DELAY/DOPPLER PROCESSING OF THE CASSINI RADAR ALTIMETER: SUPERRESOLUTION TECHNIQUES V. Poggiali[1,2], A. G. Hayes[1], M. Mastrogiuseppe[2] and J. Mullen[1] [1]Cornell University, Ithaca, NY, United States (valerio.poggiali@uniroma1.it), [2]Università degli Studi di Roma "La Sapienza".

Introduction: Coherent processing of radar altimeters data has been demonstrated as a powerful technique that greatly enhance the performances of conventional radar altimeters both in terms of an increased number of looks available for averaging and in a substantial reduction of the along-track footprint size [1].

The information included in the Doppler bandwidth generated by the Cassini spacecraft tangential motion can be conveniently exploited in order to resolve features far smaller than the half power footprint (1 vs 8 km).

The delay/Doppler algorithm performs a delay compensation that corrects for the hyperbolic wavefront curvature associated to each Doppler filter, whose outputs are relative to different along-track positions. The incoherent sum of the height estimates from all the Doppler filters relative to a specific along-track position results in a stronger radiometric response and, consequently, to lower height estimation variance.

We will show that the application of this superresolution concept to the Cassini RADAR altimeter. Coupled to a proper implementation of specific bandwidth extrapolation techniques, the result is a more precise dataset over some of the most important surficial units of Saturn's largest moon, Titan.

Super-resolution Tecniques: The 4.25MHz chirp bandwidth of the Cassini RADAR altimeter allows production of relative elevation profiles with a vertical bin size of about 35 m. Scientific interpretation of these products can be challenging if compression schemes based on the conventional Fourier techniques are adopted. The application of a parametric autoregressive (AR) time-series model can be used in order to improve range resolution of coherent radar returns by making realistic assumptions about the sinusoidal properties of the target's frequency response, especially in those cases in which it consists in the superimposition of sinusoids from a series of discrete scattering centers. As a result, extrapolation of the received signal prior to pulse compression can produce an improvement in the range resolution of a factor up to x4 [2]. Furthermore, the linear nature of this processing makes recompressed pulses still suitable for backscattering and phase responses studies.

The application of the Burg's Maximum Entropy Method (MEM) can be very useful in the Cassini RADAR data processing and analysis, as it can increase the system range resolution (up to about 15 m) and detect closely spaced point scatterers. In order to perform an accurate bandwidth extrapolation and achieve an improvement in resolution, it is important to avoid data samples near the edges of the spectrum, where spectral distortion effects from Fresnel ripples are located (see Figure 1).

In our analysis, of the 4.25 MHz Cassini radar altimeter bandwidth, we used about 2 MHz taken from the central portion of the spectrum, and after extrapolation we obtained a final bandwidth of 10 MHz.

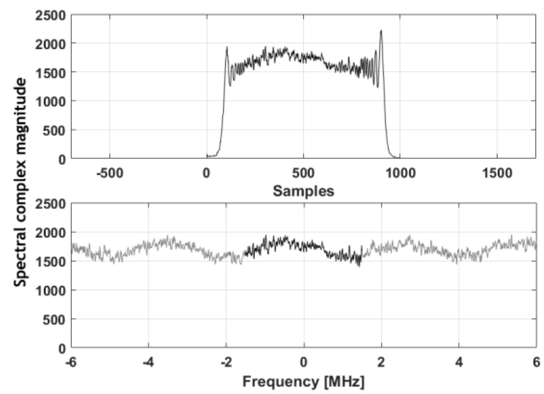

Figure 1. Example of x4 bandwidth extrapolation of a simulated pulse spectrum received from a 2 layers scenario for which we imposed 20 m of separation between the flat interfaces and 15 dB of Ps/Pss ratio. In the upper panel the original 4,25 MHz signal bandwidth, in the lower panel the extraction of the central 3 MHz (in black) is followed by a backward and forward extrapolation leading to a final bandwidth of 12 MHz (black + gray). For increasing visual clarity the spectrums have been filtered with a moving average filter with a span of 5.

