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ARM FY2025 Radar Plan

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ARM

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Acronyms and Abbreviations

ACT	Atmospheric data Community Toolkit
ADC	ARM Data Center
AMF	ARM Mobile Facility
AMS	American Meteorological Society
AMT	*Atmospheric Measurement Techniques*
ANL	Argonne National Laboratory
ANX	COMBLE site code
AR	augmented reality
ARM	Atmospheric Radiation Measurement
ARMBE	ARM Best Estimate Value-Added Product
ARSCL	Active Remote Sensing of Clouds Value-Added Product
AWARE	ARM West Antarctic Radiation Experiment
AWR	AWARE site code
BAMS	*Bulletin of the American Meteorological Society*
BNF	Bankhead National Forest
BNL	Brookhaven National Laboratory
CACTI	Cloud, Aerosol, and Complex Terrain Interactions
CAPE-k	Cape kennaook, Tasmania
CAPPI	constant-altitude PPI
CMAC	Corrected Moments in Antenna Coordinates Value-Added Product
COMBLE	Cold-Air Outbreaks in the Marine Boundary Layer Experiment
COR	CACTI site code
CoURAGE	Coast-Urban-Rural Atmospheric Gradient Experiment
CSAPR2	C-band Scanning ARM Precipitation Radar
CSU	Colorado State University
DOE	U.S. Department of Energy
DQ	data quality
DQPR	Data Quality Problem Report
DQR	Data Quality Report
ENA	Eastern North Atlantic
EPC	EPCAPE site code
EPCAPE	Eastern Pacific Cloud Aerosol Precipitation Experiment
FTE	full-time equivalent
FY24	Fiscal Year 2024
FY25	Fiscal Year 2025

GEWEX	Global Energy and Water Exchanges
GIF	Graphics Interchange Format
GISS	Goddard Institute for Space Studies
GPCI	GEWEX/WGNE Pacific Cross-section Intercomparison
GUC	SAIL site code
HOU	TRACER site code
HSRL	high-spectral-resolution lidar
IMB	Infrastructure Management Board
IOP	intensive operational period
KAZR	Ka-band ARM Zenith Radar
KaSACR	Ka-band Scanning ARM Cloud Radar
Ka/WSACR	Ka/W Scanning ARM Cloud Radar
KCG	CAPE-k site code
KDP	specific differential phase
LDR	linear depolarization ratio
LNA	low noise amplifier
MAAS	Multisensor Agile Adaptive Sampling
MAGIC	Marine ARM GPCI Investigation of Clouds
MAR	MARCUS site code
MARCUS	Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean
MICROBASE	Continuous Baseline Microphysical Retrieval Value-Added Product
MOS	MOSAiC site code
MOSAiC	Multidisciplinary Drifting Observatory for the Study of Arctic Climate
MPL	micropulse lidar
MWACR	Marine W-band ARM Cloud Radar
MWR	microwave radiometer
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NEXRAD	Next-Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NSA	North Slope of Alaska
OGRE-CLOUDS	Operational Ground-Based Retrieval Evaluation Framework for Clouds Value-Added Product
OLI	Oliktok Point
OMT	orthomode transducer
PI	principal investigator
PNNL	Pacific Northwest National Laboratory

PPI	plan position indicator
Py-ART	Python ARM Radar Toolkit
PyFLEXTRKR	Python Flexible Object Tracker
QPE	quantitative precipitation estimate
RFI	request for information
RFP	request for proposal
RHI	range height indicator
SAIL	Surface Atmosphere Integrated Field Laboratory
SGP	Southern Great Plains
SNR	signal-to-noise ratio
SPLASH	Study of Precipitation, the Lower Atmosphere and Surface for Hydrometeorology
SQUIRE	Surface Quantitative Precipitation Estimation Value-Added Product
SULI	Science Undergraduate Laboratory Intern
THERMOCLDPHASE	Thermodynamic Cloud Phase Value-Added Product
TRACER	Tracking Aerosol Convection Interactions Experiment
VAP	value-added product
WGNE	Working Group on Numerical Experimentation
XSAPR	X-band Scanning ARM Precipitation Radar
Z	nondimensional unit of radar reflectivity

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1.0 Introduction

The U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) user facility is dedicated to delivering high-quality radar data that significantly advance our understanding of cloud and precipitation processes, improving climate models. With radars operating across diverse frequencies, scanning modes, and global climate conditions, extensive staffing is essential for effective management. Due to current staffing constraints, achieving the expected level of operational excellence requires a more strategic approach. To address this challenge, ARM has developed an operational radar plan for the upcoming Fiscal Year 2025 (FY25) based on budget and staffing considerations.

This report summarizes the Fiscal Year 2024 (FY24) ARM radar-related activities and outlines the strategic plan for FY25. It presents a comprehensive radar plan that includes detailed activities, priorities, and a projected timeline aligned with the ARM radar roadmap. Key tasks, detailed in Table 1, cover various radar operational stages and coordinated efforts among ARM teams.

Table 1. Overview of ARM radar activities.

Task	Description	Who
Radar preparation and installation	Radar hardware calibration and examinations, shipping of instruments, establishment of data ingest workflow, installation process at new sites, and first evaluations of radar data quality.	Engineering, site technician, data teams
Radar maintenance and testing	Bringing the radar(s) back online and monitoring hardware and signal processing performances to ensure smooth operations. Qualitative and quantitative data evaluations.	Engineering, site technician, data teams
Radar operations, data monitoring	Routine mechanical maintenance, troubleshooting and repairs, calibrations, and training of site technicians. Routine monitoring of data collection, ingest, qualitatively stability assessment, troubleshooting and updates, and ARM official data quality initiatives (Data Quality Problem Report [DQPR]/Data Quality Report [DQR]).	Engineering, data teams
Data quality analysis and processing	Following the standard ARM data quality process to provide data bias corrections and uncertainty analysis for b1-level data, as well as generating comprehensive reports.	Data teams
Radar data products	Developing data products to facilitate the use of ARM radar data in atmospheric research and global climate models.	VAP, data analysts, data teams

2.0 Fiscal Year 2024 Summary

During FY24, radar activities included operations, data quality analysis for b-level data, data processing for c-level and value-added product (VAP) data, and data analysis activities. We review each of these activities individually in the following four subsections.

2.1 Radar Operation

During FY24, our efforts focused on radar operations and data production at three main ARM fixed sites and three ARM Mobile Facilities (AMFs). Table 2 summarizes radar operations activities, which generally align with our FY24 plan. Figure 1 illustrates data availability from the anticipated operational radars at these sites. Since there are over 20 tasks listed for FY24, we prioritize them into primary and secondary categories. Primary and secondary ARM radar operations activities, along with their operational notes, are outlined below.

Table 2. The FY24 radar operations plan at the ARM Mobile Facilities (AMF) and three fixed sites.

Site	**AMF1 EPCAPE**	**AMF1 CoURAGE**	**AMF2 CAPE-k**	**AMF3 BNF**	**ENA**	**NSA**	**SGP**
Operation Time	**2023-02 2024-02**	**2024-12 2025-12**	**2024-04 2025-09**	**2024-08 2029-08**	**All year**	**All year**	**All year**
FY24 operations radars	KAZR Ka/W SACR	KAZR preparation	KAZR MWACR	KAZR Ka/X SACR CSAPR2 preparation	KAZR2	KAZR XSAPR (spring/ summer)	KAZR

2.1.1 Primary Tasks

2.1.1.1 Ka-band ARM Zenith Radar (KAZR) Operations at Three Fixed Sites

Staffing: *Wendler, Deng, Schumann, Feng*

The KAZRs at the Eastern North Atlantic (ENA), North Slope of Alaska (NSA), and Southern Great Plains (SGP) sites have operated effectively, continuously collecting data as expected.

