MOUNTAINS ON TITAN: HEIGHT AND SLOPE ANALYSIS. Z.Y.C. Liu[1], J. Radebaugh[1], R.L. Kirk[2], E.P. Turtle[3], E.R. Stofan[4], C.A. Wood[5], and the Cassini Radar Team. [1]Department of Geological Sciences, Brigham Young University, Provo, UT 84602, USA., **zacqoo**@byu.edu. [2]Astrogeology Division, U.S. Geological Survey, Flagstaff, AZ 86001, USA., [3]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723, USA., [4]Proxemy Research, P.O. Box 338, Rectortown, VA 20140, USA., [5] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA.

Introduction: The Cassini Radar has discovered features of relatively high topography that we refer to as mountains [1]. These mountainous features are widespread and cover 12% of the Synthetic Aperture Radar (SAR) image swaths (TA-T30) of Titan's surface [2]. More SAR image swaths (T43-T71) have since been obtained, from May 2008 to July 2010. Among these mountainous features, which are radar-bright in texture, are long, linear ridges, elevated blocks which stand generally isolated, and hummocky terrain, wherein multiply adjacent peaks extend across vast regions. Titan's mountainous features have been interpreted to have several origins, including erosional and tectonic [1,3]. Radebaugh et al. [4] discussed that mountains in Xanadu have morphologies consistent with compressional and extensional tectonics, and Mitri et al. [5] modeled several sets of ridges as forming due to contractional tectonism. These results reveal Titan as the only icy satellite in the solar system on which contraction is the predominant style of tectonism (Figure 1). Thus, in order to better understand the tectonic and erosional processes on Titan, the characterization of mountain area, distribution and height are important to define these origins and mechanisms.

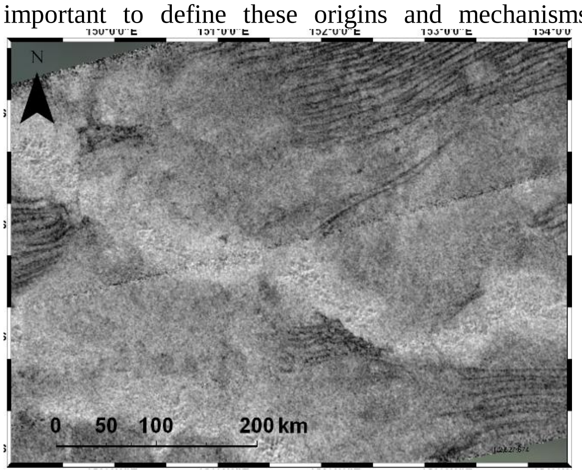

Figure 1. Linear mountain belts showed in T61 swath, at 250 W 10 S, provide morphological evidence of a tectonic origin for these mountains.

Mountain height and slope measurements: There are some available techniques for estimating topographic relief, include altimetry [6], stereogrammetry [7], SARTopo (or utilizing overlapping SAR beams to determine heights) [8], and shape-from-shading (or radarclinometry) [1]. Considerable progress has been made in many of these elevation methods for Titan, and regional and global maps of elevation are in progress. However, previous studies of geologic mapping and mountain distribution on Titan lack a connection to data for mountain height and slope [2]. Therefore, the purpose of this study is to correlate analyses of mountain height and slope with global mountain distribution and mapping.

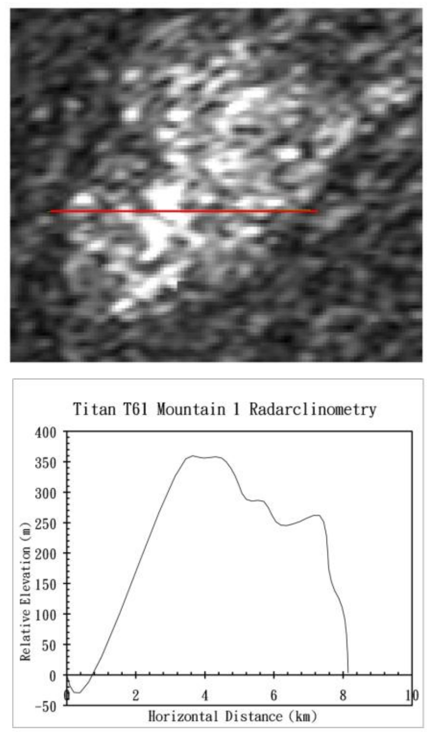

Figure 2. Radarclinometric trace across a mountain in the T61 swath, showing measured mountain height.

