Understanding Circumpolar Ecosystems in a Changing World
Outcomes of the International Polar Year

3-6 November 2010

Conference Program and Abstracts

Natural Resources Canada | Ressources naturelles Canada

Scientific Program

Understanding Circumpolar Ecosystems in a Changing World
Outcomes of the International Polar Year

University of Alberta, Edmonton, Albert

November 3-6, 2010

Northern ecosystems are increasingly becoming a high-profile topic on the political agenda. Most of the circumpolar regions are seen as pristine landscapes, which have experienced radical changes in climate, vegetation, and animals. Warming during the last 30 years has been associated with warming and disappearing permafrost, changes in growth rates of dominant trees, natural and anthropogenic disturbances, and changes in vertebrate populations. The causal links among these changes and their implications for the functioning of the circumpolar region and the people who live there are not completely understood. To understand the current and future structure, diversity, and functioning of the circumpolar region, it is important to understand how climate and disturbance interact and the implications of these interactions for ecological, economic, and cultural sustainability of the circumpolar region. The conference will address these topics.

Sponsoring Organizations

Campbell Scientific Canada Corp.
Canadian Circumpolar Institute, University of Alberta
Department of Biological Sciences, University of Alberta
Department of Earth & Atmospheric Sciences, University of Alberta
Government of Canada, IPY Federal Program Office
Hoskin Scientific Ltd.
Natural Resources Canada/Canadian Forest Service/ Northern Forestry Centre

Sponsoring Projects

PPS Arctic and PPS Canada
CiCAT and ITEX

Many individuals have contributed a large amount of their time to help with the planning of this meeting. It was a pleasure working with these individuals. We take this opportunity to thank the members of the scientific committee and organizing committee for their time and efforts to make this meeting possible.

Organizing Committee

Jagtar Bhatti, Northern Forestry Centre, Canadian Forest Service, Edmonton
Sara Dick, Conference Services, University of Alberta
Ruth Errington, Northern Forestry Centre, Canadian Forest Service, Edmonton
David Hik, Biological Sciences, University of Alberta, Edmonton
Igor Jakab, Earth & Atmospheric Sciences, University of Alberta, Edmonton
Peter Kershaw, Earth & Atmospheric Sciences, University of Alberta, Edmonton
Elaine Maloney, Canadian Circumpolar Institute, University of Alberta, Edmonton
Steve Mamet, Earth & Atmospheric Sciences, University of Alberta, Edmonton
Cynthia Mason, Canadian Circumpolar Institute, University of Alberta, Edmonton
Scott Williamson, Biological Sciences, University of Alberta, Edmonton

Scientific Programme Committee

Jagtar Bhatti, Northern Forestry Centre, Edmonton, Canada
David Cairns, Texas A & M University, USA
Nancy Doubleday, McMaster University, Hamilton, Canada
Karen Harper, Dalhousie University, Halifax, Canada
Greg Henry, University of British Columbia, Vancouver, Canada
David Hik, University of Alberta, Edmonton, Canada
Annika Hofgaard, Norwegian Institute for Nature Research, Trondheim, Norway
Peter Kershaw, University of Alberta, Edmonton, Canada.
Gareth Rees, Scott Polar Research Institute, Cambridge, United Kingdom

Program

Wednesday November 3, 2010

Location: Tory Building, Henry Marshall

	Room: 3-36
9:30	PPS Arctic Canada
1:00	CiCAT

Location: Lister Conference Centre

	Wild Rose Room
4:00	"Icebreaker Reception, Registration and Poster Hanging" cash bar (until 9:00pm)

Thursday November 4, 2010

Location: Lister Conference Centre

7:00 Registration: in the Lister Conference Centre Foyer

	Maple Leaf Room	***Aurora Room***
8:00	**Welcome and Announcements**	
8:30	Tanuja Kulkarni: Canadian International Polar Year 2007-2008	
9:15	Annika Hofgaard: Are Trees Invading the Arctic? Circumpolar Treeline Research during IPY	
10:00	Health Break: Wild Rose Room	

Thursday November 4, 2010

Location: Lister Conference Centre

	Maple Leaf Room	*Aurora Room*
	REMOTE SENSING	**DISTURBANCE**
	Chairs: Gareth Rees & Scott Williamson	*Chairs: Peter Kershaw & Carissa Brown*
10:30	Analysis of vegetation, fire and lake change on pan-arctic and local scale within the ESA Data User Element Permafrost *Marcel Urban*	Detecting the undetectable: A new dendroecological method for dealing with low-level disturbance at treeline *Andrew Trant*
10:50	Rapid retreat of a unique ecosystem, the Northern Ellesmere Island Ice shelves, and the role of a thinning perennial sea ice zone *Benjamin Lange*	Fire effects on plant-soil interactions drive alternate successional trajectories in boreal forest *Jill Johnstone*
11:10	Evaluating the quality of clear-sky MODIS Terra daytime Land Surface Temperatures (LST) using ground based meteorology station observations *Scott N. Williamson*	Research of the forest-tundra ecotone structure and changes in Russia *Annika Hofgaard, Hans Tommervik*
11:30	IPEM - A Cost Effective Predictive Modelling Approach for Developing Process-based Ecological Inventories for Arctic National Parks *Donald McLennan*	Linking fire frequency and seed production in northern black spruce (Picea mariana) forests *Jayme N Viglas*
11:50	Lunch: Maple Leaf Room	APECS mentoring session: Polar Careers Post-Graduation
	AQUATIC	**TREELINE RESPONSE TO CLIMATE CHANGE**
	Chairs: Brent Wolfe & Jennifer Nafziger	*Chairs: Annika Hofgaard & Steven Mamet*
1:20	Assessing Present and Past Lakewater Balance Conditions in the Old Crow Flats, Yukon Territory *Kevin W. Turner*	Altitudinal treeline dynamics in response to climate change in the vinicity of Kangiqsualujjuaq (Nunavik, Québec) *Geneviève Dufour Tremblay*
1:40	Tracking hydrological responses of a thermokarst lake in the Old Crow Flats (Yukon, Territory, Canada) to recent warming using aerial photos and paleolimnological methods *Lauren A. MacDonald*	North vs. South: Aspect-related differences in treeline pattern and process *Ryan Danby*
2:00	Ocean-Atmosphere Interactions: Does Life (and Death) in the water influence Arctic climate? *A.L. Norman*	Forest-tundra dynamics during the last 400 years: is treeline advancing in northern Manitoba? *Steve D. Mamet*
2:20		The effect of daily climate variability on the Canadian boreal forest *Tana Stratton*

Thursday November 4, 2010

Location: Lister Conference Centre

2:40	Health Break: Wild Rose Room	
	Maple Leaf Room	***Aurora Room***
	SOCIAL	**CLASSIFICATION and SPATIAL PATTERN**
	Chairs: Nancy Doubleday & Bryan Grimwood	*Chairs: Karen Harper & Heather Morrison*
3:10	Critical Inuit Studies and the EU Seal Ban *Barret Weber*	Evolution of Satellite Radar Backscatter and Snow and Sea Ice Properties on Miquelon Lake, Alberta *Justin Beckers*
3:30	Social science perspectives in developing synthesis activities in PPS Arctic beyond the IPY *Tatiana Vlasova*	Classification of Vegetation in Arctic Regions *Catherine E. Kennedy*
3:50	Photos and plants through time: Sharing knowledge – building adaptation *Nancy Doubleday*	Changes in the spatial pattern of vegetation across the Canadian forest-tundra ecotone *Karen Harper*
4:10		Spatial and temporal patterns in growth-climate relationships at the northern treeline in the western Canadian Arctic *Scott Green*

Friday November 5, 2010

Location: Lister Conference Centre

	Maple Leaf Room	***Aurora Room***
	Plenary Talks	
8:00	Charles Tarnocai: Largest terrestrial organic carbon pools: new results from soils of the northern circumpolar permafrost region	
8:40	Greg Henry: Recent change in tundra vegetation: Results of plot based monitoring across the tundra biome	
9:20	Peter Lafleur: Arctic Tundra - Climate Change Time Bomb or Lifeline	
10:00	Health Break: Wild Rose Room	

