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Simulating Titan's atmosphere dynamics with a global 3-D non-hydrostatic circulation model

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Saturn's largest satellite Titan is the only moon in the solar system that possesses a considerable atmosphere with a surface pressure about 1.5 times that of the Earth. Because due to the close distance of Titan to Saturn the satellite is tidally locked and has a synchronous rotation period of barely 16 days implies that the planet belongs like Venus to the group of slowly rotating bodies with a dense atmosphere. Under such conditions, the circulation of the atmosphere is not close to geo-strophic balance like on Earth or on Mars, where pressure gradients are balanced by coriolis forces but by the centrifugal forces of an almost latitudinal circulation. Titan's atmosphere is therefore in a so-called cyclostrophic balance. Titan's atmosphere has been subject to several studies with general circulation models (GCMs) providing results that differ considerable. This may be due to the fact that the temporal evolution of the temperature is mainly governed by advective and diffusive heat transports and the radiative heating term. The latter one is strongly influenced by both the aerosol absorption properties and their spatial distribution, currently under analysis by the Huygens teams. In turn, the aerosol distribution may also be influenced by the atmospheric circulation, which implies a coupled system. The temperature distribution is used in the GCMs to derive the horizontal and vertical wind dynamics. The nowadays widely used Earth GCMs as well as GCMs developed for other planetary atmospheres are mainly based on the hydrostatic equation. As a consequence, the vertical components of the wind

velocity derived from previous GCMs have values in the range of several cm/s. At the same time the observed vertical component of the wind velocity in the Earth's lower thermosphere can get up to values of 10s of m/s. This clearly shows that the existing GCMs have difficulties to correctly describe the behaviour of the vertical atmospheric winds in all regimes, especially under disturbed conditions. We present a new approach to simulate Titan's atmosphere dynamics by using a global three-dimensional circulation model. Our approach differs from previous studies in two major respects: first, our model does not use the hydrostatic equation, i.e., all three components of the neutral gas velocity are obtained from the numerical solution of the Navier-Stokes equation, and second the global temperature field is taken as a prescribed forcing function, which implies that the model does not include the energy equation. Our model provides three-dimensional global distributions of the zonal, meridional, and vertical components of the neutral winds in Titan's atmosphere, which fit well the pre-Huygens observations.