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Translator Plan: A Coordinated Vision for Fiscal Years 2023-2025

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September 2022

ARM

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Acronyms and Abbreviations

2D	two-dimensional
3D	three-dimensional
4D	four-dimensional
ACE-ENA	Aerosol and Cloud Experiments in the Eastern North Atlantic
ACI	aerosol-cloud interactions
ACSM	aerosol chemical speciation monitor
ACSMCDCE	ACSM, corrected for Composition-Dependent Collection Efficiency
ADC	ARM Data Center
ADI	ARM Data Integrator
AERI	atmospheric emitted radiance interferometer
AERINF	AERI Noise Filtered
AERIoe	Atmospheric Emitted Radiance Interferometer Optima Estimation
AMF	ARM Mobile Facility
AMS	American Meteorological Society
AMSG	Aerosol Measurement Science Group
AOD	Aerosol Optical Depth
AOD-BE	Aerosol Optical Depth- Best Estimate
AOD-MFRSR	Aerosol Optical Depth (AOD) Derived from MFRSR Measurements
AOP	Aerosol Optical Properties
AOS	Aerosol Observing System
APS	aerodynamic particle sizer
ARM	Atmospheric Radiation Measurement
ARMBE	ARM Best Estimate
ARMBE2DGRID	ARM Best Estimate 2D Gridded Surface Data Set
ARMBESTNS	ARM Best Estimate Station-based Surface Products
ARM-DIAGS	ARM Data-Oriented Metrics and Diagnostic Package
ARSCL	Active Remote Sensing of Clouds
ASR	Atmospheric System Research
AWARE	ARM West Antarctic Radiation Experiment
CACTI	Cloud, Aerosol, and Complex Terrain Interactions
CAUSES	Clouds Above the United States and Errors at the Surface
CCN	cloud condensation nuclei or cloud condensation nuclei particle counter
CCNSMPSKAPPA	CCN Counter and SMPS-Derived Hygroscopicity Parameter Kappa
CE	collection efficiency
CESM	Community Earth System Model
CFAD	contoured frequency by altitude diagram
CFMIP	Cloud Feedback Model Intercomparison Project
CLDFRAC	Cloud Fraction
CLDPHASE	Cloud Phase
CMAC	Corrected Moments in Antenna Coordinates
CMDV	Climate Modeling Development & Evaluation
CMIP	Coupled Model Intercomparison Project
COMBLE	Cold-Air Outbreaks in the Marine Boundary Layer Experiment
COSP	CFMIP Observation Simulator Package

CPMSG	Cloud and Precipitation Measurement Science Group
CSU	Colorado State University
CWV	column water vapor
DOE	U.S. Department of Energy
DQ	data quality
DQO	Data Quality Office
DQR	Data Quality Report
E3SM	Energy Exascale Earth System Model
EBBR	energy balance Bowen ratio station
ECOR	eddy correlation flux measurement system
ENA	Eastern North Atlantic
EPCAPE	Eastern Pacific Cloud Aerosol Precipitation Experiment
FY	fiscal year
G-1	Gulfstream-1
GASS	Global Atmospheric System Studies
GDAP	Global Data and Analysis Panel
GEWEX	Global Energy and Water Exchanges
HSRL	high-spectral-resolution lidar
IDL	Interactive Data Language
INTERPSONDE	Interpolated Sonde
IOP	intensive operational period
KAZR	Ka-band ARM Zenith Radar
LASSO	Large-Eddy Simulation (LES) ARM Symbiotic Simulation and Observation
LASSO-O	LASSO-Operations
LDQUANTS	Laser Disdrometer Quantities
LES	large-eddy simulation
LWP	liquid water path
MARCUS	Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean
MBL	marine boundary layer
MC3E	Mid-latitude Continental Convective Clouds Experiment
MFRSR	multifilter rotating shadowband radiometer
MICROBASE	Continuous Baseline Microphysical Retrieval
MICROBASEKAPLUS	Improved MICROBASE product with Uncertainties
ML	machine learning
MOSAiC	Multidisciplinary Drifting Observatory for the Study of Arctic Change
MPL	micropulse lidar
MPLCMASK	Cloud Mask from Micropulse Lidar
MPLCMASKML	Micropulse Lidar Cloud Mask Machine Learning
MWR	microwave radiometer
MWR3C	Microwave radiometer, 3 channel
MWRRET	MWR Retrievals
MWRRETv2	MWR Retrievals with MWRRET Version 2
NASA	National Aeronautics and Space Administration
NDROP	Droplet Number Concentration
NSA	North Slope of Alaska
PBL	planetary boundary layer
PBLHT	planetary boundary-layer height
PBLHT-MPL	Planetary Boundary-Layer Height-Micropulse Lidar

PBLHT-SONDE	Planetary Boundary-Layer Height-Balloon-Borne Sounding System
PDF	probability density function
PI	principal investigator
PNNL	Pacific Northwest National Laboratory
POC	point of contact
PSAP	particle soot absorption photometer
Py-ART	Python ARM Radar Toolkit
PyDSD	PyDisdrometer
QA	quality assurance
QC	quality control
QCRAD	Data Quality Assessment for ARM Radiation Data
RHI	range height indicator
SACR	Scanning ARM Cloud Radar
SACRGRIDRHI	SACR Grid Range Height Indicator
SACRGRIDPPI	SACR Grid Plan Position Indicator
SAIL	Surface Atmosphere Integrated Field Laboratory
SGP	Southern Great Plains
SMPS	scanning mobility particle sizer
SPHOTCOD	Sun Photometer Cloud Optical Depth
SWE	Snow Water Equivalent
TRACER	TRacking Aerosol Convection interactions ExpeRiment
TWP	Tropical Western Pacific
UEC	User Executive Committee
UHSAS	ultra-high-sensitivity aerosol spectrometer
VAD	Velocity Azimuth Display
VAP	value-added product
VARANAL	Constrained Variational Analysis
VARANAL3D	Three-dimensional Constrained Variational Analysis
VDISQUANTS	Video Disdrometer Quantities

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1.0 Introduction

Translators serve a unique role in the U.S. Department of Energy (DOE)'s Atmospheric Radiation Measurement (ARM) user facility, offering scientific input through various leadership and service roles. The Translators direct the creation of value-added products (VAPs) and analysis tools that make ARM measurements more accessible to the scientific community. Translators also serve as liaisons between users and the ARM infrastructure, collecting information about priorities and communicating ARM data and services. A key group focus is supporting the DOE Atmospheric System Research (ASR) program scientists and ASR's efforts towards a process-level understanding of cloud-aerosol interactions, and in reducing uncertainty in global climate model projections. The ARM Translator Group (Table 1) consists of the five Translators, a representative of software development, and one from the Data Quality Office (DQO). Additionally, the ARM Associate Director for Research participates in this group and provides input and direction from ARM and its programmatic priorities.

Table 1. Members of the Translator Group.

Name	Institution	Role
Jennifer Comstock	Pacific Northwest National Laboratory (PNNL)	ARM Associate Director for Research
Scott Giangrande	Brookhaven National Laboratory	Translator (Lead), Clouds and Precipitation
Scott Collis	Argonne National Laboratory	Translator, Clouds and Precipitation
John Shilling	PNNL	Translator, Aerosols
Damao Zhang	PNNL	Translator, Clouds and Precipitation
Shaocheng Xie	Lawrence Livermore National Laboratory	Translator, Cloud-Climate Modeling
Kenneth Kehoe	University of Oklahoma	Data Quality Office
Krista Gaustad	PNNL	Software Development

1.1 Motivation

In January of 2022, the Translator Group met over two days to discuss development of this coordinated three-year vision plan. As with the previous "Translator Plan", the goals are: (i) to report on Translator progress, (ii) to specify where Translators will prioritize their efforts, and (iii) to inform on how the group will adapt to ARM's changing scientific demands. Traditionally, this group prioritizes their activities based on inputs from the ASR principal investigator (PI) community, set by serving in joint leadership roles within predecessor groups to the current ASR "Working Group" structure (https://asr.science.energy.gov/science/working-groups). However, as leadership roles in ASR groups gradually shifted, Translators also shifted to incorporate feedback on priorities from a wider range of DOE workshop activities and ARM stakeholder groups.

An enduring activity since the inception of the Translators has been the creation and delivery of VAPs, sometimes in conjunction with PI sponsors, and timely VAP availability (e.g., Ackerman et al. 2016). Translators also actively engage with the climate community to promote: (i) improved accessibility, (ii) improved documentation and uncertainty estimates for ARM data sets, (iii) new support for data visualization and analyses, (iv) new modeling diagnostic or forward-instrument operator tools, and (v) new model-observational hybrid activities. Today, Translators participate on, and respond to feedback from, an increasingly diverse audience that includes ARM's User Executive Committee (UEC), ARM's Aerosol Measurement Science Group (AMSG) and Cloud and Precipitation Measurement Science Group (CPMSG), and ARM's Triennial Review. The goals outlined in this document anticipate support from those partners, and are grounded in the motivations set forth by ARM's Decadal Vision (https://www.arm.gov/uploads/DRAFT_ARM_Decadal_Vision_20200915.pdf) for responding to the needs of ARM leadership and the ARM-ASR Coordination Team (AACT).

1.2 Document Contents

This document reviews recent Translator accomplishments regarding continuing Translator high-priority activities. This is followed by a three-year plan for high-priority new activities to be advanced for the fiscal year (FY) FY2023-FY2025 period. This plan updates several areas where Translators regularly contribute: new data products, support of ARM Mobile Facility (AMF) deployments, and improvements to ARM data and user experience.

2.0 Translator Accomplishments from 2018 to 2022

Translators develop high-impact VAPs and tools, while extending several services to the ARM community. A key Translator function is maintaining existing ARM VAP capabilities, reducing delays in their availability, and building on successful products. This section summarizes progress from high-priority VAP activities over the previous "Translator Plan" period (2018-2022). An overarching goal during that time frame was to ensure more timely VAP delivery from AMFs, and to improve the AMF VAP request process working in conjunction with AMF PIs. That plan was also mindful of new VAP capabilities required in support of the Aerosol Observing System (AOS), new precipitation instrumentation, lidars, and radiometers.

Traditional Translator activities start from improvements to core VAP capabilities (introduced by our previous Translator Plan as ARM's mature, robust VAPs of primary quantities that Translators routinely guarantee for ARM users). However, efforts support the introduction of new VAPs to our capabilities (Section 2.1). Translator focus also extended to observational-modeling tools that reduce the barriers to entry for ARM data use (Section 2.2). Those efforts included support of global climate model (GCM) community products, as well as improvements to existing tools such as the Python ARM Radar Toolkit (Py-ART). Finally, Translators sought to improve the user experience, adding support for Recommended Datastreams, datastream citation, and multi-agency collaborations in support of improved ARM data use (Sections 2.3, 2.4).

Overall, the period was highly productive in service of traditional goals, and expanded efforts into community-informed activities. New ARM datastreams doubled, with VAP datastreams similarly doubling (approx. 116 VAP streams in 2018 increasing to 248 by end of 2021). Currently, ARM receives 1,000 unique VAP users per year, and these users represent half of the total unique ARM users for those years. ARM users continue to download VAPs, as VAP users represent approximately 65% of the unique ARM users, while VAP downloads account for ~20% of total ARM file downloads. These numbers are consistent with the value expected from VAPs to reduce the complexity of ARM data sets for a wide portion of the new and installed user base. From our previous plan, in which Translators demonstrated that the least progress was in communicating uncertainty for ARM data sets and the forms uncertainty statements take for an expanding ARM user community. While several Translator activities were targeted on these fronts – including revamping ARM webpage materials (so-called 1-pagers) and additional best-estimate activities (i.e., Quality-Controlled Aerosol Optical Depth [QCAOD]) – the current plan will attempt to address these continued challenges through improved data quality, metadata and AMF PI interactions (such as new Point of Contact and Data Epoch ideas, Section 4), and linking these ideas more explicitly to campaign/intensive operational period (IOP) measurement intercomparison efforts with ARM community support (Section 5.3).

2.1 Value-Added Product Updates

The Translator group was originally established to promote the development and release of VAPs. Historically, VAP activities stress partnerships with the climate community to sponsor and evaluate those efforts. In turn, ARM VAPs have seen continued advancement towards automation and/or real-time availability, with emphasis on early release VAPs released within ongoing AMF campaigns. These improvements have been made possible by advances such as the ARM Data Integrator (ADI) that reduces the development cycle of standard VAPs from several years to within a calendar year. Further advancement of open-source code and/or resources that readily integrate PI ideas into future VAP designs will likely also contribute to new VAPs, expanded core capabilities, and timely availability.

