Constraining the water content at the top of the mantle transition zone with the elasticity of wadsleyite and olivine

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The water content in the mantle transition zone (MTZ) exerts a controlling influence on the dynamical and chemical evolution of Earth, but is poorly known. In principle the water content at the top of the transition zone can be inferred by comparing the velocity and density contrasts across the 410-km seismic discontinuity with predictions based on the phase transition of olivine to wadsleyite. The high-quality elastic data of at pressure and temperature (PT) conditions of the transition zone are crucial but are very challenge for experiments to obtain. Calculating these elastic data at high PT conditions in conventional method are also very expensive. Instead, these elastic data were calculated using the method of Wu and Wentzcovitch (2011), which reduces the computational workload to tenth of the conventional method. All calculations for two phases were conducted using the same computational details as far as possible, which guarantees that the velocity and density differences between two phases have very high precise. All these calculated elastic data agree well with the available experimental data. The iron and water effect on the elasticity are also well described.

With these high-quality elastic data covered the PT condition of the transition zone, we analyze the water and wadsleyite content at the top of the transition zone. We found that the water content of wadsleyite at the top of the transition zone can be well constrained when density and velocities jumps are considered together. For a pyrolitic mantle composition with ~60% olivine, our best fit is ~ 0.5 wt% water at the top of the transition zone. If the transition zone is dry, as suggested by some electrical conductivity models, the upper mantle may only contain ~ 50% olivine.

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