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Numerical analysis of synoptic and mesoscale fire weather dynamics of extreme wildfires in Greece

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Recent destructive fire seasons around the world indicate the emergence of novel fire regimes, characterized by high-intensity burning and extreme fire behavior. While the contribution of individual factors can be debated, the scientific literature concludes that fire weather is one prominent driver of fire activity. Moreover, there is growing evidence that climate change is escalating the frequency, severity and extend of wildfires around the world. Simply put, wildfires are changing because we change the conditions in which they occur. Although the importance of weather to wildfire activity has been documented since the 1930s, there is still a lot of research effort in advancing our knowledge on the drivers and the processes that lead to the development of extreme fire weather and behavior. Here we investigate the synoptic and mesoscale fire weather dynamics associated with 9 extreme wildfires in Greece during the period from 2009—2022. We select wildfires that took place within this period to exploit the increased availability of surface weather data from the automatic weather stations network of the National Observatory of Athens as ground-truth for evaluating the numerical simulations and studying surface fire weather. The selection of the examined wildfires is based on the extremeness of satellite-derived daily growth rates of burnt area as well as the environmental and socio-economic impacts. To assess the fire weather dynamics associated with each event we conduct numerical simulations with the Weather Research and Forecasting (WRF) model initialized with ERA5 reanalysis data from the European Centre for Medium-range Weather Forecasts (ECMWF). Our synoptic and mesoscale analysis of the WRF simulations illustrates the dominant atmospheric processes that drive fire weather conditions, such as the horizontal and vertical transport of dry, warm and high-momentum air. Furthermore, our analysis demonstrates a distinct separation in atmospheric dynamics between the wind-driven and plume-dominated (i.e., wildfires that are accompanied by pyroconvection) wildfires. Finally, our work highlights the added value of high-resolution simulations to better simulate fire weather conditions in areas with complex topography such as Greece, and we discuss potential implications for fire weather forecasting.

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