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The wind, temperature, and surface pressure on Pluto from a Pluto general circulation model

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Abstract

We use a Pluto general circulation model to predict for the first time the wind on Pluto and its global, large-scale structure, as well as the temperature and surface pressure. We find that Pluto's atmosphere is dynamically active in the zonal (longitudinal) direction with high-speed, high-latitude jets that encircle the poles in gradient wind balance and in the same direction as Pluto's rotation. The meridional (latitudinal) and vertical winds do not show evidence for a Hadley cell (or other large-scale structure), due to the low altitude temperature inversion. The horizontal variation in surface pressure is a small fraction of the global mean surface pressure.

1 Introduction

A variety of methods have been used to derive Pluto's atmospheric temperature, composition, and surface pressure from spectra and stellar occultation data, while wind is less easily determined. Gravity (buoyancy) wave dissipation has been investigated[3] in the 18 March 2007 stellar occultation dataset[5], demonstrating that wind is occurring in the form of perturbations about some mean. Rossby waves have also been proposed[5] as an explanation to the 2007 dataset; however the method was used incorrectly and the result is invalid. General circulation models (GCMs) are a ubiquitous tool in the field of planetary atmospheres to solve for the global state of the atmosphere in a physically consistent manner, but only recently have they began to be developed for Pluto. We use a Pluto version of the Massachusetts Institute of Technology (MIT) GCM to solve for the first time for wind, temperature, and surface pressure globally in Pluto's atmosphere.

2 Method

The Pluto version of the MIT GCM (PGCM) uses the MIT GCM dynamical core[4] with the radiative-conductive scheme of Yelle and Lunine (1989)[6]. It includes vertical thermal conduction and non-local thermodynamic equilibrium heating and cooling by CH_4 at 3.3 μm and 7.6 μm, respectively with a CH_4 volume mixing ratio of 0.6%. A volatile cycle is not included so that we may isolate the effects of radiative-conductive heating and cooling in Pluto's atmosphere. We ran the model from rest with a globally constant surface pressure starting in the year 1973. Here we examine the 12 June 2006 stellar occultation event that was observed at Siding Spring, Australia[2]. Model light curves were calculated from the PGCM temperature output (averaged at 90 day intervals) at the corresponding date and Pluto latitudes (-33° and 53° for immersion and emersion, respectively) of this occultation.

3 Results

The match between data and model is generally good for initial surface pressures around 18 μbar, but the model light curve contains a wave-like feature while the data do not. We do not believe that this feature represents an atmospheric wave; rather, it is numerical noise in the PGCM known to occur in 2D GCMs. The PGCM-predicted zonal (longitudinal) winds are westward everywhere (prograde with Pluto's rotation) and characterized by two high-speed, high-latitude jets in gradient wind balance. Meridional (latitudinal) and vertical winds do not show any large-scale structure in the latitude-height plane such as a Hadley cell or other thermally direct circulation. The lack of Hadley cells is due to the low-altitude temperature inversion (temperature increasing with height). Such a temperature structure is quite stable and inhibits vertical motions. The fractional variation of surface pressure with latitude is much less than the magnitude of the initial surface pressure, suggesting that differences between surface pressure values derived from light curves from different years[**?**] are almost entirely temporal and not a combination of different observing locations and times.

4 Conclusion

Pluto's atmosphere is not quiescent and contains large-scale structure. Our model, the first for Pluto, is easily adaptable to other small bodies of similar composition such as Triton and other large Kuiper Belt Objects. The model can play a critical role for NASA's New Horizons mission, which arrives at Pluto in 2015.

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References

[1] Elliot, J. L., et al., 2003a. The recent expansion of Pluto's atmosphere. Nature 424, 165–168.

[2] Elliot, J. L., et al., 2007. Changes in Pluto's Atmosphere: 1988–2006. Astron. J. 134, 1–13.

[3] Hubbard, W. B., et al., 2009. Buoyancy waves in Pluto's high atmosphere: Implications for stellar occultations. Icarus 204, 284–289.

[4] Marshall, J., Adcroft, A., Hill, C., Perelman, L., Heisey, C., 1997. A finite-volume, incompressible Navier Stokes model for studies of the ocean on parallel computers. J. Geophys. Res. 102, 5753–5766.

[5] Person, M. J., et al., 2008. Waves in Pluto's upper atmosphere. Astron. J. 136, 1510–1518.

[6] Yelle, R. V. Lunine, J. I., 1989. Evidence for a molecule heavier than methane in the atmosphere of Pluto. Nature 339, 288–290.

[7] Zalucha, A., Gulbis, A. A. S., Zhu, X., Strobel, D. F., Elliot, J. L., 2011. An analysis of Pluto occultation light curves using an atmospheric radiative-conductive model. Icarus 211, 804–818.