

Enhancing Arctic Marine Domain Awareness: examples at Sandia Labs

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PRESENTED BY

Lori Parrott, J. Hardesty, Diana Bull, Mark Ivey, Erika Roesler, Jennifer Frederick, Holly Dockery



Sandia Labs Presence in the US Arctic



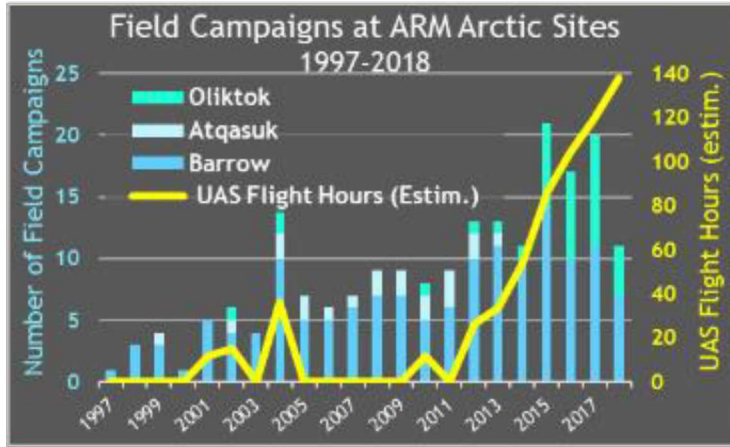
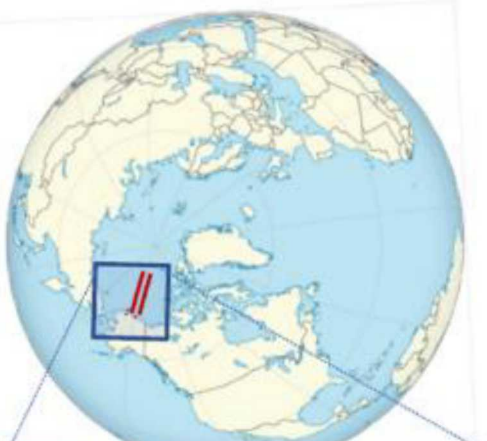
Adjacent to the Arctic Ocean, the Atkasuk, Oliktok, and Barrow facilities provide a strategically placed window into the interactions between atmosphere, land, and ocean systems

Photo credit: Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facility



ARM
CLIMATE RESEARCH FACILITY

Sandia-managed Arctic Airspace and UAS Campaigns



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

2004; Barrow, Atkasuk, 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

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

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

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

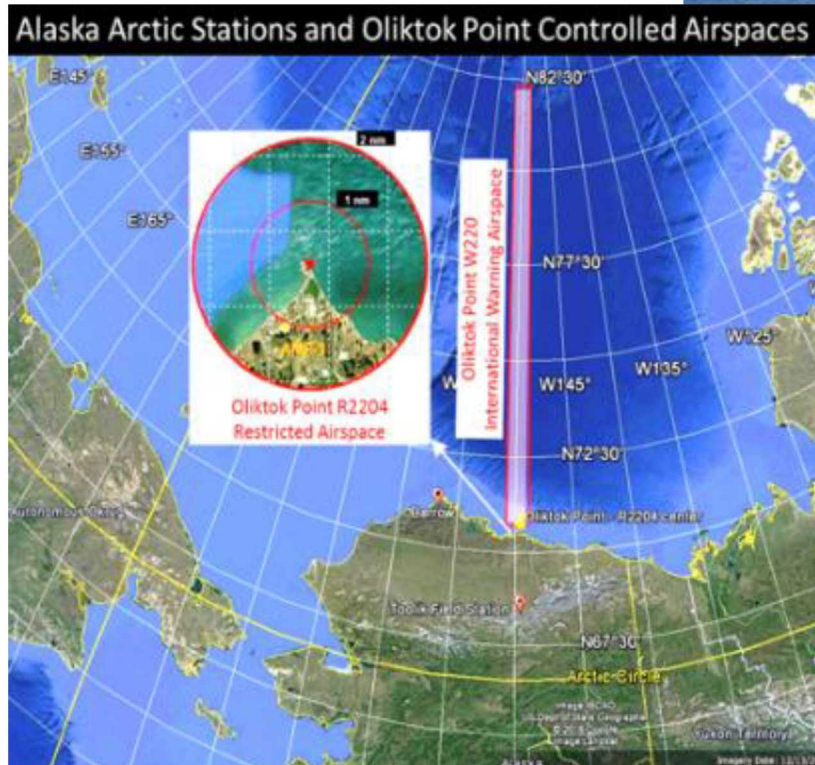
2013; Oliktok:
Marginal Ice Zone Observation & Process Experiment (MIZOPEX) using Sierra, Datahawk and ScanEagle with NASA, UAF and CU-Boulder

2018

Controlled Airspace for Arctic Maritime Domain Awareness



- SNL-managed controlled Arctic airspace
 - Response support: Arctic Shield 2015
- Unmanned aerial systems for Arctic observations
 - JUBA
 - SODA-MIZ



Arctic Shield 2015: The Oliktok Point site and controlled airspaces were used to conduct this USCG search and rescue exercise.

