Assessing the Impact of the Nocturnal Transition on the Evolution and Lifetime of Supercell Thunderstorms in the Great Plains

Matthew Gropp and Casey Davenport

University of North Carolina at Charlotte

Department of Geography and Earth Sciences

Introduction

The cooling and stabilization of the boundary layer during the nocturnal transition leads to a series of thermodynamic and kinematic changes in the low-level environment. This transition creates a challenging environment for forecasting the evolution of supercell thunderstorms, as it is not well understood how supercells respond to variations in their environment. During the nocturnal transition, there are four possible evolutions for an isolated supercell (Colman 1990; Billings and Parker 2012; Nowotarski et al. 2012; Davenport and Parker 2015):

1) Dissipation
2) Merge with other convection (e.g., supercells or MCSs)
3) Grow upscale to a larger form of convection
4) Maintenance (as elevated or surface-based convection)

The goal of this study is to increase skill in forecasting supercells during the nocturnal transition, thereby expanding our understanding of how supercells respond to kinematic and thermodynamic changes in their local environment.

Methods

Nocturnal supercell cases were identified using the Storm Prediction Center's Severe Thunderstorm Event Archive from 2005 to 2016. Cases were limited geographically to the Great Plains of the United States during the months March – June. Isolated supercells at sunset (SS) were then classified based on their evolution from SS to SS +5 hours (Fig. 1).

157 isolated supercells were confirmed at SS:

- Dissipated (Fig. 1a) - 86
- Maintained (Fig. 1b) - 14
- Upscale (Fig. 1c) - 45
- Merger (Fig. 1d) - 12

