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Constraints on Titan's crustal structure inferred from the joint analysis of Cassini gravity and topographic data

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Titan's shape has been measured by radar altimetry, synthetic-aperture radar topography and stereo radargrammetry during the Cassini mission. All these data have recently been published [1]. We have processed this data set which provides a unique but incomplete coverage of Titan's surface. The shape data are transformed into topographic data by using a reference ellipsoid defined by the degree 2 gravity coefficients [2]. The difference between the topography using the reference ellipsoid and the topography relative to an equipotential defined with the higher degree gravity field [3] is equal to 25 m at max, which is less than the uncertainty on the measurements. Titan's long wavelength topography is characterized by polar depressions and elevated equatorial regions that strongly influence interpretations of the gravity data. Several geodynamic models can explain these topographic features: variations of the crustal thickness related to the amount of tidal dissipation inside the crust [4], latitudinal variations of the heat flux at the crust/ocean interface [5], or lateral density variations between the poles and the equatorial regions [6]. The models are explored with different degrees of compensation to investigate the effect of topographic anomalies on the values of the degree 2 gravity coefficients determined from Cassini spacecraft orbit. For each model, the three moments of inertia are computed numerically by discretizing Titan's interior in spherical coordinates and then the degree 2 gravity coefficients are deduced.

Whereas the value of J2 strongly depends on the degree of compensation of the polar depressions as already reported [7], the value of C2,2 does not because the equatorial topography does not have a strong order 2. Different fits to the equatorial topography have been tested since the data set shows strong short wavelengths variations that cannot be reproduced by spherical harmonic decomposition. Determining the moment of inertia from the value of C2,2 is therefore appropriate. The simplest model is a fully compensated Pratt model for the polar depressions and fully compensated Airy model for the equatorial topography. However, if the equatorial topography is caused by exogenic processes (erosion) and the crust is strong enough to prevent compensation, then the degree 2 gravity coefficients can be explained by a 80% compensation Pratt model (or 75% compensation Airy model) for the polar depressions. Although non-unique, the crustal model is bounded by the values of the gravity coefficients and topographic data provided by the Cassini mission.

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