A precise model for the field-aligned magnetospheric plasma profiles on the basis of the velocity distribution function

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Observations from the Juno satellite revealed the downward electrons in the energy range from several hundred eV to several hundred keV in the Jovian main oval [Mauk et al., 2017]. The observed energy and pitch angle distributions suggested that the electron acceleration process by dispersive Alfvén waves (DAWs) plays a significant role in the formation of the Jovian aurora [Saur et al., 2018]. In the high-latitude region of the terrestrial magnetosphere, downward electrons in the energy range up to a few keV have also been observed [Chaston et al., 2002]. Although the importance of the electron acceleration process by DAWs in magnetized planets is increasing, the main factors that determine the upper limit of the energy range of acceleration have still been unclear.
To study the electron acceleration process by DAWs, spatial distributions of the number density and pressure are necessary, which determine the dispersion relation of DAWs. Several theoretical/empirical models have been proposed to calculate the number density and pressure distributions of the background plasma [e.g., Angerami and Thomas, 1964; Phipps et al., 2018]. However, since most previous studies treated temperature and number density independently, further development of a plasma distribution model is required to determine the distributions keeping the consistency between them. In the present study, we develop the Plasma Distribution Solver (PDS), a theoretical model that consistently determines the plasma number density and pressure profiles along the magnetic field line. We developed PDS based on the Static Vlasov Code (SVC) [Ergun et al., 2000; Su et al., 2003; Matsuda et al., 2010]. SVC is a theoretical model that calculates the number density distribution along the magnetic field line from the velocity distribution function, considering the accessibility of the plasma in velocity space [e.g., Persson, 1966; Chiu and Schulz, 1978]. We revised SVC and reconstructed to PDS by appropriately considering the spatial variation of the velocity distribution function along the magnetic field line, which enables us to calculate the plasma distributions more precisely and realistically than SVC. Using PDS, we obtain the plasma profiles in the Jupiter-Io system and compare those obtained by SVC under the same initial settings. The results show that the characteristics are different between the PDS and SVC results. Especially in the auroral cavity, the number density of PDS is constant at 2 cm^{-3}, while the SVC result shows the variation proportional to the magnetic flux density between 0.5 and 6 cm^{-3}. The obtained difference indicates a typical example caused by the different treatment of the velocity distribution function in PDS and SVC. We also calculate the Alfvén speed from these number density profiles, and the time to reach the Jovian ionosphere from Io is estimated to be 370 seconds in the PDS result. The obtained time scale gives a criterion validating the assumption of the fixed boundary condition when we use the PDS results as a background field for the calculation of Alfvén waves propagation. Besides, we introduce the details of the method and results of PDS and discuss the comparison with SVC, and the spatial change of characteristics of DAWs clarified from the PDS results.

Keywords: dispersive Alfvén waves, electron acceleration mechanism, numerical experiment, Jupiter-Io system, plasma distribution

