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

Winds

Large-scale subsidence

Ocean surface

Below-cloud scavenging

Activation

Entrainment

Collision-coalescence

Growth

Updrafts

Hygroscopic growth

Precipitation

Cloud processing

Resuspension

Surface fluxes

Sorooshian et al. (2019), BAMS
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 stratusform 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 $N_d$/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

<table>
<thead>
<tr>
<th>Baseline Mission Requirements</th>
<th>Threshold Mission Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>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).</td>
<td>b. Same as baseline but with a combination of reduced instruments collecting data and less time for instruments to collect data.</td>
</tr>
<tr>
<td>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).</td>
<td>c. Same as baseline but for 100 ‘cloud ensembles’ and 12 ‘clear air ensembles’.</td>
</tr>
<tr>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>e. Conduct analysis on the collected data in conjunction with multi-scale modeling to determine relationships between aerosols, Np, cloud micro/macrophysical properties, and meteorology, and to identify model biases in aerosols, clouds, and meteorological factors.</td>
<td>e. Same as baseline but with less comprehensive measurements based on data collected corresponding to rows b-c of the Threshold Mission.</td>
</tr>
<tr>
<td>f. Assess lidar-only, polarimeter-only, and combined lidar-polarimeter algorithms to improve the capability to retrieve aerosol and cloud optical and microphysical properties.</td>
<td>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.</td>
</tr>
<tr>
<td>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 Np-CCN-Np relationships from satellite aerosol proxies and how these translate to uncertainties in Np parameterizations in current global aerosol-climate models.</td>
<td>g. Same as baseline but for half of the flights that involve two aircraft.</td>
</tr>
<tr>
<td>h. Improve how models simulate aerosols, clouds, and their interactions for conditions in the ACTIVATE region.</td>
<td>h. Same as baseline but with less comprehensive measurements.</td>
</tr>
<tr>
<td>i. Publish and present science data to the public. Provide open data workshops for the public.</td>
<td>i. Same as baseline.</td>
</tr>
</tbody>
</table>
Platforms

High-Altitude Remote Sensing
King Air

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

Low-Altitude In-situ
HU-25 Falcon

Altitudes: 0.15 - 3 km
Airspeed: 100-130 m/s
Duration: ~4 hours
Payload: Falcon External Probes

Cloud Residual Properties (CVI)
Isokinetic Aerosol Inlet
Trace Gases
Turbulent Air-Motion Measurement
FCDP/2D-S Cloud probe (DLR)

Cloud Droplet Probe
AC3 Cloud Collector

Cloud Aerosol Precipitation Spectrometer (Langley)

DLH
Payload: Falcon In-Situ Measurements

- Trace Gases: Ozone, CO, CO2, H2O
- 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)

Dropsonde Tube Penetration

Dropsonde (AVAPS) and RSP support Electronics

U.Wyo B-200 Launcher
~90% of flights = “statistical surveys”
~10% = Process-studies
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

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

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

<table>
<thead>
<tr>
<th></th>
<th>Research Flights</th>
<th>Flight Hours</th>
<th>Joint Ensembles</th>
<th>Underflights</th>
<th>Process Study Flights</th>
<th>Dropsondes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Falcon</td>
<td>King Air</td>
<td>Joint</td>
<td>Falcon</td>
<td>King Air</td>
<td>Cloudy</td>
</tr>
<tr>
<td>Winter 2020</td>
<td>22</td>
<td>17</td>
<td>17</td>
<td>73</td>
<td>59</td>
<td>43</td>
</tr>
<tr>
<td>Summer 2020</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>60</td>
<td>67</td>
<td>58</td>
</tr>
<tr>
<td>* Winter 2021</td>
<td>17</td>
<td>19</td>
<td>15</td>
<td>56</td>
<td>66</td>
<td>47</td>
</tr>
<tr>
<td>Summer 2021</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>106</td>
<td>108</td>
<td>103</td>
</tr>
<tr>
<td>Winter 2021-2022</td>
<td>55</td>
<td>54</td>
<td>53</td>
<td>182</td>
<td>193</td>
<td>198</td>
</tr>
<tr>
<td>Summer 2022</td>
<td>30</td>
<td>28</td>
<td>27</td>
<td>97</td>
<td>98</td>
<td>86</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>174</td>
<td>168</td>
<td>162</td>
<td>574</td>
<td>592</td>
<td>535</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Baseline Mission</th>
<th>End Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250</td>
</tr>
</tbody>
</table>

*Winter 2021 had reduced Falcon payload (44 cloud ensembles and 25 clear ensembles); no PILS/AMS/CVI/trace gases
Data
- All flight data have been archived for public use
- All flight reports available

Analysis/Science
- 55 peer-reviewed publications
  - 31 – objective 1
  - 24 – objective 2
  - 9 – objective 3

Upcoming conference season
- AGU: 14 presentations and leading one session
- AMS: 6 presentations and leading one session

Selected Products
- Schlosser code for aerosol microphysical properties
- Stamnes et al. (above-cloud flag)
- Corral/McCauley leg index files
- Dmitrovic NetCDF versions of merge files

Accomplishments

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

Selected Products
- 3 open data workshop webinars in 2022 led by Joseph Schlosser – total of over 150 participants
- 2022 STM Day 1 was a recorded open data workshop

NASA Group Achievement Award (2023)
Data Details

Everything you need to know about the instruments, how to access and cite date, and usage details can be found at these resources:


Slides and recordings by the science team about instruments, downloading/using/visualizing data, and other relevant details:

Spatially coordinated airborne data and complementary products for aerosol, gas, cloud, and meteorological studies: the NASA ACTIVATE dataset

