EART290Q 2020

WEEK #2 – CONVECTION

Topics/Concepts

Constant viscosity convection, critical Rayleigh number, Nusselt number

Boundary layer theory

Variable-viscosity convection, stagnant lid, heat flux independent of shell thickness

Applications

Equations

$$Ra = \frac{\rho g \alpha \Delta T d^3}{\kappa \eta} \qquad \delta_0 \sim d\, Ra^{-1/3} \qquad Ra_{cr} \sim 10^3$$

$$\eta = \eta_0 \exp(-\gamma \Delta T) \qquad \delta_0 \sim d\, Ra^{-1/3} (\gamma \Delta T)^{4/3} \qquad \delta_1 \sim \delta_0/(\gamma \Delta T) \qquad Ra_{cr} \sim 20\, (\gamma \Delta T)^4$$

Numbers

$\eta_{ice} \sim 10^{13}$-10^{15} Pa s (near the melting point) $\qquad \alpha_{ice} \sim 10^{-4}$ K^{-1} $\qquad Q_{ice} \sim 50$ kJ mol^{-1}

References

Turcotte, D.L, G. Schubert, *Geodynamics*, 2nd ed., CUP 2002, Chapter 6.

Solomatov, V.S., Scaling of temperature- and stress-dependent viscosity convection, *Phys. Fluids.* 7, 266-274, 1995.

Hussmann, H., T. Spohn, K. Wieczerkowski, Thermal equilibrium states of Europa's ice shell: Implications for internal ocean thickness and surface heat flow, *Icarus* 156, 143-151, 2002.