QUANTITATIVE ANALYSIS OF VENUS RADAR BACKSCATTER DATA IN ARCGIS

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Introduction: Ongoing mapping of the Ganiki Planitia (V14) quadrangle of Venus and definition of material units has involved an integrated but qualitative analysis of Magellan radar backscatter images and topography using standard geomorphological mapping techniques. However, such analyses do not take full advantage of the quantitative information contained within the images. Analysis of the backscatter coefficient allows a much more rigorous statistical comparison between mapped units, permitting first order self-similarity tests of geographically separated materials assigned identical geomorphological labels.

Such analyses cannot be performed directly on pixel (DN) values from Magellan backscatter images, because the pixels are scaled to the Muhleman law for radar echoes on Venus and are not corrected for latitudinal variations in incidence angle [1]. Therefore, DN values must be converted based on pixel latitude back to their backscatter coefficient values before accurate statistical analysis can occur. Here we present a method for performing the conversions and analysis of Magellan backscatter data using commonly available ArcGIS software and illustrate the advantages of the process for geological mapping.

Methods: We used ArcGIS 9 to quantify the characteristics of georeferenced Magellan images (250 m/pixel) in Lambert Conformal Conic projection. The calculations involved are straightforward, but the conversion methods are complicated by the need to calculate the latitude for each pixel of a 125 MB image.

Calculations. Pixel latitude values were converted to incidence angles using a best-fit approximation of the values from a table of latitude vs. look angle [1]:

$$\theta = 0.00008 \times \lambda^3 - 0.0127 \times \lambda^2 + \quad \text{[Eq. 1]}$$
$$0.1825 \times \lambda + 45.665$$

where θ is incidence angle and λ is latitude. Pixel DN values were then converted to backscatter coefficient values following [1]:

$$\sigma_0 = 10^{0.02\,(\text{pixel DN} - 101)} \times (0.0118 \cos(\theta + 0.5°)/$$
$$[\sin(\theta + 0.5°) + 0.111 \cos(\theta + 0.5°)]^3\,) \quad \text{[Eq. 2]}$$

where σ_0 is the backscatter coefficient. After statistical analysis, values were converted to logarithmic form (decibels) following [1]:

$$\text{value in dB} = 10 \log_{10} \sigma_0 \quad \text{[Eq. 3]}$$

Conversion process. We developed a conversion method involving steps specific to ArcGIS 9 software. We began with pixel DN values stored in a raster data-

set, converted this to a point file, performed calculations on each point, and then converted the results into a new raster. An overview of the process (to be discussed in greater detail at our presentation) follows:

➢ Using Raster Calculator in the ArcGIS Spatial Analyst extension, clip raster into sections small enough to promote manageable computations.

For each raster section:

➢ Convert raster pixels to points, where points store DN values (Spatial Analyst).
➢ Copy point shapefile to new ArcMap dataframe.
➢ Clear dataframe's spatial reference information and manually enter geographic coordinate system.
➢ Use point_Get_Y VBA script (Easy Calculate 4.7, www.ian-ko.com; 2/27/2004) in attribute table to calculate Y values of each pixel in degrees latitude.
➢ Calculate incidence angle (Eq. 1) and backscatter value (Eq. 2) within the point file's attribute table.
➢ Convert points to a new raster with raster pixels storing σ_0 value (Spatial Analyst).
➢ Combine rasters using MosaicToNewRaster tool.

Data gap pixels should be removed from the output raster to ensure collection of accurate statistics. Statistics for material units are then calculated using the Zonal Statistics tool in Spatial Analyst. To avoid averaging error, statistical operations should only be performed on σ_0, not dB values [1]. We converted individual points and average values from σ_0 to decibels following Equation 3.

Unit	σ_0(dB)	N
Entire quadrangle	-13.4 (Err, -10.3)	103266932
Potential pyroclastic flow deposit	-16.9 (-20.8, -14.9)	216993
Section*	-16.3 (-18.4, -14.9)	21352
Dark plains (prc)	-15.5 (-28, -12.6)	40673842
Section 1*	-15.3 (-15.8, -19.7)	205303
Section 2*	-15.4 (-18.2, -13.7)	163701
Intermediate plains (prb)	-12.5 (-25.1, -9.6)	14373114
Section 1*	-13.3 (-18.3, -11.0)	128503
Section 2*	-11.6 (-15.0, -9.7)	130417
Light plains (pra)	-13.2 (-18.7, -10.8)	9118694
Section 1*	-12.2 (-16.6, -10.1)	192811
Section 2*	-12.3 (-17.5, -10.1)	70538

Table 1. * in label denotes "representative subsection" of unit, parenthetical σ_0 values indicate ± 1-σ values, and N is number of pixels analyzed.

