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A hydroclimatic model of global fire patterns

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The partial success of current land surface models and DGVMs in predicting global fire patterns suggests that they fail to capture basic mechanisms that control fire activity across different environments. Here, we go back to the fundamental biophysics of fire to formulate a new model for the prediction of global variation in the mean annual burned area fraction (F).

We model potential burned area fraction ($F_{0.99}$, the 99% quantile of F) as a function of just two environmental constraints that determine the likelihood of: i) fuel loads being high enough to facilitate fire propagation and ii) the extant fuel being dry enough to burn. Both constraints are calculated from the climatic water balance, with actual evapotranspiration (E_a) as a proxy for fuel production rates and water deficit ($D = E_0 - E_a$, where E_0 is potential evapotranspiration), as a measure of fuel drying potential.

We show that 80% of global variation in $F_{0.99}$ is explained by mean annual E_a and E_0. As expected, $F_{0.99}$ is close to zero in environments of low E_a (e.g. desert grasslands) or low D (e.g. wet forests), due to low fuel productivity or lack of fuel drying potential, and maximum for environments of intermediate E_a and high E_0 (e.g. tropical savannas). The $F_{0.99}$ response surface distinguishes two climate domains with contrasting fuel types where fire is either constrained by fuel productivity or by fuel dryness. Model predictions of how $F_{0.99}$ responds to climate could inform more complex modelling approaches such as DGVMs that simulate transient dynamics of ecosystem change.