Modeled variability of land vegetation and carbon during the Holocene

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summary

Transient, 8000 years spanning experiments starting at the Mid-Holocene (8 ka BP: 8000 years before present) until the preindustrial era (0 ka) are performed to analyze the changes in vegetation distribution, carbon storage on land, and disturbance processes (wildfire).

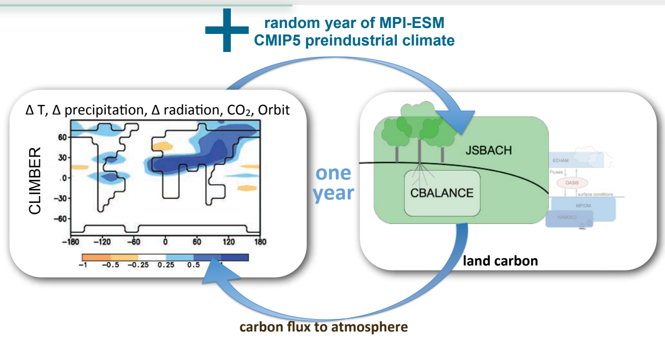
While the atmosphere and ocean processes are simulated on a coarse resolution by CLIMBER, the land processes are simulated at higher resolution with JSBACH. It is shown, that changes in secondary processes such as natural fire disturbance range at the same order of magnitude as simulated differences in the land carbon. Hence it is crucial to add further components of the carbon cycle such as CH_4 emissions and peat accumulation to get a complete picture. Recent studies with JSBACH show that during the last 6000 years the boreal wetland CH_4 emissions were slightly increased (Schuldt et al., 2013).

outlook

Further transient simulations will be performed to get estimates on the uncertainties of the underlying dynamics of the carbon storage. These experiments will include different landuse as well as peatland CO_2 emission scenarios during the Holocene to provide a range of possibilities of anthropogenic and natural impacts on the Holocene climate and CO_2 dynamics.

Schuldt RJ et al. (2013) Modelling Holocene carbon accumulation and methane emissions of boreal wetlands. An Earth System Model approach, *Biogeosciences*.

CLIMBER - JSBACH



A new climate-carbon cycle model is used, which is the asynchronously coupled EMIC (Earth System Model of Intermediate Complexity) CLIMBER-2 (Ganopolski et al., 2001) and the land component JSBACH of the Max-Planck Earth System Model (MPI-ESM) described by Raddatz et al. (2007).

Ganopolski A et al. (2001) CLIMBER-2: a climate system model of intermediate complexity. Part II: model sensitivity, *Climate Dynamics*, **17**: 735-751

Raddatz T et al. (2007) Will the tropical land biosphere dominate the climate-carbon cycle feedback during the twenty-first century?, *Climate Dynamics*, **29**: 565–574

vegetation cover and land carbon

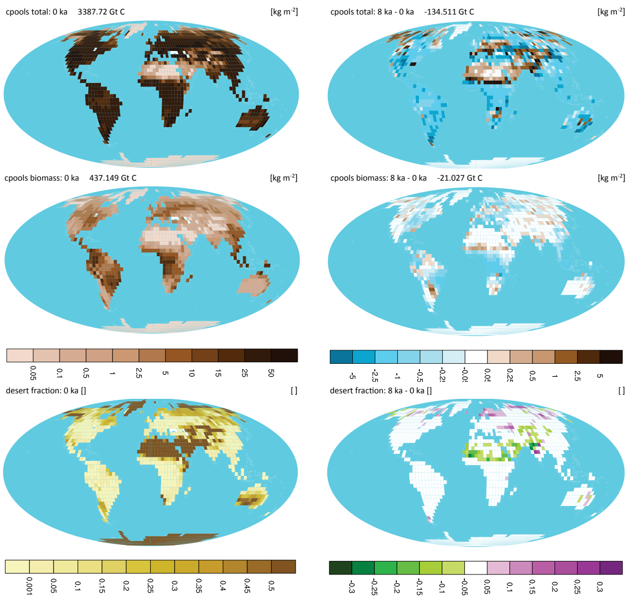


Fig. 1: Modeled carbon storage (kg m^{-2}) and desert fraction for pre-industrial climate (0 ka BP, left column), and its anomalies for the mid-Holocene (8 ka BP, right column). Shown are values for the total (top row) and biomass carbon (middle row) separately and the desert fraction (bottom row).

What happens due to the applied forcing?

