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ANALYSIS OF ESTIMATED ENVIRONMENTS FOR 2004 AND 2005 SEVERE CONVECTIVE STORM REPORTS

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1. INTRODUCTION

Analysis of the mesoscale environments associated with observed severe convective storms can provide key insights into their character and predictability, and the challenges to achieving successful severe weather forecasts. The NOAA Storm Prediction Center (SPC) has begun construction of a database of severe storm environments associated with each severe weather report and will analyze these data with the goal of improving national severe weather forecasts. This portion of the broader effort focuses on analysis of estimated environments for all severe convective storms reported during the two year period 2004 and 2005.

This manuscript briefly describes the methods used to prepare the database, describes some initial results, and summarizes the efforts to date and the next steps within the broader project.

2. DATA SET PREPARATION AND ANALYSIS

The estimated environment for each severe report is based on hourly 40 km horizontal resolution RUC analysis data above the surface, combined with objectively analyzed surface observations using RUC surface conditions as a first guess (Bothwell et. al. 2002). These grid point data are analyzed for a variety of kinematic and thermodynamic diagnostic fields using the NSHARP sounding analysis program (Hart and Korotky, 1991). Environmental conditions are assigned from the nearest analysis grid point at the closest hourly time prior to the observed severe weather. For the two year period, this database contains environmental estimates for over 54,000 reports (Fig. 1a).

The data were stratified and analyzed based on report intensity, location, and environmental characteristics. In addition to traditional graphs and scatter plots exploring key dimensions of the severe environment space, national maps of reports associated with single and multi parameter constrained environmental spaces were prepared. The spatial and temporal evolution of key environments were explored through bi-monthly and annual average continental United States plots of mean environmental conditions and through maps of the spatial distribution and frequency of the key severe storm environments.

3. RESULTS

Select preliminary results for the reports observed during 2004 and 2005 illuminate the diverse nature of the severe storm environmental parameter space and corroborate and refine results from previous investigations of severe storm environments (Rasmussen and Blanchard 1998, Rasmussen 2003, Craven et. al. 2002, Thompson et. al. 2003, Markowski et. al. 2003). Although sample sizes in some areas of the country are small, the distribution of all reports during the two year period (Fig. 1a) demonstrates that most standard attributes of the severe weather climatology of the United States are captured. The vast majority of reports occur in the eastern two thirds of the United States, with widespread tornadic activity over the Great Plains and along an axis extending through the Southeast and northward to the Mid Atlantic. Smaller clusters of tornado reports are also found in Southern California, in the central valley of California, and southern Florida. Still, caution should be exercised when examining the frequency and environmental characteristics of these smaller sub classes of severe storms in this initial two year sample.

When a constraint of large mean 100mb mixed layer convective available potential energy (MLCAPE) ($\geq$1000 J kg^{-1}) and strong 0-6 km AGL deep layer shear ($\geq$18ms^{-1}) is placed on the reports (Fig. 1b), coverage over the eastern and western United States decreases dramatically and the reports, in particular tornadoes, concentrate over the traditional severe weather "tornado alley" (Brooks et.al., 2003). This environmental space contained 44 percent of all tornadoes reported during the two year period and 59 percent of all strong and violent tornadoes (F2-F5; hereafter "strong-violent").

Examination of the spatial distribution of mean tornado environment MLCAPE and 0-6km shear (Fig. 2a) reaffirms the concentration of combined high MLCAPE, strong deep layer shear environments over the central United States. The tornadoes over the Southeast and Mid Atlantic are also characterized by strong deep layer shear but with mean MLCAPE less than 1000 Jkg$^{-1.}$ Examination of the 100 mb mean-layer lifting condensation layer (MLLCL) and low-level 0-1km AGL shear (Fig. 2b) reveals the low MLLCL and strong low level shear that characterize most tornadoes over the southeast United States. Over the central United States, a gradient in MLLCL with weaker low-level shear is collocated with the axis of maximum MLCAPE (Figs. 2a, b).

