THE NATIONAL SCIENCE DIGITAL LIBRARY

Atmospheric Visualization Collection -> Severe Weather Indices

Severe Weather Indices

One area in meteorology that is challenging to forecast is convective precipitation. Thunderstorms can form in under 20 minutes and have destructive effects. Thunderstorms may have large hail, heavy rains, deadly lightning, destructive winds, and possibly tornadoes. The analysis of the atmosphere during times of thunderstorms has prompted meteorologists to develop parameters that would indicate whether or not the conditions are favorable for thunderstorm development. These parameters describe how unstable the atmosphere is or indicate the likelihood of convection. Cold air aloft, warm air at lower levels, and an abundance of moisture all add to the instability of the atmosphere while the turning of the winds with height can influence the severity of thunderstorms. Since forecast models can forecast these factors of the atmosphere, they can forecast the instability also. The following are some of the more commonly severe weather indices used in forecasting.

Note: The guides used for each index do not represent the entire United States west of the Rocky Mountains. The guides are based on commonly accepted values used to estimate the possibility of thunderstorms.

LIFTED INDEX

$LI = T_{500} - TP_{500}$

where LI (°C) is the lifted index, T_{500} is the 500mb environmental temperature (°C), TP_{500} is the 500mb temperature (°C) which a parcel will achieve if it is lifted dry-adiabatically from the surface to its lifted condensation level (LCL) and then moist-adiabatically to 500mb. (In the lifting process, the lower 1 km mean mixing ratio is used as well as the observed/forecasted surface temperature.)

Guide:

$LI < 0$ = possible thunderstorms $LI < -4$ = possible severe thunderstorms

The lifted index (°C) provides an estimate of the instability in the atmosphere due to the difference between the 500mb level temperature and the temperature an air parcel would acquire when lifted from the surface to 500 mb. A parcel of air will rise freely when it is warmer than its surroundings. When a parcel is "lifted" it obtains an upward vertical velocity which can be a result of a surface front or trough, an orographic feature, an upper level short wave, or surface heating (convection).

