

Scaling of convection and plate tectonics in Super-Earths

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The discovery of three Super-Earths around different stars, possible only in the last year, prompts us to study the characteristics of our planet within a general context. The Earth, being the most massive terrestrial object in the solar system is the only planet that exhibits plate tectonics. We think this might not be a coincidence and explore the role that mass plays in determining the mode of convection.

We use the scaling of convective vigor with Rayleigh number commonly used in parameterized convection. We study how the parameters controlling convection: Rayleigh number (Ra), boundary layer thickness (δ), internal temperature (T_i) and convective velocities (u) scale with mass. This is possible from the scaling of heat flux, mantle density, size and gravity with mass which we reported in Valencia, et. al 2006. The extrapolation to massive rocky planets is done from our knowledge of the Earth. Even though uncertainties arise from extrapolation and assumptions are needed we consider this simple scaling to be a first adequate step.

As the mass of a planet increases, Ra increases, yielding a decrease in δ and an increase in u , while T_i increases very slightly. This is true for an isoviscous case and more accentuated in a temperature dependent viscosity scenario. In a planet with vigorous convection (high u), a thin lithosphere (low δ) is easier to subduct and hence, initiate plate tectonics. The lithosphere also has to be dense enough (cold and thick) to have the bouyancy necessary for subduction. We calculate that a convective cycle for an isoviscous planet is $\tau \sim M^{-0.3}$ considering whole mantle convection. Meaning that if these planets have continents, the timescale for continental rearrangement is shorter (about half the Earth's for a 5 earth-mass planet).

Additionally, we explore the negative feedback cycle between convection and temperature dependent viscosity and estimate a timescale for this effect.