2.1.1 Core VAP Highlights

2.1.1.1 Aerosol Optical Properties (AOP) and Aerosol Optical Depth (AOD) VAPs

The Aerosol Optical Properties (AOP) VAP combines data from two instruments, a filter-based light absorption instrument (particle soot absorption photometer [PSAP], tricolor absorption photometer [TAP], or continuous light absorption photometer [CLAP]), and scattering from a nephelometer, and calculates several intensive and extensive aerosol optical properties at three wavelengths. Calibrations and corrections are applied to both the scattering and absorption data to yield a consistent data product with uniform application of literature corrections. Notable reported extensive aerosol optical properties include corrected scattering, absorption, and absorption coefficients and reported intensive aerosol optical properties include single scattering albedo, backscatter fraction, asymmetry parameter, and Angstrom exponents for scattering and absorption. This VAP is now running autonomously for all sites including fixed sites and mobile deployments with the appropriate instrumentation. This VAP was implemented to replace and improve upon the old aerosol intensive properties (AIP) VAP. The aerosol optical depth (AOD) VAP retrieves the AOD from total and diffuse solar irradiances measured by multifilter rotating shadowband radiometer (MFRSR) at the Earth's surface. This VAP requires manual processing for many campaigns or sites with low sun angles or regular cloudy conditions. Data for several sites and campaigns with these limitations, including North Slope of Alaska (NSA), Eastern North Atlantic (ENA), and Macquarie Island (MCQ), were generated and published on ARM's Data Discovery tool. The AOD VAP was also updated to include the new 1.6um-wavelength channel that was added to the MFRSR instruments.

2.1.1.2 Improved Constrained Variational Analysis VAP (VARANAL) with Merging ECOR and EBBR Fluxes

The ARM variational analysis forcing data was improved at the Southern Great Plains (SGP) observatory with merging the turbulent fluxes measured by ECOR (eddy correlation flux measurement system) and EBBR (energy balance Bowen ratio station), which are deployed on different surface types over the ARM SGP surface observational network. The differences in ECOR and EBBR fluxes considerably impact the derived forcing, especially during non-precipitating days, which in turn affects model capability to simulate boundary-layer development and shallow cumulus clouds (Tang et al. 2019). The new method has been applied to update the continuous VARANAL product for the period between 2004 and 2018 at SGP.

2.1.1.3 "Instant" Active Remote Sensing of Clouds (ARSCL)

A new workflow was implemented for the Active Remote Sensing of Clouds (ARSCL) VAP that brings faster radar product availability, improved quality control, and accuracy. These changes include new options to better remove artifacts and designate clouds, as well as a '.c0'-level addition that provides similar-quality cloud property retrievals while avoiding extended delays from standard radar calibration needs. The ARSCL products are now available from all deployments, usually within one month of data collection. This availability is tied to interpolated radiosonde (Interpolated Sonde [INTERPSONDE]) availability that is also available within one month of data collection. These modifications allowed near-real-time delivery of ARSCL products during recent AMF campaigns (Cold-Air Outbreaks in the Marine Boundary Layer Experiment [COMBLE], TRacking Aerosol Convection interactions ExpeRiment [TRACER], and Surface Atmosphere Integrated Field Laboratory [SAIL]).

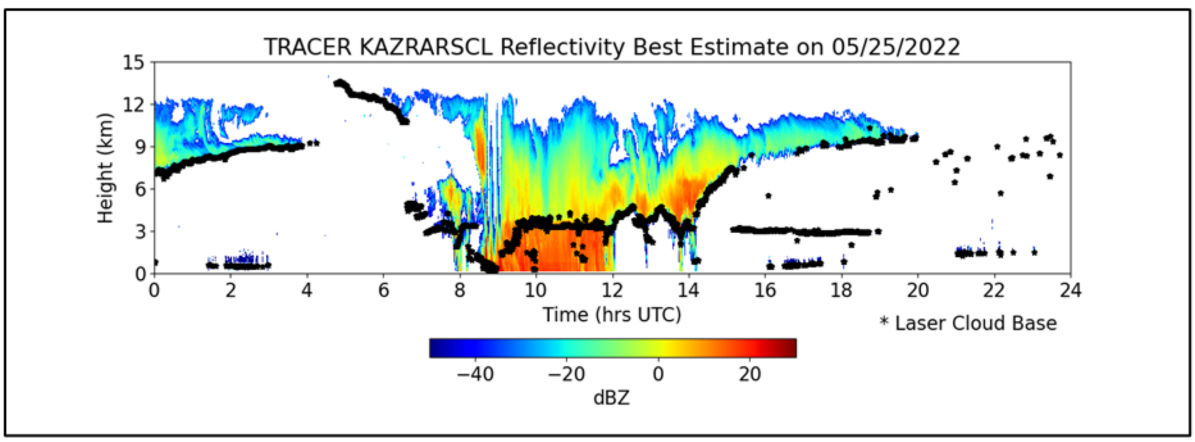

Figure 1. Example from an early release ARSCL Reflectivity Best Estimate and cloud base information product from the 25 May 2022 TRACER event.

2.1.1.4 ARM Best Estimate VAP (ARMBE) for AMFs

The ARM Best Estimate VAP (ARMBE) was created to encourage greater use of ARM data in climate studies and model development by the climate community (Xie et al. 2010). It assembles a best estimate of cloud, radiation, and atmospheric quantities, and surface/land properties that are both well observed by ARM and commonly used in model evaluation into one single data set. In addition to maintaining and updating ARMBE data products at ARM fixed sites (SGP, NSA, Tropical Western Pacific [TWP], and ENA), the ARMBE VAP has been extended to the ARM AMF deployments. Currently, ARMBE is available at the ARM West Antarctic Radiation Experiment (AWARE), Green Ocean Amazon 2014/15 (GoAmazon2014/15), Convective and Orographically Induced Precipitation Study (COPS), Cloud, Aerosol, and Complex Terrain Interactions (CACTI), and COMBLE.

2.1.1.5 ARM Best Estimate 2D VAPs (ARMBE2DGRID and ARMBESTNS)

To address the spatial variability in clouds, precipitation, and radiation, two-dimensional (2D) gridded and ARM station-based ARM Best Estimate (ARMBE) VAPs (ARM Best Estimate 2D Gridded Surface Data Set [ARMBE2DGRID] and ARM Best Estimate Station-based Surface Products [ARMBESTNS], respectively) were developed at SGP for the period between 2004 and 2015. The primary goal of these two data sets is to provide 2D spatial data of important surface variables to facilitate studies on precipitation, clouds, and radiation, for example, which require high spatial and temporal observations. ARMBE2DGIRD and ARMBESTNS can also be used to study land-atmosphere coupling at SGP (Tang et al. 2018).

2.1.2 New VAP Capabilities Added between 2018 and 2022

2.1.2.1 AOS Harmonization

ARM acquired numerous new aerosol instruments and integrated these instruments into shipping containers to create ARM's Aerosol Observation Systems (AOS). A major effort beginning in 2015, dubbed harmonization, was made to establish program-wide uniformity in terms of content, look and feel, and processing algorithms, as well as to establish a consistent approach for including advanced data quality for instruments in the AOS. In the past three years, harmonized datastreams were produced for multiple aerosol and trace-gas instruments housed in the AOS including condensation particle counters (CPCs), cloud condensation nuclei particle counter (CCN), scanning mobility particle sizer (SMPS) and nano-SMPS, ultra-high-sensitivity aerosol spectrometer (UHSAS), aerodynamic particle sizer (APS), ozone monitor (O3), sulfur dioxide monitor (SO2), and greenhouse gas instruments. The harmonization effort is expected to finish by the end of FY22. Generation of these harmonized instrument datastreams will ensure data users have consistent, calibrated, and quality-controlled data from AOS instruments.

2.1.2.2 ACSM Data Processing and the ACSMCDCE VAP

ARM operates multiple aerosol chemical speciation monitors (ACSM) that provide a quantitative measurement of aerosol particle chemical composition for non-refractory aerosol components. Prior to 2020, calibrated quality assurance/quality control (QA/QC) ACSM data were not available to users; therefore, generating reliable, calibrated data was a priority. A strategy for processing ACSM data was developed with one path processing data autonomously in real-time and led by the translator and a parallel path processing data periodically by the mentor. B-level files that incorporate calibrations and QA/QC fields are now available for all quadrupole ACSM data. One well-known limitation to the accuracy of the ACSM data is in evaluating the fraction of sampled aerosol particles that the instrument detects. This quantity is referred to as the collection efficiency (CE) and parameterizations of CE as a function of measured chemical composition exist in the literature. The ACSM corrected for Composition-

Dependent Collection Efficiency (ACSMCDCE) VAP has been developed and applies one such parameterization (Middlebrook et al. 2012) to the ACSM data. Applying this parameterization improves the accuracy of the ACSM data and brings it into better agreement with other co-located aerosol measurements.

2.1.2.3 3D Variational Analysis Forcing VAP (VARANAL3D)

The three-dimensional (3D) constrained variational analysis approach (Tang and Zhang 2015) was developed to extend the original variational analysis method from one atmospheric column into multiple sub-columns, within a similar domain size. Constraint equations are satisfied in each sub-column, and all sub-columns interact with one another through horizontal fluxes. The 3D structure of the forcing data allows for studies of spatial variation of the large-scale forcing fields and tests of physical parameterizations across scales (Tang et al. 2016, 2017). Three-dimensional Constrained Variational Analysis (VARANAL3D) products are currently available at SGP for the 2000 ARM Spring Cloud IOP and Mid-latitude Continental Convective Clouds Experiment (MC3E) field campaigns.

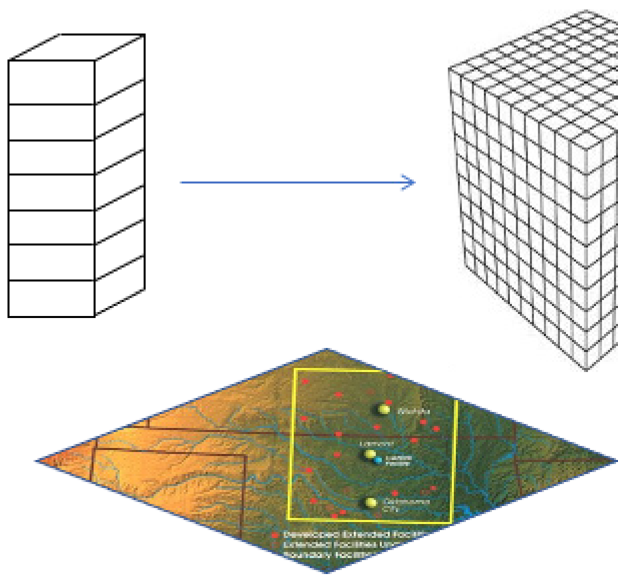

Figure 2. A schematic diagram illustrating change from the routine ARM VARANAL to 3D VARANAL.

2.1.2.4 CCN Kappa VAP

Kappa (κ) is a parameterized representation of an aerosol particle's hygroscopicity and is widely used in models to calculate cloud condensation nuclei (CCN) concentrations and cloud properties. This VAP uses κ-Köhler theory developed by Petters and Kreidenweis (2007), with fixed constants to calculate κ from the particle number size distribution from the SMPS and CCN concentrations at each supersaturation scanned by the CCN instrument as a function of time, assuming particles are internally mixed with bulk chemical composition. The data generated by this VAP will enable users to quantify the ability of aerosols to activate into cloud water droplets, providing additional insight on the influence of aerosols on climate.

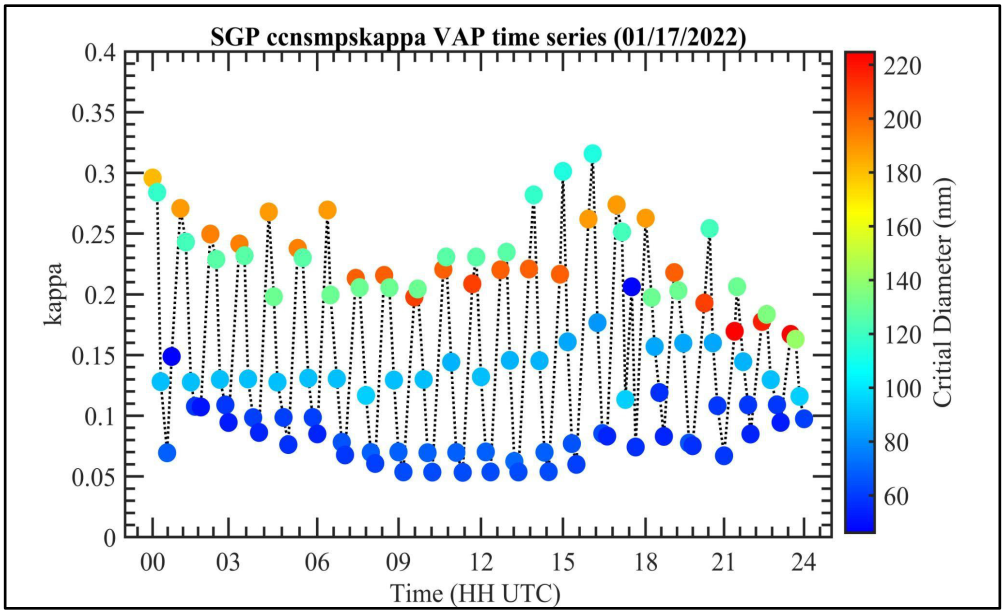

Figure 3. Kappa VAP results at SGP on 17 January 2022. Data for all supersaturation values scanned by the instrument are shown and higher instrument supersaturation values retrieve lower kappa and smaller critical diameter.

