Numerical simulation of pyro-convection caused by intense wildfire in Portugal

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Introduction

On June 17, 2017, a series of deadly wildfires spread across central Portugal resulting in 66 deaths. The wildfire occurred in Pedrógão Grande municipality showed an extraordinary spread dominated by a strong pyro-convection and the formation of a pyro-cumulonimbus **[1], [2].**

Description of the spread during the first hours:

- Ignition between 13:30h and 14:00h.
- Southward spread at moderate velocity until 17:00h.
- Westward spread at high velocity between 17:00h and 19:00h. Propagation dominated by the convection. Formation of the pyro-cumulonimbus.
- Fastest spread rate between 17:00h and 21:00h influenced by strong downbursts, causing most of the fatalities.

Objective

To understand the interactions between the fire and the atmosphere that lead to the actual spread of the fire using a fire-atmosphere coupled model.

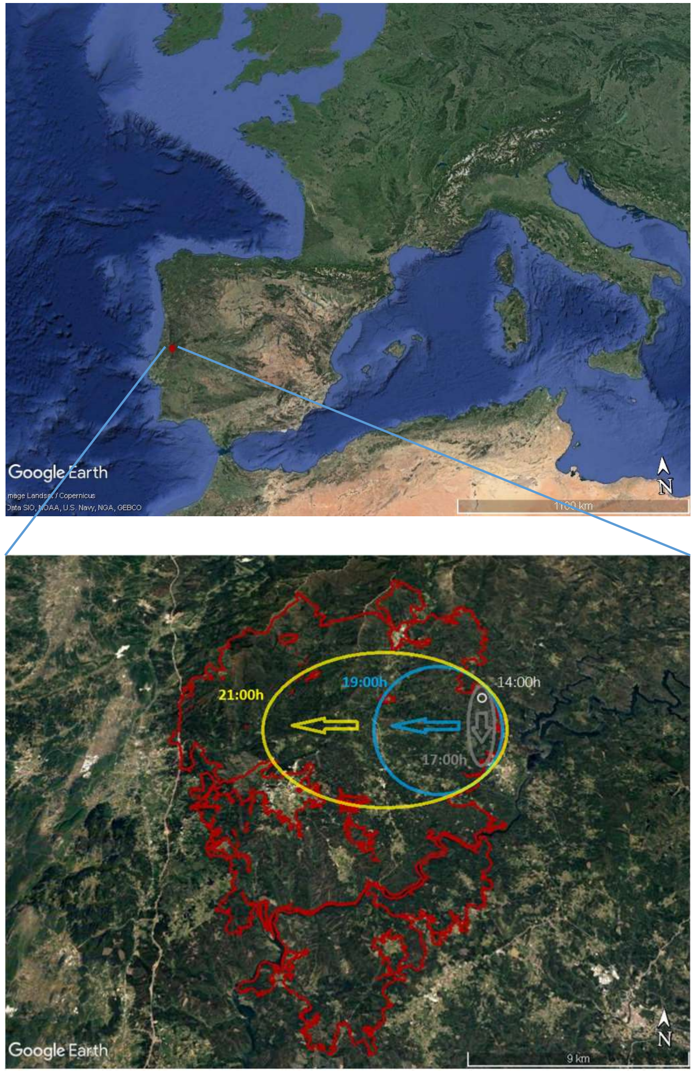

Figure 1. Location and burned area of Pedrógão Grande 2017-06-17 wildfire. Grey, blue and yellow approximated perimeters were drawn according to **[1]** and **[2].**

Methodology

WRF-FIRE is a numerical model consisting of the Weather Research and Forecasting (WRF) model **[3]**, coupled with the fire-spread model (SFIRE) module **[4]**.

Model configuration:

- Five nested domains. Horizontal resolution: 8.1km, 2.7km, 900m, 300m and 100m. Refinement subgrid ratio of 10 for fire grid.
- Finer domains (300m and 100m) run in WRF-LES (Large Eddy Simulation) mode.
- ERA5 Analysis data as initial and boundary conditions.
- Fuel data obtained from the Portuguese Institute for Nature and Forest Conservation (ICNF) **[5]**.

Fire fluxes:

Fuel consumption releases heat and water vapor. In the model, this release is partitioned into sensible and latent heat fluxes that contribute to the potential temperature and the water vapor mixing ratio **[6]**.

These fluxes depend on the amount of burned fuel. Different fuel loads were tested to obtain sensible heat fluxes intense enough to develop the observed pyro-convection.

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Results

- Following the direction of the wind at the surface, the simulated fire spread is southward until 17:00h, like the observed propagation (**Figure 2**).
- At 17:20h a pyro-cumulus is formed from the head of the fire towards the northwest (**Figure 3**) following the wind direction between 4000m and 8000m (**Figure 6**). This should be the direction of the fire spread from this moment. The height of the cloud doesn't reach the tropopause (**Figure 5**).
- Intense vertical upward and downward winds are simulated by the model (**Figure 6**), which may modify surface winds.
- The influence of the pyro-convection in the surface winds (**Figure 4**) doesn't make the fire to spread westward. It actually intensifies the southeast spread.

