

EXTRATERRESTRIAL MAGNETIC FIELD EFFECT ON THE F REGION TROUGH*

MIRELA VOICULESCU¹, TUOMO NYGRÉN²

¹ Faculty of Sciences, “Dunărea de Jos” University, Galați, Romania
e-mail: Mirela.Voiculescu@ugal.ro

² Department of Physical Sciences, University of Oulu, Finland
e-mail: Tuomo.Nygren@oulu.fi

Received September 26, 2006

Tomographic images of the high latitude F region, covering one year of routinely based observations, have been used to investigate the morphology of the ionospheric trough. The density plots are reconstructed by means of statistical inversion using the differential phase of the 150 and 400 MHz signals observed by the Finnish chain of receivers from Tromsø (69.66°N, 18.94°E), Kilpisjärvi (69.02°N, 20.86°E), Kiruna (67.84°N, 20.41°E), Luleå (65.58°N, 22.17°E) and Kokkola (63.83°N, 23.06°E). Since our results are established using a large database of F electron density plots, they can be used to test various ionospheric models attempting to predict the location of the main ionospheric trough. An important finding of our study is that the orientation of the B_y and B_z components of the interplanetary magnetic field play an important, though different, role in the occurrence of the trough for different levels of the geomagnetic activity. Our results are contributing to the understanding of the contribution of the large scale plasma transport induced by the convection electric field to the formation of the trough.

Key words: satellite tomography, ionospheric trough, interplanetary magnetic field.

1. INTRODUCTION

The ionospheric trough is a plasma density depletion that occurs at F region heights at high and mid to high latitudes between 50° and 75° in both hemispheres. It is usually considered that the trough is of different types, depending on the latitude and local time of its observation. The trough which occurs at mid-latitudes is usually known as the main trough, while the depletion forming inside the auroral oval is called the high-latitude trough. Likewise, the troughs are split according to the time of their observation in the dayside trough and the nightside trough. Both ground based (ionosonde and radar) data and satellite beacon transmissions have been applied in studying the mid-latitude trough for more

* Paper presented at the National Conference on Applied Physics, June 9–10, 2006, Galați, Romania

than four decades [1], while studies of the high-latitude trough started later [2]. During the last decade, satellite tomography has become a useful tool for monitoring the ionosphere. This technique allows the observation of the F region within a wide latitudinal range and on a continuous basis; therefore it is very suitable for trough studies [3–6]. The formation of the troughs is not the result of a single process. However, most of the troughs are connected with the ion convection [2] which, in turn, is governed by the orientation of IMF. The convection pattern is the assembly of electric potential lines in the high latitudes, where plasma is convected under the effect of the ionospheric electric fields. Therefore, the trough occurrence should be related to the IMF. In a previous paper we have analysed the diurnal and seasonal variation of the trough for different geomagnetic levels, together with its width and the gradients at the edges and investigated the relationship between the IMF structure and the occurrence of the trough [6]. In this paper we have tried to identify more characteristics of the relationship between the trough occurrence and the IMF orientation related to the seasonal variation.

2. OBSERVATIONS

The relationship between the trough occurrence and the interplanetary field is illustrated in the following figures where positive values of the IMF components are dark gray and negative values are light gray. We have divided the troughs according to the level of the geomagnetic activity, described by the value of Kp. Figs. 1 and 2 show the variation of the location of the trough, in geographical coordinates and universal time, together with the coincident orientation of the IMF, for each of the four seasons separately. The details about the data processing are found in [6].

A careful analysis of the plots shows that for low geomagnetic activity the troughs are seen during every season, but with a higher occurrence rate in autumn. Moreover, we note that generally, the dominant colour for B_y is light gray, which mean that most of the troughs seen at low geomagnetic levels coincide with negative B_y . This is seen for both poleward and equatorward edge of the trough but it seems more obvious for the equatorward edge. For summer there seems to be a clear demarcation between troughs occurring at the middle of the day, when B_y is negative, and those observed at earlier or later times, when B_y is positive. The separation is connected also with the diurnal variation of background density, due to variations in the photoionization. In winter, the situation seem to be opposite, with troughs occurring at the middle of the day for positive B_y . However, in winter time the troughs form, generally, at low latitudes. Fig. 2 shows indeed that, generally, at low geomagnetic level, the troughs occur at evening and night for negative B_y . This suggests that there is a seasonal difference between the prevailing mechanisms that form the trough.

