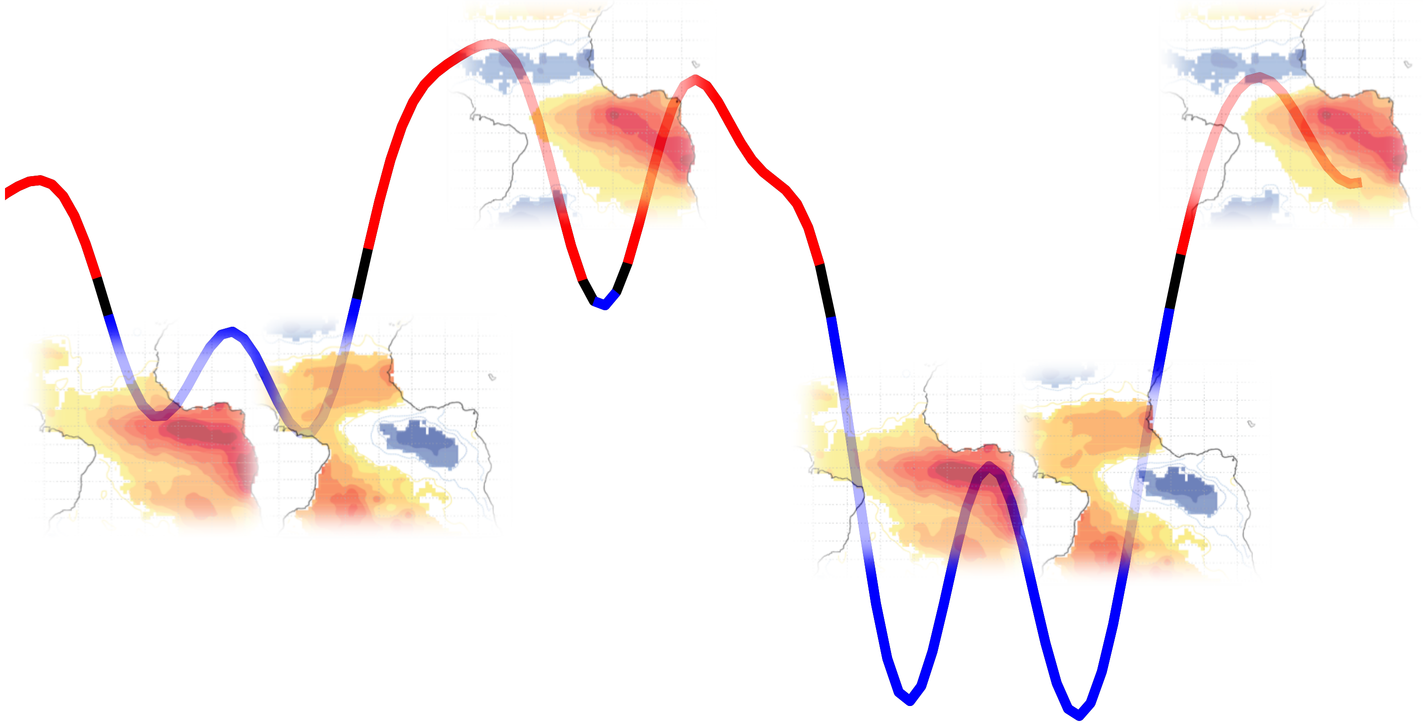
On the inter-annual tropical Atlantic variability modes under AMO phases in the observational record

(Under review in Journal of Climate)



Marta Martín-Rey [1-2], Irene Polo [1-3], Belén Rodríguez-Fonseca [1]

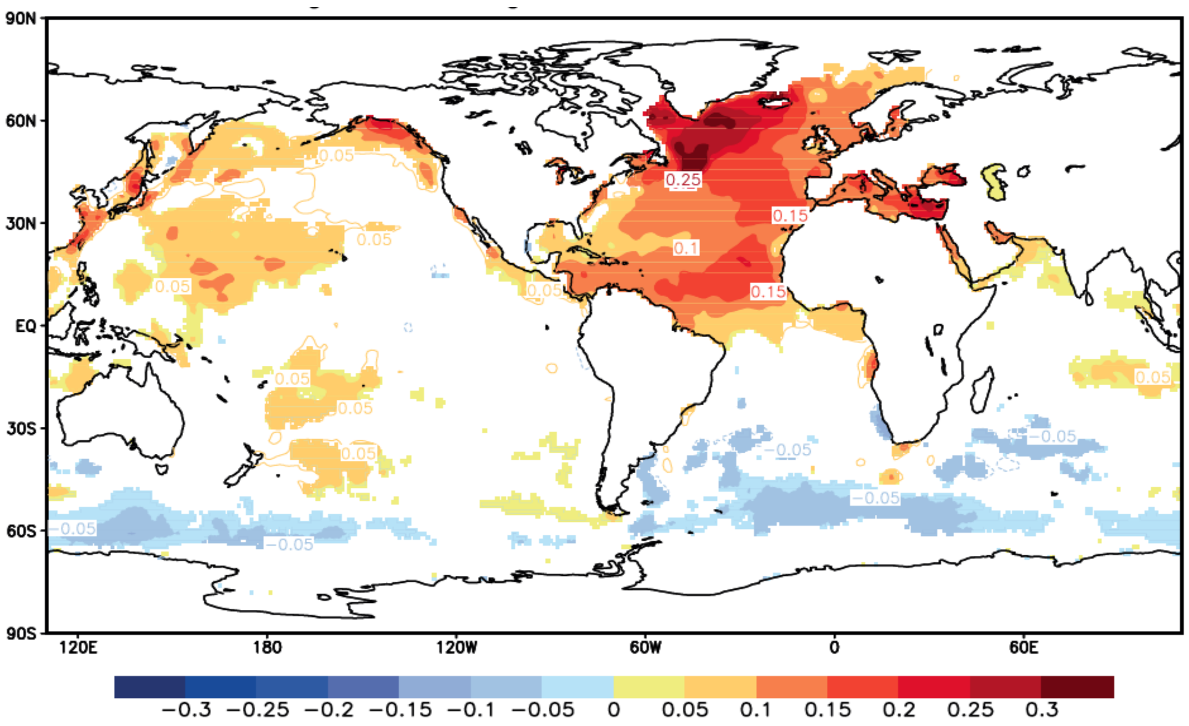
Teresa Losada[1] and Alban Lazar [2]

(1) UCM, Madrid, Spain; (2) LOCEAN-IPSL, UPMC, France; (3) University of Reading, UK

UNIVERSIDAD COMPLUTENSE MADRID

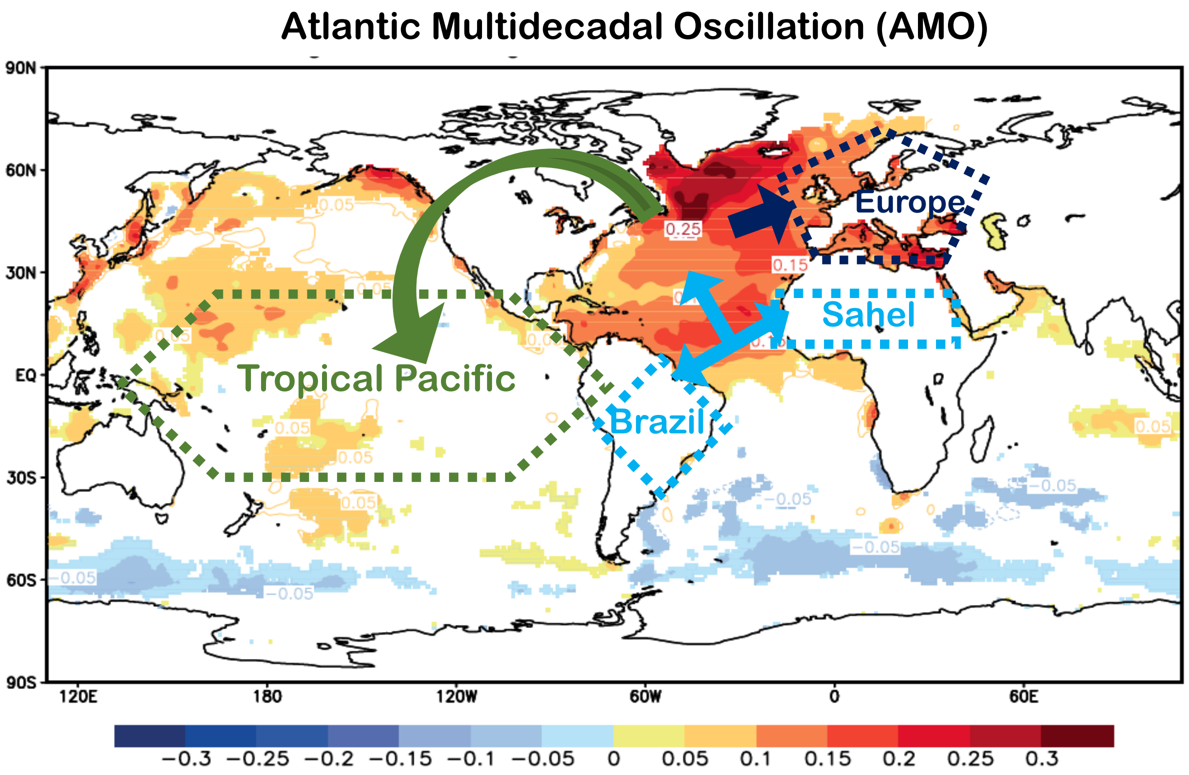
University of Reading

MOTIVATION



The decadal internal SST variability in the Atlantic Ocean is driven by the **Atlantic Multidecadal Oscillation**, AMO (Kerr 2000; Knight et al. 2006)

MOTIVATION



The AMO seems to modulate:

- The Tropical Pacific mean state and ENSO variability (Dong et al. 2006; Dong and Sutton 2007; Timmerman et al. 2007).
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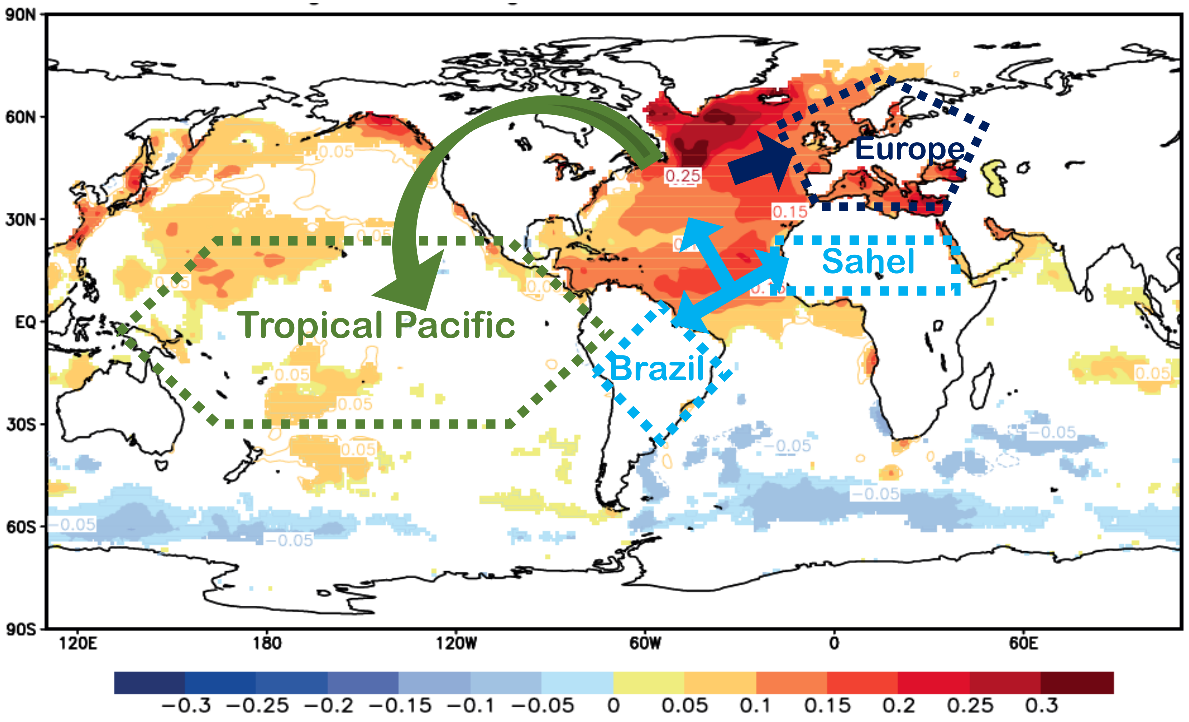
MOTIVATION

