P 8.1 An Update to the Supercell Composite and Significant Tornado Parameters

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1. Introduction

The original formulations of the supercell composite parameter (SCP) and significant tornado parameter (STP), as documented in Thompson et al. 2003 (hereafter T03), have been modified to include the effective bulk shear and effective storm-relative helicity (SRH) developed by Thompson et al. 2004a and Thompson et al. 2004b, respectively. Other changes include the addition of a convective inhibition (CIN) term to the STP to provide a version that limits areal false alarms when viewed as a contoured planar field. The RUC model close proximity sounding sample described in T03 has been expanded to include cases from 2003 and 2004, increasing the sample size to 916 soundings.

2. New Supercell Composite Parameter

The primary motivation for modifying the SCP was to expand the utility of the parameter to more directly include elevated supercell potential, and to provide more realistic estimates of surface-based supercell potential in environments with very deep (shallow) storms, as indicated by very high (low) equilibrium level heights. Specific changes to the SCP are as follows:

1. The bulk Richardson shear term is replaced by the effective bulk shear.

2. The 0-3 km SRH is replaced by the effective SRH.

The effective bulk shear discriminates strongly between supercells and nonsupercells, similar to the bulk Richardson shear term. However, the effective bulk shear does not include near-ground stable layers that may not be representative of the storm inflow. The effective SRH only focuses on vertical shear in the inflow layer of the storm (based on parcel CAPE and CIN constraints), thus providing a more realistic estimate of SRH in elevated storm environments. The effective SRH is normalized to 50 $m^2 s^{-2}$ based on the 25th percentile values associated with the nontornadic and "marginal" supercells (see Fig. 5 of Thompson et al. (2004b)), similar to T03.

The modified SCP formulation is as follows:

$$\textbf{SCP} = (\text{MUCAPE} / 1000\ \text{J kg}^{-1}) * (\text{effective shear} / 20\ \text{m s}^{-1}) * (\text{effective SRH} / 50\ \text{m}^2\ \text{s}^{-2})$$

where the MUCAPE is the most unstable parcel CAPE. The effective shear term is set to zero for values less than 10 m s^{-1}, and becomes 1 for values greater than 20 m s^{-1}.

The new version of the SCP discriminates strongly between surface-based supercells and the discrete nonsupercells (Fig. 1). A majority of the elevated right-moving supercells were associated with SCP values greater than one, while SCP values were very small for the lowest quartile of cases due to very limited buoyancy in the RUC

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model proximity soundings for elevated supercells. As expected, the sample of storms with marginal supercell characteristics (see T03) tends to reflect a transition in storm environments between supercells and nonsupercells.

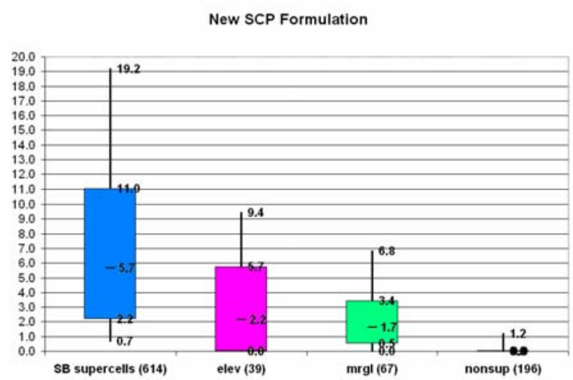

Figure 1. Box and whiskers plot of SCP calculated from RUC model proximity soundings associated with four groups of storms: surface-based (SB) supercells, elevated right-moving supercells (elev), surface-based storms with marginal supercell characteristics (mrgl), and surface-based, discrete nonsupercells (nonsup). The top and bottom of the shaded boxes denote the 75^{th} and 25^{th} percentile values, respectively, with the median marked within each box. The whiskers extend upward to the 90^{th} and downward to the 10^{th} percentiles. Sample sizes are given in parentheses.

