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Fraud Equatorial ionization Anomaly

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After the discovery of the Equatorial Ionization Anomaly (EIA) by Appleton (Appleton 1946), it is now well established that Equatorial Ionization Anomaly is characterized by a minimum in ionization density near geomagnetic dip equator flanked by two maxima at low latitudes (±15°) on either sides (Moffett and Hanson,1965). However under special condition, such double humped features in the latitudinal distribution of plasma densities with the latitude of the minimum density occurring at midlatitdes has been identified from satellite observations. Here we show from atomic oxygen density measurement by the American satellite DE-2 a case of what looks like an extreme shift of the EIA to midlatitude with [O^+] minimum occurring at midlatitude where normally it is high. A geomagnetic storm was in progress during this observation. However, we found that the minimum is very close to the epicenter of an earthquake (lat;-33.13, Longitude;73.07, M=7.5), which occurred on 16,October,1981. The detectable reduction of [O^+] is in the area of 40 degrees in latitude along the same geomagnetic longitude. It extends more than 140 degrees in longitude. The reduction of [O^+] that has highest value near epicenter finally disappears beyond the longitude 140 degrees. The minimum appeared 5 days before the earthquake, and disappeared 3 days after in this case. We conclude that the minimum is generated due to a combined action of the normal dynamo electric field and a westward electric field that is locally generated by the earthquake. The finding shows that even during magnetically disturbed days, the precursor effects in the ionosphere due to an earthquake can be detected by satellite measurements.

It is a well accepted fact that the Equatorial ionization Anomaly; (EIA), also known as the Appleton anomaly[1,2,3,4,5,6] , is formed as the combined effects of the ionospheric dynamo zonal electric field, plasma pressure gradient and gravitational forces. The eastward electric field, which is generated as a result of the interaction between the neutral wind and the magnetized charge particles around the height of 100-120 km, lifts up plasma to higher F region heights where upon the plasma flows down along the magnetic field lines under the pressure gradient and the gravitational forces. The mechanism is called the "Fountain effect" as the phenomena is similar to the behavior of the water which is ejected upward from a nozzle.

The fountain effect leads to the formation of plasma density depression at the magnetic equator flanked by two nearly symmetric crests at conjugate low magnetic latitudes (± 15°), characterizing the EIA. The EIA can be modified by the meridional neutral wind, so that the plasma density crests are not symmetrical except during equinox seasons[6] .

Disturbance electric fields during magnetic storms can cause large up lift of the ionosphere, resulting in large displacement of the EIA crests to higher latitudes[7] . However, in most cases, the minimum of plasma density (the trough) is located around geomagnetic equator[8].

We show here one surprising phenomena, that was observed by the US satellite, Dynamic Explore -2 (DE-2). The location of the minimum in the latitudinal distribution of plasma density appeared to be very close to the epicenter of an earthquake, which occurred at –33.1 in Latitude, and 286.9 in longitude at

3:25 UT on the 16th October,1981. The magnitude and the epicenter depth of this earthquake are 7.5 and 33 km respectively.

The DE-2 satellite was launched on 3 August 1981 at an inclination of 89.89 degrees with a period of 94 minutes. The periapsis and apoapsis are 309.0 km and 1012.0 km respectively. The DE-2 accommodated a Retarding potential Analyzer (RPA),a Plasma drift meter, a Neutral wind instrument, a Neutral Mass Spectrometer, a Langmuir probe, and a UV photometer.

Fig.1a and 1b show the successive orbit data of atomic ion density (denoted as [O^+] hereafter) measured with the RPA instrument , plotted versus geographic latitude during the 5 days before and after the earthquake, respectively. The day number for the days before, during and after the earthquake day (D0) is indicated at the top of each panel (- and + signs indicates the days before and after the D0, respectively). [O+] on earthquake day is plotted as a reference for two figures. The satellite paths which are within ± 50degrees from the longitude of earthquake location are included in these plots. The local time of the satellite pass is around 9 LT for all plots, because DE-2 satellite has a sun synchronous orbit. The altitude of the satellite pass that is plotted here is below 500km. Although there are two passes which is higher than 500 km during these period, we do not plot them because the ion density above 500km is too low to identify the variation of [O^+] in the same scale as of Fig.1a and b.

