The discovery of a planet with temperatures potentially similar to Earth’s was announced recently. The planet, dubbed 581c, revolves around a Star named Gliese 581. 581c is 14 times closer to Gliese 581 than the Earth is to our Sun, Gliese 581 has a radius one-third that of our Sun, and the radius of 581c is 1.5 times that of our Earth. Assume 581c experiences a flux density of radiation from Gliese 581 that is similar to ours, or 1370 W m$^{-2}$, a Sun emission temperature of 6000 K, an Earth-Sun distance $D_s$ of 1.5*10$^8$ km, a Sun radius of $R_s = 7*10^5$ km, and an Earth radius of 6000 km.

a) What is the emission temperature $T_e$ of Star Gliese 581 ?

b) What is the wavelength of maximum emission, $\lambda_m$, of Star Gliese 581 ?

(Recall Wien’s law that $\lambda_m$ is proportional to $1/T_e$)

c) It is currently unknown if planet 581c has an atmosphere, but assuming it does have one, and that its composition is similar to that of Earth, characterize how a spectral flux with a spectral width of about 0.5 micron centered at a wavelength of $\lambda_m$ interacts with

i) clear air ($N_2$, $O_2$, $H_2O$-vapor). Include a crude estimate of the clear-sky optical depth.

ii) stratiform liquid water clouds with $r_c = 10$ $\mu$m. Discuss both scattering and absorption properties; estimate a size parameter $x$, and show bounded estimates for the single-scattering albedo $\omega$ and asymmetry parameter $g$.

iii) surface snow.

Show your thinking; some possibly useful graphs are shown on the next page.

d) Extra credit: Speculate on the implications of the clear-sky-radiative interaction for the surface temperature of 581c. How might it differ from that of Earth ?