2.1.1.2 Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE; site code: EPC)

S*taffing:* *Wendle, Vagner, Rocque, Matthews, Deng, Feng, Schumann, Lindenmaier*

The AMF1 KAZR and Ka/W Scanning ARM Cloud Radar (Ka/W SACR) were deployed in La Jolla, California from February 2023 to February 2024. During FY24, KAZR data collection was nearly continuous. The SACR was stable for most of the period, although data collection was intermittent for a few days due to hardware maintenance. Minor issues with the SACR, such as overlapping time records and initial range changes, were promptly resolved during operations and will be detailed in the b1 report. In addition to marine clouds, active non-meteorological signals have been observed in the KAZR, Ka/W SACR, and National Oceanic and Atmospheric Administration (NOAA) WSR-88D radars. These non-meteorological signals were analyzed and will be addressed during the later b1 processing. Examples of these findings were also presented at the American Meteorological Society (AMS) annual meeting (Rocque et al. 2024, Deng et al. 2024) and shared with principal investigators (PIs).

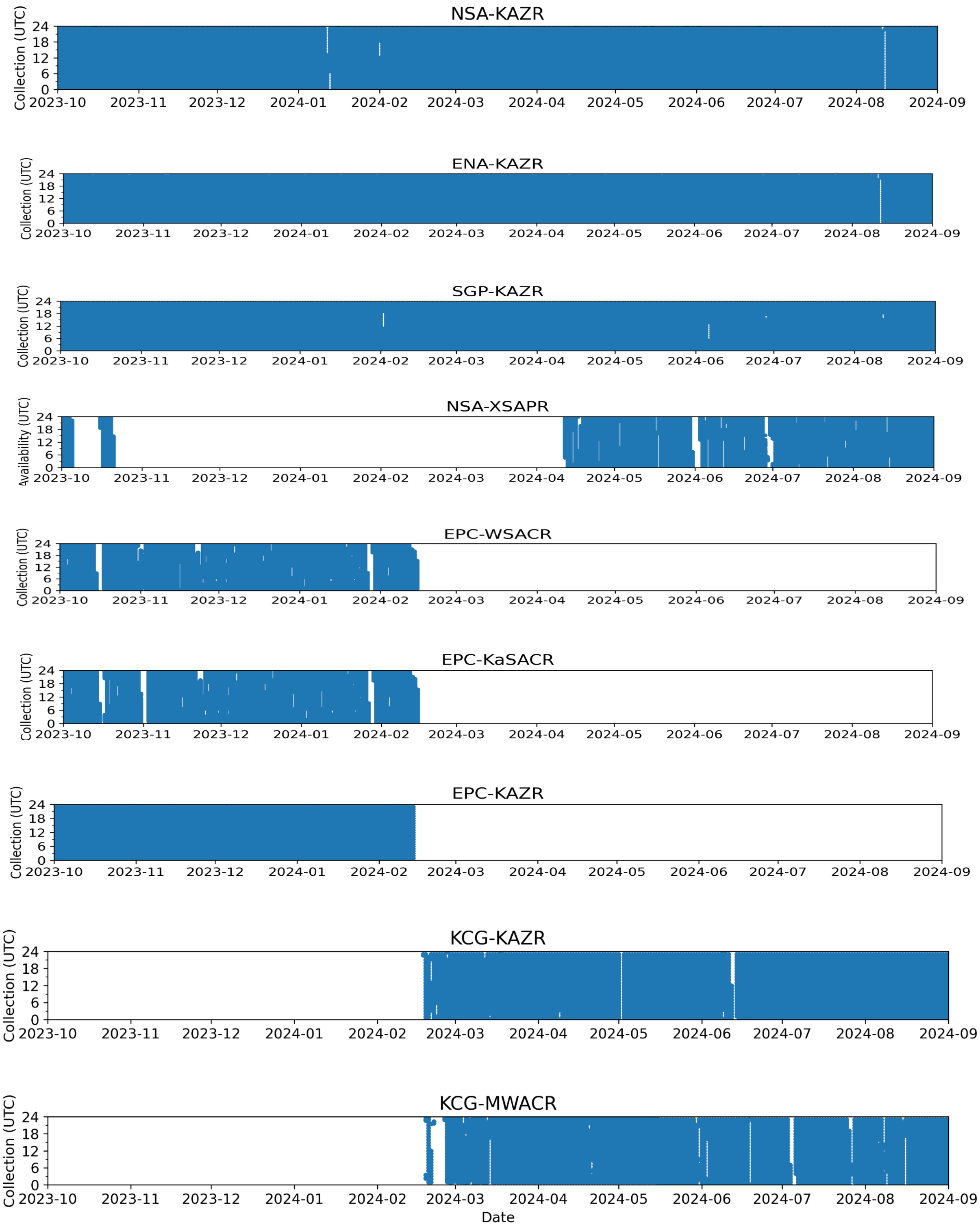

Figure 1. FY24 data availability shown in blue dots for ARM operational radars at fixed sites and AMFs.

2.1.1.3 Cloud and Precipitation Experiment at kennaook (CAPE-k; site code: KCG)

Staffing: Wendler, Lindenmaier, Vagner, Matthews, Deng, Schumann, Feng

The AMF2 KAZR and Marine W-band ARM Cloud Radar (MWACR) were installed at kennaook in Tasmania, Australia from April 2024 to September 2025 to study clouds in the pristine environment over the Southern Ocean. Both radars are operating well. Figure 2 demonstrates this improved reflectivity of MWACR, which shows greater sensitivity to weak clouds for scientific analysis.

Both KAZR and MWACR collect raw spectral data during CAPE-k, but there are some intermittent data gaps for KAZR before July 2024 (Figure 3). For the a-level spectral data in NetCDF format, the current data removed background signals using lower SNR values to keep the data in a compact size. The full spectral data in NetCDF format is available upon user request. We also re-evaluate the SNR thresholds for a-1 level data, particularly for the MWACR, to capture comprehensive cloud information for scientific uses.

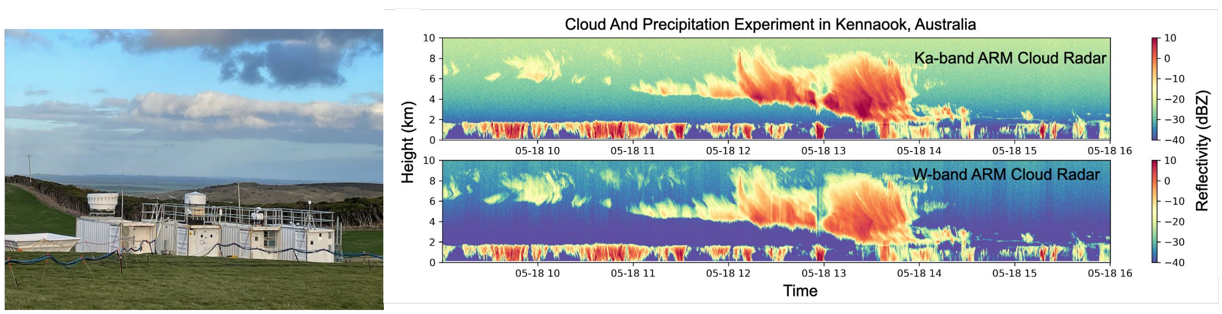

Figure 2. (Left) ARM AMF2 CAPE-k deployment. Photo credit: ARM flicker. (Right) Reflectivity fields from Ka-band GE mode and W-band cloud radars observed during CAPE-k.

