A climatology of storm reports as a function of convective morphology in the central U.S.

Jeffrey D. Duda
William A. Gallus, Jr.

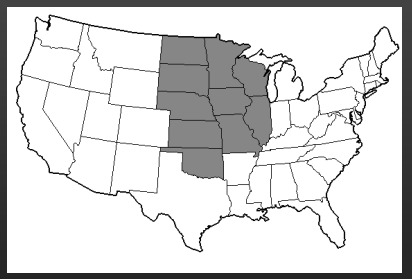
Dept. Of Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

Outline

- Background
- Methodology/Data Sources
- Results
- Discussion and Conclusions

Background

- Expansion of Gallus Jr., W. A., N. A. Snook, and E. V. Johnson, 2008: Spring and summer severe weather reports over the Midwest as a function of convective mode: A preliminary study.
  - Recently published in *Weather and Forecasting* (Feb. 08)
- Severe weather reports associated with convective systems classified according to morphology
- Ten-state domain: IL, IA, KS, MN, MO, NE, ND, OK, SD, WI
- 1 April 2002 – 31 August 2002
- Results of Gallus et al. (2008) (hereafter, G08) compared alongside those of this study
- No studies consider supercells as a morphology
  - Are considered in this study

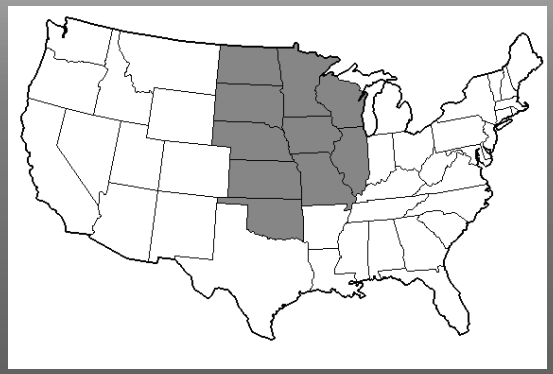


(Used with permission from G08)

Hypotheses

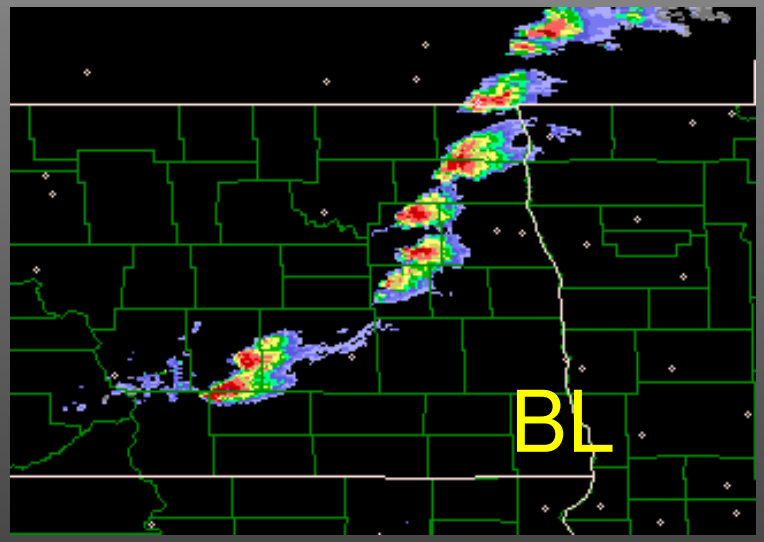
- (1): The trends exhibited by the convective systems in G08 will also be exhibited by those in the 2007 data set
- (2): Supercell systems will produce more violent and more frequent severe weather

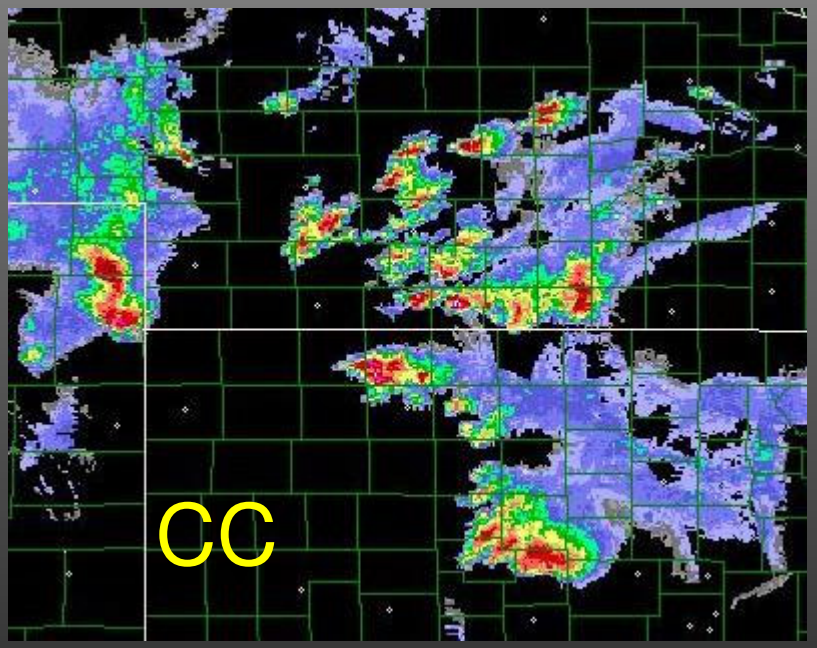
Methodology

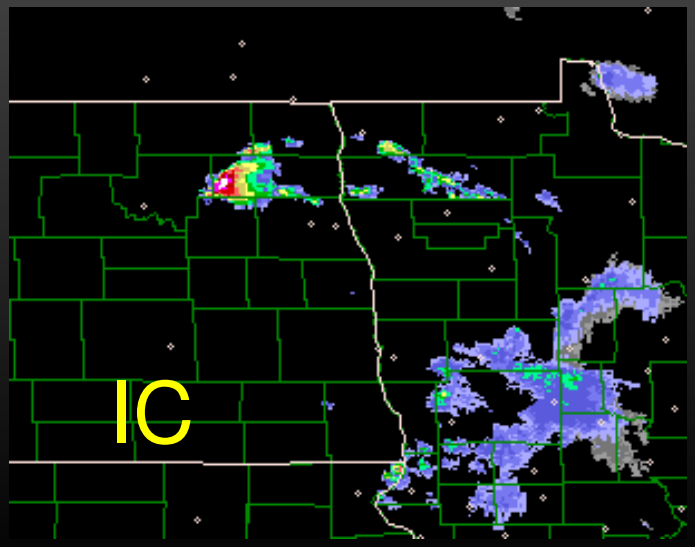


- Same/similar to that of G08:
  - Same ten-state region
  - Similar time period (01 April 2007 – 31 August 2007)
  - Nine morphologies used (pictorial examples to follow):
    - Three cellular: isolated cells (IC), clusters of cells (CC), broken lines of cells (BL)
    - Five linear: squall lines with no stratiform precipitation (NS), trailing stratiform precipitation (TS), parallel stratiform precipitation (PS), leading stratiform precipitation (LS), bow echoes (BE)
    - Non-linear convective systems (NL)
  - Supercell morphologies: only cellular considered
    - IC – supercell, CC – supercell, BL – supercell

