CHARACTERISTICS AND PREDICTABILITY OF DRY SPELLS IN SOUTHEASTERN BRAZIL

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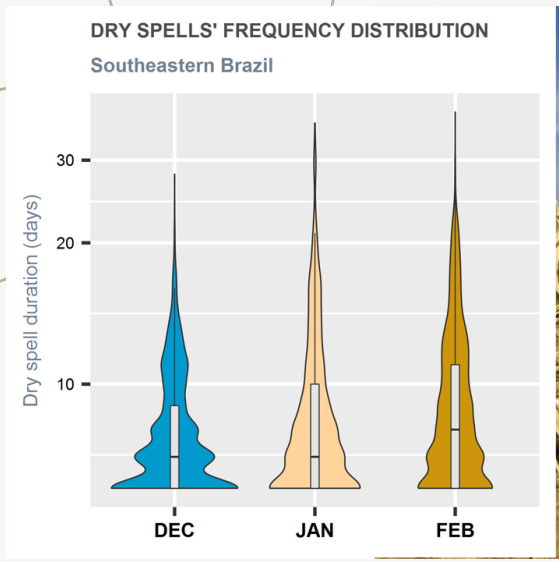


PROBLEMA

INTERVALO DE MERCADO

Poucos, se é que há, produtos no mercado que ajudam clientes como nós

CLIENTES

66% dos consumidores dos EUA gastam dinheiro em vários produtos que resolvem apenas parcialmente seu problema

FINANÇAS

A geração do milênio responde por cerca de um quarto dos US$ 48 bilhões gastos em outros produtos em 2018

CUSTOS

Perda de produtividade custando aos consumidores milhares de dólares

OBJECTIVES

1. To explore and summarize the main statistical properties of dry spells, such as duration, geographic predominance, subseasonal variability, and association with precipitation in Southeastern Brazil (SEB).
2. Objectively assess S2S forecasts of dry spells in SEB, within a context of potential value for aiding decision-makers.

DATA

The model under evaluation is the Met Office global seasonal prediction system (GloSea5; MacLachlan et al., 2015; Williams et al., 2015).

The daily rainfall used for dry spells' characterization is the multi-source weighted-ensemble precipitation (MSWEP) data set (Beck et al., 2017).

The dataset used to validate the dry spells' forecast was produced by the Climate Hazards Group Infrared Precipitation with Stations (CHIRPS; Funk et al., 2015).

WHY SOUTHEASTERN BRAZIL?

It is part of the subtropical climate region in Brazil. Monsoonal rainfall regime, SACZ episodes, frontal systems, cyclones, meso-scale systems and local convection.

It comprises four federal units: São Paulo (SP), Minas Gerais (MG), Rio de Janeiro (RJ), and Espírito Santo (ES).

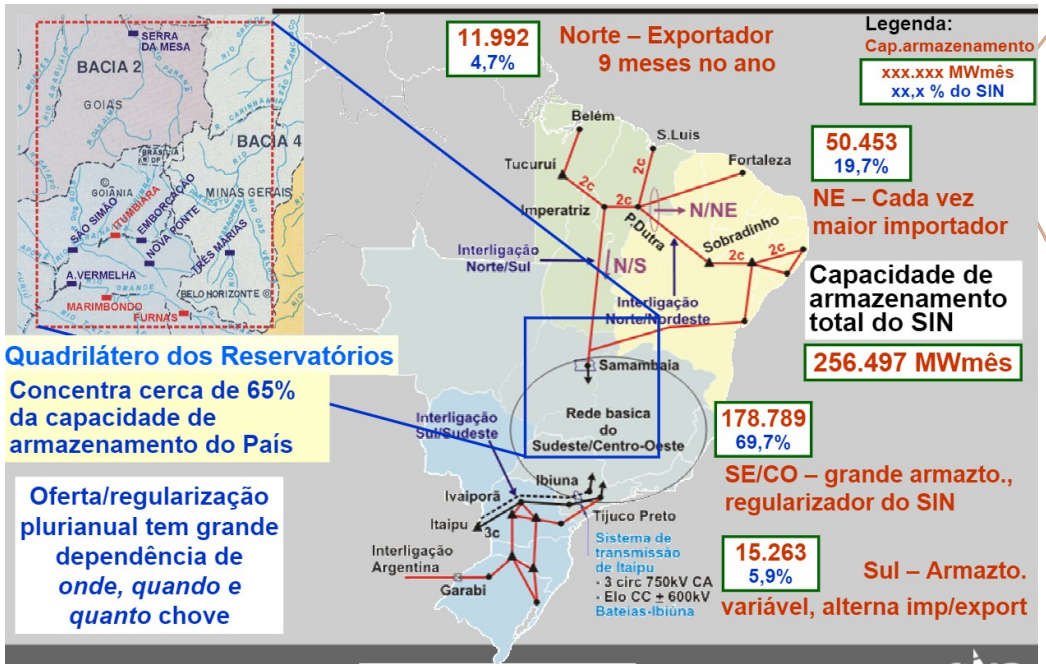
The SEB is strategic for Brazil.

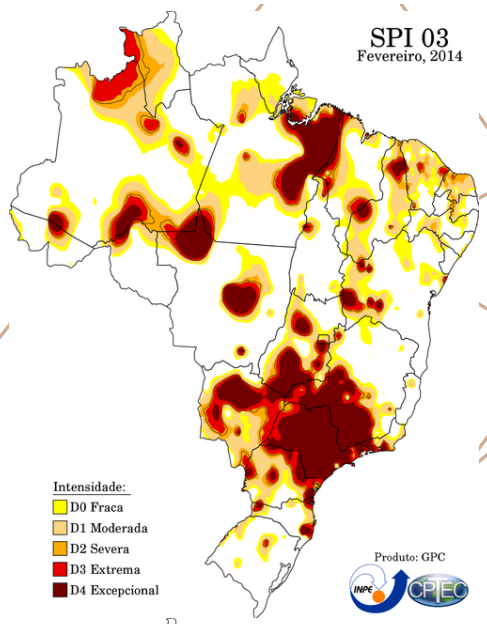
- It is the most populated region of the country. SEB concentrates 41.9% of the population of Brazil (IBGE, 2014)
- Concentrates more than half (55.3%) of the gross national product (GNP)

