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Simulation of the Titan atmosphere with the non-hydrostatic general circulation model

A.V.Rodin (1,2), I.V.Mingalev (3), K.G.Orlov (3) and Yu.V.Skorov(4)
(1) Moscow Institute of Physics and Technology, Russian Federation (alexander.rodin@phystech.edu), (2) Space Research Institute, Planetary Physics, Moscow, Russian Federation, (3) Polar Geophysical Institute, Apatity, Russian Federation, (4) Technical University of Braunschweig, Braunschweig, Germany

Abstract

We apply non-hydrostatic, gas-dynamics general circulation model to simulate the dynamics of Titan atmosphere. The model is coupled with the detailed microphysical model of tholin aerosols. Simulations reproduce zonal superrotation with a maximum velocity up to 200-240 m/sec in the jet core between 200 and 300 km altitude and wave-2 features in zonal aerosol distribution.

1. Introduction

As slowly rotating celestial body with a dense atmosphere, Titan reveals well known superrotation feature. Although the mechanisms of superrotation development are now understood and reproduced in general circulation models [1], its details are highly different from planet to planet. The specific feature of the Titan atmosphere is its exceptional vertical extent compared to relatively small size of the satellite. This implies the possibility of strong contribution of non-hydrostatic effects to the atmospheric circulation.

2. The model

The model is based on numerical solution to the full equation set describing viscous, elastic gas dynamics on the rotating sphere and inherits many features from the previous version[2].. It uses optionally either a uniform grid with 128 nodes in longitude and 64 in latitude, or triangular grid with average horizontal resolution about 2.5º. Vertical grid includes 1024 nodes and has a fixed vertical step of 500 m. Thermal forcing is applied to the model in terms of relaxation profile, with mean relaxation time of 20h.

Microphysical block includes the detailed description of tholin aerosols, including coagulation, charging and sedimentation in the atmosphere. Distributed photochemical source of tholins are assumed in the ionosphere in the upper part of the model domain. Each size bin of tholin aerosols is assumed to be passive tracer, which is transported by the atmospheric circulation. The aerosol block has been tested offline with a 1D model, where vertical mixing was simulated by the fractional eddy diffusion model.

2. Results

The model develops circulation pattern with quantitative parameters in agreement with observations. Wide midlatitude superrotation core with the amplitude 200-240 m/sec appears in the altitude range 200-300 km. Above this core, zonal wind fades and starts to increase again with altitude above 400 km. Wind velocity field reveals zonal wave-2 and wave-4 features, which may explain the diurnal variations of the Titan surface temperature retrieved from CIRS observations. The model predict formation of mesoscale circumpolar vortices at 60º-70º latitudes. Wind field discontinuity near the tropopause observed by the Huygens probe is reproduced as a result of tidal wave propagating in the medium with discontinuous static stability. Distribution of tholins is consistent with 1D simulations and reveals wave-2 and wave-4 zonal modulation.

Acknowledgements

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References

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