Land-atmosphere carbon isotope fluxes during interglacials

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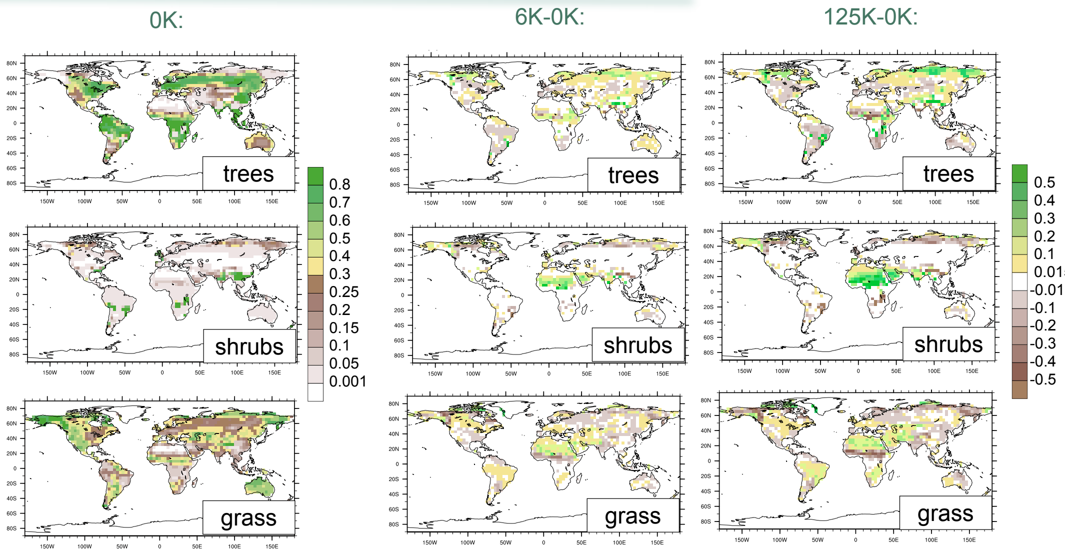
summary

Understanding carbon cycle and climate dynamics in the past is crucial to project climate and CO_2 changes in the future. To quantify a role of terrestrial mechanisms in atmospheric $\delta^{13}CO_2$ changes in the past, a model of ^{13}C discrimination during terrestrial biogeochemical processes is added to the land surface module JSBACH of the MPI Earth System Model (MPI-ESM). The parametrisation of fractionation processes for C_3 and C_4 plants is an extension of the theory by Lloyd & Farquhar (1994) and Wingate et al. (2007). The ^{13}C 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 CO_2 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 $\delta^{13}C$ as well as its change in interglacial climates. The difference in the spatial distribution is mainly correlated to changes in the C_4 vegetation cover.

vegetation cover

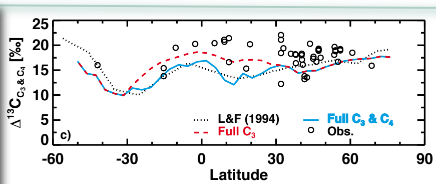


The cover fraction of eight different plant function types are derived from MPI-ESM simulations for Eemian and Holocene including a dynamical vegetation scheme and is used as a boundary condition for JSBACH.

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.

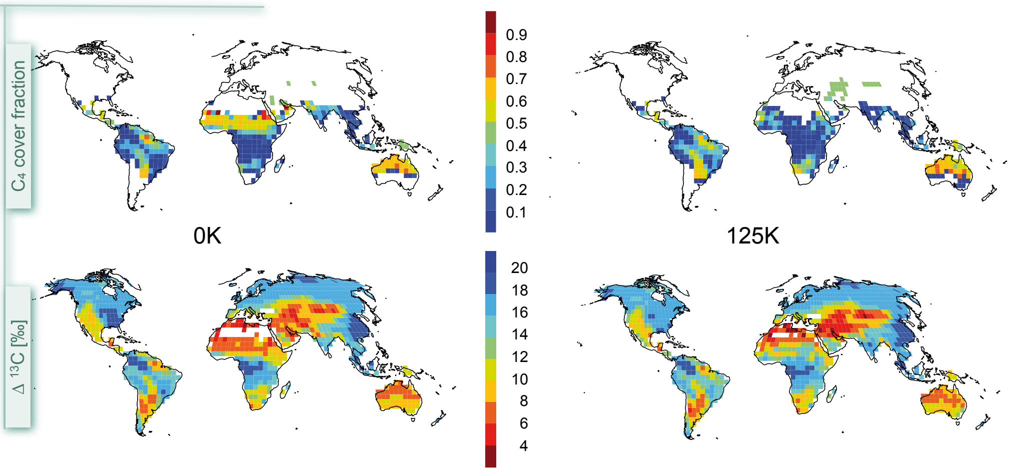
carbon isotopes



Simulated (blue + red lines) annual latitudinal mean of ^{13}C discrimination of photosynthesis compared to model estimates (black lines) by Lloyd & Farquhar (1994) and observed ecosystem discriminations (circles, Buchmann & Kaplan, 2001).

Δ ^{13}C [‰]	0K	6K	125K
C_3	16.71	16.68	16.70
C_4	3.38	3.37	3.31
all plants	14.97	14.99	15.02

Global mean values for ^{13}C discrimination of photosynthesis for C_3, C_4, and all plants.

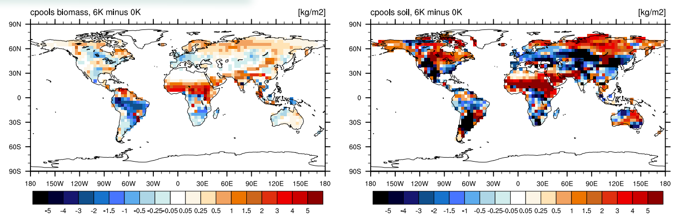


30-year annual mean of ^{13}C discrimination of photosynthesis and the location of C_4 grasses for present day (left) and the last Interglacial (right). Differences in Δ ^{13}C between these periods reflect mainly the changes in the cover fraction of C_3 and C_4 grasses.

carbon

carbon [Gt]	0K	Δ 6K	Δ 125K
vegetation	652.2	+31.3	+47.7
soil	3664.8	+26.3	+1.0
total	4317.0	+57.6	+48.7

Global carbon storage on land for 0K and the differences for 6K and 126K.



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.

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