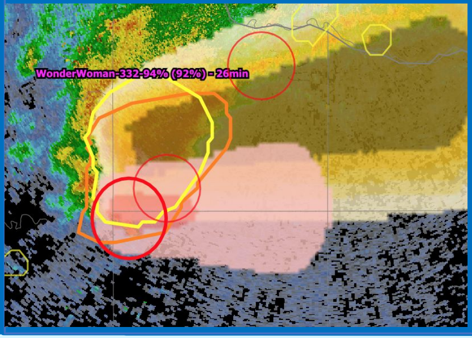
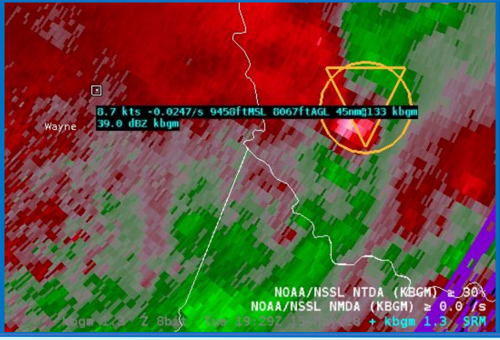
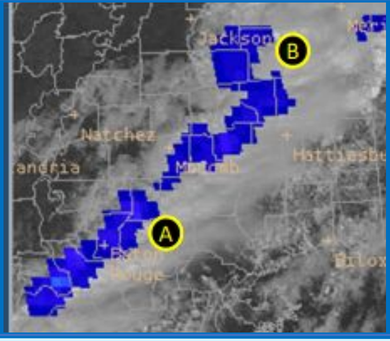
Better Forecast/Warning Tools and Techniques

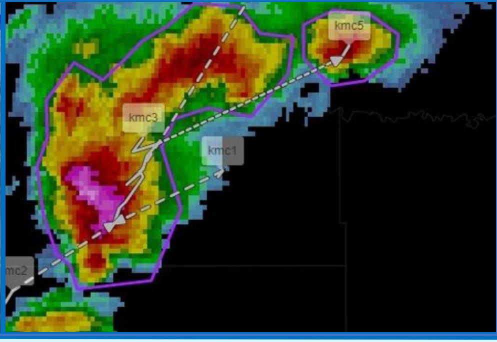
Observation-based Severe Convective Tools

Travis Smith; CIWRO Senior Research Associate; WRDD



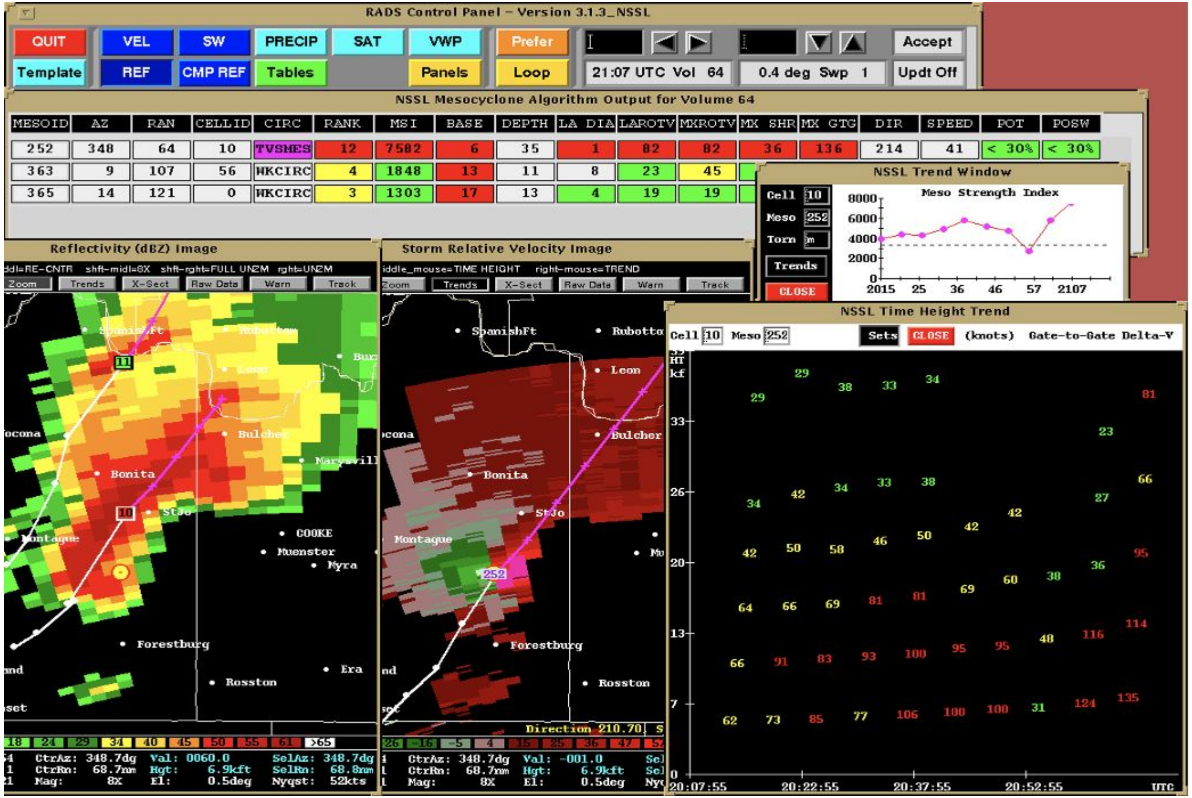






History - observation-based severe convective tools

- Ongoing at NSSL since at least the 1990s
- Early WSR-88D algorithms
- Multi-Radar/Multi-Sensor
- Very heavy collaborative effort with the NWS and other end users



History - observation-based severe convective tools

- Founding of HWT Experimental Warning Program
- Foundations of FACETs / Probabilistic Hazard Information (PHI)

New Technologies

Machine learning (since the 1990s) - detection and short-term prediction of:

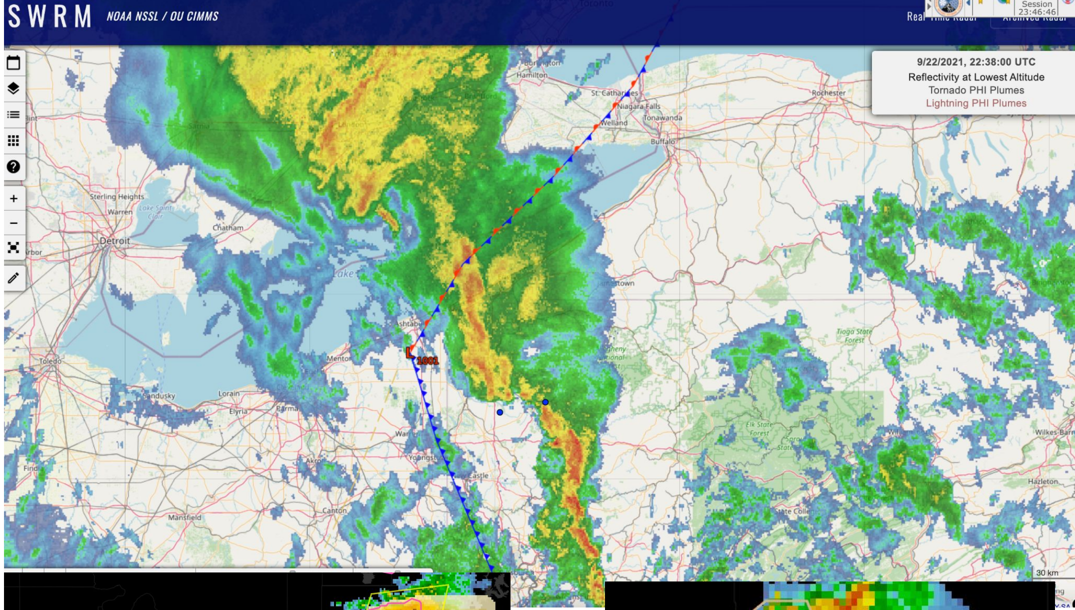
- Tornadoes
- Hail
- Damaging Convective Wind
- Flash Flooding

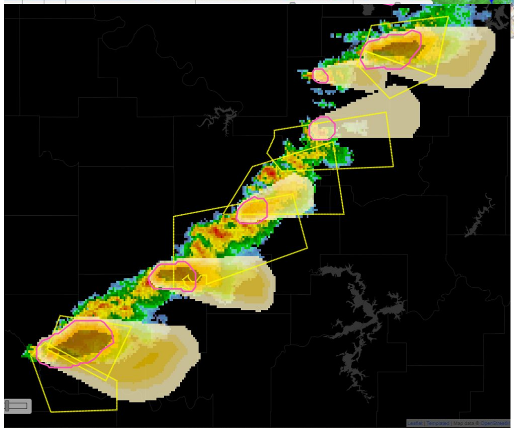
How do humans use these tools?

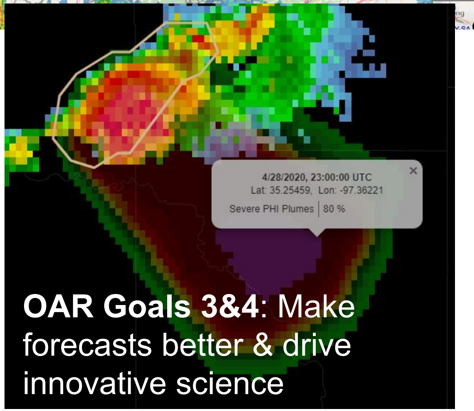
Newer web technologies

- Georeferenced data
- Modern databases

Quantifying and managing uncertainty at 0-60 minute scale







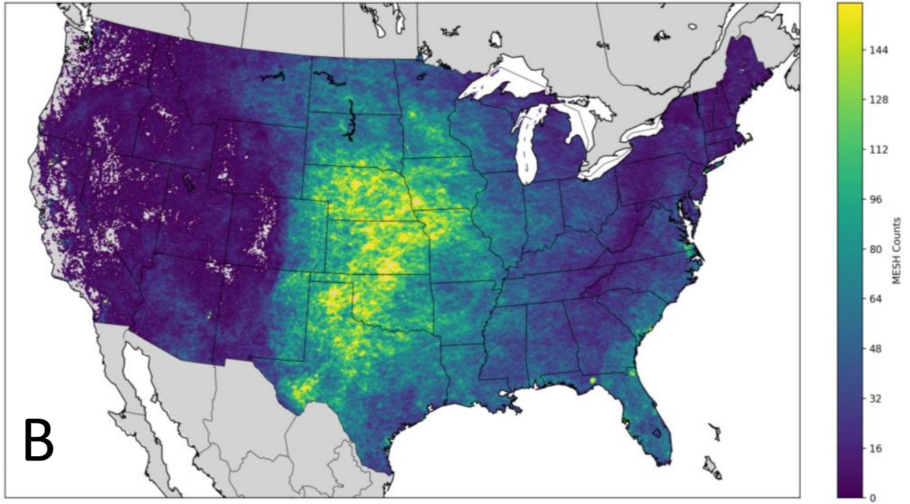
OAR Goals 3&4: Make forecasts better & drive innovative science

Large Radar Datasets, Machine Learning, and Storm-scale probabilistic hazard guidance

Over 2 decades worth of WSR-88D data covering the CONUS

Quality controlled CONUS data from 1998-2011 (more to come)

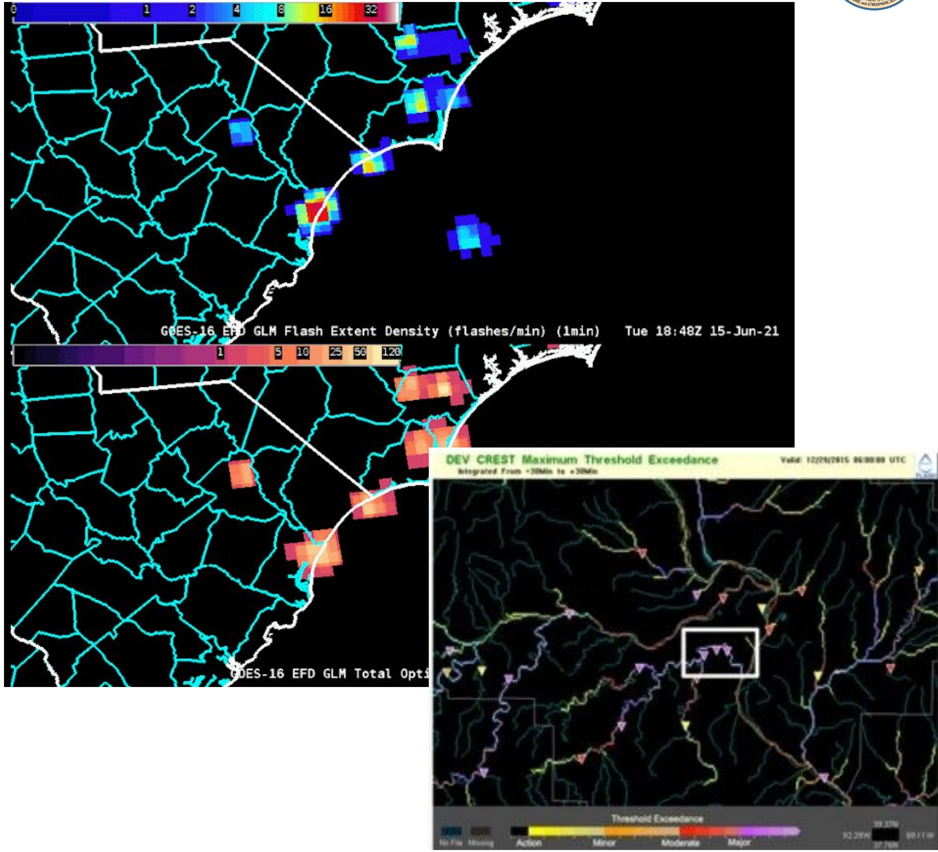
- Range of storm behaviors
- Climatology
- Training machine learning applications
- Validation of NWP models
- Guidance for “strike” probabilities



MYRORSS hail occurrence 1998-2011

Satellite, Lightning and Flash Flood Research

- Satellite R&D has greatly expanded with the new applicability to severe weather following the launch of the GOES-R series of satellites.
  - New products and algorithms
  - Data assimilation & machine learning
  - No longer dependent on radar data alone.
- Flash flood guidance change the paradigm of how flood threats are evaluated.:
  - very high resolution terrain
  - vegetation
  - MRMS precipitation estimates



Quality & Performance

2016 & 2018 National Weather Association Larry R. Johnson Special Award - for the successful transition to operations of applications that assist forecasters with warning operations and observations (MRMS-Severe and mPING).

