“Diagnostics for physical evaluation of seasonal models”

Silvio Gualdi

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Rome, Italy

Ibimet ISTITUTO DI BIOMETEOROLOGIA
Consiglio Nazionale delle Ricerche

WMO

AERONAUTICA MILITARE SERVIZIO METEOROLOGICO 1923

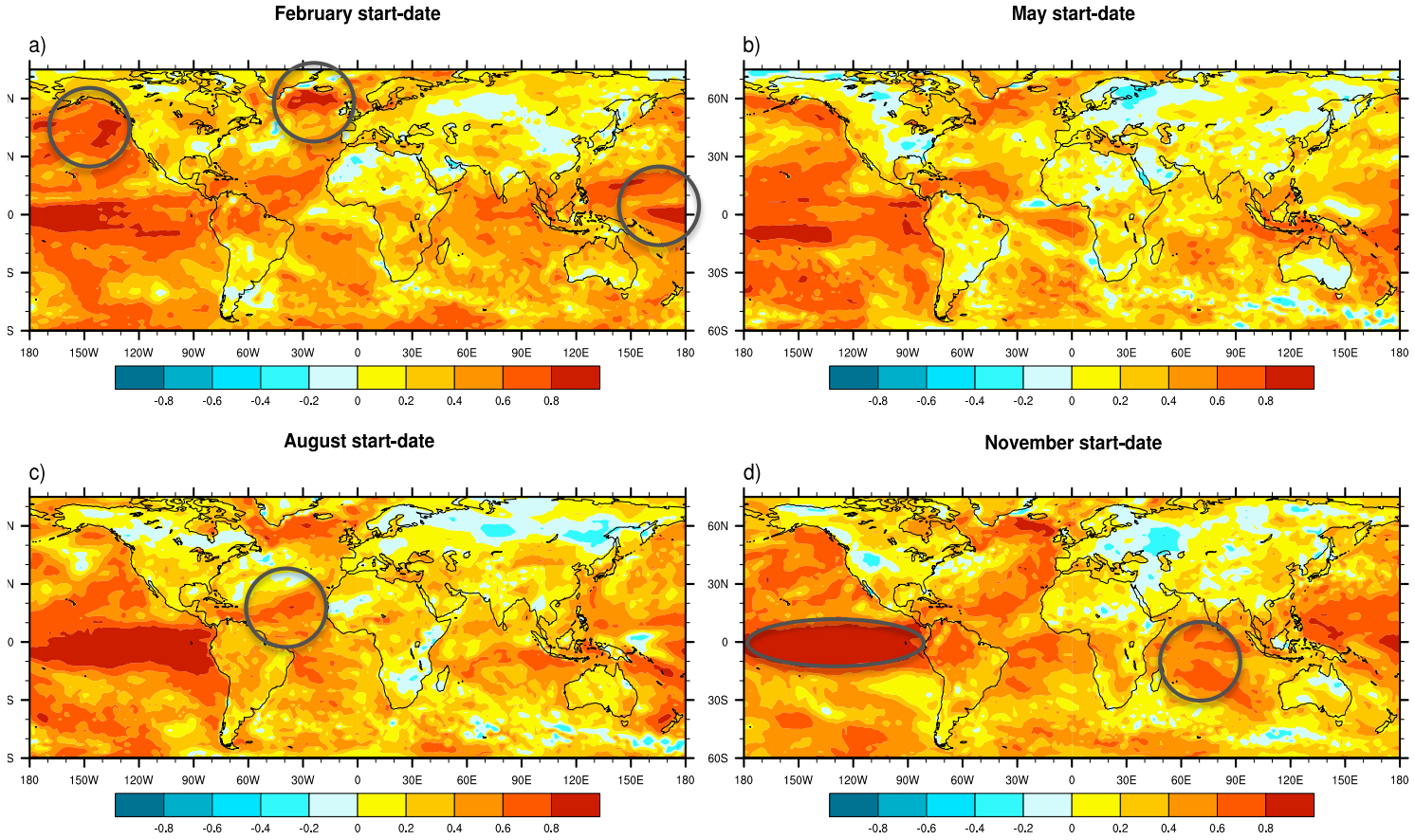
Virtute siderum tenuS

cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

Introduction: skill and physical processes

Surface Temperature ACC between forecast (Lead 1) and ERA-Interim reanalyses, for the 1981-2010 period (re-forecasts)

Lead time 1 refers to the season starting one month after the start date (e.g. Feb lead 1 = MAM)

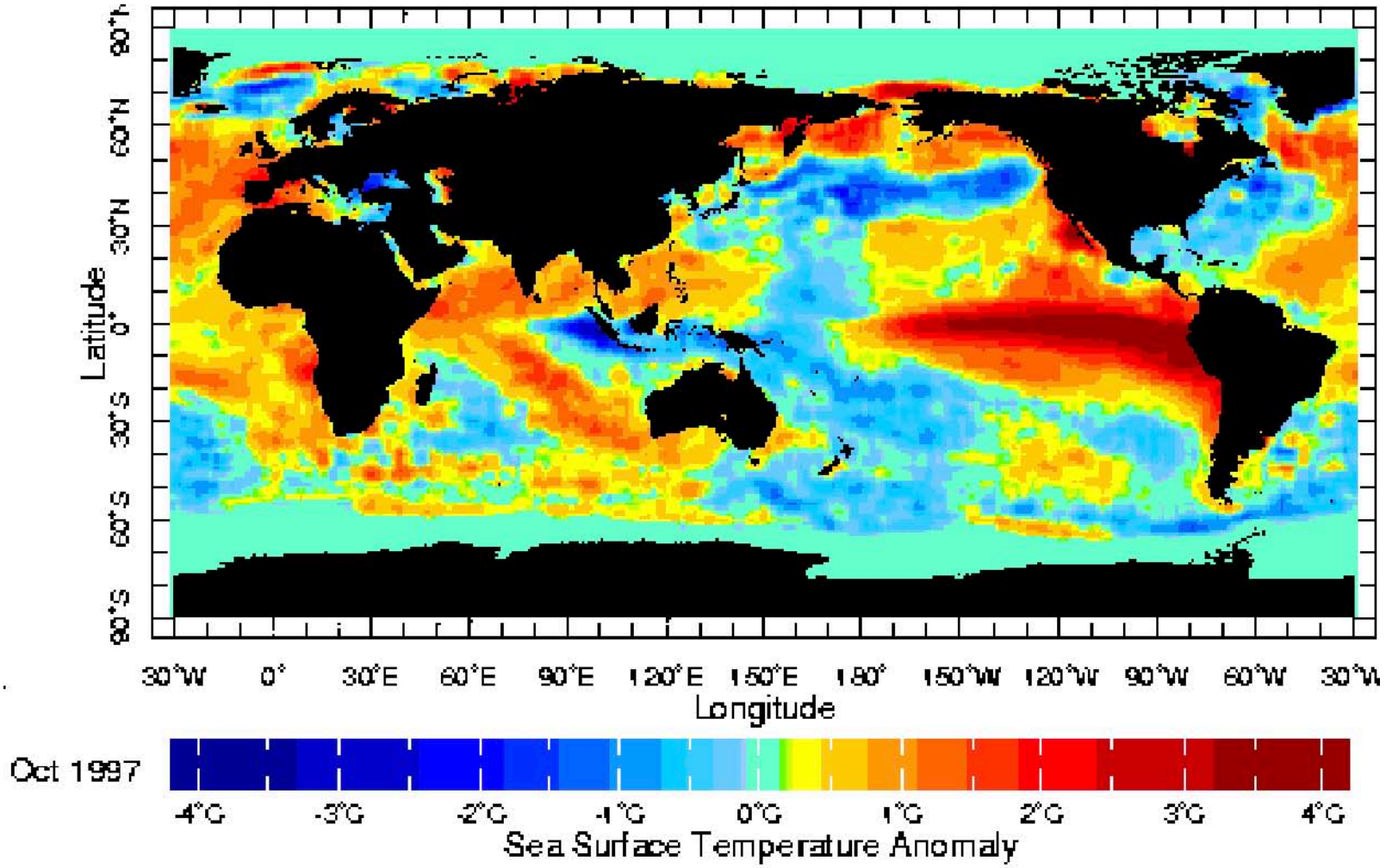


- Skill is higher in the Tropical oceans (ENSO and teleconnections)
- Good skill in the northern Atlantic region, particularly in the winter and the spring

Introduction: skill and physical processes

Anomalies are related to phenomena and physical processes

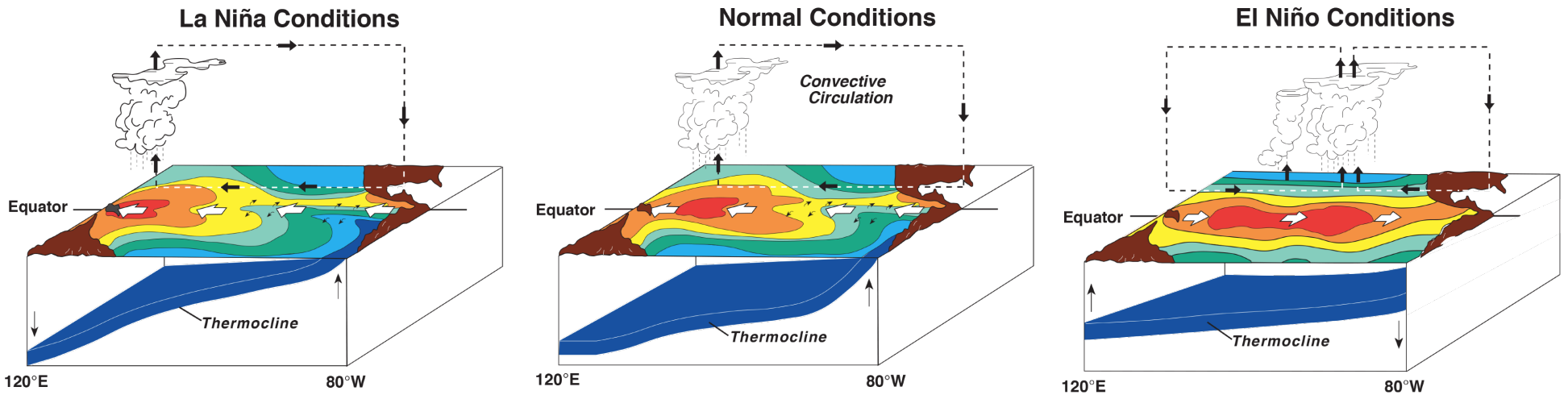
Skill in predicting anomalies → skill in representing physical phenomena and processes



Introduction: skill and physical processes

Anomalies are related to phenomena and physical processes

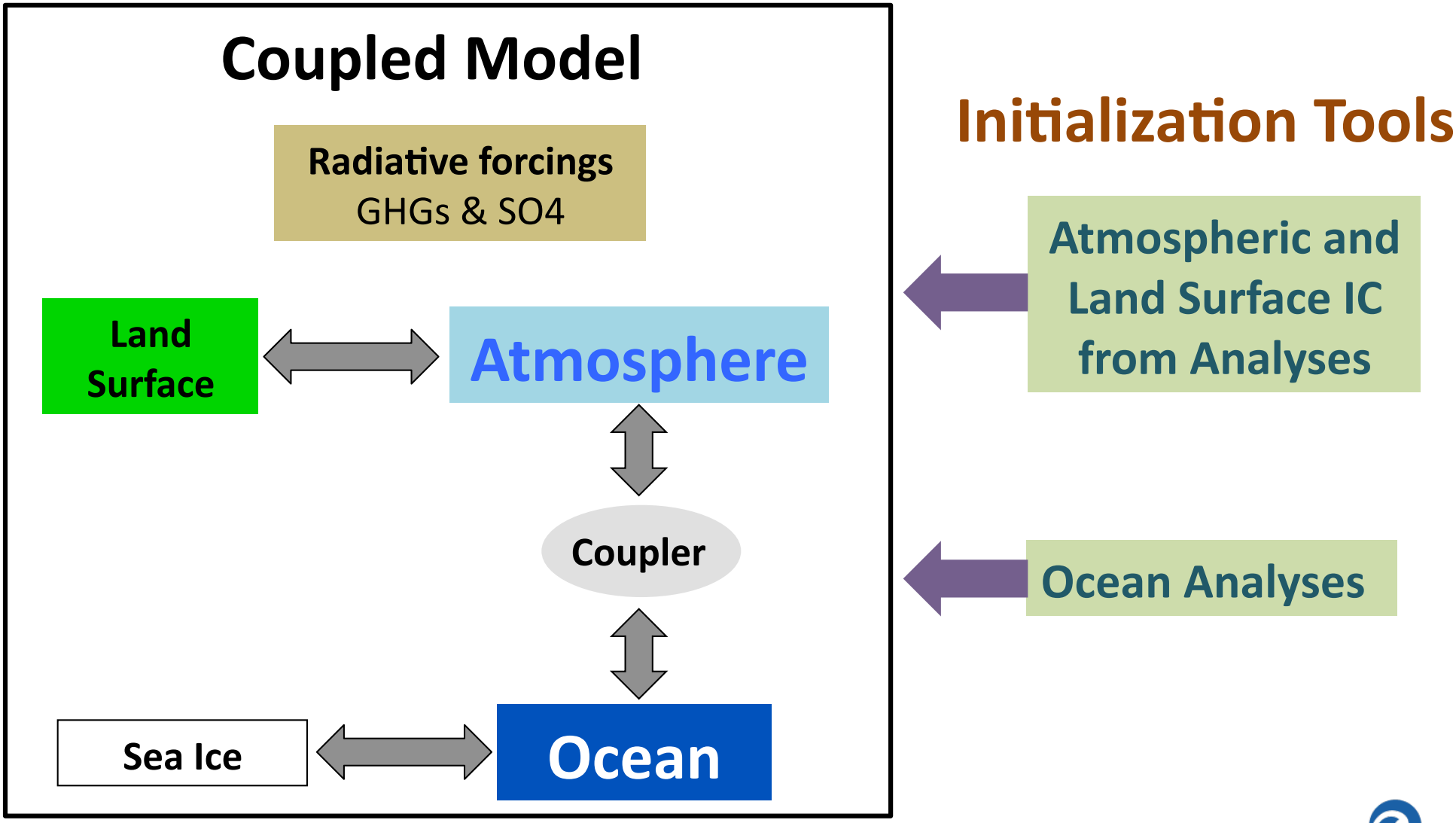
Skill in predicting anomalies → skill in representing physical phenomena and processes



