EPSC Abstracts
Vol. 6, EPSC-DPS2011-176, 2011
EPSC-DPS Joint Meeting 2011

Insolation and Titan's Tropospheric Circulation

J. M. Lora (1), P. Goodman (2), J. Russell (2) and J. I. Lunine (1)
(1) Lunar and Planetary Laboratory, University of Arizona, Tucson, USA (2) Department of Geosciences, University of Arizona, Tucson, USA (jlora@lpl.arizona.edu)

Abstract

Two insolation distributions with latitude, one at the top of the atmosphere and another approximated from heating rates based on DISR measurements, are applied to a simple box model of Titan's troposphere to compare their effects on circulation. The second case produces temperatures and methane tracer movement that better agree with observations.

1. Introduction

Titan's lower atmosphere is known to support a hydrological cycle based on methane and presumably controlled by its circulation. Several circulation models have been developed over the past two decades to explain the occurrence of observed clouds, polar hydrocarbon lakes, and an arid equator, with varied levels of success in each category. At least two sets of models (those based on Mitchell *et al.* (2006) [2] and Tokano *et al.* (1999) [4], respectively) appear to depend critically on the latitudinal distribution of the insolation in the troposphere and surface to produce a seasonally wandering pole-to-pole circulation. In the case of Rannou *et al.* (2006) [3] this is less apparent, and their resulting circulation is much less variable; nevertheless, insolation is the main driver of the circulation and a realistic prescription of it is critical.

Radiative transfer in Titan's hazy atmosphere is a complicated and largely unconstrained problem, due in large part to scattering and absorption by aerosols. A majority of the sunlight that reaches the lower atmosphere is in the form of diffuse radiation, and thus its latitudinal distribution is difficult to determine. However, based on Huygens DISR measurements, Tomasko *et al.* (2008) [5] computed solar heating rates as a function of altitude for different latitudes, and at different seasons, including a scattering model. In their results, the maximum heating below ∼50 km (in the troposphere) during solstice occurred at midlatitudes, not the poles as might be assumed from the insolation distribution at the top of the atmosphere. Therefore, in summertime, the highest temperatures near the surface would not occur at the pole.

We developed a simple box model of Titan's lower atmosphere to compare the effects of different insolation distributions on the meridional circulation.

2. Model and Results

The diurnally averaged insolation distribution can be approximated analytically given an extinction optical depth τ, assuming that the optical properties of the atmosphere are constant with latitude and time ($\tau = 0$ yields the distribution at the top of the atmosphere). Based on the solar heating rate calculations mentioned above [5], the distribution of sunlight at Titan's surface may be approximated by using an effective τ of 0.4, with the insolation normalized to match the measurement at the latitude of the Huygen probe's landing.

We use this calculated insolation distribution and the distribution at the top of the atmosphere (scaled down to values appropriate for the lower atmosphere) to force a simple box model based on the primitive equation for thermodynamic energy. The model solves for temperature and methane tracer content in twelve "boxes" that represent the troposphere, with parameterized convection that we assume drives all (meridional) advection.

Using the $\tau = 0$ distribution, similarly to e.g. Mitchell *et al.* (2006) [2], the model produces a pole-to-pole circulation with rising and subsiding motions in the summer and winter hemispheres, respectively. This acts to advect methane equatorward via the warmer, low altitude returning airflow. On the other hand, using the nonzero τ distribution, the model produces a circulation with rising air at the summer midlatitudes during solstice, but subsidence over both poles. In this case, methane is advected aloft toward both poles (where it can reach saturation), while the returning low level air again fluxes it equatorward. This difference could account for the appearance of clouds over *both* poles in late summer and around equinox, as has been observed.

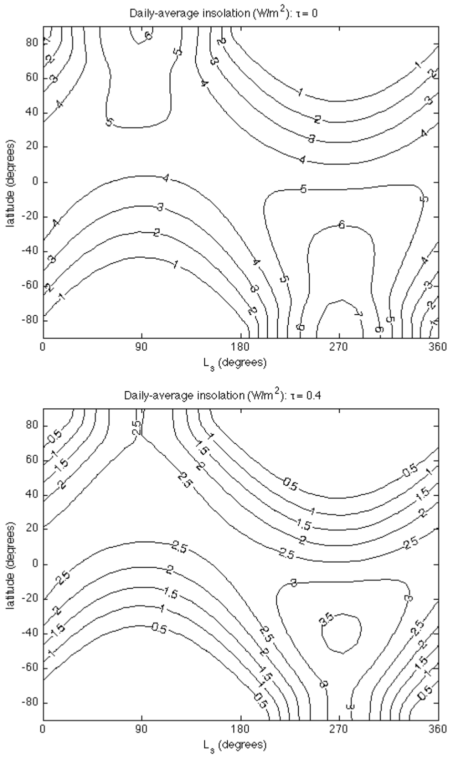

Figure 1: Calculated insolation distributions versus time for the top of the atmosphere (top) and the surface (bottom).

In addition, the latter, presumably more realistic insolation scenario produces surface temperatures around solstice that closely match CIRS observations [1], whereas the former causes the highest temperatures to occur at the poles and produces higher latitudinal temperature gradients.

Although this simple model has obvious uncertainties, the results highlight the relevance of properly accounting for the distribution of sunlight in Titan's lower atmosphere in circulation models, and suggest that our simple approach may provide a more realistic distribution than that assumed by previous, more detailed, models.

Acknowledgements

We thank M. Tomasko and the DISR team for their heating rate calculations, as well as the Cassini team for their invaluable work.

References

[1] Jennings, D. E. et al.: Titan's surface brightness temperatures, Astrophys. J., Vol. 691, pp. L103-L105, 2009.

[2] Mitchell, J. L. et al.: The dynamics behind Titan's methane clouds, PNAS, Vol. 103, pp. 18421-18426, 2006.

[3] Rannou, P. et al.: The latitudinal distribution of clouds on Titan, Science, Vol. 311, pp. 201-205, 2006.

[4] Tokano, T. et al.: Seasonal variation of Titan's atmospheric structure simulated by a general circulation model, Planet. Space Sci., Vol. 47, pp. 493-520, 1999.

[5] Tomasko, M. G. et al.: Heat balance in Titan's atmosphere, Planet. Space Sci., Vol. 56, pp. 648-659, 2008.