Over 70 refereed publications since 2015

Students mentored / degrees granted:

- Ph.D: 7
- MS: 8
- Undergraduates: 19 UGRAs,
  5 REU, 11 OU Meteorology Capstone

24 Hazardous Weather Testbed experiments led since 2015

Collaborators

MRMS

Weather Enterprise

Willis Towers Watson

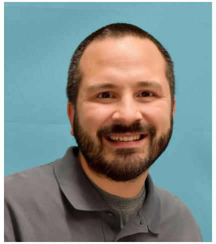
Emergency Managers

Broadcast Meteorologists

Research → Operations & Users

Upcoming presenters

2. Multi-year reanalysis of remotely sensed-storms (MYRORSS) and Machine Learning Applications



Kiel Ortega

3. Storm-scale Probabilistic Hazard Information (PHI)

Dr. Kristin Calhoun

4. Storm-scale PHI with NWS Core Partners

Holly Obermeier

5. Satellite and Lightning Convective Tools and Research

Dr. Kristin Calhoun

6. Flooded Locations and Simulated Hydrographs Project - FLASH

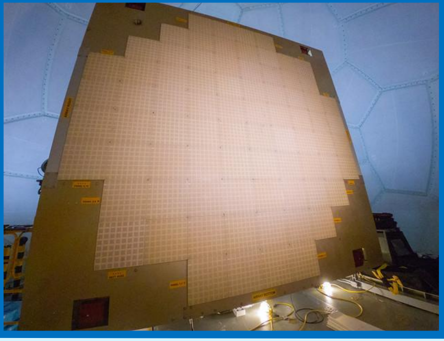
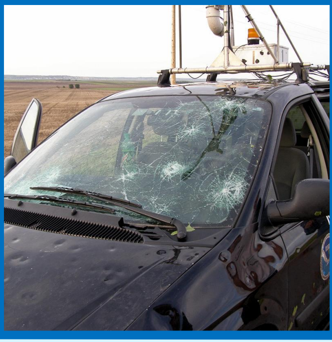
Dr. Jonathan J. Gourley

Observation-based severe convective tools

Multi-year reanalysis of remotely sensed-storms (MYRORSS) and Machine Learning Applications

Kiel Ortega; CIWRO Research Associate III; WRDD



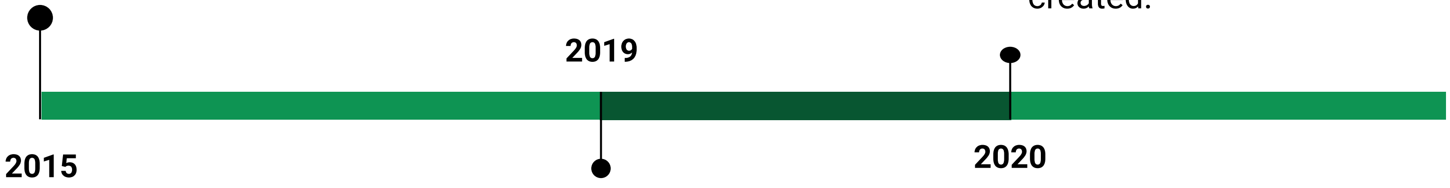
MYRORSS Timeline

Re-running of poor QC cases continues

Data processing started in 2012, finishing in 2014 and intensive quality control continuing from there. Reprocessing of azimuthal shear data using updated software begins.

Data set openly available

A DOI was minted through OU and the data set made available via DropBox. Derivative data set of storm clusters created.

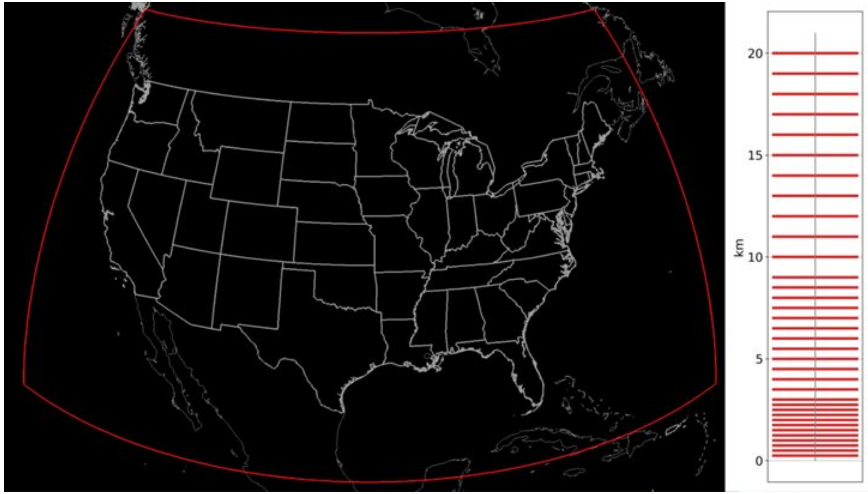


Quality control complete

Initial data set, from April 1998 through 2011, finished.

MYRORSS Products

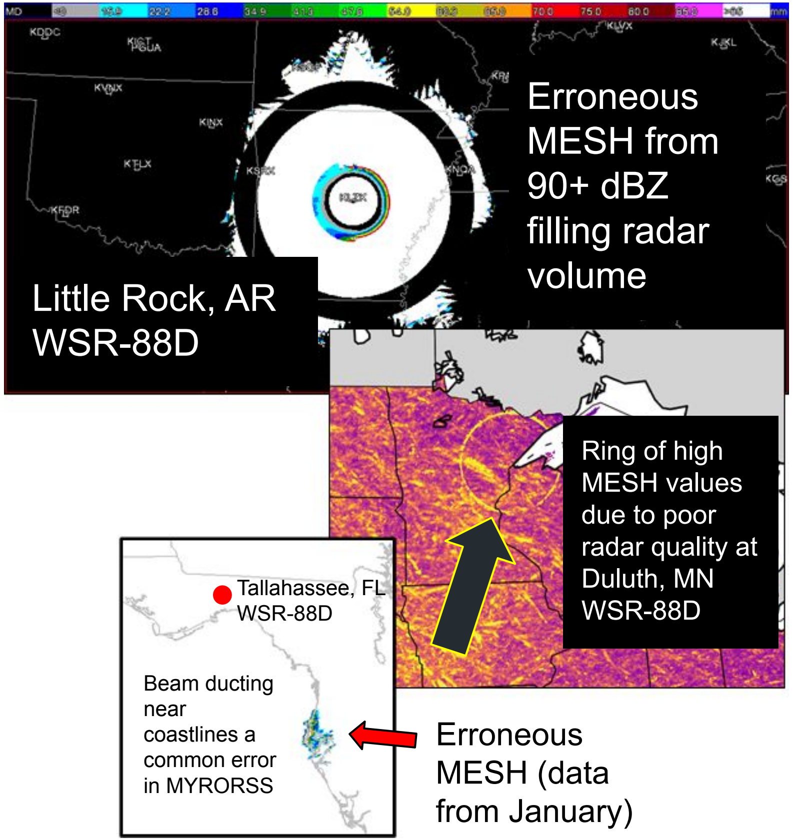
- Data from April 1998 through 2011 completed
- Includes 3D reflectivity, 2 azimuthal shear layers (low- and mid-levels)
  - Data are essentially MRMS data with manual quality control
- Reflectivity derived products, such as echo tops and a hail size estimate, included
- Near-storm environment data from operational forecast models completed
  - For product creation, isothermal heights (e.g. height of 0°C) are needed
  - Derivative products include many near-storm parameters, like instability and wind shear



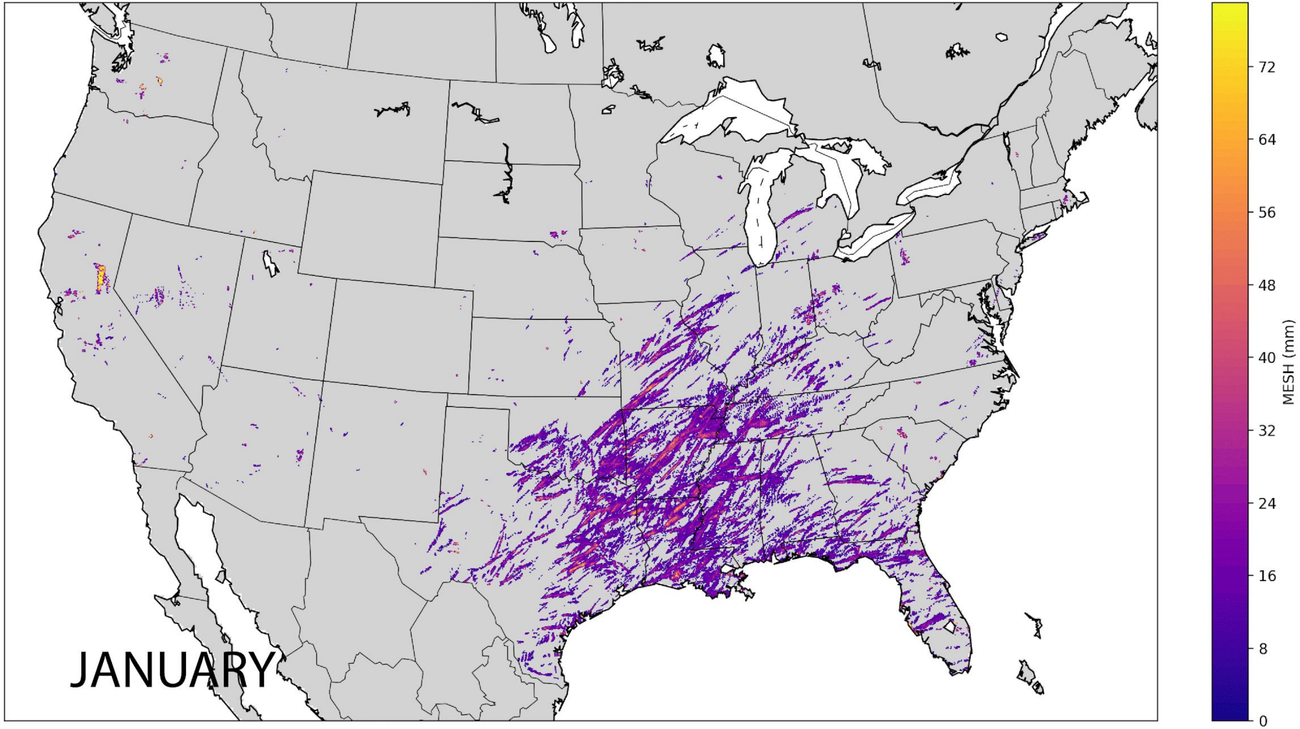
Domain outlined plus representation of the vertical grid

Quality Control Matters

- Need research-quality data set for proper development of machine learning models
- Re-processing of data can help identify shortcomings in radar data quality control as research quality data requires review of the processed data



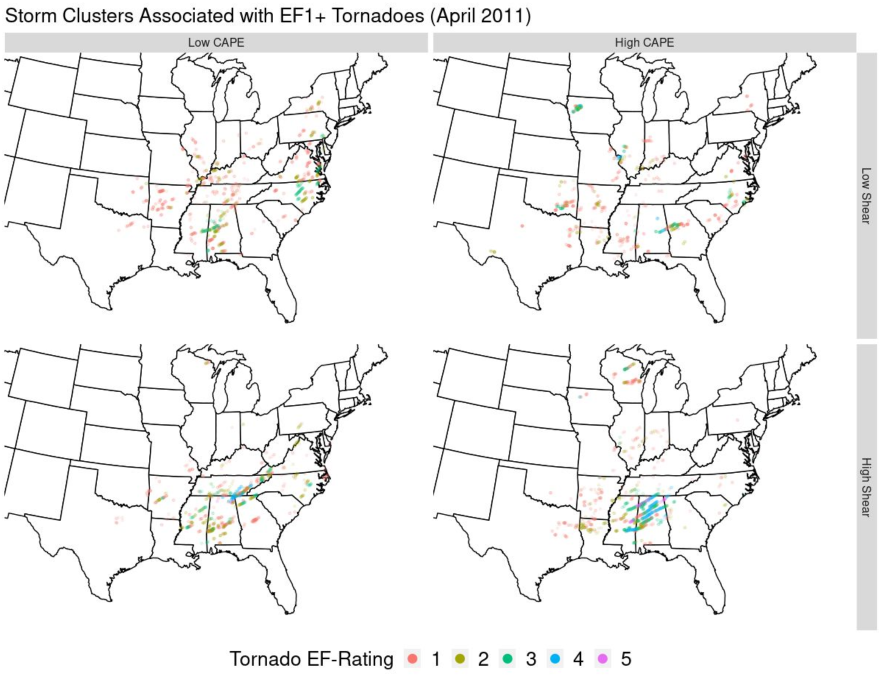
MYRORSS - Initial Climatology Development



Maximal MESH value for each month (accumulated over the entire 1998-2011 period)

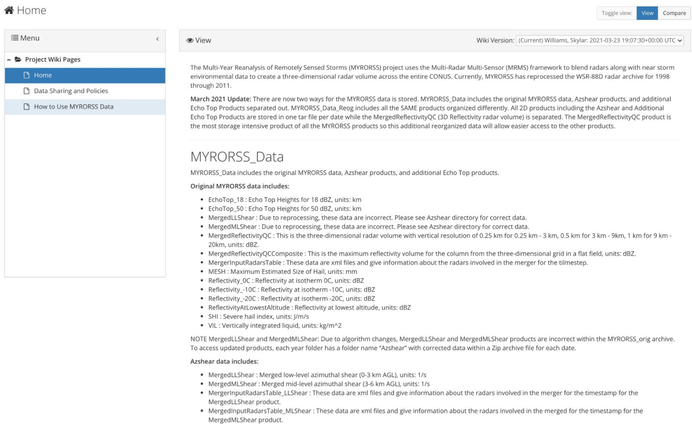
MYRORSS - Storm Object Database

- Developed database using image segmentation
- Currently being used to develop probabilities for attendant thunderstorm hazards leveraging ML
- Can be used to develop storm climatologies



MYRORSS - Open Data and Open Science

- In 2020, MYRORSS was publicly released and is accessible to all
- A BAMS article is in review summarizing the dataset and processing
- Several groups have already utilized the dataset for research
- NOAA Big Data Program hosting pending final approval


Home

Toggle view: View Compare

Menu

View

Wiki Version: (Current) Williams, Skylar: 2021-03-23 19:07:30+00:00 UTC

- Project Wiki Pages
  - Home
  - Data Sharing and Policies
  - How to Use MYRORSS Data

The Multi-Year Reanalysis of Remotely Sensed Storms (MYRORSS) project uses the Multi-Radar Multi-Sensor (MRMS) framework to blend radars along with near storm environmental data to create a three-dimensional radar volume across the entire CONUS. Currently, MYRORSS has reprocessed the WSR-88D radar archive for 1998 through 2011.

March 2021 Update: There are now two ways for the MYRORSS data is stored. MYRORSS_Data includes the original MYRORSS data, Azshear products, and additional Echo Top Products separated out. MYRORSS_Data_Reog includes all the SAME products organized differently. All 2D products including the Azshear and Additional Echo Top Products are stored in one tar file per date while the MergedReflectivityQC (3D Reflectivity radar volume) is separated. The MergedReflectivityQC product is the most storage intensive product of all the MYRORSS products so this additional reorganized data will allow easier access to the other products.

