ARM

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Tethered Balloon Systems

With fixed and mobile sites around the globe, the Atmospheric Radiation Measurement (ARM) user facility is used by scientists to obtain measurements of radiative fluxes; cloud, aerosol, and precipitation properties; and related atmospheric characteristics in diverse environments.

ARM, a U.S. Department of Energy (DOE) scientific user facility, also has aerial capabilities that enhance the utility and information content of long-term, ground-based measurements by providing:

- in situ measurements of aerosols, clouds, and trace gases
- physical sampling of particles not possible using surface- or satellite-based techniques
- context for and extension of surface-based measurements
- measurements for testing and evaluating models.

Among ARM's aerial platforms are tethered balloon systems (TBS), which consist of a helium-filled balloon, tether, winch, and sensors. TBS provide a safe way to collect data inside clouds, including mixed-phase clouds, where icing is a concern for airborne platforms. These systems are also flown above and below clouds to gather data related to wind, turbulence, thermodynamic state, aerosols, and the cloud-top environment.

TBS complement ARM's other aerial platforms and provide:

- in-cloud flight (where allowed)
- sustained flight for long periods
- multiple kilograms of payload
- flexible instrument combinations for targeted measurements
- varied flight routines
- baseline measurements and multiple campaigns to occur simultaneously
- the accommodation of guest instruments.

At Oliktok Point, Alaska, where the third ARM Mobile Facility (AMF3) is deployed, TBS have conducted routine in-cloud measurements since 2015. ARM began TBS flights over its Southern Great Plains (SGP) atmospheric observatory in Oklahoma in 2019, with plans to expand to other sites and campaigns.

Baseline TBS Capabilities

The balloons typically used by ARM are 110 m^3 aerostats and 35 m^3 helikites with a maximum instrument payload capacity of 36 kilograms (about 79 pounds).

As a baseline component of instrumentation at the AMF3 Oliktok site, TBS have provided routine, repeated measurements that represent the interannual variability of conditions while operating intermittently between April and November.

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Flights at Oliktok have included measurements in clouds at maximum altitudes of 2.1 kilometers (7,000 feet) above ground.

At the SGP, TBS are operated below clouds to perform vertical profiling—moving up and down within the boundary layer—and conduct sampling before and after convection. The maximum height allowed for TBS flights at the SGP is 1.5 kilometers (4,921 feet) above ground.

TBS are being developed toward maximum autonomy for regular airborne data collection while operating safely in extreme conditions.

Typical sensors deployed on the ARM TBS are:

- wind speed and wind direction sensors
- tethersondes and radiosondes that provide thermodynamic and wind speed measurements
- supercooled liquid water content sensors for mixed-phase conditions
- aerosol sampling sensors
- a fiber-optic-based, distributed temperature-sensing system that provides thermodynamic profiles.

The TBS uses a continuously operated ground station that measures surface pressure, temperature, relative humidity, and 1-minute average and gust wind speeds.

As part of its role as a user facility, ARM also frequently hosts guest instrumentation on the TBS.

Data from the ARM instruments flown on the TBS are evaluated by scientific staff for overall quality and then processed and made available to the world, free of charge, in near-real time through the ARM Data Center, ***www.arm.gov/data***.

Recent TBS Operations

Oliktok Point

ARM began its foray into routine measurements with TBS and unmanned aerial systems (UAS) in 2016. From April through October at Oliktok, ARM ran the Inaugural Campaigns for ARM Research using Unmanned Systems (ICARUS). ICARUS collected spatial information about the arctic environment using UAS and TBS in conjunction with ground-based instruments.

From July to September 2018, ARM supported a campaign associated with the Year of Polar Prediction (YOPP), a large international effort to collect atmospheric observations around both poles. This campaign—Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE)—coordinated alternating deployments of TBS and DataHawk UAS. In addition to collecting data on temperature and humidity, TBS measured in situ vertical profiles of the aerosol structure.

Southern Great Plains

The first TBS flights at the SGP occurred in April 2019, followed by an ARM proposal call that enabled guest instruments on TBS flights in July and September.

ARM and another DOE scientific user facility, the Environmental Molecular Sciences Laboratory (EMSL), paired their capabilities to develop and test an aerosol filter sampler designed for TBS flights. The first flights with the sampler took place at the SGP. Laboratory analysis of these samples is helping to inform researchers about aerosol-cloud interactions and to validate and improve model representation of aerosol composition.

For a study led by Chongai Kuang of Brookhaven National Laboratory, the TBS team deployed condensation particle counters (CPCs) modified to detect ultrafine particles (to 5 and 2 nanometers). The TBS performed vertical profiling so the CPCs could capture ultrafine aerosols where they might be forming.

Future TBS Operations

With AMF3 ending operations at Oliktok in 2021, ARM will focus its near-future TBS flights on the SGP and on major field campaigns.

ARM plans multiple TBS campaigns at the SGP Central Facility and two smaller "extended" facilities in 2021. TBS flights are planned from April to September 2021 during the TRacking Aerosol Convection interactions ExpeRiment (TRACER) near Houston, Texas. In addition, there is interest in TBS flights supporting the Surface Atmosphere Integrated Field Laboratory (SAIL) campaign, which will start in September 2021 near Crested Butte, Colorado.

In subsequent years, ARM expects to deploy TBS at the next AMF3 site (in the Southeastern United States), at its Eastern North Atlantic observatory, and during major campaigns.

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