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Coupling of regional atmospheric-ocean models for climate applications in the Mediterranean basin by using CORDEX-compliant simulations

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Nowadays, most regional climate models (RCMs) are essentially composed of an atmospheric component coupled to a land surface scheme and driven over ocean areas by prescribed sea surface temperature (SST). Although such a RCM can be sufficient for many applications, there are cases (like in the Mediterranean basin) in which fine scale feedbacks associated with air-sea interactions can substantially influence the spatial and temporal structure of regional climates.

Therefore, in this work we present the first testing phase of the application of a coupled atmospheric-ocean regional climate model (AORCM) for the Mediterranean basin under the framework of the CORWES project. CORWES is a Spanish consortium of research groups using the Weather Research and Forecasting (WRF) model to contribute to the Coordinated Regional Climate Downscaling Experiment (CORDEX).

We use WRF and ROMS models as the atmospheric and oceanic component, respectively. Coupling between WRF and ROMS is achieved in the following way: on a prescribed interval of 2 h, WRF sends wind stress, surface heat and water fluxes to ROMS time-averaged over the previous two hours. One hour later, and also with a prescribed interval of 2 h, ROMS sends time-averaged SST to WRF. Here, we mainly focus on the performance of the coupled system in reproducing the ocean surface temperatures. To separate effects of the coupling on SST, additional uncoupled atmospheric simulations are also done in parallel. The case study covers the years 2001-2005 and is described below.

The resolution of the domain used is 12 km. The number of vertical levels is 30 for WRF. The ROMS domain, with 32 vertical levels, is slightly smaller than WRF innermost nest and has a higher resolution of 4 km. The lateral atmospheric boundary conditions for WRF are taken from ERA-Interim reanalysis. The lateral oceanic boundary conditions for ROMS come from the downscaling of the Simple Ocean Data Assimilation analysis (SODA) by an uncoupled nested ROMS simulation covering the Mediterranean. The atmospheric forcing for this simulation is also provided by ERA-Interim. To isolate effects of coupling on the atmosphere solutions, an atmosphere-only WRF simulation forced by ERA-Interim has been run.

The results indicate that there is an overall good agreement between WRF-ROMS simulations and the E-OBS gridded dataset. During winter, the land temperature fields over most subregions in both WRF-ROMS and WRF achieve a closer agreement with E-OBS than ERAIN reanalyses, as a consequence of the dynamical downscaling. During JJA, the regional simulations exhibit a cold bias with respect to E-OBS, which is somewhat corrected by the coupled simulation. WRF-ROMS and WRF have similar average temperatures during all seasons.

During summer, WRF-ROMS provides higher temperatures in the southern Mediterranean (Alboran, Benghazi, Mersa Matrouh) and lower temperatures in the Adriatic and the north-eastern Levantine basin than the atmosphere-only WRF simulations. This pattern corresponds to the prevailing anti-cyclonic oceanic structures along the southern coasts and to the cyclonic structures along the northern Mediterranean coasts, the two being separated by the Mid-Mediterranean jet. Also, 2-m summer temperatures for coupled vs. uncoupled simulations are marked by the differences in SST. WRF-ROMS and WRF-alone have similar temperature averages. Main differences are found over coastal areas (but are lower than 0.2 ºC for all the Mediterranean basin). Therefore, the atmosphere-ocean coupling over this region does not significantly change the simulations of present climate 2-m temperature.

Moreover, the precipitation in the WRF-ROMS and WRF simulations do not present substantial differences for total precipitation, suggesting a weak effect of air-sea feedbacks on seasonal mean precipitation over land in

our modelling system. This result is somewhat expected from the well established notion that the Mediterranean area is mainly subject to large scale orographic precipitation associated to synoptic systems travelling eastward from the North Atlantic.

In the WRF-ROMS coupled simulation, mostly in the warm seasons, we find less convective rainfall over the Adriatic and the north-eastern Levantine basin (more convective rainfall over southern coasts and the eastern Mediterranean) than in the atmosphere-only simulation. The differences in convective precipitation are associated to the differences found for SST in the coupled vs. uncoupled simulations.

Last, we should highlight that the most important contribution of the WRF-ROMS coupled modelling is providing high-resolution oceanic components and fluxes over the area of analysis.