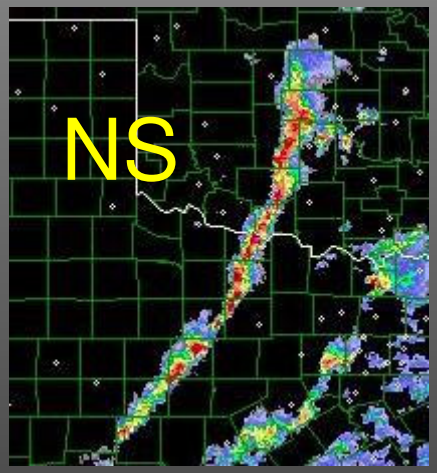
Cellular examples

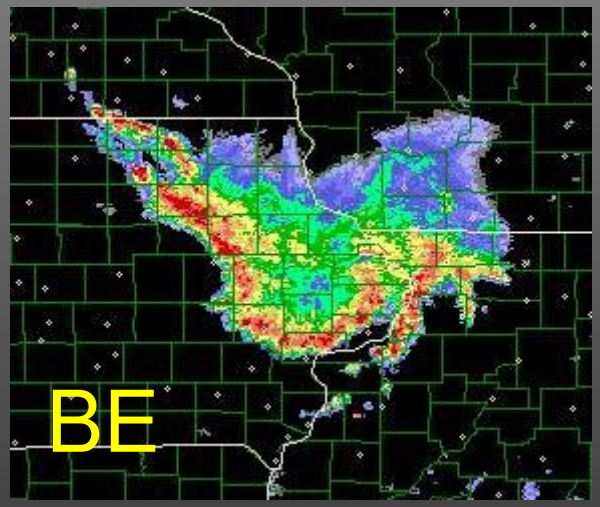


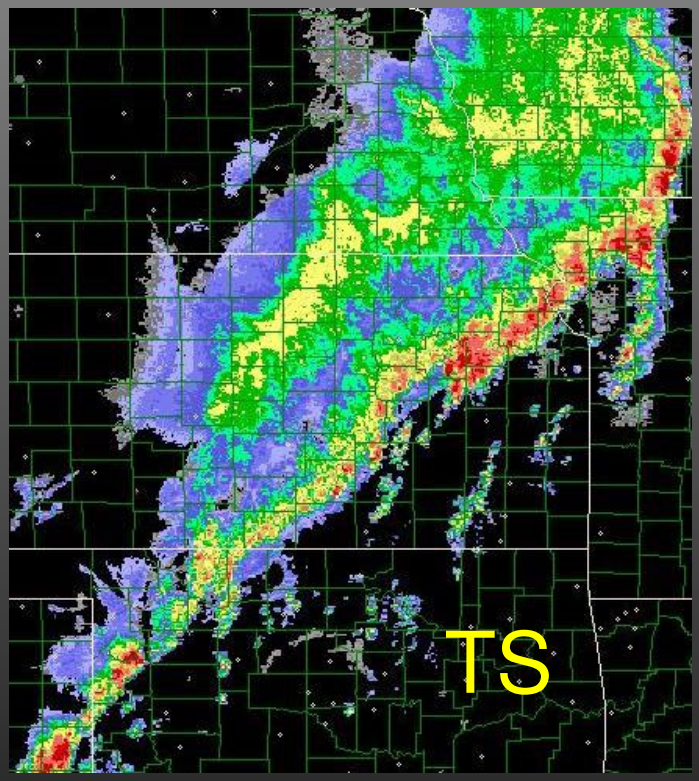


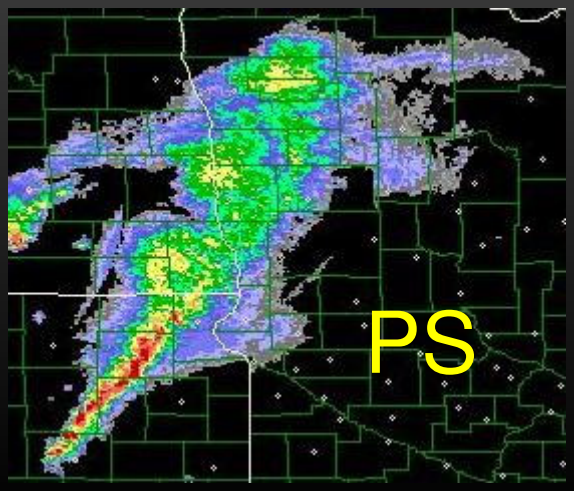


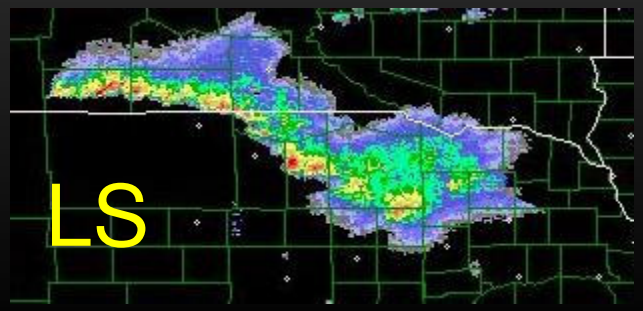
Linear examples



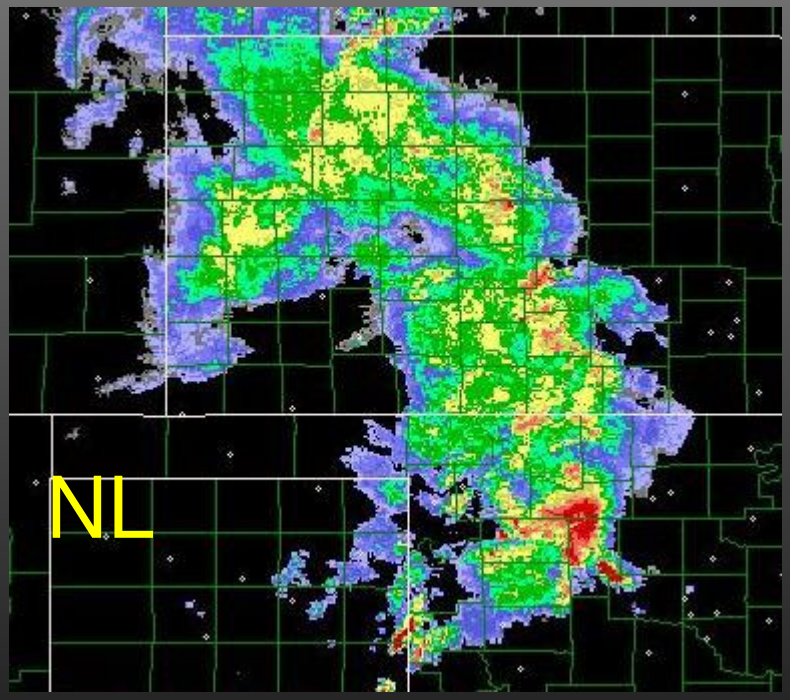








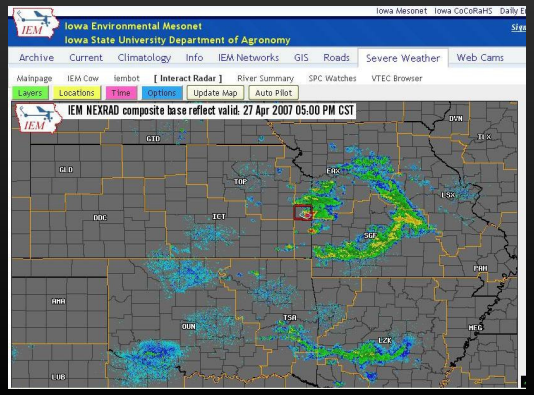
Non-linear example



Radar Data Sources

- UCAR warm season archive (http://locust.mmm.ucar.edu/case-selection)
  - Offers images and animations of archived radar data with 30 minute temporal and 2 km by 2 km spatial resolution

- Supplemented by interactive radar feature on IEM for periods when data from UCAR archive was unavailable
  - All aspects could be matched except for spatial resolution (not an issue)



Radar Methodology

- Systems had to meet basic intensity, coverage, and temporal requirements to be classified
- Systems classified according to dominant morphology
  - short-lived or chaotic changes don't affect morphology
- All severe reports from a given system associated with dominant morphology
  - Morphing to other morphologies allowed as long as radar requirements met
- Note: about 5% of systems very difficult to classify (rapid evolution or resemblance to other disparate morphologies (TL/AS?))

Note on severe reports

- Severity of systems quantified by separating reports into categories as follows:
  - Hail
    - Min. severe criteria (i.e., 3/4” ≤ Hail < 1”)
    - 1” ≤ Hail < 2”
    - Hail ≥ 2”
  - Wind
    - Min. severe criteria (i.e., 50 kt ≤ Wind < 65 kt)
    - Wind ≥ 65 kts
  - Flooding
    - Flood
    - Flash flood
  - Tornadoes (by EF-scale rating)

Supercell Data Sources

- Level III storm attribute data table
  - Indicates levels of rotation indicated by MDA and TDA for given Cell ID and location (GR3)
- Level III NEXRAD mesocyclone product from NCDC
  - Need Java Data Viewer supplied by NCDC to visualize

Supercell Methodology

- Only cellular morphologies considered
  - Embedded supercells in non-cellular morphologies not included to keep focus on morphologies and not individual convective events
- Cellular element of system must have met rotation strength and temporal requirements according to MDA
- TDA not used (looks for smaller scale, transient rotations)

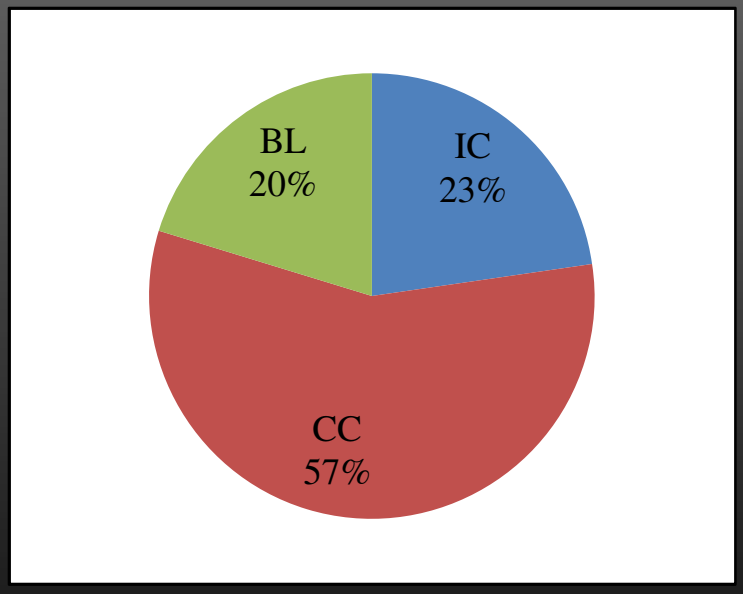
Overall Results

Data Set	Number of systems classified	Number (and %) that produced severe weather	Number (and %) that produced non-flooding severe weather	Total Number of severe reports	Number of non-flooding severe reports
2002*	949	671 (71%)	623 (66%)	10800	9678
2007*	909	553 (61%)	493 (54%)	9253	7642

**G08 used 2002 data; this study used 2007 data. This is how the two studies will be labeled in all tables and figures.*

Overall supercell component

- 207 supercell systems (23% of all)
  - All but 19 produced severe weather
- 118 CC
- 47 IC
- 42 BL

