A verification framework for South American sub-seasonal precipitation predictions

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Plan of talk

1. Introduction: Current context, aspects to be considered
2. Elucidation of the sub-seasonal verification problem and associated questions
3. Sampling strategies and information levels for sub-seasonal verification
4. Attribute-based forecast quality assessment
5. Summary

Acknowledgments: Mári Firpo, Felipe Andrade, and ECMWF for making forecast and hindcast data avail. via S2S project data base

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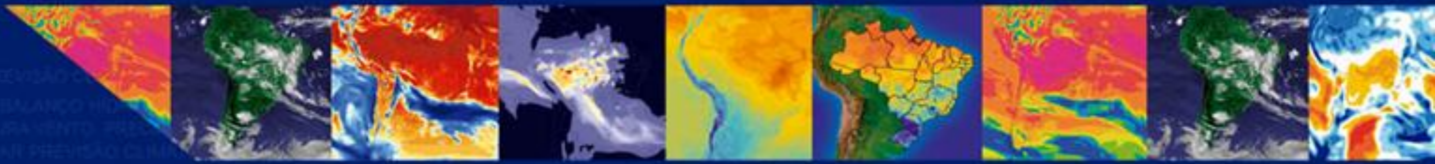

The current context

- **Recent availability of sub-seasonal predictions produced as part of the WWRP/WCRP Sub-seasonal to Seasonal prediction project (S2S, Vitart et al., 2012; Robertson et al., 2015) allows the investigation of retrospective predictions (hindcast) and near real time forecast quality levels of the participating S2S modeling centers.**

- **Verification strategy is required to document the quality of both deterministic and probabilistic predictions in support of future routine sub-seasonal predictions.**

- **This strategy is required because verification information detailing past model performance is a key prediction practice component to enhance forecasters´ confidence on the available models predictions and also in support of future model developments. This study proposes a verification framework for these purposes.**

Important aspects to be considered

• Large degree of differences in some characteristics of sub-seasonal hindcasts and real time forecasts, directly impacting the verification sample size.

• For example, the number of available sub-seasonal hindcast years (typically 20 years or less) is usually reduced compared to the number of available seasonal hindcast years (typically 30 years).

• In the S2S project very few real time subseasonal forecast years are available for verification (about 3-5 years) with a typically much larger ensemble size than usually available for hindcasts.

• These differences in sub-seasonal hindcasts and real time forecasts highlight the need for a strategy for sub-seasonal prediction verification practice.

Elucidation of the sub-seasonal verification problem and associated questions

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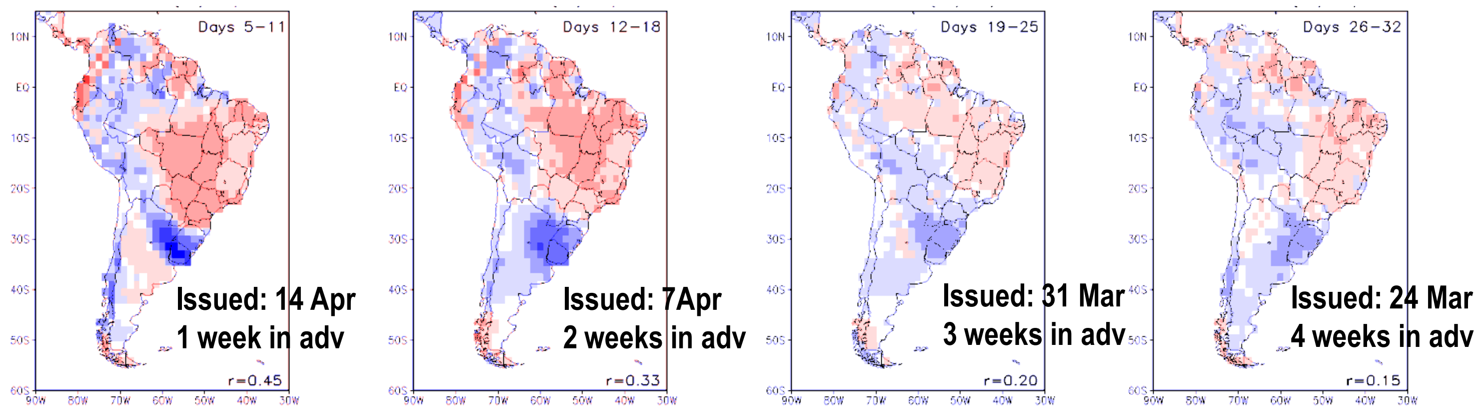
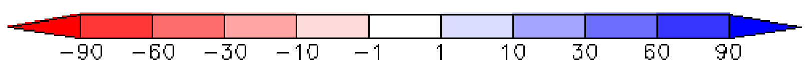
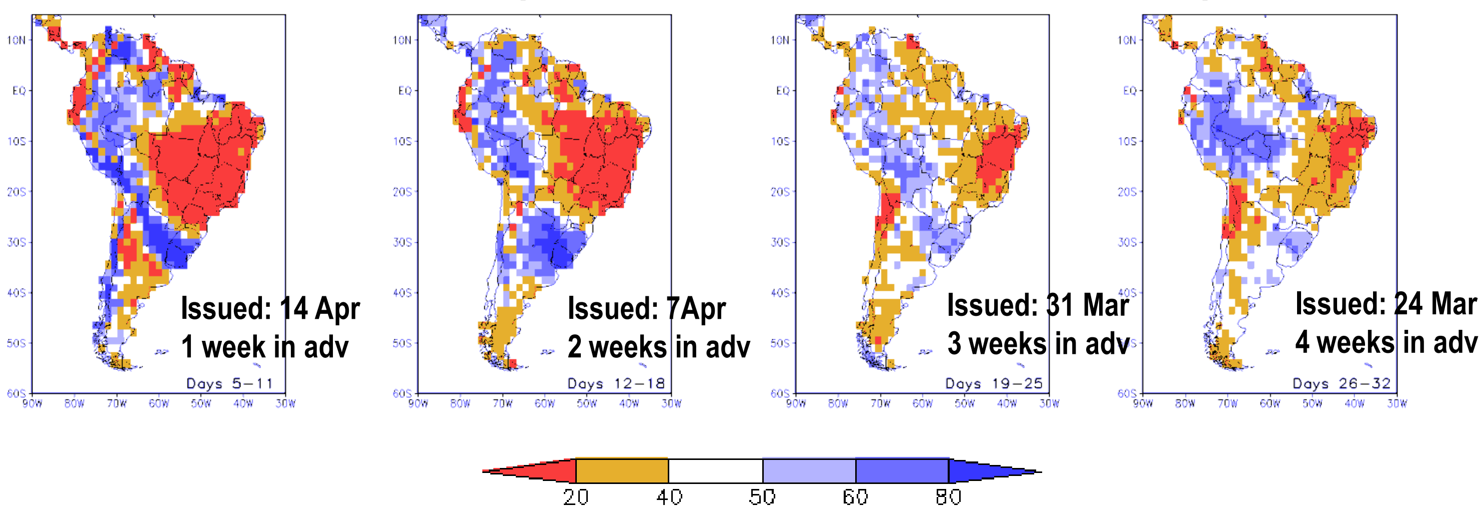
Deterministic (ens. mean anomaly) precip. forecasts for 18-24 April 2016





