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Supercells and Combinations of Helicity and Instability: A Look at the Energy-Helicity Index

by Jon Davies

For supercells to develop, wind factors (such as helicity) and thermodynamic factors (such as CAPE, or convective available potential energy) must combine to produce an environment that is favorable for the formation of rotating thunderstorms. Therefore, one important aspect of forecasting the likelihood of supercells (and by association, tornadoes) is estimating and assessing the combination of helicity and instability.

Storm enthusiasts who are focussed on supercell thunderstorms in the plains in the warm season sometimes fail to recognize that there are a variety of wind profile/instability combinations that can set the stage for supercell development. For example, in the southeast United States in the cool season (late fall, winter, early spring), tornadoes often occur with instability that at first glance may appear too weak to support significant supercells and possible tornadoes. When Bob Johns was a lead forecaster at NSSFC in Kansas City, he and I worked together on a project computing instability and helicity for a data set of tornado cases from the 1980's. We found 35 cases when tornadoes occurred in environments where instability appeared weak (CAPE less than 1000 J kg^{-1}, using an average lifted parcel in the bottom 100 mb or roughly 3000 ft). Nearly all these cases occurred in the eastern United States in the cool season, and were associated with large helicity values, most greater than 400 m^2s^{-2}, and some in excess of 600 m^2s^{-2}.

The opposite situation occurs in the plains in late spring and summer. Bob and I found 29 cases in our data set where tornadoes occurred in environments where CAPE was very unstable, greater than 3500 J kg^{-1} (again lifting the average parcel in the bottom 100 mb of the sounding). Nearly all of these cases were in the plains in the warm season, and more than half had relatively low helicity values, near 200 m^2s^{-2} or less.

In the weak instability cases, what appears to happen is that strong wind fields associated with large helicity values can (apart from their potential to induce rotation on a storm updraft) set up strong vertical pressure gradients within a storm that increase the strength of the updraft, even if the supporting instability is relatively weak by "plains" standards. In the strong instability cases, it seems that, because the highly unstable environment can result directly in strong updrafts, less helicity is needed in the wind environment to generate rotation in a storm's updraft. Many tornado cases fall into a middle ground between these two extremes.

So... how does one estimate and assess whether there is enough instability in an environment with a certain amount of helicity to potentially produce rotating storms and possible tornadoes? A useful tool is the **energy-helicity index (EHI)**, developed by John Hart and Josh Korotky, based on the data set of tornado cases that Bob Johns and I looked at.

The EHI is a simple equation that combines helicity and instability into one number for estimating and assessing these factors in a particular environment regarding potential for supercells. *It is **not** a "magic number", or a "dynamite tool" for forecasting tornadoes.* It is simply another piece of information that can be useful at times in forecasting supercells. It works well in some situations, and not so well in some others. This depends on many factors, such as the strength of winds higher up in the atmosphere and the location of sounding observation network sites.

The EHI equation is:

$$\mathbf{EHI = (CAPE \times H) \div 160,000}$$

In other words, multiply CAPE times helicity (H), then divide this quantity by 160,000. The EHI seems to work best if one uses a conservative estimate of CAPE, lifting an average parcel in the bottom 50 or 100 mb of a sounding. This is because relatively dryer air above the surface normally mixes with a warm moist parcel as it ascends, making the actual CAPE somewhat less than the largest CAPE value one can "coax" out of a given sounding, often by using a surface parcel or some other method.

Let's take the 00z 4/26/94 Stephenville sounding from my preceeding article in this issue, and compute an EHI value. Here's the temperature data from the mandatory sounding levels:

Sfc (955 mb)	T = 28°C (83°F),	T_d = 18°C (65°F)
925 mb	T = 25°C,	T_d = 17°C
850 mb	T = 19°C,	T_d = 15°C
700 mb	T = 8°C,	T_d = -1°C
500 mb	T = -12°C,	T_d = -32°C
400 mb	T = -25°C,	T_d = -42°C
300 mb	T = -42°C	
200 mb	T = -58°C	
150 mb	T = -63°C	

