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Simulating Titan's Aerosols in a Three Dimensional GCM

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1. Introduction

We present the results of a coupled three dimensional global climate model (GCM) and aerosol microphsyics model to elucidate properties of the aerosols and their radiative effects on the atmosphere. In particular, we are interested in determining the size, number density, aerosol charging, and production rate of the aerosols. The values along with DISR derived indices of refraction allow us to retrieve optical depths and extinctions at all latitudes and seasons. We couple these aerosols to the radiative transfer code and see the effects on the heating rate and temperatures. These coupled aerosols also have dynamical feedbacks. Our model also allows us to study the historical albedo seasonal cycle from a microphysics perspective. We compare these properties with spacecraft and ground based data and use them to constrain the model.

2. Model Description

We are using a three dimensional Titan GCM based on the NCAR Community Atmospheres Model (CAM) developed by Friedson et al. (2009). To this model we have added a microphysics package, the Communtiy Aerosol and Radiation Model for Atmospheres (CARMA). We coupled CARMA to the radiation code in CAM and use this model to explore the aerosol properties on Titan and their radiative and dynamical effects on the atmosphere. This model is run at a rather course grid of 10x15 degrees latitude and longitude, but it is sufficient to reproduce global scale phenomena.

3. Results

Table 1 describes some of the representative simulations we have completed. Figure 1 shows the wavelength dependence of our aerosol optical depths at three different altitudes. As you can see, we match the slope quite well although our magnitude is slightly too high. The lower atmosphere sees a softening of the slope, which we do not see while our magnitudes are too large. Below 80km on Titan there is significant condensation accumulating on the particles which our model does not consider[3]. Therefore we accept discrepancies below this altitude and focus on the stratosphere.

Table 1: Model parameters for the simulations.

Simulation parameters	Production [g/cm^2/s]	Charge ratio	Rainout lifetime
p0m10r50	10×10^{-14}	0 e$^-$/μm	50 years
p15m10r50	10×10^{-14}	15 e$^-$/μm	50 years
p10m5r0	5×10^{-14}	10 e$^-$/μm	infinite
p10m5r50	5×10^{-14}	10 e$^-$/μm	infinite
Base case, p10m10r50	10×10^{-14}	10 e$^-$/μm	50 years

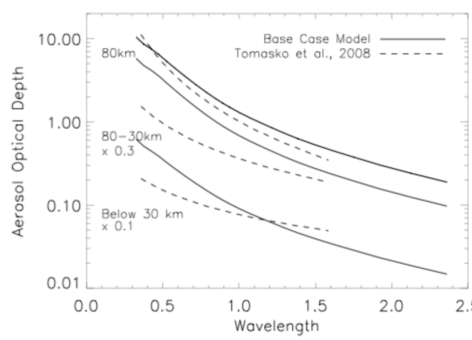

Figure 1: The wavelength dependence of optical depth from our base case simulation.

Figure 2 shows our aerosol optical depths for several different runs compared with spacecraft data. Our model simulations bracket the data and our base case model is quite close to both Voyager[2] and Cassini[3] data. Comparing these runs we can see that a production rate near 10^{-13} g/cm^2/s is required to match the optical depths. Also a charge is required on the particles to keep them from coagulating and becoming too large. It is less obvious in this figure, but removal in the form of rainout in the lower atmosphere is required to match the extinction rates.

Figure 3 demonstrates the latitudinal and seasonal gradients of the aerosol number density and effective radius. These demonstrate the importance of dynamics in the aerosol distribution and are proposed as the mechanism for the seasonal albedo cycle.

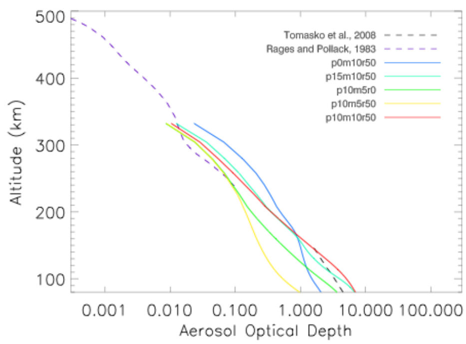

Figure 2: The aerosol optical depth at the Huygen's landing site from select simulations described in Table 1 compared with Voyager[2] and Huygens[3] data.

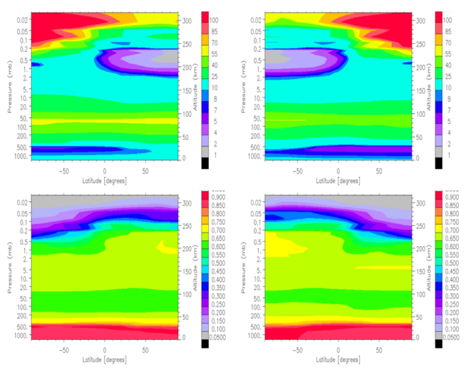

Figure 3: Number density (top) and effective radius (bottom) of Titan's aerosols in the southern summer (right) and northern summer (left) from the base run.

4. Summary and Conclusions

We find the best fit parameters for our Titan GCM to include a production rate of 10^{-13} $g/cm^2/s$. This is a factor of about 4 larger than the tholin production estimated by chemical models[4]. This production of tholins has to come at the loss of other products, such as ethane which could help explain the small amount of ethane observed on the surface. We also find a charge to radius ratio of 10 electrons per micron or less is sufficient to repress the coagulation of aerosols enough to generate particle sizes that fit the phase functions at 100km. This is smaller than the charge to radius ratio of 15 required by a recent 1-D model[5]. We also find that a rainout lifetime of 50 years in the troposphere is needed to fit the vertical extinction profile in the lowest 100 km of Titan's atmosphere.

The aerosols on Titan display strong latitudinal and seasonal gradients, especially aloft. These gradients have been suggested to cause the seasonal cycle in Titan's north/south albedo ratio. Our model produces a seasonal albedo cycle supporting this theory.

Making the aerosols interact with the radiative transfer increased our heating rates in the stratosphere. However, we are not building up the 20 K temperature gradients that are required to accelerate the winds to the observed supperrotating levels.

Acknowledgements

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