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Geodetic data support trapping of ethane in Titan's polar crust

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Titan's surface is characterized by polar depressions that strongly influence interpretations of the gravity data. This study investigates several geodynamical models that can explain these depressions. For each model, the values of the three moments of inertia are computed numerically by discretizing the interior in spherical coordinates. The study shows that a Pratt model where the polar subsurface is made of ethane clathrates can explain the polar depression, the abrupt jump in altitude at about 60 degrees latitude, and the values of the degree 2 gravity coefficients. This model, proposed by Choukroun and Sotin [1], is based on the stability of ethane clathrate hydrates relative to methane clathrate hydrates. In addition to fitting the geodetic data, it explains the absence of ethane in Titan's atmosphere although ethane is the main product of the photolysis of methane. Other geophysical models based on latitudinal variations in the tidal heating production or in the heat flux at the base of the icy crust do not provide such a good match to the gravity and topographic observations.

The ethane-clathrate model predicts that all the ethane produced by photolysis of methane at the present rate during the last billion years could be stored in the polar subsurface. It is consistent with the age of Titan's surface and that of Titan's atmospheric methane inferred from geological and geochemical observations by the Cassini/Huygens mission. The present study also emphasizes the role of mass anomalies on the interpretation of the degree 2 gravity coefficients. It shows that for Titan, a slow rotator, the values of the two equatorial moments of inertia (MoI) are largely affected by the polar depressions whereas the value of polar MoI is not. Therefore, as pointed out by previous calculations [2], calculating the moment of inertia (MoI) factor from the value of J2 could lead to major errors. This is not the case for our preferred Titan's model for which the negative polar mass anomalies are compensated at shallow depth by denser ethane-rich clathrates.

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[1] Choukroun M. and Sotin C. (2012) GRL, 39, L04201. [2] Gao and Stevenson (2013) Icarus, 226, 1185–1191.