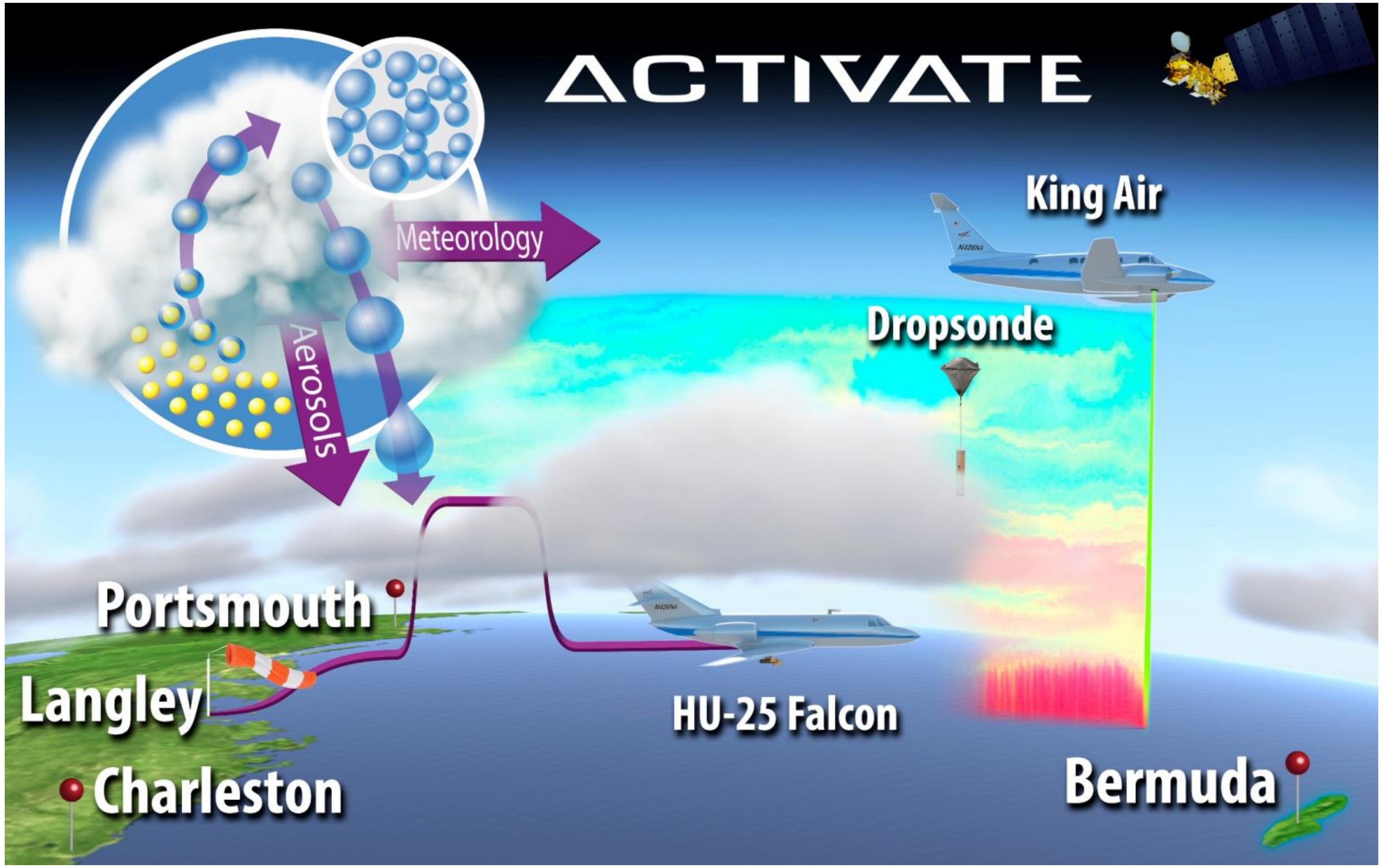

Science: Build **unprecedented dataset** to better understand aerosol-cloud-meteorology interactions, improve physical parameterizations for Earth system and weather forecasting models, assess remote sensing retrieval algorithms, and guide plans for future satellite missions.

