Project BLASTED: Boundary Layer Analysis of Supercells and Tornadoes During the Evening Diurnal Transition

Thesis and Purpose:

Each year, supercell thunderstorms produce hail, tornadoes, and damaging winds, which frequently lead to a loss of life and property (Fricker and Friesenhahn 2021). While the death rate from tornadoes has decreased due to advanced warning lead times, this trend does not appear with nocturnal tornadoes (Ashley et al. 2008). Beginning around sunset, the low-level atmosphere often undergoes a transition, referred to as the evening transition, from being turbulent during the day to stable and calm at night. Researchers have noted that aspects of the evening transition create a favorable environment for tornadoes, despite stable conditions caused by the loss of solar heating (Coffer and Parker 2015).

The proposed research seeks further understanding of supercell behavior during the evening transition by collecting *in-situ data near supercells before, during, and after the evening transition*. The Project investigates differences in shear, lift, instability, and moisture (SLIM) parameters, viewed through data collected from weather balloon launches and surface observations in near-storm environments. Analyzing how the parameters change in the boundary layer near supercells allows a better understanding of their interactions during tornadogenesis, which advances warning lead times.

Background and Significance:

The proposed work seeks to build on the previous deployments of the Thermodynamic Investigation into LCL Thresholds at Tornadogenesis and its Influence in the Northeast and Great

Plains (TILTTING) Project and focus on a new question. Our Project reorients the goals of TILTTING by studying environmental changes during the evening transition, and how they impact supercell behavior, including tornadogenesis. Storm warnings at night are typically less effective than those issued during the day (Mason et al. 2018). When nocturnal warnings are issued, people are less likely to react. Research into nocturnal supercells is needed to improve forecast lead times as much as possible. The Project is a new research initiative titled Project BLASTED that seeks to improve understanding.

Supercell thunderstorms are highly sensitive to their surrounding thermodynamic and kinematic environments. Maintaining strong, rotating updrafts requires a balance between lift, vertical wind shear, and moisture. During daytime hours, solar heating enhances surface-based instability by increasing boundary layer temperatures and steepening low-level lapse rates. After sunset, radiational cooling promotes boundary layer stabilization, potentially weakening updraft strength.

Despite these changes, some supercells continue to exhibit strong rotation, lightning, and severe characteristics well into the nocturnal period. This suggests that compensating mechanisms such as enhanced shear, elevated instability, or increased moisture may offset the loss of solar heating. In the Southern Great Plains, the nocturnal low-level jet (LLJ) is a well-known phenomenon that increases the low-level vertical wind shear, which in turn enhances the updraft strength present in the supercell (Blumberg 2018). Documented moisture increases occur during the evening transition in the Southern Great Plains, and Blumberg 2018 hypothesized that such increases may make severe weather favorable during this period.

Project Design:

Our data collection utilizes a Mobile Mesonet and Windsonde probes to record data from the surface through the entire depth of the storm environment. Windsonde probes are launched into the system, providing a technical sample of the storm mechanisms as height increases. Data gathered by Windsonde probes is used to plot a Skew-T Log-P diagram, which we use to assess the presence of ingredients such as instability, moisture, and shear (Blumberg et al. 2017). On the ground, our Mobile Mesonet utilizes the R.M. Young Wind Monitor system (Wind Monitor, n.d.), which provides data on wind conditions outside of the vehicle. In addition, a U-Tube Mobile Mesonet (Waugh 2012) instrumentation system is used to obtain measurements of temperature and relative humidity. Gathering these data sets allows us to derive dewpoint temperature values. The U-Tube and R.M. Young Wind Monitor system are secured to an aluminum rack, attached to the top of our vehicle, creating what we call our Mobile Mesonet.

The U-Tube's intake is created with a symmetric two-plate design that smooths airflow while minimizing the contact surface area where water could collect. The U-tube is unique in that it utilizes a “tube-within-a-tube" design which serves as a primary defense against thermal bias in measurements. The air gap between these two tubes will absorb reradiated thermal energy from the PVC walls before it reaches the sensors (Waugh 2012). Both the intake and outtake are designed to utilize Bernoulli’s Principle, which allows gravity to act against any liquid that may attempt to enter the system, keeping instrumentation dry. The 90-degree curve of the U-Tube also protects the sensors inside from both direct and indirect solar radiation.

For Project BLASTED, the accuracy of moisture data collected during the evening transition is vital. Capturing data without solar radiation errors and “wet-bulb” cooling ensures that our data pinpoints the exact moment the boundary layer changes in the evening (Waugh 2012). By providing data free from the thermal influence of direct sunlight or the vehicle, the U-

Tube's design allows for precise tracking of low-level moisture that can affect supercell behavior and tornadogenesis.

Expected Results and Application to Broader Community:

After collecting a set of SLIM data from supercell thunderstorms before, during, and after sunset, we use Python and Microsoft Excel to analyze storm behavior at these critical periods of the diurnal cycle. We also use publicly available storm-centered data to gather information on variables like lightning flash density that serve as indicators of supercell intensity (Chronis et al. 2015). Our research aims to answer the question: What are the differences in the thermodynamic environments of supercell thunderstorms throughout the evening transition? We expect to find an observational relationship between SLIM parameters and the fluctuation of supercell strength.

Millersville Meteorology Alumni Shane Martrich (‘23), Rhiannon Cahoe (‘23), Ryan Argenti (‘24), Grace Dauch (’25), and Gabriel Peña (‘25) previously presented their research from Project TILTTING at the American Meteorological Society Conference in Denver, CO (‘23), and New Orleans, LA (‘25). Their research led to graduate school opportunities for Cahoe (Millersville University), Martrich (University of Wyoming), Dauch (University of Alabama-Huntsville), and Peña (Texas Tech University), as well as a broadcasting position for Argenti at WGAL-TV. Additionally, Project TILTTING, and now Project BLASTED, has and will continue to introduce Millersville Meteorology undergraduate students to field work, research, and proper use and deployment of various instrumentation. These opportunities for undergraduates aren’t available at most other universities with Meteorology programs. Finally, this research will continue to be a valuable component to recruitment efforts for Millersville’s Meteorology program. The project’s exposure has led many students to choose Millersville over competing programs and entices prospective students to continue doing so in the future.

Discussion and Interpretation of Results:

With our results, we will be able to determine the impact that moisture changes around sunset have on both non-tornadic and tornadic supercells. Moisture evolution around sunset is not a well-studied idea, but general conclusions suggest that an increase in moisture allows non-tornadic supercells to become tornadic. Currently, quantification between favorable and unfavorable environments does not exist, but based on our hypothesis, an increase in moisture variables during the diurnal transition will favor supercells to be tornadic.

References

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