Science Advisory Board

Environmental Information Services Working Group (EISWG)

Report on Radar Gaps

Members: Marty Ralph (EISWG), Ilse Gayl (EISWG), David Fisher (EISWG)

6 November 2023

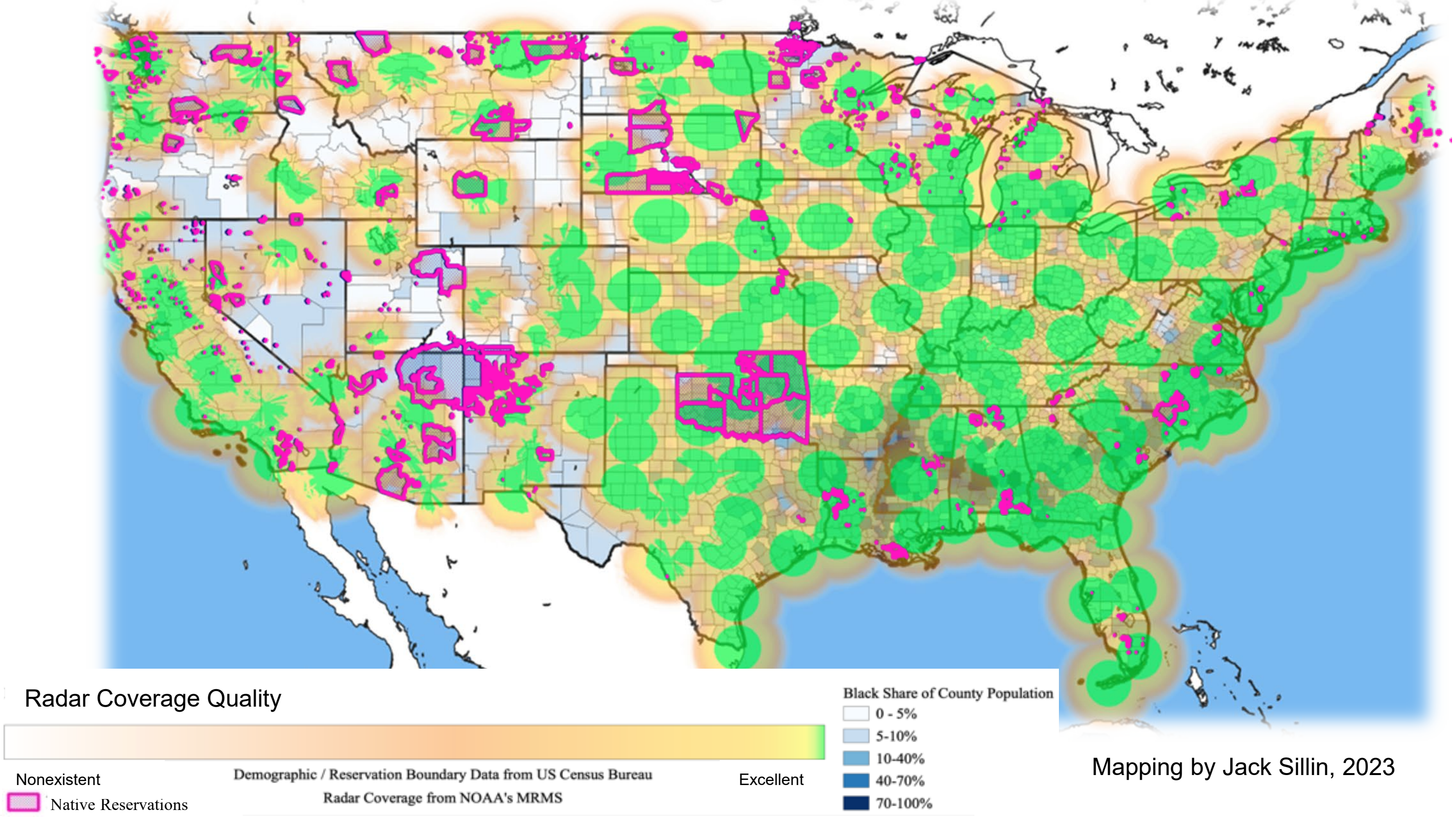
Purpose

- In 2021, the Priorities for Weather Research (PWR) report made a major recommendation to *immediately start filling gaps in the NEXRAD network radar coverage* with low-cost radars.
- At the time of this writing, some radar improvements have been made by NOAA and some radars have been added by the private sector, but the *majority of radar gaps are not being addressed*.
- Our purpose is to recommend that NOAA *start acting now*.

Motivation

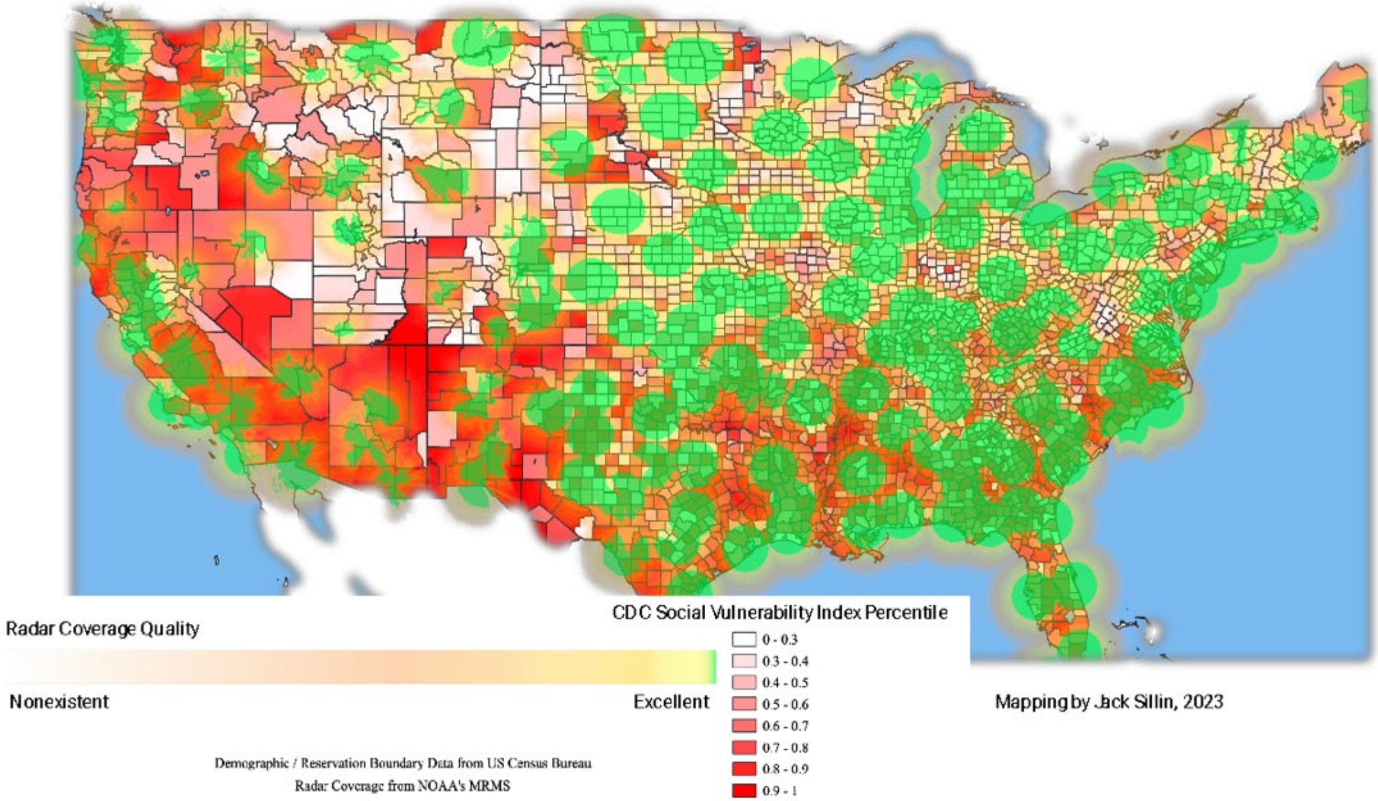
- The need for better radar coverage today is *urgent*; *underserved populations in particular need to be protected*.
- Pictures are worth thousands of words, and the following slides best illustrate the study team’s motivation.

