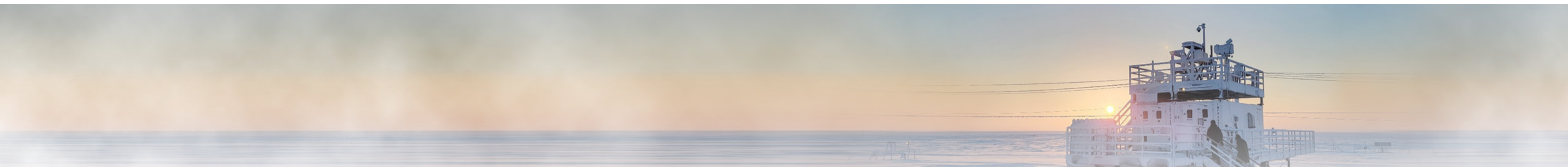
Climate Security at Sandia



ARCTIC MEASUREMENTS

Sandia's ability to precisely measure environmental conditions in the rapidly changing Arctic enables research, forecasting, and regional and national planning. Researchers gather atmospheric, marine, and cryosphere data to better understand earth system processes, predict weather, gauge climate change impacts, and develop improved earth system models.

WHAT WE DO

Sandia collects precise weather, environmental, and climate data using a variety of tools, technologies, and one-of-a-kind facilities. Arctic measurements require specialized operational and sensing equipment, providing Sandia the opportunity to develop, test, validate, and improve data-collection technologies for multiple applications. Sandia's expertise measuring in harsh, inaccessible environments also enables us to collect data identified by sponsors and stakeholders as critical to understanding key Arctic systems. For example, Arctic research and data can inform Coast Guard, commercial, and military operations, allowing them to operate more safely and effectively.

ATMOSPHERIC MEASUREMENTS

Sandia collects data related to atmospheric thermodynamics, cloud microphysics, and aerosol properties critical for forecasting weather, monitoring climatic changes and Arctic storms, and improving atmospheric models. In 2017, Sandia completed the first continuous, long-term monitoring field campaign involving measurements of methane, black carbon, and other greenhouse gases at Utqiagvik, Alaska. Capabilities that enable these atmospheric measurements in the Arctic include:

- **Tethered balloon systems (TBS)** – These unmanned aerial systems composed of a helium-filled balloon, tether, and winch can carry different types of sensors, including distributed temperature sensors to collect Arctic atmospheric temperature profiles and supercooled water sensors to measure multiphase clouds.
- **Drones** – Also known as unmanned aerial systems (UAS), drones are a reusable, lower-preparation means to collect measurements from more remote locations, more frequently, and at various altitudes.
- **Heliotropes** – Developed by Sandia, the heliotrope is a solar-powered hot air balloon that can loft sensors into the stratosphere, twice as high as commercial aircraft fly. This technology has enabled the capture of low frequency sounds that are otherwise very difficult to obtain. Heliotropes have great potential in the Arctic where it is difficult to deploy ground-based sensors but perpetual summer sunlight permits flight for perhaps weeks at a time.
- **Restricted airspace** – Access to a 700-mile-long restricted airspace over the Beaufort Sea at Oliktok Point enables Sandia to conduct experiments and exercises over Arctic waters without risk to human-piloted aircraft.
- **Arctic-based facilities** – Sandia manages a DOE Atmospheric Radiation Measurement (ARM) user facility at Utqiaġvik on Alaska's North Slope. Operational since 1997, this site provides unique data collected for global atmospheric and Earth system model development and verification. At Oliktok Point, facilities include lab space, logistical and operational support, UAS resources, lodging, and test equipment. The site also provides direct access to the Arctic Ocean and restricted airspace.

Sandia researchers used the ARM tethered balloon system at Oliktok Point, Alaska, to deploy an automated size and time-resolved aerosol collector (STAC) to measure aerosol particles in the size range of 0.1-0.5μm and with a few seconds' time resolution. Photo by Brent Peterson, Sandia National Laboratories

MARINE MEASUREMENTS

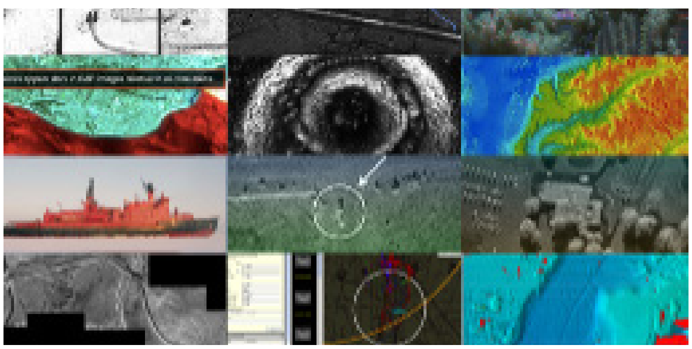
Distributed Acoustic Sensing (DAS) – Sandia scientists deployed DAS in Alaska's Beaufort Sea to collect the first-ever such data recorded beneath a frozen ocean. This technology can record acoustic and seismic signals, such as the timing and distribution of sea ice breakup, ocean wave height, sea ice thickness, and storm severity, with unprecedented temporal and spatial resolutions. It also has potential for monitoring surface shipping and whale and seal vocalizations.

