SAND2018-13831C

Scientific and National Security Missions Using Unmanned Aerial Systems and Facilities in the Alaska High Arctic

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American Geophysical Union, Fall Meeting
Global Environmental Change, GC33B-08
Wed, 12 Dec 2018

Summary of this introductory talk

1. Background on Sandia Labs and US Department of Energy Atmospheric Radiation Measurement Program
2. Sandia's Work in the Arctic, focusing on Oliktok Point
3. Recent UAS and TBS Missions in the Arctic ("field campaigns")
4. Our Vision for a High Arctic Research Center Based on our Experience at Oliktok
5. Other Related Research and Related Proposed Research at Sandia

Sandia National Laboratories

History

…"exceptional service in the national interest"

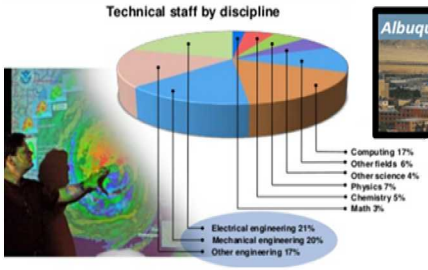
Sandia develops advanced technologies to ensure global peace

Research and Development for National Needs

Missions since 1950s now include all things nuclear, cyber security, sensors, chem/bio security, treaty verification, space systems, economic competitiveness, critical infrastructure security, global modeling, decision analysis, etc… and energy systems.

Broad Technical Capabilities and Talent

2018 workforce:



Locations:

12,400+ (*52% perform R&D work*)

Collaboration

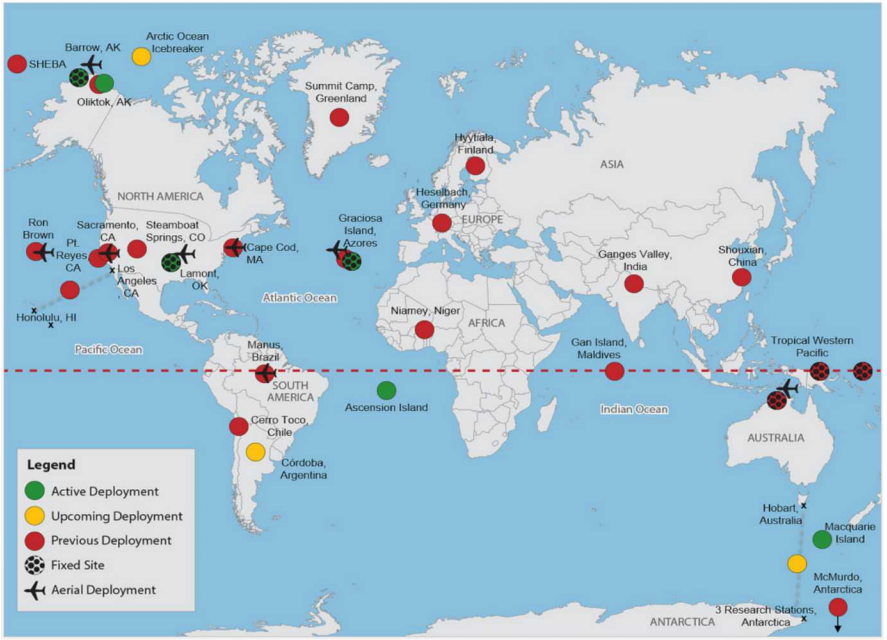
We conduct ~$3B annual business:

Partners include Government Agencies, Industry, Academia, and others.

ARM Program

Mission: The ARM Climate Research Facility, a DOE scientific user facility, provides the climate research community with strategically located in-situ and remote sensing observatories designed to improve the understanding and representation , in climate and Earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth's surface.

Vision: To provide a detailed and accurate description of the Earth's atmosphere, in diverse climate regimes, to resolve the uncertainties in climate and Earth system models, toward the development of sustainable solutions for the Nation's energy and environmental challenges.

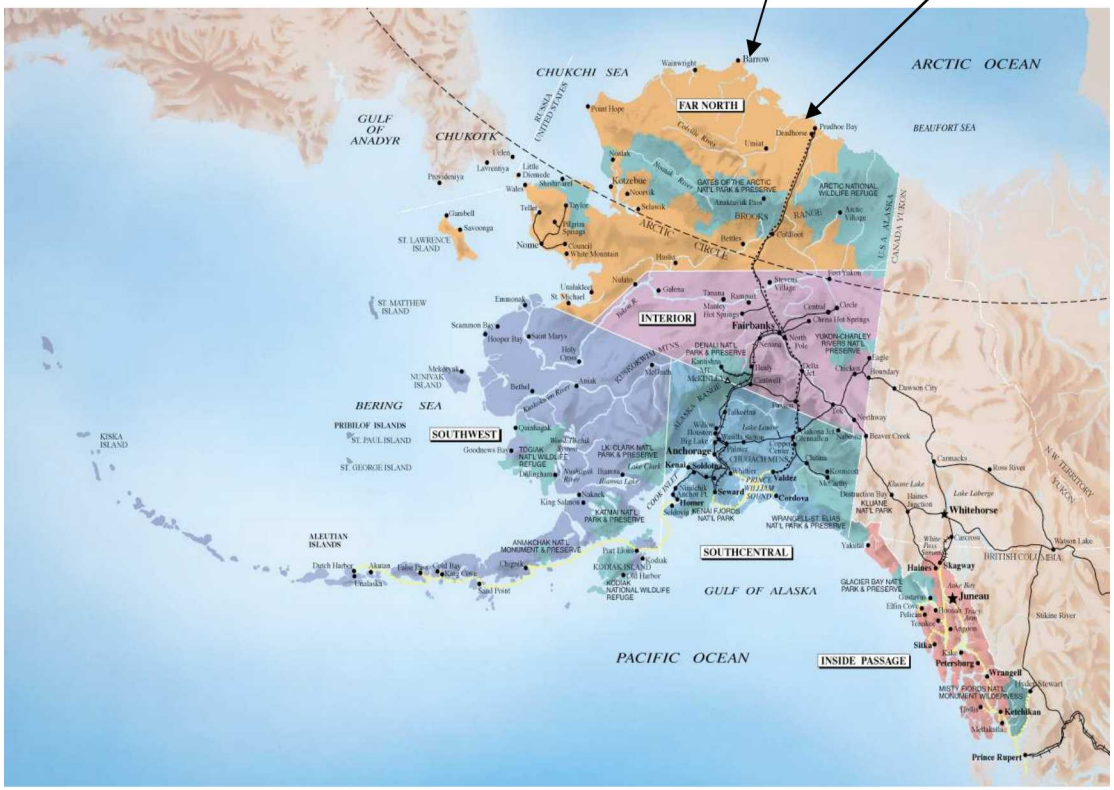


US Department of Energy Atmospheric Radiation Research (ARM) Facilities in Alaska