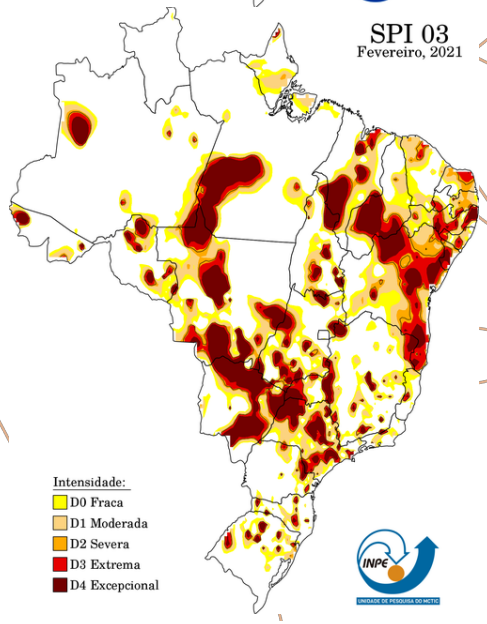
Socio-economic disasters: floods/flash floods, landslides, heatwaves, dry spells and droughts

WHY SOUTHEASTERN BRAZIL?

Large portion of **THE RESERVOIRS SQUARE** is located in SEB. It holds for 65% of the water storage in Brazil. About one third of the electricity.







2013/2014

Brazil Drought: Worst Water Crisis In 80 Years Affecting Four Million People In Country's South East

BY IBTIMES UK ON 01/25/15 AT 12:17 AM

2020/2021

Environment

Brazil on drought alert, faces worst dry spell in 91 years

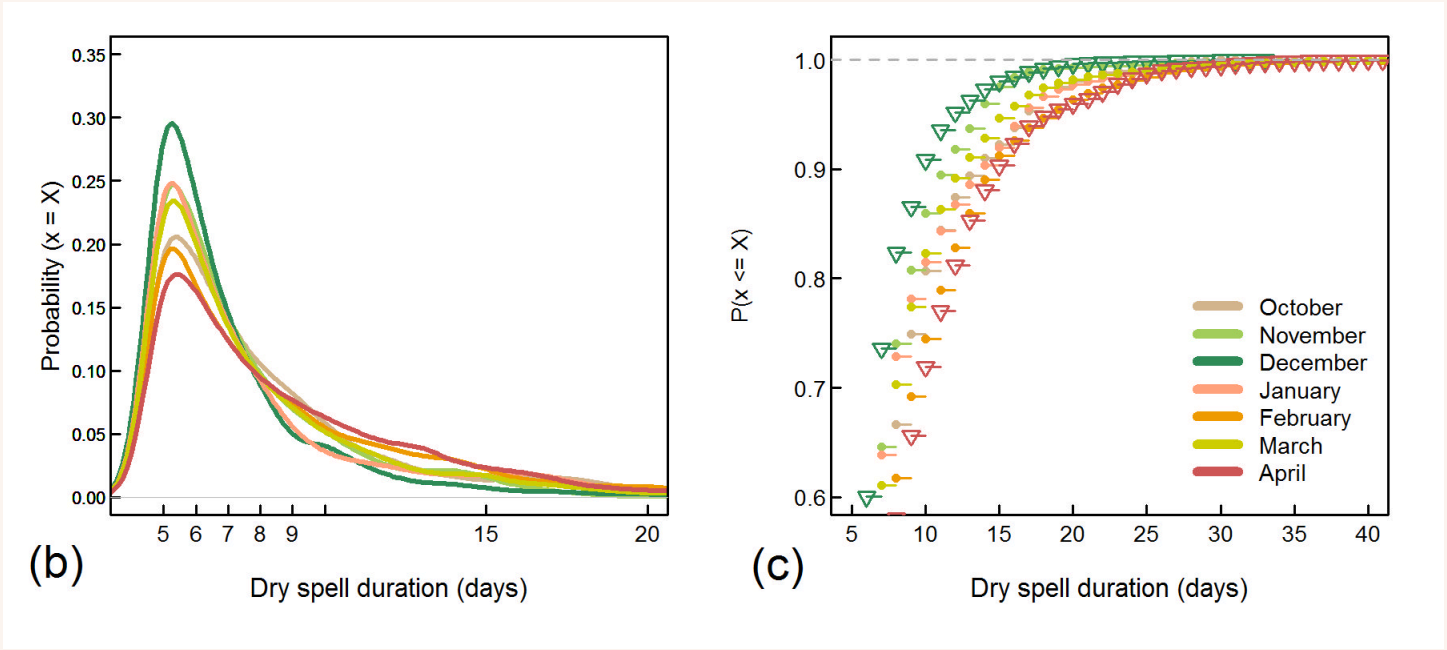
By Ana Mano and Roberto Samora

EXPLORATORY ANALYSIS OF DRY SPELLS' DURATION

Considering the whole SEB.

Enveloped by one driest (April) and one wettest month (December). For a dry spell 10 days long December is 9/100, but for April, this chance increases to 28/100.

January and February ECDFs are closer to the April's ECDF than December's ECDF



January and February ECDFs are closer to the April's ECDF than December's ECDF.

For a 10-days dry spell the chances are 18/100 and 26/100, for January and February, respectively.