3. New Significant Tornado Parameter

The original formulation of the STP has been modified in the following ways:

1. The 0-6 km bulk shear is replaced with the surface-based effective bulk shear.

2. The 0-3 km SRH is replaced with the effective SRH based on parcel constraints of 500 J kg^{-1} CAPE and -250 J kg^{-1} CIN.

3. The 100 mb mean parcel CAPE (MLCAPE) normalization value is increased to 1500 J kg^{-1}.

4. An additional STP version is created that includes a 100 mb mean parcel CIN (MLCIN) term.

First, the effective shear term (based on the surface parcel) is included to better reflect the vertical shear relevant to supercells in environments of exceptionally high or low equilibrium level heights. The effective shear discriminates strongly between supercells and nonsupercells, but there is only a slight tendency for effective shear to be stronger with significantly tornadic supercells compared to nontornadic supercells (not shown). Also, it is not apparent from our sounding sample that excessively strong bulk shear enhances significant tornado potential. Therefore, the contribution of the effective shear term is limited to 1.5 as a maximum value. Second, the effective SRH has been shown to be a better discriminator between significantly tornadic (F2 or greater damage) and nontornadic supercells than either the fixed layer 0-1 km or 0-3 km SRH (Thompson et al. 2004b). Third, the MLCAPE normalization value was increased so that the potential MLCAPE contribution to the STP would roughly match that of the effective SRH term (e.g., 90^{th} percentile values for both MLCAPE and effective SRH result in normalized term values of about three). Finally, a second version of the modified STP was developed to include MLCIN as a limiting factor. The rationale behind this modification is to reduce the spatial coverage of the STP (and associated false alarms) in contoured planar displays such as the hourly objective analysis scheme in operation at the Storm Prediction Center (Bothwell et al. 2002). This version better accounts for areas where storms are less likely to develop or persist.

The modified STP formulation is as follows:

STP = (MLCAPE / 1500 J kg^{-1}) * (SFC effective shear / 20 m s^{-1}) *

$$(\text{effective SRH} / 150\ \text{m}^2\ \text{s}^{-2}) \ast$$
$$((2000 - \text{MLLCL}) / 1500\ \text{m}) \ast$$
$$((250 + \text{MLCIN}) / 200\ \text{J kg}^{-1})$$

where the surface-based (SFC) effective shear term is set to zero for values less than 10 m s^{-1}, and becomes 1.5 for values greater than 30 m s^{-1}. Note that the MLCIN term (and the STP value) becomes zero when MLCIN is less than -250 J kg^{-1} (magnitude greater than 250 J kg^{-1}).

As shown in Fig. 2, the separation between significantly tornadic and nontornadic supercells is similar between the original and modified STP formulations, though the modified STP values tend to be reduced by roughly 50%. A little more overlap in the significantly tornadic and nontornadic supercell samples is noted when comparing the new STP with CIN to the version

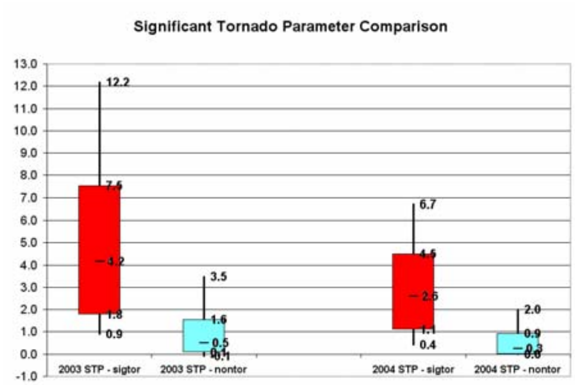

Figure 2. Box and whiskers plot of original (2003) formulation of STP, and the new (2004) formulation of STP for 95 significantly tornadic supercells, and 315 nontornadic supercells. Plotting conventions are the same as Fig. 1.

without CIN (Fig. 3). Though the version with CIN does not discriminate as well as the no CIN version between significantly tornadic and nontornadic supercells, the reason for developing the CIN version is to reduce false alarms in contoured fields generated as part of the hourly objective analysis routine in use at the Storm Prediction Center (Bothwell et al. 2002).

