Hydrological monitoring and forecasting for the Brazilian Northeast

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FUNCEME

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Joint with the Joint Working Group on Forecast Verification Research (JWGFVR)

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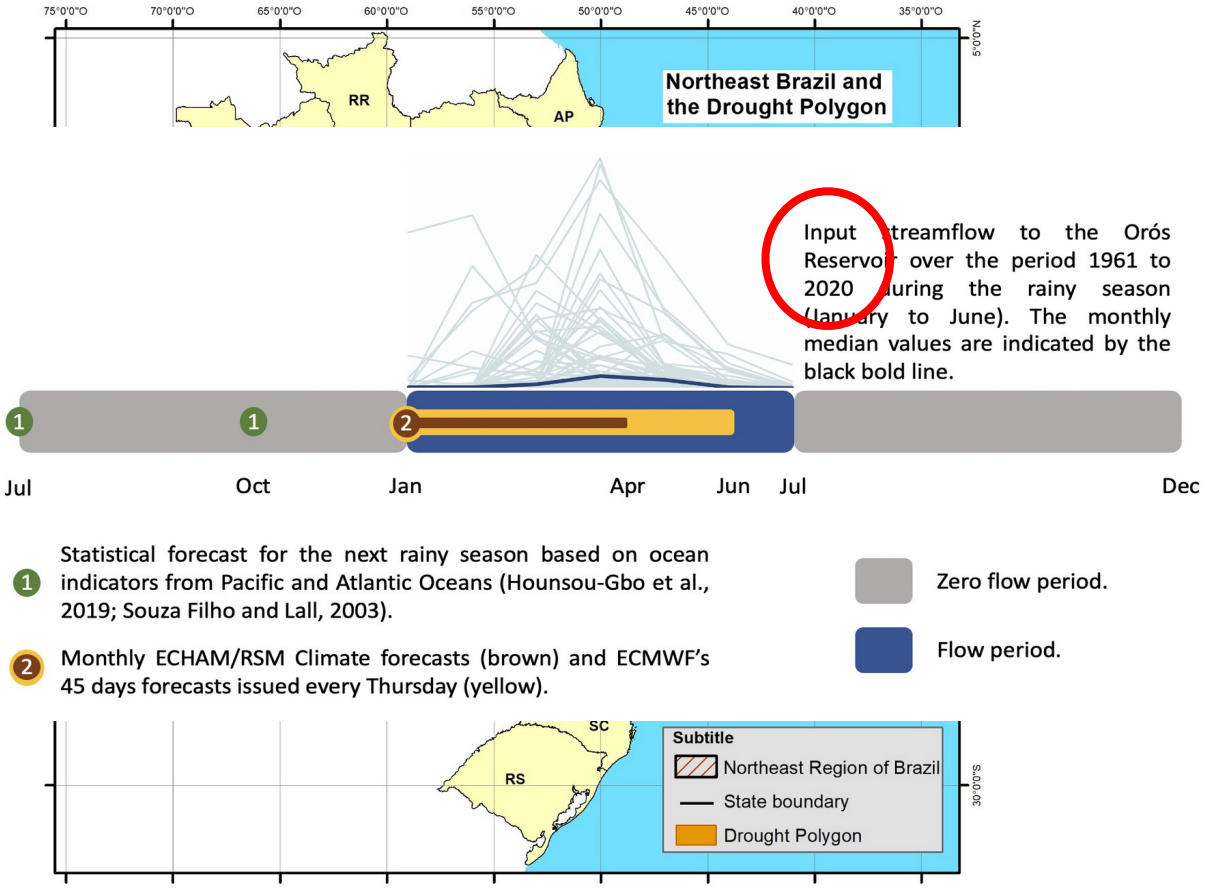
São José dos Campos, SP, Brazil

Case of Study – Ceará State, Brazil



Seasonal Forecasts in January for the horizon January to May

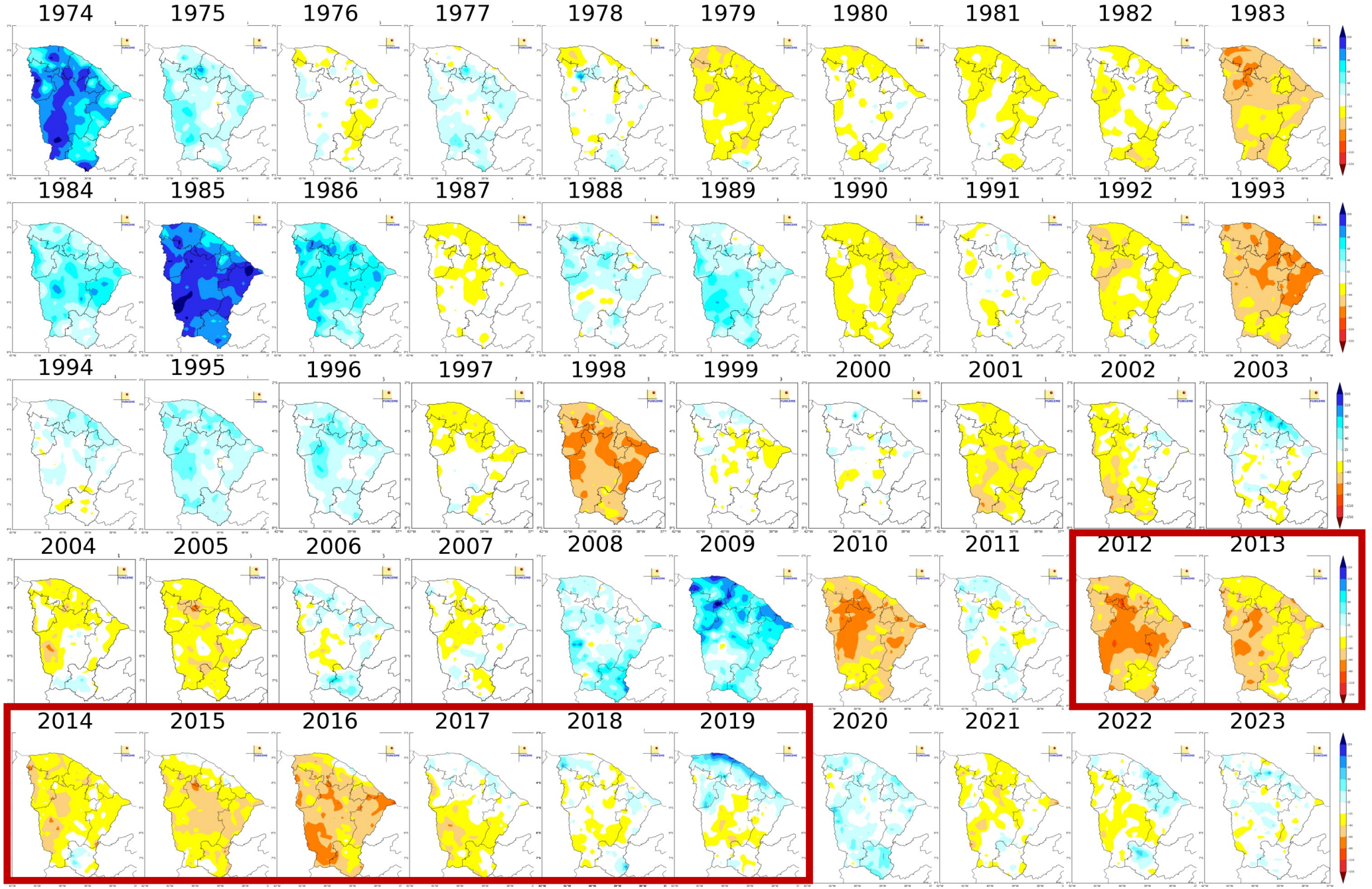
RATIONALITY OF THIS CHOICE:

1. January is the moment just before the onset of the most important season for the state (FMAM), which accounts for 75% of the year's rainfall;

