IONOSPHERIC ANOMALY FROM HUGE GAS EXPLOSION IN KAOHSIUNG CITY IN TAIWAN ON 31 JULY 2014

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ABSTRACT

This paper used two-dimensional Principal Component Analysis (2DPCA) to determine total electron content (TEC) respond in the ionosphere for the huge gas explosion in Kaohsiung, Taiwan at 15: 59 (UT) on 31 July 2014. Results have shown that at a TEC anomaly over Kaohsiung and Taiwan from 16:00 to 16:05 (UTC) with the duration time of 5 minutes. Potential causes of the results were discussed with emphasis given to acoustic shock waves with the speed of 2500m/s and caused a TEC anomaly. Supposedly, it is possible to predict this explosion time due to the gas release just short time before this explosion if such explosion is very huge to reduce the number of dead people.

Keywords: Two-Dimensional Principal Component Analysis (2DPCA), Total Electron Content (TEC), Huge gas Explosion, Kaohsiung, Acoustic shock waves.

INTRODUCTION

The potential area of application is in the study of explosion related ionospheric anomalies. Blanc and Jacobson (1989) described the ionospheric anomalies were caused through the shock wave produced by a 5-kt chemical explosion. Andreeva et al' work (2001) used the ionosphere radiotomography method to detect the Long-lived local disturbances of the ionospheric density over the site of ground industrial explosions. Calais et al found Ionospheric signature of surface mine blasts from Global Positioning System (GPS) receivers. The perturbation starts 10 to 15 min after the blast, lasts for about 30 minutes. The goal of this paper is to use Two-Dimensional Principal Component Analysis (2DPCA) to examine the ionospheric spatial distribution of any driven ionospheric TEC anomaly associated with huge gas explosion in Kaohsiung, Taiwan at 15: 59 (UT) on 31 July 2014. The exampled time period chosen is from 16:00 to 16:10 on 31 July 2014. The two-dimensional TEC data are derived NASA Global Differential GPS system (GDGPS) and global TEC maps (GIMs) in this study are derived using TEC data from ~100 real-time GDGPS tracking sites that can be available on 5 minutes basis (Kechine et al. 2004; Ouyang et al. 2008).

METHOD

2DPCA

For 2DPCA, let signals are represented by a matrix A (the dimension of n x m). Linear projection of the form is considered as followed (Sanguansat 2012),

$$y = Ax \quad (1)$$

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

$$S_x = E(y - Ey)(y - Ey)^T \quad (2)$$

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

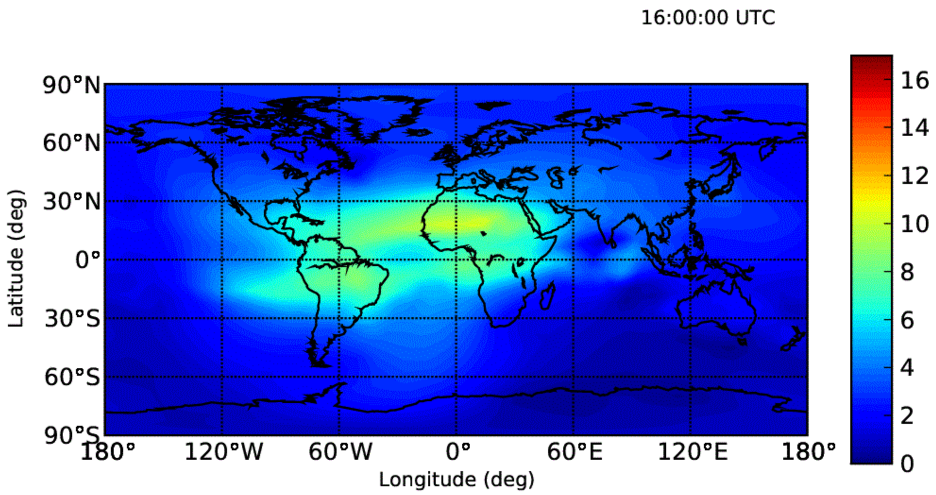
The trace of S_x is defined;

