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Characterization and mapping of the Lunar subsurface by the LRS / SELENE radar sounder: methods and preliminary results

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Introduction

The LRS (Lunar Radar Sounder) instrument on board the Kaguya spacecraft (JAXA Selene mission) has been successfully operated during most of the nominal mission. This low-frequency (5 MHz) radar measured profiles of the subsurface structure at kilometres scale over the entire Moon surface. This unique dataset allowed the characterization and mapping of lava flows stratigraphy in Lunar Mare regions [1]. We now aim to integrate all available observations in order to numerically reconstruct the three-dimensional structure of basaltic layers in different Mare regions. Whereas the smooth basaltic plains in Mare regions represent an ideal case for low frequency radar sounding, analysis of radar data in all other regions of the Moon are complicated by the presence of strong clutters (radar echoes generated by off-nadir topography in "rough" areas). To bypass this difficulty, we adapted a radar simulation code [2] already used successfully for Martian subsurface analysis (MARSIS / Mars Express instrument, [3]). Comparison between actual LRS data and clutter numerical simulations will allow us to distinguish between real subsurface interfaces and off-nadir echoes. Here, we report on recent advances regarding these two on-going activities and will present more detailed results at the time of the conference.

Methods

Analysis of subsurface features

We use a combination of numerical image analysis and Geographic Information System (GIS) methods to retrieve the three-dimensional structure of subsurface in Mare regions. Introduction of the LRS dataset in a Lunar GIS platform allows the efficient identification and selection of relevant observations for a given area. Then, selected LRS profiles are individually analyzed and interpreted using a semi-automatic interface detection algorithm. Results from all profiles (localization and depth of the interfaces) are finally combined and introduced in the GIS platform to allow for visualization and quantitative analysis.

Clutter simulation

We calculate simulated sounding profiles using topographic data obtained by the LALT / SELENE laser altimeter. So far, topographic data with a spatial resolution appropriate for our simulation were only publically released for the Polar regions (>85° in both Northern and Southern hemisphere, [4]). The LPG radar simulation code [2] is then used to calculate the echoes returned from this surface along actual LRS profiles.

Results and discussion

Mare regions

Figure 1 shows an example of a sounding profile measured in Mare Serenitatis. The nadir path of the Kaguya spacecraft is plotted as a black line on the 64 ppd shaded relief map [5]. The altitude profile obtained by the LALT laser altimeter at lower spatial resolution (16 ppd) is also provided. Horizontal interfaces are easily observed in the subsurface and cannot be explained by off-nadir surface echo. These interfaces were systematically identified and mapped in different Mare regions to build three-dimensional reconstructions that will be presented at the time of the conference. Quantitative information like the volume of layers or orientation of interfaces are also determined.

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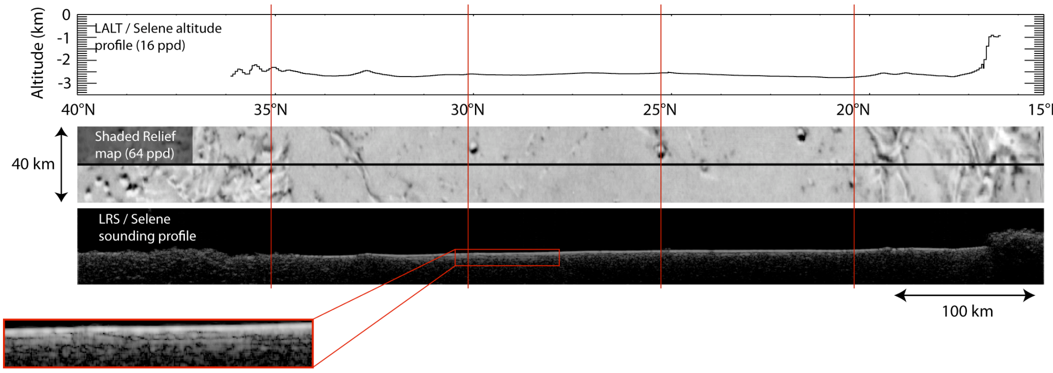

Figure 1: Example of a LRS subsurface profile measured in Mare Serenitatis (longitude: 21°E). Multiple interfaces in the first hundreds of meters below the surface are clearly observed. Semi-automatic mapping of these interfaces allow the three-dimensional reconstruction of subsurface structure.

Highlands and Polar regions

Direct identification of subsurface features outside mare regions is very challenging because of strong surface clutters. Numerical simulation of these clutters makes possible the discrimination between echoes coming from the surface and from the subsurface. Figure 2 shows an example of comparison between an actual LRS profile measured above the south pole of the Moon and a profile simulated from LALT topographic data (the altitude profile determined by this instrument is also presented).

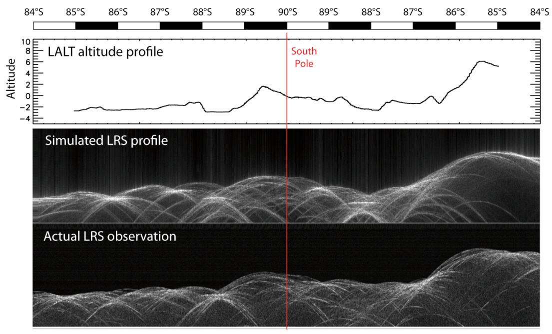

Figure 2: Comparison between an actual LRS subsurface profile acquired over the South Pole and a profile simulated from LALT / SELENE topographic data.

Whereas a satisfying general agreement is obtained between measured and simulated profiles, many strong discrepancies are also noticeable. The main source of inconsistency is thought to be the uncertainty on the localization of measurements. In the future, refined spacecraft orbit will hopefully permit a better localization of LRS observations. While, improvement of data localization is crucial for the ability of the simulation to discriminate between surface and subsurface features, we have already undertaken systematic simulations in Polar regions to determine the most appropriate places for the identification and mapping of water ice suspected at both Lunar poles [6].

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