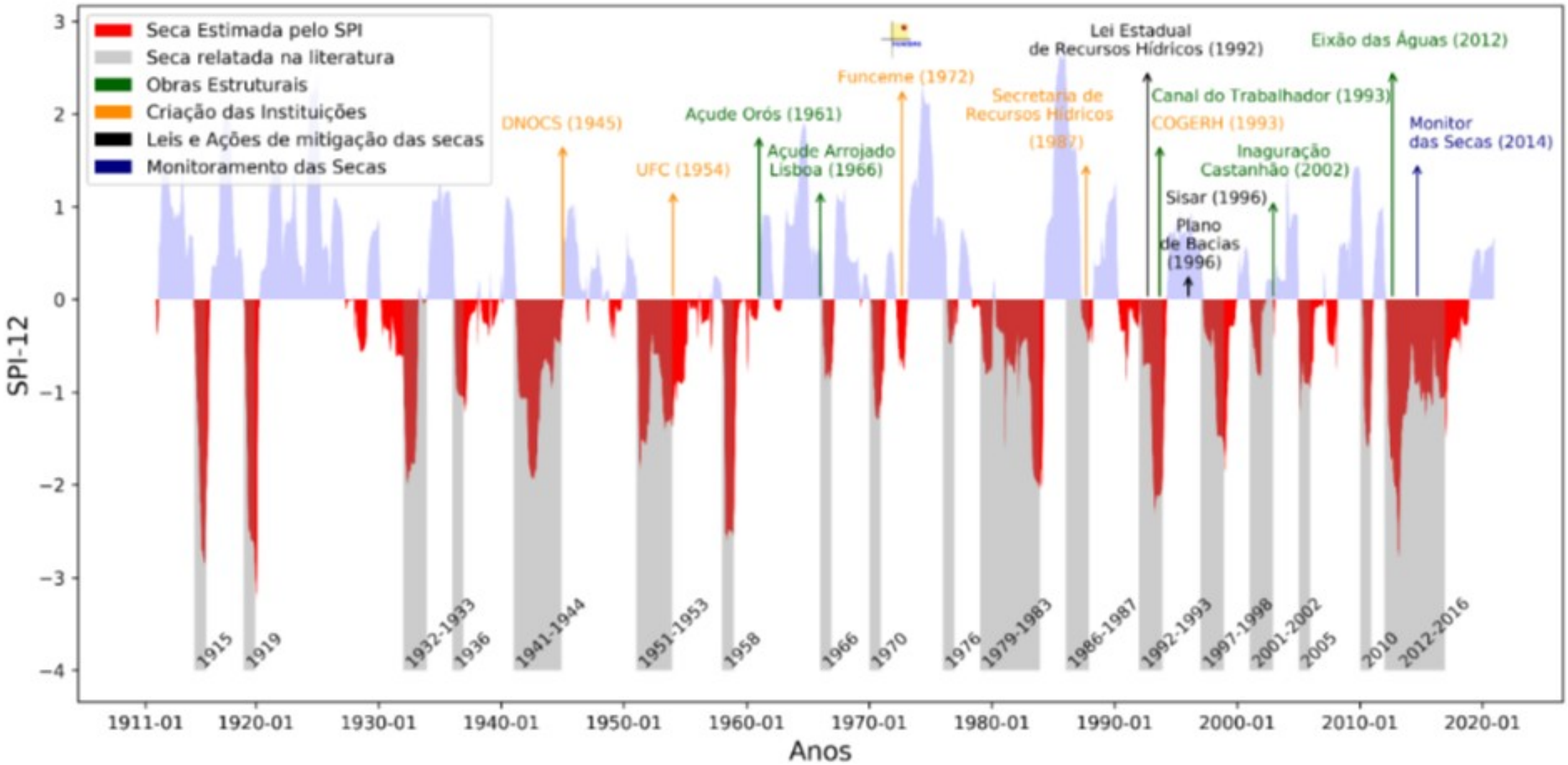
2. The relationship between inflows for all (157) monitored reservoirs of the state and average rainfall over the period JFMAM is quite well determined.

3. Other authors have explored this relationship for hydrographic basins of the state of Ceará using different techniques [Block et al., 2009].

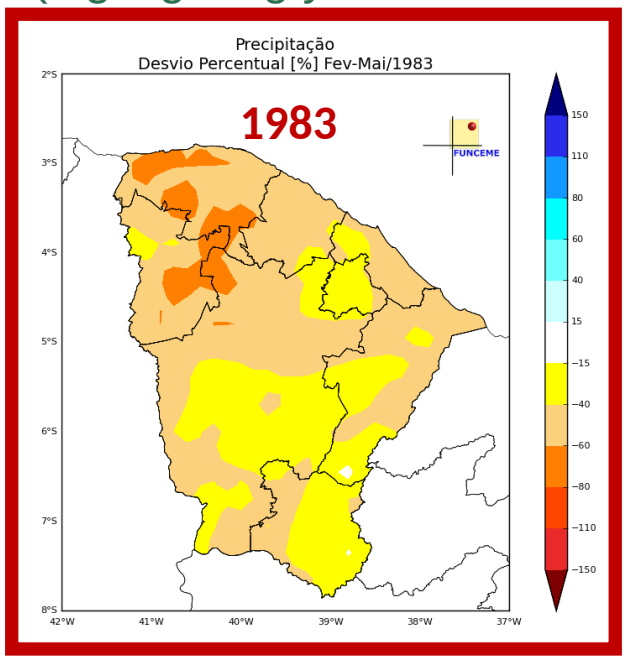
Percentage Deviation of Precipitation for the Rainy Season in Ceará (1974 to 2023)

