**TOWARDS GLOBAL LUNAR TOPOGRAPHY USING LROC WAC STEREO DATA.** F. Scholten[1], J. Oberst[1,2], K.-D. Matz[1], T. Roatsch[1], M. Wählisch[1], M.S. Robinson[3], and the LROC Team. [1]German Aerospace Center (DLR), Institute of Planetary Research, Rutherfordstr. 2, D-12489 Berlin, Germany, (frank.scholten@dlr.de), [2]Technical University Berlin, Institute for Geodesy and Geoinformation Sciences, Berlin, [3]School of Earth and Space Exploration, Arizona State University, Tempe AZ, USA.

**Introduction:** Global topographic models of planet or satellite surfaces can be derived from laser altimeter measurements as well as from photogrammetric processing of stereo-image data. In 1994 the Clementine spacecraft collected a global digital image dataset that allowed topographic measurements at scales of 500 to 1000 meters [1,2]. The LIDAR instrument onboard Clementine provided semi-global altimetry data for latitudes up to 60-70° (N and S) with a spacing of up to several tens of kilometers at the equator [3]. A global model representing the Unified Lunar Control Network 2005 is described in [4]. The LALT altimeter onboard the Japanese Kaguya mission [5] provided a global lunar topography model with longitudinal gaps of up to 10 km at low latitudes. Topography data from the Chinese Chang'e-1 mission are expected from photogrammetric stereo and laser altimetry [6], but products are not yet released.

We present our current investigations on the retrieval of almost global lunar topography at a scale of few hundred meters from data of the Wide Angle Camera (WAC) of the Lunar Reconnaissance Orbiter Camera system (LROC, [7,8]). From polar orbit tracks, LROC WAC provides image data with substantial across-track stereo coverage. After the commissioning phase (until September 15, 2009), which was characterized by an elliptical orbit (45-190 km), LRO is now in the primary mission phase circular orbit, with orbit altitude varying about a mean of 50 km. LROC is complemented by two narrow angle cameras (NAC-L/R, [9,10,11,12]), that allow for local high-resolution stereo mapping. We have adapted our DLR photogrammetric processing system for Mars Express HRSC [13,14] to carry out the LROC WAC data analysis we describe here.

**WAC data:** The LROC WAC consists of a 1k x 1k CCD frame which is split up into sub-frames for seven different spectral bands, two ultraviolet bands and five bands in the visible spectrum. While at near polar regions (|latitude| > 80°) WAC is usually operated in monochrome mode, all color bands are used for mapping at other latitudes. For the stereo processing described subsequently we used these WAC data of the visible bands, which comprise 704 pxl/line. Each band consists of 14 lines/subframe, while subframes form an image strip using the pushbroom principle ("push-frame"). WAC's IFOV is about 5.1 arcmin, its ground scale from 65 km orbit altitude is about 100 m/pxl.. While camera distortion parameters have been calibrated prior to launch, there were no prelaunch camera/spacecraft alignment data for WAC. SPICE kernels finally provide information about spacecraft clock, nominal orbit position, and pointing data.

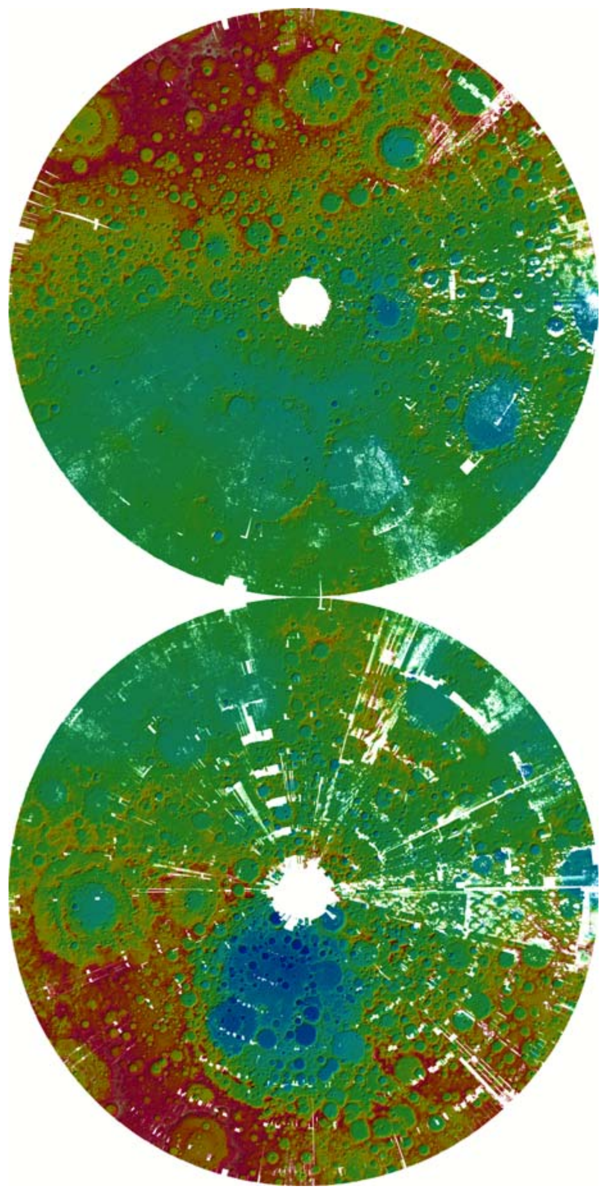

*Fig. 1: LROC WAC DTM, 1km grid, northern and southern hemisphere, Stereographic projection (preliminary results using data until Nov 25, 2009. Heights from -9,000 m (blue) to 10,750 m red/pink (gaps in white).*

**WAC alignment**: First analysis of NAC stereo models indicated that the absolute accuracy of orbit/pointing data appears to be in the scale of the WAC IFOV [12], thus we use the default orientation data without further adjustment, as well as we also use the nominal camera distortion model (currently no evidence of additional distortion). We could derive a substantial improvement of the WAC alignment by comparing DTMs from WAC data of different spectral bands, since bandwise sub-frames are placed on different positions within the focal plane and form models at different height levels in case of inaccurate alignment.

