MULTIDECADAL VARIABILITY OF THE NORTH ATLANTIC IN CMIP5 MODELS AND RELATIONSHIP WITH SAHELIAN RAINFALL

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ABSTRACT

Observed rainfall over semiarid Sahel has shown pronounced decadal variability in the 20th Century, with a wet period in the 1950s and 1960s followed by a dry one in the 1970s and 1980s (Rodriguez-Fonseca *et al*., 2010). Observational and modelling studies have highlighted the role of sea surface temperatures (SST) in driving this low-frequency variability. In addition to the tropical warming of SSTs related to the increase in greenhouse gases, several works point to an influence of the Atlantic Multidecadal Oscillation (AMO) (Mohino *et al*., 2011). This large-scale pattern of variability is generally understood as an internal consistent mode related to the meridional overturning circulation (Knight *et al*., 2005). General Circulation Models show AMO-like variability in the North Atlantic. In this work we study the low-frequency variability of the North Atlantic and its relation to Sahelian rainfall in the last generation of general circulation models, using long-term historical and preindustrial control simulations from the fifth phase of the Coupled Model Intercomparison Project (CMIP5).

METHODS

AMO index is defined as the North Atlantic (0º-60ºN and 0º-80ºW) annual mean SST obtained after subtracting the global mean SST (between 60ºN and 60ºS to avoid problems with changes in sea ice), in order to separate the global warming (GW) trend of the Atlantic internal variability (Trenberth & *Shea*, 2006). But it has been observed that this method does not isolate completely the internal variability in the CMIP5 SST simulated data. This yields a significant trend remaining. In this work an alternative method is proposed to eliminate that trend in the AMO index. It consists in subtracting to the original SSTs the GW pattern multiplied by the GW index. Thus we obtain a residual SST which shows no trend (Fig. 1).

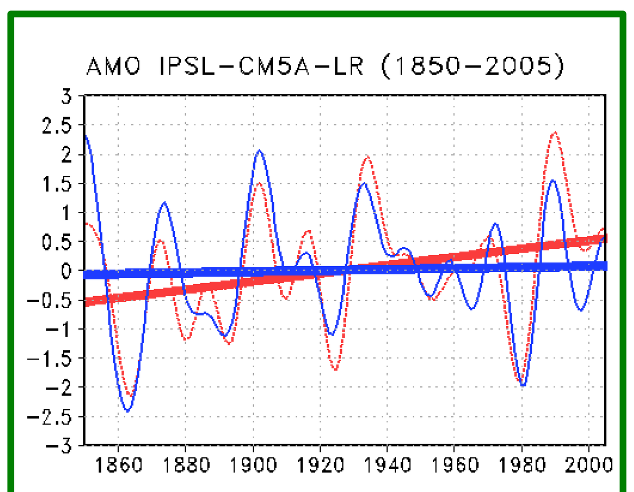

Fig. 1.- AMO standardized rates and their trend: in red the one calculated subtracting the GW trend and in blue the one obtained from the residual SST. Representative example of all the analyzed models.

DATA

We use SST outputs of CMIP5 models (Table 2) to define the AMO index and surface temperature and precipitation in order to see the impacts of the AMO. To compare with observational data we use SST data from HadISST1 data base (Rayner *et al*., 2003) and precipitation from GPCC reconstruction (Rudolf *et al*., 2003).

Database	resolution	n_years	period
HadISST1	1º x 1º	140	1870 - 2009
GPCC	1º x 1º	107	1901 - 2007

Table 1.- Observational data.

Model	nlon	nlat	experiment	n_years	period
CNRM-CM5	256	128	historical piControl	156 850	1850-2005 1850-2699
CSIRO-Mk3-6-0	192	96	historical piControl	156 500	1850-2005 0001-0500
GFDL-ESM2G	144	90	historical piControl	145 500	1861-2005 0001-0500
GFDL-ESM2M	144	90	historical piControl	145 500	1861-2005 0001-0500
GISS-E2-H	144	90	historical piControl	156 531	1850-2005 2490-3020
HadGEM2-CC	192	145	historical piControl	145 575	1860-2004 1860-2434
inmcm4	180	120	historical piControl	156 500	1850-2005 1850-2349
IPSL-CM5A-LR	96	96	historical piControl	156 1000	1850-2005 1800-2799
MIROC5	256	128	historical piControl	163 670	1850-2012 2000-2669
MIROC-ESM-CHEM	128	64	historical piControl	156 255	1850-2005 1846-2100
MPI-ESM-LR	192	96	historical piControl	156 1000	1850-2005 1850-2849
MRI-CGCM3	320	160	historical piControl	156 500	1850-2005 1851-2350

Table 2.- Description of the CMIP5 models analyzed.

