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A tool for the seismological evaluation of interior structure models of terrestrial planets

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1. Introduction

Knowledge about the internal structure and bulk composition of planetary bodies is important to understand the origin and evolution of the solar system and the Earth. Interior structure models of planetary bodies rely mainly on the average compressed density and the axial moment of inertia [4]. They aim at calculating depth variations of pressure, temperature, density, and composition.

Seismological observations allow the determination of the interior structure of terrestrial planets. Extensive measurements, however, have been conducted only on the Earth and, to a much lesser extent, the Moon, Mars, and Venus [3].

In this study, we present a tool for the seismological evaluation of interior structure models that allows investigating the effects of various interior structure models on critical seismological observables. Such observables are, for example, the epicentral distances at which phases emerge that can be used to determine e.g. crustal thickness or core radius (Pn, PcP, PKP), and travel time curves in general.

2. Method

Interior structure models exist in different complexities. For the case of two- and three-layer structural models, we assume no density variations in each chemically homogeneous layer. To calculate the depth-dependent velocity profile, we apply the Birch law [1] (3) and the Poisson ratio υ (4):

$$v_P = a + b\rho \qquad (3)$$

$$v_S^2 = v_P^2 (1-2\upsilon)/(2-2\upsilon) \qquad (4)$$

with empirical parameters a, b and υ.

For the case of more complex models [e.g., 6], the local distribution of density ρ and elastic moduli K and μ are obtained directly from an equation of state (EoS), which relates pressure, temperature, and density of a given material in thermal equilibrium. The two EoS used, Vinet-Rydberg and reciprocal-*K'*, have both proven to be superior to others for the application from Moon-sized planetary bodies to super-Earths (1-10 $M_\oplus$) [e.g., 5, 7]. Constraints for our interior structure models are planetary radius, total mass, and moment of inertia.

For our studies, it is important to obtain the variation of seismic velocities with depth. Velocities of longitudinal (P) and transverse (S) elastic waves are related to bulk modulus K, shear modulus μ, and density ρ as follows:

$$v_P = \sqrt{(K + 4\mu/3)/\rho} \qquad (1)$$

$$v_S = \sqrt{\mu/\rho} \qquad (2)$$

Ray paths and travel times are computed using the MATLAB toolbox TTBOX [2].

3. Summary

By combining interior structure models with the seismic program TTBox, we can relate the radial distribution of density within terrestrial planets composed of various bulk compositions to radial velocity profiles, ray paths, and travel time curves for seismic waves. Future missions to other planetary bodies in our solar system (e.g., International Lunar Network (ILN) [8]) would benefit from simulations of seismic ray paths, critical distances, and travel time curves as they help planning a seismological network or predict and interpret future measurements.

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