Geophysical Research Abstracts
Vol. 12, EGU2010-5294, 2010
EGU General Assembly 2010

Determining the Rotation Rates of Jupiter and Saturn Using Scalar Potential Expansions

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Scalar potentials can be used to model magnetic fields in regions where there are no significant currents, such as in the atmosphere of the Earth. If we are to use this approach in the magnetospheres of Jupiter and Saturn, we should attempt to restrict our attention to the regions not affected by their mass-loading moons, Io and Enceladus. Thus we should use field observations inside 5.8 jovian radii and 3.8 saturnian radii, respectively.

If we do this for Jupiter, we have a data set from Pioneer 10 and 11 that is dominated by the close (1.6 Rj) retrograde pass of Pioneer 11 with very little contribution from Pioneer 10. Voyager and Ulysses provide little additional data as they did not make close approaches to Jupiter. Galileo obtained some data in this radial range at orbit insertion and late in the mission. Based on the O6 model, we use these data to create a best-fit internal, dipole-plus quadrupole-plus-octupole model, with an external dipole term. From the shift of the longitude of the dipole moment, we refine the rotation rate of Jupiter. We also analyze the secular variation of the external term to probe the variation of Io's mass-loading rate.

The amount of data suitable for scalar potential modeling at Saturn is much greater with the Cassini mission, but we need to define the properties of the magnetic field much more precisely since we are trying to measure a narrow tilt angle and deduce from it the rotation rate. After we obtain the correct rotation rate, we revisit the observations of Pioneer 11 and Voyager 1 and Voyager 2 to examine the effects of the rotation rate on the magnetic field models. We find that the areal extent of the data coverage strongly affects the resulting inversions. This can affect solutions that involve varying the planet's rotation period. At some frequencies the periodic orbits used by Cassini can coalesce at a particular pseudo-longitude. This paper reveals what we can and cannot determine about the internal field of Jupiter and Saturn from the 'current-free' regions of the magnetosphere and what needs to be done in future observational programs at the two planets.