- The CO_2 concentration evolves (Fig. 2) close to ice-core reconstructions during the 8000 years (Monnin, 2004).
- The African and Asian Monsoon systems are stronger during the Mid-Holocene, which leads to a widespread greening (Fig. 1) that is also reflected in a gain of land carbon (Fig. 2)
- GPP increases over the course of the Holocene due to an increase of atmospheric CO_2 (Fig. 2).

Monnin E et al. (2004) Evidence for substantial accumulation rate variability in Antarctica during the Holocene, through synchronization of CO_2 in the Taylor Dome, Dome C and DML ice cores. Earth and Planetary Science Letters, **224**, 45-54

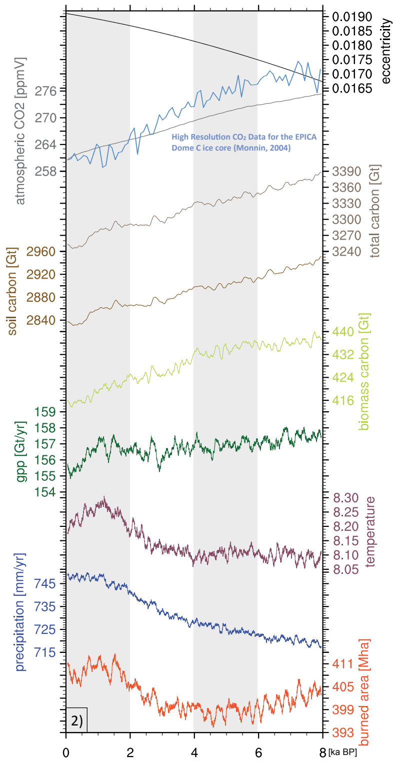


Fig. 2: global averaged trends (land only)

disturbance

Windbreak and fire are implemented as disturbances within JSBACH; they both affect the carbon cycle, although not significantly.

- Burned area during preindustrial climate is about 4×10^6 $km^2 yr^{-1}$ with hotspots in Africa, Australia, and southwest America (Fig. 3). It is higher at 8 ka BP by app. 8×10^4 $km^2 yr^{-1}$ (app. 2%)
- Wildfire emissions: 4.5 Gt yr^{-1} for pre-industrial conditions (0 ka BP), and app. 3% less during the mid-Holocene (8 ka BP) despite of a slightly higher burned area.
- Global trend of a monotonic increase in burned area after the Last Glacial Maximum (Power et al., 2008) is not captured.
- \`Z-scores like\` regional modeled trends of burned area during the Holocene (Fig. 3) agree partly to charcoal reconstructions (site level data) but show different strength of increases / decreases (Marlon et al., 2013).
- Since land use changes were not included in the simulations, an anthropogenic increase in fire activity during the last few centuries is not captured.

Power MJ et al. (2008) Changes in fire regimes since the Last Glacial Maximum: an assessment based on a global synthesis and analysis of charcoal data, Climate Dynamics, **30**: 887-907

Marlon JR et al. (2013) Global biomass burning: a synthesis and review of Holocene paleofire records and their controls, Quaternary Science Reviews, *accepted*

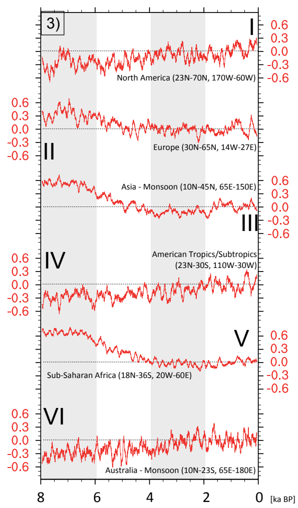


Fig. 3: \`Z-scores like\` regional trends of modeled burned area

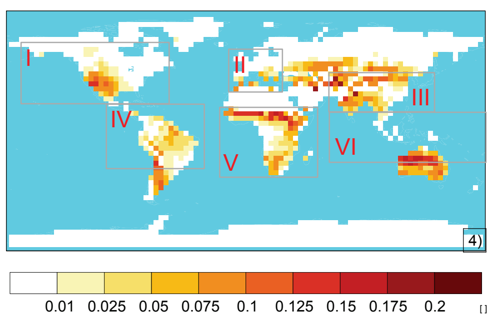


Fig. 4: burned area at 0 ka BP [fraction of grid box] total: 4.02×10^6 $km^2 yr^{-1}$

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