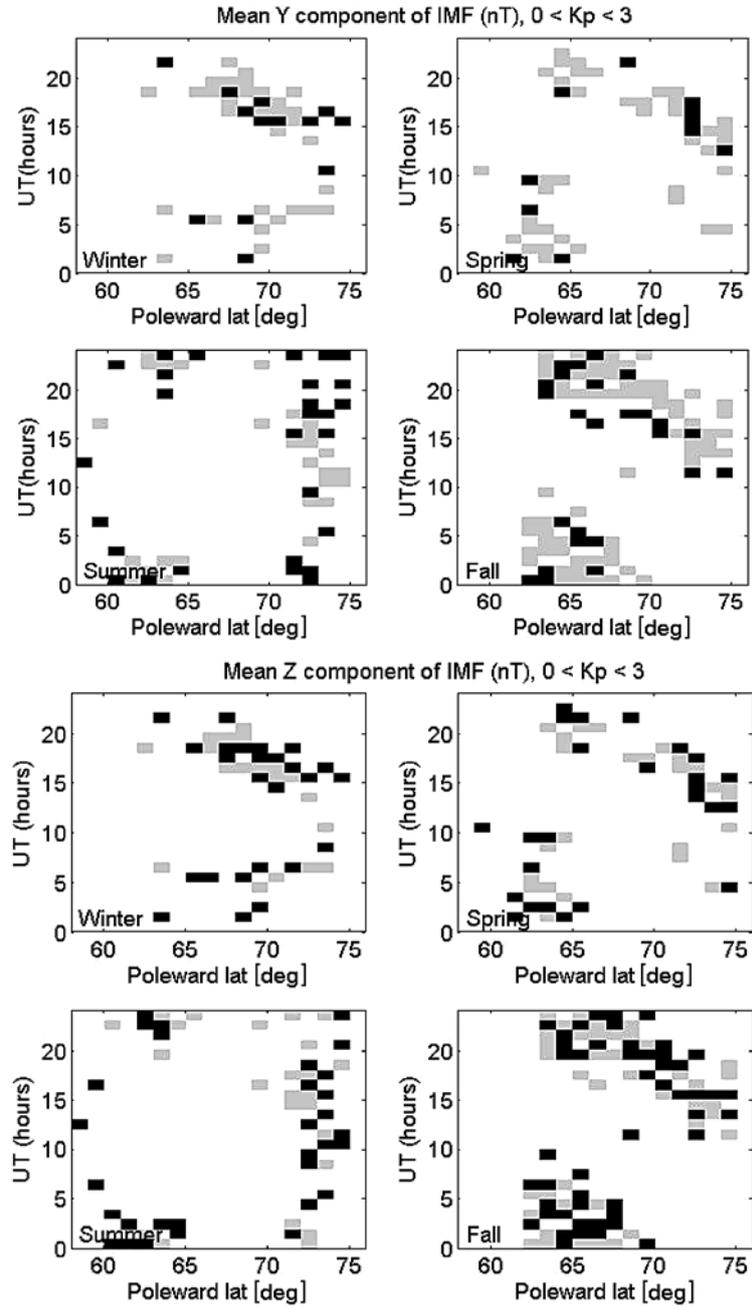


Fig. 1 – Sign of the IMF components, dark gray-positive, light gray-negative, for **low** geomagnetic activity and variation of the poleward edge with the local time.

