Regional Earth System Models for CMIP6 downscaling over the EURO-CORDEX domain

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Helmholtz-Zentrum hereon

Regional Earth System Models (RESMs) of CLM-Community

RESMs with COSMO-CLM

Hereon

Geesthacht Coupled cOAstal model SysTem (**GCOAST**)

- **CCPL5.0: CCLMv5.0 + NEMO v3.6 + WAM + OASIS3-MCT v2.0** (Grayek et al., 2023)
- **CCPL6.0: CCLMv6.0 + NEMO v3.6 + HD v5.1 + OASIS3-MCT v4.0** (Fig.1)

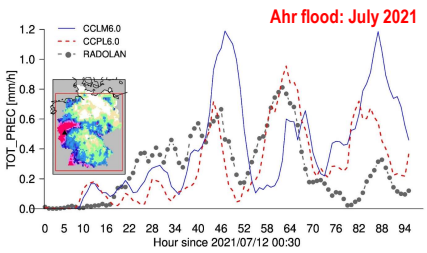


Figure 1: The coupled simulation **CCPL6.0** captured the hourly precipitation [mm/h] of the RADOLAN observation data better than the atmosphere-only **CCLM6.0**. Data are averaged over Germany for 12–15 July 2021

IOW

IOW Earth System Model (**IOW-ESM**)

CCLM v5.0 + MOM5 + OASIS3-MCT v4.0

communication on exchange grid via **flux calculator** (Karsten et al., 2023)

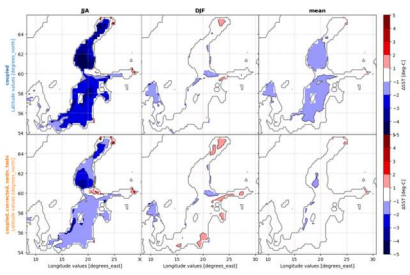
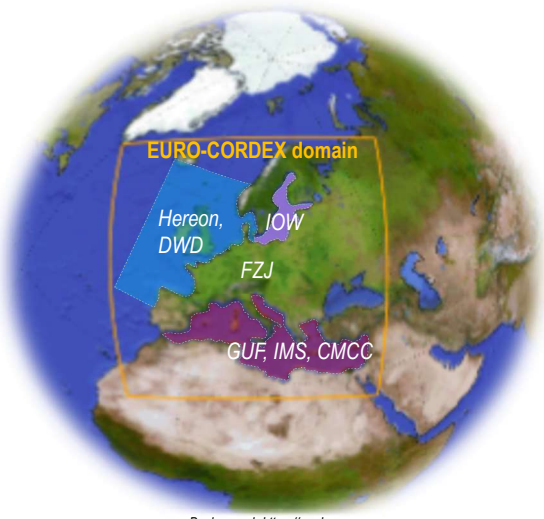


Figure 2: SST bias [°C] is reduced in the coupled simulation when applying the bias correction (increased downward radiation fluxes) for the hindcast simulation (1959-today) forced by ERA5 reanalysis data



Background: https://cordex.org

EURO-CORDEX domain and ocean coupling domains used in different Institutions within the CLM-Community

RESMs with ICON-CLM

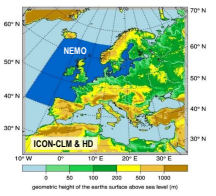
Hereon & DWD

GCOAST

ICPL266: ICON266 + NEMO v3.6 + HD v5.1 + OASIS3-MCT v4.0 (Fig.6)

Regional Ocean-Atmos. Model (**ROAM**)

ROAM2.0: ICON266 + NEMO v4.2 + OASIS3-MCT v5.0 (Fig.5)



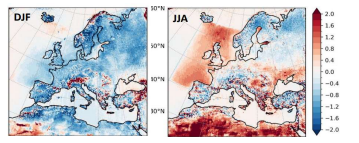


Figure 5: Winter (DJF) and summer (JJA) T_2M biases of the coupled **ROAM2.0** against the ERA5 data for 2000-2004

