Forward and Inverse Analyses of GPS Radio Occultations in the Neutral Atmosphere

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Radio occultation measurements using Global Positioning System (GPS) satellites as transmitters and low Earth orbiting (LEO) satellites as receivers have proven to be successful at probing the refractivity structure of the Earth's atmosphere. It is known, however, that the sharply varying refractivity existing in the moist, lower troposphere presents significant algorithmic and data-processing challenges to the current retrieval techniques. One limitation in the existing algorithms is the reliance on the assumption of spherically symmetric atmosphere (at least locally). Thus better forward and inverse modeling of wave propagation through a non-spherically symmetric atmosphere in the context of radio occultation needs to be developed and examined.

We carry out forward simulations of wave propagation through the neutral atmosphere using the phase screen model. In the phase screen model, the atmosphere is represented by single or multiple screens which act to introduce a phase delay to the incident wave. In general, the phase delay can vary two-dimensionally across the screen. Outside the screens, the wave propagates as in vacuum. While multiple phase screens can be used to rigorously model the extended atmosphere, employing a large number of such screens would incur significant computational cost. We show that the far-field diffraction pattern generated by a given refractivity profile can be accurately reproduced with a single phase screen, provided that the phase delay introduced by the screen is properly computed. The single phase screen method allows for simple and computationally efficient modeling of a non-spherically symmetric atmosphere, with possibly sharp gradients in the vertical and horizontal directions perpendicular to the raypath. The forward simulation results are presented in terms of the ray's bending angles, and comparisons are made with the standard geometric optics solution which assumes a spherically symmetric atmosphere.

We investigate the inversion of the forward simulation data to obtain the refractivity structure of the atmosphere. The inversion is performed using the Abel transform combined with a backpropagation algorithm which translates the field pattern from the distant observation plane to one closer to the occultation. We assess the effectiveness of the Abel inversion on different backpropagated planes and study how the presence of horizontal refractivity gradients could give rise to errors in the inverted vertical profile. Finally, we apply the backpropagation algorithm to the new radio occultation data obtained with CHAMP and SAC-C and present retrieval results.