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Case Study of the Quasi-Linear Convective System through Central Pennsylvania on August 30th, 2022 (TILTTING)

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Abstract

In this study, Millersville University students who took part in the Thermodynamic Investigation of the LCL Thresholds during Tornado-genesis in the Northeast and Great Plains (TILTTING) project, tracked a Quasi-linear Convective System (QLCS) through South Central and East Central Pennsylvania. The team split into two cars, specifically to launch Windsonds at opposing ends of the QLCS. Team 1 pursued near the tail end of the line in Yocumtown, Pennsylvania while Team 2 pursued in Kempton, Pennsylvania. Although we did not acquire tornado-genesis data, we were able to gather data of the rear inflow jet of the QLCS line. The data we collected suggests that a rear inflow jet was at least partially responsible for the rapid intensification of the QLCS.

I. Introduction

Damaging winds, intense rain, and tornadoes are all a part of our weather system and impact society. The steps in helping predict storms on a larger time scale for future generations are what is needed to save lives and protect property. Thunderstorms cause a great amount of damage with their high wind speeds, cloud-to-ground lightning, and possible production of hail. The formation of a thunderstorm can result in a QLCS, which is a type of Mesoscale Convective System (MCS) that is defined as a convective line extending across an area of terrain in a linear, rather than wide, form. These produce discrete cells along the line which lead to high precipitation events including high winds and flash flooding, resulting in damaged property. One of the difficulties in researching a QLCS is understanding the atmospheric dynamics of how they intensify with time. Although research among this type of thunderstorm has been studied through intensive observation periods (IOPs) in relation to supercell thunderstorms, it is still rather unknown how a QLCS rapidly intensifies. Students who are a part of the TILTTING Project and Millersville University's Meteorology Department pursued a QLCS through south-central and east-central Pennsylvania. What was documented can help the predictability of strong thunderstorms, especially that of the rear-inflow jet and how it plays a part in the intensification of a QLCS. Our mission for this chase was to gather upper atmospheric data using Windsonds, by Sparv Embedded, to help us understand the atmospheric environment, thus allowing us to draw conclusions depicting the storm's behavior. With a group of eight students and the project's supervisor, the team split into two cars and intercepted the line on the southern end in Yocumtown, a part of York County, and the northern end in Kempton, a part of Berks County.

II. Forecast Methodology

Forecasting plays a vital role in planning out steps accordingly. A few days prior, a low-pressure system moved its way towards the east coast below New Jersey, and a northerly cold front was pushing its way south, extending along the entire eastern side of the United States. Additionally, a mid-level trough set in over Indiana and Ohio and was expected to move eastward to the Mid-Atlantic and New England regions. There was a dense cloud formation that accompanied the mid-level trough and was present alongside the frontal area. The temperature gradient in the warm area was not favorable for strong vertical instability. However, due to the variations in temperature and rising air currents along the eastern edge of the thicker clouds, thunderstorms were likely to form in a line during the early afternoon of August 30th. These thunderstorms were expected to develop in bands and spread from northern Virginia towards central and eastern parts of Pennsylvania and New York. This was an indication that strong thunderstorms would persist as the front moved closer since surface temperatures were already warm for days prior and were anticipated to reach into the 80s. Moreover, a cold front passing over warm surface temperatures created an unstable mixing layer of the atmosphere ahead of the front, which enhanced strong thunderstorm probability as well as creating pockets of Convective Available Potential Energy (CAPE) along the line. On August 30th, 2022, around 15 UTC (11 AM EDT), a dry line, the separation between moist and dry air, appeared near central Pennsylvania and slowly traveled eastward extending from northern New York down to southern Mississippi. We had been taking note of the system of storms that developed across the Great Plains so we could prepare a plan of action. As it reached the southwestern border of Pennsylvania, the line began to extend while pushing through Pittsburgh, making its way towards central Pennsylvania.

III. Preparation Methods

Initially, the team was hesitant whether to pursue this system since it appeared to be weakening as it crossed the Appalachian Mountains. However, the line of storms reinvigorated as they developed along the dry line. Throughout the morning hours we were monitoring numerical model data as well as satellite and radar imagery. Shear and instability parameters were at their minimum thresholds required for tornado-genesis. Despite this being the case, with the influence of the dry line as our lifting mechanism, we concluded that the storms had potential for tornado-genesis. With three hours until departure, our team constructed a plan for directing which vehicles were targeting certain parts of the QLCS line. Yocumtown and Kempton were

Figure 1. *Student meteorologists Ryan Argenti, John Aytch, and Shane Martrich Testing a Windsond to ensure reliability.*

the best locations due to the most favorable tornadic conditions being in the vicinity of these areas. We gathered instrumentation and departed from Caputo Hall of Millersville University at approximately 3 PM EDT. The fieldwork plan consisted of launching three Windsonds to gather pre-storm, mid-storm, and post-storm environments an hour apart from the time of the first launch. We also used a Kestrel, an environmental meter which measures thermodynamic properties such as relative humidity, temperature, barometric pressure, and wind speed, to obtain surface observations. For visual documentation, the team in Kempton flew a Phantom 3 drone at an estimated 390 feet above the ground before the time of each Windsond launch, while also using a team member's Nikon D750 DSLR camera to document the storm from the ground as it approached.