NOAA/PMEL/TAO

A complex coupled atmosphere-ocean dynamical system →
→ crucial air-sea interactions and feedbacks

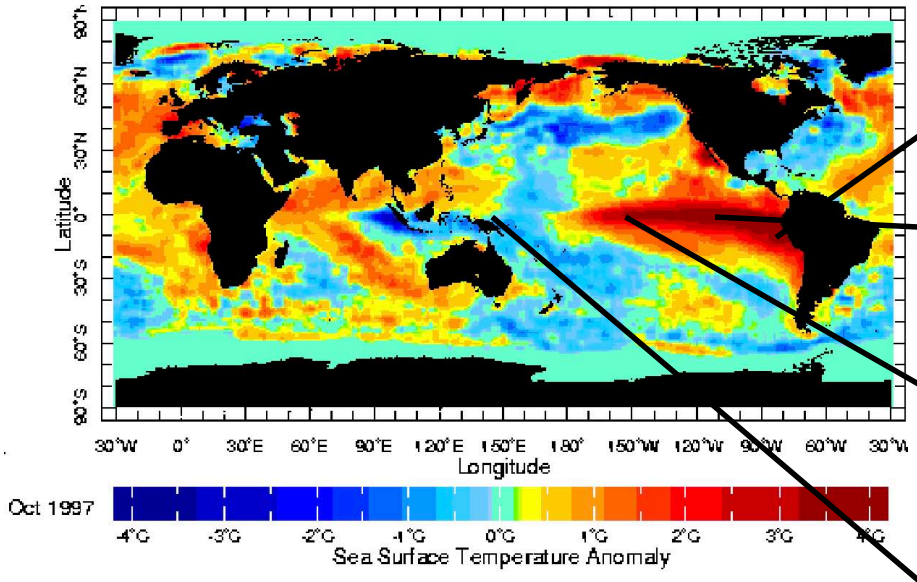
A Climate Prediction System

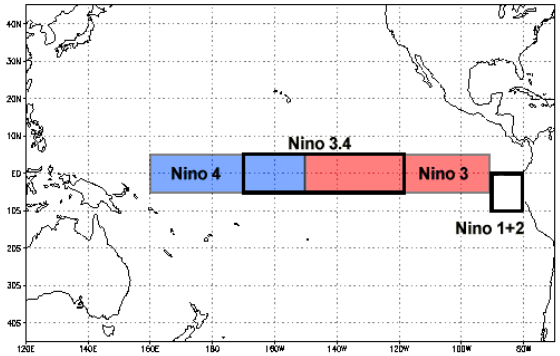


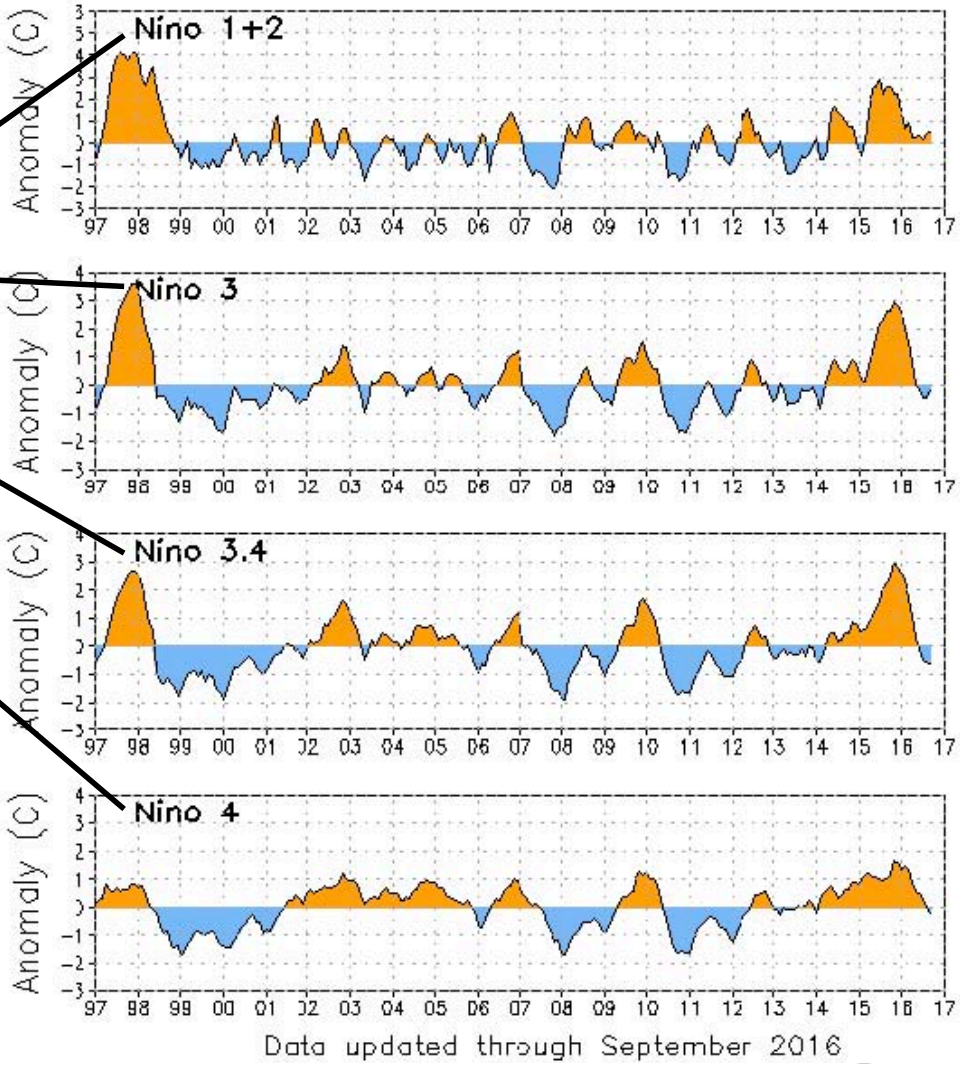
Introduction: skill and physical processes

Diagnostics for physical (process oriented) evaluation of a seasonal prediction system should quantify the ability of a system to reproduce and predict the evolution of specific metrics and indices that characterize a process or phenomenon.

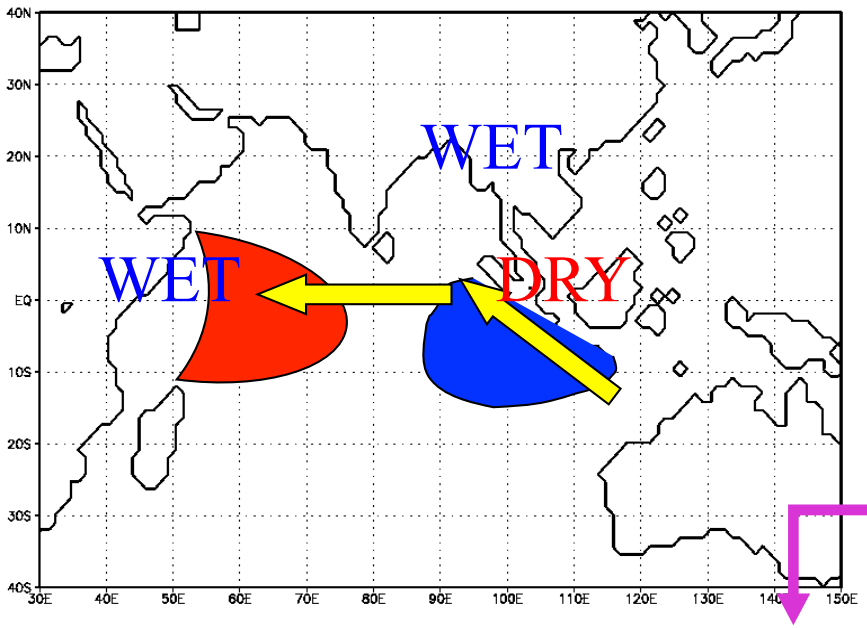
El Niño SST anomalies indices



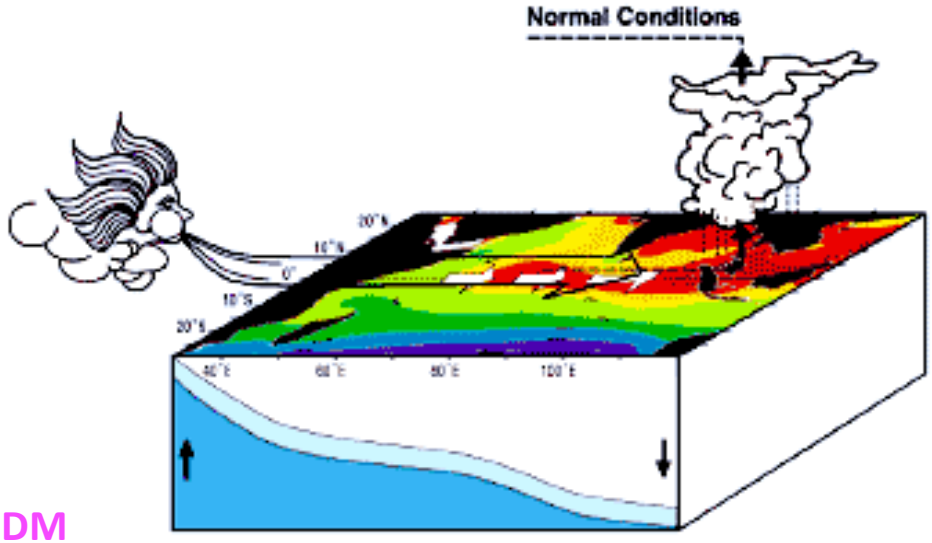


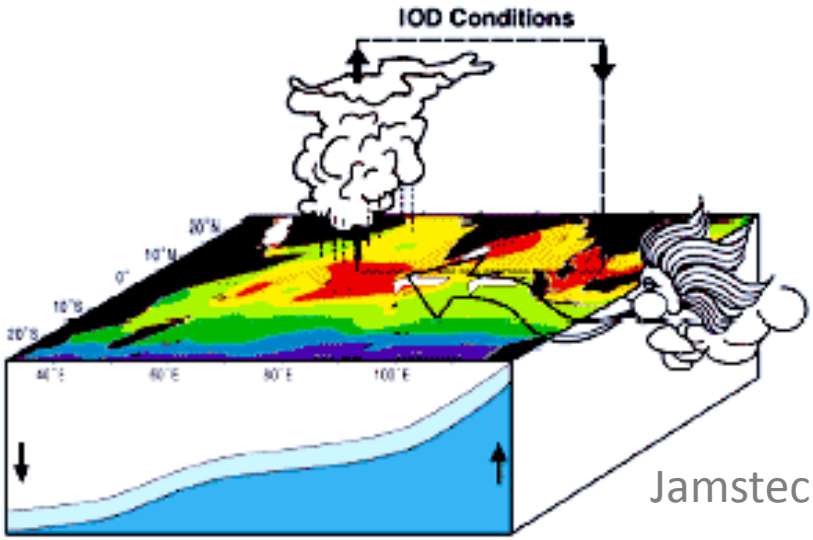


The Indian Ocean Dipole Mode (IODM)



(Reverdin et al. 1986; Meyers 1996; Webster et al. 1999; Saji et al. 1999)





surf. wind and precipitation anomalies
SSH anomalies, oceanic wave activity

STRONG SEASONALITY (OCT-DEC)

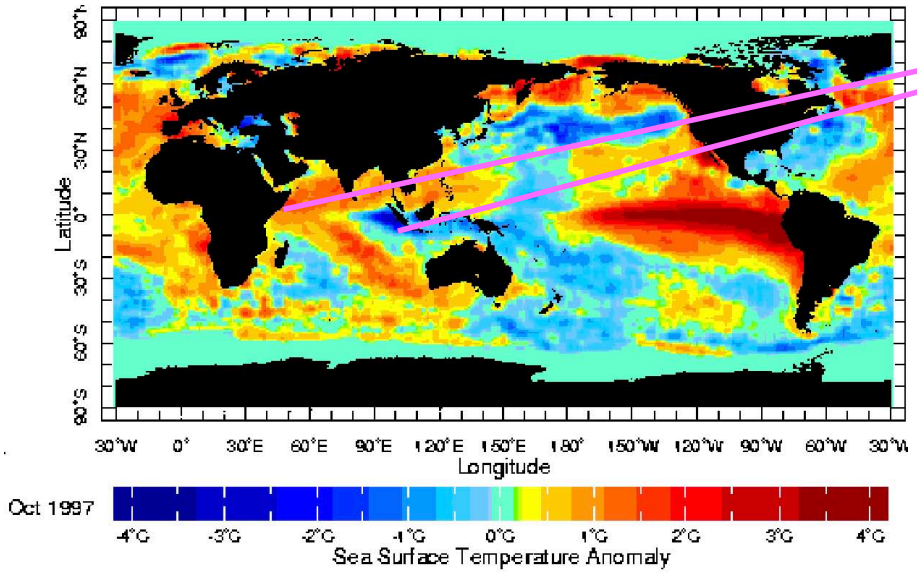
(e.g., Behera et al. 1999; Murtugudde et al. 2000; Iizuka et al. 2000; Vinayachandran et al. 2001; Black et al. 2002; Gualdi et al. 2003; Luo et al.2003; ...)

