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Aircraft observations of the urban CO_2 dome in London and calculated daytime CO_2 fluxes at the urban-regional scale

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Traffic, industry and energy production and consumption within urban boundaries emit great amounts of CO_2 into the atmosphere, creating an urban increment of CO_2 mixing ratios compared to the surrounding rural atmosphere. Monitoring CO_2 within these 'urban domes' has been proposed as a means to evaluate the effectiveness of policies aiming to mitigate and reduce CO_2 urban emissions (CMEGGE, 2010).

London is the biggest urban conurbation in Western Europe with more than 8 million inhabitants, and it emitted roughly 45000 ktn CO_2 in 2010 (DECC, 2012). In order to develop and implement observational strategies to measure the contribution of urban areas into the global carbon cycle, two airborne surveys were deployed using the Natural and Environment Research Council - Airborne Research and Survey Facility (NERC-ARSF). High frequency measurements of atmospheric CO_2, O_3, particles and meteorological variables were taken over London in October 2011 and July 2012. CO_2 mixing ratios were measured by a Non-Dispersive IR instrument developed by AOS. In July 2012, a Cavity Ring-Down Spectroscopy (CDRS) instrument developed by PICARRO was deployed measuring CO_2, CH_4 and water vapour at 1Hz resolution. The objectives of the campaigns were to measure the CO_2 dome over London and to calculate CO_2 emissions at the urban-regional-scale. London was crossed by two transects (SW-NE and SSE-NNW) at an altitude of 360 m and vertical profiles up to 2000 m were carried out to characterize the structure of the atmosphere.

Aircraft measurements allowed observation on how CO_2 domes were shaped by meteorological conditions. In October 2011, the mean CO_2 mixing ratio measured in London was on average 2 ppmv higher than the suburban measurements within the boundary layer. However, under low wind speeds, the CO_2 mixing ratio in the urban mixing ratio peaked in central London (>10 ppmv) and decreased towards the city boundaries. Under windy conditions, the structure of the urban dome was dispersed downwind, with peak concentrations displaced from the urban centre along the main wind direction.

The urban-regional surface CO_2 flux was calculated for four days in October 2011 by either the Integrative Mass Boundary Layer (IMBL) or the Column Integration method (CIM), dependent on meteorological conditions. The diurnal CO_2 flux in London obtained from the aircraft observations ranged from 36 to 71 μmol CO_2 m^{-2} s^{-1} during the day time. This compared well with continuous measurements of CO_2 exchange by an eddy-covariance system located in central London. The day-to-day variability observed in the calculated CO_2 fluxes responded to the spatial variability of the influence area and emissions that observations were sensitive to.

This study provides an example how aircraft surveys in urban areas can be used to estimate CO_2 surface fluxes at the urban-regional scale. It also presents an important cross-validation of two independent measurement-based methods to infer the contribution of urban areas to climate change in terms of CO_2 emissions that complement bottom-up emissions inventories.

References

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