A mechanism for the multidecadal modulation of the Atlantic-Pacific connection

Belen Rodríguez de Fonseca (1,2),

Irene Polo Sánchez (1,3),

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Marta Martin del Rey (4) , Teresa Losada Doval (1,2), Noel Keenlyside(4),

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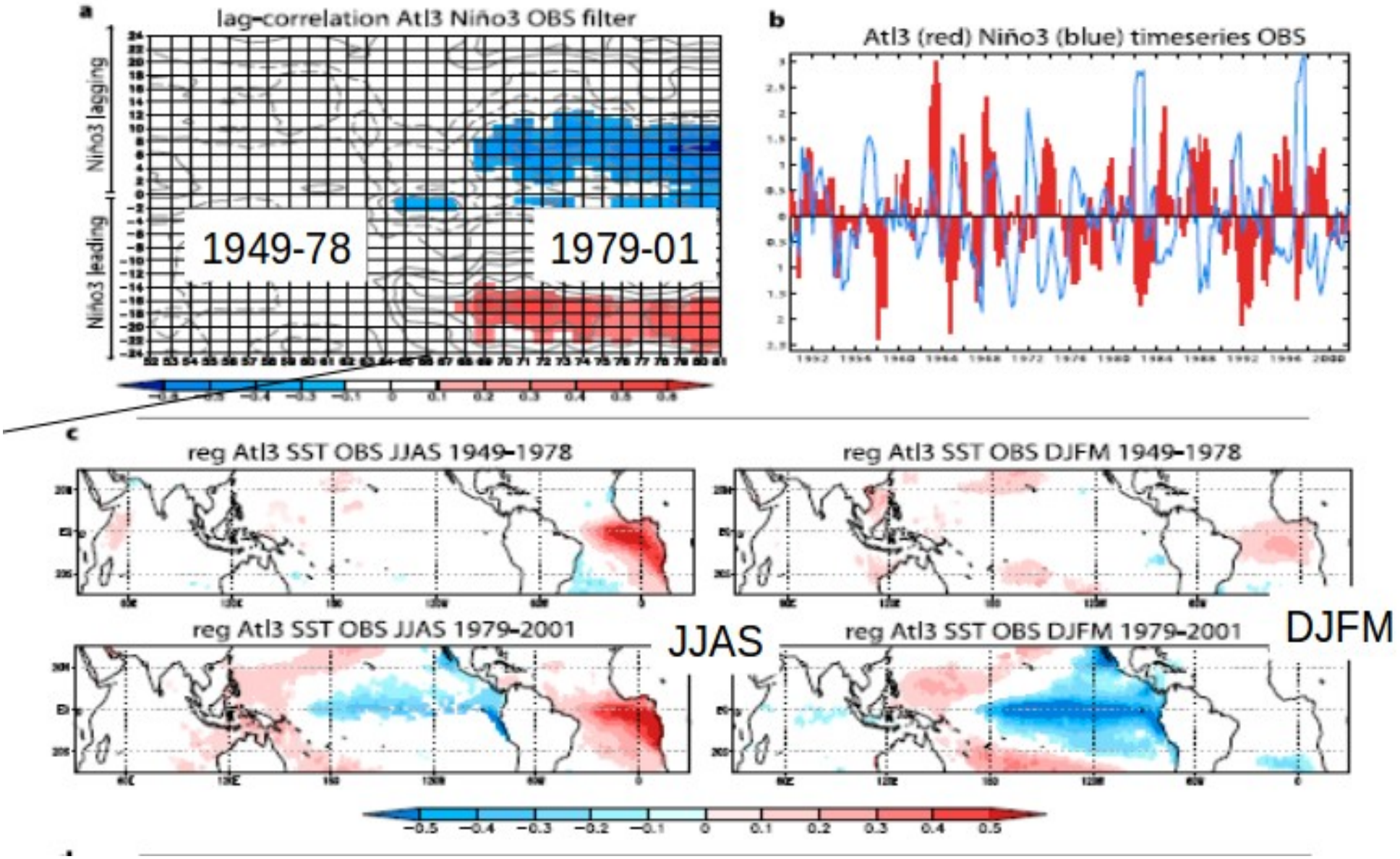
(3) NCAS-Climate University of Reading. UK, (4) University of Bergen (Norway), (5) University of California at Los Angeles (UCLA)



The Atlantic and the Pacific El Niño are linked from the end of the 1960's. Model experiments confirmed this connection

Rodríguez-Fonseca et al., GRL, 2009
Ding et al , 2011

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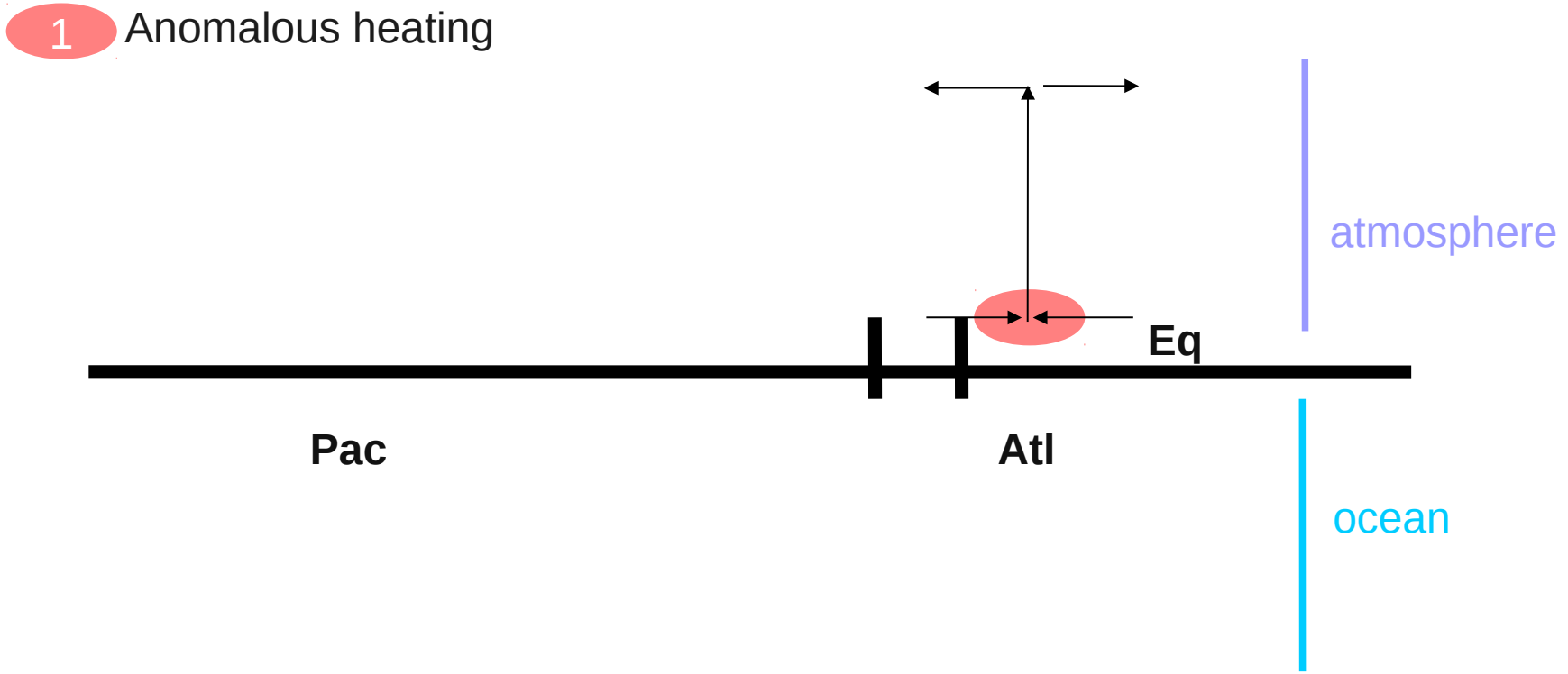
The interbasin connection can be explained by Equatorial Dynamics

Oceanic processes associated to the development of Pacific La Niña triggered by an Atlantic Niño

(Polo et al., 2015; Ding et al, 2011)



Processes in the Pacific La Niña onset triggered by the Atlantic Niño

Irene Polo · Marta Martin-Rey · Belen Rodriguez-Fonseca · Fred Kucharski · Carlos Roberto Mechoso

Polo et al , 2015

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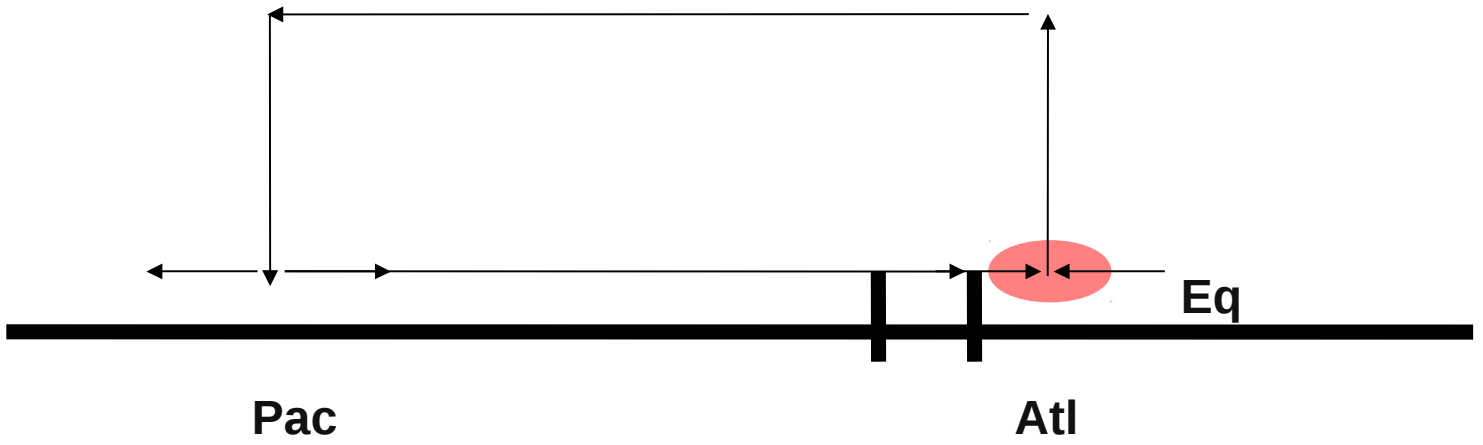
2 Change in Walker and subsidence over western Pacific



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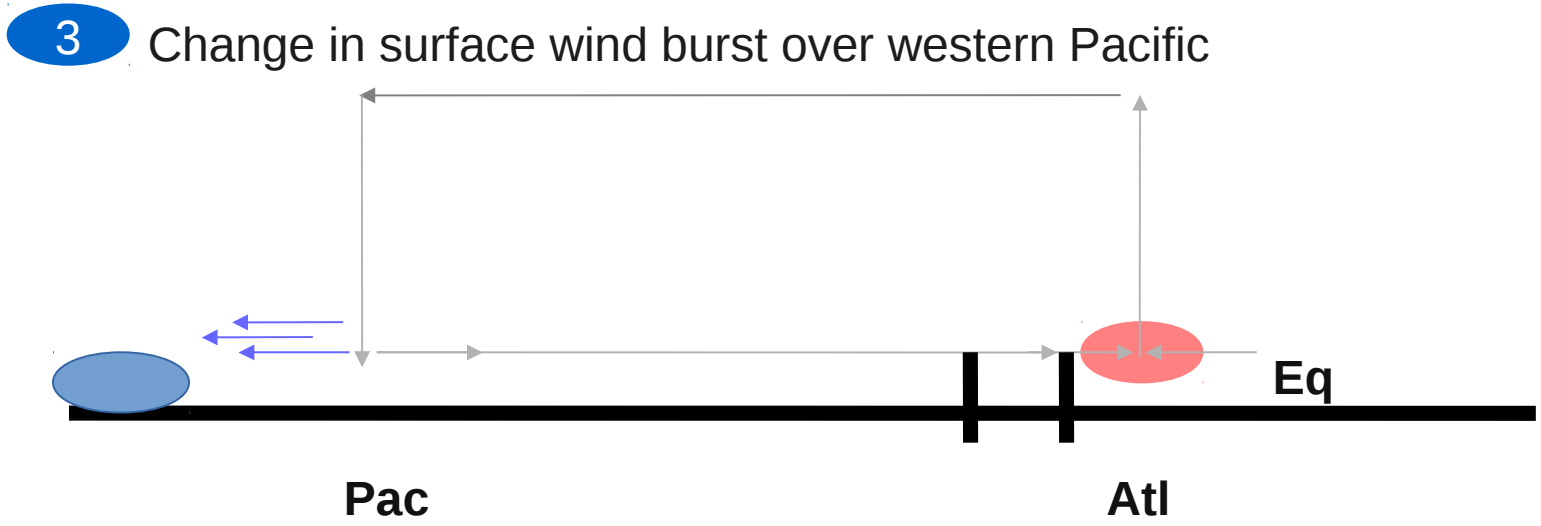

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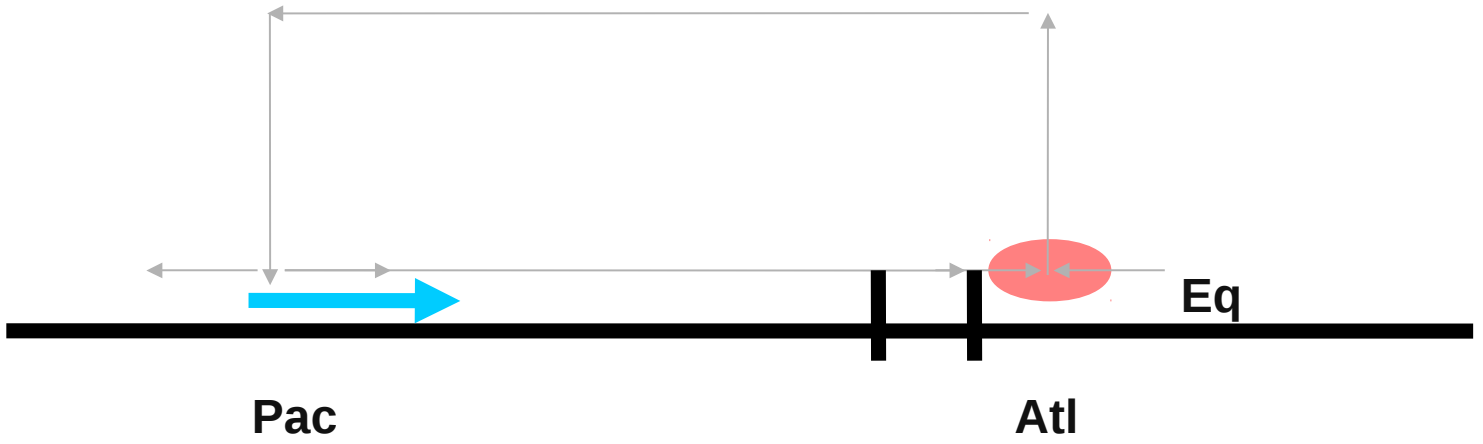
4 Kelvin wave triggering ...



