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A Relation between bending angle gradient of GNSS RO and refractive index gradient

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This study is concerned with the bending angle of microwave, passing through the Earth's atmosphere in the GNSS radio occultation (RO) experiment. We focus on a relation between the height derivative of the bending angle with the refractive index gradient.

A refractive index model for a dry atmosphere is constructed at 0-110 km, employing a temperature profile published by NOAA. We assume concentric atmospheric layers with a height interval of 100 m, which are horizontally uniform. Using the Abel inversion, a bending angle profile is computed. We found that the bending angle is mostly contributed by the layers near the tangent height; 1/3, 1/2 and 4/5 of the bending angle is attributed to the height range about 1 km, 2 km and 7 km above the tangent point, respectively.

We developed a simple ray tracing model, where the bending is approximated by a circle within every atmospheric layers with a thickness of 100 m. Curvature of the ray is calculated, referring to the general relation between the impact parameter and the refractive index gradient (Lehn, 1985). By connecting partial pay paths at interface of the spheres, a smooth ray path is constructed for the tangent height ranging from 100 m above the ground up to 70 km altitude every 100 m. The ray tracing model is consistent with the Abel inversion result less than 1% of discrepancy, except below about 5 km altitude.

We found the refractive index gradient at the tangent altitude correlates reasonably well with the height derivative of the bending angle. Because the refractive index gradient in a dry atmosphere is mostly determined by the Brunt-Vaisala frequency squared, height derivative of the bending angle can be utilized as a measure of atmospheric stability.

In the retrieval procedure of GNSS-RO, observed bending angle is optimized by combining a model atmosphere at high altitudes for suppressing the effects of ionospheric noises, resulting in a possibility to induce artificial modification of the bending angle profile. This study suggests that the original bending angle without optimization is useful for detecting atmospheric thermal structure. We further apply this method to identify characteristics of the tropopause and stratopause using recent GNSS-RO data.