Relevance of meso-scales in Central America for decadal predictability in Europe

M. Thürkow[1], I. Kirchner[1], M. Schuster[1], U. Ulbrich[1], S. Weiher[2] and A. Will[2]

[1]Institute of Meteorology, FU-Berlin; [2]Chair of Environmental Meteorology, BTU Cottbus

Freie Universität Berlin

Brandenburg University of Technology Cottbus

Overview

The Rossby Wave Trains are large-scale atmospheric phenomena of high relevance for the predictability of mean weather conditions in Europe. The project MesoTel aims at improving the simulation of the large-scale flow by an improved representation of its initial condition in the Intra-Americas Sea region and the upscaling effects in the Atlantic region. To achieve this a 2-way nesting between the model systems MPI-ESM and COSMO-CLM is being developed. The challenges of this development are the numerical efficiency of the 2-way coupling, a high quality of the meso-scale simulation in the Central America to North Atlantic region, CANA, and a physically consistent coupling between the non-hydrostatic meso-scale model system COSMO-CLM and the hydrostatic global circulation model system MPI-ESM.

1. Motivation

It is well known that upscaling effects of energy and/or potential enstrophy play an important role for the development of large-scale atmospheric phenomena. As can be seen from the mean global precipitation pattern, the high impact large-scale weather systems originate in the northern hemisphere in South-East Asia and in Central America. In particular the development of strongly growing Rossby Wave Trains (Shapiro and Thorpe 2004, Jones et al. 2006) is associated with cyclogenesis directly affecting the weather in Europe and SSTs in the Atlantic. This provides the opportunity to simulate the meso-scales in a limited region only.

In the last years, community model systems for global (MPI-ESM) and regional (COSMO-CLM) climate modeling have been established. Recently, the standard coupler OASIS3-MCT (Valcke et al. 2012) has been developed with the capability to exchange 3D fields on massively parallelized computer architectures. This provides the opportunity to develop a 2-way nested multi-scale model system consisting of COSMO-CLM, MPI-ESM and OASIS3-MCT. Thus, this project will investigate the effects of meso-beta-scale dynamics on large to planetary scales, aiming at improving climate prediction of seasonal means over Europe on a decadal time scale.

3. Performance of the 2-way nested model system

A series of 1-month-long simulations was conducted, for different types and numbers of 2D fields exchanged on IBM power 6 at DKRZ (blizzard) using one or two nodes and 64 tasks per node.

MPI-ESM (T63L47/GR15L40) and COSMO-CLM (221x111(0.44 degree) L40) grid points) each used 32 tasks per node.

Three different 2-way nesting modes were tested:

- 2D fields: exchange of n 2D fields
- 3D fields: exchange of three 3D fields concatenated from 2D fields plus two 2D fields

The results exhibit a very high efficiency of the 3D field coupling mode.

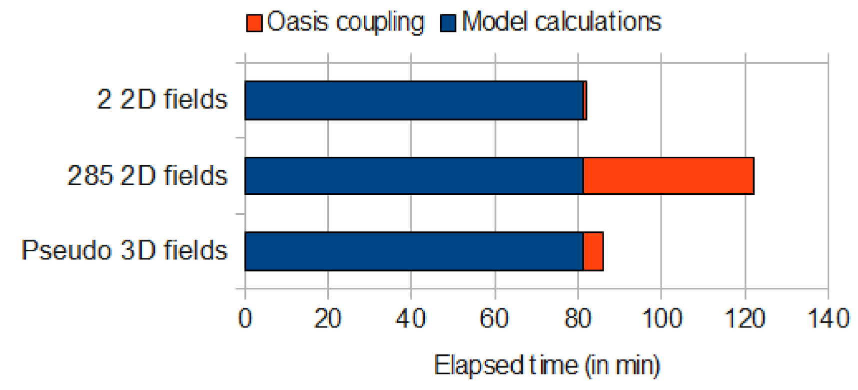

Fig. 3: Elapsed time consumed by MPI-ESM/ COSMO-CLM (blue) and by OASIS3-MCT (red) of the coupled system.

