Project: **987**

Project title: **The role of the South Atlantic Anticyclone in the Tropical Atlantic climate variability**

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Report period: **2019-01-01 to 2019-12-31**

During the year, our attention was focused on:

1. The study of the impact of the South Atlantic Anticyclone (SAA) in the Equatorial Atlantic interannual variability (EAV), in order to find how much the observed equatorial Atlantic climate variability can be explained by variations in the SAA. To this end we have used two different ensembles of the regionally coupled model ROM. All the simulations share the same ocean (TR04 configuration of MPIOM) and in each ensemble REMO, the atmospheric component of ROM, covers the same region. In the first ensemble, thereafter AFR, the SAA is fully included in the atmospheric domain and therefore is simulated by ROM with greater influence of the Pacific ocean. In the second ensemble the SAA is outside the region covered by REMO and is imposed as an external forcing. We carried out a number of simulations with both setups (see tables 1 and 2) that allowed us to elucidate the role of the SAA in the EAV in a robust manner.

Table 1. Experiments with greater influence of SAA: REMO domains: NAT(50km), NAS(25 km), NAZ(18 km) and NAX(12.5 km); ocean: TR04

#	ID	Period	Atm grid	BC	
1	579	1980 - 2012	NAS	ERAI	
2	595	1980 - 2012	NAS	ERAI	
3	564	1980 -	NAT	ERAI	

Table 2. Experiments with greater influence from the Pacific: REMO domains: DEP (50 km); DES (25 km); DED (100 km); ocean: TR04

#	ID	Period	Atm grid	
1	586	1980-2012	DEP	
2	801	1980-2012	DES	
3	803	1980-2012	DEP	
4	370	1958-2001	TR08_DED	

We found significant differences in the simulated TAV and in the development of the anomalies depending on the ensemble, and the implied dynamical and thermodynamical mechanisms seem to work differently in dependence on the SAA. In Figure 1 we can see that the correlation between the observed and simulated variability for the experiments of the NAT ensemble, in which the observed SAA is imposed (panel A) than in the experiments of the AFR ensemble (panel B) where the SAA is fully simulated by the model.

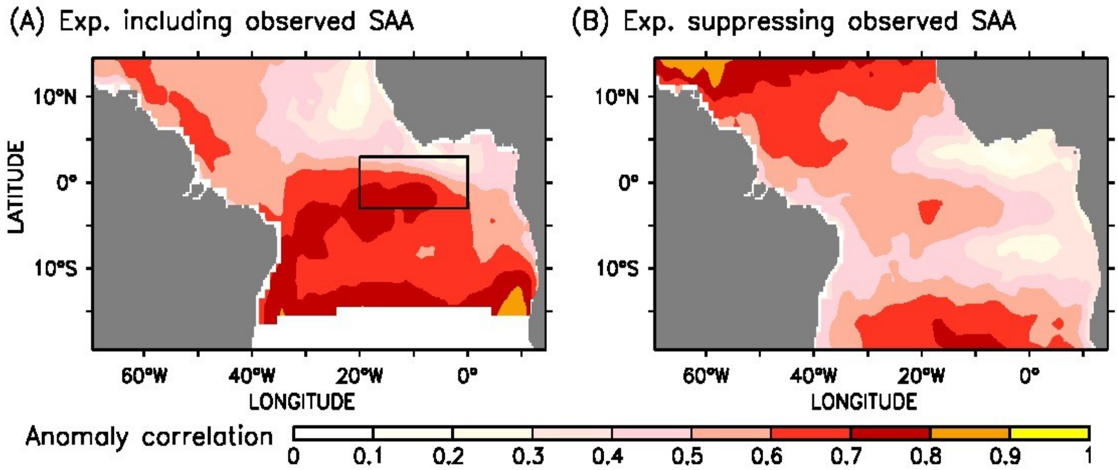

Figure 1: Impact of South Atlantic atmospheric variability on equatorial Atlantic SST. Correlation with observed SST for two the ensemble mean of two regional model experiments with an atmospheric boundary at (A) 17°S and (B) 40°S. The period considered is 1980-2001, and the ensemble sizes are eight.