Green is good radar coverage, yellow-brown weak, clear/white zero coverage. Pink outlines Indian land. Blue-dark brown shows Black counties.



Mapping by Jack Sillin, 2023

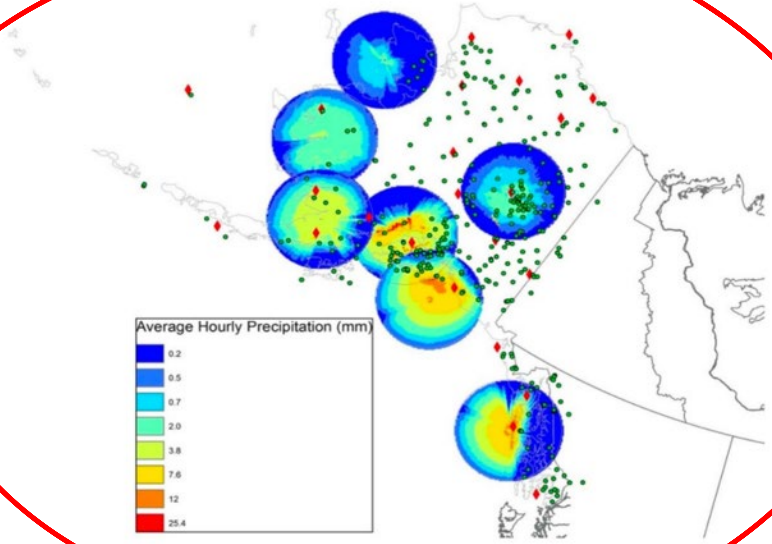
Green is good radar coverage, yellow-brown weak, clear/white zero coverage. Pink-red shows increasing social vulnerability.



Mapping by Jack Sillin, 2023

Demographic / Reservation Boundary Data from US Census Bureau
Radar Coverage from NOAA's MRMS

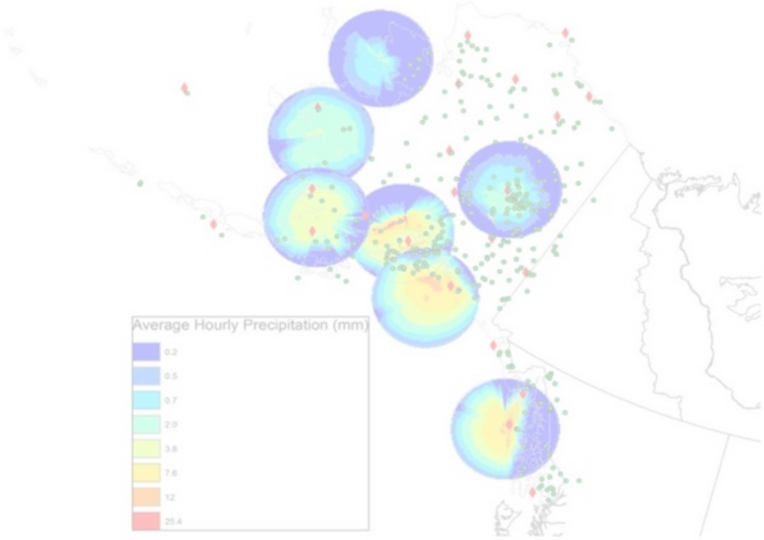
Non-CONUS areas of NOAA responsibility:
Alaska coverage is both terrain-blocked and sparse.

