A photograph of a control room with several computer monitors. The monitors display various weather-related data, including maps with color-coded regions (red, green, blue) and numerical data. The room is dimly lit, with the primary light source being the screens. The text '1967-2017: Evolving Tornado Prediction' is overlaid in large, bold, yellow font on the top left of the image.

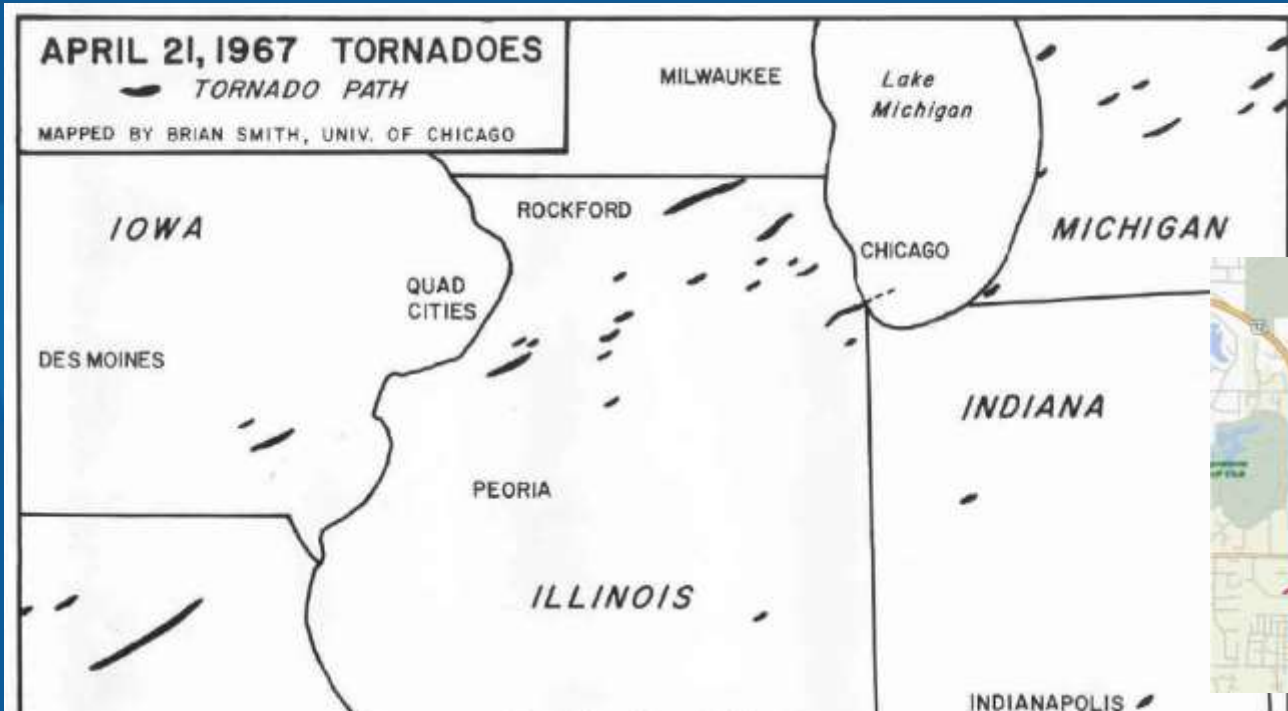
# 1967-2017: Evolving Tornado Prediction

**Edward Fenelon, NOAA/NWS Chicago, IL**

**Fermi-Lab/WGN Severe Weather Seminar – April 8, 2017**



# Northern Illinois' Worst Tornado Disaster





# Advancements since 1967

- Weather Radar
- Weather Satellites
- Atmospheric Computer Models
- Weather Research and Understanding
- Communications
  - Storm Spotters
  - Amateur Radio
  - Social Media, Smart Phones
- Collaborative Weather Enterprise
- Together we are saving lives!



# Weather Radar - 1967



Whiton et al. WAF 1998

**WSR-57 Radar: Single PPI display, manual RHI to the right, used cathode ray tube technology employing vacuum tubes, electron guns, and a phosphorescent screen.**



# Weather Radar - 1967



Chicago Daily News  
Oak Lawn Public Library

Radar image from the moment the Belvidere tornado was at its peak.

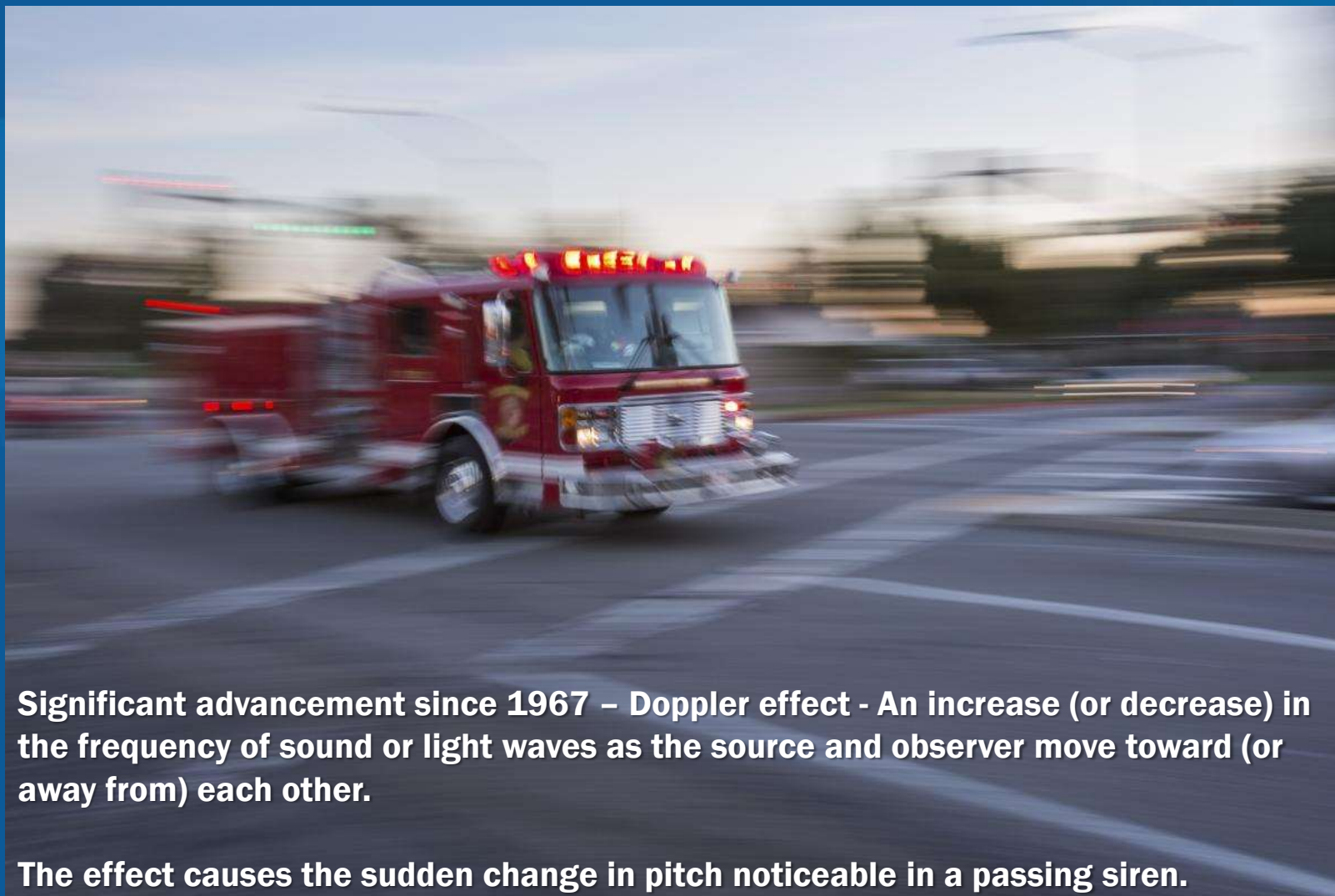


Weather Radar 1967 – 2017

# Doppler Effect



# Weather Radar 1967 – 2017



**Significant advancement since 1967 – Doppler effect - An increase (or decrease) in the frequency of sound or light waves as the source and observer move toward (or away from) each other.**

**The effect causes the sudden change in pitch noticeable in a passing siren.**



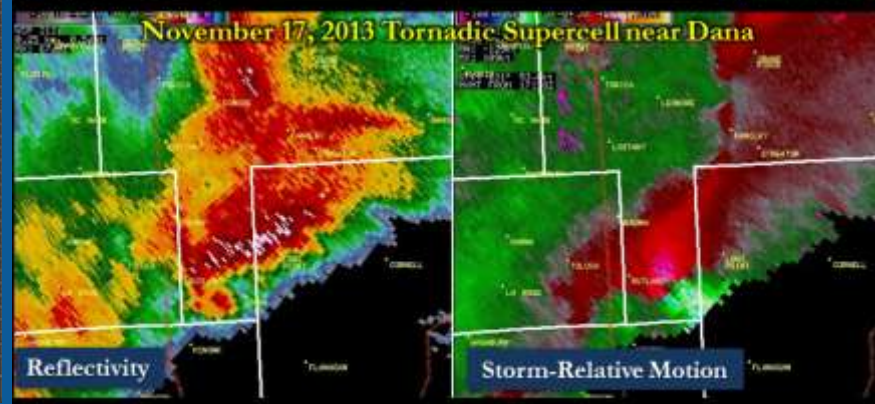
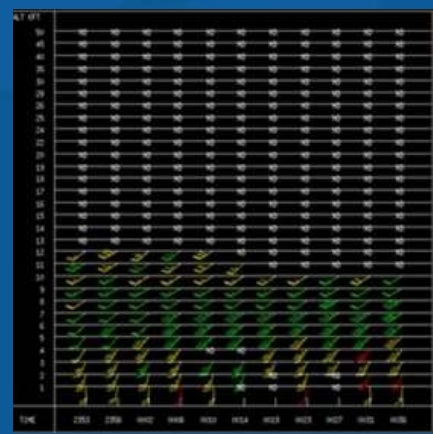
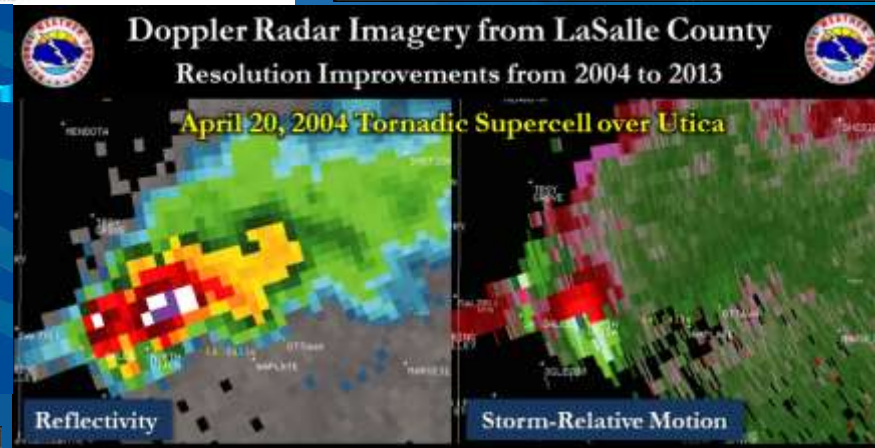
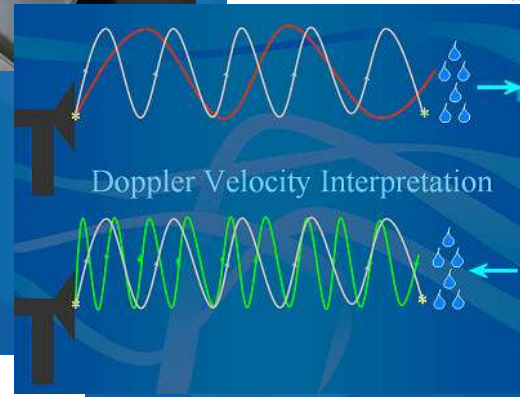
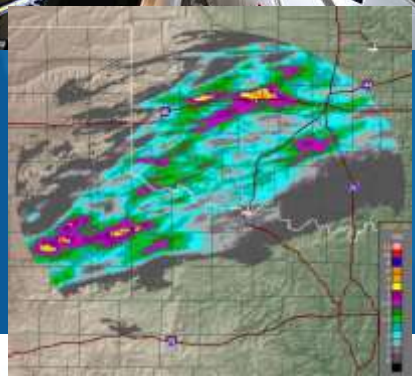
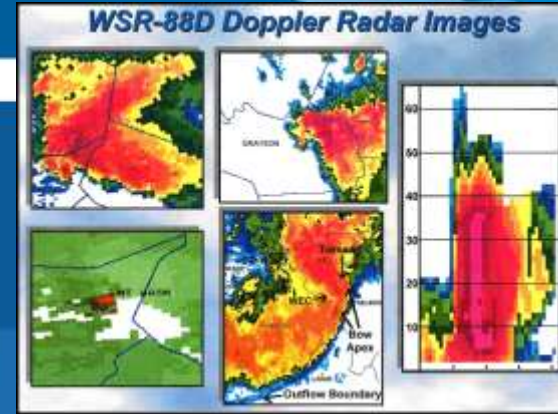
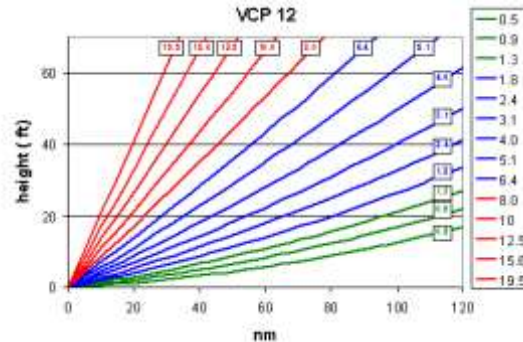
# Weather Radar 1967 - 2017







