Project: **901**

Project title: **Fire in the Earth system**

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Report period: **2016-01-01 to 2016-12-31**

Within the allocation period January 2016 until present we assessed the role of fire to drive multiple stable states of vegetation.

The presence of multiple stable states has far-reaching consequences for a system's susceptibility to disturbances, including the possibility of abrupt transitions between stable states. The occurrence of multiple stable states of vegetation is supported by ecological theory, models, and observations. We analysed the occurrence of multiple stable states with the global dynamic vegetation model JSBACH-SPITFIRE and were for the first time able to provide a global picture on multiple stable states of tree cover due to a fire-vegetation feedback (Lasslop et al., 2016). Model initialization with only woody species leads to a higher global tree covered area in equilibrium compared to an initialization with only grass species. The potential bistability occurs for gridcells with intermediately strong fire regimes in the transition zones between grasslands and forests. We find regions in mainly Africa and Asia to have multiple stable vegetation states (Figure1).

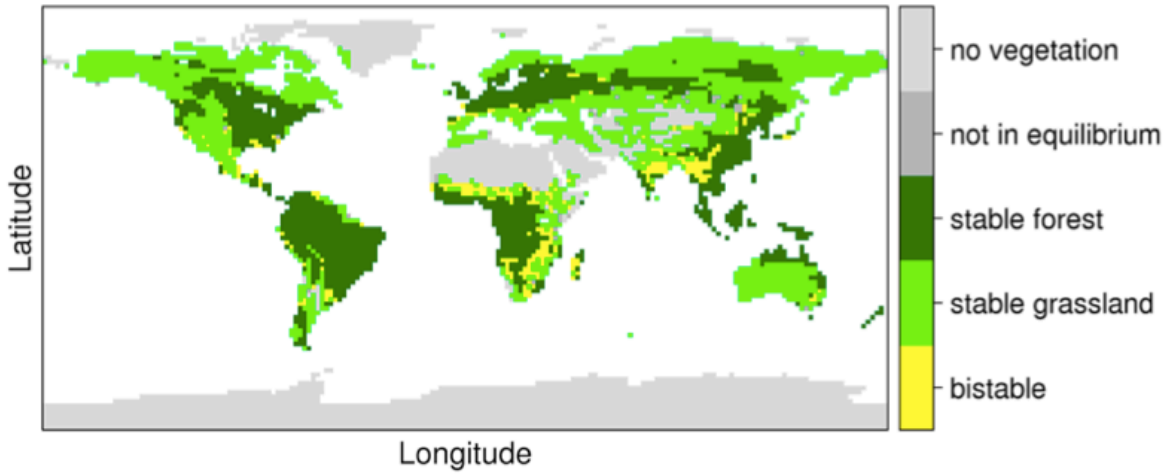

Figure 1: In JSBACH-SPITFIRE the global tree-covered area differs depending on the initialization of the vegetation state. A world initialized with only grass types leads to a lower tree cover than initialization with only tree types. The figure shows the global distribution of stable forest, stable grassland, and bistable grid cells.

By sensitivity simulations and simplifying the relevant model equations we were able to show that the occurrence of multiple states is caused by the sensitivity of the fire disturbance rate to the presence of woody plant types.

As changes in vegetation coverage and fire disturbance have a strong impact on climate we hypothesized that the occurrence of multiple stable states will be amplified when the fire-vegetation-climate feedback is taken into account (Lasslop et al., 2016). To investigate this we extended the analysis to simulations of multiple stable states in the fully coupled Earth system model.

These simulations are based on the CMIP6 version of the MPI-ESM. Up to now we have completed the 400 year spin-up simulations for a completely grass covered and a completely tree covered world. The global annual mean temperature is ~0.6 °C higher for the simulation with full tree coverage (Figure2) due to mainly reduced snow albedo and sea ice changes. The tree cover simulations lead to higher evaportation in the tropics resulting in lower temperatures and higher precipitation rates (Figure2). This potentially amplifies the effects of the fire-vegetation feedback. We are currently running simulations based on these spin-up

simulations in which we switched on the fire disturbance. The analysis of the vegetation states in these coupled simulations initialised from a grass or a tree covered state will be presented at the AGU meeting December this year (Lasslop et al., 2016b).