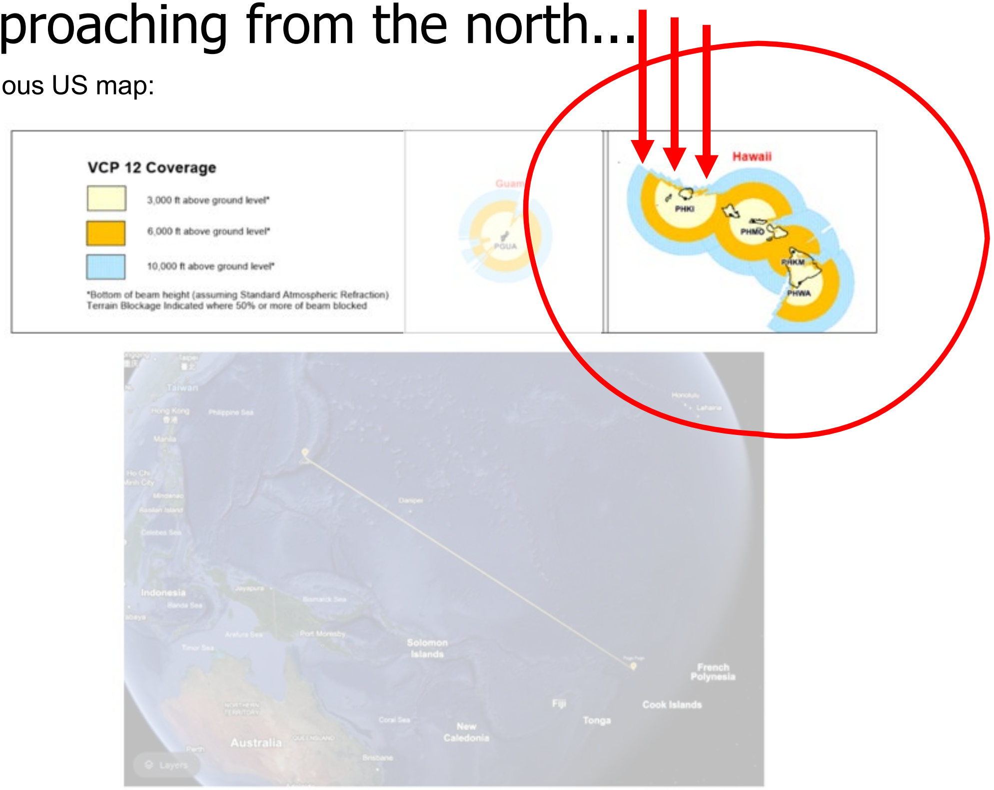


c.f. Nelson, B.R., O.P. Prat and R.D Leeper, 2021: An Investigation of NEXRAD-Based Quantitative Precipitation Estimates in Alaska. Remote Sens. 13, 3202. https://doi.org/10.3390/rs13163202

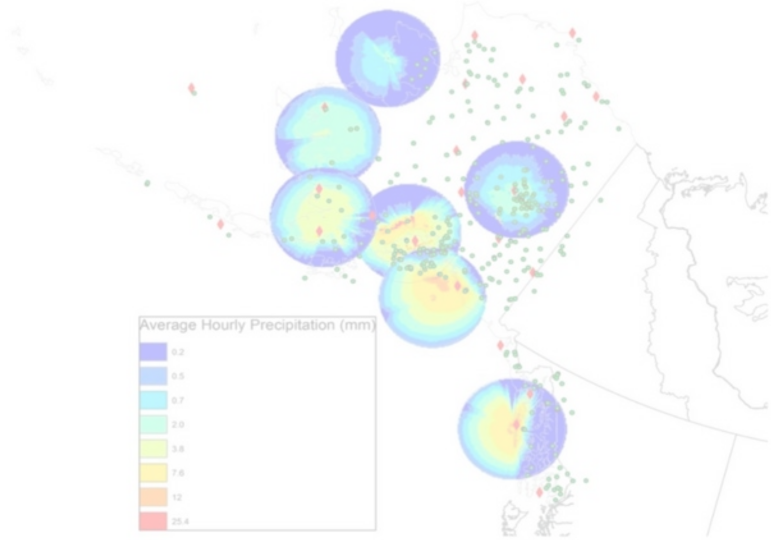
Hawaii coverage is mostly good, but with some blockage of weather approaching from the north...

(Puerto Rico VCP-12 coverage is shown on the radar website Contiguous US map: https://www.roc.noaa.gov/WSR88D/Maps.aspx)





... and the Guam NEXRAD radar is serving the Pago Pago NWS office in American Samoa, some 3,100 nautical miles distant.



A Google Earth map showing the distance between the Guam radar and Pago Pago

Background and Process

- In the 2021 PWR report, it was recommended that NOAA immediately start filling gaps in NEXRAD radar coverage with low-cost radars.
- Observing that this activity had not yet commenced, the EISWG study team sought and received input from NOAA, from public-academic research consortia, from experts in remote and American Indian tribal weather risk management, and from commercial radar and radar data providers.
- The study was carried out in parallel with the study for EISWG Report on *A NESDIS Observing System Backbone Framework*, and that report's approach to NOAA creating a backbone for core space-based observations was identified as a reusable best practice here.

Findings – Urgency

FINDING 1: Indian Reservations, counties with high proportionately Black American census numbers, and areas containing socially vulnerable populations remain underserved.

The immediate need for expanded radar coverage is urgent, especially with increasingly frequent and extreme weather, drought, rainfall, and floods.

The urgency has powered some geographical areas that could to make progress deploying academic and private sector radar solutions, so feasibility is demonstrated.

Areas of Alaska and Hawaii and the whole of American Samoa remain underserved or, in the case of American Samoa, essentially not served.

In some regions there are Alaska native populations not covered, and in other areas, NWS predictive capability is undermined by blockages of precipitation approaching and weather coming in from critical directions. In the case of American Samoa, the nearest radar is 3,100 nautical miles away.

Findings – Challenges

FINDING 2: Gap-filling radars are different from NEXRAD radars.

“Big-iron” NEXRAD S-band radars provide high quality, accurate precip and weather data over large areas, limited by terrain and by weakening “surface” observations due to higher beam elevation with distance.

“Smaller-iron” C-band and X-band radars, in order, are increasingly higher in frequency, thus with smaller coverage diameters due to less penetration through intense precipitation.

Small iron costs roughly an order of magnitude less than big iron per radar.

FINDING 3: Origins of radar gaps.

Mountains block radar, and mountainous areas of the U.S. are more difficult to cover.

Siting radars in valleys reduces areal coverage, but siting radars on mountains worsens the problem of beam elevation; vital for coverage are the lowest 5,000 of weather above the ground.

The NEXRAD S-band radars were deployed as then-best technology. However, there are long distances between radars in areas of the network resulting in zero-coverage, especially in the western U.S. and the Pacific.

Findings – Opportunities

FINDING 4: How gap-filling radars help.

Smaller-iron C-band and X-band radars make up for their lesser penetration by being deployable at many more locations due to their much lower cost.

They can be sited to fill in complicated terrain with more complete, more accurate precipitation estimates at the lower elevations and more detailed storm structures.

Commercialization of lower-cost radars has enabled 20+ years of demonstrated useful performance, and these solutions are being deployed more often both internationally and in U.S. areas of concern (i.e., with poor NEXRAD coverage and high severe weather risks).

FINDING 5: Integration of commercial data can help.

Commercial providers have installed radars in various areas and NOAA is already engaged with them in pilot projects.

Where commercial providers are ready to sell data to NOAA, NOAA can learn to integrate their data into their existing radar operations, especially in areas where there are otherwise gaps.

Commercial providers have gained experience in the U.S. and elsewhere with these radars and can be useful partners to NOAA in helping NOAA create its next-generation radar backbone, likely a hybrid of radar technologies.