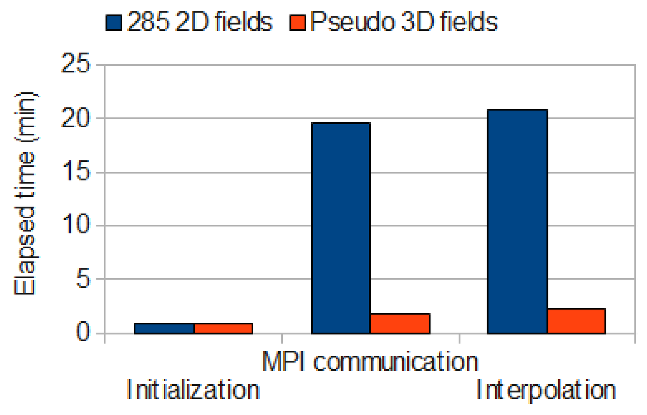

Fig. 4: As Fig. 6, but for three specific OASIS 3-MCT subroutines.

2. Model development

Fig. 1 gives a schematic overview of the 2-way coupling between the atmospheres of MPI-ESM and COSMO-CLM using OASIS3-MCT. Fig. 2 shows the time axis of the simulation and the steps of model development. At the initial time of the coupling (e.g. 00:00 simulated time) the ECHAM integration stops and the dynamic variables for two subsequent times (e.g. 23:50 and 00:00) are interpolated by OASIS3-MCT horizontally to the COSMO-CLM grid. In COSMO-CLM the ECHAM boundary conditions are interpolated vertically to the COSMO-CLM levels and the meso-scale simulation for the CANA region (see Fig. 5 and 6) between the times of the boundary condition (e.g. 23:50 and 00:00) is conducted.

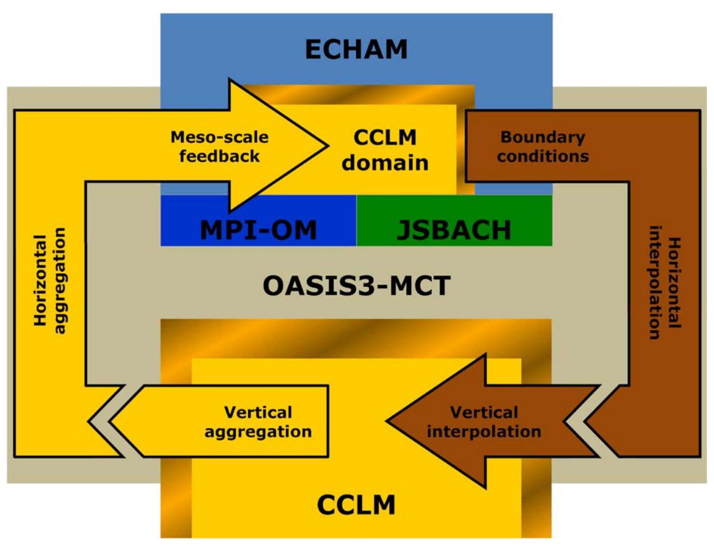

Fig. 1: Schematic flow diagram of the two-way nested system.

The solution for 00:00 is aggregated vertically to the ECHAM grid within COSMO-CLM and horizontally by OASIS3-MCT. In ECHAM the COSMO-CLM tendencies within the CANA region are calculated, the ECHAM solution is updated and the next time step is executed.