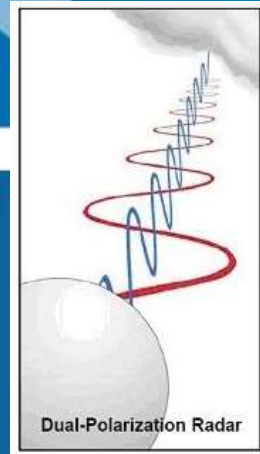
# Weather Radar - 2017



Both taken from NWS Chicago Doppler Radar 0.5° angle at comparable range from radar.

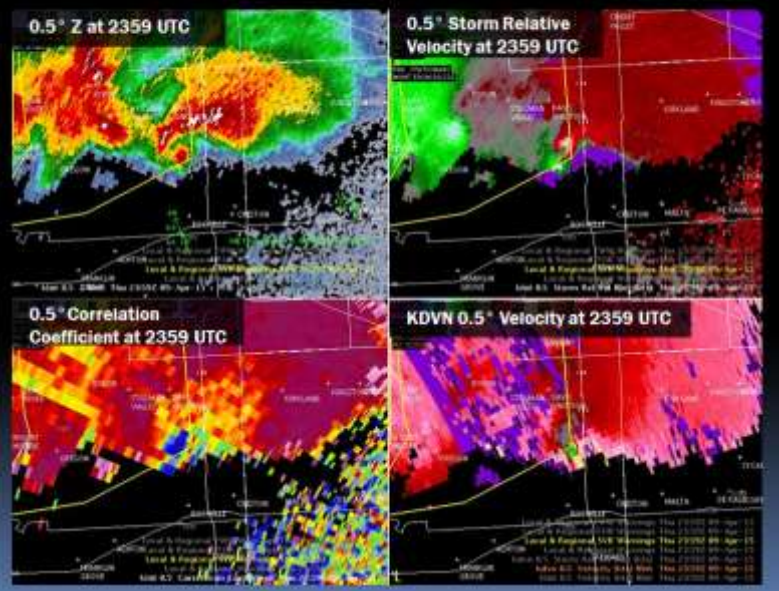


# Weather Radar - 2017



Dual-Polarization Radar

## What Meteorologists Saw on Radar 4/9/15 High End EF-4 Tornado



## Dual Polarization



[Link to GIF](#)

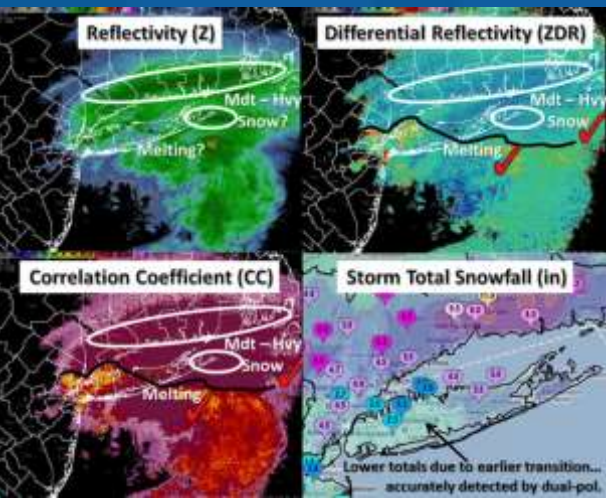
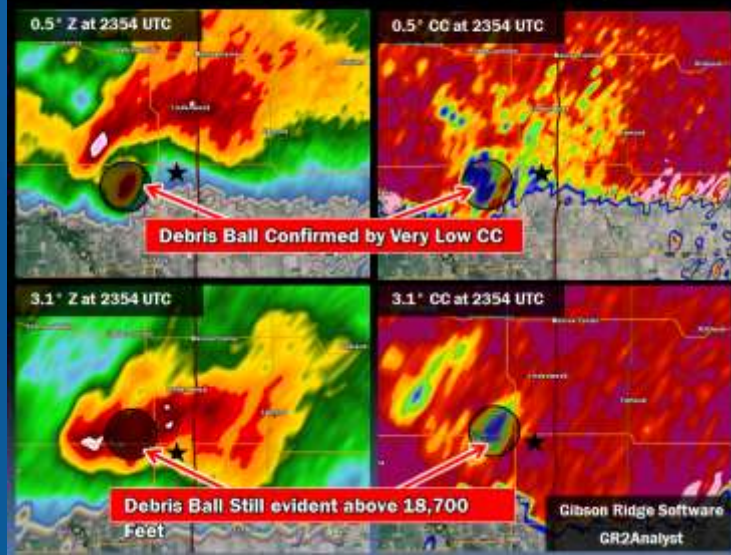
**WSR-88D Volume Coverage Pattern (VCP) Improvement Initiatives**

**VCP 215**

- Improved (Best) Vertical Coverage
- SZ-2 Doppler Processing
- Data Quality Equivalent to VCP 21
- Completes in 6 minutes

Implement Common Elevation Clear-Air VCP  
Implement Common Elevation Improved General Surveillance VCP  
Reduce the Total Number of VCPs

## Dual Polarization Radar 4/9/15



### SAILS

Supplemental Adaptive Intra-Volume Low-Level Scan

*A New Way Doppler Radar Scans the Sky*

**How Should This Help?**

- Weak, short-lived tornadoes are the most difficult to predict and detect.
- Additional low-level radar scans will be crucial in seeing tornado formation.

- The radar starts at the lowest elevation and scans up through the sky for about two minutes.
- After scanning the middle elevation, the radar goes back to scan the lowest elevation again.
- The radar then returns to the middle elevation to scan up to the highest elevation.

Total Time to Complete Steps 1-3: About 2 Minutes

www.weather.gov

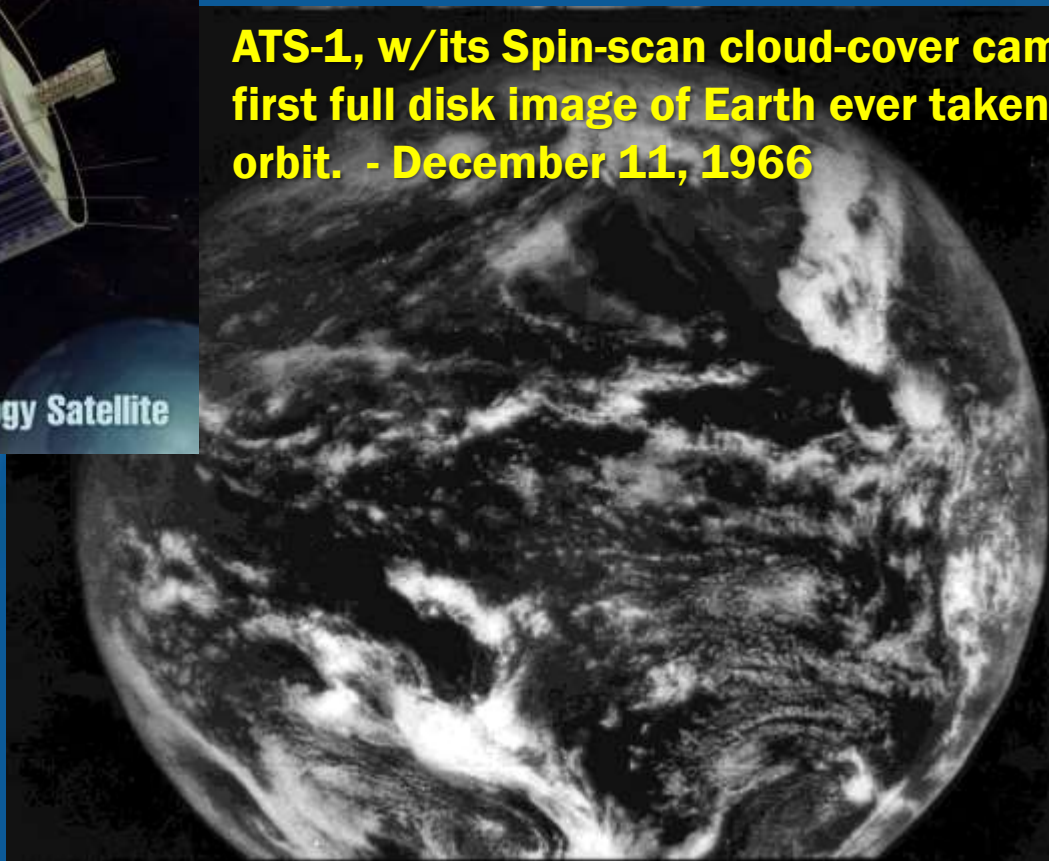
Gibson Ridge Software  
GR2Analyst



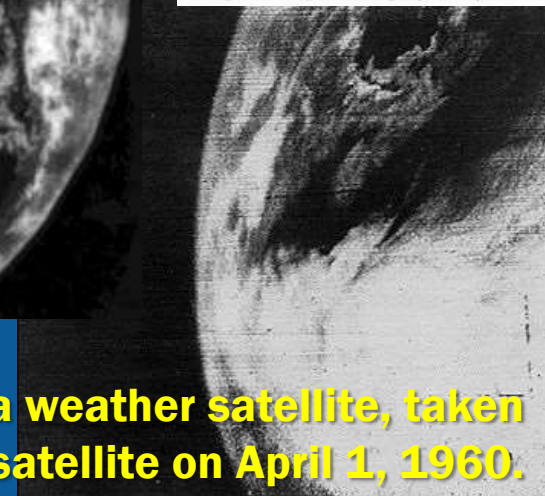
# Weather Satellite - 1967



**ATS-1, w/its Spin-scan cloud-cover camera, provided the first full disk image of Earth ever taken from geostationary orbit. - December 11, 1966**



**The first picture of Earth from a weather satellite, taken by the TIROS-1 satellite on April 1, 1960.**





# Weather Satellite - 1967

[Link to GIF](#)

Satellite Loop from ATS 3 (Applications Technology Satellite Launched 11.5.1967)  
Early satellite images were rough and showed little detail!