Findings – Private/Academic Partners

FINDING 6: Commercial radar rollouts will leave some populations uncovered.

The full rollout of private gound-based radars will fill some gaps and may enhance some areas of weaker NEXRAD coverage, *but*, …
… the impetus for private sector companies to place radars in areas of poor coverage nevertheless requires economic interests nearby to fund their operation.

Analogously, research-related interests drive funding and support of academically-supported gap-filling radars. Whereas academic participation can help with future implementations, NOAA is needed to fulfill its mission.

FINDING 7: NOAA can work with private and academic sectors on backbone.

The next-generation national radar backbone system will likely hybridize a variety of radars, including modern big iron radars to cover the majority and sited-for-purpose smaller-iron radars.

The framework developed in the EISWG report on *A NESDIS Observing System Backbone Framework* will serve NOAA well as it addresses many of the same issues, albeit for space-borne observations critical to NOAA's mission.

NOAA will benefit from full engagement with all its partners and stakeholders to complete the plan.

Recommendations

RECOMMENDATION 1.

NOAA should establish a gap-filling radar data strategy by using the EISWG Report on *A NESDIS Observing System Backbone Framework* to define the radar backbone architecture that will best serve the Nation.

RECOMMENDATION 2.

NOAA should act immediately to use commercial radar data already available, doing it under license agreement that permits NOAA to re-distribute the data on an equal-opportunity, no-cost basis, just as is the case today for NEXRAD radar data.

Recommendations (continued)

RECOMMENDATION 3.

NOAA should act immediately to implement the gap-filling radar data strategy: Using X-band and C-band radars (e.g., commercial data purchases and/or NOAA-deployed backbone), prioritize coverage of, and engagement with, underserved populations.

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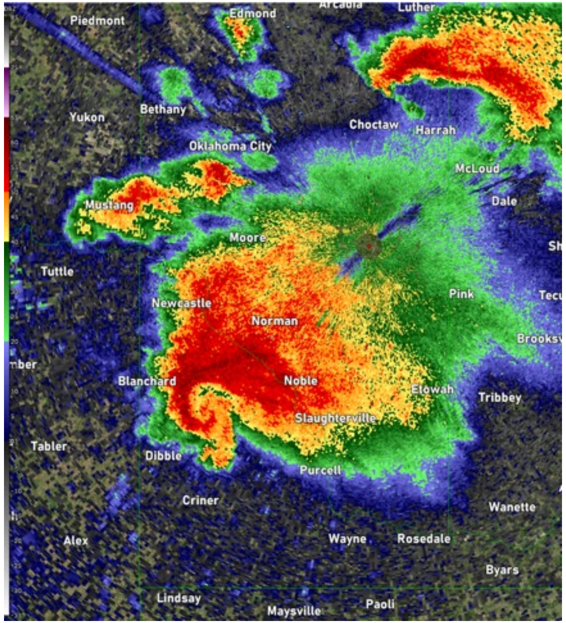
Thank you.

It is EISWG’s role to make recommendations where we non-NOAA domain experts see that NOAA has an opportunity to improve the outcomes of their dedication and work.

It has been an honor for us to work on this report.

