A estimation of the lunar surface temperature, dielectric constant, regolith thickness and Helium-3 content retrieved from brightness temperature by CE-1 microwave sounder. Wang Zhenzhan[1], Li Yun[1], Jiang Jingshan[1], Li Jing[1], [1]8701[#], Beijing, China, 100190, wzz@nmrs.ac.cn, liyun@nmrs.ac.cn, jsjiang@nmrs.ac.cn, lijing@nmrs.ac.cn

Introduction: Lunar surface parameters, such as regolith depth and dielectric constant, are important in studying the evolution of the Moon and distribution of lunar resources. Many studies have been done for a long time by various means of observations, such as the Earth-based radio observations, lunar-orbit soundings by optical and infrared sensors, to try to learn about the geophysical properties of the Moon. However, there had been no microwave brightness temperature measured by lunar-orbit-borne microwave radiometer applied to investigate the properties of lunar regolith before CE-1 microwave sounder (CELMS) being launched. The main data for lunar regolith study were derived mostly from the measurements in Apollo and Luna landing sites as well as the observations by Earth-based radars to the near side of the Moon, which resulted in great uncertainties in the researches on the parameters of lunar regolith.

CEMLS is the first passive microwave radiometer on lunar orbit in the world to sound the surface of the Moon. The brightness temperatures (T_B) sounded by CELMS include complicated information on lunar geophysical parameters, such as surface temperature, dielectric constant, lunar regolith depth and the roughness of the lunar surface. The study on lunar surface T_B will be beneficial to learning more about lunar geophysical properties directly by building up the relationship between T_B and those parameters.

The microwave radiative transfer model for simulating and retrieving lunar regolith depths is basic for sounding lunar regolith properties. The emission, multi-reflection and attenuation of each layer should be modeled, and the contributions of the underlying rock are also need to be considered for evaluating the contribution of brightness temperature due to regolith depth variation. The features of brightness temperatures from the model will be helpful to analyze the data from the microwave sounders. The algorithms for retrieving surface temperature, dielectric constant, regolith thickness and helium content are therefore developed according to the simulations of the whole Moon's T_B.

Discussion: The practices of retrieving lunar parameters from CELMS measurements show that dielectric constant's and physical temperature's profiles were the important preconditions in regolith retrieving.

The profiles of lunar regolith physical temperatures play important roles in retrieving regolith thicknesses. A database of temperature profiles of the whole Moon simulated by using multilayer heat-conduction-equation[1] are used as preconditions for regolith thickness retrieving. Since there are some biases existed in the simulations, T_B sounded by 37.0GHz channel are firstly used for correcting the effective temperatures derived from the simulated temperature profiles, and then the corrected temperatures are used for retrieving of the physical temperature, dielectric constant and the thickness of the lunar regolith.

But due to lack of accurate information on dielectric constants at present, this paper is the first attempted to retrieve dielectric constants of the lunar surfaces by simulating the relationship between T_B and dielectric constant using microwave transfer equations. Therefore, it is the accuracies of T_B at 37.0GHz that mainly determinate the accuracies of dielectric constant retrievals.

It shows that only the two parameters were fully considered and modeled, could regolith thicknesses be retrieved reasonably, so as to the evaluations of helium-3 contents. The thicknesses are the first results in the world obtained from the measurements by the microwave radiometers on Moon orbits. Compared with the other results of the past studies, our thicknesses may be much closer to the truths since the T_B received by CELMS are the direct indexes of different depth's radiation of the regolith within their penetrating depths. However, because the penetrating depths of different frequencies are different, the retrieved lunar regolith thicknesses are different for the different channels of CELMS: the penetrating depth at 3.0 GHz is about 5~6 m, which led to the accurate retrievals of the lunar regolith thicknesses only up to 5~6m. If the thicknesses are bigger than this range, the thickness is indistinguishable for CELMS and the retrievals are inexact.

Prior to CELMS, helium-3 contents in lunar regolith were basically evaluated by regolith saturation (or Is/FeO measured duration of surface exposure) and compositions (or Ti abundance based on spectra-photometry of the Moon). Whereas, we compute helium-3 contents by integrating the products of global helium-3 abundances and regolith thicknesses retrieved by T_B of CELMS. Therefore, the relationship of helium-3 abundances and dielectric constants is the key in retrieving helium-3 contents.

Summary: Some initial retrievals of these parameters are given from T_B by CELMS during its first month (Dec 5th ~ 30th, 2007) operating on lunar orbit: the global distribution of dielectric constants and temperatures of the lunar surface are mapped, and the regolith thickness and helium-3 content are derived from the T_B by CELMS. The retrievals from CELMS show that:

1) The physical temperatures of lunar surface from the equator to the two poles decrease with the latitudes, and the distributions of temperatures are inconsistent in lunar lands and the mares: the temperatures in the mares are higher than those in the lands at lunar day, but the trends is contrary at the lunar night (Figs. 1 and 2).