Photo Credit: USCG Petty Officer 2nd Class Grant DeVuyst

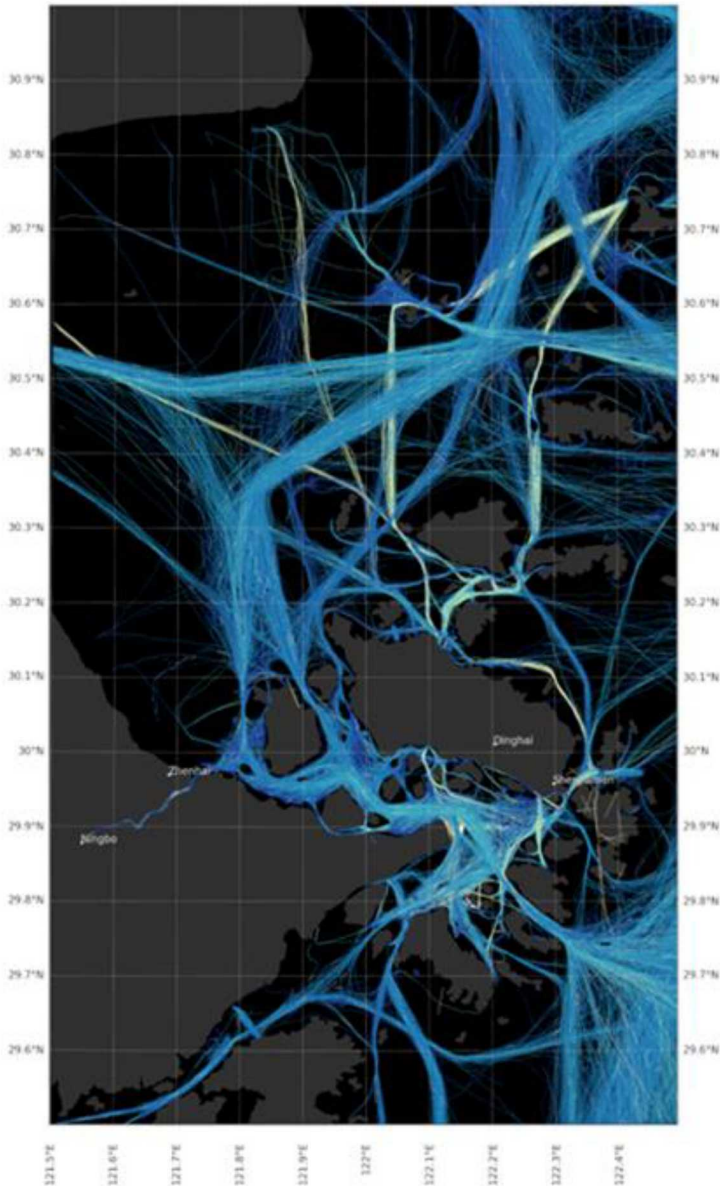
- JUBA: Unmanned aerial systems and Balloon Activities**
 - Multiple platforms and sensors (tethered balloons, rotor and fixed-wing drones, etc.)



SODA-MIZ Campaign with UAF
- Mid-size platform SeaHunter

SNL-managed controlled Arctic airspace

Sandia Maritime Expertise: recent key examples



Investments run the gamut from very specific monitoring technologies such as sensor placement, to much more broad-ranging activities such as policy decisions. **Recent Key Efforts:**

NNSA/NA-21 MegaPorts Program Technical Lead:

- Non-containerized bulk, break-bulk, Roll-On/Roll-Off, fishing, and tanker seaport experience (especially Russia).
- Design, Evaluation and Implementation of seaport physical security systems.
- Maritime Vectors Partnership (MVP) focuses on unregulated maritime commerce in sensitive areas. Incorporates detection, vessel Visit, Board, Search and Seizure (VBSS) on unregulated vessels (those that do not meet UN Safety of Life at Sea -SOLAS regulations).
- MegaPorts Initiative - Sandia is lead lab for Analysis, Design and Implementation of radiation detection systems at large international container ports (>1 Million TEU volumes).

Maritime Domain Awareness (MDA) Modeling:

- Maritime data analysis for pattern of life and anomaly detection, vessel routings and commodity analysis, etc.
- Trajectory Analysis - can study spatial and temporal patterns of trajectories (including maritime) and identify subtle changes that have occurred over time.
- Maritime Prioritization Models - Evaluates container ports based on factors such as volumes, connections, threat, etc. to prioritize security engagement strategies.
- Commodity and Inter-modal Network analysis
- Database of unregulated type ships.
- Joint Asset Win Strategy (JAWS) tools to do point of presence prediction of vessels, e.g. have worked with JIATF-South to interdict drug vessels.

Collaborative Studies: Sponsored analysis with visiting scholars to understand specific area of operation concerns.

Training, Workshops and Exercises

- Hundreds of workshops and exercises focused on topics ranging from Maritime Registries, International Ships and Port Security code, Sanctions Awareness, Port Security, Standard Operating Procedures, Regulations, Maintenance, and Operations.

Sandia staff have extensive experience with container port and ship operations, planning and security

- Experience-guided leadership to ground-truth analyses for port and maritime security activity, integration of new technologies, and effective implementation.

Systems Expertise for Maritime Security



Radiation Detection Straddle Carrier

Port vehicle monitoring



Mobile radiation detection system

Spectroscopic portal monitor



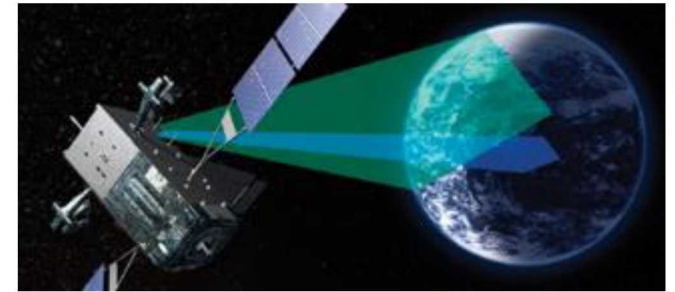
Man-portable and Contraband Detection

Sandia applies a systems approach to problem solving.

