Upper Air Observation

Skew-T Log-P Diagram



- Radiosondes measure
  - Temperature
  - Relative Humidity
  - Wind Direction and Speed
  - Pressure
  - Height



Skew-T/Log-P Diagram

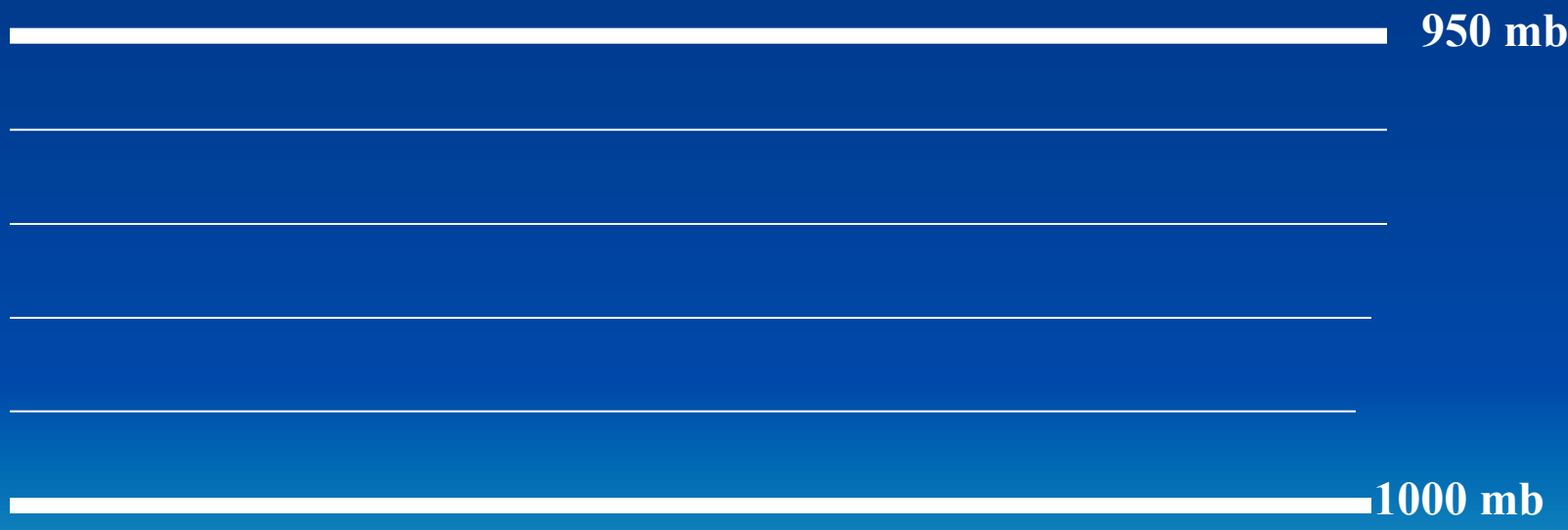
- The most common diagram used to plot rawinsonde soundings and to analyze stability is called the Skew-T/Log-P diagram
- Coordinates
  - Pressure decreases logarithmically
  - Temperature skewed at 45° angle
    - Easier to identify stable layers

Skew-T/Log-P Diagram

- Five different variables are plotted on the basic Skew-T/Log-P
  - Isobars
  - Isotherms
  - Dry adiabats
  - Pseudoadiabats
  - Mixing ratios

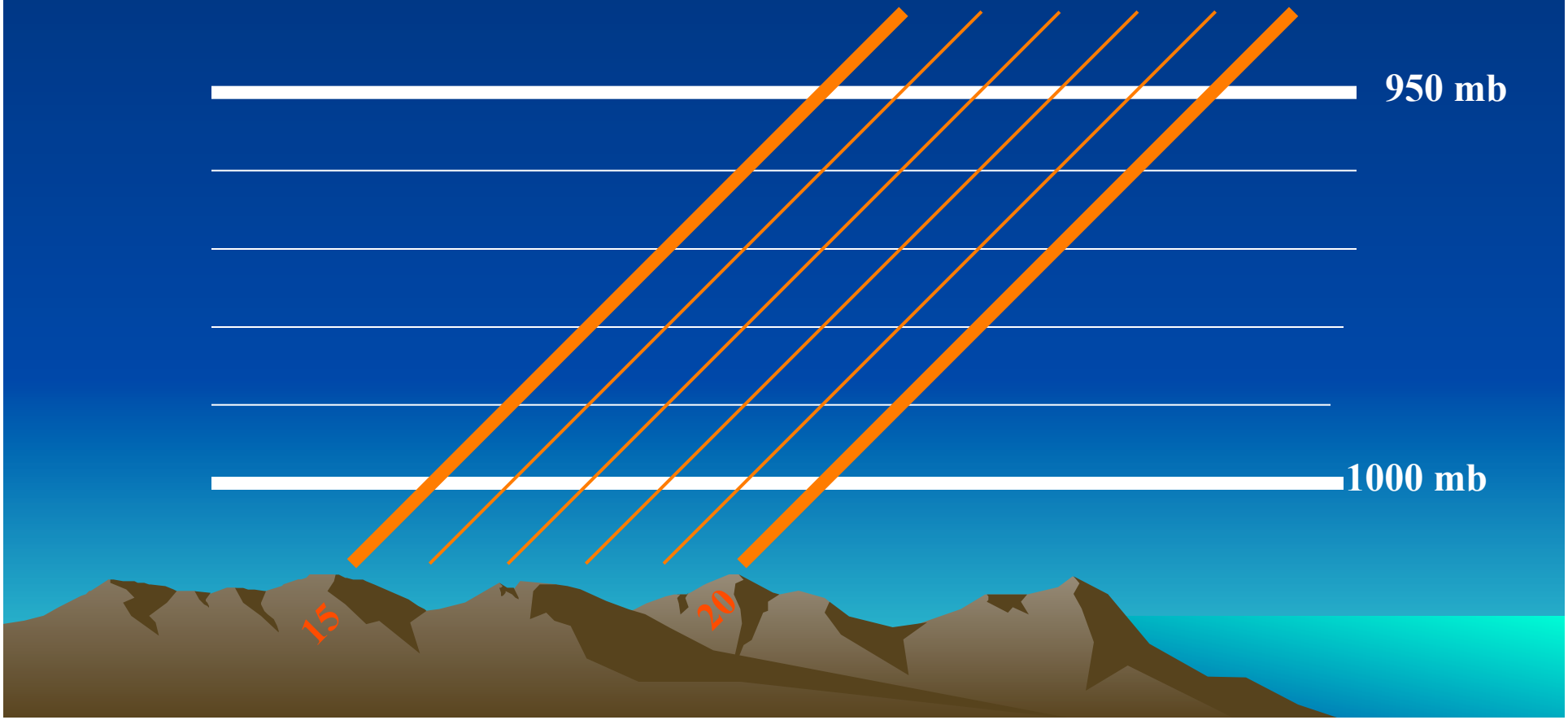
Skew-T/Log-P Diagram

1. Isobars are roughly horizontal lines that represent the pressures on the Skew-T/Log-P. They are plotted every 10 mb and are labeled every 50-100 mb



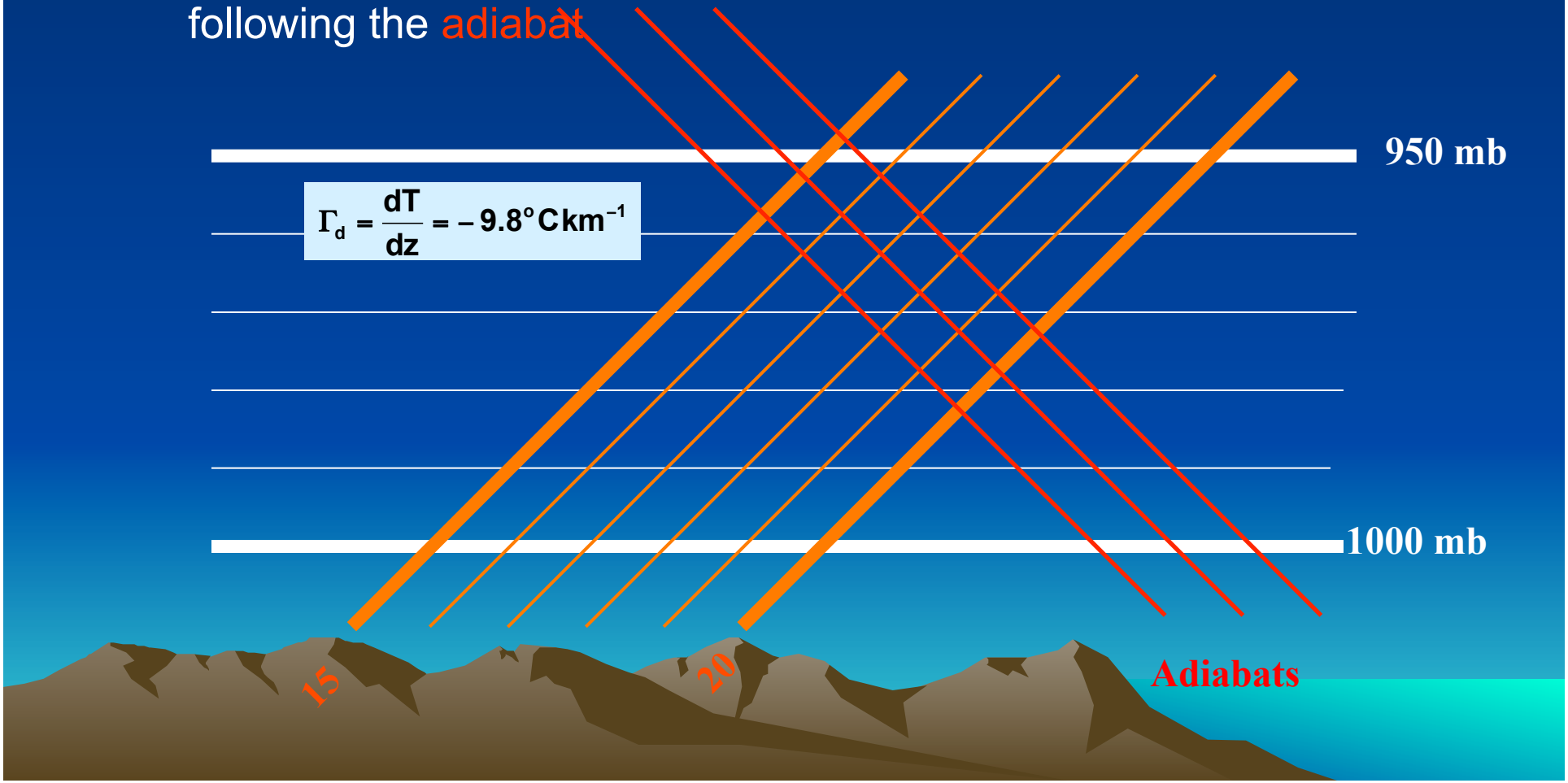
Skew-T/Log-P Diagram

2. Isotherms are nearly straight lines running from the lower left to the upper right that represent the temperatures. Both temperatures and dew point temperatures are plotted using the isotherms. Isotherms are plotted every 1°C and are labeled every 5°C.



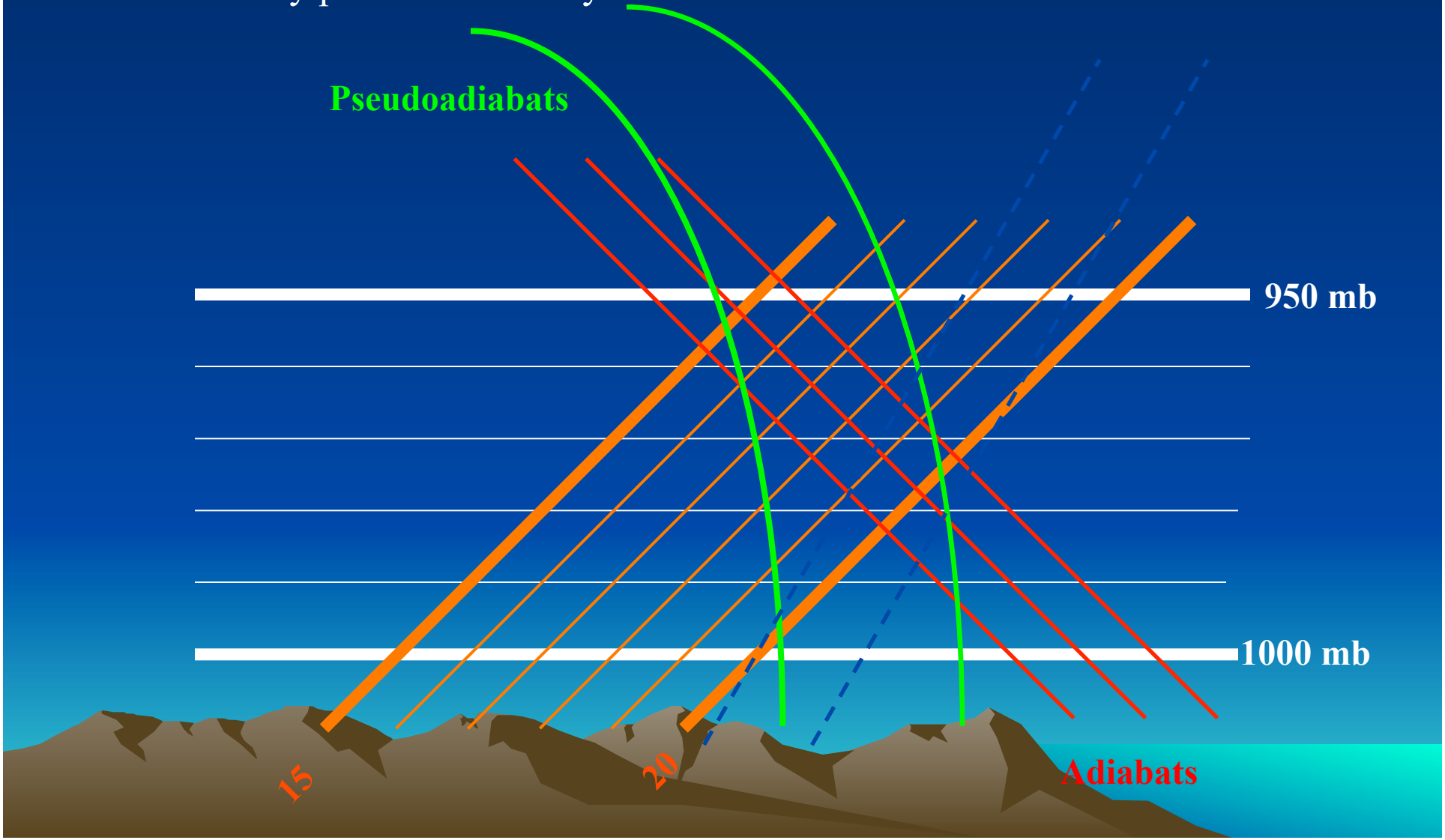
Skew-T/Log-P Diagram

3. Dry adiabats are nearly straight curves running from the lower right to the upper left that represent the Dry Adiabatic Lapse Rate. Unsaturated air parcels move vertical along the adiabats as they are lifted or sink. The temperature of an unsaturated air parcel moving vertically during and adiabatic process can be determined by following the adiabat



