Derechos: Nature's Wall of Wind

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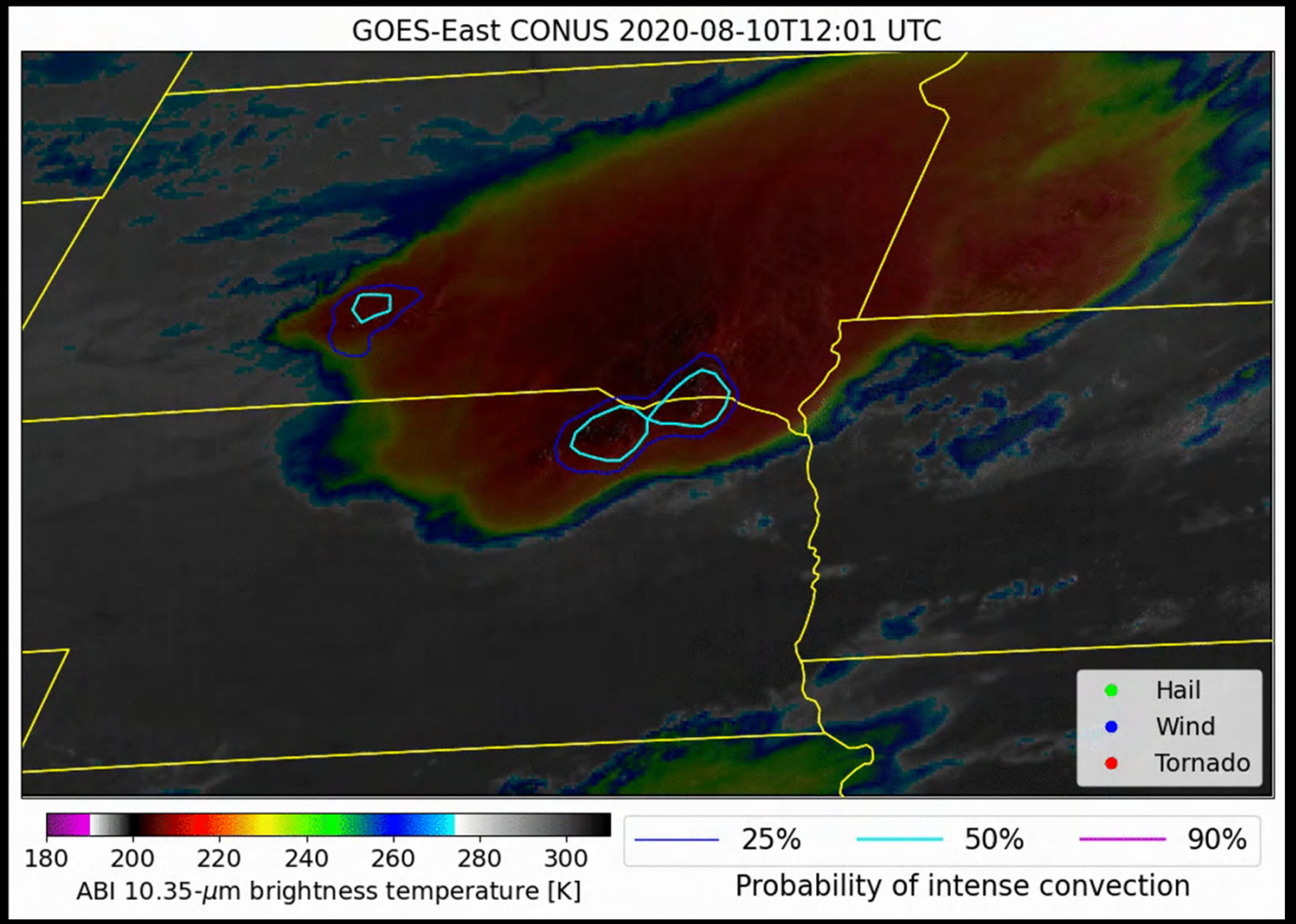
Parts of this research supported by NSF Grant ATM-1637225

Today's Discussion

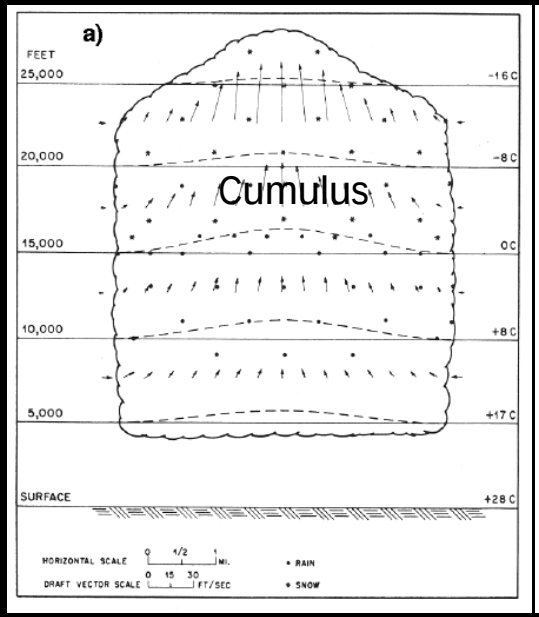
- History
- Definitions
- Types
- Climatology
- August 2020 Case
- The Future

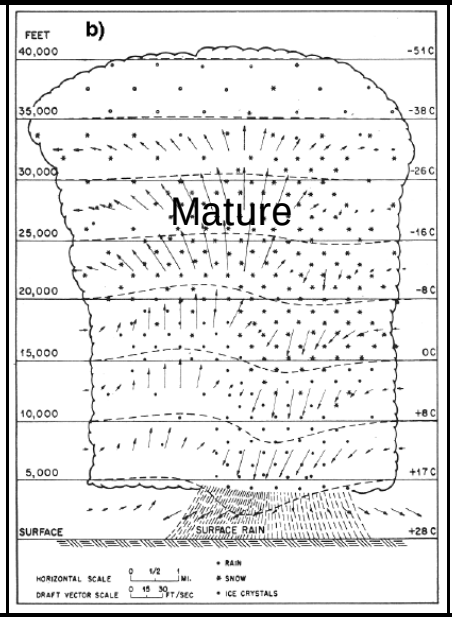


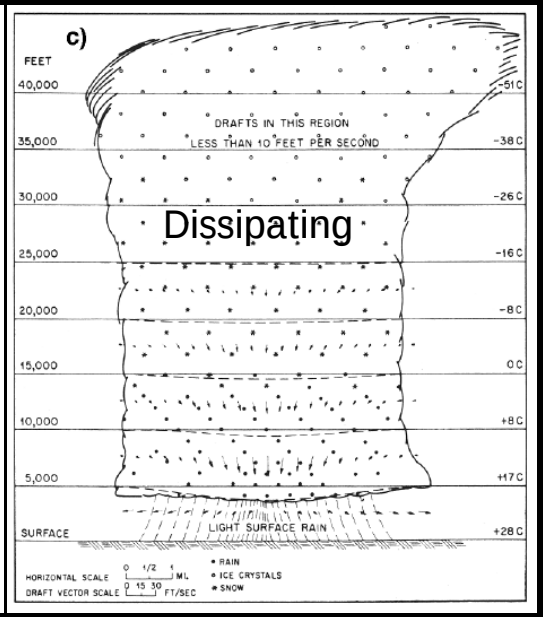
- Modern concepts of t-storms and downbursts have their origins with the post-WWII **“Thunderstorm Project”**

More on T-storm Project:
https://bit.ly/3yRRyat

- Byers and Braham (1949)
  - the cell is the basic organizational structure of all t-storms
  - t-storm **downdrafts** descend to ground and spread out
  - recognized that gusty surface winds affiliated with **outflow** could be a threat to planes







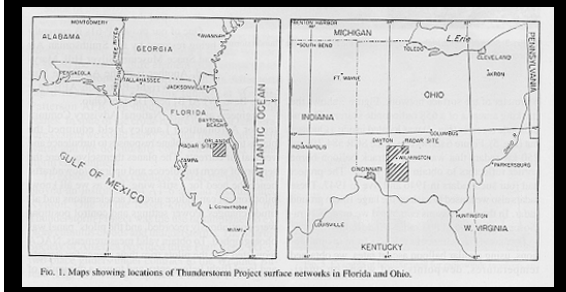
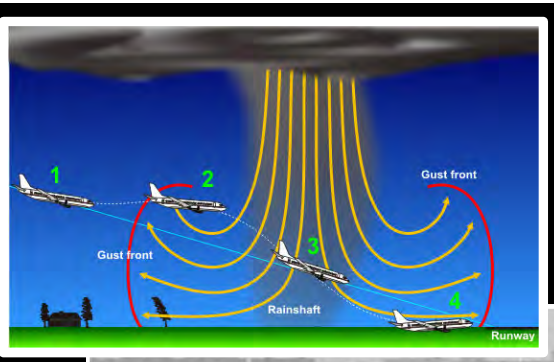
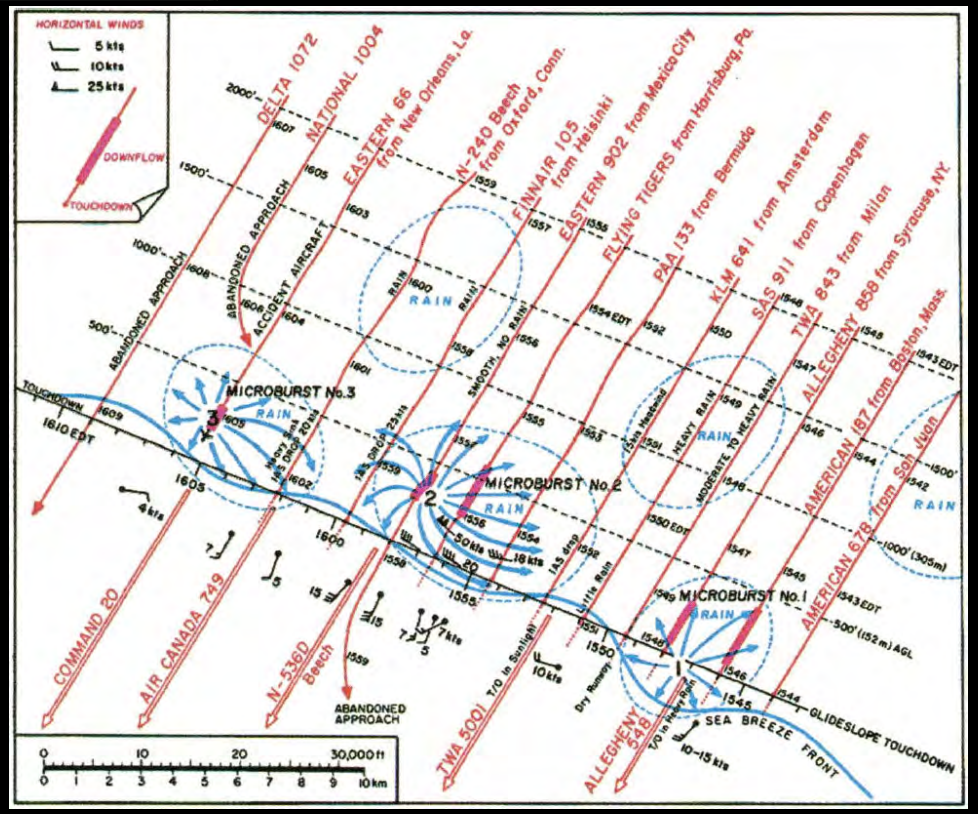


Fig. 1. Maps showing locations of Thunderstorm Project surface networks in Florida and Ohio.

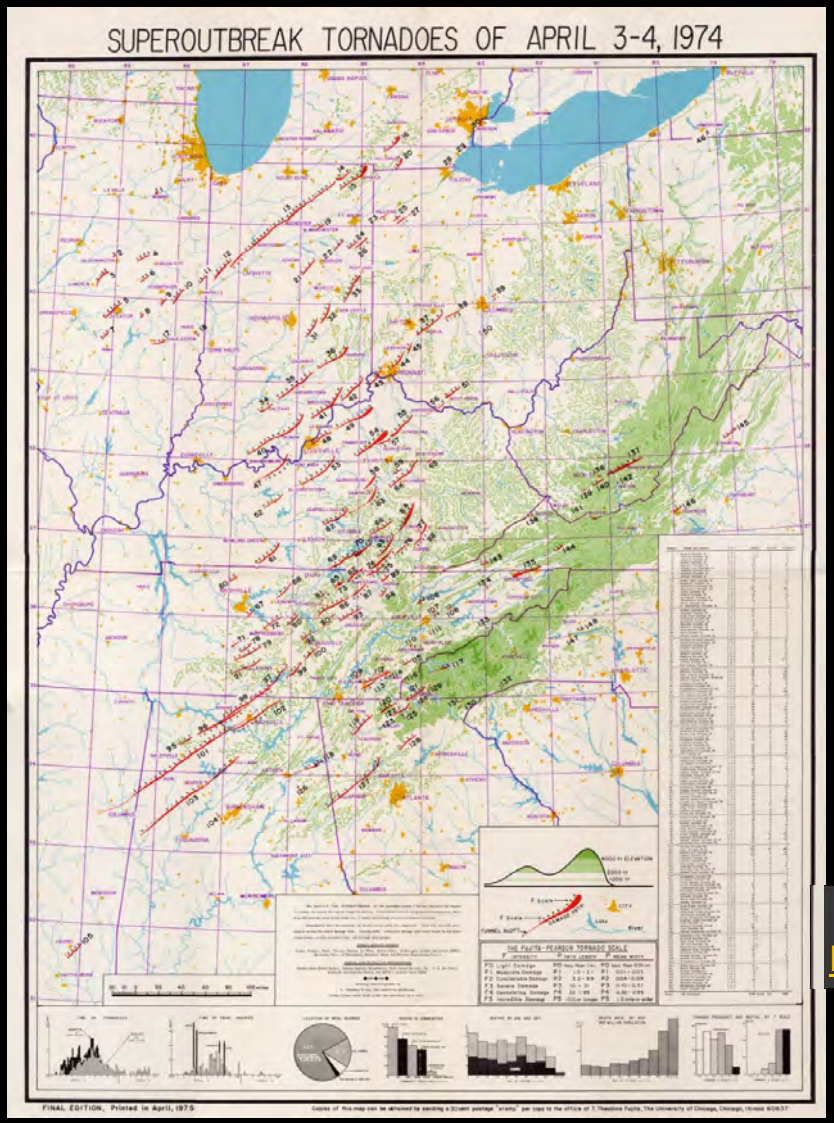
https://www.weather.gov/iln/ThunderstormProject



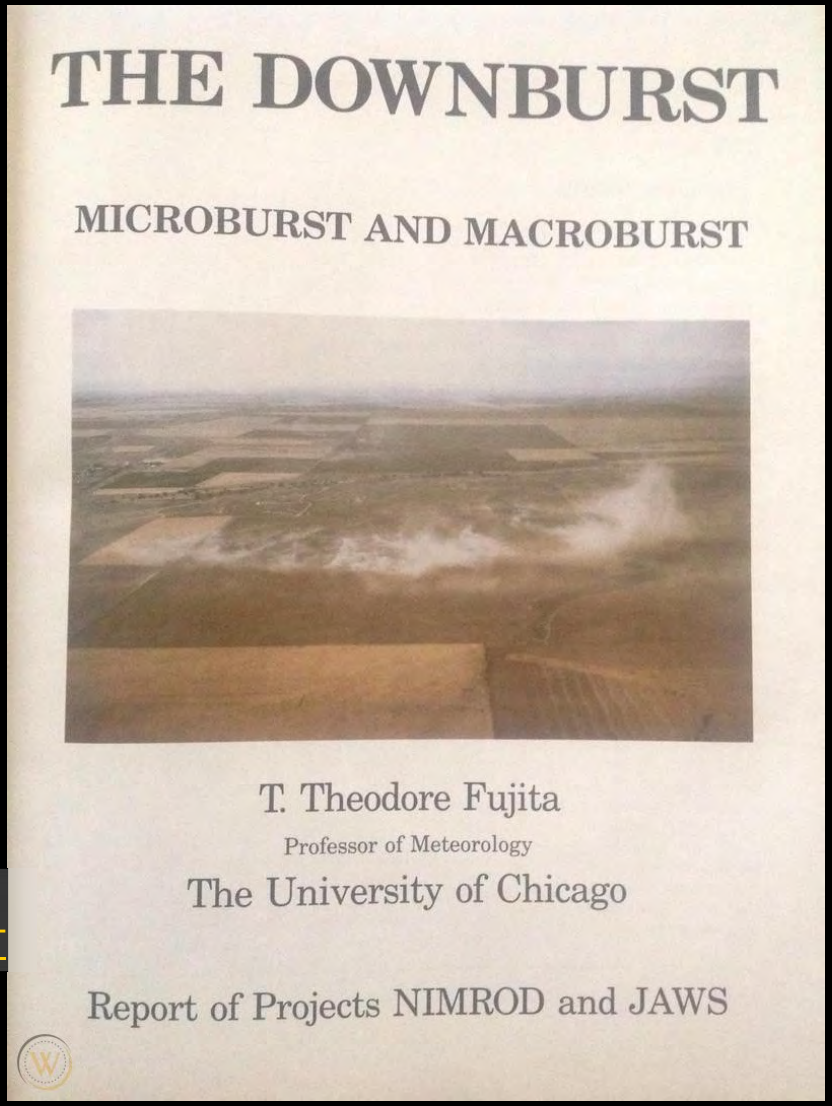
The remains of Eastern Airlines Flight 66 litter Rockaway Boulevard on June 24, 1975, after the 727 encountered a thunderstorm downdraft and crashed short of the runway. (Photo by Jim Hughes/NY Daily News Archive via Getty Images)



Fujita's analysis of the wind events and flight paths at JFK on 24 June 1975 near the time of the crash of Eastern Flight 66.



Fujita documentary:
https://to.pbs.org/2X3JwxT



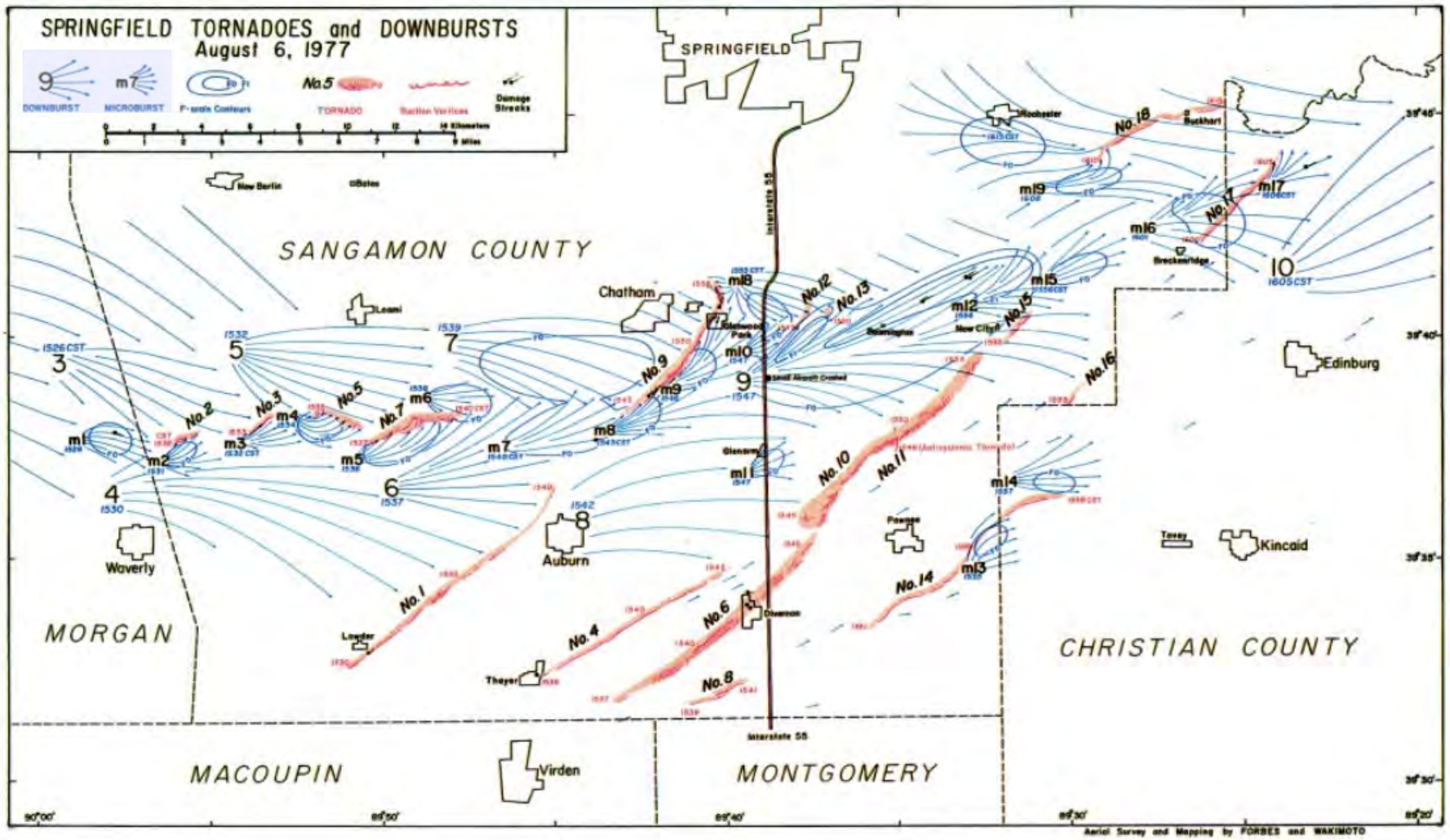


FIG. 8. Eighteen tornadoes, 10 downbursts, and 17 microbursts are depicted in this map. One tornado (no. 11) was anticyclonic. Apparently, eight tornadoes formed on the left side of microbursts. No traces of downbursts were found in the vicinity of other tornadoes. [From Fujita (1978).]

