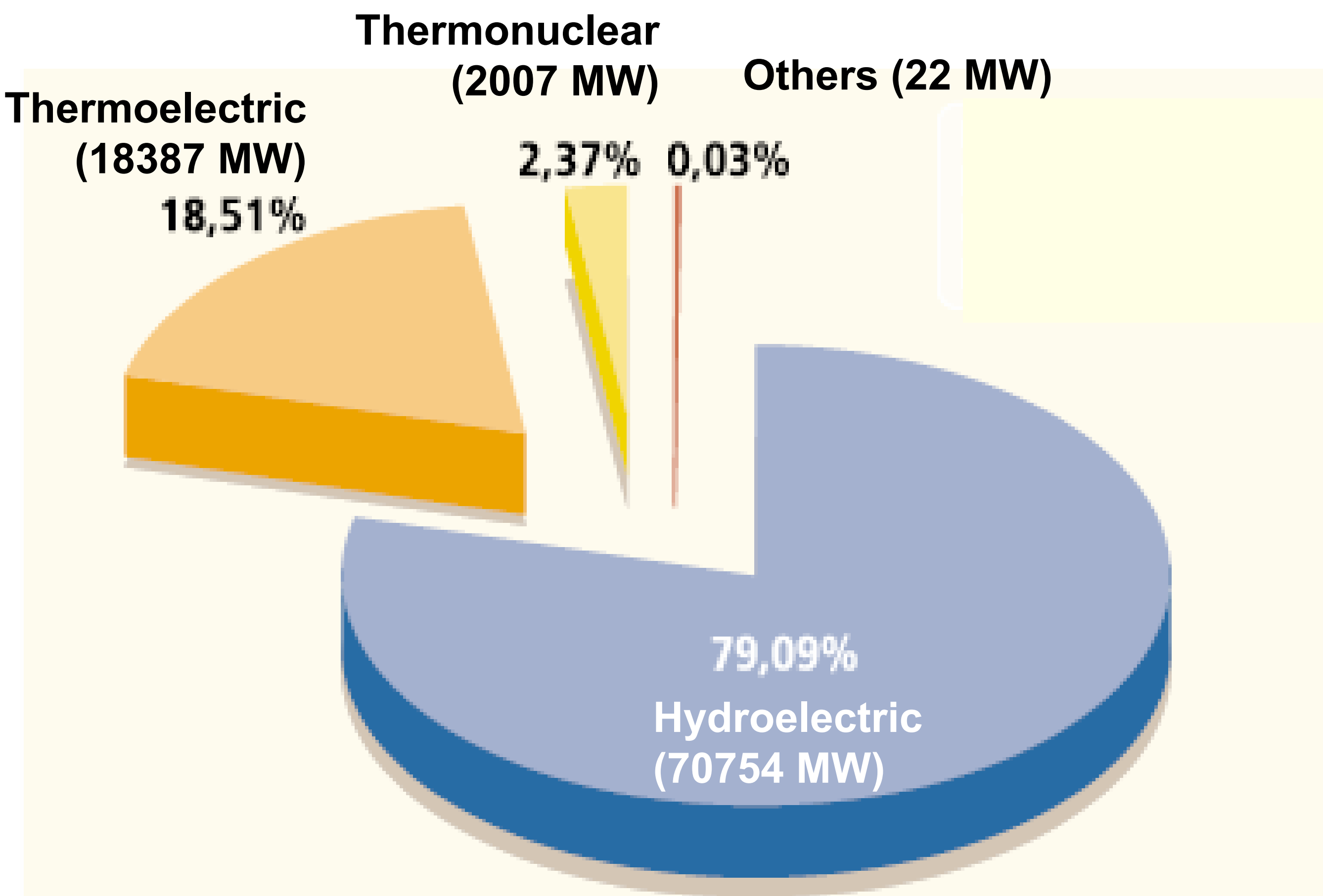
1 INTRODUCTION

•Hydropower is the main water use of Rio Grande Basin



Brazilian Total Installed Electric Energy Production

1 INTRODUCTION (cont.)

IN BRAZIL,

• The mean production uses more hydro (90%) than thermal (10%);

• Thermal is more specify and it is used hedge for sequence of draught years;

•The system has a grid of interconnection which covers all the country where the main lines capacity and regional production and distributed demand plays are condition for the system optimization.

•<u>The decision to decrease hydro and increase thermal is strongly dependent on the climate forecast.</u>

• It's a system of about 100,000 MW of Installed capacity, mean capacity of production of about 55,000 MW and mean demand of about 48,000 MW. It's a 30-40 billions dollars/ year market

Currently, the national system operator (ONS) produces flow forecasts using <u>stochastic models</u> based on precipitation and streamflow time series.

1 INTRODUCTION (cont.)

•The stochastic model are optimist during draught years since it forecast the mean.

•In 2001 there were a main draught and the population had to decreased its demand in 20%.

•This paper summarizes results obtained for short- and long-term flow forecasting in Rio Grande watershed, one of the HEPEX test beds.

•The hydropower in Rio Grande represents 12 % of total installed energy. Since it is also the water supply for Itaipu (downstream) and others it has even more importance in the forecasting.

THE MAIN OBJECTIVES:

FLOW FORECASTING AT SHORT AND LONG – TERM FOR THE HYDROPOWERS IN THE BASIN.

