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LOLA Observations of the Apollo Landing Sites

David E. Smith[1], Maria T. Zuber[1], Gregory A. Neumann[2], Erwan Mazarico[1], James W. Head[3], Mark H. Torrence[4], Olivier S. Barnouin[5]; [1]Massachusetts Institute of Technology, Cambridge, MA 02129 USA (David.E.Smith@nasa.gov; zuber@mit.edu; mazarico@mit.edu); [2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA (gregory.a.neumann@nasa.gov); [3]Brown University, Providence, RI 02912, USA (James_Head@brown.edu); [4]SGT, Inc., 7701 Greenbelt Rd., Greenbelt, MD 20770, USA (Mark.H.Torrence@nasa.gov); [5]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA (Olivier.Barnouin@jhuapl.edu)

Abstract

The laser altimeter on the Lunar Reconnaissance Orbiter spacecraft has been obtaining elevation, slope, and surface roughness observations of the Moon for over two years. Although the instrument is turned off within approximately 1 km of some of the Apollo sites, due to the presence of laser retro-reflectors that can damage the LOLA detectors, the observations in the vicinity provide scientific data on the local region around each of the landing sites.

1. Introduction

The Lunar Orbiter Laser Altimeter (LOLA) [1,2], an instrument on NASA'S Lunar Reconnaissance Orbiter (LRO) mission is a five-beam laser altimeter that operates at a wavelength of 1064.4 nm with a 28-Hz pulse repetition rate. From LRO's mapping orbit, the instrument illuminates 5-m-diameter spots on the lunar surface, returning up to 140 measurements/sec of elevation. The five profiles enable 2-dimensional slopes over various baselines to be calculated. In addition, from the measurement of the spreading of backscattered laser pulses, the LOLA instrument obtains the root mean square (RMS) roughness of the surface within 5-m laser footprints. As illustrated in Figure 1, the five spots on the surface are arranged in a cross formation which is rotated 26° with respect to the orbital motion of LRO providing 5 parallel profiles. The laser pulse rate combined with the spacecraft orbital velocity provides approximately 50-m along-track spacing between observations on each of the profiles from the 50-km altitude orbit. The arms of the cross-formation are each 25 m in length enabling surface slopes to be derived on baselines of 25-m and larger.

2. Global Elevation Observations

Since beginning of operation at the Moon in early July 2009 LOLA has acquired over 4 billion laser measurements of elevation referenced to the center of mass of the Moon. The precision of the radial measurements is 10 to 20 cm with an accuracy of about 1 m limited by knowledge of the spacecraft radial position. Accuracy of the horizontal position is estimated to be an RMS of about 10 to 20 m.

Although the along-track resolution of the data is of order 12 meters, the across-track resolution is limited by the number of orbits of the spacecraft and after 2 years of operation is an average of <0.02°, or approximately 600 m at the equator. Poleward of At latitudes 85 N&S the coverage is, on average, saturated at the 1 observation per 25-m area block [3,4].

At the Apollo landing sites, which are at mid-to-low latitudes, the longitudinal spacing is on average several hundreds of meters. Figures 2 and 3 show the regional (~100k m x 100 km) topography at 30-m resolution at the Apollo 15 and 16 landing sites. landing site locations are at the center of each figure.

3. Surface Slopes and Roughness

Using the 5-profile data of LOLA we have analyzed altimeter tracks close to the landing sites to derive estimates of the 3-dimensional slopes on 25- to 50-m baselines. One track through the Apollo 15 region that crosses the Hadley Rille in two locations shows its depth as 220 m and 240 m with slopes exceeding 30°. Away from the rim the slopes are ~3°. The surface roughness in this region is of order 1 m. We will present regional analyses of each of the six Apollo sites as seen by LOLA at 25- to 50-m horizontal resolution.

References

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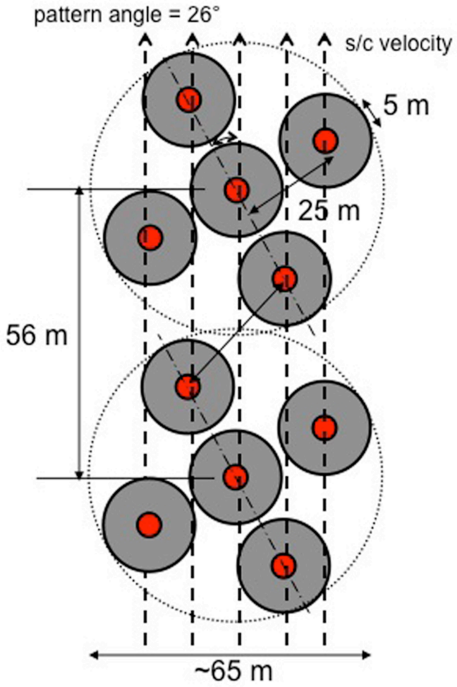

Figure 1. LOLA beam pattern on the lunar surface from the LRO polar, 50-km altitude mapping orbit. Red circles represent the beam size at full-width half maximum amplitude and grey circles represent the detector fields of view.

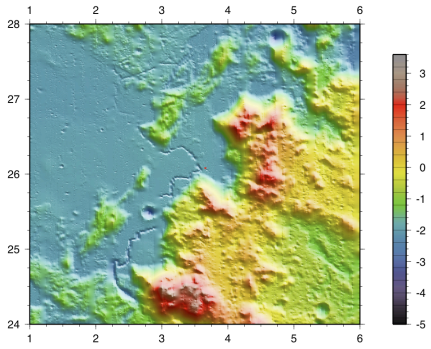

Figure 2. The Apollo 15 landing site near Hadley Rille at the foot of the Apennine mountain range. The landing site is in the center of the figure.

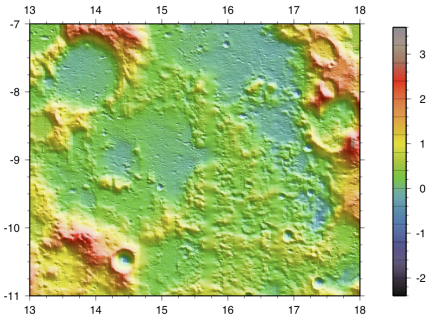

Figure 3. Apollo 16 landing site in the Descartes highlands. The landing site is in the center of the figure.