P14.6 CONVECTIVE STORM CLASSIFICATION: IS IT IN NEED OF CHANGE?

By
James G. LaDue*
NOAA/NWS Warning Decision Training Branch, Norman, OK
and
Daphne S. LaDue
NOAA/WDTB/CAPS, Norman, OK

1. INTRODUCTION

Convective classification schemes are employed as educational tools for students in a variety of venues, from primary school students, storm spotter classes, university classes, and even NWS intern training. By far, there is one classification scheme that is nearly ubiquitously taught amongst these various venues. The classification segregates all Deep, Moist Convection (DMC) into a single ordinary cell, progressing through a multicell cluster, then a multicell line (squall line) and culminates in a supercell with an increase in organization implied by this order. This classification scheme is reflected in numerous educational venues, the most popular including the University of Illinois skywarn site, WW2010 (2008), and the NWS Project JetStream website, NWS (2008). This scheme has been represented in numerous Skywarn training venues, and introductory meteorology textbooks. However, our knowledge about the archetypes of DMC that has been documented over the past two decades has increased far beyond what is reflected in this scheme.

Meteorologists need to understand the likely morphology, behavior, and hazards associated with various types of DMC. To this end, we are reviewing cognitive and educational psychology literature regarding how humans think, learn, and make sense of their world. First, the notion of how working and long term memory interplay provides a foundation for understanding cognitive limitations that necessitate grouping similar ideas and making information easy to recall. The ability to infer is also an important notion, in part because remote and in situ weather sensing systems do not provide complete information about the state of the atmosphere. Finally, there is evidence that humans naturally organize knowledge into object and events schemas. In summary, a good classification schema would reduce cognitive load, assist in the recall of important and relevant information, and help anticipate likely morphology.

In this paper, we offer a set of attributes of an improved convective classification scheme that would be applicable to a wide variety of learners. We discuss the attributes of the most commonly used classification scheme today in part 2. In part 3, we discuss the limitations of the current scheme. While we will not present an improved classification scheme in detail in this paper, we propose a set of desired attributes of an improved scheme in part 4.

2. THE CURRENT MOST POPULAR CLASSIFICATION

All convective classification schemes begin with the description of a single, ordinary cell that remains almost unchanged since its first description by Byers and Braham (1949) and its validity today remains solid (see Fig 1, top row). Doswell (2001) introduced perhaps the most significant change to this conceptual model; that was to remove the cloudy air from the precipitation core after downdraft onset, and to treat the updraft more like a bubble instead of a plume (fig 1, bottom row).

* *Corresponding Author Address:*
James G. LaDue, NOAA/NWS Warning Decision Training Branch, 120 David L. Boren Ave., Norman, OK, 73072; e-mail: james.g.ladue@noaa.gov.

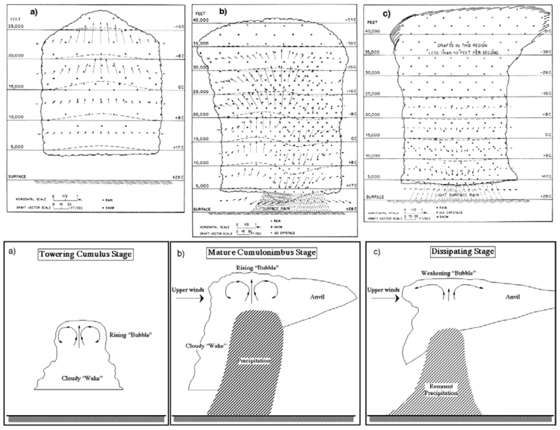

Figure 1. Conceptual model of an ordinary cell lifecycle. The top row corresponds to Byers and Braham (1949). The bottom row corresponds to Doswell (2001).

