University: Saint Louis University

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Type of Project (Partners or Cooperative): Partners

Project Title: A Composite Analysis of Major Ice Storm Events in the County Warning Area of Springfield, Missouri

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Section 1: Summary of Project Objectives

The objective of this project was to improve the ability for NWS forecasters to assess the environmental conditions and impacts associated with ice storms in the south-central U.S. This objective was accomplished through the use of composite analysis of past significant ice storms. The composite analysis not only provided typical conditions, but was also able to present the results within a probabilistic framework.

Section 2: Project Accomplishments and Findings

The completed tasks include:

1. The Identification of ice storm cases and the classification of the intensity of each event. Only events with documented ice accumulations of ¾" or more were included in subsequent analyses. A synoptic analysis of all events identified 3 events that were associated with significantly different physical environments and were excluded from the rest of the analysis (resulting in 20 cases, see Fig. 1). Using surface observations, estimates of duration and coverage for each event were obtained. Figure 2 shows that most ice storms had more the 8 hours of FZRA reports.
2. The system-relative composite fields were computed several times as information and experience indicated improvements to the selection of the system-relative feature. Initially, the system center was the intersection of the 2-m 32°F isotherm and the low-level jet axis. However, the results suggested that the low-level moisture transport axis (i.e., 850 mb moisture axis) was better at identifying the critical ice-storm features. Figure 1 shows the center points for the 20 ice storms used in the composites.
3. Having the composites of standard mass, temperature and moisture fields (see Figs. 3-4), the representativeness of the composite fields was assessed. Three of the 20 cases appeared to be

substantially different from the composites. Consequently those outlier cases were analyzed in more detail.

4. Composite fields on isentropic surfaces were also created to provide a better representation of the flow responsible for the elevated warm layer. Composite fields of pressure, moisture, and winds were created on isentropic surfaces from 260 K to 330 K.
5. After standard composite fields were constructed and investigated, additional statistics were created and examined. Rather than simply examining averages, probabilities were computed, including the probability of fields to exceed specified thresholds (e.g., probability of the elevated warm layer exceeding 3°C). The purpose was to give forecasters a depiction of the possible range of values for these events rather than focusing on one *magic* value (for example, see Fig. 5).
6. The composite fields were used to examine the thermodynamic conditions that maintain the near-surface cold layer. With latent heat of fusion occurring with freezing rain at the surface, efforts examined the potential processes that would maintain the cold layer.
7. Combinations of fields and their probabilities were investigated to assist forecasters with estimating areal coverage of significant ice accumulations. For example, the 25th percentile of the maximum temperature from the surface to 500 hPa (Fig. 5) revealed that 75% of all cases had a large elevated warm layer exceeding 4°C.

From an analysis of the completed task, the findings include:

A. Major ice storms have a large-scale signature for the south-central U.S., including a strong upper-level jet streak upstream of the ice storm, southwesterly flow at mid-levels and a modest low-level jet. The upper-level jet stream remained anchored in place (possibly the result of latent heating) and provided the large-scale support for an extend period of time (Fig. 3). Cyclonogenesis was not prevalent during these events; however system development became evident as the system moved eastward out of the domain.
B. Most of the major ice storms can be classified as a duration event and not as an intensity event. The spatial and temporal coverage of reports with moderate and heavy freezing rain (i.e., FZRA and +FZRA) was very small, however most major ice storms had at least light freezing rain (i.e., -FZRA) over an extended area for eight or more hours (Fig. 2).
C. With these events dominated by light freezing rain (-FZRA) there was little evidence of convective activity or CAPE (Fig. 6). Thus, this stratiform precipitation, in principle, should be captured by numerical models since it does not rely on cumulus parameterization schemes. However, the precipitation amounts may fall below forecaster implicit thresholds (i.e., 0.1 in/hr rates are within the noise level).
D. The spatial extent of the typical ice storm was an elongated area along and north of the 32°F isotherm, typically occupying an area 630 km by 170 km. The elevated warm layer is typically around 150-200 hPa thick (Fig. 7).
E. The composite cross sections and isentropic analysis suggested that the elevated warm layer originates near the surface in the Gulf of Mexico (Fig. 8). These composites also suggest a portion of the mid-level flow is from the southwest which is a drier source region and may

assist in suppressing precipitation north of the freezing rain zone. The cross sections provide a textbook depiction of the elevated warm layer and vertical motions associated with the upper-level jet (Fig. 9).

