HyLab

University of Alaska Fairbanks Hyperspectral Imaging Laboratory

Building capacity for airborne imaging spectroscopy for Alaskan and Arctic science and applications, and HyspIRI preparatory activities

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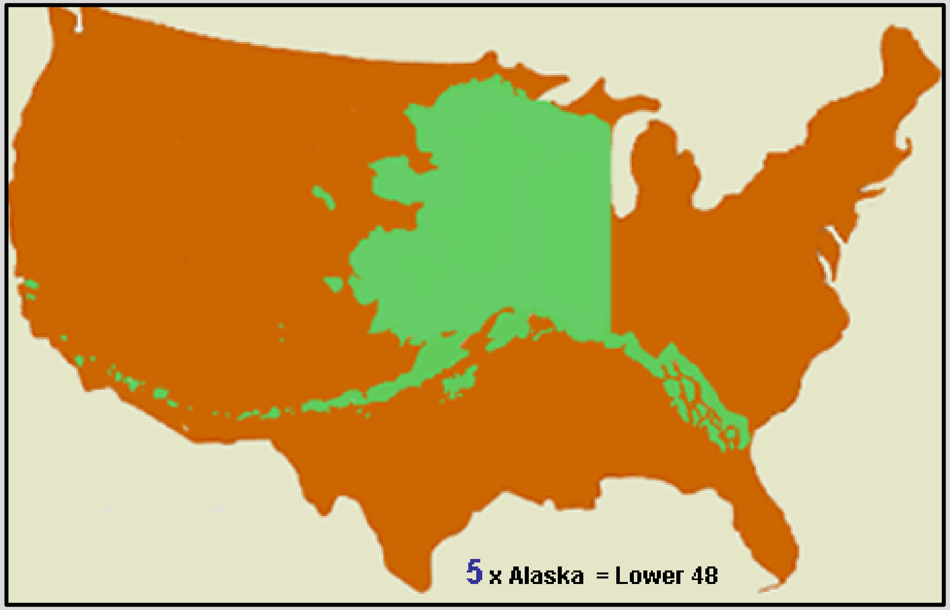
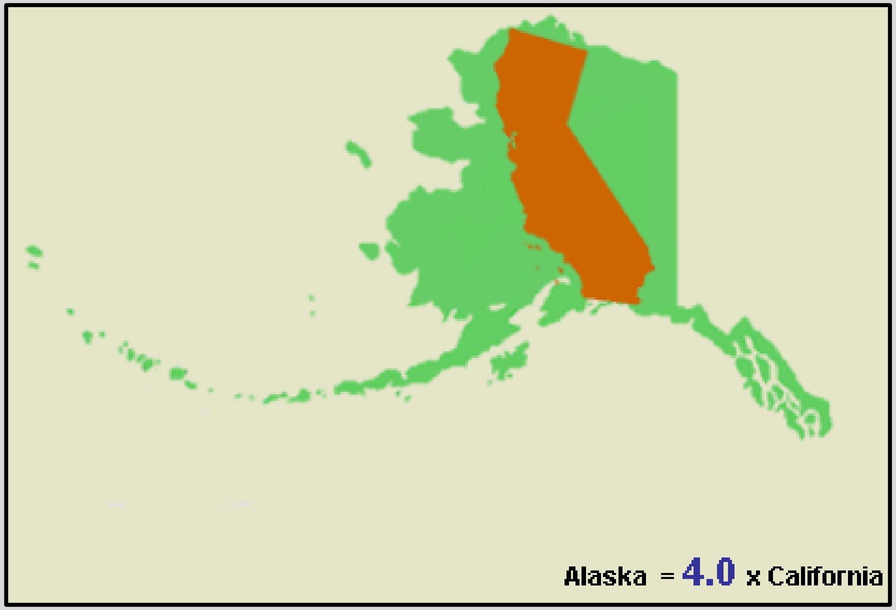
2013 HyspIRI Science and Application Workshop: Thursday, October 17, 2013

Outline

- Our need and motivation
- Project: Team and timeline
- HySpex system
- Calibration
- Data processing
- Applications
  - Ecosystems
  - Resource Exploration
- Opportunities

The Need



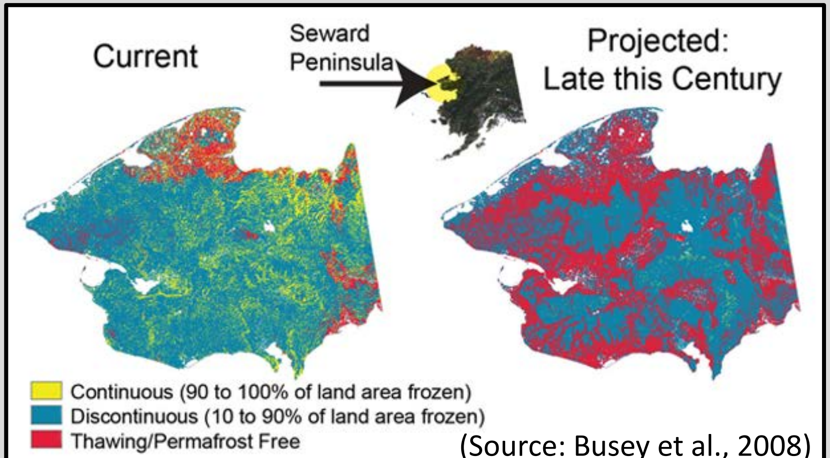


- Currently no direct access to HS imaging sensors for this remote state.
- Costs of mobilizing aircrafts to Alaska and waiting for good weather conditions have been the biggest hurdle (Only one AVIRIS campaign over Alaska since 1987).
- This will improve with AVIRIS-NG & NEON AOP (annual flights; but limited scope for temporal data over the vegetation growing season).
- Benefits of in-state capability: cost, research infrastructure, education

Alaska's Changing Ecosystems

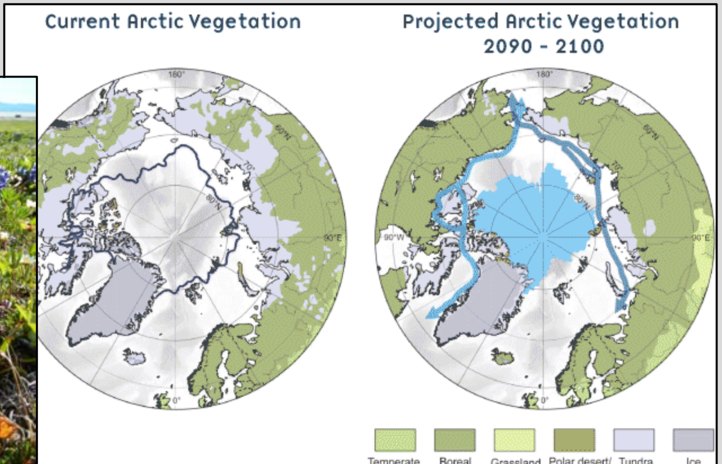
Anaktuvuk River Fire (Source: BLM)

Permafrost thaw slump (Source: Ecopost)



(Source: Busey et al., 2008)

(Source: Ecopost)



(Source: British Antarctic Survey)

Methane ebullition (Source: K Walter Antony)

Alaska's Natural Resources

- Significant natural resources, many largely unexplored!!
- Legacy of resource exploration impacts; oil spills, acid mine drainage
- We have a strong remote sensing group, but limited capacity in imaging spectroscopy.

Exploration drilling in Alaska (Source: Alaska Minerals Commission)

Acid mine drainage in Denali National Park

The State of Alaska Ranks in the *Top Ten in the World* for Important Minerals, Including:

- **Coal**: 17% of the world's coal; *2nd most in the world*
- **Copper**: 6% of the world's copper; *3rd most in the world*
- **Lead**: 2% of the world's lead; *6th most in the world*
- **Gold:** 3% of the world's gold; *7th most in the world*
- **Zinc**: 3% of the world's zinc; *8th most in the world*
- **Silver:** 2% of the world's silver; *8th most in the world*

USGS estimates

According to the USGS, Alaska has more than 70 occurrences of Rare Earth Elements (REE), including at the Bokan Mountain prospect in Southeast Alaska.

NSF Major Research Instrumentation (MRI) Award

- MRI: Acquisition of a hyperspectral imaging system to support scientific research, applied studies, and education in the state of Alaska (awarded 9/13)
- Building capabilities as part of a new UAF Hyperspectral Imaging Laboratory (HyLab)
- Aim is to stimulate use of HS remote sensing for Alaskan science and applications and build UAF institutional capabilities (supporting research training and education)
- Project objectives (2013-15):
  - Acquire, integrate, and commission HySpex system
  - Develop in-house calibration + data processing workflow
  - Deployments over Alaskan study sites in 2015 (LTER’s?)
- 2015 onwards: deployments supporting collaborative research across a range of application areas

