FINE-SCALE MAPPING OF MARE FLOW UNITS WITH MINI-RF BISTATIC DATA G. A. Morgan[1], B. A. Campbell[2], L. M. Jozwiak[3], A. M. Bramson[4,5], G. W. Patterson[3], J. Cahill[3], C. Nypaver[6], and the Mini-RF team [1]Planetary Science Institute, Washington DC, gmorgan@psi.edu. [2]National Air and Space Museum, Smithsonian Institution, Washington DC, [3]Johns Hopkins Applied Physics Laboratory, Laurel, MD, [4]University of Arizona, Lunar and Planetary Laboratory, [5]Purdue University, Department of Earth, Atmospheric, and Planetary Science. [6]The University of Tennessee, Knoxville.

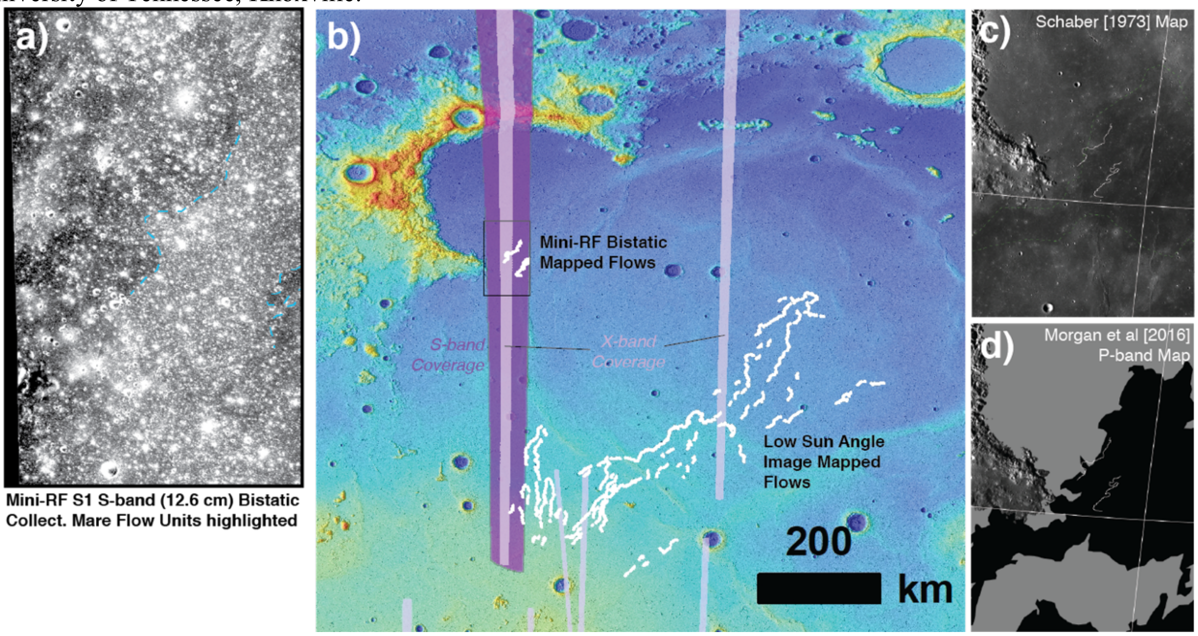

Figure 1*. Mapping mare flow boundaries in Mare Imbrium with Mini-RF bistatic data. (a) Flow unit boundaries identified in S-band data. (b). S and X-band coverage of Mare Imbrium. Flow units easily identifiable in low sun angle LROC data occupy the southern and central portions of the basin. Flow units overlain on Schaber et al [1973] albedo based map (c) and Morgan et al [2016] P-band radar based map.* ***Note:*** *the SE flow boundary is not observable in any of the non-Mini-RF based data.*

Introduction: The 6.5 $\times 10^6$ km^2 of basaltic flows that make up the lunar maria [1] represent the result of the most fundamental endogenic process to have resurfaced the face of the Moon. The lunar mare also provide a record of the thermal evolution of our nearest neighbor and provide an insight into how similar sized rocky bodies across the universe lose their heat. Unfortunately for researchers, in contrast to the Earth, Venus, and Mars, the majority of individual mare flow morphologies are subdued and further are masked by impact regolith. Reconstructing the volcanic history of the maria is therefore not straightforward. Here we document a new radar based approach to conducting fine-scale mapping of mare flows.

Mapping the Mare: In order to map the eruptive units that comprise the surface of the mare and investigate the associated stratigraphic relationships, studies have: used image/topographic data to map flow margins [2], exploited mineralogical variations inferred from ultraviolet-near infrared (UV-NIR) spectral data [e.g. 3-5], and, more recently used Earth-based P-band (70 cm) radar data to map flow units based on TiO_2 content [6-7] (Fig 1).

Radar Mapping: Earth-based P-band radar studies of Mare Serenitatis and Mare Imbrium [6-7] have found that:

- P band radar signals can probe the full depth of the mare regolith, resulting in backscatter from the blocky remains of the mare flows.
- Radar echoes are highly sensitive to the microwave loss properties of the regolith, which are in turn modulated by the ilmenite content of the original lava flows from which the regolith originated.
- Tracking broad variations in backscatter, therefore, provide a means to map flow units based on their TiO_2 content.

Mini-RF on the Lunar Reconnaissance Orbiter is currently undertaking unique bistatic radar measurements in conjunction with the Arecibo (Puerto Rico) and Goldstone (southern California) observatories. Operating in S (12.6 cm) and X-band (4.2 cm) the resulting datasets are complementary to the longer wavelength (fully) Earth-based P-band data. We have been targeting the lunar mare with Mini-RF to continue our mapping efforts and enhance our understanding of the influence of TiO_2 content on the attenuation of the radar signal.