2 METHODOLOGY

RIO GRANDE WATERSHED

- drainage area of 145000 km²
- main tributary of River Paraná in its upper basin
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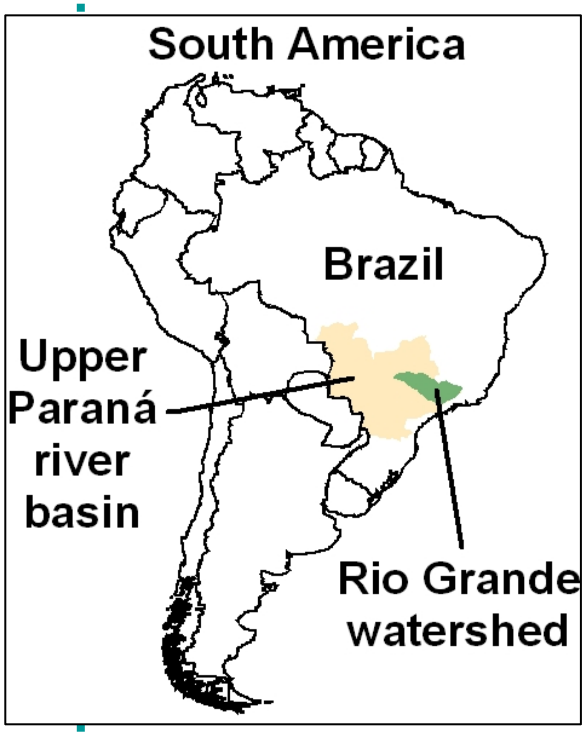
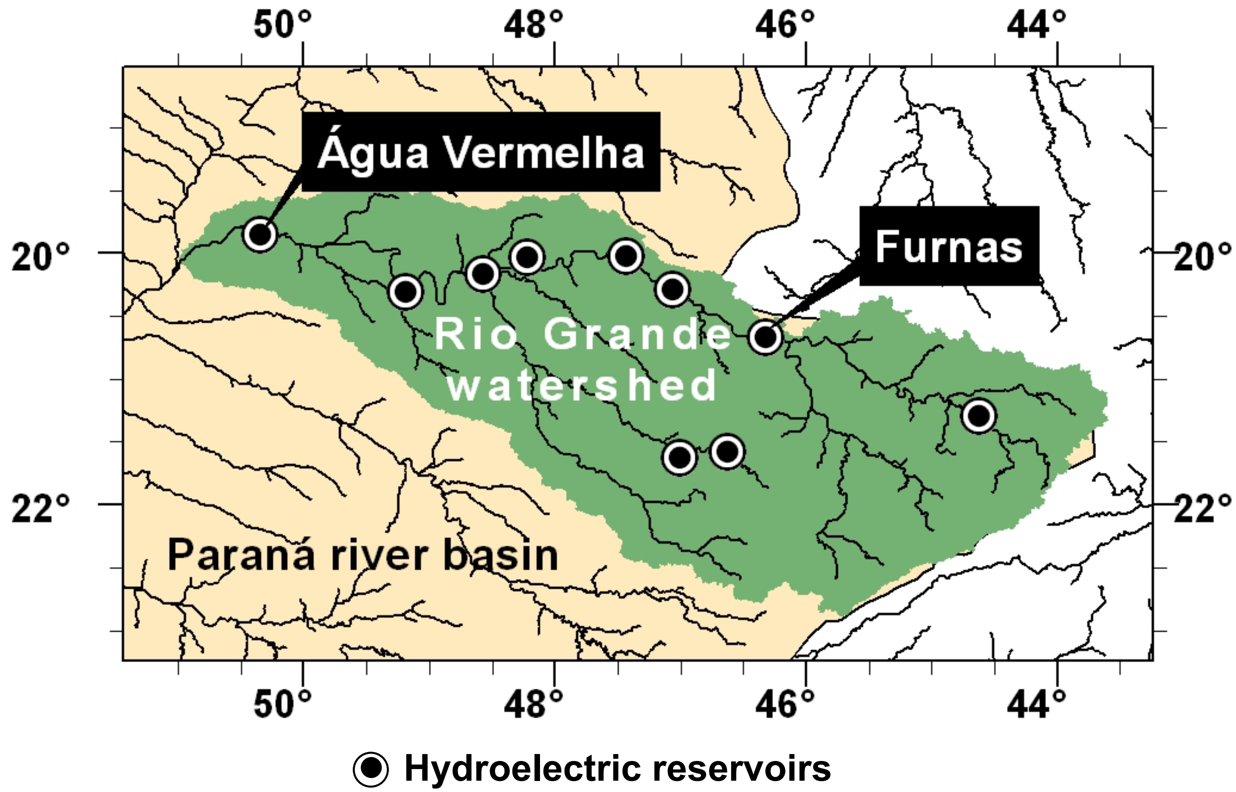




2 METHODOLOGY (cont.)

Use of a global and regional weather model for rainfall forecast and a Distributed Hydrologic Model for short and long –term flow forecast

DISTRIBUTED HYDROLOGICAL MODEL

- MGB-IPH large-scale model

- **modules: soil water budget, evapotranspiration, flow propagation inside a cell, and flow routing through the drainage network**

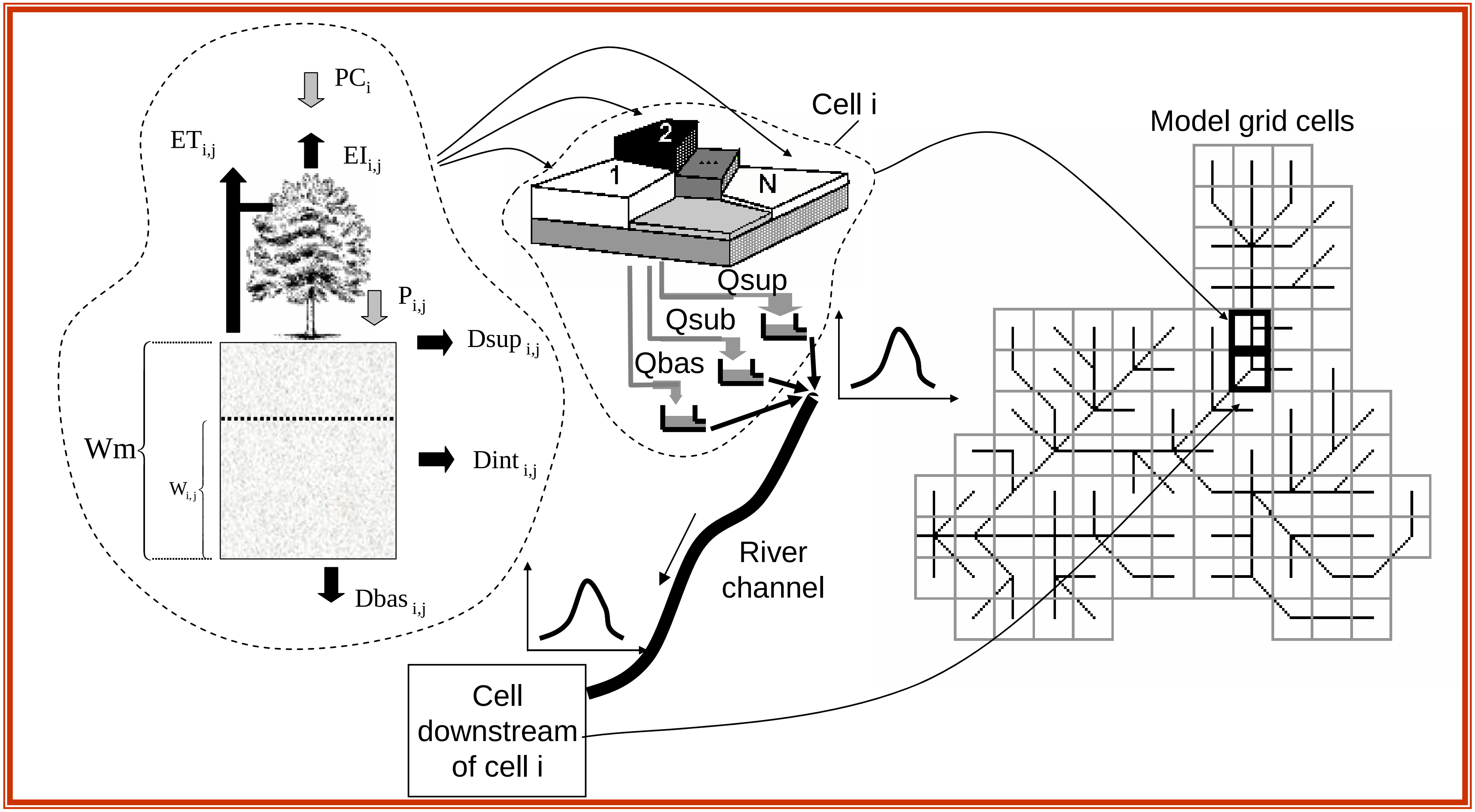
- **basin divided in square-grid cells connected by channels**

- **the Grouped Response Unit (GRU) (Kouwen *et al.*, 1993) approach is used (hydrological classification of all areas with a similar combination of soil and land cover inside a cell)**

- **each model cell composed by three linear reservoirs (surface, subsurface and groundwater)**

