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Conditions for intense ionospheric storms expanding to lower-midlatitudes

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In response to geomagnetic disturbances, the concentration of the ionosphere often changes drastically, and such changes are called ionospheric storms. The significance of ionospheric storms, however, varies from storm to storm, even when the magnitudes of the geomagnetic disturbances are similar. This is largely owing to the local time effect. Negative ionospheric storms at middle latitudes are usually observed to follow magnetic activity during the preceding night, whereas positive ionospheric storms are generally associated with magnetic activity beginning in the local daytime sector.

An important mechanism responsible for negative ionospheric storms is a chemical effect in which the production and loss rates of ionization are modified through a change in the ratio of O to N_2. On the other hand, an important mechanism responsible for positive storms is an uplift of the ionospheric layer to higher altitudes, where the recombination rate is small. The driving mechanisms of this uplift are the ion drag effect of the equatorward neutral wind and the **E**x**B** plasma drift due to the eastward electric field. These components of thermospheric/ionospheric disturbances compete in actual storms, and storm signatures in individual events are complicated, though the relationship between an ionospheric storm and the magnetic activities mentioned above is statistically true.

In this study, we focus on intense negative storms that expand to lower-midlatitudes. The origin of the chemical effect of negative storms and the uplift of the layer due to the equatorward neutral wind is thermospheric disturbances caused by energy injection into the polar atmosphere during the periods of geomagnetic disturbance. Both processes are connected to each other such that the equatorial neutral wind carries atmospheric composition changes from the polar region to lower latitudes, and both positive and negative storms could coexist. The atmosphere with neutral-gas composition changes is advected toward lower latitudes in the early-morning sector and which subsequently rotate into the day sector. As a result, intense negative storms develop during daytime. Thus, the magnitude of the negative phase directly depends on this storm-surge dynamics.

During the period of March-April 2001, geomagnetic/ionospheric storms frequently occurred. Some of these ionospheric negative storms expanded down to 20 degrees magnetic latitude. When the significance of the ionospheric storms was measured according to the foF2 depletion and the significance of magnetic disturbances according to the Dst index, the correlation between the two measures was not strong. In the two largest magnetic disturbances that occurred during this period, the Dst index reached -387 and -271 nT. While the two largest ionospheric storms occurred in response to other weaker magnetic disturbances, in which Dst reached -149 and -102 nT. For the largest ionospheric storms on 21 March 2001 and 22 April 2001, a sequence of ionospheric and thermospheric disturbances was analyzed. We found that a nighttime disturbance dynamo plays an important role in expanding ionospheric storms to lower latitudes. When an eastward disturbance dynamo electric field forms after midnight, the ionospheric layer is uplifted and the ion drags are reduced. The storm-time equatorward surge effectively reaches lower-latitude regions without decaying under the condition of reduced ion drags. The equatorward surge pushes up the ionosphere, in turn, and the ion drags might be further reduced. The large event-to-event variation of ionospheric storms might be partly owing to such a positive feedback process in addition to the well-known local time effect.