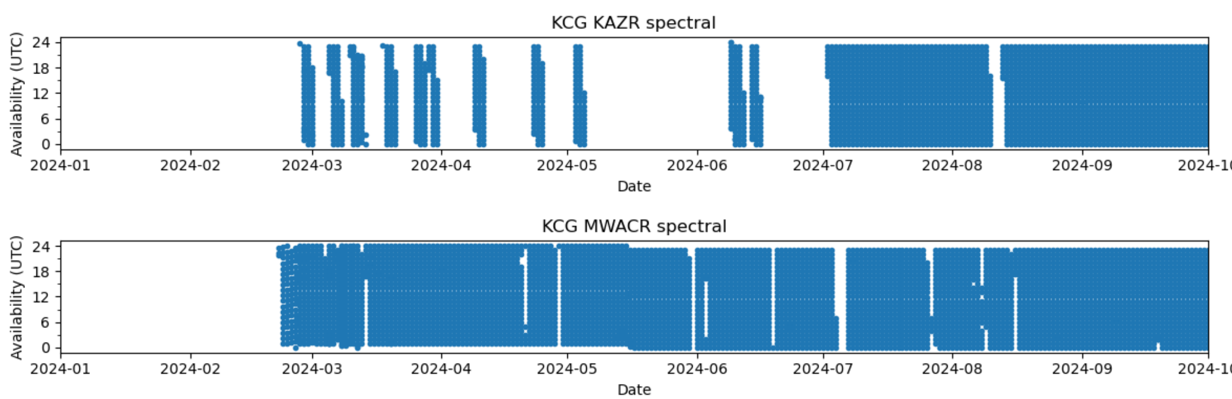

Figure 3. CAPE-k spectral data collection for KAZR and MWACR.

2.1.1.4 AMF3 Southeast U.S. in Bankhead National Forest (BNF)

Staffing: Wendler, Lindenmaier, Vagner, Feng

The AMF3 deployment at Bankhead National Forest in northwestern Alabama, which includes KAZR, X/Ka SACR, and C-band Scanning ARM Precipitation Radar (CSAPR2), is planned for a five-year duration. Currently, KAZR has been installed with initial engineering settings and hardware checks. However, the full installation and operations of AMF3 at Bankhead have been delayed due to unexpected site construction issues. SACR and CSAPR2 are now scheduled for installation in early FY25.

2.1.1.5 Coast-Urban-Rural Atmospheric Gradient Experiment (CoURAGE)

Staffing: Wendler, Lindenmaier, Vagner

The AMF1 KAZR is being prepared for installation in Baltimore, Maryland, to study cloud properties in an urban environment. Preparation testing was successful in August 2024, with installation planned for early FY25.

2.1.2 Secondary Activities

2.1.2.1 North Slope of Alaska (NSA)

Staffing: Lindenmaier, Vagner, Rocque, Feng

The NSA X-band Scanning ARM Precipitation Radar (XSAPR) operated stably and smoothly from mid-April until the end of FY24. Originally planned for spring operation only, the radar's reliability enabled us to extend its use throughout the remainder of FY24, allowing us to monitor data quality and establish routine radar data quality control methods for reflectivity and dual-polarimetric variables.

The NSA Ka/W SACR2 has been returned to Pacific Northwest National Laboratory (PNNL) for maintenance and is scheduled for reinstallation in summer FY25. Upgrades to the NSA SACR2 include replacing the cooling system with new chillers to enhance stability, as chillers are known for their high maintenance needs and are a common source of SACR hardware failures. Additionally, the pedestal motor and amplifiers have been replaced and are currently undergoing testing.

2.1.2.2 Southern Great Plains (SGP)

Staffing: Lindenmaier, Vagner

Due to limited human resources, the planned maintenance of XSAPR I6 and decommissioning of the SACR, and XSAPR I4 and I5 systems, initially scheduled for FY24, will be rescheduled in FY26.

2.2 Radar Data Quality Work

The b-level radar data, generated after post-processing the raw a-level data, provides essential quality control information. We have been developing a systematic data quality processing flow, including bias corrections for reflectivity-related fields, uncertainties analysis, and non-meteorological data masking to support quantitative applications. In addition to the conventional self-consistent radar quality methods, the data quality is examined through intercomparing multiple ARM cloud and precipitation instruments, guest instruments, satellites, and so on. For non-meteorological masking, we have dedicated efforts to establish a mask for KAZRs at AMFs and fixed sites (Figure 4). For the KAZRs at the ARM fixed sites, the radar hardware and data quality are stable, with the primary reflectivity bias falling within a 3-dB uncertainty range when compared to data from nearby cloud and precipitation instruments. This includes addressing common observed biological signals, side-lobes in the MD modes, and ground clutters. The b-level radar data products consist of quality control data and comprehensive reports, with FY24 progress detailed in Table 3.

The b1 data can be accessed and downloaded from ARM Data Discovery. The accompanying b1 report offers a summary of radar deployment, data availability, and an analysis of data quality, including corrections and uncertainties. This report is available on the ARM field experiment webpage. Additionally, insights from this data analysis, along with notable findings, have been presented to stakeholders at various meetings and conferences.

Staffing: Feng, Rocque, Matthews, Deng

Table 3. The progress of b1-level data products in FY24.

Site (site code)	Time periods/location	Radar deployment	b1 data/report progress
Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC, MOS)	Oct 2019-Oct 2020 Ship borne, in the central Arctic Sea ice environment	KAZR, MWACR KaSACR (AMF2)	Released in December 2023. https://www.arm.gov/publications/tech_reports/doe-sc-arm-tr-293.pdf
Tracking Aerosol Convection Interactions Experiment (TRACER, HOU)	Oct 2021-Sep 2022 IOP: June 2022-Sep 2022 Houston area, Texas, USA.	KAZR, Ka/X SACR CSAPR2 (AMF1)	Released in March 2024. https://www.arm.gov/publications/tech_reports/doe-sc-arm-tr-297.pdf
Surface Atmosphere Integrated Field Laboratory (SAIL, GUC)	Sep 2021-June 2023 Crested Butte, Colorado	KAZR (AMF2)	b1 products are expected to be released by the end of FY24.
Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE, EPC)	Feb 2023-Feb 2024 La Jolla, California	KAZR Ka/W SACR (AMF1)	b1 products are expected to be released by the end of FY24.
FY24 ARM fixed sites b1	2022/10-2024/03 ENA, NSA, SGP	KAZR	b1 products are expected to be released by the 2025 spring.
	2024/05-2024/08 NSA	XSAPR	