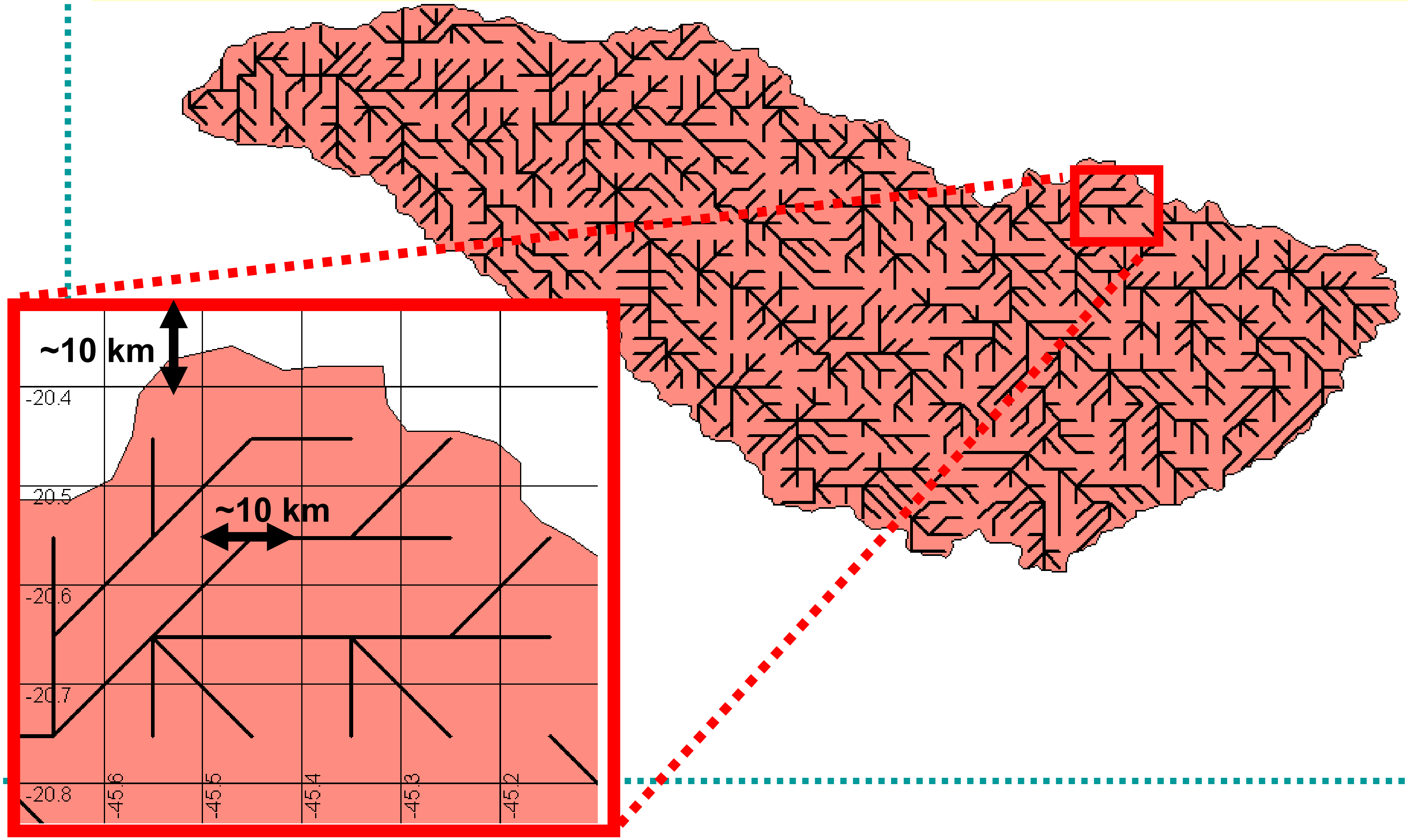
- **model calibration using the multi-objective MOCOM-UA optimization algorithm.**

OVERVIEW OF MGB-IPH MODEL



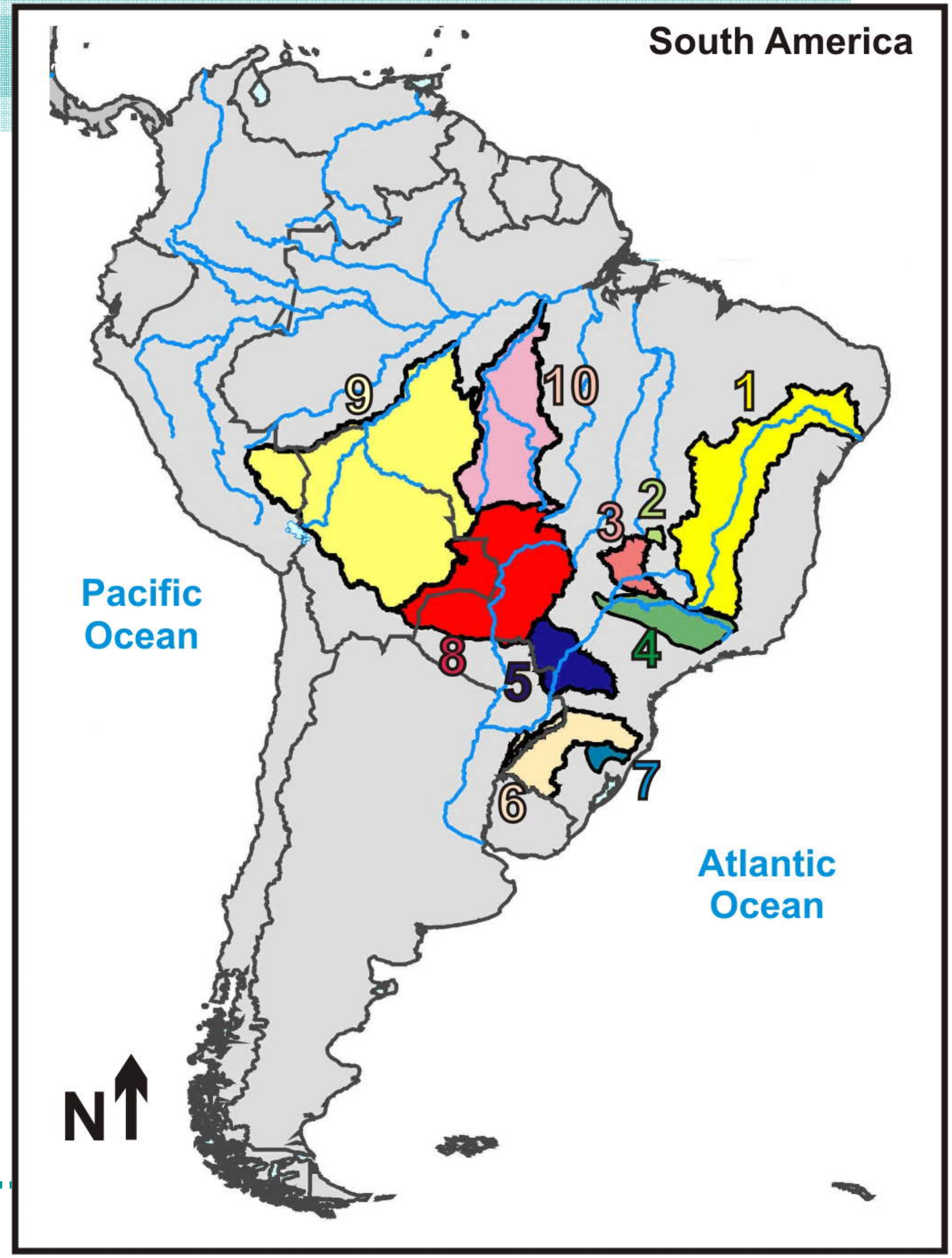
2 METHODOLOGY (cont.)