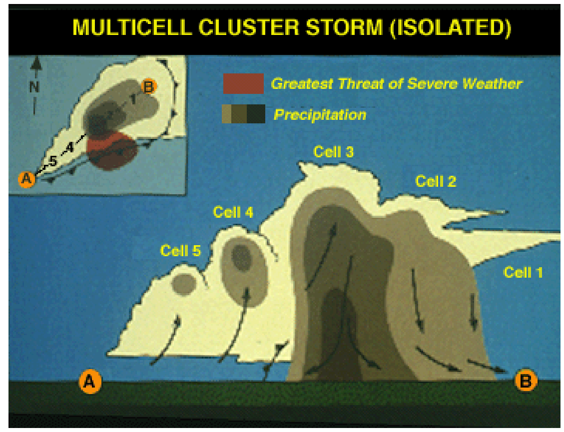

Figure 2. Conceptual model of an isolated multicell (from WW2010, 2008).

Multicell convection represents the next hierarchical step in the organization of DMC in the most popular classification schemes reflected by WW2010 (2008) and NWS (2008). The multicell cluster and multicell line storm represent two subcategories within the multicell.

As shown in figure 2, a multicell cluster is represented as a group of cells that initiate on the upwind side and gradually progress through their respective lifecycles as they move through to the downwind side of the multicell. This multicell cluster conceptual model has its roots in early conceptual models based on observational studies of hail events (e.g., Browning and Ludlam, 1960; Marwitz, 1972b) which show significant rightward propagation of multicells with respect to environmental flow, even the vertical shear vector as in Marwitz's study. Other observational studies documented multicell propagation to be almost opposite to that of the individual cell translations and the vertical shear (Miller and Fankhauser, 1976; Peterson, 1984). Although not explicitly shown in figure 2, the appearance updrafts and anvils imply at least a deep layer shear in the same general direction as the steering layer flow (from left to right).

However, there are also observationally-based studies of similarly sized multicells showing forward propagation (Chalon et al. 1976; Browning et al. 1976) where cell initiation was on the downshear side. Larger, forward propagating multicells were also documented in numerous studies (e.g., Houze et al. 1989; Houze et al. 1990). These structures often acquired linear organization. Early numerical studies of multicells tended to almost always produce forward propagating systems (e.g., Weisman and Klemp, 1982, 1986; Weisman et al. 1988). These studies explained their propagation due the favorable interaction between the low-level shear and the cold pool boundary occurring mainly on the downshear flank of multicells. The convective classification systems named forward propagating multicells as multicell line storms and they are typically illustrated with a cross-section normal to the line axis as shown in figure 3 (COMET, 1997). The implied difference between multicell cluster and multicell line storms is that the propagation of the former is backward while the latter is forward. Note there is little mention regarding the size scale of a linear or cluster multicell. Also, this is the only multicell conceptual model illustrated in COMET, 1997 (The Convective Storm Matrix).

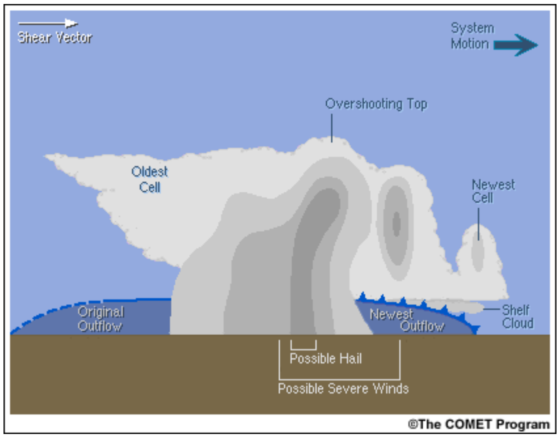

Figure 3. A conceptual model of a multicell as depicted in COMET (1997).

