**University:**

Central Michigan University

**Name of University Researcher Preparing Report:**

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**NWS Offices:**

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**NWS Researchers Preparing Report:**

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**Partners or Cooperative Project:**

Partners

**Project Title:**

Climatology and conceptual models of snowfall distribution in cold-season Central U.S. cyclones

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**SECTION 1: Summary of Project Objectives**

The primary goal of this work was to describe the variability of cold season banded snowfall environments associated with Central U.S. cyclones.

The following objectives were designed to facilitate completion of this goal:

A. Creation of a 5 year climatology of the structure and distribution of snowfall in central U.S. cyclones

B. Categorization of each time in each event into one of 8 pre-determined categories encompassing precipitation structure and location, followed by creation of composites of these categories

C. High-resolution numerical simulation of the event with the heaviest precipitation to the northeast of the cyclone

    a. This will be performed by a Central Michigan University undergraduate student, providing the student with research experience, direct interaction with NWS personnel, and experience at preparing and presenting research results.

D. Dissemination of research results through office presentations, Central Region webinars, conference presentations, and peer-reviewed publication

## SECTION 2: Project Accomplishments and Findings

The proposed objectives were met, as addressed below:

A 5-year climatology of the structure and distribution of snowfall in central U.S. cyclones has been established, spanning the winters of 2006-2007 through 2010-2011. To create this climatology, a customized website was designed which allowed us to plot composite radar images along with surface analyses. A total of 98 bands were identified, along with 38 storms that did not feature banding. The categorization of the bands was modified somewhat from what we had proposed. Both bands and storms that did not feature bands were divided into two different flow regimes, from the northwest and the northeast. Following this the location of the band or the non-banded snowfall was divided into one of three locations with respect to the surface low: northeast of the low, northwest of the low, or spanning both quadrants. The results are presented in the following two tables.

**Table 1: Banded Snow (Left); Non-Banded Snow (Right)**

| Snow Location | Flow Regime | | SUM | Snow Location | Flow Regime | | SUM |
|---|---|---|---|---|---|---|---|
| | SW | NW | | | SW | NW | |
| NE | 37 | 17 | *54* | NE | 10 | 9 | *19* |
| NW | 27 | 2 | *29* | NW | 9 | 0 | *9* |
| BOTH | 13 | 2 | *15* | BOTH | 6 | 4 | *10* |
| SUM | *77* | *21* | 98 | SUM | *25* | *13* | 38 |

After the events were placed in categories, composites centered on each surface low were generated using the North American Regional Reanalysis dataset. Five sets of composites were created: NW band, SW flow (27 cases); NE band, SW flow (37 cases); NO band, SW flow (19 cases); NE Band, NW flow (17 cases); NO band, NW flow (9 cases). Composites were generated

at four different times relative to the appearance of the band, at T-6 h, T=0 h, T+6 h, and T+12 h. The results of the five composites at t=0 are shown below.
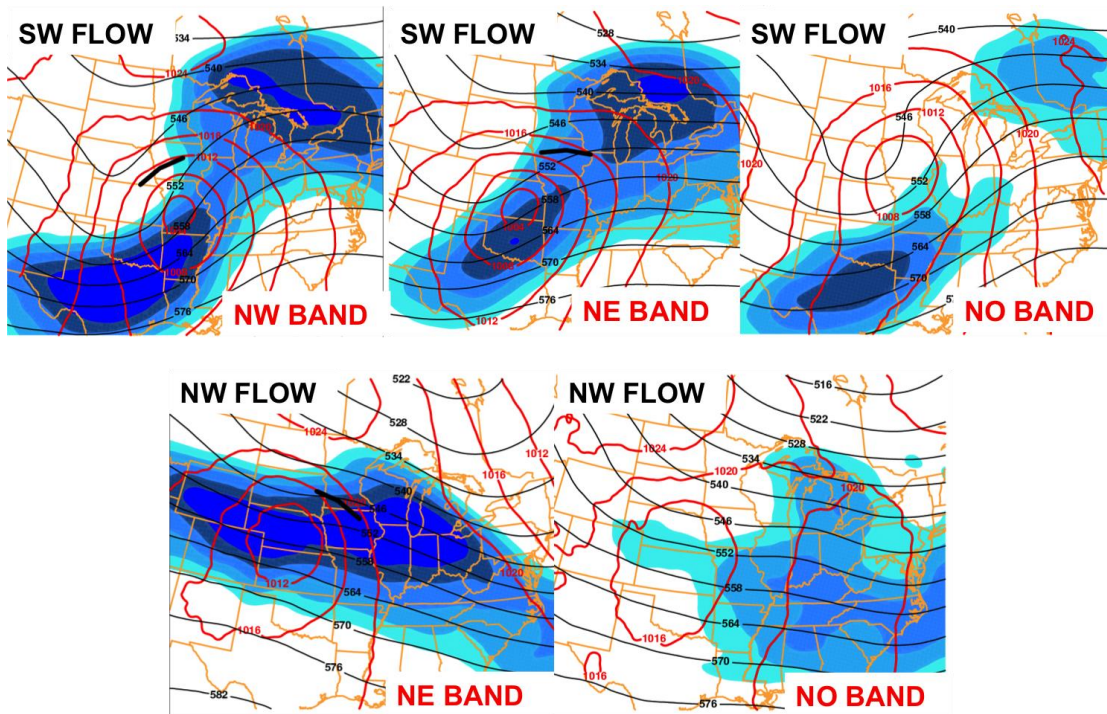