MYRORSS_Data

MYRORSS_Data includes the original MYRORSS data, Azshear products, and additional Echo Top products.

Original MYRORSS data includes:

- EchoTop_18 : Echo Top Heights for 18 dBZ, units: km
- EchoTop_50 : Echo Top Heights for 50 dBZ, units: km
- MergedLLShear : Due to reprocessing, these data are incorrect. Please see Azshear directory for correct data.
- MergedMLShear : Due to reprocessing, these data are incorrect. Please see Azshear directory for correct data.
- MergedReflectivityQC : This is the three-dimensional radar volume with vertical resolution of 0.25 km for 0.25 km - 3 km, 0.5 km for 3 km - 9km, 1 km for 9 km - 20km, units: dBZ.
- MergedReflectivityQCComposite : This is the maximum reflectivity volume for the column from the three-dimensional grid in a flat field, units: dBZ.
- MergerInputRadarsTable : These data are xml files and give information about the radars involved in the merger for the tilmestep.
- MESH : Maximum Estimated Size of Hail, units: mm
- Reflectivity_0C : Reflectivity at isotherm 0C, units: dBZ
- Reflectivity_-10C : Reflectivity at isotherm -10C, units: dBZ
- Reflectivity_-20C : Reflectivity at isotherm -20C, units: dBZ
- ReflectivityAtLowestAltitude : Reflectivity at lowest altitude, units: dBZ
- SHI : Severe hail index, units: J/m/s
- VIL : Vertically integrated liquid, units: kg/m^2

NOTE MergedLLShear and MergedMLShear: Due to algorithm changes, MergedLLShear and MergedMLShear products are incorrect within the MYRORSS_orig archive. To access updated products, each year folder has a folder name “Azshear” with corrected data within a Zip archive file for each date.

Azshear data includes:

- MergedLLShear : Merged low-level azimuthal shear (0-3 km AGL), units: 1/s
- MergedMLShear : Merged mid-level azimuthal shear (3-6 km AGL), units: 1/s
- MergerInputRadarsTable_LLShear : These data are xml files and give information about the radars involved in the merger for the timestamp for the MergedLLShear product.
- MergedInputRadarsTable_MLShear : These data are xml files and give information about the radars involved in the merged for the timestamp for the MergedMLShear product.

https://doi.org/10.15763/DBS.CIMMS.MYRORSS.DATA

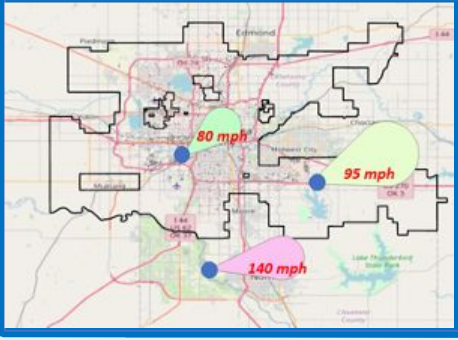
Future work

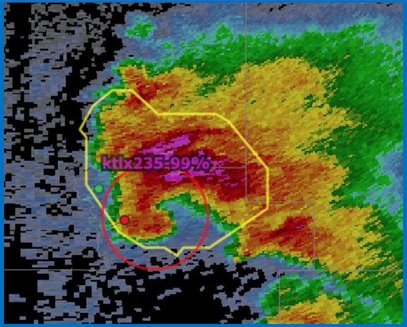
- Processing of contemporary data to complete archive through present
  - Including polarimetric products and potentially full 3D fields of azimuthal shear and divergence
  - Higher resolution? (~500-m, 2-min update frequency)
- Continue to develop derivative data sets (e.g., hail climatology)
  - Summarize data into databases for easier use by external users
- Continue developing storm cluster database
  - Time-matching clusters for storm tracking
- Use machine learning to continue exploration of severe storms
  - Continue work to model warning verification probabilities
  - Continue to use machine learning to use MYRORSS-based data to develop better climatologies
- Combine contemporary data with satellite data as satellite data archives allow

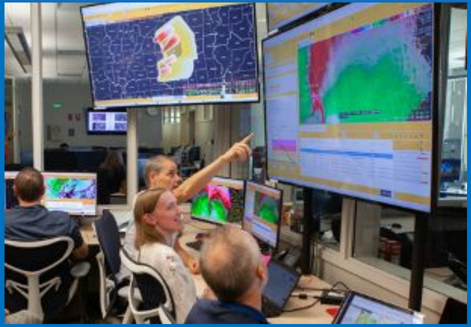
Observation-based severe convective tools

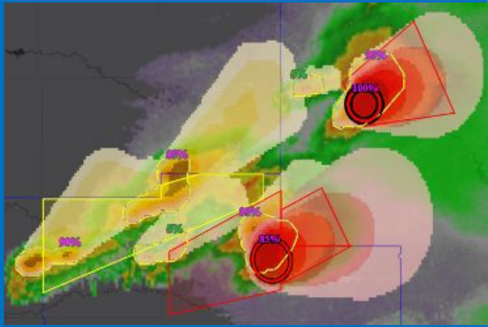
Storm-scale Probabilistic Hazard Information (PHI)

Kristin Calhoun, PhD; NSSL Research Scientist; WRDD



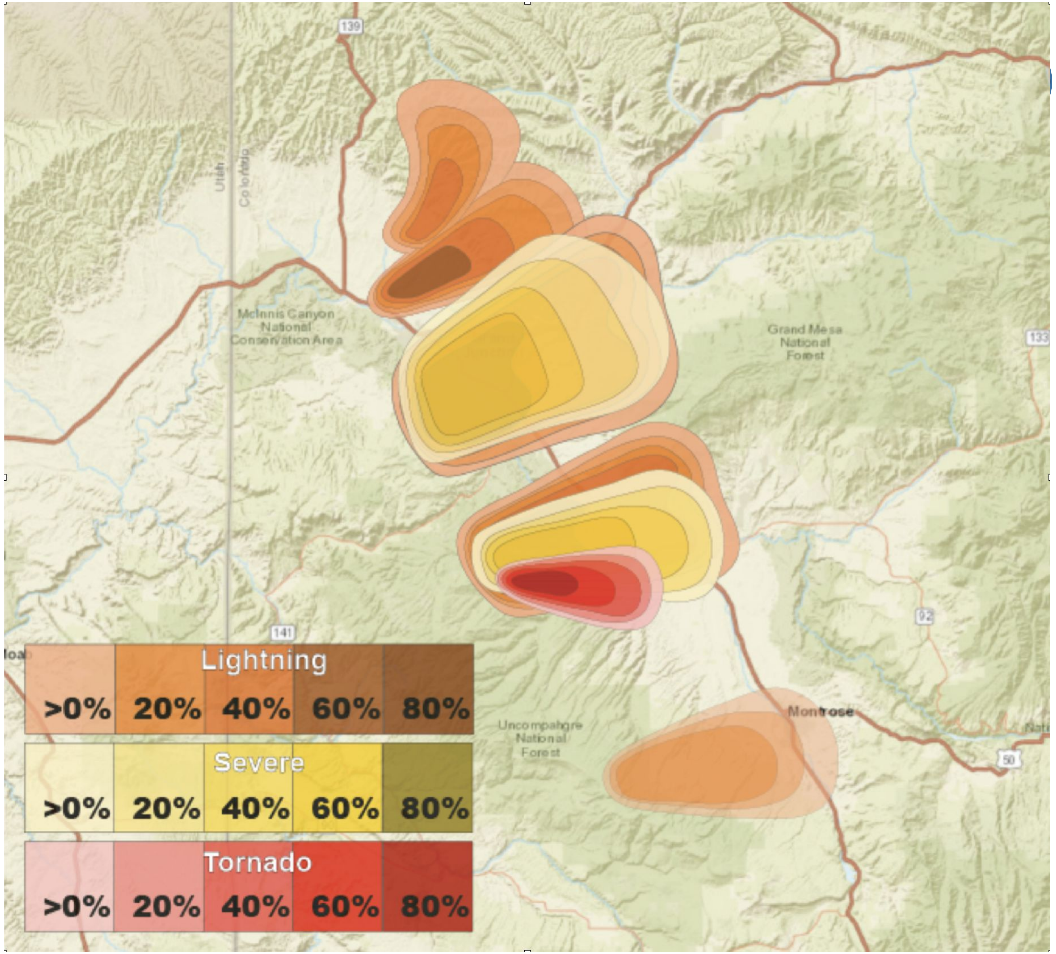


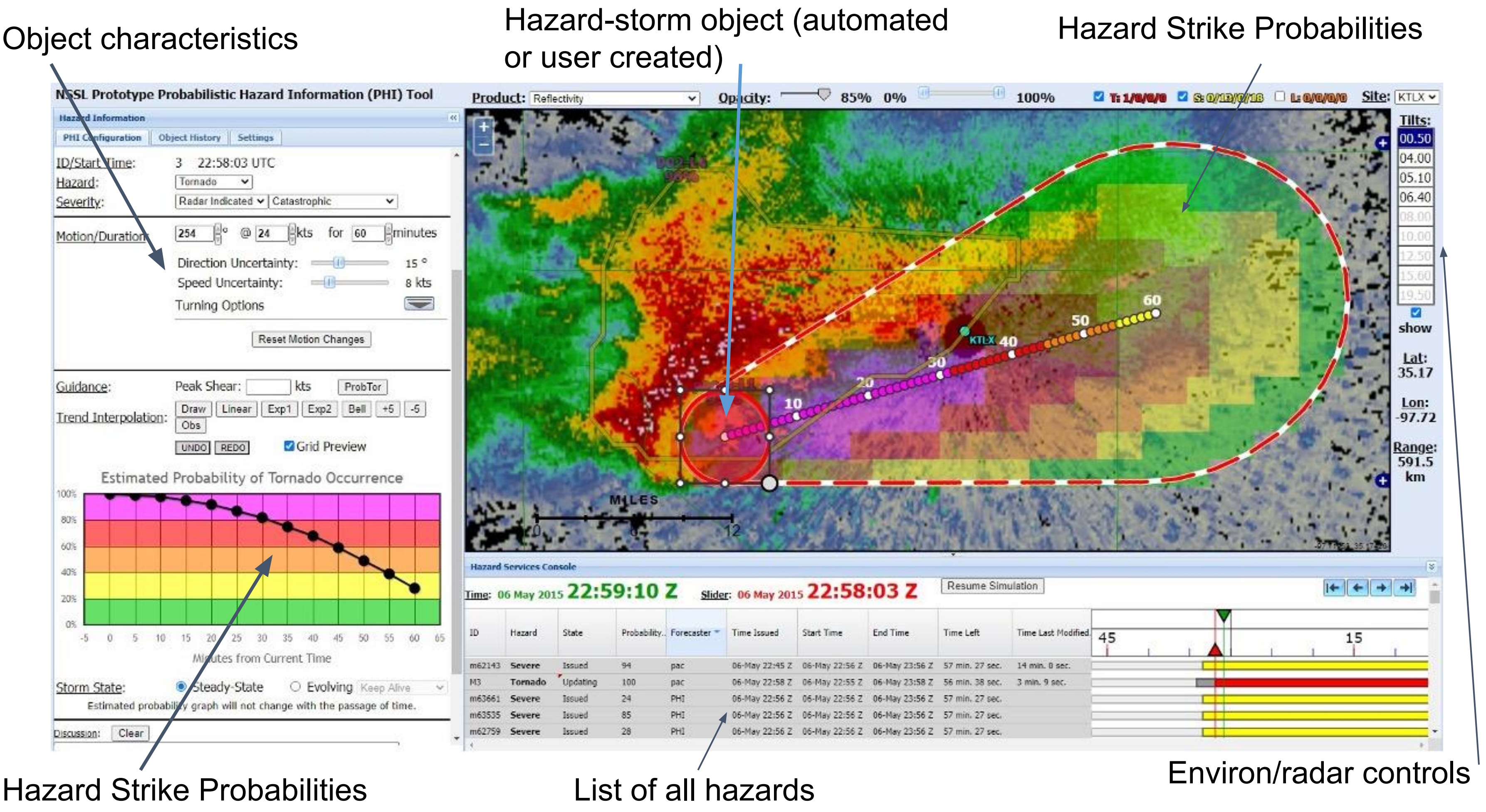


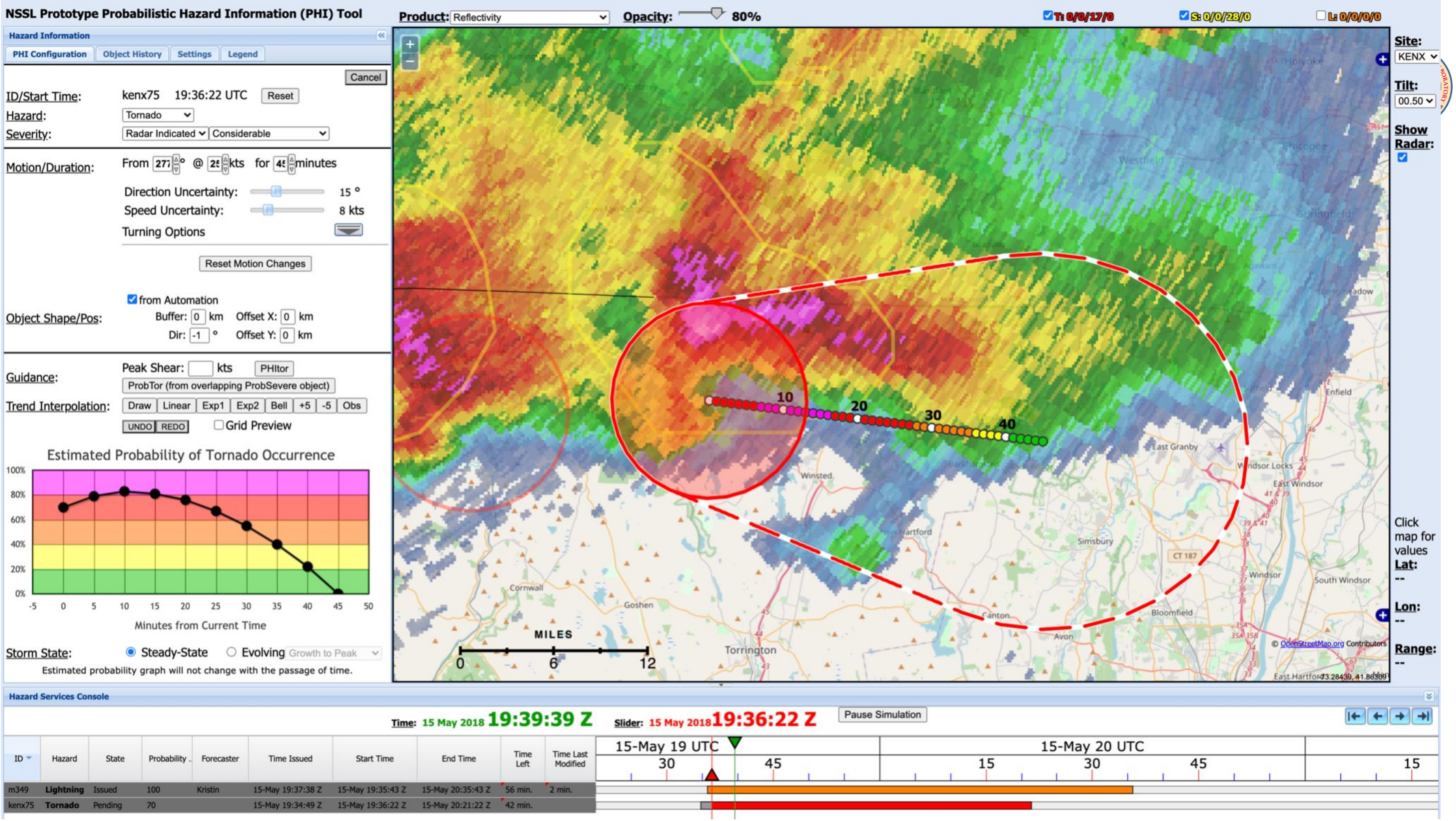


Why Probabilistic Hazard Information?