Why Conduct multi-frequency/bistatic observations?: Studying the variations in the power returned over a range of bistatic angles can impart important information about the geology of the near surface, including regolith maturity and composition [8]. Experimenting with different phase and incidence angles therefore provides another means to explore mare radar attenuation including possibly teasing out additional variations in TiO_2 content not identified from previous Mini-RF monostatic and Earth-based bistatic measurements. As the depth of penetration is governed by the transmitted wavelength, comparing the X to S-band response over the same regions will provide information on regolith attenuation.

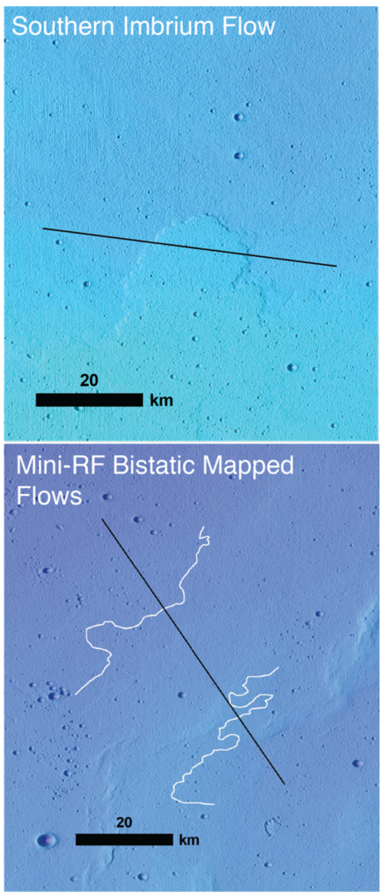

Figure 2*. Transect line across previously identified (top) and Mini-RF identified (bottom) mare flows. LOLA/SELENE DTM [Barker et al., 2016]*

Mare Imbrium: Hosts basaltic units that display a wide range of TiO_2 content [e.g. 9] and thus represents an excellent site to explore radar mapping techniques. Additionally, some of the sharpest topographically defined mare flows are found in Mare Imbrium (Fig 2–3) enabling us to easily compare image and topography based mapping with our radar-based approach. Using the [7] P-band map as a guide to targeting units that display sharp contrasts in radar backscatter, we have to date, conducted two S-band and five X-band data collects of Mare Imbrium (Fig. 1).

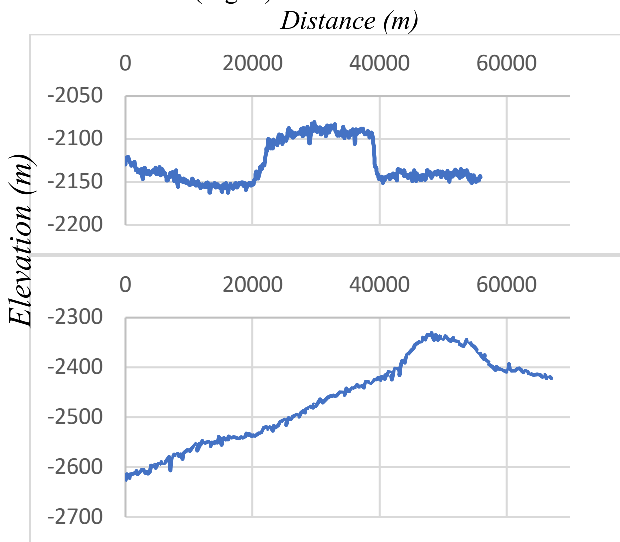

Figure 3. *Topographic profiles to accompany the transects in Fig. 2. Note the Southern Imbrium Flow is topographically distinct, whereas only the wrinkle ridge profile can be identified across the radar detected flow.*

Initial Results: Evidence of a flow boundary was only found in one of the S-band bistatic collects. The accompanying X-band data did not show the same flow boundaries. This was expected as the X-band signal will not penetrate as deep as the S-band, and thus will be less effected by the attenuating effects of the TiO_2 content of the flows. Unlike the southern/central Imbrium flows there are no topographic signatures associated with the Mini-RF mapped flow units (Fig. 2–3), however the NW flow boundary does show good agreement with previous albedo and radar based mapping (Fig. 1).

During the 51st LPSC we will consider the reasons why the SE boundary is not visible in the non-Mini-RF datasets. Several, lobate features can also be seen within the SE boundary, which possibly represent individual flows. We will compare these putative flows with other lunar examples to establish if there is any apparent differences in emplacement styles.

References: [1] Head, 1975, Conf. Origins of Mare Basalts and their Implications for Lunar Evolution. LPI, p66. [2] Schaber, 1973, Proc. Lunar. Planet. Sci. Conf., 4(1), 73–92, [3] Soderblom, et al., 1977, Proc. Lunar Sci. Conf., 8th, 1191–1199. [4] Pieters, 1978, Proc. Lunar Planet. Sci. Conf., 9th, 2825–2849. [5] Hiesinger, et al., 2000, JGR, 105, 29,239–29,275. [6] Campbell et al., 2014, JGR, 119, 313–330. [7] Morgan et al., 2016. JGR, 121, 1498–1513 [8] Sato, H., et al., 2017, Icarus, 296, 216-238.Hapke et al. 1998, *Icarus*, 133, 89-97. [9] Patterson, et al. 2017, *Icarus*, 283, 2-19.