Friday November 5, 2010

Location: Lister Conference Centre

	Maple Leaf Room	***Aurora Room***
	PRODUCTIVITY	**SHRUBS**
	Chairs: Robert Grant & Craig Emmerton	*Chairs: David Cairns & Isla Myers-Smith*
10:30	Ecological Controls on Net Ecosystem Productivity of a Mesic Arctic Tundra under Current and Future Climates *Robert Grant*	Investigating potential impacts of shrub encroachment on arctic ground squirrel behaviour and density *Helen Wheeler*
10:50	Primary Productivity in the High Arctic: Measurements and Predictions for Climate Change *Craig Emmerton*	On the ecological causes and consequences of the rapid response of dwarf birch to climate change at treeline *Stéphane Boudreau*
11:10	Microtopographic effects on vegetation cover and productivity in arctic tundra *John A. Gamon*	Shrubline advance in Arctic and alpine tundra of the Yukon Territory *Isla H. Myers-Smith*
11:30	The Greening Valleys of the Lewis Glacier and Isortoq River, North central Baffin Island, Nunavut, Canada *Patrick J Webber*	Tall shrub encroachment in the Mackenzie Delta Uplands, Northwest Territories, Canada. *Trevor Lantz*
11:50	Lunch: Maple Leaf Room	
	CARBON DYNAMICS	**TREE GROWTH**
	Chairs: Peter Lafleur & Sara Kuleza	*Chairs: Ryan Danby & Andrew Trant*
1:20	Characterization of GHG Distributions and Processes in Peatlands along a Permafrost Climatic Gradient using Stable Isotopes *Michael J. Whiticar*	Influence of environmental variation on tree growth and climate interactions at the western Canadian subarctic treeline *Sean Sweeney*
1:40	Spatial variability in soil fertility in the forest-tundra ecotones of the Kola Peninsula, Russia *Maria Orlova; Natalia Lukina; Tatiana Kravchenko*	Reproductive potential of forest expansion in the circumpolar north *Carissa D. Brown*
2:00	Role of landscape position and permafrost thawing on seasonal variations of methane emissions and soil concentrations in four ecoregions in Mackenzie Valley, region of Canada *Natalia Startsev*	The reproduction, establishment, and growth of white spruce at its northern range limit in Canada *Xanthe Walker*
2:20	Trace gas fluxes from three high-Arctic plant communities along a soil moisture gradient *Ioan Wagner*	Ancient Yukon trees of southeastern Beringia *Rodney Savidge*
2:40	Health Break: Wild Rose Room	

Friday November 5, 2010

Location: Lister Conference Centre

	Maple Leaf Room	*Aurora Room*
	SOILS and GREENHOUSE GAS DYNAMICS	**ENVIRONMENT-VEGETATION INTERACTIONS**
	Chairs: Jagtar Bhatti & Ruth Errington	*Chairs: Greg Henry & Geneviève Dufour Tremblay*
3:10	Carbon dynamics of Canada's northern forests estimated by the National Forest Carbon Monitoring Accounting and Reporting System (NFCMARS) *Juha M. Metsaranta*	Comparing Warming and Grazing Effects on Birch Sapling Growth in the Tundra Environment – a 10 Year Experiment *Annika Hofgaard.*
3:30	Processes controlling the watershed-scale carbon balance of high-Arctic ecosystems at Cape bounty, Melville Island, Nunavut *Ioan Wagner*	The role of changing vegetation on the hydrology of northern ecosystems *Philip Marsh*
3:50	NorthSTAR – a network for monitoring ecosystem carbon uptake and phenology in northern ecosystems *John A. Gamon*	Dryas integrifolia responses to experimental warming conditions in a subarctic environment *Sara D. Kuleza*
4:10	Options and limitations of operational mapping of forest biomass – a summary of 12 years of pan-boreal vegetation mapping with radar remote sensing in Siberia, China and Canada *Marcel Urban for Christina Schmullius*	Ecosystem Classification in the Northwest Territories *Dave Downing*
4:30		Atmospheric, edaphic, geological, and terrain controls on Hg in lake sediments of Great Bear Lake in North West Territories, Canada *Mina Nasr*
6:00	Banquet: Maple Leaf Room Speaker: Pat Webber "Measuring within and beyond your hypothesis increases the legacy"	

Saturday November 6, 2010

Location: Lister Conference Centre

	Maple Leaf Room
	Plenary Talk
8:30	Donald McLennan: Working Together to Develop Effective Biodiversity Climate Adaptation Strategies in the Arctic
9:15	Discussion on biodiversity issues in the Arctic – Moderator: David Hik
10:00	Health Break: Wild Rose Room
10:30	Data Management Workshop – Moderators: Greg Henry & Gareth Rees
11:50	Lunch: Maple Leaf Room
1:00	Cross-Project Synthesis Workshop – Moderators: David Cairns & Karen Harper
2:15	Health Break: Wild Rose Room
2:45	Future Collaboration Workshop – Moderators: Jagtar Bhatti & Annika Hofgaard
4:00	Closing Remarks: Jagtar Bhatti & Annika Hofgaard

Health breaks sponsored by Campbell Scientific Canada Corp. and Hoskin Scientific Ltd.

PLENARY TALKS (alphabetical by first author)

Recent change in tundra vegetation: Results of plot based monitoring across the tundra biome

Sarah C. Elmendorf, Department of Geography, University of British Columbia
Greg H.R. Henry, Department of Geography, University of British Columbia
and the Tundra Vegetation Change Group*

Results from experimental warming studies suggest tundra vegetation will respond rapidly and dramatically to climate warming, and indeed, data from remote sensing and repeat aerial photography suggest such changes may already be occurring. In particular, there has been an increase in the greening of Arctic terrestrial systems as measured by NDVI over the past 30 years. However, changes in NDVI may reflect a variety of processes that affect remotely-sensed greening and must be calibrated by ground truthing in order to determine whether the signal is correlated with an increase in biomass. Repeat measurements of permanently marked plots offer an invaluable opportunity to monitor detailed changes in vegetation composition and abundance. As part of the International Tundra Experiment (ITEX) core project in IPY, we conducted a synthesis of repeat measurements of 195 permanent plots in Arctic and alpine tundra plant communities in North America (90 plots), Europe (82 plots), Asia (10 plots), Australia (12 plots), and Antarctica (1 plot) that were revisited at least twice between 1980 and 2010, with an average timespan of 13 years between first and last sampling periods. Annual air-temperature warming over the sampling period varied considerably among sites, ranging from slight cooling to increases of nearly 2ºC/decade. We found significant tundra-wide increases in vegetation height as well as abundance of evergreen shrubs and graminoids, and declines in mosses. These changes were similar to results found in an earlier synthesis of warming experiments in ITEX. Despite this, we found no support for the hypothesis that Arctic greening is driven by local increases in air temperature; in fact, temporal change in cover of bare ground was positively correlated with site-specific changes in annual air temperature, while temporal changes in the abundance of deciduous shrubs and graminoids were negatively correlated with site-specific changes in annual air temperature. Changes in diversity measures were also complex. It is possible that vegetation dynamics in these areas are affected more by other environmental factors, including moisture availability and precipitation regimes, and other longer-term non-equilibrium processes such as recovery from glaciation. Our results show that the dynamics of tundra vegetation at the plot scale is complex, especially when detecting tundra-wide patterns from combined data sets.

*Tundra Vegetation Change Group:
Robert Björk, Anne Bjorkman, Elisabeth Cooper, Hans Cornelissen, Thomas Day, Ellen Dorrepaal, Tatiana Elumeeva, Anna Maria Fosaa, Mike Gill, William A Gould, Járngerdur Grétarsdóttir, John Harte, Annika Hofgaard, Robert Hollister, David Hik, David Johnson, Jill Johnstone, Ingibjörg Svala Jónsdóttir, Janet Jorgenson, Frida Keuper, Kari Klanderud, Julia Klein, Saewan Koh, Gaku Kudo, Mark Lara, Esther Levesque, Val Loewen, Borgthor Magnusson, Jeremy May, Joel Mercado, Anders Michelsen, Ulf Molau, Isla Myers-Smith, Steven Oberbauer, Vladimir Opichenko, Sara Pieper, Eric Post, Christian Rixen, Niels Martin Schmidt, Gaius Shaver, Marko Spasojevic, Þóra Ellen Þórhallsdóttir, Anne Tolvanen, Ørjan Totland, Tiffany Troxler, Craig Tweedie, Sandra Villareal, Carl-Henrik Wahren, Xanthe Walker, Patrick Webber, Jeffrey Welker, Sonja Wipf

Are trees invading the Arctic? Circumpolar treeline research during IPY

Annika Hofgaard, Norwegian Institute for Nature Research, Trondheim, Norway
Gareth Rees, Scott Polar Research Institute, University of Cambridge, United Kingdom
Karen Harper, School for Resource and Environmental Studies, Dalhousie University

The location of the tundra-taiga interface (TTI) zone corresponds to historic and recent climate and disturbance regimes. The zone is expected to respond rapidly to climate warming by tree and shrub advance, with ecological, socioeconomic and climatic consequences at local to global scales. However, the predicted advance is based on simple models that neglect ecological constraints and time-lags. The circumpolar TTI is diverse and complex, and cannot be expected to respond in a homogeneous manner throughout its vast geographical biome. During IPY a large number of projects have begun to reveal a varied pattern of response to recent environmental changes, challenging the assumption of a common, simplistic, rapid northward forest advance. Responsiveness is linked to both the structure of the zone and its geoclimatic location. Advance appears to prevail in alpine areas and regions affected by moist air masses, while some latitudinal treeline regions dominated by dry arctic air show stationary or even retreating behaviour. Arctic herbivores can dominate TTI dynamics at region- and species specific levels by modifying e.g. recruitment, survival and growth. Herbivore-driven modification of expected climate-driven tree expansion emphasises the need to consider changes in grazing regimes and other perturbations along with climate change, to avoid misleading interpretations regarding rates of climate-driven encroachment. The vast area and remote location of many study sites calls for remote sensing as a monitoring tool of decadal tree cover changes. Efficient algorithms have been developed for local scales and dense forest, although difficulties remain for sparse forest and global scale mapping.

