LONG-TERM TRENDS IN THE LUNAR EXOSPHERE DERIVED FROM ARTEMIS PICKUP ION MEASUREMENTS. J. S. Halekas, A.R. Poppe, J.P. McFadden, Space Sciences Laboratory, University of California, Berkeley, CA 94720 (jazzman@ssl.berkeley.edu).

Introduction: The lunar exosphere's composition, structure, variability, and sources and sinks remain incompletely understood. Exospheric neutrals are part of a coupled system that includes the surface and the plasma. Micrometeorite bombardment creates a portion of the exosphere, as does solar UV, which in turn drives a primary loss process via photoionization. Charged particles, their interactions with the surface, and the electric and magnetic fields associated with them, also contribute to source and sink processes for exospheric gases. The LADEE mission, currently in orbit around the Moon, measures neutral exospheric gases using both spectroscopic and in situ measurements. However, the ~100 day LADEE science mission does not provide a long baseline with which to investigate long-term trends in the exosphere.

ARTEMIS: The ARTEMIS (Acceleration, Reconnection, Turbulence, & Electrodynamics of Moon's Interaction with the Sun) mission [1] provides measurements with complete coverage of the time period from late 2011 to the present, potentially allowing us to investigate long-term trends. ARTEMIS measures the ionized constituents of the exosphere ("pickup ions"), and also provides comprehensive measurements of charged particles and magnetic and electric fields around the Moon, allowing us to investigate whether the source of any observed trends in pickup ion fluxes depend on the ambient plasma conditions.

Observations: ARTEMIS lacks an ion mass composition instrument, and therefore can only measure a superposition of all pickup ion species. Rough constraints on mass can nonetheless be derived from the velocity vectors of observed ions, as shown by Halekas et al., [2].

The probability of one of the ARTEMIS probes observing pickup ions depends strongly on its orbital position and the magnetic field. For a probe to observe pickup ions in its equatorial orbit, the magnetic field must point nearly perpendicular to the ecliptic, so that the convection electric field that accelerates newly born pickup ions lies in the plane of the orbit. In addition, the probe has to be located at nearly the same X-position as the Moon, so that newly born pickup ions can travel from near the Moon to the probe. Fig. 1 shows a representative example of the preferred orbital geometry, indicating the locations of pickup ion detections consistent with sodium ions (these measurements contain contributions from a range of species surrounding mass 23) from both ARTEMIS probes.

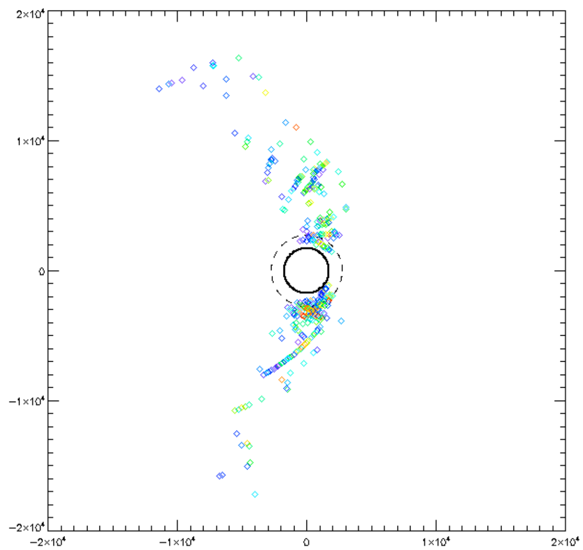

Figure 1: Location of ARTEMIS pickup ion detections consistent with Na^+, colored by log(flux), in SSE coordinates, from March-December 2013.

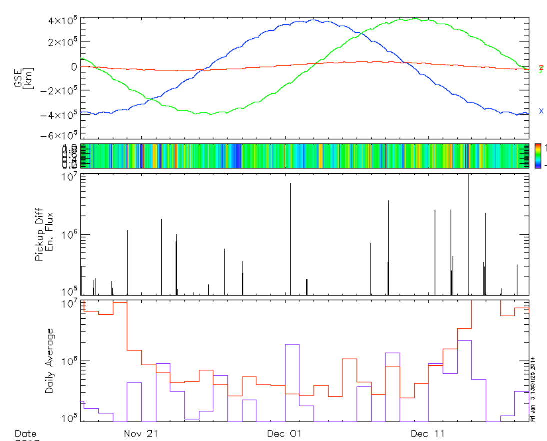

Figure 2: A month of pickup ion observations by P2, w/ GSE position, indicator statistic defining favorable observing geometry, total pickup ion differential energy flux, and daily average of pickup ion flux (blue) vs. total flux in pickup ion energy band (red).

Figure 2 shows one lunation of pickup observations from ARTEMIS P2. We consistently observe pickup ions at times with large positive values of an indicator statistic [defined as -1*Bz/B*Y/R] that encapsulates the conditions described above to observe pickup ions at the ARTEMIS orbit. Over the lunar orbit, we tend to see more pickup ion flux outside of the time period when the Moon transits the Earth's magnetotail (beginning and end of time period in Fig. 2). On the other hand, total fluxes in the pickup ion energy band increase at these times, due to the lower average flow velocity and the presence of more energetic flux from other sources in the magnetosheath and plasmasheet. Individual observations, which depend greatly on orbital geometry and other factors, display high variability, but daily averages show some consistent trends.

Long Term Trends: Early indications from a prelimary study of the most recent ten months of ARTEMIS data suggest that the lunar exosphere does not vary tremendously, though we do observe some moderate variability in pickup ion flux as a function of both lunar phase and time [Fig. 3].

The average observed pickup ion differential energy flux peaks just before and after the Moon's passage through the Earth's magnetotail (180°), as well as just before new Moon (0°), with a large decrease in the magnetotail itself. Before and after magnetotail crossings, the number of observations with flux over threshold also increases, while during the crossing we have few good observations. These trends result in part from the variation in the amount of time with favorable observing geometry, with large |Bz| occuring most commonly in the magnetosheath and least often in the magnetotail. The apparent increase in flux before and decrease at new Moon have no obvious explanation.

We also observe some trends as a function of time during the period we have thus far surveyed. In particular, we observe the largest pickup ion fluxes in December 2013. This increase is not obviously correlated with any events such as the Geminid meteor shower (which it partly predates), and may result from a fortuitous occurrence of favorable observing geometries.

We will compare observed trends for the ten lunations shown herein to the previous two years in order to better determine what factors may drive observed variations in pickup ion flux, and characterize their significance and repeatability. We will also investigate correlations with known meteor streams, as well as with solar wind conditions and UV intensity.

References: [1] Angelopoulos, V. (2011), *Space Sci Rev*, doi:10.1007/s11214-010-9687-2. [2] Halekas, J., et al. (2012), *J. Geophys. Res., 117*, E06006.

Figure 3 (Below): Trends in pickup ions for ten lunations of observations, from March to December 2013. The top three panels show average pickup ion differential flux for observations with flux over threshold, number of such observations, and number of opportunities with favorable observation geometry, as a function of lunar phase. The bottom three panels show the same three quantities as a function of time (lunation).