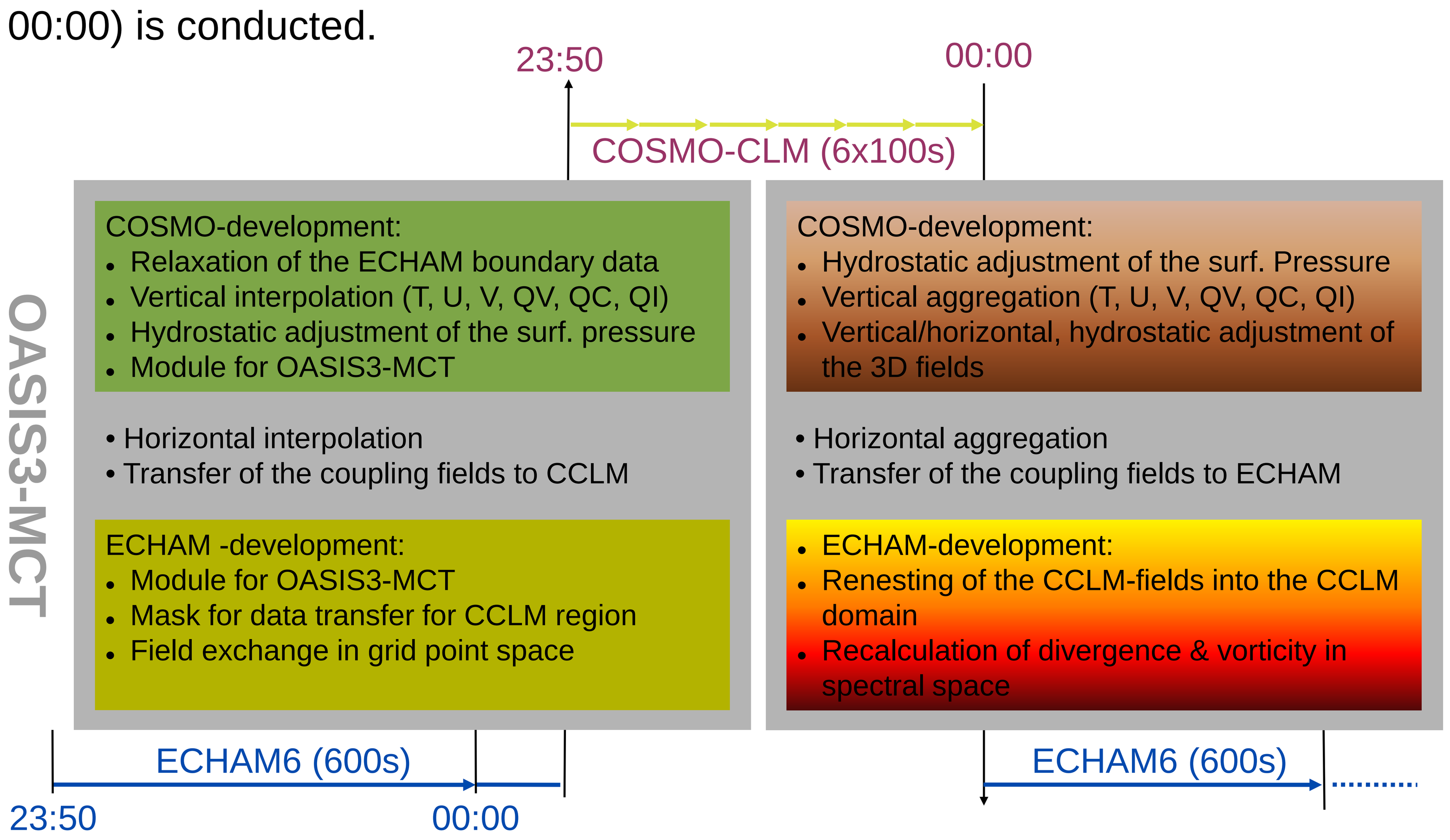

Fig. 2: Overview of the development of the 2-way nesting model system: Developments within ECHAM (light green), and COSMO-CLM (dark green). The mixed colors on their right hand side indicate that the work is not finished yet.