Discussion: Table 1 shows the calculated mean and 1-σ standard deviation of backscatter coefficients (subsequently converted to dB) for the quadrangle as a whole and for several specific material unit types. Pixel subsections selected as 'representative' of the units, the standard approach used to quantify material properties in many mapping projects to date [e.g., 2], are provided for comparison. Depending on the subsection chosen, the calculation can yield values at, above or below the true mean for the unit, demonstrating clearly that identifying a 'representative' subsection can be difficult. Subsection variability of a dB or so (e.g., prb) is problematic when units' variations are often of similar magnitude. Working with each unit in its entirety yields results which are more robust and repeatable; similarly, utilizing latitude-corrected σ_0 values helps ensure that sources of error inherent to direct averaging of DN radar values [1] are avoided.

In spite of the advantages, however, care must be taken when interpreting statistical data collected for entire units, and several sources of error must be considered. First, the best-fit approximation used to convert latitude to incidence angle creates an error that is everywhere <2%. Second, geologic features (fractures, etc.) that modify mapped geologic units will affect the backscatter averages of the unit [2]. For example, a dark plains unit deformed by radar-bright fractures, when considered as an aggregate, will yield a dB value that is greater than an undeformed section of the same plains unit. This is not necessarily an undesirable outcome, however, because it allows identification of units with greater or lesser backscatter variability and unusual properties, encouraging careful probing to discover the geological source(s) of the variability. For instance, Table 1 and Figure 1 reveal that *prb* (green circle) and *pra* (green square)—separated qualitatively using radar backscatter differences—are statistically indistinguishable. Figure 2, however, reveals that *prb* exhibits greater variance than *pra*. Tracking down the source of this difference (in this case fracturing enhances σ_0 for *prb*) yields insight into why their backscatters are comparable.

One lesson from our work to date is that quantification of material unit properties and subsequent use of the data as a mapping aide requires great care; in many instances, simple calculation of mean and standard deviation without careful consideration of a unit's geology can mislead mapping efforts. Ideally, a complete quantitative analysis will fold in the complete array of physical property data (emissivity, meter-scale surface roughness, etc.), not just backscatter coefficient and topography information; we are currently investigating tools suitable for this type of analysis [3].

Overall, the present conversion method allows effective quantitative investigation of the quadrangle; the approach is robust, and when employed thoughtfully can yield insight into geological conditions and processes. Future work will include refining conversion methods to allow efficient quantitative analysis of full resolution FMAP data (75 m/pixel) that will augment continued analyses within the V14 quadrangle.

References: [1] Campbell, B. A. (1995) *USGS* Open-File Report 95-519. [2] Rosenberg E. and McGill G. E. (2001) *USGS* Geol. Investigations Series I-2721. [3] Richards et al. (Current edition) *LPS XXXVI*.
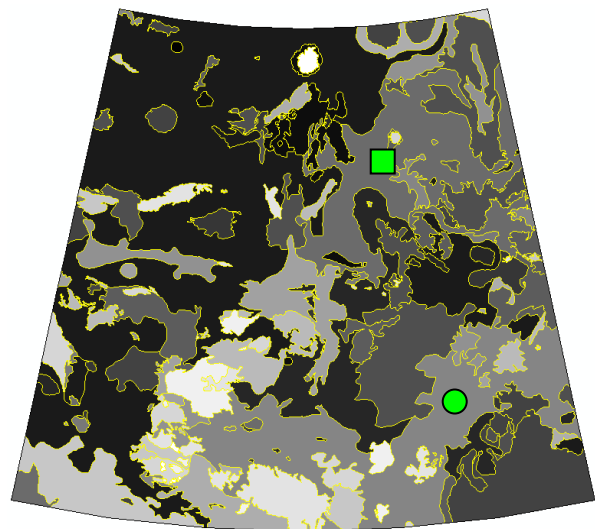
Figure 1: Mean backscatter values for each material unit. Shade corresponds to backscatter brightness.
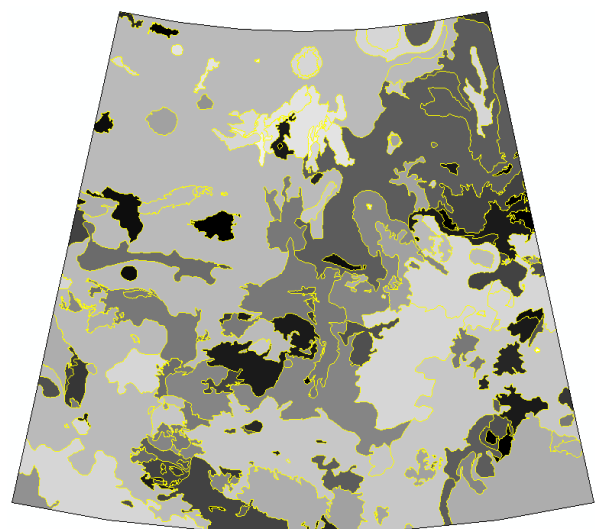

Figure 2: Positive statistical variance of backscatter values for each material unit. Lighter shades = higher variance.