# Weather Satellites - 2017

**GOES  
R/16**

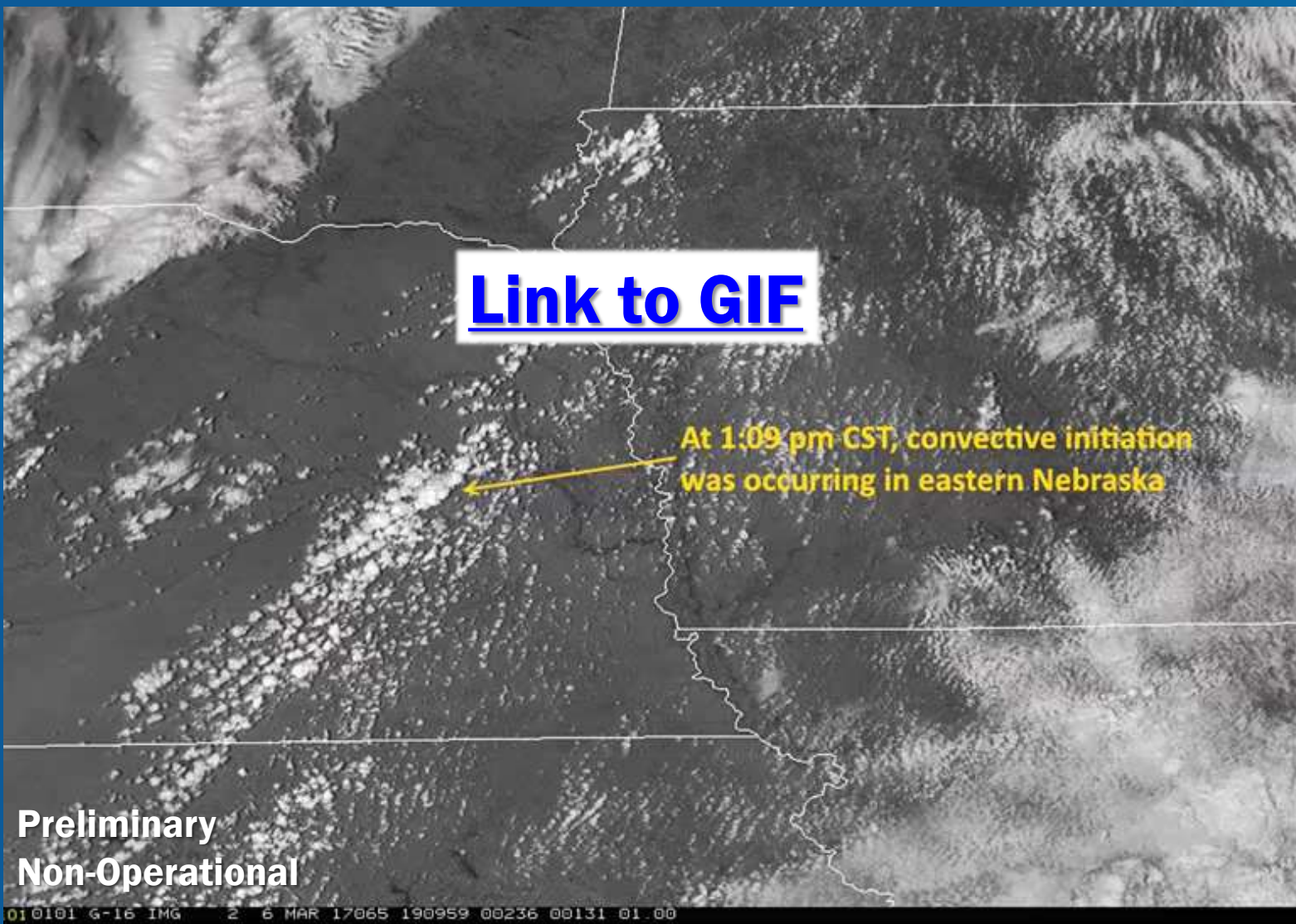


**“A  
whole  
new  
world!”**

**Preliminary  
Non-Operational**



# Weather Satellites - 2017



[Link to GIF](#)

At 1:09 pm CST, convective initiation was occurring in eastern Nebraska

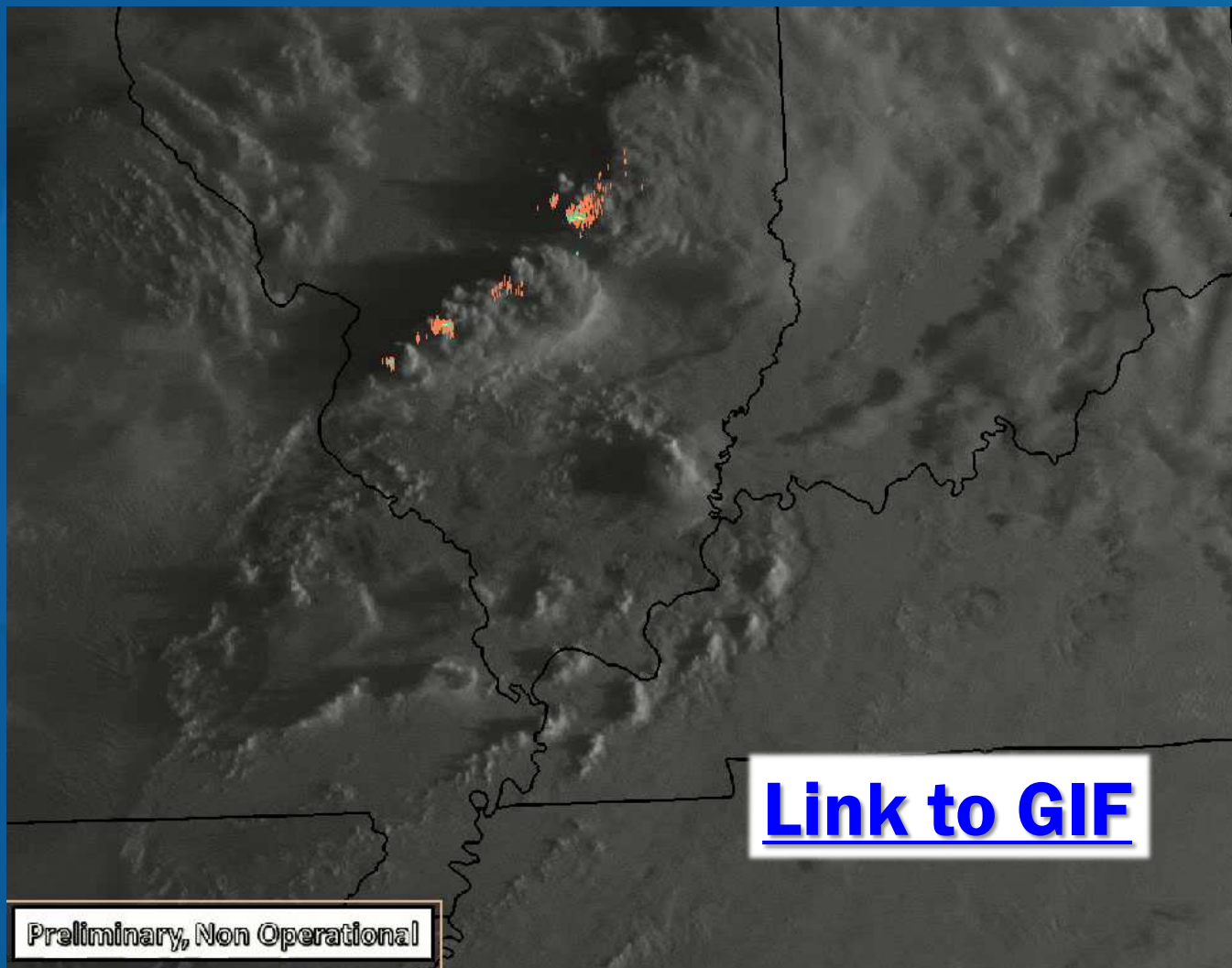
Preliminary  
Non-Operational

010101 G-16 IMG 2 6 MAR 17065 190959 00236 00131 01.00



# Weather Satellites - 2017

**GOES-16 Visible Satellite Loop March 17, 2017  
Overlaid with 1-Minute Lightning Data (non-GOES)**



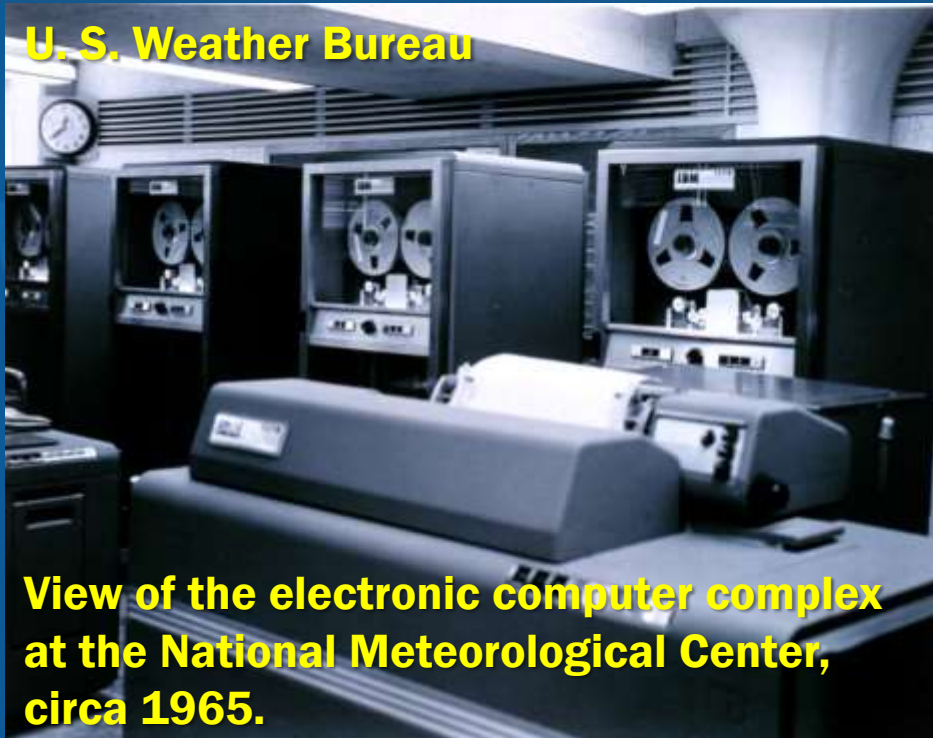
Preliminary, Non Operational

[Link to GIF](#)