Atlantic Multidecadal Oscillation (AMO)



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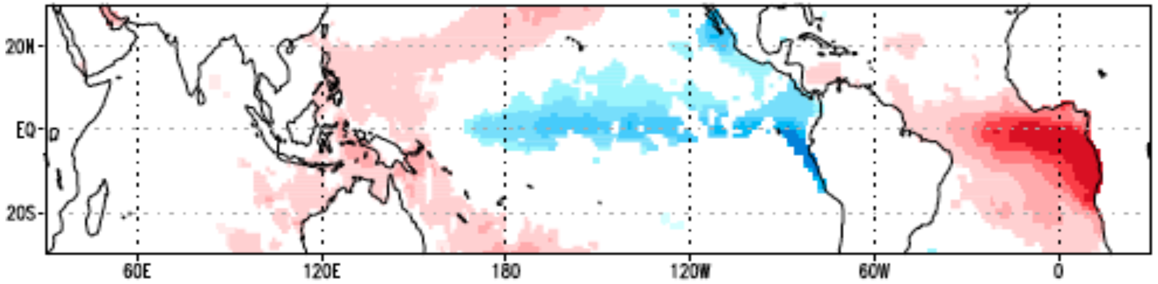
Atlantic-Pacific Niños connection



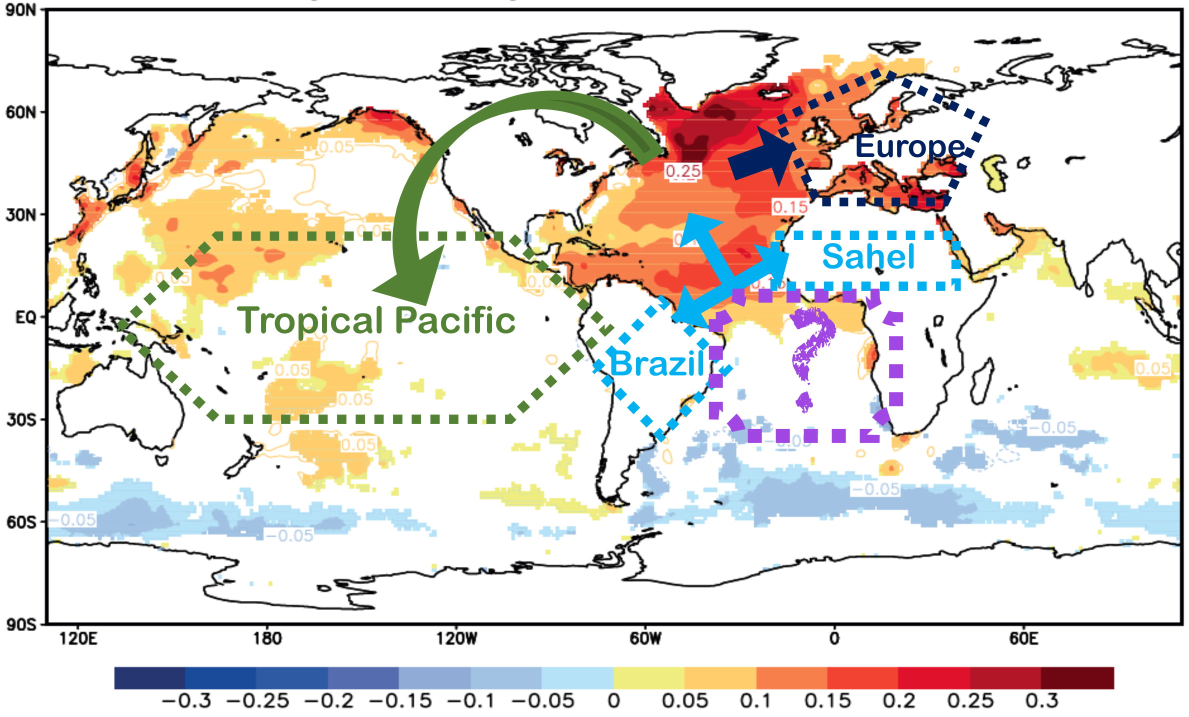
From Rodríguez-Fonseca et al. 2009

The Atlantic Niño teleconnections have been changed and strengthened after the 1970s (Polo 2008; Kucharski et al. 2009; Rodríguez-Fonseca et al. 2009;Ding et al. 2012; Losada et al. 2012a; Losada and Rodríguez-Fonseca 2015).

The multidecadal modulation of the Atlantic-Pacific Niños connection could be driven by AMO (Martín-Rey et al. 2014).

MOTIVATION

Atlantic Multidecadal Oscillation (AMO)



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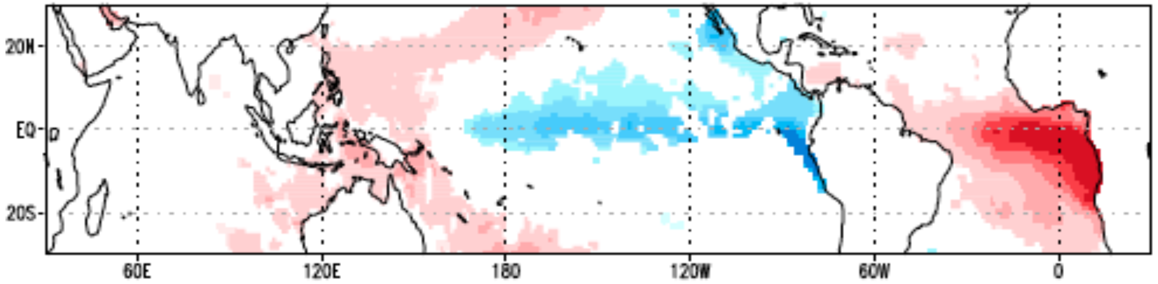
Atlantic-Pacific Niños connection



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The multidecadal modulation of the Atlantic-Pacific Niños connection could be driven by AMO (Martín-Rey et al. 2014).

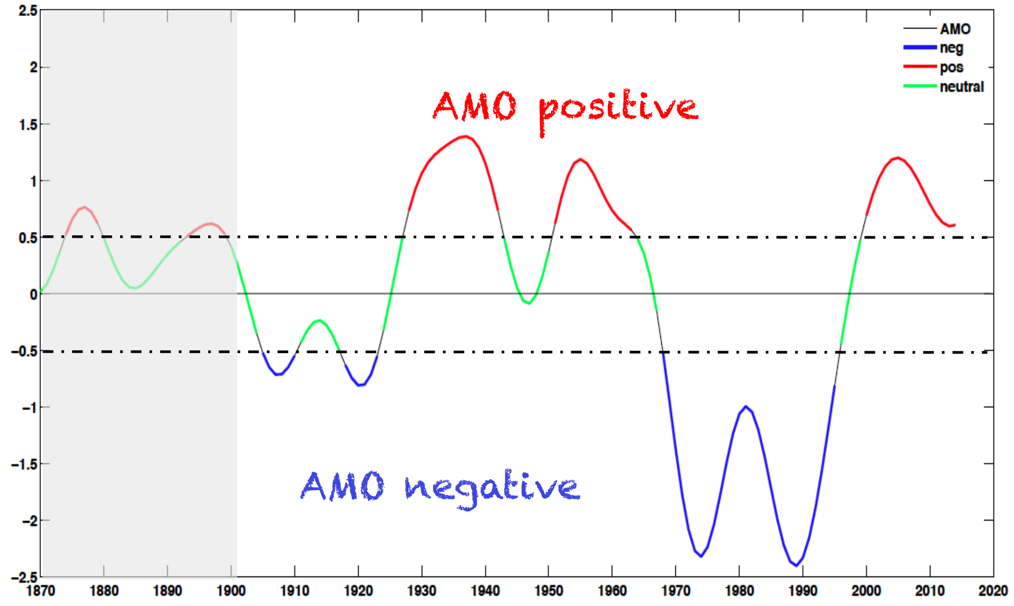
Does AMO impact on tropical Atlantic variability?

(Tokinaga and Xie 2011; Svendsen et al. 2013; Polo et al. 2013)

DATA AND METHODS

- SST for 1870-2014 from HADISST (Rayner et al. 2003)
- Surface WIND and SLP for 1900-2010 from ERA20C reanalysis (Poli et al. 2013)
- Thermocline depth (Isotherm of 16C, D16) for 1871-2008 from SODA reanalysis (Giese and Ray 2011)
- High-Pass (7 year cutt-of) Butterworth filter (Butterworth 1930)
- Common period of study: 1900-2008

AMO index 1870-2014 HADISST

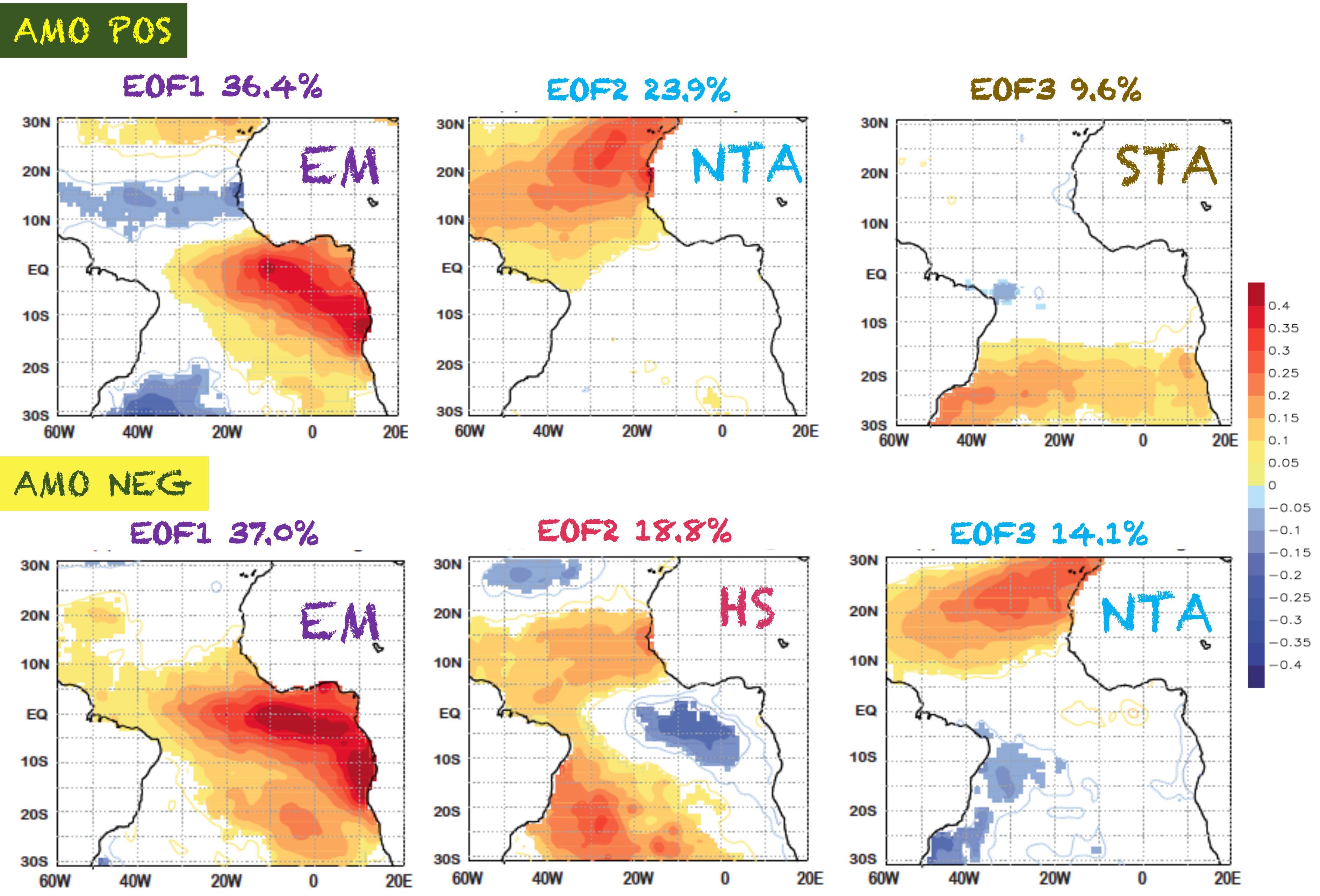


- Principal Component Analysis (PCA) applied to the summer (JJAS) SST anomalies for different AMO phases:

  - 34 years for positive AMO phase: 1928, 1929, 1939, 1931, 1932, 1933, 1934, 1935, 1936, 1937, 1938, 1939, 1940, 1941, 1942, 1951, 1952, 1953, 1954, 1955, 1956, 1957, 1958, 1959, 1960, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007.

