EPSC Abstracts
Vol. 11, EPSC2017-1007-1, 2017
European Planetary Science Congress 2017

Inter-comparison of Methods for Extracting Subsurface Layers from SHARAD Radargrams over Martian polar regions

S. Xiong (1) J.-P. Muller (1) and R. C. Carretero (1,2)
(1) Imaging Group, Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK, (2) Universidad Pontificia Comillas, Madrid, Spain. (siting.xiong.14@ucl.ac.uk)

Abstract

Subsurface layers are preserved in the polar regions on Mars, representing a record of past climate changes on Mars. Orbital radar instruments, such as the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) onboard ESA Mars Express (MEX) and the SHAllow RADar (SHARAD) onboard the Mars Reconnaissance Orbiter (MRO), transmit radar signals to Mars and receive a set of return signals from these subsurface regions. Layering is a prominent subsurface feature, which has been revealed by both MARSIS and SHARAD radargrams over both polar regions on Mars. Automatic extraction of these subsurface layering is becoming increasingly important as there is now over ten years' of data archived. In this study, we investigate two different methods for extracting these subsurface layers from SHARAD data and compare the results against delineated layers derived manually to validate which methods is better for extracting these layers automatically.

1. Introduction

Aside from surface images, radar sounding provides a non-intrusive and relatively direct way to investigate the structure and dielectric characteristics of the subsurface. Radar sounders operate at low frequency (several megahertz to hundreds of megahertz), and transmit waves into the subsurface and record the signals scattered back from subsurface structures and dielectric discontinuities [1]. The orbital images collected by these radar sounders are called radargrams which are formed by sets of radar return signals reflected from subsurface features as the platform moves forward in its orbit. Therefore, a radargram shows a sounding profile taken over a certain ground track.

Subsurface layers of PLDs have been revealed by the MARSIS and SHARAD [2-3]. These two instruments are currently orbiting around Mars and provide high-quality data which make a detailed study of the subsurface of Mars possible. Compared to MARSIS, SHARAD provides radargrams of higher range (vertical) resolution, which is 15 m in free space and 10 m within ice [3]. This makes it possible to detect fine linear interfaces in the Polar Layer Deposits (PLDs).

MARSIS and SHARAD have been orbiting Mars and collecting a huge amount of data for more than ten years. However, the analysis of such data has been carried out mainly by means of manual investigation, especially in the case of these planetary missions. The huge data collection calls for the development of automatic or semi-automatic techniques for the analysis of radar sounder data in order to extract this geometric information from the radargrams in an effective and fast way. Extracting subsurface layers from radargrams is a preliminary step before trying to connect these layers to other geological knowledge. Thus, the development of automatic techniques for the analysis of these radargrams is of fundamental importance for full data exploitation.

In this study, we developed two methods for detecting subsurface linear features from SHARAD radargrams, one of which is based on a Continuous Wavelet Transform (CWT) and Hough line detection, the other is based on an event detection algorithm, which itself is based on signal analysis by a short-term-average/long-term-average (STA/LTA) phase picker taken along a characteristic function. Radargrams from both NPLD and SPLD are used to validate the effectiveness of the proposed methods. To validate the results, we manually delineate subsurface layers from the radargrams and then compare the results with the manually delineated layers.

2. Datasets and Methods

The SHARAD radar sounder is provided by the Agenzia Spaziale Italiana (ASI).. The characteristics of this radar sounder can be found in [4]. The spatial resolution of the radargrams is approximately 450 m × 3 km (along track × across track). The range sampling is 37.5 ns, corresponding to 5.63 m in free space and slightly more than 3 m in an icy subsurface ($\varepsilon = 3.15$). The range resolution is 10 m in ice.

In this study, extraction of layering features from radargram is separated into three steps. Firstly, we apply an image enhancement by using log-Gabor filtering to the original radargram to denoise the image. Secondly, along each columns (profile) of the radargram, we apply two different methods to extract the peaks of signal, which indicate the dielectric contrasts. The first method is based on Continuous wavelet, through which the signal can be analysed at different scales, $s = \{1,2,3, \ldots N\}$. After the derivation of the scalogram, we can extract the stable peaks which show high signal at different scales. The second method is an event detection algorithm, which is based on signal analysis by a short-term-average/long-term-average

(STA/LTA) phase picker taken along a characteristic function. Finally, a Hough Line Detection (HLD) is applied to the extracted peaks to connect the peaks into line segments.

3. Results

The proposed processing flow is here applied to four radargrams in the Martian polar regions. Currently, an example of the results from one SHARAD radargram (product ID: s_00598301) is shown in Figure 1.

