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Multi-model calibration and combination of seasonal sea surface temperature forecasts over two different tropical regions

by

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Our focus : Seasonal to decadal prediction

- Francisco J Doblas-Reyes : The Head
- Isabel Andreu-Burillo: *air-sea dynamics*
- Alberto Carrassi: *initialisation techniques*
- Virginie Guemas : *Sea ice, North Pacific skill*
- Fabian Lienert : *regionalisation, PDO*
- Melanie Davis : *climate services*
- Danila Volpi : *initialisation techniques, DePreSys*
- Luis Ricardo Rodrigues : *seasonal prediction*
- Aida Pintó : *extremes*
- Muhammad Asif : *EC-Earth*
- Oriol Mula-Valls : *system administrator*
- Domingo Manubens : *autosubmit developer*

We share, on request :

1)Autosubmit

2)Our decadal hindcasts

3)Monthly sea ice restarts

4)R diagnostic functions

We run on :

1)Marenostrum (Spain)

2)ECMWF

3)Lindgren (Sweden)

4)HECTOR (Scotland)

5)Our local cluster

Contents

- **Seasonal climate prediction**
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- **Subtropical Northern Atlantic index**
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- **Conclusions**

Seasonal climate prediction

- **Definition**
  - Probabilistic in nature

- **Main sources of predictability** (Doblas-Reyes, 2010*)
  - ENSO - biggest single signal
  - Other tropical ocean SST - difficult
  - Climate change - important in mid-latitudes
  - Local land surface conditions - soil moisture, snow
  - Others

- **Methods of seasonal prediction**
  - Statistical
  - Dynamical
    - One-tier GCM
  - Mixed

* Available at http://cdsagenda5.ictp.trieste.it/full_display.php?smr=0&ida=a09167. Accessed on October 14, 2010

Seasonal climate prediction

- **Sources of uncertainty**

  - Initial conditions → Ensemble forecast

  - Model inadequacy → Multi-model ensemble forecast

Forecast quality assessment

- **Combine ECMWF System3 and NCEP CFSv2 using different methods of combination. Statistical model based on lagged SST.**

  - Deterministic point of view
    - Correlation coefficient

  - Probabilistic point of view
    - BSS
    - Reliability Skill Score
    - Resolution Skill Score

  → Probability above the *median*
  Probability above the *upper quartile*

- **Two tropical SST indices:**

  - Niño3.4 SST index (170ºW - 120ºW, 5ºS - 5ºN)
  - Subtropical Northern Atlantic (SNA) SST index (55ºW - 15ºW, 5ºN - 25ºN)

Forecast systems

- **ECMWF System 3**

  - ➢ ECMWF Integrated Forecast System (IFS)
  - Horizontal resolution: 125 km
  - Vertical levels: 62

  - ➢ Hamburg Ocean Primitive Equation (HOPE) model
  - Horizontal resolution: 0.3º x 1º within 10º of the equator and 1º x 1º mid-latitudes
  - Vertical levels: 29

  - ➢ 11 ensemble members, first of the month at 00 GMT

  - ➢ Integration: 7 months long

- **NCEP CFSv2**

➢ NCEP Global Forecast System (GFS)
- Horizontal resolution: 100 km
- Vertical levels: 64

➢ GFDL Modular Ocean Model version 4 (MOM4)
- Horizontal resolution: 0.25º x 0.50º within 10º of the equator and 0.5º x 0.50º mid-latitudes
- Vertical levels: 40

➢ 24 ensemble members (29 in November), start dates in January 11th, 16th, 21st, 26th, 31st, and the February 5th (at the synoptic times 00, 06, 12 and 18 GMT)

