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Water, viscosity and convection modelling: the effects of weakening and heterogeneity

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There is evidence for heterogeneity of water within the mantle. Studies indicate that the upper mantle may hold up to 200ppm (Hirschmann & Kohlstedt, 2012) whilst others suggest that the transition zone may be hydrous holding ∼1wt% water (Panero et al., 2015), at least locally. It is important to understand this heterogeneity since water is thought to be the volatile with the largest impact on viscosity (Fei et al., 2013). With the possibility of reducing viscosity by several orders of magnitude, water may have a considerable effect on the convective regime but how the heterogeneity of water in the mantle would affect this and it's mixing efficiency is unclear. In particular, viscosity laws used in mantle convection models often result in viscosities that increase dramatically as water decreases resulting in unrealistic viscosities.
We test various viscosity laws in a thermally evolving convection model, StagYY (Tackley, 2008; Nakagawa et al., 2015). The laws vary between two and four orders of magnitude for ∼1000ppm, similar to the rheological effects seen on olivine at relatively low pressures and temperatures. We also use this model to further investigate the effects of heterogeneously distributed water within the mantle to understand what effect this may have on the mantle's long term thermal evolution and water cycle.

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