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Is Titan's shape explained by its meteorology and carbon cycle?

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Titan, Saturn's largest satellite, is unique in the Solar System: it is the only satellite bearing a dense atmosphere and it is the only place besides Earth with stable liquid bodies at its surface. In addition complex organics are produced in its atmosphere by the photolysis of methane, the second most abundant atmospheric molecule that irreversibly produces ethane and other more complex carbon bearing molecules. The Cassini/Huygens mission has revealed that the difference between its equatorial and polar radii is several hundred meters larger than that expected from its spin rate, and that it is in hydrostatic equilibrium. Global circulation models predict a large meridional circulation with upwelling at the summer hemisphere and downwelling at the winter pole where ethane can condense and fall at the surface. Lakes and Mare have been observed at the poles only (Stofan et al., Nature, 2007). Ethane has been spectroscopically identified in one of the lakes (Brown et al., Nature, 2008). The present study investigates the subsidence associated with ethane rain at the poles. As suggested by laboratory experiments, ethane flows very easily in a porous crust made of either pure water ice or methane clathrates. Loading of the lithosphere by liquid hydrocarbons induces a tendency of the polar terrains to subside relative to the lower latitudes terrains. In addition, laboratory experiments suggest that ethane substitutes to methane in a methane clathrate crust. The present study estimates the kinetics of this transformation. It suggests that such a transformation would occur on timescales much smaller than geological timescales. To explain a value of 270 m of the subsidence as determined by the radar instrument onboard the Cassini spacecraft (Zebker et al., Science, 2009), our study predicts that the percolation of ethane liquid in the polar crust should have operated during the last 300 – 1,200 Myr. This number is in agreement with the isotopic age of the atmospheric methane and also the age of Titan's surface inferred from impact craters counting (Neish and Lorenz, Planet. Space Sci., 2012). It is also in agreement with the model of Tobie et al. (Nature, 2006) that predicted methane outgassing within this time period. For a nominal value of the subsidence equal to 270-m, the crustal thickness affected by this process is equal to 1 km over the surface area North of the 60th parallel. The substitution of methane and ethane in subsurface clathrates also provides an additional reservoir of methane that needs to be taken into account when modeling the methane cycle on Titan. Finally, the implications for the thermal profile in Titan's crust are being investigated.

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