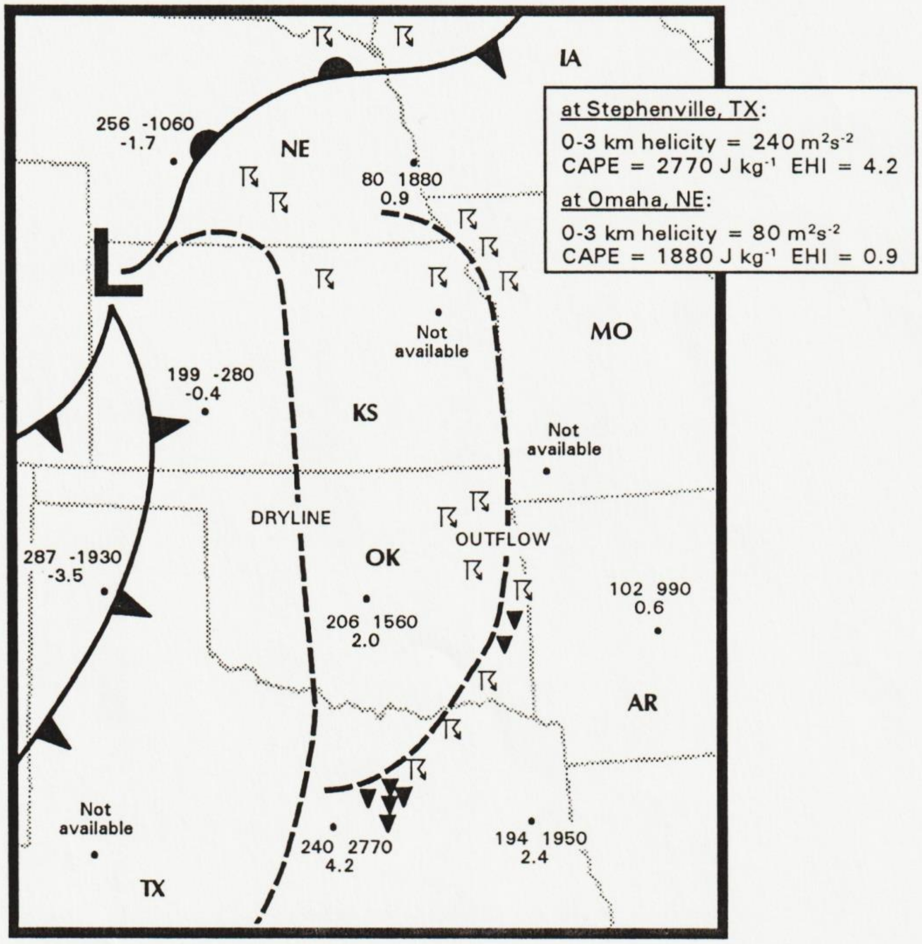
Without going into the detail and mechanics of computing CAPE values (which Tim did last issue, see *Storm Track* January-February 1995), my conservative CAPE estimate is **2770 J kg^{-1}** for this sounding.

With this information, and a helicity value of **240 m^2s^{-2}** computed from the same sounding in my article earlier in this issue, the EHI equation becomes:

$$\mathbf{EHI = (2770 \times 240) \div 160{,}000 = 4.2}$$

The EHI here is **4.2**, and has no units, because m^2s^{-2} and J kg^{-1} are basically equivalent, cancelling out.

In practical experience, I've found that EHI values approaching 2.5 or greater are significant and tend to be more indicative of supercells with potential for tornadoes. In this context, the EHI from the Stephenville sounding suggests potential for supercells and possible tornadoes in this environment. Indeed, storms 50 miles to the northeast of the sounding site produced tornadoes later that evening, including the F4 Lancaster, Texas tornado. Comparatively, other available soundings (see the map below) throughout the central plains that evening showed EHI values of much less magnitude:



at Stephenville, TX:

0-3 km helicity = 240 m^2s^{-2}

CAPE = 2770 J kg^{-1} EHI = 4.2

at Omaha, NE:

0-3 km helicity = 80 m^2s^{-2}

CAPE = 1880 J kg^{-1} EHI = 0.9

Helicity (m^2s^{-2}), CAPE (J kg^{-1}), and Energy-Helicity Index (EHI)
From RAOB soundings 00 Z 4/26/94 (7 pm CDT 4/25/94)

Other significant tornado activity occurred in the Talihina, Oklahoma area that evening. Unfortunately, the closest soundings were 150 miles or more away. Still, the EHI of 2.4 at Longview, Texas suggests that significant helicity and instability may have extended into southeast Oklahoma.

This particular April day involved a large and dynamic weather system with strong wind fields coming out through the Central U.S. As one moves more toward summer, weather systems become less intense while instability becomes more widespread through the plains. When this happens, the EHI often becomes less useful as more localized factors come into play.

An example is the May 28, 1994 LP supercell and tornado in Roberts County of the Texas panhandle (see *Storm Track*, November-December 1994). Factors measured by the EHI may have been less relevant in this localized case. And, with Amarillo to the west in dryer air, and Norman far to the east, none of the of the conventional network soundings were located properly to sample the environment of this storm. Soundings and model forecast data (not shown) didn't do much this day to suggest supercell or tornado potential when looking at both helicity and instability. This emphasizes that the EHI is only one of several complex factors that may be relevant or useful in supercell forecasting situations, and, like other parameters, is also at the mercy of the observing network density.