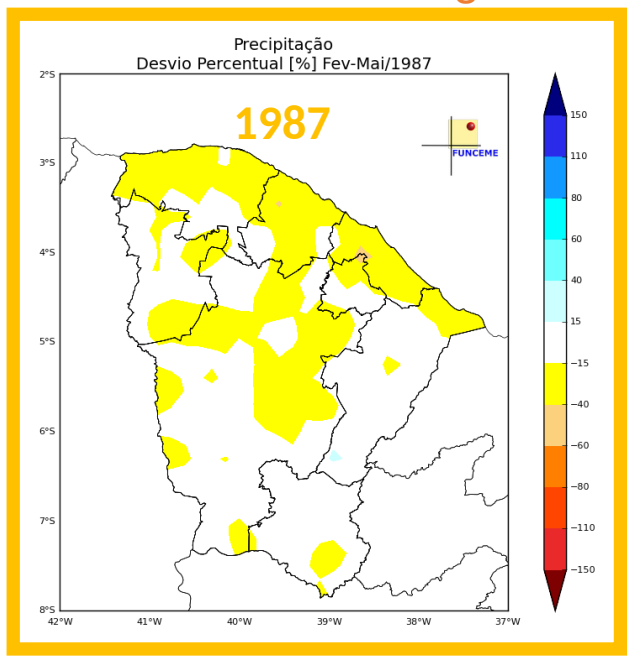


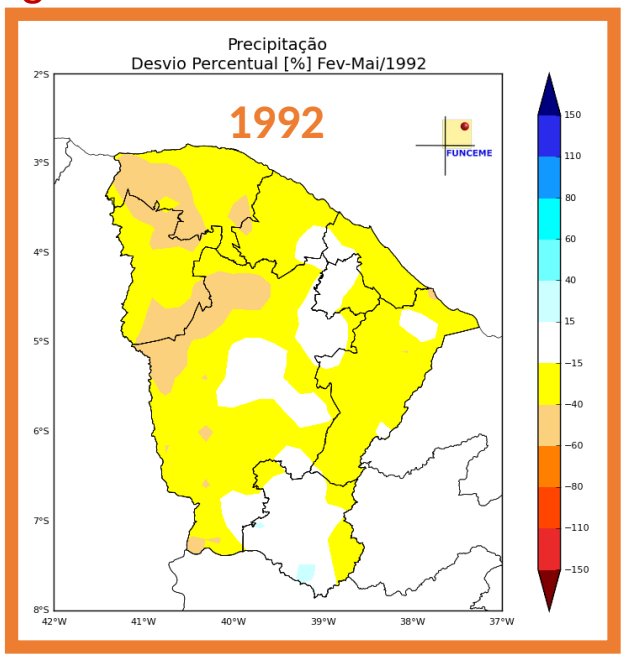
Droughts and response measures in C

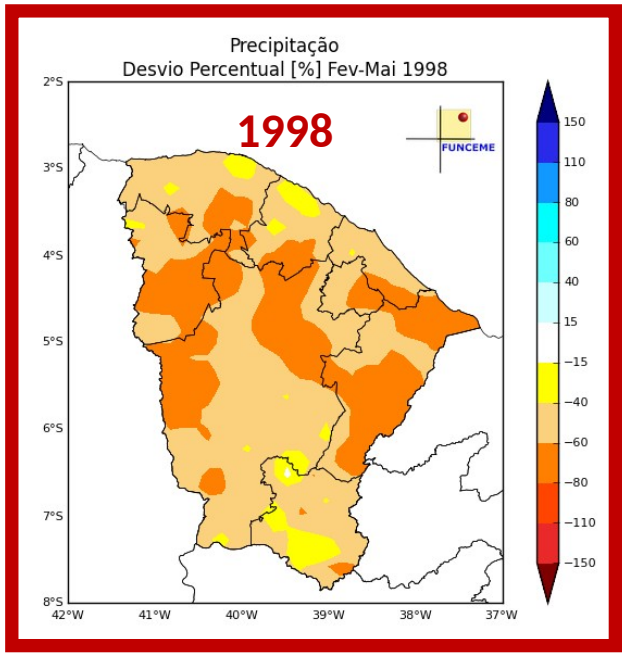


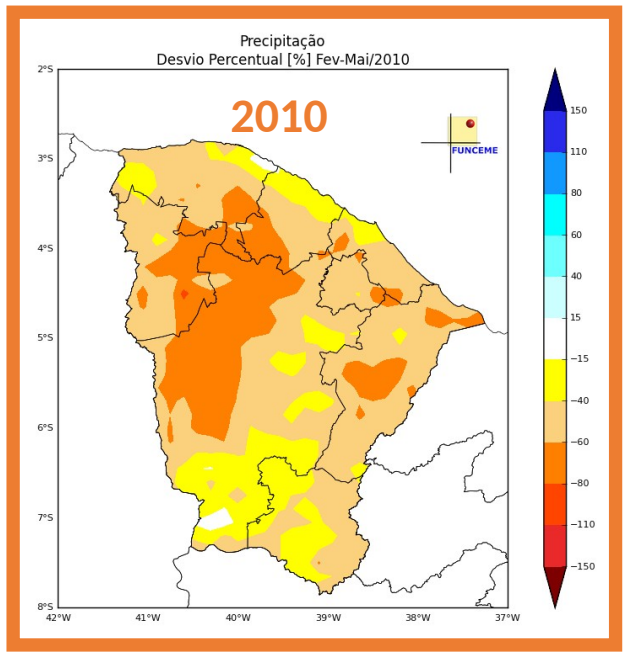
Rainfall during the rainy season from 1974 to 2023 in the state of Ceará (highlighting years with moderate, moderate to strong and strong El Niños in Dec/Jan/Feb

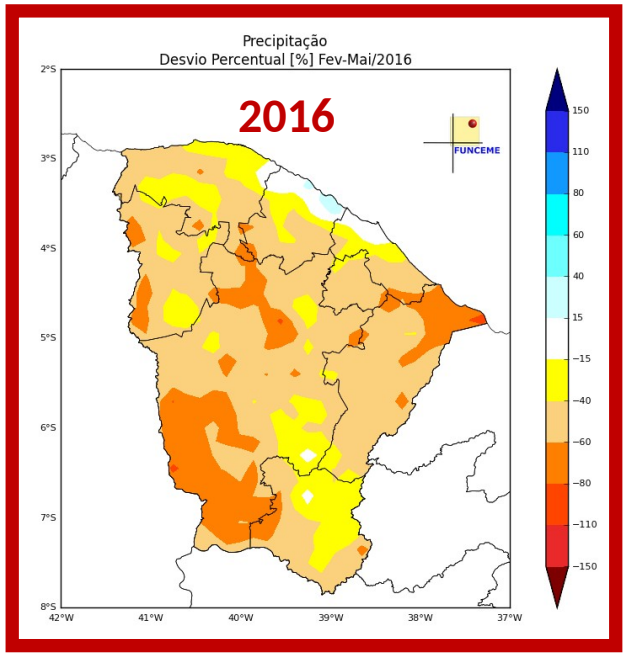










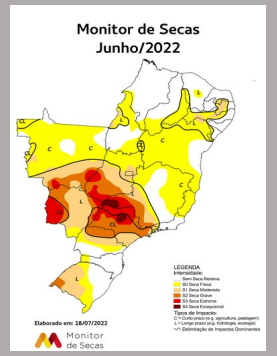


Importance of Seasonal Forecasts in Ce

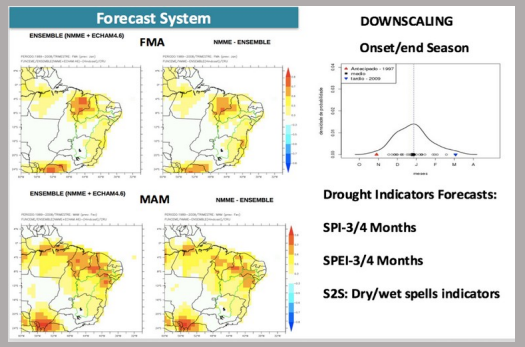
Drought Proactive Management

Water Allocation

Brazilian Drought Monitor



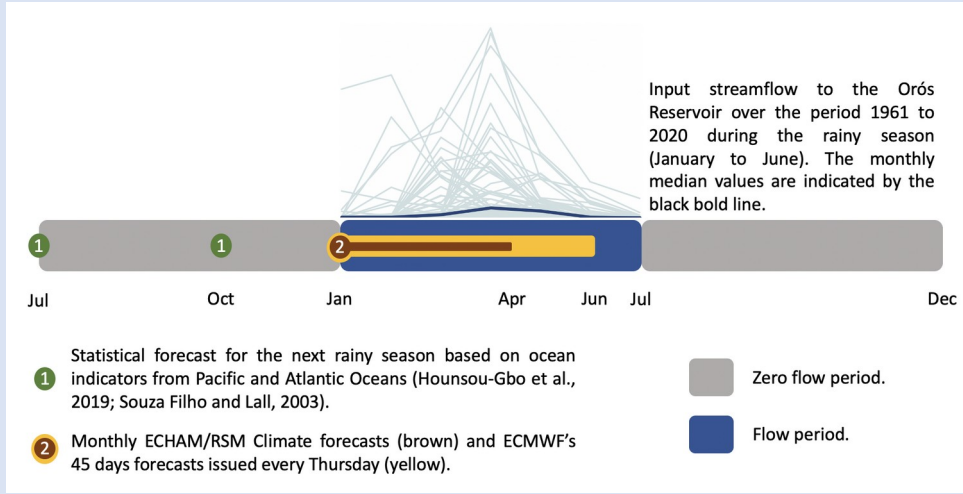
Brazilian Forecast System



Monitoring and forecasting/early warning

Vulnerability/resiliency and impact assessment

Mitigation* and response planning and measures



Seasonal Forecasts

Inflow Forecast

Water Committees Decision

Factors that affect Seasonal Forecasts

01

PERIOD OF REFERENCE
(length and timing)

02

CALIBRATION PROCESS

03

MODEL(S)'S CHOICE
Multiensemble Method

01

PERIOD OF REFERENCE
(length and timing)

