**LUNAR GLOBAL DIGITAL TERRAIN MODEL DATASET PRODUCED FROM SELENE (KAGUYA) TERRAIN CAMERA STEREO OBSERVATIONS.** Junichi Haruyama[1], Seiichi Hara[2], Kazuyuki Hioki[2], Akira Iwasaki[3], Tomokatsu Morota[4], Makiko Ohtake[1], Tsuneo Matsunaga[5], Hitoshi Araki[6], Koii Matsumoto[6], Yoshiaki Ishihara[6], Hirotomo Noda[6], Sho Sasaki[6], Sander Goossens[7], Takahiro Iwata[1], [1]JAXA, ISAS (Haruyama.junichi_at_jaxa.jp), [2]NTT DATA CCS Corporation, Japan, [3]Tokyo Univ. Japan, [4]Nagoya Univ. Japan, [5]National Institute for Environmental Studies, Japan, [6]National Observatory of Japan, [7]NASA Goddard Space Flight Center.

**Introduction:** Surface morphologies of celestial bodies are essential for investigating their origin and evolution and for planning further unmanned and/or manned exploration and activities.

Much effort has been made to attain lunar surface morphology data. For example, 40 years ago the Apollo missions collected stereo data using the Mapping Camera with a 20 m spatial resolution and the Panoramic Camera with a resolution of a few meters at nadir [e.g. 1]. However, since the Apollo manned missions adopted equatorial orbits and could only observe the lunar surface for several days, the stereo mapping coverage was limited to 20% of the entire lunar surface. In the 1990s, the Clementine spacecraft collected elevation data of the lunar surface using a Laser Image Detection and Ranging (LIDAR) system covering the equator to middle latitudes (60 to 70˚S, N) [2], though the data had greater longitudinal spacing at lower latitudes, expanding to several tens of kilometers at the equator. The topography of the lunar polar regions within 60˚S, N was derived from Clementine stereo images acquired by the UV-VIS camera with a 1km / pixel resolution [3].

The first global elevation data were collected by the Laser Altimeter (LALT) on board the Japanese lunar explorer, SELENE (Kaguya; launched in 2007) [4]. The spacing of the LALT data was improved to less than 10 km at lower latitudes. Detailed lunar polar illumination was investigated from the topography derived from LALT data [5]. The Lunar Reconnaissance Orbiter (LRO) launched in 2009 also carried an altimeter, the Lunar Orbiter Laser Altimeter (LOLA). From LRO's 50 km polar orbit, LOLA observes a 50 m-wide swath of five topographic profiles [6]. LOLA is expected to have complete polar coverage beyond 86˚S, N latitude, and the swaths will be improved to 1.25 km separation at the equator. A denser digital terrain model (DTM) dataset for latitudes < 80°S, N with 75 m/pixel resolution and no longitudinal gap, was derived from LRO Wide Angle Camera (WAC) stereo observations [7].

The Terrain Camera (TC) installed on SELENE could acquire stereo pair data from two-telescope, push-broom imagery with a one-dimensional CCD detector on each telescope [8]. The TC had a spatial resolution of 10 m/pixel from SELENE's nominal altitude of 100 km. The slant angle of the camera is 15˚. During the mission period (November 2007 to June 2009), TC successfully mapped over 99% of the lunar surface in stereo. This paper introduces the global DTM dataset derived from TC stereo observation.

**Correcting models of TC Detector Distortion and Attachment Angles:** To improve the accuracy of TC DTMs, we corrected the distortion models of TC CCD detectors and attachment angles of TC telescopes. First, we compared elevation data from TC DTMs and LALT measurements. The elevation data from TC DTMs was 80 m lower than that from LALT measurements, and lower pixel numbers tended to have lower heights, primarily due to the errors of distortion models of TC detectors in pre-flight tests (Fig. 1). We corrected the models to decrease the differences between TC DTMs and LALT measurements. Next, we corrected the errors of distortion models and attachment angles more precisely by reducing height differences among all pixels in flat mare regions, using over 5 x $10^5$ samples to decrease the morphological roughness. The corrections decreased the differences between TC DTMs and LALT measurements to 3.2 m for 1σ (Fig. 2).

**Validation Results:** We compared the longitudes, latitudes, and elevations of nine identical locations from TC DTMs acquired at different observation times. The results were 5.4 m average and 8.0 m for 1σ for longitude, 3.6m average and 7.2 m for 1σ for latitude, and 2.6 m average and 4.3 m for 1σ for elevation. We also compared the locations of Apollo LRRR [9] with TC DTMs. The results are listed in Table 1: - 17 m to 5 m for longitude, -20 m to 48 m for latitude, and 3 to 5 m for elevation.

**Future Work:** From the TC DTM dataset, we produced a global DTM mosaic with 10 m spatial resolution. In higher latitudes above 60˚N, more data were obtained at lower solar elevation angles, generating many shadows. There were also many shadows in the South Pole to Aitken (SPA) basin. We supplemented the shaded areas of the TC DTM dataset with LALT DTM data (Fig. 2). This SELENE TC and LALT DTM mosaic covers the entire lunar surface.

Different bands of Multi-band Imager (MI) on the SELENE have different view angles, thus the MI data could provide a DTM dataset. The maximum off-nadir angles of MI bands are ±3.96˚ [8]. The DTMs from MI of 20 m/pixel spatial resolution will be considered for complementing TC DTMs.

