IONOSPHERİC TOTAL ELECTRON CONTENT (TEC) ANOMALİES RELATED TO THE (MW=7.8), 25 APRİL 2015 NEPAL EARTHQUAKE

Jyh-Woei, Lin

Department of Electrical Engineering, Southern Taiwan University of Science and Technology, Tainan City, TAIWAN.

pgjwl1966@gmail.com

ABSTRACT

Two-dimensional principal component analysis (2DPCA) are used to examine the ionospheric total electron content (TEC) data during the time period from 00:00 on 20 April to 06: 10 on 25 April (UT) 2015, which are 5 days before the Mw=7.8 Nepal earthquake at 06:11:25 on 25 April 2015 (UT) with the epicenter (28.230°N, 84.731°E) and the depth of 8.2km. From the analysis result of 2DPCA, a TEC precursor of Nepal earthquake is found localized nearby the epicenter during the time period from 16:55 to 17:00 on 23 April 2015 (UT) with the duration time of at least 5 minutes. This work discusses potential reasons for the TEC anomaly related to this earthquake and possible reasons including radon gas release and P-type semiconductor effects.

Keywords: Two-dimensional Principal Component Analysis (2DPCA), Ionospheric total electron content (TEC), Nepal earthquake; Radon Gas Release; P-type semiconductor effects

INTRODUCTION

The potential for ionospheric total electron content (TEC) anomalies being associated with large earthquakes has been widely researched (Freund, 2003; Afraimovich et al, 2001; Pulinets, 2004). The cause of TEC anomalies before large earthquakes is not known though there are many potential causes. Pulinets (2004) makes an extensive list of possible causes, including radon gas release causing lower atmospheric electric fields which travel up into the ionosphere along geomagnetic lines while Freund (2003) suggests P-type semiconductor effect as the cause of lower atmosphere electric fields. Afraimovich et al (2001) states the shock-acoustic waves to be a possible factor.

Principal component analysis (PCA) has been used to detect the ionospheric total electron content (TEC) precursors regardless of non-earthquake TEC disturbances from Lin's statistical work (2010) about PCA. From his work, PCA assigns large principal eigenvalue to the earthquake related TEC anomaly (TEC precursor). When a matrix with the high dimension is transformed into the PCA domain and this matrix will be simultaneously reduced to the low dimension with minimum loss of data information in the transformed process. Therefore computing time is saved and principal eigenvalue can represent main characteristics of data (Londoño et al. 2005).

In this paper, two-dimensional principal component analysis (2DPCA) is performed to detect TEC anomaly related to three large earthquakes. The researched earthquake is Nepal earthquake at 06:11:25 on 25 April 2015 (UT) with the epicenter (28.230°N, 84.731°E) at the depth of 8.2km. The examined ionospheric total electron content (TEC) data are during the time period from 00:00 on 20 April to 06: 10 on 25 April (UT) 2015, which are 5 days before the earthquake. The TEC precursors were usually found in 5 day before the large earthquakes

Leena and Luna International, Chikusei, Japan.
(株) リナアンドルナインターナショナル, 筑西市,日本
ISSN: 2186-8476, ISSN: 2186-8468 Print
www.ajsc. leena-luna.co.jp

(Liu et al. 2006), and therefore the previous examined period is selected. The TEC data are acquired from the NASA Global Differential GPS system (GDGPS).

METHOD

2DPCA

For 2DPCA, let data be represented by a matrix *B* with the dimension of *m* x *n*. Linear projection of the matrix *B* is considered as followed (Fukunnaga 1991; Kong et al. 2005; Sanguansat 2012),

$$y = Bx \qquad (1)$$

Here x is an n dimensional project axis and y is the projected feature of this data on x called principal component vector. E is mean.

$$W_x = E(y - Ey)(y - Ey)^T \qquad (2)$$

Here W_x is the covariance matrix of the project feature vector.

