National Aeronautics and Space Administration

A New Technique to Profile the Planetary Boundary Layer with LEO-LEO Occultation

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Strategic Focus Area: Atmospheric composition and dynamics

Objectives

The objective of this research is to study a new remote sensing technique based on radio occultation (RO) between two Low Earth Orbiters (LEOs) at multiple dedicated microwave frequencies (~ 5-30 GHz) to profile water vapor and temperature within the planetary boundary layer (PBL). Through this research, we will quantitatively assess the expected accuracy, sampling, and resolution of temperature and water vapor profiles retrievable for various PBL conditions.

Background

The characterization of the Earth's planetary boundary layer (PBL), which refers to the lowest 1-3 km of the atmosphere that interacts strongly with the surface, is important for a number of Earth science areas, including weather, air quality, and climate. However, remote sensing of the PBL is extremely challenging since it is a shallow and variable layer often covered by clouds. Currently, no remote sensing techniques can achieve the desired vertical resolution (~ 100 m) of independent water vapor and temperature measurements within the PBL.

Significance/Benefits to NASA/JPL

This work is an important first step towards maturing a potentially ground-breaking future PBL instrument concept. The end-to-end simulation software developed under this task can now be leveraged to establish instrument requirements for various PBL conditions. Instrument component technology can be pursued through future NASA proposal opportunities (ACT, IIP, InVEST programs) as well as in the NASA Decadal Survey Incubation program. In the medium-term this could lead to Earth Ventures or Explorer class of mission proposals. In the longer term, this activity positions JPL to compete for instruments for an expected PBL Designated Observable in the 2027 Decadal Survey.

Approach and Results

We performed a theoretical study towards quantifying the retrieval accuracy, resolution, and depth penetration for different instrument and PBL scenarios. This was accomplished through the development of a sophisticated end-to-end simulation software.

An existing GNSS-RO forward simulation software was modified for non-GNSS frequencies and to include the effects of absorption from water vapor, oxygen, and liquid water using the Rosenkranz microwave absorption code. The forward simulation produces, for each occultation, a time series of amplitude and phase delay of the radio signals after propagation through the atmosphere. The simulated measurements are then used to retrieve water vapor and temperature profiles.

The end-to-end simulation system developed has been applied so far to subtropical PBL conditions. We found that strong water vapor absorption from the Ka-band resulted in significant attenuation of the RO signals, indicating that lower frequencies are preferable in this case. However, for the drier higher latitude environments, higher frequencies would give better sensitivity to the water vapor retrieval.

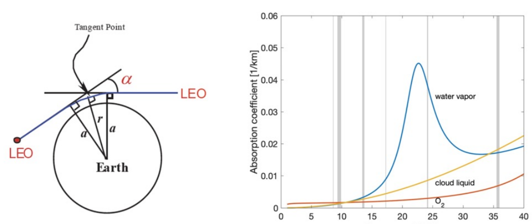

Figure 1. LEO-LEO occultation generalizes GNSS radio occultation that by utilizing radio frequencies that are sensitive to water vapor absorption, independent temperature and water vapor profiles at high vertical resolution can be obtained. Shaded vertical bands on the right indicate frequencies allocated for active remote sensing.

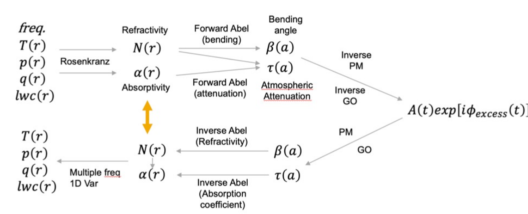

Figure 2. End-to-end simulation framework developed to assess retrieval accuracy and instrument requirements.

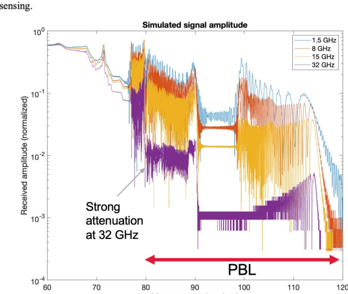

Figure 3. An example of forward simulation showing the received amplitude at various frequencies under subtropical conditions.

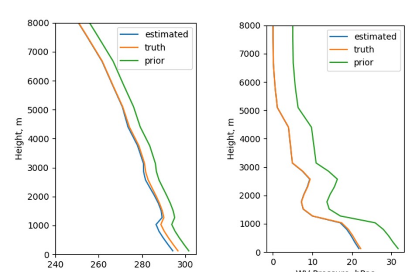

Figure 4. An example of the simulated retrieval of water vapor and temperature profiles using refractivity and absorptivity profiles. The blue is the retrieval ("estimated") which agrees very well with the input ("truth") and are essentially independent of the biased "prior" shown in green.

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