ON THE TRANSMISSION OF TITAN'S ATMOSPHERE IN APPLICATION TO FUTURE MISSIONS

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Summary: We report on the transmission of Titan's atmosphere as a function of altitude using complete radiative transfer schemes. We find that the methane windows in Titan's atmosphere do not broaden significantly unless close to the surface.

Introduction: Despite thirteen years of exploration by the Cassini mission, the detailed composition of Titan's surface remains elusive. Spectral information is limited by significant atmospheric scattering and methane absorption that, combined, limit the view of the surface from orbit to only a few narrow wavelength windows in the near-IR. The surface is believed to be a combination of complex hydrocarbons / nitriles [1] and CO_2 / H_2O ices [2,3], although the limited wavelength range accessible to Cassini made specific species identification difficult. An increased range of observable wavelengths would permit identification of specific species in Titan's surface composition [1].
A better understanding of Titan's surface composition would inform studies on surface processes and evolution [4], photochemical production in the atmosphere [5], deposition and processing of photolytic products on the surface, and constrain astrobiologically-relevant processes include prebiotic (and perhaps even exotic biotic) chemistry in the atmosphere and on the surface (potentially even water-organic interactions) [6].

With the end of the Cassini mission, new mission concepts to return to Titan and being proposed and evaluated [7]. Herein, we report on the expected transmission of Titan's atmosphere from .5-5 um for three altitudes relevant to potential mission concepts: an orbiter (represented at 1500km), a balloon (represented at 10km), and a lander (approximated at 10m) both with and without an incandescent lamp.

Methods: Titan's atmosphere was simulated using the radiative transfer code, PyDISORT [8], a plane-parallel code built around the discrete ordinates method (DISORT) [9]. It employs a full radiative transfer scheme including multiple scattering, aerosol phase functions, collision induces absorptions, and variable composition with altitude. For this analysis, we make use of the k-coefficients generated from ground based and Cassini observations of Titan [10]. These coefficients allow for broad spectral coverage, especially to shorter wavelengths, where spectral libraries are incomplete at Titan temperatures. Only

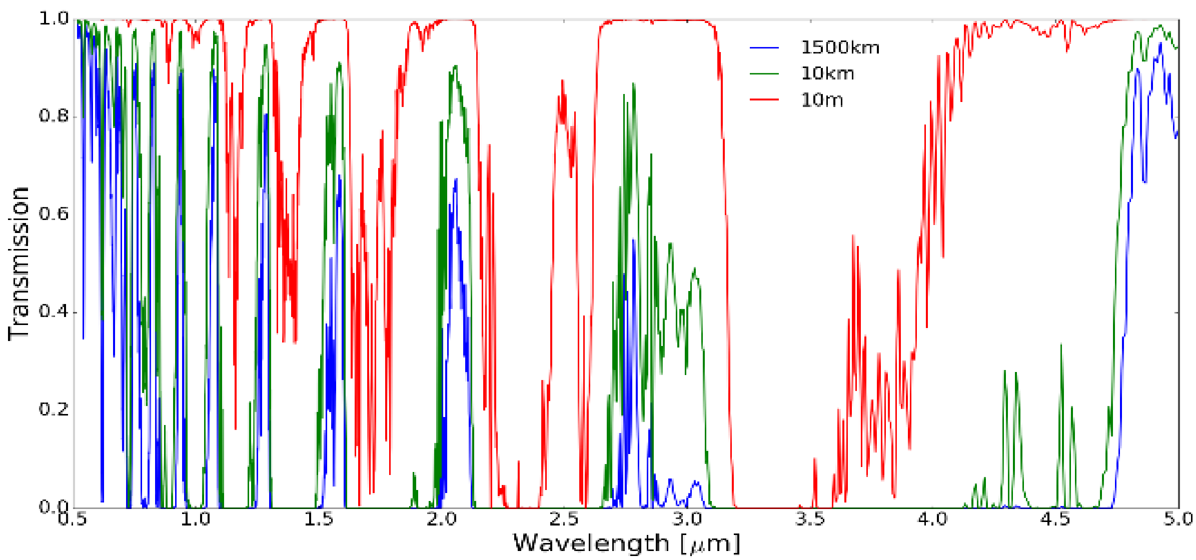

Figure 1: Plot of two-way methane transmission at three altitude in Titan's atmosphere. Significant broadening can be observed with decreasing altitude, resulting from the diminishing column of methane. Little broadening is observed at altitudes greater than 10km suggesting a minimum altitude for future mission that may require increased spectral coverage of Titan's surface.

methane is currently included in the model. Ethane and CO will be added in future work.

