THERMAL, THERMOPHYSICAL, AND COMPOSITIONAL PROPERTIES OF THE MOON REVEALED BY THE DIVINER LUNAR RADIOMETER.

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Introduction: The Diviner Lunar Radiometer is the first multispectral thermal instrument to globally map the surface of the Moon. After over three years in operation, this unprecedented dataset has revealed the extreme nature of the Moon's thermal environment, thermophysical properties, and surface composition.

Diviner Lunar Radiometer: The Diviner Lunar Radiometer is a nine-channel, pushbroom mapping radiometer that was launched onboard the Lunar Reconnaissance Orbiter in June 2009. Diviner measures broadband reflected solar radiation with two channels, and emitted thermal infrared radiation with seven infrared channels [1]. The two solar channels, which both span 0.3 to 3 μm, are used to characterize the photometric properties of the lunar surface. The three shortest wavelength thermal infrared channels near 8 μm were specifically designed to characterize the mid-infrared "Christiansen Feature" emissivity maximum, which is sensitive to silicate composition [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 and thermophysical properties [3,4].

In more than three years of operations, Diviner has now acquired observations over six complete diurnal cycles and three complete seasonal cycles. Diviner daytime and nighttime observations (12 hour time bins) have essentially global coverage, and more than 75% of the surface has been measured with at least 6 different local times. The spatial resolution during the mapping orbit was ~200 m and now ranges from 150 m to 1300 m in the current elliptical orbit. Calibrated Diviner data and global maps of visible brightness temperature, bolometric temperature, rock abundance, nighttime soil temperature, and silicate mineralogy are available through the PDS Geosciences Node [5,6].

Thermal Environment: The lunar thermal environment is complex and extreme. Surface temperatures in equatorial regions such as the Apollo landing sites are close to 400K at noon and less than 100K at night, with annual average temperatures at depth of approximately 250K [7]. Diviner has mapped the poles at diurnal and seasonal temperature extremes and the data show that large areas within permanently shadowed craters have annual average temperature less than 50K [3]. The coldest multiply-shadowed polar craters have temperatures low enough to put constraints on lunar heat flow [8]. Diviner data have also been used to estimate the thermal properties of non-polar permanently shadowed regions [9].

Thermophysical Properties: Diviner is directly sensitive to the thermophysical properties of the lunar surface including nighttime soil temperature, rock abundance, and surface roughness. Although much of the Moon has uniform regolith thermal properties, some fresh impact craters cool to lower than normal temperatures. Hundreds of these "cold spots" have been observed distributed across all lunar terrain types and may indicate a fluffier surface layer [4]. By modeling the higher thermal inertia of rocks, which stay warmer than lunar soil at night we have demonstrated the ability to quantify the areal rock fraction [4]. Diviner is also sensitive to surface roughness on the mm scale and the multispectral nature of the dataset has been used to model RMS surface slopes and show that on these scales the maria are generally rougher than the highlands (Figure 4).

Compositional Properties: Diviner was designed to characterize the Christiansen Feature (CF) and constrain lunar silicate mineralogy [2]. The CF is tied to the fundamental SiO_2 vibrational band and shifts to shorter wavelengths with increasing silicate polymerization. Leveraging the relatively restricted geochemistry of the lunar surface, we have used Diviner observations of Apollo sites, and laboratory measurements of Apollo soils to infer some geochemical abundances (e.g. FeO) [10]. Diviner is sensitive to the presence of high silica minerals such as quartz or alkali feldspar and has been used to localize these minerals on the lunar surface [11,2]. Diviner data also provided an important constraint on plagioclase abundance that can be used to infer the amount of country rock mixing [2] and when combined with near-infrared datasets can reveal more than either dataset individually.

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