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Using burned area data to explore fire spread in coupled fire and ecosystem models

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Fire is a major driver of change in many ecosystems, and ecosystem models should try to understand and model the feedbacks between vegetation and fire. To achieve this, work has started on coupling fire and ecosystem models. The fire model receives modelled vegetation as input for its fuel loads, and simulates ignitions and fire spread from a number of assumptions on fire processes. The fire model simulates fire behaviour, and also estimates how vegetation is killed by the fire. This disturbance is fed back into the ecosystem model. In the current work, we focus on the LPJ ecosystem model and on the SPITFIRE fire model. Both models haven been used in conjunction in the past to model emissions over Southern Africa. SPITFIRE makes assumptions about ignitions (either anthropogenic or due to lightning strikes), live fuel moisture, fuel load and type derived from the ecosystem model, and about fire dynamics. In a typical run at daily temporal resolution, SPITFIRE will simulate an "average fire" in terms of fire dynamics, which is combined with the estimated daily number of ignitions to calculate the burned area on that day. The use of an average fire simplifies modelling at the coarse resolutions (grid cell spacing is often around $0.5 - 1^{\circ}$) often used in these studies, but the associated penalty of a number of important fire limiting factors, such as human-driven suppression efforts or landscape elements that act as fire blocks. In the current study, we aim to explore landscape fragmentation in fire spread. To this end, we compare LPJ+SPITFIRE simulations fire area distributions with actual fire area observations from spaceborne sensors over a large region in Southern Africa. We introduce the concept of "landscape impedance", a metric that describes the difficulty of a fire spreading due to fragmentation, and estimate it spatially using satellite data. Finally, we introduce these concepts into the SPITFIRE fire model.

Recently, burned area data from the MODIS sensor on board the TERRA and AQUA satellites has been made available. These new dataset is a major improvement on previous efforts to estimate burned area from space, and with careful processing, can be used to identify individual fires with a reasonable level of uncertainty. From these individual fires, fire area distributions can be easily calculated for a given area and time period. It is found that over Southern Africa, fire area distributions do obey a power law. Deviations from this distributions at small scales are investigated, and put in the context of landscape fragmentation, as derived from metrics calculated from Landsat ETM7+ data. These metrics are analysed to explore the effect of fragmentation on stopping fire spread.

In the light of the previous analyses, the SPITFIRE model is modified so as to include a "landscape impedance" term derived from remote sensing data. Sample model runs are compared with estimates of burned area derived from MODIS observations. Finally, we discuss how to adapt SPITFIRE so that it produces fire area distributions that are realistic.