- Platforms: HU-25 Falcon + King Air
- Initial goal of 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

Aerosol Cloud meTeorology Interactions oVer the Western Atlantic Experiment (ACTIVATE)

https://activate.larc.nasa.gov/

Motivation

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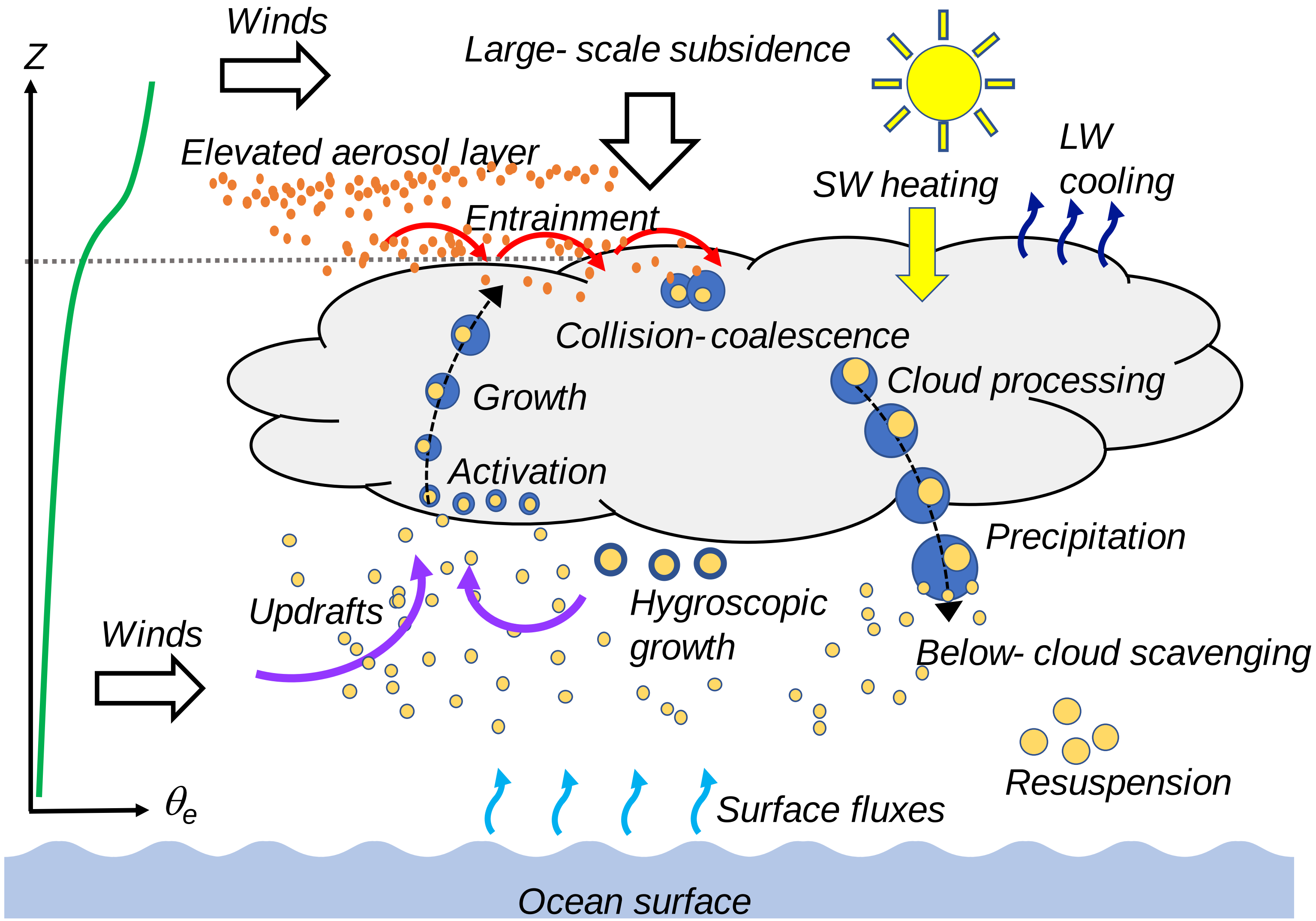