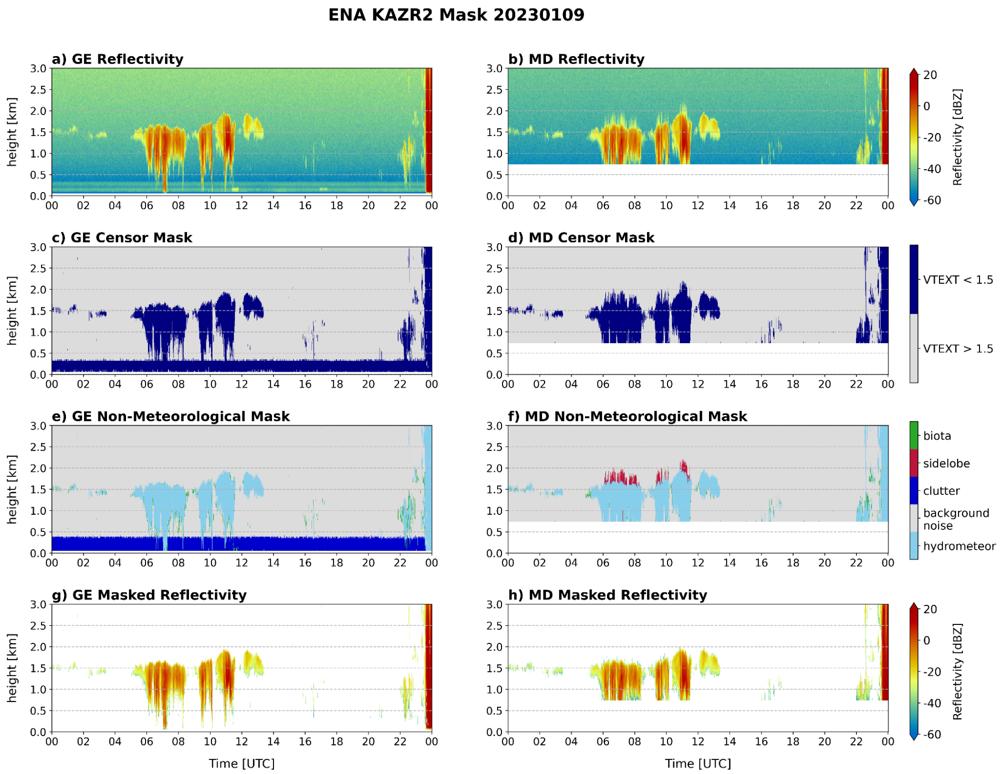

Figure 4. Example of newly developed non-meteorological masks for KAZR GE and MD modes at ENA. Non-meteorological masks include categories of ground clutter, sidelobe, and biota. These masks have been developed for fixed sites and current operational AMFs.

2.3 Radar Translator and Data Product Activities

2.3.1 Cloud VAPs

2.3.1.1 Active Remote Sensing of Clouds (ARSCL)

This VAP is a multisensor system that primarily uses KAZR data for cloud boundaries. ARSCL is a crucial input for several other VAPs, including the ARM Best Estimate (ARMBE) VAP and many others discussed in this report. The development team at Brookhaven National Laboratory (BNL) has ensured that c0 level data (uncalibrated) are available within two to three months after KAZR data collection at each site (e.g., EPC, HOU). For the ongoing campaign at the KCG site, the review of the c0 level data for the first three months of the campaign is complete, and its release is expected in the next few weeks. Additionally, calibrated ARSCL c1 level data for the mobile sites (MOS, HOU) will be released very soon, featuring improved data quality. One of the major achievements in FY24 is the correction of the clutter issue at the EPC site. The data review of the reprocessed c0-level data is in progress, and the data are expected to be released soon. Furthermore, we have completed the IDL-to-Python conversion of the processing codes for the KAZR corrections VAP, with the addition of WCAR corrections, initially coded in MATLAB, currently underway.

2.3.1.2 Continuous Baseline Microphysical Retrieval (MICROBASE)

This VAP provides estimates of liquid/ice water content and liquid/ice effective radius, with associated uncertainties determined through perturbation analysis. This product integrates data from multiple sensors, typically including the microwave radiometer and KAZR. The BNL development team has released the MICROBASE VAP for the HOU and NSA sites and is currently working on the SGP site (for recent months). The next targets are the GUC and EPC sites, pending the availability of ARSCL c1-level data. Moreover, to close out the effort related to the development of the Operational Ground-Based Retrieval Evaluation Framework for Clouds (OGRE-CLOUDS) framework, a manuscript is in progress with the help of the Science Undergraduate Laboratory Intern (SULI) students.

2.3.1.3 Gridded, Calibrated SACR (SACRGRIDPPI/SACRGRIDRHI)

The BNL developer team is currently working on processing the VAP for the HOU site. The VAP for the EPC site will be processed once the radar calibration is complete.

2.3.1.4 Thermodynamic Cloud Phase (THERMOCLDPHASE)

This VAP provides vertically resolved cloud hydrometeor thermodynamic phase classifications. Thermodynamic cloud phase classification is critical to understanding many cloud processes and to retrieve cloud properties. The VAP uses multi-sensor data from KAZR ARSCL, micropulse lidar (MPL) or high-spectral-resolution lidar (HSRL), microwave radiometer (MWR), and radiosondes to determine vertically resolved thermodynamic cloud phases. In FY24, the VAP data are available for most ARM high-latitude sites including Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE; ANX), ARM West Antarctic Radiation Experiment (AWARE; AWR), Cloud, Aerosol, and Complex Terrain Interactions (CACTI;COR), Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean (MARCUS; MAR), (MOSAiC; MOS), NSA, and Oliktok Point (OLI). An effort to use a machine learning method for thermodynamic cloud phase classification has been made, which is being wrapped up for a journal manuscript.

2.3.2 Precipitation VAPs

2.3.2.1 Corrected Moments in Antenna Coordinates (CMAC)

This VAP provides gate IDs for removing non-hydrometeorological echoes, dealiased velocities, calibrated reflectivity, and processed specific differential phase from the b1-level CSAPR2 radar for TRACER and the Colorado State University (CSU) X-band radar for SAIL. For TRACER, the CMAC product from the b1-level data is finished and currently being shipped to the ARM Data Center (ADC). It will be available for public use by the end of FY24. For SAIL, the CMAC product from the CSU X-Band radar is processed and will be available for public use for the entire campaign by the end of FY24.

2.3.2.2 Surface Quantitative Precipitation Estimation (SQUIRE)

Within this VAP, SAIL CMAC precipitation estimates are gridded to a Cartesian grid using nearest neighbor interpolation, with 250-meter grid spacing (horizontal and vertical), with a spatial domain of

20 kilometers (x) x 20 kilometers (y) x 5 kilometers (z), all in units of distance from the radar. The lowest vertical level is calculated, and the data set is subset for this vertical level, with the fields valid at the lowest vertical level for each grid point. Based on feedback from the SAIL science team, SQUIRE was recalculated into daily files and will be available for the winters of 2022 and 2023 by the end of FY24.

2.3.2.3 Extracted Radar Columns and In Situ Sensors (RadCLss)

This VAP provides radar columns that are extracted from individual CMAC processed CSU X-Band radar scans and collocated with in situ observations for various SAIL and Study of Precipitation, the Lower Atmosphere and Surface for Hydrometeorology (SPLASH) instrumented sites using the Python ARM Radar Toolkit (Py-ART) and the Atmospheric data Community Toolkit (ACT). The product has been processed for the winters of 2022 and 2023 and will be available by the end of FY24.

