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Radar Characterization of Precursors to Cyclic Mesocyclogenesis in Supercell Storms

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Project Summary: *Radar Characterization of Precursors to Cyclic Mesocyclogenesis in Supercell Storms*

The prolific severe weather generated by supercell thunderstorms is related to their unique dynamic structure, including the rotating updraft-downdraft couplet, or mesocyclone, that uniquely characterizes them. In some instances, the mesocyclone within a supercell has been observed to occlude and decay while a new updraft region forms and begins to rotate as a newly-generated mesocyclone, the process of which is referred to as cyclic mesocyclogenesis (Darkow and Roos 1970). Operational recognition of this process can be important in identifying potential impacts related to the varying intensity of the storm, linked with the varying intensity of the regenerating primary storm updraft (Beck et al. 2006; Kumjian et al. 2011).

Limited case studies and numerical simulations of cyclic mesocyclogenesis have been documented in the literature, though recent work cites the need for more detailed observations to draw more general conclusions of typical storm kinematics and microphysics associated with the process (Kumjian et al. 2011). With the increased availability of polarimetric radar observations, more recent work has characterized the evolution of hydrometeor fields and microphysical processes in supercells with respect to successive mesocyclone formation. Polarimetric data enables the inference of more information on the size, shape, and concentration of hydrometeors beyond what traditional radar reflectivity measurements afford. Examples of the variables and signatures considered when evaluating the microphysics associated with cyclic mesocyclogenesis in supercells include enhancements in the supercell hook echo, the differential reflectivity (Z_{DR}) arc, the hail signature, specific differential phase (K_{DP}) and Z_{DR} columns, and Z_{DR} and correlation coefficient (ρ_{HV}) rings (Kumjian and Ryzhkov 2008; Kumjian et al. 2010; Kumjian 2011).

Despite the increased availability of polarimetric data since the completion of the upgrade of the Weather Surveillance Radar – 1988 Doppler (WSR-88D) national network in spring of 2013, there remains a relative dearth of information with respect to the microphysical properties of supercells related to cyclic mesocyclogenesis. Further exploration of polarimetric characteristics, including the use of hydrometeor identification and analysis of bulk microphysics, may aid in enhancing the conceptual model of processes that may signal imminent or ongoing occlusion and regeneration of a supercell's main updraft and mesocyclone. Comparison of common precursor signatures or features observed during the occlusion and updraft regeneration process across varying climatic regions through the use of the expanded availability of the WSR-88D may also promote proper operational use of signatures.

For the purposes of the proposed project, the student would assemble a case list of well-resolved cyclic mesocyclogenesis over which to analyze polarimetric signatures as described in the literature. The student may also have the opportunity to integrate new observations collected during a local field project during the spring of 2016 and planned for the spring of 2017, including use of data from the local C-band Advanced Radar for Meteorological and Operational Research (ARMOR). The initial primary goal of the project would be to develop a characterization of polarimetric precursor signatures observed prior to cyclic mesocyclogenesis, facilitated by analysis of a broader, diverse set of observations than used in previous studies. Second, this knowledge would be applied to the development of a more robust conceptual model for use in operations.

Project learning and development goals include:

- Familiarization with qualitative polarimetric radar analysis
- Development of understanding of the microphysical and kinematic implications of radar signatures
- Development of skills toward quantitative radar data analysis with the use of existing software packages
- Implementation of the scientific method by conducting analysis based on specific hypotheses
- Ability to apply qualitative and quantitative results to a conceptual model for transitioning weather research to forecasting operations

Student Prerequisites: The student should be of sophomore standing or higher, with the student having completed ESS 112 (Severe Hazardous Weather) and ESS 301 (Intro to Earth Atmosphc Phys). The ideal candidate will have participated in UAH SWIRLL severe weather research operations and collected data through the launching of atmospheric soundings or assisted with real-time UAH radar operations.

Student Duties: The project will consist of four phases designed to gradually increase the student's comfort level and capabilities with the research process, data, and analysis techniques. The phases are designed to simultaneously develop research skills while defining and meeting measurable project progress.

Part 1: The initial stages of the project will include a literature review to gain an understanding of supercell thunderstorm structure; the process of cyclic mesocyclogenesis; and the variety of polarimetric radar supercell signatures, their general expected values in data, and their implications for storm microphysical and dynamical processes. While a student may continue reading literature throughout the project, he or she should be able to summarize key results from their initial review for the purpose of identifying research motivation and analysis goals. Simultaneously, the student will become familiar with data collection as well as basic radar interrogation software, including GR2Analyst. The student will also begin creating, with guidance, a set of supercell event cases displaying cyclic mesocyclogenesis. [Duration – 3 weeks]

Part 2: After becoming familiar with initial methods to assess radar data, the student will begin an in-depth assessment of pertinent polarimetric radar signatures and hydrometeor characteristics in the selected cases. This portion of the project will implement the use of hypothesis-driven analysis, guided by knowledge obtained during the earlier literature review. This will focus student efforts and insure reasonable project scope. During this phase, the student will also begin building skills with more advanced radar analysis software to enable quantitative analysis, including NCAR Solo3 or DOE Py-ART. [Duration – 4 weeks]

Part 3: At this point in the project, the student should have a sizeable case list (on the order of 5-10 supercell storms exhibiting cyclic mesocyclogenesis) complete with radar characterization. The student will compare their cases to those documented in the literature for similarities and potential differences. The student may implement quantitative and statistical analysis techniques to complement qualitative assessment of the supercell storms for this comparison. Using this characterization, the student will assess the relative operational implications and utility of qualitative differences. [Duration – 3 weeks]

Part 4: In the final stage, the student will consider secondary datasets that may couple with polarimetric radar signatures to afford additional information about supercell evolution or dynamics. This will require only broad analysis, or a basic proof-of-concept exploration. Ultimately, this final stage will allow for motivation of future research while tying together the main threads of the project, with theoretical understanding of the processes that result in the polarimetric signatures examined. The student should also be finalizing a short written summary of their work while assembling a research poster [Duration – 2 weeks]

During the 12-week period of the project, the student will also continuously work on short, written deliverables on the motivation and background of their work, methods used for analysis, and different types of results. These may be combined near the end of the project with final conclusions for a cumulative research report. Their conclusions should consider not only their accomplishment of project goals and key findings but also areas for future work or ways that they would enhance analysis.

A number of academic and professional benefits will be available to the student through the proposed project, including the opportunity to develop theoretical understanding of an area of radar science, learn practical data analysis techniques and tools, as well as have the opportunity to consider broader applications and methods for expansion of the project. The student will also work in close proximity with other undergraduates undertaking similar but varied research projects and will benefit from collaboration and team-building.

Mentor Supervision and Interaction: Dr. Carey, as well as a senior PhD student, Ms. Sarah Stough, from Dr. Carey's research group, will supervise and mentor the student throughout the duration of the project. The student will attend weekly meetings with Dr. Carey and the PhD student mentor to provide feedback and foster a collaborative research environment to assist in the student's progress and success. Additionally, the student will attend Dr. Carey's weekly research group meetings to allow the RCEU student to interact with other group members and be exposed to other radar and severe storms research. Members of Dr. Carey's graduate student team will aid the student in learning the tools necessary to complete the proposed radar analyses. They will also assist in guiding critical thinking to motivate hypothesis-driven research through each portion of the project. Lastly, the student will be stationed for the summer in the UAH SWIRLL Research Operations Center with other RCEU/REU students from the Knupp, 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.