Remote Sensing/GIS, and Cold Regions Expertise:
Data and Modeling Interests, Capabilities, and Products of USACE/ERDC/CRREL

Jeanne Roningen, John Eylander, Michael Shaw

CRREL

11/13/2015

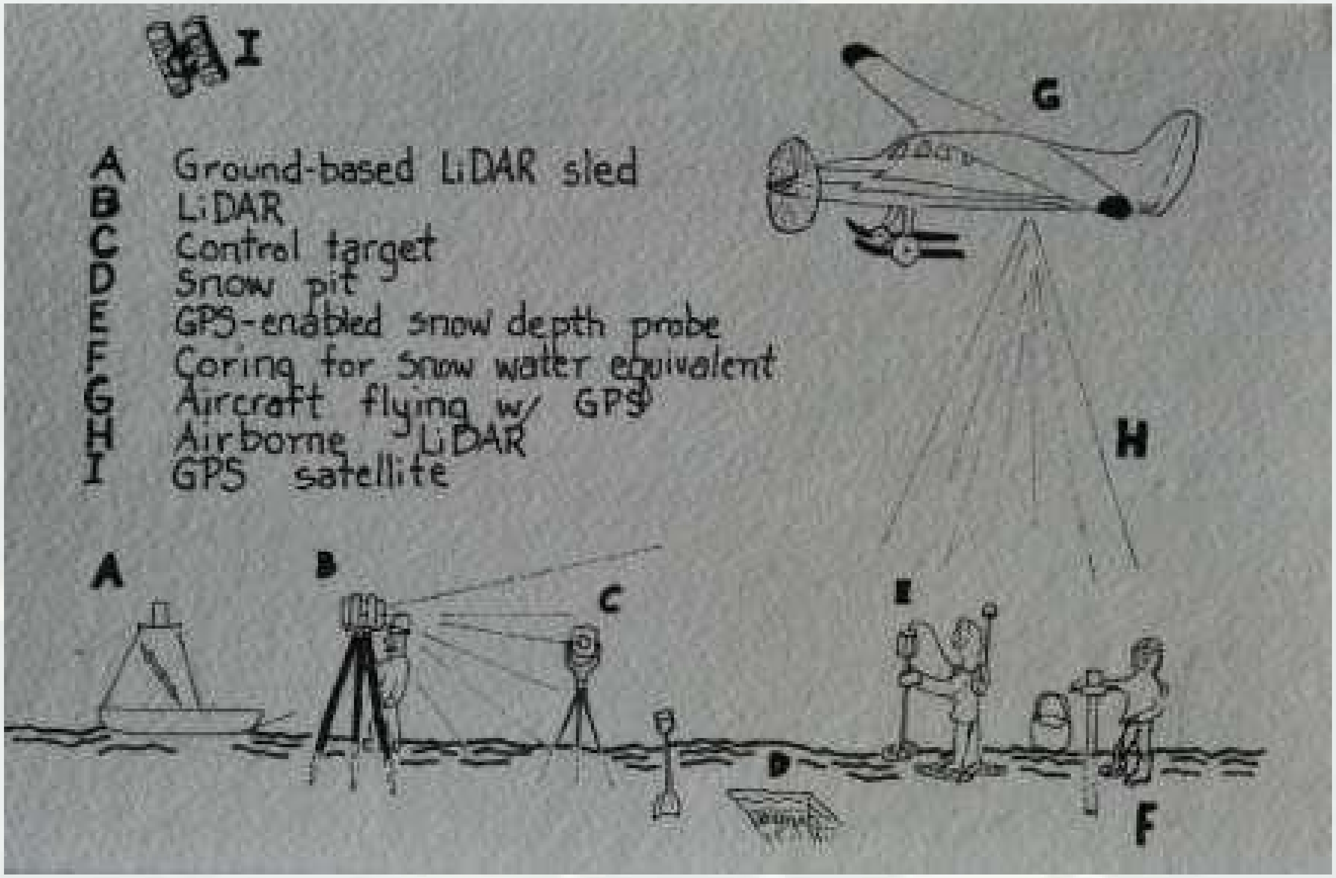
U.S.ARMY

US Army Corps of Engineers.

ERDC
Engineer Research and Development Center

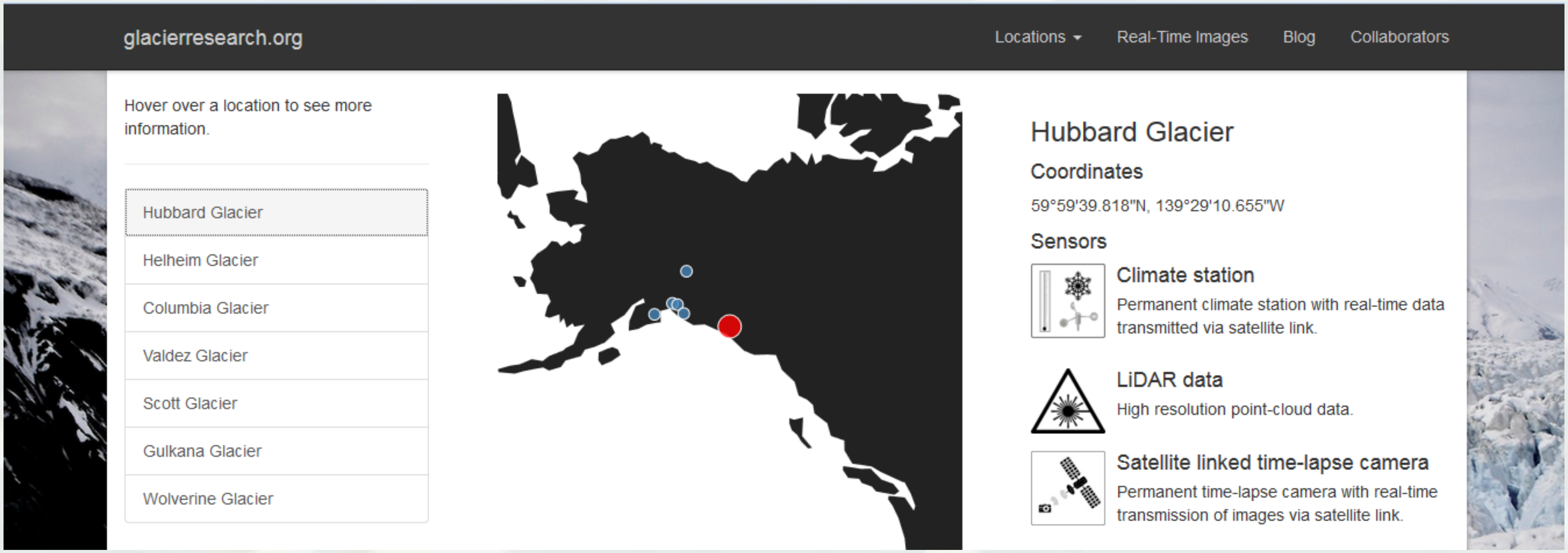
- Glaciers and LiDAR
- Sea ice
- Albedo (ice sheets, melt ponds)
- Snow and snowmelt
- Permafrost
- Coastal erosion
- Extreme environments
- Oil & gas

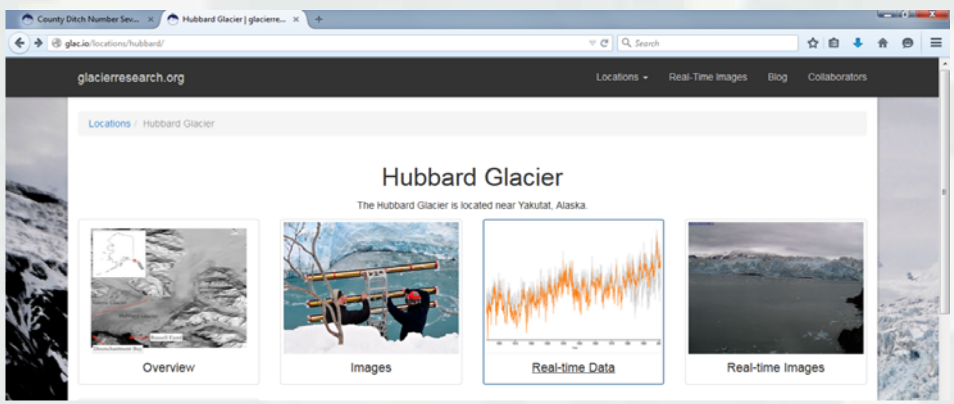
LiDAR



I
A Ground-based LiDAR sled
B LiDAR
C Control target
D Snow pit
E GPS-enabled snow depth probe
F Coring for snow water equivalent
G Aircraft flying w/ GPS
H Airborne LiDAR
I GPS satellite
G
H
A
B
C
E
D
F