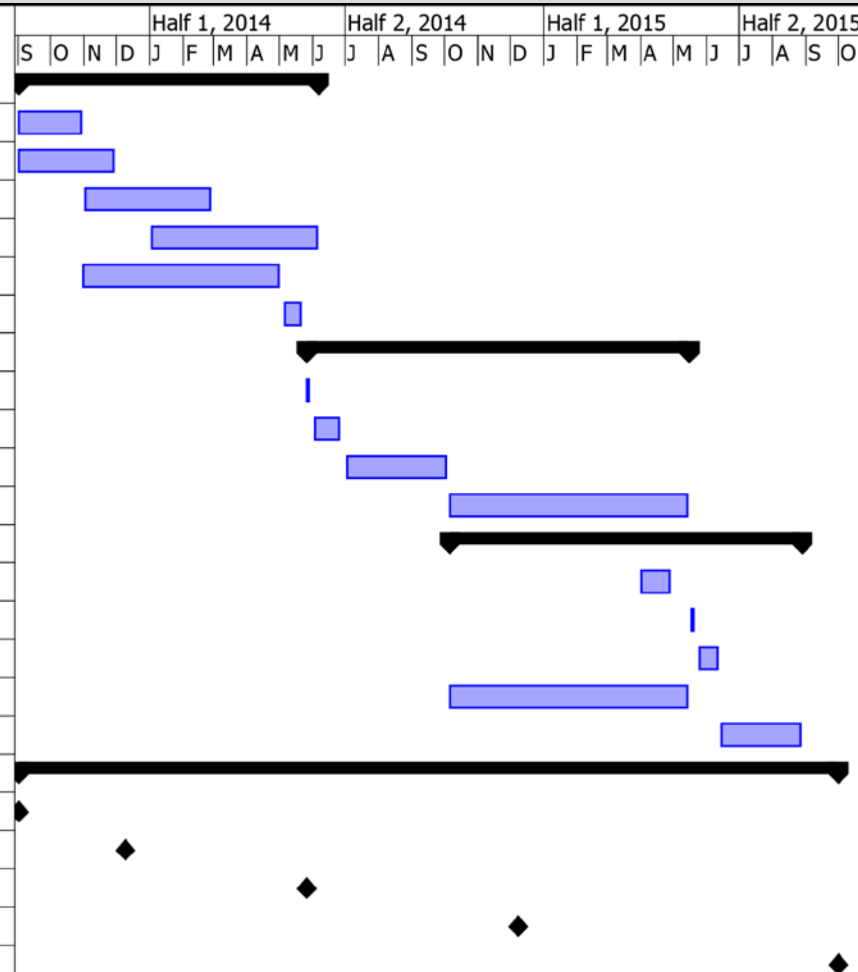
hyperspectral.alaska.edu

or

hylab.alaska.edu

Project Overview

	Task
1	⊟ **Instrument acquisition**
2	Establish final instrument specification, write contract, and place order
3	Setup project website
4	Setup instrument calibration facility
5	Preparatory work for airborne sensor integration
6	Instrument manufacture at NEO
7	Visit to DLR
8	⊟ **Instrument commissioning**
9	Instrument delivery to UAF: training and preliminary testing with NEO
10	Initial testing and laboratory calibration/characterization of instrument at UAF
11	Instrument tests at UAF including field vicarious calibration experiment
12	Development of operational procedures and data processing chain
13	⊟**Instrument deployment**
14	Laboratory calibration/characterization of instrument at NEON
15	UAF MayMester short course on "Field and Imaging Spectroscopy"
16	Laboratory calibration check at UAF, airborne integration, and field vicarious calibration
17	Planning for airborne instrument deployments in Summer 2015
18	Airborne deployments of instrument over Fairbanks and North Slope study sites
19	⊟**Potential project team meetings**
20	HyspIRI Workshop 2013
21	AGU Fall Meeting 2013
22	HyspIRI Symposium 2014
23	AGU Fall Meeting 2014
24	HyspIRI Workshop 2015



HySpex System

Manufacturer	NEO / HySpex	
Model	VNIR-1600	SWIR-384
Spectral range (nm)	400 - 1000	930 - 2500
No of bands	160	288
Radiometric resolution	12 bit	14 bit
Spectral sampling (nm)	3.7	6
Spatial pixels	1600	384
SNR (peak)	250:1	500:1
Dimensions (lwh in cm)	29 x 14 x 36	
Approx weight for system (kg)	20	
Power consumption (W)	160	

Source: NEO

Source: Virtual Outcrop Geology group at CIPR

Hyspex VNIR 1600

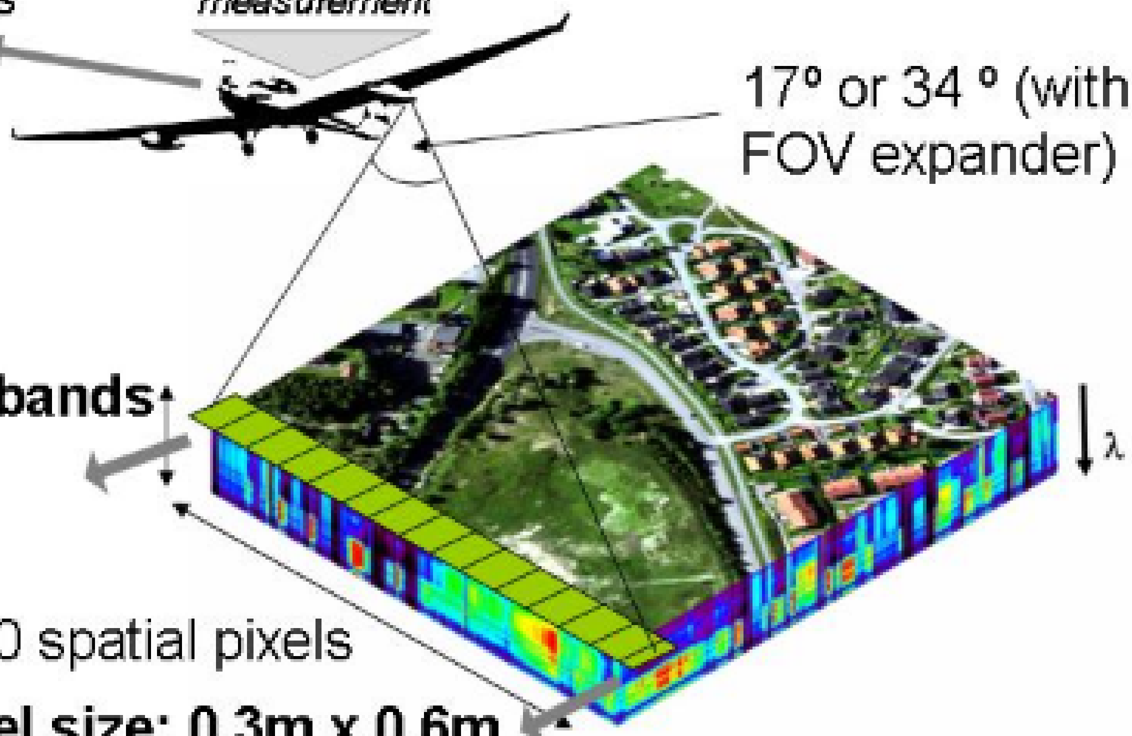
Standard Configuration:

ASD Irradiance measurement

40m/s

Flying height: 1600m (800m with FOV expander)

17° or 34 ° (with FOV expander)