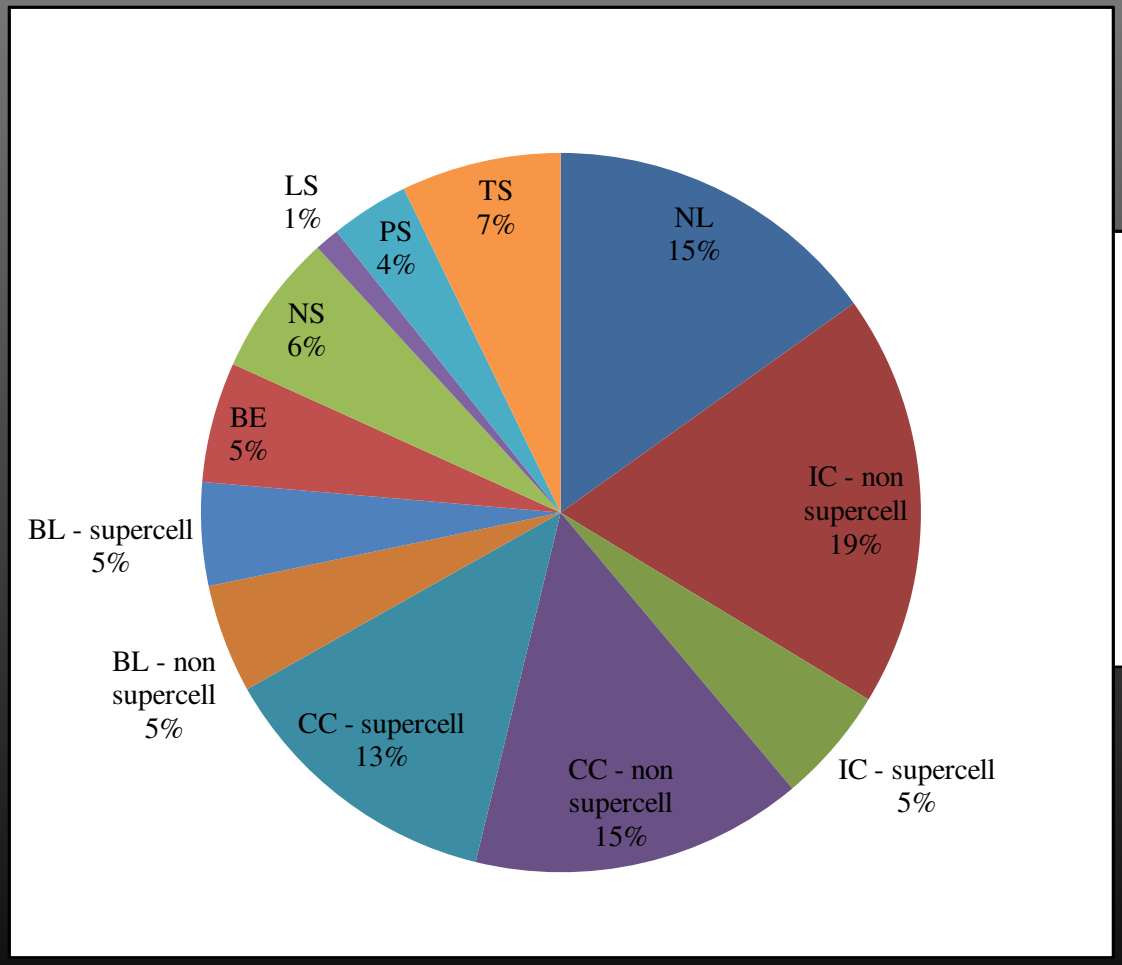


- Note: for four systems, not enough data to classify as supercellular or non-supercellular
  - (only two produced severe weather – 4 reports)

