ENSO teleconnections with the North Atlantic

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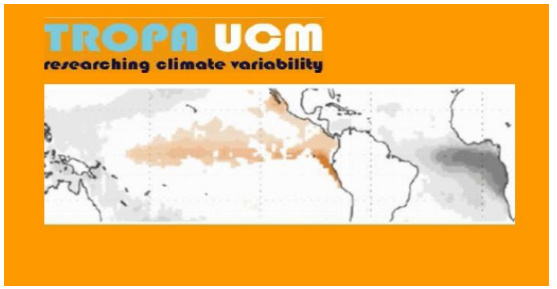

Jorge López-Parages, Roberto Suárez

The Abdus Salam International Centre for Theoretical Physics

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PAGES
PAST GLOBAL CHANGES

NOAA

- Teleconnections provide a paradigm for understanding connections between remote climates
- They can be interpreted in terms of **Rossby Waves**

DJF Precipitation / 200mb Streamfunction vs NINO 3+4

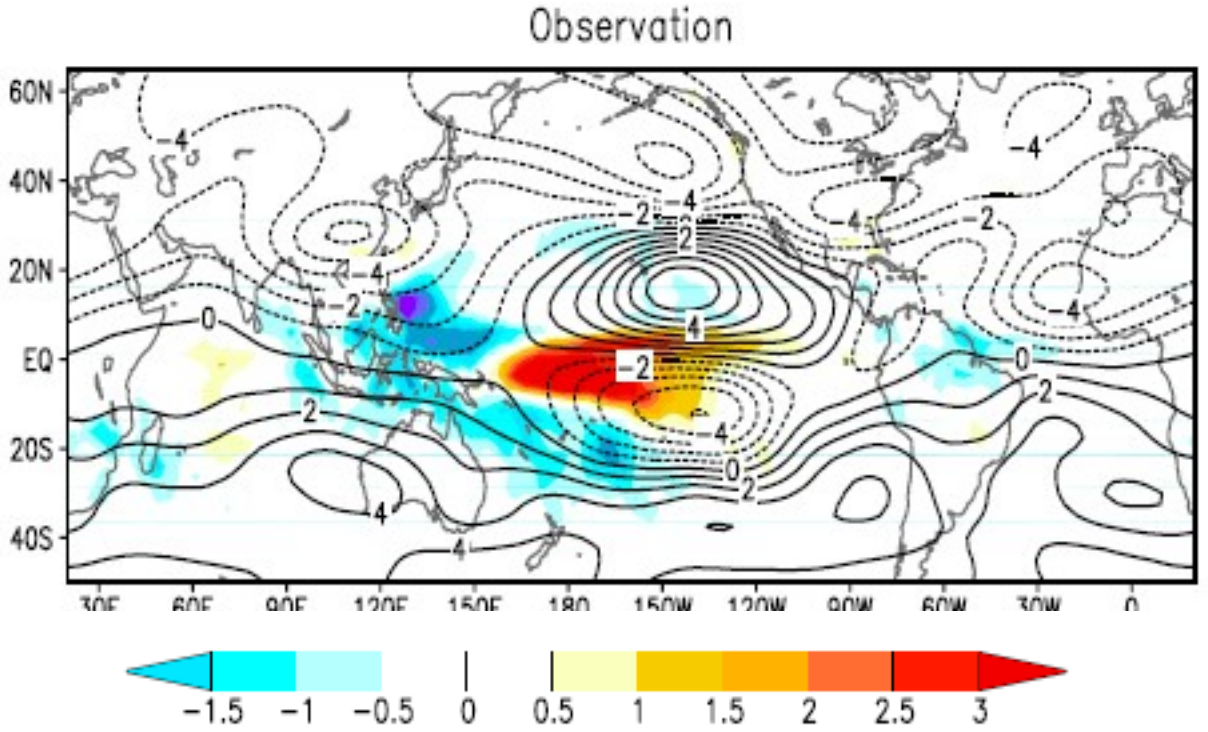
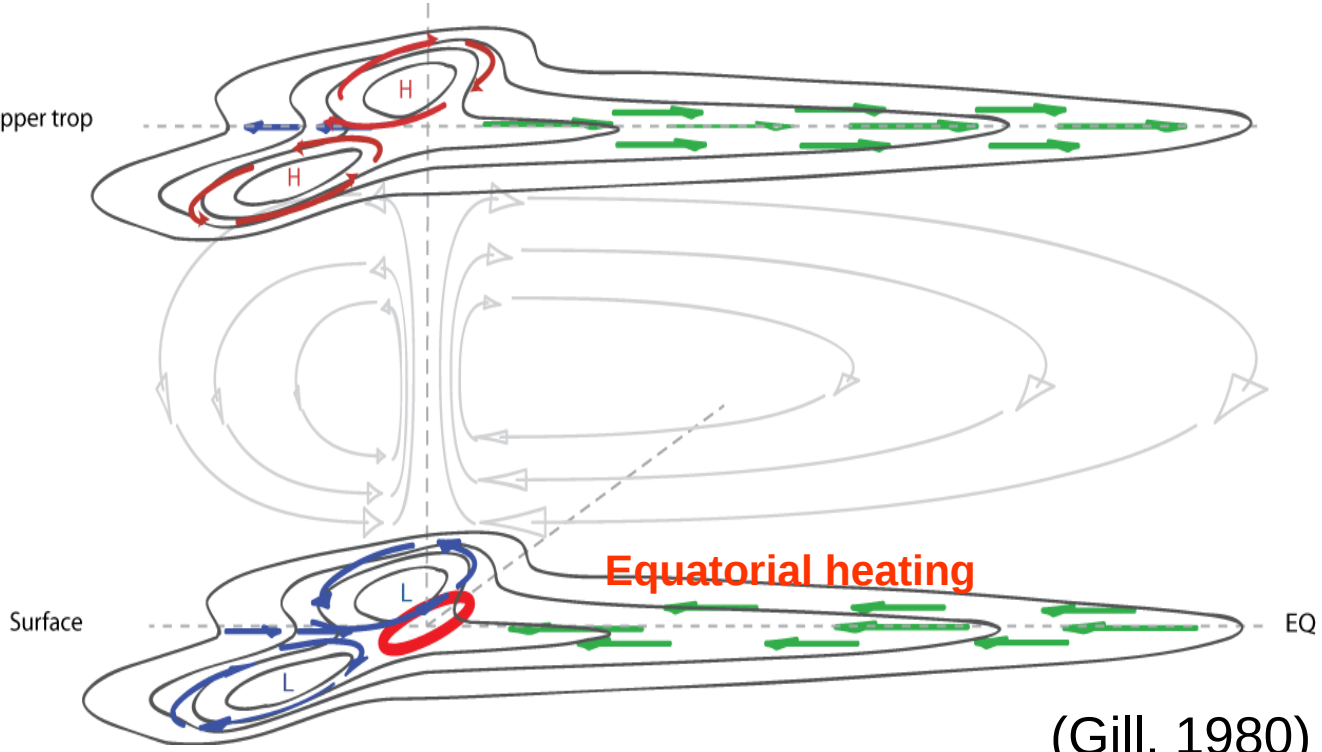


FIG. 4. Regression values of precipitation (shaded; interval 0.5 mm day^{-1} per °C) and 200 mb stream function (contours; interval 1x10^6 m^2 day^{-1} per °C) regressed on DJF ENSO index for DJF (1951-1999) for a) Observation and b) MLM. Changes in the non-divergent component of the upper tropospheric circulation accompanying ENSO may be inferred from the contour lines: positive (negative) extremes are associated with anomalous clockwise (counterclockwise) flows.

