A Generalized Clutter Simulation Software for the Analysis of Airborne and Spaceborne Radar Sounding Data. M. S. Christoffersen[1], J. W. Holt[2], S. D. Kempf[2], [1]The University of Texas at Austin, Jackson School of Geosciences, [2]The University of Texas Institute for Geophysics

Introduction: The simulation of surface clutter is an invaluable tool in the analysis of airborne and spaceborne radar sounding data in order to discriminate true subsurface reflectors from off-nadir surface echoes with similar time delays [1,2]. Software has been developed to simulate surface clutter, but to date each instance has been specifically written to work with a single dataset or instrument [1,3], for example the Shallow Radar (SHARAD) on the Mars Reconnaissance Orbiter [2-4] (Figs. 1 and 2).

The algorithms employed to perform a clutter simulation for different planetary bodies or radar instruments are not inherently different, however, so new software should not be necessary for individual missions. It could also aid in mission design, to predict clutter for specific radar paths over features of interest on any planetary body where topographic data is available. The creation of a generalized clutter simulator that can use many types of navigation files, digital elevation model formats, and coordinate reference frames is our goal, and is facilitated by the use of open source libraries such as GDAL and NumPy [5,6].

Software Description: The clutter simulation software created in the project uses a facet-based model for the calculation of surface reflection. Such a model creates a surface made of facets based on the supplied elevation model, and then calculates the return strength and two-way travel time for each facet to simulate the radar return from the surface. Facet-based clutter simulations have been shown to be effective even when the model of surface topography is of lower resolution than the radar wavelength [2]. At each point in the input navigation file the echo strengths and two-way travel times for an arbitrarily sized rectangle of arbitrarily sized facets are calculated. The return strength and two way travel time for each facet are used to create a “cluttergram,” which shows the predicted surface returns in time delay. Changing the dimensions of the surface area in which facets are computed allows for simulation of clutter for both focused and unfocused data, while modifying the dimensions of the facets allows for reduction of cluttergram quality in exchange for quicker run time and vice versa.

Generality is accomplished in the software largely through the use of the Geospatial Data Abstraction Library (GDAL) [5] that can read in many digital elevation model (DEM) formats and perform conversion between different coordinate systems. Managing input data has been the largest problem to surmount when creating the generalized clutter simulator. The DEM values are read into an array and the navigation points are converted into a standard format using GDAL. Converting the data into a standard format is the largest concern when attempting to write a generalized clutter simulator, once the data is in a standard format the facet size and number of facets is easily parameterized in the algorithm.

Another obstacle to the creation of a generalized clutter simulator is the wide variety of timing references used for radargrams. The data can be referenced simply to the location of the signal source (i.e., the spacecraft), or modified based on a spheroid or areoid model of the body being sounded. Our software has parametrized this problem, allowing the user to reference the output cluttergram to the signal source, a constant elevation, spheroid, or areoid, with the use of a DEM referenced to the areoid.

The facet-based simulation is inherently an $O(n^2)$ problem; therefore, halving the dimensions of the facets over a constant area will quadruple the number of calculations that need to be done. The inherent complexity quickly becomes a problem with small facet sizes, but there are several possible methods to speed up the calculations, which we are evaluating along with the goals of generality and code portability.

Applications: We envision this generalized clutter simulator for application with SHARAD (Figs. 1 and 2) and MARSIS at Mars, the Kaguya lunar radar sounder, airborne applications on Earth, and future planetary missions, with the ability to test scenarios for radar trajectory given a suitable topographic model.

Future work: Currently the software has no mechanism to account for the radiation pattern of the transmitting or receiving antenna; this is a necessary feature to accurately simulate received clutter for directional antennas and will be added soon. Another useful but less necessary feature would be the ability to multi-thread either the simulations for individual points in a navigation file or individual navigation files in a list of files to simulate. Memoization, saving previously computed results to memory so that they can be later referenced using input parameters instead of being calculated again, could be employed to speed up the facet return calculation, but would take a large amount of memory. Addition of the option to output the simulation data in common scientific formats such as NetCDF and SEG-Y would likely be useful since those are formats often used to quantitatively analyze radar sounding data.