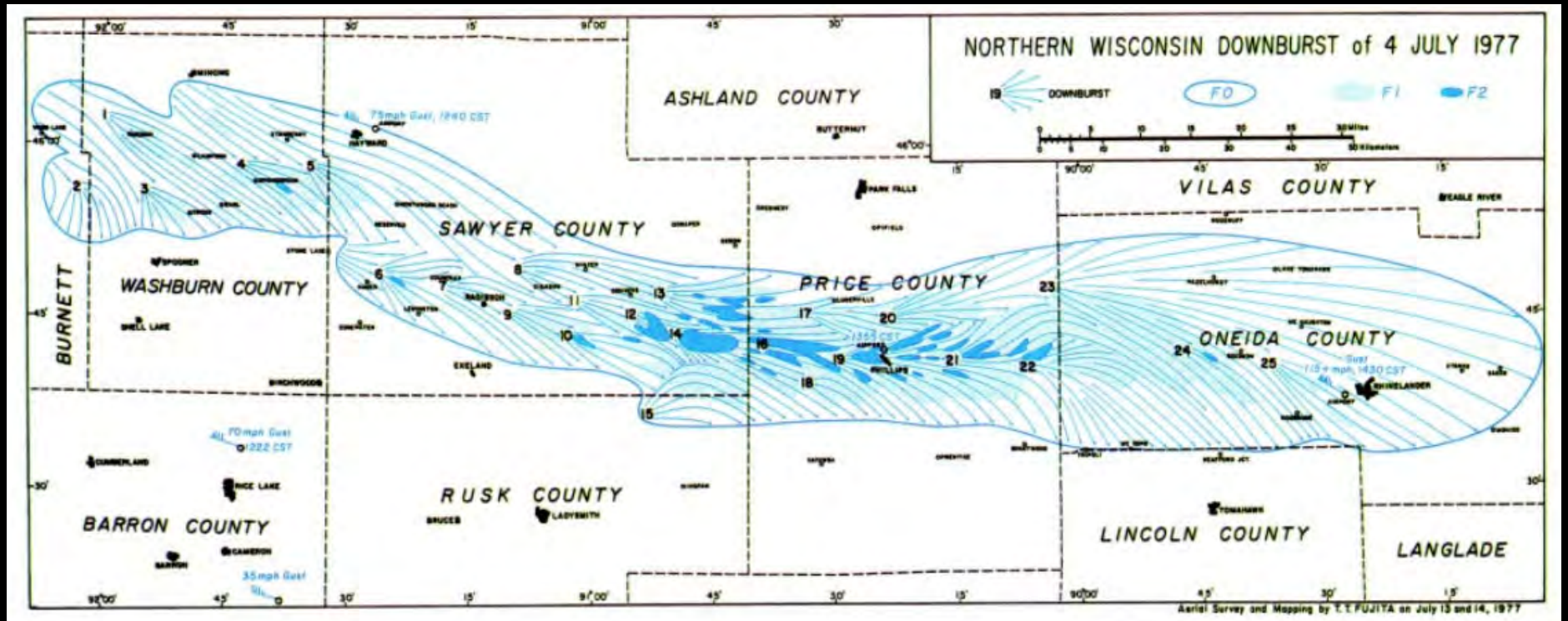
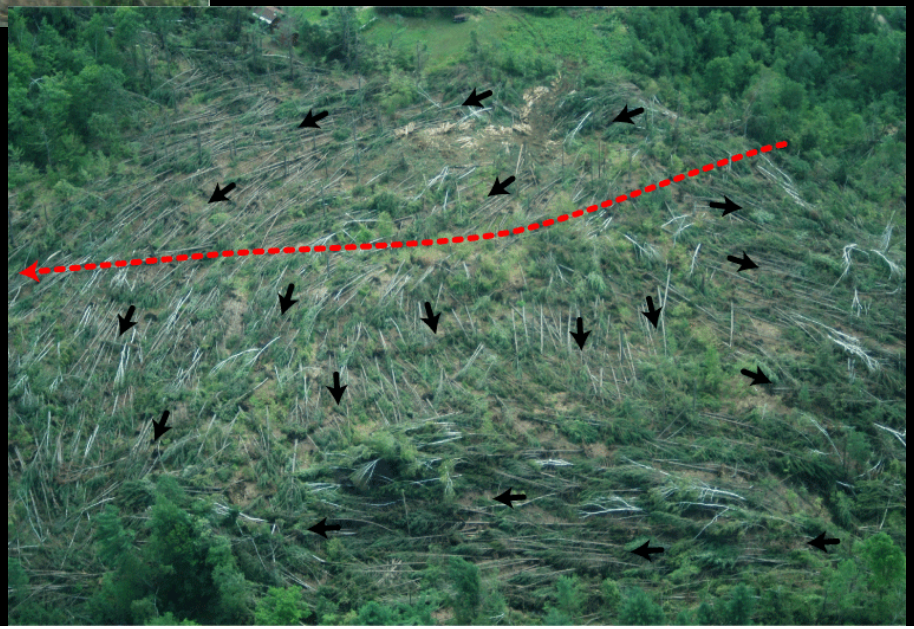


FIG. 4. Twenty-five downbursts on Independence Day in northern Wisconsin left behind a damage swath 166 mi long and 17 mi wide. No evidence of a tornado was found anywhere. [From Fujita (1978).]

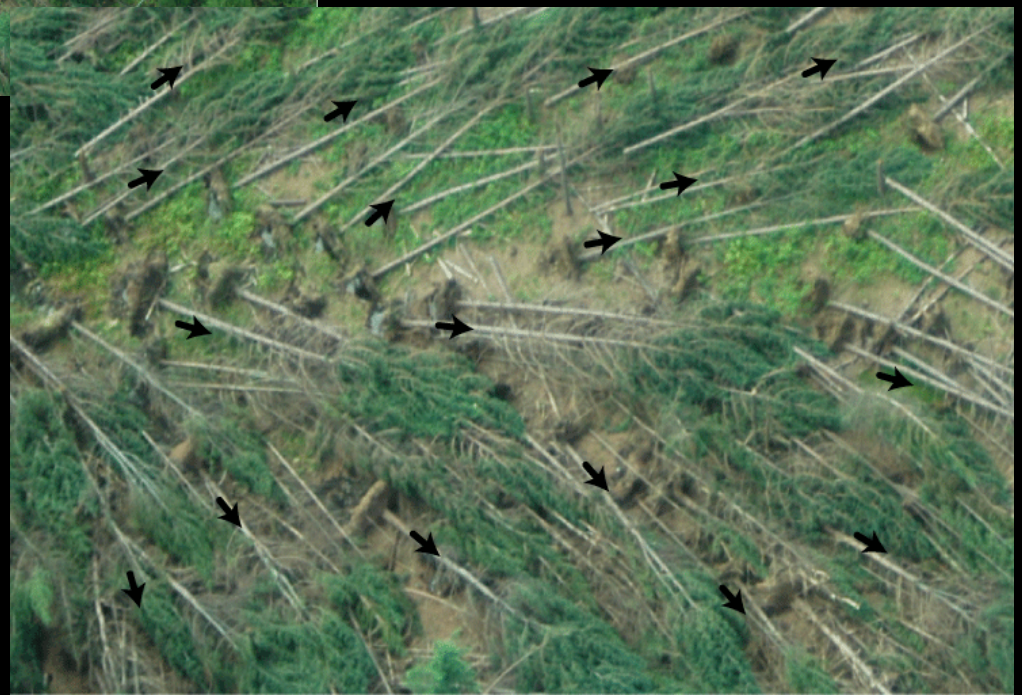


Tornadic damage:
Note cyclonic pattern

Damaging wind from t-storms is **much more common** than damage from tornadoes

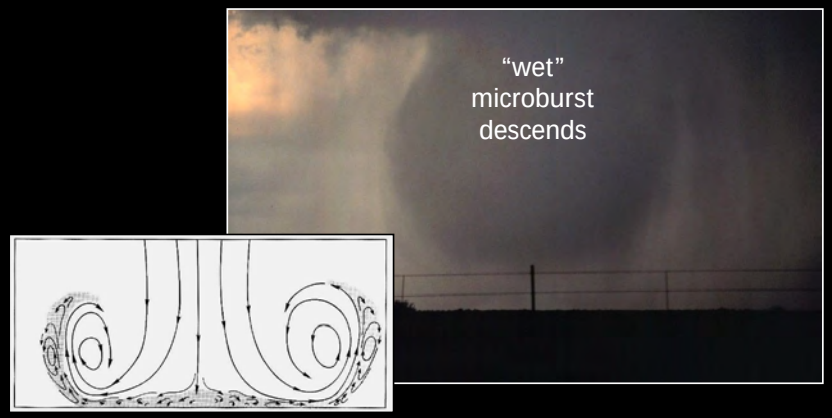
Many confuse damage produced by "straight-line" winds and often erroneously attribute it to tornadoes

Microburst damage:
Note diverging pattern



Downburst

- A strong downdraft that originates in the mid to lower part of a t-storm and descends to the ground, where it spreads out, creating strong “straight-line” winds
  - Much more intense than typical t-storm downdraft
- Winds can exceed 100 mph and can cause damage equivalent to EF2+ tornadoes
- Microburst (<2.5 mi horizontal dimension)
- Macroburst (>2.5 mi)




Kane Artie Photography
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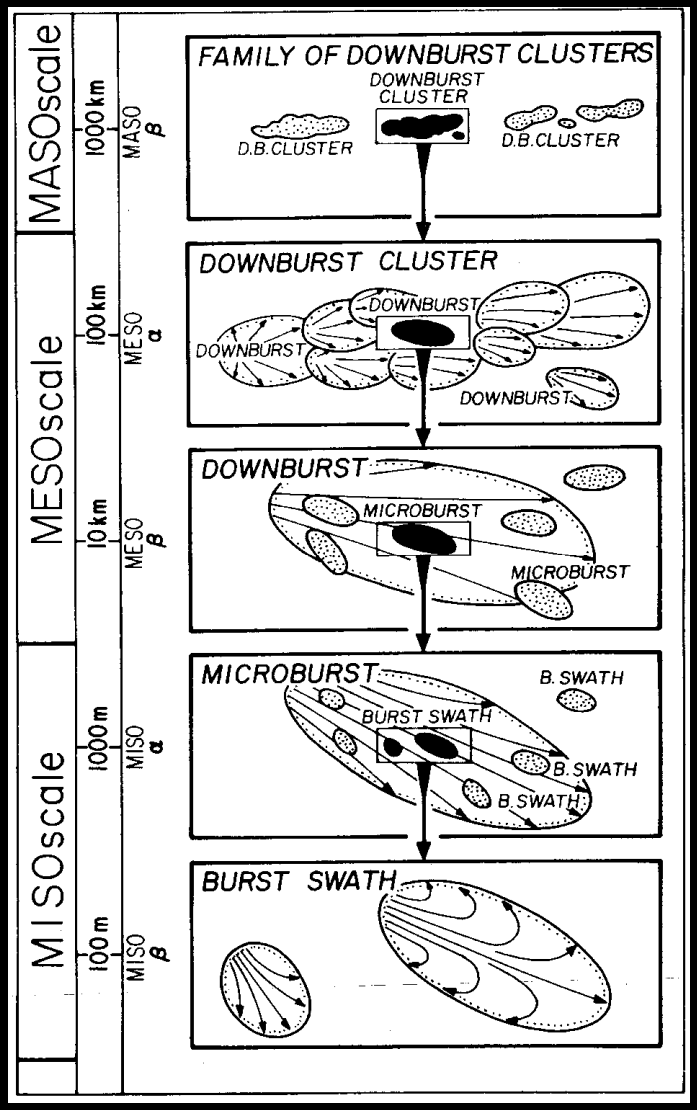
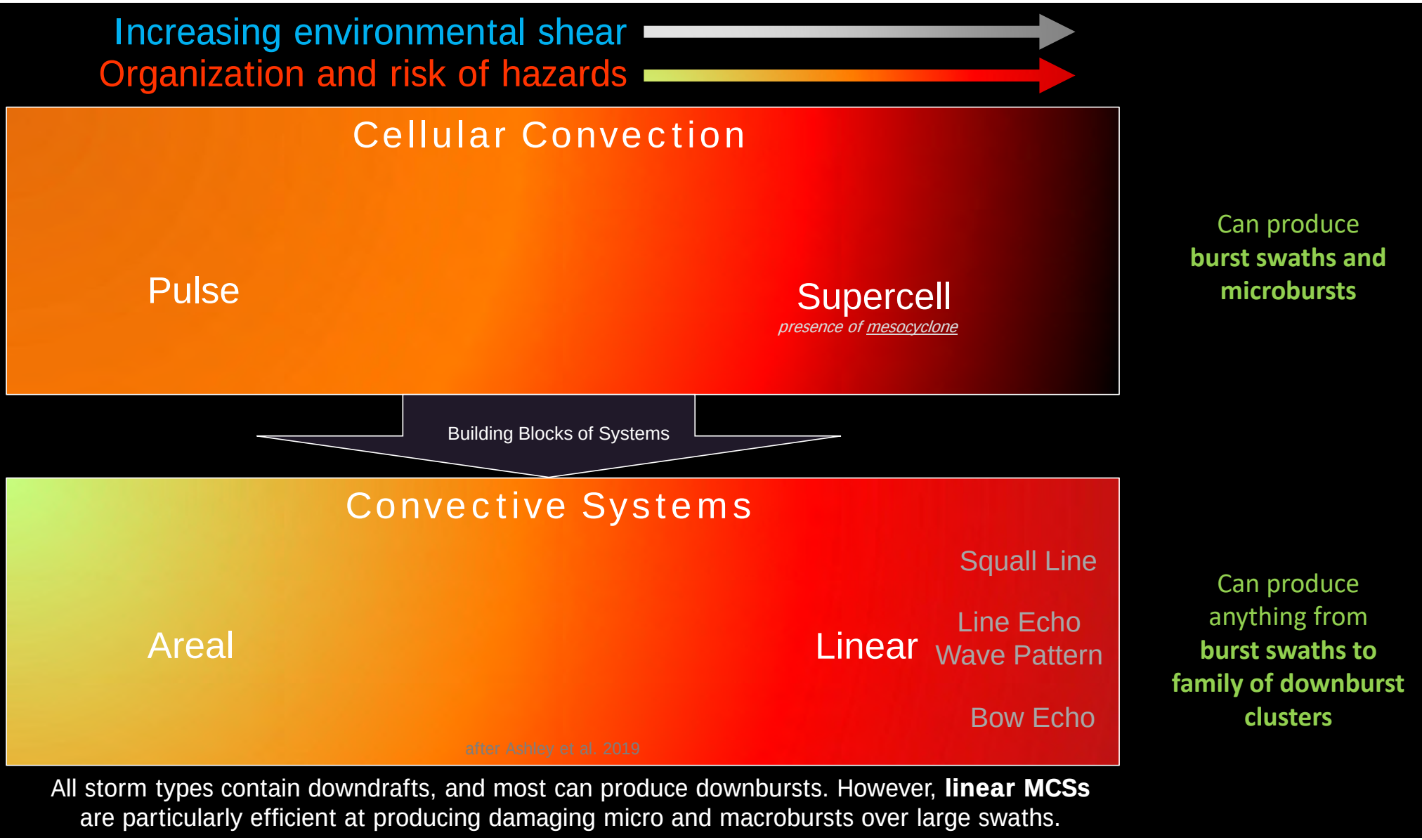
Various Scales of Downburst Winds



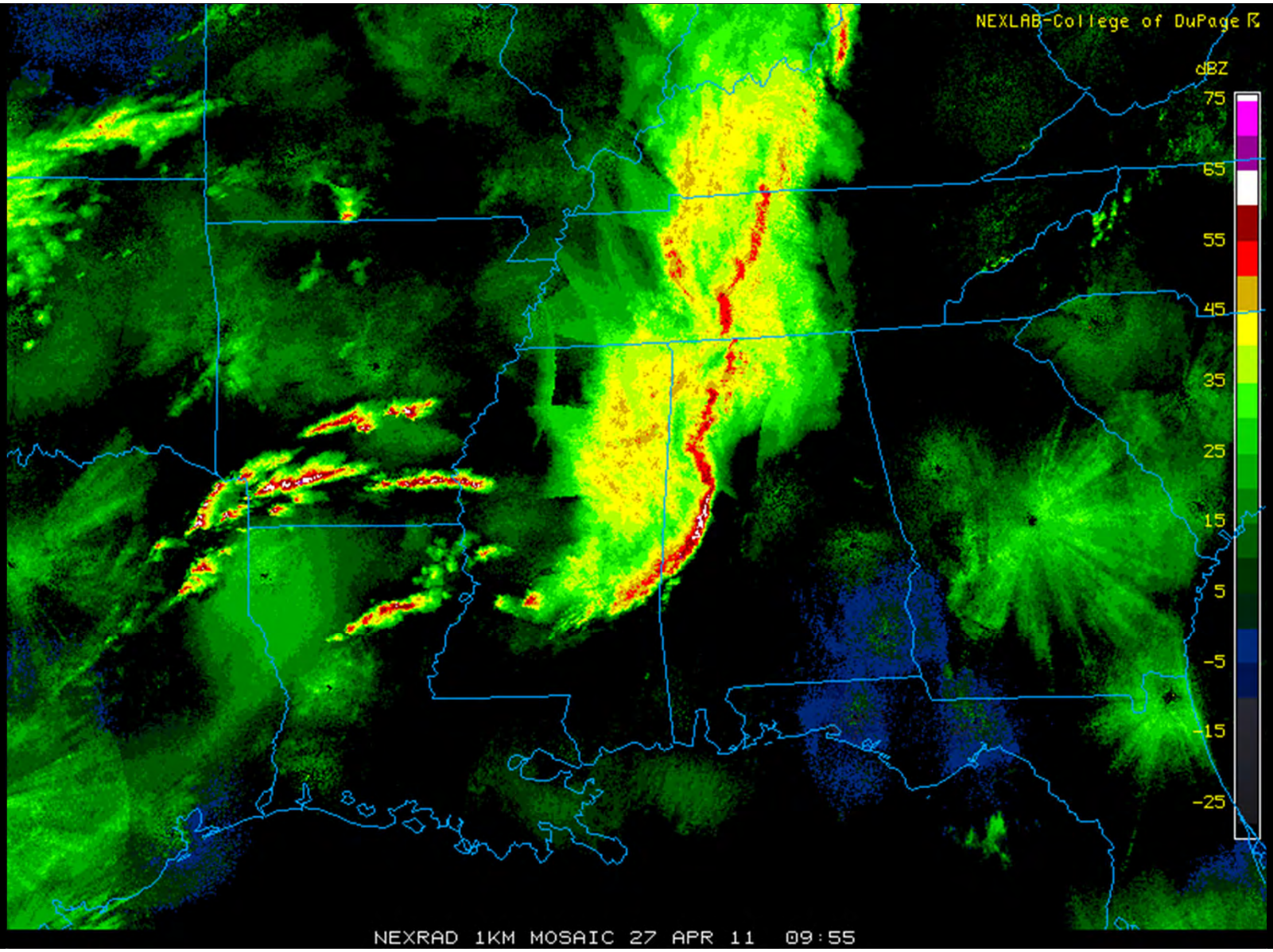
Fujita and Wakimoto (1981)