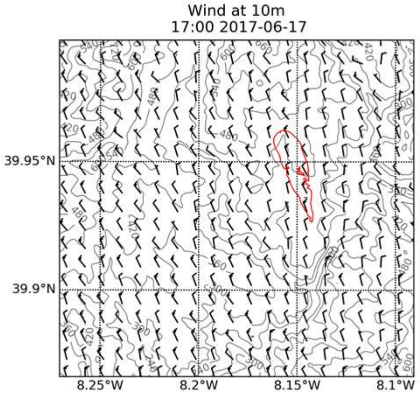

Figure 2. Surface wind and fire perimeter (red) at 17:00h.

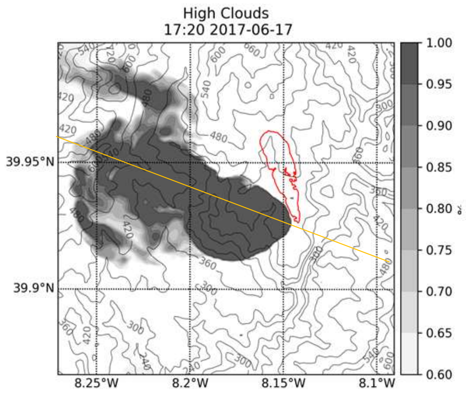

Figure 3. High cloud fraction (%) and fire perimeter (red) at 17:20h.

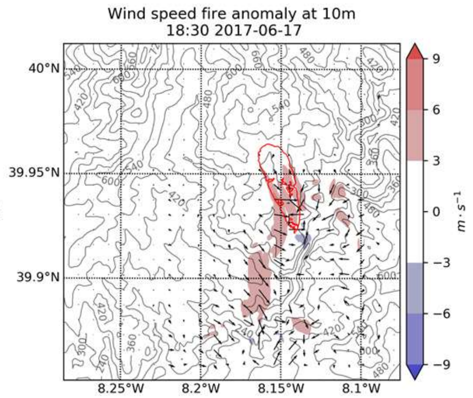

Figure 4. Wind fire anomaly and fire perimeter at 18:30h.

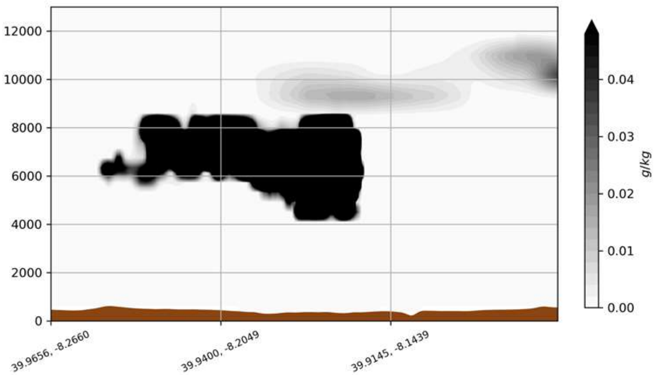

Figure 5. Cloud water and ice mixing ratio (g/kg) cross section at 17:20h.

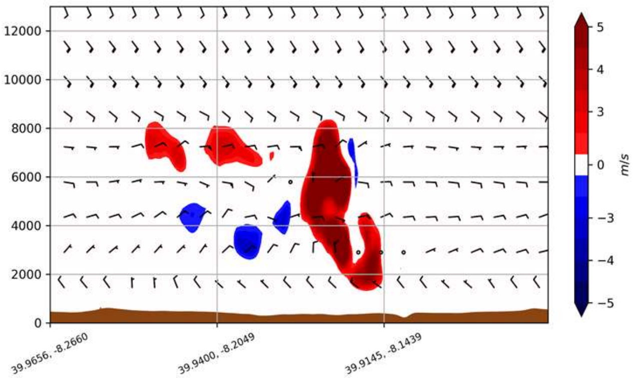

Figure 6. Wind vertical velocity (m/s) and horizontal wind (barbs) cross section at 17:20h.

Conclusions

- The amount of fuel available to burn is crucial factor in determining the fuel fluxes. Bad estimations of this variable would lead to a wrong coupling between the fire and the atmosphere.
- The spread direction of a fire that is dominated by an intense convective plume can rapidly change independently of the surface winds.
- Fire-atmosphere coupled models can be an important tool in understanding and predicting the role of pyro-convection in the spread of wildfires.

References

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[6] Coen, J. L., Cameron, M., Michalakes, J., Patton, E. G., Riggan, P. J., & Yedinak, K. M. (2013). WRF-Fire: coupled weather–wildland fire modeling with the weather research and forecasting model. Journal of Applied Meteorology and Climatology, 52(1), 16-38.