01

HINDCAST: 1981 – 2010
VERIFICATION: 1971-1980, 2011-2023

02

HINDCAST: 1991 – 2020
VERIFICATION: 1971-1990, 2021-2023

02

CALIBRATION PROCESS

01 RAW FORECASTS FITTED TO A GAMMA/NORMAL DISTRIBUTION

02 RATIO OF PREDICTABLE COMPONENTS CORRECTION FITTED TO A GAMMA/NORMAL DISTRIBUTION

03 BAYESIAN NORMAL MODEL (PRIOR & LIKELIHOOD): CONSTANT AND VARYING VARIANCE MODELS

04 BAYESIAN GAMMA MODEL (PRIOR & LIKELIHOOD): CONSTANT AND VARYING VARIANCE MODELS

03

MODEL(S)'S CHOICE

Multiensemble Method

01 **ECHAM4.6 MODEL – 20 Members**

02 **COARSE MODEL: 02 PIXELS IN CEARÁ**

03 **ATMOSPHERIC MODEL**

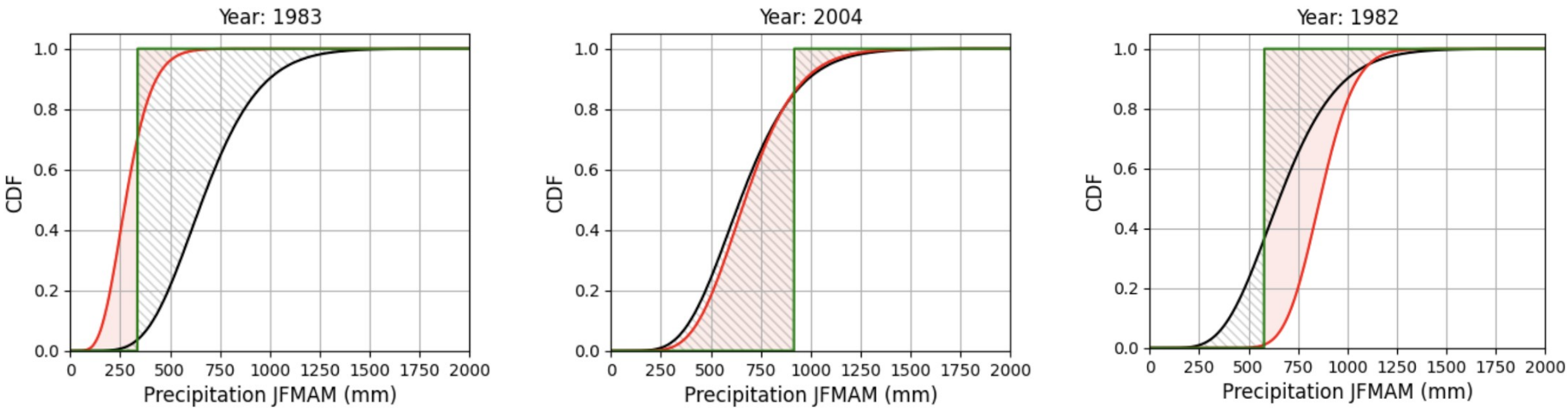
How can we define a good quality prediction?

01 Are the forecasts more accurate than climatology or even chance? (Skill)

02 How effectively do the forecasts differentiate between events and non-events? (Discrimination)

03 Can the identified probabilities be considered trustworthy? (Reliability)

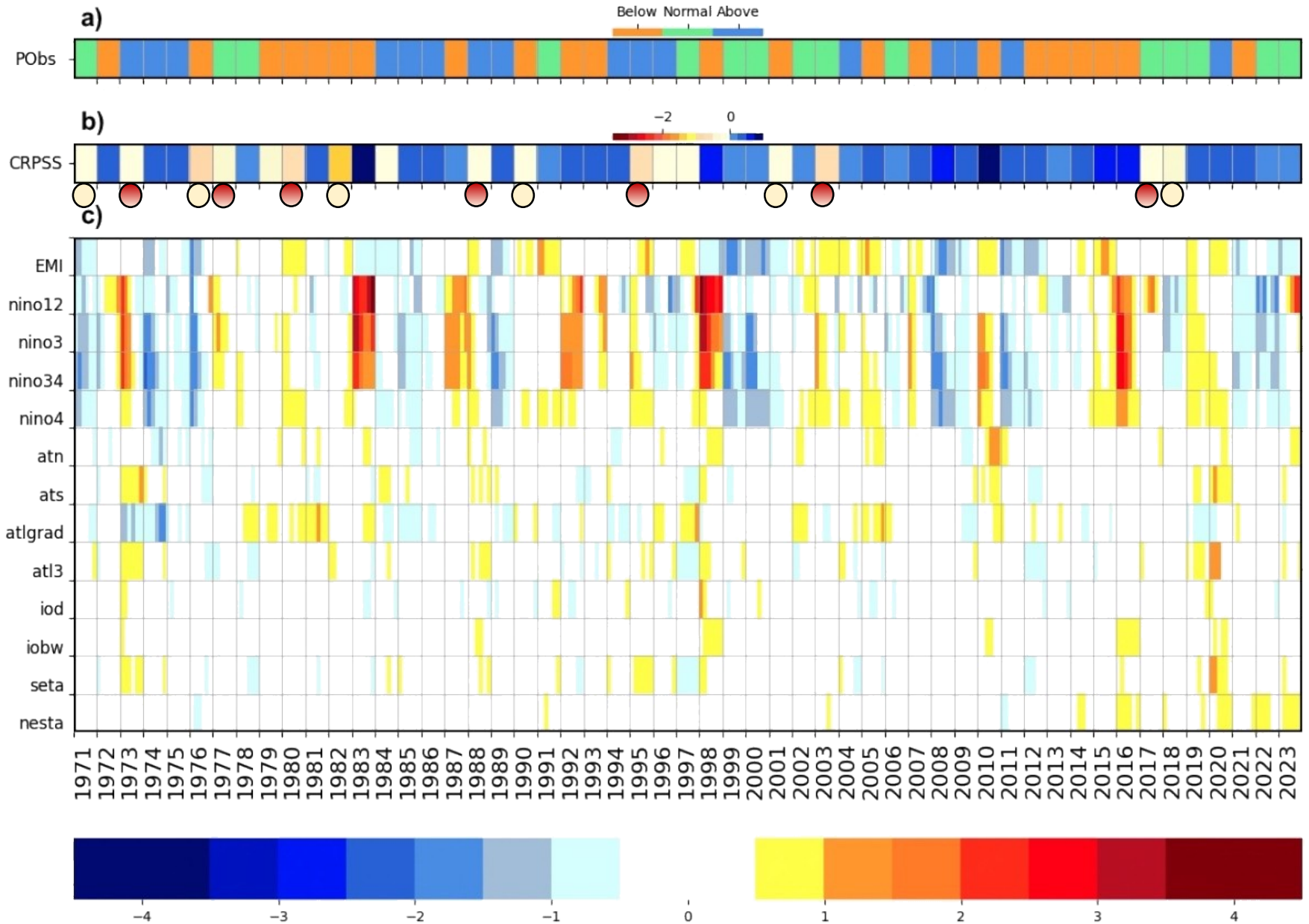
01 Are the forecasts more accurate than climatology or even chance? (Skill)



Examples of Forecasts for Ceará state and years (a.) 1983 (CRPSS = 0.84), (b.) 2004 (CRPSS = 0.08) and (c.) 1982 (CRPSS = -2.28). Pink: area between the forecast cdf and the step function; Hatched area (\\): area between the climatology cdf and the step function.

Its tercile version was also considered in the analysis.

