FLAGSHIP

Feedback of a limited area model to the global scale implemented for hind-cast and projections

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Abstract:

The quality of decadal climate predictions strongly depends on the feedbacks between different processes and spatial scales in the models. Usually, processes, which cannot be resolved are parameterised. As a parameterisation is only an approximation, the question remains, how many information is lost by parameterising processes and whether the skill of the prediction can be enhanced, if these processes are resolved and thus better represented in the model. Therefore the key questions of the FLAGSHIP project are: 1) How does regional climate change influence global climate change? 2) How do process feedbacks cross the different spatio-temporal scales?

The focus of this study is North-West-Africa. The West African Monsoon (WAM) is a multi-scale phenomenon influencing the global circulation, while the WAM itself is affected by regional aspects as land surface types or orography. Furthermore, the WAM influences European climate.

To address the questions in the framework of FLAGSHIP a comprehensive modelling system from the global to the local scale is built, which allows for feedbacks of regional phenomena to the global scale. The system is based on two community models, the German Weather Service regional forecast and climate model COSMO and the global atmosphere – ocean general circulation model ECHAM5-MPIOM. Both models have been extended by the powerful Modular Earth Submodel System (MESSy) infrastructure.

After completion of the development of the two-way coupling, simulations zooming on West-Africa will be performed, enabling an evaluation of the feedback of processes on the regional scale to a global model simulation.

In addition to a mere dynamical coupling, FLAGSHIP includes atmospheric chemistry processes (implying aerosols) allowing to investigate their scale-dependent effects.

One focus of this project is dust emissions. Africa is one of the largest dust source regions and it is well known that dust alters the radiation budget substantially, which feeds back to the dynamics and thus to global circulation. Dust emissions depend on the surface properties and the surface wind speed, hence dust emissions are very differently resolved in models of different resolutions. Therefore changes in the dynamic patterns are expected, if the West-African region is better resolved compared to a pure global simulation. Aim of this study is to provide reliable evidence about the importance of these feedbacks for the skill of global decadal climate predictions.

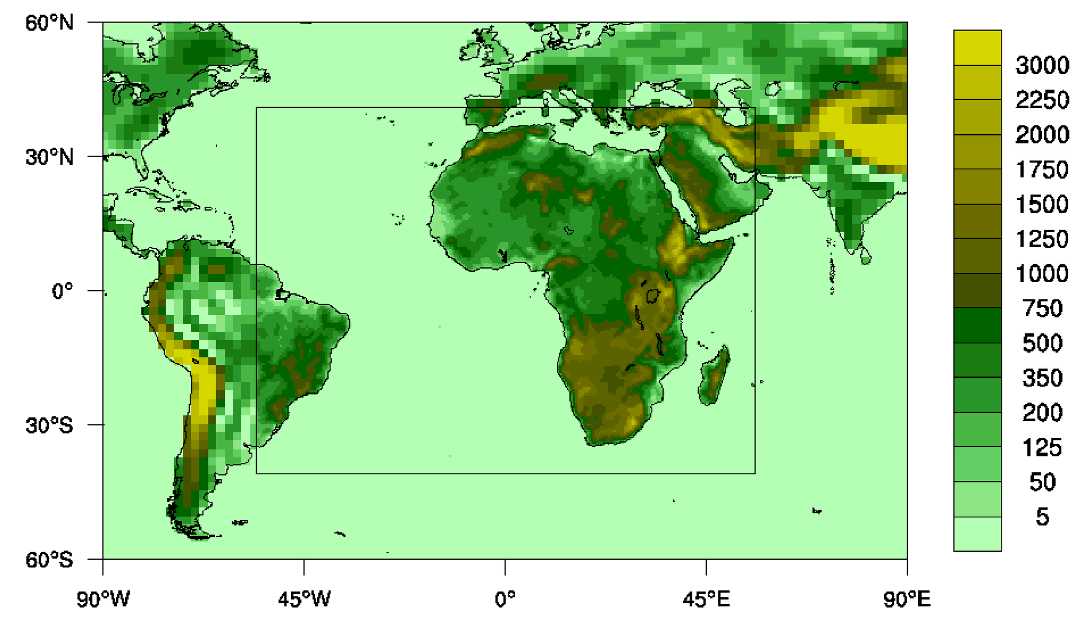


Figure 1: "DEPARTURE domain" embedded in the global EMAC *simulation. Shown is the Orography [m] of the respective model domains. The black box frames the regional model domain with a horizontal resolution of 0.44º, while EMAC is run in T63L47MA resolution.*

Test model setup for 2-way coupled scalar, conservative variables:

First, the 2-way coupling of scalar, conservative variables is implemented and tested.

Test case: a dust mobilisation event in March 2004.

Why dust? Dust mobilisation strongly depends on the 10m wind speed and surface parameters, thus distinct differences between the global and the regional (resp., the 2-way coupled) simulation are to be expected.