Distributed Temperature Sensing (DTS) – This technology can measure temperature at high spatial and temporal resolution and will be deployed to the Beaufort Sea to measure seafloor temperature on the continental shelf. Sandia scientists will use this data, in conjunction with simultaneously recorded DAS, to better understand the distribution of frozen seafloor sediments (submarine permafrost) and the location and activity level of seafloor fluid and greenhouse gas seeps in response to a warming Arctic climate.

Collaborative Projects

Sandia has supported many collaborative projects related to environmental measurements, including:

- Drone-based imaging systems for marine measurements with the University of Alaska Fairbanks (2018)
- Deployment and testing of emergency beacons in the Beaufort Sea, which bridges measurements and operational/security efforts, as part of the DHS Pfrost project (2019)
- Demonstration of a new hyperspectral imaging system that can detect oil in the presence of ice with the US Coast Guard, NOAA, University New Hampshire, and Alaska Clean Seas (2022)
- A proposed collaboration with the University of Texas El Paso that will include measurements of methane in the Arctic Ocean and seabed environments



Many of Sandia's synthetic aperture radar capabilities have the potential applications in the Arctic, including climate change assessment, environmental monitoring, and strategic surveillance.

CRYOSPHERE PERMAFROST AND LAND INTERACTIONS

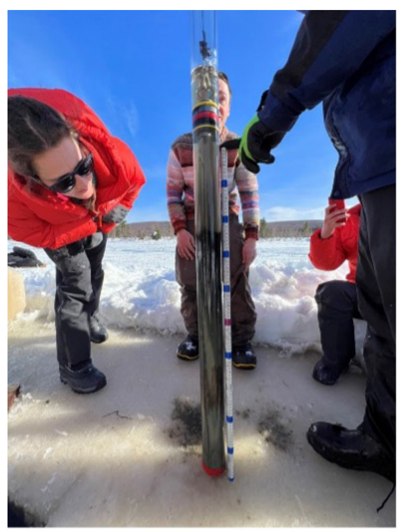
Sandia works with radar (e.g., synthetic aperture radar) and lidar (e.g., Raman lidar) systems, including hardware, software, algorithms, and data analysis for the remote sensing of sea and land ice.

Synthetic Aperture Radar (SAR) – Sandia specializes in the full-system design of exquisite SAR systems. The Rapid Terrain Visualization (RTV) interferometric SAR was used to image and create Digital Elevation Models (DEMs) for the entire coastline of Kodiak, Alaska, at both low and high tide. The SAR Crevasse Hazard Assessment, and Safety Monitor (SARCHASM) radar was used to detect bridged crevasses in Antarctica for the New York Air National Guard in support of the National Science Foundation. Existing, conventional, and novel SAR and radar technologies could potentially have other Arctic science and security applications, including:

- Strategic and tactical surveillance and reconnaissance (e.g., treaty verification, border protection and security, law enforcement, maritime situational awareness),
- Disaster relief and search and rescue (e.g., ice jams, flooding, fires, earthquakes, oil spills),
- Environmental monitoring,
- Climate change assessment, and
- Terrain, snow, and ice characterization and classification.

Permafrost microbiomes (Arctic biorisk management) – A major climate change-forcing factor, permafrost soils modulate Arctic climates and the microbial residents of permafrost that are central contributors to biogeochemical climate feedback cycles. Sandia has developed approaches to accurately characterize microbial activities in soil samples, which is critical for defining the risks of permafrost soil degradation to both chronic and acute climate perturbations. Our scientists are also developing gas measurement platforms to non-destructively determine the sub-surface microbial signatures of permafrost degradation.

Permafrost core material properties – Sandia scientists, in collaboration with the University of Alaska, Fairbanks and the University of Texas, have obtained cores of coastal permafrost for geomechanical testing and geochemical analysis. This work has enabled a better understanding of how material strength degrades as permafrost thaws, important in predictions for coastal erosion rates and infrastructure stability. Understanding the amount of carbon in coastal permafrost soils allows us to analyze terrestrial-marine carbon cycle dynamics as permafrost increasingly erodes into the ocean.



Sandia scientists and collaborators inspect sediment layers obtained from a 1-meter core of a frozen thermokarst lakebed at Big Trail Lake near Fairbanks, Alaska.

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