Observation of Planetary Waves as Seen in Ionospheric Total Electron Content (TEC) Perturbation Using GISTM Pontianak.

Asnawi Husin, Sri Ekawati, Dwiko U Prabowo
Space Science Center, LAPAN Indonesia
E-mail: asnawihs@yahoo.com

ABSTRACT
In this study, the planetary waves as seen in ionospheric total electron content (TEC) perturbation observed by GISTM (GPS Ionospheric Scintillation and TEC Monitoring) at Pontianak (-0.03 °, 109.33°) during the beginning maximum solar activity period 2011. Analysis periodicities of the VTEC time series have been done by using a Fast Fourier Transform (FFT). Results show the presence of the strong oscillations 1 day. This could be related to planetary waves type oscillations (10 and 16 days) with possible influence of the half solar rotation period (13.5 days). After the daily oscillations were removed, the VTEC time series examined by the power spectral density (PSD). There are two periodic components, quasi 10 day and quasi periodic 2 day. Quasi 10 day strong occur in the October dan April, while quasi 2 day weakly occur in September.

Keywords: GISTM, Ionosphere, Planetary, TEC

1 INTRODUCTION

It has been known that the ionospher is the part of the upper atmosphere which contains free electrons produced by ionisation of neutral atoms or molecules through solar X-rays and EUV radiation. The ionosphere exhibit various kinds of variability like diurnal, seasonal and annual and it also shows dependence on solar activity. Some author have been report that there are effect from below to the ionospheric variabilit (Bibl, 1989; Apostolov et al. 1998; Bremer, 1998). Satellite system navigation such as Global Positioning System (GPS) offers opportunity to monitor ionospheric variations and its variability. Ionospheric variability could be recognized in the total electron content (TEC), which is the integral of electron number density along the line of sight from satellite to receiver and can vary dramatically from day-to-day (Huang et al., 1989; Rastogi and Klobuchar, 1990). The main variations of the ionosphere are affected by electrical and electromagnetic phenomena (Lastovicka, 2005). It has been also known that the ionosphere is coupled to the lower atmosphere through upward propagating waves in the neutral atmosphere with quasi periods of 2 to 30 days are planetary wave types and deposit energy from below (Hoffmann and Jacobi, 2006). Although planetary waves are not usually able to penetrate to altitudes above 110 km (Lastovicka et al., 2003), oscillations with planetary periods were observed in all ionospheric layers. For example, Lawrence (2003) analyzed planetary waves from simultaneous observations in a range of 30 to 220 km based on different data sources from 10th April to 18th August (130 days) in 1997, 1998 and 1999. Pancheva et al. (2002) proved 27, 16 and quasi 2 day waves in hmF_2. Altadill et al. (2001, 2003) proved the 6.5 day and 6 day waves in the F-layer. Planetary wave activities have been investigated by various techniques, such as ionosonde measurement (Forbes et al. 2000 and Altadill et al 2003) and GPS based TEC measurement (Boris et al. (2007).

LAPAN Pontianak has installed a dual frequency GPS receiver system in (geographic: latitude 0.03 ° S, longitude 109.33°E, geomagnetic: latitude 9.9° S, longitude 178.57° E), namely GISTM the GPS Ionospheric Scintillation and TEC Monitor in 2008. In this work, the obsesrvation and analysis of planetary wave as seen on GPS TEC measurements by using GISTM Pontianak during solar begening maximum activity period 2011.

2 DATA AND METHOD

The GSV4004B computes total electron content (TEC) from combined pseudorange measurements and TEC changes from the dual-frequency carrier phase measurements. It measures the propagation delays at L1 = 1.57542 and L2 = 1.2276 GHz frequencies from a number of GPS satellites (maximum 11), and converts these to slant TEC. Data with lock time less than 240 seconds were deleted before used to analysis (GSV 4004B, 2007). The Vertical TEC is obtained by taking the projection from the slant to vertical using the thin shell model assuming a height of 350 km, following the technique given by (Klobuchar, 1986):

Vertical TEC(VTEC) =

$$STEC \times Cos[arc\ Sin(R_e\ Cos\ \theta / R_e + h_{max})] \quad (1)$$

where R_e=6378 km, h_{max}=350 km, the height of ionospheric pierce point (IPP), θ = elevation angle at the ground station.

The TEC data stored with sampled at one-minute intervals from all available satellites. To remove erroneous results at low elevation angles, TEC profiles are only obtained from satellites with elevation angle greater than 35°. This restriction has reduced the number of available satellites, but it has minimized the multipath effects and also the ambiguity that arises from sub-ionospheric points for low elevation angle. Figure 1 show geographic location of GPS LAPAN Pontianak relative to geographic equatorial and geomagnetic equatorial and all visibility satellite trajectory over 24 hour which are indicated by two color of elevation angle cutoff, the grey line is elevation angle 40° and the black line 5°.

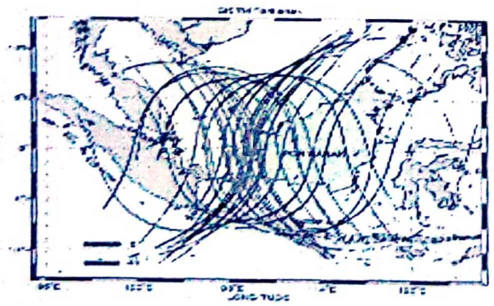

Figure 1. Coverage of IPP latitude and longitude by GPS satellites from Pontianak station with elevation angle cutoff 40° (grey line) and 5° (black line) along 24 hour observation.