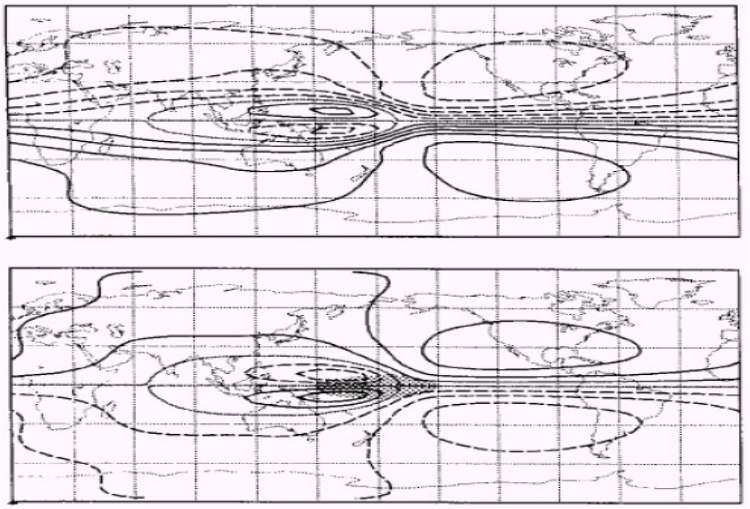
Alexander et al. *J. Climate* 2002

Teleconnection mechanisms within the tropics: Equatorial waves – Gill solution



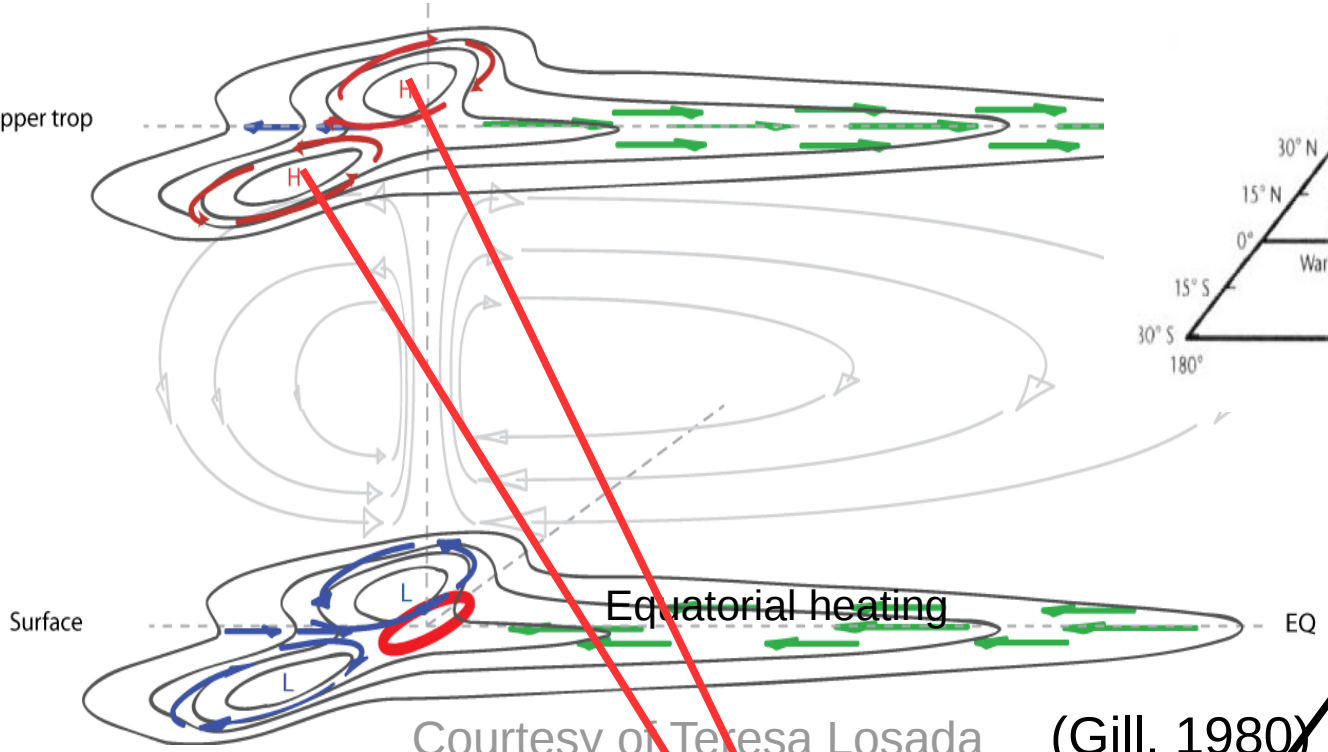
(Gill, 1980)

Courtesy of Teresa Losada



(Jin and Hoskins, 1995)

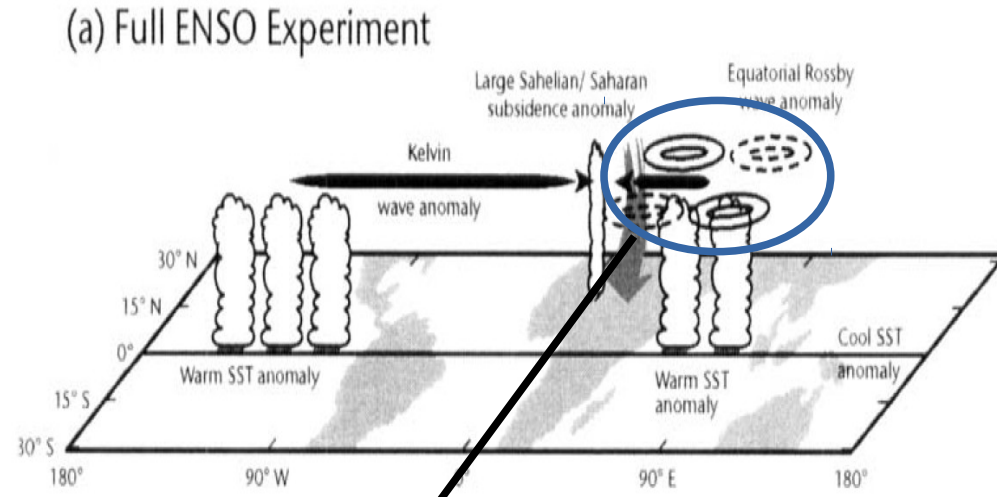
Teleconnection mechanisms within the tropics: Equatorial waves – Gill solution



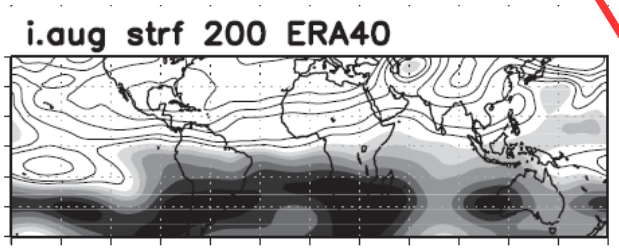
Courtesy of Teresa Losada

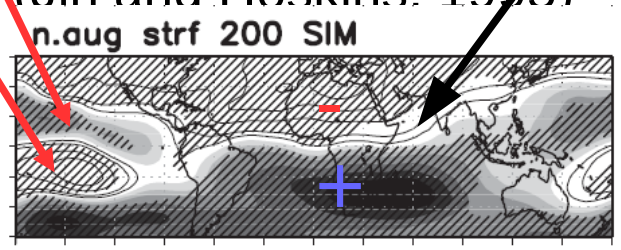
(Gill, 1980)

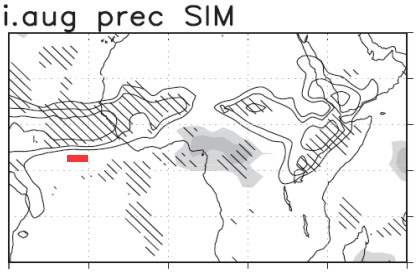
(Jin and Hoskins, 1995)

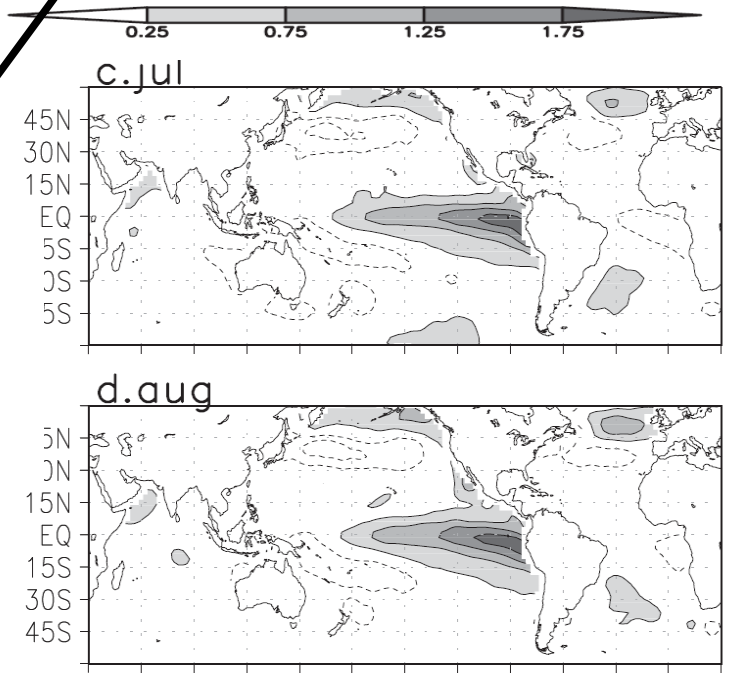


Rodwell, 2001









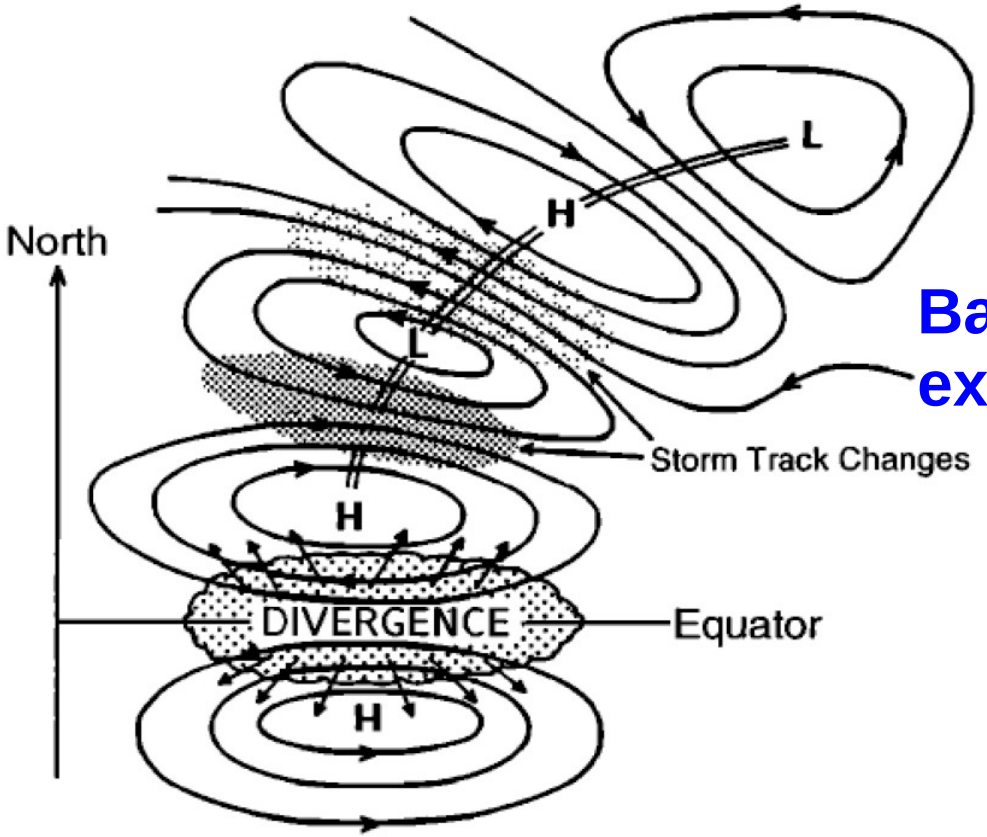
The response to El Niño over the Sahel is a reduction of rainfall

Mohino et al., 2011

Giannini et al, 2003

Teleconnection mechanisms with the extratropics:

Mechanism: Rossby Waves



$$\frac{d(\zeta + f)}{dt} = 0$$

Conservation of absolute vorticity (Rossby waves)

