Constraints from Diviner Lunar Radiometer Data for Future Lunar Landing Sites B. T. Greenhagen[1], D. A. Paige[2], and the Diviner Science Team, [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA; [2]University of California, Los Angeles, CA, USA. Email: Benjamin.T.Greenhagen@jpl.nasa.gov

Introduction: The Diviner Lunar Radiometer is the first multispectral thermal instrument to globally map the surface of the Moon. This unprecedented and growing dataset is revealing the extreme nature of the lunar thermal environment, thermophysical properties , and surface composition. Diviner data provide new constraints for future landing site selection.

Diviner Lunar Radiometer: Launched onboard LRO in June 2009, the Diviner Lunar Radiometer is a nine channel pushbroom mapping radiometer designed to measure broadband reflected solar radiation (two channels) and emitted thermal infrared radiation (seven channels) between 0.3 and 400 µm at spatial resolutions ranging from 0.2 to 1.3 km [1]. The two solar reflectance channels both span 0.3 to 3 µm and are used to characterize the photometric properties of the lunar surface. The three shortest wavelength thermal infrared channels (ch 3: 7.55-8.05 µm; ch 4: 8.10-8.40 µm; ch 5: 8.38-8.68 µm) were specifically designed to characterize the mid-infrared Christiansen Feature [2]. Diviner's longer wavelength thermal infrared channels span the mid- to far-infrared between 13 and 400 µm and are used to characterize the lunar thermal environment, including thermophysical properties such as rock abundance and surface roughness. [1]

After more than two years of nearly continuous mapping, Diviner has now acquired observations over four complete diurnal cycles and two complete seasonal cycles. Diviner daytime and nighttime observations cover approximately 80% and 90% of the surface area of the moon, respectively. Calibrated Diviner data and global maps of visible brightness, brightness temperature, bolometric temperature, rock abundance, nighttime soil temperature, and silicate mineralogy from the first year of the LRO Mapping Orbit are available through the PDS Geosciences Node [3,4].

Thermal Environment: The complex and extreme lunar thermal environment posses challenges for future landed missions, but it also provides opportunities. Surface temperatures in equatorial regions such as the Apollo landing sites are close to 400K at noon, and less then 100K at night, with annual average temperatures at depth of approximately 250K [5]. Diviner has mapped the entire Moon over a full year and has located areas that have subsurface temperatures that are significantly hotter and colder than latitudinal averages. These thermally atypical regions are of interest to future mission planners to extend the range of latitudes and the range of lunar environments that can be accessed, explored and sampled [5].

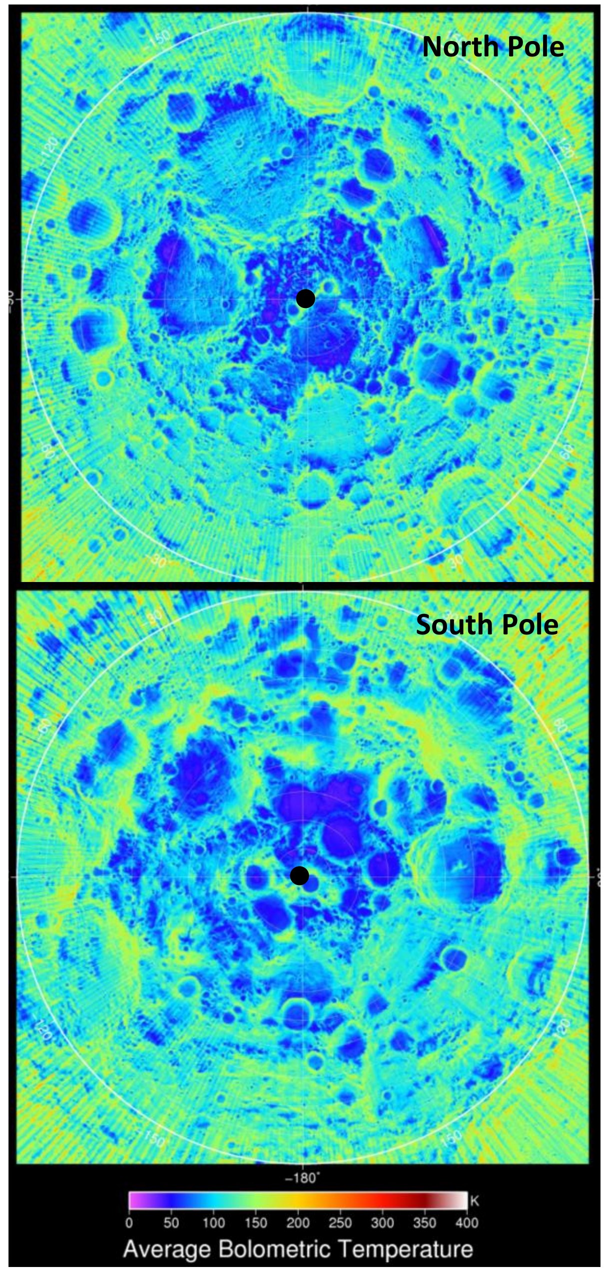


Figure 1: Maps of average bolometric temperature for the North (top) and South (bottom) Poles. Outer latitude ring is 80 degrees. Data stripping at lower latitudes is caused by a lack of overlapping coverage at all local times.

