

Space weather and the Earth ionosphere from auroral zone to equator

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Space weather conditions, geomagnetic variations, virtual ionospheric height and the critical frequency foF2 data during the geomagnetic storms are studied to demonstrate relationships between these phenomena. We examine the solar wind conditions and the auroral equatorial ionosphere response to illustrate what kind of solar wind parameters during the geomagnetic storms leads to short-term variations of the critical frequency foF2 and virtual height at the Earth ionosphere from the auroral zone to the equator. Model simulations as disturbed ionospheric wind dynamo do not allow explaining a significant part of the experimental data. Additional investigations of the ionospheric characteristics are required to clear up the origin of the short-term equatorial ionospheric variations. The critical frequency foF2 and virtual heights observed by the ionosondes are good indicators of the true layer heights and electron concentration and may provide information about the equatorial ionosphere dynamics. Intensive magnetospheric and ionospheric currents during geomagnetic storms disturb the quiet ionosphere and cause the observed short-term variations of the ionospheric characteristics. The ionospheric wind dynamo is considered as an important and the main mechanism in generation of ionospheric electric currents and fields. The disturbed ionospheric wind dynamo can be the generator of the equatorial ionospheric electric currents during geomagnetic storms in the aftermath of strong auroral heating. The magnetospheric electric field directly penetrating into the low-latitude ionosphere can be another source of electric field. During disturbed space weather conditions magnetospheric electric fields disturb the auroral ionosphere forming auroral electrojets and by the high-latitude electric field and termospheric disturbances can penetrate to the equatorial ionosphere. That is the reason the equatorial ionospheric electric field vari-

ations like geomagnetic variations are complex and result of superposition of different disturbing agents. Numerous studies present the experimental and theoretical relations between the solar wind, auroral ionosphere and geomagnetic variations. However, the equatorial ionosphere has been assumed to be free from the influence of the auroral electric fields. We study 5-min ionospheric variations using the first Western Pacific Ionosphere Campaign (1998 - 1999) observations, 5-min interplanetary magnetic field (IMF) and 5-min auroral electrojets data during a geomagnetic storm. The ionospheric 5-min variations at the equatorial stations which allow calculating in detail time delays of the auroral and equatorial ionospheric phenomena are scantily known. These data demonstrate that the auroral and the equatorial ionospheric phenomena are developed practically simultaneously. We suppose that these ionospheric phenomena are due space weather conditions and interaction between electric fields of the auroral and the equatorial ionosphere during geomagnetic storms. It is shown that the low-latitude ionosphere dynamics during these storms was defined by the southward direction of the Bz-component of the interplanetary magnetic field. A southward IMF produces the Region 1 and Region 2 the field-aligned currents (FAC) and polar electrojet current systems. We assume that the short-term ionospheric variations during geomagnetic storms can be explained mainly by the electric field of the FAC. The electric fields of the field-aligned currents can penetrate throughout the mid-latitude ionosphere to the equator and may serve as a coupling agent between the auroral and the equatorial ionosphere. We show that the equatorial ionosphere is a very sensitive indicator of the solar wind conditions and geomagnetic storms. Nowadays geomagnetic storms can be presented as a measure of energy transfer from the solar wind to the magnetosphere. Its magnitude is inevitably a function of the solar wind properties, the state of the magnetosphere, and the physical processes involved in the solar wind-magnetosphere interaction. Ionosphere effects of the solar wind is much complex. It is very difficult to separate the agents forming ionospheric disturbances during geomagnetic storms. It is considered that the storm wind driven electric fields are responsible for the larger amplitudes and longer lifetimes of the drift perturbations following sudden decreases in convection compared to those associated with sudden convection enhancements. In addition to these reasons we suppose that day-time and night-time equatorial ionosphere have to respond to westward and eastward auroral electrojets and the field-aligned currents by the different way while large-scale internal gravity waves and changes in neutral composition and in neutral wind system have to show the same effect in sign and there are problems to explain positive ionospheric storms. Furthermore, from the presented geomagnetic storms which AU and AL indices have very different amplitudes (nighttime auroral electrojets are much stronger daytime ones $AL/AU \sim 5$) and yet it is impossible from models to take account these effects from thermospheric models. It should be noted that amplitudes of AU and AL

