TRACKING SHORT-TERM VARIATIONS IN TITAN'S HAZE DISTRIBUTION. *Fiona Nichols-Fleming[1], Paul Corlies[2], A.G. Hayes[2], M. Ádámkovics[3], *Presenting Author (fnichol2@u.rochester.edu), [1]Department of Physics and Astronomy, University of Rochester, Rochester NY, [2]Department of Astronomy, Cornell University, Ithaca NY, [3]Department of Physics & Astronomy, Clemson University, Clemson SC

Summary: We present an analysis of the hydrocarbon haze distribution on Titan using eight months of frequent observations with SINFONI VLT. The latitudinal and temporal distribution of organic haze can be used to constrain Titan's global circulation as well as indicate potential regions of increased organic deposition on Titan's surface which, in the presence of liquid water from impact melt or the subsurface oceans, could be favorable for life. Preliminary results show significant latitudinal and temporal variations, suggesting a not yet understood local influence on haze production.

Introduction: Titan is the only satellite in the solar system with a thick atmosphere, which is predominantly comprised of nitrogen and methane along with a photolytically-produced hydrocarbon aerosol haze. The haze distribution throughout the atmosphere is the basis for many aerosol models which work to constrain the locations of organics across Titan [1,2].

Here we present a study of the haze distribution based on analysis of spectra from SINFONI VLT in both H+K bands acquired over a year during a broader cloud monitoring campaign [3]. We analyze 56 observations over eight months which each have four 15 second exposures coadded together to cover the entire disk. We use a spherically corrected plane parallel radiative transfer (RT) model PyDISORT [4,5] to simulate Titan's atmosphere.

We are interested in understanding the seasonal distribution of hazes in Titan's atmosphere. It has been shown through observations that winds in Titan's atmosphere can redistributue the haze [1,6,7]. To date, variations in the structure and density of Titan's hazes have been at a limited spectral resolution and wavelength coverage. The analysis presented here is based on simultaneous observations in the H+K bands, which more than doubles the spectral coverage used in [5]. This utilization of a broader wavelength bandpass gives a greater spectral resolution and wavelength coverage, which allows for a more accurate knowledge of the location of organics.

Methods: We generate synthetic spectra based upon in situ observations from the Huygen's probe [8,9] and ground based veiwing geometries with our RT model. Our model is split into 20 layers, where each layer has its own characteristics such as altitude, pressure, temperature, methane opacity, and haze opacity. The model is a DISORT plane parallel solver implemented in Python that includes properties such as multiple scattering for phase functions, layers, and altitudes, to accurately simulate Titan's atmosphere.

In this work we cover regions that correspond to a $\mu > 0.65$, where μ is the cosine of the incident or emission angle (note that these are approximately equal as the phase angles of ground based observations are small). This restriction is due to the RT model's limitations near the limb. We calculate the incidence, emission, and phase angles (as inputs for the RT) for each pixel using the JPL ephemeris, and then implement the described cutoff to determine which pixels will be analyzed.

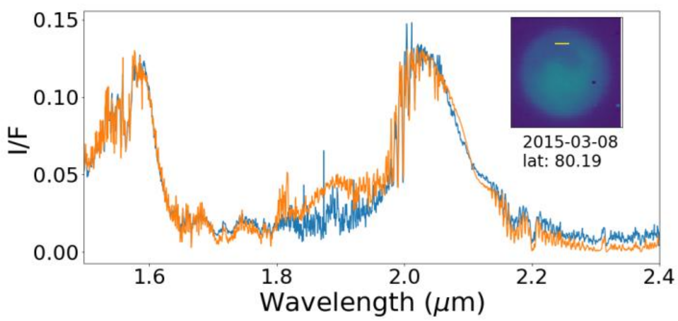

Figure 1 - An example observed spectrum (blue) and modeled spectrum (orange) with an inset image of the disk for the 03-08-2015 observation in the 2.1 μm channel. Yellow pixels indicated on the disk show the ten that were averaged to create the observed spectrum at 80.2N.

In order to fit these generated spectra to the observations, we scale the haze opacity of our model as we expect the opacity of the haze to closely correlate with the amount of haze [5]. We investigate a bimodal haze structure in this work, similar to that of [5]. This means that we use one scaling factor for the layers in the stratosphere and a different scaling factor for the layers in the troposphere.

The scaling factors for the stratospheric and tropospheric hazes are degenerate, as the stratosphere is higher in the atmosphere and therefore influences the spectral regions that are sensitive to hazes in the lower troposphere. Breaking this degeneracy required that we first fit the stratospheric haze and then fit the tropospheric haze. To further remove systematic effects of our model, we standardized the 2.2 μm dip in the model to the reflectance value of the dip in the observed spectrum.