  - 36 years for negative AMO phase 1906, 1907, 1908, 1909, 1918, 1919, 1920, 1921, 1922, 1923, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995

RESULTS: Does the TA SST variability change under AMO phases?



EM: Equatorial Mode or Atlantic Niño

NTA: North Tropical Atlantic mode

HS: Horse-Shoe mode

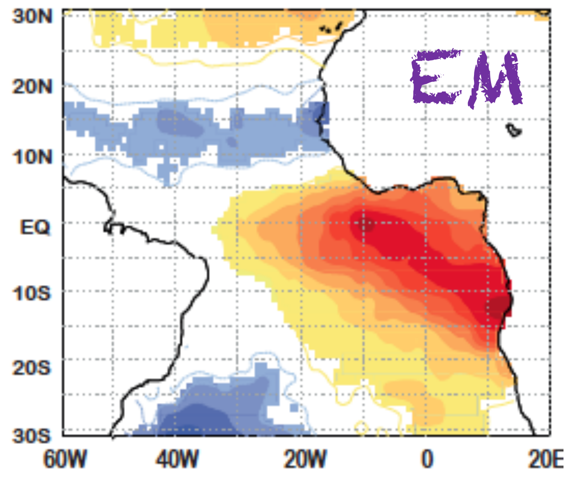
STA: South Tropical Atlantic mode

Martín-Rey et al. 2016, Jclim

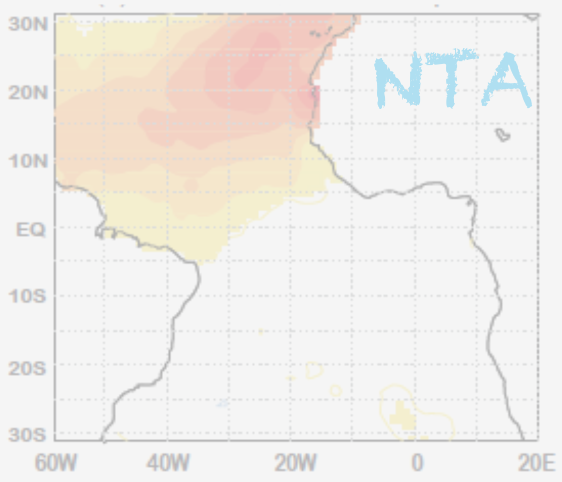
RESULTS: Does the TA SST variability change under AMO phases?

AMO POS

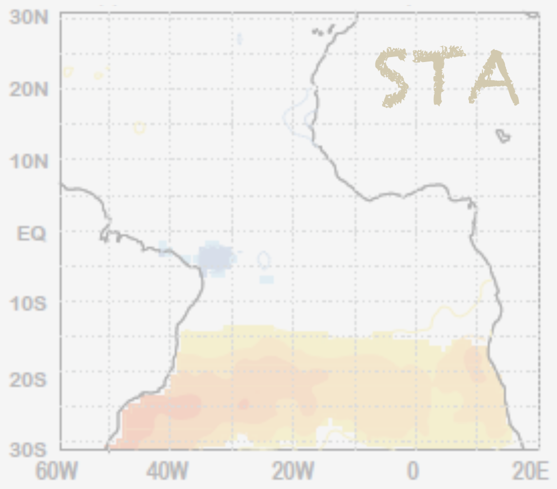
EOF1 36.4%



EOF2 23.9%

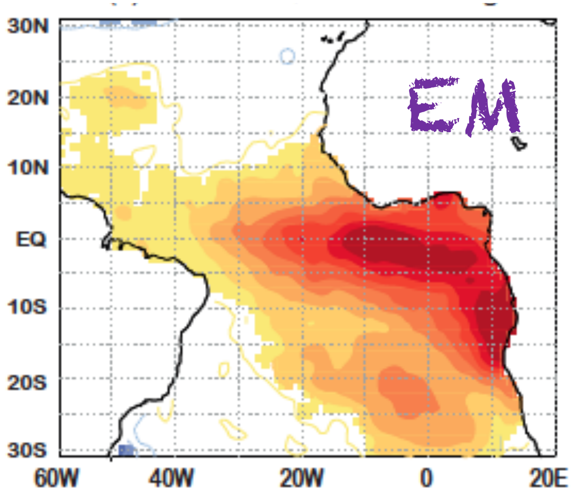


EOF3 9.6%

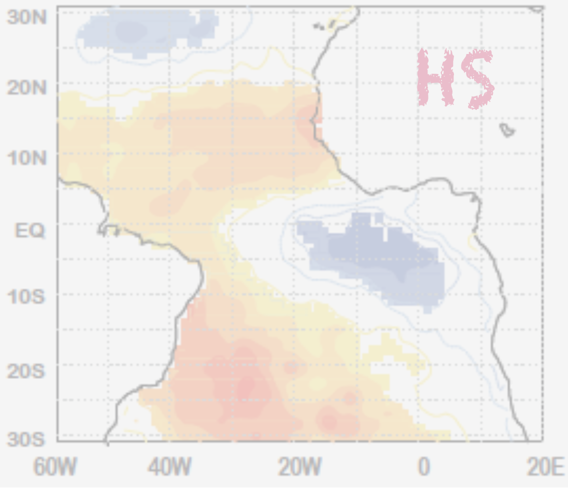


AMO NEG

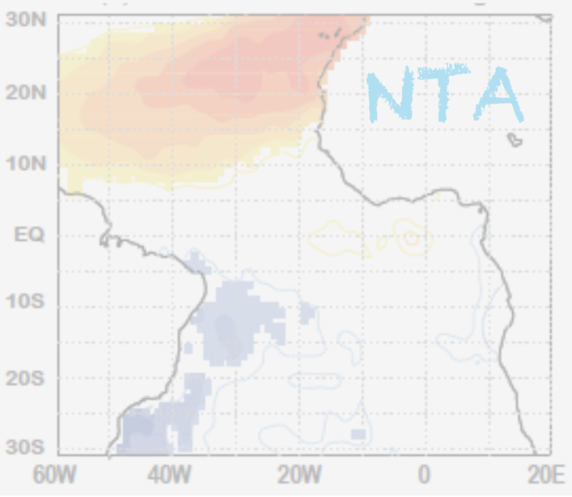
EOF1 37.0%



EOF2 18.8%



EOF3 14.1%



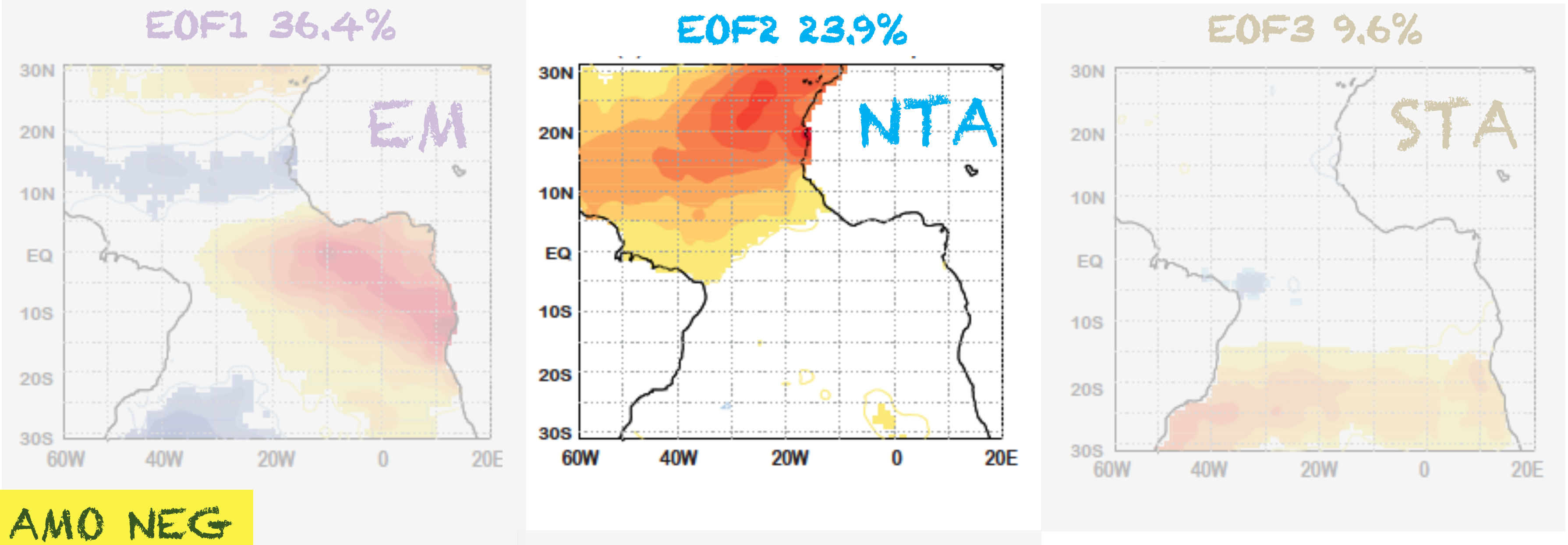
NEGATIVE AMO:

Atlantic Niño show larger amplitude and fraction of explained variance. The warm tongue presents a westward extension

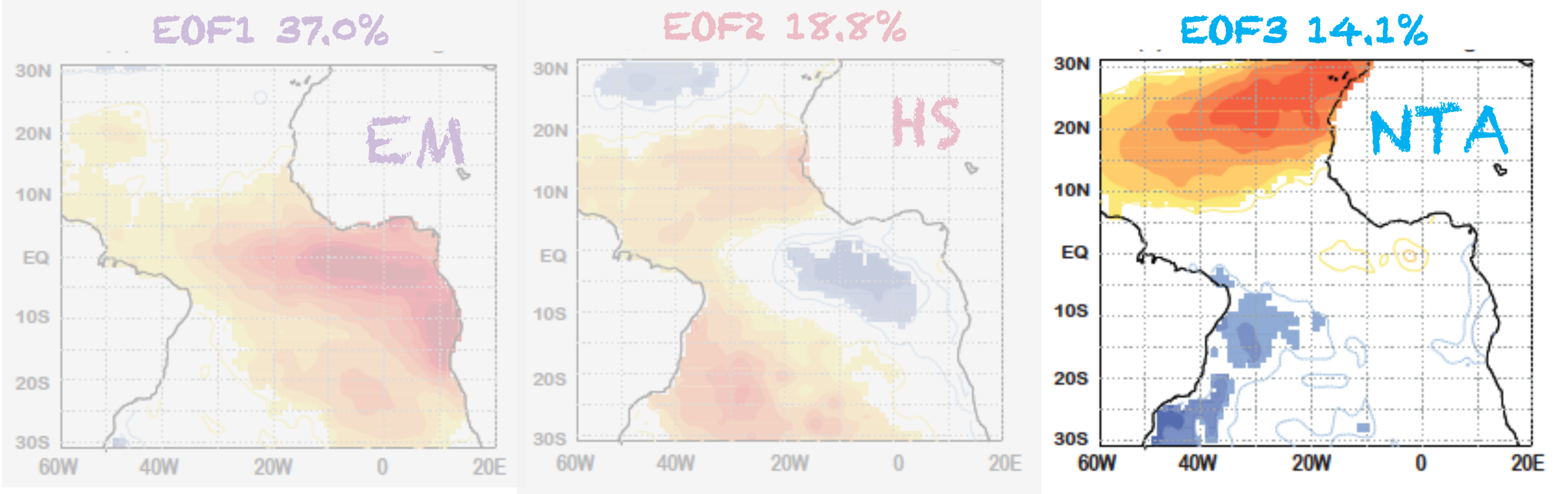
Martín-Rey et al. 2016, Jclim (under review)

RESULTS: Does the TA SST variability change under AMO phases?

