**ANALYSIS OF HIGH-FREQUENCY BRIGHTNESS TEMPERATURE OF LUNAR SURFACE FROM CHANG'E-2 MICROWAVE RADIOMETER AND INVESTIGATIONS OF MEAN DIURNAL TEMPERATURE OF REGOLITH LAYER.** Wenzhe Fa[1] and Tuo Fang[1,2], [1]Institute of Remote Sensing and Geographical Information System, Peking University, 100871 China (wzfa@pku.edu.cn). [2]Department of Geophysics, School of Earth and Space Science, Peking University, 100871 China.

**Introduction:** Near surface temperature and thermal behavior not only provide information for testing models for thermal evolution of the Moon, quantifying depth at which volatiles might be stable, but are also important for system design for human and robotic exploration of the Moon. Since 1960s, extensive studies about near surface temperature of the Moon were conducted by using theoretical simulation, in situ measurements, and remote sensed observations at infrared and radio band [1-4]. However, most of previous observations are at infrared band that only contains surface information within 1 $\mu$m, and there is almost no systematical study about subsurface temperature. In China's Chang-E 1 and 2 missions, four channel microwave radiometers (MRM) were used to measure thermal emission from the lunar surface, from which near surface temperature down to a depth of several meters can be estimated globally [5, 6].

In this study, near surface temperature of the Moon is investigated using Chang-E 2 microwave radiometer data. First, factors that affecting high-frequency brightness temperature (TB), such as surface slope, solar albedo, and dielectric constant of regolith, are analyzed. Then, using a two-layer regolith model, thermal emission from lunar surface at high frequency is modeled based on radiative transfer theory. Using this model, mean diurnal temperatures for lunar surface and subsurface are inverted from mean diurnal brightness temperature at 19.35 and 37 GHz.

**Factors that Affecting Lunar Brightness Temperatures:** At microwave band, thermal emission from lunar surface depends mainly on depth-dependent temperature and dielectric constant of regolith. During lunar daytime, the steady state surface temperature can be obtained by energy balance between solar radiation and infrared thermal radiation, which is known as Racca's model [7]. Surface slope changes local incidence angle of solar radiation, which results in a change in physical temperature. On the other hand, solar albedo affects the absorbed solar energy by lunar surface, causing a change in surface temperature. As a result of temperature dependent thermal emission, these two factors can affect the observed TB from lunar surface.

As an example, Figure 1 shows the effect of surface slope (a) and solar albedo (b) on the observed TB at 37 GHz for lunar noon. The black lines in Figure 1a and 1b indicate the observed TB by CE-2, with their ground tracks represented by the black lines in Figure 1c. The red lines represent the steady state surface temperature that estimated from Racca's model, and the blue lines represent temperature that calculated from the revised Racca's model with considering either surface slope (a) or solar albedo (b). Results for regions with latitude >70° are unreliable because shadow effect is not considered in Racca's model, and hence are not analyzed in our study. Here, solar albedo was selected as Clementine UV-VIS reflectance at 750 nm [8]. In local solar incidence angle calculation, surface topography data with a spatial resolution of 4 pixels/ degree from Lunar Orbiter Laser Altimeter (LOLA) were used [9]. Careful examinations show that most of the fluctuations in the blue lines are caused by impact craters, whose walls create a change in solar incidence angle from 15° to 20°, and this cause a variation of 10-15 K in the observed TB. Especially, variation trend of TB at 37 GHz between 39°N and 48°N follows a similar tendency as physical temperature that obtained from the revised Racca's model, indicating a strong correlation between TB and surface slope. As can be seen from Figure 1b, solar albedo can cause 5-10 K variation between maria and highlands, and this can be as large as 20 K for Mare Tranquillitatis.

The difference of real part of dielectric constant between maria and highlands is about 0.5 [10], and this causes a difference of 0.02 in surface emissivity. As a result, dielectric constant would cause a TB difference about 2-8 K between maria and highlands.

**Investigations of Mean Diurnal Temperature for Regolith Layer:** Simulations based on one dimensional heat transfer equation show that variation of diurnal mean temperature for regolith layer with depth follows a bilinear function, which can be described by three parameters: mean temperature of surface and subsurface, and thickness of the superficial dust layer. In this case, thermal emission from lunar surface at high frequency can be modeled using a two-layer model, i.e., a thin dust layer atop of a regolith layer. If thickness of the dust layer can be obtained, mean diurnal temperature of surface and subsurface can be estimated from mean diurnal brightness temperatures at 19.35 and 37 GHz.