RIO GRANDE WATERSHED **Division into cells with resolution 0.1º x 0.1º (~10x10km) with the drainage pattern used in the hydrologic model.**



2 METHODOLOGY (cont.)

South American Basins simulated using the large scale model MGB-IPH



2 METHODOLOGY (cont.)

SHORT-TERM FORECAST

PRECIPITATION FORECAST

- provided by regional ETA model
- run operationally from CPTEC
- time horizon from 1 to 10 days
- produced at weekly intervals and issued every Wednesday
- horizontal resolution: 40 km
- interpolated to the hydrologic model cells (10 x 10 km)
- extending from Jan1996 to Nov2001

FLOW FORECAST

- using MGB-IPH model, which is run in simulation mode using observed rainfall until forecast issue
- empirical data assimilation procedure before forecast issue
- forecast with time horizon from 1 to 12 days
- first 10 days using ETA precipitation forecast
- last 2 days assuming there is no further rain

2 METHODOLOGY (cont.)

THE EMPIRICAL DATA ASSIMILATION PROCEDURE

(model updating procedure)

- **Qcalc and Qobs are compared during a warming up period until forecast issue**

- **updated variables: streamflow along river network and water content in the groundwater reservoir in each model cell**

- **an updating correction factor is calculated for each gauging station: FCA = ∑Qobs/ ∑Qcalc**

- **a weighting factor based on the drainage area is used to damp out the correction far upstream from the gauging stations**

$$Qup_{i,p} = FCA_p \cdot Qcalc_i \cdot \left(A_i / A_p\right)^{ebac} + Qcalc_i \cdot \left[1 - \left(A_i / A_p\right)^{ebac}\right]$$

Detailed discussion about this procedure will be presented at IAHS Symposium to be held in Perugia.

2 METHODOLOGY (cont.)

LONG-TERM FORECAST

PRECIPITATION FORECAST

- provided by CPTEC's AGCM global atmospheric model
- using persisting SST (sea surface temperature) anomalies
- spatial resolution of ~200 km and 28 layers in the vertical
- 5 initial conditions (an ensemble of 5 forecasts)
- time horizon up to 6 months
- daily forecasts issued at monthly intervals
- period July 1997 to March 2003

FLOW FORECAST

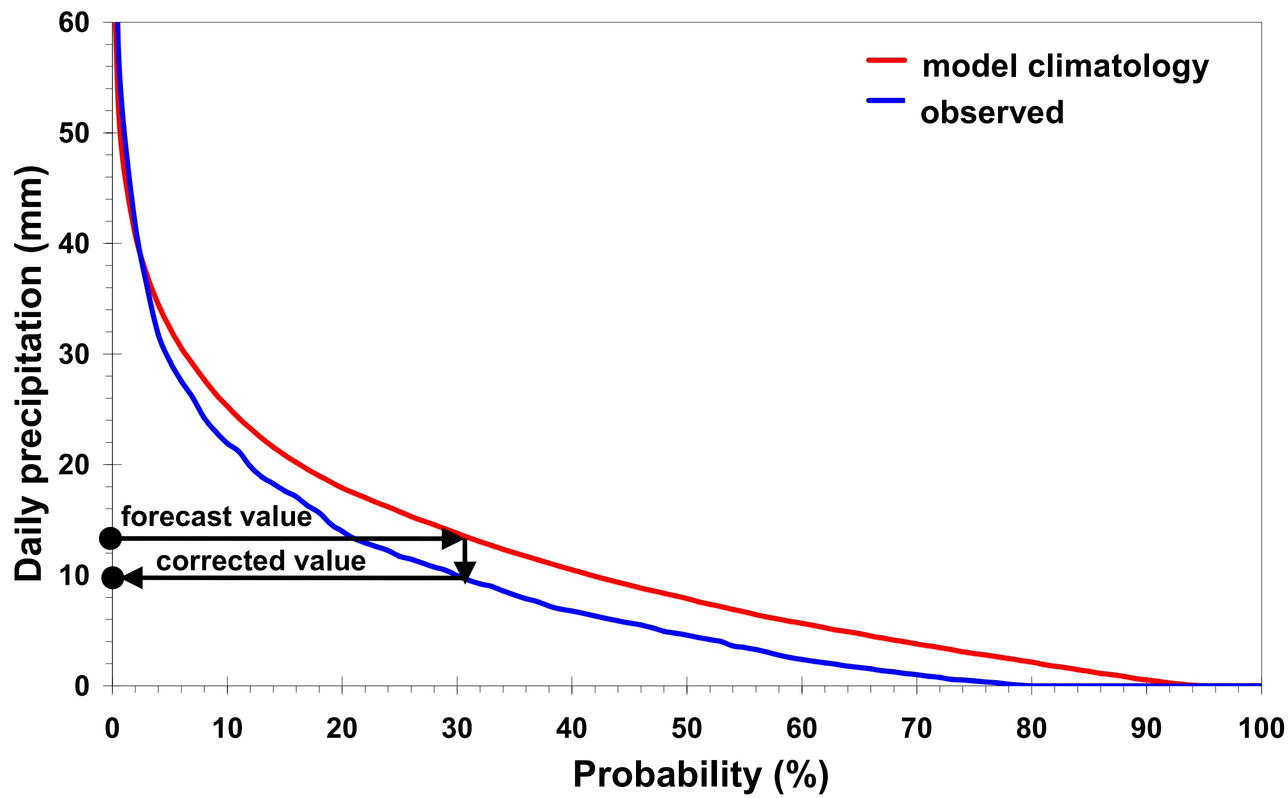
- produced with MGB-IPH model, which is run in simulation mode using observed rainfall until forecast issue
- systematic errors in precipitation forecast are corrected by a statistical technique prior to model input
- forecast with time horizon from up to 6 months
- a 5-member flow ensemble forecast is produced

2 METHODOLOGY (cont.)

CORRECTION OF SYSTEMATIC ERRORS IN RAINFALL FORECAST

- statistical technique based on a transformation of the probability distribution (Hay and Clark, 2003; Wood et al., 2002)

