NEAR REAL-TIME IONOSPHERIC PRODUCTS FROM THE EUROPEAN PERMANENT NETWORK GPS DATA

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Keywords: Ionosphere, TEC, monitoring, GNSS, Europe, products

Summary. *This paper presents the GNSS-based near real-time ionospheric products developed and available at the Royal Observatory of Belgium.*

1 INTRODUCTION

Since the beginning of the 24th solar cycle, the solar activity increases (maximum expected in 2013) together with the ionospheric activity[1]. It requires therefore having a close eye on the ionosphere to better understand the space weather effects on the radio communications and navigations systems. In this frame, the Royal Observatory of Belgium (ROB) generates now routinely in near real-time ionospheric products over Europe. These products are based on the high-rate Global Navigation Satellite System (GNSS) observations of the EUREF Permanent Network (EPN)[2]. The basic products consist of Vertical Total Electron Content (VTEC) maps published at the ROB web site http://gnss.be with a latency of 2-5 minutes. The present paper introduces: 1) the processing strategy used to generate the ionospheric maps, 2) the on-line products and tools developed around these maps, 3) a comparison with other products during periods of different ionospheric activity.

2 METHOD

The VTEC maps are generated every 15 minutes using the real time GPS observations of 122 EPN stations provided by the ROB NTRIP broadcaster[3].

In a first step, the Slant Total Electron Content (STEC), corresponding to the total number of electrons along a satellite-receiver path is estimated each 30s for each satellite/receiver pair using the geometry-free linear combination[4]:

$$STEC = \frac{{f_1}^2 {f_2}^2}{40.3({f_1}^2 - {f_2}^2)} * (P_1 - P_2 - c(DCB_r + DCB_s))$$

where P_1, P_2 are the phase-smoothed code observations at the two GNSS frequencies f_1, f_2, c is the speed of light, DCB_r and DCB_s are the Differential Code Biases of resp. the receivers and satellites. The DCB_r are estimated daily using a priori VTEC information from CODE rapid Global Ionospheric Maps (GIMs)[5] over the 5 previous days. The DCB_s are also provided by CODE.

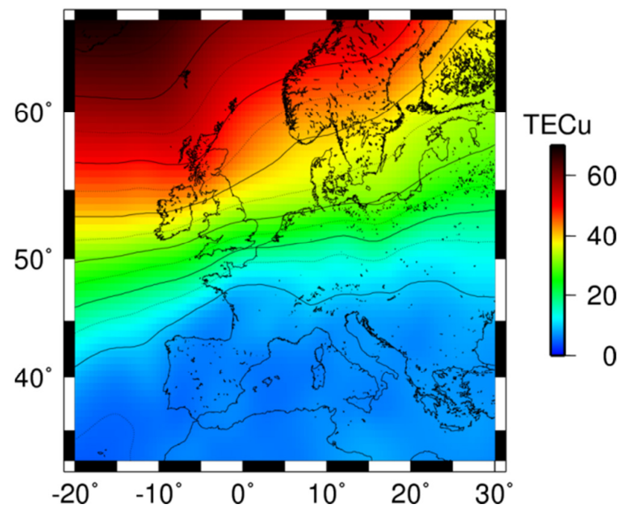

Figure 1: Example of real time VTEC map produced at ROB. This map shows the Halloween geomagnetic storm (from 23:30 to 23:45 on 30 October 2003)

The STEC is then projected as a VTEC at the Ionospheric Pierce Point (IPP) at an altitude of 450 km, using the GPS satellite positions from the ultra-rapid orbits of the International GNSS Service (IGS) [6] and an ionospheric single thin layer hypothesis.

Finally VTEC at IPPs are interpolated on a 0.5°x0.5° grid using a thin plate spline interpolation iterated with different degrees of smoothing.