- Innovative Solutions: Sandia designed and deployed specialized systems for security inspections and integrated these for non-intrusive monitoring.
- Seaport Environment:
 - Detection and interdiction of nuclear and other radioactive materials throughout the **global maritime shipping network** with focus on containerized shipments. **Specialized and innovative detection solutions** for **transshipped** containers and **low volume** ports including unregulated vessels such as dhow and other small fishing and transport vessels.



Cryosphere: Ice sensing



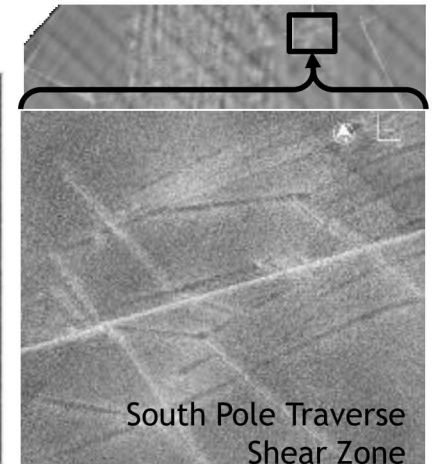
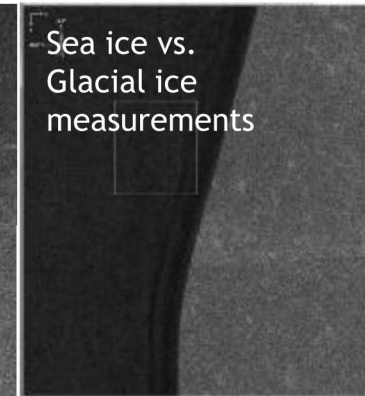
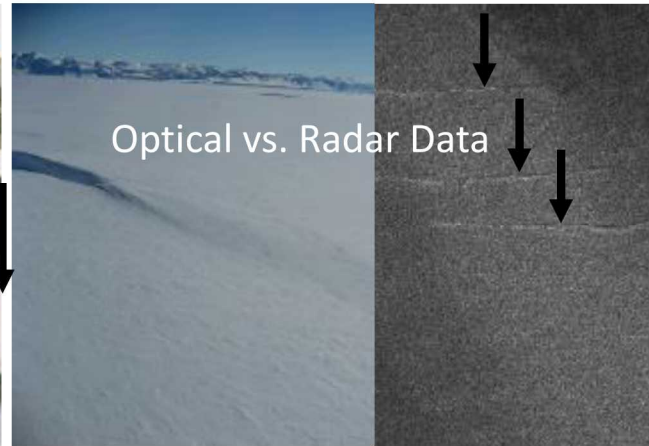
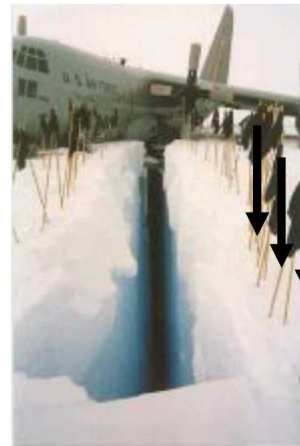
Sensing at multiple scales: Global, regional, local

- Satellites/aerial/surface observations
 - Ocean Ice: ARM SACR at BARC
 - Ocean + Land Ice: Synthetic aperture radar/SAR/mini-SAR



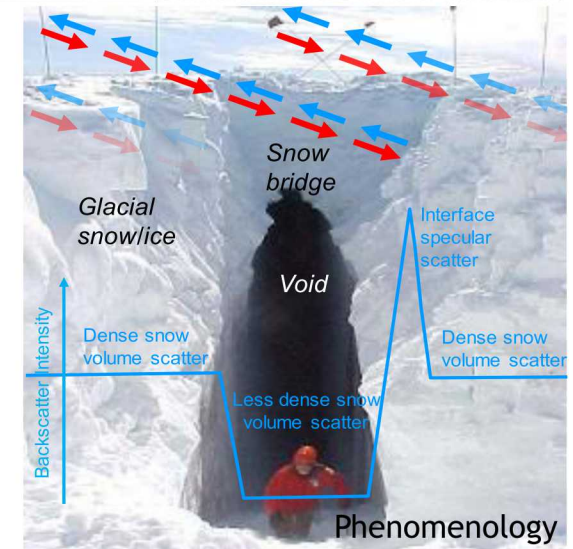
ARM SAPR Imaging of sea ice:

- DOE Radar in Utqiagvik/Barrow
- Capable of imaging near-shore and land-fast ice conditions
 - *elevated on roof of BARC facility



Synthetic Aperture Radar imaging of ice

- Response to collapse of ice runway under C-130
- Support of Antarctic program
- To relocate ice runway away from crevasses
- Also imaged land vs sea ice to demarcate edges
- Also used to image Greenland ice sheet





Sandia Radar Experimental Capabilities

SAR Remote Sensing to Improve Polar Domain Awareness

- Climate Science: land and sea snow, firn, and ice characterization, sea ice extent and thickness, permafrost subsidence/upheaval, coastal erosion
- National Security: sea ice charting (with thickness), ice flow monitoring, ship tracking, anthropomorphic activity, change detection

