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The influence of a subsurface ocean on the obliquity of Titan

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The orientation of the rotation axis of Titan is known from radar images of the Cassini Mission (Stiles et al. 2008) and its obliquity has been estimated to be about 0.3°. They also showed that the rotation axis makes a angle of about 0.1° with respect to the plane defined by the normal to the Laplace plane and the normal to the orbit of Titan. Therefore the rotation axis of Titan is assumed to be close to a Cassini state.

In the frame of the Cassini state model for a solid satellite, the estimated obliquity implies a moment of inertia $C \simeq 0.6\,MR^2$, with M and R the mass and radius of Titan, respectively (Bills and Nimmo 2009). However, from the Cassini mission radio tracking, the quadrupole field of Titan has been found to be consistent with the one of a body in hydrostatic equilibrium with a moment of inertia $C \simeq 0.34\,MR^2$ (Iess et al. 2010). Thus, the Cassini state model for a solid Titan cannot account for both the estimated obliquity and moment of inertia. Furthermore, the solid Cassini state do not explain the 0.1° departure of the rotation axis with respect to the plane defined by the normals to the Laplace plane and to the orbit.

We develop a new Cassini state model that includes the gravitational and pressure torques arising between the different layers of Titan if we assume the presence of a subsurface ocean between an ice shell and a solid interior. With this new Cassini state model, the moment of inertia and obliquity can be consistent, suggesting that Titan has a subsurface ocean. Nevertheless, the departure of 0.1° from the coplanarity is not explained, indicating that our new model is a first step towards a more realistic model of the rotation axis orientation of an icy satellite with an ocean.