4. Evaluation of COSMO-CLM in the CANA region

Three evaluation simulations have been conducted with the COSMO-CLM for different configurations in order to reduce the model bias. We used the model version cosmo_4.8_clm17. The configuration MES001 is the same as used for the IPCCAR5 downscaling experiments over Europe (Keuler et al.) but for the CANA region and the horizontal resolution of 0.44 degrees. The modifications in the configurations MES002 and MES003 are summarized in Table 1. The significant reduction of the 2m temperature bias shown in Fig. 7 (c, d) can be attributed to free convection due to higher values of *rdheight*, at which the Rayleigh damping zone begins and the reduced minimum diffusion coefficient *tkh-/tkmmin* for heat and momentum reducing the minimal mixing in the boundary layer. The reduction of the lateral boundary relaxation function exponent (*lbcexp*=-10) and the optimization of the vertical grid stretching reduced the lateral boundary numerical artifacts (see Fig.6 b, d) and reduced the summer precipitation bias (Fig.7 a).

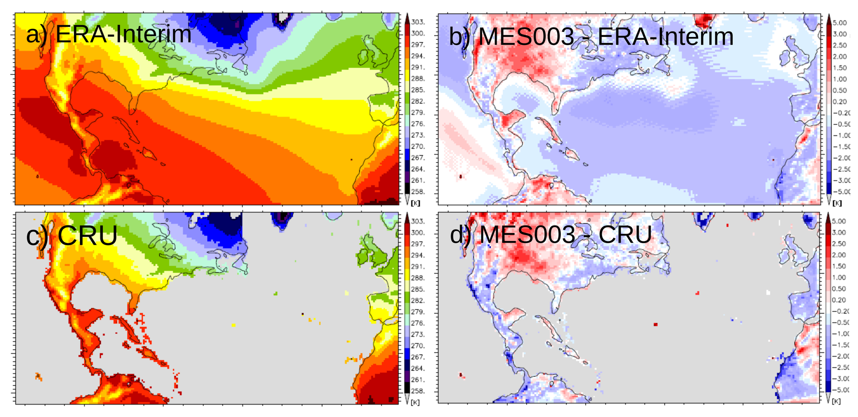

Fig. 5: Mean 2m temperature 1989 – 1993 in the COSMO-CLM domain CANA for a) ERA-Interim c) CRU, b) MES003 - ERA-Interim and d) MES003 - CRU.

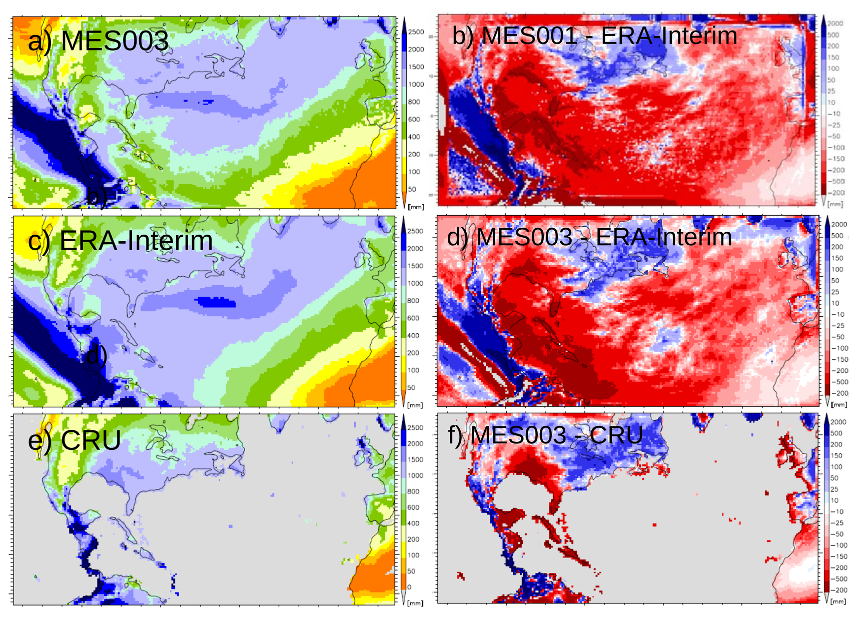

Fig. 6: Mean annual precipitation 1989 – 1993 in the COSMO-CLM domain CANA for a) CCLM-Simulation MES003, c) ERA-Interim, e) CRU, b) MES001 - ERA-Interim, d) MES003 - ERA-Interim and f) MES003 - CRU.