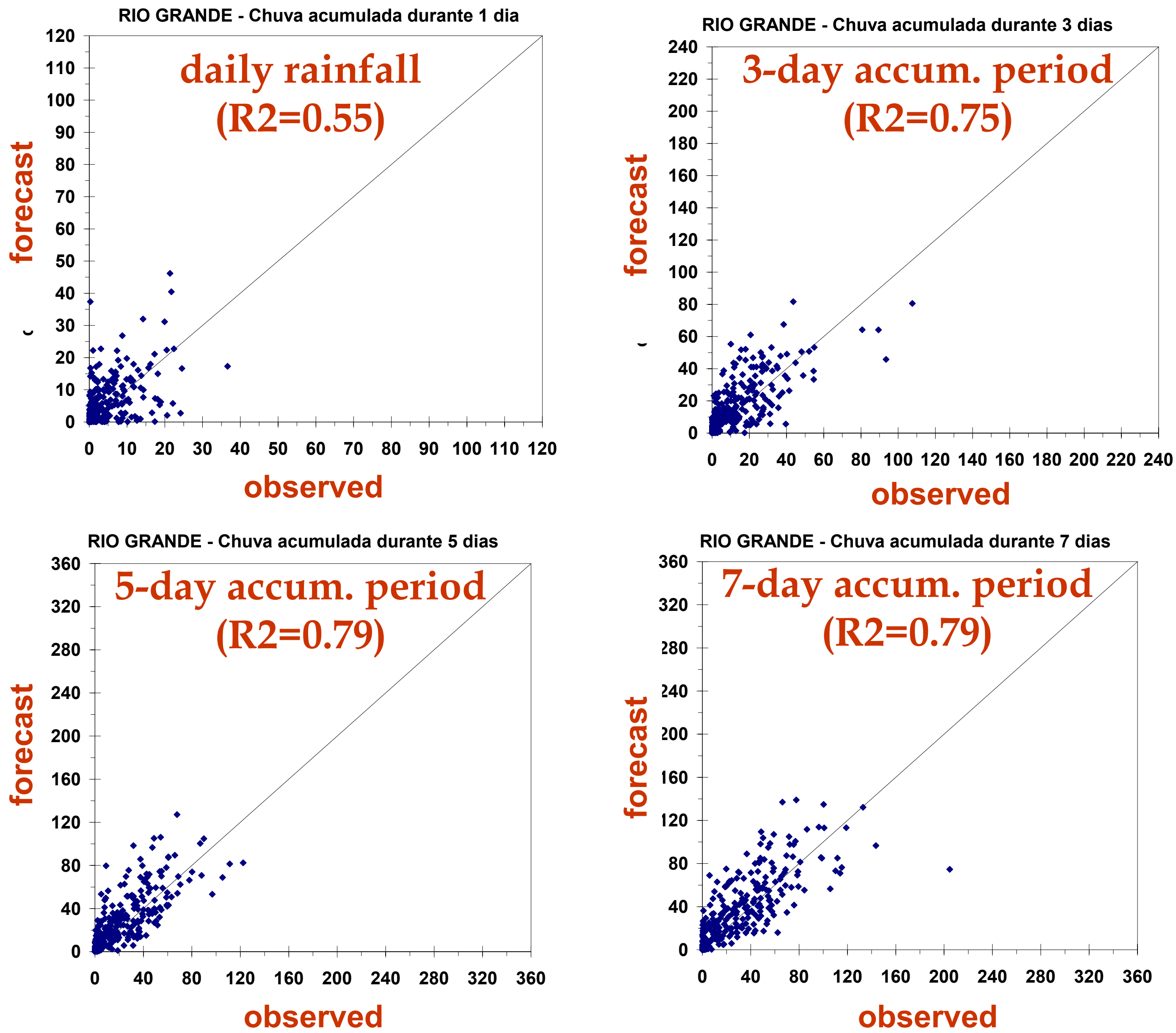
- the probability distributions of observed rainfall and of model climatology (period 1951-2001) were considered



3 RESULTS

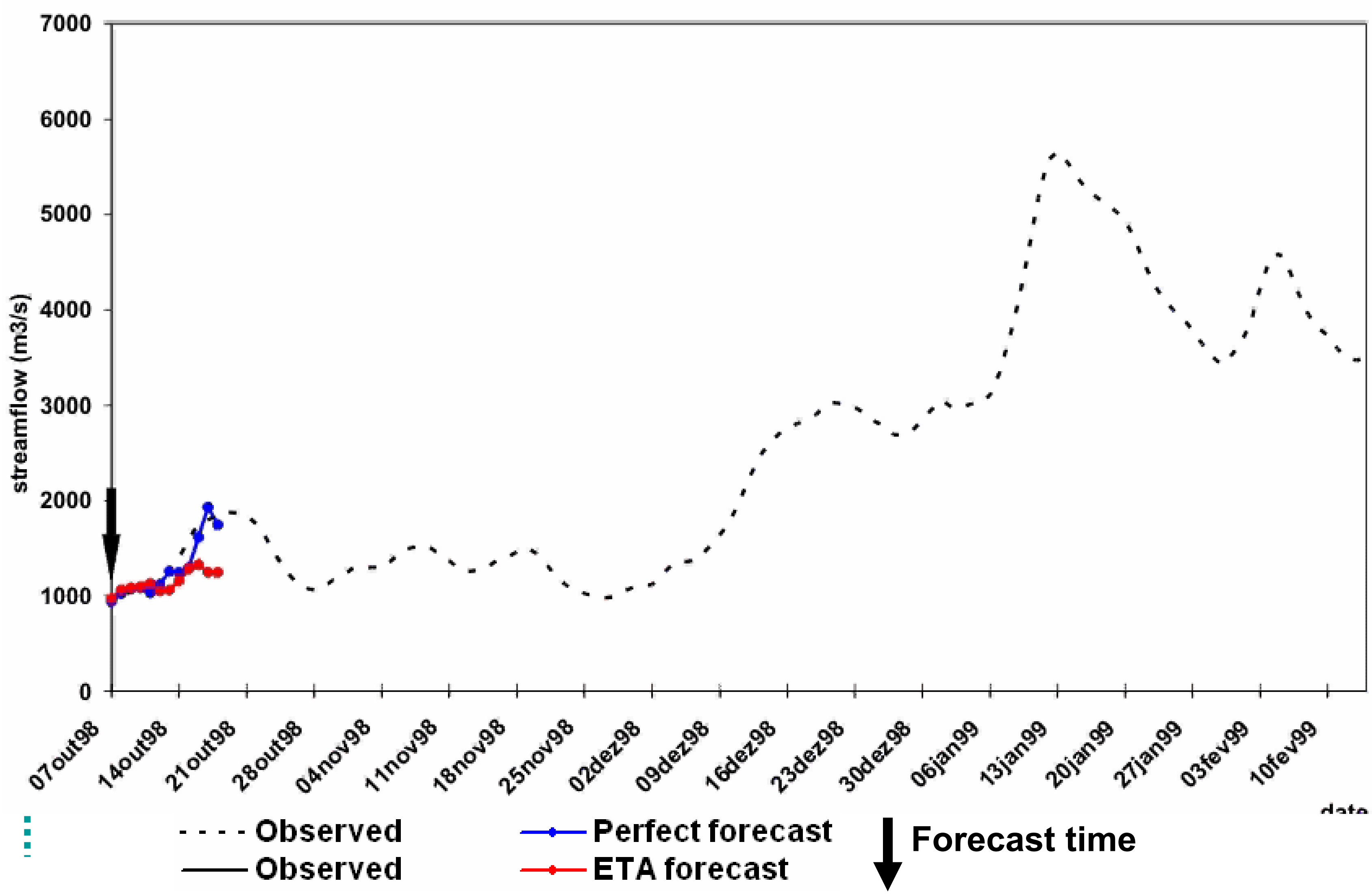
ETA-PRECIPITATION FORECAST (short-term)

