Project: **891**

Project title: **Forest management in the Earth system**

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Report period: **1.1.2016 - 31.12.2016**

1. Introduction

The main aim of this project is to better understand the role of land use change for and in a changing climate. About one quarter of the ice-free land surface has undergone anthropogenic land cover change (i.e., a change in vegetation type, such as clearing of forest for agricultural expansion), and a further half is under land management (such as wood harvest). While the effects of land cover change have been simulated to be substantial on the global scale, though with substantial uncertainties across models, recent studies indicate that the effects of land management can be of similar magnitude. Therefore, Earth system models are now moving towards including land management aspects. Here we report on steps towards reducing uncertainty of simulated land use effects by model-data comparison as well as on model improvement towards representing land management in JSBACH / MPI-ESM / ICON.

2. Separating local and non-local effects of deforestation

Land use change affects local climate directly by changes in surface properties, such as altering surface albedo, but also affects climate remotely via changes in atmospheric composition and circulation, in particular for scenarios of global land use change. Simulations from last years' report have been complemented by additional AMIP-simulations testing the statistical robustness of our approach and are now published (Winckler et al., in press). Beyond a better understanding of how local and non-local effects differ in terms of underlying mechanisms, our approach also allows for determining surface climate variables in the same way as they are derived from observational data, which implicitly represents paired-site setups (i.e., refers to local effects only). Model agreement with observations proved to be improved by isolating the local effects, allowing a much broader usage of the remote-sensing based products on land use effects that are have recently been published. The approach has been adopted by other modeling groups e.g. in the LUC4C project. In a follow-up study (Winckler et al., in prep.) we extended the simulations to a step-wise deforestation, allowing to assess non-linearities, and applied the simulated dependence of surface climate to amount of deforestation to compare different land use scenarios against each other (Fig. 1). Our finding of a strong dependence of biogeophysical effects on initial forest cover are particularly important in view of the Coupled Model Intercomparison Project 6 (CMIP6), in which idealized land use change scenarios will be compared across models.

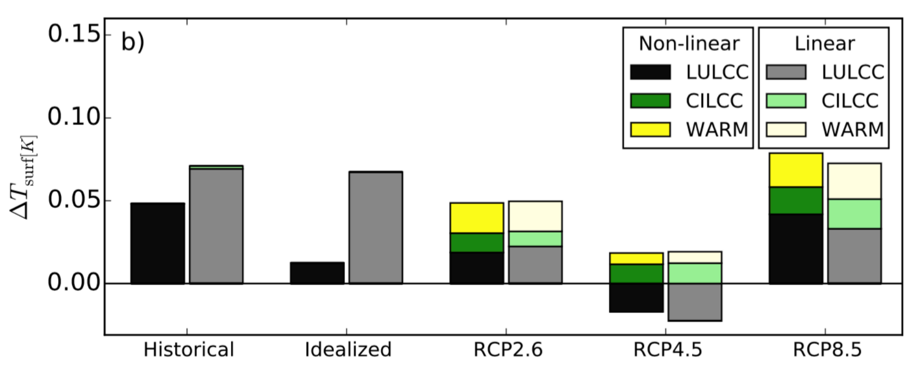

Fig. 1: Comparison of local surface temperature changes due to land-use-induced land cover change (LULCC), climate-induced land cover change (CILCC) and warming background climate (WARM) across scenarios. Solid bars account for the non-linear temperature response, light-colored bars assume a linear response.

3. Evaluation of JSBACH's response of soil carbon to land use changes

A large uncertainty of land-use effects on the global carbon cycle stems from soil carbon changes. We develop an approach that is applicable to the evaluation of any dynamic global vegetation model against existing observational meta-analyses of soil carbon changes following land-use change. Using JSBACH, we performed idealized simulations where the entire globe is covered by one vegetation type, which then undergoes a land-use change to another vegetation type. We selected the grid cells that represent the climatic conditions of the meta-analyses and compared the mean simulated soil carbon changes to the meta-analyses. Our simulated results show model agreement with the observational data on the direction of changes in soil carbon for some land-use changes, although the model simulated a generally smaller magnitude of changes. Model deviations from the observations are substantially reduced by explicitly accounting for crop harvesting and ignoring burning in grasslands in the model. We conclude that our idealized simulation approach provides an appropriate framework for evaluating DGVMs against meta-analyses and that this evaluation helps to identify the causes of deviation of simulated soil carbon changes from the meta-analyses. This study has been published in Biogeosciences (Nyawira et al., 2016).

