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SHARAD Data Analysis with High Resolution Digital Terrain Models

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Abstract

The SHAllow RADar (SHARAD) is a synthetic aperture radar (SAR) onboard Mars Reconnaissance Orbiter, in Martian orbit since 2006 [1]. With its 20MHz frequency, it can fathom the first hundreds of meters of the subsurface with a range resolution of about 10m in typical Martian materials. In order to detect subsurface interfaces with radars, we need to eliminate the echoes coming from the surface : as the design of most radars in orbit gives them a large antenna lobe, off-nadir echoes could arrive at the same delay as a subsurface nadir reflection. The classical method to remove this so called “clutter” consists in comparing the radar signal to simulations of the surface echoes using Digital Terrain Models (DTMs). Our aim is to study the first tens of meters of the Martian subsurface with SHARAD. To do so, we need high resolution DTMs because in theory, the higher we get in resolution, the more detailed the simulation will be and the clearer the discrimination between surface and subsurface features will be. We will present results on high resolution simulations performed with SPRATS, our coherent simulator. We will show that while being high resolution, models obtained by photogrammetry sometimes contain artifacts that can be misleading for radar data interpretation.

Simulations with SPRATS : first study with MOLA DTMs

SPRATS is a toolset developed at IPAG that allows to perform both coherent radar simulations of surfaces and 3D SAR processing of them [2], [3]. Those capabilities enable the simulation of the actual signal sensed by SHARAD, with the same processing applied to it, in order to get as close as possible from the instrument results. It allows for a direct power comparison and thus finer analysis. To begin, we performed simulations with DTMs generated with MOLA, a laser altimeter [4]. While having a relatively low resolution, the nature of the acquisition method give those DTMs a high accuracy and precision, resulting in very low artifacts. To study deep reflectors in areas of relatively low rugosity (i.e. the northern plains [5]), those models are sufficient. But the low resolution is a limiting factor when studying close subsurface, or simply to reproduce surface roughness effects on the radar signal. To improve the simulations, higher resolution models are necessary.

HRSC models, higher resolution but sometime containing artifacts

With a resolution of 50 to 100m, HRSC DTMs [6] yield better results in simulating smaller details. It allows to confirm or discard reflectors identified with MOLA [7]. However, these models are acquired by photogrammetry, a technique that is an estimation of the surface topography, compared to MOLA which is a direct measurement. Photogrammetry introduces artifacts that are not easy to estimate, because they depend on the actual topography. We will show a comparative study of simulations with HRSC and MOLA models on a region of interest located in Terra Cimmeria, following a study made by [8]. The amplitude of the artifacts on the HRSC models is too high to study the first tens of meters of the subsurface with SHARAD. Following the idea of getting as close as possible to the actual SHARAD data, we need models that describe the surface at a resolution better that the radar's wavelength.

Simulations with models at wavelength-scale resolution (CTX)

We will present a comparative study of simulations using CTX models — with a resolution of 12m — and HRSC models. We will also show that the scale of the artifacts on these DTMs being below the SHARAD's wavelength, CTX DTMs yield near perfect surface echoes simulation, allowing for a fine detail comparative analysis of the SHARAD data. However, given their acquisition method [9], CTX DTMs have a relatively poor surface coverage compared to HRSC, so we used photoclinometry with CTX images on lower resolution models [10] to keep the high resolution information. Comparing high resolution simulations using these models to SHARAD data allowed to highlight small-scale artifacts on the CTX DTMs, as they introduce noise in the radargram.

Conclusions

This study shows that wavelength-scale or smaller artifacts on DTMs are needed to perform shallow subsurface analysis of SHARAD data. It also showed that high resolution models acquired by photogrammetry are prone to artifacts, which can perturb the simulated signal. This artifacts issue can prove to be helpful for DTM quality estimation, especially for missions where no laser altimeter is present to validate the altimetry measurements.

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