Morphological breakdown

For all systems

2007 data set

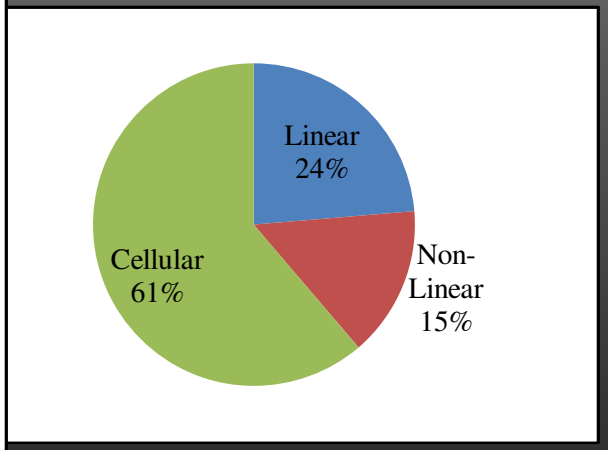


Most common

1: IC – non-supercell

2: NL

3: CC – supercell

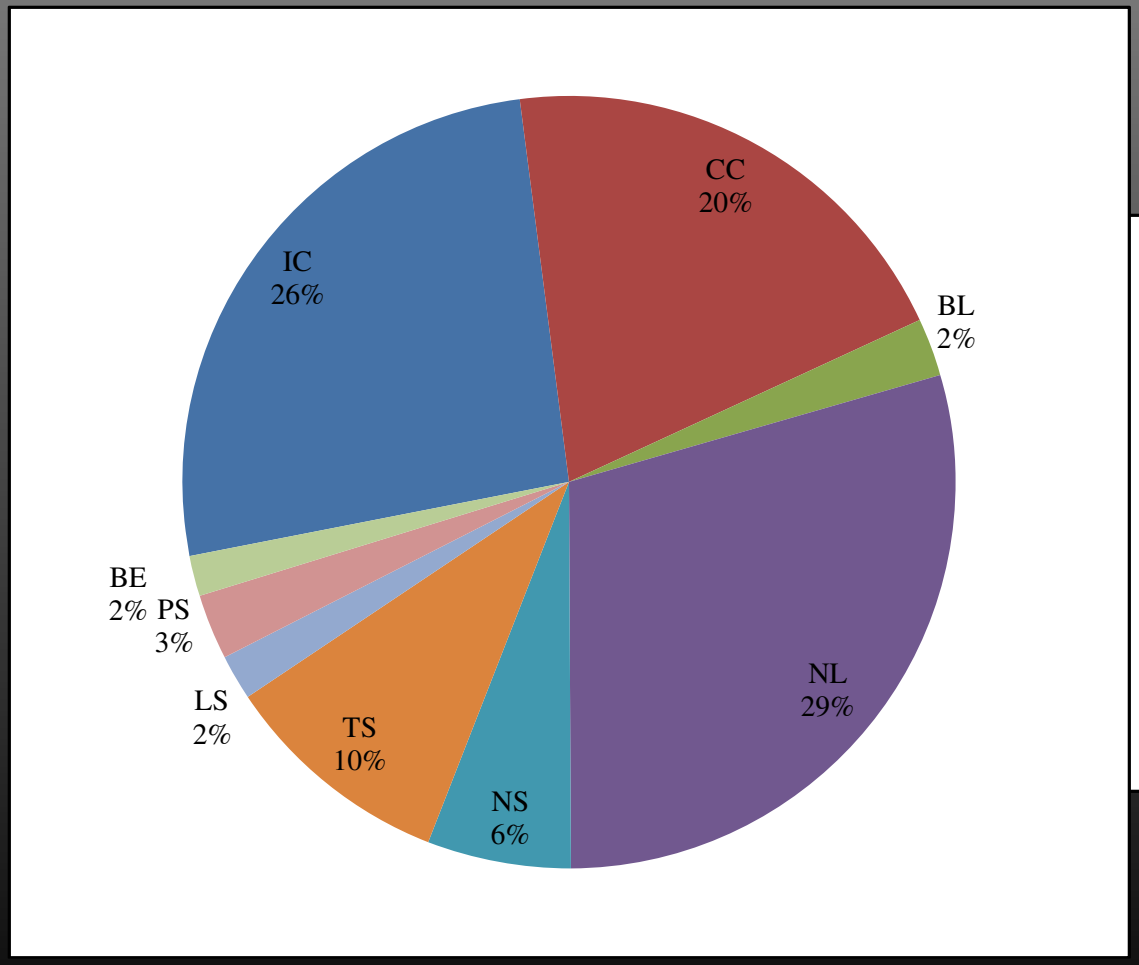


37% of cellular events supercellular

Morphological breakdown

For all systems

2002 data set

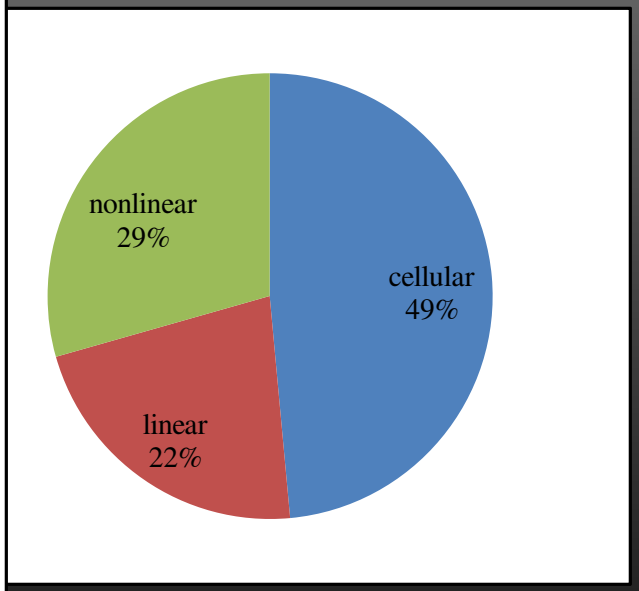


Most common

1: NL

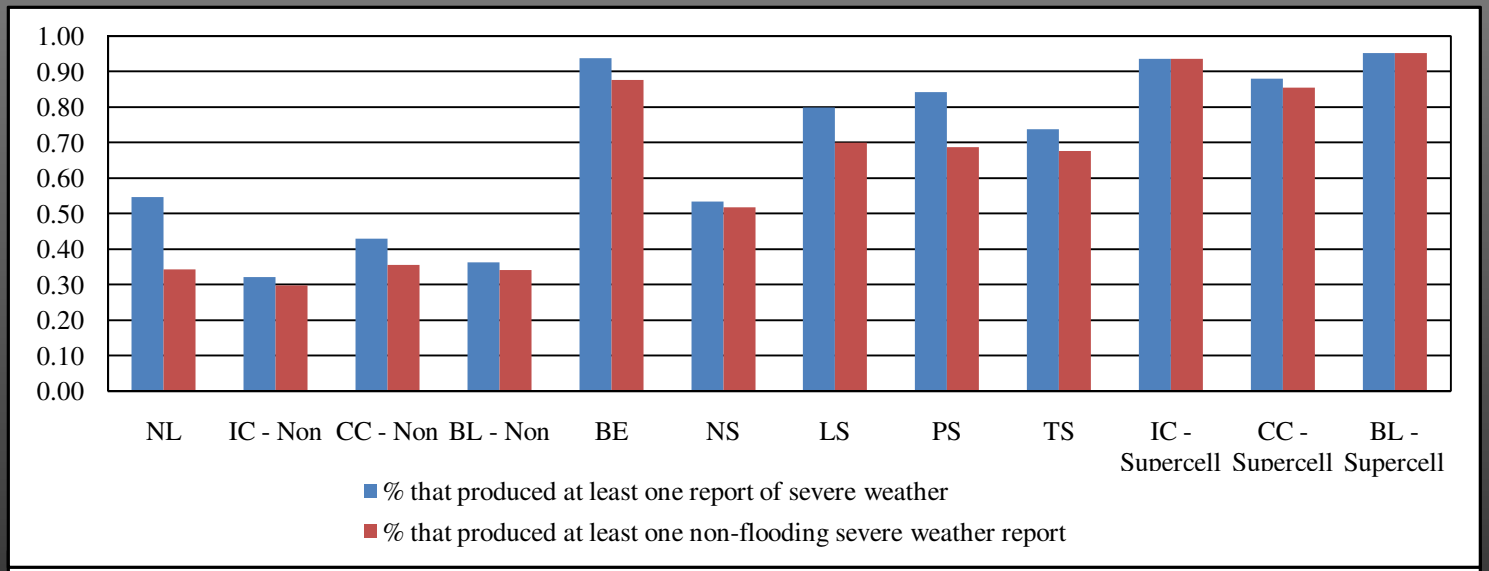
2: IC

3: CC

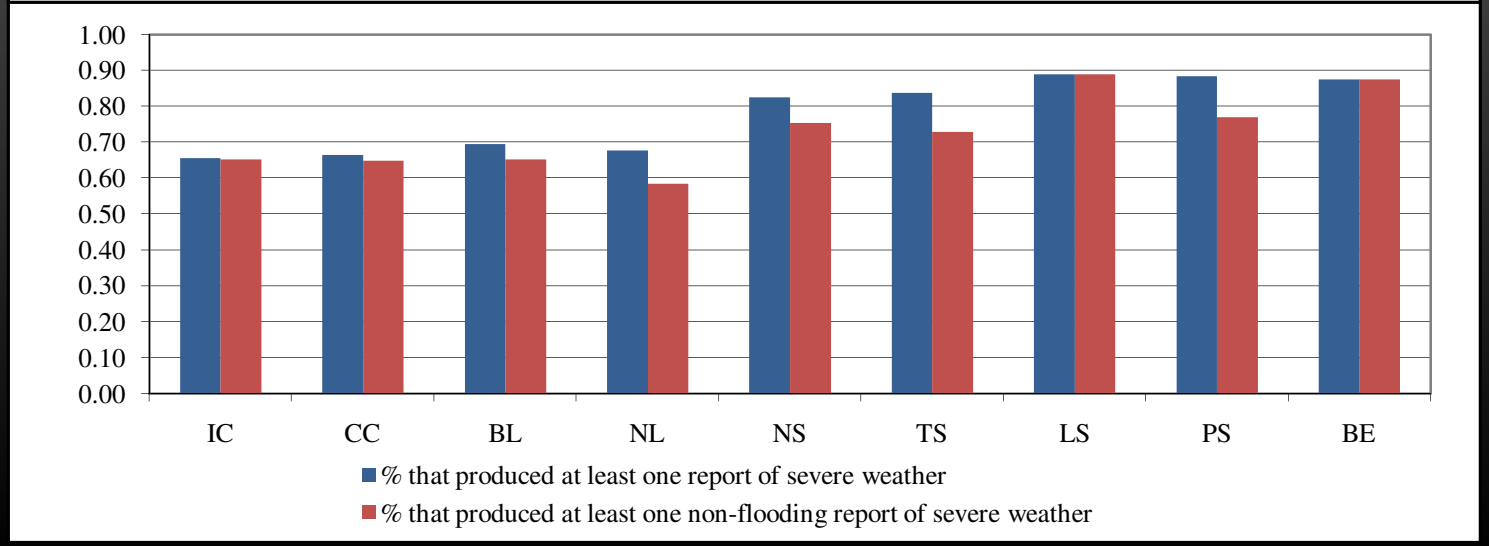


Frequency of severe weather production

2007



2002



Total number of reports

Results from G08 are shown in parentheses

Severe weather category	Most productive	Second most productive	Least productive
Tornadoes	CC – supercell (IC)	BL – supercell (CC)	LS (BE)
Hail	CC – supercell (CC)	BL – supercell (IC)	LS (LS)
Wind	BE (TS)	CC – supercell (NL)	LS (LS)
Flooding	NL (NL)	TS (TS)	LS (LS)
Total Reports	CC – supercell (CC)	BL – supercell (NL)	LS (LS)

