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## Quantifying anthropogenic methane emissions and their uncertainties using very high spatial and spectral resolution satellite and airborne data

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Methane is one of the most powerful greenhouse gases that has contributed to about a third of the 2010-2019 global warming relative to the pre-industrial times in 1850-1900. The Upper Silesian Coal Basin in southern Poland is one of the strongest anthropogenic methane (CH<sub>4</sub>) emitters in Europe, with emissions ranging from 228 to 339 ktCH<sub>4</sub>yr<sup>-1</sup>. In that region, ventilation shafts and drainage stations used in coal mines are the main sources of CH<sub>4</sub> emissions, of which the mass flows and their sources of uncertainties can be assessed using an adapted version of the Integrated Mass Enhancement (IME) method.

This challenge can be tackled using observations from Fabry-Perot imaging Short Wave InfraRed (SWIR) spectrometers onboard of the GHGSat aircraft and GHGSat satellite constellation. GHGSat acquisitions were made in June and July 2022 during a campaign including other measurements and which was partially funded in the framework of UNEP's International Methane Emissions Observatory. The GHGSat level-2 data provide full-swath CH<sub>4</sub> concentration estimations and filtered CH<sub>4</sub> plumes with spatial resolutions < 1.1 m on a swath width < 0.75 km for the aircraft, and < 28 m on a swath width < 12 km for the satellites, both featuring a spectral resolution of 0.1 nm. Furthermore, another version of the methane plumes was generated through a Z-test filter.

These observations were complemented with local wind profile and plume profile observations to estimate the effective wind speed that accounts for the effects of turbulent diffusion in the plume dissipation. This was achieved using two instruments from the University of Heidelberg: a wind lidar measuring the wind profile up to 200 m height at a sampling rate of ~8 seconds and a hyperspectral SWIR camera featuring a 1 min scanning time, a spatial resolution of 0.8 m and a spectral resolution of 7 nm. Since local wind profile measurements are rarely accessible, this study

attempted to find a relationship between the effective wind speed for the methane plumes of that region as a function of the wind speed at 10 m height from the ERA5-Land reanalysis (spatial resolution of 9 km and temporal resolution of 1 h).

Finally, a comparison is performed between the methane mass flow estimations derived from GHGSat satellites and aircraft observations with coinciding mass flow estimation from the CH<sub>4</sub> safety sensors located inside four of the same ventilation shafts (data collected by AGH University of Kraków) and the hyperspectral camera in June and July 2022. Moreover, another comparison is done with data acquired from a helicopter towed probe (HELiPOD) operated by the DLR and the Technical University of Braunschweig over one of the same shafts in June 2022. While bottom-up inventories may have delays of a few years before being available and require a certain level of trust, satellites can solve these issues through a faster top-down approach but still with relatively high uncertainties and multiple sources. The findings presented in this study can help to quantify the level of contribution from the different sources of uncertainties with high resolution data.