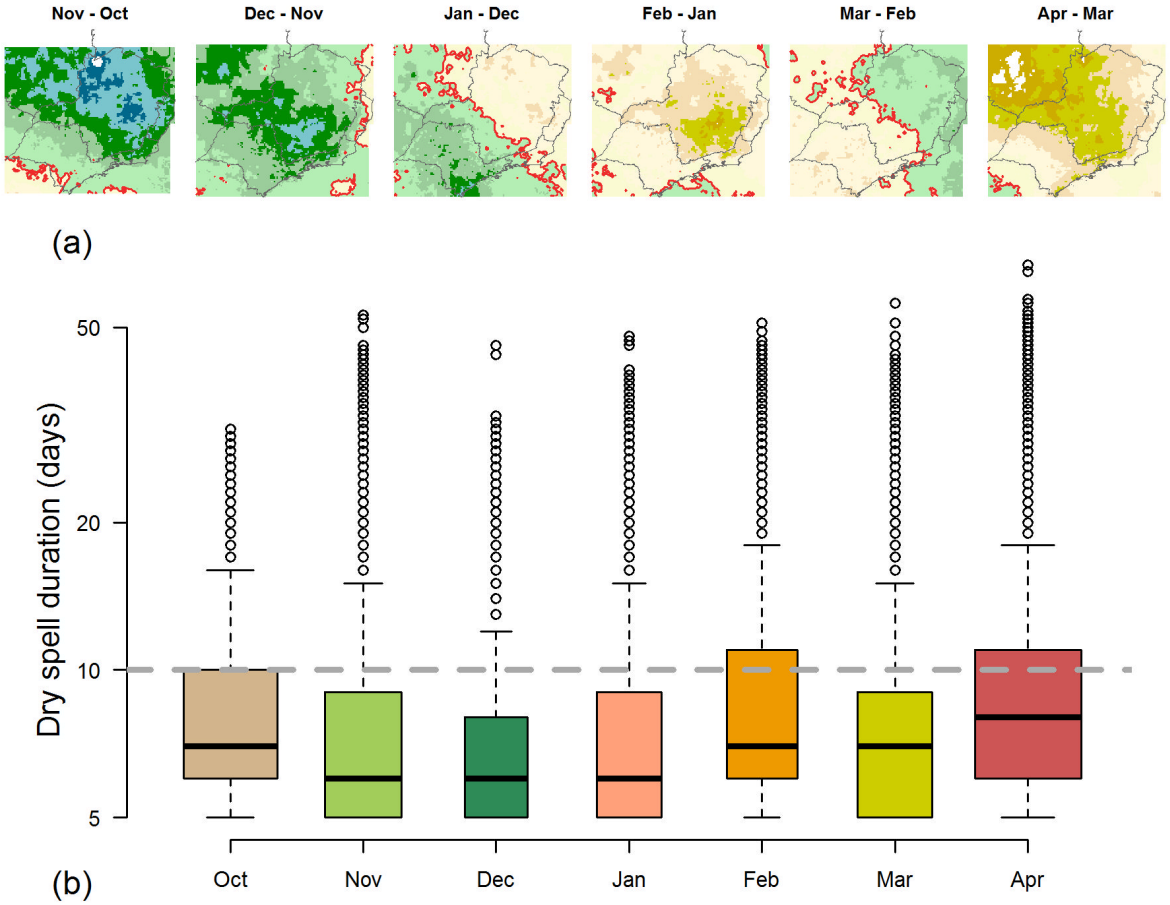
Dry spells 5–9 days long, represent 80% of all the occurrences.
10–14 days (12%), 15–19 days (3.5%), and 20–30 days (less than 2%).

SUBSEASONAL DRY SPELLS' LIFE CYCLE AND THE MONTHLY TENDENCY OF RAINFALL RATES.

December is perceptibly the month with wettest characteristics.

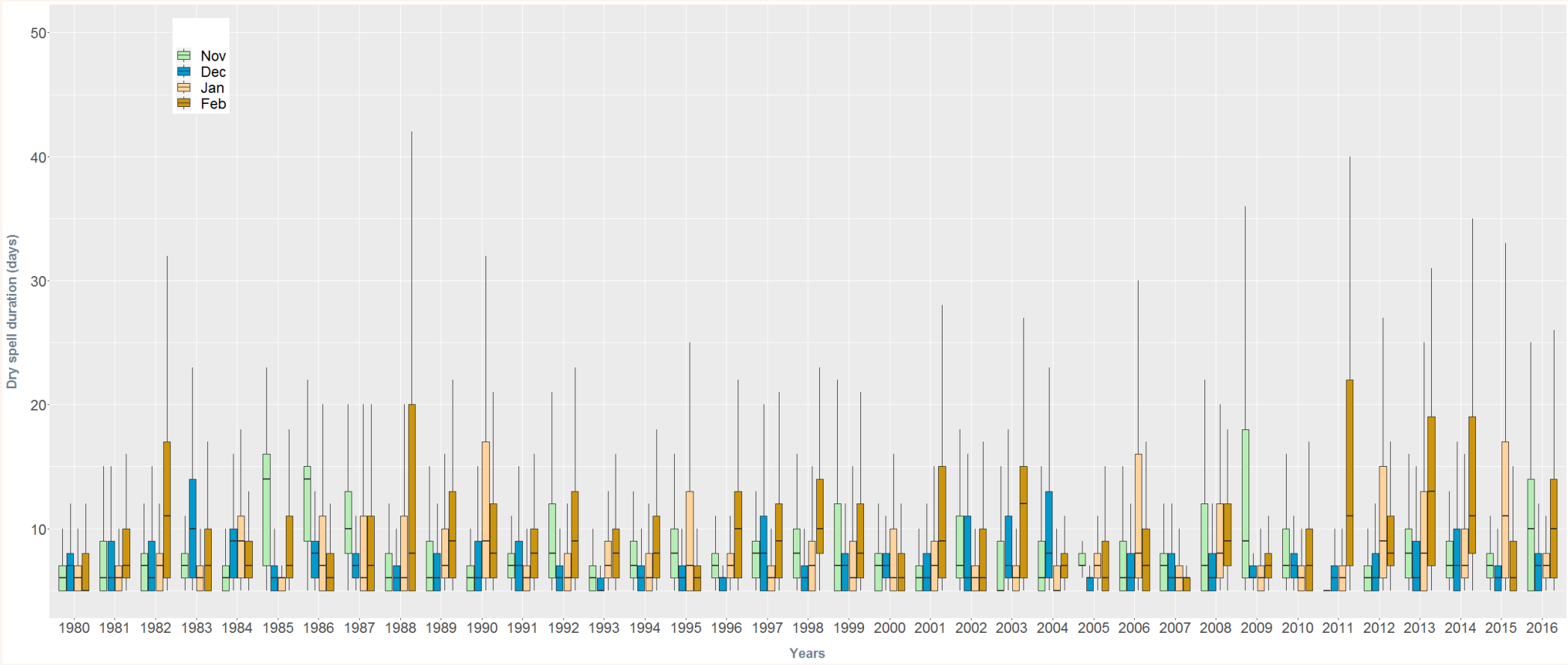
Although January and February compose the **peak rainy season** for SEB, with high rainfall rates (Grimm, 2003; Gan et al., 2004; Vera et al. 2006), from the perspective of dry spells analysis, they present drier features than December.

There is an increment in the median, mean and third quartile, mainly in February, implying that longer dry spells (up to 9 and 11 days) tend to be more frequent in January and February.



