U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-17-039

Translator Plan: A Coordinated Vision for Fiscal Years 2018-2020

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January 2018

ARM CLIMATE RESEARCH FACILITY

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AACT	ARM-ASR Coordination Team
AAF	ARM Aerial Facility
ACE-ENA	Aerosol and Cloud Experiments in the Eastern North Atlantic
ACSM	aerosol chemical speciation monitor
ADI	ARM Data Integrator
AERI	atmospheric emitted radiance interferometer
AERONET	Aerosol Robotic NETwork
AGU	American Geophysical Union
AIP	Aerosol Intensive Properties
AMF	ARM Mobile Facility
AMSG	Aerosol Measurement Science Group
AOP	Aerosol Optical Properties
AOS	Aerosol Observing System
APS	aerodynamic particle sizer
ARM	Atmospheric Radiation Measurement
ARRA	American Recovery and Reinvestment Act
ARSCL	Active Remotely-Sensed Cloud Locations
ASCII	American Standard Code for Information Interchange
ASR	Atmospheric System Research
ASSIST	Atmospheric Sounder spectrometer for Infrared Spectral Technology
AWARE	ARM West Antarctic Radiation Experiment
BAMS	*Bulletin of the American Meteorological Society*
BER	Biological and Environmental Research (DOE)
CAPS	cavity attenuated phase shift extinction monitor
CCN	cloud condensation nuclei
CDP	Community Diagnostics Package
CEIL	ceilometer
CFADS	Contour Frequency by Altitude Diagrams
CFMIP	Cloud Feedback Model Intercomparison Project
CIP	cloud imaging probe
CLAP	continuous light absorption photometer
CMAC	Corrected Moments and Antenna Coordinates
CMDV	Climate Model Development and Validation
COSP	CFMIP Observation Simulator Package
COTS	commercial off-the-shelf

CSAPR	C-band Scanning ARM Precipitation Radar
CSPHOT	Cimel Sun Photometer
DL	Doppler lidar
DMF	Data Management Facility
DOE	U.S. Department of Energy
DOI	digital object identifier
DQO	Data Quality Office
DQR	Data Quality Report
DSD	raindrop size distribution
ECMWF	European Centre for Medium Range Weather Forecasts
ECOR	eddy correlation flux measurement system
ENA	Eastern North Atlantic
FEX	Feature detection and EXtinction
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FY	Financial Year
GCM	global climate model
GHG	greenhouse gas monitor
GPM	Global Precipitation Measurement (NASA satellite)
GPS	Global Positioning System
HSRL	high-spectral-resolution lidar
HTDMA	humidified tandem differential mobility analyzer
IOP	intensive operational period
IRT	infrared thermometer
KAZR	Ka-band ARM Zenith Radar
LASIC	Layered Atlantic Smoke Interactions with Clouds
LASSO	LES ARM Symbiotic Simulation and Observation
LBL	Lawrence Berkeley National Laboratory
LES	large-eddy simulation
LW	longwave
LWP	liquid water path
MAO	Manacapuru, Brazil
MARCUS	Measurements of Aerosols, Radiation, and Clouds over the Southern Ocean
MASC	multi-angle snowflake camera
MMCG	precipitation radar Moments Mapped to a Cartesian Grid
MPL	micropulse lidar
MWR3C	three-channel microwave radiometer
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration

NOX	nitrogen oxides monitor
NSA	North Slope of Alaska
OGRE-CLOUDS	Operational Ground-Based Retrieval Evaluation for Clouds
OLI	Oliktok Point, Alaska
OLYMPEX	Olympic Mountain Experiment
OMI	ozone monitoring instrument
PI	Principal Investigator
PIP	precipitation imaging probe
PSAP	particle soot absorption photometer
PWV	precipitable water vapor
Py-ART	Python ARM Radar Toolkit
QA	quality assurance
QC	quality control
QVP	quasi-vertical profile
rBC	refractory black carbon
RL	Raman lidar
RWP	radar wind profiler
SACR	Scanning ARM Cloud Radar
SASHe	shortwave array spectroradiometer – hemispheric
SASZe	shortwave array spectroradiometer – zenith
SGP	Southern Great Plains
SIMEPAR	Sistema Meteorologico do Parana
SO2	sulfur dioxide monitor
SP2	single-particle soot photometer
SW	shortwave
TAP	tricolor absorption photometer
TOMS	total ozone mapping spectrometer
TSI	Total Sky Imager
TWP	Tropical Western Pacific
UAV	unmanned aerial vehicle
UEC	User Executive Committee
UHSAS	ultra-high-sensitivity aerosol spectrometer
UTC	Coordinated Universal Time
VAD	velocity-azimuth display
VAP	value-added product
XDC	External Data Center

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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) Climate Research Facility, offering scientific input through various leadership and service roles as well as directing the creation of value-added products (VAPs) and analysis tools to make ARM measurements more accessible to a broader swath of the scientific community. Translators also serve as a bridge between science users, particularly the ASR science team, and the ARM infrastructure, collecting information about scientific priorities and communicating information about ARM data and services to users.

The Translator Group consists of the five ARM Translators, a representative of Software Development, and the Data Quality Office (DQO) as described in Table 1. Additionally, the Engineering and Process Manager participates in the group in order to provide input and direction from ARM programmatic priorities.

Table 1. Members of the Translator Group.

Name	Institution	Role
Jennifer Comstock	Pacific Northwest National Laboratory	Engineering and Process Manager
Laura Riihimaki	Pacific Northwest National Laboratory	Translator (Lead), Clouds—Radiometric/Lidar
Scott Collis	Argonne National Laboratory	Translator, Py-ART/Precipitation Radar
Connor Flynn	Pacific Northwest National Laboratory	Translator, Aerosols
Scott Giangrande	Brookhaven National Laboratory	Translator, Clouds—Radar/sonde
Shaocheng Xie	Lawrence Livermore National Laboratory	Translator, Modeling
Justin Monroe	University of Oklahoma	Data Quality Office—DQO VAP lead
Chitra Sivaraman	Pacific Northwest National Laboratory	Software Development

1.1 Motivation

In June of 2017, the Translator Group met to develop this coordinated three-year vision plan, incorporating key feedback and aligning to ARM's mission priorities. This plan responds to a shift in how we determine our priorities, given the new needs of the ARM Facility. In the past, individual Translators have determined priorities in conversation with individual DOE Atmospheric System Research (ASR) working groups. To better support ARM's *Decadal Vision* (https://www.arm.gov/publications/programdocs/doe-sc-arm-14-029.pdf), however, the Translator Group is instead developing a coordinated response to needs from our user community to better balance resources and skills among participants. This approach agrees with direction from ARM leadership and the ARM-ASR Coordination Team (AACT).

To develop this plan the Translator Group reviewed feedback received from the User Executive Committee (UEC) and the Triennial Review, as well as priorities from ASR working groups and Principal

Investigators (PIs), the LES ARM Symbiotic Simulation and Observation (LASSO) project, and new instrumentation and activities as described by the ARM Technical Director. In particular, we are responding to the advice that we were trying to do too much, and should focus on providing additional support to data quality, uncertainty assessment, a timeline for producing core VAPs from ARM Mobile Facility (AMF) campaigns, and supporting key aspects of the *Decadal Vision*.

1.2 Document Contents

Section 2 of this document summarizes the accomplishments achieved by the Translator Group over the 2014-2016 period to give context to future plans.

Sections 3-7 describe the five key areas where the Translator Group will prioritize work in the next three years: modeling and tools to facilitate use of ARM data (Section 3); core VAPs where we will focus our efforts for maintenance and AMF deployments (Section 4); supporting new instrumentation to provide basic scientific information from new ARM instruments (Section 5); uncertainty assessment of strategic measurements (Section 6); and improving and communicating data quality of those strategic measurements (Section 7).

Section 8 lists collaboration needs we have for others in the ARM infrastructure and science community. Section 9 summarizes the main goals. A discussion on prioritization in Appendix A allows for flexibility in scope depending on funding levels. Finally, Appendix B lists potential future activities that were discussed at the Translator Workshop in June 2017, but that the Translator Group does not currently plan to work on.

2.0 Accomplishments from 2014 to 2016

To better understand the scope of what can be accomplished in three years and the current state of Translator activities, the Translator Group reviewed the accomplishments over the previous three-year period, from 2014 to 2016.

These accomplishments are summarized as progress on traditional VAP data products, support for new instrumentation including the Aerosol Observing System (AOS) harmonization and radar plan, and new tool development.

2.1 Value-Added Products

Over the course of 2014-2016, the Translator Group released 20 new evaluation or production data sets to the ARM Data Archive to be available to the scientific community. These products are shown in Table 2 along with the year in which they were started and the year in which evaluation or production data sets were released. The timing of development is influenced by a number of factors including the complexity of the product, feedback from users or science leads, roadblocks from factors outside of Translator control (such as changes to the instrument, data quality hurdles, etc.), the availability of developers with the appropriate expertise, and changes in scope or priorities over time. The table shows that the typical development cycle of most new VAPs takes more than a year, with some of the more complex VAPs requiring 3-4 years, if responding to challenges such as ensuring quality of new measurement data or developing an automated data product from a prototype that has only been run on short periods of data. Thus, thinking about VAP development over a three-year period is a useful time scale for identifying priorities. Note also that many of these data products run at multiple sites though they are listed only once in the table.