Sorooshian et al. (2019), BAMS

Original Science Objectives

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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

Threshold and Baseline Requirements

Baseline Mission Requirements	Threshold Mission Requirements
a. Conduct joint flights with two aircraft to sample the equivalent of 250 'cloud ensembles' over the western North Atlantic Ocean. A minimum of 15 additional 'clear air ensembles' will be in clear air conditions during joint flights with two aircraft.	a. Conduct flights to sample the equivalent of 200 'cloud ensembles' over the western North Atlantic Ocean of which 50% are joint aircraft flights with two aircraft; the other 50% will be with the HU-25 aircraft. A minimum of 12 additional 'clear air ensembles' will be in clear air conditions during joint flights with two aircraft.
b. During the flights described in (a), acquire in situ data on aerosol, gas, cloud, and meteorological parameters from an aircraft flying in the boundary layer (see Table 3-1).	b. Same as baseline but with a combination of reduced instruments collecting data and less time for instruments to collect data.
c. During the flights described in (a), acquire remote sensing data for aerosol and cloud parameters from an aircraft flying above the boundary layer (see Table 3-2).	c. Same as baseline but for 100 'cloud ensembles' and 12 'clear air ensembles'.
d. Deliver data, associated information, and data library of measured parameters for individual 'cloud ensembles' to ASDC for archival and public access. All details are in the data management plan. Data delivery latencies in Table 8-1, IIP.	d. Deliver data and associated information to ASDC for archival and public access. All details are in the data management plan. Data delivery latencies in Table 8-1, IIP.
e. Conduct analysis on the collected data in conjunction with multi-scale modeling to determine relationships between aerosols, N_d, cloud micro/macro-physical properties, and meteorology, and to identify model biases in aerosols, clouds, and meteorological factors.	e. Same as baseline but with less comprehensive measurements based on data collected corresponding to rows b-c of the Threshold Mission.
f. Assess lidar-only, polarimeter-only, and combined lidar-polarimeter algorithms to improve the capability to retrieve aerosol and cloud optical and microphysical properties.	f. Assess lidar-only and polarimeter-only algorithms to improve the capability to retrieve aerosol and cloud optical and microphysical properties for half of the flights that involve two aircraft.
g. Use satellite observations to assess spatial and temporal variability in aerosol and cloud properties in the study region and to determine magnitudes of biases in the N_a-CCN-N_d relationships from satellite aerosol proxies and how these translate to uncertainties in N_d parameterizations in current global aerosol-climate models.	g. Same as baseline but for half of the flights that involve two aircraft.
h. Improve how models simulate aerosols, clouds, and their interactions for conditions in the ACTIVATE region.	h. Same as baseline but with less comprehensive measurements.
i. Publish and present science data to the public. Provide open data workshops for the public.	i. Same as baseline.

Ongoing analysis activities

Platforms

High-Altitude Remote Sensing King Air

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

Low-Altitude In-situ HU-25 Falcon

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

Payload: Falcon External Probes

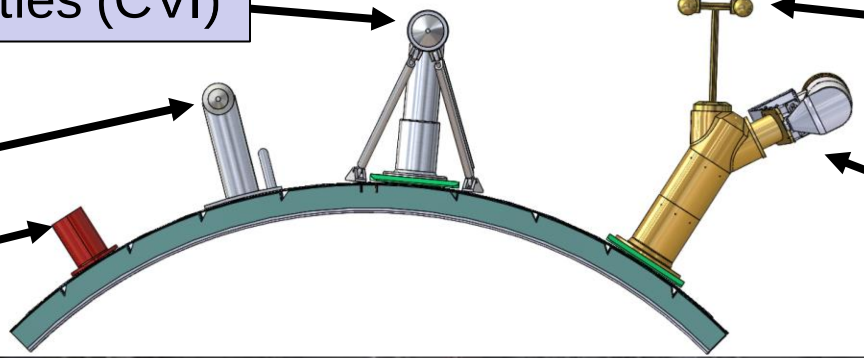
Cloud Residual Properties (CVI)