The trace of W_x is defined;

$$J(x) = tr(W_x) \qquad (3)$$

$tr(W_x) = tr\{x^T Sx\}$, where $S = E[(B - EB)^T (B - EB)]$ (4)

The matrix W_x is called covariance matrix. The alternation criterion is expressed by $J(x) = tr(x^T Wx)$, where the data inner-scatter matrix Wx is computed in a straightforward manner by

$w_x = \frac{1}{m}\sum_{k=1}^{m}(B_k - \overline{B})^T (B_k - \overline{B})$, where $\overline{B} = \frac{1}{m}\sum_{1}^{m} B_k$ (5)

The vector x maximizing Eq.4 corresponds to largest (principal) eigenvalue of W_x which represented the main characteristics of data. 2DPCA is another version of PCA. Therefore large principal eigenvalue of 2DPCA also indicates earthquake-related TEC anomaly. If the PCA is used to transform a matrix with low dimension into the PCA domain and then the dimension of this matrix in the PCA domain will be too small after reducing and become small sample size (SSS) data. Therefore the SSS problem will be caused by using PCA. The SSS problem causes larger data reconstruction error when data in the PCA domain are transformed back to their original domain and corresponding principal eigenvalue is not very precise to represent main characteristics of data. The SSS problem will be removed when performing 2DPCA due to different algorithm from the PCA. More detailed contents about the algorithm of 2DPCA can be read from the studies of Fukunnaga (1991), Kong et al (2005) and Sanguansat (2012).

TEC Data Processing using 2DPCA

The previous examined TEC data are processed 2DPCA and no earthquake-related anomaly is found. Only during the time period from 16:55 to 17:00 on 23 April 2015 (UT) related to the Nepal earthquake. Therefore the procedure of TEC data processing during this time periods is represented in this study. Figure 1(a) shows the Global ionospheric TEC maps (GIM) at that time of 16:55 on 23 April 2015 (UT). The TEC data in Figure 1(a) are divided into 600 smaller grids 12° in longitude and 9° in latitude, respectively. The resolution of the TEC data for this GPS system is 5 and 2.5 degrees in latitude and longitude, respectively

(Hernández-Pajares et al. 2009), and therefore the 4 TEC data in each grid are selected to compute. These 4 TEC data form the matrix with the dimensions 2 x 2 in Eq.1 in order to perform 2DPA. Figure 1(b) gives the corresponding magnitudes of principal eigenvalues of 2DPCA. A TEC anomaly with a large principal eigenvalue is given nearby the epicenter of the Nepal earthquake during. It is a TEC precursor for this earthquake. The corresponding magnitudes of principal eigenvalues of Figure 2(a) at that time 17:00 on 23 April 2015 (UT) using the previous processing is shown in Figure 2(b). Figure 3 shows the AE indices and DST indices from 01 to 30 April 2015 (UT). From these indices in this figure, 23, April was Geomagnetism quiet day. It could proof the previous TEC anomaly related to Nepal earthquake.

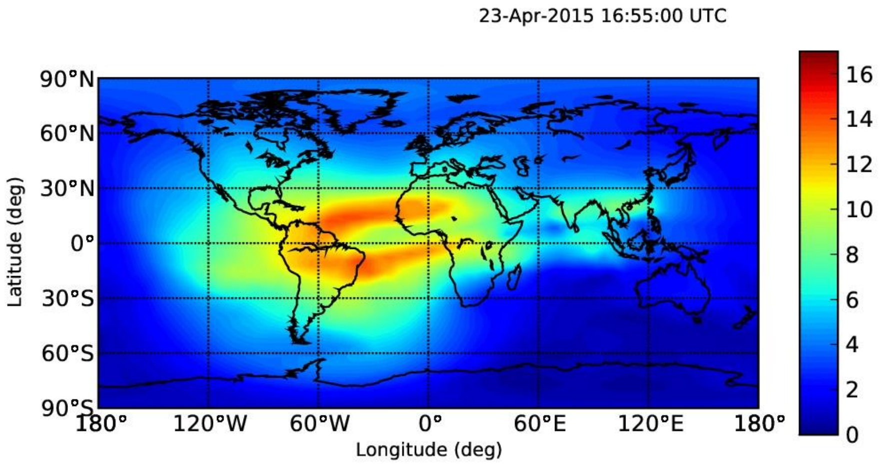

Figure 1a. The GIM at that time of 16: 55 on 23 April 2015 (UT)