# Atmospheric Models - 1967

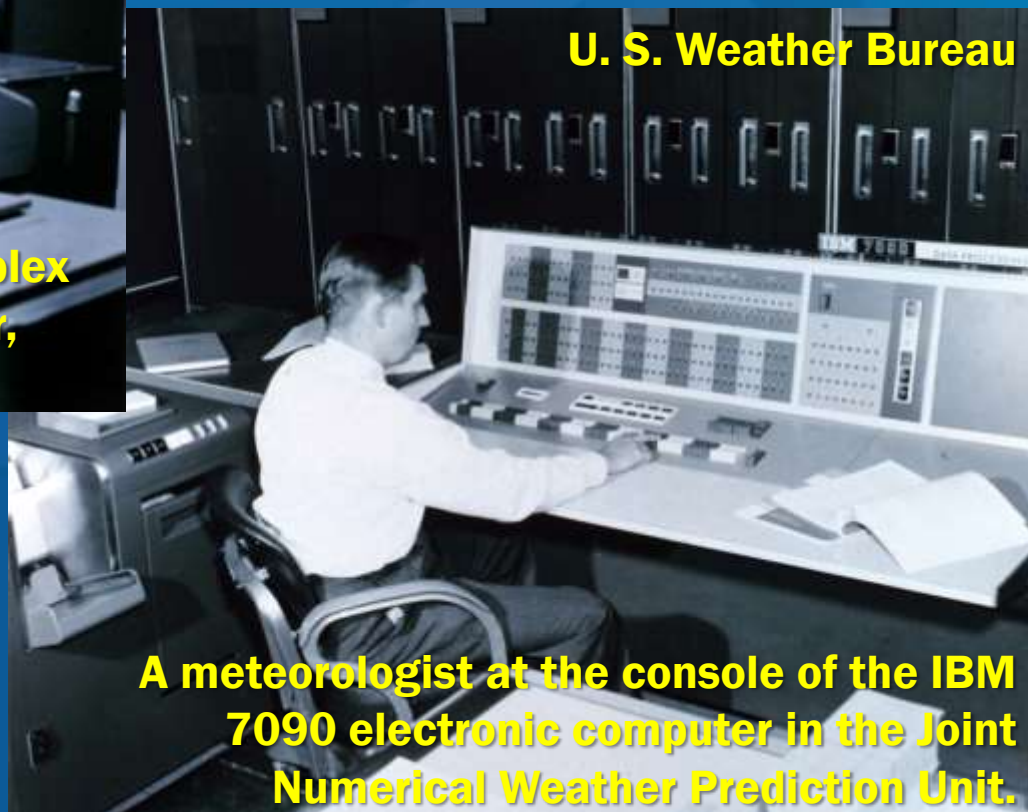
**U. S. Weather Bureau**



**View of the electronic computer complex at the National Meteorological Center, circa 1965.**



**U. S. Weather Bureau**



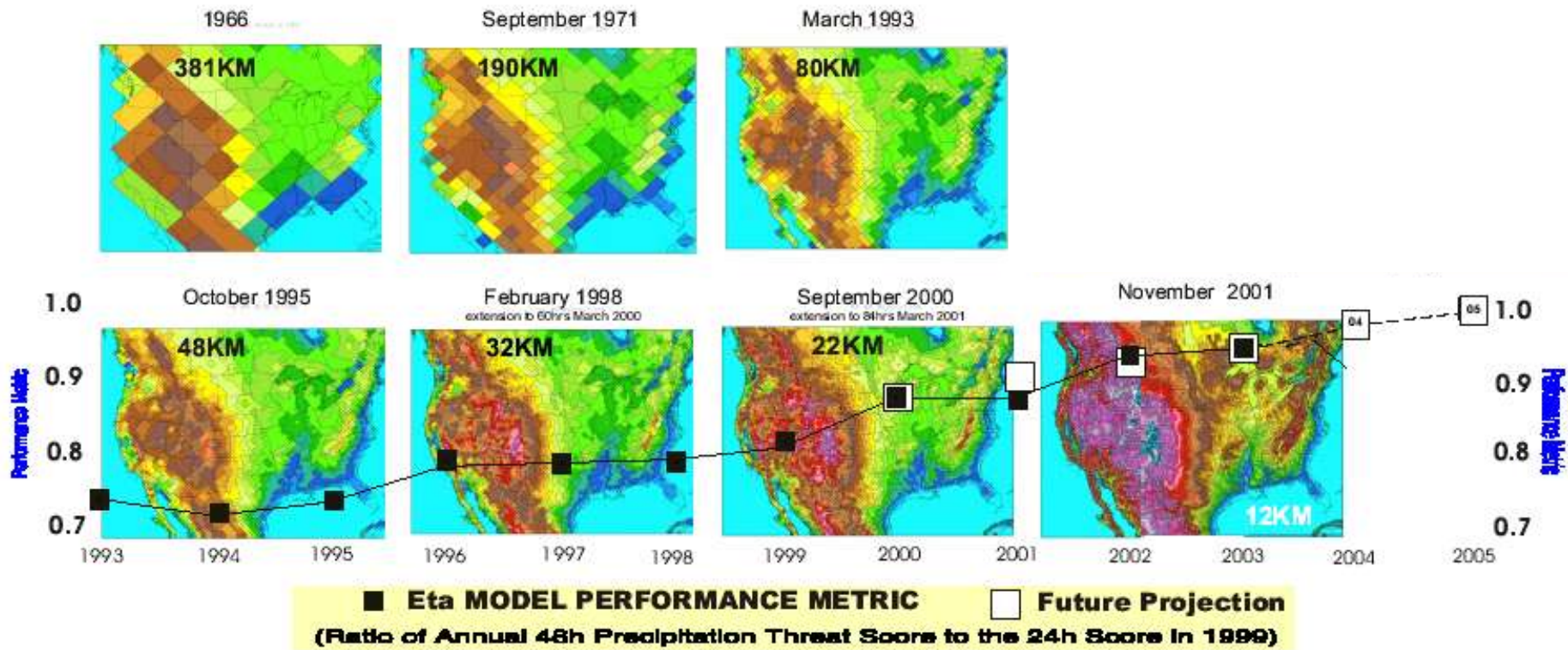
**A meteorologist at the console of the IBM 7090 electronic computer in the Joint Numerical Weather Prediction Unit.**







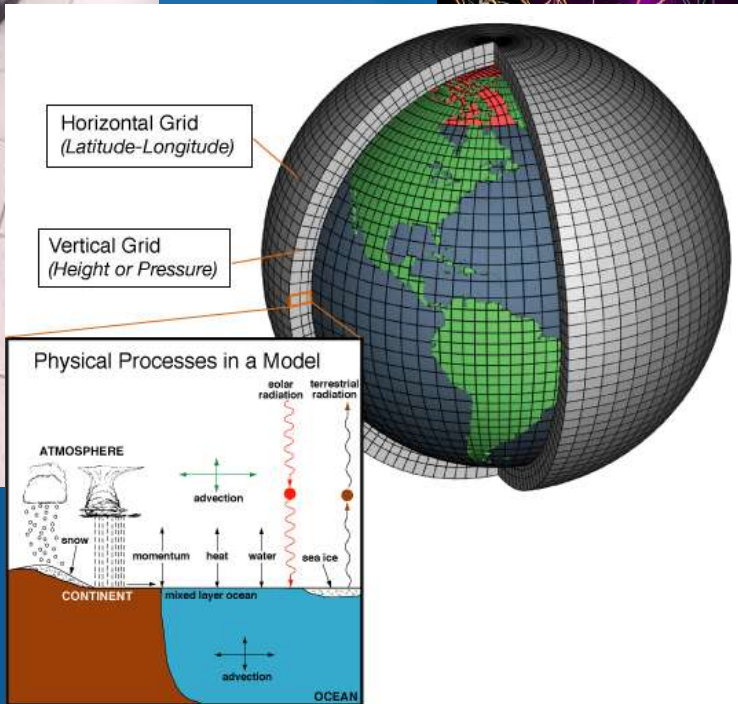
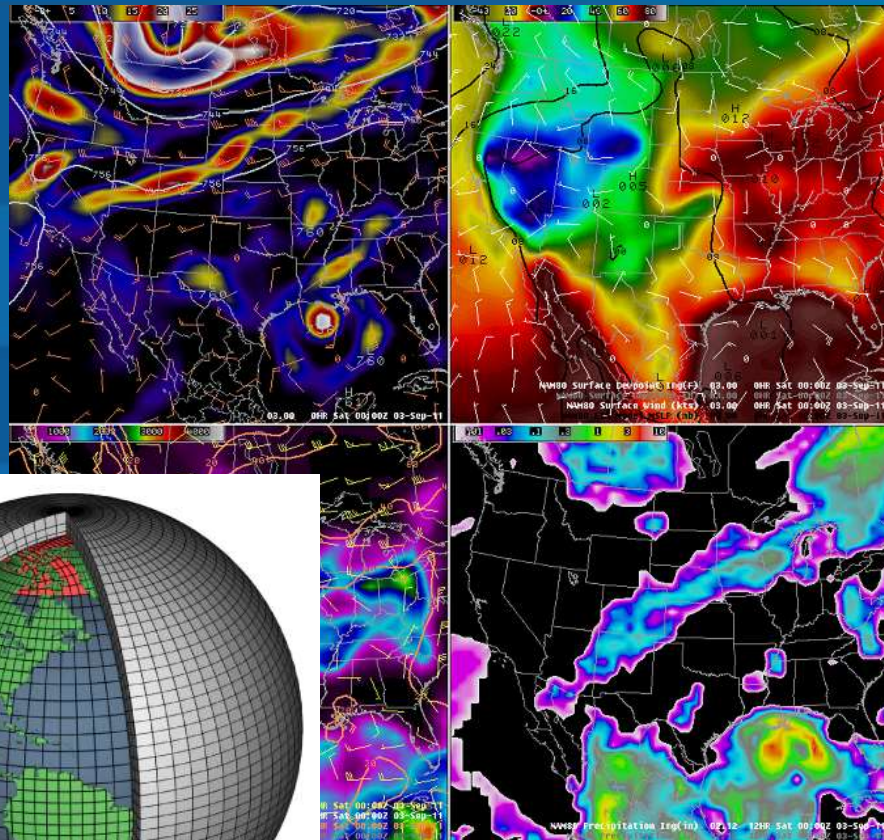
# Atmospheric Models - 1967



Improvement in horizontal resolution for modeling from 1966 to 2001, by showing the terrain resolution.