F. Martin Ralph, Ph.D., Ilse Gayl, and David Fisher

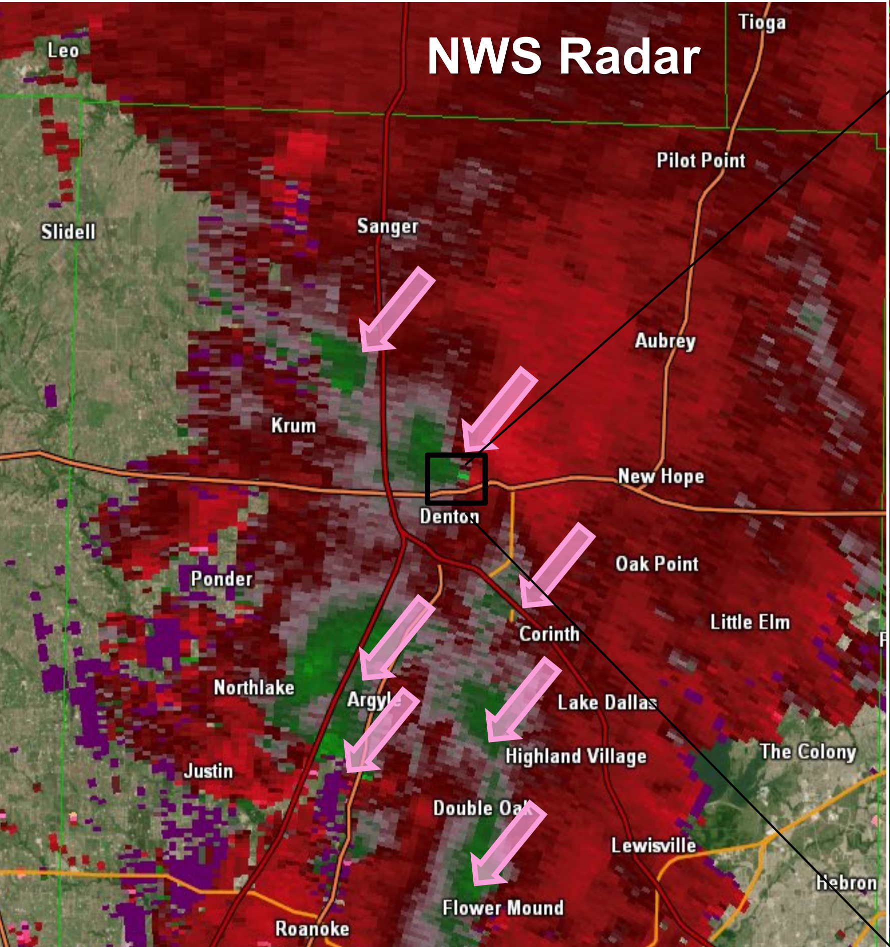


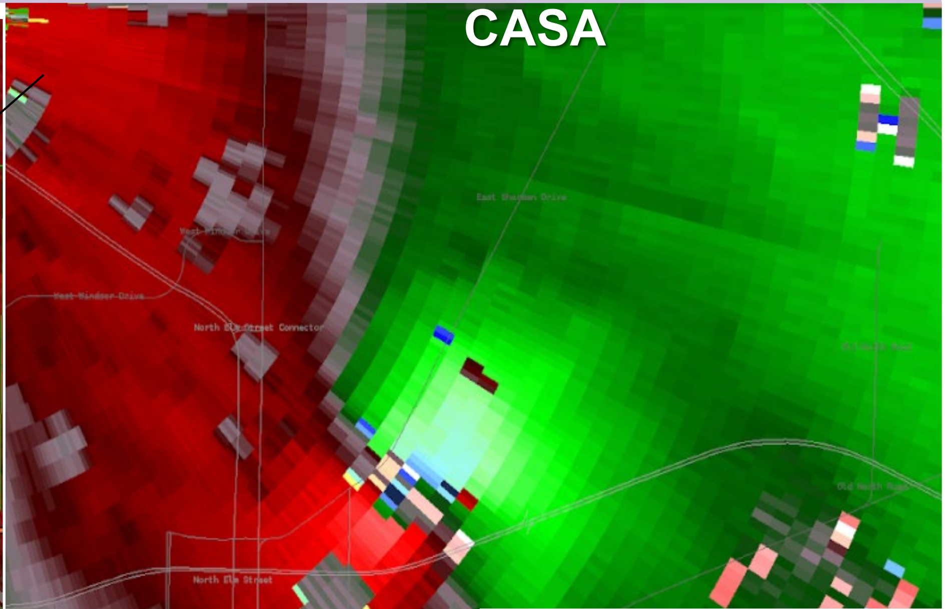
Reflectivity image of a supercell thunderstorm that produced multiple tornadoes near Oklahoma City, OK, on April 19, 2023

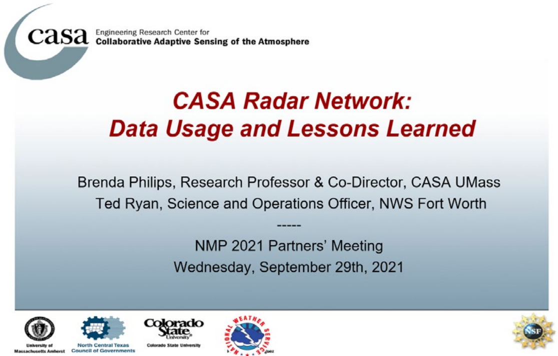
https://www.noaa.gov/jetstream/reflectivity

Back Up Slides Below

Denton Tornado April 30th, 2019





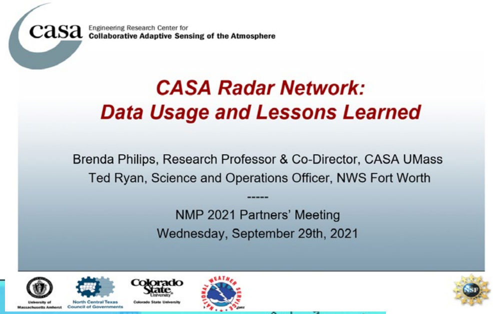

casa Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere

CASA Radar Network:
Data Usage and Lessons Learned

Brenda Philips, Research Professor & Co-Director, CASA UMass
Ted Ryan, Science and Operations Officer, NWS Fort Worth

NMP 2021 Partners' Meeting
Wednesday, September 29th, 2021

1 Hour Accumulation Products at 10:00 AM



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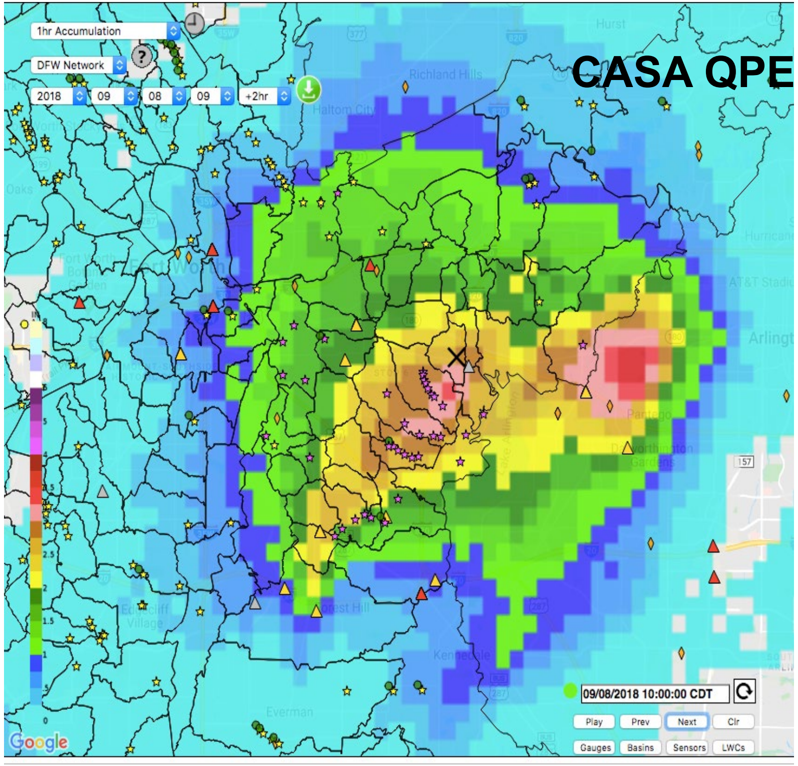
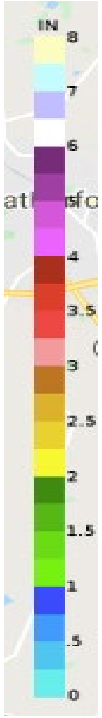
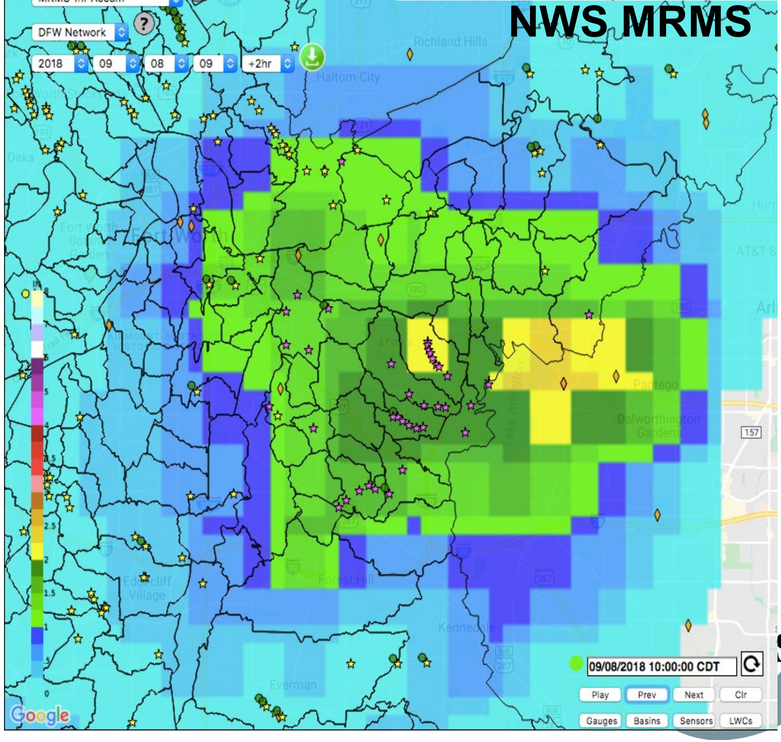
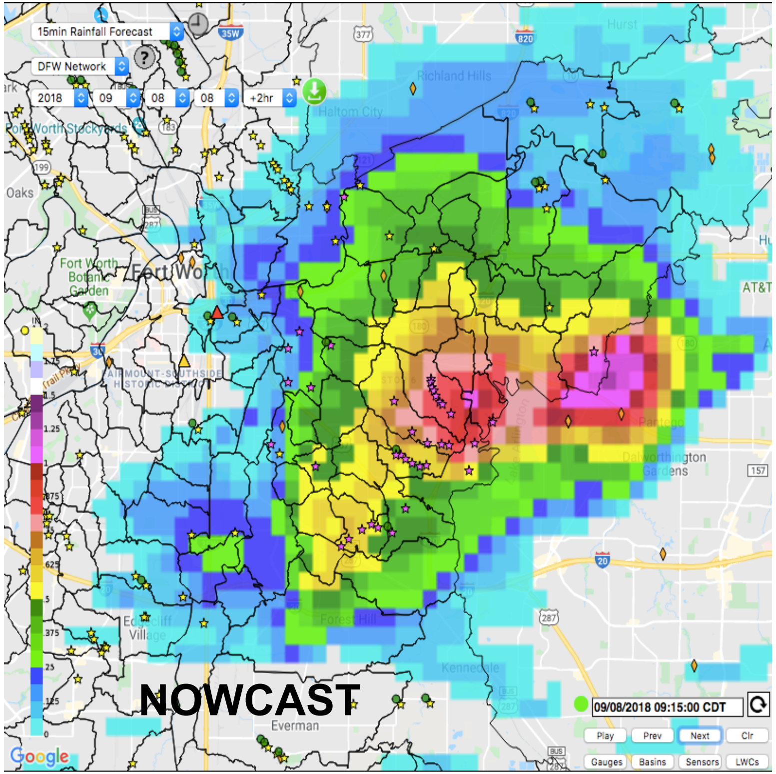




