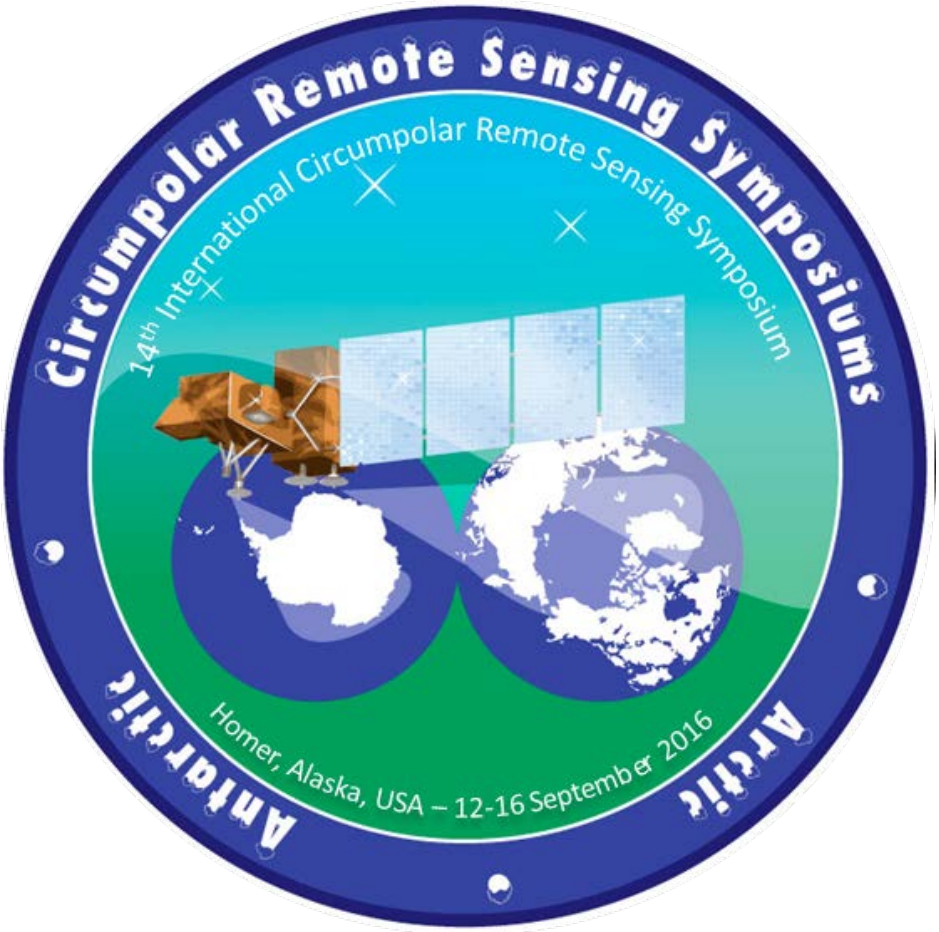
Welcome to the 14th International Circumpolar Remote Sensing Symposium



Homer, Alaska USA

12-16 September 2016

14th ICRSS Program

Monday DAY 1, September 12

5:00 - 6:00 PM	**Registration Desk Open at Islands and Ocean Center**
6:00-9:00 PM	**Icebreaker with light snacks—Islands and Ocean Center**

Tuesday DAY 2, September 13

8:00 AM	**Registration Desk Open**
8:00-9:00 AM	Coffee/Tea and small breakfast snacks
9:00 AM	Welcome Speech / Conference Kickoff
9:10 AM	Gareth Rees – History of the ICRSS
9:30 AM	Ed Berg—Drought, Fire and Bark Beetles: A Short History of the Kenai Peninsula since the Glaciers Left
10:10 AM	**Break** (coffee/tea available, with light snack)
10:40 AM	Jon Dewitz—The North American Land Change Monitoring System (NALCMS) and The U.S. National Land Cover Database (NLCD)
11:10 AM	Charles Miller—Arctic-boreal remote sensing during the 2017 ABoVE airborne campaign
11:40 AM	Elizabeth Hoy—The NASA Arctic-Boreal Vulnerability Experiment and the ABoVE Science Cloud: Accelerating Science with Cloud Technologies
12:10 PM	**Lunch** (lunch provided as part of the symposium)
1:30 PM	Dan Hayes—A model-data integration framework for NASA-ABoVE: the role of remote sensing in process-based model representation of Arctic ecosystem dynamics
2:00 PM	Teri Balser—Spatiotemporal variation in recent (2002-2015) browning and

	greening trends in the Arctic-Boreal Region of western North America: regional differences, post-fire trends, and time-series effects.
2:30 PM	Damien Sulla-Menashe—Landscape-Scale Histories and Active Monitoring of Disturbance, Seasonality and Greenness Trends for ABoVE from Landsat
3:00 PM	**Break** (coffee/tea available, and cookies)
3:20 PM	Gareth Rees—Statistical characteristics of subarctic vegetation on the basis of ground hyperspectral measurements
3:50 PM	Alison Beamish—Detection of low Arctic tundra vegetation community type, phenophase, and biophysical parameters using narrow-band indices in the visible and red-edge spectrum.
4:20 PM	Anupma Prakash—HyLab: a hyperspectral laboratory for surface water and vegetation characterization in Alaska's Arctic and boreal regions
5:00-7:00 PM	**Posters at Islands and Oceans Center with moderate snacks**
7:00 PM	**End of Day 2, Dinner on your own**

Wednesday DAY 3, September 14—Permafrost Remote Sensing Session

8:00 AM	**Registration Desk Open**
8:00-9:00 AM	Coffee/Tea and small breakfast snacks
9:00 AM	Introduction to Remote Sensing of Permafrost
9:20 AM	Ronald Daanen—Permafrost Remote Sensing Trough Airborne Electromagnetic Geophysics and Thermal Anomalies
9:50 AM	Melissa Ward—Monitoring thermokarst activity and landscape change in the Eureka Sound Lowlands, Ellesmere Island, Nunavut
10:20 AM	**Break** (coffee/tea available, with light snack)
10:40 AM	Go Iwahana—InSAR Detection and Field Evidence for Thermokarst after a Tundra Wildfire, Using ALOS-PALSAR

11:10 AM	Benjamin Jones—Remotely sensing post-fire land surface changes in the Arctic using repeat airborne LiDAR and Landsat trend analysis
11:40 PM	**Lunch** (lunch provided as part of the symposium)
1:00 PM	Guido Grosse—Remote sensing observations of lake change in Bering Land Bridge National Preserve, Northern Seward Peninsula, from 1949-2015
1:30 PM	Allen Bondurant—Thermokarst Lake Expansion Dynamics on the Arctic Coastal Plain of Alaska
2:00 PM	**End of Conference Presentations on Day 3**
5:00-8:00 PM	**Conference banquet aboard the M/V Rainbow Connection**

Thursday DAY 4, September 15

8:00 AM	**Registration Desk Open**
8:00-9:00 AM	Coffee/Tea and small breakfast snacks
9:00 AM	Bruce Quirk—Applying UAS Technology for Monitoring Wildlife and Natural Resources
9:30 AM	Mark Laker—Off the Shelf Digital Cameras for Remote Sensing Applications
10:00 AM	Isaiah Ditmer—Acquisition of airborne LiDAR data in Alaska
10:30 AM	**Break** (coffee/tea available, light snack)
10:50 AM	Ed Berg—Application of LiDAR for paleo-lake level reconstruction in closed-basin lakes, Kenai Peninsula, Alaska
11:20 AM	Carson Baughman—Remotely sensing a cold region dune field using airborne LiDAR and high resolution aerial photography
11:50 PM	**Lunch** (lunch provided as part of the symposium)
1:10 PM	Wenkai Guo—Remote sensing characterization of the location and dynamics of the arctic treeline
1:40 PM	Christopher Neigh—Delineating the Taiga-Tundra Ecotone with Landsat,

	LiDAR and Spaceborne Sub-meter Imagery
2:10 PM	Gerald V. Frost—A regional quantitative cover map of tundra plant functional types in arctic Alaska
2:40 PM	**Break** (coffee/tea available, perhaps light snack)
3:00 PM	Sam Skinner—North Yukon Disturbance Tracking
3:30 PM	Jordi Cristobal—Estimating surface energy fluxes in Arctic ecosystems using a thermal-based remote sensing model
4:00 PM	Chip Miller—Challenges for satellite remote sensing of Arctic CO2 and CH4 patterns
4:30 PM	**End of Day 4**
6:00 PM	**ICRSS Tribute Event**

Friday DAY 5, September 16

8:00 AM	**Registration Desk Open**
8:00-9:00 AM	Coffee/Tea and breakfast snacks
9:00 AM	Matt Macander—Mapping Snow Persistence Patterns at Regional Scales in Alaska
9:30 AM	Michael Verrier—Lake Ice Phenology of Southwest Alaska
10:00 AM	Tyler de Jong—Comparing sea ice conditions and acoustic data in the Amundsen Gulf to assess bowhead whale habitat
10:30 AM	**Break** (coffee/tea available, light snack)
10:50 AM	Symposium Wrap Up
12:00 PM	**End of Symposium**

Thanks to our Symposium Sponsors!

Drought, Fire and Bark Beetles - A short history of the western Kenai Peninsula since the glaciers left

Ed Berg[1]

1 US Fish & Wildlife Service (Retired), Kenai National Wildlife Refuge; Kenai Peninsula College

Tuesday, 13 September, 9:30

The Kenai Peninsula is often described as "Alaska in miniature" because it has the basic geographic elements of every part of the state, but on a smaller and more accessible scale which makes it popular with visitors. The Kenai Mountains spine of the Peninsula casts a deep rainshadow over the western Kenai lowland that creates a relatively dry landscape similar to Interior Alaska. Proximity to the Gulf of Alaska moderates air temperatures, with Kachemak Bay as the "Banana Belt" of Alaska.

The arid climate of the western Kenai makes it sensitive to drought, fire and spruce bark beetles. The last glacial period began to wind down 18,000 years ago, leaving behind hundreds of kettle-hole lakes with high water levels. There was a major drought 14,000 to 9000 years ago, which drew down closed-basin lake levels 20 to 30 ft, in a landscape dominated by hardwood shrubs. Lake levels began to rise 10,000 years ago, and reached modern levels about 5000 years ago. White spruce arrived 8000 years ago. The climate became substantially wetter and cooler about 5000 years ago, hastening the arrival of black spruce. Although black spruce is a very flammable fuel type, the fire frequency dropped by 50% with its arrival due to the much wetter climate, as shown by pollen, charcoal and plant macrofossil records from lake sediments and peat deposits.

Fire history studies using fire scars, soil charcoal and lake sediments show three distinct fire regimes: black spruce with a mean fire return interval of 80 yrs and mixed white spruce and hardwoods with a fire interval of 130 yrs in the central Kenai, and white/Lutz spruce of with a fire interval of 400-600 years in the wetter southern Kenai. Spruce bark beetles are the primary source of forest mortality on the Kenai with most stands being thinned by every 50 years or so, with major regional outbreaks in the 1880s and 1990s. The bark beetle outbreaks are closely tied to the El Nino phase of the ENSO cycle, when it produces runs of 2 or more warm summers.

