

# NATIONAL WEATHER SERVICE LOUISVILLE

## SHAREHOLDERS REPORT

# 2021



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## Goals for 2022

Improve all facets of Tornado Warnings

Begin probabilistic datasets

Provide more assistance to Mammoth Cave National Park and Abraham Lincoln Birthplace National Historic Park

Perform more flood damage surveys

Further develop the Adopt-a-County program

Begin Spanish language outreach to the Hispanic community

# Introduction

Welcome to the 17th edition of the National Weather Service (NWS) Louisville (LMK) Shareholders Report. After 150 years of providing residents of the middle Ohio Valley reliable weather information (see page 7), NWS Louisville is still strongly committed to serving you, our shareholders. This report details the activities of NWS Louisville across the 59 counties of southern Indiana and central Kentucky for which we are responsible. In the challenging global pandemic, weatherwise 2021 will be remembered for the historic nighttime Quad State Tornado Outbreak (page 4), the 10 days of winter weather in February (page 6), and extensive river flooding in late February and March (page 6).

One of the biggest highlights for the office was using our new drones for both hydrologic and storm damage surveys. NWS drones (page 5) were flown while communicating with the Ohio River Forecast Center in Wilmington, Ohio during major river flooding. Flood forecasts were updated for the Kentucky River based on drone information. Drones also discovered a distinct ground scour from a tornado on March 25 in Grayson County and several others from December twisters.

Staffing was a major challenge this year due to retirements, reassignments, parental leave, and government budget cycles. Fortunately, we were able to fill several positions and are close to full strength once again. We hired two new meteorologists, a Lead Meteorologist, Observations Program Leader (OPL), Warning Coordination Meteorologist (WCM), and a Pathways student. Specifically, Dan McKemy was promoted on station to Lead Meteorologist, and Cliff Goff to OPL. We are excited to have Mike Kochasic, who was a Lead Meteorologist at NWS Wilmington, NC, as our new WCM following the retirement of Joe Sullivan at the end of 2020.

We also hired Adrian Lopez Lago, a doctoral candidate and former meteorologist for Telemundo in Miami. Adrian will devote much of his time to squall line research and Spanish outreach. We also hired Chase Graham, who just finished his Masters degree at North Carolina State University. Chase is going to be very involved in student outreach and GIS. Pathways Student Samantha Michlowitz, also from NC State, has been a great addition to the staff and will join the NWS full-time after she graduates in 2023.

I hope you find that our activities demonstrate the sort of stewardship you expect from your public servants. We believe in integrity, customer service, proactiveness, and public accountability. The NWS cost Americans only \$3.63 per person in 2021. I welcome your suggestions as to how the NWS can be an even better investment for you.

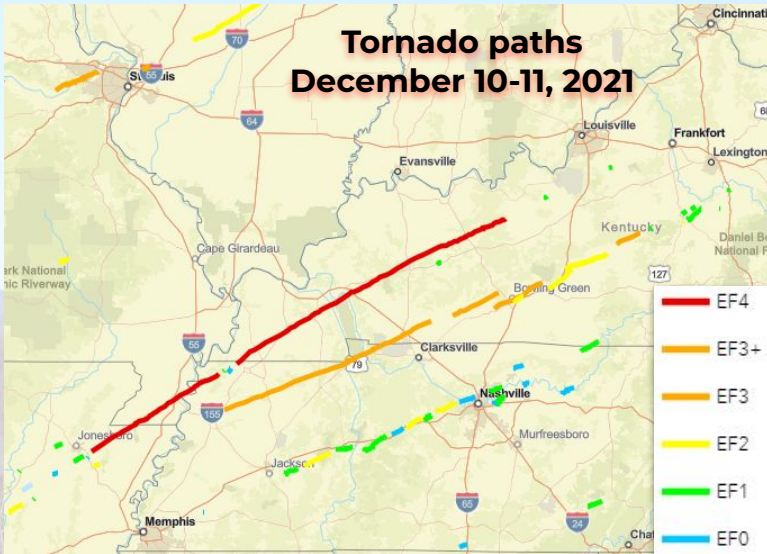
I am grateful to Lead Meteorologist and Shareholders Report Editor Tom Reaugh for assembling another excellent report, and Science and Operations Officer Ryan Sharp for his thorough review of the document.

