

Constraining the global water budget: Understanding the deep water cycle using 3D mantle convection models

M. G. Price, J. H. Davies, J. Panton

Although the presence of water within the mantle is well-known, there are many aspects of its presence that are poorly constrained. For instance, whilst it is understood that water can alter the viscosity, density and melting temperature of mantle material; to what degree, and its impact on the whole mantle convection system is still open to study. Previously, work has investigated these processes through one and two-dimensional models.

Here we present results investigating the water cycle using the 3D mantle convection code TERRA, which has previously been adapted to track compositional variations which are generated at self-consistent, evolving melting zones. These melting zones allow our models to form a basaltic oceanic crust which can be cycled through the mantle. We have now further improved TERRA to include water within the convecting mantle flow via particles and an exterior surface 'ocean' reservoir. To accurately capture the water cycle, water within our model is able to migrate via three processes: through dehydration calculated from solubility maps for given temperature, depth and composition; by rehydration at melt ridges from the ocean reservoir and; in melting where water can be partitioned into the melt. Furthermore, we can utilise plate reconstructions as a boundary condition to arrange the convecting mantle structure into a recognisable degree two structure in the lower mantle, with Earth-like subduction and spreading regions at the surface.

By varying factors such as the density, viscosity and maximum water content through the mantle, alongside the total water mass, we perform a parameter search on the deep water cycle in mantle convection. With this we attempt to constrain the total water budget with the observational constraints in Earth Science and generate discussion on how to quantify the influence of water on mantle dynamics.