Response time of Earth's magnetosphere for a southward turning of IMF: The super-high pressure magnetotail event of Dec. 10, 1996

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The lag time between the encounter of the southward IMF with the dayside magnetopause and the major onset of a substorm has been studied by a number of researchers. Using the linear prediction filtering technique for time series of the AL index, Bargatze et al. [1985] suggested that the AL response at short time lags, about 20 min, corresponds to an enhancement of global magnetospheric convection directly driven by dayside reconnection, while the response at longer time lags, about 70 min, signals the expansion onset of substorms. Utilizing 3-D MHD codes, Bargatze et al. [1999] showed that the lag times obtained by simulations are consistent with observations. These results indicate that it takes 20 min to form the so-called two-cell convection pattern, while 70 min for the growth of the magnetotail. However, it should be cautioned that the activation of the tail is often interrupted by the occurrence of magnetotail deflation. Besides, the influences of the deflation may be fed back to the convection pattern. What is then the response time of the direct driven process for changes in the IMF? Since the formation of the two-cell convection pattern can be monitored by an increase in the polar cap potential drop [Shepherd et al., 2002; and references therein], this issue is represented in the following two questions: How does the polar cap potential drop respond to the solar wind energy influx? How do changes in the tail field relate to the polar cap potential drop when the magnetotail deflation does not occur?

To study this issue, geomagnetic conditions in the nightside magnetosphere and those in the northern polar region are examined in detail for the first six hours of December 10, 1996. We are able to examine the sequences of the energy-transfer rate from the solar wind into the magnetosphere, the polar cap potential drop, electro-jet currents at auroral latitudes, magnetic field configurations at geosynchronous distance, and the mid-tail total pressure along with auroral images from POLAR. The IMF turned southward at 0100 UT. Associated with this, the polar cap potential drop estimated from SuperDARN data, and the total pressure in the mid-magnetotail gradually increased. While the southward component of the IMF decreased rapidly after 0200 UT, the polar cap potential drop peaked near 0200 UT. The mid-tail total pressure, however, continued to increase until 0250 UT. Despite an extreme intensification in the mid-tail total pressure, auroral images from the POLAR spacecraft showed that the poleward boundary of the nightside auroral oval reached about 80 GML before 0250 UT. The standard solar wind-magnetosphere coupling model suggests that the polar cap is expanded in conjunction with an increase in the mid-magnetotail total pressure. In this respect it is not appropriate to categorize the period concerned as the growth phase of a substorm.

The mid-tail total pressure peaked at 0250 UT, and then began to decrease. A sudden decrease in the total pressure generally causes a major onset of a substorm. However, various observations onboard the spacecraft and those from ground stations strongly suggest that no major onset of a substorm occurred during this period. This view is consistent with the above statement that the period between 0200 and 0250 UT cannot be classified as the growth phase. This unique event provides us with an opportunity to examine the solar wind-magnetosphere coupling without any interruption by deflations. As noted above the mid-tail total pressure peaked about 50 minutes later than the peak of the polar cap potential drop. The delay in the total pressure can be explained by a simple electric circuit model with the resonance period of about 6 hours. Therefore, it is concluded that the direct driven system responds to a southward excursion of the IMF with its inherent resonance time of about 6 hours. The circuit model predicts that space charges are in an order of 1.0x10^10 C.