2.1.2.5 Micropulse Lidar Cloud Mask Machine Learning VAP (MPLCMASKML)

An approach for cloud detection was developed that takes advantage of machine learning (ML) capabilities as applied to micropulse lidar (MPL) observations (Cromwell and Flynn 2019). The VAP provides cloud masks that record the number of cloud layers, and the boundaries for those cloud layers. These ML-based methods reduce the cloud misclassification by almost half when compared to the previous MPL cloud mask products. Since Micropulse Lidar Cloud Mask Machine Learning (MPLCMASKML) products have been demonstrated to capture low-cloud properties exceptionally well, these concepts may be integrated into the multi-sensor ARSCL for further refinements of cloud boundary estimates. MPLCMASKML data are currently available for ARM's fixed observatories SGP, ENA, and NSA, and mobile field campaigns AWARE, CACTI, and Oliktok Point, Alaska.

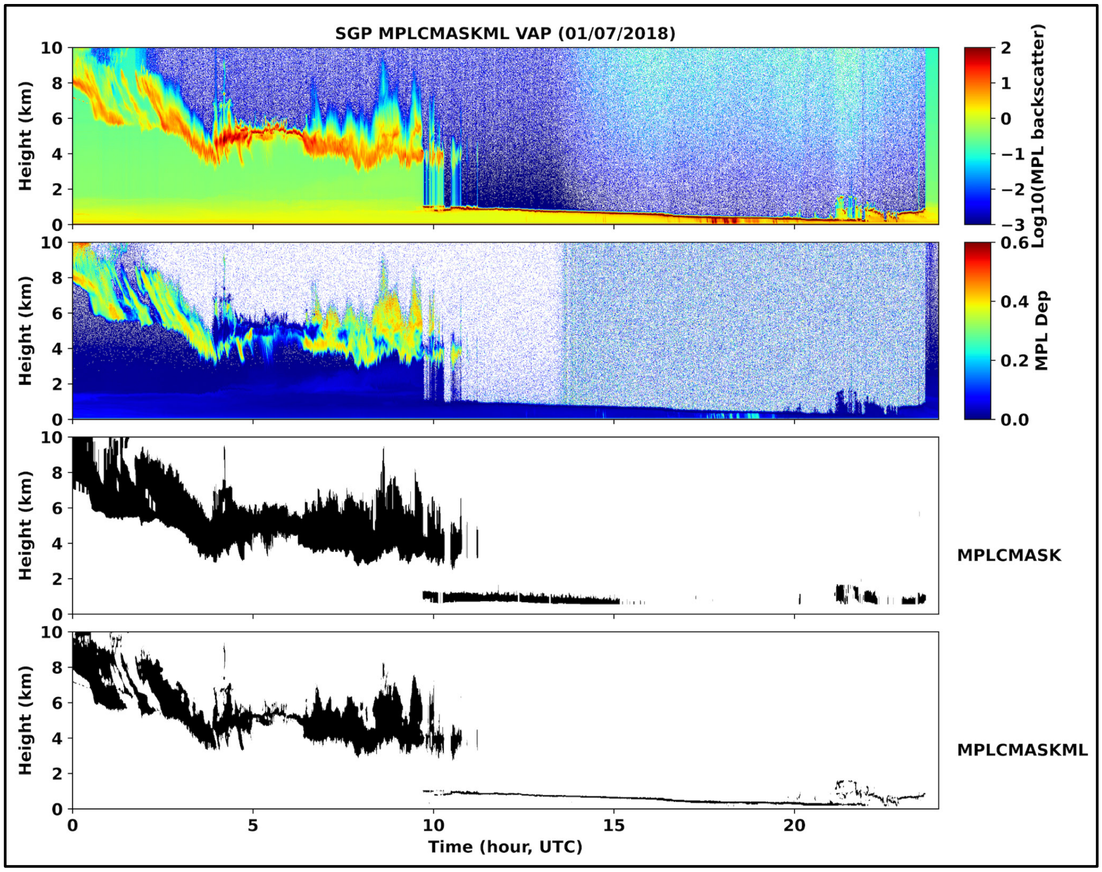

Figure 4. Clouds identified by the MPLCMASKML VAP on 01/07/2018 at SGP. Plots from top to bottom are: the MPL backscatter, MPL depolarization, MPLCMASK cloud mask, and MPLCMASKML cloud mask.

2.1.2.6 Advanced Cloud and Precipitation VAPs

Cloud and precipitation products were a focal point for the Translators, sparked by increased availability of scanning radar and surface disdrometer records from AMF campaigns such as CACTI. Translator activities prioritized several gridded radar products based on open-source and community-supported Python codes, such as Py-ART improvements (see Section 2.2.2), Corrected Moments in Antenna Coordinates (CMAC) for scanning weather radar data sets, and Scanning ARM Cloud Radar (SACR) concepts (SACR Grid Range Height Indicator [SACRGRIDRHI], SACR Grid Plan Position Indicator [SACRGRIDPPI]) and advanced VAPs that map radar measurements to cartesian grids and perform additional conditioning and corrections.

ARM laser and video disdrometers (LDIS, VDIS) also received their first formal VAPs (Laser Disdrometer Quantities [LDQUANTS]/Video Disdrometer Quantities [VDISQUANTS]) during this period, based on PI-driven and open-source code contributions (PyDisdrometer [PyDSD], Hardin 2014) that estimate raindrop size distribution quantities (number concentration, median drop diameter) and radar measurements across relevant ARM radar wavelengths (e.g., dual-polarization Z, ZDR). The vertically pointing Ka-band ARM Zenith Radars (KAZR) also received several product improvements, including availability of calibrated contour frequency by altitude (CFAD) displays using CloudSat references, improvements to baseline liquid water path (LWP) retrievals (MWR Retrievals with MWRRET Version 2

[MWRRETv2]) from 3-channel microwave radiometers (MWR3C), and advanced MICROBASE (Continuous Baseline Microphysical Retrieval) products that add uncertainties, liquid/ice water content, and liquid/ice effective radius (i.e., Improved MICROBASE product with Uncertainties [MICROBASEKAPLUS]).

2.1.2.7 Advances in Thermodynamic Profiling VAPs

High-temporal-resolution measurements of thermodynamic profiles are critical to the understanding of various atmospheric processes. A new Atmospheric Emitted Radiance Interferometer Optima Estimation (AERIoe) VAP uses an optimal estimation framework to derive temperature and water vapor mixing ratio profiles, and retrieve liquid cloud properties including LWP and cloud droplet effective radius, from atmospheric emitted radiance interferometer (AERI) infrared radiance spectra measurements and other inputs. These retrievals of boundary-layer thermodynamic profiles provide new information about the evolution of the boundary layer. Improved LWP retrievals from AERIoe allow better quantification of cloud properties for optically thin clouds and shallow cumulus.

A key parameter that characterizes the boundary-layer structure is the planetary boundary-layer height (PBLHT; also the name of a VAP). The Planetary Boundary-Layer Height-Balloon-Borne Sounding System (PBLHT-SONDE) VAP has been in production at all ARM facilities, but it suffers from poor temporal resolutions. A new Planetary Boundary-Layer Height-Micropulse Lidar (PBLHT-MPL) VAP was added and provides continuous high-temporal-resolution PBLHT estimations from MPL measurements using the advanced method developed by Sawyer and Li (2013). In response to community demand for deep convective cloud AMF deployments, Translators added a new radiosonde VAP, Convective Parameters Derived from Radiosonde Data (SONDEPARAM), for calculations of thermodynamic parameters including the convective available potential energy (CAPE) and convective inhibition (CIN) applying various assumptions for initial parcel characteristics. These VAP codes were developed in open-Python to ease user reproduction, feedback, and ARM quicklook plots.

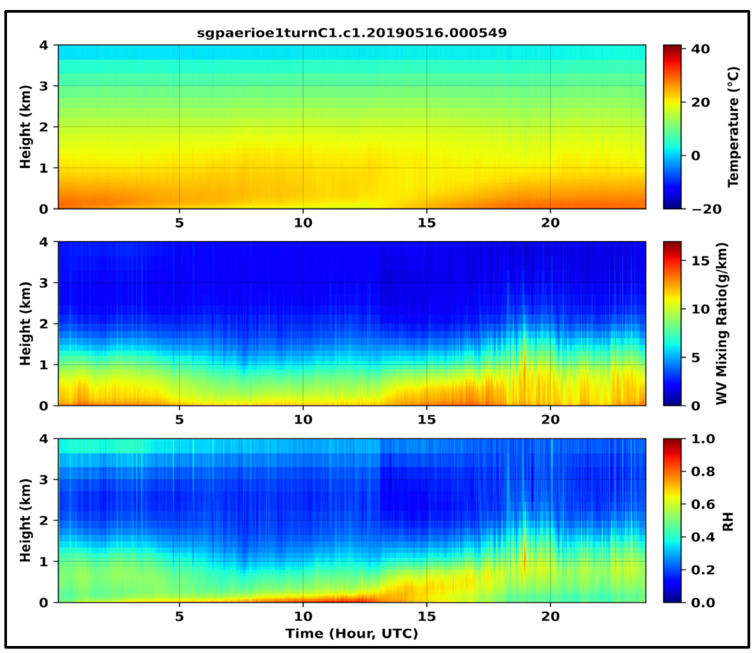

Figure 5. AERIoe retrieved temperature, water vapor mixing ration, and relative humidity profiles.

2.1.2.8 Addressing the Effect of Sloping Terrain in the Variational Analysis

The capability to treat the slope of the underlying surface in the ARM VARANAL VAP has been added by using a terrain-following sigma vertical coordinate (Tang et al. 2020). The new method in sigma coordinate calculates the column-integrated budgets more accurately over regions with steep terrain. The sigma coordinate VARANAL is being applied to generate the large-scale forcing for CACTI, which was conducted in the Sierras de Cordoba Mountain range of north-central Argentina.

2.2 Analysis Tools and Model-Diagnostic Package Highlights

Translators spearheaded the development of tools that facilitate the use of ARM data and better link ARM observations to climate models. Key activities performed between 2018 and 2022 included: (i) The ARM Data-Oriented Metrics and Diagnostics Package (ARM-DIAGS) that allows a routine assessment of climate models with ARM data; (ii) New ARM radar simulators for better comparison between model clouds and ARM detailed cloud observations; (iii) Support for the Large-Eddy Simulation (LES) ARM Symbiotic Simulation and Observation (LASSO) high-resolution modeling project to bridge ARM data and climate models, and provide diagnostics that would be difficult to obtain directly from ARM observations. Separately, the group continued support for Translator-led, open-source toolkits that enable users to work directly with ARM data.

2.2.1 ARM Diagnostic Packages/Support for Modeling Efforts

2.2.1.1 ARM Data-Oriented Metrics and Diagnostic Package (ARM-DIAGS)

The ARM-DIAGS facilitates the use of ARM long-term, high-frequency measurements in evaluating the regional climate simulation of clouds, radiation, and precipitation (Zhang et al. 2020). With growing interest in improving parameterizations using process-oriented metrics and diagnostics, ARM observations play an important role in the way cloud and precipitation processes are represented in climate models. ARM-DIAGS includes data from ARM and the Coupled Model Intercomparison Project (CMIP), as well as a Python-based analysis toolkit for computation and visualization. The package can serve as an easy entry point for Earth system modelers to compare their models with ARM data and supplementary CMIP data sets.

A second version of ARM-DIAGS has been released for public use through Github. It has also been integrated into the Energy Exascale Earth System Model (E3SM) diagnostics package, allowing users to routinely test E3SM output at multiple ARM sites against climatology and time-series files generated from ARM data. Some features from ARM-DIAGS have already been used during the development of E3SM's next-generation atmospheric physical parameterizations. ARM-DIAGS will be further enhanced by including metrics for aerosol-cloud interactions (Section 3).

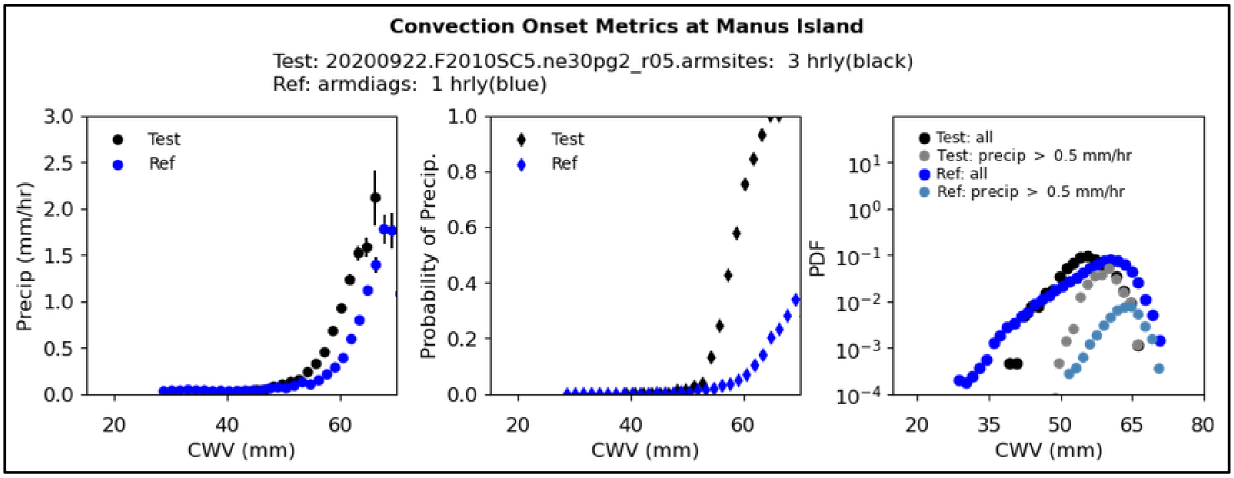

Figure 6. Left: Precipitation conditionally averaged on column water vapor (CWV) for observations based on ARM Best Estimate (ARMBE) precipitation and MWRRET radiometer CWV (blue) and a one-year E3SM model output (black) over Manus Island in Papua New Guinea. Middle: Precipitation probability (the number of CWV observations with rain rate greater than 0.5 mm/hr, divided by the total number of CWV samples in each bin). Right: The probability density functions (PDFs) of CWV for observations (dark blue) and model (black) and of the contribution to this from points with precipitation exceeding 0.5 mm/hr for observations (light blue) and model (grey).

