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Influence of lateral viscosity variations on mantle dynamics and thermal evolution of terrestrial planets

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To model the mantle dynamics and in particular the thermal evolution of terrestrial planets with convection models often lateral viscosity variations are neglected for simplicity. Instead of calculating the viscosity in every grid node, mean temperature values per shell are used to define the viscosity. This simplification, however, leads to different results, as is shown here with 2D and 3D spherical mantle convection simulations. Comparison of the viscosity law disregarding lateral viscosity variations with the more accurate viscosity law respecting radial as well as lateral viscosity variations shows that the simplification results in a convection structure with a slightly larger number of plumes and more important the plume heads become less mushroom-like. As a consequence, larger undulations of the lid thickness can be expected in the case of lateral viscosity variations. Furthermore, the Nusselt numbers of the upper and lower boundary are lower when using the accurate viscosity calculation. Hence neglecting lateral viscosity contrasts may distort the results of thermal evolution models and should be considered with some caution.