Dynamics of the mantle and lithosphere
Practical: Mantle dynamics

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Q1 Two layer convection

Fig. 1 shows a snapshot of the temperature (T) and composition (c) fields obtained from a thermo-chemical convection simulation using a temperature-dependent viscosity and constant temperature boundary conditions on the upper and lower surfaces.

The depth profile provided (left) shows both the composition c and the scaled temperature $T/\Delta T$, as a function of depth z. A composition value equal to one corresponds the red material (see right panel), whilst $c = 0$ defines the purple region.

The simulation was performed using a bottom-heated Rayleigh number (based on the average viscosity of the lower layer) of $Ra = 10^8$. The Rayleigh number is defined using the global temperature difference and the height of the box d. The buoyancy number (B) is 0.8 and the viscosity ratio between the average viscosity of the upper layer and the average viscosity of the lower layer is defined by R.

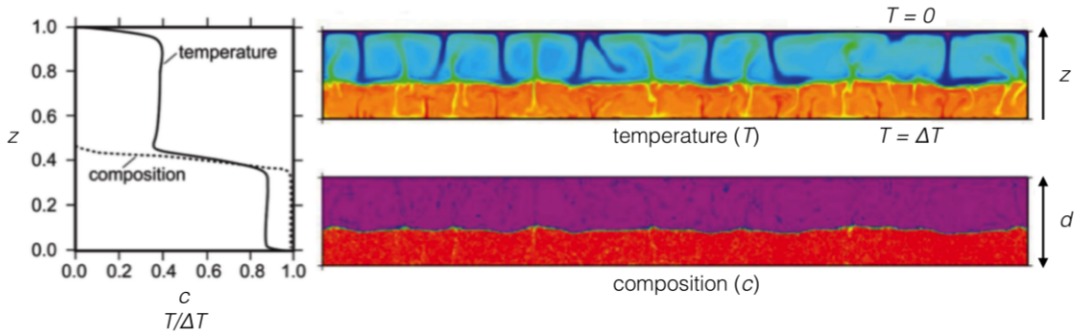

Figure 1: Snapshot of the composition and temperature fields from a thermo-chemical convection simulation (right); averaged depth profile of composition c and scaled temperature $T/\Delta T$ (left).

(a) Write down the expression for the bottom heated Rayleigh number. Regard the upper and lower convective systems as two independent systems. Derive an expression for the Rayleigh number of the lower layer (Ra_{lower}) and for the upper layer (Ra_{upper}). These two expressions should be written in terms of the global Rayleigh number (Ra) and the viscosity contrast R. Do not substitute numbers into these expressions.

(b) For this particular simulation, estimate the viscosity contrast R. Explain how you obtained this value. For which values of R will convection in the upper layer stop, but continue in the bottom layer? Justify your answer.

(c) Suppose this simulation was evolved further in time. What do you think will occur? Will the lower layer remain stable or will it be entrained (mixed) with the upper layer.