The “Data Paper” for ACTIVATE serving as a guide for anything and everything hopefully you need to know. If questions/concerns still remain, contact relevant instrument teams or the PI

https://doi.org/10.5194/essd-15-3419-2023
Table 2: Description of each of 179 flights

<table>
<thead>
<tr>
<th>RF</th>
<th>Date (mm/dd/yyyy)</th>
<th>Joint/Single</th>
<th>Flight type</th>
<th>King Air</th>
<th>HU-25 Falcon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Takeoff (UTC)</td>
<td>Landing (UTC)</td>
<td>No. sondes</td>
</tr>
<tr>
<td>1</td>
<td>2/14/2020</td>
<td>Joint</td>
<td>Statistical survey</td>
<td>17:04:42</td>
<td>20:35:34</td>
</tr>
</tbody>
</table>

Table 3-5: Instrument summary tables

Table 5. Summary of the HU-25 Falcon instrumentation and measurements. n/a – not applicable.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measured parameter</th>
<th>Uncertainty</th>
<th>Use range (ppb)</th>
<th>Time resolution (s)</th>
<th>Reference/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosol particles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B&amp;M coagulation visual impactor vs. collection sieve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSI 3770 condensation particle counter (CPC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSI 3772 CPC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSI 3772M with thermal denuder (350°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSI scanning mobility particle size (SMPS) Model 3005 (differential mobility analyzer (DMA)), Model 357A/CPC and Model 3900a condenser</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSI 3540 (time-lapse spectrometer (LAS))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSI 3551 nephelometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dry scattering coefficient

Table 7: Where to access anything generated by ACTIVATE team

<table>
<thead>
<tr>
<th>Dataset/Resource</th>
<th>Paper section</th>
<th>Website (last access: 1 May 2023)</th>
<th>DOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>All aircraft instrument data</td>
<td>Sects. 3-4</td>
<td><a href="https://asdc.larc.nasa.gov/project/ACTIVATE/">https://asdc.larc.nasa.gov/project/ACTIVATE/</a></td>
<td><a href="https://doi.org/10.5067/SUBORBITAL/ACTIVATE/DATASET">https://doi.org/10.5067/SUBORBITAL/ACTIVATE/DATASET</a> (NASA Langley ASDC User Services, 2023)</td>
</tr>
<tr>
<td>HU-25 Falcon merge files</td>
<td>Sect. 4.8</td>
<td><a href="https://asdc.larc.nasa.gov/project/ACTIVATE/ACTIVATE_Merge_Data_1">https://asdc.larc.nasa.gov/project/ACTIVATE/ACTIVATE_Merge_Data_1</a></td>
<td><a href="https://doi.org/10.5067/ASDC/SUBORBITAL/ACTIVATE_Merge_Data_1">https://doi.org/10.5067/ASDC/SUBORBITAL/ACTIVATE_Merge_Data_1</a> (NASA/LARC/SD/ASDC, 2021a)</td>
</tr>
<tr>
<td>Flight reports</td>
<td>Sect. 5.1</td>
<td><a href="https://asdc.larc.nasa.gov/project/ACTIVATE/pdocuments">https://asdc.larc.nasa.gov/project/ACTIVATE/pdocuments</a></td>
<td>n/a</td>
</tr>
<tr>
<td>HU-25 Falcon leg index</td>
<td>Sect. 5.2</td>
<td><a href="https://asdc.larc.nasa.gov/project/ACTIVATE/ACTIVATE_MetNav_AircraftInSitu_Falcon_Data_1">https://asdc.larc.nasa.gov/project/ACTIVATE/ACTIVATE_MetNav_AircraftInSitu_Falcon_Data_1</a></td>
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</tr>
<tr>
<td>Aircraft collocation product</td>
<td>Sect. 5.3</td>
<td>Data: <a href="https://asdc.larc.nasa.gov/project/ACTIVATE/ACTIVATE_Miscellaneous_Data_1">https://asdc.larc.nasa.gov/project/ACTIVATE/ACTIVATE_Miscellaneous_Data_1</a></td>
<td><a href="https://doi.org/10.5067/ASDC/SUBORBITAL/ACTIVATE_Miscellaneous_Data_1">https://doi.org/10.5067/ASDC/SUBORBITAL/ACTIVATE_Miscellaneous_Data_1</a> (NASA/LARC/SD/ASDC, 2021c)</td>
</tr>
</tbody>
</table>
Snapshots from ASDC Site

First Open Data Workshop Recording

Presentations by Instrument/Model teams about their data products

November 2022

Last year’s STM Slides and Recording

Open Data Workshop Recordings to Schools and Teachers

September 2022

The Aerosol Cloud meTeorology Interactions over the western ATlantic Experiment (ACTIVATE) team led visualize airborne data. This webinar went over the science motivation of ACTIVATE, as well as included: measurements as well as use the Google Collaboratory (Google Colab) environment to examine atmosphere.

Materials:
- Webinar Recording Webpage

July 2022

The Aerosol Cloud meTeorology Interactions over the western ATlantic Experiment (ACTIVATE) team has analysis ideas and collaborative projects in the area of aerosol-cloud-meteorology interactions. This paper atmospheric properties derived from both in situ and remote sensing products.

Materials:
- Tools for Analyzing Datasets from ACTIVATE (TADA)
- Create a GoogleAccount
- Setup EarthData Login
- ACTIVATE Research Flight 29 Video
- 11 July 2021: Webinar activities (Slides 19-39) Presented to Philippines high schools and universities

Guide for beginners to download and visualize data with Python