Isokinetic Aerosol Inlet

Trace Gases

Cloud Droplet Probe

AC3 Cloud Collector



Cloud Aerosol Precipitation Spectrometer (Langley)

Turbulent Air-Motion Measurement

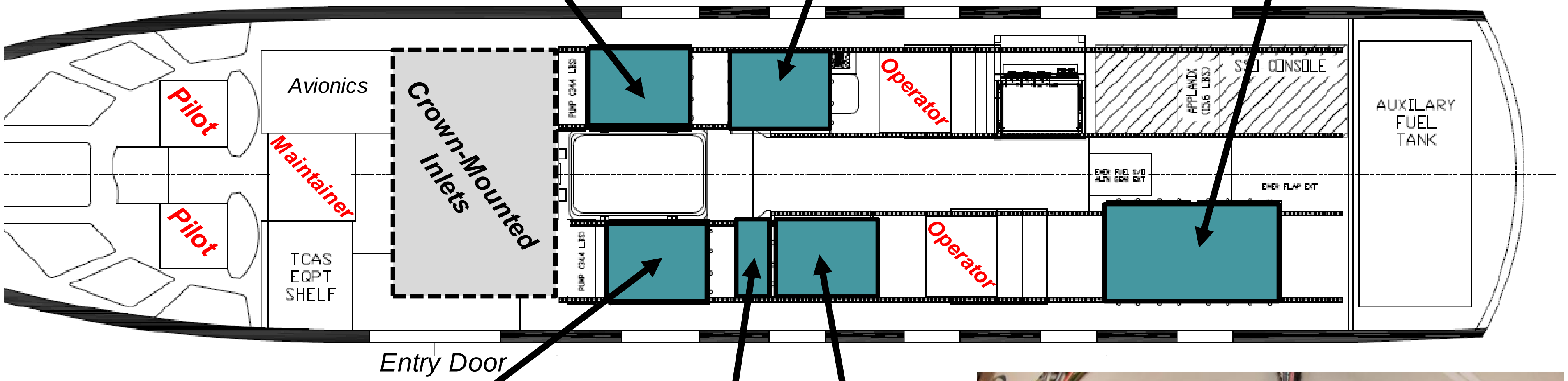
FCDP/2D-S Cloud probe (DLR)

Payload: Falcon In-Situ Measurements

Trace Gases
Ozone, CO, CO_2, H_2O

Aerosol Composition (PILS)

Aerosol Composition (HR-ToF-AMS)



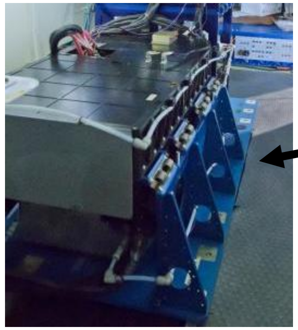
Aerosol Optical
Scattering, Absorption, Hygroscopicity