2.2.1.2 LASSO-O Bundles

The initial results from the LASSO project enabled users to compare models with ARM observations collected at the SGP site during shallow cumulus events. As part of LASSO activities, Translators supported the development of associated LASSO-O data bundles, i.e., product collections that consist of LES outputs for each event (over 100 shallow cumulus events observed from 2015-2019 over the SGP site), the surface fluxes and large-scale forcing needed to reproduce the LES results, observations from those shallow cumulus events, and skill scores/diagnostic details identifying how the LES behaved compared to those observations (Gustafson et al. 2019). A subset of the LASSO-O bundles provided high-resolution (< 1-minute temporal) data products (LASSO High-Frequency Observations [LASSOHIGHFREQOBS]) that added several new shallow cumulus VAPs. These products included a multisensor (ARSCL, total sky imager [TSI]) cloud fraction VAP (CLDFRAC), a boundary-layer temperature and moisture VAP (LASSO Boundary-Layer Thermodynamics [LASSOBLTHERMO]) derived from the AERI and Raman lidar, the cloud base height as derived from the Doppler lidar (LASSO Doppler Lidar Cloud-Base Height for Shallow Cumulus [LASSODLCBHSHCU]), and LWP retrievals (LASSO Liquid Water Path [LASSOLWP]) as based on the AERIoe VAP. In addition to those bundles available for each LASSO event day, a related Lifting Condensation Level Height VAP (LCLHEIGHT) is also produced year-round, and merges data from multiple sites around the SGP at 1-minute resolution.

2.2.2 Progress on Translator-Supported Open-Source Toolkits

It requires a significant effort to document, test, and user-support open versions of VAP codes that have become increasingly requested by ARM stakeholders. Translators believe that improving the availability of open-VAP software may empower future ARM users to adjust existing VAP decisions (i.e., grid scale, coefficients, and other variables) used in baseline retrievals. Moreover, well-crafted community software is accepting of user contributions, enabling a multi-way conduit between ARM, interested stakeholders, and others in the community. Examples of ARM-supported packages advanced by this group are outlined below.

Table 2. Recent ARM open-source visualization and VAP efforts.

Name	ARM POC	Scope	Start Date	Impact
Atmospheric Community Toolkit	Adam Theisen	N-Dimensional time series data. https://github.com/ARM-DOE/ACT	2019	Wide interagency use. Streamlined DQ plots and enables code uptake by ARM.
ARM Data Integrator	Krista Gaustad	ARM VAP implementation. Integration with ARM databases. https://github.com/ARM-DOE/ADI	2012	Streamlined VAP implementation process. Removed duplication of work.
Python ARM Radar Toolkit	Scott Collis	Data model driven IO, analyses, corrections and visualization for radar data. https://arm-doe.github.io/pyart/	2015	Highly cited (236 citations to metapaper). Democratizing radar data, used by *NY Times*. Vibrant developer community.
PyDSD	Scott Giangrande	Disdrometer analyses and radar moment calculations (Hardin 2014). https://github.com/josephhardinee/PyDSD	2018	Key to LDQUANTS. Community package integrated as a continuing core VAP.
ARM-DIAGS	Shaocheng Xie	ARM data-oriented diagnostics package for climate models (Zhang et al. 2020). https://github.com/ARM-DOE/arm-gcm-diagnostics	2015	Part of the E3SM diagnostics package and facilitated use of ARM data in climate model developments.
ARM Radar Simulator	Shaocheng Xie	Simulator for ARM ground-based radars to improve comparison of GCM-simulated clouds with ARM detailed cloud observations (Zhang et al. 2018).	2014	Part of the CFMIP Observation Simulator Package (COSP) simulator package for broad use in the climate modeling community.

We call attention to Py-ART, which has been a successful example of open-source community software within the ARM facility. Py-ART acts as a magnet for contributions from the community, and many of those contributions have made their way into ARM from VAPs to operations. Py-ART experienced growth in several metrics between 2018 and 2022 that include lines of code, papers referencing the code base, and the number of unique contributors. In the figure, we show the number of contributors (as identified by the user name on GitHub) over time, with those contributors receiving funding from DOE ARM in light blue.

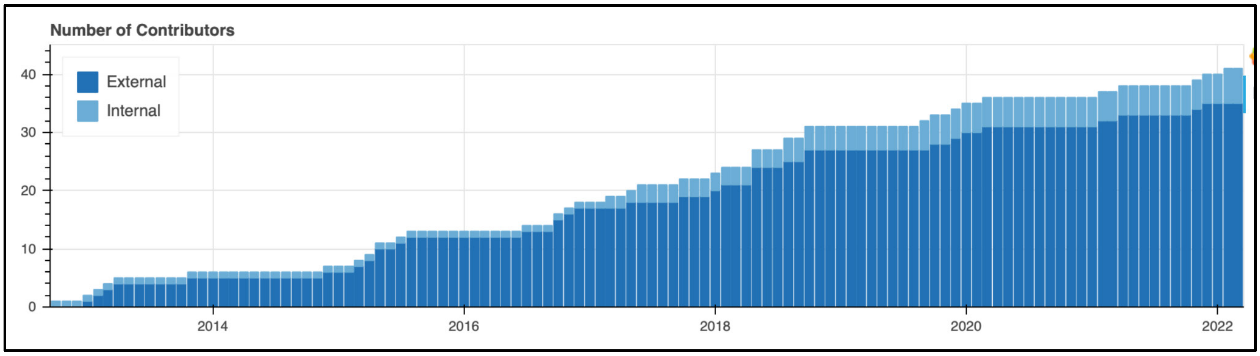

Figure 7. Number of Py-ART contributors to GitHub since 2012.

2.3 Improving the ARM User Experience

ARM services a diverse set of scientific users having various skill levels, disciplines, and exposure to ARM products. Recent years have incorporated new Translator activities targeting Improving User Experience and data services, with two supported foci described in the sections below. These priorities were (i) assigning a Point Of Contact (POC) for AMF campaigns and core VAP availability therein, and (ii) working with the ARM Data Center (ADC) on prioritizing search data results and/or providing added in-depth descriptions on applicability (also known as Recommended Datastreams).

Table 3. Points of Contact for previous, ongoing, and upcoming AMF campaigns (as of this publication).

AMF Campaign	Campaign Dates	Campaign PI	Translator POC
Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean (MARCUS)	1 October 2017–1 April 2018	Greg McFarquhar	Scott Giangrande
Cloud, Aerosol, and Complex Terrain Interactions (CACTI)	1 October 2018–30 April 2019	Adam Varble	Scott Collis
Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC)	11 October 2019–1 October 2020	Matthew Shupe	Scott Giangrande Damao Zhang
Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE)	1 December 2019–31 May 2020	Bart Geerts	Scott Giangrande
Surface Atmosphere Integrated Field Laboratory (SAIL)	1 September 2021–15 June 2023	Daniel Feldman	Damao Zhang
Tracking Aerosol Convection Interactions Experiment (TRACER)	1 October 2021–30 September 2022	Michael Jensen	John Shilling
Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE)	15 February 2023–14 February 2024	Lynn Russell	Shaocheng Xie

2.3.1 Defining Core VAP Priorities and AMF Points of Contact

The Translators maintain and distribute a list of core VAPs that are mature products routinely provided for the climate community at ARM sites and campaigns. As expected, core VAP capabilities from the

2018 Translator Plan have expanded to include core products associated with new AOS and precipitation/cloud instruments. Stalwart core VAPs include cloud boundary properties (ARSCL), and primary quantities such as LWP rather than raw microwave brightness temperatures (i.e., MWRRET → MWRRETv2). As new capabilities from our plan (Section 3) come online, we similarly anticipate that core capabilities will expand. Nevertheless, Translators also maintain several unique VAPs (i.e., AERIoe, CFAD, Droplet Number Concentration [NDROP]) and the potential to implement PI requests as supporting VAPs. The current Translator core VAP list as associated with baseline AMF deployments is provided below.

Table 4. Core ARM VAPs for ARM AMFs. New core VAPs since 2018 are highlighted in grey.

VAP Name	Description	Derived Quantities	ARM VAP URL	Expected Timetable
ACSMCDCE	ACSM corrected for non-unity particle collection	Organic, sulfate, nitrate, ammonium, and chloride mass concentration.	https://www.arm.gov/capabilities/vaps/acsmcdce	Runs in near-real time. Typically available within 1 week of data collection.
AERINF	Noise-filtered AERI measurements	Noise-filtered longwave radiance.	https://www.arm.gov/capabilities/vaps/aerinf	Data processed in 10-day chunks one week after input data are available. For AMF, produced on request (campaign end).
AOD-MFRSR[1]	Aerosol Optical Depth	Aerosol optical depth derived from MFRSR measurements.	https://www.arm.gov/capabilities/vaps/aod-mfrsr	SGP data are processed yearly. AMF data are available on request, typically 1-2 years after campaign end.
AOP	Aerosol Optical Properties	Aerosol optical properties, scattering, backscattered radiation.	https://www.arm.gov/capabilities/vaps/aop	Runs in near-real time. Typically available within 1 week of data collection.
ARMBE	ARM Best Estimate (formerly Climate Modeling Best Estimate)	Assembles a best estimate of cloud, radiation, atmospheric, and surface properties.	https://www.arm.gov/capabilities/vaps/armbe	Within one month after required VAPs are available. For ARM fixed sites, the products will be updated yearly.
ARSCL (Ka-Band, KAZR, KAZRARSCL)	Active Remote Sensing of Clouds	Cloud boundaries, layers, fraction, and best estimates of radar quantities.	https://www.arm.gov/capabilities/vaps/arscl	Within 1 month of data collection for non-calibrated '.c0' products, '.c1' calibrated products typically within 6 months of campaign end.

[1] 1AOD-MFRSR is considered core for SGP, but is available by request at other sites. AMF deployments with low sun angle or that have frequent cloud cover require more time to process.

VAP Name	Description	Derived Quantities	ARM VAP URL	Expected Timetable
CMAC	Corrected Moments in Antenna Coordinates	Corrected gate moments. CF-Radial format.	https://www.arm.gov/capabilities/vaps/cmac	Within two months of b-level radar data being produced. Certain components may not be run until in-situ data are processed (i.e., rainfall rates in new climates).
CCNSMPSKappa	Kappa parameter based on CCN and SMPS measurements	Kappa, a representation of aerosol hygroscopicity.	https://www.arm.gov/capabilities/vaps/ccnsmpskappa	Within 1-2 months of campaign end. Fixed-site data runs in near-real time and is available within 1 week of data collection.
DLPROF	Doppler Lidar Profiles	Profiles of horizontal winds and vertical velocity statistics.	https://www.arm.gov/capabilities/vaps/dlprof	Within 1 week of data collection. Typically, initiated a few months from AMF start.
INTERPSONDE	Interpolated radiosonde data sets	Continuous (fixed temporal, height grid) radiosonde data.	https://www.arm.gov/capabilities/vaps/interpsonde	Within 1 month of data collection.
LDQUANTS (and/or VDISQUANTS)	Disdrometer rainfall quantities and radar-type estimates	Dual-polarization radar estimates (Z, ZDR), drops size distribution parameters (shape, slope).	https://www.arm.gov/capabilities/vaps/ldquants https://www.arm.gov/capabilities/vaps/vdisquants	Within 1 month of data collection.
MICROBASEKaPlus	Baseline cloud microphysical property retrievals	Vertical profiles of cloud liquid water content, cloud ice water content, liquid cloud particle effective radius, and ice cloud particle effective radius.	https://www.arm.gov/capabilities/vaps/microbase https://www.arm.gov/capabilities/vaps/microbasekaplus	Within 1-2 months of campaign end, or earlier contingent on MWRRET and ARSCL availability.
MPLCMASK	Micropulse lidar cloud mask and corrected backscatter and depolarization ratios	Vertical cloud layers detected by lidar backscatter profiles.	https://www.arm.gov/capabilities/vaps/mplcmask	Runs in near-real time. Typically available within 1 week of data collection.
MWRRET	Precipitable water vapor and cloud liquid water path retrievals from the MWR	Precipitable water vapor, cloud liquid water path.	https://www.arm.gov/capabilities/vaps/mwrret	A *c1 data product is produced within a week of data collection. Final *c2 product produced a year at a time within 12 months of the year completing. AMFs usually do not produce *c1 and process *c2 before 12 months of campaign end.

