

University of Alaska Fairbanks Hyperspectral Imaging Laboratory

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

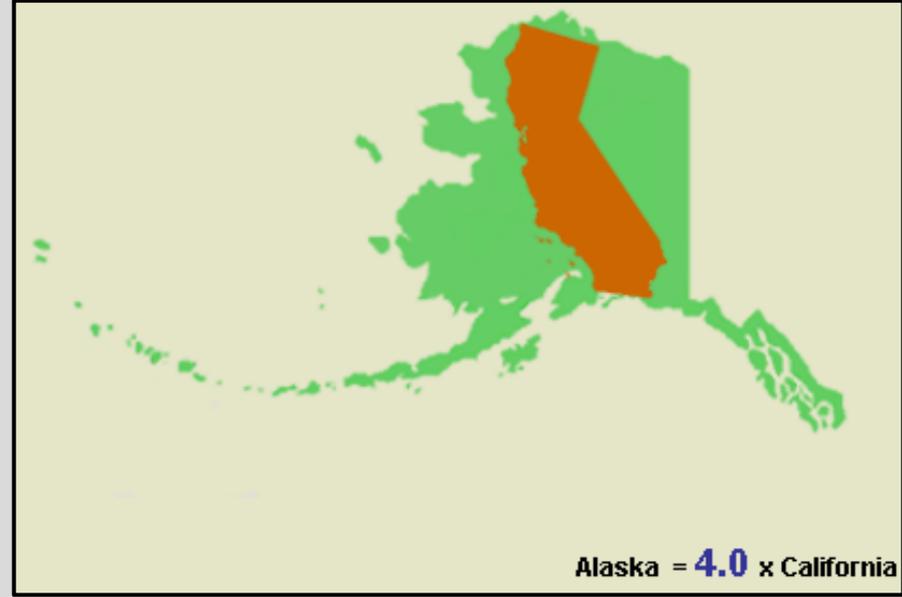
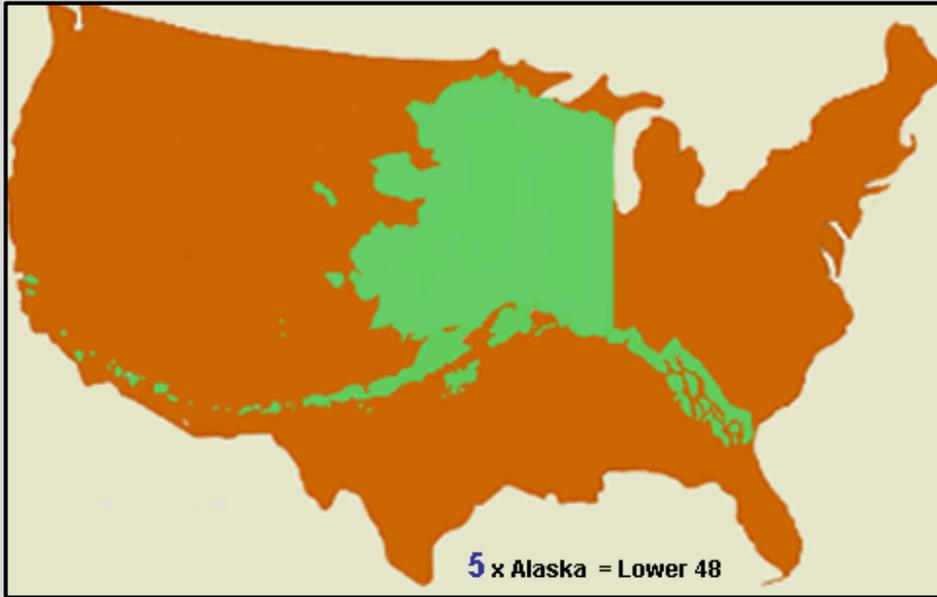
Anupma Prakash, Christian Haselwimmer, Don Hampton, Thomas Kampe,
Dar Roberts, Rob Green, Andreas Mueller, Martin Bachmann



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)

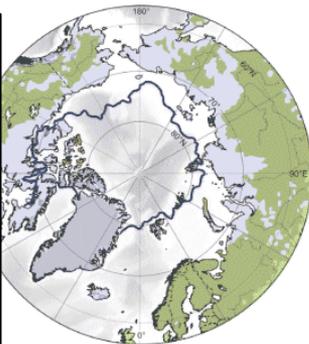


Permafrost thaw slump (Source: Ecopost)

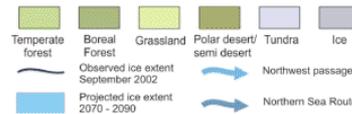
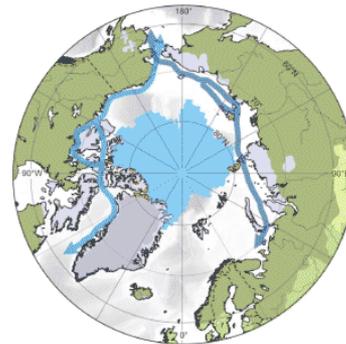
(Source: Ecopost)



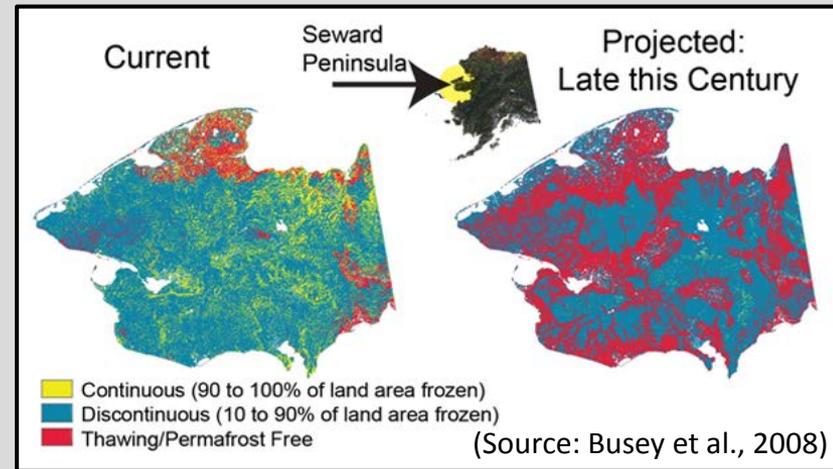
Current Arctic Vegetation



Projected Arctic Vegetation 2090 - 2100



(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



University of Alaska Fairbanks Hyperspectral Imaging Laboratory

Home

- Background
- NSF MRI grant

UAF HyLabs

- Airborne instrumentation
- Field instrumentation
- Calibration facilities
- Data processing facilities

AK APPLICATIONS

- Ecological application
- Natural resource applications

RESOURCES

- Publications
- Data
- Photo Gallery
- External Links

PEOPLE

- Partners
- Contacts

People: Partners



Principal Investigators



Anupma Prakash is a Professor in Geophysics (Remote Sensing) at the Geophysical Institute (GI), is the Associate Dean for UAF's College of Natural Science and Mathematics (CNSM), and the Director for CNSM Division of Research (CDR). Her research interests are in mapping surface composition and change. Her expertise is in thermal remote sensing and imaging spectroscopy. She serves as a member of the science study group for NASA's planned [Hydrosat](#) mission. She teaches courses in remote sensing and GIS at UAF. For more information visit www.gi.alaska.edu/~prakash or contact her at prakash@gi.alaska.edu.



Christian Haselwimmer is remote sensing scientist with interests in the applications of remote sensing to energy and geological resource studies including for exploration, assessment, and environmental monitoring. He currently works as a remote sensing scientist with the Chevron Energy Technology Company's Environmental Unit. Prior to this job, he was a postdoc at the Geophysical Institute, where besides his NSF MRI, he was involved with a variety of research projects including geothermal exploration at Pilgrim Hot Springs, harbor seal habitat mapping in glacier bay, and chinook habitat mapping in the Toolik wildlife refuge.

Contact him at chase@gi.alaska.edu



Don Hampton is a research assistant professor in the Geophysical Institute at UAF and Optical Science Manager of the Poker Flat Research Range. Prior to returning to the GI he worked as a Systems Engineer at Bell Aerospace and Technologies Corp for 10 years. His main interests are optical instrumentation, and their application to studying physical systems. Current applications include aureole and twilight, optical remote sensing from unmanned aerial vehicles, and space based instruments on the Deep Impact spacecraft observing stellar transits of known extrasolar planets and an upcoming flyby of comet Hartley-2. Contact him at dhampton@gi.alaska.edu



Tom Kempe is the Airborne Observatory Platform (AOP) Instrument Scientist responsible for the NEON imaging spectrometer and science algorithm development and validation. Prior to joining NEON, Inc., Tom was a Staff Consultant in Electro-Optics with Bell Aerospace & Technologies Corp., where he was instrumental in the design and development of earth remote sensing systems including Quickbird, CALIPSO, and conceptual designs for several ESSP missions.



Der A Roberts is a Professor in the Department of Geography at the University of California, Santa Barbara, where he started in January 1994 and currently serves as Chair. His research interests include imaging spectrometry, remote sensing of vegetation, spectroscopy (urban and natural cover), land-use/land-cover change mapping with satellite time series, height mapping with lidar, fire danger assessment and, recently remote sensing of methane. He has worked with hyperspectral data since 1984 and broad band sensors such as MSS and TM over the same period, as well as Synthetic Aperture Radar.

