ARTEMIS OBSERVATIONS AND DATA-BASED MODELING IN SUPPORT OF LADEE. J. S. Halekas[1], A.R. Poppe[1], G.T. Delory[1,2], R.C. Elphic[2], V. Angelopoulos[3], M. Horányi[4], J. Szalay[4], [1]Space Sciences Laboratory, U.C. Berkeley, Berkeley, CA 94720 (jazzman@ssl.berkeley.edu), [2]NASA Ames Res. Center, Moffett Field, CA 94035, [3]Dept. Earth & Space Sci., UCLA, Los Angeles, CA 90095, [4]LASP, Univ. of Colorado, Boulder, CO 80303.

Introduction: The goal of the LADEE mission is to understand the exosphere of the Moon, including its structure, temporal variability, and sources and sinks. To achieve this goal, we must determine how exospheric dust and neutrals behave, not in isolation, but as part of an inextricably coupled system that includes the surface and the plasma environment.

Charged particles, their interactions with the surface, and the electric and magnetic fields that they produce and respond to, contribute to source and sink processes for both lofted dust and exospheric gases, and therefore to their spatial and temporal structure and variability. The LADEE payload does not include plasma instrumentation; instead, we utilize a combination of ARTEMIS measurements of upstream plasma parameters and data-based modeling to determine plasma quantities around the Moon, including at the LADEE orbit and in the regions covered by UVS scans and those providing the source populations ultimately measured by LDEX and NMS.

ARTEMIS Capabilities: The ARTEMIS (Acceleration, Reconnection, Turbulence, & Electrodynamics of Moon's Interaction with the Sun) mission [1] consists of two probes from the heliospheric constellation THEMIS [2] retasked to the Moon in 2011. ARTEMIS provides comprehensive measurements of charged particles and magnetic and electric fields around the Moon (Fig. 1), from a two-point vantage that enables continuous upstream plasma monitoring.

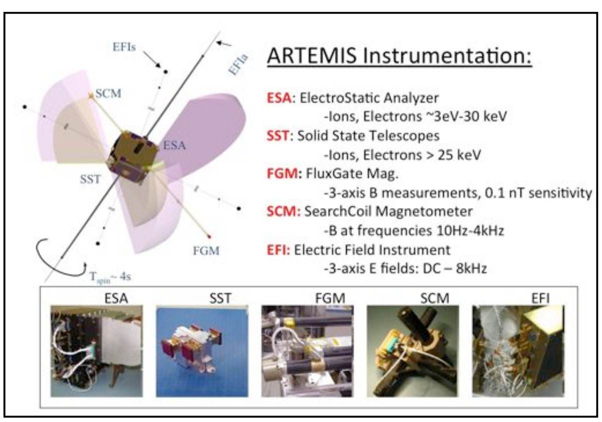

Figure 1: ARTEMIS payload.

The two ARTEMIS probes currently reside in stable near-equatorial elliptical orbits. An orbital design targeting periapses near the lunar dawn terminator, contiguous with the LADEE periapsis, achieved the configuration shown in Fig. 2, with both orbits precessing slowly clockwise with time.

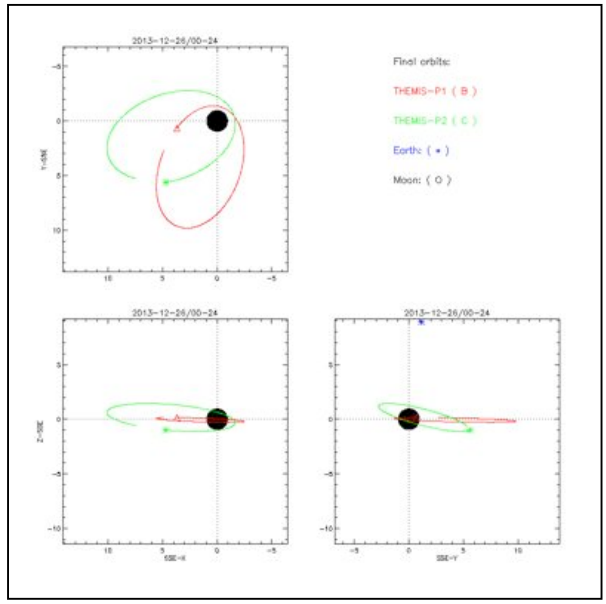

Figure 2: ARTEMIS orbits on December 26, 2013.

Key Inputs to LADEE Science: The ambient plasma, directly and through its control of the near-surface electrostatic environment, contributes significantly to the exospheric cycle. Plasma flows deliver volatiles to and sputter elements from the lunar surface, and form the sink for much of the exosphere, via pickup of ionized constituents. Meanwhile, plasma may also affect lunar-derived dust, by contributing both to the charging and to the subsequent electrostatic acceleration of detached dust particles.

Upstream Plasma Monitoring. ARTEMIS serves as an ideal plasma monitor for LADEE, with no modifications to its routine operations. ARTEMIS provides spin-period resolution measurements of all key plasma quantities, utilizing onboard spin-fits and plasma moment computations. One probe is virtually always in the undisturbed upstream medium, providing a continuous data set. At periapsis and in the wake, ARTEMIS returns high resolution 3-d particle data and higher cadence field data suitable for conjunction studies.

