Role of the Magnetospheric and Ionospheric Currents in Generation of the Equatorial Scintillations During Geomagnetic Storms

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The solar wind and the equatorial ionosphere parameters, Kp, Dst, AU, AL indices characterized contribution of different magnetospheric and ionospheric currents to the H-component of geomagnetic field are examined to test the geomagnetic activity effect on the generation of ionospheric irregularities producing VLF scintillations.

1. Introduction

The equatorial ionosphere of the Earth produces serious problems in communication and navigation systems during different kind of disturbances, much like the polar ionosphere. Because of its high conductivity, the equatorial ionosphere is very sensitive to variations of electric field due to several effects including magnetospheric convection, ionospheric dynamo disturbance, and various kinds of wave disturbances. Because of this, the equatorial ionospheric irregularities often occur in the region confined between ±20° magnetic dip latitudes. The equatorial ionospheric irregularities manifest as a spread F in ionograms, reversals of drift velocities, scintillation of radio transmissions through the ionosphere and etc. The rapid fluctuations of the phase and intensity of a radio signal that has passed through the Earth’s ionosphere, typically on a satellite-to-ground propagation channel is scintillation. Mechanisms of the equatorial scintillation are better understood than its morphology. Variation of scintillation activity with solar epoch and seasons was well established by Koster (1972) and Aarons et al. (1980). The scintillation activity during geomagnetic storms and disturbances is less well understood. Not all authors are agreed on which is the best geomagnetic index to use for predicting of scintillations. Koster (1972) found that scintillation is related to magnetic activity (Kp) through some factor which occurs (or fails to occur) during magnetic storms which inhibits nighttime scintillations. Aarons (1991) concluded that the ring current can play a leading role directly or indirectly in establishing of the conditions for equatorial F layer irregularity generation or inhibition. Koster's (1972) question of the factor, which presents during magnetic storms or not always presents with sufficient intensity to fully inhibit scintillation, is still an open question.

2. Data analysis

The aim of our study is the scintillation activity relationship with the different magnetospheric and ionospheric currents and their indices which can directly influence on scintillation activity. For this we used Dst, Kp, AL indices, Bz-component of the IMF, the ionospheric F layer height h'F. As example, the geomagnetic storms on 19 Dec. 1980 is presented in the figure 1. The ionospheric height variations h'F for Huancayo and the scintillation patch durations over Huancayo are shown by the blocks. The strong westward polar electrojet with AL = -1400 nT existed on 19 Dec. 1980. The scintillations were took place every night except the night when the Bz of the IMF had positive values. The ionospheric heights h'F at Huancayo exceeded 350 km and Kp increases were observed when scintillations occurred. The data show that the absence of scintillations is associated with Kp decrease during recovery phase of the magnetic storms. The ionospheric height h'F was less than 350 km when the westward polar electrojet (AL < 200 nT) was very small on 20 Dec 1980 night. Based on these facts, we can say that this night electric fields from the polar region didn’t penetrate to the equatorial ionosphere. It should be noted that the auroral electrojet has a faster recovery phase than the ring current as one can see from AL and Dst plots. For example, on 19 Dec. 1980 at 0000 UT (1900 LT at Huancayo) the ring current was still strong while AL already reached its quiet level. The strong ring current on 19-20 December 1980 night had no effects on the equatorial ionospheric height. So, the examples show that difficulties emerge when we consider relation of the magnetospheric ring current to the equatorial ionosphere height variations and scintillation activity. In practice, new additional injections to the ring current associated with the large negative Bz IMF may occur and we will have complex shape of Dst variations. The ring current conception ceases to have its conventional meaning to explain the scintillation activity during storms. The positive Bz IMF is likely to be the factor inhibited penetration of the high latitude electric field to the equator which can raise the equatorial ionospheric plasma up to the height where scintillations can be generated and we assume that this is the answer to Koster's question.
3. Conclusion

The relationship between the equatorial ionospheric scintillations and the IMF Bz, Dst, Kp AU, AL indices has been demonstrated. It is shown that all these indices are suitable for investigations of scintillation activity at the equatorial ionosphere. Undoubtedly, the Dst index is convenient and available one to study geomagnetic conditions during the ionospheric disturbances. However, the examples presented show that difficulties emerge when we consider relation of the magnetospheric ring current to the equatorial ionosphere height variations and scintillation activity. The reason is that the Dst index not includes the auroral sources and the ring current can’t penetrate to the equatorial ionosphere. For example, Kp as planetary (p) index carries information about auroral electrojets and we can see from our study that scintillation activity decrease when Kp reduce during positive the Bz IMF. The solar wind electric field through the FAC of Region 1 and Region 2 is likely to be responsible for generation or inhibition of the equatorward penetration of the high latitude electric field. If the equatorial ionospheric height is below or equal 350 km then scintillations are not generated. The equatorial irregularities associated with spread F can be generated above this height and scintillations can be observed. Plasma falling from the high ionospheric altitudes is favored for generation of the equatorial scintillations also. The possible source of this phenomenon is the solar wind electric fields – the auroral and equatorial ionosphere coupling. We assume that the high latitude ionospheric currents and its electric fields play principal role in the equatorial ionospheric phenomena. The negative Bz IMF enhances the auroral electric fields and the FAC electric fields can penetrate to equatorial ionosphere and the ionospheric F layer is raised above of threshold height (~ 350 km). The success of prediction of the ionospheric scintillations seems to use models explained relationship between equatorial ionospheric currents with the polar ionosphere currents and the solar wind electric field. Other processes like tides, earthquakes et al. can change the ionospheric height also and may play role in the generation of the ionospheric scintillations. Taking into account the time delay between the Bz IMF and the equatorial ionosphere phenomena, from the practical point of view, the relationships between the solar wind and the ionosphere currents can be used for predicting of scintillations. It should be noted that more detail investigations of these relationships with high-precision ionospheric and scintillation data are required.

References