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THE IMPORTANCE OF NIGHTSIDE MAGNETOMETER OBSERVATIONS FOR ELECTROMAGNETIC SOUNDING OF THE MOON

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Abstract

Understanding the structure and composition of the lunar interior is a fundamental goal in furthering our knowledge of the formation and subsequent evolution of the Earth-Moon system. Among various methods, electromagnetic sounding is a valuable approach to constraining lunar interior structure. Recent analyses of plasma and field observations provide a wealth of understanding about the dynamics of the lunar plasma environment. To perform Time Domain EM (TDEM) Sounding at the Moon, the first step is to characterize the dynamic plasma environment, and to be able to isolate geophysically induced currents from concurrently present plasma currents. The TDEM Sounding transfer function method focuses on analysis of the nightside observations when the Moon is immersed in the solar wind. This method requires two simultaneous observations: an upstream reference measuring the pristine solar wind, and one downstream at or near the lunar surface. This method was last performed during Apollo and assumed the induced fields on the nightside of the Moon expand as in an undisturbed vacuum within the wake cavity. Our results indicate that EM sounding of airless bodies in the solar wind must be interpreted via self-consistent plasma models in order to untangle plasma and induced field contributions, with implications not only at the Moon but at all airless bodies exposed to the solar wind. **Nightside TDEM sounding has the capability to advance the state of knowledge of the field of lunar science.** This requires magnetometer operations to withstand the harsh conditions of the lunar night.

Background & Motivation

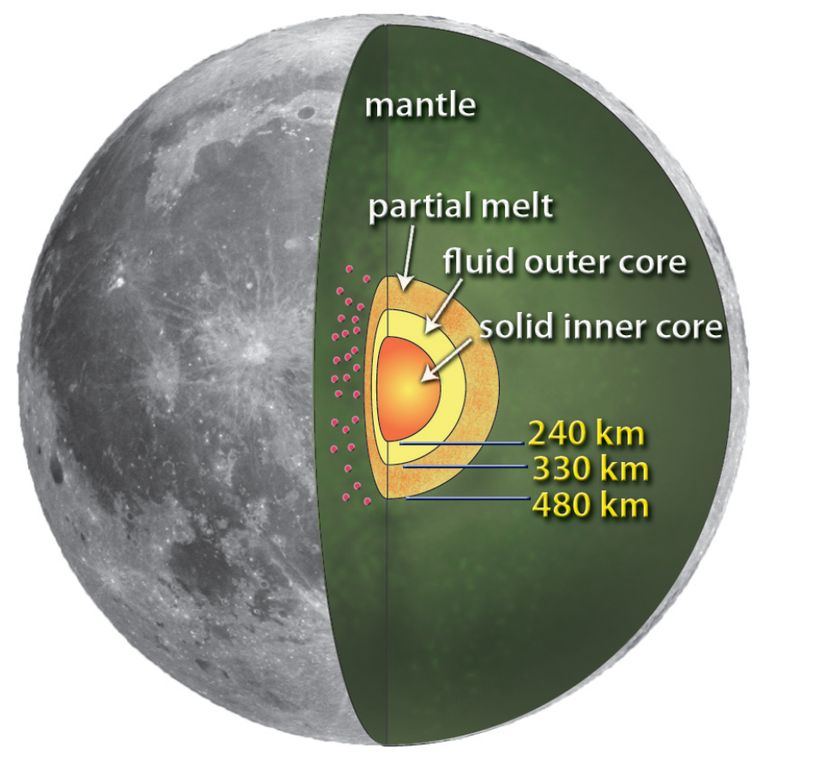


Figure 1. A summary of the lunar interior based on Apollo seismic analyses, stations shown in green on Lunar nearside [17].