The Kenai landscape began warming and drying with the end of the Little Ice Age in the 1850s, as shown by retreating glaciers and black spruce invasion of wetlands. Falling closed-basin lake levels (~1 m) and recent invasion of hardwood shrubs into wetlands show that the drying has accelerated in the central Kenai since a 1968-69 drought. Climate models to the year 2100 project a drier future Kenai, and some vegetation

models project a grass savannah, where tree growth is severely limited by drought stress. A similar landscape drying in the 14,000-9,000 yr period supported a hardwood shrubland with a high fire regime, which may be an alternative scenario to the grass savannah or perhaps more likely will be the longer term scenario beyond 2100.

The North American Land Change Monitoring System (NALCMS) and the U.S. National Land Cover Database

Jon Dewitz[1], Collin Homer[1]

[1] U.S. Geological Survey

Tuesday, 13 September, 10:40

The U.S. National Land Cover Database (NLCD) is currently designed to provide ten-year cyclical updating of Alaska's land cover and associated changes. The current NLCD product provides descriptive data on the characteristics of the land surface and is based on Landsat satellite imagery taken in 2011. This extensive database describes the land cover of each 30-meter cell of land in Alaska, and identifies which ones have changed since the year 2001. These products now provide a 10 year land cover change story for Alaska. Having a decade of change information now available enables users to better understand the trajectory of land cover change patterns, and provides critical information to advance understanding of land cover change processes. NLCD data also represents the U.S. contribution to the North American Land Change Monitoring System (NALCMS) which is a trilateral effort between Canada, the United States, and Mexico to develop a consistent continental dataset for tracking land cover change. NLCD has been modified to help create the first North American 30m landcover, due to be released later this year. This talk will discuss NLCD results in Alaska, talk about potential NLCD future plans, and highlight the current effort to transform NLCD data into a consistent North American 30m landcover database.

Arctic-boreal remote sensing during the 2017 ABoVE airborne campaign

Charles Miller[1]

[1] Jet Propulsion Laboratory, California Institute of Technology and the ABoVE Working Group

Tuesday, 13 September, 11:10

We will present an overview of integrated airborne science research strategies for NASA's Arctic Boreal Vulnerability Experiment (ABoVE). Proposals for studies and measurements in support of the 2017 campaign are due to NASA 1 August 2016, and selections are expected in late Fall 2016. Detailed flight planning will occur during Fall/Winter 2016/17.

ABoVE airborne research will link field-based, process-level studies with geospatial data products derived from satellite remote sensing, spanning the critical intermediate space and time scales that are essential for a comprehensive understanding of scaling issues across the ABoVE Study Domain and extrapolation to the pan-Arctic. ABoVE airborne campaigns can provide remote sensing data with higher spatial and temporal resolution than available from satellite sensors as well as measurements that are not currently available from space. ABoVE airborne campaigns provide unique opportunities to validate satellite data for northern high latitude ecosystems, develop and advance fundamental remote sensing science, and explore and exploit new scientific insights from innovative sensor combinations.

ABoVE is driven by the question: How vulnerable or resilient are ecosystems and society to environmental change in the Arctic and boreal region of western North America?"

To address this overarching question, research during ABoVE is organized around six Science Themes that represent critical aspects of Arctic and boreal social-ecological systems: society, disturbance, permafrost, hydrology, flora and fauna, and carbon biogeochemistry. ABoVE airborne campaigns must coordinate timing, flight lines, sensor suites, etc to maximize scientific benefit and ensure delivery of critical data over ABoVE field investigations. The size and ecological complexity of the ABoVE experimental domain further complicates the development an integrated airborne remote sensing research strategy.

ABoVE envisions major airborne campaigns in 2017 and 2019 with the potential for less comprehensive bridging activities in 2018. The strategy involves Foundational Measurements made with the NASA facility instruments UAVSAR, AirMOSS, LVIS and

AVIRIS-NG. These will provide domain-wide sampling and coverage of ABoVE field sites. Additional measurements could be made by other sensors with an emphasis on higher resolution coverage over specific field sites or portions of the experimental domain. The strategy will seek to leverage complementary NASA airborne activities such as ICEBridge and SnowEx, pre-launch airborne acquisitions for NISAR, HyspIRi and ASCENDS, as well as activities sponsored by partner agencies. Coordination with ongoing or planned Canadian airborne remote sensing (eg lidar-based boreal forest inventories) would be a key aspect of this strategy.

The NASA Arctic-Boreal Vulnerability Experiment and the ABoVE Science Cloud: Accelerating Science with Cloud Technologies

Elizabeth Hoy [1], Peter Griffith [2], Dan Duffy [3], Amy Hendricks [4], John Fitz [4]

[1] NASA Carbon Cycle and Ecosystems Office/GST, Inc.
[2] NASA Carbon Cycle and Ecosystems Office/SSAI
[3] NASA Center for Climate Simulation (NCCS)
[4] NASA Carbon Cycle and Ecosystems Office

Tuesday, 13 September, 11:40

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a field campaign sponsored and initiated by NASA's Terrestrial Ecology Program. This large-scale study is assessing changes to terrestrial and freshwater ecosystems in the Arctic and boreal regions of western North America and the implications of these changes for local, regional, and global social-ecological systems. Research for ABoVE will lead to a greater understanding of ecosystem vulnerability and resilience to environmental change through integrating field-based studies, modeling, and data from airborne and satellite remote sensing. In an effort to accelerate the pace of new Arctic science for researchers participating in the field campaign, the NASA Center for Climate Simulation has partnered with the NASA Carbon Cycle and Ecosystems Office to create a high performance science cloud. The ABoVE Science Cloud (ASC) combines high performance computing with emerging technologies and data management with tools for analyzing and processing geographic information to create an environment specifically designed for large-scale modeling, analysis of remote sensing data, copious disk storage for "big data" with integrated data management, and integration of core variables from in-situ networks. Through this architecture, the ASC provides an agile environment that contributes to data integration, geospatial product generation,

modeling, data stewardship and long-term data preservation by aiding researchers through the entire process of the data lifecycle. The ASC can provide one scientist with hundreds of virtual machines custom-configured to accelerate computation and visualization. It also serves as a Geographical Information System proximate to petascale high-resolution imagery. Furthermore, by using the ABoVE Science Cloud as a shared and centralized resource, researchers reduce costs for their proposed work, making proposed research more competitive. Here we discuss the ABoVE Science Cloud, present the scientific requirements driving the development of the ABoVE Science Cloud, and show examples of how the ASC is being used to meet the needs of the ABoVE campaign. Some of the current uses of the ASC include the creation of an ABoVE domain-wide water mask at 30-m resolution, digital elevation models made from high resolution stereo pair imagery, and burned area maps across Arctic regions.

A model-data integration framework for NASA-ABoVE: the role of remote sensing in process-based model representation of Arctic ecosystem dynamics

Daniel J. Hayes [1], Joshua B. Fisher [2], Eric J. Stofferahn [2], Christopher R. Schwalm [3], Deborah N. Huntzinger [4], A. David McGuire [5]

[1] University of Maine
[2] NASA Jet Propulsion Laboratory
[3] Woods Hole Research Center
[4] Northern Arizona University
[5] USGS / University of Alaska Fairbanks

Tuesday, 13 September, 13:30

Dynamic environmental processes in the high latitudes contribute among the largest uncertainties to global climate projections. Terrestrial biosphere models (TBMs) vary widely in their representation of key Arctic ecosystem indicators, including vegetation and active layer dynamics, soil carbon stocks, ecosystem-atmosphere carbon fluxes, disturbance impacts, freeze/thaw sensitivities and hydrologic controls. The large model spread in such indicators defines the high uncertainty for the Arctic, and reducing it requires scientists to address the significant gaps in data availability across the region and in process representation among TBMs. NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) includes a collection of projects with the overarching goal of addressing the uncertainty in these indicators through field, remote sensing and modeling research involving a set of science questions focused on the socio-ecological systems of northwestern North America. As a key part of this strategy, a model-data

integration framework is being developed for the purpose of confronting TBMs with in situ and remote sensing data collected during the ABoVE Campaign.

TBMs encompass some combination of modules representing various ecological and land surface processes, across which there are common needs for data. Many of these data needs can be satisfied by remote sensing, which is a critical source of data for large, remote and inaccessible Arctic landscapes. Here, we demonstrate the use of remote sensing to evaluate and improve model performance in simulating Arctic ecosystem dynamics, with a focus on identifying critical gaps in data and process representation. First, we present a meta-synthesis on the use of remote sensing data in the calibration, initialization, driving, and validation of TBM simulations in high latitude ecosystem studies. We then update the state-of-the-art in simulating key indicators of Arctic ecosystem dynamics with an analysis that compares results of model ensembles from the North American Carbon Program and the Permafrost Carbon Network. For benchmarking the results from these TBM ensembles, we present examples comparing simulated vegetation dynamics and soil freeze / thaw status to available remote sensing data products from MODIS, SMAP, ICESat, etc. Finally, we use the results of these preliminary analyses to initiate a larger, forward-looking discussion of the challenges and opportunities for remote sensing to advance our understanding of key processes that determine the vulnerability of socio-ecological systems in the Arctic to future change.

Spatiotemporal variation in recent (2002-2015) browning and greening trends in the Arctic-Boreal Region of western North America: regional differences, post-fire trends, and time-series effects

Teri C. Balser [1,2], Dan J. Hayes [3], Andrew W. Balser [1], Guangsheng Chen [1], Jiuchun Yang [4]

[1] Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, TN
[2] Oak Ridge Institution of Science and Education, Oak Ridge Associated Universities, Oak Ridge, TN
[3] School of Forest Resources, University of Maine, Orono, ME
[4] Northeast Institute of Geography and Agroecology, Chinese Academy of Science, Changchun, China

Tuesday, 13 September, 14:00

Climate-induced changes in northern vegetation are well documented through field and remote sensing studies, with predominant Boreal browning related to temperature

induced drought stress and insect infestation, and Arctic greening resulting from warmer and longer growing seasons. These trends have implications for the magnitude and direction of feedbacks to the regional carbon cycle and global climate systems. However, these trends are highly variable depending upon the time increment examined; each increment depicts different ecological effects wrought by different climate and weather drivers. Accurate interpretation of overall, long term trends hinges on aggregate understanding of short-term fluctuations effected by diverse drivers. To better assess recent trends in browning and greening, we evaluated spatiotemporal patterns in remotely sensed vegetation indices in the Arctic and Boreal regions of western North America using time-series MODIS (MCD43B4 NBAR 1-km resolution) data for the growing season (May 17-Sept 6) 2002-2015. We calculated the annual maximum Normalized Difference Vegetation Index, as well as Tasseled Cap Greenness, Brightness, and Wetness. Recent trends were identified using the Theil-Sen slope estimation method with Mann-Kendall significance test. Marked differences separate Arctic and Boreal trends, including post-fire greening trends. While Arctic regions tend toward consistent, gradual greening related to warmer and longer growing seasons, unburned Boreal regions reflect a slight browning trend with much more stochastic variability tied with climate directly (warming, water stress) and indirectly via climate-influenced disturbance events (wildfire, insect outbreaks). A previously unreported, significant recent browning trend was also discovered at the southern end of the Arctic biome, possibly linked with shifting seasonality and early dissipation of annual sea ice. Effectively linking future regional-scale ecosystem responses with different scenarios of climate change will rely upon more detailed synthesis of these drivers and effects.

