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Exploring Venus internal structure and its tidal response.

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Abstract

The closest planet to ours is the terrestrial planet Venus, it has a size and average density only slightly smaller (by approximately 5%) than those of Earth which indicates a similarity in the internal structure of both planets. However, the lack of self-sustained internal magnetic field in Venus points to a difference in the core structure. First by assessing already well known and demonstrated facts about the interior structure of Venus, we build an internal model of this terrestrial planet based on its similarities with Earth. Then we use this model to theoretically calculate the value of its tidal Love number of degree 2, k2, by alternating different parameters in the model. Finally we conclude the impact of different aspects of the interior planet in question on its tidal response, as the rigidity and thickness of its lithosphere.

1. Introduction

The latest gravity field of Venus is based on the Doppler tracking data of Magellan (MGN) and Pioneer Venus Orbiter (PVO) and is denoted by MGNP180U, which was modeled by Konopliv et al. in 1999 [6]. We conclude from the gravity field of MGNP180U that Venus in far from the hydrostatic equilibrium. Assuming that the planet is hydrostatic equilibrium as a starting point is essential for the computation of an internal model of Venus. We assume that Venus is spherically symmetrical and that each major layer - core, lower mantle, upper mantle and crust - are homogeneous (for further use) and we calculate the bulk modulus K, rigidity μ of each layer.

TABOO is an Earth postglacial rebound calculator, one of its tasks is to calculate the tidal/load Love numbers assuming that each layer is homogeneous. It can also be used for any other terrestrial body. After fixing an internal model of Venus we use TABOO to calculate its tidal Love number of degree 2 for different Venus internal parameters. It can be accessed online by *https://github.com/danielemelini/TABOO/releases.*

2. Internal structure

1.1 Hydrostatic equilibrium

As declared before, we assume that Venus is in a state of hydrostatic equilibrium. Hence by assuming that the pressure at its surface is zero, we obtain the following relation between the radial density ρ(r) and gravity acceleration g such as:

$$P(r) = \int_r^a g(\tilde{r})\rho(\tilde{r})d\tilde{r}. \quad (1)$$

In what follows we will use the Preliminary reference Earth model (PREM), from Dziewonski, A. M. and Anderson of 1981 [2], which gives the essential parameters for Earth structure as density, layers thicknesses and elastic parameters.

1.2 Internal density

The planet's core thickness and density are not yet well known, nonetheless its crust's thickness and density were estimated respectively by James et al. in 2010 [5] and Fegley in 2004 [3]. The mantle's density can be approximated by assuming its mantle structure is similar of that to Earth (PREM). Finally the core's density can be calculated based on our knowledge of its structure (iron fluid core). This Venusian density profile is based on Aitta 2002 [1] model of Venus.

Venus internal structure Layers radius, thickness and mean density				
Layers	Core	Lower mantle	Upper mantle	Crust
r (km)	3228	5332	6022	6052
$\bar{\rho}$ (g/cm^3)	9.80	4.85	3.76	2.90

Table: Mean density (in g/cm3) and layers' boundary radius (in km) for four major Venusian layers

1.3 Elastic parameters

The Earth core and mantle is assumed to have a linear relation between their radial Pressure P(r) and bulk modulus K(r). This relation was first estimated by Bullen in 1975, it is also called the equation of state. We estimate a new equation of state based on the Earth PREM model. We assume that both planets Earth and Venus obey the same rule, hence after calculating the pressure P(r) for both planets using equation (1), we then estimate the bulk modulus K for each of both planets. the rigidity of Earth is given by the PREM model, hence we calculate the Earth mean Poisson ratio for each of its major layer. Assuming that Earth and Venus have both the same Poisson ratio in each layer, we then calculate Venus mean rigidity for each mantle layer (lower and upper mantle).

3. Discussions

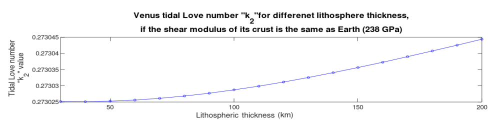

Figure1: Venus tidal Love number k2 considering a Venus crustal rigidity value as Earth (238 GPa) - for different lithosphere thickness (km).

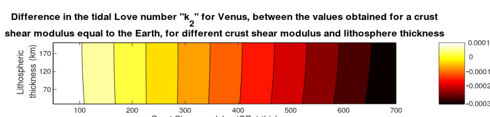

Figure2: colormap representing the variation of the elastic k2 values between the above results in Figure 1 for different crust rigidity values - also for different lithosphere thickness.

The tidal Love number values are bounded in [0.272702; 0.273185] for different lithospheric thickness and crust rigidity. For further exploration, EnVision is a European Space Agency (ESA) mission proposal that will achieve an observation of the k2 tidal Love number to a precision of +/- 0.002 after three years of observation. Hence we compare our results of the theoretically estimated tidal k2 to the pecision of the EnVision mission, for more on EnVision see [2].

4. Summary and Conclusions

By changing the lithospheric thickness and rigidity μ, the boundary values of k2 are smaller than the achievable precision of the EnVision mission orbiter after 3 years of observations. The lithospheric thickness does not have an effective impact on the value of the tidal Love number k2.

Theoretical calculation of tidal Love number k2 of Venus was done by Xia and Xiao in 2000 [7]. The authors used a radially heterogeneous and compressible model and computed a final value of k2 = 0.26182. The value of the tidal k2 for an incompressible model of Venus such as the one computed by Xia and Xiao is very close to the one obtained by using a compressible model.

Acknowledgements

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