ESCI 341 – Meteorology
Lesson 18 – Use of the Skew-*T* Diagram
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Reference: *The Use of the Skew T, Log P Diagram in Analysis And Forecasting*, AWS/TR-79/006, U.S. Air Force, revised 1979 (Air Force Skew-*T* Manual)
An Introduction to Theoretical Meteorology, Hess

SKEW-*T*/LOG *P* DIAGRAM

- **Uses $-R_d \ln p$ as the vertical coordinate**
  - **Since pressure decreases exponentially with height, this coordinate means that the vertical coordinate roughly represents altitude.**
- **Uses $T - K \ln p$ as the horizontal coordinate (*K* is an arbitrary constant).**
  - **This means that isotherms, instead of being vertical, are slanted upward to the right with a slope of (K).**
- **With these coordinates, adiabats are lines that are semi-straight, and slope upward to the left.**
  - ***K* is chosen so that the adiabat-isotherm angle is near 90°.**
- **Areas on a skew-*T*/log *p* diagram are proportional to energy per unit mass.**
- **Pseudo-adiabats (moist-adiabats) are curved lines that are nearly vertical at the bottom of the chart, and bend so that they become nearly parallel to the adiabats at lower pressures.**
- **Mixing ratio lines (isohumes) slope upward to the right.**

USE OF THE SKEW-*T*/LOG *P* DIAGRAM

- **The skew-*T* diagram can be used to determine many useful pieces of information about the atmosphere.**
- **The first step to using the diagram is to plot the temperature and dew point values from the sounding onto the diagram.**
  - **Temperature (T) is usually plotted in black or blue, and dew point (T_d) in green.**
- ***Stability***
  - **Stability is readily checked on the diagram by comparing the slope of the temperature curve to the slope of the moist and dry adiabats.**
- ***Mixing ratio* (r)**

- **Once the sounding is plotted, mixing ratio at a given level in the atmosphere is determined by locating the value of the mixing ratio line that runs through the dew point value at that level.**
- ***Saturation mixing ratio* (r_s)**
    - **Saturation mixing ratio is determined by locating the value of the mixing ratio line that would runs through the temperature value at that level.**
- ***Relative humidity***
    - **The relative humidity is determined by dividing the mixing ratio by the saturation mixing ratio.**
- ***Lifting condensation level (LCL)***
    - **The LCL is defined as the level at which an air parcel at the surface, if lifted dry adiabatically, would reach saturation.**
    - **To find the LCL, begin with the surface temperature, and follow the adiabat through the surface temperature upward to where it would cross the isohume that runs through the surface dew-point temperature. The pressure at which they cross is the *lifting condensation level*.**
    - **The LCL is roughly where you would expect cloud bases to be if the mechanism for upward motion were due to mechanical lifting (such as through orographic lifting, frontal wedging, or convergence).**
- ***Convective condensation level (CCL)***
    - **The CCL is the level at which you would expect to find the bases of convective clouds.**
    - **There are two methods for finding the CCL**
    - ***Method 1 – The mixing method***
        - **Find the average mixing ratio in the lowest 50 mb or so (by inspecting the dew-point line), and follow this mixing ratio line up to where it intersects the temperature sounding.**
    - ***Method 2 – The parcel method***
        - **Follow the mixing ratio line that passes through the surface dewpoint up to where it intersects the temperature sounding.**
        - **This is sometimes called the *mixing condensation level*.**

- **These methods will give you roughly the same answer, but not exactly the same answer.**
  - **The mixing method is more appropriate for finding the bases of deep convective clouds, such as thunderstorms**
  - **The parcel method is appropriate for finding the bases of shallow convective clouds.**
- **The convective temperature is found by following the adiabat from the CCL to the surface. This temperature is the temperature at which the surface would have to reach in order for convective clouds to form.**

