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HOURLY HELICITY, INSTABILITY, & EHI IN FORECASTING SUPERCELL TORNADOES

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1. INTRODUCTION

Storm-relative helicity has become widely used as a parameter for measuring the potential of low-level wind fields to produce thunderstorm rotation (see Davies-Jones et al. 1990), and by association, low-level mesocyclones and tornadoes. However, a focus on helicity values without careful reference to instability/buoyancy (Johns et al. 1993) can be misleading. Some violent tornado cases such as the 8/28/90 Plainfield, Illinois tornado (Korotky et al. 1993) appear to involve only marginal values of environmental helicity (< 150 m^2s^{-2}) yet very strong instability. Other tornado cases, such as the 10/3/92 Tampa area tornadoes (Davies 1993a), can be associated with large helicity (> 500 m^2s^{-2}) yet weak or only marginal instability.

In the latter scenario, strong wind fields that contain significant helicity and low-level curvature shear (Brooks and Wilhelmson 1990), as well as wind shear through a deeper layer (Weisman and Klemp 1984), induce vertical perturbation pressure gradients (Rotunno and Klemp 1982) that intensify thunderstorm updrafts in the absence of strong instability, in addition to inducing thunderstorm rotation. In the former scenario, it appears that, because strong instability is present to directly generate strong updrafts, less helicity and low-level curvature shear is required to initiate significant thunderstorm rotation.

Situations such as these, characterized by opposite extremes of helicity and instability, are a problem for forecasters to diagnose because it is difficult to subjectively assess what combinations of helicity and instability might be "optimal", as suggested by Lazarus and Droegemeier (1990), for producing strongly rotating storms in a particular thermodynamic environment. It would seem desirable, along with other parameters, to have a single parameter combining helicity and instability, which could be monitored for trends that might otherwise be difficult to see when following the progress of the two separate parameters.

Brooks et al. (1993) note that shear and buoyancy, when combined into a single parameter, cannot distinguish between tornadic and non-tornadic environments. However, they base their observation on a Canadian study (Turcotte and Vigneux 1987) using a parameter (mean shear, Rasmussen and Wilhelmson 1983) that does not represent low-level curvature shear as well as helicity (see Davies-Jones et al.). Although not well understood, observations of actual tornadic supercell environments (see Johns et al.) show that an optimal helicity/instability relationship, as suggested by Lazurus and Droegemeier, does exist to some degree. Recent experience by the author (Davies 1993a) has suggested that a parameter combining helicity (rather than mean shear) with buoyancy, when used in conjunction with other information (such as low-level inflow and mid-level winds; see Johns and Doswell 1992), can be useful in distinguishing between many tornadic and non-tornadic situations.

Based on work with a large data set of tornado cases assembled by Davies and Johns (1993), Hart and Korotky (1991) developed the *energy-helicity index* (EHI) as a tool to assess helicity and instability for forecasting purposes. Unfortunately, the EHI has not yet been widely used or evaluated by forecasters, and may have been hampered by guidelines that were only preliminary in nature.

This paper will provide updated discussion of the EHI based on recent experience with a number of severe weather cases. Several case examples will be presented using numerical weather prediction model data blended with surface observations (as in Davies 1993a) to show how the EHI might be used for distinguishing some situations that are more likely to produce significant supercell tornadoes from those that are less likely to do so.

2. THE ENERGY-HELICITY INDEX

Johns et al. (1993) computed CAPE (convective available potential energy) and helicity for 242 non-isolated tornado cases of F2 or greater intensity assembled by Davies and Johns (1993) using carefully selected radiosonde and surface data. The resulting scatter diagram is shown in Fig. 1, reproduced from Johns and Doswell (1992). The energy-helicity index (EHI) was developed by Hart and Korotky (1991) based on the dashed curve in Fig. 1 that encloses most CAPE/helicity combinations above it. The EHI is defined as:

$$EHI = CAPE(H)/160000$$

where CAPE (m^2s^{-2}, identical to j kg^{-1}) is in the same units as helicity (H, m^2s^{-2}), producing a quantity that is dimensionless. Preliminary published guidelines (e.g., LaPenta 1992) suggested that EHI values around 1.0 or greater were indicative of significant tornado potential.

In operational use, the author has found that significant mesocyclone-induced tornadoes tend to be associated with EHI values of greater magnitude than these suggested guidelines. This is supported by the subset of tornadic and non-tornadic cases from late 1992 examined in Davies (1993a), which are reproduced in Tables 1 and 2 on the next page. Note the wide range of helicity and instability values, including several non-tornadic cases with helicity values exceeding 150 m^2s^{-2}, the suggested threshold in Davies-Jones et al. (1990) for mesocyclone-induced tornado development. The author's experience, and the cases in Tables 1 and 2 suggest that EHI values in the range of 2.5 to 3.0 and greater are more indicative of potential for significant tornadoes.