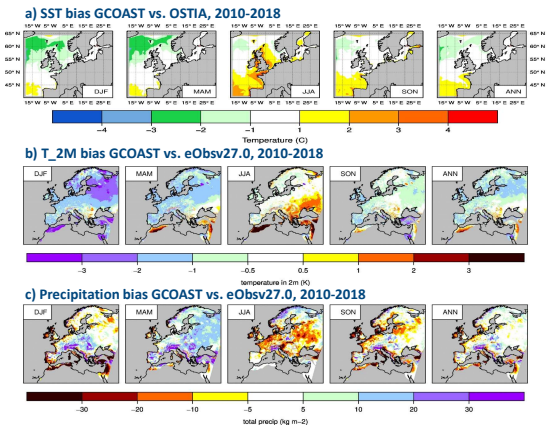


Figure 6: Seasonal biases of (a) SST, (b) T_2M, (c) Precipitation between the coupled simulation **ICPL266** of the GCOAST system and OSTIA and eObs v27.0 data. Time: 2010-2018.

GUF

CCLM v5.0_clm9 + NEMO-MED12 v3.6 + TRIP + OASIS3-MCT v2.8 (Fig.3)

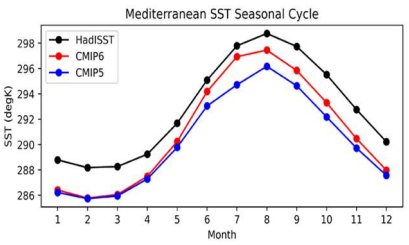


Figure 3: Mediterranean sea surface temperature seasonal cycle of HadISST and the dynamical downscaling of EC-Earth3 (**CMIP6**) and EC-Earth2 (**CMIP5**).

FZJ

TSMP: CCLM v5.01 + CLM v3.5 + ParFlow v3.9.0 + OASIS3-MCT v2.0 (Fig.4)

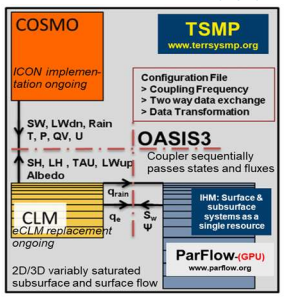


Figure 4: Coupled groundwater-to-atmosphere

Transient aerosols for RESMs

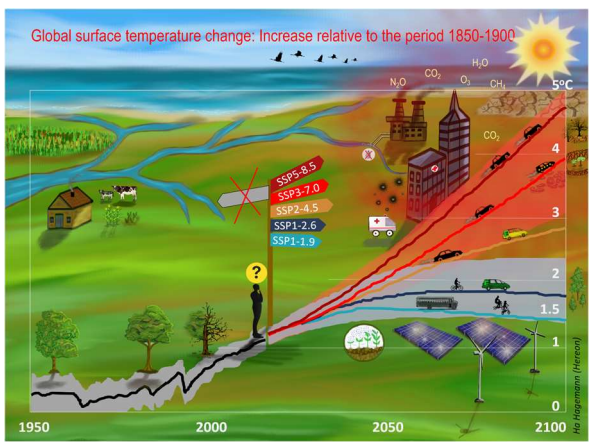
- **ICON-CLM**
  - MACv2.0-SP transient aerosols (Kinne MACv2.0 + antropogenic simple plumes) which are on the lon-lat-wave length band grid and the grid of simple plumes, respectively.
- **COSMO-CLM (CCLM)**
  - Official CCLM versions can run with only two aerosol climatologies (Tanré et al. [1984] and Tegen et al. [1997])
  - One unofficial version based on the official CCLM v5.0 can run with the MAC v2.0 aerosols but uses assumptions to convert the total optical depths into optical depths of single aerosol types (organic matter, black carbon, dust, sea salt, SO4) to mimic the Tegen aerosol data
  - The MAC v2.0 aerosols used in the unofficial version CCLM v5.0 are on a lon-lat-level grid that is not the same as MACv2.0-SP ➔ They need to be converted to a usable grid, and require source code modification in CCLM
  - MIROC6 runs from CMIP6 have suitable transient aerosols from all runs (historical and SSPs scenarios) that can be used for CCLM

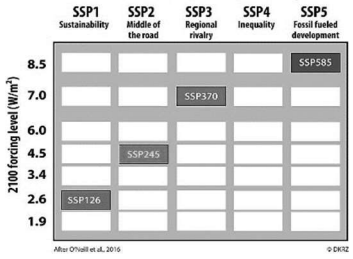
GUF & IMS & CMCC

On-going development of the regional coupled system model **ICON-CLM + NEMO_MED** for the Mediterranean Sea region (*IMS, CMCC*) with technical supports from *Hereon, DWD, GUF* (Germany) and *LMD, Meteo-France/CNRM* (France)