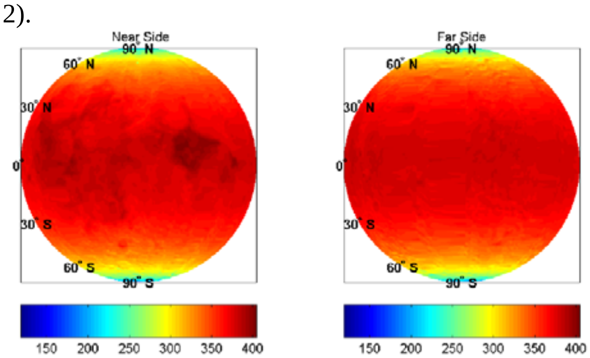

Fig. 1 The distribution of surface temperatures retrieved from CELMS T_B at 37.0GHz at lunar day

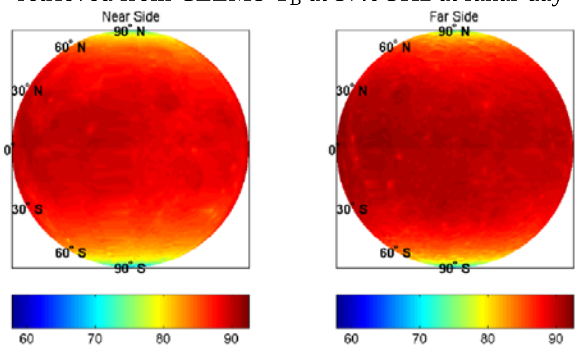

Fig. 2 The distribution of surface temperatures retrieved from CELMS T_B at 37.0GHz at lunar night

2) The dielectric constant distribution of the regolith at the near side of the Moon is similar to the results derived from the optical remote sensors[2], but at the far side of the Moon, especially at mare area of high-latitude in the South of the Moon, the dielectric constants retrieved from CELMS data (Fig.3) are obviously smaller than the results from the other sensor measurements, and the trend of their distribution is contrary to that from the optical sensors in Clementine.

3) Global regolith are uniformly distributed at most area of the Moon but lunar polar. The retrieved results, compared with those from literature and data by other sensors[2-6], show that the most of the averages of the thickness (Fig.4) are at the range of 4~6 m, which is smaller than those published in literatures, and 43% of them are deeper than 5 m.

4) Helium-3 abundances are highly correlated with the tangents of lunar regolith, and there is almost no helium at lunar polar area. Based on the assumption that the profiles of helium-3 density in lunar regolith is not changing with the depth, and the relationships between helium-3 abundance and dielectric constant derived from Apollo samples by Slyuta and Abdrakhimov[7] , lunar helium-3 content will be at least 1.03 million tons.

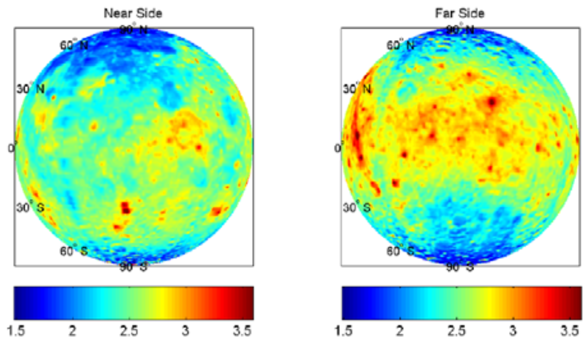

Fig. 3 The distribution of the real part of lunar regolith dielectric constants retrieved from CELMS T_B at 37.0GHz at lunar night

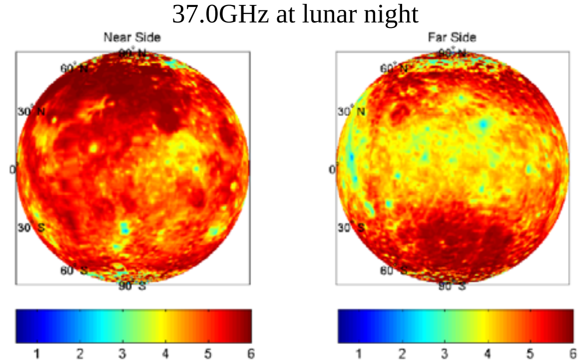

Fig. 4 The distribution of lunar regolith thicknesses retrieved from CELMS T_B at 3.0GHz at lunar night

The initial analysis on the measurements of CELMS show that there was plenty of information in T_B on the characteristic of the lunar regolith, especially, the day-and-night differences of T_B at different frequencies revealed different information on the regolith thickness and dielectric constant, which needed to be further validated and improved.

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