Multi-constellation GNSS tomography for accurate ionospheric imaging

Jon Bruno, Cathryn N. Mitchell and Karl H. A. Bolmgren

Department of Electronic and Electrical Engineering, University of Bath, U.K.

With the recent addition of Galileo, four fully operational GNSS (Global Navigation Satellite System) are available nowadays, increasing the number of navigation satellites orbiting around the globe to more than 70. Thanks to different projects, such as the Multi-GNSS Experiment (MGEX) from the International GNSS Service (IGS), a global network of multi-GNSS receivers is available for the scientific community. These initiatives have shown great improvements for different solutions, such as Positioning, Navigation and Timing (PNT) applications and Earth monitoring techniques. Many GNSS precise positioning algorithms, such as Precise Point Positioning (PPP), rely on precise ionospheric corrections to calculate the position. In this paper, a multi-GNSS based ionospheric sensing method will be described. The imaging technique called Computerised Ionospheric Tomography (CIT) uses GNSS dual frequency observations to calculate the total electron content (TEC) from each satellite to the receiver path, which are used to create three-dimensional electron density images.

One of the key issues of GPS (Global Positioning System) ionospheric tomography is the lack of data due to poor satellite and receiver coverage over the area under study. With the addition of GLONASS (Globalnaya Navigazionnaya Sputnikovaya Sistema) and Galileo constellations into the ionospheric imaging algorithm, this problem is reduced. In this paper real data from both geomagnetically calm and disturbed days is used to assess the method.

In this work, the imaging algorithm called MIDAS (Multi-Instrument Data Analysis Software) has been used. This software uses time-differenced phase observations to compute the Slant Total Electron Content (STEC) from each satellite to receiver. Results from all combinations of constellations have been analysed and compared to

1

the GPS-only solution. Reconstructions using receivers distributed all over the globe will also be compared to regional data from North America, South America, Europe. Finally, to to assess the quality of each reconstruction (GPS-only, GLONASS-only, Galileo-only, and GPS-GLONASS-Galileo combination), ionosonde data from Juliusruh in Europe, Boulder in North America and Sao Luis in South America will be used. Slant TEC measurements from stations not involved in the computing will also be used as validation. The analysis demonstrates the improvement of multi-GNSS tomography in accuracy and resolution over single-GNSS tomography for ionospheric electron density imaging. Figure 1 shows a single-epoch comparison in vertical TEC(vTEC) of GPS-only and GPS-GLONASS-Galileo ionospheric reconstruction.
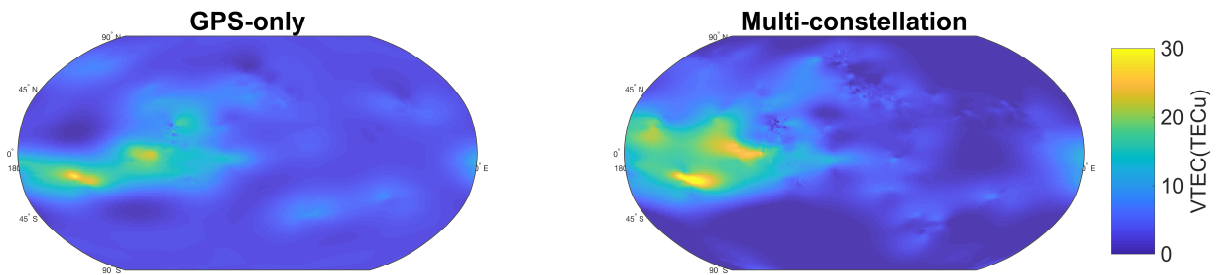

Figure 1: Comparison of GPS-only and multi-GNSS reconstructions.