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Inversion of permafrost methane emissions using TM5-MP/4DVAR with TROPOMI measurements

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Methane is a significant greenhouse gas (GHG) with a global warming potential (GWP) of 32 for the 100-year horizon. Its global concentration has increased by more than 2.6 times since the pre-industrial era, primarily due to anthropogenic activities, making it a major contributor to global warming. Since 2007, atmospheric CH4 concentrations have been rising at a faster rate, reflecting a greater imbalance between its sources and sinks. As such, accurately assessing the sources of methane emissions is important to mitigate the consequences of climate change. Our current understanding of CH4 sources is rather limited, resulting in uncertainties in both bottom-up and top-down estimation methods, along with inconsistencies between these results. Therefore, it is imperative to incorporate new data with high confidence levels into assimilation systems that estimate emission sources. The Arctic, which warms twice as fast as the global average and is highly sensitive to temperature changes, is a region of particular concern. There, a significant portion of the world's soil organic carbon is stored, mostly in permanently frozen peat. As temperatures increase, permafrost thaws faster, releasing stored carbon as CO2 and CH4 and creating a positive feedback loop on climate change.

Our study aims to assess the potential contribution of thawing permafrost to the recent increase in global CH4 concentrations. To accomplish this, we estimate global CH4 emissions at a spatial resolution of 1°×1° using the inverse modelling system TM5-MP/4DVAR. This framework is based on the TM5-MP atmospheric chemistry-transport model and its adjoint, the four-dimensional variational (4DVAR) data assimilation. The data assimilated in this work comprises tropospheric CH4 column density measurements obtained from the TROPOMI instrument onboard the Sentinel 5-Precursor satellite, retrieved with the weighted function modified differential optical absorption spectroscopy (WFMD-IUP) algorithm, as well as near-surface CH4 observations from the stations of NOAA network.