ECMWF S2S forecasts

Probabilistic forecasts (prob. of pos. precip. anom.) for 18-24 April 2016

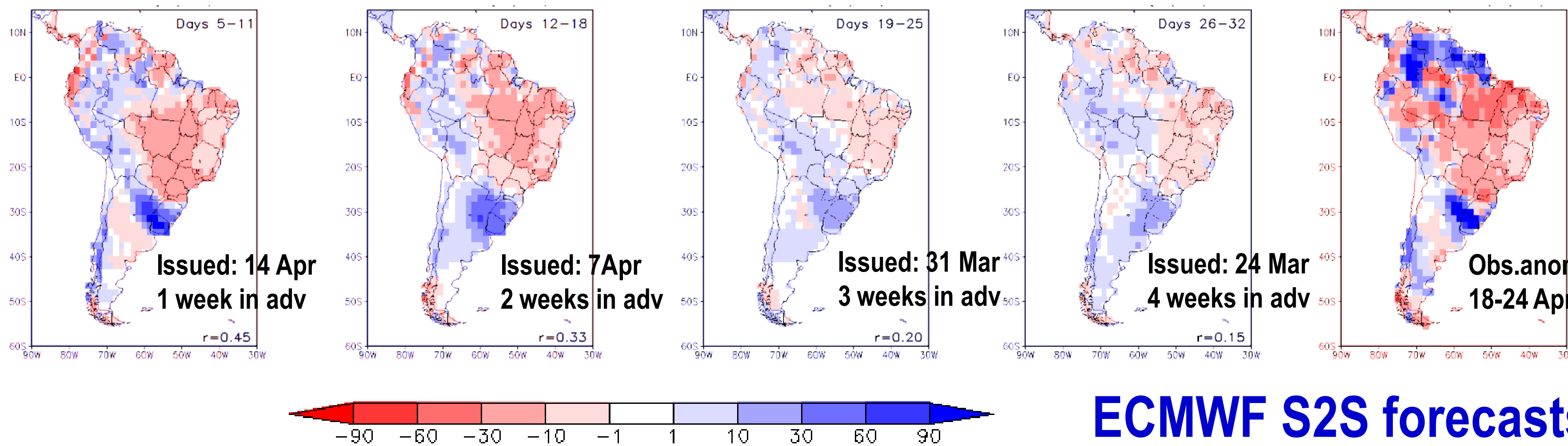


Questions from forecasters having access to forecasts prior to 18-24 April 2016

- How good are these forecasts for the week 18-24 April 2016 produced one to four weeks in advance in terms of correspondence with the observations?
- Where spatially can these forecasts be best trusted?
- How strong is the relationship between the forecast and observed precipitation anomalies?
- How accurate are the forecast precipitation anomalies compared to the accuracy of a reference naïve forecasting strategy of always issuing a constant forecast value (e.g. null anomaly for the climatological forecast)?
- How reliable are the issued forecast probabilities?
- Can the issued forecast probabilities detect the event of interest (i.e. distinguish events from non-events)?

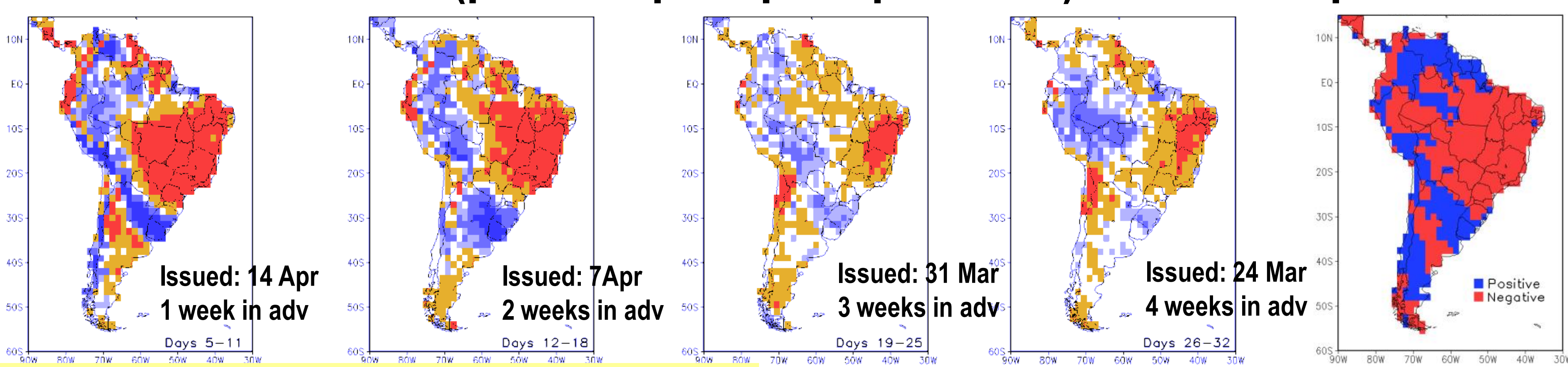
Qualitative assessment and visual identification of regions where forecasts were successful

