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Constraining Surface Winds on Titan via Infrared Sun Glints from Wind-Roughened Sea Surfaces: Observations

Jason M. Soderblom (1), Alexander G. Hayes (2) and Jason W. Barnes (3)
(1) Dept. of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, (2) Dept. of Astronomy, Cornell Univ., Ithaca, New York, USA, (3) Dept. of Physics, Univ. of Idaho, Moscow, Idaho, USA (jms4@mit.edu)

Abstract

Despite observations of aeolian landforms observed across Titan, and predictions that winds would increase in the north as Titan moved into northern summer, it was not until late northern spring that Cassini observed strong evidence of wind-driven waves [3] (there were earlier observations of rough liquid surfaces [1], but we now suspect these roughed surfaces result from fluid flow [6] rather than wind-driven waves). This evidence was in the form of bright reflections from Titan's lakes and seas that we interpret as the specular reflection of the Sun off wavy liquid surfaces. In this work, we catalogue all such observations and, for those that are consistent with wind-driven waves, derive the specular area fraction (SAF), i.e., the fraction of the surface that is oriented such that the local surface facet secularly reflects sunlight towards Cassini.

1. Introduction

Cassini observations of Titan showed no evidence of waves on its lakes and seas through the end of its Equinox Mission in December 2010. These observations were unexpected given the abundance of aeolian landforms observed across Titan, the formation of which have been predicted to result from light winter winds [5] as well as predictions that wind-waves would increase significantly in norther spring [5]. It was not until later in the mission, as the north moved into summer, that we began to see strong evidence of wave activity on Titan [3].

In the following years, Cassini observations revealed evidence of rough surfaces in numerous occasions and locations [8]. Some of these observations may be indicative of surface or subsurface flow [6,10], while others (e.g., the patches of brightness observed by [3], see Figure 1) are much more consistent with wind-driven waves. In this paper, we catalogue all Cassini observations of roughened lake/sea surfaces, identifying those that are most consistent with wind-driven waves. For the waves that are most consistent with wind, we derive the specular area fraction (SAF), which is the fraction of the surface that is oriented in a particular direction relative to the surface normal.

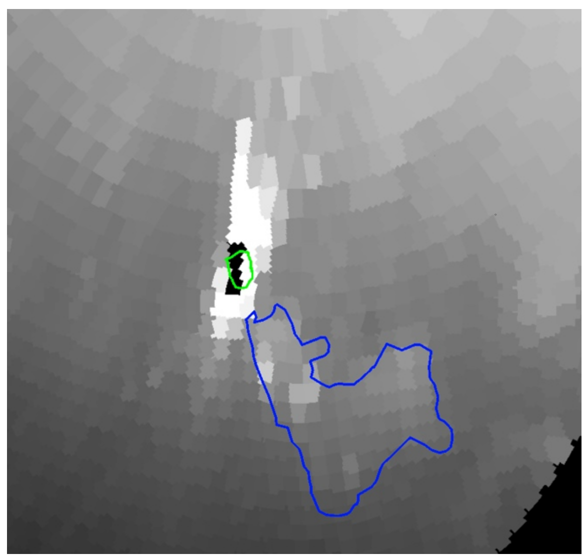

Figure 1: Cassini VIMS 5-μm image of the north pole of Titan showing multiple specular reflections. The prime specular reflection off Kivi lacus (outlined in green) is sufficiently bright to saturate the VIMS observation (the black pixels in the middle of the image). Several slightly dimmer patches are observed on Punga Mare (outlined in blue), which are attributed to wind waves. Figure is adapted from Figure 3 of Barnes et al. [3].

2. VIMS Specular reflections

During the T58 flyby of Titan (July 2009), the Cassini Visual and Infrared Mapping Spectrometer (VIMS) instrument observed the specular reflection of the Sun off Jingpo Lacus, ("mirror-lake" in Mandarin) [1,7,11]. On the following flyby, VIMS observed another series of specular reflections, from Kraken Mare [1]. Following these observations, the VIMS instrument was regularly used to observe the Sun's specular reflection off Titan, leading to a wide range of scientific investigations regarding the nature and distribution of liquid hydrocarbons on Titan's surface [2,3,6,9,10].

In this work, we present a full catalogue of the specular reflection observations observed by Cassini VIMS, including both those that occurred at the predicted location (e.g., reflection from Kivu Lacus in Figure 1) and those offset from the predicted location (e.g., the reflections observed on Punga Mare in Figure 1), hereafter referred to as "*offset reflections*". Rough surfaces are indicated when specular reflections observed in their predicted location are dimmer than modeling [7] predicts (the rough surface reflects light away that would nominally be reflected to the detector away) and for *offset reflections*.

Some *offset reflections* in Kraken Mare are observed in similar locations and on nearly every flyby, suggesting that they might be attributed to a phenomenon other than surface winds [6]. We consider all other *offset reflections* as possible candidates for wind waves. For these observations, we calculate the SAF, defined as the fraction of the surface that is tilted towards the Sun-Titan-Cassini plane such that the local surface facet is within ½ the VIMS IFOV of a specular geometry.

3. Wave Modelling

To use these observations to constrain wind on Titan, we use the universal wave and stress model, UNIWSM, a generalized version of the University of Miami Wave Model (UMWM [4]). This spectral 3D wave model calculates the wavenumber-directional spectrum on a liquid surface for a given wind speed and direction. To compare the output of UNIWSM with the VIMS-derived SAF, we must determine the fraction of the model wave field that is oriented in a specific geometry. We do so by approximating the probability density function of surface slopes with an anisotropic bivariate Gaussian, which allows us to derive the slope variance from the integration of the wave spectrum. The results of this modeling will be discussed.

Acknowledgements

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