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Evaluating the coupled vegetation-fire model, LPJ-GUESS-SPITFIRE, against observed tropical forest biomass

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Wildfire is a fundamental Earth System process. It is the most important disturbance worldwide in terms of area and variety of biomes affected; a major mechanism by which carbon is transferred from the land to the atmosphere (2-4 Pg per annum, equiv. 20-30% of global fossil fuel emissions over the last decade); and globally a significant source of particulate aerosols and trace greenhouse gases. Fire is also potentially important as a feedback in the climate system. If climate change favours more intense fire regimes, this would result in a net transfer of carbon from ecosystems to the atmosphere, as well as higher emissions, and under certain circumstances, increased troposphere ozone production– all contributing to positive climate-land surface feedbacks. Quantitative analysis of fire-vegetation-climate interactions has been held back until recently by a lack of consistent global data sets on fire, and by the underdeveloped state of dynamic vegetation-fire modelling. We recently completed a series of benchmarking and improvements on the coupled vegetation-fire model, LPJ-GUESS-SPITFIRE.

LPJ-GUESS is a process-based model of vegetation dynamics designed for regional to global applications. It combines features of the Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ-DGVM) with those of the General Ecosystem Simulator (GUESS) in a single, flexible modelling framework. The models have identical representations of eco-physiological and biogeochemical processes, including the hydrological cycle. However, they differ in the detail with which vegetation dynamics and canopy structure are simulated. Simplified, computationally efficient representations are used in the LPJ-DGVM, while LPJ-GUESS employs a gap-model approach, which better captures ecological succession. SPITFIRE (SPread and InTensity of FIRe and Emissions) mechanistically simulates the number of fires, area burnt, fire intensity, crown fires, fire-induced plant mortality, and emissions of carbon, trace gases and aerosols from biomass burning. Originally developed as an embedded model within LPJ-DGVM, SPITFIRE has since been coupled to LPJ-GUESS. However, neither LPJ-DGVM-SPITFIRE nor LPJ-GUESS-SPITFIRE has been fully benchmarked, especially in terms of how well each model simulates vegetation patterns and biomass in areas where fire is known to be important. Furthermore, neither model has been driven by daily climate data; only monthly climate data and a ‘generic’ daily rainfall generator that has, to our knowledge, never been calibrated against daily rainfall at the gridcell level. This use of monthly climate could be erroneous, however, because fires only occur on dry days, typically after a series of them.

The complex nature of simulating burnt area and fire-vegetation interactions motivated us to perform a series of LPJ-GUESS-SPITFIRE benchmarks, not just one. Here we report on the benchmarking of the fire-vegetation component of the model. Four (4) main treatments were conducted. The model was either driven by observed burnt area (based on MODIS) or fire was switched off; and the model was driven either by observed monthly climate data (CRU) (+ daily rainfall generator) or observational-based daily climate data (Princeton). The simulation ‘targets’ focused on recently published data on forest biomass (based on Lidar and ground data) for the tropics (ca. $\pm$ 30 deg. of the equator). Land-use/type data (HYDE) were also considered. Specific questions we investigated were:

1. Does LPJ-GUESS-SPITFIRE, regardless of climate driver data used, simulate an improved above-ground biomass compared to LPJ-GUESS without any fire?
2. Does LPJ-GUESS-SPITFIRE driven by daily climate data outperform the monthly climate version?
3. How does land-use potentially affect fire-vegetation interactions?
4. How does resource competition between grass and trees for light and water affect fire-vegetation interactions?

Our results are discussed in the context of improved vegetation modelling for Earth System studies.