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Thermal structure and dynamics of Titan's lower troposphere

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Abstract

A new climate model for Titan's atmosphere has been developed, using the physics of the IPSL Titan 2-dimensional climate model with the current version of the LMDZ General Circulation Model's dynamical core. The GCM covers altitudes from the surface to 500 km with the diurnal cycle and the gravitational tides included.

We realized a complete study of thermal structure of Titan's lower troposphere at the Huygen's site. We show that a convective boundary layer develops during the morning on Titan reaching a maximal height of 800 m. We interpreted the slope change in the HASI' s thermal profile at 2 km. This has consequences for winds, dunes and clouds formation.

We analysed tropospheric winds and the influence of both the thermal and the gravitational tides. Both have a very small impact on the circulation.

With topography maps, we find that anabatic winds develop on smooth and long slopes. We discuss the implications for the equatorial dune fields observed on Titan.

1. Introduction

Titan's lower troposphere is of particular interest because it controls the evolution of many surface features (dunes, lakes) and the exchange of methane between surface and the atmosphere. Yet its study is quite difficult, few observations are available. GCM appear as useful tools to understand the climate and aeolian processes on Titan. With the IPSL-GCM, we succeeded to reproduce profiles of temperature and winds measured by Huygens quite well. We interpreted these profiles and their consequences, together with a specific study of near surface winds on Titan.

2. Boundary layer and thermal structure

The HASI profile of potential temperature shows a layer at 300 m, an other at 800 m and a slope change at 2 km ([5],[2]). Dune spacing on Titan is consistent with a 2-3 km boundary layer ([3]). We have reproduced this profile (see figure) and interpreted the layer at 300 m as a convective boundary layer, the layer at 800 m is a residual layer corresponding to the maximum diurnal vertical extension of the PBL. We interpret the slope change at 2 km as a weakening of the Hadley's circulation, what produces an increase with altitude of zonal wind into stratosphere.

When averaged over more than one day, only the slope change at 2-3 km remains significant, in agreement with dunes spacing.

Finally we interpret the fog discovered in summer polar region ([2]) has clouds produced by the diurnal cycle of the PBL (as fair weather cumulus on Earth).

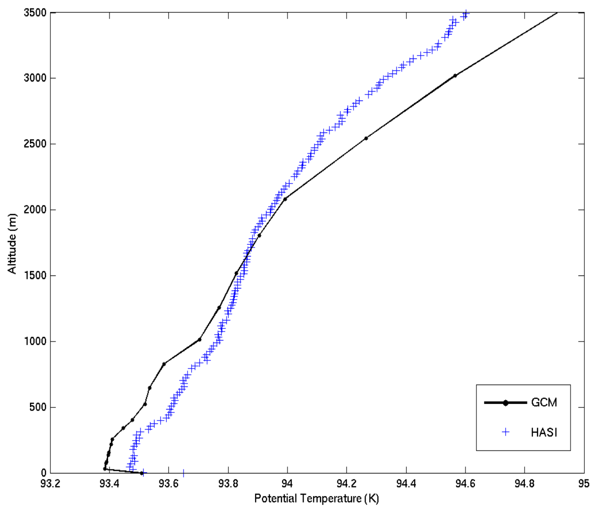

Figure: Profile of potential temperature measured by HASI and simulated by GCM

3. Surface winds

3.1 Effect of gravitational and thermal tides

We analysed tropospheric winds and the influence of both the thermal and the gravitational tides. The impact of gravitational tides on the circulation is extremely small, this caused by the pressure gradient which quickly compensates tidal forces. Thermal tides have a visible effect, though quite tenuous.

We show statistics of strengh and direction of surface winds.

3.2 Effect of topography

We produced topography maps derived from spherical harmonic interpolation ([6]) on the reference ellipsoid ([4]). Surface temperatures at high altitude appear higher that the ambient air. Vertical air movements produce anabatic winds developing on smooth and long slopes. This could be one of the main causes controlling the direction of surface winds and could have an impact for the direction of dunes observed on Titan as well.

4. Conclusion

GCM appear as perfect tools to study Titan's lower troposphere from which we have few observations. The knowledge of wind regimes on Titan is a key to understand dunes formation. Titan is an exotic world but its weather is mainly controlled by classical phenomenons occurring on Earth.

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