- ***Potential temperature* (θ)**
  - **The potential temperature is defined as the temperature the parcel would have if it is moved dry-adiabatically to 1000 mb.**
  - **It is found by following a dry adiabat through the temperature at a given level to a pressure of 1000 mb.**
- ***Equivalent potential temperature* (θ_e)**
  - **The equivalent potential temperature is defined as the potential temperature of the parcel if all of the water vapor in the parcel were condensed and the latent heat of condensation were used to warm the parcel.**
  - **The equivalent potential temperature is found by first lifting the parcel to saturation, then continuing upward along a moist adiabat to the top of the diagram, and finally descending down a dry adiabat to a pressure of 1000 mb.**
- ***Wet-bulb temperature* (T_w)**
  - **The wet-bulb temperature is found by first lifting the parcel to saturation, and then following a moist adiabat back down to the parcel's original level.**
- ***Wet-bulb potential temperature* (θ_w)**
  - **The wet-bulb potential temperature is found the same way as the wet-bulb temperature, except that instead of stopping at the original level, continue down the moist adiabat to 1000 mb.**
- ***Cloud layers* – The following rules are taken verbatim from the U.S. Air Force Skew-*T* Manual:**

- o **A cloud base is almost always found in a layer (indicated by the sounding) where the dew-point depression decreases.**
- o **The dew-point depression' usually decreases to between 0°C and 6°C when a cloud is associated with the decrease. In other words, we should not always associate a cloud with a layer of dew-point decrease but only when the decrease leads to a minimum dew-point depression < 6°C; at cold temperatures (below -25°C), however, dew-point depressions in cloud are reported as > 6°C.**
- o **The dew-point depression in a cloud is, on the average, smaller for higher temperatures. Typical dew-point depressions are 1°C to 2°C at temperatures of 0°C and above, and 4°C between -10°C and -20°C.**
- o **The base of a cloud should be located at the base of the layer of decreasing dew-point depression, if the decrease is sharp.**
- o **If a layer of decrease of dew-point depression is followed by a layer of stronger decrease, the cloud base should be identified with the base of the layer of strongest decrease.**
- o **The top of a cloud layer is usually indicated by an increase in dew-point depression. Once a cloud base is determined, the cloud is assumed to extend up to a level where a significant increase in dew-point depression starts. The gradual increase of dew-point depression with height that occurs on the average in a cloud is not significant.**

CONVECTIVE AVAILABLE POTENTIAL ENERGY (CAPE)

- **CAPE is the maximum energy available to an air parcel.**
- **Newton's second law for an air parcel can be written as (where prime indicates a property of the air parcel)**

$$\frac{dw}{dt} = \frac{\rho - \rho'}{\rho'} g \, .$$

- **Substituting from the ideal gas law for moist air we get**

$$\frac{dw}{dt} = \frac{\rho - \rho'}{\rho'} \left(-\frac{1}{\rho} \frac{dp}{dz} \right) = -\left(\frac{1}{\rho'} - \frac{1}{\rho} \right) \frac{dp}{dz} = -R_d \left(T_v' - T_v \right) \frac{d \ln p}{dz} \, .$$

Multiplying by *w* we get

$$w\frac{dw}{dt} = -R_d\left(T_v' - T_v\right)\frac{d\ln p}{dz}w,$$

which is the same as

$$\frac{1}{2}\frac{dw^2}{dt} = -R_d\left(T_v' - T_v\right)\frac{d\ln p}{dz}\frac{dz}{dt},$$

so that

$$d(KE) = -R_d\left(T_v' - T_v\right)d\ln p.$$

- **This says the change in kinetic energy of the air parcel as it rises is proportional to the temperature difference between the parcel and its environment. The total kinetic energy gained between the level of free convection (LFC) and the level of neutral buoyancy (LNB) is called the Convective Available Potential Energy (CAPE) and is found by**

$$CAPE \equiv -R_d\int_{p_{LFC}}^{p_{LNB}}\left(T_v' - T_v\right)d\ln p.$$

- **Since energy in a skew-T diagram is proportional to area, the CAPE is proportional to that area on the skew-*T* diagram between the environmental sounding and the pseudoadiabat connecting the LFC and the LNB (we assume that $T_v \cong T$.**
- **The larger the CAPE, the greater the updraft that can be developed, and the more vigorous the convection can be.**

CONVECTIVE INHIBITION (CIN)

- **Convective inhibition is the energy needed to lift an air parcel from the surface (p_s) to the LFC.**
- **CIN is defined as**

$$CIN \equiv -R_d\int_{p_s}^{p_{LFC}}\left(T_V' - T_v\right)d\ln p.$$