LUNAR SOUTH POLE TOPOGRAPHY DERIVED FROM CLEMENTINE IMAGERY. M. R. Rosiek, R. Kirk, and A. Howington-Kraus , United States Geological Survey, Astrogeology Team, Flagstaff AZ 86001, USA (mrosiek@usgs.gov).

Introduction: During the Clementine Mission both oblique and vertical multispectral images were collected. The oblique and vertical images from a single spectral band collected during the same orbit form a stereo pair that can be used to derive the topography. These stereo pairs are being used to derive the topography of an area (90°S to 65°S latitude) surrounding the Lunar South Pole. Work on the Lunar North Pole topography will start after completion of the South Pole topography. This report provides an update on the initial results for the Lunar South Pole topography.

Clementine Data: In 1994, the Clementine spacecraft acquired digital images of the moon at visible and near infrared wavelengths [1]. On board there were four camera systems and a laser altimeter. During the first pass, periapsis was at 30 S and the hig h-est resolution images were obtained in the Southern Hemisphere [2]. Over the northern polar area a series of oblique and vertical images were obtained with the ultraviolet-visible (UVVIS) camera on each orbit. During the second pass, periapsis was at 30 N and the image acquisition strategy was reversed.

Imagery. The UVVIS camera image size was 384x288 pixels with five spectral bands and one broad band. The 750 nm band stereo pairs are the primary image source for this study. The ground sample distance (GSD) for oblique images range from 300 to 400 meters. The GSD for the vertical images, acquired at the end of an orbit, are slightly larger and range from 325 to 450 meters. Using the formula for stereo height accuracy [2] an estimate of height accuracy is 180 m. This formula is $IFOV_{max}/(K \cdot B/H)$ with $IFOV_{max}$ defined as Maximum Instantaneous Field of View, B/H is the base-to-height ratio, and K is an estimate of pixel measurement accuracy on the imagery.

Altimeter. The Clementine laser altimeter (LIDAR) data were used previously to produce a global topographic model of the Moon [3]. The model has a vertical accuracy of approximately 100 m and a spatial resolution of 2.5°. Altimetry data were collected between 79°S and 81°N. This data was filtered and then interpolated to fill in the polar regions where the altimeter did not collect data. A global topography model was then derived based on spherical harmonic expansion [3].

Image Mosaic. A global image mosaic of the moon was produced from the 750 nm Clementine data [4,5]. The mosaic includes high resolution, oblique and vertical images. Match points were picked to tie the imagery together, and the camera pointing angles were adjusted to align the imagery. This adjustment used a spherical surface, and the elevation of all points was held to a constant value, 1737.4 km. This produced a seamless image mosaic with latitude and longitude information but no information on the elevation [4,5].

Analytical Aerotriagulation: The imagery and support information were downloaded to our digital photogrammetric workstation from the Integrated Software for Imagers and Spectrometers (ISIS) system. The support data included the camera location and pointing angles. Match points used to produce the image mosaic were also downloaded. The camera angles were adjusted to account for the elevation of the match points. This was accomplished with the Multi Sensor Triangulation (MST) software from LH Systems SOCET Set software package [6.] The revised camera angles allowed for the derivation of digital elevation model (DEM) from the stereo pairs.

Initial estimate. The match point latitude and longitude from the global image mosaic are accurate and used for an initial estimate of the horizontal position. The elevations of the match points were estimated from the altimetry data. The camera angles used in the altimetry processing and in the creation of the image mosaic were adjusted independently. Hence, the horizontal position of the altimetry data and the image mosaic are not aligned correctly. Clementine was designed so the altimeter shared the optical system of the HIRES camera system. The HIRES and UVVIS camera system were aligned so the HIRES image was centered in the UVVIS image [1]. We therefore made an adjustment so that the altimetry points would fall near the centerline of the UVVIS imagery.

A DEM was created from the altimetry data using the adjusted position and the match points elevations were estimated from the adjusted DEM. These points were used in the HATS software, which allows for the use of weights on the estimated position based on the accuracy of the point. The horizontal positions were given a weight of 1 km, and the vertical estimates were given a weight of 5 km.