TC DTM datasets produced using the latest SELENE trajectory (based on SGM100i gravity field model [10]) have been released via the SELENE Level 2 database [11]. A global DTM mosaic based on TC data was also released via the database, but the TC data for the mosaic had been produced with using old SELENE orbital information. We plan to release carefully revised DTM mosaics based on the newest TC DTM dataset (supplemented by other DTMs) in the near future.

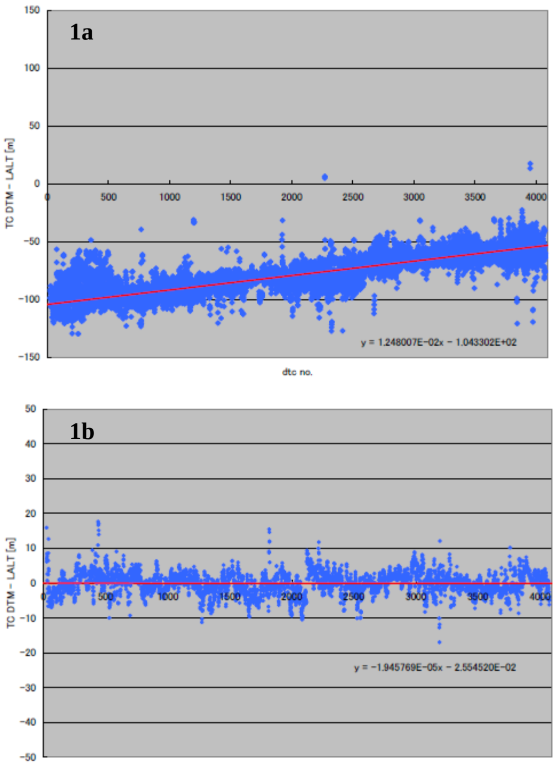


Fig. 1. Difference between SELENE TC DTM and LALT measured elevations. 1a) Before correcting distortion models of TC detectors. 1b) After correction. The difference was reduced to 3.2 m for 1σ.

Table 1. Comparison of locations of Apollo LRRR with those of TC DTMs.

| | corrected (IK:v4−b23, RISE:100i) | | |
|---|---|---|---|
| | Δ lat.[m] | Δ long.[m] | Δ elv.[m] |
| Apollo 11 LRRR | −20.8 | 3.5 | 3.0 |
| Apollo 14 LRRR | 0.6 | −16.0 | 6.0 |
| Apollo 15 LRRR | 44.6 | −17.5 | 5.0 |

* LRRR location data are from [9].

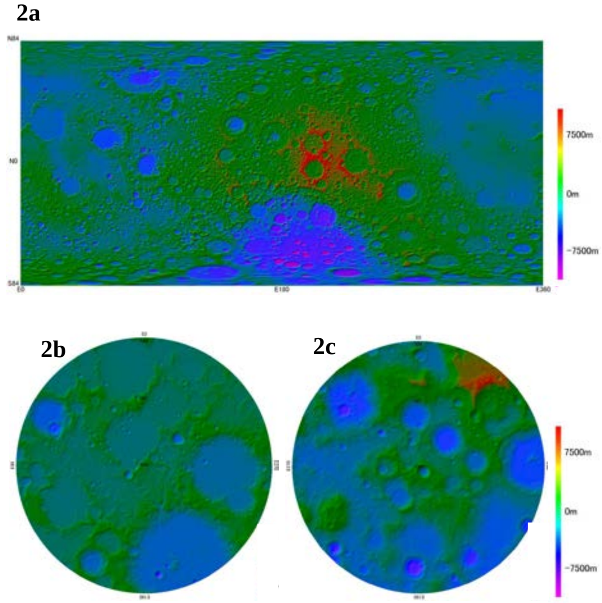


Fig. 2. Global lunar DTM based on SELENE TC and LALT data. 2a) < 84˚S, N. 2b) > 84˚N. 2c) > 84˚S. The 10 m spatial resolution TC stereo-data cover almost the entire lunar surface, but some higher latitude (> 60˚) data are unsuitable for producing good quality DTMs because of shadows and thus are supplemented by LALT data.

**References:**

[1]Apollo over the Moon: a view from orbit, (1978) eds. by H. Masursky, et al., NASA SP-362, pp. 255. [2] Zuber, M. T. et al., (1994) *Science*, 266 (5192), 1839-1843. [3] Cook, A.C. et al., (2000) *JGR*, 105 (E5), 12023-12033. [4] Araki, H. et al., (2009) *Science*, 323(5916), 897-900. [5] Noda H. et al.(2008) *GRL*, 35, doi:10.1029/2008GL035692. [6] LRO/LOLA home page, http://lunar.gsfc.nasa.gov/lola/about.html. [7] Scholten, F. et al., (2011) *LPSC XXXXII*, Abstract #2080. [8] Haruyama, J. et al, (2008) EPS, 60, 243–255. [9] Williams, J.G., et al., (2008) *JPL IOM* 335-JW,DB,WF-20080314-001, March 14. [10] Goossens, S. et al., (2011) *J Geod* 85(4), 205-228. [11] SELENE level2 data archive site, https://www.soac.selene.isas.jaxa.jp/archive/index.html.en.