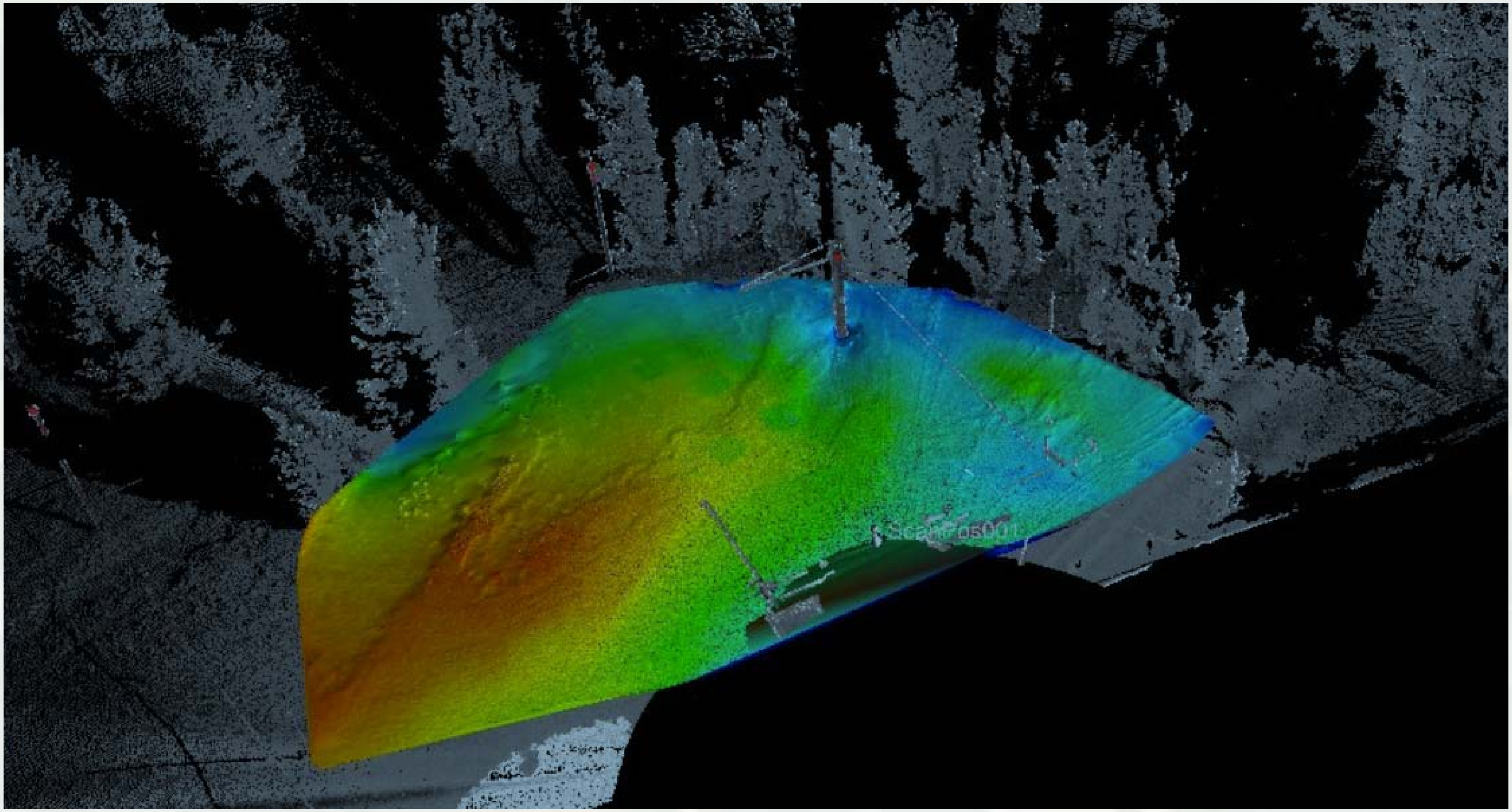
Glacier monitoring



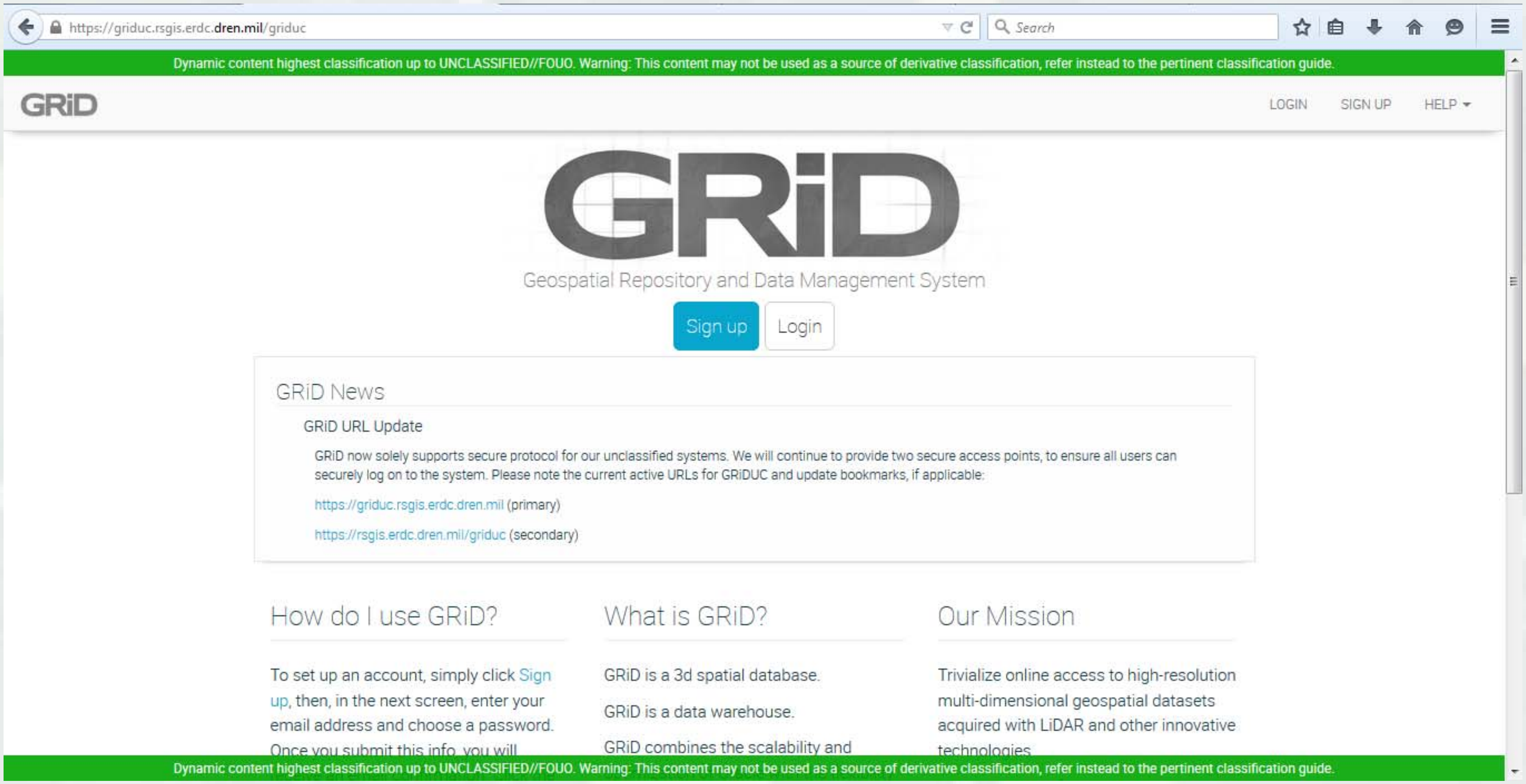


Glacier watching

Snow melt modeling

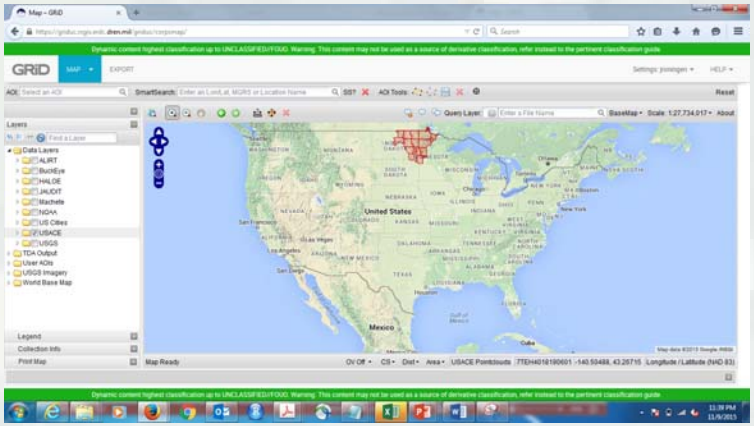


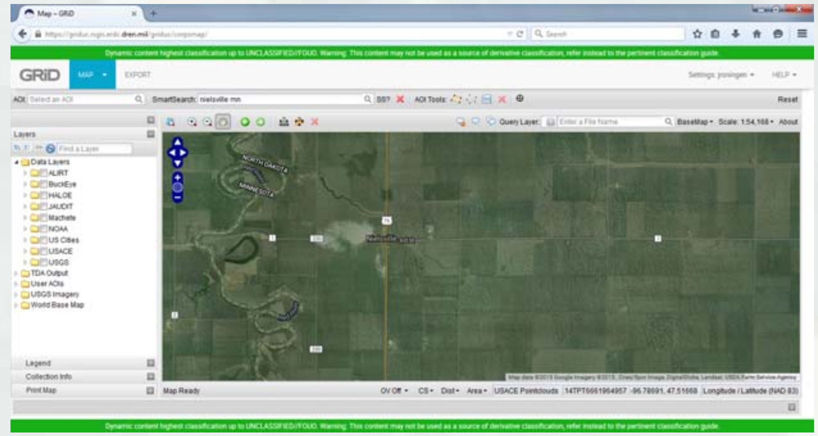
LiDAR data dissemination

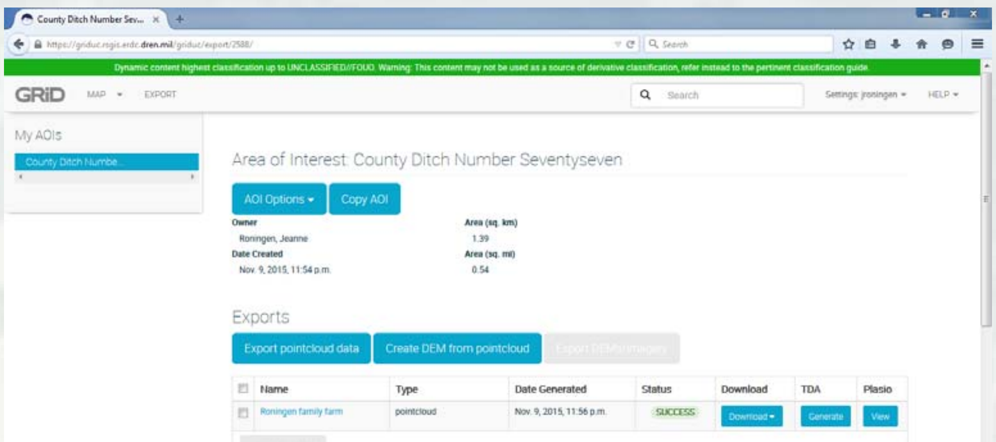


https://griduc.rsgis.erdc.dren.mil/griduc

GRiD



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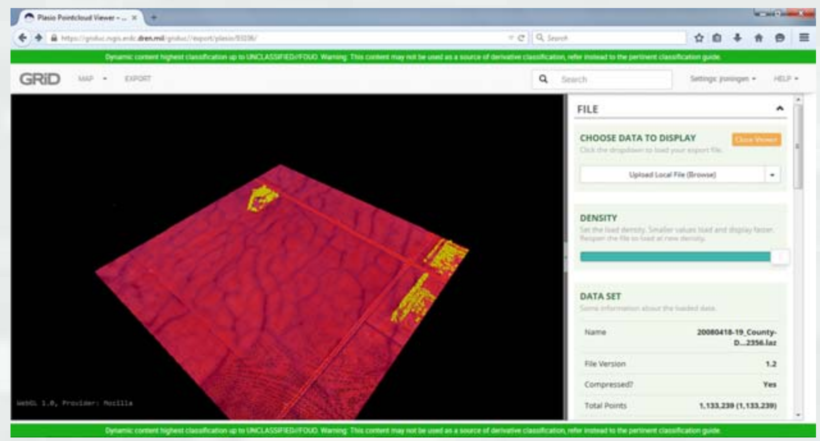
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Sea ice

US Coast Guard: Arctic Shield 2012

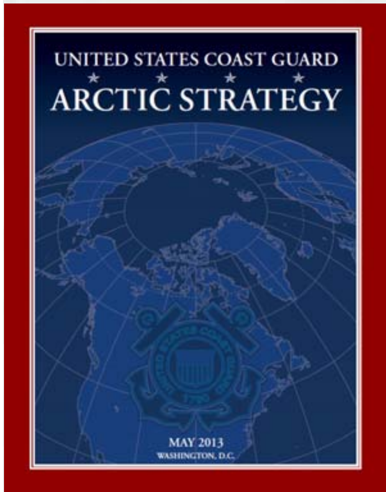
Ship traffic through the Bering Strait has nearly doubled from 2009 to 2010, reaching 430 vessels a year, but:

- Few certified ice-breakers exist
- Nearest deep-water refueling port nearly 1,000 miles away in the Aleutian Islands

The Coast Guard is proposing a gradual ramping up of operations in the Arctic, with the potential of expanded deployments in the future.

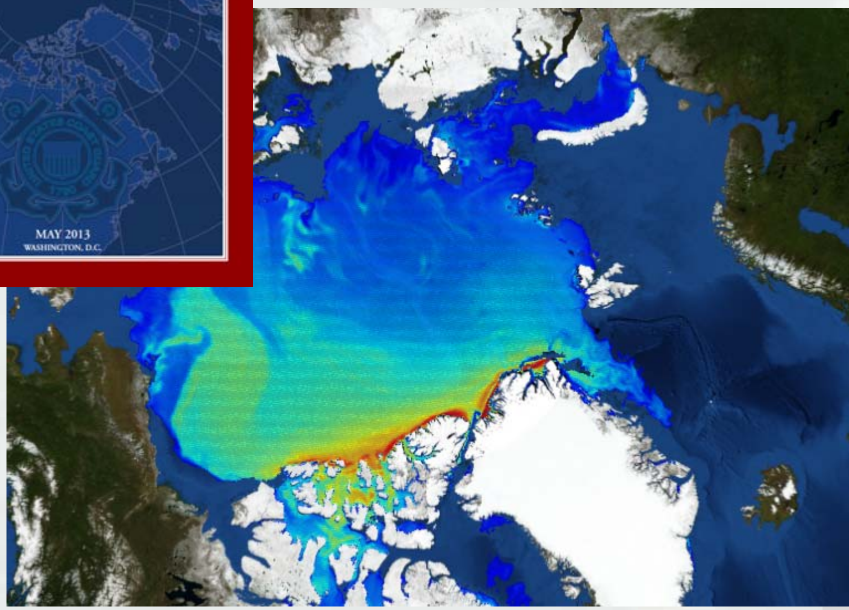
Los Angeles Times, Mar 2012

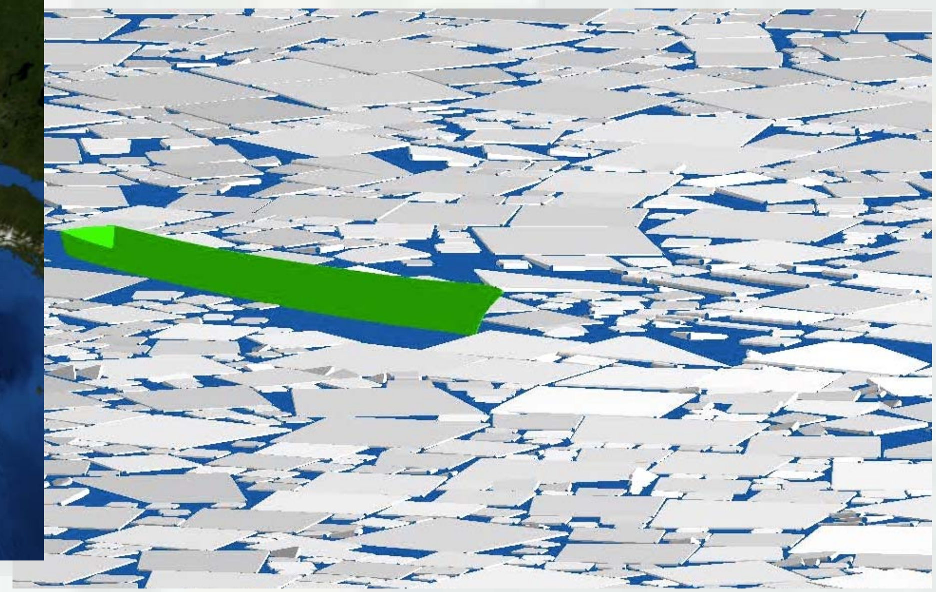
Discrete Element Sea Ice Modeling



- *Enhance awareness*
- *Achieve effective presence*

Courtesy Arnold Song, CRREL





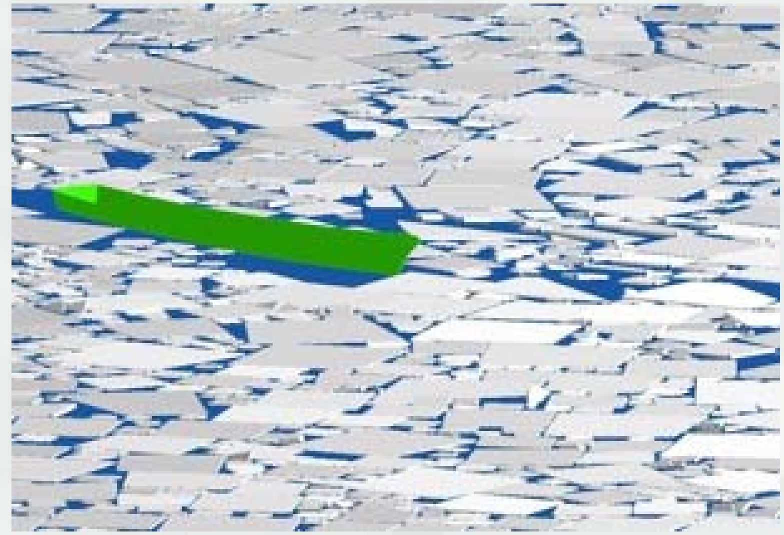
High resolution regional forecast model
- Routing
- Operations planning
- Oil spill dispersion

Ice-ship/structure interaction model
- Estimate ice loads
- Safe speeds through ice guidance
- Ice management

Ice-Ship Interactions

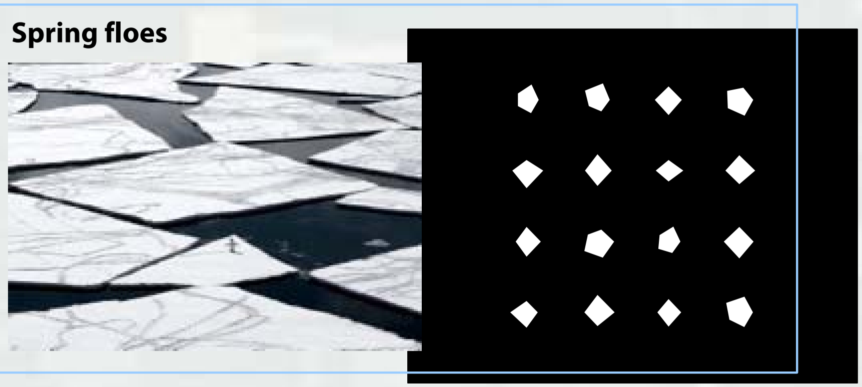
DEM model features:

