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Effects of liquid and ice clouds on GNSS radio occultation profiles

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Inversion of GNSS radio occultation (RO) measurements to profiles in the neutral atmosphere utilizes the assumption of spherical symmetry by implementation of the Abel transform. The main contribution to the retrieved refractional angle and other geophysical parameters comes from gaseous properties of the atmosphere. The atmospheric refraction is expressed by a function of air pressure, air temperature and water vapor pressure. Such commonly adopted methodology results in superior performance of radio occultation technique, especially in the upper troposphere and lower stratosphere (UTLS) region. However, in the lowermost troposphere referred to as planetary boundary layer (PBL), inversion in spherically symmetric atmosphere is an ill-conditioned problem. The presence of critical refractions introduces negative errors in the retrieved refractivity. The magnitude of the bias is at the order of 1%. We show that additional contribution to refractivity errors, both in the PBL as well as in the UTLS, comes from simplifications in the modeling of background meteorological fields. We analyze spatio-temporal distribution of clouds and investigate how the impact of associated scattering terms in the refractivity propagates to RO profiles. Results from numerical experiments by means of wave optics simulations are presented. Cloud refractivity for liquid and solid water is modeled from Global Forecasting System (GFS). The applicability of the Abel transform to account for cloud contributions is demonstrated based on effects of their horizontal irregularities in the refractivity fields.