Stereo Adjustment. In forming the Clementine Mosaic over 3,600 images and 29,000 match points were used in the southern polar region, an area defined as 64 S or less. Different techniques were tried in adjusting the images and match points. Limitations of computer memory required breaking the data into blocks that would be solved separately and then

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brought back together. Initial results had large elevation errors in the DEMs derived from different stereo pairs. This was most likely caused by the fact that although the stereo models overlapped, they did not share similar match points. One solution for this problem would require transferring all 29,000 match points to the all the images that they fall on within the set of 3,600 images. This would be a tremendous amount of work. The solution used was to thin the images to just the stereo pairs (983 images) and to thin the match points to cover the area (973 points.) The MST Software then was used to add match points with the criteria that each image should have 9 match points distributed throughout the image. This process added 1181 points. During editing and checking the match points, 45 more match points were added. The number of match points within an image range from 3 to 30 points, with 96% of the images having 9 or more points and the average image having 16 match points.

For the adjustment procedure an iterative least squares solution is used; this allows the camera angles and match point ground locations to change during the adjustment. The final Root Mean Square (RMS) error of the match points, was 0.68 pixels. Generally, a value of below one pixel is acceptable.

Elevation extraction: The SOCET SET software provides an automated routine to extract elevation data. For every stereo model, a correlation point was determined every 1 km in ground distance. These patches of the DEM were first merged along an orbit path, and then the DEM from adjacent orbits were merged together. The stereo pairs do not completely cover the entire South Pole, and these small gaps could be filled with other images or other techniques such as photoclinometry.

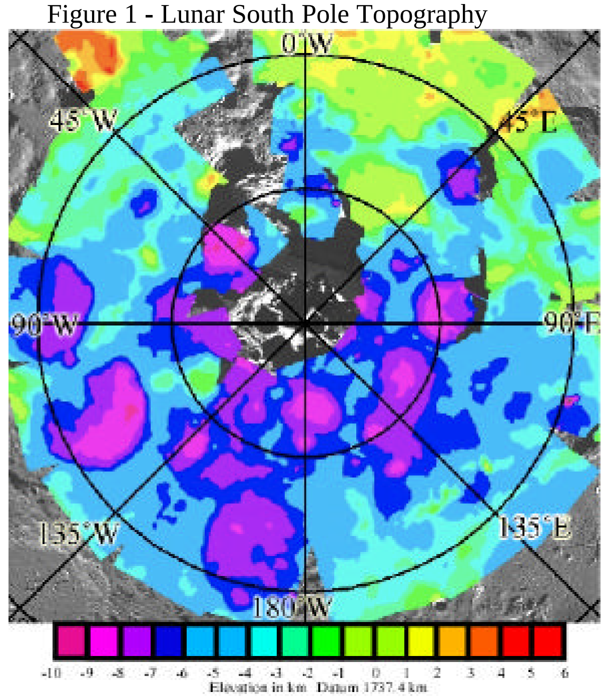
Initial Results: Data was collected starting with the models closest to the South Pole. DEMs were collected from 108 stereo models and the imagery was from 23 different orbits. Errors were summarized by number of points, RMS, standard deviation, bias, and percentage of points that were blunders (Table 1.) The elevation errors in overlapping models within an Orbit were looked at first. Within models, the RMS and Bias error are similar. This is probably caused by a tilt between the models. The standard deviation of 212m is close to the expected precision of 180m. The DEMs, from each model within an orbit, were merged together with an averaging and smoothing procedure. The elevation errors in overlapping orbits were looked at next. The bias error drops to 222m, since the orbit DEMs are based on averaged data the tilt in the models was probably averaged out. The standard deviations of the elevation errors increase to 336m.

Table 1 - Average of errors (Models: n=108, Orbits: n=23)

	Points	RMS	St. Dev.	Bias	% Blunders
Models	2125	692m	212m	636m	2.7%
Orbits	8248	447m	336m	222m	1.5%

The orbit DEMs were merged together and exported to ArcView Geographic Information System (GIS) for analysis and viewing. Figure 1 provides a false color image of the Lunar South Pole topography. The area shown covers to 80°S. This will be expanded to 65°S. Work will begin on the Lunar North Pole topography in September 1999.

Figure 1 - Lunar South Pole Topography



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