01 Are the forecasts more accurate than climatology or even chance? (Skill)

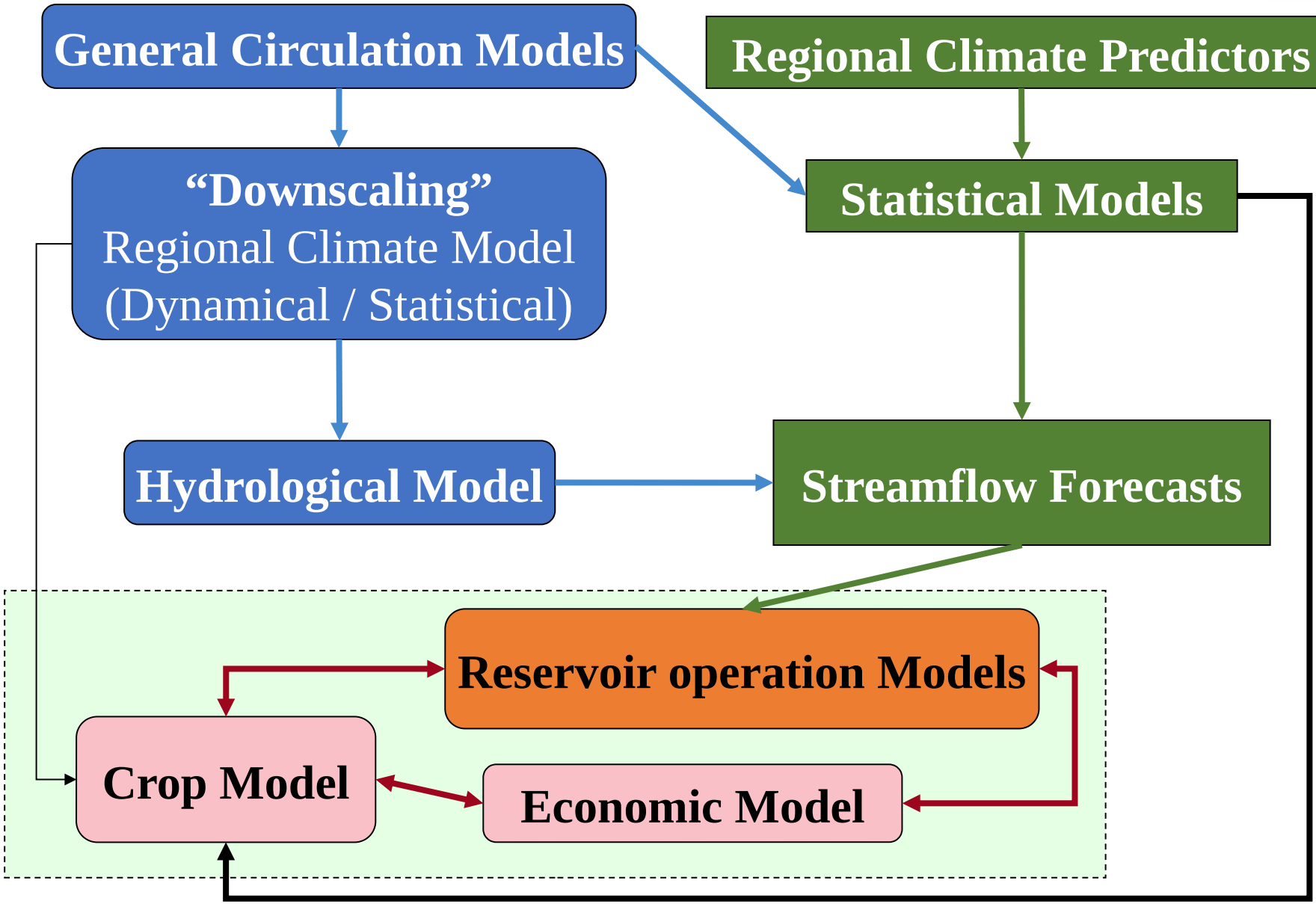


Summary for the period 1971-2023 of (a) observed precipitation category for JFMAM; (b) monthly SST indexes for the period DJFMAM; and (c) CRPSS for the forecasts calibrated by cross-validation with the hindcast 1981-2010 series and BNPL-CV.

- **Near neutral conditions in the Tropical Atlantic combined with near neutral/slightly - conditions in the Equatorial Pacific**

- **Persistent anomaly conditions are not maintained either in the Tropical Atlantic** or in **the Equatorial Pacific**

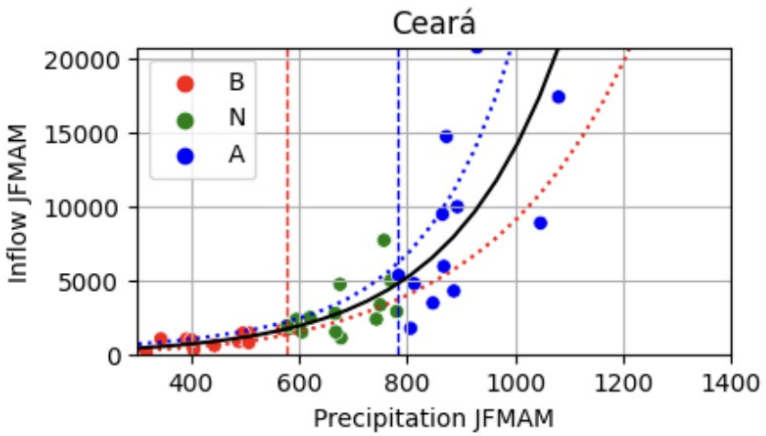
Streamflow forecasts – 3 Approaches

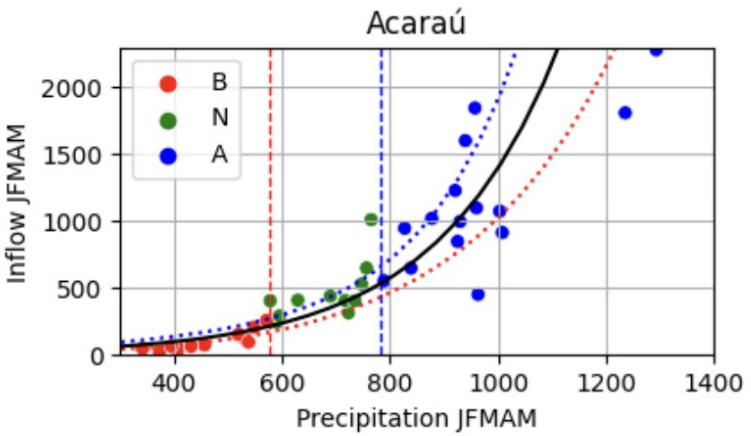


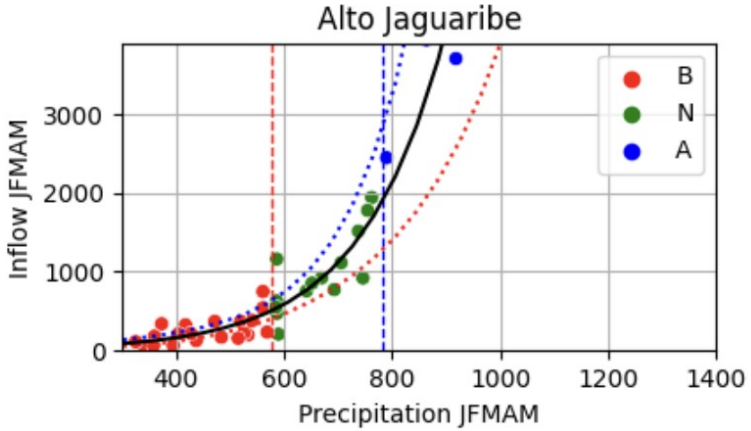
Inflow Forecasts

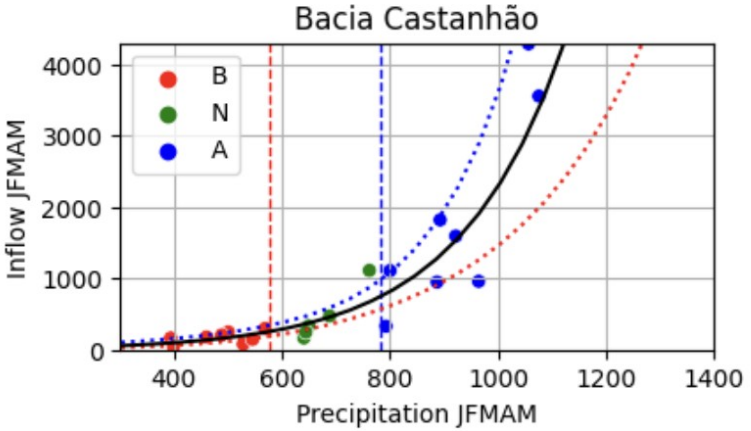
CEARÁ + H.Rs.

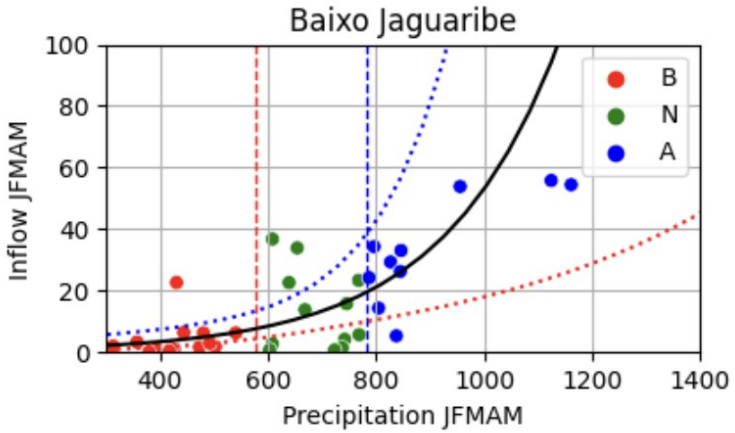
Identified Relationship by a **Generalized Linear Model (Gamma Error and Log link)** between inflows (Q) for all monitored reservoirs of the state and average precipitation (P_JFMAM) over the period JFMAM.

