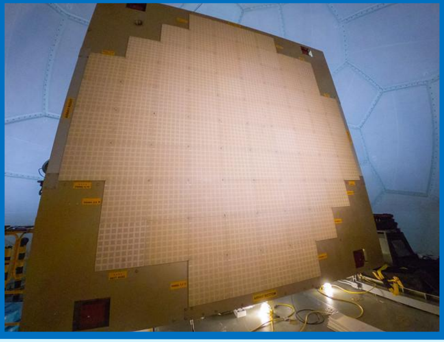
Better forecast/warning tools and techniques

Multi-Radar Multi-Sensor Overview

Heather Grams, PhD, NSSL Research Meteorologist, WRDD





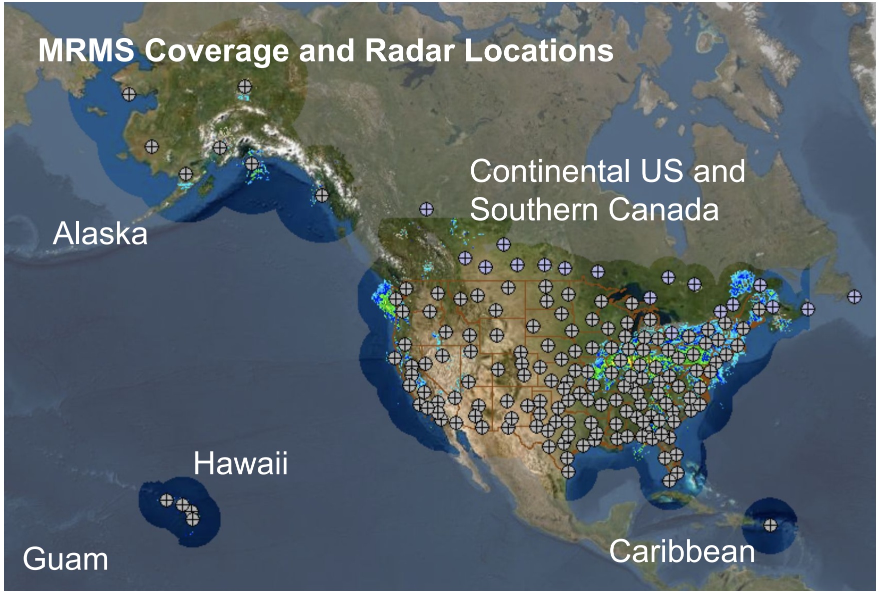

Multi-Radar Multi-Sensor (MRMS)

is an advanced remote sensing processing system that:

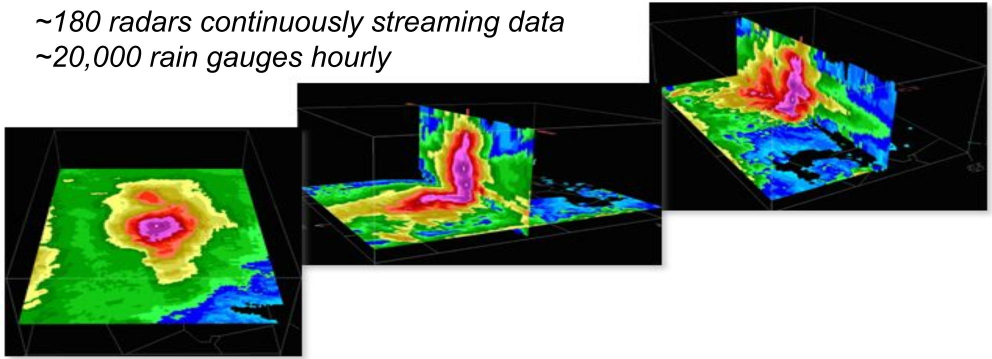
- ➢ Integrates radar, surface observations, satellite, lightning, and numerical weather prediction data into common reference grid
- ➢ Automatically generates complete seamless national 3D radar mosaic, storm attributes and multi-sensor quantitative precipitation estimates at high temporal and spatial resolution

Running operationally at NOAA/NCEP since 2014

Operational Product Viewer:
https://mrms.nssl.noaa.gov/qvs/product_viewer/

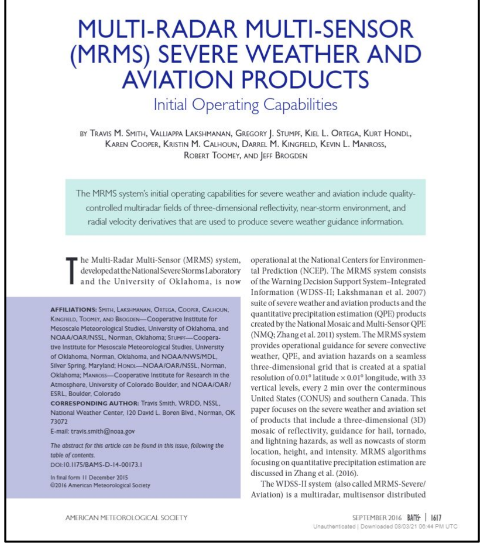


~180 radars continuously streaming data
~20,000 rain gauges hourly



MRMS Core Research Impacts

Cited over **125** times since 2016
1387 Full Text Views/Downloads this year (AMS)



MULTI-RADAR MULTI-SENSOR (MRMS) SEVERE WEATHER AND AVIATION PRODUCTS

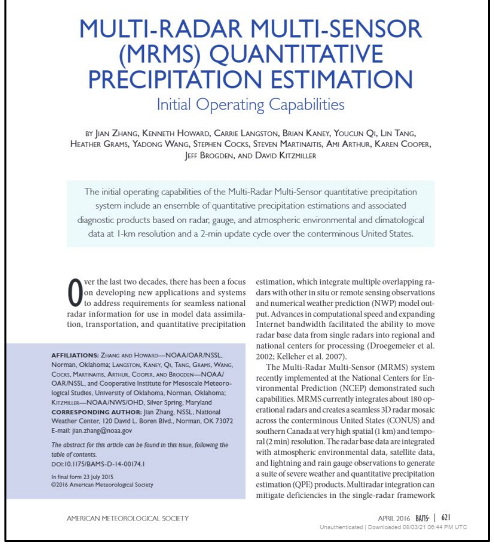
Initial Operating Capabilities

BY TRAVIS M. SMITH, VALLIAPPA LAKSHMANAN, GREGORY J. STUMPF, KIEL L. ORTEGA, KURT HONDL, KAREN COOPER, KRISTIN M. CALHOUN, DARREL M. KINGFIELD, KEVIN L. MANROSS, ROBERT TOOMEY, AND JEFF BROGDEN

The MRMS system's initial operating capabilities for severe weather and aviation include quality-controlled multiradar fields of three-dimensional reflectivity, near-storm environment, and radial velocity derivatives that are used to produce severe weather guidance information.

AMERICAN METEOROLOGICAL SOCIETY — SEPTEMBER 2016 BAMS | 1617

Cited over **350** times since 2016
2508 Full Text Views/Downloads this year (AMS)



MULTI-RADAR MULTI-SENSOR (MRMS) QUANTITATIVE PRECIPITATION ESTIMATION

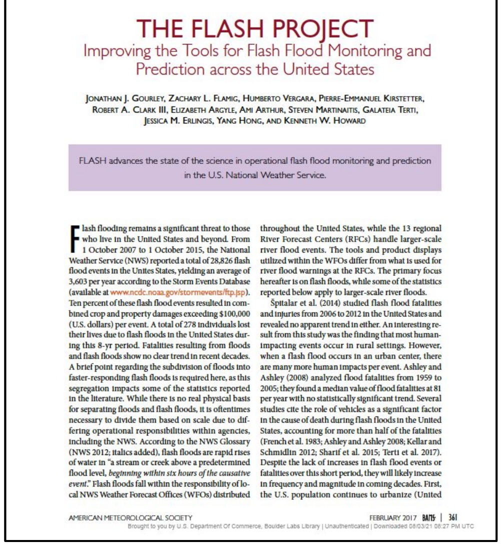
Initial Operating Capabilities

BY JIAN ZHANG, KENNETH HOWARD, CARRIE LANGSTON, BRIAN KANEY, YOUCUN QI, LIN TANG, HEATHER GRAMS, YADONG WANG, STEPHEN COCKS, STEVEN MARTINAITIS, AMI ARTHUR, KAREN COOPER, JEFF BROGDEN, AND DAVID KITZMILLER

The initial operating capabilities of the Multi-Radar Multi-Sensor quantitative precipitation system include an ensemble of quantitative precipitation estimations and associated diagnostic products based on radar, gauge, and atmospheric environmental and climatological data at 1-km resolution and a 2-min update cycle over the conterminous United States.

AMERICAN METEOROLOGICAL SOCIETY — APRIL 2016 BAMS | 621

Cited over **110** times since 2017
1551 Full Text Views/Downloads this year (AMS)



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.

AMERICAN METEOROLOGICAL SOCIETY — FEBRUARY 2017 BAMS | 361

Google Scholar Mentions (peer-reviewed journals, conference presentations):

- "Multi-Radar Multi-Sensor" returns 1,070 papers

MRMS Product Impacts

Part 1: Situational Awareness

MRMS radar mosaics in nationwide decision support displays

NWS

radar.weather.gov
SAFER Hazard Dashboard

NOAA

nowCOAST

FAA

Flight Information System for pilots

DOD

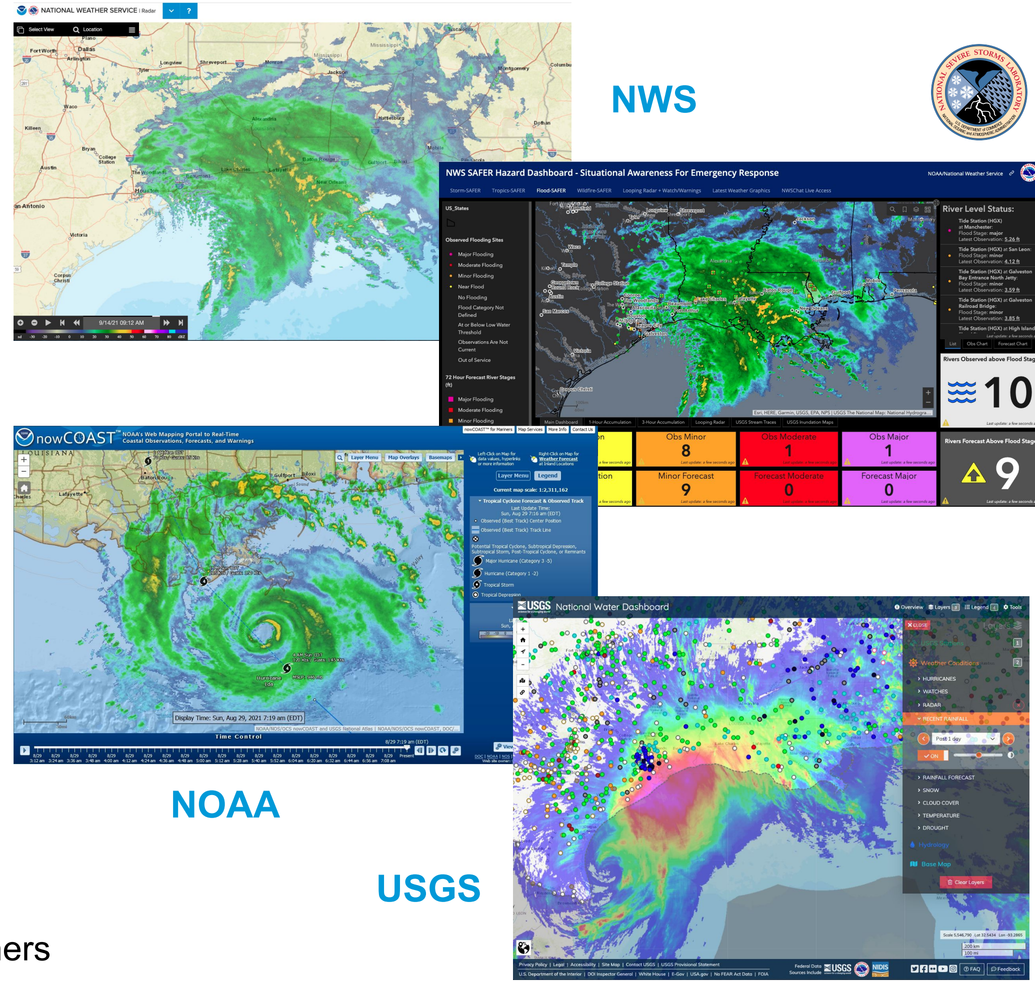
AFW-WEBS

USGS

National Water Dashboard

Private Sector

GR-Earth, mobile radar apps, and many others



MRMS History

1998 — **MRMS starts**
MRMS started with an U.S. Weather Research Program project to improve the operational radar quantitative precipitation estimates (QPE) in the western U.S.