**WAC DTM generation:** Within the overlap of WAC images from adjacent orbits we carry out area-based image matching. With the derived image coordinates and the alignment corrections we then derive ground points by 3D forward ray intersection [15]. From nominal 50 km orbit altitude we obtain approx. 50% overlap and 30° stereo angle at the equator. Single WAC images within an orbit cover 10° of latitude with small gaps between these images.

**Current results**: We selected the entire WAC stereo data of the first 5 months, acquired during commissioning and nominal mission phase until November 25, 2009 to derive a preliminary DTM with a grid spacing of 1 km (Fig. 1). This model consists of more than 350 million points (~10 points/$km^2$) from almost 7,000 single models. The image resolution varies from 60 to 100 m/pxl. The mean 3D forward ray intersection error is about 50 m, mainly caused by orbit/pointing uncertainty, but still within the WAC ground resolution. In order to minimize blunders we used only those points with 3D intersection accuracy better than 150 m. Comparisons were made to LALT data, indicating that the standard deviation is 80 m between the data sets, but we do not see a systematic bias. Apart from latitudes > 80°, which have currently been excluded from processing because of low solar elevation, the coverage is > 98% for the northern and > 94% for the southern hemisphere [Fig. 2].

**Summary and outlook:** The systematic acquisition of overlapping wide-angle images from polar orbits is a powerful strategy that enables us to carry out global topographic mapping by photogrammetric stereo processing. Using WAC image data of <100 m/pxl a preliminary lateral resolution of 1 km could be derived. This will be refined subsequently, up to a resolution of about 200-500 m for all latitudes. Within the first five months of the mission, we could already achieve a coverage of about 96% for latitudes up to 80°. Remaining gaps will be filled with data of the next months of the LRO mission. Polar regions, which suffer from poor illumination conditions, have currently been excluded, but will also be subject to stereo processing. Nevertheless, these regions with crater floors in eternal shadow can be covered properly using laser altimetry data of the LRO LOLA instrument [16]. We will intensively use both datasets for detailed comparison and will also investigate the possibility/necessity to merge both for the generation of a joint topographic dataset of the entire lunar surface.

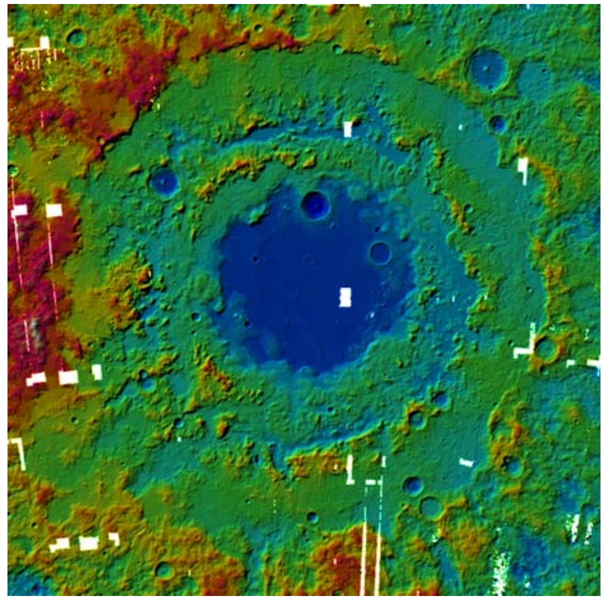

*Fig. 2: Mare Orientale, 1,100 x 1,100 $km^2$, local Lambert Azimuthal projection, 1 km grid. Heights from -4,400 m (blue) to 9,400 m red/pink (gaps in white).*

**Acknowledgement:** The authors acknowledge the tremendeous efforts of the LROC Team to operate the camera and to provide and maintain this unique dataset.

**References:** [1] S. Nozette et al. (1994) *Science, 266, 1835-1839.* [2] A.C. Cook et al. (2002) *LPSC XXXIII, Abstract #1576*. [3] M. Zuber et al. (1994) *Science, 266, 1839-1843.* [4] B.A. Archinal et al. (2006) *USGS Open-File Report 2006-1367*. [5] H. Araki et al. (2009) *Science, 323, 897-900, doi 10.1126/science.1164146*. [6] J.S. Ping et al. (2009) *Science in China G, 52 (7), 1-10*. [7] M.S. Robinson et al. (2005) *LPSC XXXVI, #1576*. [8] G. Chin et al (2007) *Space Sci. Rev., 129:391–419.* [9] R.A. Beyer et al. (2010) *this conf.* [10] B.A. Archinal et al. (2010) *this conf.* [11] J. Danton et al. (2010) *this conf.* [12] J. Oberst et al. (2010) *this conf.* [13] K. Gwinner et al. (2009) *PE&RS, 75(9), 1127-1142*. [14] K. Gwinner et al. (2009) *Earth Planet. Sci. Lett., doi 10.1016/j.epsl.2009.11.007 (in press).* [15] F. Scholten et al. (2005) *PE&RS, 71(10), 1143-1152*. [16] D.E. Smith et al. (2009) *Space Sci. Rev., 100, doi 10.1007/s11214-009-9512-y*.