Project: **891**

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

Principal investigator: **Julia Pongratz**

Report period: **2018-01-01 to 2018-12-31**

1. Introduction

The main aim of this project is to better understand the role of land use for and in a changing climate. Land use affects about three quarters of the ice-free land surface. One previously often neglected form of land use – land management (such as forestry harvest) – has been increasingly identified to matter substantially for climate and biogeochemical cycles even on global scale. Our group therefore fosters the development of the MPI Earth system model, as well as of the ICON model, towards including land management practices and required structural land representations to better understand and quantify the human impact on the Earth system (see sections 4 and 5). But it also deals with fundamental gaps in our process understanding of land use change effects on climate in general (section 2, 3 and 5). We report here on the progress of the projects proposed in the request for DKRZ resources for 2018.

2. Drought response feedback

The Amazon forests are one of the largest ecosystem carbon pools on Earth. Climate projections predict more frequent and prolonged droughts in many places of the world including the Amazon basin (Joetzjer et al., 2013). However, most vegetation models are currently unable to capture observed drought responses of forests (Powell et al., 2013, Joetzjer et al., 2014). In the 2018 part of the project we conducted development in JSBACH tuning soil moisture and LAI responses to soil moisture and incorporating new formulations of leaf phenology, litter production and tree mortality, all based on intensive field measurement of a wide range of variables from the throughfall exclusion (TFE) experiments performed in the Amazon (Nepstad et al., 2006, Fisher et al., 2007). Planned applications of the improved MPI-ESM model to quantify the feedback between leaf shedding and drought conditions have so far not been possible due to unforeseen delays with the MPI-ESM providing the required CMIP6 control and historical simulations. This computational intense task therefore will need to be postponed to the next allocation period, 2019.

3. Local and nonlocal 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. In 2016 and 2017, local effects and nonlocal effects were studied in AMIP-type and MPI-ESM simulations (Winckler et al., 2017a, b, Winckler et al., in review at GRL), with interesting ongoing analysis (Winckler et al., 2018). In this allocation period we performed simulations that tracked changes in specific surface properties to changes in the surface energy balance to temperature effects. This resolved the seeming disagreement that surface roughness changes are dominating albedo effects of deforestation almost everywhere on the globe in observational studies, but that model studies find a reduction in absorbed shortwave radiation to dominate the surface temperature response in high latitudes. In fact, in the MPI-ESM, the reduction in absorbed shortwave radiation due to the increase in albedo is fully compensated by reduced turbulent heat loss, and instead roughness changes explain the observed cooling, reconciling the opposing views (Winckler et al., internal review). Albeit not proposed for 2018 this application fruitfully utilized part of the computing time granted for the FOM project that would else have expired due to unforeseen delays external to FOM (see section 2).

4. Test and first application simulations for the cohort structure

Land use, particularly de- and reforestation and forest management, alter the forest age structure. Although biogeochemical as well as biophysical effects of such structural changes are known to be strong (Erb et al., 2016), many land surface models, such as JSBACH, neglect age effects (Pongratz et al., 2017) and assume ageless or mean-age forests. One important reason for this simplification is the increase in computational complexity when introducing cohorts/forest age-classes as new land cover

tiles, because many of the represented processes, such as photosynthesis and respiration, are calculated per land cover tile. Moreover, in models with a flat tile hierarchy, such as JSBACH3, the introduction of age-classes would be computationally inefficient since it would require a multiplication of properties common to the represented forest plant functional types (PFT). In contrast to JSBACH3, JSBACH4 provides a hierarchical tile structure enabling a common treatment of age-classes of the same forest PFT where appropriate.

In the allocation period 2018, we implemented forest age-classes in JSBACH4.2 and conducted test-simulations with JSBACH4 standalone (Nabel et al., 2018) as well as JSBACH4 in ECHAM6-AMIP and ICON-AMIP. ICON-AMIP and ECHAM6-AMIP test simulations with JSBACH4 revealed higher than expected costs and various infrastructural problems in simulations with and without cohorts, which we contributed to solve and are still working on. Overall, delays in the general development of ICON/JSBACH4 and of presupposed applications with this model in other projects (so far no carbon equilibrium available) prevented productive ICON-AMIP applications. For a first application with cohorts, we therefore used JSBACH4 standalone instead of the ICON-AMIP setup. We conducted simulations with different numbers of age-classes and age-class distribution schemes, the outcomes of which we are currently evaluating against global observations of LAI and GPP, to determine a sensible trade-off between accuracy and computation complexity (Nabel et al., in prep.). One of the preliminary findings is the necessity of using a minimum number of forest age-classes: For some climatic zones, simulations showed no increase in agreement with the GPP and LAI observational data when using five as opposed to a significant increase when using ten additional classes (Nabel et al., in prep.).

5. Participation in TRENDY

In this allocation period 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 (Le Quéré et al., 2018; Le Quéré et al., subm.). As in the last year, the FOM group also contributed with the bookkeeping of land-use emissions model BLUE (updated version of Hansis et al., 2015). TRENDY simulations are not only used in the global carbon budget, but also for further reaching studies, e.g. understanding the impact of the El Niño–Southern Oscillation on the terrestrial system (Wang et al., 2018, Bastos et al., 2018), understanding the effects of spring warming on northern plant productivity (Buermann et al., 2018) or reconciling bookkeeping estimates and country reports of anthropogenic forest sinks (Grassi et al., 2018).

