

U.S. Department of Energy 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) Office of Science 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 particle sampling 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 gather data related to wind, turbulence, thermodynamic state, and aerosols through the atmospheric boundary layer. In special situations, it is also possible to obtain measurements inside and above clouds, including mixed-phase clouds, where icing is a concern for airborne platforms.

TBS complement ARM's other aerial platforms and provide:

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



At Oliktok Point, Alaska, where the third ARM Mobile Facility (AMF3) operated from 2013 to 2021, ARM conducted routine in-cloud measurements with TBS starting in 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 ARM typically uses are 110 m³ aerostats and 35 m³ helikites with a maximum instrument payload capacity of 36 kilograms (about 80 pounds).

As a baseline component of instrumentation at the AMF3 Oliktok site, TBS provided routine, repeated measurements that represented the interannual variability of conditions while operating intermittently between April and November. Flights at Oliktok included measurements in clouds at a maximum altitude 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
- 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 frequently hosts guest instrumentation on the TBS. Scientists can also propose for two-week TBS missions. Information on how to propose for TBS missions or guest instrument flights is available at www.arm.gov/policies/campaign-guidelines/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 uncrewed aerial systems (UAS) in 2016.

From April through October at Oliktok, the Inaugural Campaigns for ARM Research using Unmanned Systems (ICARUS) initiative collected spatial information about the Arctic environment. ICARUS used TBS and UAS 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. The Profiling at Oliktok Point to Enhance YOPP Experiments (POPEYE) campaign 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.

The final campaign at Oliktok was the Ice Fog Field Experiment at Oliktok Point (IFFExO) in November 2020. TBS and AMF3 data from IFFExO are helping researchers better understand the life cycle of arctic ice fog.

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 Office of Science 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. Researchers are using laboratory analysis of these samples to learn more about aerosol-cloud interactions and to validate and improve model representation of aerosol composition.

In 2021, ARM held TBS flights at the SGP Central Facility and two smaller instrumented sites nearby.

Future TBS Operations

ARM will focus its near-future TBS flights on the SGP and on major field campaigns. Flights are planned from June through September 2022 during the TRacking Aerosol Convection interactions ExpeRiment (TRACER) near Houston, Texas. In addition, flights will take place near Crested Butte, Colorado, during the 2021–2023 Surface Atmosphere Integrated Field Laboratory (SAIL) campaign.

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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