Landscape-Scale Histories and Active Monitoring of Disturbance, Seasonality and greenness Trends for ABoVE from Landsat

Damien Sulla-Menashe [1], Curtis Woodcock [2], Mark Friedl [2], Eli Melaas [2], Chris Holden [2], Zhe Zhu [5]

[1] Boston University
[2] USGS EROS

Tuesday, 13 September, 14:30

The ABoVE domain has experienced substantial climate and ecological changes during the past three decades. The goal of our research is to use the entire Landsat archive and

produce wall-to-wall maps of forest disturbance and trends in phenological dates and peak summer greenness during this period. These products will be useful to many other ABoVE researchers and will improve understanding of the linkages between climate change and the health and productivity of boreal forests in these regions. To generate these products we will use several new methods of time series analysis that have been recently developed at Boston University, including the Continuous Change Detection and Classification (CCDC) algorithm. Here we show some prototype CCDC disturbance maps for a region of southern Alaska centered on the Kenai peninsula from year 2000 to the present. These results show interesting spatial patterns of forest change from fire, forest management and development, and inundation.

Statistical characteristics of subarctic vegetation on the basis of ground hyperspectral measurements

W G Rees [1], O V Tutubalina [2], M V Zimin [2], E I Golubeva [2]

[1] Scott Polar Research Institute, University of Cambridge, UK
[2] Geography Faculty, Moscow State University, Russia

Tuesday, 13 September, 15:20

Hyperspectral reflectance spectra, covering the visible and near infrared spectrum with a spectral resolution of around 10 nm or finer, are finding an increasingly important role in environmental remote sensing. The much higher dimensionality of the feature space of hyperspectral compared with multispectral imagery potentially allows the discrimination of many more ground cover types and end-members for spectral unmixing approaches. Detailed spectral features can be identified, and attributed to specific biophysical or biochemical features and processes. Most hyperspectral imagery is currently collected from airborne sensors although some spaceborne imagery is already available.

Interpretation and analysis of hyperspectral imagery depends on the availability of high-quality systematic in situ spectra measured for homogeneous materials. Here we describe the collection of nearly 300 spectra from subarctic vegetation in northern Europe (central Kola Peninsula, Russia, and Abisko, Sweden), spanning most vegetation groups (trees, shrubs, dwarf shrubs, grasses, mosses and lichens). The vegetation was measured in boreal forest, treeline, and mountain tundra ecosystems, and some species in the collection were sampled in a variety of growing conditions (such as altitude, moisture, degree of technogenic pollution). The data will be made freely accessible through the online library SLAP (spectral library of arctic plants).

In this paper we identify common features in the spectra and propose a number of general spectral types on the basis of statistical grouping of spectra. Such grouping may allow the identification of specific vegetation types which are distinctly different from all other groups, and, conversely, find geobotanically different, but spectrally similar vegetation, as well as define some of the driving factors for the spectral similarities. We hope that results of our research could help to advance automated knowledge-based interpretation of hyperspectral imagery and vegetation mapping in polar regions.

Detection of low Arctic tundra vegetation community type, phenophase, and biophysical parameters using narrow-band indices in the visible and red-edge spectrum

Alison Beamish [1], Birgit Heim [1], Sabine Chabrillat [2], Nicholas Coops [3]

[1] Alfred Wegener Institute for Polar and Marine Research, Periglacial Studies, Potsdam, Germany
[2] Deutsches GeoForschungsZentrum, Remote Sensing, Potsdam, Germany
[3] IRSS, Faculty of Forestry, University of British Columbia, Vancouver, Canada

Tuesday, 13 September, 15:50

The goal of this research is to test the hypothesis that narrow-band spectral data is superior for the classification of Arctic vegetation communities as well as vegetation pigment regimes at the plot, landscape and ecosystem scale. Using high spectral resolution ground-based spectroscopy I asked the following questions, (1) how the spectral response of vegetation communities change at key phenophases of green-up, maximum green, and senescence; (2) how spectral differentiation of vegetation communities change at key phenophases and (3) how the phenology of spectral signals relate to the phenology of chlorophyll and carotenoid concentrations as well as leaf area index (LAI). Ground-based spectral data was related to the following biophysical properties: chlorophyll α, chlorophyll β, carotenoids, and LAI. Using lab-based spectroscopy, pigment concentrations of the dominant species at the key phenophases were assessed. This data was then correlated to band depth of absorption features associated with pigment concentrations and canopy structure (LAI) extracted from the ground-based data. A waveband selection algorithm was also used to identify key wavebands for differentiation of phenophase and vegetation communities and spectral angle mapper was used to assess classification accuracy. The results of this research will inform current and future remote sensing missions on how to assess vegetation heterogeneity and biophysical properties of the Arctic under a changing climate regime.

HyLab: a hyperspectral laboratory for surface water and vegetation characterization in Alaska's Arctic and boreal regions

Anupma Prakash [1], Jordi Cristóbal [2], Marcel Buchhorn [3], Patrick Graham [1], Martin Stuefer [1]

[1] Geophysical Institute. University of Alaska Fairbanks
[2] Geophysical Institute and Institute of Northern Engineering. University of Alaska Fairbanks
[3] Flemish Institute for Technological Research (VITO) and Geophysical Institute. UAF

Tuesday, 13 September, 16:20

The University of Alaska Fairbanks (UAF) is an important research hub for high-latitude research. UAF's Hyperspectral Imaging Laboratory (HyLab), established in 2014 with a Major Research Instrumentation grant from NSF, adds to UAFs research infrastructure and provides a much needed local airborne hyperspectral imaging capability. Hylab houses the HySpex sensor that consists of a VNIR-1800 camera (0.4 – 1.0 μm) and a SWIR-384 camera (1.0 – 2.5 μm) that are mounted on an Avait Huskey A-1B airplane. This mobile and low-cost platform allows on–demand acquisition of high resolution imaging spectroscopy data all over Alaska. The HySpex data pre-processing workflow for geometric and radiometric correction also includes corrections to minimize the effects of bidirectional reflection distribution function (BRDF), a factor that is particularly prominent in high-latitude settings. Outputs of data processing are geo-registered, surface radiance / reflectance products as well as higher order products such as fraction of absorbed photosynthetically active radiation, albedo or land cover. For in-flight calibration of HySpex acquisitions, laboratory spectroscopy, and field spectroscopy, a Spectral Evolution PSR+ 3500 spectro-radiometer was recently added to the HyLab facility. Moreover, we are currently developing an Alaska / high-latitude vegetation spectral library using this instrument. The in-house calibration facility allows cross-calibration of all instruments in order to guarantee seamless radiometric products. This calibration and quality assurance of the HySpex camera is performed twice a year using an integration sphere. This allows us to monitor the state of the hyperspectral system and ensures that our data acquisition is of high quality. Together with the hyperspectral sensor, a Forward Looking Infrared Radiometer (FLIR) automation series A655sc camera with a 25° field-of view, acquires thermal imagery. The camera operates in the longwave infrared region spanning a single broad spectral range of 7.5 - 14.0 μm. For most high-latitude operations we collect the data in the standard low temperature range of –40°C to 150°C. Moreover, to improve the absolute radiometric calibration of the HySpex data, a GRIMM Model 1.129 Sky OPC Aerosol Spectrometer complements

our HySpex airborne instrumentation suite. The instrument detects aerosol particles in real time in the size range 0.25 μm to 32 μm in 31 size channels and displays the results as particle concentration or optionally as particle mass. The spectrometer nozzle is attached to the wing strut of the Husky airplane to avoid aerosol contamination from the aircraft engine and slipstream effects of the aircraft propeller. In 2014 and 2015, HyLab's HySpex camera system was used to acquire hyperspectral imagery in selected sites in Alaska, providing unique information on terrestrial and aquatic biogeochemical parameters, and diagnostic mineral properties in exposed outcrops. Processed imagery shows promise in mapping vegetation compositions, phytoplankton, and dissolved materials in inland water bodies, as well as detail mineral mapping in barren exposures and outcrops. In addition to current image acquisitions, the HySpex and FLIR sensor configuration has potential for broad applications in Alaska such as permafrost studies, surface energy balance, minerals mapping, snow characterization, and wildfire studies as examples More information is available at www.hyperspectral.alaska.edu.

Permafrost Remote Sensing Trough Airborne Electromagnetic Geophysics and Thermal Anomalies

Ronald Daanen, Abraham Emond, Jordi Cristobal, Burke Minsley, Anupma Prakash, Gwen Holdmann, Anna Liljedahl, Katey Walter Anthony, Vladimir Romanovsky, Dave Barnes

Wednesday, 14 September, 9:20

Few remote sensing techniques can look beyond the surface of the ground in order to better understand the landscape. Airborne Electromagnetic (AEM) resistivity is one of the methods that can distinguish frozen versus thawed sediments from the air down to 150 meters below the surface. Thermal infrared imagery does not directly look at the subsurface, but heat fluxes in the ground can be calculated based on soil surface temperatures and atmospheric properties.

AEM datasets can be used for 3D permafrost mapping. In the Goldstream Watershed, near Fairbanks Alaska with discontinuous permafrost the permafrost mapping is undertaken to better understand permafrost dynamics through time, deep groundwater movement and methane release estimations from the base of permafrost. The permafrost map is the first and important step in a larger study with the aim to quantify the feedback between climate change and permafrost carbon release. Heat can be detected

during winter in places where groundwater surfaces (springs) in Goldstream Valley, because of artesian conditions, springs often leave large quantities of aufeis/overflow near streams in winter causing local hazards. Another AEM dataset was acquired for Pilgrim Hot Springs on the Seward Peninsula, a region that is generally underlain by continuous permafrost. Here the Pilgrim River, larger lakes and the hot springs warm the ground significantly resulting in permafrost free areas locally. In addition we have thermal imagery from the geothermal anomaly that indicates strong contrasts between permafrost and non-permafrost areas. Both these datasets were acquired to assess the geothermal potential of Pilgrim Hot Springs.

In this presentation we will discuss rigorous methods and analyses of AEM datasets. We will show the importance of ground truth data and how it can be used during the analysis. We will show preliminary 3D mapping of permafrost. For the thermal imagery we will discuss the data acquisition techniques and to derive ground heat fluxes from thermal infrared images. We will show that these heat fluxes are in large driven by upward groundwater movement rather than conduction through the sediment.

The combination of electrical resistivity and thermal data make permafrost mapping easier and more reliable, because of combining two independently acquired datasets both providing complimentary information on permafrost conditions. These tools may be the key to understanding permafrost thermal stability and its potential for degradation. We have found that massive ground ice content strongly contributes to high resistivity values, even though the individual ice bodies cannot be resolved with AEM. We will not only attempt to map permafrost presence or absence we will also attempt to map massive ice content and talik (thawed layers in permafrost) conditions in the Goldstream Valley.

