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Advancing representation of anthropogenic fire in dynamic global vegetation models

James Millington[1,3], Oliver Perkins[1,3], Matthew Kasoar[2,3], and Apostolos Voulgarakis[2,3]
[1]Department of Geography, King's College London, London, UK
[2]Department of Physics, Imperial College London, London, UK
[3]Leverhulme Centre for Wildfires, Environment and Society, UK

It is now commonly-understood that improved understanding of global fire regimes demands better representation of anthropogenic fire in dynamic global vegetation models (DGVMs). However, currently there is no clear agreement on how human activity should be incorporated into fire-enabled DGVMs and existing models exhibit large differences in the sensitivities of socio-economic variables. Furthermore, existing approaches are limited to empirical statistical relations between fire regime variables and globally available socio-economic indicators such as population density or GDP. Although there has been some limited representation in global models of the contrasting ways in which different classes of actors use or manage fires, we argue that fruitful progress in advancing representation of anthropogenic fire in DGVMs will come by building on agent-based modelling approaches. Here, we report on our progress developing a global agent-based representation of anthropogenic fire and its coupling with the JULES-INFERNO fire-enabled DGVM.

Our modelling of anthropogenic fire adopts an approach that classifies 'agent functional types' (AFTs) to represent human fire activity based on land use/cover and Stephen Pyne's fire development stages. For example, the 'swidden' AFT represents shifting cultivation farmers managing cropland and secondary vegetation in a pre-industrial development setting. This approach is based on the assumption that anthropogenic fire use and management is primarily a function of land use but influenced by socio-economic context, leading different AFTs to produce qualitatively distinct fire regimes. The literature empirically supports this assumption, however data on human fire interactions are fragmented across many academic fields (including anthropology, geography, land economics). Therefore, we developed a Database of Anthropogenic Fire Impacts (DAFI) containing 1798 case studies of fire use/management from 519 publications, covering more than 100 countries and all major biomes (except Arctic/Antarctic). We discuss DAFI development, patterns in the resulting data, and possible applications. Specifically, DAFI is used with ancillary data (e.g. biophysical, socio-economic indicators), classification and regression methods to test and refine our initial AFT classification, characterise AFT fire variables, and distribute AFTs spatially. Our model will then simulate AFT distributions for alternative scenarios of change (e.g. specified by the Shared Socioeconomic Pathways).

Coupling distinct models can be achieved in a variety of ways, but broadly we can distinguish between ‘loose’ coupling in which information flow is uni-directional, and ‘tight’ coupling in which information flows are integrated with feedbacks and dynamic updating. Our intention is to tightly couple our AFT model with JULES-INFERNO, such that fire use and suppression behaviours from the former influence simulated fire ignitions and burned area in the latter. Reciprocally, total burned area simulated by JULES-INFERNO will feedback to influence spatial distribution of AFTs in the next time step, modifying anthropogenic fire patterns for the next step of DGVM simulation. We discuss the potential for this tight model coupling to capture socio-ecological feedbacks in fire regimes, as well as possible pitfalls and steps needed to test and verify model outputs. These are early steps in an important journey to improve representation of anthropogenic fire in DGVMs.