EART290Q 2020

PROBLEM SET #2

Here we'll consider what happens to an icy satellite as its surface ice shell refreezes. To be definite, we'll consider Pluto, with g=0.6 ms^{-2}, T_s=40 K and a total H_2O thickness of 300 km (you can assume Cartesian geometry).

a) Let's assume that ice viscosity is 10^{14} Pa s at the melting temperature (270 K). How thick would the ice shell have to be before convection initiates? You can take α=10^{-4} K^{-1}, Q=50 kJ/mol, ρ=900 kgm^{-3} and κ=10^{-6} m^{2}s^{-1}.

b) Roughly how long would it take a conductively-cooling ice shell to reach this critical thickness?

c) Once the ice shell is convecting, what is the characteristic heat flux? You can take k=4 Wm^{-1}K^{-1}.

d) Roughly how long will it take for the convecting ice shell to freeze completely? You can take L=300 kJ/kg.

e) If the long-term supply of heat from the rocky interior is 3 mW/m^2, what is the long-term equilibrium temperature at the base of the solid ice shell?

f) Make a sketch of how the shell thickness and heat flux evolve with time.