Senior Personnel / External Collaborators

Martin Bechmann & Andreas Muller - German Aerospace Center (DLR)

Rob Green - Jet Propulsion Laboratory

hyperspectral.alaska.edu
or
hyLab.alaska.edu

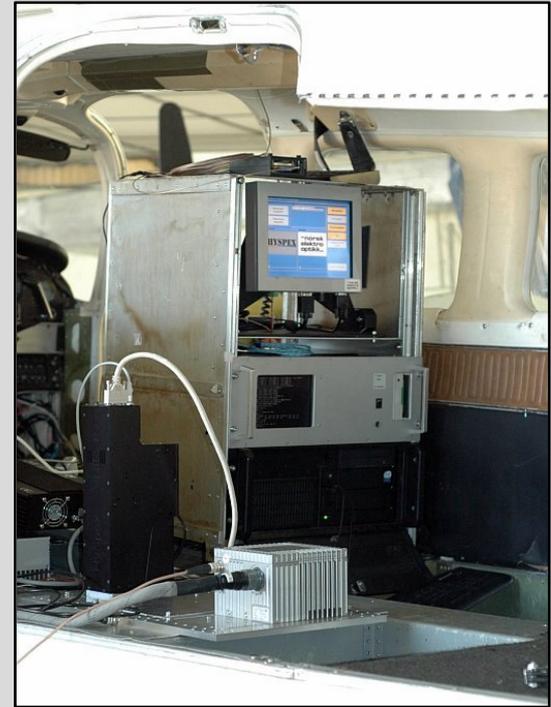
Project Overview



	Task	Half 1, 2014					Half 2, 2014					Half 1, 2015					Half 2, 2015				
		S	O	N	D	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1	<input checked="" type="checkbox"/> Instrument acquisition	[Timeline bar from start to mid-June 2014]																			
2	Establish final instrument specification, write contract, and place order	[Timeline bar from start to early January 2014]																			
3	Setup project website	[Timeline bar from start to early February 2014]																			
4	Setup instrument calibration facility	[Timeline bar from early February to early April 2014]																			
5	Preparatory work for airborne sensor integration	[Timeline bar from early March to early June 2014]																			
6	Instrument manufacture at NEO	[Timeline bar from early February to early May 2014]																			
7	Visit to DLR	[Timeline bar in mid-June 2014]																			
8	<input checked="" type="checkbox"/> Instrument commissioning	[Timeline bar from mid-June 2014 to mid-September 2014]																			
9	Instrument delivery to UAF: training and preliminary testing with NEO	[Timeline bar in mid-June 2014]																			
10	Initial testing and laboratory calibration/characterization of instrument at UAF	[Timeline bar in early July 2014]																			
11	Instrument tests at UAF including field vicarious calibration experiment	[Timeline bar from early August to early September 2014]																			
12	Development of operational procedures and data processing chain	[Timeline bar from early September to early December 2014]																			
13	<input checked="" type="checkbox"/> Instrument deployment	[Timeline bar from early September 2014 to early December 2014]																			
14	Laboratory calibration/characterization of instrument at NEON	[Timeline bar in early October 2014]																			
15	UAF MayMester short course on "Field and Imaging Spectroscopy"	[Timeline bar in early November 2014]																			
16	Laboratory calibration check at UAF, airborne integration, and field vicarious calibration	[Timeline bar in early December 2014]																			
17	Planning for airborne instrument deployments in Summer 2015	[Timeline bar from early December 2014 to early February 2015]																			
18	Airborne deployments of instrument over Fairbanks and North Slope study sites	[Timeline bar in early February 2015]																			
19	<input checked="" type="checkbox"/> Potential project team meetings	[Timeline bar from start to end of project]																			
20	HyspIRI Workshop 2013	[Timeline bar in early 2013]																			
21	AGU Fall Meeting 2013	[Timeline bar in late 2013]																			
22	HyspIRI Symposium 2014	[Timeline bar in mid-2014]																			
23	AGU Fall Meeting 2014	[Timeline bar in late 2014]																			
24	HyspIRI Workshop 2015	[Timeline bar in early 2015]																			

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	

HySpex System



Source: [NEO](#)

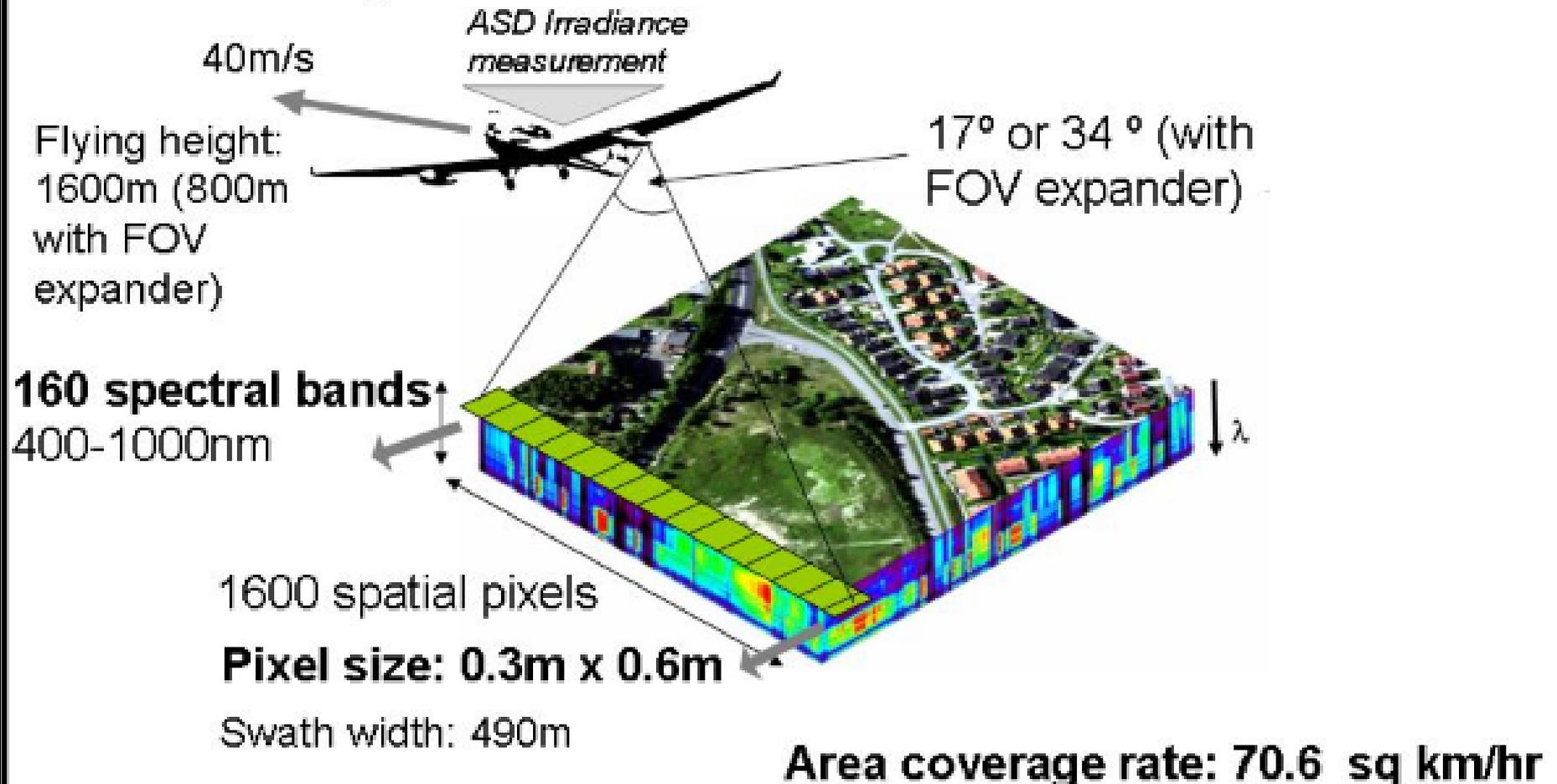


Source: [Virtual Outcrop Geology](#) group at [CIPR](#)

