Modelling dry thunderstorm environment during a wildfire episode in Portugal

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1. INTRODUCTION

A better understanding of wildfires is necessary both from physical and operational points of view, which are the goals of the CILIFO (***Centro Ibérico para la Investigacion y Lucha contra Incendios Forestales***) Interreg POCTEP project (http://cilifo.eu/). Lightning are the main natural source of wildfires and an important contributor to burned areas in many regions. In 2017, devastating forest fires were reported in Portugal. The fires near Pedrógão Grande created a huge wall of flames, killing at least 60 people.

The **goal** of this study is to discuss the atmospheric conditions that were supportive of lightning flashes to cause a fire during this event, as well as to check the possibility to correctly diagnose cloud-to-ground flashes using high resolution simulations with the non-hydrostatic atmospheric Meso-NH model (***Lac et al., 2018***).

2. DATASET

A set of meteorological data was used to validate the model results and to describe the prevailing atmospheric environment during the afternoon of 17th June 2017 over central Portugal. The Portuguese Institute for Sea and Atmosphere (IPMA) provided the data for this study.

- **# weather stations**
- **# lightning detection**
- **# radiosounding**
- **# weather radar**
- **# fires spots**

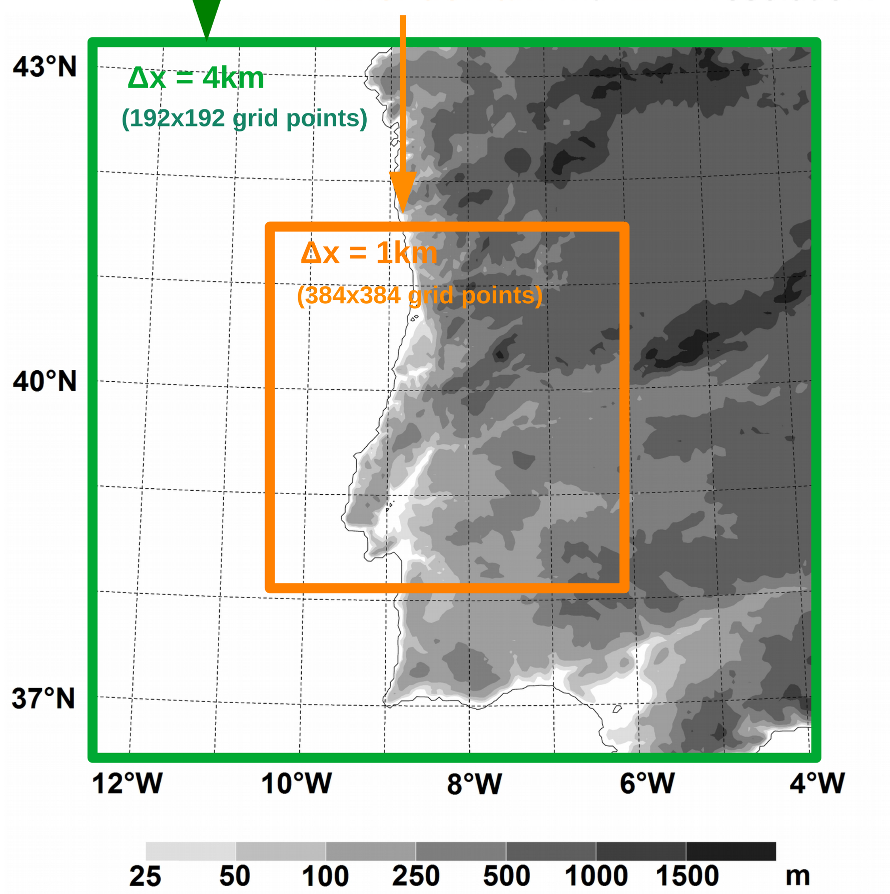
3. NUMERICAL MODELLING [*Meso-NH model configuration*]

Horizontal configuration

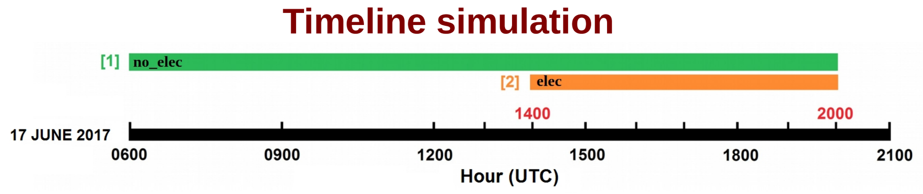
Two nested domains

Large domain with **4km** horizontal resolution.