Cheers,

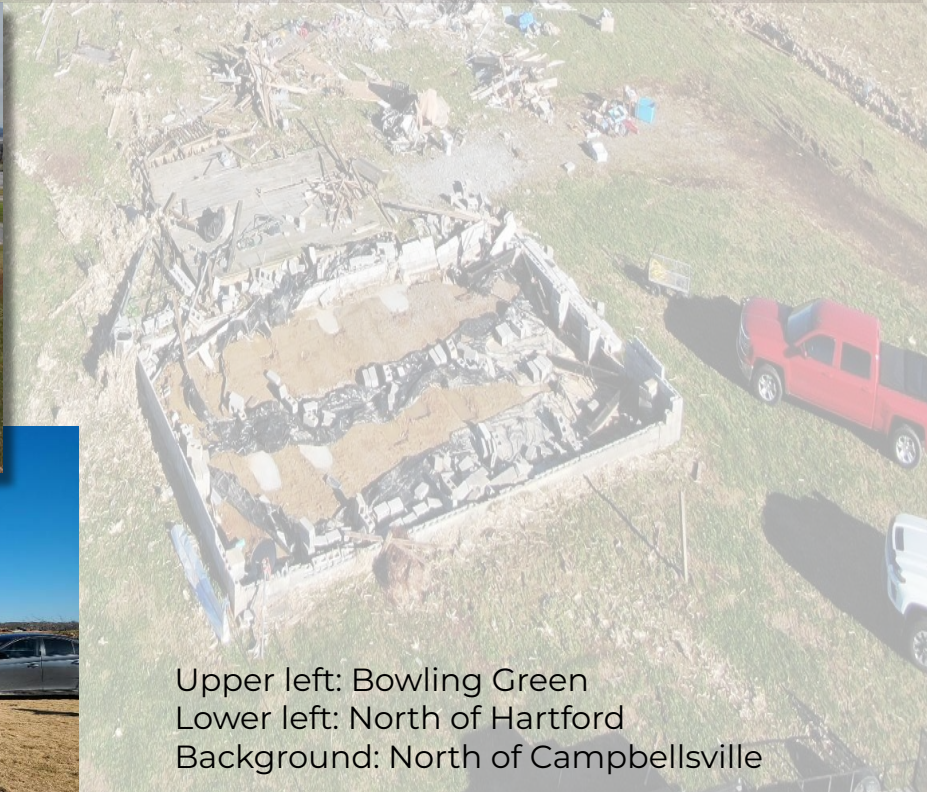
John Gordon, Meteorologist-in-Charge

# Deadly December

Tom Reaugh *Lead Meteorologist*



A strong cold front, a powerful jet stream, and strong winds varying in direction and speed with height through the atmosphere combined with enough instability to produce huge storms and devastating tornadoes from the evening of December 10 into the early morning hours of December 11. The worst twister was an EF-4 that cut a scar of destruction through Mayfield, KY, and was on the ground for almost 166 miles. In central Kentucky, Bowling Green was ravaged by a high-end EF-3 tornado that took 16 lives in a single neighborhood when it struck the sleeping city shortly after 1am. Fortunately the event was well-forecasted and warnings were issued ahead of the storms, preventing the loss of life from being any worse. Teams from NWS Louisville surveyed the damage for several days afterward. Details can be found at [weather.gov/lmk/December112021Tornadoes](http://weather.gov/lmk/December112021Tornadoes) and on our YouTube channel.

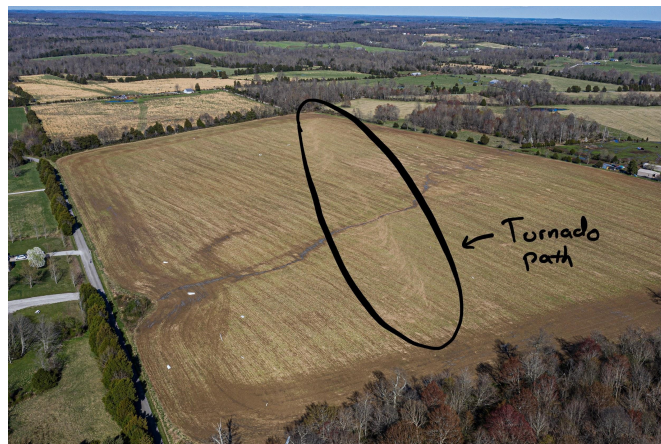


Upper left: Bowling Green  
Lower left: North of Hartford  
Background: North of Campbellsville

# A View from Above

Dan McKemy *Lead Meteorologist*

LMK received funding in 2020 to start up a drone program for the purpose of river flood and storm damage surveys. 2021 was a year that provided multiple opportunities to use the drones to survey flooding and severe weather damage that occurred.



The most impactful flooding took place in early March. Almost all of the major rivers across the region flooded after several inches of rain fell from late February into early March. LMK used drones to record the flooding and thereby improve flood warnings. These data will continue to be analyzed to improve river flood impact statements issued by our office, as well as verifying flood models and inundation maps.



The drones also proved extremely useful for tornado damage surveys this year. One particular survey in late March across Grayson County revealed 'swirls' in a field left by an EF-0 tornado! It was fascinating to see these markings from such a small, weak tornado.

The December 10-11 tornado outbreak resulted in 18 tornadoes, up to high-end EF-3 strength, across our region. The drones provided aerial views of the damage and allowed surveyors to accurately assess the paths, as well as view damage in areas that were not easily reached by ground. See our YouTube channel for drone videos of flooding and tornado damage ([youtube.com/user/NWSLouisville](https://www.youtube.com/user/NWSLouisville)).