2000 — **First real-time MRMS system**
The first real-time MRMS system (6 radars) at the Salt River Project (Arizona)

2001 — **Site Visits to NWS Offices**
Demonstrations of initial MRMS capabilities for operational stakeholders

2004 — **CONUS real-time MRMS research system**
CONUS real-time MRMS research system established (~140 radars...NEXRAD only)

2006 — **Experimental products disseminated**
Dissemination of experimental products to National Weather Service forecast offices and national centers for evaluation

2014 — **MRMS IOC operational at NCO**
MRMS Initial Operational Capability (IOC - v10) became operational at NWS NCEP Central Operations (~180 radars...US NEXRAD and Canadian networks)

2016 — **MRMS v11 operational**
MRMS v11 became operational at NWS NCEP Central Operations. Included initial deployment of FLASH products

2020 — **MRMS v12 operational**
Includes dual-pol enhancement for precipitation, addition of four OCONUS domains, first operational integration of gap-filling radar at Alamosa, Colorado

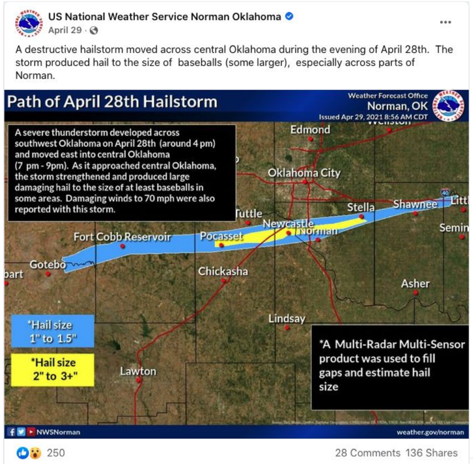
MRMS development on Public Cloud
MRMS v12 development system deployed and running in real-time on AWS Public Cloud

2022 — **MRMS v20 operational (planned)**
MRMS v20 planned operational release, featuring major code modernization and optimization

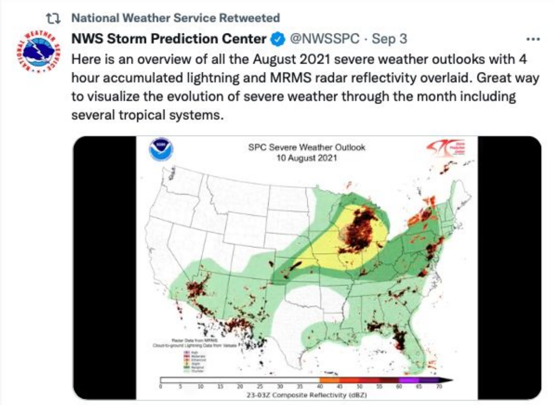
MRMS Product Impacts

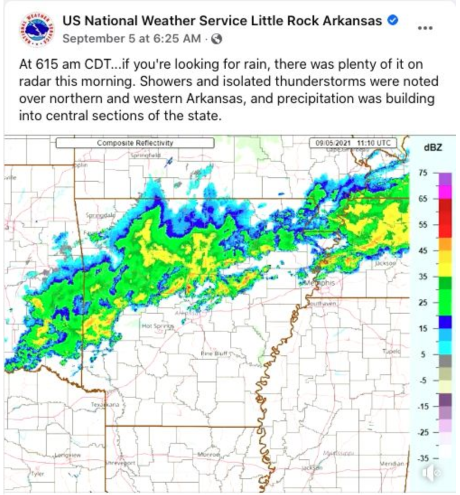
Part 2: Improving Warnings and Public Messaging

- MRMS reflectivity, hail, precipitation, and FLASH products used routinely in NWS severe weather operations and public messaging
- MRMS rotation tracks used for post-event emergency response and for tornado damage surveys



NWS Houston Office Social Media Messaging for Tropical Storm Imelda (2019)



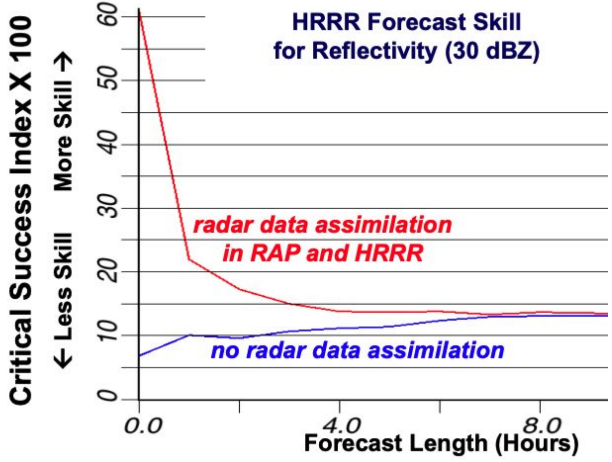


Northeast US Flash Flooding from Remnants of Hurricane Ida (2021)

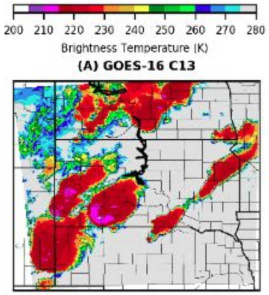
MRMS Product Impacts
Part 3: Improving NWP

- ➢ MRMS reflectivity and precipitation used for weather model data assimilation (e.g., WoFS and HRRR/RRFS) and verification
- ➢ MRMS precipitation used as driver for NWS National Water Model and as starting point for NWS River Forecast Center precipitation analysis
- ➢ Growing adoption within machine learning community as input for training and validation

Impact of Radar Data Assimilation on NWP Skill

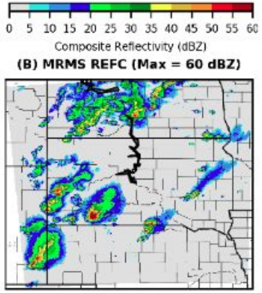


(Source: Dowell 2015)



Input: GOES Ch. 13

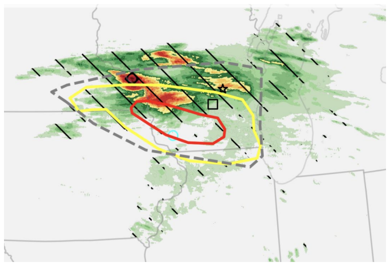
NN →



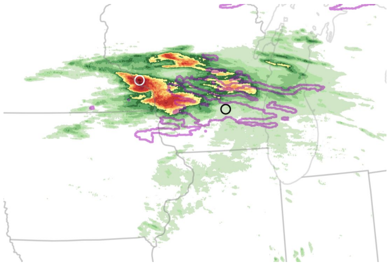
Desired Output (MRMS)

Hilburn et al. (2020) predicting MRMS radar from GOES-16 satellite using Deep Learning AI/ML

2021 FFaIR Experimental Product and Model Verification



Experimental Rainfall Outlook



Purple = Model-Forecasted Precipitation

Alignment with NOAA and OAR Goals

NOAA R&D Vision Areas 2020-2026

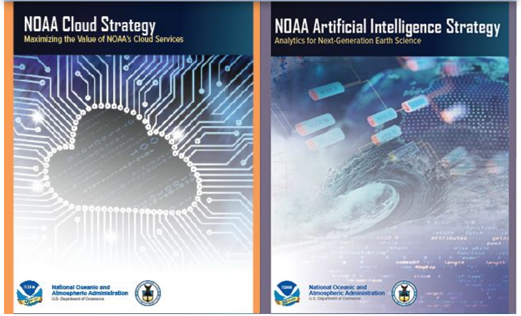
OAR Strategic Goals		**Vision Area 1:** Reducing societal impacts from hazardous weather and other phenomena	**Vision Area 2:** Sustainable use and stewardship of ocean/coastal resources	**Vision Area 3:** Robust and effective research, development, and transition enterprise
Goal 3: Make Forecasts Better	**3.1** Develop interdisciplinary Earth system models			
	3.2 Tools and Processes to forecast high-impact weather and water events	✓		✓
	3.3 Transition science that meets users' current and future needs	✓		✓
Goal 4: Drive Innovative Science	**4.1** Reinforce a culture of innovation and adaptability	✓		✓
	4.2 Invest in high-risk, high-reward science			
	4.3 Accelerate the delivery of mission-ready, next-gen science	✓		✓

MRMS serves as a key data assimilation input and a verification resource for development of atmospheric and hydrologic forecast systems

MRMS is a platform for rapid integration of new observations with a proven track record of successful transitions of new science into operational environments

Alignment with NWS Strategic Goals and Science Areas

NOAA SCIENCE & TECHNOLOGY FOCUS AREAS



NWS Strategic Plan Objectives 2.4 & 2.5 - Integrated Observations

- Supports consistent and continuously updating guidance across all NWS Offices using integration of best available observing systems

NWS Strategic Plan Objectives 2.10 & 2.11 - Research to Operation/Operations to Research (R2O/O2R)

- Use of testbeds to evaluate new techniques and algorithm improvements with NWS operational users, and close coordination with NWS/NCO to streamline transition of new versions of MRMS into operations

Cloud - The MRMS team at NSSL are leaders within NOAA to fully embrace transitioning R&D efforts to the cloud to accelerate the pace of R2O.

Artificial Intelligence - Multiple R&D efforts ongoing to integrate AI/ML techniques into MRMS processing, and improving AI knowledge/proficiency among the MRMS R&D team is a top strategic objective

Key Stakeholders & Collaborative Partners

NOAA Partners

Non-NOAA Government Agencies

Academia and Other Entities

Summary

- MRMS is a critical operational resource that provides high resolution, rapidly updating, integrated radar and sensor derived decision support products for multiple agencies

- Operational products are widely used across government, private, and academic sectors for applications ranging from severe weather warning operations to improving weather forecast models to development of new machine learning tools.