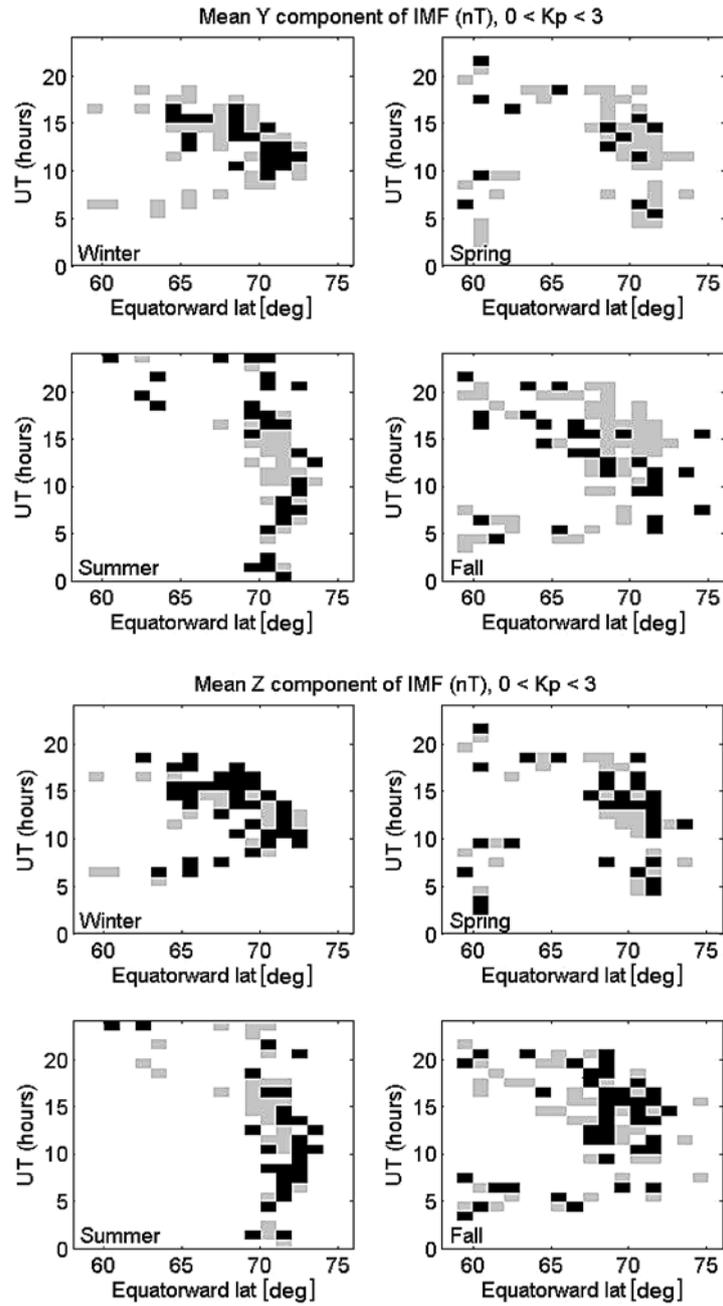


Fig. 2 – Sign of the IMF components, dark gray-positive, light gray-negative, for **low** geomagnetic activity and variation of the equatorward edge with the local time.