Table 2. VAP data released between 2014 and 2016.

	VAP	Year started	Evaluation	Production
1	NDROP	2012	2013	2014
2	KAZR1ARSCL	2012	2015	2016
3	KAZRCOR	2012	2015	2016
4	QCECOR	2012	2016	
5	MICROBASE Ensemble data	2013	2015	
6	MWRRETv2	2013	2016	
7	AREALALB	2014	2015	
8	ARMBE2DGRID	2014	2014	2016
9	ARMBE2DSTNS	2014	2014	2016
10	DLPROF VAD	2014	2014	2015
11	DLPROF WSTATS	2014	2014	2015
12	NAVBE	2014	2015	
13	RADFLUX	2014	2015	2016
14	SACRCOR	2014	2015	
15	SHIPCOR: CEIL/HSRL/MPL	2014	2015	
16	OKM SOIL MOISTURE (XDC)	2014	2016	
17	Radar CFADs	2015	2016	
18	MASC	2015		2016
19	CLDTYPE/SHCU	2016	2016	
20	SACR-ADV-VAD	2016	2016	

In addition to released VAP data, development was started on 11 additional new VAPs during 2014-2016 that are either in progress or are on hold due to higher priorities or road blocks (Table 3). Further progress was made on some of the VAPs described in Tables 2 and 3 in 2017, but statistics are only given for 2014-2016 to encompass a complete three-year period.

Tables 2 and 3 describe development on new VAPs, but work is also required to maintain operational data products. Between 2014 and 2016, minor updates were made in over 25 VAPs to fix bugs, run at new sites, respond to changes in input datastreams, or other changes. Additionally, a number of VAPs required manual processing or setup for field campaigns and new sites or time periods. Data was processed in this manner for VAPs such as Microwave Retrieval (MWRRET), MPL Cloud Mask, Variational Analysis, WACRARSCL, MICROARSCL, Aerosol Optical Depth, ARM Best Estimate, QCRAD, and Radiative Flux Analysis.

Table 3. VAPS for which development was started between 2014 and 2016.

	VAP	Year started	Evaluation	Production
1	MPLPBLHT	2014	On hold	
2	CMAC2	2014		
3	RWPCLUT	2014		
4	ACSM Harmonization	2015		
5	SACR-ADV-3D3C	2016		
6	SACR-ADV-QVP	2016		
7	Automate VARANAL	2016		
8	KAZR2ARSCL	2016		
9	SURFCLDGRID (updated version)	2016		
10	AERIoe	2016		
11	CSPHOT 3-channel cloud retrieval	2016		

2.2 Support for New Instrumentation

In addition to traditional VAP development, the Translator Group has collaborated with instrument mentors and instrument science groups to assess and improve the data quality of the large numbers of new instruments procured with American Recovery and Reinvestment Act (ARRA) funding over the last few years. In particular, time has been spent on AOS harmonization in collaboration with the Aerosol Measurement and Science Group (AMSG), and supporting the radar plan in collaboration with the radar mentors and Radar Science Group.

2.2.1 AOS Harmonization Framework

The numerous new AOS instruments obtained through ARRA funding were accompanied with rigid time tables for acceptance and deployment. This required rapid implementation of ingests for instrumentation for which ARM had little to no operational experience. Predictably, this led to an eventual need to review and improve many of the AOS raw datastreams and ingests in order to capture additional information deemed essential to subsequent processing. Also, for expediency much of the AOS processing and data quality review after initial installation had been conducted by the AOS mentors externally, leading to differences in processing of comparable measurements by different mentors.

In order 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, we developed the AOS harmonization framework. This framework coordinates the efforts of AOS mentors, the DQO, and the Data Management Facility to improve the ability of ARM operations to support the AOS systems, facilitates comparisons between collocated AOS systems or between similar measurements within a given system, and lays the foundation for future value-added products.

The quantitative indications of success of this processing framework include the number of datastream classes (>20) and individual datastreams (>100) that have been implemented, as well as the excellent agreement demonstrated between collocated but independently operated and processed measurements of aerosol number density and optical properties at Manacapuru, Brazil (MAO) and also for collocated systems at ARM's Southern Great Plains (SGP) observatory in posters presented at the ASR PI meetings (Flynn et al., 2015 "AOS Harmonized Path", and Flynn et al., 2017 "Absorbing Aerosol Measurements in the ARM AOS Suites"). The demonstrated success of the AOS harmonization framework for AOS measurements has led to it being adopted for non-AOS measurements as well, including carbon and greenhouse gas measurements and the ARM Aerial Facility (AAF) measurements.

Table 4. Detailed AOS harmonization accomplishments.

Instrumentation	Accomplishments
AOS CPC	● Developed unified b-level datastreams from unique cpc, cpcf, and cpcu a-level instrument datastreams.
AOS CCN	● Improved CCN configuration and operation to resolve identified measurement biases. ● Established comprehensive calibration protocols. ● Adapted published instrument models for general use ARM-wide. ● Improved autonomous QC. ● Developed autonomous ccnavg and ccn spectra b-level products as precursors to batch-mode c-level products.
AOS optical properties	● Integrated a-level files from impactor, nephelometer, PSAP, CLAP, CAPS, and system flows to produce b-level files at native temporal resolution and also at uniform 1-minute resolution. ● Implemented evaluation version of AOP (Aerosol Optical Properties) 1-minute and 1-hr c-level data product as a replacement and extension of the historical AIP (Aerosol Intensive Properties) data product.
AOS ACSM	● Participated in the first ARM Aerodyne ACSM user group meeting. ● Defined the scope for an end-to-end ACSM reprocessing effort intended to improve routine autonomous operation; to produce a robust b-level product; to develop quicklook plots helpful to the DQO and mentors; to develop medium-term and long-term plots to assess calibration; and to provide robust c-level products for ACSM and OA-Comp.
AOS gases, GHG	● Developed b-level autonomous processes for O3, CO, NOX, and LBL greenhouse gases.
AOS SP2	● Implemented autonomous ingest of SP2 housekeeping datastream. ● Implemented batch-processed SP2 rBC (refractory black carbon) c-level product for the AOS SP2 and extended this process to AAF SP2 measurements.

2.2.2 Support for New Radars

With a very large radar network and a limited number of radar engineers, ARM decided to take a step back from producing retrievals so skilled developers and Translators could help the Engineering team improve the quality of base-level radar data. The Translator team supported this radar plan with basic analysis of the radar data (clutter, artifacts, etc.) to provide feedback to the Engineering team as radars came "into phase". Emphasis was also placed on coding unified ingests across the radar network. More details of this work are documented in the Radar Plan, available in Service Now in ENG0003148.

While careful engineering is taking place on the radars, retrieval efforts have focused on providing code and tools to facilitate users work with radar data as it becomes available. In 2013 ARM released the Python-ARM Radar Toolkit, Py-ART. Py-ART is a community open-source architecture for interactively working with radar data. It has a vast collection of ingests to a common data model allowing for code developed on one radar to be used on many. Due to code availability on GitHub and careful implementation of industry-leading practices (standards, continuous integration, conventions), Py-ART has grown organically and now contains functions of use to ARM contributed by non-DOE-funded PIs.

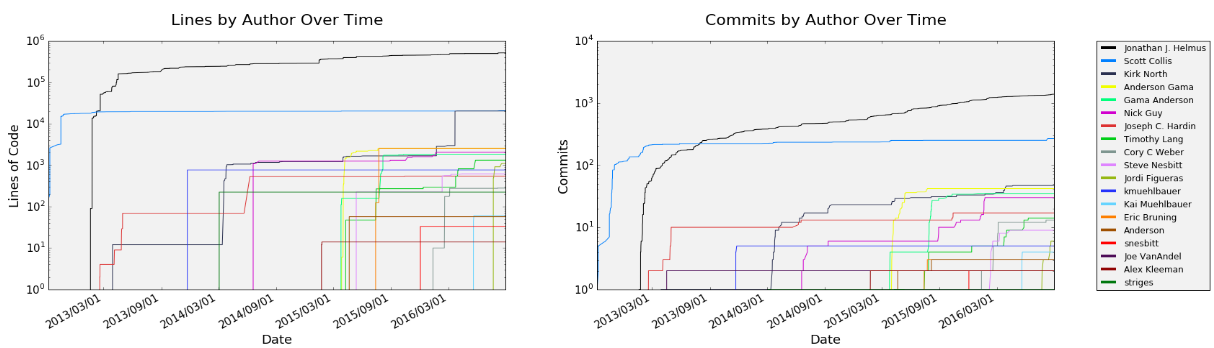

Figure 1. Growth of Py-ART use over time.