DRY SPELLS' DURATION INTERANNUAL VARIABILITY

- Most frequently is February that stands out as presenting prolonged dry spells



GEOGRAPHICAL ASSOCIATION OF DRY SPELLS AND RAINFALL

Threshold of 4 – 5 mm per day to indicate a fully developed monsoon rainy season (Marengo et al., 2001; Gan et al., 2004; Wang and Ho, 2002)

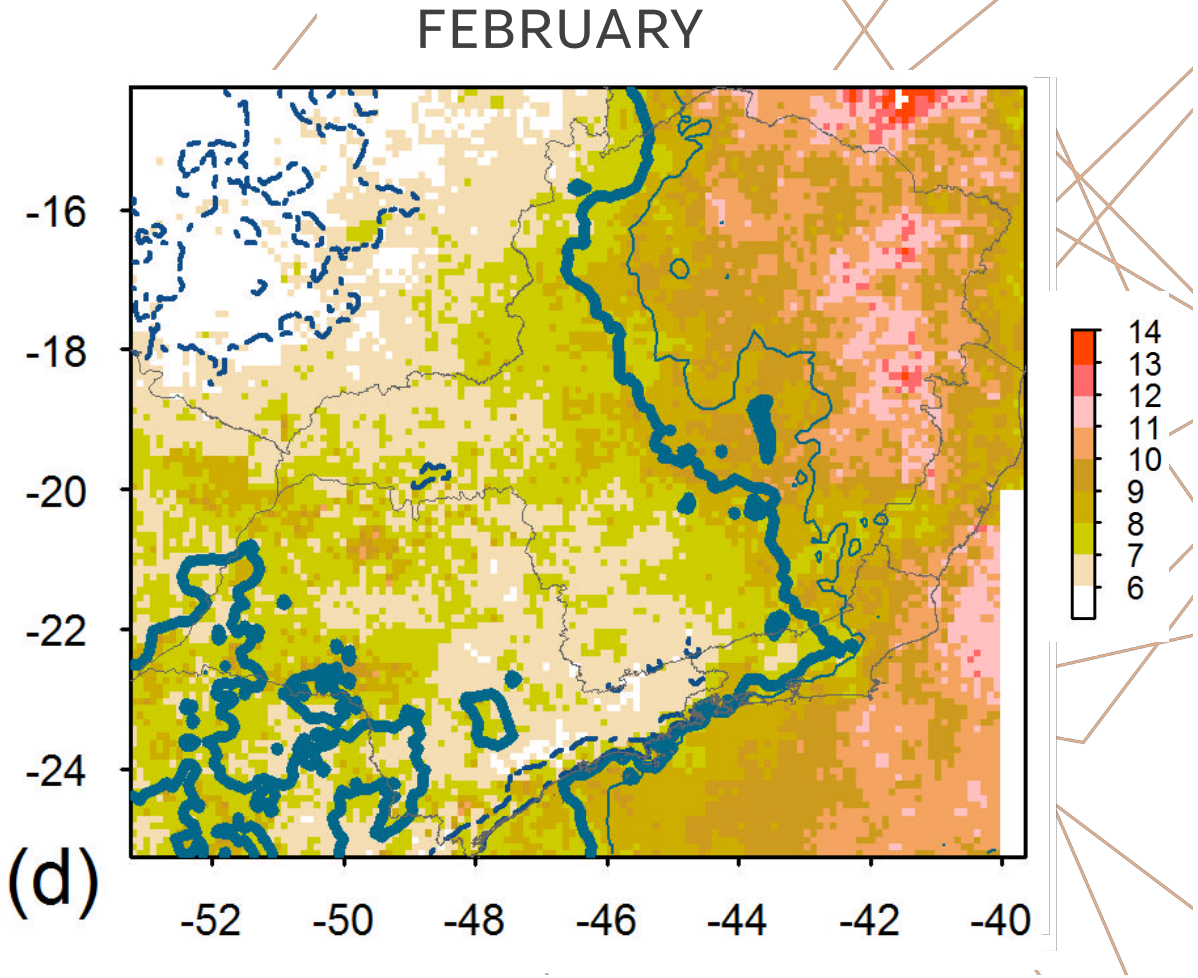
NOV: The main rainfall activity is positioned over the Brazilian Plateau and northeastward. High monthly rainfall rates might co-exist with dry spells 9 – 10 days.

DEC: The wettest month. There is an intensification of the rainfall rates (8 mm per day). Several regions with dry spells shorter than 5 days (white).

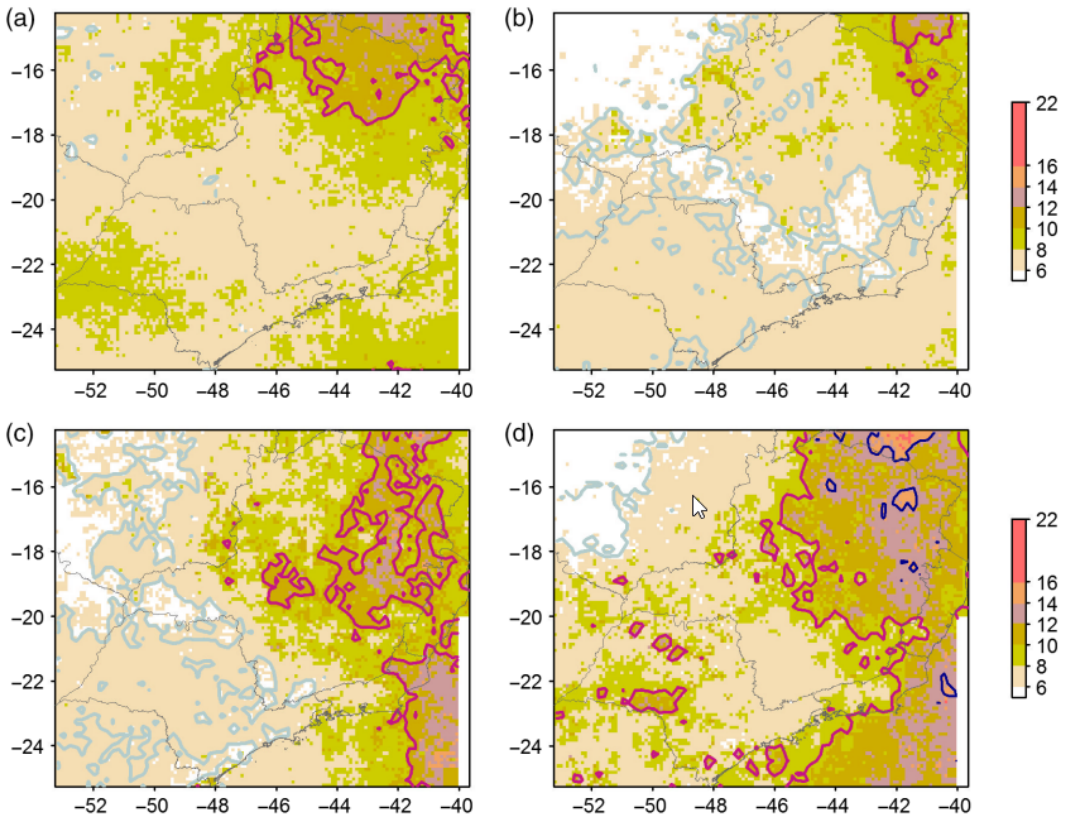
JAN: Like DEC regarding monthly rainfall rates. However, the whole envelope of substantial monthly rainfall rates is displaced southwestward. Southwestward expanding of drier conditions (7 days or longer dry spells.

