THE BULK DENSITY OF LUNAR SUBSURFACE LAYER FROM DIURNAL DIFFERENCES OF CHANG'E MICROWAVE AND LRO INFRARED BRIGHTNESS TEMPERATURE.

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Introduction: Based on returned core samples from all of the Apollo sites and three of the lunar sites, it shows that the bulk density in the same depth is different[1]. The bulk density distribution in the transverse is univestigated.

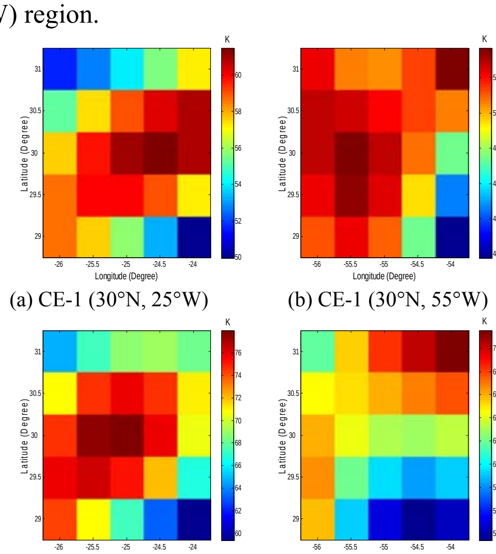
China has successfully launched two lunar orbiters of Chang'E-1 (CE-1) with a 200km altitude circle orbit and Chang'E-2 (CE-2) with a lower orbit of 100km [2] for measuring lunar microwave brightness temperature (TB). Due to the penetration property, microwave TB originates from deeper layers and contains information about the properties of the regolith below the surface. And it is chiefly concerned with dielectric constant, thermal conductivity, bulk density and heat capacity, etc. These physical parameters are in turn related to constituents of the regolith including metal abundances, especially FeO + TiO_2 content, and rocks of different sizes [3].

The Diviner experiment on board Lunar Reconnaissance Orbiter (LRO) carries out high-resolution of ~200m and global observation of the Moon in the spectral 7.55~400μm [4]. Lunar surface temperature distribution and variation over most of the lunar diurnal cycle were obtained by its diviner radiometer 8 channel of 50~100μm wavelengths. The information can provide surface boundary conditions for further interpretation of CE-1 and CE-2 microwave TB.

In this paper, comparisons of diurnal differences of 37GHz microwave TB measured by CE-1 and CE-2 and LRO diviner radiometer 8 channel infrared TB at (30°N, 25°W) in Mare Imbrium and that of (30°N, 55°W) in Oceanus Procellarum are utilized to analyze the physical properties of lunar regolith. And diurnal difference of lunar 37GHz microwave TB is discussed using a two-layer microwave TB model. It confirms that the difference of diurnal difference of lunar 37GHz microwave TB is correlated with the bulk density of the subsurface layer.

Diurnal differences of CE-1 and CE-2 37GHz microwave TB observations: Diurnal differences of 37GHz microwave TB show lunar topographic signatures with close similarity to those seen in the distribution of FeO + TiO_2 content, so there is the relationship between microwave TB and FeO + TiO_2 content. In order to eliminate the influence of FeO + TiO_2 , (30°N, 25°W) in Mare Imbrium and (30°N, 55°W) in Oceanus Procellarum are chosen as investigating objects for further analyzing the physical properties of lunar regolith, where the FeO + TiO_2 contents are respectively 28.18 and 28.16 (%). Here we regard the FeO + TiO_2 content to be uniform in these two regions.

On the contrary, diurnal differences of microwave TB have great discrepancies. Fig.1 shows diurnal differences of 37GHz microwave TB in (30°N, 25°W) and (30°N, 55°W) regions, observed by CE-1 and CE-2, where the gridded data resolution is 0.5° for each pixel. It can be found that microwave TB in (30°N, 25°W) region is about 10K higher than that of (30°N, 55°W) region.



