Three-dimensional mantle convection and material cycling with continental dispersal and coalescence

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The Earth is unique among the solar terrestrial planets, having the continents and the abundant liquid water on its surface. In this study, we have developed a three-dimensional mantle convection model that incorporates these two features into the numerical program, and investigate how the flow-temperature field and water distribution occur under the circumstances of continental dispersal and coalescence. In this numerical simulation of 3-D spherical mantle convection, supercontinent is introduced in the model set up in order to study how continental dispersal and coalescence happens and affect the structures of the interior. In addition, water is also introduced, considering water solubility of mantle rocks. The results show that water is transported to broader regions effectively once continental dispersal occurred, due to enhanced flow velocity associated with increased horizontal temperature gradient partly with the blanketing effect beneath the supercontinent. This process distributes the water in a spatially wide region as a “migrating entrance” of water into the mantle. Once the water subducts with the cold down-going flow and reaches CMB (core mantle boundary), then it horizontally spreads to be heated up. In some case, dehydration of Phase H may occur to generate a fluid that migrates upward and hydrate the overlying mantle, which occurs near the boundary between the cold continental domain and the warmer oceanic domain, yet within the hydrated cold domain beneath the (super)continent region. This mechanism, together with the near-surface process described above, may create a hydrous domain beneath the continental region where a rather uniform hydration may prevail. Therefore, the effective redistribution with a global scale structure can be created simultaneously. Such a mechanism could be important to account for the observed geochemical mantle hemispheres.

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