

Multi-Source Observations and High-Resolution Modeling to Investigate the Urban Heat Island in the City of Bolzano (Italy)

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Abstract The ability to accurately describe urban climate and the role of urban environments in determining heat conditions and hotspots is key to informing risk assessment, planning climate change adaptation measures, and developing mitigation strategies for cities. However, the characterization of Urban Heat Islands (UHI) still presents unique challenges from both observational and modeling perspectives, especially in complex mountainous terrain. This is due to the different scales of the features involved in the redistribution of the temperature field and the significant amount of data required to correctly capture the local specificities of both the city and its valley environment.

This study presents a novel approach integrating multi-source meteorological information to investigate the UHI in Bolzano, a city located in the south-eastern Alps and one of the Italian cities most exposed to high temperatures during summer months, especially during heatwave episodes. Specifically, we combine an extensive mobile measurement network with fixed observations, remote-sensing data, and high-resolution climate modeling. A unique distributed mobile measurement network, consisting of up to 25 meteorological sensors (MeteoTracker) installed on public buses, provides continuous spatial and temporal coverage of meteorological parameters (temperature, humidity, and pressure) across the urban area. The buses' fixed routes, including transitions between urban and rural areas, enable systematic quantification of UHI intensity across different temporal scales.

To bridge observational gaps and provide continuous spatial coverage, we employ two modeling approaches: (1) 100-m resolution urban climate simulations provided by the UrbClim model, resolving mesoscale features – such as thermally driven winds – for the recent period, the mid-term and the far future, and (2) weather predictions from the Weather Research and Forecasting (WRF) model at 1-km resolution covering the past 6 years. Temperature patterns described by the two model datasets, run over an extended area centered on the city, are compared and evaluated against observations, aggregated spatially and temporally to match model grid points.

To complement in-situ observations and model simulations, we generated high-resolution Land Surface Temperature (LST) images by fusing thermal data from Landsat and MODIS. This allowed for an analysis of the relationship between LST and urban morphology to assess the built environment's impact on surface heating

and to identify urban hotspots. The multi-source approach is first tested by considering recent heatwave episodes recorded in Bolzano, including the summers of 2022 and 2023. Preliminary results demonstrate the effectiveness of combining multiple observation types with high-resolution modeling to characterize UHI patterns in complex terrain.