In the figures, the blue and red lines shows two different satellite orbits. The magnetic equators on these satellite orbits are indicated on the horizontal axis by the blue and red crosses, respectively. The longitudes where the satellite crosses the minimum height is indicated at the left-top of each panels. As the inclination of DE-2 satellite is almost 90 degrees, the difference of the longitude near south pole and equator is less than 6 degrees. A red star on the horizontal axis indicates the latitude of the epicenter.

Before the earthquake, except on the day D-2, all plots shows a dip near the epicenter. There is no clear dip of [O^+] around geomagnetic equator, such as that which should normally represent the EIA trough.

The dip appears to become increasingly well defined getting closer to the earthquake day. If we are not informed about the location of magnetic equator, we surely would misunderstand the dip location for the magnetic equator.

Until 2 days after the earthquake, the [O^+] distribution still shows the minimum although at the epicenter it becomes shallower. 3 day after the quake (the day D3) the minimum disappears, and on the day D4 the minimum shifts to the geomagnetic equator , where it should normally be located.

Effect of magnetic disturbance

The 16 October earth quake occurred during the recovery phase of a magnetic storm as shown in Fig.2. Within one week of this earthquake, 5 other earthquakes were registered; those are: Oct 9 (-9.98N, 162.05E, 50km, 6.5), Oct 15 (40.23N, 142,29E, 47km,M=6), Oct 17(-7.1N, 128.97E, 179km , M=6.1), Oct 17(-45.51N,-15.18 E, 10km, M=6), and Oct 18(49.89N, 78.9E, 0km, M=6). The numbers in the bracket are latitude and longitude of the epicenter, depth, and the magnitude. The earthquake which occurred on the 16th is much more intense than the others, its energy being more than 30 times as compared to that of Oct 9 earthquake. These other weaker Earthquakes are not of our present concern.

In the lower panel of Figure 2, the auroral indices AU and AL are indicated . On Oct 11 and 13October the AL index shows about – 800 nT and –1600 nT respectively. The AU shows the maximum on the 14th , which suggests the strongest eastward electric field during the days we are discussing. In the upper panel then Dst index is presented. It shows big drop , reaching to about – 150 nT at the beginning of the 14th and gradually recovers toward the 17th. From the beginning of 17th to the noon of 20th, the Dst stays calm. In synchronizing with the Dst minimum, the AL drops to –1600 nT at the beginning of the 14th .

In Fig.1a,the [O+] distribution shows decrease pole ward of–50 degrees already –5 days prior to D0 (that is, on Oct 11). This reduction may possibly be caused by the expansion of atmosphere arising from the particle precipitation which occurred on 11 and 12 October. Toward 3 days before, (on the day D3) the [O^+] in the latitude region below -60 degrees increase. Two days prior to the earthquake , the [O^+]

decreases drastically in the southern latitudes of the epicenter . The reduction is large in the longitude of -18 degrees. This reduction might be caused by the intense precipitation of energetic particles which occurred on the 14th. The $[O^+]$ increases toward 3 days after the earthquake. On 20th October, the second large energetic particle precipitation occurred, which caused again the reduction of $[O^+]$ 4 days after the earthquake. These $[O^+]$decreases may also be caused by the effect of ionization uplift by storm associated penetration electric field of eastward polarity whereby the DE2 orbital segment entering into the bottomside of the rising F layer has a reduced density. However on the 4th day after the earthquake the minimum of the $[O^+]$ distribution moved to near the geomagnetic equator as though the usual quiet day feature of the EIA has been reestablished. This means that no electric field from high latitude or from the earthquake process appears to be present on this day. We may point out that a penetration electric field of eastward polarity may also cause an increase of the $[O^+]$ over mid latitudes if the DE2 orbit happens to be located well above the quiet time F layer peak height. Superposed on the increase of mid altitude $[O^+]$,the minimum of $[O^+]$ exists. We presume that this minimum is caused by the local westward electric field which is associated with earthquake[10]. The westward electric field pushes down the ionosphere, and electron density reduces at the DE2 orbit.

To confirm our idea, satellite pass of 16 Oct (earthquake days) is presented in Fig.3 together with 3 components of plasma drift. In the top panel, the $[O^+]$ observed by the DE2 is plotted (solid line) together with IRI model value (broken line). The $[O^+]$ distribution clearly shows a minimum over the epicenter. The middle panel of the figure shows the DE2 orbital altitude. In the bottom panel are shown the drift velocities. The light green shows eastward component (positive: eastward, while red shows upward drift. Between -40 and -24 degrees, the upward drift shows nearly constant velocity of 30 m/sec. We presume that this plateau is due to the superposition of westward electric field on the eastward electric field . The superposed velocity component is, at the most ,10 m/s.

