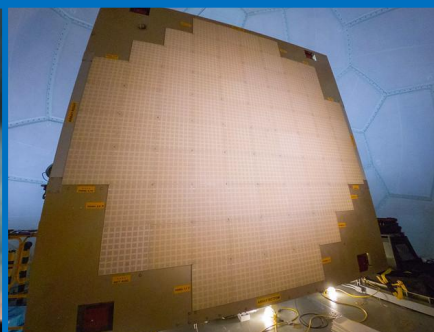


Better forecast/warning tools and techniques

Multi-Radar Multi-Sensor

Kenneth Howard, MRMS Program Manager, WRDD





Multi-Radar Multi-Sensor (MRMS)

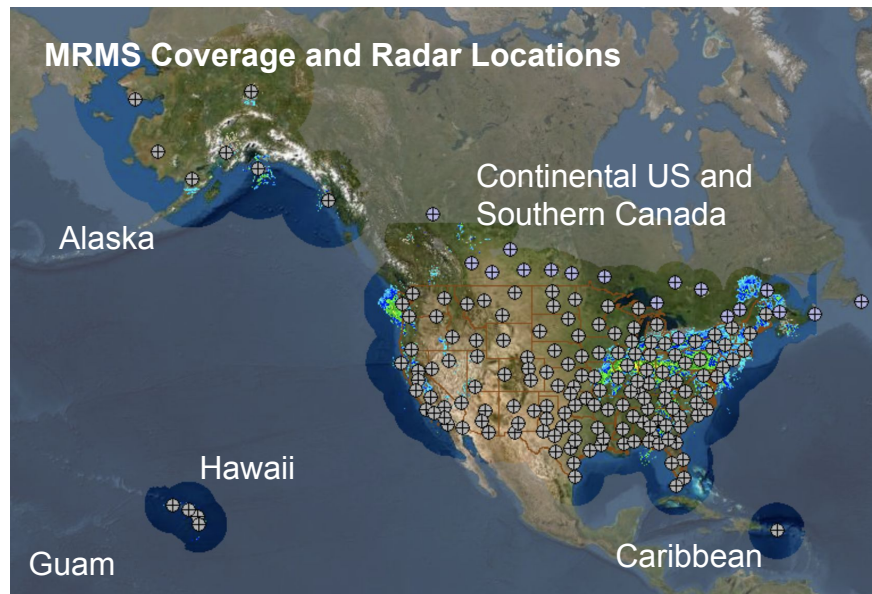
is a science processing architecture that:

- 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
- Serves as framework for advanced applications research and development for operations

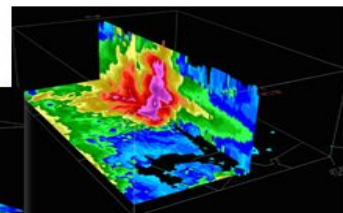
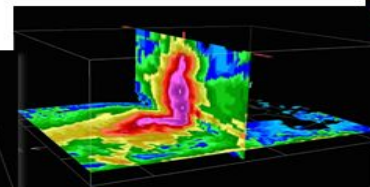
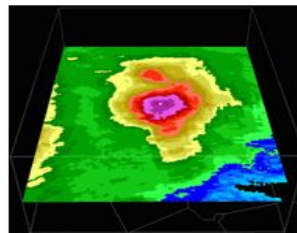
Running operationally at NOAA/NCEP since 2014

Operational Product Viewer:

https://mrms.nssl.noaa.gov/qvs/product_viewer/

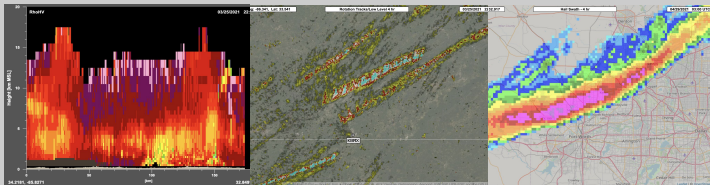


~180 radars continuously streaming data
~20,000 rain gauges hourly



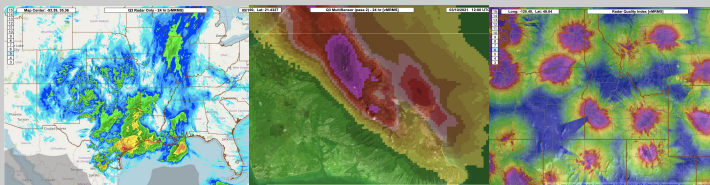
MRMS Product Categories

Severe



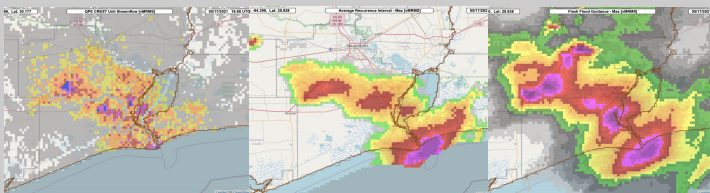
- Hail Size/Accumulated Tracks
- Rotation Tracks
- Lightning Probabilities
- 3D Mosaics of Dual Pol Radar Variables

Precipitation



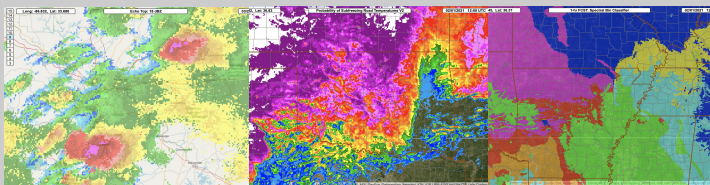
- Rain and Snow Rates
- Short and Long Term Accumulations
- Multi-Sensor Precipitation
- Radar Coverage Quality

FLASH



- Normalized Runoff/Streamflow
- Climatological Rainfall Severity
- Precip Comparisons to NWS Flash Flood Guidance

Transportation



- Aviation Hazards (i.e. hail, icing, convection)
- Surface Transportation (i.e. rapidly accumulating snow, freezing rain, low visibility)





The MRMS Development and R2O Teams at NSSL

For MRMS questions: mrms@noaa.gov

For More Information: <https://mrms.nssl.noaa.gov/>

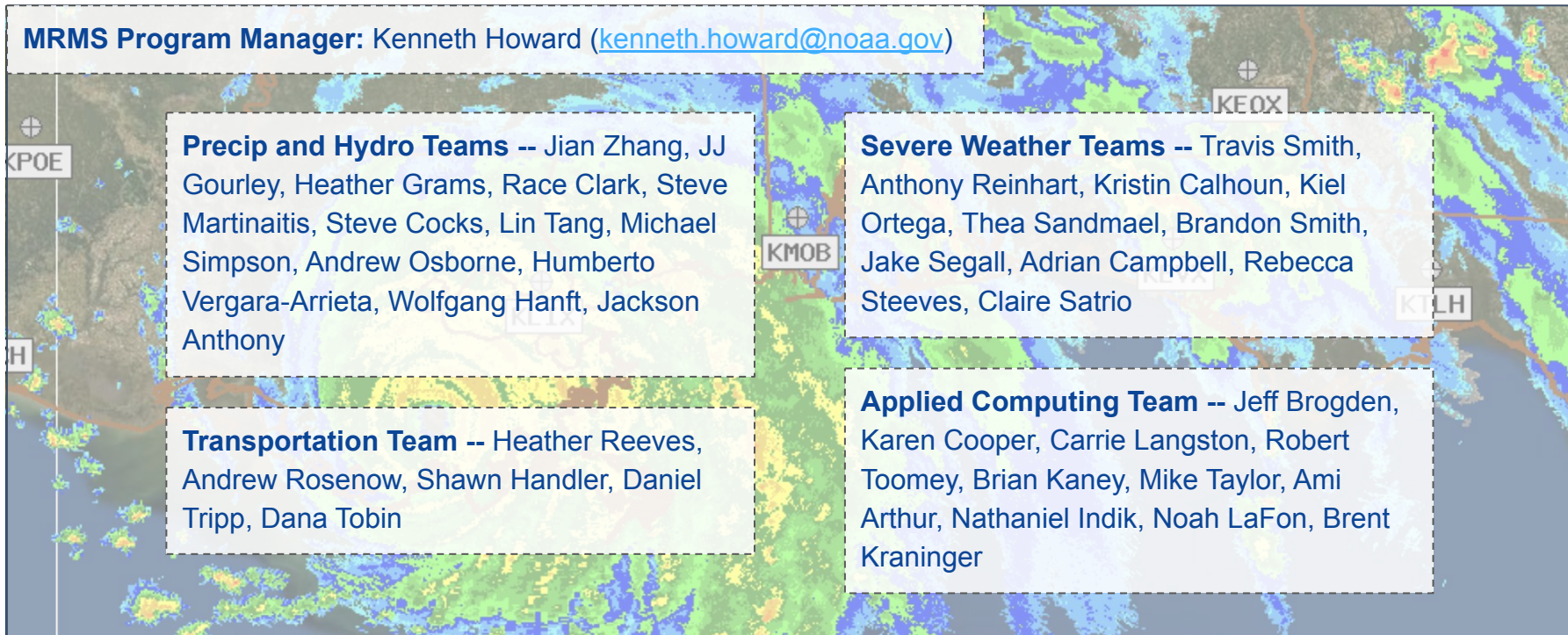
MRMS Program Manager: Kenneth Howard (kenneth.howard@noaa.gov)