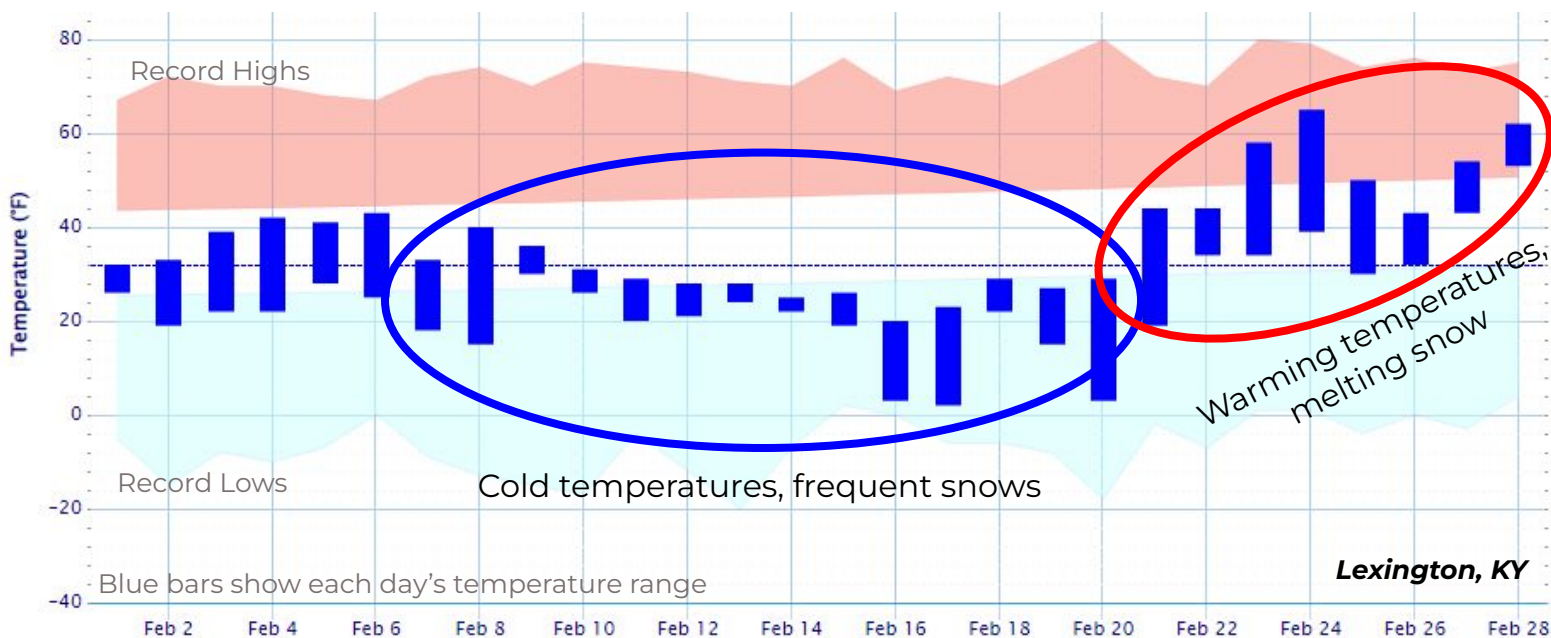
*Top: EF-0 tornado scar in Grayson County March 25.  
Middle: Ohio River flooding near Prospect, KY March 6.  
Bottom: Tree damage from an EF-1 tornado just north of Frankfort December 6.*

# Late Winter Storms and Flooding

Evan Webb *Meteorologist*

Andrea Schoettmer *Hydrologist*

In February an arctic air mass was anchored over much of the central United States and Canada. Multiple waves of low pressure associated with the jet stream moved through the cold air and produced a mix of snow, sleet, and freezing rain. Three 24-36 hour waves of wintry precipitation occurred in quick succession in the Ohio Valley: February 9-11, February 14-15, and February 17-18. The storms resulted in power outages and significant impacts to travel across the region. The graph below shows February 2021 temperatures at Lexington, Kentucky.



Melting snow pack followed by heavy rains in late February and early March brought moderate to major flooding to the Ohio Valley. Sections of the Kentucky, Green, Rolling Fork, Barren, and Ohio Rivers experienced unusually high flood waters. The Kentucky River Basin was particularly hard hit with several locations peaking in the top ten historic crests on record.

*Kentucky River crests and their historical ranking*

Lockport, 45.73', #10

Camp Nelson, 42.92', #2

Frankfort, 40.16', #9

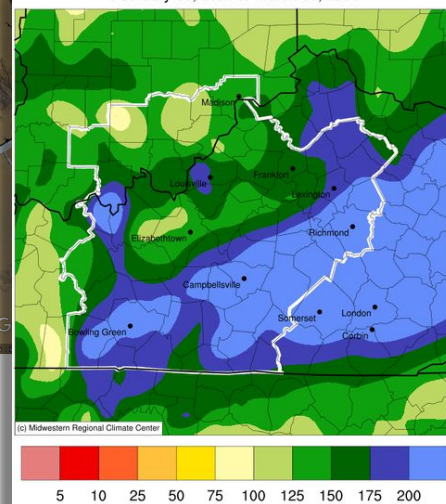
High Bridge, 38.75', #6

Ford Lock, 38.05', #2



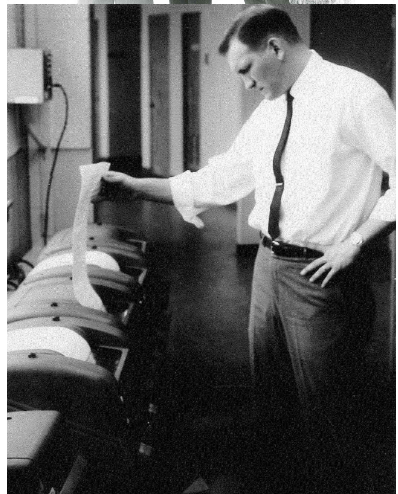
*Drone footage of Kentucky River flooding in Frankfort*