The differences are reflected in the simulated Atlantic Niño variability: the ensemble of simulations with external SAA has a correlation of *0.71* with the observations, while the ensemble with internally generated SAA has a correlation of *0.51*. Further on, the correlation between simulated and observed Atlantic Niño SST anomalies for the two ensembles are clearly different and for most of the year higher when the SAA is externaly imposed (not shown). In the NAT ensemble the influence of the SAA on the TAV is similar to the observed, while in the AFR ensemble this influence is not so well represented (see Fig. 2)

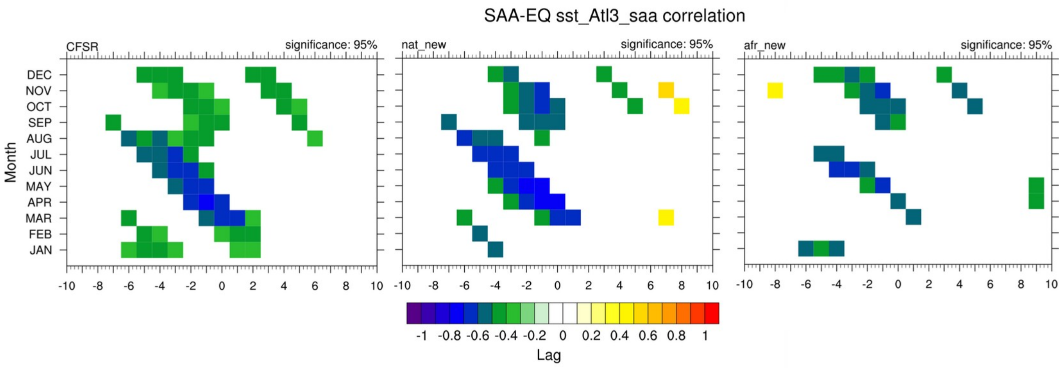

Figure 2. Link to the SAA for CFSR (left panel), NAT ensemble (central panel), AFR ensemble (right panel)

An analysis of the relationship between the variability of the Atlantic Niño in June-July and the correlation between the March SAA and the Atlantic Niño in June for all the simulations shows a dependence with r=-0.52, with stronger negative March-June correlation associated to a stronger June-July Atlantic Niño variance.

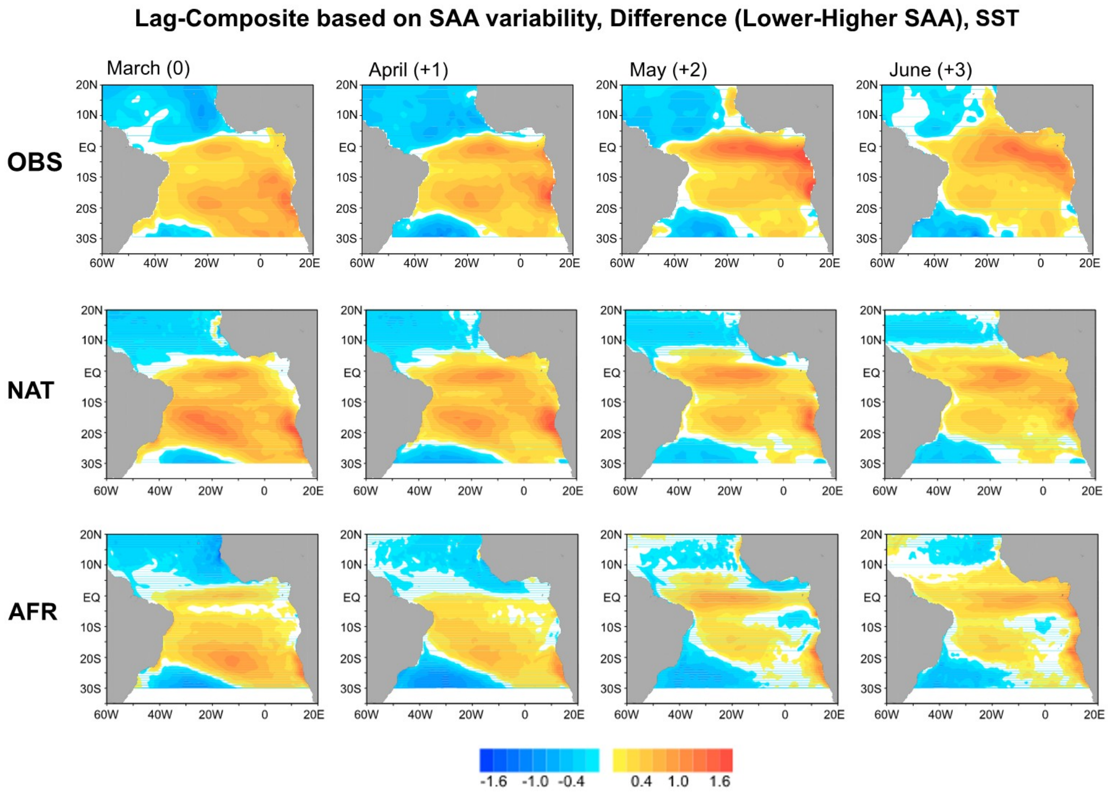

Figure 3. Lag-Composite of SST differences for years when SAA is higher and years when SAA is lower. Observations (upper panels), NAT ensemble (central panels), AFR ensemble (lower panels)