Canadian International Polar Year 2007-2008

Tanuja Kulkarni, International Polar Year, Federal Program Office, Indian and Northern Affairs Canada

International Polar Year (IPY) was established to address the need for large scale international cooperation when dealing with the poles. Only three other similar initiatives have been held over the past 125 years. During each of these undertakings, scientists from around the world came together to organize intensive scientific and exploration programs in the polar regions, resulting in important advances to scientific knowledge and geographical exploration. From laying the basic foundations of our understanding of nature's global systems to launching the modern space age, the previous International Polar Years set the stage for many other international scientific collaborations as well as a long-standing political accord. IPY 2007-2008, will mark the first initiative of its kind in 50 years. As the largest-ever international program of scientific research focused on the Arctic and Antarctic regions, it builds upon a long and distinguished legacy of international cooperation and scientific achievement.

The Government of Canada has made a significant strategic investment and worked closely with Northern and Aboriginal communities, scientists and researchers, and other domestic and international partners to ensure International Polar Year 2007-2008 was sufficiently supported to deliver important results for Canadians.

Federal funding enabled Canada to carry out an innovative, multidisciplinary program for IPY that focused on two priority areas for science and research: climate change impacts and adaptation and the health and the well-being of Northern Canadians. A range of training and capacity building initiatives were also supported to develop a new generation of northern scientists and enhance the capacity to conduct science in the North. Logistics support included a toolkit to ensure that southern and international researchers came prepared; upgrading science equipment, and training for health and safety. Other critical elements of the IPY program included communications, data management and licensing.

Although the results of IPY 2007-2008 have been published in a wide range of literature, a final journal publication is in development that will be a special issue devoted to the results of the research. A complimentary report will be produced that will synthesize the science results and will integrate the science with northern policies.

The legacy of this IPY will be echoed during the upcoming “From Knowledge to Action” conference, to be hosted by Canada in Montreal in April 2012. This final international conference will showcase the important contributions of IPY work in the domestic and international arenas.

Arctic Tundra – climate change time bomb or lifeline?

Peter M. Lafleur, Geography Department, Trent University

Polar amplification, permafrost thawing and other processes have defined the role of the arctic landscape in future climatic change as an issue of critical scientific concern. One of the large uncertainties in climate change is the potential feedback resulting from the tundra's response to future warming. There is strong evidence that both positive and negative feedbacks to climate change might exist within tundra greenhouse gas exchanges with the atmosphere. Yet, understanding and modelling these responses is confounded by the diversity of the arctic landscape and a lack of knowledge of critical processes at appropriate scales. This talk highlights the potential responses of arctic tundra-atmosphere carbon exchange to climatic change and outlines the evidence that supports them. Topics discussed include increase in growing season temperatures, in creases in growing season length, vegetation redistribution, and permafrost thawing.

Working together to develop effective biodiversity climate adaptation strategies in the Arctic

Donald McLennan, Parks Canada Agency, Hull

It is now well-accepted that marine, terrestrial, and freshwater ecosystems in Canada's Arctic, and around the circumpolar area, are already changing, and are expected to continue to change in a dramatic fashion over the next century and beyond (ACIA 2005, IPCC 2008). As an example of the potential scale of this change, recent biodiversity modelling (Lawler et al. 2009) identifies the central Canadian Arctic as a 'worldwide hotspot' of projected biodiversity change, estimating biodiversity changes in excess of 100% for bird and mammal species.
Ten Arctic national parks cover a combined area of about 160,000 km^2 across the range of Arctic ecozones, and early observations from the Parks Canada IPY program suggest significant climate driven change has been occurring for about 25 years. These ongoing and potential changes represent a significant management challenge for superintendents of national parks, who are charged with "...maintaining or restoring the ecological integrity" of the national parks within their field units. This presentation uses work completed under the CiCAT Tundra IPY Project to demonstrate the development, key components (process-based inventory, effective monitoring, focussed research, and management modelling), and applications of a management knowledge system aimed at providing park managers with critical information on park ecological change, intended to facilitate proactive decision-making and effective adaptation to ongoing and future ecological change.

Given the nature and scale of proposed climate–driven ecological change, what is also evident is that Parks Canada will not be successful in adapting to these changes within national parks unless we are all successful in assuring permeable landscapes and healthy matrix lands between parks – lands that will support species migrations and broad scale climate adaptation across the North American Arctic, and indeed around the circumpolar Arctic. In addition to climate effects, achieving these goals will be severely complicated by increases in planned and ongoing community and industrial developments across the Arctic. It is suggested in the presentation that the only successful path forward to meet this enormous challenge will involve unprecedented levels of cooperation across governments, industry, communities, universities and NGOs. The proactive adaptive management approach proposed for national parks also provides a useful model for thinking about how to be successful in a broad-scale biodiversity strategy for climate adaptation across the Canadian Arctic.

The presentation concludes by looking at the adaptive management components presented for the Parks Canada model, and briefly addresses key questions that relate to emerging developments and issues across the Canadian Arctic. Who is accountable for Arctic biodiversity? How do we coordinate emerging monitoring initiatives to make a coherent picture of Arctic ecological change? How do we focus Arctic science to contribute useful knowledge for understanding ecosystem change and predicting short and long term future changes? How does this knowledge get translated into effective pan-Arctic policies and proactive management actions? If we can work together towards these objectives then it may be possible to significantly mitigate biodiversity loss in the face of rapidly changing climates.

Largest terrestrial organic carbon pool: new results from soils of the northern circumpolar permafrost region

Charles Tarnocai, Agriculture and Agri-Food Canada

During the last decade there has been a remarkable increase in soil carbon studies in the northern circumpolar permafrost region. With the development of large soil databases, it has been possible to obtain new estimates of the amount of soil organic carbon occurring in this region. These estimates include not only the near-surface organic carbon, but also carbon in the deeper soil layer (0–300 cm) and in some of the high-carbon-content deposits that are even deeper than 3 m and were not accounted for in previous estimates.

This vast region has a soil area of approximately 18,782 x 10^3 km^2 and contains approximately 16% of the global soil area. Carbon pools were determined for all permafrost-affected and non-permafrost soils. These new carbon pool estimates are 191.29 Gt for the 0–30 cm depth, 498.80 Gt for the 0–100 cm depth and 1024.00 Gt for the 0–300 cm depth. Carbon pools in layers deeper than 300 cm were estimated for two types of high-carbon-content deposits, the yedoma deposits (407 Gt) and the deltaic deposits (241 Gt). In total, the northern permafrost region contains approximately 1672 Gt of organic carbon, of which approximately 1466 Gt, or 88%, occurs in perennially frozen soils and deposits. This 1672 Gt of organic carbon accounts for approximately 50% of the currently-estimated global belowground organic carbon pool.

Large portions (85% or more) of the permafrost-affected mineral soils are affected by cryoturbation. This process moves surface organic matter into the deeper soil layers where low soil temperatures, high soil moisture, and, in some cases low pH, slow down or restrict decomposition. The water-saturated conditions, low soil temperatures, and acidic conditions of northern peatlands (organic soils) provide an environment in which very little decomposition occurs; hence, the litter is converted to peat and preserved in the organic soil. This gradual buildup process has been ongoing in these soils during the last 5000–8000 years, resulting in peat deposits that are an average of 2–3 m thick and, in some cases, up to 10 m thick. These processes have been operating for thousands of years and, as a result, both mineral and organic soils are very effective carbon sinks.

