A study on magnetic fluctuations over the ionospheric E-region driven by the lower atmospheric phenomena

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Abstract

Magnetic fluctuations observed by low altitude satellites in middle or low latitudes with period along their orbits a couple of ten seconds are investigated. From the result of data analysis, a possibility that they are caused by the acoustic gravity waves propagating from lower atmosphere is discussed.

In Chapter 1, recent studies on the coupling between lower atmospheric phenomena and ionospheric phenomena are introduced, and the aim of this thesis is presented. The magnetic fluctuations investigated in this thesis were firstly reported from an analysis of magnetic data obtained by the Ørsted satellite. However, because of the limitation of accuracy of observation, it was difficult to separate them from artificial fluctuations and to get conclusive results.

In Chapter 2, by the analysis of the magnetic data with high accuracy obtained by the CHAMP satellite, it is shown that the small amplitude (standard deviation: 0.2 ~ 2 nT) magnetic fluctuations with period of a couple of ten seconds exists almost all the time and at any local time (LT) in middle and low latitudes. They were named as “magnetic ripples” because the magnetic fluctuations like ripples exist globally. The analysis of the CHAMP data shows following characteristics of the “magnetic ripples”: (1) They are perpendicular to the geomagnetic main field. (2) Their amplitude has the magnetic conjugacy. (3) The amplitude and the period along the orbit have latitudinal dependence, and they depend also on the geographic longitude. That is, in all the regions except for the Brazilian Anomaly sector, the amplitude tends to decrease and the period becomes longer as the satellite approaches the magnetic equator. In the Brazilian Anomaly sector, the tendency mentioned above isn’t seen. (4) The amplitude is larger on the day side than on the night side. (5) The amplitude doesn’t have dependence on the solar wind parameters nor the magnetic disturbance. (6) The amplitude has the following seasonal and topographical characteristics. That is, the amplitude during the northern summer and northern winter is larger than those during the equinoxes. In the northern summer, the amplitude over South America, Eurasia, North Africa and Australia continents, and their magnetic conjugate regions is larger than those in the other regions. In the northern winter, the amplitude over the eastern Pacific Ocean is larger.

In Chapter 3, from the above characteristics of the “magnetic ripples”, their generation mechanism, i.e., the field-aligned currents (FACs) generated through the ionospheric E-layer dynamo driven by the lower atmospheric phenomena, is proposed. The latitudinal dependence of the period along the orbit is interpreted in the following way. In all the regions except for the Brazilian

Anomaly sector, by using dipole magnetic field geometry, the tendency that the period of magnetic fluctuations becomes longer as the satellite approaches to magnetic equator is explained. In the Brazilian Anomaly sector, the effect of large declination near the magnetic equator is proposed to explain the exceptional behavior of the latitudinal dependence. The local time dependence of the amplitude is examined. It is shown that there exists a high correlation between the amplitude and the ionospheric E-layer conductivities, which suggests ionospheric dynamo current as the source of the magnetic ripples.

In Chapter 4, from analyses of the magnetic data obtained by the SWARM constellation, which is composed of three satellites, it is directly confirmed that the “magnetic ripples” are attributed to the spatial structure of the FACs along the satellite orbit. By an examination of how correlation coefficient between the magnetic fluctuations observed by the two satellites at the same latitude varies with their temporal difference along the orbit, the time scales of the FAC variation are investigated. As the result, they are estimated to be 120 – 400 s for the meridional component and 200 – 400 s for the zonal component. It is also shown that the estimated time scale has latitudinal dependence. That is, the time scale is shorter in lower latitudes than that in higher latitude. Because the estimated periods are shorter than the Brunt-Väisälä period and close to the acoustic cutoff period, it is suggested that the source of FAC generation is the acoustic gravity waves. In the similar way with the estimation of the temporal scales, the longitudinal scale of the FACs at the ionospheric E-layer altitude is estimated to be around 80 – 120 km for the meridional component and around 160 km for the zonal component.

In Chapter 5, by synthesizing the results obtained from CHAMP and SWARM data analysis, it is concluded that the “magnetic ripples” are attributed to the FACs generated through the ionospheric E-layer dynamo possibly driven by the acoustic mode gravity waves.