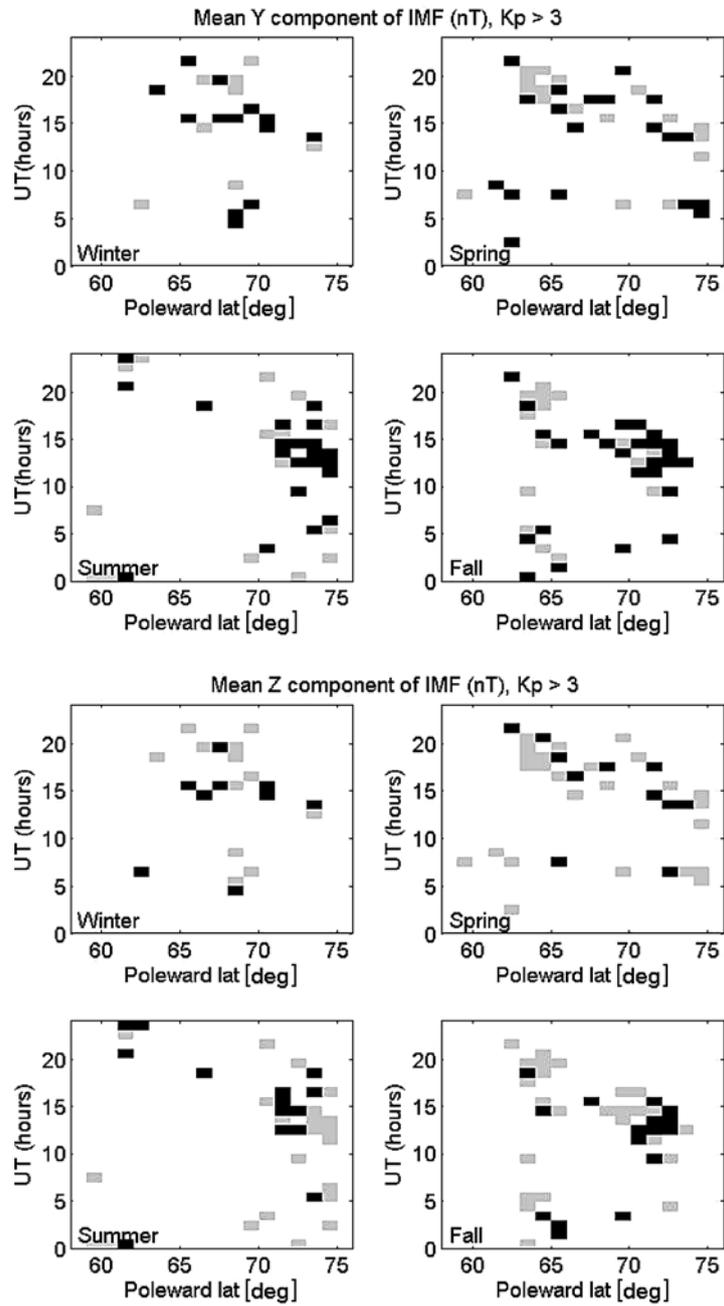


Fig. 3 – Sign of the IMF components, dark gray-positive, light gray-negative, for **high** geomagnetic activity and variation of the poleward edge with the local time.