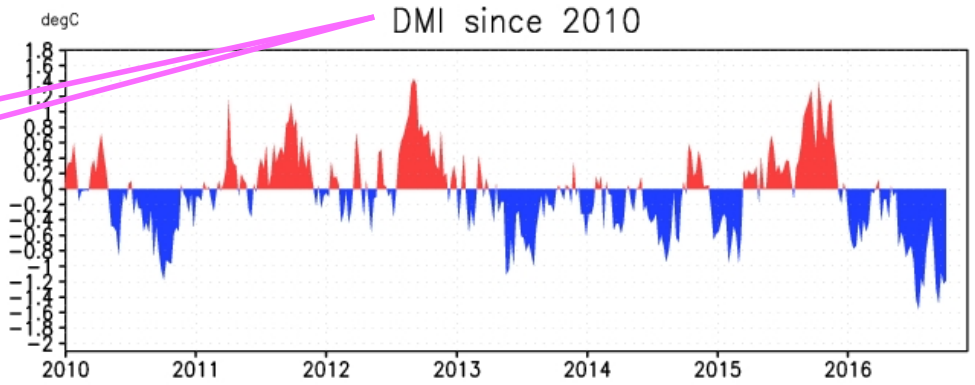
Jamstec

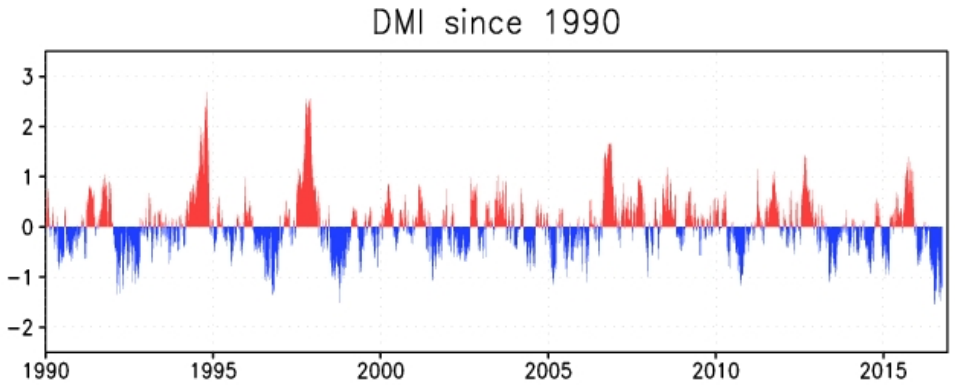
Introduction: skill and physical processes

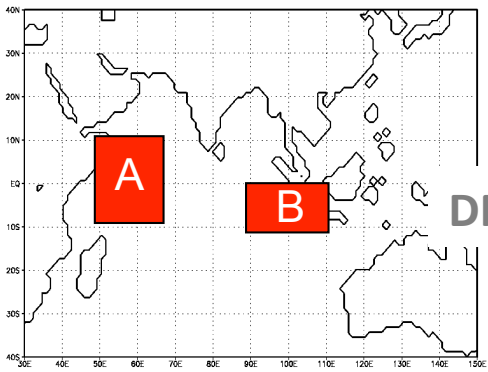
Diagnostics for physical (process oriented) evaluation of a seasonal prediction system should quantify the ability of a system to reproduce and predict the evolution of specific metrics and indices that characterize a process or phenomenon.

Indian Ocean Dipole Mode SST anomalies indices



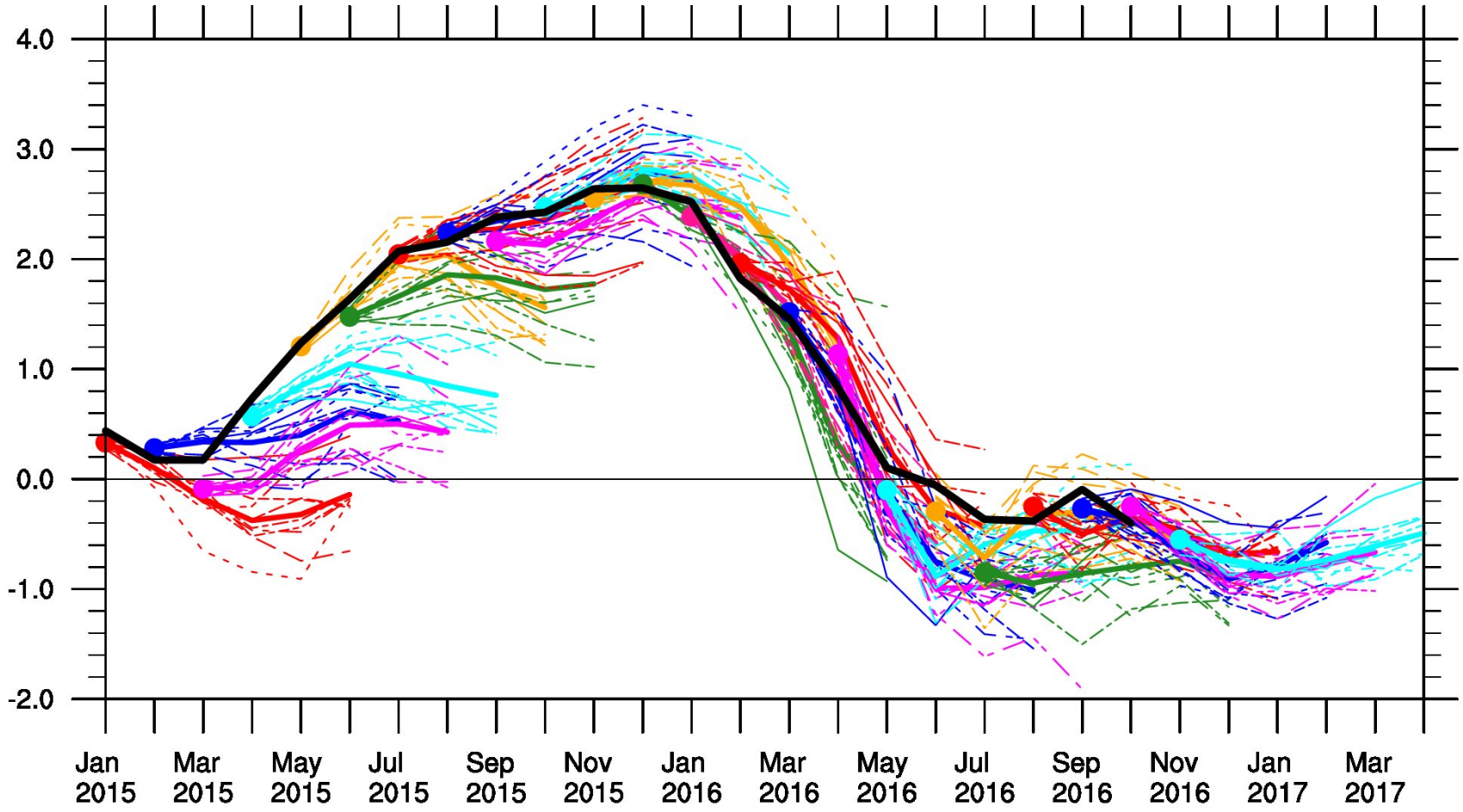




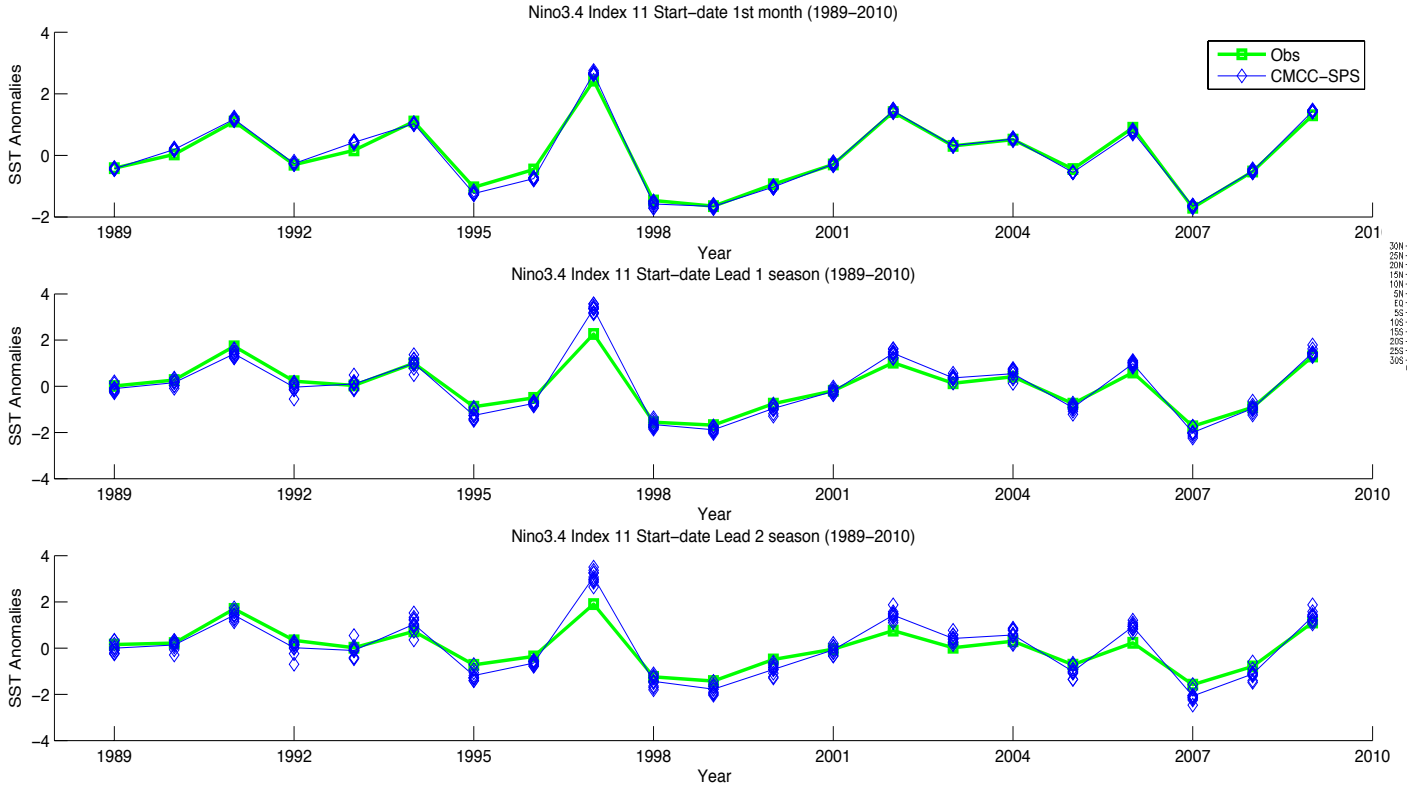


DMI = SST(A)-SST(B)

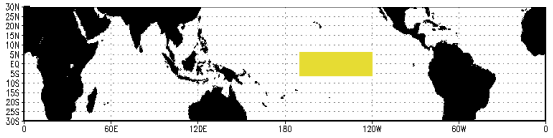
Predictions of the El Niño indices: the NINO3.4 SST anomaly



Predictions of the El Niño indices: the NINO3.4 SST anomaly



SST anomalies in the NINO 3.4 region



Lead 1 (2) refers to the season starting one (two) month after the start date (here, Nov lead 1 (2) = DJF (JFM))

The ENSO signal is well predicted by state-of-the-art seasonal prediction systems, with anomaly correlation coefficients generally higher than 95%