- More specific regarding time (when storm will affect location, when it will end);
- More specific regarding space (smaller aerial coverage advects with storm);
- More specific intensity estimates;
- Defines the temporal, spatial, and intensity uncertainties of the threats. Allows for longer lead-times, though with higher uncertainty;
- Updates continuously in real-time to reflect changes in storm motion and evolution.




Object characteristics
Hazard-storm object (automated or user created)
Hazard Strike Probabilities
NSSL Prototype Probabilistic Hazard Information (PHI) Tool
Hazard Information
PHI Configuration
Object History
Settings
ID/Start Time:
3 22:58:03 UTC
Hazard:
Tornado
Severity:
Radar Indicated
Catastrophic
Motion/Duration
254
@ 24
kts
for
60
minutes
Direction Uncertainty:
15 °
Speed Uncertainty:
8 kts
Turning Options
Reset Motion Changes
Guidance:
Peak Shear:
kts
ProbTor
Trend Interpolation:
Draw
Linear
Exp1
Exp2
Bell
+5
-5
Obs
UNDO
REDO
Grid Preview
Estimated Probability of Tornado Occurrence
Minutes from Current Time
Storm State:
Steady-State
Evolving
Keep Alive
Estimated probability graph will not change with the passage of time.
Discussion:
Clear
Product:
Reflectivity
Opacity:
85%
0%
100%
Site:
KTLX
Tilts:
show
Lat:
35.17
Lon:
-97.72
Range:
591.5
km
MILES
KTLX
Hazard Services Console
Time: 06 May 2015 22:59:10 Z
Slider: 06 May 2015 22:58:03 Z
Resume Simulation
ID
Hazard
State
Probability
Forecaster
Time Issued
Start Time
End Time
Time Left
Time Last Modified
Hazard Strike Probabilities
List of all hazards
Environ/radar controls


NSSL Prototype Probabilistic Hazard Information (PHI) Tool
Product: Reflectivity
Opacity: 80%
T: 0/0/17/0
S: 0/0/28/0
L: 0/0/0/0
Hazard Information
PHI Configuration
Object History
Settings
Legend
Cancel
ID/Start Time: kenx75 19:36:22 UTC
Reset
Hazard: Tornado
Severity: Radar Indicated
Considerable
Motion/Duration: From 277° @ 25 kts for 45 minutes
Direction Uncertainty: 15 °
Speed Uncertainty: 8 kts
Turning Options
Reset Motion Changes
from Automation
Object Shape/Pos:
Buffer: 0 km
Offset X: 0 km
Dir: -1 °
Offset Y: 0 km
Guidance:
Peak Shear: kts
PHItor
ProbTor (from overlapping ProbSevere object)
Trend Interpolation:
Draw
Linear
Exp1
Exp2
Bell
+5
-5
Obs
UNDO
REDO
Grid Preview
Estimated Probability of Tornado Occurrence
100%
80%
60%
40%
20%
0%
-5
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10
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Minutes from Current Time
Storm State:
Steady-State
Evolving
Growth to Peak
Estimated probability graph will not change with the passage of time.
10
20
30
40
Winsted
Cornwall
Goshen
Torrington
Canton
Avon
Simsbury
East Granby
Windsor Locks
East Windsor
Windsor
South Windsor
Bloomfield
Enfield
CT 187
MILES
0
6
12
© OpenStreetMap.org Contributors
Site: KENX
Tilt: 00.50
Show Radar:
Click map for values
Lat: --
Lon: --
Range: --
Hazard Services Console
Time: 15 May 2018 19:39:39 Z
Slider: 15 May 2018 19:36:22 Z
Pause Simulation
ID
Hazard
State
Probability
Forecaster
Time Issued
Start Time
End Time
Time Left
Time Last Modified
m349 Lightning Issued 100 Kristin 15-May 19:37:38 Z 15-May 19:35:43 Z 15-May 20:35:43 Z 56 min. 2 min.
kenx75 Tornado Pending 70 15-May 19:34:49 Z 15-May 19:36:22 Z 15-May 20:21:22 Z 42 min.
15-May 19 UTC
15-May 20 UTC
30
45
15
30
45
15

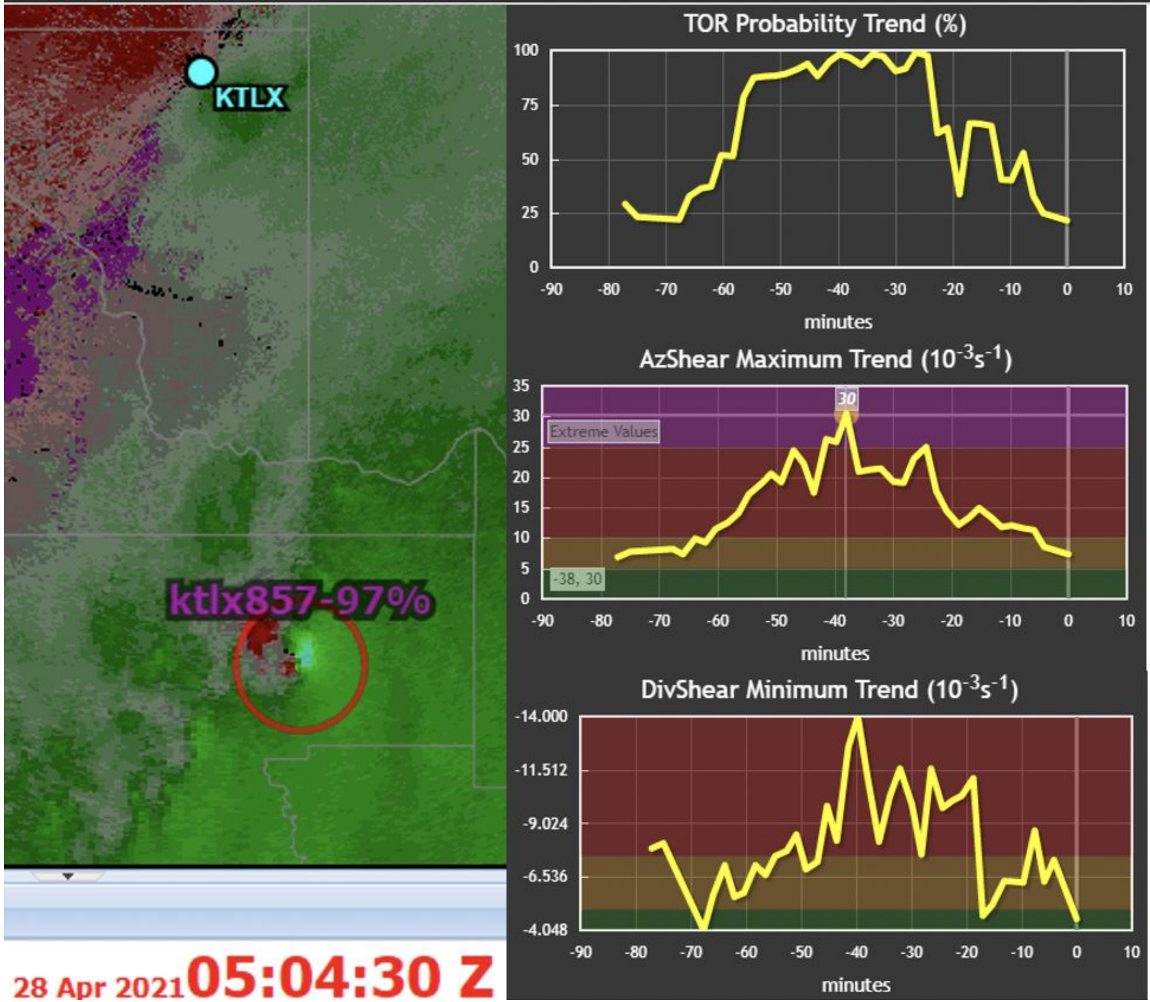
PHItor: Tornado Probabilities

Data extracted from a 2.5-km radius centered on nearest AzShear max.

- velocity, spectrum width, polarimetric values
- Median filtered, 0.5°-tilt single-radar
- Rotation max, min, and percentiles
- Range from radar

Fully automated or “Point and click” tornado probs: creates object based on strongest rotation with 2.5 km of click using most recent radar data.

Produces a current tornado probability (*not a forecast - yet*).



ProbLightning: 1-hour Cloud-to-Ground Lightning probabilities

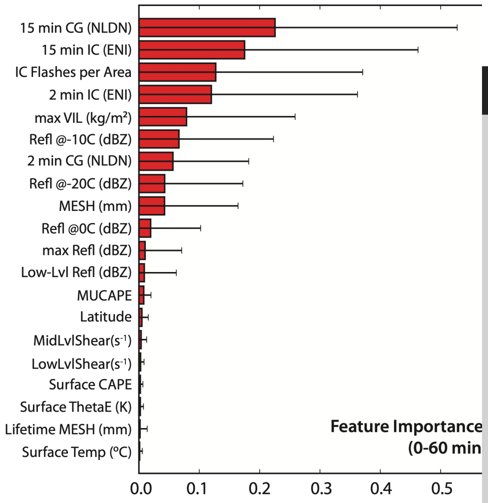
Random Forest with data from lightning detection networks, MRMS, environment.

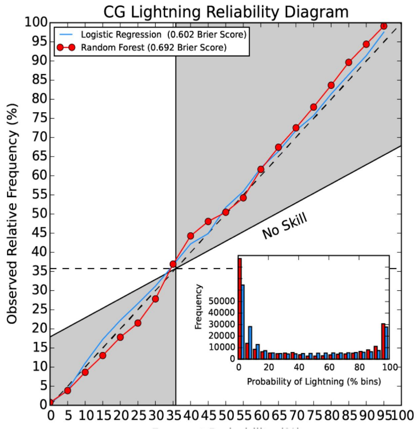
Tuned for CONUS or individual NWS regions and 15 min intervals out to one hour.

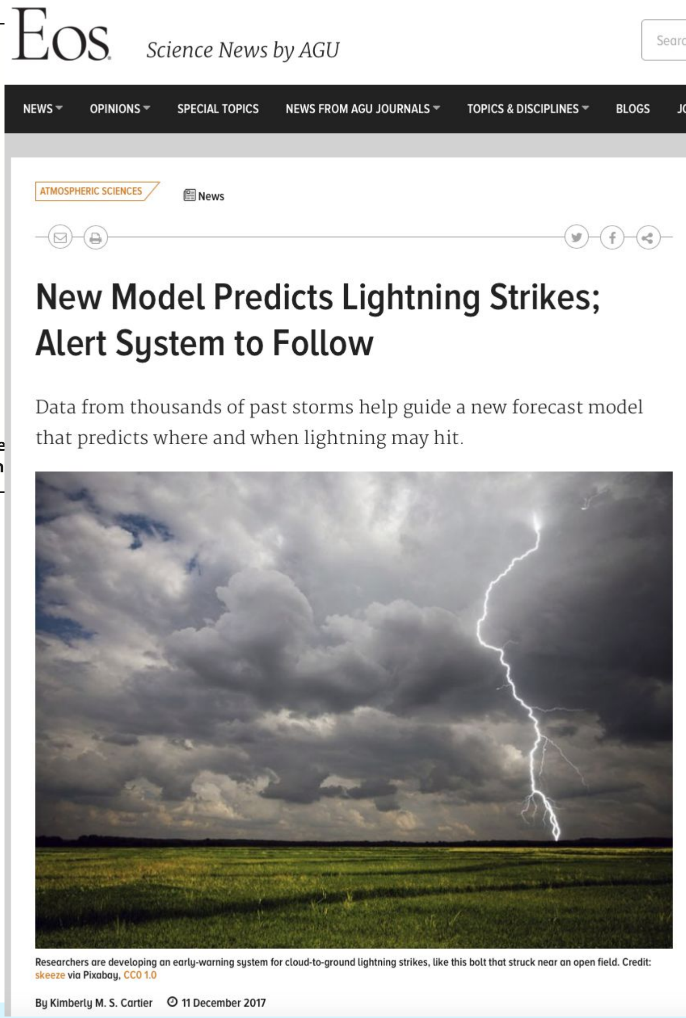
Emergency Managers loved the new information:

“This tool is very important and could see it being incredibly important for the university or any park, NASA… all locations, airports, military installations.”

*“The objects themselves make me feel more confidence. Usually just getting the actual lightning strikes. **Everything used to be reactionary, this is more proactive.”***







New Model Predicts Lightning Strikes; Alert System to Follow

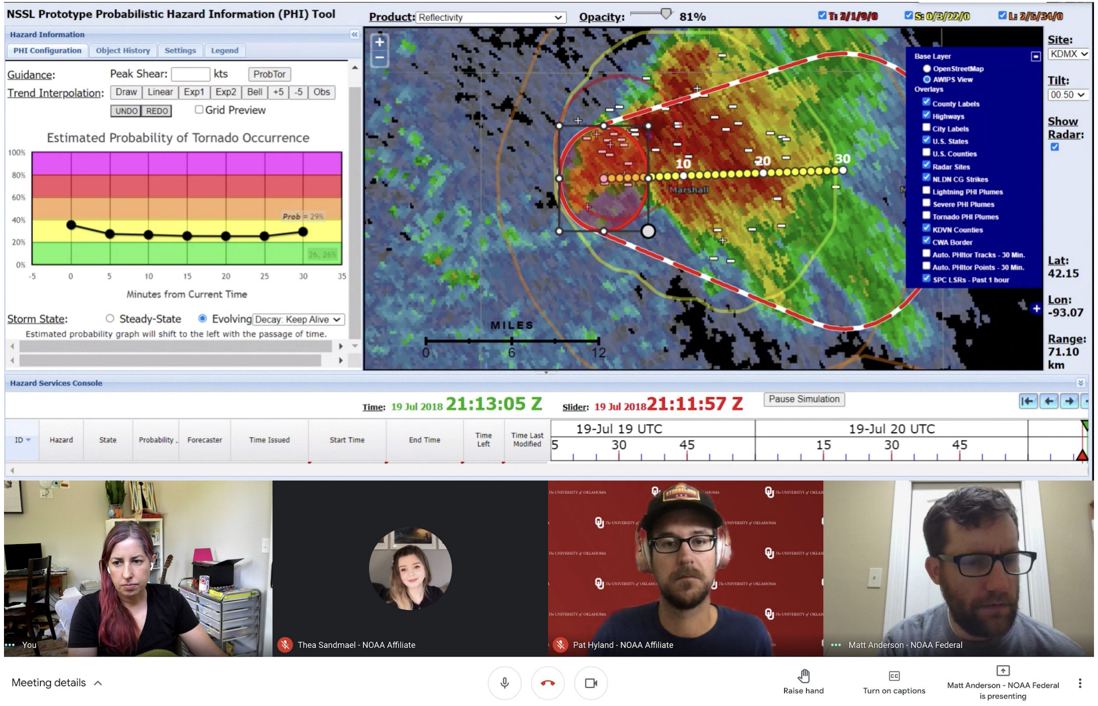
Data from thousands of past storms help guide a new forecast model that predicts where and when lightning may hit.

