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Profiling Wind and Greenhouse Gases by Infrared-laser Occultation: Algorithm and Results from Simulations in Windy Air

Andreas Plach, Veronika Proschek, and Gottfried Kirchengast
Wegener Center for Climate and Global Change (WEGC) and Institute for Geophysics, Astrophysics and Meteorology/Institute of Physics (IGAM/IP), University of Graz, Graz, Austria (andreas.plach@uni-graz.at)

We employ the Low Earth Orbit (LEO-LEO) microwave and infrared-laser occultation (LMIO) method to derive a full set of thermodynamic state variables from microwave signals and climate benchmark profiling of greenhouse gases (GHGs) and line-of-sight (l.o.s.) wind using infrared-laser signals. The focus lies on the upper troposphere/lower stratosphere region (UTLS - 5 km to 35 km). The GHG retrieval errors are generally smaller than 1% to 3% r.m.s., at a vertical resolution of about 1 km.

In this study we focus on the infrared-laser part of LMIO, where we introduce a new, advanced wind retrieval algorithm to derive accurate l.o.s. wind profiles. The wind retrieval uses the reasonable assumption of the wind blowing along spherical shells (horizontal winds) and therefore the l.o.s. wind speed can be retrieved by using an Abel integral transform.

A “delta-differential transmission” principle is applied to two thoroughly selected infrared-laser signals placed at the wings of the highly symmetric $C^{18}OO$ absorption line (nominally ± 0.004 cm^{-1} from the line center near 4767 cm^{-1}) plus a related “off-line” reference signal. The delta-differential transmission obtained by differencing these signals is clear from atmospheric broadband effects and is proportional to the wind-induced Doppler shift; it serves as the integrand of the Abel transform.

The Doppler frequency shift calculated along with the wind retrieval is in turn also used in the GHG retrieval to correct the frequency of GHG-sensitive infrared-laser signals for the wind-induced Doppler shift, which enables improved GHG estimation. This step therefore provides the capability to correct potential wind-induced residual errors of the GHG retrieval in case of strong winds.

We performed end-to-end simulations to test the performance of the new retrieval in windy air. The simulations used realistic atmospheric conditions (thermodynamic state variables and wind profiles) from an analysis field of the European Centre for Medium-Range Weather Forecasts (ECMWF). GHG profiles were taken from the Fast Atmospheric Signature Code (FASCODE) model. Three geographic regions were investigated, representing three different atmospheric conditions: Tropics (TRO) - a warm and moist atmosphere, Standard (STD) - an intermediate atmosphere at mid-latitudes, and Sub-Arctic Winter (SAW) - a cold and dry atmosphere. We will discuss the results in windy air, which show an encouraging performance both for the wind retrieval throughout the stratosphere (essentially unbiased l.o.s. winds with rms errors within 2 m/s over about 15 to 35 km) and for the GHG estimation.