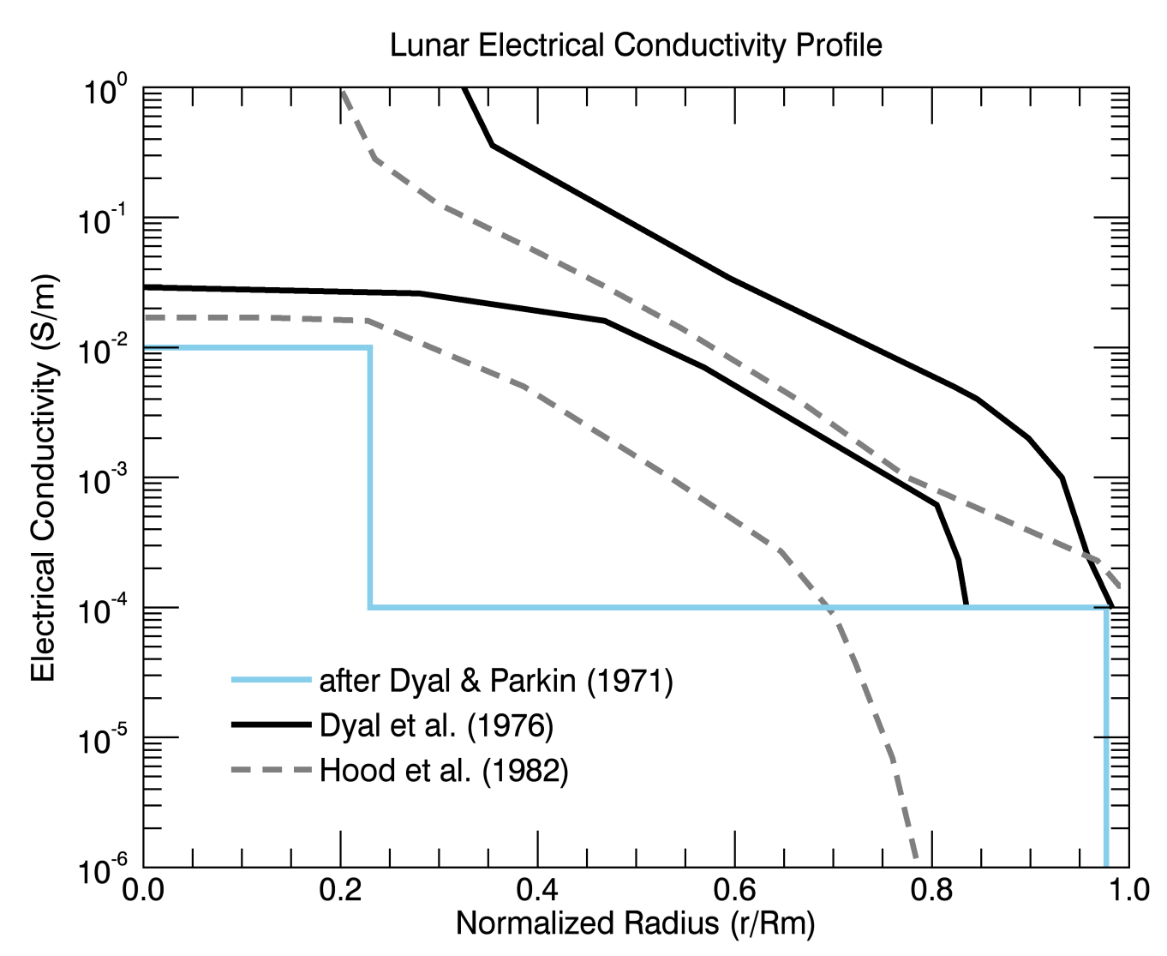


Figure 2. Summary of observed lunar conductivity profiles from Apollo and Lunar Prospector data. Blue profile indicates 3 layer model.

- The electrical conductivity of interior conducting layers of the Moon interact directly with spatiotemporal changes in IMF fields, Fig.1, 3(a).
- The nightside time domain induced response of the Moon is dependent on diamagnetic wake current systems, which act as boundary conditions, Figure 3 (c). Vacuum response is in Figure 3 (b).
- Here we study the response of a transient-induction plasma hybrid model to determine the nightside asymmetric induced response at the Moon an important step to determining interior properties of the Moon.
- Magnetometer specifications used for TDEM are provided in table.

