Geophysical Research Abstracts
Vol. 13, EGU2011-11260, 2011
EGU General Assembly 2011

Modelling climatic and vegetational changes during the Middle Miocene (17 to 14 Ma)

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The Middle Miocene Climatic Optimum (MMCO, approximately 17 to 15 Ma) is one of the last warming event of the Neogene. Data-based temperature reconstructions for the MMCO suggest a warmer climate than present with a lower latitudinal temperature gradient. In Europe, many studies on fossil floras indicate that vegetation was dominated by subtropical taxa, typical of warmer and more humid climate with weaker seasonal contrast than present. To date only few model studies have been conducted on the MMCO climate. They focused on the effect of varying CO2 concentrations or the impact of topography on the Middle Miocene climate, and were performed using atmospheric models coupled to slab ocean.

Here we present the results of the first MMCO modelling study using the coupled ocean-atmosphere general circulation model FOAM 1.5. The boundary conditions used are derived from the paleogeography reconstructed by Herold et al. (2008), with the vegetation reconstruction by Wolfe (1985). We chose a CO2 concentration of 560 ppm, which is in the range of reconstructed pCO2 for the MMCO, and consistent with previous modelling studies. Marine isotopic records suggest strong variations in the ice volume in Antarctica during the Miocene (Zachos et al., 2001), so we performed two experiments to test the effect of adding an ice-sheet on Antarctica.

Climate outputs derived from each experiment were then used to force the vegetation model CARAIB. The simulated vegetation is translated into biomes, which can be compared to vegetation reconstructions in Europe.

In all experiments, we simulate high latitude sea surface warming consistent with data, but modelled sea-surface temperatures at low latitudes are approximately 3°C warmer than reconstructed temperatures. This can be due either to a bias towards colder temperatures of reconstructions based on oxygen isotopes in the tropics or to a lack of poleward heat transport in the model. In Europe, the experiment without ice on Antarctica produces mean annual temperatures (MAT) between 12.5°C and 18°C and mean annual precipitation (MAP) between 550 mm and 1450 mm, that are consistent with reconstructions for the MMCO (MAT = 15-22°C and MAP = 800-1350 mm). A warm and humid climate prevails in this region, resulting in the development of subtropical forest at high latitudes (up to 60°N), as expected from fossil data. This subtropical forest disappears when adding an ice-sheet on Antarctica, due to lower air surface temperature and precipitation rate. These results are in agreement with data, which indicate a cooling and an increase in aridity after the MMCO, when the East Antarctic ice sheet built up.