Plasma dynamics in Saturn's middle-latitude ionosphere and implications for magnetosphere-ionosphere coupling

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Saturn's magnetosphere-ionosphere (MI) coupling is active in the auroral regions at high latitudes. The coupling process in the inner magnetosphere at less than 10 R_S (R_S: Saturn radius = 60268 km) is not well understood. However, the interaction between the ionosphere and Saturn's ring particles was recently studied by using measured depletion of $H_3{}^+$ ions in the ionosphere, called "ring rain". Ring rain ions are probably generated by photoionization of the ring surface. A similar phenomenon is expected to occur in the inner magnetosphere covering the E ring since it also contains mainly water group ions and water ice dust from Saturn's moon Enceladus. Sakai et al. (2013) showed that the magnetospheric electric field generated by the ion-dust collisions slows down the ion velocity from the co-rotation speed in Saturn's inner magnetosphere, and suggested that the dust-plasma interaction occurs via MI coupling. This magnetospheric electric field also strongly depends on the ionospheric Pedersen conductivity. A magneto-hydrodynamics (MHD) model is used to investigate the magnetosphere effect on Saturn's ionosphere. The model includes a magnetospheric plasma temperature of 2 eV as a boundary condition. The main results are (1) H^+ ions are accelerated along magnetic field lines by ambipolar electric fields and centrifugal force, and have upward velocity of about 10 km/s at 8000 km; (2) the ionospheric plasma temperature is 10000 K at 5000 km, since it is significantly affected by heat flow from the magnetosphere at high altitudes; (3) model electron densities agree with densities from occultation observations when the maximum neutral temperature at the latitude of 54 deg. is about 900 K or electrons are heated more around 2500 km; and (4) the ion temperature is high at altitudes above 4000 km and it is almost the same as the electron temperature. The ionospheric Pedersen conductivity which affects the magnetospheric plasma velocity varies with local time between 0.4 and 9 S. We suggest that the subcorotating ion velocity in the inner magnetosphere depends on the local time, because the conductivity generated by dust-plasma interaction in the inner magnetosphere is almost comparable to the ionospheric conductivity. This indicates that magnetosphere-ionosphere coupling is highly important in the Saturn system.