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

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

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

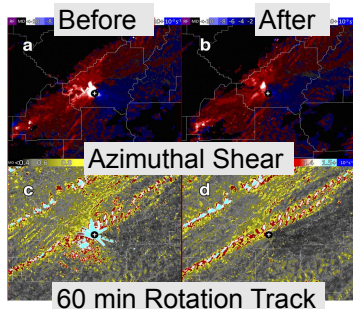
Applied Computing Team -- Jeff Brogden, Karen Cooper, Carrie Langston, Robert Toomey, Brian Kaney, Mike Taylor, Ami Arthur, Nathaniel Indik, Noah LaFon, Brent Kraninger





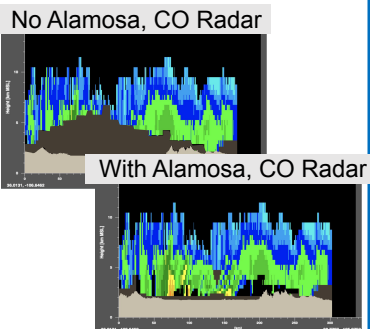
MRMS Research and Development Priorities

Operational Product Improvements



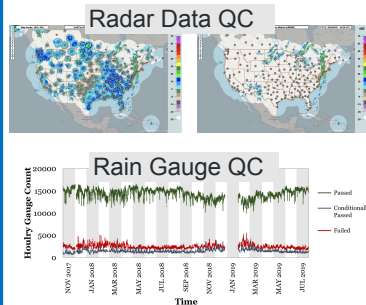
- Integration of new scientific advancements
- Modernization of software for improved efficiency/latency
- Updates based on user feedback on product performance

Integration of New Data Sources



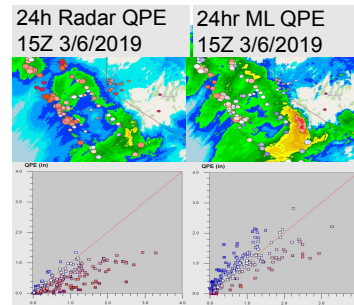
- New supplemental radar networks
- Satellite observations
- Emerging technologies

Quality Control of Observations



- Data Quality is critical step for all downstream products and uses
- Every new data source has unique QC challenges
- QC development is continuous

Leveraging Machine Learning



- Rapidly advancing capabilities and tools available
- Opportunities for new solutions in all the other categories listed here

