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New Cold-Temperature Vapor Pressure Measurements Help Constrain the Microphysical Properties of Titan's South Pole Benzene Cloud

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Cassini CIRS observations of Titan's south polar region in May 2013 revealed the presence of a benzene (C_6H_6) ice cloud in the stratosphere. During this period of southern fall, the descending branch of Titan's global Hadley cell enriched the inventory of photochemically-produced hydrocarbon and nitrile species in the deep polar stratosphere. Additionally, strong cooling was observed, resulting in condensation at higher altitudes than normally found at other latitudes. Analysis of CIRS data indicates a cloud top near 280 km at the south pole, shifting lower in altitude with decreasing latitude, and an upper limit of ~1.5 μm for the equivalent radius of pure C_6H_6 ice particles [1].

We investigate the size and number of benzene (C_6H_6) cloud particles as a function of altitude using microphysics model simulations initialized with CIRS data and augmented by new laboratory measurements of C_6H_6 vapor pressures. The Community Aerosol and Radiation Model for Atmospheres (CARMA) simulates the microphysical evolution of aerosol particles in a column of atmosphere. The particles are modeled using discrete size bins. Cloud particles are created through heterogeneous nucleation using the haze particles as cloud condensation nuclei (CCN). Cloud particle formation and growth is controlled by the vapor pressure of C_6H_6. Existing laboratory measurements for the C_6H_6 sublimation vapor pressure do not cover temperatures below 184 K and are therefore insufficient to allow CARMA to reproduce the formation of the observed cloud system on Titan [2].

We have performed new experiments using the NASA Ames Atmospheric Chemistry Laboratory (ACL) to monitor the condensation of C_6H_6 in the IR and have determined, for the first time, the nucleation supersaturation and equilibrium vapor pressure of pure C_6H_6 at Titan-relevant temperatures (135–160 K). The experimental measurements of the vapor pressure of C_6H_6 we have acquired differ in slope and magnitude from the extrapolation of [3], which has previously been used by the Titan community. These new vapor pressure measurements indicate colder temperatures and higher pressures, and they are closer to the extrapolation calculated by [4]. Here we present new simulations conducted with CARMA using both the extrapolated values from [3] and those from [4] as well as the experimental vapor pressures to see their effect on the calculation.

We simulate the southern polar atmosphere in CARMA by initializing the model with a temperature/pressure profile from CIRS data at 87 S. All particles are transported vertically through sedimentation, eddy diffusion, and a vertical wind simulating Titan's Hadley cell. The descending branch of the Hadley cell is included by calculating a downward vertical wind with a magnitude of 2.5 mm/s at 380 km, as indicated by the CIRS data. All particles are also subject to coagulation. While coagulation is an important process in growing the haze particle population, we have generally found that the number of cloud particles formed prove to be too few for efficient coalescence. Cloud particles are created through heterogeneous nucleation using the involatile particles as cloud condensation nuclei. Nucleation follows the classical theory – there is an energy barrier to efficient particle formation; this is calculated from the contact parameter between the C_6H_6 ice and tholin substrate; as the contact parameter approaches unity, the energy barrier goes to zero. Cloud particles then interact with the volatiles through condensational growth and evaporation. Our simulations show cloud particles begin to form at altitudes comparable to that derived from the CIRS data with a vertical profile extending down through Titan's tropopause. The population of cloud particles grows from an effective radius ~0.5 µm near the cloud top to ~1.5 µm in the troposphere.

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