Oliktok Point/AMF3: (2013-Present)

Barrow/Utqiagvik NSA main site (1997-present)

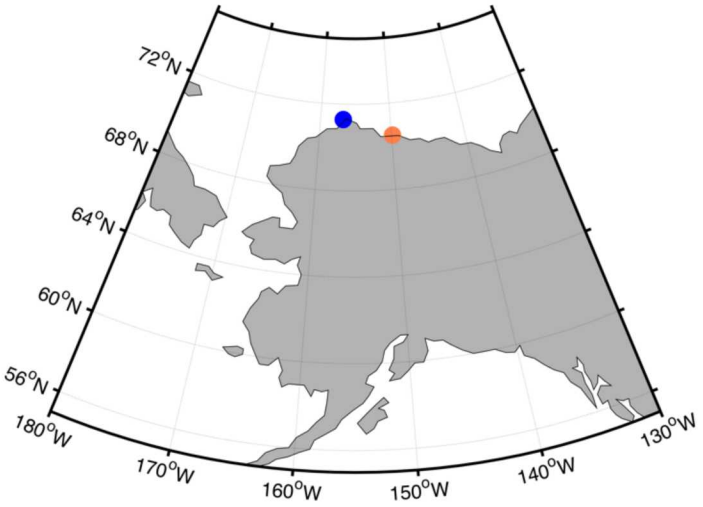
Barrow and Oliktok Pt.



ARM Duplex in Barrow

Atqasuk: Pumpkin Shelter (Inactive)

Introduction to Oliktok Point



AMF3 Includes:

Clouds:
- MPL, Raman Lidar, Ceilometer
- KAZR
- 3-channel MWR
- TSI

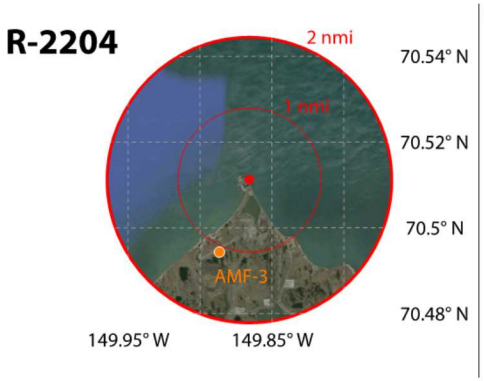
Profiling:
- Radiosondes (2x daily)
- Doppler Lidar

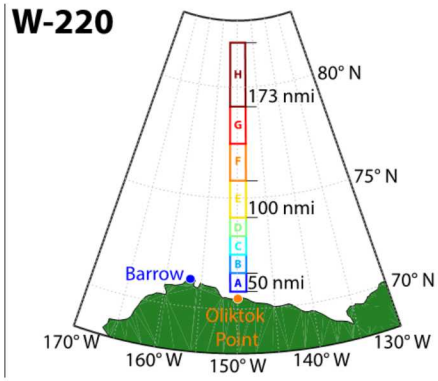
Radiometric:
- AERI
- MFR, MFRSR
- Up/Downwelling broadband
- IRT
- CIMEL Sunphotometer

Surface Meteorology/Precip:
- Surface Met
- ECOR, AMC
- MASC, NASA PIP
- Geonor
- Laser Precipitation Monitor