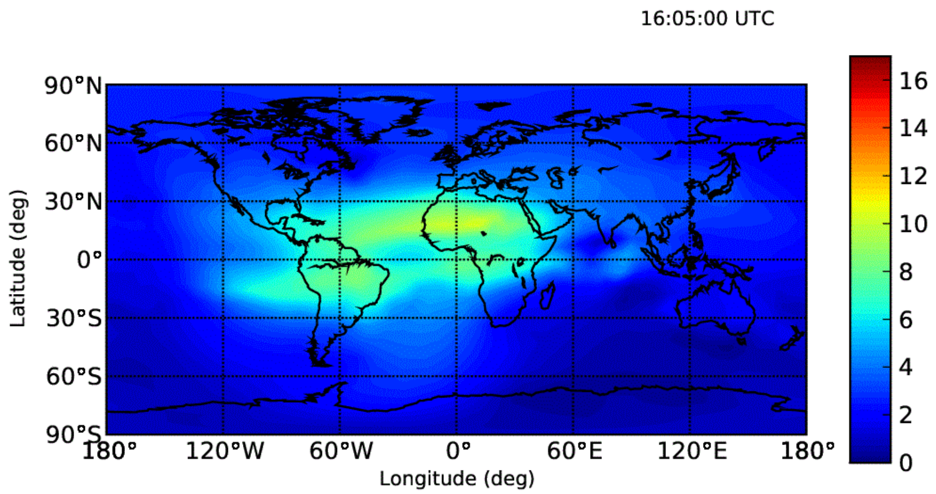
$$J(x) = tr(S_x) \quad (3)$$

$$tr(S_x) = tr\{x^T G x\}, \text{ where } G = E[(A - EA)^T (A - EA)] \quad (4)$$

The matrix G is called signal covariance matrix. The vector x maximizing Eq.4 corresponds to the largest (principal) eigenvalue of G, and let the largest eigenvalue be the most dominant component of the data, therefore largest eigenvalue is represented the principal characteristics of the data. 2DPCA can be removed small sample signal size (SSS) problem for two dimensional TEC data.

TEC Image Processing





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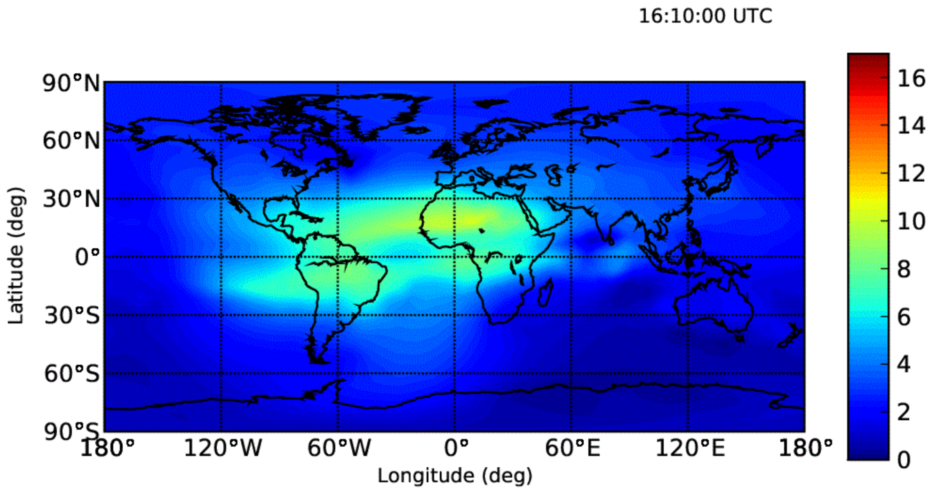
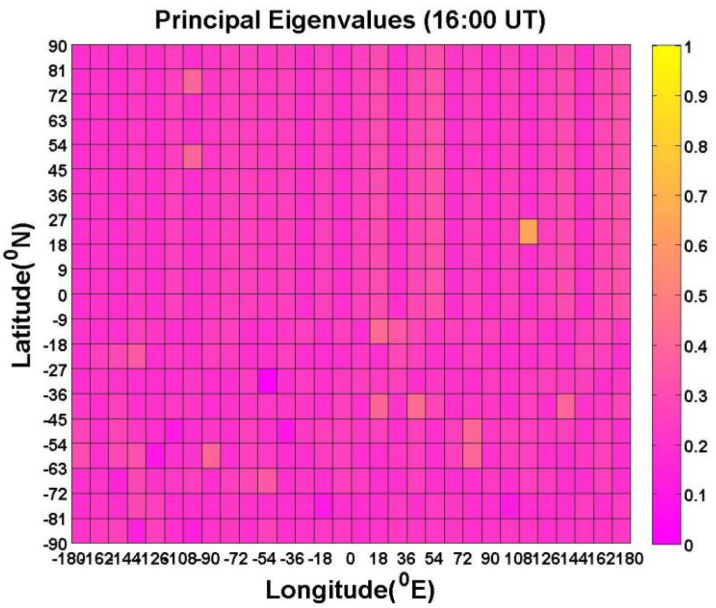


Figure 1a. These figures show GIMs during the time from 16:00 to 16:10 (UT) on 31 July 2014.