RESULTS

Warming pattern over North Atlantic in all the models. But many discrepancies on the SST outside the Atlantic Basin.

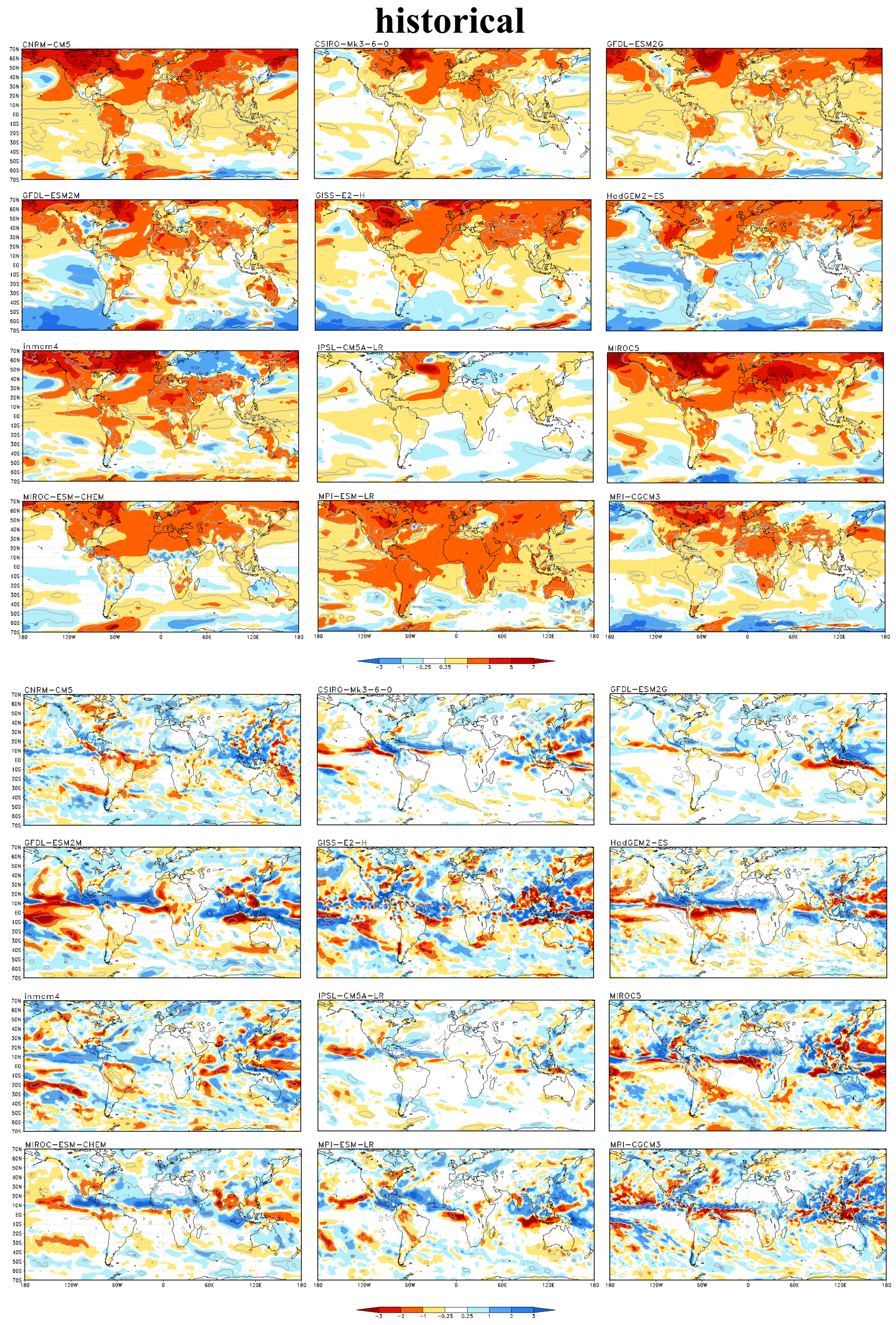

Fig. 2.- Regression of annual mean surface temperature anomaly (ºC/std.) (up) and seasonal mean precipitation anomaly (mm/day · std.) in summer (July, August and September) (down) of the historical experiment of each model onto the AMO index obtained from the low frequency filtered residual SST. Gray contour marks 95% significant correlation regions (according to a *t* test).

Positive anomalies in the Northern Hemisphere land surface associated to the AMO, especially in northeastern North America, western Europe and northern Brazil (Sutton & Hodson, 2005).

In the control run, warm anomalies are restricted to the northern North Atlantic and adjacent continental areas.