Aerosols:
- CPC
- HDTMA
- Nephelometer
- CCN

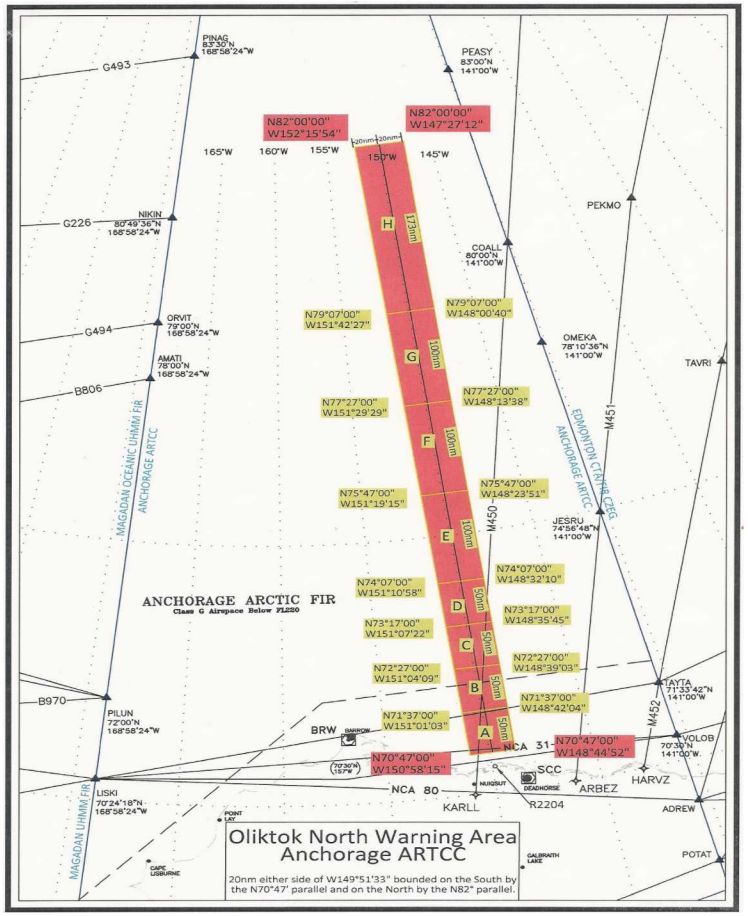
Gas Sensors:
- Picarro
- LICOR



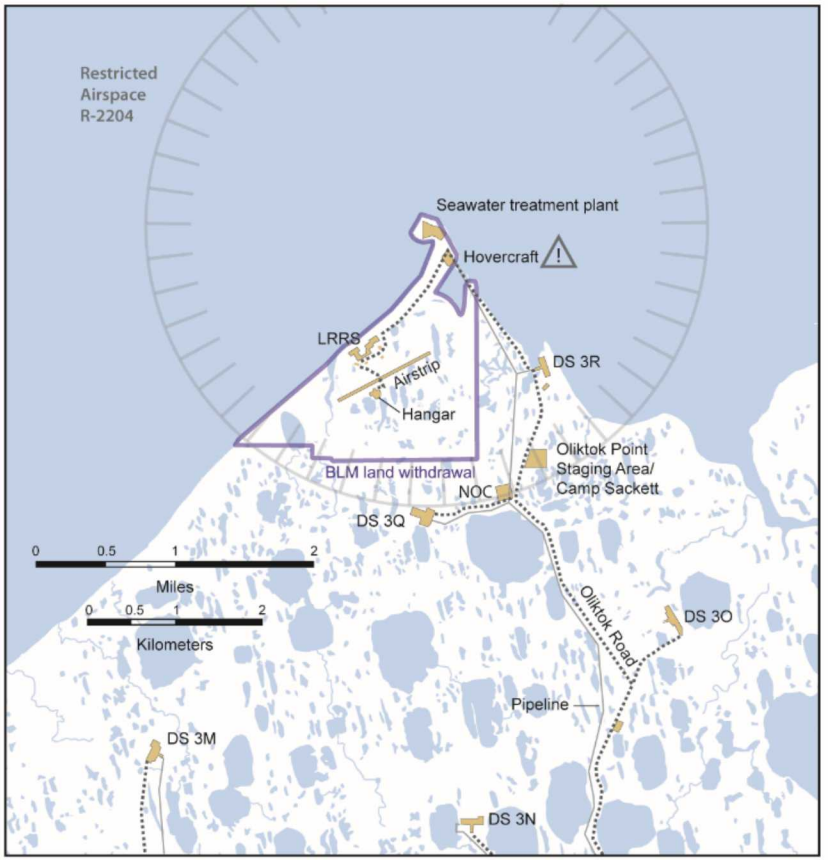


Controlled Airspace

Warning Area W-220

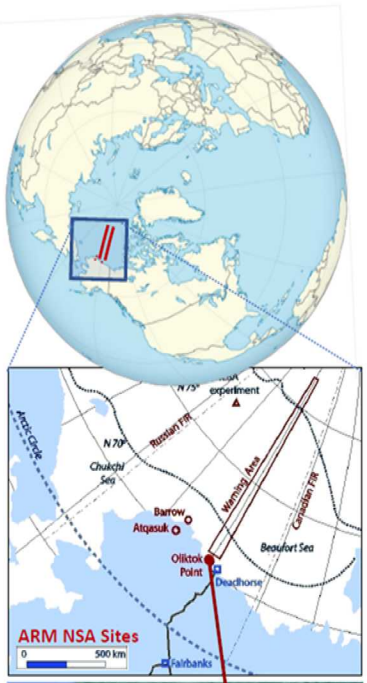


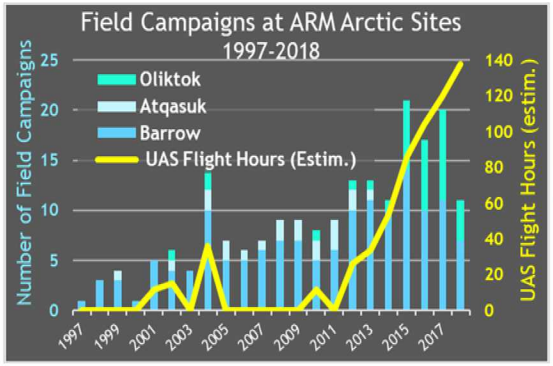
Restricted Area at Oliktok



Sandia Arctic: UAS Campaigns

ARM
CLIMATE RESEARCH FACILITY



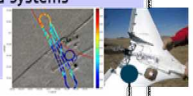


2015-16; Barrow + Oliktok:
Inaugural Campaigns for ARM Research with Unmanned Systems (ICARUS)
using multiple TBS platforms and sensors
with Sandia Labs

2015; Oliktok:
First concurrent TBS and DH platforms flights
with CIRES/CU-Boulder

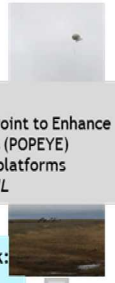
2016-17; Oliktok:
DataHawk flights
with PNNL

2015-16; Oliktok:
Evaluation of Routine Atmospheric Sounding Measurements w/ Unmanned Systems (ERASMUS-I,-II)
DataHawk & Pilatus platforms
with CIRES/CU-Boulder



2015; Oliktok:
Arctic Shield Search & Rescue exercise
using ScanEagle platform
with USCG, C-P, Insitu, NOAA, FAA, NSB and Era

2018; Oliktok:
Profiles at Oliktok Point to Enhance YOPP Experiments (POPEYE)
DataHawk and TBS platforms
with NOAA and PNNL



2016-17; Oliktok:
Radar calibration sphere on TBS
with PNNL

2014; Oliktok:
Coordinated observations of the Arctic lower atmosphere (COALA)
using DataHawk platform
with CIRES/CU-Boulder

2002; Barrow:
Simultaneous Aerosonde-Radiosondes
with ANL and NSF

2010; Oliktok:
Arctic Lower Troposphere Observed Structure (ALTOS)
using SPEC He-filled balloon;
with SPEC, PSU, Scripps and UAF

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

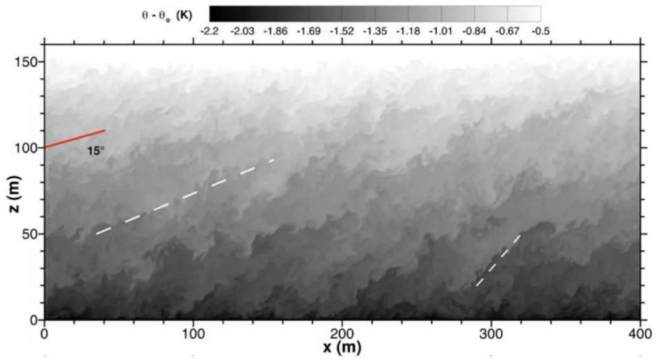
2001; Barrow:
First UAV flights on North Slope AK
Aerosonde with NSF