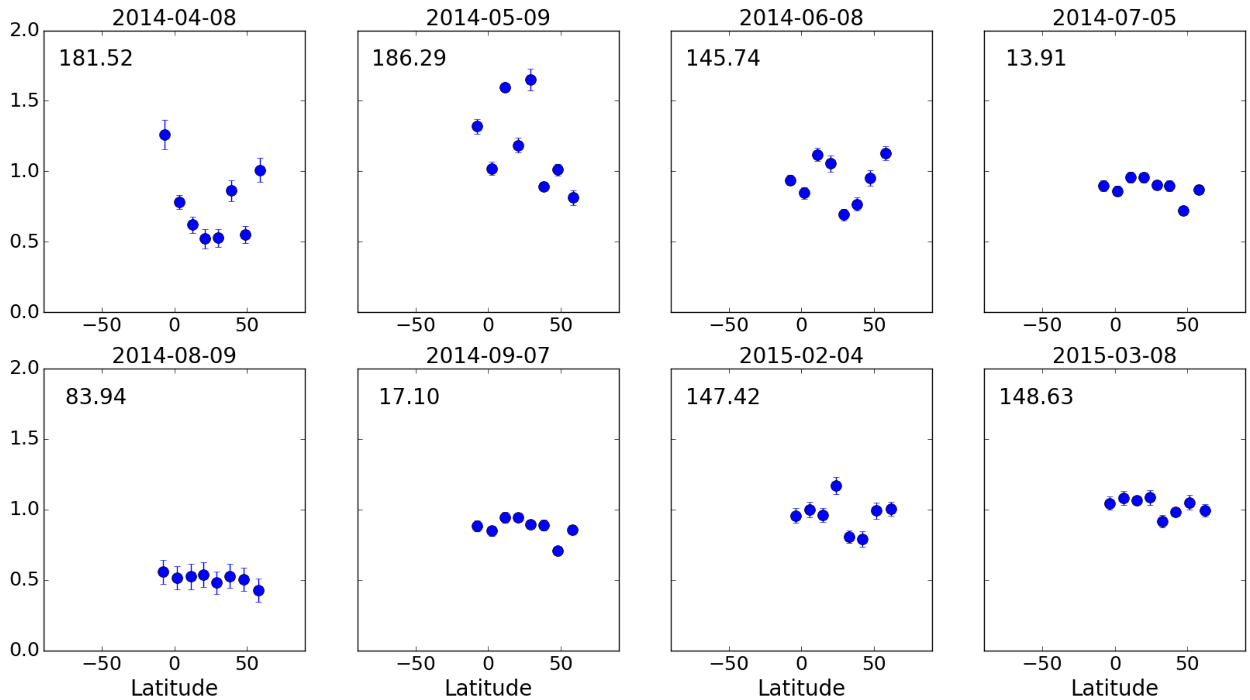

Figure 2 – Selected plots of the stratospheric haze scaling factors as a function of latitude for eight observations, one from each month, including error bars. The sub-observer longitude of each observation is indicated in the upper left corner of each frame. There appears to be similar distributions at similar sub-observer longitudes which may indicate a quasi-permanent longitudinal haze structure.

We ran altitude sensitivity tests (adapted from [5]) to determine the wavelength regions sensitive to altitude and to confirm the cutoff between our two scaling factors. We found that in general wavelength regions with higher I/F are sensitive to lower altitudes and vice versa and we determined that 20 km was a valid critical altitude as approximately half of our channels are sensitive to changes below this altitude versus sensitive to changes both above and below.

We use the scipy optimization package to perform a Levenberg-Marquardt (LM) minimization to determine the scaling factors that best fit the observations. To increase the speed of our calculations, we fit only the redward wings of the two peaks in the spectra, i.e. the methane windows, as these regions are most sensitive to changes in opacity at a wide range of altitudes. We used every seventh channel in the two regions after determining that this did not impact the quality of fits for the derived parameters.

Results and Discussion: Figure 2 presents results for 56 observations between April 2014 and March 2015. The frequency of these observations allows us to study short-term and seasonal variations in the haze distribution. The data cover latitudes -18.72 to 83.89 degrees, similar to the coverage of [5].

We do not see any overall trends in the seasonal variation of the haze, but our results do show significant latitudinal variations. The variations seen in this work are on the order of those in [5], but appear to change monthly instead of seeming to be longer term seasonal changes. This suggests that there may be local influences on the haze production that are not yet understood, for example global winds that exist on short time-scales. This also agrees with past observations that there is large scale circulation of the haze.

Additionally, there appears to be a similar shape in haze distribution at observations with similar sub-observer longitudes, which can be seen in the July and September observations or the June and February observations shown in Figure 2. This could sugest that there exists a quasi-permanent longitudinal structure of the haze.

Although we see short-term variability on the same scale as previously proposed seasonal variability [5], ongoing work is being done to investigate any systematic effects in our analysis that could cause this rapid variance.

References: [1] Lorenz R. D. et al. (2010) in *Titan From Cassini-Huygens* [2] Tomasko M. G. and West R. A. (2010) in *Titan From Cassini-Huygens* [3] Corlies P. et al. (2014) DPS XLVI, Abstract #112.06 [4] Ádámkovics M. et al. (2016) *Icarus, 270*, 376-388. [5] Ádámkovics M. et al. (2017) *Icarus, 290*, 134-149. [6] Anderson et al. (2008) *Icarus, 194*, 721–745. [7] Rannou et al. (2012) *ApJ, 748*, 4. [8] Tomasko M. G. et al. (2008) *Planetary and Space Science, 56(5)*, 669-707. [9] Niemann H. B. et al. (2010) *JGR, 115(E12)*, E12006.