Py-ART has over 100 users, and thousands of installations worldwide. Some key examples are:

- National Aeronautics and Space Administration (NASA) Goddard: Py-ART is being used to locate columns of Differential Phase in National Oceanic and Atmospheric Administration (NOAA) and ARM radars to diagnose updraft locations.
- University of Queensland: Py-ART is used as a back-end processing system for a forest-fire-sensing radar.
- The University of Illinois: Py-ART is central to teaching remote-sensing course work and is used by a number of NASA and DOE PIs.
- University of Washington: Py-ART is used as part of the data analysis chain for the OLYMPEX field campaign.
- The University of Barcelona/Meteorological Service of Catalonia: Py-ART was used to detect and filter failed in-radar dealiasing.
- The Fleet Numerical Meteorology and Oceanography Center (FNMOC) is using Py-ART to develop radar quicklooks for its well-known tropical storm page: https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi. Sometimes subtle data quality issues can be determined by viewing the output of retrieval algorithms that are harder to spot in underlying measurement data. For example, we found that errors in multifilter rotating shadowband radiometer (MFRSR) measurements were easier to find when examining aerosol optical depth (AOD) than when examining irradiance values only. Thus, as we work on determining the data quality of the measurements listed in Table 10, we will engage with instrument mentors and the DQO about methods to detect instrument malfunction or drift.

In 2017, in order to ensure value was being delivered to both ARM stakeholders and ARM itself, a five- year roadmap was developed. This roadmap guides both external and DOE-funded contributions and is available at https://github.com/ARM-DOE/pyart-roadmap.

3.0 Modeling and Tools

As described in the *Decadal Vision*, ARM is strategically emphasizing the development of new tools to facilitate higher scientific impact with limited resources. The Translators are responding to this shift in three areas. First, we are putting substantial effort into supporting the development of LASSO high- resolution modeling. Second, we are working on new tools to put ARM observations more easily into the hands of the global climate model (GCM) community. Third, we are supporting or collaborating on the development of several tools that facilitate retrieval development and observational analysis.

3.1 LASSO

To support LASSO, we have been developing or updating the strategic VAPs listed in Table 5. Preliminary versions of many of these data products have been produced to be used in the LASSO alpha releases, and additional development is now underway to make these products operational. That work will be completed in the FY18-FY20 timeframe. In addition, as LASSO moves to new sites or cloud types, we anticipate that additional Translator effort will be required to develop or update VAPs to support these new model runs.

Further, we plan to pay more attention to VAP data quality on a quicker timeframe, as it is expensive to reprocess LASSO model runs for updated observational data. We will work with the DQO to add VAPs critical to LASSO's regular data-screening routine.

Table 5. Science products under development for LASSO.

Data Product	Development
Variational Analysis	The Variational Analysis VAP is one of the forcing data sets used by LASSO to run the model. Updates are being made to make it run more efficiently using ADI, and to incorporate new observational data.
KAZRARSCL	A c0-level product is under development so that initial cloud boundaries and uncalibrated moments can be produced quickly to help identify shallow cumulus cases. This data will then be replaced with calibrated data.
AERIoe	AERIoe is a new optimal estimation algorithm from Dave Turner that calculates boundary-layer temperature and humidity profiles, and liquid water path (LWP). The latest version incorporates data from the AERI, surface Met, MWR3C, and RAP model output. The plan is to run the VAP operationally at the SGP Central Facility and four boundary facilities for use in LASSO forcing (thermodynamic profiles) and evaluation (LWP).
Cloud Type/Shallow Cumulus	The Cloud Type VAP classifies clouds using ARSCL cloud boundaries. The Shallow Cumulus VAP further classifies the low clouds type by incorporating ceilometer and TSI data. These VAPs were developed to help identify cases of interest for LASSO model runs.
RLPROF	The Raman lidar provides temperature and humidity profiles at the SGP Central Facility. New development is underway to update the RLPROF VAP for more consistent data quality and processing, and including new RLPROF-FEX processing.
DLPROF	The Doppler Lidar Profile products provide boundary-layer winds and vertical velocities. Additionally, these are the only active sensors at the new SGP

Data Product	Development
	boundary sites so they are used to identify cloud base height. Adjustments to identify cloud base height on the appropriate time scale will be made to support model evaluation of cloud height and LWP retrievals at the boundary sites.
RWP VAPs	The radar wind profilers at SGP can provide some spatial variability of horizontal wind profiles and boundary-layer heights. Evaluation products were produced for the LASSO project and additional work is needed to make these operational VAPs.
Cimel cloud retrievals	The narrow field of view of the Cimel sun photometers allows for retrievals of cloud optical depth and effective radius in broken cloud conditions that cannot be done with hemispheric-field-of-view MFRSRs. Work is underway to ingest the cloud mode (zenith) radiances and implement Christine Chiu's cloud retrievals of optical depth.

3.2 Key Products for the GCM Community

In order for ARM observations to be useful to the GCM community, the data must be easily packaged for model comparison. Several key products like ARMBE and Variational Analysis have already been developed to meet this need, and maintenance of these products will continue. Additionally, the Translator Group has prioritized producing tools that will facilitate new use of ARM data by global modelers.

A radar simulator was recently developed for use comparing GCMs to vertically pointing Ka-band reflectivities from ARM sites. The simulator was implemented in the COSP simulator package, and is currently being documented in a *Bulletin of the American Meteorological Society* (BAMS) article. To be most useful, however, the simulator needs well-calibrated radar reflectivity. Thus one focus of future work will be collaborating with instrument mentors to produce well-calibrated Ka-band ARM Zenith Radar (KAZR) reflectivity data for Contour Frequency by Altitude Diagrams (CFADs) from ARM data for comparison. To promote modeling centers using the ARM radar simulator in their model evaluation, ARM is aiding the implementation of the ARM radar simulator in major modeling centers around the world. To complement ARM radar measurements, developing an ARM lidar simulator for GCMs is also being considered for future activities.

An ARM diagnostic package was also begun in the middle of the 2015 fiscal year to make ARM data more accessible to GCM development. Initial efforts focused on quantitative metrics of unique ARM data sets as listed in Table 6. These metrics include mean bias, root-mean-square error, correlation and variance (displayed as bar charts and Taylor diagrams), and time series plots showing diurnal, monthly, seasonal, and annual variability. The diagnostic package code is accessible on the ARM GitHub site: https://github.com/ARM-DOE/arm-gcm-diagnostics/tree/master.

Further work on the ARM metrics and diagnostics package will expand it to include process-oriented diagnostics through close collaboration with science communities including ASR and modeling groups. Specifically, in the coming years the diagnostic package will be expanded to include process-oriented diagnostics and single-column model diagnostics for parameterization development, including both observational and LASSO output data. A list of specific process-oriented diagnostics is given below:

- Convection onset diagnostics (Neelin and Hales 2009; Shiro et al., 2016)

- Frequency of occurrence and intensity probability density function of clouds and precipitation (Morcrette et al., 2012)
- Cloud regime analysis using ARM Radar Simulator output (Williams and Webb 2009; Van Weverberg et al., 2015)
- Precipitation diurnal variability (Wang et al., 2010)
- Diabatic heating/drying study over various cloud regimes (Xie et al., 2014).

Table 6. ARM metrics package.

Metrics Category	Variables included
Atmospheric state and surface	• Atmospheric moisture, pressure, and temperature • Horizontal wind and vertical velocity • Latent heat flux and sensible heat flux • Precipitation and soil moisture
Cloud and radiation	• Cloud fraction profiles • Liquid water path and precipitable water vapor • TOA radiative fluxes • Surface radiative fluxes
Aerosol and microphysical	• Aerosol optical depths and angstrom exponent • CCN concentration

3.3 Analysis Tools

As described in section 2.2, Py-ART is one successful tool that allows the scientific community to collaborate with ARM in producing useful retrievals from new ARM data sets. ARM will continue to support development of Py-ART as outlined in the Py-ART roadmap (https://github.com/ARM-DOE/pyart-roadmap). Once approved, the next five years of development will focus on the capabilities outlined in the document, with an annual review of development priorities. At the time of writing, Py- ART version 1.9 is about to be released. The Py-ART roadmap will conclude with the release of Py- ART 2.0.

The Translator Group also plans to collaborate with others in the ARM infrastructure on the development of several additional tools to facilitate more efficient retrieval development and data analysis. These tools include a simpler version of the ARM Data Integrator (ADI) that will be more accessible to new developers and scientific users, the ability to order or analyze ARM data by cases of scientific interest, and setting up some VAPs to be run by users on the new Stratus cluster. These tool developments are described in more detail in Table 7.

Table 7. Collaborative tools to facilitate retrieval development and analysis.

Tool	Description and Plans
Py-ART	Tool for manipulating radar data and applying retrievals. Development will continue according to the Py-ART roadmap.
ADI for scientists	The ADI is a tool that robustly merges and transforms ARM data, aids in meeting ARM data standards, and facilitates operational processing. The ADI team plans

Tool	Description and Plans
	to focus future development of ADI on easier use by new developers and others. This will aid in code sprints and collaboration with ASR PIs creating data products. The Translator Group will contribute by providing feedback and testing of development and communicating with potential PIs.
Ordering and analyzing data by scientific period of interest	Requests have been made at ASR meetings and workshops for the ability to sort ARM data sets by cases of scientific interest for analysis and downloading. Some work to facilitate this ability has been done through LASSO and the new Cloud Type VAP, and interactive interfaces that have been created to access and visualize that data. Translators will support this work by providing additional data sets to identify periods of scientific interest, such as precipitation regime analyses. Additionally, we will work with the ADC team to define priorities and requirements for data downloads.
User-run VAPs	The new Stratus cluster provides a common platform for Translators and users to run computationally intensive data products. We will work with the ADC to set up a workflow where users can run some VAPs on Stratus using their own settings. AERIoe will be one of our initial test cases as it is computationally intensive and users may wish to run with different input settings, sites, or time periods than will be provided by ARM.