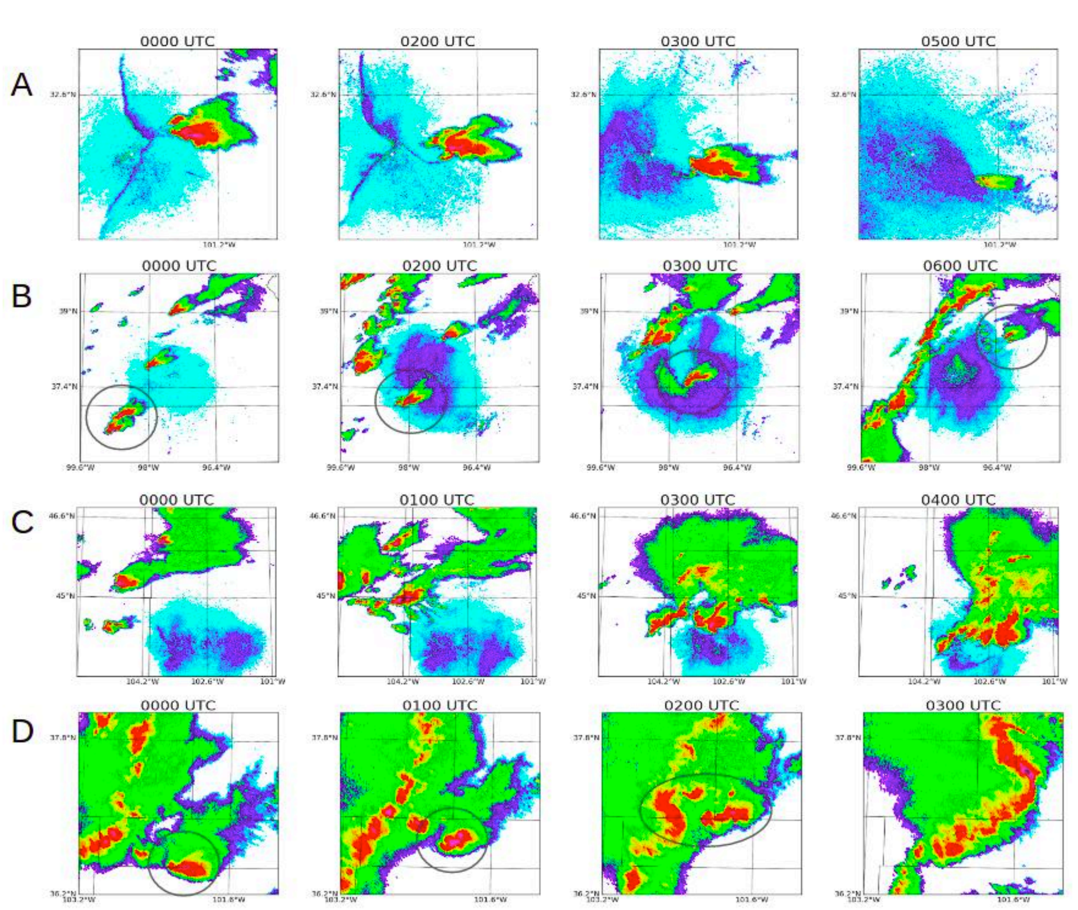

Figure 1. Example of each nocturnal supercell classification

Rapid Update Cycle and the Rapid Refresh model hour 0 analyses were used from SS -1 to SS +5 for proximity soundings (at a single point) and to describe the mesoscale environment around the supercell. Numerous thermodynamic (e.g., CAPE, CIN) and kinematic (e.g., shear and SRH over a variety of depths) parameters were derived from the model output.

Results

- Mean sounding profiles and hodographs show low-level cooling and stronger low-level winds over time for all evolution types (Figs. 2-3)
  - Unlike other evolution types, maintained cases had virtually no change in the effective layer depth through SS +5, as well as the smallest decrease in MU CAPE (Fig. 2)
  - Mean hodographs were strongly curved, favoring right moving supercells, with clear development of the low-level jet over time Maintained and merger cases contained the largest SRH, favoring stronger and longer-lived supercells (Fig. 3)

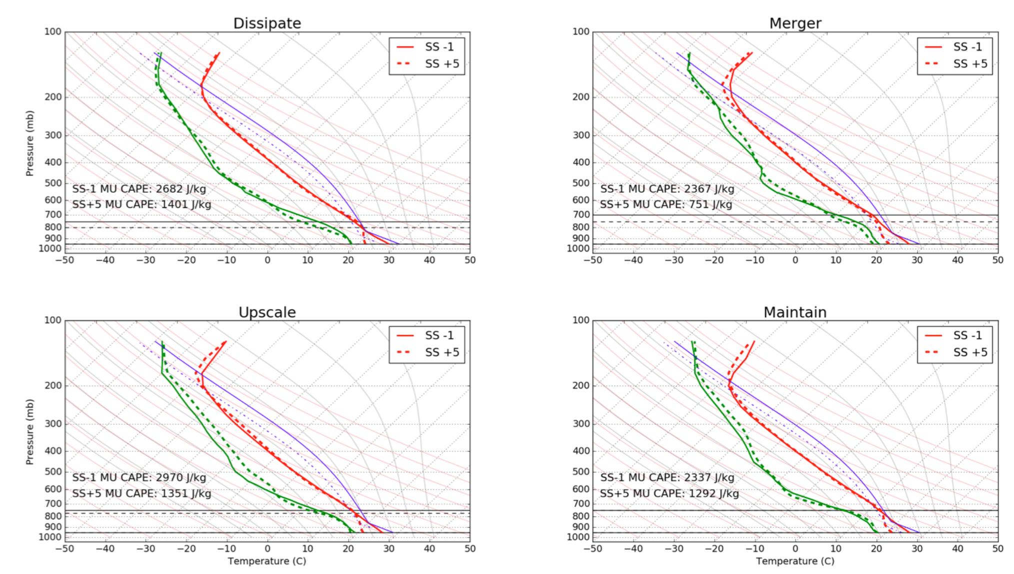

Figure 2. Mean RUC/RAP soundings at SS -1 (solid line) and SS +5 (dashed line) for each evolution classification.