Monitoring thermokarst activity and landscape change in the Eureka Sound Lowlands, Ellesmere Island, Nunavut

Melissa Ward [1], Wayne Pollard [1]

[1] Department of Geography, McGill University

Wednesday, 14 September, 9:50

The Eureka Sound Lowlands is an area underlain with over 500 m of ice-rich permafrost largely composed of massive ground ice and ice wedge polygons with a thin active layer

of a mean thickness of 57cm. The region has a polar desert climate, with a mean annual air temperature of -19°C, and approximately 67mm of annual precipitation (falling mostly as snow). The area has an Environment Canada Weather Station (located at Eureka at 79°59'N, 85°56'W) that has been conducting daily meteorological measurements since it was founded in 1947. The area is sensitive to increasing summer temperatures as observed during the summer of 2012: as one of the warmest summer on record, there was a three-fold increase in thermokarst with the accelerated collapse of ice wedge polygon troughs and widespread development of retrogressive thaw slumps. This study monitors thermokarst activity within the area using air photos from 1959, 1974 and 1982, satellite imagery (WorldView2) from 2009 and 2012, and annual air surveys (since 1989). Thermokarst activity between 2013 and 2016 has been monitored in the field using a differential GPS (Global Positioning System) to survey headwall locations of retrogressive thaw slumps. The purpose of this study is to provide a detailed baseline of landscape processes to compare future landscape changes resulting from thermokarst in the area.

InSAR Detection and Field Evidence for Thermokarst after a Tundra Wildfire, Using ALOS-PALSAR

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Wednesday, 14 September, 10:40

Thermokarst is the process of ground subsidence caused by either the thawing of ice-rich permafrost or the melting of massive ground ice. The consequences of permafrost degradation associated with thermokarst for surface ecology, landscape evolution, and hydrological processes have been of great scientific interest and social concern. Part of a tundra patch affected by wildfire in northern Alaska (27.5 km^2) was investigated here, using remote sensing and *in situ* surveys to quantify and understand permafrost thaw dynamics after surface disturbances. A two-pass differential InSAR technique using

L-band ALOS-PALSAR has been shown capable of capturing thermokarst subsidence triggered by a tundra fire at a spatial resolution of tens of meters, with supporting evidence from field data and optical satellite images. We have introduced a calibration procedure, comparing burned and unburned areas for InSAR subsidence signals, to remove the noise due to seasonal surface movement. In the first year after the fire, an average subsidence rate of 6.2 cm/year (vertical) was measured. Subsidence in the burned area continued over the following two years, with decreased rates. The mean rate of subsidence observed in our interferograms (from 24 July 2008 to 14 September 2010) was 3.3 cm/year, a value comparable to that estimated from field surveys at two plots on average (2.2 cm/year) for the six years after the fire. These results suggest that this InSAR-measured ground subsidence is caused by the development of thermokarst, a thawing process supported by surface change observations from high-resolution optical images and *in situ* ground level surveys.

Remotely sensing post-fire land surface changes in the Arctic using repeat airborne LiDAR and Landsat trend analysis

Benjamin M. Jones [1], Ingmar Nitze [2], Guido Grosse [2], Daniel Mann [3], Benjamin Gaglioti [4], Daniel Hayes [5], Eric Miller [6]

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Wednesday, 14 September, 11:10

Wildfire disturbance is an important factor contributing to ecosystem and landscape changes. The impact of fires on permafrost-influenced terrain in Boreal Forest regions is well documented; however the role of fires in initiating thermokarst development in Arctic Tundra regions is poorly understood. Rapid climate change at high latitudes has increased interest in the spatial and temporal dynamics of thermokarst and other permafrost thaw-related features in diverse disciplines including landscape ecology, hydrology, engineering, and biogeochemistry. As a result, there is an urgent need to develop new techniques and tools to observe and quantify changes to near-surface permafrost terrain. Remote sensing provides a means for documenting and

quantifying many of the changes now occurring on arctic landscapes. In particular, application of multi-temporal airborne LiDAR allows for the detection of terrain subsidence caused by thermokarst. LiDAR elevation model differencing provides a direct measure of land surface elevation changes over time. In this study, we compare two airborne LiDAR datasets covering ~400 km2, acquired in the aftermath of the large and severe Anaktuvuk River tundra fire that occurred in 2007 in northern Alaska. Digital terrain models (DTMs) at 1 m spatial resolution were developed from the LiDAR datasets that were acquired two years and seven years post-fire. These datasets were differenced using the Geomorphic Change Detection tool to quantify thermokarst development in response to the tundra fire disturbance. Results show permafrost thaw subsidence (> 0.2 m) occurring across 34% of the burned tundra area studied, compared to < 1% in similar undisturbed, ice-rich tundra terrain. Post-fire thermokarst development as detected in the airborne LiDAR data shows a relationship with trends in a dense time-series of different multi-spectral indices (Tasseled Cap, NDVI, NDMI) derived from multi-spectral Landsat satellite data. These relationships allow us to scale-up our mapping of thaw-affected terrain area across the entire ~1,000 km2 area impacted by the Anaktuvuk River tundra fire and they may allow for the assessment of thermokarst impacts across other tundra fire disturbances since the mid-1980s where sufficient cloud-free Landsat data is available. Our new methodologies will enable assessment of the vulnerabilities of ice-rich permafrost terrain to changing disturbance regimes in northern high latitude landscapes. Better understanding the processes controlling thermokarst initiation and development in Arctic regions is important because of the resulting impacts on the land-atmosphere exchange of water, energy, and greenhouse gases, along with the influence on surface hydrology, snow accumulation, and vegetation dynamics.

Remote sensing observations of lake change in Bering Land Bridge National Preserve, Northern Seward Peninsula, from 1949-2015

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Wednesday, 14 September, 13:00

Thermokarst lakes, closely tied to cold-climate conditions and ice-rich permafrost, are ubiquitous in Arctic and sub-Arctic permafrost lowlands and foothills and represent highly dynamic landscape features in western Alaska. They provide important ecosystem services as habitats, hydrological feature, biogeochemical hotspots, and for surface energy budgets. Their formation is an important mode of ice-rich permafrost degradation and is linked to surface disturbance, subsequent melt of ground ice, surface subsidence, water impoundment, and positive feedbacks between lake growth and permafrost thaw. Climate and substrate properties are key factors for their morphology, biogeochemical activity, and relevance for the carbon cycle.

To characterize the vulnerability of thermokarst lakes to climate change on the northern Seward Peninsula, a region dominated by ice-rich, warm, continuous permafrost, we assessed historic lake changes in Bering Land Bridge National Preserve for the period ca. 1949 to 2015 using various remote sensing approaches. The datasets used in this analysis include a wide range of remote sensing image types and topographic data available for this region, such as aerial photography, historic topographic maps, high resolution satellite images (Corona, Spot, Ikonos, Quickbird, Worldview, GeoEye), and the full Landsat archive. Field studies included reconnaissance flights targeting freshly drained lakes and site visits on the ground.

We here report on the analysis of multi-temporal remote sensing data for a 12,200 km2 lowland area in the Bering Land Bridge National Preserve covering the majority of the northern Seward Peninsula. We demonstrate that thermokarst lake drainage was occurring on a large scale over the observation period. We observed a net decrease in thermokarst lake area largely due to catastrophic lake drainage. Lateral lake expansion by thermo-erosion continued but did not offset the net area loss. Our findings also

suggest that in particular large lakes are vulnerable to disappearance. Climate data analysis revealed a potential correlation with increased winter precipitation that may have resulted in a combination of high lake water levels, increased spring runoff with higher potential for drainage channel formation, and near-surface permafrost degradation, ultimately enhancing lake drainage. The observed magnitude of lake drainage implicates strong and lasting impacts on regional hydrology, biogeochemical cycling, surface energy budgets, state of the permafrost, ecosystem character, and waterfowl and fish habitats. Our study highlights that lake-rich permafrost landscapes in western Alaska are already changing rapidly and permanently in a warming world.

Thermokarst Lake Expansion Dynamics on the Arctic Coastal Plain of Alaska

Allen C Bondurant [1], Christopher D. Arp [1], Benjamin M. Jones [2], Melanie J. Engram [1]

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[2] U.S. Geological Survey Alaska Science Center

Wednesday, 14 September, 13:30

Thermokarst lakes form and expand through thermal and mechanical erosion of permafrost. The growth and eventual drainage is an important component of the thaw lake cycle. One important distinction between Arctic thermokarst lakes in general is the ice regime of a lake (i.e. bedfast ice or floating ice), particularly on the Arctic Coastal Plain of northern Alaska. We hypothesize that this difference in ice regimes is a major control on the mean annual bed temperature of the lake and ultimately on the thermal state of the permafrost underneath and adjacent lakes. In floating ice lakes, the depth of thaw in soils beneath the lake can extend tens of meters deep or more, and the above freezing mean annual lake temperature warms the permafrost adjacent to the lake. In these floating ice lakes, shorelines are more susceptible to summertime thermal and mechanical erosional processes than their bedfast ice counterparts, where permafrost temperatures are colder in bluffs and there is no sub-lake talik formation. Margins surrounding bedfast ice lakes take longer to thaw in the short Arctic summer and thus are more resistant to lake shore erosional processes. Temperatures in these margins are potentially an important contributing factor to the difference in shoreline expansion rates between ice regimes. Lake ice regime was determined through the analysis of multi-year time series synthetic aperture radar (SAR) imagery from 1992-2016 and we observed a reduction in bedfast lake ice area in five of the six geographic study regions on the Alaska ACP. Analysis of modern and historical satellite and aerial imagery of

lakes located on the outer ACP has shown that whole-lake shoreline expansion rates average 0.8 m/yr for floating ice lakes, more than double the rate of bedfast ice lakes, averaging an expansion rate of 0.35 m/yr. In addition to differential erosion rates, we also observed the spatial dynamics of expansion differ by ice regime. Bedfast ice lakes erode preferentially in the north and south, while floating ice lakes display a more even pattern of erosion around their perimeter. In a warming arctic climate, maximum ice thicknesses will likely decrease through time and bedfast ice lakes will potentially shift to a floating ice regime. Because many lakes on the ACP are near the approximately 1.5 m depth threshold for shifting ice regimes, they are among the most sensitive landscape features to climate change. The increased rates of expansion from lakes that had previously experienced bedfast ice conditions will have important landscape implications including degradation of sub-lake permafrost, increased lake surface area, and mobilization and release of stored carbon. The recognition of the potential for geomorphic change of lakes in a changing climate is important for future planning and development of resources in regions of continuous permafrost, such as the Arctic Coastal Plain.

Applying UAS Technology for Monitoring Wildlife and Natural Resources

Bruce Quirk [1]

[1] U.S. Geological Survey

Thursday, 15 September, 9:00

Unmanned Aircraft Systems (UAS) are evolving as an effective, efficient, economical and environmentally friendly tool to monitor environmental conditions, respond to natural hazards, understand landscape change rates and consequences, conduct wildlife inventories and support related land management activities. The U.S. Geological Survey (USGS) is participating in a test and evaluation of UAS to see how this technology supports the mission of the USGS and the Department of the Interior (DOI). Over the last 6 years, the USGS, working with many partners, has been actively conducting proof of concept UAS missions, which are designed to evaluate the potential of UAS technology to support the mandated DOI scientific, resource and land management missions. Using small UAS, the USGS is able to tailor solutions to meet project requirements by obtaining very high-resolution remote sensing data to generate GIS-ready products. UAS technology is providing a mechanism to collect timely

remote sensing data at a low cost and at low risk over DOI lands that can be difficult to monitor and consequently enhances our ability to provide unbiased scientific information. This presentation describes the UAS technology and infrastructure being employed, pilot application projects already accomplished, lessons learned and the future of UAS within the USGS.

