Improved estimates of future fire emissions under CMIP6 scenarios and implications for aerosol radiative forcing

Matthew Kasoar\textsuperscript{1}, Douglas Hamilton\textsuperscript{2}, Daniela Dalmonech\textsuperscript{3,4}, Stijn Hantson\textsuperscript{5}, Gitta Lasslop\textsuperscript{6}, Apostolos Voulgarakis\textsuperscript{1,7}, and Christopher Wells\textsuperscript{1,8}

\textsuperscript{1}Leverhulme Centre for Wildfires, Environment and Society, Imperial College London, London, UK
\textsuperscript{2}Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, New York, USA
\textsuperscript{3}University of Basilicata, Potenza, Italy
\textsuperscript{4}Friesenstrasse, Potsdam, Germany
\textsuperscript{5}Department of Earth System Science, University of California, Irvine, USA
\textsuperscript{6}Senckenberg Biodiversity and Climate Research Centre, Frankfurt, Germany
\textsuperscript{7}School of Environmental Engineering, Technical University of Crete, Chania, Crete, Greece
\textsuperscript{8}Grantham Institute – Climate Change and the Environment, Imperial College London, London, UK

The CMIP6 Shared Socioeconomic Pathway (SSP) scenarios include projections of future changes in anthropogenic biomass-burning. Globally, they assume a decrease in total fire emissions over the next century under all scenarios. However, fire regimes and emissions are expected to additionally change with future climate, and the methodology used to project fire emissions in the SSP scenarios is opaque.

We aim to provide a more traceable estimate of future fire emissions under CMIP6 scenarios and evaluate the impacts for aerosol radiative forcing. We utilise interactive wildfire emissions from four independent land-surface models (CLM5, JSBACH3.2, LPJ-GUESS, and ISBA-CTRIP) used within CMIP6 ESMs, and two different machine-learning methods (a random forest, and a generalised additive model) trained on historical data, to predict year 2100 biomass-burning aerosol emissions consistent with the CMIP6-modelled climate for three different scenarios: SSP126, SSP370, and SSP585. This multi-method approach provides future fire emissions integrating information from observations, projections of climate, socioeconomic parameters and changes in vegetation distribution and fuel loads.

Our analysis shows a robust increase in fire emissions for large areas of the extra-tropics until the end of this century for all methods. Although this pattern was present to an extent in the original SSP projections, both the interactive fire models and machine-learning methods predict substantially higher increases in extra-tropical emissions in 2100 than the corresponding SSP datasets. Within the tropics the signal is mixed. Increases in emissions are largely driven by the temperature changes, while in some tropical areas reductions in fire emissions are driven by human factors and changes in precipitation, with the largest reductions in Africa. The machine-learning methods show a stronger reduction in the tropics than the interactive fire models, however overall there is strong agreement between both the models and the machine-learning
methods.

We then use additional nudged atmospheric simulations with two state-of-the-art composition-climate models, UKESM1 and CESM2, to diagnose the impact of these updated fire emissions on aerosol burden and radiative forcing, compared with the original SSP prescribed emissions. We provide estimates of future fire radiative forcing, compared to modern-day, under these CMIP6 scenarios which span both the severity of climate change in 2100, and the rate of reduction of other aerosol species.