Accumulated Precipitation (in): Percent of 1991-2020 Normals  
February 08, 2021 to March 01, 2021



# Serving the Ohio Valley for 150 Years

Brian Neudorff *Meteorologist*



*Top: Celebrating a white Christmas in 1963 at Standford Field (we had 3 inches of snow on the ground). NWS Louisville was in the Lee Terminal Building from 1950 to 1981.*

*Above: Former Meteorologist-in-Charge Dave Reeves checking the latest weather information in the mid-1960s.*

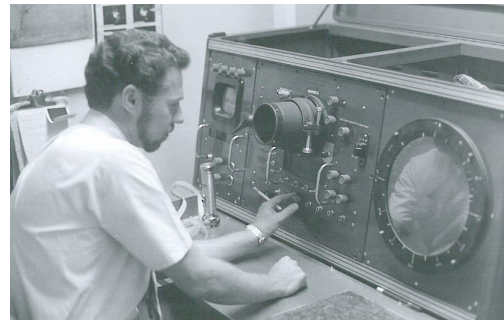
*Below: Handwritten weather observations taken during the April 3, 1974 F4 tornado that touched down just outside the weather office. There was even an earthquake that day!*

R 1255 M34112500	7	76078 69 B 21630 192	A	A	R
R 1353 M06028.4	7	75077 62 18 19 630 937			
R 1451 E45-02	10	74778 62 19 62 31 737			
R 1455 E45-02	10	74778 62 19 62 31 738			
S 1540 M32-C	4	TRW-	2426 073 957		
R 1555 E4502500	7				
R 1558 E4502500	7				
R 1614 E4502500	7				
R 1651 E4502500	10	74078 62 21 47 736			
R 1705 E4502500	7	74078 62 20 115 734			
7 2 32 3 62015	01089 940	734 52 602 12501			
R 1855 4-5-02	7	74470 61 18 69 737			
R 1858 4-5-02	7	74778 62 20 114 736			
R 1905					
EARTHQUAKE FELT AT 5:01					

In September the National Weather Service office in Louisville celebrated our 150th anniversary. We commemorated the occasion by producing a series of videos created by one of our own meteorologists, Brian Neudorff. The videos included an overview of the history of the Louisville office and how it has changed over the last 150 years. We then had testimonials from our partners in the media, emergency management community, and local and state government officials. Past LMK employees shared their stories and spoke about the events that they experienced during their time here. The final video was a look ahead into the future of the office.

Meteorologist-in-Charge John Gordon spoke about our new drone program as well as how the people and our mission of saving lives and property continues to drive us to improve and provide better service to all of you, our shareholders.

The videos are available on our YouTube Channel ([youtube.com/user/NWSLouisville/videos](https://www.youtube.com/user/NWSLouisville/videos)) as well as our Facebook video section.



*Top: Keeping an eye on the radar scope. This type of radar was used in Louisville from 1962 to 1978.*

*Middle: The women of NWS Louisville in 1978. Center, standing, is Marilyn Scholz, who was a meteorologist here from 1974 to 2009.*

*Bottom: Taking manual weather observations in 1981.*

*Below: The monthly weather report from the Great Flood in January 1937.*



ORIGINAL MONTHLY RECORD OF OBSERVATIONS at Louisville, Ky. for the Month of JAN 1937													
TIME	TEMPERATURE					WIND							
	AIR	WIND CHILL	WIND	SEA	WAVE	DIR	SPEED	MAX	MIN	PEAK	GUST	STATE	
0100	40	35	0			11	10	10	0	0	0		
0200	39	34	0			11	10	10	0	0	0		
0300	38	33	0			11	10	10	0	0	0		
0400	37	32	0			11	10	10	0	0	0		
0500	36	31	0			11	10	10	0	0	0		
0600	35	30	0			11	10	10	0	0	0		
0700	34	29	0			11	10	10	0	0	0		
0800	33	28	0			11	10	10	0	0	0		
0900	32	27	0			11	10	10	0	0	0		
1000	31	26	0			11	10	10	0	0	0		
1100	30	25	0			11	10	10	0	0	0		
1200	29	24	0			11	10	10	0	0	0		
1300	28	23	0			11	10	10	0	0	0		
1400	27	22	0			11	10	10	0	0	0		
1500	26	21	0			11	10	10	0	0	0		
1600	25	20	0			11	10	10	0	0	0		
1700	24	19	0			11	10	10	0	0	0		
1800	23	18	0			11	10	10	0	0	0		
1900	22	17	0			11	10	10	0	0	0		
2000	21	16	0			11	10	10	0	0	0		
2100	20	15	0			11	10	10	0	0	0		
2200	19	14	0			11	10	10	0	0	0		
2300	18	13	0			11	10	10	0	0	0		
2400	17	12	0			11	10	10	0	0	0		