Comparison between precipitation forecast and observed over Rio Grande watershed



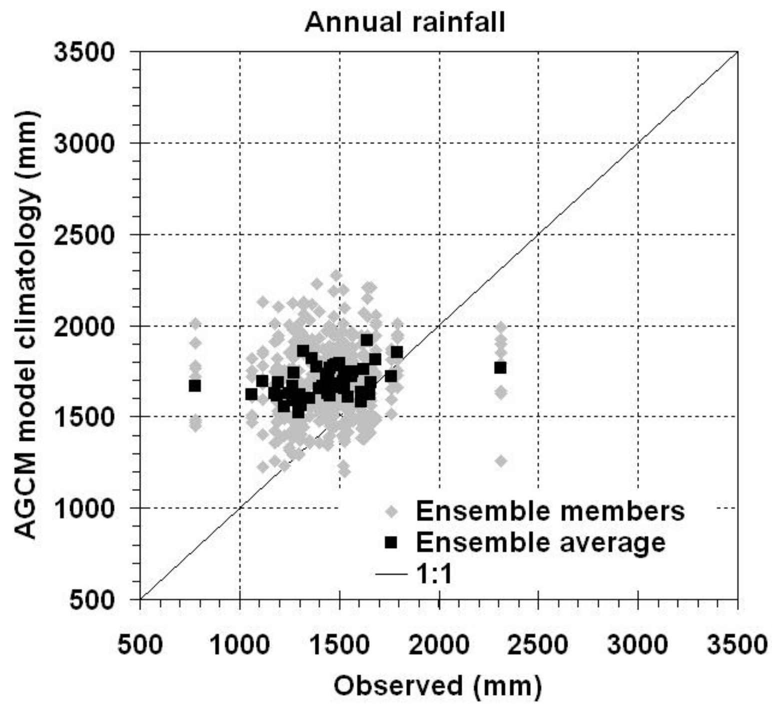
3 RESULTS

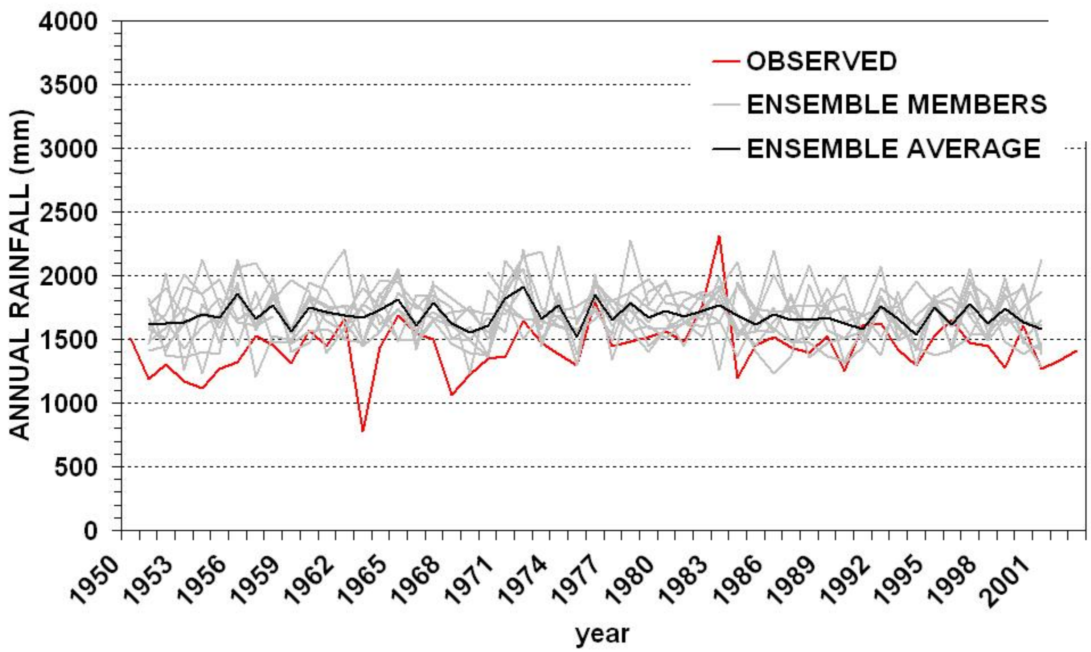
SHORT-TERM FLOW FORECAST (at Água Vermelha reservoir)



3 RESULTS LONG TERM

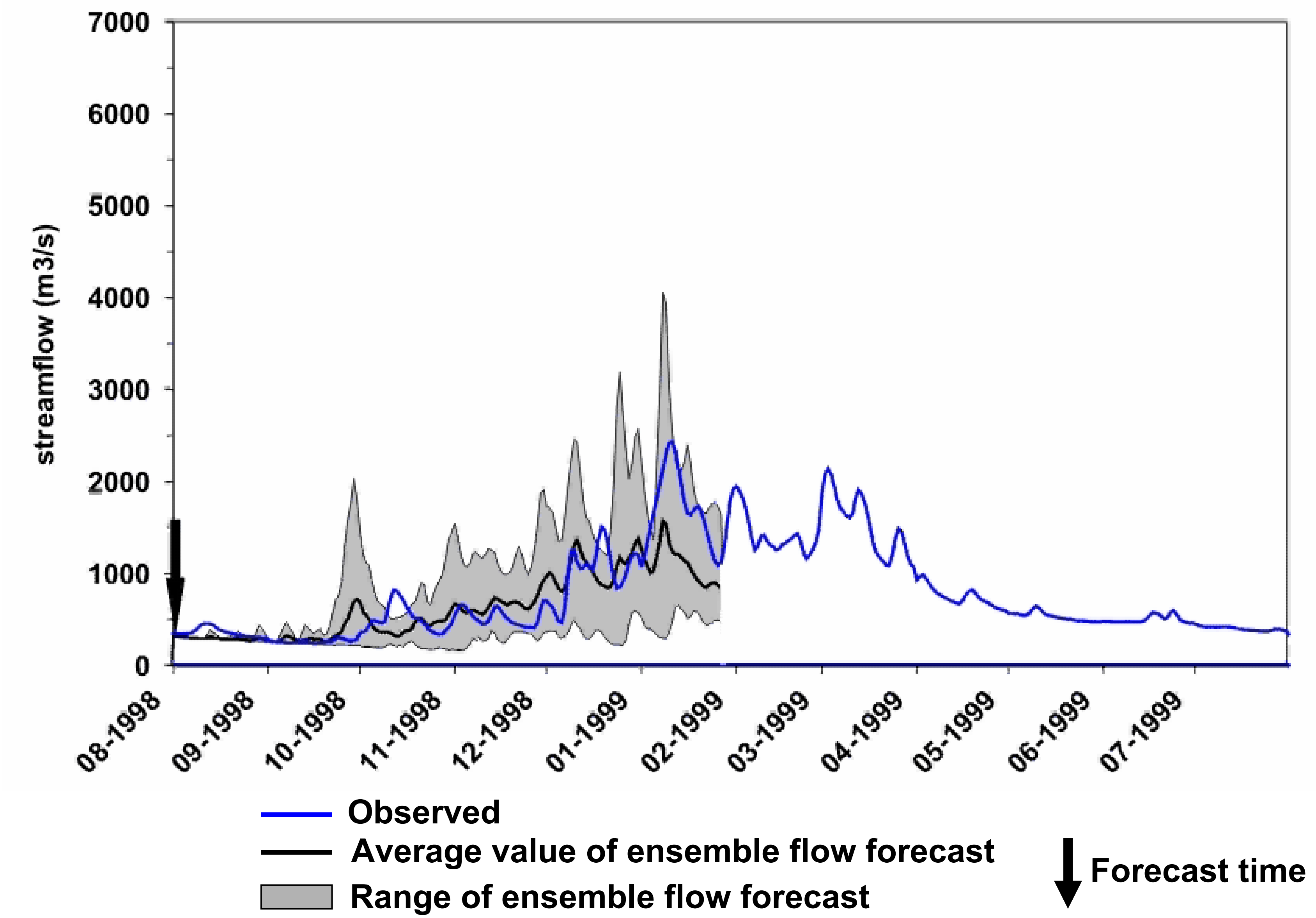
Comparison between AGCM model climatology and observed precipitation over Rio Grande watershed





3 RESULTS

LONG-TERM FLOW FORECAST (at Furnas reservoir)



3 RESULTS

LONG-TERM FLOW FORECAST (at Furnas reservoir)

The band shows a relatively wide dispersion of flow forecasts, but in general it includes the observed flow sequence (blue line).