Scatter plots of key parameters for all tornado reports and all strong-violent tornado reports further and

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Figure 1a

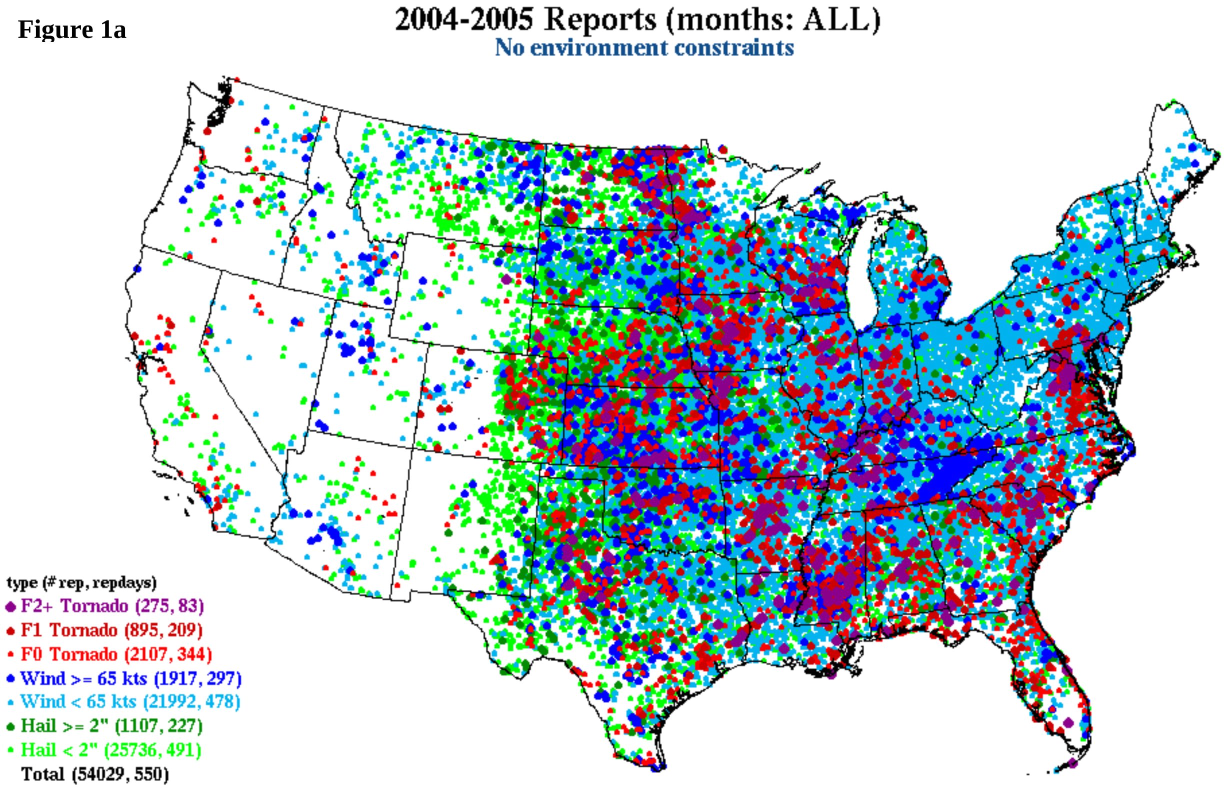

Figure 1b

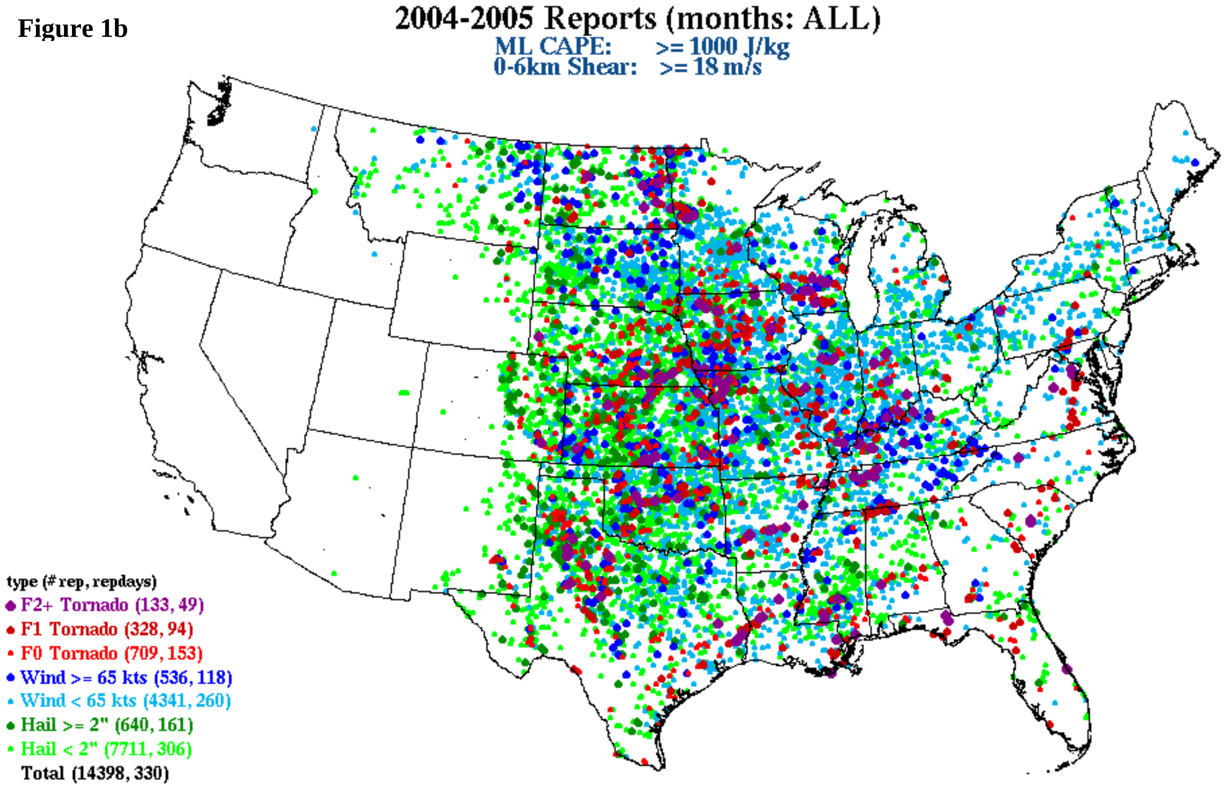

Figure 1: *Map of all reports that a) occurred for the period 2004-2005, and b) occurred for the period 2004-2005 with combined attributes of MLCAPE $\geq$ 1000 Jkg^{-1} and 0-6 km shear $\geq$ 18 ms^{-1}. The legend includes data for the number of reports and the number of report days for each report type. Environmental data is from the SPC's surface objective analysis routine and reports are plotted in order of increasing severity with strong-violent tornadoes last.*

