Researchers model carbon emission fluxes in the Boston urban region

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As the United States prepares to withdraw from the Paris Climate Accord, cities and states across the country have taken the lead in atmospheric CO2 reduction efforts. Therefore, accurate measures of anthropogenic and biogenic carbon emissions are imperative for tracking the progress of municipalities in achieving climate targets.

Boston, Massachusetts, has adopted reduction targets that include reducing emissions 25 percent below 2005 levels by 2020, and total carbon neutrality by 2050, when the world's population is expected to reach 6 billion. A collaborative of U.S. researchers has developed a model using Boston emissions data that accurately quantifies emissions in the Boston urban region for a period of 16 months, and they report that it is capable of detecting fluxes greater than 18 percent. They have published their results in the *Proceedings of the National Academy of Sciences*.

Emissions are highest in cities, which have the largest concentrations of vehicular use and carbon-based power generation, and cities are therefore ideal testbeds for models of greenhouse gas monitoring. However, although cities are leading efforts to reduce emissions, most have not adopted detailed inventories of atmospheric carbon sources.

The researchers note that emissions are largely assessed by two means: a "bottom-up" approach that derives fossil fuel use from various sources combined with the carbon content of the fuel; and a "top-down" approach that quantifies emissions based on greenhouse gas (GHG) emissions measured in the atmosphere.

The methodologies and input data for bottom-up monitoring can change between assessments in different years, creating uncertainty about flux. The researchers therefore present a new top-down method based on inverse modeling, which they report can quantify uncertainties in emissions to detect trends caused by policy, economic changes and regulations. The inverse model can also be used to monitor bottom-up inventories of carbon fuels.

The researchers write, "This study used 16 months of CO2 measurements at two sites in Boston and three boundary sites outside the city with a high-resolution modeling framework to quantify average anthropogenic emissions in the region to be 0.92 kg $C \bullet m^{-2} \bullet y^{-1}$ (95 percent CI:079 to 1.06), which is 14 percent higher than that calculated by the ACES inventory."

ACES is the first regional bottom-up inventory of hourly CO_2 emissions from fossil fuels across carbon-emitting sectors. The new top-down model has a couple of advantages. One is a so-called CO_2 concentration curtain that is tied to surface measurements but varying in altitude—the researchers report that this representation improved the agreement between the average they modeled and actual atmospheric measurements by 40 percent.

Secondly, the model uses a detailed representation of urban biological fluxes. Without this representation, it is not possible to generate an accurate model during the five-month growing season.

The researchers note that improving transport models and and remote sensing data will further narrow uncertainties, and that deploying similar modelling frameworks in other cities around the world would verify the achievement of emissions reduction goals.

More information: Anthropogenic and biogenic CO_2 fluxes in the Boston urban region. *PNAS*. 2018 Jul 2. DOI: 10.1073/pnas.1803715115

Abstract
With the pending withdrawal of the United States from the Paris Climate Accord, cities are now leading US actions toward reducing greenhouse gas emissions. Implementing effective mitigation strategies requires the ability to measure and track emissions over time and at various scales. We report CO_2 emissions in the Boston, MA, urban region from September 2013 to December 2014 based on atmospheric observations in an inverse model framework. Continuous atmospheric measurements of CO_2 from five sites in and around Boston were combined with a high-resolution bottom-up CO_2 emission inventory and a Lagrangian particle dispersion model to determine regional emissions. Our model–measurement framework incorporates emissions estimates

from submodels for both anthropogenic and biological CO_2 fluxes, and development of a CO_2 concentration curtain at the boundary of the study region based on a combination of tower measurements and modeled vertical concentration gradients. We demonstrate that an emission inventory with high spatial and temporal resolution and the inclusion of urban biological fluxes are both essential to accurately modeling annual CO_2 fluxes using surface measurement networks. We calculated annual average emissions in the Boston region of 0.92 kg $C \cdot m^{-2} \cdot y^{-1}$ (95% confidence interval: 0.79 to 1.06), which is 14% higher than the Anthropogenic Carbon Emissions System inventory. Based on the capability of the model–measurement approach demonstrated here, our framework should be able to detect changes in CO_2 emissions of greater than 18%, providing stakeholders with critical information to assess mitigation efforts in Boston and surrounding areas.

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