Atmospheric Sciences 501. Problem Set 1. Autumn 1998. Due 10/2/98.

1. Using the data shown in Fig. 2.1, verify that pressure and density in Earth's atmosphere decline by roughly a factor of 10 for each 15 km of altitude increase up to 90 km.

2. The composition of the Martian atmosphere is give by the following volume mixing ratios: CO_2: 0.97, N_2: 0.02, Argon (atomic mass = 40): 0.01.

(a) What is the mass mixing ratio of N_2?

(b) What is the value of the specific gas constant for this composition?

(c) The surface pressure and temperature are 7hPa and 200K. What is the number density at the surface?

(d) Assume that the Mars atmosphere below 100km altitude is isothermal at a temperature of 160K. The acceleration of gravity (g_o) is 3.72ms^{-2}. What are the approximate values of pressure, mass density, and number density at (geopotential) altitude 100km? [Assume uniform composition below 100km].

(e) Assume that the molecular collision cross-section is s = 2x10^{-22}m^2. What is the value of the mean free path at the surface of Mars? What is it at 100km? What is the value of the molecular diffusion coefficient at 100km?

(f) Compare the values of mean free path determined in part (e) with the average values at the surface and at 100km for Earth. [Assume that number density declines by a factor of 10 each 15km altitude gain in Earth's atmosphere; also assume the same value of s as in part (e).]

3. Assume that pressure at a particular location and time at Earth's surface (at mean sea level, msl) is 1000hPa. Also assume that surface temperature is 286K, the lapse rate between 1000 and 500hPa is 6.5K/km, and the air is dry.

(a) What is the (geopotential) height above msl at the 500hPa surface over that location?

(b) What is the temperature at 500hPa?

(c) Recalculate the geopotential height of the 500hPa surface assuming that the atmospheric temperature in the column is everywhere equal to the mean with respect to altitude of the temperature of the 1000 to 500hPa layer, [T(500) + T(1000)]/2. Compare with the value obtained in part (a). [Note that the correct average for this calculation is the average with respect to ln(p).]

(d) What is the difference between the values of virtual and actual temperature at the surface if the mole fraction of water vapor is 1%?

(e) Recalculate part (a) under the assumption that the mole fraction of water vapor is uniformly 0.5% throughout the 1000-500hPa layer. [Note that uniform mole fraction through this layer is not very realistic.]

4. An aircraft altimeter is set for a surface pressure of 1015hPa when the actual surface pressure is 1025hPa. What is the error in altimeter altitude reading when the aircraft lands?

5. The surface pressure is 1000hPa at two locations, one at 30°N, the other at 60°N. The average virtual temperature of the 1000-300hPa air column is 260K at 30°N and 240K at 60°N. What is the difference in height of the 300hPa surface between these locations?

6. Assume that the number density at 100km in Earth's atmosphere is $2.7\text{x}10^{19}$ molecules/m^3, the scale height is 6km, and the scale height increases upward above 100km at the uniform rate 0.15 (km/km) due to both upward increase of temperature and upward decrease of molar mass.

(a) Estimate the geopotential altitude of the exobase assuming that the molecular collision cross-section is approximately $s = 2\text{x}10^{-22}\ m^2$.

(b) Estimate the geometric height of the exobase.

(c) What is the ratio of the mean velocity of hydrogen atoms to the escape velocity at the exobase? [Assume that hydrogen atoms are in thermal equilibrium with the rest of the atmosphere at the exobase.]