Modelling regional climate change in Eastern Africa on orbital and tectonic time scales

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Orbital and tectonic forcing

On time scales of the last millions of years, two factors are assumed to be the major driving forces of climate change: Orbital forcing is assumed to be responsible for the cycles of glacial and interglacials. Data from ice cores indicate that interglacials occurred with a frequency of around 100,000 years at least during the last 500,000 years. Time scales of tectonically induced climate changes are typically an order of magnitude longer. The German interdisciplinary research group RiftLink (www.riftlink.de) analyses the interrelation between tectonics, climate change and human evolution in East Africa. One potential reason for the aridification of this region is the change in local topography due to tectonic uplift in the East African Rift System (Sepulchre et al., 2006). In the contribution of the Institute for Meteorology (Freie Universität Berlin) climate models are applied to analyse the role of different forcing factors. Two categories of models are applied: Coupled global ocean-atmosphere models are used to compare the effects of different driving forces that act on the global scale, mainly orbital and tectonic forcing. Regional climate models are used to analyse smaller scales effects of the complex East African topography. Here we present examples for both types of model applications.

Results of global modelling experiments: Orbital vs. tectonic forcing

In a first experiment, we used the global coupled ocean-atmosphere model ECHO-G and removed the topography of East and South Africa almost completely according to the set-up suggested by Sepulchre et al. (2006). A simulation with pre-industrial conditions is used for comparison. The climate model ECHO-G consists of the ECHAM4 atmosphere model at a spatial resolution of ~3.75° (19 vertical level) coupled to the HOPE-G ocean model at a resolution of ~2.8° (Legutke and Voss; 1999).Figure 1 illustrates the simulated effects on moisture transport during Northern Hemispheric summer (JJA). The results indicate that modifications in the topography lead to distinct change in moisture transport into the continent. The removal of the topographic barrier leads to an enhanced zonal moisture transport, e.g. stronger westward transport in the region between 15°S and 5°S during summer. This is consistent to the results of Sepulchre et al. (2006). As an example for other forcing factors, Figure 1 also shows equivalent results for the Eemian interglacial (125,000 years BP). In that case changes in Earth‘s orbital configuration lead to enhanced moisture transport from the Atlantic deep into the African continent in the region between 5°N to 10°N.

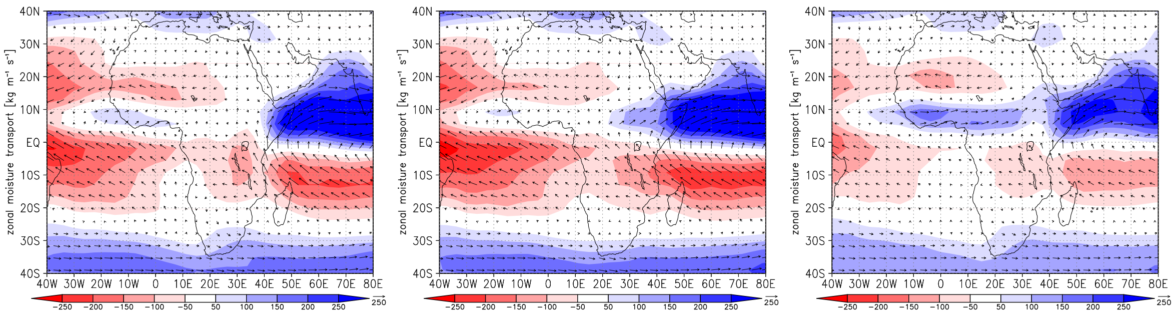

Figure 1: Vertically integrated moisture transport for northern hemispheric summer (JJA) for different forcings: (left): pre-industrial, (mid): with significantly reduced topography, (right) Eemian interglacial