Facility for Advanced RF and Algorithmic Development (FARAD) Sandia could fly FARAD collections in the Arctic

X-Band (9.6 GHz)

- Fully polarimetric
- Fully integrated dual-channel front end

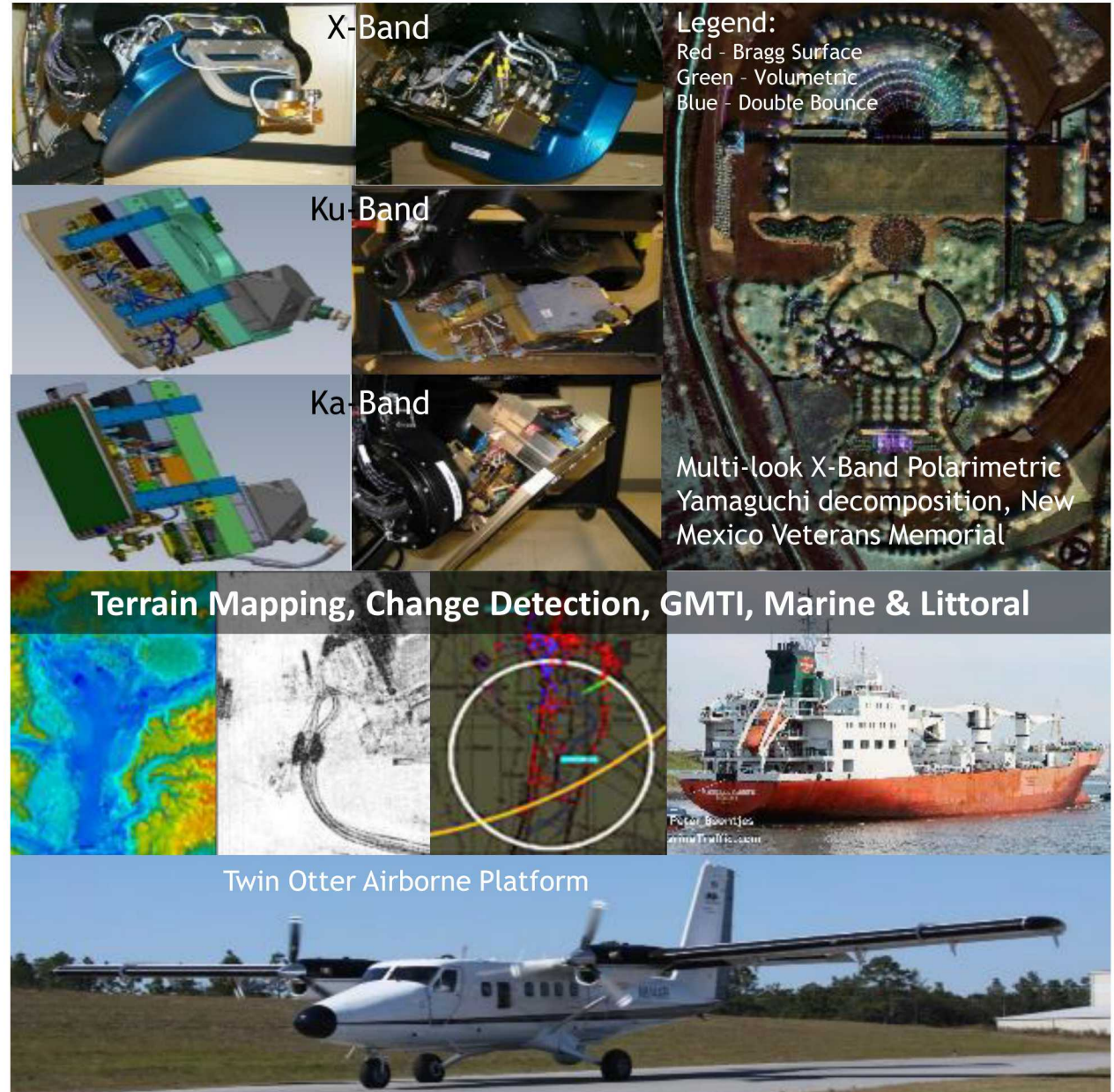
Ku-Band (16.8 GHz)

- Quad-phase-center antenna
- 4-channel front end
- Dual receive channel

Ka-Band (35 GHz)

- Ultra-fine resolution
- Azimuth monopulse antenna
- Low-minimum detectable velocity simultaneous SAR/GMTI

