Atmospheric Pressure Assignment

1. Scale Height of the Martian Atmosphere: On Mars the atmosphere is mainly CO_2, the temperature is 220 K, and the acceleration of gravity is 3.7 m s^{-2}. What is the scale height of the Martian atmosphere? Compare to the scale height of the Earth's atmosphere.

2. Scale Height and Atmospheric Mass: Many species in the atmosphere have mass concentrations (p) that decrease roughly exponentially with altitude:

$p(z) = p(0)\exp(-z/h)$ Equation (1)

where h is a species-dependent scale height.

If $\rho(z)$ is horizontally uniform, show that the total atmospheric mass (m) of such a species is given by

$m = A\rho(0)\, h$ Equation (2)

where A is the surface area of the Earth.

Equation (2) allows a quick estimate of the total atmospheric mass of a species simply from knowing its scale height and its concentration in surface air. Let us first apply it to air itself.

Calculate the mass density of air at the surface of the Earth using the ideal gas law and assuming global average values of surface pressure (984 hPa) and temperature (288 K).

Infer the mass of the atmosphere using equation (2). Compare to the value given in chapter 2. Explain the difference.

Let us now apply equation (2) to the sea salt aerosol formed by wave action at the surface of the ocean. The mass concentration of sea salt aerosol in marine air decreases exponentially with altitude with a scale height of 0.5 km (sea salt particles are sufficiently large to fall out of the atmosphere, hence the low scale height). The average mass concentration of sea salt aerosol in surface air over the ocean is $10\ \mu g\ m^{-3}$. The Earth is 70% ocean and the sea salt aerosol concentration over land is negligible. Calculate the total mass (in kg) of sea salt in the atmosphere.

3. Measuring aerosol concentrations from aircraft

Aerosol concentrations are commonly reported in mass concentration units of μg m^{-3} but this is awkward for interpreting vertical aerosol profile measurements from aircraft.

3.1 Aerosol concentrations measured in units of μg m^{-3} decrease with altitude even in a well-mixed atmosphere. Assuming an atmosphere where aerosols are well-mixed vertically and using the barometric law with scale height of 8 km, calculate the % decrease in aerosol concentration (μg m^{-3}) from the surface to 1 km altitude.

3.2 An alternative approach used in aircraft measurements is to report aerosol concentrations in units of μg sm^{-3}, where sm is a standard cubic meter of air at standard conditions of temperature and pressure (STP): 1000 hPa and 273 K. Show that if the aerosols are well-mixed vertically then the concentration measured in units of g sm^{-3} is uniform with altitude.