Inner domain with **1km** resolution.



Timeline simulation



Vertical configuration

50 levels

Initial conditions

Meso-NH model was initialized from the ECMWF Analysis every 6h.

Physical aspects

The model represents explicitly the electrical activity of the clouds, through the activation of the Cloud ELectrification and Lightning Scheme (CELLS; ***Barthe et al., 2012***).

Parametrization	4km	1km
Convection	KAFR	none
Shallow Convection	EDKF	none
Turbulence	1D	3D
Cloud microphysics	ICE3	ICE3
ELEC	none	ELE3

4. RESULTS

The possibility of the afternoon heating create a **convective instability condition** can be observed in the sounding at 1200 UTC (***Fig. 1***). **Temperatures around 30°C** are observed in the lowest hundreds of meters, reaching almost **35°C at surface**. As the air is heated enough to reach the level of free convection, instability can be released and **convective clouds** start to develop **with high bases**, nearly to the freezing level around 600 hPa, and **cloud tops above 12 km**. It is noteworthy the presence of a **drier layer at lower troposphere** having approximately **3 km depth**.

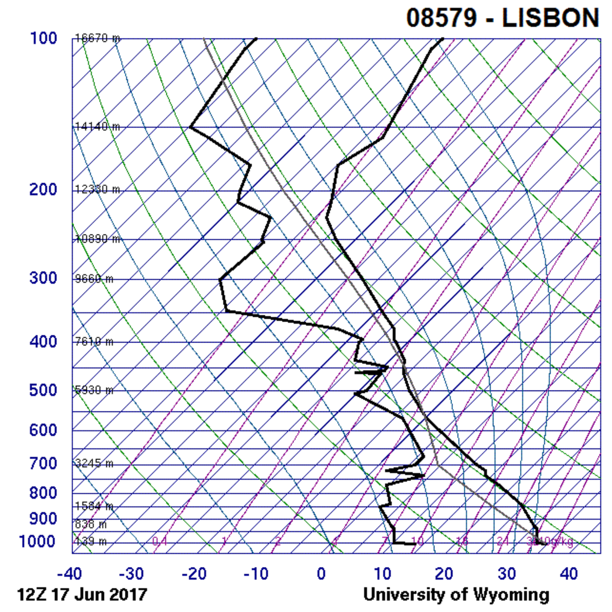


Fig. 1: thermodynamic diagram.

Fig. 2 shows a **comparison** between **observations** and **simulation** for the 2m temperature and relative humidity maps. Concerning the **temperature** (***Fig. 2a***), there is an agreement for the peak values well above **35°C near Pedrógão Grande**, and **40°C** over the south half of the domain. For the 2m **relative humidity** and despite some occasional over or underestimation, the model has captured well the horizontal distribution of the variable, with **values as low as 10 %** (***Fig. 2b***). All these features lead to **very favourable conditions to** facilitate the **fuelling** and the **propagation of wildfires.**

