URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Slant ionosphere augmentation for GNSS high-precision positioning

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Precise point positioning (PPP) is a GNSS high precision positioning technique using standalone receiver. However, it suffers from a long convergence time of about 30 minutes to a decimeter level accuracy, which significantly limits its applications. The ionosphere as one of the most larger error sources for the GNSS satellite signals. The external available ionospheric correction is crucial for improving the performance in terms of both improving accuracy and convergence

Depending on the ways of modeling ionosphere, ionospheric corrections are divided into vertical and slant categories. The vertical ionospheric modeling assumes that the ionospheric delays are condensed into a thin-layer model. An oblique factor, or mapping function is applied to convert between the vertical and the slant ionospheric delays, vice versa. The vertical ones are usually for wide and global area analysis. However, the accuracy of the vertical ones is limited to several TECUs due to the mapping errors and single-layer assumption. This accuracy is hardly useful to resolve ambiguity in the carrier-phase measurements, which are the key observations in GNSS high precision positioning (Banville et al., 2022)

It is not uncommon that the satellite-by-satellite slant ionospheric corrections in a smaller region or network are proposed to address the accuracy of ionospheric errors. As the ionosphere is highly spatial-related, the required ionospheric corrections can be interpolated from nearby reference stations. But the performance of slant ionospheric models is significantly affected by the distance to surrounding stations. Besides, the size of network also depends on the irregularities of the ionosphere activities.

(Psychas et al., 2020) investigated the impact of network scales or the inter-station distances of 68, 115, 168, and 237 km on achieving ambiguity resolution of PPP-RTK. Results show that 10 cm horizontal accuracy using ionosphere-weighted and partially ambiguity-fixed solution can be achieved instantaneously with 68 km spacing. (Li et al., 2021) applied the regional atmospheric augmentation into PPP and validated the method using Australia and Hongkong networks. The interpolated ionosphere corrections of about 2.5 cm accuracy improved the convergence time of positioning significantly. (Wang et al., 2023) studied the interpolation methods for large scale networks at about 150 km and achieved accuracy better than 1.25 cm in most cases.

Although the scholars agreed on the importance of distances among reference stations, few agreements were reached on how to decide the crucial information about the dense of reference stations. Therefore, it worthy to studying the temporal-spatial variations of ionosphere and helping to decide the network size.

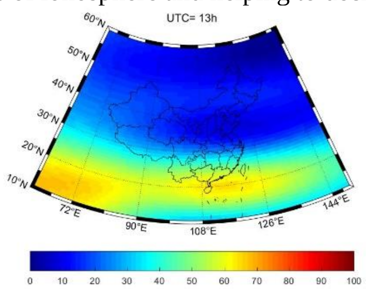

Figure 1. Ionosphere variation over China on UTC 13:00 produced based on the global ionospheric map.

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