Figure 2a

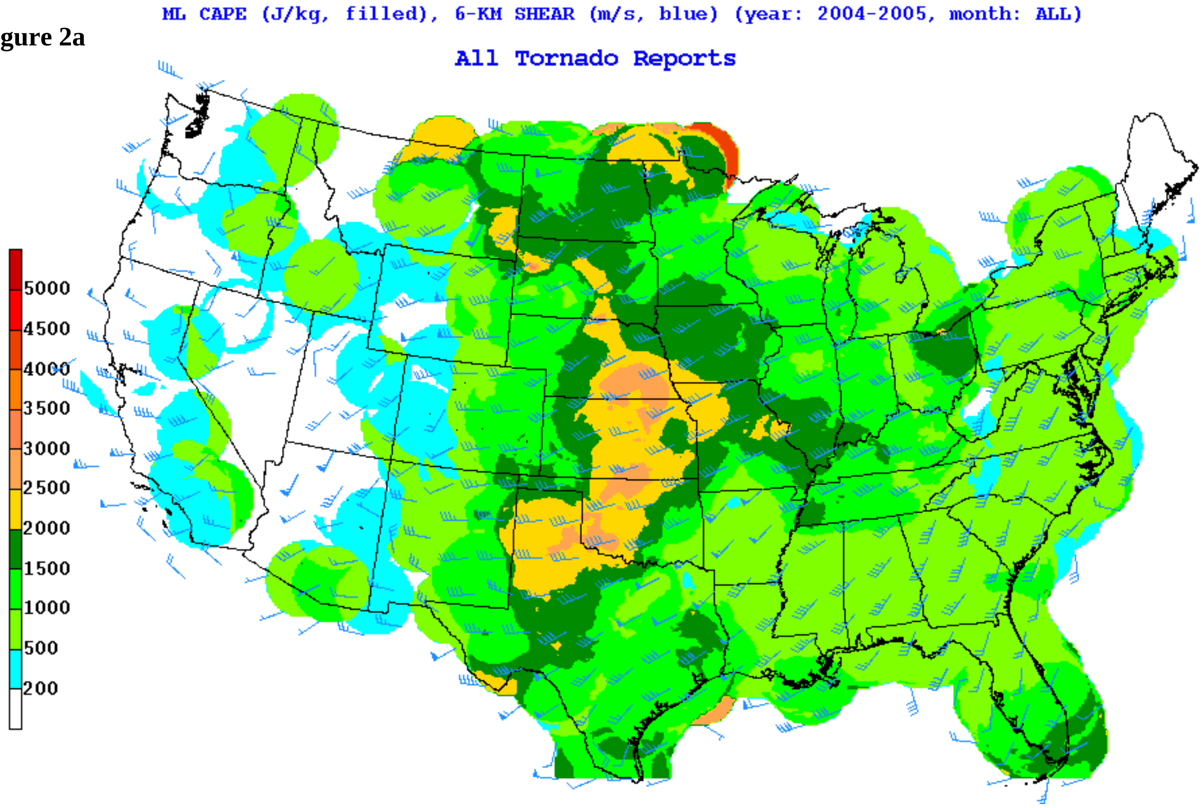

Figure 2b

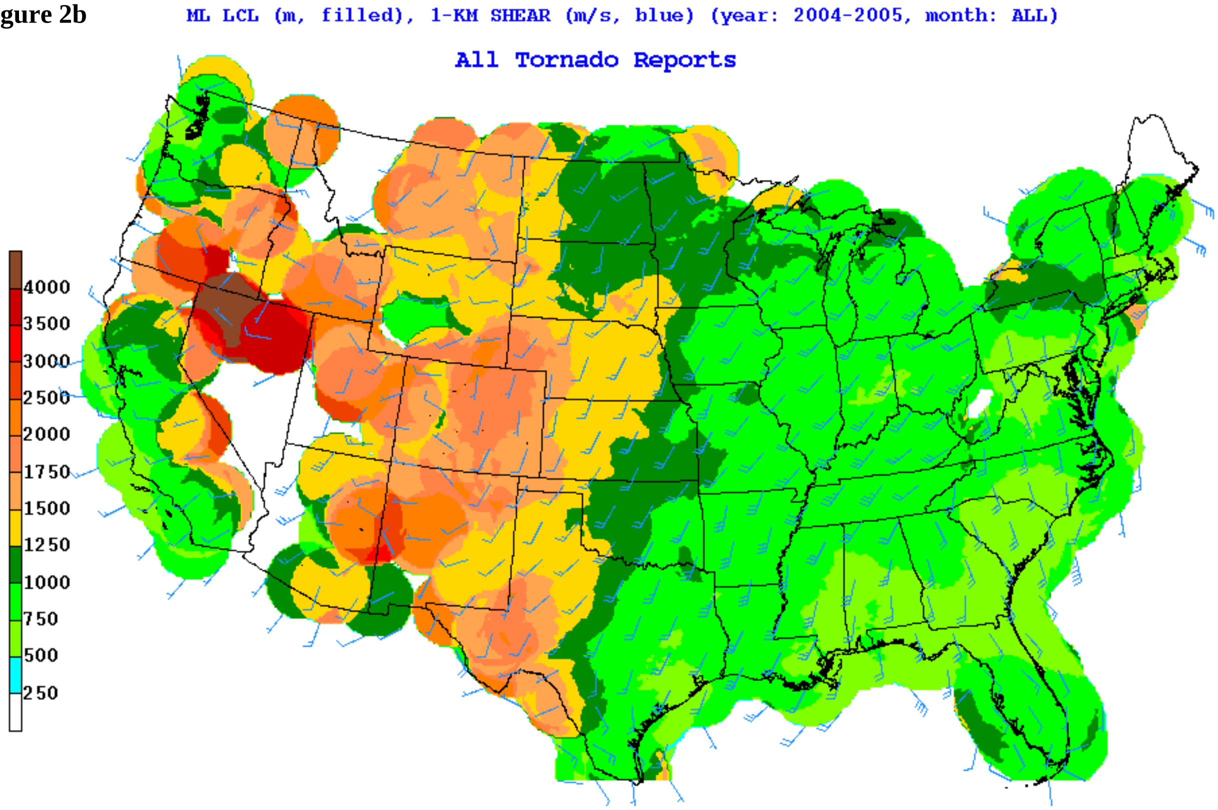

Figure 2: *Map of the mean a) MLCAPE (Jkg^{-1}) and 0-6km shear (ms^{-1}), and b) MLLCL (m) and 0-1 km shear (ms^{-1}) for tornado environments during 2004-2005. Environmental data is from the SPC's surface objective analysis routine and report environments each contribute to the mean for a radius of 160 km.*

