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Ganymede's Ocean-Magnetosphere interaction and Ionosphere response

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Abstract

The effect of a possible ocean on Ganymede and Europa is predicted to induce a magnetic dipole as a result of the varying background magnetic field of Jupiter's magnetosphere. The case for an ocean was made by the Galileo magnetometer [3], and recently strengthened via a study using Hubble observations [4]. We investigate the effect of magnetic perturbations via both external and internal drivers. By solving the Laplace tidal equations to determine basic ocean flows as per Tyler [5] and solving the magnetic diffusion equation, we find that tides may produce magnetic perturbations at the orbital period, with amplitudes of up to ~5 nT, comparable to the externally induced magnetic perturbations at the same period. These are associated with density and electric perturbations modulated by the conductivities in the ionospheric medium.

1. Introduction

In the moons' frames of reference, the tilt in Jupiter's magnetic axis produces, via the planet's rotation, large variations in the background magnetic field. The moons' motions along their weakly eccentric orbits, which at times also cross the hinging Jovian current sheet, also cause smaller variations in the magnetic field.

The response from the ocean to these external field perturbations is investigated and modeled as a simple spherical layer with given thickness and conductivity. As per Seufert et al. [1], the response is a magnetic dipole directed along the variable external magnetic field. Its amplitude varies for different values of conductivity and thickness, and the effect of these parameters on the large-scale electric field are studied.

These studies consider the ocean as a static conductive layer, neglecting the advective effect in the diffusion equation. Here, we investigate the capability of simple ocean flows to produce weak magnetic perturbations. Propagation of ocean signals through the Ionosphere is highly sensitive to the electrical conductivities in the medium, and we determine how a satellite orbiting at, or close to the ionospheric region might detect these signals.

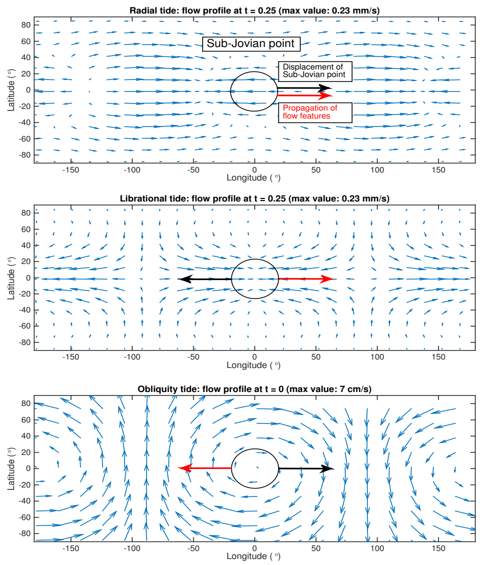
2. Methodology

Externally induced signals are determined following the method of Seufert et al. [1]: variability of the background magnetic field is found by fitting the moon's orbit in a Jovian magnetosphere model. At the orbital period, and for an infinitely conductive ocean at 150km depth, the induced dipole has an amplitude of ~1nT.

In order to determine tidal flow, we solve the Tidal Laplace Equations (TLE) using the time-varying gravitational potential at Ganymede's surface as the driving force. This produces perturbations in the equilibrium sea-surface height. Three sources are identified: radial and librational (due to orbit eccentricity), and obliquity (due to orbit tilt) driven tides.

These serve to amplify the natural oscillatory modes in the ocean, producing some resonance. The normal Eigen-modes of the TLE are found numerically as in [2], and resonance calculated for various ocean parameters (depth, thickness). Flow amplitudes found at Ganymede reach unexpectedly large values, comparable to Europa's [5], despite the much weaker gravitational variations.

The large intrinsic dipole field proves to be an excellent background for induction by advection: magnetic perturbations are determined by solving the diffusion equation for a moving conductive object assuming a steady background magnetic field.



Several simplifying assumptions are made concerning the ocean: both thickness and conductivity are considered homogenous, and flow behaviour is not affected by the upper ice layer. The latter assumption will overestimate the magnitude of the flow and will be accounted for in later work.

3. Summary and Conclusions

Under the above assumptions, both externally and internally induced magnetic fields at the orbital period (171h) are of the order of a few nT (5 nT for flow induced perturbations, and 1 nT for externally induced perturbations), with dependencies on ocean conductivity and depth.

Ocean thickness was assumed to be 100km at 150km depth, while conductivity was assumed infinite. The assumption that the conductivity is large enough to produce a large response is justified in that previous works [1][3] have determined an almost 100% response at the 11h period. While at the larger 171h the response may be reduced, we expect it to remain of the same order of magnitude. We note that while both signals have the same period, their geometry is different, and their direction of propagation is opposite (tidally driven perturbations propagate westwards as opposed to eastwards for the externally induced dipole).

Further out in the ionosphere, our calculations show that the extremely low Pedersen and Hall conductivities do not affect ocean induced signals much, but allows for large (~4-7 mV/m) electric fields that may be detectable by the JUICE RPWI instrument.

Acknowledgements

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References

[1] Seufert et al.: Multi-frequency electromagnetic sounding of the Galilean moons, Icarus, 214, 477-494, 2011.

[2] Longuet-Higgins, M.S, The Eigenfunctions of Laplace's Tidal Equations over a Sphere, Phil. Trans. Of the R. Soc. of London, Math. and Phys. Science. 262, 511-607.

[3] Kivelson, M. G.; Khurana, K.; Volwerk, M.: The permanent and Inductive Magnetic Moments of Ganymede, Icarus, Vol. 157, pp. 507-522, 2002.

[4] Saur, J. et al.: The search for a Subsurface Ocean in Ganymede with Hubble Space Telescope Observations of its Auroral Ovals, J. Geophys. Res. Space Physics, 120, 1715-1737 2002.

[5] Tyler, H.: Magnetic remote sensing of Europa's ocean tides, Icarus, 211, 906-908, 2011.