2.3.3 Radar Data Analysis

2.3.3.1 Metadata on Cell Tracking Statistics (Cell ID, Tracks) by Gupta

During TRACER, the CSAPR2 operated in cell tracking mode (June to September 2022). Multiple range height indicator (RHI) and plan position indicator (PPI) scans were conducted to sample individual convective cells every two minutes following the Multisensor Agile Adaptive Sampling (MAAS) framework. The analysis of processed radar variables during a single cloud's life cycle can improve our understanding of dynamic, kinematic, and microphysical processes governing the structure and life cycle of deep convection. However, such analyses require processing of calibrated radar data using convection tracking algorithms. This work compiles the radar scans, creates scan images for visual analysis, shifts the data set from being scan-centric (files/images/animations for different scan bundles) to cell-centric (files/images/animations for different cells). Finally, a widely used, open-source algorithm (tobac) is applied to the cell-centric data set.

a. Metadata from cells targeted for repeated sampling were summarized. Common target cells from consecutive radar scan bundles were linked along a trajectory and the radar data were processed with cell tracking software (tobac) to create estimates of cell lifetime, propagation, and evolution. Metadata were created for cells targeted repeatedly for over 15 minutes.

b. Using the PI data set, constant-altitude PPIs (CAPPIs) were created using Py-ART and cell tracking was conducted on 1-, 2-, and 3-km CAPPI and composite (column-maximum) radar reflectivity values. The cell tracking results were presented at National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS) (New York) to ARM data users and convection tracking community experts.

c. Following the release of b1-level CSAPR2 data from TRACER, cell tracking was conducted on composite reflectivity calculated using bias-corrected reflectivity and separately for the attenuation and bias-corrected reflectivity.

d. Deliverables created during FY24 include an extensive repository of individual PPI (radar coordinates and Cartesian grid) and RHI (radar coordinates) scan images and animations/GIFs from multiple images. Cells targeted over 15 to 20 minutes were identified and data files for such cells were linked and concatenated. PPI/RHI scans were merged to create animations/GIFs from the perspective of individual cells.

Ongoing work will incorporate cell tracking insights from tracking software applied to Next-Generation Weather Radar (NEXRAD) KHGX (Houston radar) level-2 data. For each cell tracked by CSAPR2 for at least 15-20 minutes, the relative portion of cell lifetime sampled by the KHGX radar will be examined. This is a key activity to determine the utility of using the MAAS framework while operating CSAPR2. A report or manuscript outlining the tracking procedures and the data set is under preparation.

2.3.3.2 KAZR Stability by Silber

In tandem with the analysis of KAZR pulse compression stability performed in FY23, the data analyst team examined the time-height stability of KAZR's SNR and reflectivity factor independently, using advanced processing and filtering techniques. This proof-of-concept analysis of the NSA KAZR is shown in Figure 5. The right panel shows a persistent 2 dB increase in radar sensitivity in early 2014 and a general signal degradation starting in late 2021. Annual mean profiles (right panel) do not exhibit height-dependent sensitivity artifacts, while the radar sensitivity generally follows the results of the time series plot. We note that the independent SNR analysis (not shown) agreed with the pulse compression stability analysis performed in FY2023. This promising proof-of-concept method might be implemented and applied to other sites in future ARM efforts.

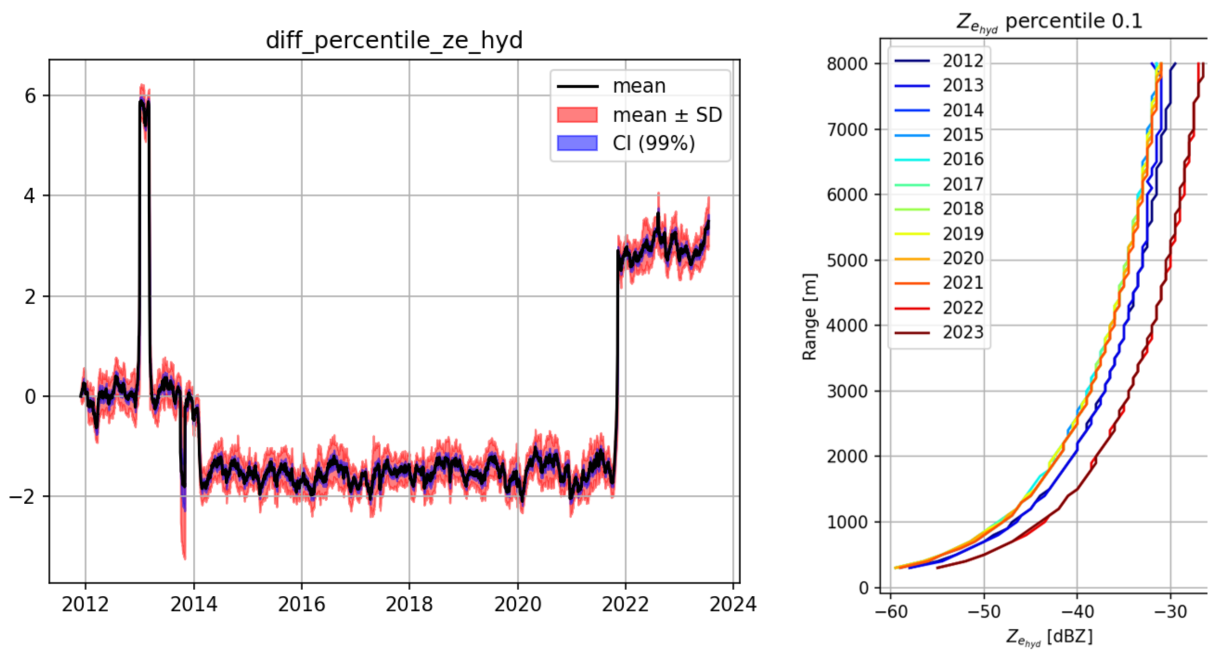

Figure 5. (Left) NSA KAZR long-term Ze signal offset (dB) depicted here using 0.1 percentile of post-processed hydrometeor signal. (Right) annual mean profiles of the 0.1 percentile hydrometeor signal.

2.3.3.3 ARM Data Epoch by Tian

In FY24, the data analyst team developed data epochs (https://adc.arm.gov/discovery/#/guidedsearch) at the ENA site, focusing on marine boundary-layer clouds with open and closed cell mesoscale organizations. We manually detected cases from ARM KAZR and employed a deep learning tool for automatic detection.

2.3.4 Automatic Data Quality Monitoring System

To evaluate the ARM radar data network more effectively, we developed targeted data metrics and hardware parameters to assess real-time data stability and quality. We categorized data evaluations into two types: ‘straightforward data issues,’ which can be automatically detected and flagged for engineers action, and ‘potential warnings,’ which require further analysis by the data team to follow up with actions. For straightforward data issues, we collaborated with the DQ office to detect these hardware issues, such as detecting unexpected transmitter sudden drops, and to adjust variable value ranges for scientific applications using DQ-Plotbrowser. For potential warnings, we adapted methods to account for the unique geographic characteristics and availability of cloud and precipitation instruments at specific sites.

2.3.5 Deployable CSAPR Procurement

A new CSAPR2 radar will be purchased for ARM to provide a deployable precipitation measurement capability. The procurement process began in late FY22, with draft specifications, and a request for information (RFI) was submitted in FY23 to determine whether the market could provide the radar as specified. In FY24, the request for proposal (RFP) was submitted, and proposals from two offerors were evaluated. The purchase order to procure the C-band radar is expected to be awarded by the end of the fiscal year.

3.0 Fiscal Year 2025 Priorities

3.1 Radar Operation and Data Quality Plan

The radar plan for FY25 outlines a comprehensive strategy aligned with the radar roadmap, including key activities, priorities, and a projected timeline. The plan includes radar operations and installation, real-time data monitoring, b-level quality-control data processing and analysis, and radar maintenance. Coordination of these activities will be managed by both engineering and data teams to ensure smooth operations and high data quality throughout all stages of deployment.

