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Evaluation of GPS-based Ionospheric TEC map accuracy by comparison with VLBI data

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Accuracy of GPS-based ionosphere TEC was evaluated with aim of ionosphere delay correction in single frequency VLBI observation such as pulsar VLBI observation. By comparison with dual frequency VLBI TEC observation, accuracy of local TEC map generated from TECMETER data was estimated as about 3 TECU. And accuracy of global ionosphere map (GIM) generated by Bern University was estimated as about 2.5 TECU. When the GIM is used for ionospheric delay correction in VLBI, it is possible to compensate the ionospheric delay within an accuracy of 0.7 TECU on 100 km baseline and 3- 10 TECU on intercontinental baseline.

Also it became obvious that more improvement of ionosphere model is necessary to use TEC rate data for ionospheric delay rate correction in practical use.

Uncertainty of signal propagation delay in ionospheric plasma is one of the causes of error in space measurement technology using microwave. Accurate measurement of ionospheric TEC is important for VLBI astrometry, geodetic observation with single frequency GPS receivers, and space navigation using range and range rate. GPS technology has been developed quickly in this decade and Total Electron Contents (TEC) map can be generated from GPS observation data. We have evaluated the accuracy of two kinds of GPS-based TEC maps by comparison with 2/8 GHz dual band VLBI observations. One was local TEC map generated by using TECMETER, which was special GPS receiver to measure ionosphere TEC. The accuracy of local TEC map was evaluated about 3 TEC unit (TECU: 1TECU=10^16 electrons/m^2) from the comparison study. The accuracy of the local TEC map decreased as the ionospheric point become distant from the observation point. The other was global ionosphere map (GIM) generated by the Center for Orbit Determination in Europe (CODE). And the accuracy was evaluated as 2.5 TECU from comparison with VLBI data. The accuracy of the GIM/CDOE was almost constant regardless with distance from observation station to ionospheric point. It became clear from the comparison study that ionospheric delay correction in VLBI observation is possible within 0.7 TECU (13 ps at 8.4GHz) accuracy on 100 km baseline and with 3-10 TECU (60 ps - 0.2 ns at 8.4 GHz) accuracy on intercontinental baseline. The value 13 ps is smaller than the root mean square (rms) residual of geodetic VLBI analysis, thus ionospheric delay correction in VLBI is useful especially on short baseline.

Delay rate caused by ionosphere is important for space navigation with range and range rate. TEC rate was computed from GIM/CODE data and compared with VLBI data for evaluation. Coincidence of TEC rate between VLBI and GIM/CODE was about zero correlation on short baseline (100 km) and 0.6 - 0.8 correlation on long baseline. The reason of the insufficient coincidence was lack of high frequency and small-scale structure components in the GIM/CODE model. Because the time interval of GIM/CODE maps is 2 hours, thus TEC variation shorter than 2 hours is not included. The GIM/CODE is expressed with 12 degrees 8 orders of spherical harmonics, then smaller than certain scale structure is not included. The certain scale is about 2500 km in longitude direction and about 1700 km in latitude direction, respectively. Numerical derivation to derive the TEC rate enhances the high frequency components, consequently error of TEC rate is dominated by error of high frequency components.

Bern University has been generating GIM data from 1st Jan. 1995 till to now without any interruption, and the data is available through the Internet. Hence these data are great benefit for TEC data user. Although still more development of TEC map model including shorter time scales and smaller spatial scales is necessary for practical use of TEC rate.