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The Comparison of Responses to Geomagnetic Activity Changes of foF2 Predicted by IRI with Observations at Magnetic Conjugate Points for Middle and High Latitudes

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ABSTRACT

In this study, the response to geomagnetic storms of the ionospheric F2 layer critical frequency (foF2) was investigated at the magnetic conjugate points. The hourly foF2 data observed at the magnetic conjugate points of middle and high latitudes for the geomagnetic stormy days around both of 1976 and foF2 data received from IRI-2016 Model for same points were used. The foF2 data observed in magnetic conjugate points and received from IRI Model were examined using the superposed epoch analysis method and the results obtained were compared. From the results of analysis, it was observed that the foF2 data observed at magnetic conjugate points and received from IRI Model simultaneously respond to geomagnetic activity changes for both the middle latitudes and the high latitudes.

Keywords: Ionosphere, conjugate points, geomagnetic activity, critical frequency, International Reference Ionosphere (IRI)

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1. INTRODUCTION

The two points on Earth that connect opposite ends of the same magnetic field are called geomagnetic conjugate points. Because charged particles are trapped on the same magnetic field lines, disturbances in plasma density during geomagnetic storms can be carried between these two points. Therefore, the ionospheric and magnetospheric processes that were observed at the magnetic conjugate points were expected to occur simultaneously and symmetrically. So, the first studies on these topics were on the detection of magnetic conjugate points and the investigation of the events occurring at these points. The definition of magnetic conjugate points and the processes occurring at these points were tried to present with the results of these studies that were conducted using magnetic field models [1-5].

Later, the investigations related to magnetic conjugate have focused on polar regions, since the ionospheric and magnetospheric traces of the conjugate event during geomagnetic storms are much easier to observe in these regions [6-14]. Also, studies were conducted to determine conjugate points in the middle and low latitude regions and to examine the ionospheric and magnetospheric processes at these points. Different ionospheric and magnetospheric data were used in these studies [15-19].

However, the determination conjugate points at medium and low latitudes and observation of conjugate effects at these points are more difficult than high latitudes. Therefore, the magnetic conjugate still remains a problem, particularly at middle and low latitudes, because there are only very few possibilities to observed the magnetic conjugate with simultaneously in both hemispheres [19-21].

In our previous study, the effects of geomagnetic activity changes were investigated and magnetic conjugate points were determined for different seasons and different latitudes. For this purpose, ionospheric F2 region critical frequency (foF2) data were taken from the stations which are thought to be magnetic conjugate points and statistical methods were used [21]. In this study, similar analyzes were made by using foF2 data from International Reference Ionosphere (IRI)-2016 Model for middle and high latitudes and the results were compared. IRI is an international project sponsored by the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI). This model has obtained using experimental data and it is not a theoretical model. It provides monthly averages of the electron density, electron temperature, ion temperature, and ion composition in the altitude range from 50 km to 2000 km for a given location, time and date. The previous studies on the determination of conjugated points using the IRI Model have not been encountered. Thus, the IRI Model has tried to be tested in determining the magnetic conjugate points.

2. DATA AND ANALYSIS METHOD

Four stations were used in this study. Akita-Brisbane and Resolute Bay-Scott Base are conjugate pair stations and two are located in the northern hemisphere and the other two are located in the southern hemisphere. The coordinates of these stations for 1976 are given in Table 1 [1].

Table 1. The locations of the stations

Station	Geographic location	Magnetic location
Brisbane	27.5° S, 152.9° E	36.7° S, 227.9° E
Akita	39.7° N, 140.1° E	32.2° N, 210.1° E
Scott Base	77.9° S, 166.8° E	79.8° S, 324.3° E
Resolute Bay	74.7° N, 265.1° E	83.9° N, 309.1° E

In this study, foF2 data and planetary activity index (K_p) data of 1976 were used. 1976 was the year in which the most complete foF2 data could be obtained in four stations, so the data for 1976 were examined. These data were obtained using the internet interface from Community Coordinated Modeling Center (CCMC-NASA) [22]. The data obtained uses the URSI option of the IRI-2016 Model and the storm mode is on.

