Titan's Lakes: Croll-Milankovitch, Seasonal and Hydrologic Cycles

Project information

TITANSLAKES

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Final Report Summary - TITANSLAKES (Titan's Lakes: Croll-Milankovitch, Seasonal and Hydrologic Cycles)

The scientific integration of the PI in the scientific community in Israel has been successful. The PI holds a tenured professorship at the Weizmann Institute of Science, where he has established a research group consisting of graduate students and postdocs. The PI is a member of multiple science team collaborations in Europe and the US, including instrument packages on board the Lunar Reconnaissance Orbiter, Cassini, and JUICE. He is the Mission Scientist for SpaceIL. He has been awarded grants from the Israeli Science Foundation.

The scientific output of this project has appeared in several publications concerning the global topography of Titan, lake elevations, lake winds and wave generation, and the overall surface geology. Work has progressed, focusing on new images acquired by Cassini Radar, on new image analysis technique we developed and applied to these images, and on aspects of their geologic interpretation.

The impact of these scientific results has been to illuminate the importance of surface-climate interactions on the surface of Titan. This, along with other research, has helped stimulate a new mission concept to Titan, currently being proposed as NASA mission.

Wave generation on Titan's lakes

Saturn's moon Titan has lakes and seas of liquid hydrocarbon and a dense atmosphere, an environment conducive to generating wind waves. Cassini observations thus far, however, show no indication of waves. We apply models for wind wave generation and detection to the Titan environment. Results suggest wind speed thresholds at a reference altitude of 10 m of 0.4~0.7 m/s for liquid compositions varying between pure methane and equilibrium mixtures with the atmosphere (ethane has a threshold of 0.6 m/s), varying primarily with liquid viscosity. This reduced threshold, as compared to Earth, results from Titan's increased atmosphere-to-liquid density ratio, reduced gravity and lower surface tension. General Circulation Models (GCMs) predict wind speeds below derived thresholds near equinox, when available observations of lake surfaces have been acquired.
Predicted increases in winds as Titan approaches summer solstice, however, will exceed expected thresholds and may provide constraints on lake composition and/or GCM accuracy through the presence or absence of waves during the Cassini Solstice Mission. A two-scale microwave backscatter model suggests that returns from wave-modified liquid hydrocarbon surfaces may be below the pixel-scale noise floor of Cassini radar images, but can be detectable using real-aperture scatterometry, pixel binning and/or observations obtained in a specular geometry.

Titan's Global Topography and Hydrology

Cassini RADAR SARtopo and altimetry data are used to construct a global gridded 1 1 elevation map, for use in Global Circulation Models, hydrological models and correlative studies. The data are sparse, and so most of the map domain (90%) is populated with interpolated values using a spline algorithm. The highest (+520 m) gridded point observed is at 48S, 12W. The lowest point observed (1700 m below a 2575 km sphere) is at 59S, 31VW: this may be a basin where liquids presently in the north could have resided in the past. If the deepest point were once a sea with the areal extent of present-day Ligeia Mare, it would be 1000 m deep. We find four prominent topographic rises, each 200 km wide, radar-bright and heavily dissected, distributed over a 3000 km arc in the southeastern quadrant of Titan (40–60S, 15–150W).

Overview of Titan Surface Geology

An overall review of the state of knowledge regarding the surface of Titan as revealed by Cassini, with particular focus on the lakes, is presented in book chapter authored by the PI and referenced below. The work provides a compilation and presentation of several disparate datasets including those mapping geologic units, fluviatile and lacustrine features, and topography, and hence provides a useful global perspective.

Titan's Hydrology Based on Enhanced Image Processing

The Cassini Synthetic Aperture Radar has been acquiring images of Titan's surface since October 2004, with significant regions imaged more than once. Radar data suffer from speckle noise hindering interpretation of small-scale features and comparison of reimaged regions for change detection. We developed and applied a new image analysis technique that combines a denoising algorithm with mapping and quantitative measurements that greatly enhance the utility of the data and offers previously unattainable insights. After validating the technique, we demonstrate the potential improvement in understanding of surface processes on Titan and defining global mapping units, focusing on specific landforms including lakes, dunes, mountains, and fluviatile features. Lake shorelines are delineated with greater accuracy. Previously unrecognized dissection by fluviatile channels emerges beneath shallow methane cover. Dune wavelengths and interdune extents are more precisely measured. A significant refinement in producing digital elevation models is shown. Interactions of fluviatile and aeolian processes with topographic relief is more precisely observed and understood than previously. Benches in bathymetry are observed in northern sea Ligeia Mare. Submerged valleys show similar depth suggesting that they are equilibrated with marine benches. These new observations suggest a liquid level increase in the northern sea, which may be due to changes on seasonal or longer timescales.

Titan's Climate, Wind-Field, and Dune Orientation

Dune fields on Titan cover more than 17% of the moon's surface, constituting the largest known surface reservoir of organics. Their confinement to the equatorial belt, shape, and eastward direction of propagation offer crucial information regarding both the wind regime and sediment supply. Herein, we present a comprehensive analysis of Titan's dune orientations using automated detection techniques on nonlocal denoised radar images. By coupling a new dune growth mechanism with wind fields generated by climate modeling, we find that Titan's dunes grow by sediment transport on a nonmobile substratum. To be fully consistent with both the local crestline orientations and the eastward propagation of Titan's dunes, the sediment should be predominantly transported by strong eastward winds, most likely generated by equinoctial storms or occasional fast westerly gusts. Additionally, convergence of the meridional transport predicted in models can explain why Titan's dunes are confined within ±30° latitudes, where sediment fluxes converge.