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Effect of disintegration of chemical layering on time-dependent behavior of the mantle

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Numerical simulation has been carried out in order to investigate the fate of the chemically dense D" zone and the effect of the disintegration, mixing and homogenization process on the time-dependent parameters characterizing the convection in the Earth's mantle. Two-dimensional cylindrical shell geometry was applied including the dense D" zone with a thickness of 300 km. The single varied parameter during the calculations was the density different between the D" zone and the overlaying mantle (β), the value of the thermal Rayleigh number was fixed at 10^7. Simulation was started from a quasi stationary state of the temperature distribution and the stabilizing effect of the dense D" layer was monitored by time-dependent parameters such as the heat flux on the surface, at the CMB and the top of D" layer; the rms velocity, the temperature and the concentration of the dense material in different zones of the mantle, as well as the concentration flux and the heterogeneity of the dense material.

It is expected that the formation process of the dense D" layer (e.g. doming, disintegration, mixing, homogenization) is hindered by the increase in density difference β. The buoyancy parameter (B) characterizes the impedimental influence as the ratio of the stabilizing density contrast and the destabilizing thermal density contrast. Based on our numerical results the disintegration of the D" layer can be deduced from three main reasons: (1) heat coming from the core warms up the dense layer reducing its density by thermal expansion, (2) the thermal convection evolving in the overlaying layer erodes the surface of the dense layer (Fig. 1); and (3) the thermal convection forming in the D" layer intermixes the light material from the overlaying zone (Fig. 1). The first phenomenon increases the thermal buoyancy force (denominator of B), the latter two phenomena decrease the chemical density contrast between the two zones of the mantle (numerator of B). While the process (1) is restricted by the total temperature drop through the mantle, the latter two are not. Thus the pollution of the overlaying zone by dense material as well as the dilution of the D" layer will induce a one-layer thermo-chemical convection that is the ceasing of the dense layer around the Earth's core. Nevertheless, in the cases of B>1 (β >2%) the time needed for the disintegration might exceed the age of the Earth.

Based on our preliminary results the deformation, evolution and ceasing of the dense layer can be well monitored by the time series observed. For instance, (a) the disintegration of the dense layer, (b) the beginning of the one-layer thermo-chemical convection, (c) the ceasing of the first dome and (d) the ceasing of the last dome (initiation of mixing) can be correlated with the characteristic modifications of different time series (Fig. 2). Applying the method the time-dependent behavior of the thermo-chemical convection can be quantified, and some events can be forecasted by e.g. the time variation of the buoyancy parameter B(t), which depends on chemical density $\beta(t)$ and temperature ΔT(t) difference between the two layers.

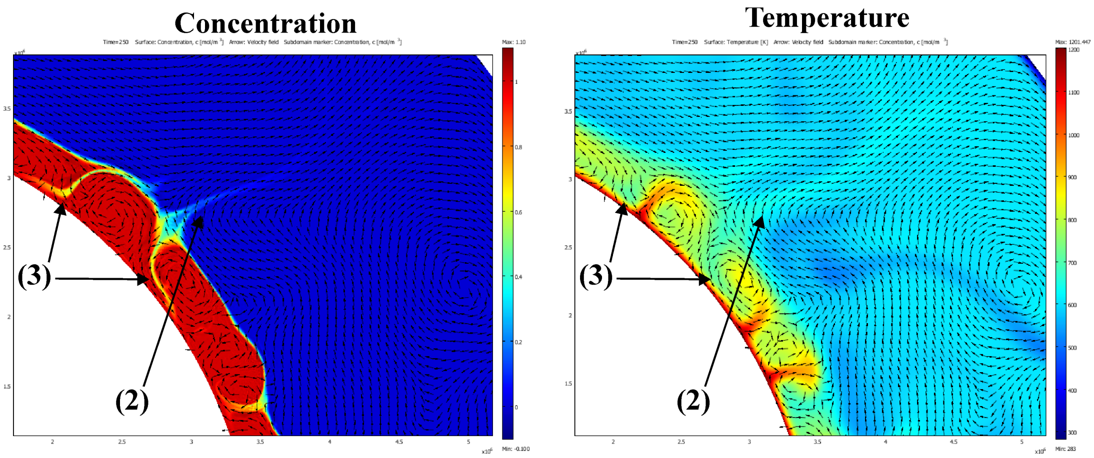

Figure 1: Thermal mantle convection eroding (2) and diluting (3) the dense D” layer.