Hourly K_p data were used in the analyzes. Hourly K_p data were calculated from 3-hour K_p data using linear interpolation method. Thus, the influence of geomagnetic events on foF2 could be examined hourly. Hourly K_p data were divided into two groups according to geomagnetic activity level. $K_p \leq 2^+$ are geomagnetically quite hours, while $K_p > 2^+$ are geomagnetically active hours. Also, these analyses were conducted for geomagnetic storms that were occurred at different seasons. These seasons were given in Table 2.

The superposed epoch analysis (SEA) method was used in the analyses. This method is used to identify the effect of an event or events on the system occurring through the time series period and to measure the magnitude of response of this system against this event. The SEA describes the impact of geomagnetic storms on foF2 and indicates the magnitude of this impact [20-21, 23-24]. In this study, geomagnetically active hours ($K_p > 2^+$) were selected as events. Table 2 shows the number of events detected for the different seasons of 1976.

Table 2. The number of detected events

1976	15-29 March	15-28 June	14-28 September	16-31 December
Number of events	180	85	203	128

The analysis was applied separately to the foF2 values for all hours and for the geomagnetically quiet hours. δfoF2 values were calculated by subtracting from each other the obtained results. These values show the measure of the response of foF2 to geomagnetic storms [20-21, 23-24]. SEA was performed for all seasons and all stations and the results were compared with each other.

3. RESULTS AND DISCUSSION

Figure 1 shows the variation according to event time of δfoF2 values calculated for Akita and Brisbane. The greatest change in foF2 values for all stations and all seasons occurs at the event time. In addition, changes in foF2 values at both stations during geomagnetic storms have a very similar structure.

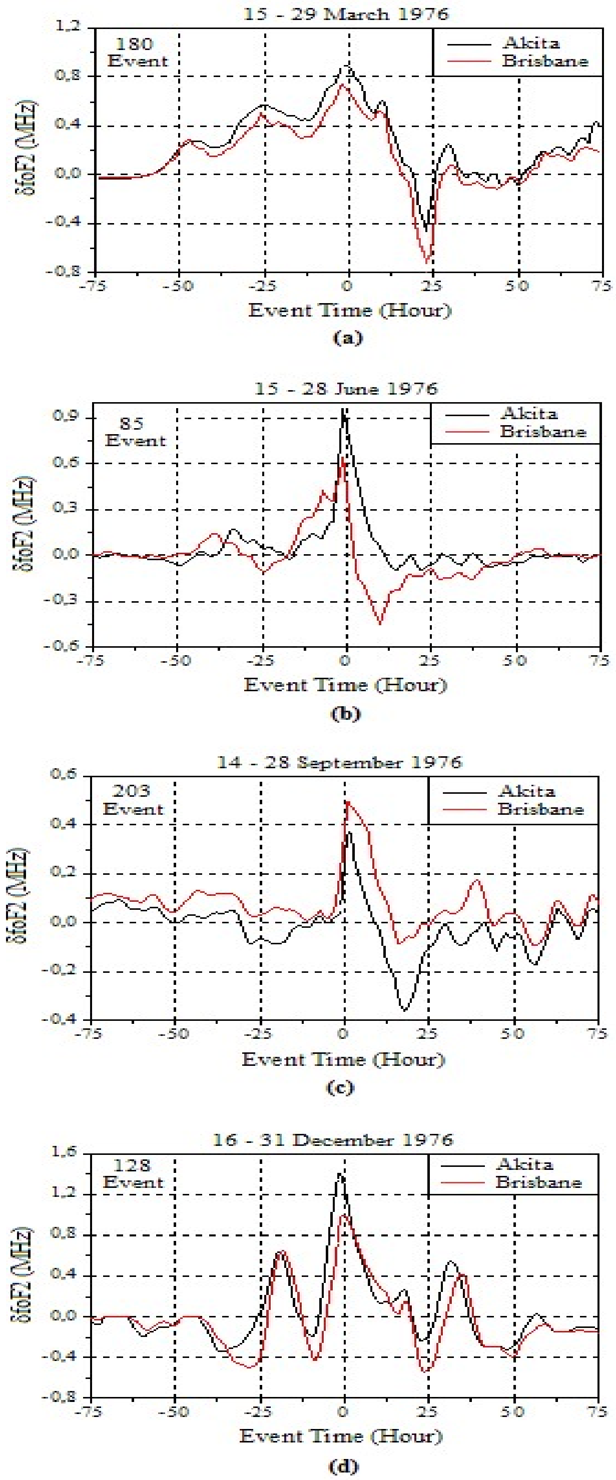

Figure 1. The changes of δfoF2 values [21]

Figure 2 shows the variation according to event time of δfoF2 values calculated for the foF2 values obtained from the IRI-2016 model for Akita and Brisbane. The greatest change in foF2 values for all stations and all seasons occurs at the event time. In addition, changes in foF2 values at both stations during geomagnetic storms have a very similar structure.

