ADVANCES IN FOREST FIRE RESEARCH 2022

Edited by

DOMINGOS XAVIER VIEGAS

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Modelling pyro-convective activity in Pedrógão Grande mega fire

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Keywords

Mega fires; PyroCb; Meso-NH model; ForeFire model.

Abstract

The development of PyroCumulonimbus (PyroCb) clouds during mega fire events has high impact in the evolution of the fire fronts and have been observed more frequently in the last years. In 2017, Portugal was affected by several episodes of extreme wildfires with associated cloud systems. The present study aims to investigate the development of pyro-convective activity during the Pedrógão Grande episode. The study used the reference fire propagation deduced from the official investigation (forced fire) as well as reference boundary condition from atmospheric analysis to simulate the coupled simulation with a mesoscale atmospheric model at high temporal and spatial resolution. The Meso-NH model has been configured into three nested domains with horizontal resolutions of 2000 m, 400 m and 80 m. The emission of heat and vapour into the atmosphere was made using the ForeFire model. The results highlight the importance of the use of cloud resolving models configured with very-high spatial and temporal resolutions for representing the development of phenomena associated to pyro-convective activity, namely those occurring in the micro-scale from the cloud microphysics processes, like very-localised microbursts.

1. Introduction

Extreme wildfires are frequently associated with strong convective processes due the heat and moisture released from the fires. Such a fire-atmosphere coupling environment lead the formation of convective clouds, also referred as PyroCumulus (PyroCu) or PryroCumulonimbus (PyroCb) clouds. The first are more common and can form as relatively small clouds above fire plumes. The second can be observed in plume dominated wildfires characterized by an intense convection column, above which a cloud resembling towering cumulonimbus (Cb) may form. The microphysics processes, as condensation of moisture in the fire plume can enhance convection by releasing latent heat, for example. Their updraughts manage, sometimes, to penetrate into the stratosphere. PyroCb activity can have a significant impact on fire behaviour through feedback processes between the atmosphere and the fire, including the increase of burn and spread rates by strong variations in surface wind direction and speed associated with convective inflows and downdraughts, and ignition of new fires by PyroCb lightning (e.g., Tory et al., 2018; Dowdy et al., 2019).

In 2017, an extreme fire season affected Portugal. The first deadly event occurred in June in the region of Pedrógão Grande and caused more than 60 fatalities (e.g., Couto et al., 2020; CTI Report, 2017). In mid-October, extreme wildfires spread across the Central region of Portugal mainland resulting in 48 fatalities (Guerreiro et al., 2018). The present study aims to investigate how a wildfire can influence the occurrence of violent pyro-convective activity.

2. Methodology

In general, the atmospheric models do not account for fire-atmosphere interactions. To investigate the pyroconvective activity, a numerical simulation was run with the Meso-NH model coupled to the ForeFire model. The Meso-NH is a non-hydrostatic model able to represent the atmospheric motions in different scales, and implemented with a rather complete parametrization package of physical processes in the atmosphere (Lac et al., 2018), whereas ForeFire is a fire propagation model (Filippi et al., 2009, 2018). The present study considers the wildfires occurred in Pedrógão Grande and Góis on June 17, 2017. The fire propagation map was constructed based in the fire propagation map presented in the CTI Report (2017).

In order to resolve the development of the fire/weather system, the two-way nesting capability of the Meso-NH model was used with three nested domains (Figure 1). Several simulations were made aiming to obtain the more realistic scenario of the event. The horizontal grid size is 2000 m for the outer domain covering 600 km × 600 km. The inner computational grids have grid increments of respectively 400, 80 m, covering a total area of respectively 120 km × 120 km, 24 km × 24 km for the innermost model. The time step is 10 s for the outermost model and decreases to 2 s, 0.5 s for the finer models. Initial and lateral boundary conditions for the outer domain are provided by ECMWF analysis, with updates every 6 h. The simulation with the coarsest resolution began on 17th June 2017 at 0600 UTC, with a progressive downscaling up to the finest resolution beginning at 1300 UTC. The vertical resolution is identical for all the nested domains, with 50 levels up to 20 km and a first level above the ground at 30 m height. All the nested models used the one and a half order closure turbulence scheme with a prognostic TKE: the two finest resolution domains use the 3D version of the scheme, while the first one only considers the 1D version, neglecting the horizontal turbulent fluxes.

