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C. L. Liu [a,c], G. Kirchengast [b,c,a], S. Syndergaard [d], E. R. Kursinski [e],
Y. Q. Sun [a,c], W. H. Bai [a,c], Q. F. Du [a,c]

[a] National Space Science Center, Chinese Academy of Sciences (NSSC/CAS) and Beijing Key Laboratory of Space Environment Exploration, Beijing, 100190, China
[b] Wegener Center for Climate and Global Change (WEGC) and Institute for Geophysics, Astrophysics, and Meteorology/Institute of Physics, University of Graz, Graz, A-8010, Austria
[c] Joint Laboratory on Occultations for Atmosphere and Climate (JLOAC) of NSSC/CAS, Beijing, 100190, China, and University of Graz, A-8010, Austria
[d] Danish Meteorological Institute (DMI), Copenhagen. DK-2100, Denmark
[e] Space Sciences and Engineering, Boulder, CO 80301, USA

Corresponding author (C. L. Liu) E-mail: liucongliang1985@gmail.com, Phone: +86 15201260640.

Abstract

Global Navigation Satellite System radio occultation (GNSS RO, or in short GRO) has become a major method to observe the Earth's atmospheric thermodynamic state variables, i.e., pressure, temperature, and humidity as retrieved from refraction measurements using the GNSS radio wave signals. The GRO data products, such as bending angle and refractivity, are widely used for numerical weather prediction and global climate monitoring. Practically, in GRO, the temperature and humidity variables in the troposphere can only be retrieved separately from refractivity by co-using a priori humidity and/or temperature information.

Fortunately, as an advanced technique beyond GRO, developed over the past two decades, future microwave occultation using centimeter and millimeter wave signals between low Earth orbit satellites (LEO-LEO microwave occultation, LMO), can exploit both the refraction and absorption of the signals to solve the temperature-humidity ambiguity in the troposphere. Thus, LMO promises to retrieve the pressure, temperature, and humidity profiles without auxiliary background information. Furthermore, it is anticipated that ozone profiles can be retrieved by absorption measurements near the 195 GHz ozone line, and line-of-sight wind speed in the upper stratosphere into the mesosphere. Liquid water and ice cloud variables as well as turbulence strength can be retrieved as by-products.

Additionally, the novel concept of LEO-LEO infrared-laser occultation (LIO), using laser signals in the short-wave infrared band 2-2.5 µm between LEO satellites, has been designed to accurately observe key trace gas species for chemistry and climate (i.e., greenhouse gases H_2O, CO_2, CH_4, N_2O, O_3, CO, including key isotopes), line-of-sight wind speed, and also profiles of cloud layers and aerosols as by-products.

In 2010, a new occultation mission concept was proposed, named ACCURATE—climate benchmark profiling of greenhouse gases and thermodynamic variables and wind from space, which combines the highly synergetic LMO and LIO techniques into LEO-LEO microwave and infrared-laser occultation (LMIO). Focusing on the LMO technique only, several other missions were proposed before, in particular ATOMMS (Active Temperature Ozone and Moisture Microwave Spectrometer) and ACE+ (Atmosphere and Climate Explorer-Plus).

In this paper, a review of the LEO-LEO occultation techniques (LMO, LIO, and LMIO) in aspects of measurement principle, retrieval algorithms, atmospheric profiling performance and demonstration experiments is performed based on available literature. As part of the conclusions, discussions of