Solar Wind Alpha Particle Abundance. The solar wind delivers many elements to the lunar surface. A particularly relevant example is Helium, which arrives in the form of alpha particles (doubly ionized helium) [3]. By performing a two-component fit to the convecting solar wind distribution measured by ARTEMIS, we provide alpha particle abundances at the Moon, for comparison with NMS and UVS measurements, in order to constrain the recycling and loss time scales, which LRO LAMP observations suggest to be on the order of days [4]

Lunar Wake Measurements and Modeling. LADEE's low-altitude near-circular retrograde equatorial orbit ensures that it spends a large percentage of its time in the lunar wake. Here, in situ ARTEMIS measurements cannot provide the needed plasma inputs, so we rely on data-driven modeling. We have developed a framework to utilize upstream measurements and propagate them to provide predicted plasma parameters in the wake [5]. Fig. 3 shows sample model outputs (in the solar wind), compared to measurements from the ARTEMIS probe transiting the wake.

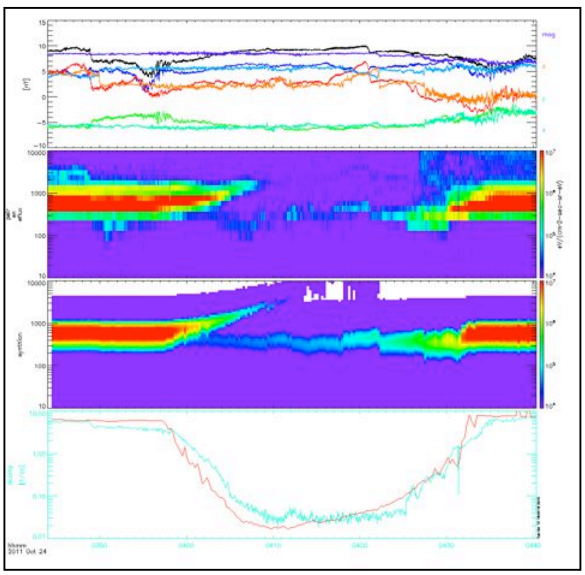

Figure 3: Data-based wake model, with measured magnetic field, measured ion spectra in the wake, modeled spectra from upstream inputs, and model (red) and measured (blue) densities compared.

Reflected Proton Measurements and Modeling. Incident solar wind protons reflect efficiently from small-scale lunar crustal magnetic fields [6], subsequently following complex cycloidal trajectories that depend on the solar wind flow and interplanetary magnetic field orientation. This population not only impacts the surface and exosphere, but constitutes a background for LDEX and NMS ion-mode measurements. We have developed a model to predict the fluxes of this population at the LADEE orbit [7] (see Fig. 4).

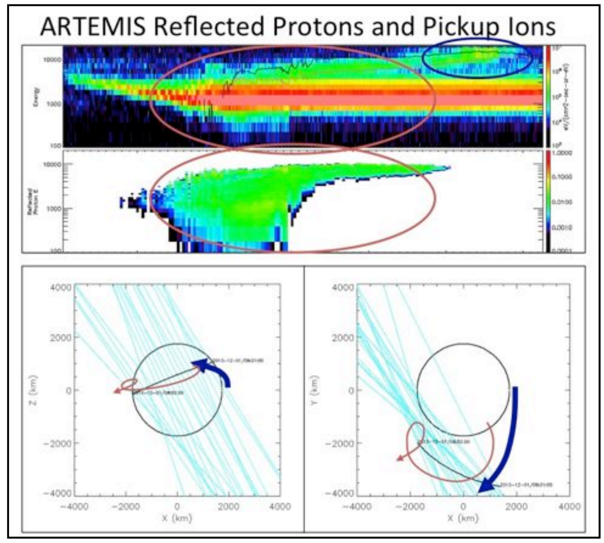

Figure 4: ARTEMIS measurements of reflected protons (brown) and pickup ions (blue) during a transit out of the wake, as compared to modeled reflected proton fluxes, with magnetic field vectors in light blue along with probe orbit and inferred ion trajectories.

Near-Surface Electrostatic Environment Measurements and Modeling. The near-surface environment through which ions and dust particles generated from the surface must travel is electrically complex, with variable field strengths and scales, and even non-monotonic structures [8]. We model these fields, as input to trajectory analysis for both ions and detached dust grains.

Pickup Ion Measurements and Modeling. LADEE detects the neutral exosphere both spectroscopically (UVS) and in situ (NMS). In addition, both LDEX and NMS are sensitive to low energy ions, while ARTEMIS measures exospheric pickup ions up to many keV (see Fig. 4). By comparing these various measurements, and utilizing ARTEMIS-measured fields to determine their trajectories and likely sources, we can obtain additional constraints on the sources, composition, and dynamics of the tenuous lunar atmosphere.

References: [1] Angelopoulos, V. (2011), *Space Sci Rev*, doi:10.1007/s11214-010-9687-2.
[2] Angelopoulos, V. (2008), *Space Sci. Rev., 141*, 5-34. [3] Hodges, R. R., and J. H. Hoffman (1974), *Geophys. Res. Lett., 1,* 69-71. [4]. Feldman, P.D., et al. (2012), *Icarus,* 10383. [5] Halekas, J.S., et al. (2013), in *Magnetotails in the Solar System,* Ed. A. Keiling. [6] Lue, C., et al. (2011), *Geophys. Res. Lett., 38,* L03202. [7] Halekas, J.S., et al. (2013), *Geophys. Res. Lett., 40,* 4544-4548. [8] Poppe, A., et al. (2011), *Geophys. Res. Lett., 38*, L02103.