EPSC Abstracts
Vol. 12, EPSC2018-600, 2018
European Planetary Science Congress 2018

High resolution 3D global climate modelling of Pluto's atmosphere to interpret New Horizons observations

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1. Introduction

In July 2015, our vision of Pluto changed as the New Horizons spacecraft flew by Pluto and revealed an active frozen world, with unprecedented landscapes in the Solar System [1]. Its surface is notably covered with frosts and spectacular glaciers, including a kilometers-thick icecap of nitrogen ice, mixed with methane and CO [1][2]. Surprisingly, this half-heart shaped icecap did not form at the poles and at high elevation, like Antarctica on the Earth. It is located near the equator, at the bottom of a vast basin called Sputnik Planitia. New Horizons also detected methane ice almost everywhere in the northern hemisphere, with different brightness and textures: bright deposits at high latitudes and darker deposits in the equatorial regions [2][3]. The atmosphere of Pluto was also astonishing. New Horizons determined the surface pressure and the atmospheric temperature profile at two opposite locations, including one in Sputnik Planitia [4]. The two profiles were found to differ, which was not expected. Also, by observing Pluto in backlight, a magnificent organic haze was revealed, with a maximal extent at the North Pole [5].

Here we used high resolution simulations performed with the LMD Global Climate Model (GCM) of Pluto's atmosphere to simulate the Pluto climate system in 2015 and interpret New Horizons observations. Below we detail the modeling strategy and the results that we will present at the conference.

2. The LMD Pluto GCM

The Pluto 3D GCM is described in details in [6]. It takes into account the sublimation and condensation cycles of N_2, CH_4, and CO [6], the cloud formation, the atmospheric circulation and turbulence, the radiative transfer, the organic haze formation [7], as well as many other physical processes.

However it simulates the atmosphere of Pluto over only thirty terrestrial years. In order to ensure our simulations, sensitive to our initial conditions and our surface parameters (e.g. albedo, emissivity, thermal inertia), correctly describe reality, we initialize the GCM with a set of subsurface temperatures and ice distribution, which converged toward steady state after millions of years simulated with a fast 2D version of the model [8][9]. This 2D model also enables us to identify "realistic" simulations which differ by their spatial distribution in 2015 but remain consistent with the evolution of the surface pressure [10] and the amount of atmospheric methane observed on Pluto [11].

3. Results

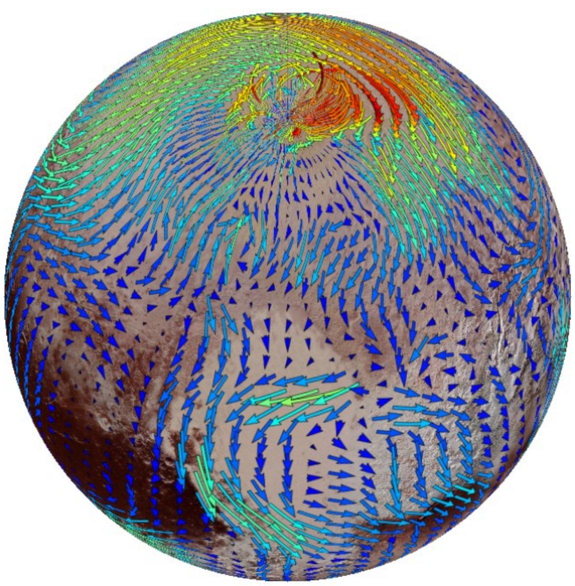
We perform a comprehensive characterization of Pluto's atmosphere in 2015 using these best-case simulations. Wind regimes and near surface winds can be compared to wind streaks and dunes orientation on Pluto, while the simulated waves and thermal structure can be compared to the New Horizons occultations measurements [4].

We discuss the sensitivity of the general circulation to the distribution of the nitrogen ice on the surface. Our latest results suggest that Pluto's atmosphere undergoes a retrograde rotation, a unique circulation regime in the Solar System (except maybe on Triton), induced by the condensation-sublimation of nitrogen in the Sputnik Planitia basin. In Sputnik Planitia, the near-surface winds favor a deposition of haze particles in the northern and western part of the ice cap, which helps to interpret the different colors observed.

The GCM also shows that several atmospheric phenomena are at the origin of the cold boundary layer observed deep in the Sputnik Planitia basin: the sublimation of cold nitrogen, katabatic winds bringing cold air in the basin, and the formation of a western boundary current transporting cold air from the northern to the southern part of Sputnik Planitia (Figure 1). This allows us to understand the near-surface differences observed between the entry and exit temperature profiles, measured by REX on-board New Horizons. However it does not reproduce the differences observed between 6 and 30 km above the mean surface.

Our work confirms that despite a frozen surface and a tenuous atmosphere, Pluto's climate is remarkably active. The nitrogen icecap within Sputnik Plantia is the heart of this climate system since it regulates the general circulation.

Figure 1: Map of the horizontal winds at 1 km above the local surface, obtained from a GCM simulation at the date of July 14, 2015 (the local time at longitude 180° is 2:00pm). At the center of the figure, within the bright half-heart shaped Sputnik Planitia ice sheet, we obtain a western boundary courant crossing the basin from the north to the south. These winds, induced by the sublimation of nitrogen in the northern latitudes of the basin and the Coriolis force, transport cold nitrogen air toward the southern latitudes of the basin.



Acknowledgements

T. B. was supported for this research by an appointment to the National Aeronautics and Space Administration (NASA) Post-doctoral Program at the Ames Research Center administered by Universities Space Research Association (USRA) through a contract with NASA.

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