Importance of Storm Type


“Cells”
Howie Bluestein
“Systems”
© 2010 Walker Ashley



All storm types contain downdrafts, and most can produce downbursts. However, **linear MCSs** are particularly efficient at producing damaging micro and macrobursts over large swaths.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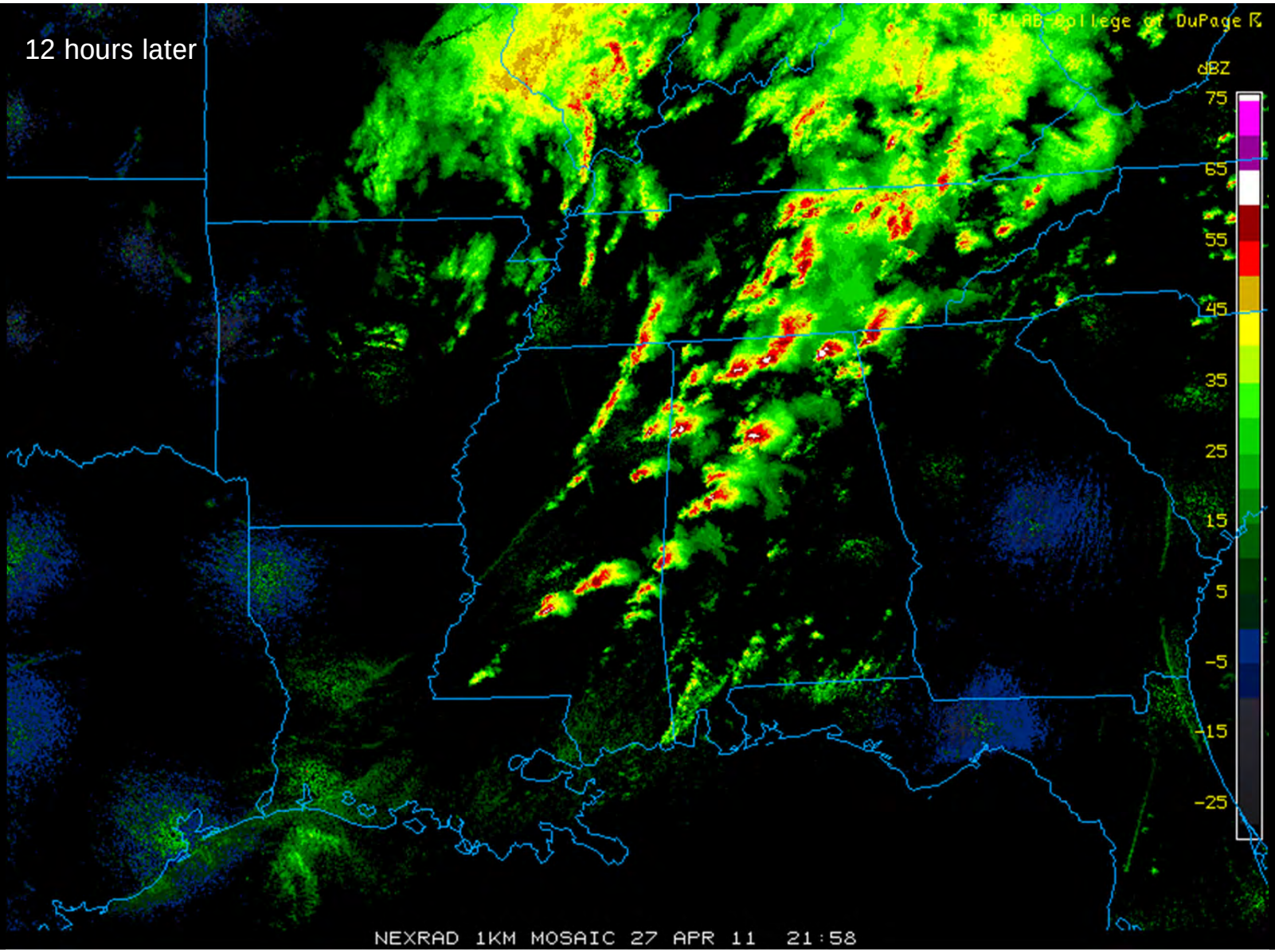
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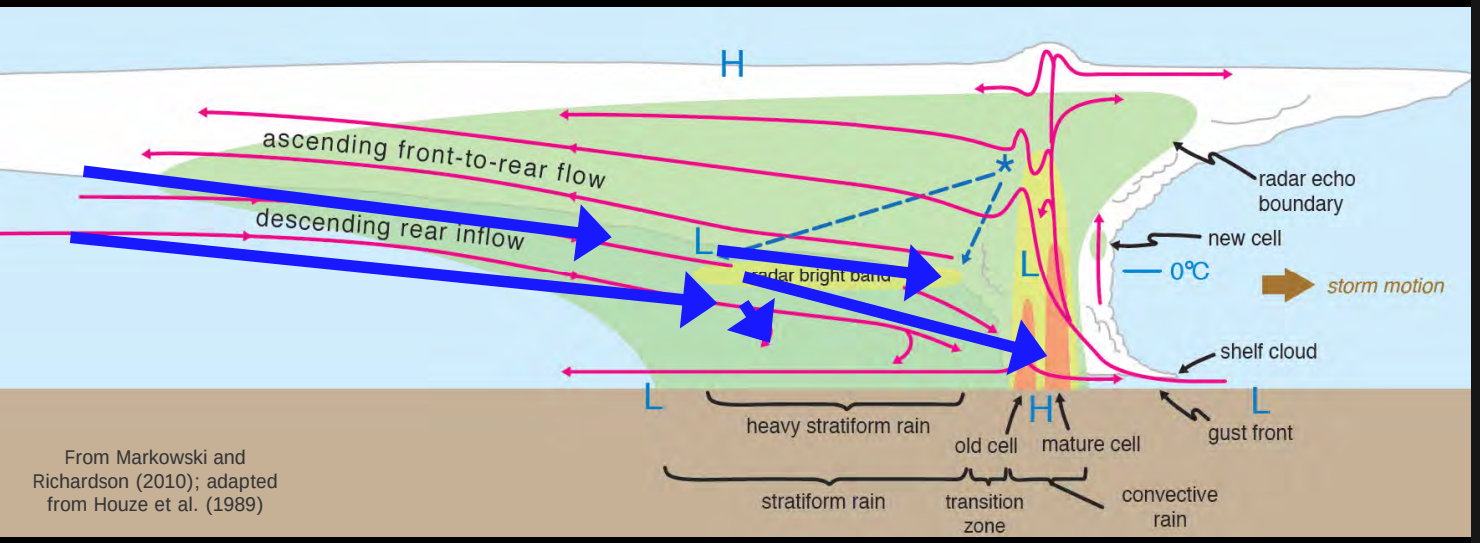
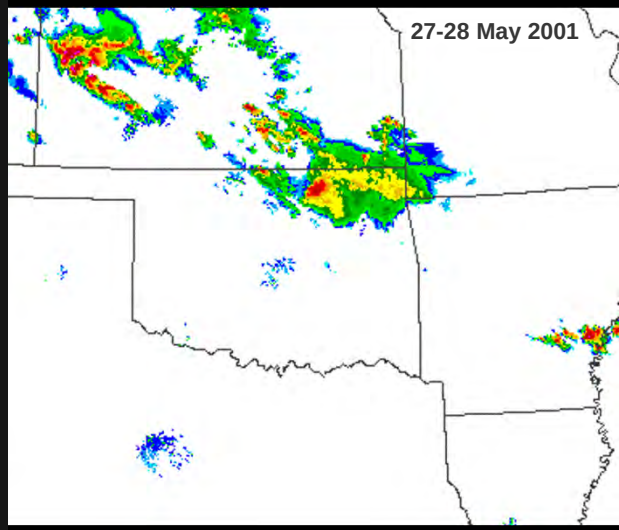
Mesoscale Convective System (MCS)

an assemblage of thunderstorm cells identified using radar reflectivity that persists for ≥3 hours and contain a contiguous or semi-contiguous convective area ≥60 miles along the system's major axis (after Parker and Johnson 2000)



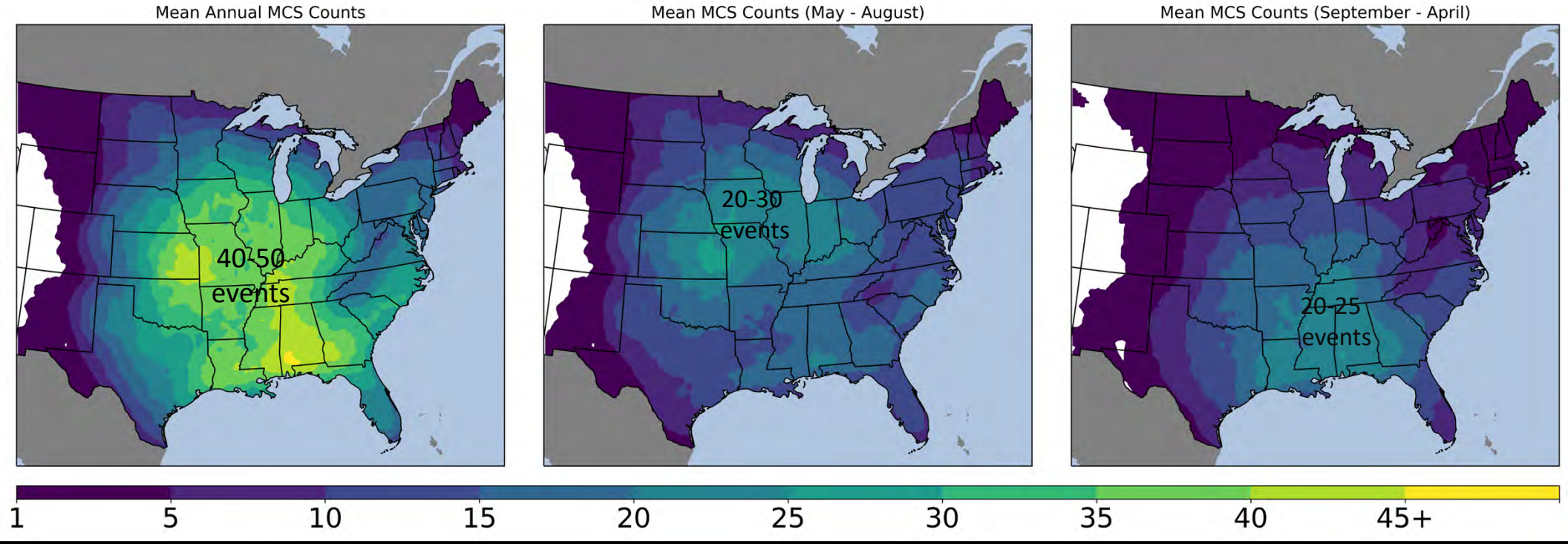
From Markowski and Richardson (2010); adapted from Houze et al. (1989)



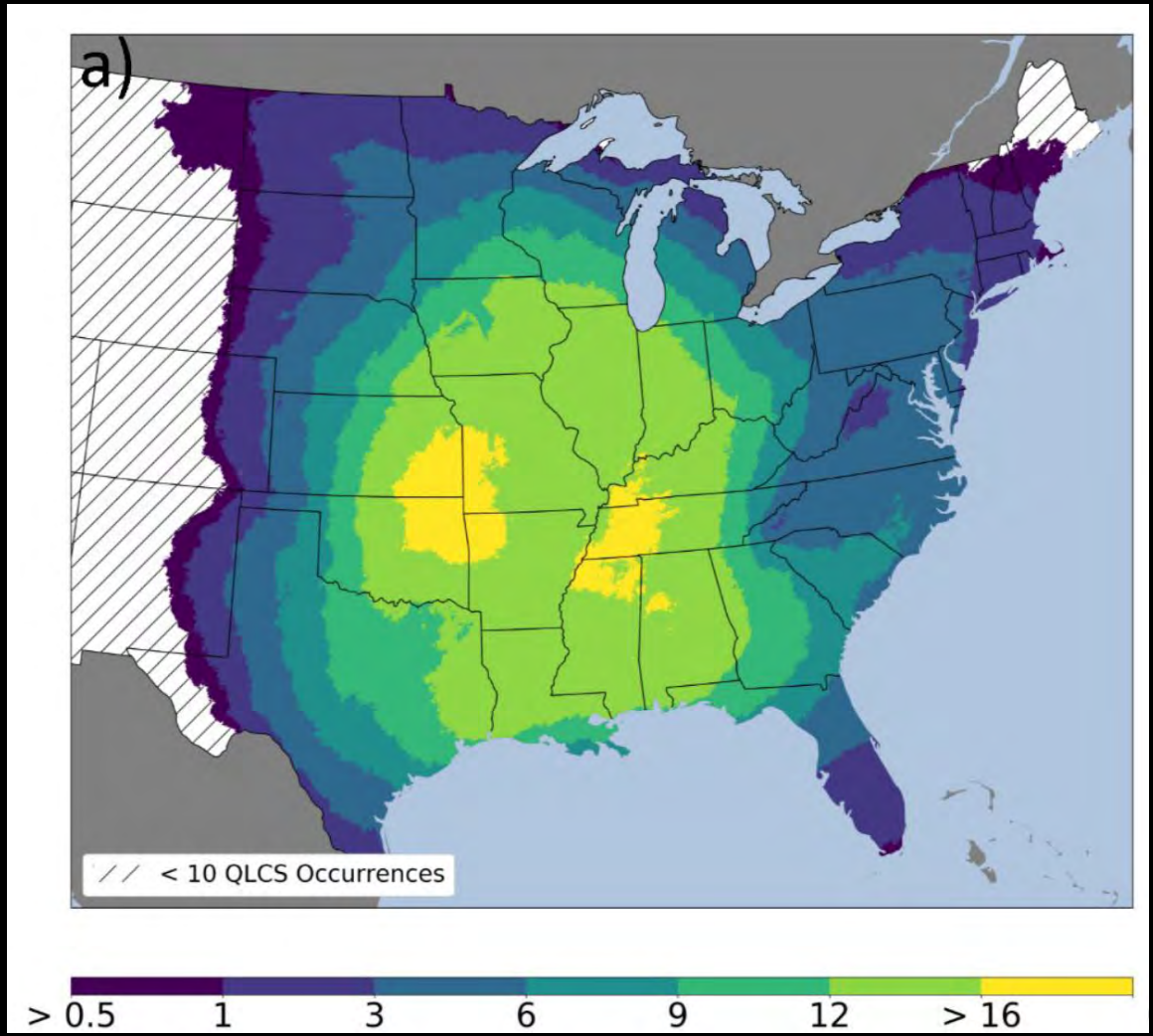
Quasi-linear Convective System (QLCS

an MCS that has thunderstorm regions that are longer than 60 miles and must be at least **three times as long as they are wide** (after Grams et al. 2012, Smith et al. 2012)

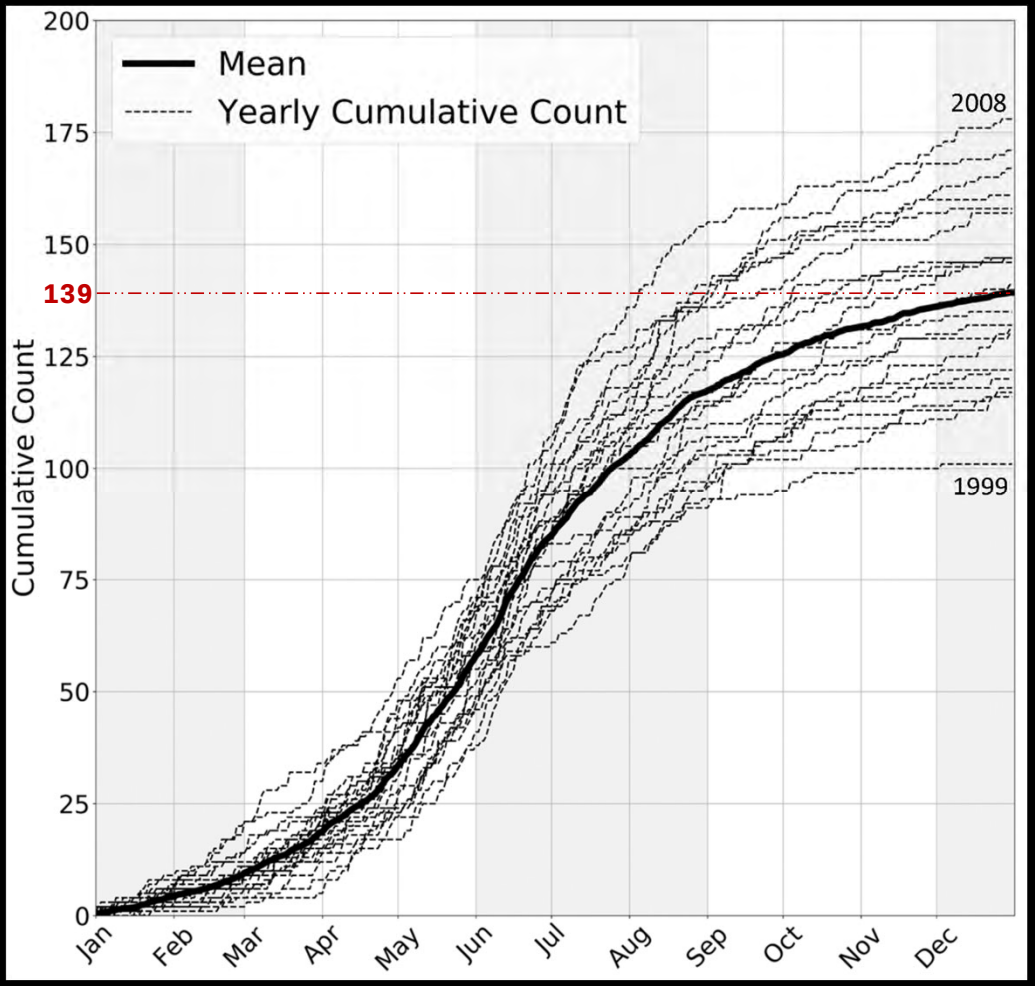
Mean Annual/Seasonal MCS Counts

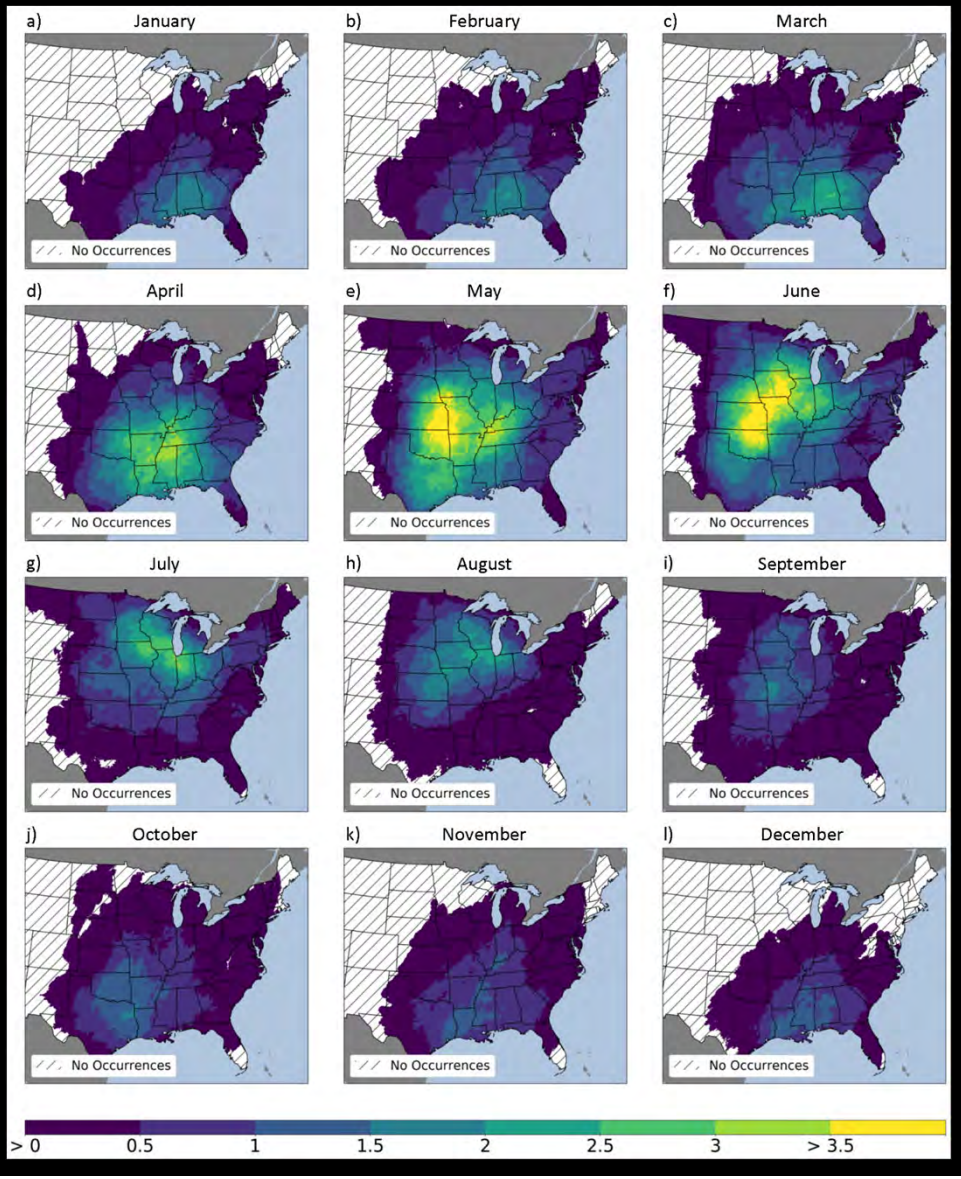


Mean annual QLCS occurrence



Annual Cumulative QLCS Counts, 1996-2017





Mean monthly QLCS counts

Arcus: A low, horizontal cloud formation associated with the leading edge of t-storm outflow (i.e., the gust front).

Roll cloud: Relatively rare; they are completely detached from the t-storm base, differentiating them from the more familiar shelf clouds. Roll clouds usually appear to be "rolling" about a horizontal axis, but should not be confused with funnel clouds.