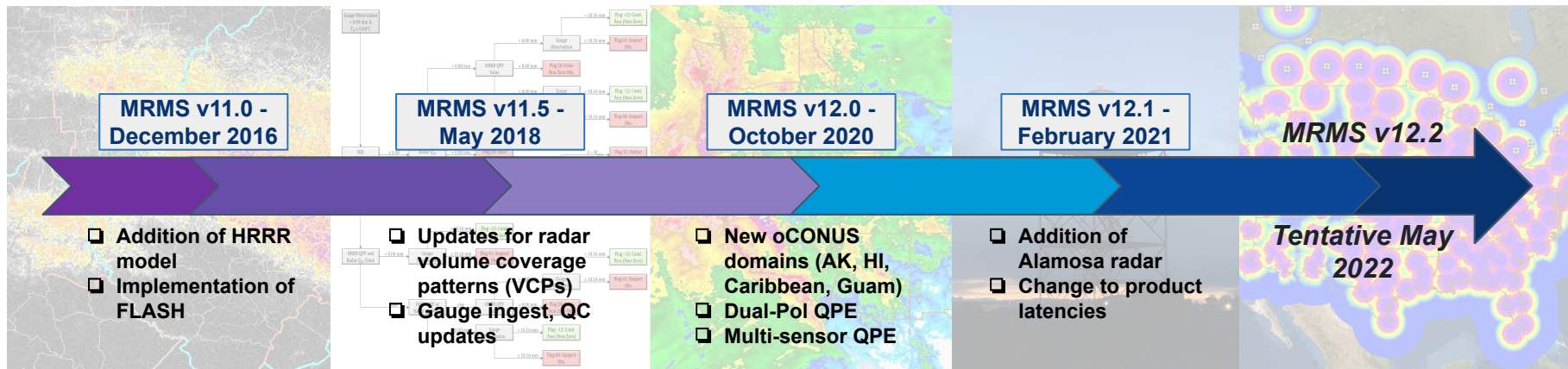




MRMS Operational Success

- 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 Core Research Impacts

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

Initial Operating Capabilities

BY TRAVIS M. SMITH, VALIAPPA LAKSHMANAN, GREGORY J. STUPHS, KILL L. O'LEGA, KURT HONIG, KAREN COOPER, KRISTIN M. CALHOUN, DARRIL N. KINGFIELD, KEVIN L. MANNING, ROBERT TOONEY, AND JIM BROEDEN

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 radar velocity derivatives that are used to produce severe weather guidance information.

The Multi-Radar Multi-Sensor (MRMS) system, developed at the National Severe Storms Laboratory and the University of Oklahoma, is now

operational at the National Centers for Environmental Prediction (NCEP). The MRMS system consists of the Warning Decision Support System-Integrated Information (WDSIS-H; Lakshmanan et al. 2007) suite of severe weather and aviation products and the quantitative precipitation estimation (QPE) products created by the National Mosaic and Multi-Sensor QPE (NMQ; Zhang et al. 2011) system. The MRMS system provides operational guidance for severe convective weather, QPE, and aviation hazards on a seamless three-dimensional grid that is created at a spatial resolution of 0.141° (lat) × 0.141° (longitude), with 33 vertical levels, every 2 min over the conterminous United States (CONUS) and southern Canada. This paper focuses on the severe weather and aviation set of products that include a three-dimensional (3D) mosaic of reflectivity, guidance for hail, tornado, and lightning hazards, as well as mosaics of storm location, height, and intensity. MRMS algorithms focusing on quantitative precipitation estimation are discussed in Zhang et al. (2016).

The WDSIS-H system (also called MRMS-Severe/Aviation) is a multiradar, multisensor system distributed

AFFILIATIONS: SMITH, LAKSHMANAN, O'LEGA, COOPER, CALHOUN, KINGFIELD, TOONEY, AND BROEDEN—Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, and NOAA/OAR/OSLS, Norman, Oklahoma; STUPHS—Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, Norman, Oklahoma; HONIG—National Severe Storms Laboratory, Norman, Oklahoma; O'LEGA—National Severe Storms Laboratory, Norman, Oklahoma; COOPER, KRISTIN M., CALHOUN, DARRIL N., KINGFIELD, KEVIN L., MANNING, ROBERT, TOONEY, AND JIM BROEDEN

