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

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

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)

Current Arctic Vegetation

Projected Arctic Vegetation 2090 - 2100

Current

Seward Peninsula

Projected: Late this Century

- Continuous (90 to 100% of land area frozen)
- Discontinuous (10 to 90% of land area frozen)
- Thawing/Permafrost Free

(Methane ebullition (Source: K Walter Antony)

(Source: Ecopost)

(Source: British Antarctic Survey)

(Source: Busey et al., 2008)
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.

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

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 Imaging Laboratory

People: Partners

PrincipalInvestigators

Anupama Prakash is a Professor in Geophysics (Remote Sensing) at the Geophysical Institute (GI), is the Associate Dean for UAF's College of Natural Sciences and Mathematics (CNSM), and is the Director for CNSM Division of Research (CDR). Her research interests include in situ and remote sensing. Her expertise is in thermal remote sensing and imaging spectroscopy. She also teaches courses in remote sensing and GIS at UAF. For more information visit www.alaska.edu/prakash or contact her at prakash@alaska.edu.

Christian Haselwimmer is remote sensing scientist with interests in the application of remote sensing to energy and environmental resource studies. He is currently a remote sensing scientist at the Chevron Energy Technology Company. Prior to this, he was a postdoc at the Geophysical Institute, where he used hyperspectral data to identify seafloor geologic features in the Beaufort Sea. His research interests include optical remote sensing and hyperspectral imaging. He can be reached at chthrus@gmail.com.

Glen Hampton is a Press Assistant Professor in the Department of Geology at the University of California, Santa Barbara, where he started in January 2014. He currently serves as Chair of the Geology Department. His research interests include in-situ measurement of surface water and geophysical properties of water. He can be reached at hampton@alaska.edu.

Tom Kempa is the Airborne Observatory Platform (AOP) Instrument Scientist responsible for the SEON Imaging Spectrometer and science algorithm development and validation. Prior to joining NEON, Inc., he was a Staff Consultant in Electronic Design at Ball Aerospace & Technologies Corp. where he was instrumental in the design and development of earth remote sensing systems including QuickBird, CAI-FOR, and conceptual designs for several SEES missions.

Senior Personnel / External Collaborators

Martin Sachmann & Andreas Muller - German Aerospace Center (DLR)
Rob Green - Jet Propulsion Laboratory

hyperspectral.alaska.edu or hylab.alaska.edu
### Project Overview

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<td>1</td>
<td>Instrument acquisition</td>
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<td>2</td>
<td>Establish final instrument specification, write contract, and place order</td>
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<td>3</td>
<td>Setup project website</td>
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<td>4</td>
<td>Setup instrument calibration facility</td>
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<td>5</td>
<td>Preparatory work for airborne sensor integration</td>
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<td>Instrument manufacture at NEO</td>
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<td>7</td>
<td>Visit to DLR</td>
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<td>8</td>
<td>Instrument commissioning</td>
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<td>9</td>
<td>Instrument delivery to UAF: training and preliminary testing with NEO</td>
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<td>10</td>
<td>Initial testing and laboratory calibration/characterization of instrument at UAF</td>
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<td>11</td>
<td>Instrument tests at UAF including field vicarious calibration experiment</td>
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<td>12</td>
<td>Development of operational procedures and data processing chain</td>
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<td>13</td>
<td>Instrument deployment</td>
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<td>14</td>
<td>Laboratory calibration/characterization of instrument at NEON</td>
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<td>15</td>
<td>UAF MayMester short course on &quot;Field and Imaging Spectroscopy&quot;</td>
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<td>16</td>
<td>Laboratory calibration check at UAF, airborne integration, and field vicarious calibration</td>
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<td>17</td>
<td>Planning for airborne instrument deployments in Summer 2015</td>
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<td>18</td>
<td>Airborne deployments of instrument over Fairbanks and North Slope study sites</td>
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<tr>
<td>19</td>
<td>Potential project team meetings</td>
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<td>HyspIRI Workshop 2013</td>
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<td><strong>Manufacturer</strong></td>
<td>NEO / HySpex</td>
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<tr>
<td><strong>Model</strong></td>
<td>VNIR-1600</td>
<td>SWIR-384</td>
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<tr>
<td><strong>Spectral range (nm)</strong></td>
<td>400 - 1000</td>
<td>930 - 2500</td>
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<tr>
<td><strong>No of bands</strong></td>
<td>160</td>
<td>288</td>
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<tr>
<td><strong>Radiometric resolution</strong></td>
<td>12 bit</td>
<td>14 bit</td>
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<td><strong>Spectral sampling (nm)</strong></td>
<td>3.7</td>
<td>6</td>
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<tr>
<td><strong>Spatial pixels</strong></td>
<td>1600</td>
<td>384</td>
<td></td>
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<tr>
<td><strong>SNR (peak)</strong></td>
<td>250:1</td>
<td>500:1</td>
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<tr>
<td><strong>Dimensions (lwh in cm)</strong></td>
<td>29 x 14 x 36</td>
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<tr>
<td><strong>Approx weight for system (kg)</strong></td>
<td>20</td>
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<tr>
<td><strong>Power consumption (W)</strong></td>
<td>160</td>
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Hyspex VNIR 1600

Standard Configuration:

- Flying height: 1600m (800m with FOV expander)
- 160 spectral bands: 400-1000nm
- 1600 spatial pixels
- Area coverage rate: 70.6 sq km/hr
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

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%

Comparison of 1\textsuperscript{st} and 2\textsuperscript{nd} ground measurement campaigns.
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
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.

<table>
<thead>
<tr>
<th>Vegetation Class</th>
<th>Vegetation Class (%)</th>
<th>Permafrost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>8.1</td>
<td>0.0</td>
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<tr>
<td>Closed Spruce</td>
<td>34.0</td>
<td>87.0</td>
</tr>
<tr>
<td>Deciduous</td>
<td>7.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Mixed Spruce and Deciduous</td>
<td>36.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Open Spruce</td>
<td>11.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Wetland Meadow</td>
<td>3.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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.

- 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)
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
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

- 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
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