VAP Name	Description	Derived Quantities	ARM VAP URL	Expected Timetable
PBLHT	Planetary boundary-layer (PBL) height estimates (radiosonde)	Multiple PBL height estimates from multiple radiosonde methods.	https://www.arm.gov/capabilities/vaps/pblht	Runs in near-real time. Typically available within 1 week of data collection.
QCECOR	Quality-Controlled Eddy Correlation Flux Measurement	Improved surface turbulence fluxes from ECOR measurements, sensible and latent heat flux.	https://www.arm.gov/capabilities/vaps/qcecor	Within one month after a field campaign ends. For the ARM fixed sites, the product will be updated yearly.
QCRAD/ RADFLUX	Quality-Controlled ARM Radiation Data	Direct and diffuse SW, upwelling SW, downwelling and upwelling LW irradiances, downwelling SW.	https://www.arm.gov/capabilities/vaps/qcrad	QCRAD *c1 data produced within a week of data collection. RADFLUX *c1 within a week of QCRAD availability. Final *c2 products produced a year at a time within 3 to 12 months of the year completing.
SACRGRID	Gridded SACR (Scanning Cloud Radar) PPI and RHI data sets	Gridded radar moments, reflectivity factor, mean Doppler velocity.	https://www.arm.gov/capabilities/vaps/kasacrgridppi https://www.arm.gov/capabilities/vaps/kasacrgridrhi	Within 2 months of data collection for non-calibrated '.c0' products; '.c1' calibrated products typically within 6 months of campaign end.
SPHOTCOD	Cloud optical depth and additional microphysical retrievals from the sun photometer cloud mode	Cloud optical depth, liquid water path, cloud drop effective radius.	https://www.arm.gov/capabilities/instruments/csphot	Within 6 months of the end of non-ship-based deployment campaigns, contingent on photometer calibration availability.
VARANAL	Model large-scale forcing data sets through variational analysis techniques	Advective tendency, atmospheric state, precipitation.	https://www.arm.gov/capabilities/vaps/varanal	Available for modeling-focused AMF field campaigns. Generally within 6 months of the end of the selected field campaigns. For the ARM SGP site, the continuous ARM forcing data will be updated yearly.

Specific to AMF deployments, the Translators also kickstarted a new initiative for Points of Contact (POCs) with campaign PIs, a role that our group proposes to expand within this Plan (Section 4.1). POC efforts are intended to improve interaction between ARM, Translators, and AMF PIs for instrument and VAP information, new VAP requests, and anticipated timetables for products. Translator interactions with PIs were refined across several campaigns, with initial feedback that this interaction should: (i) occur earlier in AMF deployment cycles, (ii) support the monitoring of VAP-critical instruments throughout the campaign, and (iii) assist with documentation for campaign-specific data sets at campaign close.

2.3.2 Improvements in Support of ARM Data Center (ADC)/Data Discovery

ARM data search engine results have historically been presented alphabetically, meaning ARM users would routinely be guided to less appropriate sources of data. To help improve Data Discovery, Translators were integrated with the ADC Data Discovery teams working on Recommended Datastreams changes. The Translator's job was to identify subject-matter experts to give feedback on datastream suitability. Each datastream was assigned a three-tier ranking from "least recommended" to "most recommended", as well as the possibility of being given no recommendation. These rankings are not visible to users, but determine the order in which search results are presented. Other improvements to support Data Discovery included the creation of Digital Object Identifiers (DOIs) for datastreams, and the solicitation for their use. Translators have also started a process to revamp ARM webpage content to include 1- page summary descriptions of VAPs in an effort to help users understand VAP use, uncertainty, and limitations. Activities also included leading working group breakout sessions on the concepts of Data Epochs (i.e., Section 4.2). Data Discovery and Recommended Datastream efforts will be further refined in our current plan (Sections 4 and 5).

2.4 Additional Multi-Agency Outreach Efforts

Translators request feedback from a broad science community including the ARM UEC, ARM AMF campaign PI scientists, ASR Working Groups and focus groups, and modeling communities to understand and address the community needs of ARM data. Outreach highlights from this period included:
(i) Assigning a Translator as a POC to each of the UEC subcommittees, the AMSG and CPMSG groups, and the ASR Working Groups; (ii) Developing tools and data products suitable for climate models;
(iii) Promoting and supporting use of ARM data in community process studies, including multi-model intercomparisons using process models; (iv) Co-organizing ARM/ASR meetings (scientific, mentor, developer) and participating in meetings related to process studies and use of field observations; and
(v) Serving as panel members in data and modeling committees (e.g., the Global Atmospheric System Studies – GASS panel). This section further details several outreach efforts from this period.

2.4.1 Translator Outreach within the DOE-ARM Community

A continuing emphasis has been fostering communication and collaborations within the local DOE-ARM-ASR stakeholder community. Primary outreach focused on improving interactions during the joint ASR-ARM PI Meeting with the associated Working Group leads, including assigning a POC to each working group for providing product updates to the ASR community. Translators routinely participated in several smaller-group discussions including the ASR-ARM Radar Science focus group. In particular, radar discussions led to the sponsorship of radar code sprint activities, and associated VAP products (e.g., SACR Advanced VAPs → SACRCOR, SACRGRID). The Translators also designed and co-led parts of the Environmental Molecular Sciences Laboratory (EMSL)-ARM summer school in 2019 that introduced graduate students and postdocs to aerosol measurements and ARM-generated aerosol data sets.

Recently, new constituent groups such as the AMSG and CPMSG have begun to offer feedback that will be incorporated into future Translator plans. Multiple Translators served as members of these groups. Translators also have maintained active memberships on the ARM UEC during this period (elected representatives). A lead Translator role is also to serve as a regular member of the ARM-ASR Coordination Team (AACT). Additional activities include representing ARM across a variety of multi-lab and/or multi-agency meetings, including "Town Halls", information booths, and product demonstrations. Examples of those activities include courses and sessions sponsored by DOE-ARM (e.g., Mentor, Developer, or Product Developer workshops) and the American Meteorological Society (AMS) and American Geophysical Union (AGU) annual meetings. Specific examples include the 2021 Python for Climate and Meteorology at the AMS annual meeting (virtual) co-convened with the University Corporation for Atmospheric Research (UCAR), the State University of New York (SUNY) − Albany, and The Carpentries (materials were uploaded to YouTube), where participants were taught Python basics and how to interact with model/observational data using a variety of tools. Recently, several courses were run as part of the 2022 ARM-ASR Open Science workshop, where participants learned how to interact with ARM data using tools like Py-ART and Jupyter notebooks hosted on ARM systems. ARM also participates in the yearly Open Radar short courses that rotate between the European Radar conference and the AMS Radar Conference. The most recent event was held in Nara, Japan (2019), where participants were guided on how to use ARM radar data with Py-ART and other open community codes.

2.4.2 Translator-Led Outreach to the Modeling Community

Outreach to the modeling community and addressing its data needs is critical for ARM to increase its impact in improving Earth system model simulations. A major effort from our group during this period was to participate in and support the modeling community's single-column and cloud-resolving model intercomparison studies by providing variational analysis forcing over the ARM sites. This includes the previous Global Energy and Water Exchanges (GEWEX) Cloud System Study (GCSS) single-column model (SCM)/cloud-resolving model (CRM) intercomparison studies on various cloud systems at ARM SGP, NSA, and TWP sites (e.g., Ghan et al. 2000, Xie et al. 2002, 2005, Klein et al. 2009, and Fridlind et al. 2012). Recently, Translators have been involved in the GEWEX GASS panel activities that include the GASS Clouds Above the United States and Errors at the Surface (CAUSES) project to understand the warm bias over the continental United States (CONUS) in climate models, and the project on the diurnal cycle of precipitation simulated in weather and climate models (Ma et al. 2018, Zhang et al. 2018, Van Weverberg et al. 2018, Morcrette et al. 2018, and Tang et al. 2021). In both studies, ARM data are the key data products used to drive and/or evaluate models.

3.0 Translator Plan: Support for New Data Products (2023-2025)

As recently called out in its Decadal Vision document, ARM has a long history of providing aerosol and cloud properties obtained from in situ measurements, specialized instruments, and active and passive remote sensors. The Translators, in turn, develop new products, services, and retrievals in line with that Decadal Vision, and the recommendations from ARM stakeholders and input from the ARM Triennial Review process. The proposed plan that follows adds support for several new products and services following those recommendations. These activities complement existing VAPs, their maintenance, and other data services that Translators currently provide to the ARM community (Section 2). In the table below, we list the highest-priority VAPs that Translators will emphasize for the upcoming FY23.

Table 5. Science product priorities to be addressed in FY23 (activities exceeding core VAP capabilities).

Translator	VAP/Tool Name	Topic/Area	Description
Collis	Snow Water Equivalent (SWE) retrievals during the SAIL field campaign	Precipitation products	Retrievals of snowfall rate from the Colorado State University (CSU) X-band radar deployed to SAIL. Building on CMAC, an ensemble approach using multiple literature-based radar-snow relations with an aim of highlighting the range of accumulation rates possible. Working with the wider community (watersheds science focus area [SFA]) to build understanding and encourage use.
Collis	Columns of radar data matched to in situ ARM and other data	Radar products	Linked to work on SWE at SAIL and needed for CMAC at TRACER; the extraction of columns of radar data above ARM in situ microphysical measurements. Both a software package and VAP, this effort will provide “shovel-ready” data for radar data quality analysis and retrieval development.
Collis	Advanced visualization in the Python ARM Radar Toolkit	Data visualization	Leveraging the data model overhaul in Py-ART, this activity will link to advanced Python-based visualization codes like Holoviews, enhancing data exploration.
Giangrande	Advanced ARSCL	Cloud properties	Implementation of an open-Python version of ARSCL and formal intercomparison with existing legacy Interactive Data Language (IDL) codebase.
Giangrande	SPHOTCOD and MICROBASE expansion and intercomparison	Cloud and precipitation properties	Advance SPHOT Cloud Mode VAP into routine production for existing fixed and ongoing/future AMF campaigns, intercomparison with existing core MICROBASE VAP outputs.
Giangrande	RWP product suite	Cloud and precipitation properties	Initial Precipitation merged gridding, Cloud Mask Product Design, and Evaluation from ARM RWPs in precipitation modes.
Shilling	Merged size distribution	Aerosol properties	Merged size distributions from SMSP/APS and SMPS/UHSAS.
Shilling	AOD-BE	Aerosol properties	Best estimate of AOD and other aerosol optical properties from comparison and evaluation of several co-located remote-sensing instruments.
Shilling	CCN vertical profile	Aerosol properties	Vertical profile of CCN number up to cloud base at multiple supersaturations.

Translator	VAP/Tool Name	Topic/Area	Description
Xie	ARM-DIAGS0LAI	Modeling	Enhancing the ARM diagnostics package by adding diagnostics for Land-Atmosphere Interactions.
Xie	Enhance EMC^2 ground-based radar/lidar simulator	Simulator	Adding the COSP statistical module to EMC^2 and creating simulator-oriented ARM radar/lidar data products to compare with simulator output.
Zhang	PBL Height Best Estimate	Boundary-layer properties	Boundary-layer height best estimate derived from four different lidar measurements.
Zhang	Aerosol feature detection – high-spectral-resolution lidar (HSRL)	Aerosol properties	Aerosol feature detection derived using HSRL scattering and depolarization ratio.
Zhang	Vertical aerosol size distribution	Aerosol properties	Aerosol size distribution derived using multi-wavelength lidar retrieval combining Raman lidar and HSRL.

3.1.1 Proposed New Clouds and Precipitation VAP Support

Translators are actively developing new cloud microphysical retrievals to respond to the requests of the ARM community for advanced cloud properties as critical to cloud-aerosol-climate process studies and model evaluation. Specifically, the Decadal Vision called out several capabilities that Translators are pursuing within this Plan, including advancements in the areas of cloud hydrometeor phase, cloud number concentration, and frozen/ice cloud properties. Several proposed VAPs piggyback on the existing ARSCL VAP and its advancement, which will include a redesign of the core ARSCL codebase to open-source Python availability and improved accessibility (see Section 3.1.4). Planned activities are as follows.

3.1.1.1 ARM's Droplet Number Concentration VAP (NDROP)

The NDROP VAP is being updated with improved inputs from Cloud Optical Properties from MFRSR Using Min Algorithm (MFRSRCLDOD) and MWRRET. This activity will start with an evaluation against in situ measurements collected during the ARM Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA) field campaign, and comparisons with lidar-based cloud number concentration retrievals. We anticipate the revised VAP will be available for ARM fixed sites and AMF campaigns in FY23-24, and plan to add future AMF deployment as available.

3.1.1.2 Development of a New Cloud Phase VAP (CLDPHASE)

Cloud phase designation was specifically called out by the Decadal Vision as a high-priority retrieval for the ARM community. A proposed Cloud Phase (CLDPHASE) VAP will provide vertically resolved cloud hydrometeor phase, as well as cloud layer thermodynamic phase classifications, using combined lidar, radar, and radiometer measurements (following Shupe 2007). We anticipate this VAP will be available for ARM fixed sites and AMF campaigns in FY23-24, and plan for future AMF deployment as available.

3.1.1.3 Improved MICROBASE VAPs (MICROBASEKaPlus)

The CLDPHASE VAP provides a key contribution to the advancement of additional microphysical retrievals such as ARM's existing MICROBASE products (MICROBASEKaPlus, MICROBASEW → MICROBASE). The MICROBASE chain will add support for baseline retrievals of ice effective radius and similar quantities as partitioned by those cloud phase designations. The expanded activities in FY23-24 and beyond will also leverage a radiative closure and in situ comparison framework to evaluate several additional liquid cloud retrievals of LWP (i.e., Caddedu et al. 2020), drizzle properties (i.e., O'Connor et al. 2005) and cloud properties (i.e., adiabatic and Frisch 1995). These efforts will use the Rapid Radiative Transfer Model (RRTM) to determine radiative flux profiles for radiative closure, and take advantage of campaign options such as ARM aerial Gulfstream-1 (G-1) in situ observations during ACE-ENA periods for evaluation.