Off the Shelf Digital Cameras for Remote Sensing Applications

Mark Laker [1]

[1] US Fish and Wildlife Service, Kenai National Wildlife Refuge

Thursday, 15 September, 9:30

The multispectral and multidimensional data available from modern sensors has greatly improved our ability to research and understand ecosystem functions on a large scale. The success of these technologies has likewise created a large demand for the data at a variety of spatial and temporal scales. Both cost and accessibility have presented barriers in acquiring remote sensing data. This has been changing with the availability of inexpensive digital cameras and Structure from Motion (SfM) software. From hobbyists to researchers, people are collecting their own data using a variety of airframes and sensors. Over the last few years we tested several camera systems for the purpose of producing color and multispectral orthophotos, point clouds and digital surface models at a variety of spatial scales. Some systems did produce excellent results. Developing workflows and testing these systems required a great deal of time and collaboration with numerous individuals around the State and country doing similar work. This presentation will briefly describe the camera setups, processing steps, potential products, limitations and costs of employing these systems.

Acquisition of airborne LiDAR data in Arctic

Isaiah Ditmer [1]

[1] Kodiak Mapping Inc.

Thursday, 15 September, 10:00

An overview of aerial lidar acquisition and applications in the Arctic, with illustrations taken from a variety of projects acquired throughout Alaska. Discussion to include summary of airborne lidar technologies and the respective data outputs that can be generated. Data analysis scenarios and project considerations for stakeholders and end users will be outlined.

Application of LiDAR for paleo-lake level reconstruction in closed-basin lakes, Kenai Peninsula, Alaska

Ed Berg[1]

[1] US Fish & Wildlife Service (Retired), Kenai National Wildlife Refuge; Kenai Peninsula College

Thursday, 15 September, 10:50

Closed-basin lake levels are climatically driven and are good indicators of available water on the landscape. This study used old shorelines to identify high-level lake stands; nearby fen peat records were used to identify low-level stands. We examined GoogleEarth and bare-earth LiDAR imagery for the glaciated Kenai Lowland from Kachemak Bay to Pt. Possession and located 33 kettle lakes with no visible outlets. Using the Global Mapper profile tool we constructed multiple profiles for each lake and measured heights of shorelines (typically heavily forested wave-cut scarps) above modern lake-levels. Mean scarp height was 3.9 m (range 1.2 to 11.8 m) above modern lake levels, indicating a very wet period in the early history of these lakes. To constrain the timing of this wet period we took multiple cores in fen peat deposits lying within the old shorelines (satellite fens) of 8 lakes; these peats accumulated after the high-stand scarps were cut because the peats showed no evidence of flooding. Basal peat dates were as old as 14,000 years (calibrated 14C dating), indicating that the high water period occurred during the late post-glacial – early Holocene, when Kenai glaciers were in full retreat from their 18,000 years ago maximum extent.

We also examined open-basin lakes. Many showed several poorly defined scarps that represented pauses in the downcutting of their outlets; others showed no scarps at all. A few, such as Rainbow Lake, showed prominent scarps above their present lake levels, suggesting that they were initially closed-basin lakes until they overflowed in the wetter late Holocene and began downcutting their outlets.

The satellite fen peats provided a remarkable record of extreme lake level drawdown, where lake levels were drawn down as much as 7 m below modern lake levels, and as much as 10 m below the old shorelines. Similar drawdowns have been observed at Birch Lake (Abbott et al. 2000) and Harding Lake (Finkenbinder et al 2014) in the Interior during the same time period of 14-9000 years ago. The central Kenai has dried considerably since 1968 (with a 60% decline of available water), and closed-basin lake levels have declined by a meter or more. SNAP mid- and hi-range emission scenarios forecast available water of ~0 mm water by 2100 for this area, so it appears likely that the next century will see a much drier landscape on the Kenai with attendant changes in vegetation and fire activity, reminiscent of the earlier dry period recorded in the fen peat deposits.

Remotely sensing a cold region dune field using airborne LiDAR and high resolution aerial photography

Carson A. Baughman [1], Benjamin M. Jones [1], Esther L. Babcock [1], Karin L. Bodony [2], Daniel H. Mann [3], Chris F. Larsen [3], Jeremy Smith [4]

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Thursday, 15 September, 11 :20

Sand dunes and sand sheets respond sensitively to global and regional climatic changes, ecological succession, and disturbance events. Approximately 100,000 km2 of active and stable sand sheets occur in the Arctic and Subarctic today. These cold regions dunes are also subject to changes in permafrost conditions. Permafrost can influence soil moisture and vegetation, which then influences sand availability and sand-transport potential. In this study, we describe the morphometry and dynamics of the Nogahabara Dunes, a subarctic dune field in interior Alaska's discontinuous permafrost zone, and local

permafrost conditions using a recent airborne LiDAR dataset, historic aerial photography, ground penetrating radar, and historical climate data. The Nogahabara Dunes consist of a 45-km2 area of active dunes surrounded by 3,200 km2 of stabilized, vegetated dune landforms. The average dune height in the active dune field is 10 meters, with a maximum dune height of 28 meters. In places where dune crests are linear, parallel, and evenly spaced, dune spacing is approximately 130 meters. Where dunes are irregularly shaped and have variable orientation, dune spacing ranges from 40 to 200+ meters. Between 1952 and 2015, the dunes migrated substantially (mean: 63cm yr-1) within the active portion of the dune field. Dune migration direction was variable; however, the predominant direction of movement was to the southeast. This agrees with historical wind records indicating that predominant winds are from the northwest. Despite substantial within-field movement, the overall extent of the active dune field has not changed significantly in 60 years; however, small blow-out features were observed in the aftermath of fires that occurred in the vegetated portion of the dune field in 2015. Inferred reflectors in GPR data show that permafrost is present within the active dune field 2-4 meters below ground surface, but there does not appear to be any morphometric features directly related to permafrost. Depth-to-permafrost is shallower within the inactive dunes adjacent to the active dune field due to surface stability and cover by vegetation and insulating soil organics. Fissure-like features are common within the inactive dunes and may represent past thermokarst events. Alternatively, they could be related to a major 1958 earthquake (magnitude 7.3) that had its epicenter near the dunes. Recent fire on the inactive dunes has the potential to reactivate dormant dunes through the degradation of underlying permafrost however long term monitoring will be required to validate this scenario. Acquisition of contemporary airborne LiDAR data provides a baseline from which to quantify potential activation of currently stable dune landforms as permafrost warms and thaws in Alaska. Better constraining the processes controlling dune field dynamics at the Nogahabara site provides information that can be used to model possible re-activation of more northerly sand sheets and dune fields in response to climate change.

Remote sensing characterization of the location and dynamics of the arctic treeline

Wenkai Guo [1], Gareth Rees [1]

[1] Scott Polar Research Institute, University of Cambridge, UK

Thursday, 15 September, 13:10

The Arctic treeline, or the tundra-taiga ecotone (TTE) region, is the world's longest vegetation transition zone stretching around arctic North America, Scandinavia and Eurasia. It derives major significance from the fact that it represents a strong gradient in terrestrial albedo, carbon and water fluxes and the study of its dynamic response to climate change has been recognised as a major challenge in understanding the global bioclimatic system. However, a clear characterization of the arctic treeline and its temporal progression through observation is lacking despite this high climatological and ecological significance. This study is an attempt to use coarse- to moderate- resolution satellite image products to study the configuration of the arctic treeline and its variation over the last few decades. Several treeline delineation approaches are tested for their performance in treeline delineation in several selected regions in the circumpolar region, and experiments are conducted to progressively derive the optimal set of parameters used in the delineation methods as well as the appropriate spatial scale at which the delineation process should take place. This study will specifically attempt to exploit the powers of the spatial structures of treelines (treeline 'forms') in distinguishing between different types of treelines, and treelines from other vegetation zones. The delineation results are compared in terms of classification accuracies based on a set of site data compiled from previous studies with known vegetation types. The selected optimal treeline delineation method is then applied to the time series of remote sensing vegetation product over the whole circumarctic region to derive arctic treeline positions over the few decades, which can potentially serve as the basis of future modelling of treeline dynamics.

Delineating the Taiga-Tundra Ecotone with Landsat, LiDAR and Spaceborne Sub-meter Imagery

Christopher Neigh [1], Paul Montesano [2], Joe Sexton [3], Min Feng [3], Saurabh Channan [4], K. Jon Ranson [1]

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[2] Science Systems Applications Inc., NASA Goddard Spaceflight Center Biospheric Science Laboratory Code 618
[3] University of Maryland College Park Department of Geographical Sciences
[4] Director of the Global Land Cover Facility, University of Maryland College Park Department of Geographical Sciences

Thursday, 15 September, 13:40

Climate change has altered vegetation productivity and structure, carbon sequestration and many other processes in the higher northern latitudes. The taiga-tundra ecotone

(TTE) which is the circumpolar transition zone from 50° to 75° north latitude is expected to change in form and distribution from global warming. Some evidence of change has been documented in small-scale studies but large amounts of uncertainty remains in current global estimates of circumpolar forest extent. Establishing the TTE extent is challenging because of variations in vegetation structure, site-level interactions between microclimate, topography, winter snow depth, wind, edaphic conditions and other factors. These interactions have produced TTE forest patterns that include sporadic forest cover patches to growth-stunted trees resembling shrubs. These patterns are evident at local scales, but are often not apparent in moderate resolution imagery from most earth observing satellites. Such scale problems have contributed to large TTE geographic uncertainties. Recent advances using the global archive of Landsat data have provided vegetation continuous fields (VCF) at 30-m resolution, which may improve TTE delineation. Furthermore, U.S. federal access to sub-meter DigitalGlobe data provides the means to improve estimates of the extent of the TTE with observations of individual trees and structure from stereoscopic observations. We are currently processing these data with NASA GSFC super-computing resources to extract detailed forest structure information over vast and remote areas of the TTE. These derived products will be used to optimize the Landsat VCF delineation of the ecotone. The resulting products could become a baseline to identify sites of potential TTE structure change and be used in ecosystem models. An overview of our current work will be presented.

