Abstract

The ionospheric conductivity and the electric field are related to each other in various current systems in the magnetosphere and ionosphere. Based on relationships between the ionospheric conductivity and the electric field induced from European Incoherent Scatter (EISCAT) radar measurements, the present study aims at quantitatively assessing how the solar wind-magnetosphere-ionosphere coupling system controls complex feedback processes between the plasma motion (equivalently electric fields) and the particles, some of which are enforced to precipitate into the ionosphere and enhance the ionospheric conductivity.

Firstly, we statistically investigate the generation mechanisms of the current systems, and the relation between the electric field and the ionospheric conductivity, which is enhanced by precipitating electrons mostly driven by field-aligned electric fields or pitch angle diffusion.

We have developed a refined method to investigate a number of IS radar measurements of the conductivity and the electric field. The present method of analysis addresses the division of the magnetosphere-ionosphere system into states of strong, medium, and weak levels of the current intensity, and how strongly the conductivity or the electric field relatively contributes to the current in different magnetic local time (MLT) regions. This method enables us to evaluate quantitatively the relative contribution, and also enables us to determine quantitatively how strongly the ionospheric conductivity or the electric field contributes to the ionospheric current for different levels of the current intensity. Obviously this method can provide significant statistical characteristics only when it is applied to a large number of data, such as the EISCAT radar long-term database

Using 10 years of EISCAT radar data, Pedersen and Hall currents are generally enhanced especially on the nightside, and the MLT dependences of these two types of ionospheric currents are similar to field-aligned currents (FACs) and auroral electrojets, respectively. On average, higher Pedersen conductivities are seen at 2000–0800 MLT in comparison with other MLT intervals and these conductivities crucially contribute to Pedersen currents over two MLT sectors, around midnight and in the late morning. However, when the Pedersen current is stronger, not only the Pedersen conductivity but also the electric field becomes higher statistically on the nightside. This implies that the

filed-aligned electric field or pitch angle diffusion is well developed with stronger convection electric fields.

Next, we assess the ionospheric closure and distribution of the three-dimensional current system, and discuss the characteristics of polarization electric fields due to inhomogeneity of ionospheric conductivities and their active role on the re-distribution of the electric field and hence the modification of the current systems.

For this purpose, we have conducted a special EISCAT radar experiment on October 9, 1999, which enabled us for the first time to determine the spatial distributions of both the electric field and the ionospheric conductivity quasi-simultaneously and thereby allows us to derive the spatial distribution of ionospheric currents and hence FACs. In order to derive the gradient of the ionospheric conductivity and the divergence of the electric field nearly simultaneously, a special experiment employs an EISCAT radar mode which lets the transmitting antenna sequentially point to four directions within 10 minutes; two pairs of the four directions form two orthogonal diagonals of a square.

Our analysis of the EISCAT radar data have disclosed that $\Sigma_P \mathrm{div}\boldsymbol{E}$ and $\boldsymbol{E} \cdot \mathrm{grad}\Sigma_P$ produce FACs with the same direction inside a stable broad arc around 0500 MLT, when the EISCAT radar presumably crosses the boundary between the large-scale upward and downward current regions. In the most successfully observed case in which the conductances and the electric field are spatially varying with little temporal variations, the contribution of $\Sigma_P \mathrm{div}\boldsymbol{E}$ is nearly twice as large as that of $\boldsymbol{E} \cdot \mathrm{grad}\Sigma_P$. On the other hand, the contribution of $(\boldsymbol{b} \times \boldsymbol{E}) \cdot \mathrm{grad}\Sigma_H$ is small and not effective in closing FACs.

The present EISCAT radar mode along with auroral images also enables us to focus on the temporal or spatial variation of high electric fields associated with auroral arcs. In the present experiment, the electric field associated with a stable arc is confined in a spatially restricted region, within ~100 km from the arc, with no distinct depletion of electron density. We have also detected a region of the high arc-associated electric field accompanied by the depletion of electron density above 110 km, implying that ionospheric electrons are carried into the magnetosphere as a downward FAC carrier. Using auroral images, this region is identified as a dark spot with a spatial scale of over 150 × 150 km. The dark spot and the electron depletion are likely lasting for a limited time of a few minutes.