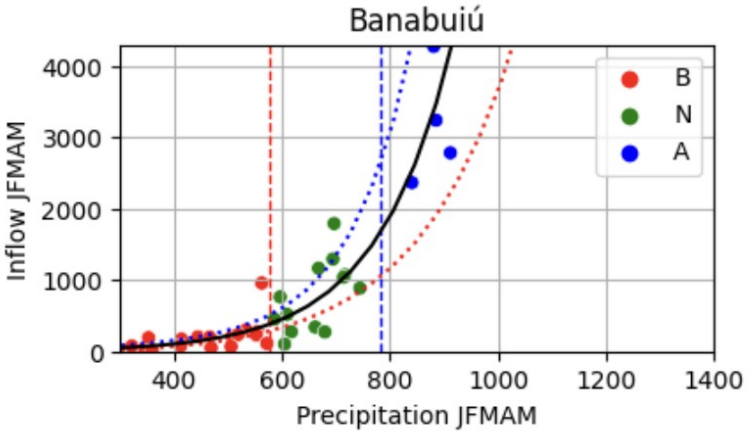






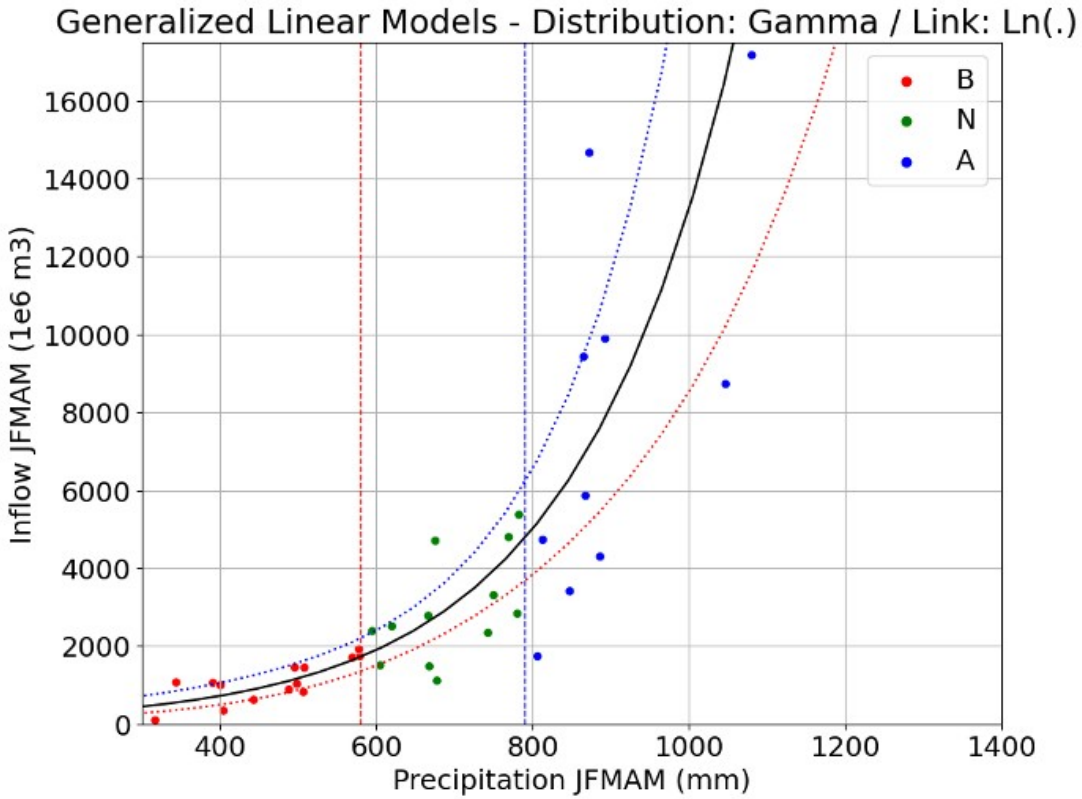






Inflow Forecasts

CEARÁ

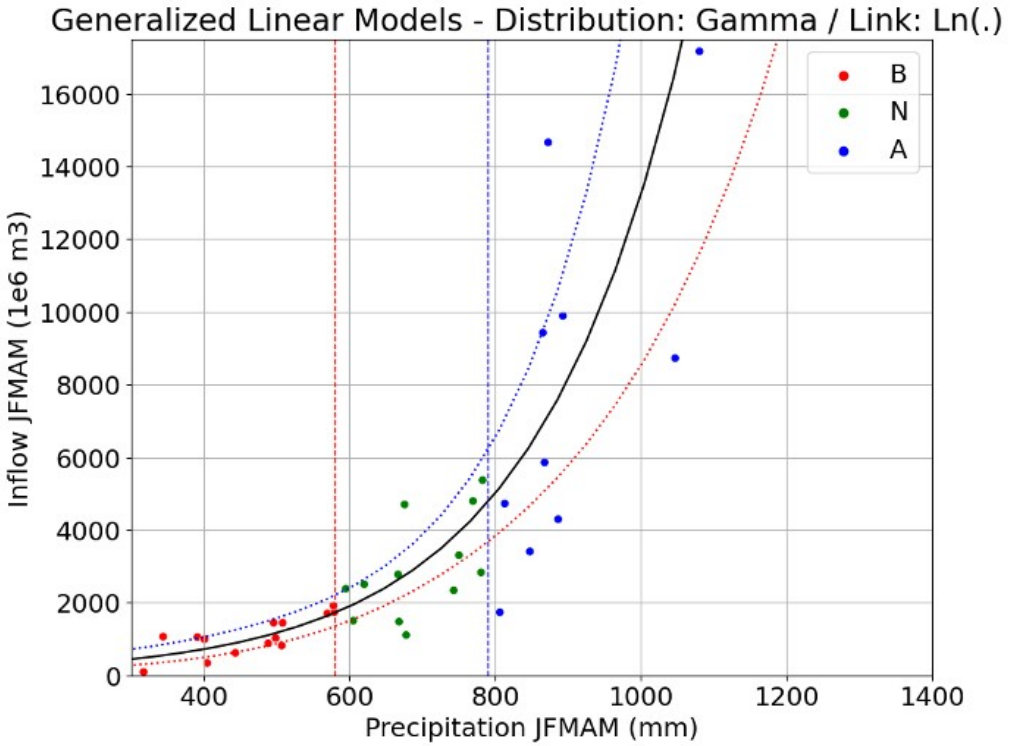


Identified Relationship by a Generalized Linear Model (Gamma Error and Log link) between inflows (Q) for all monitored reservoirs of the state and average precipitation (P_JFMAM) over the period JFMAM.

Inflow Forecasts – Gamma Model

Precipitation Gamma distribution

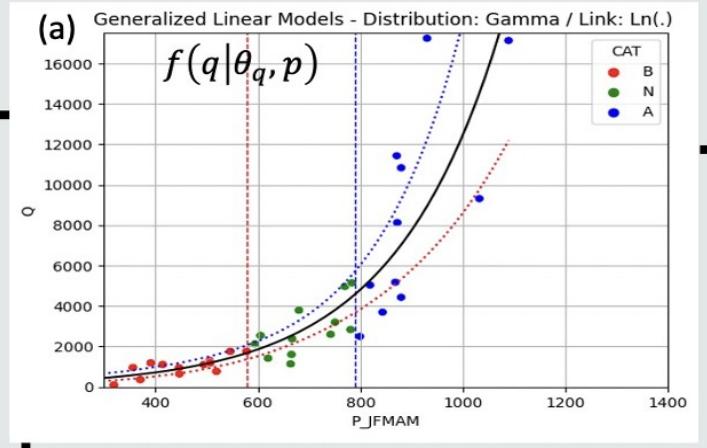
Inflow Gamma-Log GLM

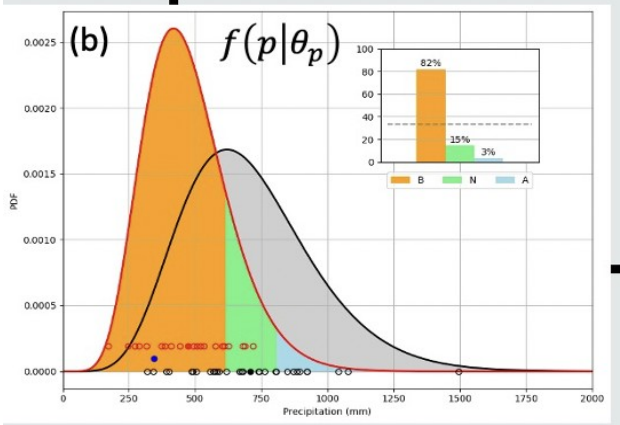


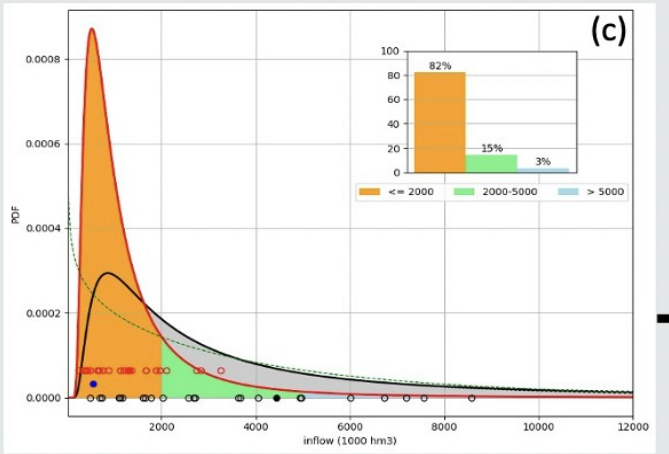
Identified Relationship by a Generalized Linear Model (Gamma Error and Log link) between inflows (Q) for all monitored reservoirs of the state and average precipitation (P_JFMAM) over the period JFMAM.