Downscale CMIP6 over the EURO-CORDEX domain with RESMs

Climate change scenarios Shared Socioeconomic Pathways (SSPs)





https://www.dkrz.de/en/communication/climate-simulations/cmip6-en/the-ssp-scenarios

SSP1: Sustainability – Green Road
SSP2: Middle of the Road
SSP3: Regional rivalry – Rocky Road
SSP4: Inequality – Road Divided
SSP5: Rapid growth – Fossil-fueled Highway

Figure 7: Adaptation of Figure SPM.3a of the Intergovernmental Panel on Climate Change (IPCC), Climate Change 2022: Impacts, Adaptation and Vulnerability, Summary for Policymakers.

Table 1: Planned simulations with RESMs to downscale CMIP6 over the EURO-CORDEX domain

GCM / RESM	Coupling Area	ERA5 + ORAS5 Reanalysis	EC-Earth3-Veg r1i1p1f1	MPI-ESM1-2-HR r1i1p1f1	MIROC6 r1i1p1f1	CMCC-CM2-SR5 r1i1p1f1
COSMO-CLM (0.11°)						
+NEMO+HD/WAM	NS, BS, NA	Hereon	Hereon (1,2,3)	Hereon (1,2,3)	Hereon (1,2,3)	
+NEMO_MED+TRIP	Mediterranean		IAU-GUF(1,4)*			
+CLM+ParFlow	Europe	FZJ		FZJ (1,2,3)		
+MOM5	BS	IOW	IOW (1,3)	IOW (1,2,3)	IOW (1,3)	IOW (1,3)
ICON-CLM (R13B5)						
+NEMO+HD	NS, BS, NA	Hereon	Hereon (1,2,3)	Hereon (1,2,3)	Hereon (1,2,3)	
+NEMO(+HD)	NS, BS, NA	DWD	DWD (1,2?,3)	DWD (1,2?,3)	DWD (1,2?,3)	
+NEMO_MED	Mediterranean	IMS	IMS (?)	IMS (?)	IMS (?)	

*Finished

Historical (1) SSP126 (2) SSP370 (3) SSP585 (4)

We acknowledge B. Rockel (Hereon, retired) for the starter package for CCLM & ICON (SPICE) & P. Ludwig (KIT) for the GCMs converter to prepare CMIP6 forcings for CCLM and ICON

Summary

- Further develop the Regional Earth System Models (**RESMs**) of COSMO-CLM coupled to ocean models (NEMO, MOM5), hydrological discharge model (HD), wave model (WAM) via the OASIS3-MCT coupler for the EURO-CORDEX domain, with a focus on the North Sea and Baltic Sea regions (*Hereon, IOW*) and the Mediterranean Sea (*GUF*)
- Further develop the RESMs of COSMO-CLM/ICON-CLM coupled to the community land model (eCLM) and the groundwater model (ParFlow) via OASIS3-MCT (*FZJ*)
- Further development of the RESM including ICON-CLM, NEMO and HD coupled via OASIS3-MCT for the North Sea and Baltic Sea regions (*Hereon*, *DWD*)
- Set up a joint activity of CMIP6 RESMs downscaling using the above mentioned RESMs for the EURO-CORDEX domain (*Hereon, DWD, IOW, GUF, FZJ*)
- New development of the regional coupled system model ICON-CLM + NEMO_MED for the Mediterranean Sea region (*IMS, CMCC*) with technical supports from *Hereon, DWD, GUF* (Germany) and *LMD, Meteo-France/CNRM* (France)
- Transient aerosols for COSMO-CLM will be handled following the EURO-CORDEX's protocol and based on the available transient aerosols forcing data which can be used for COSMO-CLM

New publications:

- Grayek, S., Wiese A. , Ho-Hagemann, H. T. M., Staneva, J. (2023): Added Value of Including Waves into a Coupled Atmosphere-Ocean Model System within the North Sea Area, Frontiers in Marine Science https://doi.org/10.3389/fmars.2023.1104027
- Karsten, S., Radtke, H., Gröger, M., Ho-Hagemann, H. T. M., Mashayekh, H., Neumann, T., and Meier, H. E. M.: Exchange-grid coupling approach for the IOW Earth System Model (version 1.04.00) of the Baltic Sea region, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2023-166, in review, 2023

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