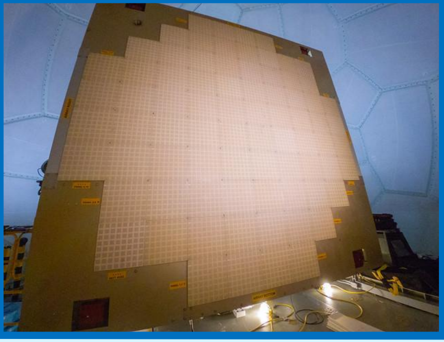
- MRMS research, development, and transitions into operations align with multiple strategic areas across NOAA, OAR, and the NWS

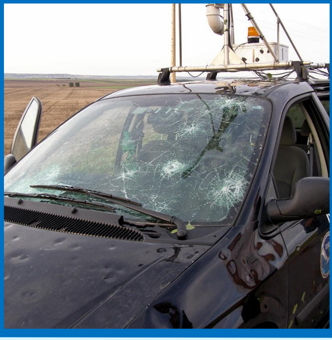
NSSL and CIWRO researchers discussing MRMS and NWS operations with RFC forecasters (January 2020)

Better forecast/warning tools and techniques

MRMS Products and Capabilities

Steven Martinaitis, CIWRO Research Associate, WRDD



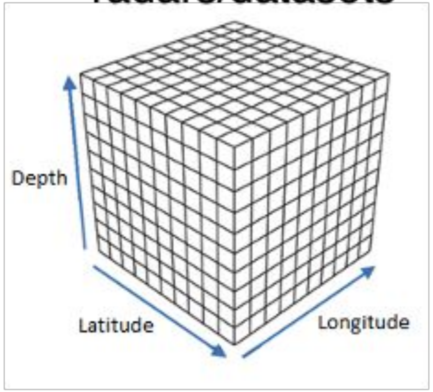


MRMS: Product Creation Process

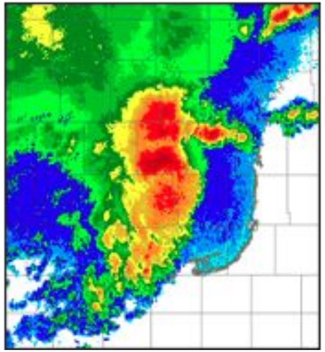
Data collection:
Active "listeners" that download data as soon as it becomes available

QC
Immediately processes data as soon as system ingest is finished

Interpolation & 3D Mosaic
Data is converted to regular grid and merged with other radars/datasets



Derivatives
Final products are computed from the mosaics (< 90 secs start to finish)



MRMS Radar Quality Control

Mitigation of non-meteorological radar echoes:

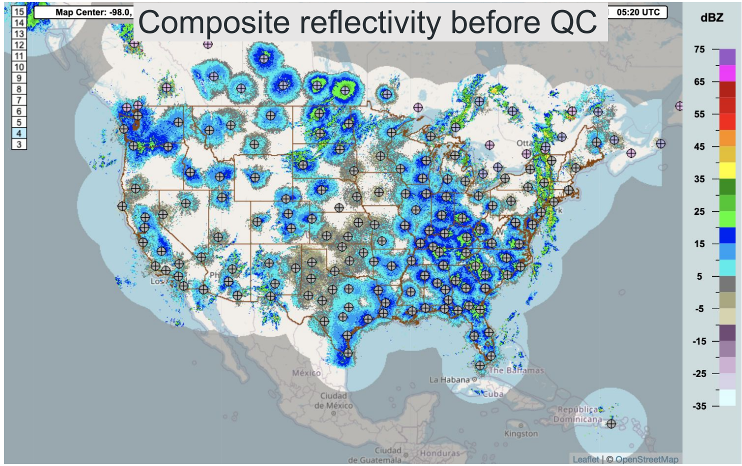
- Ground clutter (terrain, trees, buildings, etc.)
- Biological returns (birds, bats and bugs)
- Sunspikes & electronic interferences
- Wind Farms

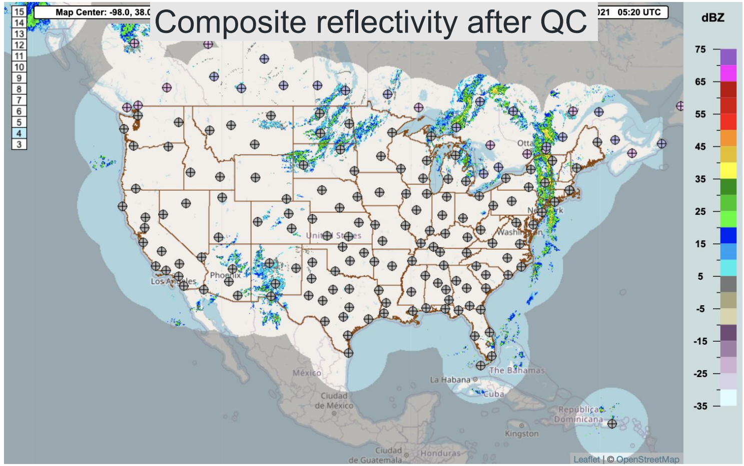
Mitigation of meteorological artifacts/influences in radar data:

- Bright banding from melting layer
- Three-body scatter spikes
- Virga and anvil overhang

Different QC measures used for different applications

Tang et al. 2014 WAF
Tang et al. 2020 JTECH





0520 UTC 24 September 2021

Gauge Quality Control

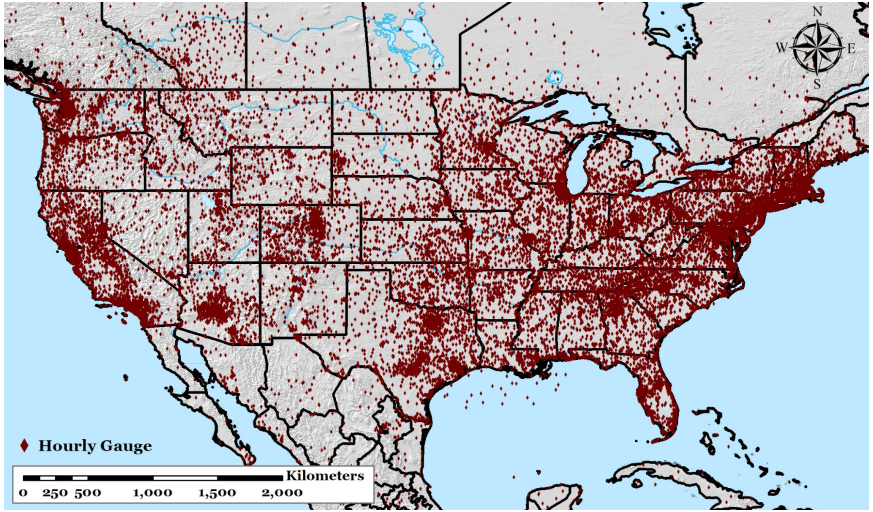
Ingest over 20,000 hourly automated gauge observations per hour across all MRMS domains

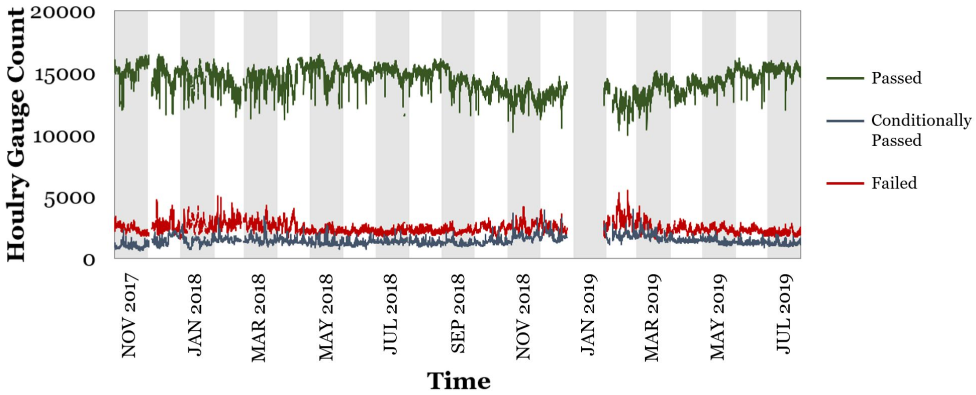
Complex decision trees leveraging radar and model data to remove erroneous observations

Average of 86% of all observations are retained per hour (Varies seasonally)

Automated gauge QC conducted in MRMS system correctly matches manual QC > 99%

Qi et al. 2016 JHM
Martinaitis et al. 2021 JHM





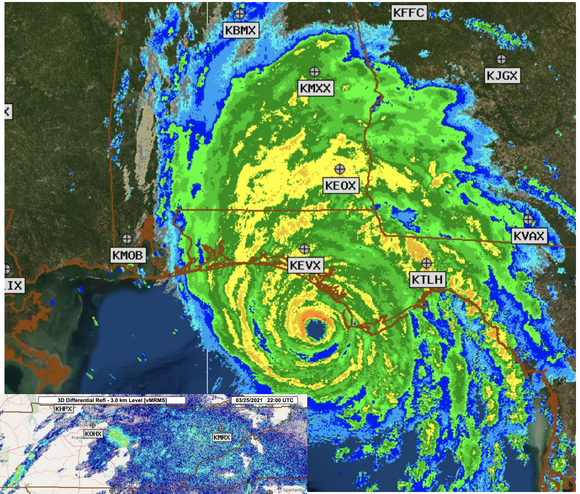
MRMS Radar Mosaics

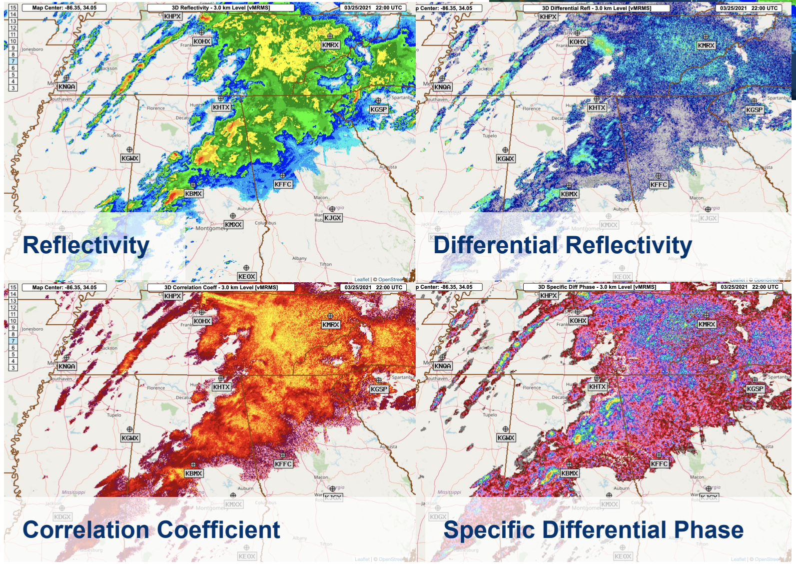
Creation of three-dimensional, multi-radar cubes of fundamental dual-polarization radar variables at a 2-minute resolution

- *Horizontal resolution of 1-km or 500-m*
- *33 vertical levels*

Two-dimensional multi-radar mosaics of derived radar values used to drive product development within the MRMS system

MRMS Composite Reflectivity from Hurricane Michael (2018)



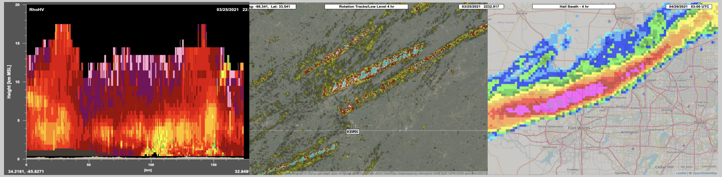


Dual-Polarization Variables at 3-km height level from 3-D mosaic

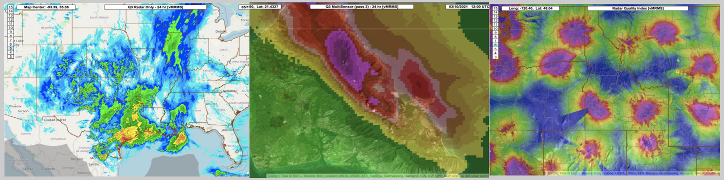
Zhang et al. 2016 BAMS

MRMS Product Suites

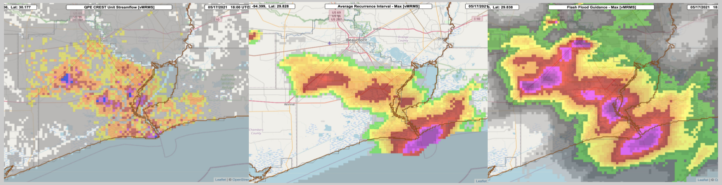
Severe Weather Applications



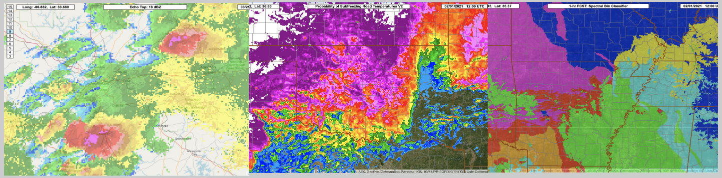
Quantitative Precipitation Estimation (QPE)



Flooded Locations and Simulated Hydrographs (FLASH)