Figure 2. *Pictured is student meteorologists Phillip Jacolow and John Aytch preparing to launch for the mid-storm environment in Kempton, PA. Photo taken by student meteorologist Rhiannon Cahoe.*

The rear-inflow jet is a feature found in bow echoes of an MCS that helps to intensify the cold pool and downdraft of a thunderstorm. It develops due to the interaction between an upshear-tilted convective circulation and horizontal pressure gradients. Before the line strengthened in Yocumtown, a slight bow echo was detected in the radar imagery as we launched the mid-storm Windsond. The rear-inflow jet was also visible on radar imagery due to its placement near the inflow notch in the rear of the developing line. As the QLCS developed through Kempton, a shelf cloud formed along the line of storms. With the dry air behind the front, this is a strong physical indication that the rear-inflow jet is at least partially responsible for the rapid intensification of the QLCS.

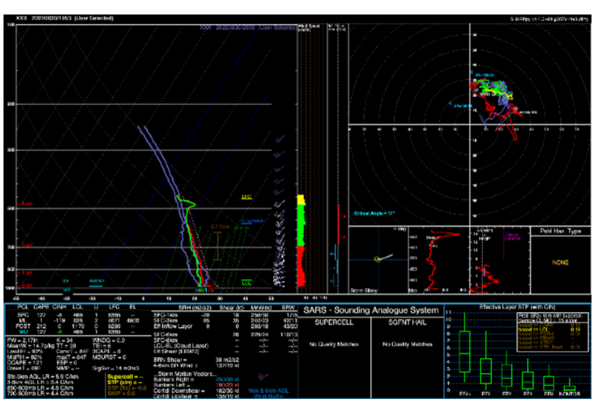
Figure 3. *Image of the shelf cloud in Kempton, PA. Photo taken by student meteorologist Rhiannon Cahoe.*

IV. Data Methods and Results

While performing data analysis, we created two compiled Skew-T soundings from the Windsond data for both areas to enhance our comprehension of each type of storm environment while examining the collected data. Skew-T's are extremely helpful in understanding the atmosphere, since they are a graphical representation of the atmosphere that plots temperature and dewpoint in correspondence to pressure. The platform we used to execute this is the Sounding and Hodograph Analysis and Research Program (SHARPy). This is a Cross Platform that is written in the Python programming language and is used to visualize and process sounding data. However, there was a result of corruption in the pre-storm Yocumtown soundings and the mid-storm Kempton soundings. After analyzing each corrupted data file, we deduced there was an unwanted frequency exchange between both teams at the time of launch. The exchange resulted in the merging of pre-storm and mid-storm data, providing false information of the upper atmospheric dynamics. Regardless of the exchange, the key area of interest was the mid-storm and post-storm environments in Yocumtown, as well as the post-storm environment in Kempton, which were observed to be unaltered.

The Figure 4 sounding illustrates what was observed in Yocumtown, which shows drying of the low to mid-levels beneath 625

Figure 4. *Mid-storm (green and red) and post-storm (blue) compiled Skew-T from Yocumtown, PA.*



millibars in the post-storm launch, suggesting the presence of the rear-inflow jet. The sounding created from the Kempton data shows drying below 850 millibars, which is consistent with the data in Yocumtown, as shown in Figure 5.

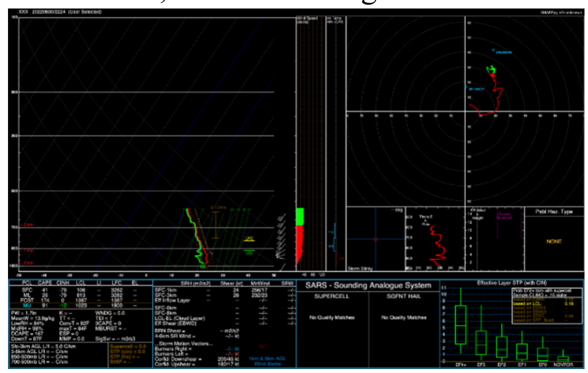


Figure 5*. Post-storm Skew-T from Kempton, PA.*

V. Future Work

In the future, Project TILTTING will focus on several areas of severe weather, but mainly on the differences in Lifting Condensation Level (LCL) height thresholds between the Northeast and Great Plains. First, we plan to conduct more extensive data collection by traveling to the Great Plains for a two-week period where tornado-genesis is forecasted to be evident. We plan to do the same within the Northeast so we can compare each dataset. This will enable us to investigate the relationships between the variables and factors that influence the formation of tornadoes in both regions. Additionally, we will use advanced statistical and machine learning techniques to analyze the collected data and identify patterns and correlations. We also intend to compare our findings with existing literature to confirm the novelty of our research and determine the potential implications and applications. Finally, we aim to disseminate our results through publications and presentations to share our findings with the scientific community and contribute to the advancement of knowledge in the field.

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Recommended Citation
Cahoe, R., Argenti, R., Martrich, S., Elliot, K., & Blumberg, W. (2023). Case Study of the Quasi-Linear Convective System through Central Pennsylvania on August 30th, 2022 (TILTTING). *Made in Millersville Journal*, 2023. Retrieved from https://www.mimjournal.com/meteorology-2023