EPSC Abstracts
Vol. 12, EPSC2018-255, 2018
European Planetary Science Congress 2018

A novel data processing technique for detection of deep subsurface echoes of lunar maria by Kaguya Lunar Radar Sounder

Takao Kobayashi, Seung Ryol Lee, and Kyo-Yeong Song
Korea Institute of Geoscience and Mineral Resources, Korea (tak@kigam.re.kr)

Abstract

A technique to enhance weak radar signals of deep subsurface echoes was developed for the purpose of identifying a deep subsurface boundary interface in the lunar subsurface. The technique comprises of two sub-techniques: one is mean subtraction technique and another is data stacking technique. The mean subtraction technique subtracts the mean value from the observation data so as to enhance small variation of the target signal whereas the data stacking technique stacks data acquired from a few orbits to enhance echo image pattern. The technique was applied to radargram image data of Kaguya Lunar Radar Sounder. The preliminary application successfully detected a deep boundary interface at an apparent depth of 2 km in Mare Crisium, which had been previously unknown.

1. Introduction

Volcanism is the important geologic event in the early history of the Moon. Volume of lava that filled basins to make today's maria is the key parameter to quantitatively evaluate the lunar volcanism. The lava volume is evaluated based on the information of lava layer thickness.

Currently the only source of lava layer thickness information is Kaguya Lunar Radar Sounder (LRS) data [1]. LRS was an HF radar whose observation frequency was 5 MHz. LRS was an on-board science mission of Kaguya, a lunar exploration program of Japan, which was launched in 2007 and finished its operation in 2009. The primary objective of LRS was subsurface geologic structure of the Moon. LRS carried out global survey of the Moon, and its footprint covered almost entire surface of the Moon during the mission period. LRS detected subsurface "reflectors", or subsurface boundary interfaces, in maria, but, against initial anticipation, the detection points were located only in limited areas in maria [1, 2]. Furthermore, the depths of those detected subsurface reflectors were much shallower than those which had been expected [1].

We developed a technique to process radargram image data of LRS for detecting weak echoes from a deep subsurface reflector. This paper describes the technique, and presents an application result of Mare Crisium observation.

2. Data processing

Our data processing technique comprises of two techniques; one is 'mean subtraction' and another is 'image data stacking.'

2.1 Mean subtraction

A radargram is regarded as a 2-dimensional image data set, $I(x,r)$, which is a function of two variables, observation position, x, and observation range, r. $I(x,r)$ may be expressed as

$$I(x,r)=I_0(r)+\Delta I(x,r) \qquad (1)$$

where $I_0(r)$ is the mean range-echo profile and $\Delta(x,r)$ is small residual term representing either surface clutter or subsurface echo. $I_0(r)$ a function of only the observation range and is defined as

$$I_0(r)=\frac{1}{N}\sum^{N} I(x_n,r) \qquad (2)$$

A subsurface reflector is recognized as a horizontal pattern image in a radargram which is made of appearance of a number of $\Delta(x,r)$ at a depth. If

$$I_0(r) \gg \Delta I(x,r), \qquad (3)$$

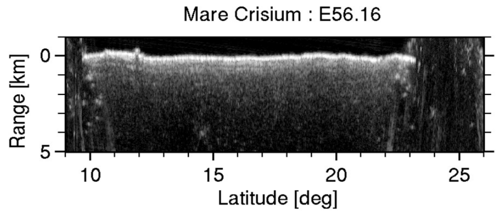

Figure 1: A radargram of LRS observation of Mare Crisium.

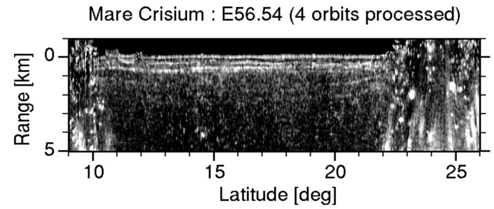

Figure 2: Produced radargram after the proposed process. Observation data of closely located four orbits including that of Fig. 1were processed.

then, $I_0(r)$ would dominate $\Delta I(x,r)$ so that $\Delta I(x,r)$ would be omitted in $I(x,r)$. In such a case, however, if $I_0(r)$ is removed from $I(x,r)$, then $\Delta I(x,r)$ would be easily recognized. We first calculate $I_0(r)$ after Eq. (2), then subtract it from $I(x,r)$ to obtain $\Delta I(x,r)$.

2.2 Image data stacking

Though weak echoes can be recognized now, clutters are also more conspicuous. However the subsurface boundary echoes appear in rather coherent fashion at limited depths around boundary interfaces while clutters appear in a random manner at all depths. We make use of these natures to distinguish weak subsurface echoes by stacking more than one set of $\Delta(x,r)$.

3. Result

Figure 1 shows a radargram presentation of LRS data which were acquired over Mare Crisium along a longitudinal line at E56.16 degrees. The data are released SAR-processed data [3] with a synthetic aperture 5 km. Shallow subsurface reflector echoes are recognized at apparent depths (ranges) shallower than 1 km, however none but clutters can be recognized at deeper depth than 1 km.

Figure 2 shows a radargram which was produced by the proposed technique. The data were acquired from closely located four orbits along longitudinal lines of E56.16, E56.52, E56.72, and E56.74. The process obviously improved visibility of subsurface reflector echoes: the echoes from depths shallower than 1 km appear more prominent while those from deeper reflectors are now recognized. The depth of the deepest reflector echo is measured as 2 km in the radargram.

4. Conclusion

This paper described newly proposed technique which is to be applied to the LRS data for the purpose of improving detectability of weak subsurface echoes. An application example showed previously unknown deep weak subsurface echoes at an apparent depth of 2km in Mare Crisium.

Acknowledgements

This work is supported by the basic research 18-3111-1 of Korea Institute of Geoscience and Mineral Resources.

References

[1] Ono, T. et al.: Lunar Radar Sounder observation of subsurface layers under the nearside maria of the Moon, Science, Vol. 323, pp. 909 – 912, 2009, DOI: 10.1126/science.1165988.

[2] Pommerol, A. et al.: Detectability of subsurface interfaces in lunar maria by the LRS/SELENE sounding radar: Influence of mineralogical composition, G.R.L, 2010, Vol. 37, L03201.

[3] SELENE data archive, JAXA, http;//darts.isas.jaxa.jp/planet/pdap/selene/index.html.en.