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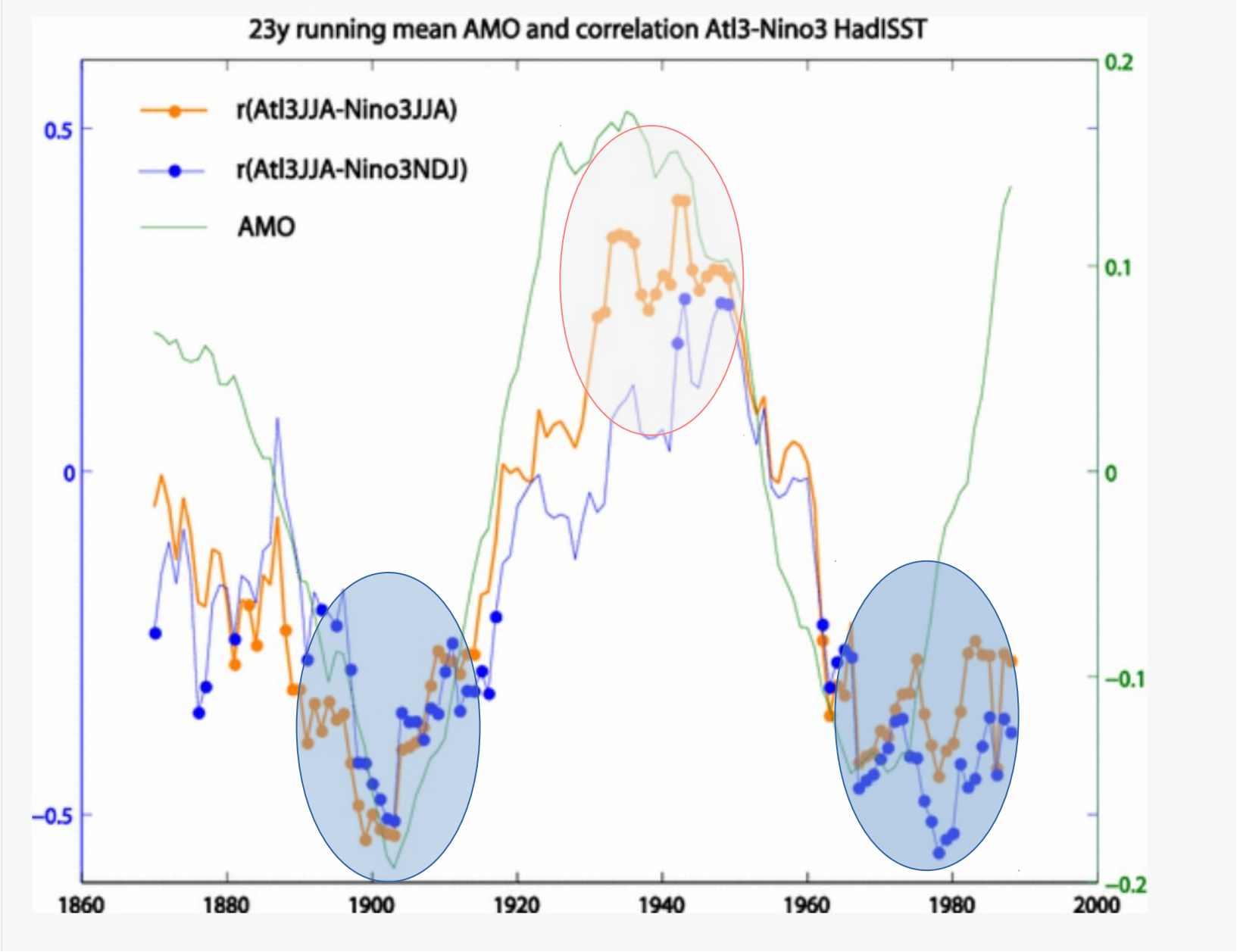
Clim Dyn (2014) 43:3163–3178
DOI 10.1007/s00382-014-2305-3

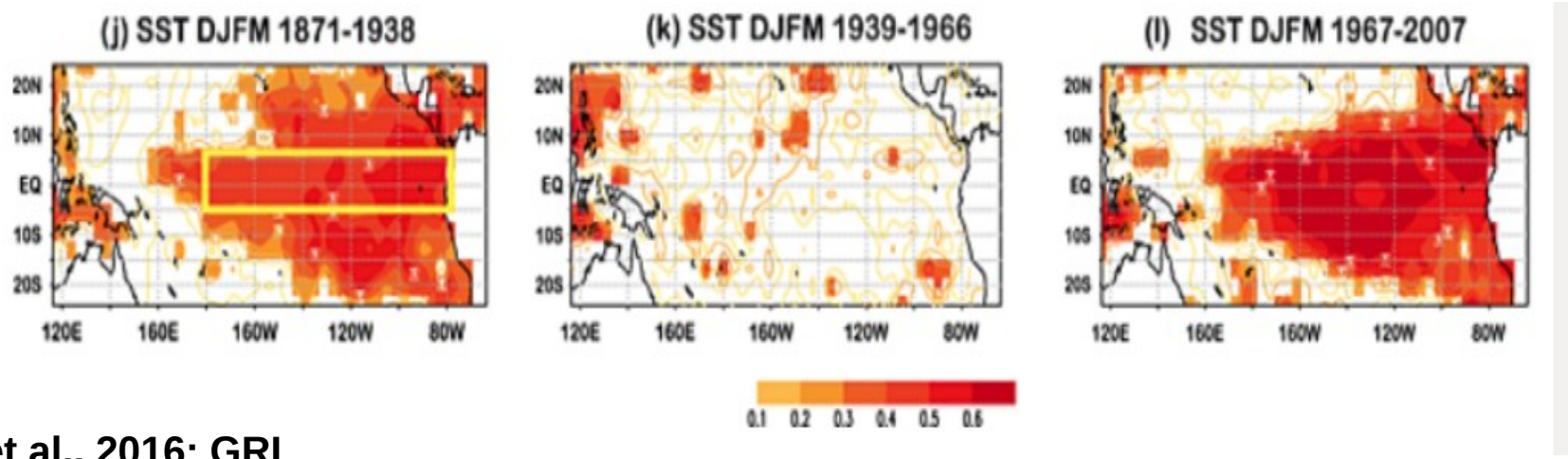
On the Atlantic–Pacific Niños connection: a multidecadal modulated mode

Marta Martín-Rey · Belén Rodríguez-Fonseca · Irene Polo · Fred Kucharski



Polo et al (2015)

ENSO predictability in certain decades: Correlation between observed SSTs and hindcast (predictor SST JJAS in tropical Atlantic)



Martin del Rey et al., 2016: GRL

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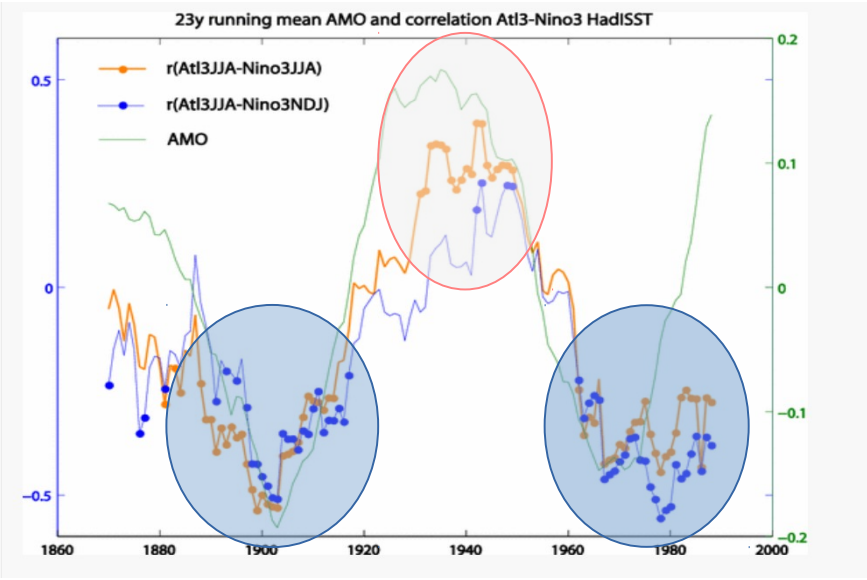
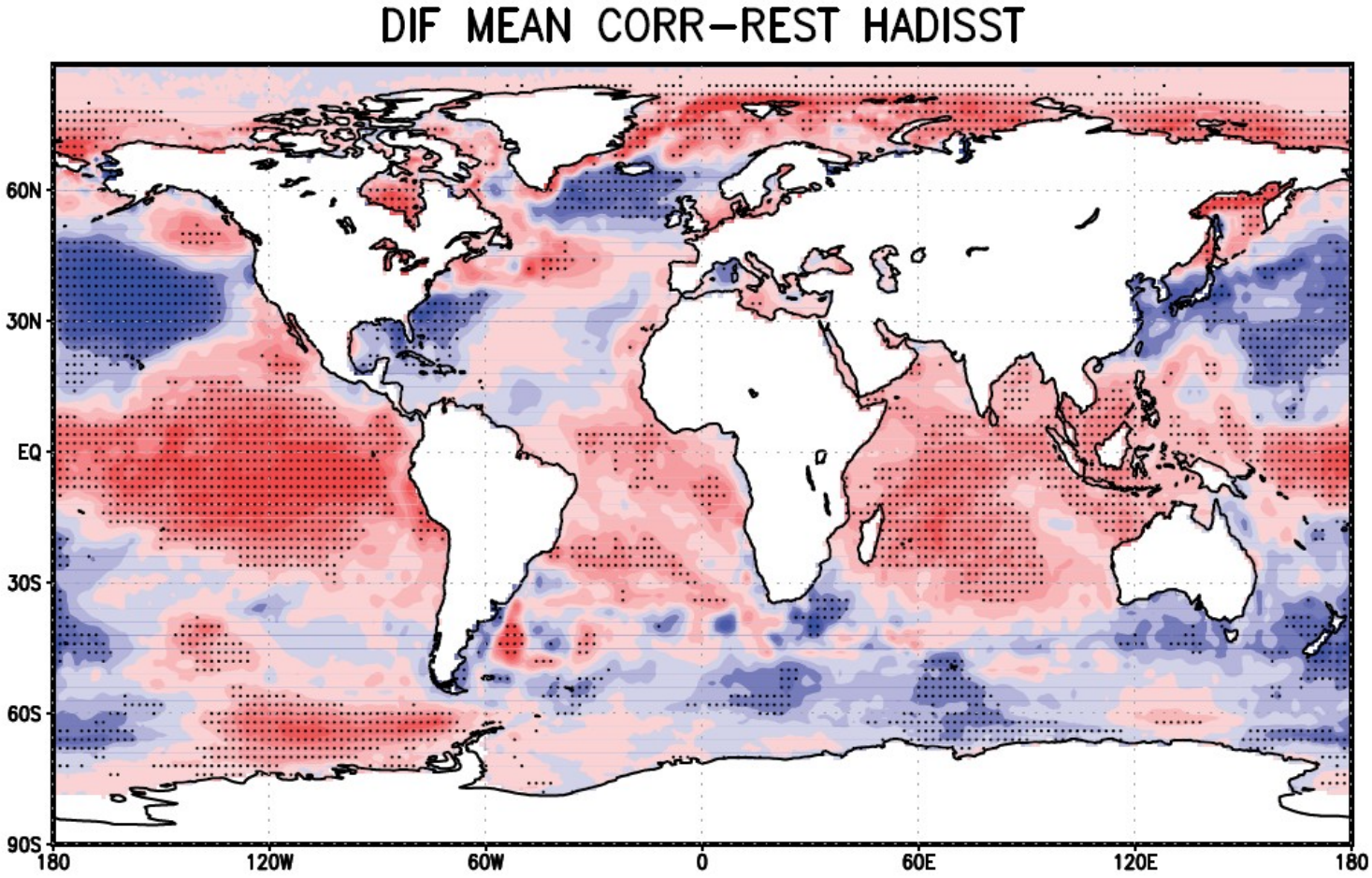


Martin del Rey et al (2015)

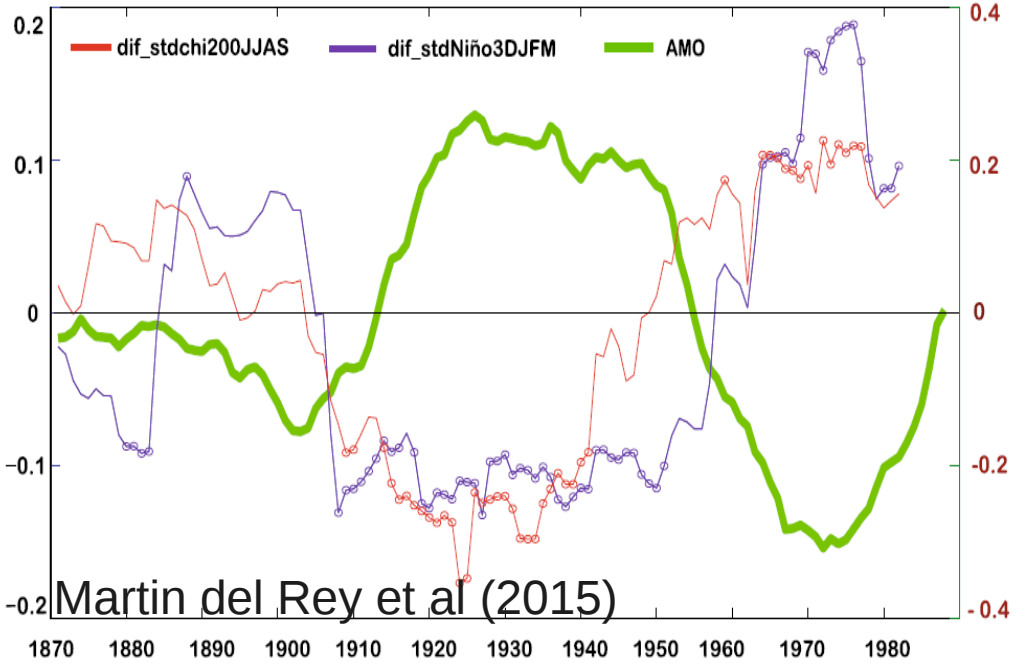
What about the background?

How is the ocean climatology during the periods in which the Atlantic-Pacific is active?

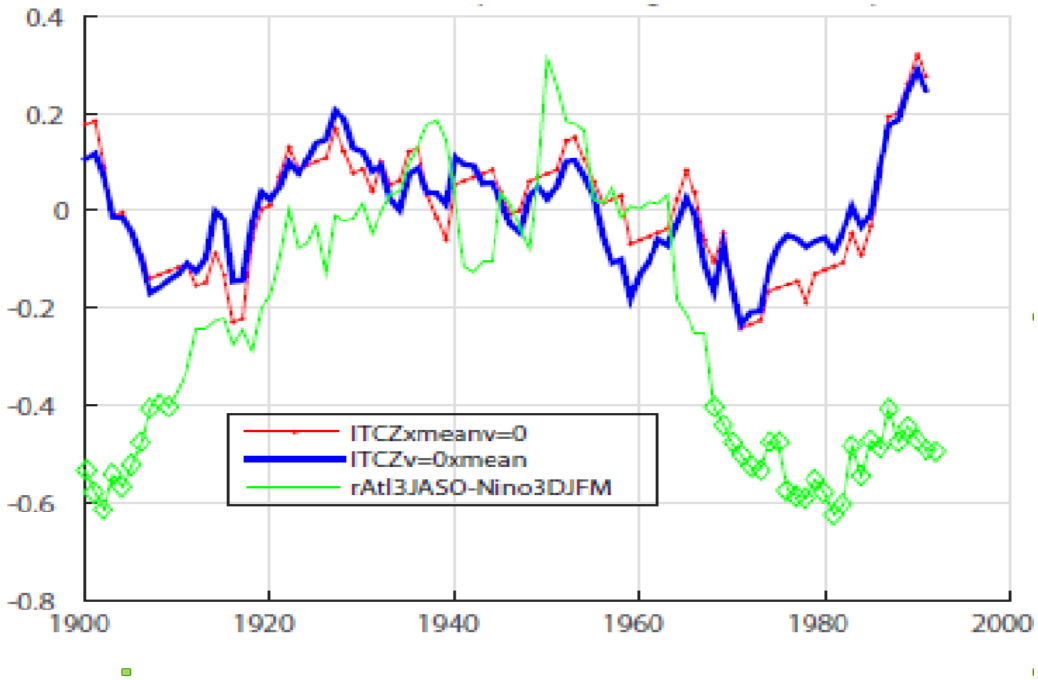
Difference beetween the anual mean SST during periods with Atl-Pac connection and periods without connection



The connection appears during warmer equatorial regions and southern tropics

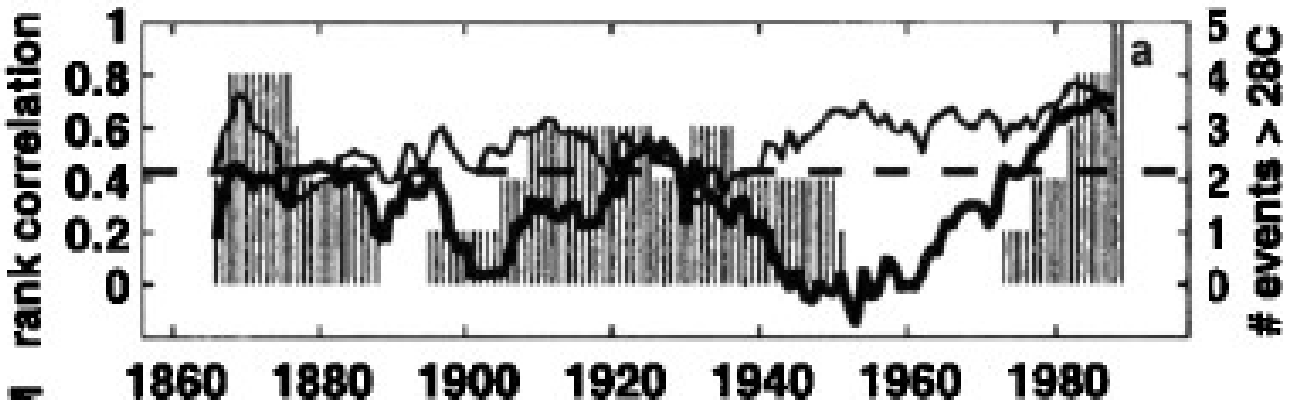


AMO (green), change in west Eq Atlantic 200 hPa velocity potential std (red),change in Niño3 std (blue)



Atl3-Niño3 evolution of correlation (green), change in the position of the ITCZ (red and blue)

The relationship takes place under a equatorward shift of the ITCZ



Multidecadal variability of ITCZ Chiang et al (2000)

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The interbasin connection can be explained by Equatorial Dynamics

But...

