MINI-RF EVIDENCE FOR WATER ICE AT THE POLES OF THE MOON P. D. Spudis[1], D.B.J. Bussey[2] and the Mini-RF Team 1. Lunar and Planetary Institute, Houston TX 77058 (spudis@lpi.usra.edu) 2. Applied Physics Laboratory, Laurel MD 20723

The existence of ice in the polar cold traps of the Moon has been debated for many years [1, 2]. Lunar Prospector found enhanced hydrogen levels in the polar regions [3]. The question was whether this hydrogen is present in the form of water ice [2]. Mini-RF is a synthetic aperture radar that flew on both the Indian Space Research Organization's Chandrayaan-1 mission to the Moon and on NASA's Lunar Reconnaissance Orbiter spacecraft [1]. Mini-RF is designed to map the permanently dark areas of the lunar poles and characterize the nature of the deposits there.

Mini-RF uses an unusual analytical approach to look for ice [4]. Traditionally, the key parameter used to determine if ice is present is the circular polarization ratio (CPR). This quantity is defined to be the magnitude of the same sense (i.e., the left or right sense of the transmitted circular polarization) divided by the opposite sense polarization signals that are received. Volumetric water-ice reflections are known to have CPR greater than unity, while surface scattering from dry regolith has CPR less than unity [2]. Mini-RF transmits a left-circular polarized signal and receives coherently the linear Horizontal and Vertical polarizations. This hybrid architecture preserves all of the information conveyed by the reflected signals [4]. From these data, all four Stokes parameters of the backscattered field are fully recoverable. These characterizations are critical to determine if the returned signal is caused by an ice-regolith mixture, or simply rocks on the lunar surface.

Mini-RF obtains data in S-band (2380 MHz, 12.6 cm) or X-band (7140 MHz, 4.5 cm) has an illumination incidence angle of 48°, and image strips have spatial resolution of 30 or 150 meters. Because the instrument looks off-nadir, there is a gap in SAR coverage within a couple of degrees of latitude around both poles. Portions of these gaps in coverage were partly filled by high-incidence angle SAR obtained by rolling the spacecraft slightly. Our data products include complete maps of both polar regions of the Moon at 15 and 75 m/pixel in both wavelengths. These images consists of Stokes parameters and derived maps of CPR and other Stokes "daughter" products, including degree of linear polarization [4].

Both poles have been well covered by Mini-RF data. The polar regions display backscatter properties typical for the Moon, with circular polarization ratio (CPR) values in the range of 0.1- 0.3, increasing to > 1.0 for young primary impact craters. These high CPR values likely reflect a high degree of surface roughness associated with these fresh features [5]. We have identified a group of craters in the north polar region that show elevated CPR (between 0.6 and 1.7) in their interiors, but no enhanced CPR in deposits exterior to their rims ([5], typical CPR values ~0.2 to 0.4; Fig. 1). Almost all of these features are in permanent sun shadow and correlate with proposed locations of polar ice modeled on the basis of Lunar Prospector neutron data [6]. The high interior and low exterior CPR are seen in data taken at both wavelengths and from opposite look directions, so it is a property of the Moon, not an observational artifact. These relations are consistent with deposits of water ice in these craters [5]. The south polar region shows similar relations, except that it has more extensive low CPR terrain and fewer anomalous high-CPR interior craters. Small areas of high CPR are found in some south pole craters, notably Shoemaker and Faustini; these areas might be deposits of water ice. Additionally, recent studies of the interior of Shackleton suggest patchy ice deposits may occur within this crater [7]. Modeling the response of mixtures of lunar regolith with varying degrees of ice and comparison with Mini-RF data for these anomalous craters supports the interpretation that the craters contain variable amounts of water ice [8]. Work continues to more fully understand the properties of these anomalous craters and ice at the poles.

References [1] Spudis P.D. *et al*. (2009) *Current Science* (India) **96**, 533; Nozette S. *et al*. (2010) *Space Science Reviews* **150**, 285-302 [2] Spudis P.D. (2006) *The Space Review* http://tinyurl.com/5g8kf4 [3] Feldman W. *et al.* (2001) *JGR* **106**, 23231 [4] Raney R. K. *et al*. (2010) *Proc. IEEE* **99**, 1-6, 10.1109/ JPROC. 20102084970 [5] Spudis, P. D. *et al*. (2010) *Geophys. Res. Lett*. **37**, L06204, doi:10.1029/2009GL042259 [6] Eke V.R. *et al.* (2009) *Icarus* **200**, 12-18 [7] Thomson B.J. *et al*. (2011) *Lunar Planet. Sci.* **XLII**, 1626 [8] Thompson, T. W. *et al*. (2011) *JGR* **116**, E01006, doi:10.1029/2009JE003368

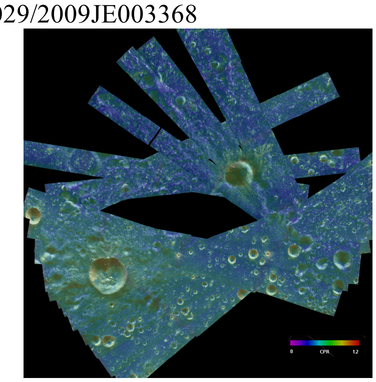

Fig. 1 CPR map of the lunar north pole. Small craters with high interior CPR and low exterior CPR probably contain deposits of water ice [5].