AMO POS



AMO NEG



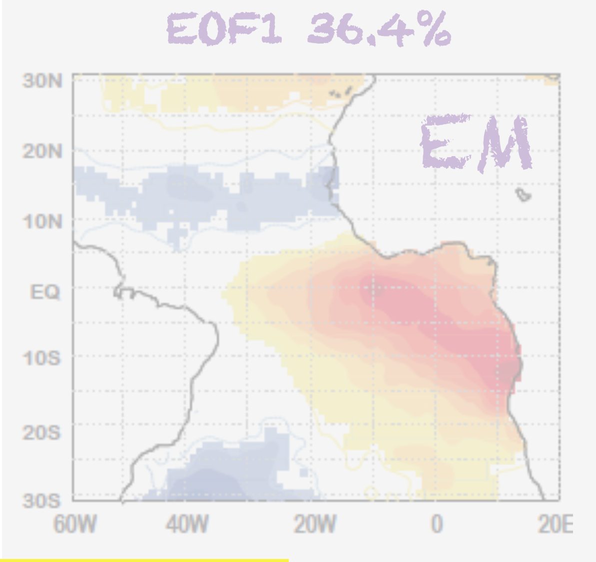
NEGATIVE AMO:

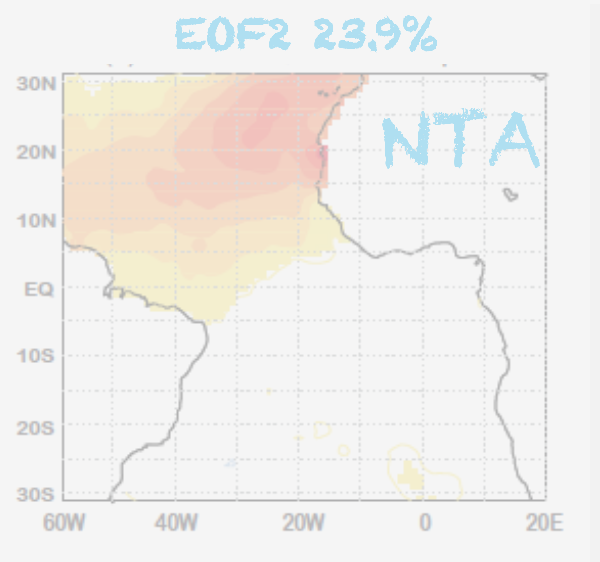
NTA mode is relegated to the third mode and shows a meridional northward displacement

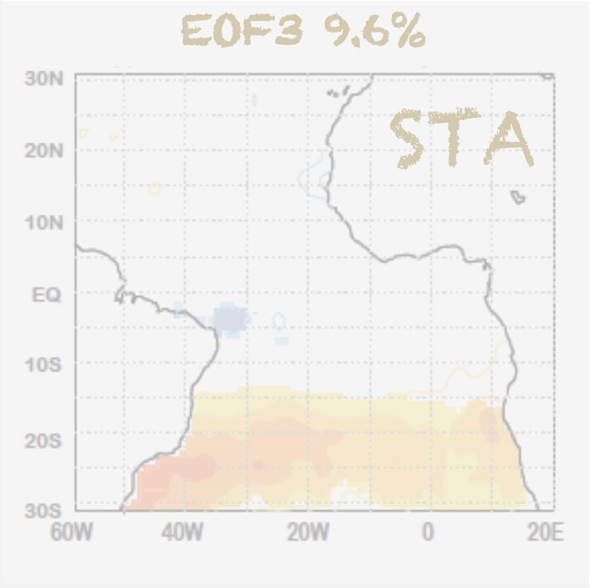
Martín-Rey et al. 2016, Jclim

RESULTS: Does the TA SST variability change under AMO phases?

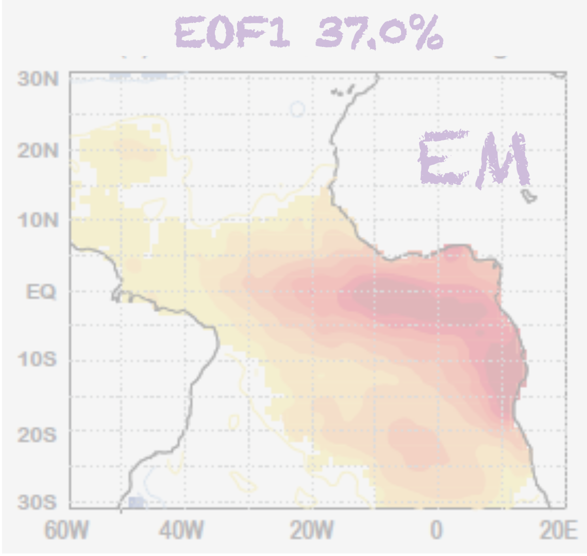
AMO POS

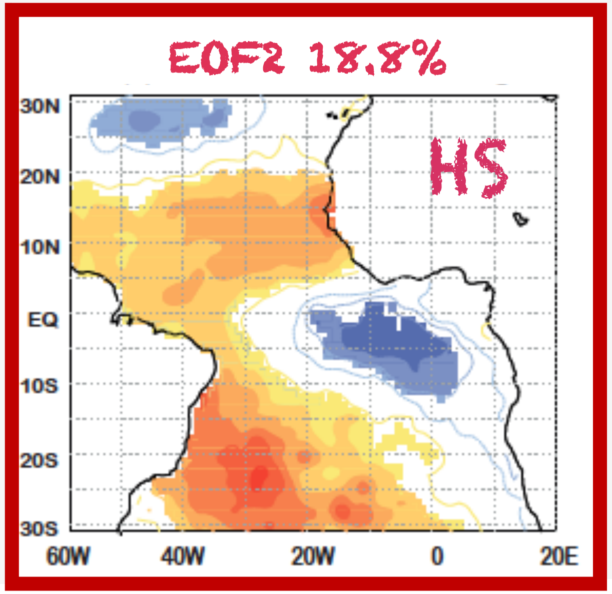


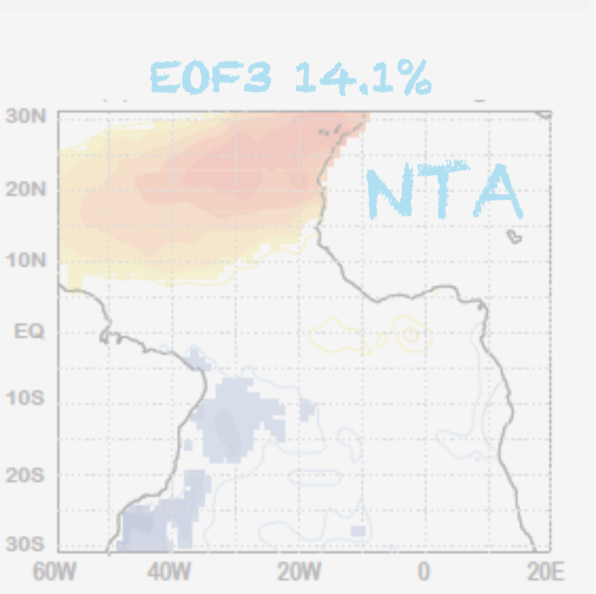




AMO NEG







NEGATIVE AMO:

HS mode only emerges in negative AMO periods as the second variability mode.

Martín-Rey et al. 2016, Jclim (under review)

RESULTS: Does the TA SST variability change under AMO phases?

AMO POS

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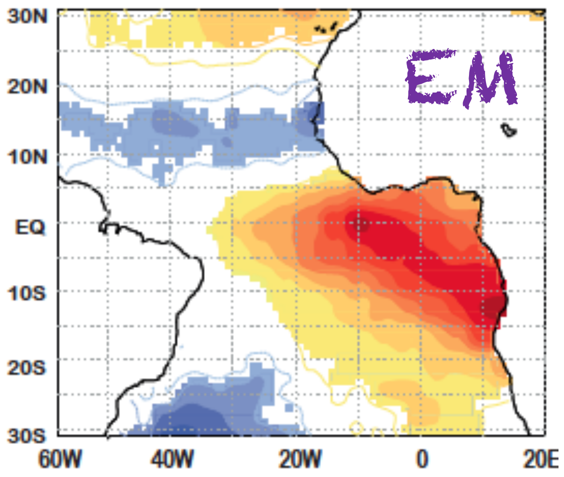
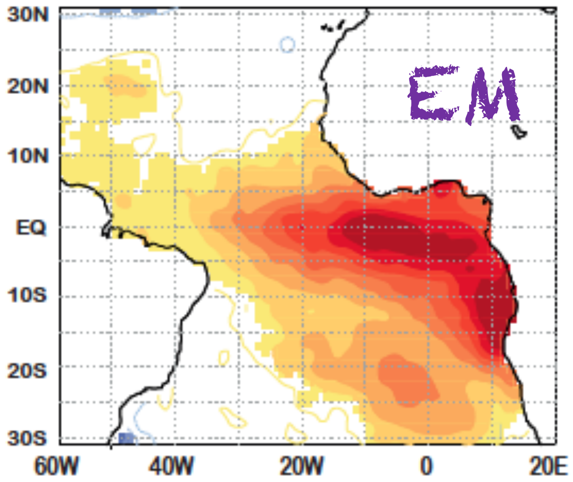


What are the causes of different Atlantic Niño configurations under AMO phases?

AMO NEG

EOF1 37.0%



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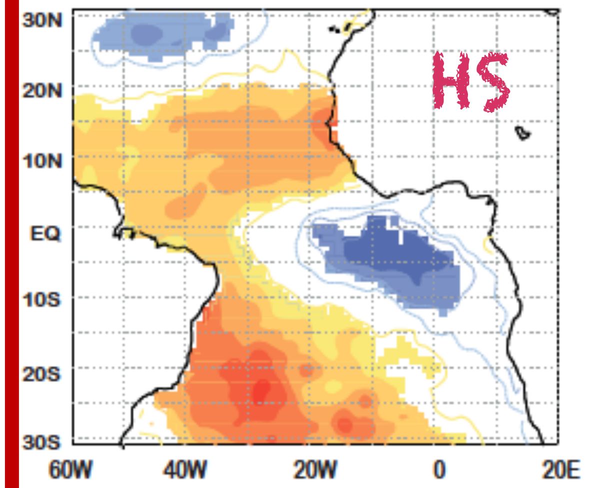


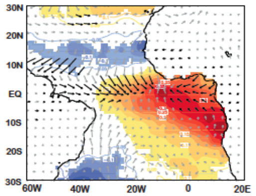
Why does a new mode emerge in the TA during negative AMO?

Martín-Rey et al. 2016, Jclim (under review)

RESULTS: What is the role of the Subtropical Highs in the Atlantic Niño?

