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# NASA's Mission ACTIVATE: Objectives, Strategies, and Limitations

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## Abstract

The primary goal of this report is to describe the operational concepts of NASA's ACTIVATE mission. ACTIVATE hopes to improve the understanding of aerosol dispersion and models, provide accurate data for aerosols' characterization and ozone profiles, and establish knowledge of the relationships between aerosols and water. ACTIVATE's science objectives are to quantify Na-CCN-Nd relationships and reduce uncertainty in model cloud droplet activation parameterizations, improve process-level understanding and model representation of factors governing cloud micro/macro-physical properties and how they couple with cloud effects on aerosol, plus assess advanced remote sensing capabilities for retrieving aerosol and cloud properties related to aerosol-cloud interactions. ACTIVATE utilizes the fixed-wing B-200 King Air to collect data. Data collected by ACTIVATE is highly relevant for meteorologists and environmental scientists looking to understand more about aerosol-cloud formations. Finally, ACTIVATE is a 5-year mission spanning from January 2019 to December 2023 and has used, and will continue to use, instruments such as the High Spectral Resolution Lidar-2 (HSRL-2), the Research Scanning Polarimeter (RSP), and the Diode Laser Hygrometer (DLH).

## Keywords

Atmosphere, Aerosol-Cloud Interactions, Marine Boundary Layer, NASA, Activate, High Spectral Resolution Lidar-2, Research Scanning Polarimeter, Diode Laser Hygrometer

## 1. Introduction

NASA's ACTIVATE, short for *Aerosol Cloud Meteorology Interactions over the Western Atlantic Experiment*, is a five-year NASA mission studying changes in marine boundary layer cloud systems, atmospheric aerosols, and multiple feedbacks that warm or cool the climate. While ACTIVATE's goal is to characterize aerosol-cloud-meteorology interactions, there are multiple other factors and purposes detailing ACTIVATE's mission subjects, objectives, mission types, duration, mission elements, and its constraints. It is this study's goal to briefly outline them.

## 2. Atmospheric Components and Conditions

ACTIVATE studies the atmosphere, and its goal is to characterize aerosol-cloud-meteorology interactions. Its purpose is to improve an understanding, as well as model representations, of relationships between aerosol concentrations (Na), cloud condensation nuclei (CCN), and cloud droplets (Nd). These concentrations simultaneously supply a very unique and disparate dataset for both international model intercomparisons and process-based studies. Additionally, ACTIVATE evaluates current remote sensing retrievals and prototypes for future satellite missions and develops improved satellite-based Nd retrievals, as well as CCN proxies during the data collection period. Moreover, ACTIVATE's mission is sub-orbital, so its craft, the B-200 King Air, only flies at specific altitudes in order to record data. The B-200 King Air typically operates only up to altitudes of 28,000 ft but can operate at 31,000 ft if planned prior to take-off. This preplanning allows ACTIVATE to remain nested between clouds for a majority of the time, which means ACTIVATE can typically stay between 20,000 to 60,000 feet in the air if desired [1].

### Quantifying Na-CCN-Nd

ACTIVATE's first science objective is to quantify Na-CCN-Nd relationships and reduce uncertainty in model cloud droplet activation parameterizations. This objective is important because it furthers our knowledge of the relationships between Na-CCN-Nd. ACTIVATE's secondary science objective is to improve process-level understanding and model representation of factors governing cloud micro/macro-physical properties and how these couple with cloud effects on aerosol, another vital objective since it provides us detailed models of relationships between Na-CCN-Nd. Lastly, the optimal science objective has been to assess advanced remote sensing capabilities for retrieving aerosol and cloud properties related to aerosol-cloud interactions, especially since this objective entails the current capabilities of what could be deemed as some of NASA's most cutting-edge technology to date [2].

## 3. ACTIVATE's Craft

Selected for ACTIVATE's mission was a fixed-wing, B-200 King Air craft, since the U.S. Marine Corps previously used the B-200 King Air until 2007. ACTIVATE's craft has two custom nadir-viewing ports to accommodate a wide variety of optical, laser, or R-F instruments [3] [4]. Moreover, it has a range of 800 nautical miles if carrying its standard 1000 lb. payload capacity.