FEB: The threshold that defines a mature monsoon is displaced southwestward in the north flank, in a clear association with the expansion of areas affected by longer dry spells (> 9 days).

The “core” monsoon season (Nov - Feb).
Climatology: long-term means (79/80 to 15/16)



RELATIONSHIP BETWEEN DRY SPELLS AND MONTLHY RAINFALL

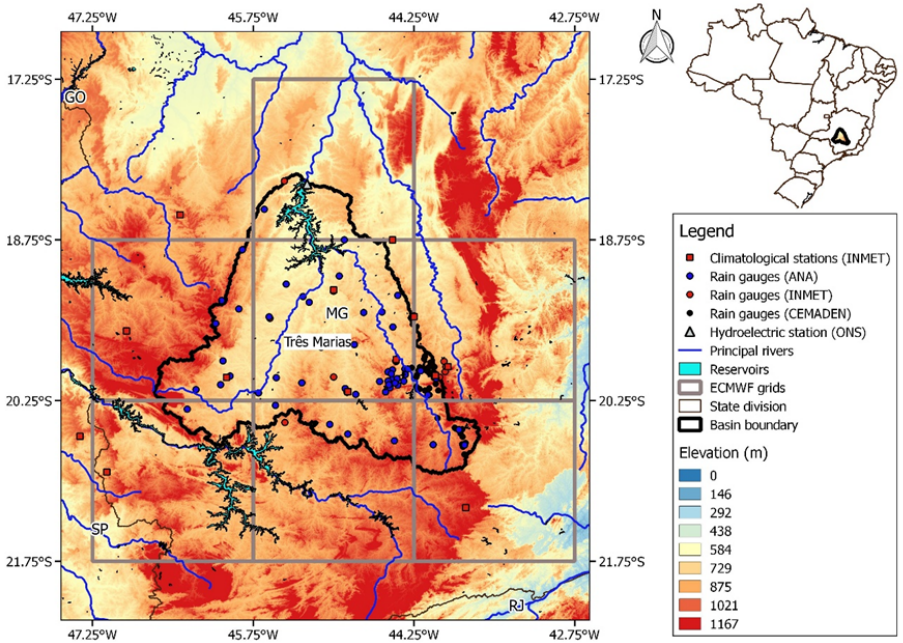


Geographical distribution of the upper quartile of dry spells' duration (shades) and severity (contours) during (a) November, (b) December, (c) January, and (d) February. Contour lines indicate the severity as the fraction of the LTM monthly totals: 0.20 (grey), 0.40 (red), and 0.50 (blue). The white areas are dry spells 5 days long.

- **The severity of a dry spell** may be assumed as the cumulative volume of the associated rainfall's deficiency (Yevjevich, 1967; Mishra and Singh, 2010)
- Given by the **multiplication of upper quartile** of the dry spell's duration by the climatological monthly rainfall rate (mm per day).

- Short dry spells (5-8 days long) may be associated with losses of 20% of the total monthly rainfall.
- Losses of the order of 40% tend to be restricted to the extreme north and northeast during November and December, associated with dry spells 10 days long
- In February, besides the areas in the northeast also southwestern SEB presents some localized regions with losses of the order of 40%.

THE TRES MARIAS WATERSHED

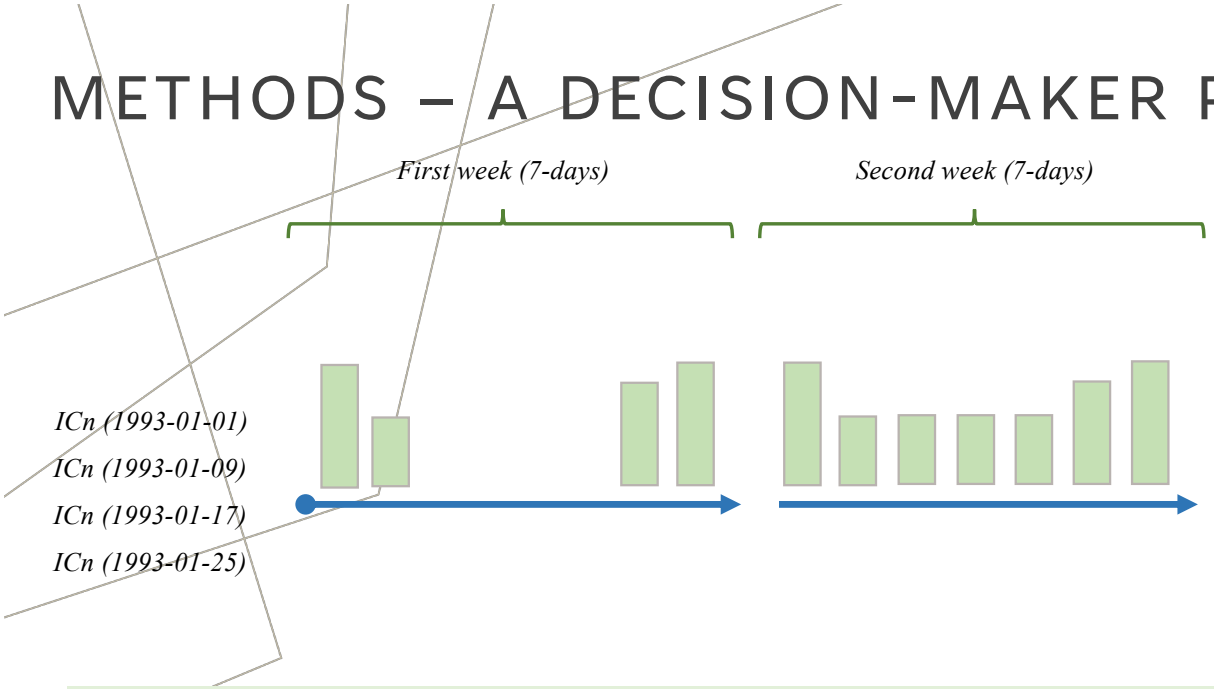


Stakeholders who are potential users of the subseasonal data for supporting strategic planning

Navigation, electricity generation, agriculture/irrigation, tourism.