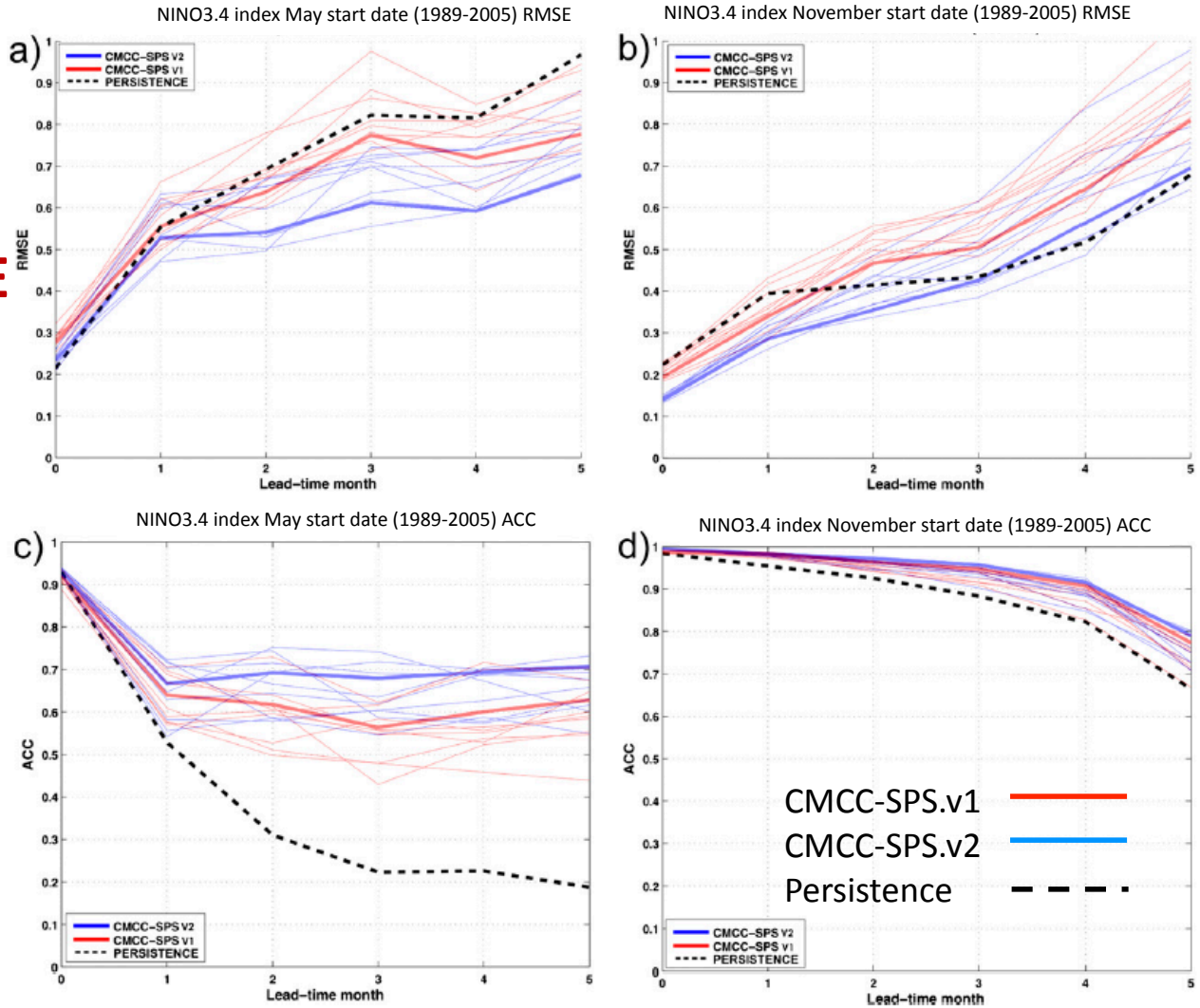
Predictions of the El Niño indices: the NINO3.4 SST anomaly

May

November

RMSE

ACC

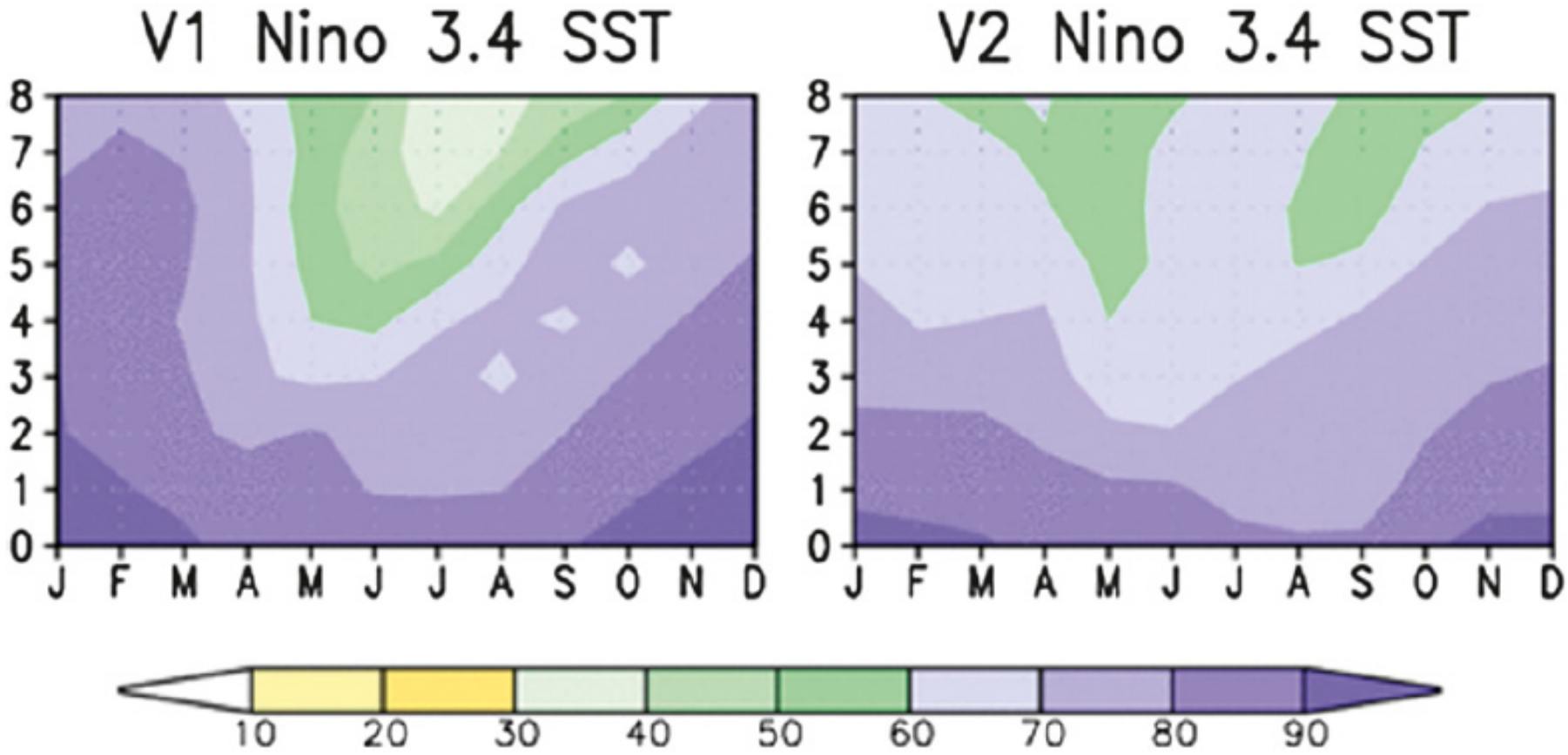


The **introduction of land-atmosphere initial condition** demonstrates an important and potentially predictable impact on the forecasts of equatorial Pacific SST (particularly in May), either as a result of the intra-seasonal stochastic component of the atmospheric initial state (Shi et al., 2011), or for the amplification of initial condition error in such a coupled system (Hudson et al., 2011).

Materia et al. J. Clim 2014

Predictions of the El Niño indices: the NINO3.4 SST anomaly

Evaluation of anomaly correlation as a function of target month (x-axis) and forecast lead (y-axis) for two versions of the CFS (NCEP) seasonal prediction system



Predictions of the El Niño indices: the NINO3.4 SST anomaly

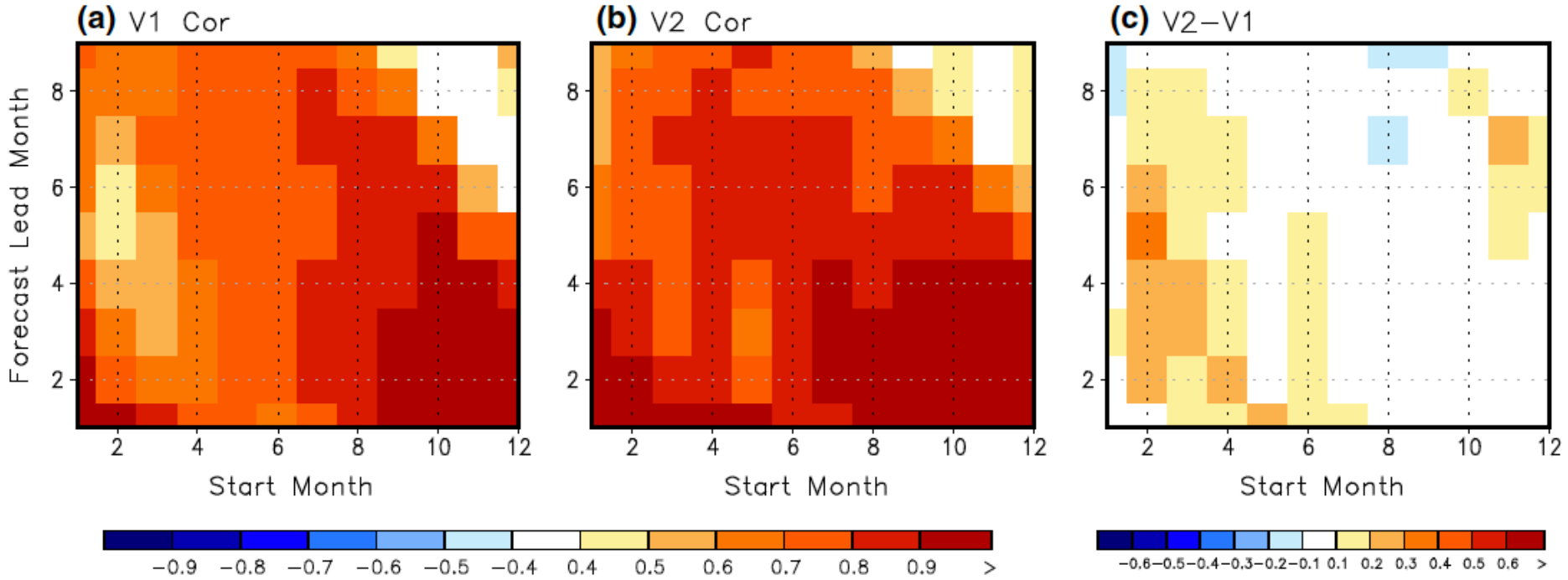
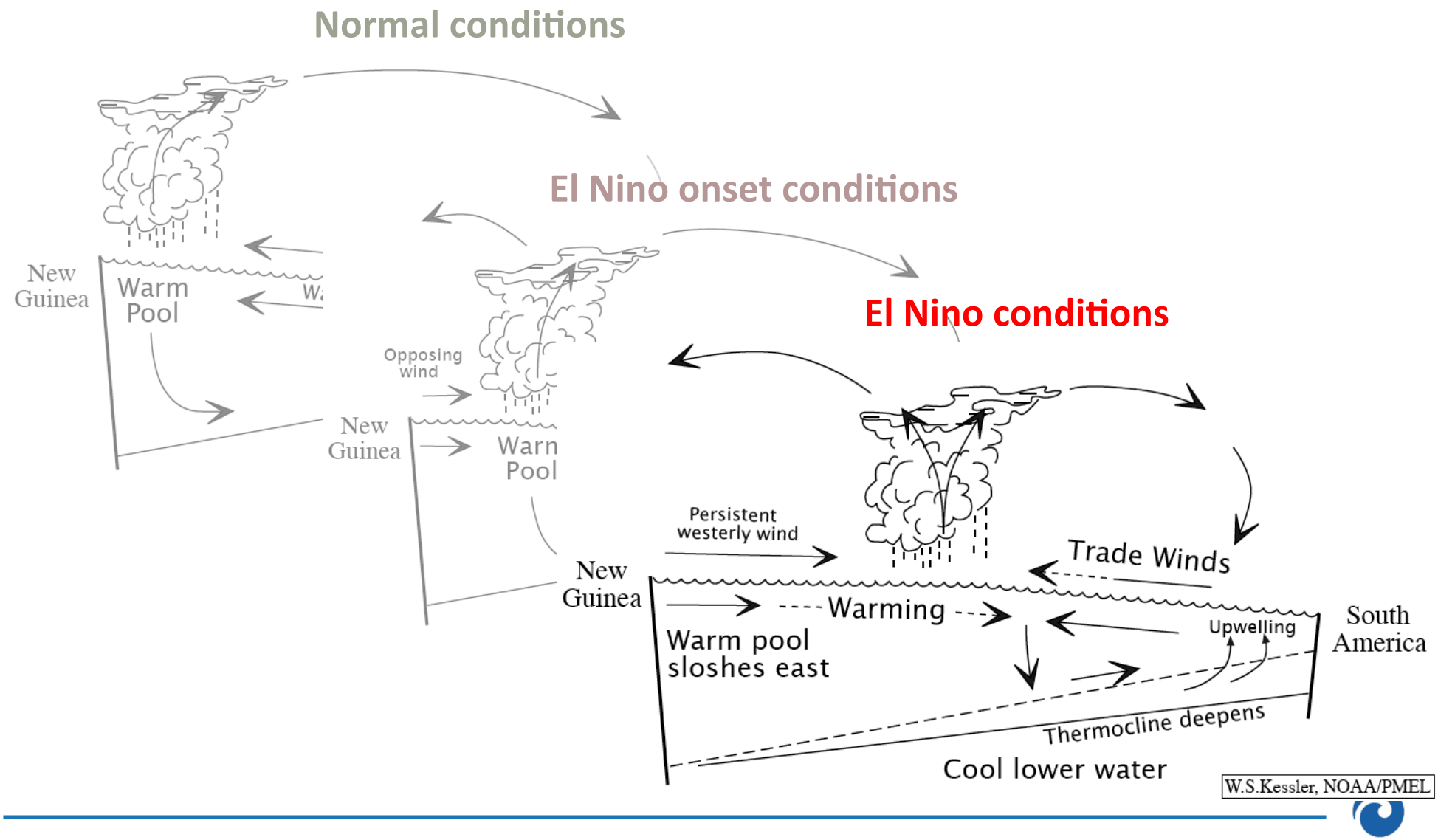
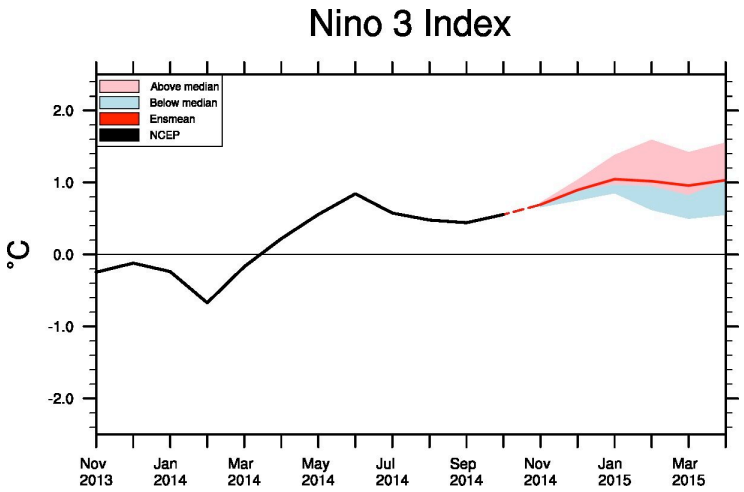