Apollo 12 Lunar Surface Magnetometer (launch 1969) [20]	ARTEMIS Fluxgate Magnetometer (launch 2007) [18,19]
Range: 0-+/-400 nT	Offset stability: <0.2 nT/12 hr
Resolution: 0.2 nT	3 pT
Frequency Range: DC to 3 Hz	DC to 128 Samples/s
Power: 3.4 W average daytime	800 mW
Weight: 8.9 kg	Sensor (75 g), Harness (150g or 60 g/m), Electronics(150g)
Size: 25 X 28 x 63 cm	Sensor (d:70, h:45mm), Board (100 mm × 120 mm)

Day and Nightside Plasma Processes

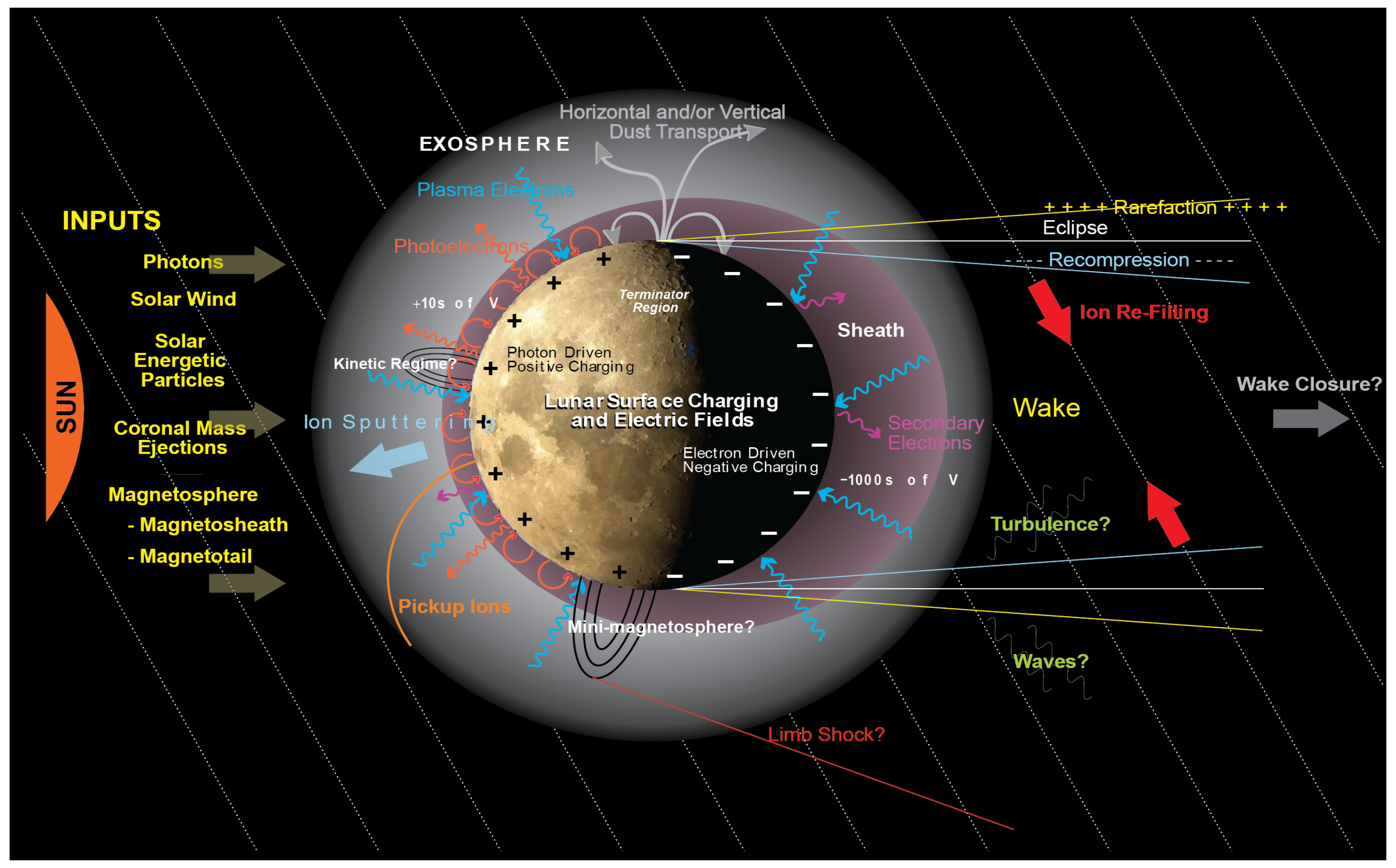


Figure 4. Day and nightside plasma processes behave differently. EM Sounding at the moon requires a full characterization of the plasma environment in which the magnetometer observations are taken. Dayside induced fields are confined within the lunar sunlit surface. Nightside induced fields interact with the plasma wake. *Delory, 2013, personal communications.*

