Correlation Analysis of Vertical Total Electron Content

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Abstract

It is necessary to model and analyze the ionospheric effects due to a direct relationship between Global Positioning System (GPS) applications and changes in the ionosphere. In order to monitor these changes, the ionosphere can be represented by the vertical total electron content ($VTEC$) which can be used to analyze ionospheric conditions from a variety of stations. In this study, 21 stations were used to carry out analysis and estimation of $VTEC$. Three days during a geomagnetic storm, namely, 7, 8, and 9 January 2005, are chosen for investigation. In addition, the de-correlation time of the $VTEC$ was estimated to define ionospheric variations in time using autocorrelation analysis. The de-correlation time of the ionosphere is based on correlation times estimated by using autocorrelation functions. From the high-latitude stations, the mean of the correlation times decreased from 8 to 6 epochs during a storm. In this time period, it was found from the station results that the ionosphere was more affected at the high-latitude than at the mid-latitude region.

Key words: GPS, ionosphere, vertical total electron content, autocorrelation.

1. INTRODUCTION

Since Global Positioning System (GPS) signals travel through the ionosphere, it is crucial to obtain as much information about this medium as possible. There have been several studies related to the ionosphere and space weather conditions in order to get this information (e.g., Orús et al. 2002, Komjathy et al. 2006, Stanislawska and Belehaki 2009, Cander and Ciracolo 2010, Tsagouri et al. 2010). The research concerning the ionosphere and
GPS differ in respect to the type of mathematical models that are used (Liu et al. 2005, Rideout and Coster 2006, Hernández-Pajares et al. 2009). The basic equation for the ionosphere modeling is a geometry-free linear combination with differential code bias (DCB) information in a single layer (Sardón and Zarraoa 1997, Dach et al. 2007). The basic parameter of this model is the vertical total electron content (VTEC) represented by the TEC unit (TECU). 1 TECU is equal to $10^{16}$ el/m$^2$, introducing a range error of 16 cm on the $L_1$ signal. A TEC along the signal path can be converted to VTEC by using various mapping functions (Dach et al. 2007, Wild 1994, Rideout and Coster 2006, Hernandez-Pajares et al. 2004). There are several studies that are related to spatial and temporal behavior of the ionosphere. Wu et al. (2006) studied temporal and spatial variations of VTEC over Victoria. Yue et al. (2007) investigated the spatial correlation of ionospheric day-to-day variability by the statistical analysis of GPS and Incoherent Scatter Radar observations. Grejner-Brzezinska et al. (2009) mentioned the correlation of double difference (DD) ionospheric delays, DD ionospheric correction residuals, and VTEC in time at continuously operating reference stations (CORS).

This paper reports on a study that modeled and analyzed VTEC data using autocorrelation from 21 stations in Europe.

2. THE VTEC MODELING

The ionosphere, containing free electrons and ions, is a layer of the upper atmosphere located 60 km to 1000 km above the Earth’s surface. The electrons and ions are approximated by the Single-Layer Ionosphere Model (SLIM) that assumes all free electrons and ions are concentrated in a shell of infinitesimal thickness at the height of a single layer (Dach et al. 2007).

There are several causes of changes in the ionosphere; for example, the temporal changes of this layer can be related to solar activity, seasonal and diurnal variations with solar activity represented by sunspot activity that peaks every 11 years. The ionospheric conditions also vary with respect to the geographic locations, namely, the ionization process is higher at high-latitude and equatorial regions than in mid-latitude region. However, the temporal and spatial variations in the ionosphere at the mid latitudes are smaller than in the equatorial region (Rama Rao et al. 2006). There is a correlation between the degree of ionization and ionospheric disturbances, such as geomagnetic storms. The high energy in the solar wind reaches the Earth and disturbs the terrestrial magnetic field, which, in turn, generates additional electrons resulting in large variations in electron density and TEC (Haro Barbás et al. 2002). The geomagnetic storms are monitored according to different indexes, such as $Kp$ and $Dst$. When TEC is adversely affected by