2004; Barrow, Atqasuk, Oliktok, Toolik Lake:
Mixed-Phase Arctic Cloud Experiment (M-PACE)
using Vaisala sondes and ARM-Proteus UAV
with UAF, PSU, UIUC, UND, UWisc, PNNL and NOAA

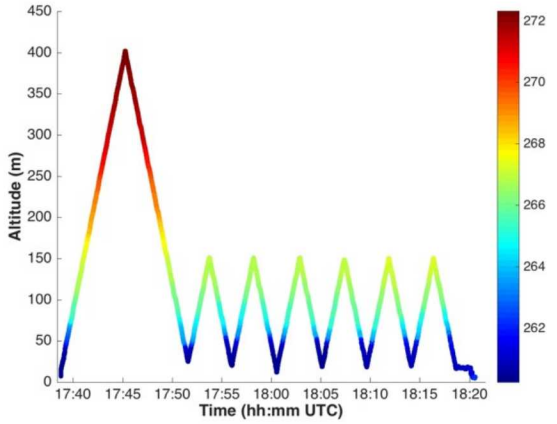
2012; Oliktok:
UAS Test Maneuvers using BAT-3 and Aeryon Scout
with NMSU

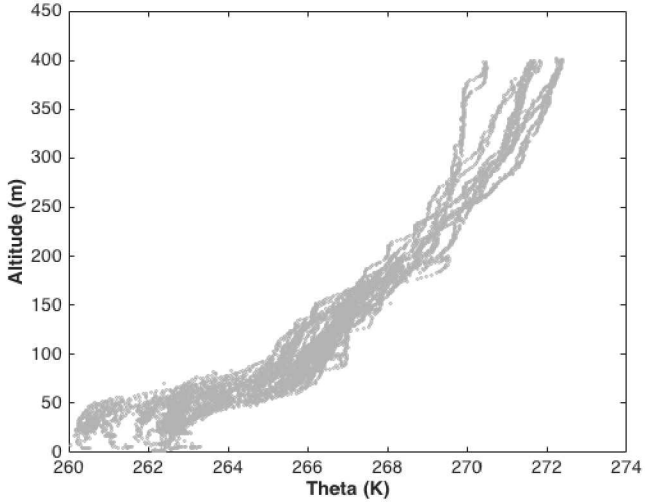
2013; Oliktok:
Marginal Ice Zone Observation & Process Experiment (MIZOPEX)
using Sierra, Datahawk and ScanEagle
with NASA, UAF and CU-Boulder

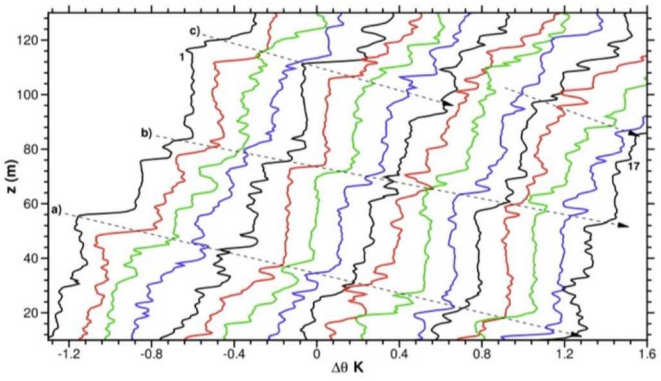
Science Topics: Boundary Layer Structure

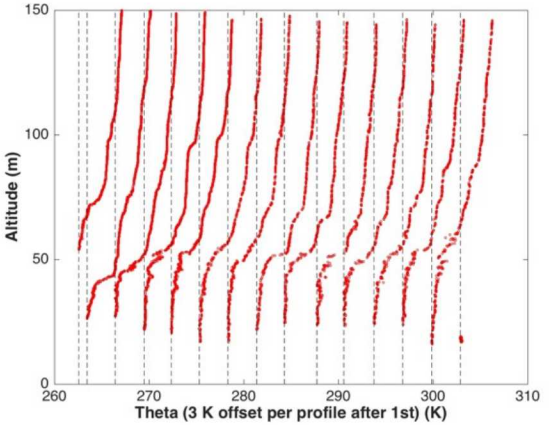


(Sullivan et al., 2016)









Introduction to POPEYE

POPEYE Campaign Schedule

July

	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu
	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TBS												C												C								
DH												C												C								
Sondes																																

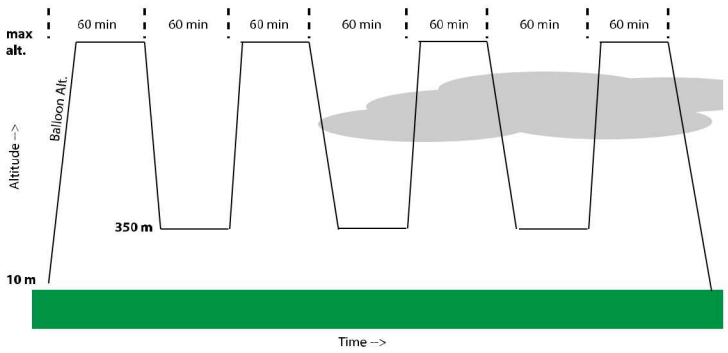
August

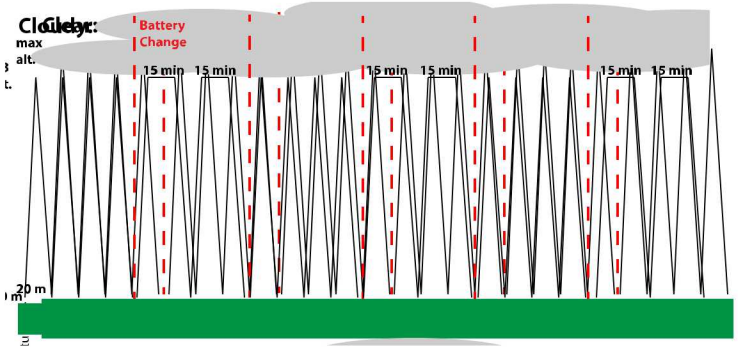
	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TBS				C													C														
DH				C													C														
Sondes																															

September

	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
TBS																			C											
DH																			C											
Sondes																														

Set Up Days | Operational Days | No UAS/TBS sampling | C Focus on intercalibration | 3x daily sondes | 2x daily sondes

