Land-atmosphere carbon isotope fluxes during interglacials

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Understanding carbon cycle and climate dynamics in the past is crucial to project climate and CO₂ changes in the future. To quantify a role of terrestrial mechanisms in atmospheric δ¹³CO₂ changes in the past, a model of δ¹³C discrimination during terrestrial biogeochemical processes is added to the land surface module JSBACH of the MPI Earth System Model (MPI-ESM). The parameterisation of fractionation processes for C₃ and C₄ plants is an extension of the theory by Lloyd & Farquhar (1994) and Wingate et al. (2007). The ¹³C model component simulates land-atmosphere carbon isotope exchanges on sub-daily time scale.

We present a JSBACH model study focusing on the last two interglacials Holocene (last 6000 yrs. BP, 6K) and the Eemian (125.000 yrs. BP, 125K). The climate forcing is taken from MPI-ESM simulation based on a constant atmospheric CO₂ concentration of 280 ppm and an orbital forcing following the PMIP-2 exercises (Fischer and Jungclaus, 2010 & 2011). Here we show the present day distribution of observed and modeled δ¹³C as well as its change in interglacial climates. The difference in the spatial distribution is mainly correlated to changes in the C₄ vegetation cover.

The cover fraction of eight different plant function types are derived from MPI-ESM simulations for Eemian and Holocene including a dynamical vegetation scheme and is used as a boundary condition for JSBACH.

On the global, annual mean scale, the changes in climate (e.g. precipitation and 2m temperature) are small. At regional scale and annual mean, the climate is changing significantly and these changes are most pronounced at a seasonal basis (not shown here). These changes in climate lead e.g. to an expansion of boreal and tropical forests replacing grassland simulated for both interglacials. At a first glance, 125K and 6K patterns are looking similar but they are more pronounced in the warmer 125K case.

Simulated (blue + red lines) annual latitudinal mean of δ¹³C discrimination of photosynthesis compared to model estimates (black lines) by Lloyd & Farquhar (1994) and observed ecosystem discriminations (circles, Buchmann & Kaplan, 2001).

Global mean values for δ¹³C discrimination of photosynthesis for C₃, C₄, and all plants.

30-year annual mean of δ¹³C discrimination of photosynthesis and the location of C₄ grasses for present day (left) and the last Interglacial (right). Differences in δ¹³C between these periods reflect mainly the changes in the cover fraction of C₄ grasses.

While the soil carbon storage is too high, the relative changes between the time slices are quite reasonable. For 125K (not shown) and 6K the patterns are similar and reflect the vegetation shifts during the warm interglacials.

Global carbon storage on land for 0K and the differences for 6K and 125K.