160 spectral bands
400-1000nm

1600 spatial pixels

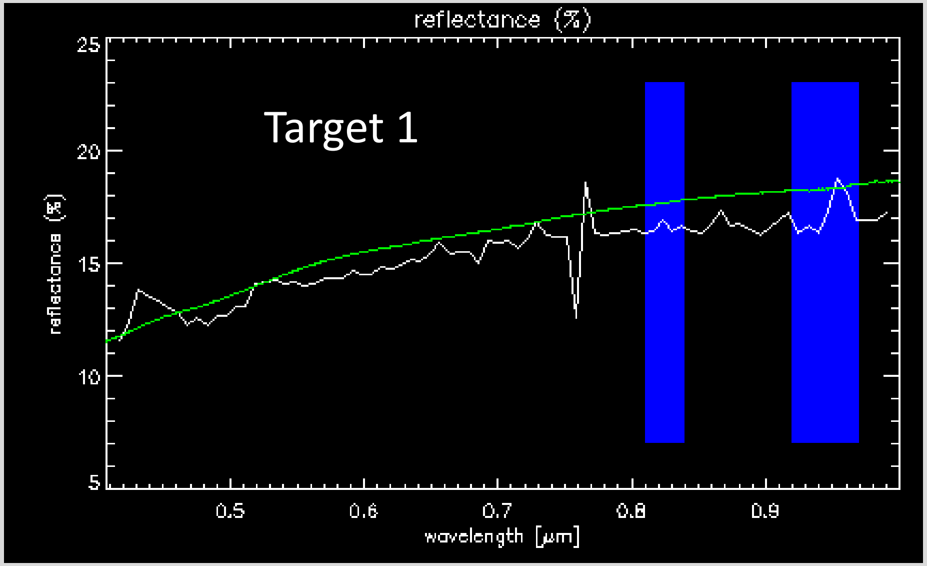
Pixel size: 0.3m x 0.6m

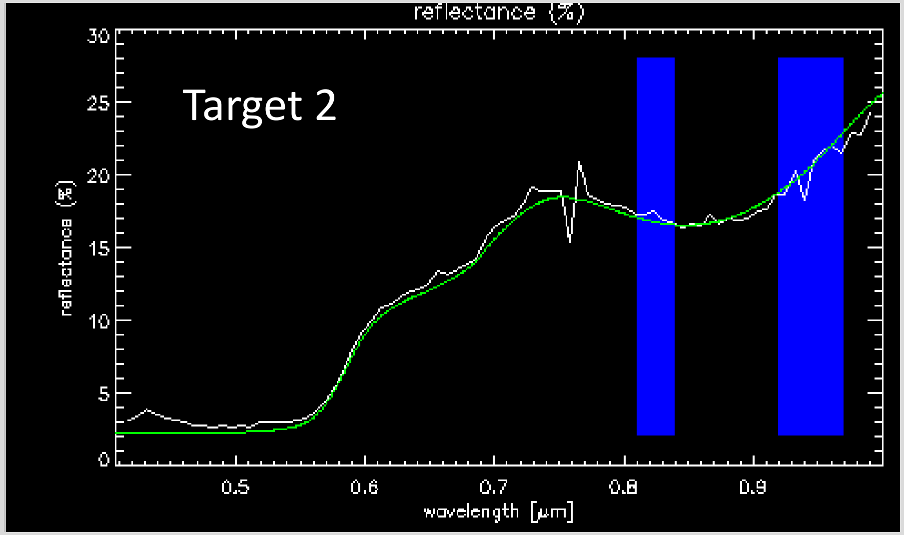
Swath width: 490m

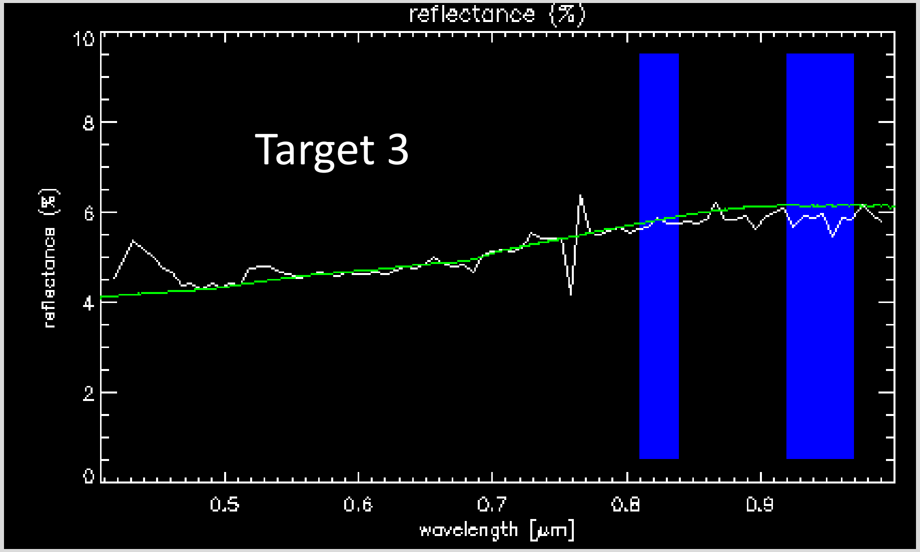
Area coverage rate: 70.6 sq km/hr

Source: Univ of Edinburgh

In-flight analysis of HySpex at OpAiRS DLR





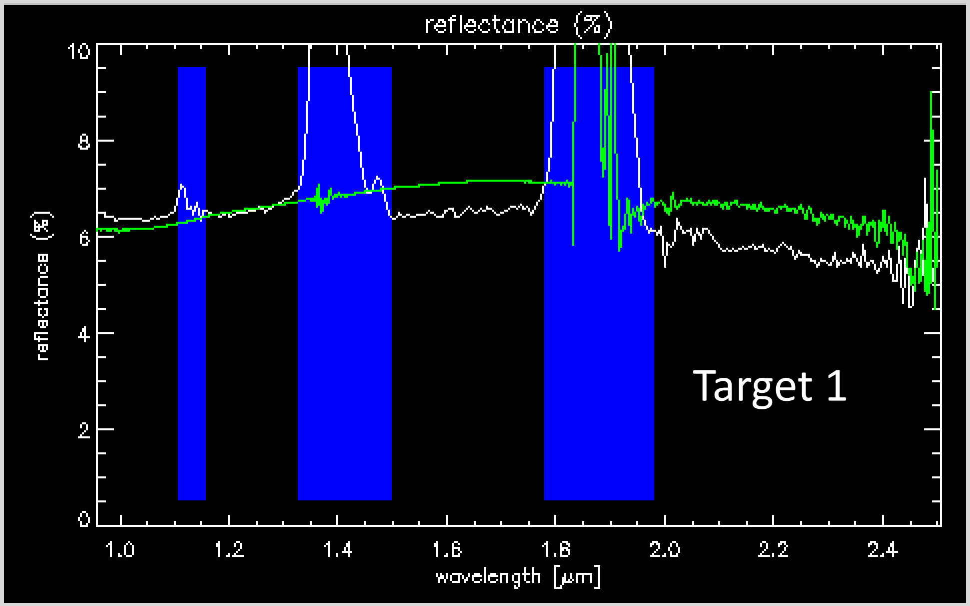


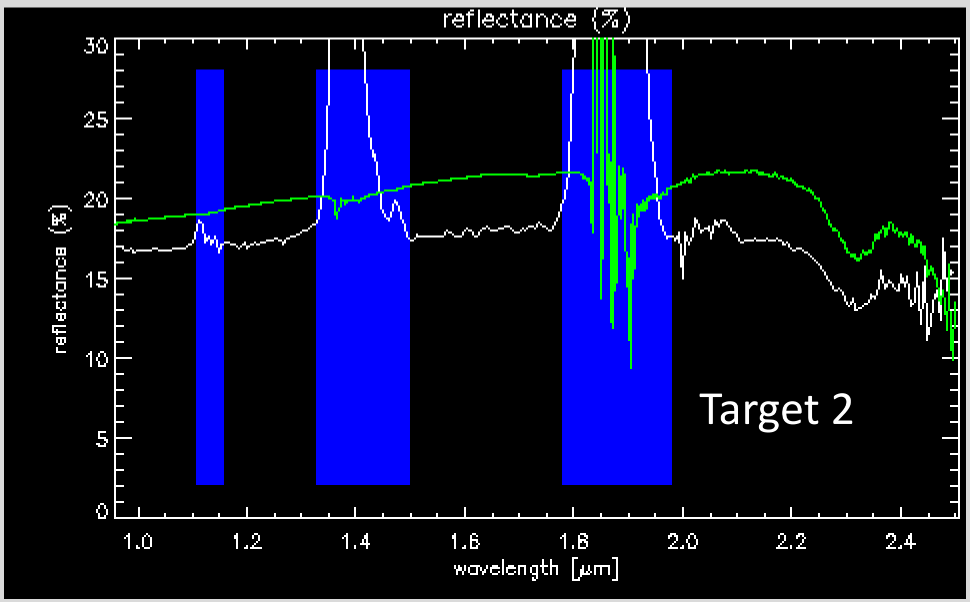
First results of VNIR sensor: comparison of ground reflectances, in-situ measurements as green lines, first ATCOR results as white lines. No spectral or radiometric in-flight calibration applied!

=> Excellent agreement. Well within 2% absolute reflectance for first tests

Slide Courtesy of Martin Bachmann, DLR

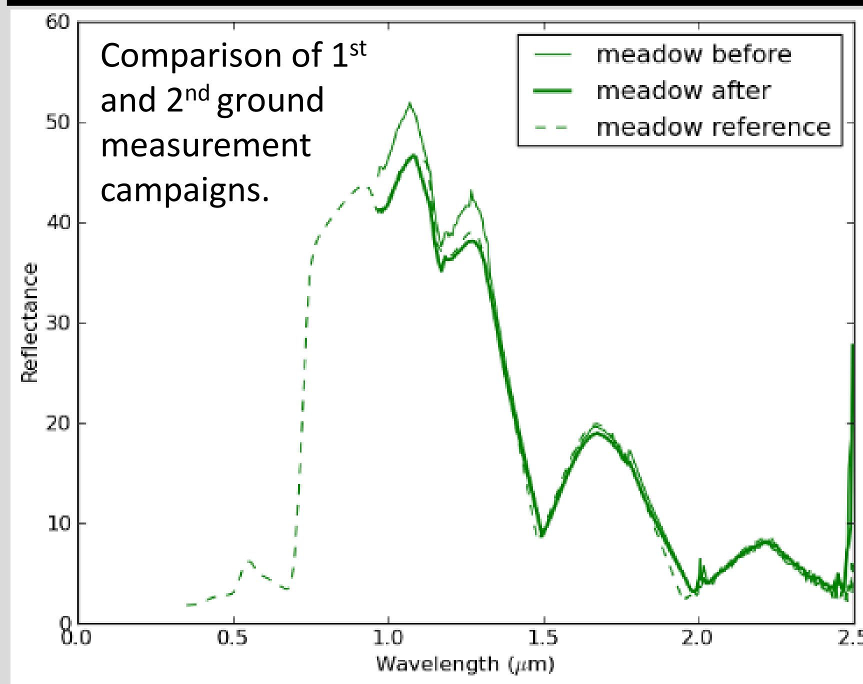
In-flight analysis of HySpex at OpAiRS DLR



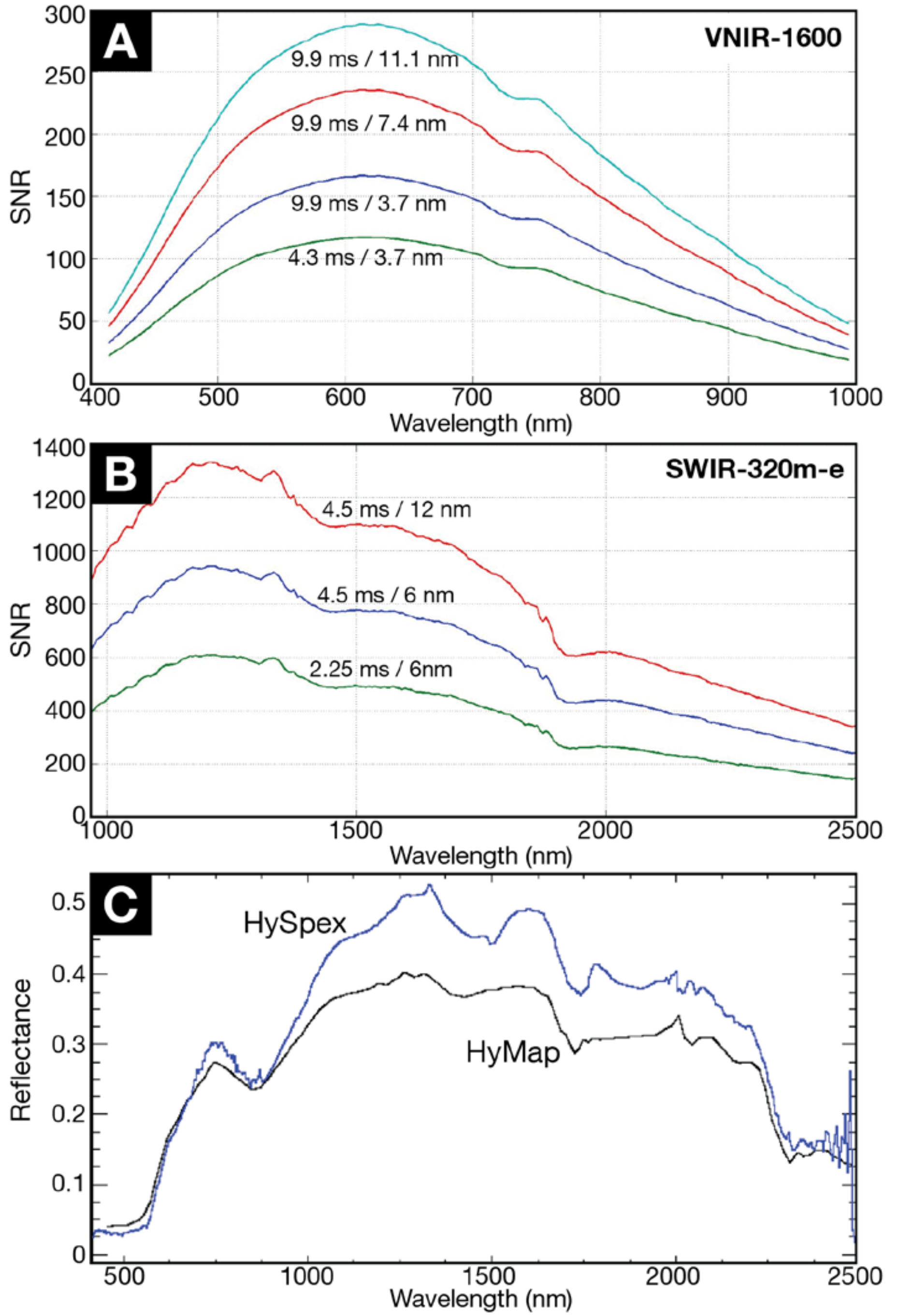


<u>First results for SWIR sensor</u>: Comparison of ground reflectances, in-situ measurements as green lines, first ATCOR results as white lines. No spectral or radiometric in-flight calibration applied!

