ONTARIO LACUS : BRILLIANT OBSERVATIONS OF A TITAN LAKE BY THE CASSINI RADAR ALTIMETER.

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Abstract: The first nadir-pointed radar altimeter observations of a known extraterrestrial lake were acquired by Cassini over Ontario Lacus during the T49 Titan pass on December 21st, 2008. These data show the lake to lie in a 300m topographic depression and to be exceptionally flat. The altimeter echoes over the lake surface are narrowly-peaked and brilliant in intensity, consistent with a very smooth surface. Coincident passive radiometry indicates the lake to be highly emissive, consistent with a deep body of hydrocarbon liquids.

Introduction : Near-IR images from Cassini ISS detected a 235-km long lake-shaped dark feature, later named Ontario Lacus, at ~183°W, 72°S [1]. Synthetic Aperture Radar (SAR) observations have mapped hundreds of similar hydrologic features in the north polar regions [2,3] and showed them to be both smooth and emissive, consistent with liquid hydrocarbons. Initial results from the southern hemisphere show a relative paucity of such features [4], an asymmetry which is not yet fully understood. Spectroscopic observations acquired by Cassini/VIMS in December 2007 determined [5] that at least a thin layer of liquid containing ethane was present at Ontario Lacus.

Although close approaches on Radar flybys are usually for SAR imaging, T49 had a groundtrack directly across Ontario Lacus (Fig.1), providing our first opportunity to obtain nadir-pointed altimetry from ~1700km over a known or suspected lake.

Topographic Results : A preliminary estimate of surface height using a predicted ephemeris is determined from the centroid of the altimeter echo waveforms (other approaches will be applied in future analyses). An improved ephemeris available some weeks hence will refine these absolute altitudes, yet it is already clear (Fig. 2) that Ontario lies in a broad depression some ~300m below its surrounds. This is consistent with the ~200-300m depressions interpreted as empty lakes in the northern polar regions [3] and indications that many liquid-filled northern lakes lie in steep-sided depressions [3].

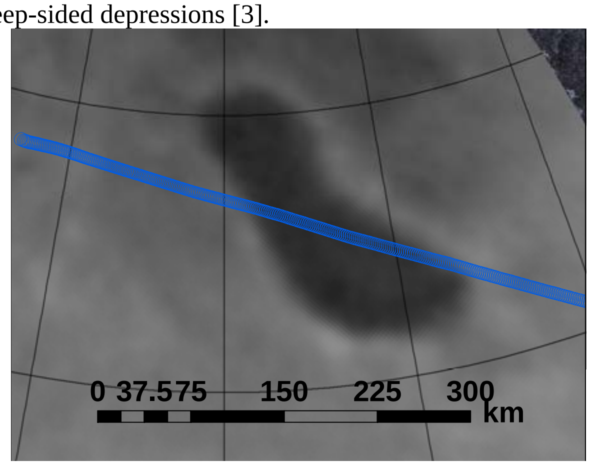

Figure 1. Approximate groundtrack and representative width of the beam-limited altimeter footprint. Improved navigation may displace the beamtrack by roughly its width. Note that the background ISS image was acquired over 3 years before the T49 radar data..

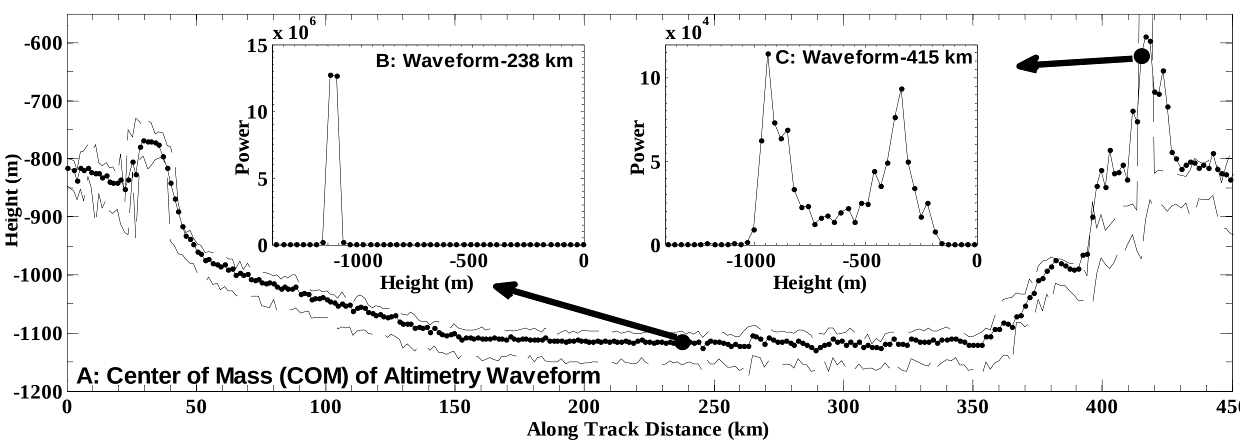

Figure 2. A: Altimetry profile (west to east) across Ontario. Central solid line shows the echo centroid. Dashed lines indicate echo width – the echoes are wide outside Ontario, although both the flat lake itself and the western ramp have narrow echoes, suggesting the ramp may have a texture similar to the lake surface. B: Echo waveform inside lake Ontario at 238 km. C: Echo waveform outside lake Ontario at 415 km.