- Dynamics ice-ship interaction are explicitly modeled
- Geometry and thickness of floes is explicitly defined
- Floe is also subject to stresses at the atmosphere-ice and ocean-ice interface to highlight weather and current effects on ice motion that in turn affect shipkeeping
- Able to test a variety of floe fields (rubble ice, small first year floes, large multi-year floes) giving insight into the capability of hull designs for routing and operational planning (i.e., operational seasons)
- 3-dimensional, 6-DOF buoyancy model allows for realistic ice motion including floe underturning and rafting

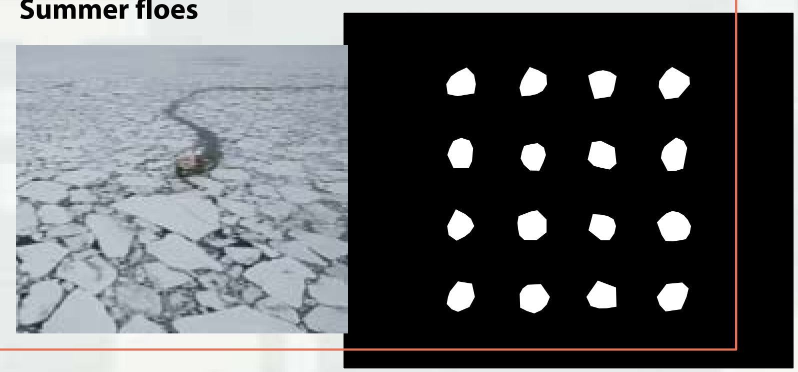


Detail view of DTMB 5415 hull traveling through ice field

Spring floes

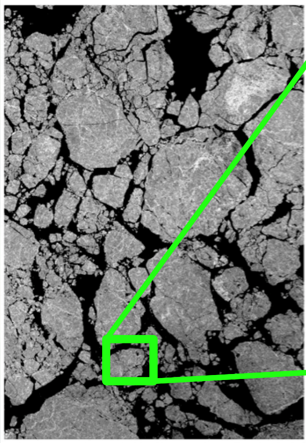


Summer floes



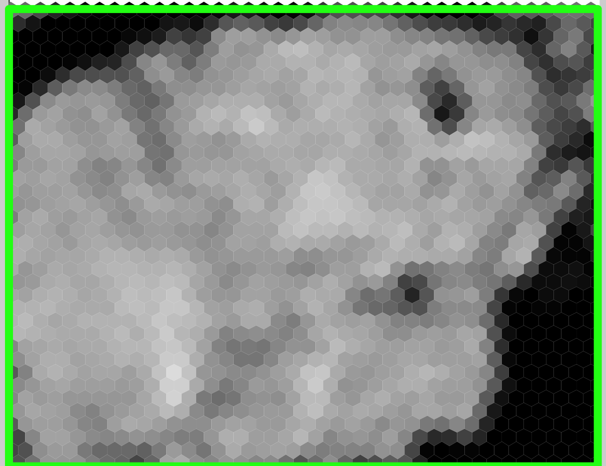
Courtesy Arnold Song, CRREL

Original SAR image:
30 km x 43 km region



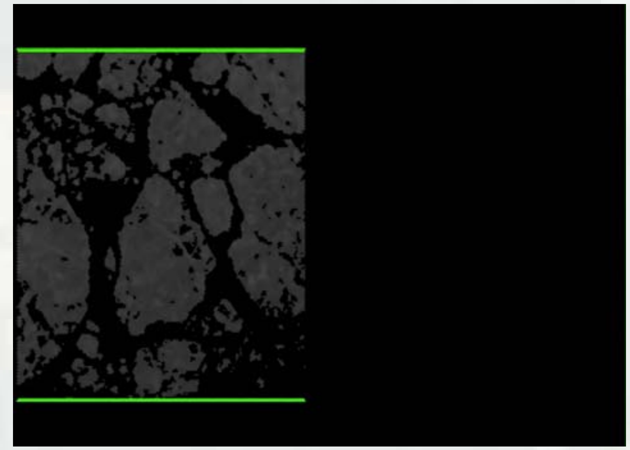
2.5 m/px

Remote sensing assimilation



- Ice / water classification
- Ice thickness
- Linear features
    - Ridges
    - Cracks

Preliminary result

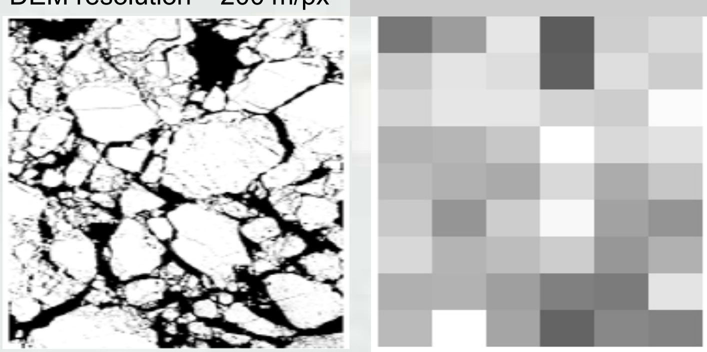


Domain size: 14.4 km x 17.6 km
Particle size: 200 m

- Uniform wind field (10 m/s, L to R)
- Fixed top and bottom boundaries (in green)

Model comparison

Areal ice concentratio
DEM resolution – 200 m/px

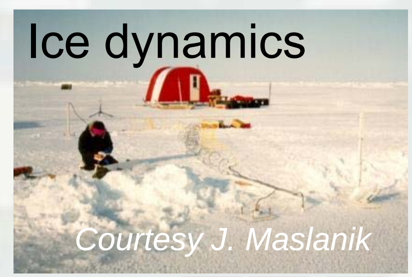


ement method (DEM) sea ice model

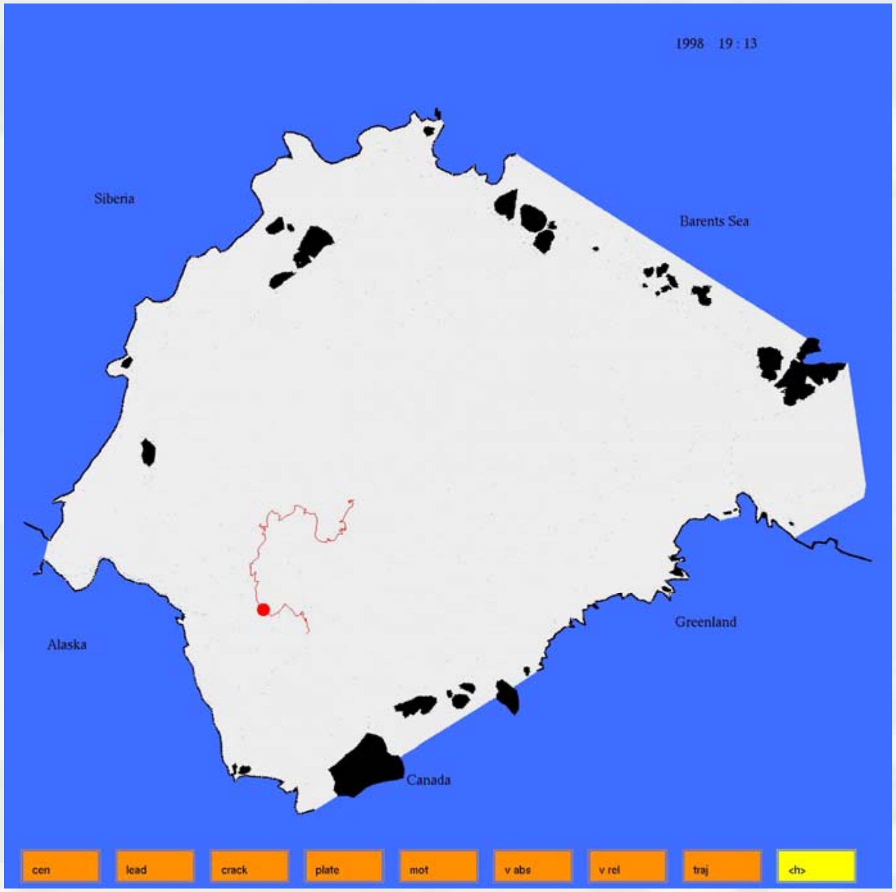
- High fidelity, high resolution sea ice forecast model
- Discrete description of ice field and Lagrangian floe trajectories
- Well-suited for local and regional scale sea ice forecasting (trajectory, concentration, estimate of breakup timing, etc.)
- Realistic floe geometries derived directly from remote sensing imagery
    - Assimilation of high resolution remote sensing imagery (e.g., SAR) for model initialization and nudging
- Integration of weather forecast data for model forcing
- Straightforward parallelization for deployment onto HPC systems to achieve operationally relevant run times

Courtesy Arnold Song, CRREL

Sea ice: In situ



Arctic sea ice simulation



Courtesy Arnold Song, CRREL

Comparison with SHEBA camp drift path:
Jan 19 – Feb 26, 1998 (38 days)

- **Particle size:** 7 km
- **Particle number:** ~150,000
- **Surface wind data:** POLES

SHEBA camp drift path

Simulated drift path

Model inputs

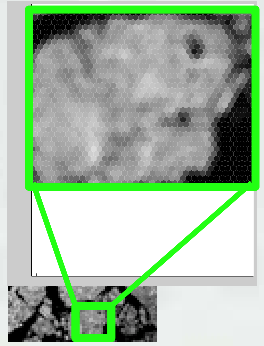
Courtesy Arnold Song, CRREL

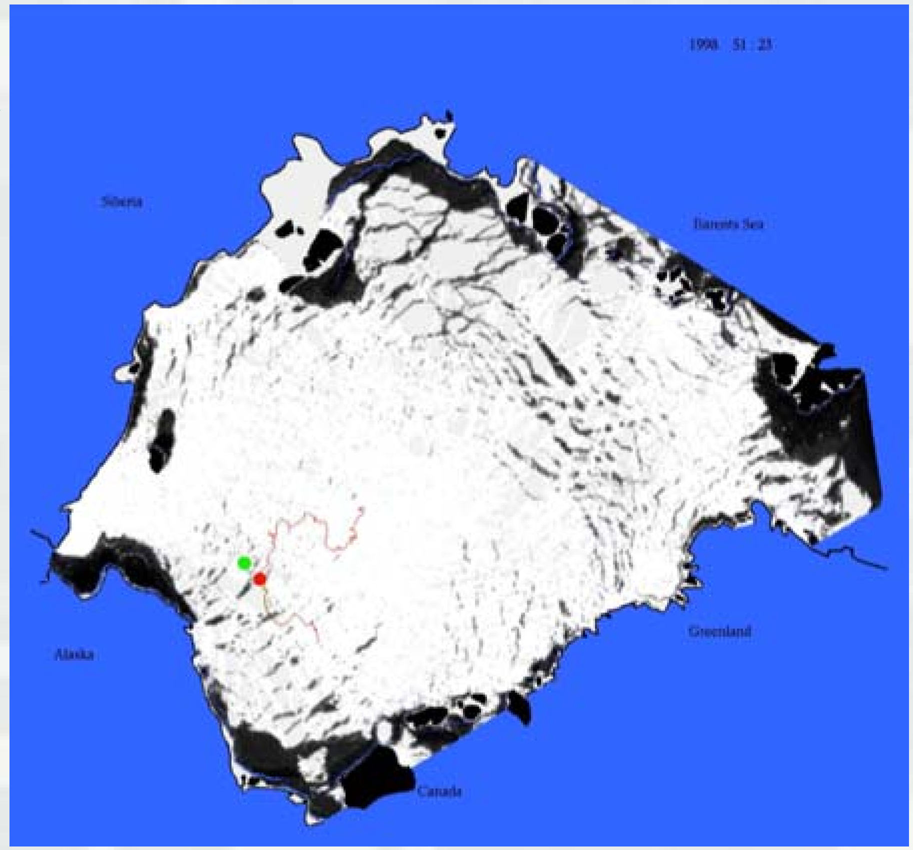
Remote sensing

SAR

Visible

IR





Derived sea ice extent

MASIE

Weather forecast

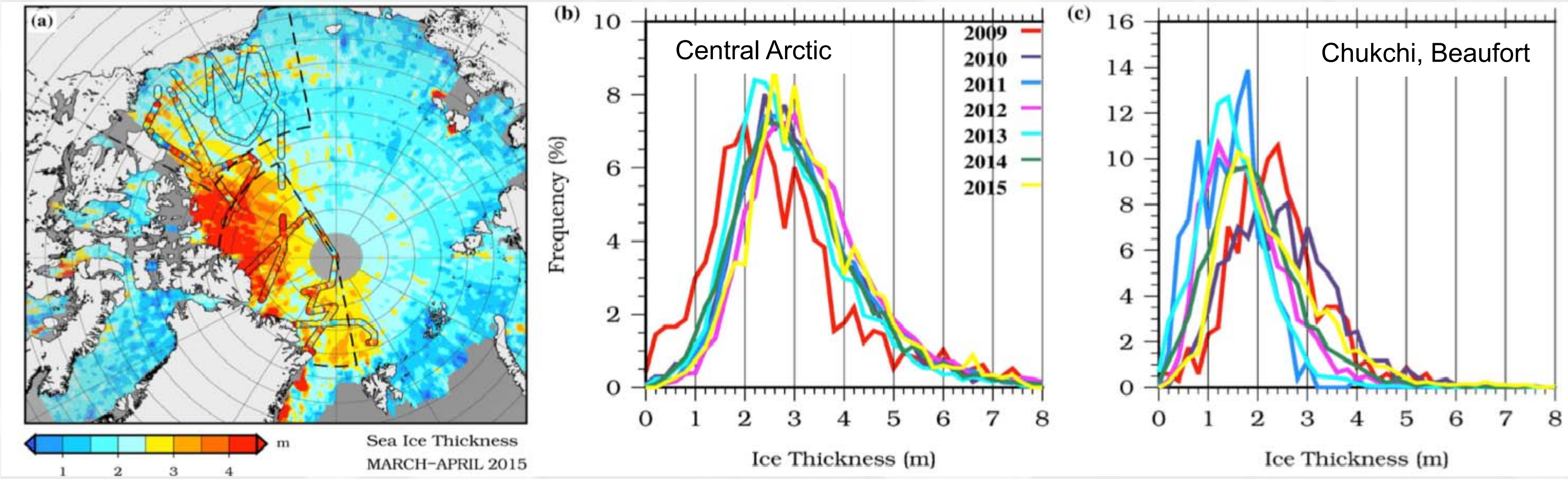
GFS

NAVGEM

WRF

Sea ice: Remote sensing

NASA Operation IceBridge: bridging the gap between IceSat and IceSat 2



- Arctic sea ice surveys made in March/April, 2009 – 2015
  - – Cross-basin gradients are apparent
  - – Older ice has more snow
  - – Extensive first year ice in Beaufort and Chukchi Seas
- Quick-look product: Snow depth and ice thickness estimates within 1 month
  - – Initiated in 2012; used to support seasonal ice forecasts