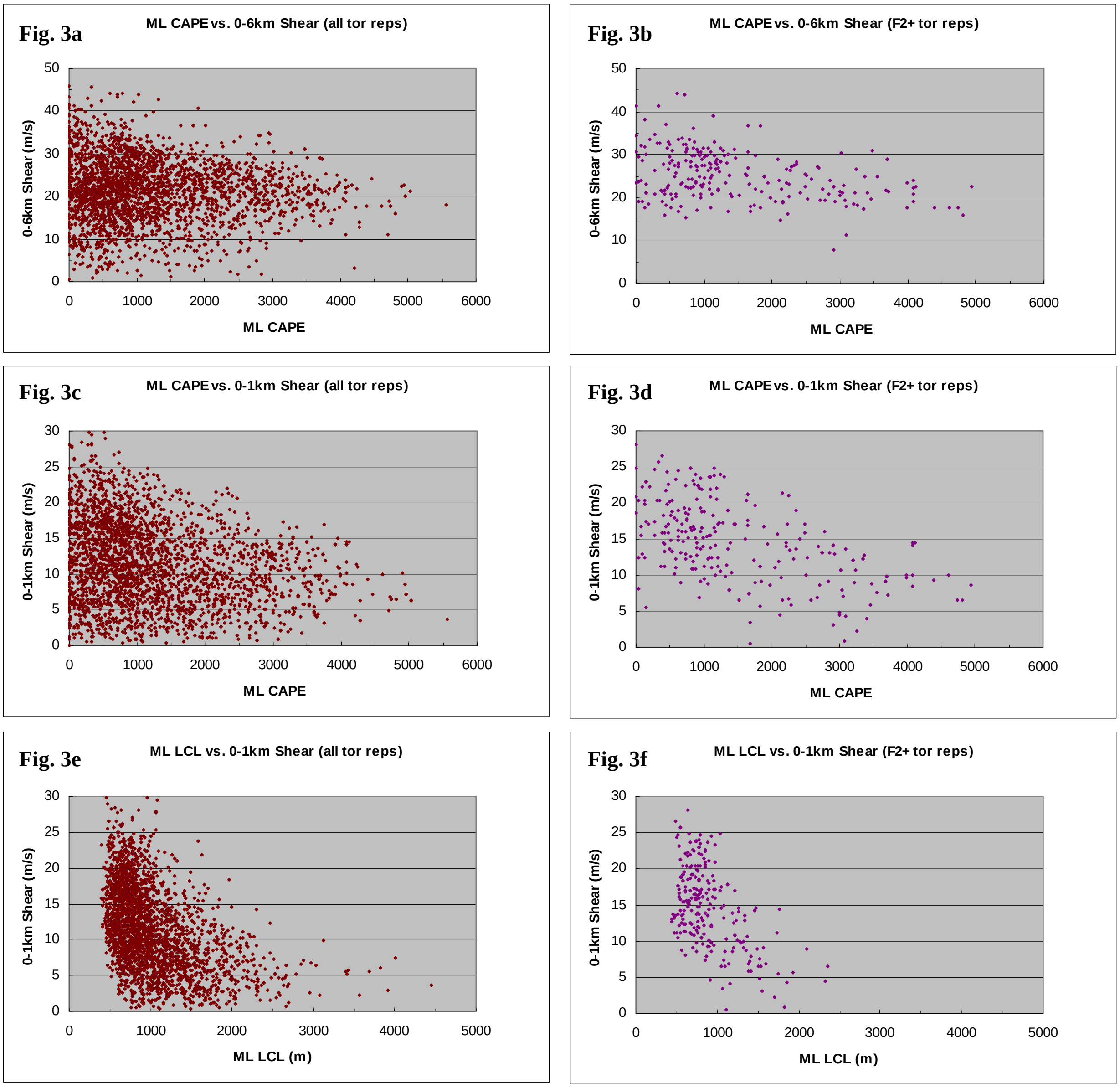

Figure 3: *Scatter plots of reports during 2004-2005 for: a) all tornado reports as 0-6 km shear (ms^{-1}) versus MLCAPE (Jkg^{-1}), b) F2-F5 tornado reports as 0-6 km shear versus MLCAPE, c) all tornado reports as 0-1 km shear (ms^{-1}) versus MLCAPE, d) F2-F5 tornado reports as 0-1 km shear versus MLCAPE, e) all tornado reports as 0-1 km shear (ms^{-1}) versus MLLCL (m), and f) F2-F5 tornado reports as 0-1 km shear versus MLLCL.*

illuminate the environmental similarities and differences between these two tornado intensity classes and indirectly the characteristics of the Great Plains and Southeast tornado maxima (Fig. 3). For each parameter examined, a much smaller environmental space is found to support strong-violent tornadoes versus all tornadoes. Nearly all (97%) strong or violent tornadoes occurred in environments with 0-6km shear greater than 15 ms^{-1} (Fig. 3b), while 496 of all tornadoes (15%) occurred in environments below this threshold (Fig. 3a). The distinction between the strong-violent and general tornado environments for 0-1km shear is most pronounced for MLCAPE less than 1000 Jkg^{-1} (Fig. 3c, d). For significant tornadoes associated with MLCAPE less than 1000 jkg^{-1}, only 5 of 127 reports (4%) occurred in environments with 0-1 km shear less than 10 ms^{-1}. MLLCL heights are generally low for both the all tornado and strong-violent tornado populations (Fig. 3e, f), but for strong-violent tornadoes the combination of 0-1 km shear greater than 10 ms^{-1} and MLLCL less than 1000 m accounts for 72 percent of the events (197 of 275) in this two year sample. Low-CAPE (MLCAPE ≤ 1000 Jkg^{-1}) strong deep layer shear (0-6km shear ≥ 18 ms^{-1}) conditions are associated with 54 percent (107 of 197) of this strong-violent tornado subset. For strong-violent tornadoes with MLCAPE above 1500 Jkg^{-1}, the

