Atmospheric Thermodynamics

Lecture 7. Skew-T Log-P diagrams

https://www.weather.gov/source/zhu/ZHU_Training_Page/convective_parameters/skewt/skewtinfo.html

7.1 Skew-T Log-P Parameters

The Skew-T Log-P is a diagram which offers an almost instantaneous snapshot of the atmosphere from the surface to about the 100 mb level.

7.2 Why do we need Skew-T Log-P diagrams?

- Can assess the stability of the atmosphere.
- Can see weather elements at every layer in the atmosphere
- Determine cap strength, convective temperature, forecasting temperatures
- Determine character of severe weather

Notes:

- **Cap strength:** refers to how strong the temperature inversion (for stable layer) is that prevents air from rising vertically.
- **Convective temperature**: is the surface air temperature that must be reached for convection to begin.

7.3 The basics lines that make up the Skew-T Log P diagram

Isobars: Lines of equal pressure. They run horizontally from left to right and are labeled on the left side of the diagram. Pressure is given in increments of 100 mb and ranges from 1050 to 100 mb. Notice the spacing between isobars increases in the vertical (thus the name Log P).

Isotherms: Lines of equal temperature. They run from the southwest to the northeast (thus the name skew) across the diagram and are SOLID. Increment are given for every 10 degrees in units of Celsius. They are labeled at the bottom of the diagram.

Saturation mixing ratio lines: Lines of equal saturation mixing ratio (mass of water vapor divided by mass of dry air – g/kg). These lines run from the southwest to the northeast and are DASHED. They are labeled on the bottom of the diagram.

Wind barbs: Wind speed and direction given for each plotted barb. Plotted on the right of the diagram.

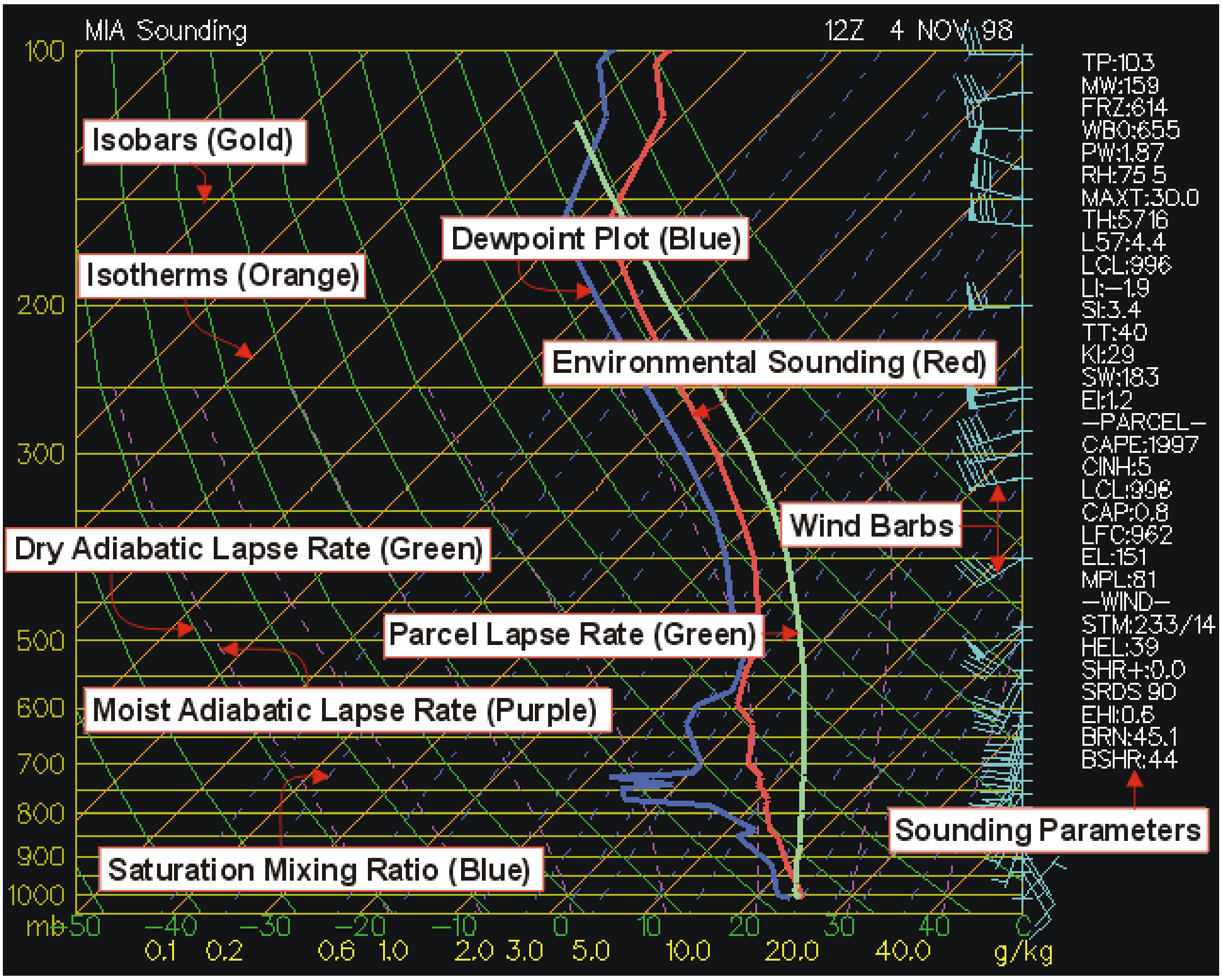
Dry adiabatic lapse rate: Rate of cooling (10 ºC/km) of a rising unsaturated parcel of air. These lines slope from the southeast to the northwest and are SOLID. Lines gradually arc to the North with height.