Supercells are depicted last in classification systems, and have the implied highest level of organization. They have been identified as a version of a single cell whose updraft is more plume-like, well correlated with vertical vorticity, and long-lived. The conceptual model shown in figure 4 represents a compilation of radar-based conceptual models of supercells (e.g., Moller et al. 1994), and visual-based documentation of supercell features (Fujita 1960; Lemon and Doswell 1979; Moller 1978). Moller et al. 1994 also describe variations of supercell types (Low-Precipitation, Classic, and High Precipitation) dependent on the low-level precipitation distribution around the low-level updraft. However Bluestein and Parks 1983 offered a definition of LP supercells biased towards visual cues.

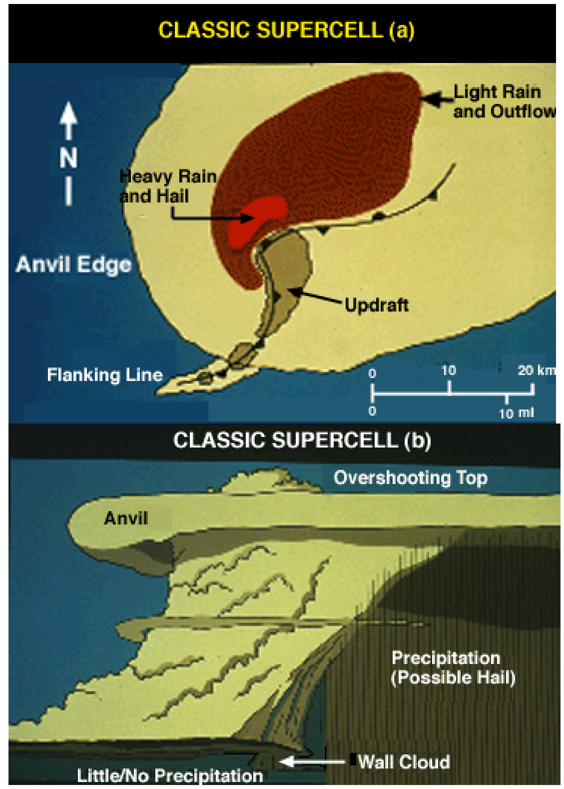

Figure 4. A conceptual model of a supercell (from WW2010, 2008).

3. DEFICIENCIES IN THE CURRENT SCHEME

3.1 Multicells and their position with respect to ordinary, and supercells

Numerous online and printed media describing a thunderstorm classification system place a multicell DMC in between a single ordinary cell and a supercell as if a multicell represents some intermediate level in the hierarchy of organization (e.g., NWS, 2008; WW2010, 2008). This is analogous to classifying a human being, a multicellular organism, between a simple stem cell and a neuron. Sure, a neuron is a long-lived version of the simpler generic cell, but both types help to compose a part of the whole organism. This analogy should be considered in a convective classification within reason. Instead, we reiterate the definition that multicells contain individual ordinary cells and/or supercells in various stages of development (see definition of a multicell in AMS 2008). Recall that a multicell is composed of individual cells that interact with each other in some way. The multicell is therefore a higher order structure than its individual elements, the single cell.

Perhaps multicells have been placed there owing to the argument that they exist in some intermediate shear parameter space (see Weisman and Klemp, 1982). However, most of the observational studies quoted in Weisman and Klemp, 1982 focused on the most significant storm in the area with little regard as to presence of other forms of DMC in the vicinity or other cases of similar shear where multicells formed. Note in figure 5, supercells and Derechos (large multicells) occupy a very similar space with regards to deep layer vertical shear as shown in figure 5 (Doswell and Evans, 2003).