Shelf cloud: Unlike the roll cloud, the shelf cloud is attached to the base of the parent cloud above it. Rising cloud motion often can be seen in the leading (outer) part of the shelf cloud, while the underside often appears turbulent and boiling.

after NWS SR-145

NE Roll Cloud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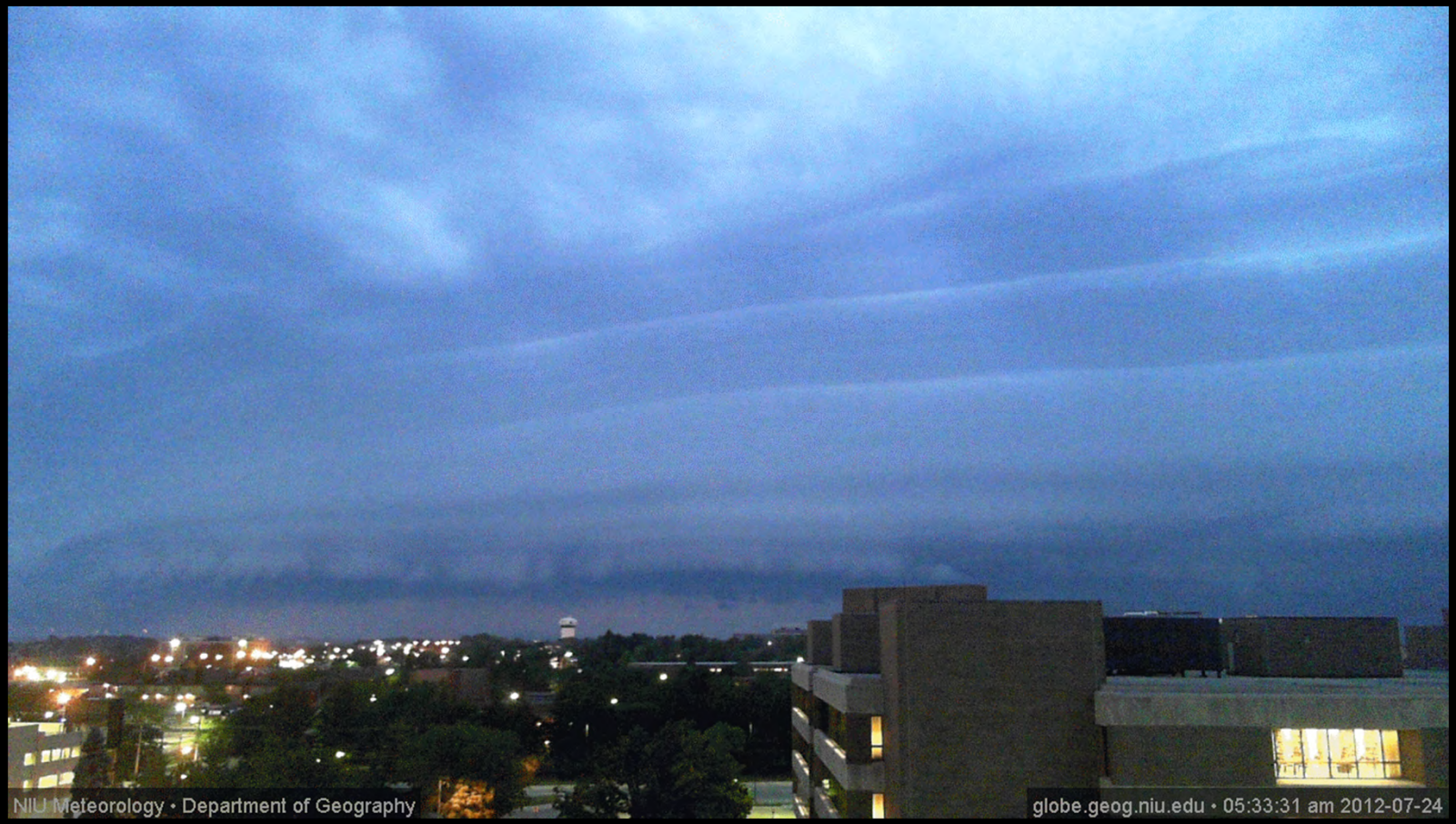
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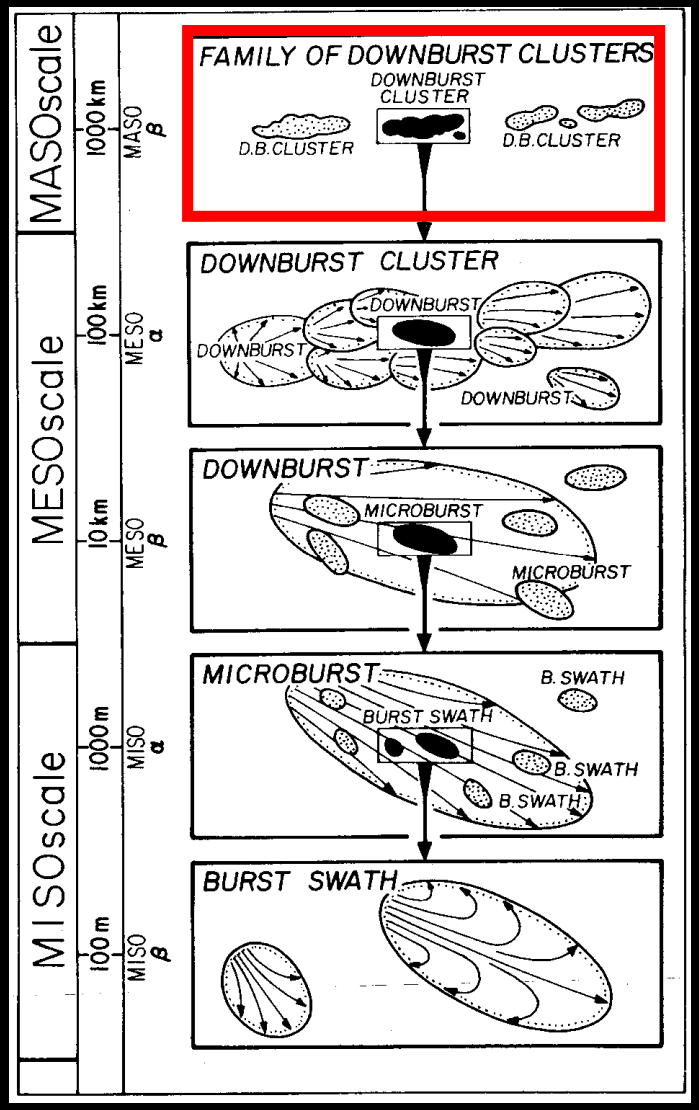
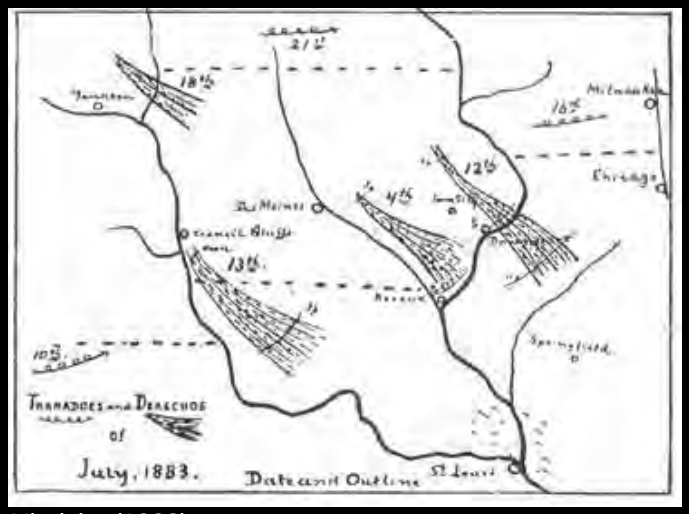


Fujita and Wakimoto (1981)

Derecho

- Term coined by Gustavus Hinrichs in **1888**
  - Spanish derivative meaning "straight-ahead" or "direct"
  - In correspondence with tornado (“tornar” ≈ to turn)

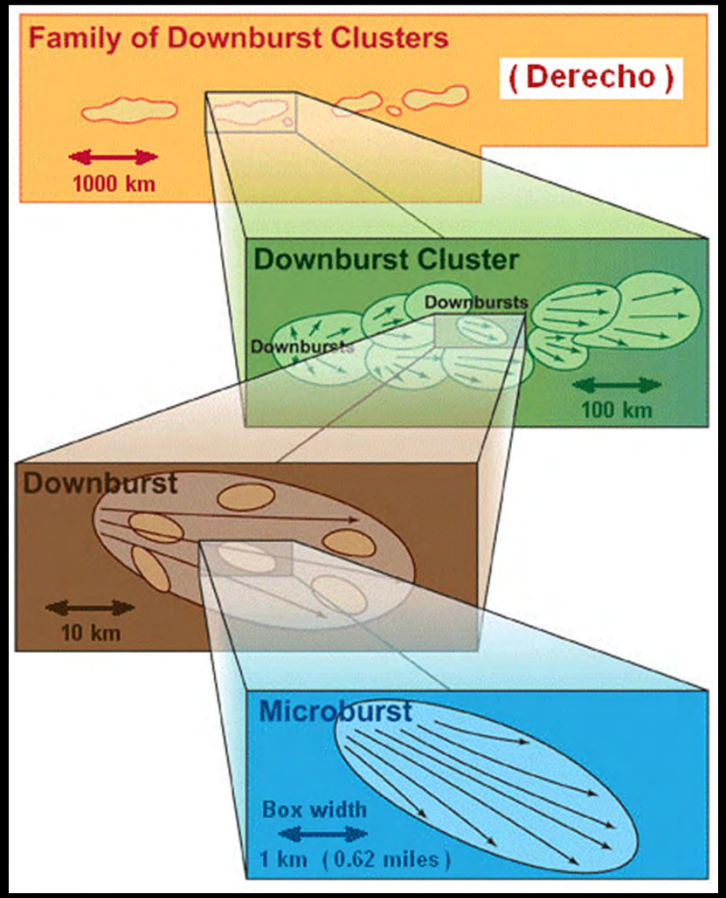


Hinrichs (1888)

*“The climate of Iowa has been most outrageously maligned by thoughtless or sensational newspaper correspondents and by official and semi-official publications of the Signal Service in ascribing to Iowa an **excessive tornado frequency**” – Hinrichs 1888*

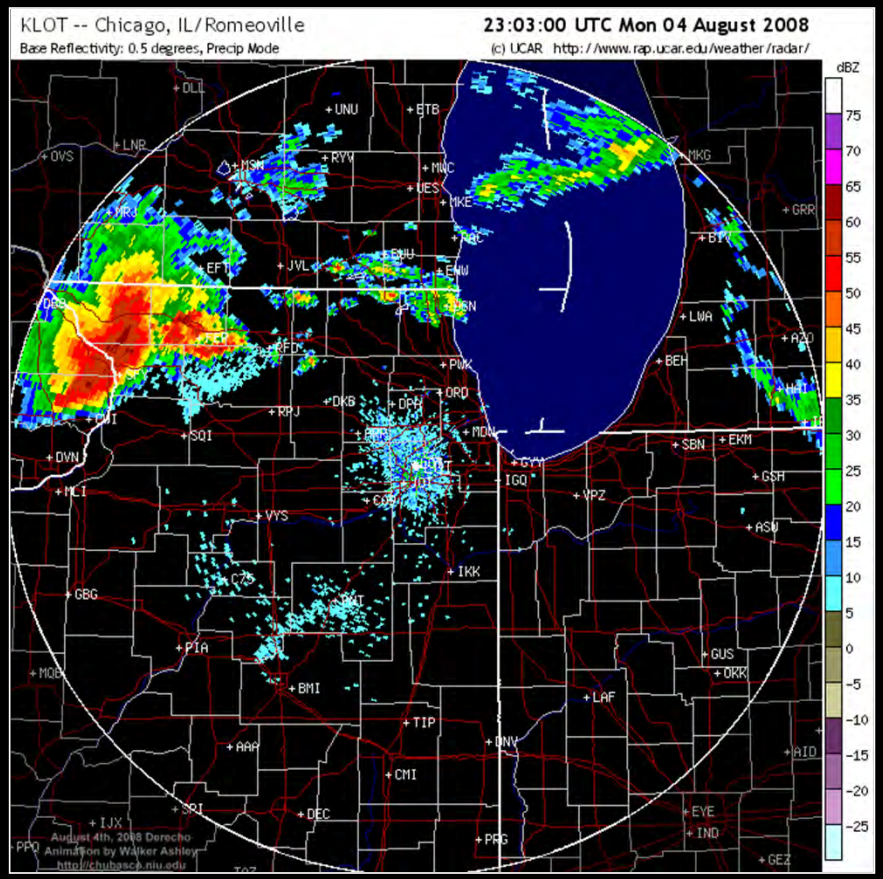
What is a derecho?

- Modern definition by the late **Bob Johns** (NOAA SPC) in **1980s**
  - Criteria based on Fujita and Wakimoto's (1981) **"family of downburst"** criteria



Fujita and Wakimoto (1981); Modified by Dennis Cain

- ✓ *There must be a concentrated area of t-storm induced wind gusts ≥ 58 mph that has a major axis length of **240 mi or more**;*
- ✓ *The wind reports must have **chronological progression;***
- ✓ *Multiple swaths of damage must be part of the same **t-storm system**;*
- ✓ *The associated t-storm system must have **temporal and spatial continuity***



A derecho:

… is a particularly long-lived and widespread damaging windstorm produced by a mesoscale convective system.

… is made up of a "family of downburst clusters" and, by definition, must be at least 240 miles in length.

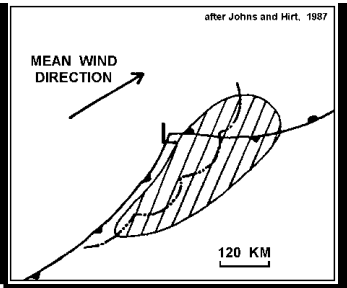
… results from a series of particularly strong downbursts and can travel many hundreds of miles before dissipating.

… are typically produced by QLCSs with high-precipitation supercells embedded in a line.

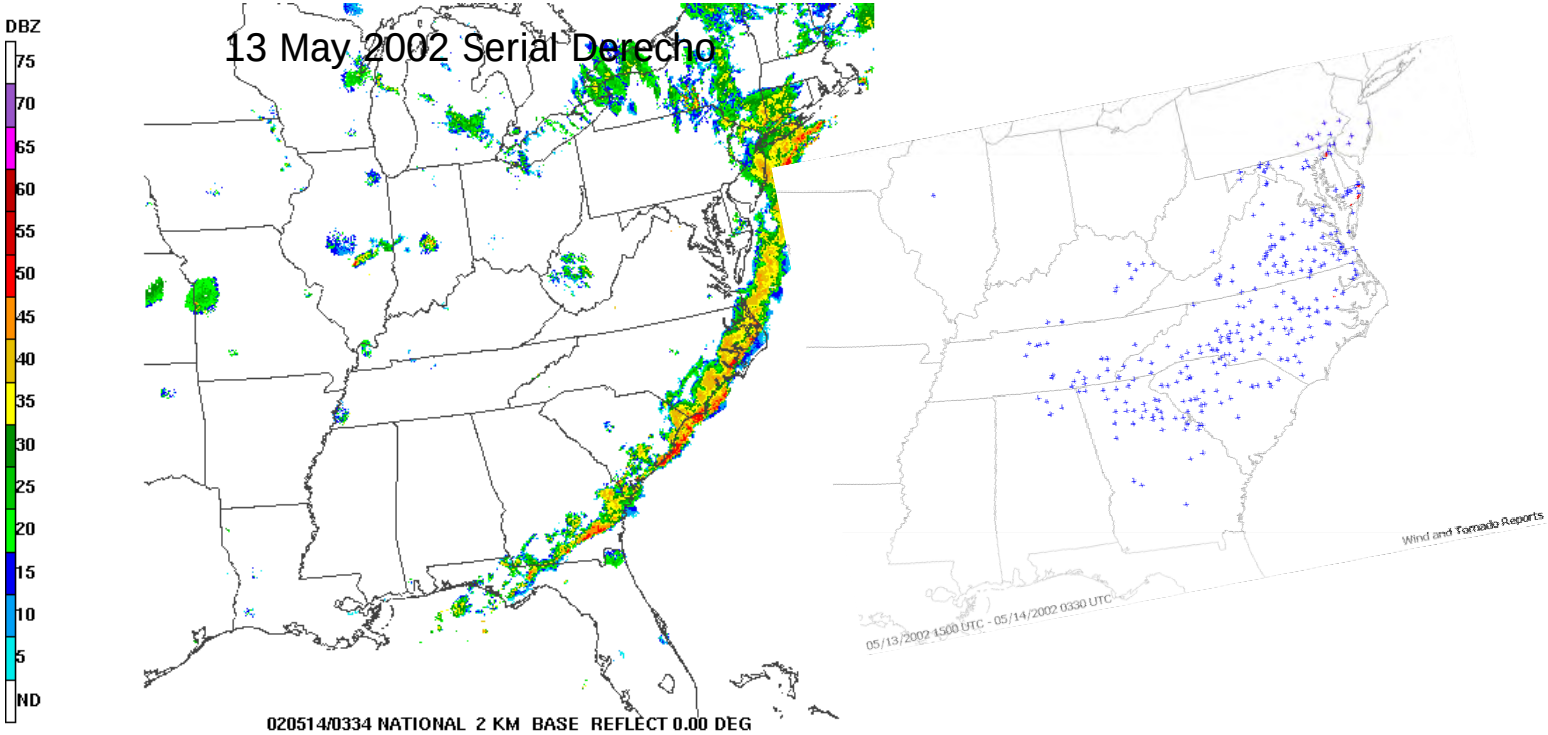
… have two primary dangers:

The <u>duration</u> of the damaging winds and <u>widespread coverage</u> of such winds

“Serial” Derechos

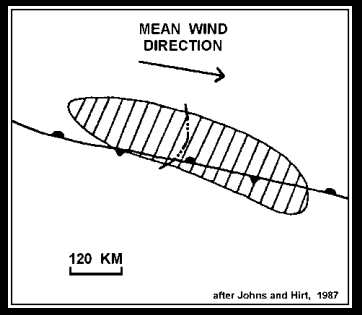


- Typically form within a “dynamic” weather pattern
  - Events can occur throughout the year
- Usually affiliated with an expansive **squall line** develops ahead of a **cold front** and is associated with a strong extratropical low