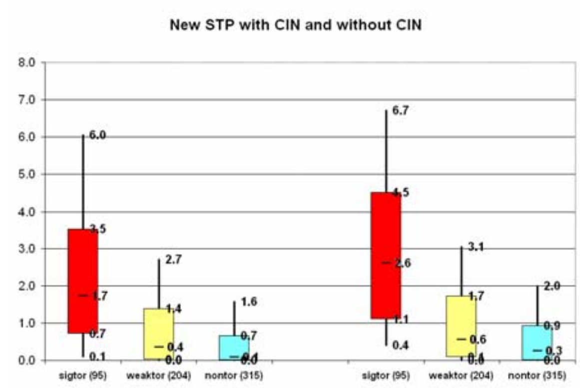

Figure 3. Box and whiskers plot of the new versions of STP with CIN on the left, and without CIN on the right, for three groups of surface-based supercells: significantly tornadic (sigtor), weakly tornadic (F0-F1 damage, weaktor), and nontornadic (nontor). Plotting conventions are the same as Fig. 1.

A comparison of STP forecast value thresholds, via 2 x 2 contingency tables constructed from our full set of 614 surface-based supercells (after Doswell et al. 1990), reveals that values in the range of 0.5 to 1 result in the greatest skill based on the True Skill Statistic (TSS) at the highest probabilities of detection for the new STP formulation (Fig. 4). A comparison of metrics from the original formulation (not shown) and Fig. 4 for the same percentiles (e.g., the 25th percentile value of ~ 1 for the original formulation and ~0.5 for the modified formulation) suggests that forecast performance is nearly identical.

4. Conclusions

The original formulations of the SCP and STP, as developed by T03, have been modified in several important ways. Changes to both parameters center on inclusion of the effective bulk shear and effective SRH, as opposed to fixed layer shears in the original formulations. The primary advantage to the effective shear approach in the modified SCP is to improve estimates of vertical shear in elevated storm environments. The net result is a composite parameter that can be used to identify supercell potential in a wider range of environments.

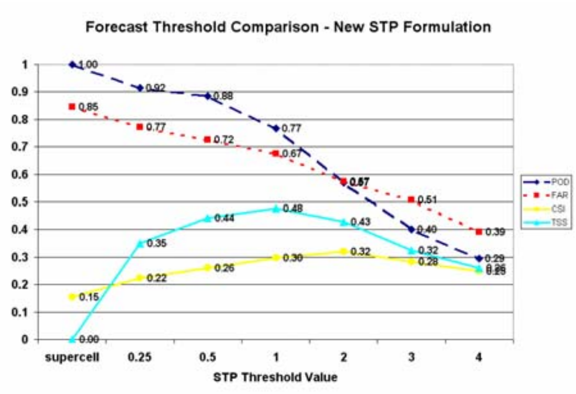

Figure 4. Plot of probability of detection (POD, dashed dark blue), false alarm ratio (FAR, dashed red), critical success index (CSI, yellow), and true skill statistic (TSS, cyan) for significant tornado forecasts based on six threshold values for the new STP. The "supercell" threshold, which presumes the occurrence of a significant tornado given a supercell, represents the climatology of the 614 surface-based, right-moving supercell sample.

The STP modifications were based largely on inclusion of the effective bulk shear and effective SRH, as with the SCP. However, the effective shear terms in the STP are those versions that most clearly favor significantly tornadic supercells, not simply supercells. The ability of the STP to discriminate between significantly tornadic and nontornadic supercells is maintained from the original version. An additional STP formulation with CIN has been developed to reduce areal false alarms in plan views of STP produced by the objective analysis routine in use at the Storm Prediction Center.

5. Acknowledgments

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6. References

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