Final Report

Project title: Simulation of the Mediterranean climate in the framework of HyMeX
Project: 896
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The main objective of this work was the implementation and evaluation of the ocean-atmosphere coupled regional climate model in the framework of HyMeX (Hydrological cycle in Mediterranean Experiment) for the better understanding of ocean-atmosphere interactions. HyMeX aims to improve the understanding of the Mediterranean water cycle, with emphasis on extreme events by monitoring and modeling the Mediterranean atmosphere-land-ocean system (www.hymex.org).

The semi-enclosed Mediterranean Sea has a strong impact on the local and even remote climate system as a source of moisture and heat. Its climate is known for its large contrast in seasonal temperature variations, strong winds, heavy precipitation, and cyclones. The Mediterranean region is also known as a "Hot Spot" in future climate change projections due to a large decrease in mean precipitation and increase in precipitation variability during warm and dry seasons (Giorgi 2006). Therefore, it is important to understand how large-scale climate variability and climate change influence the climate of the Mediterranean region as well as the influence of the Mediterranean Sea on the global climate. The Mediterranean oceanic mesoscale processes (costal current and eddies) and thermohaline circulation (the deep-water formation that takes place in the Gulf of Lions, the Ligurian Sea, the Adriatic Sea, the Aegean Sea and the Levantine basin) are influenced by the air-sea fluxes and in turn, affect the sea surface temperature (SST).

In this project, we employed a regional atmosphere-only and ocean-atmosphere coupled model. Alongside the scientific studies, technical efforts have also been undertaken to improve/upgrade and extend the coupled system.

Experimental set-up

We employed the regional climate model COSMO-CLM (CCLM), based on the non-hydrostatic equations (Rockel et al. 2008), in atmosphere-only and in coupled (atmosphere-ocean) with ocean component NEMOMED12 configurations. The NEMOMED12 ($1/12^{o}$ and 50 vertical levels) is a regional configuration of the ocean general circulation model NEMO for the Mediterranean Sea (Madec and the NEMO Team, 2008, Beuvier et al. 2012). Coupling has been implemented using OASIS-MCT (Valcke 2013). The CCLM uses the lateral boundary conditions from the ERA-Interim reanalysis data (or from other GCMs) for both coupled and atmosphere-only simulations. In the coupled configuration, Sea Surface Temperature (SST) as a lower boundary condition is also prescribed using ERA-Interim except over the Mediterranean Sea where it is calculated by NEMOMED12. The coupled system used the climatological values of freshwater discharge into the Mediterranean Sea. The computational domain follows the MED-CORDEX (www.medcordex.eu) requirements (Ruti et al. 2016).

PHASE 1

Simulations

In the first phase, CCLM v4.21 and NEMOMED12 v3.2 were used. The following simulations have been performed using above described setup with atmosphere-only (CCLM) and coupled CCLM-NEMOMED12:

- Atmosphere-only and coupled simulations with three different horizontal atmospheric resolutions (0.44°, 0.22°, 0.08°) were performed to study medicanes (Mediterranean hurricanes) over the Mediterranean Sea (for more details see Akhtar et al. 2014)
- The historical atmosphere-only and coupled simulations (with 0.44° atmospheric grid resolution) were performed over the whole ERA-Interim period. In these simulations, 30-years of the Mediterranean Sea spin-up have been performed in coupled configurations. These simulations have been used to study different oceanic (Harzallah et al. 2016, Llasses et al. 2016) and atmospheric (Fantini et al. 2015, Flaounas et al. 2016, Cavicchia et al. 2016, Drobinski et al. 2016, Gaertner et al. 2016) processes
- Atmosphere-only and coupled simulations (with 0.08° atmospheric grid resolution) were performed from 2000 to 2003 to analysis the impact of ocean coupling and atmosphere grid resolution on sea surface heat fluxes (Akhtar et al. 2017)
- Atmosphere-only simulations (with 0.44° and 0.08° atmospheric grid resolution) forced with 5-days averaged SST over the Mediterranean Sea from their corresponding coupled simulations were performed to analysis the impact of SST diurnal variations on the sea surface heat fluxes (Akhtar et al. 2017)
- Other interesting studies have been executed using inter-comparison of models involved in HyMeX and MED-CORDEX (Ruti et al. 2016, Obermann et al. 2016, Obermann-Hellhund et al. 2017)

PHASE 2

In order keep the coupled system up to date, in the second phase more efforts have been spent on the extension and upgradation/improvement of the coupled system.

