Cold-air ventilation and the nocturnal boundary layer structure above an urban ballast facet

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Abstract

The ballast facet of a goods station with its railway track leading towards the rural surroundings of the city of Osnabrück, Germany, was studied in terms of its thermal behaviour and its significance as an urban ventilation path for nocturnal cold-air transport from the rural surroundings. The investigations are based on sulfurhexafluoride (SF$_6$) tracer experiments, tethersonde soundings and energy-balance measurements. Although the ballast facet absorbs much of the incoming solar radiation during the day it is able to cool significantly throughout the night. The dispersion of nocturnal cold-air about the urban centre of Osnabrück is shown to be spatially and temporally variable and affected by the vertical structure of the nocturnal boundary layer. Even in moderate topography the near-surface flow is able to partly decouple from the flow aloft resulting in a two-layered structure of the nocturnal boundary layer above the goods station area. The bottom part can be attributed to the cold-air flow from the eastern surroundings with a vertical extension of about 20–30 m while the upper part is influenced by the larger scale orography.

1 Introduction

The urban heat island (UHI) belongs to the best-known and most intensively studied phenomena in the field of urban climatology. However, the spatial and temporal behaviour of the UHI is highly variable and dependent on the geographic and topographic setting, on the geometric shape, height and density of the buildings as well as on the building materials of the city under consideration – to name just a few. In recent years applied urban research focused on better understanding of the phenomenon but also on possible ways to mitigate nocturnal urban warming. Adequate urban ventilation through open spaces or ventilation paths is thought to be helpful in decreasing the UHI-intensity by drainage and transport of colder air from rural surroundings especially during clear and calm summer nights but also to reduce trace substance concentration due to dilution and mixing (KUTTLER, 2000).

In this context railway tracks are believed to serve as potential ventilation paths since they combine advantageous geographic exposition – in most cases they lead from rural environment into the urban centre – with favourable aerodynamic properties for air drainage and transport (small roughness length $z_0$, negligible displacement height $z_d$, sufficient length to width ratio, no barriers (MAYER et al., 1994)). The impact of different ventilation paths or inner-urban open spaces on cold-air transport and UHI-intensity are described for a couple of cities (e.g. GROSS et al., 1996; THORSSON and ELIASSON, 2003) whereas fewer studies deal with the thermal properties and the energy-balance of the specific facets and ventilation paths with regard to their influence on the air transported above. ASAEDA et al. (1996) and ANANDAKUMAR (1999) conducted research on different pavement-types. ANANDAKUMAR (1999) showed that asphalt with a thermal conductivity of 1.7 W m$^{-1}$ K$^{-1}$ rapidly conducts the heat received during the day to deeper layers releasing it during night leading to upward sensible heat fluxes due to high surface temperatures throughout summer nights. This feature was