EPSC Abstracts
Vol. 6, EPSC-DPS2011-1482, 2011
EPSC-DPS Joint Meeting 2011

Dynamical atmospheric modeling of condensation flows on an N_2 frost covered body

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Abstract

We used a modified NASA Ames Mars General Circulation Model to simulate wind patterns on Triton. We present results on the evolution of wind patterns for several points along Triton's orbit between the 1952 equinox and the Voyager 2 flyby in 1989.

1. Introduction

Triton and Pluto are the only currently known members of a possible class of bodies with an N_2 frost covered surface and an N_2 atmosphere. Modeling the dynamics of such an atmosphere is useful for several reasons. First, winds on Triton were inferred from images of surface streaks and active plumes visible at the time of the Voyager 2 flyby in August 1989. An analysis of these features indicated that near surface winds moved preferentially to the north and east, or retrograde to Triton's rotation, and winds at 8 km in height moved west, or prograde [1, 2]. Atmospheric modeling can show at what points in Triton's orbit such winds might be expected and therefore how long before the Voyager 2 encounter the ground streaks may have been deposited. Second, atmospheric conditions on Pluto at the time of the New Horizons flyby are expected to be similar to those on Triton in several important aspects such as nitrogen frost temperature and average surface pressure. A dynamical model of a cold N_2 atmosphere can be used to predict wind directions on Pluto at the time of the New Horizons encounter with the Pluto/Charon system in July 2015.

2. Methodology and Results

We used a 3-D General Circulation Model (GCM) derived from the NASA Ames Mars GCM, version 2.0. The Ames GCM incorporates several physical processes critical to modeling the atmosphere of Triton, including condensation and sublimation of the main atmospheric constituent gas as well as subsurface storage and release of heat. We altered the Ames GCM to allow simulation of an N_2 atmosphere on a body corresponding to the size, axial inclination, rotation rate, and distance from the Sun of Triton. Our initial simulations did not include atmospheric radiative heat transfer, but did include conduction, convection, and surface-boundary layer heating. We ran simulations with an initial global covering of 20 cm of N_2 frost to examine the condensation flow caused by the sublimation and condensation of surface frosts.

Figures 1 and 2 shows results of preliminary simulations with a model that did not incorporate radiative transfer. Figure 1 shows the diurnally averaged zonal and meridional winds at Triton's 1952 equinox up to one scale height, or approximately 14 km. Surface zonal winds are mostly prograde except at the equator. Figure 2 shows the zonal and meridional winds at the time of the Voyager 2 encounter. Surface zonal winds over the subliming south pole flow retrograde to a height of about 1 km, then shift prograde at higher altitudes, with a zonal velocity of 18 m s^{-1} at a height of 8 km. These results are in rough agreement with winds observed by Voyager 2. We are in the process of adding a Newtonian heating/cooling mechanism to model realistic heating and cooling rates in the thin N_2 atmosphere. We will present results from this latest model at several points along Triton's orbit between the 1952 equinox and the 1989 Voyager 2 flyby.

This study was funded by a NASA Earth and Space Science Fellowship through grant number NNX09AQ96H.

References

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[2] Soderblom, L. A., Becker, T. L., Kieffer, S. W., Brown, R. H., Hansen, C. J., and Torrance, T. V.: Triton's geyser-like plumes - Discovery and basic characterization, Science, Vol. 250, pp. 410-415, 1990.

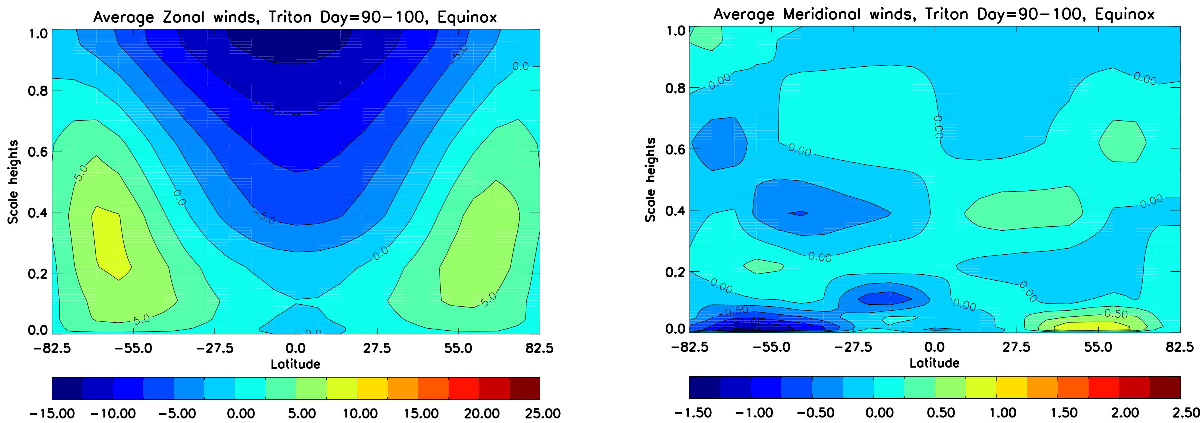

Figure 1: Diurnally averaged zonal (Left panel) and meridional (Right panel) winds at equinox in November 1952. Wind velocity is in m s^{-1}. Positive values of zonal wind velocity indicate prograde (westward) flow and negative values indicate retrograde (eastward) flow. Positive values of meridional wind velocity indicate south to north flow while negative values indicate north to south flow. One scale height equals approximately 14 km.

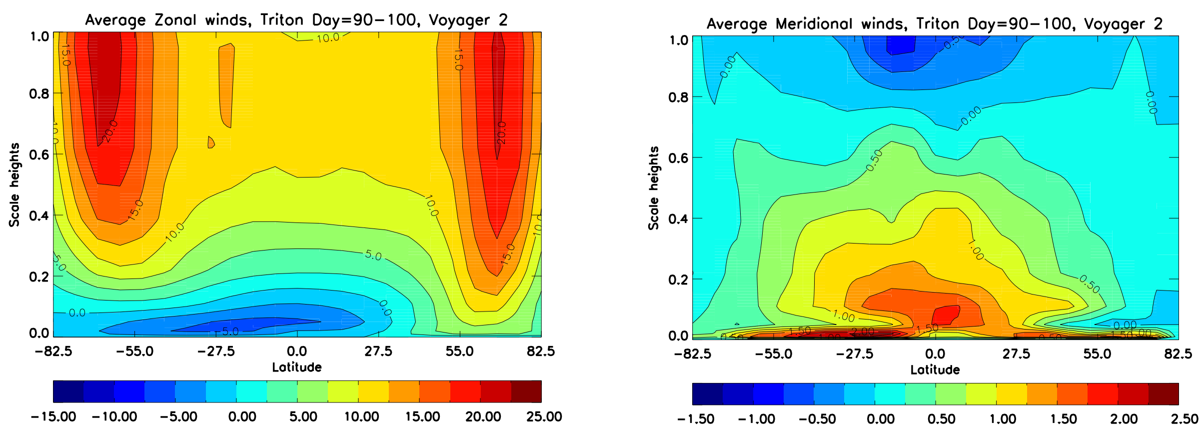

Figure 2: Diurnally averaged zonal (Left panel) and meridional (Right panel) winds at time of the Voyager 2 flyby in August 1989. Wind velocity is in m s^{-1}. Positive values of zonal wind velocity indicate prograde (westward) flow and negative values indicate retrograde (eastward) flow. Positive values of meridional wind velocity indicate south to north flow while negative values indicate north to south flow. One scale height equals approximately 14 km.