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Tropospheric methanol observations from space: Retrieval evaluation and constraints on the seasonality of biogenic emissions

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Methanol retrievals from nadir-viewing space-based sensors offer powerful new information for quantifying methanol emissions on a global scale. Here we apply an ensemble of aircraft observations over North America to evaluate new methanol measurements from the Tropospheric Emission Spectrometer (TES) on the Aura satellite, and combine the TES data with observations from the Infrared Atmospheric Sounding Interferometer (IASI) on the MetOp-A satellite to investigate the seasonality of methanol emissions from northern midlatitude ecosystems. Using the GEOS-Chem chemical transport model as an intercomparison platform, we find that the TES retrieval performs well when the degrees of freedom for signal (DOFS) are above 0.5, in which case the model:TES regressions are generally consistent with the model:aircraft comparisons. Including retrievals with DOFS below 0.5 degrades the comparisons, as these are excessively influenced by the a priori. The comparisons suggest DOFS > 0.5 as a minimum threshold for interpreting retrievals of trace gases with a weak tropospheric signal. We analyze one full year of satellite observations and find that GEOS-Chem, driven with MEGANv2.1 biogenic emissions, underestimates observed methanol concentrations throughout the midlatitudes in springtime, with the timing of the seasonal peak in model emissions 1-2 months too late. We attribute this discrepancy to an underestimate of emissions from new leaves in MEGAN, and apply the satellite data to better quantify the seasonal change in methanol emissions for midlatitude ecosystems. The derived parameters (relative emission factors of 11.0, 1.0, 0.05 and 8.6 for new, growing, mature, and old leaves, respectively, plus a leaf area index activity factor of 0.75 for expanding canopies with leaf area index < 2.0) provide a more realistic simulation of seasonal methanol concentrations in midlatitudes on the basis of IASI, TES, and ground-based measurements.