CORRESPONDING AUTHOR: Travis Smith, WRMS, NSSL, National Weather Center, 120 David L. Boren Blvd., Norman, OK 73072
E-mail: trsmith@ou.edu

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

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

Initial Operating Capabilities

BY JIAN ZHANG, KENNETH HOWARD, CARLE LANGSTON, BRIAN KANEK, YOUNG QI, LIN TANG, HEATHER GRAHS, YAODONG WANG, STEPHEN COOKS, STEVEN MARTINAITIS, AMI ARTHUR, KAREN COOPER, JIM BROEDEN, AND DAVID KRIZVILLER

The initial operating capabilities of the Multi-Radar Multi-Sensor quantitative precipitation estimation 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.

Over the last two decades, there has been a focus on developing new applications and systems to address requirements for seamless national radar information for use in model data assimilation, transportation, and quantitative precipitation

estimation, which integrate multiple overlapping radars with other in situ or remote sensing observations and numerical weather prediction (NWP) model output. Advances in computational speed and expanding Internet bandwidth facilitated the ability to move radar base data from single radars into regional and national centers for processing (Frogeberg et al. 2002; Kelleher et al. 2007).

The Multi-Radar Multi-Sensor (MRMS) system recently implemented at the National Centers for Environmental Prediction (NCEP) demonstrated such capabilities. MRMS currently integrates about 180 operational radars and creates a seamless 3D radar mosaic across the conterminous United States (CONUS) and southern Canada at very high spatial (1 km) and temporal (2 min) resolution. The radar base data are integrated with atmospheric environmental data, satellite data, and lightning and rain gauge observations to generate a suite of severe weather and quantitative precipitation estimation (QPE) products. Multiradar integration can mitigate deficiencies in the single-radar framework

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E-mail: jian.zhang@noaa.gov

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THE FLASH PROJECT

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

JONATHAN J. GOURLAY, ZACHARY L. FLANG, HUBERTO VIEGAMA, PIERRE-EMMANUEL KRISTETTER, ROBERT A. CLARK III, ELIZABETH ARGYLE, AMI ARTHUR, STEVEN MARTINAITIS, GALATIYA TERZI, JESSICA M. ERICKSON, 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 United States, yielding an average of 5,603 per year according to the Storm Events Database (available at www.ncep.noaa.gov/stormevents/rep.jsp). Ten percent of these flash flood events resulted in completed 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 the subcategory of floods into faster responding flash floods is required here, as this segregation impacts some of the statistics reported in the literature. While there is no real physical basis for separating floods and flash floods, it is often times necessary to divide them based on scale due to differing operational responsibilities within agencies, including the NWS. According to the NWS Glossary (NWS 2012), lakes added, flash floods are rapid rises of water in "a stream or creek above a predetermined flood level, beginning within six hours of the causative event." Flash floods fall within the responsibility of local NWS Weather Forecast Offices (WFOs) distributed

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 that study was the finding that most human-impacting events occur in rural settings. However, when a flash flood occurs in an urban center, there are many more human impacts per event. Ashley and Ashley (2008) analyzed flood fatalities from 1959 to 2005; they found a median value of flood fatalities at 81 per year with no statistically significant trend. Several studies cite the role of vehicles as a significant factor in the cause of death during flash floods in the United States, accounting for more than half of the fatalities (Frensch et al. 1988; Ashley and Ashley 2008; Keller and Schmalzer 2012; Shatt et al. 2015; Terzi et al. 2017). Despite the lack of increases in flash flood events or fatalities over this short period, the will likely increase in frequency and magnitude in coming decades. First, the U.S. population continues to urbanize (United

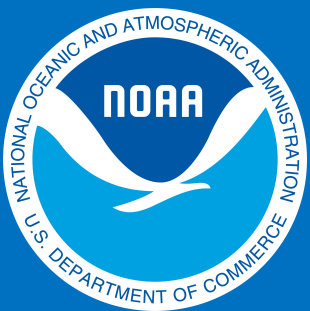
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Peer-Reviewed Publications from MRMS Team (2015-2021):

