ABSTRACTS (MASTER THESIS)

Development of real-time three dimensional analysis system of the ionosphere over Japan based on GPS-TEC observations

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Real-time information of the ionospheric electron distribution is important for the correction of the measurement errors in satellite navigation. It is hoped that tsunami warning systems may be realized if such real-time monitoring of ionospheric disturbances is available. In this study, we developed three-dimensional ionosphere tomographic analysis based on the GPS-TEC data from 200 stations over Japan (Figure 1) and the tomography analysis technique proposed by Gopi *et al*. [1]. As the GPS-TEC data are available at every second, we constructed a software system for the real-time monitoring of the ionosphere over Japan.

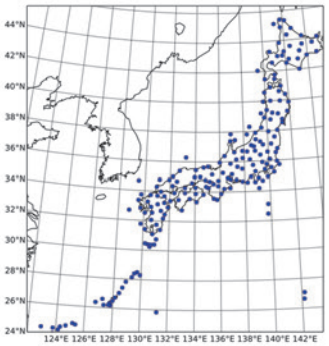

Figure 1. Distribution of 200 GPS stations where 1s data are available.

The developed system consists of four parallel processes; parallel decoding of BINEX binary data, estimation of instrument bias, two-dimensional fluctuated and absolute TEC distribution analyses and the three-dimensional tomographic analysis.

The instrument biases are calculated in parallel by using the previous 24 hour data. By adapting an algorithm of sparse matrix for matrix operations, the computation time was reduced from about two hours to less than one second, which makes it possible to update the instrumental biases every hour. And the estimation error of instrumental biases was reduced by this way.

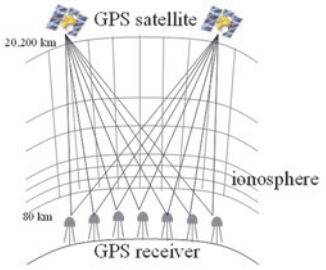

Figure 2. Conceptual figure of the ionospheric tomography.

In the three-dimensional tomographic analysis (Figure 2), calculation time of the tomographic matrix was reduced to less than 10 minutes by adapting the algorithm of spline interpolation and sparse matrix operations. It is about three times faster than the previous program. L-curve method was adopted for determining hyper parameter of the evaluation function. Boundary conditions are applied to three-dimensional grids. Because of these changes, now we can obtain stable solutions within about 10 minutes after the measurement by GEONET 200 stations. Figure 3 shows an example of meridional-height section of the plasma density obtained from the tomography analysis. The results show good agreement with other observations from the GPS occultation and ionosondes.

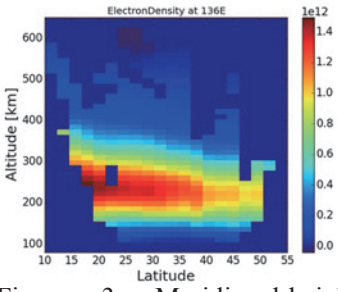

Figure 3. Meridional-height section of the plasma density from 3D tomography at 7:00UT on May 23, 2012.

The real-time tomography system started its service in April 2016 at Electronic Navigation Research Institute (ENRI). Now the 3D ionospheric plasma density is available at every 15 minutes with about 10 minutes latency from the following URL.

http://www.enri.go.jp/cnspub/tomo3/

Reference

[1] Seemala, G. K., Yamamoto, M., Saito, A. and Chen, C.-H.: Three-dimensional GPS ionospheric tomography over Japan using constrained least squares, *J. Geophys. Res. Space Phys.*, **119**, 3044-3052, 2014.