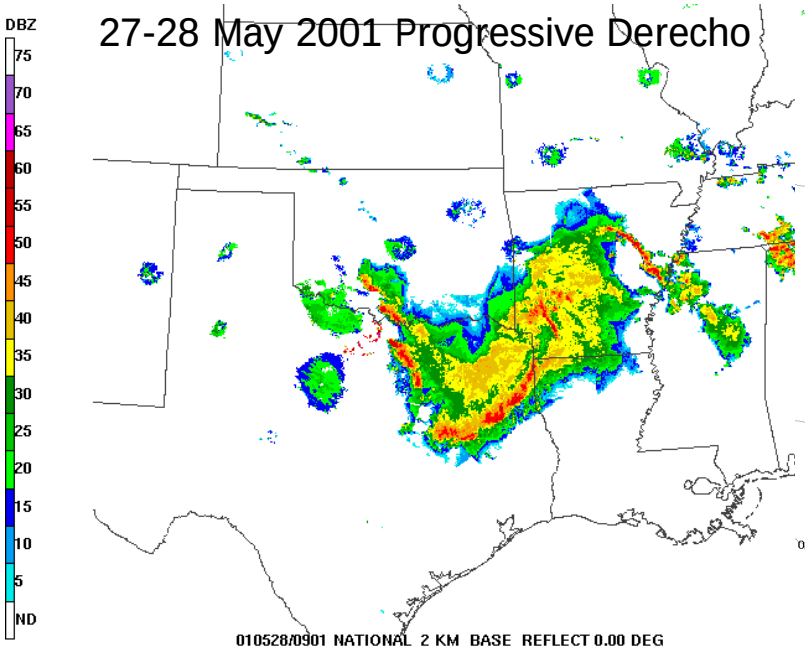


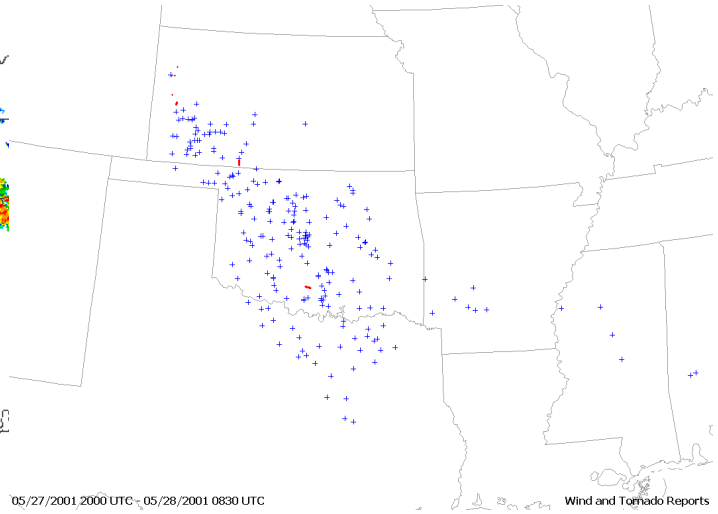
“Progressive” Derechos

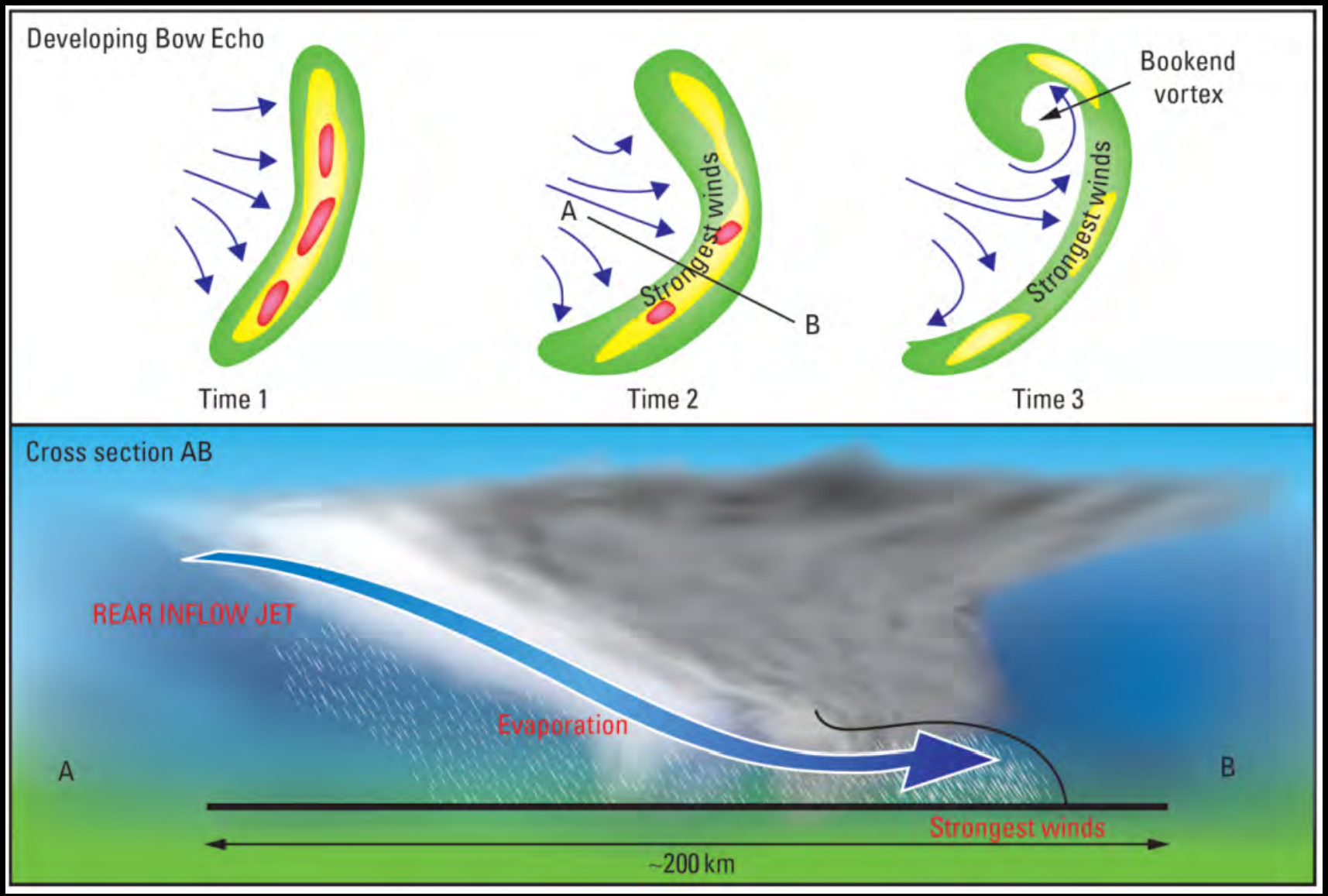
- Typically form in a relatively benign weather pattern
- Usually form in the **late spring or summer months**
- Characterized by a short, curved squall line, resembling a large **bow echo**
- Typically move **very fast**
- Travels along a quasi-stationary front



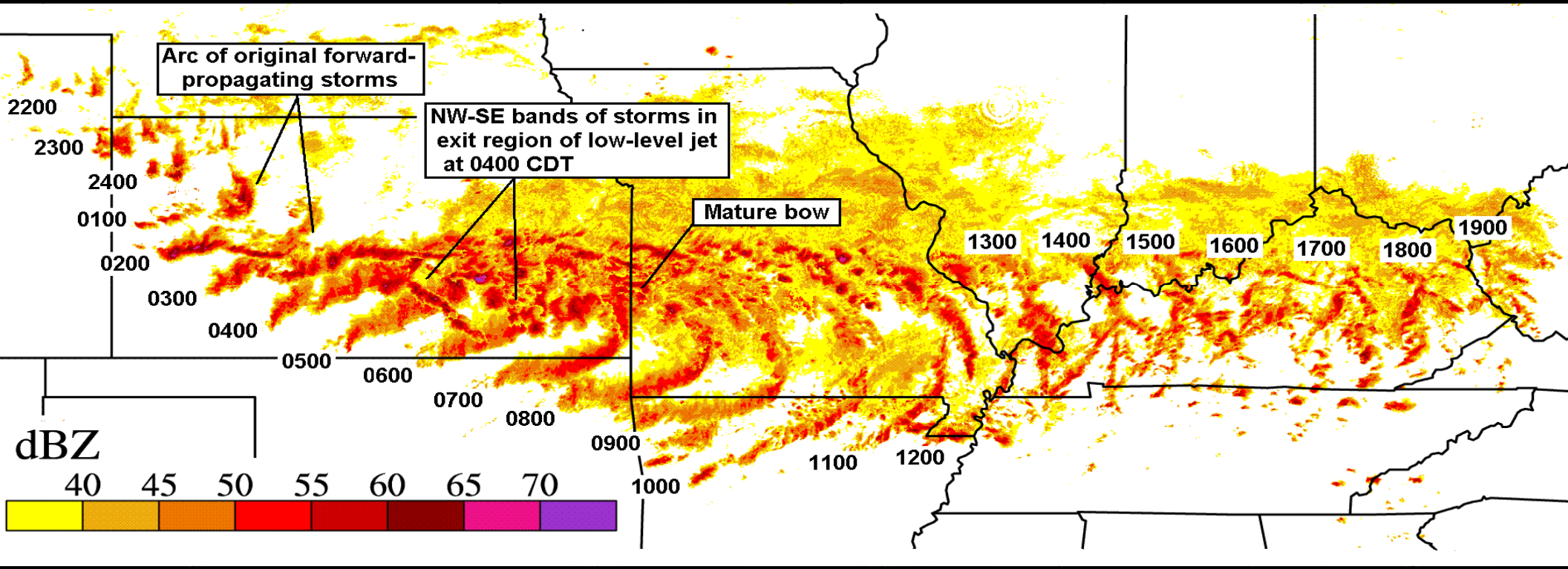
27-28 May 2001 Progressive Derecho






Developing Bow Echo
Time 1
A
Strongest winds
B
Time 2
Bookend
vortex
Strongest winds
Time 3
Cross section AB
REAR INFLOW JET
Evaporation
A
B
Strongest winds
~200 km

The 'Super Derecho' of May 8, 2009



traveled 1,300 miles in 22 hours!

A PROPOSED REVISION TO THE DEFINITION OF "DERECHO"

BY STEPHEN F. CORFIDI, MICHAEL C. CONIGLIO, ARIEL E. COHEN, AND COREY M. MEAD

A revised, more physically based definition of "derecho" is proposed that is more specific to the type of intense convective windstorm that first inspired the term in the late nineteenth century.

On 4–5 April 2011, an expansive quasi-linear convective system (QLCS) crossed the southern and eastern United States accompanied by a broad swath of strong winds that produced a record number (1096) of nonduplicate damaging wind reports and nearly four-dozen tornadoes in a 24-h period (Figs. 1a and 3a). The windstorm extended more than 1000 km (620 mi) from the Ohio River southward to the Gulf Coast and was responsible for several deaths, at least 30 injuries, and millions of dollars in damage, mainly to trees and power lines.

Collectively, the spatial and temporal extent of the damage easily met the definition of a "derecho" as given by Johns and Hirt (1987, hereafter JH87): "Any family of downburst clusters associated with an extratropical mesoscale convective system," a definition that only has been slightly modified in more recent years (American Meteorological Society 2014):

> A widespread, convectively induced straight-line windstorm, more specifically, any family of downburst clusters produced by an extratropical mesoscale convective system.

The event also satisfied the following supplementary criteria established by JH87 based on Fujita and Wakimoto (1981) to identify derecho events in *Storm Data* and in the National Severe Storms Forecast Center (predecessor to the Storm Prediction Center) database:

1) There must be a concentrated area of reports consisting of convectively induced wind damage and/or convective gusts > 25.7 m s^{-1} (50 kt). This area must have a major axis of at least 400 km (250 mi).
2) The reports within this area must also exhibit a nonrandom pattern of occurrence; that is, the reports must show a pattern of chronological progression, whether as a singular swath (progressive) or a series of swaths (serial).
3) Within the area there must be at least three reports, separated by 64 km (40 mi) or more, of

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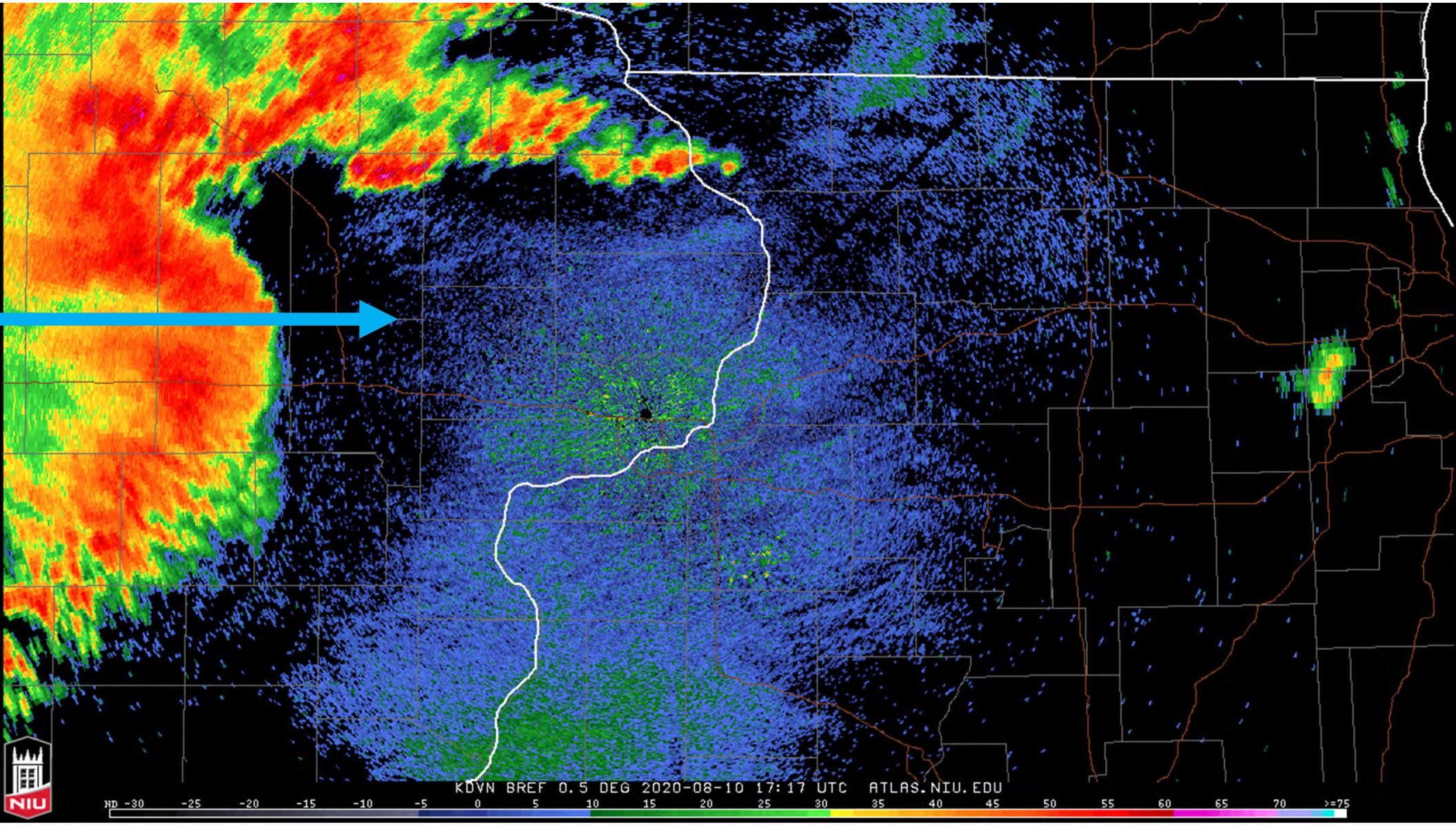
E-mail: stephen.corfidi@noaa.gov

The abstract for this article can be found in this issue, following the table of contents.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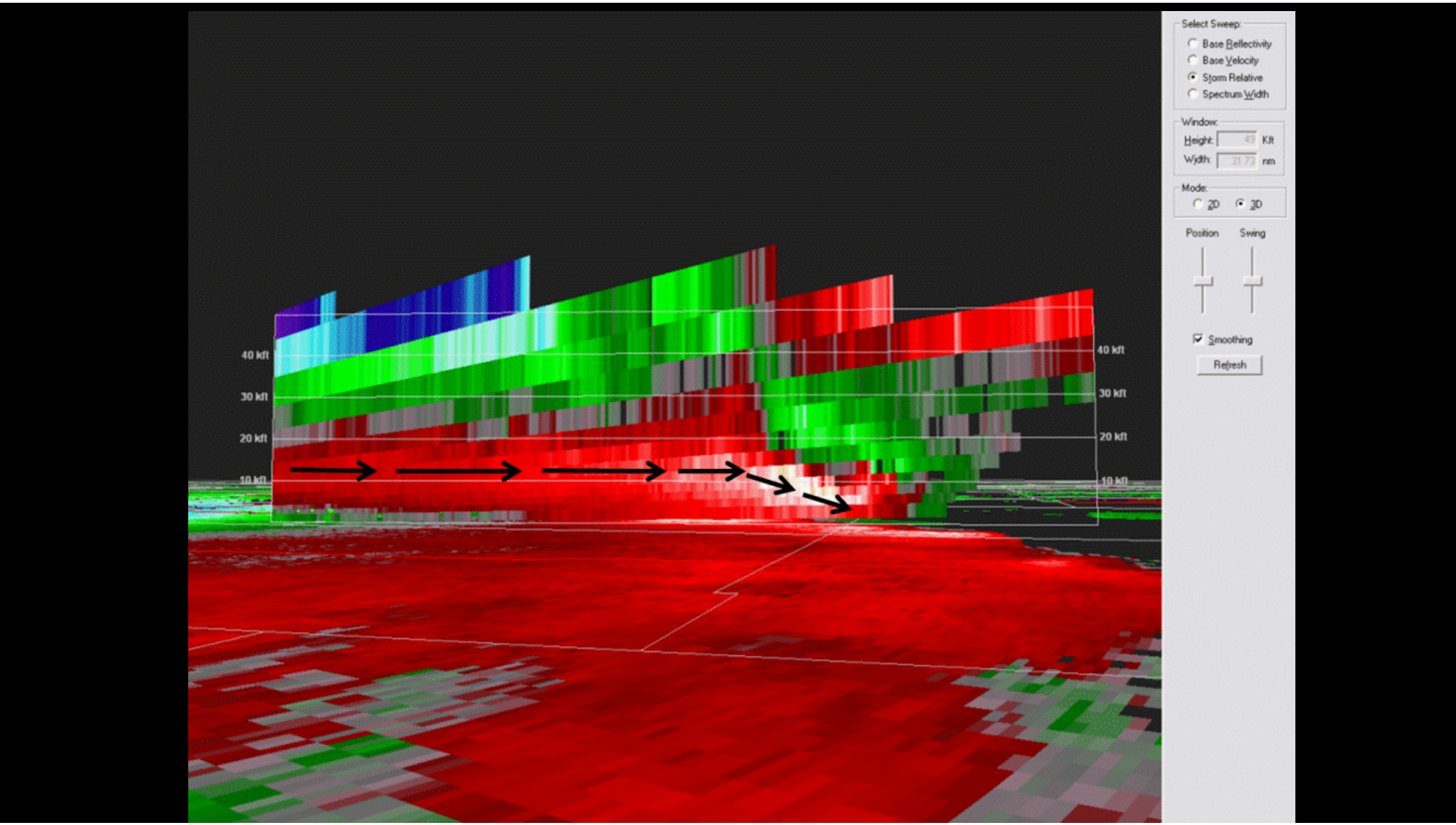
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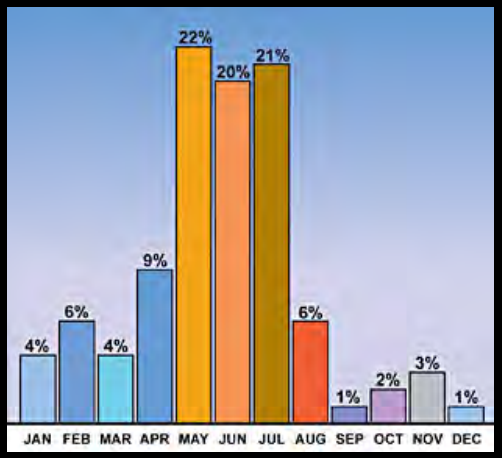
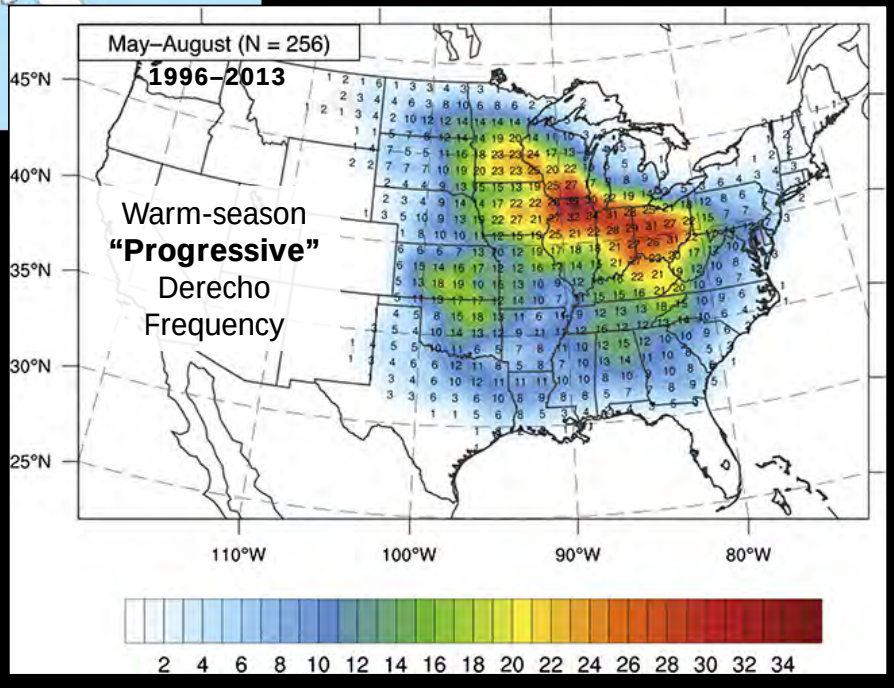
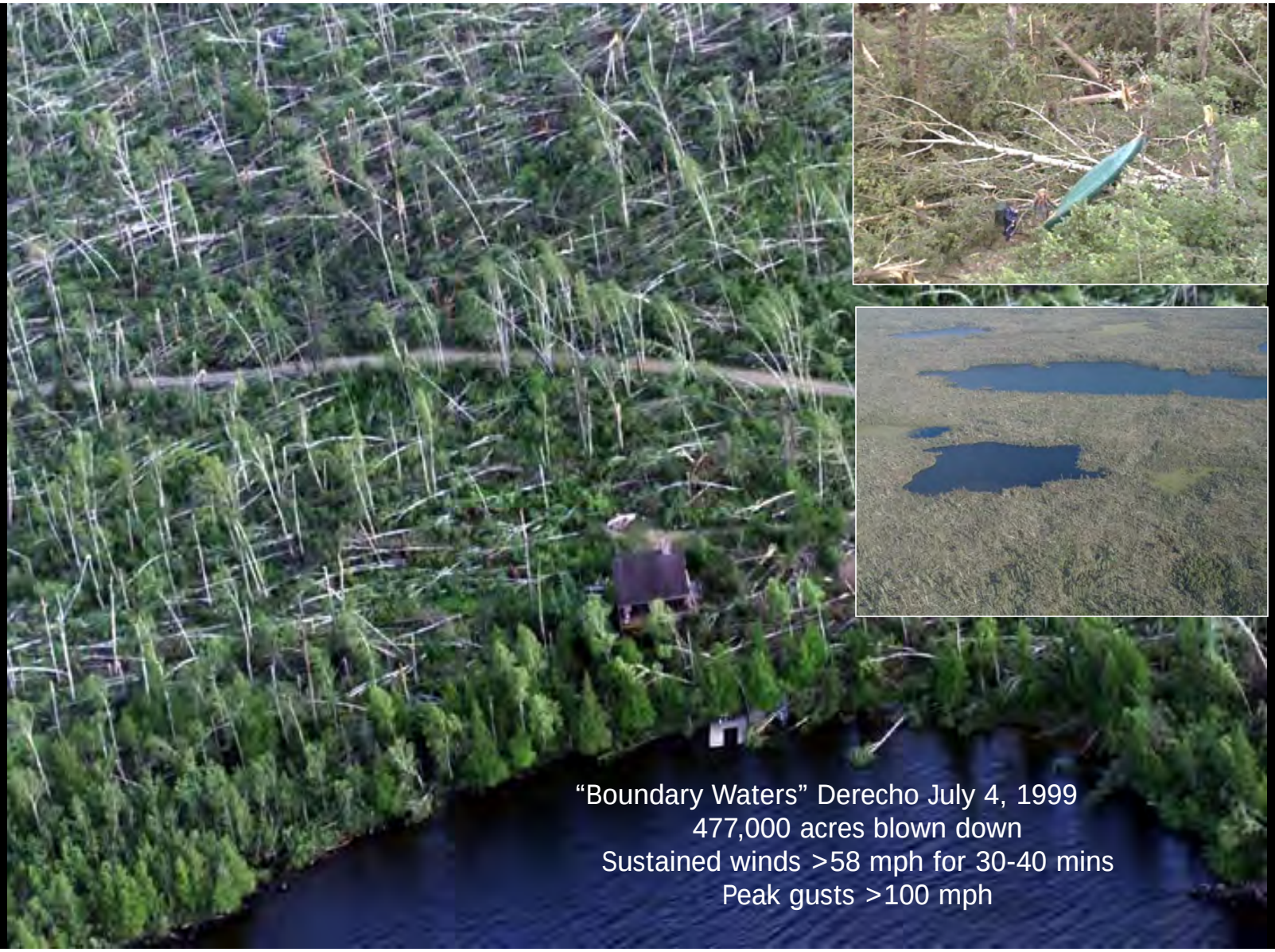




