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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. Dynamic vegetation-fire modelling is an essential part of our forecasting armory for examining the possible impacts of climate, fire regimes and land-use on ecosystems and emissions from biomass burning beyond the observation period, as part of future climate or paleo-climate studies.

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 and hence ecosystem changes due to disturbance such as fire. 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. This information is crucial if we are to have confidence in the models in forecasting fire, emissions from biomass burning and fire-climate impacts on ecosystems. Here we report on the benchmarking of the LPJ-GUESS-SPITFIRE model.

We benchmarked LPJ-GUESS-SPITFIRE driven by a combination of daily reanalysis climate data (Sheffield 2012), monthly GFEDv3 burnt area data (1997-2009) (van der Werf et al. 2010) and long-term annual fire statistics (1901 to 2000) (Mouillot and Field 2005) against new Lidar-based biomass data for tropical forests and savannas (Saatchi et al. 2011; Baccini et al., 2012). Our new work has focused on revising the way GUESS simulates tree allometry, light penetration through the tree canopy and sapling recruitment, and how GUESS-SPITFIRE simulates fire-induced mortality, all based on recent literature, as well as a more explicit accounting of land cover change (JRC's GLC 2009).

We present how these combined changes result in a much improved simulation of tree carbon across the tropics, including the Americas, Africa, Asia and Australia. Our results are compared with respect to more empirical-based approaches to calculating emissions from biomass burning. We discuss our findings in terms of improved forecasting of fire, emissions from biomass burning and fire-climate impacts on ecosystems.