Barotropic in the extratropics

Baroclinic in the tropic

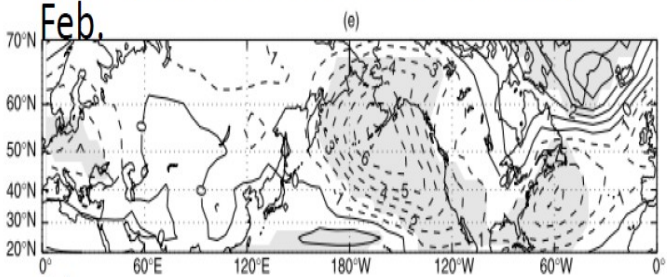
(Hoskins y Karoly, 1981; Liu y Alexander, 2007)

Teleconnection mechanisms with the extratropics:

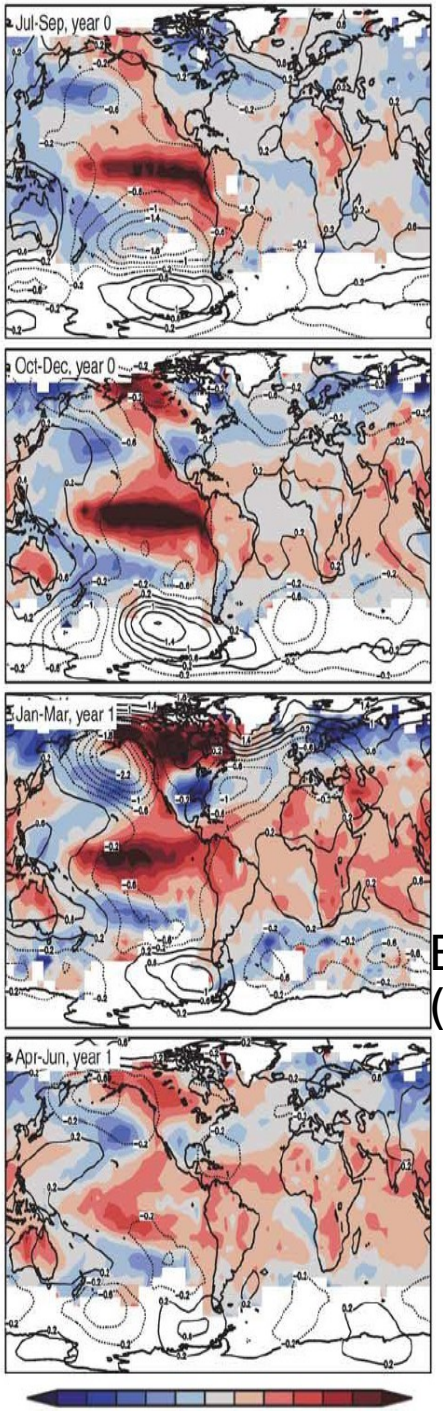
Euromed climate ⟺ ENSO

Consistent and statistically significant ENSO signal (Fraedrich and Müller 1992; Moron and Plaut, 2003 ; Brönnimann et al. 2006)

(Moron and Gouirand, 2002)



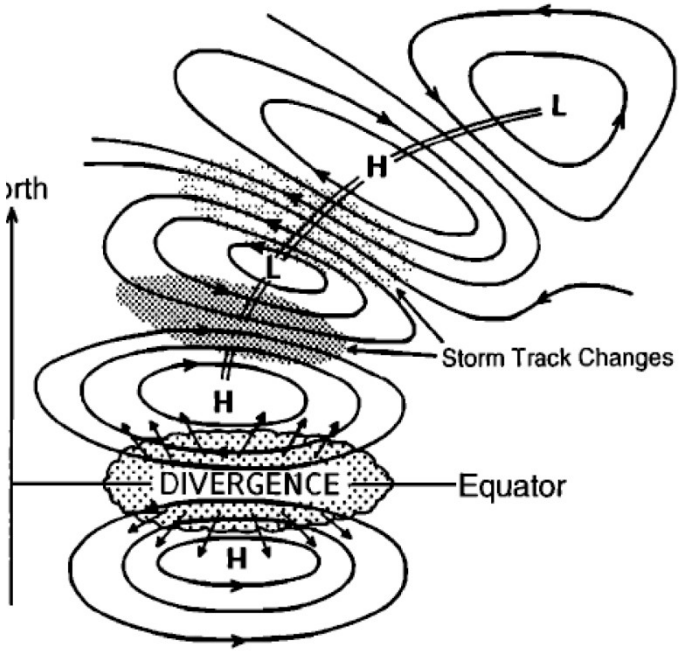
SLP: Difference between warm and cold ENSO composite maps



Brönnimann (2007)

• El Niño (Niña) impact tends to be accompanied by a negative (positive) NAO-like pattern

Mechanism: Rossby Waves



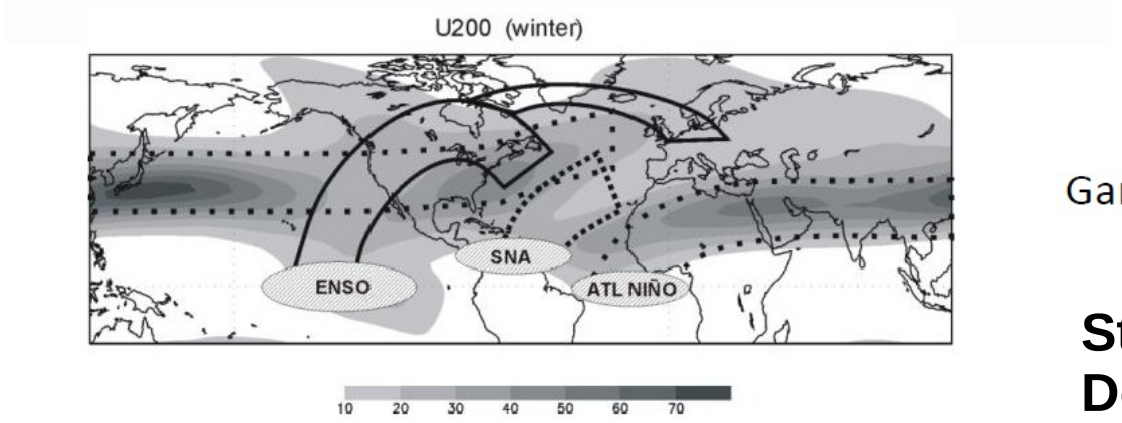
(Hoskins y Karoly, 1981; Liu y Alexander, 2007)

In Europe and the Mediterranean region the impacts are stronger in late winter-spring (and fall)

Regression between ENSO index and surface air temperature and SLP

This is stationary view

Nevertheless ,teleconnections depends on the upper level mean flow as Rossby waves propagation depend on its intensity and location



García-Serrano, PhD Thesis 2010

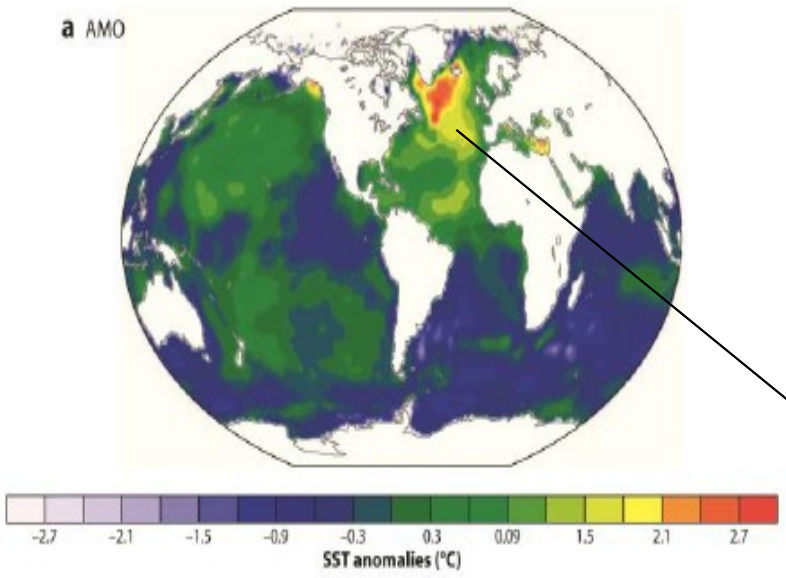
$$K_s^2 = k^2 + l^2 = \frac{\beta - \frac{\partial^2 U}{\partial y^2}}{U}$$

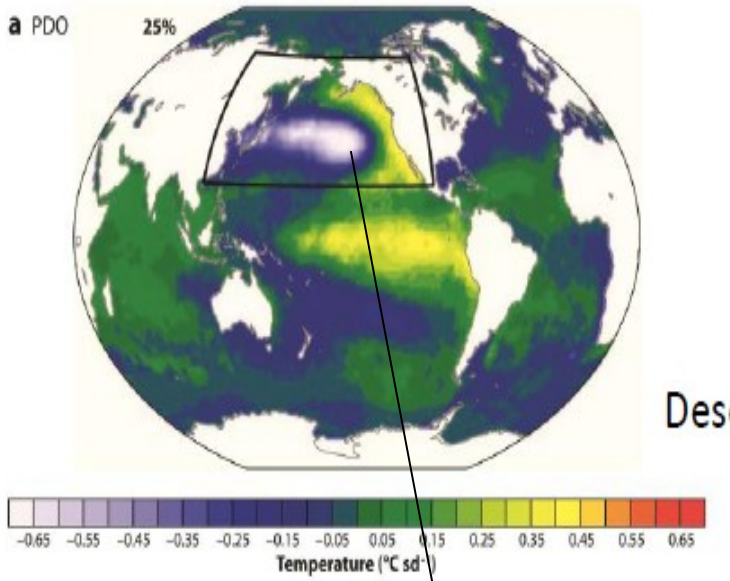
(Hoskins & Ambrizzi, 1993)

Stationary wave number Depends of the jet meanders and intensity

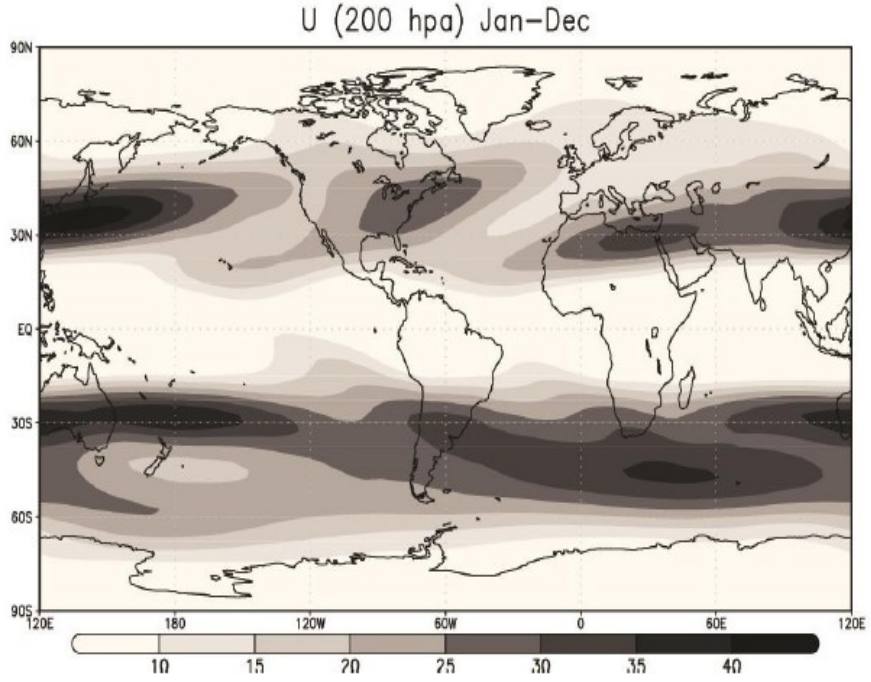
Arching patterns of Rossby Waves propagates through the weakenings of the jet

How does decadal variability affect interanual teleconnections?