**Figure 1: 500 mb heights (black),MSLP (red), 300 mb isotachs (image), black line indicates composite band location**
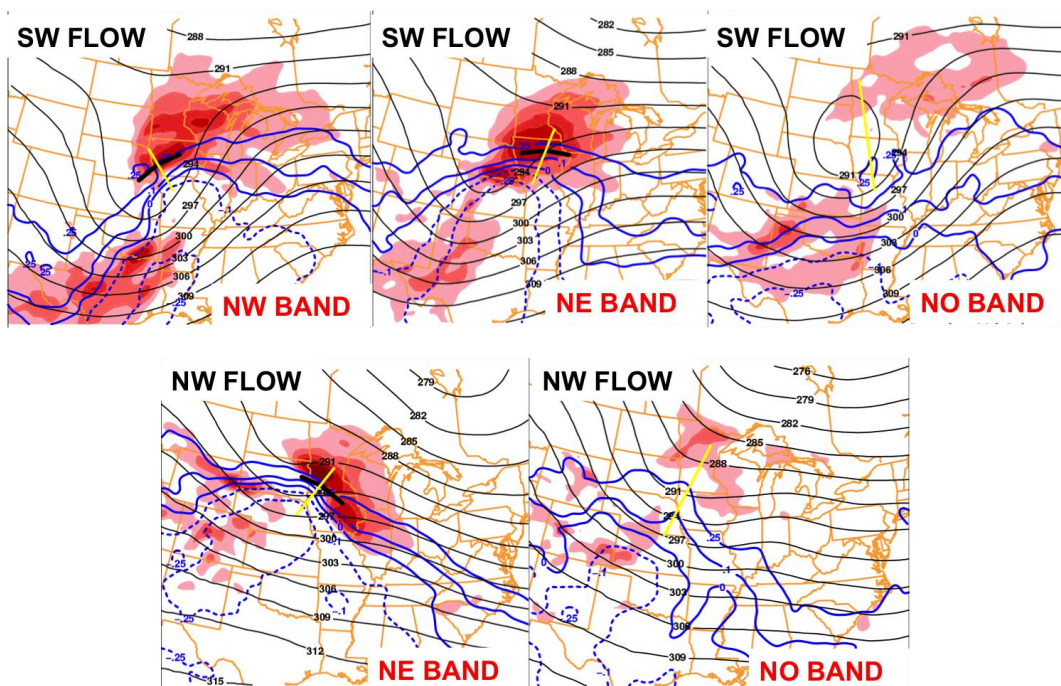


**Figure 2: 700 mb heights (black), 600-700 mb saturated equivalent potential vorticity (blue), 700 mb frontogenesis (image), black line indicates composite band location**

The climatology indicates that there were nearly twice as many instances of northeast quadrant bands than northwest quadrant bands. Also, more banding occurred in southwest flow than northwest flow. Northwest quadrant bands in northwest flow are very uncommon.