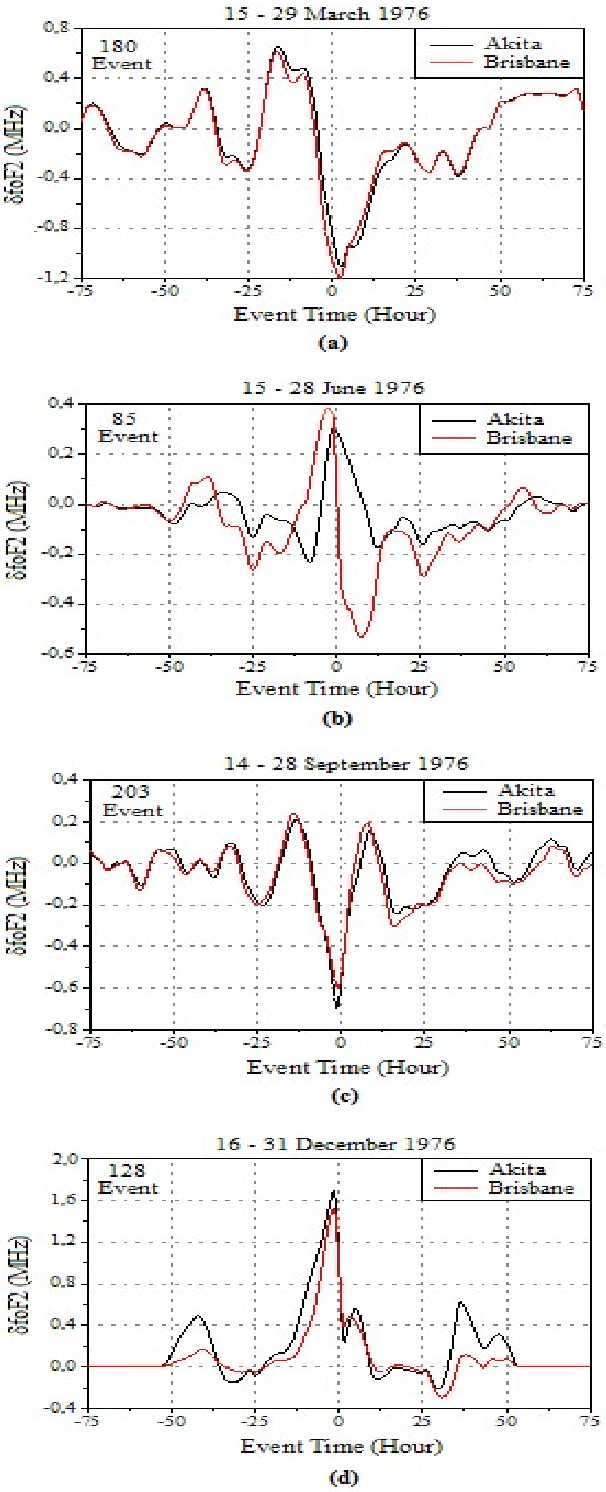

Figure 2. The changes of δfoF2 values calculated using foF2 values from IRI 2016

Figure 3 shows the variation according to event time of δfoF2 values calculated for Resolute Bay and Scott Base. The greatest change in delta fof2 values for both stations occurs at the event time. There is a very high relationship between the changes of these values.

