PHYS319 Laura's Assignment Timothy Allen 66522411

1. Using hydrostatic balance and the ideal gas law

$$\begin{aligned} z &= \frac{R_d T}{g} ln(\frac{P_s}{P}) \\ &= \frac{287 * (20 + 273.15)}{9.81} ln(2) \\ &= 5944.67681413 \\ z &= 5.9km(2sf) \end{aligned}$$

So the altitude at which atmospheric pressure decreases to 0.5 atm is 5.9 km.

2. (a) Not given Q, the solar constant(S_0) can be determined in reference to Earth. Emission temperature(T_e) and wavelength of maximum emission(λ_m) follow clearly. For Mars:

$$\begin{aligned} S_0 &= \frac{Q}{4\pi r^2} \\ S_0(Mars) &= S_0(Earth)\frac{r^2_{Earth}}{r^2_{Mars}} \\ &= 1367 * \frac{(150 * 10^9)^2}{(2.28 * 10^{11})^2} \\ &= 591.672437673 \\ S_0(Mars) &= 590Wm^{-2}(2sf) \end{aligned}$$

$$\begin{aligned} T_e(Mars) &= \left(\frac{(1-\alpha)S_0}{4\omega}\right)^{\frac{1}{4}} \\ &= \left(\frac{(1-0.25)591.672437673}{4 * 5.67 * 10^{-8}}\right)^{\frac{1}{4}} \\ &= 210.317246822 \\ T_e(Mars) &= 210^\circ K(2sf) \end{aligned}$$

$$\begin{aligned} \lambda_m(Mars) &= \frac{2.898 * 10^{-3}}{210.317246822} \\ &= 0.0000137791837987 \\ \lambda_m(Mars) &= 14\mu m(2sf) \end{aligned}$$

For Venus:

$$S_0(Venus) = 1367 * \frac{(150 * 10^9)^2}{(1.08 * 10^{11})^2}$$
$$= 2636.95987654$$
$$S_0(Venus) = 2600Wm^{-2}(2sf)$$

$$T_e(Venus) = \left(\frac{(1 - 0.77)2636.95987654}{4 * 5.67 * 10^{-8}}\right)^{\frac{1}{4}}$$
$$= 227.40346449$$
$$T_e(Venus) = 230°K(2sf)$$

$$\lambda_m(Venus) = \frac{2.898 * 10^{-3}}{227.40346449}$$
$$= 0.0000127438691688$$
$$\lambda_m(Venus) = 13\mu m(2sf)$$

(b) So Mars and Venus primarily emit radiation in the infrared part of the EM spectrum.

3. (a) At z_1 the pressure is 1000 hPa and temperature is 288 °K. This allows us to calculate the density using the ideal gas law.

$$\rho = \frac{P}{R_d T}$$
$$= \frac{1000 * 10^2}{287 * 288}$$
$$= 1.20983352691$$
$$\rho = 1.21kgm^{-3}(3sf)$$

So the density of the parcel of air is $1.21kgm^{-3}$.

(b) Environmental lapse rate ($(\frac{\mathrm{d}T}{\mathrm{d}z})_E$) can be found from the difference in temperatures and altitudes:

$$T_2 \approx T_1 + (\frac{\mathrm{d}T}{\mathrm{d}z})_E \delta z$$
$$(\frac{\mathrm{d}T}{\mathrm{d}z})_E \approx \frac{T_2 - T_1}{\delta z}$$
$$\approx \frac{270 - 288}{2}$$
$$(\frac{\mathrm{d}T}{\mathrm{d}z})_E \approx -9Kkm^{-1}(1sf)$$

(c) As the air cools it will eventually become saturated. When the air is saturated it will start to condense releasing latent heat and massively changing the lapse rate to the saturated adiabatic lapse rate. This is known as the condensation line or tropopause and is a significant place of cloud formation. In the stratosphere above, ozone absorbs UV-B radiation causing the temperature to eventually increase. Above this ozone layer is the mesosphere where temperature once again decreases with altitude until the mesopause above which radiation will be able to ionize parts of the air.

(d) At z_2 the pressure is 800 hPa.

(e) At z_2 the temperature is 270 K.

(f) The dry adiabatic lapse rate is $10Kkm^{-1}$. This means the environmental temperature gradient is greater than the negative of the dry adiabatic lapse rate which means the atmosphere is stable to dry convection.

(g) While the Earth indeed does not have a roof or walls, this presents a misunderstanding of the effect of gravity on air. The Earth's gravitational pull affects the molecules which make up the air, holding them to the surface and creating the pressure of the atmosphere which we need to live. Without this force not only the hot convection currents but indeed all of the atmosphere would leave to space. This is something we see for example with the moon, it is close enough to Earth's amgnetic field to have some protection from the solar winds but does not have enough gravity to have a very strong atmosphere.

Convection occurs as emergent phenomena from the nature of temperature. Temperature is a way of measuring the random motion of particles due to kinetic energy. Particles with more energy move faster and random chance means when all particles are pulled towards something the slower random movements will be able to resist leading to hot particles rising and cool particles falling. This makes it clear that heat does not rise unless it is "pushed" up by cooler particles being pulled down more effectively. Extending this to this edge of space, eventually there won't be enough cool particles to push them up. This would have happened when the Earth was first created but the "excess" has mostly disappeared over the lifetime of the Earth.

So while there is an amount of gas lost to space due to this random movement from gas in the far upper atmosphere this is a very small amount and has almost no effect on climate change. All together this creates a balance and convection currents can essentially be considered a closed system in terms of heat.