A NEW METHOD TO SIMULATE CHANG'E BRIGHTNESS TEMPERATURES USING THERMAL CONSTRAINTS FROM DIVINER DATA. G. Wei1,2,3 and S. Byrne1, 1Center for Lunar and Planetary Sciences, Institute of Geochemistry, CAS, Guiyang, 5500081, 2CAS Center for Excellence in Comparative Planetology, Hefei, 230026, China (guangfeiwei@email.arizona.edu), 3Lunar and Planetary Laboratory, The University of Arizona, AZ, 85721, USA (shane@lpl.arizona.edu).

Introduction: Study of the thermal behavior of the lunar surface/subsurface is important to understand regolith thermal properties, and even the thermal evolution of the Moon itself. Several ground-based observations with wavelengths from the infrared to radio bands have been used to investigate the surface thermal environment since the 1930s [1,2]. However, only the nearside of the Moon can be observed from Earth and most of these observations suffered from calibration difficulties and coarse spatial resolution.

In 2007 and 2010, the Chang'E-1 (CE-1) and Chang'E-2 (CE-2) lunar probes were launched with Microwave Radiometers (MRMs) onboard both satellites. These instruments were designed to investigate the lunar surface and subsurface thermal environment and its regolith thickness. Comparing these two datasets to theoretical thermal models at the Apollo 15 and 17 landing areas, it is has been reported that there might be some calibration uncertainties from heat contamination [3].

In 2009, the Lunar Reconnaissance Orbiter (LRO) was launched with the Diviner thermal radiometer onboard. Diviner has obtained large amounts of high-quality thermal infrared data, which constrain the lunar surface thermal environment at all local times and locations [4].

Diviner data provides a good surface thermal constraint to simulate microwave brightness temperature (T_b), and evaluate CE-1 and CE-2 observations.

Data and Methods: The MRMs observed microwave emissions from the surface with four nadir-viewing antennas operating at 3, 7.8, 19.35 and 37 GHz [5]. As CE-2 had a lower orbital altitude than CE-1 (~100 km vs. ~200 km), the spatial resolution of CE-2 observations is improved by a factor of 2 compared with CE-1. Thus, the spatial resolution of CE-2 MRMs’s 3 GHz is ~25 km and ~15 km for other channels. Calibrations on both missions were done using measurements of a high-temperature on-board source and data from cold space-looking reference horns [6].

The Diviner experiment onboard LRO is a nine-channel radiometer with two spectral channels from 0.35 to 2.8 μm for reflected solar radiation, and seven channels for infrared emission, spanning 7.55 to ~400 μm [7]. The footprint at the nominal 50 km observation altitude is ~3.4 km, with a spatial resolution of ~200 m [4]. Additionally, the global bolometric brightness temperature (T_bol) gridded at 0.5°×0.5° of longitude and latitude has been derived from independent measurements of Diviner thermal channels [4] for many different local times. T_bol is more directly related to the surface thermal balance, and can represent the lunar surface kinetic temperature.

In this study, we filtered the MRM datasets to the same spatial grid as Diviner-provided T_bol within latitudes 70° N/S. We use the gridded Diviner data to drive a 1D subsurface thermal conduction model following the work of [10]. More traditionally, such models calculate surface and subsurface temperatures using incoming solar radiation and out-going IR radiation adjusted for albedo, emissivity, slopes, phase-functions, shadowing, and radiation reflected from surrounding terrain etc. In our approach, we use the directly observed surface temperatures as the surface boundary condition to avoid this complexity and derive accurate sub-surface temperatures.

Microwave emission is heavily influenced by the regolith dielectric constant, which is especially sensitive to titanium content (mostly in the mineral ilmenite). Clementine multispectral data were used to derive the distribution of ilmenite [9]. We used the method of [11] to derive effective dielectric profile and adjust the microwave emissivity based on these values.

Thus, we can simulate microwave brightness temperature [8] based on our improved thermal model and dielectric constants, and then compare them to CE-1 and CE-2 observations.