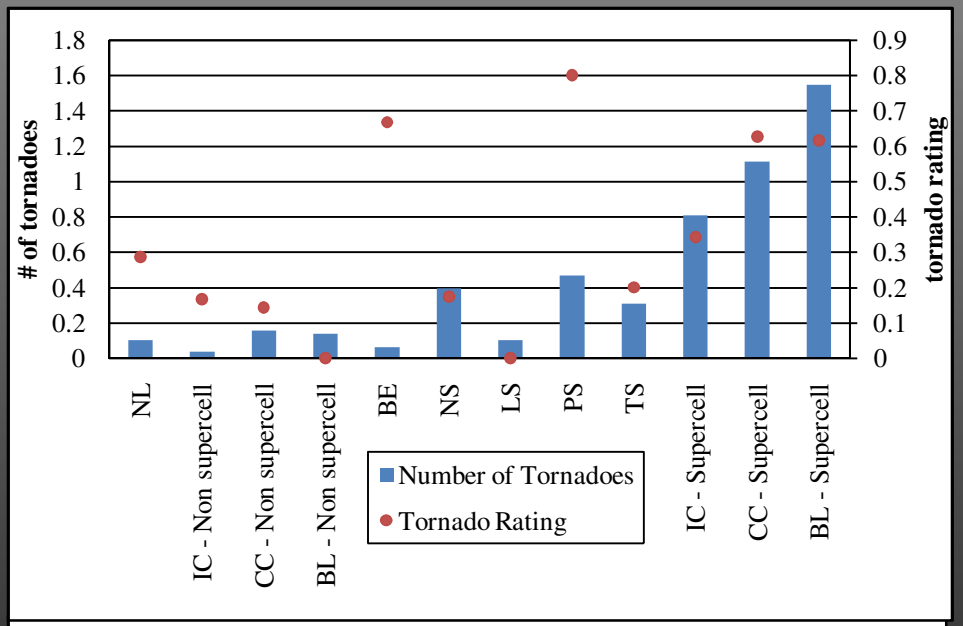
Averages per system

Tornadoes

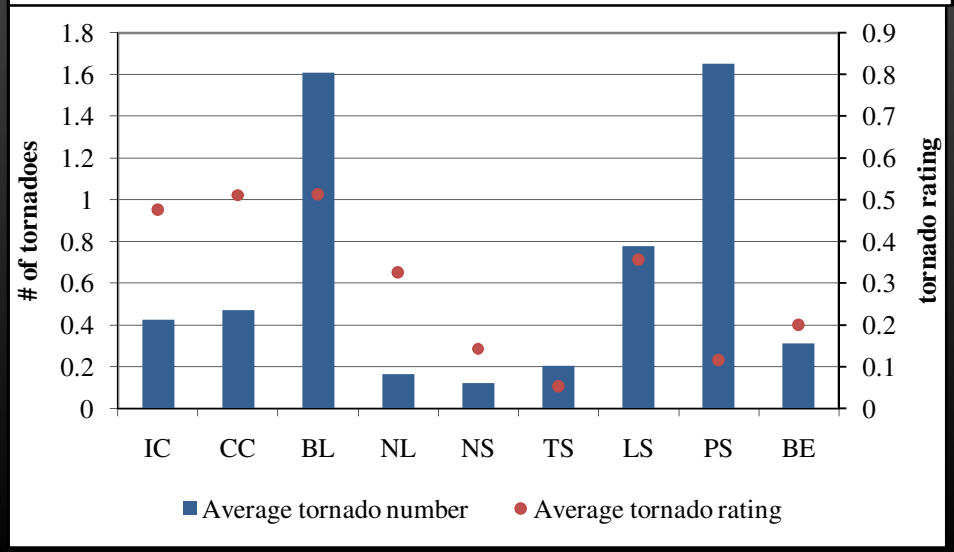
2007

Data set	Number of tornadoes	Tornado rating
2007	BL – supercell (1.55)	PS (0.80)
2002	PS (1.65)	BL (0.51)

Note for the 2007 data set: PS and BE systems produced only 15 and 6 tornadoes, respectively, compared to 131 by CC – supercell systems.