➢ Integration: 9 months long

- **Statistical model**

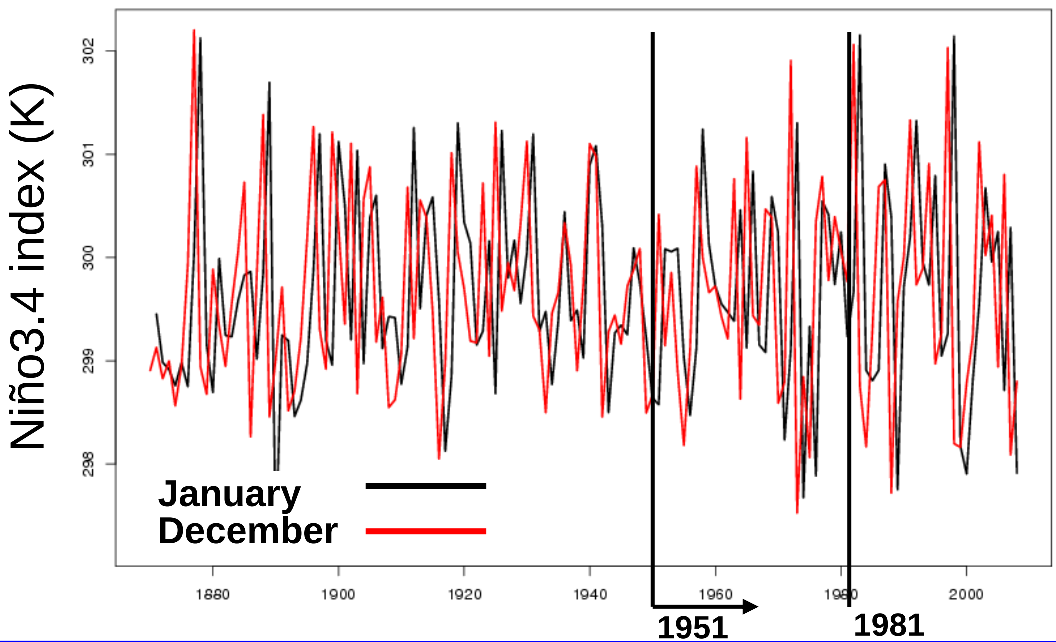
  - Simple Linear Regression ⟶ Lagged SST as predictor
  - First training period: 1951 - 1981, adding a new year at a time
  - Target period: 1982 - 2010

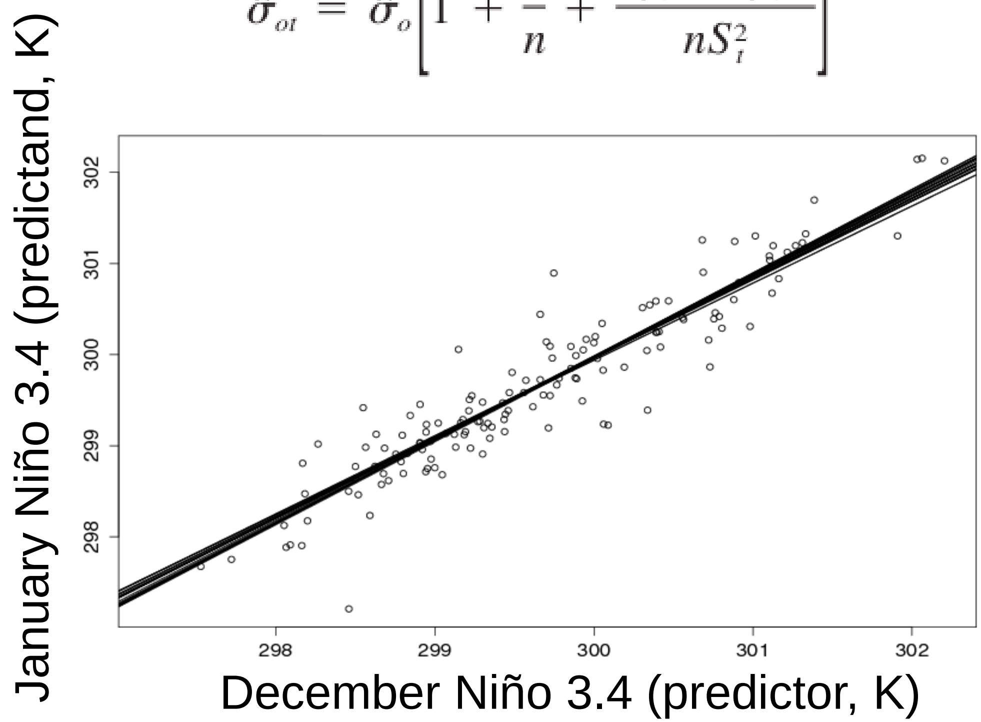
$$\mu_{ot} = \beta_o + \beta_1 \psi_t$$

$$\hat{\sigma}_{ot} = \hat{\sigma}_o \left[1 + \frac{1}{n} + \frac{(\psi_t - \overline{\psi}_t)^2}{n S_t^2} \right]^{1/2}$$

