Helicity and Hodographs Revisited

by Jon Davies

A little over a year ago, I wrote an article giving some background about wind profiles that can contribute to supercell development (see *Storm Track*, Vol. 17, No. 2, January-February 1994). We discussed using a **hodograph**, a curving line "trace" that represents winds at different levels above ground on a circular graph. We also discussed how to use a parameter called **helicity** to measure the rotational potential of a given wind profile (hodograph trace) regarding possible development of supercells (rotating thunderstorms that sometimes produce tornadoes). In this article I'll review some concepts, and introduce a more accurate method (if you don't have a computer program) for computing helicity using overlay templates.

As noted in last year's article, it has been known for several years that hodographs that curve clockwise with height usually indicate better potential for storms to rotate. This, of course, assumes that instability is significant for the situation and that a strong enough trigger mechanism is present to kick off some storms in the first place. When winds become more westerly with height and increase in speed in the first 10,000 ft (roughly 3 km) above ground, this imparts a sort of "spin" to the air in low levels along a horizontal axis, not unlike a football that spirals when thrown. A developing thunderstorm can "ingest" this spin into its main updraft, tilting the axis of spin from horizontal to vertical, which in turn may cause the updraft and thunderstorm to begin rotating. Helicity is a useful parameter for measuring the potential of the low-level winds to produce this spin.

Helicity amounts to the pie-shaped area (shaded in Figure 1) "under" a clockwise-curved hodograph, enclosed by the hodograph trace itself and two lines drawn to the hodograph trace from the tip of a vector representing an estimated storm motion (see Figure 1). The section of the hodograph trace between the two lines should represent roughly the first 10,000 ft or 3 km above ground (containing the low-level flow that can be "ingested" into the base of a storm updraft), which is roughly equivalent to the layer from surface to 700 mb when east of the high plains.

In my January 1994 article, I discussed estimating the helicity area on a hodograph by counting the approximate number of boxes formed by the background grid (speed circles and directional azimuth lines) on the hodograph diagram that make up the pie-shaped area in question. The problem with that method is the background grid: the boxes formed by that grid vary significantly in size as one moves outward from the center/origin of the hodograph diagram. So, this method is not very accurate, and can result in significant errors.

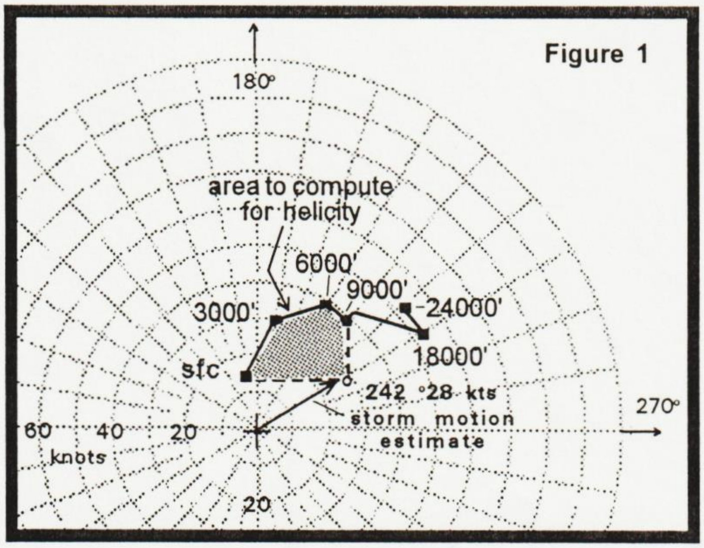
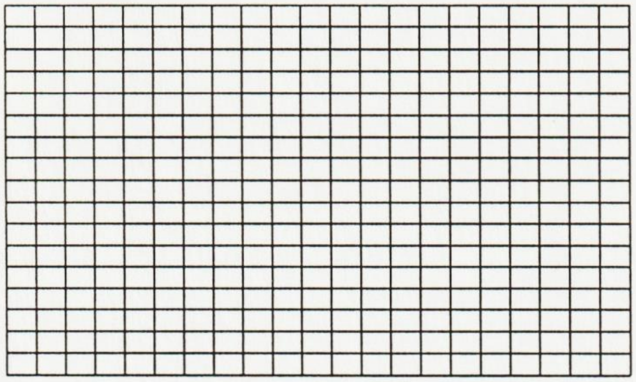


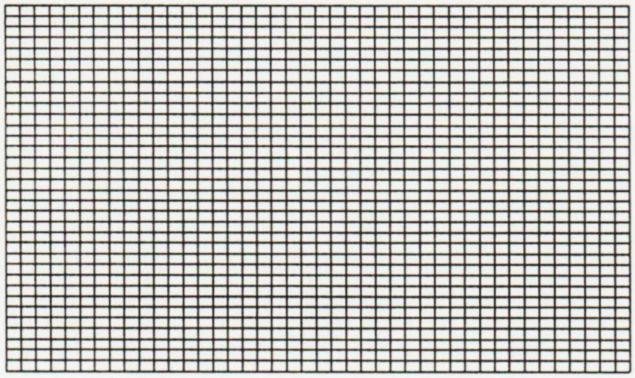
Figure 1

In the interest of being more accurate (apart from using a computer program), I've developed a couple of overlay templates (see Figure 2) that use boxes of equal size for estimating helicity when using the hodograph background diagram shown (also in Figure 2). For those who are somewhat less concerned with accuracy and don't want to count so many boxes, the top template with larger grid (each box equals 25 m^2s^{-2} of helicity area) can be used. For more accuracy, the template with smaller grid (each box equals 6 m^2s^{-2}) is best. To use the templates, run a copy of them on clear transparency film, and use them only with a same size copy of the hodograph background diagram in Figure 2.

