Development of a radial diffusion model of Jovian inner magnetospheric plasma transportation for a comparison with HISAKI data

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We developed a time-dependent radial diffusion model to calculate chemical reactions and radial transport of ions and electron in the Jovian inner magnetosphere. We compared the model results with HISAKI observation, and found that the neutral source rate from Io to the magnetosphere is 5.0×10^{-4} (/m^3/s), the oxygen-sulfur ratio is 2.0, and the radial diffusion coefficient is 4.2×10^{-8} ($/R_J^2/s$) near Io.
Jovian first satellite Io has active volcanoes and releases the plasma of the volcanic gas origin to the magnetosphere. The 90% of total mass of the plasma is mainly supplied from Io (Hill, Dessler, and Goertz, 1983). The plasmas co-rotate with Jupiter and distribute in a donut shape called Io Plasma Torus (IPT). The plasma diffuses outward on the time scale of several tens of days while obtaining the rotation angular momentum of Jupiter. Revealing the mass and energy balance of plasmas is an important subject to understand the macroscopic physical phenomena in the Jovian inner magnetosphere. The radial distribution of Jovian magnetospheric plasma has been examined based on steady state models and observations of Voyage 1, 2 and Cassini spacecraft. However, the time dependent model and comparison of the model with continuous observations have not been reported yet.
The purpose of this study is to develop a model that has a capability to track the time variation of the radial plasma distribution and compare it with HISAKI observation.
In the model, we track mass and energy balances of major heavy ions of Io origin (O^+-O^{3+} and S^+-S^{4+}). The equation system is based on the mass and energy transport model of steady state magnetospheric plasma developed by Delamere et al. (2005). The time evolution of radial transport was solved with the Fokker-Planck equation and we used FTCS method for numerical computation. The radial diffusion coefficient is expressed as $D_{LL}=D_0(L/L_0)^m$, where L is the L-value, L_0=5.9, and D_0 is a free parameter of the model. We set a radial grid size (dL) as a function of exponentials of the radial distance so that radial dependence of the Courant number ($2D_{LL}dt/dL^2$, dt is a time step) becomes weak. For the inner and outer boundary conditions, we set the radial gradient of the density and temperature to 0 at the Io's orbit (5.9 R_J), and fixed them with extrapolated values of HISAKI observation at 30 R_J. We considered several chemical interactions: charge exchange, electron impact ionization, electron recombination, Coulomb interaction and radiation due to electron collision excitation based on Delamere & Bagenal (2003). Radiative and recombination rates are calculated from the CHIANTI atomic database. The initial values of temperature and density of each ions and thermal electrons were given from the HISAKI observations in November 2013 when Io's volcanic activity was quiet (Yoshioka et al. 2018). The density of neutral atoms (O, S) were also given by HISAKI observation (Koga et al. 2018b) as initial values, and their total source rates and the source composition ratio (O/S) are free parameters.
In order to verify the validity of the model, the steady state temperature and density of ions and electrons in the region of 6-10 R_J were compared with the HISAKI observation. We found that highly ionized ions have low density, and temperature of ions is almost stable around 100 eV except S^+ which has 200 eV. We obtained the parameters that best matched with HISAKI observation. As a result, the O/S is 2.0, the neutral source rate is 5.0×10^{-4} (/m^3/s), and D_{LL} is estimated to be 4.2×10^{-8} ($/R_J^2/s$) near Io. The source

characteristic is consistent with the main atmospheric composition of Io (SO_2) and DLL is found within a range of previous estimations. As a future work, we aim at quantitative verification by comparing with D_{LL} based on a numerical analysis.
In this presentation, we' ll show the correspondence between the quantitative inspection results of each parameter and the observation results of HISAKI.

Keywords: Jovian magnetosphere, HISAKI satellite, Io plasma torus