Composite Analysis of Major Ice Storms in the Central United States

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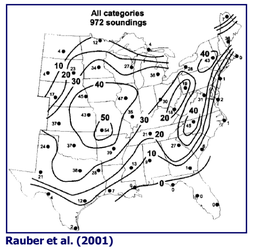
Introduction

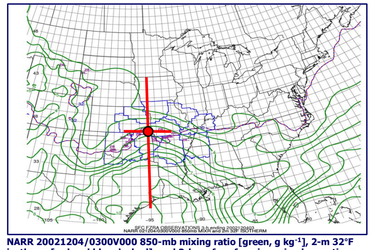
- Branick (1997) found that during a 13-year period, 12% of all winter weather events that occurred in the continental United States qualified as an ice storm (based on the National Weather Service criteria of either structural damage or ice accumulations of at least 0.25").
- Ice storms, while relatively rare, are capable of posing a significant forecast challenge due to limited research on these events and their associated environments.
- One approach is to examine the climatology of ice storms and their environmental conditions to provide situational awareness for forecasters.
- Previous research such as Beebe (1956), Glass et al. (1995), Bierly and Winkler (2001), Moore et al. (2003), Thomas and Martin (2007), and Novak et al. (2010) have shown the effectiveness of a composite analysis approach to diagnose the robust synoptic and mesoscale signals associated with certain weather events.
- In this presentation, ice storms that affected the Central United States over a 31-year period are analyzed using composite fields to illustrate the evolution of common features.



Rauber et al. (2001)

Methodology

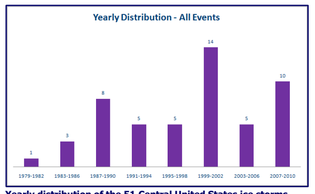
- The Cold Region Research Engineering Laboratory (CRREL) Ice Storm Database, Storm Data from the National Climate Data Center (NCDC), and NWS office event archives were examined for ice storms between January 1979 and March 2010 (October – March).
- This analysis revealed 51 ice storms containing maximum ice accumulations ≥0.25" in a domain containing the County Warning Areas (CWA) of SGF, TOP, EAX, LSX, ICT, PAH, OUN, TSA, LZK, and MEG.
- Of the 51 ice storms, 37 had maximum ice accumulations ≥0.75" (major), and of those 37 events, 24 had a southwest-northeast 2-m 32°F isotherm orientation at the ice storm start time.
- Ultimately, these 20 major ice storms were used in the composite analysis (4 events were considered outliers – FZRA within the TROWAL structure of a mid-latitude cyclone).



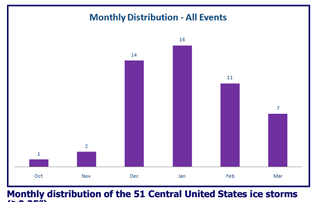
NARR 20021204/0300V000 850-mb mixing ratio [green, g kg^{-1}], 2-m 32°F isotherm [red and blue dashed], and 3-h surface freezing rain observations [purple]. The intersection of the low-level moisture axis and 2-m 32°F isotherm is indicated by the red cross hair and the CWA-centric domain is in blue.

- An ice storm start time was defined as the hour at which 2 or more FZRA surface observations occurred within the domain, a maximum coverage time was defined as the first hour at which the maximum number of FZRA surface observations occurred within the domain, and an end time was defined as the hour at which no FZRA surface observations remained within the domain.
- Using the General Meteorological Package (GEMPAK) with the North American Regional Reanalysis (NARR), system-relative composites were generated using software developed by Saint Louis University.
- The intersection of the low-level moisture axis (based on 850-mb mixing ratio field) and the 2-m 32°F isotherm were determined for each ice storm at the start, maximum coverage, and end times. These locations were used to create system-relative composites to analyze each stage of a typical Central United States ice storm.
- Finally, the average latitude and longitude positions of the low-level moisture axis and the 2-m 32°F isotherm at each stage were used to display the resulting composite fields in a geographical framework.

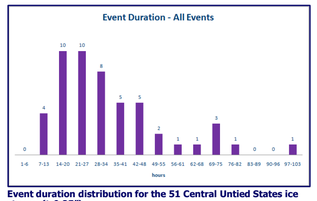
Characteristics of Ice Storms (≥0.25") in the Central United States



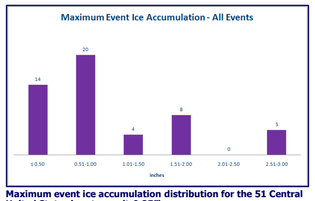
Yearly distribution of the 51 Central United States ice storms (≥0.25").