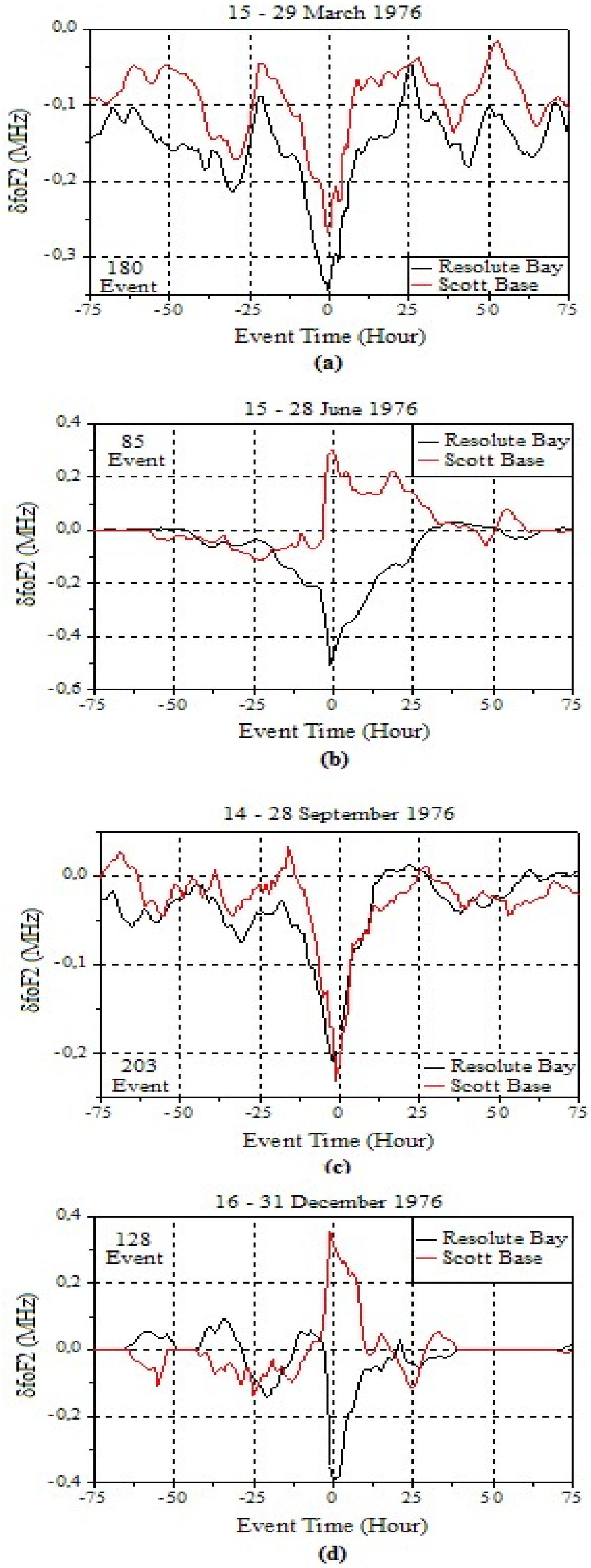

Figure 3. The changes of δfoF2 values [21]

Figure 4 shows the variation according to event time of δfoF2 values calculated for the foF2 values obtained from the IRI-2016 model for Resolute Bay and Scott Base.

