# TOPOGRAPHIC INFLUENCING OF CLOUDS ON TITAN

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**Summary:** We present an analysis of clouds on Titan observed by Cassini VIMS. Results are compared to mesoscale model simulations and show agreement with convective cloud formation through orographic forcing.

**Introduction:** Saturn's largest moon, Titan, is the only other known place with an active hydrologic cycle [1]. Clouds are one of the few direct observables of this complex system, and have regularly been observed by Cassini since its arrival to the Saturnian system in 2004 [2,3,4].

Previous work has demonstrated the presence of low altitude clouds (fog) on Titan, but their formation mechanisms remained unknown [5]. Mesoscale modelling has predicted the influences that topography may have on Titan cloud formation [6], but, until now, comparisons between observed clouds and topography have not been possible.

We present an analysis of several low atltidue clouds observed by Cassini VIMS at the South Pole of Titan between 2009 and 2012 (equinox to fall). In combination with improved topographic maps, we look for correlations between topography and observed cloud evolution.

**Methods:** For the topography, we use recently updated topographic maps produced a resolution of ~10 km/pixel [7]. For modelling clouds, we use the radiative transfer code, PyDISORT [8], a plane-parallel code built around the discrete ordinates method (DISORT) [9], allowing for fast retrievals.

Clouds are observed because of their increased scattering efficiency, resulting in higher observed albedos. To find possible clouds of interest, all cubes in the VIMS dataset that observed the South Pole during the course of the mission were projected using a stereographic polar projection. Cloud are then found through a manual search using a combination of filters designed to accentuate cloud features. Although many clouds were observed, two are discussed here in detail, as well as the previous observations of fog [5].

Clouds can be modelled by inserting an additional layer into the radiative transfer model, containing the radiative characteristics of the cloud. Free parameters include the cloud's optical depth and altitude. To simulate self-consistent scattering properties for the cloud layer, Mie scattering is used to determine the single scattering albedo, phase function, and optical depth as a function of wavelength.

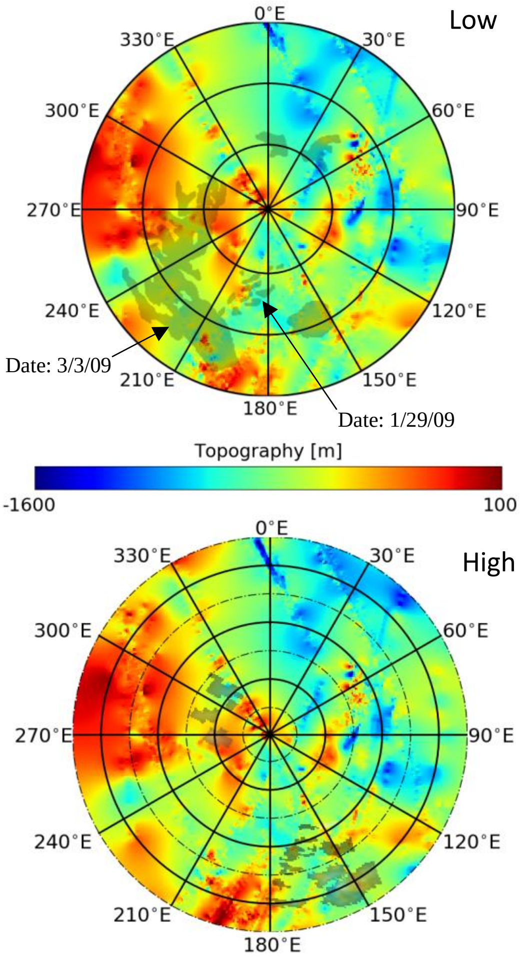

**Figure 1: Top – Stereographic projection of Titan's South Pole with observed fog features [5] over-plotted in grey. All fog is found to correspond to local minima. Two observations are outlined for greater clarity (see text). Bottom – same as top, but over-plotting two observations of higher altitude clouds, believed to be convective in nature and the result of orographic forcing.**

We employ a combination of systematic and gradient minimization search techniques to quickly and accurately find the best fit parameters for each cloud.