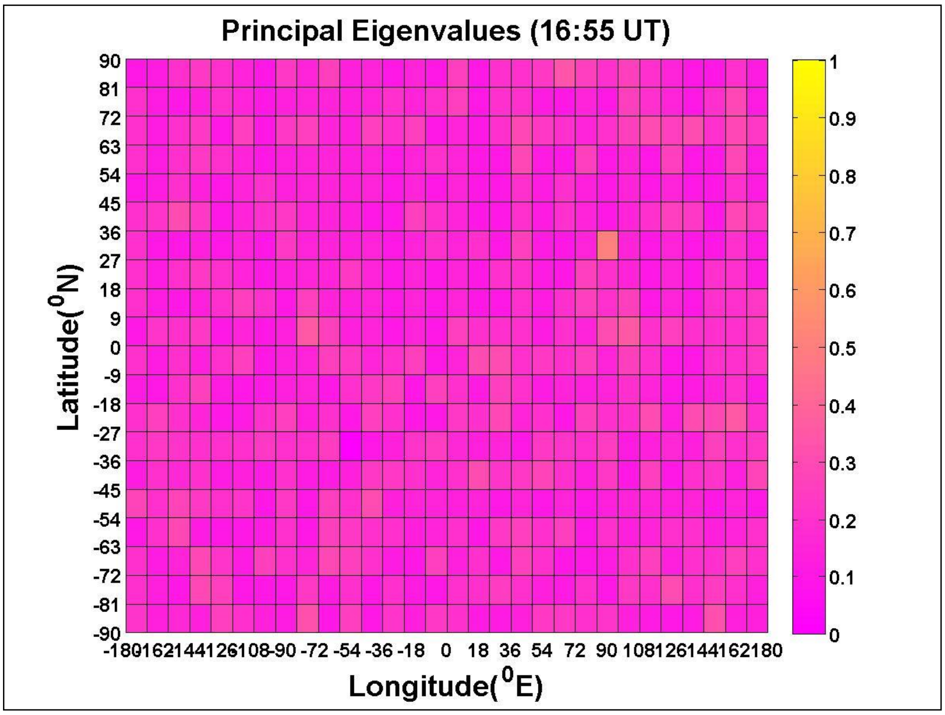

Figure 1b. A color-coded scale of the magnitudes of principal eigenvalues of 2DPCA corresponding to Figure 1a. The color within a grid denotes the magnitude of a principal eigenvalue corresponding to Figure 1a, so that there are 600 principal eigenvalues assigned for 600 grids in each small map, respectively

Leena and Luna International, Chikusei, Japan.
(株) リナアンドルナインターナショナル, 筑西市,日本
ISSN: 2186-8476, ISSN: 2186-8468 Print
www.ajsc. leena-luna.co.jp

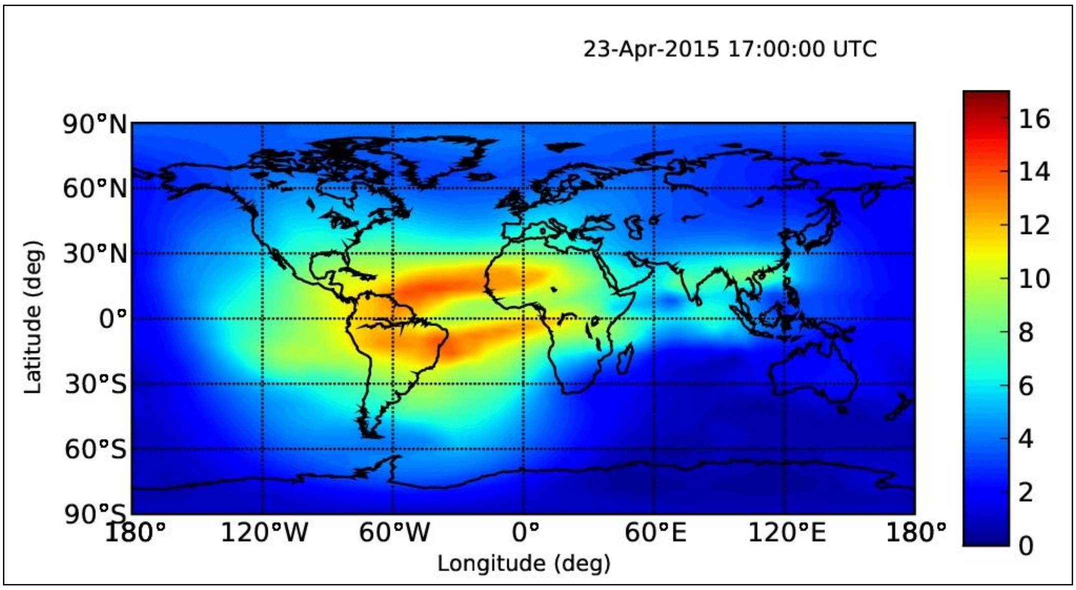

Figure 2a. The GIM at that time of 17: 00 on 23 April 2015 (UT)

