A primary assumption in atmospheric physics that applies to all but the upper-most reaches of the atmosphere is that the atmosphere is an ideal gas whose constituents obey Dalton’s Law. Effectively what is implied is that all atmospheric constituents in a volume have the same temperature and can be treated as independent quantities so far as their pressure is concerned.

So, the instantaneous pressure of a mixture of gases is equal to the sum of partial pressures of the gases. The total pressure is

\[ p = \frac{n}{V} R^* T \]

where \( p \) is pressure, \( V \) volume and \( n = \frac{m}{M} \) is the number of moles, or the mass of material \( m \) divided by its molar mass \( M \). \( R^* T \) is the universal gas constant (8314 J K kmol\(^{-1}\)) times the temperature. Because we assume the temperature is the same for all species and that all gases occupy the same volume (i.e. they are “well-mixed”), each individual gas obeys

\[ p_i = \frac{m_i}{V} R_i T = \rho_i R_i T \]

where \( R_i = \frac{R^*}{M_i} \) is the specific gas constant for the particular gas and \( \rho_i \) is its density. Thus, we have

\[ p = \sum p_i = \frac{T}{V} \sum m_i R_i = T \sum \rho_i R_i \]

So it is convenient to separate gases into their major constituents. Due to the hydrological cycle, water varies very quickly, so it is usually we reference atmospheric composition according to its proportion relative to dry, non-wet portion of air

\[ p_d = \frac{m_d}{V} R_d T = \rho_d R_d T \]

\[ p_i = \frac{m_i}{V} R_i T = \rho_i R_i T \]

We’ll introduce an important parameter here

\[ \epsilon_i = \frac{R_d}{R_i} = \frac{M_i}{M_d} \]

For example, the mean molar weight for dry air is 28.97 kg/kmol so \( R_d = 287 \text{ J deg}^{-1} \text{kg}^{-1} \), and for moist air \( M = 18.0 \text{ kg/kmol} \) so \( R_v = 461 \text{ J deg}^{-1} \text{kg}^{-1} \).

We define the mixing ratio in the atmosphere as

\[ r_i = \frac{m_i}{m_d} \]

Thus,

\[ r_i = \frac{m_i}{m_d} = \frac{p_i V / R_i T}{(p - p_i) V / R_d T} \]

\[ = \epsilon_i \frac{p_i}{p - p_i} \]

\[ \approx \epsilon_i \frac{p_i}{p} \]