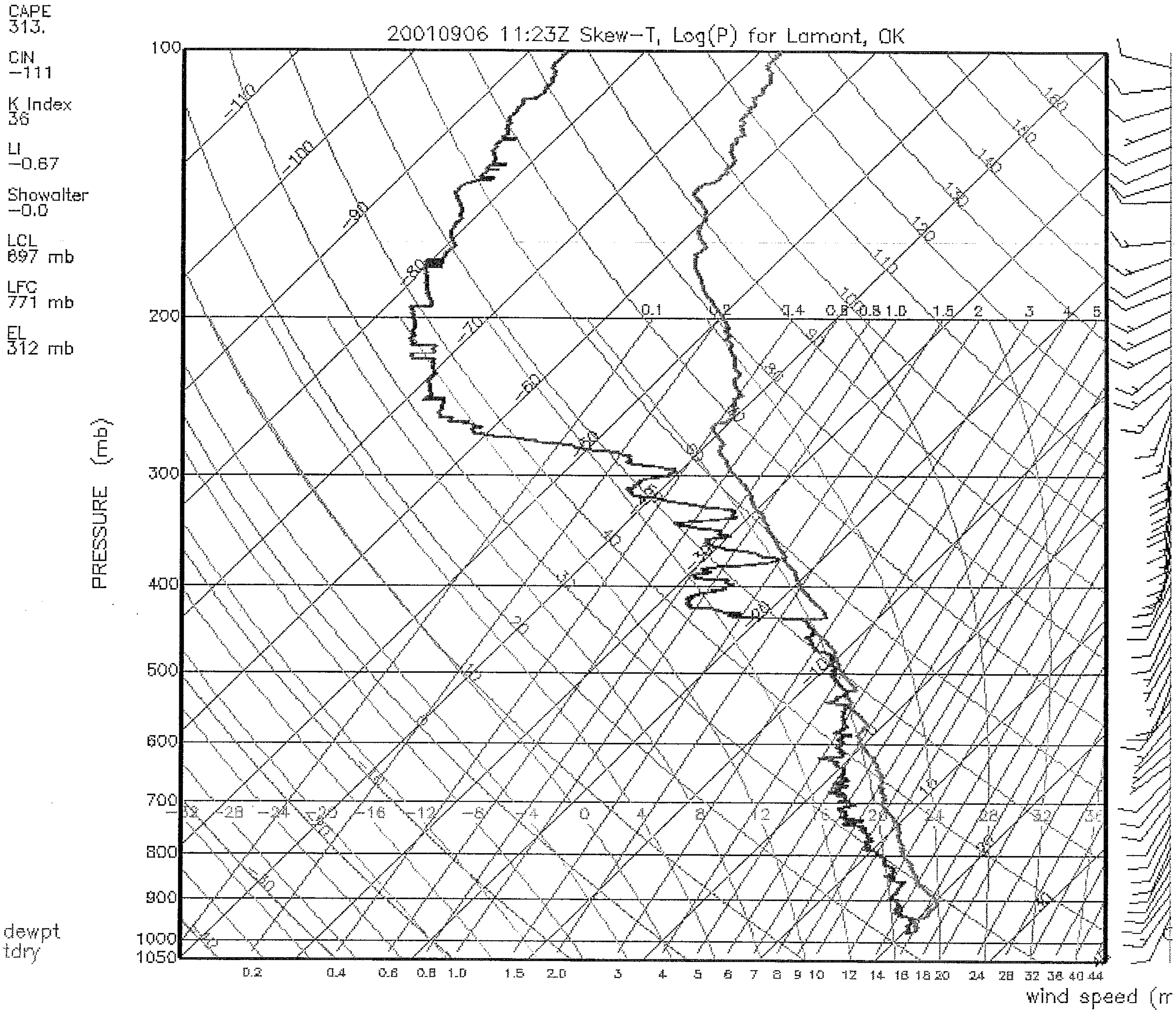

Figure 1: Sounding on 6 September 2001 from Lamont, Oklahoma.

The lifted index in the sounding of Fig. 1 is -.67 (or -.67°C). It is sometimes called the surface based lifted index because the process to compute it involves theoretically lifting a parcel from the surface. The parcel was lifted dry adiabatically from the surface to it's LCL and then lifted moist adia-batically to the equilibrium level (EL) where the parcel becomes negatively buoyant. To compute the lifted index, we consider the environmental 500 mb temperature (red line) and the 500mb lifted temperature. The difference between these two temperatures is the lifted index. In Fig. 1, if we examine the isotherms (dark blue lines) of the air parcel and the environment (red line) at the 500 mb level, we can compute the lifted index to be the following: LI = -10°C - (-9.33°C) = -.67 °C. The three main factors involved in obtaining a low (more unstable) lifted index value are cold air aloft, low level moisture, and a warm surface temperature.

A variation of the lifted index is the "best lifted index" or "4-layer lifted index." In this version, initially the lifted index is found for a few levels between the surface and 1600m. Then the best (most unstable) lifted index value is kept. This is helpful when the surface lifted index may misrepresent the true instability (e.g. morning soundings).

SHOWALTER INDEX

Showalter = T_{500} - TP_{500}

where Showalter is the Showalter index, T_{500} is the 500mb environmental temperature (°C), TP_{500} is the 500mb temperature (°C) which a parcel will achieve if it is lifted dry-adiabatically from 850 mb to its condensation level and then moist-adiabatically to 500mb.

Guide:

SI < +3 = showers and possible thunderstorm SI < -3 = severe convective activity The Showalter index is similar to that of the lifted index. The SI provides an estimate of the instability due to the difference between the 500mb temperature and the temperature an air parcel would acquire when lifted from 850mb to 500 mb. It is applied when use of the 850 mb level would be a better representation of atmospheric instability versus the surface based lifted index (e.g. cool surface temperatures).

TOTAL TOTALS INDEX

$$TT = Td_{850} + T_{850} - 2(T_{500}) \text{ or } (Td_{850} - T_{500}) + (T_{850} - T_{500})$$

cross total + vertical total

where TT is the total totals index (°C), Td_{850} is the dew point temperature (°C) at the 850 mb level, T_{850} is the temperature at the 850 mb level, and T_{500} is the temperature at the 500 mb level.