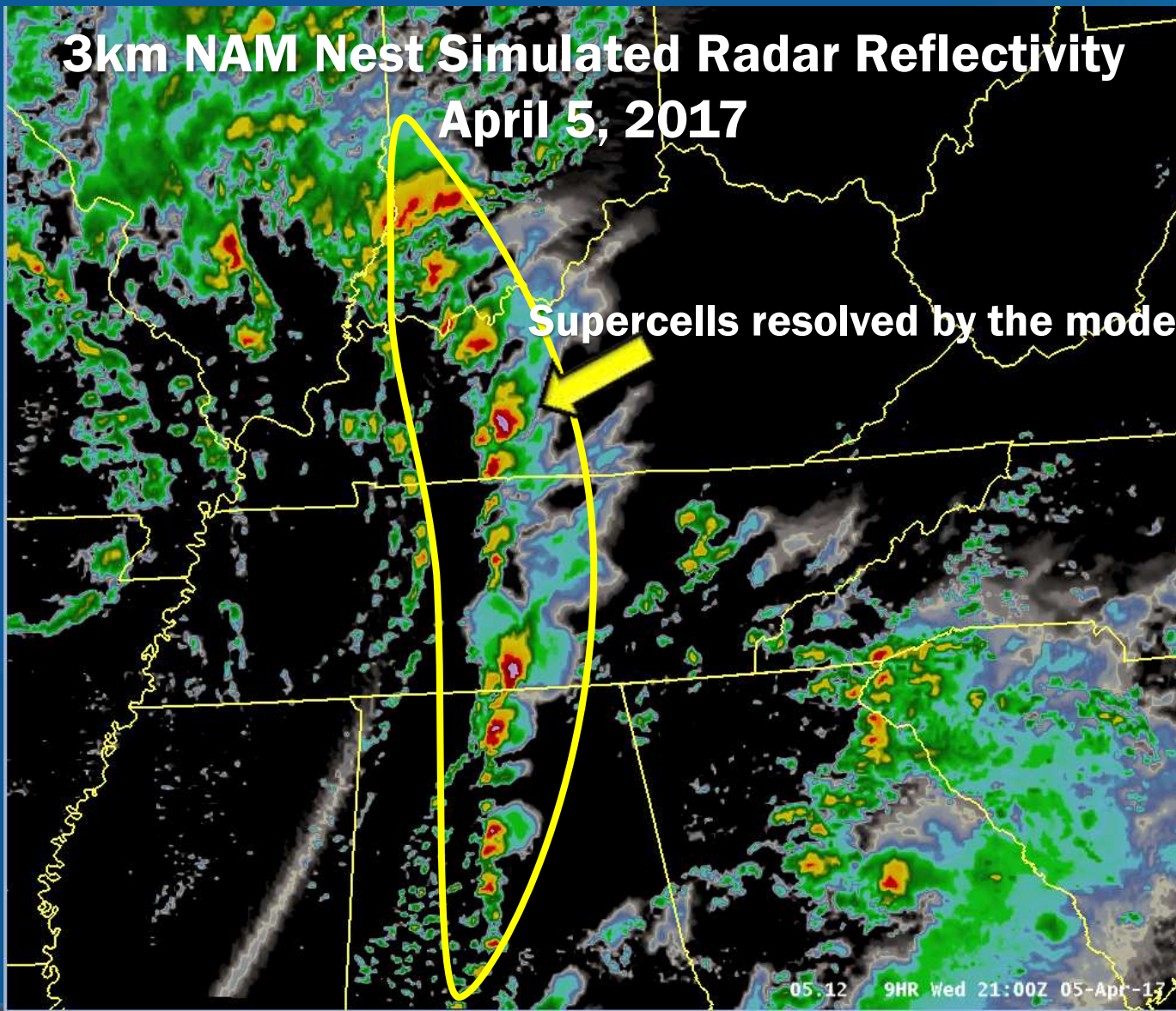
# Atmospheric Models - 2017





# Atmospheric Models - 2017

**3km NAM Nest Simulated Radar Reflectivity  
April 5, 2017**



**Supercells resolved by the model**



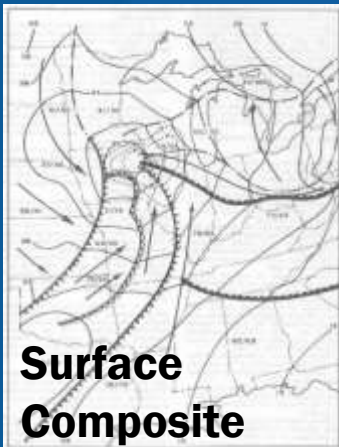
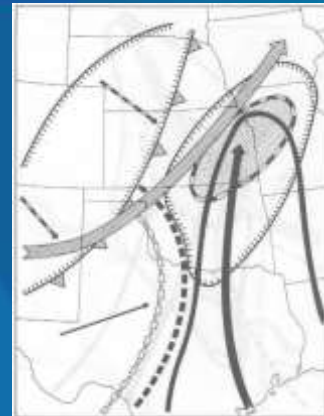
# Research to Operations 1967



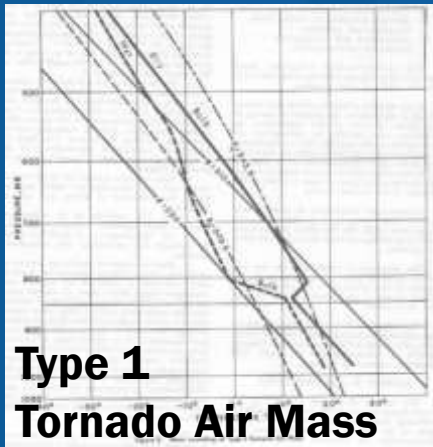
1960s SELS Analysis Area



Tornado Producing Synoptic Patterns



Surface Composite



Type 1 Tornado Air Mass

TORNADO WATCH BULLETIN NUMBER 100  
 ISSUED 1350CST APR 21 1967

THE WEATHER BUREAU HAS ISSUED A TORNADO WATCH FOR...

MOST OF NORTHERN AND CENTRAL ILLINOIS  
 EXTREME SOUTHEAST WISCONSIN  
 NORTHWESTERN INDIANA AND  
 A PORTION OF EXTREME EASTERN IOWA

THE THREAT OF A FEW TORNADOES WILL EXIST IN THESE AREAS FROM 2 PM UNTIL 8 PM CST THIS FRIDAY AFTERNOON. A FEW SEVERE THUNDERSTORMS WITH LARGE HAIL AND LOCALLY DAMAGING WINDS ARE ALSO FORECAST.

THE GREATEST THREAT OF TORNADOES AND SEVERE THUNDERSTORMS IS IN AN AREA ALONG AND 60 MILES EITHER SIDE OF A LINE FROM 40 MILES NORTH-EAST OF QUINCY ILLINOIS TO 30 MILES NORTHEAST OF CHICAGO ILLINOIS. THIS INCLUDES THE CHICAGO AREA.

PERSONS IN OR CLOSE TO THE TORNADO WATCH AREA ARE ADVISED TO BE ON THE WATCH FOR LOCAL WEATHER DEVELOPMENTS AND FOR LATER WEATHER STATEMENTS AND WARNINGS.

Tornado Watch - April 21, 1967

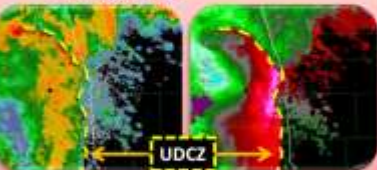


# Research to Operations 2017

## Three Ingredients Method for Mesovortex Genesis and Intensification Within a QLCS

### A – Find Balanced or Slightly Shear Dominant Regimes of the QLCS

1. Define the Updraft Downdraft Convergence Zone (UDCZ)
  - Convergence zone coincident with gust front
2. Along UDCZ, look for:
  - Deep nearly vertical updraft
  - Tight reflectivity gradient
  - Trailing stratiform, also possibly thin/leading stratiform
  - Entry/reflection points



NOTE: Examine 0.5° Z/SHM or Z/V plots to identify regimes.

### C – Look for Surges or Bows in the Line

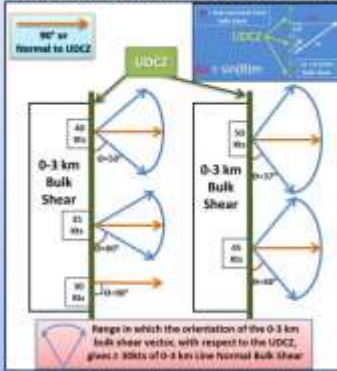
- A descending rear inflow jet or enhanced outflow are likely candidates to cause a surge or bowing
- NOTE: 0.5° SRM and V plots can often reveal developing line surges and bows before the classic “concave” reflectivity signature appears.

When all three (A, B, and C) ingredients are co-located in a QLCS, there is an increased likelihood for mesovortex genesis and intensification, along with increased tornado potential.

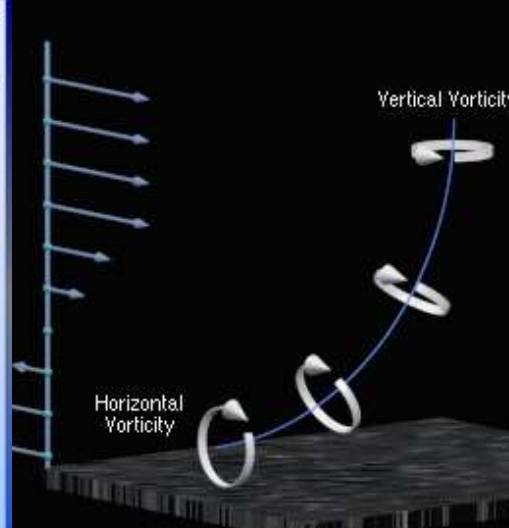
### B – Find Line Normal 0-3 km Bulk Shear $\geq 30$ Knots

1. Find 0-3 km bulk shear just ahead of the QLCS (must be  $\geq 30$  knots for ingredient to be fulfilled)
2. Use equation below to determine line normal bulk shear values  $\geq 30$  knots with respect to the orientation of the shear vector to the UDCZ

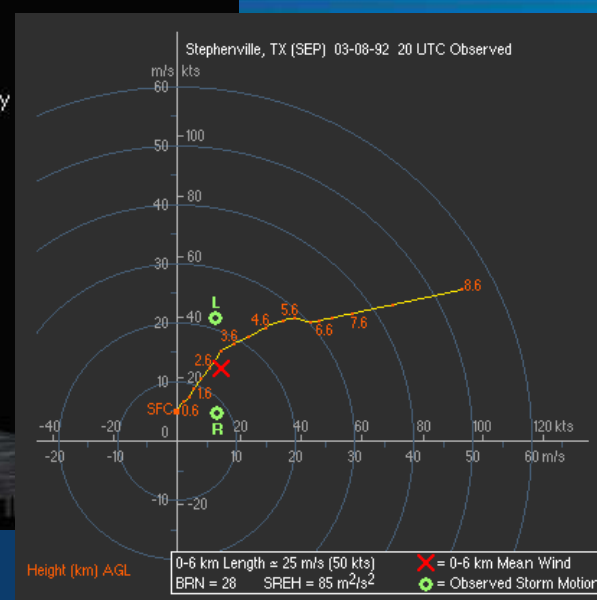
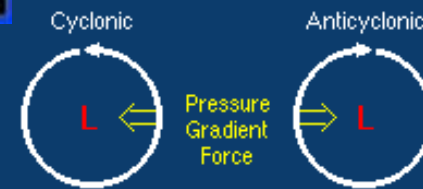
TIP: Watch bowing segments of the line...as the bow becomes more pronounced it often changes the orientation of the UDCZ. This is especially the case for the northern portion of the bowing segment.