$$\phi \text{ is the scale parameter of the Gamma - Log GLM model } Q(p$$

Inflow Forecasts

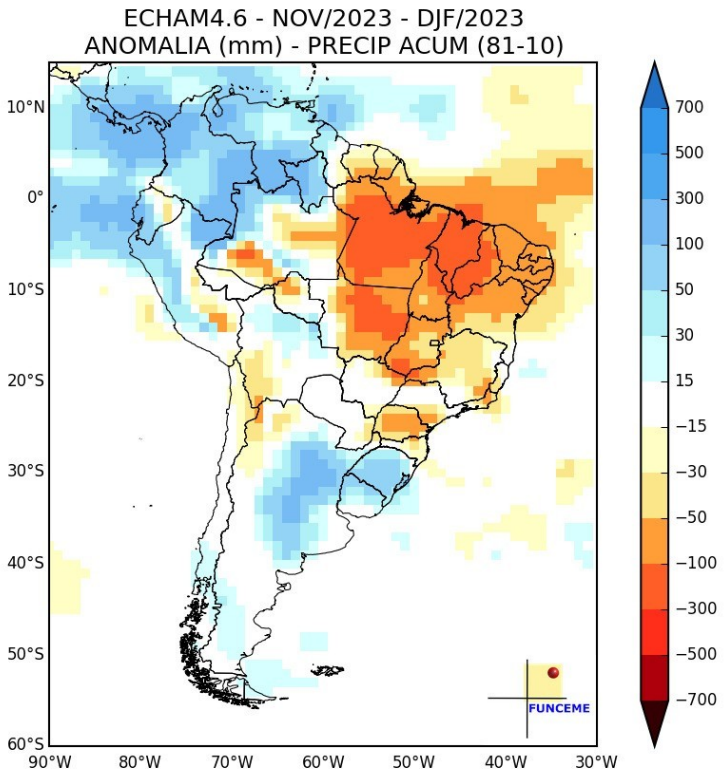


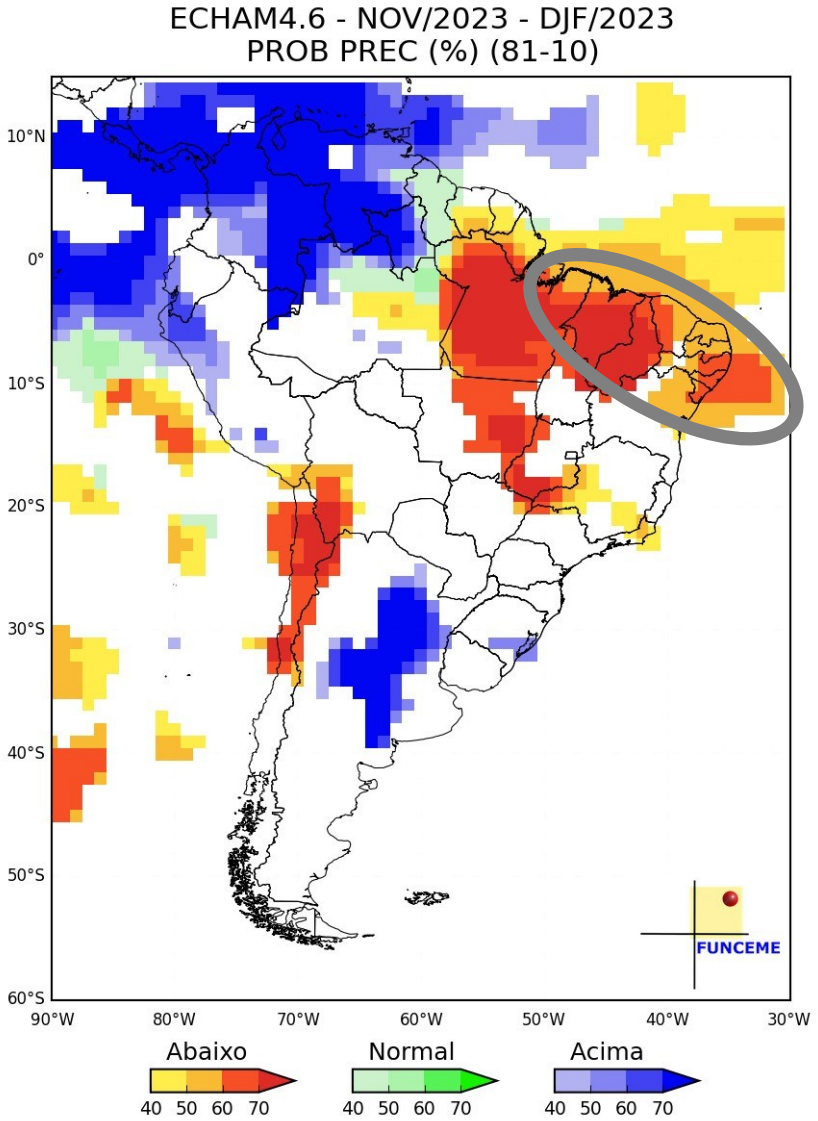




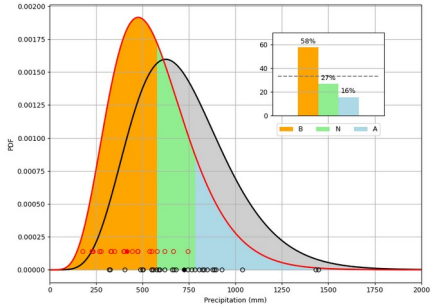
$$f(q_i|\theta_q). = \int_0^{+\infty} f(q_i|\theta_q, p). f(p|\theta_p) \, . dp$$