Guide: TT > 44 = possible thunderstorms, slight chance of severe TT > 50 = moderate chance of severe thunderstorms TT > 55 = strong chance of severe thunderstorms

The total totals index (TT) is an index of atmospheric instability composed of two indices: the cross total and the vertical total. The cross total is a measure of how buoyant the air parcel is due to less dense, moist air in the lower levels. It is defined as the difference between the 850 mb dew point temperature and the 500 mb temperature. The vertical total is a measure of how buoyant the air parcel is due to warm air at lower levels. It is defined as the difference between the 850 mb temperature and the 500 mb temperature. The sum of the cross and vertical totals is the total totals index. The vertical total deals with the thermal difference while the cross total takes into account the amount of moisture present. Hence, the three main factors in obtaining high total totals index values are the following: a high 850mb temperature, a high 850 mb dew point temperature, and a low 500 mb temperature. Note: The total totals index has not been calculated for Fig. 1.

K INDEX

$$K = T_{850} - T_{500} + Td_{850} - (T_{700} - Td_{700})$$

where K is the K index (°C), T_{850} is the temperature at the 850 mb level, T_{500} is the temperature at the 500 mb level, Td_{850} is the dew point temperature (°C) at the 850 mb level, T_{700} is the temperature (°C) at the 700 mb level, and Td_{700} is the dew point temperature (°C) at the 700 mb level.

Guide: K < 15 = 0 % probability of thunderstorms K from 15 to 20 = 20 % probability of thunderstorms K from 21 to 25 = 20 to 40 % probability of thunderstorms K from 26 to 30 = 40 to 60 % probability of thunderstorms K from 31 to 35 = 60 to 80 % probability of thunderstorms K from 36 to 40 = 80 to 90 % probability of thunderstorms K > 40 = near 100 % probability of thunderstorms

The K index was composed for forecasting air mass thunderstorms, or thunderstorms with no dynamic triggering mechanism. To compute this index, first take the 850 mb temperature minus the 500 mb temperature. Secondly, add the 850 mb dew point temperature to this difference. Larger values of this dew point indicate low level moisture present and increase the chance of convection. Finally, we subtract the 700 mb dew point depression for moisture input at the mid levels. A small dew point depression at 700 mb indicates a possibility for deep convection. If there is no significant moisture at 700mb then there is a greater chance that entrainment of dry air would occur, given a parcel were lifted from beneath the 700 mb level. If entrainment of dry air occurs, the parcel will become less buoyant (Bluestein, 1993).

CONVECTIVE AVAILABLE POTENTIAL ENERGY

similar to that of Djuric, 1994

where CAPE is convective available potential energy (J/kg), R is the universal gas constant, pLFC is the pressure at the lifted condensation level, pEL is the pressure at the equilibrium level, T is the temperature of the lifted parcel, Ta is the ambient temperature, and p is the pressure at the level which it is evaluated at.

Guide:

CAPE < 1000 weak convection CAPE 1000 to 2500 moderate convection CAPE > 2500 strong convection Convective available potential energy (CAPE), also known as buoyant energy, is the area on a thermodynamic diagram enclosed by the environmental temperature profile and the moist adiabat connecting the level of free convection (LFC) to the equilibrium level (EL), (Bluestein, 1993). The EL is the level near the top of the troposphere where negative buoyancy is prevalent because the parcel has cooled (moist adiabatically) to the same temperature as its surroundings. When thunderstorms have overshooting tops (a protrusion of cloud above the thunderstorm top), the EL is the level the updraft is overshooting. The CAPE is measured in units of work per unit mass and represents the potential energy per kilogram the air parcel contains, or the energy that would be expended if the parcel were raised past it's LFC. The greater the CAPE, the greater the difference will be between the environmental lapse rate and the temperature of the lifted parcel. If the temperature difference is great, the acceleration upward will be strong due to the buoyancy force.

CONVECTIVE INHIBITION

similar to that of Djuric, 1994

where CIN is convective inhibition (J/kg), pLFC is the pressure at the lifted condensation level, pNSFC is the average pressure (of which the average temperature is a function of) in the lowest 500 or 1000 m, T is the temperature of the lifted parcel, Ta is the ambient temperature, and p is pressure.