Atmospheric profiles are derived from the HASI instrument [11], aerosol properties from the DISR instrument, and species abundances from the INMS instrument on the Huygens Probe [12]. These profiles are varied to explore the effects that composition and altitude have on Titan's spectrum.

In order to inform future mission planning, we estimate the expected incidence flux for an orbiter, balloon, and lander (or low altitude aircraft), including an onboard light source, currently represented by a 100W incandescent bulb with 1° divergence lamp.

Results and Discussion: Figure 1 plots the derived two-way methane transmission as observed at 1500km, 10km, and 10m. We find significant broadening in the windows with decreasing altitude, but only at altitudes less than 10 km. This is a result of most absorption occurring in the lowest part of the atmosphere due to the atmospheric density and methane abundance being greatest in this region. However, significant broadening of all windows is observed for the lowest altitudes (10 m). Most notable is the broadening of the 5µm window to wavelengths as short as 3.5µm. We note, though, that this is an upper limit as CO has a strong absorption band at 4.9um, which will act to truncate this window.

In order to access these additional regions of the spectra, an onboard lamp is required. Figure 2 plots the expected I/F (direct component only) at 1500km, 10km, and 10m altitudes. We find little benefit from decreasing the target altitude until very near to the surface. This is because incident solar radiation is absorbed quickly in Titan's upper atmosphere, and therefore missions using passive solar radiation cannot take advantage of the increased transmission in the lowest parts of the atmosphere. The addition of onboard illumination addresses this issue by reducing the path length over which radiation is absorbed to strictly a two-way path between the spacecraft and surface. Even a modest lamp, no brighter than a common 100W incandescent lightbulb, is sufficient to provide an observable signal in all of the broadened spectral regions at a distance of 10m. We are further exploring the minimum power light source that would provide a reasonable SNR across all of the widened windows, given the large role that power constraints play in the selection of instrumentation.

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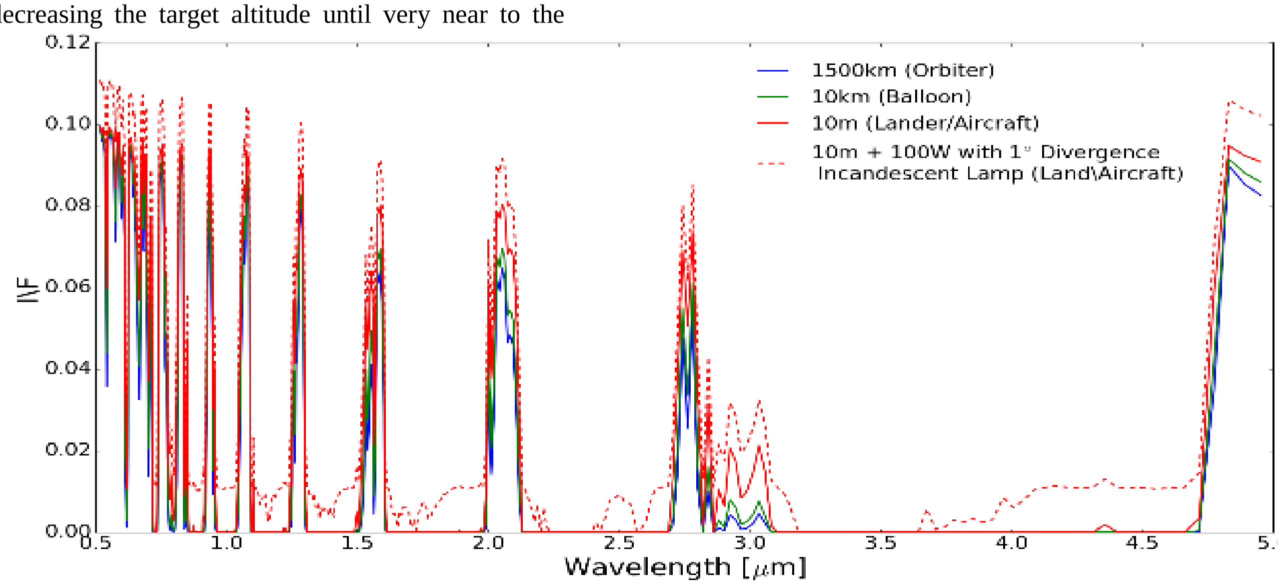

Figure 2: Expected I/F (direct component only) of Titan at 1500km, 10km, and 10m, including a lamp for the lander concept at 10 m (in daylight). Comparison between the cases demonstrate that onboard illumination is required in order to access the broader spectral regions available at lower altitudes. This is because incident solar flux is largely absorbed by the time it reaches the surface, except for regions within the narrow methane windows.