This connection does not hold on during the whole observational period

The connection appears during negative phases of the Atlantic Multidecadal Oscillation

a colder Northern Hemisphere? warmer tropics? → **ITCZ shift to the Equator** → **Enhancement of equatorial dynamics**

Hypothesis:

As the Atlantic Multidecadal Oscillation is a internal natural variability mode, this relation should be found in CMIP5 models in PI control simulations.

Multidecadal changes in the background with warmer tropics or souther ITCZ should have a stronger Atl-Pac connection

Questions

1 .Can we find the Atlantic -Pacific connection in CMIP5 models?
2. When does the Atlantic-Pacific connection take place?
3. What is the role of model bias?

Rodriguez-Fonseca et al., 2016 (to be submitted)

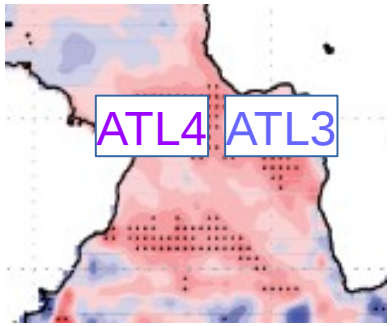
Data used

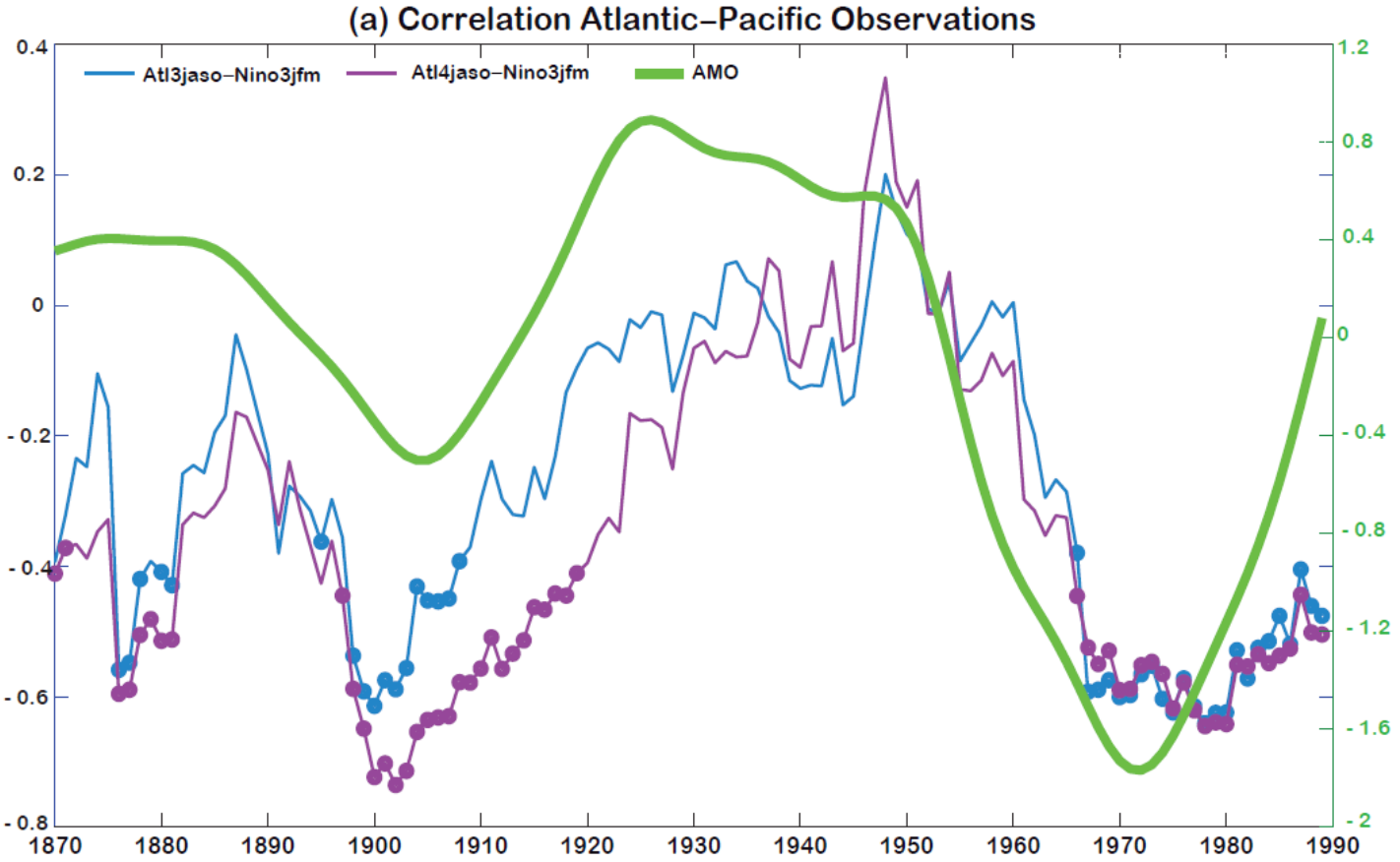
Modeling Center (or Group)	Institute ID	Model Name	Nyears/ Resolution
Canadian Centre for Climate Modelling and Analysis	CCCMA	CanESM2	996/128x64
National Center for Atmospheric Research	NCAR	CCSM4	501/288x192
Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	CNRM-CERFACS	CNRM-CM5	850/256 x 128
Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence	CSIRO-QCCCE	CSIRO-Mk3.6.0	500/192x96
NOAA Geophysical Fluid Dynamics Laboratory	NOAA GFDL	GFDL-ESM2G GFDL-ESM2M	500/ 500
NASA Goddard Institute for Space Studies	NASA GISS	GISS-E2-H GISS-E2-R	531/144x90 550/144x90
Met Office Hadley Centre	MOHC	HadGEM2-CC HadGEM2-ES	240/192x145 575/
Institute for Numerical Mathematics	INM	INM-CM4	500/180x120
Institut Pierre-Simon Laplace	IPSL	IPSL-CM5A-LR	1000/96x96
Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	MIROC	MIROC-ESM-CHEM	255/128x64
Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	MIROC	MIROC4h MIROC5	100/640x320 670/256x128
Max Planck Institute for Meteorology	MPI-M	MPI-ESM-LR	1000/192x96
Meteorological Research Institute	MRI	MRI-CGCM3	500/320x160
Norwegian Climate Centre	NCC	NorESM1-M	501/144x96
Met Office Hadley Centre	MOHC	OBS-HadISST	142/360x180

Table 1: Description of the CMIP5 models used in this work. 18 models

Rodriguez-Fonseca et al., 2016 (to be submitted)

2 indices: Atl3 and Atl4
21 window correlation between JJAS Atl3 (Atl4) and Niño3 DJFM

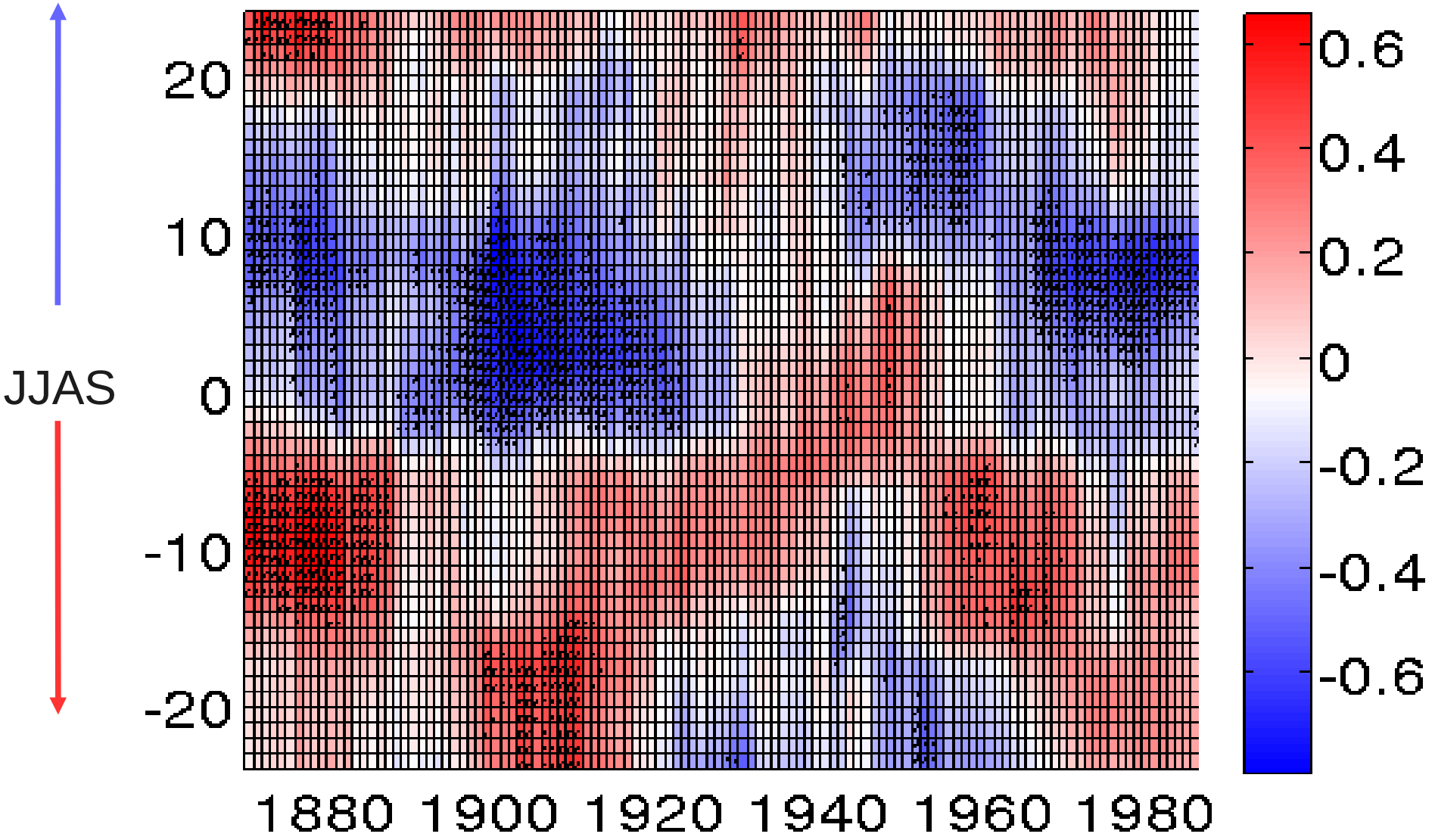




The connection is even clear for the sst in the western equatorial Atlantic

OBSERVATIONS

Lead-lag 21 window correlation between JJAS Atl3 (Atl4) and Niño3 DJFM

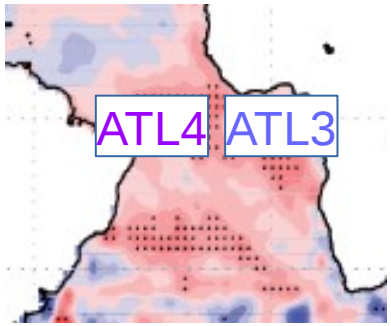


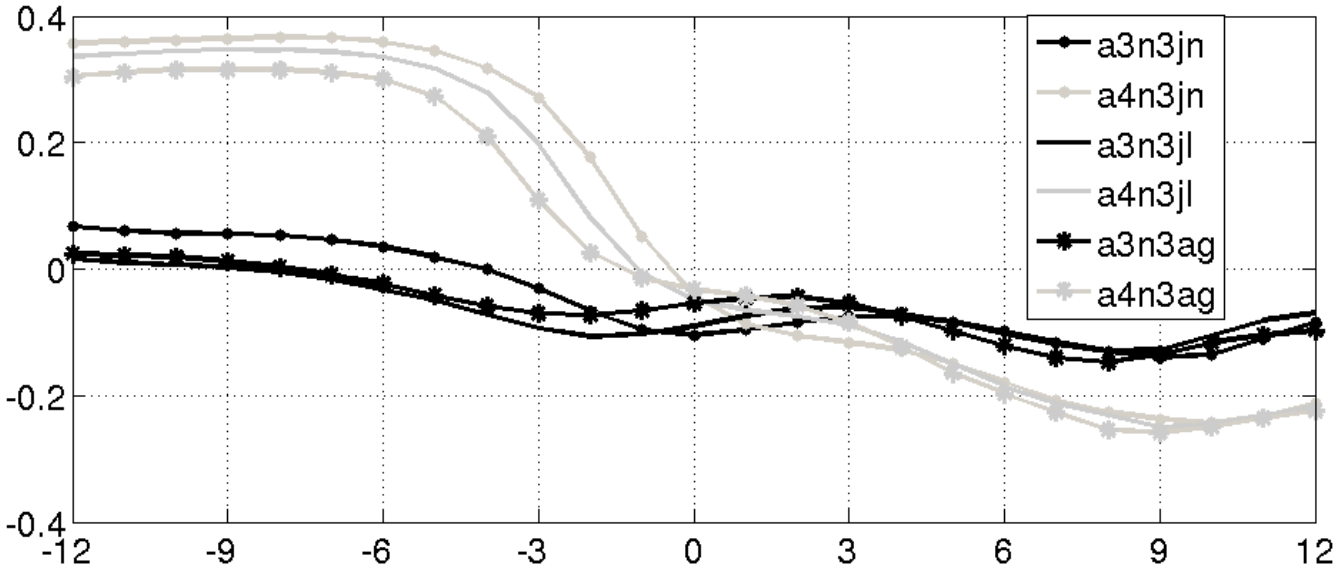
Rodriguez-Fonseca et al., 2016 (to be submitted)

Niño 3 leading

Atl 4 leading

21 window correlation between Junne, July and AugustAtl3 (Atl4) and Niño3 in different lags