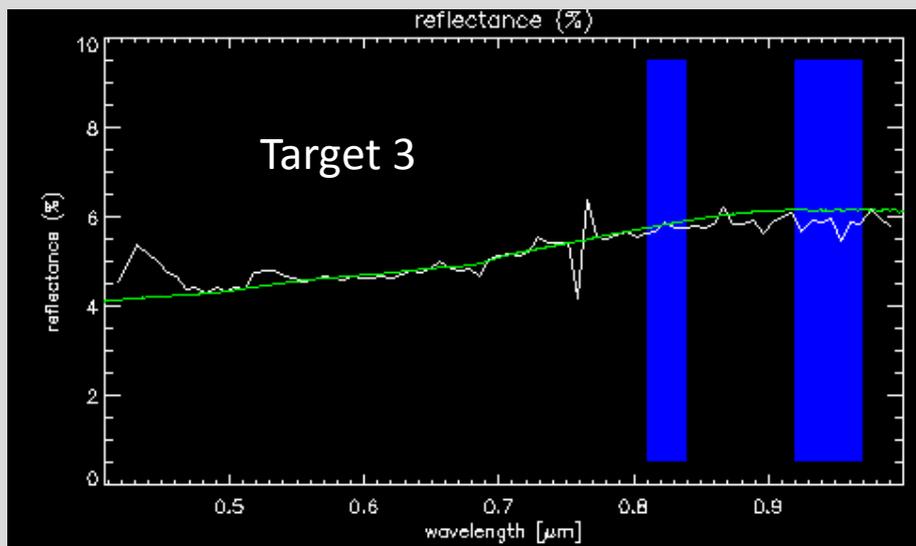
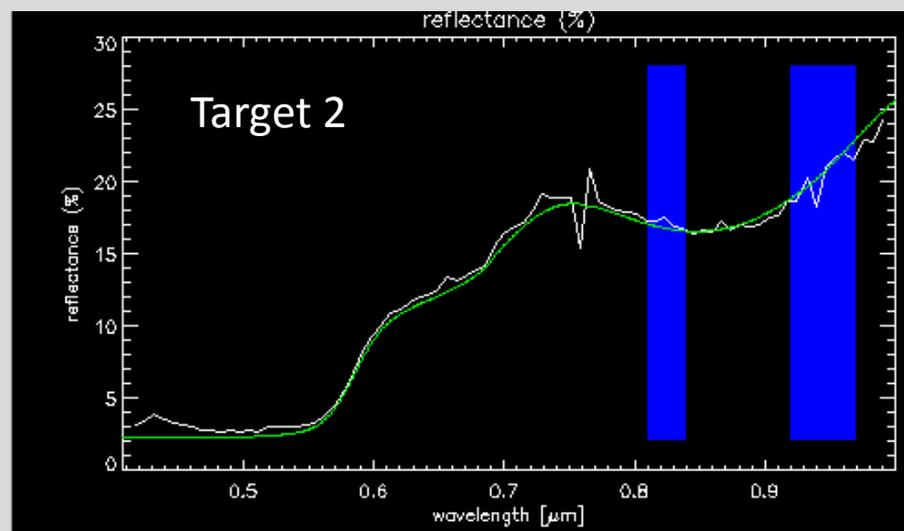
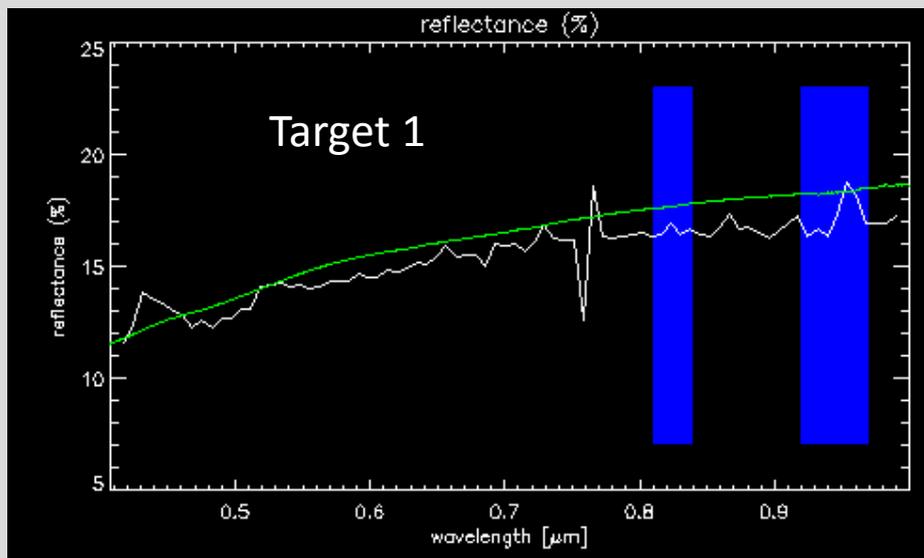


Hypex VNIR 1600

Standard Configuration:



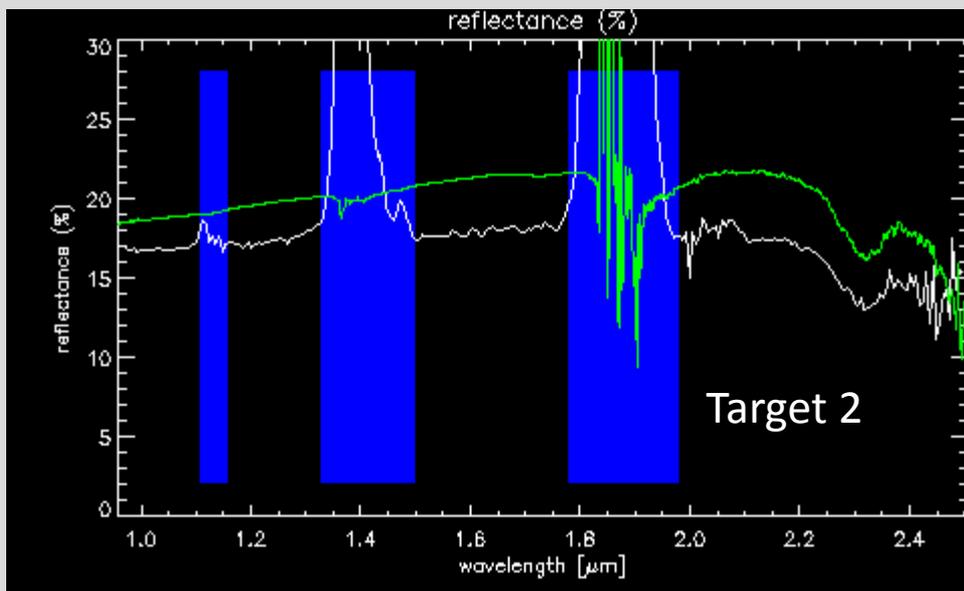
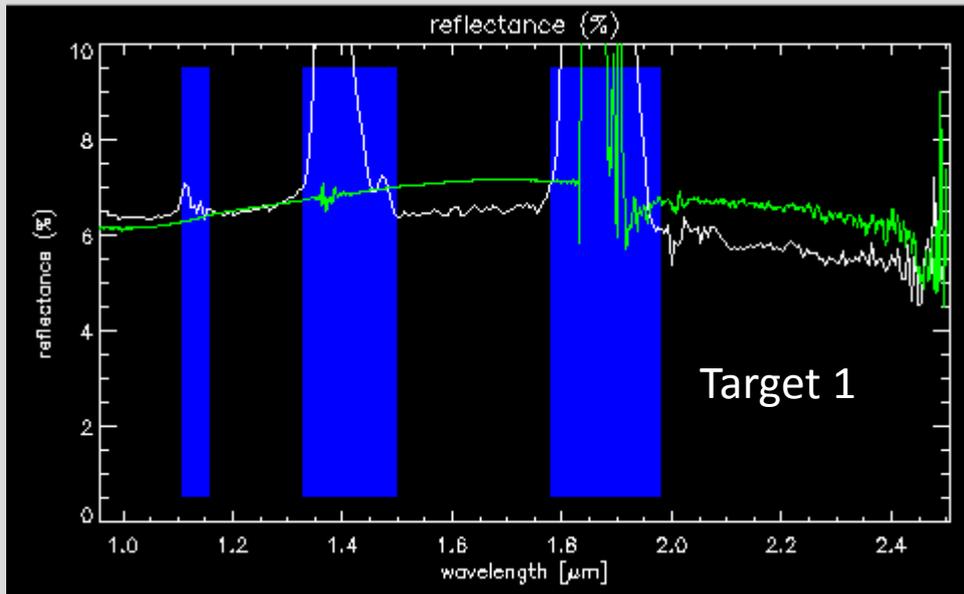
In-flight analysis of HySpex at OpAiRS DLR



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!

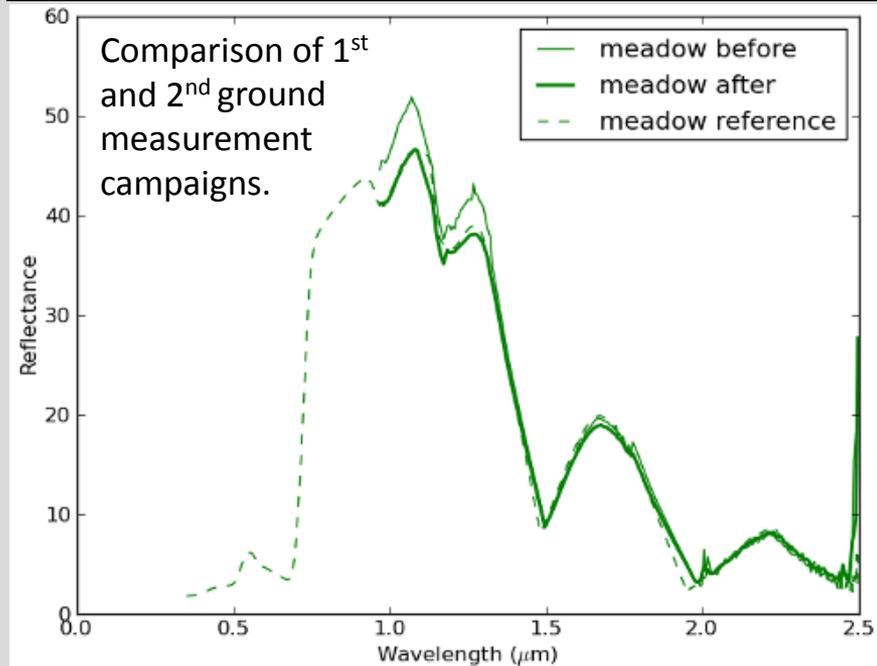
=> Excellent agreement. Well within 2% absolute reflectance for first tests

