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# Multi-scale measurements combined with inverse modeling for assessing methane emissions of Hamburg

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Urban areas are hotspots for greenhouse gas emissions. The short-lived greenhouse gas methane is the second-most prevalent greenhouse gas emitted by human activities, and its reduction will help mitigate climate change effectively. However, the source strengths and locations of methane emitters in the urban areas are highly uncertain.

Here we present a multi-scale measurement campaign for assessing methane emissions in Hamburg. Hamburg is the second largest city in Germany with a population of about 1.8 million, and an important international harbor city. It has an interesting mixture of methane sources caused by anthropogenic emitters such as refineries and biogenic emitters such as wetlands associated with the strong tide of the Elbe River. Commissioned by UNEP, we conducted a campaign using remote sensing instruments and mobile surveys to investigate methane emissions of Hamburg. We deployed four automated solar-tracking Fourier transform spectrometer systems (Dietrich et al. 2021), one in the west, south, east and center of Hamburg to capture the total city emissions using a Bayesian inversion framework (Jones et al. 2021). Mobile measurements with a Picarro laser spectrometer in a car and a boat were performed to refine the spatial pattern of the emission inventory that is used as a prior for the inversion. We also deployed a wind LiDAR instrument to measure the 3D wind field that provides constraints to the transport model. In addition, an isotope ratio mass spectrometer was installed on a rooftop in the city center to distinguish anthropogenic and biogenic sources.

Using the column measurements and inverse modelling, we are able to determine the total city emissions and have found a major natural source, whose emissions are not yet included in the standard emission inventories. This dominant biogenic source is also indicated by the stationary

isotopic measurements of δ13C and δD. Nevertheless, more than half of the city emissions are attributed to anthropogenic emissions, indicating the importance of reducing these emissions. With our study, we show that the combination of mobile measurements and column measurements is a powerful technique to correct for the strength and spatial distribution of urban greenhouse gas emission inventories.

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