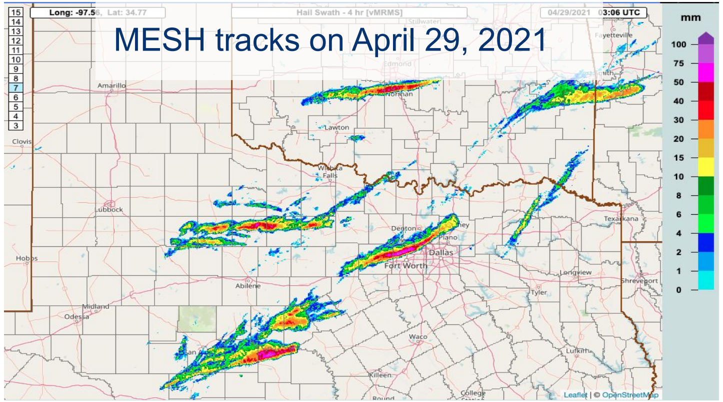


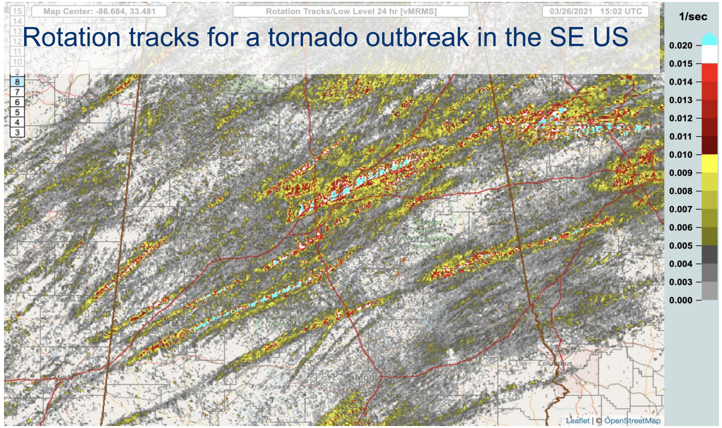
Transportation Applications



MRMS Severe Weather Products

- **Maximum Estimated Size of Hail (MESH)** provides hail size estimation that can be expected
- **Rotation Tracks** indicate where rotation in storms is occuring; Strong values indicate high tornadic likelihood
- **Vertically Integrated Liquid and Ice** indicate the amount of liquid or ice in a storm vertically at each point and relates to rainfall/hail potential
- **Lightning Probability** is a machine learning algorithm that determines the likelihood of cloud-to-ground lightning that could occur over a given area in the next 30-60 minutes



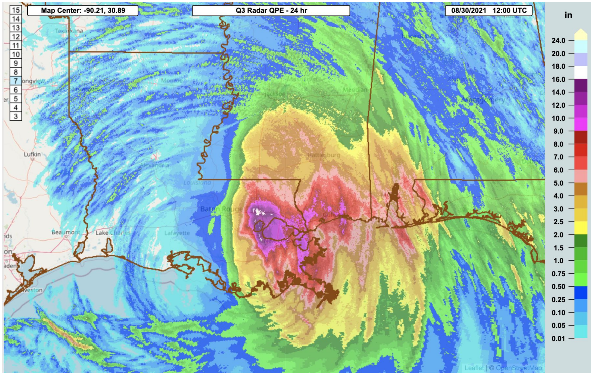


Smith et al. 2016 BAMS

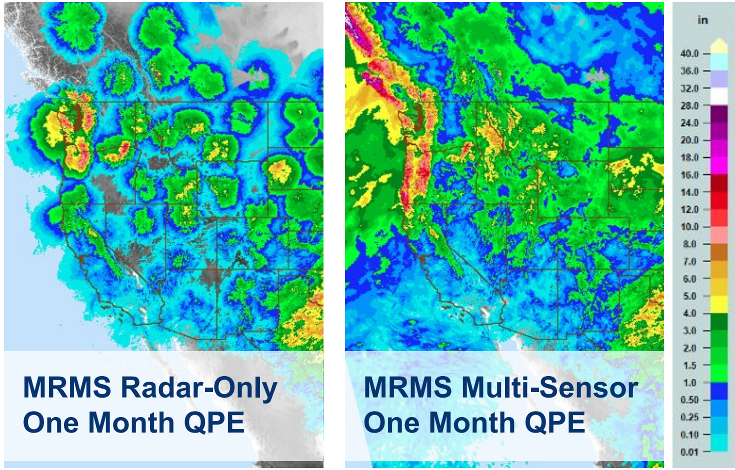
MRMS Precipitation Estimation Products

- **Radar-Only QPE:** Dual-polarization scheme with evaporation correction algorithm
  - Instantaneous rates
  - Accumulations from 15-min to 72-h
- **Radar Quality Index (RQI)** product shows best coverage of radar-based precip estimates based on radar beam height, beam blockage, and beam location with respect to the melting layer
- **Multi-Sensor QPE:** Leverage non-radar sources like quality-controlled gauges and short-term model forecasts to supplement radar coverage and improve QPE accuracy

Zhang et al. 2016 BAMS
Martinaitis et al. 2020 JHM



24-hour Rainfall Totals from Hurricane Ida (2021)



MRMS Radar-Only One Month QPE

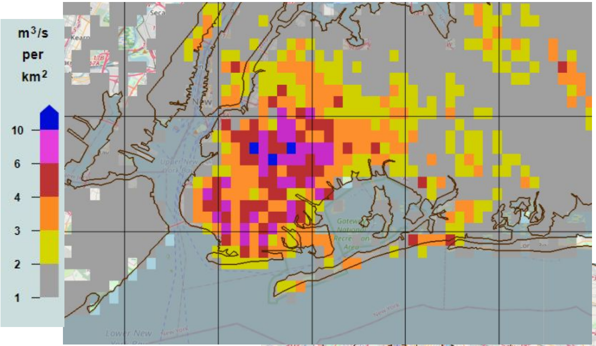
MRMS Multi-Sensor One Month QPE

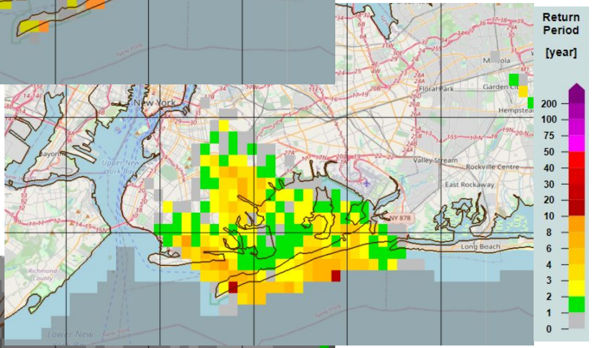
MRMS Flooded Locations and Simulated Hydrographs (FLASH) Products

- **Unit Streamflow** is based on hydrologic rainfall-runoff simulations driven by MRMS radar-only QPEs; Surface water flow is normalized to the basin area, providing standardized values to identify anomalous runoff

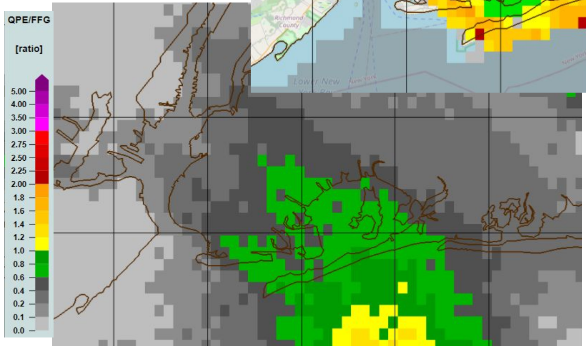
- **QPE Average Recurrence Intervals** compare observed precipitation in real-time to historic records (NOAA Atlas 14) to estimate the rarity of a rainfall event for a specific location

- **QPE to Flash Flood Guidance Ratio** indicates when rainfall can initiate out-of-bank flows in small creeks and streams





Tropical Storm Henri: *Analysis at 0100 UTC 22 August 2021*



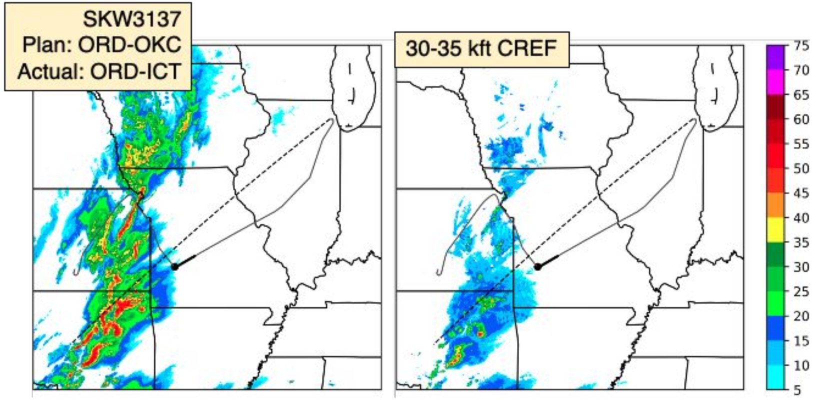
Gourley et al. 2017 BAMS

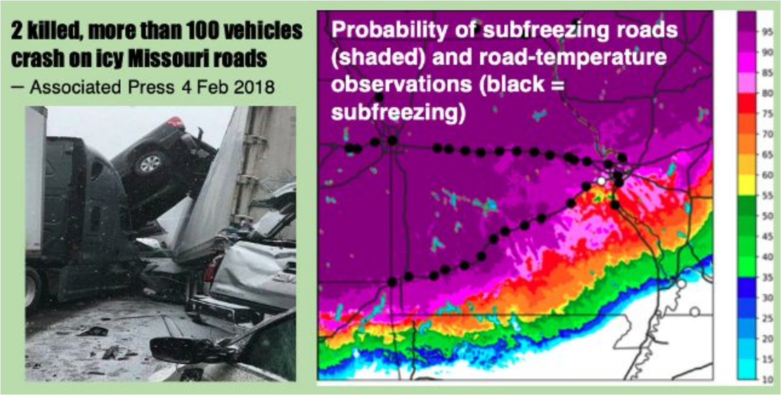
MRMS Transportation Products

- **Echo Top Heights** provide an estimate of storm top heights from radar, which is useful for both severe weather warning operations and aviation

- **Flight-Level Composite Reflectivity** provides derived reflectivity layers (from the 3D mosaic) in the flight-level reference frame that pilots need for routing around storms

- **Probability of Sub-Freezing Roads** is a machine learning-based, probabilistic depiction of where freezing of roads and highways are most likely to occur



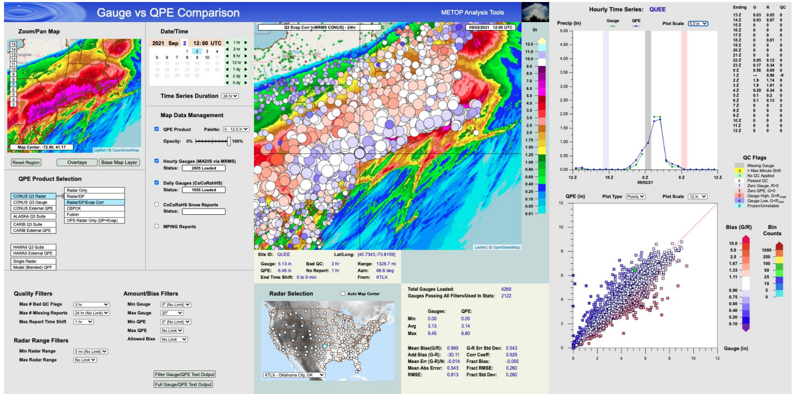


Product Testing/Validation

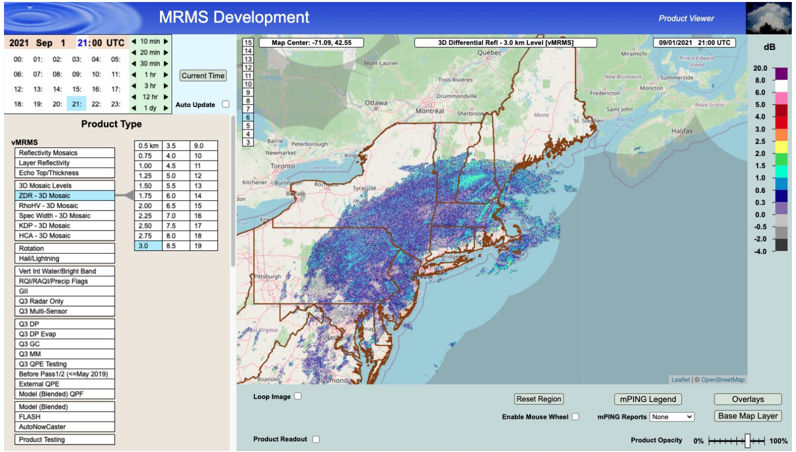
Operational and experimental MRMS are evaluated in real-time on the NSSL development system to verify product stability and quality