Most remarkably, the western part of Ontario in particular is completely flat – the elevation difference over the 150-250km section is within 10m, a difference that an updated ephemeris may reduce (though note that the formal resolution of the altimeter is only ~30m) and thus the lake surface lies on a constant elevation.

The eastern part of the lake (250-350km) appears to have some roughness, but this may be centroid displacement due to a subsurface echo component in shallows, exposed lakebed, or possibly interactions with the shoreline which runs close to the groundtrack in this section. Near-IR data [6] independently suggests some bed exposures at the edge of Ontario. Although the eastern lake margin appears steep in the plot (actually the slope over 50km is only ~0.3^o), the western margin has a gentle ramp of about ~0.1^o.

Radiometric Results : The data were acquired very recently and conversion to calibrated physical units has not yet been performed. However, a semi-quantitative preliminary assessment (Fig. 3) can be made with uncalibrated integration of the echo waveform (a crude proxy for the normalized backscatter σ_0) and the raw counts of the antenna temperature (a rather cruder proxy for the surface brightness temperature).

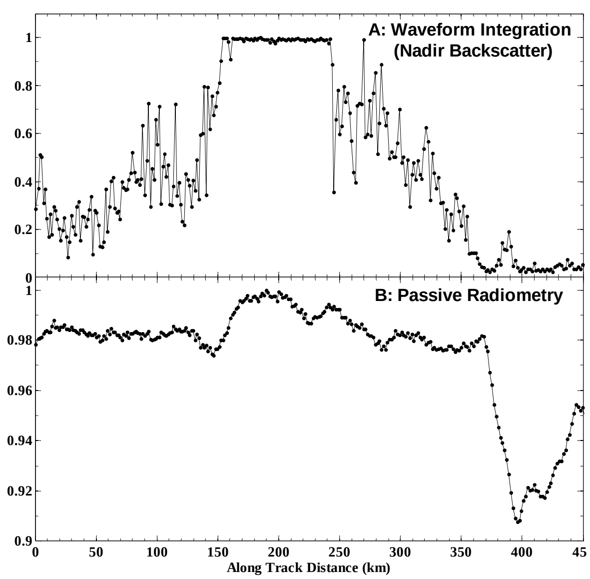

Figure 3. Preliminary backscatter and radiometric observations (not yet calibrated into physical units).

The western part of Ontario (150-250km – the flattest section in Fig. 2) is very bright (indeed, saturating the radar signal in places) - consistent with a very smooth, flat surface. While smooth hydrocarbon lakes look dark to SAR, even poorly-reflective hydrocarbon liquid acts as a mirror, giving a locally-bright specular reflection at nadir incidence. Note that the Fresnel zone over which most of the coherent power from this reflection comes is only a few hundred meters across, much smaller than the beam-limited footprint shown in Fig. 1. Thus the rapid variation over short spatial scales in Fig. 3a is real (if the plot represented properties averaged over the ~10km beam footprint, it might be expected to be smoother) and not noise. The antenna temperature in Fig. 3b samples the full beam and includes contribution from the sidelobes (which are filled at this low altitude [7]) and thus is less clear-cut. However, it is notable that Ontario as a whole, and its central flat part in particular are radiometrically bright, as would be expected from a deep body of liquid.

Waveforms : The shape of altimeter waveforms provide information regarding surface and subsurface structure. Although a detailed analysis of the waveform profiles cannot be reported on here, we note (Fig. 2) that the echoes over the lake proper are symmetric and narrow, typically taking up only a handful of altimetry bins. We see no evidence of a separate bottom echo. Waveform shapes outside of the the lake show asymmetric forms and occasional double peaks more typical of complex surfaces with non-zero roughtness and volume scattering. Detailed analysis of waveform structure, especially when SAR imaging of this area is available, will provide additional information about the surface properties surrounding Ontario Lacus.

Future Work : After calibration (challenging due to saturation of the signal over the lake : the T60 flyby may provide another Ontario altimetry opportunity where the observation can be tuned better), these data may be interpreted to yield estimates of surface roughness and dielectric constant, which will lead to constraints on depth. In July 2009, we hope to acquire SAR imaging of Ontario during the T58 Titan pass which will provide a high-resolution view of the geomorphological setting for Ontario, indicating perhaps whether it is channel-fed and/or represents a cut into regional hydrcarbon aquifer. Furthermore, the combination of inclined SAR and nadir altimetry (and their accompanying radiometry) will provide powerful constraints on interpretations of the surface and subsurface texture and composition of this most exotic feature.

References: *1) Turtle, E. P. et al., Geophysical Research Letters, in Press. 2) Stofan, E. et al., Nature, 445, 61-63 (2006) 3) Hayes et al., Geophysical Research Letters,35 (2008) 4) Lopes, R. et al., EOS, (2007) 5) Brown, R. et al., Nature,454, 607-610 (2008) 6) Barnes, J. W. et al., Icarus, in press 6) Janssen, M. et al., Icarus, in press.*

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