Cloud Condensation Nuclei

Aerosol Microphysics

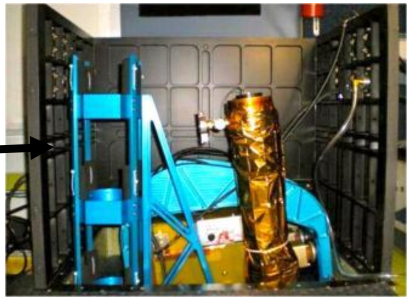

Falcon Layout for ACCESS

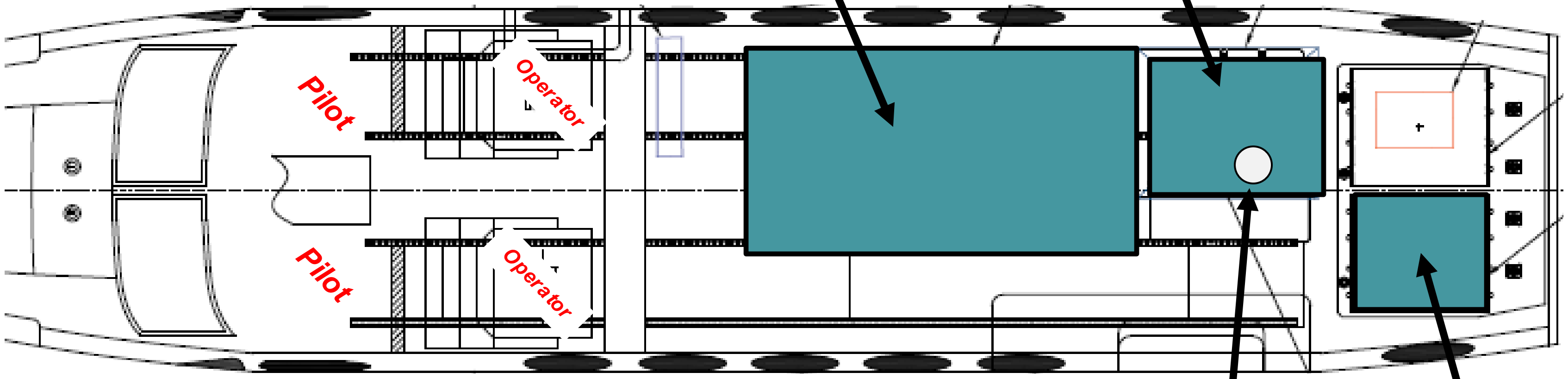
Payload: King Air

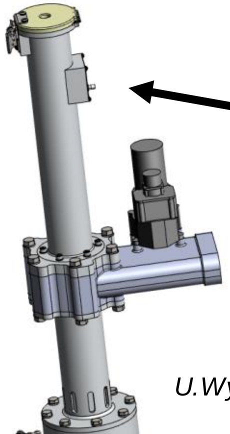


High Spectral Resolution Lidar (HSRL-2)

Research Scanning Polarimeter (RSP)