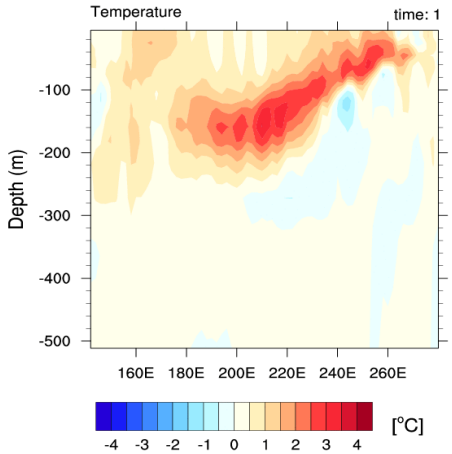
Fig. 3 The correlation skill of Nino3.4 index with respect to the start month (*x*-axis) and forecast lead month (*y*-axis) in **a** V1, and **b** V2. The panel (**c**) shows the difference of the correlation skill (i.e. V2–V1)

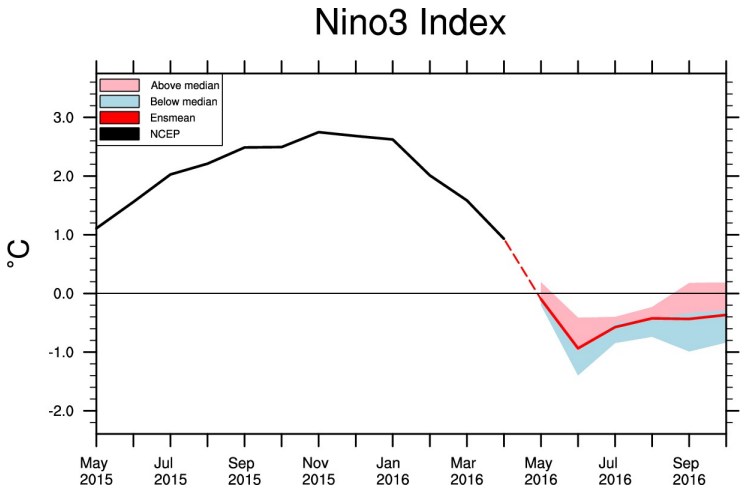
How do we manage to predict El Niño ?

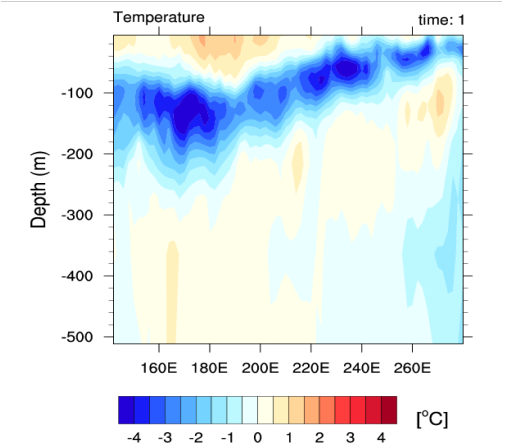


Predictions of the El Niño indices: the NINO3.4 SST anomaly



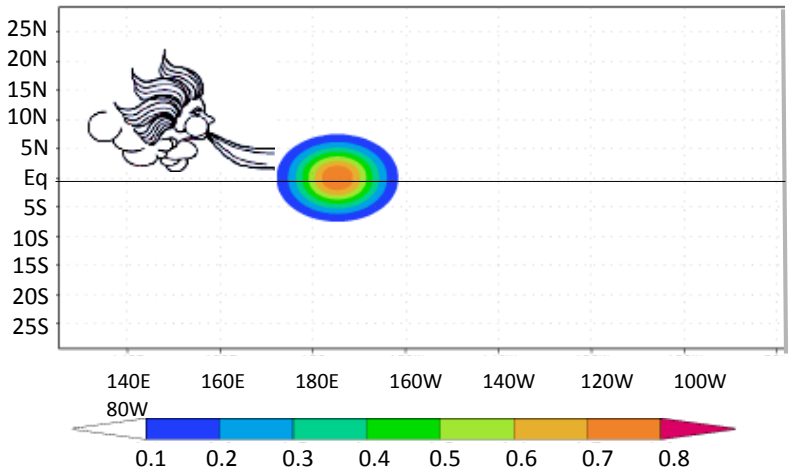




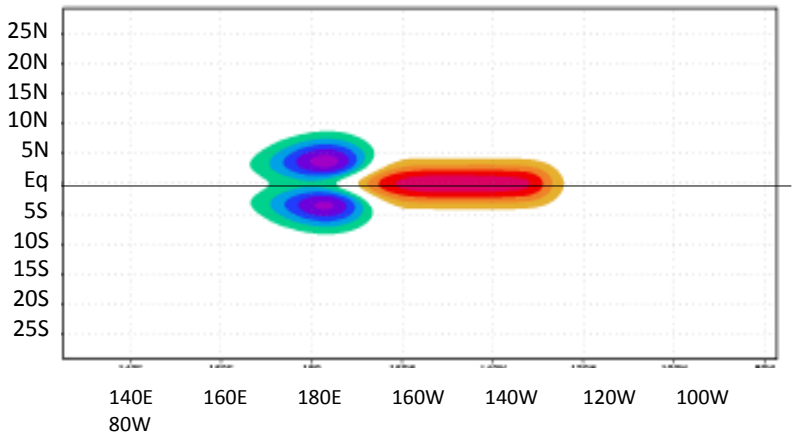


Delayed Oscillator Theory: evolution of RW and KW

Zonal wind anomaly on the Equator (westerly)



Ocean thermocline anomaly

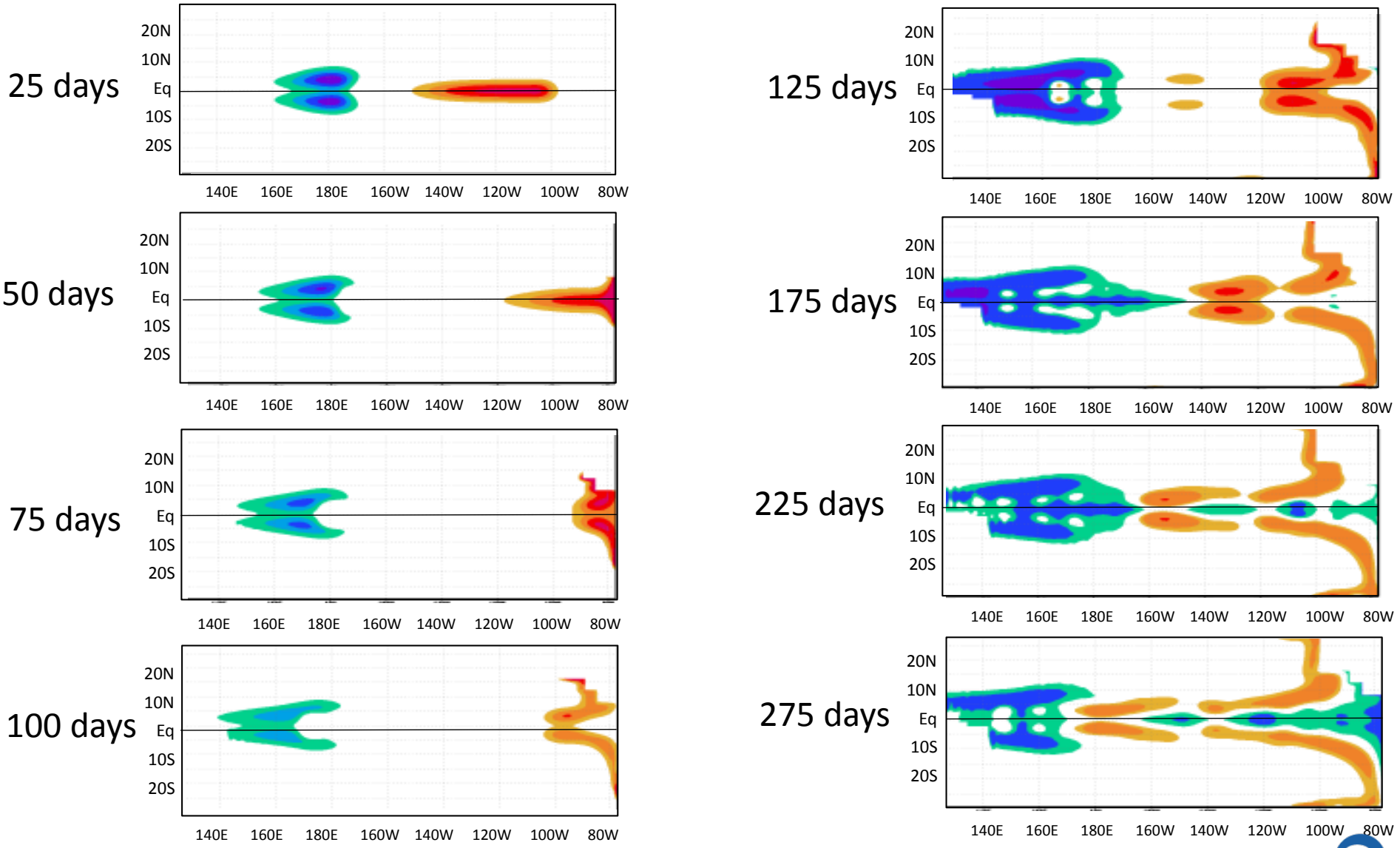


1. Kelvin wave: travels as a first baroclinic mode gravity wave with speed to the east, about 3 m/s to the EAST. Crosses the Pacific in about 2 months.

2. Rossby wave (first meridional mode) travels as a first baroclinic mode with phase speed, about 1 m/s to the WEST Cross the Pacific in 6 months.

