Project: **893**
Project title: **Convection and Clouds in Earth System Modelling**
Project lead: **Holger Tost**
Report period: **1.1.2014 - 31.12.2015**

In the past allocation period, the PI and his research group have performed tasks in all of the proposed work packages of the request for 2014/15. However, WPIII, in which a direct link between convective transport and scavenging has been proposed, did not work out to be feasible for global applications as it is too computational expensive to run for more than a few days of simulation period without stability and performance problems. Consequently, no results from this WP can be presented.

As not all the packages are directly linked, we summarise the results individually per WP.

WPI: Convective Superparameterisation in the EMAC model

In this PhD project (funded by the JGU Mainz) the candidate has implemented a superparameterisation for clouds and convection in the EMAC model, i.e. a cloud resolving model (CRM) is embedded in each GCM grid cell to describe cloud and convective processes by an ensemble of small scale clouds with grid width of a few kilometres, but not a full global scale cloud resolving model. The technical implementation has been achieved by linking the code of the CRM as an external library, which is merged with the EMAC model by a newly designed interface, following the MESSy infrastructure standards, which is called SP-EMAC from here on. Restart capabilities are fully functional (and required due to the additional computational costs of the CRM). The CRM ensemble provides tendencies for the moisture quantities, temperature and depending on the configuration also horizontal wind velocities. Additionally, the advection routines of the CRM are also made capable for tracer transport within the CRM, representing cloud scale tracer transport, especially vertical mixing. A "tuning" of the radiation balance has been performed to achieve an equilibrated radiation balance at the top of the atmosphere in case of prescribed sea surface temperatures. The resulting surface precipitation distribution has been compared to observations (GPCP data, see Fig. 1). Using SP-EMAC, the overestimation of tropical precipitation, especially over the warm pool has been reduced, and several other regions also show an improved precipitation distribution compared to the observations and the standard configuration of EMAC, using the Tiedtke convection scheme. However, in the midlatitude storm tracks a slight overestimation of precipitation occurs. A dominant difference of SP-EMAC compared to EMAC with Tiedtke is the ratio of cloud water and cloud ice. In SP-EMAC cloud ice has substantially increased at the expense of cloud water, such that the total cloud hydrometeor content is only affect to a lesser degree. However, the SP-EMAC cloud phase partitioning agrees much better with satellite data (CERES). This shift in the cloud phase partitioning has substantial influences on the radiative properties of the clouds. Currently, we have modified also the radiation calculations to be performed on the CRM grid, providing also an ensemble of the radiative fluxes for each GCM grid cell, in which the cloud optical properties are more consistently treated and test simulations are performed and analysed.

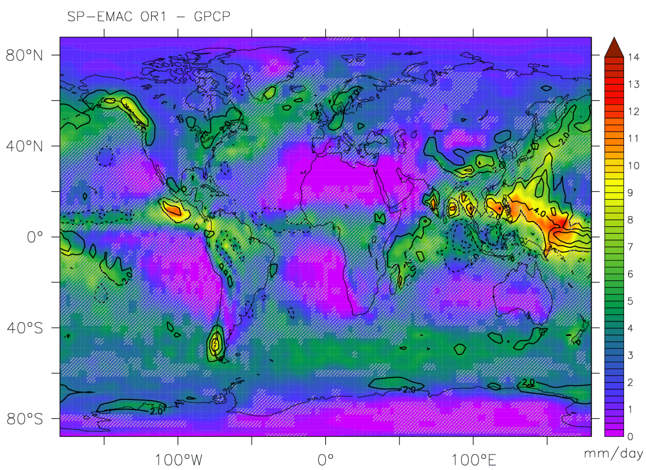

Fig.1: Surface precipitation using SP-EMAC. The contour lines denote the deviations from the GPCP data and the pattern area marks regions in which the difference is not statistically significant (95% confidence level).