Table 4 outlines the proposed primary radar operational plan for FY25, considering scientific needs, budget constraints, and staffing resources as recommended by the ARM Infrastructure Management Board (IMB). Figure 4 shows a Gantt chart detailing these planned activities. Table 5 provides a detailed distribution of the workload, including staffing, priorities, and planned full-time equivalents (FTEs). The estimated total FTEs required are 6.75, with three FTEs allocated to the radar engineering team and 3.75 FTEs allocated to the data team. Additionally, site technicians play a crucial role in supporting the radar engineering team. Their combined FTEs are approximately 0.75, and these FTEs are listed under site management and are not included in this table. The primary task FTEs for the engineering and radar teams are 2.9 and 3.63, respectively. Available FTEs will be allocated to secondary tasks as determined by ARM management.

In FY25, our primary focus will be on operating three AMFs for nearly the entire year. This includes CAPE-k, which will continue its operation from FY24, along with two new AMF deployments for

CoURAGE and BNF. These new deployments will require additional resources and testing hours for radar operations, scanning strategy tests, data ingest, and data quality evaluations. These working efforts are listed as the tasks of preparation and installation.

b-level data quality-control work is anticipated to be completed within three to six months, contingent on whether any adjustments or new methodologies are necessary. For newly installed sites, the development of data products may extend due to logistical considerations and the need to integrate data from additional instruments. With the development of data quality procedures and routine radar monitoring, several consistent, reliable procedures have been established and applied that frequently appear in b1 reports. In FY25, we will summarize and document the established standard procedures. Future b1 reports will then reference this document and focus on final data quality results, radar deployment, newly developed methods for geographical or site adjustments, and any notable or unusual analyses that require further attention.

Staffing details:

- Engineering staffing: Iosif Lindenmaier, Timothy Wendler, Vagner Castro, Julia Flaherty
- Data staffing: Ya-Chien Feng, Marqi Rocque, Alyssa Matthews, Min Deng, Eddie Schuman
- Site technicians staffing: Todd Houchens (NSA, AMFs), Brandon Androes (SGP, AMFs), Peter Argay (ENA, AMFs), David Breedlove (SGP)

Table 4. List of operational and maintenance radars during FY25. AMFs were deployed in CoURAGE, CAPE-k, and BNF. Three fixed sites encompassed ENA, NSA, and SGP.

Site	AMF1 CoURAGE	AMF2 CAPE-k	AMF3 BNF	ENA	NSA	SGP
Time	**2024/12 2025/11**	**2024/04 2025/09**	**2024/10 2029/9**	**All year**	**All year**	**All year**
FY25 primary operations	KAZR	KAZR	KAZR	KAZR	KAZR	KAZR
		MWACR	Ka/XSACR	XSAPR2 reinstall	Ka/W SACR2 reinstall	
			CSAPR2			

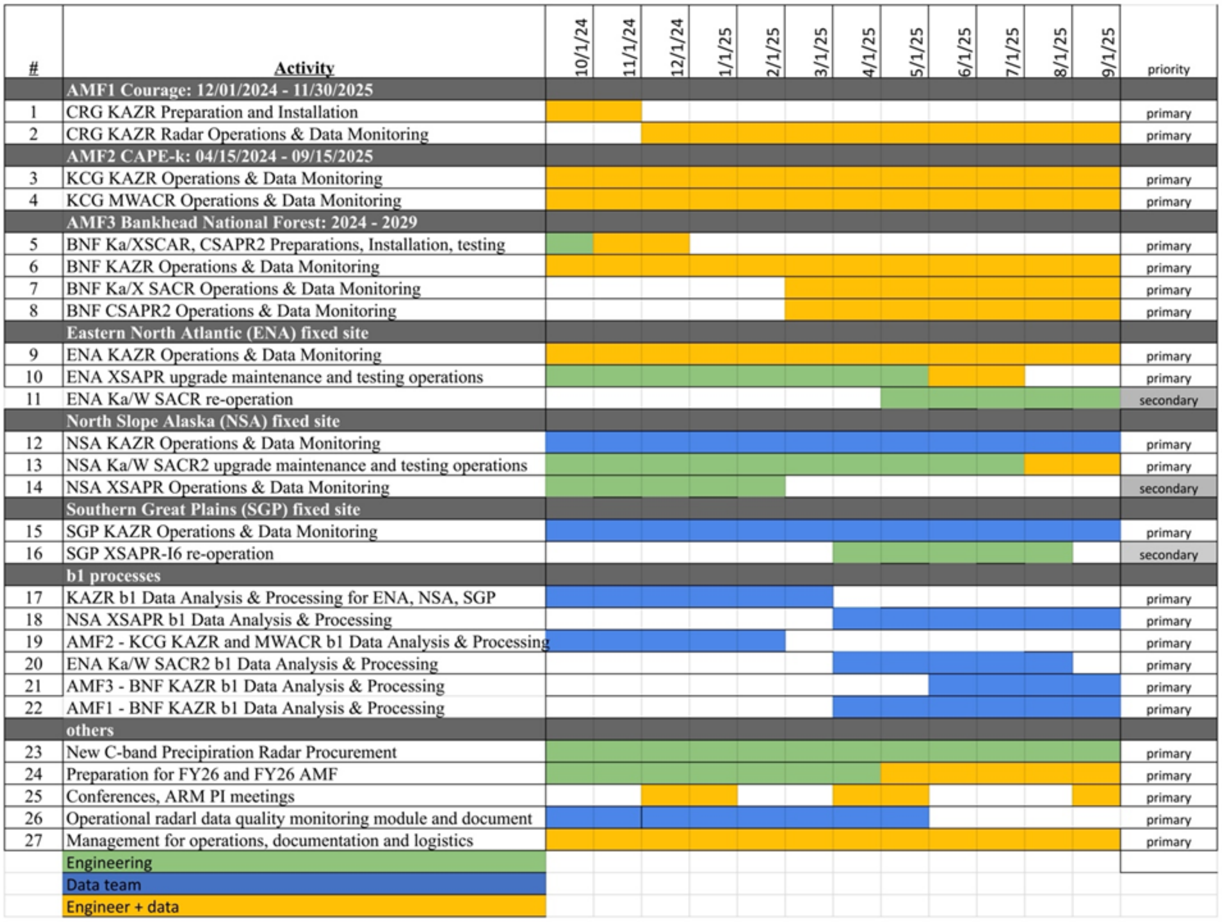

Figure 6. The FY25 Gantt Chart. The color-coded bars represent the following activities: Yellow bar: both engineering and data teams work for preparation and operational period, blue bar: data processing, green bar: engineering maintenance works.

Table 5. List of activities planned for FY25 radar engineering and data team.

