The Role of Low-Level Instability on Tornado Intensity

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Motivation

A substantial amount of research has been completed on environments supportive of significant tornadoes (EF2+).

Although violent tornadoes (EF4/EF5) only account for less than one percent of all reported tornadoes, they are responsible for ***66 percent*** of all fatalities associated with tornadoes.

Even though the number of violent tornadoes is relatively small, the environments associated with the tornado subset were worth investigating to discover if a discriminating signal exists to assist operational meteorologists forecasting these rare events.

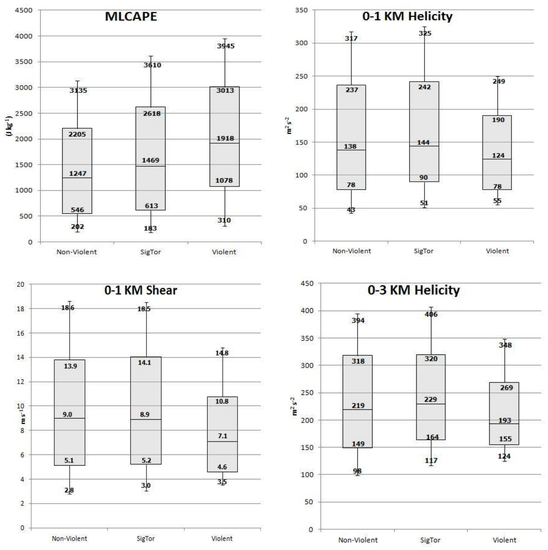
Data & Methodology

Obtained North American Regional Reanalysis (NARR) data for EF4/EF5 tornadoes from 1990 to 2011, EF3 from 2006 to 2011, and EF2/EF1 from 2009 to 2011.

Proximity and data quality checks ensured accurate environmental conditions were represented. Final sample consisted of: 576 EF1, 221 EF2, 130 EF3, and 117 EF4/EF5 tornadoes.

A comparison of various parameters was conducted to discover signals that would help forecasters differentiate between violent and non-violent tornado environments.

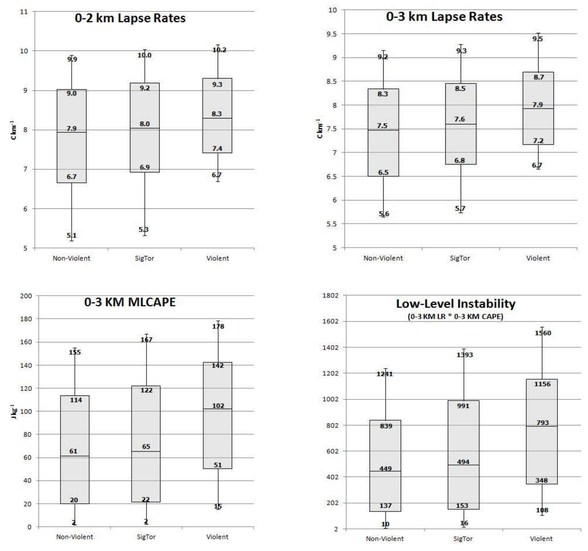
Previously Researched Parameters



Higher values of MLCAPE seem to be associated with stronger tornadoes, including violent tornadoes.

Although storm relative helicity and low level shear have been shown to distinguish between non-tornadic and significant tornado environments, neither parameter is useful for discriminating environments supportive of violent tornadoes.

New Parameters Researched for Violent Tornadoes



Multiple low-level instability parameters have shown a strong signal of violent versus non-violent tornado environments.

To create a value with larger mathematical differences, a product of 0-3 km lapse rate and 0-3 km MLCAPE was computed as an index (Low-Level Instability, LLI).

The substantial increase of mean LLI values and the differences of the 25th to 75th percentiles do give operational meteorologists an easier method to distinguish environments supportive of violent tornadoes.

Statistical Analysis

Performed an analysis to determine if there was a statistically significant difference regarding the violent and non-violent tornado environments with the samples of 0-3 km lapse rates, 0-3 km MLCAPE, and LLI.

Performed Mann-Whitley test and non-pooled t-test and all fields indicated a 99% confidence level the data provided sufficient evidence that the means of the populations were not equal.

Performed a right tailed t-test and all fields indicated a 99% confidence level that the means of the violent tornado environments exceed the means of non-violent tornado environments.

Ran these tests again to find a practical significance by taking the differences of the means at the 95th percent confidence level to prove that the LLI was operationally significant.

- 0-3 km MLCAPE = 17 J kg^{-1} difference
- 0-3 km Lapse Rate = 0.27 C km^{-1} difference
- LLI = 162 difference

Conclusions

Low-level wind fields such as 0-1 km shear and 0-1 km & 0-3 km storm relative helicity are crucial to not only tornadogenesis but also with intensification into EF2 and EF3 strength.

Low-level instability shows promise in identifying violent tornado environments.

Therefore, when forecasting environments favorable for violent tornadoes, operational forecasters should closely investigate low-level instability in addition to low-level shear.