DeHavilland DHC-6



Arctic Coastal Erosion



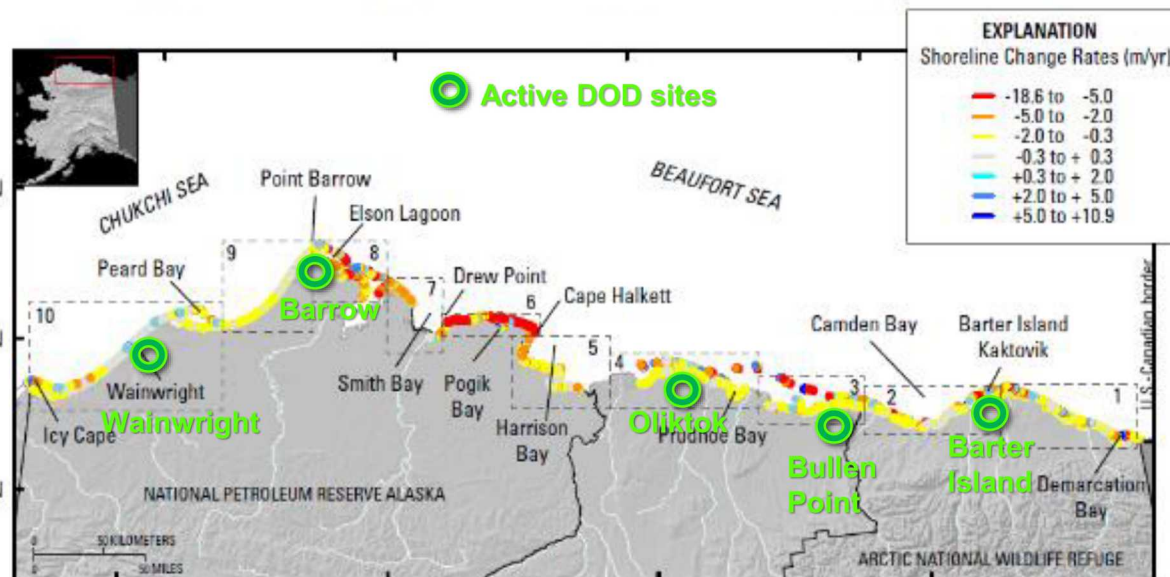
Problem Statement

Arctic is warming at 2-3 times of the rest of the US, with accelerated coastal erosion rates due to:

- Sea ice loss: 51% loss in area; 75% loss in volume since 1979 → result: increased time and energy of waves
- Sea temperature: increasing sea water temperatures further melts ice (feedbacks: albedo change, intrusion)
- Permafrost: warming/thawing at coast and subsea

Erosion is threatening:

- Coastal communities
- Nearshore ecological stability
- DOD, coastal, maritime infrastructure
- Global carbon balances



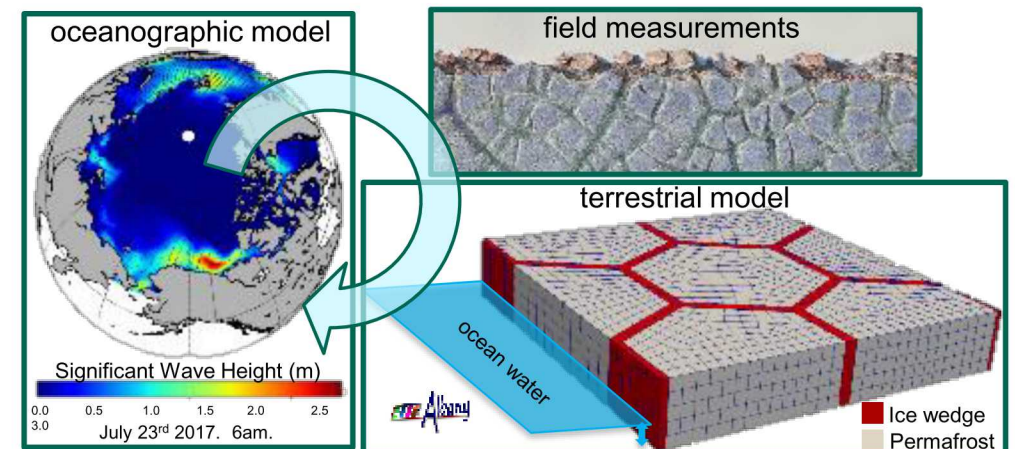
Technical Approach

Capture evolving thermodynamics in permafrost: ice binds unconsolidated soils and thus imparts material strength characteristics

- Field and lab measurements
- Coupling a multi-physics finite element terrestrial model with high-fidelity model of coastal water levels

Failure determination from constitutive relationships to couple strength with ice content

- First fully physics based approach to modeling failure
- Enables modeling of all deformation mechanisms (block erosion, slumping, etc.)



Example: Oliktok Point North Warning System Infrastructure



Stabilization measures are temporary

- Potential need to relocate
 - How soon?
 - Where?