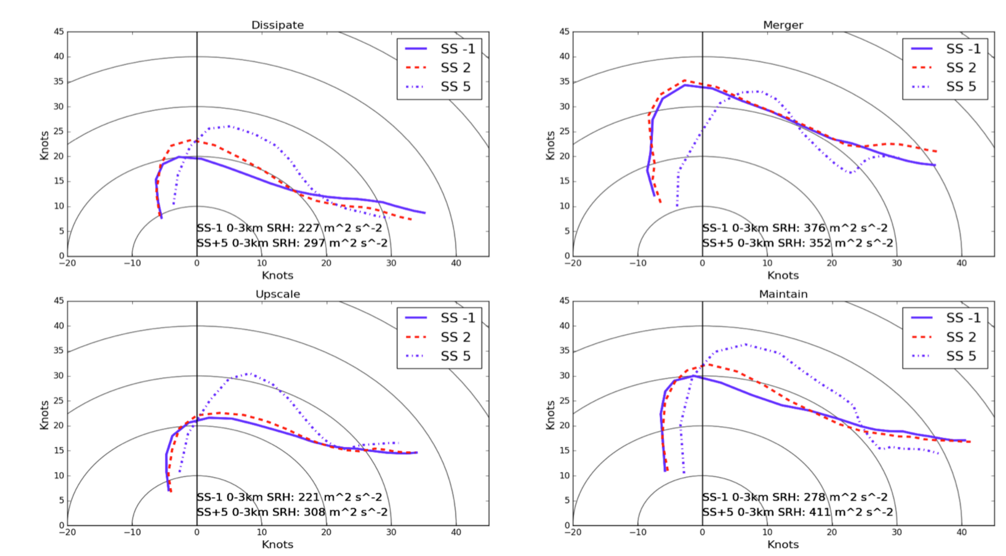

Figure 3. Mean hodographs at SS -1 (blue), SS +2 (dashed red) and SS +5 (dashed blue) for each evolution classification.

- The general synoptic setup is favorable for all supercell classifications, though a more amplified trough is evident in maintained and merger cases (Fig. 4)
- The mesoscale inflow environment contains significant spatial heterogeneity, with notable differences evident in MU CIN and effective SRH among all classification types (Fig. 5)
- Dissipating cases had the least favorable mean values and overall trends for supercell maintenance for the majority of parameters, including effective SRH, effective bulk shear, and MU CIN (Table 1, Fig. 6)

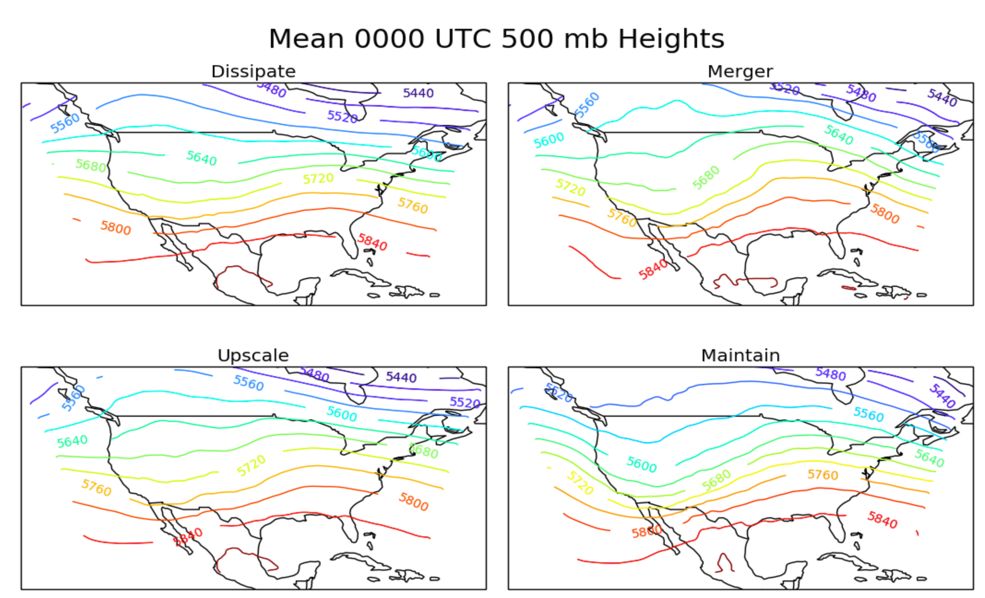

Figure 4. Mean RUC/RAP 500 mb height field for each classification at 0000 UTC.