- Real-time products are displayed on internal web pages to allow scientists and software developers to monitor their quality
- Internal displays of products under development are made available for key external stakeholders for additional quality assurance and feedback prior to operational transition

Rain Gauge vs. QPE Comparisons



Real-Time Display of Internal and Operational Products



MRMS Operational Success

- ➢ NSSL team works directly with the NWS National Centers for Environmental Prediction (NCEP) Central Operations staff on the operational implementation for the NWS, including on-site training and interactions
- ➢ NSSL built and maintains a real time MRMS system processing environment nearly identical to the NCEP system, in addition to a second real-time system in the Cloud

Notable MRMS Builds over the Past Five Years

MRMS v11.0 - December 2016
- ❑ Addition of HRRR model
- ❑ Implementation of FLASH

MRMS v11.5 - May 2018
- ❑ Updates for radar volume coverage patterns (VCPs)
- ❑ Gauge ingest, QC updates

MRMS v12.0 - October 2020
- ❑ New oCONUS domains (AK, HI, Caribbean, Guam)
- ❑ Dual-Pol QPE
- ❑ Multi-sensor QPE

MRMS v12.1 - February 2021
- ❑ Addition of Alamosa radar
- ❑ Change to product latencies

MRMS v12.2

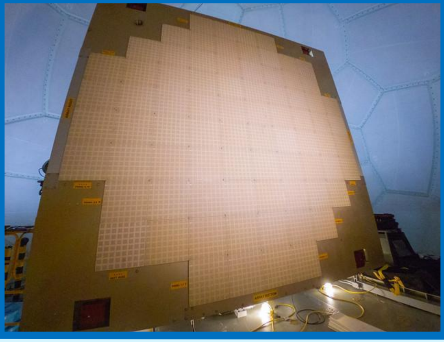
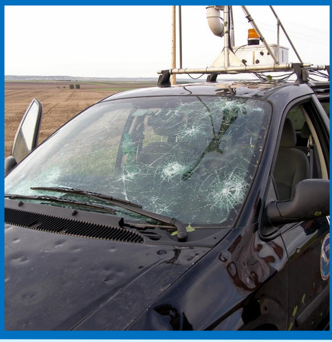
Tentative May 2022

Better forecast/warning tools and techniques

MRMS Development Update

Jian Zhang, PhD; NSSL Research Meteorologist; WRDD



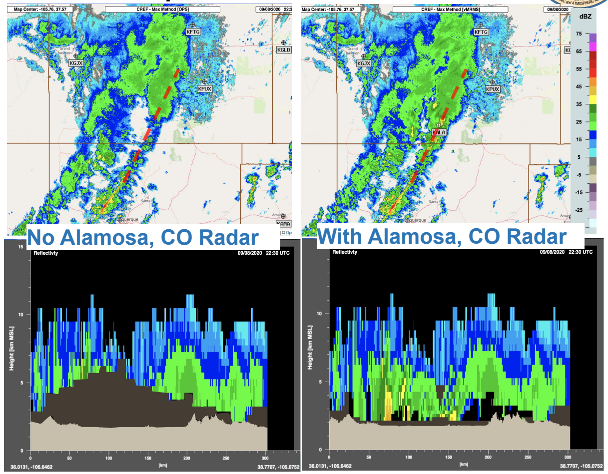



MRMS Development (2016-present)

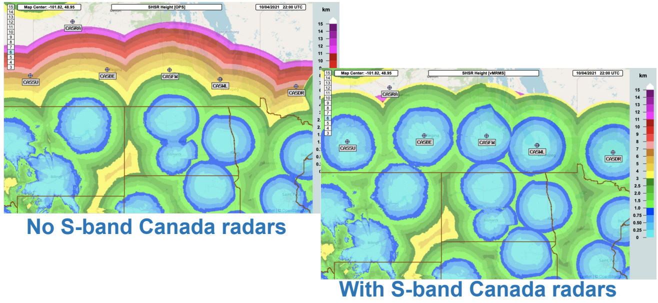
- Integration of new radars
  - S-band dual-pol Canadian radars; Alamosa, CO radar
- Radar data quality control (QC) improvements
- 3D dual-pol radar mosaic and hydrometeor classification
- Severe weather and aviation hazard warning products
- Dual-pol vertical profile of reflectivity (VPR) correction
- Dual-pol radar synthetic QPE with evaporation correction
- Gauge QC improvements
- Multi-sensor QPE
- Enhanced multisensor precipitation estimator (eMPE) prototype
- Software/system optimizations

In addition to the scientific challenges, MRMS development tries to address various data quality challenges ***across large domains on a 24/7 basis****.*

Comp. Refl. 22:30Z 9/8/2020



Lowest radar beam bottom height (AGL)



MRMS Radar QC Challenges and Solutions

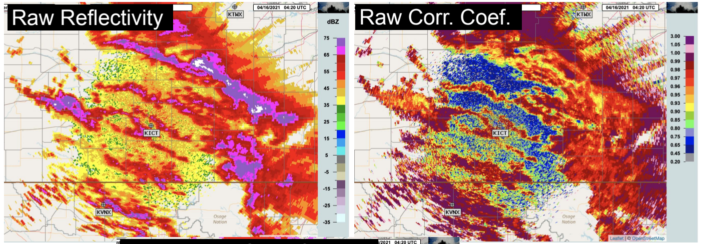
While dual-pol radar observations provided significant QC improvements over single-pol, some challenges remain, e.g.:

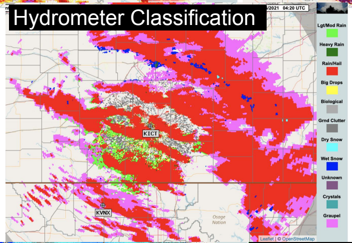
- Corrupt data from hardware malfunctions
- Wind farms contaminations, especially when mixed with precipitation

Specific techniques were developed to address these issues, e.g.:

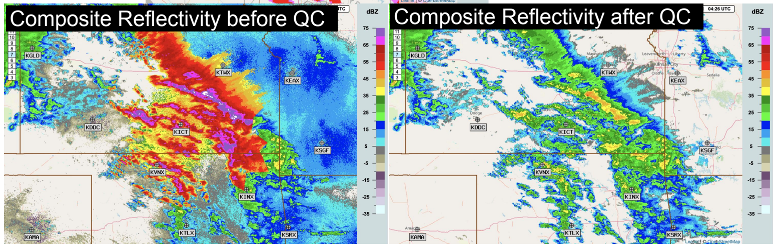
- Application of global properties to identify corrupt data (figures to the right)
- Targeted QC in pre-defined wind farm areas to mitigate contaminations more effectively

Example corrupt data: KICT 04:20Z 4/16/2021





pixel-based QC



global QC based on intensity and areal coverage

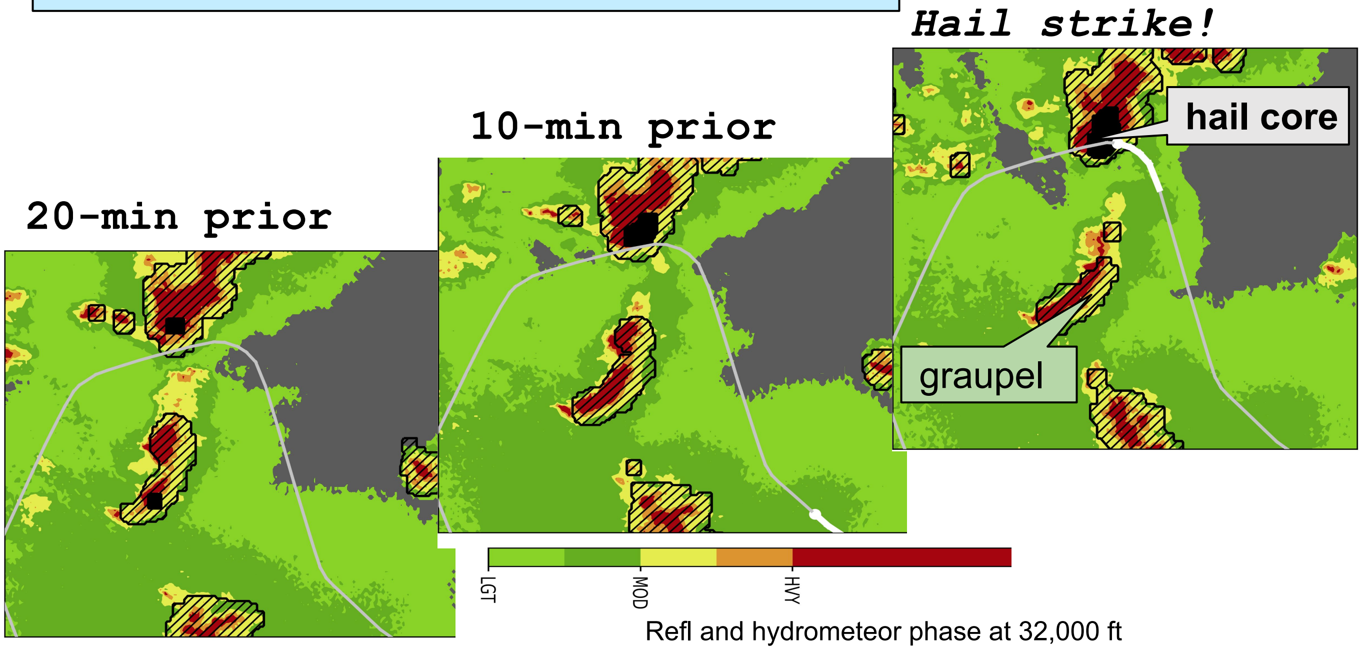
Flight Level Hail/Graupel Detection

Hail smashes nose of plane that flew into towering storm

-Washington Post, 5 June 2018

3D hail/graupel detection

Dual-pol-based detection of graupel and hail at flight level for improved avoidance of weather hazards

