Chemistry-Climate Model with Interactive Ocean (EMAC-MPIOM): Preliminary results

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Introduction

Long time-scale variations of the climate system may be induced by greenhouse gases and modulated by the interaction with the oceans. Marine circulation plays a major role in timing the global warming and in shaping its geographical distribution. Atmosphere-ocean interactions impact atmospheric fluctuations near the surface which are communicated to the whole atmosphere especially via the tropical upwelling and influence thus also the stratospheric circulation patterns. Changes in the stratospheric chemical composition of radiatively active gases lead to changes in temperature distribution which subsequently influences the troposphere. A chemistry-climate model with interactive ocean simulation is needed to account for these components.

Methods

The Chemistry-Climate Model ECHAM/MESSy Atmospheric Chemistry (EMAC), version 1.7 (Jöckel et al., 2006) with FUBRad shortwave radiation scheme (Nissen et al., 2007) has been coupled to the ocean model MPIOM (Jungclaus et al., 2006) via OASIS (Legutke et al., 2007) (EMAC-MPIOM). The atmosphere model has T42 resolution (2.8°x2.8°) and 39 layers with a model top at 0.01 hPa (~80 km); the ocean model has a GR15 horizontal resolution and 40 levels in the vertical. Starting conditions for the interactive ocean component have been taken from the AO-GCM ECHAM5/MPIOM IPCC AR4 20th century climate reconstruction experiment.

EMAC with interactive ocean has been run without chemistry in order to obtain a well balanced system for further investigations.

15 years of data have been obtained until now. The run is going to be continued to simulate at least another 100 years. Preliminary results are presented.

Ocean

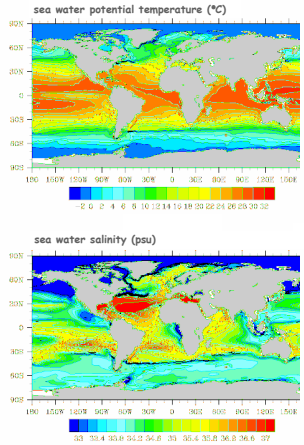

Fig. 1

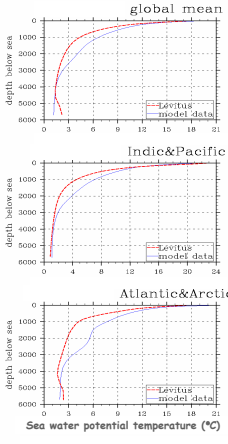

Fig. 2

Fig. 1 shows the simulated 15 years mean surface potential temperature and salinity while Fig. 2 compares the EMAC-MPIOM simulations to observed deep ocean temperature means indicating reasonable results considering the short period of the model integration.

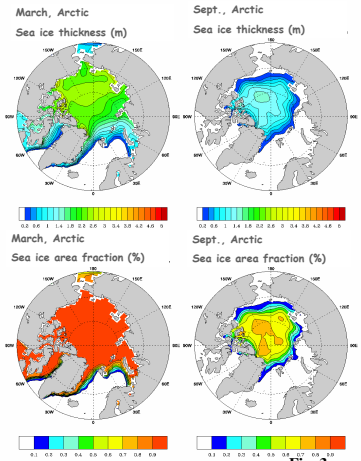

Fig. 3

Next to tropical sea surface temperatures sea ice cover over the Artic and Antarctic regions (Fig. 3) is believed to determine the strength, timing and distribution of climate change. Therefore, the interactive simulation of these regions is especially important to assess global temperature changes due to anthropogenic influence.

Stratospheric austral ozone has successfully simulated with chemistry climate models in the past. Springtime ozone depletion has a crucial effect on surface wind stress, oceanic currents and sea ice distribution. Thus, online coupled Chemistry Climate Ocean Atmosphere Models are needed.

Atmosphere

EMAC with interactive ocean (EMAC-MPIOM) output has been compared to EMAC with observed SST and interactive chemistry (EMAC_Chemistry).

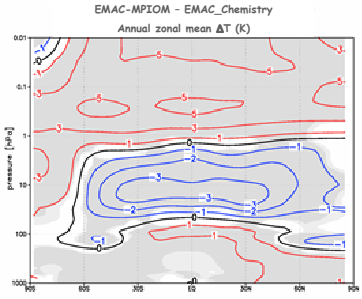

Fig. 4

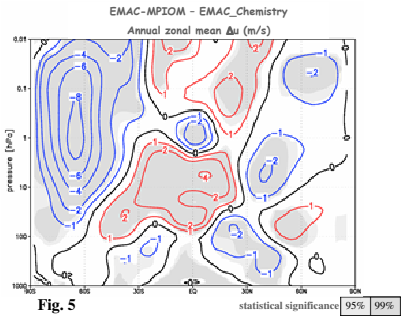

Fig. 5

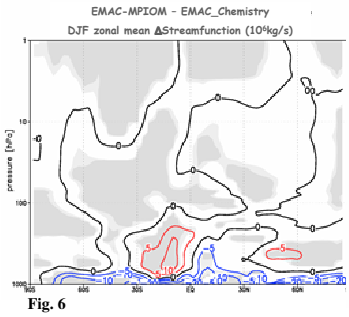

Fig. 6

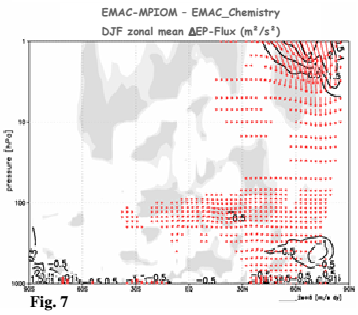

Fig. 7

Temperature:
Annual mean temperature in the troposphere is slightly higher in the EMAC-MPIOM version (Fig.4). EMAC with coupled chemistry module simulates higher mean temperatures in the tropical stratosphere and lower mean temperatures in the mesosphere due to chemical reactions which are not included in the EMAC-MPIOM setup.

Zonal wind:
EMAC-MPIOM simulates considerably lower wind speeds (Fig. 5) in the upper stratosphere and mesosphere high latitude austral regions than EMAC with interactive chemistry due to considerably higher temperature gradients between tropics and south-pole (Fig. 4)

DJF stream function:
Fig.6 shows a lower simulated mass flow from the lower atmospheric levels towards higher layers when EMAC is coupled to the interactive ocean compared to model run with observed SSTs during boreal winter.

DJF EP-Flux:
Wave propagation and dissipation during winter season is an important mechanism for modifying mean flow characteristics. Fig. 7 indicates that EP-flux is altered by the interactive ocean simulation. 15 years wave propagation statistics, however, is too few to draw definite conclusions.

Conclusions

The chemistry climate model EMAC has been successfully coupled to the ocean model MPIOM. First simulation output analysis has shown a reasonable behaviour of the new system. The considered time period comprises only 15 years and makes a sound evaluation impossible. However, the modelled oceanic mean temperature and salinity surface fields depict reality in a satisfactory way. First comparisons to observed deep ocean measurements indicate agreement to modelled potential temperature means.

Moreover, it could be shown that interactive ocean has an influence on mass flux in the lower atmosphere and wave propagation. Differences in the upper stratosphere and mesosphere, especially in the simulated temperature and wind fields, are due to chemical reactions not being included in the EMAC-MPIOM version until now.

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