=> Excellent agreement. Within 5% absolute reflectance for first tests



Slide Courtesy of Martin Bachmann, DLR



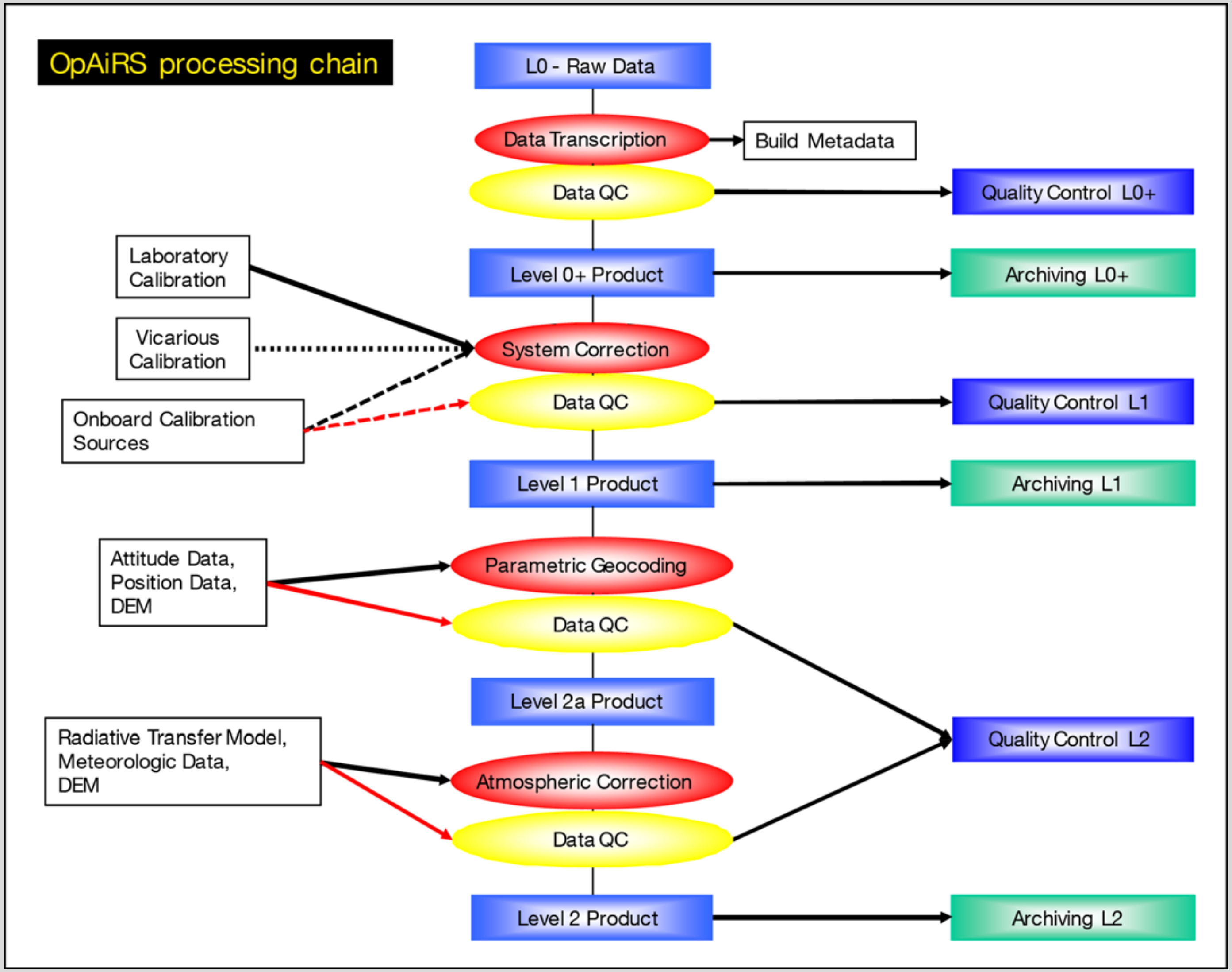
SNR of HySpex (a) VNIR-1600 and (b) SWIR-320m-e cameras for various integration times and binning settings. (c) Comparison of HySpex and HyMap reflectance spectra for ground calibration targets acquired 3 years apart (source: DLR).

Calibration

- Full calibration (to NIST standards) performed prior to each flying season at external facilities
- In-house calibration facilities will be used to monitor instrument stability (GI Optical Lab)
- Field calibrations
- Support from NEON, JPL, DLR

Source: NERC

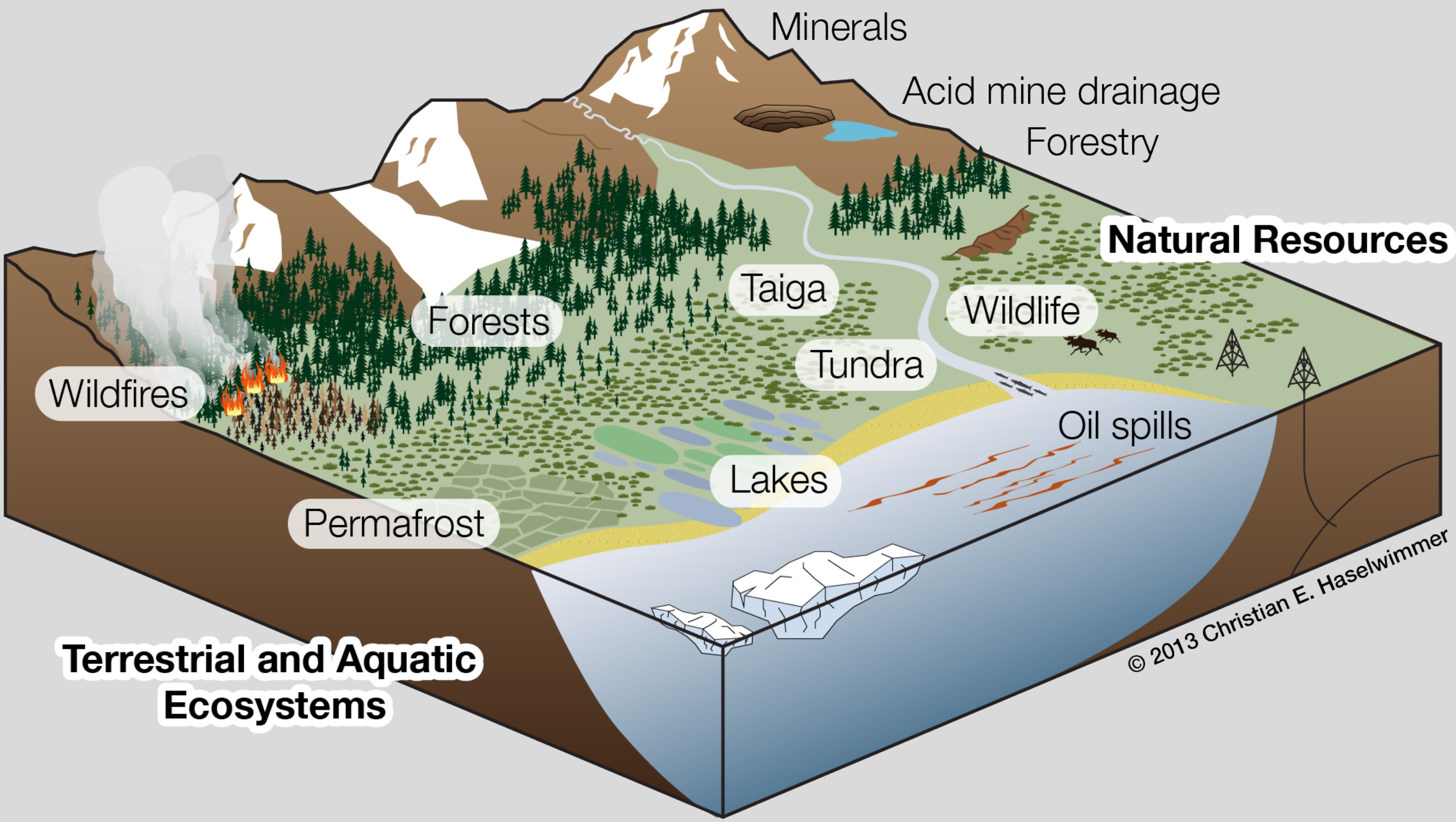
Data Processing



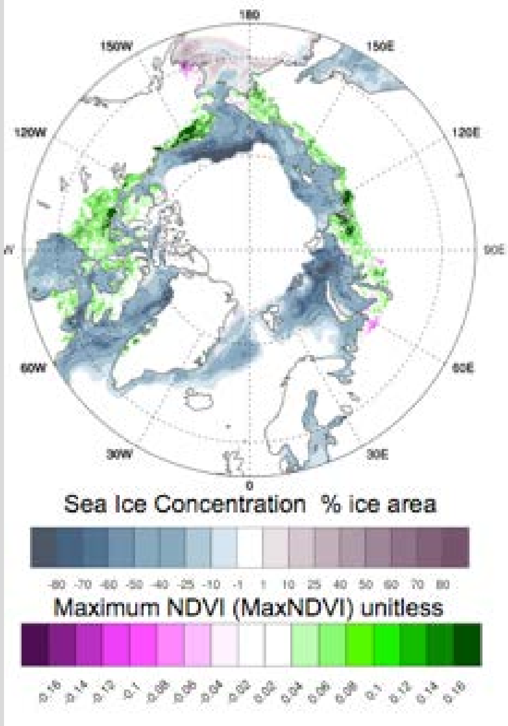
Pre-processing chain used by the DLR OpAiRS facility to convert raw HySpex data to Level 2 georegistered and atmospherically corrected surface radiance and reflectance products (from Bachmann et al., 2012)

