Efficient global ionospheric modeling based on multi-source and massive observation data

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Abstract Ionosphere is an important error source of satellite navigation and a key component of space weather. With the rapid development of multiple Global Navigation Satellite System (GNSS) and other ionospheric research technologies, and the high precision and near-real-time requirements for ionospheric products, it is necessary to carry out a research on multi-source data fusion, massive data processing and near-real-time solution of global ionosphere model (GIM); therefore, we modified the traditional ionospheric modeling technology and generate the GIM products (GIM/SHA). In view of the defect of ground-based GNSS data missing in the ocean regions, the method of adding virtual observation stations to the data missing regions in a large range was adopted, which not only enhanced the accuracy of the GIM in the ocean regions, but also avoided the weight determination among different data sources. In terms of near-real-time modeling, the multi-threaded parallel modeling strategy was adopted. Four GNSS (GPS, GLONASS, BEIDOU, Galileo) observation data, eight virtual observation stations and a server with a CPU frequency of 2.1 GHz and 16 threads were utilized. It took less than 30 minutes to construct the GIM by using parallel modeling strategy, which was 10.3 times faster than serial modeling strategy. The accuracy of the GIM/SHA was verified by using the ionospheric products of International GNSS Service (IGS) Ionosphere Associate Analysis Centers (IAACs) in the period of day of year (DOY) 200-365, 2019. Compared with the ionospheric products of CODE, ESA/ESOC, JPL, UPC, EMR, CAS and WHU, the vertical total electron content (VTEC) root mean squares (RMSs) were 1.09 TEC units (TECu), 1.51 TECu, 2.32 TECu, 1.88 TECu, 2.24 TECu, 1.25 TECu and 1.38 TECu, respectively. The result shows that the GIM/SHA have comparable accuracy with IGS ionospheric products. Satellite altimetry data was exploited to verify the accuracy of GIM/SHA in ocean regions, and it can be concluded that the accuracy of the GIM in ocean regions can be significantly reinforced by adding virtual observation stations in ocean regions. Multi-system and multi-frequency differential code bias (DCB) products (DCB/SHA) were simultaneously generated. Compared with IGS DCB products, the satellite DCB RMSs of DCB/SHA were 0.16 ns for GPS, 0.08 ns for GLONASS, 0.17 ns for BEIDOU and 0.14 ns for Galileo; the GNSS receiver DCB RMSs of DCB/SHA were 0.69 ns for GPS, 1.06 ns for GLONASS, 0.75 for BEIDOU and 1.03 ns for Galileo. It can be proved that the accuracy of DCB/SHA are comparable to IGS DCB products.

Keywords Multi-GNSS; GIM; Virtual observation station; Near real-time; VTEC; DCB