Parameters	MES001	MES002	MES003
Δt [s]	240	240	150
Δλ [°]	0.440	0.440	0.165
Lon x Lat x Lev	221x111x40	221x111x40	599x301x45
rlwidth [km]	200	400	200
lbcexp	-6	-6	-10
lfilter_oro	T	F	F
rdheight [km]	11	18	18
Vertic. Grid	Stand.	Stand.	cos
tkh/tkm-min	1.0	1.0	0.1
Albedo	Mean	mean	dry/wet
Extpar. version	1.5	1.5	1.6

Tab. 1: Model setup of the COSMO-CLM evaluation runs.

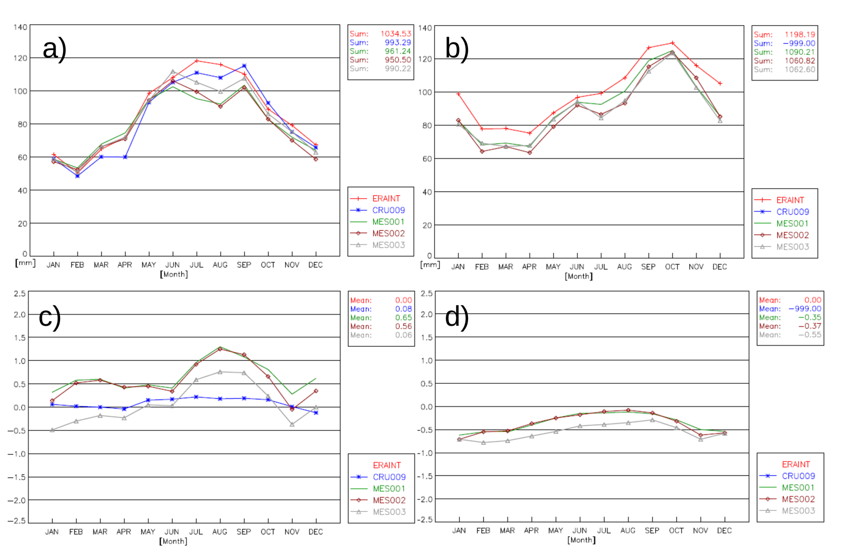

Fig. 7: Yearly cycles 1989 – 1993 of a, b) mean monthly precipitation and c, d) 2m temperature anomaly between ERA-Interim and CRU/MES001-MES003.

Summary and Outlook:

We demonstrated a very high efficiency of the 2-way nested model system MPI-ESM/COSMO-CLM using the OASIS3-MCT coupler. Furthermore, the capability of COSMO-CLM to simulate the regional climate in Central America could be shown as well, even though the simulated spatial distribution of mean precipitation is not satisfactory. This provides the opportunity to address the following question in the near future: Do regional processes affect the large-scale predictability?

References:

Jones et al. (2006): Die Umwandlung tropischer Wirbelstürme in außertropische Tiefdruckgebiete und ihr Einfluss auf das Wetter der mittleren Breiten, promet, Jahrg. 32, Nr. 3/4

Shapiro and Thorpe (2004): THORPEX International Science Plan, Version III

Valcke et al. (2012): OASIS3-MCT User Guide, OASIS3_MCT_1.0 (The user guide is included as pdf in the source that can be downloaded from https://verc.enes.org/oasis/ after registration.)

M. Thürkow, markus.thuerkow@met.fu-berlin.de

S. Weiher, weiher@tu-cottbus.de; A.Will, will@tu-cottbus.de

FONA Decadal Climate Prediction BMBF

MiKlip