4. Representation of age-dependent growth in JSBACH / MPI-ESM

The current representation of forests in JSBACH always assumes a mature forest, in terms of productivity, despite the fact much of the world's forest is young due to past or continuous forest management or natural disturbances. This shortcoming needs to be overcome for our assessments of forest management effects on climate. We have improved the representation of forest growth in JSBACH (and ICON-les) by replacing the maximum leaf area, which previously was a prescribed constant, with an interactive simulation of leaf area constraint by the available carbon stocks. Various parameterizations have been tested. The new scheme is able to capture forest regrowth and structural changes after management and performed better than the standard scheme in an evaluation against global observations of LAI and GPP. We implemented different harvest schemes depending on age, diameter or carbon density. Three different harvest rules (proportional from all age classes; fixed rotational cycle; age class distribution matching FAO product usage) were then compared for their impacts on carbon storage and biogeophysical properties. For the same amount of harvest, preliminary results show substantially higher mean age and carbon storage for the product usage rule than the other rules, showing the potential to optimize carbon sequestration by land management (Sabot et al., in prep.).

5. Contribution to international model intercomparison projects (MIPs)

JSBACH has again participated in the long-standing MIP of the Global Carbon Project, TRENDY ("Trends in the global carbon cycle"), which delivers annual updates of the global carbon budget (LeQuere et al., 2015 and subm.). In a spin-off project additional simulations tested the relevance of gross land use transitions (such as shifting cultivation) and wood harvest, and, in other participating models, the relevance of cropping and tillage representation. These land management effects contributed towards higher land use emissions across most models (Fig. 2). Since land management representations have only recently been included in models, earlier estimates of land use emissions have been systematically underestimated, implying that the residual terrestrial sink must be larger than previously thought. This work is currently under review at Nature Geoscience (Arneth et al.).

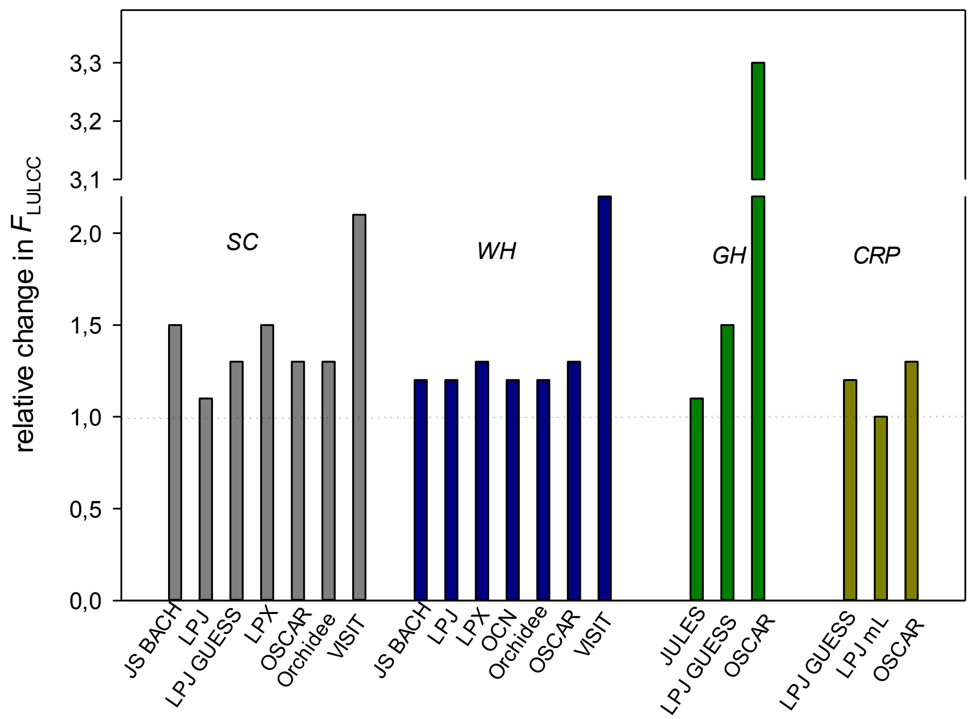

Fig. 2: Response ratio of cumulative net land use change flux (1901-2014) for different models when certain land management activities are included (SC: shifting cultivation; WH: wood harvest; GH: harvest using the grass functional type; CRP: full crop representation).

References (* indicates results of project 891):

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