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ACCURATE: Greenhouse Gas Profiles Retrieval from Combined IR-Laser and Microwave Occultation Measurements

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The new climate satellite concept ACCURATE (Atmospheric Climate and Chemistry in the UTLS Region And climate Trends Explorer) enables simultaneous measurement of profiles of greenhouse gases, isotopes, wind and thermodynamic variables from Low Earth Orbit (LEO) satellites. The measurement principle applied is a combination of the novel LEO-LEO infrared laser occultation (LIO) technique and the already better studied LEO-LEO microwave occultation (LMO) technique. Resulting occultation events are evenly distributed around the world, have high vertical resolution and accuracy and are stable over long time periods.

The LIO uses near-monochromatic signals in the short-wave infrared range ($\sim$2-2.5 μm for ACCURATE). These signals are absorbed by various trace species in the Earth's atmosphere. Profiles of the concentration of the absorbing species can be derived from signal transmission measurements. Accurately known temperature, pressure and humidity profiles derived from simultaneously measured LMO signals are essential pre-information for the retrieval of the trace species profiles. These LMO signals lie in the microwave band region from 17-23 GHz and, optionally, 178-195 GHz. The current ACCURATE mission design is arranged for the measurement of six greenhouse gases (GHG) (H_2O, CO_2, CH_4, N_2O, O_3, CO) and four isotopes ($^{13}CO_2$, $C^{18}OO$, HDO, $H_2^{18}O$), with focus on the upper troposphere/lower stratosphere region (UTLS, 5-35 km). Wind speed in line-of-sight can be derived from a line-symmetric transmission difference which is caused by wind-induced Doppler shift. By-products are information on cloud layering, aerosol extinction, and scintillation strength.

We introduce the methodology to retrieve GHG profiles from quasi-realistic forward-simulated intensities of LIO signals and thermodynamic profiles retrieved in a preceding step from LMO signals. Key of the retrieval methodology is the differencing of two LIO transmission signals, one being GHG sensitive on a target absorption line and one being a close-by reference outside of any absorption lines. The reference signal is used to remove atmospheric broadband" effects by this differential absorption" approach. Refractivity and impact parameter of the LIO signals, needed for the retrieval, can be computed from the LMO-derived thermodynamic profiles. An Abel Transform converts the differential LIO log-transmission profile to the absorption coefficient. Based on the absorption coefficient and the absorption cross section of the GHG under investigation, that can as well be computed from the LMO-derived profiles, the number density profile or volume mixing ratio of the desired GHG can be finally derived. When using several LIO signals, best sensitive to the same GHG at different heights, a joint optimal GHG profile can be constructed by combining the individual profiles in an inverse-variance-weighted manner (practically used for H_2O, obtained from 3-4 signals, and for CO_2, obtained from 2 isotope signals).

The thermodynamic parameters (temperature, pressure and humidity) derived from LMO as basis for the LIO retrieval are found to be accurate to better than 0.5 K for temperature, 0.2% for pressure, and 10% for humidity. The accuracy of retrieved trace species profiles is found better than 1% to 4% for single profiles in the UTLS region (outside clouds which block infrared) and the profiles are essentially unbiased (biases $<$0.1% if properly implementing SI traceability and target-line spectroscopy). The methodology shows promising prospects for GHG monitoring of climate benchmark quality based on the combined LIO and LMO technique.