



## Characterization of thermally-driven flows and their interaction with the urban heat island in Madrid

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Madrid is located in a topographically complex environment, with the Sierra de Guadarrama being the most relevant mountain system in the area, where thermally-driven flows (TDFs), such as mountain and valley breezes, interact with the urban heat island (UHI) and modulate local meteorological conditions. Over recent decades (1970–2020), the population of Madrid has doubled while the urbanized area has expanded by a factor of five. Future projections indicate a further urban expansion of 1.15 to 2.14 times the 2010 extent, accompanied by an approximate 15% population increase by 2037 (Gao & Pesaresi, 2021; INE, 2022). In this context, understanding how urbanization modifies wind regimes through changes in surface properties and terrain roughness, as well as its interaction with the UHI, is essential.

The main objective of this study is to characterize the TDFs affecting Madrid and to analyze their interaction with the UHI, assessing their spatial and temporal variability and their influence on the thermal and dynamical structure of the urban atmospheric boundary layer. The study is based on long-term observational and statistical analysis of meteorological datasets from urban and rural stations, complemented by field campaigns. These observations allow for the assessment of diurnal, seasonal, and annual variations in wind patterns, with a particular focus on detecting and characterizing breeze events, as well as quantifying differences in their intensity, direction, frequency, and duration between the urban environment and the surrounding mountainous areas.

In addition, numerical simulations are performed using the mesoscale Weather Research and Forecasting (WRF) model with advanced urban schemes, such as BEP-BEM (Martilli et al., 2002; Salamanca et al., 2010; Carbone et al., 2024), to further explore the underlying physical processes and to assess the impact of urbanization and thermally-driven flows on thermal comfort and air

quality.

This research is part of the MULTIURBAN-II and AIRTEC2-CM projects. The results are expected to advance the understanding of urban atmospheric processes in topographically complex settings and provide critical information for urban planning and climate adaptation strategies.