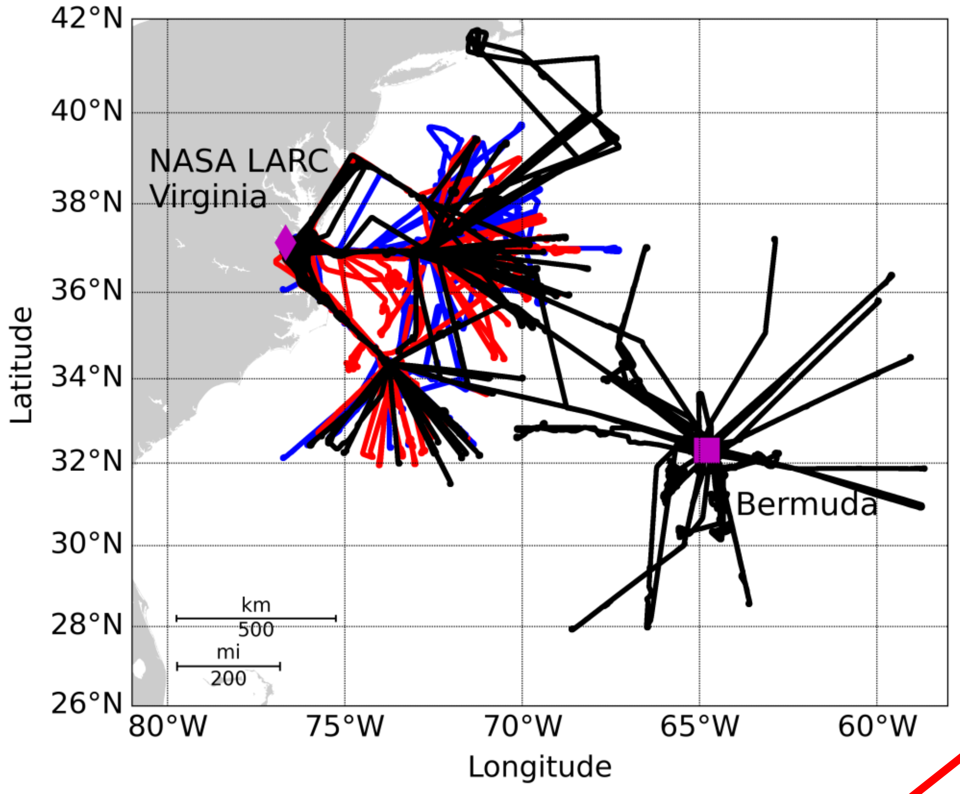
U.Wyo B-200 Launcher

Dropsonde Tube Penetration

Dropsonde (AVAPS) and RSP support Electronics

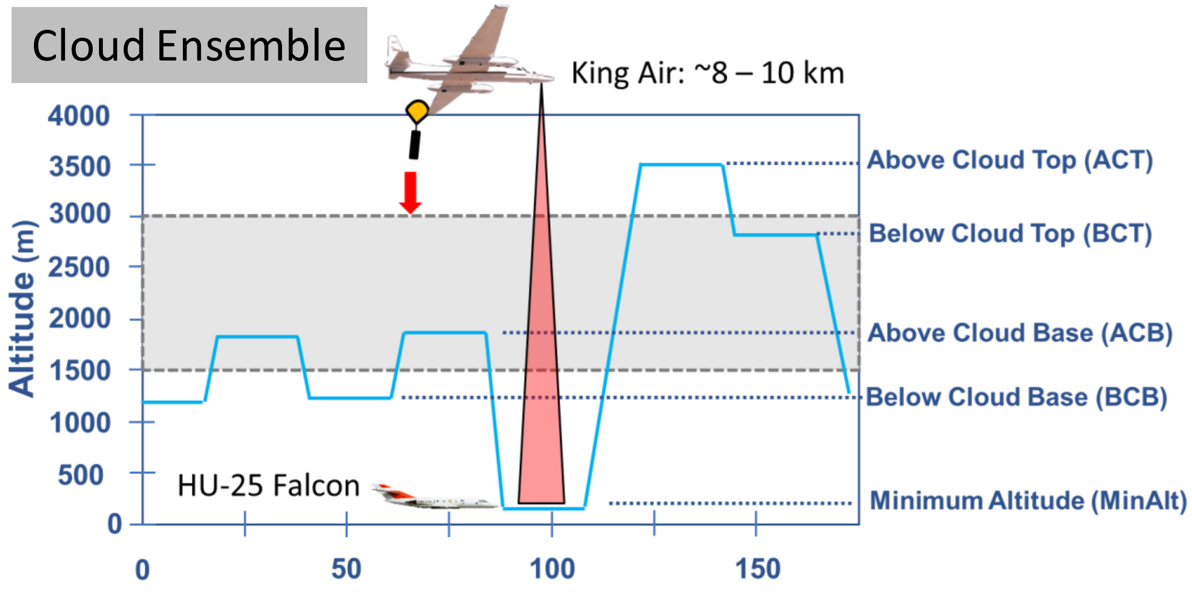
Flight Strategy

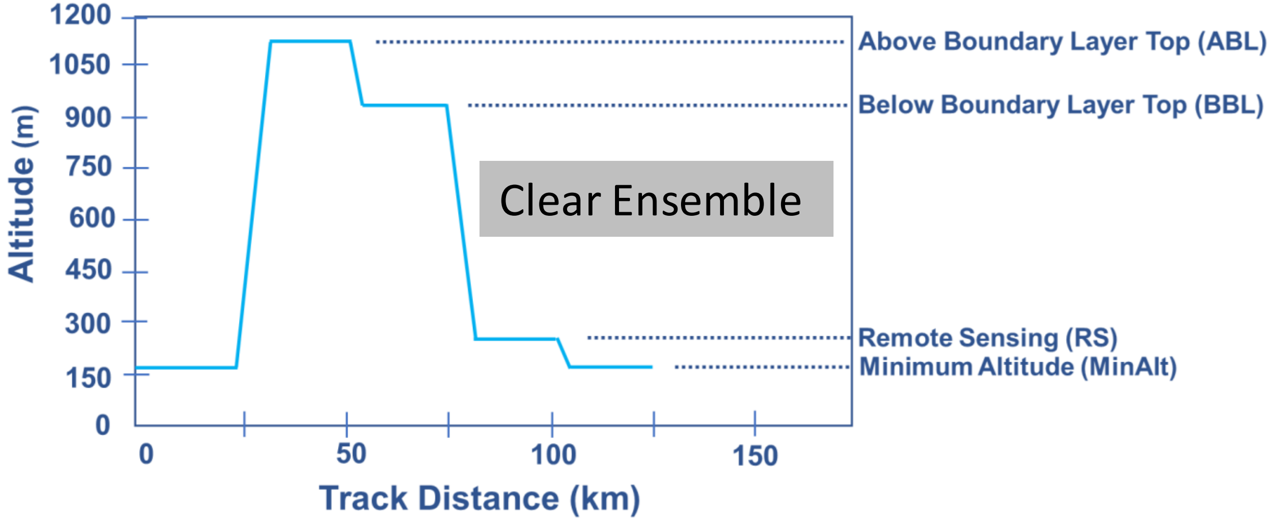
Blue = 2020; Red = 2021; Black = 2022



~90% of flights = "statistical surveys"

~10% = Process-studies





Process Study Example