The mean value of the ensemble of forecasts can be considered satisfactory when compared with observed flows, given the long lead-time of forecasts.

4 CONCLUSIONS

The results obtained with the combination of atmospheric and hydrologic models for flow forecast show potential improvements for hydropower systems management in Brazil.

For short-term forecast, this method reduces error by 10% to 20% in comparison with the currently stochastic model used, and there is space for improvement since the hydrologic module represents roughly 43% to 53% of the total error.

Meanwhile, long-term flow forecast is more dependent on atmospheric model due to the required long lead time. In the final period of the wet season the atmospheric model did not forecast the rainfall satisfactorily, but the band resulted from the ensemble would be helpful for planning purpose.

There is a need for improvement in the ensemble selection based on the flow forecast.

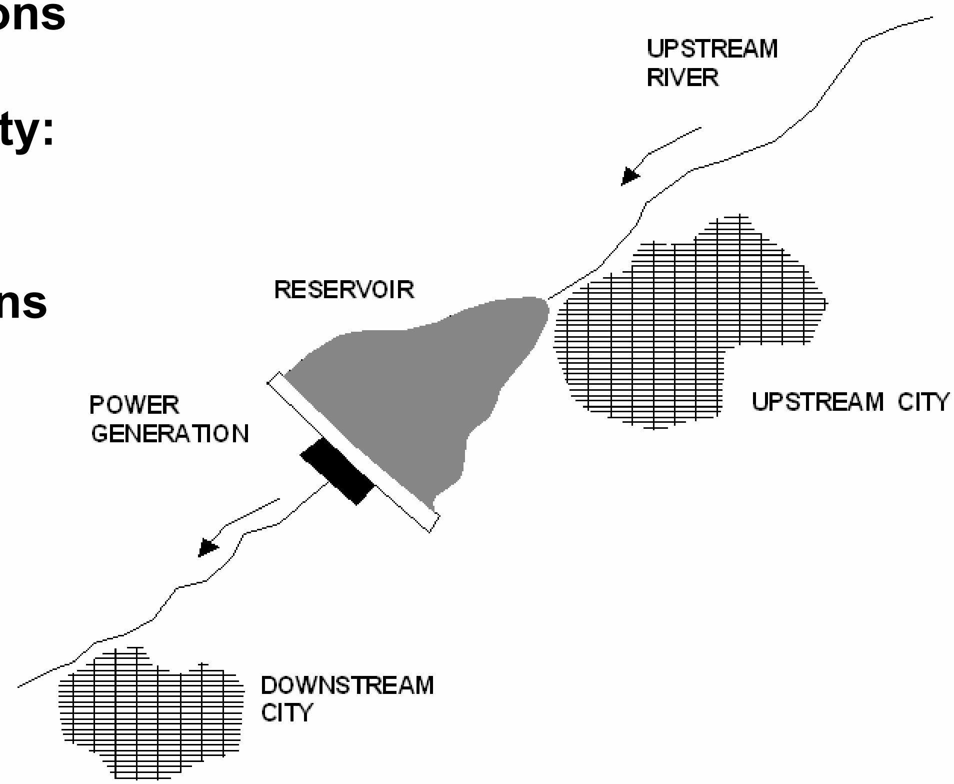
5 BENEFITS OF THE FORECASTING

Assessing the benefits of inflow forecast on multipurpose reservoir operation: Três Marias dam, São Francisco River

Flood control to downstream cities:
Maximum Releases restrictions

Flood control to upstream city:
Maximum Level restrictions

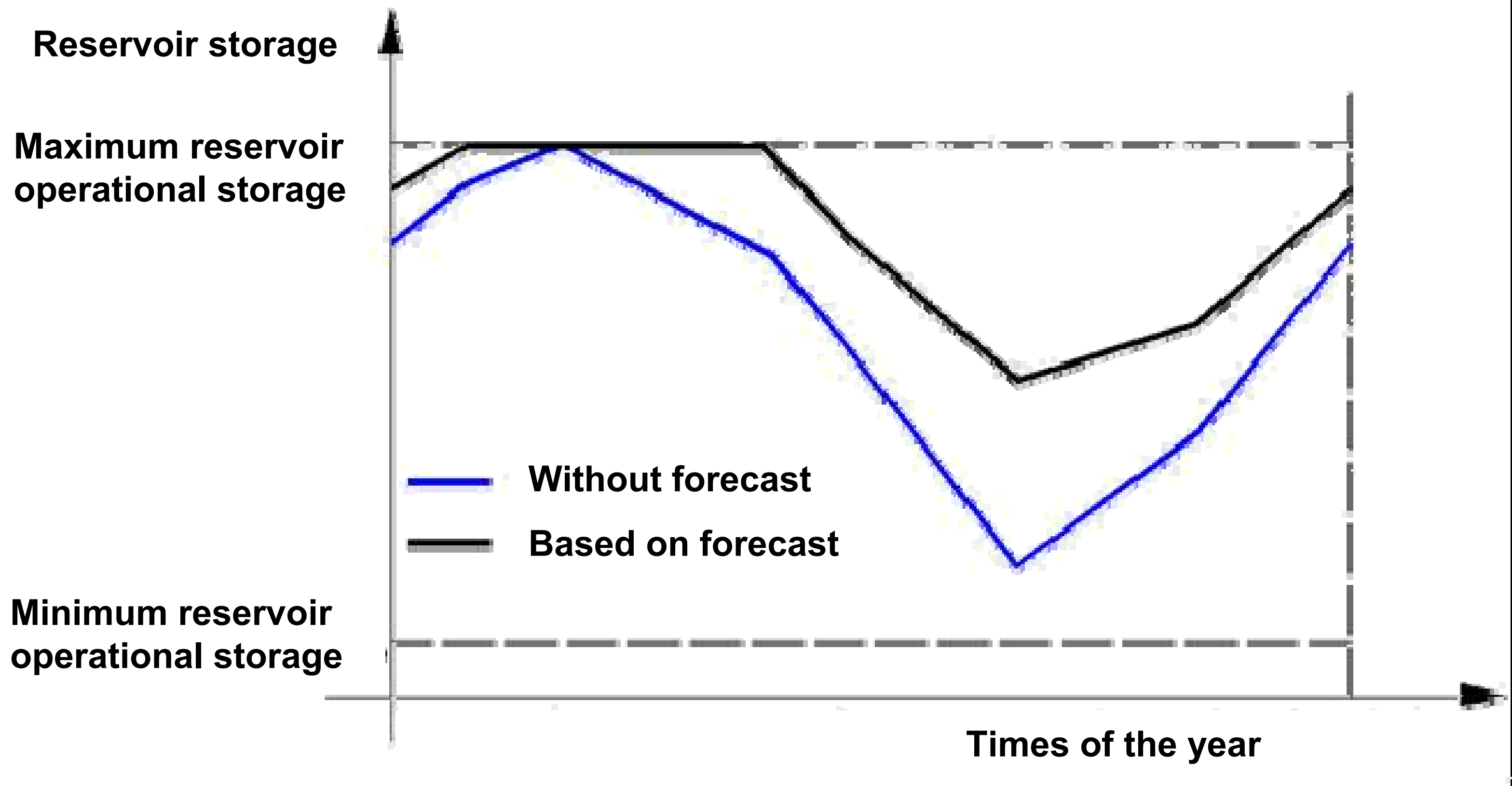
Maximizing power generations
(Simplified problem)



5 BENEFITS

Assessing the benefits of inflow forecast on multipurpose reservoir operation: Três Marias dam, São Francisco River

Optimal rule curves based on inflow forecast and without forecast.