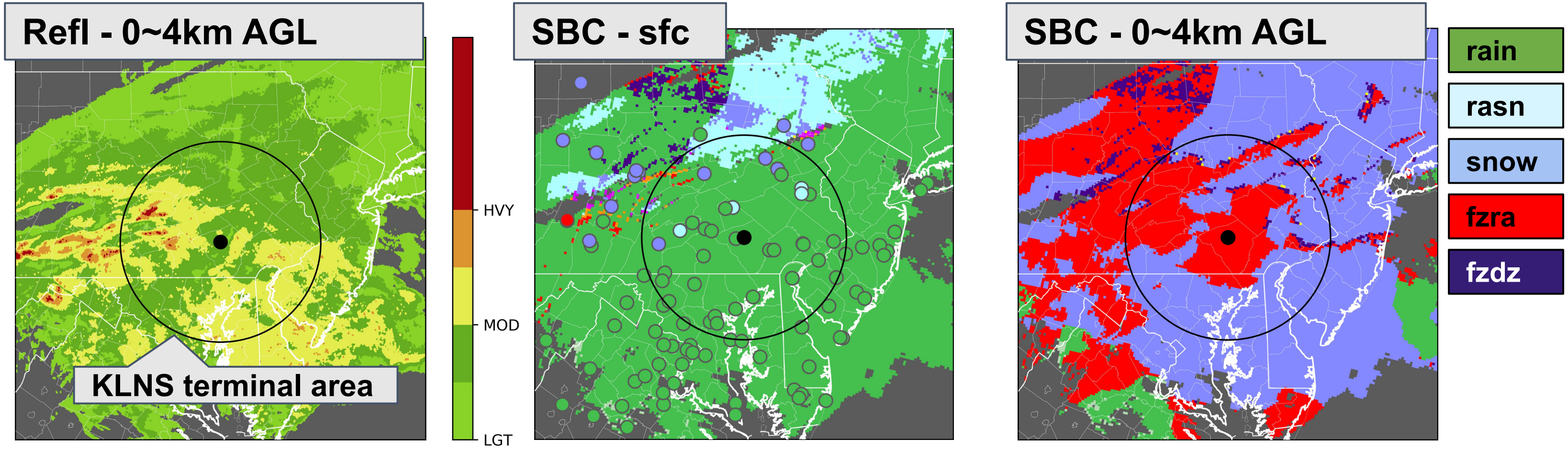


Refl and hydrometeor phase at 32,000 ft

Low Altitude Freezing Rain/Freezing Drizzle Identification

Terminal-area phase diagnosis
3D microphysics-based phase diagnosis (spectral-bin classifier or "SBC") allows for discrimination between FZRA and FZDZ

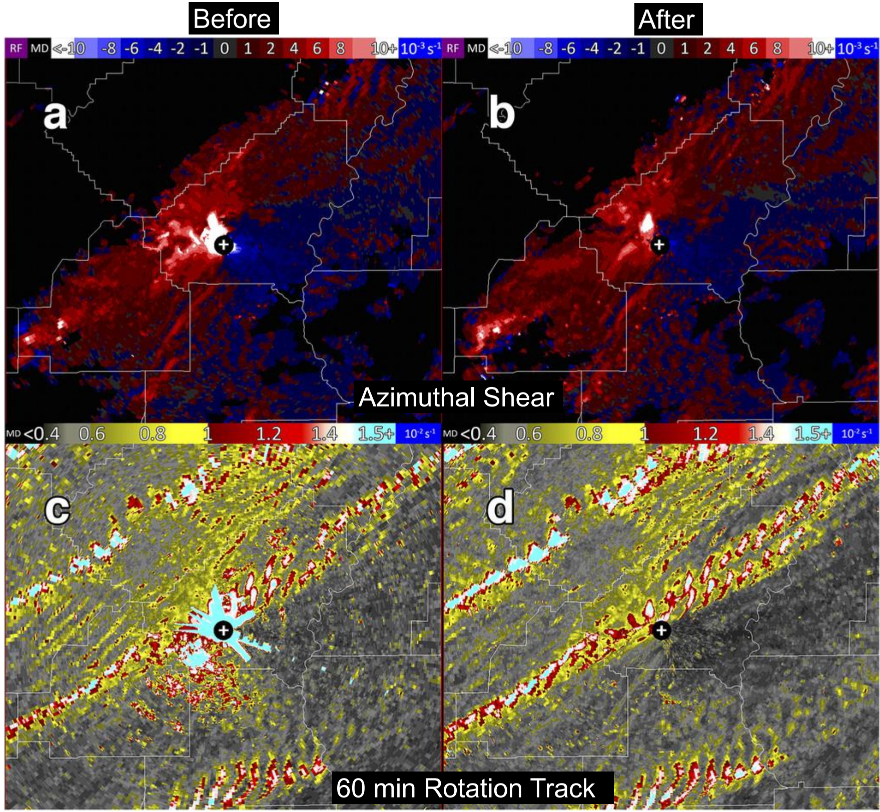
Regulation on flight in freezing drizzle to be issued "soon"
-Aviation Safety Journal, 26 Feb 2010



Rotation Track Improvements

- Azimuthal Shear was reengineered
  - Reducing near radar artifacts
  - Spike removal to account for velocity errors
  - Implemented a better linear least squares algorithm
  - Accounts for beam broadening
- Allows for more consistent values across all rotation events

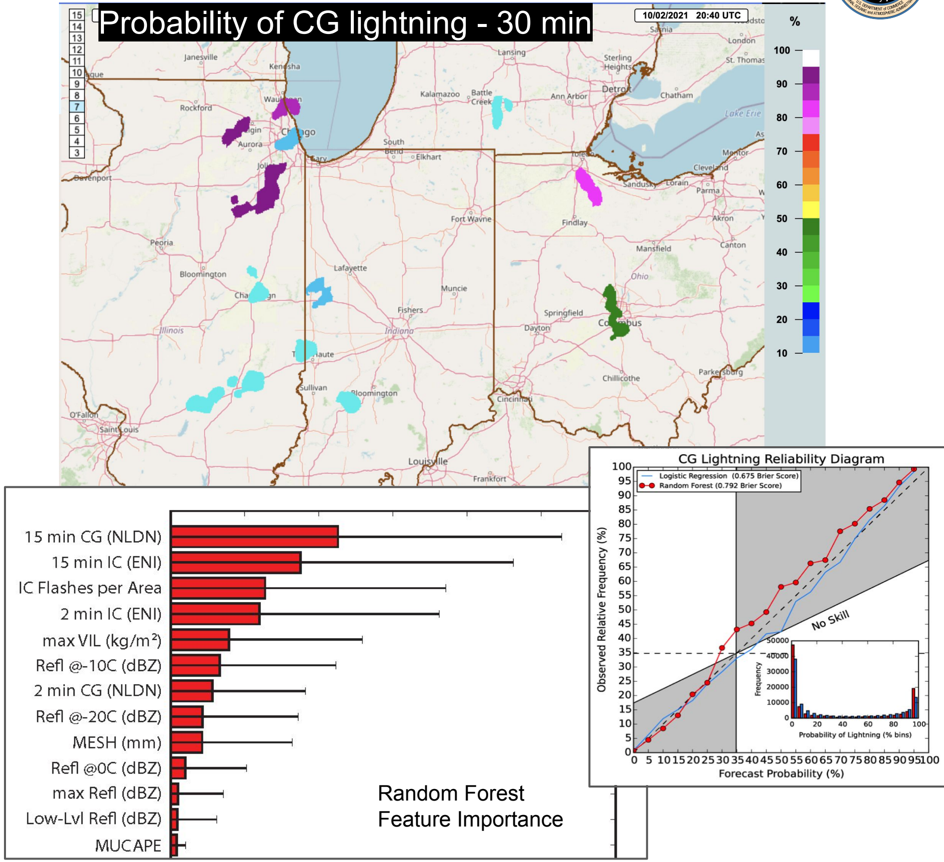
Mahalik et al. 2019 WAF



ProbCG: Storm-based Probability of Cloud-to-Ground (CG) Lightning

- Provide guidance on the likelihood of CG lightning activity associated with a storm over the next 30 to 60 minutes

- Machine learning (random forest) used to train a model using inputs from multiple lightning networks, MRMS radar data, and near storm environment information.



Dual-pol Radar Synthetic QPE

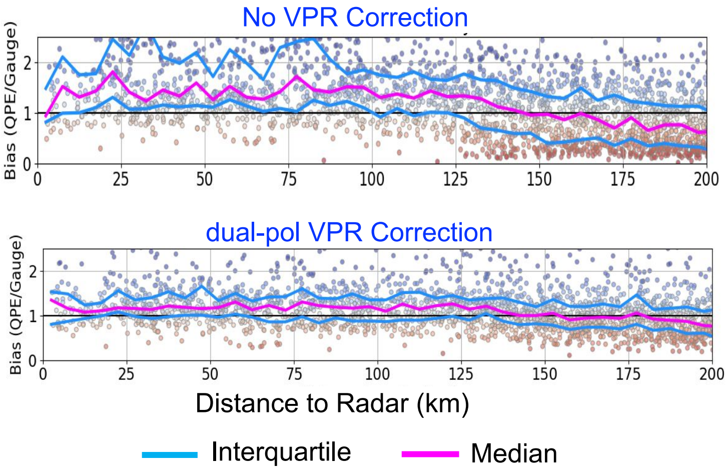
Advancements in radar QPE and their impacts

Techniques	Impacts
Specific attenuation based QPE	Significantly lowered dry biases and uncertainty in heavy to extreme rainfalls
Dual-pol VPR correction	Reduced range dependent biases and random errors (see Figure to the right)
Evaporation correction	Improved QPE accuracy in cool season and in semi-arid regions
Non-standard blockage mitigation	Reduced discontinuities and underestimation in QPE
Improved precipitation classification	Reduced false convective rain identification in bright band and reduced overestimation errors

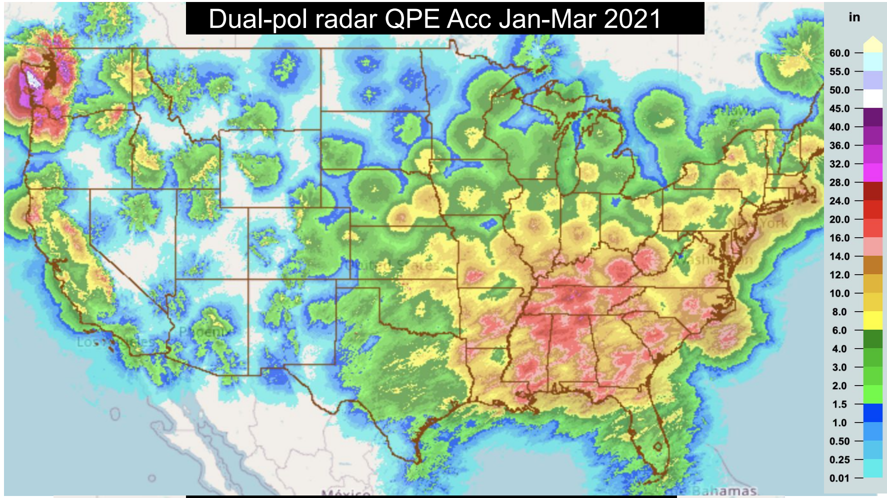
Wang et al. 2019 JHM
Cocks et al. 2019 JHM
Zhang et al. 2020 JHM

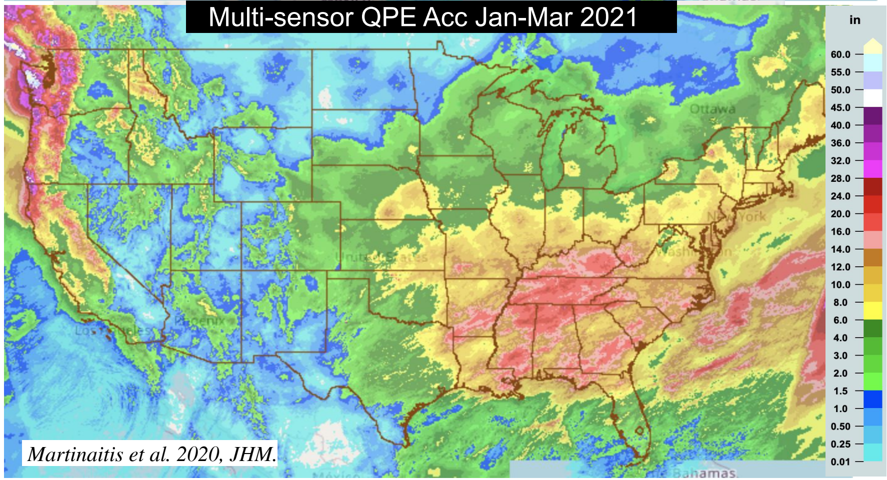
Radar QPE/gauge bias ratios vs. range

14 cases of different melting layer heights across CONUS



Hanft et al. 2022 JHM (under internal review)





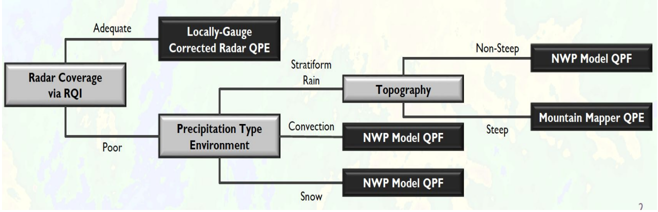
Martinaitis et al. 2020, JHM.