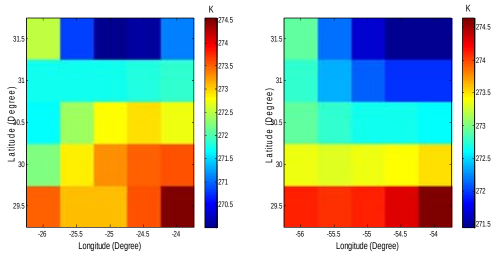
(a) CE-1 (30°N, 25°W) (b) CE-1 (30°N, 55°W)

(c)CE-2 (30°N, 25°W) (d) CE-2 (30°N, 55°W)

Fig. 1 Diurnal differences of lunar microwave TB of 37GHz at (30°N, 25°W), (30°N, 55°W), observed by CE-1 and CE-2. (a) CE-1 Tb_{37} at (30°N, 25°W); (b) CE-1 Tb_{37} at (30°N, 55°W); (c) CE-2 Tb_{37} at (30°N, 25°W); (d) CE-2 Tb_{37} at (30°N, 55°W).

While the LRO diviner 8 channel infrared TB is compared, there is no obvious difference between these two regions, as shown in Fig.2.

In addition, Fig.3 shows the LRO infrared TB versus local time. Their diurnal changes in (30°N, 25°W) and (30°N, 55°W) regions are coincident; That is to say, the materials of lunar top surface layer have the same thermal properties. It demonstrates that the diurnal differences of 37GHz microwave TB are different possibly due to the bulk density of the subsurface layer.



(a) (30°N,25°W) (b) (30°N,55°W)

Fig.2 Diurnal differences of LRO 8 channel infrared TB in (30°N, 25°W) and (30°N, 55°W) regions.

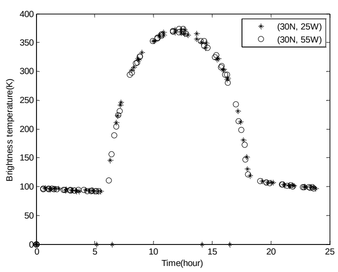


Fig.3 LRO 8 channel infrared TB versus local time at (30°N, 25°W) and (30°N, 55°W) regions.

Lunar surface Microwave TB model: The influence on microwave TB by the bulk density of lunar subsurface layer can be explained by a lunar surface microwave TB model. Based on the radiative transfer theory, 37GHz microwave TB from the two-layer media can be calculated as follows [5]:

$$T_b = e_0 T_0 + e_1 T_1$$

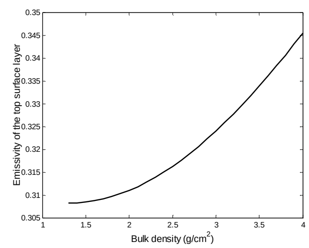
where e_0 and e_1 stand for effective emissivities, which are related to the frequency, dielectric constant. T_1 and T_2 are the physical temperature of lunar surface layer and subsurface layer, respectively. Hence the diurnal difference of microwave TB is given as

$$T_d = e_0(T_0\_noon - T_0\_night) + e_1(T_1\_noon - T_1\_night)$$

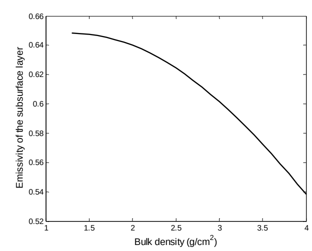
where T_0_noon and T_0_night are the physical temperatures of lunar top layer at noon and midnight; T_1_noon and T_1_night are those of the subsurface layer at noon and midnight.

Suppose the bulk density is a constant of 1.3g/cm^3 for the top surface layer, and that is ranging from 1 to 4g/cm^3 for the subsurface layer. As shown in Fig.4, the effective emissivity of the top layer is increasing with the increasing bulk density, while it is converse of the subsurface layer. Here, we assume the top layer thickness is 0.02m, and the total thickness is 0.5m according to the penetration depth of 37GHz microwave and the FeO + TiO_2 content is 28.16 (%). The simulation confirms that the bulk density of subsurface layer has a strong influence on effective emissivity, especially the subsurface layer.

It is interesting to note that The dinual difference of 37GHz microwave TB is distinct due to the different effective emissivity of lunar surface layer. Mare Imbrium is the youngest major basin located entirely on the lunar nearside, younger than Oceanus Procellarum[1]. And the subsurface of Mare Imbrium region probably consists of larger size rock which has larger bulk density than that of Oceanus Procellarum region.



(a)



(b)

Fig.4 The effective emissivities of lunar top surface layer (a) and subsurface layer (b) versus the bulk density of lunar subsurface layer.

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