TEC Image Processing

Figure 1(a) shows the GIMs during the time from 16:00 to 16:10 on 31 July 2014. The TEC data of the global region (not dividing the GIM for image processing) shown in Figure 1(a) are divided into 600 smaller areas 5 and 2.5 degrees in longitude and latitude, respectively. The size of each small area is 12° in longitude and 9° in latitude. The spatial resolution of the TEC data for GDGPS system is 5 and 2.5 degrees in longitude and latitude, respectively (Hernández-Pajares et al. 2009) and therefore 4 TEC data (two-dimensional data) are take in each area. The 4 TEC data form a matrix *A* of Eq.1 with the dimensions of 2 x 2 as small sample signal size (SSS) in each are of Figure 1 (a). This allows for principal eigenvalues to be computed for each of the 600 smaller areas.



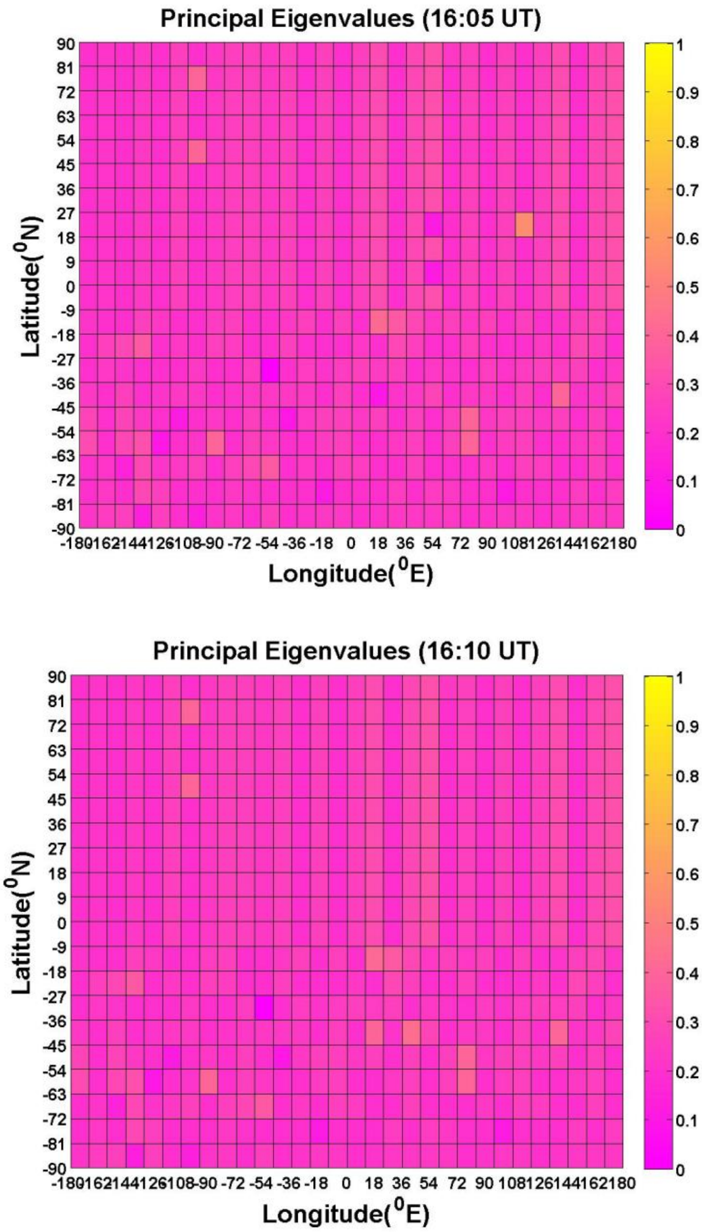


Figure 1b. The figures give a color-coded scale of the magnitudes of principal eigenvalues corresponding to Fig. 1a. The color within a grid denotes the magnitude of a principal eigenvalue corresponding to Fig. 1a, so that there are 600 principal eigenvalues assigned, respectively.

