RADAR TOPOGRAPHY OF DOME VOLCANOES ON VENUS AND TITAN. C. D. Neish[1], R. D. Lorenz[1], and R. L. Kirk[2]. [1]Department of Planetary Sciences, Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson AZ 85721-0092, cdneish@lpl.arizona.edu. [2]United States Geological Survey, 2255 N Gemini Drive, Flagstaff, Arizona 86001, rkirk@usgs.gov.

Introduction: In October 2004, SAR imaging from Cassini's TA encounter uncovered features suggestive of cryovolcanic constructs on Titan, including flows, sinuous channels, and the 180 km structure Ganesa Macula [1]. Ganesa Macula is a radar-dark, circular feature with bright flanks, sinuous channels, and a bright region in the center that may be a central depression. In many ways, Ganesa Macula resembles the domes seen on Venus. Some 145 'pancake' domes (steep-sided flat-topped circular-plan-view domes of probable volcanic origin) were identified in a survey covering 95% of of Venus' surface [2].

While altimetry was available from Magellan all over the Venusian surface [3], Cassini altimetry coverage is very sparse. Thus, we rely on SAR imaging alone to obtain topography on Titan. In this work, we adjust simulated SAR images to match the TA data in order to recover the shape and height of Ganesa Macula. With both altimetric and SAR data available for several domes, Venus provides an opportunity to test our assumptions and techniques. Further, because the intrinsic spatial resolution of SAR is much higher than altimetry, finer-scale topography can be resolved than was used in prior work to characterize the Venusian features. This is a particularly important benefit on the flanks of the domes, where typically only one or two altimeter footprints define the shape.

Methods: An individual SAR image can reveal topography by radarclinometry, or shape-from-shading [4, 5]. In this work, we use a forward-modeling approach. We assumed a certain topographic profile, calculated the radar backscatter for each local incidence angle on the feature, and looked for a model that most closely resembles the observed SAR image. These models also include a correction for 'layover' distortion, whereby an elevated feature appears tilted towards the subspacecraft point.

The radar backscatter observed by SAR varies as a function of the transmitting and receiving geometry, as well as the roughness and composition of the reflecting surface. Scattering models describe the radar backscatter function, σ^0, for different local incidence angles. The Muhleman model [6] was used to describe the average backscatter of the Venusian surface during the Magellan mission,

$$\sigma^0 = \frac{0.0118\cos(i)}{(\sin(i) + 0.111\cos(i))^3}. \tag{1}$$

No clearly defined backscatter function is yet available for Titan. Elachi et. al. [1] fit the Cassini scatterometry data to a simple cosecant backscatter model. This function represents the overall pattern in the images, for 3° to 45° incidence angles, well. However, it cannot be correct at all angles, as it goes to constant at zero incidence (i.e., in shadows). We favour the straightforward modification to a model proportional to the cotangent of incidence angle, giving similar behavior to the previous model at low incidence but no return at zero incidence.

To model the domes, we first assume a height profile, h(r). Volcano morphology is a function of several interdependent factors, including the eruption process, conduit size, the physical and chemical properties of the lava, and the surrounding environment. Little is known about the nature of the Titanian magmas or their eruption style, so we looked to the work done on the Venusian domes as a starting point.

McKenzie et al. [3] compared altimeter profiles with three analytic models, one described by Huppert [7] for a spreading viscous drop,

$$h_{huppert}(r) = h_0\left(1 - \left(\frac{r}{r_0}\right)^2\right)^{1/3} \tag{2}$$

one described by Nye [8] for a rigid-plastic rheology,

$$h_{nye}(r) = h_0\left(1 - \left(\frac{r}{r_0}\right)\right)^{1/2} \tag{3}$$

and one described by Iverson [9] for a dome constrained by skin strength. The Huppert model was favoured, since it has a flatter top which agrees better with the altimeter data, while the Nye model has a central peak due to the non-zero slope at zero radius (Figure 1).

We are experimenting with a alternative empirical functions for dome shape which may combine the best features of these: one such function is of the form

$$h_{empirical}(r) = h_0\left(1.0183 - \exp\left(4\frac{r}{r_0} - 4\right)\right). \tag{4}$$

This reproduces the shape defined by altimetry (the flat top) while potentially agreeing better with the SAR data, which is primarily sensitive to the slopes at the edge. The Huppert model yields unphysical (at the km-scale) vertical slopes at the edge of the feature, whereas our empirical function gives slopes of 20 degrees, less than the angle of repose.

