DID CLEMENTINE OBSERVE LUNAR HORIZON GLOW? D. A. Glenar[1,2], T. J. Stubbs[3, 2], J. Hahn[4] and R. Vondrak[5,2]; [1]Astronomy Dept., New Mexico State University, Las Cruces, NM 88003, dglenar@nmsu.edu; [2]NASA Lunar Science Institute (Dynamic Response of the Environment at the Moon); [3]Goddard Earth Sciences and Technology Center, Baltimore County, Baltimore, MD 21228; [4]Space Science Institute, Austin, TX, 78750; [5]NASA Goddard Space Flight Center, Greenbelt, MD, 20771

Introduction: Lunar horizon glow (LHG) from forward scattering of sunlight by exospheric dust was tentatively observed by the Clementine Star Tracker Cameras, as reported by Zook et al. [1], but that finding remains controversial. The inferred intensities were dimmer than Apollo-era observations, and they did not include corrections for Coronal-Zodiacal Light (CZL). Although photometric imaging was not the purpose of the Star Trackers (ST), it has been demonstrated [2] that well calibrated images can be recovered from the ST dataset, once a number of instrumental artifacts are removed. Zook et al. [3] developed an algorithm that recovered "destreaked" images from the raw data, and Hahn et al. [2] subsequently produced a well-calibrated map of CZL in geocentric ecliptic coordinates. Such a map can be easily translated into spacecraft "camera coordinates", which is a necessary precursor to a quantitative search for the presence of LHG.

Evidence for LHG in the Clementine ST Data-set: Figure 1 shows an enhanced ST image acquired close to orbital sunrise, at a limb solar elongation angle of ~5.9°. The glow above the horizon consists mostly of CZL, and the top of the image is illumination by Earthshine. However, visual inspection also suggests a component that is correlated with the lunar limb, possibly sunlight forward-scattered by dust within a few km of the surface.

Figure 1. Clementine Star Tracker image acquired prior to sunrise during Orbit 193, showing CZL, Earthshine and possibly LHG.

Quantitative Estimates of LHG: We are presently examining the ST data set (Table 1 below) with the goal of quantifying the LHG component, or at minimum, placing a sensitive upper limit on dust column abundances above the terminator at the times and locations of the ST images.

Table 1. Clementine Star Tracker Image Sequences

Orbit	Date ('94)	N images	$\varepsilon^{(1)}$	z (km)
66	Mar 5.9	13	18.2 - 4.8	2410
110	Mar 15.0	4	27.8 - 15.0	2570
164	Mar 26.4	57	28.7 - 2.6	3520
193	Apr 1.5	40	10.2 – 0.7	2850
206	Apr 4.0	38	30.9 – 4.6	TBD
253	Apr 13.9	48	24.3 – 4.3	TBD

Notes: (1) Approximate solar elongation angle (deg).

Modeling the CZL Intensity Distribution. Proper separation of the spatial contributions of CZL and LHG requires multiple calibration steps, which we are still refining. The CZL spatial distribution is taken from Hahn et al. [2]. Photometric measurements of zodiacal light [4] establish a color (wavelength) axis. The spectral "colors" of CZL and LHG are quite different as a result of grain size differences, so the spectral distributions of both CZL and LHG must be weighted over the spectral response of the star tracker. The resulting CZL intensities are aligned to our model coordinate frame and fine-adjusted, both in intensity and spatial scale to optimally remove the CZL component.