Deser et al. (2010)



Zonal mean flow (January-December) at 200hPa for 1949-2015.

Strong meridional temperature grandient at midlatitudes

Thermal wind equation

$$\left(\frac{\partial u_g}{\partial p}, \frac{\partial v_g}{\partial p}\right) = \frac{R}{fp}\left(\left(\frac{\partial T}{\partial y}\right)_p, -\left(\frac{\partial T}{\partial x}\right)_p\right)$$

Regions with strong SST gradients can change the mean flow

Hypothesis

Teleconnections in terms of Rossby Waves depend on the climatological upper level winds.

Changes in the intensity of the upper level winds are related to changes in the SST gradients.

Teleconnections with extratropical north Atlantic requires weakening of the jet.

Teleconnections with the tropics requieres changes in mean Walker circulation.

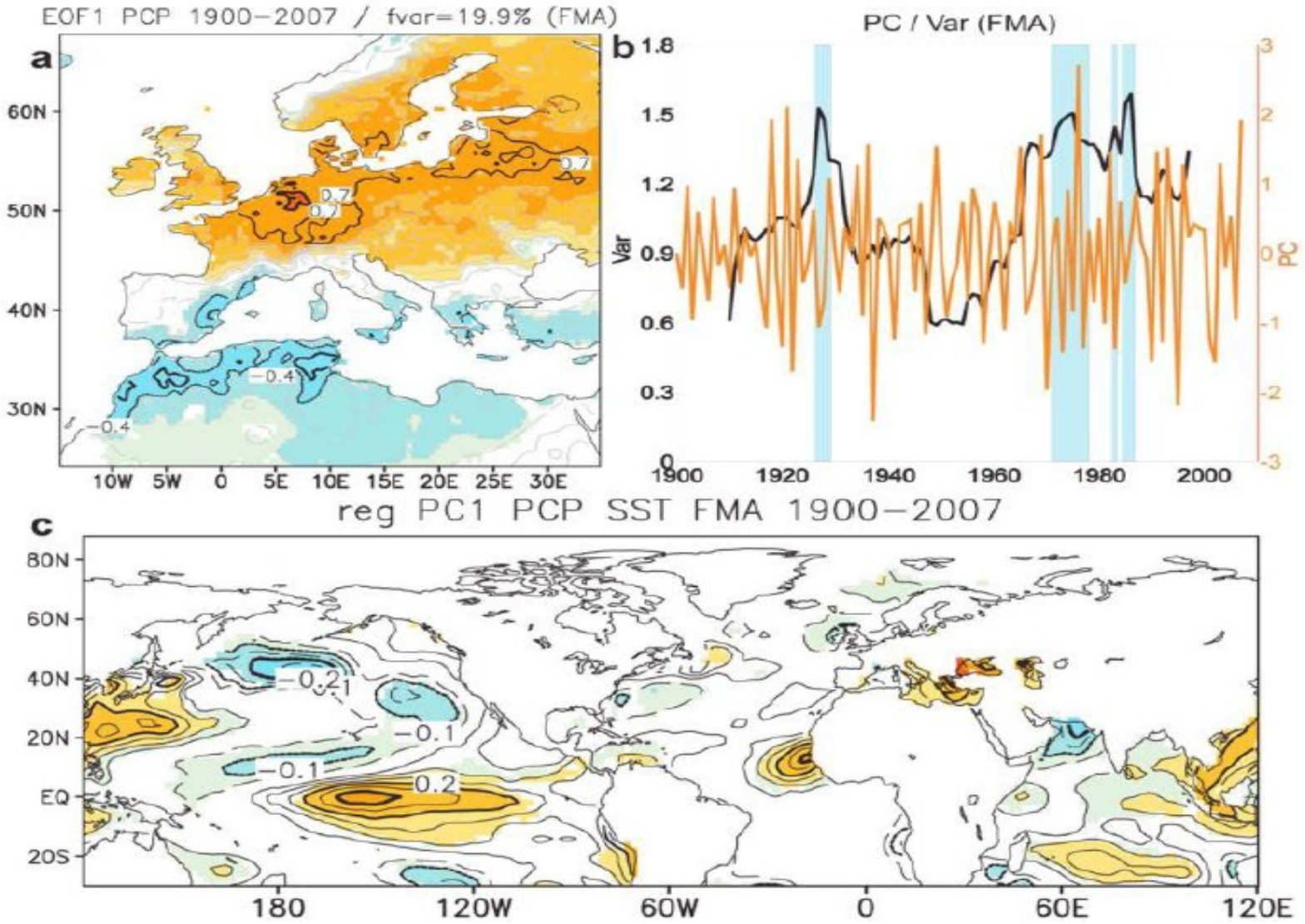
Decadal SST modes exhibit strong meridional and zonal gradients which could change the way in which the teleconnection take place.

Do we see this in observations?

-extratropics

-tropics

Do we see this in observations? Europe

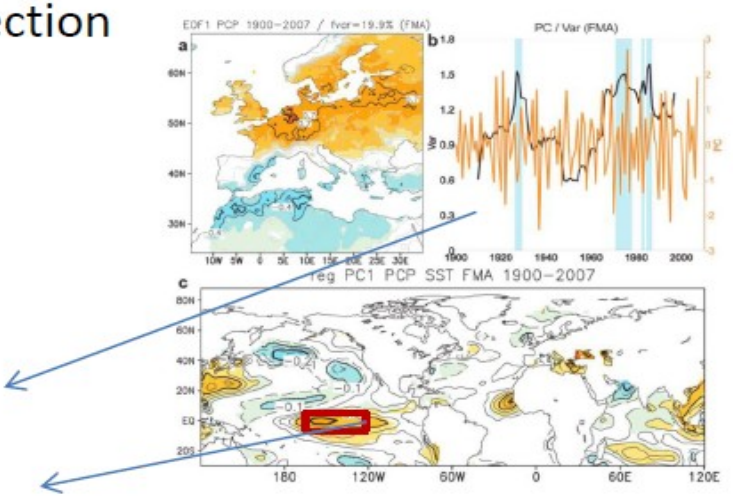


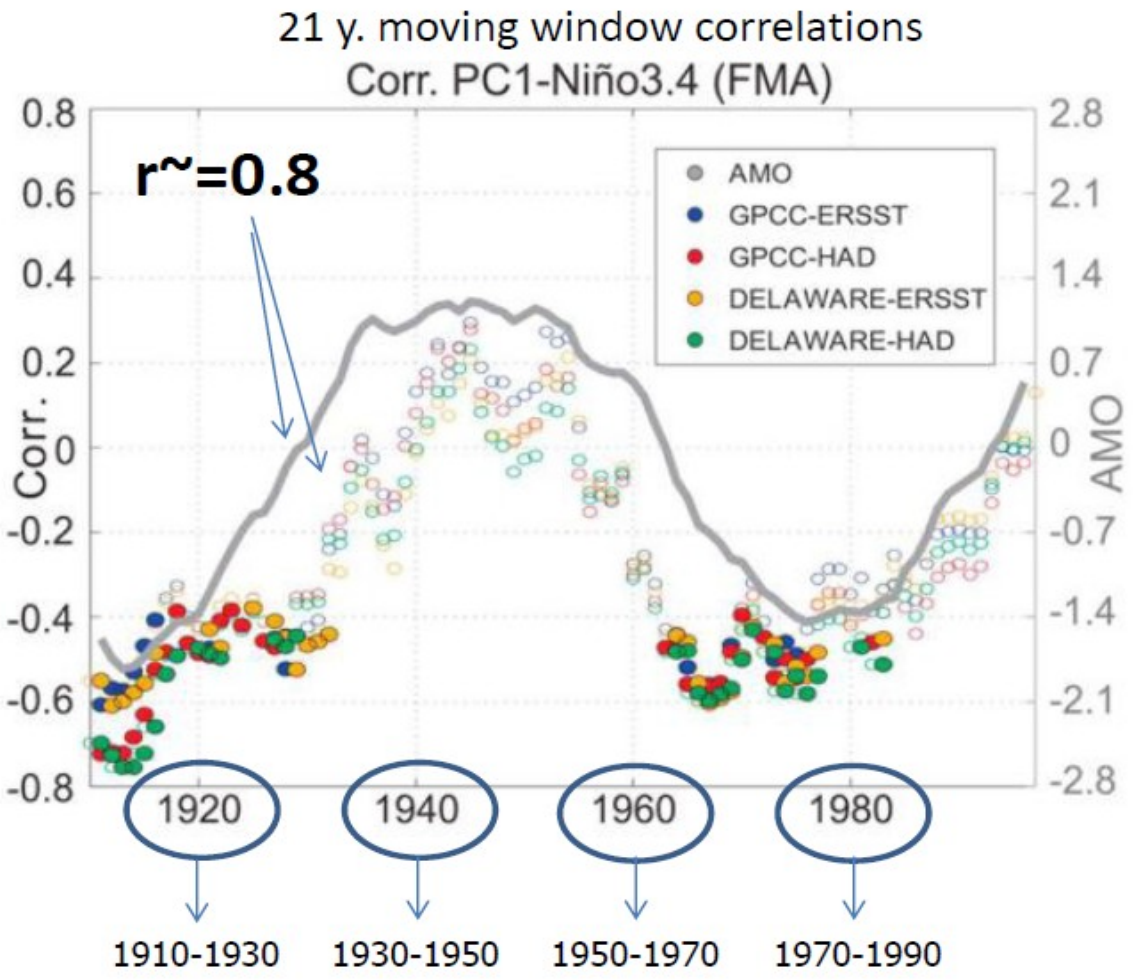
a) Leading EOF of Emed rainfall in FMA. b) PC1 and its variance.
c) SST regression map onto PC1

López Parages and Rodríguez de Fonseca, 2012. Geophysical Research Lett.

