A NEW THERMAL CORRECTION FOR OVIRS DATA: IMPLICATIONS FOR DISTRIBUTION AND ORIGIN OF WATER ON BENNU. S. Li[1] and H. H. Kaplan[2]. [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i. [2]NASA Goddard Space Flight Center. shuaili@hawaii.edu

Introduction: The Near-Earth asteroid (NEA) (101955) Bennu (hereafter Bennu) recently visited by NASA'S OSIRIS-REx sample return mission is spectrally and dynamically linked to the Polana family in the main belt [1, 2]. Water may play a key role in the formation and evolution of Bennu. Reflectance data from the mission suggest complex aqueous alteration processes operated on the Bennu parent body [3] leading to ubiquitous hydrated materials on present day Bennu. However, the distribution of water (e.g., OH and/or H_2O) on Bennu's surface may have been substantially altered by ongoing processes including impacts and solar irradiation. The discovery of exogenic basalts on Bennu's surface indicate a complex collision history between Bennu and asteroids in the main belt [4]. Understanding the distribution and origins of water on Bennu's surface can help to reveal surface processes associated with water and shed light on similar processes on main belt asteroids and icy bodies [e.g., 5, 6].

It is essential to remove the thermal component from reflectance spectra to accurately characterize the spatial and temporal variation of OH and possible H_2O features on Bennu's surface to unveil their origins. We test a new thermal correction and map the strength of water absorptions globally using the reflectance spectra (0.4 – 4.3 µm) acquired by the OSIRIS-REx Visible Near Infrared Spectrometer (OVIRS). The water bands occur from around 2.65 µm to 4.0 µm due to the fundamental stretching of OH and the first overtone of H_2O vibration. However, NIR spectra can be affected by thermal emissions at wavelengths >2 µm [2], which can weaken and distort the shape of absorptions in the ~2-4 µm region in the OVIRS data, precluding accurate mapping of water and other components showing absorptions at this region (e.g., CH, CO [3]). We will apply our new developed semi-empirical model to remove thermal contaminations from the OVIRS data.

Data & Methods: In this study, we use the Detailed Survey OVIRS data for global coverage of Bennu's surface at multiple local times. The temperatures on Bennu's surface may exceed 380 K [7]. Thermal emissions at such high temperatures may substantially skew the OVIRS radiance data beyond 2 µm. The OVIRS radiance (L_o) data at 2 – 4 µm are generally composed of reflected solar spectrum (L_r) and thermal emissions (L_T) from the surface:

$$L_o = L_r + L_T$$

Where $L_r = \frac{RF}{\pi} * J$, J is the solar spectrum and RF is the radiance factor. $L_T = \varepsilon B(T)$, ε is the emissivity, and $B(T)$ is the Planck function to calculate the thermal emission of a black body at temperature T. To accommodate the anisothermality of Bennu's surface, we assume multiple facets with a wide range of temperatures (n) in each OVIRS pixel: $L_T = \varepsilon_i \sum_i^n a_i * B(T_i)$, a_i is the portion of thermal emission at temperature T_i and $\sum a_i = 1$. We also assign the emissivity ε_i as free parameters at each temperature T_i, which is used to account for different thermal properties within individual OVIRS pixels. Previous work mapping Bennu's hydration has used a single temperature thermal correction. Studies suggest that the variation of reflectance on Bennu's surface is very small [8], which leads us to assume the reflectance (RF) as a constant parameter. Regarding the anisotropic scattering and anisothermal nature of Bennu's surface, the sum of the reflectance (RF) and emissivity (ε_i) may not exactly be 1 (the Kirchhoff's law). Thus, RF and ε_i are assumed as free parameters and are independently solved. We use our model to fit the OVIRS radiance data from 2 to 3.9 µm to derive the surface temperatures, reflectance, and emissivities.

Our analysis of 163 CC spectra from the RELAB database suggests that if the downturn positions of water absorptions are shorter than 2.74 µm, the thermal emission may be overestimated (**Fig. 1a**). While if the reflectance near 4 µm is 15% higher than that at 2.6 µm (**Fig. 1b**), the thermal component may be underestimated.