#	Activity	Start date	End date	Staffing	Priority	Planned FTE (Engineering/ Data)	
AMF1 CoURAGE (Site: CRG) Coast-Urban-Rural Atmospheric Gradient Experiment (1 December, 2024-30 November, 2025)							
1	CRG KAZR preparation and installation	10/01/2024	11/30/2024	Wendler, Castro, Deng, Schuman	primary	0.1	0.02
2	CRG KAZR radar operations & data monitoring	12/01/2024	12/01/2025	Wendler, Deng, Schuman	primary	0.1	0.08
AMF2 CAPE-k (site: KCG) Cloud and Precipitation Experiment at kennaook (15 April, 2024-15 September, 2025)							
3	KCG KAZR operations & data monitoring	04/15/2024	09/15/2025	Wendler, Deng, Schuman	primary	0.1	0.08
4	KCG MWACR operations & data monitoring	03/01/2025	07/31/2025	Wendler, Matthews, Schuman	primary	0.1	0.08
AMF3 BNF (site: BNF) Bankhead National Forest (2024-2029)							
5	BNF Ka/XSCAR, CSAPR2 preparations, installation, testing	10/1/2024	12/31/2024	Lindenmaier, Wendler, Castro, Rocque, Matthews, Deng, Feng, Schuman	primary	0.3	0.11
6	BNF KAZR operations & data monitoring	10/1/2024	9/30/2025	Wendler, Deng. Schuman	primary	0.1	0.1
7	BNF Ka/X SACR operations & data monitoring	6/1/2025	9/30/2025	Wendler, Matthews, Schuman	primary	0.2	0.16
8	BNF CSAPR2 operations & data monitoring	3/1/2025	9/30/2025	Lindenmaier, Rocque, Schuman	primary	0.12	0.13
Eastern North Atlantic (ENA)							
9	ENA KAZR operations & data monitoring	10/1/2024	9/30/2025	Wendler, Rocque, Schuman	primary	0.1	0.08
10	ENA XSAPR upgrade, maintenance, testing operation	10/1/2024	5/31/2025	Lindenmaier, Castro, Rocque, Schuman	primary	0.35	0.08
11	ENA Ka/W SACR re-operation	6/1/2025	7/31/2025	Wendler, Matthews, Schuman, Feng	secondary	0.15	0.12

#	Activity	Start date	End date	Staffing	Priority	Planned FTE (Engineering/ Data)	
North Slope of Alaska (NSA)							
12	NSA KAZR operations & data monitoring	10/1/2024	9/30/2025	Wendler, Matthews, Schuman, Feng	primary	0.1	0.08
13	NSA Ka/W SACR2 upgrade, maintenance, testing operation	10/1/2024	5/31/2025	Lindenmaier, Castro, Matthews, Schuman	primary	0.4	0.12
14	NSA XSAPR operation	10/1/2024	3/31/2025	Lindenmaier, Castro, Rocque	secondary	0.1	0.1
Southern Great Plains (SGP)							
15	SGP KAZR operations & data monitoring	10/1/2024	9/30/2025	Wendler, Rocque, Schuman	primary	0.1	0.08
16	SGP XSAPR-I6 upgrade, maintenance, testing operation	4/1/2025	8/31/2025	Lindenmaier, Vagner, Rocque, Schuman	secondary	0.1	0.1
b1 Process							
17	KAZR b1 data analysis & processing for fixed sites	10/1/2024	3/31/2025	Rocque, Feng, Matthews, Schuman	primary	0	0.45
18	NSA XSAPR b1 data analysis & processing	5/1/2024	8/31/2025	Rocque, Feng, Schumann	primary	0	0.35
19	AMF2 - KCG KAZR and MWACR b1 data analysis & processing	10/1/2025	2/28/2025	Matthews, Deng, Feng, Schuman	primary	0	0.3
20	ENA Ka/W SACR2 b1 data analysis & processing	4/1/2025	8/31/2025	Matthews, Feng, Schuman	primary	0	0.35
21	AMF1 - KAZR b1 data analysis & preliminary processing	4/1/2025	9/30/2025	Deng, Schuman, Feng	primary	0	0.1
22	AMF3 -BNF b1 data analysis & preliminary processing	7/1/2025	9/30/2025	Feng, Deng, Matthews, Rocque, Schuman	Primary	0	0.6
Others							
23	New C-band precipitation radar procurement	10/1/2024	9/30/2025	Flaherty	primary	0.1	0
24	Preparation for FY26 and FY 26 AMF	10/1/2024	9/30/2025	Lindenmaier, Castro, Feng	primary	0.2	0.1
25	Conferences, ARM PI meetings	10/1/2024	9/30/2025	Engineering and data staffing	primary	0.2	0.26
26	Radar operational monitoring matrix and data quality document	10/1/2024	5/31/2025	Feng, Matthews, Rocque, Deng	secondary	0	0.45
27	Management for operations, documentation, and logistics	10/1/2024	9/30/2025	Lindenmaier, Feng	primary	0.1	0.1
	Total FTE for primary tasks					2.9	3.63

3.1.1 AMF1 CoURAGE

Task #: 1, 2, 21 10/1/2024 – 1/31/2025 *Primary task FTE: 0.3*

Staffing: Lindenmaier, Wendler, Castro, Deng, Schuman, Feng

A KAZR will be set up in Baltimore, Maryland, to examine the difference of cloud characteristics between urban and rural areas during CoURAGE. The initial two months of FY25 will focus on radar hardware preparations, installation, operation testing, and preliminary data quality assessments. The field experiment is scheduled to begin in December 2024, with the b1 data quality process commencing at the start of FY26.

3.1.2 AMF2 CAPE-k

Task #: 3,4,19 10/1/2024 – 9/15/2025 *Primary task FTE: 0.66*

Staffing: Lindenmaier, Wendler, Matthews, Deng, Schuman, Feng

The AMF-2 KAZR and MWACR have been operating in Tasmania, Australia, since February 2024. In FY25, the focus will be monitoring real-time data collection and initiating the first-year b1 data quality efforts, which include developing methodologies to assess reflectivity biases and uncertainties for both KAZR and MWACR. This b1 work will also involve MWACR masks developing and revisiting spectral data masks to balance operational data storage limits with the detailed scientific requirements for sensitivity analyses.

3.1.3 AMF3 BNF

Task #: 5-8, 22 10/1/2024 – 9/30/2025 *Primary task FTE: 1.82*

Staffing: Lindenmaier, Wendler, Castro, Rocque, Matthews, Deng, Schuman, Feng

The AMF3 is scheduled for a five-year deployment in the Bankhead National Forest (BNF) in Northern Alabama. In FY24, the operations team has been preparing for radar site installations, which have faced delays due to construction and logistics. The KAZR has been installed but currently has hardware issues that require replacements. In FY25, the installation of Ka/X SACR and CSAPR2 is planned for the beginning of the fiscal year. After installation, a data testing period will assess preliminary data quality and ingestion. The KAZR will operate continuously, while scanning radars, SACR and SAPR, will focus on convection during the tree growth seasons from March to September as the PIs suggest.

In the b-level quality-control data plan, we aim to initiate the b1 processes at the end of FY25. Due to limited FTEs, this task is categorized as a secondary priority for FY25 but will become the primary focus in FY26.

3.1.4 ENA

Task #: 9-11,17, 20 10/1/2024 – 9/30/2025 *Primary task FTE: 1.21*

Staffing: Wendler, Castro, Lindenmaier, Feng, Matthews, Rocque, Schuman

The ENA observatory, located on Graciosa Island in the Azores archipelago, is dedicated to the long-term investigation of marine stratocumulus clouds and their interactions with aerosols and precipitation. In FY25, operations will continue with the KAZR all year and include the reinstallation of the XSAPR during spring and summer, which previously experienced transmitter issues encountered in 2019.

In the b-level quality-controlled data plan, we aim to establish routine KAZR data processes that ensure long-term stability, Z bias correction, and non-meteorological masks for climatology studies across all three fixed sites. During FY25, our focus will be on applying these methods and analyzing the KAZR data from 2022 to 2024. Furthermore, to enhance radar data coverage, we also aim to work on establishing the routine processing of the ENA Ka/W SACR2 data and produce collected data over a six-month period in FY23.