In-flight analysis of HySpex at OpAiRS DLR

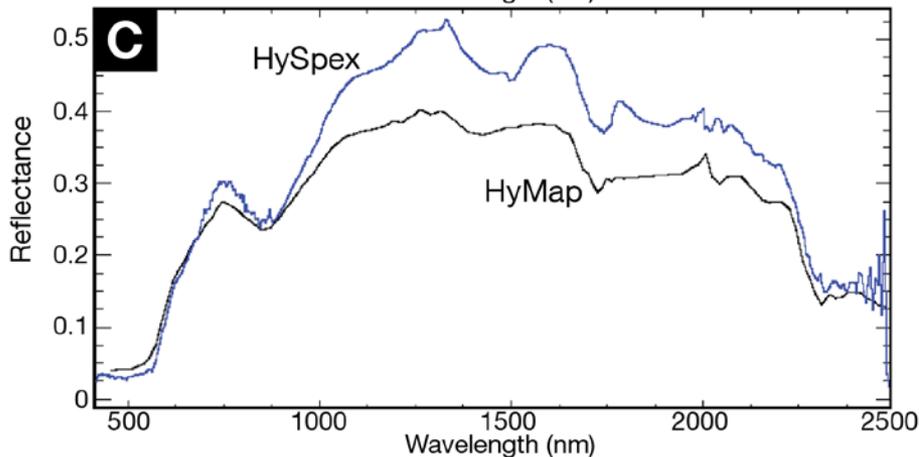
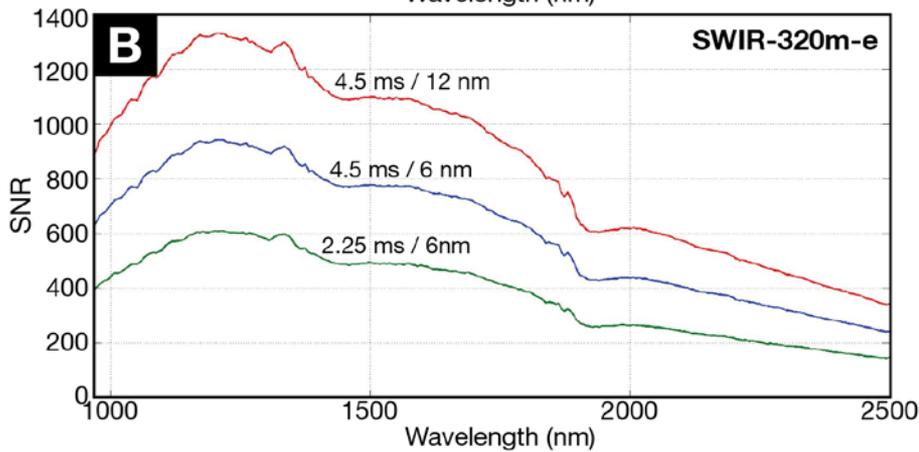
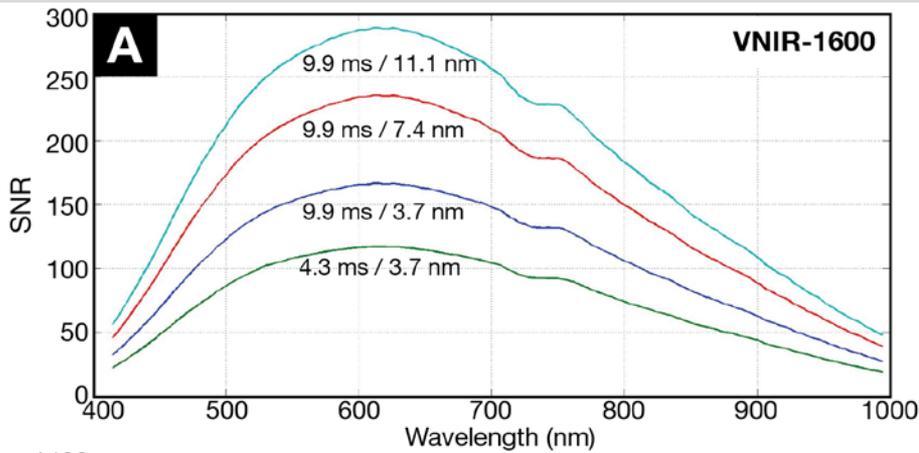


First results for SWIR sensor: Comparison of ground reflectances, *in-situ* measurements as green lines, first ATCOR results as white lines. No spectral or radiometric in-flight calibration applied!

=> Excellent agreement. 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).

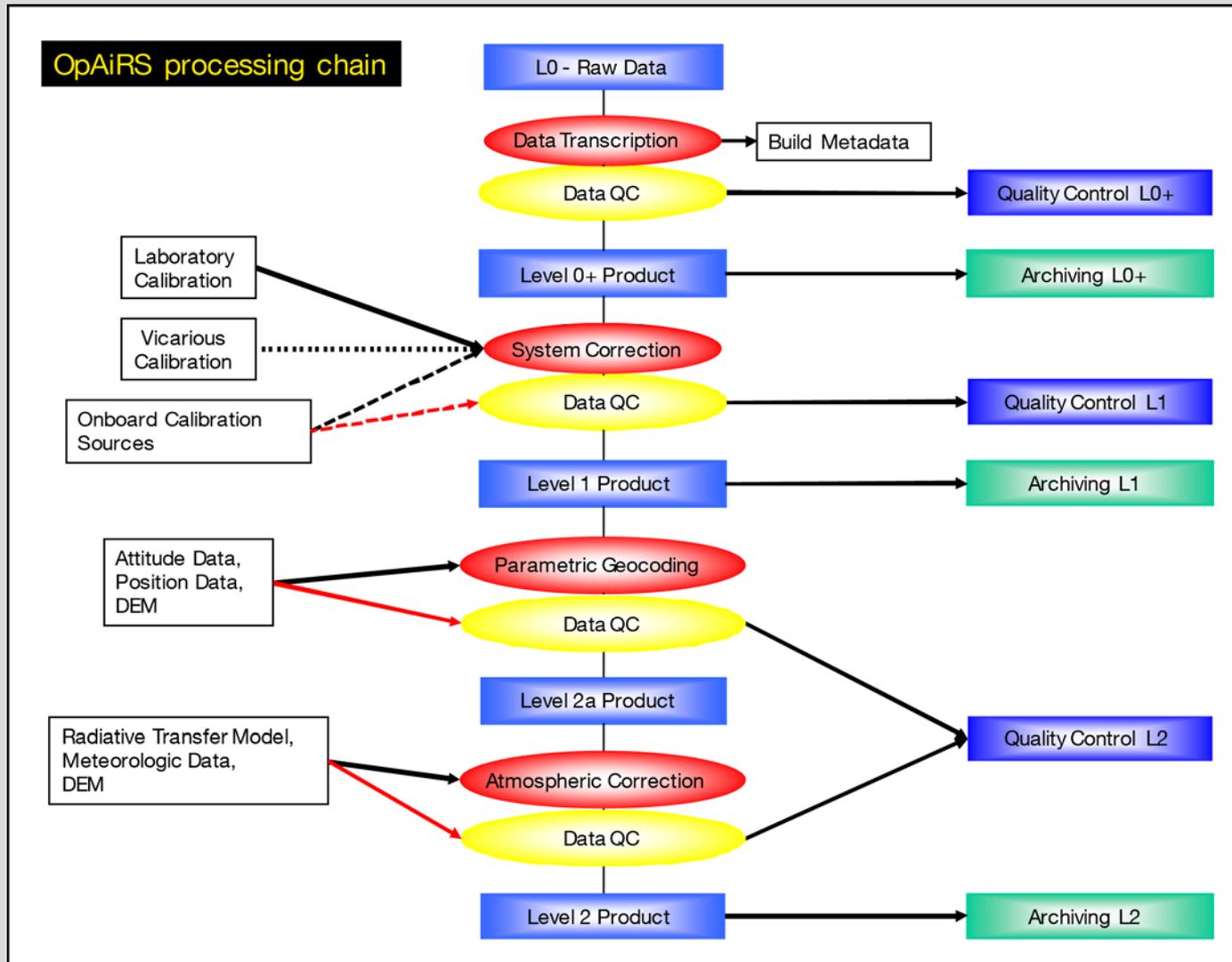
Calibration

- 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](#)