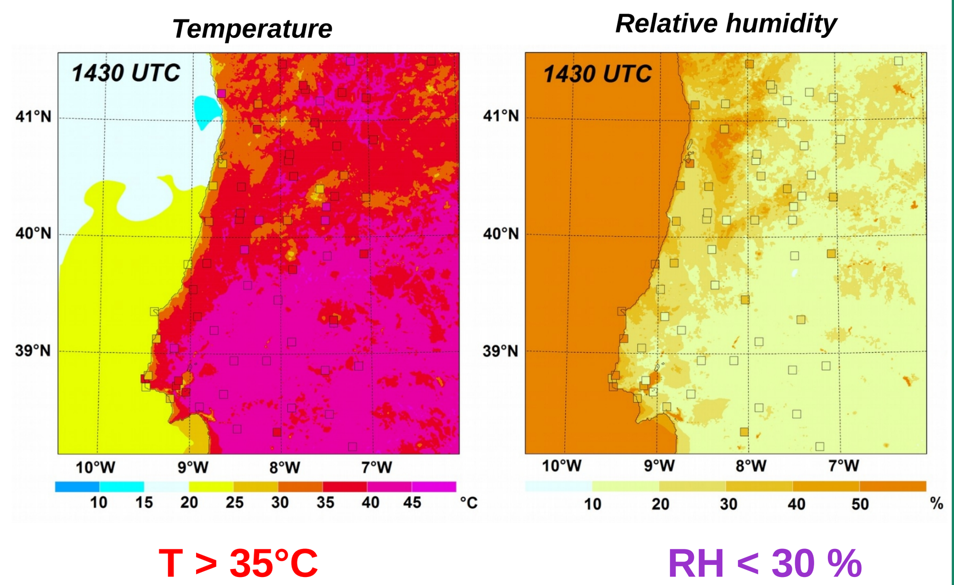


Fig. 2: (a) T2m, and (b) RH2m. The small squares represent the records of each weather station.

The Meso-NH system includes a **grid point radar diagnostic** given by the total equivalent radar reflectivity. It is calculated as a sum of radar reflectivities produced by each hydrometeor type illuminated by the radar wave.

Fig. 3 shows a cross-section of **radar reflectivity**, built from the **radar** scans and by the **simulation** at the same place. The vertical structure of the simulated **convective system over the region where fires occurred** is marked by an anvil of similar vertical and horizontal extensions of the observed one.

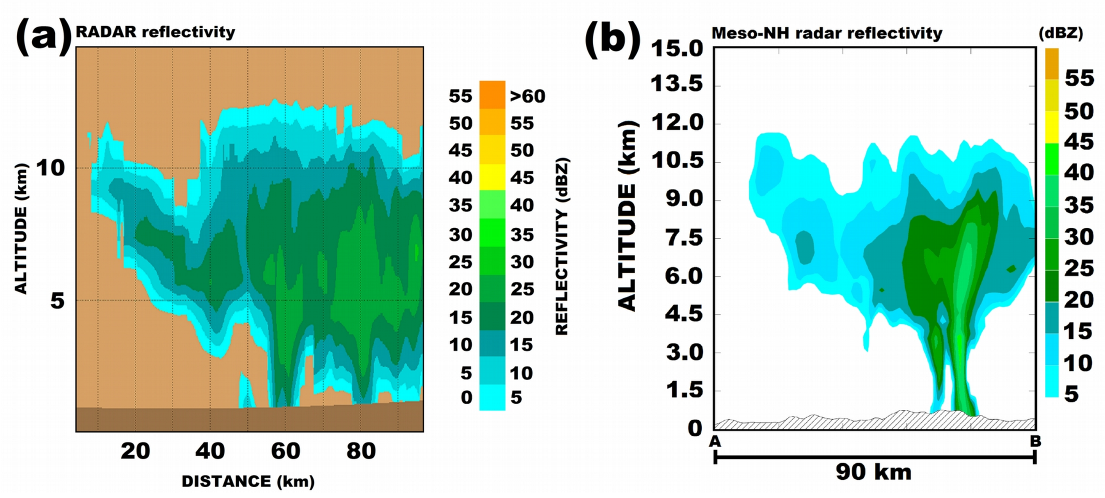


Fig. 3: vertical cross-section at 1700 UTC (a) radar observation, and (b) Meso-NH reflectivities. Adapted from ***Couto et al. (2020).***

The description of the electrical state of a thunderstorm is based on the monitoring of the electrical charge densities, the computation of the electric field and the production of lightning flashes. The cloud charging involves mostly the non-inductive mechanism, and both Intra-Cloud (IC) and Cloud-to-Ground (CG) flashes are considered. The CELLS scheme provides a realistic representation of the electrical properties of precipitating cloud systems from representing the charge density of each hydrometeor.