Guide:

CIN < 15 fair weather cumulus field (CIN overcome early) CIN 15 to 50 a few strong thunderstorms can form (if CIN is overcome) CIN 50 to 150 strong lines of thunderstorms can form (if CIN is overcome) CIN > 200 strong cap, no thunderstorm development likely (CIN usually not overcome)

Convective inhibition (CIN) can be considered a measure of how unlikely thunderstorm development is, or the energy needed for thunderstorms to develop. The CIN represents the amount of energy which must be expended by a lifting mechanism or surface heating to initiate thunderstorm development. When there is an inversion present or stable layer aloft, the CIN can be signified as the strength of the "cap." If the cap is weak it may be easily eroded early in the morning by heating and the energy would be expended to form a cumulus field. If the cap is too strong (CIN > 200 J/kg) the energy might not be overcome and no development may occur. For favorable thunderstorm conditions, the CIN is neither too strong nor too weak but ranges from 50 J/kg to 150 J/kg. The CIN can be seen diagrammed in the image above. The CIN is represented in magenta and is the "negative" area between the lifted thermodynamic path and the environmental lapse rate.

SEVERE WEATHER THREAT INDEX

SWEAT = 12 D + 20 (TT - 49) + 2 v8 + v5 + 125 (S + 0.2) (Djuric, 1994) where D = Td_{850} (°C); if $D < 0$, change it to $D = 0$

TT = total totals index; if $TT < 49$ then drop term v8 = 850 mb wind speed (kts) v5 = 500 mb wind speed (kts) S = sin [wind direction at 500 mb (degrees) - wind direction at 850 mb] the term $125(S + 0.2)$ should be dropped in any of the following cases:

when the wind direction at 850 mb is between 130° and 250° when the wind direction at 500 mb is between 210° and 310° when (wind direction at 500 mb - wind direction at 850 mb) > 0 when v8 < 15 kts and v5 < 15 kts

---

Guide:

SWEAT > 300 severe thunderstorms possible SWEAT > 400 thunderstorms with tornadoes possible

The severe weather threat index is an index intended to discern between periods of severe and non-severe thunderstorms. This index is a conglomerate of other thunderstorm development factors such as low level moisture and instability, but also takes into account another severe thunderstorm parameter other indices don't. This parameter is the wind velocities at lower and upper levels. Once a thunderstorm develops, the factor determining whether or not the thunderstorm will sustain itself or dissipate, is the wind. If there is no vertical wind shear the storm's precipitation will fall into the updraft and the storm will fail to sustain itself. The lifecycle of this storm type is around one hour. On the other hand, if the winds are veering with height (turning clockwise with height) then the updraft and downdraft can be diverted from intersecting each other and a longer lifetime can be expected. Veering winds (Fig. C) also often indicate warm air advection at lower levels which increases the instability. In addition, wind shear aids in the development of storm rotation which leads to the production of tornadoes. In the SWEAT index the 850 mb and 500 mb are the two levels where the winds are considered. The wind shear between these two levels is a major factor to be considered when forecasting severe weather. Note: The severe weather threat index has not been calculated for Fig. 1.

The probability and severity of thunderstorms are topics forecasters strive to perfect. Analysis and interpretation of severe weather indices can aid in the understanding of atmospheric conditions. This understanding can lead to an accurate analysis/forecast of thunderstorms and their severity. Examining one parameter alone may cause an inaccurate interpretation of conditions. If all parameters are considered, the dynamics are studied, and current conditions monitored, the accuracy of the analysis/forecast will be greatly increased.

REFERENCES

Knutsvig, Ryan, [Severe Weather Indices page]

Bluestein, H.B., 1993: Synoptic-Dynamic Meteorology in Midlatitudes, Oxford University Press, Vol. 2, 594 pp.

Brown, R. A., 1992: Initiation and Evolution of Updraft Rotation within an Incipient Supercell

Thunderstorm. J. Atmos. Sci., 49, 1997-2014.

Djuric, D., 1994: Weather Analysis, Prentice-Hall Inc., 304 pp.