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Spatial and temporal variability of turbulent vertical fluxes in Helsinki, Finland

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The eddy-covariance technique has been widely used above vegetated surfaces to measure the turbulent exchange of momentum, heat and gases between the surface and the atmosphere. Above an urban surface, however, observations are scarce and complex measurement surroundings bring challenges to the measurements and the representativeness of the fluxes in a city scale.

The fluxes of sensible (Q_H) and latent heat (Q_E), and CO_2 (F_c) have been measured at three sites in Helsinki, Finland. At the SMEAR III station the measurements have been ongoing since December 2005 and the site is located next to a busy road about 4 km from downtown Helsinki. Two of the sites, Erottaja Fire Station (EFS) and Hotel Torni (HT), are located in downtown within a distance of 400 meters from each other. In EFS, the measurements have been carried out in June 2010 – January 2011, while in HT, the measurements have been ongoing since September 2010. The present dataset allows the studying of the inter-site variability of the exchange processes. Simultaneous measurements from all three sites cover four months in autumn/winter time. The high-latitude location allows a detailed examination of the effect of seasonal variation to the exchange processes.

Q_H tends to be higher in city centre than in SMEAR III and a difference of 50 W m^{-2} is observed in winter. During the simultaneous measurements, stable atmospheric stratification is observed half of the time at SMEAR III whereas the occurrence in the city centre is less than 5%. This is a result of the urban heat island effect which is stronger in downtown than in the outside region. On the other hand, higher Q_E is measured in SMEAR III than in downtown particularly during spring and summer months when a difference of 100 W m^{-2} is observed. In downtown the low fraction of green areas limits the evaporation. Despite the short distance there are also differences between the two downtown sites. Both the median Q_H and Q_E are 7 W m^{-2} smaller in EFS than in HT. This difference arises likely from variations in storage and anthropogenic heat emissions. F_c reaches higher values in downtown than at SMEAR III, where the anthropogenic emissions are weaker. In summer, downtown acts as a source for CO_2 through the day while in SMEAR III downward median fluxes are observed. In SMEAR III however, the fluxes are highly dependent on the wind direction and downwind from the road F_c is as high as in downtown. Annually, the surroundings of SMEAR III act as a net source for CO_2 with 1760 g C m^{-2}, with a biased error of 6.1 g C m^{-2}caused by the gap filling method. Differences between the years are small and are mainly related to changes in the prevailing wind direction. Seasonal differences in F_c downwind from the road are mainly caused by reduced traffic rates in summer, while in other directions road traffic is the most important factor in winter but in summer the exchange is mainly determined by solar radiation.