TEMPERATURE DEPENDENT SPECTRAL RESPONSIVITY OF THE LROC WAC. H. Sato[1], M. S. Robinson[1], P. Mahanti[1], A. K. Boyd[1], [1]School of Earth and Space Exploration, Arizona State University, 1100 S. Cady Mall, INTDS-A, A116C, Tempe, AZ 85287-3603 (hsato@ser.asu.edu).

Introduction: From a multispectral near-global mosaic of Lunar Reconnaissance Orbiter (LRO) Wide Angle Camera (WAC) images, we detected an artifact in radiance factor (*I/F*) [1] between the bands that increases at high latitudes. Each pixel of this mosaic is given by the median of multiple photometrically corrected WAC images acquired from 23 months of observations. All images were preprocessed by the radiometric calibration and the photometric normalization using an innovative "tile-by-tile" method [2]. After a comprehensive error investigation that includes the radiometric calibration, photometric parameter calculations, and the spatial heterogeneity of WAC data sets, we found a correlation between the artifact and CCD focal plane temperature. By calculating the spectral responsivity change as a function of CCD temperature from 23-month image dataset, we corrected this artifact (here after called "temperature correction").

Method: First we classified the 23 months of WAC data by incidence (i) and phase (g) angle in 3° bins from 34° to 69° (e.g. 34°<(i, g)<37°, 37°<(i, g)<40°, …; 12 bins total), to minimize the photometric effect on the *I/F*. For each angle bin, we further sorted the *I/F* measurements to 5°C bins from -30°C to 10°C (8 temperature bins total). From each classified group, we produced a one pixel/degree mosaic for 70°S to 70°N latitude, 0° to 360°E longitude area (here after called "1° mosaic"), including the *I/F* and the CCD temperature.

Then we calculated a derivative ($D_{(T1,T2)}$) for all the temperature group combinations. $D_{(T1,T2)}$ is given by the median of $D_{axy(T1,T2)}$, which is given by

$$D_{axy(T_1,T_2)} = \left[\frac{I/F_{axyT_2}}{I/F_{axyT_1}} - 1\right] / \left(t_{axyT_2} - t_{axyT_1}\right) \quad (1)$$

where a denotes the angle groups, x and y denote the longitude and latitude of the 1° mosaic, T_1 and T_2 denote the two temperature groups of each temperature group combination, and t is the CCD temperature. Since D_{axy} is computed at each pixel of the 1° mosaic, the influence of regional albedo variation is minimized, at least in 1° by 1° size. The CCD temperature at each pixel is used here to take the variation (up to 5°C) within a same temperature group into account to improve the accuracy.

Then for all the temperature combinations, we calculated a ratio value ($R_{(T1,T2)}$), which is given by

$$R_{(T_1,T_2)} = D_{(T_1,T_2)}\left(tm_{T_2} - tm_{T_1}\right) + 1 \quad (2)$$

where tm is a middle temperature of each temperature group bin. $R_{(T1,T2)}$ basically means a representative ratio of *I/F* at T_2 to *I/F* at T_1. From all the $R_{(Tx,Tx)}$ values, we calculated normalized *I/F* change curve ($Tc(t)$) as a function of the CCD temperature, which satisfies the $R_{(Tx,Tx)}$ values as much as possible. By least-square optimization, we first calculate the multiplier (M) so as to minimize the standard deviation of RM at each temperature group. RM is given by

$$RM_j = R_{(T_k,T_j)} M_k \quad (3)$$

where j and k both denote the temperature group from 1 to 8. Notice that each RM_j has 8 variables. Then the $Tc(t)$ is obtained as the 4th order polynomial fitting curve against all the RM. Finally the *I/F* including our temperature correction (I/F_{tc}) is obtained by

$$I/F_{tc} = \frac{I/F}{Tc(t)} \quad (4)$$

where t is the CCD temperature when the image was acquired.

Results: The RM and the 4th order polynomial fit curve ($Tc(t)$) for 689 nm band are plotted in Fig.1. The plots indicate the continuous *I/F* increase with CCD temperature, except in the -30°C to -25°C range. The total offset of *I/F* is up to about +/- 5%. This increasing trend of *I/F* with the temperature depends on the wavelength as shown in Fig.2. The 566, 604, 643 and 689 nm bands show increasing trends, whereas the 360 and 415 nm bands show weak negative correlations. The 321 nm band plot is

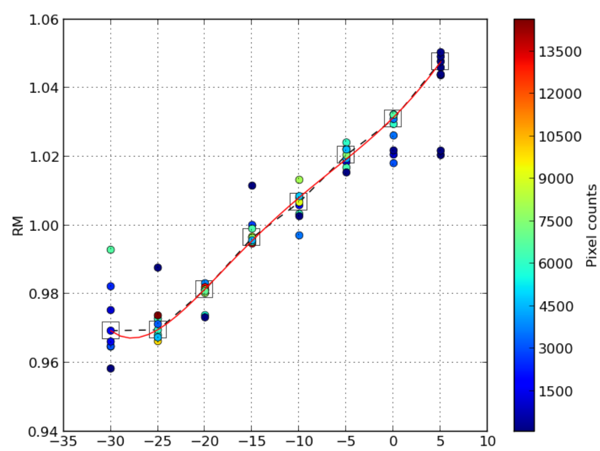

Fig.1 Plots of *Tc(t)* (red line) in 689 nm band. The black dashed line with the square corresponds to the median of $R_{(Tk,Tn)}M_k$ at each temperature (T_k). *Tn* denotes all the temperature groups.

nearly flat, suggesting that little correlation between *I/F* and temperature. At -30°C to -25°C temperature range, all the bands exhibit poor correlation likely due to systematically small amount of data compared to the other temperature ranges.