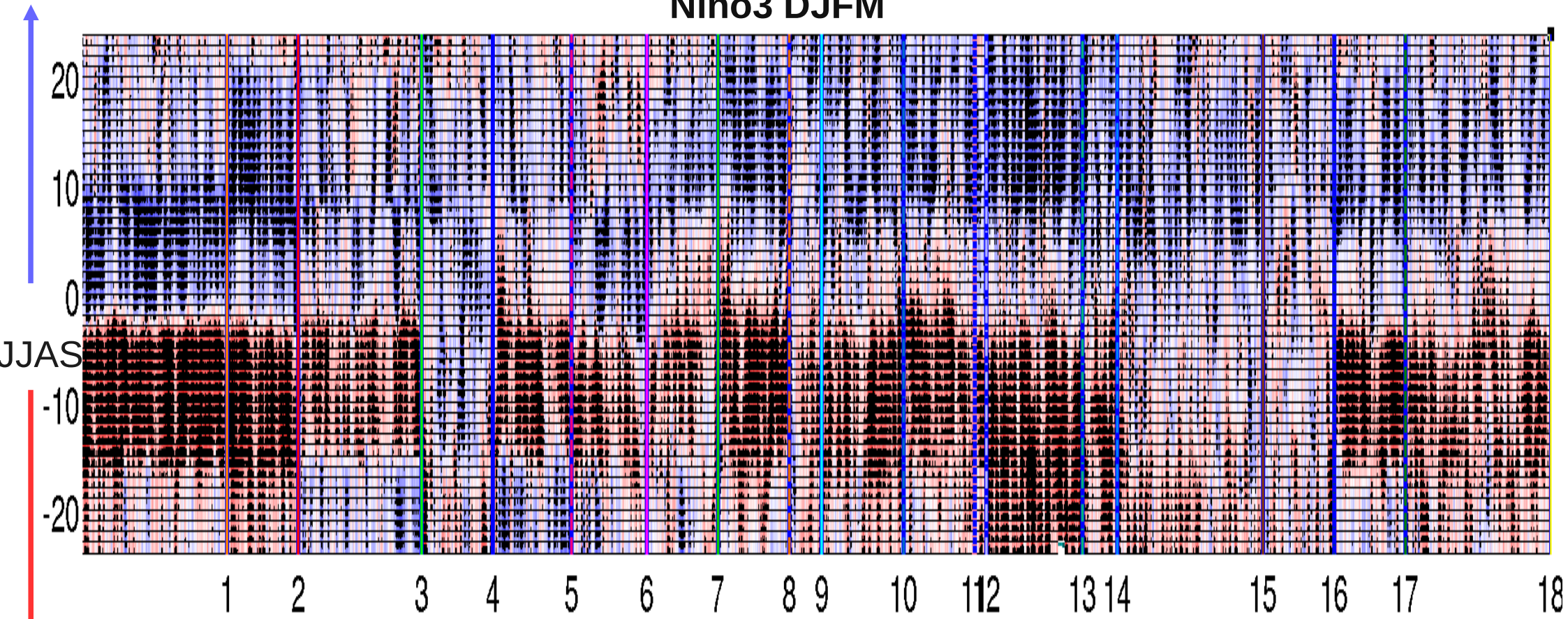




CMIP5 models: The connection is even clear for the sst in the western equatorial Atlantic (ATL4)

Rodriguez-Fonseca et al., 2016 (to be submitted)

CMIP5 modesl: Lead-lag 21 window correlation between JJAS Atl4 and Niño3 DJFM



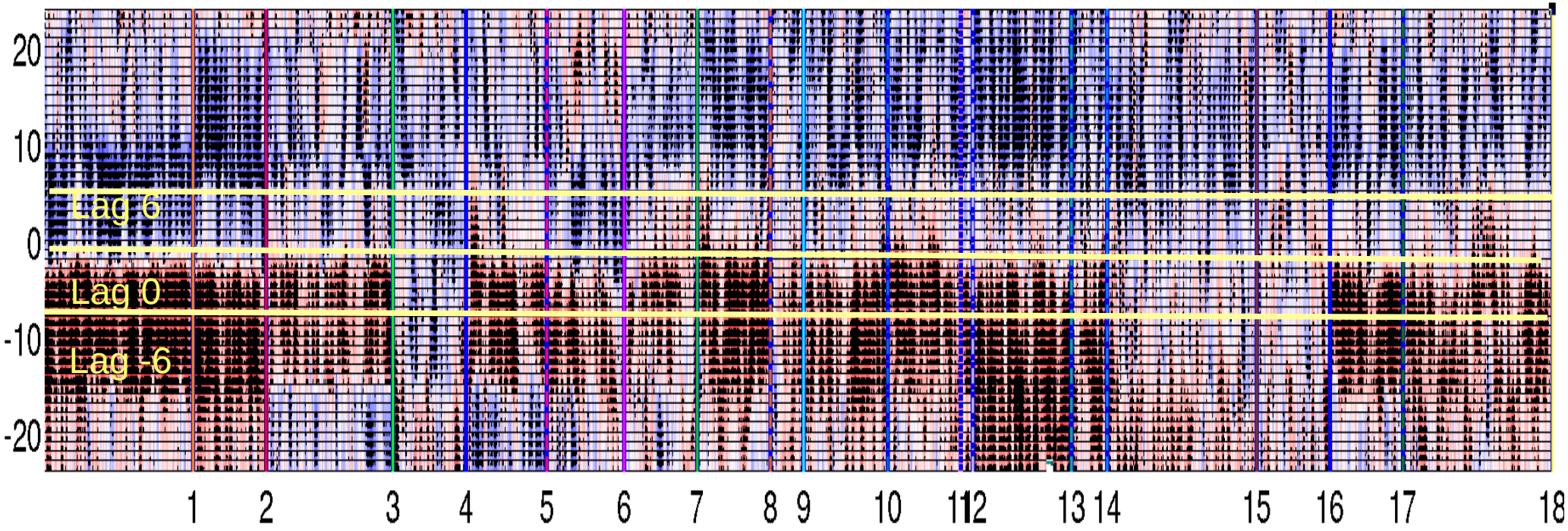
1 CanESM2
2 CCSM4
3 CNRM-CM5
4 CSIRO-Mk3
5 GISS-E2-R
6 GISS-E2-H
7 GFDL-ESM2G
8 GFDL-ESM2M
9 HadGEM2-CC
10 HadGEM2-ES
11 inmcm4
12 MIROC4h
13 MIROC5
14 MIROC-ESM
15 MPI-ESM
16 MRI-CGCM3
17 NorESM1
18 IPSL-CM5

Niño 3 leading

Rodriguez-Fonseca et al., 2016 (to be submitted)

Atl 4 leading

2. How is the Atlantic-Pacific connection in CMIP5 models?



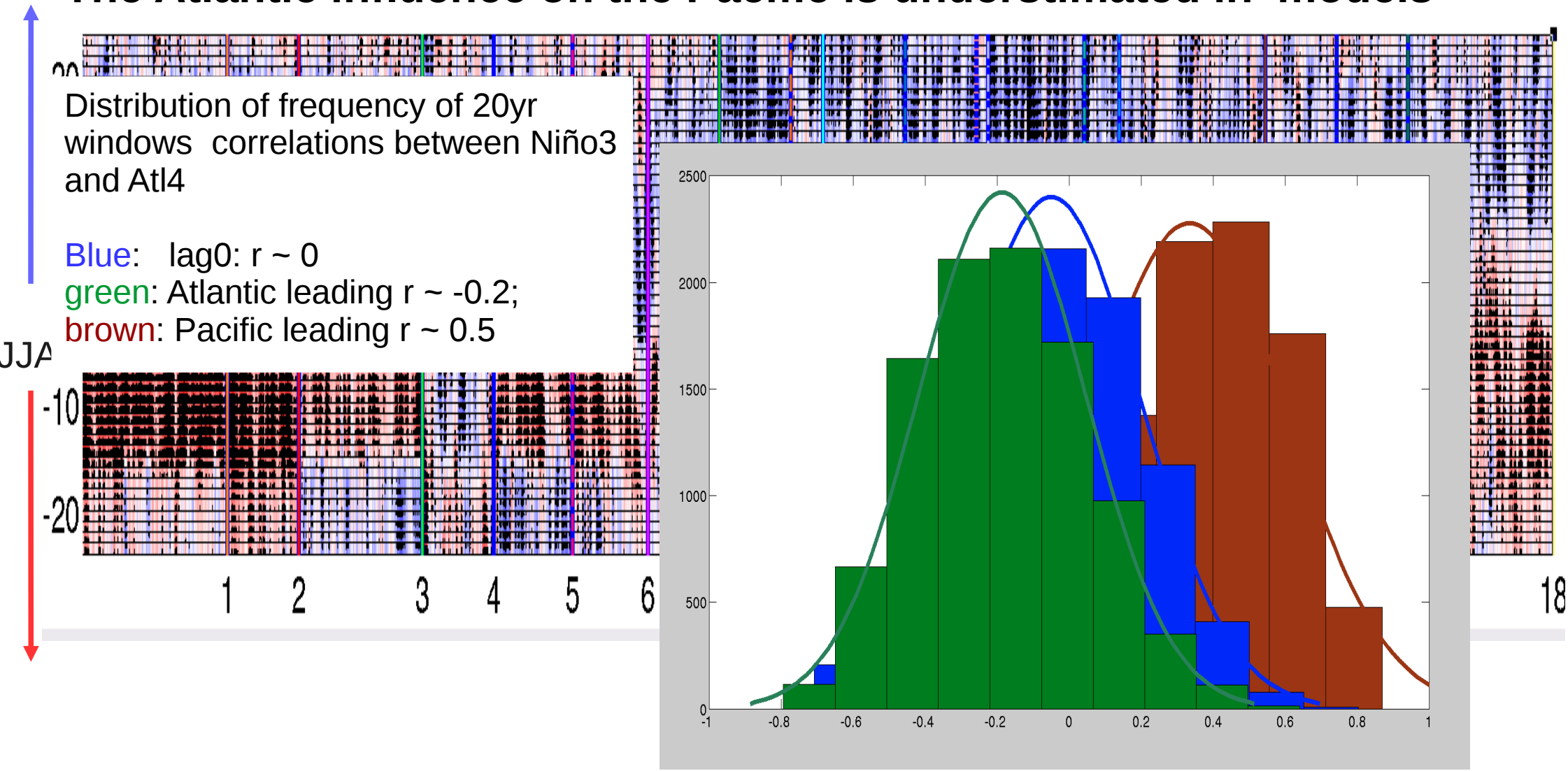
We calculate
Distribution of frequencies for correlations at different lags

Rodriguez-Fonseca et al., 2016 (to be submitted)

The Pacific influence on the Atlantic is overstimated in models.
The Atlantic influence on the Pacific is understimated in models

Distribution of frequency of 20yr windows correlations between Niño3 and Atl4

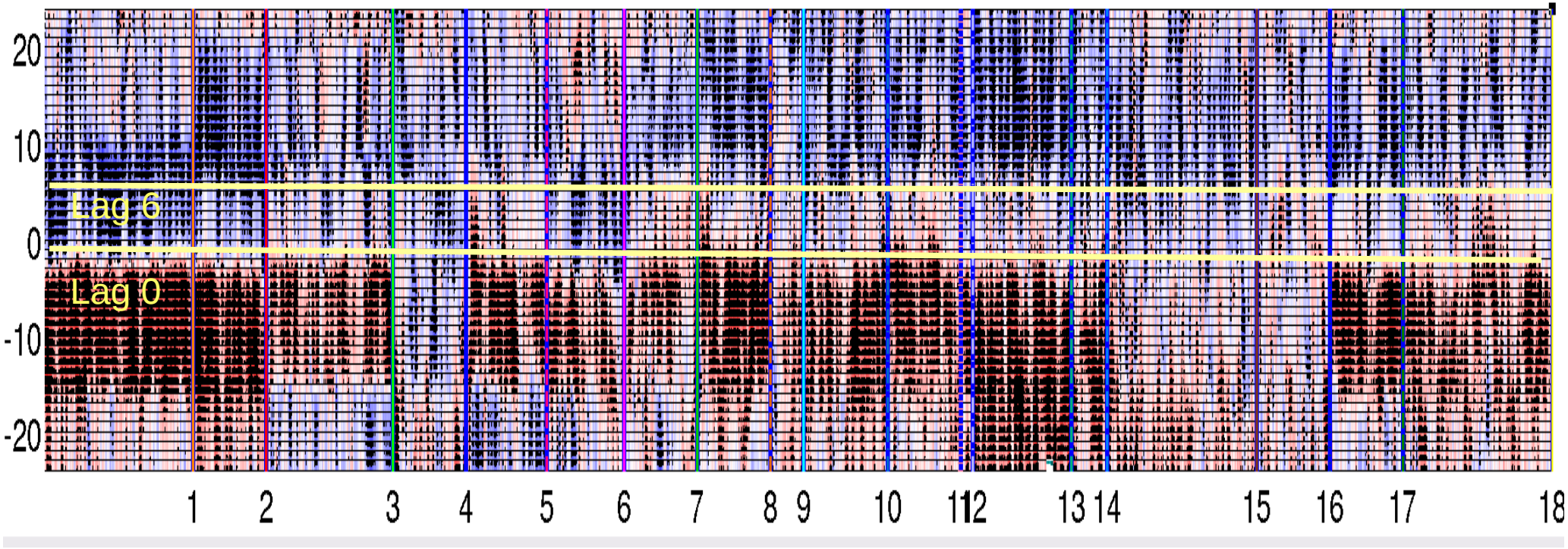
Blue: lag0: r ~ 0
green: Atlantic leading r ~ -0.2;
brown: Pacific leading r ~ 0.5



Niño 3 leading

Atl 3 leading

2. When does the Atlantic-Pacific connection take place?



We calculate

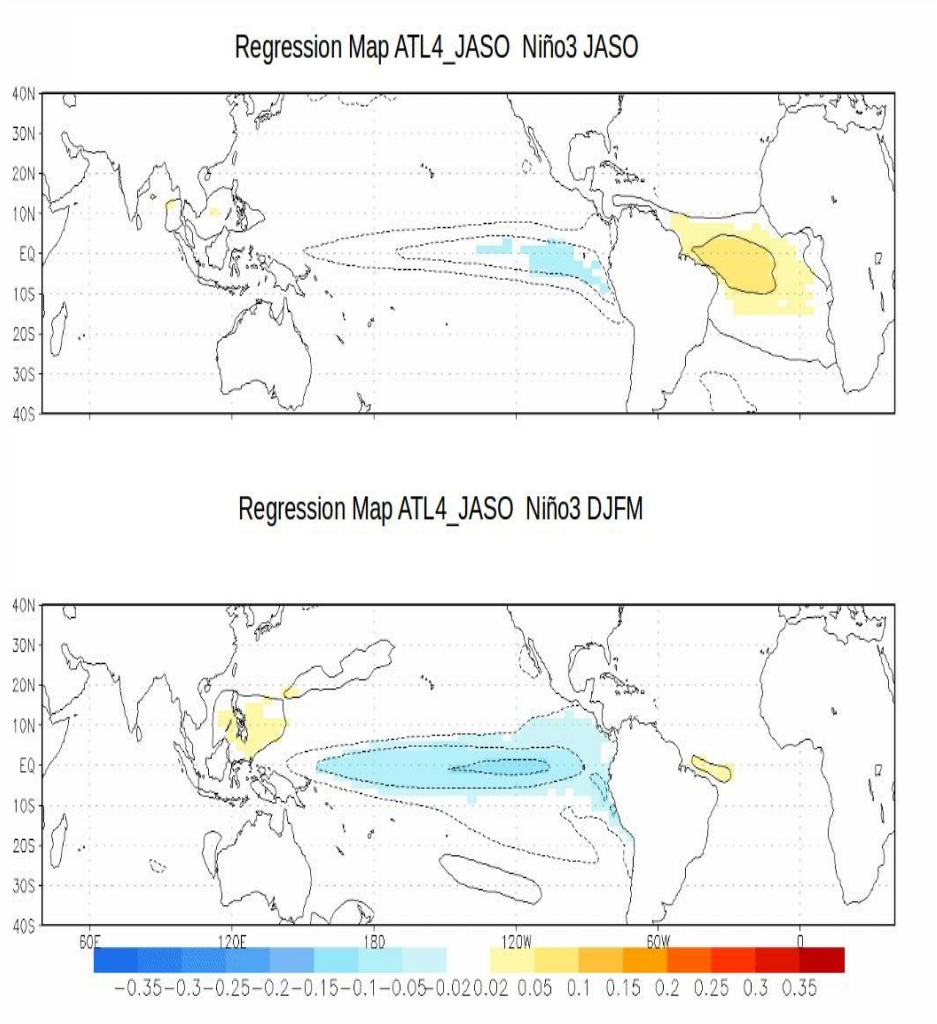
Composites for all significant 20-yr windows