This platform was chosen because it enabled the craft to have vital instruments as near to the subject as possible. Also, meteorologists and environmental scientists benefitted from the specific manner in which new data was collected, since the new data garnered was highly relevant to the model parameterizations for estimating aerosol impacts on cloud properties, as well as showed a reduction in any uncertainties concerning climate model simulations of cloud formations [1]. This also became relevant for climatologists, since this new information led to a greater understanding of climate variability, hence improving climate change estimation. Moreover, environmental scientists also benefited greatly from the ozone profiles they received, as these new findings aided insurmountably in assessments pertaining to ozone depletion, which was still not completely understood.

## 4. Timespan, Tables, and Findings

ACTIVATE is a five-year project spanning from January 2019 to December 2023. Assigned to collect data during its 150 planned and scheduled flights, the project will lead to approximately 600 total flight hours over a three year span. Thus far, scheduled flights occurred between February-March and May-June of 2020, 2021, and 2022, respectively [5]. During which, ACTIVATE collected data with its High Spectral Resolution Lidar-2 or HSRL-2, the Research Scanning Polarimeter (RSP), and the Diode Laser Hygrometer (DLH).

### High Spectral Resolution Lidar-2 (HSRL-2), Research Scanning Polarimeter (RSP), and the Diode Laser Hygrometer (DLH)

ACTIVATE utilizes the High Spectral Resolution Lidar-2 (HSRL-2), the Research Scanning Polarimeter (RSP), and the Diode Laser Hygrometer (DLH). The High Spectral Resolution Lidar-2 (HSRL-2)'s measurements include the following: Aerosol Depolarization Ratio, Aerosol Scattering Ratio, Aerosol Backscattering, and Aerosol Extinction [6] [7]. This data from the High Spectral Resolution Lidar-2 (HSRL-2) directly helps ACTIVATE characterize aerosol-cloud-meteorology interactions. Moreover, The Research Scanning Polarimeter (RSP) provides ACTIVATE with accurate estimates of aerosol loads and microphysical models over land and water to further characterize aerosols in marine boundary layer clouds, and finally, the Diode Laser Hygrometer (DLH) measures water vapor percentages in situ [8].

As stated, the primary function of the HSRL-2 is to measure aerosols and clouds, but one interesting fact about the HSRL-2 is that it combines the technology of the former High Spectral Resolution Lidar (HSRL), its predecessor, with the Differential Absorption LiDAR (DIAL), plus the new High Spectral Resolution LiDAR II (HSRL2). The biggest limitation to this device is its size, however, although it is already compact enough to go airborne.

Another instrument, the Research Scanning Polarimeter (RSP), characterizes materials through polarimetry, either in the air or on the ground, but one interesting feature of the RSP is that it can avoid false polarization due to its optical assemblies being mounted at an offset in azimuth of 45 degrees of one another, ensuring the polarization signal is not contaminated by light intensity fluctuations. One downside with the RSP is that it requires its sensors to be cooled to 163 Kelvin during ground and airborne operations [9].

The data provided by the Diode Laser Hygrometer (DLH) helps ACTIVATE model relationships between aerosols and water vapor. While the DLH measures water vapor percentages in situ, one remarkable feature of the DLH is that it uses differential absorption detection techniques to detect water vapor. However, the downside of this is that it is limited with its water vapor measurements [8].

## 5. Summary and Unresolved Issues

The amount of data collected is still somewhat constrained. Unlike a satellite, the B-200 King Air flies directly over the clouds, not under, so data collection is somewhat limited to the instruments' viewing angles. Moreover, the B-200's range also restricts the amount of data collected [5]. Details, such as mission subject, objective, type, duration, elements, and constraints, are the only truisms scientists can rely upon, but although the mission has limitations, the data has still proven beneficial for meteorologists and environmental scientists alike.

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## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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