Setup:

a) a MECO(1) setup (i.e., one COSMO/MESSy nest) with the African domain used in the MiKlip-DEPARTURE project (see Fig. 1) as regionalisation area.

resolution: global T63L47MA, regional: 0.44˚ (0.22˚)

b) chemisry/physics setup:

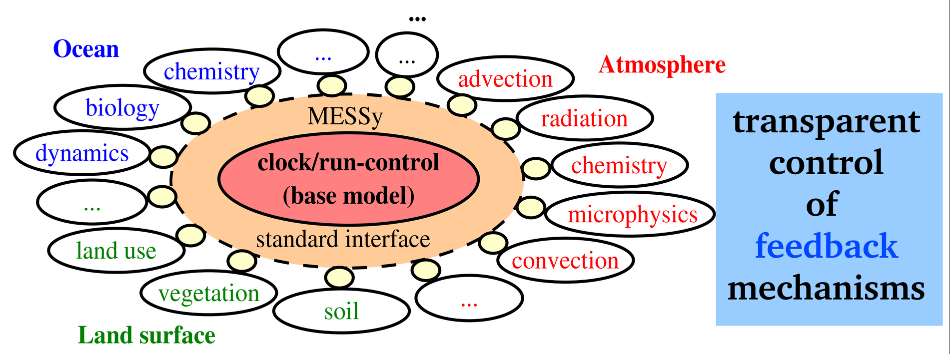
- simplified sulphur + stratospheric halogen chemistry scheme
- aerosol microphysics (M7)
- gas and aerosol source and sink processes

The 1-way coupled MECO(n) system:

MECO(n)=MESSy-fied ECHAM and COSMO models nested n-times => the basemodel ECHAM5 and COSMO equipped with the MESSy interface are nested into each other on-line,

i.e., all model instances are coupled via MPI and running at the same time. Figures 2a demonstrates a possible model setup. In this setup the model with the finer mesh is called the client and the driving model the server, as this model provides the data required for the boundary conditions of the limited area model.

process oriented approach of MESSy



- **Interface with infrastructure to couple 'processes' (= submodels) to a base model (e.g. GCM / RCM)**
- **Set of processes coded as switchable submodels**
- **Coding standard**

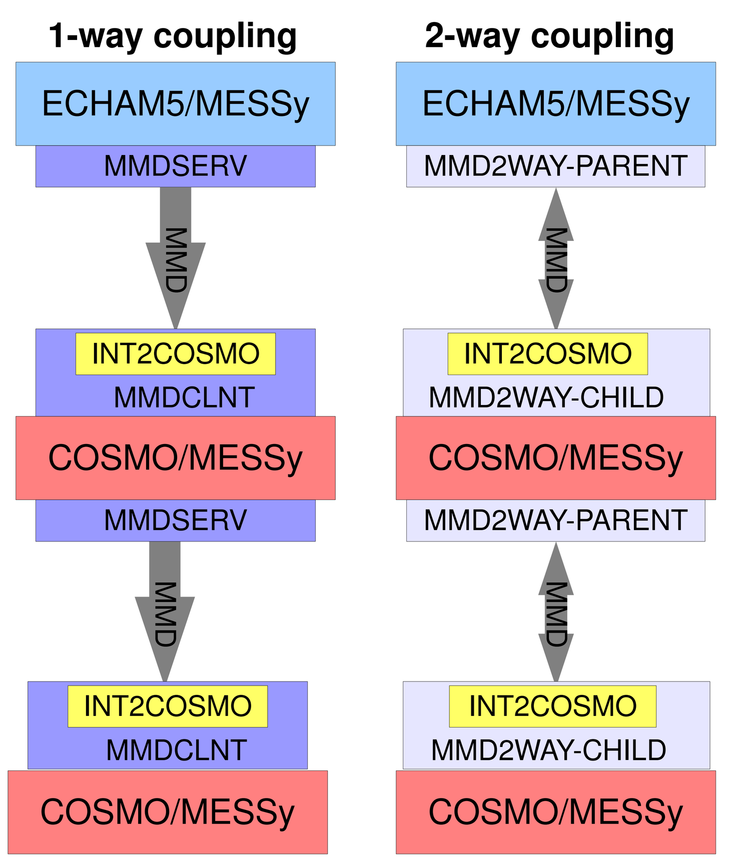


Figure 2: a) sketch of the 1-way coupled MECO(n) model setup: the MESSy submodels MMDCLNT and MMDSERV drive the data exchange using the Multi-Model Driver (MMD) library. MMDCLNT includes INT2LM (the COSMO preprocessor for initial and boundary conditions) called INT2COSMO here. b) sketch of the 2-way coupled MECO(n)- system. The MESSy submodels MMDCLNT and MMDSERV have been joined to the submodel MMD2WAY containing two sub-submodels CHILD and PARENT dedicated to the specific tasks in the coarser and the finer model domains. Additionally the MMD library was extended for 2-way data exchange.

