CONSTRAINTS ON TITAN'S TOPOGRAPHY THROUGH FRACTAL ANALYSIS OF SHORELINES

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Introduction: The recent discovery of lakes at Titan's North Pole by the Radio Detection and Ranging (RADAR) instrument onboard the Cassini spacecraft is one of the most exciting discoveries of the Cassini-Huygens mission.

Previous analyses of terrestrial coastlines have revealed them to be closely approximated by fractals, geometric shapes that can be subdivided in parts, each of which is a reduced-size copy of the whole. The measured lengths of these coastlines increase, as the measuring scale decreases [4]. This is because smaller measuring scales are sensitive to smaller features of the coastline. Also, the measured perimeter can be related to the measuring scale by a specific fractal dimension (D), which varies from one coastline to another [$P \alpha L^{(1-D)}$; where P: perimeter, L: measuring scale, D: fractal dimension]. Using the fractal dimension and another related roughness parameter called the Hausdorff dimension, information can be extracted about how rough or intricate a particular coastline is. These roughness parameters for coastlines can be related to landscape roughness parameters to obtain information about local topography [5,6].

The aim of this study was to carry out a similar analysis for coastlines on Titan and relate the coastline roughness parameters to topography parameters for Titan's landscape. As pooled liquids form equipotential surfaces, a coastline is equivalent to a topographic contour line. The complexity of the coastline can thus be related to the complexity of the surface it is embedded in. Thus, information on Titan's topography can be extracted through analysis of these shorelines.

Data: For this study, we used projected Cassini Radar observations that are already in the public domain [7]. The images used have a resolution of about 350m/pixel near the centre of the swath, for example, fig. 1 shows a Radar swath from Cassini's T19 (Oct. 9, 2006) flyby of Titan.

Figure 1. PIA01943 from Cassini's T19 flyby

As of now, we have analyzed three coastlines from the Radar swaths PIA09179 and PIA08630, taken from the T18 (Sept. 23, 2006) and the T16 (July 21, 2006) flybys of Titan, respectively. For comparison, the terrestrial coastline of Ireland, taken from the online database of the Shuttle Radar Topography Mission, was also analyzed.

Shoreline complexity can be related to landscape complexity only if the coastline is controlled by topography but the topography is unaffected by the coastline. Coastlines on Titan have been classified into different types: the filled dark units, in which inferences about topography can be made from analyzing coastline roughness; and the empty bright units, for which the topography seems to have been influenced by the presence of the lake [8]. Our study focuses only on the filled dark units, and not the empty bright units.

Approach: We will outline the approach adopted for analyzing the Radar images, by taking the example of one of the coastlines.

Fig. 2a shows the Radar swath PIA08630 from the T18 flyby. The top image is centered near 80°N, 92°W. We measured the perimeter of the lake in the top radar image, centered at 76.6N, 16.7W. Fig. 2b shows a zoomed-in view of the lake under consideration.

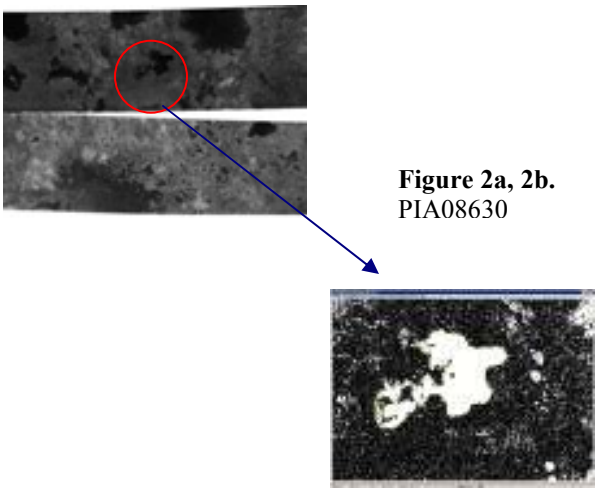


Figure 2a, 2b. PIA08630

The perimeter of the lake's coastline was measured at different image resolutions, which confirmed the

expected decrease in the measured perimeter as the resolution gets poorer, and thus the length of the measuring scale increases. The measurements were then fit to a straight line. Fig. 3 shows a log-log plot of the measurements and the line fit.

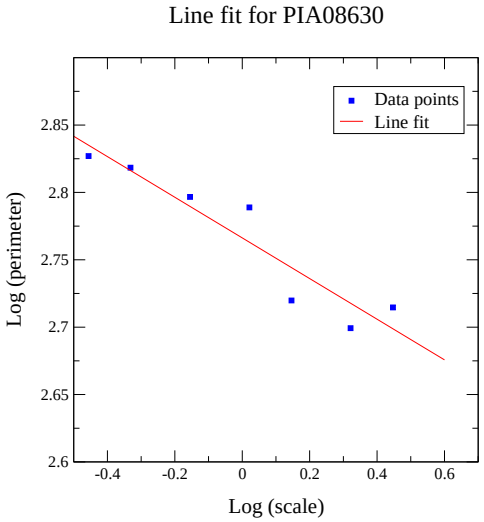
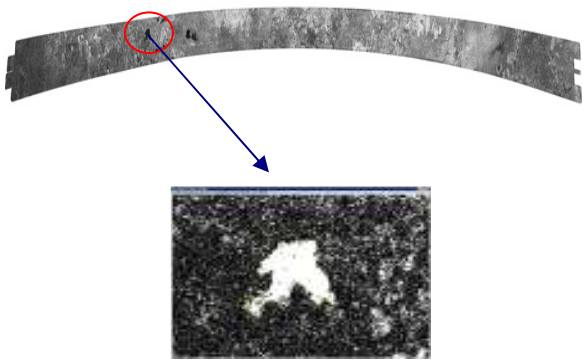


Figure 3. Results for PIA08630

The slope of this line fit was calculated to be -0.15085. The line slope can be related to the roughness parameters D (fractal dimension) and H (Hausdorff dimension) as follows:

D = 1-slope
H = 1+slope ;
thus giving values of 1.15085 and 0.84915 for D and H respectively.
Similar analysis was also done for the other Radar images. The other Cassini Radar swath that was analyzed was PIA09179, which covers the north polar region beginning at about 63°N, 255°W (Fig. 4a). Fig. 4b shows a zoomed-in view of the coastline.

Figure 4a, 4b. PIA09179



Summary: Table 1 summarizes the results of this study:

Image	Slope of line fit	Fractal dimension (D)	Hurst exponent (H)
PIA09179	-0.2429	1.2429	0.7571
PIA08630	-0.15085	1.15085	0.84915
PIA08630 (2nd lake)	-0.1577	1.1577	0.8423
PIA06672 (Terrestrial coastline of Ireland)	-0.19392	1.19392	0.80608

Table 1

In this preliminary analysis, we have thus far come to the following conclusions:

-Fig. 3 supports the property of fractal behavior of Titanian coastlines.

- Lakes in the same region have similar values of the Fractal and Hausdorff dimension.

-The calculated values of the Fractal and Hausdorff dimensions are comparable to the dimensions of terrestrial coastlines of Britain (1.25) and Germany (1.15) [4]. Such high values of the roughness parameters suggest the Titanian coastlines to be rough and intricate, which implies a rugged landscape.

Future work: We are extending this study by analyzing a larger set of Radar data and developing automated methods of coastline measurements. These measurements would provide us information about the variation of roughness of Titan's landscape from one location to another.

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