Modified from Battisti (2000)

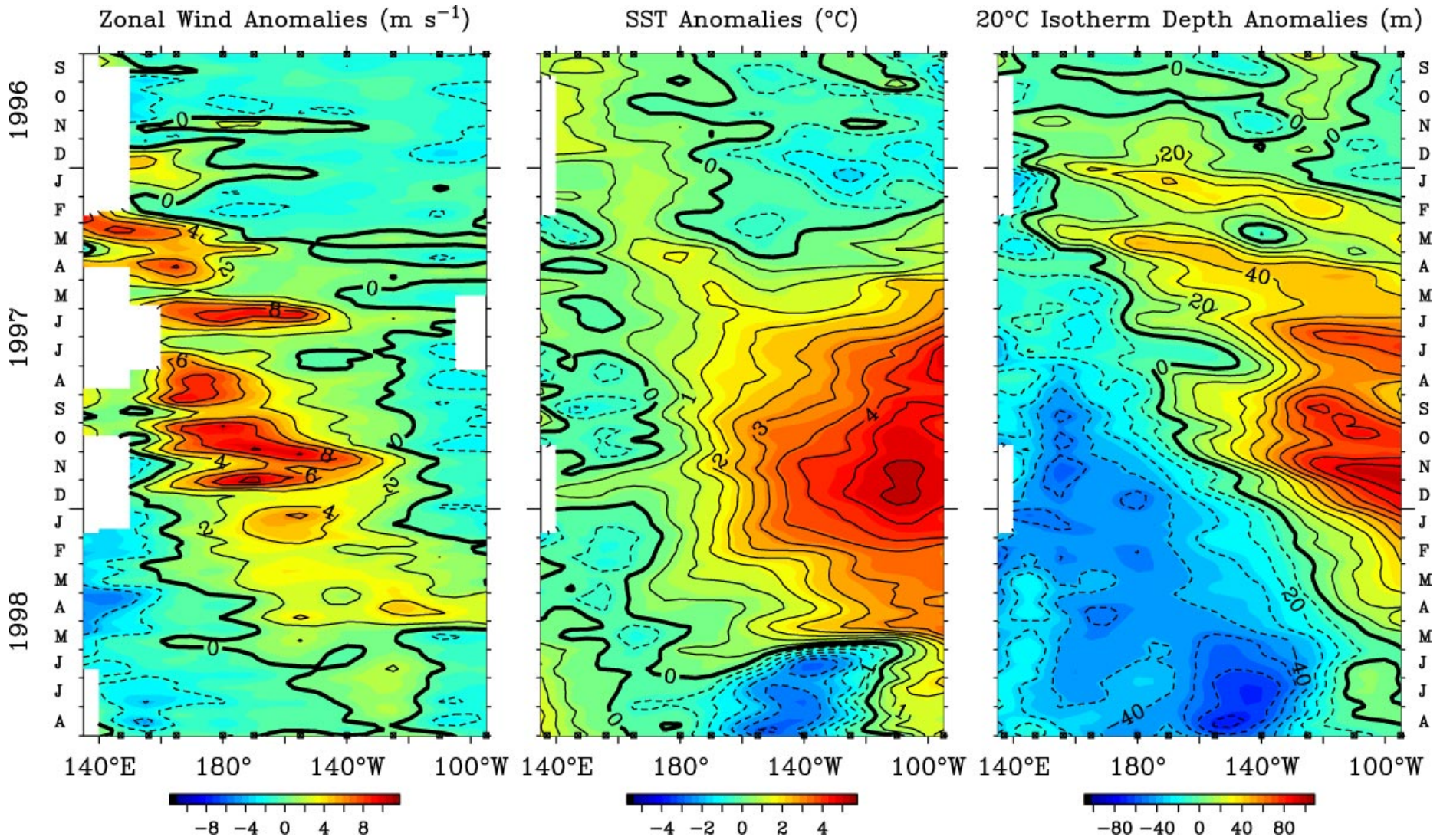
Delayed Oscillator Theory: evolution of RW and KW



Modified from Battisti (2000)

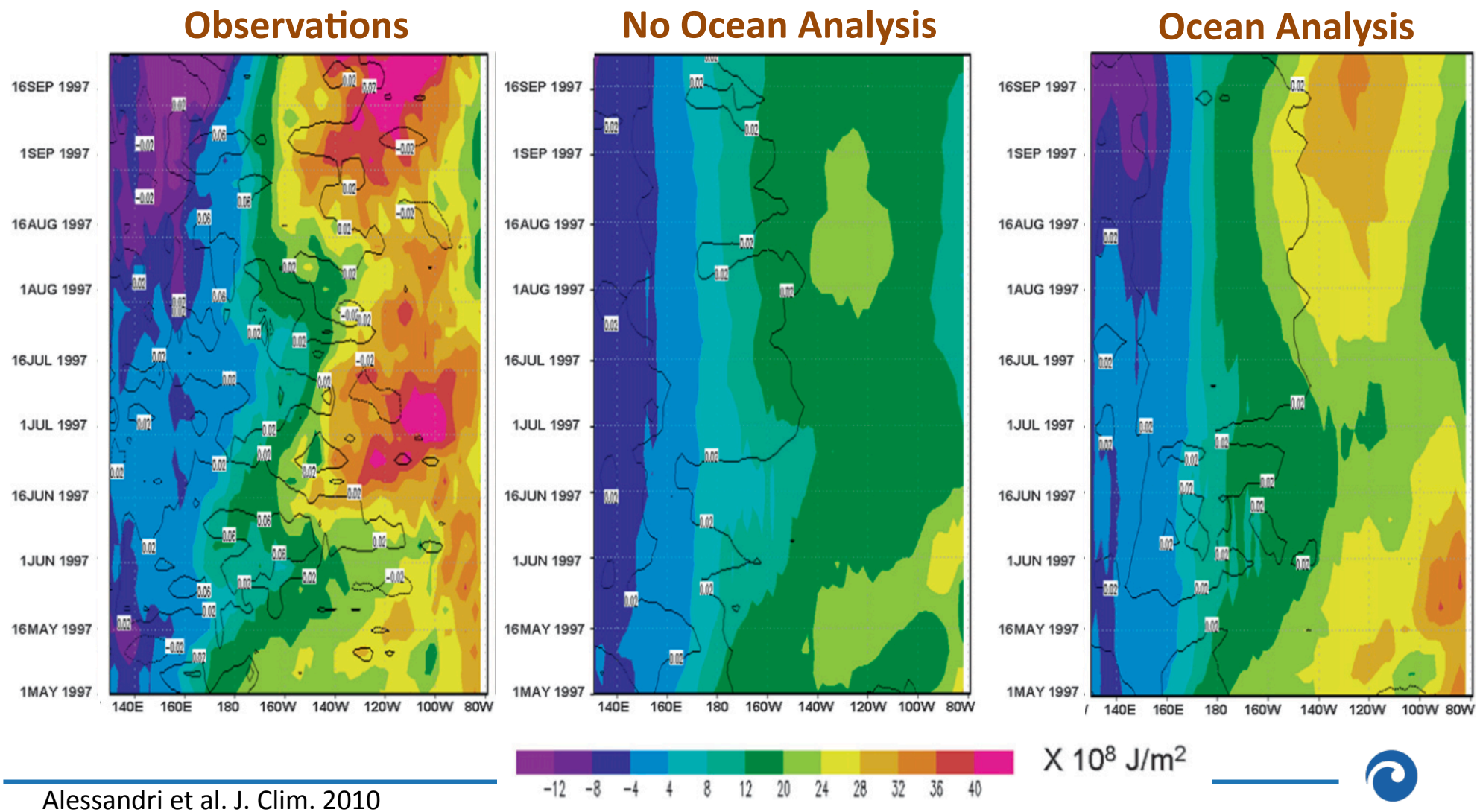
Process oriented evaluation: El Niño (ENSO)

The 1997-98 El Nino event



Improved initial conditions

Forecast of the onset of the 1997/98 El Nino: evolution of the heat content anomaly (shaded) and the zonal wind stress anomaly (contour)



Alessandri et al. J. Clim. 2010

Improved Resolution

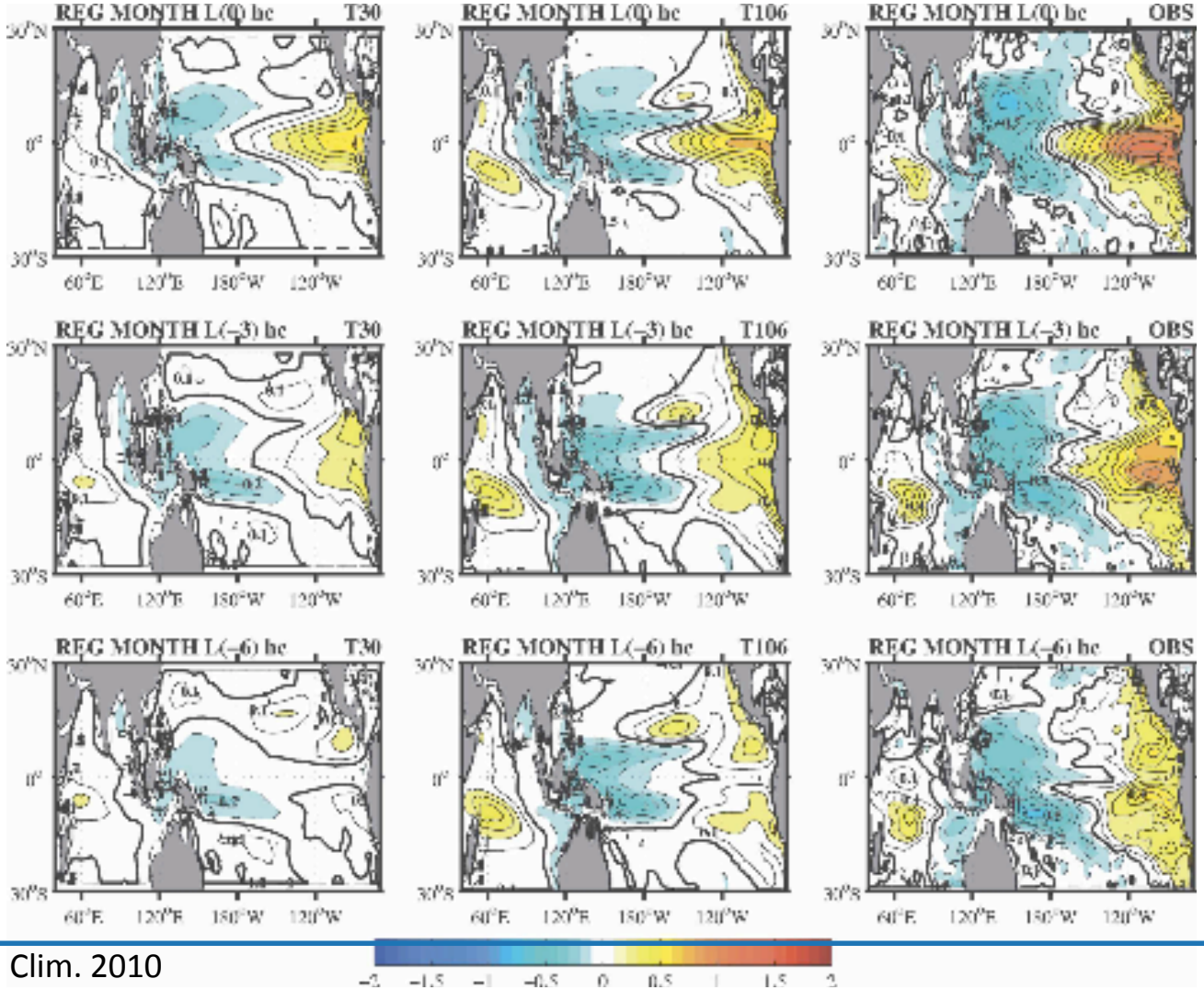
High-Resolution GCMs sustain a more realistic ENSO

Low-resolution | High-resolution | Observations

Lag 0

+ 3 months

+ 6 months



Navarra et al. J. Clim. 2010

Improved Resolution

1982-83, 1986-87, 1997-98 El Niño predictions, start date 1st of Feb

Thermal structure of the equatorial Pacific

Observations | Low-resolution | High-resolution

FEB-MAR

APR-MAY

JUN-JUL

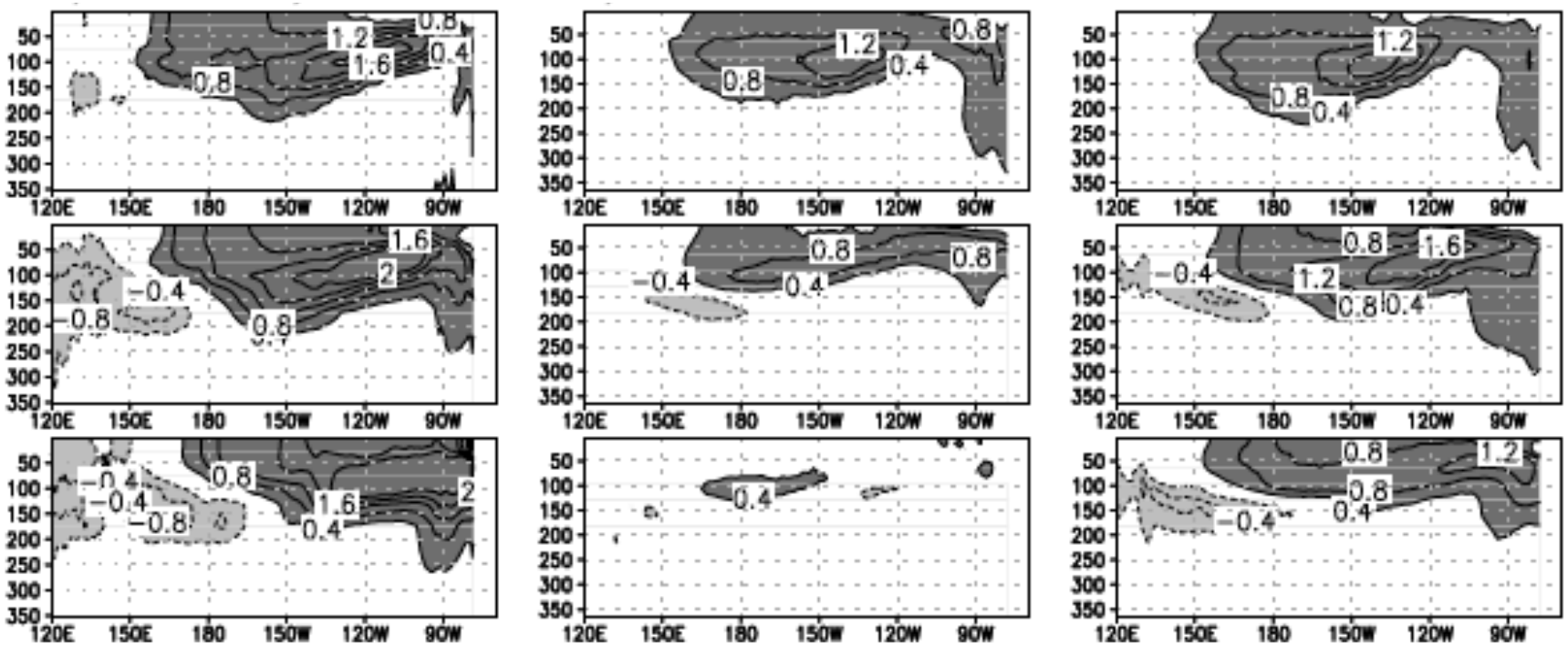


Fig 12. Composites of the temperature anomaly in the upper 350 m of the equatorial Pacific (average between 2.5°N and 2.5°S), during the developing (February–July) phase of warm ENSO events. As in Fig. 10, the evolution of the anomalies is depicted by composting the oceanic temperature anomaly over the year 1982, 1987 and 1997. Left panels, ocean analysis; middle panels, T42 forecasts; right panels, T106 forecasts. Contour interval is 0.4°C. Dashed contour and light shaded patterns correspond to negative values; solid contour and dark shaded patterns correspond to positive values.

