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Simultaneous ground-geosynchronous observation of Pi 2 pulsations associated with the substorm current wedge

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The formation of a substorm current wedge (SCW) is one of the fundamental processes in the expansion phase of the magnetospheric substorm [e.g. *McPherron et al.*, 1973]. A Pi 2 magnetic pulsation always occurs at the expansion onset [*Saito*, 1969]. High- and mid-latitude Pi 2s in the *D* (east-west) component, which are observed away from the auroral breakup region, have been understood as an oscillation of the field-aligned currents (FAC) associated with SCW [*Lester et al.*, 1983; *Uozumi et al.*, 2009]. *Sakurai and McPherron* [1983] examined Pi 2s that observed at the geosynchronous orbit, and presented that the initial perturbation in the azimuthal component of a Pi 2 is in the same sense as the perturbations caused by the SCW. *Uozumi et al.* [2010] found that the ground Pi 2 timeseries had high coherencies with simultaneously observed AKR timeseries, regardless of whether the Pi 2 timeseries were associated with upward FAC or downward FAC; this fact suggests that the upward SCW and the downward SCW oscillated in a synchronized manner. This aspect was deduced from ground observations, and should be verified by a simultaneous observation on the ground and in the magnetosphere. In order to clarify the timing relation of Pi 2s that are associated with SCW oscillations, we made a comparative study by combining the ground and satellite data.

We analyzed simultaneous ground-satellite observation of Pi 2 pulsations at the ETS-VIII geosynchronous orbit (GGLon=146.0E) [*Koga and Obara*, 2008] and at MAGDAS/CPMN [*Yumoto and the MAGDAS Group*, 2006] high-, mid- and low-latitude stations, CST (GGLat.=68.5N, GGLon.=179.2E), ZYK (65.8N, 150.8E) and KUJ (33.1N, 131.2E). ETS-VIII was located in the geomagnetic southern hemisphere (GMLat = ˜ 12S), and a foot point of the magnetic field line is estimated as GGLat = 70.5N, GGLon = 152.9E by using Tsyganenko 96 model. The nearest ground station to the foot point was ZYK. We picked up Pi 2 events that exhibited a high coherency in the waveform among the ground and satellite Pi 2s. Pi 2s occurred around 1250 and 1300UT on May 5, 2008. MLT of each ground station and ETS-VIII at the occurrence of the first Pi 2 was as follows: KUJ: 21.4h, ZYK: 22.4h, ETS-VIII: 22.5h and CST: 23.6h. ETS-VIII was located at almost the same magnetic meridian as ZYK. The first Pi 2 occurred without any significant magnetic bay. The second Pi 2 was accompanied with magnetic bay signature. Characteristics of the Pi 2s are summarized as follows: (1) the initial deflection of the ground Pi 2s at ZYK and CST indicate the signature of the upward and downward FAC of the SCW, respectively. (2) Pi 2 oscillated in- or 180deg out-of-phase among the *D* (eastward) on the ground and *N* (eastward) components at the geosynchronous altitude. (3) Pi 2 oscillations in the *H* (northward) and *P* (parallel to the earth rotation axis) components exhibited phase (time) difference among them (d*T* = 10˜30s). We found other Pi 2 events that have the same characteristics.

By taking into account that the polarity of the *D* and *N* components Pi 2 oscillations were demarcated by the direction of the SCW FAC (upward or downward) and the sign of the geomagnetic latitude (northern- or southern-hemisphere), the present results suggest that the entire part of the SCW system oscillated in a synchronized manner. On the other hand, the time differences in the *H* and *P* components Pi 2 can be explained by a characteristic of Pi 2 propagation in the magnetosphere, which was examined by *Uozumi et al.* [2000 and 2009].

Keywords: Pi 2, substorm current wedge, simultaneous ground-geosynchronous observation, substorm, MAGDAS/CPMN, ETS-VIII