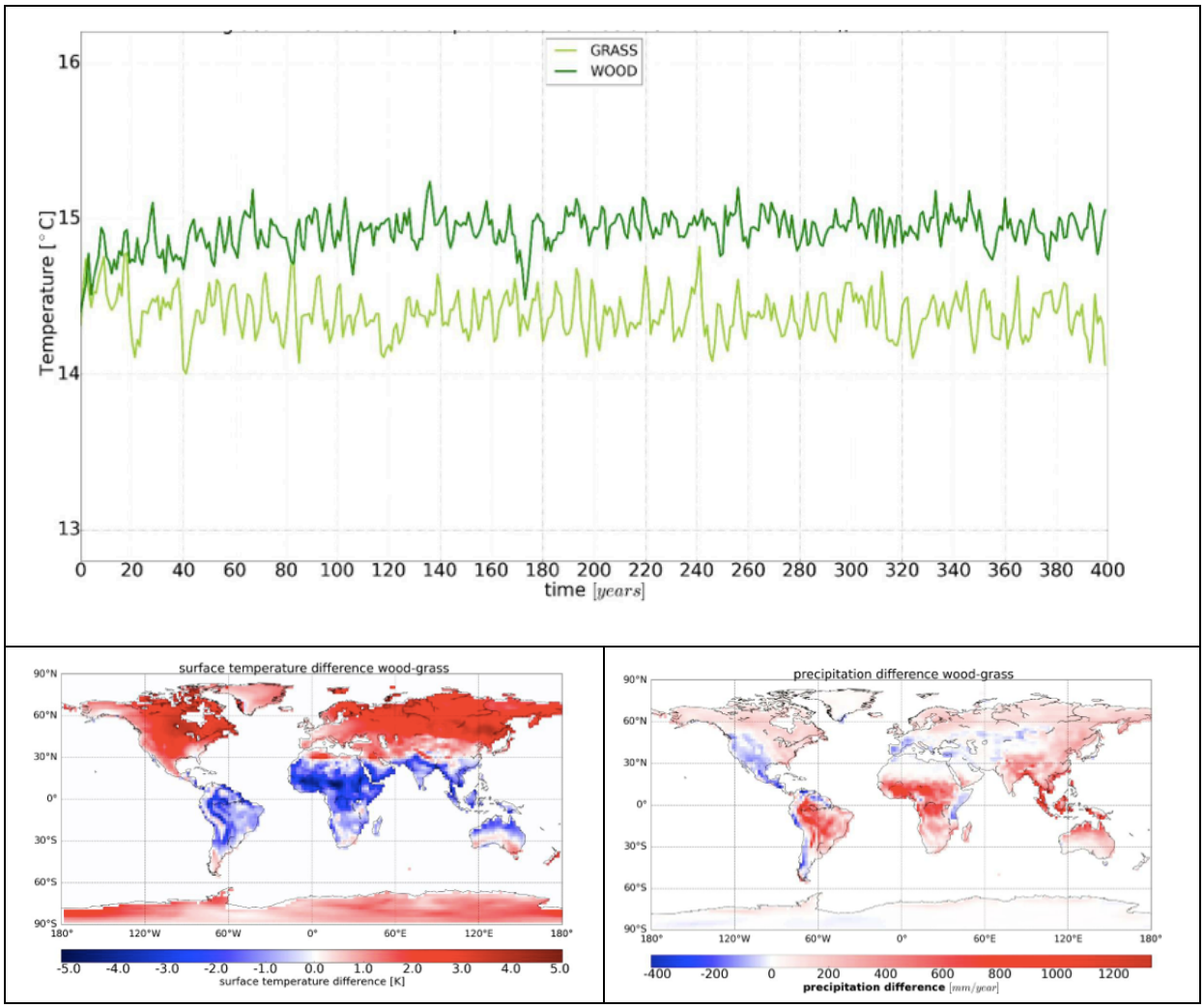

Figure 2: Differences in temperature and precipitation in a tree or grass covered world.

Computational Resources:

In reference to the requested computing resource, we started a bit later with the simulations as originally planned due to delays in the model completions for CMIP6. In addition, we realised that we will need spin-up simulations for grass and tree covered states to reach a climate equilibrium state before we can switch on the fire disturbance. This required ~10.000 CPUNodeh. Our remaining resources will be sufficient to finish the simulations to assess the multiple stable states in the coupled system for present day climate. We will, however, not be able to do future climate simulations as originally proposed.

Lasslop, G., Brovkin, V., Reick, C., Bathiany, S. & Kloster, S. (2016). Multiple stable states of tree cover in a global land surface model due to a fire-vegetation feedback. *Geophysical Research Letters*, *43*, 6324-6331 , doi:10.1002/2016GL069365.

Lasslop, G., Brovkin, V., Reick, C., Bathiany, S. & Kloster, S. (2016b). Multiple stable states of tree cover due to a fire - vegetation feedback, AGU abstract, oral presentation, https://agu.confex.com/agu/fm16/meetingapp.cgi/Paper/171285