F. The near surface cold layer appears to be maintained through cold dry air advection from the northeast (allowing for evaporative cooling) rather than just cold air advection.
G. The correlation of the composites with each member of the composite revealed that the composite fields are representative of these events (Fig. 10). A systematic analysis of the three cases with poor correlations indicated that differences were the result of changes in the location and orientation but not a change in the critical features.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

The results from this study will be the foundation for ice storm training for years to come. Our collaboration with Saint Louis University (SLU) has yielded a comprehensive anatomy of an ice storm. Parameters vital to ice storm production have been isolated, with a much greater understanding of the three dimensional structure inherent to freezing rain events. The principles learned have allowed forecasters to produce multiple procedures for use in AWIPS. One procedure in particular blends the Top-Down weather approach (Dan Baumgardt – ARX) with the essential spatial and vertical parameters that characterize freezing rain events for our area of concern. This procedure was extremely popular amongst the staff during the winter 2011, and enhancements to these procedures are planned for the upcoming winter based on the final conclusions of this study. These procedures will be made available to other NWS offices.

The presentations developed by SLU have been placed on our winter weather intranet web page, providing a quick reference when there is a threat of a freezing rain event. A comprehensive review of this ice storm study will once again be provided during our upcoming Winter Weather Seminar; ultimately, this information will be integrated into our Intern training program. Working with Dr. Graves, Kris Sanders and Chad Gravelle has been a very rewarding experience. We were very happy to welcome this group of gentlemen to our office on two occasions to work together on this project and to expose everyone to our operations. This allowed the staff at the Springfield WFO to develop a rapport with the principle investigators, which in turn enhanced the collaboration between our office and SLU. The results of this study have exceed our expectations and we will continue to collaborate with SLU to further refine ice storm risk analysis products for use in our decision support operations.

Section 4: Benefits and Lessons Learned: University Partner Perspective

This project provided the means to maintain and expand interactions with SLU and NWS forecasters and extend research into ice storms. The eagerness of the SGF office to dedicate time and effort provided a stimulating environment. Interactions both in person and through electronic means included the free exchange of ideas. Saint Louis University students were challenged by thought provoking questions from the SGF forecasters both on theoretical and operational issues.

One MS student (Kris Sanders) funded by this COMET project was awarded a SCEP position with the LSX office starting in August 2011. The opportunities provided with this COMET project contributed to his strong application and eventual success in getting this award.

As SGF forecasters and SLU researchers worked toward the end of this project a major tornado event (the May 22nd, Joplin tornadoes) impacted the SGF office. The demands of this event required significant resources from the SGF office which affected their ability to contribute during that period.

While the financial commitments of this project are completed, we still plan to continue interactions with the SGF office. We are currently working to publish our findings and will continue to look for ways to help SFG forecasters incorporate the results into the forecast process and decision support (see Section 6). We hope to engage another graduate student in a study to examine the robustness of the ice composites using the Cooperative Institute for Precipitation Systems (CIPS) analog guidance software.

Section 5: Publications and Presentations

NWA Poster Presentation:

Sanders, K., C. Graves, J. Gagan, C. Gravelle, 2010: A Composite Analysis of Major Ice Storms in the Central United States. Poster session, NWA 35th Annual Meeting, Tucson, Arizona.

NWA Newsletter article in the professional development series:

Sanders, K., C. Graves, J. Gagan, and C. Gravelle, 2010: A Composite Analysis of Major Ice Storms in the Central United States. NWA November 2010 Monthly Newsletter, p10-11.

Manuscript under development:

Sanders, K., C. Gravelle, J. Gagan, and C. Graves, 2011: Characteristics of Major Ice Storms in the Central United States, Submission to NWA Digest planned in September.

Section 6: Summary of University/Operational Partner Interactions and Roles

The identification of ice storms, the composite and statistical analysis was performed by SLU researchers.

The SGF forecasters and SLU researchers met in Springfield, MO to review the ice storm cases and the initial composite analysis. SGF forecasters were provided with the presentation in advance to allow time to review the results. At the meeting, characteristics of the ice storm environment from the point of view of SGF forecasters were discussed and additional analysis was proposed.