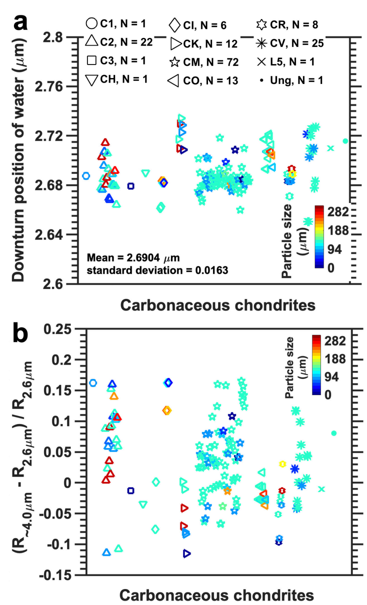

Fig. 1. a. Downturn position of water near 3 µm of 163 CCs; **b**. Variations of reflectance near 4 µm in comparison to that at 2.6 µm

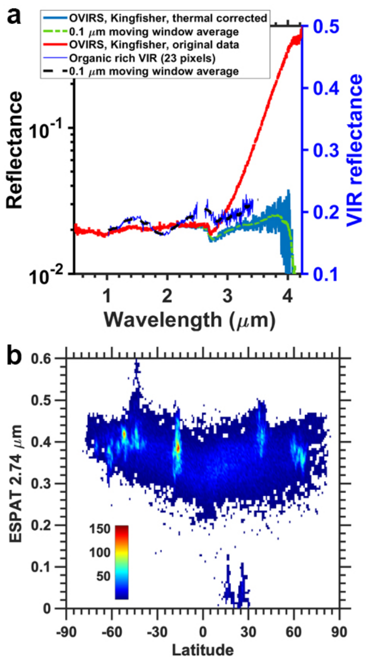

Fig. 2. a. Examples of thermally corrected (light blue and green) and uncorrected (red) OVIRS data in comparison to organic rich VIR spectra from the Dawn mission on Vesta; **b**. A density plot of water absorption strength (ESPAT) derived from corrected OVIRS data versus latitude.

Hapke's radiative transfer model [9] is used to perform photometric correction to the OVIRS data. Hapke's Effective Single Particle Absorption Thickness (ESPAT) parameter is used to quantify the absorption strength of water, which can be used as a proxy for the water content [10].

Results: Figure 2a shows an example of OVIRS spectra at one of the four final candidate sample sites, Kingfisher, before and after our thermal correction. Strongly tilted reflectance between 3 and 4 µm is indicative of thermal emissions from the surface. The overall OVIRS spectrum is relatively flat after thermal correction (**Fig. 2a**). We also plot the DAWN VIR spectra at a very dark region that was thought to be rich in CC impact remnants [11]. The absorption near 3 µm in the VIR data is attributed to CC remnants on Vesta's surface [11]. The VIR spectra at less than 3.3 µm are free of thermal contaminations because the maximum temperatures on Vesta's surface are less than 280 K [12]. Thus, the spectral shape of CC absorptions near 3 µm in the VIR data can be used as a reference for the thermally corrected OVIRS data. Any tilt in the corrected OVIRS data near 3 µm in comparison to the VIR spectra should indicate thermal residuals. The similarity between the VIR spectrum and our thermally corrected OVIRS spectra may be indicative of appropriate thermal removal in the OVIRS data with our model.

We calculate the absorption strength of water near 2.74 µm using Hapke's ESPAT parameter for the entire Detailed Survey dataset. Our derived absorption strength near 2.74 µm exhibits latitudinal dependence (**Fig. 2b**). The ESPAT values near 60º N/S latitude are around 30% higher than those near the equator (**Fig. 2b**); similar results are shown in previous studies [13,14]. Our derived ESPAT values at phase angles between 60º – 80º are around 15% lower than those at phase angles less than 10º, which may be attributed to residuals of photometric correction. However, since the phase angles of OVIRS data are not dependent on latitude, the photometric residuals cannot challenge the observed latitudinal dependence of water absorptions on Bennu's surface.

Discussion: The multi-temperature, and empirically constrained thermal correction presented here facilitates detailed analysis of Bennu's hydration across multiple datasets. For instance, the latitudinal dependence of water absorptions on Bennu's surface could be due to much higher temperature or stronger solar wind sputtering and thus more efficient water loss at low latitudes, or dehydration from impacts [13, 14], but it is difficult to disentangle these sources. The thermal correction described here allows us to investigate hydration from multiple local solar times to determine hydration variation from solar wind implantation, which has been observed on the Moon. If solar wind implantation contributes little to Bennu's surface water, the observed water on Bennu could be mostly indigenous. We will also search for evidence of impact-related dehydration.

Our thermally corrected dataset will be tested and improved to ensure fidelity required for these investigations. We will validate our thermal correction results using the OSIRIS-REx Thermal Emission Spectrometer (OTES) and will compare our results to the single temperature, unconstrained OVIRS correction used in previous work. We will compare our modeled temperatures with those derived from the OTES data at the same local time, although surface anisothermality may result in different temperatures at different wavelength range. Our photometric correction for the OVIRS data will be improved in the next step.

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