- 57 Lead Authored, 103 Co-Authored
- Google Scholar Mentions (peer-reviewed journals, conference presentations):
- “Multi-Radar Multi-Sensor” returns 1,070 papers



Kenneth Howard



Heather Grams



Steven Martinaitis



Jian Zhang



Anthony Reinhart



Heather Reeves



Travis Smith



Jeffrey Brogden



Kristin Calhoun

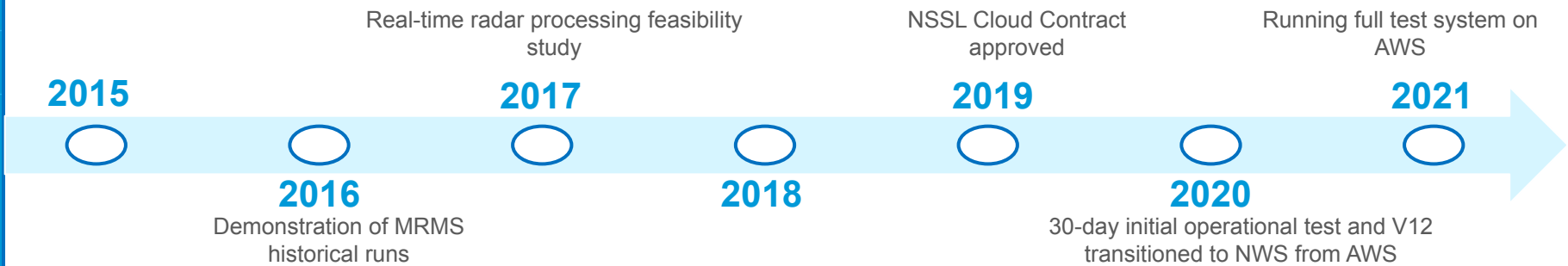
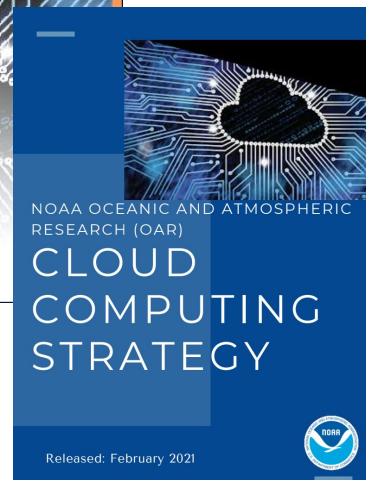
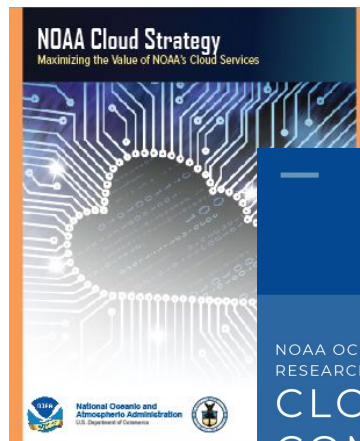
Questions for the MRMS panel?





MRMS - Cloud Computing

- NOAA/OAR priority to leverage cloud computing
- Successful implementation of MRMS on 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
 - Costs competitive with on-prem hardware
- Web display and research tools migrated
- Innovating how NSSL does research
- Support from NOAA partners



Alignment with NOAA and OAR Goals



NOAA R&D Vision Areas 2020-2026

OAR Strategic Goals

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	✓	MRMS serves as a key data assimilation input and a verification resource for development of atmospheric and hydrologic forecast systems	✓
	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	✓		MRMS is a platform for rapid integration of new observations with a proven track record of successful transitions of new science into operational environments
	4.2 Invest in high-risk, high-reward science			
	4.3 Accelerate the delivery of mission-ready, next-gen science	✓	✓	





MRMS Research-to-Operations Strategy

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
- Remaining flexible to capitalize on new remote sensing opportunities and new science