Table 8. Core VAPs that will be run for AMFs when instrumentation is available.

VAP NAME	Primary Measurements	Instruments Required	VAPs Required	Effort Level	Num Users 2014-2016
AERINF	longwave spectral radiance	AERI (or ASSIST in future)	none	Low	28
AOD	aerosol optical depth	MFRSR (or nimfr/SASHE), surface pressure, ozone (from OMI or TOMS)	Langley VAP	Low/ Med	107
AOP	aerosol optical properties from AOS	AOS	none	Low	--
ARSCL KAZRARSCL WACRARSCL	cloud boundaries, radar reflectivity, radar moments	vertically pointing cloud radar (KAZR/WACR), ceilometer, lidar, MWR, rain gauge	MPLCMASK, MWRRET (KAZRARSCL), KAZRCOR	Med	139
DLPROF (WIND & WSTATS)	UV wind profiles, clear air vertical velocity stats,	Doppler lidar, MET, EBBR, CEIL	none	Low	50
INTERPSONDE	profiles of temp, humidity, pressure, wind	sonde, surface MET, MWR	gridded sonde, SONDEADJUST	Low	34
LSSONDE	profiles of temp, humidity, pressure, wind	sonde, MWR	none	Low	37

VAP NAME	Primary Measurements	Instruments Required	VAPs Required	Effort Level	Num Users 2014-2016
MPLCMASK	cloud mask, attenuated backscatter, depolarization ratio	MPL, sonde	MPLAVG	Low	136
MWRRET	liquid water path, precipitable water vapor	2-channel MWR, ceilometer, sonde	ARSCL (for best results)	Med/ High	126
PBLHT	PBL height	sonde	none	Low	151
QCECOR	latent heat flux, sensible heat flux	ECOR	none	Low	35
QCRAD	LW, SW surface irradiances	broadband SW/LW down/up radiometers, diffuse/direct SW irradiance, surface MET, IRT & MFRSR optional inputs	GSWCORR	Med	142
RADFLUX	clear sky broadband surface irradiances, cloud fraction	broadband SW/LW down/up radiometers, diffuse/direct SW irradiance, surface MET	QCRAD	Med	47 (+ 69 from old version)
Ship-Based Deployments Only					
NAVBE	Lat, Lon, pitch, roll, yaw, surge, sway, etc.	GPS and Inertial Navigation System	none	Med	--
SHIPCOR	Ship-motion-corrected data	Could include MWACR, MPL, HSRL, KAZR, CEIL	ARSCL, MPLCMASK	Med/ High	--

4.0 Identifying Core VAPs for AMF Deployments

This section discusses existing core VAPS, others under development, and formalization of the process for designating still others in the future.

4.1 Core VAPs

In response to feedback from the DOE Triennial Review and the UEC, the Translator Group defined a list of core VAPs, representing mature, robust algorithms, that we expect to deliver at all AMF deployments fielding the needed instrumentation. Most of these VAPs are automated or semi-automated and standardized, and many are necessary to provide basic atmospheric information from measurements, for example, providing primary scientific variables like liquid water path rather than raw microwave brightness temperatures, or aerosol optical depth rather than spectral irradiances. Table 9 lists core VAPs that are already developed. The last column of Table 9 shows how many unique users downloaded each

VAP during 2014-2016 when that information is available. This is one measure of how frequently the data is used, though each VAP may also be used as input to other VAPs. VAPs that are currently being developed that we anticipate will become core VAPs are described in Section 4.2.

In addition to these core VAPs, Translators produce a number of VAPs of high value for specific scientific goals, listed in Table 9. These VAPs may depend more on the availability of specific instrumentation or climate conditions, or require more manual testing and evaluation to create a robust product. These VAPs will need to be requested by science users or specifically recommended by Translators for particular AMF deployments in order to ensure they are appropriate for the campaign conditions and sufficient resources are available to produce them. As described in Section 4.3, we will work on standardizing our method to communicate with field campaign PIs earlier in the AMF deployment process to determine which core VAPs are appropriate for a given campaign (e.g., have the correct instrumentation) and whether additional scientifically specific VAPs are of high priority.

Table 9. Additional high-value VAPs for specific science goals that may be requested for AMF deployments.

VAP NAME	Primary Measurements	Instruments Required	VAPs required	Effort Level	Num Users 2014-2016
AERIoe	Boundary-layer temp, humidity, LWP, PWV	AERI, met Optional: RUC/RAP/similar, MWR	AERINF	High	--
ARMBE	Hourly-mean data with additional QCs	Can be adjusted based on instrument availability	ARSCL, QCRAD, QCECOR, MWRRET, LSSONDE, QPE	Med	245
CFAD	Reflectivity CFAD for comparison to simulator output	KAZR/MMCR	(KAZR)ARSCL	High (for radar calibration)	--
MERGESONDE	profiles of temp, humidity, pressure, wind	sonde, surface MET, MWR	ECMWF input, lssonde, gridded sonde	Low	136
MFRSRCIP	Column-intensive aerosol properties	MFRSR	Mfrsraod1michal sky surfspecalbedo	med	--
MFRSRCLDOD	cloud optical depth, effective radius (when mwr data available)	MFRSR, cloud fraction (from TSI or FLUXANAL VAP), MWR (required for effective radius but not optical depth)	Mfrsrlangley, MWRRET (for effective radius)	Low (High if manual Langley)	51
MICROBASE	ice water content, liquid water content, cloud droplet size	cloud radar, sonde, MWR, ceilometer, rain gauge, lidar	ARSCL, MERGESONDE, MWRRET	Med	61
NDROP	droplet number concentration, cloud adiabaticity	MFRSR, (MWR, ceilometer, ARSCL required for best results)	MFRSRCLDOD (or other cloud OD in future),	Med/ High	25

VAP NAME	Primary Measurements	Instruments Required	VAPs required	Effort Level	Num Users 2014-2016
			MWRRET, ARSCL, MERGESONDE		
SURFSPECALB	spectral surface albedo	Upward- and downward-looking MFR, and broadband SW irradiance	BEFLUX, QCRAD	High	28
VARANAL	Large-scale advective tendencies of temperature and moisture, vertical velocity, and analysis domain mean surface and TOA fluxes	precipitation radar, and instruments for other VAPs listed in the next column	QCRAD, QCECOR, MWRRET, LSSONDE, QPE	Med/ High	--

4.2 Core VAPs under Development

In addition to the core VAPs listed in Section 4.1, four VAPs are currently under development that we anticipate will become core VAPs when development is complete. These represent critical processing of new instrumentation to allow the data to be scientifically accessible. Development for each of these is described in more detail in Section 5, but summarized here for clarity.

Aerosol Optical Properties (AOP): The AOP VAP calculates aerosol optical properties from AOS instruments, and replaces the former Aerosol Intensive Properties (AIP) VAP. This VAP will allow better comparison between AOS measurements and remote-sensing properties, including facilitating calculation of aerosol profile properties. This is part of the AOS harmonization work described in Section 5.1.

Radar Wind Profiler (RWP) products: Several RWP products are under development as described in the new instrumentation in Section 5.2. These products will provide consensus winds and boundary-layer products, which will make RWP data usable by more users than just RWP experts.

Corrected Moments and Antenna Coordinates (CMAC2.0): Several products are under development for precipitation radars. The base of all of these products in CMAC 2.0, which is an ARSCL-like product for scanning precipitation radars. The VAP will provide corrected moments like reflectivity, as well as identify boundaries of precipitation (similar to the ARSCL cloud mask). CMAC2.0 development, and additional downstream products, are described in more detail in Section 5.2.

Liquid Water Path (LWP) retrievals: Liquid water path retrievals are critical for many scientific applications. Two new products are under development that can produce liquid water path from the new three-channel microwave radiometers (MWR3C). Microwave Radiometer Retrieval version 2 (MWRRETv2) is an extension of MWRRET to the MWR3C instruments, adopting Dave Turner's optimal estimation code. Another path forward for retrieving LWP in low-liquid-water-path clouds is using the combined MWR3C and atmospheric emitted radiance interferometer (AERI) measurements in the AERIoe retrieval. The best solution for LWP retrievals may depend on instrumentation and conditions at a given site. The focus of current development is handling data quality and bias correction.

4.3 Formalize Process of Determining VAPs for AMF Deployments

Early in the coming three years we plan to better formalize the process for determining which VAPs will be run for AMF deployments. We will develop information and a process for communicating early on with field campaign PIs and science teams about which VAPs will be run on what timeline. This will help determine how we should prioritize our efforts to maximize the scientific input, and set realistic expectations about when data can be made available.