Since data used in this study were derived from a number of sources with different rates of accuracy and uncertainty, assigning a single confidence value to the new carbon estimate for the entire northern circumpolar region would not be realistic. Instead, it was divided into two subregions, North America and Eurasia, and IPCC confidence levels were assigned to the 0–100 cm layer of each subregion. In addition, separate IPCC confidence levels were assigned to the deeper layers and to other deposits throughout the whole region. The North American data (0–30 cm and 0–100 cm) was given a medium to high confidence level (66–80%). The Eurasian data was given a low to medium confidence level (33–66%) based on the smaller dataset. The deeper layers and other deposits were given a very low to low confidence level (<33%) since the dataset was very small.

Soils in the Northern Circumpolar Permafrost region contain approximately three times more carbon than is stored in the above ground biomass, two times more than the anthropogenic carbon in the ocean and many times more than the annual carbon input into the atmosphere by human sources. Recent observations have shown that soil carbon is being released from thawing permafrost. Understanding permafrost dynamics will thus be the key to understanding the fate of carbon in these soils. We need to quantify the feedback of this carbon, the lability of organic matter stored in these soils and deposits, and the rate of decomposition of this organic matter in a warmer climate. The thawing and collapse of these soils will cause water-saturated conditions as well as drying and this will determine whether the thawed carbon will be released through aerobic (CO_2) or anaerobic (CH_4) decomposition. In addition, permafrost models will be needed to predict the changes in landscapes, surface hydrology (drainage) and ground subsidence. We have a tremendous research challenge ahead to reach an understanding of the complex issues occurring in this increasingly important vast northern region.

ORAL PRESENTATIONS (alphabetical by first author)

Contrasting Climate- and Landuse-Driven Tree Encroachment Pattern of Sub-Arctic Tundra in Northern Norway and Kola Peninsula

S. Aune, Deptartment of Biology, Norwegian University of Science and Technology, Trondheim, Norway
Annika Hofgaard, Norwegian Institute for Nature Research, Trondheim, Norway
L. Söderström, Department of Biology, Norwegian University of Science and Technology, Trondheim, Norway

High latitude regions are experiencing substantial climate change and the forest-tundra transition is assumed to sensitively track these changes through advancing treeline and increased tundra encroachment. However, herbivores may influence these responses. Present study address how mountain birch treelines and sapling cohorts beyond the treeline has responded to last decade's climate warming in six areas across North European sub-arctic regions with different climate and grazing characters. The results show deviating response patterns, representing advancing-, stationary-, and possibly retreating treelines, among regions. Recruitment was abundant over last decades in all areas except one, with predominantly arctic conditions, where both tree- and sapling cohorts were old. Areas with high annual precipitation show advancing birch populations characterized by young individuals and partly overlapping tree- and sapling age distributions. Areas in reindeer summer-herding districts show stationary or retreating birch populations characterized by non-overlapping age distributions, and sapling survival constraints. Recruitment pattern beyond the treeline generally corresponded with non-growing season climate variables, with emphasis on precipitation, indicating importance of a protecting snow cover throughout the winter. The results highlight the important interplay between abiotic and biotic control over tundra encroachment and treeline dynamics, and the importance of multi-site studies when addressing forest-tundra ecotone responses to global warming.

Evolution of Satellite Radar Backscatter and Snow and Sea Ice Properties on Miquelon Lake, Alberta

Justin Beckers, University of Alberta
Christian Haas, University of Alberta
Ben Lange, University of Alberta
Thomas Busche, German Space Agency (DLR) Microwaves and Radar Institute

Sea ice coverage in the arctic is changing more rapidly than expected. To better understand these changes, more information on ice and snow thickness is required. However, little is known about their spatial distribution and change. Improved snow thickness information is required for ice thermodynamic models, and ice thickness retrieval from satellite altimetry. In order to refine observations and modeling of the properties of snow on sea ice, and to support satellite radar algorithms for the retrieval of snow properties such as snow water equivalent, we have performed a seasonal study of snow and ice properties on Miquelon Lake, a saline lake in Alberta, which serves as a sea ice analogue. In the winters of 2008/09 and 2009/10, measurements of snow and ice thickness and temperatures were performed at hourly intervals using an autonomous station. Additional snow and ice sampling was conducted every 2-3 weeks to gather data of snow density, stratigraphy, and the spatial variability of snow and ice thickness. Airborne measurements of ice thickness and freeboard were performed by means of electromagnetic sounding and laser altimetry to develop advanced algorithms for snow and ice thickness retrieval. Results of the seasonal development of snow and ice thickness and properties from the field measurements are compared to changes in X and C-band backscatter imagery from the TerraSAR and Envisat platforms.

On the ecological causes and consequences of the rapid response of dwarf birch to climate change at treeline

Stéphane Boudreau, Centre d'études nordiques, Université Laval
Pascale Ropars, Centre d'études nordiques, Université Laval
Marie-Pascale Villeneuve Simard, Centre d'études nordiques, Université Laval

One of the major responses of terrestrial subarctic ecosystems to climate change is the densification and expansion of deciduous shrub species. In the western part of the Québec-Labrador peninsula, for example, dwarf birch (*Betula glandulosa* Michx.), the dominant shrub species, was shown to increase rapidly over the last few decades. In this study, we investigated whether this is also the case in eastern subarctic Québec, where no data were available. Our objectives were to evaluate the extent of dwarf birch response to recent warming and to investigate the importance of climate on the growth of dwarf birch individuals. Change in birch cover between 1957 and 2008 was evaluated with two sets of orthorectified aerial photographs. In general, birch cover increased by at least 20% in each of the selected sites. Such rapid expansion is most likely related to both the establishment of new individuals (by seeds) and to clonal growth. In light of such results, we will discuss the fact that the lack of post-fire tree regeneration over the last millennia, combined with soil disturbances might have created suitable conditions for dwarf birch expansion. Moreover, we will review some of the evidence which suggests that dense shrub cover could even inhibit tree species regeneration and influence treeline movement. Preliminary dendrochronological results suggest that dwarf birch radial growth is positively correlated to summer temperature (growing degree days), at least in well-protected sites, suggesting that the response of dwarf species to climate change could be more important as temperatures continue to rise.

Reproductive potential of forest expansion in the circumpolar north

Carissa D. Brown, University of Saskatchewan
Xanthe Walker, University of British Columbia
Ryan Jameson, Memorial University
Geneviève Dufour Tremblay, Université Laval
Annika Hofgaard, Norwegian Institute of Nature Research

The boreal forest is predicted to move northward as the climate warms, expanding into tundra ecosystems. For this to occur there must be a source of viable seed. Adverse environmental conditions at the forest-tundra transition may limit seed production and dispersal, seed viability, and/or tree growth and survival, thereby limiting forest expansion. Our objective was to measure seed production and viability of the dominant tree species across the circumpolar forest-tundra transition. We hypothesized that the reproductive ability of individuals would be lower at the margin of tree occurrence than within continuous forest. Study sites were established within the forest-tundra transition in northern Canada, Sweden, and Norway. Cones or catkins were collected from the dominant tree species (black and white spruce, tamarack, balsam fir, and mountain birch) in each study site for one to three years from 2007-2009. Germination tests were carried out to determine seed viability. Although the dominant species at each study site differed, the overall patterns in reproduction remained the same: 1) trees in continuous forest produced more seed than individuals in treed tundra during the sampling period; and 2) seed production and viability were variable across sampling years. Comparisons to historic patterns in reproduction indicate that production has increased since the 1990s in some areas of northern Canada. However, the relatively low production of viable seed and annual variability in reproduction may generate time lags between the occurrence of favourable environmental conditions with climate change and the expansion of forest into tundra ecosystems.

North vs. South: Aspect-related differences in treeline pattern and process

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The influence of insolation on vegetation pattern and landscape heterogeneity is a longstanding theme in arctic and alpine ecology. However, comparison of ecological processes on opposing slopes has been much less common. I present results from an ensemble of studies from southwest Yukon that has uncovered a distinct difference in ecological processes between treelines on north and south-facing slopes. Varied insolation creates differences in snow depth and timing of melt, soil temperature, and permafrost on opposing slopes that result in distinct physiological differences in white spruce (*Picea glauca*), the dominant treeline conifer. Measurement of young individuals indicated that secondary growth and lateral growth was significantly greater on south-facing slopes. Photosynthetic efficiency was reduced in individuals on south-facing slopes, while over-winter damage and mortality was significantly greater. Population-level processes also differed. Dendroecology and repeat photography indicated that treeline advanced on south-facing slopes during the 20th century, but that range expansion was limited on north-facing slopes. These process-related differences appear to be the mechanism for differences in treeline pattern at the landscape scale, including a higher treeline elevation and greater clustering of individuals on south-facing slopes. Insight gained from these results can be used to inform theory on the functional causation of treeline, rationalize the differential treeline dynamics observed worldwide, and better inform the prediction of future treeline dynamics under global climate change.

