EPSC Abstracts,
Vol. 4, EPSC2009-649, 2009
European Planetary Science Congress,

Convective clouds on Titan

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Abstract

In terms of weather, Titan is the most Earth-like object in the Solar System. Atmospheric temperatures are warm enough to permit methane condensation, both as ice and liquid, and so methane may participate in a cycle similar to the Earth's hydrological cycle. Observations of clouds from this cycle have been documented now for more than a decade. The data on cloud tops ranges from ~ 14 to 25 km (1; 2; 3) from ground-based observations and up to the tropopause ~ 40 km with higher resolution Cassini VIMS observations (4).

Despite the abundance of cloud observations, there are still many unknowns assciated with cloud formation on Titan. The Titan Regional Atmospheric Modeling System (TRAMS) is a coupled dynamic and microphysics model. The governing equations for the dynamical core are the standard non-hydrostatic Reynolds-averaged primitive equations, similar to those given in (5). (6) recently completed a study with TRAMS detailing environments which allow convection and the resulting characteristics of the clouds formed in those environments. Table 1 summarizes the cloud characteristics for initialization with three different methane surface humidities.

Table 1: Characteristics of clouds as a function of methane environment

	50%	60%	70%
Cloud Base (LCL)	4.3 km	3.0 km	1.9 km
Lev. of Free Convection	6.8 km	4.9 km	2.7 km
Equilibrium Level	24 km	28 km	30 km
Approx initial CAPE	200 J/kg	540 J/kg	900 J/kg
Max Cloud Altitude†	28-30 km	32-34 km	36-38 km
Time at max altitude	4 hrs	2 hrs	1 hr
Horiz Extent at 10 km	180 km	350 km	500 km
Horiz Extent at 20 km	120 km	270 km	320 km
Horiz Extent at 30 km	-	180 km	200 km
Max Updraft Velocity	9 m/s	18 m/s	20 m/s

† At VIMS resolution and assuming maximum size of cloud particles; if coalescence is inhibited cloud tops are raised by 2-4 km.

Each of these environments is *wetter* than that found at the Huygens landing site. However, no optically thick clouds have been observed there and (7) could only form stratiform clouds in TRAMS simulations. Independent of methane amount, the convective clouds described in Table 1 follow a general life cycle. A cloud is triggered to rise in the center of the model domain and forms a rapidly rising, narrow (few km extent) plume. Methane droplets freeze once the plume reaches 15 km. The cloud top initially overshoots the equilibrium level and then spreads horizontally at lower altitudes, forming an anvil (Fig. 1). As with terrestrial thunderstorms, additional clouds are formed near the cloud base, moving horizontally outward from the central cloud (along the gust front, Fig. 2).

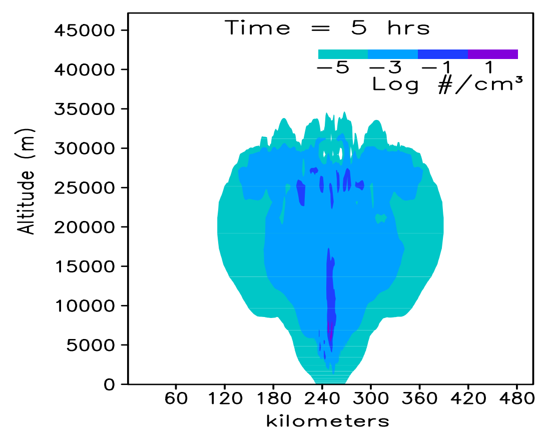

Figure 1: Snapshot from a TRAMS simulation showing the full extent of the initial convective cloud.

A number of other factors (particularly those associated with the nucleation and coalescence processes) also influence the morphology of the clouds, but the most significant factor is the amount of methane near the surface. The large methane humidities needed to create cloud tops near the tropopause are puzzling give the amount of methane we expect to find near Titan's surface. Certainly, the Huygens landing site value could be an indication of dryer near-equatorial conditions with an increase in surface methane abundance proceeding poleward. However, a 50% increase in methane mole fraction from 10° to 40° S is extreme and some ground-based observations have pointed to a dryer overall methane abundance. An alternative explanation to cloud tops near the tropopause is using methane convection as a trigger for ethane cloud formation. Ethane's source region is at high altitude (from methane photochemical destruction) and has been observed condens-

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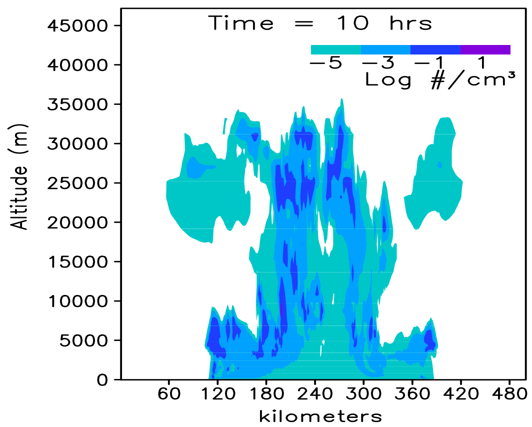

Figure 2: Snapshot from a TRAMS simulation after initial cloud has begun to dissipate and further cloud formation is triggered near the cloud base.

ing at altitudes above the tropopause (8).

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