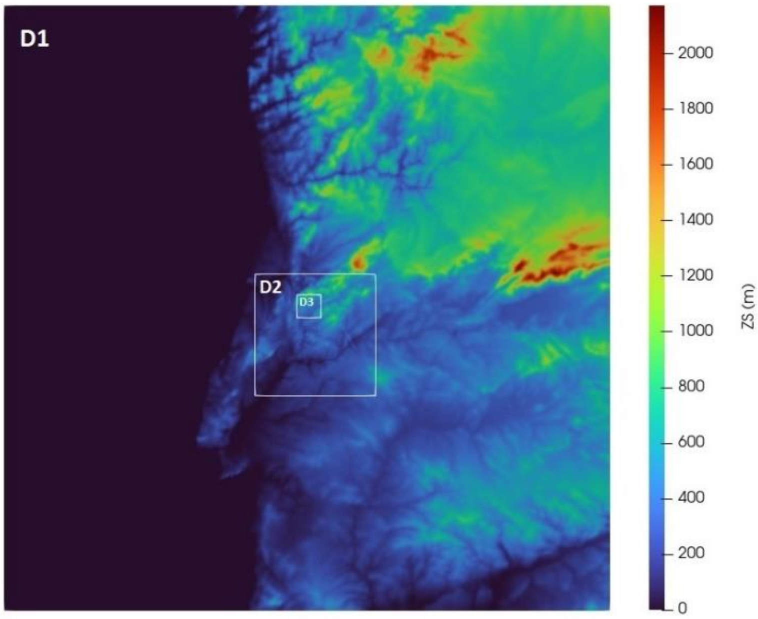

Figure 1- Meso-NH configuration with orography obtained from the SRTM database.

3. Results

Figure 2 shows the fire line representing the fire front propagation as well as the strong fire-atmosphere interaction, with the fire leading to intense convective updraughts. The role of the fire in this episode is presented by the development of a deep convective cloud. In the figure, the plume is associated with a PyroCb cloud, which result from condensation inside the plume. Such a cloud is represented by five hydrometeos species (e.g., cloud droplet, raindrops, graupel, snow or aggregates, pristine ice crystals). The convection was likely enhanced by the strong wildfire activity and penetrated into the higher troposphere above 10 km altitude. The extreme pyro-convective activity was also verified in the simulation by the development of microbursts originated from the PyroCb cloud (not shown).