SLU researchers developed a draft of the poster for the NWA annual meeting. It was reviewed by SGF forecasters and suggestions were provided. At the NWA meeting Kenneth Carey, asked us to provide an article for the NWA newsletter, which appeared in the November 2010 issue. SLU researchers developed a draft manuscript and received comments from SGF forecasters.

From the presentations assembled by SLU researchers, SGF forecasters developed training materials for the SGF office. Specialized products were generated by SLU researchers at the request of SGF forecasters.

A second meeting in Springfield was used to review the findings of the case studies of the three apparent outliers. Environments as reviewed by SGF forecasters were compared to the composite results. At the meeting, SGF forecasters also demonstrated to the SLU researchers how the composite results and the top-down approach of Dan Baumgardt lead to the development of AWIPS procedures.

Currently SLU researchers are developing a manuscript that will be reviewed by SGF forecasters. The plan is to have the manuscript ready for submission at the end of September.

SGF forecasters suggested products that might assist forecasters in decision support for ice events. The products are currently being developed in GIS format by SLU researchers and will be provided to SGF forecasters for evaluation over the next several months.

The SLU researchers included Charles Graves, Kris Sanders, and Chad Gravelle. The SGF forecasters directly involved with this project included John Gagan, Jason Schaumann, Andy Foster, Gene Hatch and Megan Terry.

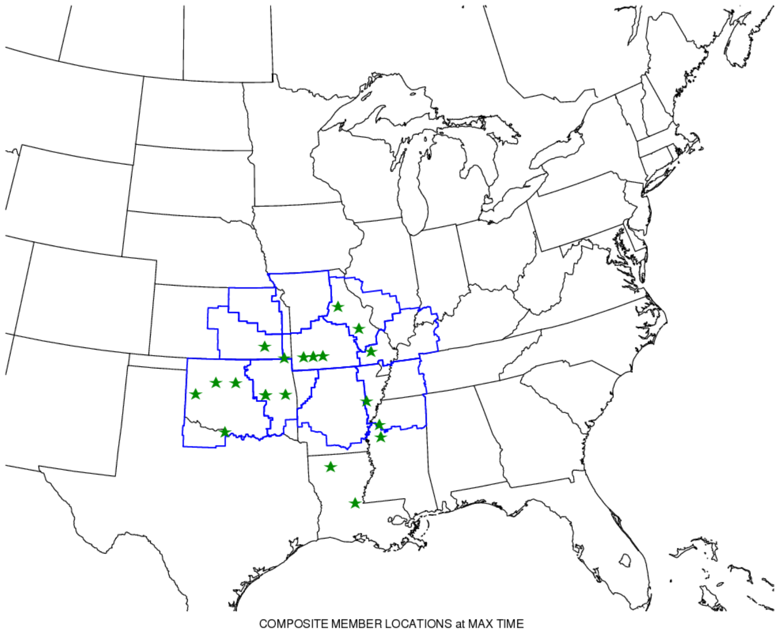

Figure 1: Center composite locations for all 20 ice storms.