WPII: Transport and mixing: Comparison between present day climate and the Early Earth

In this project we have applied the EMAC modelling system including the ocean component MPIOM (linked via the MESSy infracstucture) to investigate the climate during the Permian (262 Mio years b.p.). Using paleostratigraphic data to estimate orography and bathymetry, we simulated several scenarios (time slice experiments) with varying atmospheric CO2 content and analysed both horizontal and vertical mixing during that time period. Using an interactive ocean has been a requirement, since with prescribed sea surface temperatures the meridional ocean heat transport has been underestimated, such that simulated climate in the high latitudes has been too cold compared to proxy data derived from sedimental and phytogeographical data. Several centuries have been used as spin-up period to balance the ocean deep water temperatures, before data for an analysis period has been selected. Fig.2 shows the resulting annual mean surface temperatures for 6 scenarios ranging from present day CO2 content to a tenfold increase in atmospheric CO2. Especially, in the low CO2 scenarios the ice-albedo feedback plays an important role for the climate of high latitudes. The meridional ocean heat transport is crucial for the temperatures in the high latitudes. Compared to present day conditions the poleward energy flux is substantially larger during the Permian. Comparing our simulation results with other modelling studies, out simulated distribution shows higher values in the low latitudes and less pronounced oceanic heat transport in the high latitudes. However, the differences should be interpreted carefully, since also for present day conditions our simulated profile is more pronounced compared to the other study. Investigating the role of convection and convective clouds, we have found that the intensity of convection is very much dependent on the selected convection parameterisation. As the continents in the low latitudes are mostly characterised by deserts, there are not many continental convective clouds due to the absence of excess moisture destabilising the atmosphere. Consequently, mixing occurs mostly by dry convection only. As convection schemes respond to maritime convection in a different way, the total precipitation distribution and hence the hydrological cycle shows substantial differences. This is currently further investigated.

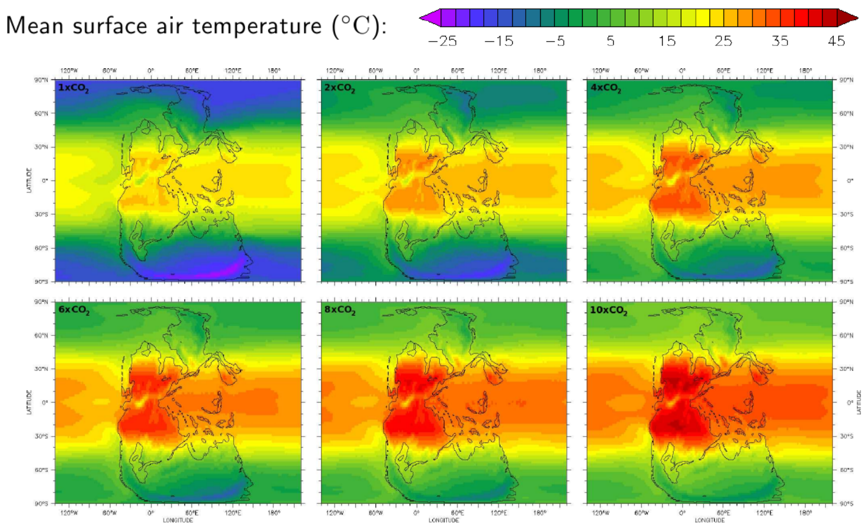

Fig. 2: Mean temperature distributions under varying CO2 concentrations for the Permian Earth using an interactively coupled atmosphere- ocean model setup.

WPIV: Sensitivities in aerosol, cloud radiation calculations in addition to the ESCiMo consortial project

In this WP the PI has spent CPU time for testing various configurations within the consortial project ESCiMo (ID0853). The resulting final simulations within ESCiMo including prognostic aerosol particles (RC1-AERO und RC1-AECL), the latter including aerosol feedback on clouds and radiation would not have been possible without the extra CPU time of this WP. Mostly, sensitivity simulations concerning the distribution of particulate emissions, the sensitivity of the chemistry scheme to aerosol particles and he cloud feedback required additional efforts before the long simulations could have been performed. For further information see (Jöckel et al., GMDD, 2015).