5.0 Supporting New Instrumentation

A large number of new instruments were added to the ARM facilities in recent years. Many of these new instruments are at the cutting edge of measurement efforts to quantify items such as aerosol composition, aerosol absorption, cloud and precipitation microphysics, vertical velocities, and higher temporal and spatial resolution information of cloud and aerosol processes. Significant progress has been made to get these instruments running at ARM sites and understand the quality of the data coming from them. In the next few years, the Translator Team plans to continue to collaborate with instrument mentors to address some known data quality issues and produce basic products of high scientific interest from the following instruments.

5.1 Aerosol Observing System

As described in the Accomplishments section above, the AOS harmonization framework has been developed to coordinate ARM Facility resources (mentors, the DQO, the Data Management Facility [DMF]) to improve the ability of ARM operations to support these complex systems and to lay the foundation for science-ready value-added products. Here we define the AOS harmonization effort as establishing a processing including these two main aspects:

1. To harmonize processing of the AOS data so that data from the old ("NOAA-mentored") and new ("BNL-mentored") systems would be processed equivalently.
2. To move away from the paradigm of "mentor-processed" data wherever feasible, and integrate the AOS data collection and processing with the DMF and the DQO. In essence, this was really a "harmonization" of the AOS mentors with the established ARM infrastructure at the DMF and DQO.

The AOS harmonization process described above is solidly established. Complete families of measurements have been enveloped in this comprehensive framework with some additional effort remaining to complete documentation. Accomplishments include baseline work for system configuration and monitoring, aerosol number density (CPC family), cloud condensation nuclei concentrations (CCN family), aerosol optical properties (AOP family), several trace gases, improvements in real-time monitoring of ACSM and SP2, science-ready c- level products for optical properties, and SP2 refractory black carbon.

We will continue to apply the harmonization framework to the remaining AOS instruments as needed over the next three years in communication with the Aerosol Measurement Science Group (AMSG) and ARM infrastructure in response to scientific priorities. In the short term, we will complete the following instrument streams—aerosol chemical speciation monitor (ACSM), sulfur dioxide monitor (SO_2), nitrogen oxides monitor (NOX), aerodynamic particle sizer (APS), aeth1spot, aeth2spot, CAPS, tricolor absorption photometer (TAP), APS, and humidified tandem differential mobility analyzer (HTDMA)—and document these and existing products. In the longer term, we expect to include assessment of the OA-Comp product first at SGP and then at all other sites where the ACSM has been deployed. We also need to review and improve the baseline integration of the aerosol chemical speciation monitor-time of flight (ACSM-TOF) for which no ingest currently exists. We will work to develop and assess the CCN best-estimate evaluation product in collaboration with funded PIs. The AOP process will be extended to additional optical measurements from CAPS, TAP, and aethalometer measurements. We will evaluate the feasibility and cost/benefit of applying automated calibration of AOS trace gas components.

5.2 Radars

This section discusses planned development work for each type of ARM radar.

5.2.1 Cloud Radars

For the complement of ARM scanning and vertically pointing cloud radars, of high priority is the more timely delivery of standard products and ARSCL-type VAPs, as well as improved characterization, calibration tracking, and contaminant identification. Initial efforts will work toward the completion of near-automatic ARSCL production under a ‘c0’ format listing. These ‘c0’ files will reflect a similar standard of quality as previous ARSCL files in terms of the standard functions that are immune to radar miscalibration (e.g., cloud boundary designations), but will not contain a calibrated ‘best estimate’ radar reflectivity factor field. However, this ‘c0’ procedure should ensure the timely delivery of ARSCL products over fixed and AMF deployments to within one-month windows.

Second, ARSCL products will also work towards incorporating new MicroARSCL input streams (information from Doppler spectral processing), with MicroARSCL also being automated to ensure additional spectral moment insights to be delivered to users on a sub-monthly schedule as well. Incorporation of these spectral insights should improve the mitigation of clutter and insects (improved significant echo masking) from existing ARSCL products, as well as provide new insights into cloud processes (microphysical fingerprints). Existing SACR ADV VAPs (e.g., QVP, VAD, Gridding) will be refined to accommodate additional cloud radar wavelengths, as well as adopt the recommendations and changes inevitable once continued data collection and scan strategy refinement uncover new cloud situations from these systems (discovery/early stages).

To accompany the more timely release of ARSCL-type streams and initial quicklook cloud radar products, another critical activity will be to automate KAZR and SACR radar offset monitoring (field calibration) against standard references on a routine basis (quarterly, or as data collection allows). This specifically includes adopting a statistical (Protat 2011) approach to monitor cloud radar offsets to measurements from CloudSat satellite-calibrated reflectivity profiles and additional ground gauge references (2DVD disdrometers) as available.

5.2.2 Radar Wind Profilers

We will also work with the Radar Science group to complete a new set of RWP boundary-layer and precipitation VAPs (SGP, MAO). These VAPs propose quality-controlled and calibrated RWP data sets containing quantities of interest such as an estimate for the boundary-layer height, boundary-layer wind profiles, calibrated reflectivity factor measurements, and eventual precipitation estimates. These products should facilitate various measurement needs at the SGP facility including possible ARSCL cloud boundary designation (top) support in precipitating conditions, LASSO product bundles, site radar calibration monitoring, precipitation estimation, echo classification and vertical velocity retrievals, and potential forcing data set assimilation.

5.2.3 Precipitation Products from Scanning Radars

In past years the focus has been on basic products that can be improved over time. This led to Corrected Moments in Antenna Coordinates (CMAC2.0) as the base product for the X and C-band radars. At the heart of CMAC2.0 is a fuzzy logic gate identification algorithm (tuned for each radar and each site) that determines what processing chain will be carried out. CMAC2.0 is currently being tested on the I5 X- SAPR at the SGP site.

As part of this three-year plan the focus will shift towards improving data and retrieval quality by:

1. Determining and monitoring calibration offsets using external ARM and other instruments, specifically, NASA active remote-sensing satellites (Global Precipitation Measurement [GPM], CloudSat) and ARM disdrometers.
2. Adding error bars to precipitations estimates. Starting with X-SAPR-I5 at the SGP we will be using the network of disdrometers to understand the conditional limitations of rainfall retrievals and adding uncertainties to radar VAPs. This is tied into the aforementioned calibration offset task as we need information on uncertainties for the base measurements and these, for radars, are largely calibration driven.

Py-ART is essential to the success of the aforementioned tasks. Py-ART allows us to focus on developing the methodologies that can be applied to the instrument datastreams as they become available.

5.3 Lidars

ARM obtained several advanced lidar systems through ARRA funding: two high-spectral-resolution (HSRL) systems, two Raman lidar (RL) systems, and numerous Doppler lidar (DL) systems. ARM also purchased updated ceilometers and MPLpol systems.

The DLPROFWIND and DLPROFWSTATS VAPs have already been made operational VAPs giving vertical profiles of winds and vertical velocities respectively. Work is also ongoing to standardize HSRL operational processing code. The Raman lidar produces profiles of temperature, humidity, feature extinction, and linear depolarization ratio. The RLPROF VAP is a suite of VAPs that process different pieces of information needed to produce reliable data and apply additional calculations like a feature mask. RLPROF is being updated to incorporate new data quality improvements and feature identification algorithms from the Feature detection and EXtinction (FEX) algorithm (Thorsen and Fu 2015; Thorsen et al., 2015). Updates are also being made to streamline automated processing and make it easier to run at new sites.

Datastreams were developed for each of these instruments as independent systems. Now that all systems are operational, there is substantial value to be gained from intersystem comparisons for improving the quality of profile measurements of backscatter and depolarization ratio as well as cloud and aerosol identification.

A number of issues have recently been discovered in the micropulse lidar (MPL) data and data products. The quality of the backscatter and depolarization ratio from the MPL has been affected by instrument issues such as polarization crystal alignment and condensation on the window. Other issues related to backscatter corrections were also discovered, including a change mid-data set in the method to apply the range, dead time, and overlap corrections. Improving the MPL data quality and quality of the cloud mask identification in the MPLCMASK VAP is a high priority because MPLCMASK cloud boundaries are a popular VAP download, and are an important input into the ARSCL product.

To improve data quality for lidar profiles and cloud boundaries, an end-to-end analysis comparing MPL with ARM's advanced calibrated systems (RL and HSRL) is needed. Analysis is also needed to improve identification of aerosol layers in lidar profiles. An important component of these comparisons is to understand the extent of calibration for each advanced lidar system (RL and HSRL) to provide confidence in the retrieved quantities.

5.4 Radiometers

This section discusses planned development work for each type of ARM radiometer.

5.4.1 Sun Photometry

ARM has invested in upgrading and purchasing additional Cimel sun photometers (CSPHOT) at each of the main facilities. The Cimels are operated at the ARM sites and are included in the global NASA AErosol RObotic NETwork (AERONET) consortium. The ARM Cimels have all been upgraded to include a 1.6 micron channel. They measure direct normal solar irradiance, angularly resolved diffuse sky radiance, and cloud-mode zenith radiances. ARM also has MFRSR instruments at each of the main facilities as well as at supplemental and extended facilities. The MFRSR heads are in the process of being upgraded to include a 1.6 micron channel. The collocated operation of the Cimels and MFRSRs is the focus of new efforts combining scientific expertise and machine-learning strategies to better identify data quality issues. These efforts are in their infancy but are already shedding considerable light on the instrument operation that will be useful both for improving or flagging questionable data and for defining "epochs" of known good-quality measurements.