Precipitation Anomaly Forecast issued in Nov for Dec2023 to Jan2024

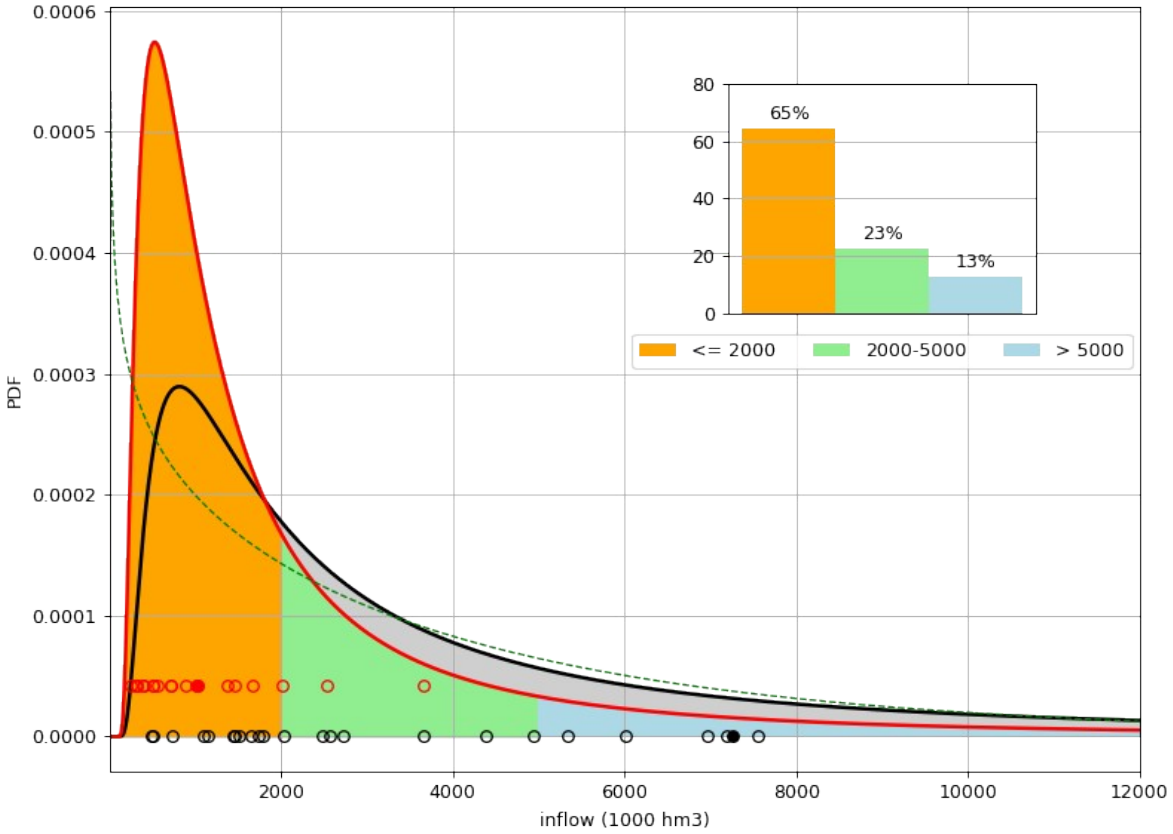




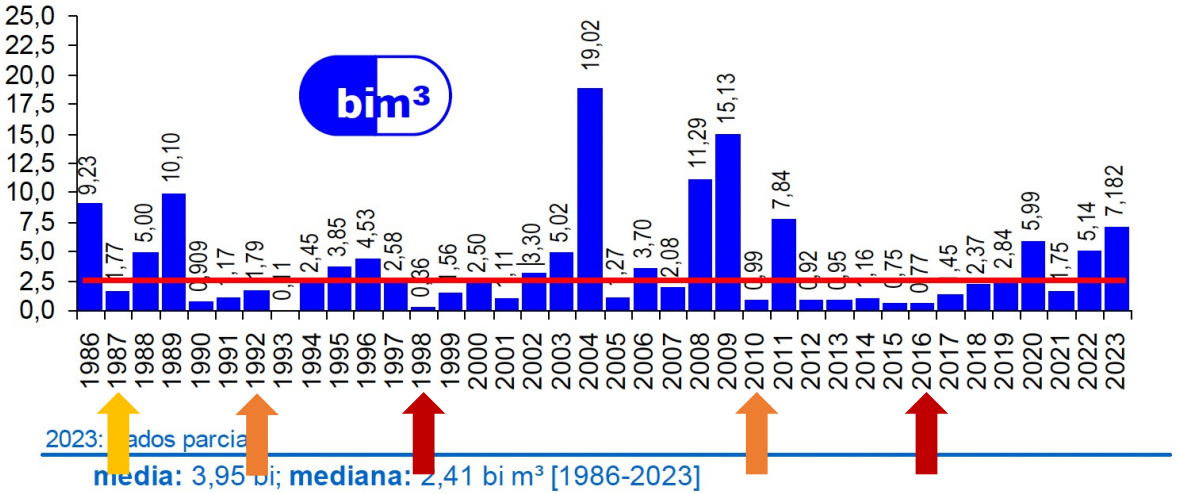
Inflow forecasts for the monitored reservoirs of Ceará (Jan to May)



2024 JFMAM

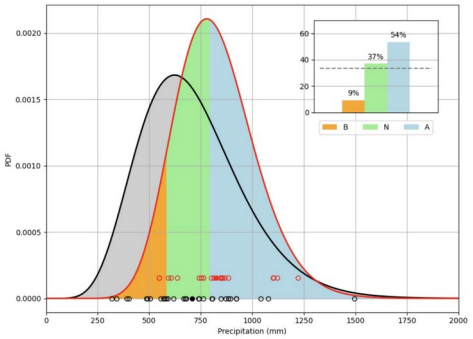


EVOLUÇÃO APORTE*

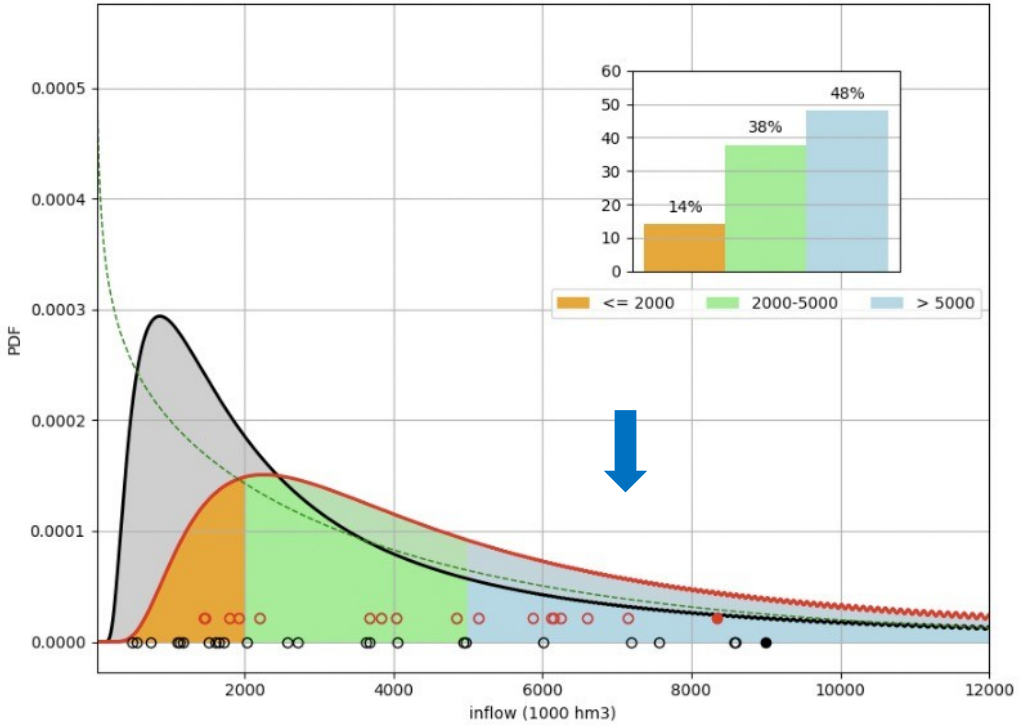


Moderate, moderate to strong and strong El Niños

Inflow Forecasts



2023 JFMAM



Observed inflow fo the state: 7.6 bi m^3

Inflow Forecasts

Precipitation forecast calibration method	H: 1986-2010	V: 2011-2023	1986-2023
RPC Gamma	0.22	0.53	0.33
BGPL	0.17	0.46	0.27

Conclusions – Seasonal Forecasts

- Seasonal forecast skill for the ECHAM4.6 model/Inflow forecasts varies over time and depends on choices made by the modeler, including reference hindcast series, calibration strategy, and calibration method;

- Performance is significantly influenced by the presence and timing of multiyear droughts (e.g. 2012-2018 multi-year drought);

- The choice of hindcast series and calibration methods impacts the results, with cross-validation strategy showing more stability than fixed period calibration;

- Skill is highest when the calibration and verification periods encompass the multi-year drought;

Conclusions 01 – Seasonal Forecasts

- Among all methods tested, BNPL-CV, LR-OLS, and BGPL are prominent in terms of RPSS/CRPSS results, with **BNPL-CV** showing the fewest extreme negative values.

- Poor CRPSS values can be attributed to:
  - Near neutral conditions in the Tropical Atlantic combined with near neutral or slightly negative conditions in the Equatorial Pacific (e.g., 1971, 1976, 1982, 1990, 2001, 2018)
  - Persistent anomaly conditions are not maintained either in the Tropical Atlantic (e.g. 1984, 1996, 1997) or in the Equatorial Pacific (1973, 1977, 1980, 1988, 1995, 2003, 2017) during the period from December to May.

- Among all calibration experiments, the BNPL-CV method stands out as the most reliable for raw predictions.

Conclusions 01 – Seasonal Forecasts

- In conclusion, after extensive evaluation, the BNPL-CV method emerges as the most promising for its skill, category discrimination, and reliability. It consistently produces accurate and trustworthy seasonal forecasts across different experiments.