Relating this observation to the CAPE/helicity scatter diagram, the solid curve in Fig. 1 corresponds to EHI = 2.5, and retains 71% of

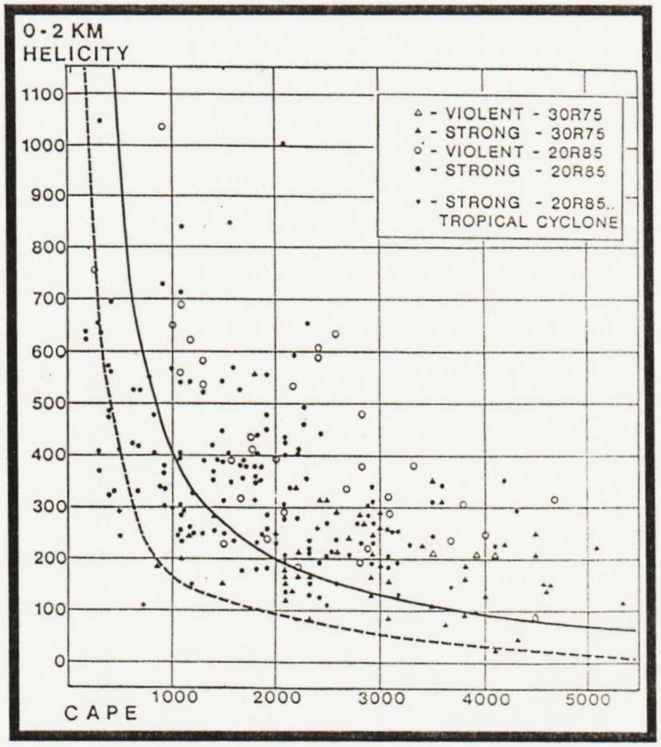

Fig. 1. *Scatter diagram from Johns et al. (1993) showing distribution of 0-2 km AGL helicity and CAPE (using mean temperature and moisture in bottom 100 mb) for 242 tornado cases during 1980-1990. Dashed curve is EHI = 1.0; solid curve is EHI = 2.5 (see equation in text). Reproduced from Johns and Doswell (1992), curves added.*

Table 1: **Tornadic cases**

Date and time of tornadoes	Location	Maximum F-scale		0-3km Helicity (m^2s^{-2})	SLI	EHI	0-2km Inflow (kts)	3-6km wind (kts)	Forecast (Fcst) sites and Sounding (RAOB) sites used
8/30/92 01-02UTC	C. WI	F3	Fcst:	312	-4.2	3.1	24	41	GRB-DBQ 8/29/92 23UTC
	(1 death)		RAOB:	313	-5.1	3.6	25	41	GRB 8/30/92 00UTC
9/6/92 00-02UTC	S.C. KS	F2	Fcst:	130	-10.2	2.8	20	26	ICT/PNC 9/5/92 23UTC
			RAOB:	181	-9.7	3.7	21	35	TOP-OKC 9/6/92 00UTC
9/7/92 01-04UTC	W. KS	F0	Fcst:	177	-8.1	3.1	21	28	GCK 9/7/92 00UTC
			RAOB:	221	-8.1	3.8	26	28	DDC 9/7/92 00UTC
11/22/92 04-09UTC	MS	F4	Fcst:	497	-2.4	3.1	31	58	JAN 11/22/92 03UTC
	(15 deaths)		RAOB:	342	-5.8	4.4	26	57	LCH 11/22/92 00UTC
11/22/92 21-23UTC	N.C. KY	F4	Fcst:	184	-7.7	3.1	21	68	LOU/LEX 11/22/92 21UTC
	(1 death)		RAOB:	470	-3.3	3.7	28	66	DAY 11/23/92 00UTC
11/23/92 04-10UTC	C. NC	F3	Fcst:	403	-3.3	3.2	22	60	RDU 11/23/92 06UTC
	(2 deaths)		RAOB:	296	-3.4	2.4	23	53	GSO-HAT 11/23/92 00-12UTC
	Parameter averages		**Fcst:**	**284**	**-6.0**	**3.1**	**23**	**47**	
			RAOB:	**304**	**-5.9**	**3.6**	**25**	**47**	