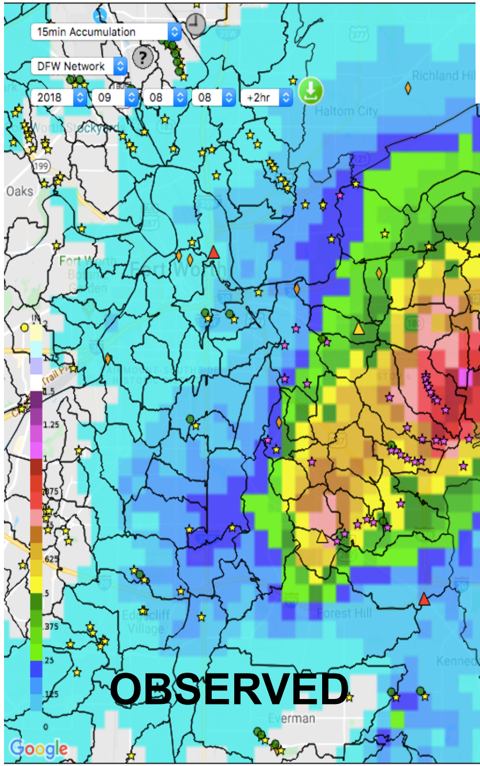


15 Min Nowcast 9:30 vs. Actual Observation 9:30



15min Rainfall Forecast
DFW Network
2018 09 08 08 +2hr
09/08/2018 09:15:00 CDT

NOWCAST

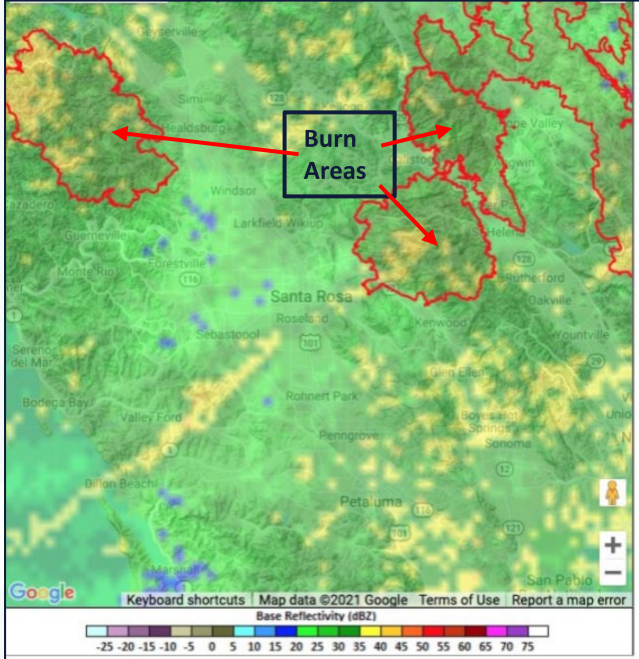


15min Accumulation
DFW Network
2018 09 08 08 +2hr
09/08/2018 09:30:25 CDT

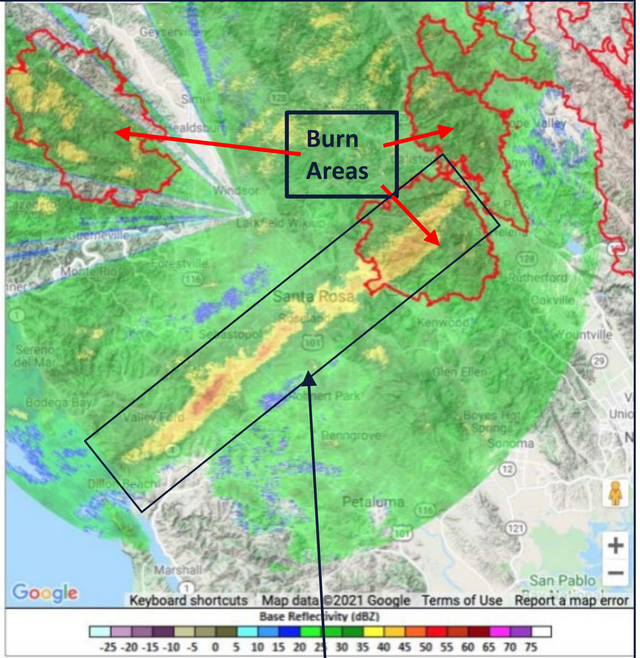
OBSERVED

Santa Rosa, CA - 24 Oct 2021 ~1845 UTC

NEXRAD (s-band) from Monterey



AQPI (x-band) from Santa Rosa



NCFR!