Researchers are developing an early-warning system for cloud-to-ground lightning strikes, like this bolt that struck near an open field. Credit: skeeze via Pixabay, CC0 1.0

By Kimberly M. S. Cartier 11 December 2017

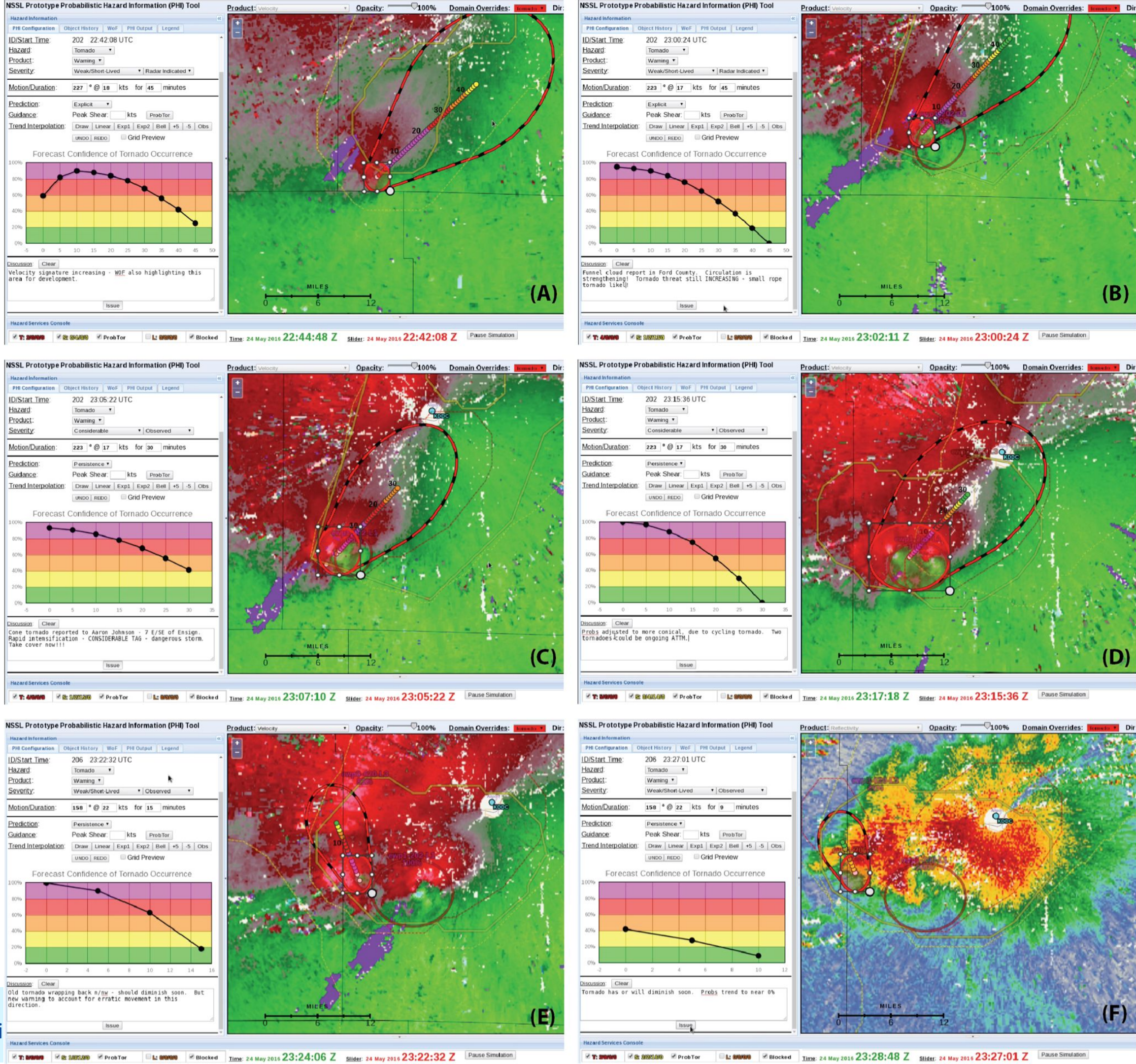
Hazardous Weather Testbed Experiments

Virtually (Spring 2021):

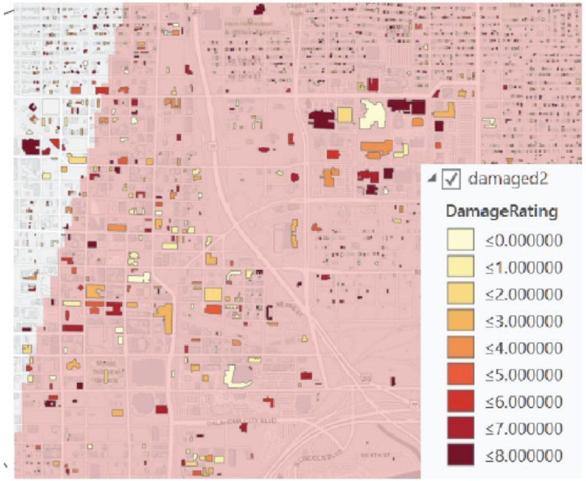


Integrated Warning Team (with Emergency Managers and Broadcast Mets, 2016-2017):

Example of forecaster produced PHI in HWT



Ongoing and Upcoming Development



- Automated impacts guidance - uses machine learning with past damage indicators, structure type records, and local zoning information
- Test rapid update capabilities with forecasters in HWT
- Extend forecast probabilities through additional machine learning approaches and blending of Warn-on-Forecast
- Continue to work with Global Systems Laboratory for Hazard Services connected development (Threats-in-Motion and PHI connection)

Observation-based severe convective tools

Storm-scale PHI with NWS Core Partners

Holly Obermeier; CIWRO Research Fellow; WRDD

Why are we engaging NWS core partners?

- Leveraging **user-centered design** principles, we created a capability to **engage** emergency managers, broadcasters, and forecasters (as user groups).

- Their **insights, preferences, and needs** increasingly drive our innovation process.

History of Core Partners & Probabilistic Hazard Information

2015

First year for emergency managers

2016

First year for broadcast meteorologists, Full Integrated Warning Team

2017

2 emergency managers & 1 broadcast meteorologist per week

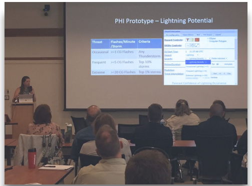
2018

4 emergency managers & 2 broadcast meteorologists, first year with the fully-functioning studio

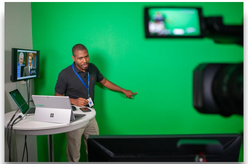
Focus groups with emergency managers, search & rescue, land managers, wildland fire teams with NWS Grand Junction

2019

Redesigned EM timeline, 4 emergency managers & 2 broadcast meteorologists per week



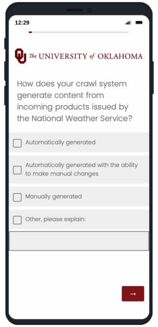
2020



Nationwide survey of broadcast meteorologists

2021

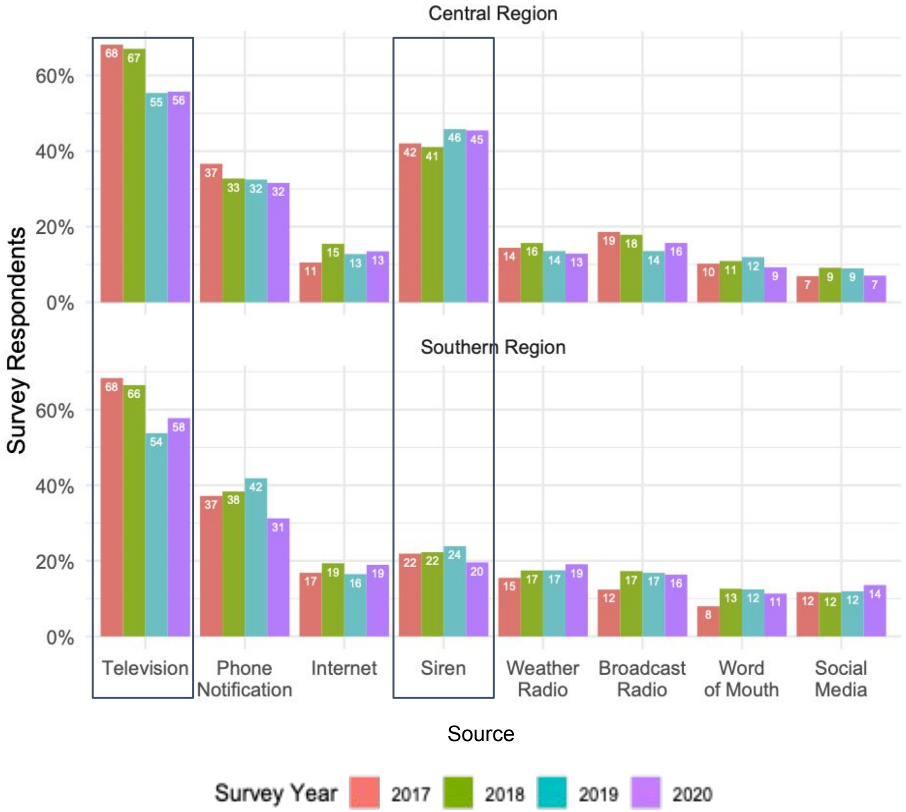
Nationwide survey of emergency managers



Why do we engage these core partners?

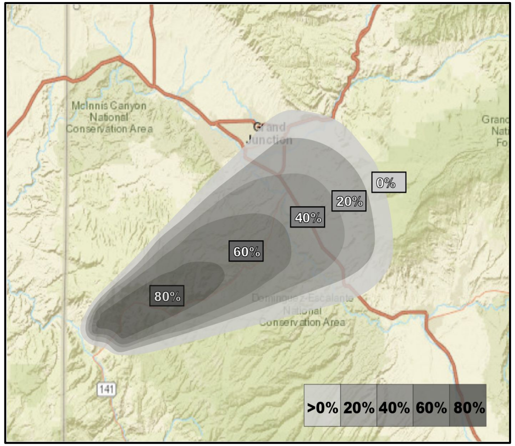
- Engaging NWS core partners **early** allows them to **set the requirements** for future NWS products
- When new research transitions, it **meets partners' needs** - they are **able** and **can** use the product effectively

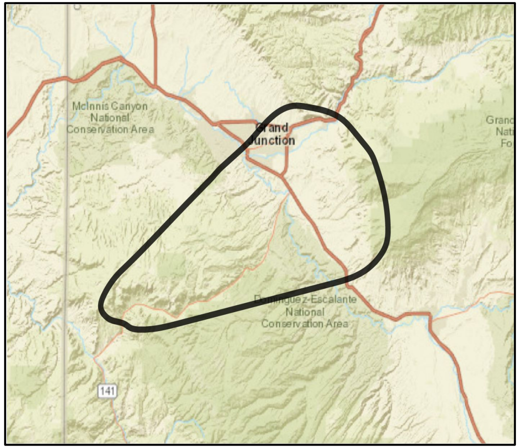
Broadcast meteorologists are still the primary source of tornado warning information across all regions of the United States. Sirens are an important function of EM duties and are still used commonly (right).

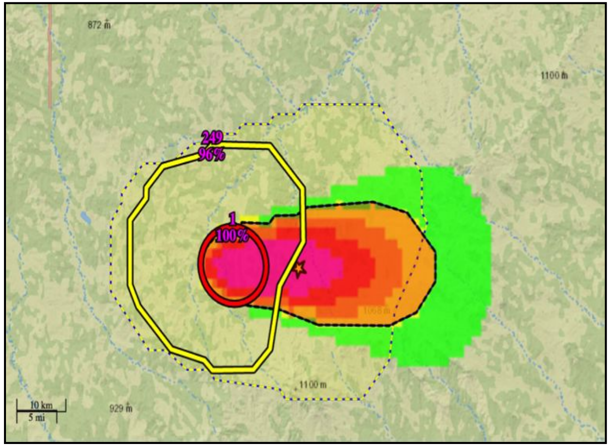


Key Findings: Warnings

- Core partners **need** a warning - probabilistic thresholds alone **don't work** for severe convective weather
- Warnings have **layers of meaning** beyond likelihood & always require **NWS forecaster** judgment and intervention

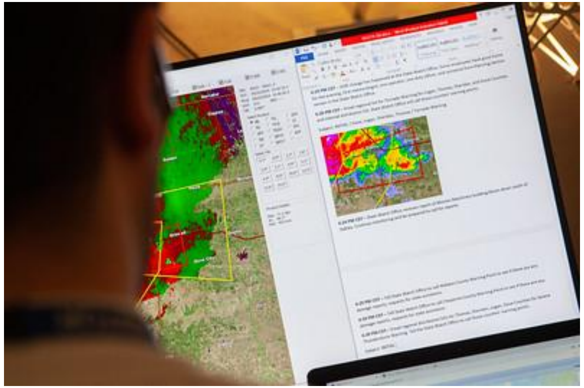






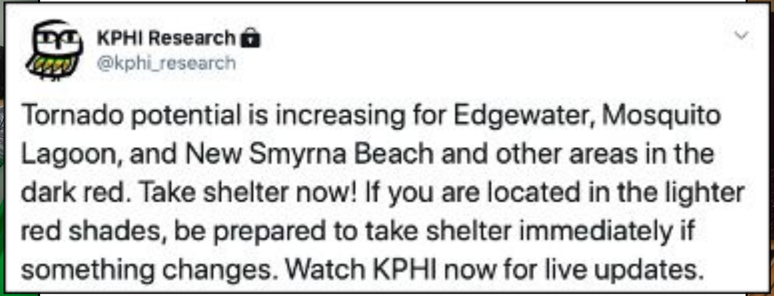
Key Findings: Emergency Management

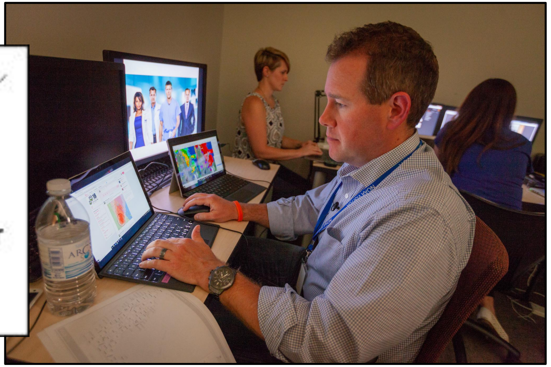
- Experiment evolution includes a **complete decision-making timeline** (including days & hours before)
- Partnership with Oklahoma State Department of Emergency Management supports experiment development, especially **naturalistic decision elements**