Table 2: **Non-tornadic cases**

Date and time tornadoes expected	Location		0-3km Helicity (m^2s^{-2})	SLI	EHI	0-2km Inflow (kts)	3-6km wind (kts)	Forecast (Fcst) sites and Sounding (RAOB) sites used
9/6/92 18UTC-9/7/92 01UTC	S. MI/C.& E. IN /N.W. OH	Fcst:	49	-5.8	0.6	12	19	IND 9/6/92 21UTC
		RAOB:	83	-3.4	0.7	14	23	FNT-DAY 9/7/92 00UTC
9/20/92 23UTC-9/21/92 04UTC	S. OK/N. TX	Fcst:	179	-5.3	2.2	17	27	SPS 9/20/92 23UTC
		RAOB:	96	-3.9	0.9	17	29	OKC-SEP 9/21/92 00UTC
10/4/92 10-16UTC	C. & N.E. FL	Fcst:	216	-3.6	1.9	17	31	MLB/ORL 10/4/92 09UTC
	peninsula	RAOB:	233	-2.8	1.6	20	32	AYS-PBI 10/4/92 12UTC
11/1/92 00-05UTC	N. & C. TX *	Fcst:	175	-5.9	2.3	21	35	DAL 11/1/92 00UTC
		RAOB:	167	-5.6	2.1	22	30	SEP 11/1/92 00UTC
11/4/92 20UTC-11/5/92 01UTC	S. GA/N.W. FL	Fcst:	96	-2.9	0.7	14	40	TLH 11/4/92 21UTC
		RAOB:	198	-2.0	1.1	22	44	TLH 11/5/92 00UTC
11/25/92 07-14UTC	S.E. AL/S.W. GA	Fcst:	171	-5.5	2.1	17	36	PFN 11/25/92 09UTC
	/FL panhandle	RAOB:	185	-1.6	0.8	20	43	TLH 11/25/92 12UTC
	Parameter averages	**Fcst:**	**148**	**-4.8**	**1.6**	**16**	**31**	
		RAOB:	**160**	**-3.2**	**1.2**	**19**	**34**	

**One brief, weak F0 tornado occurred with this case, but it is unclear whether the tornado was of supercell or non-supercell origin.*

Tables 1 and 2. *Parameter values and averages for six tornadic cases associated with supercells and six non-tornadic cases in late 1992. Forecast (fcst) values blend 6 or 12 hr FD forecast[1] winds and temperatures aloft with a surface observation for the same or a nearby site within 3 hrs prior to the valid time of the forecast. Sounding (RAOB) values are from appropriate radiosonde sites, for comparison. From Davies (1993a).*

the cases above it. There are probably several reasons why roughly one quarter of the cases fall below the solid curve. These include: (1) even though care was taken in the study by Johns et al. to select cases with sounding locations that would be likely to sample environments associated with tornadic supercells, some of the sounding data was probably less than representative of the true environments involved, and (2) there are clearly other factors in addition to helicity and CAPE that support thunderstorm rotation and supercell tornado development (see Johns and Doswell). Still, the results from the study by Davies imply that, when using the updated guidelines, the EHI is a significant parameter that may possess some skill distinguishing between tornadic and non-tornadic environments.

The EHI should be an improvement over the shear/CAPE comparison method evaluated by Turcotte and Vigneux (1987) because storm-relative helicity is used rather than mean shear (Rasmussen and Wilhelmson 1983; Davies 1989). Although mean shear is a useful ground-relative parameter for evaluating vertical shear in moderate to strong wind fields (see Davies and Johns), it is not as stable computationally as helicity, and does not factor in storm motion (Davies-Jones et al.). Also, helicity is normally computed as a *total* quantity over the lowest 2 or 3 km, rather than as an *average* over a vertical distance (roughly 0-4 km AGL in the study by Turcotte and Vigneux) that tends to deemphasize strong shear magnitudes present through lower levels (Davies 1989). Because of these disadvantages with mean shear, helicity is typically a better representation of low-level curvature shear, particularly in situations that involve wind fields that are relatively weak yet still strong enough to support supercells and tornadoes (e.g., in the late spring).

Bluestein and Parker (1993) note in their study of 61 dryline storms on 34 days that no significant differences could be found between helicty, vertical shear, and CAPE parameters derived from sounding data for tornadic and non-tornadic storms. However, only parameter *averages* are presented in their study, and no attempt is made to examine combinations of helicity and CAPE for the individual cases and storms.

In this paper, several examples of parameter fields derived from surface data and numerical model forecast data will be examined to suggest *general areas* of potential for significant thunderstorm rotation, rather than to deal specifically with the storm scale and individual storms, which is beyond the limitations of the model and surface data used here.