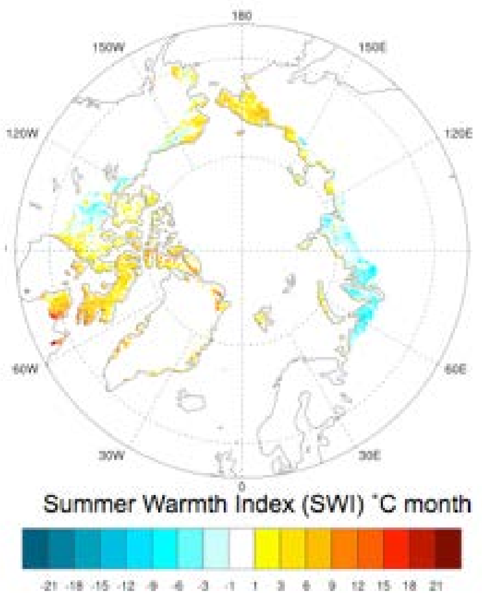
Alaskan/Arctic Applications

- Terrestrial and aquatic ecosystem applications
- Natural resource studies

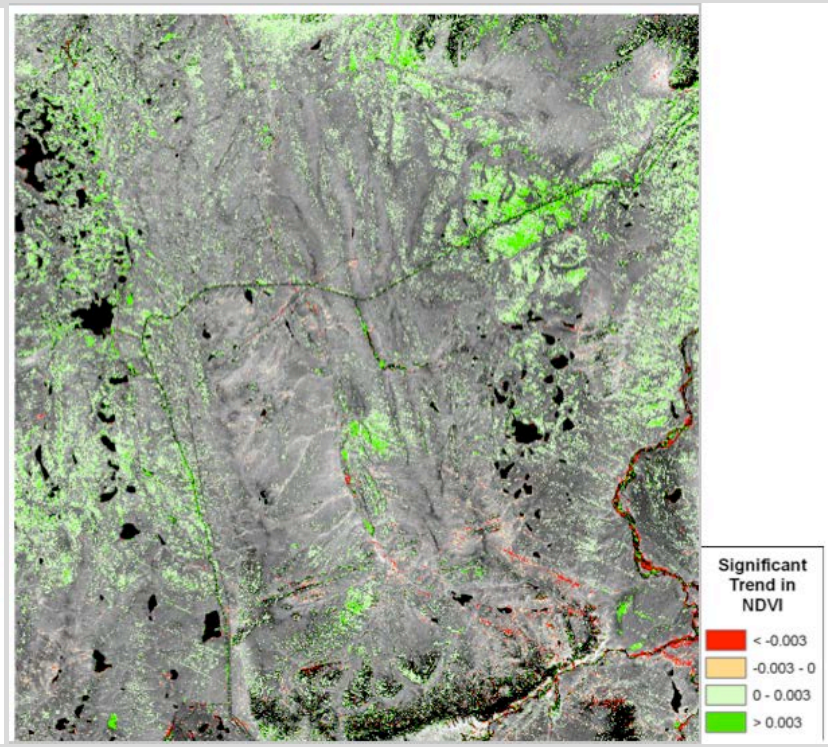


Ecology: Arctic/Boreal Vegetation Change





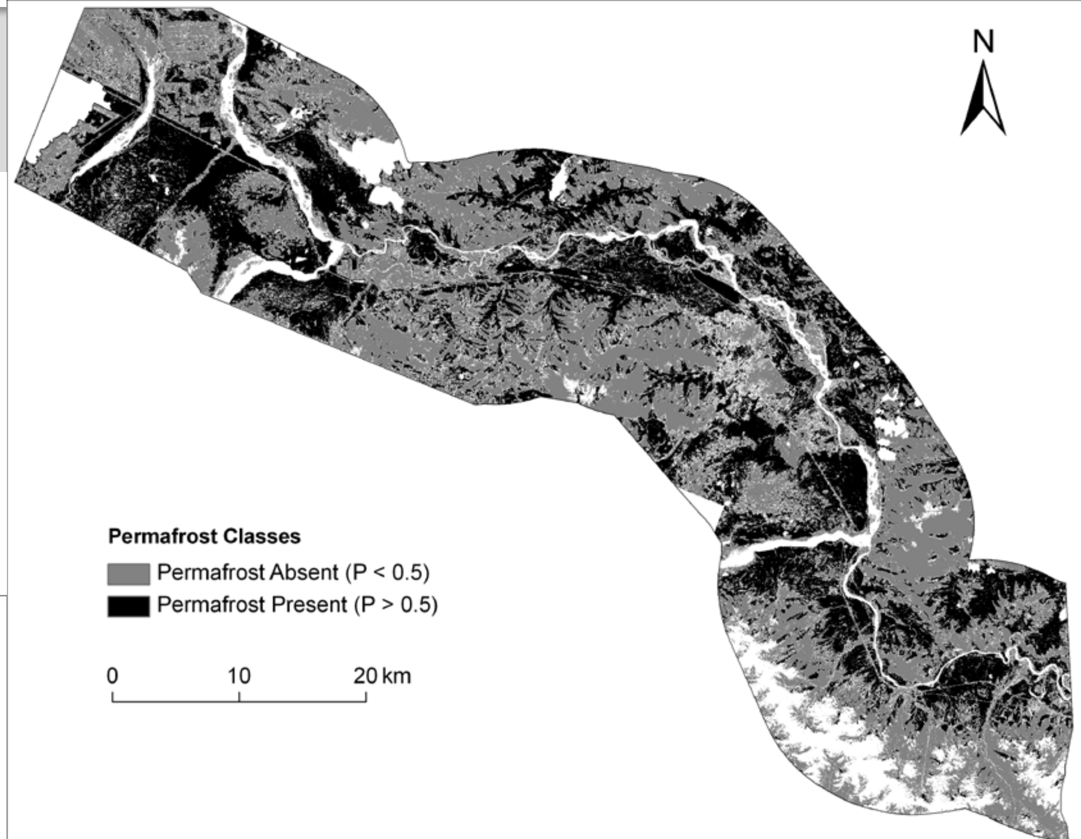
(*Credits: Uma Bhatt and team, UAF*).



- Left: Relation between summer temp increase; sea ice decline, and greening of the Arctic. Right: The Toolik Lake region of Alaska, showing greening trends from 1985 to 2007 based on time series of Landsat TM data. Strong greening trends are associated with younger more recently glaciated landscapes. HS data could help unravel some of the causes of the greening patterns. (*Credits: Skip Walker and team, UAF*).

Ecology: Permafrost

There is a documented correlation between surface vegetation and presence / absence of near-surface permafrost!



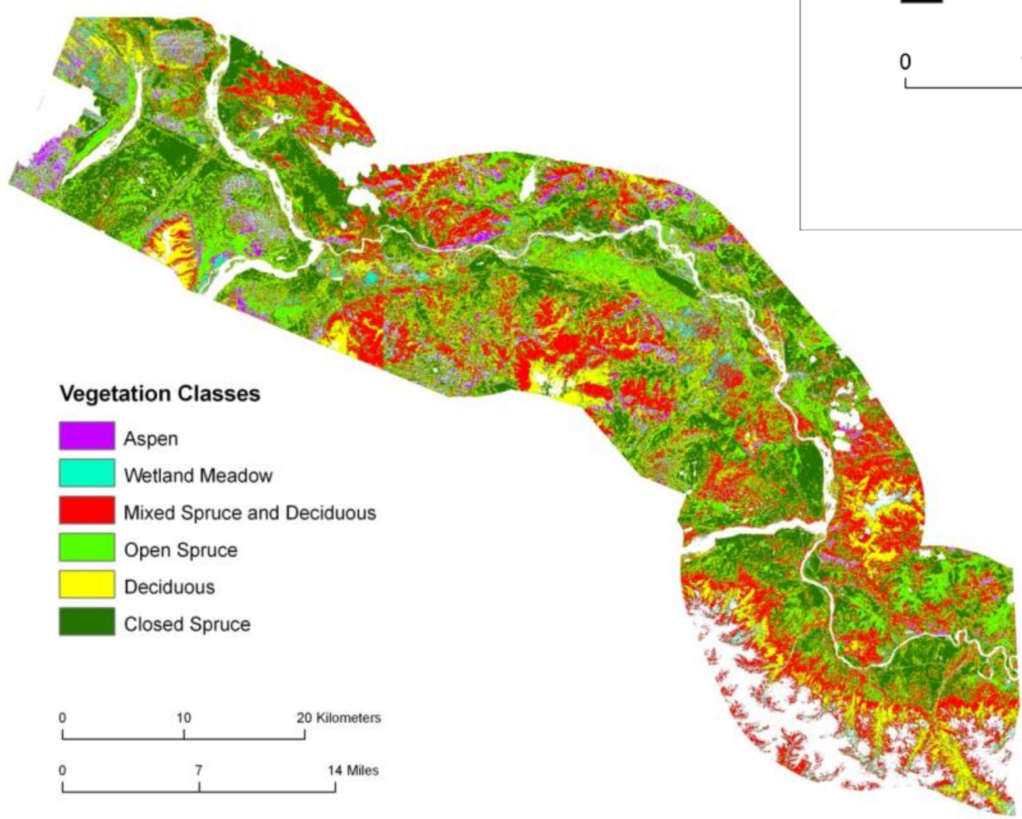


Table 7: Percentage of mapped vegetation classes and percentage of each vegetation classes underlain by shallow (< 1.6 m) permafrost in the study area.

