Thermodynamic Chart: Skew T - $\ln P$

⋄ Atmospheric Pressure Lines P

Pressure (in mb = hPa) is plotted along the vertical axis. Constant pressure lines are horizontal across the graph. Note the spacing between the lines increases with height. That is, the spacing between 1000 mb and 900 mb is much less than the spacing between 200 mb and 100 mb. The spacing is determined by the difference in the natural log of the pressure instead of the difference in pressure. Let $P = 1000e^{-z}$, where z is the "height" along the vertical axis for the given pressure P. Solving this equation for z gives $z = -\ln\left(\frac{P}{1000}\right)$. The values of z corresponding to values for P of 1000, 900, 800, 200, and 100 mb are, 0, 0.105, 0.223, 1.609, 2.302, respectively. Note that the z-spacing between 1000 and 900 mb is 0.105-0=0.105, while the spacing between 200 and 100 mb is 2.302-1.609 = 0.693. So the later spacing is roughly seven times as great as the former.

⋄ Atmospheric Temperature Lines T

Temperature lines (in °C) are skewed (slanted) to the right so that following a vertical line upwards on the graph (like following a rising air parcel) will indicate a decrease in temperature as usually observed in the atmosphere.

⋄ Potential Temperature Curves θ

The potential temperature of the parcel is the temperature it would have if it were moved, dry adiabatically, to the 1000 mb pressure level. The formula for θ as a function the parcel's actual temperature T (in K) and the parcel's pressure P (in mb or hPa) is

$$\theta = T\left(\frac{1000}{P}\right)^{R/c_p} ,$$

where $R = R_d = 287$ JK^{-1}kg^{-1}, and $c_p = c_{pd} = 1004$ JK^{-1}kg^{-1}.

The potential temperature (in °C) curves on the chart represent the dry adiabatic cooling (warming) an unsaturated parcel would experience if it were moved up (down) in the atmosphere.

⋄ Saturation Mixing Ratio Lines W_s

The saturation mixing ratio W_s of a parcel is the ratio of its water vapor mass to its dry air mass at saturation (evaporation rate = condensation rate). The temperature at which these rates are in equilibrium is the dew point temperature. Consequently, the dew point of a rising air parcel can be tracked using a constant saturation mixing ratio line W_s.

W_s is a function of the parcel's temperature, the greater (lesser) the temperature, the greater (lesser) the saturation mixing ratio W_s. Because the parcel temperature decreases as pressure decreases in a standard atmosphere, the saturation mixing ratio W_s must decrease with elevation. Therefore, the constant mixing ratio lines slant rightward to account for the decrease in saturation mixing ratio as pressure decreases.

As a parcel of air is lifted from the surface, its mixing ratio will <u>not</u> change as long as there is no change in the parcel's vapor mass, a valid assumption in the absence of phase change. However, as the parcel is lifted (pressure decreases), its dew point temperature <u>will</u> decrease (at an average rate of about 2 °C per 1000 m), but not as quickly as its temperature decreases. Consequently, continued lifting will result in the parcel's temperature, eventually, decreasing to its dew point temperature and condensation of parcel vapor begins. If the parcel is lifted further, its mixing ratio decreases because its vapor mass is decreasing as further condensation occurs.

◇ **Equivalent Potential Temperature Curves θ_e**

The equivalent potential temperature θ_e is the temperature a parcel would have if it were moved to the 1000 mb level and all of its vapor mass were to condense and warm the dry constituents of the parcel. An approximate formula for determining θ_e is

$$\theta_e = T_e \left(\frac{1000}{P}\right)^{R/c_p} = \left(T + \frac{L_v}{c_p} W\right) \left(\frac{1000}{P}\right)^{R/c_p}$$

The quantity $T_e = T + \frac{L_v}{c_p} W$ is called the "equivalent temperature" of the parcel. The terms L_v and W represent the latent heat of vaporization (or condensation, the value is 600 cal/gm) and the parcel's mixing ratio, respectively.

For a completely dry parcel (mixing ratio $W = 0$), the equivalent potential temperature is equal to the potential temperature. The θ_e curves on the thermodynamic chart represent the "moist" adiabats, or the curves one would use to determine the parcel's temperature once the lifted parcel reaches its dew point.

The θ_e value of a parcel is determined from the skew-T chart in the following way: Identify the parcel's temperature and dew point at a given pressure level. Lift the parcel along the dry adiabat until it reaches saturation. After saturation, continue to lift the parcel along the moist adiabat until the moist and dry adiabats run parallel. Now, follow the dry adiabat to determine the parcel temperature at 1000 mb. This is θ_e for the parcel.

◇ **Wet-bulb Potential Temperature θ_W**

The wet-bulb temperature of a parcel is the temperature that results after complete evaporational cooling at constant pressure. It is found on the chart by lifting the parcel along a dry adiabat until saturation. Next, the parcel is returned along the moist adiabat to its original pressure level. The wet-bulb potential temperature is found the same way as the wet-bulb temperature except the wet-bulb temperature is moved along the moist adiabat to the 1000-mb level. Wet-bulb potential standardizes wet-bulb temperature thus allowing for direct comparison of wet bulb temperature at different pressure levels.