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Shape, Topography, Gravity Anomalies and Tidal Deformation of Titan

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Abstract

Gravity measurements and elevation data from the Cassini mission have been used to create shape, global topography and gravity anomaly models of Titan. We provide constraints on the averaged ice shell thickness and its long-wavelength lateral variations, as well as the density of the subsurface ocean using gravity anomalies, the tidal Love number, k_2, measurement and long-wavelength topography.

1. Introduction

The gravity field of Titan is determined with a spherical harmonic expansion to degree three [1,2] whereas the abundance of altimetry and SAR-Topography data have allowed the estimation of Titan's shape up to degree 7 [3]. The measured tidal Love number, k_2, of Titan indicates that the outer ice I shell is decoupled from the deep interior by a global subsurface ocean [2]. We produced shape, topography and gravity anomaly models of Titan to constrain the outer ice shell structure and subsurface ocean density. We modelled the tidal deformation of Titan to constrain the density of the subsurface ocean.

2. Results

We determined the best-fit to Titan's shape calculating the spherical harmonic expansion to the sixth order using surface elevations derived from Cassini RADAR altimetry and SAR-Topography data products (acquired through June 2011). Then we determined Titan's topography defined as the elevation with respect to a reference ellipsoid, inferred from the quadrupole moments (J_2 and C_{22}) of the measured gravity field (Iess et al., 2012). Figure 1 shows the topography of Titan determined through both the third (upper panel) and sixth order (lower panel) of the shape. The topography varies between -500 to +600 m with respect to the ellipsoid. Distinct topographic features on Titan's surface include (1) the Xanadu region (10°S, 120°W), which has a maximum topographic elevation of ~300 m, and (2) both polar regions, which present distinctly depressed elevations relative to Titan's geoid. With respect to the geoid, Titan's South Polar Region is ~400 m lower than the North Polar Regions, despite the North Polar Regions containing the majority of exposed surface liquid.

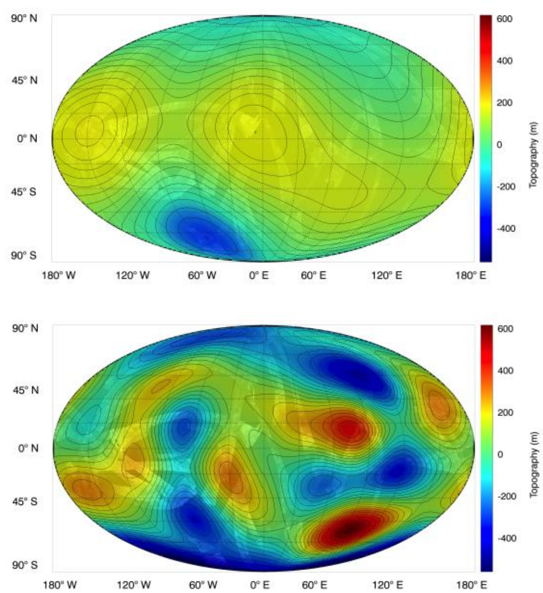

Figure 1: Topography of Titan determined through third order of the shape (upper panel), and through sixth order of the shape (lower panel). The topography is overlain by a gradient image derived from Cassini's RADAR.

We determined both free air and Bouguer gravity anomalies. Figure 2 shows the map of the Bouguer anomalies determined through the third order of the topography and third order of the gravity field. The free air anomalies determined at the degree three are weak, ranging between -3 to +3 mGal. Negative as well as positive Bouguer anomaly features determined to degree three are observed on Titan ranging between -10 mGal to +10 mGal (Fig. 2).

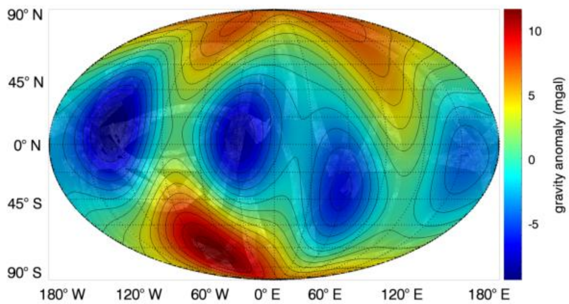

Figure 2: Bouguer gravity anomalies of Titan determined through the third order of the shape and third order of the gravity field.

The surface topography (Fig. 1) and the Bouguer anomalies (Fig. 2) determined to degree three present an approximate inverse correlation. The approximate inverse correlation between the Bouguer anomalies and the surface topography together with the presence of weak free air anomalies indicates that the outer ice I shell approximates isostatic compensation, and that the gravity anomalies are likely produced by variations of the ice shell thickness implying the presence of subsurface topographic features under the ice shell. The weak free air anomalies could be produced by local non-hydrostatic compensation of the outer ice shell as well as by the deeper interior.

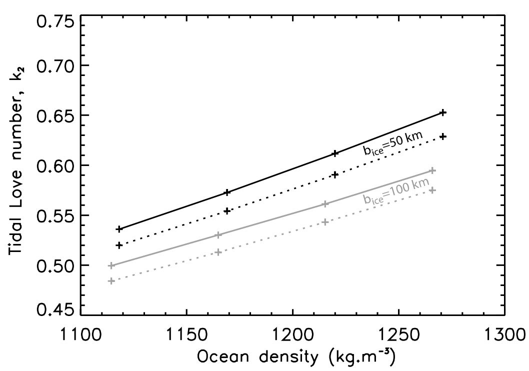

Figure 3: Tidal Love number as a function of averaged ocean density: comparison between constant density layer (dotted lines) and depth-varying density profile (solid lines) for ice shell thickness of 50 (black) and 100 km (grey).

Because the short time scale of lateral ice flows at the base of the ice shell tends to level each local ice shell thickness variation [e.g. 4], local variations of the ice shell thickness are expected only if the ice is stiff and has a high value of viscosity, implying that the ice shell is likely in a conductive state or at most in a subcritical convective state.

We compute the tidal response of Titan's interior and determine the tidal Love number (see [5] for the adopted method), assuming a viscoelastic compressible interior. For the viscoelastic deformation of the solid layers, we assume a compressible Andrade model. Figure 3 presents how the computed Love number evolves as a function of ocean density. The large measured value of the tidal Love number (k_2=0.589±0.150; Iess et al., 2012) indicates the presence of a relatively dense ocean. The large uncertainties on k_2 preclude any firm conclusion about the ocean density for the moment. However, if the nominal value of 0.6 is confirmed by future measurements, this will clearly indicate that Titan possesses an ocean with an average density of at least 1200 kg m^{-3} and that the ice shell thickness exceeds 50 km.

3. Conclusions

Titan's surface topography is consistent with an approximate isostatically compensated ice shell of variable thickness, likely in a thermally conductive or subcritical convective state, overlying a relatively dense subsurface ocean.

References

[1] Iess, L. et al.: The Tides of Titan. Science 337, 457, 2010.

[2] Iess, L. et al.: Gravity Field, Shape, and Moment of Inertia of Titan. Science 327, 1367, 2012.

[3] Zebker, H. A. et al.: Size and Shape of Saturn's Moon Titan, Science, 324, 921-923, 2009.

[4] Lefevre, A., Tobie, G., Choblet, G., and Čadek, O.: Structure and dynamics of Titan's outer icy shell constrained from Cassini data, Icarus, doi.org/10.1016/j.icarus.2014.04.006, 2014.

[5] Tobie, G., Mocquet, A., and Sotin, C.: Tidal dissipation within large icy satellites: Applications to Europa and Titan. Icarus 177, 534-549, 2005.