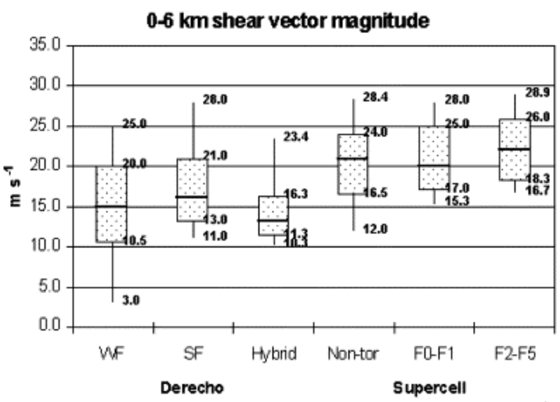

Figure 5. Box and whiskers plot showing the presence of Derechos and supercells as a function of 0-6 km shear. Labeled along the X-axis are Weakly Forced (WF) , Strongly Forced (SF), and Hybrid derechos followed by Nontornadic (Non-tor), F0-F1 tornadic (F0-F1), and F2-F5 tornadic (F2-F5) supercells. The boxes represent the 25 to 75% while the wings represent the 10 to 90% percentiles (after Doswell and Evans, 2003).

An argument could be made that multicells are governed by the cold pool and its interaction with the environmental vertical shear, and that this interaction favors multicells when shear becomes significant, or at least more than that of ordinary cells. This argument is based from numerical simulations of a small subclass of multicells, those being surface-based, cold pool governed (Rotunno et al. 1988). However, there are multicells that produce no cold pool at all. Types of multicells for which are not dependent on cold pools for their organization include elevated DMC, (Colman, 1990; Corfidi et al. 2008),. Multicells occupy the entire parameter space of instability and vertical wind shear for which DMC develops because they are as much dependent on the type of forcing as they are on the strength of shear or its cold pool, if it has one. A new classification scheme must be made that does not put multicells in the same spectrum as ordinary, and supercells.

3.2 Multicell conceptual models are insufficient to reflect the true diversity.

The multicell cluster model forwarded by WW2010 2008, NWS 2008, and others represent a backward propagating small multicell with preferred cell development implied to be on the upshear side. Meanwhile, COMET, 1997 presents only the forward propagating multicell where the interaction of shear and cold pool govern its behavior. The COMET model is similar to the WW2010 and NWS2008 depiction of the "multicell line". Clearly both conceptual models occur in nature and should be presented together.

Beyond just the multicell cluster and line, numerous names and titles have been added to which there is little reflection in the classification system. There are names such as Mesoscale Convective Systems (MCS) (Zipser 1982), Mesoscale Convective Complexes (MCC)s including tropical cyclones (Maddox 1980), squall lines, and bow echoes (Fujita 1978). Squall lines have been further broken down into those with Leading Stratiform (LS – fig. 6a), Parallel Stratiform (PS – fig. 6b), Trailing Stratiform (TS – fig. 6c), and Training Line Adjoining Stratiform precipitation (TL/AS – fig 7) regions (Parker and Johnson 2000; Schumacher and Johnson 2005). Even the leading stratiform precipitation squall lines have been further subdivided into front fed, and rear fed components (Pettet and Johnson 2003) shown in figure 8.

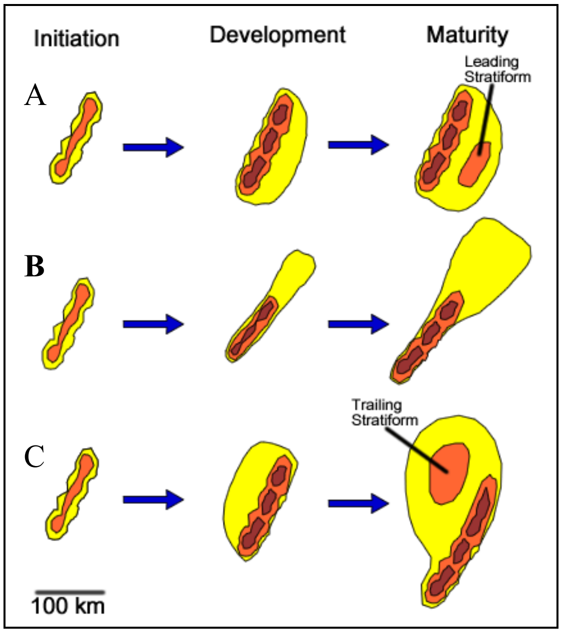

Figure 6. Three archetypes of linear multicellular DMC where the LS, PS, TS models are represented by a), b), and c) respectively. The yellow area indicates light precipitation while the red areas indicate the heaviest precipitation.