Davies (1993a) developed a method for computing helicity, instability, and EHI fields using NGM-based forecast winds and temperatures aloft from NMC's FD products[1] (similar to Woodall 1990, and Piltz 1992) blended with surface observations. These computations verified reasonably well in most cases with radiosonde observations, and were shown to be a potentially useful short-term forecast product. Because temperature and moisture detail is lacking in the transmitted FD products, a method was devised for computing the EHI using the surface-based lifted index (Hales and Doswell 1982). The following equation was developed by Davies:

$$EHI = ((-SLI)322 - 208)\ H\ /160000$$

where SLI is the surface-based lifted index, and H is the 0-3 km AGL helicity (m^2s^{-2}), similar to Davies-Jones et al. (1990).

This same method will be used to examine EHI fields associated with several tornadic and non-tornadic cases in the next section.

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[1] In Davies (1993a) and Woodall (1990), the wind and temperature aloft forecasts used are incorrectly described as being LFM-based. Recent communication by the author with programmers at NMC has revealed that, although the *graphic* FD winds aloft product is LFM-based, the *bulletin* FD product has been NGM-based since 1987; this is not noted in the the published bulletin documentation.

3. CASE EXAMPLES

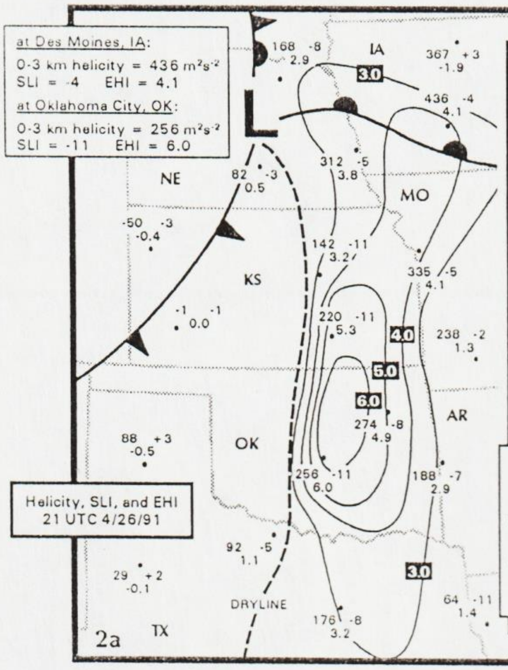
Although large tornado outbreak days are often "synoptically evident" (Doswell et al. 1993), it is nevertheless instructive to compare EHI fields and magnitudes on such days with those in less intense or less well-defined forecast situations.

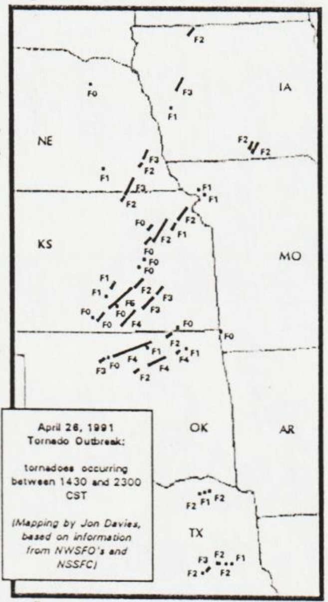
April 26, 1991 (the day of the Andover, Kansas tornado) is a good example of a large tornado outbreak day. Fig. 2a shows the EHI field using the NGM-based FD winds and temperatures aloft forecast (hereafter referred to as the *FD forecast*) for 12 hrs valid 00 UTC 4/27/91 blended with 21 UTC surface observations. EHI values in excess of 3.0 extend over a large area, from Iowa and eastern Nebraska southward to northern Texas, which fits well with the location of tornado occurrences during the 4 to 8 hour period following 21 UTC (Fig. 2b). It is interesting that the largest EHI values (> 5.0) center on southern Kansas into northern Oklahoma, which is where the largest and most violent tornadoes occurred. It appears that the helicity/instability combination is more optimal over this area, even though helicity is indicated to be larger further north (compare Des Moines and Oklahoma City in Fig. 2a).

Two weeks earlier, on April 12, 1991, a small outbreak of less intense tornadoes, oriented in similar north/south fashion, occurred in Oklahoma and Kansas (Fig. 3b). The 12 hr FD forecast valid 00 UTC 4/13/91 is blended with 21 UTC 4/12/91 surface data to show the mid-afternoon EHI field in Fig. 3a. An axis of EHI values larger than 2.5 extends across central Kansas and Oklahoma where tornadoes occurred later in the afternoon. The values are not as strong as on 4/26/91, yet are still in the range suggestive of tornadic supercells.