The Três Marias watershed (18654.66 km² – 7.95 %), sub-basin of the São Francisco River basin (641000 km²).

METHODS – A DECISION-MAKER PERSPECTIVE



The goal of such approach is to mimic an operational condition, when you have real-time predictions for the upcoming weeks (1 to 4).

- Operational perspective: is a dry spell of a length ***L*** being predicted in the near future (1 – 4 weeks)? Did it really occur?
- The dry spells' lengths (***L***) evaluated are *L = 3, 4, ... , 7* days.
- UKMO S2S model; 7 members; 45 days of forecast horizon.
- 552 weekly forecasts (ICns 1993-01-01 to 2015-12-25)

SCHEME FOR THE ENSEMBLE FORECAST (THE MODE)

The most frequent state (hot or dry) among the members

ICnDate	FctDate	FctM1	FctM2	FctM3	FctM4	FctM5	FctM6	FctM7	EnsFct	Obs
3/17/1993	3/18/1993	0	0	1	0	0	1	0	0	0
3/17/1993	3/19/1993	1	1	1	1	1	1	1	1	0
3/17/1993	3/20/1993	1	1	1	1	1	1	1	1	1
3/17/1993	3/21/1993	0	0	1	1	1	0	0	0	0
3/17/1993	3/22/1993	1	1	1	1	1	1	1	1	1
3/17/1993	3/23/1993	1	1	1	1	1	1	1	1	1
3/17/1993	3/24/1993	1	1	1	1	1	1	1	1	0

The ensemble forecast is indicating a 3-days dry spell.

Table 1 – Example of the categorization in dry days (1) or non-dry days (0) for a random week-1. The rightmost column indicates the observed categories, and the immediate column to the left is the EnsFct, calculated as the mode of the members.

- Deterministic forecast, dichotomous assessment (Y/N)
- Lead times: from week-1 to week-4
- Dry spells (CHIRPS): 552 forecast weeks (1993 - 2016)
- Events are categorized by duration: 3, 4, 5, 6 and 7 days.

SCORES

The scores calculated are of straightforward interpretation for the decision-makers.

$$\mathrm{POD} = \frac{hits}{hits + misses} \qquad (1)$$

$$\mathrm{SR} = \frac{hits}{hits + false\ alarms} = 1 - FAR, \text{ where } \mathrm{FAR} = \frac{false\ alarms}{hits + false\ alarms} \qquad (2)$$

Probability of detection: *What fraction of the observed "yes" events were correctly forecast?*

Success ratio: *What fraction of the forecast "yes" events were correctly observed?*

$$\mathrm{BIAS} = \frac{hits + false\ alarms}{hits + misses} \qquad (3)$$

$$\mathrm{CSI} = \frac{hits}{hits + misses + false\ alarms} \qquad (4)$$

BIAS: *How did the forecast frequency of "yes" events compare to the observed frequency of "yes" events?*

CSI: *accuracy* when correct negatives have been removed from consideration, that is, *CSI* is only concerned with forecasts that count. Sensitive to hits, penalizes both misses and false alarms.

$$\mathrm{BS} = \frac{1}{n}\sum_{k=1}^{n}(y_k - o_k)^2 \qquad (5)$$

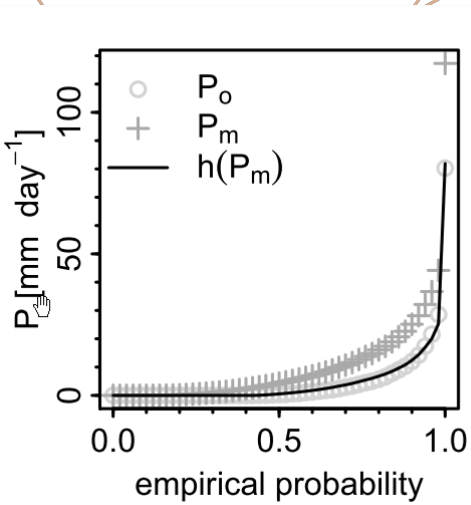
Brier Score: *What is the magnitude of the probability forecast errors?*

$$\mathrm{BSS} = \frac{BS - BS_{ref}}{0 - BS_{ref}} = 1 - \frac{BS}{BS_{ref}}$$

Brier Skill Score: *What is the relative skill of the probabilistic forecast over that of climatology, in terms of predicting whether or not an event occurred?*

THE CORRECTION

QUANTILE MAPPING: a statistical transformation method that finds a function to map the modelled variable such that its new distribution equals the distribution of the observed variable (Gudmundsson et al., 2013).