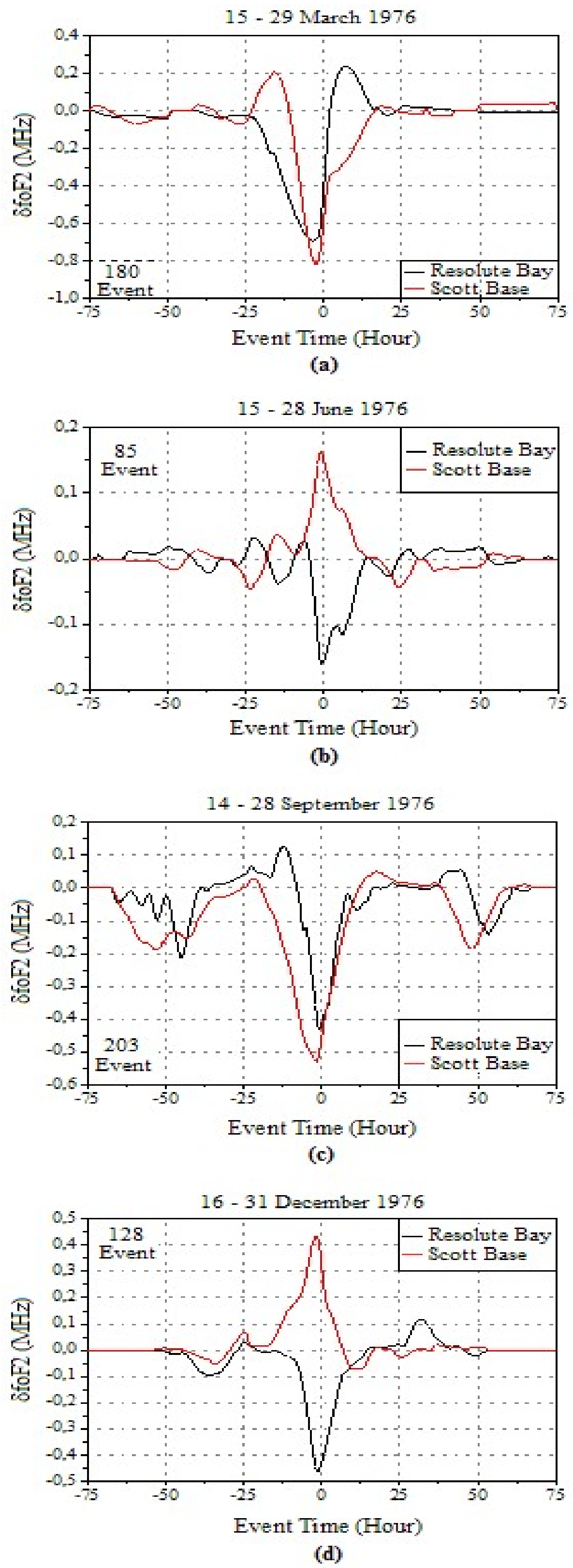

Figure 4. The changes of δfoF2 values calculated using foF2 values from IRI 2016

The greatest change in foF2 values for all stations and all seasons occurs at the event time. In addition, changes in foF2 values at both stations during geomagnetic storms have a very similar structure.

4. CONCLUSIONS

In this research, the influence of magnetic events on the foF2 values obtained from IRI-2106 for the magnetic conjugate stations located in the middle and high latitude regions was investigated using the superposed epoch analysis method. The results obtained from this study were compared with the results obtained from our previous study that were conducted for ionospheric critical frequencies obtained from same locations [21]. Thus, it was tried to determine whether the international ionosphere model can be used to determine the magnetic conjugate points.

Although the magnitude of the responses observed both from the data and the IRI model was different, they show similar characteristic properties for both the equinox and solstice.

The δfoF2 values at high latitudes have a negative relationship in June and December. This result is due to the fact that the electric fields are in the same direction at the equinoxes and opposite direction at the solstices. In other words, electric fields in different hemispheres also exhibit conjugate structure. It is take attention that is also seen from the results obtained from the IRI.

The results obtained from this research show that IRI model can be used to determine the magnetic conjugate points for medium and high latitudes.

Research and Publication Ethics

This paper has been prepared within the scope of international research and publication ethics.

Ethics Committee Approval

This paper does not require any ethics committee permission or special permission.

Conflict of Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this paper.

REFERENCES

[1] T. Oguti, “Conjugate point problems”, Space Science Reviews, vol. 9, pp. 745-804, 1969.

[2] K. D. Cole and J. A. Thomas, “Maps of the difference in geomagnetic field at conjugate areas”, Planetary and Space Science, vol. 16, pp. 1357-1363, 1968.

[3] E. M. Wescott, “Magnetoconjugate phenomena”, Space Science Reviews, vol. 5, pp. 507-561, 1966.

[4] W. H. Campbell and S. Matsushita, “World maps of conjugate coordinates and L contours”, Journal of Geophysical Research, vol. 72, pp. 3518-3521, 1967.

[5] F. D. Barish and R. E. Wiley, “World contours of conjugate mirror locations”, Journal of Geophysical Research: Space Physics, vol. 75, pp. 6342-6346, 1970.

[6] K. Makita, T. Hirasawa and F. Ryoichi, “Visual auroras observed at the Syowa station-Iceland conjugate pair”, Polar Res. Spec., vol. 18, pp. 212-225, 1981.

[7] K. Makita, C. I. Meng and S. I. Akasofu, “Comparison of the auroral electron precipitation in the northern and southern conjugate regions by two DMSP satellites”, Polar Res. Spec., vol. 26, pp. 149-159, 1983.

