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Assessing the Effects of Storm Depth on TDS Height Interpretation in Tornado Intensity Estimation

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RCEU Summer 2018 Project Proposal

Title: Assessing the Effects of Storm Depth on TDS Height Interpretation in Tornado Intensity Estimation

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Project Summary:

Tornadoes pose a significant threat to life and property across the middle and eastern United States. This threat is particularly notable across the southeastern United States. Not only are tornadoes common across the region, including within the state of Alabama, but intense tornado activity is also commonplace. Aside from the basic climatology of tornado occurrence, numerous additional factors significantly increase the vulnerability of the southeastern United States to tornadoes. Hills and trees provide significant obstruction to spotters and chasers attempting to view the lower portions of storms, where tornadoes would be visible. High water vapor content in the lower-levels of the atmosphere due to proximity to the Gulf of Mexico can lead to very low cloud bases, and typical Southeast severe storm patterns often lead to storms that wrap tornadoes in curtains of heavy rainfall. Many tornadoes in the Southeast occur at night (as many as 1/3 to 1/2 of tornadoes), when spotting is particularly difficult and dependent not only on the previously aforementioned spotting hindrances but also on light sources, such as lightning or power flashes, to illuminate the tornado. Additionally, socioeconomic factors such as poverty rates and density of mobile home stock lead to increased vulnerability to tornadoes.

Dual-polarization radar, now deployed across the country by the National Weather Service (NWS), has been shown in past work to serve as a useful utility in severe weather detection. Data from polarimetric radars have been shown to be useful in detecting tornado debris as well as precipitation microphysical properties linked to storm-relative inflow and related storm-scale processes important to severe weather and tornado production. A particular focus for polarimetric radar technology among radar meteorologists has been the detection of tornado debris and the attempt to estimate tornado intensities based off the characteristics of observed polarimetric tornado debris signatures (TDSs). Observational studies performed by NWS personnel have found that substantial relationships exist between tornado damage intensity and the depth of a TDS within isolated supercell thunderstorms, the storms most commonly responsible for large, violent tornadoes. In these storms, increasing TDS depth in the atmosphere is generally correlated with increasing tornado intensity. However, this relationship is not particularly strong for tornadoes produced by quasi-linear convective systems (QLCSs), or "squall lines". One hypothesis for why the QLCS tornado strength-TDS depth relationship is weaker is that QLCSs, particularly those that produce tornadoes, can vary greatly in the total depth of the storm. Many tornadic QLCS events in the Southeast are produced by shallow storms with relatively low cloud top heights. The relationship between the total depth of a parent storm, either supercell or QLCS, TDS height (and corresponding TDS depth as a percentage of total storm depth), and tornado intensity has not yet formally been investigated.

This project will expand upon previous work by the NWS, academia (including UAH), and other research institutions to improve the ability of tornado intensity estimation using radar. The student will collaborate with the NWS office in Jackson, Mississippi, to expand upon their dataset of TDSs and collect information on the total depth of the parent storms in order to normalize TDS depth by storm height. This normalized depth will then be analyzed to compare statistics between weak (EF0-EF1), strong (EF2-EF3), and violent (EF4-EF5) tornadoes, as well as to compare performance of a normalized depth metric between supercell and QLCS tornadoes. These data will be compared to past results to assess whether normalization of TDS depth by total depth of the parent storm adds value for meteorologists attempting to estimate the likely intensity of a tornado and tailor a correspondingly appropriate warning message for the public.

Student Prerequisites

The student should be of sophomore standing or higher, with the student having completed ESS 212 (Severe and Hazardous Weather) and ESS 301 (Intro to Earth & Atmos Science). The ideal candidate will have class or work experience using GR2Analyst software to perform radar analyses on thunderstorms, and have previously (or concurrently) participated in UAH SWIRLL severe weather research operations.

Student Duties

In order to ensure sound deliverables from this project, a structured, three-phase approach will be employed. The phases of the project are broken into two-week, four-week, and six-week increments as follows.

Phase 1: The first two weeks of the project will focus on developing the student's background on QLCSs, tornadoes, and polarimetric radar. This development will be accomplished through a focused, intensive literature review. The literature the student will review will offer insight into a variety of topics related to this project, including after which the student will provide a summary presentation of pertinent literature to the faculty and graduate student mentors. [2 weeks]

Phase 2: The next four weeks of the project will focus on building skills necessary to accomplish this proposed research project. These skills include proper identification of TDSs and total storm depth utilizing NWS radar data. To accomplish these tasks, the student will become familiar with data sources and software tools common to radar meteorology. The student will learn how to access radar data from the National Centers for Environmental Information (NCEI), how to read it into the Gibson Ridge Level 2 Analyst Edition (GRLevel2 Analyst), and how to utilize GRLevel2 Analyst to assess TDS and storm depth statistics. The student will also learn how to retrieve official NWS tornado survey and classification data, maintained by the National Center for Environmental Information's (NCEI) Storm Data publication and most directly disseminated through the Storm Prediction Center (SPC). Additionally, the student will be trained in basic programming in the Python language for statistical analysis and visualization of the complete dataset, once it is collected. [2 weeks]

Phase 3: The remaining six weeks of the project will comprise expanding the TDS dataset by adding additional cases and adding information about the total storm depth. TDS height statistics will then be compared to and normalized by total depths of the parent storms. The statistics of the normalized TDS depth will be compared to using true TDS depth alone to determine if total depth of the parent storm plays a meaningful role in TDS depth interpretation in assessing the potential intensities of the tornadoes responsible for the signatures. [8 weeks]

The student will gain an appreciable insight into recent advancements in radar meteorology through this project. He or she will gain experience with state-of-the-art tools to quality control and analyze radar data and with statistical analyses. Upon completion of the project, the student will present his or her work to the NWS forecast office in Jackson, Mississippi, in order to demonstrate the process of transitioning research to forecasting operations. Additionally, the student will be encouraged to gain presentation experience through both the Von Braun Research Symposium and potentially the 2018 National Weather Association Annual Meeting in St. Louis, MO.

Mentor Supervision and Interaction

Dr. Kevin Knupp, as well as Tony Lyza, a senior PhD student from Dr Knupp's research group, will supervise the student for the duration of the project. Tony will meet up to several times per week with the student to ensure development of a solid foundation of background knowledge on the subject matter, ability to use the necessary tools for this project, and satisfactory progress in achieving the project goals stated above. The RCEU student will attend Dr. Knupp's weekly research group meetings to allow the student to interact with other research group members, thereby benefiting from the availability of multiple "go-to" experts on polarimetric radar analysis. Additionally, the student will be stationed for the summer in the UAH SWIRLL Research Operations Center with other RCEU / REU students from the Carey, Bitzer, and Wade research groups. These RCEU / REU students will interact with one another, participate in group radar training sessions, attend seminar talks, and participate in other planned group team building exercises.