Moist adiabatic lapse rate: Rate of cooling (depends on moisture content of air) of a rising saturated parcel of air. These lines slope from the south toward the northwest. The MALR increases with height since cold air has less moisture content that warm air.

Environmental sounding: Same as the actual measured temperatures in the atmosphere. This is the jagged line running south to north on the diagram. This line is always to the right of the dewpoint plot.

Dewpoint plot: This is the jagged line running south to north. It is the vertical plot of dewpoint temperature. This line is always to the left of the environmental sounding.

(Parcel lapse rate) - The temperature path a parcel would take if raised from the Planetary Boundary Layer. The lapse rate follows the DALR until saturation, then follows the MALR. This line is used to calculate the LI, CAPE, CINH, and other thermodynamic indices.



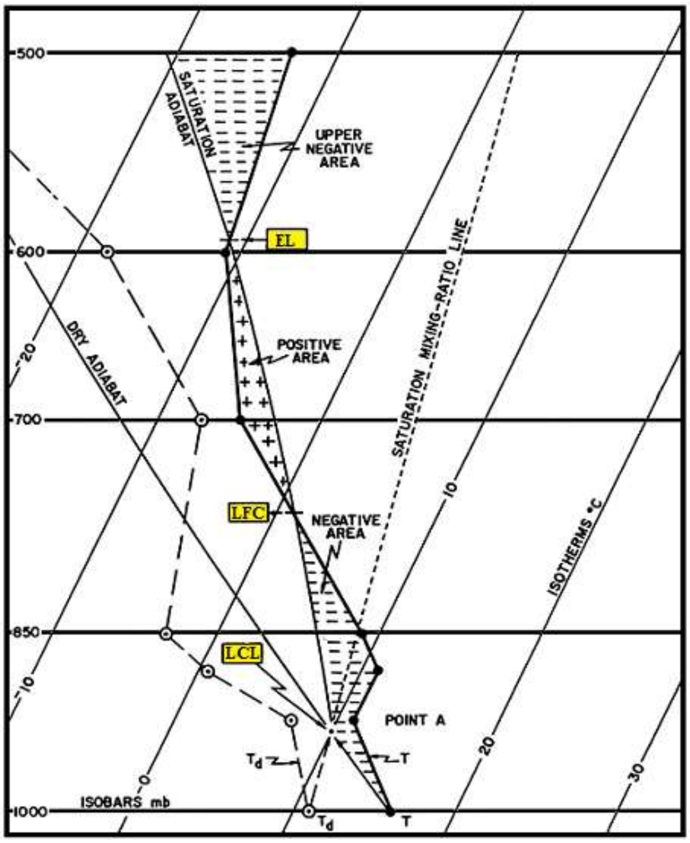
7.4 Skew-T Derived Parameters

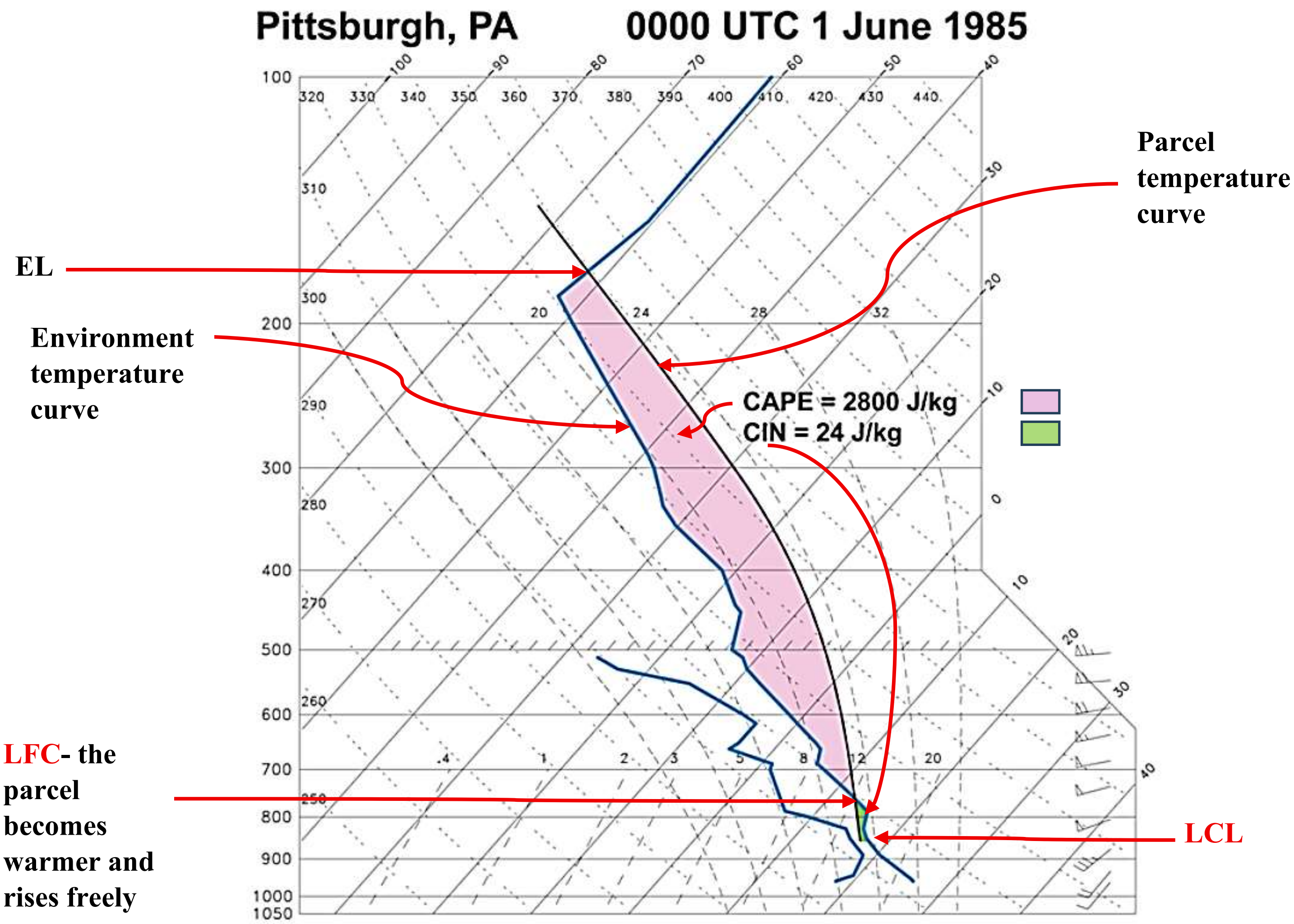
CAPE: CAPE stands for **C**onvective **A**vailable **P**otential **E**nergy and is an important parameter in atmospheric thermodynamics that measures the amount of energy available for convection. It represents the potential for a parcel of air to rise, accelerate upward, and form convective clouds, such as cumulonimbus, due to being warmer and less dense than its surrounding environment.

- 1 to 1,500 (Positive CAPE)
- 1,500 to 2,500 (Large CAPE)
- 2,500+ (Extreme CAPE)

- Max upward vertical velocity = (2*CAPE)^1/2.
- Largest CAPE will occur in the warm sector of a mid-latitude cyclone
- High values of CAPE will result in high values of upward vertical velocity in the updraft region of a thunderstorm
- CAPE is increased by low level warm air advection, daytime heating, low level moisture advection (high low level dewpoint), upper level cold air advection (cooling temperature in mid-levels)
- CAPE values tend to be highest in the warm season (especially late Spring)

CAPE in the diagram represents the positive area on a sounding (the area between the parcel and environmental temperature).





Skew-T diagram from a major tornado outbreak in the Pittsburgh area in 1985. Courtesy: National Weather Service.