Courtesy J. Richter-Menge, CRREL

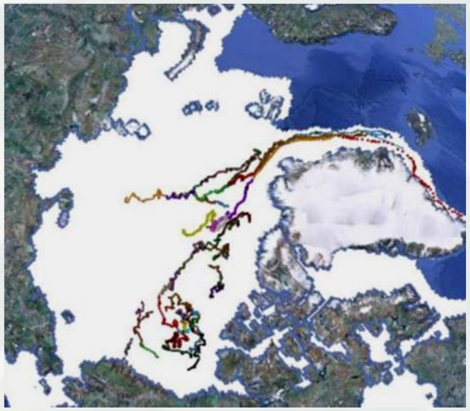
Sea ice: Autonomous buoys

Courtesy J. Richter-Menge, CRREL

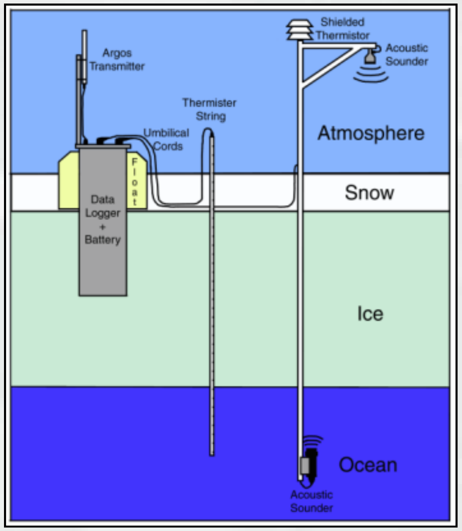
Sea ice: Ice mass balance buoys

Measures

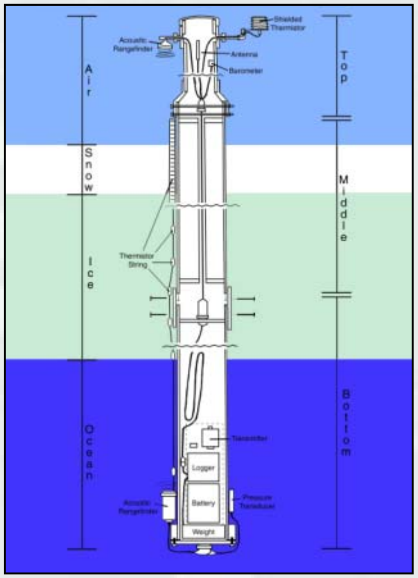
- Position
- Barometric pressure
- Start of freezeup
- Start of melt
- Ice growth
- Surface melt
- Bottom melt
- Temperature profile
- Air, snow, ice, ocean
- For up to 3 years



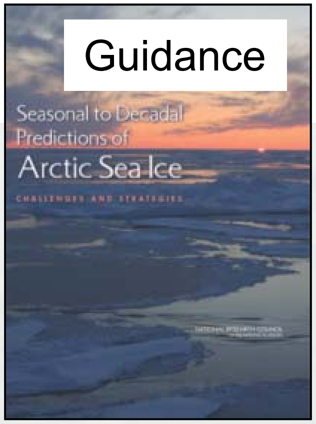
Multi-year Ice

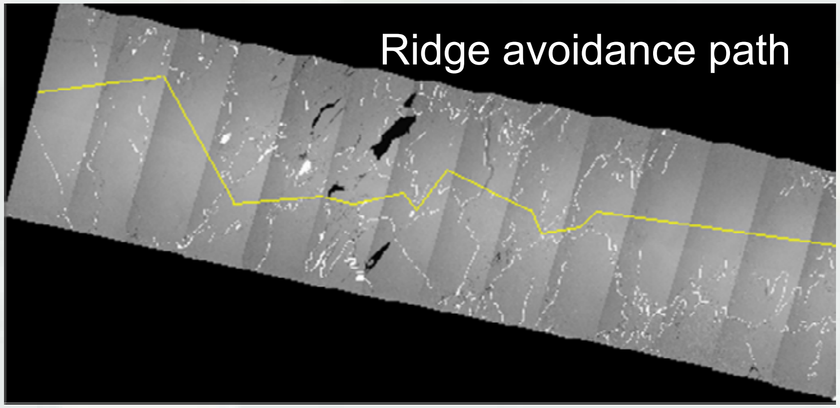


Seasonal Ice



Sea ice: Operations





Courtesy Sally Shoop, CRREL

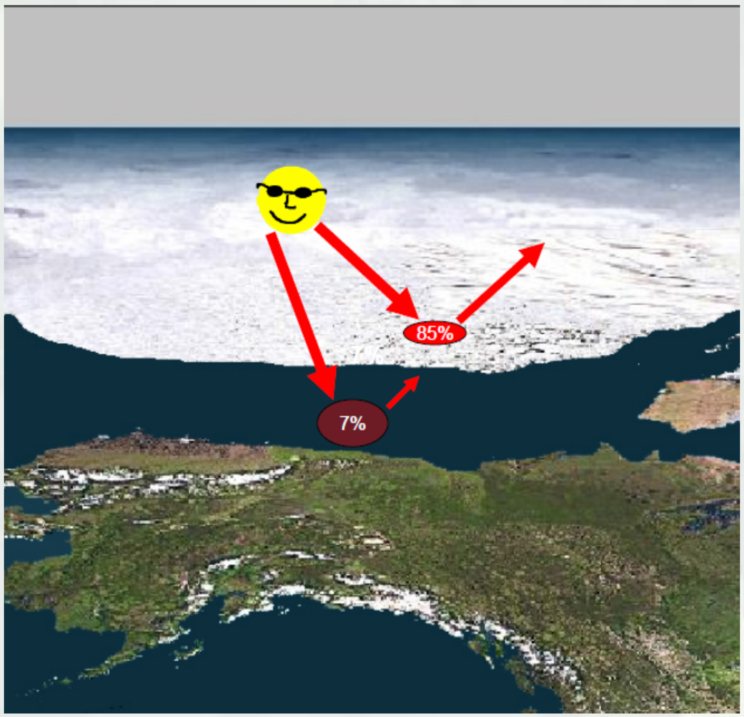
Sea ice – operations and logistics

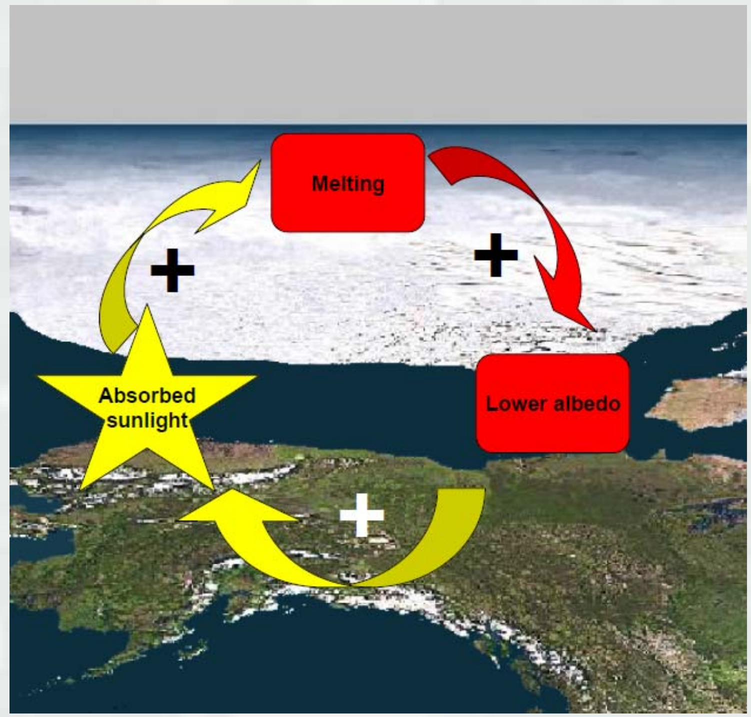
NU ’14 Skiway Exercise Objectives

The objectives of the Skiway Exercise during NU ’14 were:

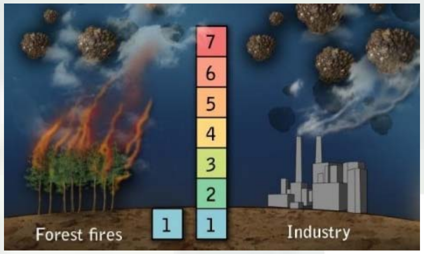
- Demonstrate the capabilities of the LC-130
- Develop a training relationship with Canada at JTFN
- Provide transport support to Canadian arctic ground forces
- Exercise the mobile maintenance recovery team
- Teach skiway construction techniques and procedures
- Exercise sea-ice landings & combat offload
- Train on Arctic runway reconnaissance techniques
- Document lessons learned and technology/research needs
- Readiness for future Arctic military support missions