Results: The advanced processing presented here is able to increase the number of points in the altimetric profiles up to a factor of 1:13, depending on the spacecraft altitude and, thus, on the available Doppler bandwidth.

Our test analysis has been performed over a 40 km empty lake observed both on April 10, 2007 during the fly-by T28. The basin, that is shown in Figure 2, was re-observed by the radar in its altimetric mode one month later, during the fly-by T30. The improved radargram permits a more precise analysis of the shape of this feature, with the early-late tracker indicating a maximum depth respect to the top of the surrounding rims of ~700 m and >35° steep walls. Please refer to [3] for a detailed description of the results obtained in this study case.

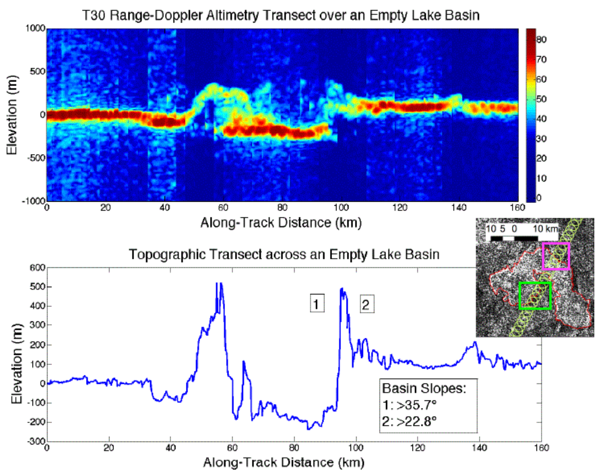

Figure 2. Radargram and altimetry profile obtained with the advanced processing for an empty lake located at (69.77N, 4.06E).

The second test surface is a dune filed observed by the Cassini radar altimeter during the flyby T98 (see Figure 3). In this case, the spatial resolution increased from the 24-60km diameter of the pulse limited footprint to about 1-3 km Doppler-bin.

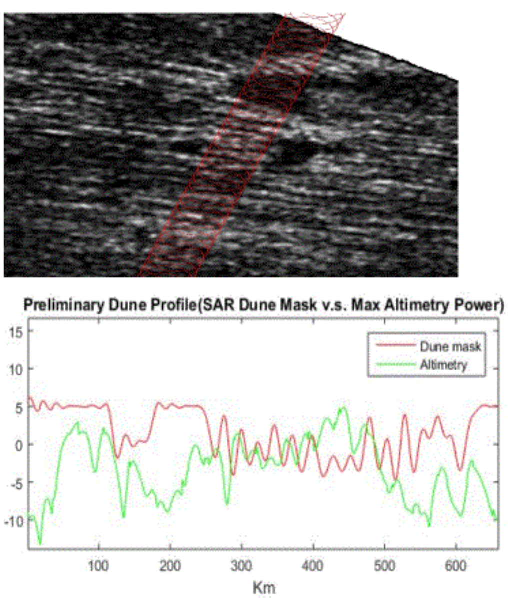

Figure 3. Comparison between SAR and altimeter backscattering along a few tens kilometers transect traversing perpendicularly the dunes field.

Discussion: These preliminary results show that delay-Doppler processing and super-resolution algoritms are valuable tools for optimizing the process of extraction of all that information still hidden inside the Cassini radar altimeter dataset. More tests will follow in order to assess the algorithm performances over a selection of different kinds of surficial units, including dunes, impact craters, tectonic features, and putative criovolcanic features.

References: [1] Raney R. K. (1998) IEEE Transactions on Geoscience and Remote Sensing, 36, 1578-1588. [2] Cuomo K. M. (1992) Project Report CJP-60, Lincoln Laboratory, MIT. [3] Michaelides R. J. (2016) Icarus, 270, 57-66.