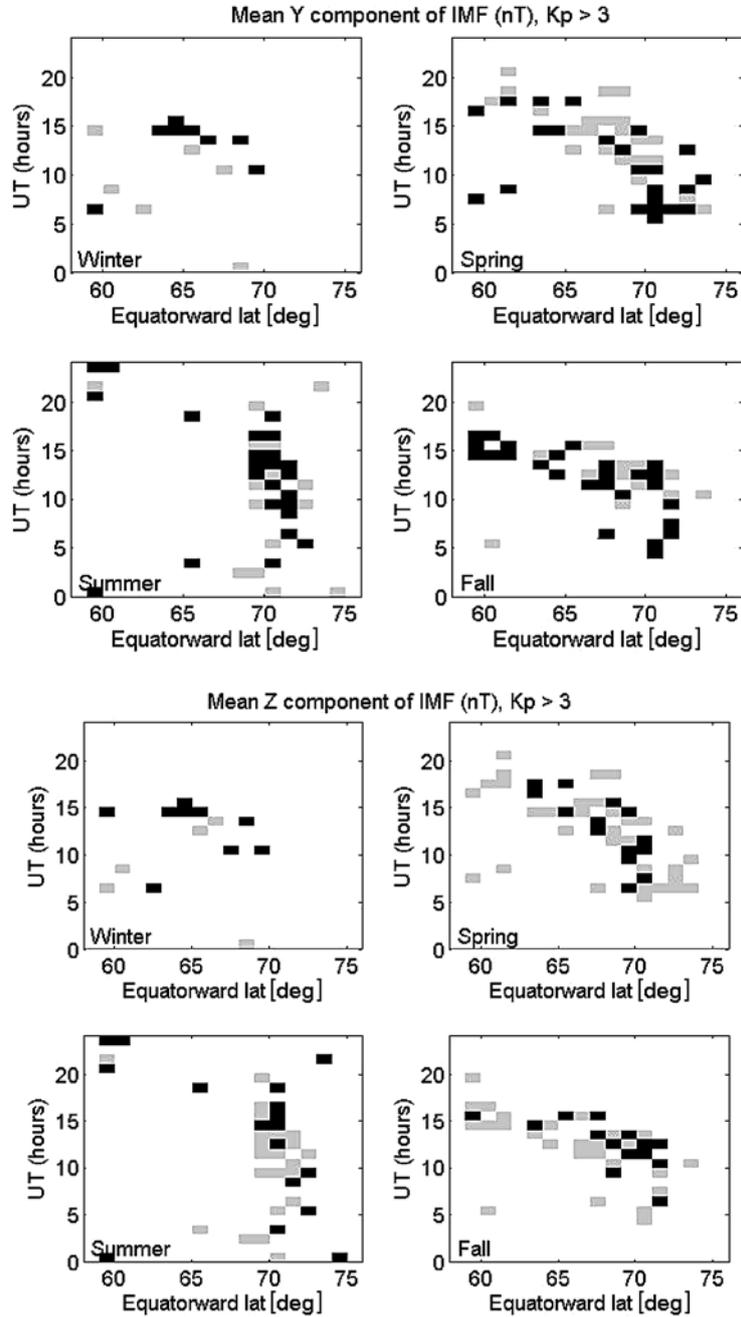


Fig. 4 – Sign of the IMF components, dark gray-positive, light gray-negative, for **high** geomagnetic activity and variation of the equatorward edge with the local time.

The majority of troughs occur during low geomagnetic activity when B_z is positive. In this case the convection shrinks towards poles so that the stagnation line is located at higher latitudes. If the geomagnetic activity would be high, the auroral precipitation associated with the auroral oval would extend towards lower latitudes so that the depletion caused by the decay caused by the stagnation would be rapidly compensated by auroral ionization.

Curiously, there is not a clear association of certain signs of B_z with troughs occurring at certain time of day during different seasons. This is due to the fact that the convection pattern changes significantly when B_z turns from negative to positive. As a matter of fact, B_z is the main driver of the electric field structure at high latitudes. On the other hand, the sign of B_y controls the asymmetry of the convection cells relatively to the noon-midnight meridian.

For high geomagnetic activity, Figs. 3 and 4, things change. The troughs occur mostly for negative B_z and positive B_y . The preference of troughs for positive B_y is better seen in summer. In this case there is a latitudinal dependence of the relationship between the trough occurrence and the B_z sign, in the sense that the few troughs occurring for positive B_z are situated at higher latitudes. This is in line with the fact that for positive B_z the equatorward limit of the convection oval is at higher latitudes. The number of troughs is generally lower during higher geomagnetic activity. This might be also the result that the ionospheric density profile becomes highly irregular during high geomagnetic activity. However, more troughs occur during equinox than at winter. Except for the summer, lower geographic latitude of the equatorward edge coincides, generally, with negative B_z . This is better seen for spring and fall. On the other hand, no association between the trough location and the B_y sign can be inferred, except, again, for the summer.

The role of IMF is better seen in Fig. 5, where we show how the total number of troughs is distributed for different orientation of B_y and B_z during

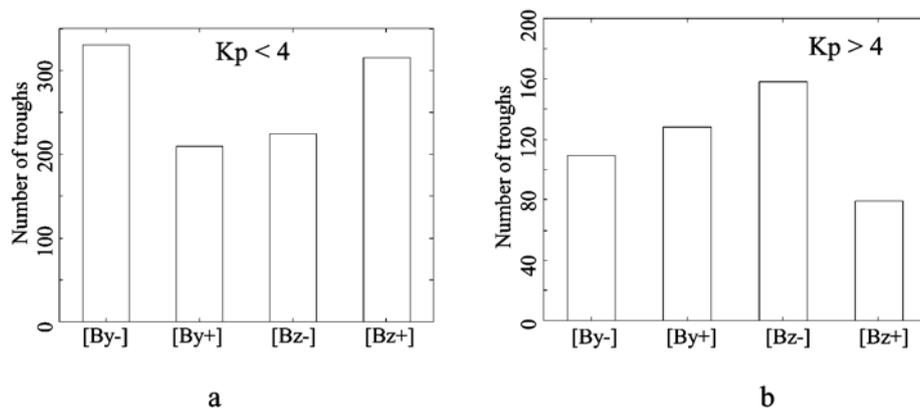


Fig. 5 – Total number of troughs coincident with positive and negative B_y and B_z for $K_p < 4$ (a) and for $K_p > 4$ (b).