Coelho et al. (2004)

Observed HadISST Niño3.4 index from 1951 to 2009





Forecast systems

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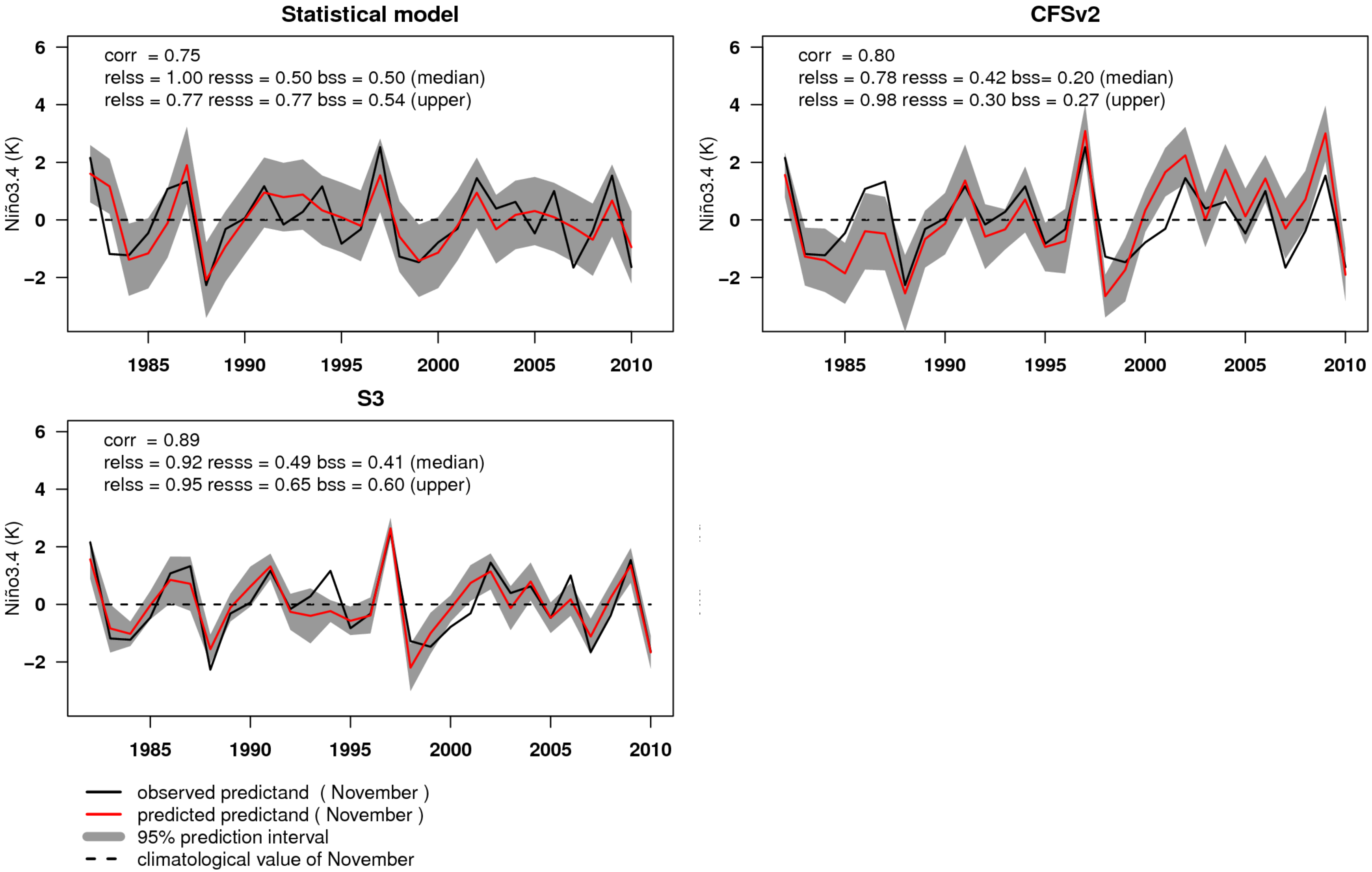
Niño 3.4 index forecasts for the target month of November with lead time 4
Start date in July