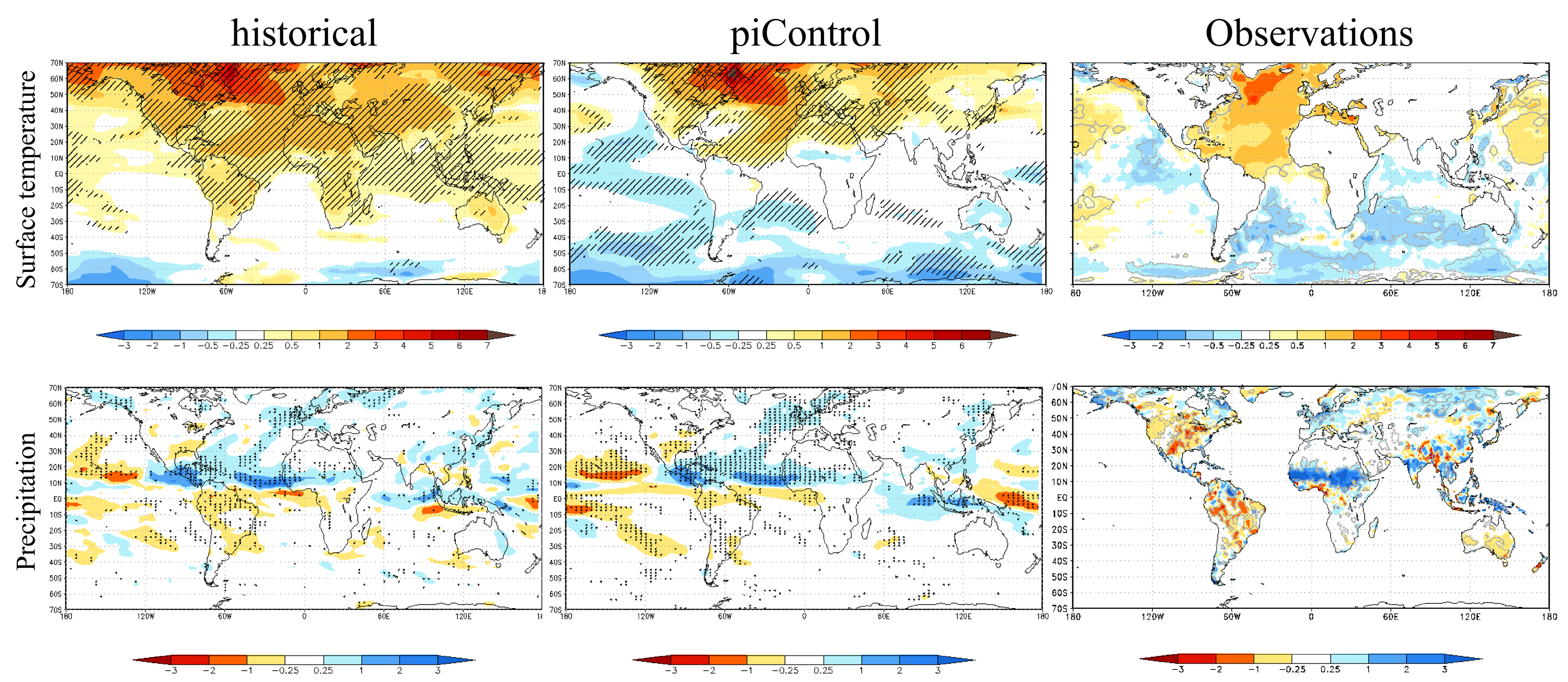

Fig. 3.- (a) Average of the twelve regression maps of each model of annual mean surface temperature anomaly (ºC/std.) and (d) seasonal mean precipitation anomaly (mm/day · std.) in summer (July, August and September) of the historical experiment onto the AMO index obtained from the low frequency filtered residual SST. (b) and (e) show the same as (a) and (d) but for the control simulation and with an AMO index calculated from the low frequency filtered SST. Hatched area in (a) and (b) indicates the regions where the regression rate of at least 8 of the 12 models have the same sign. (c) Regression of SST anomaly (ºC/std.) and (f) precipitation (mm/day · std.) over the continents observed onto the AMO index obtained from the residual SST of HadISST1 database. Gray contour marks 95% significant correlation regions (according to a *t* test).

The impact of the AMO over the precipitation anomalies is similar in both experiments and observations. Positive anomalies over the Sahel, Central America and western Europe and negative anomalies over the Guinea Gulf and northern Brazil. Models do not show a consistent increase of precipitations over India

Most models simulate the northward shift of the tropical rainbelt associated to a positive AMO that leads to increased (reduced) precipitation over the Sahel (northern Brazil), in accordance with Mohino *et al.* (2011) and Knight *et al*., (2006).