3.1.1.4 Expanded Release of Sunphotometer "Cloud Mode" VAPs (SPHOCOD)

New sunphotometer cloud VAPs are expected in production by late FY22 and provide ARM users new retrievals for cloud optical depth, liquid water path, and cloud drop effective radius for a variety of broken-to-overcast cloud conditions. These property retrievals will become available for multi-year records at ARM's fixed sites (SGP, ENA, NSA) and AMF deployments starting in FY23-24. Intercomparisons of key retrieved quantities with ARM's MICROBASE VAP will also be performed during the plan period.

3.1.1.5 Towards Improved Retrievals in Shallow Clouds

Vertical velocity and its retrieval has been highlighted as an ongoing challenge for studying cloud processes, specifically process studies in shallower clouds. This Translator Plan proposes several advancements that may improve future retrievals working in conjunction with the ARM mentors and ASR PIs. Proposed activities include implementation of cloud radar Doppler spectra decluttering and higher-moment spectral processing to a new KAZR radar data set product working with ARM radar data mentors. The efforts will start from SGP in FY23 and build to additional sites including TRACER by FY24. Such changes will immediately improve the quality of existing VAPs such as ARSCL cloud designations by mitigating insect contaminants. These ideas have been recently applied to the SGP LASSO data sets working in conjunction with ASR PIs (e.g., Williams et al. 2021).This new availability of decluttered moments and higher-order spectral quantities (i.e., skewness, kurtosis) will be directly useful for sparking new process studies, and potential retrievals of vertical air motions or particle size distributions in-cloud typically require these quantities as their input.

3.1.1.6 Profiling Precipitation Radar Capabilities

ARM operates multiple radar wind profilers (RWPs) that enable profiling of precipitation properties immune to attenuation in rain. These RWPs will undergo improved moment processing (de-cluttered, de-aliased) and routine calibration procedures in FY23 starting with the SGP site and AMF-TRACER. This standardization includes adding calibrated radar reflectivity factor measurements to existing RWP data sets. The changes allow a more immediate incorporation of RWP streams into ARSCL (deep convective cloud masks), cloud or hydrometeor phase (i.e., CLDPHASE), and new retrievals of vertical air velocity in deep convective cells following published methods (e.g., Giangrande et al. 2013). Given conditioned RWP data sets, initial higher-level RWP products should be obtainable within this upcoming Translator Plan period into FY25.

3.1.1.7 Advanced Scanning Radar and/or Precipitation Capabilities

The Translators will continue to support the improvements for the Corrected Moments in Antenna Coordinates (CMAC) VAP. CMAC is tailored to site and seasonal changes, and is a framework ready to accept new science from the literature. Looking forward, the major anticipated activity for CMAC in FY23 and beyond will be in support and application to the C-SAPR2 deployment at TRACER, and initial pre-deployment efforts for C-SAPR2's AMF3 move to the Southeast U.S.

In addition to traditional products and anticipated improvements to Py-ART, the Translator group will continue to assist the ARM Radar Engineering group in tool development, data analysis, and similar monitoring to ensure data quality that enables the development of downstream products. Plan activities include radar intercomparisons between ARM radars and nearby partner facilities (i.e., Next-Generation Weather Radar [NEXRAD]), as well as in situ assets including ARM disdrometers. The group expects to finalize availability for radar products for ARM's TRACER and SAIL campaigns, and expand to the EPCAPE deployment and the next AMF3 deployment. New product development with the support of the AMF3 Site Scientist Team is anticipated, including additional echo classification and rainfall information based on standard dual-polarization concepts.

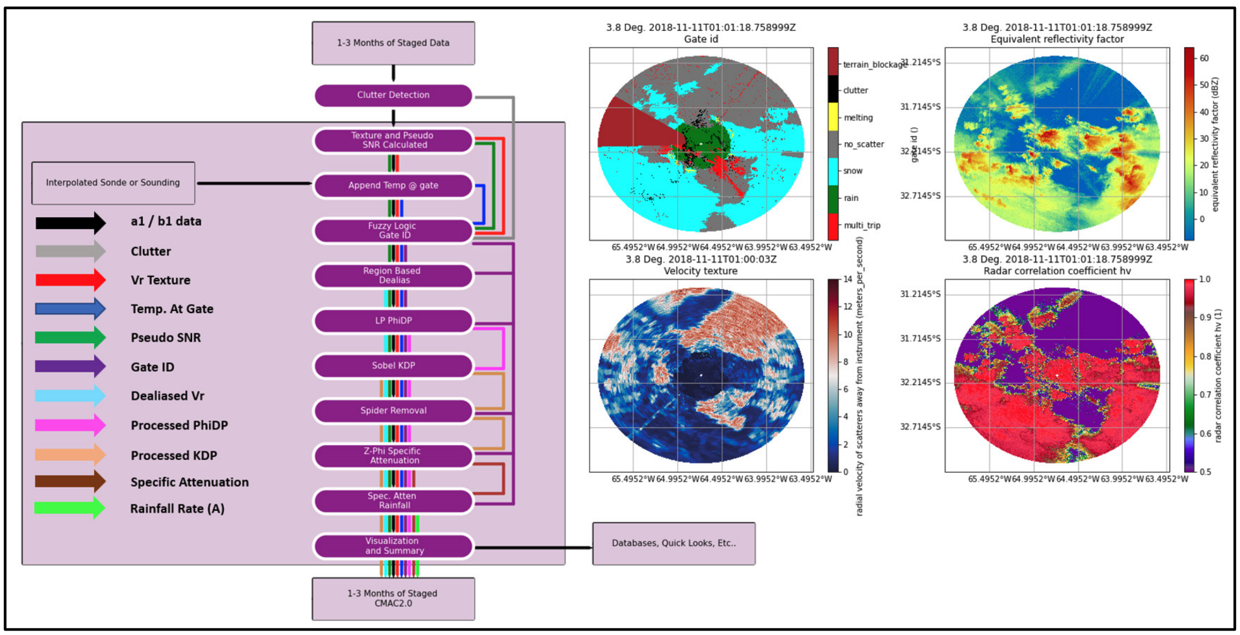

Figure 8. Diagrammatic representation of the CMAC modular framework and an example from C-SAPR2's deployment to CACTI. Each module can be changed. For example, during winter at SAIL, attenuation and/or rainfall modules will be replaced by a snow water equivalent rate retrieval.

Short-term scanning radar priorities during the plan period include:

- Application of CMAC to TRACER. Deriving new rainfall relations for Houston from the literature (or from LDQUANTS). Assessment of the performance on rainfall retrievals.
- Availability of gridded, calibrated SACR data sets (SACRGRIDPPI/SACRGRIDRHI) to include TRACER, EPCAPE, and other SACR deployments at fixed sites (ENA).
- Application of CMAC to the X-Band radar deployed to SAIL. Assessment of performance of the ensemble snowfall product and mapping of the lowest clutter/blockage-free tilt to the surface to make a hydrology product for the SAIL community. Assessment of the conditional performance of the snowfall retrieval.

In addition to the above, new Py-ART activities considered for the plan include:

- Expanded ingest and use of WSR-88D data. Developing a long-term 3D (lat/lon/time) climatology of rainfall over the SGP site.
- Enhancement of ARM remote-sensing assets by curating WSR-88D data in and around the proposed AMF3 SE U.S. deployment site, and value-adding by running CMAC on the data.
- Incorporating (by leveraging available open-source Py-DDA codes from DOE Climate Modeling Development & Evaluation [CMDV]) and generating a 4D (time, height, latitude, longitude) velocity retrieval product over the ARM TRACER, AMF3 site using ARM and nearby partner radars to include WSR-88D and a reanalysis background (e.g., High-Resolution Rapid Refresh [HRRR] analyses).
- Assess community demand for several AMF development VAPs, including Quasi-Vertical Profile (QVP) concepts, wind retrievals by the Velocity Azimuth Display method (VAD) and other gridded radar data options such as the Precipitation Radar Moments Mapped to a Cartesian Grid (MMCG).

3.1.1.8 Two-Way Radar-Retrieval Science Community Activities

Starting with AMF SAIL, the Translators also plan to develop new products aimed at improving the interactions with the radar-retrieval science community, such as extractions of radar gate and other environmental data matched to ARM in situ assets. This is a task often repeated by the community and by doing this ARM can serve a wide range of users. Translators will develop time series and define Epochs for events in which precipitating systems generate measurable solid or liquid precipitation over measurements locations. We will package these as VAPs and include other variables that may be involved in the precipitation process. As an example, the dendritic growth-layer depth for snowfall events may be an interesting variable the community may use in retrieval development. Well-conditioned data sets such as these may be amenable to machine learning approaches.

3.1.2 Proposed New Aerosol VAP Support (2023-2025)

Translators are actively developing responses to the requests of the ARM/ASR communities for advanced aerosol and coupled aerosol-cloud properties as critical to cloud-aerosol-climate process studies and model evaluation. ARM's Decadal Vision called out several capabilities that ARM Translators are pursuing within this Translator Plan, including advancements in the areas of merged aerosol size distributions, CCN profiling and properties, and AOD best estimate products. Several planned activities are detailed below.

3.1.2.1 Merged Size Distributions

Currently, ARM operates at least four different instruments that measure a portion of the ambient aerosol size distribution. Most ARM users are interested in the entire size distribution or a portion of the size distribution that extends across the measurement range of multiple instruments. However, merging these partial size distributions is not trivial because the instruments all employ different measurement principles and, in most cases, report data as a function of different representations of the aerosol diameter. To meet this need, we are developing an algorithm for merging SMPS and APS size distribution measurements. We generated test data at two sites with co-located SMPS and APS and plan on releasing evaluation data. Once SMPS/APS merged distributions are released, we will begin working on merging data from other sizing instruments (e.g., SMPS and UHSAS).

3.1.2.2 CCN Profiles

Surveys of aerosol data users have consistently highlighted the need for information on the vertical distribution of aerosol particles. To meet this need, we began re-evaluation of a CCN vertical profile VAP that was begun but never finished and released. This VAP combines CCN and Raman lidar data to estimate the vertical profile of CCN up to cloud base. We released evaluation data for a 9-month period at SGP. Unfortunately, the existing algorithm required an input datastream that no longer exists, so we are currently developing a replacement datastream based on measurements available at more ARM sites. We will also implement more advanced QA/QC tests and compare this VAP data to available in situ aircraft measurements.

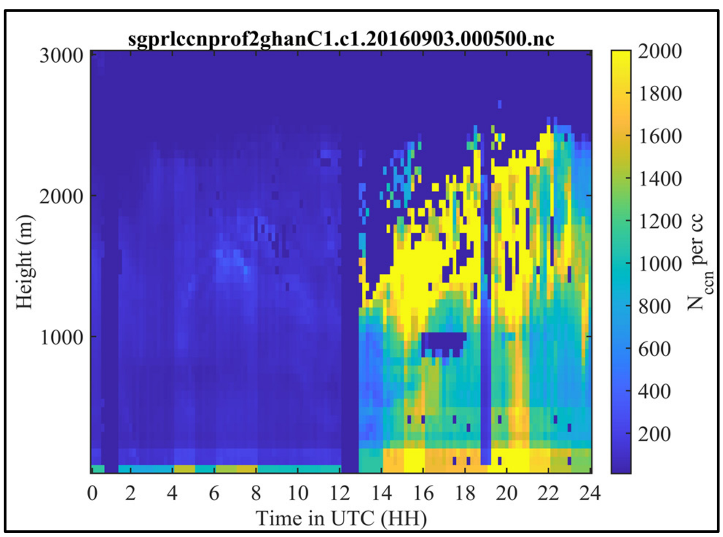

Figure 9. CCN vertical profile at 0.4% supersaturation at the SGP site on September 3, 2016. Data are preliminary.

3.1.2.3 AOD Best Estimate (AOD-BE)

ARM deploys several instruments capable of reporting AOD and related remote-sensing aerosol optical products (e.g., MFRSR and Cimel sunphotometer). The AOD-BE VAP assesses agreement between collocated multiple measurements, evaluates measurement uncertainty, and provides a recommended value for several aerosol optical properties. This VAP covers the spectral range spanned by silicon photodetectors for the SGP site and we are working toward extending it to ENA and NSA. AOD-BE will make clear to users the best AOD measurements available.

3.1.2.4 Aerosol Feature Detection

A new VAP providing vertically resolved aerosol feature detection using ARM lidar measurements will be developed in FY23. The VAP first uses HSRL backscatter coefficient and depolarization data to detect aerosol features following the lidar scattering ratio method by Thorsen et al. (2015), and then it will be extended to fully calibrated MPL data so that the VAP can be available for all ARM fixed sites and AMF field campaigns.