Figure 1. Diurnal mean temperature at 1 m depth calculated by our improved thermal model.

Topography plays an important part in our 1-D thermal model, especial for the high latitudes. Here we only calculate subsurface temperatures at mid-to-low latitudes. In the example shown in Fig.1 the subsurface temperature decreases with latitude. The temperatures in the maria are relatively higher than that
of highlands, which might be attributed to their lower albedo. The temperature at high latitudes has an obvious correlation with topographic slopes.

Based on the derived subsurface temperatures, we simulated the brightness temperature at 19.35 GHz (\(T_{B19}\)) and 37 GHz (\(T_{B37}\)), respectively. To minimize topographic effects and for better \(T_B\) comparison between CE-1 and CE-2 observations and our simulation results, we only modeled nighttime \(T_B\) within 70\(^\circ\) N/S.

**Results:** Fig.2 shows that the \(T_{B19}\) and \(T_{B37}\) comparisons between CE-2 observations and modeled values are highly dependent on local time. It can be inferred that the surface thermal behavior, in-orbit calibration uncertainties and even heat contaminations are quite different at different times.

![Figure 2. \(T_B\) comparisons between CE-2 observations and modeled values at (a) 19.35 GHz and (b) 37 GHz in the nighttime. To eliminate the potential light scattering effect near terminator (dawn and dusk), the \(T_B\) data in the time ranges 1800-1900 and 0500-0600 were excluded.](image)

![Figure 3. \(T_B\) comparisons between CE-1 (red) and CE-2’s (blue) observations and our simulation results at (a) 19.35 GHz and (b) 37 GHz near midnight. The dashed lines are 1:1 lines. Each data point corresponds to the same local time of CE-1 and CE-2 observations and modeled \(T_B\).](image)

Because only \(T_B\) data near noon and midnight were collected during the CE-1 mission, we selected both CE-1 and CE-2’s \(T_{B19}\) and \(T_{B37}\) near midnight for further comparison. As shown in Fig.3a, both CE-1 and CE-2 observations at 19.35 GHz agree well with our modeled values. This indicates that these two datasets revealed similar surface/subsurface thermal environment near midnight with similar data quality. However, there is a large difference between CE-1 and CE-2 observations when compared to our simulation results at 37 GHz (Fig.3b). This may mean the lunar surface thermal environment observed by CE-1 and CE-2 at the same local time and the same channel behaves differently. However, this is more-likely caused by large calibration uncertainties, low signal-to-noise values and more heat contamination during the CE-2 37 GHz channel observations. The better agreement of CE-1 observations with our simulation results show that CE-1 \(T_{B37}\) data are higher quality than that of CE-2.

**Discussion and Conclusion:** Due to the relatively short wavelength of the 37 GHz channel, it is more sensitive to surface temperature compared to 19.35 GHz. In addition, the lower altitude of the CE-2 orbit (half of CE-1’s) causes the cold-reference antennae of MRM to “see” a larger area of the warm lunar surface during in-orbit calibration. As a result, large calibration uncertainties from this surface heat contamination might be caused for CE-2’s MRM, especially for the sensitive 37 GHz channel.

Although the new method used here to model \(T_B\) cannot eliminate the uncertainties such as topographic effects completely, the consistency with CE-1 observations and CE-2 \(T_{B19}\) validate our simulations. Although offset from our simulations and the CE-1 data, CE-2 \(T_{B37}\) observations scale linearly with our modeled values. We interpret this to indicate that future recalibration of CE-2 observations will be possible.

Compared to CE-1 MRM observations, the higher resolution of CE-2 \(T_B\) data will reveal more details of the subsurface thermal regime and regolith thermal properties. However caution should be used when interpreting CE-2’s high frequency \(T_B\) before data evaluation and recalibration are conducted. The CE-1 observations (at least at midnight) are of a relatively higher quality than that of CE-2. Nevertheless, more comparisons and evaluations of CE-1 and CE-2 data needs to be conducted in future work.

**References:**