

ACCURATE - CLIMATE BENCHMARK PROFILING OF GREENHOUSE GASES AND THERMODYNAMIC VARIABLES AND WIND FROM SPACE

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ACCURATE is a LEO-to-LEO occultation mission concept conceived at the Wegener Center late 2004, then pioneer-developed in Europe 2005-2010 and recently proposed in ESA context as an Earth Explorer Opportunity mission that aims to initiate a novel fundamental atmospheric state dataset for climate and composition monitoring and research in the global free atmosphere. The core rationale is that expanding the observational foundation for climate change studies by accurate, long-term, consistent benchmark data is a fundamental need of climate science (see, e.g., IPCC reports) and Earth observation from space is the key means to obtain such data globally (see, e.g., WMO/GCOS reports). Current methods of sounding Earth's free atmosphere (above boundary layer) do collectively enable global observations of GCOS Essential Climate Variables, including on thermodynamic state (temperature, pressure, humidity), dynamics (wind), and composition (O₃, CO₂, CH₄, other greenhouse gases), but are unable to provide them as consistent benchmark dataset.

The latter requires joint sensitivity to all essential variables, measurement stability over decades and longer, high accuracy tied to international metrological standards and un-biased spatiotemporal sampling. Despite the demand and having GNSS radio occultation as a valuable asset for refractivity profiling, such a fundamentally needed "full atmospheric state" method did not exist so far. ACCURATE furnishes this method enabling to profile all variables noted above over the upper troposphere and lower stratosphere (UTLS, 5-35 km) and beyond with 1 km height resolution as consistent benchmark dataset. It combines LEO-to-LEO microwave occultation (LMO) in the 17-23/178-183 GHz band for thermodynamic state profiling with LEO-to-LEO infrared-laser occultation (LIO) in the 2-2.5 μm band for greenhouse gas and line-of-sight wind (Vlos) profiling, jointly referred to as LMIO method.

LMIO is capable to provide ground-breaking contributions to science goals such as monitoring of climate variability and trends, diagnostics of changes and analysis of processes in the UTLS, testing of global climate, composition and weather models, and provision of authoritative reference data for calibration and validation of data from other space/airborne/ground observing systems.

The key for reaching the science goals is the accurate LMIO profiling, based on self-calibrated

Doppler shift and differential log-transmission data, of the “full atmospheric state” $X = (z, T, p/Z, q/H_2O, V_{los}, CO_2, ^{13}CO_2, C^{18}OO, CH_4, N_2O, O_3, CO, HDO, H_2^{18}O)$, complemented by profiling of aerosol, cloud layering, and turbulence. All profiles come with accurate height knowledge ($< 10\text{-}20$ m uncertainty).

The presentation will introduce ACCURATE along the lines above, with emphasis on the climate science value and the new LIO capability, and discuss LMIO performance.

The results provide evidence that the GHG and isotope profiles can generally be retrieved within 5-35 km with $< 1\text{-}4\%$ rms error (outside clouds), V_{los} with < 2 m/s rms error (outside clouds), and temperature/ pressure/ humidity from LMO with < 0.5 K/ 0.2% / 10% rms error (incl. in clouds), all at 1 km vertical resolution. Monthly mean climatological profiles, assuming 30-40 profiles per “grid box”, are found unbiased and accurate to $< 0.15\text{-}0.5\%$ (GHGs, e.g., $CO_2 < 1$ ppm), $< 0.5\text{-}1$ m/s (wind), and $< 0.1\text{-}0.2$ K (temperature); more details Proschek et al. talk.

This encouraging performance is discussed in light of the science potential of ACCURATE. Also on-going work towards ground-based demonstration of the IR-laser links, for CO_2 and CH_4 as key species, is briefly addressed; more details Schweitzer et al. talk.