Geophysical Research Abstracts
Vol. 13, EGU2011-14137, 2011
EGU General Assembly 2011

Glacial CO_2 cycle as a succession of key physical and biogeochemical processes

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Ice core records of atmospheric CO_2 concentration through the last 800,000 years show the carbon cycle amplifying the climate forcing from variations in Earth's orbit. This positive climate-carbon cycle feedback could weaken or even possibly reverse present-day fossil fuel CO_2 uptake by the natural carbon cycle. Despite much effort over the last two decades, a mechanistic, process-based explanation of the carbon cycle feedbacks responsible for the glacial / interglacial CO_2 cycles remains elusive. We will present first transient simulations of the last glacial cycle using an Earth System model of intermediate complexity to predict atmospheric CO_2 , driven by orbital changes and reconstructed radiative forcing from greenhouses gases, ice, and aeolian dust. The model is able to reproduce the main features of the CO_2 changes: a 50 ppmv CO_2 drop during glacial inception, a minimum concentration at the last glacial maximum 80 ppmv lower than the Holocene value, and an abrupt 60 ppmv CO_2 rise during the deglaciation. The model deep ocean d13 C also resembles the reconstructions from the real ocean. The main drivers of atmospheric CO_2 evolve with time: changes in sea surface temperature and volume of bottom water of southern origin exert CO_2 control during the glacial inception and deglaciation, while changes in carbonate chemistry and marine biology are dominant during the first and second parts of the glacial cycle, respectively. Changes in terrestrial carbon storage counteract oceanic mechanisms during glacial inception and deglaciation, unless the potential for permafrost development is included in the soil carbon model. These feedback mechanisms could also significantly impact the ultimate climate response to the anthropogenic perturbation.