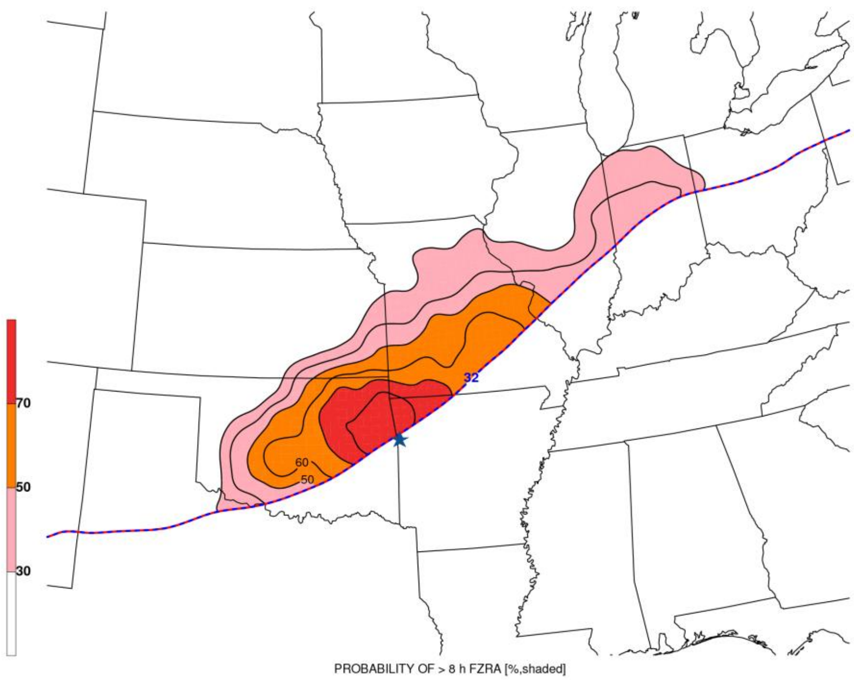

Figure 2: Probability of 8 or more hours of FZRA reports.

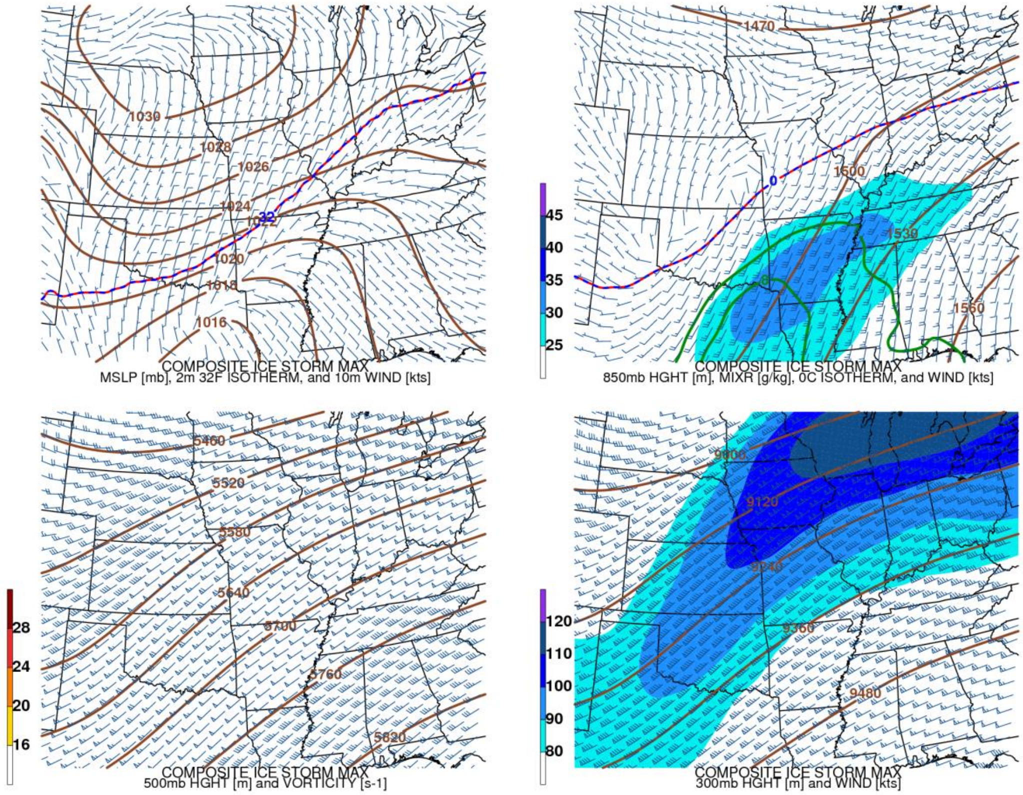

Figure 3: Composite of standard mass fields at the time of the maximum number of FZRA reports. Upper left is the surface, upper right is at 850 hPa, lower left is at 500 hPa, and the lower right is at 300 hPa.