Application of the regional climate model COSMO-CLM to East Africa

Applications of regional climate model to Eastern Africa are sparse (Sun et al.,1999a; Anyah and Semazzi, 2007). Here we apply the non-hydrostatic regional climate model COSMO-CLM (see: www.clm-community.eu), that is derived from the local weather prediction model of the German meteorological service (DWD). As first test case, the model is driven with ERA40 reanalysis in order to analyse its ability to realistically simulate present-day climate of that region. Figure 2 shows a comparison of simulated precipitation and observed data (GPCC) for the ‘short rains season’ (October to December). The figure shows results of model configurations with two different convection scheme (following Tiedtke (1989) and Kain and Fritsch (1993)). Overall, relatively good agreement with observed precipitation is achieved in a configuration with the ‘Tiedtke’-convection scheme and a two category cloud ice scheme (see Kaspar and Cubasch (2008) for more details). This configuration is also used in operational weather prediction. As next step, the model will be driven by boundary conditions from the above mentioned ECHO-G simulations. An example driven by the pre-industrial ECHO-G simulation is also included in Figure 2.

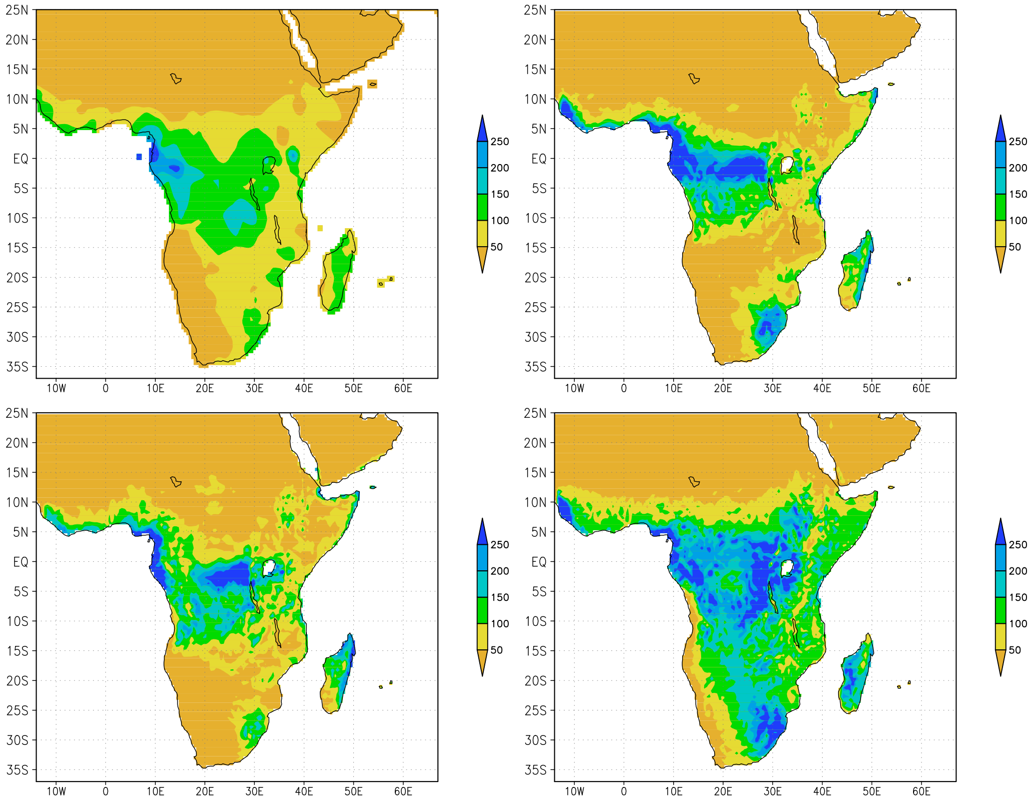

Figure 2: Precipitation of the short rains season (Oct.-Dec.): (top, left): GPCC observation, (top, right): simulated by COSMO-CLM with ERA 40 boundary conditions, Tiedtke convection scheme and two-category cloud ice scheme, (bottom, left): as before but with boundary conditions from a pre-industrial ECHO-G simulation (bottom, right): as (top, right) but with Kain-Fritsch scheme.

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