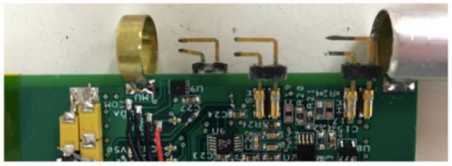




DataHawk 2

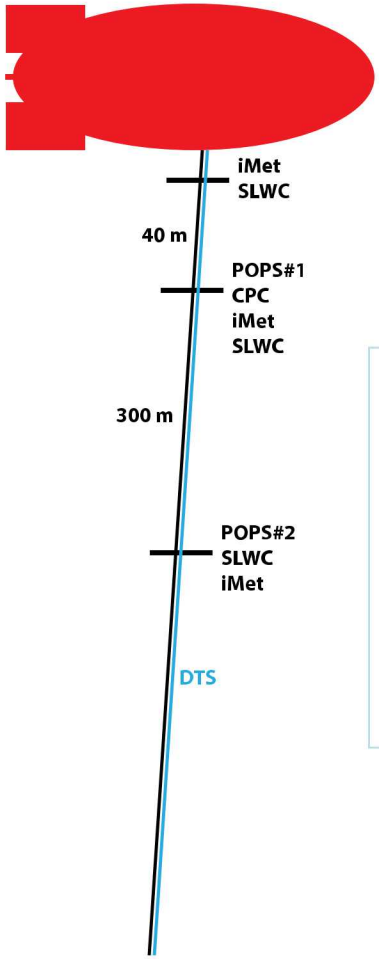
Description:
Small (~1 m wingspan, 850 g)
~$1000 vehicle parts cost
15-20 m s^{-1} typical airspeed
75 min flight duration (level)
~70 km range (level)

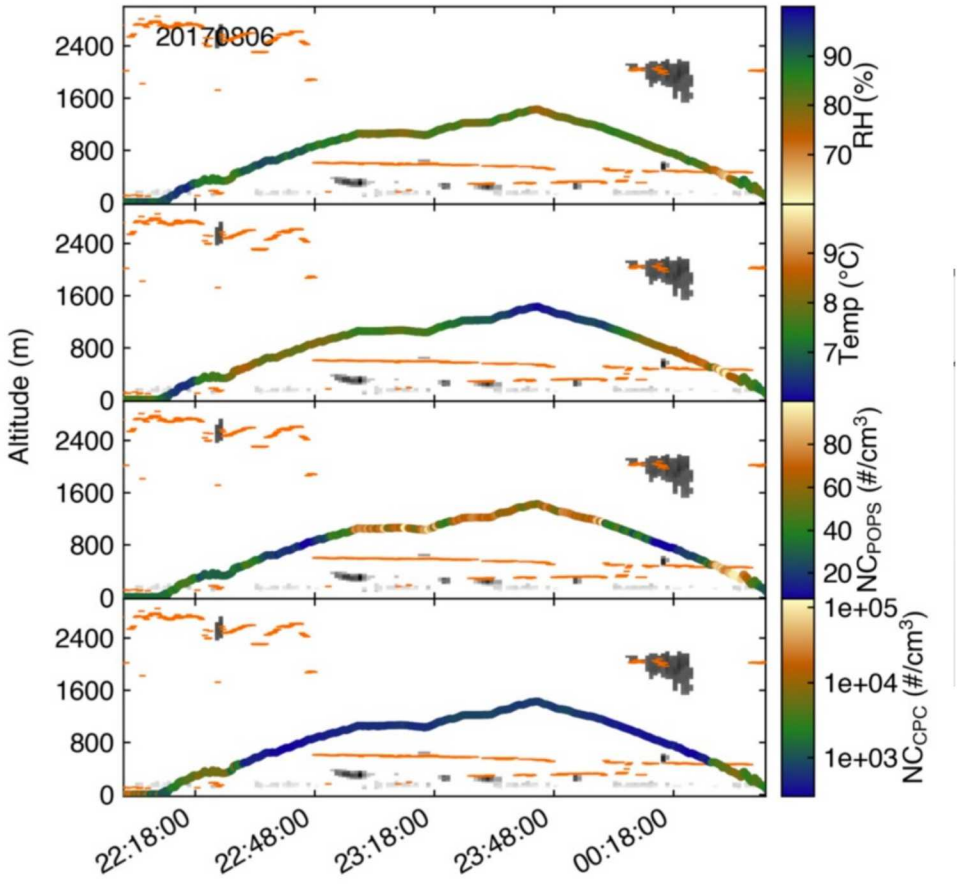
Measurement Capabilities
Temperature (fast, slow)
Relative Humidity (slow)
Pressure
3D wind vector estimate (fast)
IR Surface Temperature
Location



Vehicle developed at the University of Colorado and operated by DOE for POPEYE

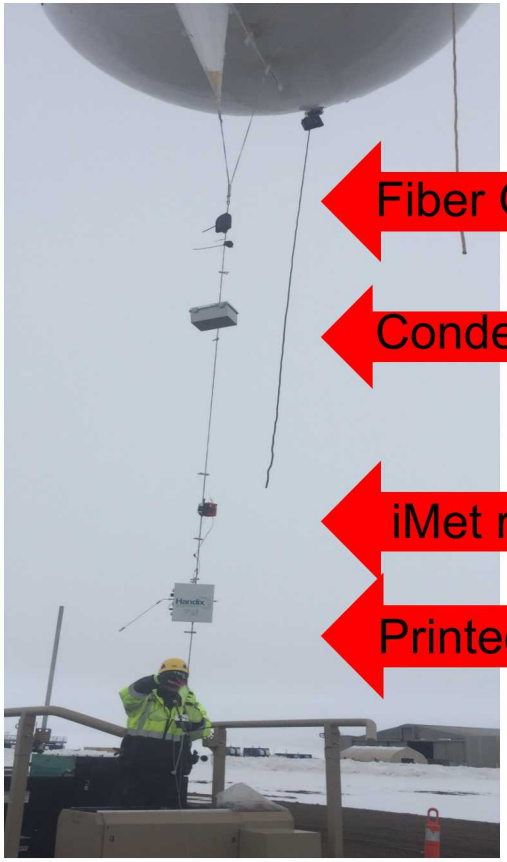
Tethered Balloon System





Summary of recent POPEYE campaign

- Almost 135 hours of TBS flights and 63 hours of small UAS flights were conducted at the AMF3 from 7/1/18 – 9/30/18 as part of the POPEYE (Profiling at Oliktok Point to Enhance YOPP Measurements) campaign. Instruments operated on the TBS include:



Fiber Optic Distributed Temperature Sensing

Condensation Particle Counter

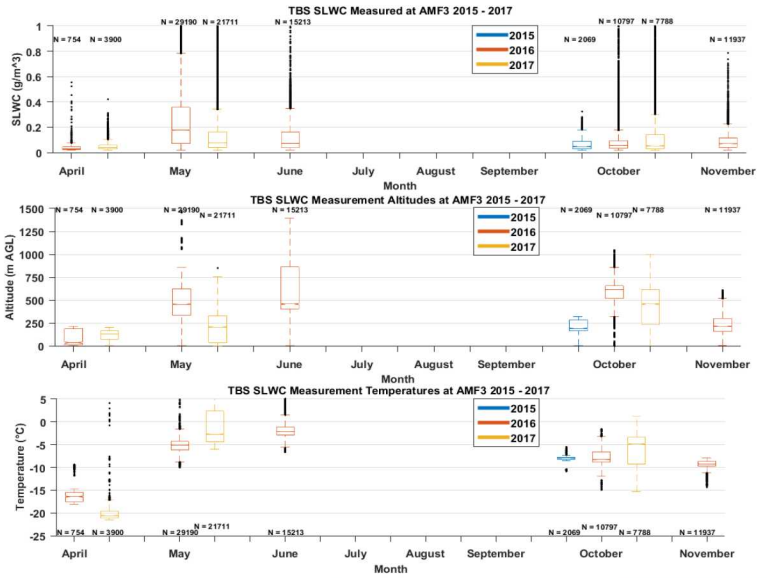
iMet radiosondes and XQ2s

Printed Optical Particle Spectrometers (2)

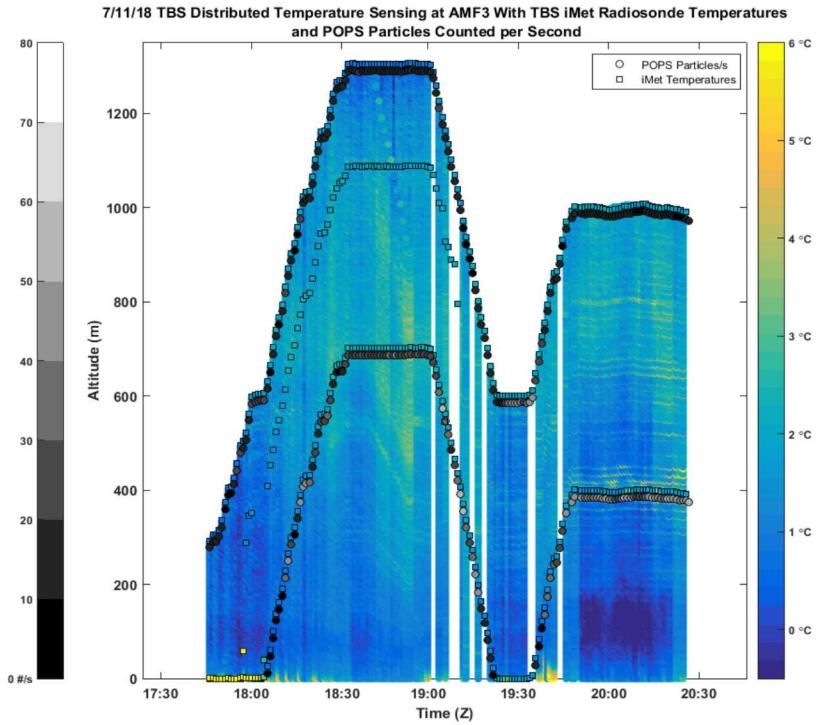
Tethered Balloon System on the North Slope

- Over 350 hours of tethered balloon flights have been conducted to collect atmospheric data at Oliktok Point between March and November in 2015 – 2018. Flights have also been conducted in Barrow/Utqiagvik and from a vessel in the Beaufort Sea.

Supercooled Liquid Water Climatology



Airborne Distributed Temperature Sensing



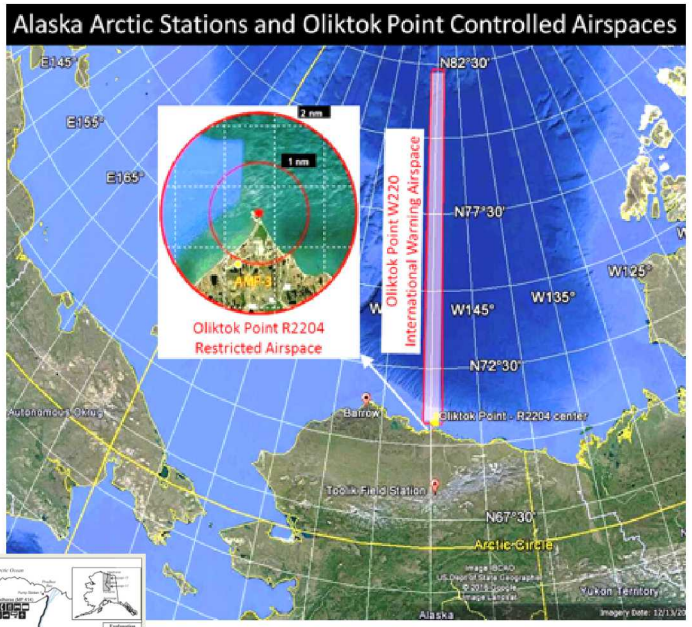
“SODA” Campaign at Kuparuk and Oliktok, October 2018

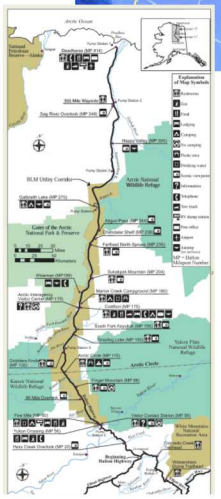
Photo Credit: Chase Plane Pilots Jordan W. Murdock and Robert J. Edison