Since the WAC CCD temperature basically increases from the pole to pole during daytime in every single orbit. Thus the images acquired in the ascending orbit and in the descending orbit have significant difference in the CCD temperature, especially at the high latitudes. The ratio map of *I/F* at descending orbit to *I/F* at ascending orbit at $59° < i < 62°$, $59° < g < 62°$ (Fig.3a) shows systematic change in the latitude direction, which is consistent with the latitude trend of the CCD temperature difference between the descending and ascending orbit (Fig.3b). After the temperature correction was applied, the ratio map of *I/F* shown in Fig.3a becomes almost flat (Fig.3c), with about 1.0+/-0.01 at 60°S to 60°N latitude range (Fig.3d), meaning that the temperature correction is successful in this example.

Discussion: The CCD temperature variation increases from equator to the poles in the 23 months of WAC data set, due to the mixtures of the ascending and descending orbit observations. Also the fraction of the ascending vs descending orbit observations is not even, and it changes depending on the locations of the Moon. Thus the temperature conditions in the WAC data set are quite heterogeneous for most locations on the Moon. Furthermore, the *I/F* dependence on the CCD temperature differs at each wavelength as shown in Fig.2. All these effects induced the color artifacts (non-geologic *I/F* offsets between the bands) observed in the initial (uncorrected) mosaic.

At this stage of our analysis, the real cause of this *I/F* shift is still unknown. The CCD temperature is likely the real cause, or a proxy for another as yet undiagnosed issue.

References: [1] Hapke B. (1993) *Cambridge Univ. Press*, New York. [2] Sato H. et al. (2012) *LPS XXXXIII*, Abstract #1771.

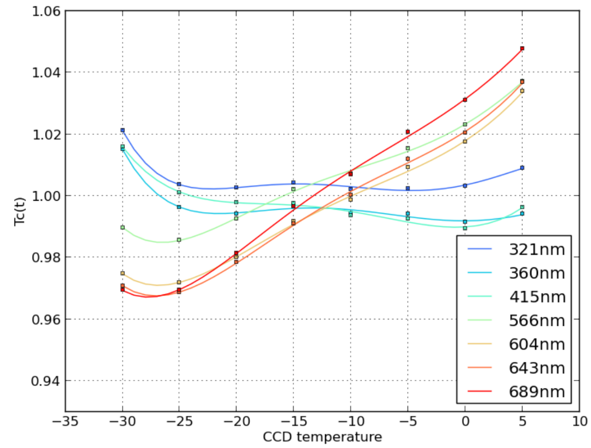

Fig.2 Plots of *Tc(t)* for the all bands. The square corresponds to the median of RM at each temperature group.

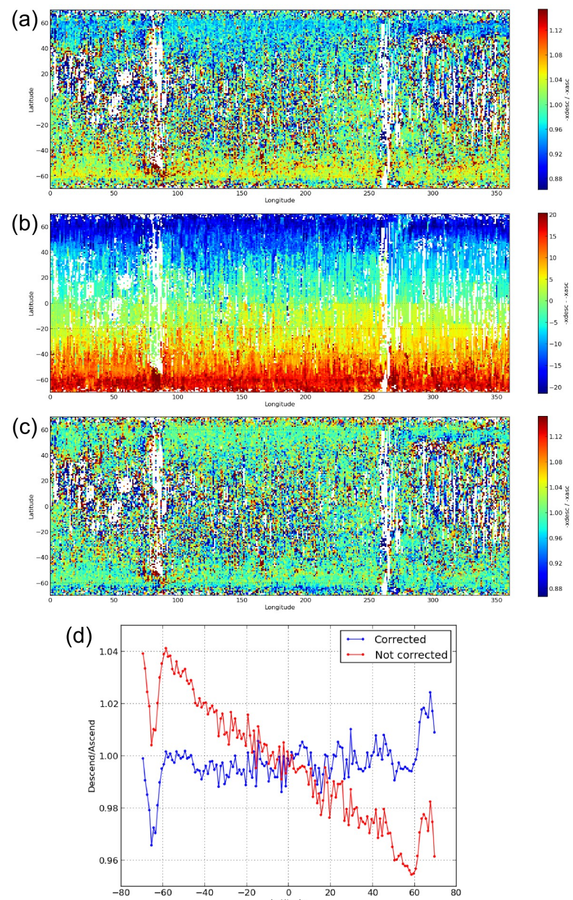

Fig.3 The ratio of I/F from the descending orbit to the ascending orbit in 689 nm band (a), the CCD temperature of descending orbit – the one of ascending orbit (b), the ratio of I/F from descending over ascending after the temperature correction (c), and the median at each latitude before (red) and after (blue) the temperature correction (d).