Deterministic (ens. mean anomaly) precip. forecasts for 18-24 April 2016

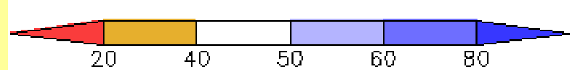


ECMWF S2S forecasts

Probabilistic forecasts (prob. of pos. precip. anom.) for 18-24 April 2016



Useful initial assess: **Quantitative approach required** to document past fcst quality (support to fcst users)



Binary obs
18-24 Apr

The need for a quantitative approach

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• Although the visual inspection provides useful a posteriori initial forecast quality assessment, when issuing the forecast for the week 18-24 April 2016, it would also be useful for the forecasters to have available, in addition to the forecast maps, some historical performance assessment of the hindcasts and forecasts previously produced for the target week of interest.

• Such historical information can help the forecasters identify regions where the model consistently shows acceptable performance and regions where the model shows deficiencies, and therefore contribute to building forecasters´ confidence on the forecast model guidance information.

• However, a quantitative approach is required in order to appropriately document past forecast quality and provide support to those using the forecasts.

Sampling strategies and information levels for sub-seasonal verification

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Proposed framework for quantitative sub-seasonal precip. forecast quality assessment

- **Level 1: Target week hindcast verification (11 ens. members)**
  Similar to traditional seasonal forecast verification (~30 samples)
  Uses ECMWF S2S hindcasts intialized on Thu 14 April, 7 April, 31 March and 24 March of the 2016 calendar for the 1996-2015 period (20 samples)

- **Level 2: All season hindcast verification (11 ens. members)** Increased robustness
  In addition to hindcasts produced for the 4 Thu initialization dates previously selected, aggregates hindcasts produced for 9 additional initialization dates during the weeks of the previous and following month in order to incorporate in the sample all hindcasts initialized on Thu of March, April and May of the 2016 calendar for the 1996-2015 period (260 samples: 13 initialization dates times 20 years)
  MAM: Austral autumn season, similar atmospheric features in S. American regions
- **Level 3: All season near real time forecast verification (51 ens. members)**
  Aggregate the real time forecasts produced on Thu during the 13 weeks of March, April and May of each of the past three years (2015, 2016 and 2017).
  This aggregation leads to a verification sample of 39 pairs of near real time forecasts and observations (39 samples: 13 initialization dates times 3 years)

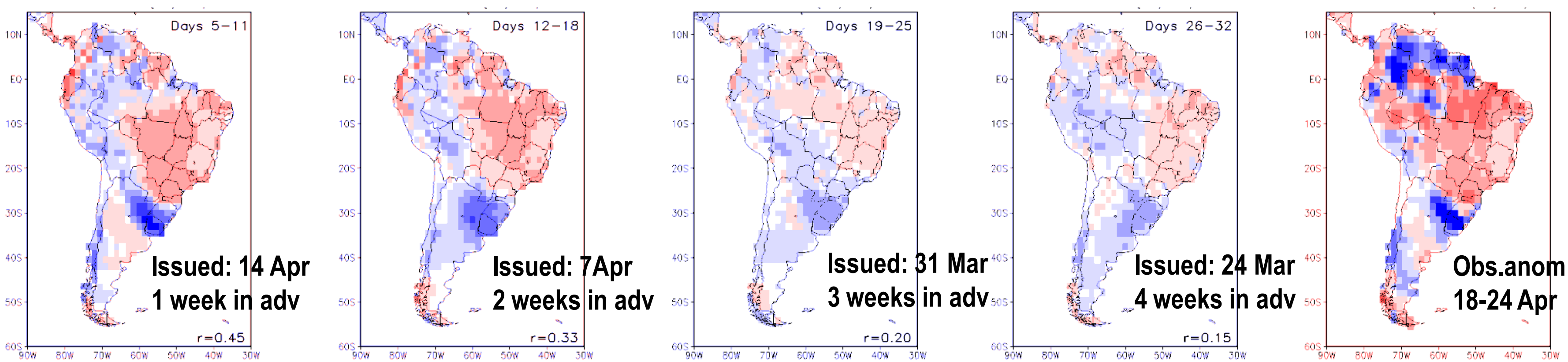
Attribute-based forecast quality assessment

Murphy (1993) defined a number of aspects, so-called attributes, for assessing forecast quality (corresp. btw. fcsts and obs). The proposed procedures for assessing sub-seasonal precipitation predictions is based on a selection of some of the most fundamental attributes: association, accuracy, discrimination, reliability and resolution.

Proposed metrics:

• Spatial pattern correlation (r) btw forecast and obs anomalies: quantify the degree of correspondence between the deterministic forecasts and the observations

Deterministic (ens. mean anomaly) precip. forecasts for 18-24 April 2016



r: 0.45 r: 0.33 r: 0.20 r: 0.15

Association comparative assessment: Corr. btw pred. ens. mean and obs. precip. anom.

