Water storage capacity of Earth's mantle and its temporal evolution

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Hydroxyl point defects can be incorporated into mantle silicates, potentially constituting the Earth's largest water reservoir [1]. Converting the water storage capacity of minerals on the atomic scale to the water budget of the Earth's interior, however, remains a grand challenge. Here, we present a numerical model for the water storage capacity of a pyrolitic mantle under water-saturated conditions. Pressure (*P*) and temperature (*T*) dependence of water storage capacity are quantified for olivine, pyroxene, garnet and their high-pressure polymorphs combining experimental data in the literature with thermodynamic models of water solubility and partitioning that are exponential functions of *P* and *T* [2]. These storage capacities are integrated through the phase assemblages at the relevant *P*-*T* conditions along a series of adiabats computed using the HeFESTo code [3]. We estimate that the total water storage capacity of the Earth's mantle is 1.43 ocean masses (OM) at present day with a mantle potential temperature T_p = 1600 K. 0.16 OM are present in the upper mantle, 0.80 OM in the transition zone, and $0.47^{+1.2}_{-0.47}$ OM in the lower mantle. Based on the strong *T* dependence of water storage capacities, our results put a tigher constaint on the water content of the present-day mantle (1-2 OM) compared with previous estimates (few to tens of oceans) [4]. The water in the transition zone is estimated to be less than 0.3 wt.% for the current average mantle temperature and less than 0.1 wt% for a hotter mantle, which fits into the geophysical observations from electromagnetic induction [5]. The total storage capacity was 0.55 OM for an Archean mantle with T_p = 1900 K. A much smaller water storage capacity is expected for the Archean mantle, which has a profound influence on water exchange between surface and interior throughout the evolution of the planet.

[1] Pearson et al. (2014), *Nature* 507(7491), 221. [2] Keppler & Bolfan-Casanova (2006), *RMG,* 62(1), 193-230. [3] Stixrude & Lithgow-Bertelloni (2011), *GJI,* 184(3), 1180-1213. [4] Hirschmann et al. (2005), *EPSL*, 236(1-2), 167-181. [5] Kelbert et al. (2009), *Nature*, 460(7258), 1003.