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Trade-offs between Urban Heat Island mitigation and air quality in an idealized urban valley.

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Many urban areas located in valleys experience exceedances in air quality standards as a consequence of factors related to orography, the state of the atmosphere, and the emission of pollutants. In urban valleys with limited ventilation (due to topographic barriers), the main mechanisms for the transport of pollutants is associated to thermally-driven valley flows. These valley flows are influenced by urbanization processes, as these modify the exchange of heat and momentum between the surface and the atmosphere. Consequently, phenomena such as the urban heat island (UHI) effect have consequences on air quality, but its impacts are not completely understood.

In this study we analysed the impacts of mitigating the UHI effect on the transport of pollutants in an idealized valley. We conducted a series of ideal numerical simulations using the Weather Research and Forecasting model in large-eddy simulation mode (WRF-LES). The ideal valley topography is composed of cosine-shaped slopes. The urban and rural areas are distinguished by differences in thermal forcing (specified sensible heat flux). We considered three different conditions of thermal forcing between the rural and urban areas (rural: Q_{h_max} = 100 W m^{-2}; urban: Q_{h_max} = 100, 250 and 400 W m^{-2}), and two different conditions of static stability (specified as a potential temperature gradient of 1 K km^{-1} and 3 K km^{-1}). The simulations (6 in total) cover the daytime period.

We found that pollutant concentration over the urban area increases with both increasing stability and decreasing UHI intensity. This is associated to a UHI-induced circulation where most of the transport of pollutants occurs at the valley centre by an ascending flow, instead of occurring by the upslope flows. The presence of the UHI also reduces the time required for the breakup of the temperature inversion, which is necessary for the ventilation of pollutants out of the valley.

These results suggest that the environmental and social benefits of mitigating the UHI in urban valleys should be analysed including the potential negative impacts in air quality, especially in urban areas where ventilation depends on thermally-driven flows. Our results are in contrast to several studies that suggest that UHI mitigation can reduce air pollution.