TITAN'S NORTH-SOUTH ASYMMETRY AT VISIBLE WAVELENGTHS OVER THE CASSINI MISSION.

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Introduction:

Titan exhibits many properties not found in other satellites. As first observed by Voyager 1 [1], Titan's ubiquitous atmospheric haze prevents optical imaging of the surface. The haze distribution varies as a function of latitude [2], altitude [3,4], and time [5,6]. Titan's haze also shows albedo differences between its northern and southern hemispheres that shift near the equator. As the seasons progress, atmospheric circulation changes the global haze distribution, culminating in a seasonal reversal every 14 years [7].

The reversal presents as an albedo dichotomy in the otherwise featureless atmosphere. The existence of the asymmetry also results in a distinct boundary that separates the Northern and Southern hemispheres (Figure 1). The Voyager 1 flyby highlighted the existence of a North-South Asymmetry (NSA) between the hemispheres [1]. Previous discoveries also found a tilt of the boundary line relative to the solid-body equator of Titan [8]. The boundary, as reported by [2], which utilized Voyager 1 data, was located at roughly 5.5◦S. More recent discoveries show a seasonal reversal in the latitude of the asymmetry across the equator.

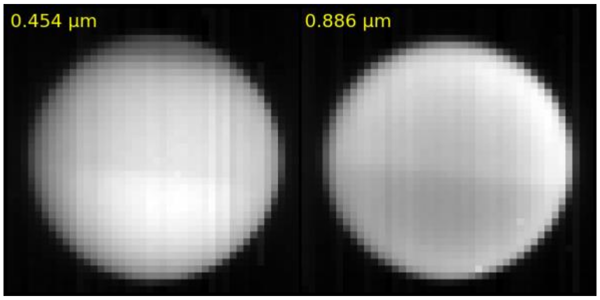

Figure 1: Titan's NSA is evident in two individual band images from VIMS cube CM_1634082284_1. In the left image, the southern hemisphere appears brighter at blue wavelengths. In contrast, the NSA reverses in the right image within a methane absorption band at 0.886 µm. Vertical striping artifacts are present in the images.

Movement of the NSA boundary reveals important details of the global atmospheric properties and circulation patterns of Titan [9]. Titan disk observations from flyby missions and professional telescopes provide sporadic temporal and wavelength coverage of the NSA, leading to incomplete records on haze circulation with large errors [10,11]. In addition, previous studies often use special case methodologies, where results are tied to their datasets to calculate and subsequently compare those previous NSA boundary latitudes [8]. More recent works have the temporal coverage to study detailed aspects for a substantial portion of the NSA cycle with individual datasets. [12] modeled the NSA reversal at different altitudes with HST Space Telescope Imaging Spectrograph image cubes. [13] completed an analysis of circumglobal haze bands in a variety of Cassini imagery datasets.

We document on the seasonal changes in Titan's lower atmospheric haze near the equator using the Cassini observations of visible wavelengths for purposes of comparison with previous studies. The observation of seasonal haze changes through visible wavelengths allows us to extend the time baseline of previous observations and to coherently track one seasonal cycle with a single uniform dataset. The Cassini Visual and Infrared Mapping Spectrometer Visual instrument (VIMS-V) collected spectral maps at 96 visible and near-infrared wavelengths between 0.35-1.05μm, which predominantly sampled the stratosphere (∼70-120 km). Using methods from [8] with considerations for the VIMS-V data characteristics, we determine the latitude of the asymmetry at 76 of the 96 distinct wavelengths, excluding atmospheric windows where the surface is visible and precluding haze measurements [14]. Each distinct wavelength accesses a different altitude because of the varying atmospheric opacity. Through the observation of 13 temporally distinct flybys we also determine the albedo contrast between the Northern and Southern hemispheres with regard to wavelength to calculate the boundary latitude, North-South flux ratios, and tilt angles of the asymmetry. We finally compare our results to the existing archive of NSA boundary observations and discuss the implications of these findings on the atmospheric conditions of Titan (Figure 2).

