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Introducing the Urban Wind Island Effect

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Researching the urban climate has increasingly become a focus point in meteorology over the past decades. The combination of ongoing urbanisation and climate change makes cities extra vulnerable to extreme weather. To make cities "climate-proof", additional knowledge of the complex urban climate is required. While urban meteorological research has typically focused on the Urban Heat Island, less is known about a city's impact on wind, which can be highly variable from street to street, and is difficult to capture in models or observations due to its highly turbulent and heterogenous nature. Urban wind studies are often focused on one isolated building, to assess mechanical load, or on an idealised urban canyon, with advanced Large Eddy Simulation models to (partly) resolve turbulence.
Instead, this study focuses on the mean wind in cities, to learn how the city as a whole impacts wind behaviour. Using a conceptual bulk model of the atmospheric boundary layer, we show that for certain conditions the boundary-layer mean wind speed in a city can be higher than its rural counterpart, despite the higher roughness of urban areas. This Urban Wind Island effect (UWI) is typically found in the afternoon, and appears to be caused by a combination of differences in boundary-layer growth; surface roughness and the ageostrophic wind, between city and countryside. Enhanced mixing in the urban area deepens the boundary-layer, and effectively mixes free tropospheric momentum into the boundary layer. Furthermore, the oscillation of the boundary-layer wind around the geostrophic equilibrium can create episodes where the urban boundary-layer mean wind speed is higher than the rural wind. By altering the surface properties within the bulk model, the sensitivity of the UWI to urban surface properties is studied for the 10 urban Local Climate Zones (LCZs). The ideal circumstances for the UWI to occur are a deeper initial urban boundary-layer depth compared to the rural value, low-rise buildings (up to 12 metres, LCZs 3 and 6) and a moderate geostrophic wind ($\sim$5 m/s). The UWI phenomenon challenges the commonly held perception that urban wind is usually reduced due to drag processes. Understanding the UWI is vital to accurately model urban air pollution, quantify urban wind energy potential or create accurate background conditions for urban Computational Fluid Dynamics models.