The influence of the SAA on the development of the SST anomalies in the Tropical Atlantic can be seen in figure 3. The NAT ensemble reproduces well the time evolution of the lag-composites of the differences in SST between the years when the SAA is stronger and years when the SAA is weaker. The spatial structure is also well reproduced, although is a little weaker in the equatorial band in May and June, especially in the eastern part of the Gulf of Guinea. The AFR ensemble fails to reproduce the strengthening of the SST differences in the equatorial band and the Angola-Benguela Frontal Zone that can be seen both in observations and in NAT. In May and June the equatorial band is better reproduced, although the spatial patterns are poorly reproduced. This behaviour is associated to a better simulation by the NAT ensemble of the evolution of the wind stress and heat flux anomalies: like in the observations the zonal winds in the central part of the equatorial band start to weaken in march, causing the associated warming that can be seen in figure 2. The negative heat flux anomalies, which tend to dump the positive temperature anomalies, become stronger as the winds relax further in May. By the peak of the event the winds start to strength back and the anomalous heat flux becomes weaker. The AFR ensemble starts to show a behaviour similar to observations only in May, in a band that is narrower than in observations and in NAT. This behaboir has a fundamental influence in the dynamics of the development of a warming event in the Tropical Atlantic, as is showed later.

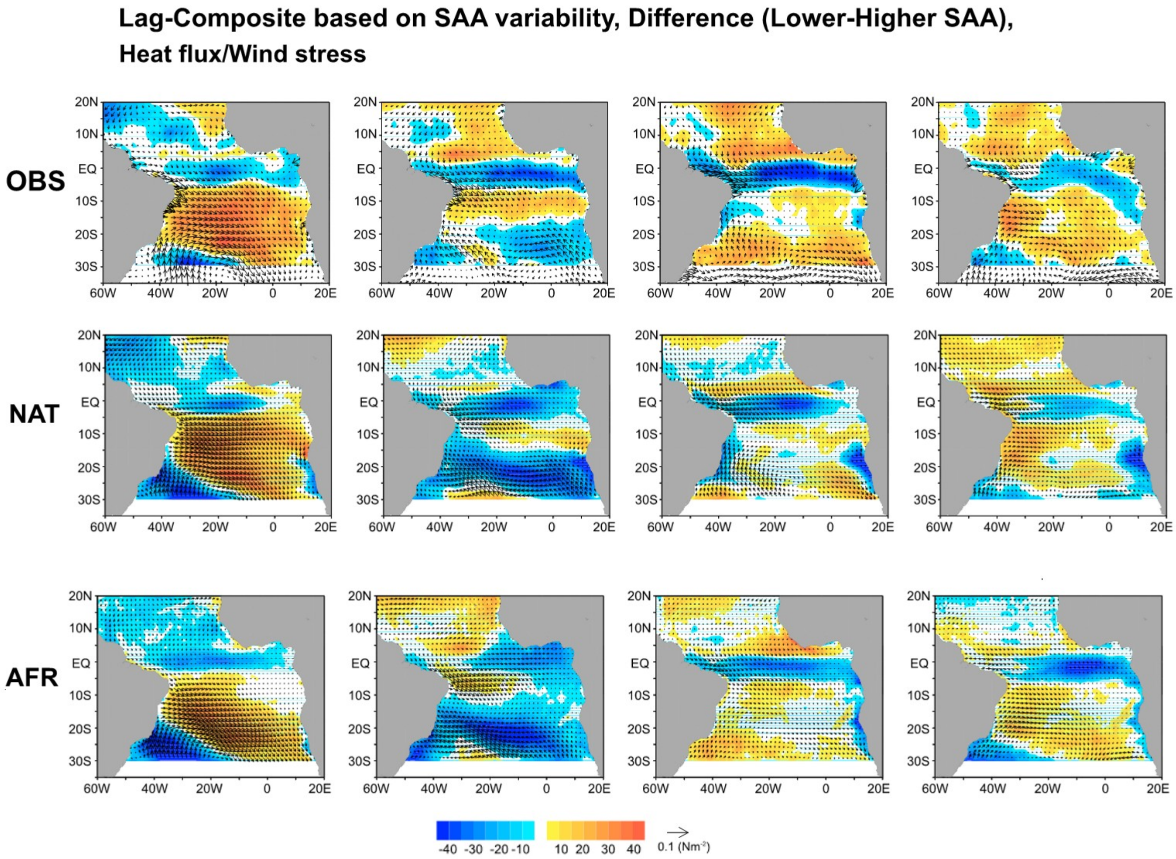

Figure 4. Lag-Composite of Heat Flux and Wind Stress differences for years when SAA is higher and years when SAA is lower. Observations (upper panels), NAT ensemble (central panels), AFR ensemble (lower panels)

2. Using the same set of simulations, we investigated the relationship between sea surface temperature (SST) in the equatorial Atlantic and EAV for both ensembles and found that its relationship is completely different. In the NAT ensemble, the larger the EAV tends to be, the cooler the SST is in the equatorial Atlantic. This tendency seems to be consistent with conclusion of previous study; following the global warming, the amplitude of the EAV becomes smaller (Tokinaga and Xie, 2011). Conversely, in the AFR ensemble, the warmer SST has larger

