Modeling Magnetic Induction from Transient Events Impinging upon a Conducting Moon

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Introduction: Electromagnetic sounding measurements utilize magnetic induction theory to constrain the interior geophysical properties of planetary bodies. Under certain conditions, the Earth's Moon can be approximated by the response of a conducting sphere in a vacuum. Transient magnetic fields originating from the Sun can interact directly with the conducting layers of the lunar interior, producing eddy currents that in turn generate an induced magnetic field proportional to the electrical conductivity [2]. This paper describes how COMSOL Multiphysics is used to solve the full time domain response of the Moon for varying conductivity profiles.

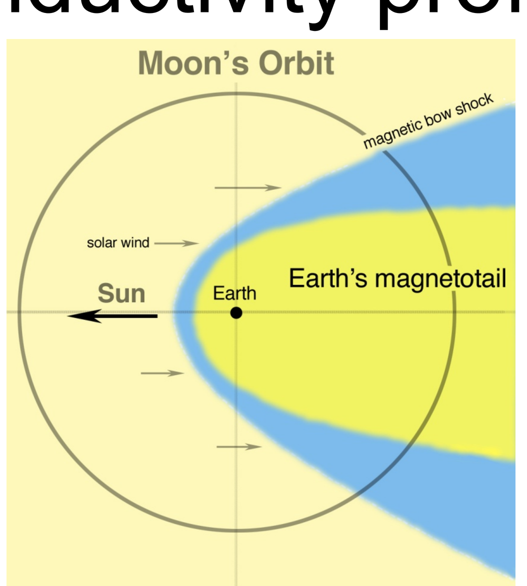

Figure 1. The Moon exists in a variety of plasma environments [5].

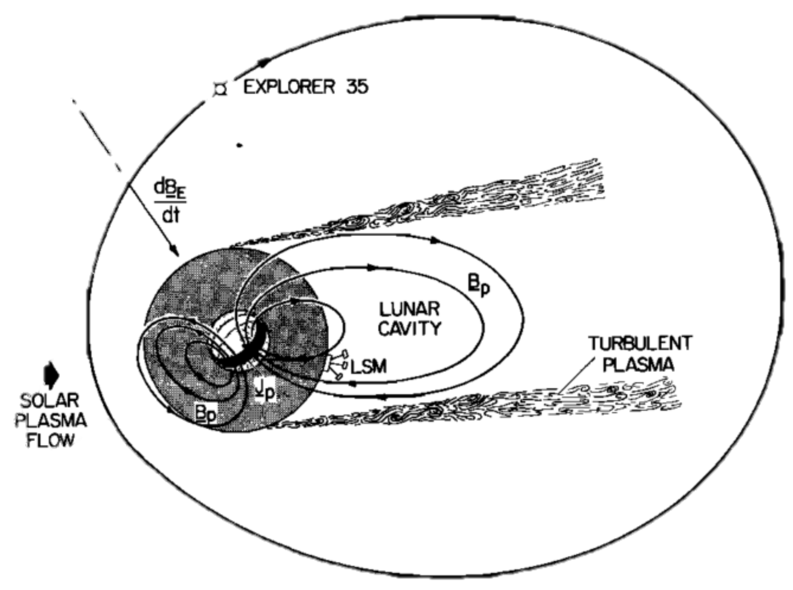

Figure 2. Dyal et al. depict the asymmetric induced field produced due to the pressure of the Solar Wind [1].

Computational Methods: 2D and 3D lunar electrical conductivity models were used in the AC/DC Module. The vacuum induction response to various input functions was solved and correlation between this forward model and ARTEMIS magnetic field data was found. The diffusion equations solved include:

$$\sigma \frac{\partial \mathbf{A}}{\partial t} + \nabla \times (\mu_o^{-1} \mu_r^{-1} \mathbf{B}) - \sigma \mathbf{v} \times \mathbf{B} = \mathbf{J_e}$$

$$\nabla \times \mathbf{A} = \mathbf{B}$$

Homogenous and 3 layer conductivity models were studied. Each model was tested against analytic equations and compared with data.