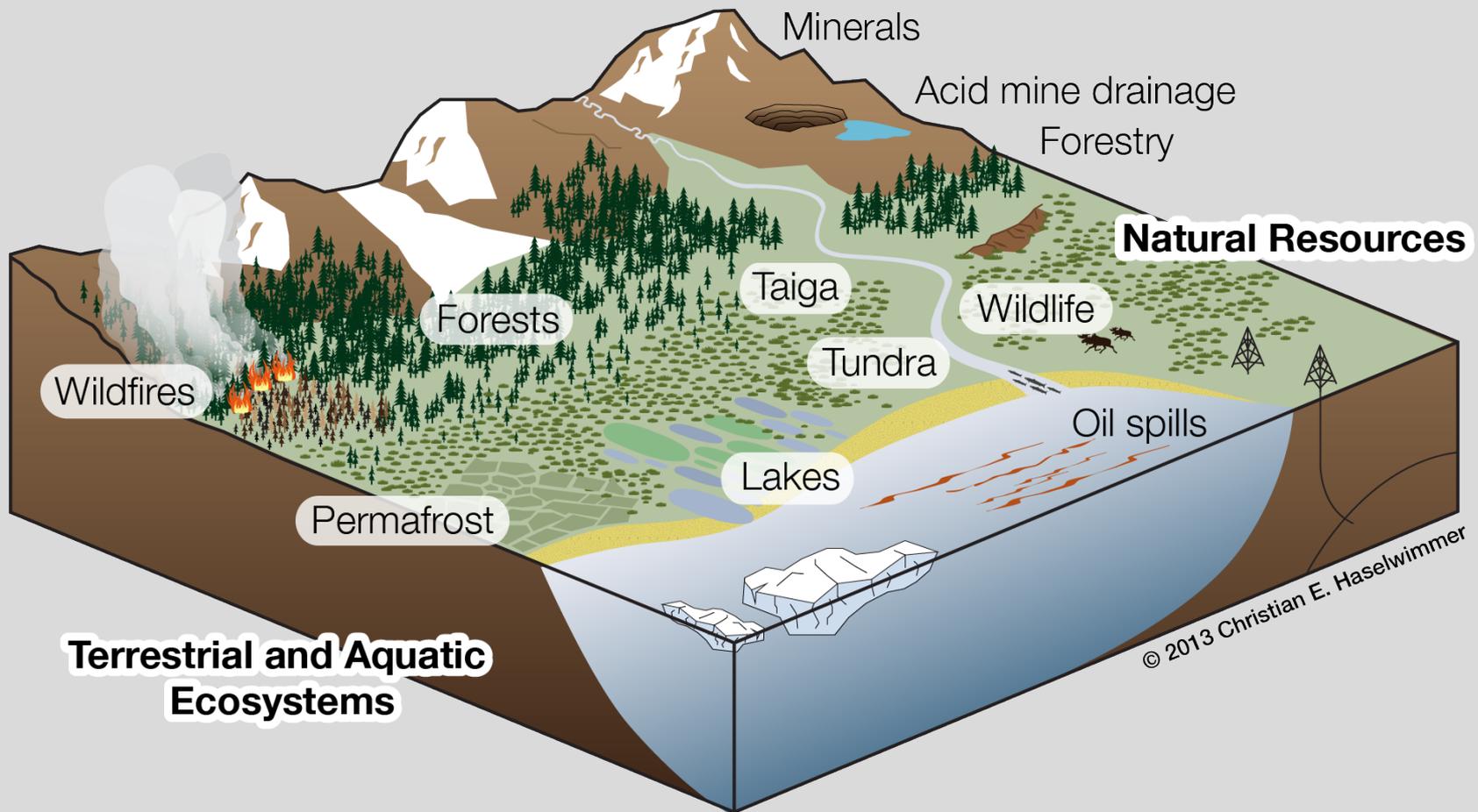
Data Processing



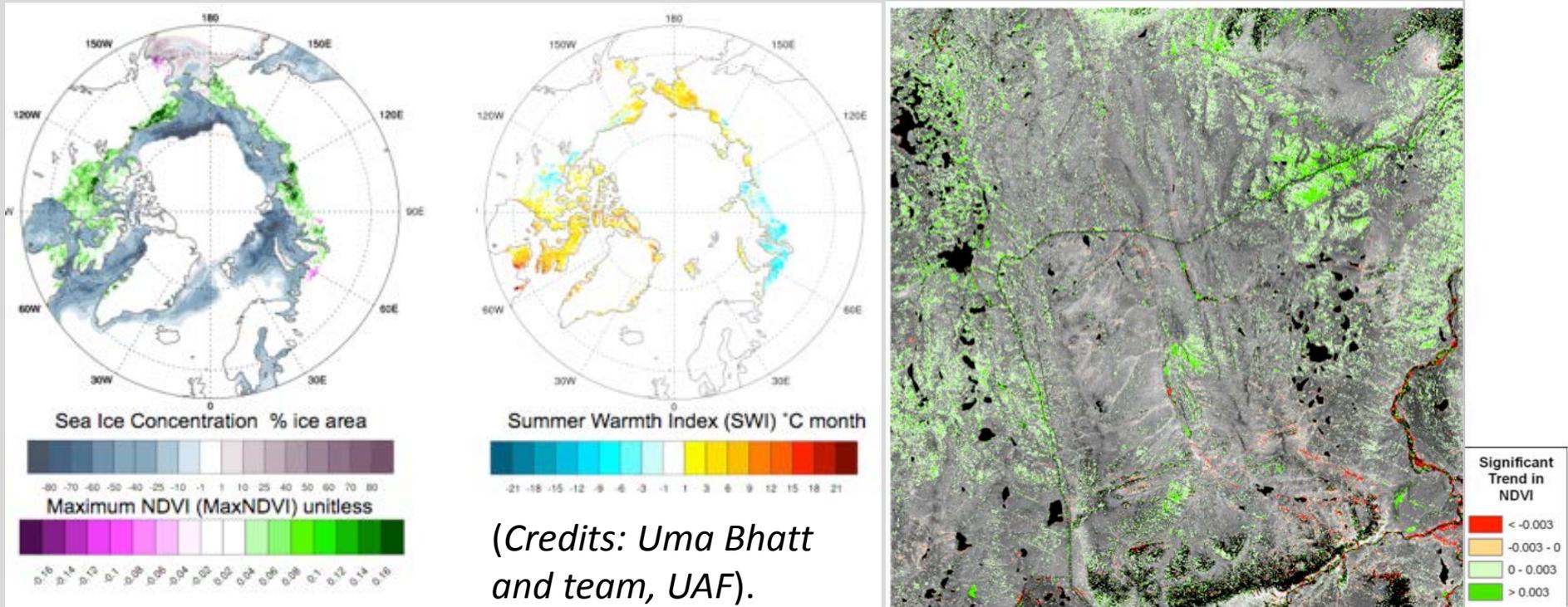
Pre-processing chain used by the DLR OpAiRS facility to convert raw HySpex data to Level 2 georegistered and atmospherically corrected surface radiance and reflectance products (from Bachmann et al., 2012)

Alaskan/Arctic Applications

- Terrestrial and aquatic ecosystem applications
- Natural resource studies



Ecology: Arctic/Boreal Vegetation Change



- 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!

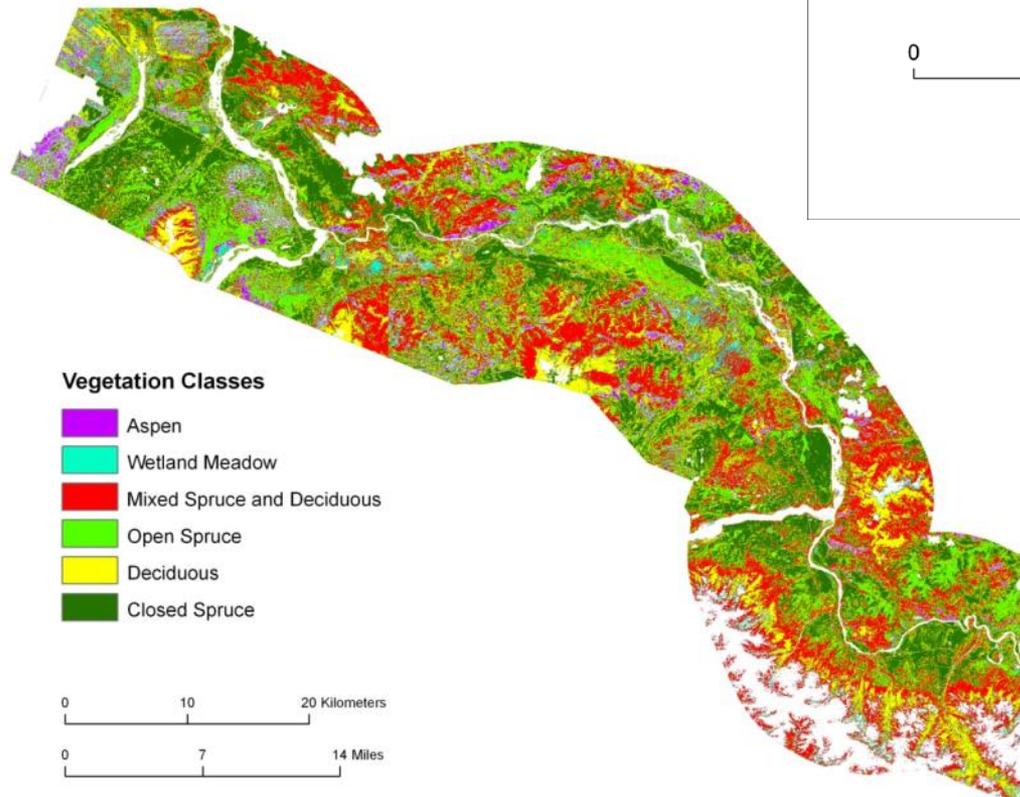
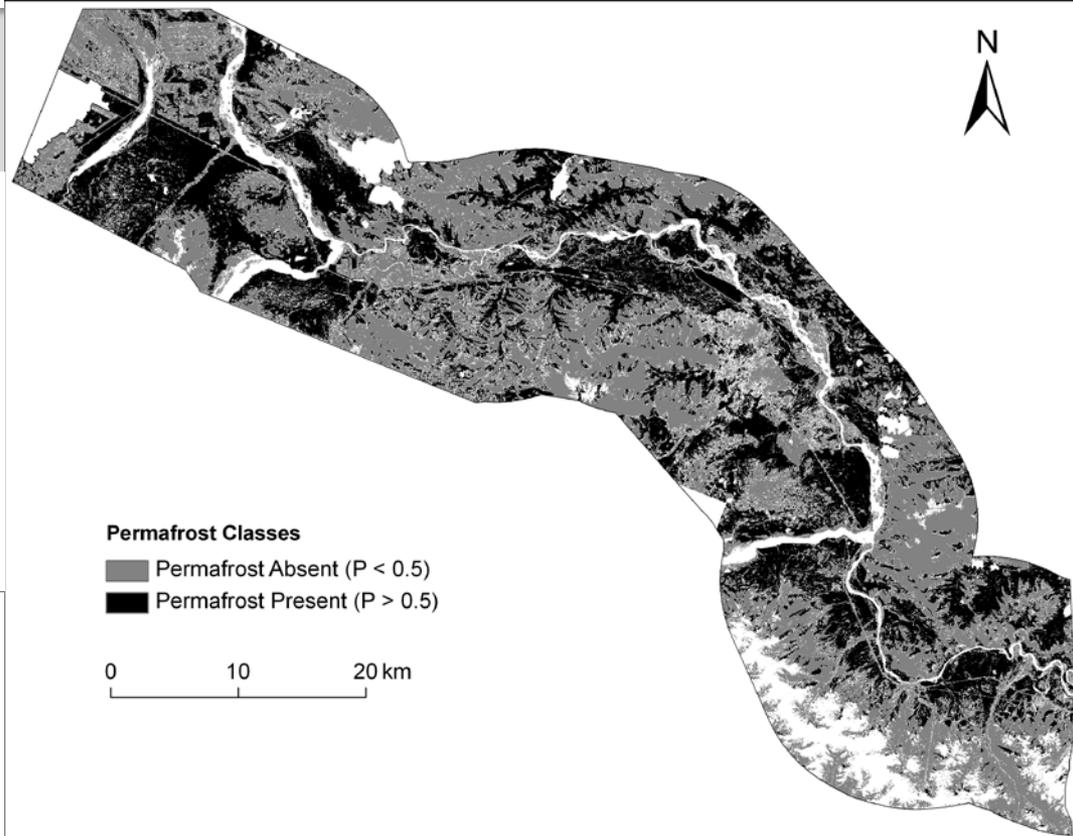


Table 7: Percentage of mapped vegetation classes and percentage of each vegetation classes underlain by shallow (< 1.6 m) permafrost in the study area.

