Seminar “Physics and Chemistry of the Atmosphere”,
Institute of Environmental Physics (IUP), Univ. Bremen
Date: 16-Jan-2026, 14:15
Place: Building NW1, Room S1360

Parametric weighting of satellite data: Towards robust global CH_4 emission inversions

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Despite progress in understanding processes and improved estimates, significant uncertainties in CH_4 sources and sinks persist, leading to discrepancies between bottom-up and top-down approaches. Recent satellite missions carrying high-resolution, and more accurate instruments, have provided improved information on the concentration and spatial distribution of atmospheric trace gases. These observations offer the potential to reduce uncertainties in inversion estimates and, consequently, narrow the gaps between methane emission estimates.

In this study, we evaluate the feasibility and effectiveness of performing inversions that integrate satellite-based remote sensing observations with in-situ measurements. A key motivation is to address limitations of previous approaches that used constant weighting between observation types, which tended to suppress gradients in regions with sparse satellite coverage. For this, we assimilate retrievals from the TROPOMI WFMD v2.0 methane product and background observations from the NOAA monitoring network, applying weights that depend on the temporal and spatial distribution of individual observations. This parametric weighting reduces the heterogeneity of regional contributions to the inversion, primarily caused by differences in pixel availability, and helps balance the large disparity in data volume between TROPOMI and NOAA measurements. As a result, the optimization becomes more robust and preserves sensitivity in poorly observed regions, reducing the vanishing-gradient problem inherent to constant weighting approaches.