Understanding Titan's Chemical Factory: Insights from the VIMS Occultation Data

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Background/Motivation: Titan's atmosphere is an organic factory, producing high-order hydrocarbons from the photolysis of methane by solar ultraviolet radiation. These organics aggregate together to form tholins, which then sediment out of the atmosphere to the surface. Constraining the temporal evolution and distribution of Titan's aerosols is required to understand the roles of haze production in the Titan system including radiative heating, dynamics, atmospheric chemistry, and surface erosion/dune formation. Studies of Titan's hazes have demonstrated significant variability in haze abundance over the course of the Cassini mission and beyond. We seek to expand on this work by considering newly analyzed data from the Cassini Visual and Infrared Mapping Spectrometer (VIMS) in combination with radiative transfer (RT) models.

Here, we present an analysis of all the VIMS solar occultation data over the course of the Cassini mission. These unique data offer the ability to sample fine vertical structure in both gaseous composition and aerosol abundance. Past studies have leveraged the occultation data occurring in the first half of the mission. Now, we double the dataset, including data from the second half of the mission, providing both a longer temporal baseline and greater spatial coverage through which to understand the formation and distribution of Titan's aerosols. The final profile of derived vertical abundance permits both a study of the spatio-temporal variability in Titan's aerosols and more accurate atmospheric profiles for RT modelling, which generally assume constant profiles as derived from the Huygens probe. Accurate RT is critical for atmospheric compensation and interpretation of retrieved surface properties.

Preliminary Results: Significant variability in sampling resolution is observed between the datasets. This results from differences in the integration time, image frame size, and distance of Cassini from Titan at the time of acquisition. Resolutions range from 5-40 km on average. All plots have been color coded to correspond to similar altitudes ranging from 50-500 km. Strong absorptions are observed around 2.3- and 3.3-μm from methane, with additional weaker absorptions around 1.2- and 1.4-μm. Also evident in most observations is the strong carbon monoxide (CO) doublet at 4.8-μm. However, this signature appears to be significantly weaker in later observations, suggesting the potential for spatio-temporal variability in CO on Titan. Variability in the spectral slopes in the continuum from 1.0 - 2.2-μm also demonstrate changes in vertical aerosol abundance over the course of the observations. Most notable is decreased transmission on the T103/T116 ingress datasets, corresponding to similar latitudes at ~30°N, at ~150km altitudes. These data suggest a significant increase in aerosol abundance at mid-latitudes later in the Cassini mission and will be used to place constraints on seasonal circulation of Titan's atmosphere.

Summary: Titan's atmosphere hosts a rich organic factory resulting in the formation of haze particles that obscures the surface and gives the moon its distinct orange hue. In this work, we use a special occultation observation mode with the Visual and Infrared Mapping Spectrometer (VIMS) on Cassini to better understand Titan's haze. This observations mode follows the Sun as it passes behind Titan, slowing becoming obscured by the atmosphere and allowing a unique opportunity to study the vertical structure of the aerosols and gaseous absorbers. By understanding the spatial and temporal variability in these vertical profiles, constraints can be placed on the formation and distribution of Titan's aerosols and allow interpretation for the roles these particles play in the Titan system.