2002

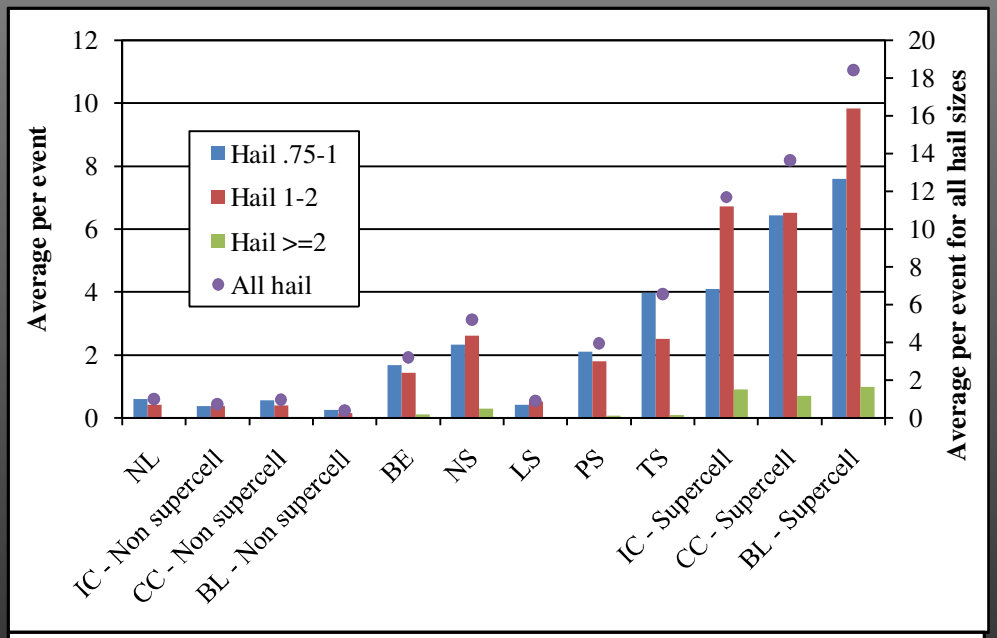


Averages per system

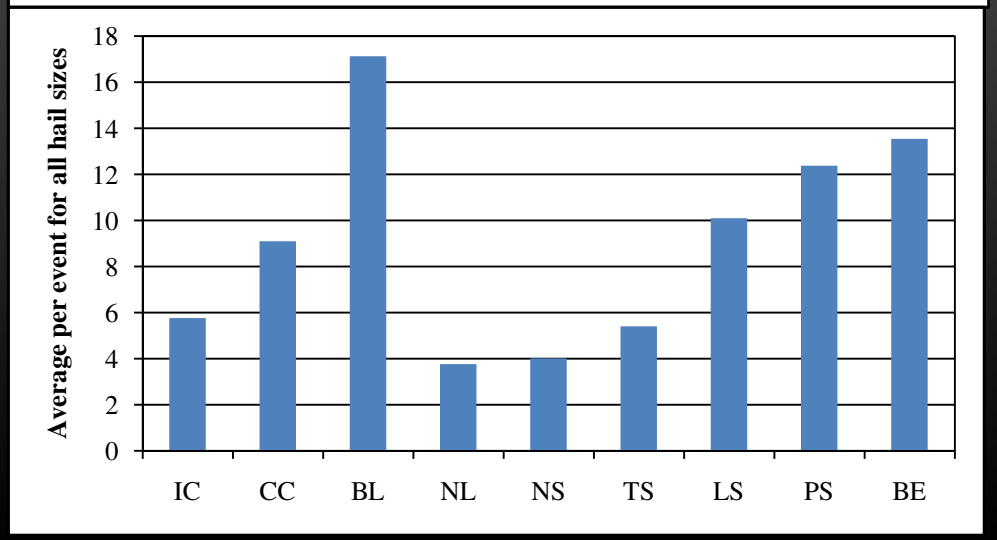
Hail

2007

Data set	2007	2002
Hail 0.75" – 1"	BL – supercell (7.60)	BE (9.88)
Hail 1" – 2"	BL – supercell (9.83)	BL (8.30)
Hail ≥ 2"	BL – supercell (0.98)	PS (0.77)
All hail	BL – supercell (18.40)	BL (17.13)



2002

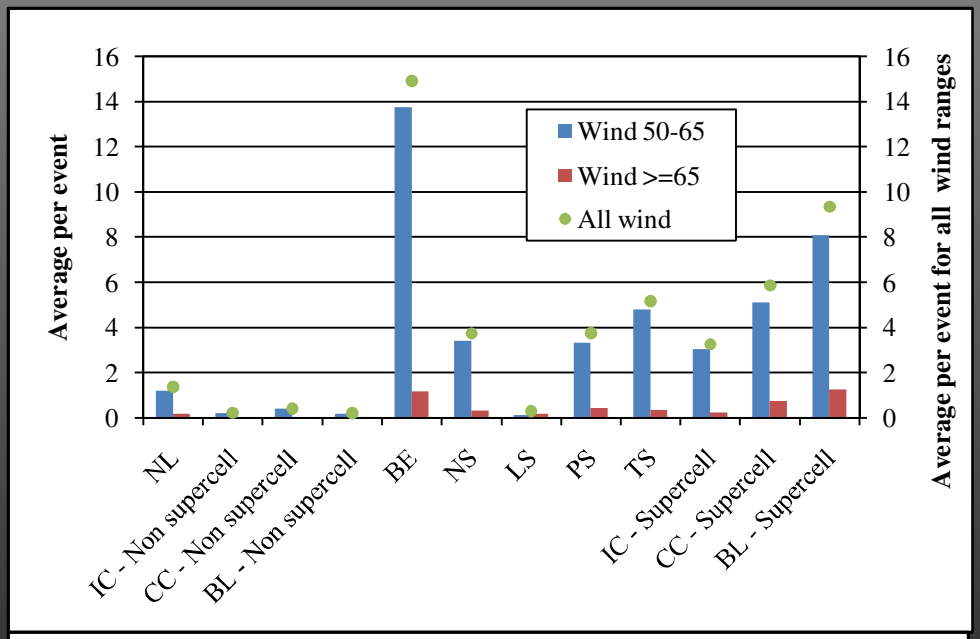


Averages per system

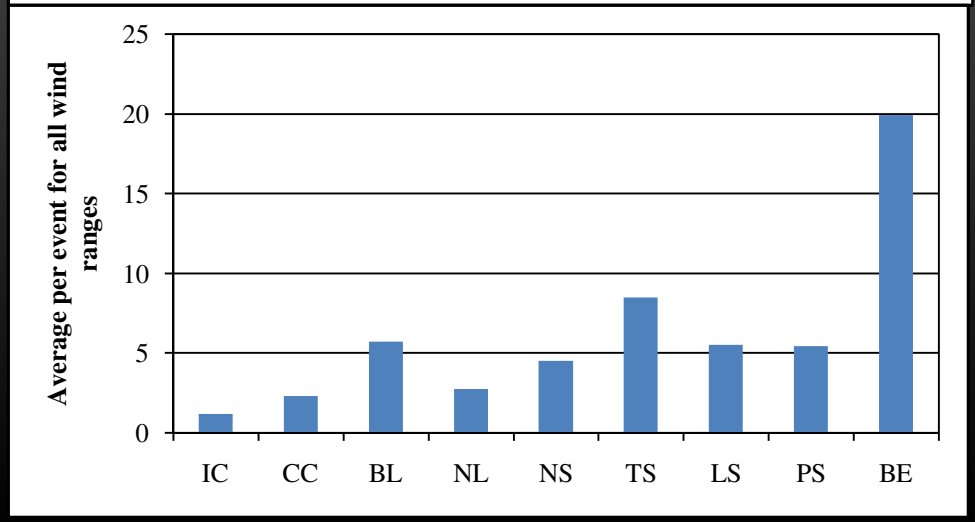
Wind

Data set	Wind 50 – 65 kts	Wind ≥ 65 kts	All Wind
2007	BE (13.76)	BL – supercell (1.57)	BE (14.94)
2002	BE (18.56)	BE (1.38)	BE (19.94)

