Cloud Condensation in Titan's Lower Stratosphere

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ABSTRACT

A 1-D condensation model is developed for the purpose of reproducing ice clouds in Titan's lower stratosphere observed by the Composite Infrared Spectrometer (CIRS) onboard Cassini. Hydrogen cyanide (HCN), cyanoacetylene (HC_3N), and ethane (C_2H_6) vapors are treated as chemically inert gas species that flow from an upper boundary at 500 km to a condensation sink near Titan's tropopause (~45 km). Gas vertical profiles are determined from eddy mixing and a downward flux at the upper boundary. The condensation sink is based upon diffusive growth of the cloud particles and is proportional to the degree of supersaturation in the cloud formation region.

Observations of the vapor phase abundances above the condensation levels and the locations and properties of the ice clouds provide constraints on the free parameters in the model. Vapor phase abundances are determined from CIRS mid-IR observations, whereas cloud particle sizes, altitudes, and latitudinal distributions are derived from analyses of CIRS far-IR observations of Titan. Specific cloud constraints include: 1) mean particle radii of 2-3 μm inferred from the ν_6 506 cm^{-1} band of HC_3N, 2) latitudinal abundance distributions of condensed nitriles, inferred from a composite emission feature that peaks at 160 cm^{-1}, and 3) a possible hydrocarbon cloud layer at high latitudes, located near an altitude of 60 km, which peaks between 60 and 80 cm^{-1}. Nitrile abundances appear to diminish substantially at high northern latitudes over the time period 2005 to 2010 (northern mid winter to early spring).

Use of multiple gas species provides a consistency check on the eddy mixing coefficient profile. The flux at the upper boundary is the net column chemical production from the upper atmosphere and provides a constraint on chemical pathways leading to the production of these compounds. Comparison of the differing lifetimes, vapor phase transport, vapor phase loss rate, and particle sedimentation, sheds light on temporal stability of the clouds.