Monthly distribution of the 51 Central United States ice storms (≥0.25").



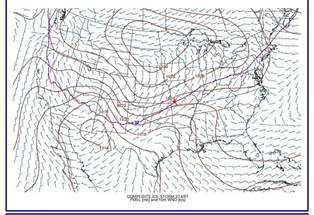
Event duration distribution for the 51 Central Untied States ice storms (≥0.25").



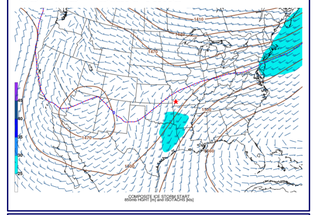
Maximum event ice accumulation distribution for the 51 Central United States ice storms (≥0.25").

Synoptic-Scale Composites

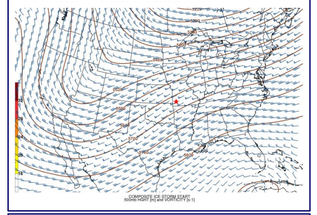
SFC – Start Time



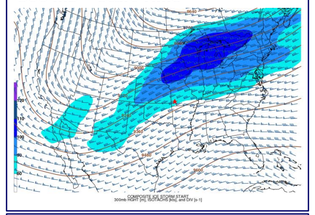
850 mb – Start Time



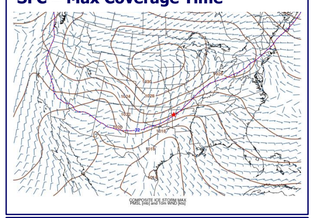
500 mb – Start Time



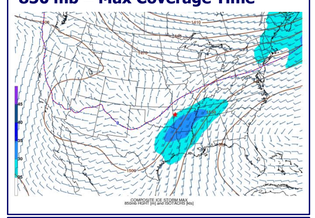
300 mb – Start Time



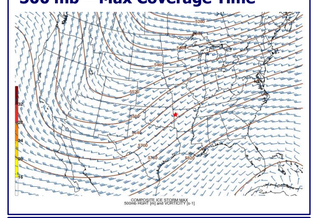
SFC – Max Coverage Time



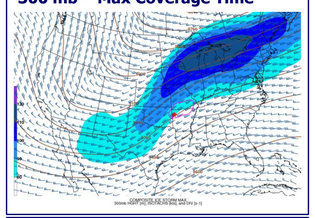
850 mb – Max Coverage Time



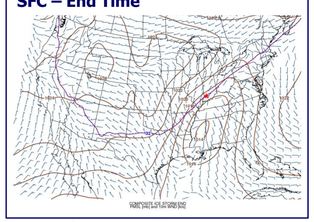
500 mb – Max Coverage Time



300 mb – Max Coverage Time

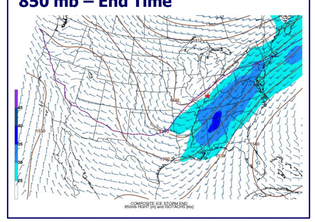


SFC – End Time



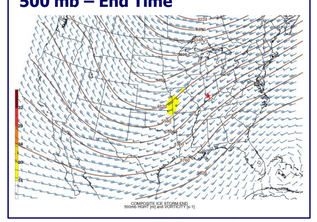
Mean composite analysis of NARR sea-level pressure [brown, mb], 2-m 32°F isotherm [red and blue dashed], and 10-m wind [barbs, kts] at the start, maximum coverage, and end times (from top to bottom). The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.

850 mb – End Time



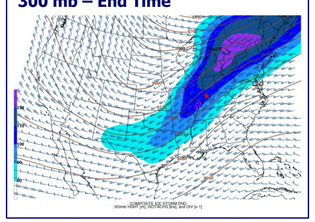
Mean composite analysis of NARR 850-mb height [brown, m], 0°C isotherm [red and blue dashed], isotachs [shaded, kts], and wind [barbs, kts] at the start, maximum coverage, and end times (from top to bottom). The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.

500 mb – End Time



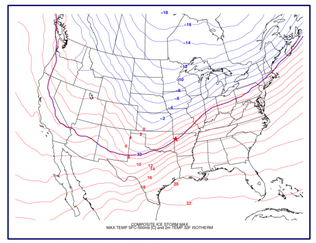
Mean composite analysis of NARR 500-mb height [brown, m], absolute vorticity [shaded, s^{-1}],wind [barbs, kts] at the start, maximum coverage, and end times (from top to bottom). The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.

