



Constraining GHG emissions across the Japan East Coast using satellites, models and first continuous year-round ship-based measurements

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Remote sensing by satellites is especially crucial for coverage across places where in-situ observations are challenging such as oceans. In this work, we explore the potential of using multiple species (CO_2 , NO_2 , CO) remote sensing observations from satellites such as GOSAT2 and GEMS to constrain outflows towards oceans from megacities and large point sources. Characteristic enhancement ratios of multiple species are found to more accurately constrain anthropogenic combustion sources. These satellite observations however require extensive validation to ensure data quality and understanding of associated uncertainties. Oceanic in-situ observations are mostly available from ship-borne measurements. However, ships are only known to collect discontinuous short-term measurements. This study addresses this gap by making the first continuous year-round (Jan 2022-Mar 2023) simultaneous measurements of GHG and SLCFs (CO , CO_2 , CH_4 , NO , NO_2 , NO_y , O_3 , SO_2 , PM, BC, EC and OC) over the cargo ship Nichiyu-maru along Japanese East coast. Spatial and temporal variations of the species are studied to identify the regions and periods of high emissions, specifically found over major urban areas: Tokyo, Nagoya, Kobe and Hiroshima. Observed data and the Flexpart model are used to identify the emissions from point sources (industries, power plants). The impact of anthropogenic activities is reflected in the excess levels of CO_2 that reached as high as 35 ppm in the four urban regions. Excess levels and GridFED emissions are further used to estimate CO top-down emissions. The performance of the satellites and NICAM-TM model in reproducing CO_2 and CH_4 and their enhancements over the coastal regions is also evaluated. With the upcoming GOSAT-GW satellite set to make the first, simultaneous observations of CO_2 , CH_4 and NO_2 , this work lays the baseline for future studies that aim to validate these satellite observations and improve emissions estimates over Japan.

Keywords: greenhouse gases, top-down emissions, short-lived climate forcerrrs, GOSAT, GEMS, ship measurements