3 IONOSPHERIC PRODUCTS AVAILABLE ON-LINE

Different ionospheric products are available on the ROB web site. First, we provide animated ionospheric VTEC maps (movies) where the VTEC values can be displayed at a given point and time. Then, a second page highlights the ionospheric activity w.r.t the median of the 15 previous days. Finally, a repertory of the observed ionospheric events provides VTEC time series around the event at 3 locations in Europe. In addition, the ionospheric maps are freely available in the IONEX format[5] via an ftp server.

4 COMPARISON WITH GLOBAL IONOSPHERIC MAPS AND CLIMATOLOGICAL MODEL

To test the robustness of ROB's near real-time ionospheric products, they were compared to the GNSS-based CODE final GIMS (latency of 5 days) during an ionospheric quiet day and during a disturbed day (e.g. during a Solar Coronal Mass Ejection impact). Results show that ROB maps are not biased 0.0±1.1TECu w.r.t. CODE final GIMs products except during ionospheric disturbed periods (absolute bias of 2.4 ± 2.0 TECu). This is mainly due to the large scale smoothing caused by the spherical harmonics used to model VTEC in the CODE

GIMs.

Moreover, the VTEC extracted from ROB maps at 3 locations in January 2012 is compared with the ones from CODE GIMs and the climatological model of International Reference Ionosphere (IRI)[7] 2012 (Figure 2). Differences between VTEC extracted from CODE GIMs and ROB products are of the order of 0.0±1.3 TECu in Northern Europe, 0.2±0.8 TECu above Brussels and -0.9±1.5 TECu in Southern Europe. Mainly during daytime, a bias is observed w.r.t. IRI. For example at noon, there are biases of: -6.4±3.9 TECu in the North, -9.5±3.2 TECu above Brussels and -5.6±4.2 TECu in the South.

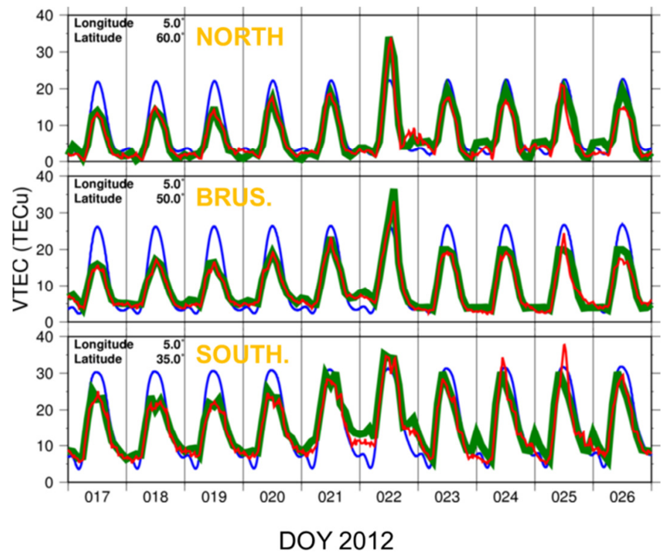

Figure 2 : VTEC time series from the 17th to the 27th of January 2012 a) in the North (lon:5°, lat:61°), b) above Brussels (4.5°,51°) and c) in the South (5°,36°); ROB in red, ROB median model of the 15 previous days in grey, CODE in green, IRI in blue

Consequently, near real-time ROB products are well calibrated with respect to global ionospheric maps such as CODE GIMs and reflect rapid variations in the ionospheric state with higher resolution in time and space domains.

6 CONCLUSIONS

The regional GNSS-based near real-time ionospheric VTEC Maps of ROB cover Europe with a resolution of 0.5°x0.5° and are available on-line every 15 minutes with a latency of 2-5 minutes at http://gnss.be. In addition, associated web pages highlight the ionospheric activity w.r.t to the 15 previous days and identify ionospheric events since January 2012. These ROB VTEC maps allow any user within the geographical scope of the maps to estimate in near real-time the ionospheric delay induced along the signal of any observed satellite.

Finally, ROB is developing new products to satisfy ionospheric, GNSS and radio-science communities: IONEX format, maps of the foF2 Critical Frequency, and GNSS signal to noise ratio.

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