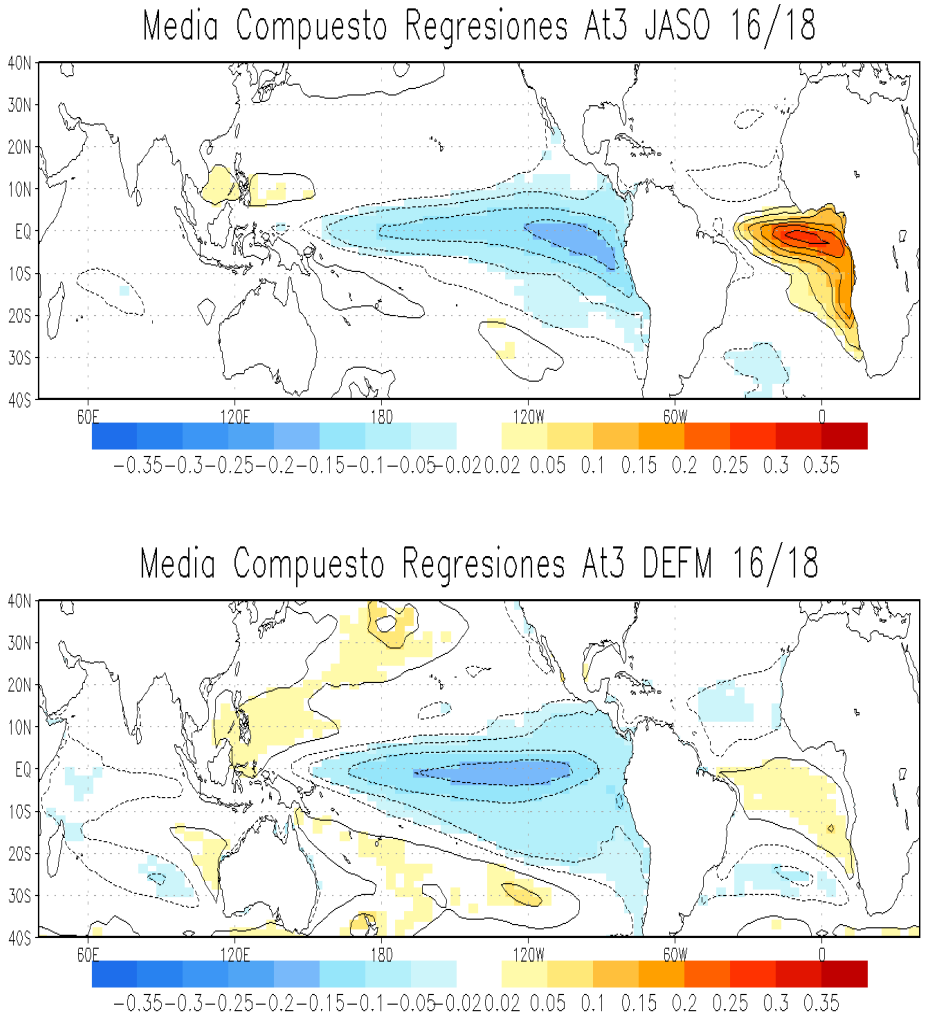
a) of the Atl4 global SST projection==> **interanual ensemble signal**

b) of the annual SST mean when there is significant relation in lag 0 and lag -6 minus the anual SST mean when there is no relation ==>**Decadal ensemble signal**

Rodriguez-Fonseca et al., 2016 (to be submitted)

Interannual signal:
Composites for all significant 20-yr windows of the Atl4 global SST projection. Ensemble

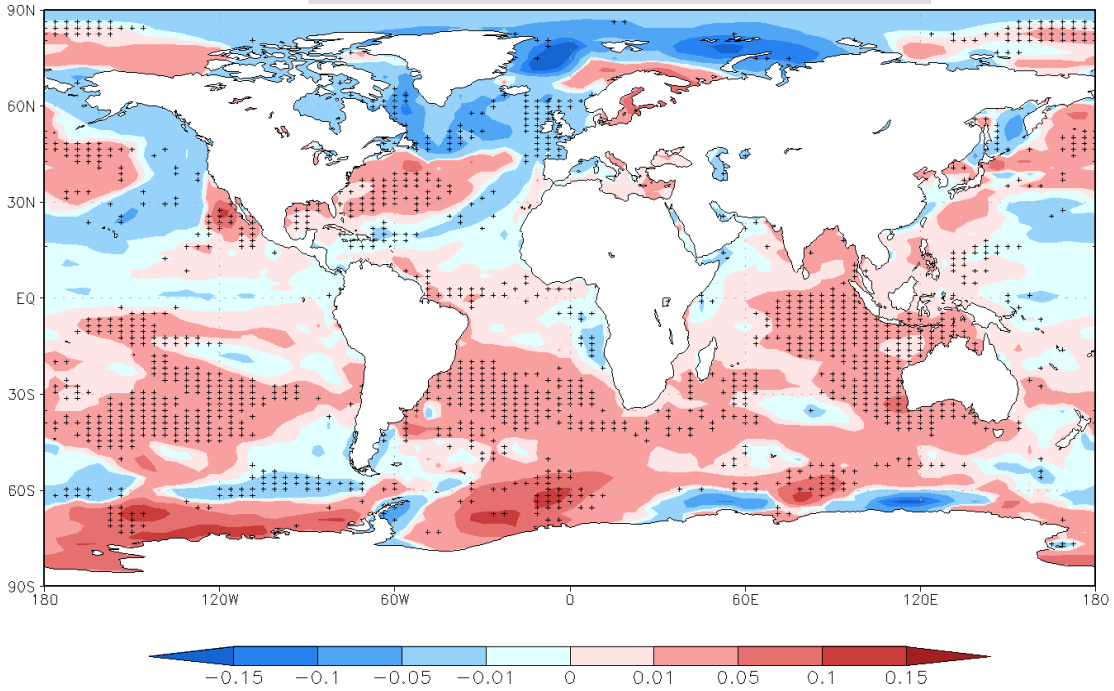




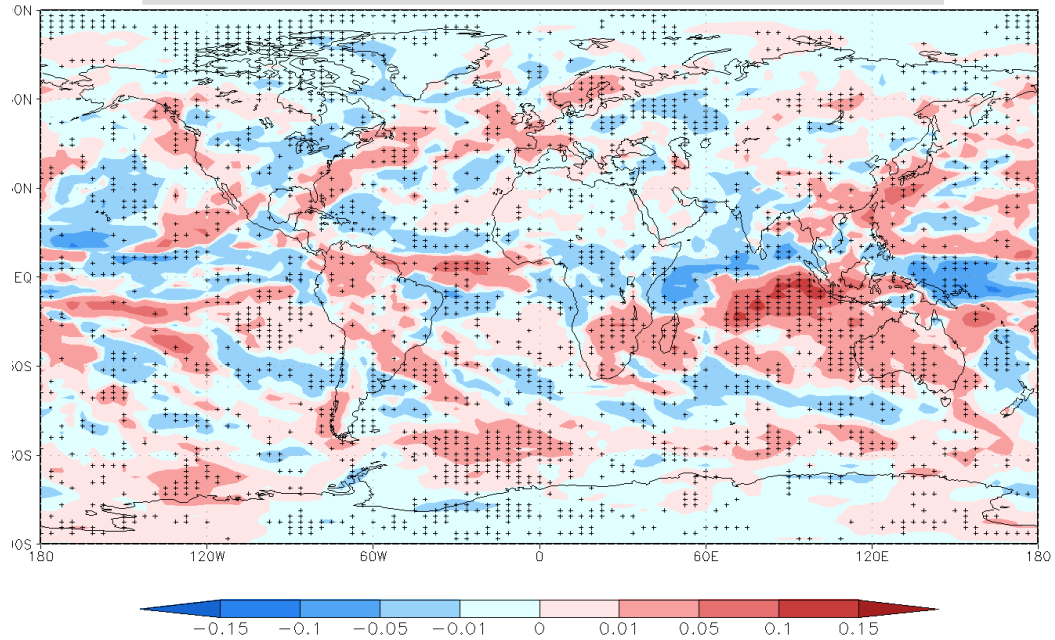
Rodriguez-Fonseca et al., 2016 (to be submitted)

Mean Anomalous background under which the Atlantic-Pacific takes place

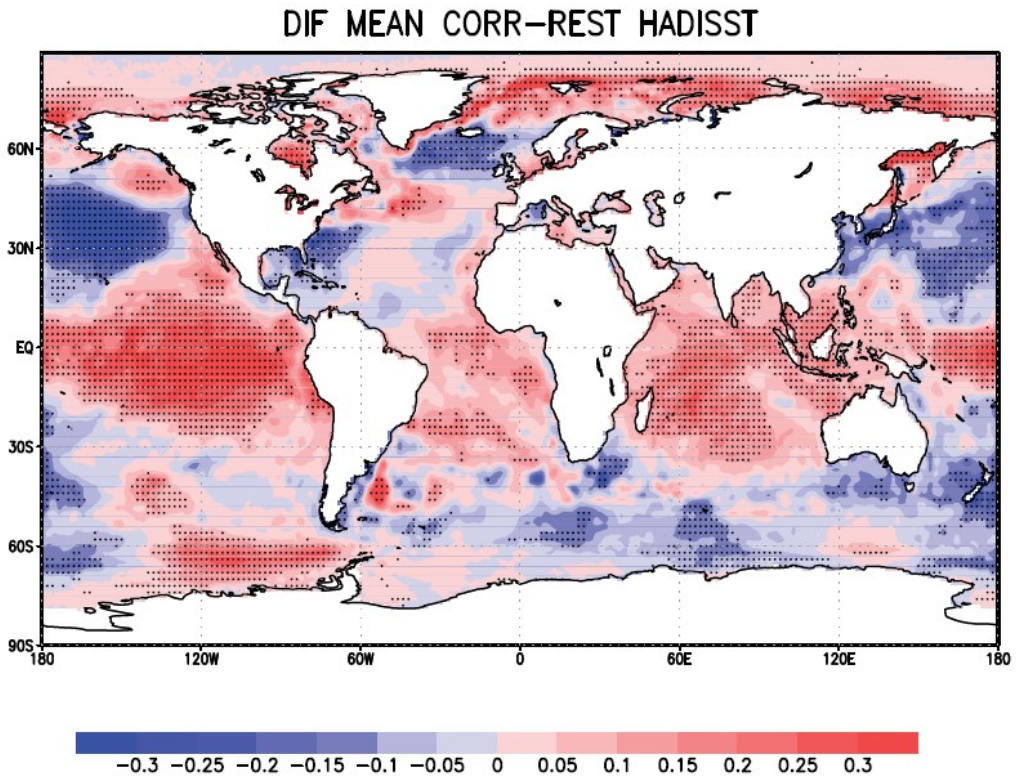
SST

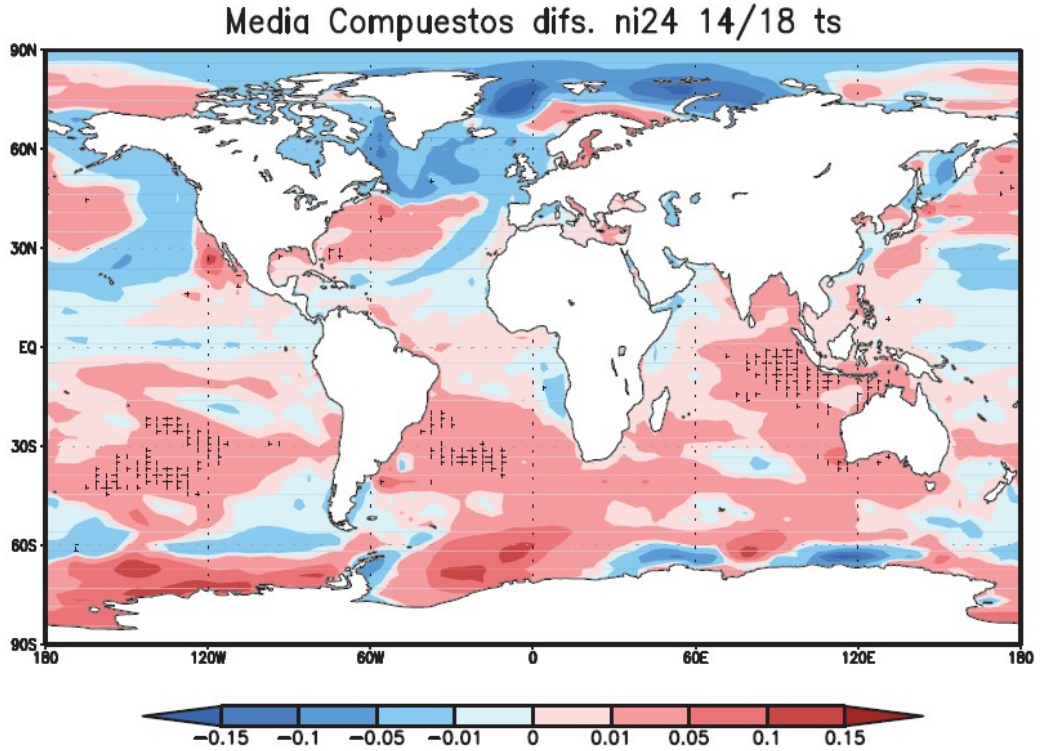


rainfall



Warmer Southern ocean, warmer Indian ocean,
southward Atlantic and Indian ITCZ, lower pressure in Indian ocean, NAO+





Comparison with observations...

When does the Atlantic-Pacific takes place?

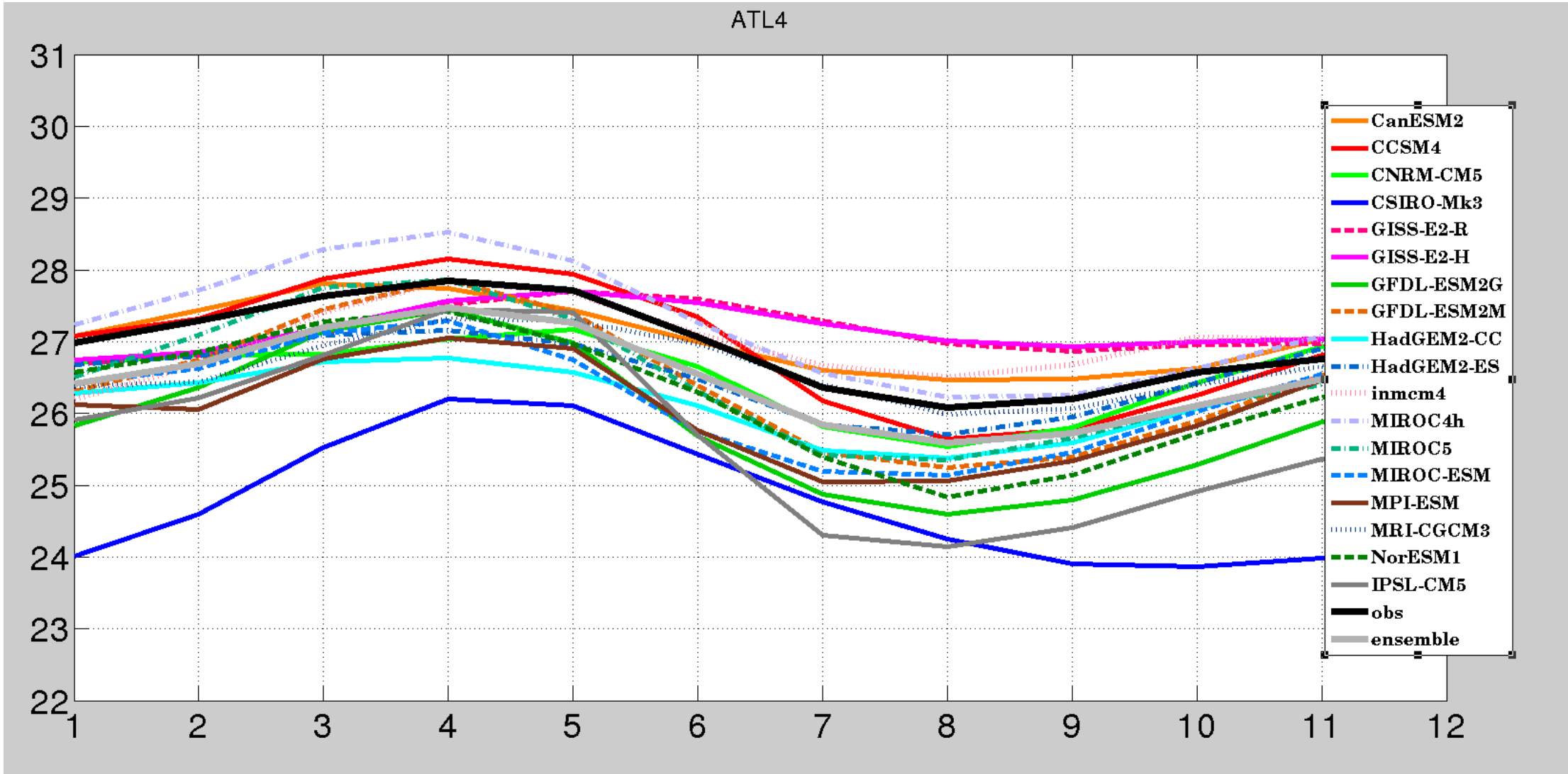
It takes place under warmer conditions in the tropics and the southern Ocean, under a southward Atlantic and Indian ITCZ shift.