Courtesy of Michael Mathews & Jason Schaumann - NOAA/NWS



### Cyclonic Pressure Pattern



## For Small Scales of Motion:

### Conditional Probability of a Significant Tornado

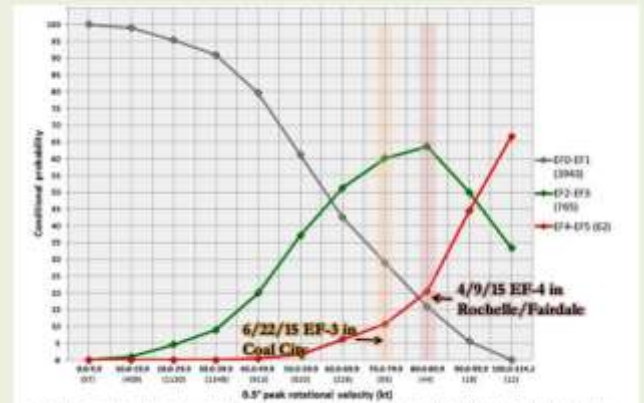
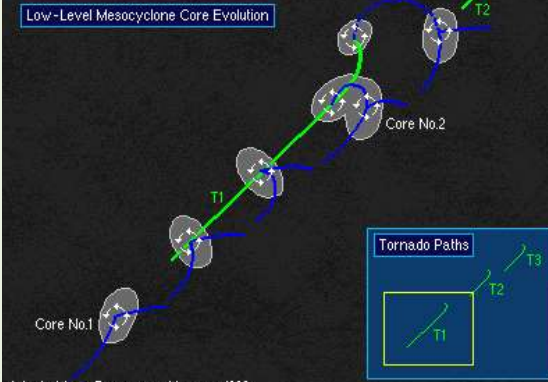
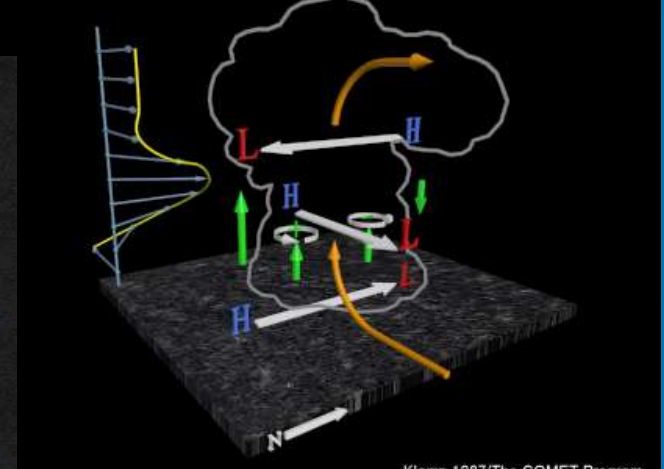


FIG. 13. Conditional probability of grouped EF scale rating classes (legend on right; EF0 and EF1, EF2 and EF3, and EF4 and EF5) for 0.5° peak  $V_{rot}$  (kt; a coordinate; sample size) for all convective mode tornado events (2000–03, at 0.5° intervals) ARL with 1–101 mi radius).  
 Adapted from Schultz et al. 2005

### Supercell Occlusion Process



### Pressure Pattern in Supercell Developing with Clockwise-curved Shear





# Research to Operations 2017

NATIONAL WEATHER SERVICE  
OCEANIC AND ATMOSPHERIC ADMINISTRATION

## Feb 28, 2017 Tornado Event

### Tornadoes

Eight total in northern and central IL

Five in the NWS Chicago CWA

Strongest were EF-3 (~155 mph)

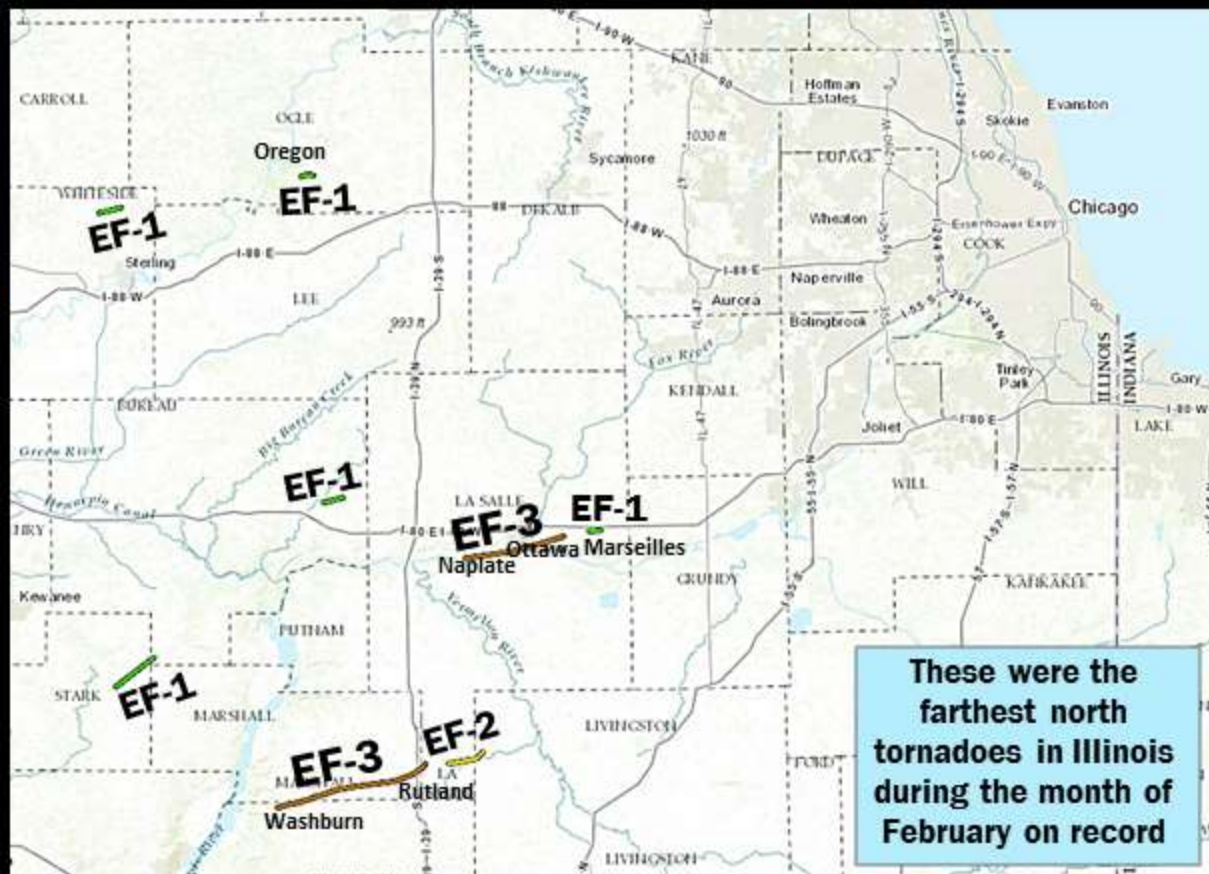
- Naplate/Ottawa tornado
- Washburn/Rutland tornado

EF-2 near Long Point, IL

EF-1 near the communities of Bradford, Cherry, Coleta, Marseilles, and Oregon

### Hail

Largest was baseball size in Ottawa



These were the farthest north tornadoes in Illinois during the month of February on record

Information from NWS offices in Chicago, Lincoln, & the Quad Cities

5:34 PM - Sunday, March 05, 2017

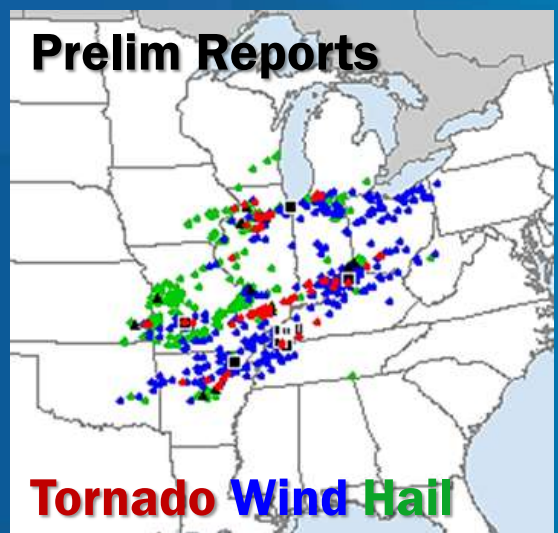
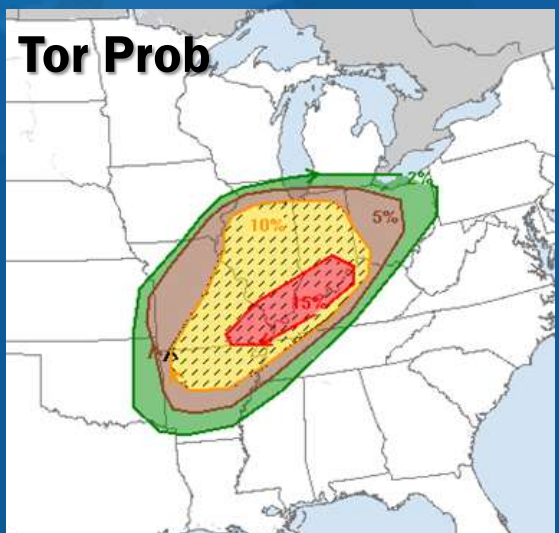
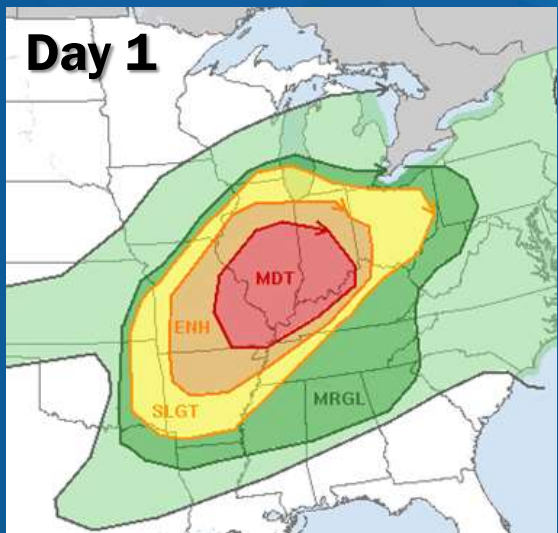
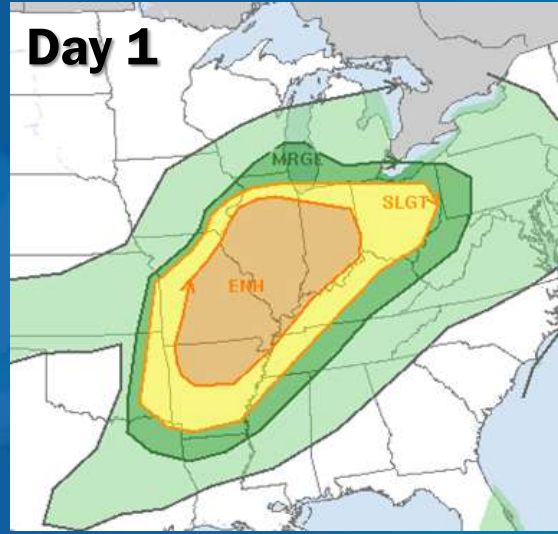
weather.gov/chicago