Albedo and Arctic Amplification

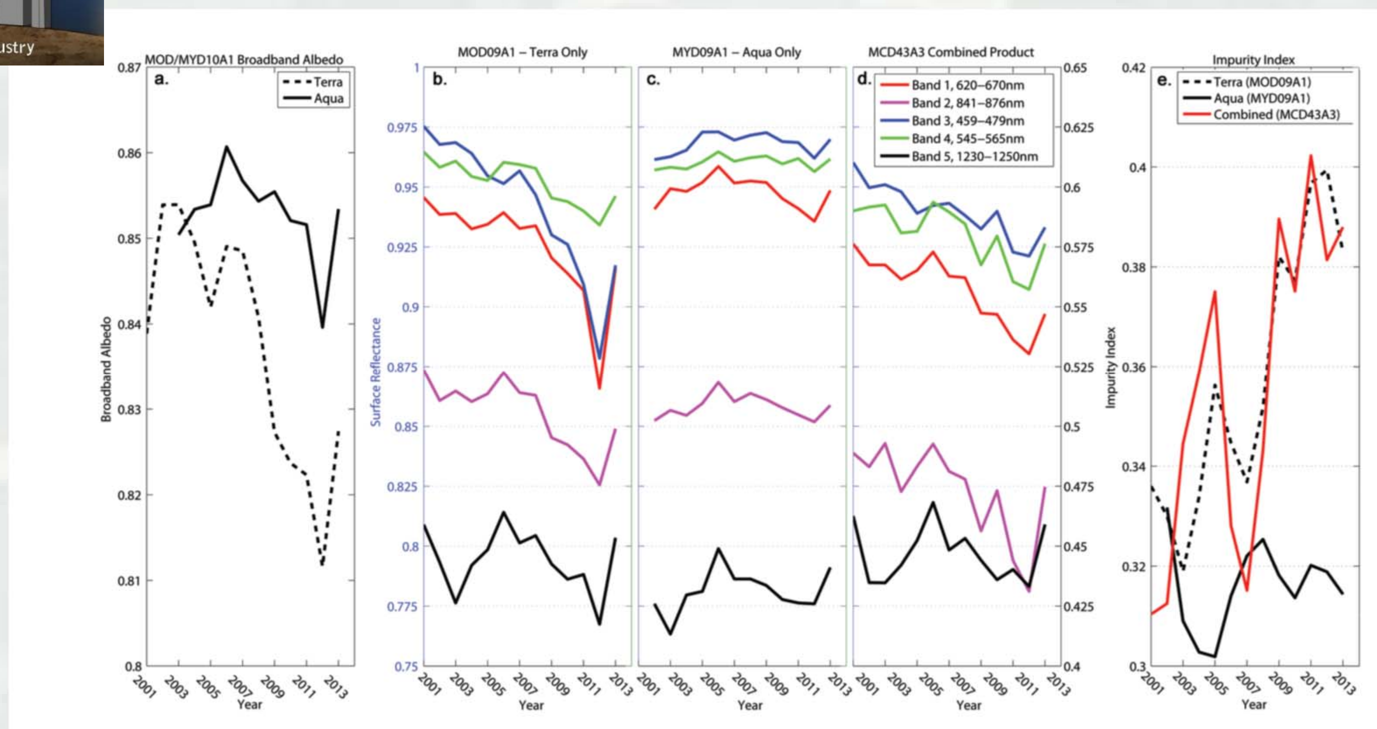




Black carbon in Greenland

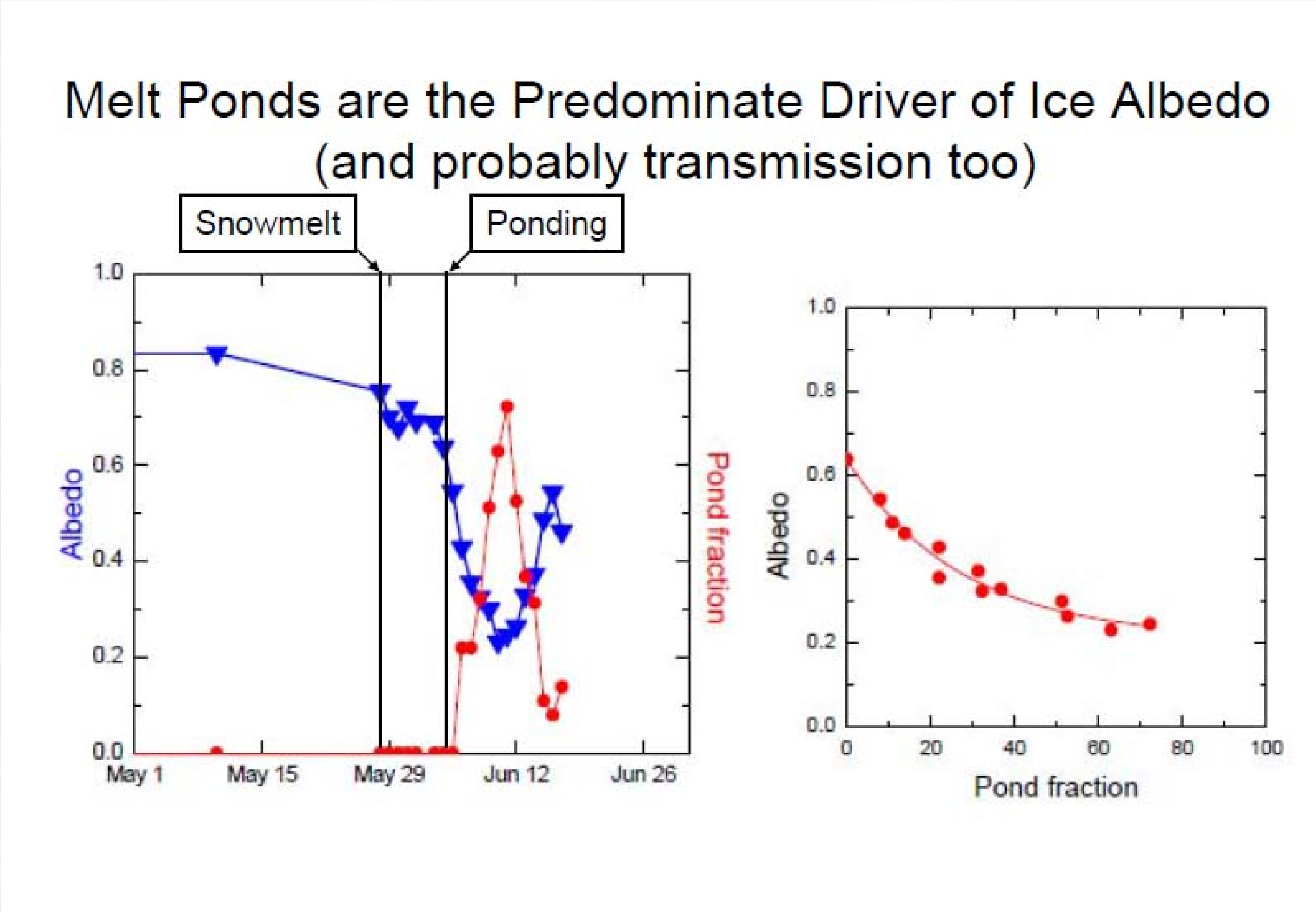


Polashenski et al (2015). Neither dust nor black carbon causing apparent albedo decline in Greenland's dry snow zone; implications for MODIS C5 surface reflectance, Geophysical Research Letters, doi 10.1002/2015GL065912