- The atmospheric and ocean models in the coupled system are upgraded to their latest versions (i.e., CCLM is upgraded to version 5 and NEMOMED12 is upgraded to version 3.6).
- For more realistic representation of freshwater river discharge into the Mediterranean Sea coupling of a river routing scheme TRIP/HD is under development.

Simulations

To test the stability and performance of the coupled system few short (monthly/yearly) and a long term (35 years; covering whole ERA-Interim period) simulations were performed. Also different test/sensitivity simulations were performed to analyze the impact of the Mediterranean Sea initialization on the atmosphere and impact of aerosol climatology on air-sea heat fluxes. The following simulations have been performed using CCLM v5 coupled with NEMOMED v3.6,

- CPL (with 0.22° atmospheric grid resolution) covering the whole ERA-Interim period. In these simulations, NEMOMED12 was initialized using 30-years of spun-up state.

- CPL_noSP (with 0.22° atmospheric grid resolution) covering over the whole ERA-Interim period. In these simulations, NEMOMED12 was initialized using MED-ATLAS-II climatology. These simulations were performed to analyse the impact of Mediterranean Sea initialization on the atmosphere.
- CPL_INI2 (with 0.22° atmospheric grid resolution) from 1990 to 2010. In these simulations NEMOMED12 was initialized every year with the MED-ATLAS-II climatology.

Mediterranean Sea initialization

The Mediterranean Sea's initialization experiments show that the SST quickly (in a couple of months) adopts the atmospheric conditions. However, more detailed analysis is required. Further, these simulations can be used to analyze the impact of the Mediterranean Sea interaction on short time scale and in case of extreme events (Fig. 1).

Aerosol Optical Depth

The aerosol optical depth (AOD) climatology is very important in the ocean-atmosphere coupled system, especially in regions like the Mediterranean Sea area which is an aerosol crossroad. We used two different AOD climatologies (MACC and Tegen) with two different atmospheric grid resolutions (0.44° and 0.22°). The initial results showed that the sea surface heat fluxes over the Mediterranean Sea are strongly sensitive to the AOD. The AOD climatology effects the surface heat fluxes which in return modify the sea surface temperature in the coupled simulations (Fig. 2). These simulations still need more detailed analysis to quantify the impact of AOD with different atmospheric grid resolution on surface heat fluxes.