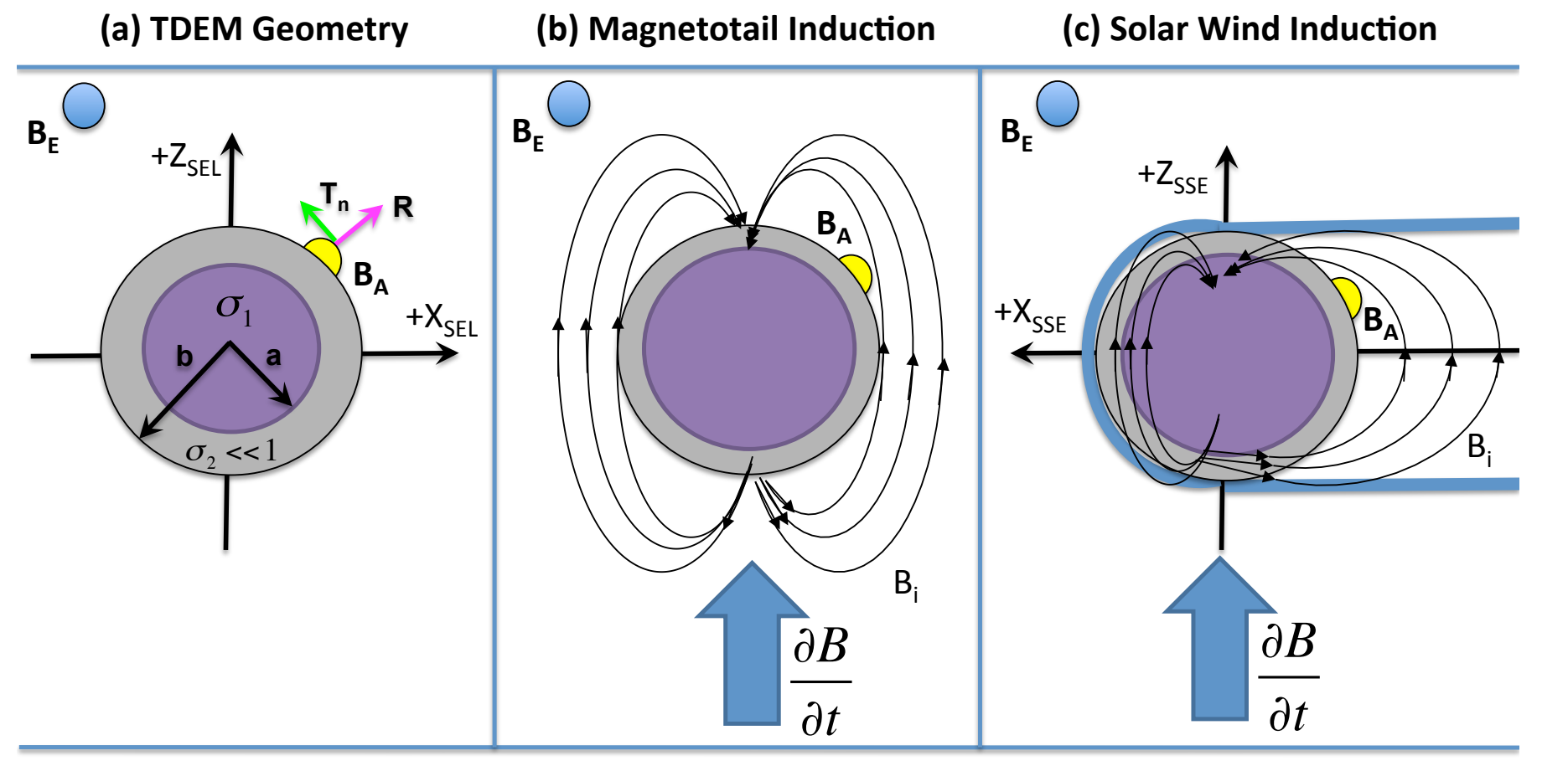


Figure 3. (a) TDEM Sounding requires an observer at or near the lunar surface (B_A) and a reference well outside of lunar effects (B_E). The induced magnetic field, B_I , opposes the external field, B_E. Boundary conditions vary: (b) vacuum, (c) Solar wind varies day and night-side confinement [7].