Multi-Sensor QPE

Seamlessly blend different precipitation information sources via physically-based methodology for optimal coverage and accuracy.

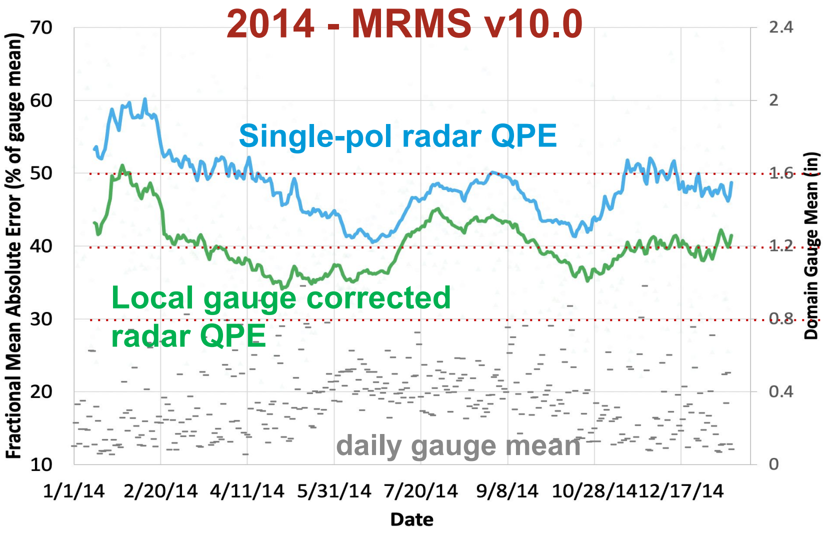
The blending scheme is based on the following information:

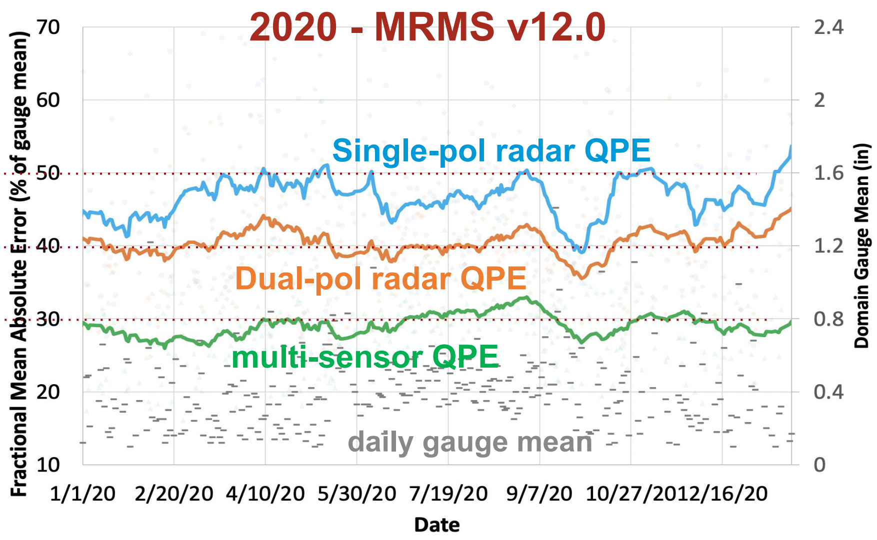
- Radar QPE Quality Index (RQI)
- Topography
- Precipitation Type
- MRMS Locally Gauge-Corrected Radar QPE
- MRMS Mountain Mapper QPE
- Model 1-hr Quantitative Precipitation Forecasts (QPFs)



MRMS QPE: Advancements Since 2015

30-day Running Mean of Daily Fractional Mean Absolute Errors of MRMS QPEs
(with respect to CoCoRaHS Gauges over CONUS)



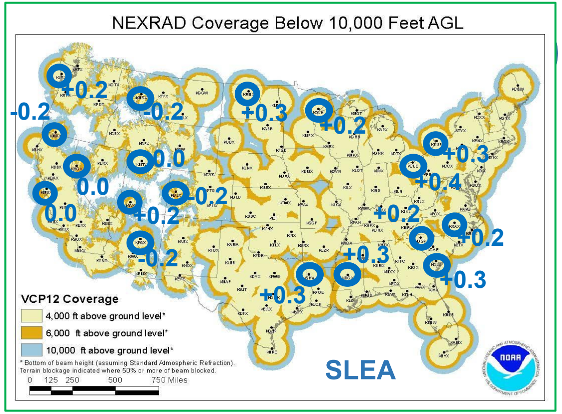


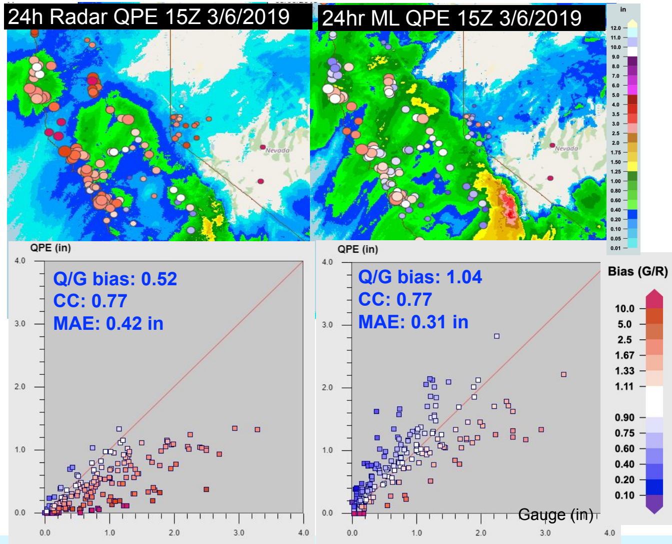
Error reductions:

Dual-pol vs. single-pol radar QPE: ~5-10%
Multi-sensor vs. dual-pol radar QPE: ~10-13%

MRMS Development (2021 and beyond)

- ➢ Integration of new data and new radars, e.g.,
  - ○ WSR-88D supplemental low elevation angle (SLEA)
  - ○ Terminal Doppler Weather Radars
  - ○ Radars deployed by local governments
- ➢ Divergence Shear
- ➢ Transportation safety products:
  - ○ Surface ice accretion and snow accumulations
- ➢ Machine Learning QPE and severe weather products
- ➢ Probabilistic QPE
- ➢ Satellite QPE
- ➢ New Multisensor Precipitation Estimator for NWS River Forecast Centers



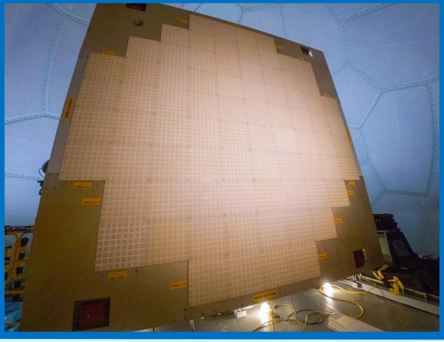
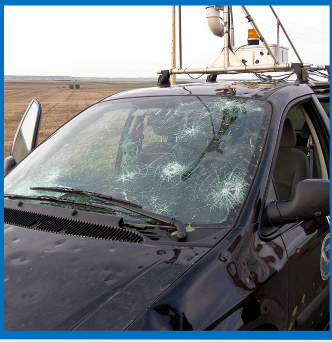


Better forecast/warning tools and techniques

MRMS Cloud Computing

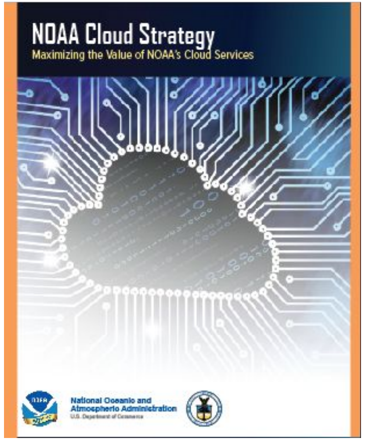
Anthony Reinhart PhD; NSSL Research Meteorologist; WRDD

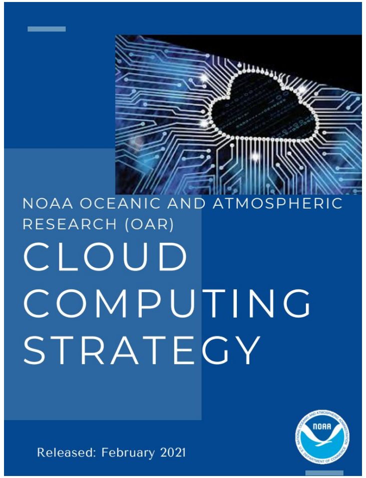


Cloud Computing at NSSL

- Leading the way in utilizing cloud computing
- Aided in developing OAR Cloud Strategy
- Scientific advances are dynamic and fast paced
- Decrease risk while increasing innovation
- Embrace transitioning R&D efforts to the cloud
  - Accelerate scientific research
  - Increase collaboration across the weather enterprise
  - Improve the R2X paradigm
- Drive down costs





MRMS Cloud

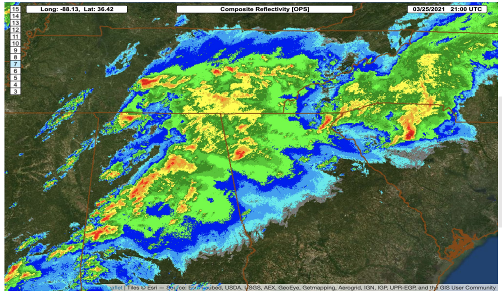
- **2015**
- **2016** — Demonstration of MRMS historical runs
- **2017** — Real-time radar processing feasibility study
- **2018**
- **2019** — NSSL Cloud Contract approved
- **2020** — 30-day initial operational test and V12 transitioned to NWS from AWS
- **2021** — Running full test system on AWS

MRMS–Cloud

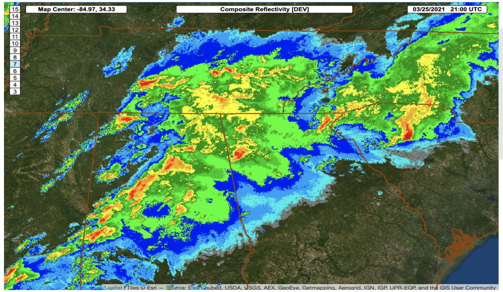
- MRMS system test run in 2020

- MRMS Development system
  - Implemented on AWS January 2021
  - Real-time and 24/7
  - Data availability and quality match both operational and on-prem hardware systems.

