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A New Ionosphere Tomography Algorithm with Two-Grids Virtual Observations Constraints and 3D Velocity Profile

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Due to the sparsity of world's GNSS stations and limitations of projection angles, GNSS-based ionosphere tomography is a typical ill-posed problem. There are two main ways to solve this problem. Firstly the joint inversion method combining multi-source data is one of the effective ways. Secondly using a priori or reference ionosphere models, e.g., IRI or GIM models, as the constraints to improve the state of normal equation is another effective approach. The traditional way for adding constraints with virtual observations can only solve the problem of sparse stations but the virtual observations still lack horizontal grid constraints therefore unable to fundamentally improve the near-singularity characteristic of the normal equation. In this paper, we impose a priori constraints by increasing the virtual observations in n-dimensional space, which can greatly reduce the condition number of the normal equation. Then after the inversion region is gridded, we can form a stable structure among the grids with loose constraints. We then further consider that the ionosphere indeed changes within certain temporal scale, e.g., two hours. In order to establish a more sophisticated and realistic ionosphere model and obtain the real time ionosphere electron density velocity (IEDV) information, we introduce the grid electron density velocity parameters, which can be estimated with electron density parameters simultaneously. The velocity parameters not only can enhance the temporal resolution of the ionosphere model thereby reflecting more elaborate structure (short-term disturbances) under ionosphere disturbances status, but also provide a new way for the real-time detection and prediction of ionosphere 3D changes. We applied the new algorithm to the GNSS data collected in Europe for tomography inversion for ionosphere electron density and velocity at 2-hour resolutions, which are consistent throughout the whole day variation. We then validate the resulting tomography model using independent GNSS station data, and results using the conventional algorithm (Multiplicative Algebraic Reconstruction Techniques), as well as ionosphere ionosonde data in the study area.

Key words

Ionosphere Tomography, Grid Constraints, Virtual observations, 3D Ionosphere Velocity Image