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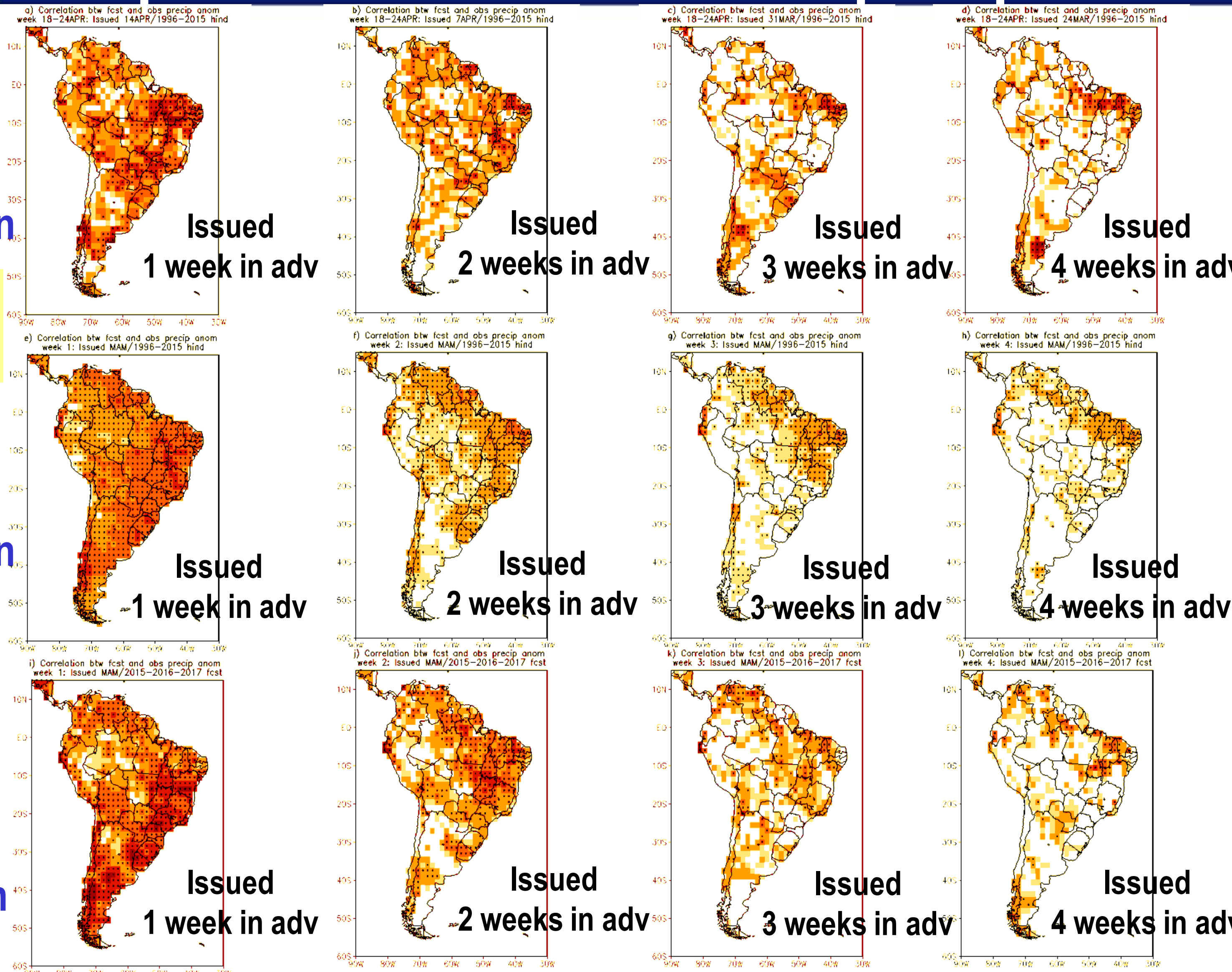
Level 1:
Target week hindcast verification

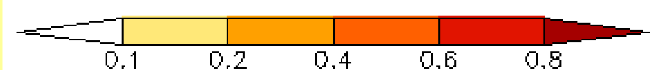
Phase assessment
Consit. across 3 lev.

Level 2:
All season hindcast verification

Level 3:
All season near real time forecast verification



Measure strength of linear association btw pred ens mean and obs anom



Accuracy comparative assessment: MSSS for ens. mean precip.anom pred. wrt clim.

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Level 1: Target week hindcast verification

