Dissertation for Ph.D. in Science

A study on the origin of small-scale field-aligned currents as observed in topside ionosphere at middle and low latitudes

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Abstract

The Swarm satellites, which are the low Earth, polar orbiting satellites, observed small-amplitude (0.1–5 nT) magnetic fluctuations, so-called magnetic ripples (MRs), with period around a few tens of seconds along the satellite orbit in the topside ionosphere at mid and low latitudes. They are the spatial structure of small-scale field-aligned currents, and I confirmed with the Swarm observations their basic characteristics to be exactly the same with those obtained by the CHAMP satellite. That is, the global distribution of the averaged MR amplitudes has clear geographical, seasonal and local time dependence highly correlated with the ionospheric conductivities. I found that the averaged amplitudes of the MRs derived from the Swarm-B satellite which flies about 50 km higher altitude are slightly smaller than those of the Swarm-A and -C, suggesting that the location of origin of the MRs is below ~470 km altitude, i.e., not in the magnetosphere.

From the global distribution and its characteristics, the source of the MRs has been expected to be the atmospheric waves generated by lower atmospheric disturbances including the effects of earthquakes or volcanic eruptions. The fact that the MRs appear almost always suggests that some typical meteorological phenomena are the main source of MRs. To confirm the suggestion, I tried to find the connection between the MRs and typhoons as the first step. To show the evidence which correlates the MRs with typhoons, I performed an event and a statistical analyses with track data of typhoons. The data of 54 typhoons during the period from 26 November 2013 to 31 July 2016 are used for the statistical analysis. The results show that the averaged amplitudes of the MRs during typhoon activity are, in general, larger than those during non-typhoon condition. The event analyses indicate amplitudes enhancement of the MRs around the typhoons, and the latitude of the enhancement moved with the typhoon.

These analyses indicate that typhoons are one of the source meteorological phenomena of the MRs. The convection activity other than typhoon also seems to affect the amplitude of MRs.

Other than the meteorological phenomena, for example, a volcanic eruption can generate the MRs. The Calbuco volcano in southern Chile erupted on 22 April 2015. About two hours after the first eruption, a Swarm satellite passed above the volcano, and observed enhancements of small amplitude (0.1–5 nT) magnetic fluctuations with wave packet structure which extends 15 degrees in latitude. The similar wave packet is seen at the geomagnetic conjugate point of the volcano. Just after the eruption, geomagnetic fluctuations with the spectral peaks around the vertical acoustic resonance periods, 215 and 260 sec, were also observed at Huancayo Geomagnetic Observatory located on the magnetic equator. Besides these observations, around 4-min period, i.e., 175, 205 and 260 sec, oscillations of total electron content (TEC) were observed at global positioning system stations near the volcano. The horizontal propagation velocity and the spatial scale of the TEC oscillation are estimated to be 720 m/s and 1600 km, respectively. These observations strongly suggest that the atmospheric waves induced by explosive volcanic eruption generate TEC variation and electric currents. The Swarm observation may be explained as a manifestation of their magnetic effects observed in the topside ionosphere at middle and low latitudes.

These results indicate that the MRs are generated by the lower atmospheric waves, in particular, the acoustic mode waves through the ionospheric dynamo.