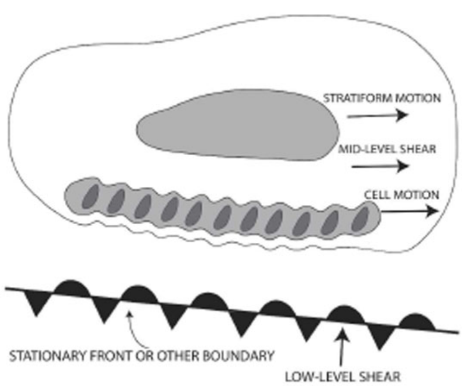

Figure 7. A conceptual model of a Training Line, Adjoining Stratiform precipitation MCS taken from Schumacher and Johnson (2005).

The confusion lies in the fact that one multicell can be identified by more than one of these names simultaneously because these descriptors are based on a combination of size, shape, and motion. As an example, a multicell can be called an MCC owing to its round shape and large size from satellite imagery but it could also be a candidate for one of the TS, PS, LS archetypes based on the precipitation pattern and its motion based on radar data. Perhaps knowing the precipitation shape and its anvil shape are both useful in understanding the potential behavior of a multicell. This problem is exactly analogous to the problems of identifying a type of supercell based on visual signals vs. those by radar. To date, no classification system adequately puts the diversity of multicellular names into a broader context.

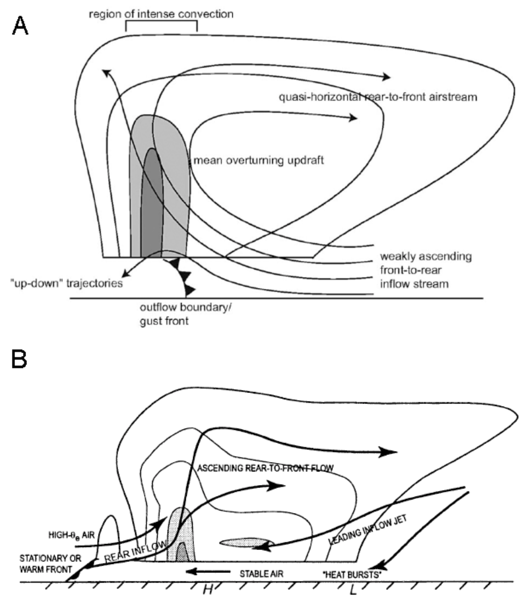

Figure 8. Conceptual model of a) Front Fed LS MCS, and b) Rear Fed LS MCS (adapted from Pettet and Johnson, 2003).

Also missing in a classification system are those descriptions that help convey and evoke useful conceptual models of other aspects of multicells important to anticipating their behavior. Attributes that may be important may include size, forcing mechanisms, shear, instability and perhaps more.

Little mention is made of the impact of size on a multicell behavior. There is a large difference in behavior between an isolated small multicell and an MCS due to the Coriolis force.

Regarding forcing, most multicells are significantly influenced by cold pool forcing, but a significant number are governed by other mechanisms. Other forcing mechanisms can be surface-based as Fankhauser and Mohr (1977) described as being important in determining the size of the multicell complex or they can be elevated sources (Colman 1990; Corfidi et al. 2008). Cold pool forcing was likely not a significant player in evolving the multicell depicted in figure 9. There are other important dynamical aspects which can be included in the classification system in order to help convey better conceptual models of multicells.