As a contrast to the above cases, Fig. 4 is an example of a non-tornadic situation involving large helicity magnitudes during the cool season. On the morning of 2/25/93, an area of moderate to strong thunderstorms moved across northeast Texas into northwest Louisiana between 10 UTC and 14 UTC, producing several wind damage reports. Forecasters anticipated possible tornadoes with some of the storms due to large helicity values (400-700 m^2s^{-2}). However, no tornadoes occurred according to preliminary reports. In Fig. 4, the 12 hr FD forecast valid at 12 UTC blended with 12 UTC surface observations indicates virtually no instability over northeast Texas; this was confirmed by the 12 UTC sounding at Longview (not shown). It seems that the thunderstorms were supported largely by strong dynamics and forcing, in lieu of measurable instability. In this case, the displacement of the instability axis to the west of the axis of large helicity results in poor combinations of helicity and instability, and negligible EHI values. This may be one reason why tornadoes did not occur even though helicity values were quite large and suggestive of violent tornadoes according to the values noted in Davies-Jones et al. (1990). In cases that produce significant tornadoes, the axes of helicity and instability are colocated.

An example of a non-tornadic situation involving weaker wind fields during the warm season is shown in Fig. 5, corresponding to the afternoon of 6/24/93 when scattered severe thunderstorms developed along a cold front from Illinois to Oklahoma. Surface observations from 22 UTC combined with the FD forecast valid 00 UTC 6/25/93 indicate strong instability along most of the length of the front. However, helicity values are weak, resulting in EHI values less than 1.5 at locations along the front, and less than optimal combinations of helicity and instability. With the possible exception of a brief tornado that produced minor damage in northeast Illinois early in the afternoon, no significant tornadoes were noted on preliminary reports. Given the weak helicity and poor EHI magnitudes in this case, the lack of significant tornadoes is not surprising.

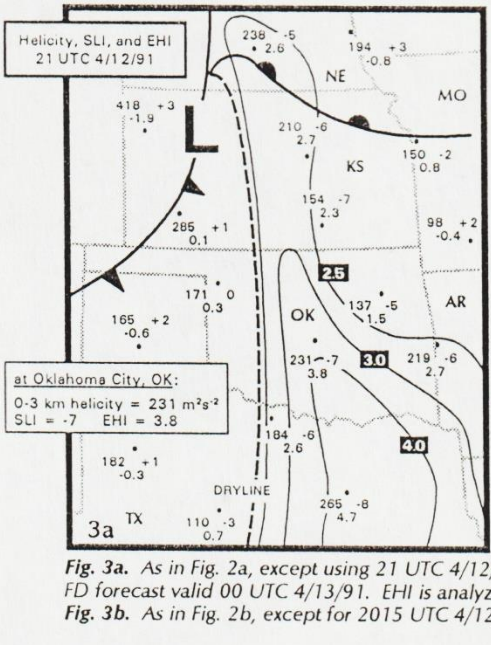


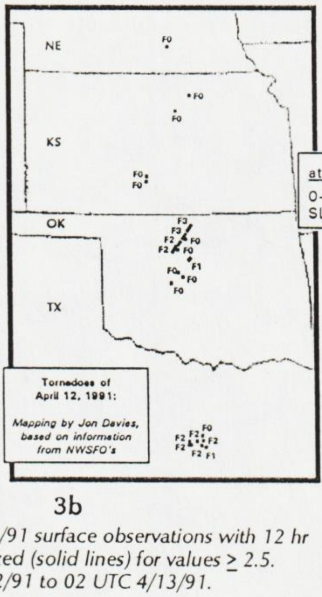


2b

Fig. 2a. Helicity, SLI, and EHI derived by blending 21 UTC 4/26/91 surface observations with 12 hr FD forecast valid 00 UTC 4/27/91. EHI is analyzed (solid lines) for values ≥ 3.0. Surface features are shown.

