National Aeronautics and Space Administration

Quantification of Urban Emissions using OCO-3 Snapshot Area Maps

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Program: FY21 R&TD Topics **Strategic Focus Area: Earth Science Data Analysis**

Overall Objectives:

- Create estimates of CO_2 emissions for a broad sample (~10) of the Chinese cities 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

Towards sector-based attribution using intra-city variations in satellite-based emission ratios between CO2 and CO. *In preparation*

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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 CO_2 enhancements over cities and near powerplants. This modeling tool has been upgraded to also simulate CO concentrations, the NO_2 emissions and the atmospheric decay of NO_2. The measurements of CO_2 in the OCO-3 Snapshot Area Map measurements over cities are being evaluated along with the TROPOMI NO_2 and CO measurements. In the first step, ratios of CO_2/NO_2 were evaluated to downselect cases from the large OCO-3 SAM dataset. Dr. Wu then ran her simulation models, using up to three estimates of emissions (EPA for the US, and EDGAR for other regions). Figure 1 shows Baotou, China region, with the region that is background, or not influenced by emissions, marked with a black line. The simulation models are used to trace the path of air parcels and allows the background to be clearly identified.

Comparing the model simulation and the satellite observations demonstrates our ability to explain CO_2 enhancements. 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 2 show results of the analysis of the emission ratio of CO to CO_2, based on OCO-3 and TROPOMI data. This is a measure of combustion efficiency, and typically heavy industry is expected to result in higher CO/CO2 ratios. The more industrial city of Baotou (Figure 2) does indeed have higher ratios that Shanghai (not shown). The next step was to assess how well we can differentiate enhancements due to source such as transportation, heavy industry, and residential energy use. In results not shown here, we are exploring the power of the data to differentiate areas of industry from transportation and residential areas within the city, using the spatial variations of the data.

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.

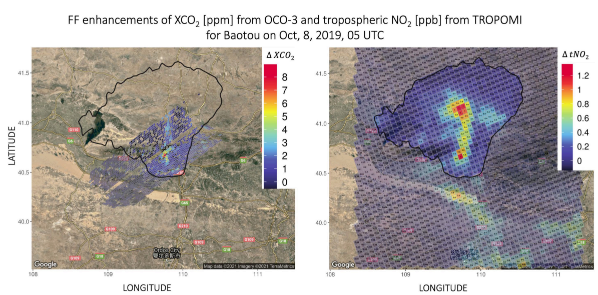

Figure 1: Observed anthropogenic enhancements of XCO2 [ppm] from OCO-3 b10r and tropospheric NO2 [ppb] from TROPOMI over Baotou at 05 UTC on Oct 8, 2019. Initial tropospheric column density of NO2 has been converted to tropospheric mixing ratio using modeled tropospheric dry-air column density. Baotou includes a number of large coal-fired power plants.

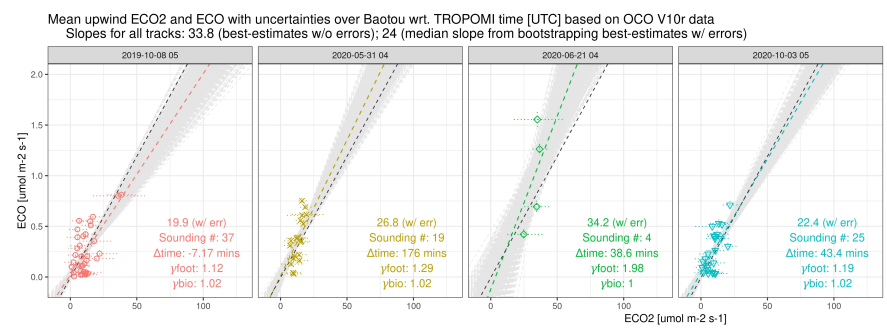

Figure 2: A summary figure for derived ERs [mmol mol-1] from six overpasses over Baotou using OCO-3 SAMs and TROPOMI XCO data. a) Scatter plot of mean upwind CO and CO2 fluxes [umol m-2 s-1] and their uncertainties (error bars). Linear regressions using the standardized major axis (SMA) method are fitted for the data from each track (dashed colored lines) and all tracks (dashed black line). TROPOMI overpass time in UTC, total TROPOMI sounding numbers, discrepancies in overpass time between OCO and TROPOMI (Δtime), impacts from different column footprints (γfoot) and urban-rural biogenic gradient (γbio) are labelled on each panel. These ERCO are almost twice as the ER for megacities like LA and Shanghai.

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