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Quantifying global fossil-fuel CO_2 emissions: from OCO-2 to optimal observing designs

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Cities house more than half of the world's population and are responsible for more than 70% of the world anthropogenic CO_2 emissions. Therefore, quantifications of the fossil-fuel CO_2 emissions from major cities across the globe should facilitate the monitoring of the global emissions, in an independent and objective way. Satellite platforms, e.g. NASA's OCO-2 and Japanese GOSAT missions, provide observations of total column CO_2 (XCO_2) with favorable temporal and spatial coverage to estimate urban fossil-fuel CO_2 emissions. This work aims to address different error components in the urban CO_2 emission estimates, in order to shed insights on the optimal observation design for future satellite missions.

Based on real-data (i.e. OCO-2) and Observing System Simulation Experiments (OSSEs), we identified the major sources of emission estimation uncertainties for various types of cities with different ecosystems and geographical features, i.e. plume cities over flat terrains, basin cities with entrapped emissions, and coastal cities with mesoscale systems. The atmospheric transport errors under various meteorological conditions were characterized using the Weather Research and Forecasting (WRF) simulations at 1-km spatial resolution, and emissions imposed from the Open-source Data Inventory for Anthropogenic CO_2 (ODIAC) emissions. We quantify the errors due to limited sampling and modeling errors, including the seasonality in cloud cover and emissions, spatial distribution of biospheric fluxes, and daytime sampling bias. These factors are combined in pseudo data experiments, in order to evaluate their relative impact of uncertainties on inverse estimates of CO_2 emissions form 70 major cities across different latitudinal and climatological zones. The results indicate difficulties in sampling over the tropical cities, and the comparatively stronger impact of biogenic fluxes on the uncertainty of emission estimates for the cities in temperate zone. We propose here several sampling strategies to minimize the uncertainties for tracking urban fossil-fuel CO_2 emissions over the globe for future satellite missions, such as OCO-3 and forthcoming GOSAT missions.