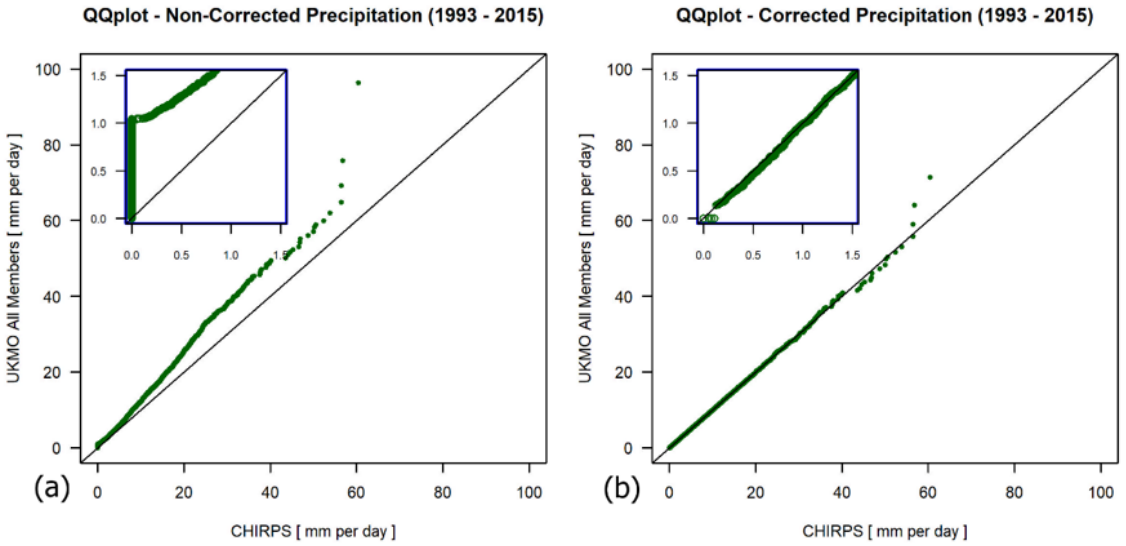


Figure 2 – quantile-quantile plots comparing the UKMO model's and the CHIRPS precipitation for week-3. (a) Raw (non-corrected) forecasts. (b) Corrected forecasts.

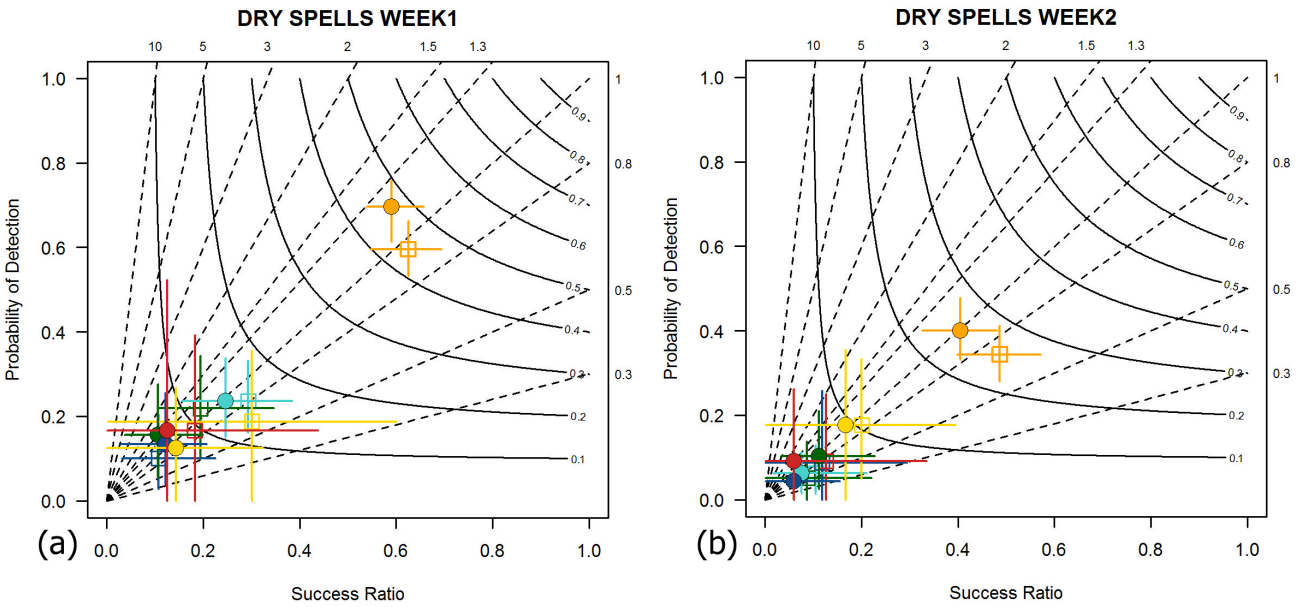
When verifying the quantile mapping method results, we adopted a **cross-validation** approach.

The UKMO model presents a misrepresentation of days with no rainfall (vertical line on the left): **too many days with low rainfall, lack of days with ZERO rain**.

In the CHIRPS (UKMO) time series, the transition from zero rainfall to rainfall occurs approximately at 0.31 (1.7) mm per day quantile.

THE PERFORMANCE DIAGRAM - 1

Exposes the geometric relationship between four measures of dichotomous forecast performance (Roebber, 2009)



LIGHT BLUE: 3-days
GREEN: 4-days
BLUE: 5-days
YELLOW: 6-days
RED: 7-days
SQUARES: raw forecast, **CIRCLES**: corrected forecasts

For **week-1** the better performance occurs when the model is forecasting 3-days dry spells (cyan points). For **week-2** the best performance is predicting a 6-days dry spell.

Week-3: max POD and SR are respectively 0.06 and 0.25 (raw forecasts) for a 6-days dry spell, and 0.11 and 0.14 (corrected forecasts) for a 4-days dry spell.
Week-4 raw: POD and SR are respectively 0.10 and 0.25, for a 6-days dry spell. **Week-4 corrected:** 0.10 and 0.22 (POD and SR, respectively) for a 3-days dry spell.

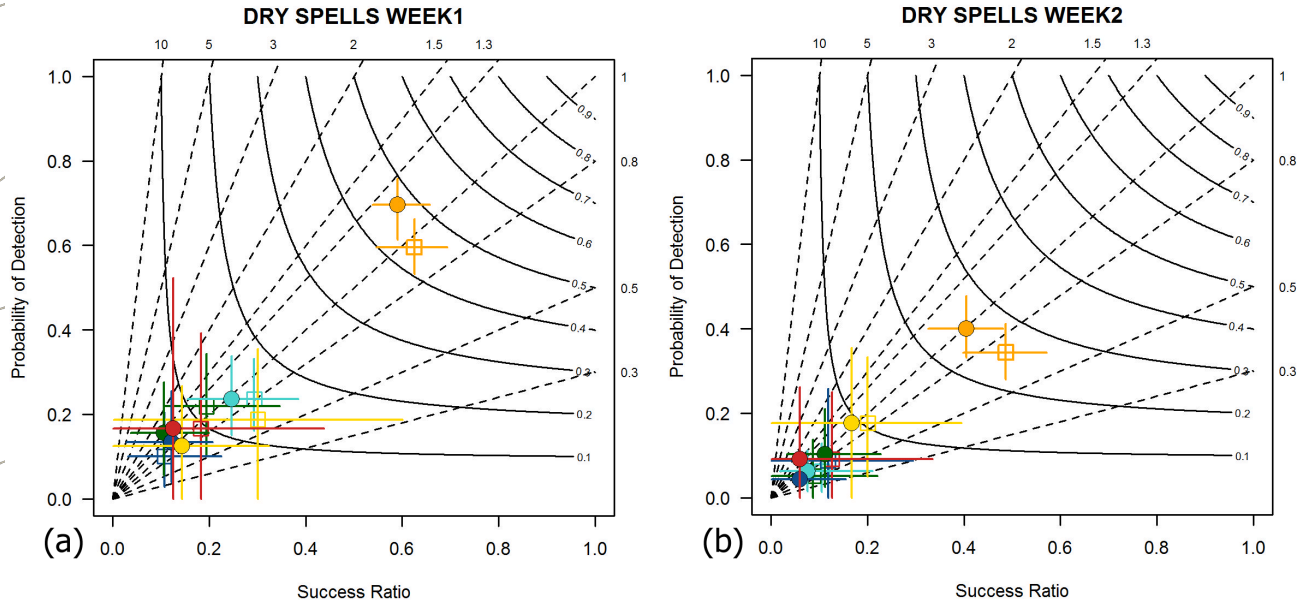
The forecasts **misses** more than issue **false alarms**.