2007



2002

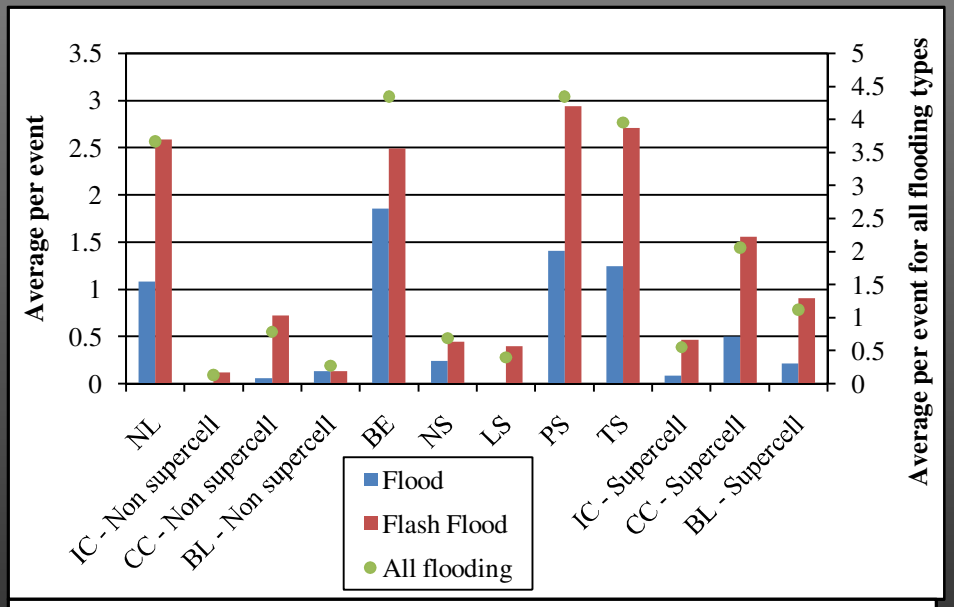


Averages per system

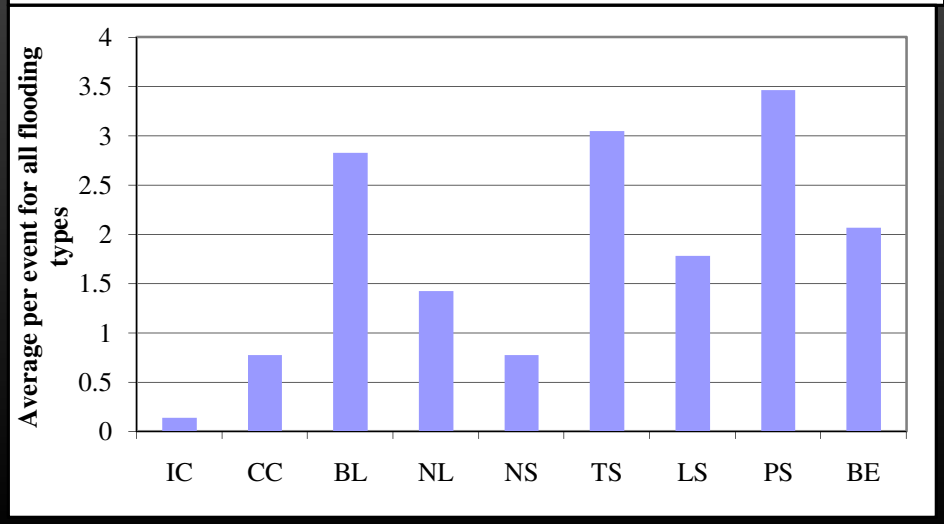
Flooding 2007

Data set	Flood	Flash flood	All flood
2007	BE (1.86)	PS (2.71)	BE (4.35)
2002	LS (0.94)	PS (2.73)	PS (3.46)*

*Note: G08 includes urban/small stream flood reports, which were not included in this study. (*StormData* no longer considers urban/small stream flooding as severe)



2002



Supercell vs. non-supercell systems

By percentages

Percentage of all		Tornadoes	Hail	Wind	Flooding	All reports
All morphologies	**Supercell**	68.2	67.2*	44.2	19.6	51.0*
	Non-supercell	31.8	32.7*	55.8	80.4	48.9*
Only cellular morphologies	**Non-supercell**	9.6	6.2	3.5	8.7	5.9

Percentage of all		All systems	Only severe systems	% that produced severe weather
All morphologies	**Supercell**	22.8*	34.0*	90.8
	Non-supercell	76.8*	65.6*	52.0
Only cellular morphologies	**Non-supercell**	38.2	23.1	36.9

*Note: percentages do not add to 100% due to 4 systems for which data was not available to determine if each contained supercells

Supercell vs. non-supercell systems

By averages

Average number of reports per system		Number of tornadoes (rating)	Hail	Wind	Flooding	All reports
All morphologies	**Supercell**	1.13 (0.56)	14.16	5.99	1.53	22.80
	Non-supercell	0.16 (0.28)	2.04	2.43	1.86	6.49
Only cellular morphologies	**Non-supercell**	0.10 (0.12)	0.78	0.29	0.40	1.57

Conclusions and discussion

- Awards:
  - "Most dangerous": BL – supercell (2007) (by tiebreaker) and BE (2002)
    - Honorable mention: CC and BE (due to frequency of occurrence and overall production of severe weather)
  - "Least dangerous": BL – non supercell (2007) and NL/NS/IC (2002)
    - (Dis?)honorable mention: LS (due to infrequent occurrence and low production)

Conclusions and discussion

- Hypothesis (1) – mostly correct
  - Common between both studies
    - NL, IC, CC (cellular) systems most common
    - CC most productive by total number of reports
    - BE, PS, and BL systems among top for production of severe weather
  - Differences between studies
    - Difference in percentage of systems that produced severe weather and number of reports that occurred
    - Nitpicky – minor differences in percentage values and average values for some categories
    - Difficult to compare LS and PS systems due to supplementation of 24 in G08

Conclusions and discussion

- Hypothesis (2) (almost completely correct)
  - Supercell systems dominated over all other systems in every aspect except flooding
    - Produced fewer reports of wind overall, but more reports per system
    - Only PS systems outperformed supercell systems in terms of average tornado rating due to small number of moderate intensity tornadoes produced
- Non-supercellular cellular systems much less productive compared to supercellular versions

Future work

- Expanding areal coverage to cover U.S.
- Expanding time to include entire year
- Addition of other morphologies like TL/AS from Schumacher and Johnson (2005)
- Inclusion of embedded supercells
  - suggest separating reports by convective elements, not just morphologies

Acknowledgements

- Nathan Snook, Elise Johnson, and especially Bill Gallus for his help dealing with the subjectivity of the study
- Daryl Herzmann for supplying storm attribute data and providing help finding data
- Robert Lee, ROC, for his advice on the definition of a mesocyclone

References

- Some images used with permission from Gallus et al. (2008); others adapted from it
- Gallus Jr., W. A., N. A. Snook, and E. V. Johnson, 2008: Spring and summer severe weather reports over the Midwest as a function of convective mode: A preliminary study. *Wea. Forecasting*, **23**, 101-113.
- Schumacher, R. S., and R. H. Johnson, 2005: Organization and environmental properties of extreme-rain-producing mesoscale convective systems. *Mon. Wea. Rev.*, **133**, 961-976.

End

Thank you for attending and listening!

Questions?