Rodriguez-Fonseca et al., 2016 (to be submitted)

What is the role of model bias?

How does model bias influence in the modulation of the Atlantic-Pacific connection performed by each model?

Bias


ATL4
31
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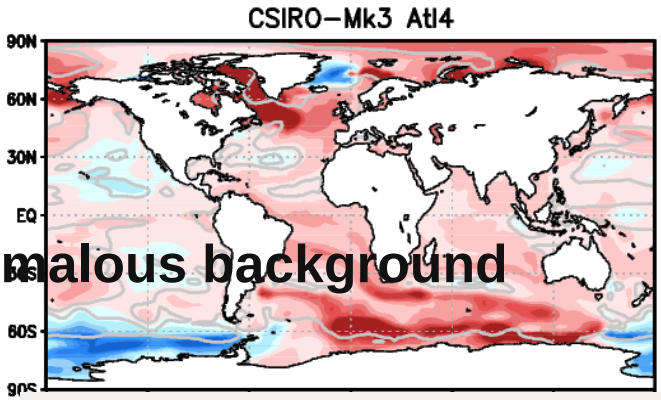
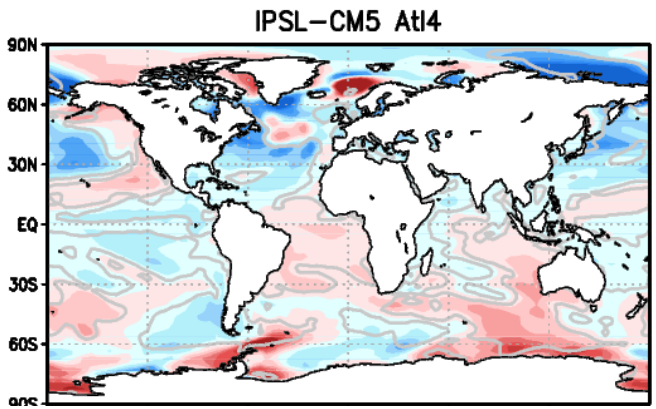
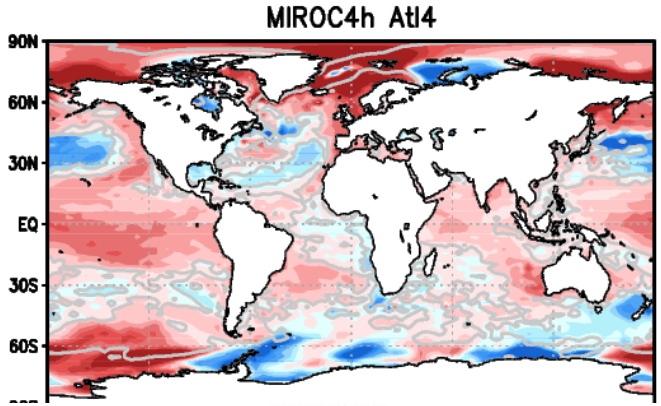
10
11
12
CanESM2
CCSM4
CNRM-CM5
CSIRO-Mk3
GISS-E2-R
GISS-E2-H
GFDL-ESM2G
GFDL-ESM2M
HadGEM2-CC
HadGEM2-ES
inmcm4
MIROC4h
MIROC5
MIROC-ESM
MPI-ESM
MRI-CGCM3
NorESM1
IPSL-CM5
obs
ensemble

