Title: Lava planets night-side surface temperature

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In the absence of a global volatile atmosphere, lava planet night-side surface temperature can be estimated by balancing the endogenic heat flux coming from the interior with the radiative surface heat flux. The heat flux coming from the interior is sustained by thermal convection that transports heat either from the dayside to the night, i.e. horizontal convection and from the interior to the night side, i.e., vertical convection. It seems difficult to anticipate which heat transport mechanism matters the most for lava planets.

$$Q_{end}^1 \sim k\frac{\Delta T}{L}Ra^{1/5}, \tag{1}$$

$$Q_{end}^2 \sim k\frac{\Delta T}{L}Ra^{1/3}, \tag{2}$$

$$Q_{end}^3 \sim k\frac{\Delta T}{L}Ra^{2/7}Pr^{-1/7}, \tag{3}$$

for horitonzal convection (Hughes & Griffiths, 2008), low Rayleigh number thermal convection, and high Rayleigh number thermal convection (Solomatov, 2000), respectively. k stands for the thermal conductivity, ΔT is the temperature difference that drives cooling, L is the length scale over which heat must be transported, Ra is the dimensionless thermal Rayleigh number, and Pr is the dimensionless Prandtl number.

$$Ra = \frac{\rho_0 \alpha \Delta T g L^3}{D\eta},\ Pr = \frac{D}{\rho_0 \eta}, \tag{4}$$

where ρ_0 is the mean density of the fluid, α is the thermal expansivity, g is the gravity acceleration, D is the thermal diffusivity, and η is the fluid viscosity.

By equating the endogenic heat flux with a radiative heat flux of the form $Q \sim \sigma T^4$, we get,

$$T_{ns} = \sqrt[4]{k\frac{\Delta T}{\sigma L}Ra^a Pr^b} \tag{5}$$

where T_{ns} is the night-side surface temperature, a and b are constant that corresponds to different scaling laws discussed above. As the thermal Rayleigh number depends mostly on the fluid viscosity, we plot the surface temperature as function of the fluid viscosity in Figure 1. **This shows that only a molten interior with low viscosity is able to sustain a high night-side temperature.** At solid-state, thermal convection is not vigorous enough to balance thermal radiation.

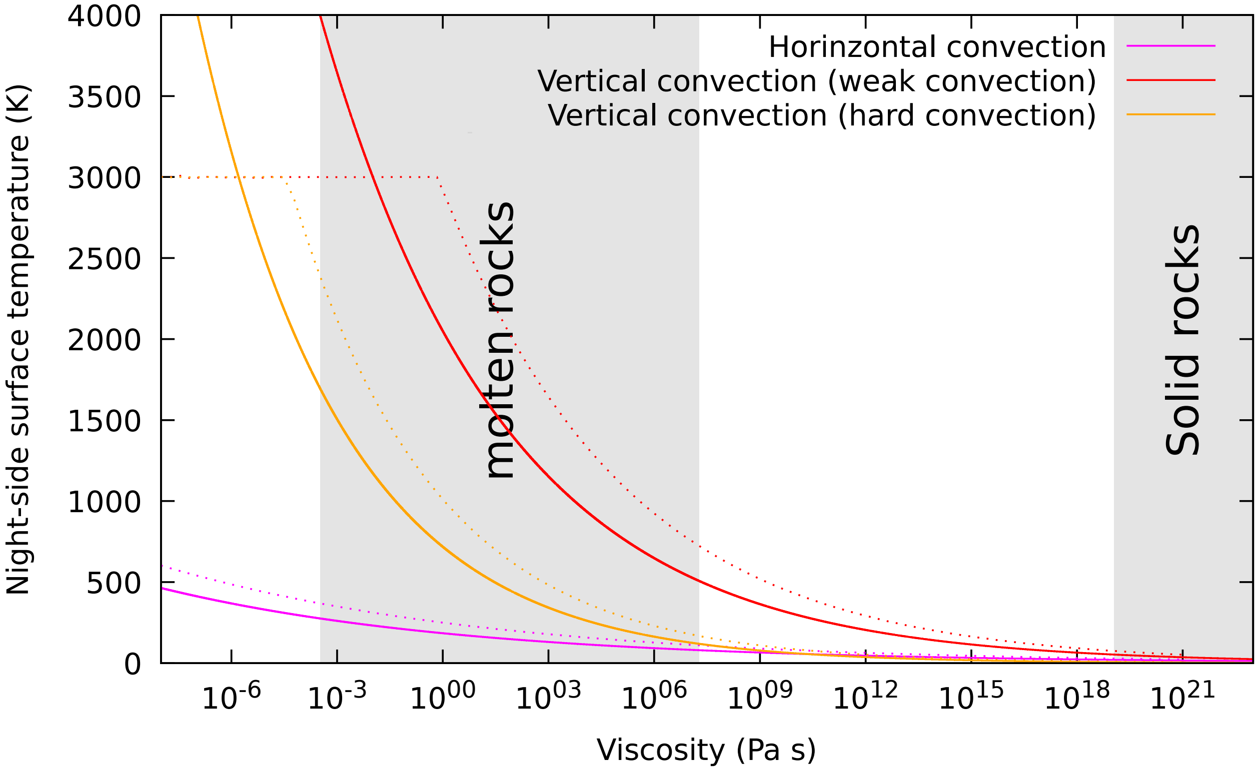

Figure 1: Lava planets night-side temperature as function of the visocsity of the interior. Only a low viscosity interiors, consistent with vigorous convection is able to sustain a high surface temperature.

References

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