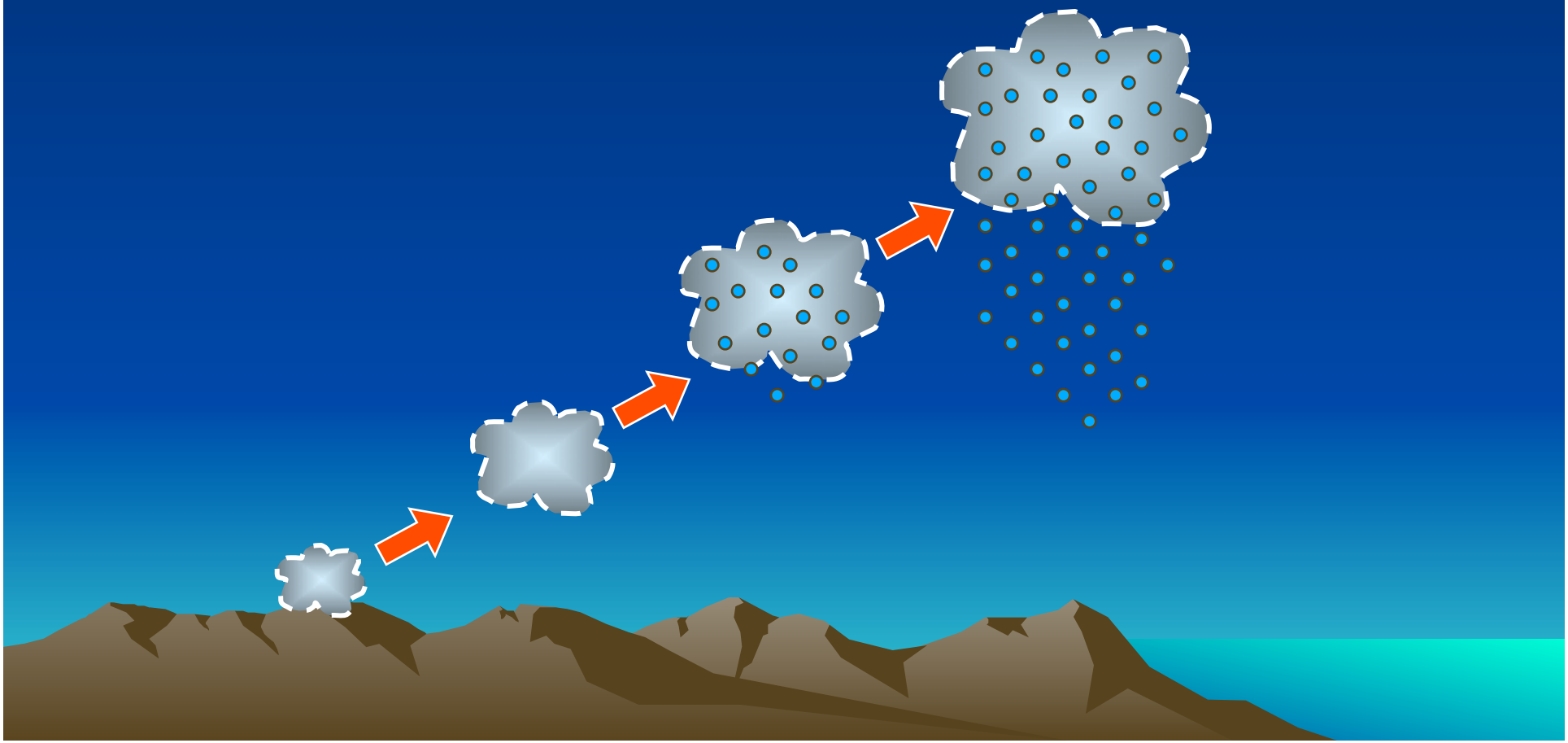
Skew-T/Log-P Diagram

4. Pseudoadiabats are curves running from the bottom of the diagram and gradually curving toward the upper left that ultimately become nearly parallel to the dry adiabats.



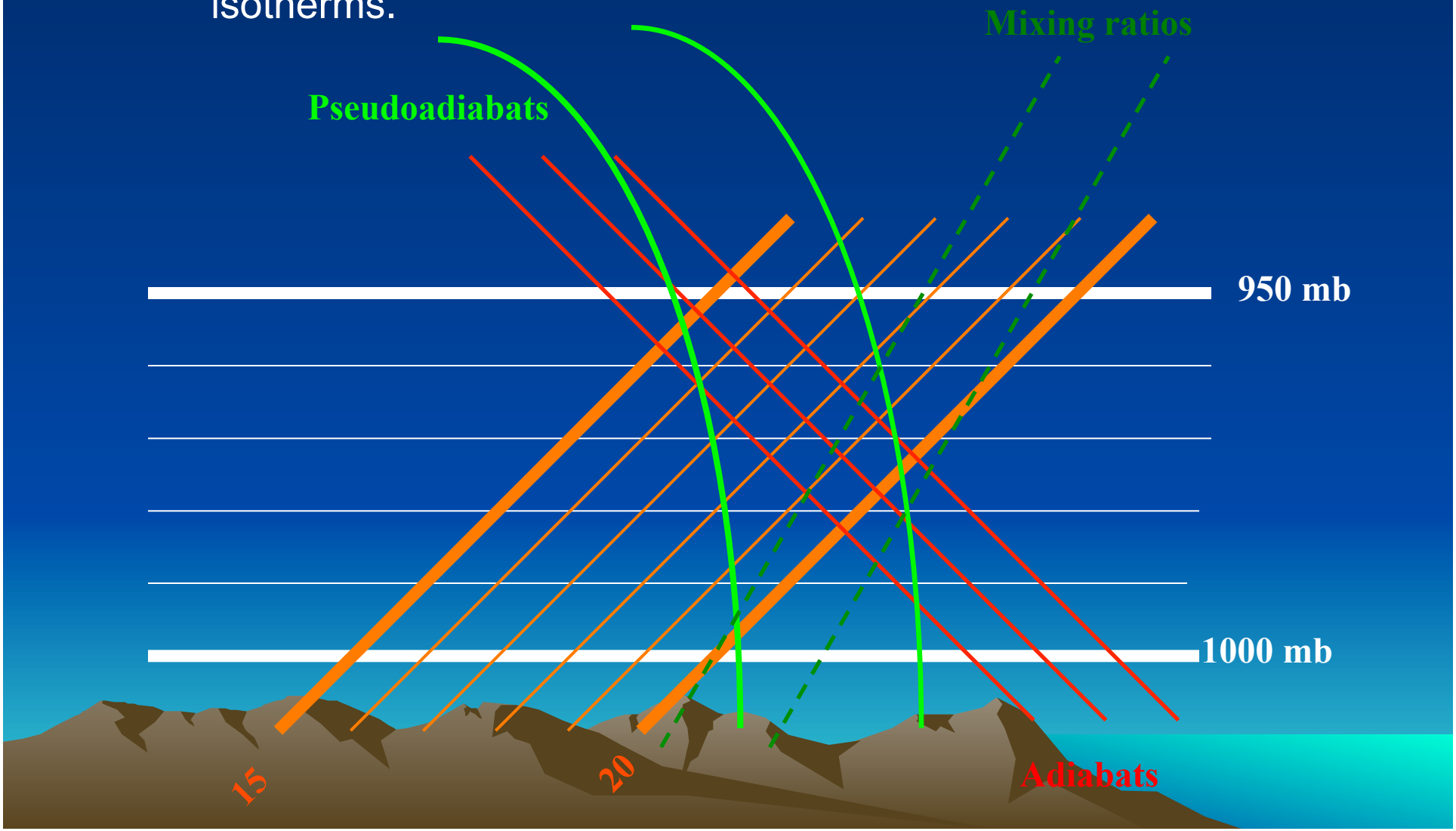
Skew-T/Log-P Diagram

- Pseudoadiabats represent the Saturated Adiabatic Lapse Rate (lines of constant saturated adiabatic lapse rate).
- The change in temperature of saturated air parcels moving vertically occurs along the pseudoadiabats.

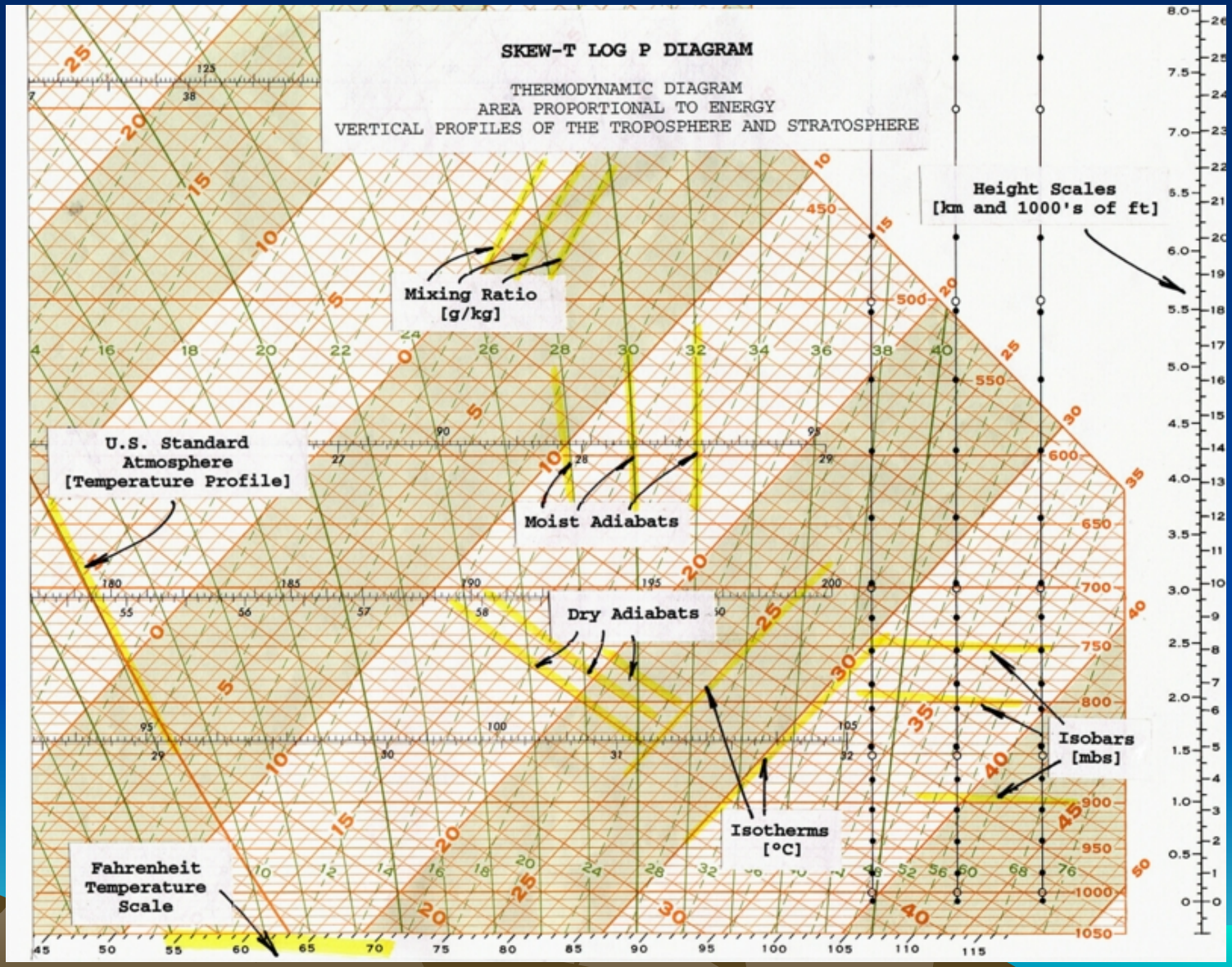


Skew-T/Log-P Diagram

5. The mixing ratios are also plotted as straight dashed lines running from the lower left to upper right more steeply than the isotherms.



Skew-T/Log-P Diagram



Skew-T/Log-P Diagram

- Skew-T/Log-P advantages
  - Determine stability, instability, weather elements at every layer (such as severe weather).
  - Used in numerical weather prediction models

- Skew-T/Log-P disadvantages
  - Temporal resolution (only available twice a day (00Z & 12Z), i.e., weather can change dramatically between soundings
  - Sounding does not give a true vertical dimension & instantaneous measurements

Soundings on Skew-T/Log-P Diagram

- One of the most basic uses of a SKEWT diagram is to plot temperatures and dew point temperatures observed by radiosondes in order to display and analyze the vertical structure of the atmosphere.