Ecosystem classification in the Northwest Territories

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Understanding the distribution and characteristics of regional to local ecosystems is a prerequisite for strategic and operational resource management. In response to this need, federal, provincial and territorial governments have developed ecosystem classification frameworks. The national ecosystem classification framework developed by Environment Canada in 1996 was reviewed and applied by the NWT, but resource managers found that it did not adequately reflect the range of variability in boreal and arctic landscapes and thus had limited utility to address resource management questions. In 2004, a review of the national framework was commissioned and the review concluded that although the framework was valid, significant adjustments were required. An in-depth revision of the entire NWT ecosystem classification has been underway since 2004 and is scheduled for completion in 2012-13; it has been designed to fit within the North American continental ecosystem classification framework that unifies Canada, the United States and Mexico. The revision process involves an intensive aerial survey involving the collection of georeferenced images and focused field visits. This information is integrated with existing environmental data to produce a detailed summary of ecological regions presented at various scales. Three reports have been produced to date and are available for review and download at http://www.enr.gov.nt.ca/_live/pages/wpPages/Ecosystem_Classification.aspx. These reports, the accompanying maps, and the georeferenced image collection will serve both as a framework for current resource management and as a benchmark against which future ecosystem changes can be assessed.

Altitudinal treeline dynamics in response to climate change in the vicinity of Kangiqsualujjuaq (Nunavik, Québec)

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Treelines are known to be among the most temperature-sensitive ecotones. As a result, they are able of rapid expansion in response to the observed climate warming. Treelines responses are yet variable, such ecotones being also controlled by different ecological constraints. Near Kangiqsualujjuaq, in Eastern Nunavik, preliminary observations suggest that eastern larch (*Larix laricina*) seedling establishment on hilltops above the current altitudinal treeline is widespread while the recruitment of black spruce (*Picea mariana*), the other dominant tree species, seems to be seldom. The objectives of this project are to characterize the dynamics of the altitudinal treeline near Kangiqsualujjuaq in subarctic Québec and to determine which factors are responsible for the differential response of the two tree species. To do so, we mapped all trees, saplings and seedlings along an altitudinal gradient expanding from the forested valley to the hilltop. Individuals were harvested for dendrochronolological datation. Lastly, growth ring analysis of treeline individuals was conducted to evaluate the response of both species to the recent warming trend. Preliminary results suggest the establishment of several young eastern larches above the current treeline. Moreover, seedling and sapling survival seem to be relatively high as few dead individuals were observed. Our preliminary dendrochronological results also suggest that there has been an important radial growth increase since the 1990s, at least for the eastern larch (no data available yet for black spruce). Those results suggest that treeline might become denser and expand upslope in the tundra in a near future in response to current warming.

Primary productivity in the high Arctic: Measurements and predictions for climate change

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Joel Barker, Ohio State University
Elyn Humphreys, Carleton University
Peter Lafleur, Trent University

Human activities have elevated atmospheric concentrations of greenhouse gases to levels resulting in an unequivocal warming of our climate. This is especially true in the high Arctic, where in the past century annual temperatures have increased at twice the global rate. Climate models predict that in certain regions of the Canadian Arctic, by 2100, autumn/winter temperatures will increase by up to 9ºC, while annual precipitation will likely rise by 35%. In polar regions, large amounts of CO_2 could be sequestered from the atmosphere through primary production if tundra vegetation colonizes desert ecosystems and wetlands form in response to increased warming and wetting. Using the eddy covariance approach, we are quantifying the net ecosystem exchange (NEE) of CO_2 from desert and wetland landscapes on northern Ellesmere Island, Canada. These measurements are essential to determine if this region is currently in a phase of net primary productivity or net decomposition. We are observing that desert landscapes are a continuous sink of CO_2 throughout the growing season. Our wetland site consumed 6x the CO_2 as the desert site, with measures of NEE larger than at a low Arctic wetland. These wetlands have similar daytime CO_2 uptake rates but in the high Arctic, net uptake is possible nearly 24 hours a day, leading to the greater daily C uptake. Water, and likely the nutrients it delivers, is an important resource in the dry Arctic, and our results show that warming and wetting of this region will result in a much greener landscape.

Microtopographic effects on vegetation cover and productivity in arctic tundra

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Using field spectrometry, we examined patterns of vegetation cover and productivity at a high-centred polygon tundra site in Churchill, Manitoba. NDVI, derived from field spectrometry, revealed distinct patterns of productivity, apparently driven by microtopography and hydrology. In general, low-lying regions were more productive, implying a water limitation to plant growth. However, deep standing water suppressed stand growth. Vegetation type closely followed gradients in microtopography and moisture, with low, wet areas dominated by taller sedges, and high, dry areas dominated by shorter broadleaved species and lichens. These patterns also influenced the diurnal patterns of spectral reflectance detectable from remote sensing, with wetter areas dominated by tall sedges yielding more striking diurnal patterns than the areas covered by shorter vegetation. These diurnal patterns (due to the interaction of sun angle and canopy structure) have implications for remotely sensed estimates of plant productivity for arctic regions.

NorthSTAR – a network for monitoring ecosystem carbon uptake and phenology in northern ecosystems

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This presentation examines ecosystem photosynthetic light-use efficiency (LUE) using an emerging network ("NORTHSTAR") of automated optical sampling stations (phenology stations) linked to carbon flux (eddy covariance) measurements across several northern terrestrial ecosystems. By combining surface reflectance and irradiance data in two broad bands (visible and NIR), we calculate an absorbed radiation for each site, and compare this to either net or gross ecosystem exchange (NEE or GEE) for different ecosystems. The slope of the APAR-GEE relationship reveals LUE differences, reflecting different environmental constraints on photosynthetic carbon uptake. By adopting a common architecture employing identical sensors and methods across sites, the method enables direct comparison of contrasting environmental and physiological controls on carbon uptake, and can be readily compared to satellite data. In addition to providing basic phenological information, this method reveals contrasting constraints on ecosystem productivity associated with moisture and functional type.

Ecological controls on net ecosystem productivity of a mesic Arctic tundra under current and future climates

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Peter Lafleur, Department of Geography, Trent University, Peterborough
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Changes in C stocks with climate are thought to be caused by rising net primary productivity (NPP) during longer and warmer growing seasons, offset by rising heterotrophic respiration (Rh) in warmer and deeper soil active layers. In this study, we used the process model ecosys to test hypotheses concerning the impacts of weather and climate on NPP and Rh of a mesic arctic tundra. The impacts of weather were tested with CO_2 and energy fluxes measured by eddy covariance (EC) over a mesic shrub tundra at Daring Lake, Canada under varying growing season lengths, temperatures and precipitation from 2004 to 2007. These tests corroborated substantial rises in annual NPP, smaller rises in annual Rh, and hence rises in annual net ecosystem productivity (NEP) from 17 to 45 g C m^{-2} y^{-1} (net C sink), modelled with lengthening growing seasons and rising precipitation from 2004 to 2007. However net CO2 uptake was found to decline sharply during midsummer warming events (air temperatures > 20ºC) in warmer years. A 150-year model run under transient climate change predicted for Daring Lake by the Canadian Regional Circulation Model (CRCM) v4.2, indicated that rises in annual NPP from current values would exceed those in Rh during the first 100 years, causing annual NEP to rise. However greater declines in net CO_2 uptake also occurred during more frequent and intense midsummer warming events as climate change progressed, causing annual NEP to decline later in the model run.

Spatial and temporal patterns in growth-climate relationships at the northern treeline in the western Canadian Arctic

Scott Green, University of Northern British Columbia
Sean Sweeney, University of Northern British Columbia

Recent studies have suggested that tree-growth sensitivity to climate may be changing in some sub-Arctic and Arctic environments, though the underlying causes remain unclear. An assessment of tree growth-climate relationships (using dendroecology) was undertaken along the northern Dempster Highway corridor in Yukon and the Northwest Territories. One objective of this study was to assess the spatial and temporal stability of tree growth-climate relationships to clarify potential mechanisms underlying the so called "Divergence" in tree-growth sensitivity over the last half century. We examined 33 chronologies of white and black spruce across a range of site conditions. Early results suggest that considerable temporal instability exists across the range of site conditions, with sites showing increasing, decreasing and stable growth sensitivity to climate over the last 80 years. Some sites showed inverse correlations between early- and late-chronology growth-climate relationships, essentially cancelling out the growth-climate signal over the entire climate record. Results underscore the importance of considering temporal scale in the assessment of tree sensitivities to climate change in northern latitudes.