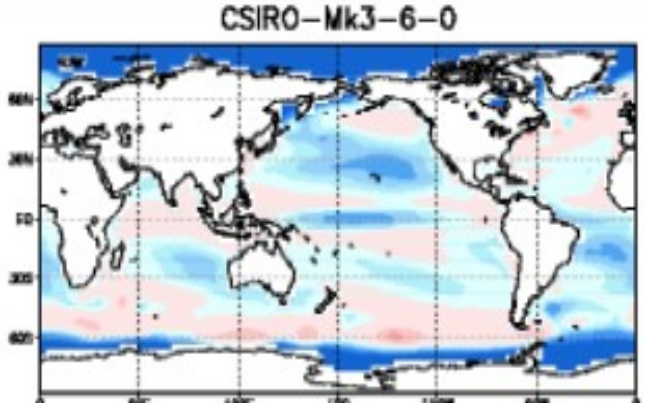
Anomalous background

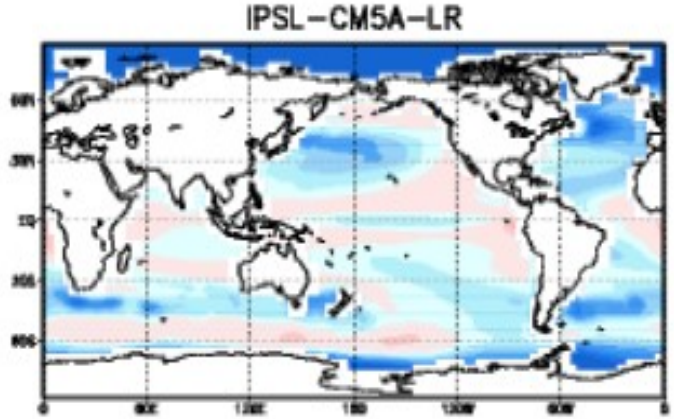
bias

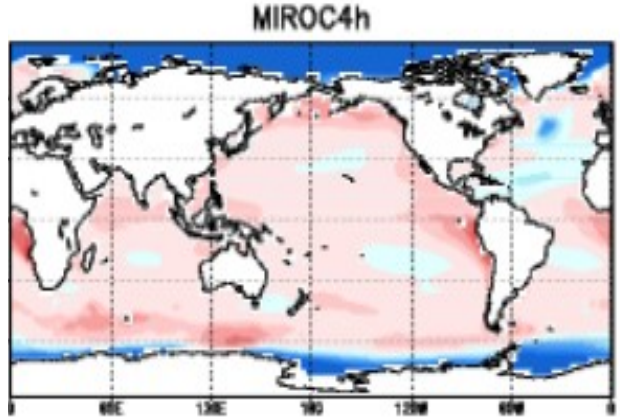


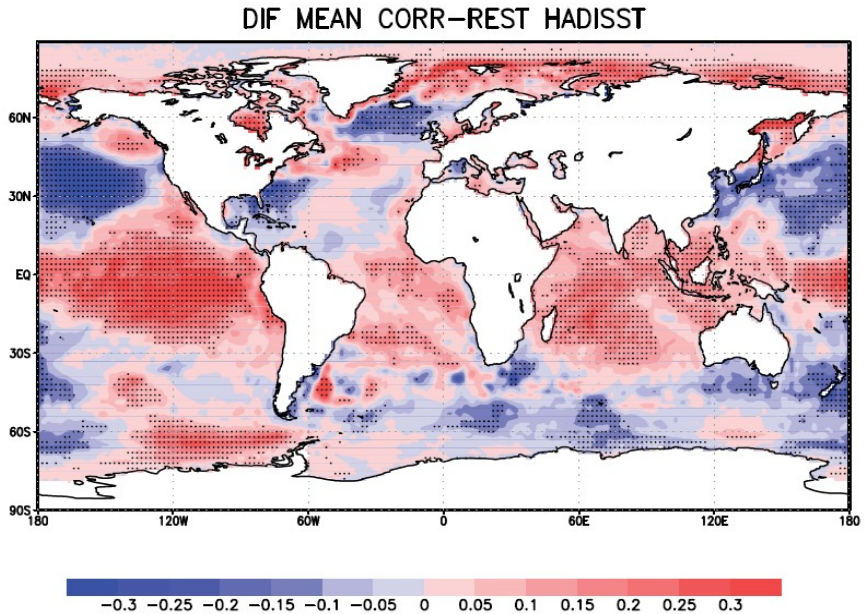


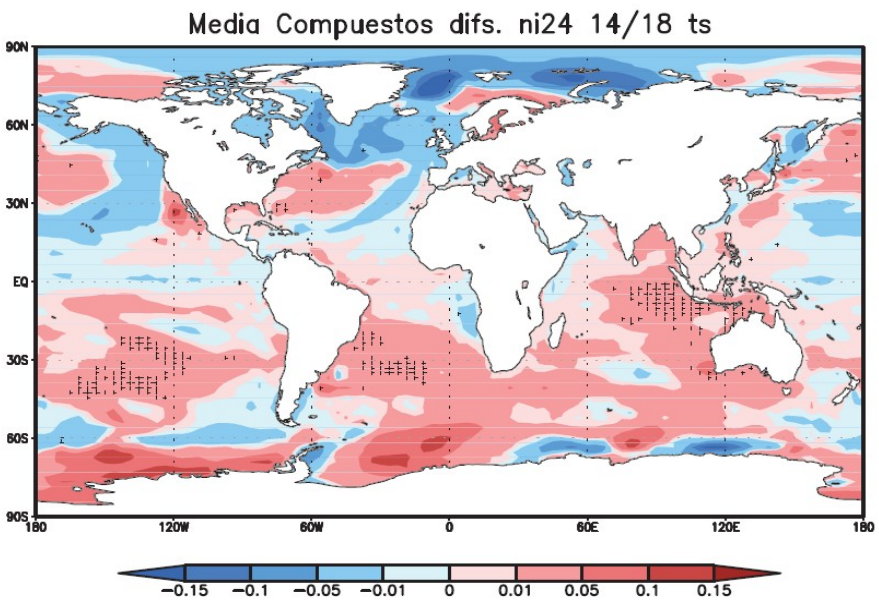




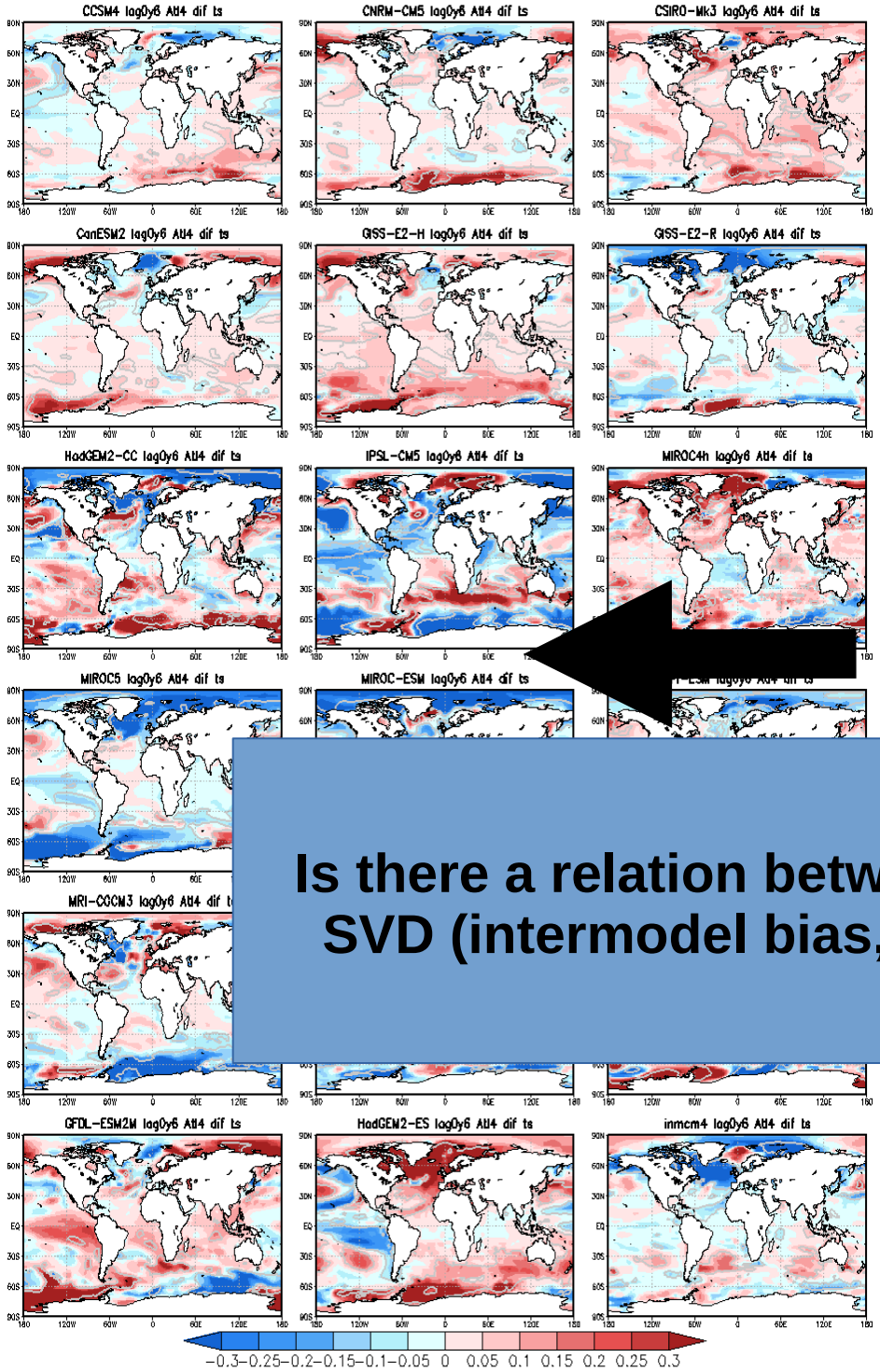




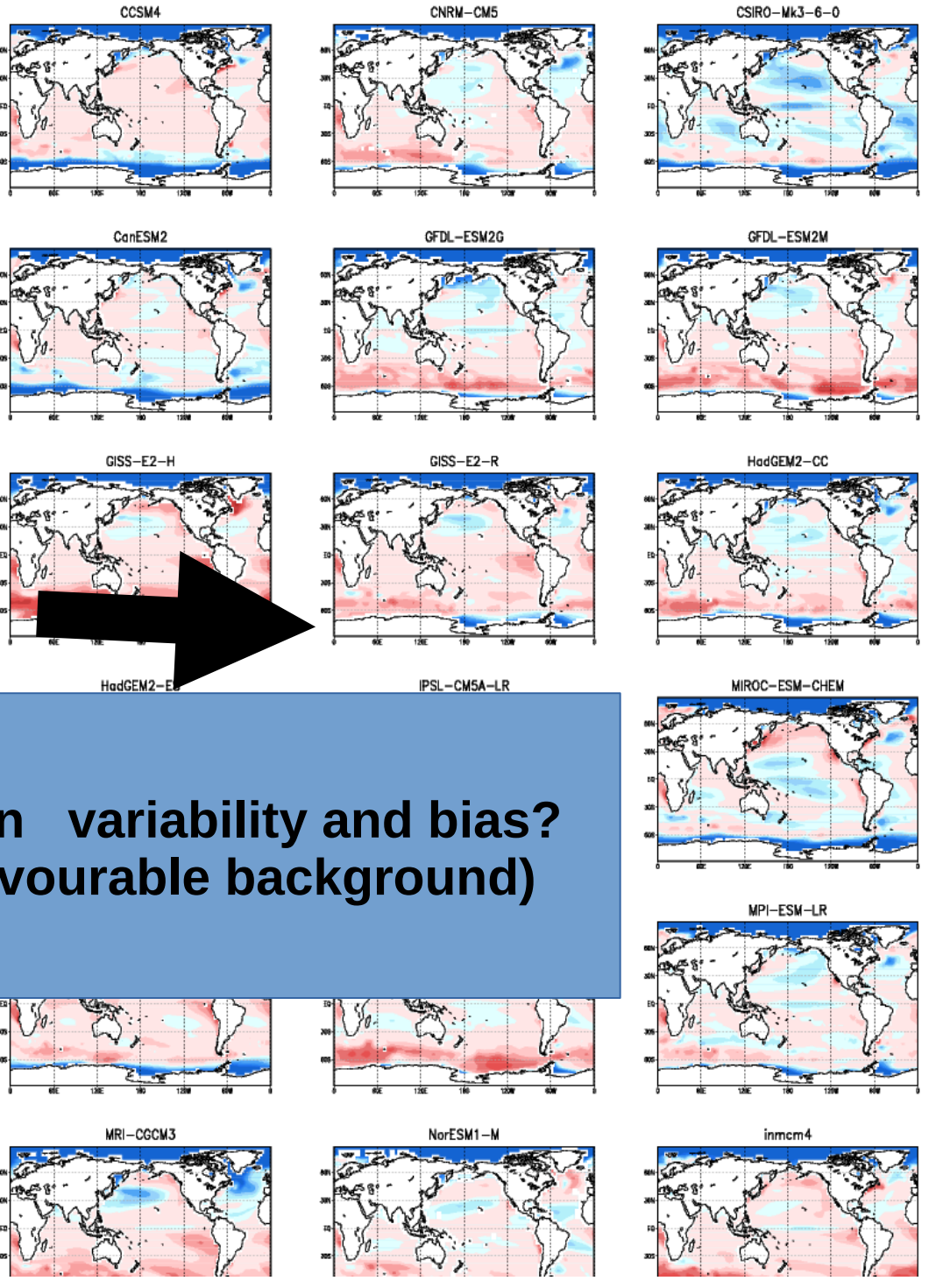




Background in Atl-Pac connected periods

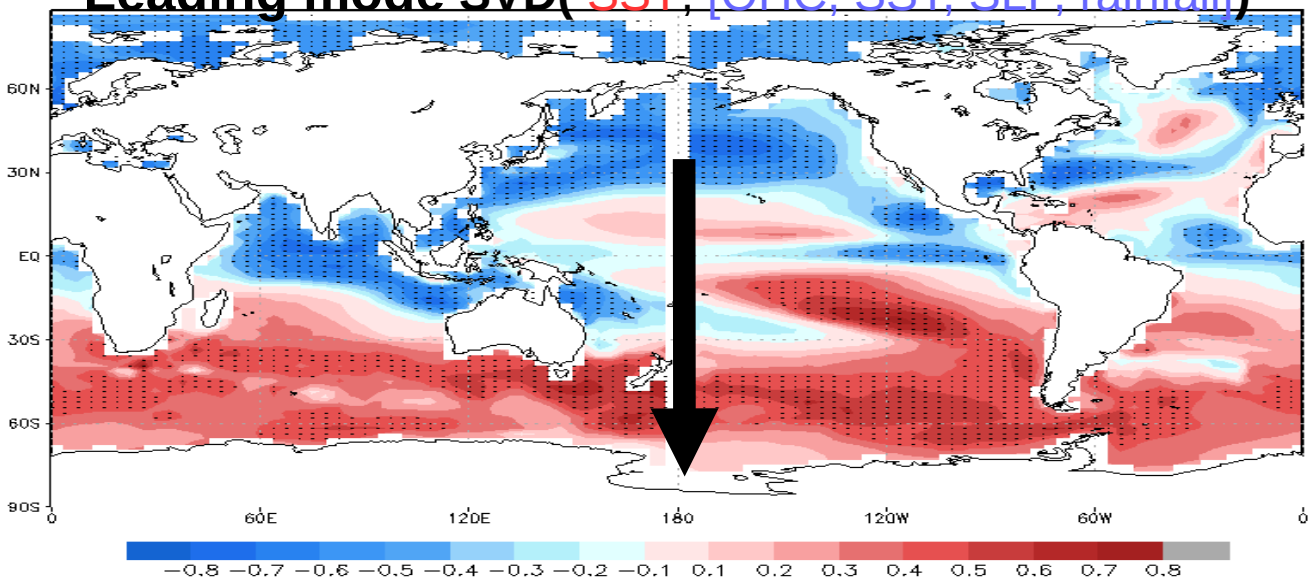


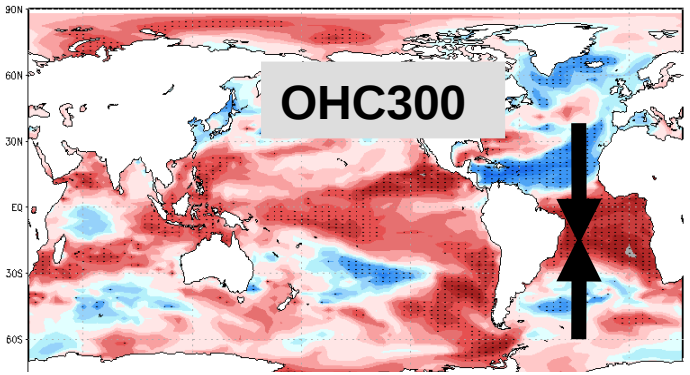
Bias

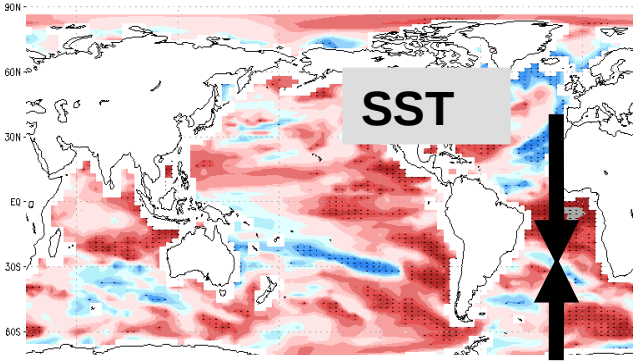


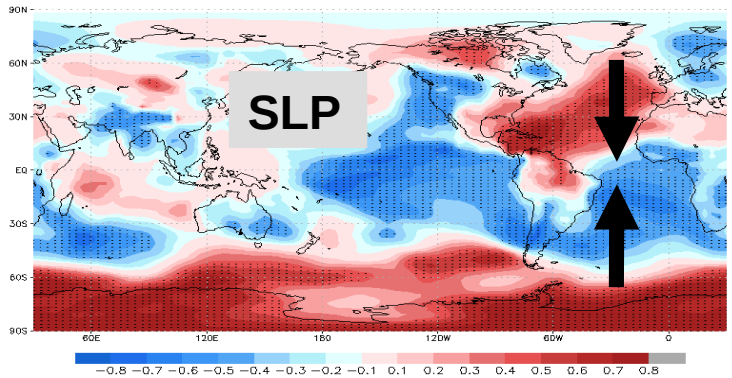
Is there a relation between variability and bias?
SVD (intermodel bias, favourable background)

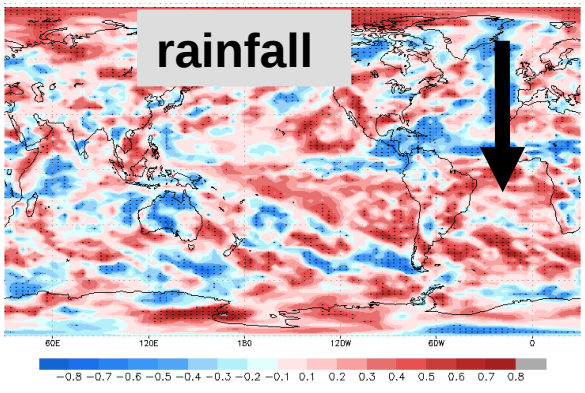
Leading mode SVD(SST, [OHC, SST, SLP, rainfall])

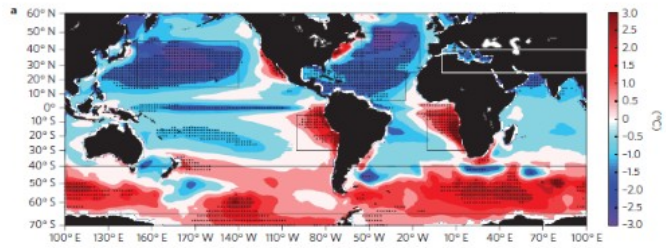




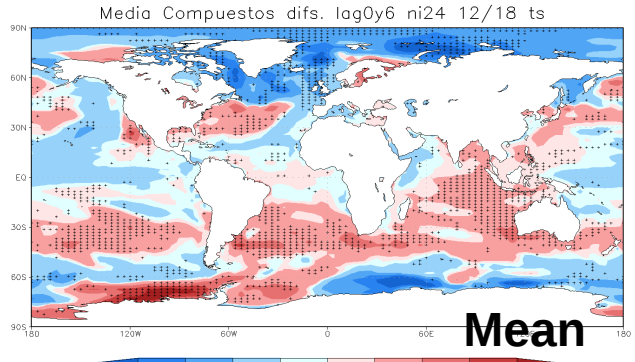








Mean bias



Mean background

Models with warmer bias in the south Pacific and colder in Eq Atlantic and Maritime continent, tend to warm up the south Atlantic by anomalous interhemispheric gradient in the SST and OHC, displacing the ITCZ to the south.

Rodriguez-Fonseca et al., 2016 (to be submitted)

Can we find the Atlantic -Pacific connection in CMIP5 models?

Yes, it takes place in both directions Atlantic influence on Pacific and vice-versa

Comparing with observations:

- **The Pacific influence on the Atlantic is overstimated in models.**
- **The Atlantic influence on the Pacific is understimated in models**

When does the Atlantic-Pacific takes place?

It takes place under warmer conditions in the tropics and the southern Ocean, under a southward Atlantic and Indian ITCZ shift. May be related with AMOC?

What is the role of model bias?

Models with warmer bias in the south Pacific and colder in Atlantic and Maritime continent, tend to warm up the south Atlantic by anomalous interhemispheric gradient in the SST and OHC, displacing the ITCZ to the south.

Thank you very much

All suggestions are wellcome!!!

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Rodríguez-Fonseca B., T. Losada, E. Mohino, S. Janicot, M. Joly, A. Voldoire, B. Fontaine, I. Polo, J. García-Serrano, J. Bader, C. Caminade, F. Chauvin, P. Ruti, S. Gervois and P. Roucou (2011) Interannual and decadal SST forced responses of the West African Monsoon. Atmos. Sci. Lett., 12, 67-74, doi:10.1002/asl.308.

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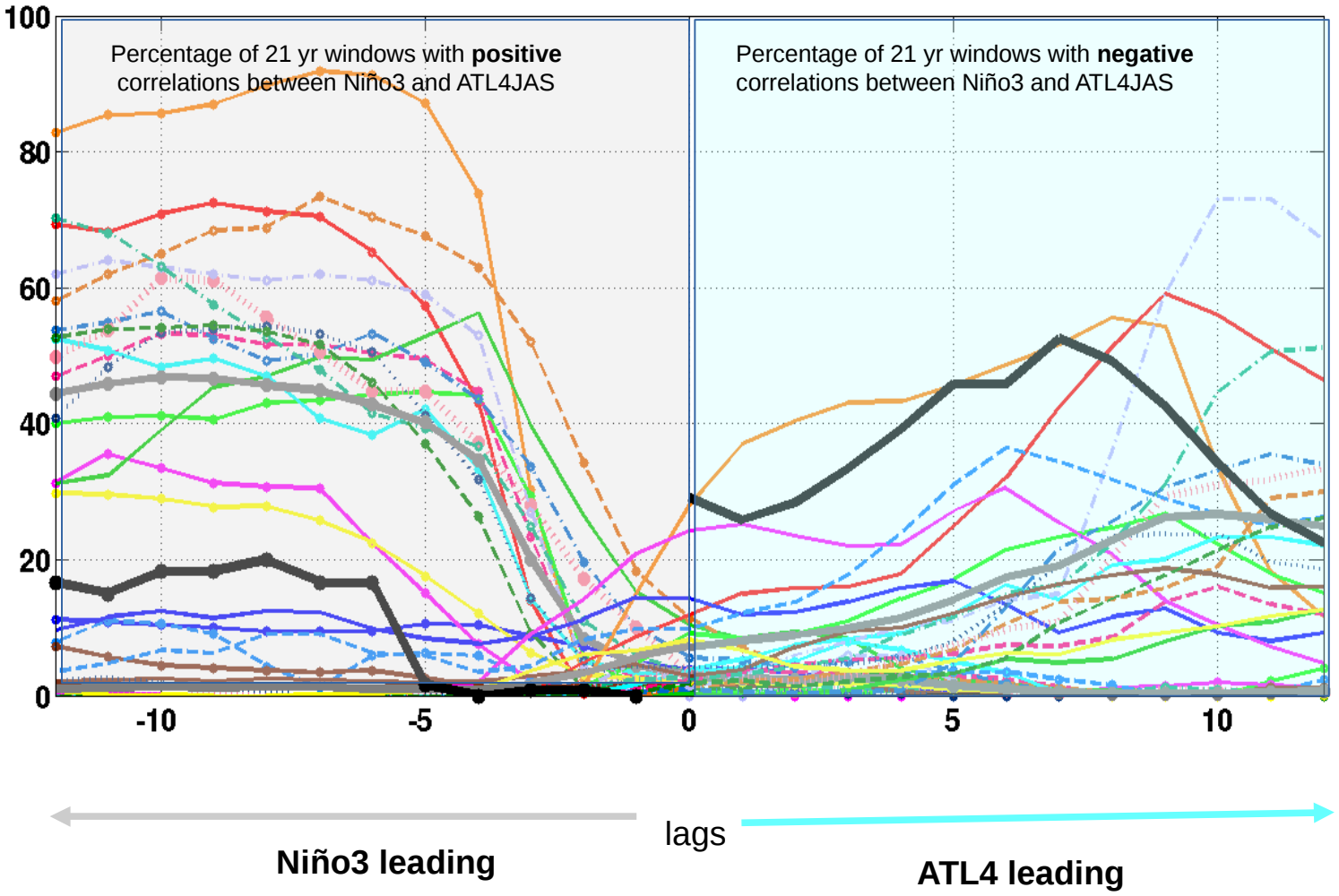


Significant Correlations: Atlantic leading less frequent than in observations
Pacific leading more frequent than in observations

Rodriguez-Fonseca et al., 2016 (to be submitted)

Wang et al, 2014: A simulated weak AMOC is associated with cold biases in the entire Northern Hemisphere with an atmospheric pattern that resembles the Northern Hemisphere annular mode. The AMOC weakening is also associated with a strengthening of Antarctic BottomWater formation and warm SST biases in the Southern Ocean