Note: CIN: convective Inhabitation, LFC: Level of free condensation, LCL: Lifting Condensation Level, EL: Equilibrium Level

(CCL) - Convective Condensation Level. Level at which condensation will occur if sufficient heating causes rising parcels of air to reach saturation. The CCL is greater than or equal in height (lower or equal pressure level) than the LCL. The CCL and the LCL are equal when the atmosphere is saturated. Found at the intersection of the saturation mixing ratio line (through the surface dew point) and the environmental temperature.

(EHI) - Energy helicity index. Combines CAPE and Helicity into a single index. EHI increases as CAPE and/or Helicity increases. Tornadic development often initiates in region of EHI max (especially if EHI max is 5 or greater).

EQUATION: (SR HEL * CAPE) / 160,000

- EHI > 1 (Supercells likely)
- EHI from 1 to 5 (F2, F3 tornadoes possible)
- EHI 5+ (F4, F5 tornadoes possible)

Equivalent Potential Temperature: Also known as **THETA-E**. Temperature of a parcel after all latent heat energy is released in a parcel then brought to the 1000 mb level. From pressure of interest (typically the surface) find the LCL, lift the parcel wet adiabatically to 100 mb. Next, descend the parcel dry.
FRZ:- Pressure level at which the environmental sounding is exactly zero degrees Celsius. Find intersection of 0-degree isotherm with environmental sounding.
K: The K Index is primarily applicable in the prediction of air mass thunderstorms. Low values of the K Index in the presence of other strong thunderstorms indicators (sharp trough, high level jet, etc.) may suggest a severe thunderstorm potential. For example, a low K value might result from a 700 mb dry tongue.

EQUATION: (T850-T500)+(Td850-Td700)
Lapse rate + available moisture
Or *EQUATION:* (T850-T500)+(Td850)-(T700-Td700)
(Lapse rate) + (low-level moisture) - (extent of moist layer)

- <15 (Convection not likely)
- 15 to 25 (Small potential for convection)
- 26 to 39 (Moderate potential for convection)
- 40+ (High potential for convection)

LCL: (Lifted Condensation Level). Measured in millibars using surface data. This is the level in the atmosphere clouds will form if forced lifting takes place. LCL is found by the following process:
1. Draw a dry adiabat from the surface temperature.
2. Draw a mixing ratio line from the dewpoint.
3. Intersection is the LCL.

LFC: (Level of Free Convection). The level at the bottom of the area of positive CAPE. If a parcel reaches this level, it will begin to accelerate in the vertical.
LI: Lifted Index. This is the temperature difference between the environmental and parcel temperatures at the 500 mb level. In theory, the LI is computed by taking parcel 25 mb above the surface and lifting it dry-adiabatically to saturation; then moist adiabatically to 500 mb. The difference between the sounding temperature and the parcel temperature yields the LI.

EQUATION: 500 mb environmental temperature - 500 mb parcel temperature

- 0 or greater (stable)
- -1 to -4 (marginal instability)
- -5 to -7 (large instability)
- -8 to -10 (extreme instability)
- -11 or less (ridiculous instability)

Potential Temperature: Temperature found by lifting or descending a parcel to the 1000 mb level from the pressure level of interest.
RH: Relative Humidity. Found by dividing the mixing ratio by the saturation mixing ratio or the vapor pressure divided by the saturation vapor pressure. Find the saturation mixing ratio value that runs through the dewpoint and the temperature. Next, divide the dewpoint mixing ratio by the temperature mixing ratio. The average relative humidity between the surface and 500 millibars.

SI: Showalter Index. Same as LI, except parcel is lifted from 850 mb. Use SI instead of LI in the cool season especially when surface is capped by a cool front. *EQUATION:* 500 mb environmental temperature - 500 mb parcel temperature

A. Lift the 850 mb temperature dry adiabatically until it intersects the mixing ratio line which passes through the 850 mb dewpoint.

B. Lift the parcel moist adiabatically to 500 mb.

C. The difference between the ambient air temperature at 500 mb and the parcel temperature determines the SI.

SWEAT: Severe WEAther Threat Index. Indice combining many thermodynamic and wind values. The SWEAT Index was developed by AWS to indentify areas of potentially severe convective activity. Formula covers: low level moisture, instability, low level jet, upper level jet, warm air advection

- 150 to 300 (Slight severe)
- 300 to 400 (Severe storms possible)
- 400+ (Tornadic severe storms possible)

TP: Tropopause Level. Location in mb of the tropopause, generally near 150 millibars.

Wet Bulb potential temperature: Found the same as the wet bulb. When the wet bulb value is found, keep descending wet adiabatically to the 1000 mb level.