Engaging Youth- The Green I.C.E. Project

Jodi Gustafson, The Green I.C.E. Project
Sytse Tacoma, The Green I.C.E. Project

My name is Jodi Gustafson and I am a second year undergraduate student from Whitehorse, Yukon. I am currently studying in the BSc Global Resource System through UBC. My project partner, Sytse Tacoma is a third year mechanical engineering student at Canterbury University in New Zealand. Together, we have just started an environmental humanitarian project called The Green Innovative Climate Engineering Project (The Green I.C.E. Project). The goal of our project is to construct an environmental device to be used in polar regions. As I am from an Arctic gateway city, and Sytse is from an Antarctic gateway city, we see this opportunity as quite fitting. We will be combining each of our very different skill sets to build this device. Currently, we are in the stage of interviewing professionals with experience in the polar regions to determine a cause that is linked to both the Arctic and Antarctic to focus our efforts on. Our project mandate and further details can be found at our website: thegreeniceproject.wordpress.com. We would really appreciate any opportunity to tell the circumpolar community at the IPY conference about our project, both to demonstrate the interest and concern youth have for polar regions, as well as to gain advice and suggestions from the knowledgeable presenters there.

Changes in the spatial pattern of vegetation across the Canadian forest-tundra ecotone

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Danielle DeFields, Dalhousie University
Ryan Danby, Queen's University
Keith Lewis, Memorial University
Andrew Trant, Memorial University
Brian Starzomski, University of Victoria
Rodney Savidge, University of New Brunswick
Luise Hermanutz, Memorial University

The forest-tundra ecotone may be shifting due to climate change, affecting both regional biodiversity and northern communities. We were interested in how this could affect the spatial pattern of vegetation. We investigated the spatial pattern of trees, shrubs and ground vegetation cover in the forest-tundra ecotone across Canada in Yukon, Manitoba and Labrador. Our objectives were to describe trends in the spatial pattern of trees, shrubs and other plants across the forest-tundra ecotone and to investigate geographical variation. Cover of trees, shrubs and other plant types was measured in contiguous quadrats along transects up to 100 m long at different locations along the forest-tundra gradient at each site. Spatial pattern analysis was used to estimate patch size, as well as the scale and amount of aggregation. Initial results show that patches of trees tend to be smaller, farther apart and less dense away from the forest. Shorter trees may be clumped at some sites due to shelter from the wind. Competition does not seem to be a contributing factor to tree recruitment since there were few sites with regular spacing of trees. With climate change, forests will likely develop above the current treeline as patches of trees enlarge and new patches establish. While temperature may be a limiting factor for treeline advance, wind may be a structuring factor in determining the spatial configuration of treeline. However, site-specific results indicate that local factors appear to be strongly affecting processes within the forest-tundra ecotone.

Comparing warming and grazing effects on birch sapling growth in the tundra environment – a 10 year experiment

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Background:Tree encroachment of tundra is a generally predicted response to climate warming. However, herbivory play an important role in structuring tundra systems and responsiveness to warming.
Aims: To experimentally test how grazing and increased growing season temperature influence growth and physiognomic stature of birch in the alpine zone.
Methods: Trait responses, of natural regenerated birch saplings, to warming (OTCs), changed grazing regime (exclosures) and unmanipulated conditions were analysed over a 10 year period (1999-2008). Effect of treatment over time and differences between treatments was analysed with repeated measures GLM and simple contrasts in GLM.
Results: Warming alone had no major effect on trait response, however significantly smaller leaves and increased number of short-shoots indicated warming related growth constraints. Grazing showed a strong hampering effect on most traits, conserving a low stature sapling stage characterized by fewer shoots and larger leaves, compared to non-grazed treatments.
Conclusions: The results points to a grazing controlled response to environmental change in the alpine tundra, with climate (warming) as a secondary force. This herbivore-driven concealing of expected climate-driven tree expansion emphasizes the necessity to consider changes in grazing regimes along with climate change, in order to avoid misleading interpretations regarding climate-driven tundra encroachment.

Research on forest-tundra ecotone structure and change in Russia

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We present results of collaborative research carried under three nationally funded IPY projects - BENEFITS, PPS Arctic Norway, and IASOS-CASEAS. We applied the PPS Arctic concepts to the Russian territory by characterising structure, position and dynamics of the forest-tundra ecotone and comparing these in mountains and plains, under continental and oceanic climatic conditions. We analyzed the influence of soils and terrain, and of anthropogenic factors, including air pollution and land use.
The study was an integration of i) field ecological research, characterizing vegetation, soils and terrain at key sites; and ii) traditional and novel ways of extracting information on position and structure of the ecotone areas from remotely sensed imagery, with particular focus on very high resolution (0.5-4 m for key sites) and moderately-high resolution (15-30 m for larger areas) satellite images. Project activities were conducted in two contrasting regions: north-west Russia (2008-2010, centre and northern Kola Peninsula, as well as Vaigach Island) and northern Central Siberia (2010, Ary-Mas in southern Taimyr and the south-central shore of Lake Lama on the western portion of Putorana Plateau). Key tree species include birch, pine and spruce in NW Russia and larch on the Siberian sites. Within sites controlled by mostly natural factors, advance or stagnation of treeline was recorded; recession of treeline was found only in sites severely damaged by industrial activity, e.g. near the Monchegorsk nickel smelters.
The social science research is developing Socially-oriented Observation (SO) networks as an important component of the overall monitoring system for the arctic-boreal boundary.

Fire effects on plant-soil interactions drive alternate successional trajectories in boreal forest

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Plant-soil feedbacks between vascular plants, mosses, and microbial decomposition maintain deep organic soils in the black spruce forests of Alaska and Yukon Territory. This internal feedback has been a key source of ecosystem resilience under the historical fire regime: moist, cold soils, poorly drained due to permafrost, burn at low severity and create a seedbed that favors the re-establishment of black spruce and the recovery of the organic soil layer. With more severe or frequent fires, however, these soils can burn deeply. When less than ~5 cm of organic soil remains after fire, deciduous tree species such as aspen and birch establish at high densities and catalyze a switch to alternate plant successional trajectories that are dominated or co-dominated by deciduous trees. Here, a new plant-soil feedback domain emerges where shallow organic soils are maintained by rapidly decomposing litter from highly productive deciduous species. Degradation and loss of permafrost is likely under these conditions, leading to a state change that permanently alters ecosystem structure and function. Shifts between domains of spruce vs. deciduous dominance have large implications for ecosystem productivity and carbon storage, feedbacks to regional climate, the goods and services that boreal ecosystems provide to humans.

Classification of Vegetation in Arctic Regions

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The Canadian National Vegetation Classification (CNVC) is expanding to include vegetation associations of the arctic and sub-arctic. The goal is to produce a vegetation classification based on the analysis of existing ecological releve data from across the arctic.
The first phase of this project focused on identifying and acquiring pertinent ecological releve data and entering them into a database compatible with the CNVC national standard. To date, over 7,000 arctic and sub-arctic vegetation releves have been entered into the datbase. The data collection period spans a period of more than 50 years, from the 1960's to the present.
A first approximation classification of arctic vegetation associations north of the arctic treeline has been completed, following the protocols of the CNVC, supported by scientific and local ecological knowledge of the region.
Work is currently underway to continue the acquisition of data from the sub-arctic, largely comprised of taiga. These data will be entered into the classification database, followed by classification analysis.

Spatial variability in soil fertility in the forest-tundra ecotones of the Kola Peninsula, Russia

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Spatial variability in the soil fertility is related to main soil forming factors including climate, soil forming rock and vegetation. This paper addresses the influence of soil forming rock, vegetation, and the potential impacts of climate-change-induced vegetation shifts and successions on soil fertility in the forest-tundra ecotones on the Kola peninsula in the Khibiny Mountains (altitudinal gradient) and in the surroundings of Lake Kanentiavr (latitudinal gradient). We carried out comparisons between the ecotones, zones/belts and compartments with Norway spruce (*Picea abies* (L.) Karst.), Scots pine (*Pinus sylvestris* L.), white birch (*Betula pubescens* Ehrh.), shrubs, herbs, green mosses and lichens using large-scale mapping of soil and vegetation cover based on information from ground mapping, soil sampling, and very high resolution satellite images. Results of our work demonstrate that against the background of differences in soil forming rock between the ecotones, plant-induced changes in soil fertility were similar. We have found close relationships between plants and soils in terms of dynamic soil properties, first of all bio-available nutrients, on the level of zones/belts and compartments. Increased presence of tree and shrub species in moss- and lichen-dominated tundra, induced by climate change, will result in soil fertility improvement, which could cause higher rate of C and N mineralization, and would promote further colonization by trees and shrubs.