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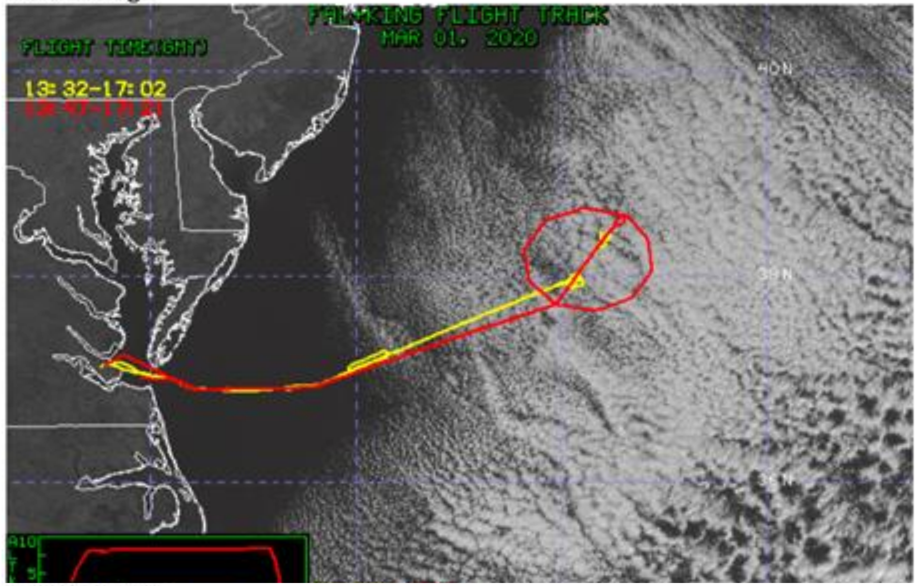
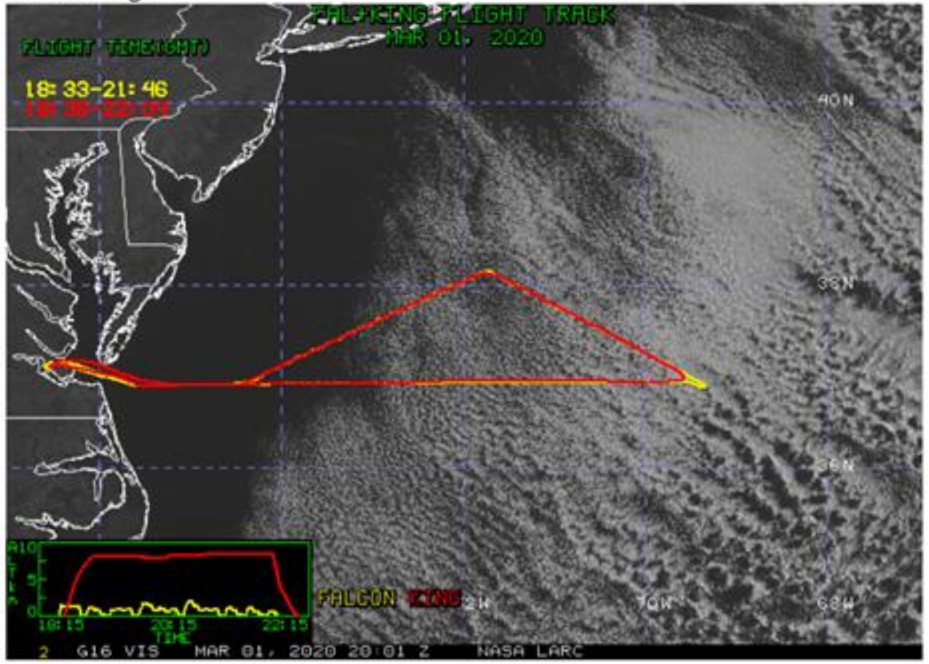
AM Flight Plan
- King Air (red) performs a dropsonde circle, with a remote sensing transect down the center
- Falcon (yellow) executes a wall pattern along the remote sensing transect
- Remote sensing transect and wall oriented perpendicular to the boundary layer winds