A regional quantitative cover map of tundra plant functional types in arctic Alaska

Gerald V. Frost [1], Matthew J. Macander [1], Peter R. Nelson [2], Christopher S. Swingley [1]

[1] ABR, Inc.
[2] University of Maine–Ft. Kent

Thursday, 15 September, 14:10

The integrated analysis of ground-based vegetation and remote sensing data supports ecosystem mapping, landscape-change detection, wildlife habitat assessments, and monitoring of phenological events such as green-up and senescence. To support quantitative mapping of tundra plant functional types (PFTs) and abiotic cover for ~100,000 km2 of Alaska's North Slope, we analyzed a detailed field dataset for tundra vegetation obtained using a point-intercept sampling method at 224 circular plots (50–100 m radius) spanning gradients of climate, landscape physiography (upland, lowland,

riverine), and geomorphic setting (colluvial uplands, yedoma uplands, sand sheet coastal plain, alluvio-marine coastal plain). We summarized field measurements of live vegetation, litter, water, and bare ground using two cover metrics: top cover (uppermost "hit" as seen from above) and total cover (total areal cover up to 100%). The live vegetation cover measurements were stratified by nine PFTs: tall deciduous shrub, low deciduous shrub, dwarf deciduous shrub, dwarf evergreen shrub, sedge, grass, forb, moss, and lichen. We then produced 30 m resolution spatial models of PFTs and abiotic cover types by applying the random forest data-mining algorithm. Model inputs included (1) the field training dataset; (2) spectral predictors derived from bi-monthly composites of Landsat ETM+ surface reflectance from mid-May to late August 1999–2015; and (3) environmental predictors (e.g., vegetation map, surficial geology map, gridded summer temperature product). We used the field training data, an independent ground dataset of reserved validation plots, and an extensive archive of very-high-resolution (<2-m pixel) commercial imagery to evaluate model results. The quantitative maps for tundra PFTs at 30-m resolution provide significant advantages over traditional thematic maps for a variety of applications such as simulation modeling, resource selection functions, and long-term monitoring.

North Yukon Disturbance Tracking

Sam Skinner [1], Manon Desforges [2]

[1] Yukon Land Use Planning Council
[2] Yukon Government -Energy Mines and Resources

Thursday, 15 September, 15:00

The North Yukon Planning Region encompasses 55,568 km2 of the Vuntut Gwitchin traditional territory in northern Yukon, Canada, and is comprised of sub-arctic taiga plateau, basin and mountain landscapes underlain by continuous permafrost. It also includes much of the winter range of the Porcupine Caribou herd, one of the largest migratory barren ground caribou herds in North America. The key issue addressed by the Region's land use planning Commission was oil and gas exploration and potential development in a significant portion of the annual range of this herd. In response, their plan recommended that two cumulative effects indicators, surface disturbance (polygonal) and linear disturbance, be tracked and ideally kept below levels specified for each geographic sub-division of the region, or "Land Management Unit" (LMU). Therefore, disturbances need to be tracked over time.

The plan implementers have struggled to determine how to best quantify the variety of recent and legacy disturbances given the plan's inconsistent definitions of disturbance and recovery, the number of agencies involved, inaccurate and/or incomplete existing disturbance data, and poor understanding of the current state and likely recovery trajectories of existing disturbances. The methods must be practical, defensible, accurate at a regional scale, scalable to all or most of the Yukon as more regional plans are made, and must be able to be efficiently communicated to all agencies.

SPOT6 and Pleiades (1.5 and 0.5m resolution, respectively) imagery is being evaluated on how well it can be used to interpret disturbances versus costs of imagery acquisition and interpretation. This evaluation is being done in a small study area (~200km2) where both types of images and other ancillary data are available. Beyond using the imagery to map the extent of visible surface disturbances (both polygonal and linear), a number of disturbance attributes may also be interpreted with the help of ancillary information. These include: type of disturbance, approximate year of disturbance, current vegetation class, and width (for linear disturbances).

Estimating surface energy fluxes in Arctic ecosystems using a thermal-based remote sensing model

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[3] Hydrology and Remote Sensing Laboratory, United States Department of Agriculture, Agriculture Research Service
[4] Institute of Arctic Biology. University of Alaska Fairbanks
[5] Institute of Northern Engineering. Water Environmental Research Center, University of Alaska Fairbanks

Thursday, 15 September, 15:30

The Arctic has become generally a warmer place over the past decades leading to earlier snow melt, permafrost degradation and changing plant communities. Increases in precipitation and local evaporation in the Arctic, known as one of the acceleration components of the hydrologic cycle, coupled with land cover changes, have resulted in significant changes in the regional surface energy budget. Quantifying spatiotemporal trends in surface energy flux partitioning is a key to forecasting ecological responses to changing climate conditions in the Arctic regions. An extensive evaluation of the two-source energy balance model (TSEB) - a remote sensing-based model using thermal

infrared retrievals of land-surface temperature - was performed using tower measurements collected over different tundra types in Alaska in all sky conditions over the full growing season from 2008 to 2012, and in a birch boreal forest in summer 2012. Based on comparisons with flux tower observations, refinements in the original TSEB net radiation, soil heat flux and canopy transpiration parameterizations were identified for the unique Arctic tundra conditions. In particular, a revised method for estimating soil heat flux based on relationships with soil temperature was developed, resulting in significantly improved performance. These refinements result in mean flux errors around 50 W·m-2 at half-hourly timesteps similar to errors typically reported in surface energy balance modeling studies conducted in more temperate climatic regimes. MODIS LAI remote sensing product proved to be useful for estimating energy fluxes in Arctic tundra in the absence of field data. This work builds toward a regional implementation of the TSEB model over Arctic tundra and boreal ecosystems, using thermal satellite remote sensing to assess response of surface fluxes to changing vegetation and climate conditions.

Challenges for satellite remote sensing of Arctic CO2 and CH4 patterns

Charles Miller [1]

[1] Jet Propulsion Laboratory, California Institute of Technology

Thursday, 15 September, 16:00

Pan-Arctic measurements of atmospheric carbon dioxide (CO2) from the Orbiting Carbon Observatory (OCO-2) have the potential to provide unprecedented observational constraints on northern high latitude (NHL) carbon dynamics. OCO-2 records over one million soundings per day, ~14% of which fall in the NHL. Assuming ~10% of NHL soundings are cloud free, we expect ~14,000 XCO2 soundings per day and ~400,000 per month in the NHL. Actual yields have been far lower, peaking at 87,000 in June, dropping to ~3500 in September and less than 100 per month for October – April.

ESA's TropOMI satellite will launch in late 2016 and deliver pan-Arctic measurements of atmospheric methane (CH4) that have similar potential to dramatically improve our understanding of NHL methane dynamics. However, TropOMI also relies on measurements of near infrared solar radiation reflected from the Earth's surface. We therefore expect significantly reduced NHL retrieval yields from TropOMI as well.

The NHL pose significant remote sensing challenges: high solar zenith angles, low light levels during the long cold season (September – April), extensive cloud cover, and reduced signal-to-noise ratios (SNR) over land due to inundated (growing season) or snow-covered surfaces (cold season). These can compromise CO2 and/or CH4 yields from algorithms that were developed to deliver robust performance for the tropics and temperate latitudes.

We will discuss potential solutions to these remote sensing challenges and suggest approaches for tailoring CO2 and CH4 retrieval algorithms to optimize data yields for the northern high latitudes, especially over snow-covered land. Our inspection of the OCO-2 data products suggests significantly improved XCO2 yields are possible, especially for the September – April cold season. Each approach offers the promise of order of magnitude increases in 'good' retrieval yield.

Mapping Snow Persistence Patterns at Regional Scales in Alaska

Matt Macander [1]

[1] ABR, Inc.

Friday, 16 September, 9:00

Snow persistence and snow depth patterns affect important aspects of northern ecosystems. Snow cover can protect plants from dessication, wind abrasion, and herbivory, and controls winter heat exchange to plants, soils, and subnivean wildlife habitat. Deep snow can facilitate shrub growth and expansion. Snowbed plant communities often have unique species assemblages, have delayed phenology, and melt from late-lying snowbeds can help support streamflow during dry summers. Snow drifts provide denning habitat for large animals such as polar bears and wolverines. Shallow-snow and snow-free areas provide early spring habitat for grazing and nesting. Many important local-scale controls on snow depth and snow persistence are too fine to be resolved with daily 500 m MODIS data and other similar products.

We analyzed the entire collection of Landsat imagery from March 1-August 31, 1999-2015 to characterize snow persistence patterns in northern Alaska. Snow cover extent for each image was mapped using the SnowMap algorithm, including refinements for improved detection of snow under forest canopies and in terrain/cloud

shadows. Google Earth Engine was used to rapidly summarize the entire Landsat archive without time-consuming data discovery, acquisition, and pre-processing steps.

The stack of snow- and snow-free observations from all years was combined, and was analyzed using a binary classification tree to identify the day of year that best separated the snow-covered season from the snow-free season, at 30 m resolution. The snow persistence map was compared to the SNOTEL record, local snow depth maps, and MODIS snow metrics. We compared the results from 1) using all available Landsat data and 2) excluding the Landsat 7 SLC-Off data collected after May 2003. The striped gaps in the SLC-Off imagery result in some artifacts in the results, which may reduce the utility of the mapping for identifying fine-scale snow patterns.

Lake Ice Phenology of Southwest Alaska

Michael Verrier [1], Peter Kirchner [1]

[1] National Park Service, Southwest Alaska Network Inventory and Monitoring

Friday, 16 September, 9:30

The duration and seasonality of lake ice is sensitive to wind, air temperature, and snow accumulation and is correlated with climate variability and change. In Northern high latitudes, a trend of continued warming, which is nearly double that of lower latitudes, is expected to alter “lake ice phenology” or the freeze and break-up timing of lake ice. Reductions in the duration of annual lake ice cover are expected to be associated with changes in biological productivity in aquatic and terrestrial ecosystems, reduced albedo, the timing of ice-jam flooding, and impact on human activities including transportation and subsistence. We present a 15 year analysis of lake ice phenology for 17 southwestern Alaska terrestrial lakes and lake clusters, including the largest freshwater lake in Alaska, using near-daily 250-m resolution true color, corrected near-infrared (NIR), and shortwave infrared (SWIR) reflectance data from the MODIS Terra and Aqua sensors. The near-daily coverage of these sensors allow the detection of ice cover on lakes as it forms, intermittently thaws, and clears when lake extents are free of cloud cover. A grid-based mapping approach to estimate percentages of lake area covered by ice is accomplished through supervised classification using a 1 km2 grid masked to lake margins. Calibration and validation of results is accomplished using ground-based observations from lake temperature arrays and remote automated weather stations. The complete freeze (>90% ice cover) of lakes in this study ranges from late-October to late-March, a variability of 158 days. Break-up occurs more rapidly than freeze-up and

timing of break-up end dates (<10% ice cover) demonstrate a range of 174 days between early-January and late-June. The relatively large range of freeze-up and break-up is associated with strong El Niño events occurring in the 2003 and 2016 water years and record high wintertime temperatures in 2015. In 2003, 2015 and 2016, 5 to 8 lakes did not freeze and the average duration of freezing across all lakes was 55-67 days, 42-53% below the annual average duration of 115 days. In contrast, 2009 and 2012 demonstrated the highest duration of average ice coverage at 146 days each, 27% above the annual average. These results suggest that large-scale atmospheric and oceanic conditions like the El Nino Southern Oscillation and above average winter air temperatures have significant impacts on the timing of lake ice formation and break-up.

