Comprehensive Exam MPO 531, May 24, 2007 Name:

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, λ_m, of Star Gliese 581 ?

(Recall Wien's law that λ_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 λ_m interacts with

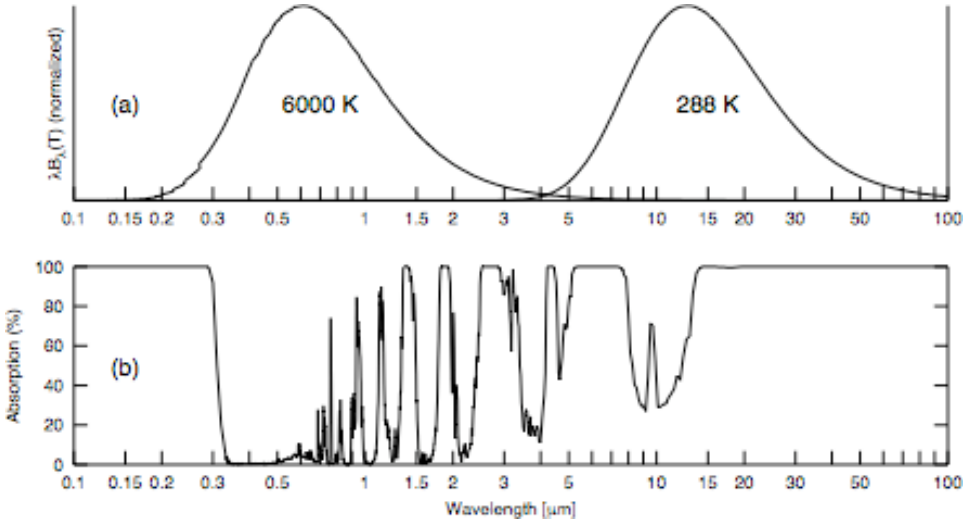
i) clear air (N_2, O_2, H_2O-vapor). Include a crude estimate of the clear-sky optical depth.

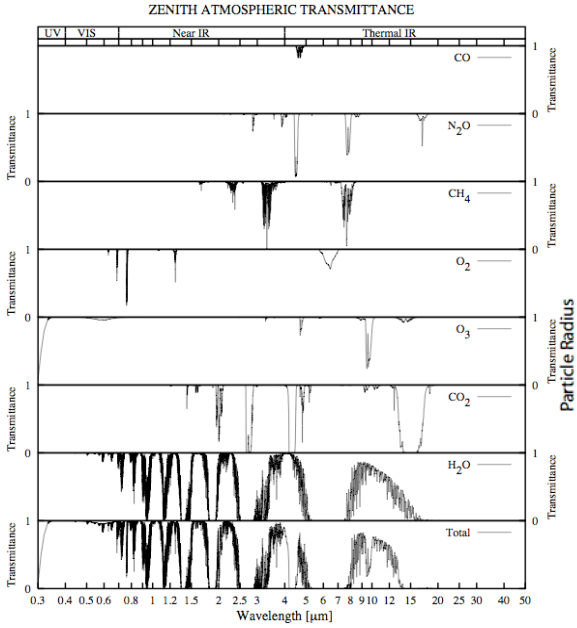
ii) stratiform liquid water clouds with r_e = 10 μm. Discuss both scattering and absorption properties; estimate a size parameter x, and show bounded estimates for the single-scattering albedo ω and asymmetry parameter *g*.

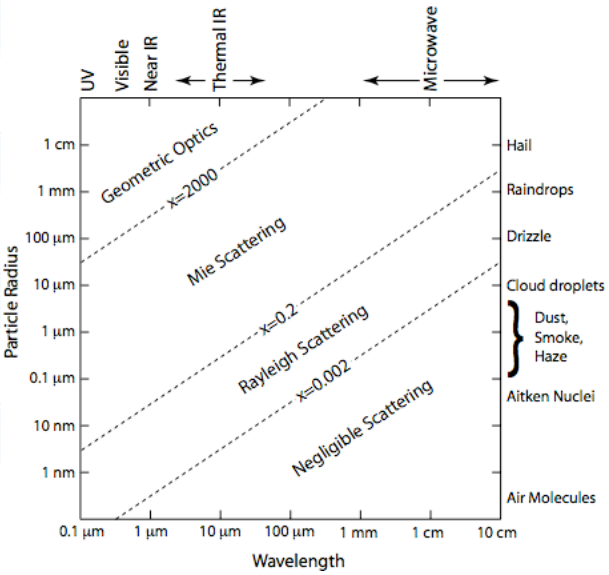
iii) surface snow.

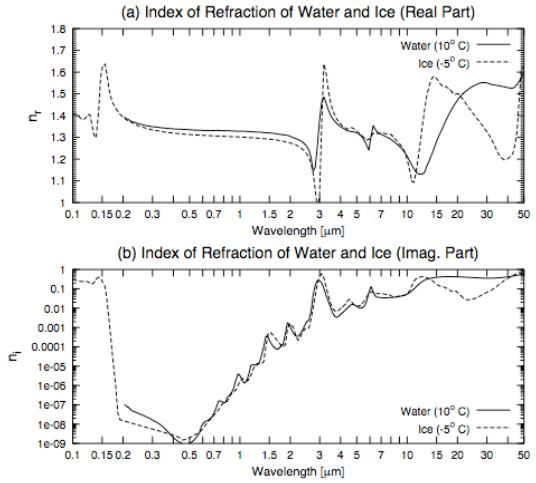
Show your thinking; some possibly useful graphs are shown on the next page.

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 ?


(a)
6000 K
288 K
λB_λ(T) (normalized)
0.1 0.15 0.2 0.3 0.5 1 1.5 2 3 5 10 15 20 30 50 100
(b)
Absorption (%)
0 20 40 60 80 100
Wavelength [μm]


ZENITH ATMOSPHERIC TRANSMITTANCE
UV
VIS
Near IR
Thermal IR
CO
N2O
CH4
O2
O3
CO2
H2O
Total
Transmittance
0.3 0.4 0.5 0.6 0.8 1 1.2 1.5 2 2.5 3 4 5 6 7 8 9 10 12 15 20 25 30 40 50
Wavelength [μm]


UV
Visible
Near IR
Thermal IR
Microwave
Geometric Optics
x=2000
Mie Scattering
x=0.2
Rayleigh Scattering
x=0.002
Negligible Scattering
Particle Radius
1 cm
1 mm
100 μm
10 μm
1 μm
0.1 μm
10 nm
1 nm
Hail
Raindrops
Drizzle
Cloud droplets
Dust, Smoke, Haze
Aitken Nuclei
Air Molecules
0.1 μm 1 μm 10 μm 100 μm 1 mm 1 cm 10 cm
Wavelength


(a) Index of Refraction of Water and Ice (Real Part)
Water (10° C)
Ice (-5° C)
n_r
1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8
0.1 0.15 0.2 0.3 0.5 0.7 1 1.5 2 3 4 5 7 10 15 20 30 50
Wavelength [μm]
(b) Index of Refraction of Water and Ice (Imag. Part)
n_i
1 0.1 0.01 0.001 0.0001 1e-05 1e-06 1e-07 1e-08 1e-09
Water (10° C)
Ice (-5° C)
0.1 0.15 0.2 0.3 0.5 0.7 1 1.5 2 3 4 5 7 10 15 20 30 50
Wavelength [μm]