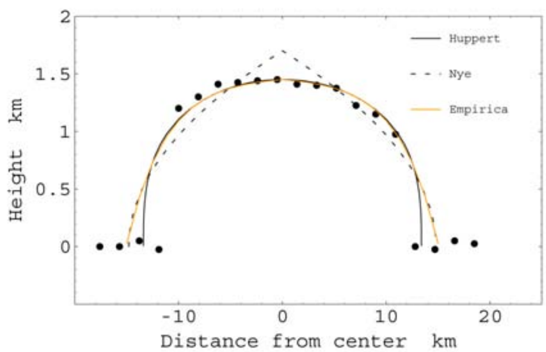

Figure 1: Altimeter profile across a dome in Rusalka Planitia. The black line shows the best fit obtained by McKenzie et. al. [3] using Eq. 2. The dashed line shows the best fit obtained by McKenzie et. al. [3] using Eq. 3. The orange line shows the empirical model described by Eq. 4.

Applications to Venus: To ensure that the technique described above will give a reliable height estimate for Ganesa Macula, we are testing it on three domes on Venus with known heights. We calculated a χ^2 measure of goodness-of-fit for each model by subtracting the uprange half of the model dome from the data, and performed a multidimensional minimization to find the best-fit parameters.

The technique is currently being optimized to reproduce the heights observed by the Magellan altimeter. In an initial run shown in Figure 2, a 1.26 km high dome in Alpha Regio is predicted to be 1.15 km high with the Huppert model. We will repeat this technique for the other Venusian domes and Ganesa Macula on Titan.

Further Work: In principle, a SAR image permits an alternative and entirely independent recovery of topography via the 'layover' distortion. If a feature is symmetric in its true planform, the asymmetry of the SAR image in the range can be interpreted as an altitude or depth. We are exploring how well this approach agrees with the other methods.

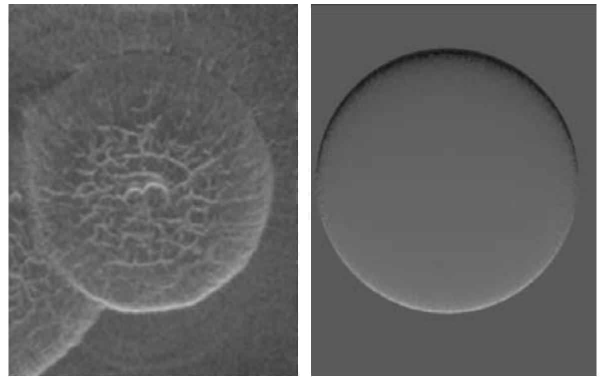

Figure 2: a.) Magellan image of 1.26 km high pancake dome in Alpha Regio. b.) Best fit Huppert model with height of 1.15 km.

One complication that our investigation allows us to explore is how well the edge brightness is recovered with a given backscatter function. Such a function (typically derived by fitting the brightness in a scene assumed to be flat that is imaged at a range of incidence angles) assumes a constant roughness over the dome. In geological reality, there may be a dependence of roughness on slope. This may prevent a single function from fitting everywhere (at different azimuths on a symmetric dome, a single slope appears at a range of incidence angles.)

Our initial motivation was to determine the height and therefore infer the cooling history of Ganesa Macula. However, both the model shape, and potentially a slope-dependent roughness, may have rheological implications and may shed insight into the emplacement process of these features.

References: [1] Elachi C. et. al. (2005) *Science, 308*, 970-974. [2] Pavri B. et. al. (1992) *JGR, 97*, 13445-13478. [3] McKenzie D. et. al. (1992) *JGR, 97*, 15967-15976. [4] Wildey, R.L. (1986) *Photogrammetric Engineering and Remote Sensing, 52*, 41-50. [5] Kirk, R.L. et. al. (2005) *LPS XXXVI*, Abstract #2227. [6] Muhleman, D.O. (1964) *Astron. J., 69*, 34-41. [7] Huppert H.E. (1982) *J. Fluid Mech., 121*, 43-58. [8] Nye J.F. (1952) *J. Glaciol., 2*, 82-93. [9] Iverson R.M. (1987) *Spec. Pap. Geol. Soc. Am., 212*, 47-69.