Figure 2 shows the inverted mean diurnal temperature for surface and subsurface using TB at 19.35 and 37 GHz with the ground tracks represented by Line 3 in Figure 1c. The red lines in Figure 2 indicate the inverted mean diurnal temperatures and the black lines are the best-fitting curves for the inversion results. The results show that latitude variation of mean temperatures for surface and subsurface follows a rule as $\cos^{0.32}\phi$ and $\cos^{0.36}\phi$, respectively. Mean surface temperature has a larger fluctuation, which might be caused by surface slope or solar albedo. In contrast, fluctuation in the inverted mean temperature of subsurface is minor, which is consistent with the Apollo heat flow measurement.

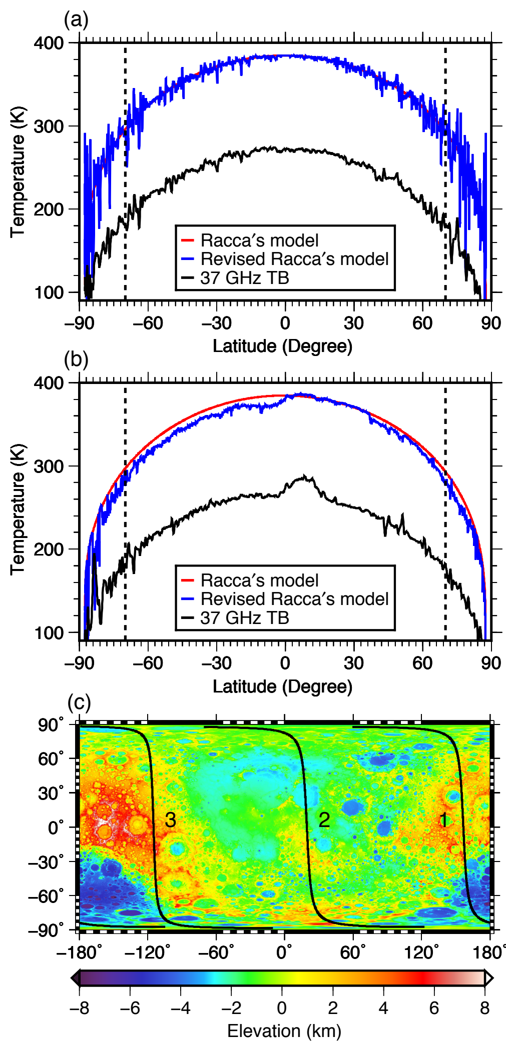


**Figure 1**. (a) Effect of surface slope on the observed TB at 37GHz TB with orbit No. 0743. (b) Effect of solar albedo on the observed 37 GHz TB with orbit No. of 0870. (c) Sub-satellite ground tracks for orbit No. 0743 (line 1) and 0870 (line 2) and 0661 (line 3).

**Conclusions:** In this study, factors that affecting lunar surface TB from CE-2 MRM are analyzed based on Racca's temperature model. Then, using a two-layer thermal emission model of lunar surface, mean diurnal temperatures for lunar surface and subsurface are estimated using TB at higher frequency channels. Our analyses show that at the scale of CE-2 MRM spatial resolution, crater wall with a slope of 15° to 20° can cause a variation in TB about 10-15 K. Solar albedo between maria and highlands can cause a TB difference of 5-10 K, and dielectric constant of regolith can cause a TB difference of 2-8 K between maria and highlands. Inversion results indicate that latitude variation of mean diurnal temperatures for surface and subsurface follows a rule as $\cos^{0.32}\phi$ and $\cos^{0.36}\phi$, respectively.

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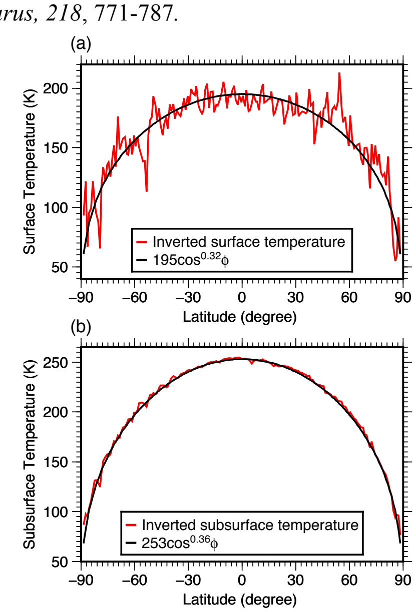


**Figure 2**. Inverted mean diurnal temperature for lunar surface (a) and subsurface (b) from TB at 19.35 and 37 GHz, where the ground track is represented by Line 3 in Figure 1c.