amplitude of the EAV. This indicates that the realistic SAA forcing is responsible for the EAV behavior. However, the bias of the SST is relatively smaller in both NAT and AFR runs than the state-of-the-art Coupled global models (CGCMs).

As a next step, the Bjerknes Feedback, which is fundamental dynamics for the EAV (e.g., Keenlyside and Latif, 2007), has been performed for NAT and AFR runs. Both simulations show a relationship in which the better Bjerknes Feedback (correlation between equatorial SST and zonal wind stress) cases have the larger EAV, however, in general, the NAT runs have more ensemble members with better Bjerknes Feedback than the AFR runs.

Moreover, the lag-composite analysis based on the Atlantic Niño/Niña events (warm/cold SST anomalies in the equatorial Atlantic and a main part of the EAV) in June has been demonstrated to see if there is any difference in evolution in the Atlantic events. In the observations, both events evolve gradually from February to June in the equatorial Atlantic and their amplitudes and spatial distribution are highly symmetric (e.g., Lübbekce and McPhaden, 2017). In the NAT runs, the evolution in the events is very realistic and the symmetric characteristics are also captured well. Inversely, in the AFR runs, the evolution in the events is unrealistic: the warm and cold SST anomalies decay from March to April and they gets more activated again from April to June. This unrealistic feature has been seen in the previous analysis with only one ensemble member of AFR and this result can be more robust with 8 ensembles. Similar analysis is conducted for 3D temperature and ocean current. As shown in Figure 1, both simulations show that the warm anomaly of subsurface temperature evolves gradually from February to June. However, the warm anomaly in AFR runs is limited in the shallower subsurface (down to 150m depth) and that in NAT is much deeper (down to 250m). Regarding the vertical velocity anomaly corresponding to the warm event in June, NAT runs shows that the downward anomaly is well confined along the equator in evolution of the warm event, but in AFR runs, the downward anomaly is much weaker than NAT runs. On the other hand, in the cold events, the subsurface temperature and vertical motion anomalies are quite comparable between NAT and AFR runs. This indicates that the SAA variability plays some role at least in the warm events in the equatorial Atlantic.