Finally we present in Fig.4 the location of the $[O^+]$ minimum for the different days plotted versus longitude in the upper panel. The epicenter is marked by a star. The location of the minimum is nearly parallel to the geomagnetic equator. It might be noted that another $[O^+]$ minimum appear near the epicenter along the latitude of earthquake. (Thus there are two minima separated by ~ 20° in latitude along the African longitude). This fact might be related to the generation mechanism of electric field, which is not clear[11,12,13].

In the lower panel of the Fig 4 is shown the ratio of $[O^+]$ reduction with respect to the ambient maximum in $[O^+]$ plotted against longitude. The numbers attached to the data points indicate the day counted from the day of the earthquake. The data points which are obtained on the same day are connected to show their dependence on distance. The largest reduction tends to occur around epicenter and it reduces as the observation point departs from the epicenter and finally the $[O^+]$ minimum cannot be seen beyond 60 degrees in longitude on either side of the epicenter. The minimum only appears 5 day prior to the earthquake and disappears 4 days after the earthquake in this case. The area extension of the minimum is consistent with our previous results [10].

Conclusion

We have presented here evidence for an amazing shift of the trough of Equatorial Ionization Anomaly towards the epicenter of the major earthquake that occurred on 16 October 2001. The association of the $[O^+]$ minimum with the epicenter of this large earthquake, started form 5 days before the earthquake and disappeared 4 days after the earthquake. The affected region extended 150 degrees in longitude and 40 degrees in latitude.

The minimum in the O^+ density appears to have been produced due to the combined effect of a magnetic storm related eastward electric field and the earthquake related westward electric field. The generation mechanism of electric field associated with large earthquake is not yet known[11,12,13].

Apart from the scientific interest regarding Appleton anomaly, our study suggests one important issue. The precursor effect can be detected even during a moderate magnetic disturbance. The key problem in the discussion on the existence of earthquake effect on the ionosphere was magnetic disturbance, as it is very difficult to distinguish the disturbance due to earthquake from magnetic disturbance[14,15] . Our study shows that by using the disturbed data positively, we can find the precursor effects of some earthquake.

It should be noted that there is also a possibility that this interesting feature is incidentally produced by the combination of satellite orbit and ionosphere features.

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Figure captions

Fig.1 Representative plots of atomic ion density before and after the earthquake . The data are plotted for the satellite altitude below 500km. Grey and black lines decriminate the different satellite orbits. X of different colors indicates magnetic equators corresponding to different orbits respectively.

Fig.2 Diurnal variation of AU, AL, and Dst Index for October 1981. Tip mark below which days are indicated shows 0 UT. A star on 16th October indicates the earthquake.

Fig.3 Upper panel: Reduction of ion density near epicenter (black line) . Dashed line is the density calculated from IRI. Lower panel: three components of plasma drift . Solid line shows Upward drift(positive). Dotted line shows East-West component (Eastward is positive). Dashed line shows North_ South drift (Northward is positive). Other three thin lines show average drift components corresponding to the three thick lines. Star and cross indicate epicenter and geomagnetic equator. The

Fig.4 Plot of the location of the minimum (upper panel), and reduction of [O+] versus longitude on the different days before and after the earth quake considered in the analysis Lower panel). Numbers attached to the circle indicates the days counted from earthquake day. Minus Sign attached to the circle indicate that data are obtained before the earthquake.

