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Stochasticity in fire spread and the fire size distribution

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Wildfire data show a clear pattern world wide: the distribution of fire sizes is heavy-tailed. These heavy-tailed size distributions can be fitted with power-laws, enabling the construction of fire risk maps in a manner analogous to that done for earth-quakes. While this provides fire management with useful information, we still lack a detailed mechanistic understanding of how these heavy-tailed distributions arise.

Most existing fire models are complex due to their purpose of predicting the spread of a specific fire. This complexity limits our understanding of their statistical properties. Many parsimonious models including SOC have a severe limitation: although heavy-tailed distributions are obtained, the steepness of this distribution remains constant and does not exhibit the variability observed in the data. This limitation is more robust than intuition suggests. One way to escape from this seemingly 'universal' distribution is to introduce fluctuations in flammability between fires, as might be due to short term changes in meteorological conditions. Nevertheless, although weather plays an important role, it is only one of many factors influencing fire spread.

We present an alternative model that is able to generate both heavy-tailed distributions and the steepness range observed in the data. The model considers that fire size is controlled by the stochastic dynamics of the fire front. The range of steepness (exponent -1.9 to -1.3) observed in the data is obtained by varying the average success of a fire front to travel across the fuel, which regrows locally depending on the time since last fire. For a critical parameter value, the model analytically predicts a power-law distribution of fire sizes of exponent -1.5. We conclude that regionally characteristic stochasticity during the spread of a fire is able to generate the observed fire size distributions. We discuss the role of vegetation, topography and climate in generating this stochasticity and its implications for associated control strategies.