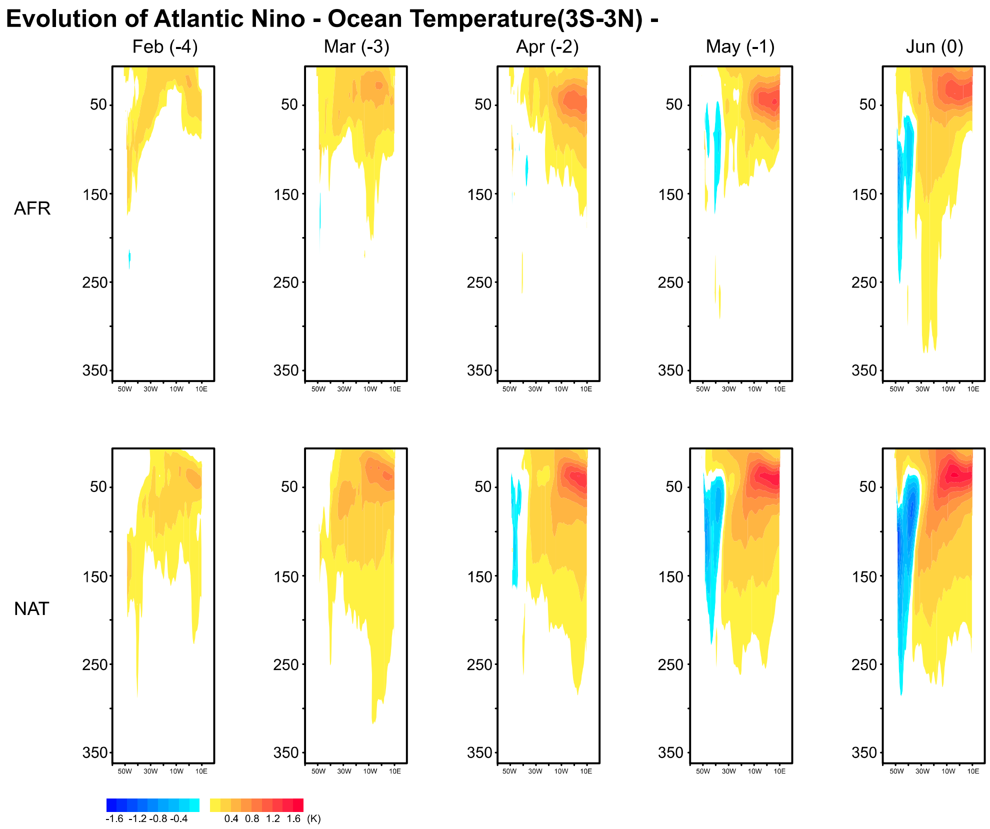

Figure 5Evolution of the Atlantic Niño Ocean temperature averaged in the 3S-3N equatorial strip. AFR ensemble mean (upper panels), NAT ensemble mean (lower panels).

Related papers

1. Keenlyside N, Cabos W, Sein D, Koseki S. South Atlantic Anti-Cyclone as driver for Atlantic Nino's. in preparation
2. De la Vara A, Cabos W, Sein D, Sidorenko D, Koldunov N, Koseki S, Soares PMM, Danilov S. On the impact of atmospheric vs oceanic resolutions on the representation of the sea surface temperature in the South Eastern Tropical Atlantic. *Clim. Dyn*. under review
3. Cabos, W, De la Vara, A, Koseki S. Tropical Atlantic Variability: Observations and Modeling. Atmosphere 2019, 10(9), 502; https://doi.org/10.3390/atmos10090502
4. Darmaraki, S., Somot, S., Sevault, F., Nabat, P., Cabos W., Cavicchia, L., Djurdjevic, V., Li, L., Sannino, G., & Sein, D. V. (2019). Future evolution of marine heat waves in the Mediterranean Sea. *Climate Dynamics*, **53**, 1371– 1392.
5. Lima, D C, Soares, P M , Semedo A, Cardoso R M , Cabos W, and Sein D. (2019) How will a warming climate affect the Benguela coastal low-level wind jet? ,Journal of Geophysical Research: Atmospheres .doi:https://doi.org/10.1029/2018JD029574
6. Parras-Berrocal, I., Vazquez, R., Cabos, W., Sein, D., Mañanes, R., Perez-Sanz, J., and Izquierdo, A.: The climate change signal in the Mediterranean Sea in a regionally coupled ocean-atmosphere model, Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-42, in review, 2019

7. Cabos W, Sein V, Durán-Quesada A, Giovanni Liguori G, Koldunov N, Martínez-López B, Alvarez F, Sieck K, Limareva N, Pinto J. (2019) Dynamical downscaling of historical climate over CORDEX Central America domain with a regionally coupled atmosphere–ocean model. *Climate Dynamics*. **52**, 7–8, 4305–4328
8. Vazquez R, Parras I, Cabos W, Sein D, Mañanes R, Perez J, Izquierdo A (2019) Climate Evaluation of a High-Resolution Regional Model over the Canary Current Upwelling System. In: Rodrigues J. et al. (eds) Computational Science – ICCS 2019. ICCS 2019. Lecture Notes in Computer Science, vol 11539. Springer, Cham. https://doi.org/10.1007/978-3-030-22747-0_19