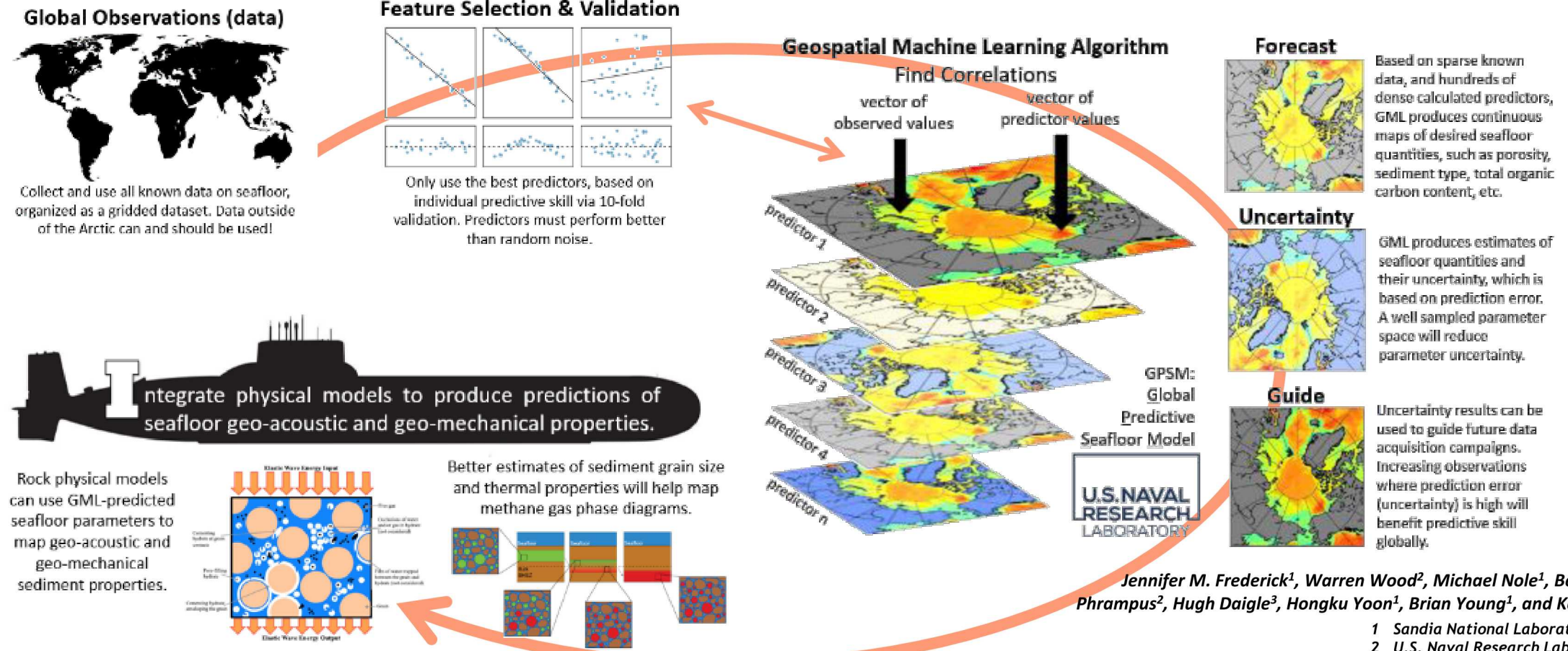
Forecasting Marine Sediment Properties with Geospatial Machine Learning

Forecast of seafloor conditions via a novel integration of geospatial machine learning and physical models:



U.S. NAVAL
RESEARCH
LABORATORY

TEXAS
The University of Texas at Austin



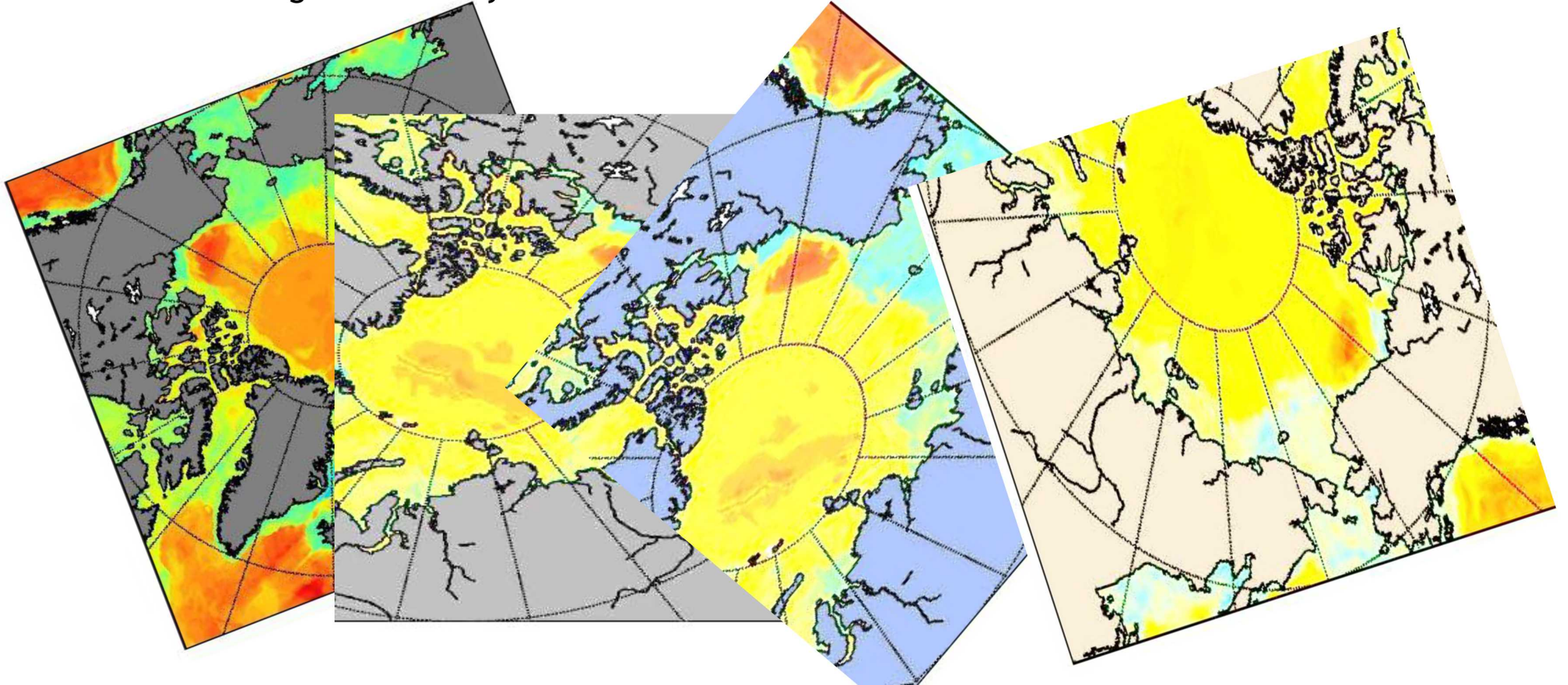
Jennifer M. Frederick¹, Warren Wood², Michael Nole¹, Ben Phrampus², Hugh Daigle³, Hongku Yoon¹, Brian Young¹, and Ken Sale¹