For those familiar with the surface-based lifted index (SLI) as a measure of instability, I've developed a version of the EHI using surface-based lifteds:

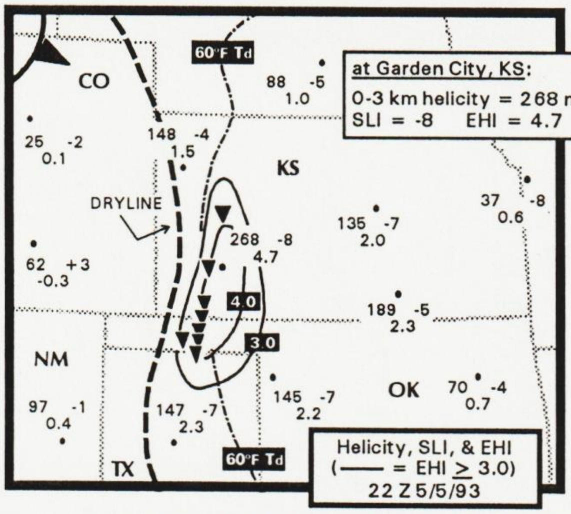
$$\mathbf{EHI = ((-SLI \times 322) - 208) \times H) \div 160{,}000}$$

In other words, reverse the sign of the SLI (if it is negative, make it positive), multiply this by 322 and subtract 208. Then multiply this quantity by the helicity (H), and divide by 160,000. Even though we're using a surface parcel here, I've adjusted the equation so that the instability is treated conservatively to encourage reasonable estimations. This version is not as accurate as using CAPE, but is still useful in providing estimates when one doesn't have the temperature and dew point profile detail needed for computing CAPE from a sounding.

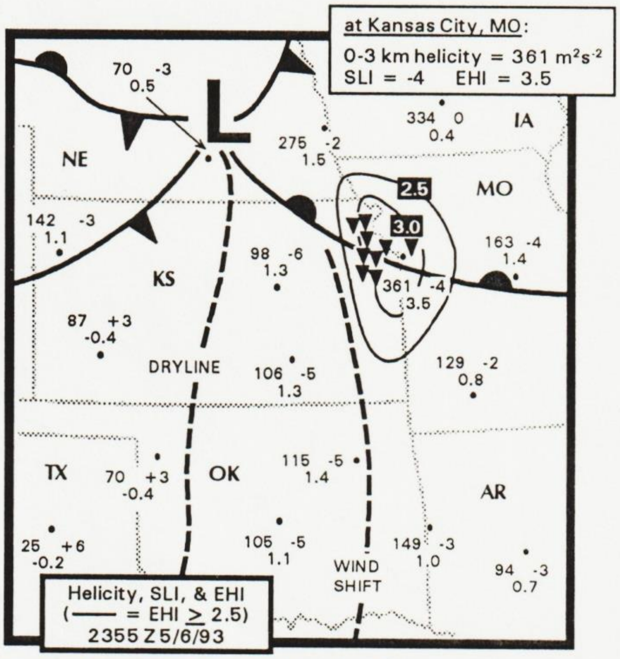
This version of the EHI allows one to use the relatively coarse "FD" forecast winds and temperatures aloft (see my article on hodographs in the January-February 1994 issue of *Storm Track*) from the NGM model to make a crude estimate of helicity, instability, and EHI values in the absence of soundings. When combined with surface data, such computations can sometimes provide useful information. This depends, of course, on how localized the situation is and how well the models are forecasting winds and temperatures aloft (unfortunately, at times the FD winds can be very much in error). Keep in mind, too, that capping inversions don't care about EHI values. A strong capping layer that prevents storms from developing makes EHI values a moot point; if no storms fire, then there can't be any supercells.

To show how the EHI can be useful on days when the models are handling systems reasonably well, the following page presents some maps showing helicity, surface-based lifted index, and EHI computed by combining observed surface data with FD wind and temperature forecasts aloft. These forecasts are from the infamous "Wedge Week" in 1993 (May 5-9, one map for each day) when on 5 consecutive days numerous tornadoes, several of strong and violent intensity, occurred at various locations in the plains. Notice how significant helicity values may be widespread, but when combining instability with helicity, an EHI estimate can sometimes help to narrow the area of concern regarding potential for rotating storms and possible tornadoes. While the higher EHI values on these analyses do a reasonable job of highlighting general areas of tornado occurence, do keep in mind that fairly dynamic weather systems were involved here. In less well-defined situations, the EHI will likely be less useful for some of the reasons mentioned earlier, particularly when the model forecasts are poor.

