Project: **987**

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

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During the year, our attention was focused on four topics:

1. In ref. 1 we explore the question of whether the representation of the oceanic influence and the role of air-sea coupling is adequately represented in regional models used for downscaling the European climate as the usually include a relatively small area of the Atlantic Ocean and are uncoupled, with the SST used as lower boundary conditions much coarser than the mesh of the regional atmospheric model. To this end, we carried out a set of coupled and uncoupled experiments with the regionally-coupled model ROM and its atmospheric component, the regional atmospheric model REMO forced by the ERA-Interim reanalysis and by the global climate model MPI-ESM. In order to focus in the physical mechanisms involved, we explore the impact of including explicitly the North Atlantic in the regional domain and the added value that coupling brings to the climate of the Iberian Peninsula (IP). We find that the impact of air-sea coupling on the IP winter biases can be traced back to the features of the simulated North Atlantic Ocean circulation. In summer, it is the air-sea interactions in the Mediterranean that exert the largest influence on the regional biases. Despite improvements introduced by the eddy-permitting ocean, it is suggested that a higher resolution could be needed for a correct simulation of the features of the large-scale atmospheric circulation that impact the climate of the IP.

2. In ref. 2, we analyze the climate change signal in the Mediterranean Sea using ROM, explicitly simulating the water exchanges with the adjacent North Atlantic and Black Sea. Simulations forced by ERA-Interim show an accurate representation of the present Mediterranean climate. Our analysis of the RCP8.5 (representative concentration pathway) scenario using the Max Planck Institute Earth System Model shows that the Mediterranean waters will be warmer and saltier throughout most of the basin by the end of this century. In the upper ocean layer, temperature is projected to have a mean increase of 2.7 °C, while the mean salinity will increase by 0.2 psu, presenting a decreasing trend in the western Mediterranean in contrast to the rest of the basin. The warming initially takes place at the surface and propagates gradually to deeper layers. Hydrographic changes have an impact on intermediate water characteristics, potentially affecting the Mediterranean thermohaline circulation in the future.

3. In ref. 3 we explore the role of the oceanic and atmospheric resolutions of the model in the representation of the sea surface temperature (SST) over the South Eastern Tropical Atlantic. To this end, we use four different configurations of the AWI Climate Model (AWI-CM). Our results show that a sole refinement of the oceanic resolution reduces warm biases further than a single increase of the atmospheric component. An increased oceanic resolution is required (i) to simulate properly the Agulhas Current and its associated rings; (ii) to reinforce the northward-flowing

Benguela Current and (iii) to intensify coastal upwelling. The best results are obtained when both resolutions are refined. However, even in that case, warm biases persist, reflecting that some processes and feedbacks are still not optimally resolved. Our results indicate that overheating is not due to insufficient upwelling, but rather due to upwelling of waters which are warmer than observations as a result of an erroneous representation of the vertical distribution of temperature. Errors in the representation of the vertical temperature profile are the consequence of a warm bias in the simulated climate state.

4. In ref. 4, we study in a systematic way how the warm SST biases found in de la Vara et al. (2020) affect the climate change signal. As these biases are resolution-dependent and are influenced by the representation of the processes that affect the biases, we expect that they also play a role in the magnitude and spatial patterns of the SST changes and their impact on the climate of the region. To this end we analyze a set of historical simulations with the Alfred Wegener Institute Climate Model (AWI-CM) which only differ in their atmospheric and oceanic grids. The unstructured grid of the ocean component of AWI-CM allows for the use of a low- (non eddy permitting) and a high-resolution (eddy permitting) oceanic configurations, while the atmosphere component has two relatively low resolutions (~1.9° and ~0.9°). With this design of the numerical experiments we can distinguish between the effects of increasing the atmospheric and oceanic resolutions individually. These resolutions are still insufficient to fully represent the mesoscale features in the ocean and the atmosphere, but are in the upper limit of the computational resources of most modelling groups that contribute to CMIP6. However, our setups allow us to discern to what extent the increase of resolution in the atmospheric and the oceanic components contributes to the characteristics of the SST change in the SETA in long-term climate simulations with state-of-the-art coupled models.

References

1. Cabos W, de la Vara A, Álvarez-García F J, Sánchez E, Sieck K, Pérez-Sanz JI, LImaerva N, Sein D V (2020) Impact of ocean-atmosphere coupling on regional climate: the Iberian Peninsula case. Clim Dyn 54: 4441–4467. https://doi.org/10.1007/s00382-020-05238-x.

2. Parras-Berrocal, I. M., Vazquez, R., Cabos, W., Sein, D., Mañanes, R., PerezSanz, J., and Izquierdo, A. The climate change signal in the Mediterranean Sea in a regionally coupled atmosphere–ocean model, Ocean Sci., 16, 743–765, https://doi.org/10.5194/os-16-743-2020, 2020.

3. de la Vara, A., Cabos, W., Sein, D.V. et al. On the impact of atmospheric vs oceanic resolutions on the representation of the sea surface temperature in the South Eastern Tropical Atlantic. Clim Dyn 54, 4733–4757 (2020). https://doi.org/10.1007/s00382- 020-05256-9

4. Cabos, W., de la Vara, A., Sein, D.V., et al. The role of atmospheric vs oceanic resolutions on the representation of the climate change signal in the South Eastern Tropical Atlantic. ***In preparation***