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Improving the LPJmL4-SPITFIRE vegetation-fire model for South America using satellite data

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Vegetation fires control global vegetation distribution, ecosystem functioning, and global carbon cycling. Specifically in South America, changes in fire occurrence together with land use change could accelerate forest fragmentation and increase the vulnerability of tropical forests and savannas to climate change. Dynamic Global Vegetation Models (DGVMs) are valuable tools to estimate the effects of fire on ecosystem functioning and carbon cycling under future climate changes. However, fire-enabled DGVMs have partly poor performances in capturing the magnitude, spatial patterns, and temporal dynamics of burned area as observed by satellites. As fire is controlled by the interplay of weather conditions, vegetation properties and human activities, fire modules in DGVMs can be improved in various aspects.

As a starting point, we here focus on improving the controls of climate on fire danger and hence fuel moisture content in the LPJmL4-SPITFIRE DGVM in South America and especially for the Brazilian fire-prone ecoregions Caatinga and Cerrado. We therefore test two alternative model formulations (Nesterov index and water vapor pressure deficit) for climate effects on fire danger within a formal model-data integration setup where we estimate model parameters against satellite datasets of burned area (GFED4) and above ground biomass of trees.

Our results show that an optimized version of the fire danger indices improves the model performance significantly especially in the Cerrado/Caatinga region. In addition, the fire controlled vegetation patterns improve in terms of plant functional types (PFT) distribution and above ground biomass. While both optimized fire danger parameterizations improved the model performance, we obtained the best results by using the water vapor pressure deficit (VPD) for the calculation of fire danger. The VPD includes in comparison to the Nesterov index a representation of the air humidity and the vegetation density.

This work shows the successful application of a model-data integration setup, as well as the integration of a new fire danger formulation in order to optimize a process based fire model. It further highlights the potential of this approach to be used in a global setting in order to achieve a new level of accuracy in comprehensive fire modeling and prediction.