# Our New Normal(s)

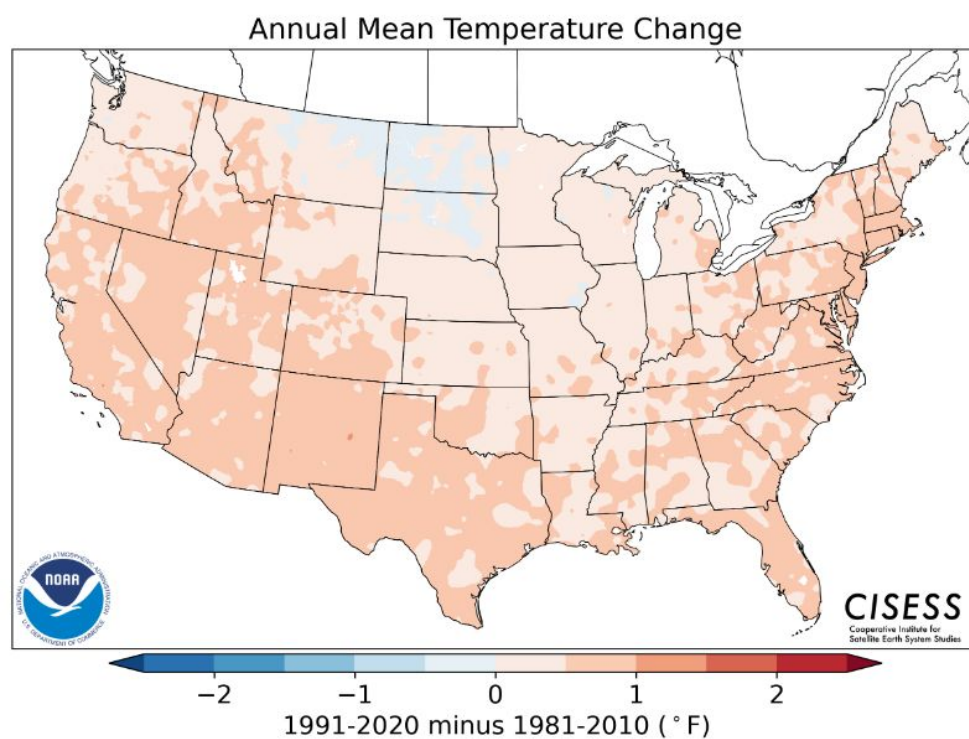
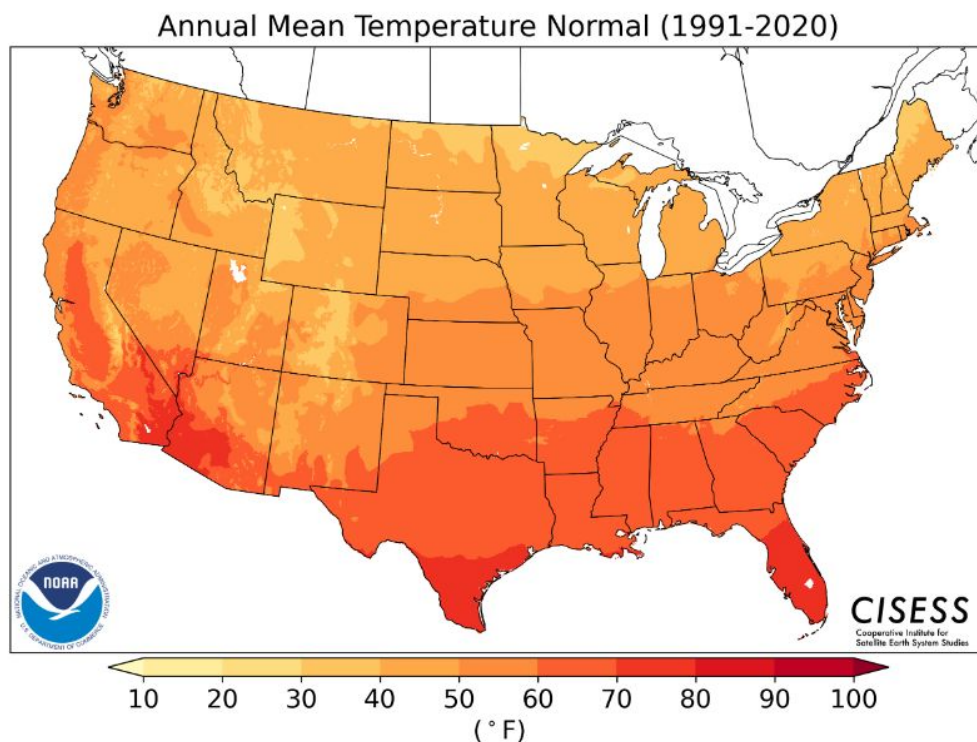
Tom Reaugh *Lead Meteorologist*

“Normals” are similar to averages and give us an idea of what kind of weather to expect at a given time and place. They can be calculated for a variety of meteorological variables, but are most often used for temperature and precipitation. For example, if the normal high temperature in Lexington on June 1 is 80 degrees, then we can generally expect, from a climatological point of view, a high temperature in the neighborhood of 80 degrees in Lexington on June 1. If the actual high temperature that occurs on a particular June 1 in Lexington in a given year is, say, 90 degrees, then we can say that the high temperature that day was 10 degrees warmer than what we would expect climatologically, that is, warmer than normal.

