Study of the Jovian magnetosphere-ionosphere coupling using an ionospheric potential solver: Contributions of H+ and meteoric ions to ionospheric conductivity

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The corotation of Jovian magnetospheric plasma dominates the convection in the Jovian inner magnetosphere. Therefore, the solar wind hardly influences the plasma convection there. However, the Hisaki satellite showed that the brightness intensity of the Io plasma torus (IPT) changed asymmetrically between the dawn and the dusk sides. Furthermore, it was confirmed that this asymmetric change coincided with a rapid increase in the solar wind dynamic pressure. Such change can be explained by the existence of a dawn-to-dusk electric field of ~4-9 mV/m around Io’s orbit. This dawn-to-dusk electric field shifts the position of IPT toward dawn side by ~0.1-0.3 RJ. Associated with this shift, the plasma in the IPT is adiabatically heated at dusk and cooled at dawn, which makes the dawn-dusk brightness asymmetry. The following processes have been suggested as a possible cause of the dawn-to-dusk electric field. First, the Jovian magnetosphere is compressed by the increase of solar wind dynamic pressure. Then, the magnetosphere-ionosphere coupling current system is modified, and the field-aligned current (FAC) connected to the high-latitude ionosphere increases. As a result, the ionospheric electric potential increases and penetrates to lower latitude regions. It is mapped to the equatorial plane of the inner magnetosphere along magnetic field lines, and the dawn-to-dusk electric field is created around Io’s orbit.

We have constructed a 2-D ionospheric potential solver in order to demonstrate this scenario quantitatively. We used a time-averaged intensity of the total FAC obtained from Galileo observations. The intensity of the dawn-to-dusk electric field at Io’s orbit depends on the global distribution of the ionospheric conductivities, because Io’s orbit connects to the ionosphere at a lower latitude region than the FAC and the aurora regions. We modeled the ionospheric conductivities from collision frequencies, cyclotron frequencies and density distributions in the upper atmosphere. Because the limited area of the ionosphere was observed by Galileo and Voyager, we used a photo-chemical model to estimate the global distributions of the ionospheric densities, which took into account ionizations caused by the solar EUV and aurora electrons precipitating at the upward FAC region.

We have calculated the ionospheric electric potential distribution and the magnetospheric dawn-to-dusk electric field, with the FAC and conductivity distributions described above. The calculated dawn-to-dusk electric field was two orders of magnitude larger than that expected from the Hisaki observations. We considered that this difference would be caused by the underestimation of the ionospheric electron density, especially on the night side. Our model has not considered H+ ions and ions originating from meteoroid ablation. We have regarded these ions as the reasons to underestimate the electron density.

H+ and meteoric ions have a long life time until its loss by the recombination. Therefore, the electron density is increased on the night side under the quasi-neutral condition. In order to estimate the influence of H+ and the meteoric ions on the ionospheric conductivities, we added the densities of these ions to the result of our photo-chemical model. The ionospheric electron density increased by a factor of two at the H+ density peak of around ~700 km at noon, and the density peaks at ~400 km around the meteoric ion layers. As a result, the height-integrated conductivities showed a negligible local time dependence. The dawn-to-dusk electric field is calculated as ~9-30 mV/m at Io’s orbit, which is still higher but marginally agrees with the Hisaki observations. Our results suggest that H+ and the meteoric ions are important to consider the ionospheric conductivity and the dawn-to-dusk electric field in the Jovian inner magnetosphere.

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