Dryas integrifolia responses to experimental warming conditions in a subarctic environment

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A standard experimental design (International Tundra Experiment - ITEX) to passively warm the subarctic dry upland tundra 1-3ºC was used to examine vegetation and soil responses to climate warming in a subarctic environment. Dryas integrifolia was monitored in twelve ITEX open top chambers (OTCs) and control plots near Churchill, Manitoba from 2007 to present. After three years of experimental warming, the phenological changes and vegetative and reproductive responses of *D. integrifolia* were examined to determine the species response to experimental warming. Soil physical and chemical properties within each plot were analyzed in year two (2008) to establish the soil response to warming. Results showed that *D. integrifolia* had a statistically significant increase in reproductive effort (e.g. number of flowers) with warming conditions in all years whereas the vegetative response was not statistically significant in all years. Soil conditions in the plots showed no statistically significant difference after two years of treatment. The addition of a subarctic ITEX at Churchill provides additional spatial coverage to the ITEX network and long-term monitoring of this site will examine the complex interactions of vegetation and soil in response to warming conditions.

Rapid retreat of a unique ecosystem, the Northern Ellesmere Island Ice shelves, and the role of a thinning perennial sea ice zone

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Over the past century there has been a >90% reduction in the ice shelves along the northern coast of Ellesmere Island (England et al., 2008). What was once a large mass of ice spanning 500 km and covering an area of ~8900 km^2 is now only a few small residual remnant and vulnerable ice shelves. Radiocarbon analysis of driftwood samples demonstrate the inception of multiyear landfast sea ice and consequent formation of the Ellesmere ice shelf occurred along the northern coast approximately 5500 cal yr BP (England et al., 2008). Climate change and associated warming in the High Arctic have been proposed to be major factors in the collapse of the Ellesmere ice shelf (Vincent et al., 2001). Here we will present changes in the perennial sea ice zone (namely thinning) over the past century and how sea ice processes are in part responsible for the rapid retreat of the Ellesmere Island ice shelf. In addition, the importance of these features will be presented based on their facilitation of unique ecosystems found in very few regions of the world (Vincent et al., 2001). Another occurrence of such an ecosystem can be found on the Petermann Ice Shelf (Greenland) which has recently calved a large ice island (250-290km^2). The Petermann ice shelf will be presented using aerial videography, images and remotely sensed thickness and laser data in order to gain a visual representation of these features and to demonstrate future applications of aerial borne EM thickness surveys for all ice shelves.

Tall shrub encroachment in the Mackenzie Delta Uplands, Northwest Territories, Canada.

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Steve Kokelj, Indian and Northern Affairs Canada
Philip Marsh, Environment Canada

Local observations and analysis of historical photos suggest that tall shrubs (Alnus, Salix, and Betula) are becoming an increasingly dominant component of Low Arctic ecosystems. Increases in the abundance of tall shrubs have the potential to alter surface energy balance (albedo), sensible and latent heat flux (evapotranspiration), snow conditions, and ground thermal regime. We examined the regional spatial pattern of tall shrub cover and patch size in the upland tundra north of Inuvik, Northwest Territories using object-based classifications of airphotos. Subsequently, we used soft-copy stereo visualization of airphotos to map fine-scale changes in tall shrub cover between 1972 and 2004. Tall shrub cover (2004) was also mapped in areas affected by tundra fires that occurred between 1960 and 1968. At the regional scale, the cover and patch size of tall shrubs decreased with latitude and were strongly correlated with summer temperatures. Fine-scale mapping showed that tall shrub cover has increased significantly at undisturbed sites and that areas impacted by tundra fire had higher shrub cover than undisturbed sites in both time periods. Taken together, our results suggest that shrub proliferation is likely to increase with continued regional warming and that these changes will be magnified by larger and more frequent tundra fires.

Tracking hydrological responses of a thermokarst lake in the Old Crow Flats (Yukon, Territory, Canada) to recent warming using aerial photos and paleolimnological methods

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Remote sensing analysis of lake-rich thermokarst landscapes has documented evidence of declining lakewater surface area in response to recent warming. However, images alone cannot identify whether these observations are due to increasing lake drainage events associated with accelerated thermokarst activity or increasing evaporation in response to longer ice-free season. Here, we explore the potential of combining aerial photos with paleolimnological analyses to track changes in hydrological conditions of a thermokarst lake (OCF48) in the Old Crow Flats. Images show that water level declined markedly between 1972 and 2001. In a sediment core from OCF48, declines in organic matter content, organic carbon isotope values and pigment concentrations from ~1967-1989 are interpreted to reflect an increase in minerogenic turbidity, and subsequent decline in aquatic productivity, caused by increased thermo-erosion of shoreline sediments. These stratigraphic trends terminate at ~1989, which likely marks the year which the lake drained. Above-average precipitation during the previous year probably raised lake level and promoted further thermo-erosion of sediments and lake drainage. These are meteorological conditions that have led to recent lake drainage events in the OCF. Thus, the decline in lake level evident in the aerial photo from 2001 is unlikely to have been caused by evaporation, but rather is a remnant of a drainage event that took place more than a decade earlier. These findings indicate that combined use of aerial photos and paleolimnology offers much promise for identifying hydrological consequences of recent warming on thermokarst lakes.

Forest-tundra dynamics during the last 400 years: Is treeline advancing in northern Manitoba?

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G. Peter Kershaw, University of Alberta

Extratropical air temperatures have warmed noticeably during the last several decades - particularly in arctic regions, and recent evidence suggests this warming will continue during the next century. Increased warming can result in a change in treeline location due to the well-documented relationship between thermal regime and position of treeline. Near Churchill, Manitoba, tree cores and cross-sections from snags, as well as seedlings and saplings were collected from three sites within the forest and forest-tundra transition in order to evaluate age-structure across the ecotone. A total of 380 trees, 322 saplings and 358 seedlings and three species, *Picea glauca, Picea mariana* and *Larix laricina*, were collected. Preliminary analyses show similar peaks in establishment among sites concurrent with warm periods; though with differences between species. Discussion will focus on variability in establishment and recruitment across the ecotone, with emphasis on linkages to past climate.

The role of changing vegetation on the hydrology of northern ecosystems

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Stefano Endrizzi, University of Zurich
Paul Bartlett, Environment Canada
Murray Mackay, Environment Canada
Stefan Pohl, Environment Canada; University of Victoria
Trevor Lantz, Environment Canada; University of Victoria

Rising air temperature in Alaska and the western Canadian Arctic has resulted in well documented changes in vegetation. As temperatures continue to rise in the coming decades, the area of the Arctic biome that is predicted to respond most rapidly is the transition between upright and dwarf shrub tundra. As shrubs expand in area and height, it is expected that it will have a significant impact on both the hydrology and regional climate. This paper will consider the role of shrub expansion on various aspects of the hydrologic system, including: snow accumulation and melt, turbulent fluxes of sensible and latent heat, and soil temperature and active layer thickness. Field observations during IPY were conducted over a typical tundra and shrub tundra site north of Inuvik, NWT. The GEOtop hydrological model and the Canadian Land Surface Scheme were used to further interpret the field observations. Preliminary results show that the presence of shrubs results in an increased end of winter snowcover, a lower albedo during melt, and increased snowmelt due to the complex effects of the shrubs on solar radiation.

IPEM - A cost effective predictive modelling approach for developing process-based ecological inventories for Arctic National Parks

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Canada's arctic national parks have been established to 'maintain or restore the ecological integrity' of 10 protected areas over about 160,000 km^2 of the Canadian arctic. Their large size and remote locations make ground-based sampling to support map interpretations both expensive and impractical. Through the IPY-funded CiCAT program, and in partnership with the Canadian Centre for Remote Sensing, we have developed a reliable predictive method for delineating tundra ecotypes. Ecotypes are defined as units of the landscape uniform in floristic structure and composition, and in landform and dominant ecosystem processes. Changes in ecotypes on zonal sites across the landscape are used to identify the boundaries of bioclimatic zones, using units that link to the 5 class system of the CAVM Team (2007). The Integrated Predictive Ecosystem Mapping (IPEM) approach marries the cost effectiveness and broad coverage of 'top-down' satellite data with the 'bottom up' detail of process-based air photo interpretations to produce accurate representations of park ecotypes and bioclimatic zones. Variables such as slope, aspect, elevation and soil moisture derived from the digital elevation models were the strongest predictors of park ecotypes, while data from optical sensors were less important. Models and map products are shown for 3 contrasting national parks – Wapusk, Ivvavik, and Torngat Mountains.