Key Findings: KPHI-TV

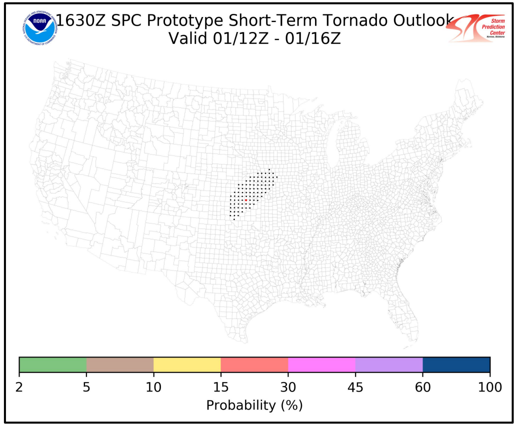
- Mock television studio infrastructure built to allow broadcasters to **present, communicate, and provide feedback** on experimental data in a **naturalistic environment** (on-camera)
- Protected **social media accounts** allow study concerning how broadcasters communicate probabilistic information on **alternative platforms**

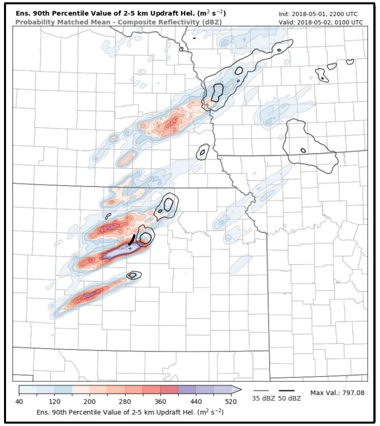


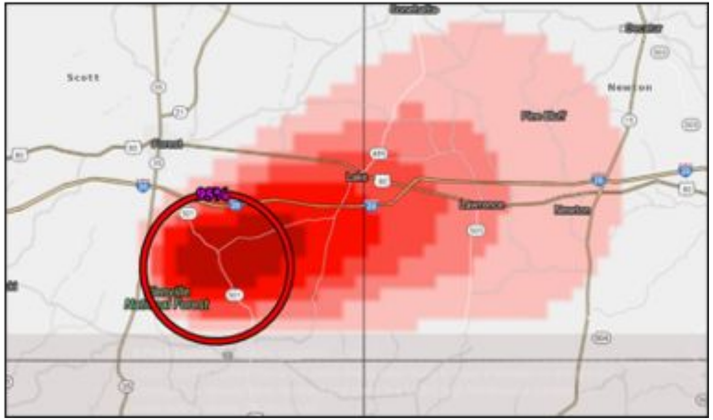


Future Work with Core Partners

- **Expand experiment timeline** for broadcast meteorologists (hours and days ahead of the severe weather event)
- Research across the **entire continuum** to identify gaps and ensure products are telling a **cohesive story** across all time/space scales



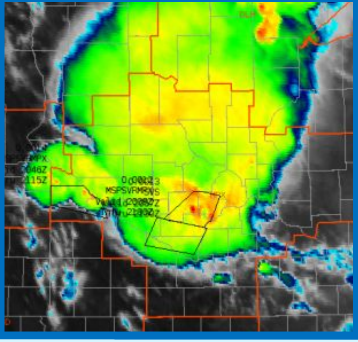


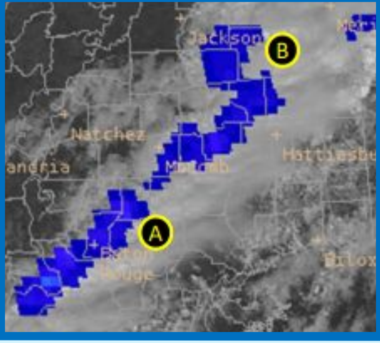


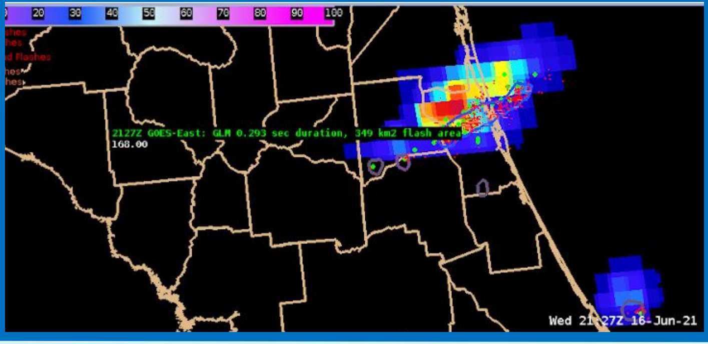
Observation-based severe convective tools

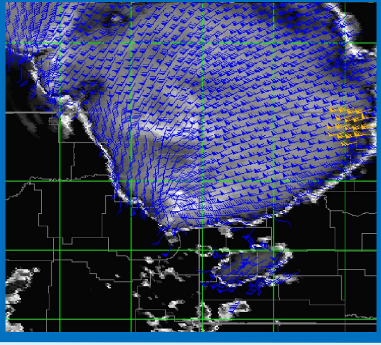
Satellite and Lightning Convective Tools and Research

Kristin Calhoun, PhD; NSSL Research Scientist; WRDD



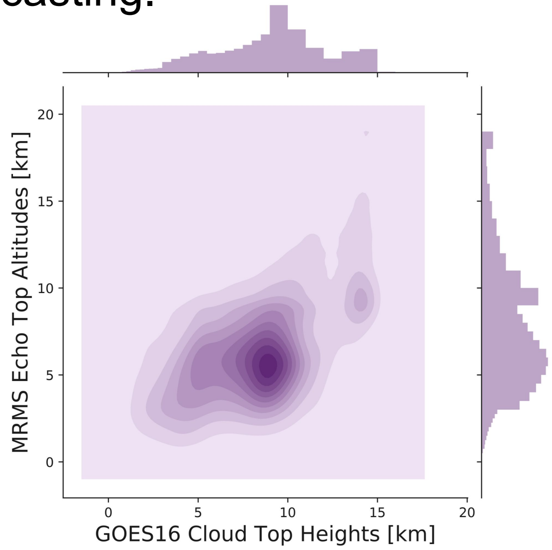


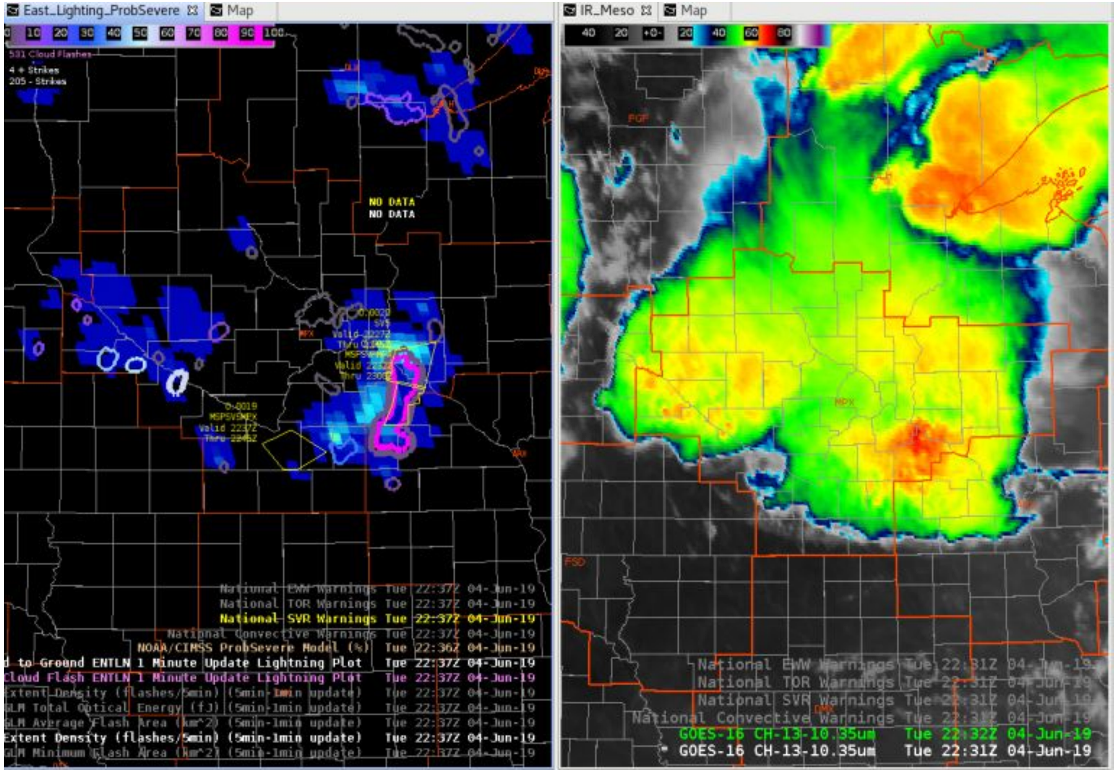




Satellite, Lightning and Severe Weather

With GOES-R series of satellites, satellite data is now more relevant than ever for severe weather analysis and forecasting.





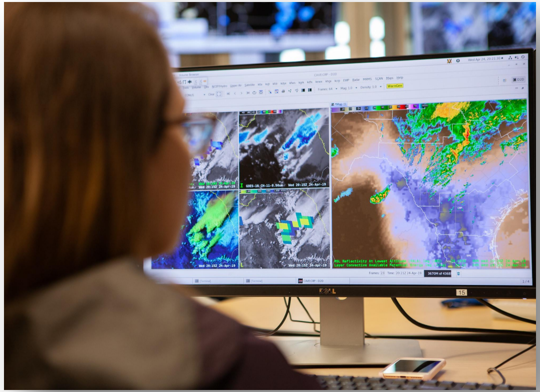
Satellite Proving Ground collaboration in the HWT

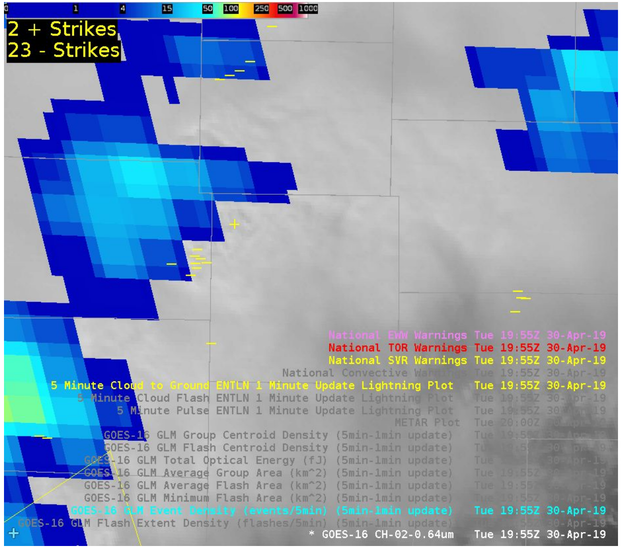
- Forecasters define what products are needed, feedback on visualizations, and training requirements.
- New algorithms, such as the Geostationary Lightning Mapper (GLM) Minimum Flash Area and multi-instrument displays, developed due to HWT testing and collaboration.
- In the end we make an instrument such as the GLM operationally relevant.
- Scientists and developers better understand how these satellite data can be used within forecasting and warnings of severe and hazardous weather.

Innovations with the Geostationary Lightning Mapper (GLM)

2020 NOAA Science Report Highlight

Collaboration with NESDIS, NASA, and academic sectors



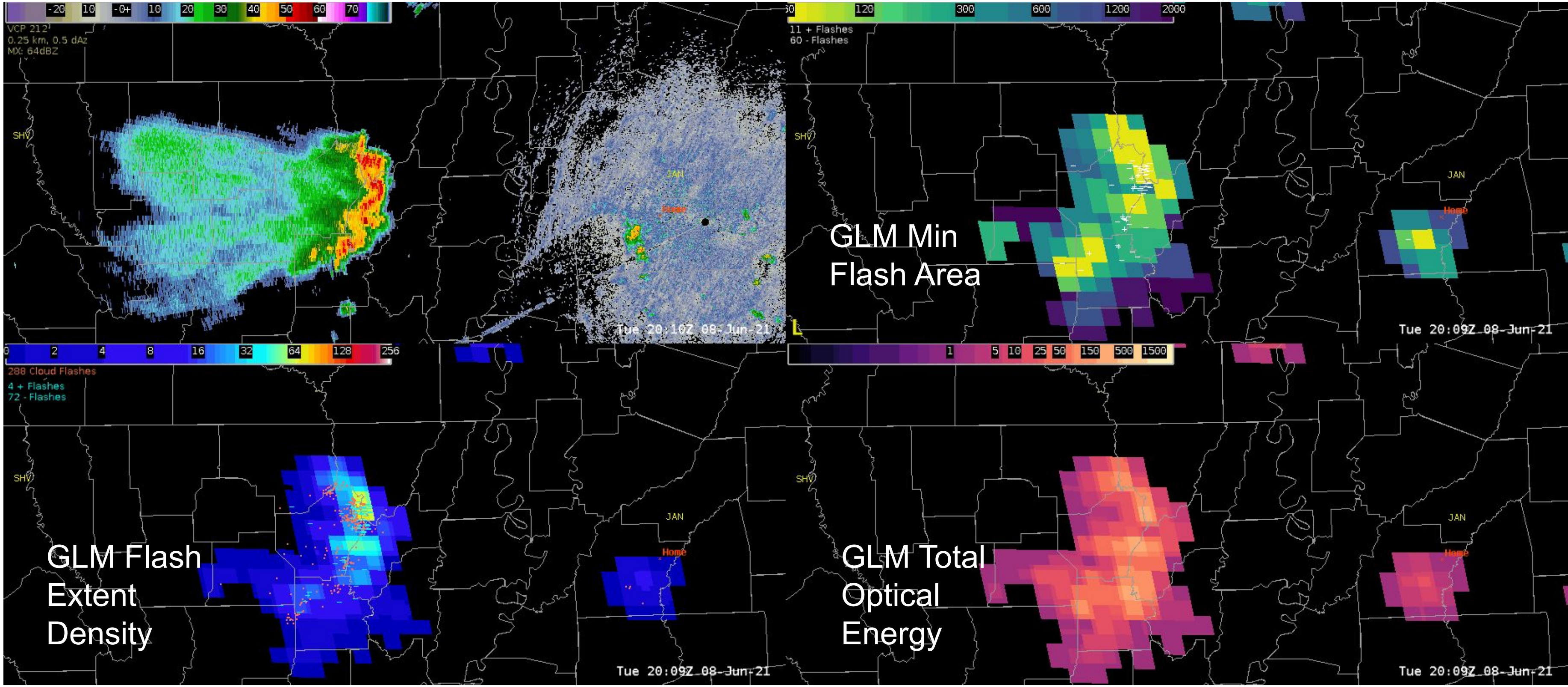


Following launch of the instrument in 2016, initial review in the HWT noted the GLM visualization of base data did not originally make use of full capabilities of the new instrument and lacked usability.

