Geophysical Research Abstracts
Vol. 15, EGU2013-7752, 2013
EGU General Assembly 2013

Plate tectonics on large exoplanets and the importance of the initial conditions

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Several numerical studies have been published in the past years speculating about the existence of plate tectonics on large exoplanets. These studies focus on various aspects like the mass of a planet [1,2,3,5], the interior heating rate and mantle temperatures [4,5] and the occurrence of water in the upper mantle [6]. Different trends in the propensity for plate tectonics have been observed in particular when varying the planetary mass: with increasing mass the surface mobilization is found to be either more [2,3,5], equally [3,6] or less [1,4] likely than on Earth. These studies and their implications are, however, difficult to compare as they assume different initial conditions and parameter sets, and either neglect the pressure effect on the viscosity or assume a rather small influence of the pressure on the rheology. Furthermore, the thermal evolution of the planets (i.e. cooling of core and decrease in radioactive heat sources with time) is typically neglected.

In our study, we us the finite volume code GAIA [7] and apply a pseudo-plastic rheology. We investigate how a strong pressure-dependence of the viscosity [8] influences not only the convective regime in the lower mantle, but also the upper mantle and hence the likelihood to obtain plate tectonics. We investigate how our results change when assuming different initial conditions, focussing on the initial temperature in the lower mantle and at the core-mantle boundary.

We find that the initial temperature conditions have a first-order influence on the likelihood of plate tectonics on large exoplanets and (as observed in earlier studies) surface mobilization may either be more, equally or less likely than on Earth.

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