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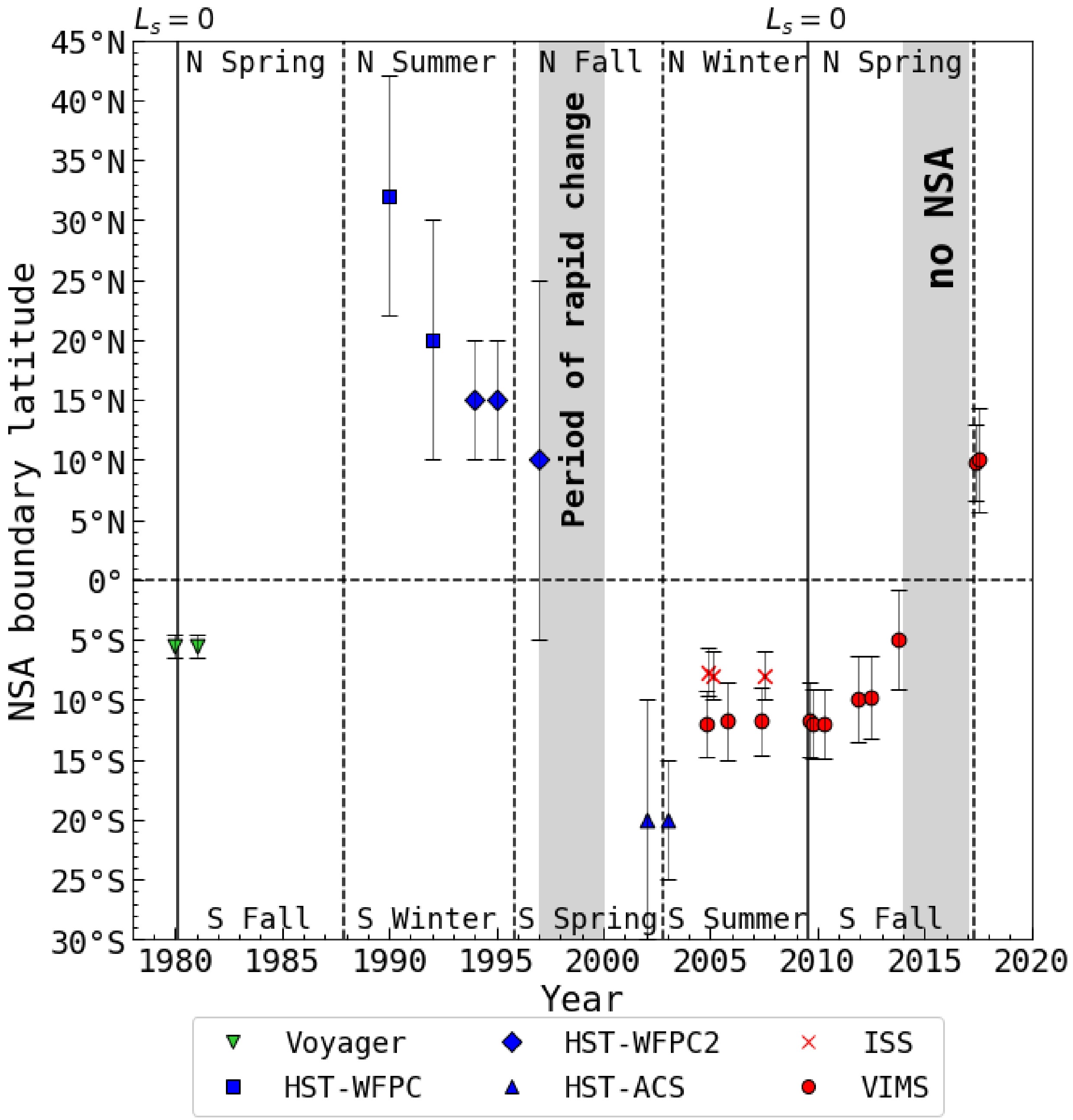

Figure 2: The timeline of the NSA boundary latitude as measured by instruments aboard Titan flyby missions and space telescopes. Before 2000, there was more uncertainty in the NSA boundary due to the reliance on noisier Hubble images. The period of rapid change applies to the early Hubble observations of seasonal NSA changes reported in Lorenz et al. (2001). A large segment of the 16-year seasonal cycle is precisely documented with the new VIMS NSA boundary dataset. A period of a stable NSA from 2004 to 2014 was halted by an abrupt change in the fading of the NSA boundary from 2014 until its reversal and reappearance in 2017. Note that small systemic variations within the uncertainties exist in the NSA boundary latitude estimations between Cassini ISS and VIMS images from 2004-2007. Ls refers to solar longitude: 0◦ at Titan's Northern Spring Equinox.