National Aeronautics and Space Administration

Quantification of Urban Emissions using OCO-3 Snapshot Area Maps

Principal Investigator: Annmarie Eldering (329); Co-Investigators: Junjie Liu (329), Robert Nelson (329), Paul Wennberg (California Institute of Technology), Dien Wu (California Institute of Technology)

Program: FY21 R&TD Topics (RPC-113) **Strategic Focus Area: Earth Science Data Analysis**

Overall Objectives:

- Create estimates of CO_2 emissions for a broad sample (~10) of cities and powerplants sampled by OCO-3 and quantify the uncertainty and benefit of OCO-3 SAM data.

- Integrate remote sensing CO and NO_2 estimates in the analysis system and quantify the sectoral contributions to the urban fossil fuel. NO_2 and CO are co-emitted with CO_2 during fuel combustion, but emissions ratios differ among different types of combustion.

- Evaluate the uncertainty reduction in CO_2 emission estimates for spring and summer when the biosphere model estimate net ecosystem exchange (NEE) based on remotely sensed solar induced fluorescence (SIF) data from OCO-3.

Significance/Benefits to JPL and NASA:

Our project has allowed us to develop the most complete set of tools for exploiting the OCO-3 SAMs over cities and powerplants, resulting in accurate emission estimates with uncertainties. The critical accomplishment is development of these new methodologies, which demonstrate the power of the remote sensing data. This work also supports the development of future missions, by providing a quantified way to show the benefit of spatially resolved simultaneous measurement of CO, CO_2, and NO_2. This information will be important for the development of Explorer proposals for Earth Science Designated Observables.

Publications

Wu, D., Liu, J., Wennberg, P. O., Palmer, P. I., Nelson, R. R., Kiel, M., and Eldering, A.: Towards sector-based attribution using intra-city variations in satellite-based emission ratios between CO2 and CO, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-1029, accepted, 2022.

Wu, D., Wennberg, P. O., Liu, J., Laughner J., Palmer, P. I., Lin, J., Kort, A. E., Nelson, R. R, and Eldering, A.: Simplified representation of the nonlinear NOx chemistry for quantifying NOx emissions from space. In prep.

Approach and Results:

The approach of this work is to begin with state-of-the art analysis tools of the postdoc, Dien Wu, which are capable of modeling/simulated the expected atmospheric CO2 enhancements over cities and near powerplants. This modeling tool was then upgraded to also simulate CO and NO2 atmospheric columns and the atmospheric decay of NO2. The measurements of CO2 in the OCO-3 Snapshot Area Map measurements over cities were evaluated along with the TROPOMI NO2 and CO measurements. In the first step, ratios of CO/NO2 were evaluated to downselect cases from the large OCO-3 SAM dataset. Dr. Wu then ran her simulation models, using up the three estimates of emissions (EPA for the US, and EDGAR for other regions).

By comparing the model simulation and the satellite observations of tropospheric NO2, we demonstrate our ability to identify the biases in wind direction and emission location (Figure 1) **that can improve the emission constraint of CO2**. NO_2 is co-emitted with CO_2, and because it stays in the atmosphere for just a short time, it is valuable to identify emissions plumes. This work examined the different calculated NO_2 enhancements for a US powerplant as well as the TROPOMI measurement, revealing the value of the more precise EPA emissions estimates, and the importance of including the chemical transformation of NO_2. This work is the only analysis of this type to include NO_2 decay in analyzing OCO-2 or OCO-3 data.

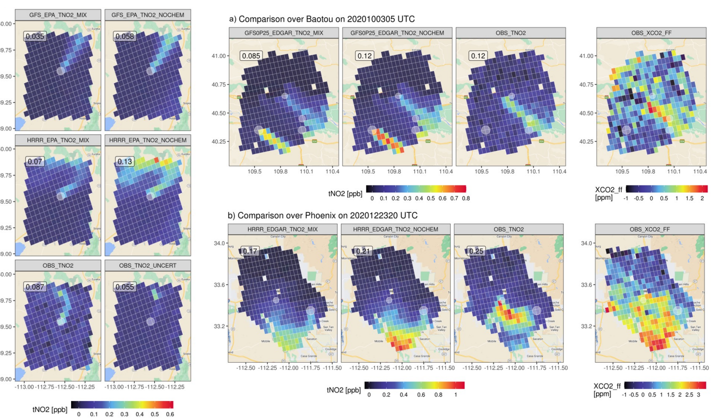

Figure 1. (LEFT) An example of the spatial distribution of modeled plumes based on GFS 025 and hourly EPA (1st row), and 3km HRRR and EPA (2nd row) with observed plumes from TROPOMI (3rd row). For each model combination, simulations with several configurations are also presented - concentration with or without the account of NOx chemistry but with a NO2-to-NOx ratio of 0.74. Emission locations according to EDGAR or EPA are labeled as white circles with their radius denoting the emission magnitude. (RIGHT) Similar figures of the modeled and observed tropospheric NO2 plumes for cities of Baotou, China and Phoenix, USA. The rightmost column shows the observed anthropogenic XCO2 signals from OCO-3 SAMs.

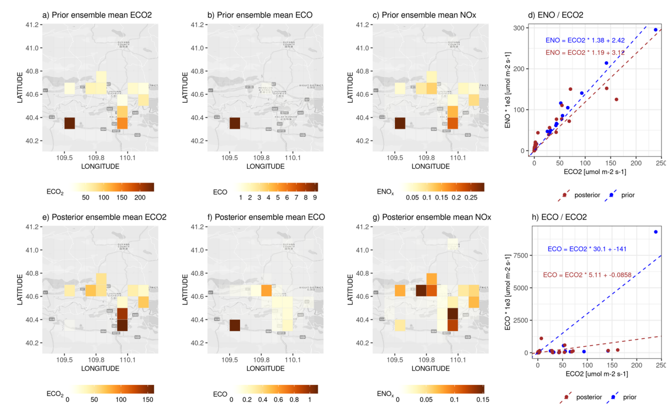

Figure 2. Prior (a-c) and posterior emissions (e-g) of CO_2, CO and NOx for Baotou. The prior and posterior emission ratios of NOx:CO_2 and CO:CO_2 are shown in panel d and h. Posterior values are obtained by conducting a chemical atmospheric inversion that is coupled to a Lagrangian modeling framework.

Figure 2 further demonstrates the ability of our inverse modeling system in optimizing emissions from NOx, CO, and CO2 and their emission ratio for urban areas. For example, the emission ratio of NOx:CO2 from top-down perspective is smaller than that from the bottom-up inventories (i.e., EDGAR) for Baotou. Since emission inventories usually have years of latency in updating their emission quantifications, this timely satellite constraints can help inform emission ratios in a near-real-time fashion and track possible changes in emission ratio that varies with different sectoral activities.

The overall flow of work closely followed our proposed milestones of installing the tools on the cluster, selecting 10 cases to start with, upgrading the NO_2 treatment, and integrating SIF data in the analysis. Analysis of cities in Africa was not possible due to limited data collects there. We have not found it necessary to evaluate alternate wind sources, as we had proposed. An additional finding beyond the proposed milestones was that sector specific emissions can be estimated in some cases. A manuscript is in preparation from the work that was completed.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Contact: Junjie.liu@jpl.nasa.gov

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