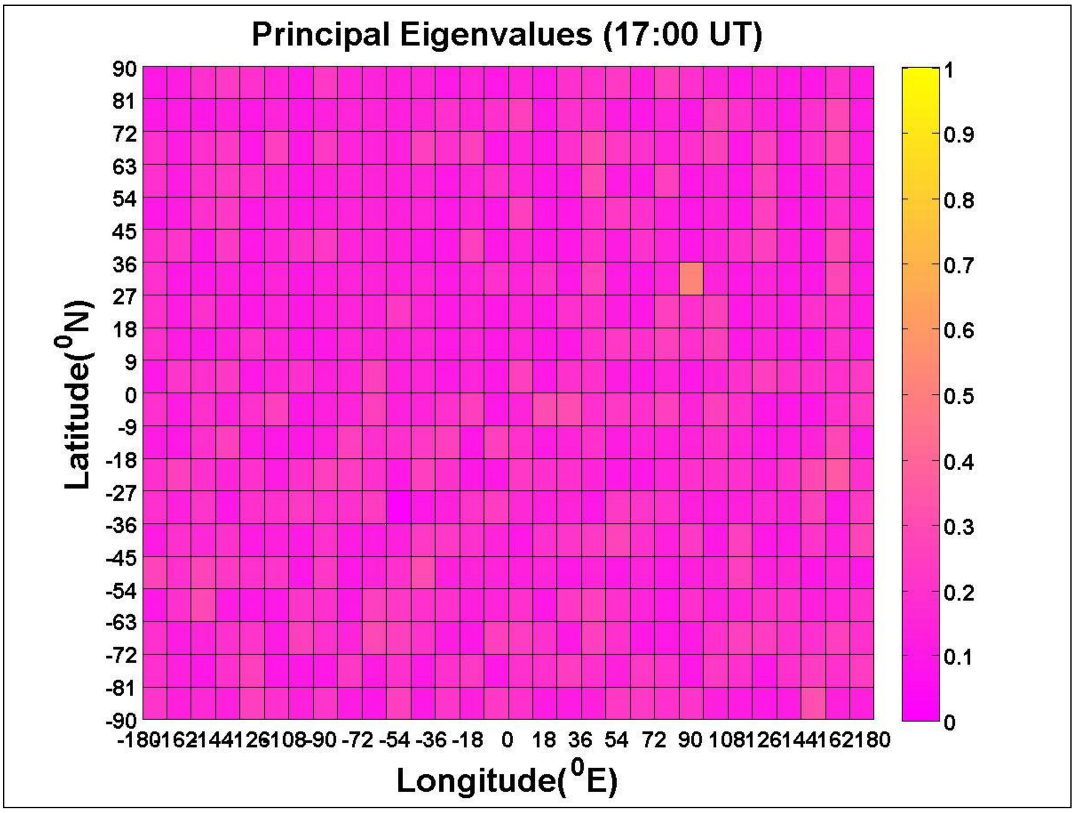

Figure 2b. A color-coded scale of the magnitudes of principal eigenvalues of 2DPCA corresponding to Figure 2a. The color within a grid denotes the magnitude of a principal eigenvalue corresponding to Figure 2a, so that there are 600 principal eigenvalues assigned for 600 grids in each small map, respectively