[8] N. Sato, R. Fujii, T. Ono, H. Fukunishi and T. Hirasawa, “Conjugacy of proton and electron auroras observed near L=6.1”, Geophys. Res. Lett., vol. 13, pp. 1368-1371, 1986.

[9] T. Nagata, “Research of geomagnetically conjugate phenomena in Antarctica since the IGY”, Polar Res. Spec., vol. 48, pp. 1-45, 1987.

[10] H. C. Stenbeak-Nielsen and A. Otto, “Conjugate auroras and the inter-planetary magnetic field”, J. Geophys. Res., vol. 102, pp. 2223-2232, 1997.

[11] L. L. Lazutin, L. P. Borovkov, T. V. Kozelova, I. A. Kornilov, V. R. Tagirov, A. Korth, J. Stadsnes and S. Ullaland, “Investigation of the conjugacy between auroral breakup and energetic electron injection”, J. Geophys. Res., vol. 105, pp. 18495-18503, 2000.

[12] R. W. Schunk and A. F. Nagy, Ionospheres: Physics, Plasma Physics and Chemistry, Cambridge University Press, pp. 366-432. 2000.

[13] N. Østgaard, S. B. Mende, H. U. Frey, T. J. Immel, L. A. Frank, J. B. Sigwarth and T. J. Stubbs, “Interplanetary magnetic field control of the location of substorm onset and auroral features in the conjugate hemispheres”, J. Geophys. Res., vol. 109, A07204-A07214, 2004.

[14] N. Østgaard, S. B. Mende, H. U. Frey, J. B. Sigwarth, A. Asnes and J. M. Weygand, “Auroral conjugacy studies based on global imaging”, J. Atmos. Sol-Terr. Phys., vol. 69, pp. 249-255, 2007.

[15] A.S. Besprozvannaya, “Empirical modelling of the F2 peak density at 50°–70° invariant latitude using magnetic conjugacy”, Advances in Space Research, vol. 11, pp. 23-28, 1991.

[16] H. Le, L. Liu, X. Yue and W. Wan, “The ionospheric behavior in conjugate hemispheres during the 3 October 2005 solar eclipse”, Ann. Geophys., vol. 27, pp. 179-184, 2009.

[17] T. L. Gulyaeva, F. Arikan and I. Stanislawska, “Inter-hemispheric imaging of the ionosphere with the upgraded IRI-Plas model during the space weather storms”, Earth Planets Space, vol. 63, pp. 929–939, 2011.

[18] N. Yu, M. Ganushkina, V. Kubyshkina, N. Partamies and E. Tanskanen, “Interhemispheric magnetic conjugacy”, Journal of Geophysical Research: Space Physical, vol. 118, pp. 1049-1061, 2013.

[19] E. Timoçin, “The north and south symmetry of the ionospheric storms at magnetic conjugate points for low latitudes during the March 1976 severe geomagnetic storms and the relation between daily changes of the storms with geomagnetic activity indices”,

Advances in Space Research, vol. 63, pp. 3965-3977, 2019.

[20] E. Timoçin, "The effect of different phases of severe geomagnetic storms on the low latitude ionospheric critical frequencies", Advances in Space Research, vol. 64, pp. 2280-2289, 2019.

[21] E. Timoçin, İ. Ünal, Y. Tulunay and Ü. D. Göker, "The effect of geomagnetic activity changes on the ionospheric critical frequencies (fof2) at magnetic conjugate points", Advances in Space Research, vol. 62, no. 4, pp. 821-828, 2018.

[22] NASA Goddard Space Flight Center (GSFC), https://ccmc.gsfc.nasa.gov/modelweb/models/iri2016_vitmo.php, [Accessed April 15 2018].

[23] Y. Tulunay, "Variability of mid-latitude ionospheric foF2 compared to IMF-polarity inversions", Adv. Sapace Res., vol. 15, no. 2, pp. 35-44, 1995.

[24] C. J. Davis, M. N. Vild, M. Lockwood and Y. K. Tulunay, "Ionospheric and geomagnetic responses to changes in IMF B_Z: A superposed epoch study", Annali Di Geofisica, vol. 39, no. 4, pp. 853-862, 1997.