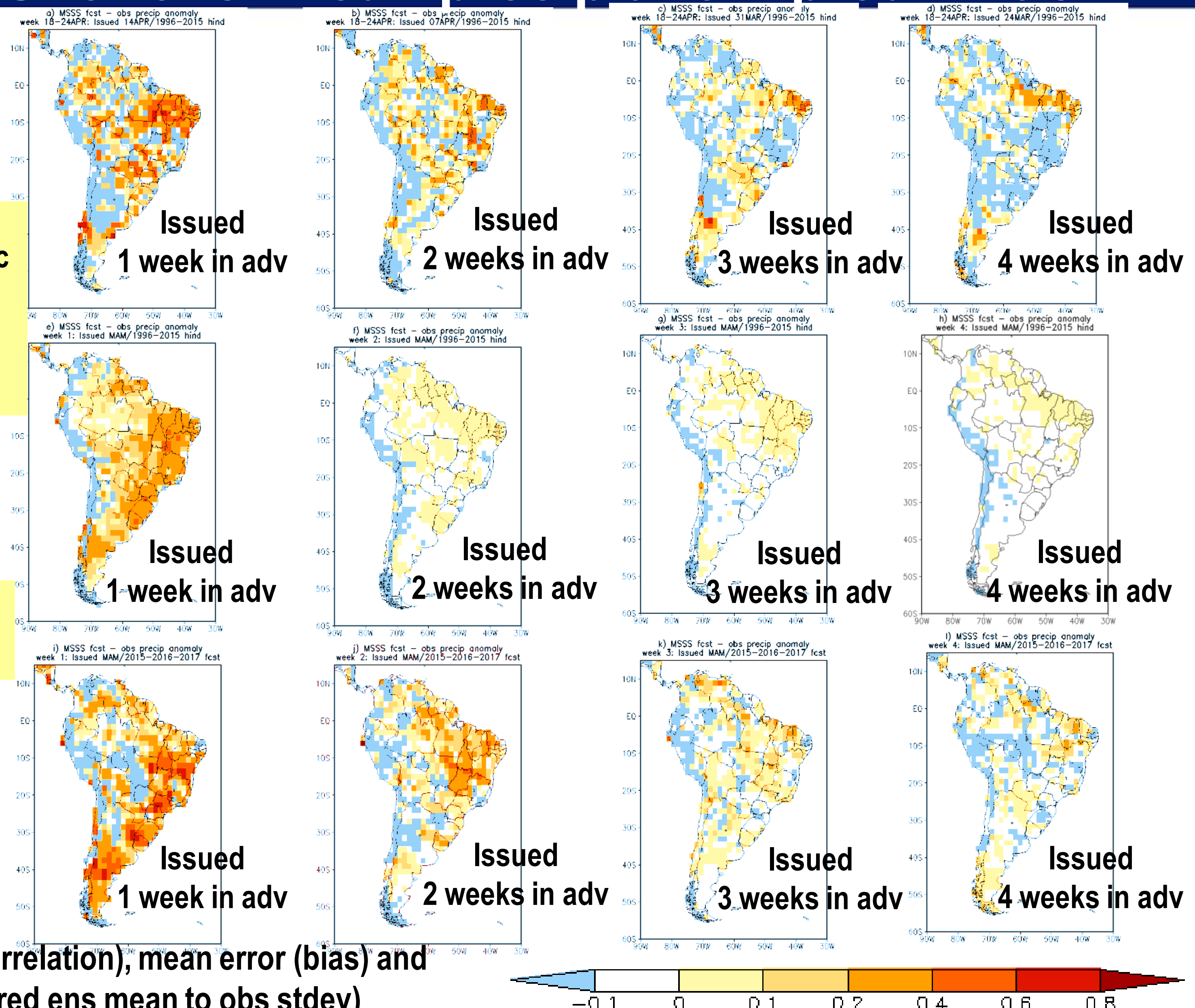
$MSSS=1-MSE/MSE_c$

MSSS>0 greater accuracy than ref (climat.) prediction

Level 2: All season hindcast verification

MSE: det. meas. (ave square diff btw pred ,obs)

Level 3: All season near real time forecast verification



Murphy (1988):
MSSS incl phase error (correlation), mean error (bias) and amplitude error (ratio of pred ens mean to obs stdev)

Amplitude error comparative assessment: Ratio btw. pred. precip. ens. mean anom. stdev and obs. anom. stdev

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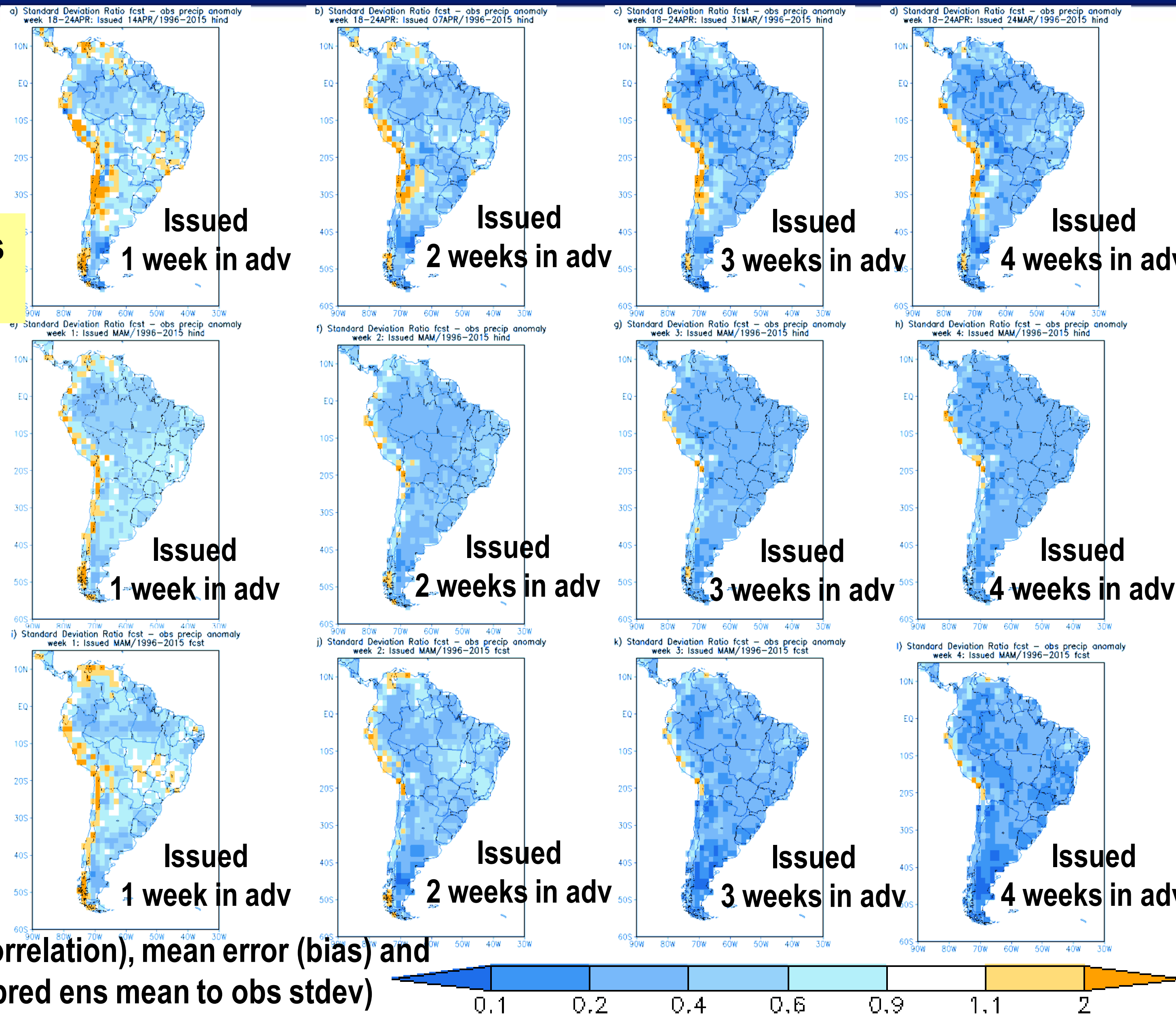
Level 1:
Target week
hindcast verification