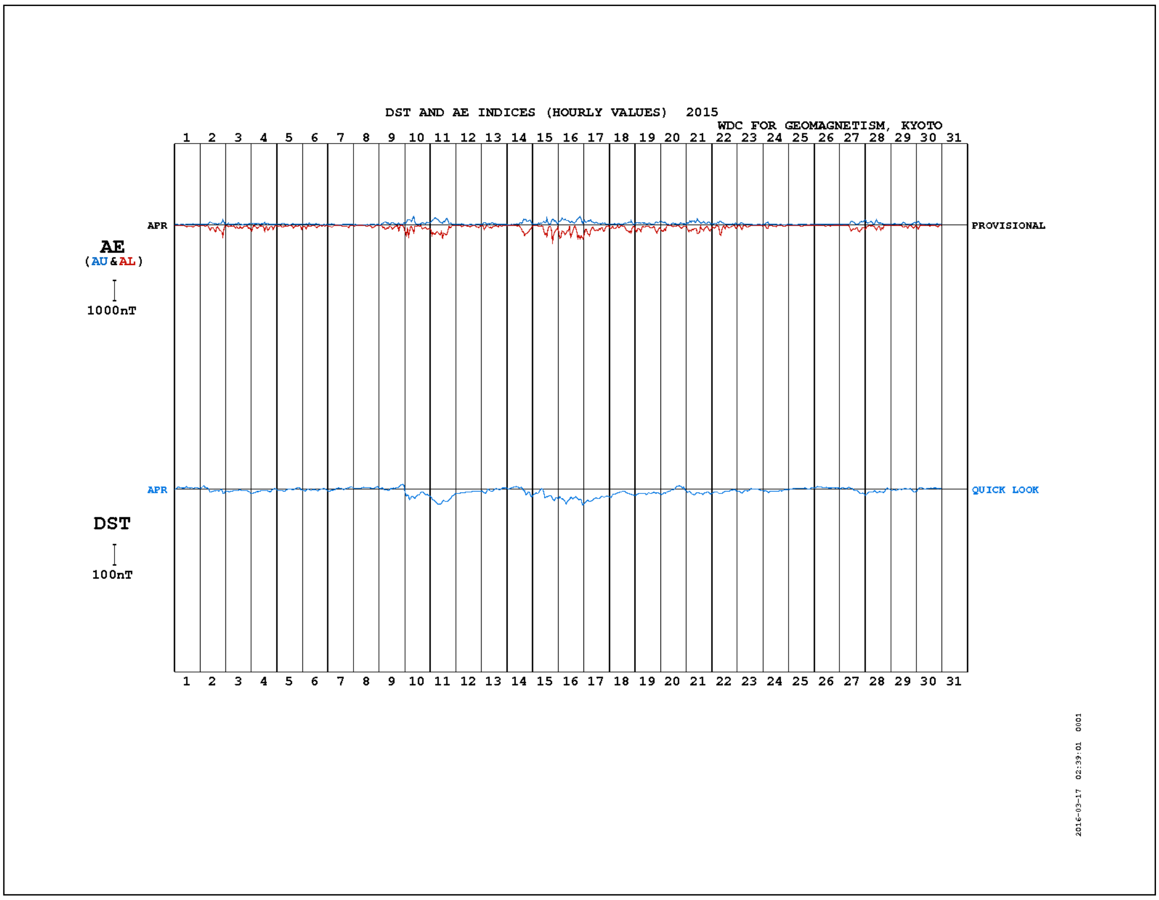

Figure 3. The AE indices and DST indices from 01 to 30 April 2015 (UT)

(World Data Center for Geomagnetism, Kyoto)

DISCUSSION

The earthquake TEC disturbance with the obvious possibility of acoustic shock waves creating ionospheric disturbance due to large ground surface vibrations and the natural amplifier effect of decreased density with height in the atmosphere. However, before the earthquake, large ground surface vibrations should be impossible to occur. Therefore, the possible reasons should be radon gas release and P-type semiconductor effects.

2DPCA is able to detect a TEC precursor nearby the epicenter of Nepal earthquake during the time period from 16:55 to 17: 00 on 23 April 2015 (UT) with the duration time of at least 5 minutes. 2DPCA has the ability to detect the clear TEC anomalies related to the large earthquakes in this study. 2DPCA has shown its credibility to estimate the duration time of the earthquake-associated TEC anomaly. An argument always exists; principal eigenvalue could not indicate true ionospheric variations or situation. However, if a mathematical index can indicate an ionospheric precursor and then the aim of earthquake precursor research is already to be satisfied. More detailed corresponding precursor research can be examined from the reports of VAN group (Varotsos, Caesar Alexopoulos and Kostas Nomikos) and some studies (Varotsos and Lazaridou 1991; Pulinets et al. 2000; Freund 2003; Pulinets and Boyarchuk, 2004; Harrison et al. 2010; Michael and Harrison, 2012).

