Analysis of the Factors Promoting Tornadogenesis Using NCDC Storm Events and IGRA Data

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ABSTRACT

Official tornado reports from the NCDC Storm Events Database and radiosonde sounding data from the Integrated Global Radiosonde Archive were gathered to analyze linear correlations between various sounding parameters and tornadogenesis. Proximity was defined as a tornado occurring within 200 km of the sounding. Creation of the number/latency of soundings occurring in proximity to each sounding was taken. Only 00 UTC soundings were considered. Low cloud bases, thermodynamic instability, and high helicity/shear values are shown to be correlated with tornadogenesis, in agreement with past literature. Helicity and shear are shown to be the best discriminators between soundings taken in proximity to strong tornados and those taken in proximity to only weak tornados. This research suggests that the most-unstable parcel’s lifted condensation level is the most useful approximation to cloud base height in forecasting tornados. An experimental parameter that reflects the average instability of parcels within the effective inflow layer shows potential to be an effective tornado forecasting aid. A new composite parameter was developed and verified using multivariate linear regression that appears to be strongly correlated with tornadogenesis.

INTRODUCTION

Motivation/Goals –
• Improve the reliability of tornado forecasts
• Apply novel linear correlation technique to verify past findings and modify current understanding of tornadogenesis
• Analyze efficacy of effective CAPE and effective CIN
(experimental parameters)
• Utilize multivariate regression to develop a new composite parameter to assist in the prediction of tornados

Existing Literature –
• LCL (lifted condensation level), an approximation to cloud base height, discriminates well between strong/weak tornados (Rasmussen and Blanchard 1998; Edwards and Thompson 2003)
• Superposition of low-level moisture and steep lapse rates (creating high CAPE values) is ideal for tornado formation (Doswell 1985)
• 0-6 km bulk shear values of 20 m/s are sufficient to promote supercell formation (Weisman 1996)
• 0-1 km storm-relative helicity statistically significantly discriminates between strong/weak/no tornadoes (Edwards and Thompson 2000)
• As the intensity of tornados increases, CAPE increases, LCL decreases, 0.1 km and 0.6 km bulk shear increases, and 0.1 km and 0-3 km storm-relative helicity increases (Thompson 2003)
• Composite parameters (e.g., the “Significant Tornado Parameter,” or SigTor) are effective in tornado forecasting (Thompson 2003)
• “Effective” bulk shear and “effective” storm-relative helicity are most useful in tornado forecasting than 0-6 km bulk shear and 0.1-3 km storm-relative helicity (Thompson, Edwards, and Mead 2005)

MATERIALS AND METHODS

• NOAA National Climatic Data Center’s “Storm Events Database” provides data on every confirmed tornado in the United States from January 1st, 1996 through October 31st, 2013 (24,929 tornadoes are considered in total)
• NOAA National Climatic Data Center’s “Integrated Global Radiosonde Archive” (IGRA) provides the locations of all registered radiosonde release locations in the United States and provides raw data from all 00 UTC soundings taken at these locations (5,085 soundings taken from 122 locations are considered in total)

For each sounding, three measures of tornado activity were recorded:
• Number of proximal tornadoes
• Number of proximal strong (EF-rating ≥ 2) tornadoes
• Tornado Parameter, defined as the sum of (EF-rating + 1) for all proximal tornadoes

For each sounding, 35 parameters were calculated:
• Lifted condensation level (LCL), level of free convection (LFC), equilibrium level (EL), convective available potential energy (CAPE), convective inhibition (CIN) — these five parameters calculated for each of the four parcels in Table 1
• Effective CAPE/CIN (eCAPE/eCIN) (as well as effective inflow layer base/top)
• Downdraft CAPE (DCAPE)
• Bulk Shear (0-1km, 0-3km, 0-6km, effective, effective inflow layer)
• BRI Shear Term
• Storm-Relative Helicity (SRH) (0-1km, 0-3km, effective inflow layer)
• Storm Motion (speed) (ID/Bunkers method for right-moving supercells)

RESULTS

• Linear correlation coefficient (R) was calculated between each of the 35 sounding variables and each of the three measures of tornado activity
• Because R values were low (0.26 for effective bulk shear was the largest in magnitude), plots were heavily cluttered, and outliers may have skewed the R values, an averaging procedure was developed
• For every value of “tornado parameter” (defined in Materials and Methods), if at least three soundings possessed that tornado parameter value, the average value for each of the 35 sounding parameters was calculated, and R was re-calculated between the averaged values and the tornado parameter, yielding the R values in Table 2

• Soundings were divided into those taken in proximity to one or more strong tornadoes and those taken in proximity to no strong tornadoes
• Student’s T-test was used to compare sample means for each of the 35 sounding parameters among “strong tornado” and “weak tornado” soundings, producing Table 3

• One of the most commonly used composite parameters in tornado forecasting is the Storm Prediction Center’s “Effective” Significant Tornado Parameter (SigTor)
• SigTor = μCAPE + μERB + μSRH – μECCINE 

• Soundings taken in 2006 and prior (1438 soundings) were used to develop a new composite parameter using multivariate linear regression (with the raw data instead of the averaged values). This yielded the following parameter (TGP, or tornadogenesis parameter), above:

• Using the independent data from post-2006 (1647 soundings), plots of SigTor vs. Tornado Parameter (Figure 1) and TGP vs. Tornado Parameter (Figure 2) were made:

DISCUSSION

Verification of Previous Studies –
• Low LCL heights, thermodynamic instability, high helicity values, and high shear values (especially low-level shear) support tornadogenesis
• Effective SigTor strongly correlated with tornadogenesis

New Findings –
• Most-unstable LCL (among LCLs) is best correlated with tornadoes and best discriminates between strong/weak tornadoes
• eCAPE (among CAPEs) is best correlated with tornadoes and best discriminates between strong/weak tornadoes
• Storm motion/DCAPE strongly correlated with tornadogenesis
• TCP appears to be a useful parameter in tornado forecasting — it is most strongly correlated with tornadogenesis than SigTor and discriminates very strongly between strong and weak tornadoes

REFERENCES


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