Modelling the global water cycle – the effect of Mg-sursassite and phase A on deep slab dehydration and the global subduction zone water budget

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Numerous geological, petrological, and geophysical processes depend on the abundance, distribution, and transport of water between the Earth's surface and its interior. Especially important is the role of the hydrated lithospheric mantle in cold subduction zones, where the amount of water transported into the deeper mantle is determined by the stability of the hydrous phases. Stability of these hydrous phases is controlled by the chemical composition, initial hydration intensity and thermal structure of the subducting slab, as well as the thermodynamic properties of the hydrous phases in the subducting slab.

To investigate the global water transport in subduction zones, we implement different published thermodynamic data for the two dense hydrous magnesium silicates (DHMS) Phase A [$Mg_7Si_2O_8(OH)_6$] and Mg-sursassite [$Mg_5Al_5Si_6O_{21}(OH)_7$] in a global set of 56 subduction zone thermal patterns (Syracuse et al., 2010) in a gridded two-dimensional thermodynamic forward model, taking into account the migration of fluids within the slab. The model is based on a combination of MATLAB and Perple_X, which uses Gibbs energy minimisation to calculate amounts of stable phases and coexisting fluid. This provides a tool to quantify and compare the effects of different thermodynamic databases, thermal and geometric patterns of subduction zones, and chemical compositions on the water budget in the subducting slab.

Our results show that, beyond the breakdown of Lawsonite, mafic and sedimentary rocks play a minor role for the globally subducted water budget. The absolute amount of deeply subducted water in subducted ultramafic rocks as well as the different dehydration patterns and the migration of fluids within the plate strongly depends on the intensity and depth of the initial slab mantle hydration and the Clapeyron slopes of the dehydration reactions of phase-A and Mg-sursassite. The global amount of deeply subducted water for different investigated models varies between 8×10^8 Tg/Ma and 1.4×10^9 Tg/Ma. In subduction zones with an intermediate temperature structure, the differences span several orders of magnitude. Depending on the choice of the thermodynamic data set the globally subducted water modelled with a 2 wt.% H_2O hydrated 12 km slab mantle is equal to subduction of the entire Earth's surface water in 1 to 1.7 billion years.

References

Syracuse, E.M., van Keken, P.E. & Abers, G.A., 2010: The global range of subduction zone thermal models. *Physics of the Earth and Planetary Interiors*, 183(1-2), pp.73-90.