CONCLUSION

A TEC precursor has been detectable for the Nepal earthquake during the time period from 16:55 to 17: 00 on 23 April (UT) and its duration time was at least 5 minutes. Radon gas release and P-type semiconductor effects should be the possible reasons.

ACKNOWLEDGEMENTS

The author is grateful to NASA Global Differential GPS system (GDGPS) and World Data Center for Geomagnetism, Kyoto for their useful references Data. This paper is selected in memory of people died due to Nepal earthquake.

REFERENCES

[1] Afraimovich, E. L., Perevalova, N. P., Plotnikov, A. V., & Uralov, A. M. (2001). The shock-acoustic waves generated by earthquakes. *Annales Geophysicae*, *19*, 395-409.

[2] Antonopoulos-Domis, M., Xanthos, S., Clouvas, A., & Alifrangis, D. (2009). Experimental and theoretical study of radon distribution in soil. *Health Physics*, *97* (4), 322-331.

[3] Freund, F. T. (2003). Rocks that crackle and sparkle and glow: Strange pre-earthquake phenomena. *Journal of Scientific Exploration*, *17* (1), 37-71.

[4] Fukunnaga, K. (1991). *Introduction to statistical pattern recognition*. USA: Academic Press.

[5] Harrison, R.G., Aplin, K. L., & Rycroft, M. J. (2010). Atmospheric electricity coupling between earthquake regions and the ionosphere. *Journal of Atmospheric and Solar-Terrestrial Physics*, *72* (5–6), 376–38.

[6] Hernández-Pajares, M., Juan, J. M., Sanz, J., Orus, R., Garcia-Rigo, A., Feltens, J., Komjathy, A., Schaer, S. C., & Krankowski, A. (2009). The IGS VTEC maps: A reliable source of ionospheric information since 1998. *J Geod*, *83*, 263-275.

[7] Kong, H., Wang, L., Teoh, E. K., Li., X., Wang, J. G., & Venkateswarlu, R. (2005). Generalized 2D principal component analysis for face image representation and recognition. *Neural Networks*, *18*, 585–594.

[8] Lin, J.W. (2010). Ionospheric total electron content (TEC) anomalies associated with earthquakes through Karhunen-Loéve Transform (KLT). *Terrestrial, Atmospheric and Oceanic Sciences*, *21*, 253-265.

[9] Liu, J. Y., Chen, Y. I., Chuo, Y. J., & Chen, C. S. (2006). A statistical investigation of pre-earthquake ionospheric anomaly. *J. Geophys, Res. Space Phys.*, *111*.

[10] Londoño, E. G., López, L. C., & Kazmierczak, T. S. (2005). Using the Karhunen-Loève Transform to suppress ground roll in seismic data. *Earth Sci. Res. J. 9* (2), 139-147.

[11] Michael, J. R., & Harrison, R. G. (2012). Electromagnetic atmosphere-plasma coupling: The global atmospheric electric circuit. *Space Sci Rev.*, *168*, 363–384.

[12] Pulinets, S. A. (2004). Ionospheric precursors of earthquakes: Recent advances in theory and practical applications. *Terrestrial Atmospheric Oceanic Sciences*, *15* (3), 413-435.

[13] Pulinets, S. A., Boyarchuk, K. A., Hegai, V. V., Kim, V. P., & Lomonosov, A. M. (2000). Quasielectrostatic model of atmosphere-themosphereionosphere coupling. *Advances in Space Research*, *26* (8), 1209– 1218.

[14] Pulinets, S., & Boyarchuk, K. (2004). *Ionospheric precursors of earthquakes*. Berlin: Springer-Verlag.

[15] Sanguansat, P. (2012). *Principal component analysis*. Croatia: InTech.

[16] Varotsos, P., & Lazaridou, M. (1991). Latest aspects of earthquake prediction in Greece based on Seismic Electric Signals. *Tectonophysics*, *188*, 322.

Leena and Luna International, Chikusei, Japan.
(株) リナアンドルナインターナショナル, 筑西市,日本
ISSN: 2186-8476, ISSN: 2186-8468 Print
www.ajsc. leena-luna.co.jp