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Modeling the effects of fire and rainfall regimes on extreme erosion events in forested landscapes

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Damaging floods and debris flows are hydro-geomorphic hazards that often emerge in mountainous landscapes due to the combination of wildfire and intense rainfall. The frequency and magnitude of events (i.e. hazard) depends on local catchment properties as well as the frequency and severity with which catchments are conditioned (or primed) by fire disturbance and storms. Predicting the frequency and magnitude of events therefore involves capturing the nature of the interaction between fire disturbance, rainfall and landscapes. However, the physical modeling of fire disturbance, rainfall and subsequent erosion events is a complex undertaking, requiring detailed deterministic fire and erosion models with many parameters and time-series of forcing inputs. The resulting uncertainties can obscure the effects of key elements within the system, such as the frequency of fire and rainfall events, which are directly impacted by climate change or fire management. In this paper we ask the question, "What is the first-order effect of the interaction between fires and storms?" The aim was to isolate the effects of fire and rainfall regimes on the frequency of extreme erosion events such as runoff generated debris flows. Fire disturbance and storms were represented as independent stochastic processes with properties of spatial extent, temporal duration, and frequency of occurrence. These parameter values were used to model the average annual area affected by extreme erosion due to the intersection of fire disturbance and storms in a germ-grain model. Parameter values were obtained from long term data records on fire and rainfall in two regions of southeast Australia. Climate change effects were modeled using projections for future fire weather and subsequent changes in fire frequency. The modeled long term erosion rate from extreme events under current climate conditions was found to correspond well with other estimates of long-term erosion rates in the region. The model indicates that the frequency of extreme erosion will increase with climate change, although regions with frequent storms were more sensitive to fire-regime changes than areas with infrequent storms. In future work the model will incorporate other parameters such as recovery and fire severity and will be extended to represent a wider range of post-fire responses.