Oliktok Point Assets

Oliktok Point Location, Assets and Experience

- **Location**: Near Prudhoe Bay, USHARC has access to coastal, marine and terrestrial environments. Connections via road and air transport to Barrow/Utqiagvik and Toolik Lake serve to connect a network of Arctic facilities.
- **Road Access**: Dalton Highway connects Deadhorse to sub-Arctic Alaska, Toolik Lake Field Station, and the contiguous U.S. The site has access to local services, as well as seaports and airports for deliveries and global services.
- **Controlled Airspace**: At Oliktok and across the ocean toward the North Pole. This enables coordinated terrestrial + marine + aerial research and operations.
- **Unmanned Aircraft Systems (UAS)**: A UAS Facility at the Station operated by UAF, with an airstrip and hangar; to serve research, testing, and development.
- **Communications and Data**: Broadband fiber-optic cable at Oliktok is fully operational. A secured communications SCIF at the USAF LRRS is present.
- **Infrastructure and Services**: UAF and Sandia relationships with North Slope Alaska partners offer equipment, skills and services; including medical facilities and emergency response teams.
- **Collaboration**: Spaces and systems for Arctic stakeholders at USHARC will connect to a Network of Arctic Stations for coordinated projects.
- **Research & Exercise Support**: UAF and Sandia have experience with logistics and research in the Alaskan High Arctic. Station will be developed with lab spaces, logistic and operational support, prep areas, UAS facilities, utility systems, and lodging.




Dalton Highway


Bi-facial PV panels


miniSAR radar

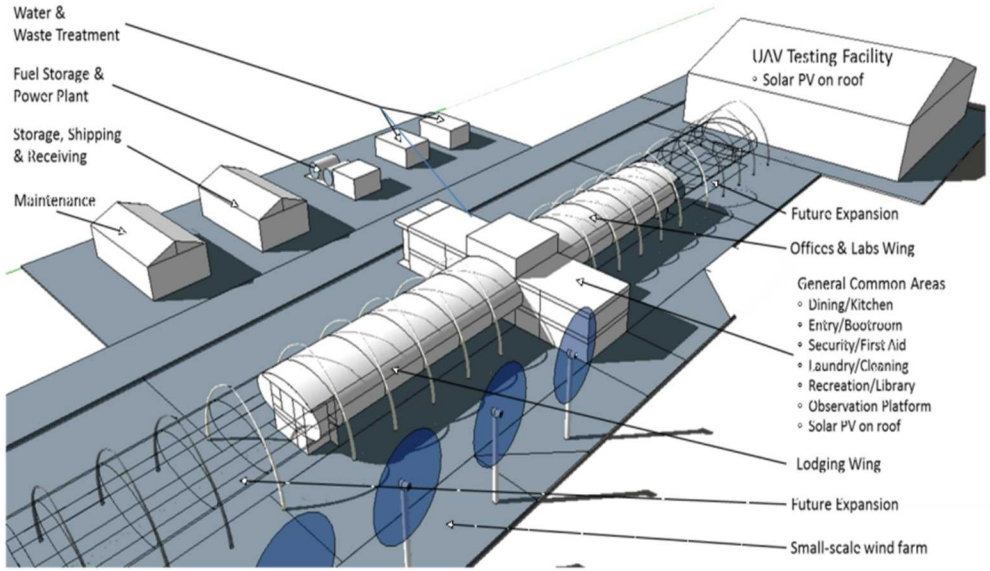

Unmanned aircraft and Tethered balloon systems

USHARC: Greater Arctic Presence

Increase High Arctic presence:

- U.S. has the smallest active presence in the Arctic among Arctic Nations (and some non-Arctic Nations)
- America's former 63 Arctic DEW Line radar bases, set up with allies to detect a Soviet airstrike over the North Pole, were mostly abandoned in the 1990s.
  - No permanent base in the U.S. north of the Arctic Circle.
  - Only U.S. base north of the Arctic Circle is at Thule, Greenland

- USHARC will increase U.S. Arctic presence:
  - Permanent, year-round facility
  - Infrastructure for Arctic research, technology, and training
  - Shoreline location for campaigns across domains (land, sea, air, ice)
  - Increased domain awareness (*and research for same*)
  - Increased logistic capabilities (*and research for same*)
  - Increased communications (*and research for same*)



Oliktok Point High Arctic Station Concept

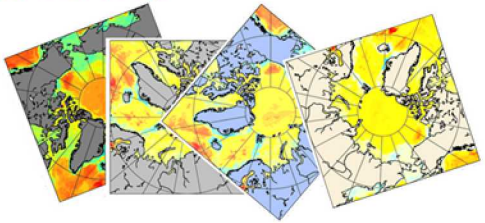
Photo Credit: USCG Petty Officer 2nd Class Grant DeVuyst

The Oliktok Point site and controlled airspaces were used to conduct the USCG search and rescue exercise Arctic Shield in 2015. An unmanned aerial vehicle (UAV) was launched from Oliktok Point, which was "handed off" to the USCG Healy to locate simulated "survivors" in Arctic ice-covered waters within Sandia-managed airspace. Manned aircraft were then dispatched to provide a faster and more efficient rescue operation via coordination of government and private assets.

Sandia-funded Projects

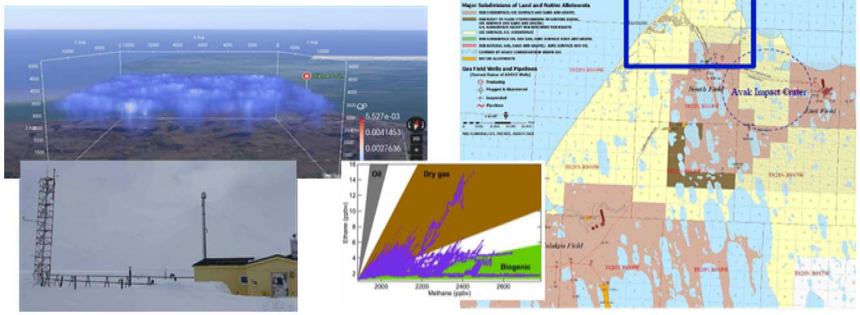
Permafrost Thaw

- Permafrost in Active Layer Seismic Interferometry (PALSIE) (to monitor active layer thickness change with seismic measurements at Poker Flat)
- *Forecasting Marine Sediment Properties On and Near the Arctic Shelf (generate probabilistic maps for best estimates of Arctic seafloor properties; with NRL)*



