

WHY TITAN'S LAKES HAVE BEEN SMOOTH SO FAR – AND MAY BE ABOUT TO GET ROUGH.

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Introduction: Observations of Titan's polar lakes and seas to date suggest that their surfaces have been qualitatively smooth. Yet it might be expected from the thick atmosphere and low gravity that lakes on Titan would have wave-roughened surfaces. Here we show results (discussed in more detail in a submitted paper [1]) that there are two possible explanations. First, that some or all of Titan's lakes are viscous and thus never have waves. A second possibility is that observations to date in both hemispheres have been during seasons when winds may have been relatively weak. In contrast, upcoming observations of the north (including SAR imagery of Ligeia Mare on T64 in December 2009, to be reported at this meeting) will instead be during the windier summer, and thus northern lakes may display much brighter, wind-roughened surfaces than have been seen so far. Wind-roughening is readily apparent in radar images of terrestrial lakes as a modest brightness enhancement, identifiable either morphologically (it is suppressed in the sheltered lee of topographic obstacles such as islands) and by comparison with previous imagery. Figure 1 shows a radar image with obvious wind-roughening on Lake Janisjarvi, an impact crater lake in Karelia, Russia that illustrates what might be soon visible on Titan.

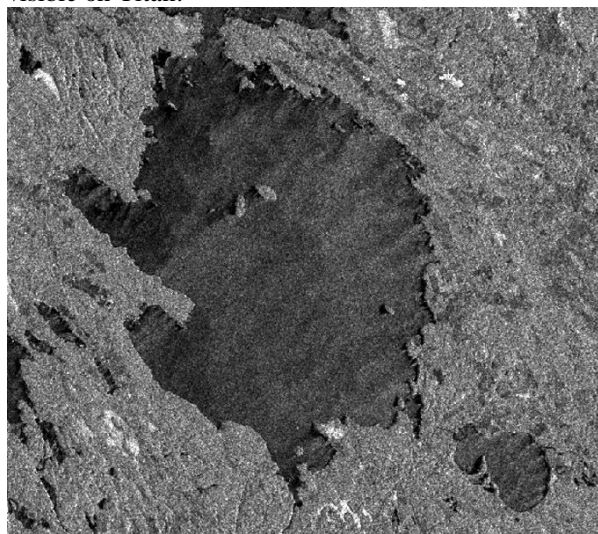


Figure 1. SAR image of Lake Janisjarvi (14x11km). Lake surface is especially dark (smooth) in the left-upper edge, and in the lee of islands, consistent with sheltering from wind-roughening. Credit: ESA. Will we see something similar at Ligeia on Titan in coming months?

Wave Threshold: Despite a century and a half of investigation, no single clean theory for wind-wave generation exists. The generation of large gravity waves begins, however, with the small-scale roughening to form capillary waves. This roughening substantially affects the radar reflectivity of liquid surfaces, and the potential for specular reflection of sunlight. We thus defer the question of gravity waves to future work and consider only capillary waves: these depend only on the liquid properties and not on any difference in gravity between Earth and Titan.

Laboratory wind-tunnel experiments with modest fetches produce water waves with speeds of around 2 m/s: outdoor observations with longer fetch and perhaps more turbulent wind suggest a threshold of 1 m/s. The only non-water wave experiments to date [2] suggest a lower threshold for kerosene than water, but the density, viscosity and surface tension are all lower than for water, and it is not clear which of these factors matter most. However, since Titan's atmosphere is 4x denser than sea-level air on Earth, we might expect the 1-2 m/s terrestrial wave generation threshold to correspond to 0.5-1 m/s for water (or liquid with water-like properties) on Titan.

Hydrocarbon liquids on Titan may be more or less viscous than water, depending on the composition and temperature. Wind tunnel data (figure 2) show that increased viscosity can substantially reduce wave amplitude for a given windspeed. Thus, if Titan's lakes are 'tarry' or 'muddy' they may be viscous enough to suppress wave generation.

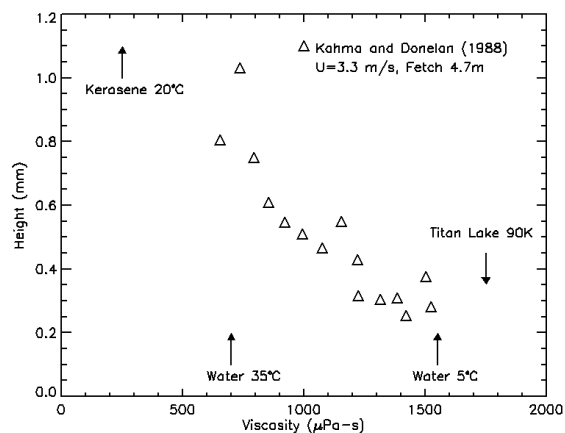


Figure 2. Data from wind tunnel experiments with water at different temperatures (and thus viscosities) showing that wave height can be substantially attenuated by viscosity.