AMO POS

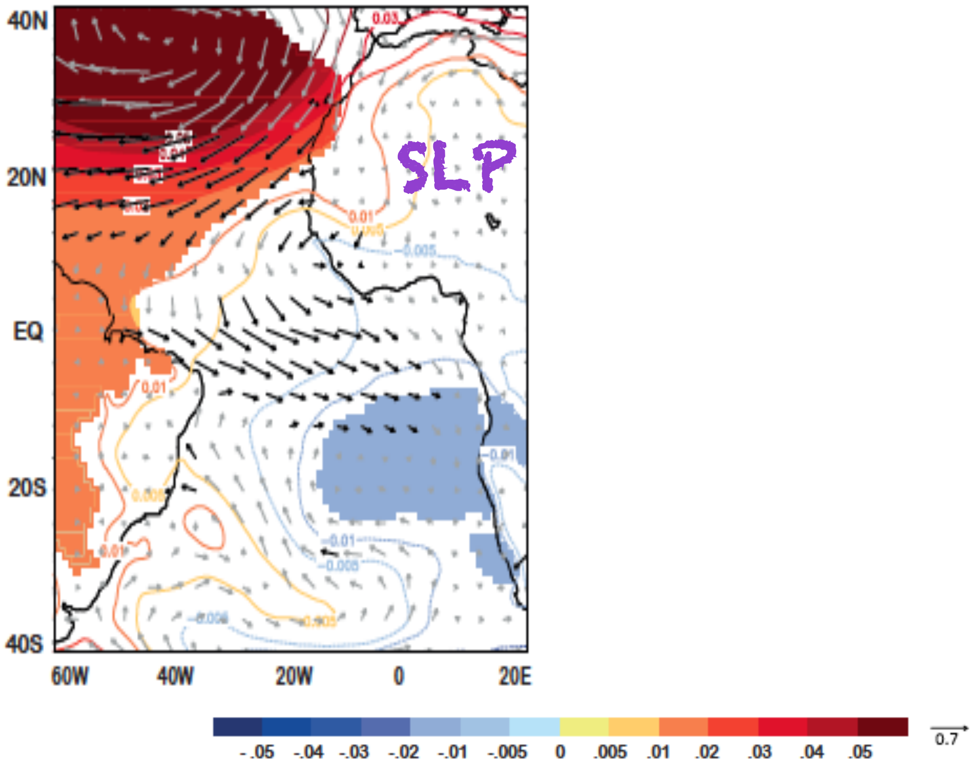
ATLANTIC NIÑO

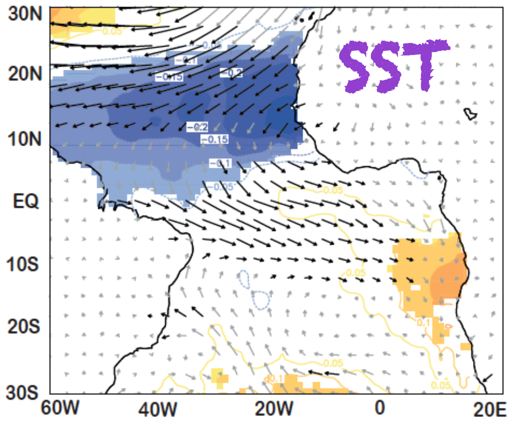


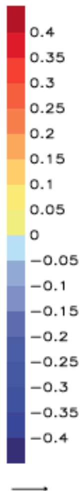
JFMA:

- Strengthening of Azores High → intensified north-easterlies → enhanced the evaporative cooling.
- low pressure in eastern STA → weakened southern trades → reduced the AB upwelling
  *local winds (Polo et al. 2008; Richter et al. 2010)
  *Wind-excited equatorial KW (Lübbecke et al. 2010)

JFMA



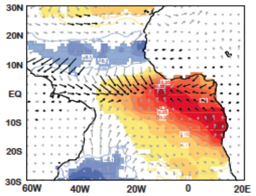




Martín-Rey et al. 2016, Jclim (under review)

RESULTS: What is the role of the Subtropical Highs in the Atlantic Niño?

AMO POS ATLANTIC NIÑO



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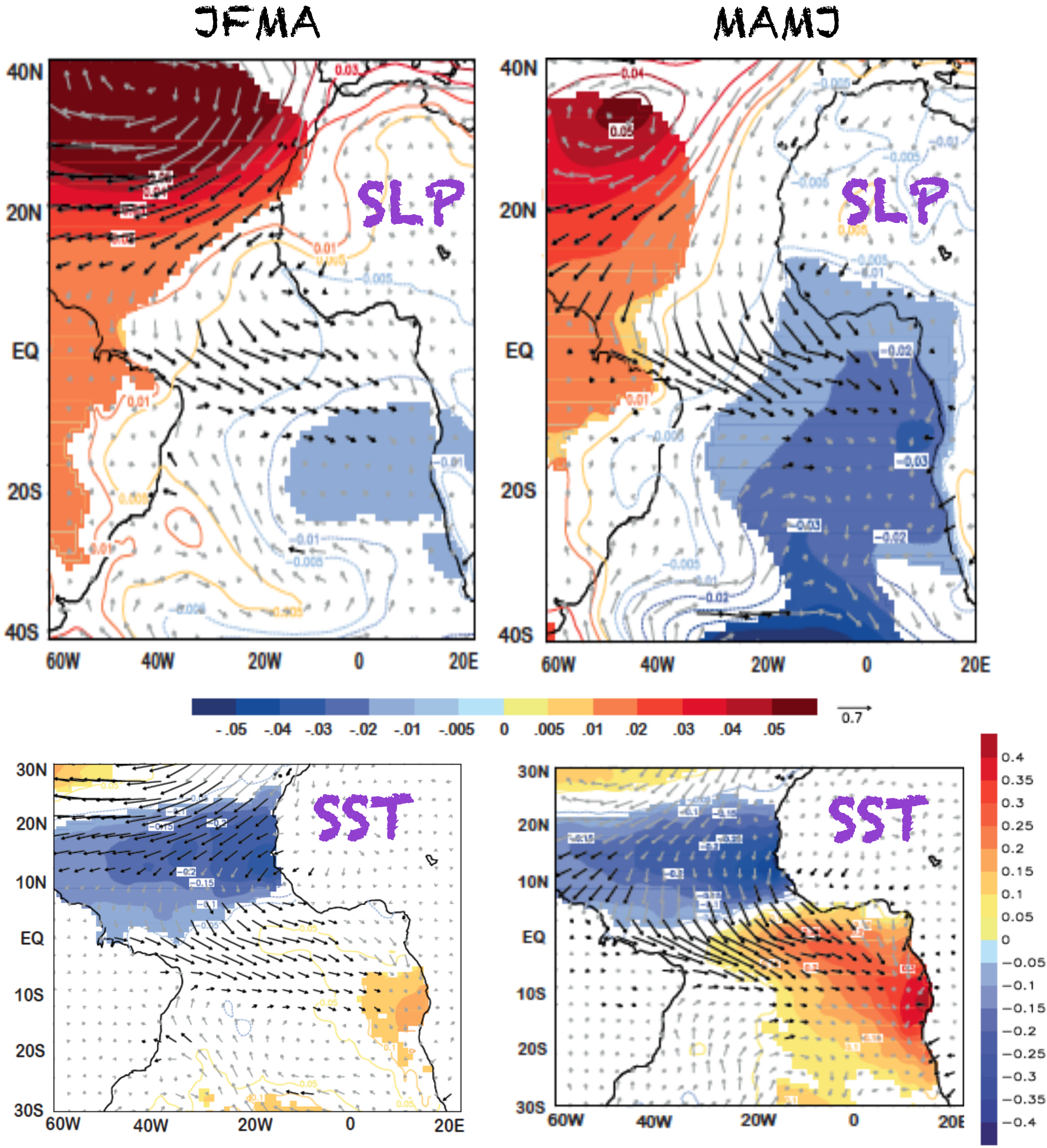
MAMJ:

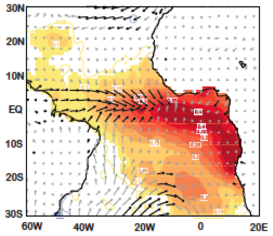
- Meridional evolved into east-west tropical SLP gradient → reinforced westerlies at the equator → deepened thermocline and warming.
  * Bjerknes feedback (Keenlyside and latif 2007)
  *Wind-excited equatorial KW (Lübbecke et al. 2010)
- Negative Meridional Mode-type SST pattern in spring precedes the Atlantic Niño (Servain et al. 1999; Foltz et al. 2010; Lübbecke and McPhaden 2012).



Martín-Rey et al. 2016, Jclim (under review)

RESULTS: What is the role of the Subtropical Highs in the Atlantic Niño?

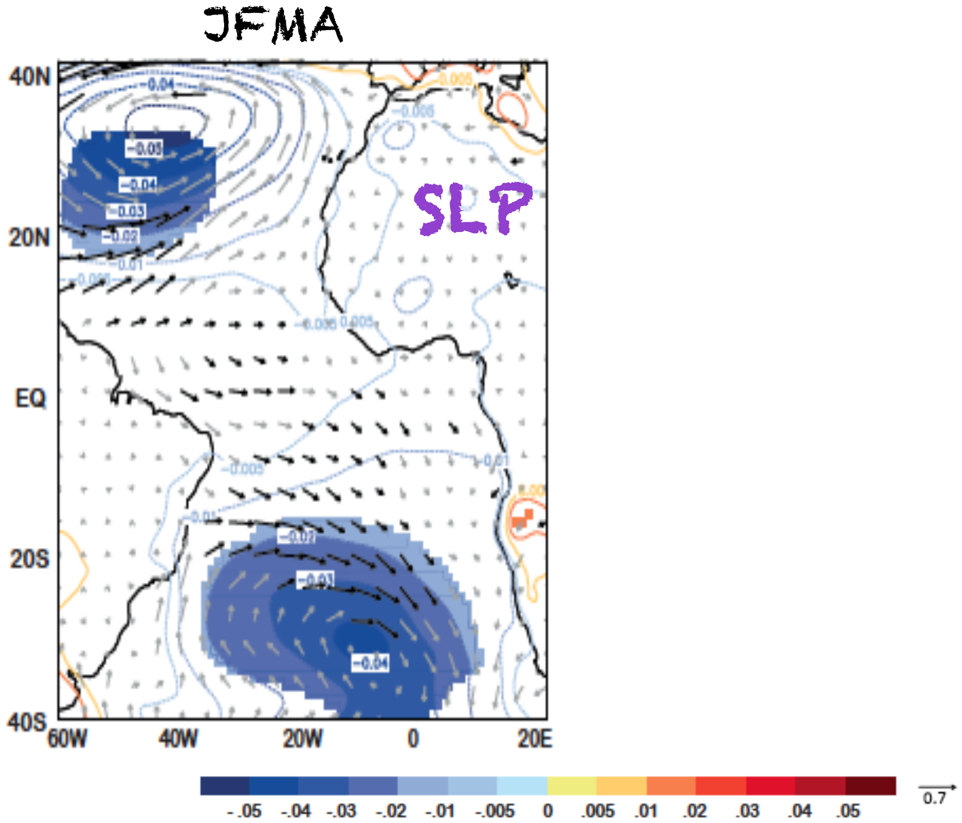
AMO NEG ATLANTIC NIÑO

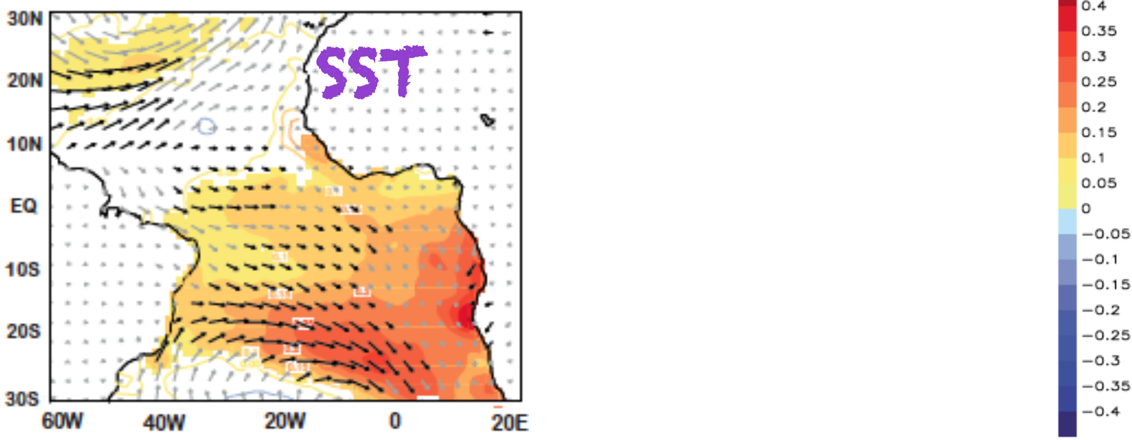


JFMA:

- Simultaneous weakening of Azores and St Helena High → reduction north-eastern and south-eastern trades → Decreased latent heat loss →warm the underneath regions.

- Anomalous southward alongshore winds in AB region or excited KW → deepened thermocline → reduced the upwelling (Polo et al. 2008; Richter et al. 2010 al. 2010; Lübbecke et al. 2010).





Martín-Rey et al. 2016, Jclim (under review)

RESULTS: What is the role of the Subtropical Highs in the Atlantic Niño?