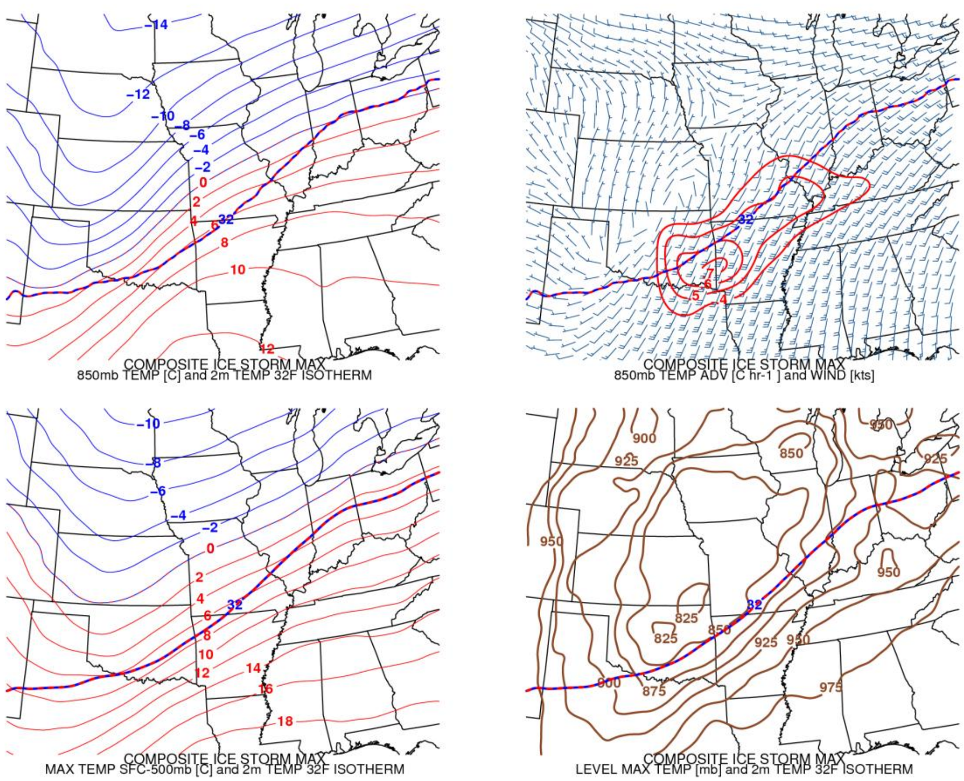

Figure 4: Composite thermodynamic fields. The upper left is the 850 hPa temperature, the upper right is the 850 hPa temperature advection, the lower left is the maximum temperature in the surface to 500 hPa layer, and the lower right is the level of the maximum temperature found to the left.

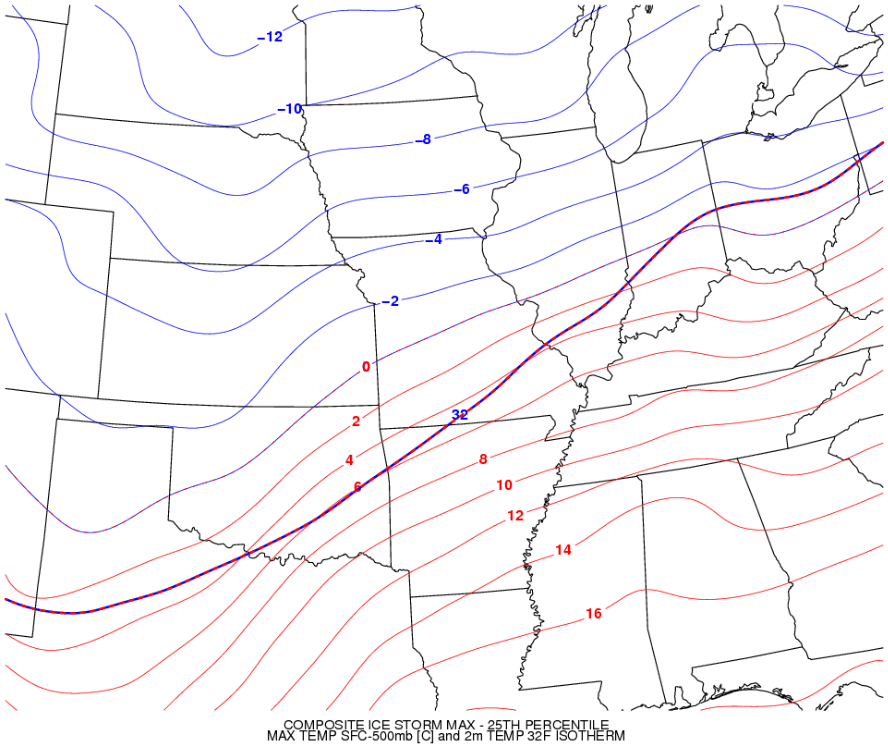

Figure 5: The 25th percentile for the maximum temperature in the elevated warm layer. That is, 75% of all the cases had a maximum temperature equal to or greater than this value.

