MULTI-MODEL APPROACH FOR ARTEMIS TIME DOMAIN ELECTROMAGNETIC SOUNDING ANALYSIS OF THE MOON. H. Fuqua-Haviland$^{1,2}$, S. Fatemi$^1$, A.R. Poppe$^1$, G.T. Delory$^1$, I. de Pater$^2$, R.E. Grimm$^3$, $^1$Space Sciences Laboratory, University of California, Berkeley, CA 94720, (heidi.fuqua@ssl.berkeley.edu), $^2$Department of Earth & Planetary Science, University of California, Berkeley, CA 94720, $^3$Department of Space Studies, Southwest Research Institute, 1050 Walnut St. #300, Boulder, CO 80302.

Introduction: Time Domain Electromagnetic (TDEM) Sounding isolates induced magnetic fields to remotely deduce lunar material properties at depth. The first step of performing TDEM Sounding at the Moon is to characterize the dynamic plasma environment, and to be able to isolate geophysically induced currents from concurrently present plasma currents. TDEM Sounding transfer function method requires a two-point measurement: an upstream reference measuring the pristine solar wind, and one downstream near the Moon. This method was last performed during Apollo assuming the induced fields on the nightside of the Moon expand as in an undisturbed vacuum within the wake cavity [1]. TDEM sounding is particularly well suited for measurements from moving satellite platforms directly accounting for changing altitudes.

Here we develop a multi-model approach to isolating induction and performing TDEM with ARTEMIS. The ARTEMIS mission consists of two twin satellites currently orbiting the Moon [2]. Our models include a plasma induction model capturing the kinetic plasma environment within the wake cavity around a conducting Moon, and a geophysical forward model capturing geophysical induction in a vacuum. The combination of these two models enables analysis of the ARTEMIS data within the wake cavity.

Plasma Induction Model: Plasma hybrid models use the upstream plasma conditions and interplanetary magnetic field (IMF) to capture the wake current systems formed around the Moon. The plasma kinetic equations are solved for ion particles with electrons as a charge-neutralizing fluid. These models accurately capture the large scale lunar wake dynamics for a variety of solar wind conditions (ion density, temperature, solar wind velocity, and IMF orientation) [3]. Previously, Fatemi et al. (2015) [4] showed that magnetic fields representative of induction are not confined within the wake cavity according to the wake-induced field interaction. Given the 3D orientation variability coupled with the large range of solar wind conditions seen within the lunar plasma environment, we must understand the environment one case at a time. Fatemi et al. (2017) [5] uses a GPU-based three-dimensional hybrid model (AMITIS) to accurately capture the coupled plasma and induced response self-consistently.

Geophysical Forward Models: The global electromagnetic induction response of the Moon in a vacuum has been solved numerically for a variety of electrical conductivity models using the finite-element method implemented within the COMSOL software, AC/DC module. This model solves for the geophysically induced response in vacuum to any driving transient event for any specified 3D conductivity profile. Our 3D model has been shown to fit the analytic solutions to a Root-Mean-Square Error (RMSE) of better than 1%.

Case Study: We use a right-handed coordinate system centered at the Moon, with the +X axis directed toward the Sun, which is the Selenographic Solar Ecliptic (SSE) coordinate system. Here, the solar wind flows along the -X axis. The simulation cell size is 200km, and the lunar radius is $R_L=1800$ km. The conducting lunar interior is modeled as $R_1 = 1400$ km, $\sigma_1 = 1.0e-4$ S/m, surrounded with a resistive layer of 400km and 3.0e-8 S/m. The vacuum region is 1.0e-8 S/m. The downstream measurement location is ($-\sqrt{2/2,+\sqrt{2/2}},0$)$R_L$. The upstream probe is located at (+2,0,0)$R_L$. In SSE, the initial external magnetic field $B_{e1}$ is (0,+3,0) nT and the final $B_{e2}$ is (0,-3,0) nT. Thus, the $\Delta B$ in SSE is (0,-6,0) nT or in RNE is (+4.24,0, -4.24) nT.

![Figure 1. The hybrid $B_{ueh}$ and COMSOL $B_{de}$ models are compared with an analytic $B_{da}$ solution [1] in the RNE frame located at downstream observer. The upstream probe ($B_{au}$) is shown only for the Hybrid model, and is representative of the input signal for all three cases.](image)

We conclude, for this case study, the effect of the diamagnetic wake currents is longer than the geophysical induction only. Thus, the plasma-induction models are needed to characterize the plasma current systems created by this configuration of solar wind conditions and orientation of the transient event within the IMF.
**Future Work.** In order to fully characterize the plasma current systems, two plasma-induction models are needed: one with and one without a conductivity structure within the Moon. The first captures the coupled induced-plasma response. The second model captures the plasma current systems only. The residual of these two runs can be subtracted from the ARTEMIS downstream probe signal removing the non-geophysical component of the signal. The amount of distortion is analyzed to verify a vacuum response can be representative of the induced field. The remaining signal is fit with the geophysical induction model to constrain the electrical conductivity of the lunar interior.