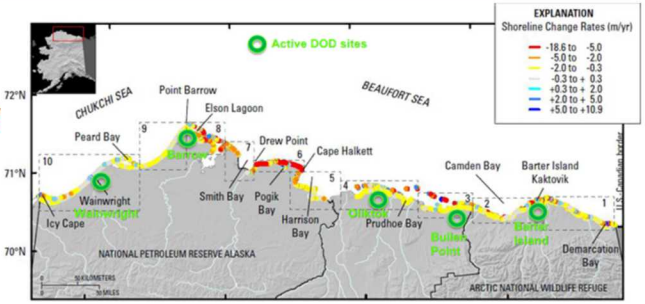
Climate Modeling

- *Atmospheric Measurements + Ultra-High Resolution Modeling in the Arctic*
- Arctic Methane, Carbon Aerosols and Tracers in the Arctic (longest continuous measurements of these on North Slope Alaska)
- Methane Emissions Attribution (comparisons between Utqiagvik and Prudhoe Bay)
- Sensor Networks Optimization (software to optimize sensor placement)



Coastal Erosion

- *A Predictive Model for Arctic Coastal Erosion (field research and analysis at Drew Point)*



Ice Formation and Migration

- Deciphering Atmospheric Ice Nucleation Using Molecular-Scale Microscopy (to improve model predictions, inform de-icing technologies)

Observation Capabilities

- Tethered Balloon Maritime Operations (with sensors and fiber optic system)
- Heliotropic Platforms in the Arctic (use 24-hr solar to provide simple, inexpensive long-term high-altitude flight with sensors)
- Joint UAV and Balloon Arctic Operations (JUBA) (sensors integration and calibration, preparations for icing tests for UAV flight safety, reliability)

Proposed North Slope Projects

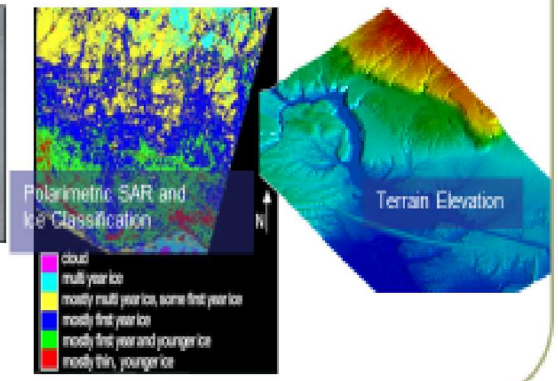
Research to Advance Arctic Domain Awareness and Operations

Overview of objectives and tasks

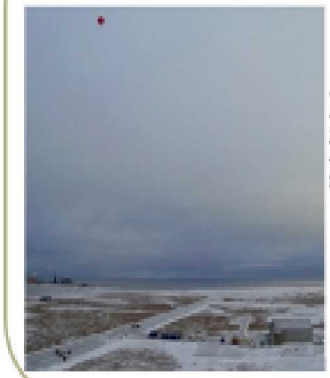
Sandia National Laboratories

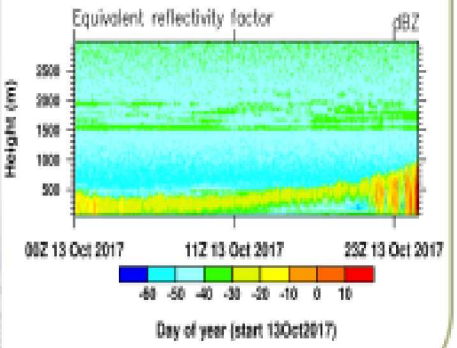
#1 SAR measurements of ice

Sandia real-time, multi-band, fine resolution SARs

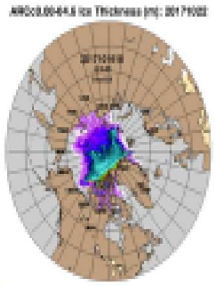


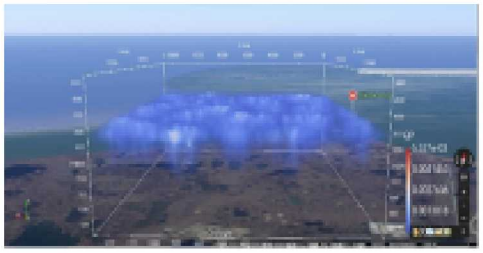
#2 Collect UAS & Surface-based data



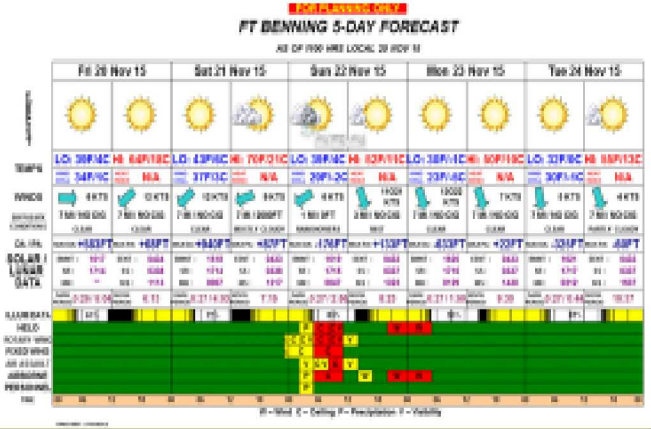


#3 Assimilate high resolution atmosphere and sea ice data with models (LES, MPAS CICE or PIPS)





#4 Improve Operational Forecast



Summary

We have used unmanned aerial systems (UAS) and operated facilities for observations that include:

- Atmospheric measurements, including thermodynamic state, aerosol and cloud measurement, upward and downwelling radiation, and ice particle measurements;
- Ground (tundra) measurements using imaging, lidar, and radar;
- Sea ice imaging, concurrent with atmospheric and ocean measurements;
- Thermal imaging for search and rescue applications;
- Research and Development missions for UAS technology assessment, including Arctic maritime domain awareness.

Essential capabilities for a facility to support UAS missions and measurements include:

- Communications, preferably high-bandwidth network access;
- Affordable access to the contiguous lower 48 states for scientific and logistics support;
- Access via road, air, and ocean for year-round affordable use;
- Work space, maintenance support, instrument testing space, and lab facilities;
- Accommodations for research and support personnel and associated requirements for safe operations;
- Ground-based measurements for instrument calibrations and validation.

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