References (* indicates results of project 891):

* Bastos, A. , ..., Nabel, J., Pongratz, J., et al.: Impact of the 2015/2016 El Nino on the terrestrial carbon cycle constrained by bottom-up and top-down approaches. Phil. Trans. R. Soc. B 373.1760, 20170304 (2018).

* Buermann, Wolfgang, ... Nabel, J.E.M.S., et al. Widespread seasonal compensation effects of spring warming on northern plant productivity. Nature 562.7725, 110 (2018).

* Erb, K.H., Luyssaert, S., Meyfroidt, P., Pongratz, J., et al., Land management: data availability and process understanding for global change studies. Global Change Biology, doi: 10.1111/gcb.13443 (2016).

Fisher, R. A., Williams, M., Da Costa, A. L., Malhi, Y., Da Costa, R. F., Almeida, S., & Meir, P.: The response of an Eastern Amazonian rain forest to drought stress: results and modelling analyses from a throughfall exclusion experiment. Global Change Biology, 13(11), 2361-2378 (2007)..

* Hansis, E., Davis, S. J., Pongratz, J.: Relevance of methodological choices for accounting of land use change carbon fluxes. Global Biogeochem. Cycles, 29, 1230-1246 (2015).

* Grassi, G., ... Nabel, J.E.M.S., et al.: Reconciling global-model estimates and country reporting of anthropogenic forest CO_2 sinks." Nature Climate Change 8.10, 914-920 (2018).

Joetzjer, E., Douville, H., Delire, C., &Ciais, P.: Present-day and future Amazonian precipitation in global climate models: CMIP5 versus CMIP3. Climate Dynamics, 41(11–12), 2921–2936 (2013).

Joetzjer, E., Delire, C., Douville, H., Ciais, P., Decharme, B., et al..: Predicting the response of the Amazon rainforest to persistent drought conditions under current and future climates: A major challenge for global land surface models. Geoscientific Model Development, 7(6), 2933–2950 (2014).

* Le Quéré, C., ... Pongratz, J., ... Nabel, J.E.M.S., et al.: Global Carbon Budget 2017, Earth Syst. Sci. Data, 10, 405–448 (2018).

* Le Quéré, C., ... Pongratz, J., ... Nabel, J.E.M.S., et al.: Global Carbon Budget 2018, submitted to Earth Syst.

Sci. Data.

* Nabel, J., Naudts, K., Pongratz, J.: JSBACH4.2 feature/forests: Implementing forest age classes in the land surface model of the ICON-ESM. In preparation.

* Nabel, J., Naudts, K., Pongratz, J.: Influence of forest-age structure on land-atmosphere fluxes in the land surface model JSBACH. EGU Geophysical Research Abstracts, volume 20, 6526 (2018).

Nepstad, D. C., Moutinho, P., Dias-Filho, M. B., Davidson, E., Cardinot, G., et al.: The effects of partial throughfall exclusion on canopy processes, aboveground production, and biogeochemistry of an Amazon forest. Journal of Geophysical Research: Atmospheres 107.D20, LBA-53 (2002).

* Pongratz, J., ... Naudts, K. : Models meet data: Challenges and opportunities in implementing land management in Earth system models. Global change biology 24.4, 1470-1487 (2018).

Powell, T. L., Galbraith, D. R., Christoffersen, B. O., Harper, A., Imbuzeiro, H. M. A., et al.: Confronting model predictions of carbon fluxes with measurements of Amazon forests subjected to experimental drought. New Phytologist, 200(2), 350–365 (2013).

* Wang, J., ... Nabel, J., et al.: Contrasting interannual atmospheric CO_2 variabilities and their terrestrial mechanisms for two types of El Ninos. Atmospheric Chemistry and Physics, 18, 10333-10345 (2018).

* Winckler, J., Reick, C.H., and Pongratz, J.: Why does the locally induced temperature response to land cover change differ across scenarios? Geophys. Res. Lett. 10.1002/2017GL072519 (2017a).

* Winckler, J., Reick, C.H., and Pongratz, J.: Robust Identification of Local Biogeophysical Effects of Land-Cover Change in a Global Climate Model, J. Climate, 10.1175/JCLI-D-16-0067.1 (2017b).

* Winckler, J., Reick, C.H., Luyssaert, S., Cescatti, A., Stoy, P.C., Lejeune, Q., Raddatz, T., Chlond, A., Heidkamp, M., and Pongratz, J., Different response of surface temperature and air temperature to deforestation in climate models, Earth System Dynamics Discussion (2018).

* Winckler, J., Lejeune, Q., Reick, C.H., and Pongratz, J.: Nonlocal effects dominate the global mean surface temperature response to the biogeophysical effects of deforestation, in review (minor revisions) at Geophys. Res. Lett.

* Winckler, J., Reick, C.H., Bright, R., and Pongratz, J.: Importance of surface roughness for the local biogeophysical effects of deforestation, internal review.