Forecast systems

- **Simple Multi-model (SMM)**
  - Combine S3 and CFSv2 with no weighting, used as a benchmark

- **Multiple Linear Regression (MLR)**
  - Combine S3 and CFSv2 with weighting
  - Weights estimated from the MLR of the observation anomalies on the S3 and CFSv2 anomaly values

- **Principal Component 1 regression (PC1)**
  - Perform a PCA on S3 and CFSv2 anomaly values
  - Simple linear regression of the observation anomalies on the PC1

- **Principal Component Analysis regression (PCA)**
  - Perform a PCA on S3 and CFSv2 anomaly values
  - MLR of the observation anomalies on the PC1 and PC2

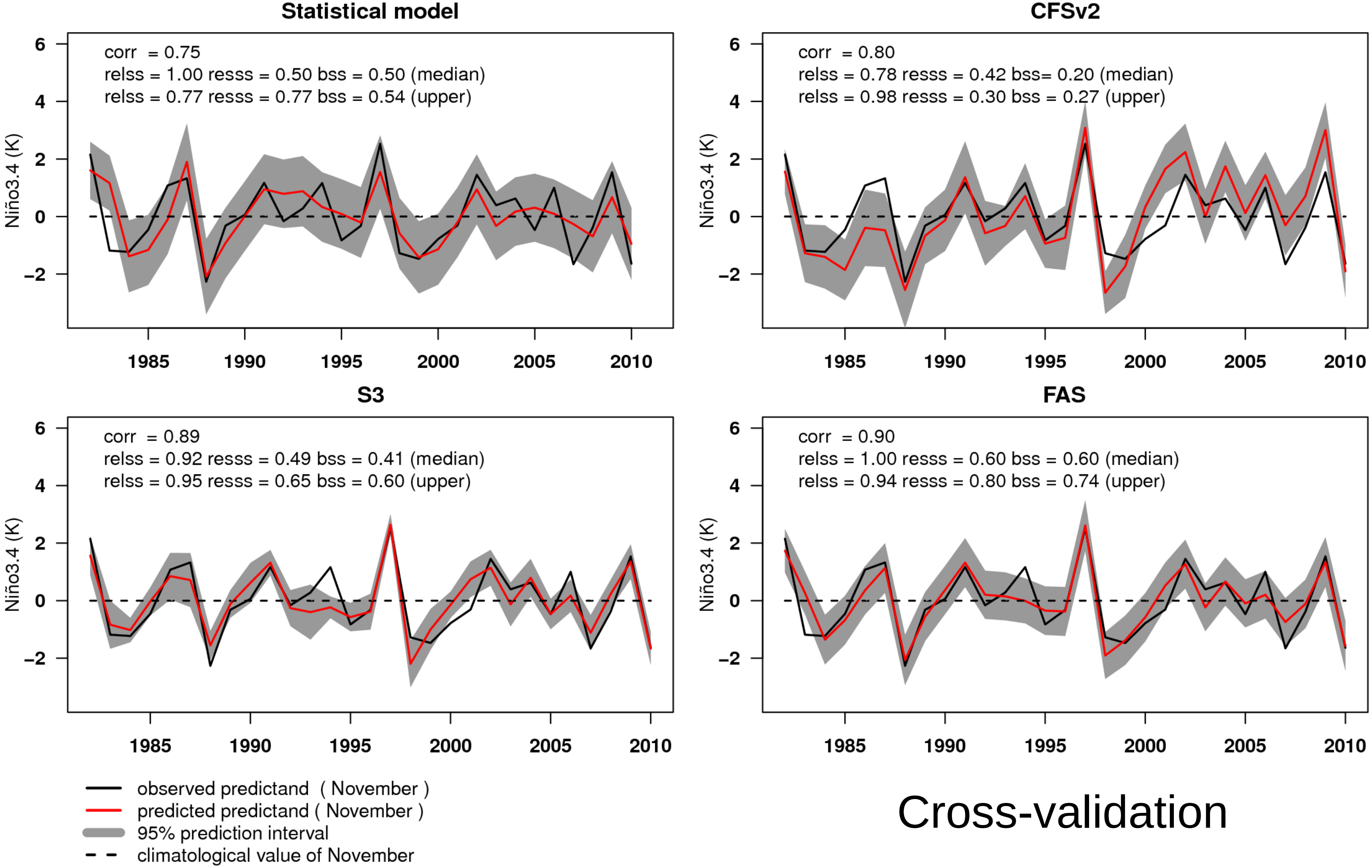
Forecast systems

- **Forecast Assimilation - Climatology (FAC)**
  - Estimate the likelihood PDF with S3, CFSv2 and statistical model
  - Climatology as prior