Data and Methods: The SAR data swaths we use are from Titan flybys TA-T71, all those obtained from October 2004 to July 2010. All swaths contain some mountains; the only other geologic features on Titan for which this is true are channels (Even impact craters are seen less commonly, exceedingly unusual for an icy satellite). We are undertaking to make measurements for all swaths, but measurements have only been made in TA-T30, T43 and T61. In this study, we use shape-from-shading, or radarclinometry, similar to the methods used for photoclinometry, dependent on the backscatter expected from a given surface, to determine slopes and heights of the peaks of isolated mountains and mountain chains. We assume the backscatter law for mountainous materials to be $\sigma_0 (i) \propto \cos$ (incidence angle), which gives constant backscatter across a range of incidence angles and agrees well with scatterometry results [1]. Measurements are obtained across mountain peaks of modest widths, typically <30 km, using USGS ISIS software. Then, we have overlain these results on a global map of Titan which includes SAR swaths and global image maps of Cassini Imaging Science Subsystem (ISS) and Visual and Infrared Mapping Spectrometer (VIMS) [9,10] to analyze the distribution of mountain peaks with heights and slopes using ArcGIS software.

Results: The measurement of slope and height of a mountain is shown in Fig. 2 and the distribution and peak heights of mountains are shown in Fig. 3. Peaks range from 120 m to ~3300 m in elevation as derived from radarclinometry corrected for the effects of image resolution [1]. Summit flanks measured from these flybys have a maximum slope of 37^{o}, and the highest mountains reach 3310 m. In this initial analysis, mountains of varying heights are located across Titan, although most of the maximum highest mountain peaks we measured so far are located in the Xanadu hummocky terrain and closer to the equator. These are preliminary results, more results will follow.

Implications: Mountain height and slope analysis and our study of mountain distributions show that mountainous features are elevated above the surrounding terrain. These elevated features could have resulted from internal processes that have raised them up, or from erosion having removed surrounding materials. Although the morphologies of Titan's mountains, similar to mountains on Earth, indicate erosive processes have acted on them, the curvilinear extents (Fig. 1) of many mountain ranges imply their origin is tectonic, and perhaps contractional [5]. In contrast, extensional tectonism is observed on almost all icy satellites of the outer solar system, with little evidence of contractional tectonism. Our map of mountain distribution with height shows most of the highest mountain peaks we measured so far are located in Xanadu province and closer to the equator, which could be the result of contractional energy being larger at the equator as in Mitri's model [5], however very few values are reported thus far. Most of Titan's mountain belts, though curvilinear, do not appear to be related to impact cratering, unlike on other icy satellites. Their morphologies in most cases are less curved than on mountains related to impact craters, suggesting instead tectonism in their formation. Moreover, the mountains are always the locally oldest stratigraphy. Interestingly, in Xanadu, which is thought to be among the oldest terrains, mountain peaks are among the highest seen on Titan [4] suggesting erosional efficiencies are not what we might expect. Studies of the distributions of these features with height will illuminate our understanding of the formation and erosional evolution of the mountains on Titan.

Reference: [1] Radebaugh J. et al. Mountains on Titan observed by Cassini RADAR. (2007) *Icarus 192,77-91* . [2] Lopes R.M.C et al. Distibution and interplay of geologic processes on Titan from Cassini radar data. (2010) *Icarus 205, 540-558.* [3] Moore et al. Titan: An Exogenic World? *Icarus*, in press. [4] Radebaugh J. et al. Regional geomorphology and history Titan's Xanadu province. (2010) *Icarus.* [5] Mitri G. et al. Mountains on Titan: Modeling and observations. (2010) *Journal of Geophysical Research, vol 115.* [6] Kirk R.L. et al. Radar reveals Titan topography. (2005) *LPS XXXVI, 2227.* [7] Stiles et al. (2010) *Icarus*. [8] Kirk et al. in review. [9] Turtle E.P. et al. Cassini imaging of Titan's high-latitude lakes, clouds, and south-polar surface changes. (2009) *GRL 36, L02204.* [10] Barnes, J. W. et al. (2009) *PSS.*

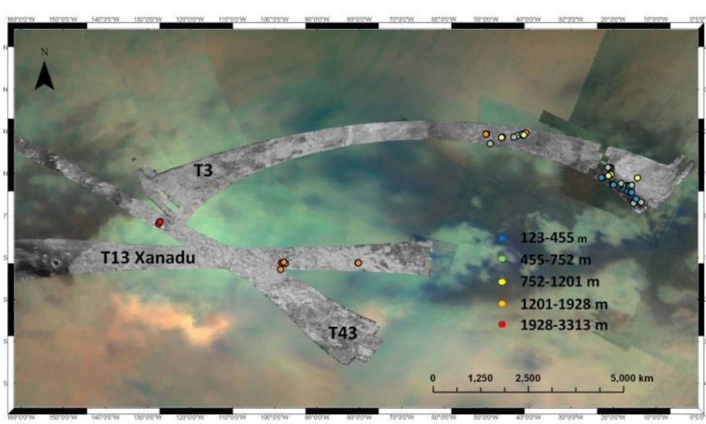

Figure3.

Mountain distribution with mountain height. These dots represent different mountain peaks and colors represent different peak height. This is a preliminary results which only shows T3, T13 and T43 swaths; more results will follow.