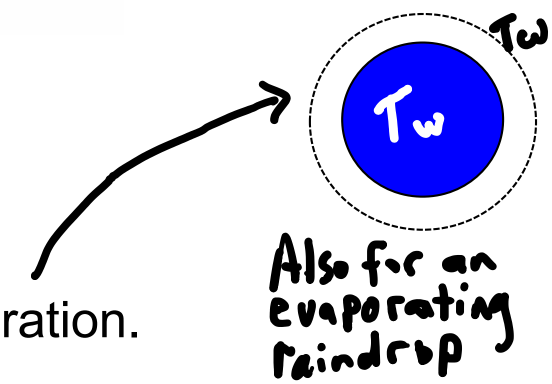
Wet Bulb Temperature, T_w



1. Surrounding air cools due to evaporation.
2. Water vapor enters surrounding air.
3. T_w is reached when the surrounding air becomes saturated.

Comparison: T_{dew} and T_w

T_{dew}

w=mixing ratio
Cool at constant pressure
until saturation at
the dew point temperature

T_w

w'=mixing ratio.
w'=w + evaporated water vapor.
Now cool at constant pressure.
until saturation occurs at Tw.

Notes: $w' > w$ so $T_{dew} \leq T_w \leq T$, equal at the LCL.

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Calculation of T_w, the Wet Bulb Temperature

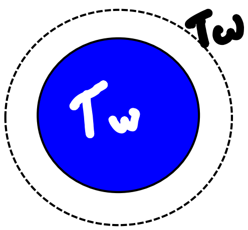
T_o = ambient temperature

W_o = ambient mixing ratio

Moist cloth over thermometer

Air flow

T_w



Also for an evaporating raindrop

Constant Pressure Process

Enthalpy

$$dq = C_p dT - \alpha dP = -L_{ev}\, dw$$

Latent heat

Evaporated water vapor mixing ratio.

dq=heat required to overcome the H20 liquid state potential energy of attraction. dq comes from the surrounding air.

Integrating, $C_p(T_w - T_o) = -L_{ev}\left(W_s(T_w) - W_o\right)$

Solve for T_w.

Recall: $w_s(T) = \dfrac{\epsilon\, e_s(T)}{p}$, $e_s(T_c) = 6.112\text{mb}\exp\left(\dfrac{17.67T}{T+243.5}\right)$

Compare: $e_s(T_{dew}) = e_{observed}(T_o)$

T_{dew} Solve for T_{dew}.

Note: $W_o = \dfrac{\epsilon\, e_{sat}(T_{dew})}{p}$

Analysis of T_{dew} from T and T_w

Analysis For T_{dew} :

From the first law of thermodynamics:

$$w_0(T_{dew},P_0) = w_s(T_w,P_0) - \frac{c_p}{L_{lv}}\left(T_0 - T_w\right)$$

General Definition:

$$w_0(T_{dew},P_0) = \frac{\varepsilon e_{sat}(T_{dew})}{P_0}$$

From Bolton,

$$e_{sat}(T_c) = e_0 \exp\left(\frac{17.67\,T_c}{243.5+T_c}\right),\ e_0 = 6.112\ mb$$

So

$$\frac{e_{sat}(T_{dew})}{e_0} = \frac{e_s(T_w)}{e_0} - \frac{P_0\,c_p}{\varepsilon\, e_0\, L_{lv}}\left(T_0 - T_w\right) \equiv R = \exp\left(\frac{17.67\,T_{dew}}{243.5+T_{dew}}\right)$$

Solving,

$$T_{dew} = \frac{243.5\ln(R)}{17.67-\ln(R)} \quad \textit{Celsius units,}$$

where

$$R = \frac{e_s(T_w)}{e_0} - \frac{P_0\,c_p}{\varepsilon\, e_0\, L_{lv}}\left(T_0 - T_w\right).$$

$$\varepsilon = 0.622,\ c_p = 1004\frac{J}{kg\,K},$$

$$L_{lv}(T) = 1000\left(2500.8 - 2.36T + 0.0016T^2 - 0.00006T^3\right)\frac{J}{kg} \quad T \text{ in Celsius.}$$

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