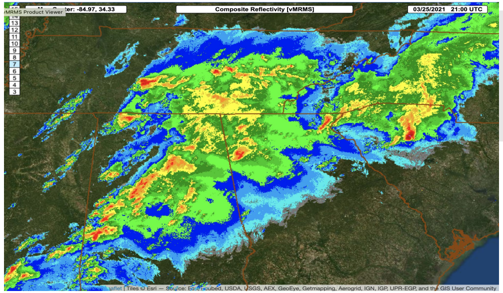
- V12.0 and later operational updates come from AWS as they transition to NWS



NCO OPS (remote)



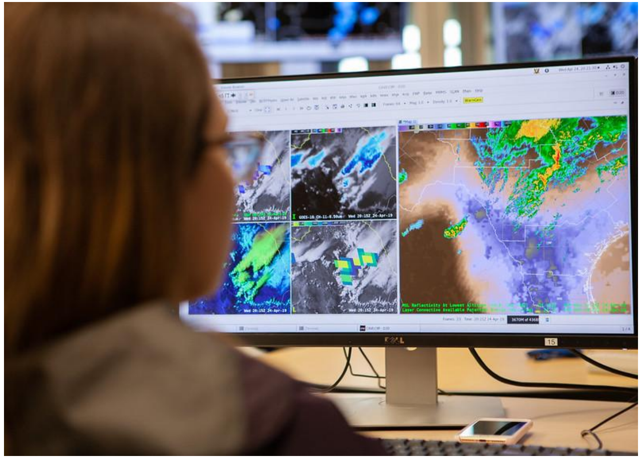
AWS DEV (cloud)



NSSL DEV (on prem)

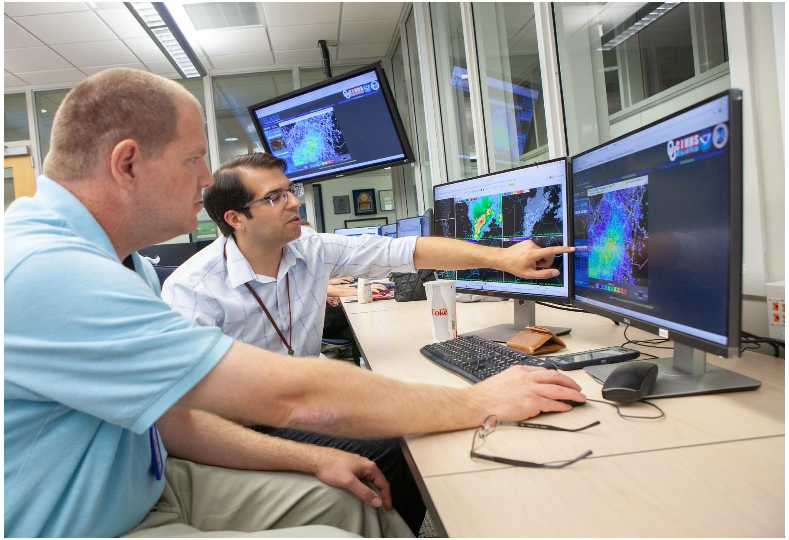
MRMS - Cloud accomplishments

- Transitioned MRMS on to AWS
- Used in the testing and transition of MRMS updates to NWS since 2020
- Developmental version of MRMS running 24/7
  - 99% uptime since January 2021
  - 2 minor hardware failures
- Web display and research tools migrated
- Innovating how NSSL does research
- Support from NWS and OAR partners



MRMS Cloud Future

- Evolutionary step in computing
- Migration of scientific tools to cloud using best practices
- Continue to reduce barriers to cloud adoption
- Harness cloud native technologies
  - Automated testing and integration of software to accelerate R2X
  - Improve implementation of AI/ML tools



Better forecast/warning tools and techniques

MRMS Research-to-Operations Continuing Success and Evolution

Heather Grams, PhD; NSSL Research Meteorologist; WRDD

MRMS R2O Process: Where we are now

- NSSL team works directly with NWS staff on the operational implementation including on-site training and interactions (pre-covid)

- NSSL maintains a real time MRMS system processing environment nearly identical to the operational environment, in addition to a second real-time system in the AWS Public Cloud
  - Provides a straightforward and cloud-ready research-to-operations integration platform

- Collaborative transition/implementation plan with each major release
  - Schedule detailed tasks and identify roles/responsibilities
  - Communication!
  - User and stakeholder awareness and buy-in

MRMS R2O Process: Goals and Objectives

Objective: Accelerate delivery of latest science and high quality software into operational environments

Deliver the Latest Science

- Integrate and fully leverage all existing and emerging observing systems, datasets, and technology to optimize MRMS performance

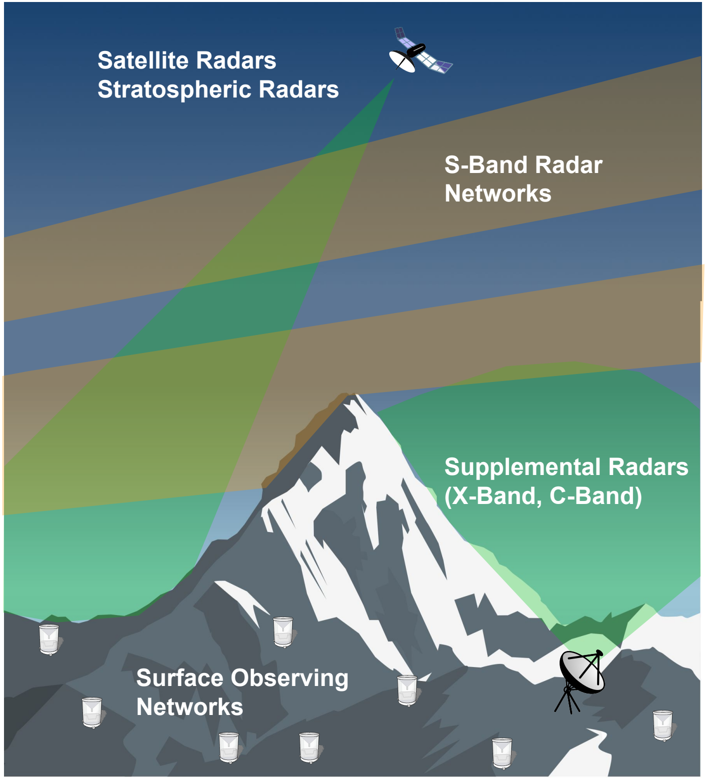
Deliver High-Quality Software

- Work with NWS to plan and schedule R2O release cycles
- Embrace proven industry best practices for software development
- Long-term planning and coordination with operational partners

MRMS as an R2O Platform for new Observations

MRMS is ideally positioned to serve as the R2O gateway for new and emerging observing systems.

- Initial successes demonstrated with Canadian radar networks and supplemental radars
- Established processes for ingest, quality control, and optimized merging of widely varying data sources
- Established pathway to model data assimilation and operational agencies



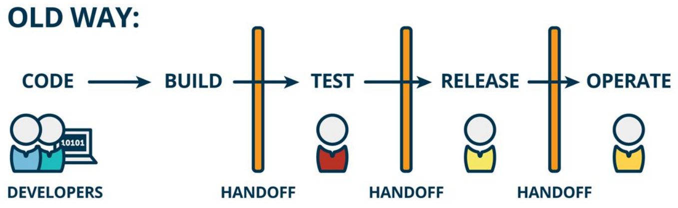
What are DevOps and DevSecOps?

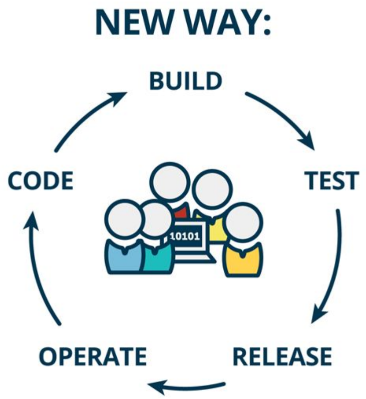
DevOps

“Development and Operations”. Shared collaborative model for system with both sides working continuously to implement improvements. Testing occurs at all phases.

DevSecOps

“DevSecOps stands for Development, Security, and Operations. It's an approach to culture, automation, and platform design that integrates security as a shared responsibility throughout the entire IT lifecycle.” - RedHat.com



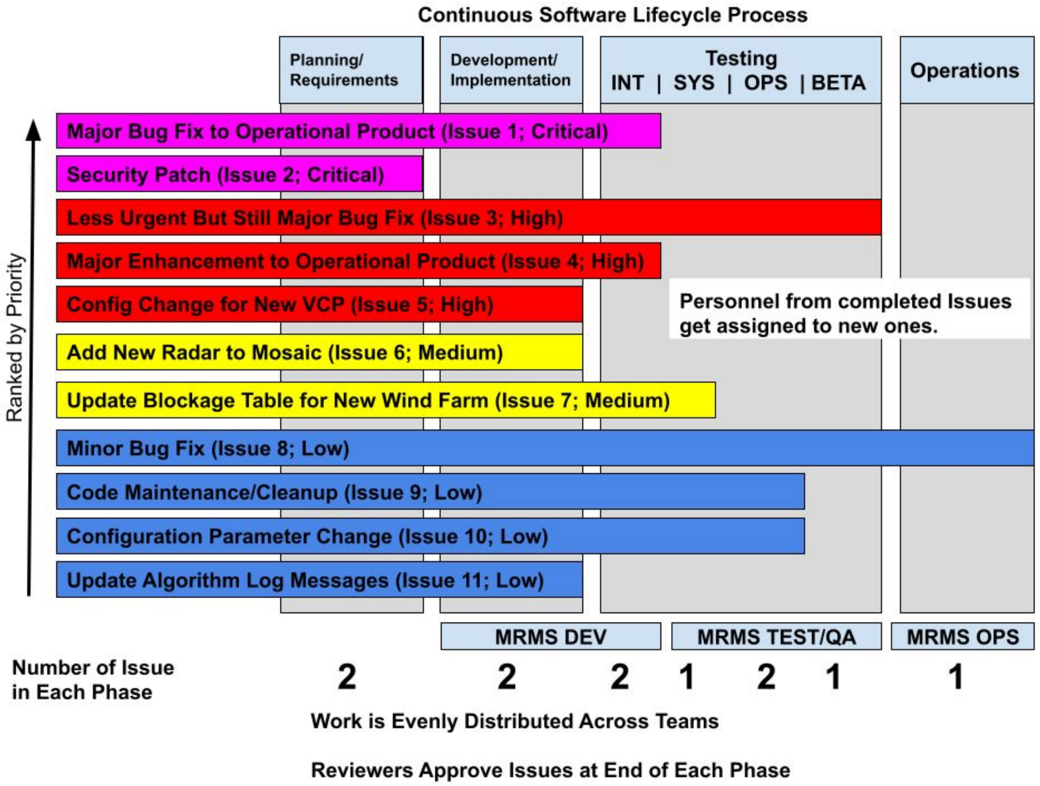


Source: https://tech.gsa.gov/guides/what_is_devops/

The MRMS R2O Lifecycle: Where we are going

Concept Planning	Development	Implementation	Operations and Maintenance
Close coordination with operational stakeholders. Validating user requirements and needs for updates before development phase	Centralize and standardize software development across all teams Culture shift for developers to “DevOps” All development in cloud environment	Asynchronous implementation of small updates based on criticality Paradigm shift for testing/QA to “DevOps” All testing/validation in cloud environment	Frequent, small updates rather than multi-year release cycles Established process for user feedback, which informs concept planning phase

Concept for Accelerating Transitions to Operations



Critical Updates can be moved to operations quickly without waiting for a scheduled major release

Status and progress of each update is documented and tracked

List and timeline of changes are transparent to all stakeholders

R2O Accomplishment(s)

MRMS code has been on-boarded to NWS directly from AWS cloud development system for all releases since Version 12.

MRMS development system has been running in real-time on AWS 24/7 since January 2021 with high availability and reliability.

Funding and support from NOAA to build out cloud-based development environment and change management processes.

The MRMS Development and R2O Teams at NSSL

For MRMS questions: mrms@noaa.gov **For More Information:** https://mrms.nssl.noaa.gov/

MRMS Program Manager: Kenneth Howard (kenneth.howard@noaa.gov)

Precip and Hydro Teams -- Jian Zhang, JJ Gourley, Heather Grams, Race Clark, Steve Martinaitis, Steve Cocks, Lin Tang, Micheal Simpson, Andrew Osborne, Humberto Vergara-Arrieta, Wolfgang Hanft, Jackson Anthony

Severe Weather Teams -- Travis Smith, Anthony Reinhart, Kristin Calhoun, Kiel Ortega, Thea Sandmael, Brandon Smith, Jake Segall, Adrian Campbell, Rebecca Steeves, Claire Satrio

Transportation Team -- Heather Reeves, Andrew Rosenow, Shawn Handler, Daniel Tripp, Dana Tobin

Applied Computing Team -- Jeff Brogden, Karen Cooper, Carrie Langston, Robert Toomey, Brian Kaney, Mike Taylor, Ami Arthur, Nathaniel Indik, Noah LaFon, Brent Kraninger