Wet-bulb temperature overview

The wet-bulb temperature is the temperature a parcel of air would have if it were cooled to saturation (100% relative humidity) by the evaporation of water into it, with the latent heat being supplied by the parcel. It can be useful in determining precipitation type, preventing crop damage from sub-freezing temperatures, and for the creation of snow at ski resorts. For example, knowing the wet-bulb temperature is useful for scheduling irrigation to prevent frost forming on fruit crops.

For snow-making at ski resorts, see the chart at http://www.snowathome.com/pdf/wet_bulb_chart_fahrenheit.pdf to make "good snow" (dry snow with relatively low moisture, so its light and powdery), plus information at https://www.snowathome.com/snowmaking_science.php, http://www.snowmakers.com/snowmaking-basic.html and http://adventure.howstuffworks.com/outdoor-activities/snow-sports/snow-maker.htm/printable . It's also a good time too refresh your knowledge on the Bergeron-Wegener process (see http://danatobin.weebly.com/uploads/2/8/4/4/28441795/bergeron_process.pdf)

For crop protection information, see details at: http://www.awis.com/ag/fact_sheets.html and http://lake.ifas.ufl.edu/agriculture/citrus/documents/CriticalTemperatures120214.pdf .

As discussed in the supplemental notes, there are two definitions of wet-bulb. Isobaric wet-bulb temperature is the temperature an air parcel would have if cooled adiabatically to saturation at constant pressure by evaporation of water into it, all latent heat being supplied by the parcel. Adiabatic wet-bulb temperature (or pseudo wet-bulb temperature) is the temperature an air parcel would have if cooled adiabatically to saturation and then compressed adiabatically to the original pressure in a moist-adiabatic process. Both give similar answers. The adiabatic (SkewT) version will be less than the isobaric version by a decimal point.

On a thermodynamic diagram, adiabatic wet-bulb is found by following the moist adiabat from the LCL back to the original level. The isobaric version is represented by the following equation:

$$T_w = T - \frac{L}{c_p}(q - q_s(T_w))$$

This equation, as well as the adiabatic version, require an iteration technique to solve for T_w.

However, Stull (2011) recently derived the following empirical equation that does not require an iteration:

$$T_w = 273.15 + (T - 273.15)atan\left[0.151977(RH + 8.313659)^{1/2}\right] + atan[(T - 273.15) + RH] - atan[RH - 1.676331] + 0.00391838(RH)^{\frac{3}{2}}\, atan[0.023101RH] - 4.686035$$

A plot of this equations is shown below. Note this equation assumes a pressure of 1013 mb, and has errors for low relative humidity if the pressure is not 1013 mb. The gray curved lines represent 800 or 600 mb.

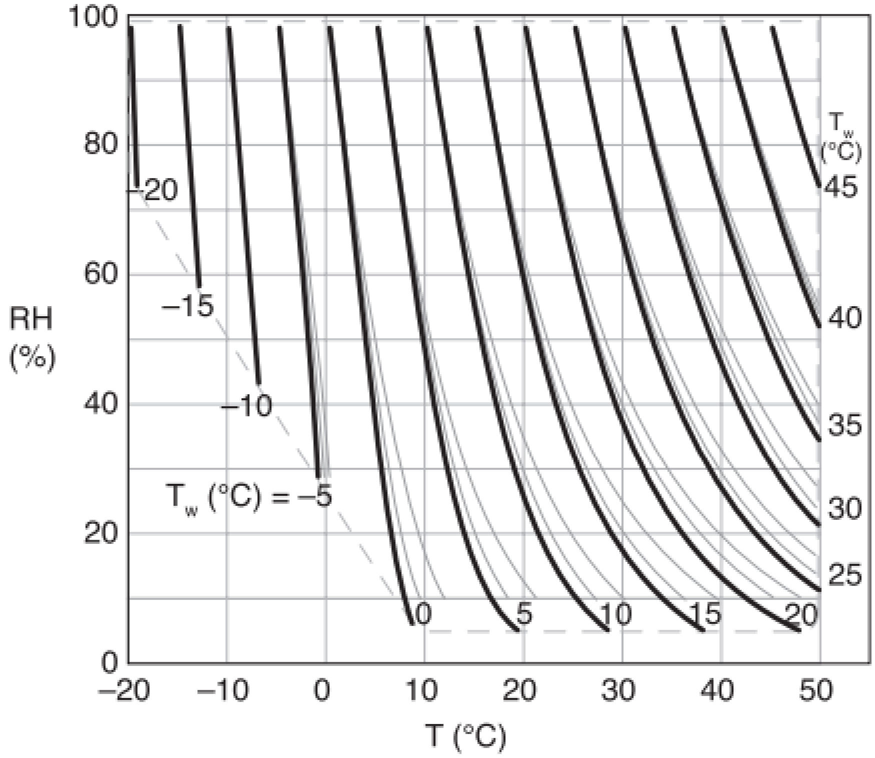

FIG. 2. Isopleths of T_w (thick black curves) vs RH% and T, found from Eq. (1). The valid range is enclosed by a dashed line, and the valid pressure is 101.325 kPa. The gray curves associated with each T_w are for P = 80 kPa (thinner lines) and P = 60 kPa (thinnest lines, located farther away from each black line). These gray curves [not found from Eq. (1)] are useful for estimating the error if Eq. (1) is applied to pressures that are not equal to 101.325 kPa.

A "back of the envelope" technique that forecasters use to determine the wet-bulb temperature is called the "1/3 rule" and "1/2 rule." This technique only works for units Fahrenheit.

First, let's introduce a new term called the "dewpoint depression." This is simply $(T - T_d)$. However, its used in meteorology jargon enough to define in these notes. It does not mean the dewpoint temperature needs an antidepressant.

Here is the technique: if the air temperature is between 30 and 60°F, subtract one-third the dewpoint depression from air temperature; if the air temperature is greater than 60°F, then divide the dewpoint depression by half. Warmer air will cool at a greater rate than colder air since more water vapor can evaporate into warm air. Evaporation is a cooling process that absorbs latent heat, therefore the more evaporation the more cooling.

Reference: Stull, R., 2011: Wet-bulb temperature from relative humidity and air temperature. *Journal of Applied Meteorology and Climatology*, **50**, 2267-2269.

SkewT exercise

Initial values: p=980 mb; T=27°C=300.15°K, T_D=11°C=284.15°K. Assume T_{LCL}=280°K=7.5°C , p_{LCL}=775 mb, and RH=36.8%.

Calculations

Stull's equation:

$$T_w = 273.15 + (300.15 - 273.15)atan\left[0.151977(36.8 + 8.313659)^{1/2}\right] + atan[(300.15 - 273.15) + 36.8] - atan[36.8 - 1.676331] + 0.00391838(36.8)^{\frac{3}{2}}\, atan[0.023101(36.8)] - 4.686035$$

After converting to Celcius

T_w=17.4°C

"Back of envelope" rule of thumb, in which T=27°C=80.6°F, T_D=11°C=51.8°F .

Since T>60°F, use one-half rule

$T_w = T - 0.5(T - T_d) = 80.6 - 0.5(80.6 - 51.8)$= 66.2°F

After converting to Celcius

T_w=19°C

The SkewT gives T_w≈18°C