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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Calibration of the new regional ocean-atmosphere model based on ICON and NEMO for the EURO-CORDEX domain

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The coupled regional ocean-atmosphere model based on ICON and NEMO (ROAM2.0) was developed within the framework of the DAS core service, based on developments by Helmholtz-Zentrum Hereon. It will be used for the downscaling of CMIP6 GCM's for the EURO-CORDEX domain. The aim is to provide consistent projections for both the atmosphere and the ocean e.g. for the investigation of storm surges on the German coast or as a forcing for impact models as e.g. estuary models.

Components of the coupled model
1) ICON-CLM

ICON in climate limited-area mode (ICON-CLM, Pham et al. 2021) is the successor of COSMO-CLM used as regional climate model by the CLM community. It is essentially the same model version as used for operational numerical weather prediction in Germany, Italy, Poland, Greece, Rumania, Russia, and Israel. For uncoupled ICON-CLM simulations, SST and sea ice are prescribed at the same temporal frequency as the LBC's. Evaluations of simulations for the EURO-CORDEX domain have shown that an upper boundary nudging has to be used as well.

2) NEMO-GCOAST

The NEMO-GCOAST setup (Ho-Hagemann et al., 2020) includes the entire North-West-Shelf (Fig. 1) to take into account the impact of the North Atlantic weather systems on the dynamics of the seas and the cross-shelf transport. As the setup should deliver climate projection data for the target regions North Sea and Baltic Sea with focus on the German coastal region and its estuaries, it has to be adapted to regional characteristics like narrow straits, shallow coastal areas and wetting and drying of tidal flats. An adjusted bathymetry based on up-to-date measurements of the sea floor from the EMODNET network is implemented. The setup has a horizontal resolution of 2 nm.

3) Coupling

The coupling of ICON-CLM and NEMO-GCOAST is done via oasis3-mct5. As in the global ICON-based earth-system model currently under development, ICON-CLM sends the energy and radiation fluxes on surface tiles. All exchanged variables are indicated in Fig. 2. SST and sea ice cover have to be taken from the forcing data in ocean regions not covered by NEMO-GCOAST.
An online adaptation of the atmospheric land-sea mask to the one of the ocean is used to ensure a consistent exchange of variables along the coast.

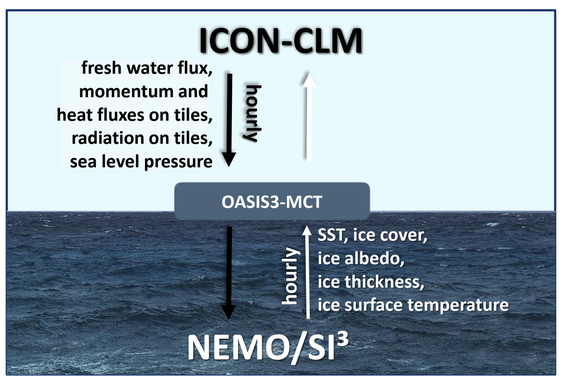

Figure 2: Coupling variables and frequency for ROAM2.0

Experiment setup

- **forcing data**: ERA5 / ORAS5; FES 2014 for the tides; own dataset for river runoff
- **initialization** of the ocean from a synthesis of CMEMS reanalysis, ORAS5 and Met Office NWS data; additionally, a 2-year spin up in the ocean was made
- NEMO version 4.2
- ICON based on release 2.6.6
- simulations from Sep. 1999 – Dec. 2004, **evaluation for 2000-2004**
- **reference data** for evaluations: ERA5, E-OBS and CERES (atmosphere), OSTIA and in-situ observations (ocean)

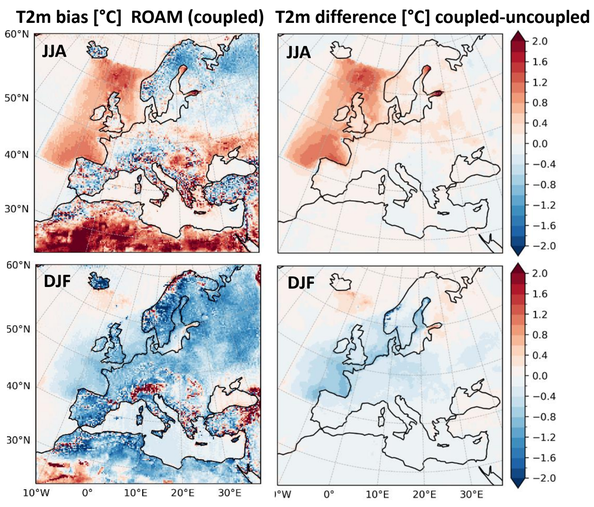

Figure 3: 2m temperature bias against ERA5 (left) and 2m temperature difference between the coupled and the uncoupled simulation (right), both for summer (top) and winter (bottom).

