# Urban Heat Island intensity and Thermal Extremes in Lisbon: Observational insights for Urban Climate Adaptation

## Urban Heat Island intensity and Thermal Extremes in Lisbon: Observational nsights for Urban Climate Adaptation

D. Vilão (1,2), M.G. Pereira (2,3)

(1) Divisão de Meteorologia Aeronáutica, Dep. Meteorologia e Geofísica, Instituto Português do Mar e da Atmosfera, Lisboa, Portugal. (2) Centre for Research and Technology of Agro-Environmental and Biological Sciences (CITAB), Inov4Agro, University of Trás-os-Montes and Alto Douro (UTAD), Vila Real, Portugal. (3) Instituto Dom Luiz, FCUL, Lisboa, Portugal

**RESUMEN**

The increasing frequency and severity of heat extremes represent a major challenge for urban areas under ongoing climate change. In this context, the Urban Heat Island (UHI) effect acts as a local-scale amplifier of thermal stress, intensifying exposure during heatwaves and prolonging unfavourable thermal conditions, particularly at night. A robust observational characterisation of UHI is therefore essential to support climate risk assessment and evidence-based urban adaptation strategies. This study provides a detailed observational assessment of the UHI effect in Lisbon, Portugal, focusing on the role of land use/land cover, urban density, and morphological characteristics in shaping urban thermal patterns. The analysis is based on air temperature data from a reference station operated by the Portuguese Institute for Sea and Atmosphere at Lisbon Airport and a quality-controlled municipal meteorological network in contrasting urban environments, compliant with World Meteorological Organisation installation standards. Several urban indices were considered, including aerodynamic roughness, compactness (height-to-width ratio), volumetry, urban density class and biomass, allowing a comprehensive evaluation of the links between urban form and thermal behaviour. UHI intensity was quantified as the temperature deviation between each urban station and the reference site, and its diurnal and nocturnal evolution was analysed separately to capture the dynamics of heat accumulation and release. Results reveal a clear and consistent relationship between UHI intensity and urban structure, the critical role of urban greenery and permeable surface and the importance of natural ventilation corridors and wind exposure. Asphalted areas characterised by high urban density, compactness, roughness, and low biomass exhibit the highest UHI intensities, reaching average values close to 2 °C. These areas display pronounced nocturnal heat retention, reflecting the combined effects of a higher thermal inertia and reduced ventilation. In contrast, locations with greater vegetation cover and higher biomass exhibit significantly lower UHI intensities, even when situated within densely built environments and characterised by high surface roughness. Areas that preserve favourable ventilation conditions experience reduced heat accumulation, reinforcing the need to integrate climatic considerations into urban planning. Overall, this work demonstrates how high-resolution observational networks can effectively diagnose urban thermal patterns and extremes and identify priority areas for intervention. The results provide strong empirical support for nature-based solutions, strategic land-use planning, and climate-sensitive urban design as key components of urban heat adaptation and resilience in Mediterranean cities facing increasing thermal risk.