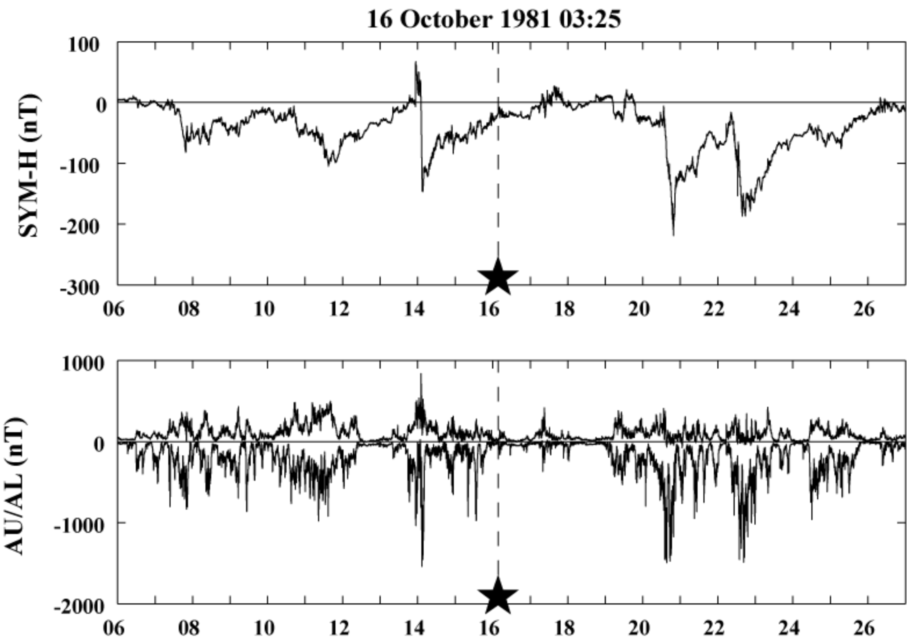
16 October 1981 03:25
SYM-H (nT)
AU/AL (nT)

Fig.1

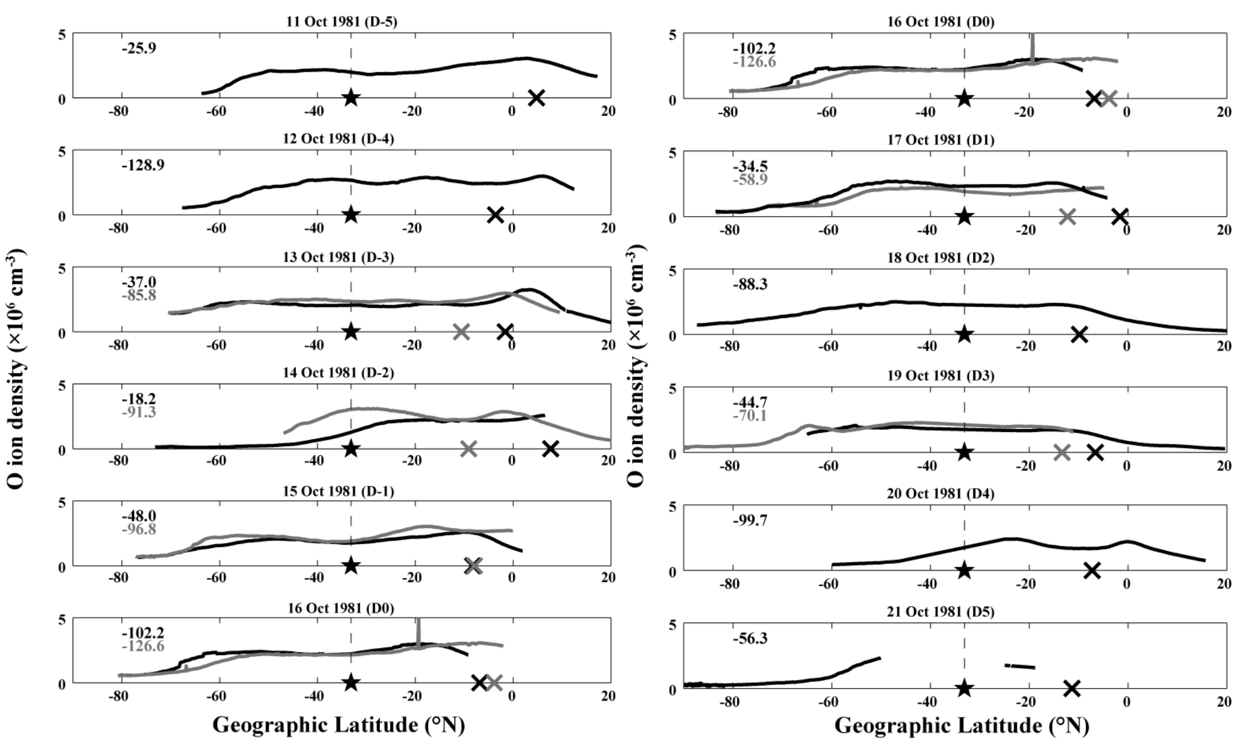
O ion density (×10⁶ cm⁻³)
Geographic Latitude (°N)
11 Oct 1981 (D-5)
12 Oct 1981 (D-4)
13 Oct 1981 (D-3)
14 Oct 1981 (D-2)
15 Oct 1981 (D-1)
16 Oct 1981 (D0)
17 Oct 1981 (D1)
18 Oct 1981 (D2)
19 Oct 1981 (D3)
20 Oct 1981 (D4)
21 Oct 1981 (D5)