Comparing sea ice conditions and acoustic data in the Amundsen Gulf to assess bowhead whale habitat

Tyler de Jong [1], Stephen Insley [1], William Halliday [1]

[1] Wildlife Conservation Society Canada

Friday, 16 September, 10:00

Sea ice in the Beaufort Sea and Amundsen Gulf area is experiencing some of the most drastic reductions in concentration across the entire arctic region. Decreasing sea ice concentrations will likely cause increased shipping traffic, which may have important implications for the acoustic habitat of bowhead whales. Bowhead whales evolved in an acoustic habitat that is heavily influenced by sea ice, and has had little influence from loud anthropogenic sources like ship traffic. The first step in understanding how changing sea ice conditions will affect the acoustic habitat of bowhead whales is to understand how sea ice conditions affect ocean ambient noise levels in the absence of anthropogenic noises. In this study, Synthetic Aperture Radar (SAR) imagery is used to assess sea ice concentration and form. These ice characteristics are compared with submerged acoustics data from a hydrophone in the Amundsen Gulf (near Sachs Harbour, Northwest Territories) to determine the noise contribution caused by sea ice. This will ultimately lead to conservation efforts to determine the vulnerability of bowhead whale acoustic habitat in an area with increasing shipping and less seasonal ice cover. Future work should reveal the influence of anthropogenic activities (i.e. shipping) on ambient noise levels and indicate how this will impact bowhead whales.

Tuesday Poster Session

Evaluating Scenarios of Arctic Freshwater Ecosystem Responses to Climate and Land-Use Change using Remote Sensing and Geospatial Analysis

Fish CAFÉ Team

The Fish Creek Watershed encompasses a diverse mosaic of aquatic habitats representing much of the Arctic Coastal Plain of northern Alaska. Beyond surface water and permafrost responses caused by changes in climate, this landscape is subject to potential land-use impacts related to petroleum development in the National Petroleum Reserve – Alaska (NPR-A). Multi-agency efforts to establish environmental baselines have led to a comprehensive monitoring infrastructure. This combination of drivers of environmental change and established research infrastructure make this an ideal setting to address aquatic habitat questions of longstanding interest to Arctic resource managers and scientists. Thus, our multidisciplinary team of scientists and managers is focusing on the broad hypothesis that surface-water availability, connectivity, and temperature mediate aquatic habitat and trophic dynamics in this watershed. This analysis is being done in the context of scenarios of potential climate and land-use changes developed iteratively among our multi-disciplinary team and stakeholders in the Fish Creek Watershed and broader NPR-A.

An important component of this research is the development of a new classification system representing arctic lakes in a watershed and landscape context. High-resolution aerial photography and airborne Interferometric Synthetic Aperture Radar (IfSAR) data were used to systematically identify and delineate 4362 lakes within this 4900 km2 watershed. Lake classes representing habitat characteristics and ecosystem dynamics include lake origin and morphology, hydrological connectivity, surface area dynamics, and surrounding terrestrial ecotypes. In particular, classes for connectivity, derived from digital terrain analysis of flow accumulation thresholds using ArcGIS hydrology toolset, and lake depth, derived from late winter synthetic aperture radar (SAR) data, explained much of the variation in aquatic habitat for plankton, fish, and waterbird communities. Landsat derived trends in surface area dynamics helped identify that most lakes were either stable or expanding, which may eventually link this classification to variable habitat responses to climate change and inform management decisions regarding localized development and water extraction. This lake classification system is already

being used to design landscape-scale habitat studies, population inventories and occupancy models, and guide water-use permitting. Future work will test the portability of this lake classification to other arctic landscapes, such as lake-rich lands of the Seward Peninsula in northwest Alaska.

'Lake colour' in permafrost landscapes of the central Lena River Delta and central Yamal - case studies of Coloured Dissolved Organic Matter (cDOM) and turbidity regimes

Heim Birgit[1], Bartsch Annett[3], Dvornikov Yury[2], Fedorova, I.[4], Grosse Guido[1], Leibman Marina[2], Morgenstern Anne[1], Skorospekhova Tania[4], Widhalm Barbara[3]

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We provide a first field-based & satellite-based inventory of optical lake types in the permafrost landscapes of the central Lena River Delta (Arctic Siberia) and central Yamal (Western Arctic Siberia) using field investigations and multi-sensor satellite data. Within the thematic network between our groups we seek to investigate:

- the water-leaving spectral signal of the lake water bodies: 'the lake colour'
- how to link 'lake colour' to SAR-derived information
- geochemical and hydrodynamical in-situ investigations measurements (cDOM, DOC, SPM)

We give an overview on different optical types of lakes in the thermokarst landscapes of central Yamal and the Lena River Delta. For several of the lakes in Yamal and for some lakes in the central Lena River Delta we were able to sample for Dissolved Organic Carbon, DOC, and coloured dissolved organic matter, cDOM (the absorbing fraction of the DOC pool) and SPM. The cDOM regimes influence the transparency of the different lake types. We show simulations of cDOM influence on lake colour using the 'Water Colour Simulator' WASI©. However, turbidity seems to play the dominant role in providing the water-leaving colour of thermokarst lake types.

Landscape trends in lake ice regimes measured from space

Melanie Engram [1], Christopher D. Arp [1], Benjamin M. Jones [2], Olaniyi Ajadi [3], Franz Meyer [3]

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Lakes cover vast extents of lowland Arctic landscapes. Because of thick ice growth (1.1 to 1.9 m) in the Arctic, shallow lakes often freeze solid by the end of winter (bedfast ice regime) and slightly deeper lakes retain liquid water (floating ice regime). Whether a lake has a bedfast or floating ice regime determines winter water availability for fish habitat, human use, such as ice road construction, and also impacts sub-lake permafrost stability. We compare lake ice regimes from 1992-2016 using synthetic aperture radar (SAR) data (C-band, wavelength = 5.6 cm) in six distinct geographic regions of Arctic Alaska to determine the extent and trends in bedfast and floating lake ice conditions. We use a no-bias, equal-error threshold approach that accounts for changes in backscatter intensity from lake ice due to aging SAR instruments, different SAR platforms, and variable lake ice conditions. Lake ice regime classifications are in excellent agreement with ground-truth measurements acquired in the study region between 2007 and 2011. Results for the Barrow study area are in agreement with a recently published study covering a shorter time frame. Preliminary results show large variability in the area of bedfast lake ice from year to year, with significant declines in the area of bedfast ice in some of the six study areas of the Alaska Arctic Coastal Plain, indicating the quantity of landscape area in each study zone that is vulnerable to permafrost degradation.

Land Deformation Products from the Alaska Satellite Facility

Jessica Garron [1]

[1] Alaska Satellite Facility, Advanced Prototype Development group

In the Spring of 2016, the Alaska Satellite Facility, Advanced Prototype Development group, began development on a synthetic aperture radar (SAR) derived, land deformation map product. Sentinel-1 SAR images over areas of known land deformation were selected for interferometric processing using the GAMMA software suite, with GDAL integration. Unwrapped interferograms were used to calculate the subsidence of particular areas of interest, and were compared to vetted deformation maps for accuracy. ASF created deformation maps were comparable to published deformation products for the area, identifying major and minor areas of subsidence in the images. Some difference in coherence between previously published and prototype interferograms was visible, but was likely a result of the differences in parameters associated with the particular sensor used for interferogram creation. The APD group is now refining the process to effectively support the identification of subsidence features associated with permafrost degradation in the Arctic.

GLOBPERMAFROST - EARTH OBSERVATION FOR UNDERSTANDING OF PERMAFROST

Annett Bartsch [1,2], Guido Grosse [3], Andreas Kääb [4], Sebastian Westermann [4], Tazio Strozzi [5], Andreas Wiesmann [5], Claude Duguay [6], Frank Martin Seifert [7], Jarošlav Ob [4]

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The ESA DUE GlobPermafrost project develops, validates and implements Earth Observation (EO) products to support research communities and international

organisations in their work on better understanding permafrost characteristics and dynamics.

Permafrost cannot be directly detected from space, but many surface features of permafrost terrains and typical periglacial landforms are observable with a variety of EO sensors ranging from very high to medium resolution in various wavelengths. In addition, landscape dynamics associated with permafrost changes and geophysical variables relevant for characterizing the state of permafrost, such as land surface temperature or freeze-thaw state can be observed with space-based Earth Observation. Prototype product cases will cover different aspects of permafrost by integrating in situ measurements of subsurface properties and surface properties, Earth Observation, and modelling to provide a better understanding of permafrost today.

The project will extend local process and permafrost monitoring to broader spatial domains, support permafrost distribution modelling, help implementing permafrost landscape and feature mapping in a GIS framework, and will complement active layer and thermal observing networks. Lowland (latitudinal) and mountain (altitudinal) permafrost issues are addressed.

The results of a user requirements survey and the observation strategy will be presented.

Permafrost carbon pool estimation for the Ikpikpuk and Fish Creek river delta, North Slope, Alaska

Matthias Fuchs [1,2], Guido Grosse [1], Benjamin Jones [3], Ingmar Nitze [1,4]

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Arctic river deltas are highly dynamic environments at the interface of land to ocean. They are underlain by permafrost deposits, which are highly vulnerable to a warming climate. The amount of soil carbon stored in these deltas and potentially vulnerable to mobilization is poorly known and based on few data only. In this study, we investigate the soil carbon pools of two Arctic river deltas entering the Beaufort Sea on the Alaska North Slope: the Ikpikpuk and the Fish Creek river deltas. Our approach couples soil carbon information with remotely sensed data to estimate the total carbon stock in the

upper two meters for these environments. Both river deltas are characterized by typical fluvial-deltaic features and processes, as well as by permafrost processes such as thaw, erosion, transport, and accumulation dynamics within these deltas. As a result, features specific to permafrost-dominated deltas are widespread such as thermokarst lakes, drained thaw lake basins and ice wedge polygonal tundra. Under future climate warming projections, Arctic river deltas will be threatened due to thawing permafrost and a rising sea level in combination with coastal erosion. To better estimate how much soil carbon may be vulnerable to mobilization under these projected changes and might be released as greenhouse gases, it is necessary to study the total soil carbon storage in Arctic permafrost river deltas.

This study presents the first carbon storage estimation in surface soils and sediments for these two Arctic deltas (~100 km2). Nine different soil cores between 54 and 215 cm depth, including both, non-permanently and permanently frozen deposits, were collected in April 2014 and July 2015, and were analyzed in the laboratory for total organic carbon (TOC), total carbon (TC), total nitrogen (TN). The soil C parameters were upscaled to each delta based on landcover classifications derived from Landsat and Spot images. Different remote sensing approaches were compared, including the correlation of near surface soil carbon storage with various remotely sensed landcover indices. These indices, such as the Tasseled Cap or NDVI for the year 2014 were derived from linear trend analyses of Landsat data taking into account the full Landsat 5-8 archive from 1985-2014. Additionally, supervised classifications (maximum likelihood and random forest) with Landsat 8 and Spot 5 images were established based on training areas derived from field information, very high resolution aerial and satellite images, and high resolution surface elevation information. The organic carbon content was finally upscaled based on mean carbon values for the different landcover classes.

The total organic carbon storage for the two deltas ranges between 1.5 and 2 teragrams (Tg) of organic carbon each for the first meter of soil (excluding all water areas), depending on the upscaling method and dataset used. The results compare favorably (comparing the mean carbon storage values per square meter) with what has been previously estimated for other, larger Arctic river deltas and this study shows that remote sensing is a suitable tool to upscale soil carbon values in remote Arctic river deltas where only few soil data is available.