Vegetation Class	Vegetation Class (%)	Permafrost (%)
Aspen	8.1	0.0
Closed Spruce	34.0	87.0
Deciduous	7.2	0.0
Mixed Spruce and Deciduous	36.3	11.0
Open Spruce	11.4	100.0
Wetland Meadow	3.0	0.0

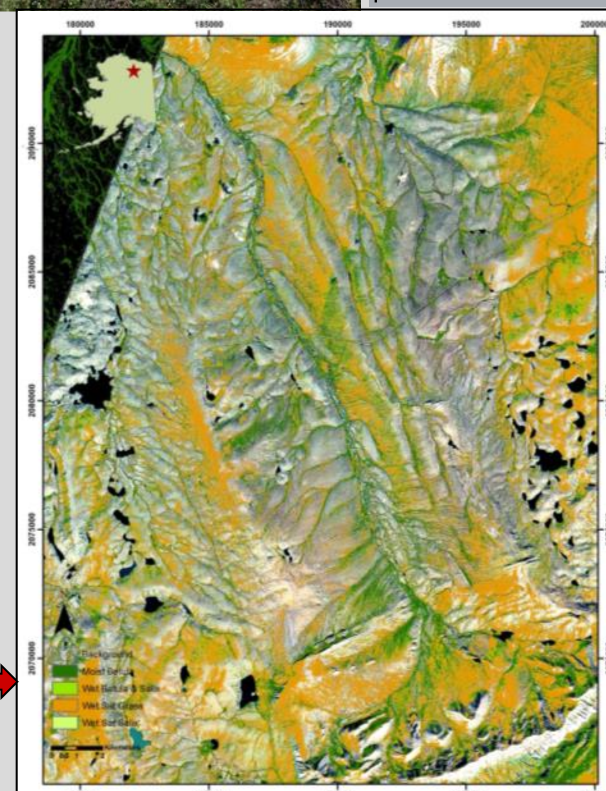
Source: Panda et al., 2012, Application of multi-source RS and field data to mapping permafrost distribution in Interior Alaska, *GIScience and Remote Sensing*, 49(3), 346-363.

Ecology: Permafrost (Thermokarst / Watertracks)

Thermokarst (feature and process) is caused due to thawing of ice-rich ground and is a classic indicator of climate change in permafrost rich areas.

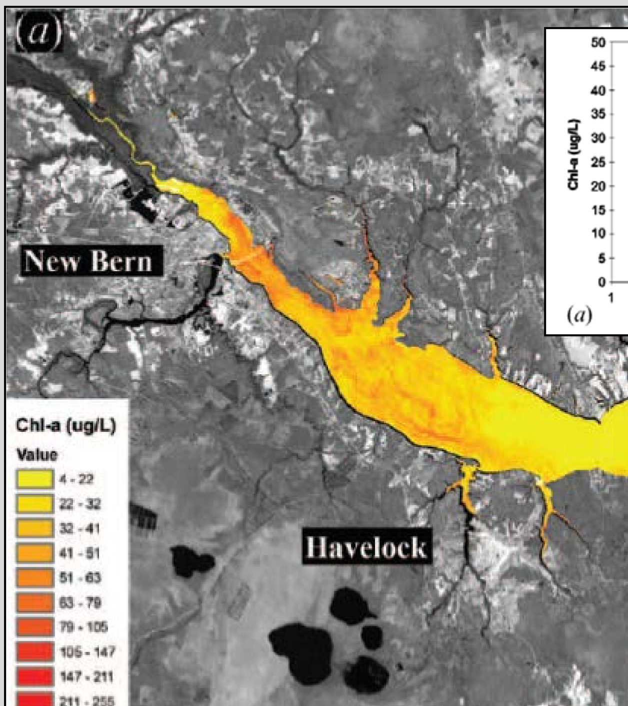
Evolution of water track to gully to stable incised channel. Water tracks are saturated curvilinear features where flow is confined by the permafrost table

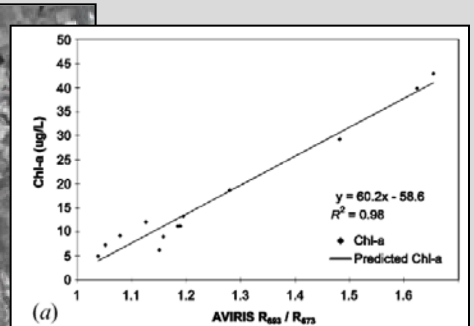
- In parts of the Arctic (e.g. Imnavait Basin in Alaska), soil temperatures have been warming at a rate of 0.17 °C per year since 1993 [*Hinzman et al., 2008*].
- Thermokarst features, such as water tracks, are widely prevalent. They are characterized by rough textures, high moisture content, and shrubby vegetation.
- Improved mapping of moist *Betula nana*, facilitated by HS data, will help map watertracks and thermokarst prone areas. [*Trochim et al. 2010*]



Ecology: Investigating Arctic/sub-Arctic lakes

- Lakes are a critical component of the northern carbon cycle: thermokarst lake development, carbon sinks, CH_4
- Retrieve lake properties, e.g. DOM, Chl, lake depth, substrate
- Links to HyspIRI: algorithm development / upscaling



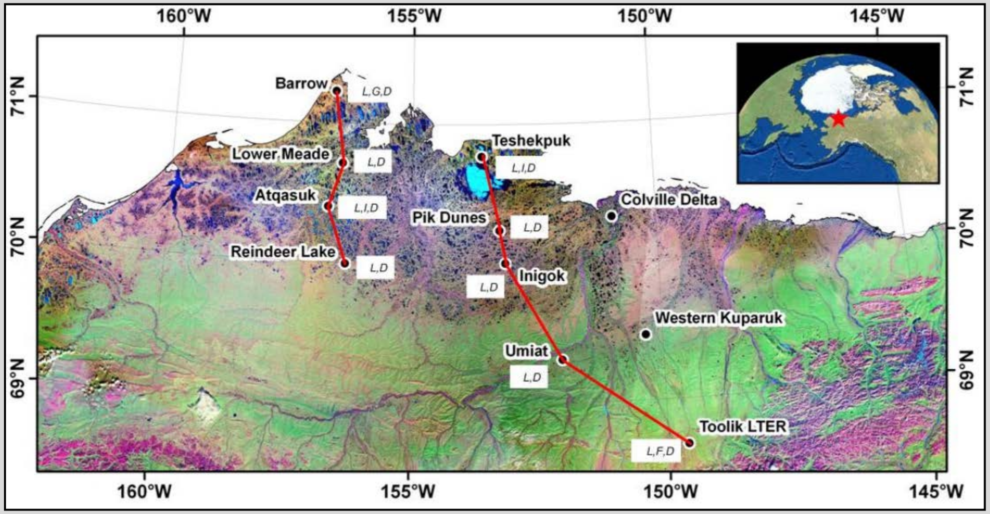


←AVIRIS Chl-a retrieval (from Lunetta et al., 2009)

Lakes on the North Slope, Alaska (from Hinkel et al., 2012) →

Arctic/sub-Arctic lakes: Projects

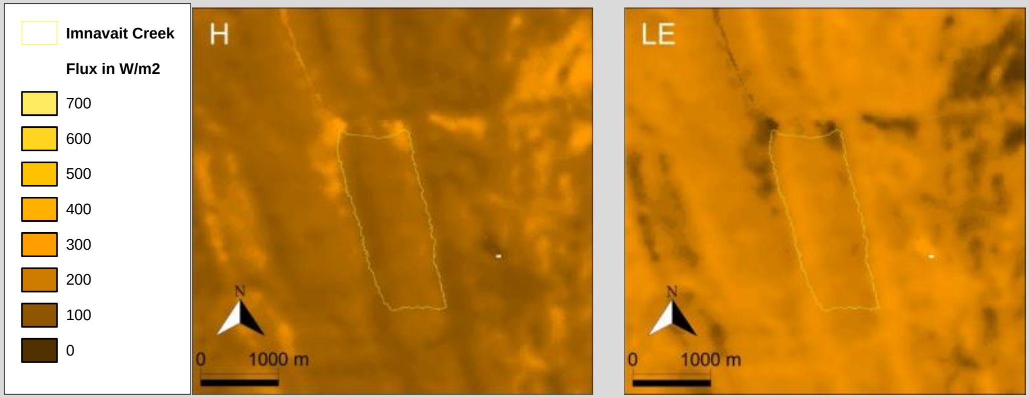
- NSF: Toward a Circumarctic Lakes Observation Network (CALON)- Multiscale observations of lacustrine systems (Hinkel: U Cincinatti, Grosse: UAF)
- NASA Carbon Cycle Sciences: Characterization of CH_4 emissions from high latitude lakes in North America using multi-scale remote sensing (Walter Anthony, Gross: UAF)



CALON instrumented lake network (Source: Hinkel et al., 2012)

