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Regionally coupled modelling of the Tropical Atlantic

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1. Introduction

Currently, Global Coupled Models (GCMs) have difficulty capturing key phenomena and achieving accurate climate projections on regional and local scales because limitations in computer power do not allow them to reach the necessary horizontal resolutions. Regional climate models (RCMs) provide dynamically downscaled climate information within the region of interest, improving this drawback of current GCMs. At this point, naturally raises the question of how much, if any, the RCM can improve the GCMs results. It has been argued that regional models can reproduce an observed climatology but are not able to predict the change of the climatology in response to a changing climate (e.g. Kerr, 2013). However, Feser et al. (2011) could demonstrate an added value in those parameters that exhibit high spatial variability such as near surface temperature in different regional atmospheric models. They show that the added value originates mainly from the higher resolved orography in the regional models.

2.! Regional atmosphere-ocean climate models

However, there are cases when fine scale atmosphere-ocean feedbacks can substantially influence the spatial and temporal structure of regional climate (Li et al., 2012). Recent studies have shown that regional atmosphere-ocean climate models (RAOCMs) are capable of simulating these features of the climate system. Compared to global coupled atmosphere-ocean models, RAOCMs could go for much higher resolution, providing a more accurate representation of the morphological complexity of the land-sea contrasts and relevant mesoscale processes and the associated energy and mass air-sea exchanges. The combination of these factors allows RAOCMs to bring additional added value in those regions where they are important. For instance, Ratnam et al. (2008) found that coupling considerably improved the simulation of the Indian monsoon rain band over both the ocean and land areas.

3.! The ROM model

ROM is a RAOCM comprised of the REgional atmosphere MOdel (REMO), the Max Planck Institute Ocean Model (MPIOM), the HAMburg Ocean Carbon Cycle (HAMOCC) model, and the Hydrological Discharge (HD) model which are coupled via OASIS coupler. All the models but REMO are run in a global configuration. MPIOM has high horizontal resolution in the region of interest and its global domain is divided into two different subdomains: coupled, where the ocean and the atmosphere are interacting, and uncoupled, where the ocean model is driven by prescribed atmospheric forcing and runs in a so-called stand-alone mode. Therefore, choosing a specific area for the regional atmosphere we can assume that in that area the ocean-atmosphere system is "free", whereas in the remaining areas the ocean circulation is driven by prescribed atmospheric forcing.

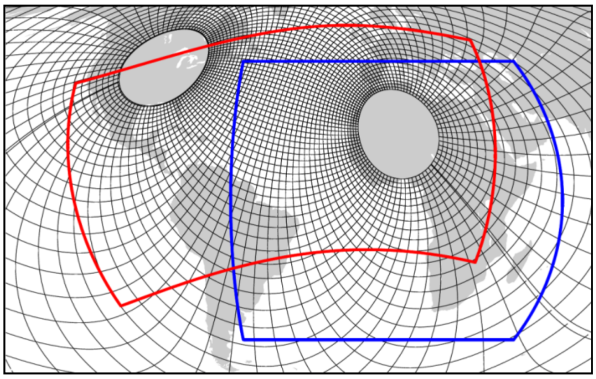

Figure 1. MPI-OM TR04 setup (black lines). REMO-DEP setup (blue line) and REMO-NAT setup (red line). Every 12th grid line is shown.

4. Tropical Atlantic simulations

A set of experiments were carried with different combinations of MPIOM and REMO configurations, as illustrated in Fig 1. The MPI-OM TR04 horizontal resolution reaches 10 km in the North Tropical Atlantic and gradually diminishes, reaching 200 km in the southern oceans The model has 40 vertical levels with increasing level thickness. For REMO we use two different horizontal domains labeled DEP and NAT. Both the domains include the TA region and are defined as follows: 1) DEP extending to the South Atlantic, with Africa and part of the Indian Ocean and Mediterranean region inside the domain and 2) NAT which covers a large portion of North and South America and also the North Atlantic, the Eastern tropical Pacific and the Mediterranean Sea. The model was forced with different realizations of the present day climate with the MPI-ESM Global Circulation Model. Here we present results obtained with the DEP REMO setup.

