

SSSCDD Case for Titan

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0. **Science Background:** Titan is unique among worlds in the solar system. It is the only known planetary body apart from Earth to have a thick, nitrogen dominated atmosphere with stable surface liquid. Additionally, its low gravity, reducing, hydrocarbon and nitrile rich atmosphere make it a tantalizing analogue for possible cold and hazy exoplanets and early prebiotic Earth. Titan's effective solar orbit takes 29.5 Earth-years to complete, with its 27 degree effective solar obliquity giving rise to approximately 7.5 Earth-year length seasons, each with distinct chemical and dynamical structures. While the Cassini Saturn orbiter monitored Titan's seasonal evolution for just under one half of a Titan year (14 Earth years), many questions remain to be answered about the seasonal evolution of Titan's atmospheric composition and dynamics. HWO is uniquely posed to conduct long-term, multi-decadal monitoring of Titan's evolving atmosphere from the near-infrared to ultraviolet in ways not possible through past observatories and missions.
1. **Science Goal:** Determine the behavior of the chemistry and dynamics of Titan's atmosphere from subseasonal (~Earth months) to interseasonal (~Earth decades) timescales, from near surface to upper atmosphere
2. **Science Objective:**
 - O1) What is the atomic hydrogen environment around Titan?
 - O2) How does the size distribution of aerosols vary across seasons?
 - O3) What is the abundance of trace molecules in Titan's upper atmosphere?
 - O4) What is the seasonal-scale behavior of tropospheric methane clouds?
3. **Physical Parameters:**
 - a. Distribution of escaping H-atoms across time, latitude
→ *constraint on Titan atmospheric loss rate, analog for low-g puffy exoplanets*
 - b. Vertical/horizontal profiles of mid to upper atmospheric aerosol size distribution
→ *constrain formation pathways for Titan's surface material*
 - c. Abundance profiles of trace molecules through the atmospheric column
→ *constrain formation pathways for Titan's aerosols*
 - d. Rapid-cadence observations of tropospheric clouds
→ *constrain how energy, methane distributed near surface*
4. **Description of Observations:**

Desired Observations
Lyman- α (121 nm) emission of Titan's orbital environment

→ possibly improving on HST obs since HWO may be out of Earth's Hydrogen corona
 Global maps of aerosol brightness (incl. limb) across a range of UV/Vis/NIR wavelengths
 → UV/vis scattered light combined with radiative transfer modeling for size profile
 High S/N disk-averaged spectra
 → identifying weak upper atmospheric molecules
 UV/Vis extinction profile spectra during stellar occultations
 → best way for vertical profiles of atmospheric structure and aerosols if stars available
 Rapid-cadence measurements of spatially resolved NIR to identify surface clouds

Future Work Needed

Determine the occurrence rate of visible stellar occultations.

Forward modeling for limb darkening constraints of UV, vis scattered light from aerosols to determine required integration time

5. Impact on Requirements:

<i>Capability or Requirement</i>	<i>Necessary</i>	<i>Desired</i>	<i>Justification</i>	<i>Comments</i>
UV observations (specify wavelength)	Low R at 338 & 187 nm		Builds on obs from Cassini ISS/UVIS for aerosol size vertical profile	Scattered light for aerosol and absorption for stellar occ
Long wavelength observations (> 1.5 microns)	~2 microns, R > 100		Sensitive to near surface, tropo clouds (low R), stratospheric composition (at high R)	
Timing of observations in different bands	Contemp. (few weeks)		Would reduce systematic errors in constraining particle size distribution of aerosols	
High spatial resolution	0.05 arcsec		Useful meridional information needs two points per low/mid/high latitude bin need ~0.05"	Titan's diameter is ~0.7 arcsec, Nyquist requires 6 samples/hemisphere: ~0.7"/12 = 0.05 arcsec
High spectral resolution	Yes		Trace molecules can be measured at higher certainty with higher R.	<i>What R is needed for UV?</i>
Large field of view	No	No	Titan maximum angular diameter is ~ 0.7 arcsec	
Large field of		Would be	Would enable more time	

regard		useful	for triggered HWO observations	
Rapid response	No	Yes (as above)	A triggered response to ground-based observations, depends on final wavelengths range of instruments	Not desired if just UV/vis, but could be useful if NIR capable for observing near surface meteorology