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High-resolution inversion of fossil fuel emissions and biogenic fluxes over the Paris region during 2019-2020

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The study aims to quantify the Paris region's CO and CO_2 emissions from fossil fuel and biogenic CO_2 fluxes during the spring season (March-May) of 2019-2020, based on a network of six ground-based stations. Hourly CO_2 mixing ratio gradients between the station Saclay (SAC), located in the south-west of Paris region and five other sites in the urban area are used to estimate the 5-day mean daytime budgets of the fossil fuel CO_2 emissions and biogenic fluxes. The inversion relies on the transport model simulations using the Weather Research and Forecasting model at 1 km × 1 km horizontal resolution, combined with 1-km fossil fuel CO_2 emissions from the Origins inventory, and biogenic CO_2 fluxes from the VPRM model. The methodology is based on a Lagrangian particle dispersion model (LPDM) approach that could efficiently determine the sensitivity of downwind mixing ratio changes to upwind sources. The inversion adjusts both fossil fuel emissions and VPRM biogenic CO_2 fluxes using tower observations and transport matrix generated from LPDM hourly footprints. The emission map shows noticeable changes in the central Paris region, whereas the biogenic fluxes do not show any noticeable change after inversion. This can happen if the choice of background station is not representative concerning biogenic fluxes. The inversion could reduce the uncertainty up to 20% for the fossil fuel emission but the biogenic flux uncertainty does not show a significant difference from the prior. In comparison with the 2019 pattern, the rate of increase in fossil fuel emission after inversion was considerably reduced for 2020 (up to 20-30%). The same pattern is observed in the 5-day total flux time series where the magnitude of posterior fluxes falls below prior fluxes except for the first few days of March, before the lockdown period. This aspect is further analysed in the second part of the study. Analysis of hourly mixing ratios generated from prior and posterior fluxes shows that prior mixing ratios increased as a result of large observed CO_2 gradients. A comparison of diurnal mixing ratios generated from prior and posterior fluxes shows that the mixing ratio gradient of all the sites shows a similar pattern, but the direct observations show an offset in the diurnal pattern. The second part of the study aims to quantify the changes in the CO_2 emission pattern over the Paris region during the recent COVID19 lockdown during 2020. Here, a multisystem comparison is carried out for the Lagrangian-based inversion and Eulerian WRF-CO_2 inversion. Both systems capture the effect of lockdown, with a significant reduction in traffic emissions. To improve the inversion and to reduce the uncertainty, the third part of the study uses a gridded CO/CO_2 mole fraction ratio to further constrain anthropogenic CO_2 emissions. Our study shows that It is an

added advantage to assimilate CO mixing ratios alongside CO_2 to increase the accuracy of anthropogenic carbon estimates.