Do we see this in observations? Europe

ENSO-Euromediterranean rainfall: a changing teleconnection





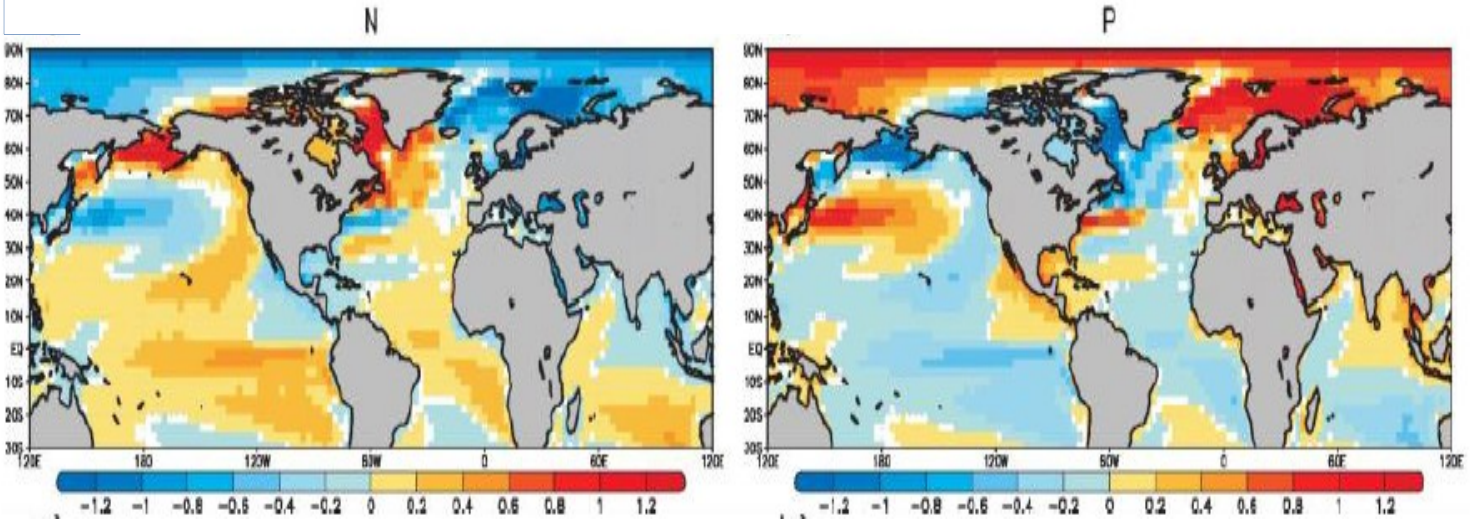
PC1 is only correlated with El Niño under negative AMO phases.

95% significance Monte-Carlo test

Correlations are inverse in sign to match the AMV

López Parages and Rodríguez de Fonseca, 2012. Geophysical Research Lett.

SST decadal patterns

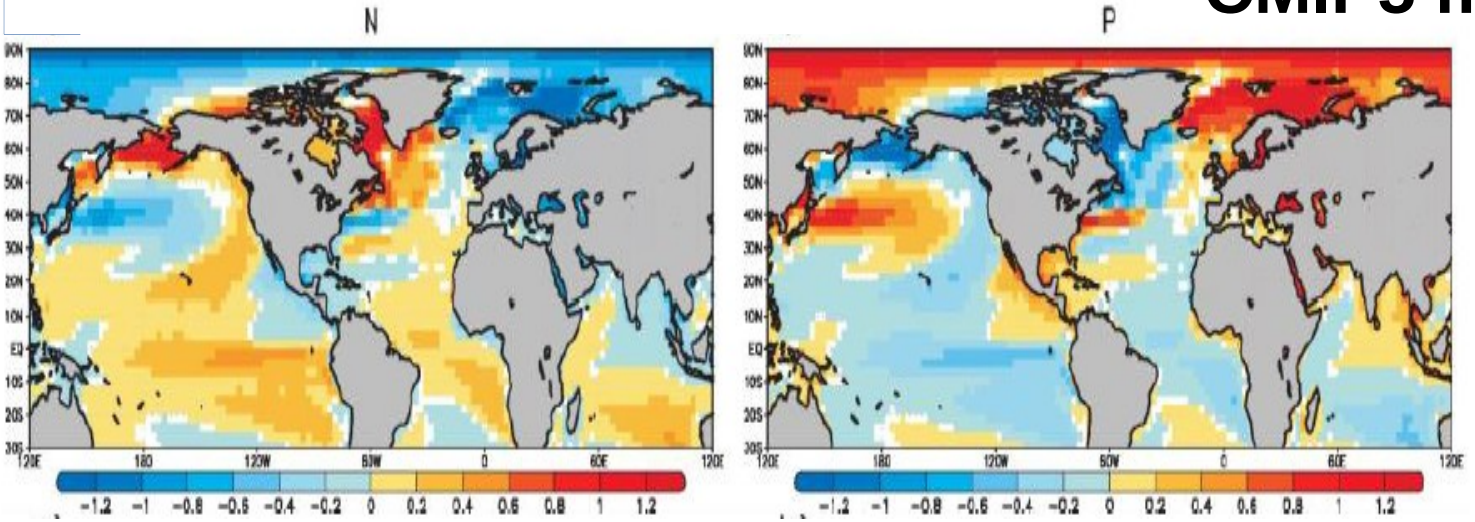


How about CMIP5 models?
Pi-control simulations

López Parages et al (submitted to J Climate)

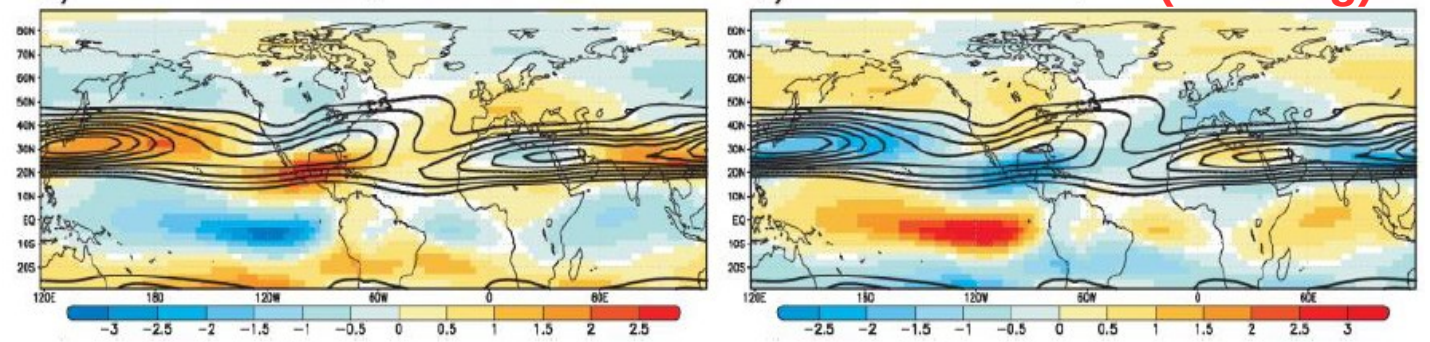
SST decadal patterns

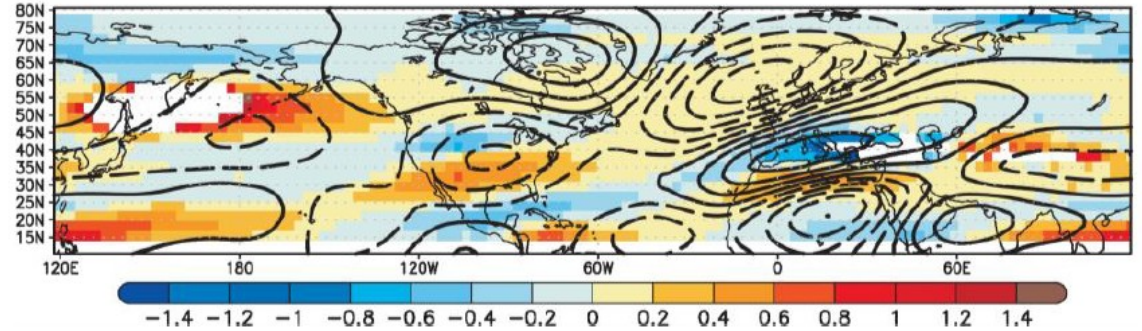
CMIP5 models



$$\left(\frac{\partial u_g}{\partial p}, \frac{\partial v_g}{\partial p}\right) = \frac{R}{fp}\left(\left(\frac{\partial T}{\partial y}\right)_p, -\left(\frac{\partial T}{\partial x}\right)_p\right)$$

Clim. U200 (contour)
Diff in N & P (shading)