Entire product suite was redesigned to retain the quantitative physical measurements and spatial extent native to the GLM.

New visualizations show extent and density information, providing details on cyclic nature of storms.

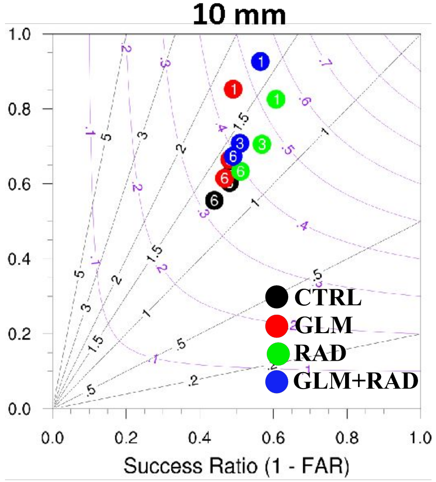
Left: The increase in lightning density signaling intensification of the storm's updraft.



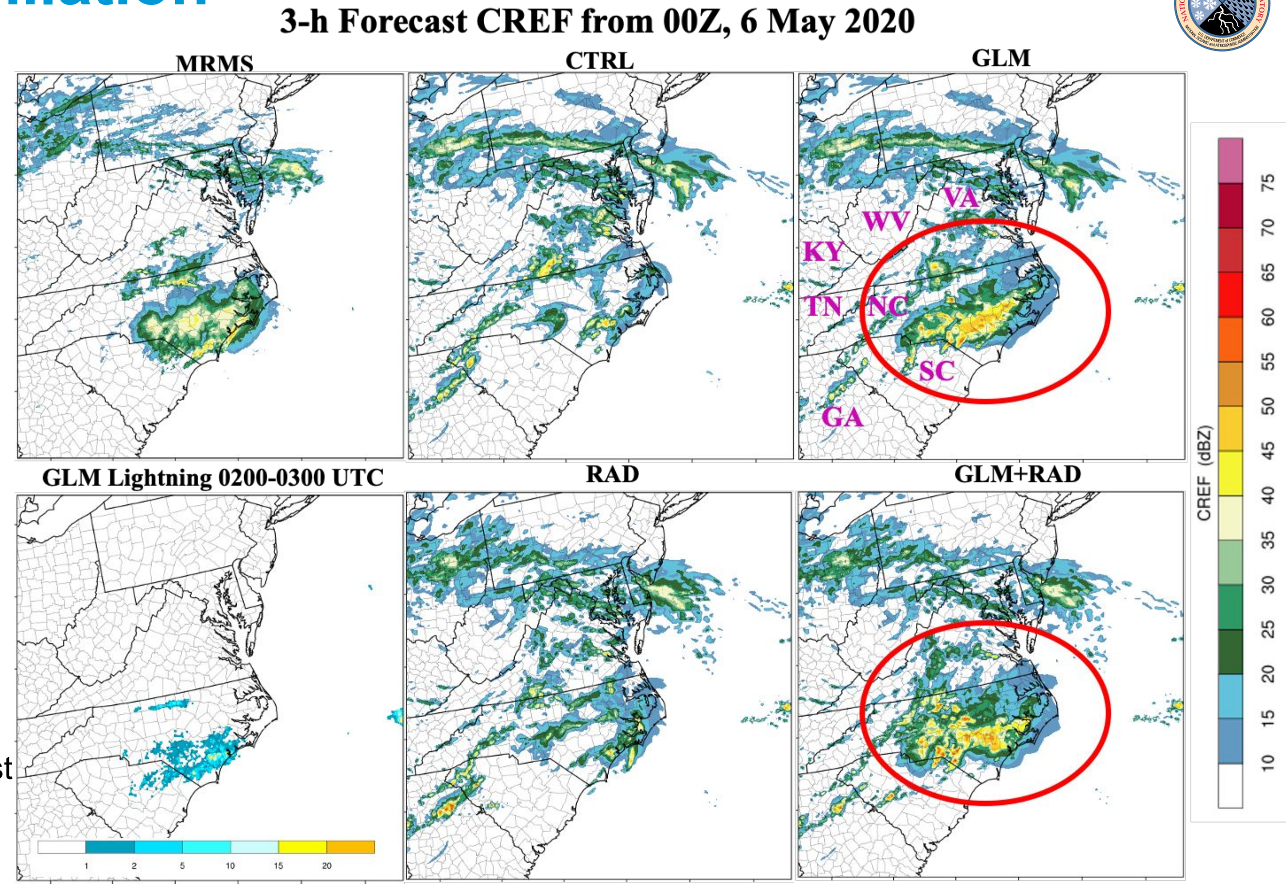
Northeast Louisiana (8 June 2021): Formation of trailing stratiform region and lightning begins to extend westward. Forecaster blog post:
"GLM can be helpful in time when you may have a DSS event and the main line has passed through, but lightning is still present in the trailing light rain. Pairing the ground networks with the GLM extent and area allows a forecaster to give DSS on the latest CG stroke within the large area."

GLM Data Assimilation

GLM and GLM+Radar have higher success ratio than radar data alone. Below: hourly estimated rainfall from different DA methods:



Example of positive impact on forecast of radar coverage and precipitation in southeastern North Carolina.

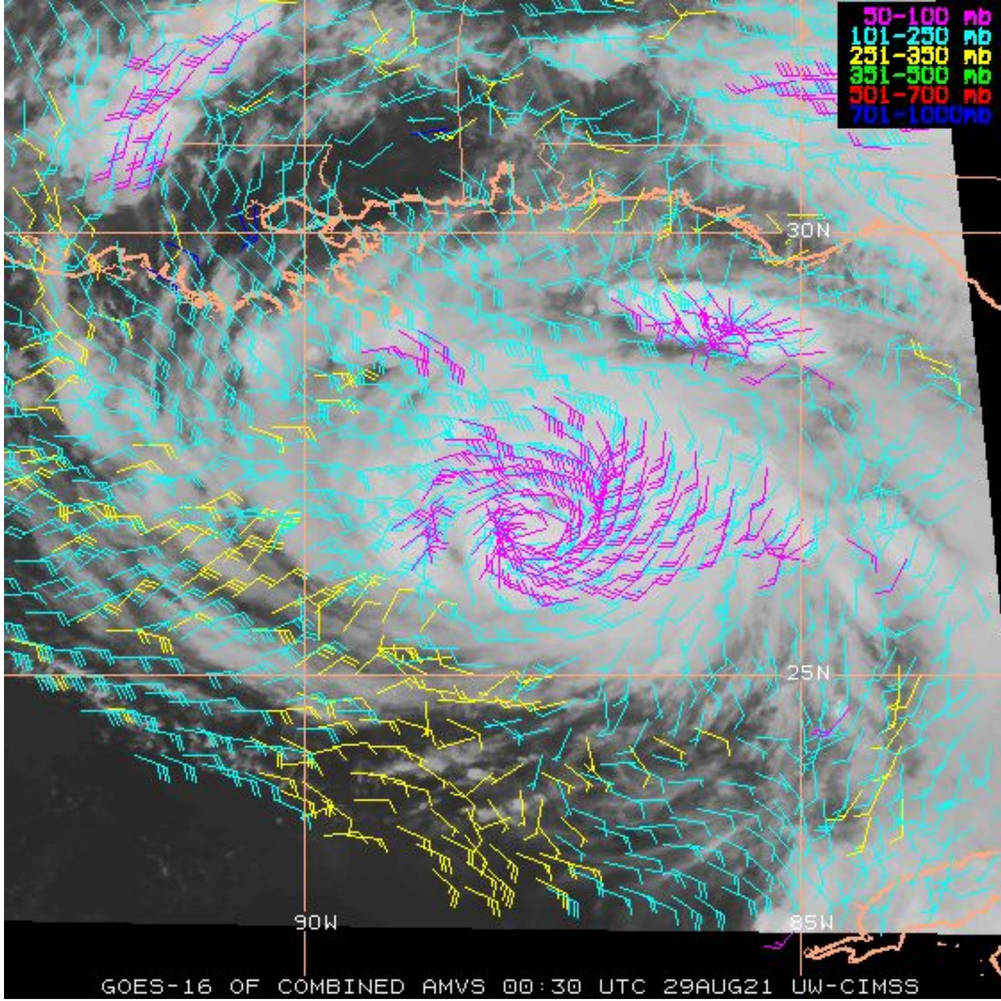


Cloud top winds from optical flow

- Adds wind values in the inner cold cloud ring where legacy winds are lacking. Tested with live data at both the NHC and the 2021 HWT.

- Assimilating the combined winds into forecast models at EMC appear to improve storm track forecasts from the 2020 hurricane season.

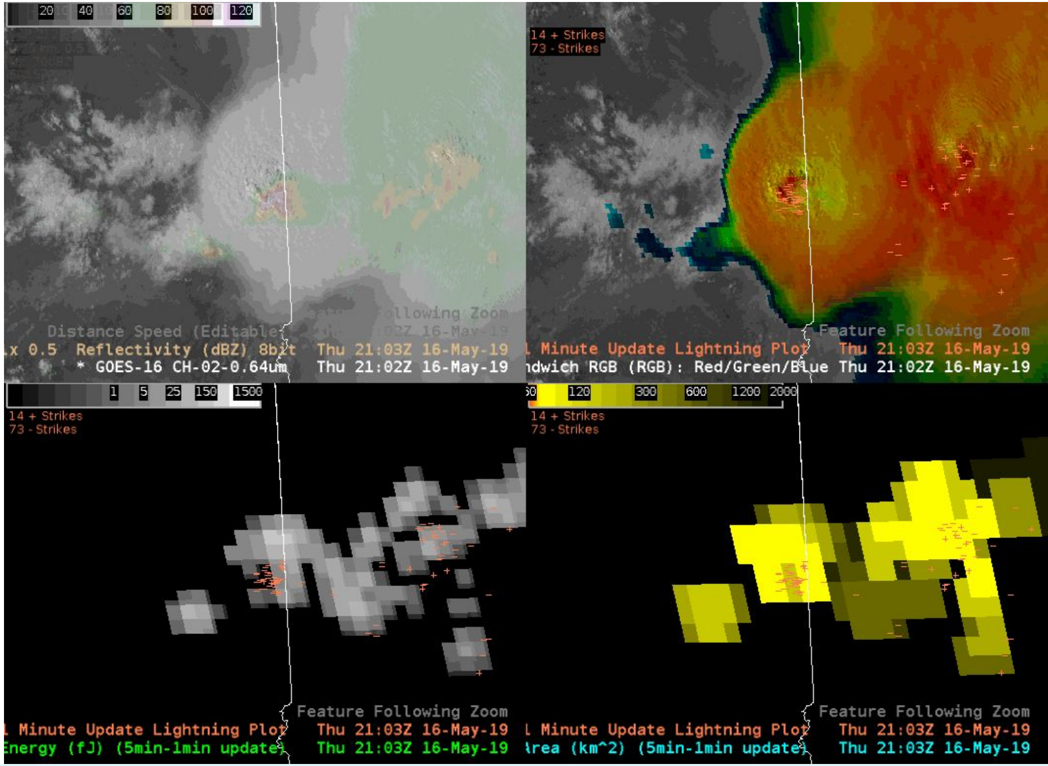
- Based on these preliminary studies at EMC, real-time assimilation of the satellite winds into the next generation forecast model (HAFS) is being tested this tropical storm season (August-October 2021).



Right: Cloud top winds from an optical flow technique for Hurricane Ida (2021). Bob Rabin.

Ongoing and Future work

- Continue bringing more ABI and GLM products into the MRMS operational suite.
- Work with partners (UW-CIMSS, NASA, Academic) to include satellite data and algorithms such optical winds and cloud-top divergence in machine learning development and data assimilation.
- Creation of overall lightning density (blending networks/lightning sensors)
- Stereo estimates of cloud heights using ABI and GLM imagery
- Provide input and feedback on GEO-XO requirements and recommendations



Summarized Story to tell

GLM specific:

•Lightning detections have historically been point based, typically represented by +, - , or
•The Geostationary Lightning Mapper is an 'optical' sensor -- We can create gridded imagery that may be animated like other weather satellite images, making it more suitable for diagnosing thunderstorm behavior.

Unfortunately, the GLM visualizations were initially created to match older sensor displays. Worked together with academic (TTU/UM), private (Lockheed-Martin) and government partners (NESDIS and NASA) to create new visualizations and products that more adequately represented the data including spatial extent information so critical for lightning safety and IDSS applications.

ABI specific:

•Satellite data is now of the spatial and temporal resolution that it can be used in severe weather analysis and warnings.

GOESR risk reduction work prior to the launch of the new satellites

Ongoing work to begin using data in MRMS as well as create new products/algorithms for forecaster use:

Grams: Hydro and flash flooding

Calhoun: relating MRMS echo top heights with cloud top heights from ABI

Rabin: Parallax correction, optical wind flows

Satellite data assimilation:

•Don't want to repeat other sections (please tell me to remove, if necessary)

Fierro/Hu: GLM data assimilation

Thomas/ : ABI and WoF work

Goal and Accomplishment(s)

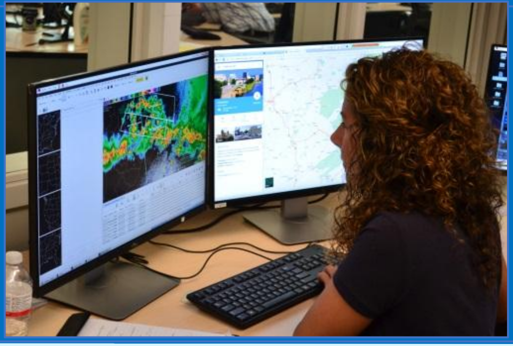
HWT in coordination with the satellite proving ground. Pre-launch prep (risk reduction) and post-launch applications and new products /algorithms first evaluated. Experiments 2015-2019 and 2021.