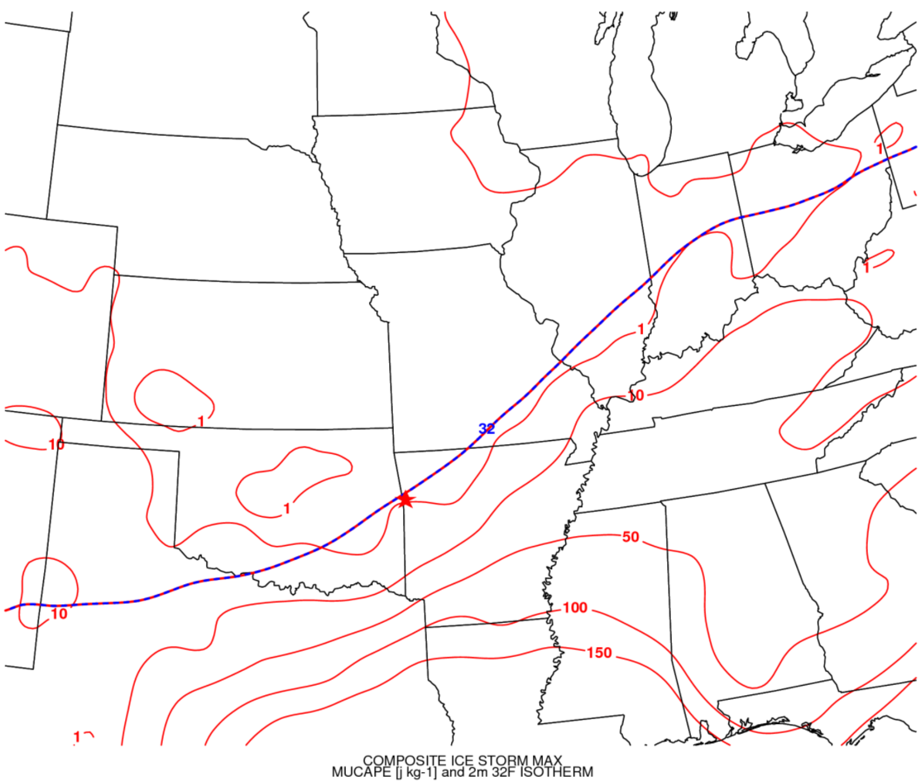

Figure 6: Composite most-unstable CAPE (J/kg)