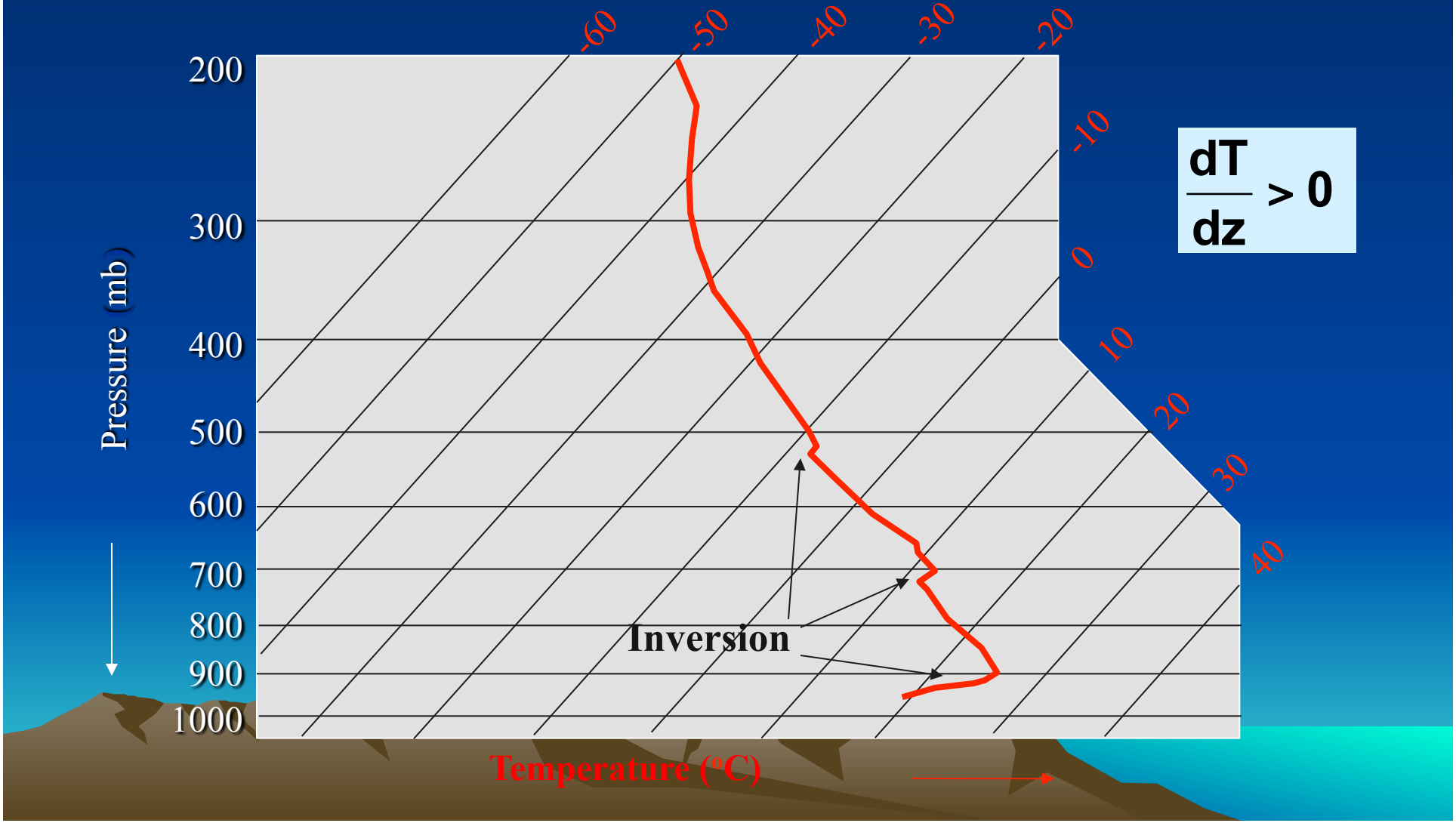


Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Useful Parameters of Skew-T/Log-P
  - Temperature Inversion
  - Precipitation Type
  - Tropopause height
  - Freezing Level
  - Clouds
  - Thickness of a layer
  - Height of the 1000 mb surface
  - Pressure altitude
  - Density altitude
  - Mixing ratio
  - Saturation mixing ratio
  - Relative humidity
  - Vapor pressure
  - Saturation vapor pressure
  - Potential temperature
  - Wet-bulb temperature
  - Wet-bulb potential temperature
  - Equivalent temperature
  - Equivalent potential temperature
  - Virtual temperature

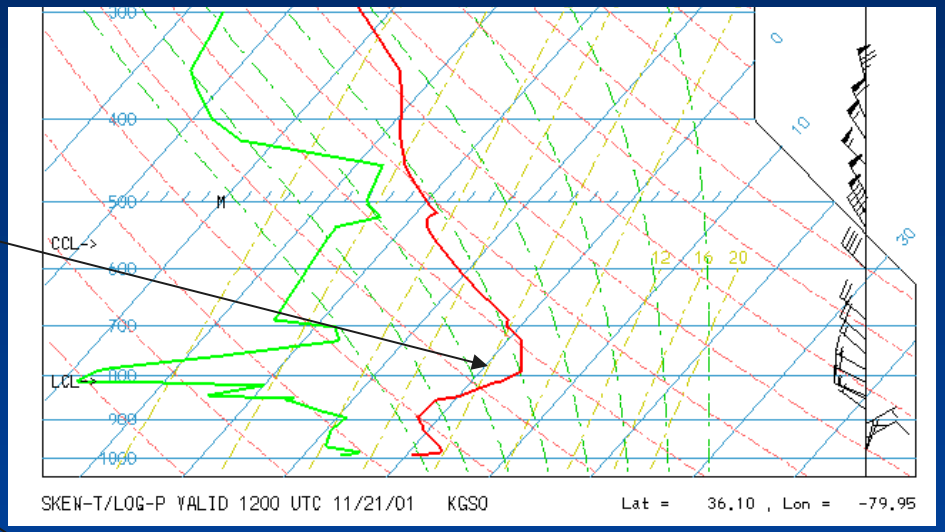
Skew-T/Log-P Diagram
Temperature Inversion