Visit the "About Derechos" page at the SPC:
https://bit.ly/3jSYr7o

2 dangers associated with derechos: The **duration** of the damaging winds and **widespread coverage** of such winds

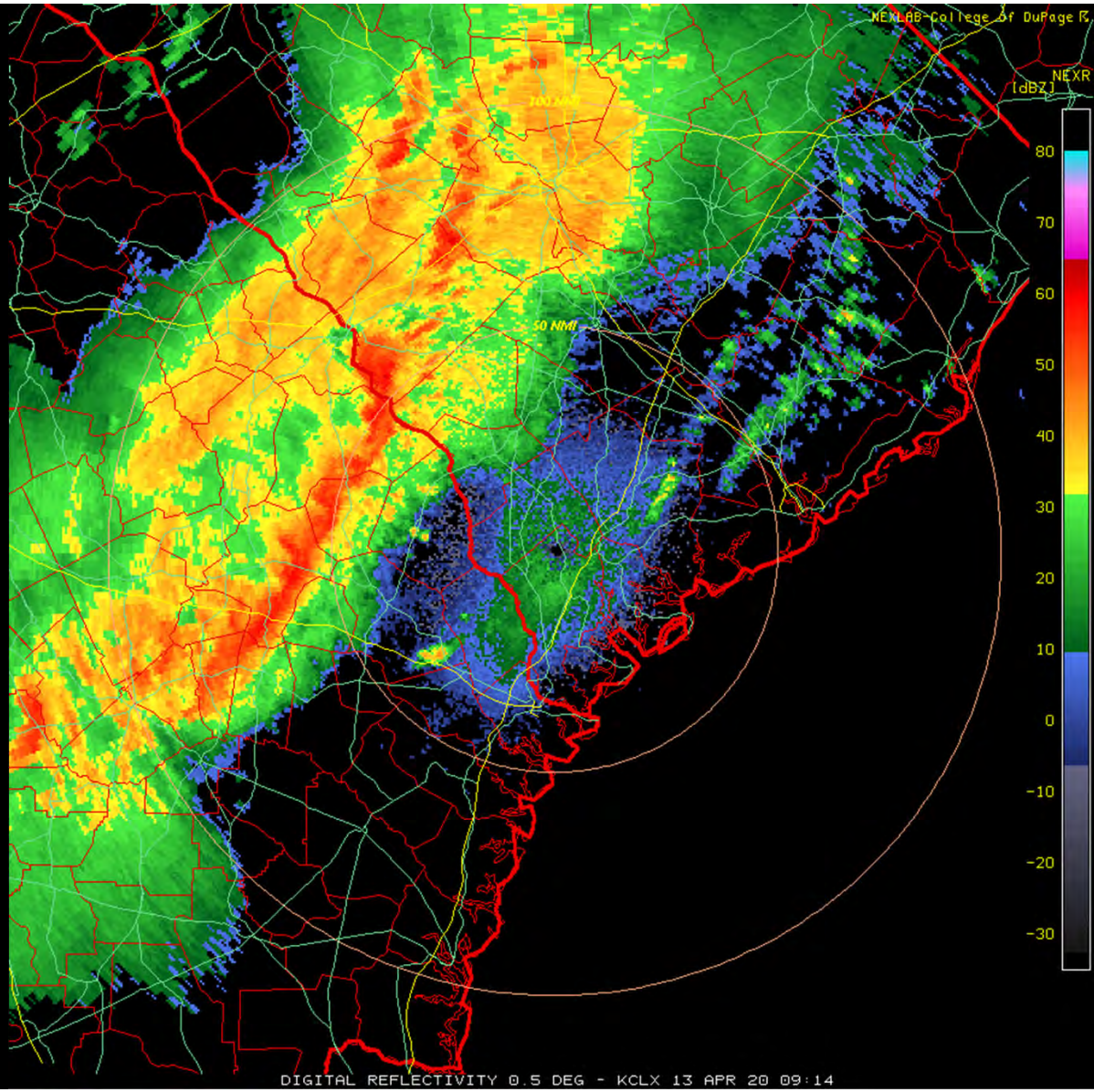
https://bit.ly/3BkJMra

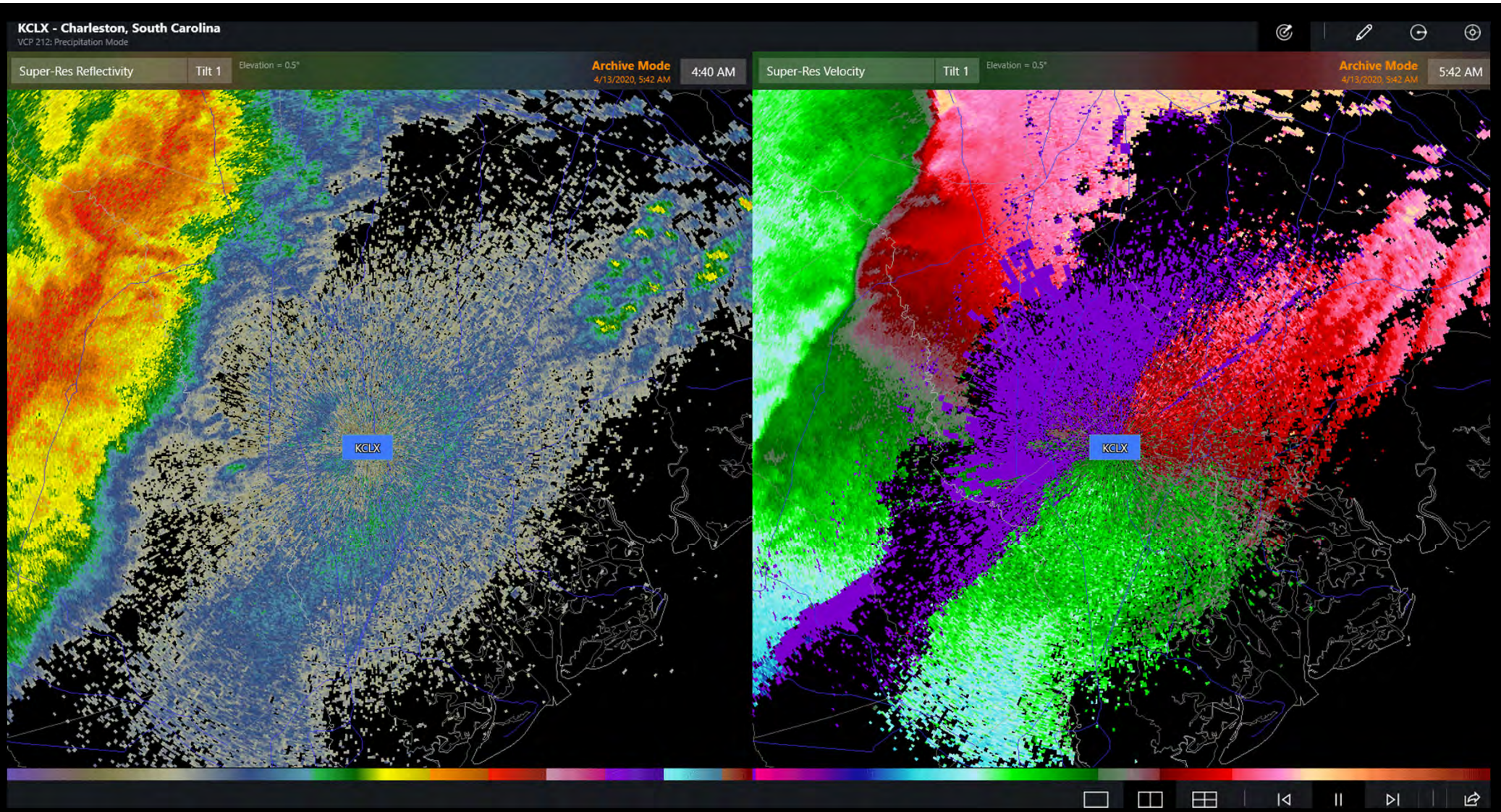


“Boundary Waters” Derecho July 4, 1999
477,000 acres blown down
Sustained winds >58 mph for 30-40 mins
Peak gusts >100 mph

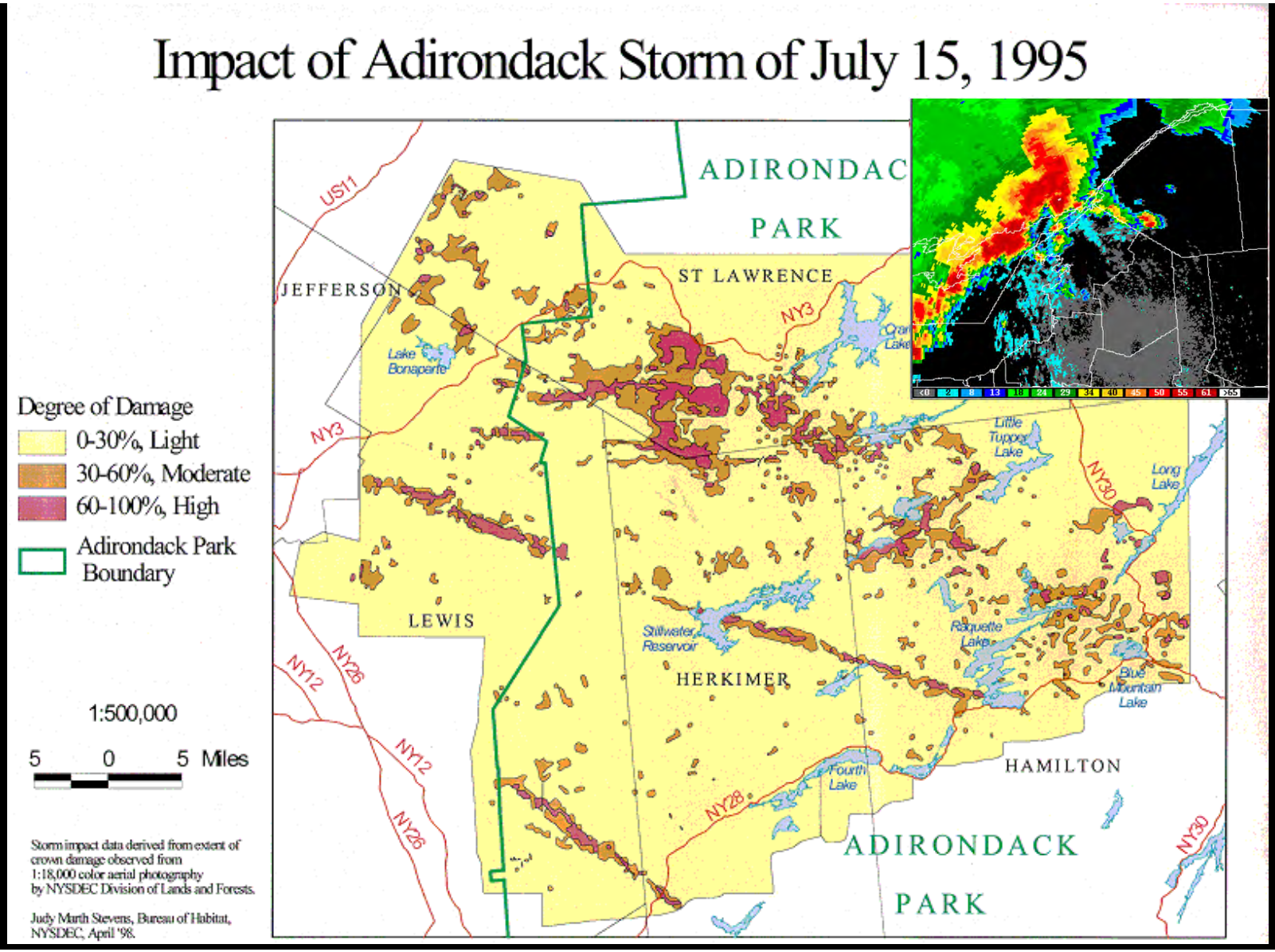
Sources of Damaging Winds

- Evaporation-cooled air
  - Sinks to ground and splashes out
- Rear-inflow jet
  - Takes strong winds with momentum in the mid-levels of the atmosphere and brings to the surface
- Embedded supercells
  - Unique and strong downdrafts




KCLX - Charleston, South Carolina
VCP 212: Precipitation Mode
Super-Res Reflectivity
Tilt 1
Elevation = 0.5°
Archive Mode
4/13/2020, 5:42 AM
4:40 AM
KCLX
Super-Res Velocity
Tilt 1
Elevation = 0.5°
Archive Mode
4/13/2020, 5:42 AM
5:42 AM
KCLX

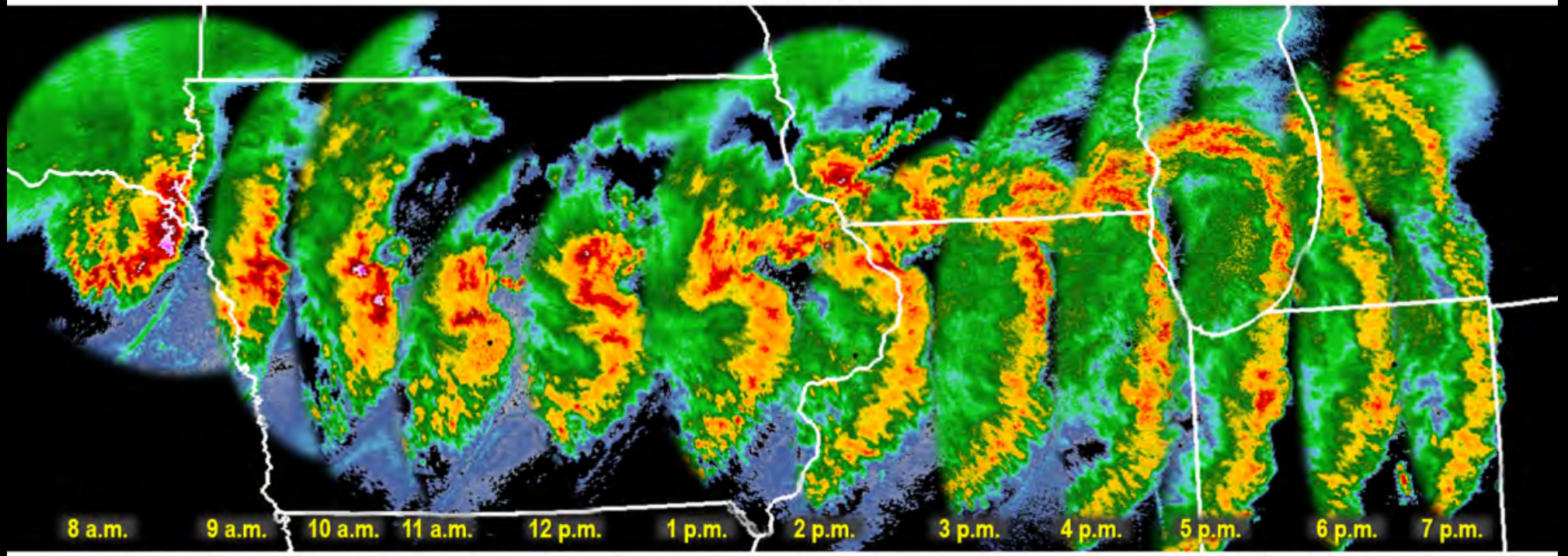
Impact of Adirondack Storm of July 15, 1995



EVENT	BEGIN DATE	END DATE	SUMMARY	CPI-ADJUSTED ESTIMATED COST *(IN BILLIONS)*	DEATHS
Hurricane Laura † *August 2020*	2020-08-27	2020-08-28	Hurricane Laura was a powerful category 4 that made landfall at Cameron Parish, in southwestern Louisiana on August 27. Winds up to 150 mph and storm surge in excess of 15 feet caused heavy damage along the coast and inland to the city of Lake Charles. Many broken water systems and a severely damaged electrical grid in southern Louisiana will slow the recovery process. Laura was the strongest hurricane (by maximum sustained windspeed at landfall) to hit Louisiana since the 1856 Last Island hurricane. Laura also had highest landfall wind speed to impact the U.S. since Hurricane Michael in 2018. There were additional impacts to surrounding states including Texas, Mississippi and Arkansas.	$19.7 CI	42
Western Wildfires - California, Oregon, Washington Firestorms † *Fall 2020*	2020-08-01	2020-12-30	A record-breaking U.S. wildfire season burned more than 10.2 million acres. California more than doubled its previous annual record for area burned (last set in 2018) with over 4.1 million acres. Five of the top six largest wildfires on record in California (dating to 1932) burned during August and September. The August Complex was the largest California wildfire, which began as 37 separate wildfires within the Mendocino National Forest, set off after storms caused >10,000 lightning strikes across Northern California. Approximately 10,500 structures were damaged or destroyed across California. Oregon also had historic levels of wildfire damage, as over 2,000 structures burned. These wildfires spread rapidly and destroyed several small towns in California, Oregon and Washington. Colorado also had a severe wildfire season, as its three largest wildfires on record burned during 2020. Dense wildfire smoke also produced hazardous air quality that affected millions of people that also included major cities for weeks. Hundreds of additional wildfires also burned across other Western states.	$17.1 CI	46
Central Severe Weather - Derecho † *August 2020*	2020-08-10	2020-08-10	A powerful derecho traveled from southeast South Dakota to Ohio, a path of 770 miles in 14 hours producing widespread winds greater than 100 mph. The states most affected included Iowa, Illinois, Minnesota, Indiana and Ohio. This derecho caused widespread damage to millions of acres of corn and soybean crops across central Iowa. There was also severe damage to homes, businesses and vehicles particularly in Cedar Rapids, Iowa. In addition, there were 15 tornadoes across northeastern Illinois several affecting the Chicago metropolitan area. This is the third severe weather event (since 1980) with inflation-adjusted costs over $10.0 ($10.4) billion joining the late-April and May 2011 tornado outbreaks across the Southeastern and Central states, respectively.	$11.5 CI	4

August 10, 2020 Derecho: Lowest Angle NWS Radar Reflectivity at One-Hour Time Steps

