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Urban greenhouse gas emissions from the Berlin area: A case study using airborne CO2 and CH4 in situ observations in summer 2018

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Urban areas are recognised as a significant source of greenhouse gas emissions (GHG), such as carbon dioxide (CO_2) and methane (CH_4). The total amount of urban GHG emissions, especially for CH_4, however, is not well quantified. Here we report on airborne in situ measurements using a Picarro G1301-m analyser aboard the DLR Cessna Grand Caravan to study GHG emissions downwind of the German capital city Berlin. In total, five aircraft-based mass balance experiments were conducted in July 2018 within the Urban Climate Under Change [UC]^2 project. The detection and isolation of the Berlin plume was often challenging because of comparatively small GHG signals above variable atmospheric background concentrations. However, on July 20th enhancements of up to 4 ppm CO_2 and 21 ppb CH_4 were observed over a horizontal extent of roughly 45 to 65 km downwind of Berlin. These enhanced mixing ratios are clearly distinguishable from the background and can partly be assigned to city emissions. The estimated CO_2 emission flux of 1.39 ± 0.75 t s^{-1} is in agreement with current inventories, while the CH_4 emission flux of 5.20 ± 1.61 kg s^{-1} is almost two times larger than the highest reported value in the inventories. We localized the source area with HYSPLIT trajectory calculations and the high resolution numerical model MECO(n) (down to ~1 km), and investigated the contribution from sewage-treatment plants and waste deposition to CH_4, which are treated differently by the emission inventories. Our work highlights the importance of a) strong CH_4 sources in the surroundings of Berlin and b) a detailed knowledge of GHG inflow mixing ratios to suitably estimate emission rates.