

New magnetic field and current sheet models of the night-side Jovian magnetosphere and their long-term variations

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In the night side of the Jovian magnetosphere, there exists a sheet-like plasma-rich region, so-called the current sheet (CS), and its shape is variable with the oscillation of the Jovian intrinsic magnetic field, solar wind conditions, and so on. The CS generates a magnetic field by the currents flowing within itself, which is comparable with the Jovian internal field and dominant in the night-side magnetosphere.

The shape of CS and the magnetic field have been modeled since Pioneer 10 observed the Jovian magnetosphere for the first time. However, those models have not sufficiently been updated with newly added data by Galileo and Juno. In this study, we focused on a CS shape model by Khurana (1992) and a magnetic field model by Khurana (1997) and updated these models with new data and methods. Furthermore, we estimated the errors of parameters of the magnetic field model and found that several parameters show significant long-term variations exceeding the error estimates.

The shape of CS is represented as an oscillating surface according to Jovian rotation with the following characteristics: (i) westward bendbacks of magnetic lines of force originating from the finite velocity of the oscillation propagation, and (ii) hinge (saturation of CS height) stemming from the solar wind dynamic pressure. As results of the model updates by this study, we found the weak bendback in the Galileo model, which implies that the average Alfvén velocity in the magnetosphere was strengthened in the Galileo mission period. We also found the weakened hinge effect in the Juno model. This is possibly related to the weakened solar wind dynamic pressure during the solar minimum.

The model of the magnetic field by the CS is expressed with two scalars called Euler potentials and depend on the shape of CS. Our updated Euler potential models explained the observed magnetic field well and we found that the values of the model parameters are dependent on the used data. In addition, we estimated the errors of the Euler potential parameters using resolutions of the magnetic measurements as threshold and found that several parameters changed significantly over decades beyond the error bars. It is possible that the major causes of the changes in the Jovian magnetospheric magnetic field are either solar activity or the amount of electric current in the CS. Comparison among the updated models implied the long-term variation related to the former, with no clear evidence of the latter. Namely, the amount of electric current in the CS significantly decreased in the Galileo mission period.

Our updated models enable us to predict the magnetic field that the forthcoming spacecrafts will observe, to calculate the current density by the CS, and to estimate the time-varying magnetic field at each Galilean satellite. The surfaces of Europa, Ganymede and Calisto are all covered with ice and thought to have subsurface oceans. Our methods and results are expected to be utilized when the new data by Europa Clipper and JUICE are analyzed to detect the subsurface oceans by electromagnetic induction methods.

Keywords: Jupiter, magnetospheric magnetic field, current sheet, long-term variation