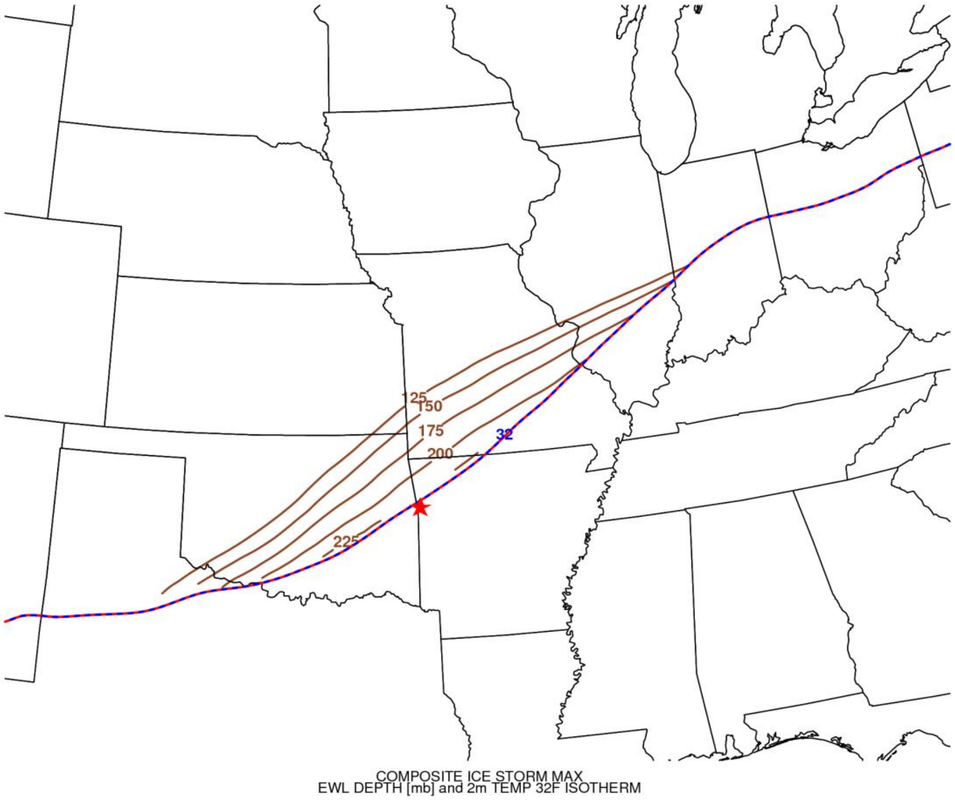

Figure 7: Composite depth of the elevated warm layer in hPa

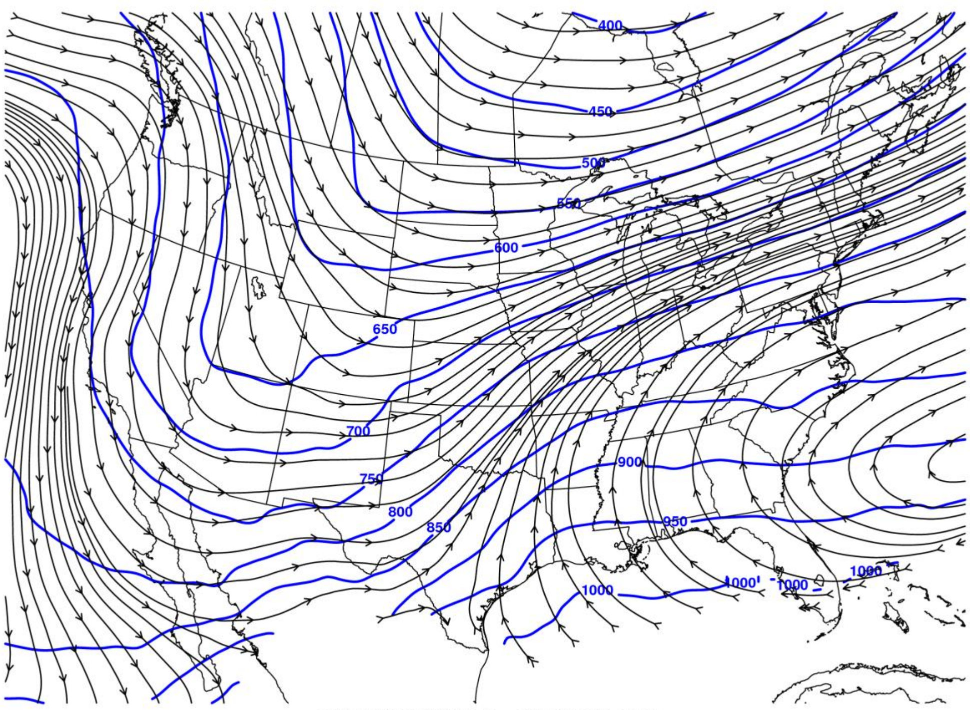

Figure 8: Composite streamlines and pressure (hPa) on the 294 K surface.