3.1.3 Proposed Modeling VAPS and Modeling Outreach

To increase the impact of ARM data on improving Earth system model simulations, the Translators propose to continue their activities in support of the data analysis needs of modelers, and further outreach to the modeling communities for feedback. The Translator group currently has a close tie to the DOE E3SM community, and the GEWEX Global Atmosphere System Studies (GASS), Global Land-Atmosphere System Studies (GLASS), and Global Data and Analysis Panel (GDAP) panels. Planned efforts will emphasize making connections to a broader modeling community including Community Earth System Model (CESM), Geophysical Fluid Dynamics Laboratory (GFDL), Weather Research and Forecasting Model (WRF), Model Diagnostics Task Forcing (MDTF), National Center for Environmental Prediction (NCEP), and European Center for Medium-Range Weather Forecasts (ECMWF). An anticipated pilot program in FY23-25 will be to assign a Translator to each of the identified modeling groups to routinely seek feedback from communities using ARM data. To complement the current crop of VAPs aimed at modeling users (e.g., ARMBE, VARANAL, LASSO-O), Translators propose to develop the following new VAPs aimed at these communities.

3.1.3.1 ARMBE for Aerosol and Cloud Properties

The current ARMBE data products do not include the needed aerosol and cloud microphysical properties that are often used in model evaluation and aerosol-cloud interaction diagnostics. These quantities include aerosol extinction, AOD, CCN, cloud droplet effective radius, cloud droplet number concentration, cloud liquid water content, cloud optical depth, etc. The new ARMBE product will be produced based on a best estimate of these quantities from the ARM observations. Additional stringent data quality controls will be applied to these quantities.

3.1.3.2 ARM-DIAGS for Aerosol-Cloud Interactions and Land-Atmosphere Interactions

The ARM Translator team has developed an ARM data-oriented metrics and diagnostic package (ARM-DIAGS) for the global climate community to facilitate the use of ARM data in climate model development and evaluation. This package will be enhanced to include diagnostics for Aerosol-Cloud Interactions (ACI) and land-atmosphere interactions (LAI). The ACI diagnostics include metrics such as the climatology of cloud and aerosol properties, and the magnitude of an index describing the ACI processes. The LAI diagnostics are based on the Local Coupling metrics described in Santanello et al. (2018) for the ARM SGP site.

Additionally, several VAP activities targeted at modeling users are under various stages of development for availability over the next few years across the Translator groups. These include:

- ARM radar CFAD (contoured frequency by altitude diagram) data products, for example, as based on CloudSat-calibrated ARM KAZR data sets, to couple with ARM forward radar simulators.
- An ARM lidar backscattering ratio joint histograms data product to pair with an ARM forward lidar simulator.
- A cloud phase VAP (CLDPHASE) and/or fractional liquid/ice cloud properties as determined by radar and/or multi-instrument methods (e.g., MICROBASEKaPlus, SPHOTCOD).
- Various new PBL Height VAPs for multiple ARM instruments (i.e., PBLHT, PBLHT-MPL).

3.1.4 Proposed Software Tools, Development, and Enhancement

Owing to recent ARM success in open-source tools, the Translators expect increasing community support for open science as an area of potential VAP growth/demand. While the pace of this transition may vary across Translator activities, this tracks with similar advancements seen in other agencies (i.e., the Transform to Open Science [TOPS] initiative at the National Aeronautics and Space Administration [NASA] https://science.nasa.gov/open-science/transform-to-open-science), journals, and institutions that are moving in this open-source, open-science direction.

Several mainstay VAPs such as ARSCL are mature projects that have migrated through various coding languages (i.e., C, IDL, Matlab) over several decades. While these VAPs are currently functional and/or stable, it is often inevitable that previous production choices become less flexible to handle updates at low cost. For example, current code-language choices (i.e., IDL) for existing VAPs do not as easily address demands for anticipated drivers such as the ADC’s “Data Workbench” that will enable users to access/process data and run VAP codes directly on ARM’s high-performance computing. A shift to an open codebase for several VAPs should also promote user-driven improvements, new methods for ARM to incorporate uncertainty estimates, and increased data use. We anticipate that modernized codebases in Python will be more requested over the next few years, cheaper, and/or potentially required to maintain VAP functions on newer ARM systems. These efforts should help streamline the VAPs, and serve as a proper foundation to incorporate several known fixes to VAPs that ultimately will replace the legacy code.

In addition to support of modernized codebases, Translator activities for open-science projects include:

- In coordination with ADC’s Data Workbench, an initiative to make open workforce development tutorial materials available as Jupyter cookbooks that operate on those systems (Section 5).
- Translators will identify key VAPs to develop/advance open-source/Python materials, either as new packages, redesigns of core VAPs in more open-accessible languages, or as cookbook/workflows to improve VAP visualization. High-impact examples will include ARSCL and ARSCL-adjacent VAPs such as MICROBASE.

4.0 Support for ARM AMF Deployments

In ARM's 2020 Triennial Review, it was recommended that ARM pursue improvements to AMF data set characterization, and provide detailed analysis of product availability and instrument performance. Beginning with the CACTI campaign, Translators undertook a pilot program to assign a Translator POC to AMF campaigns and their lead PIs to coordinate with the associated AMF staff, ensure VAP appropriateness, provide timely VAP delivery during or shortly following campaigns, improve instrument monitoring throughout the campaign, and assist PIs with post-campaign documentation. One successful example was Translator support for supplemental materials, instrument availability and characterization, and designation of cold-air outbreak (CAO) events for the ARM COMBLE campaign (e.g., Geerts et al. 2022). For this cycle, the Translators are confident in establishing these AMF POC roles and responsibilities for PI interactions, including promoting AMF Data Epochs to permanent fixtures for Data Discovery moving forward. Expectations governing these roles are found below.

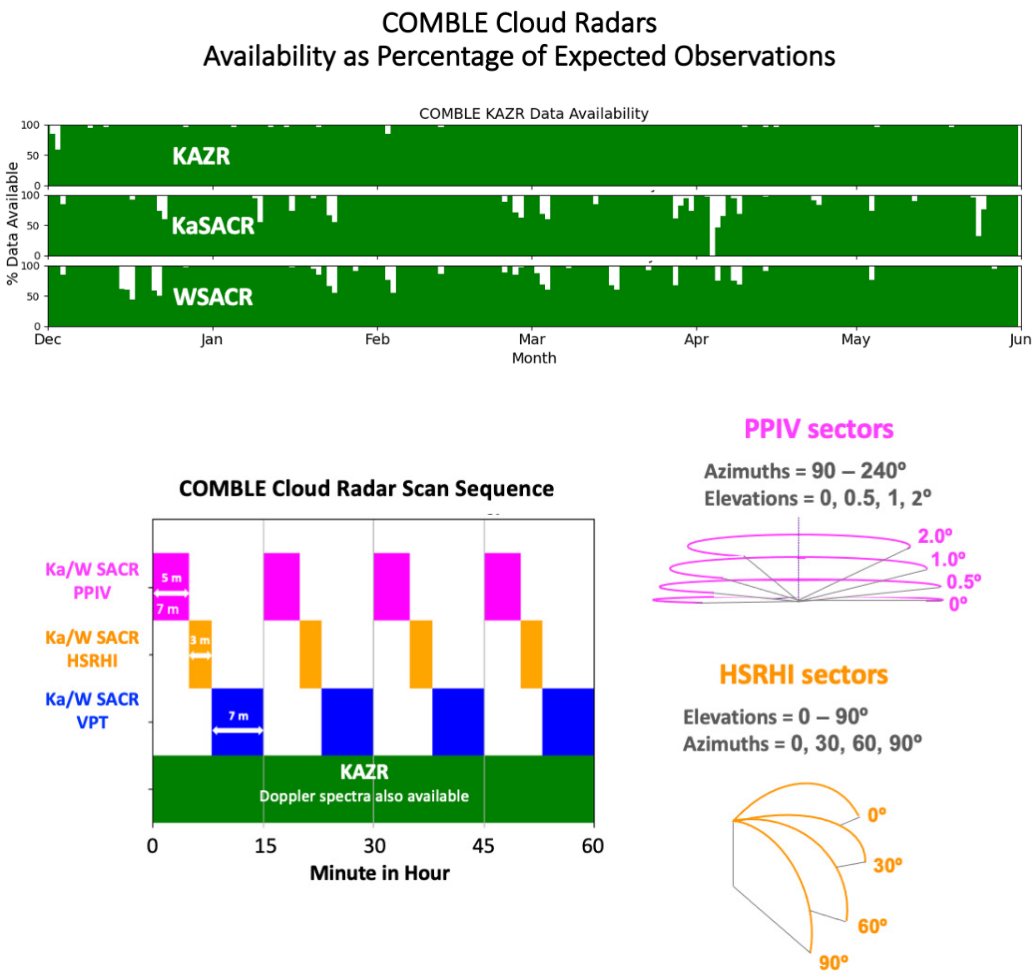

Figure 10. Example of ARM radar uptime and scanning information provided for the COMBLE campaign.

4.1 POCs: Roles and Responsibilities

For upcoming AMF deployments, the Translators will assign a POC to assist campaign PIs. While the needs of every campaign and its PIs will be different, Translators will be encouraged to work with infrastructure leads to assist in AMF planning, monitoring, and identification of potential product/instrument gaps or limitations. These roles may include, but are not limited to the following.

4.1.1 Pre-Campaign POC Roles and Responsibilities

- Translators assign a POC for the AMF deployment and coordinate as needed with the associated ARM AMF infrastructure leads and ARM's instrument mentors.
- Engage in initial outreach to the AMF PI as the POC.
- Establish core VAP expectations (e.g., as based on AMF Science Plan, etc.), anticipated VAP timetables, and supplemental VAP requests that may be accommodated by Translator groups.
- Identify external data sets or model outputs of campaign/VAP interest, partner/IOP data sets, PI product possibilities, and similar opportunities for possible ARM archival.
- Identify, with support from the AMF PI, Translator teams, as well as constituent/stakeholder groups, any potential Epoch or virtual IOP conditions for campaign scientific foci or attendant atmospheric regimes. Monitor these conditions for eventual Data Discovery incorporation.
- Identify key instruments and potential downtimes most critical for high-impact VAP production.

4.1.2 In-Campaign POC Roles and Responsibilities

- Maintain routine communication with the AMF PI, including potential attendance on regular AMF team/operations telecoms, or other campaign vehicles (i.e., Slack, email, field campaign dashboard).
- Establish and/or support ongoing monitoring of the record for ARM instrument performance and uptime. This will be in coordination with ARM mentor leads.
- In conjunction with, and/or as requested by ARM and/or the AMF PI, assist with advanced coordination specific to potential forecast-driven, agile, IOP or other necessary instrument changes. In particular, identify those changes that may impact routine VAP delivery or Data Discovery.

4.1.3 Post-Campaign POC Roles and Responsibilities

- Ensure delivery and/or follow-up for requested VAPs and their documentation.
- Support AMF PI in final campaign reporting to the ARM facility.
- Work with AMF PIs and/or ARM's ADC and Data Discovery to implement any associated Data Epoch or virtual IOP campaign summary, incorporation of data into ARM data search capabilities (see Section 4.2), or code/processing needs.

4.2 Data Epoch/Virtual IOP

ARM stakeholders repeatedly request an ARM Data Discovery capability that incorporates location, regime classifications, improved data quality, or similar concepts into ARM search options. Within the Data Discovery tool, ARM's response has been to develop a framework to display Data Epochs (i.e., periods of well-characterized data) and provide other allowances for the filtering of ARM data using metadata tags. For example, metadata tags may include concepts such as cloud regime or type, aerosol loading, or other meteorological conditions that help identify cases of scientific interest. A proof-of-concept unveiling for Data Epoch search capability is currently available for a small subset of observations during field campaigns for which data sets have been well-characterized by mentors, Translators, and the Data Quality Office working in conjunction with PIs to ensure attention to measurements, and/or where PIs kept detailed logs of interesting cases (i.e., CACTI and COMBLE).

There are several plans in which Translators will help expand this library of Epochs and complement the Data Discovery efforts that are already underway. First, Translators serving as POCs for upcoming field campaigns (previous section) will play a critical role in working with PIs for identifying and consolidating metadata information in submissions to the ADC metadata team. Second, our group can identify key data sets that are commonly bundled and/or ordered jointly, and support efforts to group data sets often requested on a common temporal resolution grid (Data Consolidation, see Section 5.1). Lastly, Translators will contribute to the development of unique Epochs at ARM's fixed sites through analysis of long-term data sets, VAPs, or the generation of new-regime VAPs. For example, existing VAPs may help identify periods of interest, such as cloud regimes at SGP using the CLOUDTYPE VAP, or use of the CLDPHASE VAP to identify mixed-phase clouds at NSA. Additional analysis of VAP output, such as comparisons of data from aircraft, satellite, or similar ground-based instruments (i.e., AOD Best Estimate, or QCRAD), would provide additional characterization of ARM's key data sets.

In FY23-25, we anticipate ARM and its Translators will dedicate effort to the following Epoch-related data sets (not comprehensive):

- Long-term characterization of ARSCL at SGP;
- Lidar aerosol profiles at SGP;
- Liquid water path estimates (and additional microphysical retrievals) at SGP and ENA.