Guerneville

Santa Rosa

Source:
https://www.pressdemocrat.com/article/news/atmospheric-river-lashes-the-north-bay-bringing-flooding-power-outages/

Center for Western Weather and Water Extremes

Santa Cruz Case Study

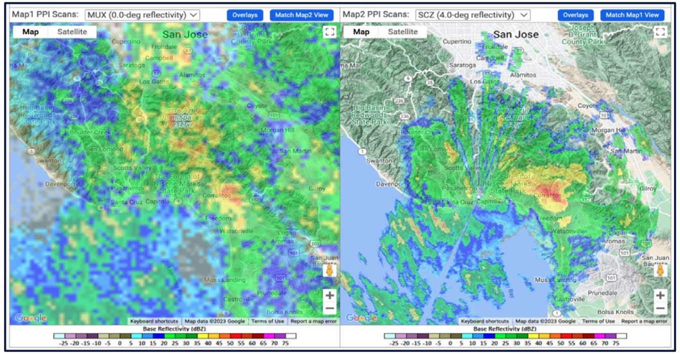
AQPI recently partnered with Bay Planning Coalition and officials from Santa Cruz County to highlight benefits of AQPI to the decision-making process during storms on 10 Mar 2023 (slide 7 from this presentation):

- Accessible online: here
- The bottom line: AQPI radar data was used and the higher level of detail provided confidence in issuing both evacuation and return-to-home orders for ~450 residences whose accessibility was heavily impacted by flooding / road washouts

AQPI Case Study

Winter 2022/2023 Atmospheric River Storms in Santa Cruz County

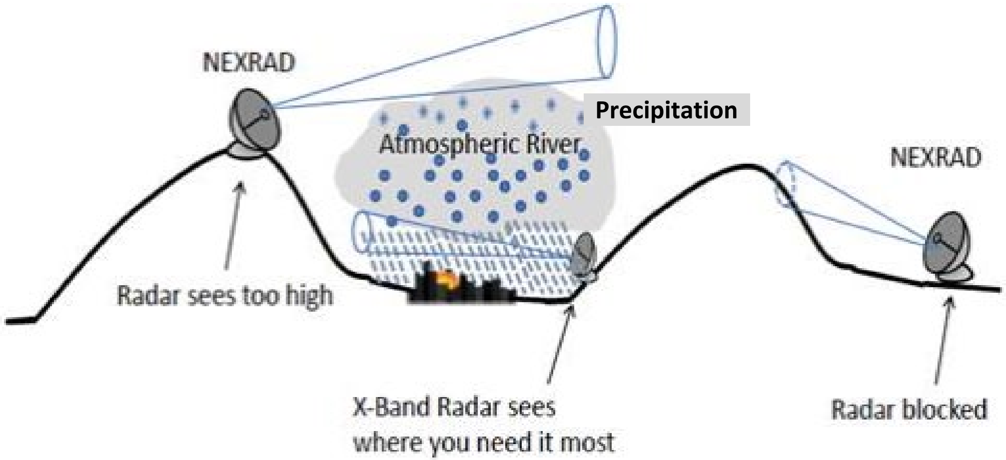
AQPI
Advanced Quantitative Precipitation Information



Why is AQPI Needed?

AQPI is needed for a number of reasons:

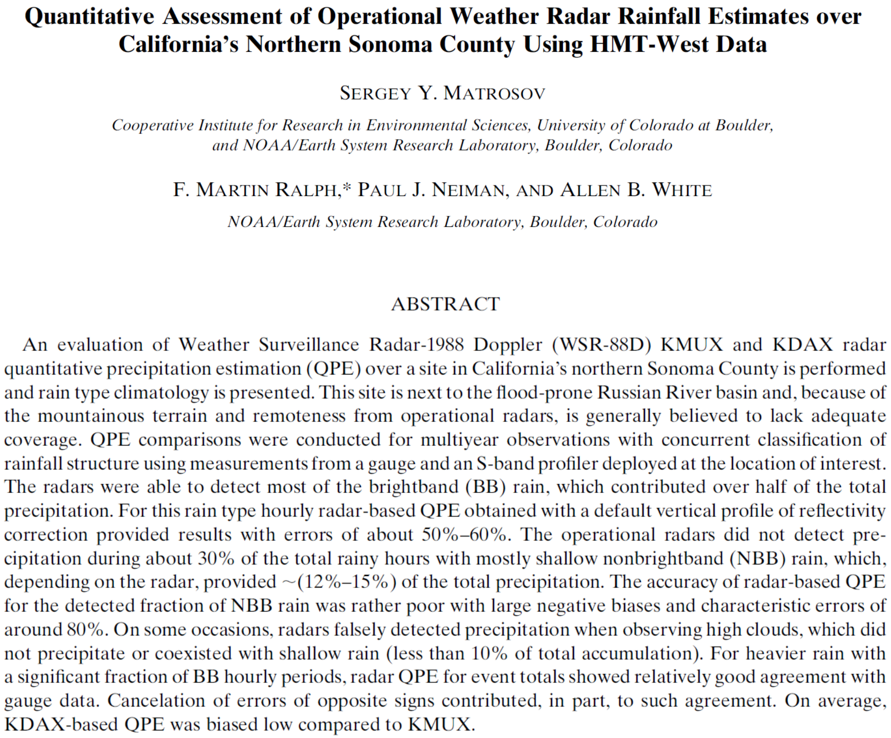
- Radar Beam Blockage and Overshoot: NEXRAD radar can be blocked by terrain, overshoot areas of precipitation, or see precipitation that is not reaching the surface
- Radar Spatial and Temporal Frequency: NEXRAD spatial (x) and temporal (x) frequency are not sufficient for stakeholder operations in a high-density, high-value urban environment
- Weather Forecasting: operational staffing, logistics planning, wastewater and water resource management
- Coastal Concerns: flooding and inundation



Who Needs AQPI?