# Research to Operations 2017

## NWS/SPC Outlooks leading up to Feb 28, 2017 Outbreak





# Emphasis on Spotters

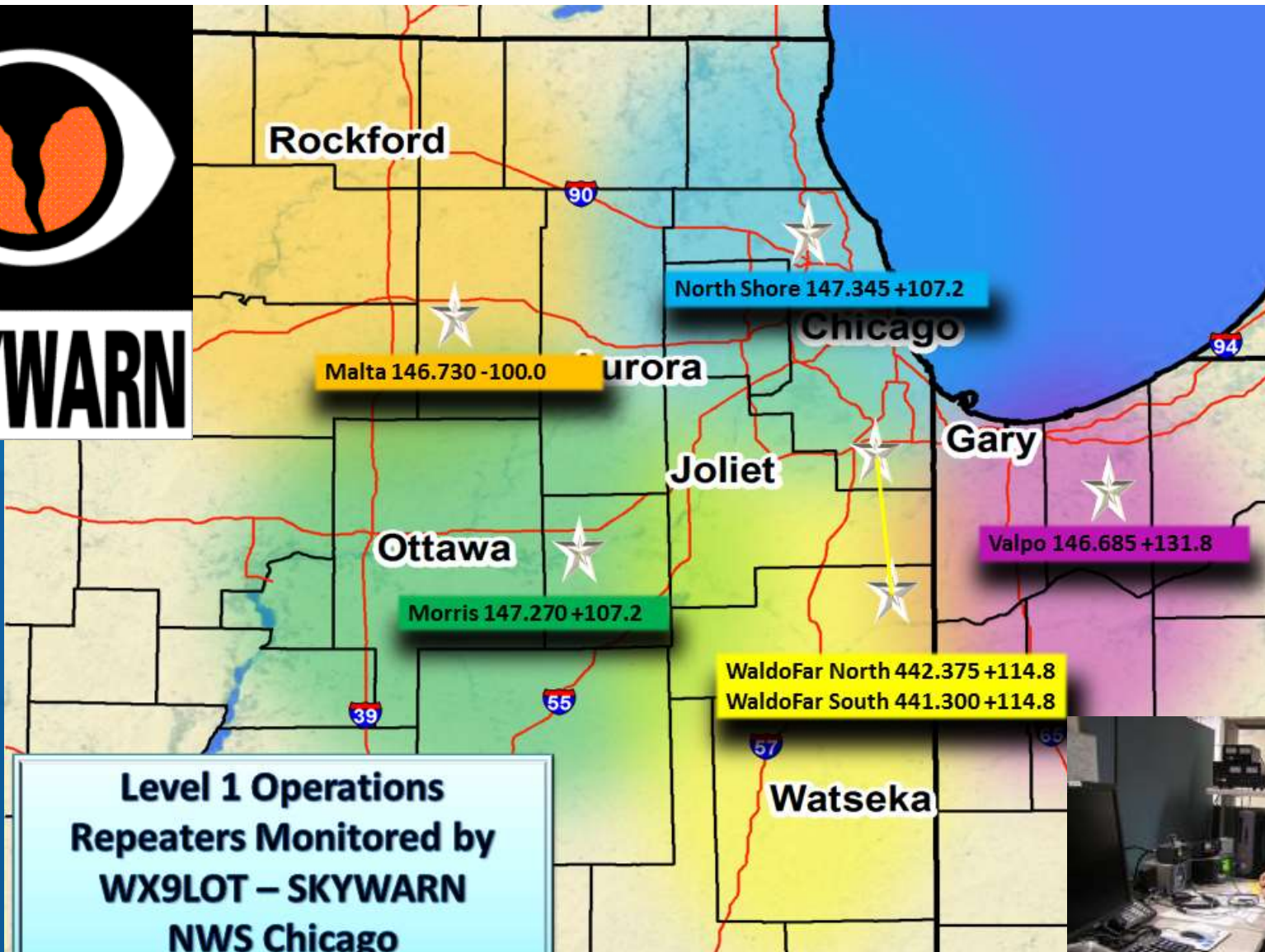
- **Storm spotters existed in 1967**
  - Were unorganized and scattered sporadically
- **Greater emphasis on creating a spotter network**
  - Natural Disaster Warning system
    - (NADWARN)
  - Became known as SKYWARN
  - Continually educate







# Amateur Radio Operations



**Level 1 Operations  
Repeaters Monitored by  
WX9LOT – SKYWARN  
NWS Chicago**





# NOAA Weather Radio

***“The smoke detector of severe weather”***

- Only ~60 stations prior to 1967
  - 125 by 1974 outbreak -> 300-400 following
- Today – 1025 stations covering 97% of the U.S.
- All hazards network





# Social Media 2017

## Thunderstorms Starting Across Area

Valid Tuesday February 28th, 2017 at 3:40 PM CST



### Highlights/Hazards

- Area that will see storms through 6 pm will mainly be north central Illinois
- Large hail, damaging winds and tornadoes possible
- Tornado watch in effect until 10 PM

#### FORECAST

[weather.gov/chicago](http://weather.gov/chicago)

#### REPORT RAINFALL

Twitter: @NWSChicago  
using: #wx #lwx

NWS Chicago

Issued: 2/28/2017 3:45 PM Central

facebook



US National Weather Servi... Timeline 2013



US National Weather Service Chicago Illinois  
November 17, 2013



936AM: Tornado WARNING for east central Boone and northwestern McHenry until 1015AM CST. This storm will be near Harvard around 945, Hebron around 10am, and Richmond around 1005 am. Take cover now!

Like · Comment · Share

20,304 people saw this post



US National Weather Service Chicago Illinois  
November 17, 2013

\*\*\*PLEASE SHARE\*\*\*

A Particularly Dangerous Situation Tornado Watch has been issued for all of NE Illinois & NW Indiana thru 4 PM CST.

In the watch area, several intense tornadoes, damaging wind gusts to 80 mph and large hail to 2" in diameter are possible.

For the text of the watch, go <http://www.spc.noaa.gov/products/watch/ww0561.html>



PDS Tornado Watch  
All of NE Illinois & NW Indiana thru 4 PM CST.



#### Tornado Watch Means

- Conditions favorable for tornadoes in watch area.
- Be ALERT and PREPARED to seek shelter if a warning is issued.
- Stay tuned to local media or NOAA weather radio for warning information.
- Large hail up to 1 in., strong damaging winds, torrential downpours & dangerous lightning are also possible.
- PDS - Particularly Dangerous Situation.



[weather.gov/chicago](http://weather.gov/chicago) Search National Weather Service Chicago @NWSChicago | Updated 02/27/2013 9:45 AM CST

Like · Comment · Share

125 17 1,618



Severe Weather for November 17  
November 16, 2013



National Weather Service

Chicago/Romeoville, IL

<http://www.weather.gov/chicago>  
[facebook.com/US.NationalWeatherService.Chicago.gov](https://www.facebook.com/US.NationalWeatherService.Chicago.gov)  
[@NWSChicago](https://twitter.com/NWSChicago)



## Severe Thunderstorms Producing Tornadoes

Valid Tuesday February 28th, 2017 at 5:02 PM CST



### Highlights/Hazards

- Severe thunderstorms producing tornadoes across LaSalle county
- Stay informed on the weather

#### FORECAST

[weather.gov/chicago](http://weather.gov/chicago)

#### REPORT SEVERE

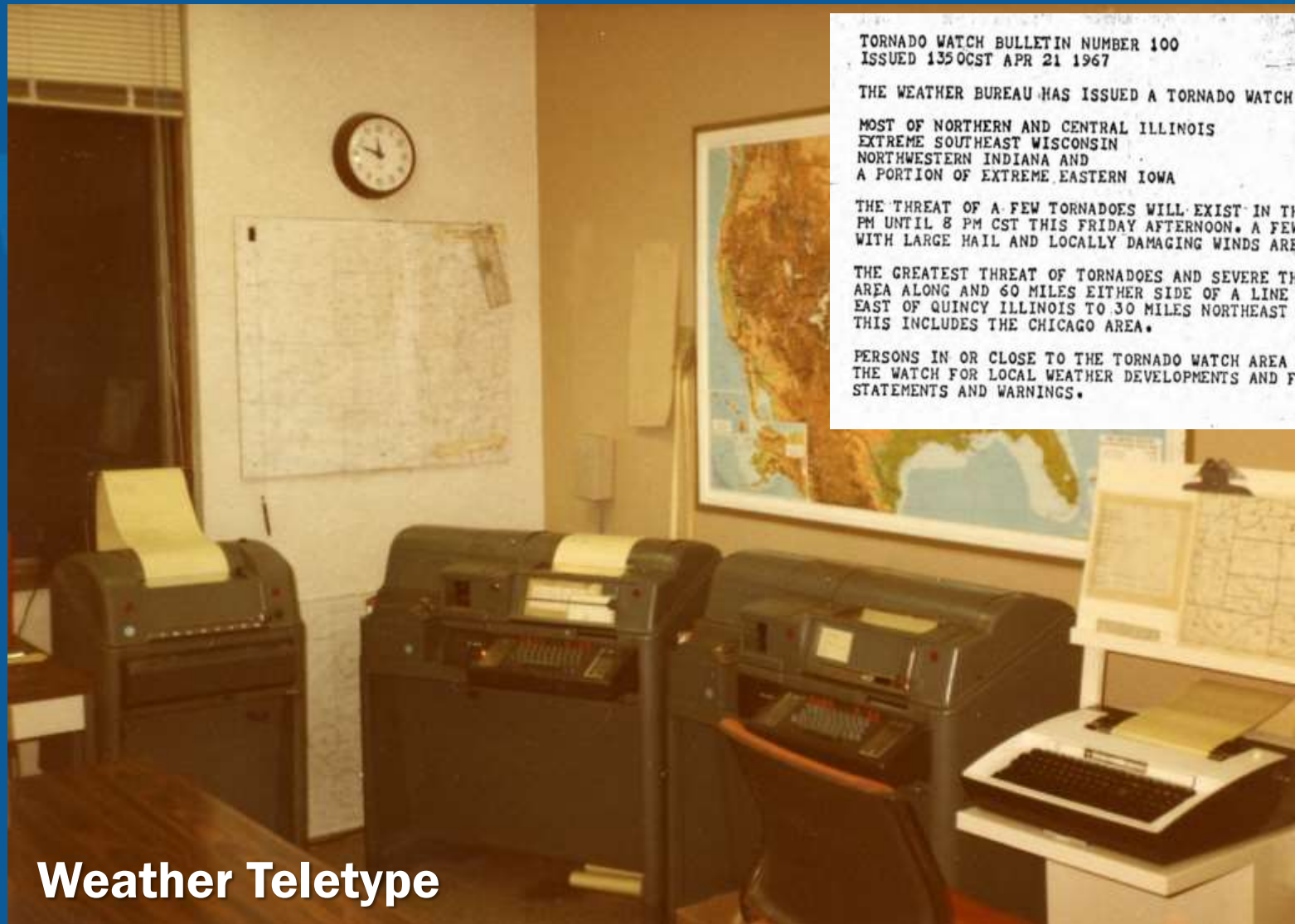
Twitter: @NWSChicago  
using: #lwx #lwx

NWS Chicago

Issued: 2/28/2017 5:22 PM Central



# Communications 1967



TORNADO WATCH BULLETIN NUMBER 100  
ISSUED 1350CST APR 21 1967

THE WEATHER BUREAU HAS ISSUED A TORNADO WATCH FOR...

MOST OF NORTHERN AND CENTRAL ILLINOIS  
EXTREME SOUTHEAST WISCONSIN  
NORTHWESTERN INDIANA AND  
A PORTION OF EXTREME EASTERN IOWA

THE THREAT OF A FEW TORNADOES WILL EXIST IN THESE AREAS FROM 2  
PM UNTIL 8 PM CST THIS FRIDAY AFTERNOON. A FEW SEVERE THUNDERSTORMS  
WITH LARGE HAIL AND LOCALLY DAMAGING WINDS ARE ALSO FORECAST.

THE GREATEST THREAT OF TORNADOES AND SEVERE THUNDERSTORMS IS IN AN  
AREA ALONG AND 60 MILES EITHER SIDE OF A LINE FROM 40 MILES NORTH-  
EAST OF QUINCY ILLINOIS TO 30 MILES NORTHEAST OF CHICAGO ILLINOIS.  
THIS INCLUDES THE CHICAGO AREA.

PERSONS IN OR CLOSE TO THE TORNADO WATCH AREA ARE ADVISED TO BE ON  
THE WATCH FOR LOCAL WEATHER DEVELOPMENTS AND FOR LATER WEATHER  
STATEMENTS AND WARNINGS.