Normals were first developed in the 1930s. The World Meteorological Organization in Geneva has asked that nations calculate a new set of normals every 30 years, though in the United States they are refreshed every 10 years using 30 years' worth of data. The most recent set of normals was released in May of 2021 using data from 1991 through 2020.

For select local normals: [weather.gov/lmk/climate](https://weather.gov/lmk/climate)

For all normals across the country: [ncei.noaa.gov/products/land-based-station/us-climate-normals](https://ncei.noaa.gov/products/land-based-station/us-climate-normals)



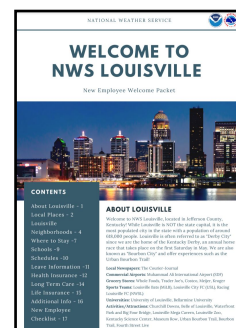


# Culture Club

Jess Lee *Meteorologist*

As part of a new initiative across the National Weather Service, a local Culture Team was developed at NWS Louisville in 2021 to help promote a positive and healthy office. Culture impacts everything we do, from how we develop and train our employees to how we interact with our partners. A healthy culture can energize an office and allow it to flourish, while an unhealthy culture saps energy, decreases morale, and discourages personal and team growth. **Research has also shown a high correlation between office culture and severe weather warning verification statistics.** Within a high performance culture, positive values such as teamwork, open communication, strong customer orientation, trust, and respect lead to highly accurate storm warnings. On the other hand, in a low performance culture, issues such as unresolved conflict, climate of fear, lack of empowerment, poor sense of goals, and lack of customer focus tend to lead to only moderately accurate warnings.

One of the first projects that the NWS Louisville Culture Team worked on this year was the development of a Welcome Packet for new employees. This was key as we welcomed four new employees and a student to the office during the second half of the year. The Welcome Packet introduces people to the area while also familiarizing them with important office information.



Another key project of the Culture Team has been the development of a peer recognition program called Slugger of the Month. This program allows employees to show appreciation to their fellow colleagues by nominating them to receive recognition for random acts of kindness, good deeds, or a job well done. The actions of the individual can be big or small, but overall they have made a difference to keep things running smoothly and ensure that office goals were accomplished. One person is then selected from the nominations to be the Slugger of the Month, with everyone able to read through

the nominations that were submitted for them each quarter to receive that appreciation from their coworkers.

The Culture Team is excited to continue improving upon office culture. Future projects include leadership training for the office as well as community volunteer activities.

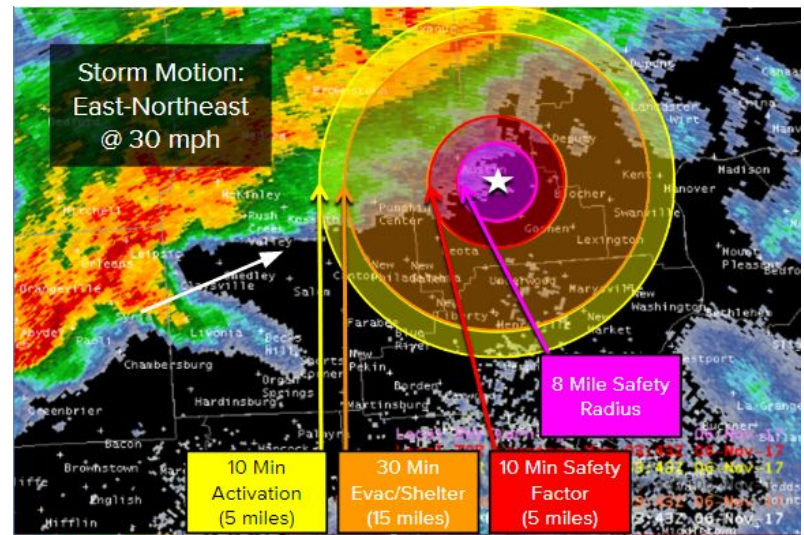
# Event Ready

Brian Schoettmer *Lead Meteorologist*

Event planners and organizers face the task of making tough decisions with regard to weather hazards that may threaten the safety of their patrons. Depending on how rapidly the threat evolves, sometimes these decisions need to be made quickly enough to allow time for safety plans to be activated and executed. In addition, planners and organizers must be sure that there is proper sheltering available. Often times, planners and organizers do not have time to monitor weather as an event is ongoing due to many other duties that may be asked of them. It has been determined that events need to have a person solely dedicated to monitoring and acting on potential weather threats, otherwise situational awareness may be lost and patrons attending the event could be threatened if not given enough advance notice. This identified need is where the concept of having a weather watcher was born.

A weather watcher for a public event is a lot like a trained storm spotter. Weather watchers need to be weather savvy enough to communicate with NWS meteorologists, interpret basic weather information, and apply that information to a predetermined action plan. They also need to know where to find the appropriate weather data and how to use tools that have been made available from the Emergency Management community in recent years. Although still experimental, the training and the response from the training participants have shown promise.

A group of meteorologists from NWS offices in Louisville, Paducah, Jackson, Wilmington OH, and the Ohio River Forecast Center conducted a day-long weather watcher training session for Emergency Managers and first responders at the annual Kentucky Emergency Services (KESC) Conference in Louisville in September. The training featured several new tools and procedures for event planners that would help them stay situationally aware and proactive for their events ahead of any threatening weather. The morning session gave an overview of event ready planning and what tools could be used to help make planning decisions. The afternoon session featured real-time and interactive training examples during which participants were able to apply what they learned to make evacuation decisions ahead of approaching storms. Creators of the training really wanted to make the scenario as realistic as possible including live radar loops, watch/warning updates, and interactive questions and polling. Based on the positive feedback from participants, they succeeded!