Figure 4a

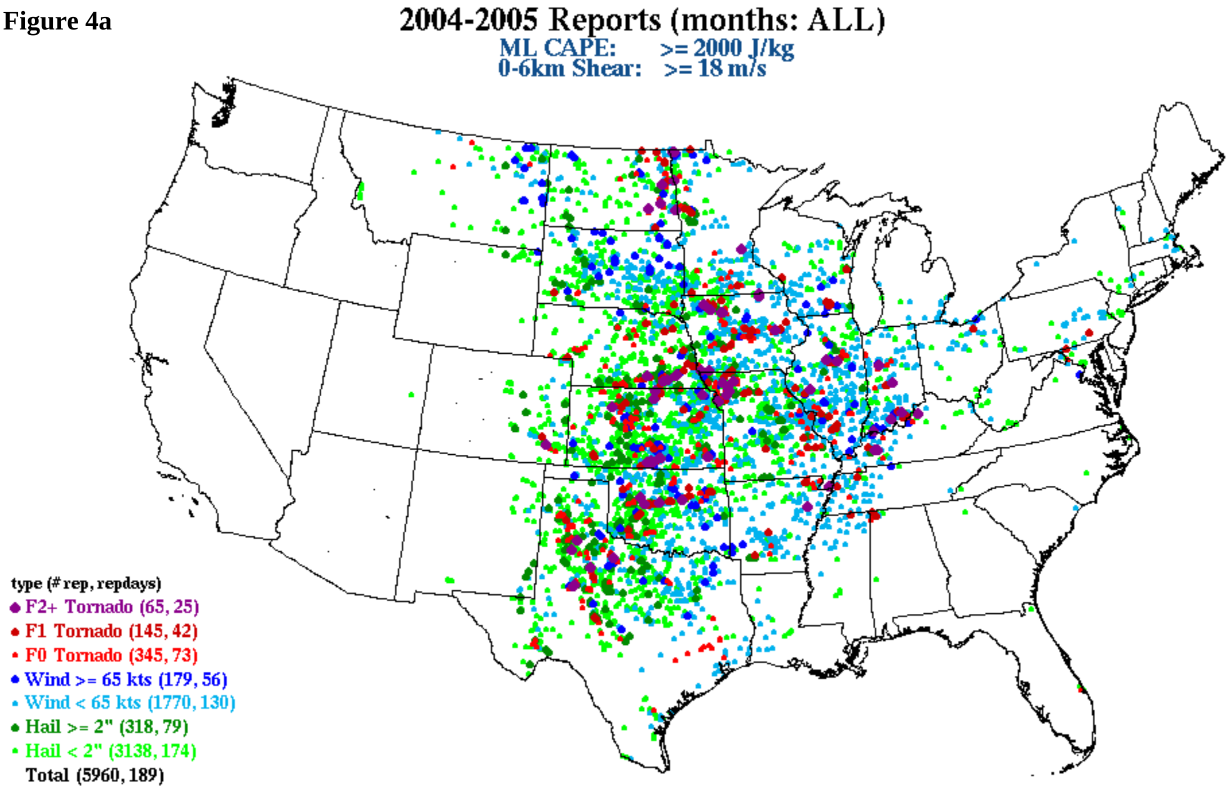

Figure 4b

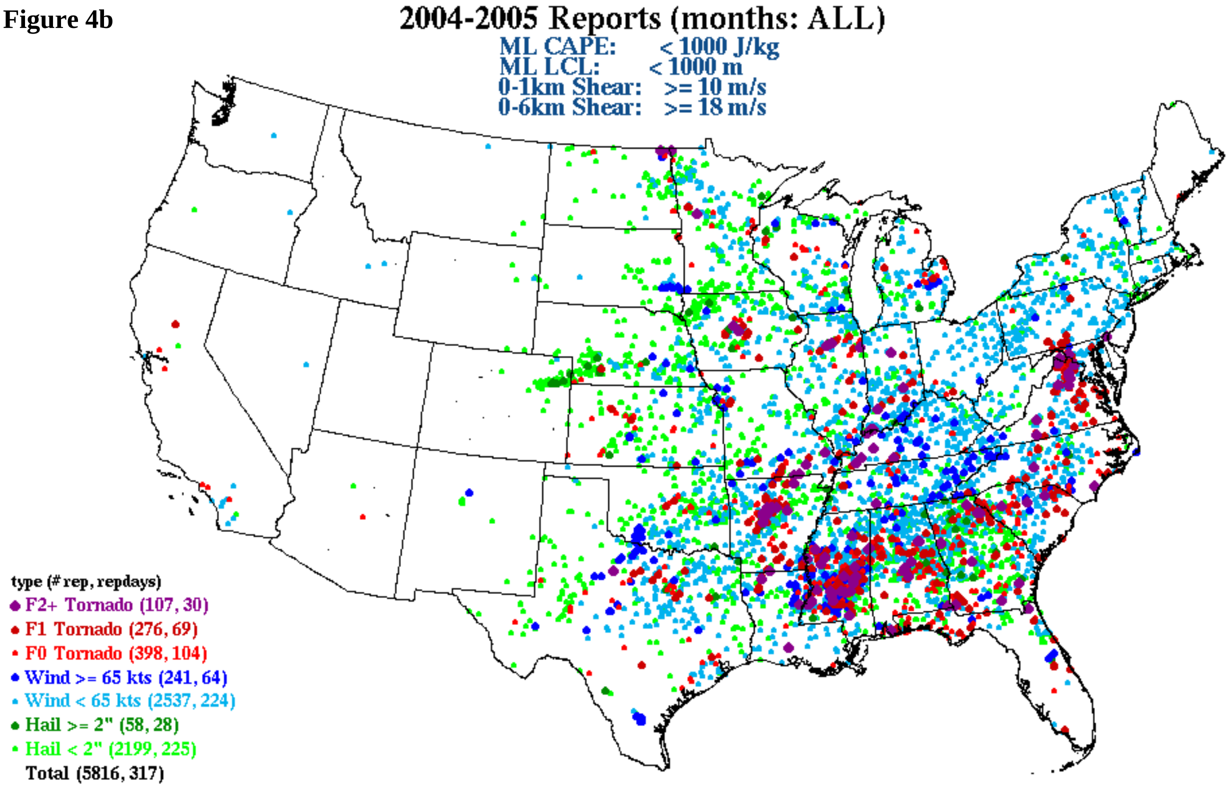

Figure 4: *The same as figure 1, only for a) combined attributes of MLCAPE $\geq$ 2000 Jkg^{-1} and 0-6 km shear $\geq$ 18 ms^{-1}, and b) combined attributes of MLCAPE $\leq$ 1000 Jkg^{-1}, MLLCL $\leq$ 1000m, 0-1 km shear $\geq$ 10 ms^{-1}, and 0-6 km shear $\geq$ 18 ms^{-1}.*

diversity of observed 0-1 km shear (Fig. 3d) and MLLCL (not shown) increases dramatically.

Two key subclasses of United States severe weather environments associated with strong deep layer shear (≥ 18 ms^{-1}), one with large MLCAPE (Fig. 4a) predominantly in the central United States, and another with small MLCAPE, strong 0-1km shear and low MLLCL (Fig. 4b) primarily in the Southeast emerge from the analysis. Although an essential part of the parameter space resides between these extremes, 63 percent (172 of 275) of the strong-violent tornadoes in this two year sample fall in these two subclasses with the low MLCAPE portion (Fig. 4b) contributing the majority of events. The peculiarities of the 2004 and 2005 severe weather seasons likely contribute significantly to this result. Of the 107 strong-violent tornadoes in the low MLCAPE-high shear environment (Fig. 4d), 56 percent (60 events) occurred during the cool season (November through March) and 33 percent (36 events) were associated with the core of hurricane season (August through October).

4. SUMMARY AND FUTURE WORK

Preliminary analysis of severe weather report environments for 2004 and 2005 allowed isolation of key regional and seasonal characteristics for the continental United States. While statistical plots and national maps of reports associated with specific environments reaffirm some previous relationships, they also reveal new complexities and limitations of this knowledge when applied to forecasting severe storms nationwide. The results indicate a strong association in the southeast United States between significant tornadoes and environments with 100 mb mixed-layer CAPE less than 1000 Jkg^{-1}, 0-6 km shear greater than 18 ms^{-1}, 0-1 km shear greater than 10 ms^{-1}, and LCL's less than 1000m. However, this multi-variant relationship becomes more complex for significant tornadoes occurring in environments with CAPE greater than 1500 Jkg^{-1}, which are characterized by a much wider range of shear and LCL values.

Additional dimensions of this study (not shown) include analyses of regional and seasonal differences in severe weather environments and maps of the frequency of occurrence for key severe weather environment subclasses. The ultimate goal of this effort, in addition to analysis of the environments of storms, is to link these data to SPC products and services (Dean et. al. 2006).

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