4. Discussion and Conclusions

In this study, we proposed two methods to extract subsurface layering features from SHARAD radargrams. From the preliminary results, we can see that by using CWT, more peak signals in the radargram have been picked out than those from the event detection algorithm, in which a number of peaks is largely dependent on the window selection. In this example, the selected window size tends to choose a moderate number of peaks to depress the background noise signal. On the other hand, the CWT tends to pick out more signal peaks, and in the following HLD, the peaks can be connected, while scattered background noise is depressed. The HLD results in long continuous lines when there are more peaks which belong to the same layer have been detected. However, when a smaller number of peak signals have been detected, then it results in short segmented lines.

Acknowledgements

Part of the research leading to these results has received funding from the STFC "MSSL Consolidated Grant" ST/K000977/1 and partial support from the European Union's Seventh Framework Programme (FP7/2007-2013) under iMars grant agreement No. 607379 as well as from the China Scholarship Council and the UCL Dean of MAPS fund.

References

[1] Ferro, A., and Bruzzone, L. Automatic Extraction and Analysis of Ice Layering in Radar Sounder Data. IEEE Transactions on Geoscience and Remote Sensing, 51, 1622-1634, 2013. doi:10.1109/TGRS.2012.2206078.

[2] Picardi, G., Biccari, D., Seu, R., et al. MARSIS: Mars Advanced Radar for Subsurface and Ionospheric Sounding. European Space Agency ESA SP (1291): 97–114, 2009.

[3] lamini, E., Fois, F., Calabrese, D., et al. Sounding Mars with SHARAD & MARSIS. In Proceedings of the 2007 4th International Workshop on Advanced Ground Penetrating Radar, IWAGPR, 2007. doi:10.1109/AGPR.2007.386561.

[4] Seu, R., Roger, J. P., Biccari, D., et al. SHARAD Sounding Radar on the Mars Reconnaissance Orbiter. Journal of Geophysical Research: Planets (1991--2012) 112 (E5): 1-18, 2007.

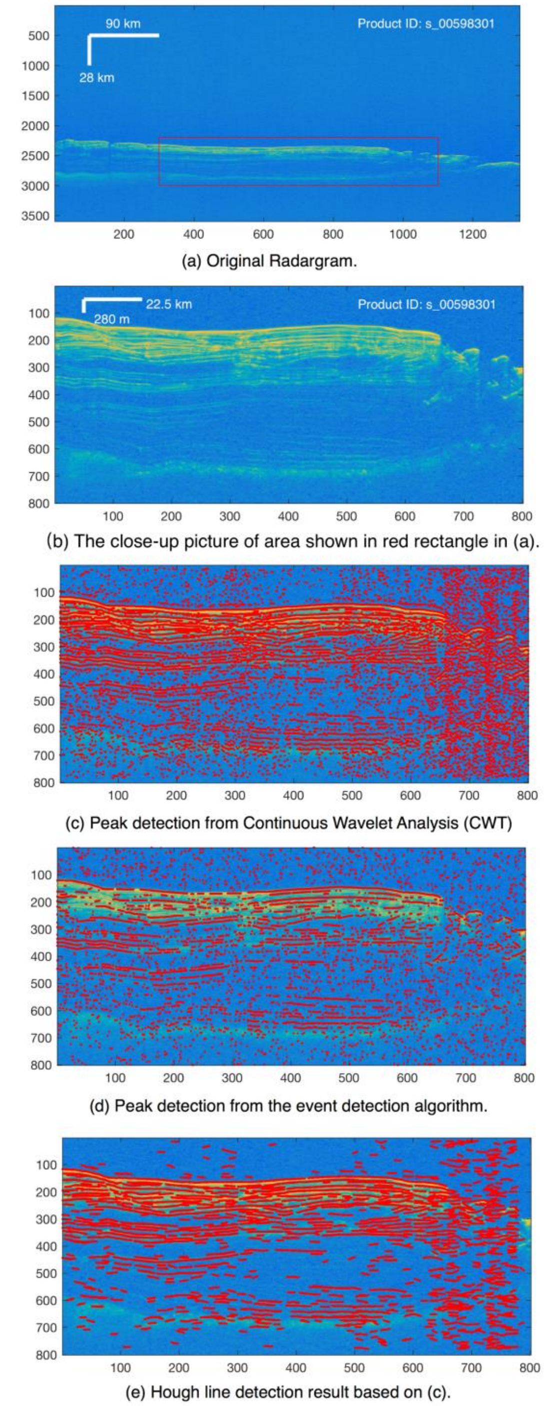

Figure 1. Preliminary results from CWT + HLD, and an event detection algorithm with short-term window of 9 pixels and long-term window of 13 pixels (the vertical scale bar in (a) and (b) is in the free space).