Inversion Methods for GPS Occultations

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Radio occultations have long been used in the remote sensing of planetary atmospheres. Recently, thanks to the GPS satellite constellation, similar techniques have been applied to provide vertical profiling of the Earth's atmosphere and ionosphere as well. The GPS Meteorology (GPS/MET) proof-of-concept experiment, which operated from April 1995 to February 1997, has already provided a wealth of interesting data for scientific analysis. The currently operating CHAMP and SAC-C spacecrafts, carrying the more advanced BlackJack GPS receiver, are capable of tracking deep into the lower troposphere and yield approximately 300 occultations per day.

The standard retrieval method converts the excess phase measurements due to atmospheric refraction into the raypath's bending angle α as a function of impact parameter a. The relation $\alpha(a)$ is then integrated — via Abel inversion — to yield the vertical profile of the refractive index. This method assumes that the atmosphere is locally spherically symmetric and that geometric optics is valid. However, sharp refractivity gradients could cause multiple signals to arrive at the receiver simultaneously. In this case, which is quite common in the lower troposphere, the retrieval system infers multiple values of bending for the same impact parameter. An *ad hoc* procedure must then be applied to the data to compute the Abel inversion integral, which results in retrieval biases.

Radioholographic methods such as backpropagation, radio optics (or sliding spectral method), and canonical transform, have been proposed to circumvent difficulties encountered by the standard retrieval method and to improve the vertical resolution of the retrievals. These methods use both the amplitude and phase of the received signal in reconstructing the ray structure of the refracted field. We shall present assessments in the performance of radioholographic methods versus the standard retrieval method.

It is important to recognize that the final step of these radioholographic methods, where the refractivity profile is computed, is still carried out through Abel inversion. Thus the basic assumption of a locally spherically symmetric atmosphere remains. This constraint is especially problematic in the ionosphere or when weather fronts are present in the troposphere. To bypass such limitation, we investigate the inversion of radio occultation data based on a least-squares minimization technique. A fast forward model is implemented through the use of dynamic ray tracing. The unknown coefficients of the properly parameterized refractivity profile can then be obtained by minimizing the cost function that characterizes the differences between the computed signal and the measured signal. The parameterization can accommodate horizontal as well as vertical refractivity variations; therefore, the least-squares method has the potential of unraveling 3-D refractivity structures from occultation measurements.

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