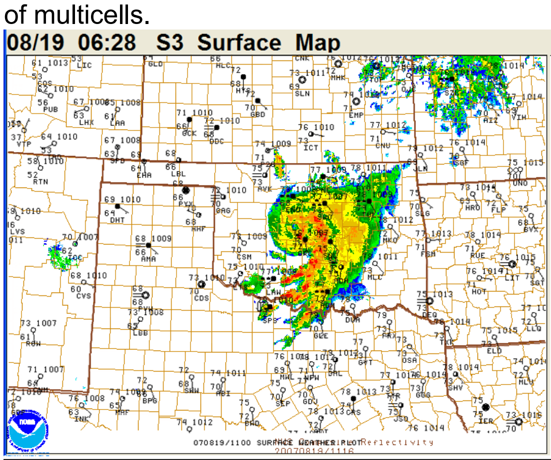

Figure 9. A surface map with mosaic radar reflectivity of the remains of tropical storm Erin as it reintensified briefly back to tropical storm strength. This is an example of a large surface-based multicell that is not governed by cold pool forcing.

It is interesting to note that the definition of a multicell in the Glossary of Meteorology focuses heavily on gust front forcing (AMS 2008). Perhaps a broader, more relevant definition of multicells is that of a group of cells whose perturbations in basic quantities affect each other (Doswell, 2001).

3.3 Should a Supercell be classified as a single cell?

The authors have heard many say, 'you know a supercell when you see it'. Yet, even a typical supercell is multicellular to varying degrees (e.g., Vasiloff et al. 1986). Some supercells could be arguably called a single cell though it is rare that there is truly a single steady state updraft. Some supercells appear quite unsteady so that it may be difficult to distinguish between an unsteady supercell and a fairly steady multicell that undergoes frequent strong updraft pulses. Foote and Frank (1975) called this behavior a hybrid storm, or a "weak evolution" multicell; weak evolution being that updraft pulses were so frequent that the intense reflectivity core aloft remained a persistent feature. Yet they acknowledge that each updraft pulse carried with it significant vertical vorticity (see their figure 18) suggesting supercell-like character. Supercells may appear more steady state in the lower levels and may explain the perception that they are steady state while upper-level updrafts have been observed to exhibit more pulse-like behavior above the LFC (Nelson and Braham, 1975).

Many supercells produce more than one mesocyclone. Tornadic and nontornadic supercells frequently produce multiple mesocyclones, each colocated with an enhanced updraft, and all of them sharing a common reflectivity envelope. One mesocyclone typically matures, occludes, then breaks off, moving to the left of the track of the main reflectivity core while a new mesocyclone forms on the leading edge of the rear flank downdraft (Burgess et al., 1982; Dowell and Bluestein, 2002). At times, even more than two mesocyclones may simultaneously exist within the "supercell". Each mesocyclone can be associated with a tornado, its own enhanced downdraft, and updraft. What appears to be a supercell is actually a multicell with more than one supercells embedded.

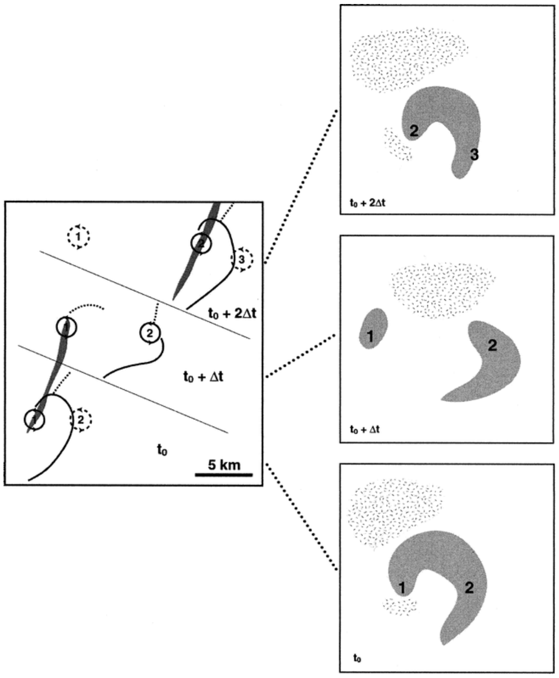

Figure 10. Schematic of a cyclic tornadic supercell from Dowell and Bluestein (2002). The thick swaths indicate tornado tracks produced by the mesocyclones (numbered circles) for three times. The dark lines indicate surface boundaries. On the right side, the dark shaded areas represent updrafts, stippled areas indicate downdraft and numbers indicate mesocyclone locations.