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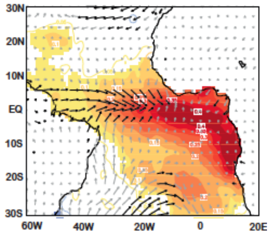

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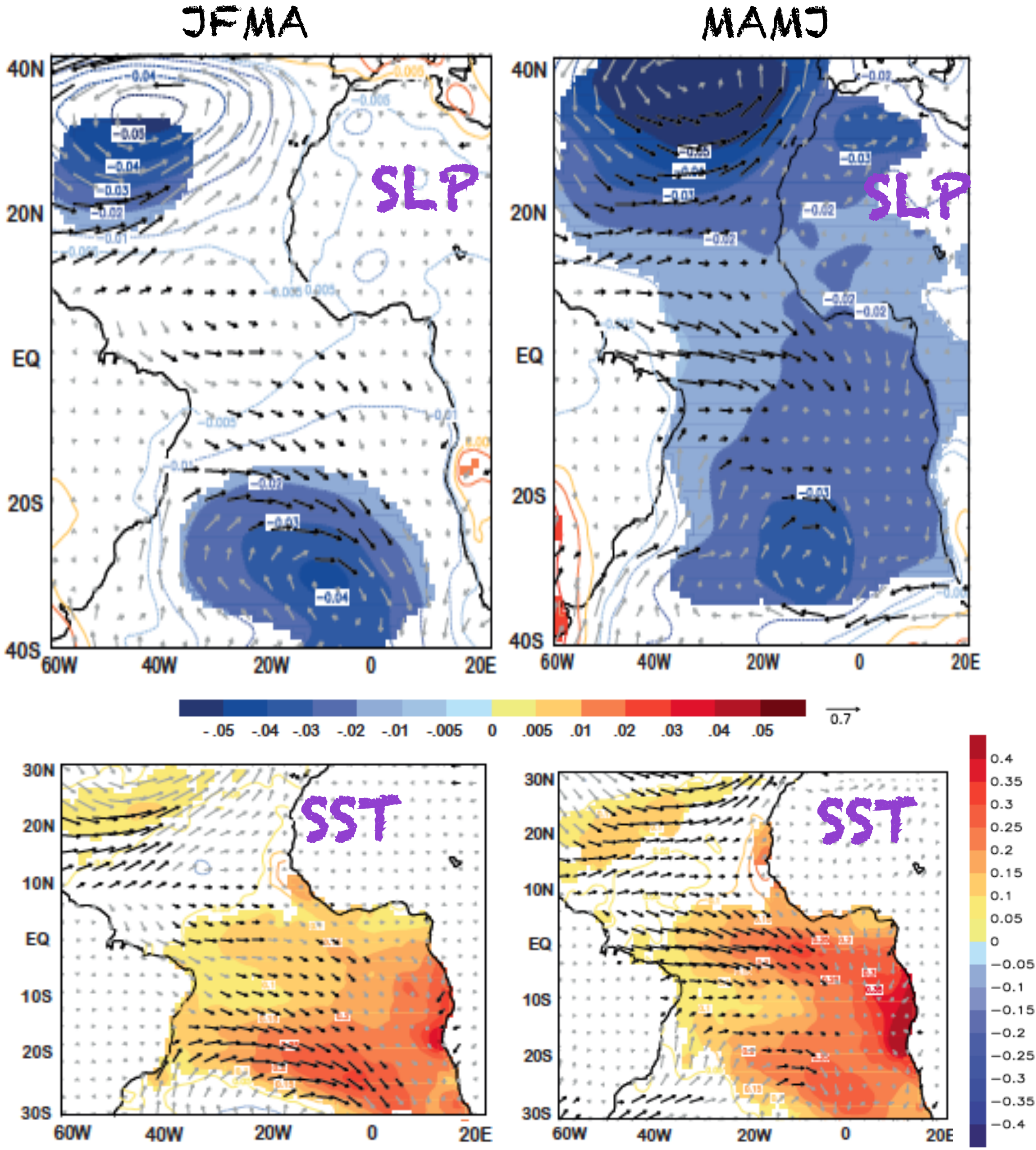
MAMJ:

- Large scale anomalous low SLP conditions → general reduction of the tropical trades.

- Stronger westerlies along the equatorial band → deepened thermocline → equatorial and coastal warming → Bjerknes feedback (Keenlyside and latif 2007)

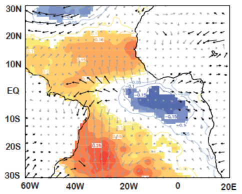


Martín-Rey et al. 2016, Jclim (under review)

RESULTS: Which are the atmospheric forcings of the Horse-Shoe

AMO NEG

HORSE SHOE



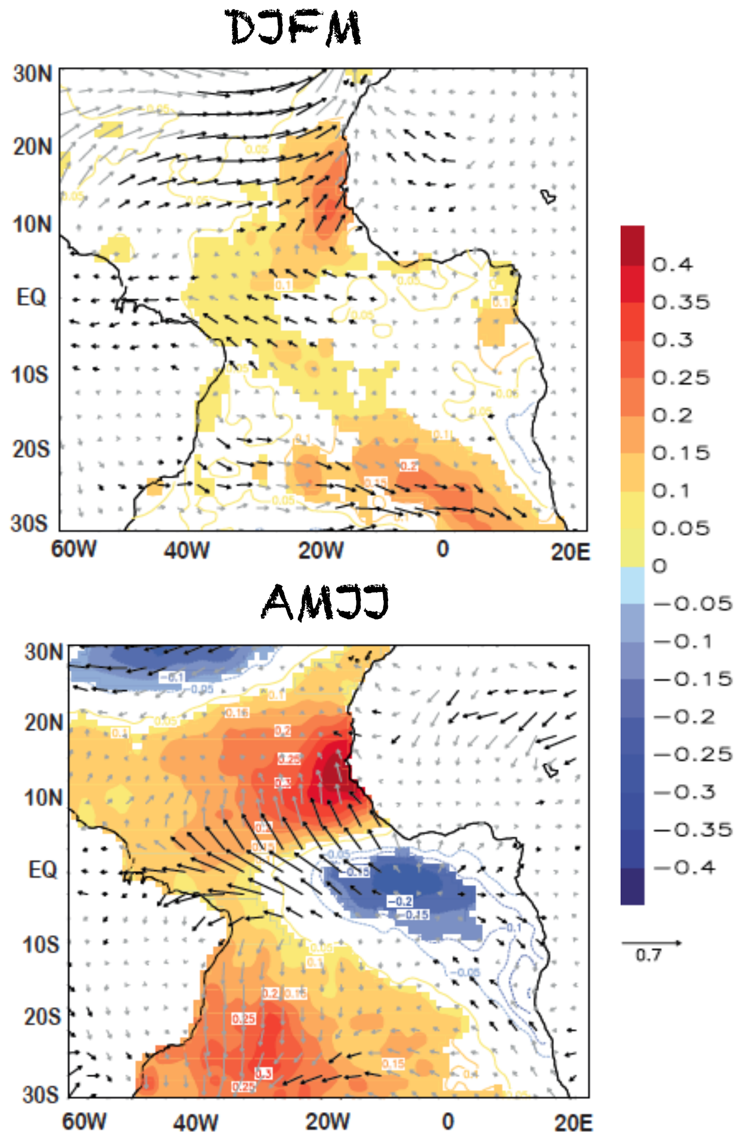
- Weakened northern trades and south-easterly trades → reduced evaporative cooling.

- Anomalous northward winds along Senegal-Mauritanian coast → deepen thermocline through Ekman pumping and reduce the upwelling.

- Meridional SST gradient between NTA and EQ → reinforced cross-equatorial winds

- Intensified equatorial easterly winds → enhanced eastern equatorial upwelling.

- The cold tongue developed → shallows the thermocline and reinforced the easterlies → activating the Bjerknes feedback (Keenlyside and latif 2007).



Martín-Rey et al. 2016, Jclim (under review)

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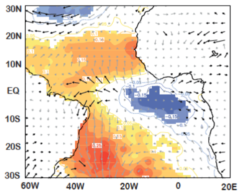
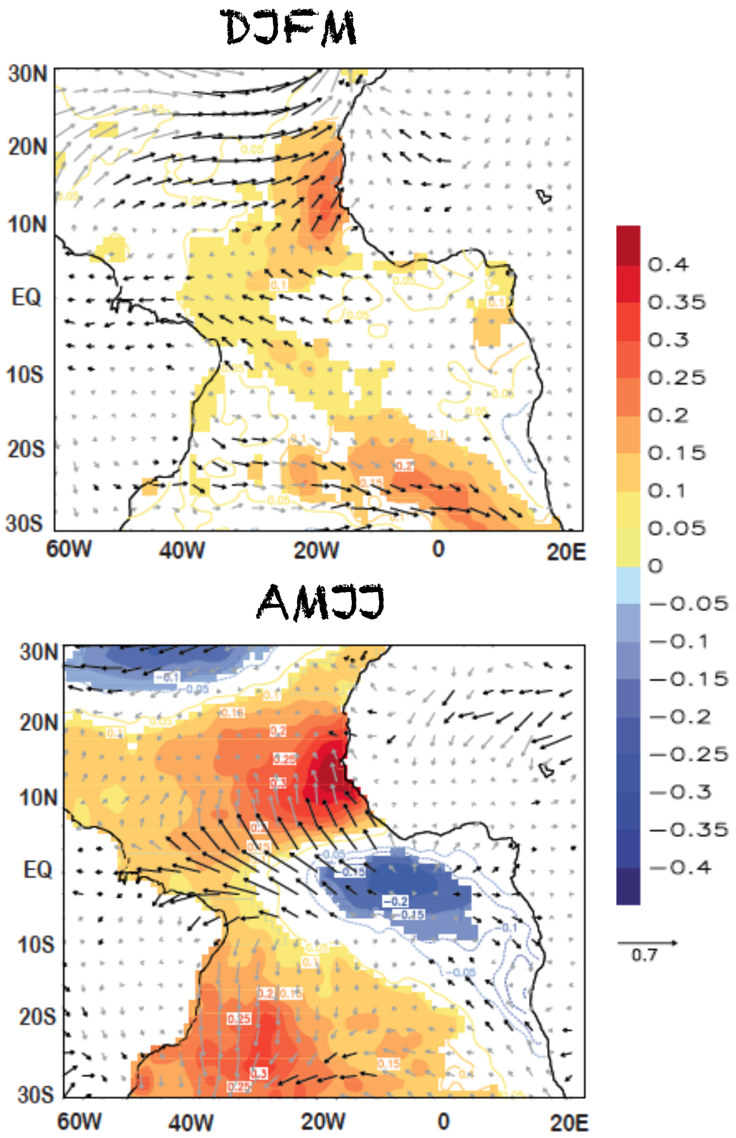


Which is the responsible to generate the HS mode?