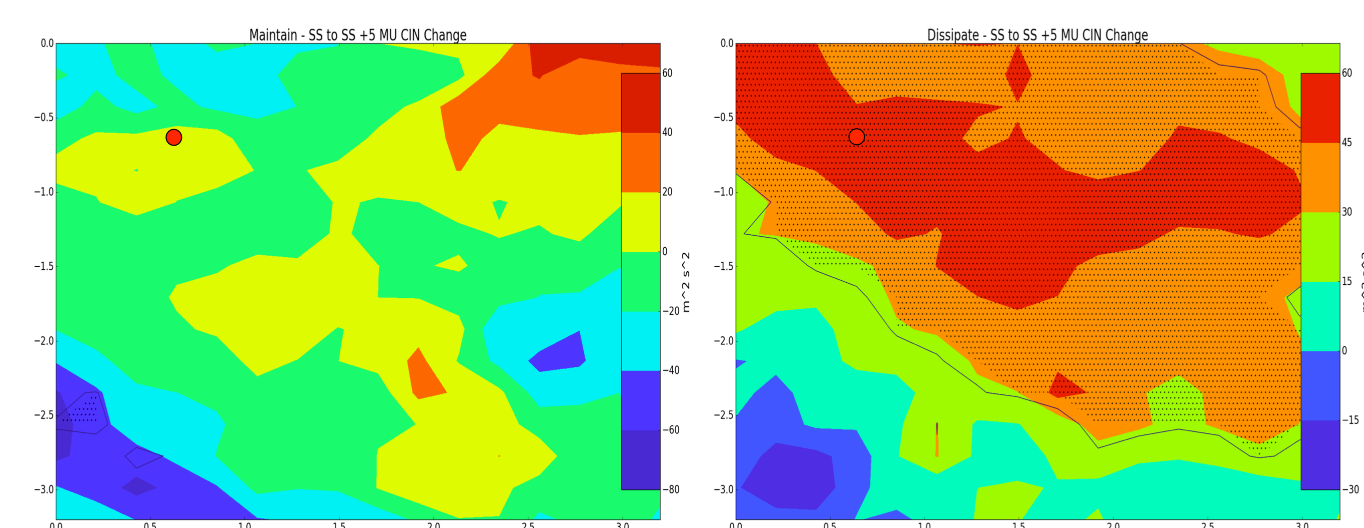

Figure 5. Inflow grid of mean MU CIN change from SS to SS +5. Hashing indicates regions where change was significant (p-value < 0.05). Red dot indicates supercell location.

	SS -1	SS	SS +1	SS +2	SS +3	SS +4	SS +5
Dissipate to Upscale	-	-	SCP Eff. SRH	SCP Eff. SRH	SCP Eff. SRH MU CIN	BRN Eff. SRH MU CIN	SB CAPE MU CIN
Dissipate to Maintain	-	-	0-3km SRH Eff. SRH	0-1km SRH 0-3km SRH Eff. SRH SCP	MU CIN 0-1km SRH 0-3km SRH Eff. SRH SCP	MU CIN SB CIN 0-1km SRH 0-3km SRH Eff. SRH SCP	MU CIN 0-1km SRH 0-3km SRH BRN
Dissipate to Merger	0-1km SRH 0-3km SRH Eff. SRH 0-3km Shear 0-1km Shear BRN	0-1km SRH 0-3km SRH 0-1km Shear BRN	MU CAPE 0-1km SRH 0-3km SRH Eff. SRH 0-1km Shear Eff. Shear	SBCAPE 0-1km SRH 0-3km SRH 0-1km Shear	MU CAPE 0-1km Shear	SB CAPE MU CAPE 0-3km SRH 0-1km Shear BRN	SB CAPE MU CAPE 0-3km SRH 0-1km Shear BRN
Maintain to Upscale	-	-	0-3km SRH 0-3km Shear BRN	0-3km SRH 0-3km Shear	0-3km SRH	0-3km SRH SCP	BRN
Maintain to Merger	-	-	-	SFC CAPE	ML CAPE MU CAPE SCP	SB CAPE ML CAPE MU CAPE Eff. SRH SCP	MU CAPE SCP
Upscale to Merger	BRN 0-3km Shear 0-3km SRH MU CAPE SB CAPE	BRN 0-1km Shear 0-3km SRH MU CAPE	BRN 0-1km Shear 0-3km SRH 0-1km SRH MU CAPE	0-1km Shear 0-3km SRH	SCP MU CAPE	SCP BRN MU CAPE	BRN

Table 1. Hourly comparisons between evolutions and the corresponding significant parameters (p < 0.05) based on the Two-Way Kolmogorov-Smirnov and Student's T-tests.