As a result of the successful first training session and enthusiasm for new local training opportunities, NWS Louisville plans to continue these experimental training classes going forward into 2022 and beyond. Contact us at [nws.louisville@noaa.gov](mailto:nws.louisville@noaa.gov) for more information.

# Kentucky's Strongest Wind Gust

Tom Reaugh *Lead Meteorologist*

Late on the evening of April 25, 2011 a squall line crossed the middle Mississippi Valley and moved through western Kentucky around midnight. As the storms approached Murray, Kentucky, radar indicated a local surge and an area of enhanced winds near the location of the Calloway County Kentucky Mesonet station. At 12:25 am CDT on the 26th, the Kentucky Mesonet anemometer recorded a peak wind gust of 100.8 mph.

In April 2021 a State Climate Extremes Committee (SCEC) was convened to discuss whether the 100.8 mph gust was a state record measured wind gust for Kentucky. The SCEC considered several factors including meteorological plausibility of the gust occurring, a review of the equipment that was used to measure the gust, degree of nearby damage, and a search through the historical records for any other gusts that might be contenders for the record. After completing the research, the team came to the conclusion that this would indeed be the strongest wind gust measured in Kentucky via reliable, verifiable equipment.

*And then December 10th happened*

Six miles before the infamous Mayfield Tornado devastated that town on December 10, the tornado struck the Kentucky Mesonet site in Graves County. EF1 damage was found about 900 feet away, and the wind equipment measured a 107 mph gust. If verified, that gust would be a new record for Kentucky...

*Until 61 minutes later*

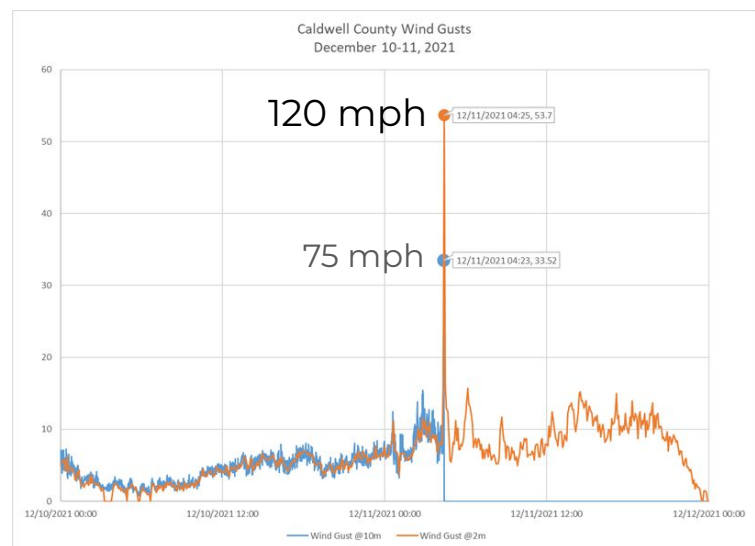
As the twister passed southeast of Princeton about an hour later, it struck the Mesonet's anemometers again. EF3 damage occurred 1300 feet away from the measuring site. While the anemometer installed at a height of 33 feet failed when the tower collapsed, the anemometer positioned at just under 7 feet survived. It recorded an amazing 120 mph gust!

So, the SCEC will reconvene in 2022 to decide if one of these new gusts will become the strongest wind gust ever reliably measured in the Commonwealth of Kentucky.

*Below: The Kentucky Mesonet site near Princeton after the storm. The anemometer on the left measured a 120 mph wind gust with the tornado.*



*Right: Wind gust graph taken from the Princeton site, showing the 120 mph peak wind. The 75 mph wind is from equipment that failed when the tower collapsed.*



# Improving Warnings

Ryan Sharp *Science and Operations Officer*

With each passing year, meteorologists see new datasets and tools to help with forecast decisions. Because the mission of the NWS includes the protection of life and property by providing warning of impending hazardous weather conditions, the decision to issue Tornado Warnings and Severe Thunderstorm Warnings must be supported by as much information as can be assessed in a timely fashion. New techniques and conceptual models have been developed in the past few years to diagnose where to focus attention for tornado development, specifically when it comes to the quick spin-up tornadoes that form along the squall lines that frequent our area. Considering all of these datasets and tools can be daunting for one person to accomplish alone, so NWS Louisville implements two-person warning teams.

One member of the team expressly reviews radar data and actually issues the warning product, while the other is tasked with reviewing other data, performing mesoscale analysis by formulating an idea of what the environment is very close to the storm, and providing a second opinion before the issuance of the warning.