Evaluation of coupled simulations and tuning tests

- surface and 2m temperature show a warm bias in summer and a cold bias in winter over the Atlantic ocean (Fig. 3)

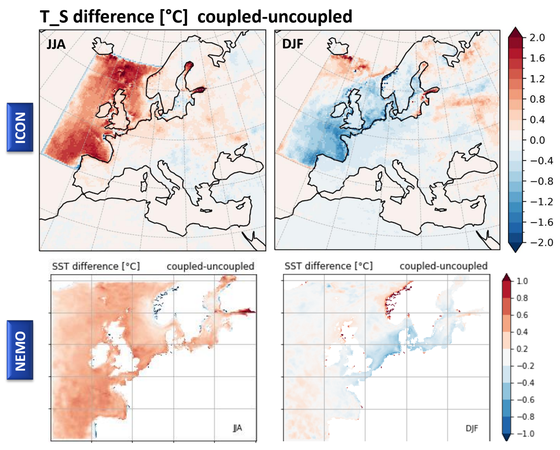

Figure 4: Surface temperature (top) and SST differences (bottom) between the coupled and the uncoupled model for ICON and NEMO, respectively, both for summer (left) and winter (right)

- differences of coupled to uncoupled simulation smaller for NEMO than for ICON, but same directions (Fig. 4)
  → both models have biases
  → most prominent: warm bias over the Atlantic ocean in summer
  → *surface forcing by ICON too strong?*
- in summer, surface net shortwave and surface net radiation have a positive bias compared to CERES data (Fig. 5)
- surface energy balance has a positive bias compared to ERA5 over the ocean (Fig. 5)
  → surface energy balance over the ocean usually not validated in uncoupled atmospheric models

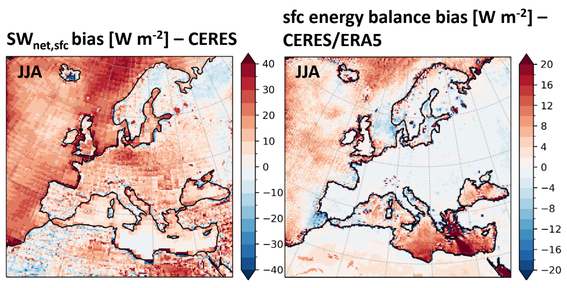

Figure 5: Surface net shortwave radiation bias against CERES (left) and surface energy balance bias (right) against ERA5 (fluxes) and ERA5 (radiation), both for summer.

- cloud cover has a negative bias over the ocean compared to CERES (Fig. 6)
  → increasing the cloud cover by a simple parameter tuning reduces the radiation bias and, to less extent, the temperature bias (Fig. 6)

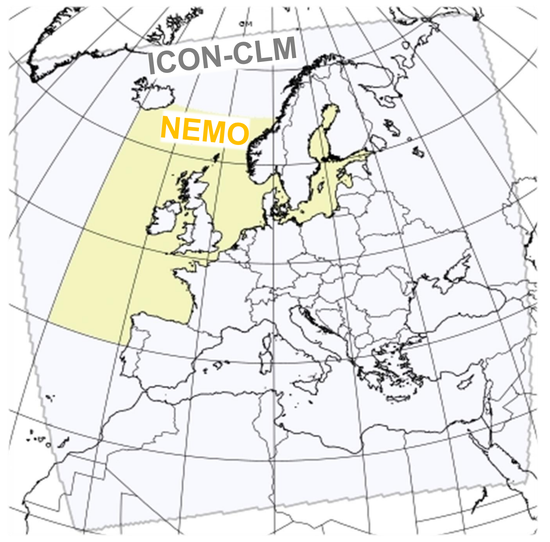

Figure 1: EURO-CORDEX domain for ICON-CLM (gray quadrangle) and NEMO-GCOAST domain (in yellow).

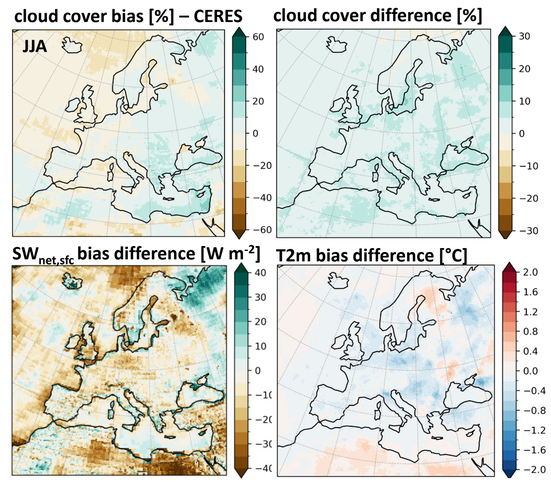

Figure 6: Cloud cover bias of the reference simulation against CERES (top left), difference of the cloud cover after tuning compared to the reference (top right), and bias difference of surface net shortwave radiation (bottom left) and of 2m temperature (bottom right) between the tuning and the reference simulation.

Conclusions and Outlook

The calibration of the coupled model, i.e. the refinement of the setups of both model components, of the coupling itself and of the tuning has improved ROAM2.0 considerably. Still, calibration is ongoing and an improvement of ICON skill scores for the EURO-CORDEX domain is expected from further tuning activities currently done by the CLM community. The coupling with a runoff model, which will be used for projections, has to be evaluated as well.

The „German strategy for adaptation to climate change" (DAS) is the political framework for adapting to the impacts of climate change in Germany. The Deutscher Wetterdienst, the Federal Maritime and Hydrographic Agency (BSH), the Federal Institute of Hydrology (BfG) and the Federal Waterways Engineering and Research Institute (BAW) are collaborating within the framework of the DAS core service to provide a data basis that supports the DAS process.

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Ho-Hagemann, H.T.M., Hagemann, S., Grayek, S., Petrik, R., Rockel, B., Staneva, J., Feser, F., & Schrum, C. (2020): Internal Model Variability of the Regional Coupled System Model GCOAST-AHOI. Atmosphere 2020, 11, 227, doi:10.3390/atmos11030227
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