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.

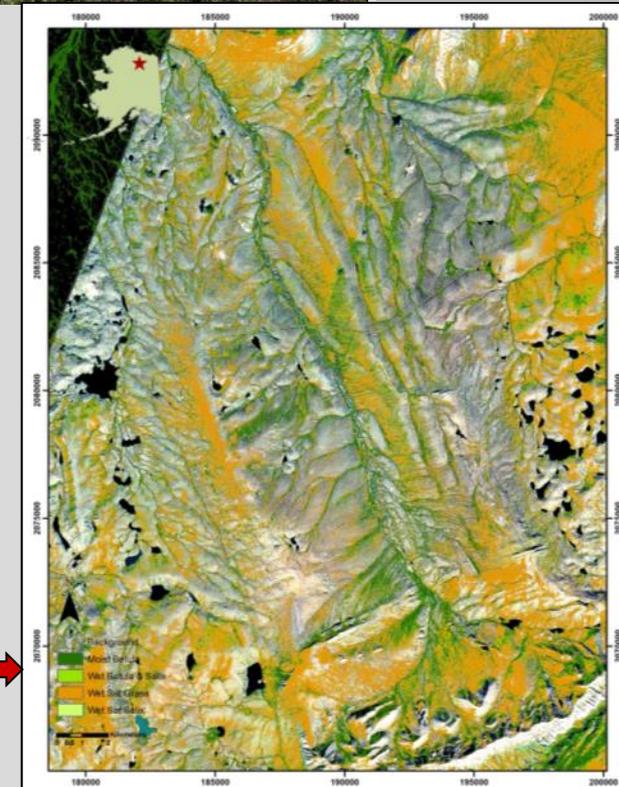
Ecology: Permafrost (Thermokarst / Watertracks)

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.



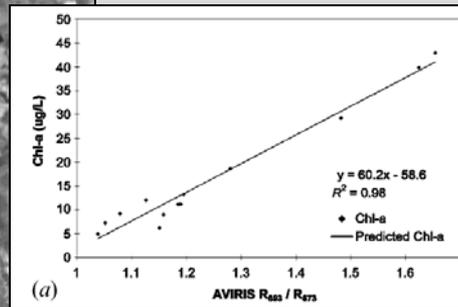
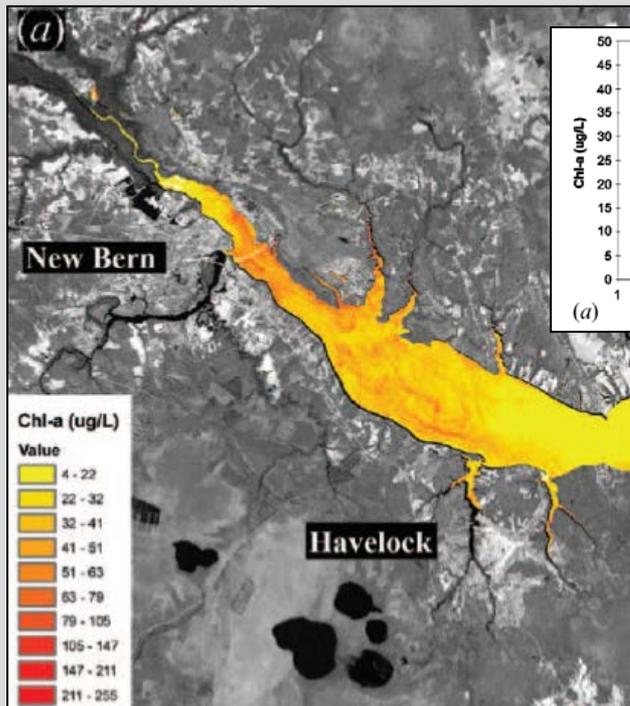
Evolution of water track to gully to stable incised channel. Water tracks are saturated curvilinear features where flow is confined by the permafrost table

- 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]



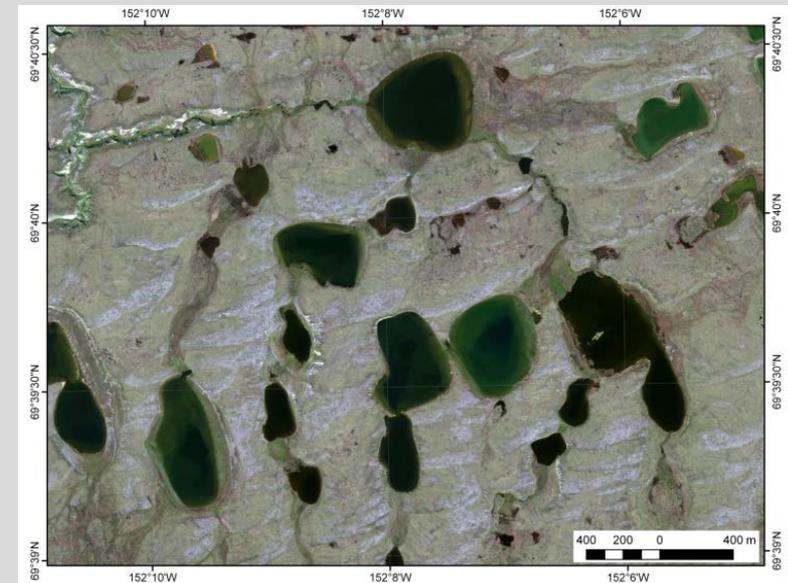
Ecology: Investigating Arctic/sub-Arctic lakes

- Lakes are a critical component of the northern carbon cycle: thermokarst lake development, carbon sinks, CH₄
- Retrieve lake properties, e.g. DOM, Chl, lake depth, substrate
- Links to HypSIRI: algorithm development / upscaling



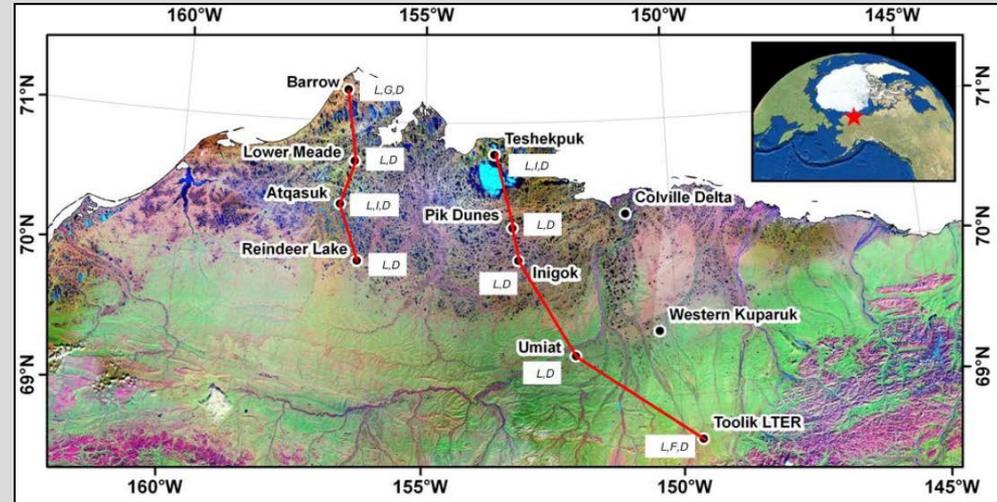
← AVIRIS Chl-a retrieval
(from Lunetta et al., 2009)

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 CH₄ emissions from high latitude lakes in North America using multi-scale remote sensing (Walter Anthony, Gross: UAF)

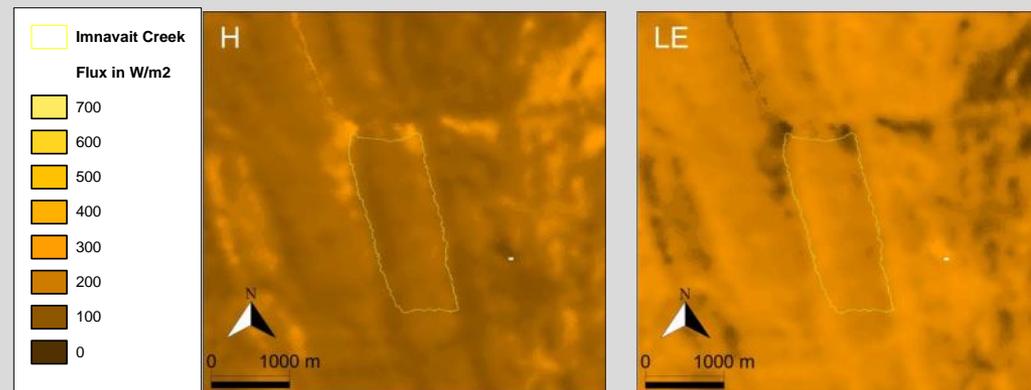


CALON instrumented lake network (Source: Hinkel et al., 2012)