**Results and Discussion:** There are clear correlations when comparing the observations to topography. All previous reported observations of fog

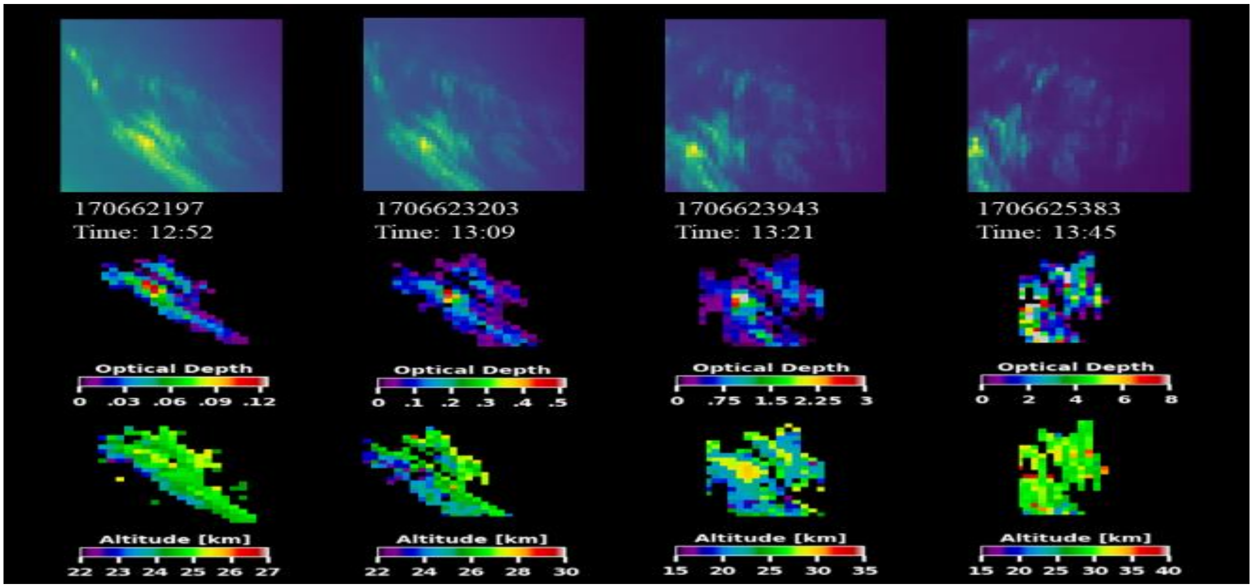

**Figure 2: Analysis of orographic cloud from Figure 1. Top – Sequence of VIMS observations of the cloud with associated cube numbers and times. Images plot an average of spectral bands designed to highlight cloudy features. Bottom – Retrieved optical depths and altitudes for each pixel in the VIMS observation. The cloud is found to evolve rapidly, growing in optical depth and rising from 25km to 30km with a lofting velocity of ~1.4m/s and lateral velocity of ~22m/s.**

are found to occur within local topographic minima (see Figure 1). Two particularly striking features were observed on January 29th, 2007 and March 9th, 2007. The former is a small patch of fog cells that seem to trace around the local hill, possibly fueled from increased humidity from evaporation of the nearby Ontario Lacus. The latter is a large bank of fog that was observed to maintain stationary position, confined by local topography, throughout the course of observations. The location of this fog system is contained within the valley between mountains and suggests a possible cold air drainage formation mechanism, similar to that observed for valley fog.

Higher in the atmosphere, topography is observed to influence the onset of convective clouds (see Figure 1). An observation on May 28th, 2008 shows a typical orographic cloud pattern of a “standing wave” of clouds as the air cools through orographic lift and oscillates on the leeward site of the mountain. Unfavorable viewing geometries prevent detailed studies of this system, but spectral signatures place them at least several kilometers off the surface.

A second set of convective clouds were observed on January 20th, 2012 with sufficient signal to be effectively modelled (see Figure 2). This complex cloud system shows many individual clouds, each corresponding to a local rise in elevation, suggesting possible orographic influences. Previous mesoscale modelling of Titan demonstrated that even small hills (on the scale of ~200m) can lead to the onset of convective cloud formation downwind from a mountain range [6]. Through radiative transfer we model the evolution of the cloud and find that it appears to be convective in nature, located at approximately 25km altitude and developing rapidly over the course of the observations (~1 hour). Optical depths increase from τ~.5 to τ~3 and the altitude is found to rise to approximately 30km, corresponding to an ascent speed of ~1.4 m/s. Finally, the observed horizontal cloud speed is found to be ~22m/s. All values agree with models in terms of the speed and intensity of convective cloud evolution.

Combined, these observations suggest that there can be significant influences of topography on the local weather on Titan. Further mesoscale and general circulation modelling is needed to fully understand the role that topography plays in Titan’s complex hydrologic cycle, from cloud formation to the location of liquids in drainage basins.

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