Forward Modeling of LHG. Quantative simulations of LHG are made using a flexible light scattering code [5] that we have evolved to simulate both imaging and spectral measurements of optical scattering from within lunar shadow between near-UV and near-IR wavelengths. Specifically, the code simulates: (i) forward scattering by exospheric dust, (ii) superimposed CZL as described above, and (iii) line emission from Na and K, which have been measured and documented from ground based observations [6,7]. While the motivation for this modeling is to simulate measurements from the LADEE point spectrometer, it is likewise a valuable tool for the Clementine image study. Mie theory provides good estimates for the radiative transfer properties, provided that grain radii are ≤ 1 μm, as expected for exospheric dust grains. We use the Murphy and Vondrak [8] vertical dust distribution near the terminator, which is derived both from Apollo excess light measurements [9] and from Lunokhod-II observations at the surface [10]. The solar irradiance spectrum is taken from NASA's Solar Radiation and Climate Experiment (SORCE). Path integrations are carried out within a spherical coordinate geometry framework, which requires spacecraft altitude and solar zenith angle of the satellite ground track position. Additional model input parameters are: instrument and/or pixel field-of-view (FOV), spectral resolution $\Delta\lambda$ and observation wavelengths λ_i.

Figure 2 shows a quantitative simulation of LHG and CZL under one set of Clementine observing conditions. LHG becomes increasingly pronounced (relative to CZL) at small values of solar elongation angle ε, due to the difference in forward scattering behavior between lunar and interplanetary dust. This is shown quantitatively in the 1D plots which show the intensities of LHG and CZL where they are brightest.

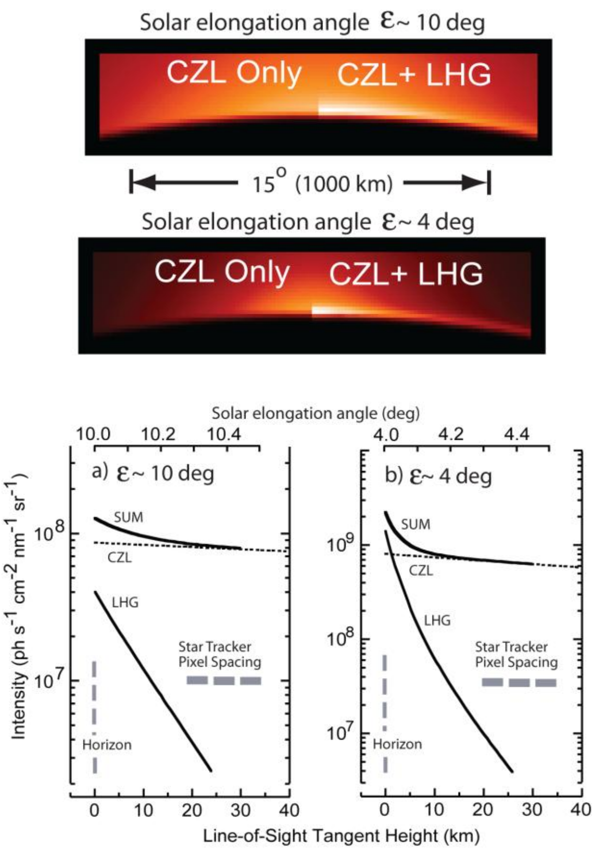

Figure 2. Light Scattering Code simulations of combined LHG and CZL, under the observing geometry of Clementine Orbit 193. Top panels: Joined half images of CZL only and CZL+LHG at two solar elongation angles. Vertical plots show the central column intensities.

Summary

The Clementine Star Tracker data set is being analyzed using an accurate scattering simulation code, in order to quantify the spatial distribution of horizon glow due to exospheric dust. Results of the work now underway will be presented.

References:

[1] Zook H. A. and McCoy J. E. (1991) *GRL, 18*, 2117–2120. [2] Hahn J. M. et al. (2002) *Icarus, 158*, 360-378. [3] Zook H. A. et al. (1997) *LPS XXVIII*, Abstract#1103. [4] Pitz et al. (1979) *Astron. Astrophys., 74*, 15-20. [5] Stubbs T. J. et al. (2008) *LPS XXXIX*. [6] Potter A. E. and Morgan T. H. (1988) *GRL, 15*, 1515-1518. [7] Kozlowski R. W. H. et al. (1990) *GRL, 17*, 2253-2256. [8] Murphy D. L. and R. R. Vondrak (1993) *LPS XXIV*, 1033. [9] McCoy J. E. (1976) *Proc. LSC 7th*, 1087-1112. [10] Severny et al. (1975) *The Moon, 14*, 123.