Fig. 2b. *Mapping from Storm Data showing tornadoes occurring 2030 UTC 4/26/91 to 05 UTC 4/27/91.*





3b

Fig. 3a. *As in Fig. 2a, except using 21 UTC 4/12/91 surface observations with 12 hr FD forecast valid 00 UTC 4/13/91. EHI is analyzed (solid lines) for values ≥ 2.5.*

Fig. 3b. *As in Fig. 2b, except for 2015 UTC 4/12/91 to 02 UTC 4/13/91.*

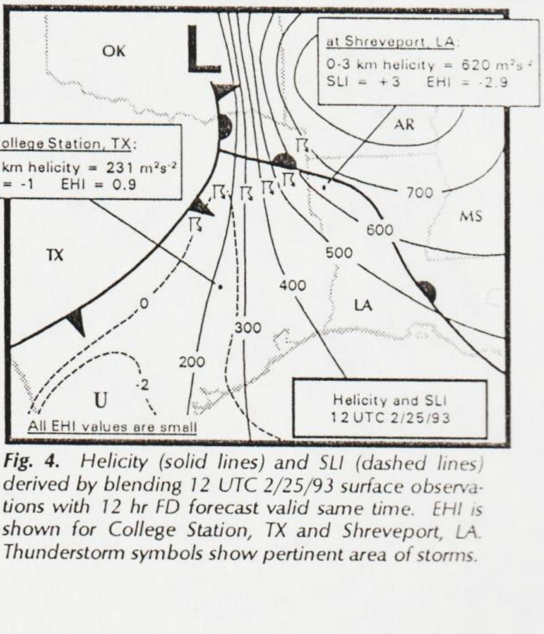


Fig. 4. *Helicity (solid lines) and SLI (dashed lines) derived by blending 12 UTC 2/25/93 surface observations with 12 hr FD forecast valid same time. EHI is shown for College Station, TX and Shreveport, LA. Thunderstorm symbols show pertinent area of storms.*

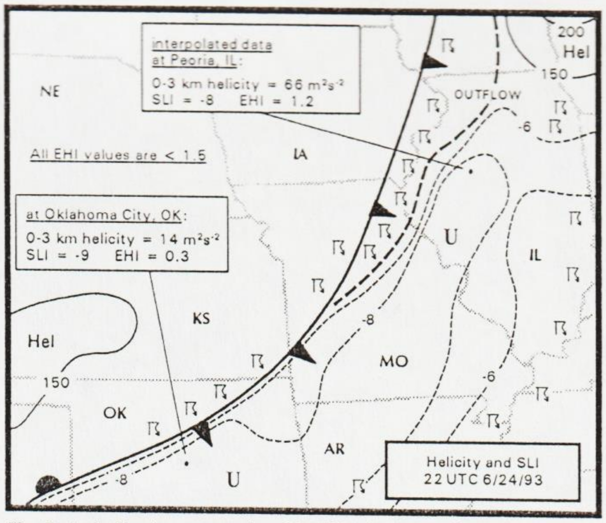


Fig. 5. *As in Fig. 4, except using 22 UTC 6/24/93 surface observations with 12 hr FD forecast valid 00 UTC 6/25/93. EHI is shown for Peoria, IL and Oklahoma City, OK.*

As might be expected, somewhere between the tornadic and non-tornadic cases described above there appears to be a "grey area" of helicity and instability combinations that is "border-line" and difficult to assess regarding mesocyclone-related tornadoes. An example is the evening of 6/1/93 when several hail-producing storms with characteristics suggestive of supercells occurred over northwest Kansas and southern Nebraska. Storm observers documented such supercell-related features as visible rotation and cloud striations, clear slots suggesting rear flank downdrafts, inflow "tails", and movement to the right of the mean wind with some of the storms. Fig. 6 shows the EHI field derived from the FD forecast valid 00 UTC 6/2/93 blended with surface observations for the same time. Although the Bulk Richardson Number (Weisman and Klemp 1984) is between 10 and 40 to suggest supercells (see Hays, Kansas in Fig. 6), and EHI values over northwest Kansas approach 2.5, no tornadoes were noted on preliminary reports. The environment further south, where EHI values exceed 2.5 to 3.0, was capped and no thunderstorms occurred.

A case involving similar helicity/instability combinations and EHI values (around 2.5) occurred on the evening of 4/30/93 in western Kansas (not shown). Unlike the 6/1/93 case, several tornadoes were reported, including one near Ness City that was associated with a mesocyclone detected on the Dodge City WSR-88D. Cases such as this and the 6/1/93 case seem to suggest that supercells forming in environments characterized by combinations of helicity and instability in the approximate EHI range from 2.0 to 2.5 may or may not produce tornadoes, depending perhaps more heavily than in cases associated with larger EHI values on storm-scale factors such as boundary interactions, inflow/outflow orientation, and storm movement. Although the EHI computation is certainly not precise enough to discriminate between tornadic and non-tornadic supercell potential in such situations, it can be said that EHI values in the general range from 2.0 to 2.5 suggest that any tornadoes that do occur are not likely to be as long-lived or significant as tornadoes that develop in environments containing more optimal combinations of helicity and buoyancy.

