Fire–Atmosphere Modeling: Some Findings and Current Challenges Based on Iberian Case Studies

Rui Salgado[1], Flávio T. Couto[1], Cátia Campos[1], Filippe Santos[1], Roberta Baggio[2], Jean-Baptiste Filippi[2], João Rio[3], Carolina Purificação[3], Miguel Pardal[3], Margarida Belo-Pereira[3], Nuno Guiomar[4], Juan Picos[5]

[1] Universidade de Évora / CREATE
[2] CNRS – Université de Corse
[3] IPMA – Instituto Português do Mar e da Atmosfera
[4] Universidade de Évora / MED & CHANGE
[5] Universidade de Vigo

Abstract

Wildfires in the Iberian Peninsula have shown an increase in extreme behavior in recent decades. Wildfire behavior depends on atmospheric conditions, terrain, available fuels and fire-induced processes.

Using high-resolution coupled simulations (Meso-NH/ForeFire), we analyze a set of Iberian case studies, including summer megafires associated with pyro-convection, including Pedrógão Grande and Quiaios (2017), and a winter trans-boundary fire event (January 2022), which highlights the role of dry conditions, easterly flow, orographic forcing and atmosphere-fire feedbacks in fire propagation, frequently generating strong updrafts and downbursts that significantly modify near-surface winds and accelerate fire spread.

Placing these events in a broader context, a multi-decadal analysis (1980–2025) reveals that large wildfire occurrence is not governed by a single atmospheric pattern, but by a combination of favorable large-scale conditions and regional-scale processes. While no clear long-term trend is found in circulation types, warming temperatures and drier conditions are shifting the fire season earlier and increasing background fire danger.

At finer scales, convection-permitting simulations (down to 500 m) demonstrate that fire danger metrics such as the Fire Weather Index (FWI) exhibit strong sub-daily variability and sensitivity to mesoscale processes . Sea-breeze circulations, orographic flows and local wind systems produce sharp spatial gradients in fire danger that are not captured by standard daily products, revealing critical windows of enhanced risk.

Together, these results show that wildfire behavior in Iberia emerges from a multi-scale coupling between synoptic forcing, mesoscale dynamics and fire-induced processes. However, key challenges remain, including the representation of pyro-convection, fuel–atmosphere interactions, and the integration of high-resolution modeling into operational frameworks.

Advancing fire-atmosphere modeling towards operational use will require bridging scales, improving data assimilation and enhancing the temporal resolution of fire danger products. This is essential to anticipate extreme fire events in a warming climate.

Keywords: pyro-convection; fire-atmosphere modeling; Meso-NH: ForeFire; FWI

Acknowledge
Results presented in this communication were obtained with the support of the Centre for Research in Science and Technology for the Earth System and Energy (CREATE, doi:10.54499/UID/06107/2025), and of the projects: CILIFO (0753_CILIFO_5_E); FIREPOCTEP (0756_FIREPOCTEP_6_E); FIREPOCTEP+ (0139_FIREPOCTEP_MAS_6_E); PyroC.pt (doi:10.54499/PCIF/MPG/0175/2019).