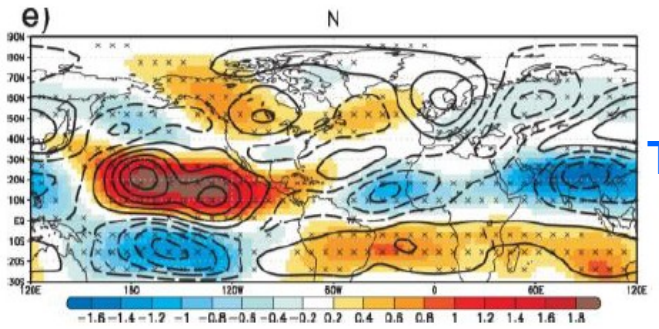




$$K_s^2 = k^2 + l^2 = \frac{\beta - \frac{\partial^2 U}{\partial y^2}}{U}$$

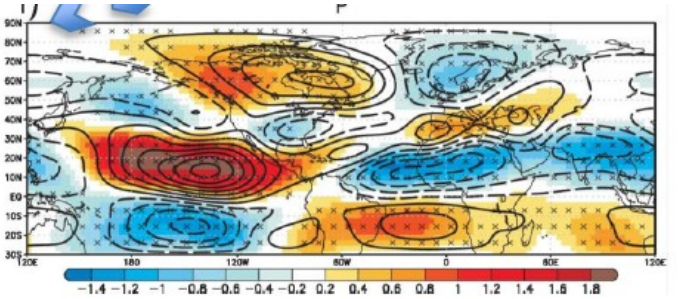
K P- N
(shading)

López Parages et al (submitted to J Climate)



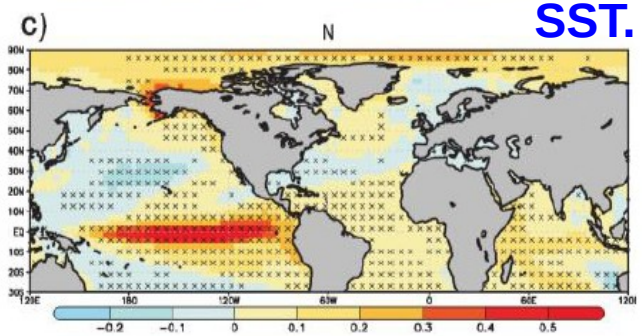
Telec. In N

Telec. In P

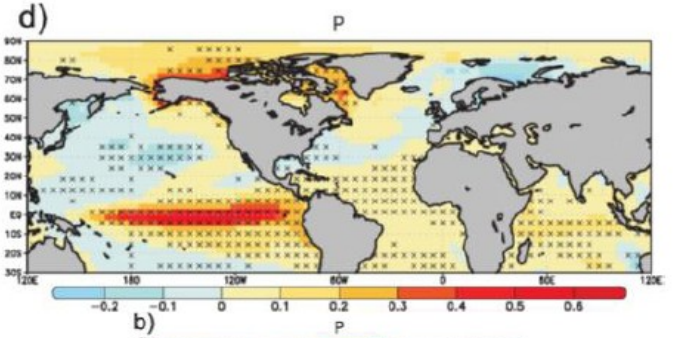


SST. In N

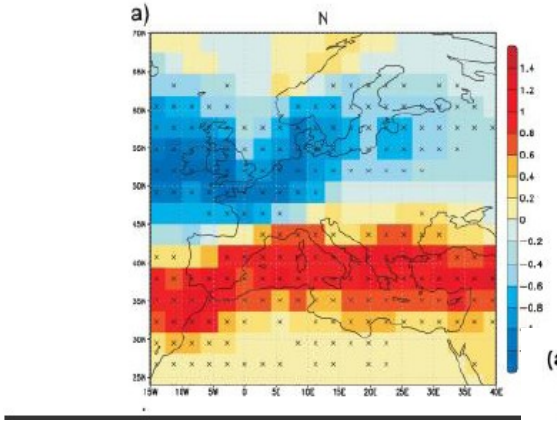
SST. In P

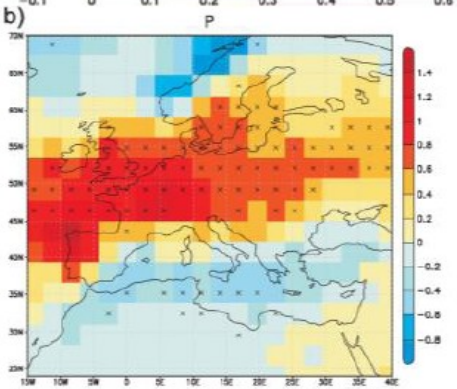


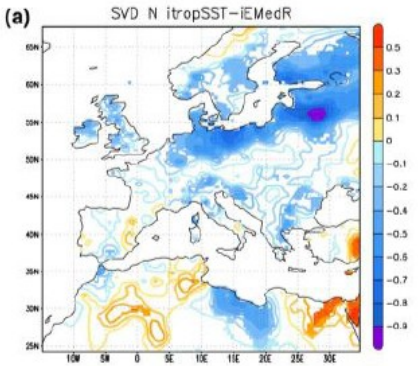
EL Niño forcing have opposite impacts depending of the period

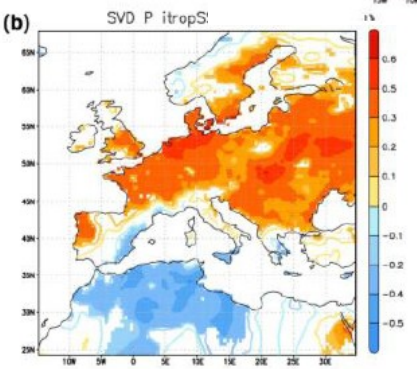


CMIP5 models









López Parages et al (submitted to J Climate)

Do we see this in observations? Sahel

Losada et al., 2012

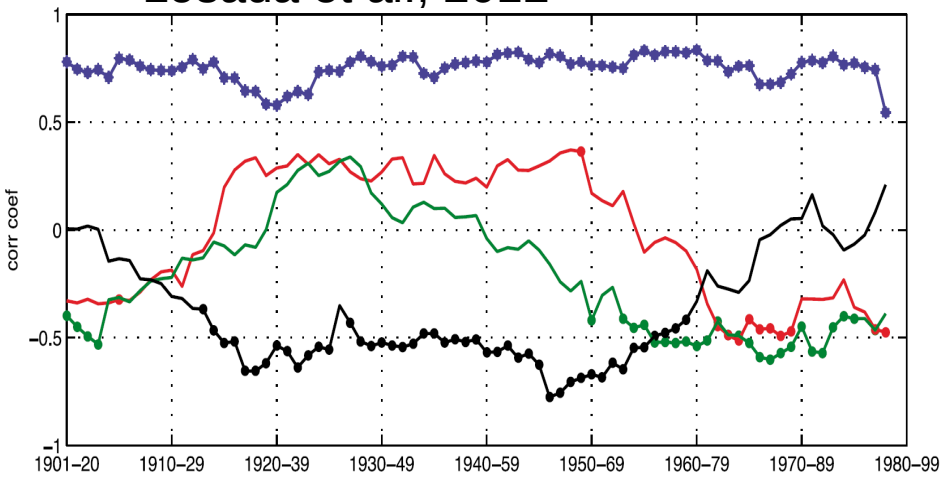


Figure 6: 20 yr -sliding window running correlation between the Niño 3 and Sahelian rainfall indices (discontinous line), the Atl3 and Sahelian rainfall indices (bottom continous line) and the Atl3 and Guinea rainfall indices (top continuous line) in June-to-September. Modified from Losada et al.(2012). Atl3 is defined as the SST area averaged over the region {3N-3S, 20W-0}. Niño3 is defined as the SST area averaged over the region {5N-5S, 150W-90W}. Guinea index is defined as the rainfall area averaged over the region {8-4N, 20W-10E} and Sahelian index is defined as the rainfall area averaged over the region {20-10N, 20W-10E}. Dots indicate the 20-year windows in which the correlation is significant at 95% of confidence level.

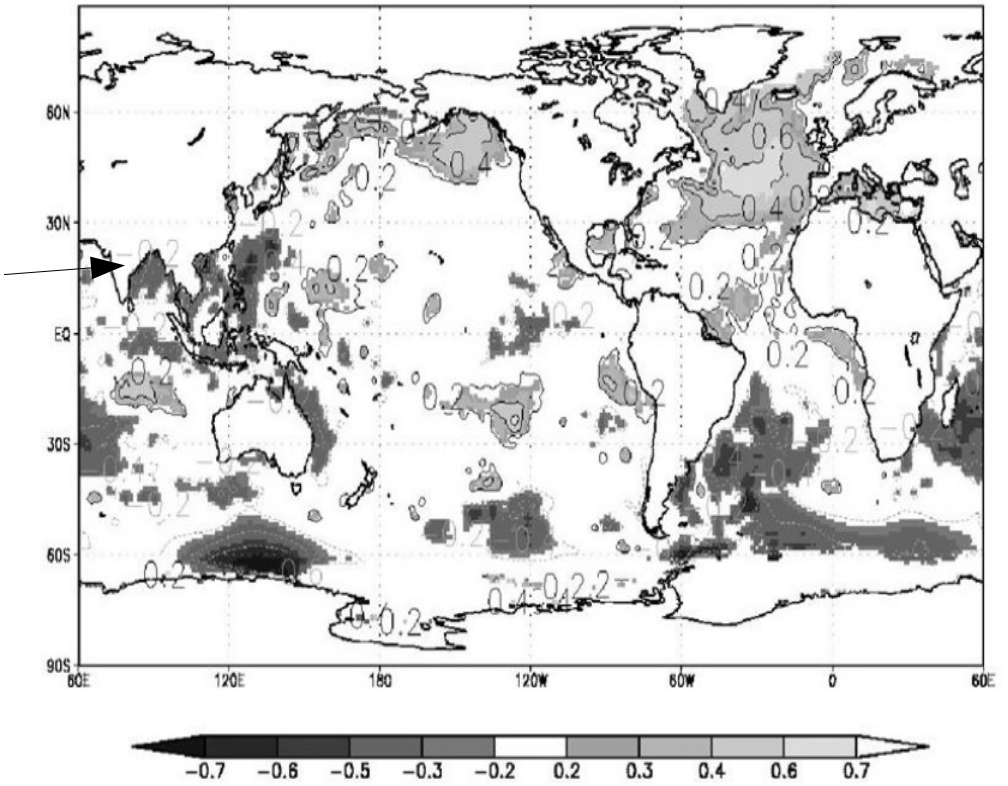
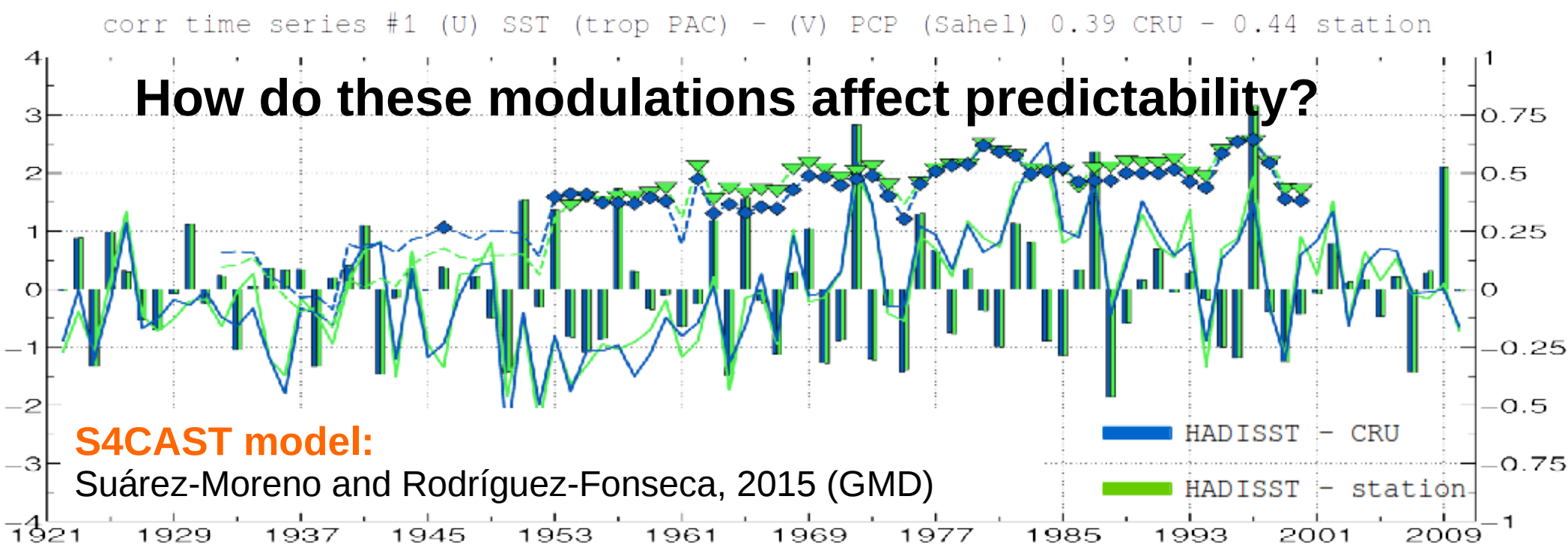