QM increases the dry spells' frequency, the BIAS and false alarms (decreases the SR).

The overall performance, considering all duration categories, is low. The POD is roughly lower than 0.2, which means that for every five observed dry spells, on average, only one is correctly predicted. The SR present values of the same order (0.2).

THE PERFORMANCE DIAGRAM - 2

Considers HIT if the EnsFct predicts an event (dry spell or heatwave) of *any duration* (3 to 7 days) and an event of *any duration* is observed



LIGHT BLUE: 3-days
GREEN: 4-days
BLUE: 5-days
YELLOW: 6-days
RED: 7-days
SQUARES: raw forecast, **CIRCLES**: corrected forecasts

For week-1, POD and SR are around 60% (0.60 and 0.63, respectively) for the raw forecasts; and 0.7 and 0.59, respectively, for the bias-corrected forecasts.

For week-2, the POD and SR are respectively 0.34 and 0.49 (0.40 and 0.41) for the uncorrected (corrected) forecasts and for the corrected forecasts.

Week-3: POD and SR are respectively 0.12 and 0.30 (raw forecasts) and 0.30 and 0.40 (corrected forecasts)

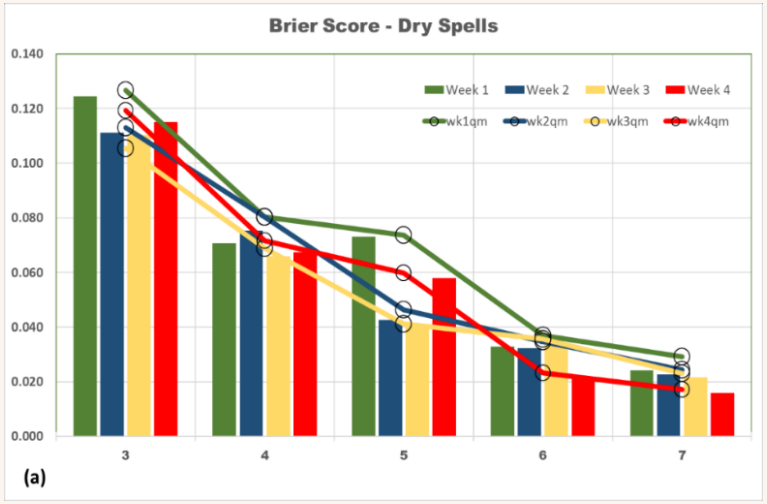
Week-4: POD and SR are respectively 0.18 and 0.54 (raw forecasts) and 0.28 and 0.48 for the corrected forecasts.

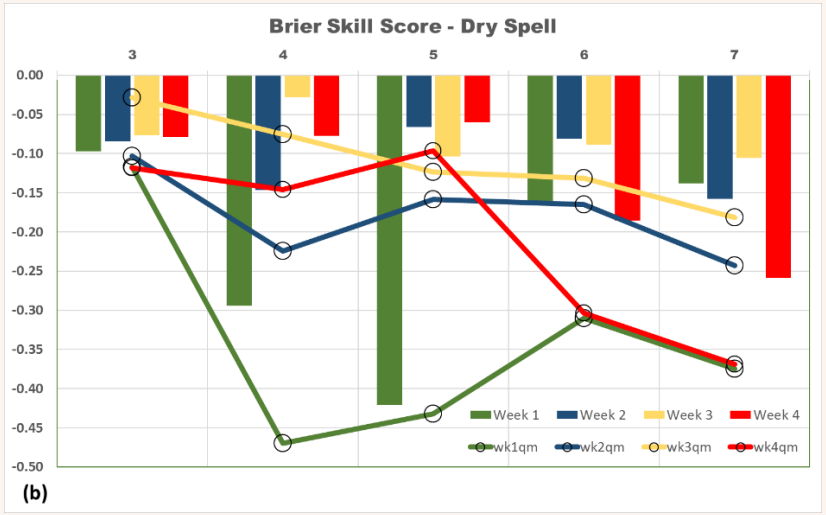
DRY SPELLS FORECAST QUALITY – PROBABILISTIC FCT

The decreasing error as function of the dry spell length is misleading

There is no general increase in probability errors with increasing lead time (from green to red)

The quantile mapping results, in general, in worst probabilistic forecasts (bars vs lines)





The forecasts are less skillful than a sample climatology (negative BSS). Overall average deficits are O~0.20

Week-3 stands out as the best predicted under the probabilistic perspective. Though still lower than climatology, the skill debt is lower than for the other lead times.

FINAL REMARKS

CLIMATOLOGICAL CHARACTERISTICS OF DRY SPELLS

The general picture is that during the peak of the Monsoon Season, January and (mostly) February are predisposed to the occurrence of dry spells, compared with December.

ASSESSING DRY SPELLS' FORECASTS

- The non-probabilistic forecasts, represented by the members' mode, present detection chances of approximately 1 in 5.
- Probabilistic forecast are less skillful than a sample climatology (20%). The probabilistic errors are relatively invariant as the lead time become longer.

NEXT

To explore potential atmospheric system that might be associated to the observed dry spells' variability.

NEXT

To explore Artificial Intelligence (AI) mechanisms, in association with atmospheric indexes (MJO, AAO, PSA, ...), aiming to improve the forecast quality of dry spells in the Três Marias region.

OBRIGADO. THANKS.

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