**Thermal Gradient Of Regolith In Lunar South Polar Region Inferred From LRO Diviner And CE-2 MRM Data.** J. Feng, M. A. Siegler, P. O. Hayne, Planetary Science Institute (1700 East Fort Lowell, Suite 106 Tucson, AZ 85719-2395, jfeng@psi.edu), University of Colorado, Boulder.

**Introduction:** Lunar polar region is an ideal place to study the thermophysical properties of lunar regolith at low temperatures (<100 K). The long-term stability of water ice in the permanent shadowed region (PSR) depends on regolith’s subsurface temperature and thermal properties. Previous studies [1] show the thermal inertia of lunar regolith fines are remarkably uniform. However, Far-ultraviolet reflectance properties indicates that the surface regolith in PSRs may have much larger porosities than non-PSR regions [2]. Also, extremely low temperatures in PSRs (as low as 20 K) are observed by Lunar Reconnaissance Orbiter (LRO) Diviner Lunar Radiometer Experiment [3], revealing apparently lower thermal inertia than explainable by existing theory.

Woods-Robinson et al. [4] derive a semiempirical model of specific heat and thermal conductivity of lunar regolith in a temperature range of 20-400 K from measurements of lunar simulants. Their results show the thermal conductivity is as much as an order of magnitude lower than expected from current models. To better understand the thermal behavior of regolith in lunar polar region, we use the data from Diviner and Chang’e-2 (CE-2) microwave radiometer (MRM) to estimate subsurface density, thermal gradients and conductivities.

**Data set:** The CE-2 MRM measured the brightness temperature ($T_B$) of the moon in 2010-2011 with a space resolution of approximately 25 km at 3 GHz and 17.5 km at 7.8, 19.35, 37 GHz. The overlapping ratio between adjacent observations is very high along the track (~ 80%). Also, near the pole the MRM measurements is much denser than low latitude. This gives a feasibility to make higher resolution maps in polar regions. South-polar maps of mean $T_B$ at 3 GHz and 19.35 GHz with a resolution of 5 km are made. The $T_B$ at 3 GHz at terminator orbit is excluded because of contamination on calibration horn [5].

Diviner is a nine-channel visible and infrared instrument which has been observing the Moon for over 10 years. It provides an excellent constraints of surface temperature variation in polar region. Recently [3] compiled these data into polar maps of the summer and winter seasonal temperatures at a resolution of 120 m. We average the yearly temperature and resample the map into 5 km/pixel. To simulate the convolution effect of MRM data, the map is smoothed by mean filtering with a window of 5×5.

**Approach and Methods:** Using the 1-D thermal model described in [1] and [5], we simulate the temperature profile of the regolith at ~85°. Due to low temperature at high latitude area, the radiative component in thermal conductivity becomes very small. As a result, the mean temperature profile is almost linear from top to the bottom.

Thus, the mean temperature profile of a specific location could be expressed by

$$\overline{T}(x) = \overline{T_B} + bx,$$

where $\overline{T}(x)$ is the mean temperature at depth of $x$, $\overline{T_B}$ is the mean surface temperature and $b$ is the average thermal gradient. According to the 1-D incoherent radiative transfer model [6], the $T_B$ of a semi-infinite scatter-free homogeneous medium under nadir observation is given by

$$T_B = (1 - \Gamma) \int_0^{\infty} \kappa \alpha T(x) e^{-\kappa x} dx,$$

where $\Gamma$ is the reflectivity on the boundary and $\kappa$ is the power absorption coefficient which is a function of frequency, dielectric permittivity and loss tangent.

To simplified the calculation, we assume the lunar regolith has a uniform density from the top to the bottom. Substituting formula (1) to equation (2), we can derive the formula of mean $T_B$ of regolith:

$$\overline{T}_B = (\overline{T}_B + bx) (1 - \Gamma),$$

where the $\overline{T}_B$ is measured by Diviner and $\overline{T}_B$ is observed by CE-2 MRM. $\Gamma$ and $\kappa$ can be determined once the density of regolith is selected. To reflect the low density
suggested in [2, 3], a density of 1.1 g/cm$^3$ is used at all depths in this study. $b$ is the only unknown.

Due to the calibration error of absolute value which is recognized by previous studies [5, 7], 3-GHz data, which are relatively constant with time, are only utilized to calculate the relative thermal gradient. As the 19.35-GHz $T_B$ vary with local times and seasons, we only apply it in non-illuminated PSRs to calculate the absolute thermal gradient. Finally, the relative thermal gradient adding the absolute value in PSR generates the thermal gradient of polar region (Figure 2).

Figure 2 and thermal gradient vs mean surface temperature (Figure 3) suggest that some largest thermal gradient happen in PSRs (except some anomalies in the edge of map). What’s more, the thermal gradient has a linear relationship with mean surface temperature, which implies the thermal conductivity has a temperature dependence. The relationship between the thermal gradient ($b$) and conductivities ($k$) is described by:

$$k = \frac{Q}{b} \quad (4)$$

Assuming the lunar heat flux is 0.009 Wm$^{-2}$, we compute the $k$ by equation (4). The result (Figure 4) shows thermal conductivity under 120 K is smaller than previous study [1] and has a distinct temperature dependence, which is generally consistent with [4].

Figure 5 shows an example of how PSR model predictions based on this lower density (of 1.1 g/cm$^3$), $-9$mW/m$^2$ heat flux, and thermal conductivity similar to Woods-Robinson [4] match well with Diviner and Chang’E 2 data, lending confidence to this model approach.

**Conclusion:** We use the mean surface temperature measured by Diviner and brightness temperature at 3 and 19.35 GHz from CE-2 MRM to calculate the thermal gradient in lunar south polar region. Our results show that the thermal gradient decrease with temperature. PSRs have the largest thermal gradient. We believe this is due to low density of regolith and substantial temperature dependence at low temperature.

**References:**