

Recap: We are interested in the partial pressure of water in atmosphere.

Clausius - Clapeyron:

$$e_s = e_{s, \text{tr}} \exp \left\{ \frac{L_{ev}}{R_v} \left(\frac{1}{T_{tr}} - \frac{1}{T} \right) \right\}$$

latent heat

$p_{\text{sat}} @ T$ $p_{\text{sat}} @ T_{\text{ref}}$ specific constant for water vap T_{ref}

Usually the reference T, P are @ the triple point; so that both expressions for ice and liquid water have the same reference. The two curves only then differ in the " L ", and its T -dependence.

However, C-C is not as accurate as we may want. Why? (go to assumptions made then ask for it):

- ideal gas (may not be strictly valid)
- $P = P_w + (P_{O_2} + P_{N_2})$
 - $\underbrace{\hspace{1cm}}$ changes total P , so \rightarrow affected a bit by T_w
 - f phase eqn.

→ $L_{ev} = f(T)$

- Empirical correlation of e_s should be used instead for calculations: e = six order polynomial or Antoine's equation

e^s is used to determine some commonly used variables for humidity. You have

relative humidity, $H = \frac{e}{e_s}$ ← vapor pressure of water
 ← saturation v.p. conditions at P, T .

relative humidity w.r.t. ice saturation:

$H_i = \frac{e}{e_{si}}$ ← saturation ratio

→ Q: If $H > 1$ (or 100%), what happens?

A: Liquid water can form (because you are in 2-phase region of phase diagram)

→ Q: $H_i > 1$? A: ice forms

→ Q: how does H_i relate to H ?

A: Take Clausius-Clapeyron.

$$\frac{e_s}{e_i} = \exp \left\{ \frac{L_{ie}}{R_v T_{tr}} \left\{ \frac{T_{tr}}{T} - 1 \right\} \right\} > 1$$

↖ heat of freezing

if $T < T_{freezing}$

that also means that if $H=1 \rightarrow H_i > 1$
 i.e. an atmosphere saturated with water is
saturated with ice as well.

Q: How big is the transition between 99% and 101% environment "slaty" airplane ride
 A: $\xrightarrow{100.5\%}$ 101% typical of cumulus clouds
 105% very strong Thunderstorm.

a "small" supersaturation has a huge effect on the dynamical activity of the atmosphere

→ Water vapor mass mixing ratio, $w_v =$

$$= \frac{m_v}{m_{dry air}} = \frac{e_v}{e_{dry}} = \epsilon \frac{e}{p-e} \quad (1)$$

water vapor dry air ideal gas law

$$\epsilon = \frac{k_{H_2O}}{k_a} \sim 0.62$$

→ saturation mixing ratio, w_s , is then given by:

$$w_s = \epsilon \frac{e_s}{p - e_s} \quad (2)$$

Since there is little water in atmosphere relative to the O_2, N_2 content, $p - e_s \approx p$

$$\text{from (2): } e_s \approx p \frac{w_s}{\epsilon} \quad (3)$$

$$\text{and from (1): } e \approx p \frac{w_v}{\epsilon}$$

$$\text{So: } \frac{e}{e_s} \approx \frac{w_v}{w_s}$$

w_v can also be related to specific humidity q_v (or water vapor mass fraction):

$$q_v = \frac{m_v}{m_a + m_v} = \frac{\epsilon e}{p - (1 - \epsilon)e} = \frac{w_v}{1 + w_v}$$

$\uparrow \quad \uparrow$
 $e \text{ for } v = 1 \text{ m}^3$

Since $1 + w_v \sim 1$

$$\uparrow w_v < 10^{-2}$$

$$\Rightarrow \boxed{q_v \approx w_v}$$

→ Precipitable water, W_v , is related to the maximum amount of water you can ever 'hope' to precipitate out of the atmosphere.

Q: what do you think it is?

$$A: W_v = \int_0^{\infty} \rho_v dz$$

W_v can be related to q_v by incorporating

the hydrostatic eqn:

$$dW_v = \frac{1}{g} \frac{\rho_v}{\rho_a} dp \Rightarrow W_v = \frac{1}{g} \int_p^{p_0} \frac{\rho_v}{\rho_a} dp \Rightarrow$$

$$\Rightarrow \boxed{W_v = \frac{1}{g} \int_p^{p_0} q_v dp}$$