low, respectively medium/high magnetic activity. For small Kp the troughs occur mostly for positive Bz, while for higher Kp the number of troughs which coincide with negative Bz is almost double than for positive Bz. These plots show also that there is a preferred orientation for By when the geomagnetic activity is low, while in the other case there is no significant effect of By on the occurrence of trough. Partly, this is due to the fact that the troughs occurring during high Kp are associated with negative Bz. In this latter case, the effect of By on the convection pattern is less important than when Bz is positive.

3. CONCLUSIONS

Our study confirms that indeed, there is a relationship of the rough with the IMF. This was expected because the position of the trough is related to the ionospheric-magnetospheric convection, which is driven by the IMF. A qualitative explanation of the relationship between IMF, geomagnetic activity and trough occurrence relies, most likely, on the high-latitude convection pattern. When Bz is positive the convection cells are small so that the stagnation points that form between regions of corotating plasma and zonal convection flow is at high latitudes, where the troughs form when Kp is small. When Bz is negative, the margins of the convection cells extend to low latitudes, the ionosphere is opened to magnetospheric processes and the stagnation point is at lower latitudes, where the trough forms when Kp is high. There is also a seasonal difference, seen mainly between summer and winter, in the response of the trough formation to the variation of the IMF orientation. Also, the equinoxes behave differently from winter and summer, especially for high geomagnetic activity. The seasonal difference originates, most likely, in the variation of the ionospheric photoionization during different seasons.

However, further studies are necessary to clarify the role of the IMF orientation in the trough occurrence and the physical mechanisms which are behind this space weather ionospheric effect.

Acknowledgments. The Scandinavian tomography chain is run by Sodankylä Geophysical Observatory, Finland. We are grateful to T. Raita and J. Manninen for their continuous effort in maintaining the receiver chain and to M. Lehtinen, M. Markkanen and late J. Pirttilä for their efforts in developing the tomographic inversion routine. We also thank I. Virtanen for the trough identification routine. Grant (project No 51465) from the Academy of Finland and support from Space Institute at the University of Oulu is also gratefully acknowledged.

REFERENCES

1. R. J. Moffet, S. Quegan, The mid – latitude trough in the electron concentration of the ionospheric F-layer: a review of observations and modeling, *J. Atm. Terr. Phys.*, **45**, 5, 315–343, 1983.

-
2. A. S. Rodger, R. J. Moffet, S. Quegan, The role of ion drift in the formation of ionization troughs in the mid- and high-latitude ionosphere – a review, *J. Atmos. Terr. Phys.*, **54**, 1, 1–30, 1992.
 3. D. G. Jones, I. K. Walker, L. Kersley, Structure of the poleward wall of the trough and the inclination of geomagnetic field above the EISCAT radar, *Ann. Geophys.*, **15**, 740–746, 1997.
 4. L. Kersley, S. E. Pryse, I. K. Walker, J. A. T. Heaton, C. N. Mitchell, M. J. Williams, C. A. Willson, Imaging of electron density troughs by tomographic techniques, *Radio Sci.*, **32**, 1607–1621, 1997.
 5. S. E. Pryse, L. Kersley, M. J. Williams, I. K. Walker, The spatial structure of the dayside ionospheric trough, *Ann. Geophys.*, **16**, 1169–1179, 1998.
 6. M. Voiculescu, I. Virtanen, T. Nygren, The F region ionospheric trough: seasonal dependence and relation to IMF, *Ann. Geophys.*, **24**, 1, pp. 173–185, 2006.