300 mb – End Time

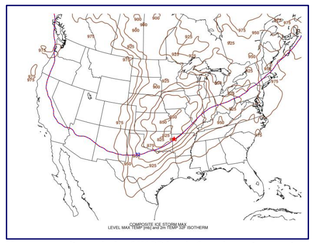


Mean composite analysis of NARR 300-mb height [brown, m], isotachs [shaded, kts), divergence [pink, 10^{-5} s^{-1}], and wind [barbs, kts] at the start, maximum coverage, and end times (from top to bottom). The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.

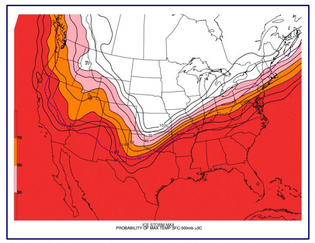
Temperature, Moisture, and Isentropic Composites at Maximum Coverage Time



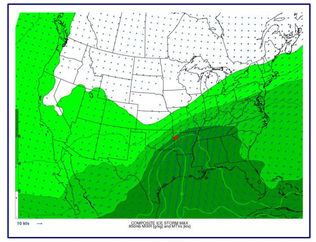
Mean composite analysis of NARR maximum temperature between surface and 500mb [solid, C] and 2-m 32°F isotherm [red and blue dashed] at the maximum coverage time. The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.



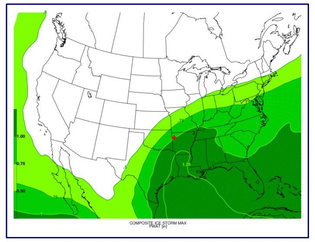
Mean composite analysis of NARR level of maximum temperature between surface and 500 mb [brown, mb] and 2-m 32°F isotherm [red and blue dashed] at the maximum coverage time. The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.



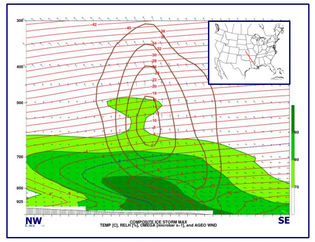
Probability of composite members' NARR maximum temperature >3°C between surface and 500mb [shaded, percent] and 2-m 32°F isotherm [red and blue dashed] at the maximum coverage time.



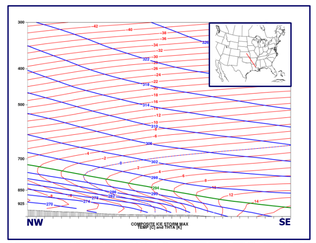
Mean composite analysis of NARR 850-mb mixing ratio [shaded, g kg^{-1}] and moisture transport vectors [arrows, kts] at the maximum coverage time. The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.



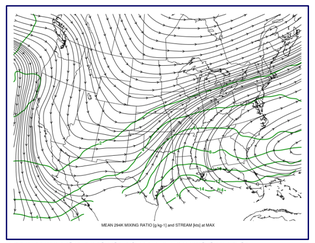
Mean composite analysis of NARR precipitable water [shaded, in] at the maximum coverage time. The red star indicates the average position of the low-level moisture axis and 2-m 32°F isotherm intersection for the composite members.



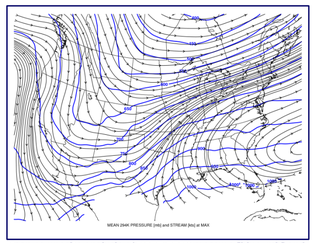
Mean composite analysis of NARR temperature [red, C], relative humidity [shaded, percent], omega [brown, μbar^{-1}], and ageostrophic wind [arrows, m s^{-1}] at the maximum coverage time. Inset figure provides the orientation of the cross section.



Mean composite analysis of NARR temperature [red, C] and theta [blue, K] at the maximum coverage time. Inset figure provides the orientation of the cross section.



Mean composite analysis of NARR 294K mixing ratio [green, g kg^{-1}] and streamlines [black, kts] at the maximum coverage time.



Mean composite analysis of NARR 294K pressure [blue, mb] and streamlines [black, kts] at the maximum coverage time.

Conclusions

- Common synoptic-scale features include: a dome of high pressure to the north, veering flow with height in the vicinity of a prominent thermal boundary, and an upper-level jet streak anchored in the Great Lake region providing support for upward vertical motion.
- A thermal profile just behind the sub-freezing surface conditions depicts a 200-mb warm layer (i.e., 4-6°C) centered at 850 mb capable of melting ice crystals. Furthermore, a warm layer that exceeded 3°C was present in 70% (14 of 20) of all cases.
- Isentropic analysis shows air parcels originating near the Gulf of Mexico that ascend while traveling north provided substantial heat and moisture above the frontal zone.

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