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Interactions between D" and mantle convection – the role of radiogenic heating in D"

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The main region of our interest, the lowermost mantle and the core-mantle boundary, is the interface between the geodynamo-controlling outer core and convecting mantle. The heat flow through this layer is crucial to the Earth's dynamics and it may result in certain behavior relevant to the whole planet, like switching off the geodynamo in case of too low heat flow or considerable growth of the inner core in the opposite case. The region itself is very complex and diverse: recent tomographic models revealed large-scale structures of lower than average S-wave velocities beneath Africa and Pacific at around 2800 km depth (Large Low Shear Velocity Provinces), which are believed to be caused either by thermal or chemical heterogeneities, or most probably by both. The edges of these regions are correlated with rising of stable mantle plumes. Geodynamic modeling of this area is not fully resolved since viscosity may vary here up to several orders of magnitude. Moreover, we must face phase transitions present in these p-T conditions, the most important one being the perowskite-postperowskite transition discovered in 2004.

We assume that LLSVPs correspond rather to chemical heterogeneities, so in simulations we consider dense material which is floating on the core-mantle boundary, forming chemically distinct bodies of sharp edges. The main goals of our project are to estimate the density difference for which mantle plumes rising from these edges remain stable and to check the radiogenic heat production ratio between the upper crust and the lowermost mantle. We use 2D numerical model based on the following equations:

$$\rho(T, Z_a, Z_b) = \rho_0 - \alpha\rho_0 T - \gamma_a Z_a + \gamma_b Z_b \tag{1}$$

$$\frac{DT}{Dt} = \nabla^2 T + f(Z_a, Z_b) \tag{2}$$

$$f(Z_a Z_b) = (1 - Z_a - Z_b)Q_m + Z_a Q_a + Z_b Q_b \tag{3}$$

$$\nabla^2(\eta\nabla^2 S) = R_T\frac{\partial T}{\partial t} + R_{Z_a}\frac{\partial Z_a}{\partial x} + R_{Z_b}\frac{\partial Z_b}{\partial x} \tag{4}$$

$$\frac{DZ_{(a,b)}}{Dt} = C_{(a,b)}[\frac{\partial^2}{\partial x^2} + \frac{\partial}{\partial y}(\frac{\partial}{\partial y} - B_{(a,b)})]Z_{(a,b)} \tag{5}$$

where $\frac{D}{Dt}$ denotes substantial derivative, η is viscosity, R_T corresponds to Rayleigh number in the case of internal heating and $R_{Z_a}, R_{Z_b}, C_{(a,b)}$ and $B_{(a,b)}$ are non-dimensional parameters characterizing gravitational differentiation. We use two different fractions of material: the crust, referred as Z_a, and c-continents, referred as Z_b. Assuming whole-mantle convection and given initial density distribution and initial temperature, we calculate temperature T, stream function S and distribution of both fractions. The function f in the temperature equation (2) describes radioactive heat production in each of the fractions considered (3), where Q_m and Q_a denote the concentration of heat sources in the mantle and in the crust respectively. The concentration of radiogenic heat sources in c-continental matter, Q_b, is virtually unknown.

The limit of density contrast for which mantle plumes are stable is estimated to be around 2%. We want to determine if this limit is similar in the case of no phase transitions and whole-mantle convection. Estimating probable ratio between heat production in the crust and in the dense material on the core-mantle boundary may help answering the question of the origin of this material – whether it is more likely to be generated from primeval residual melt or from delamination of subducted slabs.