Ratio < 1 pred with less variability than obs

Level 2:
All season
hindcast verification

Level 3:
All season
near real time
forecast verification



Murphy (1988):
MSSS incl phase error (correlation), mean error (bias) and amplitude error (ratio of pred ens mean to obs stdev)

Discrimination comparative assessment: Area under the ROC curve for event pos. precip. anom.

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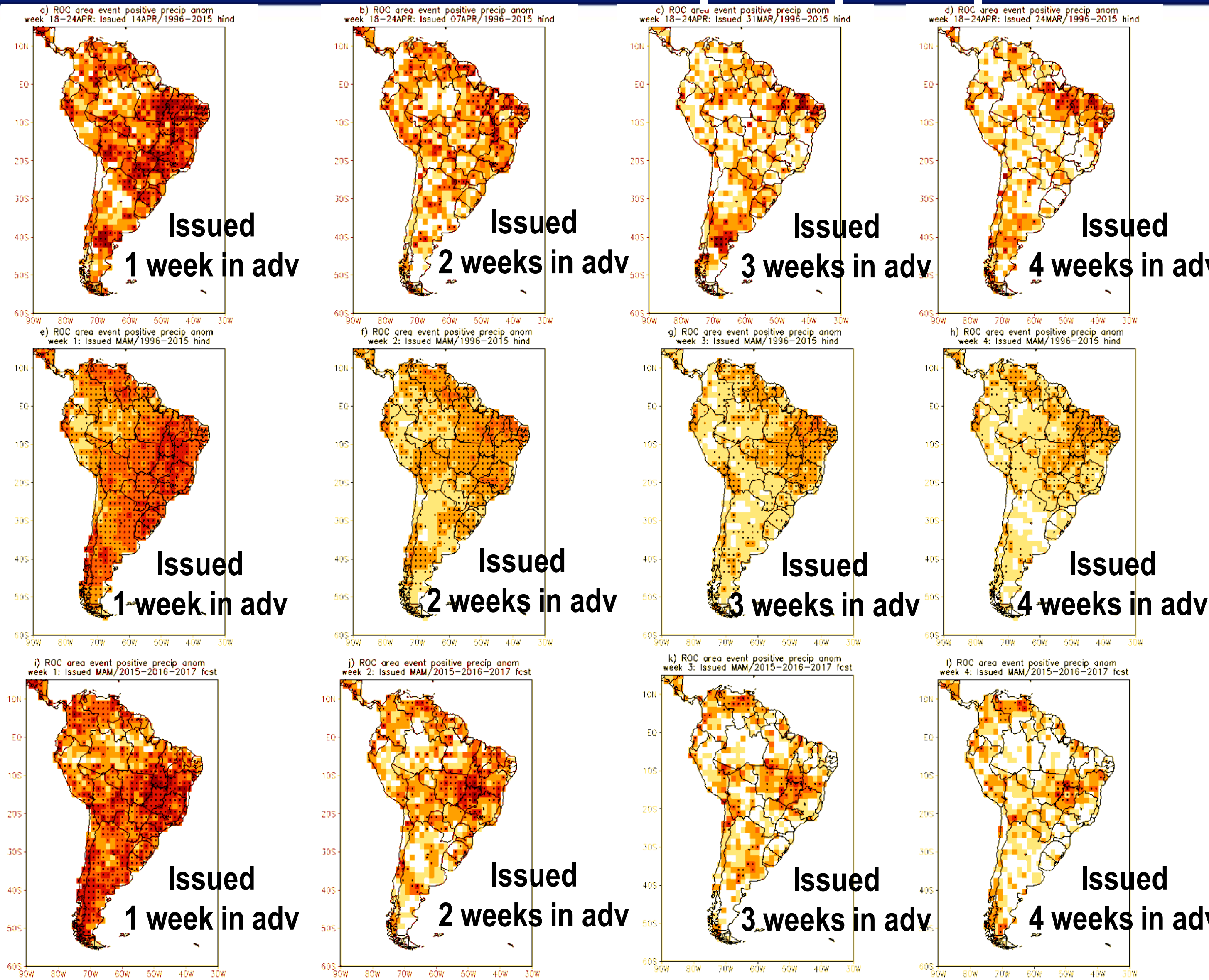
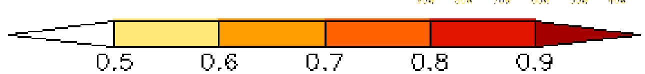
Level 1:
Target week
hindcast verification

Level 2:
All season
hindcast verification

Level 3:
All season
near real time
forecast verification

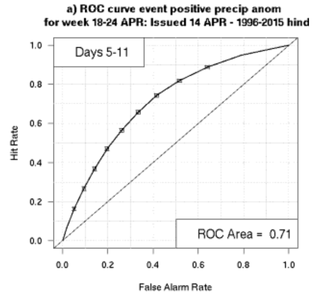


Discrimination: ability to distinguish events from non-events



Discrimination comparative assessment: ROC curve for event pos. precip. anom.

