

The ARM logo consists of the letters "ARM" in a bold, blue, sans-serif font. Below the letters is a thin, blue, curved line that arches over the text.

**ARM**

# The Atmospheric Radiation Measurement (ARM) Climate Research Facility

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# Outline

- Facility Introduction
- Science Highlights
- Field Campaigns
- Decadal Vision Activities
  - ▶ Unmanned Aerial Systems
  - ▶ High-Resolution Modeling
- Data Management
- Triennial Review



## Overview of ARM Facility

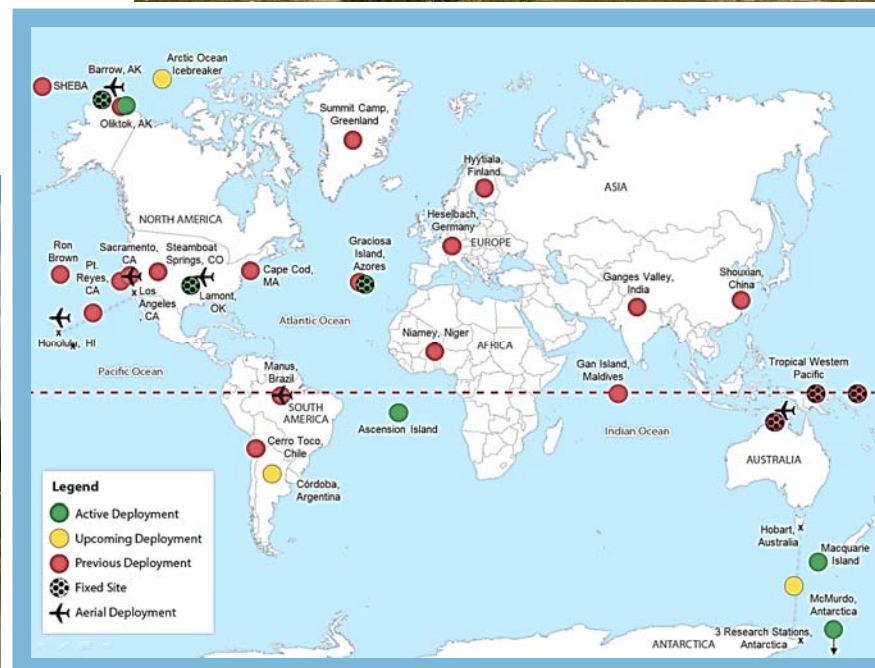
### *Long-term, comprehensive atmospheric observing network*

- Since 1992, providing measurements of cloud & aerosol properties, and their impacts on Earth's energy balance
- Network of 3 fixed & 3 mobile atmospheric observatories providing comprehensive instrument suites across diverse climate regimes
- Manned & unmanned aerial measurement platforms
- Extensive data management infrastructure that has accumulated over 1 petabyte of data to support atmospheric research
- Broad array of freely available data products to support the advancement of atmospheric research & global model development
- 200 staff spanning 9 DOE laboratories and other institutions
- Work closely with the DOE Atmospheric System Research (ASR) program and serve the international climate research community



# ARM's Vision

To provide a detailed & accurate description of the earth atmosphere in diverse climate regimes to resolve the uncertainties in climate and earth system models toward the development of sustainable solutions for the Nation's energy & environmental challenges.



# Comprehensive Sets of Measurements Supporting Atmospheric Research



Background Atmospheric State  
Temperature, humidity, wind, and precipitation



Surface Energy Balance  
Radiation, latent, and sensible heat fluxes



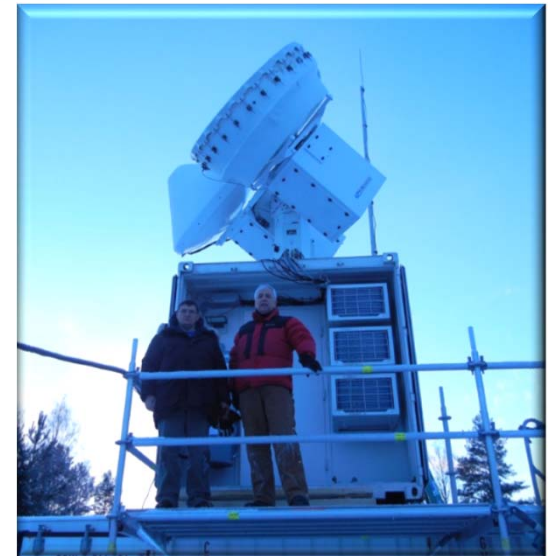
Aerosol and Hydrometeor Profiles  
Remote sensing of aerosol, cloud, precipitation optical and microphysical properties



Near-Surface Aerosol Properties  
In situ optical, microphysical, chemical aerosol properties, and trace gases



Upper-Air Parameters  
Aerial measurements of background state, aerosol, trace gas, and cloud properties



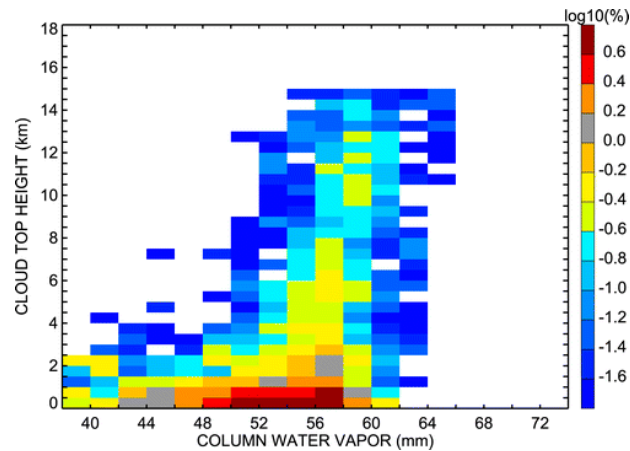
*Scanning Cloud Radar*



*In situ probes on the G-1*

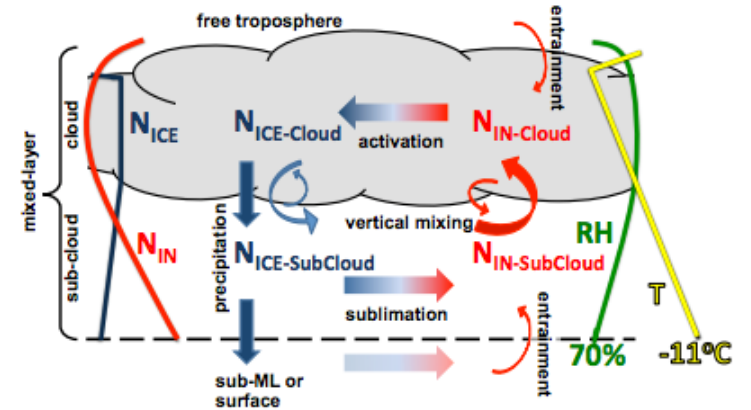
# Produces High Impact Science

Provides unique measurements of scientifically important but under-observed phenomena

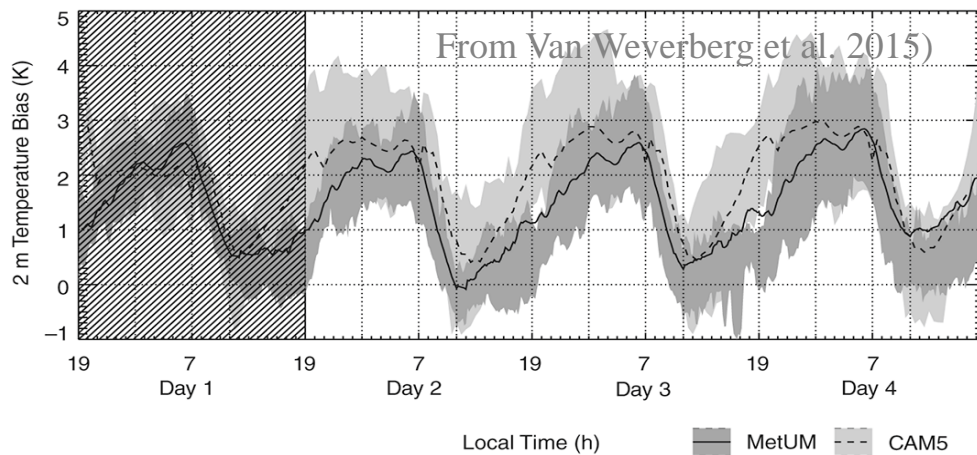


*Vertical distribution of cloud occurrence as function of water column in Darwin, Australia*

Enables fundamental advances in understanding of cloud and aerosol processes



*Theoretical description of arctic mixed-phase cloud maintenance*



Enables the evaluation and improvement of global models

*Multi-model study of the central U.S. temperature bias*



# New Data Sets Reveal Marine Cloud & Boundary Layer Structures

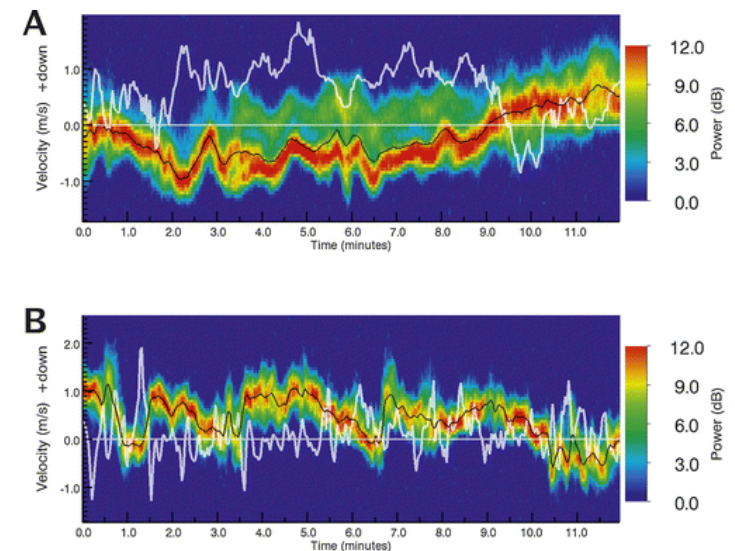
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## ■ Drizzle Onset

- ▶ New algorithms separate cloud and drizzle properties using radar Doppler spectra fills gap in understanding drizzle onset (Luke and Kollias 2013; Fielding et al., 2015)
- ▶ Nearly half of all clouds are drizzling (Remillard et al., 2012)

## ■ Azores data used to identify 50% to 100% error in model simulations of warm rain

- ▶ Improving representations of precipitation formation processes have led to more accurate cloud cover & condensate estimates in models (Ahlgrimm and Forbes 2014)

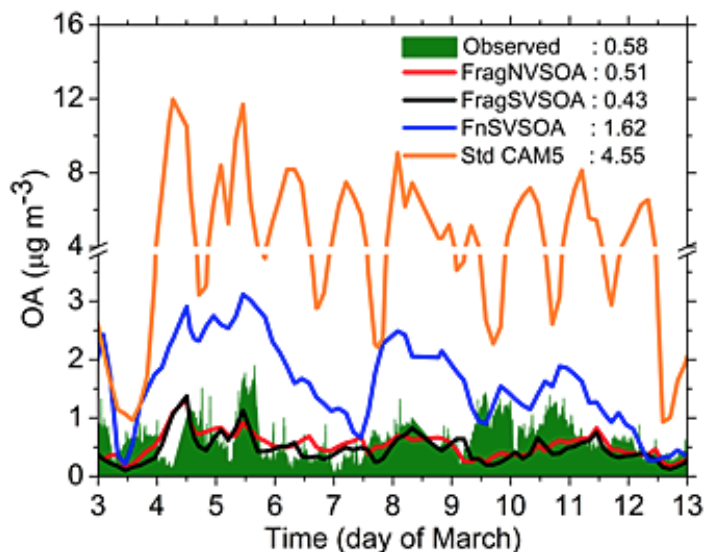


*Radar Doppler spectra help separate cloud & drizzle properties (Luke and Kollias 2013)*

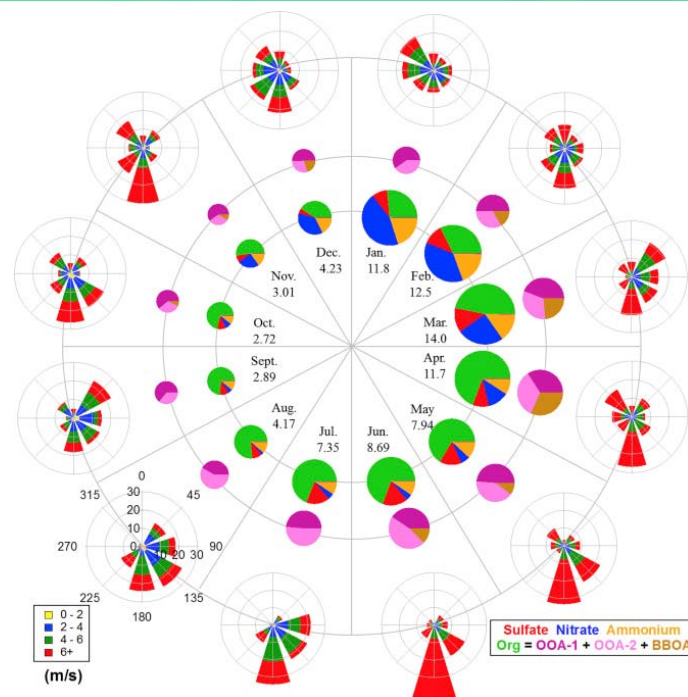
# First Long-Term Measurements of Aerosol Chemical Species in Great Plains Region

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- First seasonal characterization of chemical & physical properties of aerosols
- SOA transported from southeast U.S. main source of aerosol distributions in the Southern Great Plains



*Shrivastava et al. 2013, 2015;*  
*Bateman et al., 2017*



*Parworth et al., 2015*

- New SOA parameterization implemented into CAM-5 global model significantly improves agreement with observations of aerosol optical depth

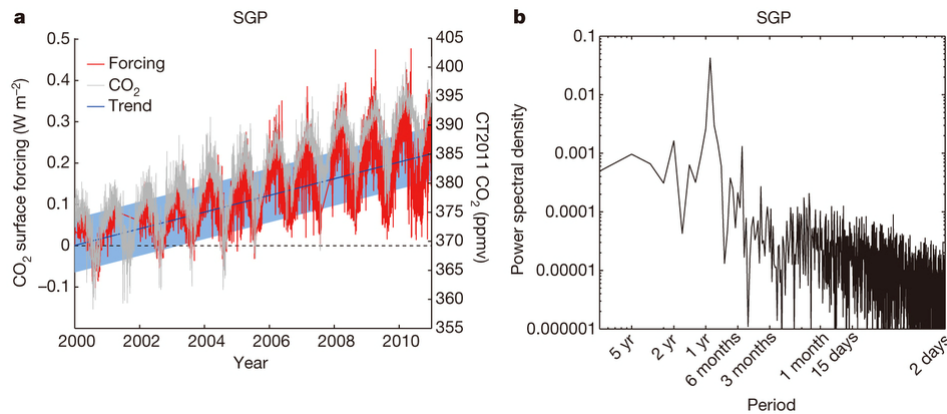


# Contributing to Diverse Science Themes and Communities

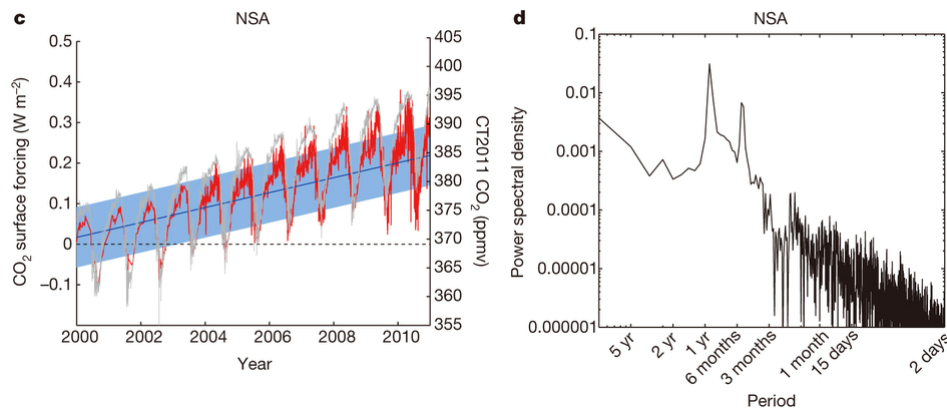
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Confirms predictions of atmospheric greenhouse effect and provides first empirical evidence of rising CO<sub>2</sub> levels effect on surface energy balance (Feldman et al., Nature 2015)

*Southern Great Plains*

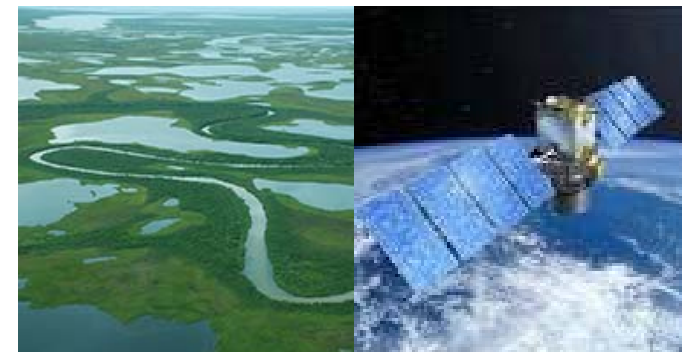


*North Slope of Alaska*



Use by other programs and agencies

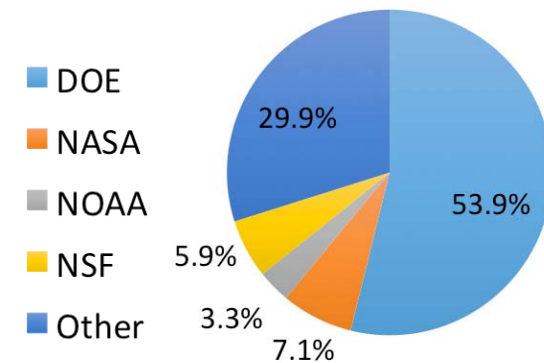
- ▶ Model Evaluation including E3SM, CESM, and ECMWF
- ▶ Satellite Validation
- ▶ Renewable Energy – Wind & Solar
- ▶ Terrestrial Ecosystem – Carbon & Land Properties



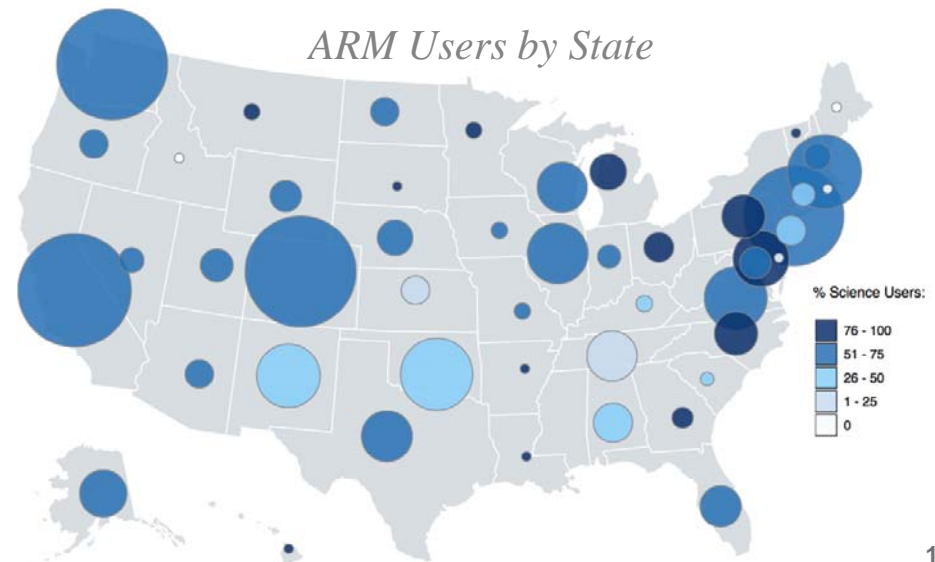
# An Overview of ARM Activities and Impact

- Over 200 journal articles from 2016 spanning topics related to the properties and interactions among clouds, aerosols, precipitation, and radiation
- 145 IPCC AR5 citations
- 1,177 active science users
- Users in 46 states and 38 countries including 10 with more than 10 users
- 55 field campaigns in 2016

*Distribution of ARM science users by primary funding source*

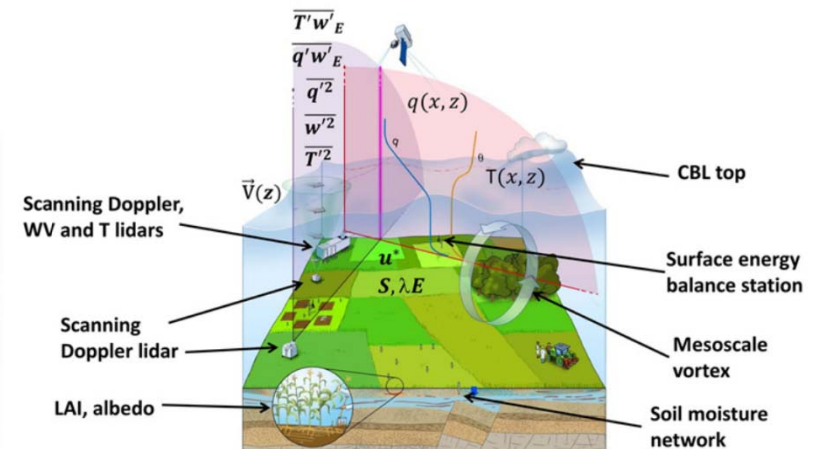


*ARM Users by State*



## Major Field Campaigns in FY2017

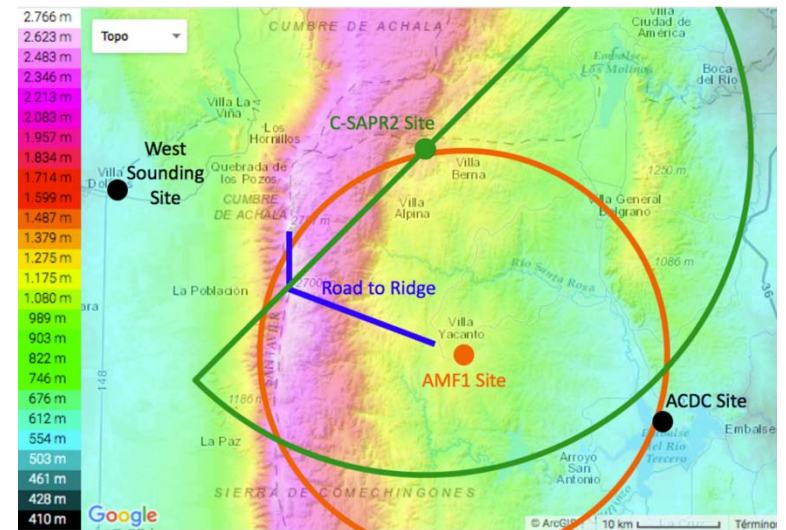
- AWARE— Mobile facility Antarctica deployment to study clouds and their impact on the surface energy balance
- LASIC – Mobile Facility on Ascension Island in the Southeast Atlantic to study impact of aerosol plumes on marine stratocumulus.
- LAFE – Lidar study of boundary layer processes at the Southern Great Plains
- ACE-ENA Deployment of G1 aircraft to the ARM site in the Eastern North Atlantic to study marine boundary layer clouds and aerosol-cloud interactions.





# Major Upcoming Field Campaigns

- Measurements of Aerosols, Radiation and Clouds over the Southern Ocean (MARCUS), Oct 2017 – Apr 2018
  - ▶ Ship-based mobile facility in the Southern Ocean
- Cloud, Aerosol, and Complex Terrain Interactions (CACTI), Oct 2018 – Apr 2019
  - ▶ Deployment of mobile facility and G-1 in Argentina to study deep convection
- Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAIC), Sep 2019 – Oct 2020
  - ▶ Deployment of mobile facility on ice-breaker in Arctic Ocean



# Planning for the G-1 Replacement: Air-ARM



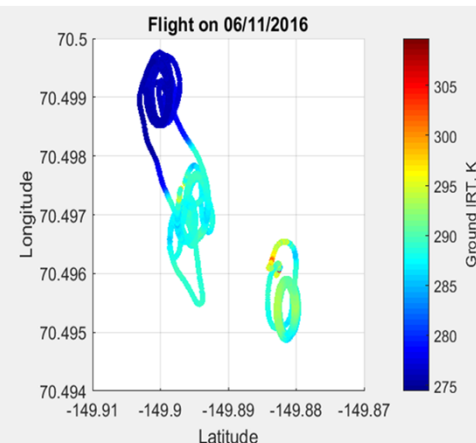
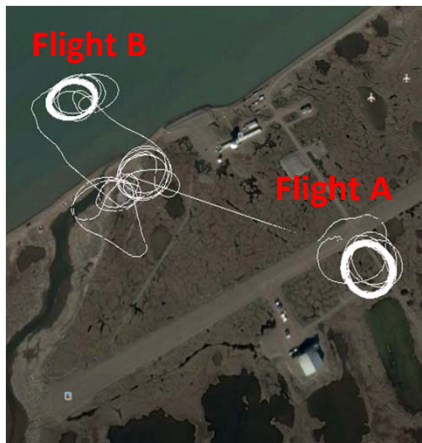
- The G-1 piloted aircraft continues to play a critical role but will be retired in the next several years
- Requirements for new aircraft based on 2015 DOE workshop
- Replacement process is underway:
  - ▶ Mission Need Assessment (CD-0) is complete
  - ▶ Analysis of Alternatives (CD-1) is in progress
  - ▶ Planning for FY19 acquisition and FY20 aircraft integration



# Inaugural Campaigns for ARM Research using Unmanned Systems (ICARUS)



- Deployed small UAS and Tethered Balloon to Oliktok Point, Alaska, for two periods in 2017 to support second season of ICARUS flights
- UAS measurements include T, RH, Surface Temperature
- TBS measurements included T, RH, liquid water content
- Compared to ICARUS 2016 - significantly expanded operational envelope (minimum and maximum flight altitudes, geographical extent of the operations area)
  - ▶ Total number of flights: 35
  - ▶ Total days flown: 11
  - ▶ Total flight hours: 28:41





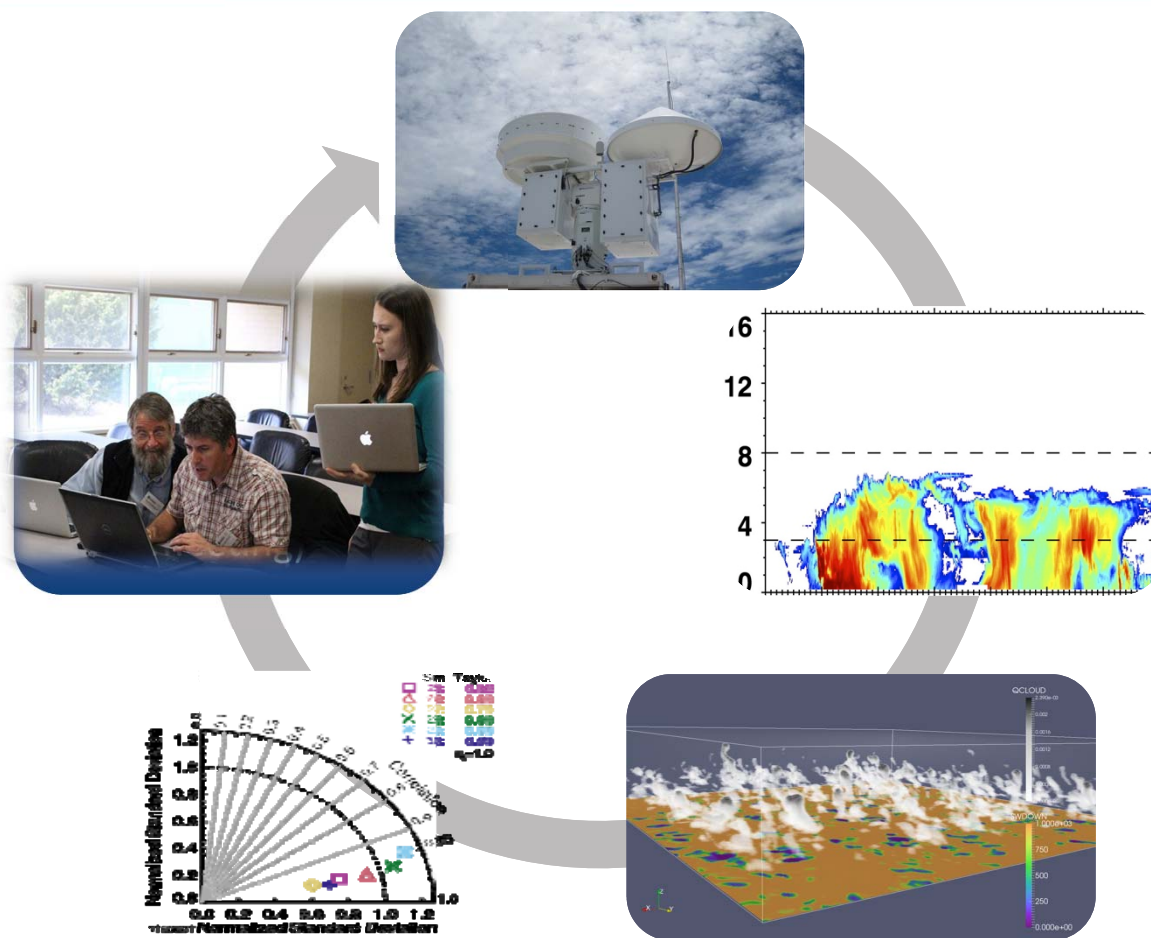
# Implementing a Mid-Size UAS for Regional Cloud and Aerosol Sampling



- The Arctic Shark has a payload capacity of 46 kg, endurance of 8 hours, and a maximum altitude of 5.5 km
- The UAS has been received and the AAF pilot team has been trained on the platform and has carried out test flights at the Pendleton, Oregon, test range



# LES ARM Symbiotic Simulation and Observation (LASSO)



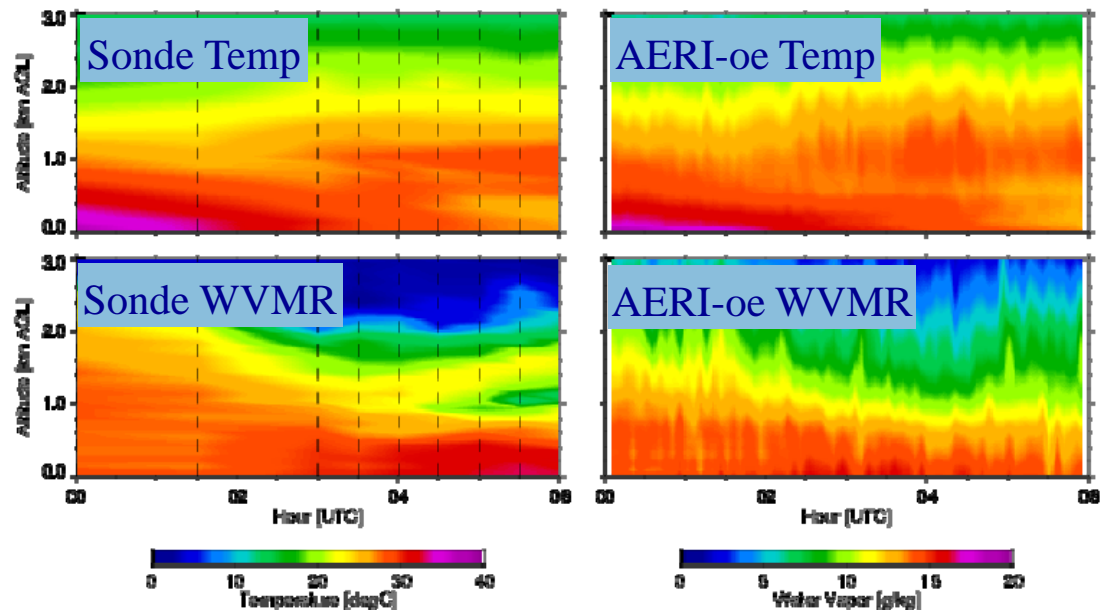
## LASSO activities this fall

- ▶ Alpha2 simulations released
- ▶ Recommendations for operations provided to ARM management and modeling group
- ▶ Transitioning to operations
- ▶ Community engagement including upcoming Town Hall at AGU

*Comprehensive strategy to integrate ARM observations and model simulations*

# FY2018 Science Product Priorities

- Products supporting LASSO
- Supporting Value Added Products for ARM Mobile Facilities
- Radar Products that make radar data accessible to users
- ARM Products for modelers
  - ▶ Variational analysis based forcing
  - ▶ ARM Best Estimate
  - ▶ Diagnostics and metrics
- Improved data quality and uncertainty
  - ▶ Data epochs (virtual field campaigns)
  - ▶ Machine learning

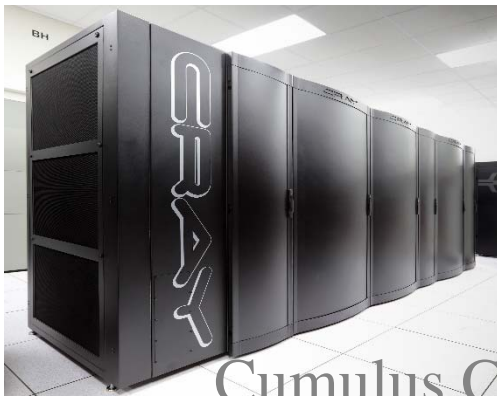




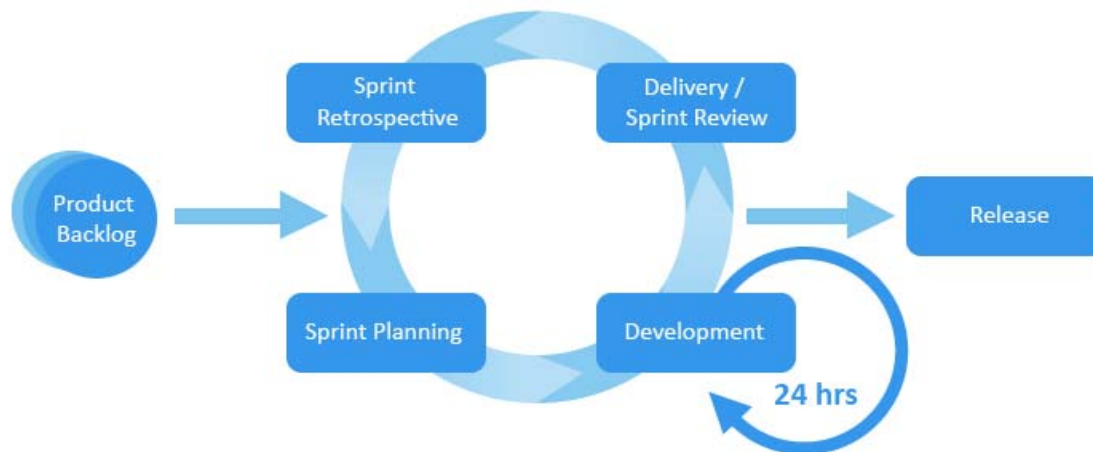
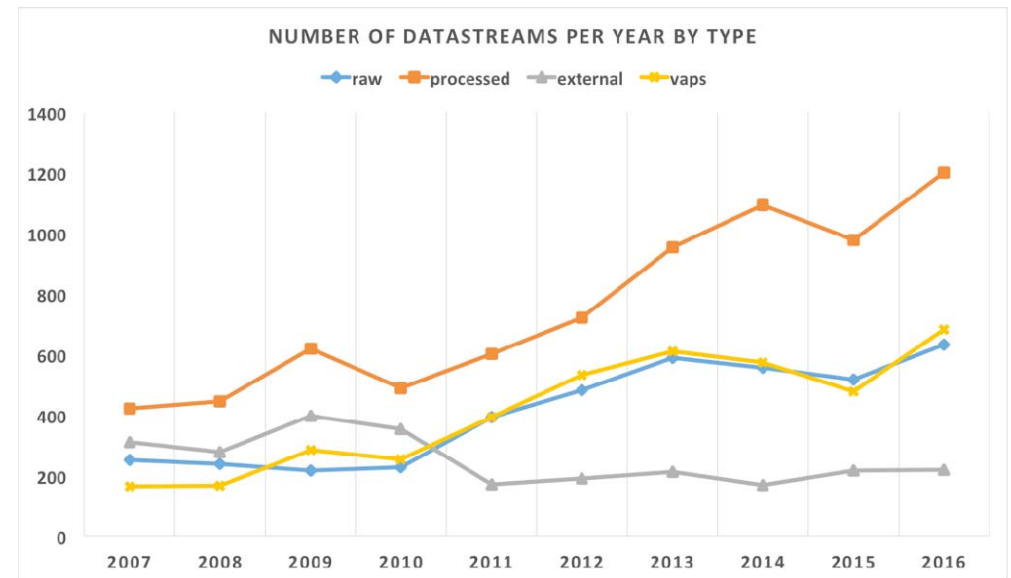
# Developing Infrastructure and Processes to Manage Growing Dataset



- 1,800 processed datastreams
- 1 petabyte data stored



Cumulus Cluster

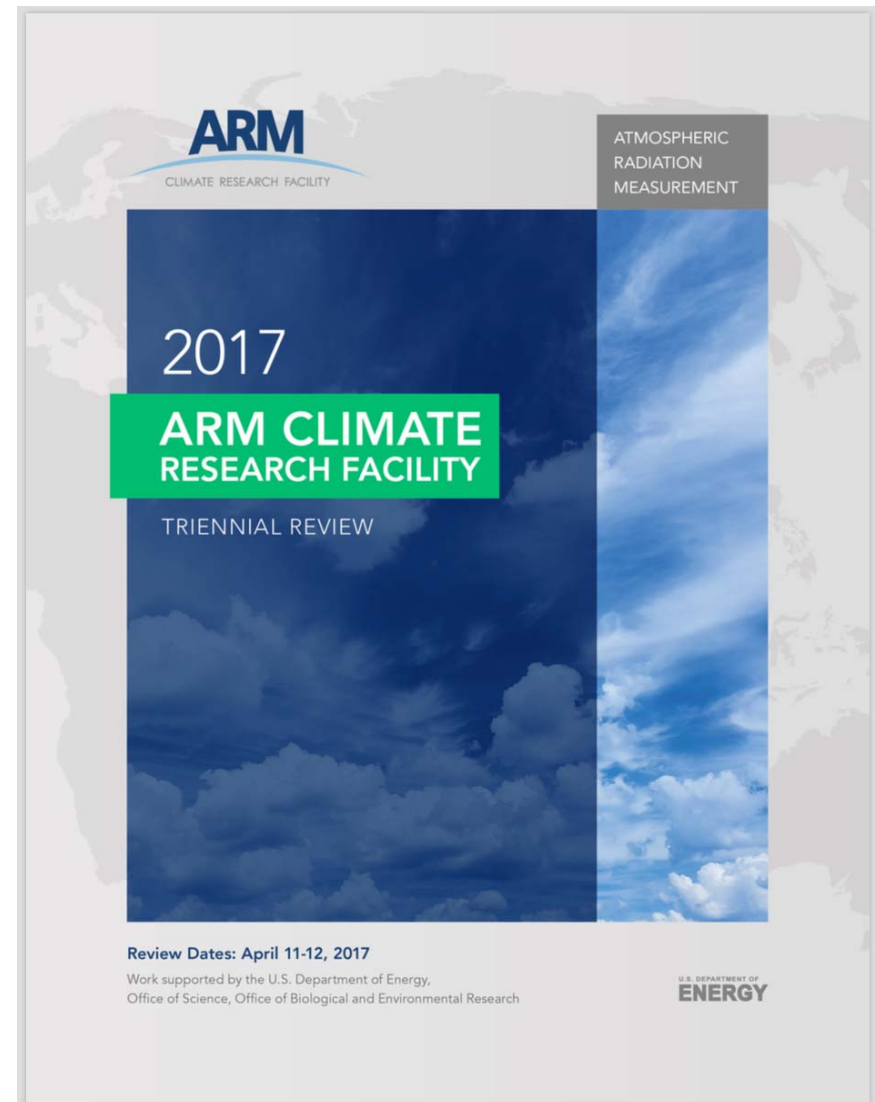


- Consolidation of data processing services
- Agile development methods including code sprints
- Development of an open source community
- Machine learning

# Triennial Review

**ARM**

- The review evaluated the following questions:
  - ▶ Is the ARM Facility having a significant impact on climate science?
  - ▶ Is the ARM Facility managed and operated effectively and efficiently?
  - ▶ Does the ARM Facility have an engaged user community?



- The reviewers found that ARM:
  - ▶ Has unique capabilities
  - ▶ Enables high impact science supporting Climate and Environmental Sciences Division strategic goals
  - ▶ Has effective management and operations
  - ▶ Engages effectively with the BER user community
  - ▶ Has addressed the recommendations from the 2014 review



## Recommendations

- Provide measures of success for outreach and science impact
- Broaden reach beyond DOE and Atmospheric System Research users
- Develop a plan for more timely release of VAPs for AMF campaigns
- Develop a plan for continued improvements to the Data Discovery Tool
- Develop process for reviewing priorities
- Update plan for radars and develop plan for aerosol measurements
- Develop plan for LASSO including scope, goals, metrics, and next steps

## Summary

- Comprehensive atmospheric measurements in diverse climate regimes
- Impacting a broad range of science themes
- Extending ARM impact through field campaigns
- Small UAS operations continue at Oliktok while preparations are underway to implement the mid-size ArcticShark UAS
- Working to replace the G-1, which will be retired soon and which continues to provide critical measurements
- LASSO is transitioning to operations and seeing first applications
- Developing new data management processes and infrastructure to manage growing data volume and complexity
- Acting on recommendations from the triennial review to better serve the science community