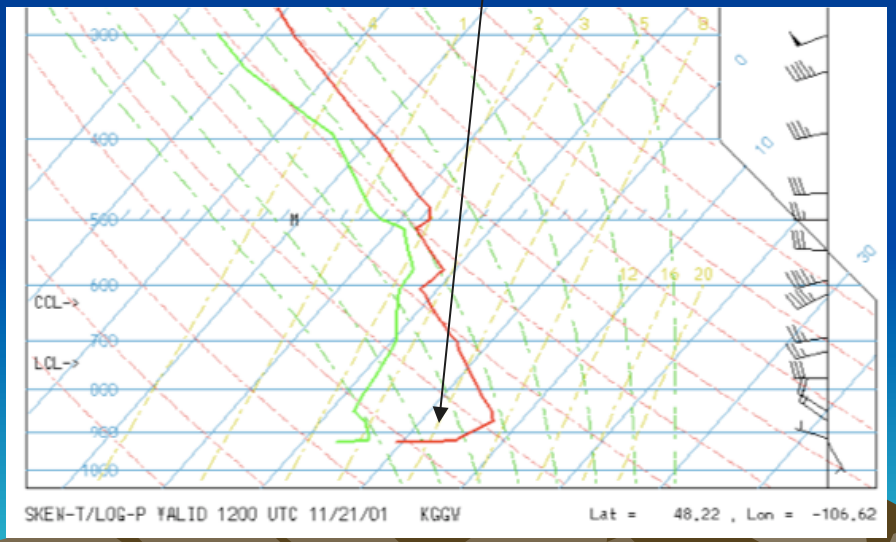
- Increase in temperature with height

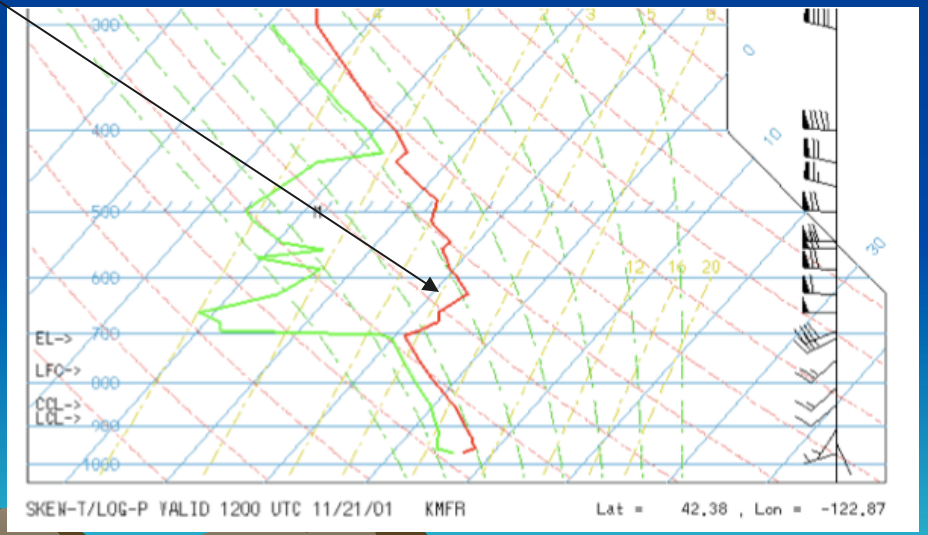


Skew-T/Log-P Diagram
Temperature Inversion

- Types
  - Subsidence
  - Frontal
  - Radiation

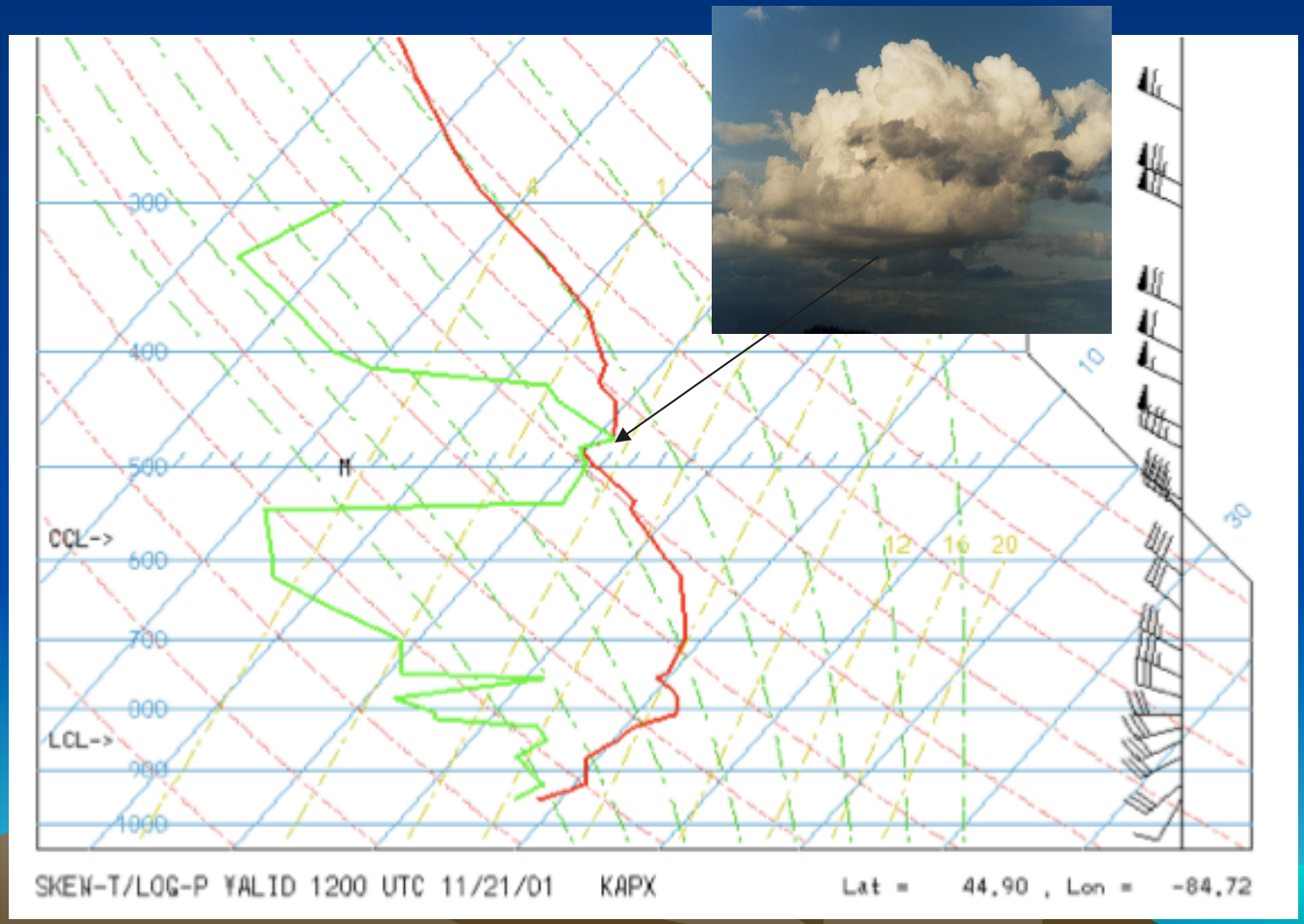






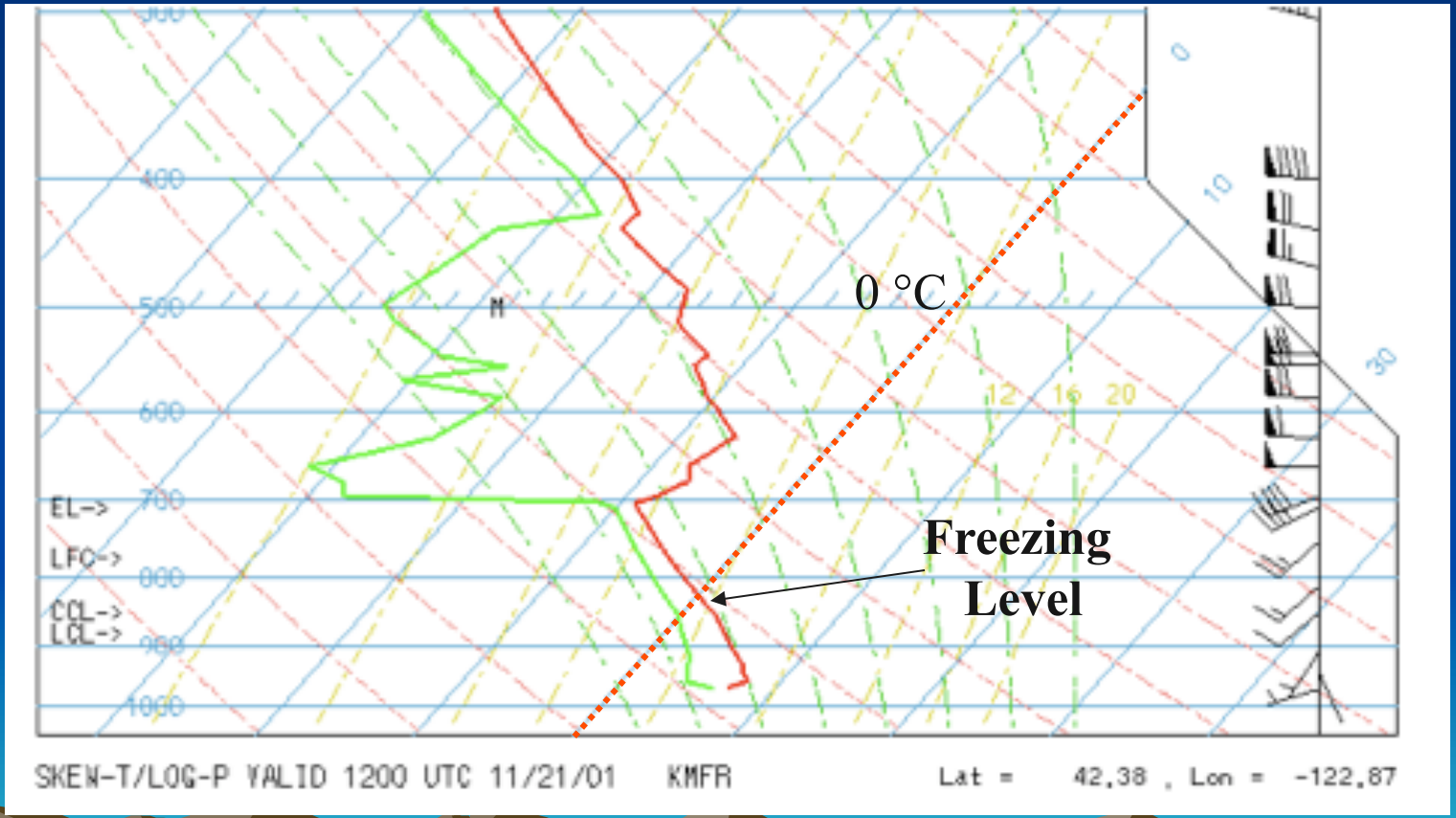
Skew-T/Log-P Diagram
Clouds

- Temperature – Dew Point Temperature
  - Less than 5 °C



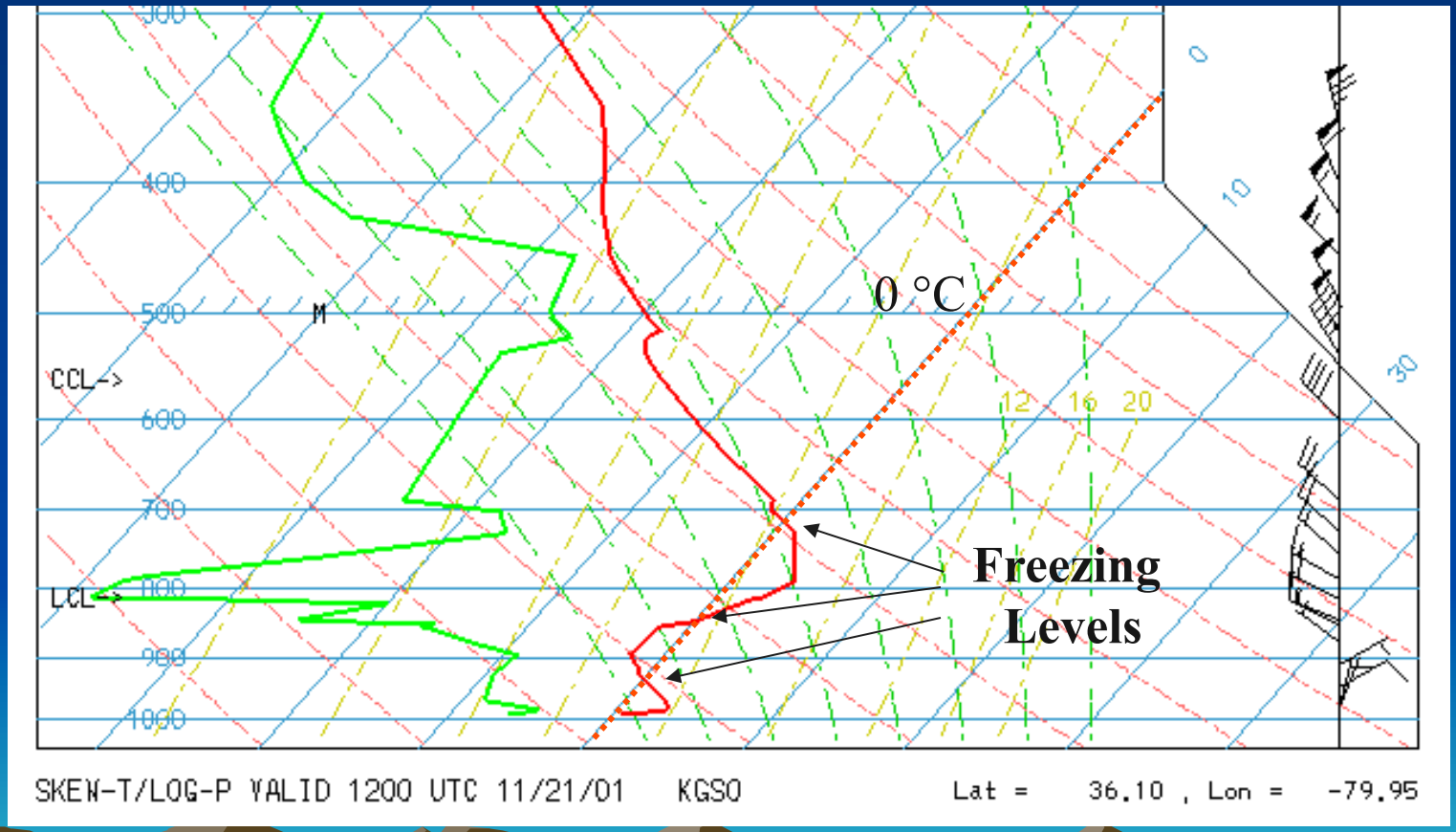
Skew-T/Log-P Diagram
Freezing Level

- Freezing level is the height at which 0 °C occurs in the atmosphere



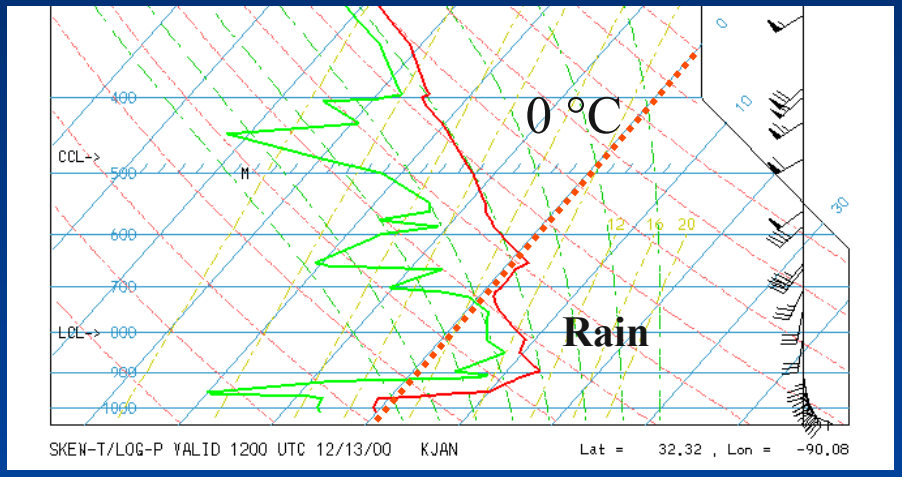
Skew-T/Log-P Diagram
Freezing Level

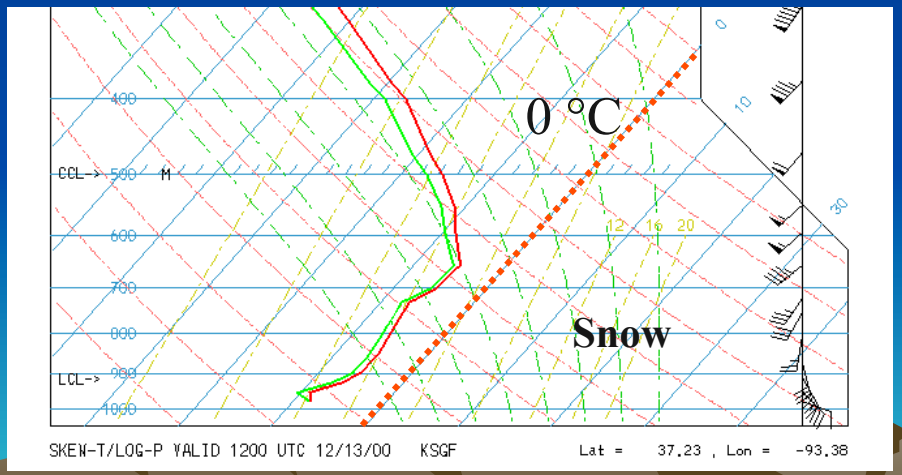
- Multiple freezing levels
- Important in forecasting type of precipitation

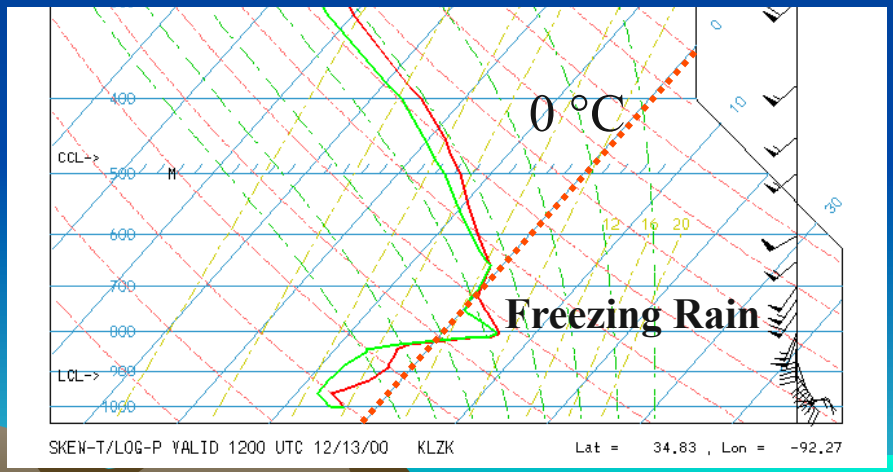


Skew-T/Log-P Diagram
Freezing Level

- Important in forecasting type of precipitation

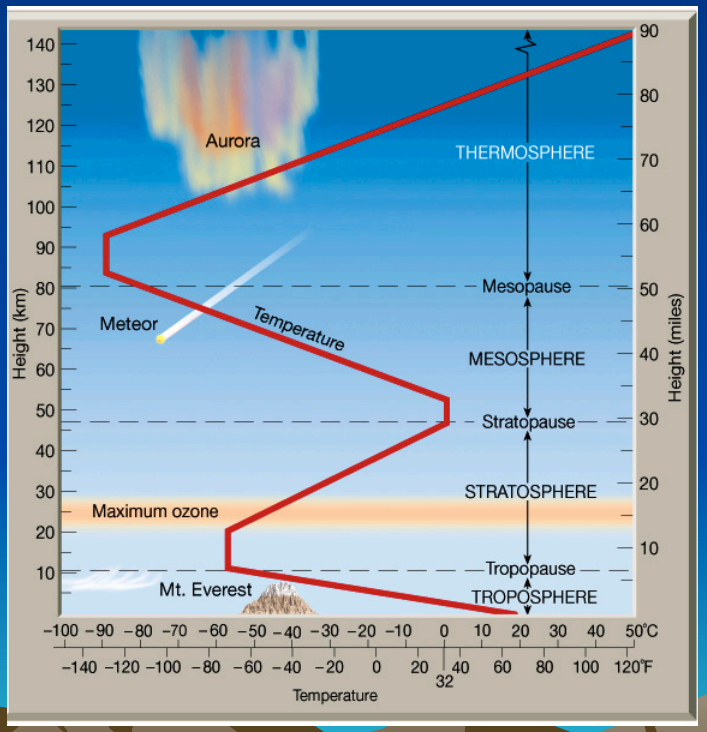


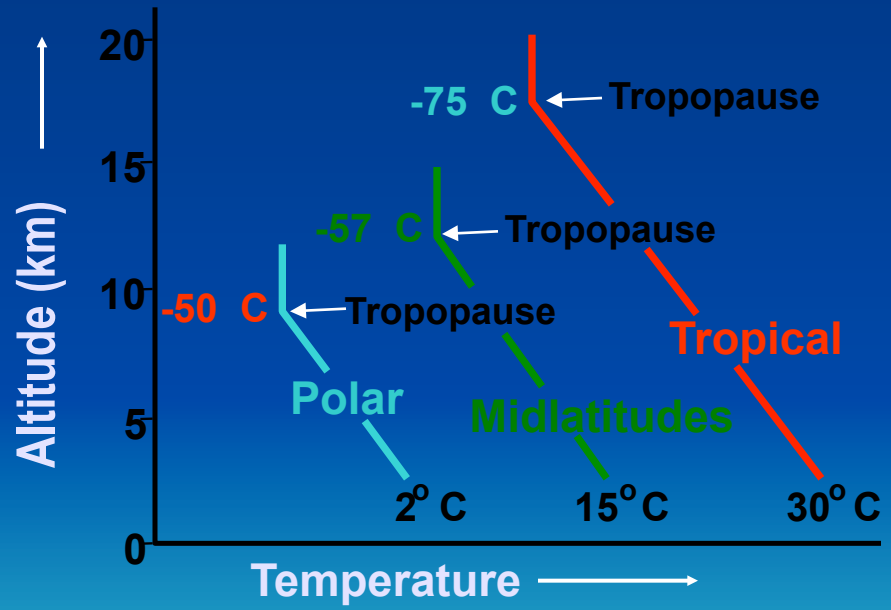




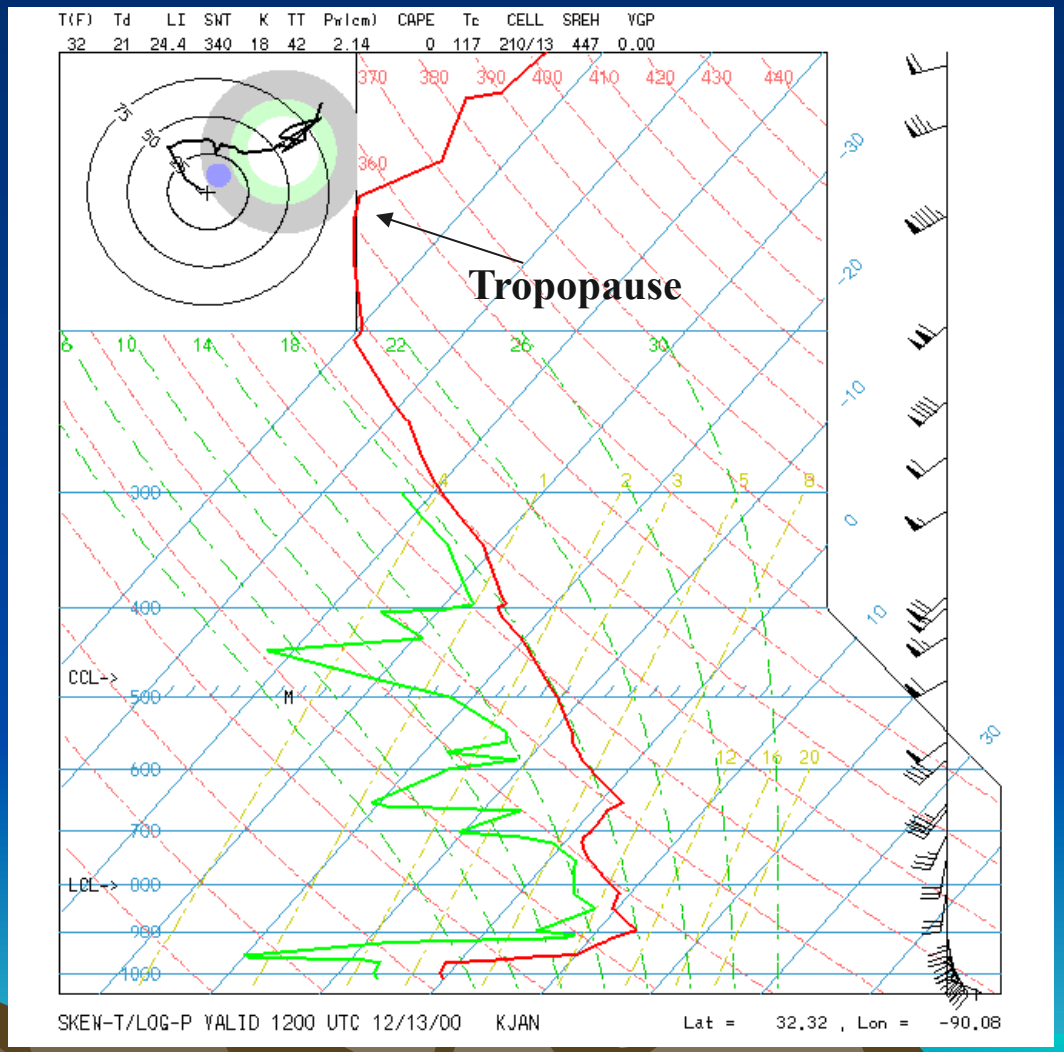
Skew-T/Log-P Diagram
Tropopause

- Top of Troposphere depends on latitude
  - Warmer at Poles
  - Colder at Equator