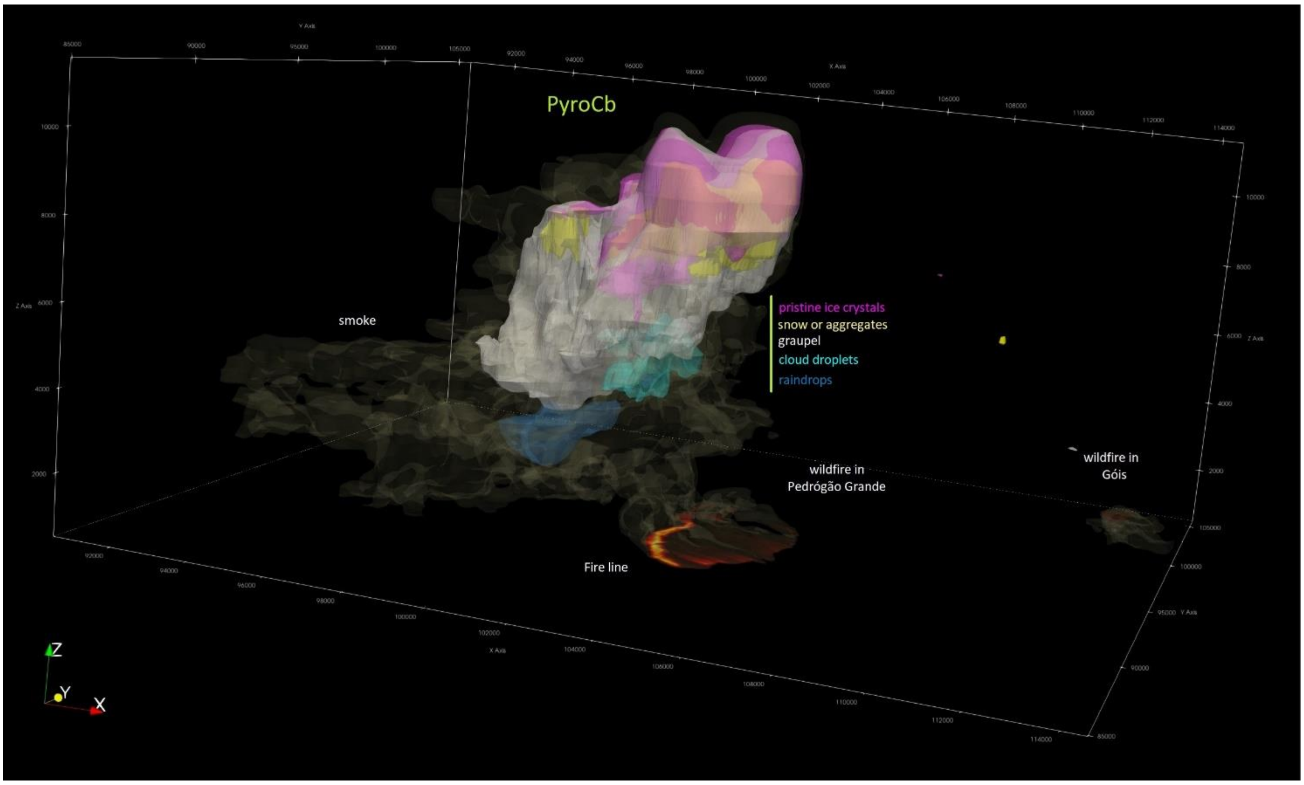

Figure 2- Anatomy of the PyroCb cloud simulated in the Pedrógão Grande mega fire episode. Animation available online at https://youtu.be/vn7PaFh88ss.

4. Conclusions

Fire spread associated with extreme pyro-convective activity is currently highly unpredictable and difficult to suppress. In this study, the findings show the benefits of the use of cloud-resolving models in order to assess the potential for dangerous fire conditions associated with pyroconvection. Moreover, the preliminary results indicate that the model, when configured in high temporal and spatial resolution, is able to represent the pyro-convective plume height from a wildfire and the main processes associated to the interaction of the fire with the atmosphere. In the Pedrógão Grande mega fire event, the violent fire-driven convection manifested as a PyroCumulonimbus cloud. It is important to note that one of the goals was to obtain a reference high resolution (10s, 80m) weather analysis for the reference fire line behaviour from the official report, so fire is forced in the simulation (the impact of the atmosphere in the fire front evolution is not represented).

The study is on-going and will help us to better understand pyro-convective events, namely the atmospheric processes in a micro-scale context, and also in terms of fire behaviour to associate local wind and temperature and humidity to the fire line evolution and local rate of spread. Overall, an improved understanding of these events is important for a range of fields related to the pyroconvection and extreme fire events.

6. Acknowledgments

This research is funded by the European Union through the European Regional Development Fund in the framework of the Interreg V A Spain – Portugal program (POCTEP) through the CILIFO project (Ref.: 0753_CILIFO_5_E), FIREPOCTEP project (0756_FIREPOCTEP_6_E), RH.VITA project (ALT20-05-3559-FSE-000074), H2020 FIRE-RES (GA: 101037419), and also by Portuguese national funds through FCT - Foundation for Science and Technology, I.P. under the PyroC.pt project (Refs. PCIF/MPG/0175/2019) and ICT project (Refs. UIDB/04683/2020 and UIDP/04683/2020).

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