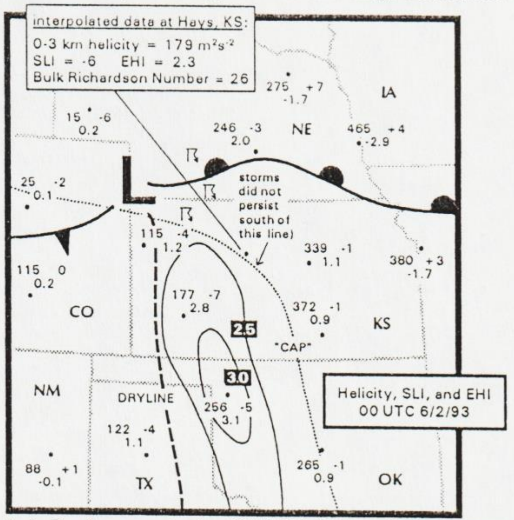


Fig. 6. *As in Fig. 3a, except using 00 UTC 6/2/93 surface observations with 12 hr FD forecast valid same time. Thunderstorm symbols show pertinent area of storms.*

Some significant tornado events are localized in character, and detection of an environment conducive to strong thunderstorm rotation depends on the availability of observations that measure localized backing of the surface wind or other pertinent features. The Catoosa, Oklahoma tornado (near Tulsa) that caused several deaths on the evening of 4/24/93 seems to fall into this category. The surface observation at Tulsa for 22 UTC (see Table 3) blended with the 12 hr FD forecast valid 00 UTC 4/25/93 suggests that EHI values across eastern Oklahoma were marginal (i.e., around 2.0). Such magnitudes don't do much to suggest significant tornadic supercell potential. However, special observations between 23 UTC and 00 UTC (see Table 3) show a pronounced backing of the surface wind and slight increase in dew point prior to the tornado at 2355 UTC. When combined with the FD forecast, these changes cause a sharp increase in the EHI (see Table 3), suggesting that the wind and thermodynamic environment in the Tulsa area near an approaching surface low rapidly became more favorable for low-level rotation and tornadoes. Except for one or two brief and isolated tornado reports in southeast Oklahoma, tornadoes on 4/24/93 were confined to the localized corridor from Tulsa to near Fayetteville, Arkansas near the path of the surface low, even though storms developed southward into Texas.

Table 3. **EHI at Tulsa, OK 2000-2335 UTC 4/24/93**

Surface ob time (at TUL)	EHI	0-3km Helicity (m^2s^{-2})	SLI	sfc T, sfc T_d, & sfc wind (kts)
2200 UTC	1.8	165	-4.7	77°F 61°F 190°15
2300 UTC	1.9	183	-4.5	76°F 61°F 160°15
2331 UTC	2.6	251	-4.4	74°F 62°F 130°15
2335 UTC	3.5	329	-4.7	73°F 63°F 100°10

Table 3. *EHI, helicity, SLI at Tulsa 2200-2335 UTC 4/24/93, using surface observations and 12 hr FD forecast valid 00 UTC 4/25/93.*

Finally, to emphasize contrasting helicity/instability combinations for well-defined tornadic and non-tornadic days, parameter fields are shown in Fig. 7 for 5/9/93, an outbreak day in Texas that included the Wylie tornado (near Dallas), and Fig. 8 for 5/10/93, which saw scattered severe weather reports over the Mississippi River area, but no tornadoes according to preliminary reports. In the former case (Fig. 7), EHI values computed using surface and model data for 18 UTC suggest strong potential for supercell tornadoes over north-central Texas. The following day (Fig. 8), wind field parameters had weakened considerably, and resulting EHI magnitudes indicated poor helicity/instability combinations, which is one probable reason why only hail and wind reports were noted.

Additional examples of hourly helicity, instability, and EHI values in tornadic and non-tornadic cases can be found in Davies (1993b).

4. SUMMARY/DISCUSSION

As suggested by the cases in the prior section, and Tables 1 and 2 from section 2, a parameter such as the EHI, combining low-level curvature shear with instability, appears to demonstrate at least some ability to distinguish environments containing significant potential for supercell-induced tornadoes from those that are less likely or unlikely to produce tornadic supercells. Of course, a parameter like the EHI must be cross-referenced with other parameters that support thunderstorm rotation (e.g., mid-level wind strength and low-level storm-relative inflow; see Davies 1993a) to be consistently useful. Also, as events become more localized, the ability of numerical model data and the surface observation network to diagnose such environments becomes more dependent on the availability of observations located in proximity to developing storms, as suggested by the Catoosa event examined above.