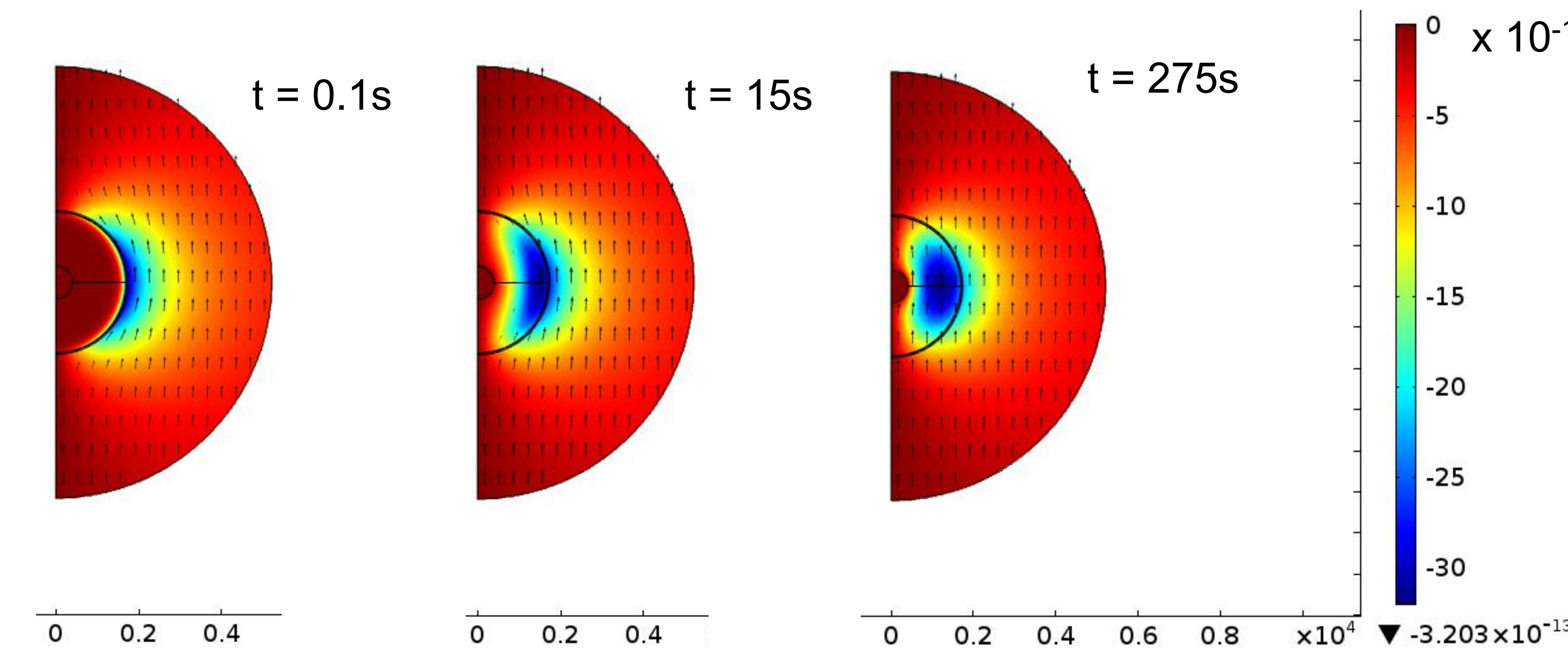

Figure 3. Time Domain response to a step input field showing diffusion of Electric (in color) and Magnetic fields (arrows).

Results: Results demonstrate good correlation with analytic models [1,4]. Comparison with ARTEMIS data underway.