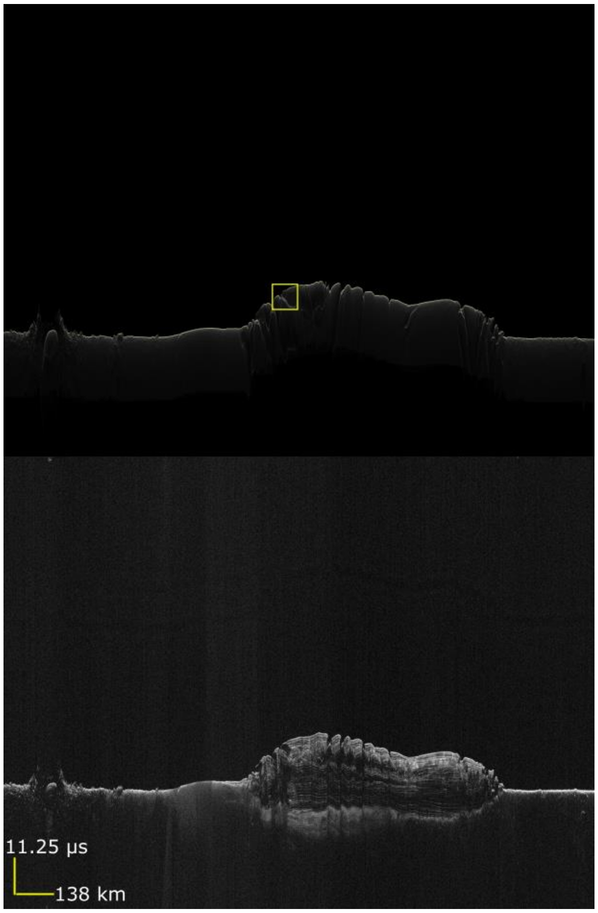

Figure 1: Cluttergram (top) generated for SHARAD radargram (bottom) 1294501 crossing Planum Boreum, Mars. This uses the MOLA gridded data product [7].

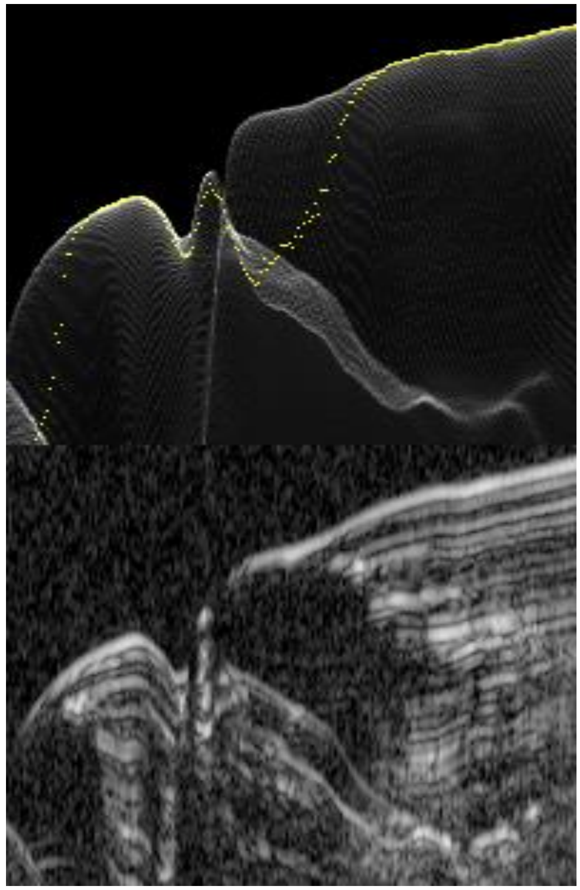

Figure 2: Comparison of cluttergram (top) and radargram (bottom) for yellow-boxed portion of Figure 1. Yellow dots represent the calculated time delay of the surface return.

References:

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