Case Study: Wake and Interior Fields

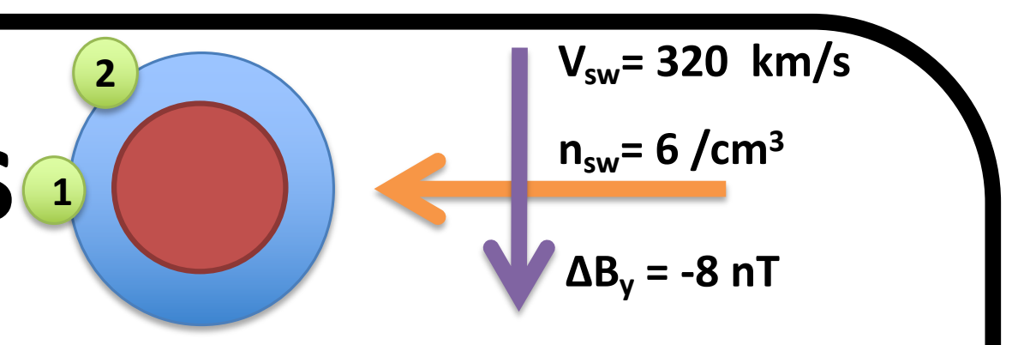
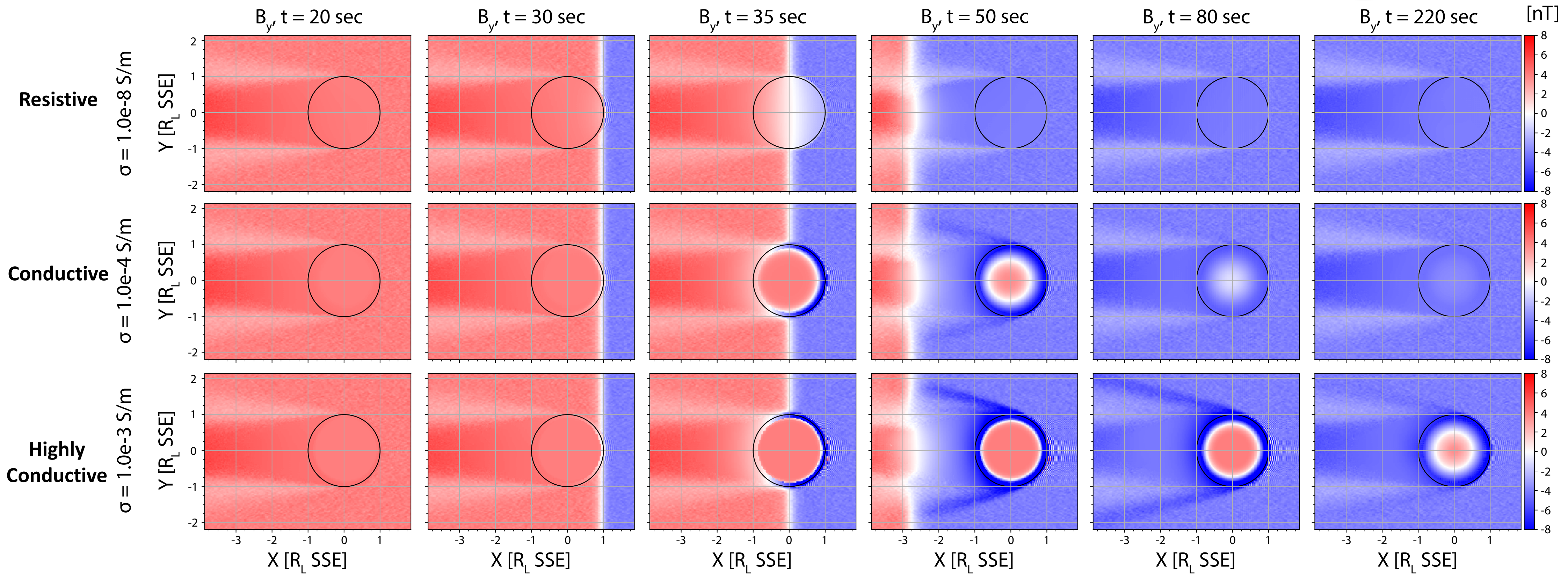
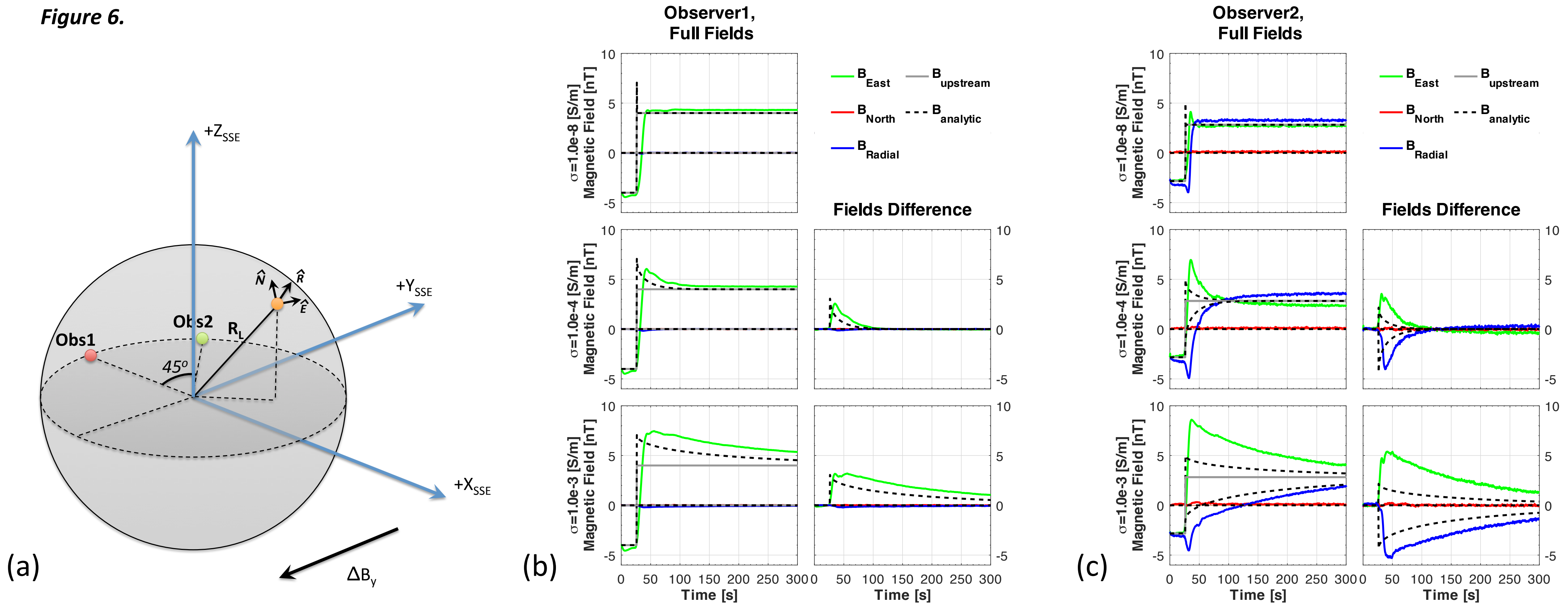


Figure 5.



- **Figure 5:** The y-component of the magnetic field is plotted for three interior conductivities, at six time steps. The diamagnetic wake current systems responding to the transient event is captured in the resistive case (top row).
- The wake current systems are influenced by the presence of time decaying induced fields (t=75s).
- **Figure 6:** The total field observed at two nightside surface locations is compared against a vacuum analytic response [2] for all three components.
- Diamagnetic wake fields dominate the signal from ~50-100s. The long period signal preserves interior conductivity. Exponential decay, as predicted by analytic theory, is not observed, but a near linear coupled induction-plasma response providing pressure balance.

Figure 6.



Summary

- Day and Nightside plasma conditions are distinct.
- Differences in Apollo Day and Nightside EM Sounding analyses remain over an order of magnitude in mantle conductivity.
- Solar wind and plasma wake processes are better characterized than other plasma locations (such as the Magnetotail), providing the ideal location for two point EM Sounding analyses.
- Nightside magnetometer observations are critical to fully characterizing the lunar subsurface.

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