5. Results

As reported in other studies (e. g. Ratnam et al. 2008), RAOCMs can bring added value not only to near surface temperature, but also to precipitation, as shown by Ratnam et al. (2008) for the Indian Monsoon precipitation. In this work we investigate if our model can

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bring added value in the simulation of the Tropical Atlantic (TA) climate. In fig.2 we compare the ROM precipitation with observations, the stand alone REMO and the MPI-ESM realization used to force both ROM and the RCMs.

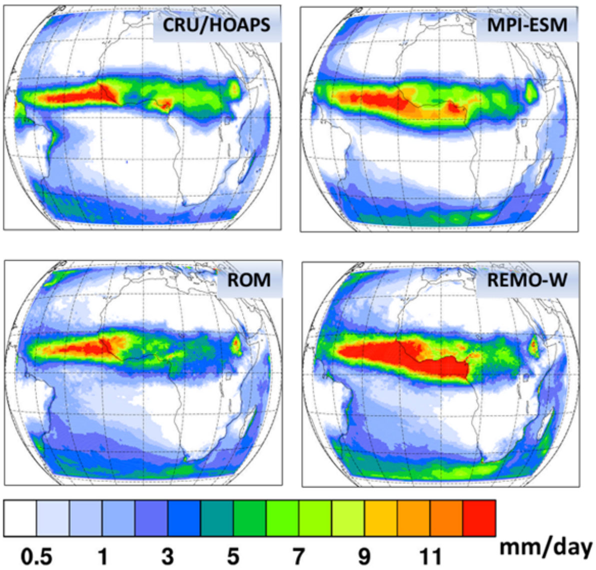

Figure 2. JJA precipitation for the 1966-1975 period. CRU-HOAPS is a blend of HOAPS oceanic and CRU land precipitation data sets. MPI-ESM is the model used to force the ROM and stand-alone REMO configuration. ROM is run in the DEP setup.

ROM precipitation is clearly closer to CRU/HOAPS than MPI-ESM, especially over the ocean. Moreover, ROM simulates the ITCZ better than stand alone REMO. This point to the fact that coupling contributes significantly to the added value in regions where air-sea interaction is important.

The added value from AORCMs is not restricted to the atmosphere. Regional coupled models can also show better results than the forcing GCMs in the ocean component. ROM shows a better representation of the climatology and interannual Tropical Atlantic variability. In figure 3 we represent the correlation of the ORAS4 reanalysis sea surface temperatures with MPI-ESM and ROM forced by MPI-ESM for ensembles of 10 years simulations. ROM shows clearly better SST variability in the Tropical Atlantic region. In particular near the North Africa where the most of the Tropical Cyclones are generated.

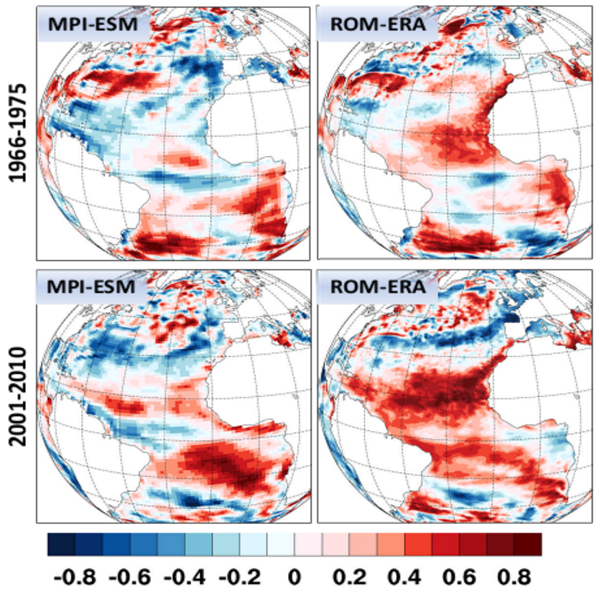

Figure 3. SST correlation between the ORAS4 and MPI-ESM (left column) and ROM-DEP (right column) for the 1966-1975 and 2001-2010 periods.

6. Conclussions

The coupling to an active ocean provides further added value to the REMO RCM when compared to the global MPI-ESM. The smaller-scale air-sea feedbacks resolved in ROM provide a better representation of the precipitation, especially over the ocean and also improve the simulation of oceanic variables, like the SST.

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