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DOMINGOS XAVIER VIEGAS
ADAI/CEIF, UNIVERSITY OF COIMBRA, PORTUGAL

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Generation and evaluation of ensemble simulations of wildfire spread for probabilistic forecast

Frédéric Allaire[1*]; Jean-Baptiste Filippi[2]; Vivien Mallet[1]

[1]Inria, 2 rue Simone Iff, Paris, France and CEREMA, Sorbonne Universités, UPMC, Lab. Jacques-Louis Lions UMR CNRS 7598. {frederic.allaire@inria.fr, vivien.mallet@inria.fr}*

[2]SPE - UMR 6134 CNRS. Université de Corse, France. {filippi@univ-corse.fr};

Abstract

Typical simulation of a large wildfire requires semi-empirical models for rate of spread (ROS) such as the Rothermel model. ROS models usually take into account several physical parameters such as slope, wind speed, moisture content and other fuel properties (load, height, surface-to-volume ratio, heat of combustion, etc.). However, these parameters can be highly uncertain. In addition, the model itself is far from perfect and the solver is subject to numerical approximations. A promising direction for the prediction of wildfire spread is to rely on an ensemble of simulations instead of a single deterministic simulation.

The generation of an ensemble may follow a Monte Carlo strategy where the input parameters are sampled according to given discrete or continuous probability distributions. Each sample is independent from each other and is used to run one wildfire simulation. For a wildfire starting at a given location and time, we can use the outputs from the ensemble of simulations to estimate a burn probability map. One main challenge of the method lies in the choice of the distributions of the input parameters. Depending on the sensitivity of the model to the input parameters, small changes on the probability distributions could yield highly different outputs. At this stage, a suggestion of distributions is introduced, although calibration should be applied in order to improve simulation outputs.

Similar probabilistic approaches have already been developed in wildland fire and particularly in forest fire behavior models such as the FSPro system. A significant difficulty regarding the evaluation of such systems is to properly take into account their probabilistic aspects. We propose to perform ensemble evaluation considering all the burn probabilities that are predicted at the scale of a specific fire event. It also requires the observed burned surfaces corresponding to the specific event. Then, probabilistic scores that are commonly used in meteorological applications, such as the Brier Score, can be computed. The whole methodology is applied to a wildfire that occurred in Corsica in summer 2017 and could be extended to more fire cases.

Such probabilistic framework could then be completed with a description of ignition probability and vulnerability in order to assess fire risk over a region like Corsica.

Keywords: simulation ; wildfire ; uncertainty quantification ; Monte Carlo ; probabilistic score

1. Introduction

In an operational context, being able to accurately forecast how a wildfire will spread would provide invaluable help in decision making, not only in a crisis situation where a fire just ignited but also in the assessment of fire risk. In the latter case, one goal is to identify areas that require high-priority land planning actions in the long run or the mobilization of firefighting resources in the short term. In spite of the significant efforts in modeling to provide better and faster-to-compute forecasts of fire spread, systematically making an accurate prediction remains a distant goal (Gollner et al., 2015). One of the reasons lies in the difficulty to predict and describe the weather conditions and the state of the vegetation that will drive the fire spread. In this uncertain context, one may think that a range of likely outcomes might be more useful than a single forecast. This can be achieved by running many