1-way coupling:

SERVER: the "driving" model, i.e., the model providing the data required by a limited aread model for initial and boundary data (I&BD) calculations (in Fig. 2a, ECHAM5/MESSy and the first COSMO/MESSy instance)

CLIENT: always a limited area model, requiring the data for initial and boundary data calculation (in Fig. 2a: both COSMO/MESSy instances).

2-way coupling:

PARENT: the "driving" model, i.e., the model providing the data to the limited area model for I&BD calculations, here also the model forced by the 2-way coupling by subgrid-scale processes (in Fig. 2b, ECHAM5/MESSy and the first COSMO/MESSy instance)

CHILD: always a limited area model, requiring the data for initial and boundary data calculation and the model providing resolved subgrid scale processes to the PARENT (i.e. the coarser) model (in Fig. 2b both COSMO/MESSy instances)

- Documentation of the MECO(n) system:
- COSMO/MESSy:
  Kerkweg A. and P. Jöckel: The 1-way on-line coupled model system MECO(n): Part 1: COSMO/MESSy ; Geosci. Model Dev., 5, 87-110, 2012
- On-line Coupling:
  Kerkweg A. and P. Jöckel: The 1-way on-line coupled model system MECO(n): Part 2: On-line Coupling ;Geosci. Model Dev., 5, 111-128, 2012
- Meteorological Evaluation:
  Hofmann, Ch., A. Kerkweg, H. Wernli and P. Jöckel: The 1-way on-line coupled model system MECO(n): Part 3: Meteorological Evaluation Geosci. Model Dev., 5, 129-147, 2012

Developing the 2-way coupled MECO(n) system

The implementation of 2-way coupling is split into three substeps:
A) extension of 1-way to 2-way data exchange
B) implementation of interpolation methods
C) implementation of forcing of coupled variables

A) Extension to 2-way data exchange:

Fig. 2b sketches the developments required to enable the 2-way data exchange:
1) The Multi-Model-Driver (MMD) library, build for the 1-way data exchange between the driver and the driven model was expanded to enable the exchange of 2- and 3-dimensional fields in both directions.
2) The independent submodels MMDCLNT and MMDSERV have been joined to the submodel MMD2WAY. This enables the efficient usage of exchanged information about the two model grids and, even more important, the use of the same MPI buffer in the MMD library.
3) The data exchange in both directions is fully namelist driven.

C) Implementation of the forcing of coupled variables:

last but not least, the data interpolated from the childs grid to the parent grid is used to "nudge" the respective parent variables to the subgrid scale information. Scalar, conservative variables will always be forced in grid point space, the wind (u,v) or divergence and vorticity and the temperatur are most likely changed in spectral space. This will bedecided on in accordance to the MesoTel project.

B) Implementation of interpolation methods:

the interpolation from the child to the parent model domain (see left boxes for a clarification of these terms) will be performed by the child. Therefore an interpolation method able to interpolate curvi-linear grids is required. Interpolation in 3D space is split into horizontal and vertical interpolation. The horizontal interpolation will be performed by the SCRIP software (http://climate.lanl.gov/Software/SCRIP), while the vertical interpolation will be performed either by using the vertical interpolation procedure of INT2COSMO or the vertical interpolation of NCREGRID (Jöckel, ACP, 2006), which is already implemented in MESSy, but only applicable for rectangular geographical grids. The implementation of the SCRIP software in MESSy is finished. The vertical interpolation and the implementation of SCRIP into MMD2WAY is on-going work.

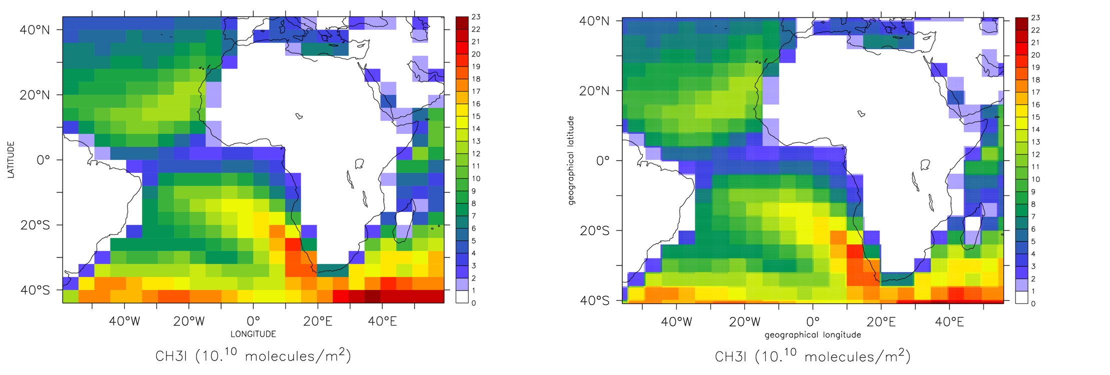


Figure 4: Example for a horizontal regridding application using the newly implemented SCRIP software for the DEPARTURE domain. Shown is the emission flux of CH3I. Left: input as provided by file. Right: COSMO/MESSy model domain.