Visible Image



PM Flight Plan
- Both aircraft survey out to the center of the morning circle, then SE before returning to base
- SE leg oriented along the wind for a semi-Lagrangian transect

Visible Image



We discuss this case at length in a previously recorded data workshop:
https://asdc.larc.nasa.gov/news/activate-data-webinar-materials

Final flight metrics

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	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
Winter 2021-2022	55	54	53	182	193	198	72		1	2	215
Summer 2022	30	28	27	97	98	86	46	2	3	4	155
Sum	***174***	***168***	***162***	***574***	***592***	***535***	***281***	***6***	***11***	***12***	***789***
Baseline Mission End Goal						250	15				

**Winter 2021 had reduced Falcon payload (44 cloud ensembles and 25 clear ensembles); no PILS/AMS/CVI/trace gases/hygrometer RH*

Overcoming Challenges

- COVID ~ impacts throughout deployments 1-6
- 2020: VP Pence visited Langley forcing us to stop operations - 2 days
- 2021: Falcon power system failed ~ 30 days
- 2021: A new holiday was introduced motivating us to stop flights - 2 days
- 2022: King Air experienced electrical smell on first flight during Bermuda deployment; the spare parts needed couldn’t return with the other King Air as it itself had a pressurization issue when it took off to go to Bermuda and then had to return; so Falcon went itself to pick up parts and come back to Bermuda to repair the UC-12 - 5 days
- 2022: June 10-11: UC-12 having load shed issues where research power shuts off. Happened in flight during RF172 on 11 June and AVAPS system's computer failed - 2 days
- 2022: On morning of one of our last flights in Bermuda (RF177, 6 June 2022), the Falcon had a hydraulic fluid leak which grounded it and King Air had to RTB after burning enough fuel - 1 day
- Throughout: Had to adjust flight dates/time/locations to avoid conflicts of rockets launched from Wallops Is. as well as restricted airspace reserved for DoD aircraft exercises.

Accomplishments

- Data
  - All 2022 data to be archived by early January 2023
  - All flight reports available
- Analysis/Science
  - 44 peer-reviewed publications
    - 29 – objective 1
    - 18 – objective 2
    - 4 – objective 3
- Selected Products
  - Schlosser code for aerosol microphysical properties
  - Stamnes et al. (above-cloud flag)
  - Corral leg index files
  - Dmitrovic NetCDF versions of merge files
- Outreach
  - In-person outreach events
    - Media day at LaRC
    - 2 events in Bermuda
    - Middle school in Tucson, Arizona
  - Virtual
    - >10 events (led by Brenna Biggs) including seven graduate students targeting over 400 students across nine schools and three countries
    - 3 open data workshop webinars in 2022 led by Joseph Schlosser – total of over 150 participants

Key Points

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- Finally have the full dataset in hand and can do the most robust analysis for aerosol-cloud interactions
- Day 1 goal: familiarize participants with data types and their applications
- Days 2-3 goal: Identifying challenges and key gaps, along with strategies to address them moving forward

Source: Johnathan Hair (LaRC)