A third multicellular behavior occurs as individual isolated supercells approach each other. An example of approaching supercells is shown in figure 11, where the lead (trailing, or western) supercell took a sharp left (right) turn. This behavior repeated itself more than once with this complex. This is a behavior where each cell influenced the other's behavior. We believe the approaching supercells constituted a multicell where the individual cells affected each other, though likely not by their outflows.

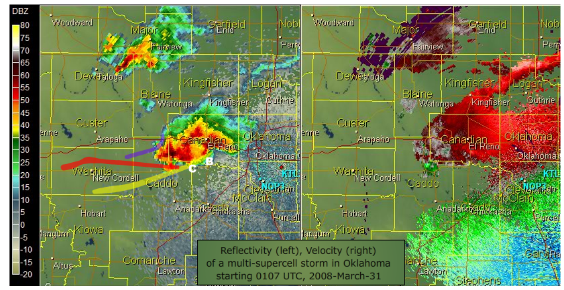

Figure 11. Lowest elevation reflectivity (left) and storm-relative velocity (right) of a supercell complex in Canadian, county, OK on 2008 March 31 - 0246 UTC. The red, yellow and purple tracks on the left represent the paths of supercells taken since 0045 UTC.

Moller et al. 1994 suggests that the multicellular character of a supercell is not important in its identification. However, this approach creates an inconsistency in the DMC classification scheme. The term supercell itself is singular and strongly suggests that it lie on the other end of the spectrum from the ordinary cell. In addition, when forecasting its behavior, there is more information needed than just identifying a supercell. The nature of its multicellular behavior is important in determining its future behavior. A supercell following a weak evolution following that of Foote and Frank (1975) behaves quite differently than a cyclic supercell or supercells converging upon each other.

3.4 Issues with the LP, Classic, HP supercell spectrum

Analogous to different naming conventions of multicells based on radar or satellite, there is an inconsistency in the visual vs. radar-based descriptions of supercell type. A storm spotter's definition of an LP often differs markedly from that of a warning forecaster viewing the same storm by radar. It is important to know what supercell type exists because of the implications to the type of expected severe weather, and its motion. There is a consensus starting to build that precipitation distribution around the low-level updraft is the best method for determining the nature of the supercell (see Rasmussen and

Straka, 1997). Likewise, the stratiform precipitation distribution about the convective line also is an important descriptor in multicells.

4. WHAT A NEW CLASSIFICATION SCHEME SHOULD REPRESENT

We are still in the process of engaging the community in a discussion that will lead to the construction of an improved storm classification scheme. However, we mention below several desirable traits such a scheme would have:

- An improved classification structure should reflect that DMC does not adhere to hard-fixed categories and that there is a spectrum of continuously evolving structures.
- The scheme should represent the fractal nature of DMC. For example, multicells can be made up of smaller multicell structures, and so on down to the individual cell level.
- The scheme should include that single cells almost always make up some kind of larger multicell structure. Get rid of any notion that there's some spectrum that progresses from single, to multi, to supercell. There may be an ascending level of order going from ordinary cell to supercell but a multicell cannot fit into that kind of ascending order. The classification scheme should show two parallel tracks, one for individual cells, and one for multicells.
- A classification scheme to represent the diversity of multicells needs to be created. The multicell classification should be the largest part of the total classification system.
- Naming convective archetypes should include attributes that are recognizable and have implications as to the expected behavior and threats likely. Descriptions may be shape-based, or based on underlying dynamics influencing the storm.
- The dependency of the classification on the sensor needs to be deemphasized.

At the conference, we hope to engage in a discussion towards the goal of creating an improved classification scheme.

5 ACKNOWLEDGEMENTS

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