Aerosol and Cloud Experiments in the Eastern North Atlantic

With their extensive coverage of Earth, low clouds greatly impact atmospheric processes. Currently, the extent and brightness of marine low clouds are poorly represented in earth system models, and the response of low clouds to changes in atmospheric greenhouse gases and aerosols remains a major source of uncertainty in earth system projections. This uncertainty is due in part to inadequate observations in regions where aerosol impact is the greatest.

The Eastern North Atlantic (ENA) is one such region where persistent, but diverse, subtropical marine boundary layer clouds are highly susceptible to disturbances in aerosol properties. Boundary layer aerosol in the ENA region is influenced by a variety of sources, leading to strong variations in cloud condensation nuclei concentration and aerosol properties. To provide the observations needed to improve models for this region, the U.S. Department of Energy established an Atmospheric Radiation Measurement (ARM) user facility site on Graciosa Island in the Azores.

Data from the ARM ENA site provide much-needed observations of aerosol, trace gases, cloud, drizzle, and atmospheric thermodynamics. However, there is a need for airborne characterization of the vertical structure, horizontal variability, and detailed physical and chemical properties of aerosol and cloud particles to understand and quantify the processes controlling the life cycle of marine boundary layer clouds and the cloud response to aerosol changes.

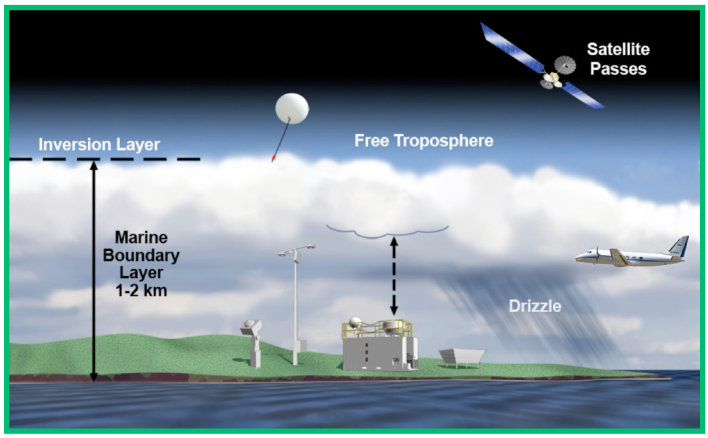
The **Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA)** brought the ARM Aerial Facility Gulfstream-159 (G-1) aircraft to the ENA site during summer (June to July) of 2017, and it returned in winter (January to February) of 2018. The campaign studied both seasons to measure key aerosol and cloud processes under various meteorological and cloud conditions with different aerosol sources. During the summer, the Azores experience overcast stratocumulus clouds that transition to broken trade cumulus clouds, while the winter experiences maritime frontal clouds. The ARM Aerial Facility (AAF) flew the G-1 into these clouds in both spiral patterns and horizontal legs at multiple altitudes near the ARM ENA site to collect vertical profile data of aerosols and clouds in 39 flights, for a total of 153.2 flight hours, spanning both intensive operational periods.

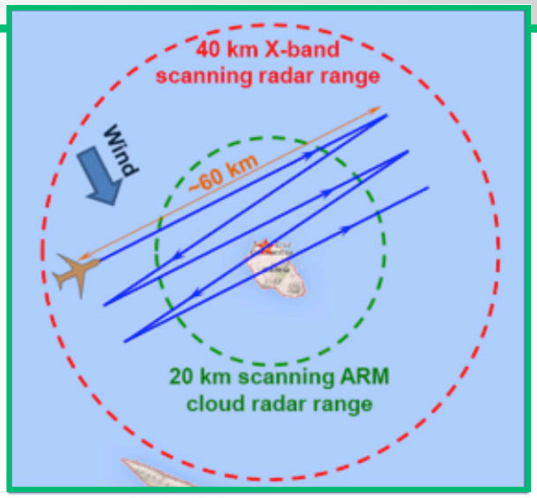
Science Objectives

The overarching scientific objective of ACE-ENA was to understand key processes that drive the properties and interactions between aerosols and clouds under a variety of representative meteorological and cloud conditions. ACE-ENA collected comprehensive in situ data of boundary layer and lower free troposphere structure, and associated vertical distributions and horizontal variations of low clouds and aerosols in the Azores. Scientific objectives and research were focused along five themes:

1. Budget of marine boundary layer cloud condensation nuclei and its seasonal variation
2. Effects of aerosol on cloud and precipitation
3. Cloud microphysical and macrophysical structures and entrainment mixing
4. Advancing retrievals of turbulence, cloud, and drizzle
5. Model evaluation and processes studies.

In addition, ACE-ENA deployments provided high-quality, in situ measurements for validating and improving ground-based data from the ARM ENA site. This data set will have a long-lasting impact on the research and modeling of clouds and aerosols in remote marine environments.





The G-1 flew in spiral and horizontal patterns over the ARM ENA site to collect observations that can be compared with the data from the site's scanning and precipitation radars.

Research Instrumentation

Ground-based – Established in late 2013, the ENA site located on Graciosa Island in the Azores hosts a full suite of atmospheric and meteorological instrumentation. Sophisticated cloud radars and lidars, radiometers, and aerosol observation instruments operate 24 hours a day, seven days a week. Data from the site are freely available to scientists around the world through the ARM Data Center.

Airborne – For ACE-ENA, the G-1 aircraft was equipped with nearly 50 instruments for measuring various atmospheric components. The instrument suite measured the following:

- aerosol concentration and size distribution
- aerosol composition and gas chemistry
- aerosol optical properties, such as reflectance, scattering, and absorption
- energy (radiation) coming from the sun and Earth
- temperature, pressure, humidity, wind speed, and direction.

Collaborations

Strong synergies were coordinated between ACE-ENA deployments and a number of field studies that took place nearby, such as the North Atlantic Aerosols and Marine Ecosystems Study (NAAMES), a NASA Earth Venture Suborbital mission (2015-2019), and the measurements collected at the Pico Mountain Observatory. In addition, aerosol particle samples were brought back to the Environmental Molecular Sciences Laboratory (EMSL) at Pacific Northwest National Laboratory and the Advanced Light Source at Lawrence Berkeley National Laboratory for subsequent laboratory analyses.

The ENA site collaborates frequently with the University of the Azores, Azorean government, and the Portugal Meteorological Institute.

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Additional information is available on the ARM website at www.arm.gov.