5.4.2 Hyperspectral Radiometry

ARM has developed and deployed a total of four hyperspectral radiometers (two SASZe and two SASHe) with ARRA funding. Both the SASZe and SASHe use commercial off-the-shelf (COTS) spectrometers to report continuous "hyperspectral" measurements over a wavelength range from about 385-1700 nm. The SASZe (Shortwave Array Spectrometer – Zenith) measures zenith radiance with a 1-degree field of view at 1 Hz. The SASHe (Shortwave Array Spectrometer – Hemispheric) uses a shadow-band cycle to report hyperspectral measurements of direct solar and diffuse hemispheric radiation (from which column- integrated aerosol properties may be retrieved) on an interval of about 30 seconds.

Basic corrections and calibrations have been implemented for both systems (lamp-calibrations for SASZe, Langley calibrations and cloud-screened AOD for SASHe) and foundational products have been developed to permit quality assessment of these instruments through intercomparison with existing collocated measurements from filter-based instruments. This initial development shows that while the instruments are functioning properly, additional higher-order corrections are still needed to obtain the desired level of agreement. These higher-order corrections include improvements to the existing stray light correction and implementation of non-linearity corrections (for both SASZe and SASHe systems), better cosine corrections for SASHe, and more robust calibrations for SASZe. Each of these developments requires non-trivial effort to develop and assess. Currently, these efforts are on hold pending the results of existing QA efforts related to the MFRSR and CSPHOT sun photometers.

5.4.3 Radiometric Liquid Water Path Retrievals

New 3-channel microwave radiometers (MWR3C) were purchased for all fixed and AMF sites under ARRA. These radiometers have an additional 90 GHz channel that is more sensitive to low-liquid-water-path clouds compared to previous 2-channel radiometers containing 23 and 30 GHz channels. However, the running bias correction method used with the 2-channel systems will not work with the new MWR3C instruments because there are too many unknown variables. These bias corrections are important to data quality, as uncorrected brightness temperatures can give large biases in the retrieved liquid water path (10-20 g/m^2). Investigations are underway to improve the bias corrections and identify other instrument problems such as liquid water pooling on top of the radiometer after rain.

New AERI instruments were also deployed at SGP extended facilities as part of the boundary-layer profiling sites. AERIoe, a new retrieval method (Turner and Lohman 2014), is being implemented to calculate thermodynamic profiles and liquid water path from these instruments. The infrared channels are an alternative information source to the 90 GHz microwave channels to constrain retrievals at low liquid water paths. Incorporating the MWR3C brightness temperatures at 23 and 30 GHz channels into AERIoe has the potential to give good LWP retrievals for a broad range of LWP values with fewer calibration problems than the 90 GHz channel. However, handling relative instrument biases and instrument fields of view adds additional challenges in this multi-instrument optimal estimation method.

Currently, test runs of MWRRETv2, AERIoe, and mwrretv1 at SGP show significant differences in LWP retrievals. Additional work in the coming months will focus on understanding and improving these LWP retrievals, and determining the best retrieval methods for each site.

6.0 Uncertainty

A key recommendation we received from the User Executive Committee was to focus additional effort on improving data quality and assigning uncertainties to key measurements and datastreams. Assigning uncertainties to retrievals is an active area of research as it can be quite difficult. The QUICR focus group made progress in highlighting the disagreement of different cloud microphysical retrievals and their sources of uncertainty, but a complete error characterization of the retrievals proved too much of a challenge.

We do not want our inability to do everything to keep us from doing anything on uncertainty. Thus, in order to address this recommendation, the Translator Group decided to focus on a strategic set of measurements that require uncertainty characterization and will be useful to inform retrievals or model comparisons. These measurements are described in Section 6.1. We will also focus on assessing information available to describe the uncertainty of core VAPs as described in Section 6.3.

6.1 Measurement Uncertainty

Rather than starting with retrieval uncertainties, the Translator Group will focus on assigning uncertainty to measurement uncertainties critical to core VAPs and model evaluation. We will collaborate with instrument mentors, but take the initiative to pursue uncertainty quantification on measurements as needed. Table 10 lists the measurements that the Translator Group has prioritized for uncertainty quantification. These variables were chosen because they are important to core VAPs and because providing data of known quality with quantified uncertainty will be a step forward for the field. Other important measurements like surface meteorology, radiosondes, and surface irradiance are critical to core VAPs and science, but here ARM measurement quality is already high and uncertainty estimates in the literature are largely sufficient for use in model or retrieval work.

The variables in Table 10, however, include those where uncertainties may not be well characterized or instrument quality in field conditions may not be sufficiently labeled in operational data products to be able to use uncertainty estimates in the literature. Thus additional work to quantify uncertainty and determine data quality will move the science forward. A plan forward for each measurement will be developed individually. For some, such as AOD, a good value may be known when good data can be ensured. Others may be achievable through comparison between measurements or through propagating multiple known uncertainties into a more accessible format for users.

Table 10. Priority measurements for determining good data epochs and uncertainties.

Measurement	Instrument	Notes
Radar reflectivity	KAZR	Virtual Field Campaign Periods OLI: 20160328-20160910 ENA: 20150920–20151012, 2016, ACE-ENA NSA: Dec 2011–Dec 2013, simulator SGP: Jan 2006–Feb 2014, simulator TWP: Jan 2006–2014, simulator
Radar reflectivity	CSAPR/XSAPR	Still defining scope; may not prioritize uncertainties.
Microwave Brightness Temperatures	MWR, MWR3C	Ultimate goal is LWP and PWV uncertainties. Random uncertainties already available in MWRRET optimal estimation method, but not instrument uncertainty.
Surface Turbulent Fluxes (SH, LH)	EBBR, ECOR	Potentially large errors and uncertainties. Used to drive model, land-atmosphere interactions.
AOD (spectral radiances or irradiances/transmittance)	MFRSR, CIMEL	Goal is AOD uncertainty. Retrieval uncertainty may be achievable in this case.

Measurement	Instrument	Notes
Cloud base height	MPL, CEIL, DL, other lidars	This is a retrieved quantity, but one that we can quantify by comparison between measurements. The MPL in particular has a number of quality concerns in backscatter and depolarization ratio profiles, as well as cloud layer determination.
Precipitation (rain rates)	Gauges, disdrometers	Start with the instruments that directly measure precipitation before tackling retrievals.

6.2 Communicating Uncertainty

As we add additional uncertainty information to science products, we want to communicate that uncertainty in a standard form. Thus the Translator Group is interacting with Ken Kehoe and the ARM Standards Committee about creating uncertainty standards. This will allow for easier machine-readable processing and display as more uncertainty information is determined.

We have made the following recommendations regarding uncertainty standards:

1. The Translator Group would like uncertainty to be included as an ancillary variable (e.g., RLPROF- FEX) or attribute (e.g., disdrometers) but not an extra dimension. The flexibility to include either a variable or an attribute is needed depending on whether uncertainty is known as a time- dependent value or a single scalar for all time.
2. Uncertainty information should be provided to users at the time of download automatically when available (not as an option). Whether in an ancillary file or in the file itself, it should be merged at the time of download so that users get one file with measurement variables and associated uncertainties. As a start, we could just include information in the file itself, though if the capability for including the information in an ancillary file existed, we would probably use it in order not to reprocess historical VAPs to add that information. The most important piece to the Translators is that users get one data file that includes the variable and its associated uncertainty.
3. The Translator Group also recommends that updates be sent to users if uncertainty is added or updated to a datastream (including if an ancillary uncertainty file is added or updated that will be merged with a datastream).

6.3 Assessing Available Uncertainty on VAP Uncertainty

Because of the difficulty involved, assigning uncertainties to retrievals could well be more than can be accomplished in the next three years. However, the Translator Group will start by assessing what information is available to assess the uncertainty in core VAPs, and what paths forward are available for assigning uncertainties where needed. We will also communicate with ASR PIs and others who are actively working on uncertainty assignment in retrievals to decide whether that information can and should be incorporated into operational VAPs.

7.0 Improving and Communicating Data Quality

Determining data quality goes hand in hand with uncertainty quantification in developing robust data sets useful for statistical studies or model evaluation. The Translator Group will focus efforts in this area on determining good data epochs for strategic datastreams and collaborating with instrument mentors and the DQO on how information in VAPs can be helpful to determine when instruments are not malfunctioning.

7.1 Good Data Epochs

In response to recommendations from the User Executive Committee, the Translator Group will work to identify good data epochs in strategic datastreams. Good data epochs are data sets that take into account good measurement quality, conditions appropriate for an instrument or retrieval, and labeling of any significant changes in instrumentation or algorithms feeding into a science product. We will focus on the instruments and time periods listed in Table 10, the same ones we will focus on for the uncertainty work. The goal is to create datastreams that have been sufficiently screened for data quality that statistical summaries can be created and the uncertainty information will be valid. This would provide the quality of information needed for evaluating models, producing robust operational retrievals, and assimilating the observational data into models.

We will also align our efforts with the time periods determined in the Virtual Field Campaigns Breakout Session at the 2017 ARM/ASR Meeting. These periods were identified by site scientist teams and ARM data users as potential cases studies or long-term periods of scientific interest. These times are listed under the KAZR Reflectivity row in Table 10.

7.2 Data Product Dependencies

In addition, one development need is a way to more easily transfer known data quality information (e.g., DQRs) into upstream or downstream data products. One large source of error in VAP output is the quality of measurement data. As DQRs are entered on measurement data, it would be very useful if those data were also propagated to downstream data products so users know those data are also likely impacted.

7.3 New Tools and Methods

New tools and techniques are being developed to more efficiently identify good data epochs and operational data quality issues. Two of these techniques are taking better advantage of redundant information in ARM measurements, and machine-learning algorithms for automating detection of data quality problems. Examples of software tools currently being developed that take advantage of those techniques are described below. We will continue to apply similar techniques to new datastreams in the future to support identification of good data epochs.

7.3.1 Datastream Comparison

The DQO has developed a group of Python 3 software modules and scripts to facilitate ARM datastream comparisons. The modules, currently available as part of an ARM GitLab project at https://code.arm.gov/dq/dqo_python3_libs, provide several classes and functions that enable users to easily read and visualize data from ARM-standard netCDF files. Some specific capabilities of these modules related to datastream comparison include the ability to 1) combine and concatenate variable data from multiple ARM datastreams over user-specified time ranges into a single data object with options to automatically handle daily UTC, daily solar, and monthly data files, 2) easily filter the data using embedded QC variables, user-prescribed parameters, and the ARM Data Quality Reporting (DQR) web service (http://www.archive.arm.gov/dqrws/), and 3) visualize the data through the creation of customizable single- or multi-panel time series plots with an option to average data from different time grids for comparison in difference, percent difference, and scatter plots.

As part of a project to investigate and improve MFRSR data quality, software scripts have been written to simplify the use of the above modules for operational short-term and long-term instrument and VAP comparisons using a blend of command line options and configuration files. These scripts currently handle visualization, the generation of daily or longer-term statistics, and the generation of status information for each date based on statistical comparisons of ARM datastreams using thresholds for linear correlation, bias, root-mean-square difference, slope of linear fit, and/or the number of samples available for comparison. This software is currently being used to investigate data quality issues and compare the consistency of AODs produced by the MFRSRAOD and CSPHOT for the co-located SGP C1 and SGP E13 facilities from 1997 to the present.

A primary goal of the MFRSR data quality project is to refine or expand the statistical comparisons in order to automate much of the process required to generate epochs for good, bad, or questionable data when co-located instruments are available. The software and methodology developed from this project should be easily applicable to many other ARM data products.

7.3.2 Machine Learning

The External Data Center (XDC) group at BNL has developed a suite of machine-learning applications for the automatic identification of periods of good data and periods in which instrument problems may be affecting the data quality. These are currently being applied to several instruments. The first application is an anomaly detection algorithm for the CSPHOT. The input of the application includes AOD data for each filter. The application automatically identifies time periods when the data quality may be compromised by the performance of the instrument due to issues such as obstructions and filter degradation. Evaluation is performed daily after the application is trained on periods of data when the instrument is operating normally. The second application performs a similar function for the MFRSR using irradiance measurements from each filter as input. The MFRSR application also contains a Fast Fourier Transform algorithm test for misalignment of the shadow band on a daily basis. Both of these applications are being modified to use the Python 3 datastream tools that have been developed by the DQO in preparation for deployment as an ARM data product.

The third application uses machine learning to detect sources of local emissions for AOS systems. The input to the AOS application consists of multiple datastreams from multiple instruments including ultra- high-sensitivity aerosol spectrometer (UHSAS), greenhouse gas monitor (GHG), and PSAP. The application successfully identifies large sources of local emissions such as airplanes and fire trucks traversing the airport tarmac adjacent to the ENA site. The application also appears to be sensitive to smaller emission sources, which may include passing automobiles. The performance of the application will soon be further evaluated at the ENA site using comparisons to AOS data taken from a companion site being deployed away from the airport and from AOS data from an aerial deployment near the site. This application produces a measurement-by-measurement mask for each AOS instrument. The mask is output as both a time-stamped ASCII file and as netCDF files that copy the instrument datastreams with the addition of the mask as a separate datastream. The application is easily configurable to handle any combination of AOS instruments and datastreams, so it is easy to port to other AOS sites.

8.0 Collaboration

The work described in this plan depends on collaboration with others in the scientific community and within ARM. In particular, we intend to work closely with ASR working group chairs and DOE Biological and Environmental Research (BER) PIs, ARM instrument mentors, and other members of the ARM infrastructure team in developing new data and communication tools.

8.1 Scientific Community

As the Translator Group shifts to spending more effort on improving the data quality and processing of core VAPs and away from developing new retrievals, we will encourage the submission of PI products to fill that need. We have proactively reached out to ASR data product PIs, Climate Model Development and Validation (CMDV) groups, and OLI and ENA site science teams to provide any information that will be useful in the submission of PI products. Besides meeting with these PIs, we hosted a tutorial at the last ASR meeting with information on how to better collaborate with ARM on science product development. We will continue these communication efforts.

In addition, we have identified a need for more expert evaluation of science products for feedback on methodology and results. We hope that better communication of our efforts through the priorities on the new ARM website and newsletter, this three-year plan and activities described within it, and a more formalized method of interacting with field campaign PIs about VAPs will foster better collaboration and evaluation of scientific data.

8.2 ARM Instrument Mentors

The efforts to develop core VAPs from new instrumentation, and improve the data quality and uncertainty estimation in core VAPs, have to be done in collaboration with instrument mentors. We have already been working towards better interaction with mentors through groups like the Radar Science Group and the Aerosol Measurement Science Group. We have likewise had success collaborating between mentors, Translators, and PIs to improve MFRSR data quality following the MFRSR workshop held in 2016. We will make a similar effort to collaborate with instrument mentors on other data quality and uncertainty projects.

8.3 High-Priority Needs for Internal ARM Development

The Translator Group has identified several updates to current ARM systems that will be treated as high- priority areas for new development in order to meet the goals described in this document. This work will need to be done in collaboration with others within ARM such as the communications and data services groups.

8.3.1 Communicating Data Quality and Uncertainties

- **Method of reporting data epochs**: As we define good data epochs we need to allow users to access those data, including a method to display that information to users, and download the data. This may be a solution within a datastream, or in some other format.
- **Propagating Instrument DQRs**: When a data quality report is submitted on an instrument datastream or VAP datastream, it is often relevant to data products that are up or downstream in the processing chain. However, there is no automatic way to propagate that DQR to other datastreams. For instance, if there is an instrument error from an MPL, it is likely to be relevant to the cloud mask product derived from the MPL, but in order to also label the MPLCMASK data, another DQR must be manually entered.
- **Communicating data versions**: We are interested in finding new ways to communicate important general information about data quality on the website and the data discovery tool. For example, when a major change is made to a datastream (such as an upgrade of a key instrument) or an algorithm, it would be nice to be able to label that simply and clearly for users. If a user is doing a statistical or trend-based study, that change may be important for interpreting the scientific results. Additionally, the developer of a science product can often give basic information on the maturity of the algorithm behind it. Some products are considered quite robust while others are new and more experimental.
- **Uncertainty standards**: As we begin to develop more datastreams with uncertainty information, we want to follow a consistent method of labeling that uncertainty within data files. This should be added to the ARM data standards.
- **Data quality screening of LASSO VAPs**: Because LASSO model runs are computationally expensive, any observational data feeding into those runs should be screened for data quality issues quickly before model runs are done. We recommend that the DQO prioritize screening of measurements/VAPs for LASSO, and can collaborate to help identify datastreams and quality checks.

8.3.2 Data Ordering and Discovery

- **Recommended datastreams**: At the moment it can be quite difficult for an inexperienced ARM user to find datastreams of interest. We need to improve how we recommend datastreams to users and develop new ways to find data of interest.
- **Subset data scientifically for ordering**: As the Translator Group develops scientific indices to find cases of interest, we need new capabilities for users to be able to conditionally subset data based on those indices for ordering or analysis.

8.3.3 Tools to Speed Development of Operational Products

- **ADI support:** We support efforts proposed by the ADI team to make ADI more accessible to new developers and advanced scientific users. In particular, more documentation, support, and training would help new users, as would additional interface simplifications.
- **Evaluation VAP workflow:** The Translator Group supports the efforts underway to change the method of submitting evaluation VAPs to the Archive as described in ENG0003295. The switch to entering evaluation VAP metadata in MMT/ARMINT2 and housing data in the archive rather than

intensive operational period (IOP) area will help standardize the metadata and give users a more consistent way to find ARM products.

- **User-run VAPs on Stratus:** The ability for users to run computationally intensive VAPs on Stratus themselves could help improve collaboration between PIs and Translators, allowing faster development of VAPs, and let users create the data sets of most interest to them scientifically. In order for this to work, a workflow will need to be developed for how users would run the data and how the data could be made available to the science community.

