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Planetary Boundary Layer Height Retrievals from COSMIC-2

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The Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) 2 mission and Formosa Satellite Mission 7 (COSMIC-2/FORMOSAT-7, hereafter COSMIC-2) provides more than 4,000 atmospheric Bending Angle (BA) and refractivity profiles per day over the tropical and sub-tropical regions from 45°N - 45°S. The NOAA National Centers for Environmental Prediction (NCEP) operational numerical weather prediction system has started to assimilate COSMIC-2 data since early 2020. COSMIC-2 signals have higher Signal-Noise-Ratio (SNR) compared to other Global Navigation Satellite System (GNSS) Radio Occultation (RO) missions. Studies show that COSMIC-2 bending angle profiles have a deeper penetration than those from other RO missions.

Within planetary boundary layer, physical quantities such as flow velocity, temperature, and moisture show rapid fluctuations (turbulence) and strong vertical mixing, especially within a convective boundary layer. Therefore, the planetary boundary layer height (PBLH) is an essential indicator for the surface heat and moisture transfer and air quality. With high vertical resolution (~ 200 to 600 meters) and deeper penetration, COSMIC-2 can detect the layer of the sharp atmospheric density change (thus to define PBLH) near the surface. This study presents a method to retrieve PBLH using GNSS BA measured by COSMIC-2. First, a Locally Weighted Scatterplot Smoothing (LOWESS) approach is used to eliminate high-frequency BA variation from the original COSMIC-2 BA profiles. Second, the first and the second derivatives are calculated to locate the local minimum in the BA gradients between 0.5 km and 5 km altitude. The final local minimum is defined as the PBLH.

This PBLH retrieval algorithm was applied to nearly one-year (from September 2019 to August 2020) COSMIC-2 BA data. Preliminary results show that PBLH derived from COSMIC-2 exhibits distinguished diurnal cycle and peaks at 15:00 local time which is consistent with published studies. One notable feature is that retrieved PBLH diurnal cycle is land type dependent. Over vegetation-covered regions, the derived PBLH has a weaker diurnal cycle amplitude than those over desert area. This feature can be explained by the physics of planetary boundary layer. The PBL and its height vary considerably due to the nature of the underlying surface, which affects surface sensible heat, diurnal cycle, thermal stratification, entrainment, and advective processes, etc.

This study compares the retrieved PBLH from COSMIC-2 with the following two independent datasets: 1) PBLH derived from ECMWF Reanalysis generation-5 (ERA5) data, and 2) those collocated low cloud top heights detected by the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO). The results indicate that COSMIC-2 PBLHs under all-sky conditions are generally comparable with the ERA5 reanalysis PBL heights. The geographical distribution of daily maximum COSMIC-2 PBLH corresponds well with CALIPSO low cloud top height distribution. Moreover, cross comparison with the PBLHs retrieved by operational Radio Occultation Processing Package (ROPP) is also performed. Results indicate that the algorithm presented here can provide reliable PBLH under all-sky conditions over various underlying surfaces.