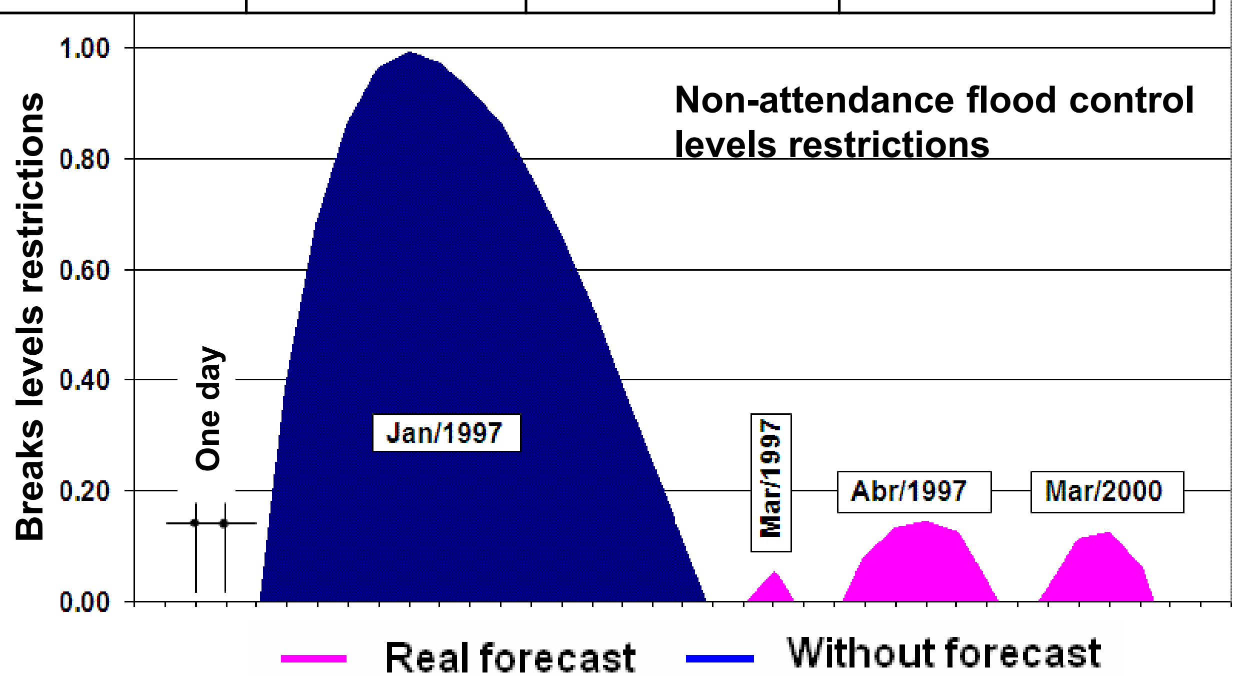
5 RESULTS

Assessing the benefits of inflow forecast on multipurpose reservoir operation: Três Marias dam, São Francisco River

Inflow forecast	Mean power (MWmed)	ΔPow (%)	Non-attendance Flood control levels restric.	ΔBenefits (US$/year)
Without forecast	240,8	-	Yes	-
Perfect forecast	244,1	1,39	No	0,88 millions
Real (MGB+ETA) forecast	242,6	0,74	Yes	0,47 millions

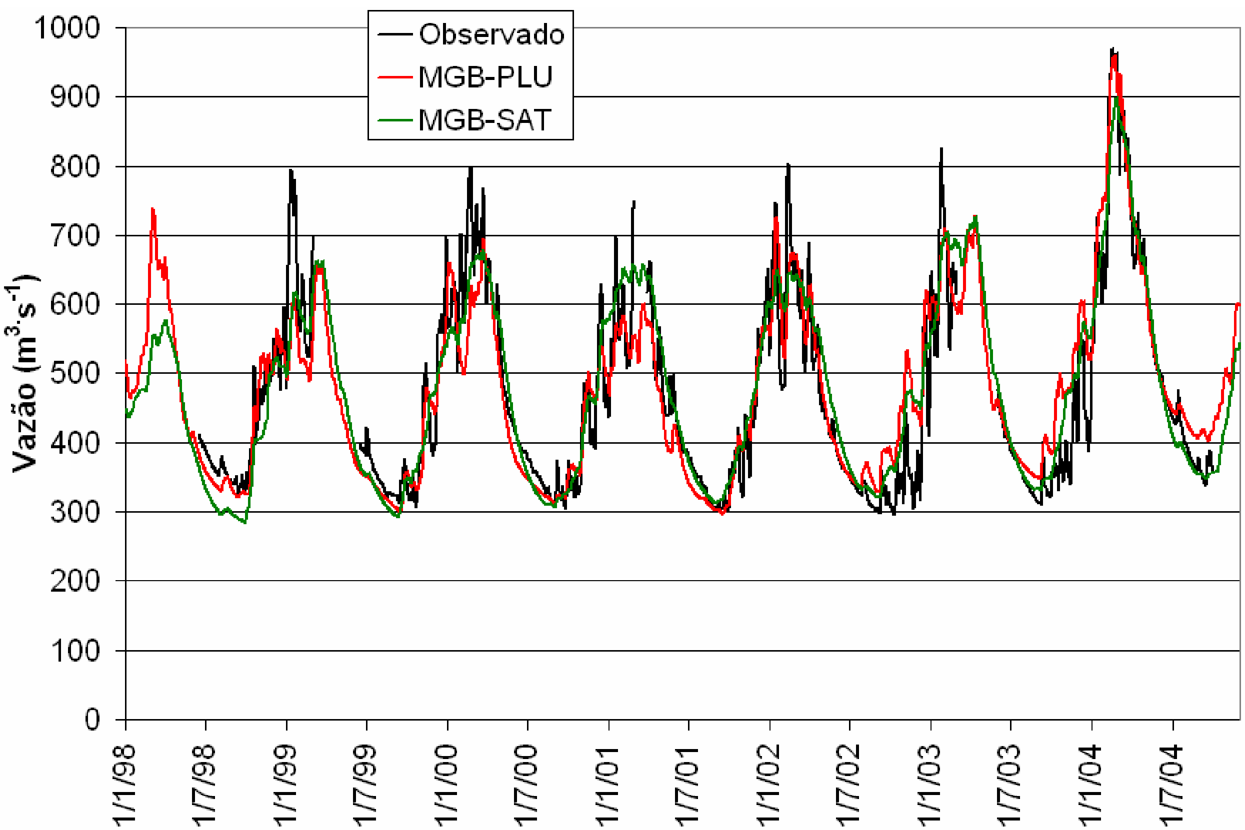
<u>Verification period results:</u>

(Critics events are larger than those in the calibration period).



6 OTHER RELATED RESEARCHES

•RAINFALL ESTIMATED BY SATELITE (TRMM) AS INPUT OF A HYDROLOGIC MODEL IN TAPAJOS, AMAZON BASIN ½ MILLION KM^2



•HYDRODYNAMIC SIMULATION OF LARGE FLOOD PLAINS – PANTANAL, UPPER PARAGUAY BASIN