Gualdi et al. Tellus, 2005

Improved Resolution

1982-83, 1986-87, 1997-98 El Niño predictions, start date 1st of Feb

Heat Content (upper 300-metre temperature)

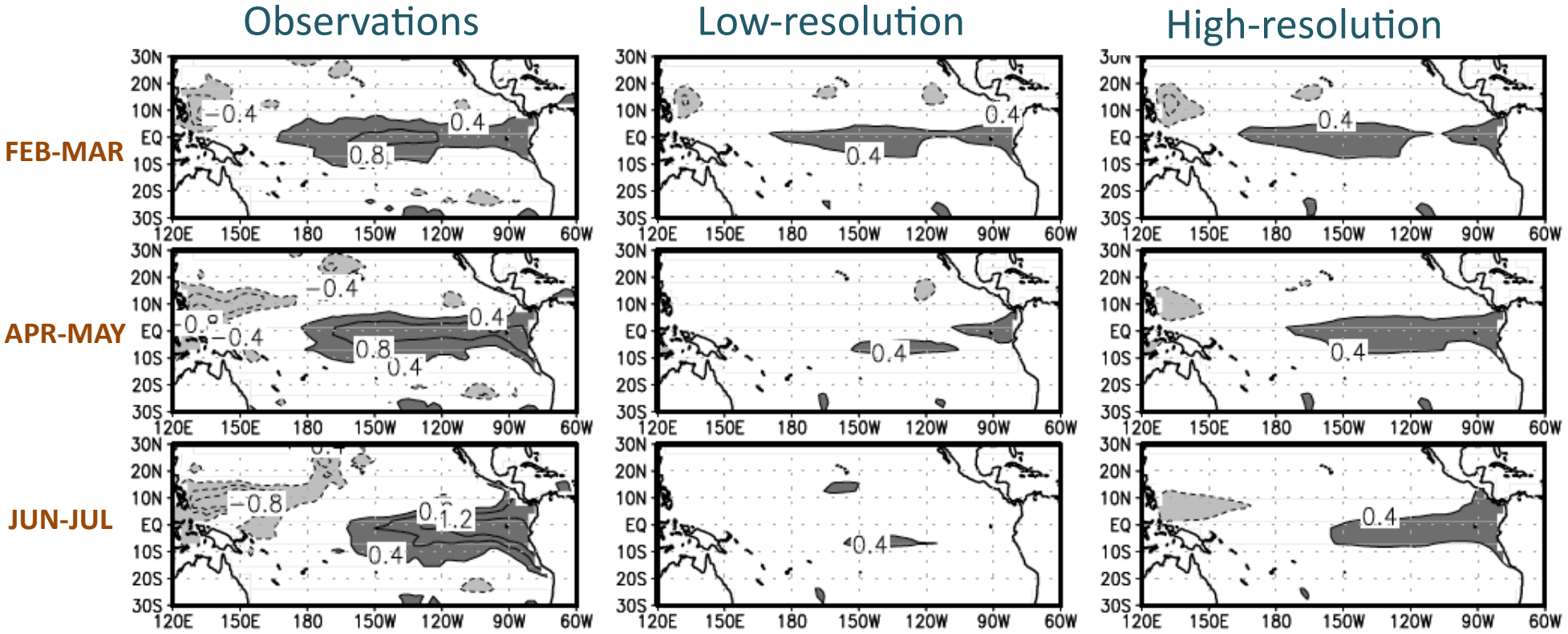


Fig 11. Composites of the HC anomaly in the tropical Pacific during the developing phase of warm ENSO (El Niño) episodes. The composite patterns depict the evolution of the HC anomalies for the period February–July, by averaging over the years 1982, 1987 and 1997. Left panels, ocean analysis; middle panels, T42 forecasts; right panels, T106 forecasts. Contour interval is 0.4×10^9 J m^{-2}. Dashed contour and light shaded patterns correspond to negative values; solid contour and dark shaded patterns correspond to positive values.

Gualdi et al. Tellus, 2005

Improved Resolution

1982-83, 1986-87, 1997-98 El Niño predictions, start date 1st of Feb

SST and 1000-hPa zonal wind

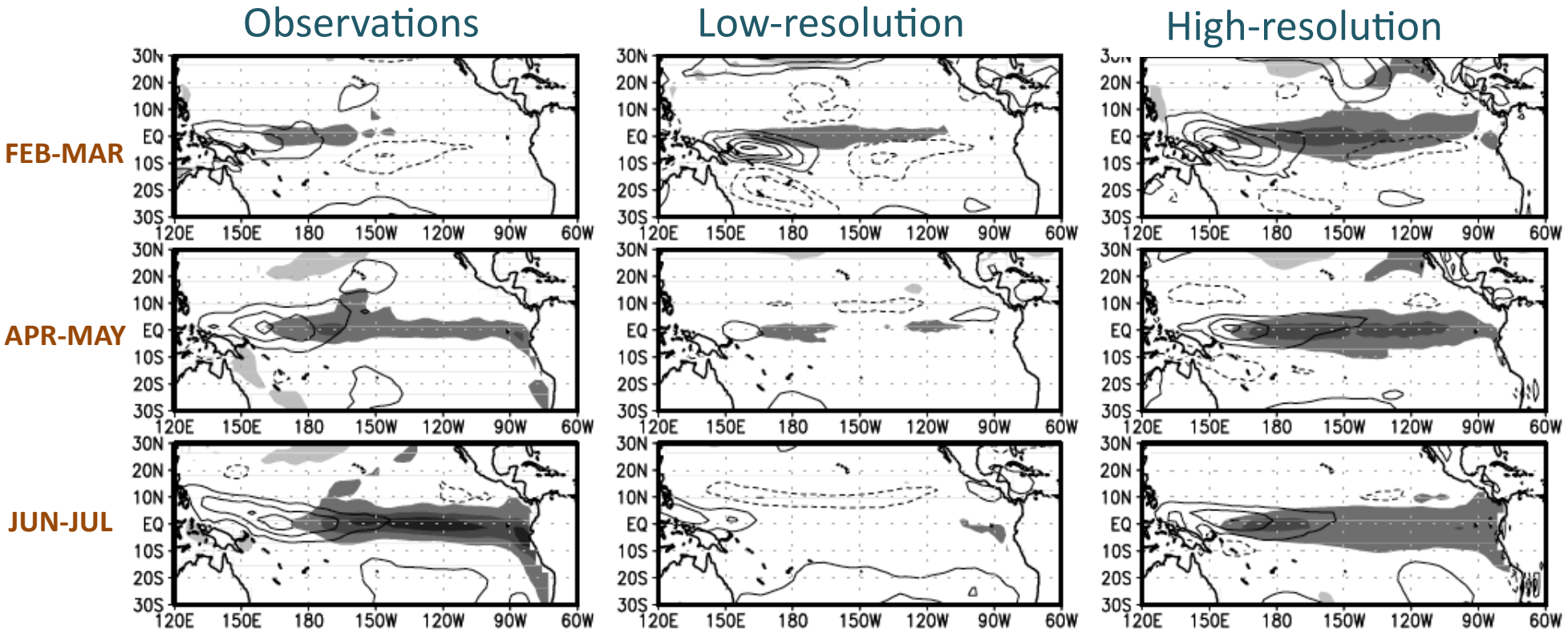


Fig 13. Composites of the SST (shaded patterns) and 1000-hPa zonal wind (contour patterns) anomaly in the tropical Pacific during the developing period (February–July) of El Niño events. The composites are obtained by averaging the anomalies over the years 1982, 1987 and 1997. Left column panels, ERA-40 results; middle column panels, T42 forecasts; right column panels, T106 forecasts. The SST contour interval is 0.5°C. Light (dark) shaded patterns correspond to negative (positive) values. Zonal wind contour interval is 1 m s^{-1}. Dashed (solid) contour corresponds to negative (positive) values.

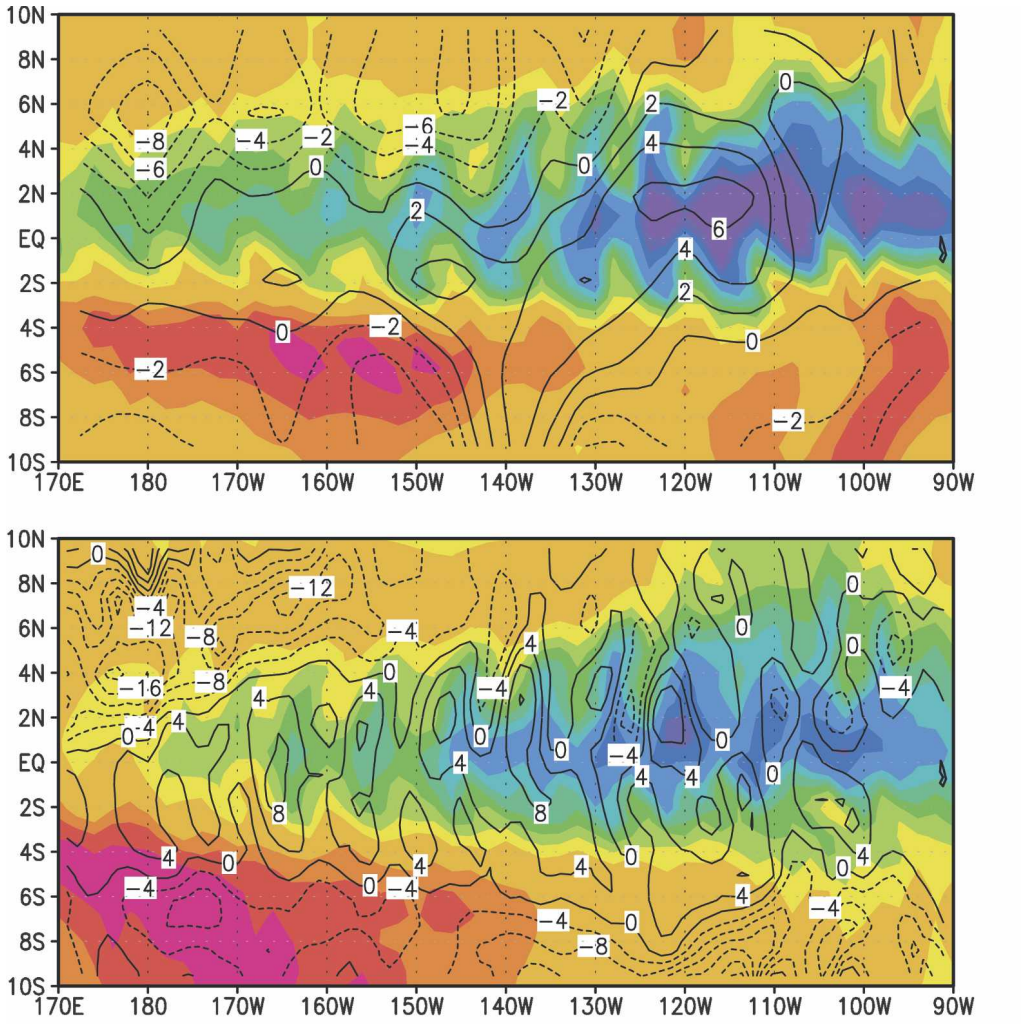
Gualdi et al. Tellus, 2005

Improved Resolution

High-Resolution GCMs sustain a more realistic air-sea interaction

Low resolution
~300km

High resolution
~100km



Snapshot of SST (shaded 0.5°C) and divergence of surface stress (contours 10^{-5} m^2/s) for pentads.