Although the notion of "threshold" values is empirical in nature, it is nevertheless practical to know a general range of values for a given

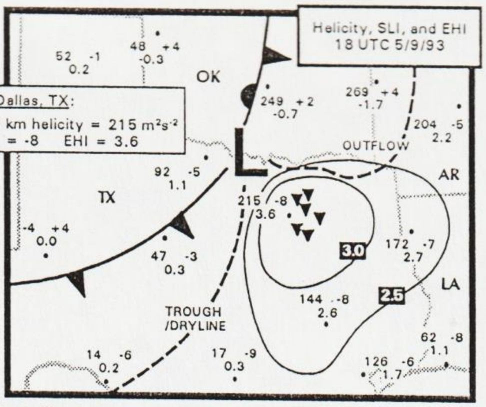


Fig. 7. As in Fig. 3a, except using 18 UTC 5/9/93 surface observations with 6 hr FD forecast valid same time. Triangles are preliminary tornado reports 1800-1930 UTC.

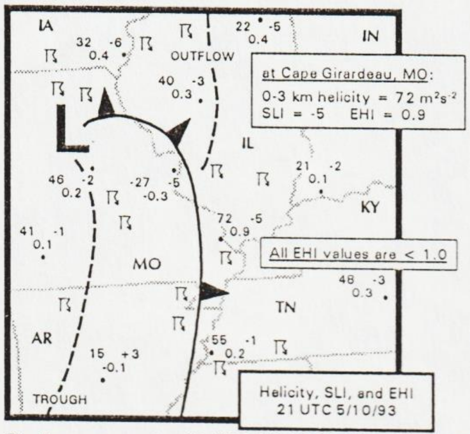


Fig. 8. As in Fig. 3a, except using 21 UTC 5/10/93 surface observations with 12 hr FD forecast valid 00 UTC 5/11/93.

parameter that appear significant for monitoring purposes. This study and the author's experience with surface and model data in a number of severe weather cases during 1991, 1992, and 1993 support the observation that EHI values approaching 2.5 and greater are indicative of significant potential for mesocyclone-induced tornadoes. EHI values less than 2.0 suggest that significant supercell-induced tornadoes are not likely. Conversely, EHI magnitudes near 4.0 and greater suggest potential for violent tornadoes, if other supporting factors such as low-level inflow and mid-level winds are strong.

These suggested guidelines are summarized in Table 4. While only general in nature, the author has found these to be more useful than guidelines relating to tornado potential and intensity based only on helicity magnitudes (Davies-Jones et al. 1990) without reference to specific magnitudes of instability/buoyancy.

Tornadoes are often reported with EHI values less than those noted in Table 4; however, many of these tornadoes appear to be of non-supercell origin (Wakimoto and Wilson 1989). Examination of non-supercell cases such as the Woodward, Oklahoma tornadoes on 4/9/92 (Davies 1993b) suggests that steep lapse rates involving significant low-level moisture over elevated terrain may contribute to some non-supercell tornado events. In such cases, instability and/or lapse rates will be quite strong, while helicity and EHI fields will be weak.

Table 4.	**Suggested EHI guidelines**
< 2.0	significant mesocyclone-induced tornadoes unlikely to occur
2.0-2.4	mesocyclone-induced tornadoes possible, but unlikely to be strong or long-lived
2.5-2.9	mesocyclone-induced tornadoes more likely
3.0-3.9	strong tornadoes (F2-F3) possible
≥ 4.0	violent tornadoes (F4) possible

These guidelines assume adequate support from mid-level winds (≥ 25-30 kts) and 0-2 km storm-relative inflow (≥ 20 kts).

Table 4. Updated and revised guidelines for using EHI.

It is also important to note that large EHI values do not guarantee that tornado development will occur. Although the mechanisms and specifics are unclear, some rapidly-moving squall line events suggest that rapid initiation and propagation of storms over a large area can in some cases dominate storm organization and evolution at the expense of potential for thunderstorm rotation. Acknowledging this observation, it can still be said that large EHI values are, more often than not, indicative of significant potential for mesocyclone-induced tornadoes, *if thunderstorms occur within the axis of optimal helicity/instability.*

Given the wide range of helicity and instability magnitudes encountered in storm environments, the ability of the EHI to assign a value to a given combination of helicity and instability appears important. This study suggests that the EHI computation is a useful supplement to the separate helicity and instability parameters in evaluating trends pertinent to potential thunderstorm rotation. Although helicity and instability certainly do not comprise a complete analysis of supercell and mesocyclone potential, experience suggests that the EHI, when computed routinely using sources such as numerical model forecast data and current surface observations, would be helpful as a diagnostic tool in tornado forecasting .

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