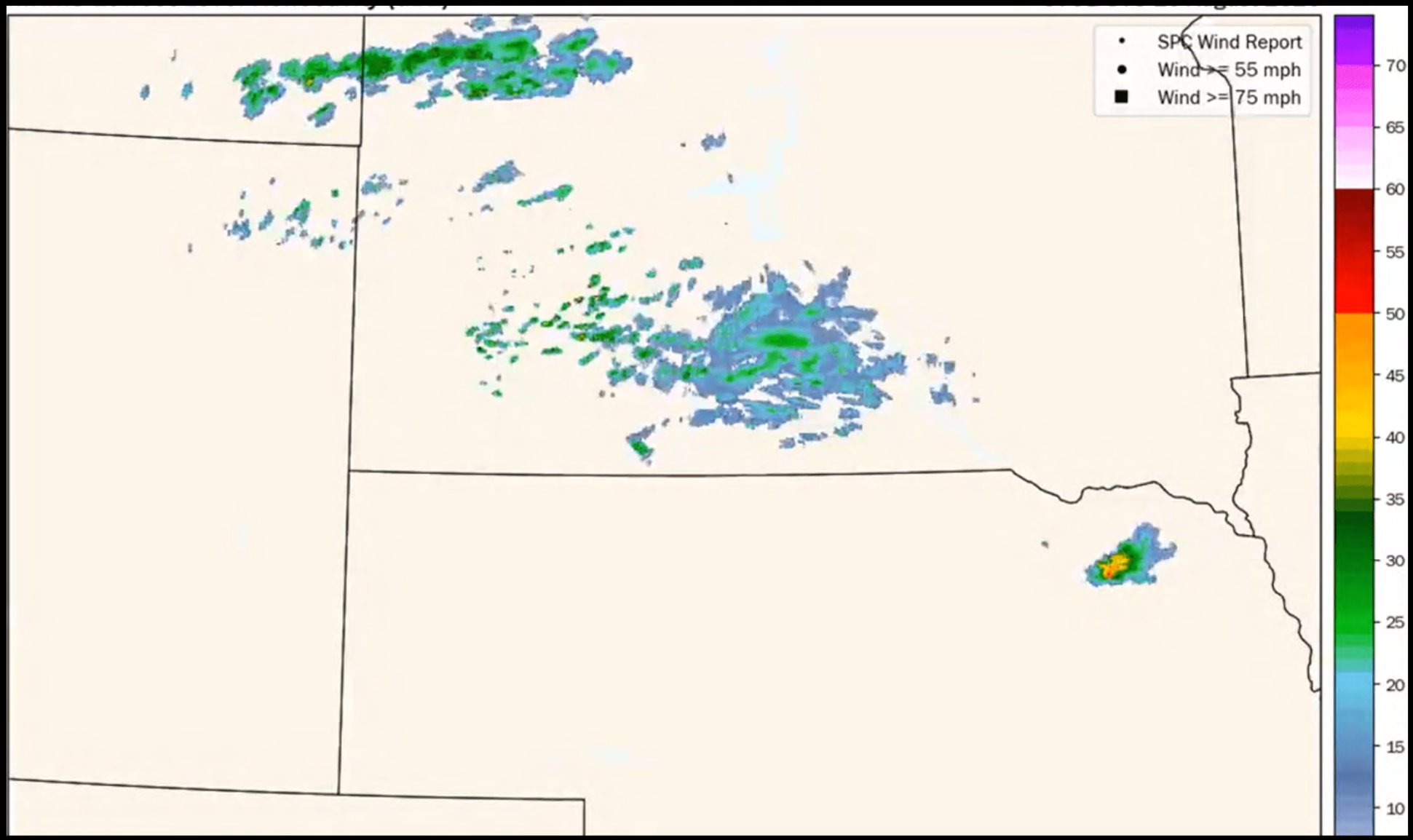
All times in CDT

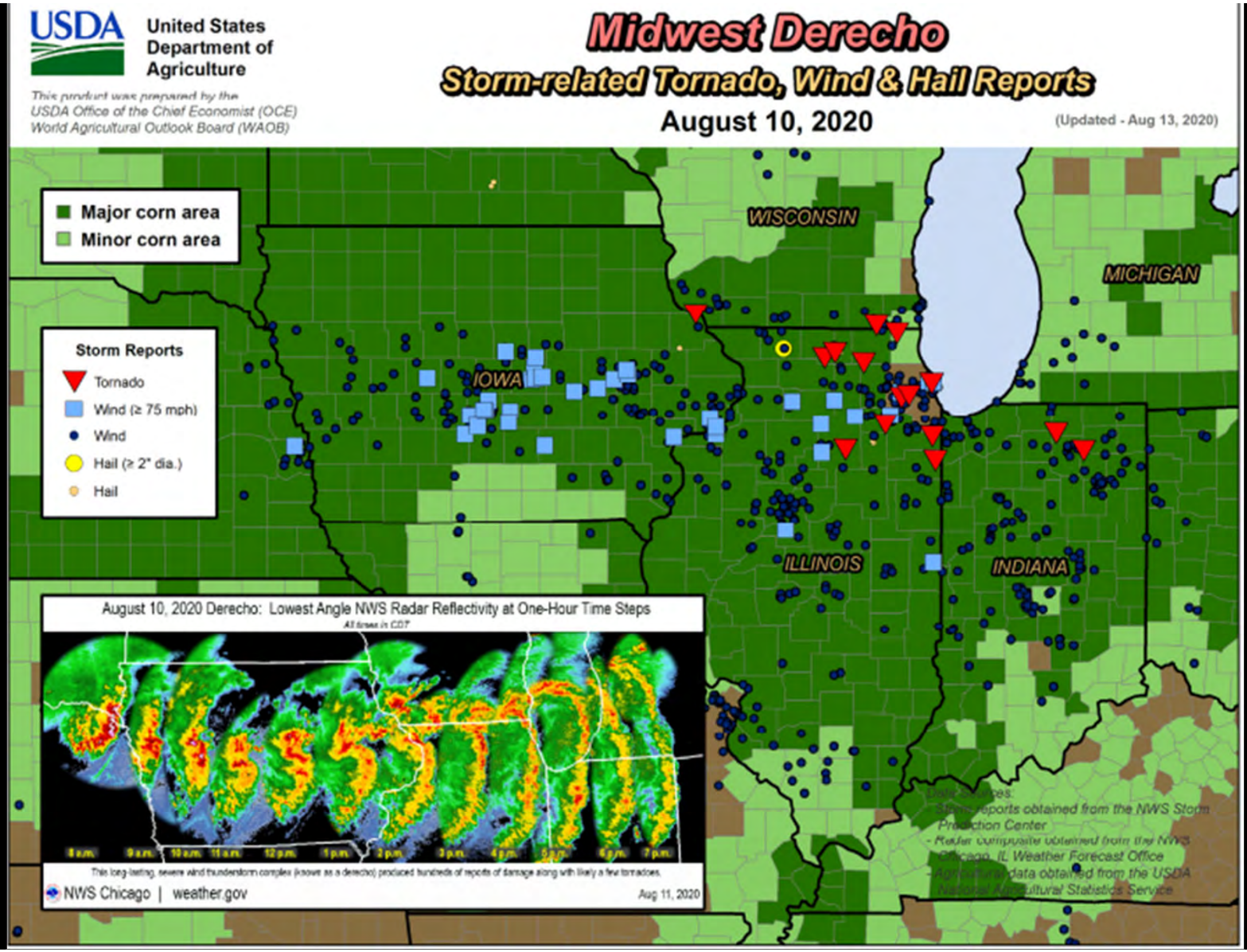


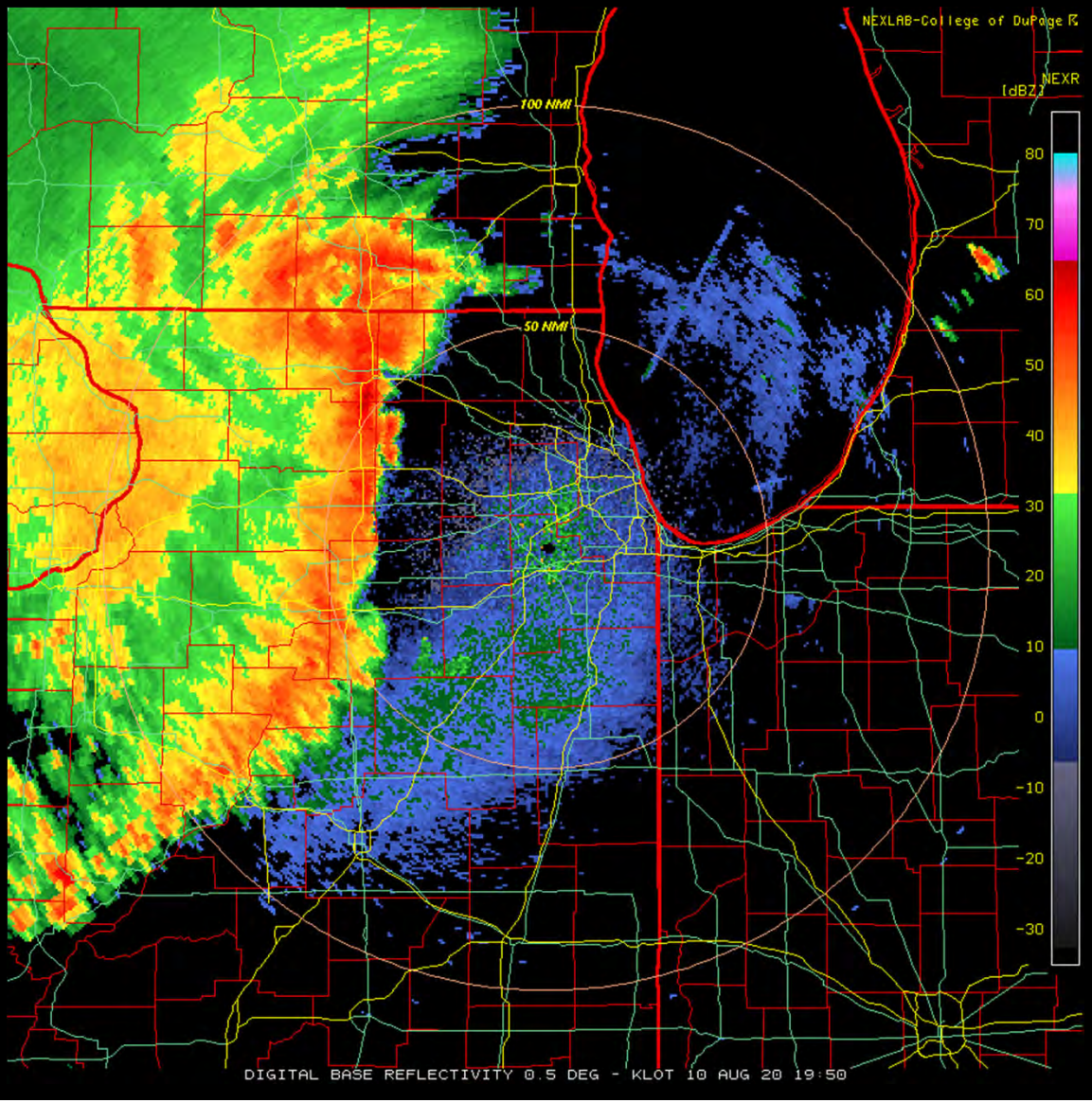
This long-lasting, severe wind thunderstorm complex (known as a derecho) produced hundreds of reports of damage along with likely a few tornadoes.

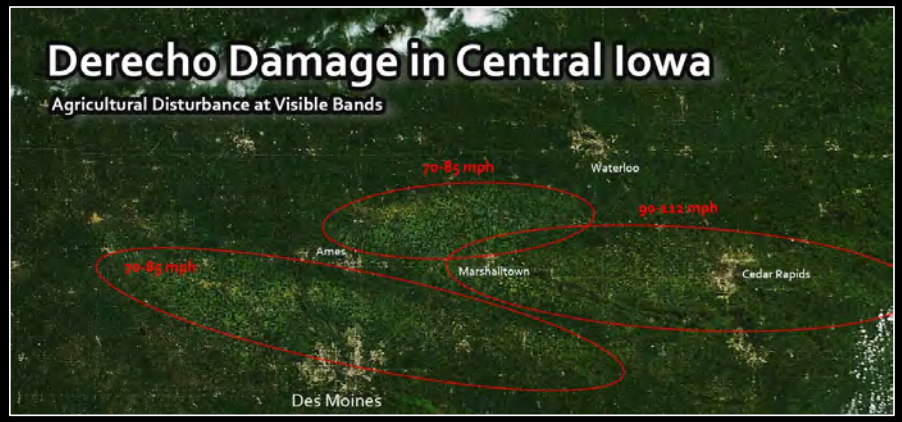
NWS Chicago | weather.gov

Aug 11, 2020

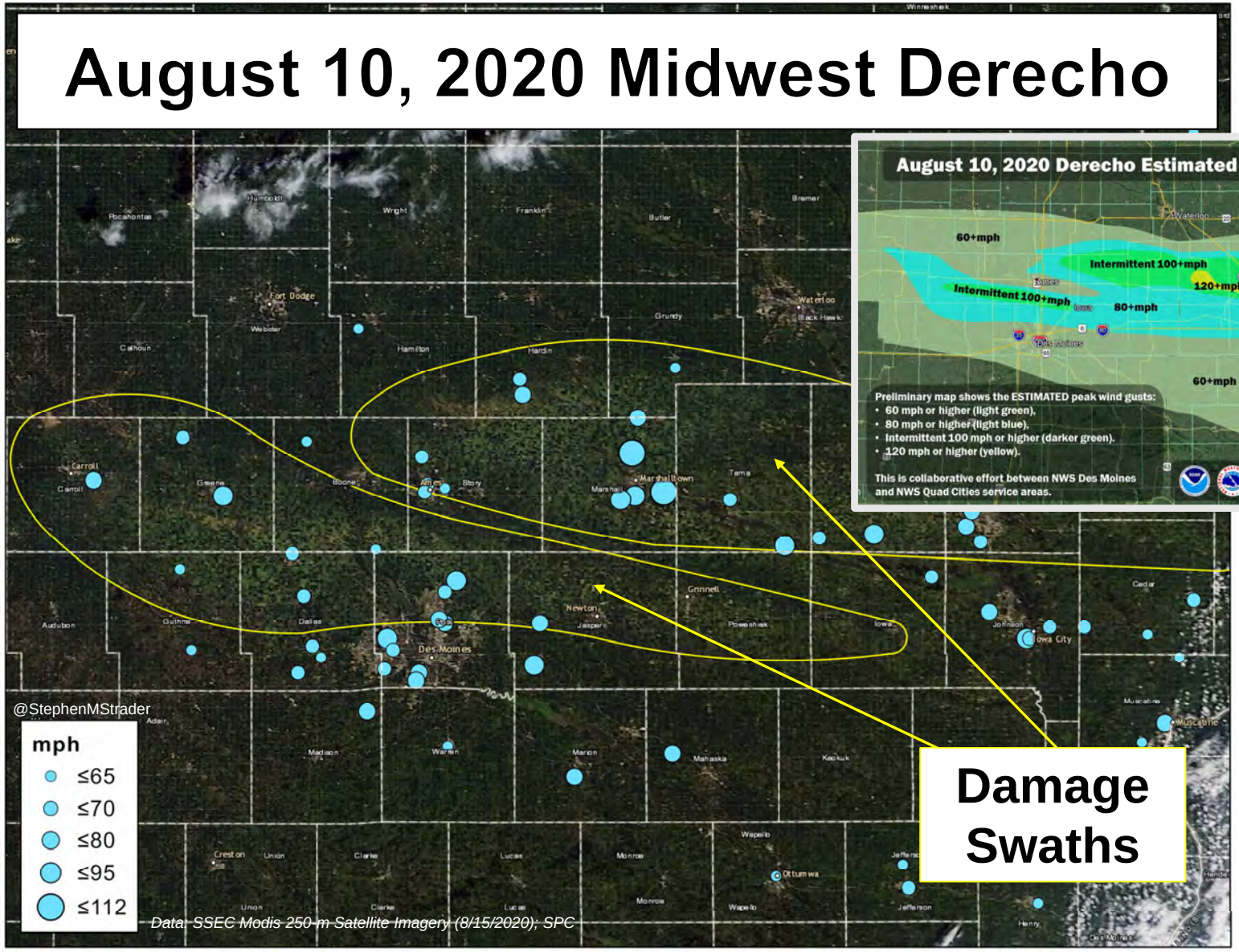

SPC Wind Report
Wind >= 55 mph
Wind >= 75 mph
70
65
60
55
50
45
40
35
30
25
20
15
10


USDA
United States Department of Agriculture
This product was prepared by the USDA Office of the Chief Economist (OCE) World Agricultural Outlook Board (WAOB)
Midwest Derecho
Storm-related Tornado, Wind & Hail Reports
August 10, 2020
(Updated - Aug 13, 2020)
Major corn area
Minor corn area
Storm Reports
Tornado
Wind (≥ 75 mph)
Wind
Hail (≥ 2" dia.)
Hail
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
INDIANA
August 10, 2020 Derecho: Lowest Angle NWS Radar Reflectivity at One-Hour Time Steps
All times in CDT
8 a.m. 9 a.m. 10 a.m. 11 a.m. 12 p.m. 1 p.m. 2 p.m. 3 p.m. 4 p.m. 5 p.m. 6 p.m. 7 p.m.
This long-lasting, severe wind thunderstorm complex (known as a derecho) produced hundreds of reports of damage along with likely a few tornadoes.
NWS Chicago | weather.gov
Aug 11, 2020
Data Sources:
- Storm reports obtained from the NWS Storm Prediction Center
- Radar composite obtained from the NWS Chicago, IL Weather Forecast Office
- Agricultural data obtained from the USDA National Agricultural Statistics Service

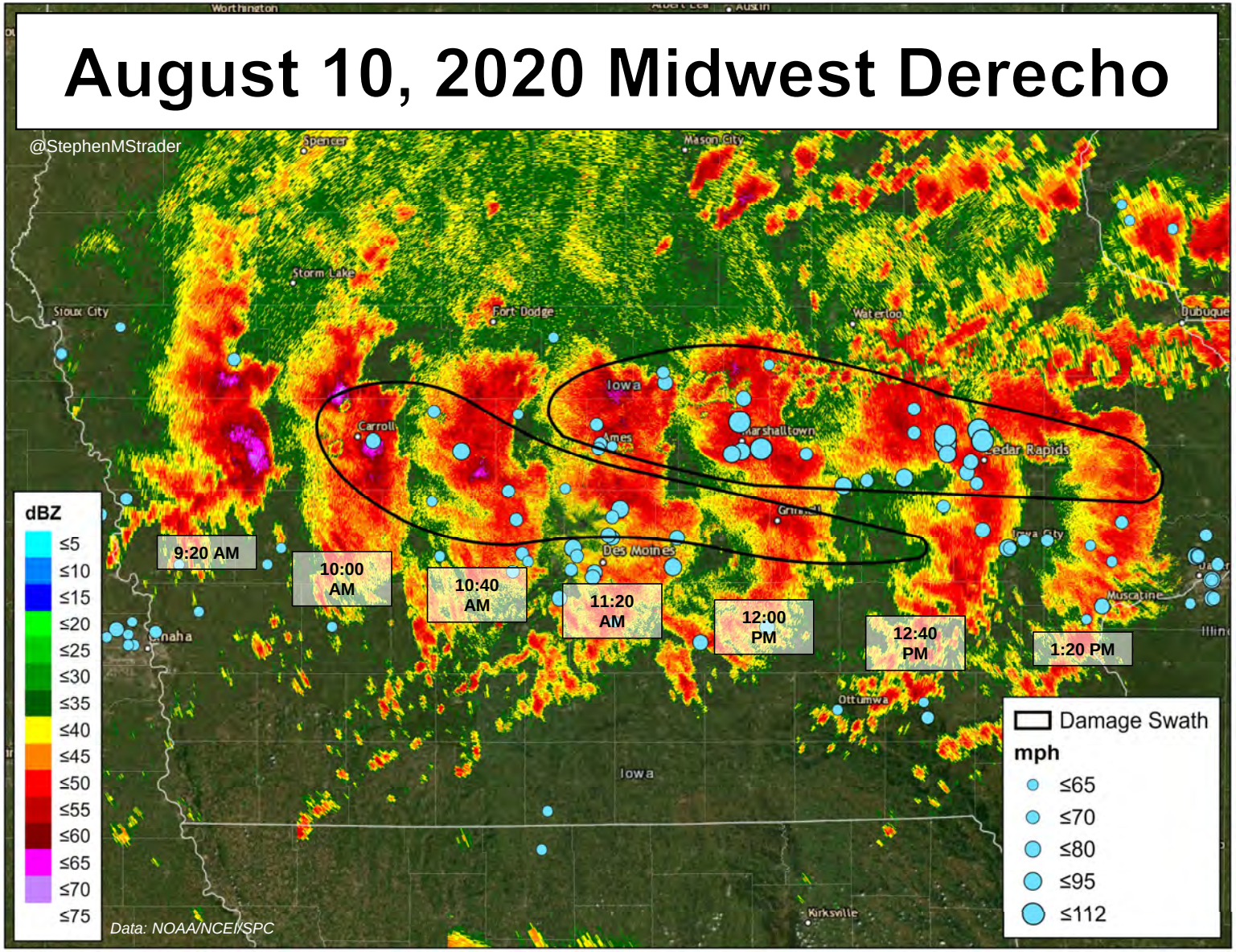

NEXLAB-College of DuPage
NEXR
[dBZ]
100 NMI
50 NMI
80
70
60
50
40
30
20
10
0
-10
-20
-30
DIGITAL BASE REFLECTIVITY 0.5 DEG - KLOT 10 AUG 20 19:50


Derecho Damage in Central Iowa
Agricultural Disturbance at Visible Bands
70-85 mph
Waterloo
90-112 mph
Ames
70-85 mph
Marshalltown
Cedar Rapids
Des Moines

August 10, 2020 Midwest Derecho



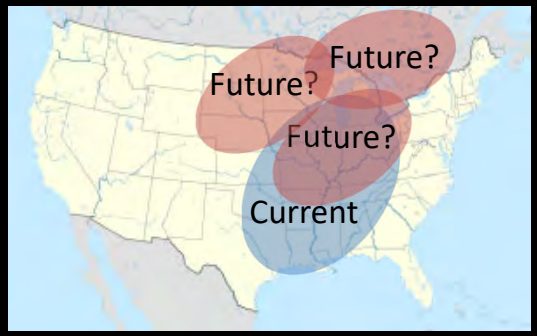
August 10, 2020 Midwest Derecho

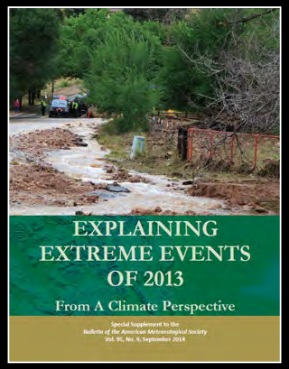



FUTURE
PAST

Is the derecho climatology changing?