Navarra et al. J. Clim. 2010

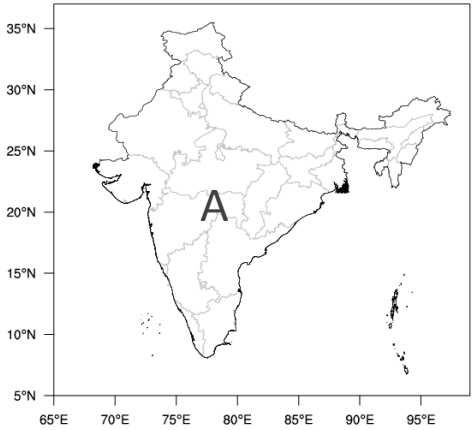
Prediction of the Indian monsoon

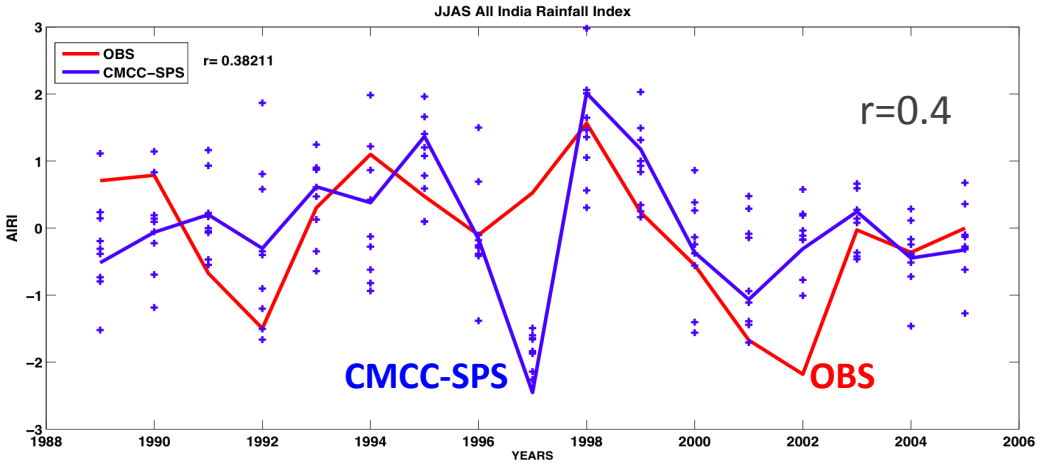
All India Rainfall Index

[e.g., Parthasarathy et al. (1995)]

$$\int_A (prp - \overline{prp})\,dA$$

CMCC SPS.v1

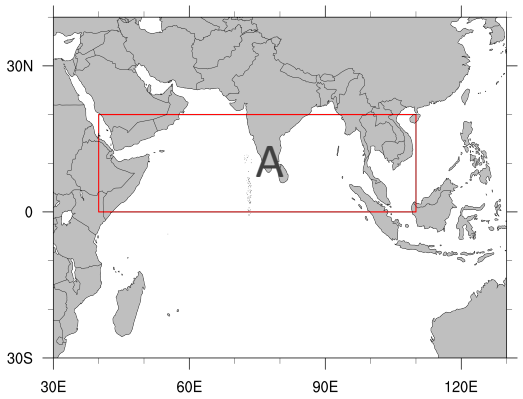


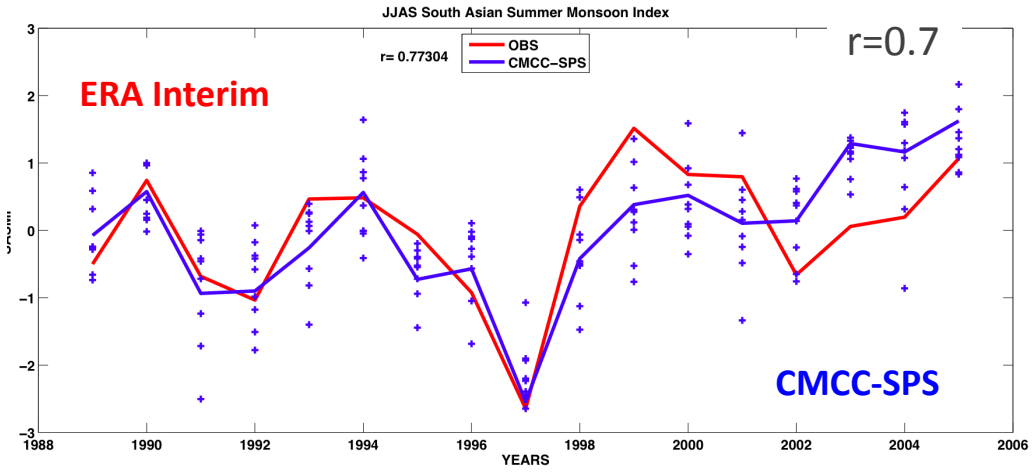


South Asian Summer Monsoon Index

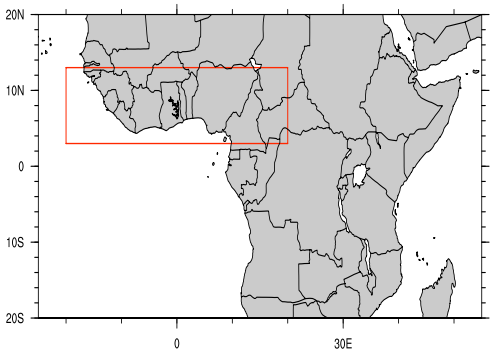
$$\int_A U_{850} - U_{200}\,dA$$

(Webster and Yang, 1992)





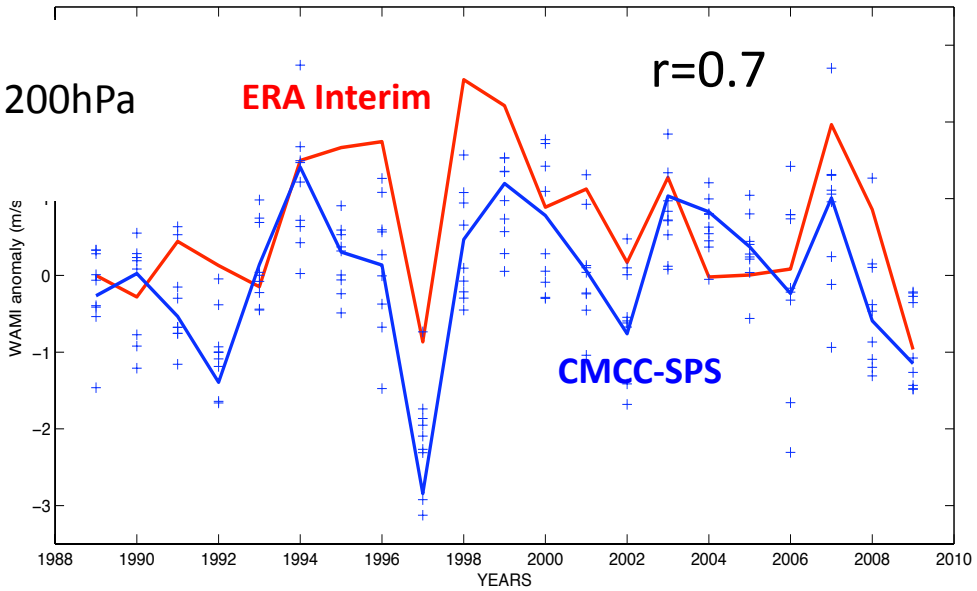
Predictions of the West African monsoon



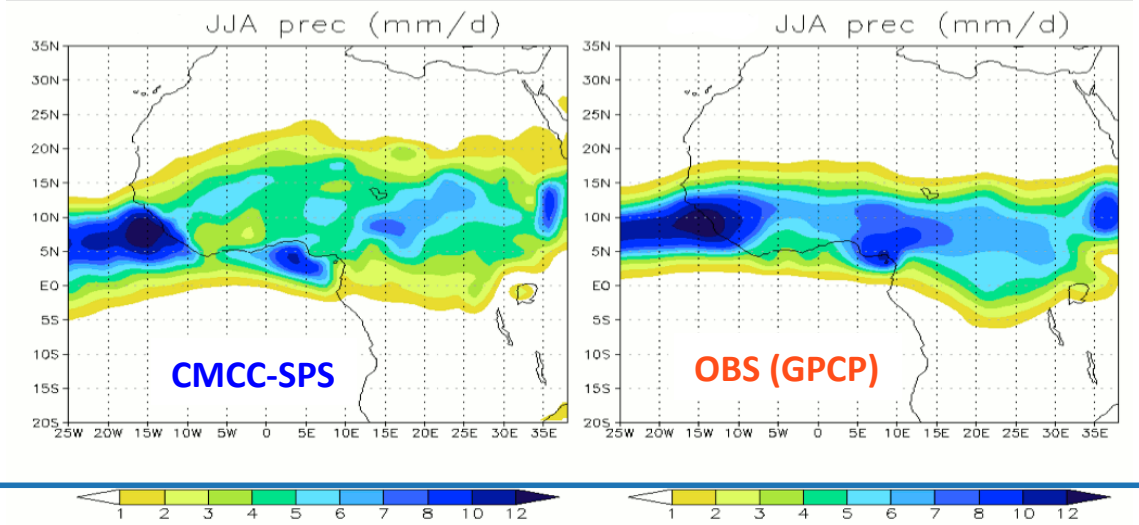
$$WAMI = u_{850hPa} - u_{200hPa}$$

(Fontaine et al., 1995 J.Clim)

WAMI anomaly (m/s) May start date, lead 1 (JJA)

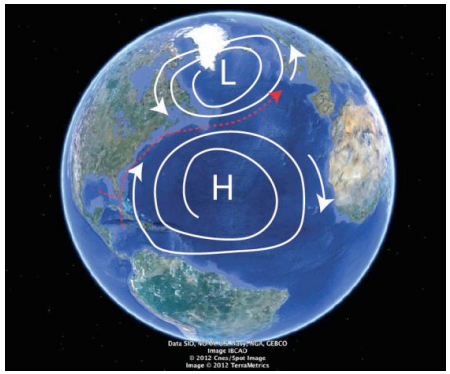


CMCC-SPS intercepts the interannual variability of Monsoon winds.

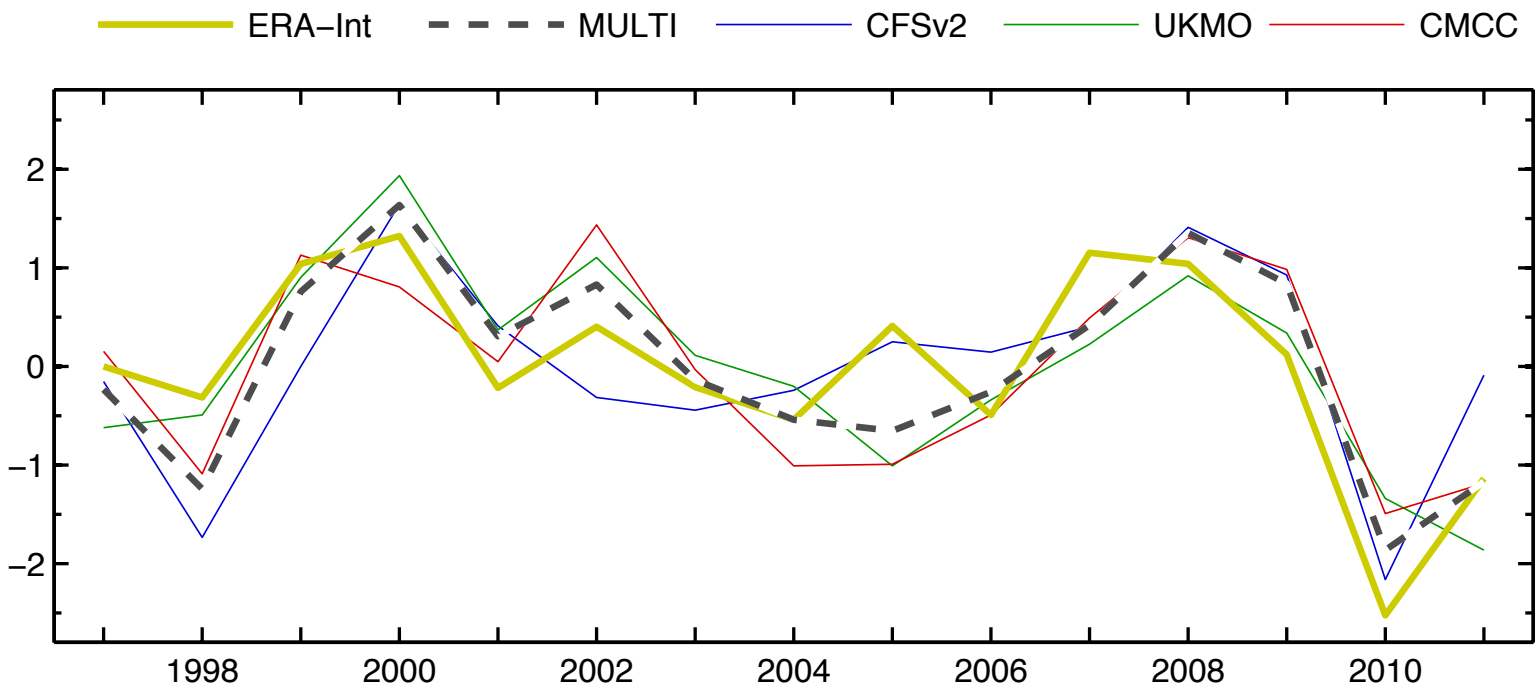


Nevertheless, precipitation during the summer, turns out to be too weak and to penetrate too much inland.

Predictions of the winter NAO



SPSs show skill also in the Extra-Tropics, in particular in the North Atlantic, where several SPSs show some ability to reproduce the interannual variability of the NAO index in the 1997-2011 period



Mean-winter NAO for the three prediction systems, ERA-Interim and the multi-system mean. Ensemble sizes: UKMO=24, CFSv2=24, CMCC=9, MULTI=57.

Athanasiadis et al. (2015)

Thank you

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WMO

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SERVIZIO METEOROLOGICO
1923

Virtute siderum tenus

cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici