The Aerosol Cloud meTeorology Interactions oVer the western ATlantic Experiment (ACTIVATE)

ACTIVATE Science Team
Represented by: Armin Sorooshian (University of Arizona)

AOS Application Impact Team Seminar: 23 September 2021

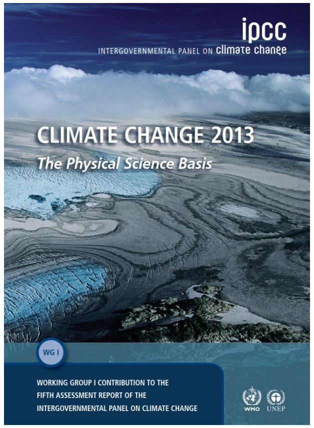
Outline

- Motivation for ACTIVATE
- Relevance to AOS & AIT
- Mission overview
- Programmatic insights: successes and challenges
- Open data workshop

Motivation

IPCC 5th Assessment (2013)

- "Clouds and aerosols continue to contribute the largest uncertainty to estimates and interpretations of the Earth's changing energy budget."
- "Aerosols and their interactions with clouds contribute to the largest uncertainty to the total radiative forcing estimate"



NAS Decadal Study Report (2018)

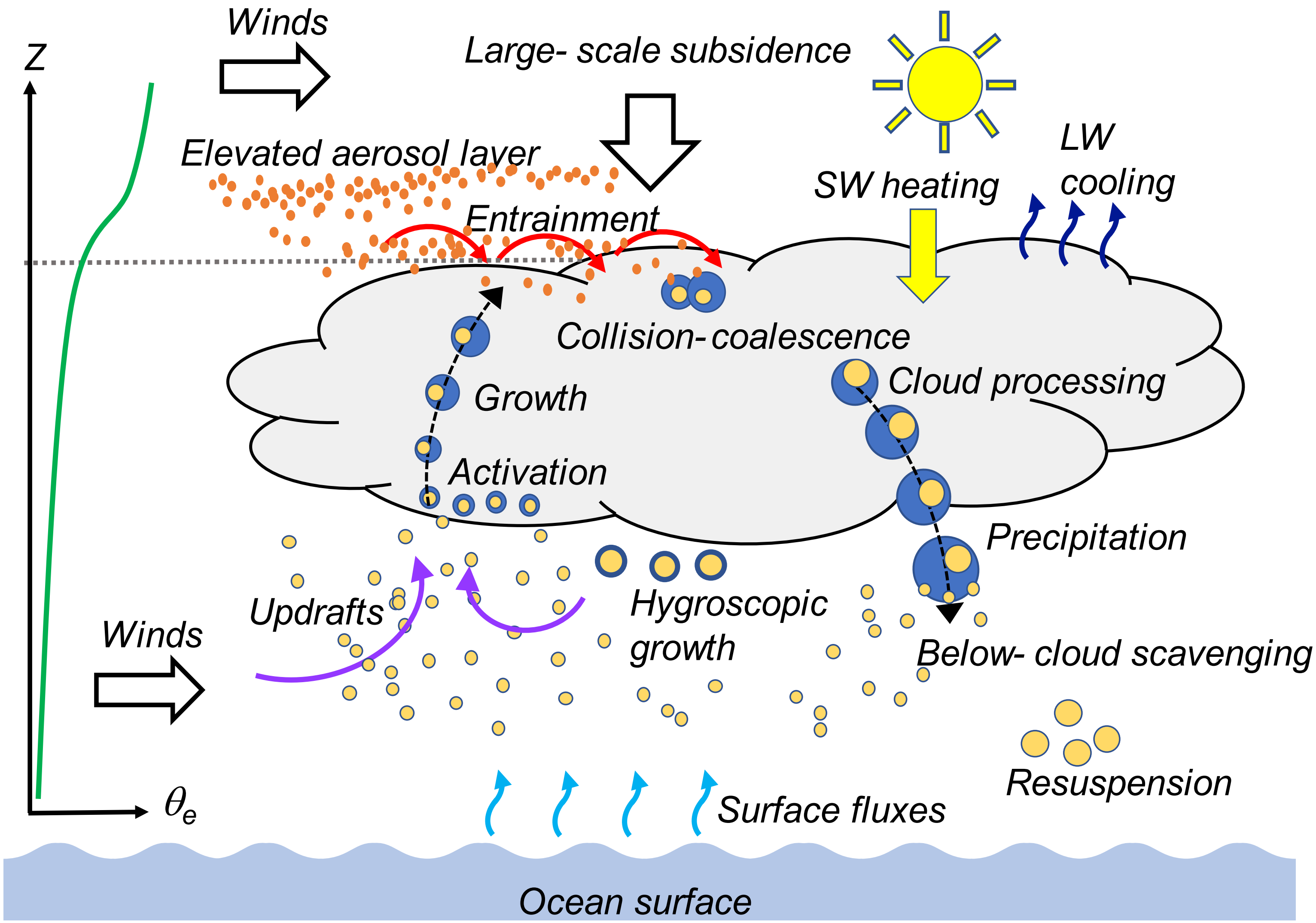
- "Improving our understanding will require measurements capable of examining aerosol and cloud vertical profiles and sizes. Vertical profiles of aerosols are also essential for determining how and whether aerosols affect cloud microphysical properties."
- "It is likely that only such a combination of platforms (models, in situ observations, space-based platforms) would resolve the roles of the naturally-occurring and anthropogenic aerosols on clouds."

NASA A-CCP/AOS Study (ongoing)

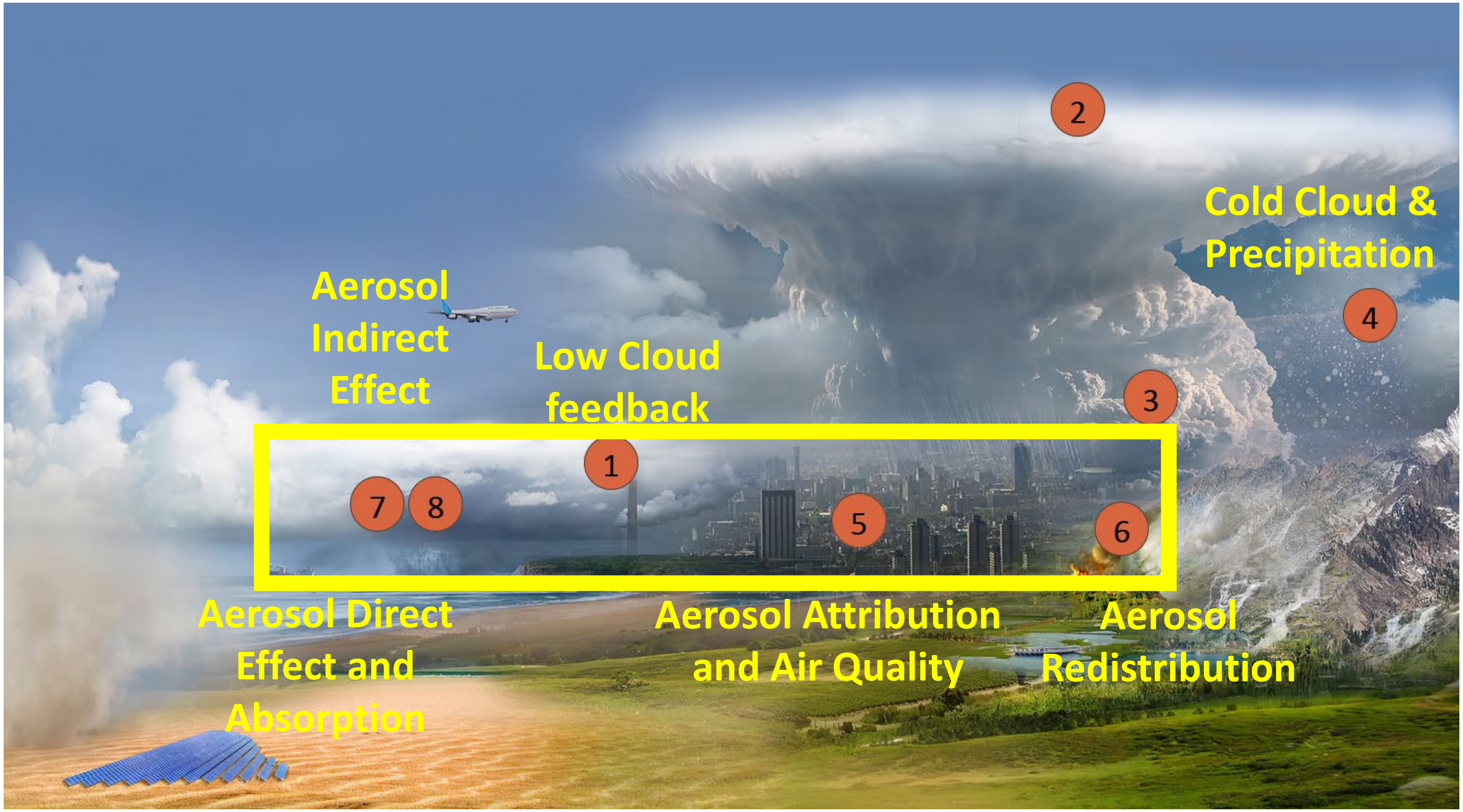
- In response to NASA's *Designated Observables Guidance for Multi-Center Study Plans*

Why such high uncertainty?
Complexity of clouds and difficulty in untangling influences from aerosols and meteorology.

Why ACTIVATE?
Will quantify relationships between aerosols, clouds, and meteorology with a new experimental approach.

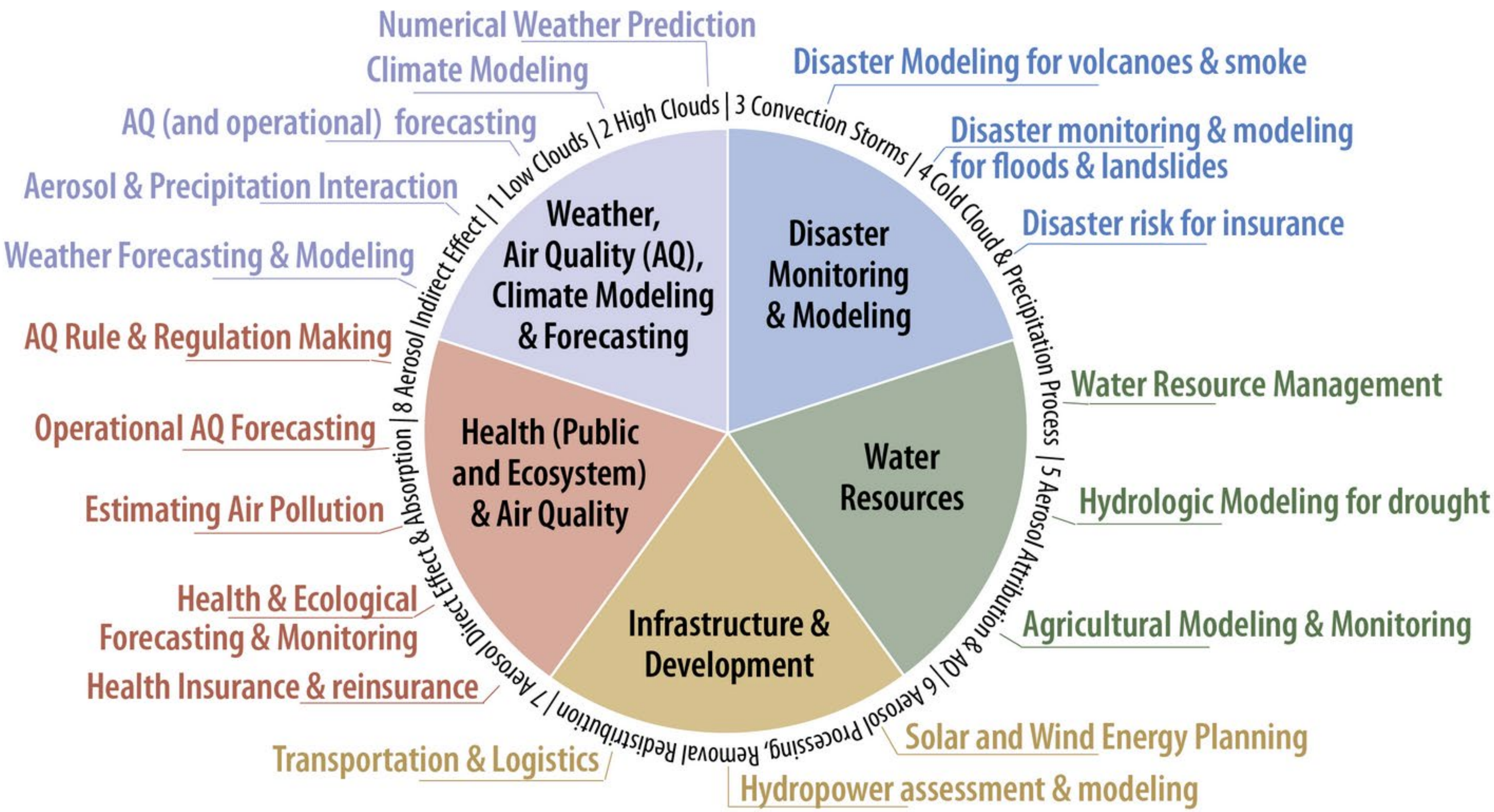

Winds
Large- scale subsidence
Z
Elevated aerosol layer
SW heating
LW
cooling
Entrainment
Collision-coalescence
Growth
Cloud processing
Activation
Precipitation
Updrafts
Hygroscopic
growth
Winds
Below- cloud scavenging
Resuspension
Surface fluxes
θ_e
Ocean surface

Relevance to AOS



Source: https://vac.gsfc.nasa.gov/accp/science-goals.htm

Relevance to AOS



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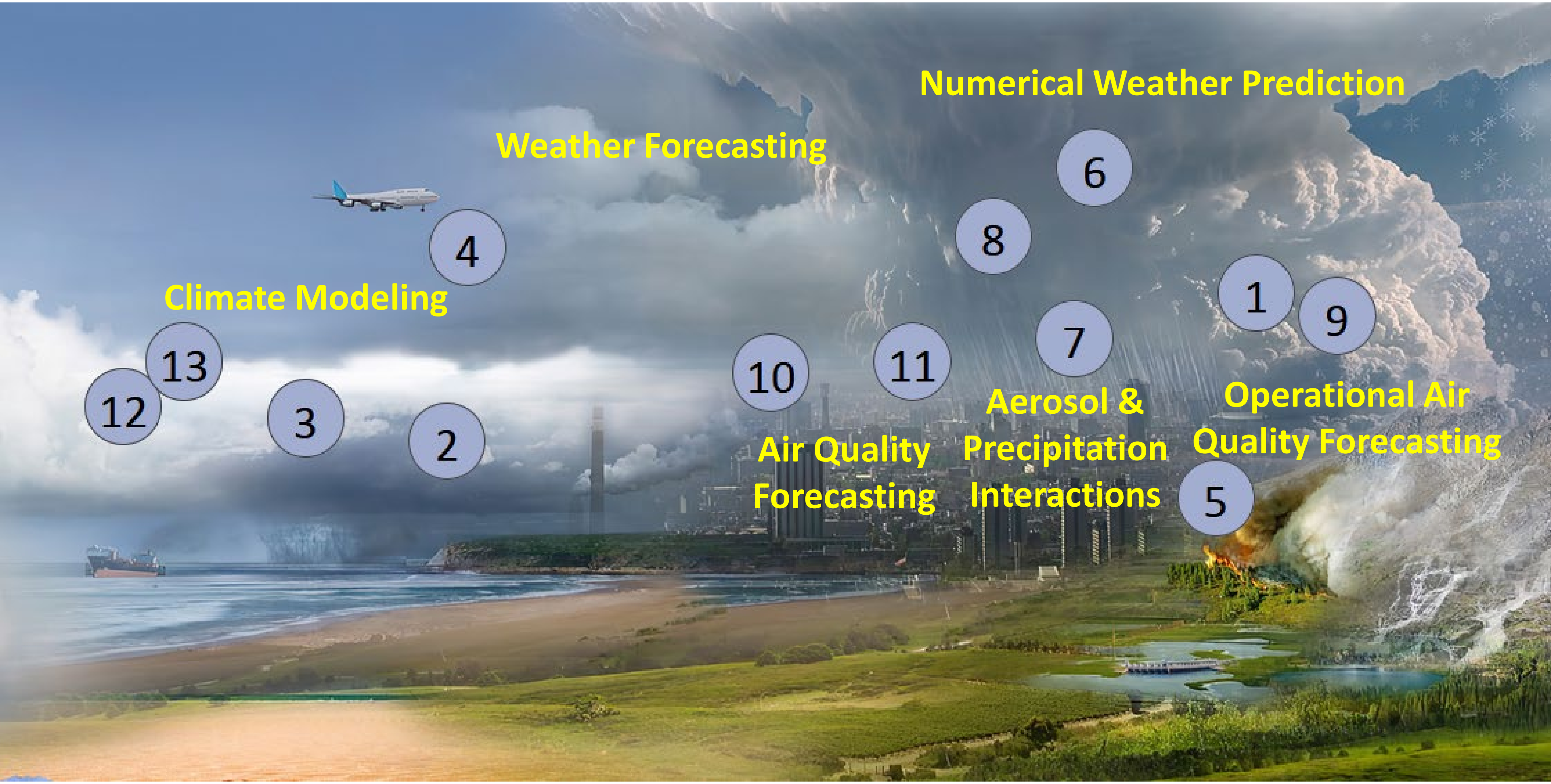
Relevance to AOS



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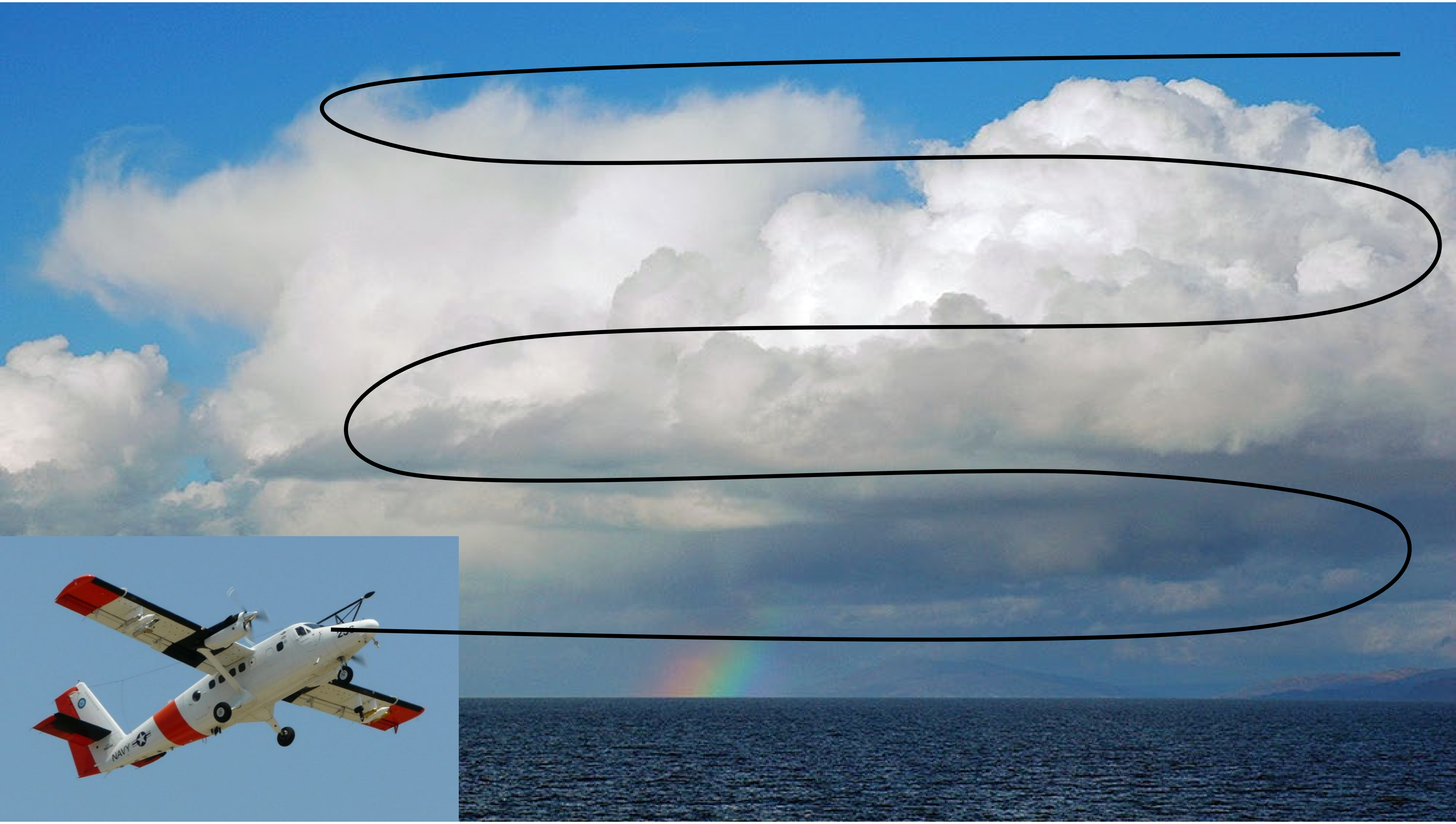
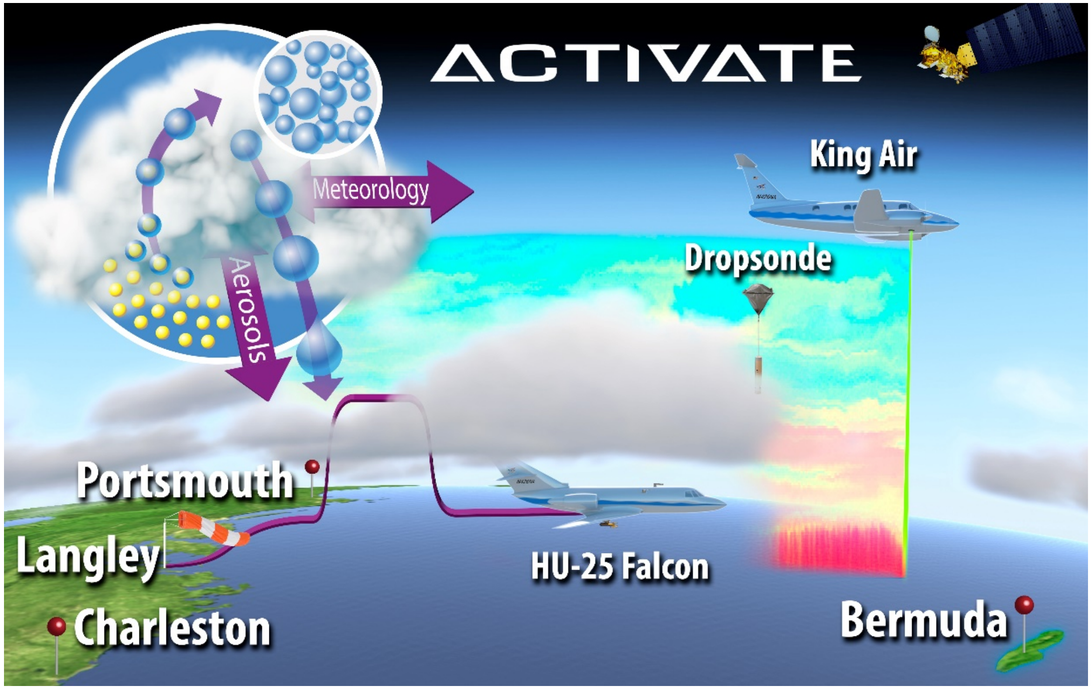

NAVY

ACTIVATE

Mission Website: http://activate.larc.nasa.gov/

Publicly Available Data: https://www-air.larc.nasa.gov/cgi-bin/ArcView/activate.2019

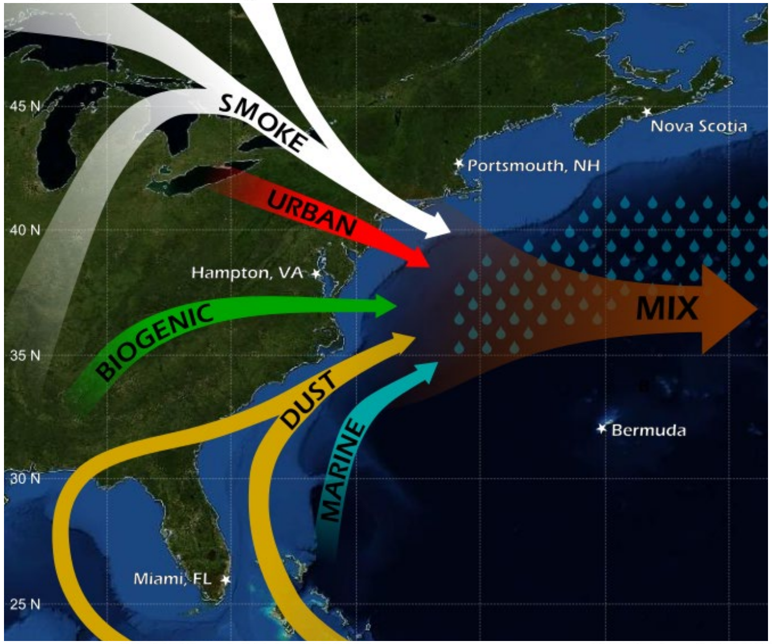


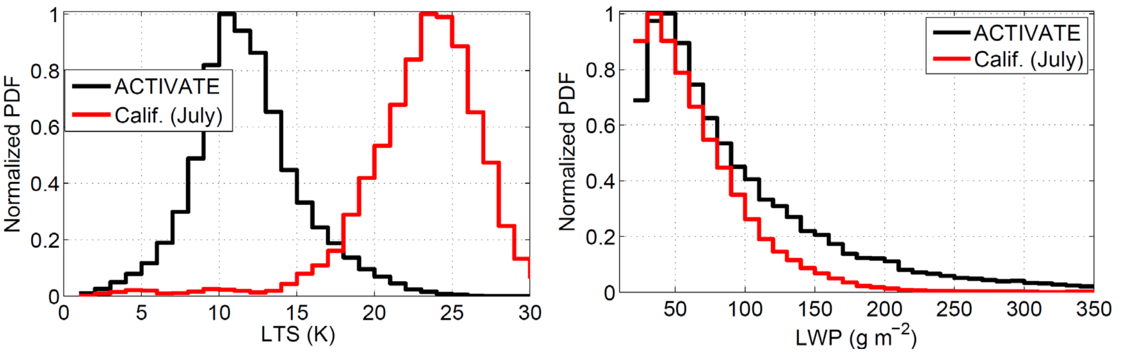
Science: Build **unprecedented dataset** to better understand aerosol-cloud-meteorology interactions, improve physical parameterizations for Earth system and weather forecasting models, assess remote sensing retrieval algorithms, and guide plans for future satellite missions.

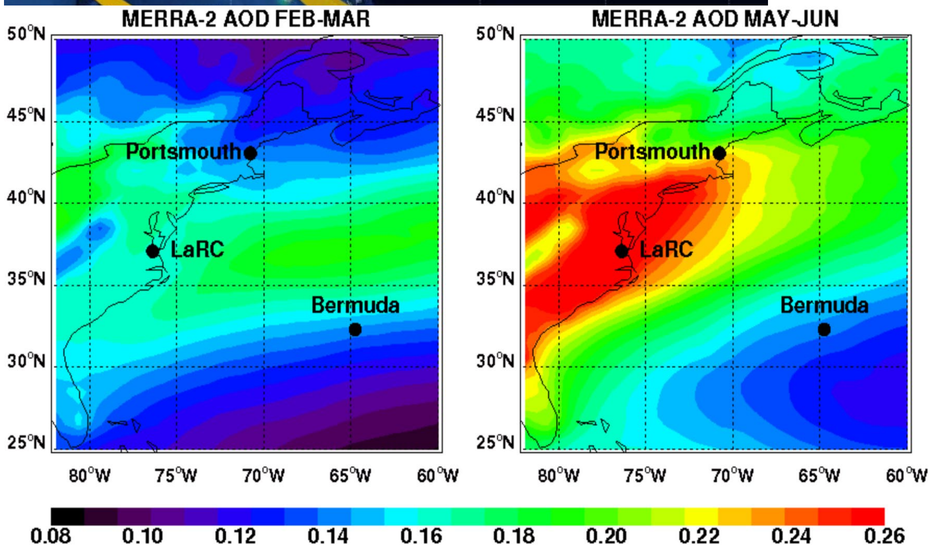
- PI: Armin Sorooshian (U. Arizona)
- Project Scientist: John Hair (NASA LaRC)
- NASA Earth Venture Sub-orbital (EVS-3) Mission
- Partnering Institutions: U. Arizona, NASA LaRC, NASA GISS, NCAR, SSAI, NIA, PNNL, BNL, BAERI, U. Miami, College of William & Mary, Bermuda Institute of Ocean Sciences, DLR (Germany)
- Over 130 participants on science team

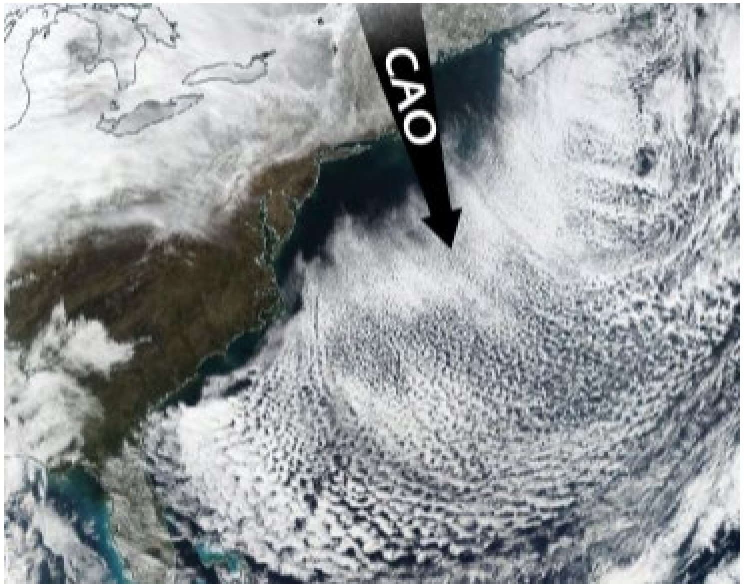
- Platforms: HU-25 Falcon + UC-12 King Air
- 150 joint airplane missions (~600 hrs per plane) over western North Atlantic Ocean
- Based out of NASA LaRC, Hampton, VA
- Measurements: In situ and remote sensing measurements of aerosol and cloud distributions and properties, atmospheric state

Why Western N. Atlantic Ocean?



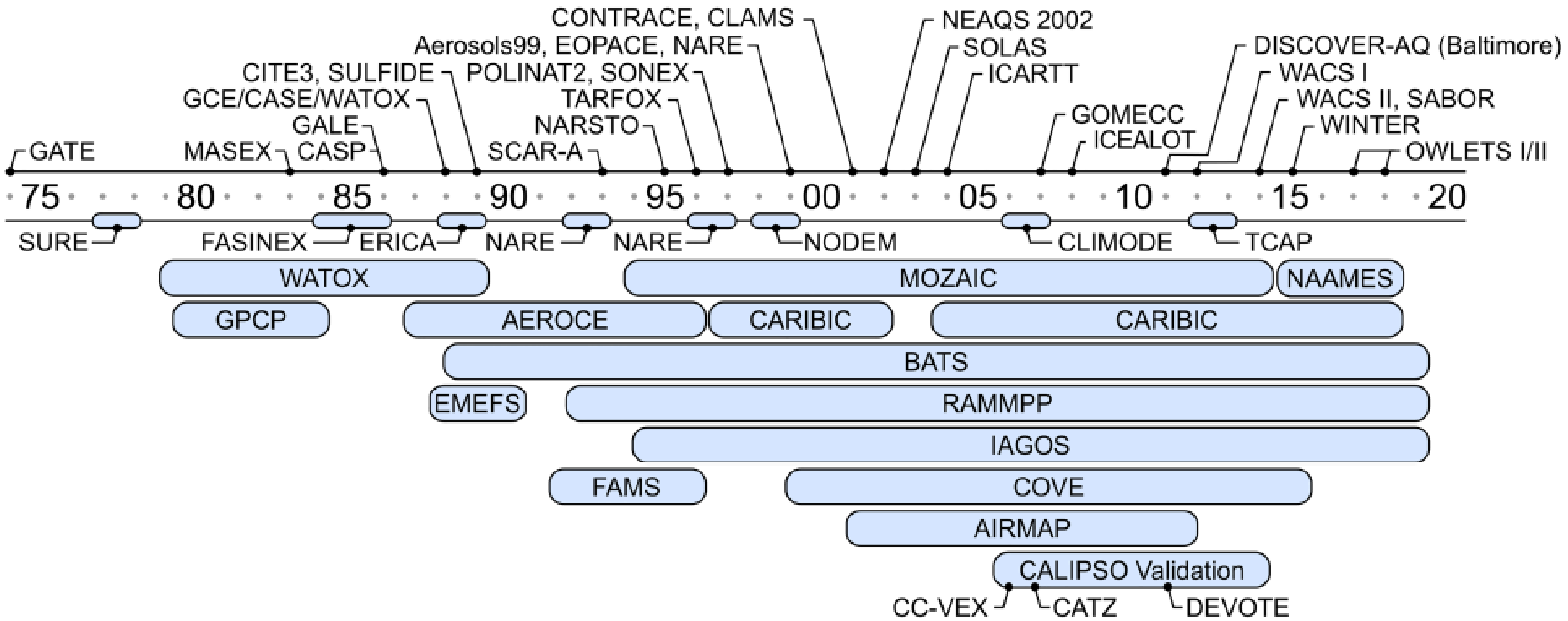






A Well-Studied Region: US East Coast and W. North Atlantic Ocean

- ~50 combined field campaigns
- ~715 peer-reviewed publications
- Most studied topic: aerosol properties (295 publications)
- Least studied topic: aerosol-cloud interactions (24 publications)



Sorooshian et al. (2020), *JGR– Atmos.*

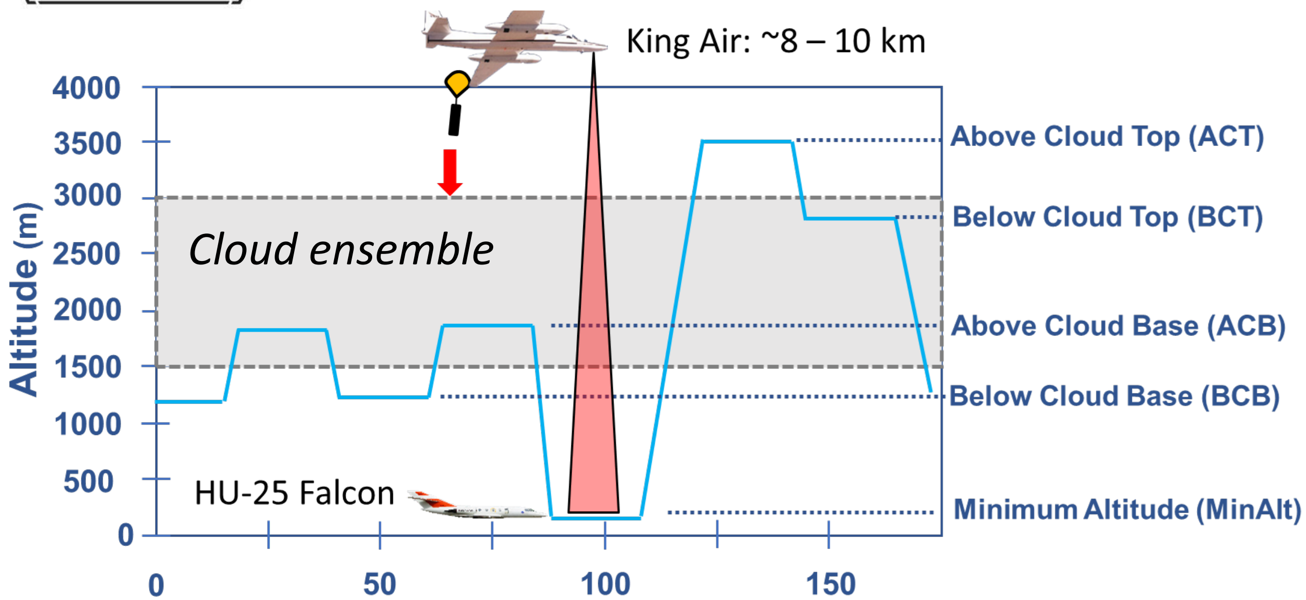
Science Objectives

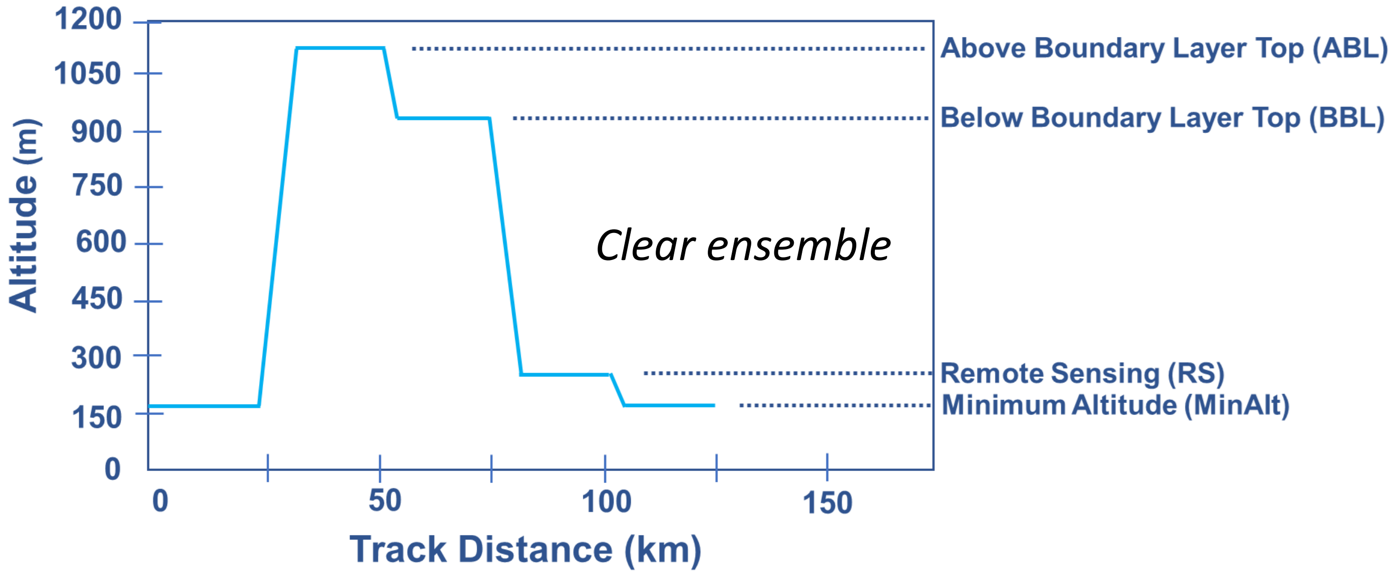
Objective 1: Quantify relationships between aerosols, cloud condensation nuclei (CCN), and cloud drops and reduce uncertainty in model parameterizations of cloud droplet activation.

Objective 2: Improve process-level understanding and model representation of factors governing cloud micro/macro-physical properties and how they couple with cloud effects on aerosol.

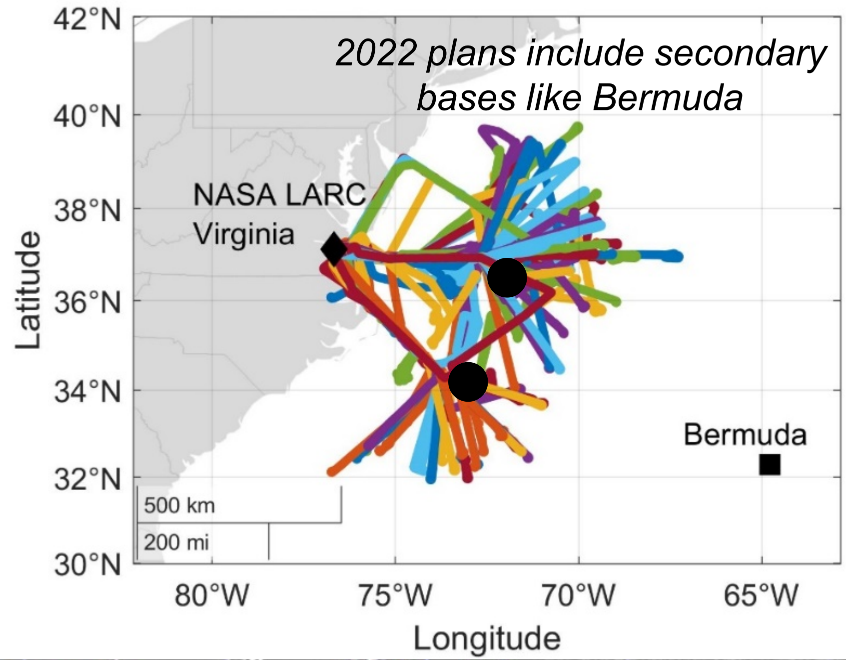
Objective 3: Assess advanced remote sensing capabilities for retrieving aerosol and cloud properties related to aerosol-cloud interactions.

Flight Strategy

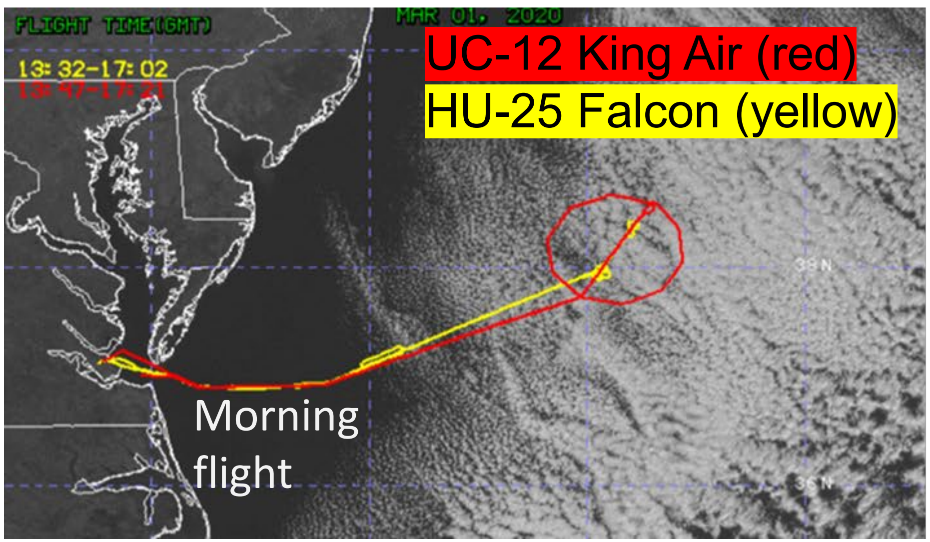


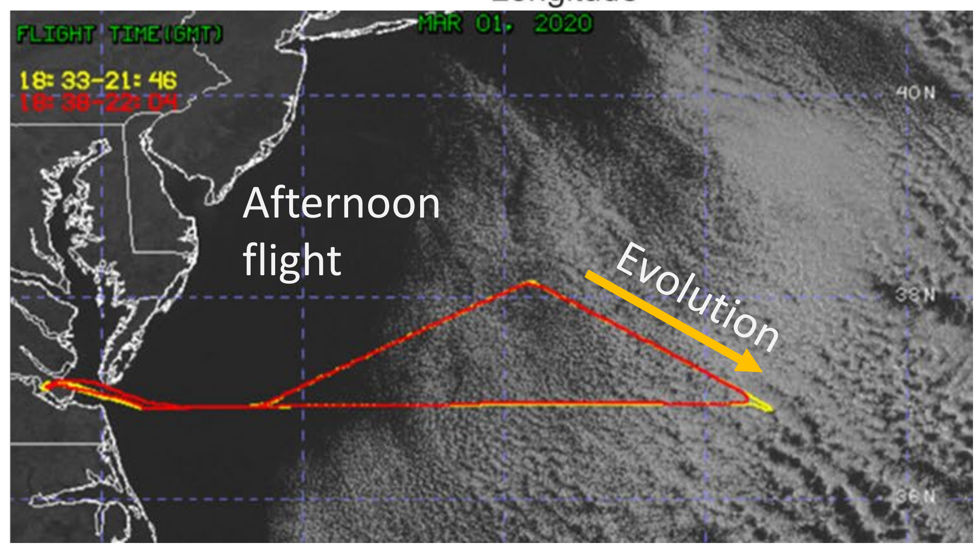


Flight Strategy



- Back-to-back joint flights on 3/1/2020 in cold air outbreak conditions shown below; shallow cumulus clouds in these conditions are treated poorly by current models





Mission Progress

	Research Flights			Flight Hours		Joint Ensembles		Underflights			
	Falcon	King Air	Joint	Falcon	King Air	Cloudy	Clear	ASTER	CALIPSO	Process Study Flights	Dropsondes
Winter 2020	22	17	17	73	59	43	28	1		2	59
Summer 2020	18	18	18	60	67	58	36	1	3	2	108
Winter 2021	17	19	15	56	66	47	25	1	3		102
Summer 2021	32	32	32	106	108	103	74	1	1	2	150
Sum	***89***	***86***	***82***	***295***	***300***	***251***	***163***	***4***	***7***	***6***	***419***

- ~90% of flights are "statistical surveys": out-and-back doing traditional ensembles
- ~10% of flights are "process studies": specially designed for model intercomparisons and/or studying targets of opportunity requiring custom-flight design in areas of interest

Platforms

High-Altitude Remote Sensing
King Air

<u>Range</u>: 1,500 km
<u>Altitude</u>: 9 km
<u>Airspeed</u>: 120 m/s
<u>Duration</u>: ~4 hours

Low-Altitude In-situ
HU-25 Falcon

<u>Range</u>: 3,000 km
<u>Altitudes</u>: 0.15 - 3 km
<u>Airspeed</u>: 100-130 m/s
<u>Duration</u>: ~4 hours

Payload: Falcon External Probes

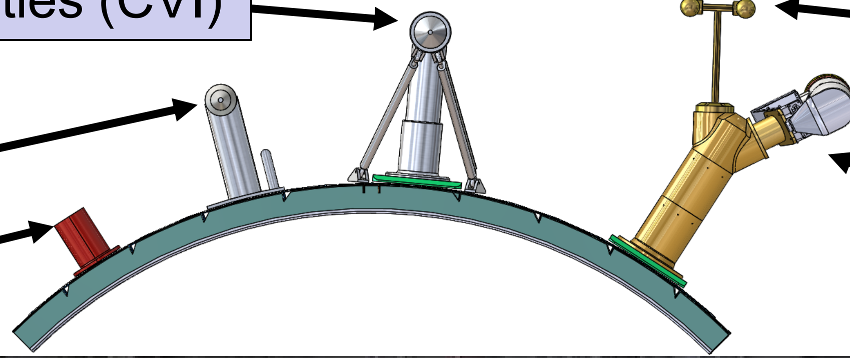
Cloud Residual Properties (CVI)

Cloud Droplet Probe

Isokinetic Aerosol Inlet

AC3 Cloud Collector

Trace Gases

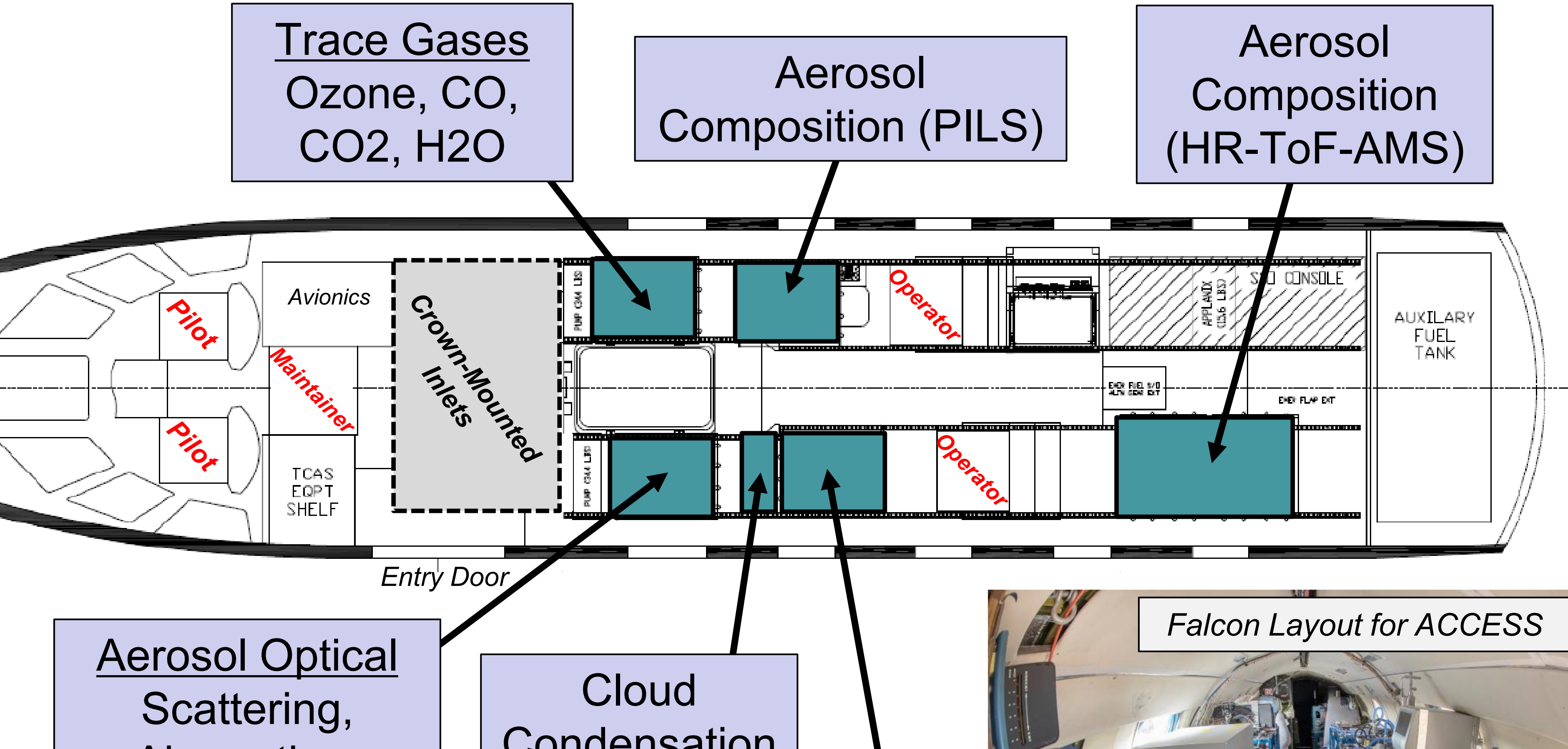


Cloud Aerosol Precipitation Spectrometer (Langley)

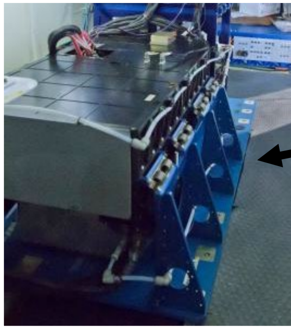
Turbulent Air-Motion Measurement

FCDP/2D-S Cloud probe (DLR)

Payload: Falcon In-Situ Measurements

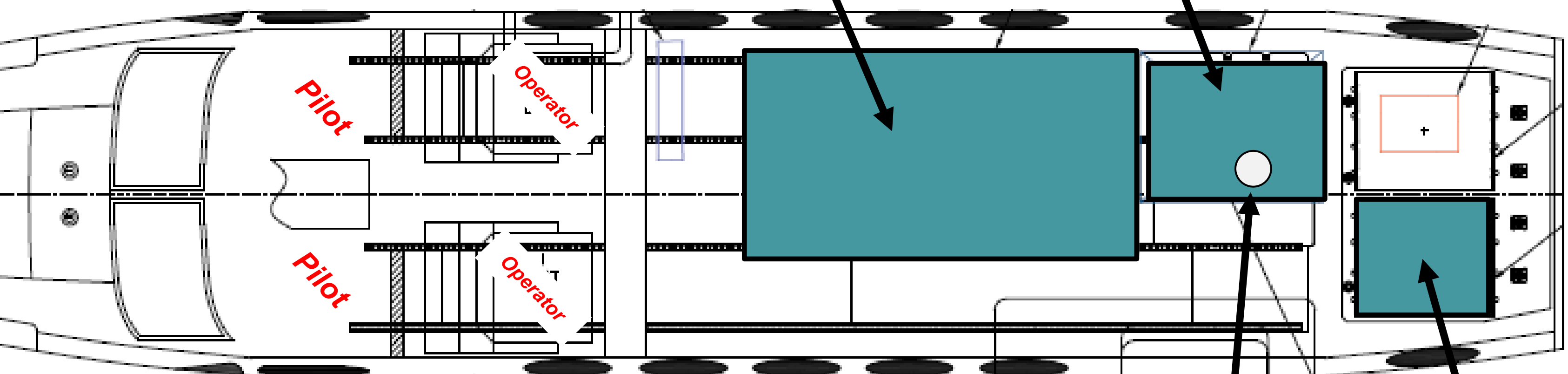


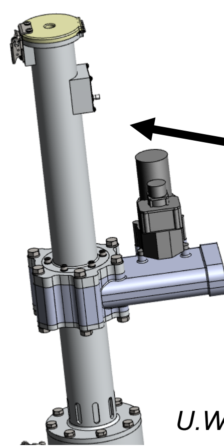
Payload: King Air



High Spectral Resolution Lidar (HSRL-2)

Research Scanning Polarimeter (RSP)





U.Wyo B-200 Launcher

Dropsonde Tube Penetration

Dropsonde (AVAPS) and RSP support Electronics

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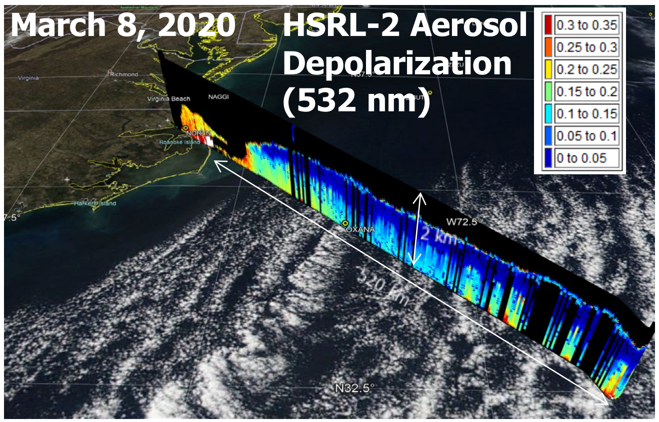
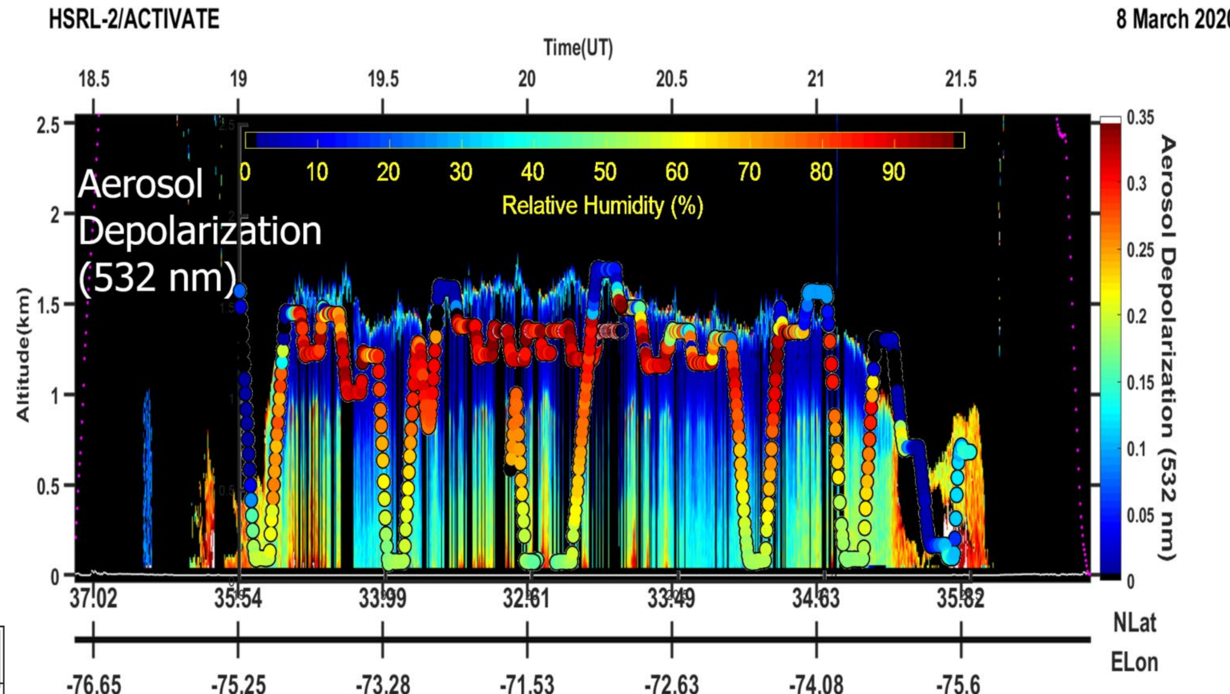
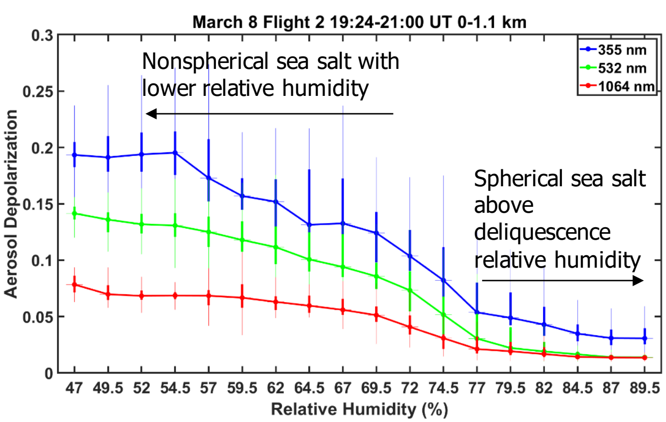
Example of Joint Flight Success: Enhanced Aerosol Depolarization Associated with Nonspherical Sea Salt particles

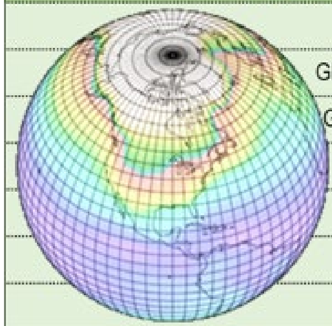






- Typically, lidars observe low (<5%) aerosol depolarization from spherical sea salt particles
- During several ACTIVATE flights in both winter and summer, airborne HSRL-2 observed enhanced (>15%) aerosol depolarization due to nonspherical sea salt particles associated with low relative humidity during cold air outbreaks
- Major Implication: nonspherical sea salt impacts CALIOP inferences of aerosol type and retrievals of aerosol extinction and aerosol optical thickness

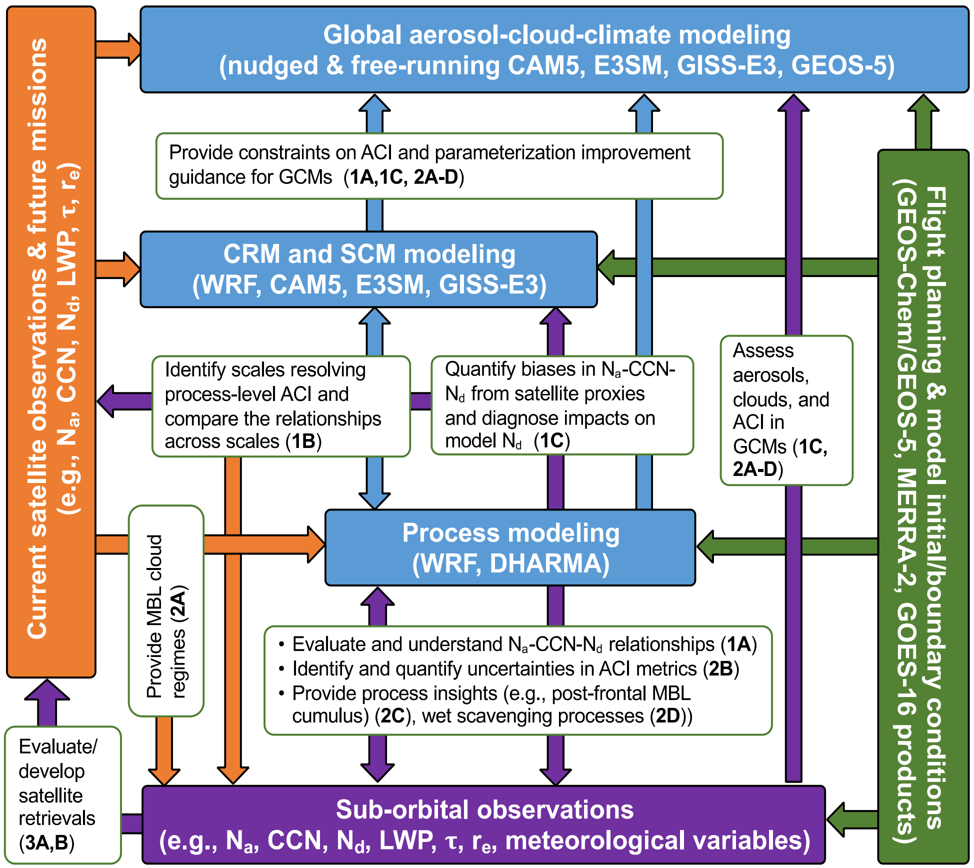
Modeling/Analysis Efforts



Models	Organization
DHARMA (LES)	NASA GISS
GISS-E3 (SCM and Global)	NASA GISS
GEOS-5 and GEOS-Chem	NIA/NASA LaRC
FLEXPART	NIA/NASA LaRC
WRF (LES and CRM)	PNNL
E3SM (SCM and Global)	PNNL
CAM5 (SCM and Global)	PNNL/UA

<u>Global, regional, LES modeling</u>

- Flight planning/guidance
- Post-flight field data analysis
- Parameterization development and testing
- Model-measurement intercomparisons



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Dissemination of Early Findings:
https://activate.larc.nasa.gov/publications/

Sorooshian et al., (2019) - BAMS

JGR Atmospheres

REVIEW ARTICLE
10.1029/2019JD031626

Atmospheric Research Over the Western North Atlantic Ocean Region and North American East Coast: A Review of Past Work and Challenges Ahead

Key Points:
- A total of 50+ field studies and 700+ papers illustrate the complexity of atmospheric phenomena over the West North Atlantic and North American East Coast
- The widest body of work has been devoted to atmospheric chemistry and has characterized urban outflow and marine emissions
- Multidisciplinary topics such as aerosol-cloud and air-sea interactions have not been sufficiently addressed and warrant high priority

Armin Sorooshian[1,2], Andrea F. Corral[1], Rachel A. Braun[1], Brian Cairns[3], Ewan Crosbie[4,5], Richard Ferrare[4], Johnathan Hair[4], Mary M. Kleb[4], Ali Hossein Mardi[1], Hal Maring[6], Allison McComiskey[7], Richard Moore[4], David Painemal[4,5], Amy Jo Scarino[4,5], Joseph Schlosser[1], Taylor Shingler[4], Michael Shook[4], Hailong Wang[8], Xubin Zeng[2], Luke Ziemba[4], and Paquita Zuidema[9]

[1]Department of Chemical and Environmental Engineering, University of Arizona, Tucson, AZ, USA, [2]Department of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, AZ, USA, [3]NASA Goddard Institute for Space Studies, New York, NY, USA, [4]NASA Langley Research Center, Hampton, VA, USA, [5]Science Systems and Applications, Inc., Hampton, VA, USA, [6]NASA Headquarters, Washington, DC, USA, [7]Brookhaven National Laboratory, Upton, NY

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2020JD032592

An Overview of Atmospheric Features Over the Western North Atlantic Ocean and North American East Coast – Part 1: Analysis of Aerosols, Gases, and Wet Deposition Chemistry

This article is a companion to Painemal et al. (2021), https://doi.org/10.1029/2020JD033423.

Key Points:
- Significant reductions in CO and particulate SO_4^{2-}, black carbon, and primary organic matter are observed over multiple decades

Andrea F. Corral[1], Rachel A. Braun[1], Brian Cairns[2], Vesta Afzali Gorooh[3], Hongyu Liu[4], Lin Ma[1], Ali Hossein Mardi[1], David Painemal[5,6], Snorre Stamnes[5], Bastiaan van Diedenhoven[2,7], Hailong Wang[8], Yang Yang[8], Bo Zhang[4], and Armin Sorooshian[1,9]

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2020JD033423

An Overview of Atmospheric Features Over the Western North Atlantic Ocean and North American East Coast—Part 2: Circulation, Boundary Layer, and Clouds

This article is a companion to Corral et al. (2021), https://doi.org/10.1029/2020JD032592.

Key Points:
- Atmospheric circulation and sea surface temperature drive large

David Painemal[1,2], Andrea F. Corral[3], Armin Sorooshian[3,4], Michael A. Brunke[4], Seethala Chellappan[5], Vesta Afzali Gorooh[6], Seung-Hee Ham[1,2], Larry O'Neill[7], William L. Smith Jr.[2], George Tselioudis[8], Hailong Wang[9], Xubin Zeng[4], and Paquita Zuidema[5]

ACTIVATE

Programmatic Insights

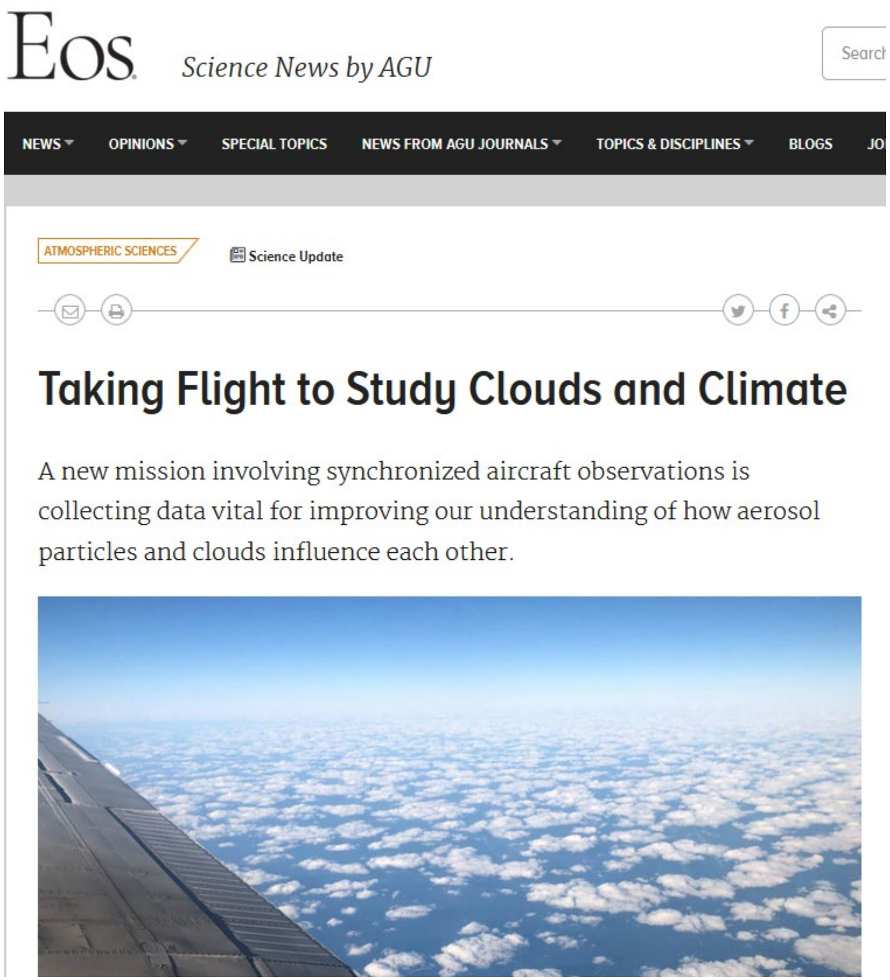
Successes:

- Experienced project scientist and manager who make many aspects of mission planning and execution easier; much of team has EVS mission experience
- Forecasting team is very strong
- Flight scientists are good at having their ‘heads out of instruments’ and optimizing flights for best science
- Instrument teams have extensive performance heritage and worked together numerous times which has made operations smooth
- Have multiple modeling/analysis groups who are using flight data and producing papers and presenting at meetings
- Operations team members based locally at LaRC, which has paid major dividends especially with COVID
- Two plane strategy is working well and should be considered for future missions

Programmatic Insights

Challenges:

- COVID impacts on flights, meetings in person, and other general activities
- The usual aircraft issues
- Takes time for different modeling teams to find effective ways to work together
- Strong desire to recruit data users



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ATMOSPHERIC SCIENCES

Science Update

Taking Flight to Study Clouds and Climate

A new mission involving synchronized aircraft observations is collecting data vital for improving our understanding of how aerosol particles and clouds influence each other.

Open Data Workshop

Goal: Enhance data usage (recruit more users and make it easier for them to use the data); also, entrain those in Applications (end users, decision-makers) rather than just the immediate downstream science users

Wednesday, 20 October 2021

9:00-9:20 What is ACTIVATE all about? – Sorooshian
9:20-9:25 Where can I access data? – DAAC/ASDC
9:25-9:45 What data are there? What are ICARTT files and what is in them? What are Merge Products/Tools? – Chen/Shook
9:45-10:00 Discussion (or break individually as needed)
10:00-10:30 Case Study: 29 February 2020 (Research Flight 12 = Statistical Survey Flight)

- Forecasting details leading to flight plan decision
- Steps the day of the flight (from pre-flight weather meeting to post-flight briefing and instrument checks)
- Detailing the flight path
- Data results and utilization of Merge Tools

(break as needed)
10:30-11:00* Begin discussion (e.g., how would you use the data? what questions do you have about the data? are you interested in collaborating around a topic?)
*End time can be extended based on interest; this discussion will continue on Day 2 at greater length to allow the day's materials to soak in to generate more topics to discuss

Thursday, 21 October 2021

9:00-9:45 Case Study: 1 March 2020 (Research Flights 13-14 = Process Study flights)

- Forecasting details leading to flight plan decision
- Steps the day of the flight (from pre-flight weather meeting to post-flight briefing and instrument checks)
- Detailing the flight path
- Data results and utilization of Merge Tools

9:45-10:00 Discussion and Break
10:00-11:00* External guest discussion time (including feedback for next year's workshop)
*End time can be extended based on interest

<u>Ideas that have come up:</u>

- Converting ICT files to NETCDF files
- Holding tutorials at conferences

Early Adopter Activities

- Significant overlap between ACTIVATE and AOS
- This implies that AOS data users will benefit from ACTIVATE data and vice versa
- Still learning about this - hopefully in discussion I can learn how we can move forward on this front…

Acknowledgements
NASA and ACTIVATE Team

ACTIVATE

Extra Slides

ACTIVATE Team

Name	Role	Organization
	Investigation Leadership	
Armin Sorooshian	Principal Investigator	U. 0f AZ
Xubin Zeng	Science Data Analysis Lead (Deputy PI)	U. of AZ
Mary Kleb	Investigation Manager	NASA LaRC
Johnathan Hair	Science Mission Implementation Lead (Project Scientist)	NASA LaRC
Richard Ferrare	Deputy Project Scientist	NASA LaRC
Gao Chen	Science Data Manager	NASA LaRC
Luke Ziemba	Payload and Logistics Manager	NASA LaRC
	Modeling, Satellite Data, & Analysis	
David Painemal	Co-I, Cloud-Aerosol Analysis/Modeling, Satellite Retrievals and Analysis Lead	SSAI/LaRC
Paquita Zuidema	Co-I, Aerosol-Cloud Analysis/Modeling	U. of Miami
Allison McComiskey	Co-I, Aerosol-Cloud Analysis/Modeling	BNL
George Tselioudis	Co-I, Cloud Analysis/Modeling Lead	NASA GISS
Susanne Bauer	Co-I, Aerosol /Cloud GCM Modeling Lead	NASA GISS
Hailong Wang	Co-I, Aerosol/Cloud Modeling (Global, LES, CRM, SCM) Lead	PNNL
Andrew Ackerman	Collaborator, Cloud LES Modeling (LES)	NASA GISS

ACTIVATE Team (cont)

Name	Role	Organization
	Forecasting/Met Support	
Michael Shook	Co-I, Operational Weather Forecasting	NASA LaRC
Bill Smith Jr.	Co-I, Geostationary Satellite Retrieval Operational Products	NASA LaRC
Hongyu Liu	Co-I, Aerosol Modeling and Operational Forecasting	NIA/LaRC
	Airborne Science & Instruments	
Bruce Anderson	Collaborator, In Situ Aerosol and Cloud Measurements (LARGE)	NASA LaRC
Richard Moore	Co-I, LARGE CCN and 1D Modeling	NASA LaRC
Ewan Crosbie	Co-I, LARGE Cloud Water	SSAI/NASA LaRC
Luke Ziemba	Co-I, LARGE Aerosol Mass Spectrometer, Dropsondes	NASA LaRC
Christiane Voigt	Co-I, FDCP/2D-S Cloud/precip droplets	DLR
Kenneth Thornhill	Co-I, Turbulent Air Motion System, Winds (TAMMS) and dropsondes	SSAI/NASA LaRC
Terry Hock	Co-I, Dropsondes	NCAR
Chris Hostetler	Co-I, High Spectral Resolution Lidar (HSRL-2) Lead	NASA LaRC
Brian Cairns	Co-I, Research Scanning Polarimeter (RSP) Lead	NASA GISS
Glenn Diskin	Co-I, Diode Laser Hygrometer (DLH) and trace gas Lead	NASA LaRC
	Flight Operations Support	
Michael Wusk	Aircraft Operations Lead	NASA LaRC
David Klassman	Aircraft Integration Engineer	NASA LaRC

Science Traceability Matrix

Science objectives and questions related to acquisition and use of a large in situ and remote sensing dataset of aerosols and MBL clouds (spanning the continuum from stratiform to cumulus)
Objective 1. Quantify N_a-CCN-N_d relationships and reduce uncertainty in model cloud droplet activation parameterizations. A. How do these relationships depend on aerosol characteristics (e.g., amount, size, composition, type) and dynamic and thermodynamic properties? B. How consistent are these relationships across the complete range of spatial scales provided by in situ measurements and airborne and satellite remote sensing retrievals? C. What are the magnitudes of biases in the N_a-CCN-N_d relationships from satellite aerosol proxies? How do these translate to uncertainties in N_d parameterizations in current global aerosol-climate models? Deliverables: Improved model representations of N_a-CCN-N_d relationships; unique dataset using a sustained long-term strategy for model intercomparison and process-based studies

Objective 2. Improve process-level understanding and model representation of factors governing cloud micro/macro-physical properties and how they couple with cloud effects on aerosol. A. What are the relationships between N_d, cloud micro/macro-physical properties, and meteorology? B. To what extent do uncertainties in N_a/cloud/meteorology relationships within the targeted cloud regimes in global aerosol-climate models come from biases in aerosols, clouds, and meteorological factors? How can the identified model biases and uncertainties be reduced using the measurements? C. How can climate models better represent conditions with known challenges, such as post-frontal clouds and cold air outbreaks? D. What is the signature of cloud effects on the CCN budget (e.g., wet scavenging, aqueous processing). Deliverables: Improved model parameterizations for relationships between cloud microphysical and macrophysical properties; unique dataset using a sustained long-term strategy for model intercomparison and process-based studies
Objective 3: Assess advanced remote sensing capabilities for retrieving aerosol and cloud properties related to aerosol-cloud interactions. A. How well and under what conditions can active and passive remote sensing retrievals provide improved measurements for N_d and proxies for CCN concentration? B. How well can a combination of remote sensors improve measurements of LWP? Deliverables: Evaluation and intercomparison of CCN and N_d retrievals and measurements; evaluation of LWP as a function of scale