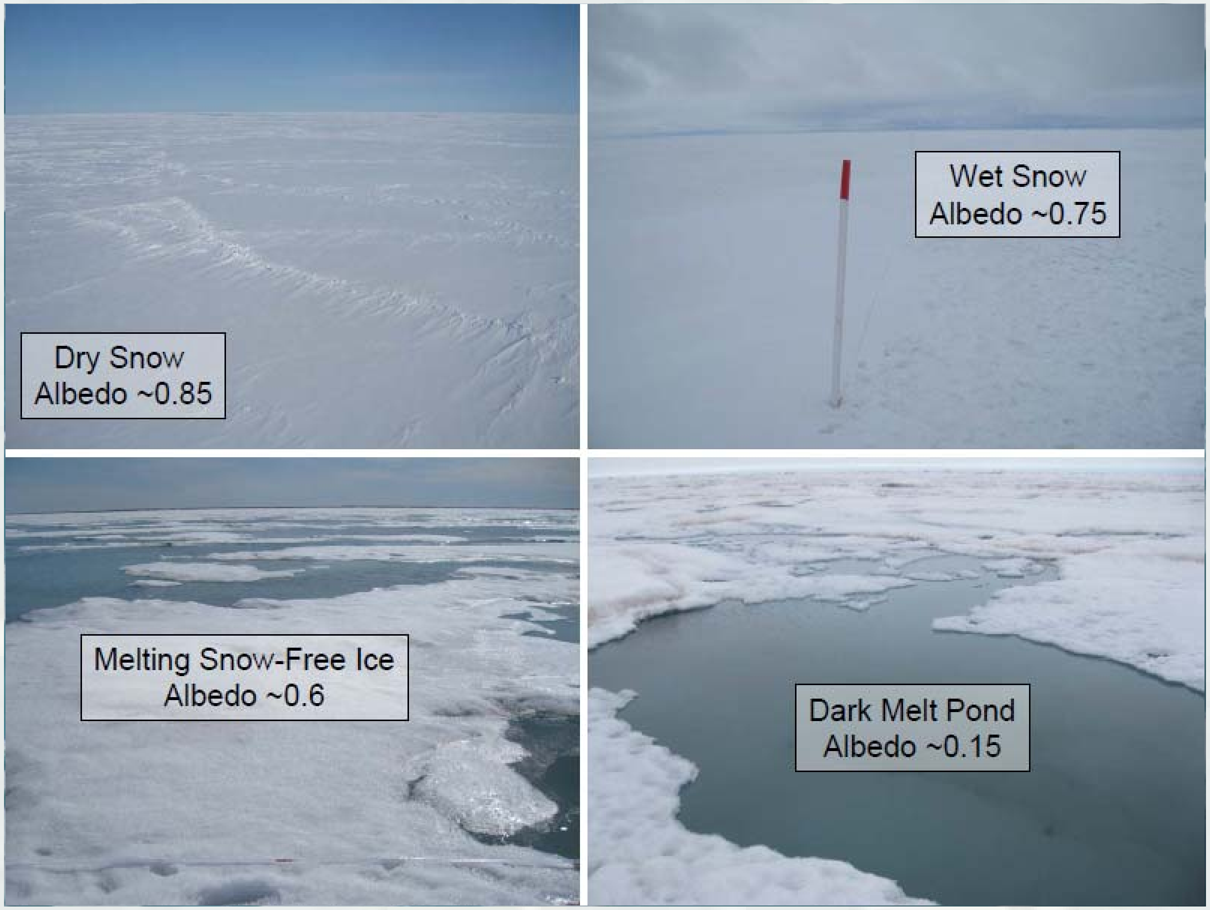
Courtesy Chris Polashenski, CRREL

Melt Ponds on Arctic Sea Ice



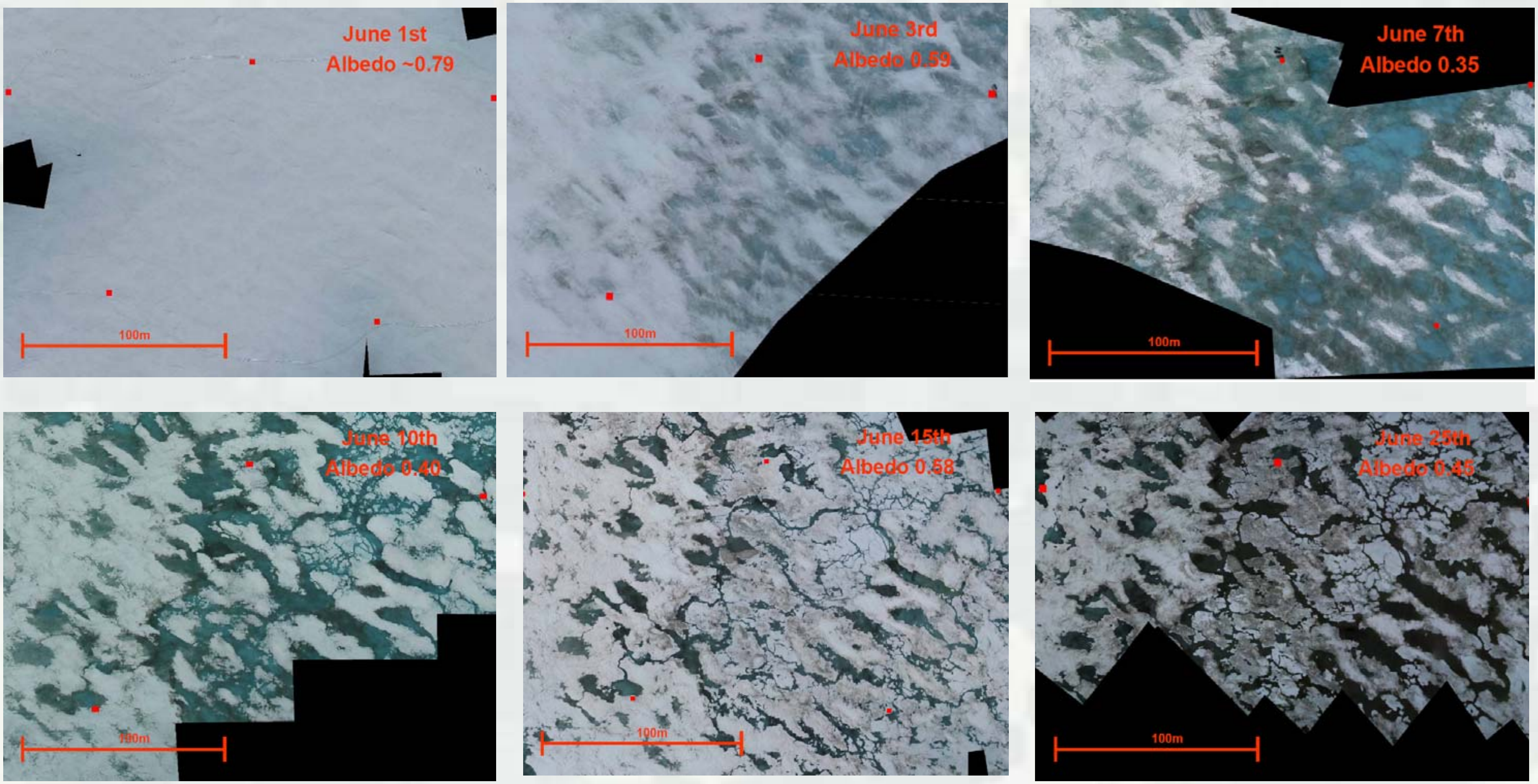
Courtesy Chris Polashenski, CRREL

Sea Ice Albedos



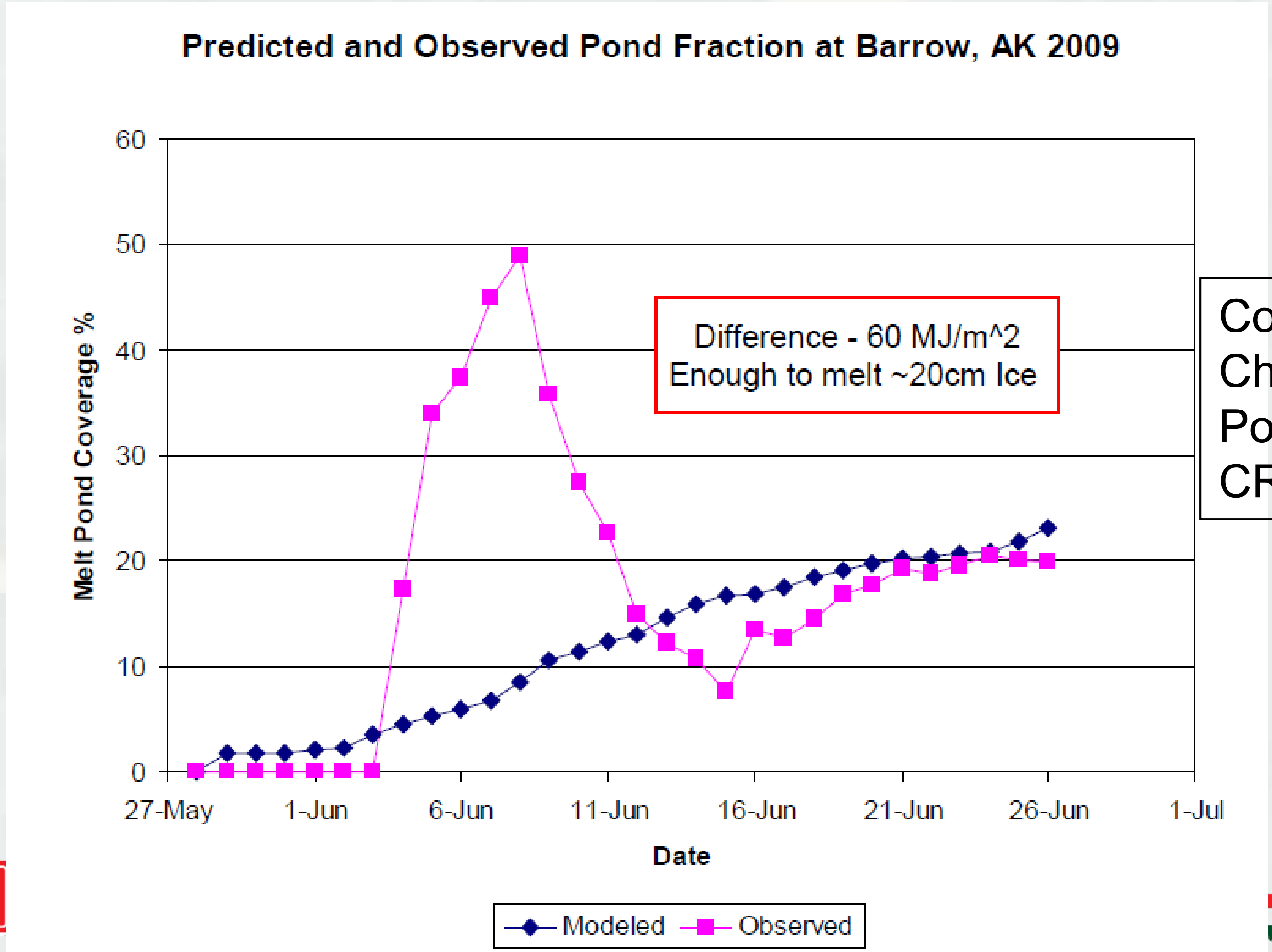
Courtesy Chris Polashenski, CRREL

Summer Evolution of Melt Ponds



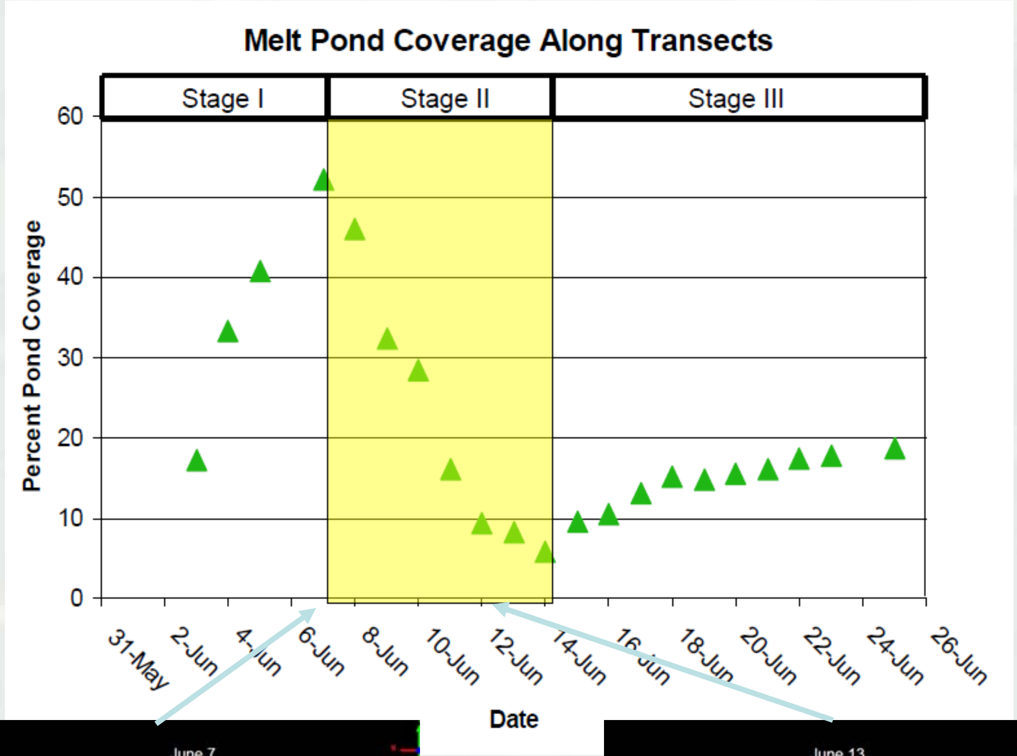
Courtesy Chris Polashenski, CRREL

Predicted vs. observed melt pond fraction

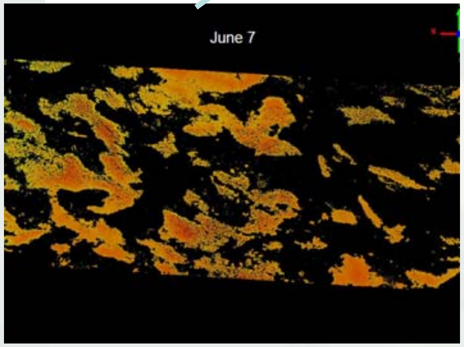


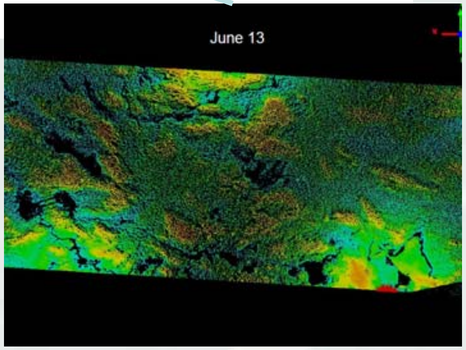
Courtesy Chris Polashenski, CRREL

Melt pond water balance



Courtesy Chris Polasheski, CRREL





Research for operations: Snow

CRREL objectives:

- Improve spatial resolution for global applications
- Inform applications of mobility, hydrology, flood hazard, and drought
- **R&D** and **transition** to operational products with DoD and academic partners

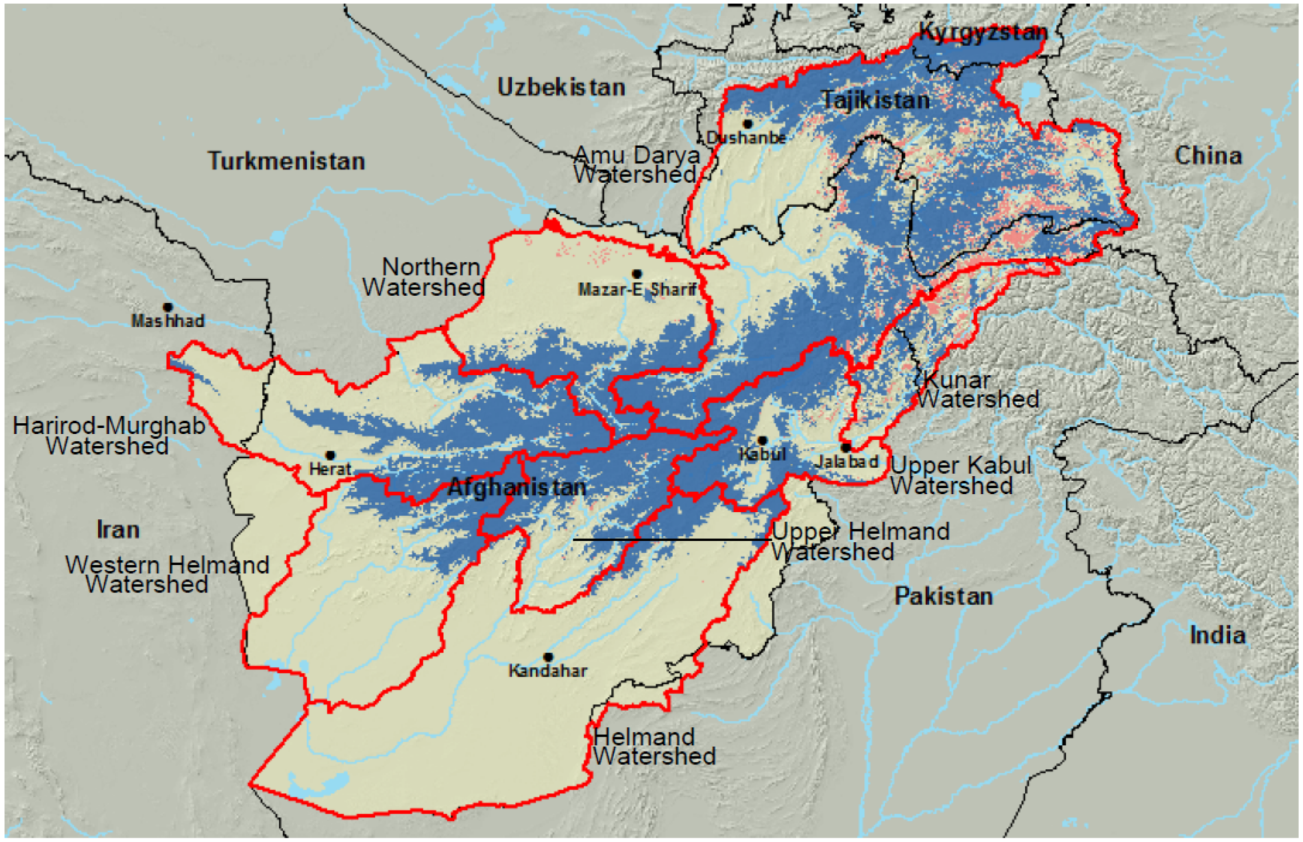
Snow properties

from microstructure to watershed scales

through remote sensing, modeling, and data assimilation

- Snow-covered area (SCA)
- Bulk properties
  - depth
  - density
  - snow water equivalent (SWE)
- Snow microstructure
  - Snow wetness
  - diurnal amplitude variation (DAV)
- Snow modeling
- Data assimilation

Afghanistan Snow Covered Area



Country Boundary

Watershed Boundary

SCA

Clouds/Missing Data

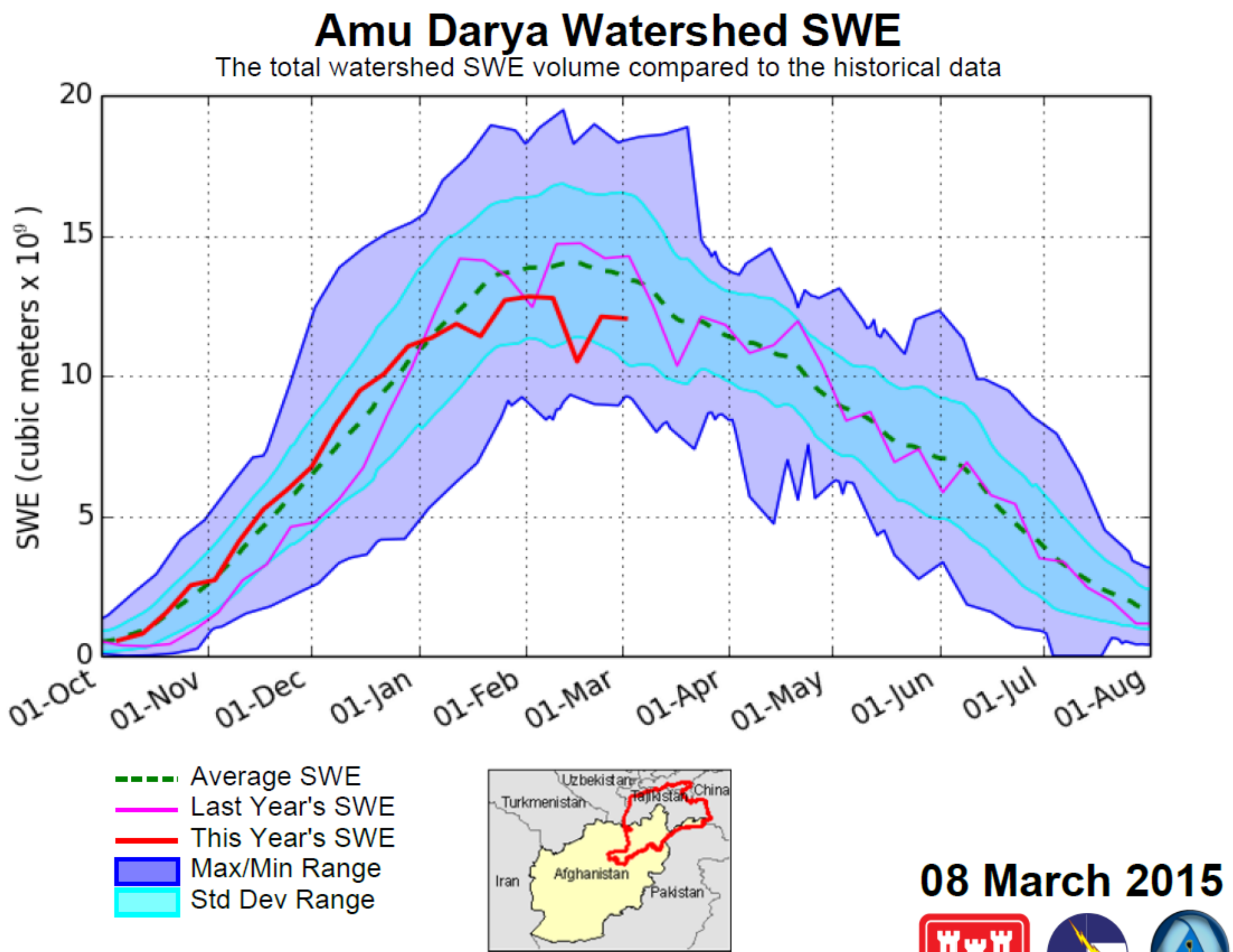
08 March 2015

Unclassified

Approved for Public Release; Distribution Unlimited

BUILDING STRONG®

Innovative solutions for a safer, better world



Unclassified

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Operational Snow Assessments

Operational Support:
For the past 8 winter seasons, provided bi-weekly assessments of the snowpack to U.S. Military personnel in Iraq and Afghanistan.

Clients

- Marine Corps Intelligence Agency
- American Embassy in Iraq
- Iraq Ministry of Water
- U.S. Central Command
- US Army - 82nd Airborne Division
- US Navy
- US Air Force, AFWA
- Canadian Forces
- British Forces
- NATO
- USGS
- USDA
- USAID
- Dept of Disaster Response
- German Embassy
- Academic Institutions
- National Geospatial-Intelligence Age
- And others

Mission Relevance:

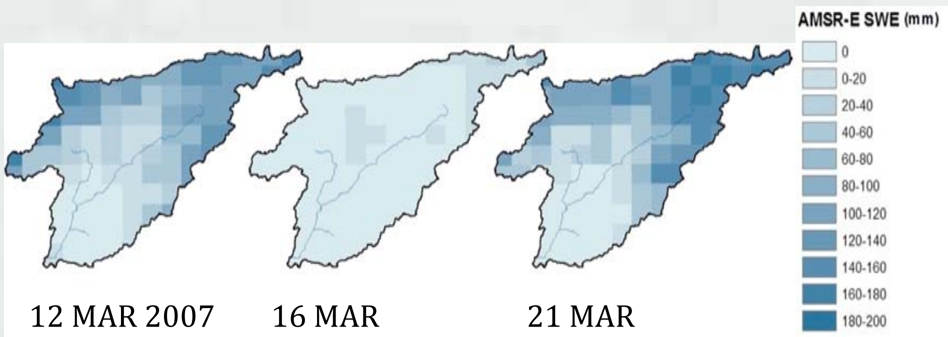
- Operation planning
- Supplies/Transport
- Flood forecasting
- Water supply

32

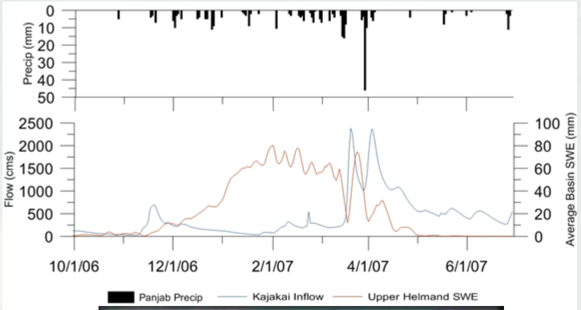
Snowmelt runoff estimates

Objective: *To use the strong passive microwave response to wet snow to improve snowmelt runoff estimates.*

Motivation Snowmelt runoff can cause widespread, damaging floods. Observations of snowpack state are almost non-existent, and models can miss the timing or extent of melting, particularly in remote regions.