Figure 12: Projection of the anomalous SSTs onto the discontinous correlation lines in figure 6. Only 95% significant regions under a Monte Carlo test are represented.

Rodríguez-Fonseca et al. 2015, J Climate

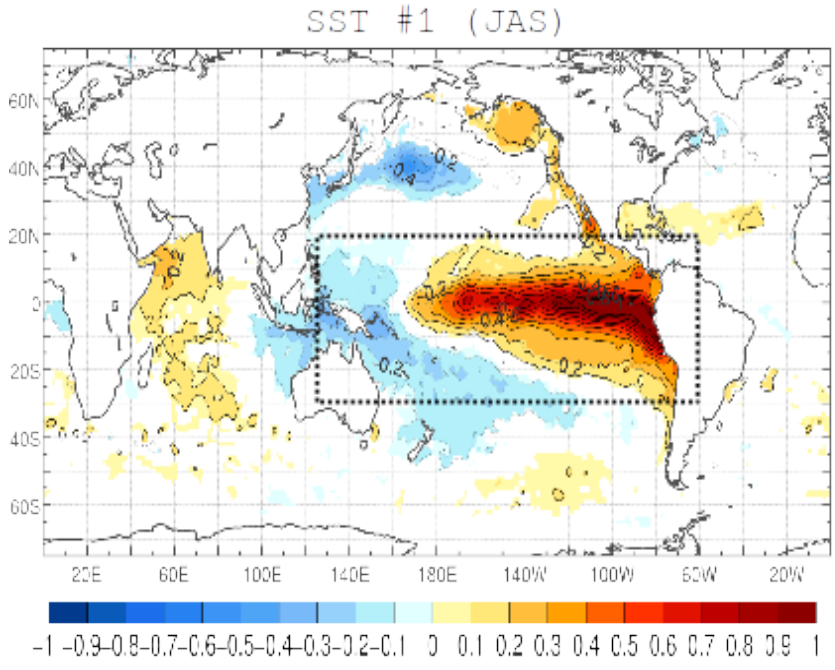
___ Atl3 vs Guinean rainfall
___ Niño3 vs Guinean rainfall
___ Niño 3 vs Sahel rainfall
___ Atl3 vs Sahel rainfall

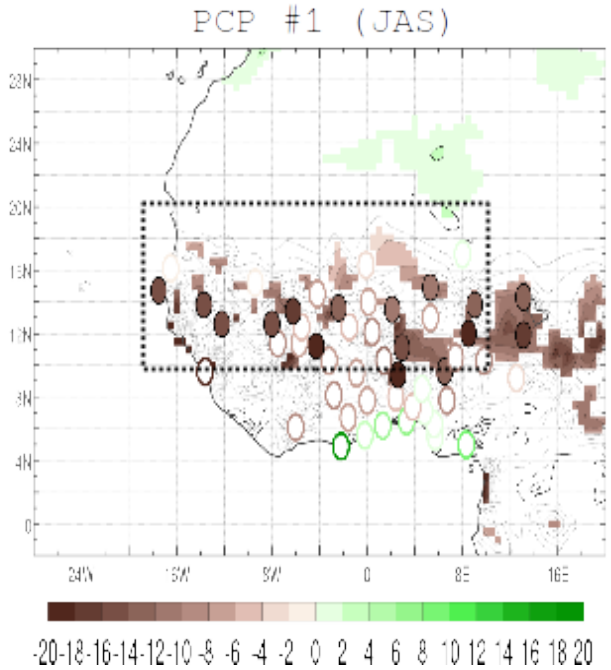
How do these modulations affect predictability?

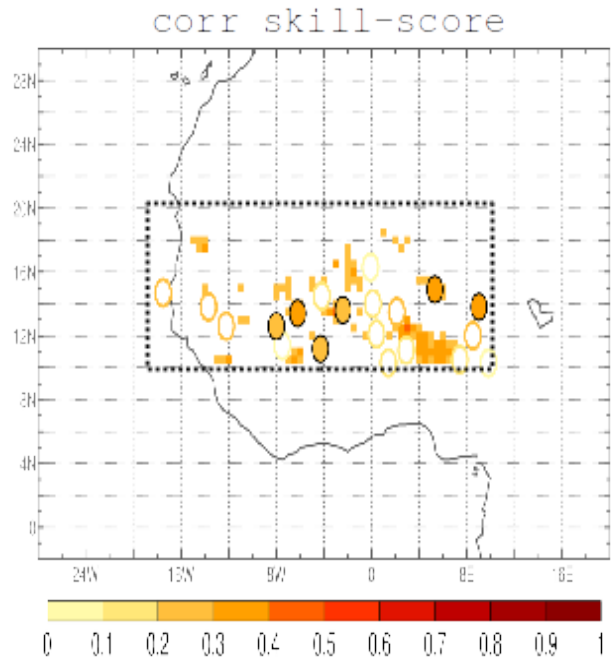


S4CAST model:

Suárez-Moreno and Rodríguez-Fonseca, 2015 (GMD)