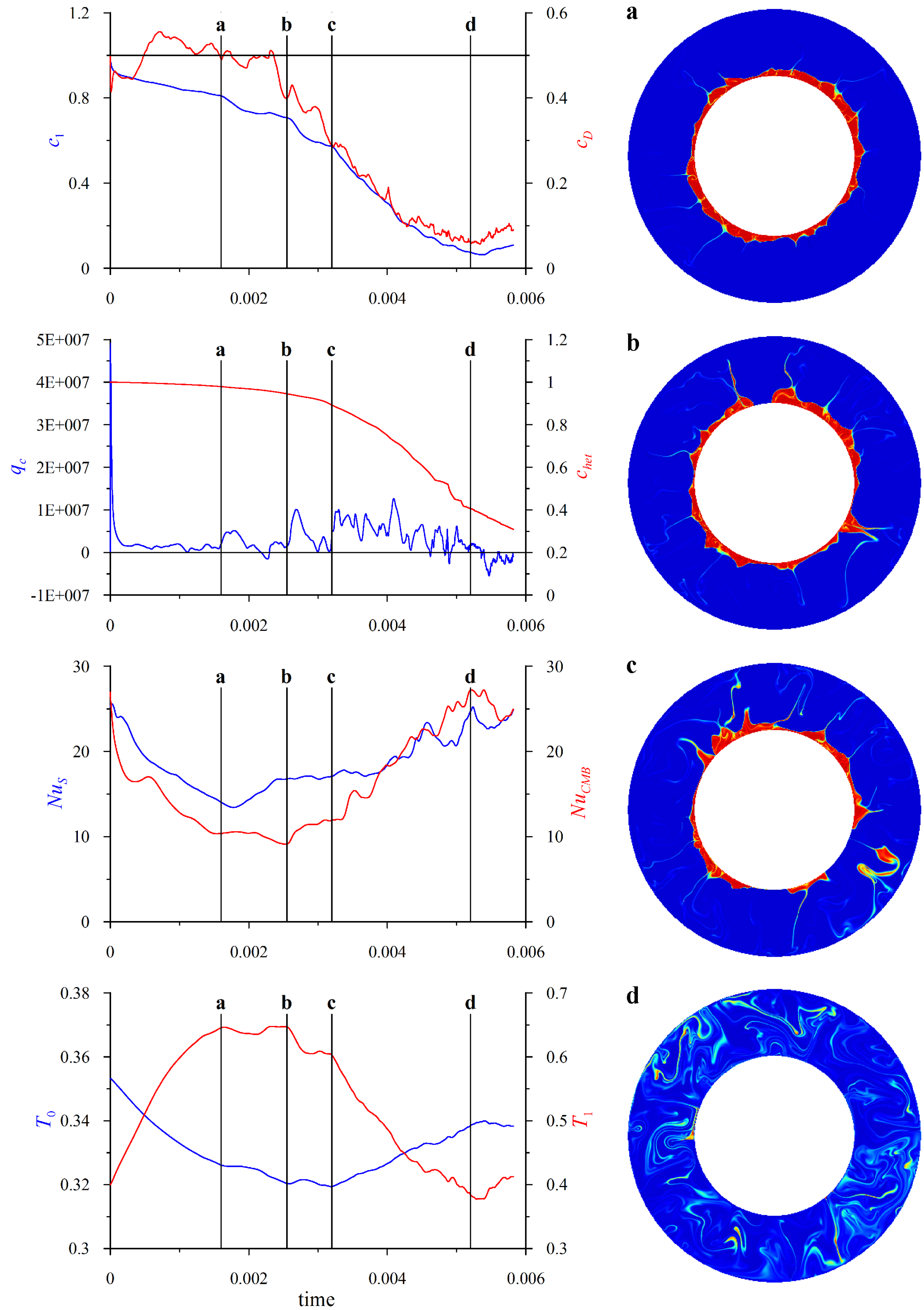

Figure 2: Snapshots from the evolution of the dense D” layer. Right: (a) Disintegration of D”, (b) beginning of the one-layer thermo-chemical convection, (c) ceasing of the first dome and (d) ceasing of the last dome with initiation of mixing. Left: time-dependent behavior of the concentration of the dense material in the upper layer (c_1) and at the top of D” (c_D), the flux of the dense material at the top of D” (q_c), the heterogeneity function (c_{het}), the Nusselt number on the surface (Nu_S) and the CMB (Nu_{CMB}), as well as the temperature in the upper (T_0) and the D” (T_1) layer.