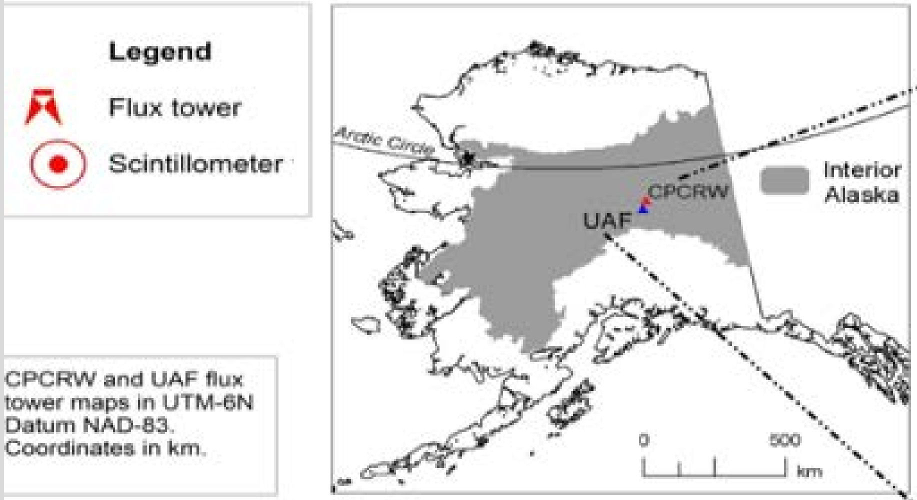
Ecology: Evapotranspiration Mapping

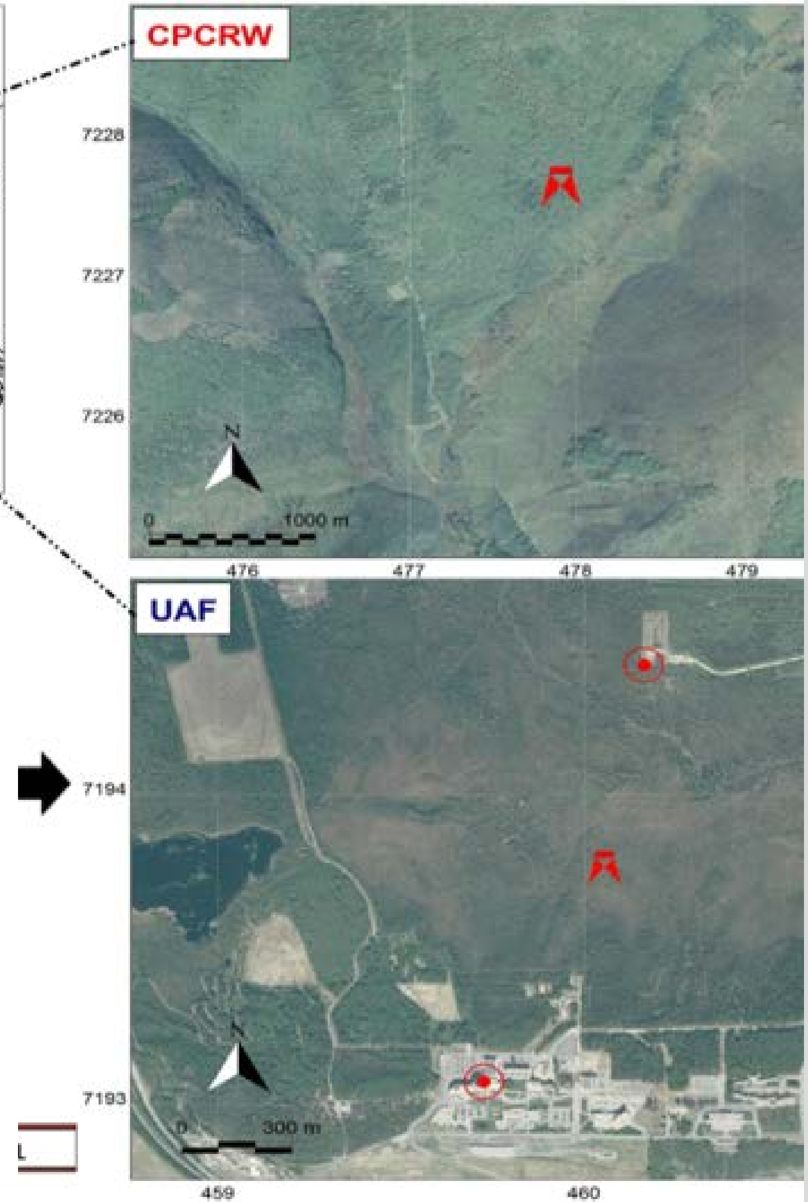
- ET mapping requires scaling from plot to satellite scales. Models require image based LST, LAI (or a proxy), and LC dependent clumping factor.
- Airborne HS data will allow upscaling, providing intermediate scale between field and MODIS scale. It will aid characterizing vegetation (especially differentiating the contribution of canopy and underlying mosses – huge issue in ET retrieval in high latitudes!)



www.et.alaska.edu

Ecology: Evapotranspiration Mapping

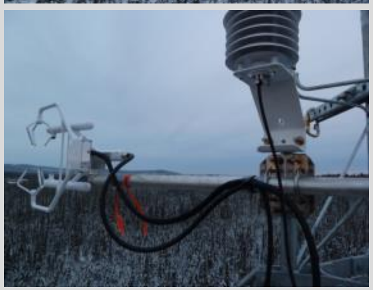


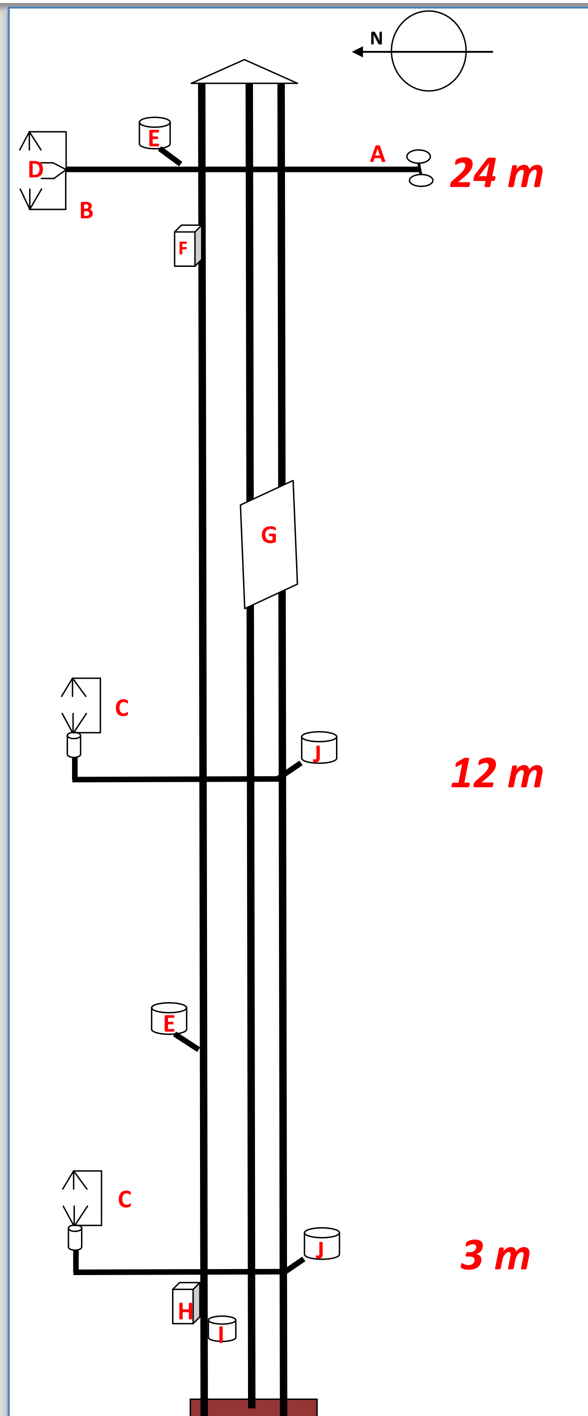


Two flux towers covering the most important sub-Arctic habitats in Alaska: black spruce (University of Alaska Fairbanks, **UAF**) and paper birch (Caribou Poker Creek Research Watershed, **CPCRW**)

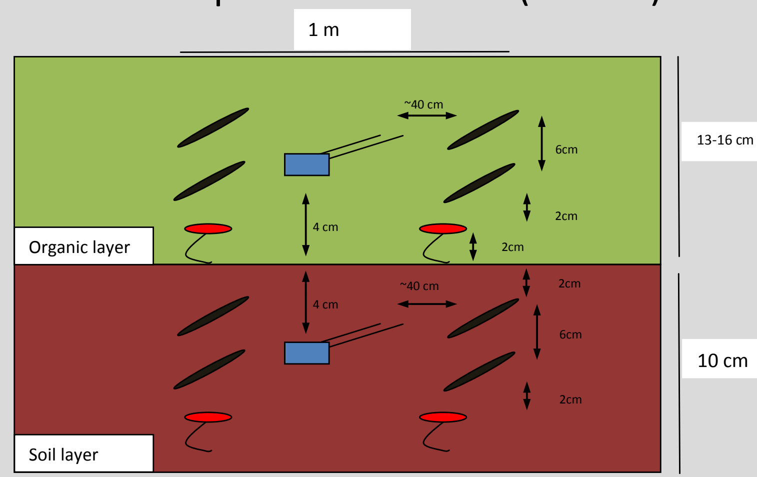
Image credits: Jordi Cristóbal

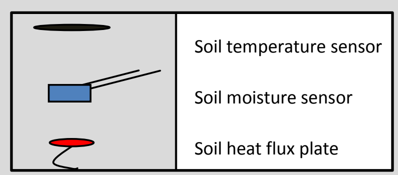






A = Net radiation, 4 comp (Hukseflux)
B = 3D Sonic anemometer (Campbell)
C = Ultrasonic anemometer (RM Young)
D = Gas analyzer (Campbell)
E = Air temperature sensors (Campbell)
F = EC processing unit (Campbell)
G = Solar panel - 130W
H = Data logger (Campbell)
I = Barometric pressure (Vaisala)
J = Air temperature and RH (Vaisala)