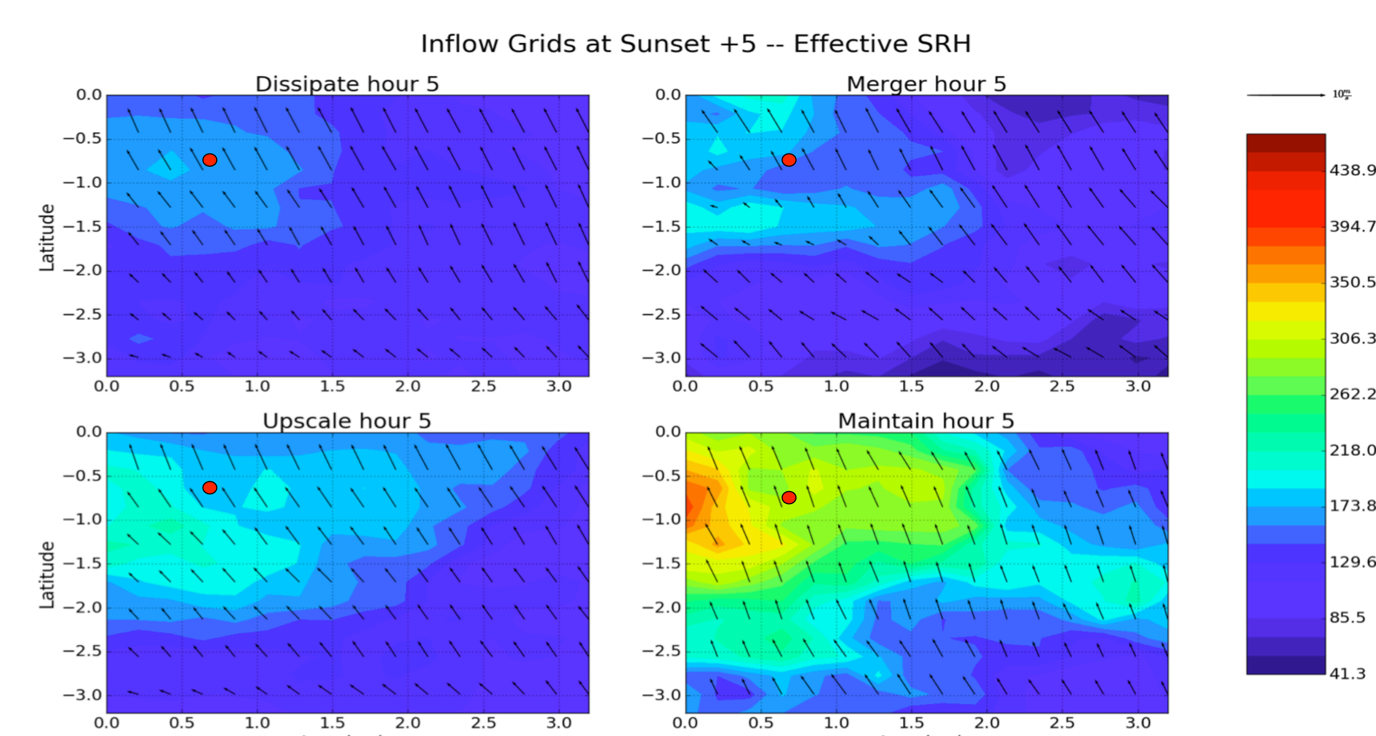

Figure 6. Inflow grids of mean effective SRH at SS +5 with surface wind vectors. Red dot indicates location of supercell.

- Comparing the distributions of all computed parameters among each pair of supercell classifications at each hour reveals numerous statistically significant parameters (Table 1). The most common discriminating parameters include shear and SRH in a variety of layers, supercell composite parameter (SCP), MU CAPE, and MU CIN.

Discussion and Conclusions

The strongest statistical signal was between maintained and dissipated supercells:

- Increasing MU CIN values, combined with decreasing MU CAPE, and steady effective SRH likely caused the dissipating supercells to no longer be able sufficiently lift parcels into the updraft
- These results indicate that a balance between MU CIN and effective SRH is likely needed sustain supercells through the nocturnal transition

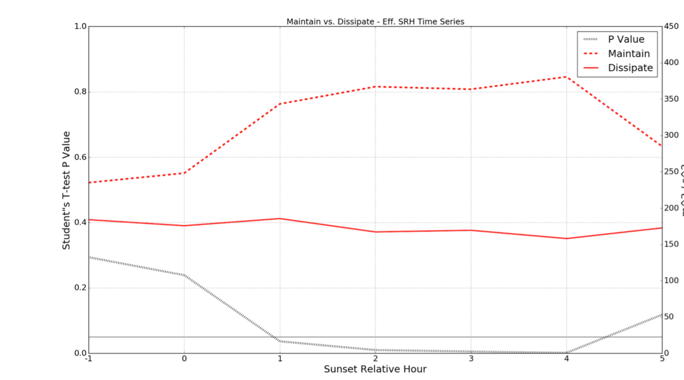

Figure 7. Time series of mean effective SRH for dissipation (solid) and maintained (dashed), with the corresponding p-value at each hour.