Regional thermokarst lake area trends across the Arctic based on Landsat time-series

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Observed and projected climate change in the Arctic increases the vulnerability of terrestrial ecosystems to disturbances. For example, significant increases in air temperatures especially in high latitudes will impact the stability of permafrost landscapes that cover 24% of the northern hemisphere and dominate large parts of the Arctic. Resulting potentially large-scale permafrost thaw and subsequent changes in geomorphology, hydrology, and vegetation as well as mobilization of previously frozen soil organic matter will provide regional to global scale feedbacks that require better quantification. The release of this carbon as methane and carbon dioxide, both active greenhouse gases, would result in a positive feedback with climate warming ("permafrost carbon feedback").

Permafrost affected areas are distributed over different climatic and biogeographic zones, from coastal tundra lowlands to continental boreal or mountainous regions and are therefore exposed to different natural conditions. In many of the permafrost lowland areas, thermokarst lakes have developed and are still actively shaping landscape dynamics by lake formation, expansion, and rapid or gradual drainage or desiccation. So far these thermokarst lake dynamics are monitored only within limited areas and often with low temporal resolution. These localized studies revealed different magnitudes and directions of changes ranging from a net gain to a net loss of lake surface area. However, a consistent monitoring and comparison of permafrost thaw processes across broader spatial scales and high temporal resolution has not been accomplished yet.

With a robust trend analysis on data from the entire Landsat archive (Nitze & Grosse, 2016) it is possible to monitor several key surface indicators such as vegetation, water or albedo over time. Lake dynamics, such as expansion or drainage, exhibit a specific

spatio-temporal signature within the trend analysis, which allows for an automated detection and extraction of thermokarst lake related landscape features based on object-oriented machine-learning analysis. With the knowledge of lake specific surface area change zones and rates we were able to calculate lake area trends from regional to lake specific spatial scales. Within our study, we expand the monitoring of thermokarst lake dynamics over several different permafrost regions of diverging climatic and biogeographical conditions across North America and Siberia (Alaska North Slope, Northern Seward Peninsula, Lena Delta, Kolyma Lowlands, Central Yakutian Lowlands).

In general, the majority of study sites exhibited slightly negative (2 to 6 % net lake area loss) or neutral (net lake area stability) lake surface area trends over the last 15 years. However, strong outliers were detected, such as central Yakutia, where a massive lake surface area increase (>50 %) has been detected. Within the different study regions, a further differentiation of lake dynamics could be accomplished between sub-regions of lake change intensity.

The high level of automation and the free and global availability of Landsat-data provide a great opportunity to extend the current data base to a much broader scale. A combination of this dataset with more localized high-resolution studies could provide an unprecedented detailed knowledge about the spatial-temporal dynamics of thermokarst lakes across multiple spatial and temporal scales.

A Raster Version of the Circumpolar Arctic Vegetation Map (CAVM)

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The Circumpolar Arctic Vegetation Map (CAVM) is a vector (polygon) map showing the dominant physiognomy of the vegetation of the Arctic. The legend has 15 vegetation types, glacier, water, and non-arctic land. A line layer shows major riparian corridors, which were too narrow to map in polygonal format. This map was published in 2003, and has been cited over 700 times. The main value of the map was that it mapped the

vegetation of the whole Arctic in a consistent legend, so that different parts of the Arctic could be compared.

Although the CAVM has proved to be a very useful tool, there has been interest in a raster version of the map. The raster format would match environmental data such as climate and substrate data from satellite sensors and other sources. Many researchers have used a simple rasterized version of the polygon map in their models. This project will create a 1-km resolution raster map using the same legend categories as the CAVM. The raster map will provide greater resolution (1-km pixels vs. the 14-km minimum polygon diameter), while maintaining the same consistent vegetation legend. This resolution allows more detailed mapping of mountainous areas, portrays coastal-inland gradients, and better reflects the heterogeneity of vegetation type distribution.

LANDSCAPE CHANGE DETECTED OVER A 60 YEAR PERIOD IN THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, USING HIGH-RESOLUTION SATELLITE IMAGERY AND HISTORIC AERIAL PHOTOGRAPHS

Janet C. Jorgenson, Mark T. Jorgenson, Meghan Buchholtz and Kathleen M. Orndah

We conducted an analysis of landscape change over a 60 year period in the Arctic National Wildlife Refuge in northeastern Alaska using aerial photography and satellite imagery. Study sites were chosen randomly, to allow extrapolation to the whole refuge. A stratified random sample was used, with five random sites in each of seven ecoregion. Each site had a grid of 100 systematic points for a total of 3500 points.

Within each ecoregion we chose study sites in the overlap area covered by acceptable imagery in three time periods. We acquired digital scans of aerial photographs for the two first time periods (1947-55; 1980s). For the last time period (2000s) we acquired Quick Bird and IKONOS satellite images.

Image interpretation was done in ARC-MAP. At each point, the area in a 10 meter radius circle was visually evaluated in each time periods for vegetation type and disturbance. We recorded presence of ice wedge polygon microtopography and surface water. A landscape change category was assigned to each point based on the differences detected between the three periods. Change types were assigned for time interval 1, interval 2, and overall.

Additional variables included elevation, slope, aspect, bedrock geology, physiography, mean annual temperature from CRU6-9 and Summer Warmth Index (Comiso 2006).

Overall, 23% of all 3500 points changed over the ~60 year period. Fire was the most common change agent, affecting 28% of the South Side points. The next most common change was degradation of soil ice wedges (thermokarst), detected at 12% of the points on the North Slope. The other most common changes included increase in cover of trees or shrubs (7% of South Side and Brooks Range points) and erosion or deposition on river floodplains and at the coast.

Changes on the North Slope Tundra tended to be related to landscape wetting, mainly thermokarst. Changes on the South Side tended to involve landscape drying, including fire, reduced area of lakes and tree increase that may be caused by soil drying. The second time interval (1980s to 2000s) coincided with a shift towards a warmer climate and had greater change in several categories including thermokarst, lake changes and tree and shrub increase.

Understanding future changes in snow cover in response to climate change

Rebecca Vignols [1], Gareth Rees [1], Gareth Marshall [2]

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Understanding future changes in snow cover in response to climate change is an important research field. This is principally because the extremely high albedo of snow means that changes in snow cover have a significant impact on the Earth's global energy

budget. This project focusses on the Northern Hemisphere snow cover, which comprises approximately 98 percent of the global total and which is responsible for the largest annual and inter- annual differences in land surface albedo. Using remote sensing, meteorological observations and field data, changes in snow cover of the Kola Peninsula in Arctic Russia will be analysed. Field measurements of snow parameters will be used to ground-truth the satellite data: MODIS (visible and near-infrared) and passive microwave data will be combined in order to maximise spatial resolution and the number of parameters that can be investigated. The initial focus on the area around the Khibiny Mountains in the Kola Peninsula will subsequently be extrapolated to obtain a wider regional picture, focussing on northern Europe. Atmospheric reanalysis data will be utilised to determine how atmospheric circulation variability affects the regional snow cover. Based on these relationships, and the output from a regional climate model forced by future runs from the best CMIP models, snow cover predictions will be made until the end of the century based on the four main IPCC RCP scenarios. These regional predictions may then be extended to the entire Northern Hemisphere.

Detailed Wetlands Map for the Barrow Region, Northern Alaska, 2010 to 2013

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The detailed Wetlands Map for the Barrow Peninsula was created from a land cover classification derived from very high-resolution (0.5m) WorldView-2 satellite imagery (2010, 2012) obtained from the Polar Geospatial Center (PGC). Training site data and ground control points (GCPs) were collected in the field during the summers of 2013 and 2015 by the University of Texas at El Paso. In preparation for the image classification, multispectral and panchromatic images were fused to increase the spatial resolution from 2m to 0.5m using the Gram-Schmidt pan-sharpening method. The images were

then mosaicked and orthorectified using GCPs distributed across the peninsula. We classified the mosaicked block using a minimum-distance supervised classification based on field training using ENVI 5.1. The resulting land cover raster map of about 1,800 km2 contained nine classes across a moisture gradient. Wetlands were classified by cross-walking the land cover map classes with NWI wetland codes and standards using the Wetlands and Deepwater Habitats Classification Hierarchy chart and classification key. Wetlands were classified as marine, estuarine, palustrine, and lacustrine wetlands.

Sixty-five years of Colville River dynamics and its impacts on present river navigability near Nuiqsut, North Slope of Alaska

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Dynamics of the Colville River on the North Slope of Alaska impact the traditional harvest practices of the Native community of Nuiqsut. Recent reports from residents indicate accelerated changes in the environment, influencing river navigability and their ability to harvest subsistence food. This study 1) explores how channel migration, gravel bars, and bank erosion have evolved over the last 65 years, 2) assesses drivers of change, and 3) identifies impacts on river depth and navigability. The study focuses on selected key areas with significant change in river geomorphology. We use georeferenced panchromatic photos acquired by US Geological Surveys in the mid-1950s, color infrared aerial photos from 1979 and 1982 acquired by the Alaska High Altitude Photography (AHAP) mission, and high resolution satellite images for more recent years from Digital Globe, Inc. for this study. We map the selected areas into water, vegetation, and gravel/non-vegetated classes, and identify the risk areas for river navigability. Also, we map the river bathymetry using a multispectral ratio-based water depth retrieval algorithm to identify problem sites for boat travel. Remote sensing products and analyses will be validated using field data as ground truth for mapping risk areas along

the river. This study has the potential to be implemented on a larger scale for predictive mapping to aid river navigation. Findings from this study will provide insight whether recent changes are anomalies or if they are part of a directional trend that will require local adaptation.

Research Progress on the effect of wildfire on permafrost environment on the Northern Da Xing'anling Mountains, Northeastern China

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The wildfire is one of the main factors influencing the boreal forest ecosystem in many aspects; not only the nutrient cycles and surface energy balance, the changes of soil physical and chemical properties, but also the changes of active layer thickness and soil temperature. Under the context of global warming and increase of the anthropogenic activities, the occurrences of the wildfire have been frequently increased in boreal forest. Previous studies indicated that the wildfire had significant impacts on the hydrothermal of active layer and permafrost, which tends to irreversible degradation of permafrost, converse succession of forest and wetland, the loss of carbon storage, thermal subsidence and slumping. Besides, it threated the buildings on permafrost. In this paper, we summarized conclusions of research progress on the effect of wildfire on permafrost environment , the result shows that , the research on permafrost has made breakthrough progress. But the research on the wildfire and permafrost are little, and mainly short-time, small scale, qualitative description and inference, it lacks of quantitative analysis for a long time. In the Da Xing'anling Mountain, there were few related studies in the early 90s (e.g., Liang et al., 1992; Zhou et al., 1994): the active layer thickness increased, the soil temperature rose, vegetation recovery was slow and ground

subsidence, etc. Although there are scattered reports since these studies (e.g., Zhou et al., 2008; Bai et al., 2013), still, long-term and systematic observations and numerical simulations are scarce as well as the applications on the research of frontier discipline basic theory and practical engineering. By means of spatial method instead of time method, the long and short-term field investigation combination numerical simulations, it aims to quantitatively study the change of hydrothermal condition, process and mechanism of permafrost after wildfire. This study could provide important scientific basis for reasonable assessment of the impacts of wildfire on boreal forest and wetland in permafrost region, the environmental restoration and management, and the research of shallow carbon pool in mid- and high latitude in China.

Thanks again to our Symposium Sponsors!