- 1 Sandia National Laboratories
- 2 U.S. Naval Research Laboratory
- 3 University of Texas at Austin

Seabed Forecasts: Resulting in Probabilistic Maps

These maps will provide the best calculated estimates of continuous seafloor properties to date. For any Navy-relevant quantity:

- speed of sound, seafloor bearing strength, etc.
- areas with high uncertainty tell us where more data is needed



HARC: 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)

- Most of the 63 Arctic DEW Line radar bases were abandoned in the 1990s. Currently:
 - No permanent base in the U.S. north of the Arctic Circle.
 - Single U.S. base north of the Arctic Circle is Thule, Greenland
- HARC will increase U.S. Arctic presence:
 - A permanent, year-round facility, in the High Arctic;
 - Infrastructure for Arctic research and development, technology testing, and training;
 - A shoreline location for campaigns across land, sea, air, and ice;
 - Domain awareness support (deployment support, sensor systems testing, data systems, unmanned/autonomous platforms support facilities);
 - Logistical support and equipment for field ops, training, and exercises;
 - Forecasting and real-time updates on conditions.
 - Expanded communications (and research for same);
 - Space to forward deploy equipment to assist with search and rescue and emergency response incidents.








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.

Prudhoe Bay: Unique Infrastructure and Assets

Controlled airspace
46 x 775 miles north (W220)

Airspace
toward
North Pole
(W220)

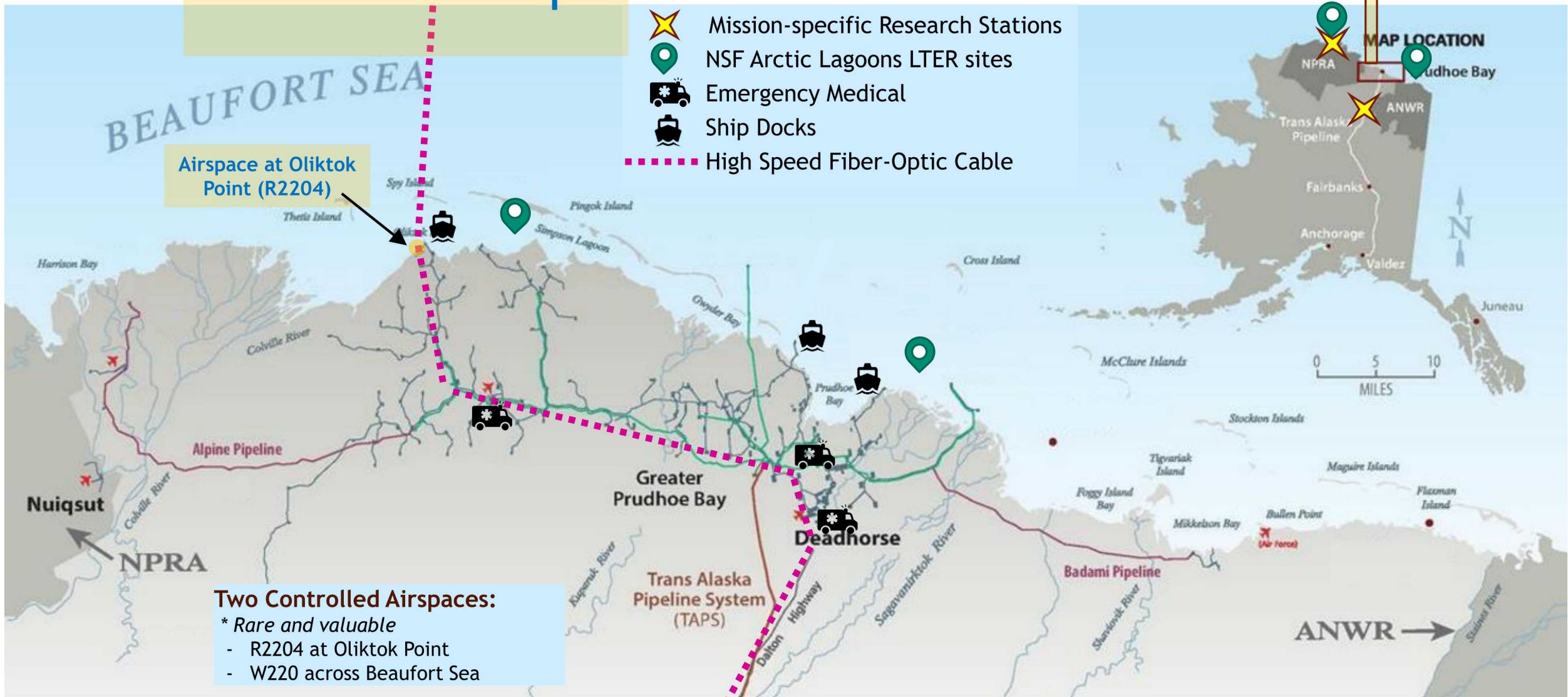
-  Mission-specific Research Stations
-  NSF Arctic Lagoons LTER sites
-  Emergency Medical
-  Ship Docks
-  High Speed Fiber-Optic Cable

Airspace at Oliktok Point (R2204)

Two Controlled Airspaces:

* Rare and valuable

- R2204 at Oliktok Point
- W220 across Beaufort Sea

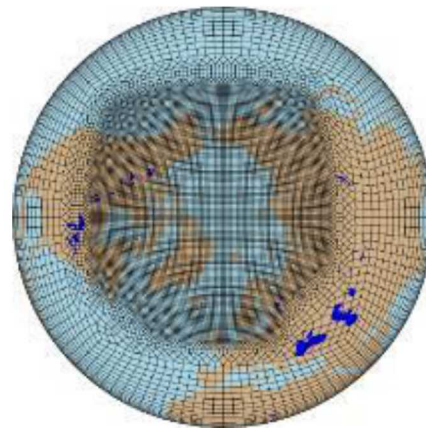
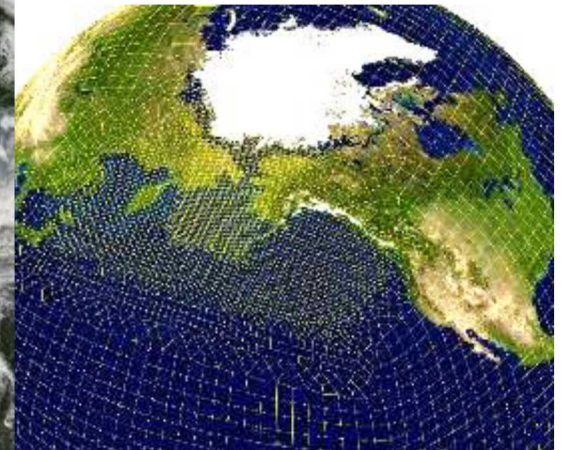
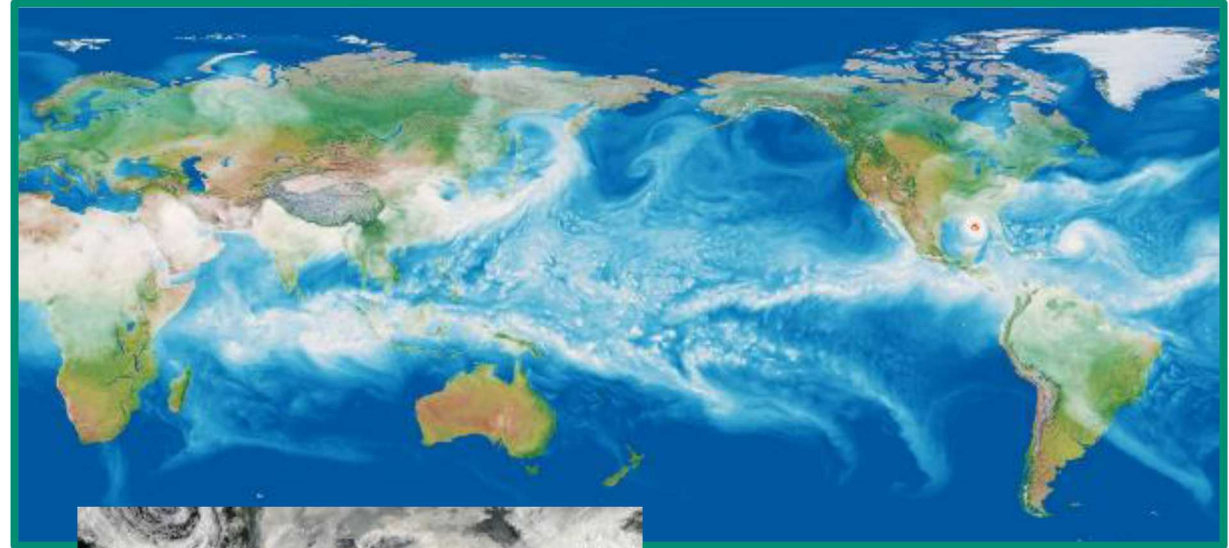


Modeling Arctic Storms and Impacts of Diminishing Sea Ice



New project: Arctic Storms and Impacts of Diminishing Sea Ice

- collaboration with other DOE Labs, led by University of Alaska Fairbanks
- Compare two models:
 - WRFR/Weather Research and Forecasting Regional Model
 - E3SM Regionally Refined Model for the Arctic
- Understand effects of domain resolution and coupling between Ice, Ocean, and Atmosphere in Extremes



Anthropogenic Aerosol-cloud Interactions Detection



Project in development...

- Key questions to explore:
 - Can we detect impacts of local emission sources?
 - How large or concentrated does the emission need to be for detection?
 - For what length of time do the emissions noticeably affect clouds?
 - Under what atmospheric conditions is it possible to detect changes in clouds?
 - Are there global dead zones in our source detection capabilities?
- Data validation for cloud-based ship tracks:
 - Where do we see an abundance of cloud-based ship tracks (MODIS)?
 - Do we have marine traffic data (AIS) that match what we see?



Images: Visible ship tracks from mobile source emission paths in the North Pacific Ocean from MODIS; and the combined impact on cloud properties as seen in invisible ship tracks in infrared mode as seen from MODIS in the North Pacific Ocean near the Aleutian islands in 2009.

Arctic Heliotropic Platform: sensing and stratospheric monitoring during high latitude summer

- The Heliotrope: A solar hot air balloon
 - Can loft sensors into the stratosphere, twice as high as commercial aircraft fly.
 - Has enabled capturing low frequency sounds that are otherwise very difficult to obtain
 - Research and security communities can benefit from these capabilities
 - 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



Thank You