8.3.4 Website and Documentation

- **Datastream citation:** It can be difficult for users to find the correct DOI and citation generator tool for a datastream. We recommend including that information in more locations to encourage users to cite datastreams.
- **Publications using data products:** The new information on the website including publications that use a science product is excellent. That gives useful information internally to ARM for understanding impact and externally for users to understand how data products can be used well. We support efforts to create more complete publication lists associated with a given product.
- **Website location for tools:** As the Translator Group shifts attention to developing some tools such as Py-ART, the GCM diagnostics package, and radar simulators, we think the website should give these tools more visibility. There is currently a page that includes some information about tools to work with arm data: https://www.arm.gov/data/work-with-arm-data. Ideally, however, it would be as easy to find information about ARM tools as it is to find data products.

9.0 Summary

This document contains a coordinated vision of priorities the Translator Group intends to work on for the next three years as discussed in a meeting of the Translator Group in June of 2017. The document was influenced by feedback from the Triennial Review, the User Executive Committee, the *ARM Decadal Vision*, and user feedback from DOE BER programs. 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 five key areas, as follows:

1. Prioritize maintaining the identified list of core VAPs and formalize the process of deciding which VAPs are run at AMF deployments. This should improve communication and efficiency of data products for field campaign science.
2. Complete key retrieval products from new instrumentation installed at ARM sites including AOS, radars, radiometers, and lidars.
3. Develop new products and tools to support climate model development including supporting LASSO, GCM-focused tools and products, and tools that will speed PI development of retrievals.
4. Make progress assigning uncertainties to a strategic list of measurement datastreams in collaboration with instrument mentors.

5. Determine periods of good data quality (good data epochs) for those strategic measurements and associated retrievals.

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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Appendix A

Prioritization

A.1 Science Product Development

Science product development priorities in FY17 are focused around the following activities:

- Products supporting LASSO
- Supporting VAPs for AMFs
- Basic radar products that provide corrected, quality controlled data
- Precipitation products
- Aerosol composition, aerosol profiles, and size distribution
- ARM products for modelers (VARANAL, ARMBE, Diagnostics and Metrics)
- Improved data quality and uncertainty
- Ingest development.

Science products priorities were formulated based on input from the following sources:

- Aerosol Strategic Planning Workshop Report
- Radar Science and Engineering Group
- ARM/ASR PI Meeting breakout session reports
- Translator input
- Program management
- Triennial Review
- LASSO requirements.

Table 11. Science products priorities that will be addressed in FY18.

Translator/Contact	Topic	VAP Keywords	Description
Collis	Radar Products	CMAC2.0	Basic product includes corrections and calibrations for XSAPR and CSAPR.
Collis	Radar Products	Py-ART	Continue Py-ART support with focus on outcomes of the Roadmap.
Flynn	Aerosol	Aerosol Composition	ACSM – Analysis and reprocessing of ACSM based on new information from vendor.
Flynn	Aerosol	Aerosol Absorption	Improve measurements and corrections for aerosol absorption measurements. Aethalometer, CAPS, TAP, PSAP.
Flynn	Aerosol	Spectral Radiance Data Quality	Comprehensive quality assessment of spectral radiometers. Includes MFRSR, SASHe, AOD, CIP.
Flynn	Aerosol	Aerosol Profiles Data Quality	Improved aerosol profile products (quality and uncertainty). Coordinating with Riihimaki.
Flynn	Aerosol	AOS harmonization	Documentation for the AOS harmonization efforts.
Giangrande	Radar Products	RWP Winds LASSO	Operational RWP wind and BL height product for LASSO.
Giangrande	Atmos. State	Mergesonde	Minor upgrades to core VAP. These changes will address several issues brought up by users.
Giangrande	Precipitation	Rain Rate & DSDs	Includes incorporating a disdrometer algorithm for DSDs and a merged datastream for new liquid precip measurements.
Giangrande	Radar Products	Radar Calibration	Develop ARM capability to calibrate radar systems using satellite observations.
Giangrande	Radar Products	ARSCL Clutter Rejection	Further develop automation of clutter rejection using MicroARSCL and RWP cloud boundary information.
Giangrande	Radar Products	MicroARSCL	Higher moments of Doppler spectrum – make basic product operational.
Riihimaki	Clouds & Radiation	Expand core VAPs to AMF and ENA	Adapt VAPs for LASIC and ACE-ENA including QCRAD, RADFLUX, and MFRSRCLDOD. MPLCMASK and PBLHeight will be run for MARCUS. Will explore SST VAP.

Translator/Contact	Topic	VAP Keywords	Description
Riihimaki	Aerosol	MFRSR AOD Data Quality Data epoch	Complete ongoing work to develop QA/QCd MFRSR AOD datasets (epochs) with documentation. With DQO, Flynn, and Gregory.
Riihimaki	Clouds	LWP – MWR3C Data Quality AMF LASSO	Address the many issues with MWR3C data quality and error assessment (bias). Apply MWRRETv2 to LASIC, MARCUS, ACE-ENA; assess bias corrections for operational algorithms at fixed sites.
Riihimaki	Clouds & Radiation	AERI Profiles LASSO	Operational AERIoe algorithm for SGP C1 and BL sites. Includes working with ASSIST data. Supports LASSO.
Riihimaki	Clouds	MPLCMASK Data Quality LASSO/ARSCL	Improve MPLCMASK for BL clouds and improve DQ of backscatter and depol ratio; identify good data epochs. Develop new metrics with DQO to better identify problems with MPL data. This will improve both the ARSCL and cloud classification scheme for LASSO.
Xie	Modeling	VARANAL LASSO AMF	Includes LASSO ops, adding BL site obs, continuous forcing, AMF deployments.
Xie	Modeling	ARMBE	ENA and selected AMF sites; automation of QC checks and processing.
Xie	Modeling	Radar Simulator	Update radar CFADs with calibrated radar data; Implement simulator to GCMs; finalize simulator for COSP.
Xie	Modeling	Radar Simulator	Create CFAD for ENA, AWARE, LASIC.
Xie	Modeling	Model Diagnostics	Includes cloud, convection, and precip data in the ARM metrics package. Integrate into the Community Diagnostics Package (CDP).
Gustafson	Modeling	LASSO	Phase 2 LASSO development and transition to operations.
Gaustad	Software Development	ADI	Develop 3-5-yr vision document.

A.2 New Science Products, External Products, and Modeling

Several new science products and activities that fall outside the Translator work scope will be addressed in FY18. These include the new cloud properties retrieval project (OGRE-CLOUDS) and the photogrammetry products. In addition, VAPs that use external data will be added to the Science Products portfolio. As the LASSO high-resolution modeling project transitions to operations, a few remaining high-priority development tasks relate to automation of the workflow, publications, and exploring the next steps for LASSO (Phase 2). There are new opportunities in the area of machine learning that will address data quality and uncertainty in ARM data products.

Table 12. New science products, external products, and LASSO modeling.

Contact	Topic	VAP Keywords	Description
Jensen	Cloud Properties	OGRE	Cloud properties retrieval framework
Romps	Cloud Properties	Photogrammetry	3D cloud fields
Gregory	Land Properties	Soil Moisture External Data	OK Mesonet Soil moisture – evaluate data; metadata review and move to production.
Gregory	Cloud Properties	CSPHOT Cloud Mode	Move CSPHOT Cloud Mode VAP to production and apply automated ML quality checks.
TBD	Software Development	Machine Learning, Data Quality, Uncertainty	Fund white papers to labs for improving DQ and Unc. using machine-learning approaches.
Gustafson	LASSO Modeling	Implement operational LASSO software	Includes data assimilation, model runs, and data bundling.
Gustafson	LASSO Modeling	Publications	Complete overview paper and forcing methodologies paper.
Gustafson	LASSO Modeling	Community outreach	AGU Town Hall
Gustafson	LASSO Modeling	LASSO Phase 2	Exploratory work for LASSO Phase 2 including forcing generation and LES modeling for new locations/meteorology.

Appendix B

Activities Not Currently Prioritized

These are items discussed by the Translator Group that were deemed important to ARM but not on our current high-priority list because either there is not a clear path forward for Translator involvement or they were deemed new products rather than core VAPs. Some of these may well become items that we will actively support as the scope is better defined and budget allows. Some tasks may remain more aligned with the responsibility of others.

1. Implementing new LASSO diagnostic merged products (e.g., cloud fraction, thermodynamic profiles)
2. Additional improvements to data quality of hyperspectral radiometers (SASHE, SASZE)
3. Evaluation or testing of RS92 to RS41 sonde upgrade
4. New in situ instrumentation: MASC/PIP/UAV/Tethersonde
5. Implementing VAPs from new products emerging from ASR projects and CMDV projects
6. ARM lidar simulator for GCMs
7. ARM data statistical error bar estimates
8. Aerosol Size Distribution and Hygroscopicity (Kappa)
9. Advanced SAPR products (QVP, MMCG, SCP, VAD)
10. Adaptive scanning and cell tracking using polarimetric radar
11. Searchable catalog of convective phenomena using multi-sensor analysis
12. SIMEPAR, a public/private partnership in the Paraná state of Brazil uses Py-ART to pre-process radar data and grid before performing cell tracking for hydrological forecasts.