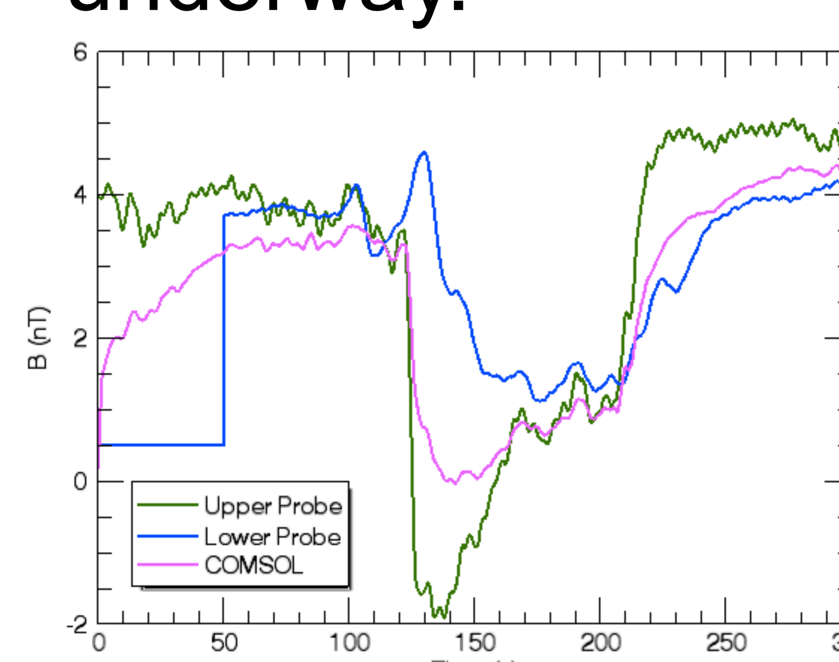

Figure 4. COMSOL forward model (pink) shows good correlation with observed data (blue) from 200-300s.

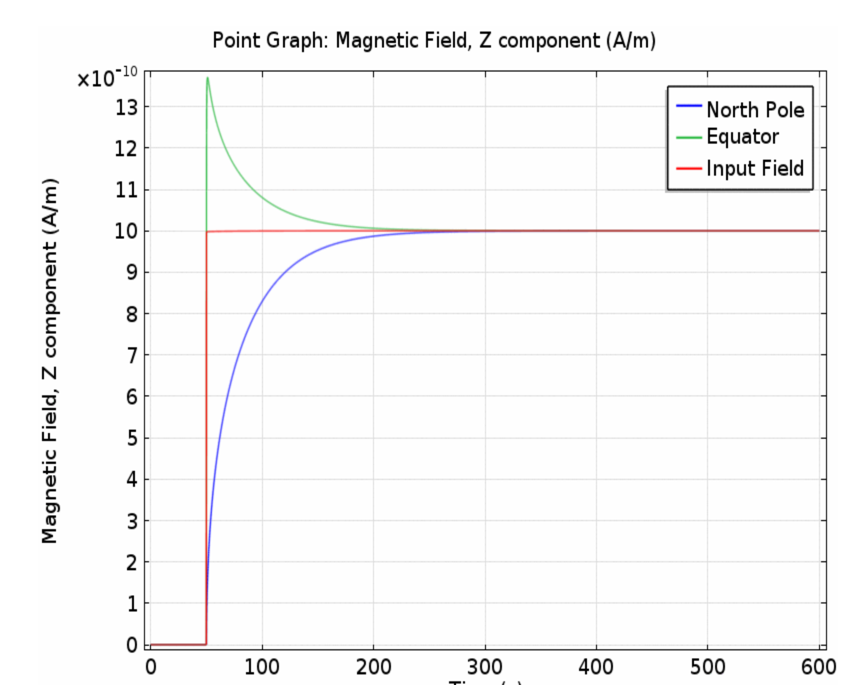

Figure 5. Tangential overshoot (Equator) and radial damping (North Pole) are expected time domain response. [1, 4]

Conclusions: This forward model demonstrates consistency with vacuum theory and is an important first step to understanding the lunar electromagnetic interior [3]. Next steps will study effects of asymmetric boundary constraints.

References:

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