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Direct Measurements and Modelling of Neighbourhood-scale Carbon-Dioxide Emissions in Vancouver, Canada

Combustion of fossil fuels in the transportation, industry and residential sectors is responsible for most direct anthropogenic carbon-dioxide (CO_2) emissions in North America. Emissions are highly concentrated in urban areas or linked to urban activities. Specifically, it has been shown that emissions from residential activities are controlled by density, land use mix, transportation networks, technology and climate. However, when planning more sustainable urban development strategies, quantifying the actual impact of those controls is challenging, because information on total emissions is typically restricted and available only on coarse scales (nation, state, city) or for certain units/sectors (e.g. for individual houses using building energy models). However, most decisions in urban planning are made at the neighbourhood-scale and would need to integrate various emission components (buildings, transportation, vegetation).

Recent advances in atmospheric measurement techniques allow a direct and continuous measurement of all CO_2 emissions from an urban ecosystem. The eddy-covariance (EC) approach uses instruments on tall towers that can resolve hourly profiles of local CO_2 emissions (and uptake) at the 'block' or 'neighbourhood'-scale. Measured signals respond to the changing strength of emission processes (and uptake by photosynthesis). The EC approach allows us to quantify the temporal course of emissions and link it to the urban metabolism (e.g. diurnal course, weekday-weekend differences). In about 30 cities globally, EC systems were or are recording CO_2 emissions and show interesting relations between climate, land-use and density.

The presentation will discuss how we can benefit by combining long-term CO_2 emission measurements in an urban area using the EC method with fine-scale emission models. We will focus on a case study of a residential area in Vancouver, BC, Canada. Detailed maps of modelled local CO_2 emissions were calculated at 50 m resolution for a 4 km^2 area using a bottom-up approach. CO_2 emissions were modelled using input from an urban object classification (buildings, trees, land cover) automatically derived from Light Detection and Ranging (LiDAR) in combination with census, assessment, traffic and measured climate data. Different sub-models for buildings, transportation, human respiration, soils and vegetation were aggregated. Using a source-area model, the 'simulated' signal on the tower (7.42 kg C m^{-2} yr^{-1}) corresponds well with the actual measured total of 6.71 kg C m^{-2} yr^{-1}. The EC measurements show significant seasonal differences (16.0 g C m^{-2} day^{-1} in Aug vs. 22.1 g C m^{-2} day^{-1} in Dec correlated with the demand for space heating) and weekday-weekend differences (25% lower emissions measured on weekends attributed to traffic volume differences). The study demonstrates that direct CO_2 flux measurements based on the EC approach - if sites are carefully chosen - are a promising method to validate fine-scale emission inventories / models, and can allow interesting and relevant insights into the urban metabolism at the block or neighbourhood scale.