The northwest band composite matches up very well with previous research. The northeast band composite in southwest flow features a positively tilted trough and zonal downstream flow, resulting in a jet streak configuration more favorable for confluence in the northeast quadrant. The northeast band composite in northwest flow features a weak trough, but a strong height gradient and associated jet streak, resulting in a deep layer of frontogenesis. The nonbanded events featured weaker cyclones and jet streaks, little to no frontogenesis, and more stable air. Interestingly, the troughs in the nonbanded events were stronger than in the banded cases.

In addition, a CMU undergraduate student ran a WRF simulation of a unique event that featured banded snowfall in both the northeast and northwest quadrants during its lifetime. This event spanned three days, and the WRF did a reasonable job of representing relevant physical processes at higher resolution (12 km and 4 km domains). Over time, the location of banding shifted from the northeast quadrant to the northwest quadrant, coincident with the location of maximized moisture, lift, and instability. The system was observed to evolve from an open wave to a closed circulation at 500 mb, perhaps promoting the evolution of deformation from the northeast quadrant to the northwest quadrant. Trajectory analysis demonstrated that the residual moisture and moisture advection from the Pacific Ocean were crucial in supplying moisture for the nascent banding in the northeast quadrant. Further research would be necessary to more robustly determine what makes this case different from other events that feature banding in only one quadrant.

**SECTION 3: Benefits and Lessons Learned: Operational Partner Perspective**

The NWS PI was able to gain a greater appreciation of the variety of structures that appear on radar associated with heavy snowfall in the central United States. The NWS PI has benefitted from the University PI's technical expertise, which allowed us to easily measure the snowbands within a web interface. The NWS PI has acquired new knowledge of the variability of environments conducive to banded snowfall in the Central U.S., which he will incorporate into forecast training. If this work is well received, it is possible that it could be included in WDTB's Winter Weather AWOC course, which the NWS PI has previously been involved with. It is hoped that the snowfall climatology and composites will aid forecasters in identifying the various classes of banded snow environments.

**SECTION 4: Benefits and Lessons Learned: University Partner Perspective**

The University PI was able to gain a greater appreciation of the variety of structures that appear on radar through examining 4 years worth of cold-season radar with the NWS PI. The University PI gained greater knowledge of the frequency in which different types of events occur in the Central U.S. and the variability of difficulty in forecasting them. The University PI was able to successfully mentor another student on a research project and provide some well-deserved funding to the student to be involved. This student was able to learn about the physical processes responsible for banded snowfall, as well as how to set up and run a numerical model and present

her research findings at a national conference. Next year, the student will be pursuing an MS degree in Geography with a focus in Climatology at Michigan State University. The University PI enjoyed working with the NWS PI on our second COMET Partners project, and the program has allowed us to build a working relationship that will hopefully survive for many years.

**SECTION 5: Publications and Presentations**

5.1     Three poster presentations have been given on the funded research:

Casey, M.E., and M.A. Baxter, 2013: Numerical Simulation of a Snowfall Event with Mesoscale Snowbands to the Northeast and Northwest of the Surface Low: March 30th 2009. 12th Annual Student Conference, American Meteorological Society, Austin, TX.

Baxter, M.A., and P. N. Schumacher, 2013: Climatology and Conceptual Models of Snowfall Distribution in Cold-Season Central United States Cyclones. 20th Conference on Applied Climatology, American Meteorological Society, Austin, TX.

Baxter, M.A., and P. N. Schumacher, 2012: Climatology and Conceptual Models of Snowfall Distribution in Cold-Season Central United States Cyclones. 27th Annual Meeting of the National Weather Association, Madison, WI.

5.2     The PIs are currently preparing a submission to Weather and Forecasting, as all of the research has been completed. If this submission is published, the PIs will attempt to schedule a Central Region webinar.

**SECTION 6: Summary of University/Operational Partner Interactions and Roles**

The PIs met in Sioux Falls at the NWS PI's office and worked together to identify the snowbands used for the climatology and composites. The remainder of the collaboration was done via email. The University PI took the lead in the more technical aspects of the project – data retrieval and organization, website design, etc. The NWS PI used his operational experience to help determine how we should categorize events and what information should be included in our spreadsheet for each event.

Despite being awarded the COMET Partners grant, the NWS PI was unable to receive funding in support of this research. Funding restrictions prevented the NWS PI from travelling to visit the University PI, and from attending either of the two conferences the University PI and student presented at. Unfortunately, the lack of funding was a hindrance to achieving rapid progress on the work. The NWS PI and the CMU undergraduate student were never able to meet in person.