- Water Agencies
- Municipal Utility Districts
- Wastewater Management
- Emergency Response
- Flood Management
- Public Works Departments

JHM, 2014



Quantitative Assessment of Operational Weather Radar Rainfall Estimates over California's Northern Sonoma County Using HMT-West Data

SERGEY Y. MATROSOV

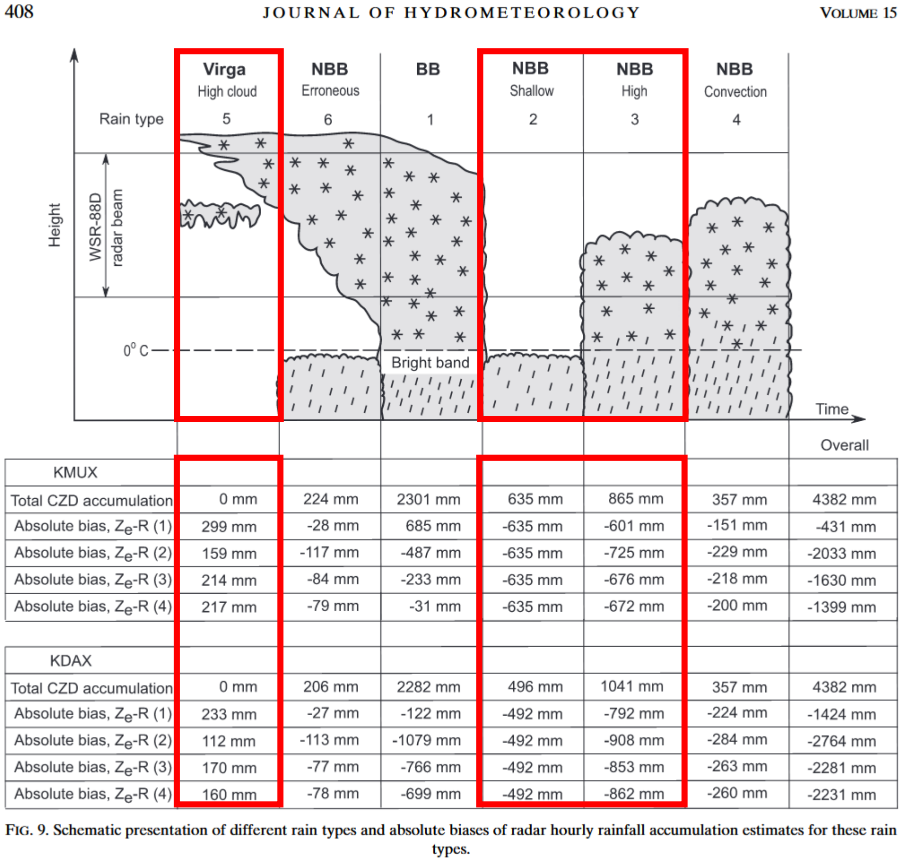
Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder,
and NOAA/Earth System Research Laboratory, Boulder, Colorado

F. MARTIN RALPH,* PAUL J. NEIMAN, AND ALLEN B. WHITE

NOAA/Earth System Research Laboratory, Boulder, Colorado

ABSTRACT

An evaluation of Weather Surveillance Radar-1988 Doppler (WSR-88D) KMUX and KDAX radar quantitative precipitation estimation (QPE) over a site in California's northern Sonoma County is performed and rain type climatology is presented. This site is next to the flood-prone Russian River basin and, because of the mountainous terrain and remoteness from operational radars, is generally believed to lack adequate coverage. QPE comparisons were conducted for multiyear observations with concurrent classification of rainfall structure using measurements from a gauge and an S-band profiler deployed at the location of interest. The radars were able to detect most of the brightband (BB) rain, which contributed over half of the total precipitation. For this rain type hourly radar-based QPE obtained with a default vertical profile of reflectivity correction provided results with errors of about 50%–60%. The operational radars did not detect precipitation during about 30% of the total rainy hours with mostly shallow nonbrightband (NBB) rain, which, depending on the radar, provided ~(12%–15%) of the total precipitation. The accuracy of radar-based QPE for the detected fraction of NBB rain was rather poor with large negative biases and characteristic errors of around 80%. On some occasions, radars falsely detected precipitation when observing high clouds, which did not precipitate or coexisted with shallow rain (less than 10% of total accumulation). For heavier rain with a significant fraction of BB hourly periods, radar QPE for event totals showed relatively good agreement with gauge data. Cancelation of errors of opposite signs contributed, in part, to such agreement. On average, KDAX-based QPE was biased low compared to KMUX.



Rain type	Virga High cloud 5	NBB Erroneous 6	BB 1	NBB Shallow 2	NBB High 3	NBB Convection 4	Overall
KMUX							
Total CZD accumulation	0 mm	224 mm	2301 mm	635 mm	865 mm	357 mm	4382 mm
Absolute bias, Z_e-R (1)	299 mm	-28 mm	685 mm	-635 mm	-601 mm	-151 mm	-431 mm
Absolute bias, Z_e-R (2)	159 mm	-117 mm	-487 mm	-635 mm	-725 mm	-229 mm	-2033 mm
Absolute bias, Z_e-R (3)	214 mm	-84 mm	-233 mm	-635 mm	-676 mm	-218 mm	-1630 mm
Absolute bias, Z_e-R (4)	217 mm	-79 mm	-31 mm	-635 mm	-672 mm	-200 mm	-1399 mm
KDAX							
Total CZD accumulation	0 mm	206 mm	2282 mm	496 mm	1041 mm	357 mm	4382 mm
Absolute bias, Z_e-R (1)	233 mm	-27 mm	-122 mm	-492 mm	-792 mm	-224 mm	-1424 mm
Absolute bias, Z_e-R (2)	112 mm	-113 mm	-1079 mm	-492 mm	-908 mm	-284 mm	-2764 mm
Absolute bias, Z_e-R (3)	170 mm	-77 mm	-766 mm	-492 mm	-853 mm	-263 mm	-2281 mm
Absolute bias, Z_e-R (4)	160 mm	-78 mm	-699 mm	-492 mm	-862 mm	-260 mm	-2231 mm

FIG. 9. Schematic presentation of different rain types and absolute biases of radar hourly rainfall accumulation estimates for these rain types.