The observed AMO index shows a period between 50 and 70 years, in agreement with other works (e.g. Kerr, 2000). However most models do not show a well-defined AMO frequency.

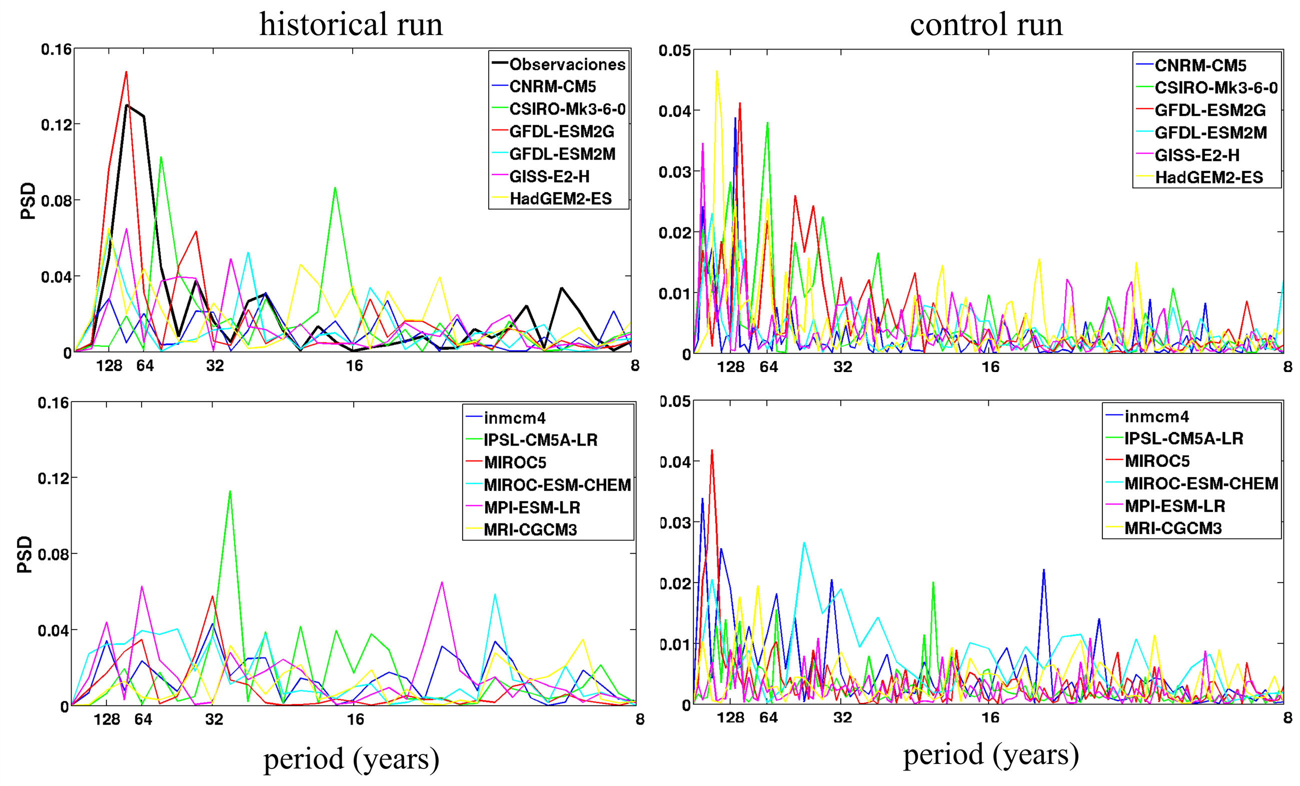

Fig. 4.- Power spectrum of the AMO indexes calculated for each CMIP5 model and for the historical (right) and control (left) simulations.

CONCLUSIONS

- All models show a low frequency SST variability with a pattern of warming over the North Atlantic similar to the observations.
- Land surface widespread warming across the Northern Hemisphere is simulated in historical experiment associated to the AMO. But in the Southern Hemisphere there is much disagreement between different models (Fig. 2).
- The difference in the AMO impact on the surface temperature between control and historical run can be due to a remaining external forcing that we could not separate (Fig. 3).
- Models show much influence of the AMO on sahelian rainfall (Fig. 3).
- On average, the response of precipitation in models is very similar to the observed one with positive anomalies over the Sahel and negative ones over the Guinea Gulf and South America (associated to a northward shift of the tropical rain belt) and increase rainfall over western Europe (Fig. 3).
- Most models do not simulate AMO indexes with a well-defined periodicity (Fig. 4).

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