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Evaluating responses of burned area to environmental and human controls in global vegetation-fire models using satellite data and machine learning

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Fire is a major disturbance agent in terrestrial ecosystems that affects the land-atmosphere exchange of carbon, water, and energy and that controls the global distribution of vegetation and biomass. The interplay of human activities, weather conditions, and the properties of vegetation and litter fuels control the occurrence and spread of wildfires and thus the burned area. Most global vegetation models represent such controls on fire to simulate fire effects on vegetation. However, state-of-the art global vegetation-fire models poorly reproduce temporal dynamics or regional patterns of burned area, which suggest that models misrepresent the sensitivities of fire to climate, vegetation, and human controls.

Here we aim to diagnose to which extent state-of-the art global vegetation-fire models from the Fire Model Intercomparison Project (FireMIP) reproduce sensitivities of burned area to climate, vegetation, and human controls in comparison to sensitivities from observational datasets. In order to derive sensitivities for the observational domain, we train the random forest machine learning algorithm based on various satellite and climate datasets to predict the observed burned area. We then also train random forest to forcing and state variables of each FireMIP model to predict the model-simulated burned area. Sensitivities between burned area and each control are then derived from the random forest models. This approach allows a consistent comparison of observational- and model-derived response functions and can serve as an example for a more general novel pattern-oriented evaluation of terrestrial biogeochemical models.

The results reveal no general but fire model-specific weaknesses in representing observation-based sensitivities. The use of two burned area datasets reveals some uncertainty in observation-based sensitivities especially in boreal regions. Sensitivities of burned area to climate variables are similar for observational datasets and FireMIP models. On the other hand, most FireMIP models do not reproduce the observational increase of burned area with increasing precedent plant productivity in grasslands. In summary, the results suggest that the links between plant productivity, biomass allocation and turnover, and thus fuel production need further improvements to better represent fire dynamics and fire effects on vegetation in terrestrial biogeochemical models.

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