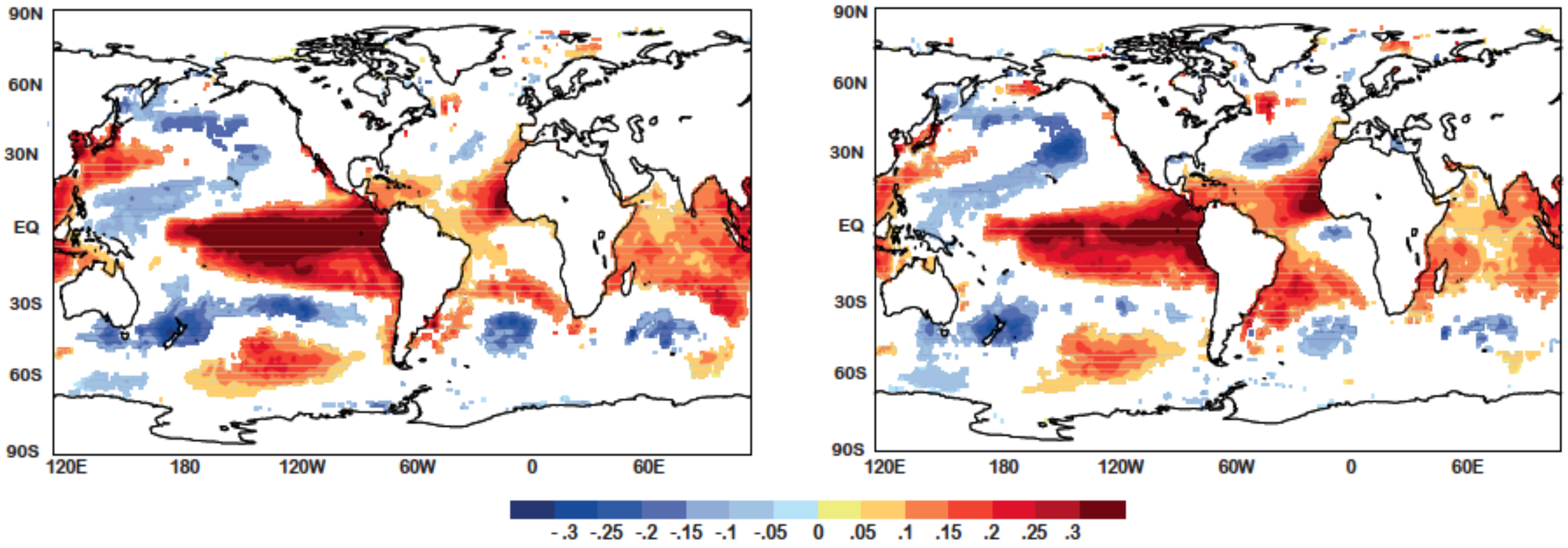
Martín-Rey et al. 2016, Jclim (under review)

RESULTS: Is the HS mode remotely forced?

El Niño pattern during previous winter forced the HS mode.

Regression HS - SSTglob JFMA

Regression HS - SSTglob MAMJ

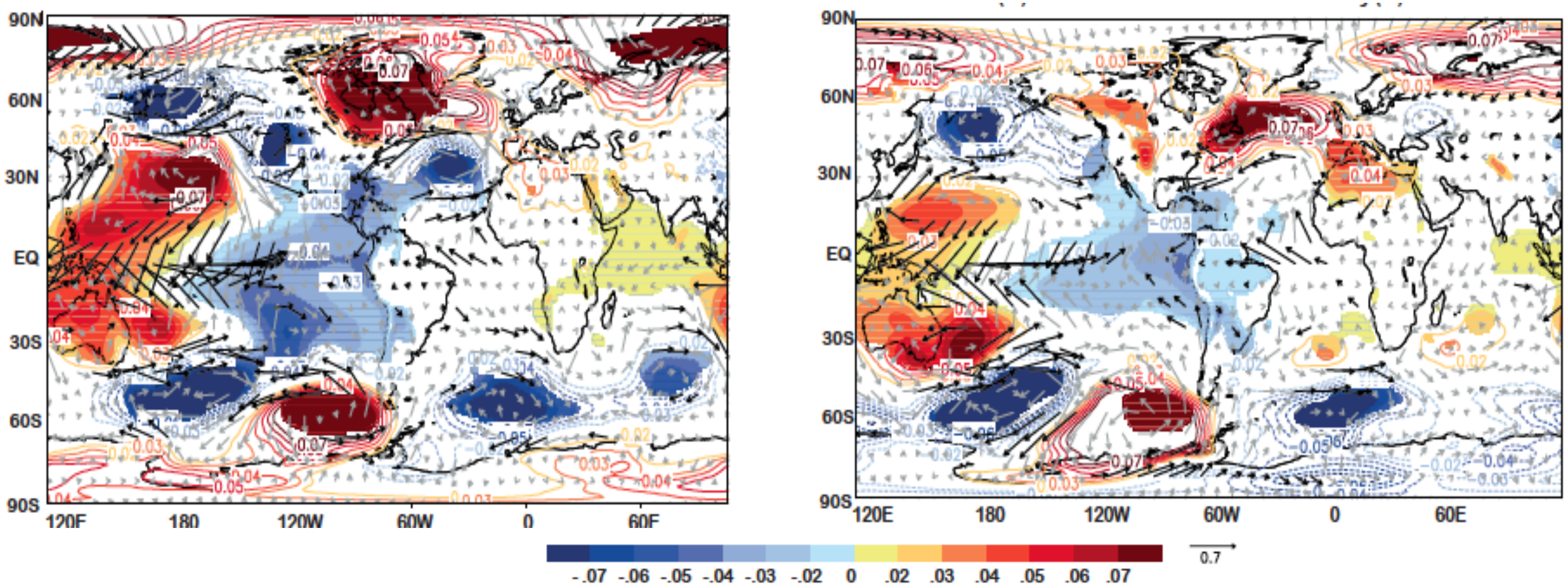


Atmospheric Rossby waves: PSA and PNA patterns (Handoh et al. 2006a,b; López-Parages and Rodríguez-Fonseca 2012)

Walker circulation (Wang 2006)

Regression HS – SLPWIND glob JFMA

Regression HS – SLPWIND glob MAMJ



Martín-Rey et al. 2016, Jclim (under review)

Contrasting with previous results (Polo et al. 2008; Lübbecke et al. 2010; Nnamchi et al. 2016):

Both Subtropical High Pressure Systems seems to drive the development of different Atlantic Niño configurations and HS pattern under AMO phases.

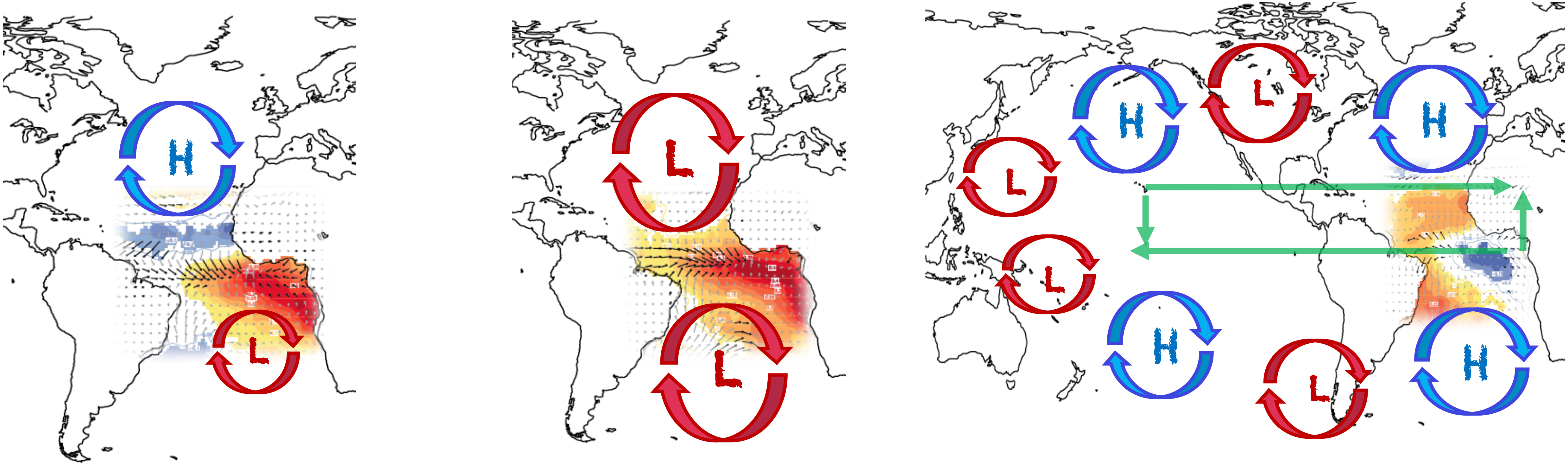
AMO POS

AMO NEG

Atlantic Niño

Atlantic Niño

Horse-Shoe pattern



Martín-Rey et al. 2016, Jclim

CONCLUSIONS

- Observed inter-annual TAV seems to be modulated by AMO: the emergence and spatial configuration of the modes vary under AMO phases.

- During negative AMO phases the Atlantic Niño presents larger amplitude and a westward extension of its warm tongue. Its development is associated with the weakening of both Azores and St Helena Highs, reducing the tropical trades.

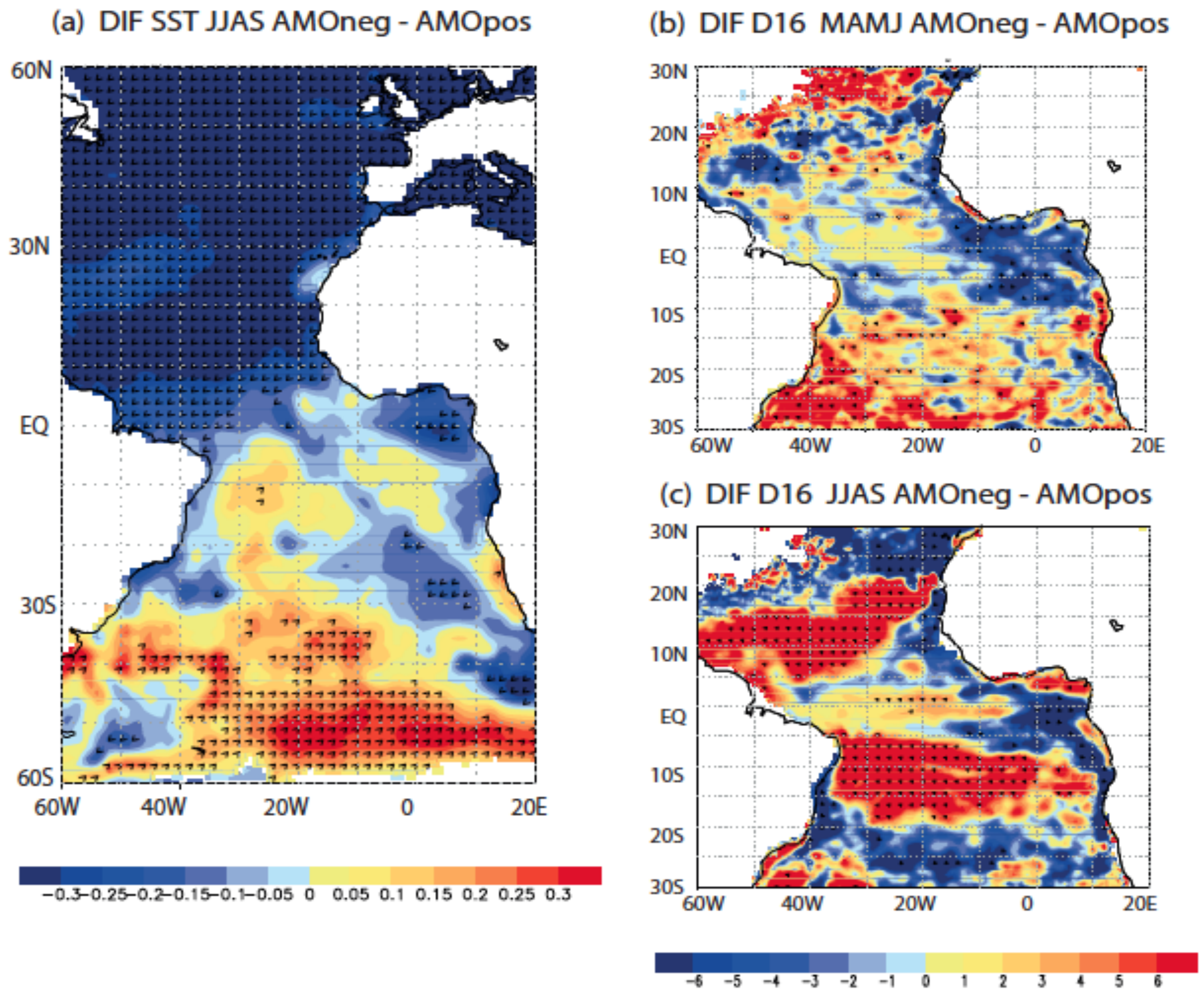
- For positive AMO phases, the Atlantic Niño is related to a meridional SLP pattern, intensifying the northern trades. This SLP configuration evolves into a east-west tropical gradient, reinforcing the westerlies along the equatorial Atlantic.