Microwave SWE signal before, during, and after a rain on snow event in the Upper Helmand watershed, Afghanistan (from Vuyovich, 2010).



Flooding in Helmand Basin, 2007

Courtesy Carrie Vuyovich, CRREL

Approach to domains of interest

- Select study areas of operational/tactical interest combined with analogues that exist in well-instrumented basins

Operational/tactical domain	Well-instrumented analogue
North/South Korea	New England, USA
Afghanistan	Colorado, USA

- Build modeling capabilities in both tactical and well-instrumented domains at spatially relevant scales
- Explore sensitivity of different ancillary data sources to both models and satellite retrievals
  - Land cover type and distribution, forest density and canopy structure, elevation distribution (slope and aspect), snow grain size distribution, etc.
- Investigation of scale (both temporal and spatial) dependencies

Courtesy Carrie Vuyovich, CRREL

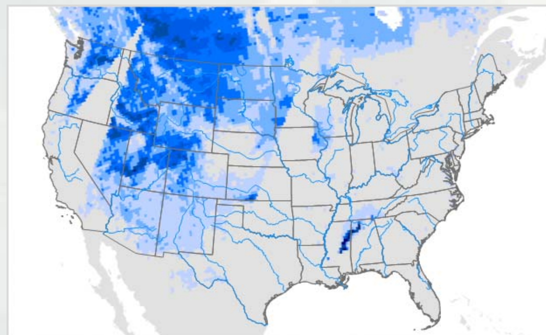
SnowPEx: Remote sensing

Comparison of passive microwave SWE estimates from 4 global satellite-based products to SNODAS daily gridded SWE products in the U.S. on a watershed scale.

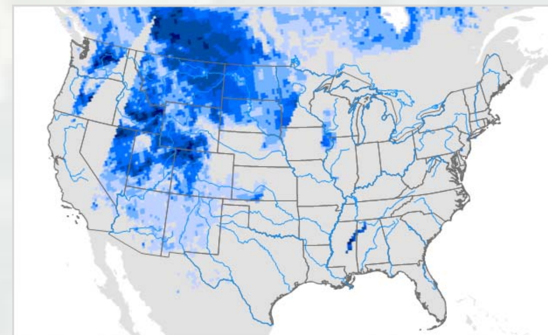
Analysis specifically focused on:

- Regional differences
- Effects of vegetation, deep snow
- Relative magnitude
- Timing

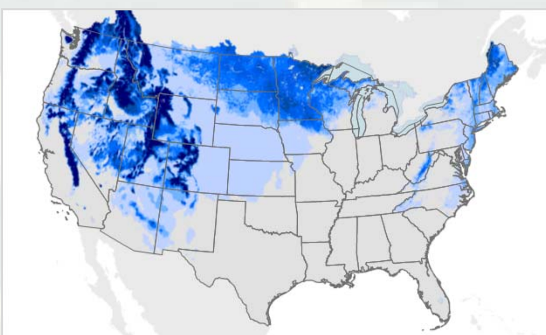
AMSR-E STANDARD



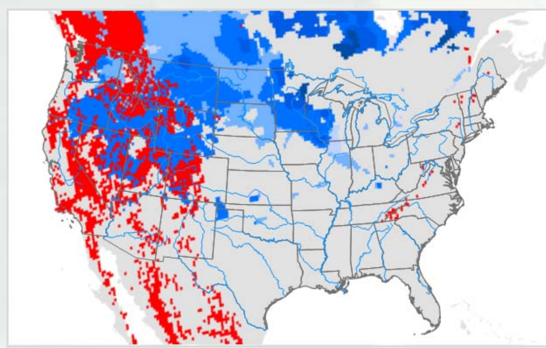
AMSR-E PROTOTYPE



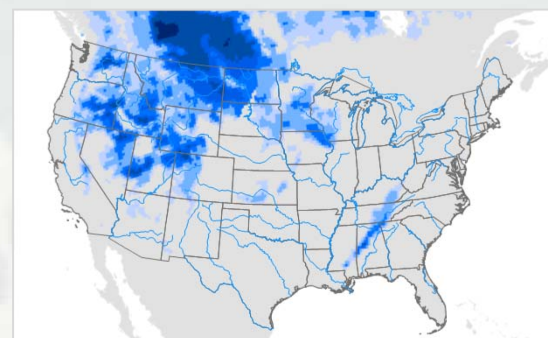
SNODAS



GLOBSNOW



SSM/I



01 JAN 2011 SWE (mm)

Courtesy Carrie Vuyovich, CRREL

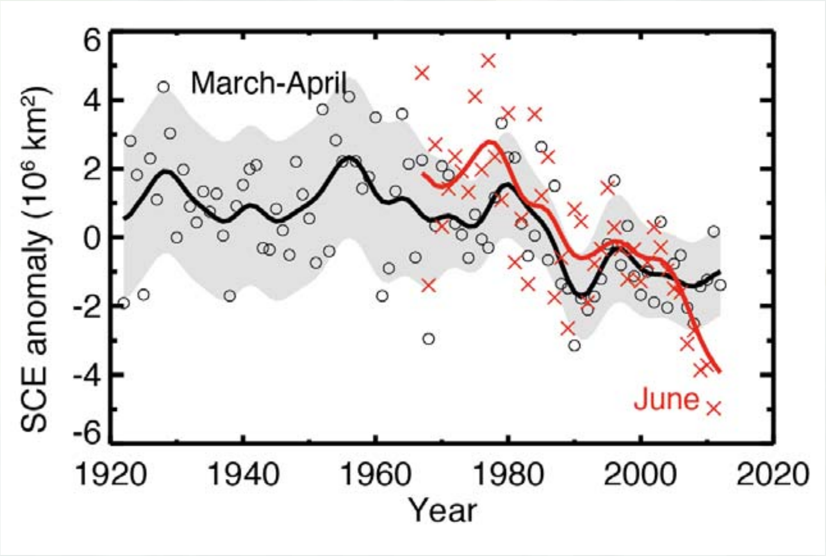
کابل بی زر باشد و بی برف نه

"Kabul can be without gold but not without snow"
Afghan proverb

Spare slides…

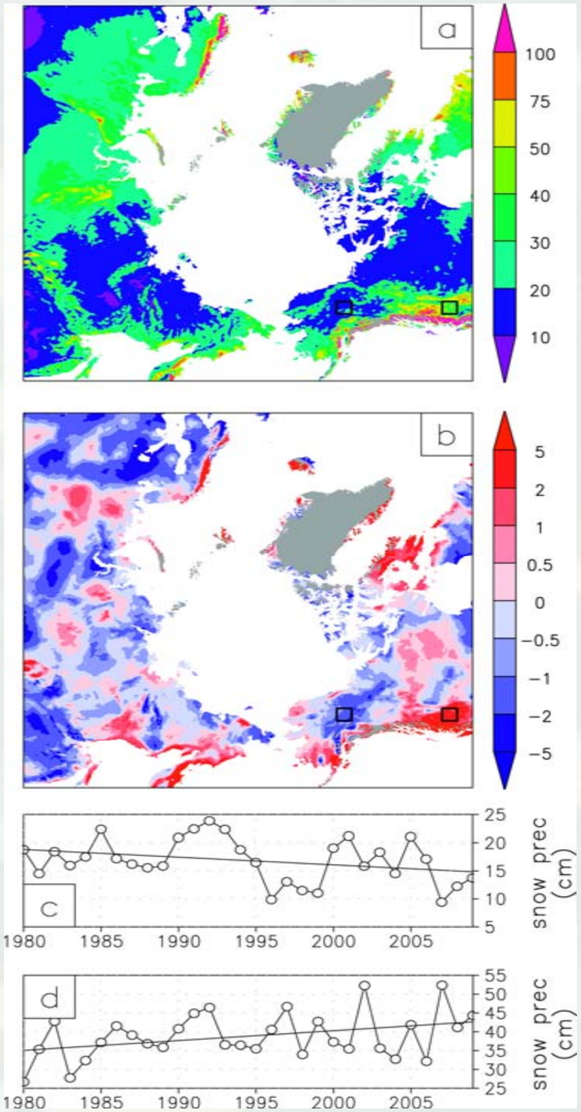
Snow Loads

Snow Story



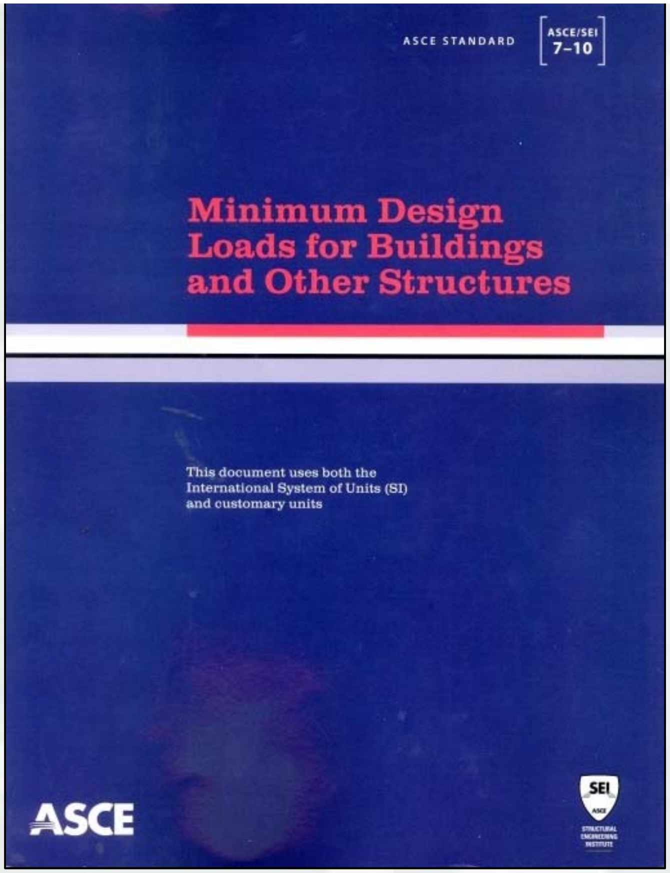
IPCC, 2013; Brown and Robinson 2011

- Decreased Snow Cover
- Decreasing and Increasing SWE



Liston and Hiemstra (2011)

Courtesy Chris Hiemstra, CRREL



ASCE Standard 7

Ground snow loads for a 50-yr mean recurrence interval (MRI)

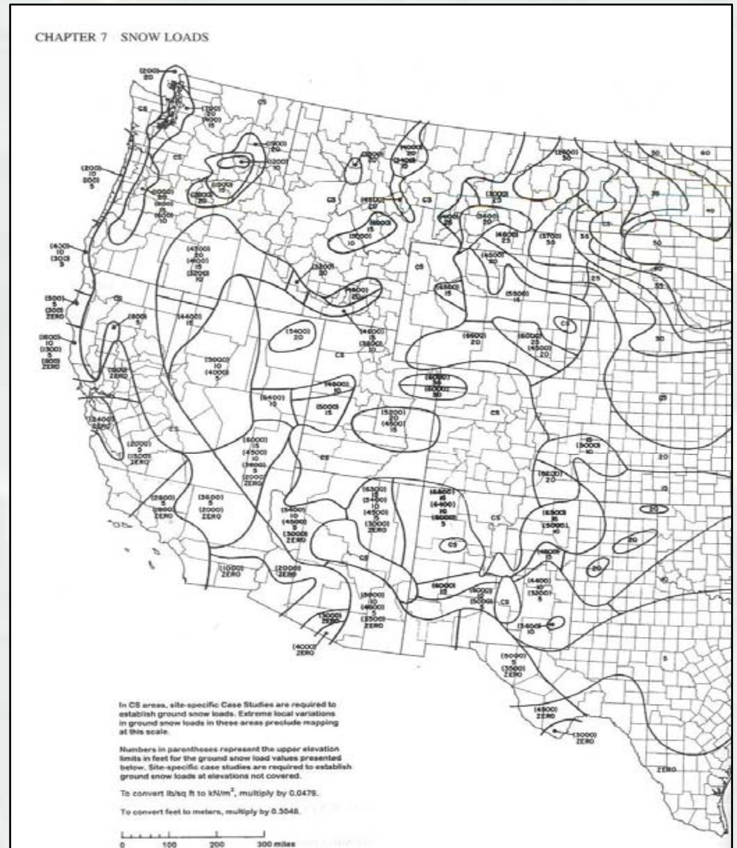


FIGURE 7-1 Ground Snow Loads, p_g, for the United States (Lb/Ft²).