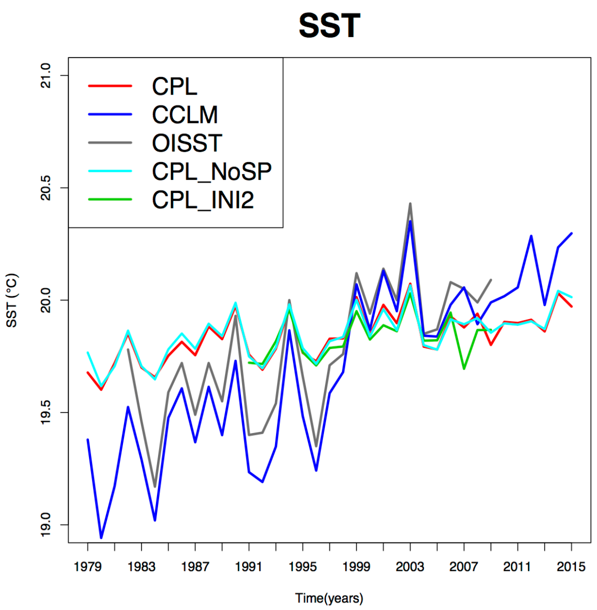
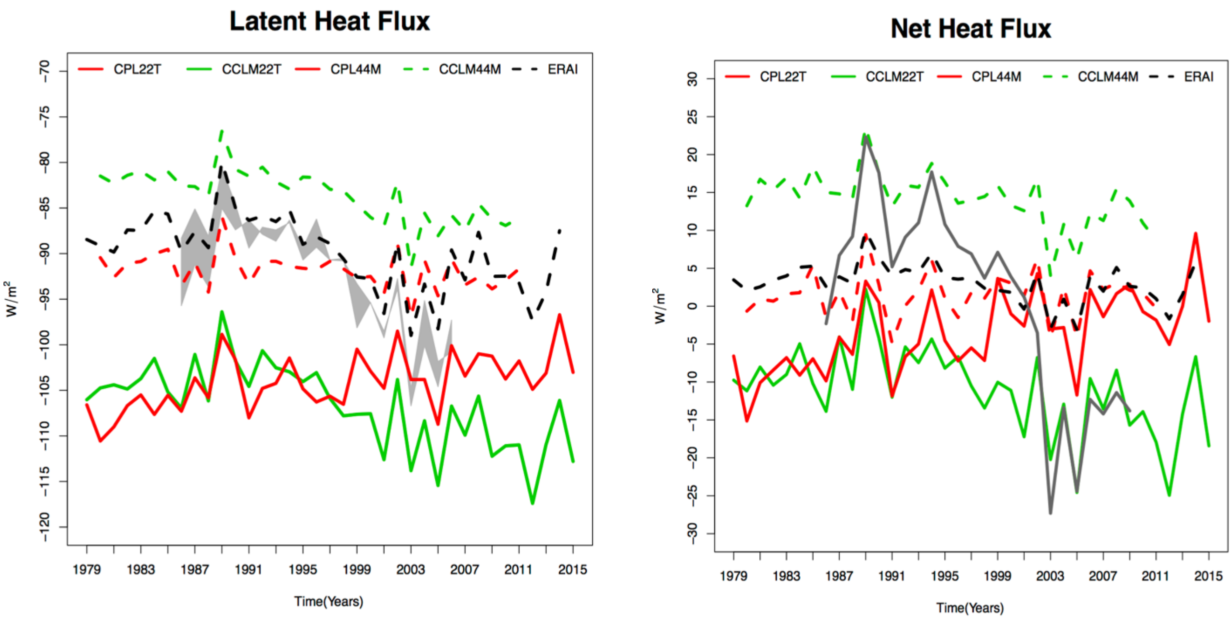


Fig. 1. Sea surface temperature of the Mediterranean Sea in the simulations CPL, CPL_no_SP, CPL_INI2 with COSMO-CLM and in the OISST observations derived from AVHRR satellite data.



(a) (b)

Fig.2. (a) Latent heat flux and (b) total heat flux over the Mediterranean Sea in the coupled simulations (CPL22T; resolution = 0.22°, AOD = Tegen and CPL44M; resolution = 0.44°, AOD = MACC) and un-coupled (CCLM22T; resolution = 0.22°, AOD = Tegen and CCLM44M; resolution = 0.44°, AOD = MACC), ERA-Interim data and OAFlux data (gray color).

Conclusion

The simulations performed at DKRZ were very useful not only for HyMeX community but also for the MED-CORDEX community. The simulations were translated into a good number of peer-reviewed scientific publications.

Outlook

In future, we want to continue the development of the coupled system. The implementation of river routing scheme (TRIP or HD) in the coupled system is necessary for more realistic freshwater discharge (which is also a future constraint of MED-CORDEX). We would like to continue our participation in MED-CORDEX, where high resolution (0.11°) with the fully coupled system are already planned.

References:

Note: The reference list also includes the list of publications established on simulations produced at DKRZ. Names of the project members are in bold.

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