Skew-T/Log-P Diagram
Tropopause

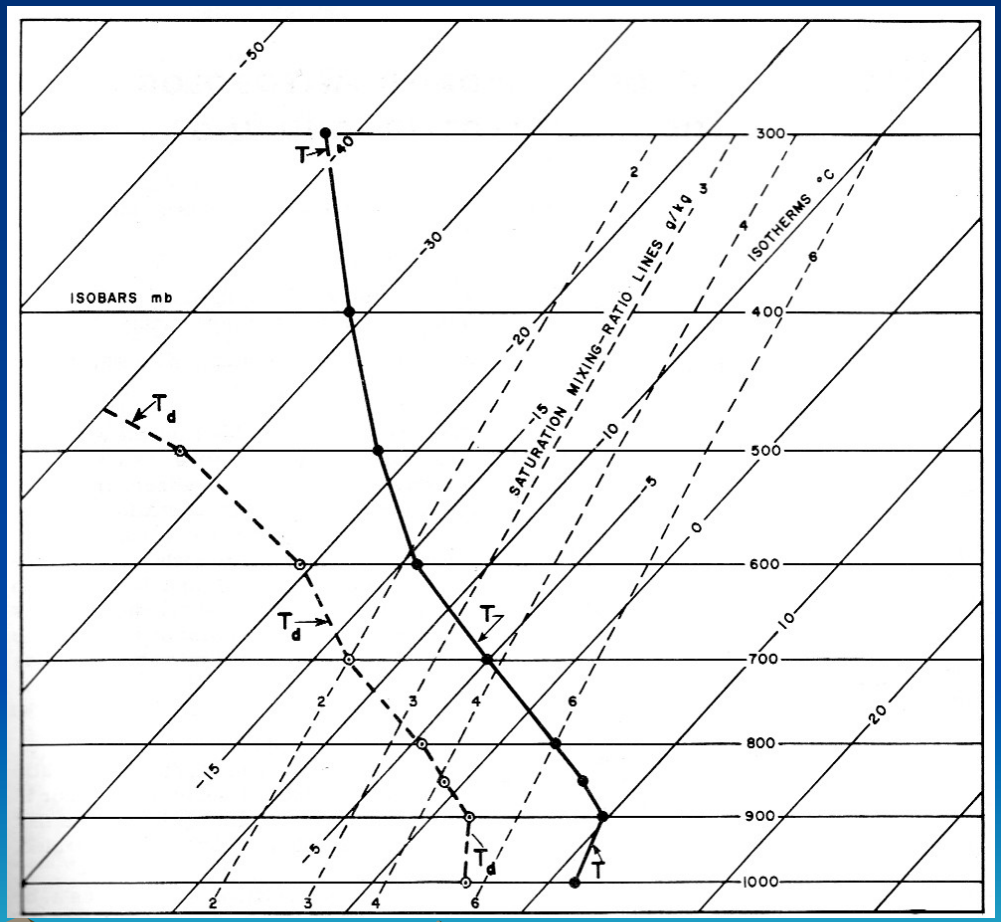


Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Mixing ratio
  - Mixing ratio (w) is the ratio of the mases of water vapor (m_v) to mass of dry air (m_d)

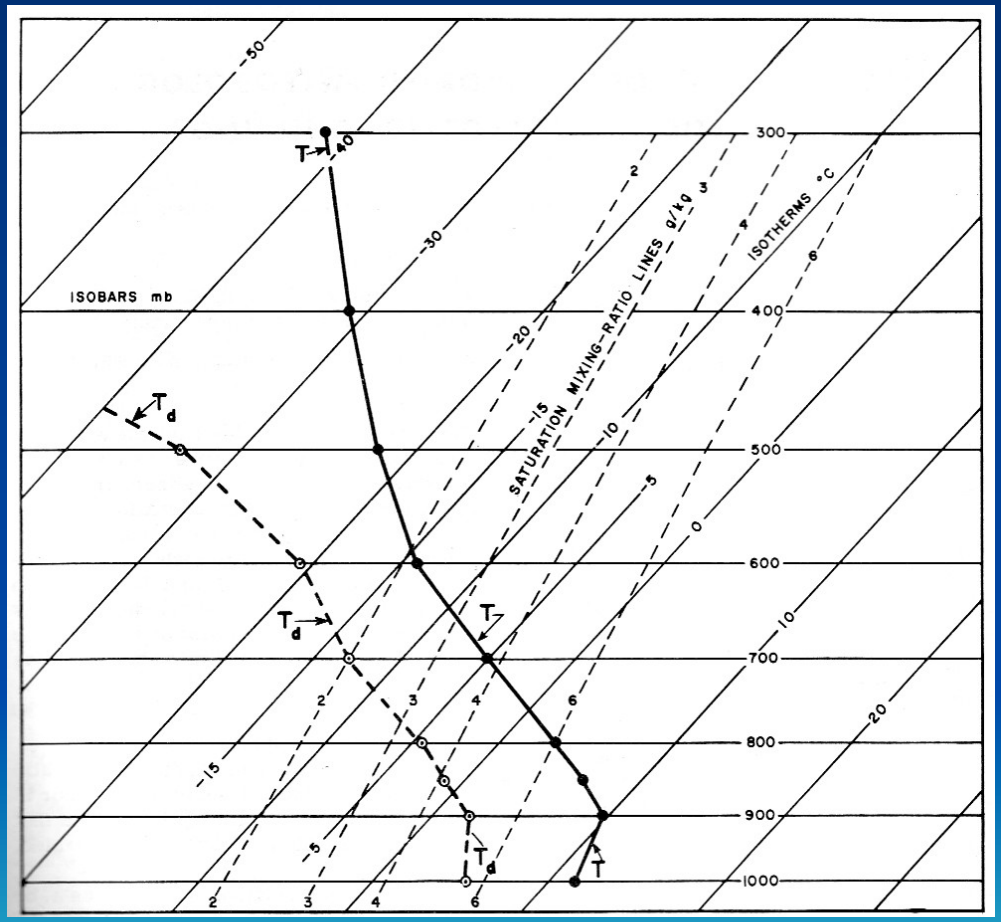
$$w = \frac{m_v}{m_d} \text{ (gm/kg)}$$

- Read the value, either directly or interpolation, of the saturated mixing-ratio line that crosses the T_d curve at an given pressure.
- E.g., mixing ratio of the air at the 700-mb level is 2 gm/kg



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Saturation mixing ratio
  - Saturation mixing ratio (w_s) is the mixing ratio a sample of air would have if saturated
- Read the value, either directly or interpolation, of the saturated mixing-ratio line that crosses the *T* curve at an given pressure.
- E.g., saturation mixing ratio of the air at the 700-mb level is 3.8 gm/kg

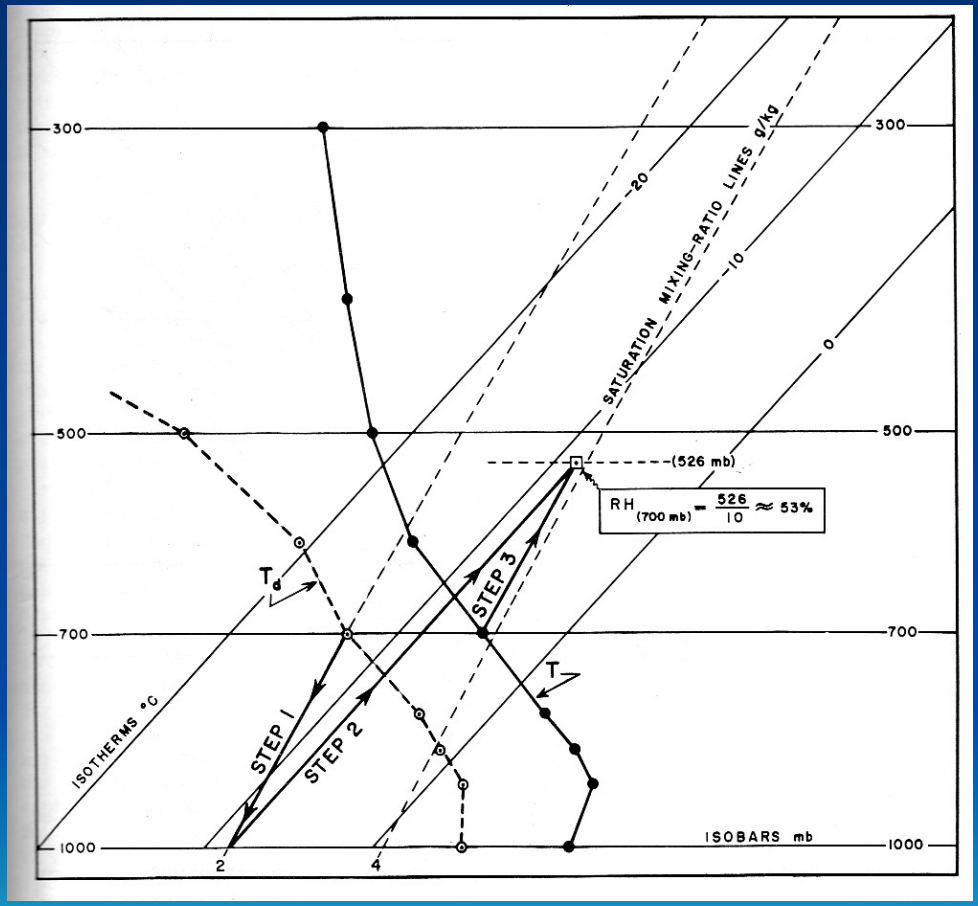


Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Relative humidity
  - Relative humidity (*RH*) is the ratio (in percent) of the amount of water vapor in a given volume of air to the amount that volume would hold if the air were saturated
- Use equation

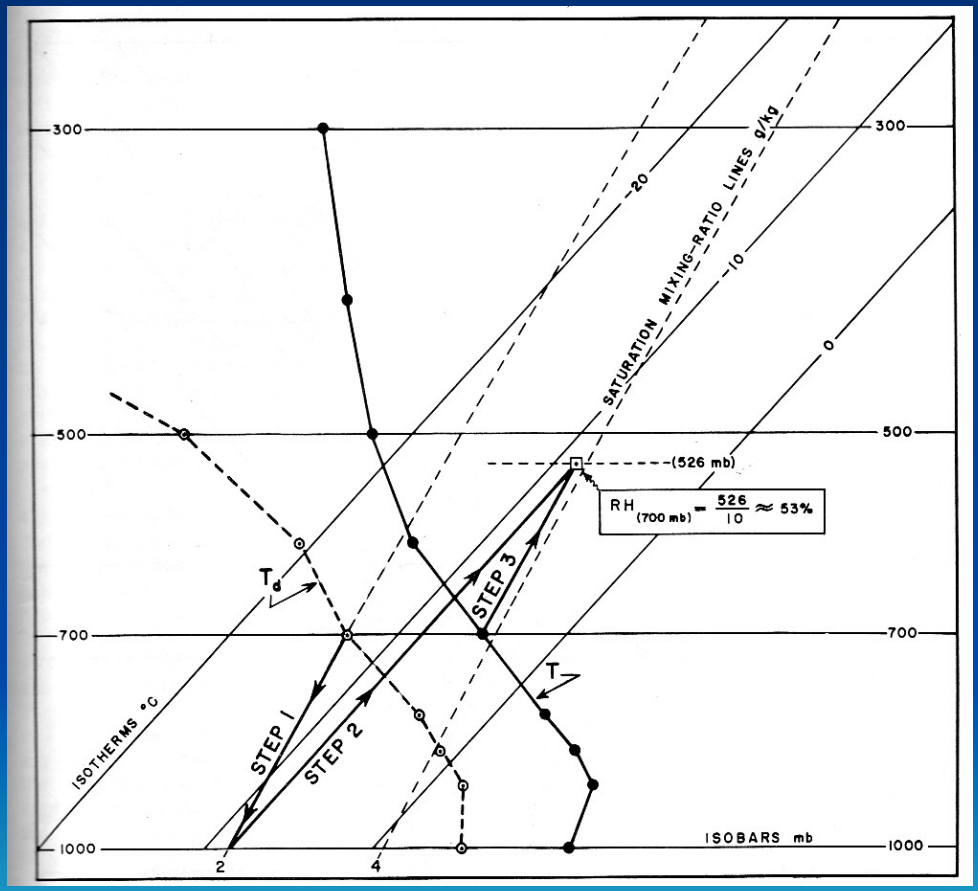
$$RH = 100 \times \left(\frac{w}{w_s} \right)$$

  - E.g., in previous example RH = 100 (2.0/3.8) = 53%



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

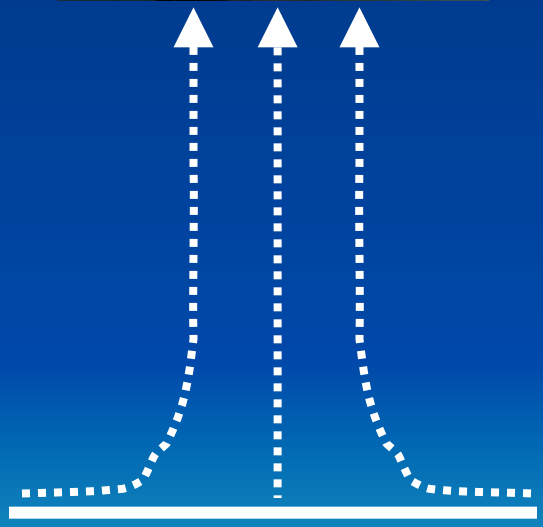
- Relative humidity
- Alternative procedure
  - From the T_d curve at the given pressure, follow the saturation mixing-ratio line to the 1000-mb isobar
  - From this intersection, draw a line parallel to the isotherms
  - From the T curve at the given pressure, follow the saturation mixing-ratio lines to the intersection with the line drawn in Step 2
  - The numerical value of the isobar through this last intersection point is then divided by ten.