The diurnal VTEC variations is represented by 1 hour moving average with elevation cutoff 35° of all visible satellite for a day observation. Thus, for a day observation we obtained about 100 data points, which corresponded to 24 hours of data (Figure 2).

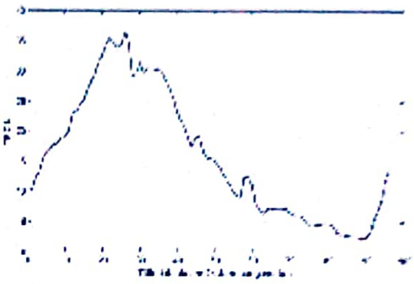

Figure 2. VTEC series data for a day observation which corresponded to about 96 points.

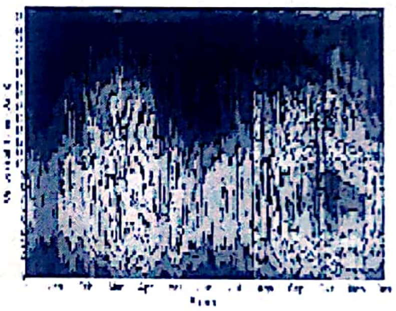

Figure 3. Contour of VTEC seasonal variation at LAPAN Pontianak for January to December 2011

From Figure 3, one can see that maximum VTEC occurance in the March and September (equinox month) and the months it around (February, April, October). The subsolar point is around the equator during the equinox months whereas the eastward electrojet associated electric field is often largest. Thus, in equinox months due to collocation of the peak photoelectron abundance and the most intense eastward electric field regions, one would expect that the fountain effect should be developed the most (Wu et al., 2004, 2008). On the other hand, during the solstices, photoelectrons at the equator decrease because the subsolar points moves to higher latitudes and fountain effect is expected to wane.

3 ANALYSIS

Temporal TEC variations show several periodic activities, which are related to the diurnal and seasonal variations and the solar activity cycle. The main variation of TEC in the time scale of days is the daily cycle due to the Earth's rotation. While the seasonal variation show several of quasi-periodical fluctuations with periods of planetary waves, tides, internal gravity waves. As explained in the section 2 that the diurnal VTEC variations is represented by 1 hour moving average with elevation cutoff 35° of all visible satellite for a day observation. Thus, for a day observation we obtained about 96 data points, which corresponded to 24 hours of data (Figure 2).

Analysis periodicities of the VTEC time series was performed using a Fast Fourier Transform (FFT). Figure 3a shows 1 day period appearances as the result of FFT of the VTEC time series. The oscillation period of 1 day periods could be related to planetary waves type oscillations (10 and 16 days) with possible influence of the half solar rotation period (13.5 days) (Fagundes et al. 2005). The daily oscillations (1 day period) need to be isolated in order to look at some other shorter frequencies. Signal processing techniques were developed to extract 2-13 day period component (Orfanidis, 1996). These techniques are realized with MATLAB, which has many the basic routines needed. For example design band pass filter by using elliptic filter with frequencies band 1.75×10^{-3} Hz to 1.05×10^{-2} Hz which are corresponded to 1 to 5 day period. After the daily oscillations were removed, the VTEC time series examined by the power spectral density (PSD).

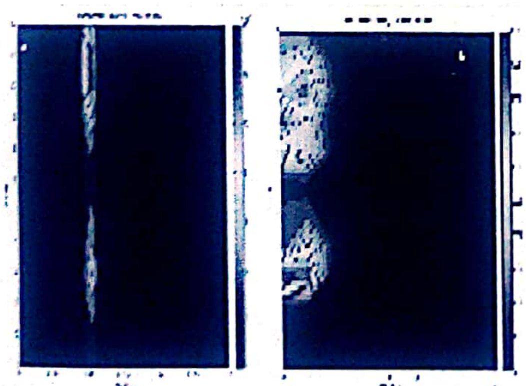

Figure 3. Power spectra density VTEC series before filter (a) and after filter (b). Strong oscillations in the range of 1 day (diurnal variation) occur in the equinox months (March and September (a). Two periodic components, quasi 10 day and quasi 2 day (b).

The estimate of the PSD is based on calculating a fast Fourier transform (FFT) of the time series. Shown in Figure 3b are the resulting power spectra densities from the TEC after filter. Results from Figure 3a show strong oscillations in the range of 1 day (diurnal variation) during the equinox months (March and September). In Figure 3b there are two periodic components, quasi 10 day is clearly seen and quasi periodic 2 day weakly seen. Quasi 10 day strong occur in the October dan April, while quasi 2 day weakly occur in September.

4 CONCLUSION

Results from analysis periodicities of the VTEC time series by using a Fast Fourier Transform (FFT) show the presence of the strong oscillations 1 day. This could be related to planetary waves type oscillations (10 and 16 days) with possible influence of the half solar rotation period (13.5 days). After the daily oscillations were removed, the VTEC time series examined by the power spectral density (PSD) there are two periodic components, quasi 10 day and quasi periodic 2 day. Quasi 10 day strong occur in the October dan April, while quasi 2 day weakly occur in September.

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