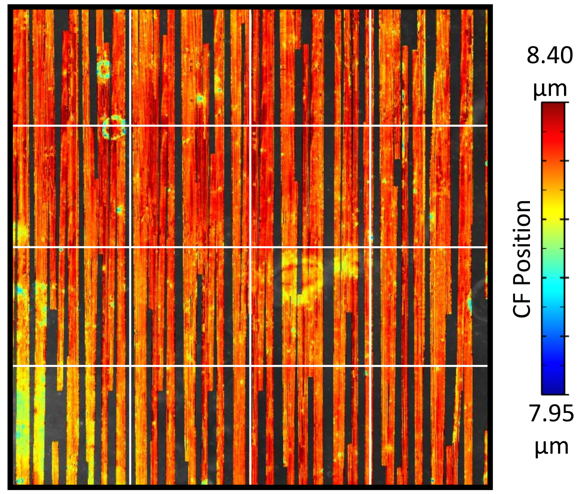
Polar Volatiles. Diviner's thermal mapping results place strong constraints on the thermal stability of polar volatiles. In the lunar polar regions there are large areas within permanently shadowed craters with annual average temperatures of less than 50K (Fig. 1). These regions are cold enough to permit the stability of water ice, as well as a range of more volatile and less volatile compounds. Frozen volatiles are thermally stable below the surface in large regions surrounding permanently shadowed areas within ~10 cm of the surface. [6]

Silicate Mineralogy: Diviner was designed to characterize the Christiansen Feature (CF) and constrain lunar silicate mineralogy [2]. The CF is tied to the fundamental vibrational band and shifts to shorter wavelengths with increasing polymerization of the SiO_4 tetrahedra (e.g. quartz and plagioclase feldspar exhibit CFs at shorter wavelengths than less polymerized pyroxene and olivine) [e.g. 7]. Also, given the relatively restricted geochemistry of the lunar surface (plagioclase feldspars have little Fe and higher Al and Ca; pyroxenes and olivines have high Fe and/or Mg and essentially no Al), Diviner measurements of CF position can be use to infer some geochemical abundances such as FeO [8].

South Pole Aitken Basin. Diviner data provide an important constraint on plagioclase abundance that can be used to infer the amount of country rock mixing [2]. This is a critical quantity for evaluating high value SPA Basin targets that have been identified using near-infrared spectroscopy. The use of near-infrared datasets with Diviner data reveal more than either dataset individually.

Silica-rich Sites. Diviner data have been used to confirm the presence of high silica minerals such as quartz or alkali feldspar for several lunar “red spots” and the Compton Belkovich anomaly on the lunar farside [9,2]. This class of landing site offers a unique opportunity to study evolved lunar crust and siliceous lunar magmatic processes.

Rock Abundance and Surface Roughness: Surface hazards for future landing sites include rock abundance and surface roughness. Both the presence of rocks in a predominately particulate surface and surface roughness induce variable temperatures or anisothermality within a given Diviner pixel. Anisothermality causes a wavelength difference in apparent brightness temperature. By using multispectral Diviner observations, it is possible to assess the magnitude of anisothermality and quantify the surface coverage of rocks, the temperature of the rock-free regolith, or the approximate RMS roughness of the surface. [10]



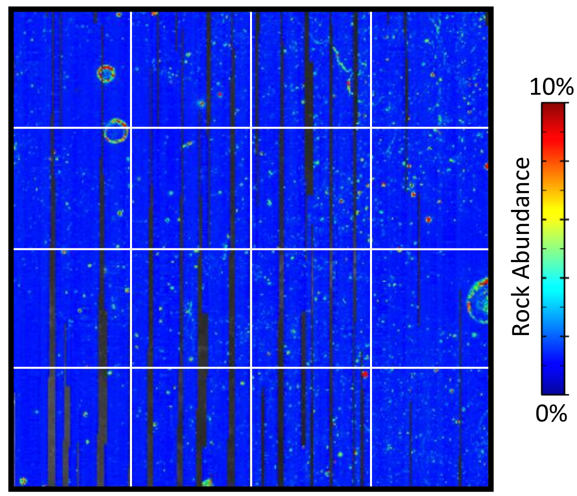


Figure 2: Examples of Diviner composition and rock abundance data products for the Rainer Gamma region. The map of CF position (top) shows variations in composition and space weathering across the scene. The rock abudance map highlights small fresh craters and the walls of larger, older craters. Latitude and longitude lines are drawn at 2.5 degree increments around -60E / 8N. Diviner data are overlain on the Clementine v2 basemap.

References: [1] Paige D.A. *et al*. (2010) *SSR*, *150*, 125. [2] Greenhagen B.T. *et al*. (2010) *Science*, *329*, 1507. [3] Paige D.A. *et al*. (2011) LPSC XLII, #2544. [4] Greenhagen B.T. *et al*. (2011) LPSC XLII, #2679. [5] Paige D.A. *et al*. (2011) *JGR*, submitted. [6] Paige D.A. *et al*. (2010) *Science*, *330*, 479. [7] Logan L.M. *et al*. (1973) *JGR*, *78*, 4983. [8] Allen C.C. *et al*. (2011) LEAG (this mtg). [9] Glotch T.D. *et al*. (2010) *Science*, *329*, 1510. [10] Bandfield J.L. *et al*. (2011) *JGR*, in press.