Fig.2

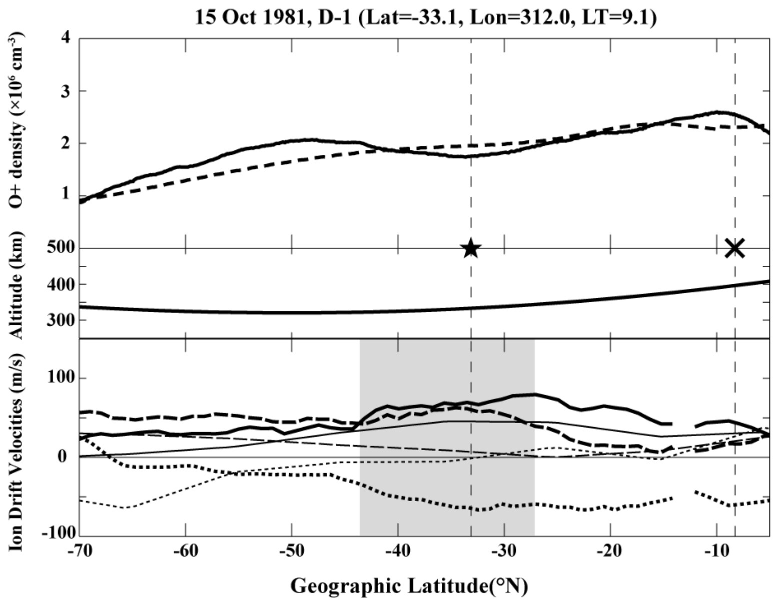
15 Oct 1981, D-1 (Lat=-33.1, Lon=312.0, LT=9.1)
O+ density (×10⁶ cm⁻³)
Altitude (km)
Ion Drift Velocities (m/s)
Geographic Latitude(°N)

Fig.3

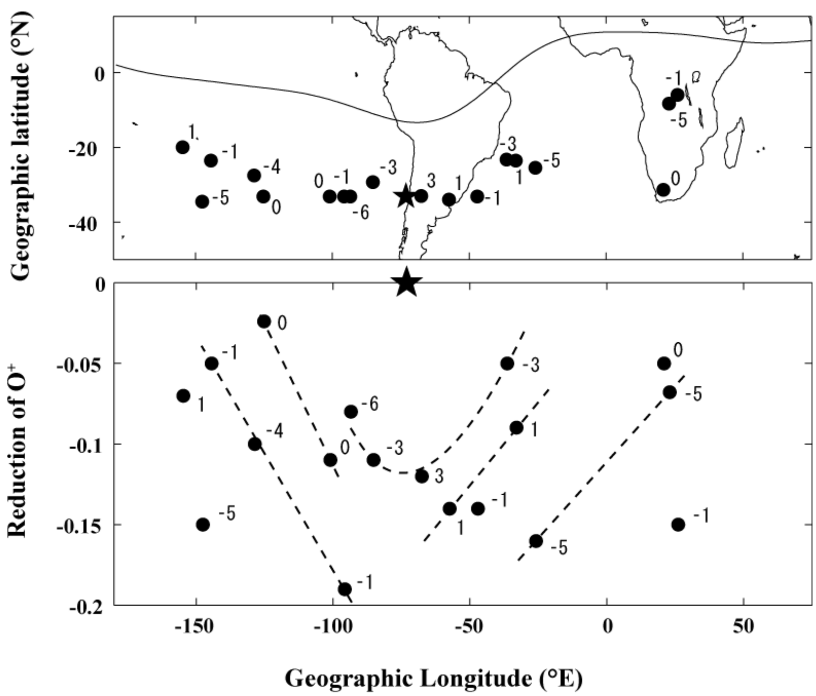
Geographic latitude (°N)
Reduction of O+
Geographic Longitude (°E)

Fig.4