Level 1: Target week hindcast verification



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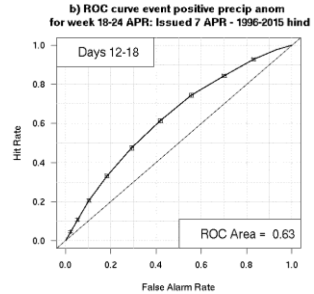

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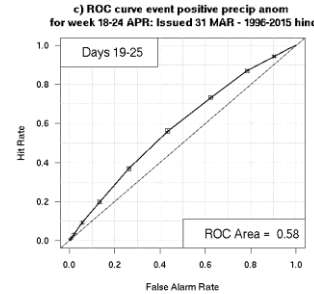

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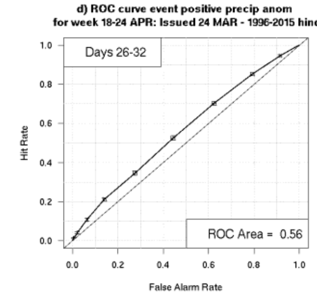

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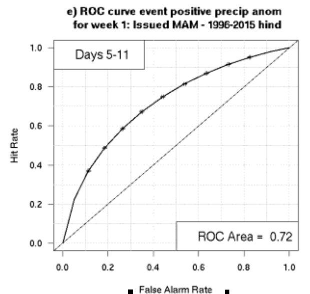
Level 2: All season hindcast verification



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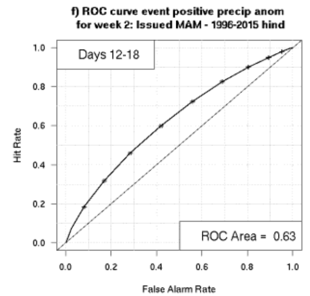

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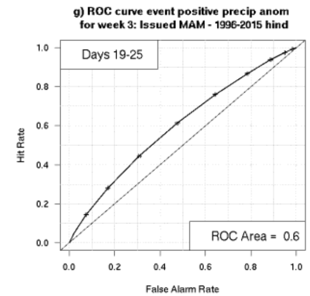

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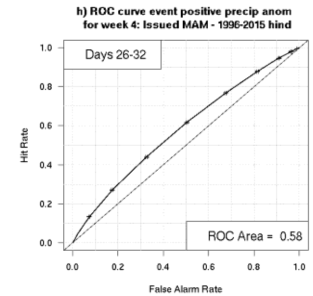

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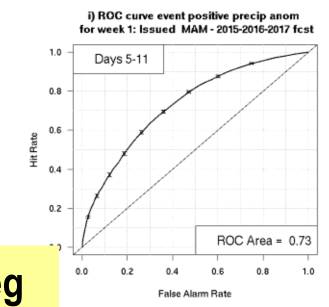
Level 3: All season near real time forecast verification



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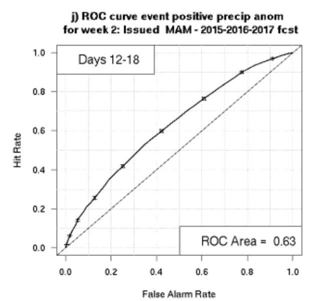

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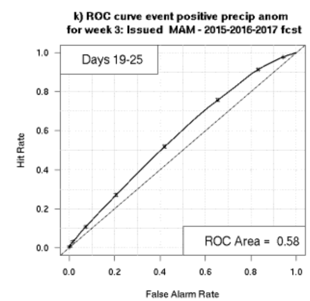

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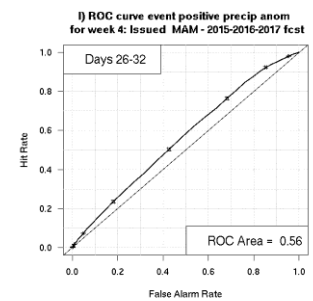

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Overall discrimination: aggreg all hindcasts/forecasts in space and time

Reliability/Resolution comparative assessment: Reliability diagram for event pos. precip. anom.

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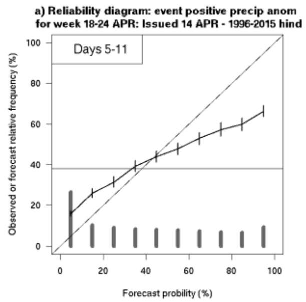
Level 1: Target week hindcast verification

Reliab: how well calibr. issued probs. are
Resol.: how the freq of occurr of the event differs as issued prob changes



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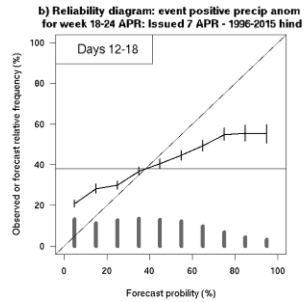

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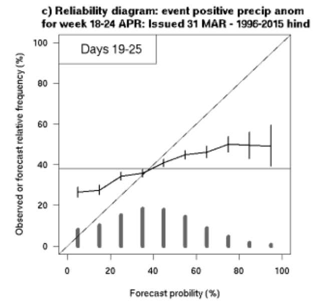