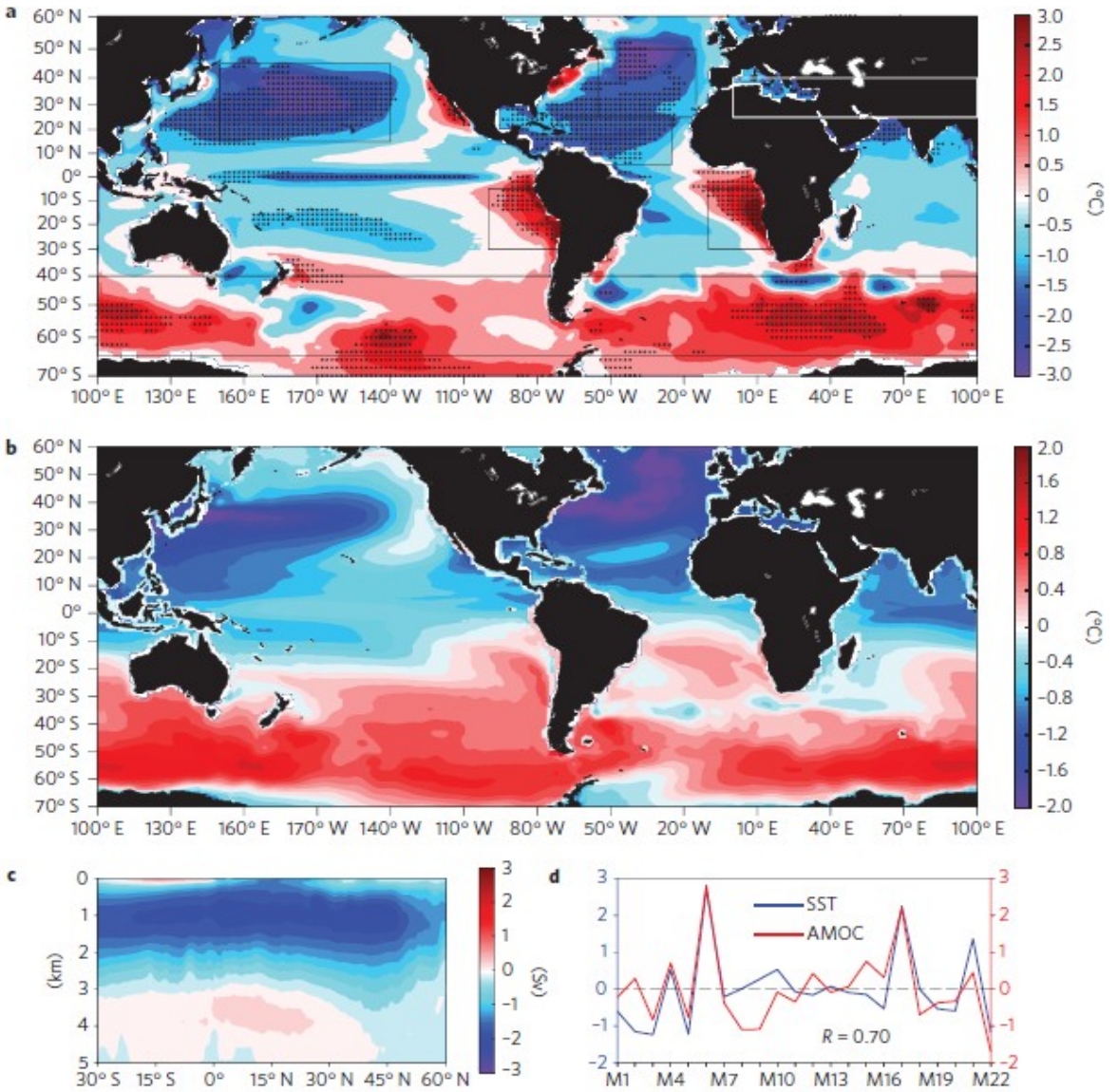
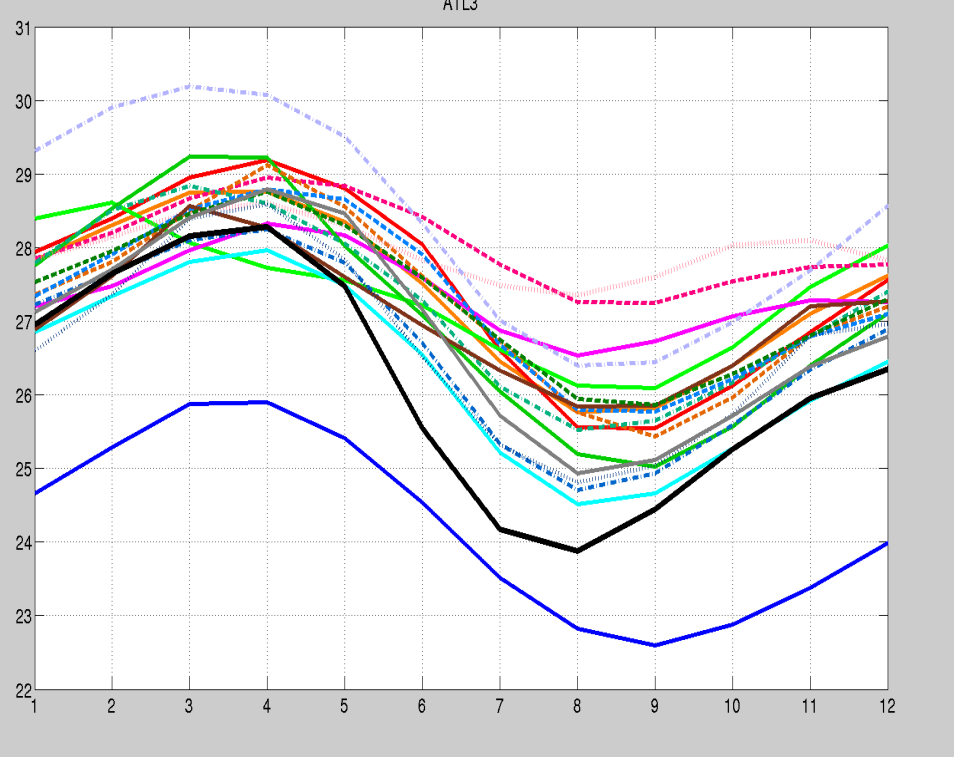


Figure 1 | Global SST bias and its relationship with the AMOC. a, The annual-mean SST bias averaged in 22 climate models. The SST bias is calculated by the SST difference between the model SST and extended reconstructed SST. The dots denote where at least 18 of 22 models (82%) have the same sign in the SST bias. The rectangles represent the focused regions. **b**,**c**, Spatial maps of SST bias and the AMOC for the first inter-model SVD mode (accounting for 45% of total covariance). **d**, Their corresponding coefficients. The *x* axis in **d** represents different models (Supplementary Table 1). The coefficients have been normalized by their own standard deviations.


ATL3
31
30
29
28
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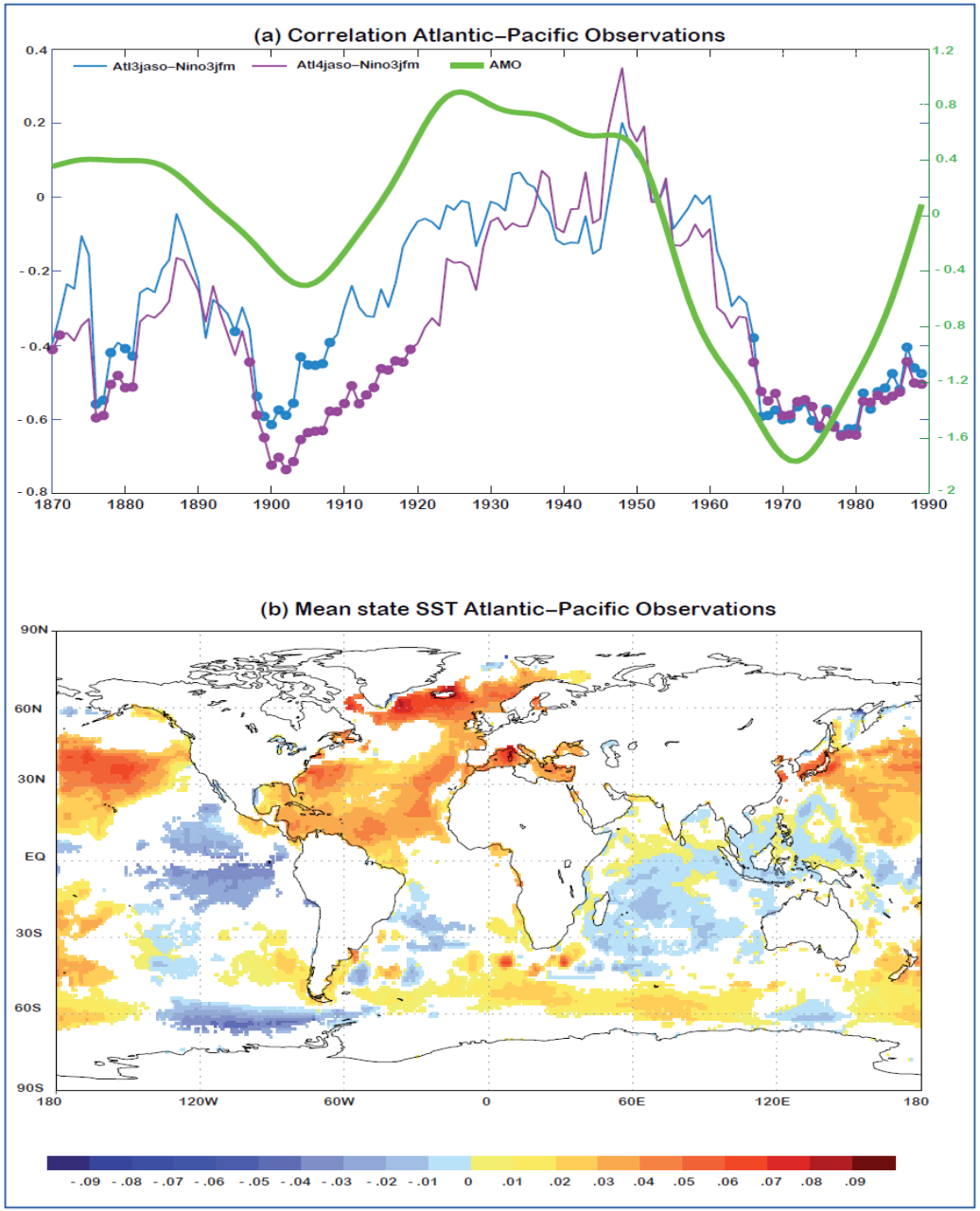
(a) Correlation Atlantic–Pacific Observations
Atl3jaso–Nino3jfm
Atl4jaso–Nino3jfm
AMO
0.4
0.2
0
- 0.2
- 0.4
- 0.6
- 0.8
1.2
0.8
0.4
0
- 0.4
- 0.8
- 1.2
- 1.6
- 2
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
(b) Mean state SST Atlantic–Pacific Observations
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
- .09
- .08
- .07
- .06
- .05
- .04
- .03
- .02
- .01
0
.01
.02
.03
.04
.05
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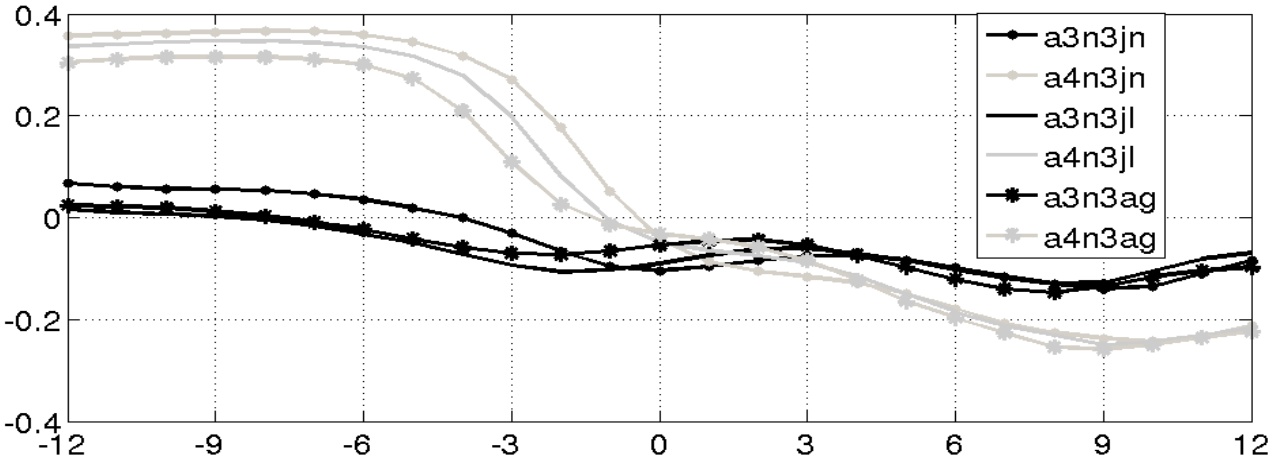
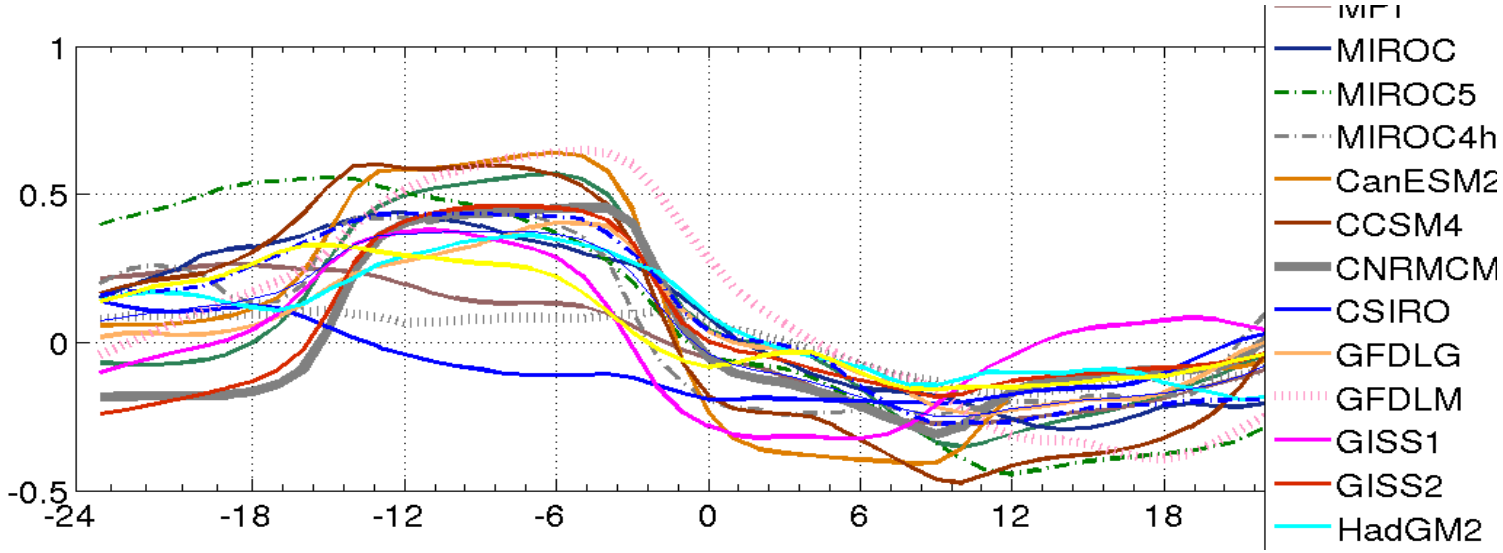
.08
.09


0.4
0.2
0
-0.2
-0.4
-12
-9
-6
-3
0
3
6
9
12
a3n3jn
a4n3jn
a3n3jl
a4n3jl
a3n3ag
a4n3ag


1
0.5
0
-0.5
-24
-18
-12
-6
0
6
12
18
MIROC
MIROC5
MIROC4h
CanESM2
CCSM4
CNRMCM
CSIRO
GFDLG
GFDLM
GISS1
GISS2
HadGM2