Weather Teletype



# Communications 1967

**“...we found most people who were at home were aware of the watch and warning from listening to it on the radio. But it was those persons who were not at home... here was where the high death toll resulted.”**

**“Most of those killed were people who were not in a position to hear the warnings because they were away from home.”**

**- Weather Bureau survey, April 1967**



# Mobile Smart Phones 2017

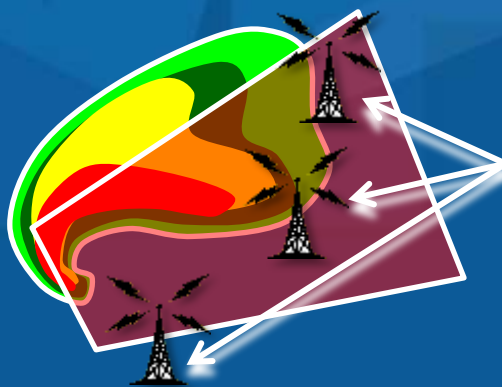
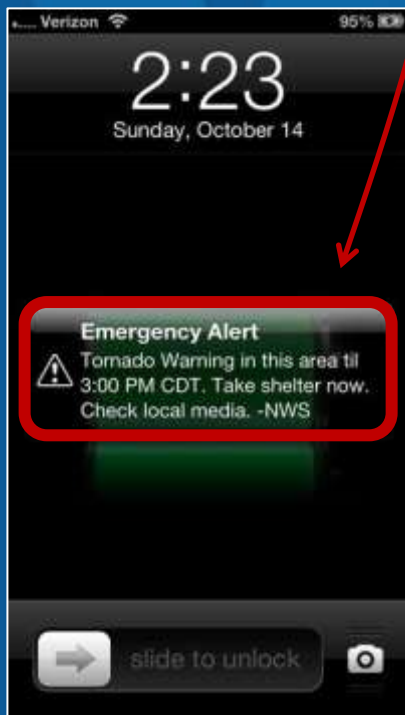
## WEA is... Wireless Emergency Alert

- *Automatic, text-like message informing you of dangerous situations*
- *No charges to receive a WEA message*
- *WEA messages have a special tone and vibration*



Check to see  
if your phone is  
WEA-Capable

Go to...  
[www.ctia.org/wea](http://www.ctia.org/wea)



## If you...

- ✓ Have WEA messages enabled
- ✓ And are by a cell tower covering a Tornado (Flash Flood) Warning polygon

*You will automatically receive message telling you of a Tornado (Flash Flood) Warning.*





# Communications 2017

# www.weather.gov/subscribe

**NATIONAL WEATHER SERVICE**  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HOME FORECAST PAST WEATHER SAFETY INFORMATION EDUCATION NEWS SEARCH ABOUT

**WPN** WEATHER READY NATION

**Email and SMS Weather Alert Services** National Weather Service  
National Headquarters

[Weather.gov](#) > Email and SMS Weather Alert Services

Customize Your Weather.gov

City, ST

Email Your City, ST or ZIP Code

Remember Me

Get Weather

Privacy Policy

The National Weather Service (NWS) provides alert and warning information through official dissemination sources, including [NOAA Weather Radio](#), [NOAA Weather Wire Service](#), and [Weather.gov](#) to the public, and the [NWS service](#) for core partners (emergency management community, government partners of an NWS office, or members to the electronic media who need direct interaction with NWS). The National Weather Service does not provide direct email/SMS alerts to the general public. For hurricane-specific information, see [Hurricane Information](#). For tsunami-specific information, see [Tsunami Information](#).

Third party sources that deliver email and SMS weather alerts are listed below. This list contains the providers/services that we know. If you are a provider of a weather alerting service and want your service added to the list below, please contact [nws.subscribe@noaa.gov](mailto:nws.subscribe@noaa.gov). **Note: This email address is not for subscribing to NWS alerts.**

*DISCLAIMER: NWS does not endorse the services or providers listed in the table below. Information presented in the table is believed to be correct at the time of posting. Any fee or payment required for service is the responsibility of the consumer. The NWS recommends using multiple sources of information to validate the information that is received.*

**NOTE: Unless otherwise indicated, all links below take you outside this federal government website. You may wish to review the privacy notices on these sites as their practices may differ from ours.**

LISTING OF ALTERNATIVE SOURCES OF WEATHER ALERTS	
General Information	Access
<p><a href="#">ACEMWIN/HURR/J. Hurricane Bulletins Listgroup</a> Alachua County Skywarn maintains a listserve to provide email alerts of hurricane/tropical storm information for the Atlantic and Gulf of Mexico regions. Information is generated at the National Hurricane Center.</p>	E-mail free
<p><a href="#">AccuWeather</a> AccuWeather.com provides free email forecast and severe weather alerts.</p>	E-mail, text free
<p><a href="#">Alabama SAF-Net</a> Alabama SAF-Net is a free, personalized severe weather alerting service, available via SMS and Email within Alabama as well as via Smartphone App nationwide. It was initiated at the request of Alabama governor Robert Bentley following the April 27, 2011 tornado outbreak. It currently has over 300,000 subscribers and continues to grow, all completely without charge to the user.</p>	E-mail, text, phone free
<p><a href="#">Alachua County EMWIN Project</a> The Alachua County EMWIN Project provides free weather bulletins to your e-mail, pager, or cellphone - as a public service to the local Alachua County and surrounding North Central Florida communities.</p>	E-mail, text free
<p><a href="#">AlertFM</a> ALERT FM is an aggregator of State and Local emergency information with multiple contact paths for mass notification. Emergency information is delivered via the data subcarrier of existing FM radio stations, SMS (text) and email. This personal alert and messaging system allows emergency management officials to create and send digital alerts and messages to recipients such as first responders, school officials, businesses, and citizens based on geographic or organizational groupings. Such alerts and messages might include NOAA weather warnings, evacuation instructions, homeland security notices, Amber Alerts, or school closings.</p>	E-mail and commercial receivers Buy receiver



# Collaborative Partnerships



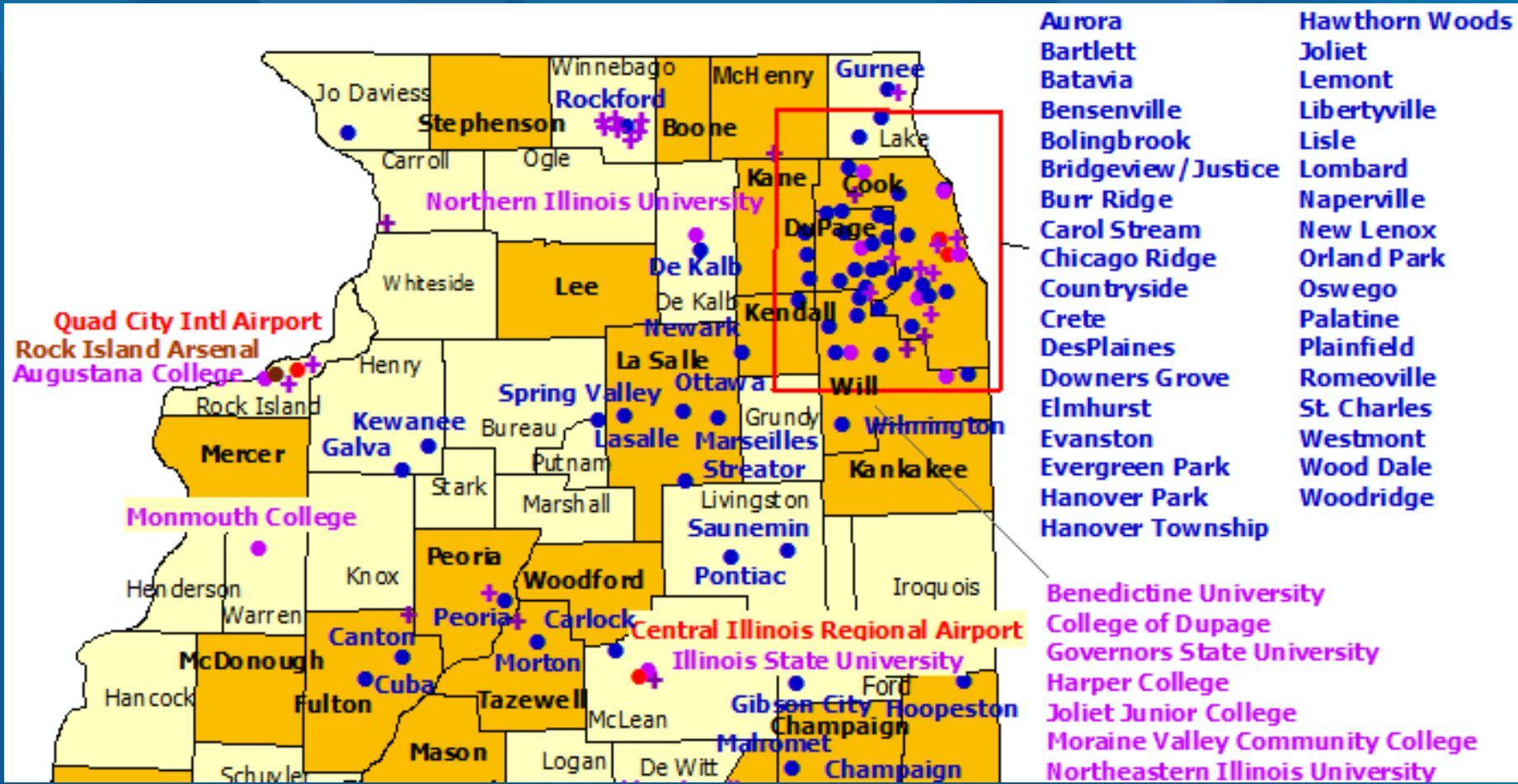




# Collaborative Partnerships



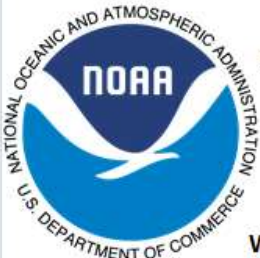
	County		University
	Community		Commercial
	Government/Military		Supporter





# Collaborative Partnerships

Aroma Park (IL) Fire Department	City of Joliet (IL) EMA	City of Rockford (IL)	Evergreen Park Fire Department (IL)	Curie Metropolitan High School (IL)	Digity Media-Waukegan (IL)	DuPage County OHSEM
Auto Truck Group	Benedictine University	College of DuPage	Orland Square Mall (IL)	Harvest Food Group	WGN-TV/CLTV	
Boone County Health Department	WGN-TV (Chicago, IL)	Commonwealth Edison	UOP a Honeywell Company	Park Ridge Community Emergency Response Team	Storm Tech	
Cherry Logistics	Illinois Storm Chasers	Northern Illinois University			Plainfield EMA (IL)	
Chicago (IL) Police Department-25th District	WLS TV	<b>AMBASSADOR™</b>		Lake County (IL) Skywarn	WX9MCS Skywarn	
Chicago Premium Outlets (IL)	Kane County ARES (IL)	<b>WRN</b>		Rockford Metro Skywarn		
Chicago Ridge EMA (IL)	Village of Romeoville (IL)	<b>WEATHER-READY NATION</b>		Rockford Fire Department (IL)		
Chicago Weather Group	Lake County (IL) EMA	Lee County (IL) EMA	LaSalle County (IL) EMA	St. Charles (IL) EMA	Sandwich (IL) EMA	
City of DeKalb (IL)	Ford County (IL) Skywarn	Leyden Fire Protection District (IL)	Tac-WX Operations Grp	Streator Fire Department (IL)		
JWSevereWeather			Northwest Community Emergency Medical Services System (IL)	Valley Ambulatory Surgery Center (IL)		
Grundy County (IL) EMA	Lighthouse Place Premium Outlets (IN)	Melrose Park Departments of Homeland Security & Public Safety (IL)		WREX-TV (Rockford, IL)		
	McHenry County (IL) EMA	Will County (IL) EMA		Weather Command/Murray & Trettel, Inc.		
	Woodfield Mall (IL)	TMN-Mariposa Chicago	Wood Dale (IL) Police Department	WTVO-TV/WQRF-TV (Rockford, IL)		





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**THANK YOU!**



*S.S. 10/11*