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A 3D Global Climate Model of the Pluto atmosphere coupled to a volatile transport model to interpret New Horizons observations, including the N2, CH4 and CO cycles and the formation of organic hazes

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To interpret New Horizons observations and simulate the Pluto climate system, we have developed a Global Climate Model (GCM) of Pluto's atmosphere. In addition to a 3D "dynamical core" which solves the equation of meteorology, the model takes into account the N2 condensation and sublimation and its thermal and dynamical effects, the vertical turbulent mixing, the radiative transfer through methane and carbon monoxide, molecular thermal conduction, and a detailed surface thermal model with different thermal inertia for various timescales (diurnal, seasonal). The GCM also includes a detailed model of the CH4 and CO cycles, taking into account their transport by the atmospheric circulation and turbulence, as well as their condensation and sublimation on the surface and in the atmosphere, possibly forming methane ice clouds. The GCM consistently predicts the 3D methane abundance in the atmosphere, which is used as an input for our radiative transfer calculation.

In a second phase, we also developed a volatile transport model, derived from the GCM, which can be run over thousands of years in order to reach consistent initial states for the GCM runs and better explore the seasonal processes on Pluto. Results obtained with the volatile transport model show that the distribution of N2, CH4 and CO ices primarily depends on the seasonal thermal inertia used for the different ices, and is affected by the assumed topography as well. As observed, it is possible to form a large and permanent nitrogen glacier with CO and CH4 ice deposits in an equatorial basin corresponding to Sputnik Planum, while having a surface pressure evolution consistent with stellar occultations and New Horizons data. In addition, most of the methane ice is sequestered with N2 ice in the basin but seasonal polar caps of CH4 frosts also form explaining the bright polar caps observed with Hubble in the 1980s and in line with New Horizons observations.

Using such balanced combination of surface and subsurface conditions as initial conditions, we run the GCM from 1975 to 2015, so that the model become insensitive to the assumed atmospheric initial states (that are not constrained by the volatile transport model). The simulated thermal structure and waves can be compared to the New Horizons occultations measurements. As observed, the horizontal variability is very limited, for fundamental reasons.

In addition, we have developed a 3D model of the formation of organic hazes within the GCM. It includes the different steps of aerosols formation as understood on Titan: photolysis of CH4 in the upper atmosphere by the Lyman-alpha radiation, production of various gaseous precursor species, conversion into solid particles through chemistry and aggregation processes, and gravitational sedimentation. Significant amount of haze particles are found to be present at all latitudes up to 100 km. However, if N2 ice is already condensing in the polar night, the majority of the haze particles tend to accumulate in the polar night because of the transport of the haze precursors and aerosols by the condensation flow.