

### PROBLEMS 4 – CLIMATE MODELING

(Due: December 4, via email)

Further on planetary engineering

Let's suppose we want to make Venus habitable for humans, by changing its temperature. Currently, we have

Planet	Distance from sun [A.U.]	Albedo	Outgoing radiation [W-m <sup>-2</sup> ]	Radiative temperature [K]
Venus	0.72	0.76		
Earth	1.00	0.30	238	255

At the Earth's orbit, the solar flux = 1360 W-m<sup>-2</sup>, producing the outgoing radiation and radiative temperature seen in the table above.

- (a) The albedo of Venus is 76 %. What is the radiative temperature for Venus?
- (b) We can assume that any sunlight (solar radiation) that does not get reflected by clouds reaches the surface (effectively, no absorption of solar radiation). Given that the current, planetary average surface (ground) temperature for Venus is estimated to be 737 K, what is the optical depth of the atmosphere in the infrared?
- (c) You send a space probe into the upper atmosphere as part of your pre-engineering evaluation of its atmosphere. These values are reported back as the probe descends:

Level	Temperature [K]	Optical depth, $\tau$
1	200	
2	300	

What is the optical depth at each level?

- (d) Suppose we focus on altering the optical depth to give a surface (ground) temperature of  $T_g = 288$  K. What must the optical depth be for this case?