The discriminatory power of effective SRH, MU CIN, and SCP (Table 1, Figs. 5-7) led to the development of a CIN-scaled Supercell Composite Parameter (CSCP; Equation 1). Effectively, SCP is lowered when MU CIN is present. This new parameter has skill in separating the various evolution types (Figs. 8-9).

$$CSCP = \frac{MUCAPE}{1000J/kg} \times \frac{Eff.SRH}{50m^2s^{-2}} \times \frac{EB.Shear}{20m/s} \times \frac{-25J/kg}{MUCIN}$$

Equation 1. SCP equation with MU CIN scaled term. The CIN-scaled term is equal to zero when MU CIN < -25 J/kg.

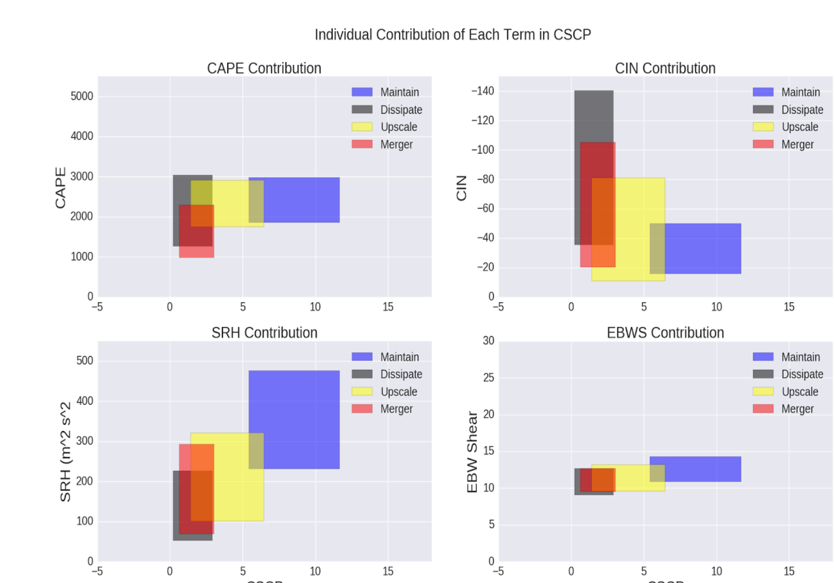

Figure 8. Individual contribution of each term in the CSCP equation. Each box represents +- one standard median deviation from the median.

Breaking the CSCP down into the contributions of each parameter (Fig. 8) shows the relative importance of effective SRH and MU CIN compared to CAPE and bulk shear. When comparing 0-1 km shear with CSCP (not a function of 0-1 km shear), strong forecasting skill is seen (Fig. 9).

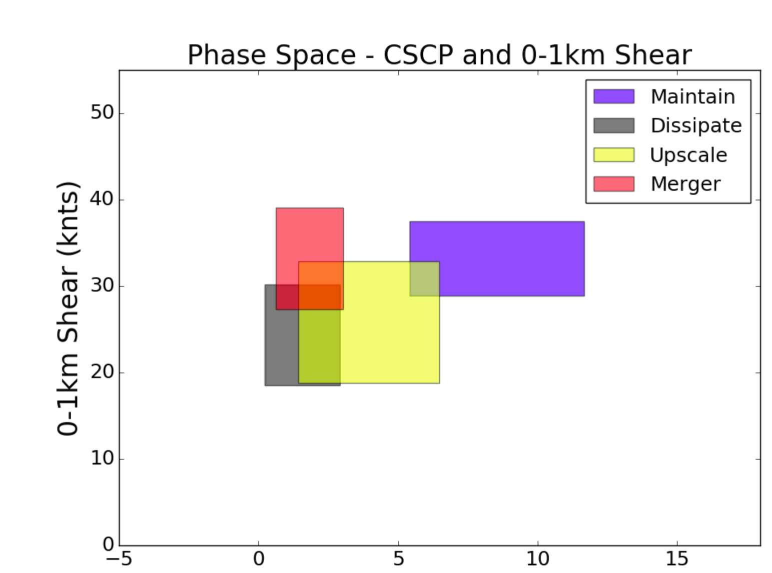

Figure 9. Phase space of CSCP and 0-1 km shear. Each box represents +- one standard median deviation from the median.