Fig. 4 shows the **vertical electrical structure** of the thunderstorm. For the polarity of individual hydrometeor ice categories, **graupel** is *negatively charged* (***4a***). The **snow** carries most of the *positive charges* (***4b***), while the small **ice crystals** are responsible for the *upper negatively charged zone* (***4c***). In ***Fig. 4d***, the hatched area corresponds to the mixing ratio of the condensate above 0.1 g/kg and where the **total electrical charge density** of the liquid and ice particles is superimposed. The **electrical structure** reveals that the model simulates a **tripole** with an **inverted polarity**. A main **positive charge region** between 7 and 8 km height is **surrounded by two negatively charged regions**.

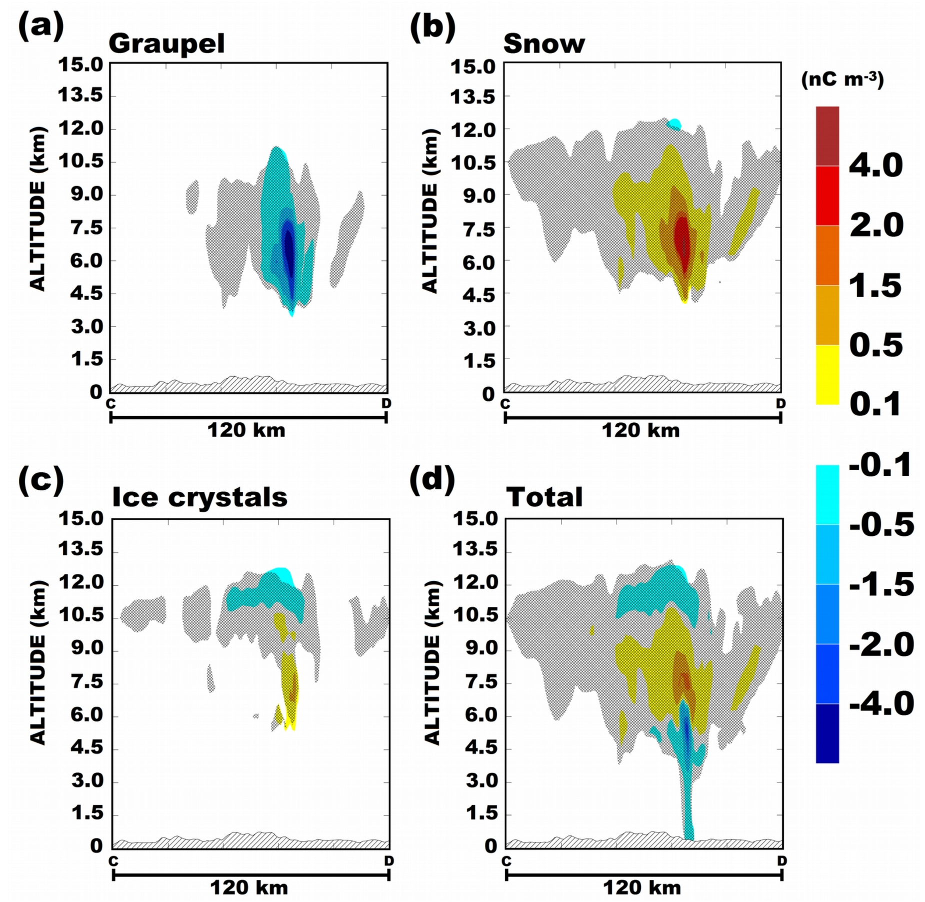


Fig. 4: charge density (coloured areas) and hydrometeors mixing ratio (hatched area) at 1630 UTC. Source: **Couto et al. (2020)**.

5. CONCLUSIONS

The **dry thunderstorm environment** configured a **perfect scenario** for the **natural ignition and evolution of some fires**, since **lightning activity** came **from high-base thunderstorms** with relatively **dry air at lower levels** favouring the **evaporation of rain** before it reaches the ground, as well as **intense outflows**. Therefore, the fires on 17th June 2017 occurred in an exceptional hot day, with fire ignitions in places with complex terrain and a favourable vegetation state producing uncontrolled wildfires. The spatial distribution of the simulated CG lightnings showed a good agreement with the lightning strokes obtained from the national lightning detection network. Besides the identification of favourable conditions for the occurrence of wildfires, **this study also introduces a possible application of the Meso-NH electrical scheme, namely the study of forest fire ignition by lightning strokes.**

A complete description of the study can be found in Couto et al. (2020).

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