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The plume of CO_2 from Paris as seen OCO-2, TCCON and a high resolution transport model: analysis of the potential for inverting the emissions from Paris based on satellite CO_2 column data

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There is a growing interest in the monitoring of urban CO_2 emissions from space in order to further improve the quality of national greenhouse gas emission inventories. The preparation by the European Commission and ESA of a polar CO_2 imager with kilometric resolution (4 km2 per sounding) within the Copernicus programme well illustrates this emerging challenge. The comparable spatial resolution of the measurements of the CO_2 column-average dry-air mole fraction (XCO_2) made by NASA's second Orbiting Carbon Observatory (OCO-2) allows prefiguring some of this future data, even though OCO-2 does not have an imaging capability in nominal operation mode, and has a very limited one in target mode. A few Total Carbon Column Observing Network(TCCON) stations have also been installed in urban areas, like in Paris, and provide some original information about XCO_2 within urban plumes.

In this study, we take the example of the Paris mega-city, whose CO_2 plume can be well documented by a diverse ensemble of surface in situ and sand ground based remote sensing measurements and by a dedicated modelling infrastructure including local inventories. Compared to other mega-cities, the Paris case also has the advantage of a relatively flat terrain that does not challenge the model simulations. We use the modelling infrastructure to study the shape of the XCO_2 plume around the Paris mega-city in the northern part of France throughout the year at kilometric resolution. We compare the model simulations with corresponding OCO-2 measurements in both nominal mode and target mode, and with TCCON measurements (Paris and Orleans sites).

Both the model and the OCO-2 XCO_2 fields reveal large influences from remote natural and anthropogenic fluxes, and that the XCO_2 plume from Paris often has a complex structure. We also find some large disagreements between the model and the measurements regarding the temporal variability, amplitude and width of the plume from Paris. This occurs even for favorable situations with winds that are relatively constant and homogeneous in the vicinity of Paris, and when the amplitude of the plume is large enough to allow for characterizing it despite the measurement noise in the OCO-2 data. This highlights the challenge for filtering the XCO_2 plume from Paris in the OCO-2 measurements and for envisaging a regular atmospheric inversion of the CO_2 emissions from Paris with these data. However, some positive comparisons of the modeled and observed signature of the plume in the OCO-2 soundings will also be highlighted, raising expectations that the model and retrieval improvements could support such an inversion.