Case analysis of SAPS wave structure events observed by ERG, DMSP, and SuperDARN

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Subauroral Polarization Stream (SAPS) and Subauroral Ion Drift (SAID) are ionospheric high-speed westward flows found in the subauroral region mainly on the dusk side, and are considered to be driven by a strong poleward electric field [Spiro et al., 1979; Anderson et al., 1993; Foster and Burke, 2002]. Ericson et al. (2002) reported that irregular substructures with a scale size of the order of tens of km presented within SAPS. These structures are called “SAPS wave Structure (SAPSWS)”. Based on CRESS satellite observation, Mishin and Burke (2005) showed that high-temperature ions were transported into the inner magnetosphere, and showed a spatial distribution with characteristic energy dispersion (ion nose structure) when the electromagnetic field fluctuations of SAPSWS were observed. Ebihara et al. (2009) performed a simulation of coupling processes between the inner magnetosphere and the subauroral ionosphere, and reported that hot plasma with complex pressure distribution was transported into the inner magnetosphere, and contributed to the temporal and spatial variations of SAPS. Further detailed comparisons among electromagnetic field fluctuations and hot ions in the magnetosphere and plasma flows in the ionosphere are important for understanding the mechanism of SAPSWS.

In this study, we used data from the ERG satellite [Miyoshi et al., 2018], which measures the electromagnetic fields and the flux of ring current particles in the magnetosphere. For 15 events of ion nose structures found from the observations of particle instruments (MEP-i, LEP-I, LEP-e), we examined electric field variations in the radial direction and hot ion isotropic pressure derived from the particle flux in an energy range of 10-180 keV (measured by MEP-i). In several of the 15 events, we also analyzed data measured at the ionospheric conjugated positions by DMSP satellites and SuperDARN radar. DMSP satellites measure the drift velocity of ions and magnetic field in the ionosphere. SuperDARN radar [Greenwald et al., 1995] observes two-dimensional distribution of ionospheric plasma flow velocity in the direction of the line of sight.

In 7 of the 15 ion nose structure events, the amplitude of the electric field was more than twice as large as 1 mV/m. In 6 of the 7 events, the hot ion pressure variations were more than twice as large as those of the rest 8 events with electric field variation smaller than 1 mV/m. In a conjugated event between ERG and SuperDARN Christmas Valley East (CVE) in a period from 2:30 to 3:00 UT on July 9, 2017, a small-scale structure with a flow velocity fluctuation of 200 m/s or larger was observed by CVE radar. In a conjugate event between ERG and DMSP F18 satellite in a period from 8:40 to 9:10 UT on August 31, 2017, small substructures with 200 m/s ionospheric flow were observed. In both events, variations of the ionospheric poleward electric field derived from ionospheric flow observations are about 10 mV/m. The electric field measured by ERG can be mapped to the ionosphere by assuming a dipole magnetic field. ERG observed a strong electric field with an amplitude of 2 mV/m or more near 17-19 MLT and L = 4-5. From the electric field measured in the magnetosphere, the electric field in the ionosphere was estimated to be 30-40 mV /m. The Electric field in the ionosphere based on SuperDARN and DMSP is comparable but a little smaller than that based on ERG. For further detailed comparison, we should take it into consideration that SuperDARN and DMSP measured a flow speed in a little different direction from westward, and the actual magnetic field could be different from the dipole field model. In the conjugate event between ERG and SuperDARN, the scale of the structure in the magnetosphere was estimated to be 4,000 km from the SuperDARN observation in the ionosphere and 3,000-3,600 km from the ERG observation in the magnetosphere. Based on ERG observation, we also confirmed the correspondence between variations of hot ion pressure and magnetic field, which indicated the existence of the field-aligned currents in the magnetosphere.

From the observations of plasma flows in the ionosphere, electric field, and hot ions pressure variations in the magnetosphere presented in this study, it is suggested that hot ions moving toward the earth with small-scale pressure inhomogeneities in the inner magnetosphere generate field-aligned currents and thereby cause SAPSWS in the ionosphere.

Keywords: SAPS, ERG / Arase, SuperDARN