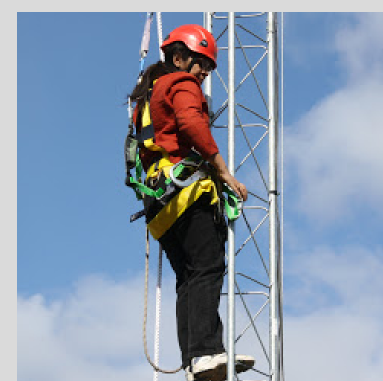
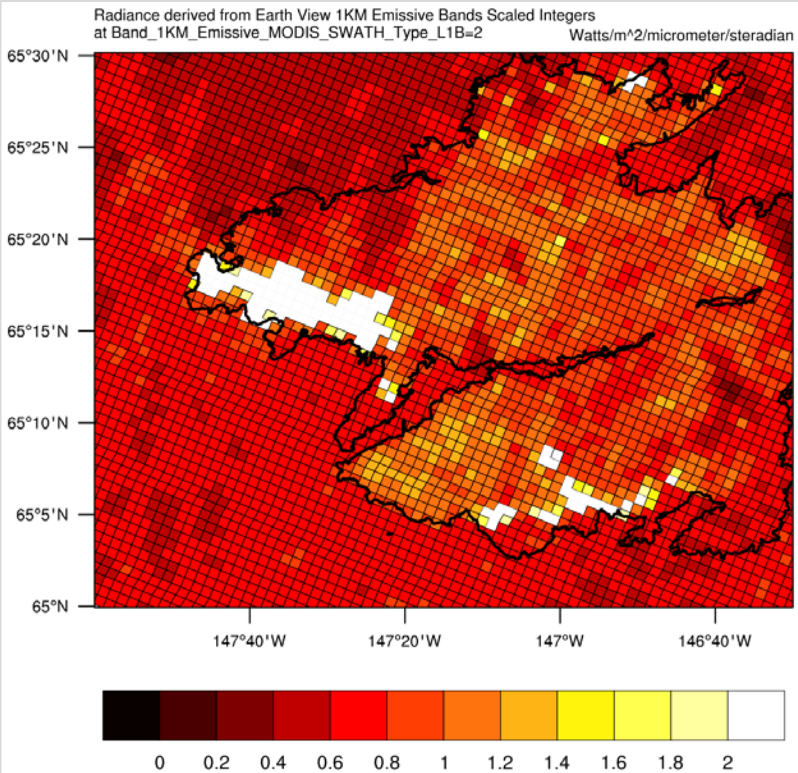
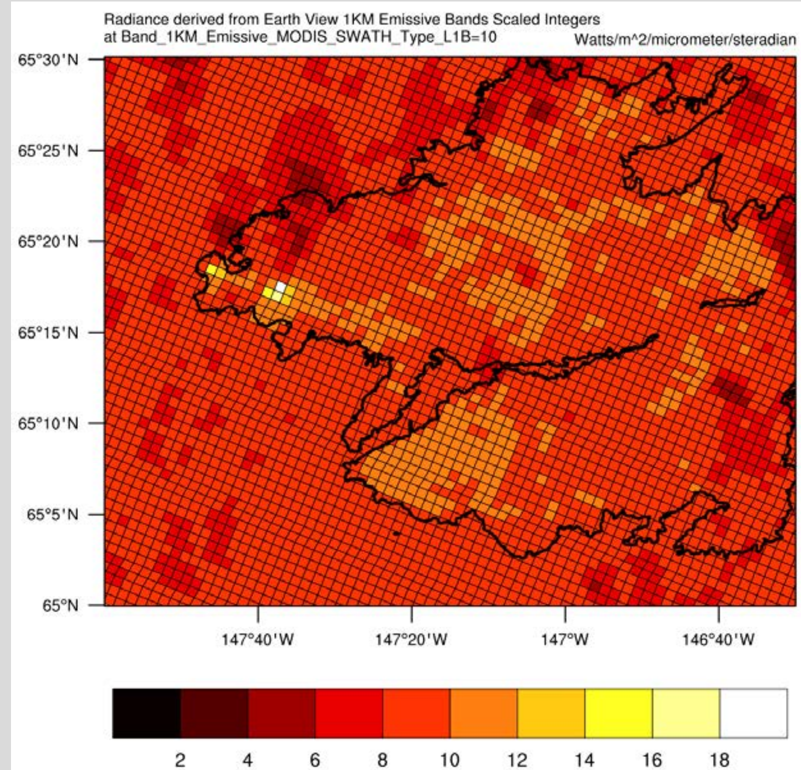


Image credits: Jordi Cristóbal

Ecology: Boreal Forest Fires

MODIS band 22 (3.96 µm)

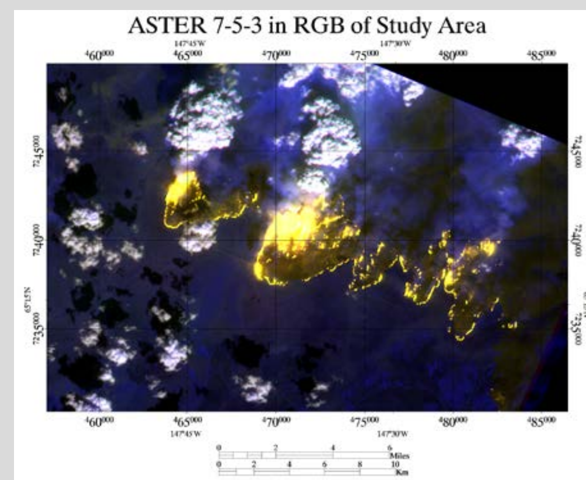




MODIS band 31 (11.03 µm)

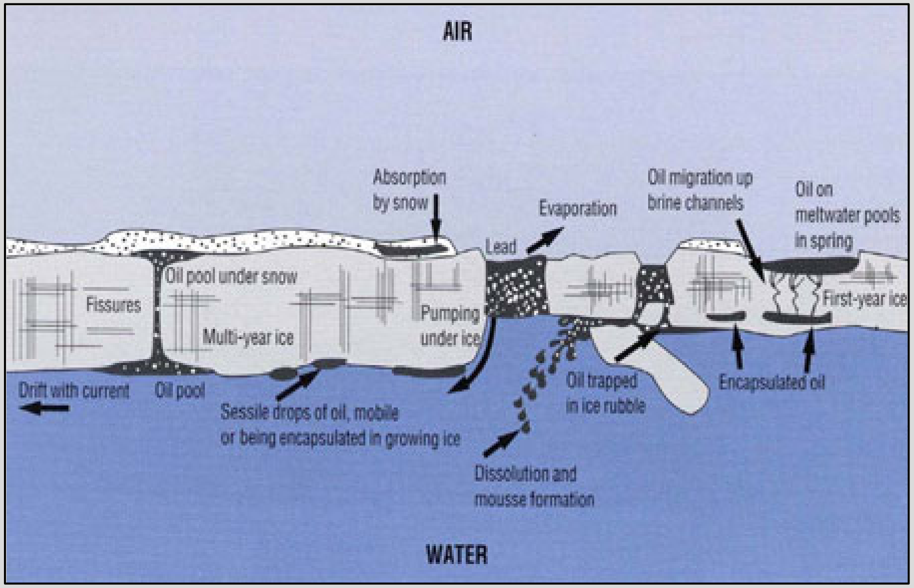
7-17-04, 21:42 UTC, Boundary fire; Credits: Chris Waigl, UAF

- Boreal forest fires are extensive and can have flaming fronts with temperatures over 1000K, providing opportunities for temperature retrievals from Hyspex SWIR channels.



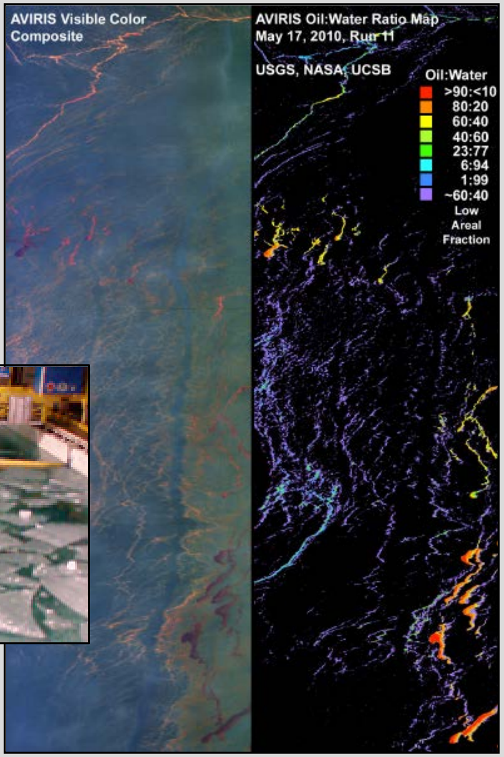
Arctic oil spills

- UAF building Arctic Center for Oil-Spill Research and Education (A-CORE)
- Investigate potential of HS remote sensing for oil spill mapping in Arctic environments
- HyspIRI contributions: establish Arctic oil spill mapping potential



Manifestations of oil ↑ spills in ice-covered waters

AIVRIS oil spill→ mapping results from Gulf oil spill (from Clark et al., 2010)

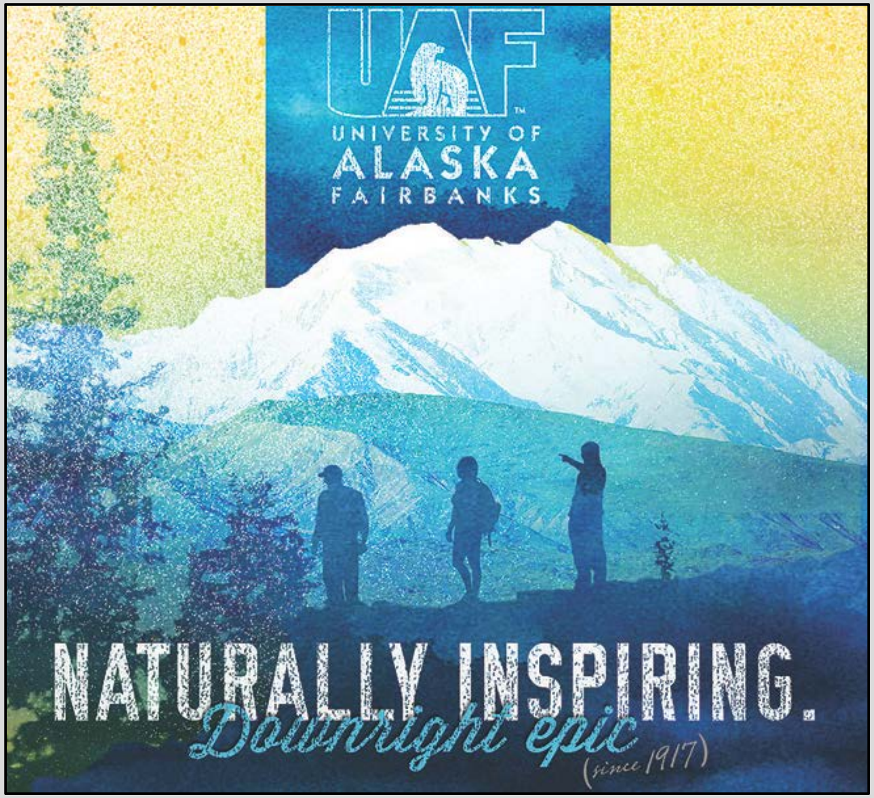


↑ Experimental oil spills at CRREL facility

Synergies with NEON/AVIRIS

- We would love to have an AVIRISng sensor
- BUT what are realistic and meaningful synergies?
- Cross calibration over Alaskan LTER's
- Local capability providing potential for improved temporal resolution
- Broader question of what can commercial systems contribute?

Opportunities at UAF



- Partnerships
- Post-doctoral position
- Sabbatical host
- Visiting scientist
- We need expertise

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Image Source: Dan Sullivan's talk at the 2nd AK Minerals Summit