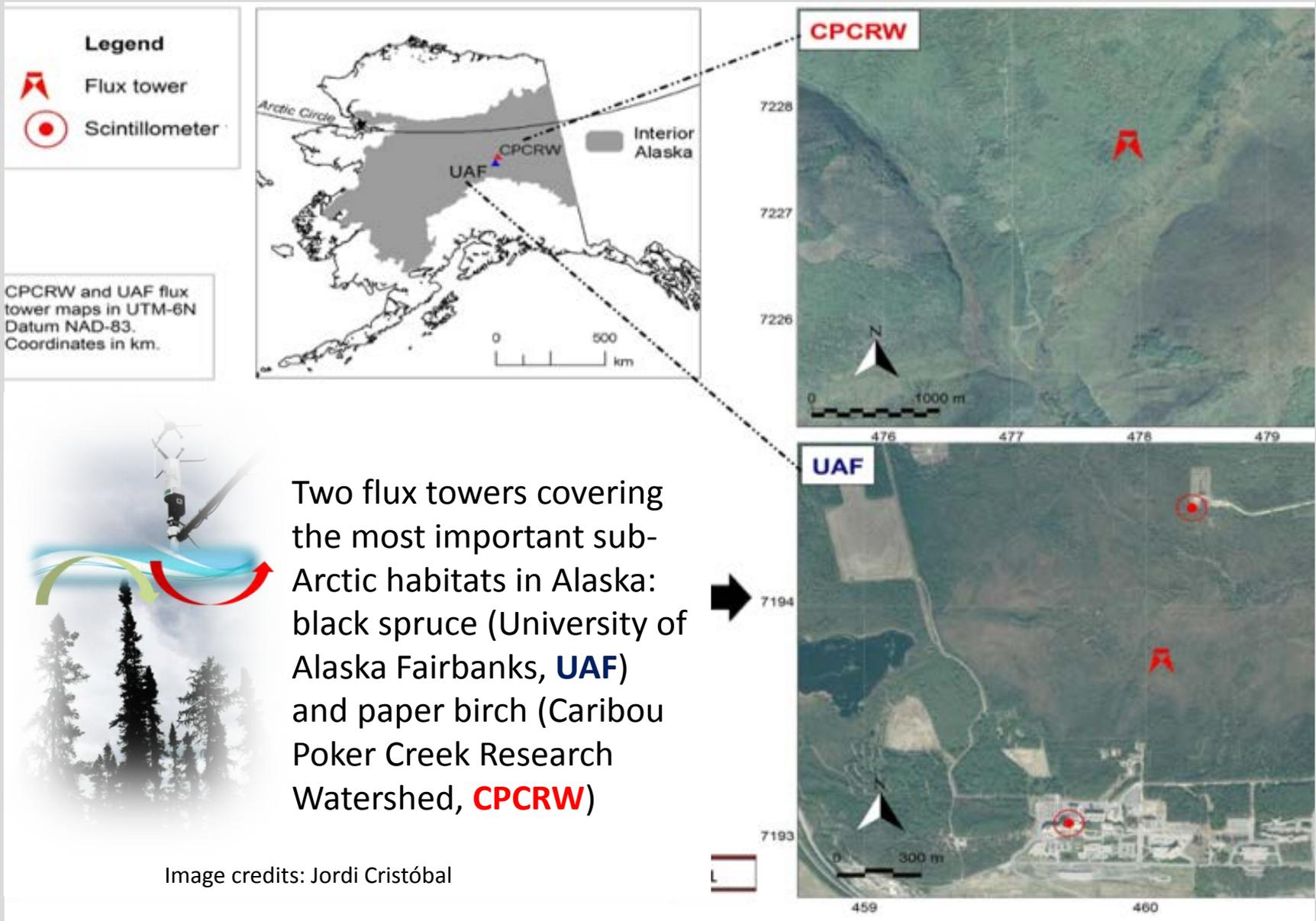


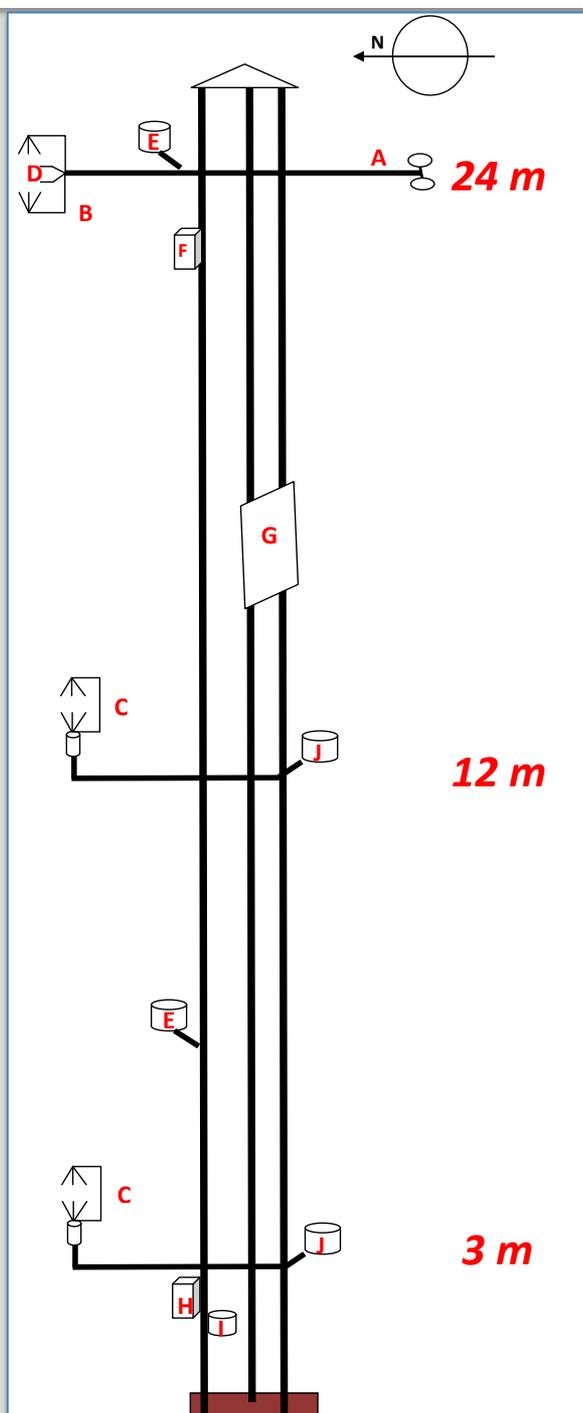
Ecology: Evapotranspiration Mapping

- 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!)



Ecology: Evapotranspiration Mapping





- 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)

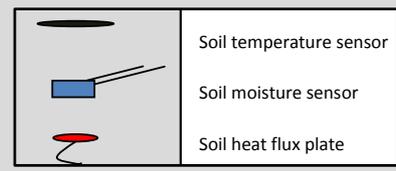
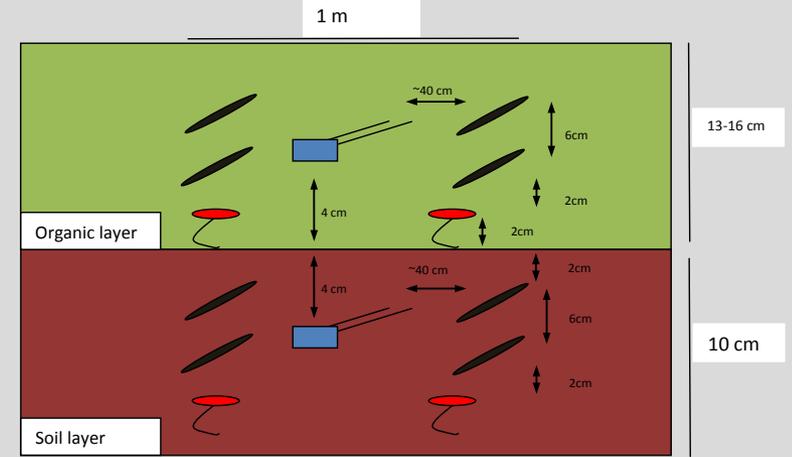
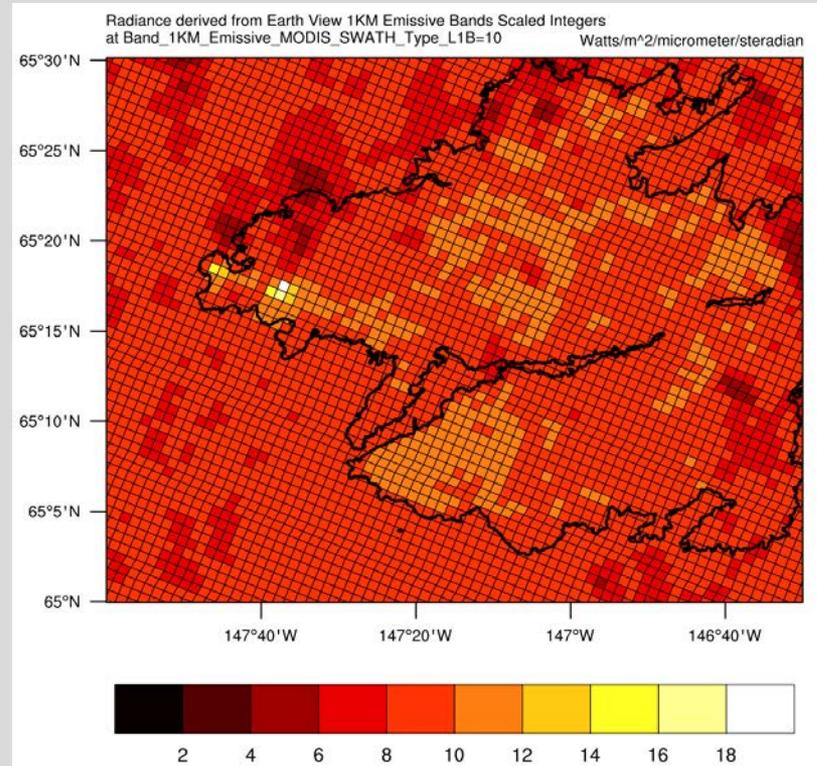
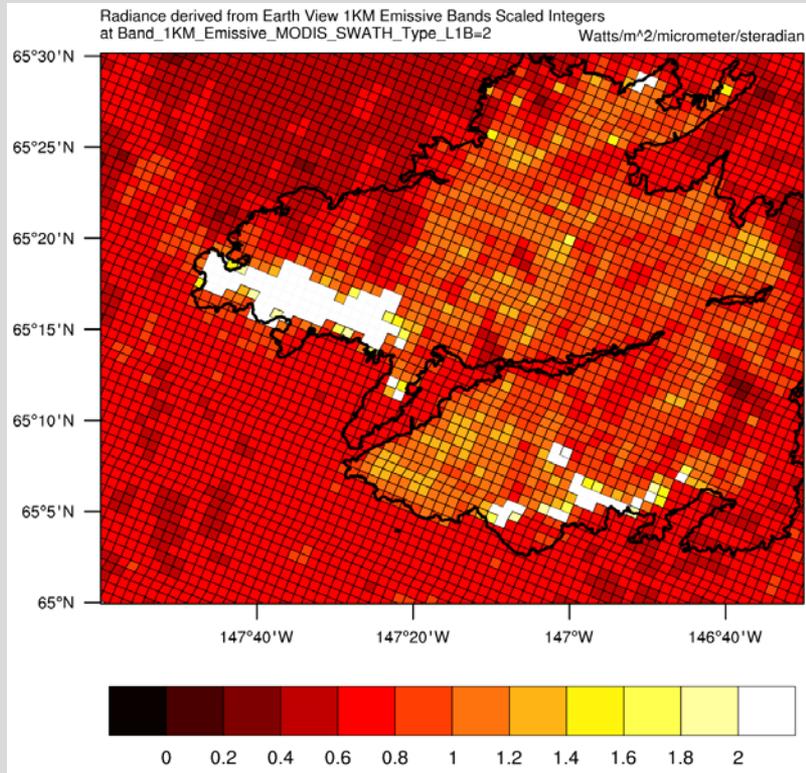