As a review and example, let's do a helicity computation using one of the new templates. We'll use the Stephenville (SEP) sounding data Tim Marshall published in the Sept./Oct. '94 issue of *Storm*



Overlay Template for computing Helicity
1 box = 25 m^2s^{-2}



Overlay Template for computing Helicity
1 box = 6 m^2s^{-2}

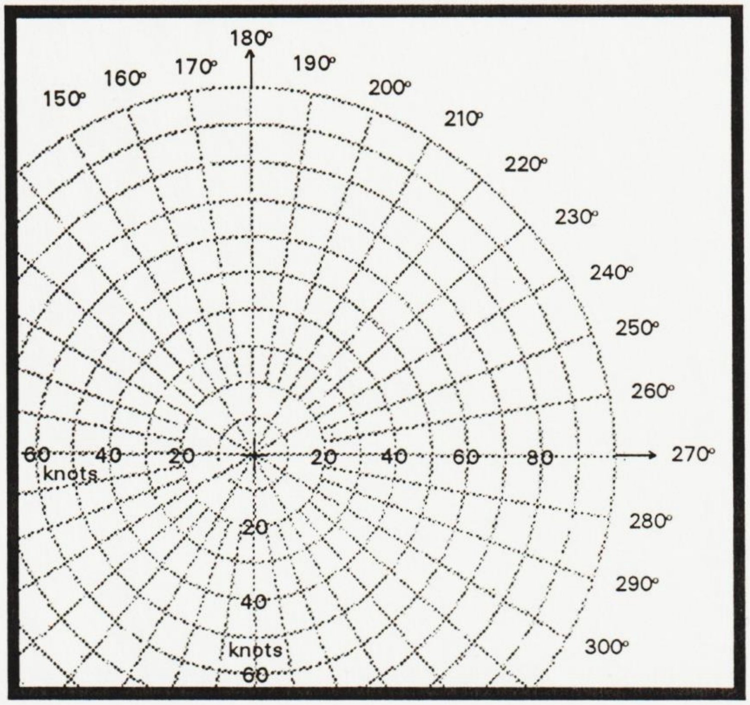


Figure 2:
Large and small grid overlays (left) for measuring helicity using the hodograph background diagram above.

Track (pg. 6) for the evening of April 25, 1994 (00z 4/26/94), roughly three hours before an F4 tornado at Lancaster, Texas, about 50 miles east-northeast of the sounding site. To pick up some important low-level detail missing from Tim's data, I'm adding the 925 mb winds (roughly 3000 ft or 1 km above sea level) from the SEP mandatory level sounding data I archived. To keep things reasonably simple we'll carry things only to 400 mb (6 to 7 km above sea level):

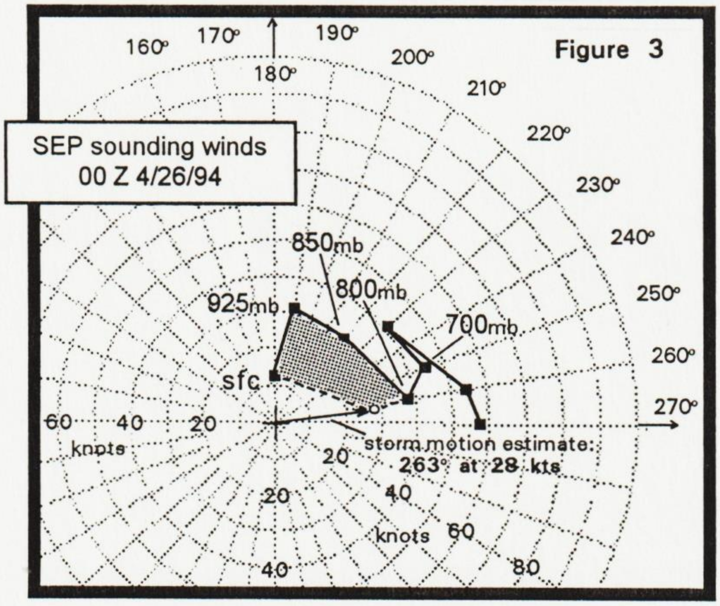


Figure 3

SEP 00 Z 4/26/94 (7 pm CDT 4/25/94)

Surface	180° at 12 kts
925 mb (˜3000 ft MSL)	190° at 31 kts
850 mb (˜5000 ft MSL)	220° at 30 kts
800 mb (˜6000 ft MSL)	260° at 38 kts
700 mb (˜10000 ft MSL)	250° at 45 kts
600 mb (˜14000 ft MSL)	230° at 41 kts
500 mb (˜18000 ft MSL)	260° at 54 kts
400 mb (˜24000 ft MSL)	270° at 58 kts

This hodograph is plotted in Figure 3 at left, with a point representing the wind vector at each level. Each point is plotted by moving outward from the origin or center of the circular diagram along the directional line/azimuth to the appropriate speed in knots (represented by the background circles). The "zigzag" line connecting these points is the hodograph.