3.1.5 NSA

Task #: 12-14, 17, 18   10/1/2024 – 9/30/2025   Primary task FTE: 1.8

Staffing: Wendler, Castro, Lindenmaier, Rocque, Feng, Matthews, Schuman

The NSA observatory collects long-term data on clouds and precipitation to study high-latitude cloud and radiation processes in the changing Arctic. In FY25, the operation plan includes year-round KAZR operations, eight-months of XSAPR operations, and maintenance of the NSA Ka/W SACR2 in preparation for its reinstallation in FY26.

In FY25, the b-level quality-controlled data plan aims to establish routine KAZR and XSAPR data processes. We will focus on establishing data quality processes for the ice-phased clouds and precipitation.

3.1.6 SGP

Task #: 15,16,17   10/1/2024 – 9/30/2025   Primary task FTE: 0.33

Staffing:Wendler, Castro, Feng, Rocque, Schuman

In FY25, we will focus on the SPG KAZR operations and b1 data processing. The XSAPR operation at I6 will be the secondary tasks. The other XSAPR and SACR retirements will be deferred to FY26 due to limited FTE availability.

3.1.7 Radar Logistics and Management

Task #: 23-27   10/1/2024 – 9/30/2025

Some logistics and management tasks include procuring the new C-band precipitation radar, preparing for the upcoming fiscal year and AMF deployment, and participating in conferences.

In addition, we will focus on establishing the ARM radar data operational monitoring matrix for records and communications. This work also includes documenting the ARM radar network monitoring, data quality activities for longer-term ARM data, communicating recent developments to users to better understand longer-term ARM radar data ,and systematic work.

3.2 Radar Translator and Data Product Activities

3.2.1 Cloud VAP

Staffing: Die Wang, Meng Wang, Karen Johnson, Aifang Zhou, Lynn Ma, Damao Zhang

3.2.1.1 ARSCL

In FY25, the goal is to ensure that c0-level data are available within two to three months after KAZR data collection at each site (including new campaigns, BNF, and fixed sites). We will prioritize the release of the data for the BNF site. Additionally, calibrated ARSCL c1-level data will be processed for all past campaigns (e.g., EPC, GUC) and upcoming ones. The conversion of WCAR MATLAB codes into Python will be prioritized, with the goal of releasing the Python version of the entire ARSCL processing codes. These efforts will be summarized in a manuscript to the *Bulletin of the American Meteorological Society* (*BAMS*). New activities will also include providing ground-based validation for EarthCare overpasses at the ARM fixed sites.

3.2.1.2 MICROBASE

This VAP requires inputs from several other VAPs, such as microwave radiometer and KAZR. Its release for the GUC and SGP sites is expected to be completed in FY25, with the possibility of releasing data for EPC, KCG, and BNF if all inputs are available. In any case, we will prioritize the release of the data for the BNF site. The manuscript about the OGRE-CLOUDS framework is expected to be submitted to *Atmospheric Measurement Techniques* (*AMT*).

3.2.1.3 SACRGRID

The data will be released for the HOU and EPC sites. For new deployments, this VAP will be processed for BNF and other SACR locations.

3.2.1.4 THERMOCLDPHASE

The VAP will do end-to-end reprocessing for all the THERMOCLDPHASE-available sites, including ANS, AWR, COR, MAR, MOS, NSA, and OLI, using the newly developed non-meteorological masks for KAZR GE and MD modes, depending on the availability of the non-meteorological masks data. The VAP will also be processed for the BNF and KCG sites once ARSCL is available for these two sites.

3.2.2 Precipitation VAP

Staffing: Scott Collis, Robert Jackson, Zach Sherman, Joe O'Brien, Max Grover, Bhupendra Raut

During FY25 the planned activities are: CMAC and quantitative precipitation estimate (QPE; SQUIRE) for C-SAPR at BNF and CMAC and RadCLss for the NSA XSAPR. Activities involving BNF are predicated on the radar data being available, so until the data are available, work on the NSA data will proceed. When data is available, the BNF site product development will have the priority.

3.2.2.1 CMAC (BNF)

The output products of CMAC and the b1-level CSAPR2 ingest are similar in scope, outside of phase processing and dealiasing. However, processed phase and dealiased velocities are corrections to raw data products, which belong in the b-level data product space, but are currently a c1-level product. To streamline radar data processing, Argonne National Laboratory (ANL) will work with the radar data team to incorporate the phase processing and dealiasing code in CMAC into the CSAPR2 b1-level ingest.

3.2.2.2 SQUIRE (BNF)

ANL will develop a gridded quantitative precipitation estimate product for BNF from CSAPR2. We will use the coefficients developed pre-deployment to develop estimates of rainfall rate based on R-(nondimensional unit of radar reflectivity [Z], specific differential phase [KDP], augmented reality [AR], etc.) relationships from the CSAPR2. We will evaluate the radar estimated hourly rainfall accumulations from the different estimates against those from the ARM rain gauges and disdrometers at BNF.

3.2.2.3 CMAC on XSAPR (NSA)

With the start-up of operations of the XSAPR at NSA, science-ready products are needed to promote the radar and greater NSA science efforts. To meet this end, CMAC will run on XSAPR b1-level products to create science-ready c1-level products that will address the unique challenges of NSA, such as radar clutter due to varying degree of sea ice coverage and varying precipitation phase as operations bridge the northern Alaskan spring/summer. This CMAC product will contain clutter ID and tagging to address sea ice coverage, determination of gate-ID for hydrometeor classification, and dealiasing velocities for summer precipitation events.

3.2.2.4 RadCLss (NSA)

With the science-ready c1-level CMAC product, radar observations will be co-located with in situ ground sensors to provide a data set to identify surface precipitation state. Rainfall rate retrievals will be applied to rain gates identified within the CMAC products. Emphasis will be placed on determining locations of rainfall with respect to the NSA snowpack. We will focus on site E12 and the central facility. We will work closely with the mentors of new in situ microphysical and snowpack sensors to improve RadCLss to include a suite of measurements empowering the retrievals community.

3.3 Radar Data Analysis

Staffing: Israel Silber, Jingjing Tian, and Sid Gupta

3.3.1 Data Epochs on Mesoscale Cellular Organizations

In FY25, the data analyst team plans to continue developing data epochs on mesoscale cellular organizations, extending our focus to other ARM field campaigns over the ocean, such as MARCUS and Marine ARM GPCI Investigation of Clouds (MAGIC).

3.3.2 Cell Tracking

Cell tracking efforts will be expanded to other sites similar to the TRACER cell tracking efforts and tracking efforts for the CACTI campaign (conducted by colleagues at PNNL using Python Flexible Object Tracker [PyFLEXTRKR]). Once the BNF CSAPR is operational and data is available, the tracking efforts will be prioritized for BNF. In the meantime, if delays occur, the efforts will focus on the SGP. Metadata similar to the TRACER data set will be provided along with scan images and animations/GIFs for visual interpretation of the radar data.

3.3.3 Sub-Cloud Ice Precipitation Retrievals

Sub-cloud ice precipitation retrievals combining KAZR and other ARM passive and active remote-sensing instruments powered by ML methods will be developed as well.

3.3.4 KAZR Spectra

Finally, the analyst team will start working on the decomposition of KAZR spectra to automate the identification and characterization of hydrometeor populations and, ultimately, integrate the final decomposed spectral product in ARM ingest to leverage KAZR capabilities that hitherto were not used to their fullest potential (e.g., vertical air motion retrievals, advanced artifact removal with minimal loss of hydrometeor information in “contaminated” range gates, and more).

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