Table 7-1 Ground Snow Loads, p_g, for Alaskan Locations

Location	p_g lb/ft²	p_g kN/m²	Location	p_g lb/ft²	p_g kN/m²	Location	p_g lb/ft²	p_g kN/m²
Adak	30	1.4	Galena	60	2.9	Petersburg	150	7.2
Anchorage	50	2.4	Gulkana	70	3.4	St. Paul	40	1.9
Angoon	70	3.4	Homer	40	1.9	Seward	50	2.4
Barrow	25	1.2	Juneau	60	2.9	Shemya	25	1.2
Barter	35	1.7	Kenai	70	3.4	Sitka	50	2.4
Bethel	40	1.9	Kodiak	30	1.4	Talkeetna	120	5.8
Big Delta	50	2.4	Kotzebue	60	2.9	Unalakleet	50	2.4
Cold Bay	25	1.2	McGrath	70	3.4	Valdez	160	7.7
Cordova	100	4.8	Nenana	80	3.8	Whittier	300	14.4
Fairbanks	60	2.9	Nome	70	3.4	Wrangell	60	2.9
Fort Yukon	60	2.9	Palmer	50	2.4	Yakutat	150	7.2

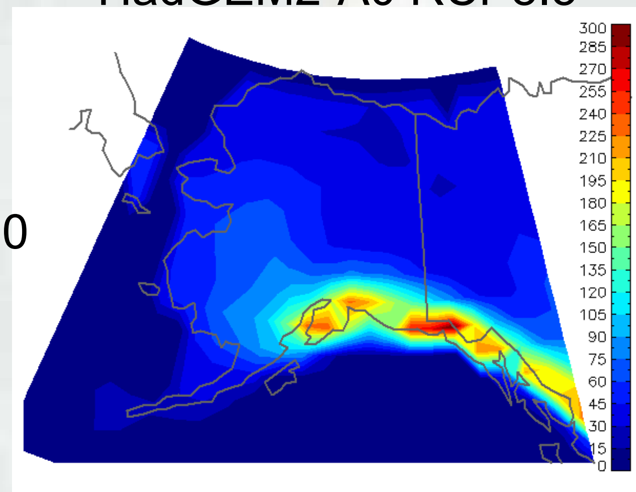
Courtesy Kathy Jones, CRREL

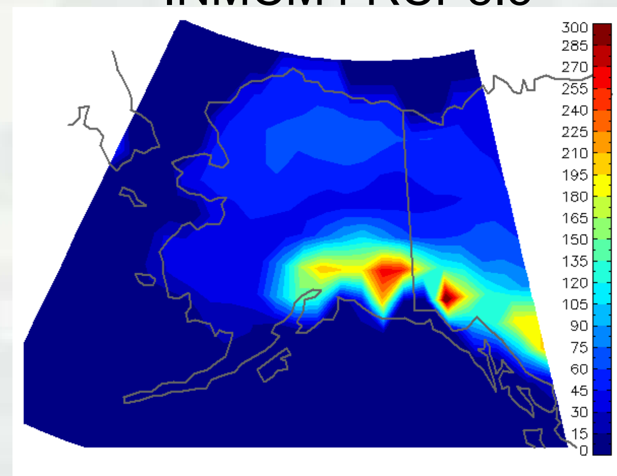
Change in CMIP5 30-yr snow loads (lb/ft^2)

HadGEM2-A0 RCP8.5

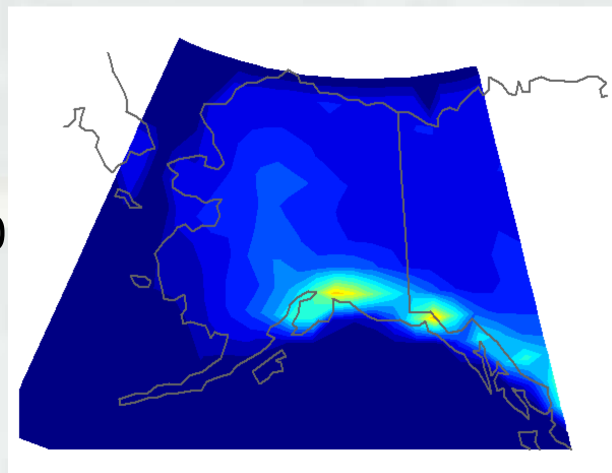
INMCM4 RCP8.5

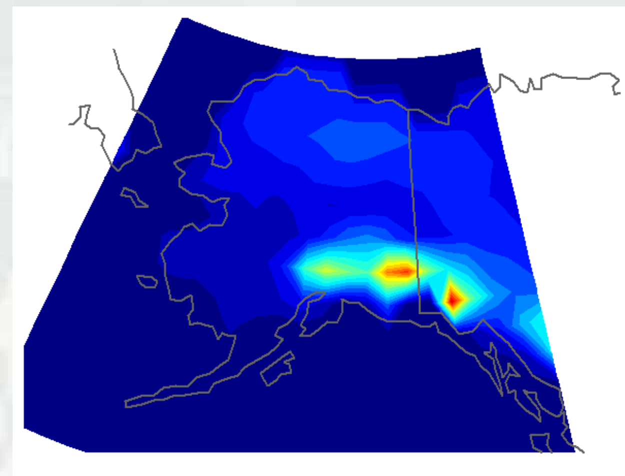
2007-2040





2067-2100





Courtesy Kathy Jones, CRREL

CRREL Permafrost Tunnel

Thawing permafrost

CRREL Archive

CRREL Archive

bakerinstitutealaska.org

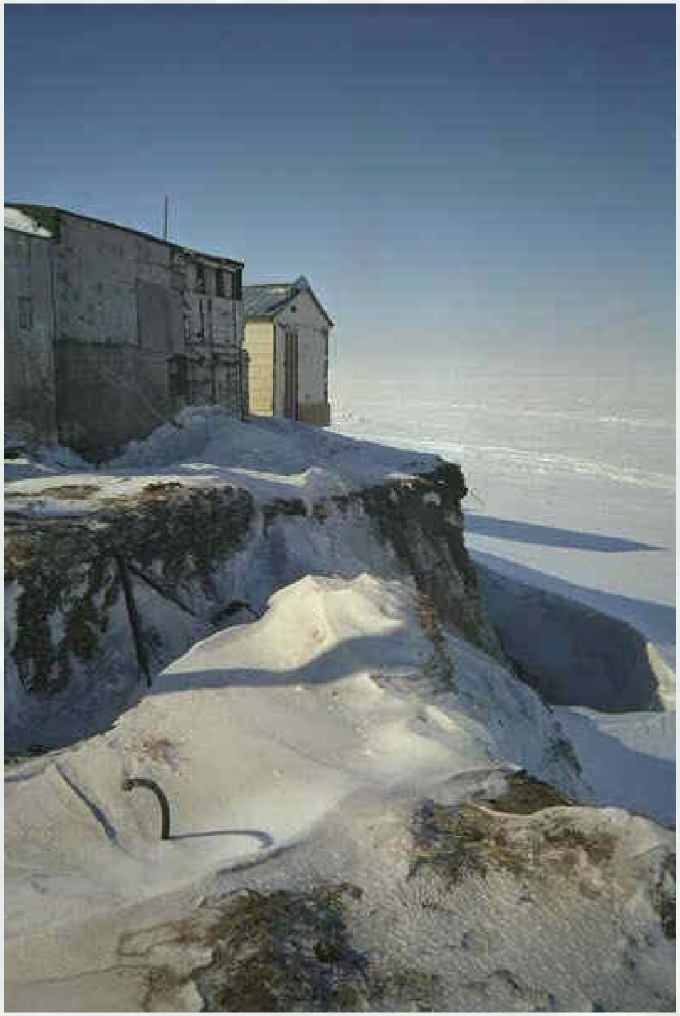
nsidc.org

43

CRREL Permafrost Initiatives

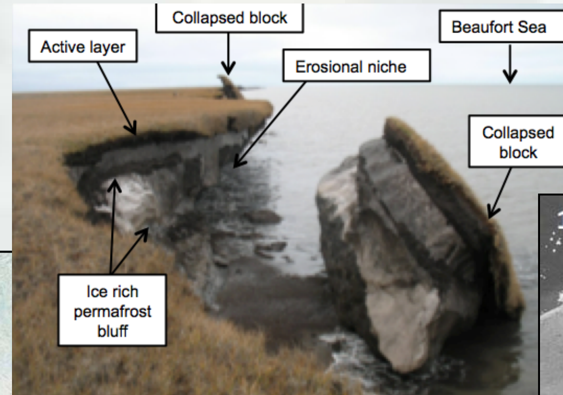
- Integrating technologies for delineating permafrost and ground state conditions
- Use of ground, air, and space-based platforms to delineate permafrost geomorphology
  - ► Boreholes, subsurface geophysics, multispectral, LiDAR, radar, etc. to map vegetation\ecosystem and surface subsidence
- Determine whether variety of measurements and methods can be synthesized into detection of patterns indicating permafrost conditions

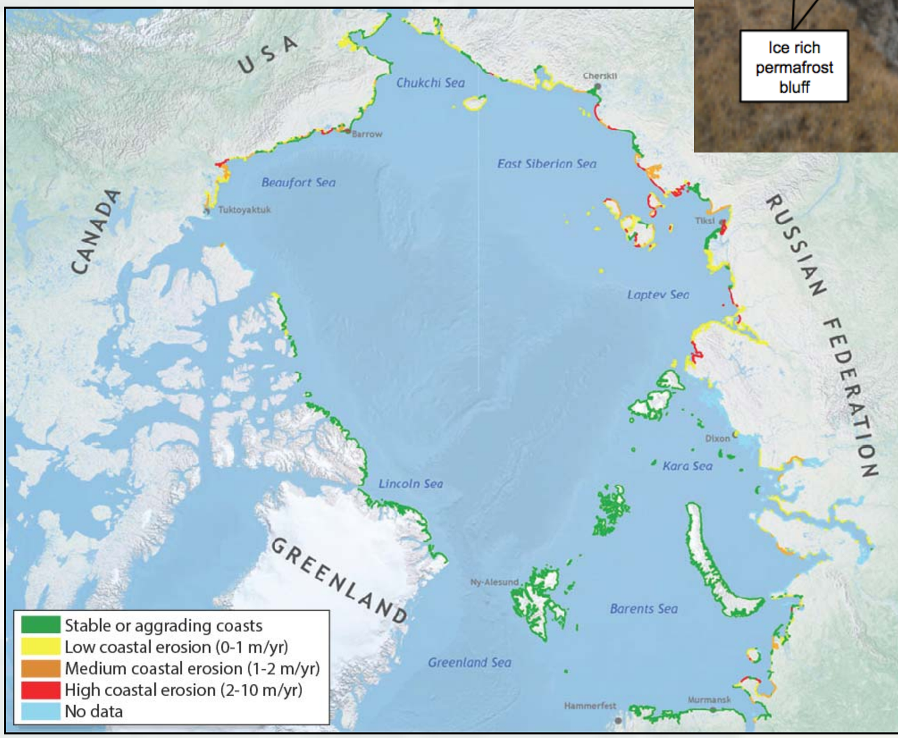
Coastal Erosion



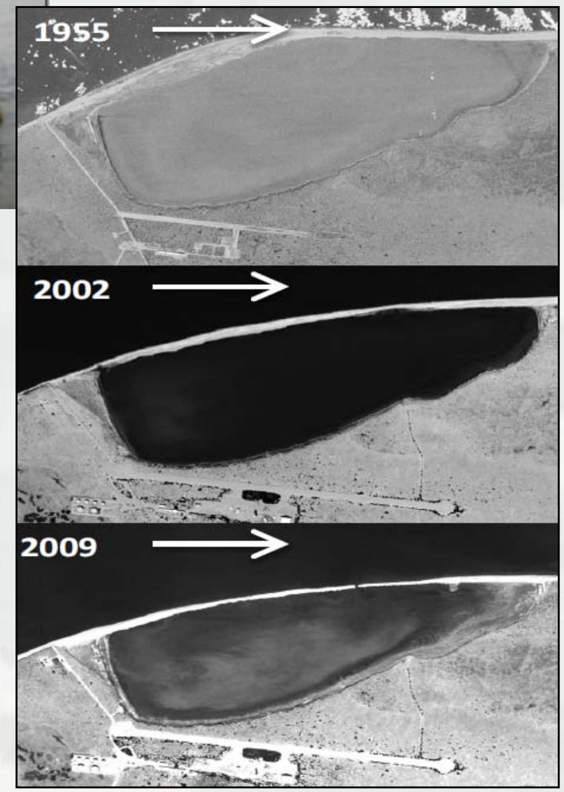
- Decreased sea ice buffer
- Increased storm action
- Thawing permafrost

Coastal Erosion





Modified from
Lantuit et al. (2012)



46

ERDC/CRREL Rapid Deploy Buildings for Extreme Environments

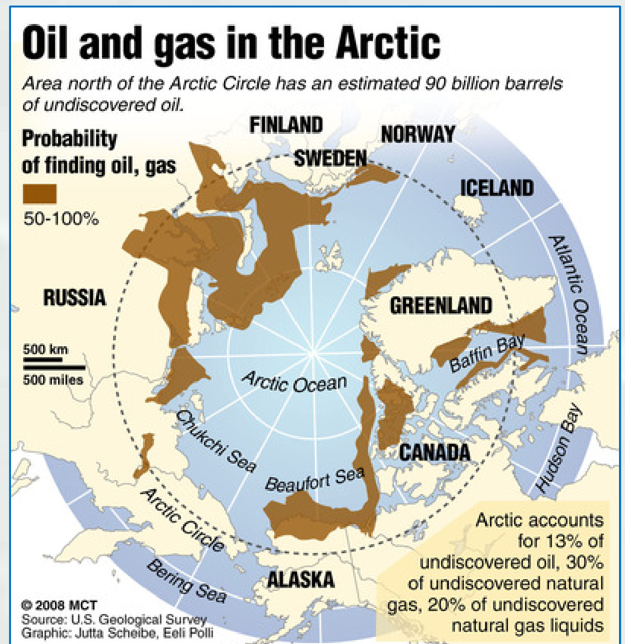
- In Collaboration with U.S. Army Natick Soldier Research Center
- Airbeam Quonset Huts
  - Light-weight & durable
  - Field tested outside of Thule, Greenland
- Current SBIR Project
  - Deploy w/in 20 min (2 people)
  - Withstand 100 mph winds
  - Endure temperatures of -50˚ to +60˚C
  - Energy efficient
  - Antarctic deployment in phase 2.

47

Oil & Gas

U.S. Geological Survey believes the Arctic holds up to 25% of the world's undiscovered oil and gas reserves

Gazprom, Shell, BP/Conoco



Hazardous Spill Detection and Response

- Detection of oil in/under ice
  - ► Oil and Gas Producers Joint Industry Project
  - ► Sub sea – camera, sonar, fluorescence, multibeam/low frequency acoustic
  - ► Suface/air – radar, spectral radiance, fluorescence, visible, infrared
- Mitigation and response
  - ► OHMSETT (Oil Spill Response Research Test Facility – Bureau of Safety and Environmental Enforcement)
  - ► Alaska Clean Seas – oil spill response training