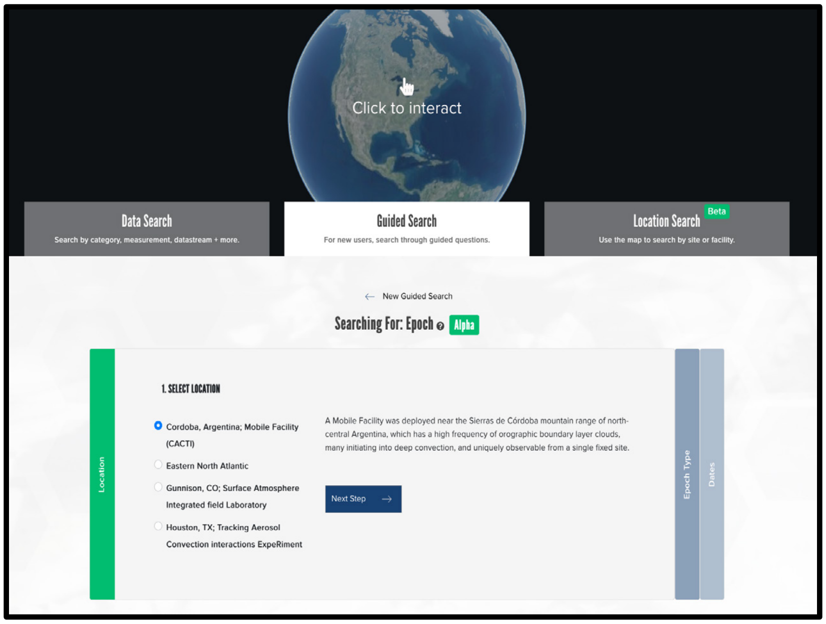

Figure 11. Example of Epoch-searching capability on the ARM Data Discovery website.

5.0 Improving User Experience/Data Discovery and Accessibility

Translators are a key link between ARM and constituent user groups. Practically speaking, Translators are the first point of contact when users have questions regarding the best data sets to meet their needs, data quality, or difficulties encountered when finding, downloading, or using ARM data. Thus, Translators are often in a unique, best position to contribute improvements to the typical ARM user experience with the goal of increasing the use and impact of ARM data. Our current plan proposes to continually improve Data Discovery and services, improve data accessibility by providing tools for data visualization and analysis, and improve uncertainty quantification in ARM data sets.

5.1 Data Consolidation

The Translators and ARM/ASR stakeholders have expressed a need for a data services mechanism that consolidates ARM data – as from multiple instrument streams or VAPs – on a coordinate grid of their choosing. These tools will eliminate a common PI bottleneck for having to expend time and resources in preprocessing ARM data to perform these forms of data consolidation. One advantage for an ARM- and Translator-supported initiative is to ensure that this data consolidation is done correctly, while incorporating advanced capabilities such as importing/aggregating the associated Data Quality Reports (DQRs) or similar Data Quality (DQ) assessments. The existing ARM Data Integration (ADI) framework provides this capability through web interfaces used to define the VAP process and data object design (DOD) definitions. Several Translators, mentors and ARM PIs regularly use these capabilities when developing prototype VAP algorithms and performing ARM/ASR research, but most ARM users are not familiar with these capabilities. The functionality supported from the ADI Process Configuration Manager (PCM) Process browser window includes:

- Providing a "wizard mode" interface that walks a PI user through a simplified set of steps to select variables from ARM products, to help define the new time/output grid, to help select a data transformation, and/or names to assign the variable in the output.
- Execution of this consolidation process for a given site and time range, with run-time options to integrate QC and DQR assessments that will result in output values being automatically set to missing value as appropriate.
- Ability for the user to review output data, create plots, and review logs.
- Ability for the user to download output data.

The short-term ADI development plan milestones include an effort to provide the capabilities described above to the ARM Translators, stakeholder groups, and extended ARM data users by also setting up non-ARM versions of the PCM and Dataset Database (DSDB) databases on separate servers and web service that are available to those users with an ARM Lightweight Directory Access Protocol (LDAP) password.

5.2 Improved Data Visualization and "Cookbooks"

Current VAP visualization includes quicklook plots created by the VAP algorithms, and thumbnail plots of individual measurements supported through Data Discovery. These provide users a method to explore, develop, and understand ARM data. However, the static nature of the plots limits their usefulness. It is recognized that more dynamic and flexible visualization tools could improve a data user's ability to quickly and accurately identify the data that best meets their needs. ARM is evaluating the use of Jupyter notebooks to provide such a mechanism. By design, Jupyter notebooks (or related "cookbooks") present a framework for providing executable Python source code to the user in a way that allows them to simply use the notebook as is, make minor modifications, or augment it with their own code. This implies that Jupyter notebooks provide users who have little programming experience with an easy-to-use, dynamic data exploration experience, but also give more advanced users the platform/access to ARM data to perform advanced analysis.

A suite of Jupyter notebooks (one for each ARM VAP data product) that use Python programming language and ARM ACT plotting libraries are currently being prototyped and evaluated. The source code of the notebooks is generated using templates that (i) provide basic measurement plotting capabilities, (ii) present code in a manner (with supporting information) that makes it easy for users to understand the code, and (iii) add ability to apply small alterations to produce plots for the locations and at the scale that interests users. The template script uses the ARM metadata and VAP processing databases to determine the measurements, sites, and date ranges that should be plotted for each ARM VAP data product. It also supports creating custom plots or customizing the standard plots for particular VAPs via a configuration file. Separately, Translators will be empowered to review these defaults, add modifications, and replace or improve plotting as appropriate for each VAP. These changes would be codified in the form of notebooks that are versioned and released as part of the normal VAP development cycle. A possible approach to maintain security and minimize impact on ARM processing resources could be to configure JupyterHub such that it would create a container within which a user's instance of a specific notebook could be launched. By operating within a container, the notebooks would be isolated from the ADC system to minimize the security risk, but still can be given read-access to archived data.

This approach would also provide a mechanism to control the amount of memory provided per container and how long the container is allowed to run.

As above, this initial set of notebooks with generic plotting capabilities to support custom plotting is currently being prototyped to establish proof of concept. If our assessment reveals this is an appropriate avenue to improve the ARM data user's data exploration experience, additional efforts that could be pursued in FY23-25 include:

- Refining existing notebooks to address errors, develop a uniform method of error handling.
- Working with Translator groups to:
  - Determine whether generic plot support is appropriate for their VAP products.
  - Determine whether the basic plotting can be modified or augmented (via limits overlayed on variable plots, or text displayed when plotting certain variables).
  - Identify and develop custom plots.
- Examining extending plot templates to include plots that highlight ARMs recommended measurements and Data Epochs.
- Exploring how to make this capability widely available to typical ARM users so they can use it as a means of exploring data before ordering.

A screen shot from one of the prototype notebooks is provided below. The source code provided to the users presents all possible launch samples and allows the user to select which of those to plot.

Skew-T Plot

```
launch_times = [str(datetime.strptime(''.join(f.split('.')[-3:-1]), '%Y%m%d%H%M%S'))
for f in files_list]
print('Available sonde launch times:')
display(pd.DataFrame(launch_times, columns=['Launch Time']))
# select sonde launch time from the list
launch_time_index = 0
sonde_file = files_list[launch_time_index]
sonde_ds = act.io.armfiles.read_netcdf(sonde_file)
# Calculate stability indicies
sonde_ds = act.retrievals.calculate_stability_indicies(
    sonde_ds, temp_name='tdry', td_name='dp', p_name='pres', rh_name='rh'
)
# Set up plot
skewt = act.plotting.SkewTDisplay(sonde_ds, figsize=(7, 10))
# Add data
skewt.plot_from_u_and_v('u_wind', 'v_wind', 'pres', 'tdry', 'dp',
                        set_title=f'Skew-T Plot for {launch_times[launch_time_index]}')
sonde_ds.close()
plt.show()
```

```
Available sonde launch times:
```

	Launch Time
0	2012-08-31 05:32:00
1	2012-08-31 11:29:00
2	2012-08-31 17:28:00
3	2012-08-31 23:34:00

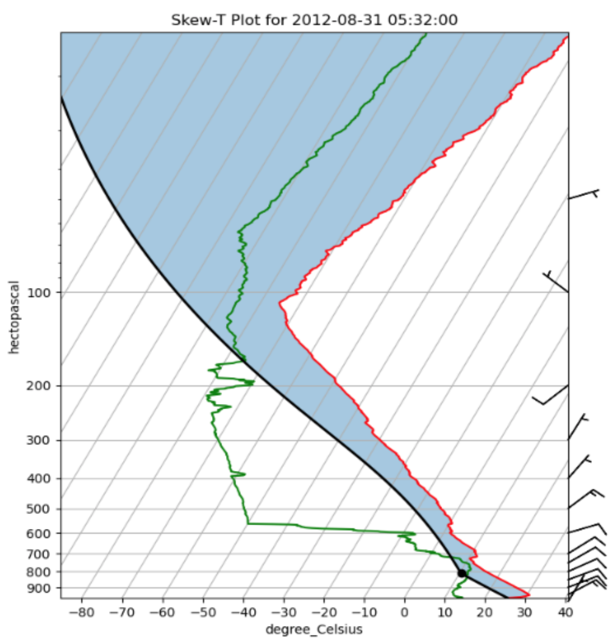

Figure 12. An example of a VAP notebook providing users with the ability to explore data prior to ordering.

5.3 Uncertainty

Uncertainty and/or uncertainty quantification is an ongoing challenge in ARM and its extended community that will undoubtedly continue past the end date for this Translator Plan. The challenges for uncertainty and its reporting are exacerbated because it is often difficult to define what uncertainty a user demands: for example, whether a user is satisfied with an instrument system uncertainty (random or systematic errors), a field or multi-instrument/collocated measurement uncertainty, uncertainty as related to the measurement or retrieval resolution, a retrieval uncertainty that may stem from physical process variability, among many other contributing factors (e.g., Sisterson 2017). Overall, we suggest there are few one-size-fits-all solutions that work perfectly for all data or retrievals/products, though ARM Translators will continue to pursue data set documentation and attributes, webpage content updates, and other media to inform users of data quality and appropriate use.

Specifically, Translators have attempted to address these issues by incorporating various instrument or retrieval uncertainty efforts into their VAP activities. For several planned VAPs, the most common and continuing approaches include input or retrieval coefficient perturbation techniques that help establish a potential range of possible solutions and/or variability as related to instrument miscalibration or other physical process uncertainty (i.e., MICROBASEKaPlus, SPHOTCOD). Translators have also guided several recent efforts including radar calibration reporting (e.g., Geertz et al. 2022), as well as disdrometer intercomparisons to understand how systematic biases between collocated instruments may impact downstream products and variability/interpretations therein (e.g., Giangrande et al. 2019, Wang et al. 2021; LDQUANTS). Similarly, AOD from multiple co-located remote-sensing instruments is compared and assessed in the AOD-BE VAP. Currently, the aerosol Translator group is participating in an intercomparison exercise with other ARM PIs aimed at understanding uncertainties in deriving kappa from CCN and SMPS measurements (i.e., the CCN kappa VAP data). Similarly, the aerosol Translator and ACSM instrument mentor have investigated the closure between ACSM-derived aerosol volume (from the ACSMCDCE VAP) and aerosol volume derived from co-located aerosol size distribution measurements. Uncertainty assessments are also included in AERIoe, MWRRET (e.g., Turner and Lohnert 2014), using optimal estimation techniques, and DLPROF and Raman Lidar Vertical Profiles (RLPROF) (e.g., Newsom et al. 2017) using standard error propagation of random and systematic errors.

However, Translator activities will require further two-way interaction with the ARM stakeholders (e.g., UEC, CPMSG, AMSG) and PIs on these themes. For the upcoming plan period, the Translators will propose several ARM product intercomparisons that benefit from the longer-term ARM data records. At the time of this writing, the Translators suggest that there is momentum within ARM stakeholder groups for many forms of cloud property intercomparisons that include studies of ARM cloud base measurements, PBL height product comparisons, and evaluation of other basic microphysical retrievals in shallow/marine boundary-layer (MBL) clouds (e.g., LWP, cloud optical depth [COD]). Our efforts will also cover continued Translator support for radar calibration and monitoring support as critical to advanced radar product development needs (outlined also by ARM's recent Radar Plan and radar mentor activities).

6.0 Summary

This document summarized the accomplishments by the Translator group since the previous Translator Plan, and covered a coordinated vision of Translator priorities for the next three years as discussed in a meeting of the Translator Group in January of 2022. This document was influenced by feedback from the recent Triennial Review process, the User Executive Committee, the ARM Decadal Vision, and user feedback from DOE Biological and Environmental Research (BER) and ASR program groups. This document intends to improve communication and prioritization with various stakeholders and maximize the impact of our work.

In particular, we will focus our development over the next three years on several key areas, as follows:

1. To provide new products and tools, as well as improvements to existing data products and services, for the retrieval of aerosol and cloud properties, atmospheric and thermodynamic profiling, and ease in model-observational intercomparison.
2. To support ARM AMF deployments and deployment PIs, including improved communication on data products, services and VAP request processes, including through service as POCs for AMFs, as well as through new Data Discovery search capabilities from AMF-themed Data Epochs.
3. To improve the ARM user experience through support of new tools for data consolidation, additional resources including cookbooks and similar open-source ARM data visualization and processing materials, and improved communication of uncertainty through interactions and activities with the ARM PI community.

This work will be done in collaboration with others in ARM and our user community, as new tools, techniques, and developments in ARM systems are made to facilitate new science. The Translator Group will provide leadership to others in the ARM infrastructure on high-priority science needs for additional development.

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