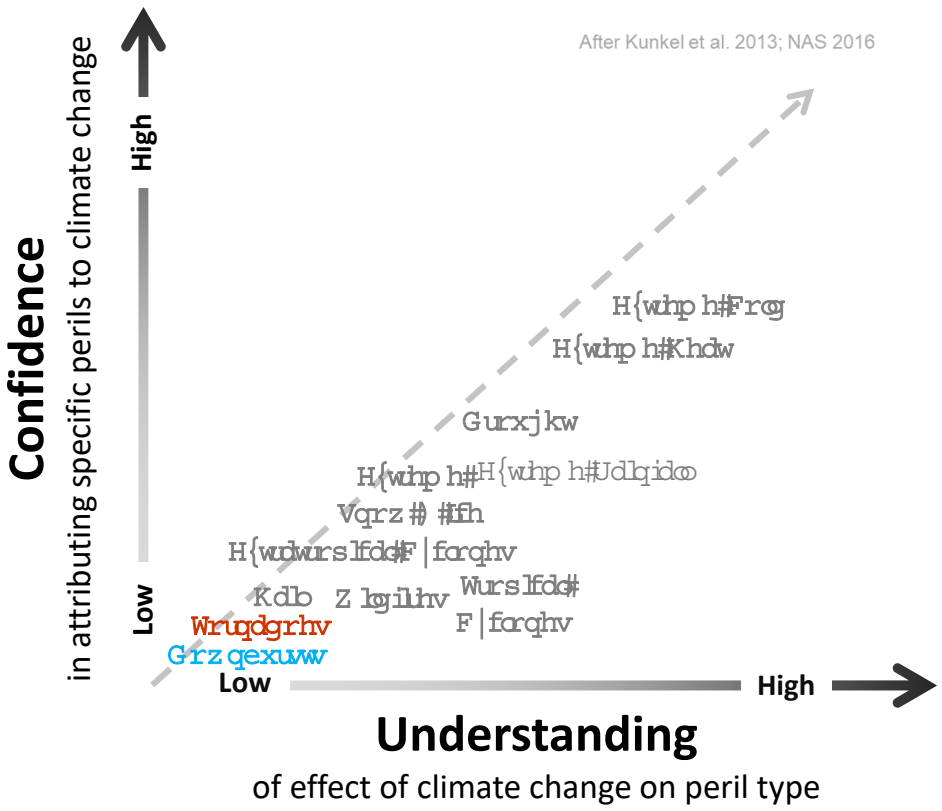
- Can climate change be blamed?
  - Blamed for what?
- Framing it as cause vs. contributor
- Difficulty of attribution





BAMS (2011-21)

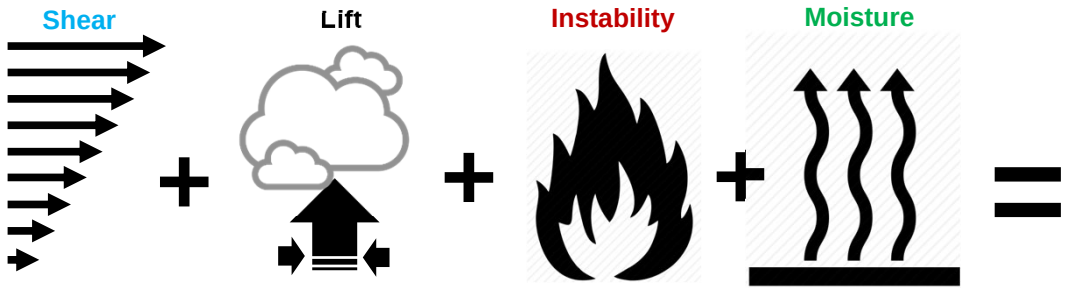
Climate Change Attribution



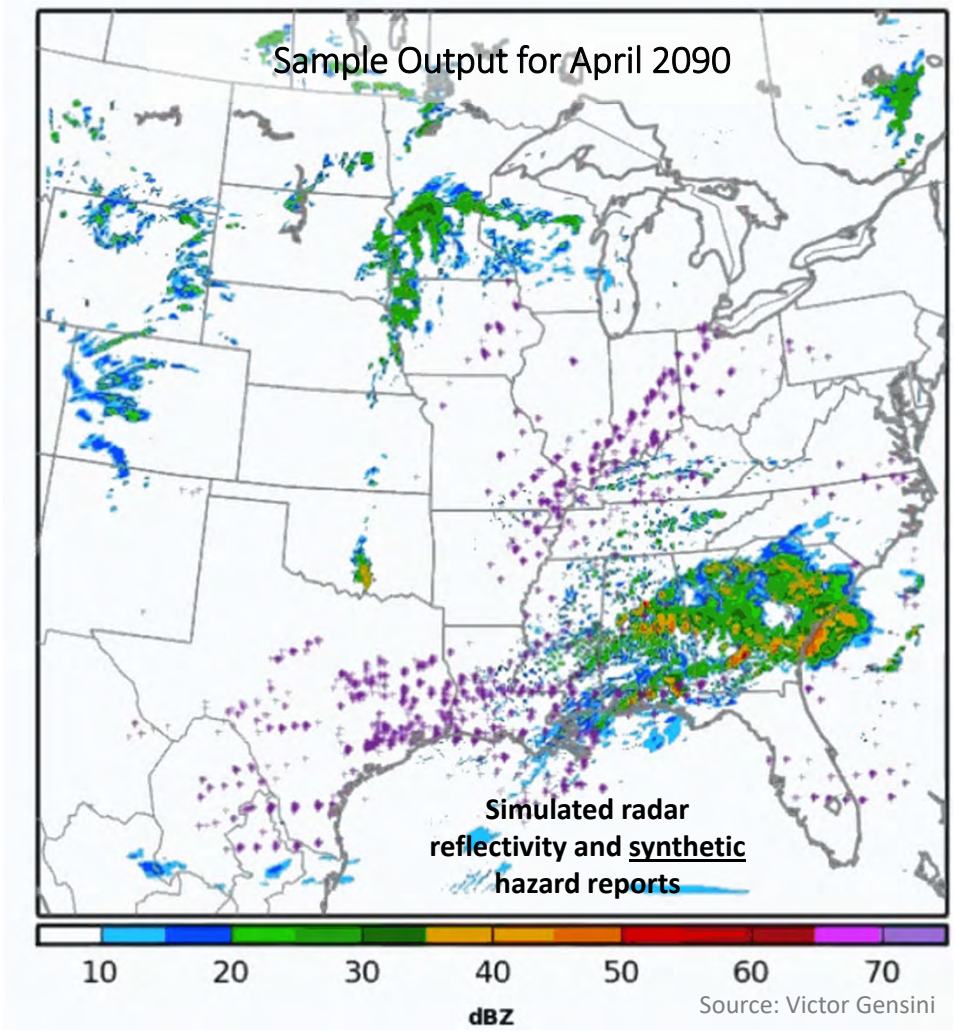
More severe storms?

- Limited evidence *to date*
  - *"No clear trend in the annual number of tornadoes"* -Brooks et al. 2014
  - *"Few robust trends are seen over recent decades"* -Tippet et al. 2015
  - *"Confidence in past trends for hail and winds… is low"* -U.S. GCRP 2017
- Some *eastward* shift in tornado supportive environs
  - Gensini and Brooks 2018; Tang et al. 2019
- More "clustering" of tors
  - decreasing days per year with tors but increasing days with multiple tors –Brooks et al. 2014

Future of Storms: Implicit View



Future of Storms: Explicit View



Models suggest …

- increasing frequency of severe storm environments in future
- increasing variability
- earlier season start, and running later
- possible increase in “intense” storms

- Issues and concerns:
  - increasing capping inversion, decreasing number of extratropical cyclones, etc., may reduce *realization* of environments?
  - Storm type?

There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.

(Donald Rumsfeld)

The future?

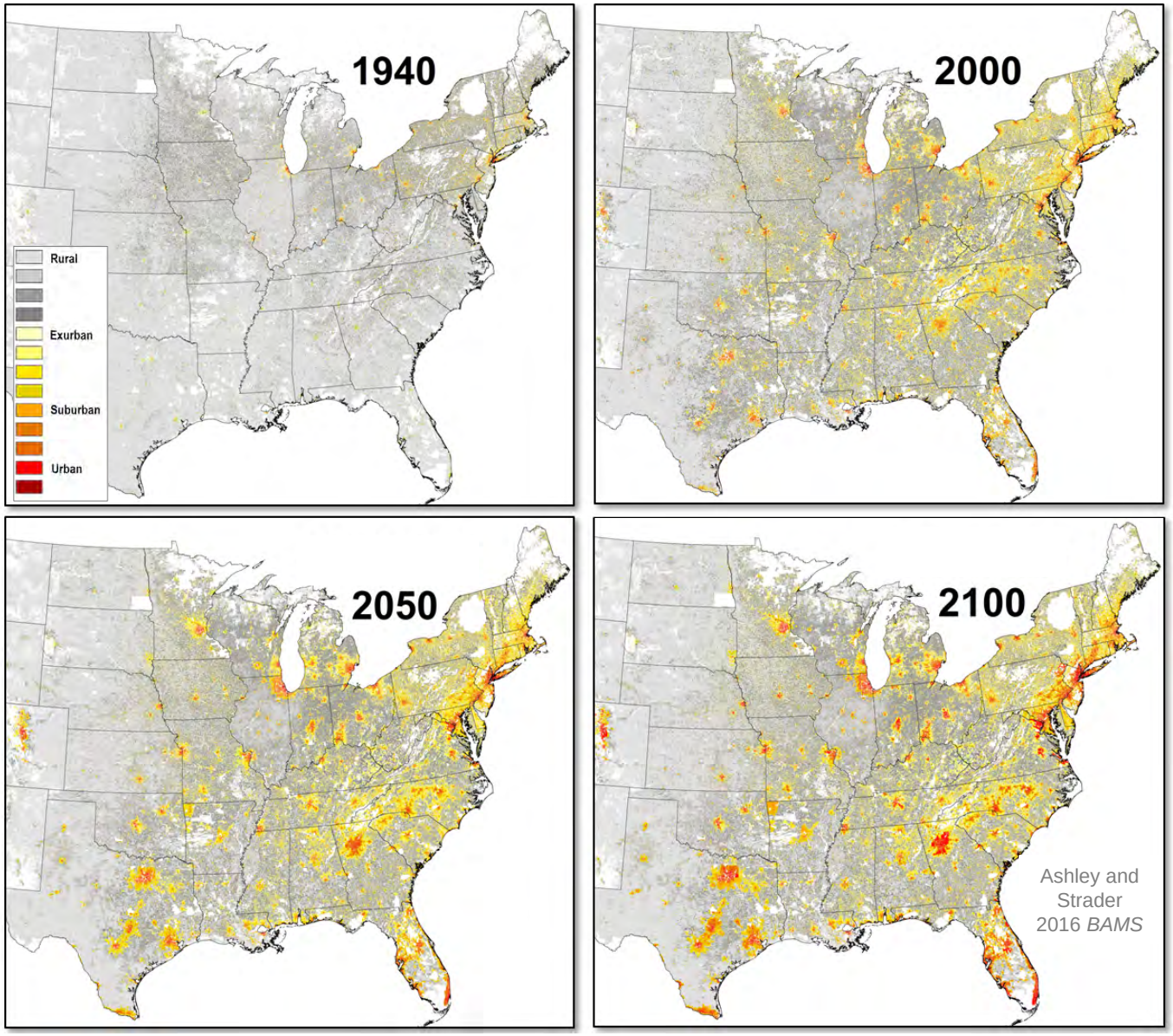
Population more than doubled the past 80 years

Housing increased well over 300%

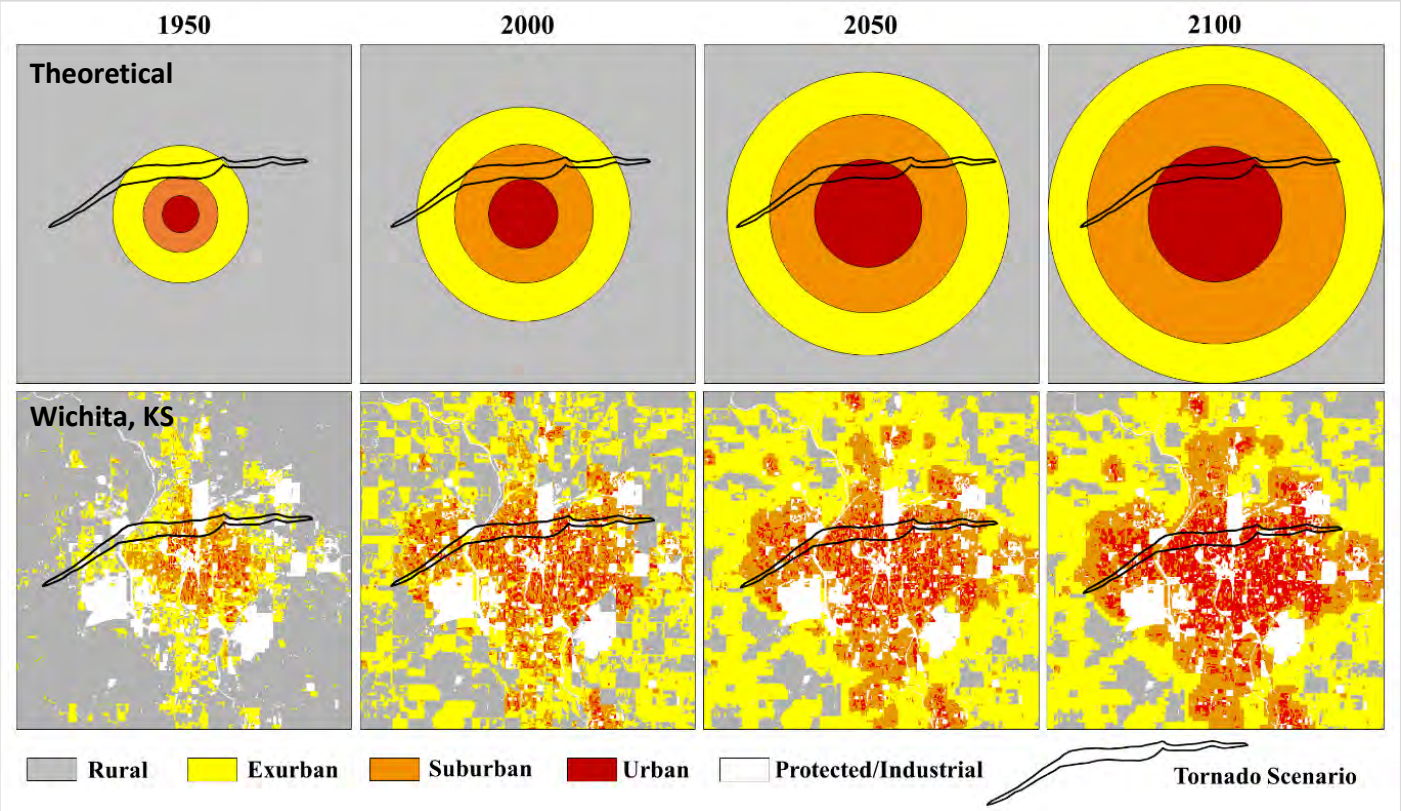
Transitioned from a rural to urban to suburban development character

Urban footprint 5X

Escalated exposure of population and built environment to hazards



Expanding Bull's Eye Effect

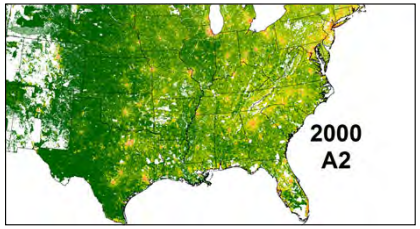


"Targets"—i.e., humans and their possessions—of hazards are increasing as populations grow ... and spread

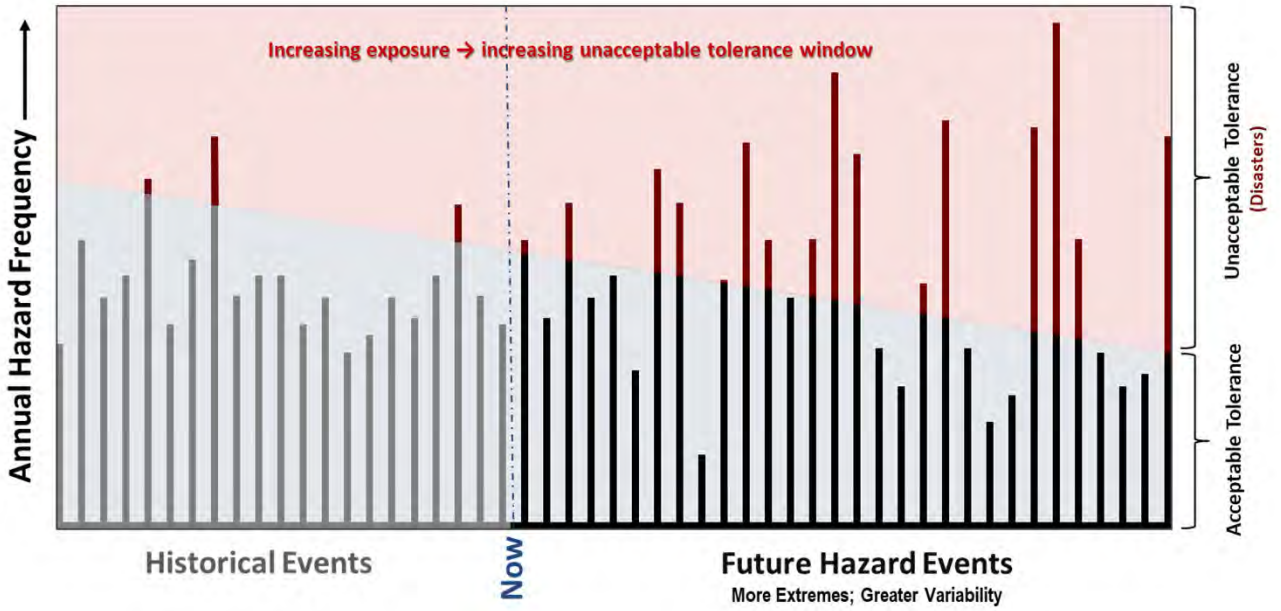
Ashley et al. 2014 *WCS*; Strader and Ashley 2015 *Weatherwise*

chubasco.niu.edu/ebe.htm

- Climate change may modify severe storm seasonality, frequency, magnitude, and/or location; but, **impacts and disasters are social constructs**
  - Overlapping risk and vulnerabilities



- Increasing magnitude—and spread!—of built-environment exposure is the major contributing factor to the impacts/disasters problem
- Individual odds of being affected by a severe storm may not be changing much, but odds of a severe storm hitting something or someone are increasing significantly



Questions?

https://bit.ly/3jSYr7o

ABOUT DERECHOS

Part of the NOAA-NWS-NCEP Storm Prediction Center web site
Prepared by Stephen F. Corfidi, Jeffry S. Evans, and Robert H. Johns (with the help of many others)

For feedback on "About Derechos," contact Stephen Corfidi

Last updated May 15, 2018; see What's New for recent additions and changes.

"The Line Storm," by John Steuart Curry, 1897-1946, a painting possibly inspired by the approach of a derecho-producing storm in Curry's home state of Kansas. (Oil and tempera on panel, 1934; Collection of Sidney Howard, New York; Lithograph in Smithsonian American Art Museum, Washington, D.C.)

Gust front "shelf cloud" (or "arcus") on the leading edge of a derecho-producing convective system. The photo was taken on the evening of July 10, 2008 in Hampshire, Illinois as the storm neared the Chicago metropolitan area. The derecho had formed around noon in southern Minnesota. (Courtesy of Brittney Misialek)