- **Forecast Assimilation - Statistical (FAS)**
  - Estimate the likelihood PDF with S3 and CFSv2
  - Statistical model as prior

Forecast systems

Niño 3.4 index forecasts for the target month of November with lead time 4
Start date in July



Cross-validation

Niño 3.4 index: ensemble-mean correlation

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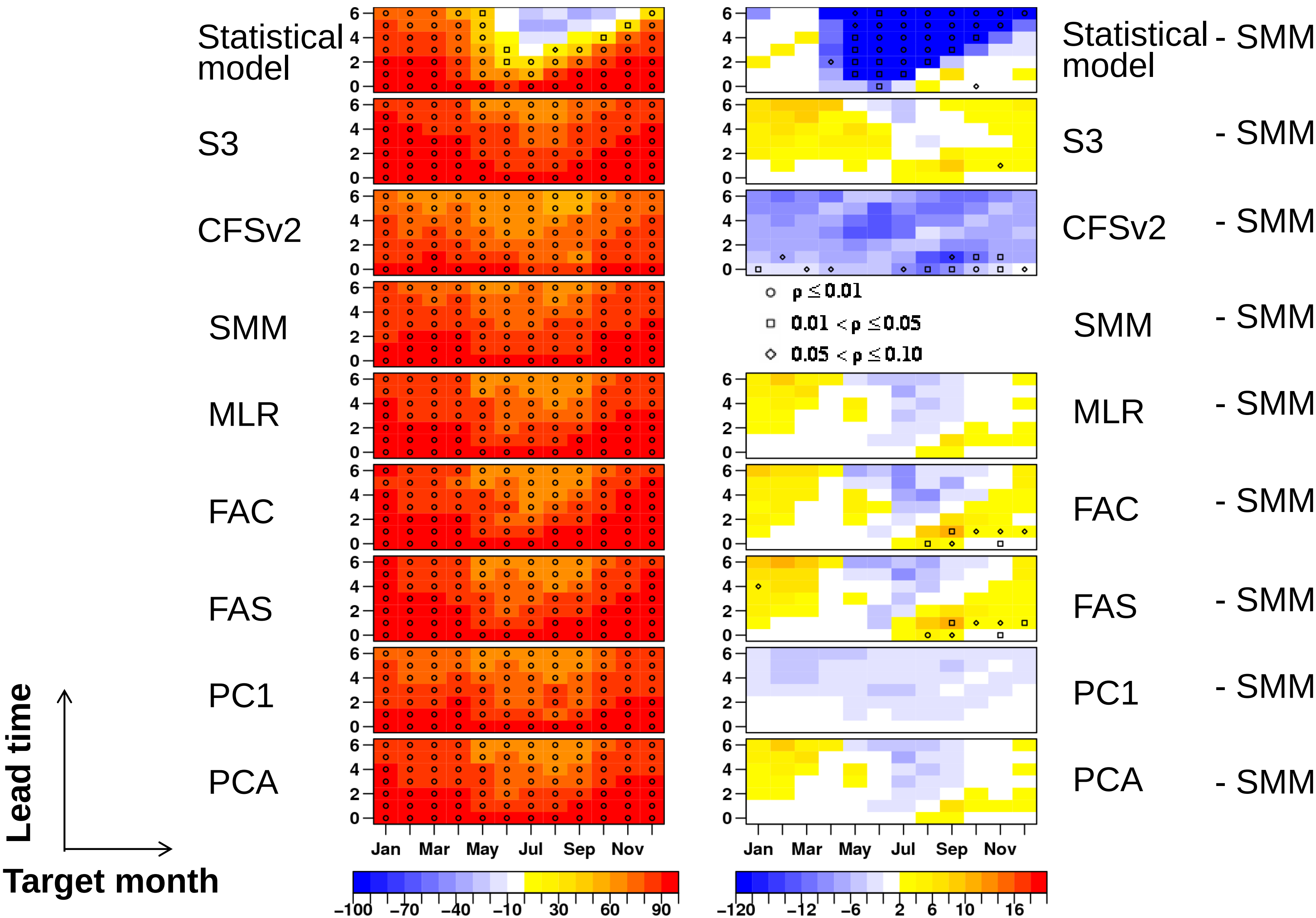