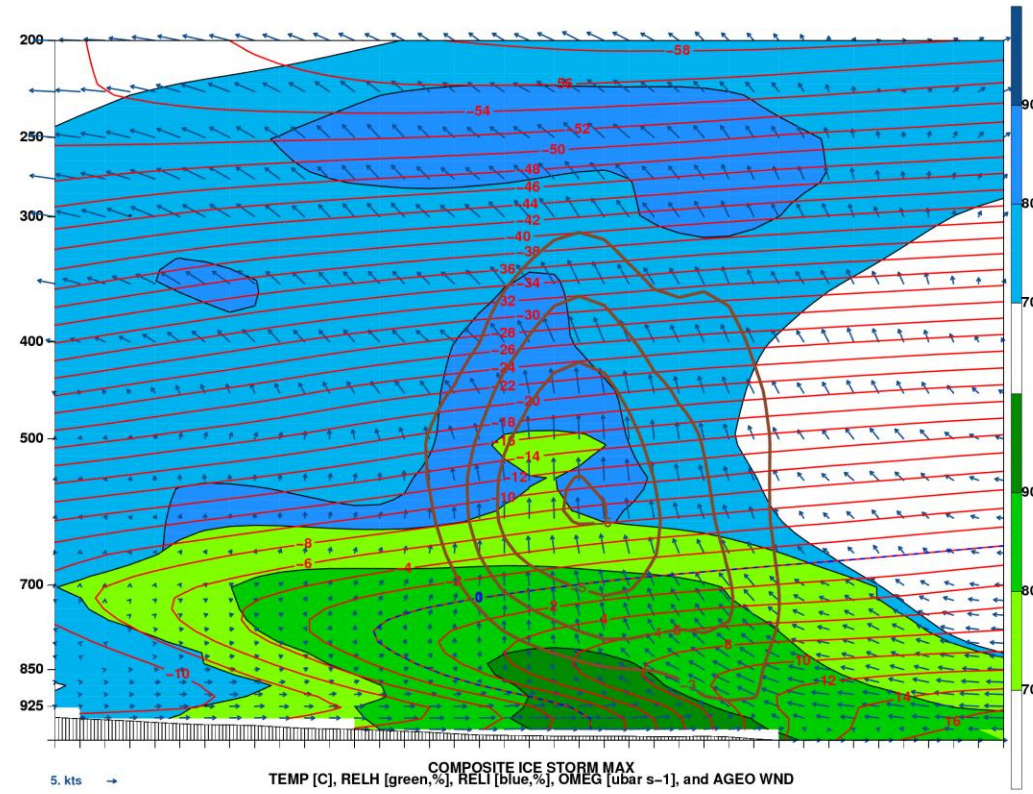

Figure 9: Cross section perpendicular to the thermal gradient. Shown are temperatures in C, Relative humidity with respect to water shaded in green and relative humidity with respect to ice shaded in blue.

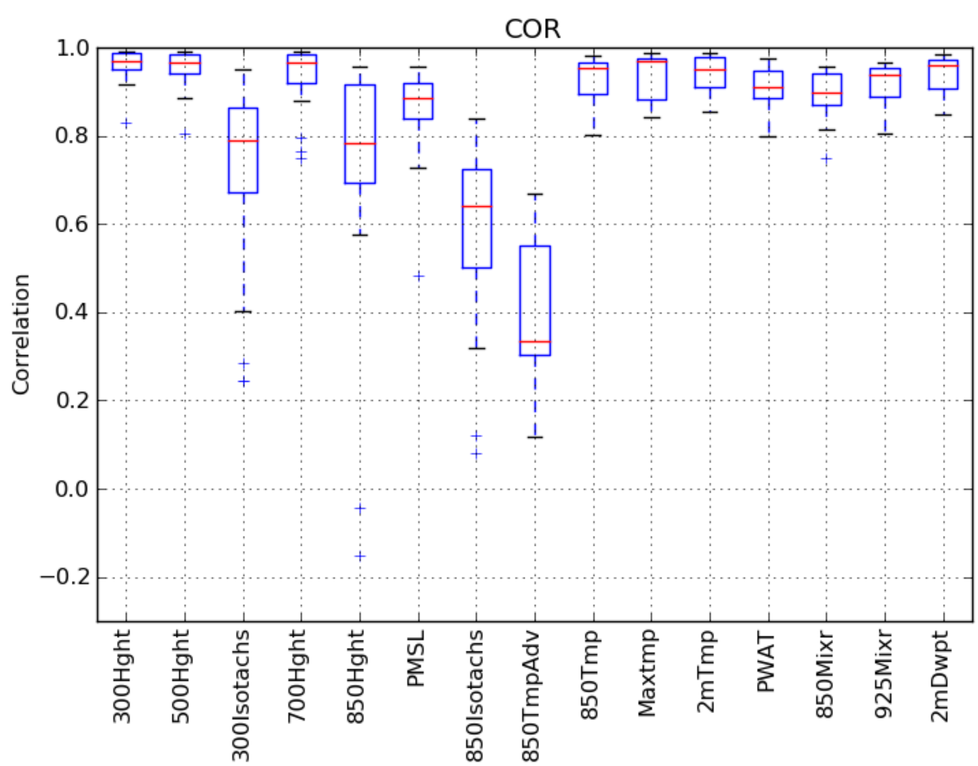

Figure 10: Box and whisker plot depicting the correlations of the composite fields with each individual member. The fields are labeled on the horizontal axis.