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

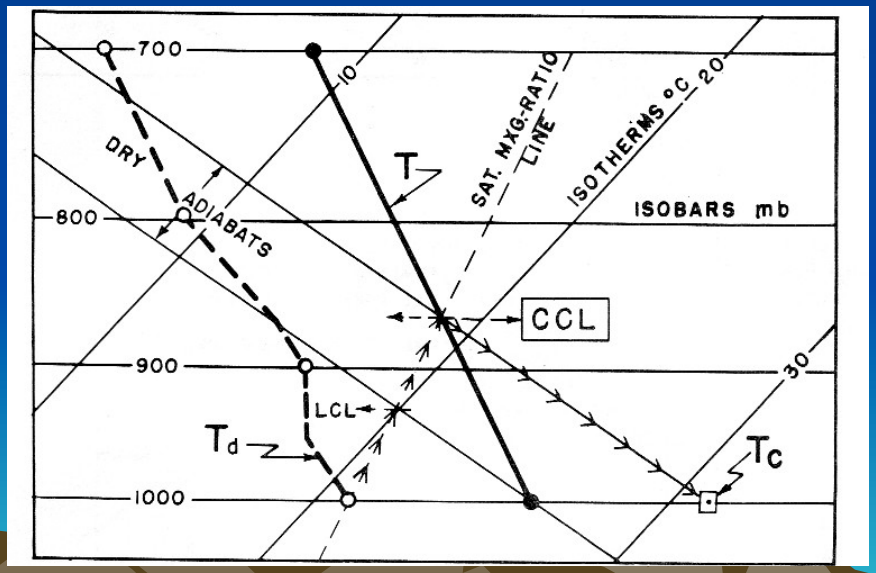
- Convective Ascent (Updraft)
  - Air becomes buoyant by contact with warm ground
  - Usually microscale or mesoscale

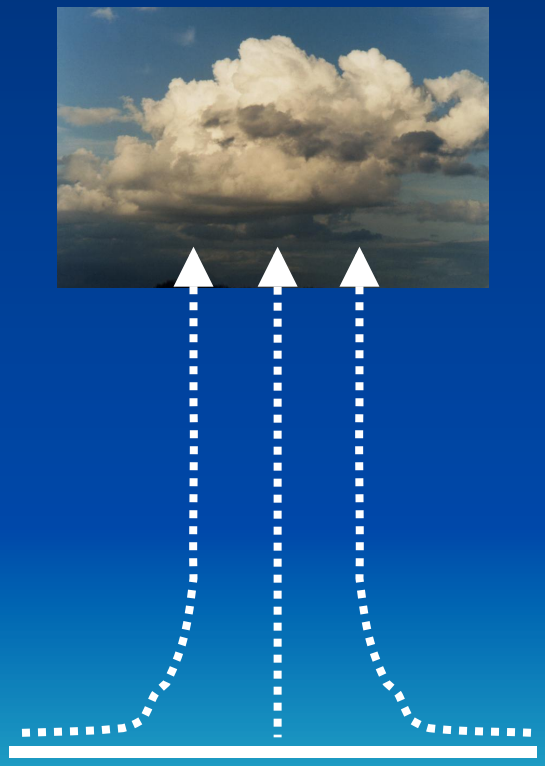




Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

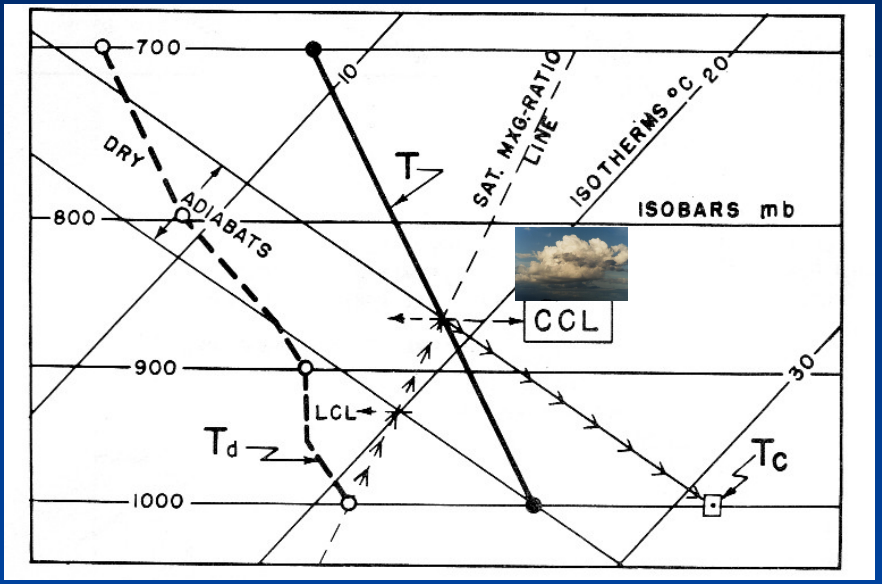
- Convection Condensation Level (CCL)
  - The CCL is the height to which a parcel of air, if heated sufficiently from below, will rise adiabatically until it is just saturated (condensation starts)

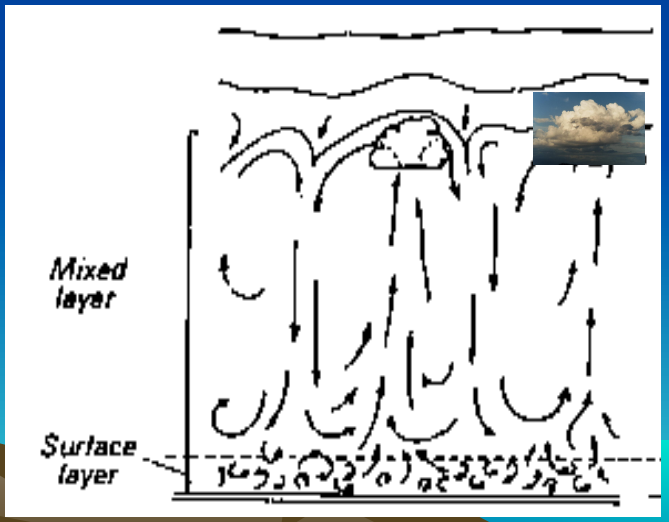




Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

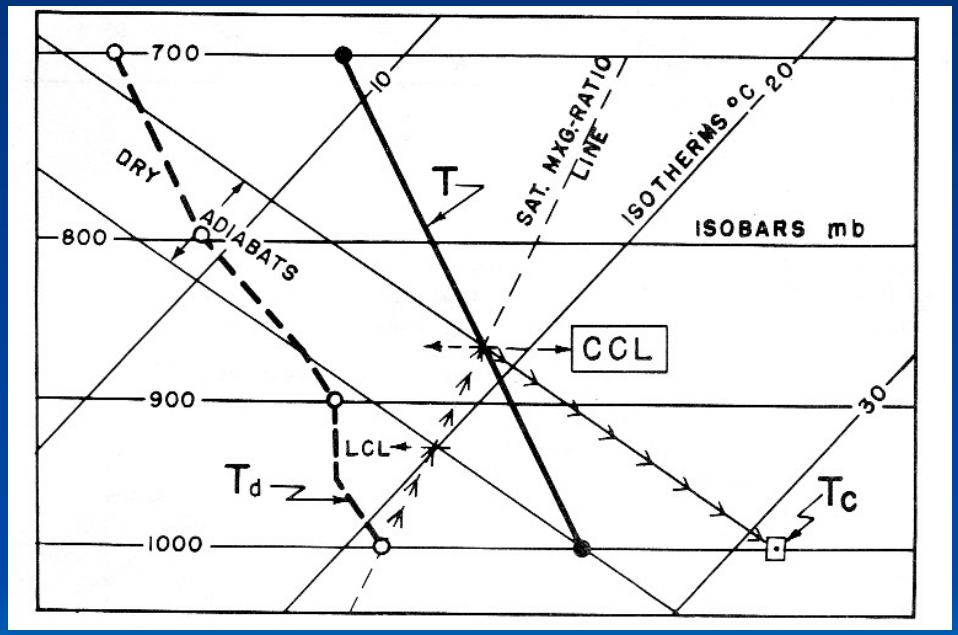
- Convection Condensation Level (CCL)
- Procedure
  - It is the height of the base of cumuliform clouds which are produced by thermal convection solely from surface heating
  - Proceed upward along the saturation mixing-ratio line through the surface dew-point temperature until this line intersects the *T* curve on the sounding





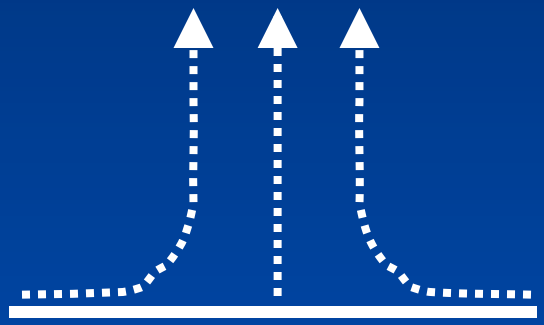
Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Convection Temperature
  - The convection temperature (T_c) is the surface temperature that must be reached to start the formation of convective clouds by solar heating of the surface layer
- Procedure
  - From the CCL point on the T curve of the sounding, proceed downward along the dry adiabat to the surface-pressure isobar.
  - The temperature read at this intersection is the convection temperature (T_c)



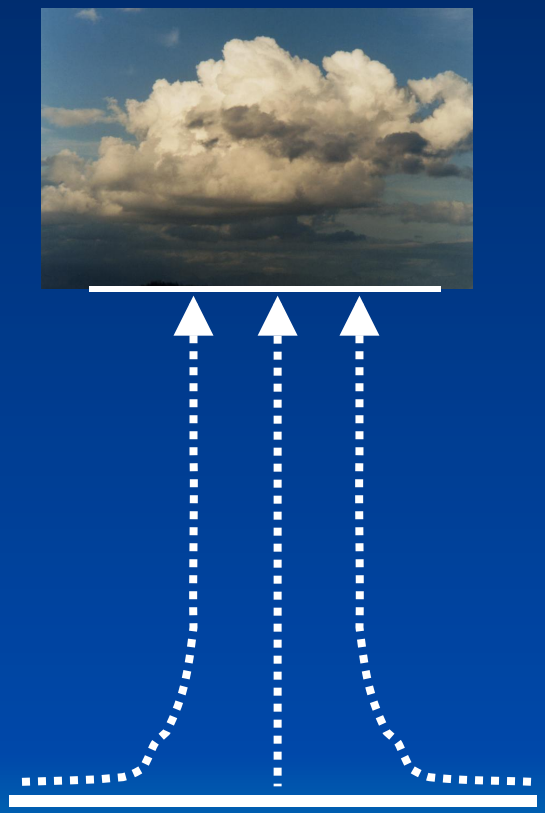
Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Convection Temperature
  - Forecasting thunderstorms (will the afternoon thunderstorms develop?)



$T<T_c$

  - Thermals will form, but will not rise high enough to condense, NO THUNDERSTORMS WILL DEVELOP.



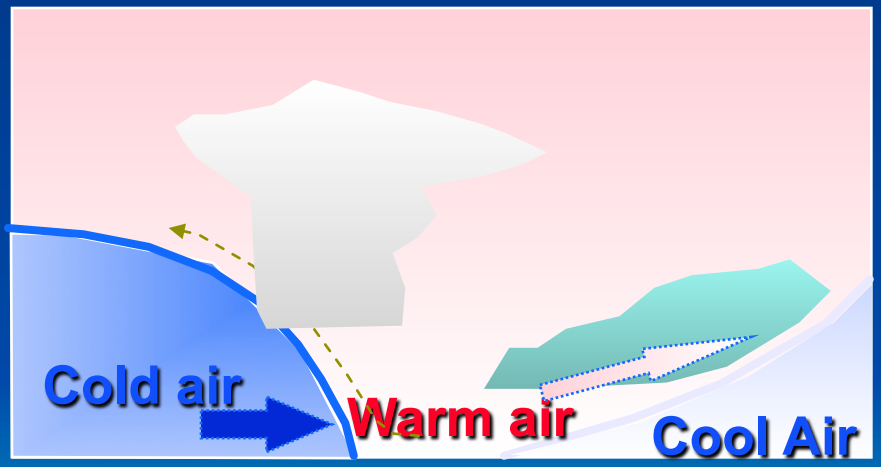
$T>T_c$

  - Thermals will rise high enough to condense, YES POSSIBLY THUNDERSTORMS WILL DEVELOP.

Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Mechanically Forced Ascent (Upward)
  - Some mechanism forces air aloft
  - Usually mesoscale - synoptic scale features





Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

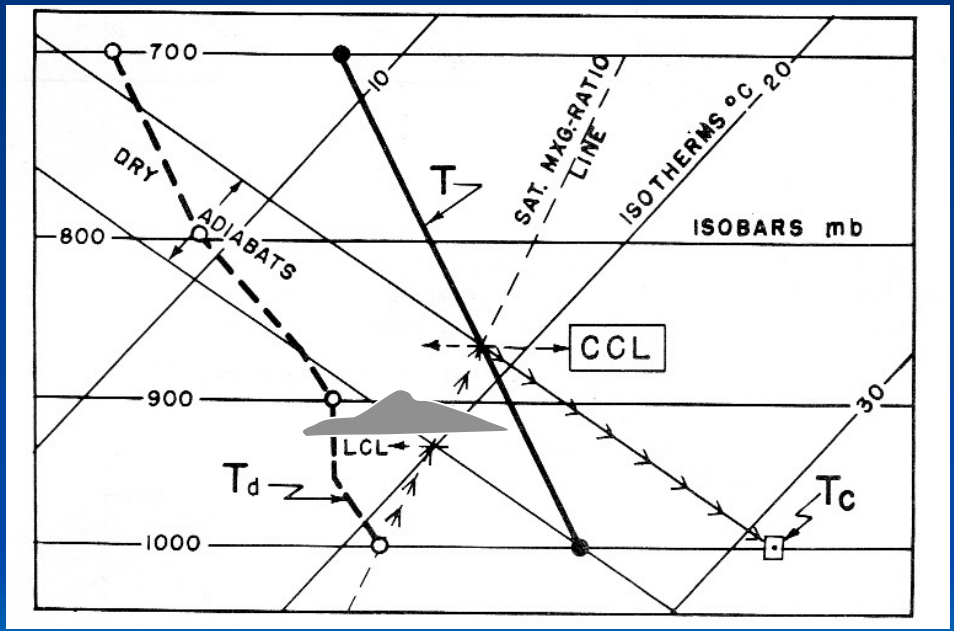
- Mechanically Forced Ascent (Upward)
  - Type of clouds depends on stability
  - Lifting Condensation Level (LCL)
  - Level of Free Convection (LFC)
  - Equilibrium Level (EL)





Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Lifting Condensation Level (LCL)
  - The LCL is the height at which a parcel of air becomes saturated when it is lifted dry adiabatically
  - The LCL for a surface parcel is always found at or below the CCL
- Procedure
  - The LCL is located at the intersection of the saturation mixing-ratio line through the surface dew point temperature with the dry adiabat through the surface temperature

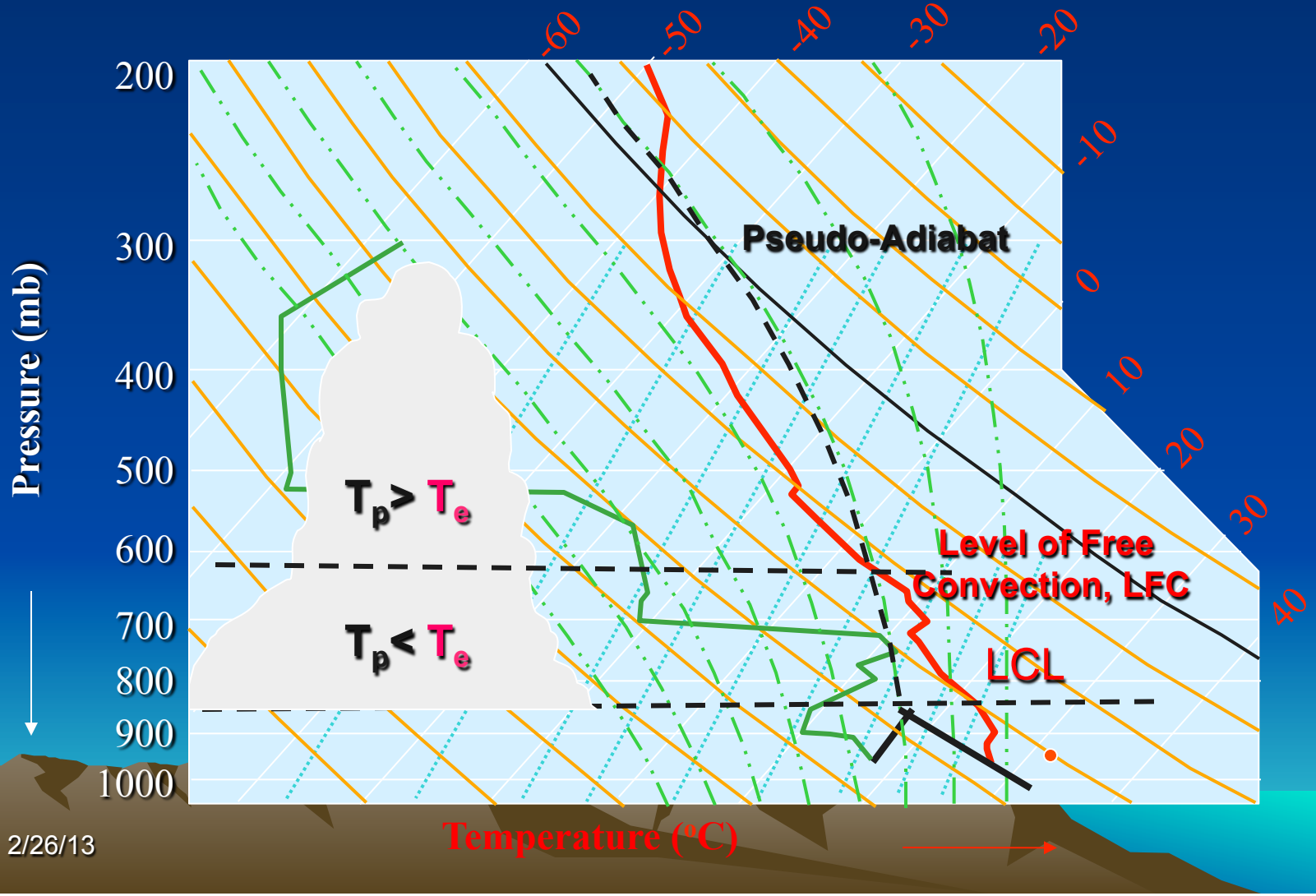


Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Level of Free Convection (LFC)
  - The height at which a parcel of air lifted dry adiabatically until saturated and pseudoadiabatically thereafter would first become warmer (less dense) that the surrounding air
  - The parcel will then continue to rise freely above this level until it becomes colder (more dense) than the surrounding air.

Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Level of Free Convection (LFC)

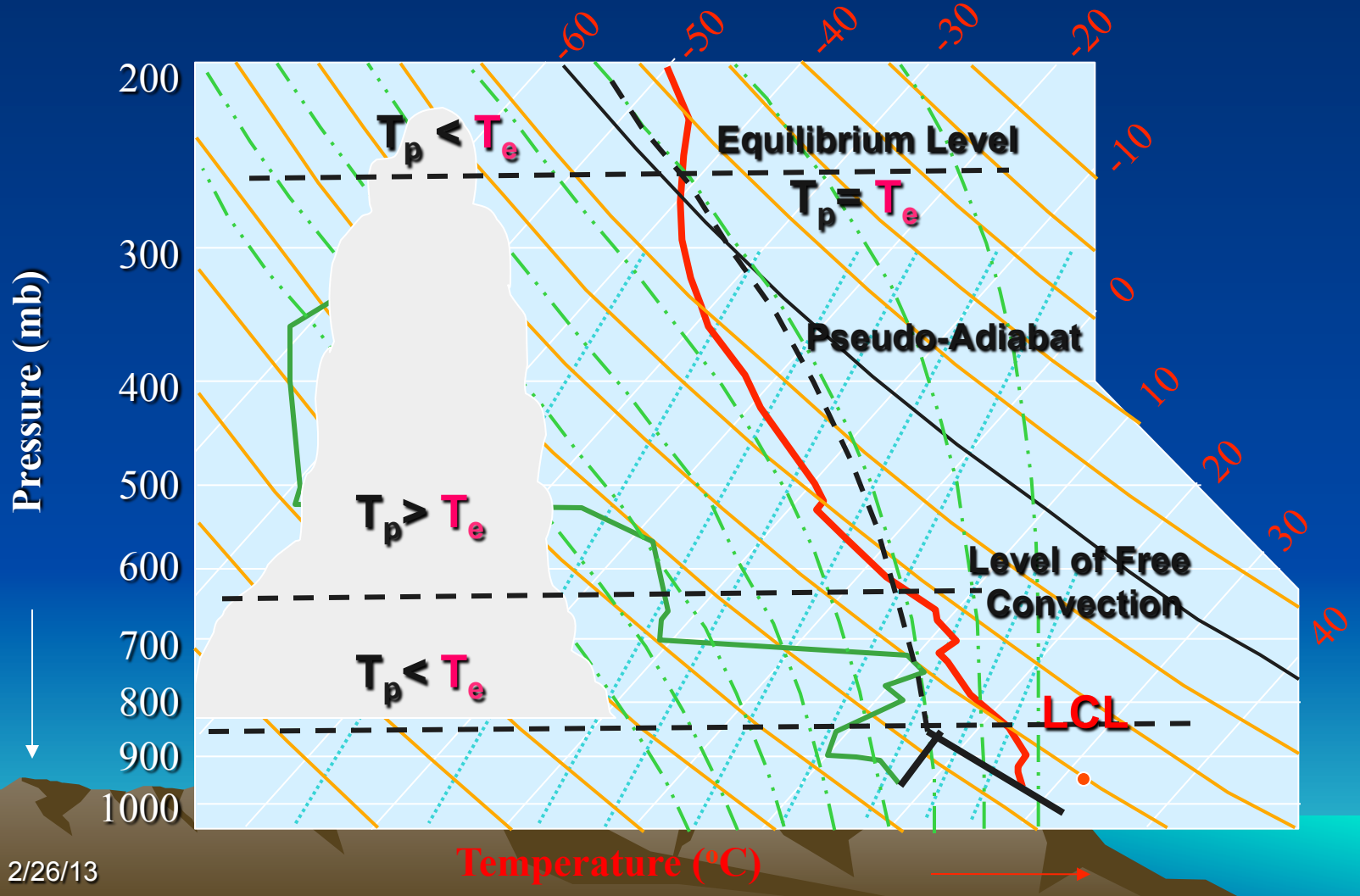


Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Equilibrium Level (EL)
  - The height where the temperature of a buoyantly rising parcel again becomes equal to the temperature of the environment

Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Equilibrium Level (EL)



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

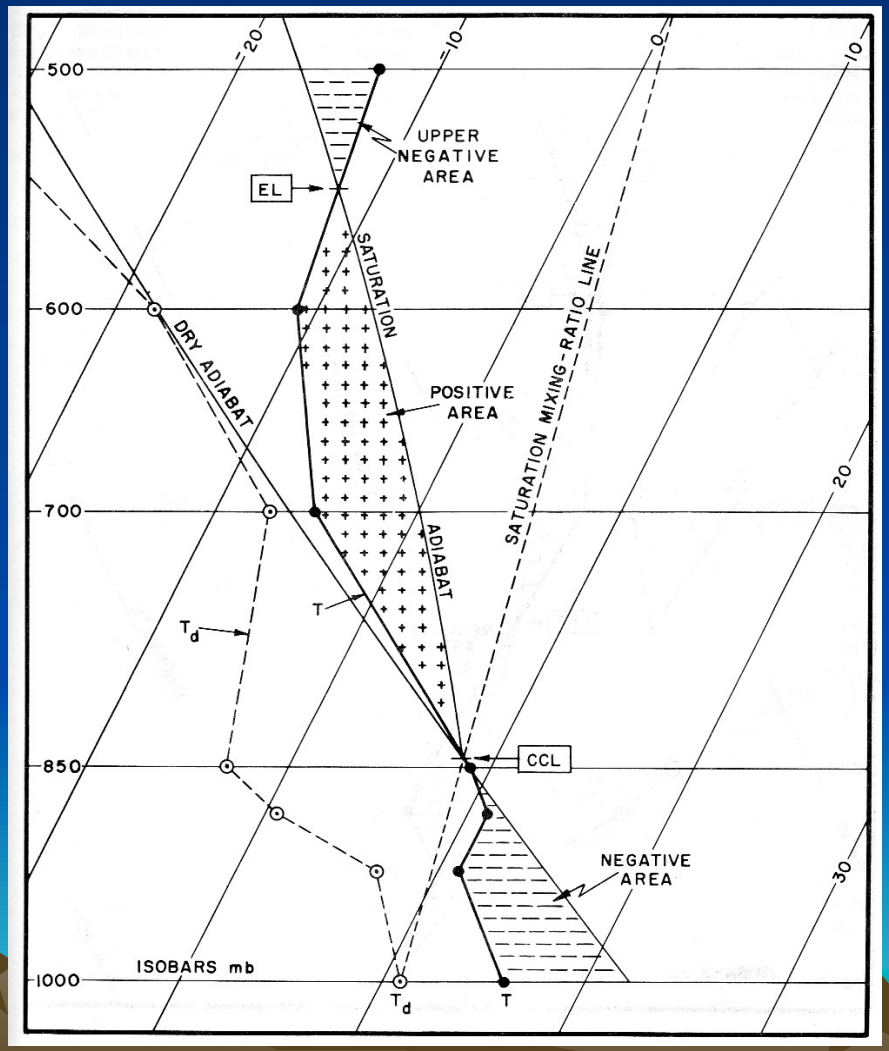
- Positive & Negative Areas
  - On Skew-T/Log-P, a given area can be considered proportional to a certain amount of kinetic energy of a vertically and adiabatically moving air parcel
  - NEGATIVE Area
    - When a parcel on a sounding lies in a stable layer, energy has to be supplied to it to move it either up or down
    - The area between the path of such parcel moving along an adiabat and the sounding curve is proportional to the amount of kinetic energy that must be supplied to move it. This is called negative area.
  - POSITIVE Area
    - When a parcel can rise freely because it is a layer where the adiabat it follows is warmer than the surrounding environment, the area between the adiabat and the sounding is proportional to the amount of kinetic energy the parcel gains from the environment. This is called positive area.

Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Positive & Negative Areas
  - On Skew-T/Log-P, a given area can be considered proportional to a certain amount of kinetic energy of a vertically and adiabatically moving air parcel
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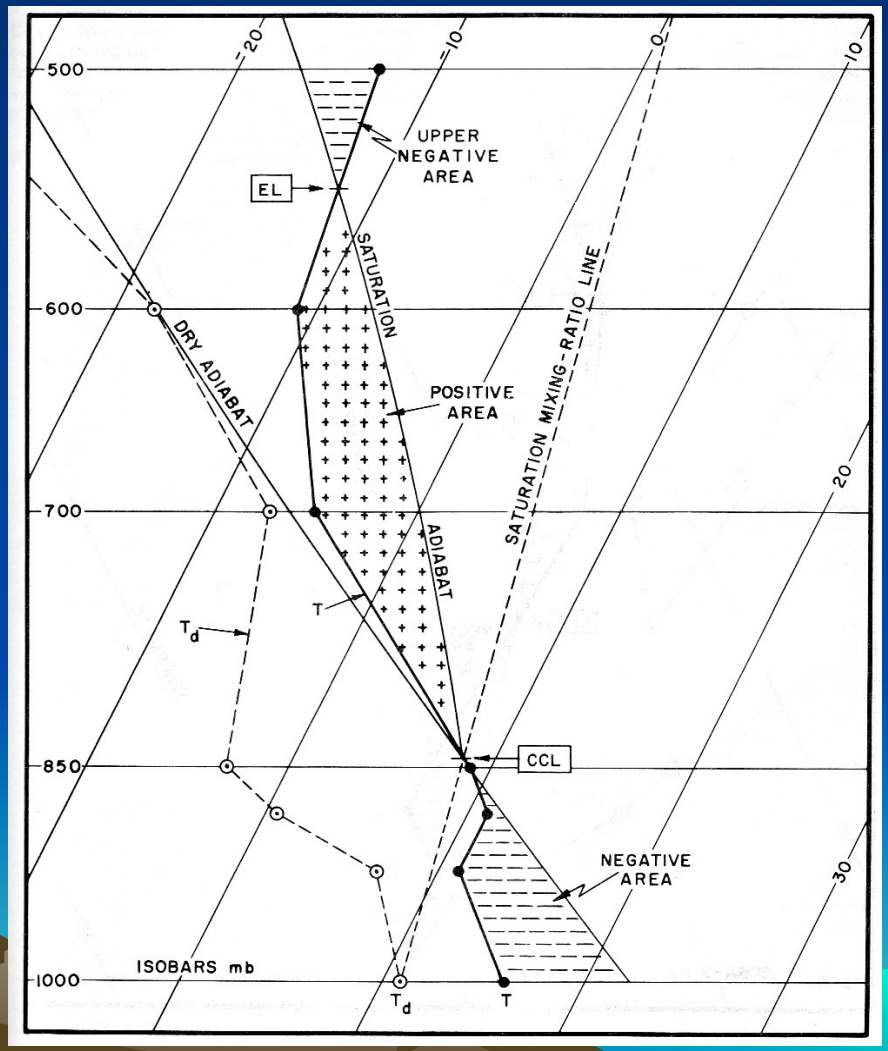
Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Positive & Negative Areas



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Energy Determination on the Skew-T/Log-P
  - One square centimeter (cm^2) area equals 0.280 X 10^6 ergs or 0.0280 joules, per gram of air in the sample



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Lifted Index (LI)
  - Temperature difference between
    - The environmental air at 500 mb and the temperature of an air parcel at 500 mb
      - first lifted dry adiabatically until saturated and then pseudoadiabatically from that level upward

$$LI = T_{500_e} - T_{500_p}$$

LI only provides information about the possible stability/instability of a parcel that is lifted to 500 mb.

Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

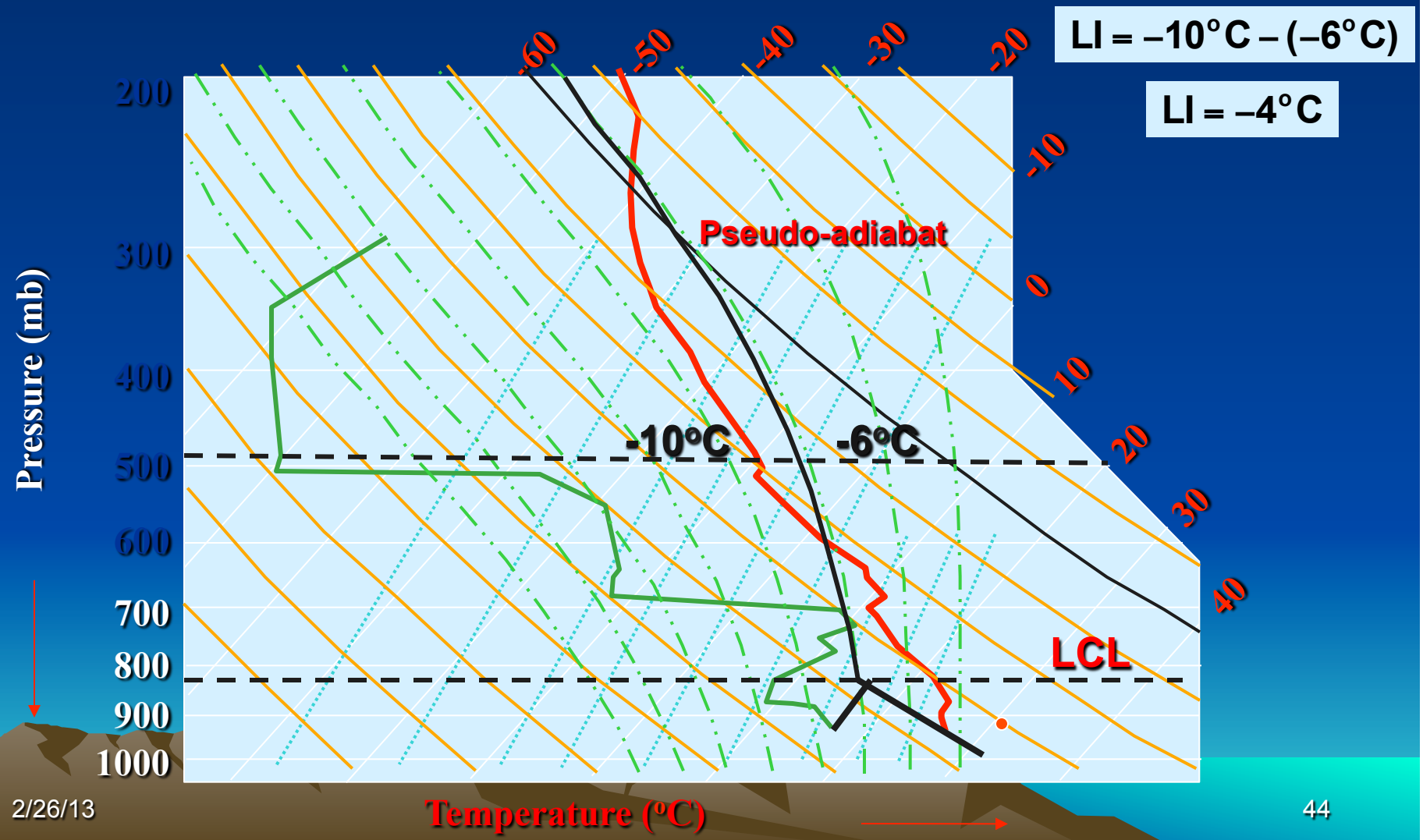
- Lifted Index (LI)
  - Positive – Stable
  - Negative – Unstable

$$LI = T_{500_e} - T_{500_p}$$

– 0 to -2	Thunderstorms possible
– -3 to -5	Unstable – Thunderstorms Probably
– Less than -5 potential	Very unstable – Heavy to strong thunderstorm

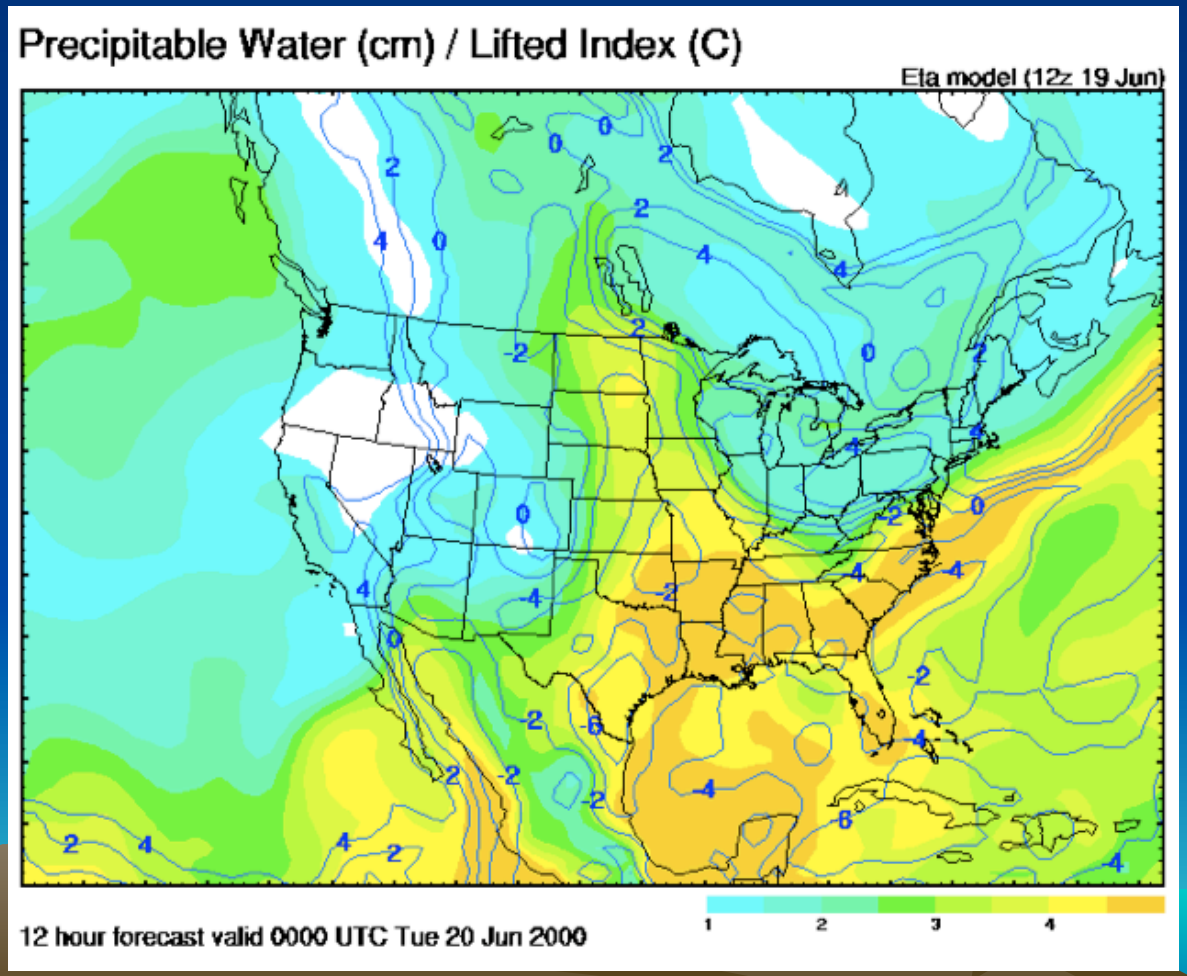
Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Lifted Index (LI)



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- Lifted Index (LI)



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

Convective Available Potential Energy (CAPE)

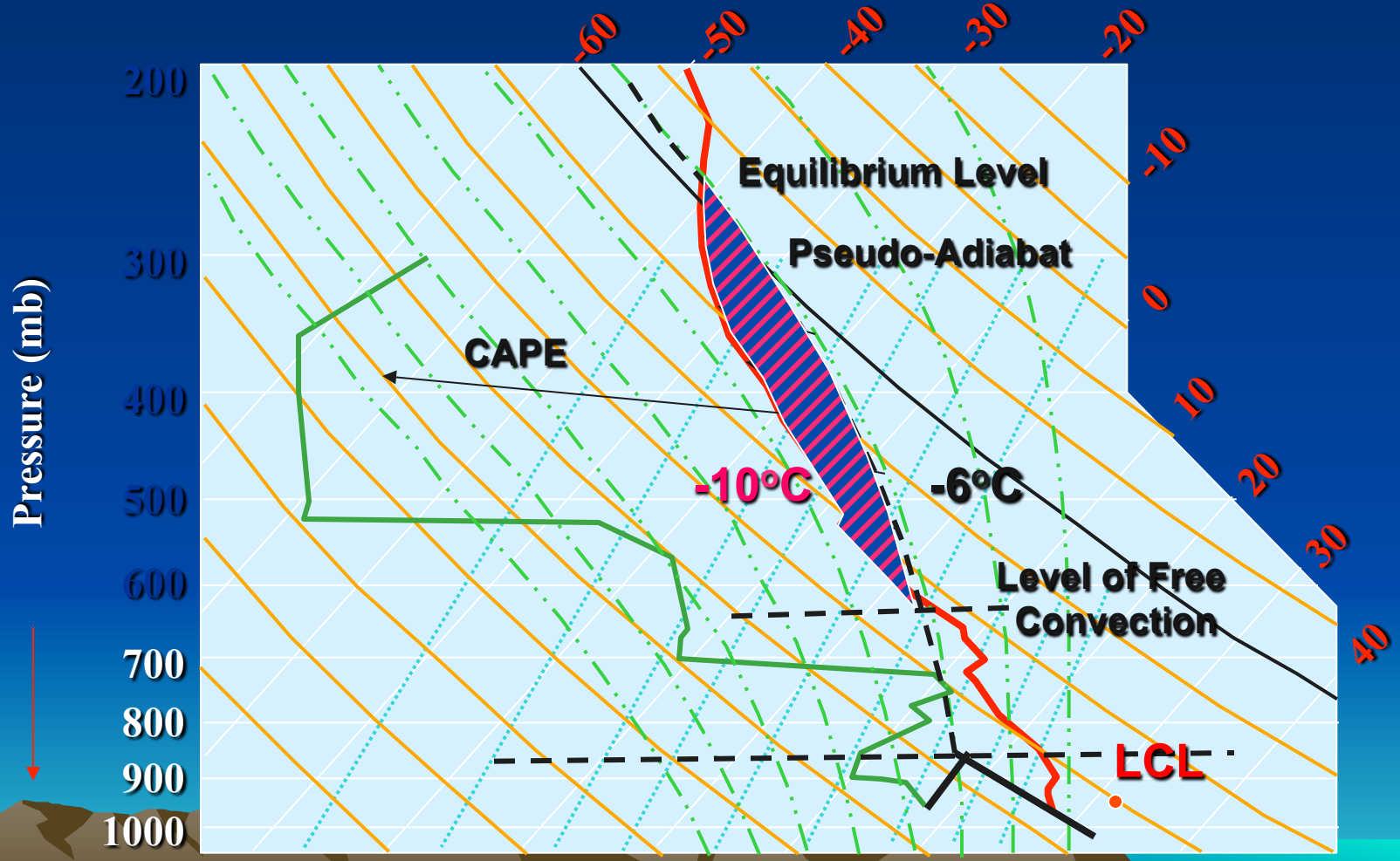
- Buoyantly energy, CAPE is measure of the amount of energy available for convection
- The area (above the LFC) between the environmental sounding and the pseudoadiabat

$$CAPE = \int_{z_{LFC}}^{z_{EL}} g\left(\frac{T_p - T_e}{T_e}\right) dz$$

(courtesy F. Remer)

Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

- CAPE



Skew-T/Log-P Diagram
Determination of Unreported Meteorological Quantities

Convective Available Potential Energy (CAPE)

- Unlikely Development of Strong Convection
  - <1000 J kg^{-1}
- Strong or Severe Thunderstorms
  - 2000 J kg^{-1}



CAPE (J/kg) / CIN (J/kg)