To compute helicity, we need a storm motion estimate. A rough estimate can be obtained by averaging the speed and direction of the wind at our eight levels (surface through 400 mb), and then making an adjustment for supercells, which almost always move to the right of this average wind. Using a calculator, I come up with a wind average of 233° at 38 knots for our eight levels (just add the speed and direction numbers up separately, and divide each total by 8). For movement of plains supercells in the warm season, a reasonable estimate for computing purposes is 30° right of this average wind (looking downwind), and slowing the speed down by 25%. Going right of 233° by 30° gives us **263°** (233 + 30), and multiplying our average speed of 38 knots by 75% (25% less) gives us **28 knots.**

If we plot this point on our diagram (the small open circle in Figure 3), and draw two lines from this point to the hodograph trace to "enclose" an area from the surface to 700 mb, we now have an area to compute for helicity. However, in this example note that the hodograph doubles back to the left above 800 mb, instead of continuing to curve clockwise. Because we want to compute only the area under *the clockwise curve* in low levels (note that the hodograph segment from 800 mb to 700 mb moves *counterclockwise*), in this case we'll just enclose the area between surface and 800 mb (shaded in Figure 3). Again, we define this area by drawing two dashed lines from our storm motion estimate point to the hodograph trace at 1) the surface point, and 2) the 800 mb point.

Now, all we have to do is compute this area, and the templates make this relatively easy. Using the template with smaller grid from Figure 2, and tilting the template so that it fits this five-sided area better for convenience of counting of boxes (see Figure 4 below), I come up with 39 or 40 boxes, depending on how one counts a few bits and pieces. Taking 40 times 6 (each box equals 6 m^2s^{-2}), the helicity in this example computes to **240 m^2s^{-2}**.

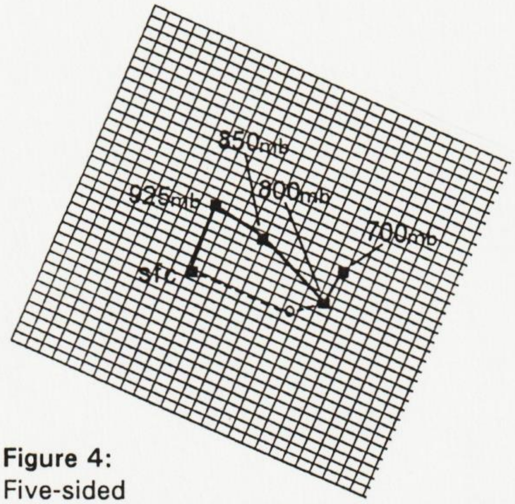


Figure 4: Five-sided area from Fig. 3 with template overlay.

Because tornado-producing supercells tend to be associated with environments having helicity greater than roughly 150 (if instability and other factors combine properly with the wind environment), *this is a significant amount of helicity.* As Tim pointed out in the Sept./Oct. '94 issue, as the surface wind backs and becomes more easterly (which it did during the evening of April 25 further east of Stephenville), this adds even more area under our hodograph, resulting in more helicity.

This Stephenville sounding example makes a significant point about the importance of low-level wind data. If we had computed the helicity area without the wind information from 925 mb, we would have come up with a helicity value 90 to 100 m^2s^{-2} <u>less</u> than our result from Figures 3 and 4; this would be a much poorer estimate and could be very misleading. When computing a helicity estimate from wind profiles, one should at the very least have data from the surface, 925 mb, 850 mb, 700 mb, and 500 mb levels (east of the high plains). If using forecast winds from one of the numerical models, at the bare minimum one should have forecast wind information available for the surface and roughly 3000, 6000, 10000, and 18000 ft above sea level (east of the high plains).

Helicity and hodographs <u>by themselves</u> are <u>not</u> very useful in severe storms forecasting. One needs additional information, such as a useful estimate of instability in the environment (among other factors), to make a reasonable assessment of potential for rotating storms. Tim has discussed instability as measured by CAPE in the last issue of *Storm Track* (January-February 1995). The article on the following pages will discuss a little about how to combine information from both a measure of the wind profile and also the instability to evaluate potential for supercell development.

For additional reading about helicity, see the paper <u>Test of Helicity as a Tornado Forecast Parameter</u> by Davies-Jones, Burgess, & Foster in the preprint volume for the 16th Conf. on Severe Local Storms (AMS, 1990).