Variable Winds: Lakes and Seas on Earth can be rough or smooth, depending on the wind conditions when they are observed. The same is true for Titan – it may be that if winds strong enough to generate waves do occur, but are rare, then the handful of observations of seas so far might have missed the choppy days.

Variations on timescales of days are likely in winds due to diurnal heating, gravitational tides and the propagation of waves, although these variations in speed and direction are not readily predictable. However, a major effect in surface winds is the overall insolation, with polar winds stronger during summer. As shown in figures 3 and 4, winds predicted by the TitanWRF GCM model [1] were strongest at Ontario before Cassini arrived at Saturn and have since been somewhat weak. Winds in the north have been steadily building since Cassini's arrival and may have recently increased to above the threshold discussed earlier. If this is true, then T64 in December 2009 and subsequent radar observations planned in the Cassini Solstice Mission (as well as other observations such as optical and near-IR observations of specular reflection of sunlight, and bistatic radar observations) may find Kraken and Ligeia Mare much rougher than prior observations have indicated.

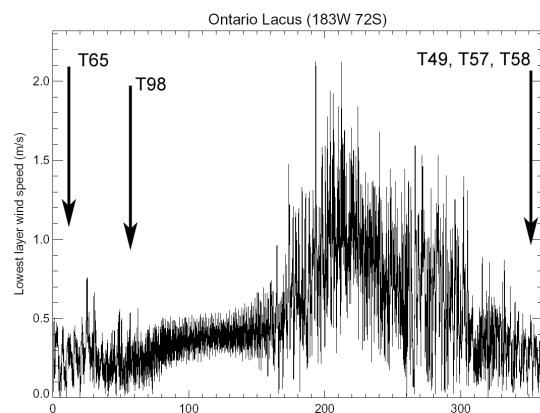


Figure 3 (From [1]) GCM predictions suggest winds over Ontario Lacus have been weak during radar observations made so far, and indeed during anticipated Solstice mission observations. Windspeed is plotted against solar longitude L_s ($=0$ at Northern Spring Equinox)

This potentially-dramatic change is reminiscent of the deceptive impression the Titan community had in the 1990s of Titan's clouds. Overall these are some-

what rare, but highly localized and seasonally-variable: early telescopic searches for clouds on Titan in the 1990s were often unsuccessful, but the combination of more frequent observation and stronger activity during southern summer in 2000-2005 yielded an altogether different impression. So it may be with waves.

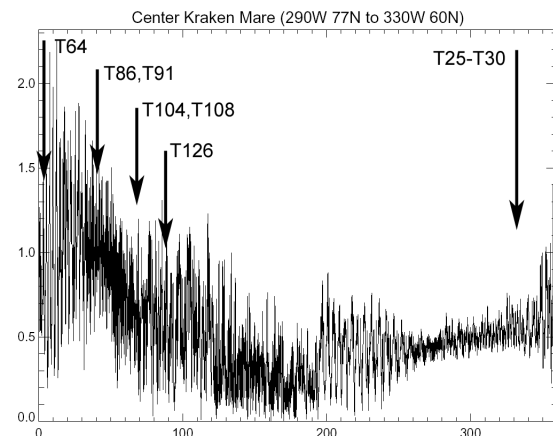


Figure 4. (from[1]) GCM simulations for the north polar regions suggest fairly weak winds when the lakes were first observed in 2006 (T16-T30), but upcoming observations T64 et seq may see rather stronger winds.

Finally, we note that not all lakes on Titan are equal : it may be that southern lakes such as Ontario Lacus are drying out on seasonal and/or astronomical [4] timescales. This distillation of methane to the north may leave southern lakes richer in ethane and heavier compounds, with higher viscosity. Thus at any one time, the wave generation threshold may be different for lakes in the north and the south.

References: [1] Lorenz, R. D. et al., Threshold of Wave Generation on Titan's Lakes and Seas : Effect of Viscosity and Implications for Cassini Observations, *Icarus*, accepted. [2] Lorenz, R. D. et al. (2005) Sea-Surface Wave Growth under Extraterrestrial Atmospheres - Preliminary Wind Tunnel Experiments with application to Mars and Titan, *Icarus*, **175**, 556-560 [3] Wall, S. D. et al., submitted. [4] Aharonson et al. (2009), *Nature Geoscience*, 2, 851-854