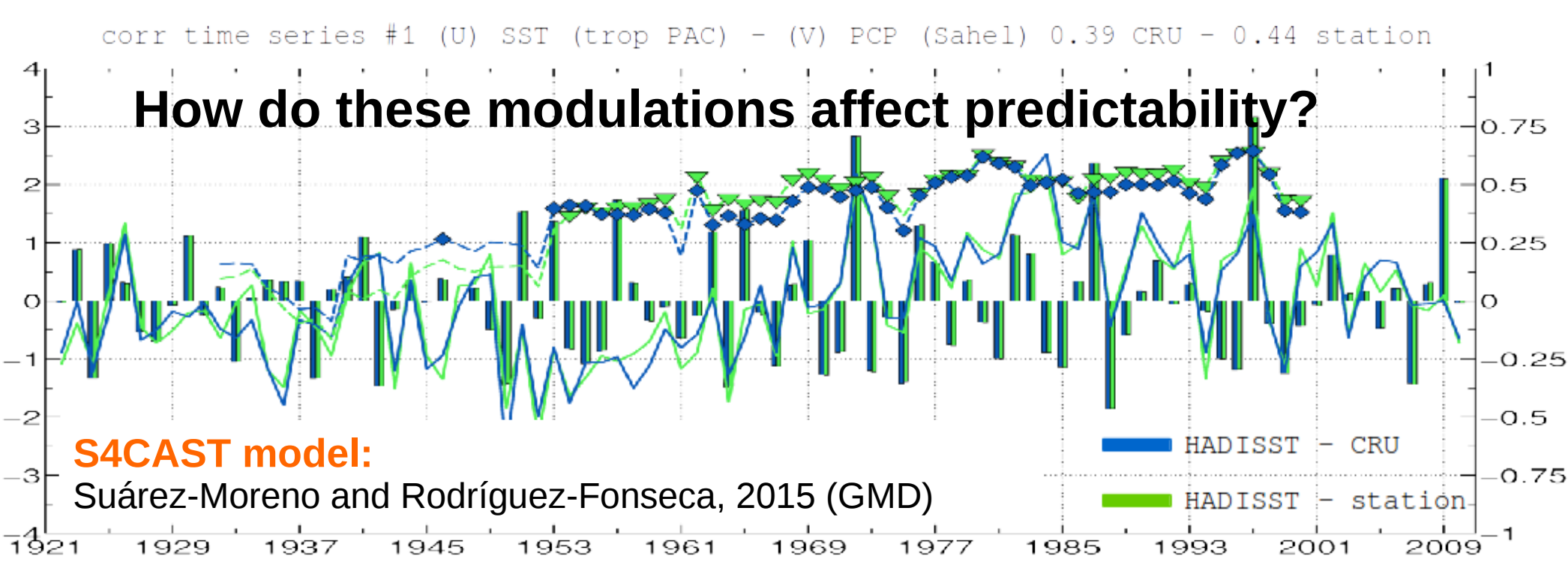


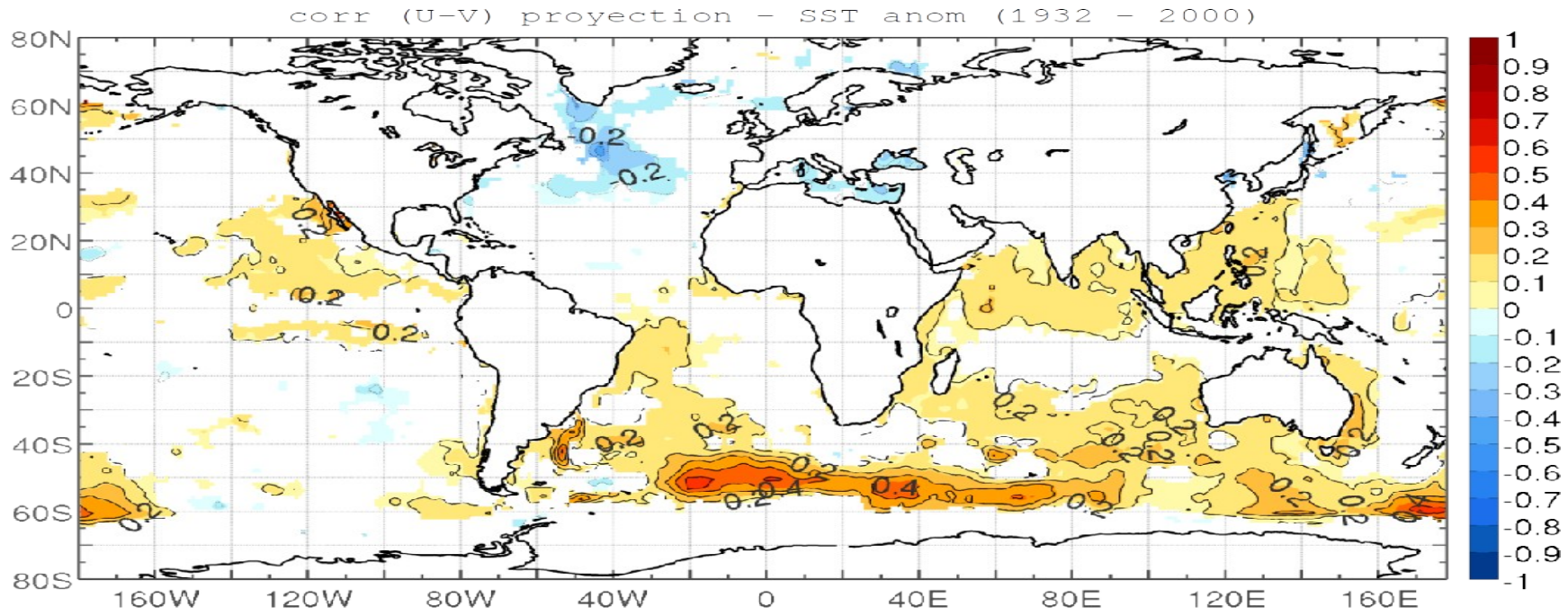




Suárez-Moreno et al (in preparation): multidecadal changes in the interanual SST-forced teleconnections with the Sahel

Station data (Sanogo et al., 2015).

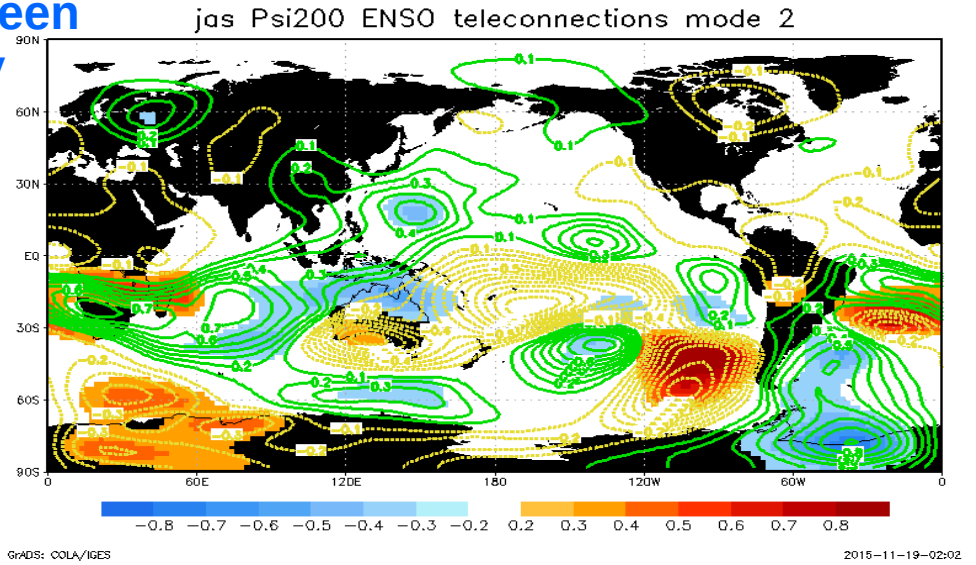




Suárez-Moreno et al (in preparation): multidecadal changes in the interanual SST-forced teleconnections with the Sahel

How does the ENSO response change at multidecadal time scale? JAS

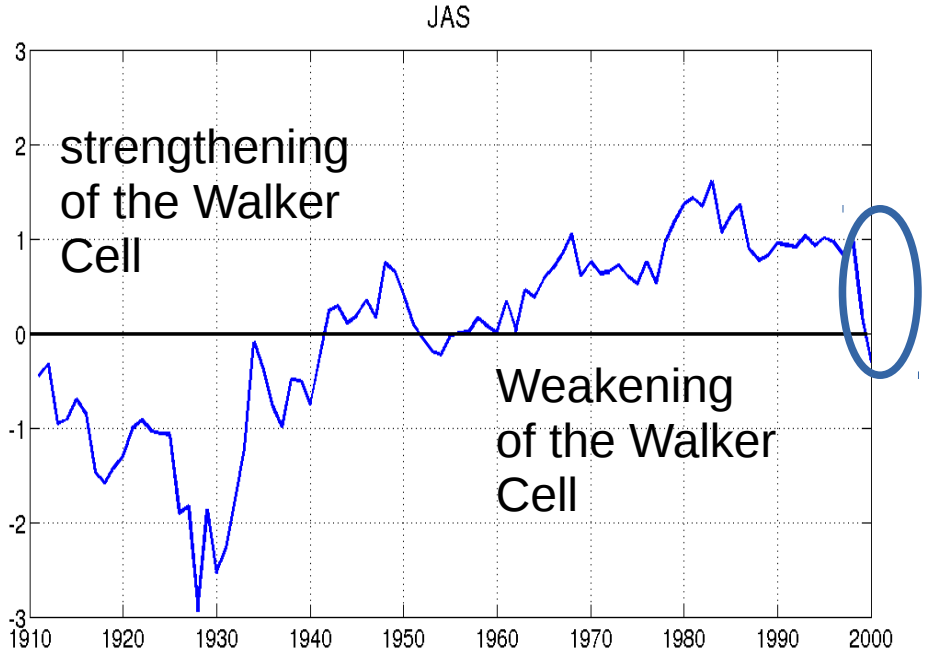
EOF of the 20-yr regression maps done between Psi200 and Niño34 in JAS along 20th century From ERA-20CR



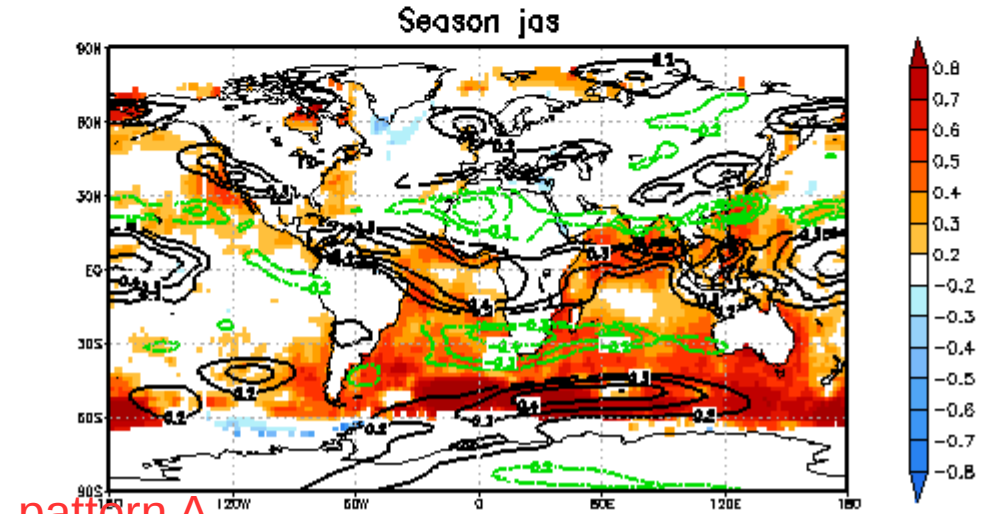
Streamfunction response:

a) In positive phases of pattern A (contours)

b) In negative phases of pattern (shadings)



Evolution of pattern in A



pattern A

Rodríguez-Fonseca et al (in preparation)

50% of the variance

conclusions

ENSO teleconnections should be interpreted as the sum of a stationary and a non stationary component.

The non-stationary component of ENSO teleconnection varies at multidecadal timescales, acording to decadal oceanic patterns.

These decadal changes are related to changes in the upper level winds, which determine the response to a thermal forcing, changing the wave guides and associated teleconnection patterns.

In Europe, the AMV global patterm seems to be responsible of changes in the upper level winds, which determine the existence of teleconnections (more effective in negative AMV)

CMIP5 models exhibit multidecadal modulation of El Niño according with a PDO-AMV pattern.

In Sahel, the response changes with a trend pattern related to changes in the mean Walker circulation, which determines the location of the response to an equatorial diabatic heating.

The non-stationarity of ENSO teleconnection and the existence of a multidecadal modulation opens windows of oportunity when predicting with ENSO.