very variable during different storms, so there are different the IMF Bz and By patterns of auroral electrojets and related the field-aligned currents. Numerical modeling of auroral electrojets during geomagnetic disturbances effects of FAC as well as the polar cap potential drop difference in the auroral electrojet distribution and precipitation of high-energy auroral particles are considered. We suppose to explain of substorm effects in foF2 it is not enough to involve local processes but it is necessary to consider existential distribution of all parameters of near-Earth plasma. In our cases the IMF Bz and Joule heating can show the same effect to decrease of foF2 variations but quick foF2 depression and its correlation the negative the IMF Bz duration seems to show the field-aligned current effect on the equatorial ionosphere. The examples demonstrated in our study show that the strong auroral electrojets were formed by coupling of the solar wind with the magnetosphere when the Bz turned southward and the solar wind velocity increased. At the same time the equatorial night-time ionosphere parameters showed the short-term variations in the virtual ionospheric height and foF2. For example, the ionospheric heights and the critical frequency foF2 at low latitudes were very different in periods when the Bz-component turns to north (the quiet day conditions) and when Bz-component turns on south (the main phase of magnetic storms). Distinction between the quiet and disturbed periods in the heights reached values up to 150 km and more. It is also evident from these examples that the solar wind controls not only the auroral ionosphere but the equatorial ionosphere too. Time delay around 40 min between the Bz IMF and the equatorial ionospheric variations during the geomagnetic storms allows us to make this assumption. The latitudinal and the longitudinal extent the auroral electrojets and its movements are well determined by the IMF Bz. These conditions and a good conductivity of the night ionosphere allow the auroral electric fields move closer to the equator. In consequence, the auroral electric fields penetrate to the equator and an additional night-time current system can form at the equatorial ionosphere and change the true layer heights and electron concentration. This current system may be linked to the Region II field-aligned currents (FAC) during the westward auroral electrojet formation at the night ionosphere. It is well known that the field-aligned currents are closely connected with the auroral electrojets and the DP systems. These currents location and intensity are defined by the solar wind conditions. If the electric fields from FAC of Region II can penetrate through the midlatitudes to the low-latitude ionosphere and create the eastward equatorial electric field there then this electric field can decrease the nighttime equatorial electrojet current and increase the ionospheric plasma vertical drift velocity. In this case, the plasma moves upward away from the F layer, the F2 maximum is observed at the greater heights and one can see the foF depression caused by the upward movement of electrons. Unfortunately, we do not have high latitude ionospheric data with 5-15 min resolution for our data, resolution auroral indices too rough for cal-

ulation of time-delay. Furthermore, the auroral and equatorial ionospheric variations have differences associated with geomagnetic field of the Earth that produce additional troubles for comparison. It should be noted also that during geomagnetic storms the low latitude stations can provide more precise measurements than auroral stations. It is well known that auroral zones are the major regions of the ionospheric instability, especially during geomagnetic storms and substorms. The equatorial ionosphere has often been neglected and only the auroral ionosphere has been taken into account when considering the solar wind, magnetosphere and ionosphere coupling. Therefore the coupling between high and low latitude ionosphere is the least understood aspect of this problem. In recent years one can observe a revived interest in the equatorial ionosphere because as with the polar ionosphere it produces serious problems in communication and navigation systems during geomagnetic disturbances and storms. Because of its high conductivity, the equatorial ionosphere in the region confined between 20 degrees magnetic dip latitudes is very sensitive to variations of electric field due to several effects including magnetospheric convection, ionospheric dynamo disturbance, and various kinds of wave disturbances. So, from the practical point of view, the relationships between the solar wind and the ionospheric parameters can be used for prediction of different ionospheric phenomena. For example, the changes of the ionosphere height may serve as a good measure for predictions of the spread F or intense ionospheric scintillations. It should be noted that more detailed investigations of the high and low latitude quantitative relationships with high-precision data are required to include in features of the ionospheric models during geomagnetic storms.