Niño 3.4 index: BSS (prob > median)

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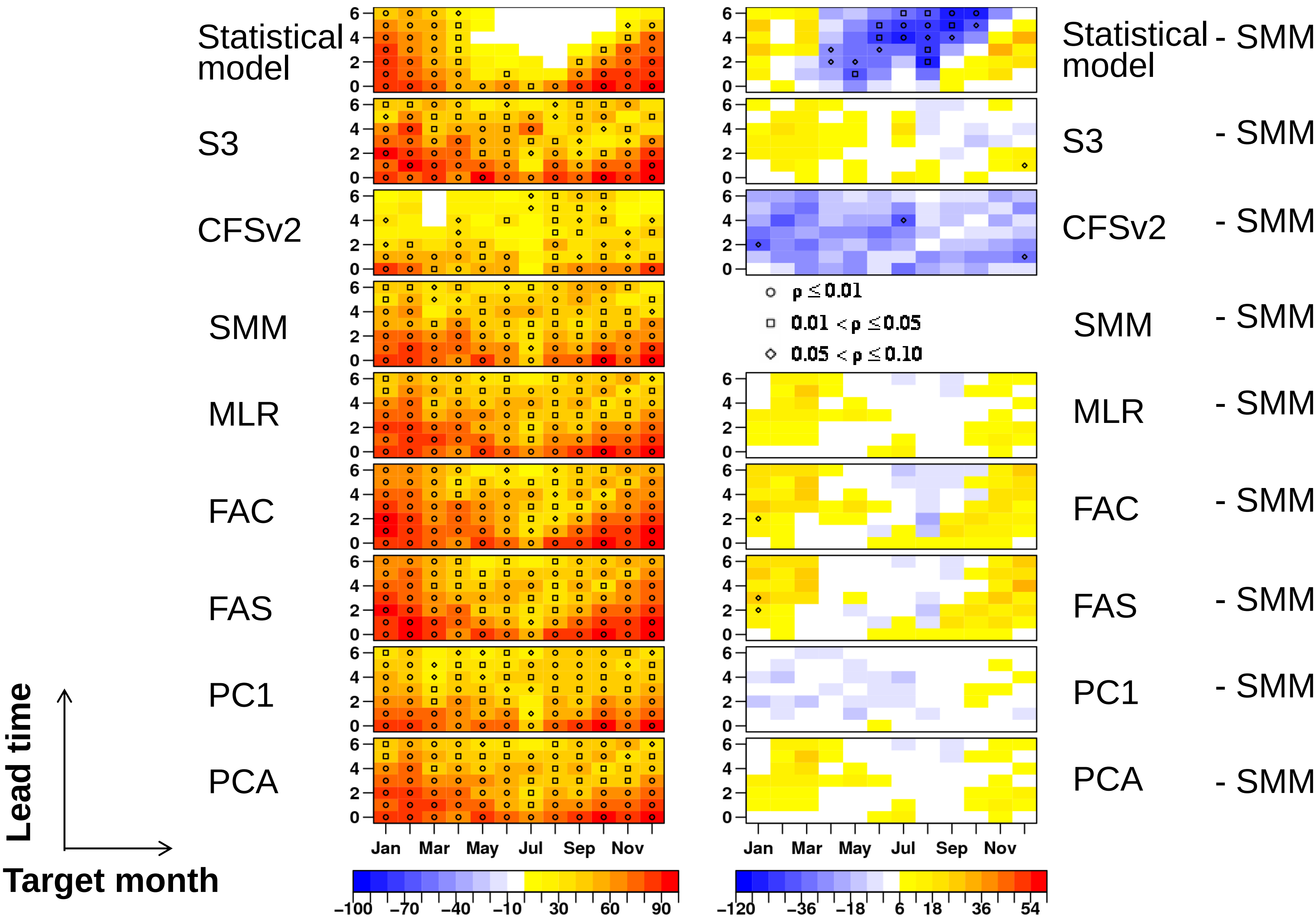
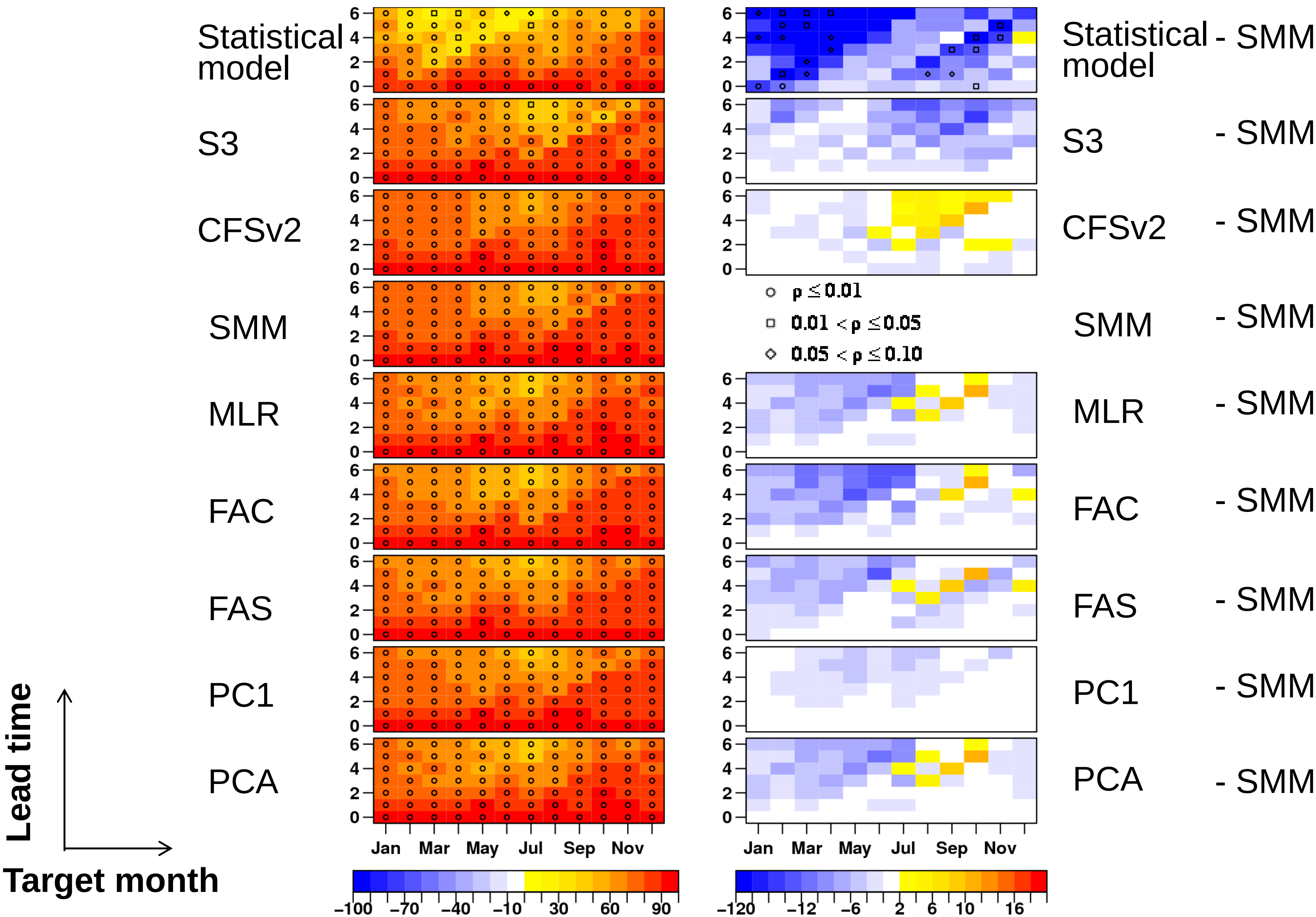