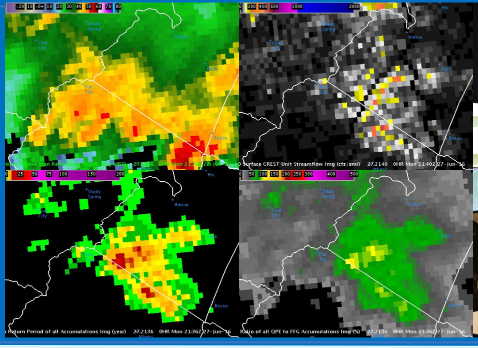
GLM: created and evaluated new GLM products. Provided recommendations for the operational implementation based on HWT evaluation by forecasters. Top products, such as FED and Minimum Flash Area, set to move into NESDIS ground-system processing in 2022.

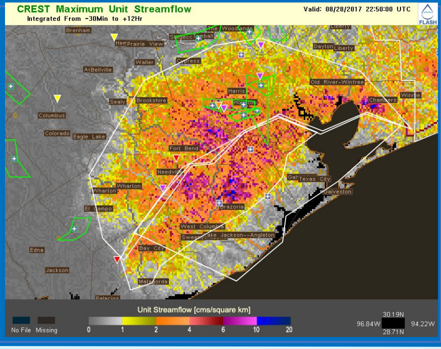
Observation-based Severe Convective Tools

Flooded Locations and Simulated Hydrographs Project - FLASH

Jonathan J. Gourley, Ph.D.; NSSL Research Hydrologist; WRDD





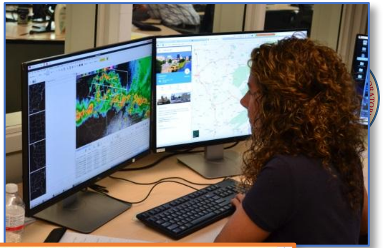


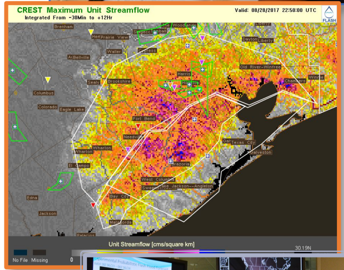
Flooded Locations and Simulated Hydrographs Project - FLASH

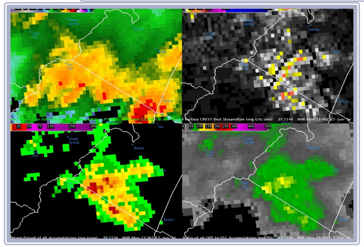
- The FLASH project was launched in 2012; a result of the availability Multi-Radar Multi-Sensor precipitation estimates capturing precipitation at flash flood scale (1 km/2 min)

- FLASH was transitioned to the NWS/National Centers for Environmental Prediction in 2016

- FLASH changes the paradigm for operational flash flood prediction in the NWS and doubles the skill of the legacy system

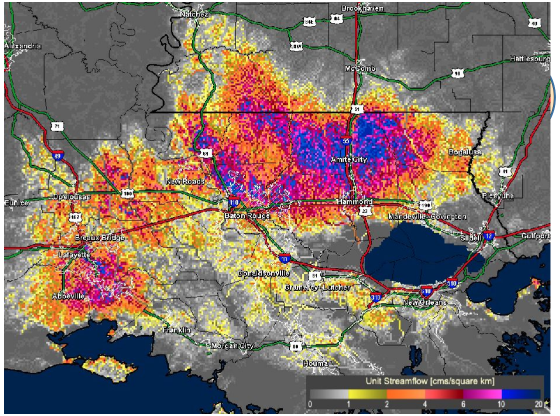






Relevance (Why are we doing this)

- FLASH products, aided by training materials developed by the NWS/Warning Decision Training Division and guidance thresholds from forecasters' experience, have rapidly evolved the tools used for issuing flash flood warnings in the US and outer territories
  - Doubling the accuracy of the legacy system and improving spatial resolution by 500 percent
  - Providing up to six hours of forecast lead time
  - Improving NWS forecasters' ability to identify rare, severe flash floods from minor ones

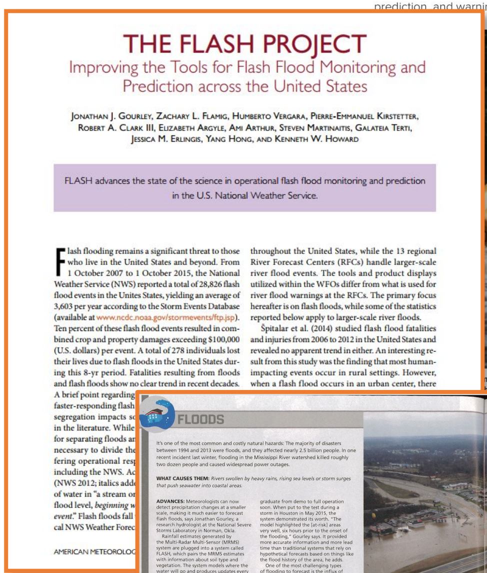


FLASH pinpointed areas in Louisiana impacted by severe flooding in August 2016. (Blue areas depict severe flash flooding)

Aerial image showing flooding in Louisiana. August 13, 2016. (Patrick Dennis/The Advocate)

Goal and Accomplishment(s)

- Team published **20 articles** related to the FLASH project in the peer-reviewed journals from 2016-present
  - Four in February 2017 issue of *BAMS*
- FLASH featured in September 2016 issue of *Discover* magazine
- 5 PhD's, 3 MS degrees, and several visiting international faculty and student interns, all doing research related to FLASH project



THE FLASH PROJECT

Improving the Tools for Flash Flood Monitoring and Prediction across the United States

Jonathan J. Gourley, Zachary L. Flamig, Humberto Vergara, Pierre-Emmanuel Kirstetter, Robert A. Clark III, Elizabeth Argyle, Ami Arthur, Steven Martinaitis, Galateia Terti, Jessica M. Erlingis, Yang Hong, and Kenneth W. Howard

FLASH advances the state of the science in operational flash flood monitoring and prediction in the U.S. National Weather Service.

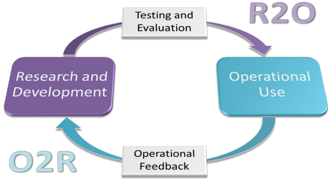
Flash flooding remains a significant threat to those who live in the United States and beyond. From 1 October 2007 to 1 October 2015, the National Weather Service (NWS) reported a total of 28,826 flash flood events in the Unites States, yielding an average of 3,603 per year according to the Storm Events Database (available at www.ncdc.noaa.gov/stormevents/ftp.jsp). Ten percent of these flash flood events resulted in combined crop and property damages exceeding $100,000 (U.S. dollars) per event. A total of 278 individuals lost their lives due to flash floods in the United States during this 8-yr period. Fatalities resulting from floods and flash floods show no clear trend in recent decades. A brief point regarding faster-responding flash segregation impacts s in the literature. While for separating floods a necessary to divide the fering operational resp including the NWS. A (NWS 2012; italics add of water in "a stream o flood level, *beginning w event*." Flash floods fall cal NWS Weather Forec

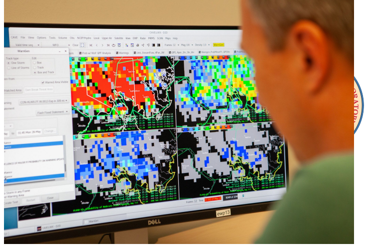
throughout the United States, while the 13 regional River Forecast Centers (RFCs) handle larger-scale river flood events. The tools and product displays utilized within the WFOs differ from what is used for river flood warnings at the RFCs. The primary focus hereafter is on flash floods, while some of the statistics reported below apply to larger-scale river floods.

Spitalar et al. (2014) studied flash flood fatalities and injuries from 2006 to 2012 in the United States and revealed no apparent trend in either. An interesting result from this study was the finding that most human-impacting events occur in rural settings. However, when a flash flood occurs in an urban center, there

AMERICAN METEOROLOG

Goal and Accomplishment(s)





- The Hydrometeorological Testbed Multi-Radar Multi-Sensor Hydro Experiment (**HMT-Hydro**) played a vital role in garnering feedback from NWS forecasters and serving as an effective training conduit

- Hosted 72 NWS forecasters over 5 summers (2014-2019) for 3-4 weeks

- Participants issued experimental Flash Flood Watches and Warnings based on the FLASH tools across the CONUS and evaluated them the following day

- Tested out precipitation forcings from the High-Resolution Rapid Refresh and Warn-on-Forecast system models to generate probabilistic FLASH products

THE HMT MULTI-RADAR MULTI-SENSOR HYDRO EXPERIMENT

STEVEN M. MARTINAITIS, JONATHAN J. GOURLEY, ZACHARY L. FLAMIG, ELIZABETH M. ARGYLE, ROBERT A. CLARK III, AMI ARTHUR, BRANDON R. SMITH, JESSICA M. ERLINGIS, SARAH PERFATER, AND BENJAMIN ALBRIGHT

NOAA/National Severe Storms Laboratory and National Weather Service forecasters evaluate new tools and techniques through real-time test bed operations for the improvement of flash flood detection and warning operations.

Goal and Accomplishment(s)

- FLASH was transitioned to operations in the NWS in 2016 and has advanced the tools for flash flood forecasting in NWS Forecast Offices
- Training materials developed by the NWS/Warning Decision Training Division released in 2017
- Multi-Radar Multi-Sensor precipitation products were upgraded with dual-polarization variables in 2019, enabling more accurate estimates with extremes rainfall rates
- Guidance thresholds for FLASH were updated accordingly and reported in 2021

MARCH 2021 CORRESPONDENCE

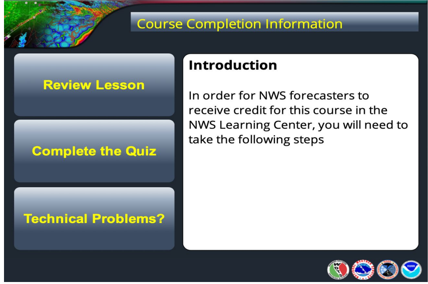
CORRESPONDENCE

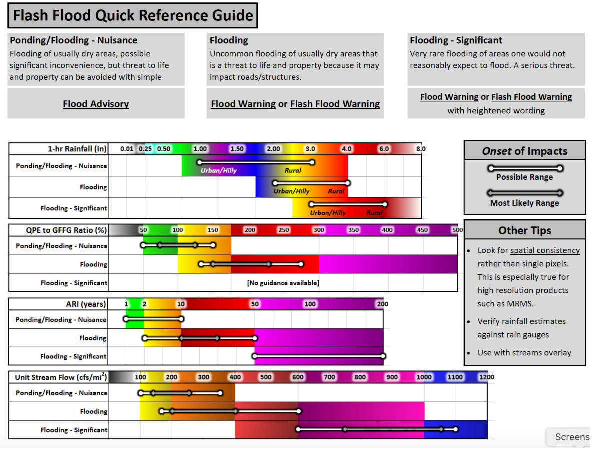
Comments on "Flash Flood Verification: Pondering Precipitation Proxies"

JONATHAN J. GOURLEY[a] AND HUMBERTO VERGARA[b,a]

[a] NOAA/OAR/National Severe Storms Laboratory, Norman, Oklahoma
[b] Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, Norman, Oklahoma

(Manuscript received 10 September 2020, in final form 2 December 2020)



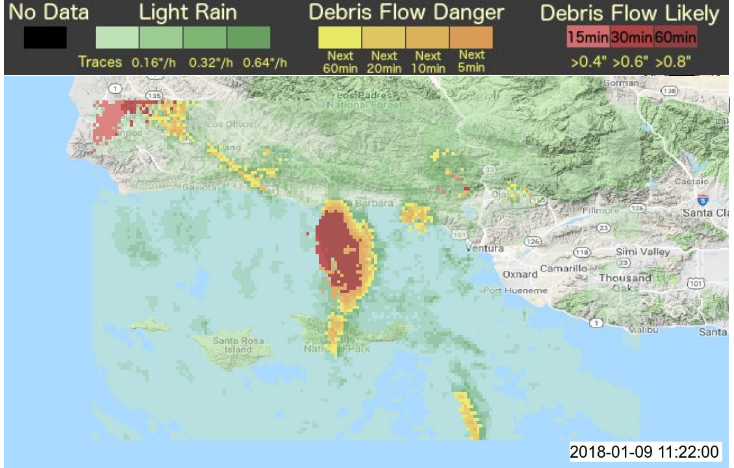


[23:30:22]
<nws-scott.overpeck@nwschat.weather.gov/NWSChatLive_140.90.75.204_133724>
Okay folks -update on flash flooding. Warning for Liberty and Chambers will drop as rain rates well below 1 inch an hour. FLASH max unit stream flow data showing decreasing stream flow so feel good threat is subsiding. There is still the areal flood warning out which will cover any ongoing flooding.

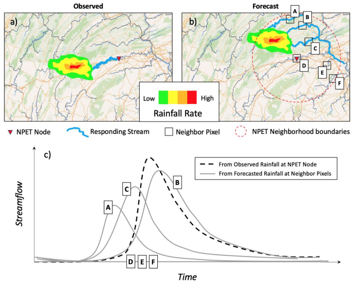
09/01 8:45 PM	nwsbox-kristie.s...	Hi All - just wanted to give an update on why we are getting ahead of things on these flash flood warnings. Given significant reports of flash flooding and extremely high values from our flash flood parameters, like CREST unit streamflow (3000+ units in some cases), hourly rain rates (an ASOS in NJ had an hourly rate of almost 3 inches) etc. coming out of PA/NJ/NY we have high confidence that flash flooding will occur across our area. Several areas of the mid atlantic are currently experiencing greater than 1 in 200 year (our scale stops at 200) flooding, which is quite a concerning figure given that this wall of water is pushing into our area. In an effort to alert the public before they wind down for bed and to really push messaging encouraging people to stay off roadways during the morning commute, we have tossed out flash flood warnings for several of our "flashy" counties, including Hampden and Worcester counties in MA and Hartford Co in CT. More flash flood warnings will be forthcoming. Stay safe everyone and please let us know if you have any questions! - Kristie

Future work (1-3 years)

- Improving guidance on burn scars by comparing rainfall to USGS debris flow thresholds and adjusting land cover and soil infiltration parameters in hydrologic models
- Increasing lead time using precipitation nowcasts and forecasts from Warn-on-Forecast System
- Accounting for spatial displacements in forecast precipitation objects
- Entire system being transitioned from deterministic to probabilistic to support new impact-based warning paradigm (JTTI award)



MRMS-based WildfireRain implementation outputs for the Jan. 9th 2018 event



Flash Flood Damage Threat Tag	Explanation
"Base" (No Tag)	Use most of the time, when flash flood impact damage is possible.
CONSIDERABLE*	Use rarely, when there are indications flash flooding capable of unusual severity or impact is imminent or ongoing and urgent action is needed to protect lives and property.
CATASTROPHIC*+	Use exceedingly rarely, when a flash flood threat to life and catastrophic damage is occurring or is imminent, and floodwaters have risen or will rise to levels rarely if ever seen.