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Tree cover bistability in the MPI Earth system model due to fire-vegetation feedback

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The global distribution of tree cover is mainly limited by precipitation and temperature. Within tropical ecosystems different tree cover values have been observed in regions with similar climate. Satellite data even revealed a lack of ecosystems with tree coverage around 60% and dominant tree covers of 20% and 80%. Conceptual models have been used to explain this tree cover distribution and base it on a bistability in tree cover caused by fire-vegetation interactions or competition between trees and grasses. Some ecological models also show this property of multiple stable tree covers, but it remains unclear which mechanism is the cause for this behaviour. Vegetation models used in climate simulations usually use simple approaches and were criticised to neglect such ecological theories and misrepresent tropical tree cover distribution and dynamics.
Here we show that including the process based fire model SPITFIRE generated a bistability in tree cover in the land surface model JSBACH. Previous model versions showed only one stable tree cover state. Using a conceptual model we can show that a bistability can occur due to a feedback between grasses and fire. Grasses and trees are represented in the model based on plant functional types. With respect to fire the main difference between grasses and trees is the fuel characteristics. Grass fuels are smaller in size, and have a higher surface area to volume ratio. These grass fuels dry faster increasing their flammability which leads to a higher fire rate of spread. Trees are characterized by coarse fuels, which are less likely to ignite and rather suppress fire. Therefore a higher fraction of grasses promotes fire, fire kills trees and following a fire, grasses establish faster. This feedback can stabilize ecosystems with low tree cover in a low tree cover state and systems with high tree cover in a high tree cover state. In previous model versions this feedback was absent.
Based on the new JSBACH model driven with ECHAM forcing (preindustrial, present day and future scenarios) we investigate which regions are potentially bistable and how these regions change with changing climate.