RESULTS

The respective results are given in Figure 1(b). The representative of large principal eigenvalues in the Figs 1(b) shows the existence of explosion-related TEC anomaly represented by a large principal eigenvalue at the time from 16:00 to 16:05 on 31 July 2014 with the duration time of about 5 minutes. The possibility of other factors such as solar flare and geomagnetic effects affecting the results are considered by examining Kp indices. July, 31 was geomagnetic quiet day shown in Figure 2 (Kp<4). The region of TEC anomaly is wide that may be due to ionospheric disturbances with very quick horizontal spreading.

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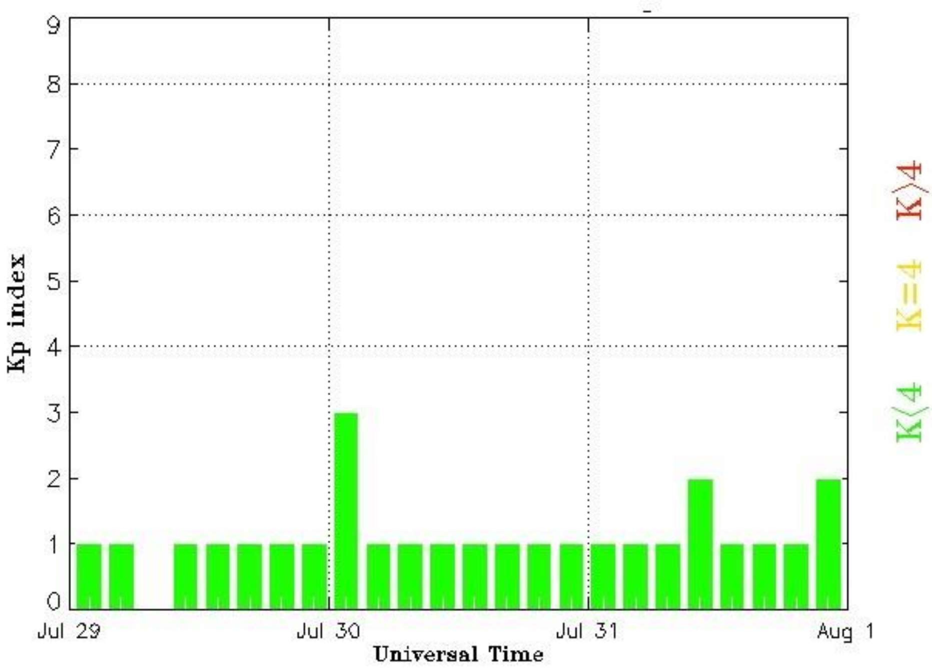

Figure 2. Kp indices from 29 July to 31 July 2014 (Space Weather Prediction Center).

DISCUSSION

2DPCA was able to detect Explosion-TEC anomaly was found by 2DPCA at the time 16:00 to 16:05 UT on 31 July 2014 over Kaohsiung and Taiwan and the most evident physical mechanism was acoustic shockwave waves (Blanc and Jacobson, 1989) creating large scale ionospheric density irregularities and traveling up into the ionosphere. The duration time of TEC anomaly was estimated at least 5 minutes. The computing process of the shock wave speed was as follows; the time difference from original time of the explosion to beginning time of TEC anomaly is 60 sec, and the F-lay is above 150km, then 150km÷60 sec is about 2500 m/s. Afraimovich et al (2001) researched shock acoustic wave due to occurring of the earthquakes to affect ionosphere. They studied the earthquake effects in Turkey on 17 August and 12 November 1999 and in Southern Sumatra on 04 June 2000 and found the ionospheric response related to the earthquakes due to shock acoustic wave is 180-390 s. Compared with the result of this study, 2DPCA has shown its advantage and credibility to estimate the duration time of Explosion-related TEC anomaly. It is worth noting if this explosion is very huge and then it is possible to predict this explosion time due to much gas release just short time before the explosion to reduce the number of dead people.

CONCLUSION

2DPCA had the advantage to detect an explosion-TEC anomaly due to high speed acoustic shock wave. Results have shown that a local ranging TEC anomaly was detectable at the time 16:00 to 16:05 UT on 31 July 2014. The TEC anomaly could be indicative of a speed acoustic shock wave with the speed of at least 2500m/s. The duration time of the TEC anomaly was at least 5 minutes.

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