Climate models of Triton and Pluto

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We have developed two kinds of models: a 3D general circulation model of Triton and Pluto's atmosphere and a 2D model to predict the long-term evolution of the N_2 frost's distribution on these 2 bodies.

3D Model of Triton's atmosphere : The General Circulation Model includes parameterizations of 1) the N_2 condensation and sublimation both in the atmosphere and on the ground, 2) the vertical turbulent mixing and the convection in the planetary boundary layer, 3) the radiative transfer due to methane and carbon monoxide (using the correlated k method), 4) the molecular thermal conduction with a prescribed flux at the top of the model representing heating from the upper atmosphere and 5) a surface and subsurface thermal model with 22 layers. The dynamical core employs a grid point model composed of 32 longitudes, 24 latitudes and 25 layers distributed from the surface to about 45 km. Simulations have been performed assuming several realistic surface frost distributions and compared to the different observations of Voyager 2 : retrograde surface winds, prograde winds at 8 km, temperature profiles. We found that to match these observations, we must assume the presence of a N_2 ice polar cap in the south and an unfrosted equatorial band, assuming a relatively high thermal inertia for the substrate (see below). To properly initialize the surface and subsurface temperature in the unfrosted area we initially perform energy balance calculations for thousands of therrestrial years. In such a case circulation is driven by a combination of condensation flow (driving the surface retrograde winds) and thermal contrast in altitude (allowing the 8 km prograde wind). We also find that radiative heating and cooling in the lower atmosphere plays a negligible role.

3D Model of Pluto's atmosphere : Our Pluto General Circulation Model is based on similar parametrizations than on Triton, except that the prescribed flux at the top of the model is equal to 0 W m^2 and that atmospheric CH_4 and CO have an important effect on the thermal profile of the atmosphere as a results of their higher abundance [5]. The model includes 25 layers distributed from the surface to about 100 km. The model is run for three different periods : 1989, 2002 and 2015. For every date, we vary the emissivity, the surface albedo and the amount of CH_4 and CO in the atmosphere. The initial surface distribution corresponds to a planet with an extended south polar N2 ice cap, a smaller northern polar N_2 ice cap and a dark equatorial band without N_2 ice [4]. For a run corresponding to 1989 with an albedo of 0.6 and an emissivity of 0.7, preliminary results show a themal structure in agreement with the observations : isothermal upper atmosphere with a weak cooling due to CO molecules, a high temperature inversion just below and a surface temperature about 40K at most latitudes. Further results on the dynamic and on the N_2 condensation and sublimation cycle will be presented....

2D Model of the long term evolution of the N_2 frost's distribution on Triton : This 2D model is a simplified and adapted version of the 3D model with atmospheric processes negligible in the surface energy balance removed.The evolution of latitude of the subsolar point is calculated using a new equation of the orbital evolution based on rotationnal elements combined with a relatively complete dynamic solution adapted to Triton [2]. As suggested by [4], the model tends to form a permanent polar N_2 ice cap between about 90° and 60° latitude, with limited seasonal N_2 ice deposits in the opposite hemisphere in winter. With a permanent southern cap, the surface pressure on Triton from 1989 to 2000 increases, in agreement with stellar occultation measurements [1]. We explore the sensitivity of the permanent cap locations to possible hemispherical asymmetry in geothermal flux and topography. .

2D Model of the evolution of the N_2 frost's distribution on Pluto : As for Triton, the 2D model is an adapted version from the 3D Pluto's model. The evolution of the N_2 frost's distribution on Pluto will be compared to observations and results of Triton.

Conclusion : Combining 3D and 2D models allows to constrain and understand the distribution of frost on Triton and Pluto and help prepare the interpretation of New Horizons Pluto flyby.

Refererences :
[1] Elliot et al. Nature, vol. 393, Issue 6687, pp. 765-767, 1998.[2] Forget, F. et al. : A New Model for the Seasonal Evolution of Triton, DPS, 2000 [3] Ingersoll, A. P., Nature, 344:315-317,1990.[4] Spencer and Moore, Icarus, 99:261-272,1992.[5] Strobel et al., Icarus, vol. 120, Issue 2, pp. 266-289, 1996.