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Dust-plasma interaction in Saturn's inner magnetosphere and its magnetosphere-ionosphere coupling

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We investigated the magnetosphere-ionosphere coupling with a dust-plasma interaction in Saturn's inner magnetosphere by using a modeling of ionosphere and inner magnetosphere. From our previous model, it was revealed that the magnetospheric ion velocity was significantly reduced by the electric fields generated by the ion-dust collisions when the dust density is high and the thickness of dust distribution is large. It was consistent with observations when the dust density is larger than ˜10^5 m^{-3} for ionospheric conductivity of 1 S. An average electron density of Saturn's ionosphere obtained from radio occultations by Cassini spacecraft was ˜10^{10} m^{-3} at 2000 km where density had a peak and gradually decreased with the increasing altitude. The density was ˜10^8 m^{-3} at 10000 km. Plasma densities calculated by models also were similar to the observations and the topside temperature is ˜650 K. However, electron densities from those models were calculated at the altitudes below 4000 km.

We estimated the ionospheric Pedersen conductivity from the plasma densities, and the plasma temperatures and velocities by using a magnetohydrodynamics model. We used the magnetospheric plasma temperature, which was 2 eV, as a boundary condition to investigate the magnetospheric influences. The plasma density was about 10^9 m^{-3} at the altitude of 1200 km, and it decreased to about 10^7 m^{-3} at the altitude of 10000 km. Below 10000 km altitudes the light ion has the upward velocity, while heavy ions have zero or downward velocity at low altitudes. This might be due to the difference of mass. The electron temperature increased to 20000 K at the altitude of 10000 km due to the heat flow from the inner magnetosphere. The electron temperature was about 2000 K at the altitude of 1000 km, and the collision and joule heating were contributing to the temperature below 2000 km. The peak density changed between about 10^8 and 10^{10} m^{-3} during one Saturn's day, and the electron density decreased with increasing the altitude. On the other hand, the electron temperature didn't depend on the local time. The Pedersen conductivity was the maximum 0.77 S on day time and the minimum 0.30 S on dawn time. The Pedersen conductivity strongly depends on the ionospheric plasma density.

We estimated the magnetospheric ion velocity by using the calculated conductivity. The Pedersen conductivity was the largest value at L = 3 and it decreased with the increase of the distance from Saturn. The conductivity changed in local time. The maximum was on the day time and the minimum was on the dawn time. The calculated ion velocity decreases from the co-rotation speed outside 3.5 R$_S$. The ion velocity was 60-80% of the co-rotation speed in the inner magnetosphere. The ion velocity was smaller than the co-rotation speed since the magnetospheric electric field is smaller than the co-rotational electric field when the current due to the ion-dust collision flows in the inner magnetosphere. The ion velocity strongly depended on the local time since the conductivity also depended on the local time. It is suggested that the dispersion of the observed speeds could show the dependence of local time. The ion velocity is fast during the solar irradiation since the Pedersen conductivity is large, while it becomes slow after the sunset because of the small conductivity.

The magnetosphere-ionosphere coupling is significantly important for the dust-plasma interaction. It is impossible to understand the dust-plasma interaction in Saturn's inner magnetosphere without understanding of the Saturn's ionosphere, since the magnetosphere and ionosphere is intimately-connected.

Keywords: Saturn, Dust-plasma interaction, Magnetosphere-ionosphere coupling, Dusty plasma