CONCLUSIONS

- A new TAV pattern shows up during negative AMO phases: the Horse-Shoe mode. It is characterized by a horse-shoe of positive SST anomalies in NTA and STA, surrounding an anomalous cooling in the eastern equatorial Atlantic.
- HS only emerges during negative AMO phases, forced by an El Niño phenomenon from previous winter.
- These changes in Atlantic Niño configuration and HS pattern are related to the interaction of both Subtropical Highs Pressure Systems.

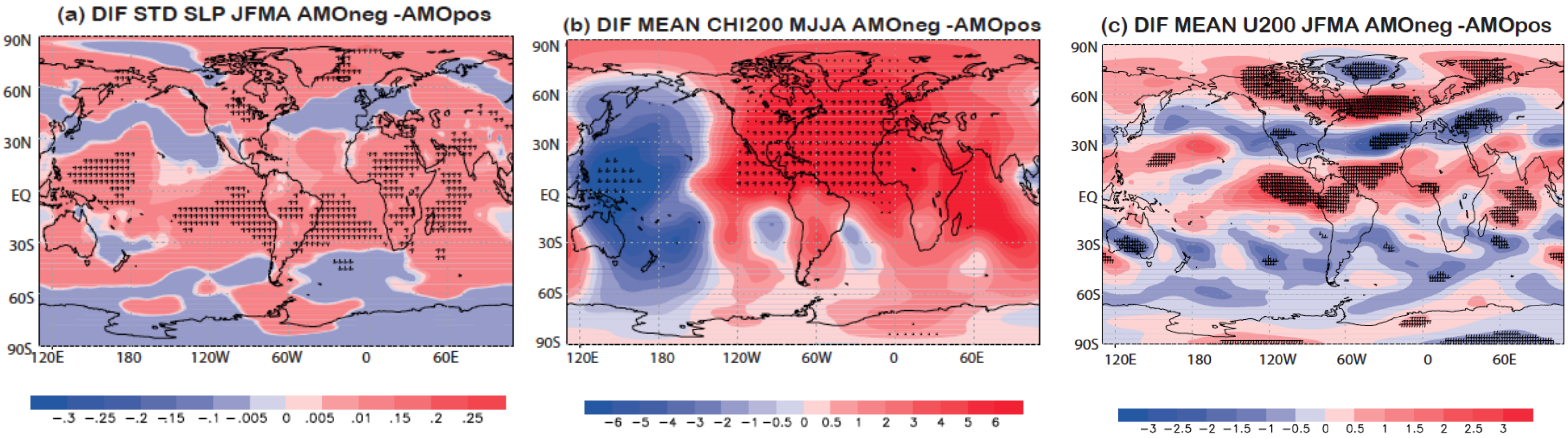
The research leading to these results received funding from the EU FP7/2007-2013 under grant agreement no.603521 (PREFACE project). This study was also supported by the Spanish MINNECO project CGL2012-38923-C02-01.

- Changes in the Atlantic Niño amplitude could be caused by shallower thermocline along the equatorial band from boreal spring to summer months, which increases the effect of the Bjerknes feedback and in turn the SST variability during negative AMO phases.



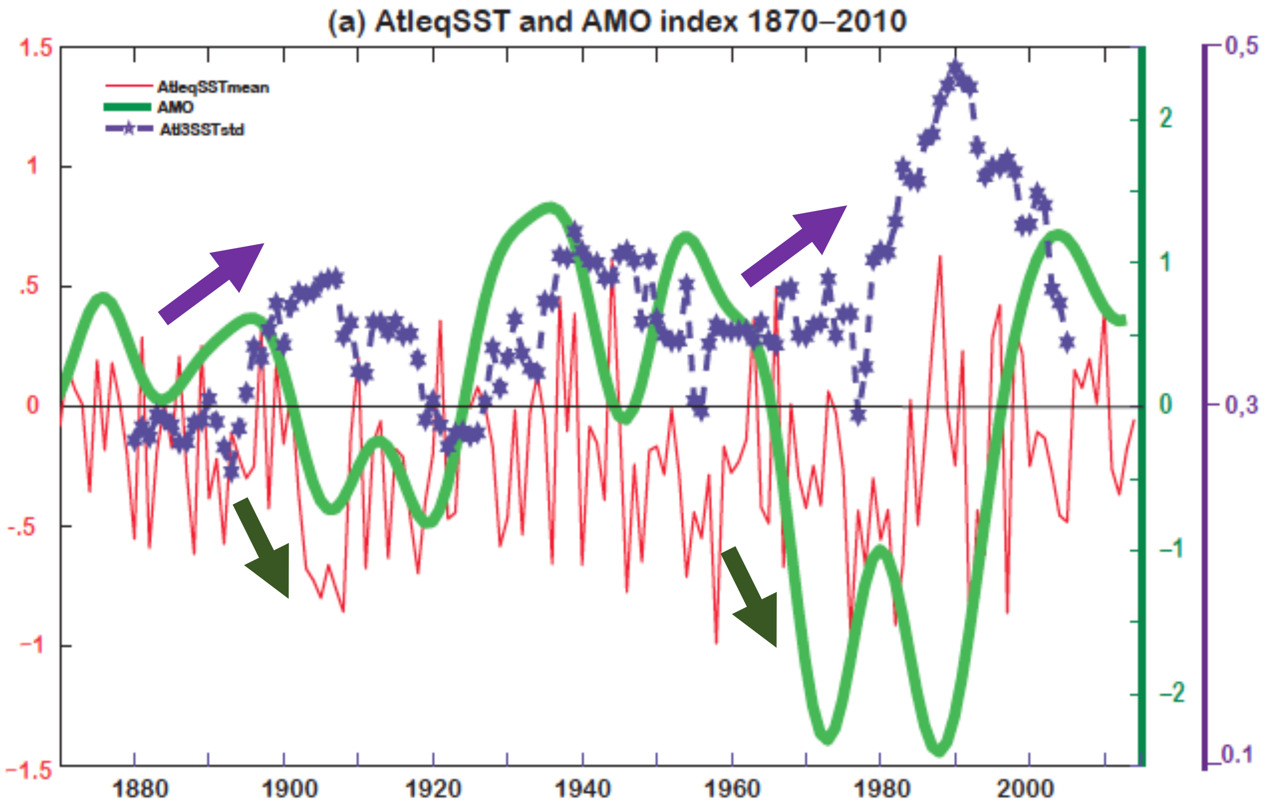
Martín-Rey et al. 2016, Jclim (under review)

- An enhancement of ENSO tropical-extratropical teleconnections over the Atlantic, together with an intensification of the Walker circulation could favour the ENSO impact on the TAV during negative AMO periods.

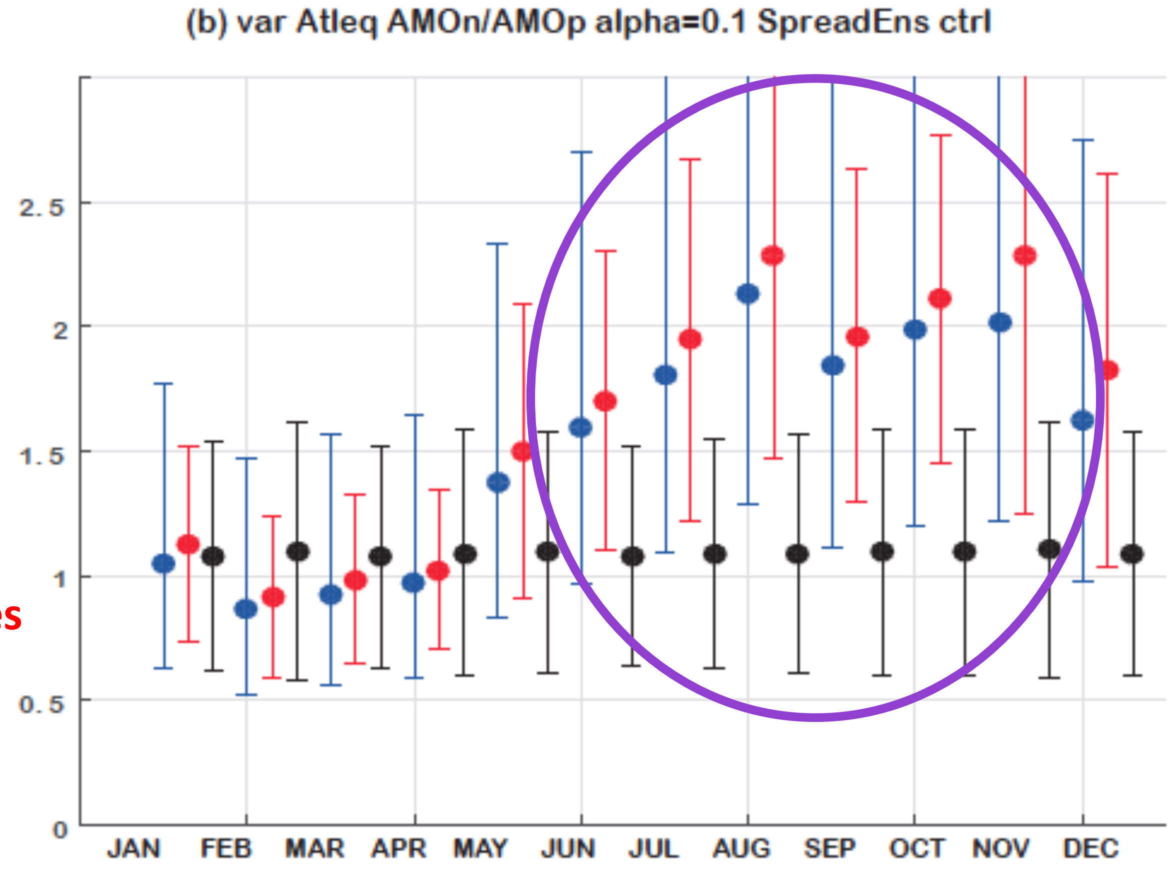


Martín-Rey et al. 2016, Jclim (under review)

CHANGES IN THE EQUATORIAL ATLANTIC SST VARIABILITY ALONG THE 20th CENTURY



Increased equatorial SST variability
in negative AMO phases
from July to November.

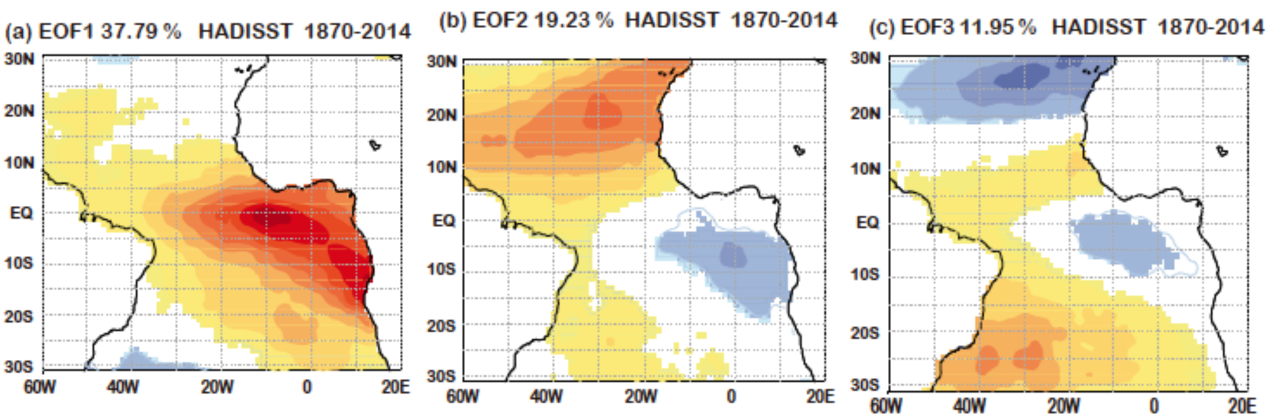


● Ratio 20-yr AMO neg period respect to AMOpos period

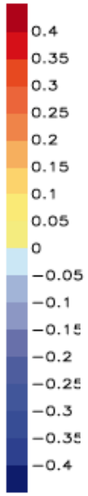
● Same as ● but permuting 10000 times the years in AMO phases

● Same as ● but considering 20 y randomly in the entire record of AMO phases

Martín-Rey et al. 2016, Jclim (under review)



Martín-Rey et al. 2016, Jclim (under review)



The TAV modes change along the 20th century under different AMO phases