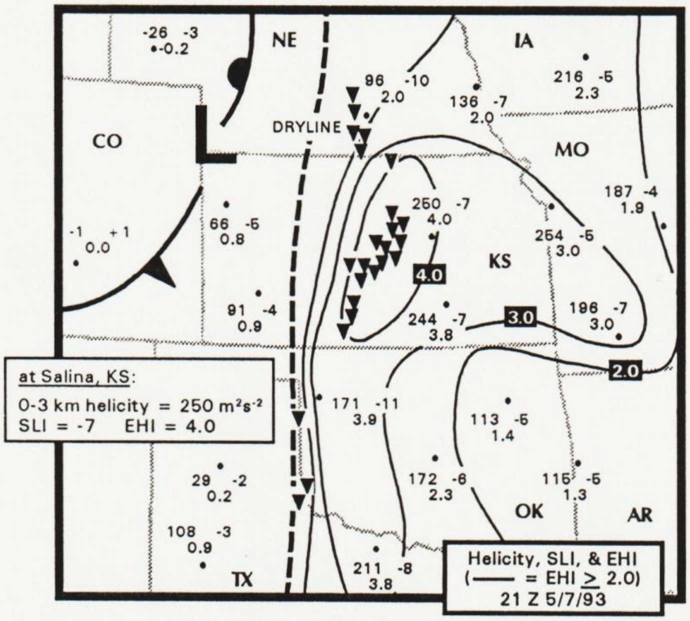
Hopefully this discussion will give interested readers, chasers, and forecasters an introductory idea about how the potential for supercell development depends to a significant degree on the interaction of wind factors and instability. In this respect, the energy-helicity index is a parameter that can be helpful.



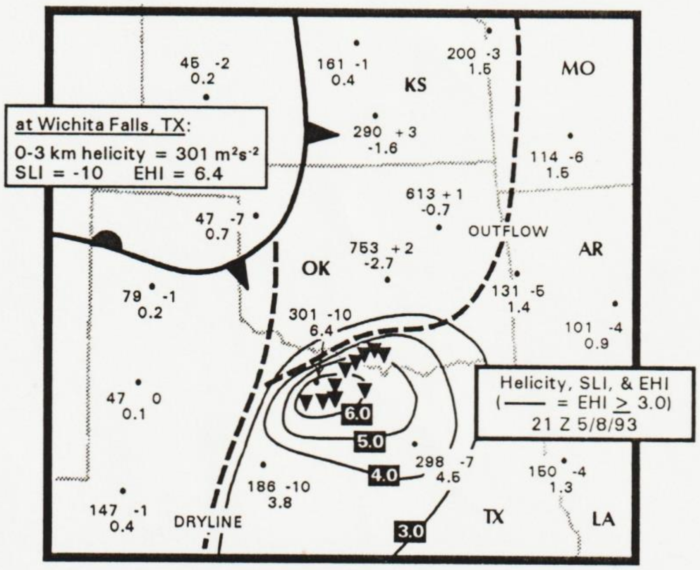
From sfc obs 22 Z 5/5/93 & 12 hr FD fcst valid 00 Z 5/6/93
(triangles are preliminary tornado reports 22 Z - 03 Z)



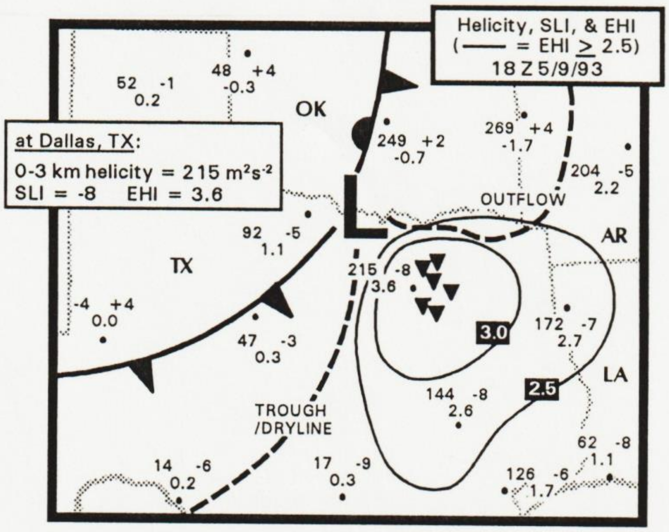
From sfc obs 2355 Z 5/6/93 & 12 hr FD fcst valid same time
(triangles are preliminary tornado reports 00 Z - 02 Z)



From sfc obs 21 Z 5/7/93 & 12 hr FD fcst valid 00 Z 5/8/93
(triangles are preliminary tornado reports 21 Z - 00 Z)



From sfc obs 21 Z 5/8/93 & 12 hr FD fcst valid 00 Z 5/9/93
(triangles are preliminary tornado reports 21 Z - 23 Z)



From sfc obs 18 Z 5/9/93 & 6 hr FD fcst valid same time
(triangles are preliminary tornado reports 1800 Z - 1930 Z)