Along a similar line, NWS Central Region Headquarters in Kansas City worked with several field meteorologists and experts to develop a Remote Mesoanalyst Assistant program. This program is implemented whenever a large outbreak of storms is expected. A field expert is assigned to the event and diagnoses local atmospheric conditions to assess areas that have a greater, or lesser, chance of tornadoes and severe thunderstorms. The analyst collects

*Continued next page...*

*The Remote Mesoanalyst Assistant (RMA) is able to take advantage of very high resolution meteorological data (see below) when evaluating the atmosphere. The RMA can even draw on the maps and share graphics and information via Google Chat (see right),*



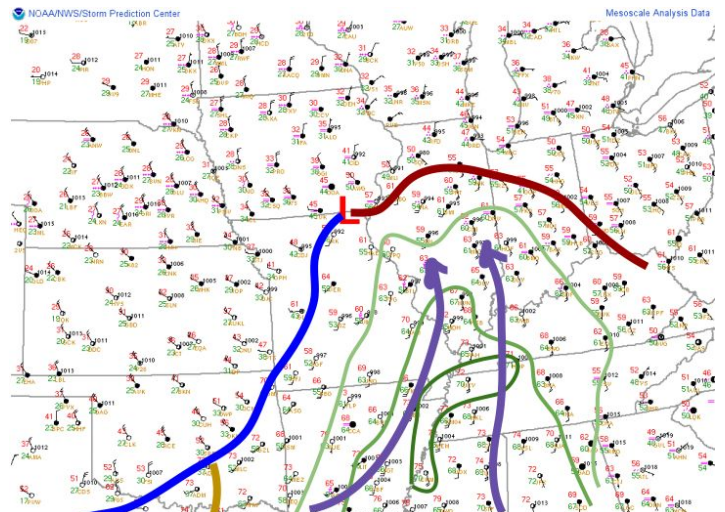
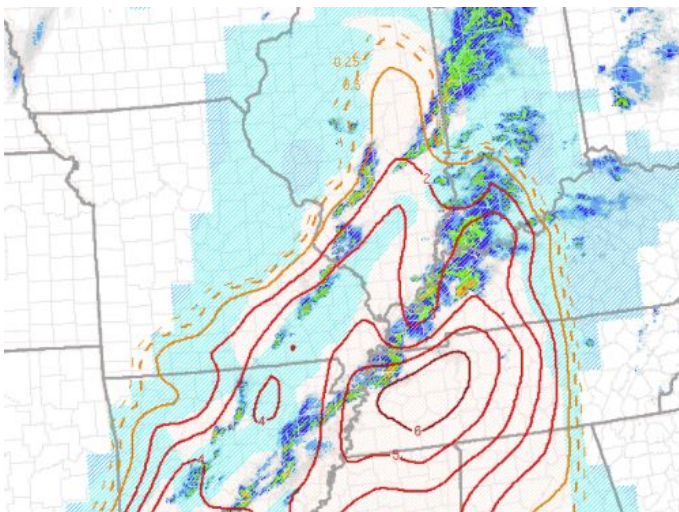
Bryan Baerg - NOAA Federal Dec 11, 1:15 AM

As Keith mentioned earlier, the cell crossing the KY/TN border will continue to progress into an even better low-level thermal environment across southern KY. In addition, surface wind obs to the east are slightly more backed suggesting additional streamwise vorticity ingestion. For the time being, there doesn't appear to be any open warm sector cells that could disrupt the main updraft, unfortunately.



Bryan Baerg - NOAA Federal Dec 11, 2:03 AM

Mode has certainly become messy with the embedded supercell west of BG and QLCS/hybrid SC southwest of BG. With the outflow orientation associated with this cluster being NNW to SSE -- this yields the potential for an eventual transition to a QLCS tornado threat with 0-3km vectors nearly orthogonal at 60 kts.



input from many meteorologists across the region, including those where the weather is quiet. The field expert then relays critical information to the impacted weather office.

A training curriculum for this program has been developed at the national level. A few meteorologists at each office take this broader suite of coursework to become subject matter experts. At NWS Louisville we have four meteorologists who are studying to become our local experts: Mark Jarvis, Jess Lee, Adrian Lopez-Lago, and Evan Webb. The goal of this training is to give meteorologists scientific tools they can use to anticipate tornado development well ahead of a radar signature, even sending out messaging on where the greatest risk for severe weather is as much as an hour or two before it develops!

The historic tornado outbreak of December 10-11, 2021 gave our office an excellent chance to test the program. Expert meteorologists, one in South Dakota and another in Kansas where the weather was quiet, were tasked with assisting NWS Louisville and Paducah. Thanks to their efforts along with the local teams in Kentucky, warnings were issued with substantial lead times. People sought shelter and lives were saved.

Fortunately, outside of the December storms, our region has been in a relative severe weather drought over the past couple of years. Mesoanalysis has still played an important role, however. There have been instances when the warning team made good decisions **not** to issue Tornado Warnings on strongly rotating storms that did not produce tornadoes.

Congratulations to 2021's Weather-Ready Nation Ambassador of Excellence, The Parklands of Floyd's Fork! Each year NWS Louisville recognizes a local partner that has gone above and beyond with helping to create a more Weather-Ready Nation. In 2021 that distinction went to the Parklands for their role in what has become a mutually beneficial relationship between them and the National Weather Service. For more information on this program see [weather.gov/wrn](https://weather.gov/wrn).



A photograph of a snowy field with a barn in the background under a sunset sky. The foreground is filled with snow-covered grasses, some of which are covered in frost. The barn is dark and silhouetted against the bright orange and yellow sky. The overall scene is a winter landscape.

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