Image credits: Jordi Cristóbal

Ecology: Boreal Forest Fires

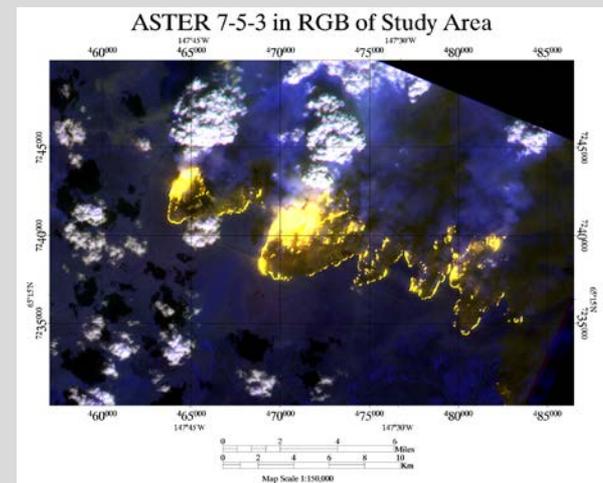
MODIS band 22 (3.96 μm)



MODIS band 31 (11.03 μm)

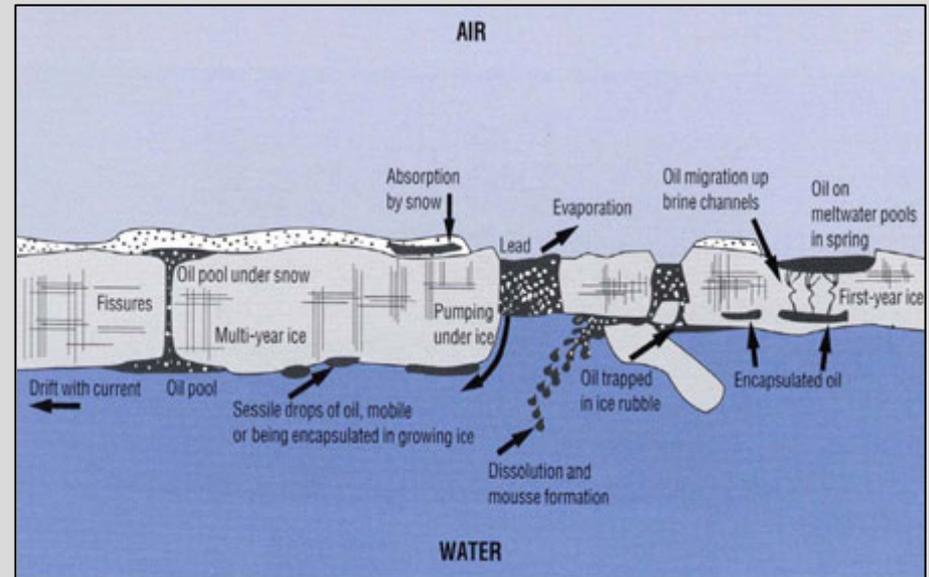
7-17-04, 21:42 UTC, Boundary fire; Credits: Chris Waigl, UAF

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



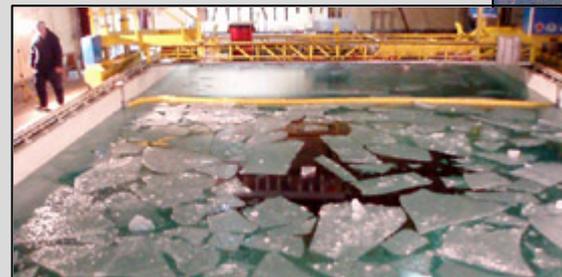
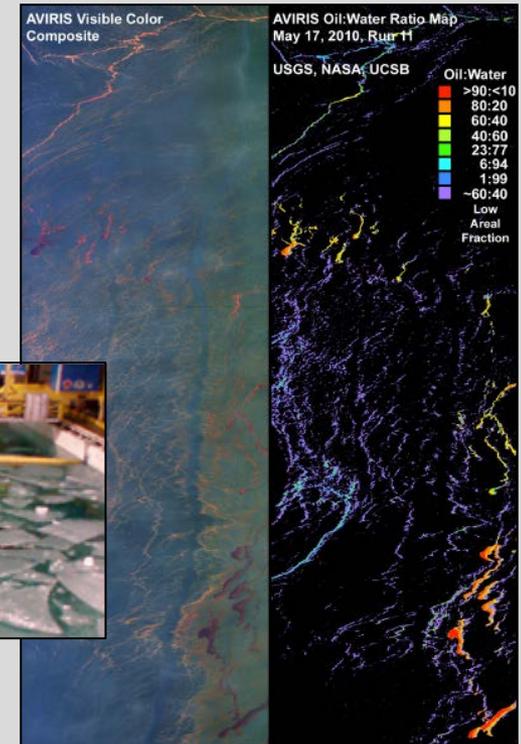
Arctic oil spills

- 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
- HypsIRI contributions: establish Arctic oil spill mapping potential



Manifestations of oil ↑ spills in ice-covered waters

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

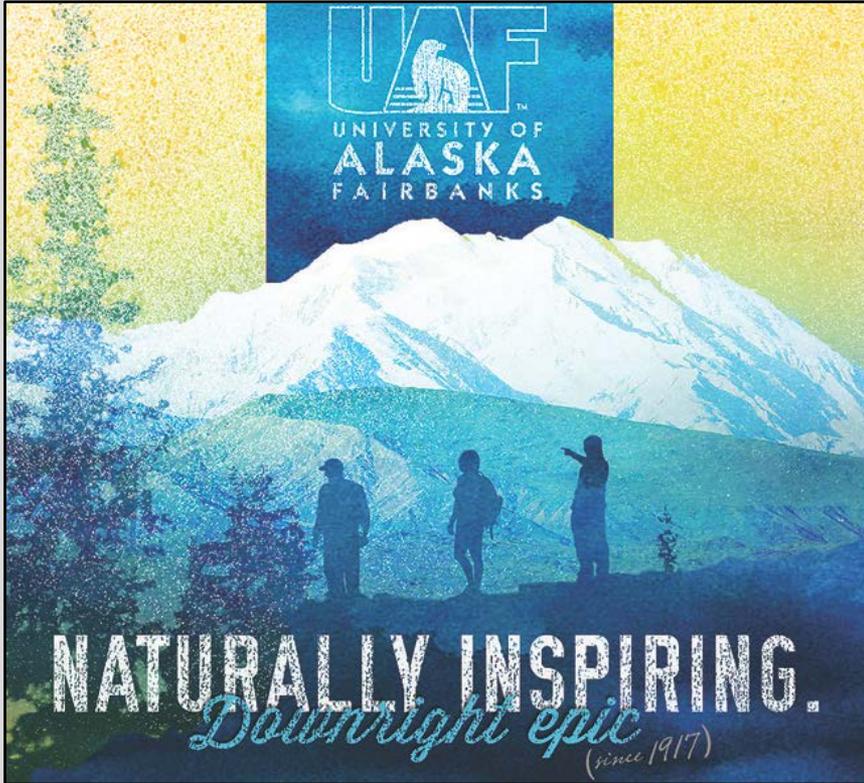


↑ Experimental oil spills at CRREL facility

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

hyperspectral.alaska.edu

