Atmospheric chemistry-climate feedbacks in a coupled climate model

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***K. Matthes and S. Wahl**, GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel*

In Short

- Validate a new coupled chemistry climate model
- Improve understanding of coupled chemistry climate models
- Evaluate the importance of chemical processes in coupled climate models

It is becoming increasingly recognized that resolving the stratosphere and modeling its variability and interaction with e.g. ozone chemistry are necessary to correctly simulate tropospheric weather and climate ([1]). Perhaps the clearest example of this is the change in the tropospheric jet stream associated with the development of the Antarctic ozone hole ([1]). Another example is the solar influence on climate where chemical processes and most importantly ozone significantly enhance dynamical signals in the stratosphere-troposphere-ocean system ([3,4]). The latter topic has been tackled in various projects at GEOMAR using the Community Earth System Model CESM1(WACCM), and some of them suffered from limiting factors in their model configuration. For example, CESM1(WACCM) has, on the one hand, a well-tested interactive chemistry module implemented (MOZART3), but, at the same time, is not able to simulate the quasi-biennial oscillation internally and therefore needs to be nudged in the tropical stratosphere ([2]).

To overcome the aforementioned shortcomings, and to fill the "chemistry gap" in our newly developed modelling framework Flexible Ocean and climate infrastructure (FOCI, Figure 1), ECHAM6-HAMMOZ (ECHAM6 with interactive chemistry scheme based on the MOZART chemical solver, and optionally fully interactive aerosols) has been implemented in FOCI as part of project shk00018 in 2017, and can now be used with prescribed sea surface temperatures or coupled to the NEMO ocean model.

We use the HAMMOZ version of ECHAM6.3 in the atmosphere ([5]), under review at GMD) in this project. ECHAM6-HAMMOZ technically allows to run both the Hamburg Aerosol Model (HAM) and version 3 of the Model for Ozone and Related Chemical Tracers (MOZART3 or MOZ) separately or simultaneously. We implemented a simplified chemical solver into HAMMOZ which uses 52 chemical tracers and takes into account 185 reactions including 50 chemical reactions for photolysis related reactions. Atmosphere and land components run on a T63 (1.875°) grid with 95 vertical levels in the atmosphere and a top height of 0.01 hPa (80 km). This model is thus able to internally generate a QBO. The ocean model runs in a global 1/2? grid (ORCA05 grid) configuration with 46 vertical levels. The, to our knowledge, unique nesting features of FOCI are explored in sister projects shk00028 and shk00029. Ocean and atmosphere are coupled via the OASIS3-MCT coupler.

We plan to run a set of simulations using FOCI-HAMMOZ under past, present and future climate conditions. Although we do not officially participate in CMIP6, our simulations will follow the DECK protocol. A first set will use ECHAM6-HAMMOZ with prescribed sea surface temperatures and sea ice following the Atmosphere Model Intercomparison Project"'s (AMIP) protocol from 1979 to 2014. A second set of experiments will use the fully coupled FOCI-HAMMOZ system to simulate both historical and future climate following the Representative Concentration Pathways scenario 8.5 (RCP8.5, [6]). To save CPU time we initialize the scenario experiments in 1960 using initial conditions from year 1960 from the historical simulations started in 1850 as part of project shk00018 using the standard FOCI system (see HIST experiments in section 5.4 of project shk00018"'s granted proposal for 2018). From a scientific point of view, not much information is lost as the most dramatic change in the chemical composition of the stratosphere, the formation of the ozone hole, starts well after 1960. Chemical tracers for FOCI-HAMMOZ are initialized from model year 1960 from historical simulations with CESM1(WACCM) which are currently analyzed. Again, we plan to run a small ensemble (we limit ourselves in the coupled setup to 3 ensemble members to reduce both the need in CPU and storage resources). The output of our model simulations will be used to tackle the following questions:

- How does our model perform in comparison with other coupled climate models, models that are part of Coupled Climate Model Initiative, or existing CESM1(WACCM) simulations that are available and well-understood from previous projects (e.g. [7])?
- What is the importance of interactive chemistry

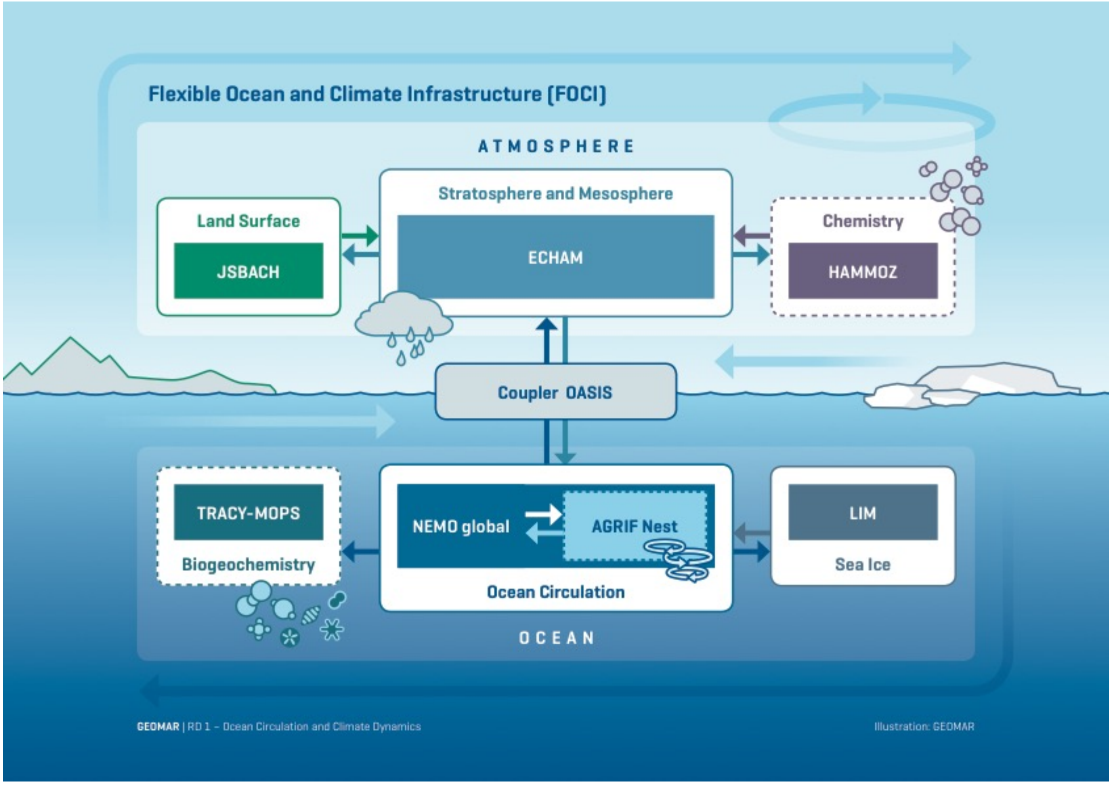

Figure 1: *Schematic of our new model system. Individual model components can be used interactively or in forced-mode (atmosphere-only, ocean-only)*

by comparing the simulations from this project with the same type of simulations using standard FOCI in project shk00018?

In addition, ozone data derived from our simulations will be used to study the importance of interactive vs. prescribed ozone (either 2D or 3D, thus capturing the effect of asymmetric ozone effects, i.e. ozone waves) for climate variability and climate change, and is planned for investigation in a future project.

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http://www.geomar.de/id=kmatthes

More Information

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