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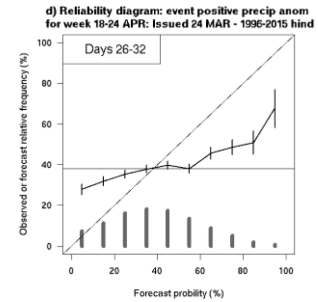

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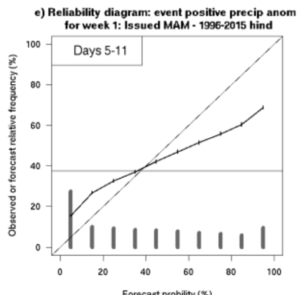
Level 2: All season hindcast verification



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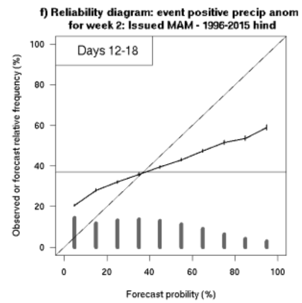

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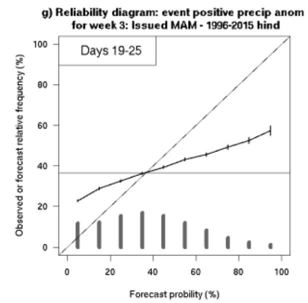

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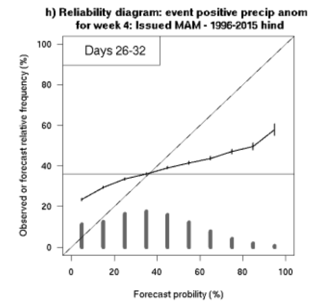

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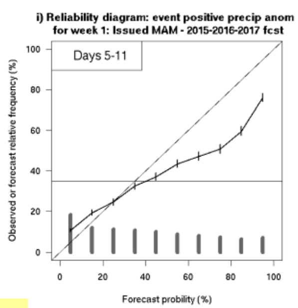
Assessment reveals need for calibration

Level 3: All season near real time forecast verification



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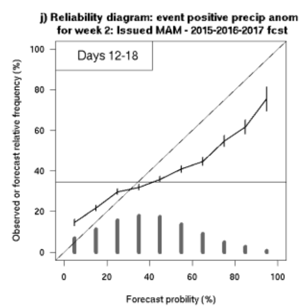

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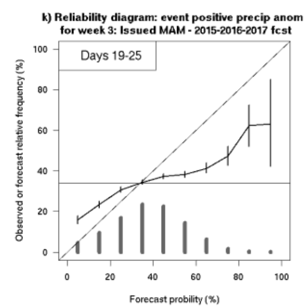

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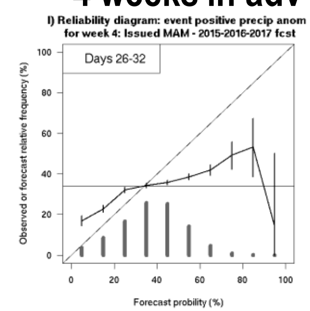

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Aggreg all hindcasts/forecasts in space and time

Strengths and weaknesses of such three level strategy

• The three level strategy of the proposed verification framework has strengths and weaknesses, making it challenging to decide and choose a single approach.

• For this reason it is important to recognize the differences, merits and limitations of the three approaches and, most importantly, consider then as complementary verif. strategies.

• The hindcast datasets of level 2 (all season hindcast verification) provide extensively large samples compared to the reduced samples of level 1 (target week hindcast verification).

• The level 2 hindcast quality is, however, likely to be lower than level 3 (all seasonal near real time forecast verification) quality, particularly because the initial conditions from the reanalysis dataset used for producing hindcasts are of poorer quality than the operational analysis used as initial conditions for producing real time forecasts.

• This is due to the fact that the observing system has improved over the past 20 years and the reanalysis used for initializing hindcasts is based on a model and data assimilation system that are outdated compared to the operational model version used for producing real time forecasts.

Strengths and weaknesses of such three level strategy

• Besides, the ensemble size for the produced hindcasts is smaller than for real time forecasts (11 hindcast ensemble members against 51 real time forecast ensemble members for the ECMWF sub-seasonal predictions here investigated).

• Additionally, the level 3 (all season near real time forecast verification) quality assessment cannot be considered comprehensive either due to the limited number of available forecast years (3 years for the ECMWF sub-seasonal predictions here investigated).

• In level 3, forecast quality is heavily affected by the specific interannual variability due to the El Niño Southern-Oscilattion (ENSO) and the Madden-Julian Oscilation (MJO) activity, and the model version changes that occurred during this three year period.

Summary

• Proposed a necessary verification framework for sub-seasonal precip. predictions based on a three level strategy according to the available hindcasts and near real time forecasts of recent past years characterized by a large degree of complexity/differences

• Most fundamental prediction quality attributes were assessed: association, accuracy, discrimination, reliability and resolution

• Verification information provided in the three levels found to be consistent and complementary and when used together with forecasts help a) forecasters building confidence in the model forecast guidance information when issuing sub-seasonal forecasts (by addressing various questions), and b) model developers/forecasters indentifying forecast aspects in need of improvement

• Probabilistic assessment aggregating all predictions over South America revealed modest discrimination ability, with predictions clearly requiring calibration for improving reliability and possibly combination with other model predictions for improving resolution

• C.A.S. Coelho, M.A.F. Firpo, F.M. de Andrade, 2018: A verification framework for South American sub-seasonal precipitation predictions. Meteorologische Zeitschrift
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Thank you for your attention!

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