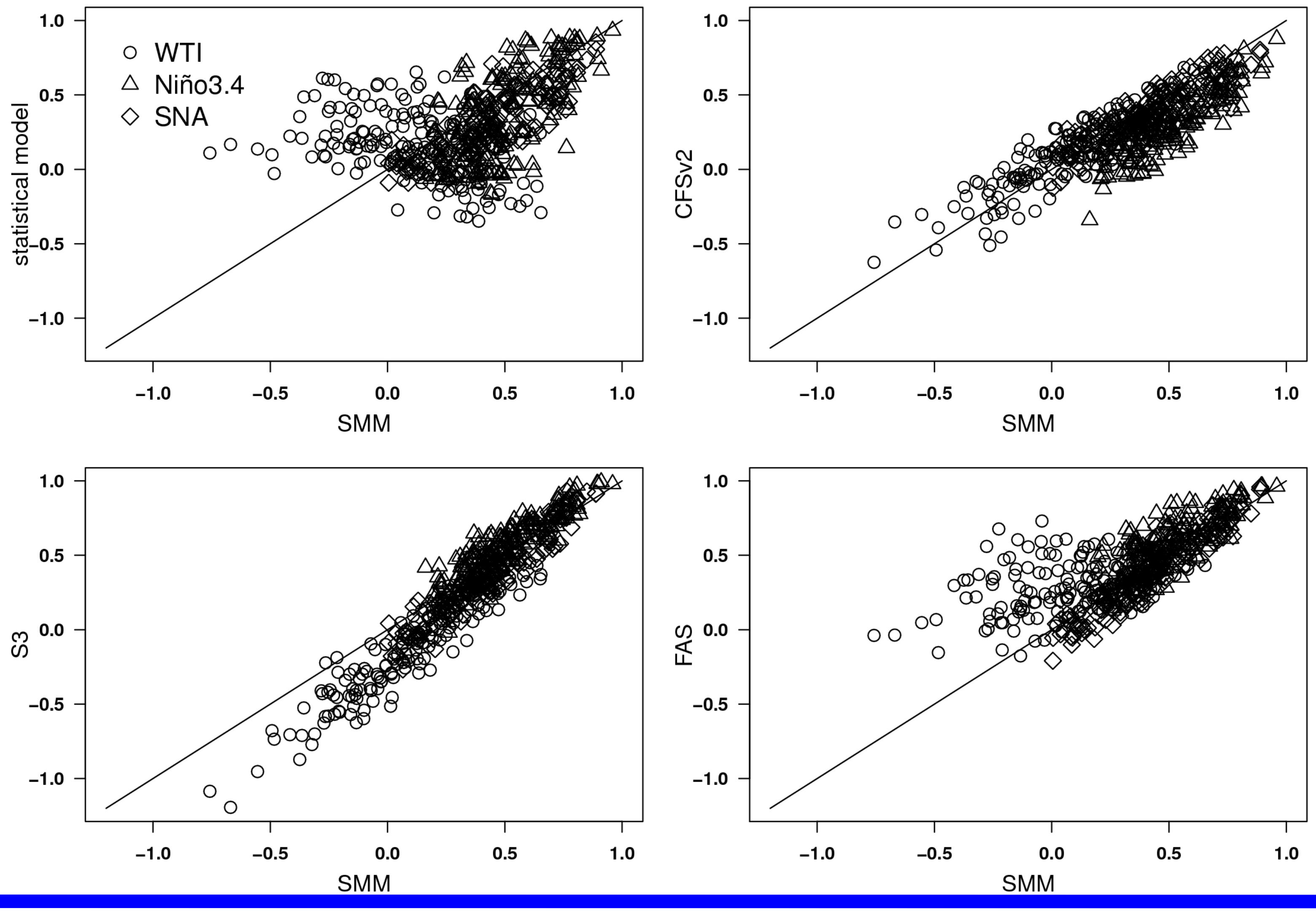
SNA index: ensemble-mean correlation



Scatterplot of three indices: BSS

All aspects: three indices, 12 target months, 7 lead times, two events (Prob > Median and Prob > Upper)

Western Tropical Indian ocean **(WTI) SST index** (50ºE - 70ºE, 10ºS - 10ºN)



Conclusions

- **Seasonal forecast is probabilistic in nature**
- **Quantify sources of forecast uncertainty (initial conditions and model inadequacy)**
- **SMM outperforms single forecast systems**
- **SMM is a difficult benchmark to beat due to:**
  - Short time series available
  - Small number of dynamical forecast systems
- **Unequally weighted combination methods improve both reliability and resolution, but not accuracy**
- **FAS improved both accuracy and reliability**

Thank you