Carbon dynamics of Canada's northern forests estimated by the National Forest Carbon Monitoring Accounting and Reporting System (NFCMARS)

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Canada's National Forest Carbon Monitoring Accounting and Reporting System (NFCMARS) generates annual estimates of the C and GHG balance of Canada's managed forest to meet international reporting requirements under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. These estimates are based upon empirical data typically used in forest management planning. We present here estimates of ecosystem production (NPP, NEP, Rh) as well as the carbon (C) and greenhouse gas (GHG) balance for the northern boreal forest regions over the period 1990-2008, as predicted by the NFCMARS. At present, there are several uncertainties in these results, (1) only the portions of Canada's northern boreal forest where provincial and territorial agencies actively suppress fire are considered managed are included in the managed forest, (2) forest inventory and productivity data in northern regions are often limited or based on extrapolation from other regions, and (3) northern regions contain extensive peatlands that are not presently well-represented by the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3), the ecosystem model at the core of NFCMARS. We also discuss future work aimed at quantifying and reducing these uncertainties.

Shrubline advance in Arctic and alpine tundra of the Yukon Territory

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Growing evidence indicates an expansion of canopy-forming woody shrubs up mountain slopes and northward into Arctic tundra. The correlation between warming and greening has been used to link climate change with shrub expansion; however, the exact mechanisms driving observed increases in canopy-forming shrubs are probably more complex. We surveyed the abundance of all tundra willow species (*Salix* spp.) growing at three sites in the Yukon Territory: the mountains of the Kluane Region, the Richardson Mountains, and on Qikiqtaruk – Herschel Island in the Beaufort Sea. We compared age distributions of willow individuals at and below shrubline and found younger populations at higher elevations, particularly on warm, south-facing aspects. Younger willows at shrubline and a lack of significant mortality in the field surveys indicate that shrubs have advanced up slope at the mountainous sites. Photographic and long-term plot data indicate increases in cover and height of willow shrub patches at the coastal site. We compared growth rings to regional weather data, and found positive correlations between annual growth and summer temperatures. Our results indicate that willows grew most in years with a warm June and July. This evidence of a direct response of shrub growth to early summer temperatures suggests that shrubline expansion will continue, possibly at a faster rate, with projected warming in Arctic and alpine ecosystems in the Yukon Territory.

Atmospheric, edaphic, geological, and terrain controls on Hg in lake sediments of Great Bear Lake in Northwest Territories, Canada

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This study aims to develop a geospatial framework for mercury (Hg) and methyl mercury (MeHg) concentrations and loadings in lake sediments of high-subarctic region of Great Bear Lake watershed in North West Territories, Canada. The study is based on watershed and wet-area coverage delineations derived from on digital elevation data, satellite imagery, and the open file lake sediment data compiled by the Geological Survey of Canada (GSC) pertaining total Hg (THg) and other heavy metal concentrations and other affiliated data and data layers included mean monthly air temperatures, precipitation rates, and Hg deposition estimates as supplied and modelled by the Atmospheric Environment Service of Environment Canada. The geospatial analysis of the data revealed that the Hg concentrations within the lake sediments generally positively correlated with (i) wet-area coverage per lake watershed, (ii) loss of ignition (LOI, %), (iii) copper (Cu) concentrations, (iv) lake depth, and (v) low lake area per lake watershed area (multiple regression analysis: R2=0.462). Both LOI and THg concentrations were higher in brownish color sediments than grey, tan and tan black color sediments. In comparison with lakes along gradients from the high arctic (Bathurst Island) to British Columbia and Southern Ontario, it appears that THg accumulations in lakes sediments decrease with increasing ice cover and increase with increased vegetation cover, and are therefore affected by changing climatic conditions across the wider region.

Ocean-atmosphere interactions: Does life (and death) in the water influence Arctic climate?

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Climate is often considered to drive the life cycle of marine organisms, but it may be the other way around, that the life and death of organisms in Arctic waters may be important factors affecting Arctic climate. Northern communities and larger mammals depend on the abundance of smaller marine life such as fish, and/or small shrimp-like krill, for food. Krill, a form of zooplankton, are abundant throughout the Arctic and graze on algae and phytoplankton. As the cell walls of these ocean organisms break, they release a sulfurous compound, dimethylsulfide (DMS) that is expected to play an important role in climate regulation. Once this sulfurous gas makes its way to the atmosphere, it is oxidized, forming sulfate. Sulfate in turn, is very efficient in forming new particles, that can grow to become cloud condensation nucleii (CCN), thereby influencing cloud albedo, formation and longevity.

DMS in air and water, and its oxidation to sulfate, were studied during the International Polar Year Arctic SOLAS (Surface Ocean Lower Atmosphere Study) aboard the Canadian Coast Guard ship the Amundsen, in the fall of 2007 and 2008. Measurements of vertical profiles of DMS and its precursor in the water column at selected stations were complemented by detailed information on related atmospheric components. Size-segregated aerosols, aerosol composition, and sulfate formed from DMS were examined during this study for comparison with ice conditions and cloud formation parameters.

Ancient Yukon trees of southeastern Beringia

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Observations were made on the flora in subalpine Yukon Beringia. Young >5-m-tall trees of *Populus balsamifera*, *Salix* spp. and other species stand in tundra above the altitude (≈1300 m a.s.l.) of *Picea glauca* timberline. *Alnus* spp. occur in montane valleys and above-timberline tundra east of Beringia, but their absence from upland Beringia is evidence that the mountains have remained insulated from post-glacial invasion until recently. Besides *Picea glauca* var. *albertiana* and var. *porsildii*, a diversity of unusual white spruce phenotypes occur above pre-Reid tors to the northwest of the Reid-pre-Reid glaciation boundary. *Picea mariana* occurs in subalpine valley bottoms. Widely scattered, century-old *Pinus contorta* also occur above timberline in this permafrost region. Within the nunatak hypothesis it is proposed that ancestors of these high-altitude-adapted never-disturbed populations could well have persisted throughout the last glacial maximum (LGM) and served as subsequent colonizers of the sub-arctic boreal forest. Climate change is conducive to permafrost melting and, considering the extraordinary scientific information which may be gained from the Yukon's southeastern Beringia, it is recommended that palynological investigations be done immediately to discover the history of the subalpine vegetative composition during the LGM and earlier. Acknowledgement: Funding was from the Government of Canada Program for International Polar Year, grant number 2006-SR1-CC-027 to PPS Arctic Canada, a sub-project under PPS Arctic as part of International Polar Year 2007-2008 sponsored by the International Council for Science and the World Meteorological Organisation.

Options and limitations of operational mapping of forest biomass – A summary of 12 years of pan-boreal vegetation mapping with radar remote sensing in Siberia, China and Canada

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1. INTRODUCTION

A global assessment of biomass and its dynamics is an essential input to climate change forecasting models and mitigation and adaptation strategies. Currently, biomass is 'grown' in models using information about the soil and the climate. There are no spatial maps of biomass with which to improve these biomass models. From these modelled 'biomass' maps various greenhouse gas flux components, carbon stores and sinks and ecosystem productivity are estimated. The errors associated with their biomass estimates are at least 50% and in most cases cannot be validated at all; there simply is not a validation dataset available. In landscape based approaches for greenhouse gas accounting, the forest biomass (phytomass) is derived from information on species, age, site index and relative stocking contained in forest inventory databases.

This paper 1) analyses advantages and shortcomings of existing optical global products that can be used as approximations for biomass, e.g. Vegetation Continuous Field (VCF) and LAI, 2) it presents current capabilities and limitations of radar biomass products from operational C- and L-sensors, and 3) we suggest a combined multi-scale radar-optical methodology using interferometric coherence, land cover maps based on temporal signatures, VCF and a new hyper-temporal algorithm.

3. PROJECTS, DATA AND REGIONAL COVERAGE

This paper gives an overview of state-of-the-art methodologies for large area mapping of forest biomass with the radar sensors on board ERS-1/-2, Envisat ASAR, JERS-1 and ALOS PALSAR. The continuous acquisition of C-band data since 1991 and L-band data for 1991-97 and again since 2006, represents a great resource of information about very specific vegetation parameters only radar sensors are able to detect: height and density of forest. These parameters are especially crucial when time-relevant information is needed, e.g. after fire events or deforestation monitoring, and cloud cover is an obstacle. Large area forest mapping was performed in the projects SIBERIA (1998-2000), SIBERIA-II (2002-2005), GSE Forest Monitoring (2005-2008) and Forest DRAGON (2005-2008) where the first validated biomass maps were generated over more than 1 million square kilometres. These products were generated using 20-50 m resolution interferometric data. In our recent project BIOMASAR, we developed a new and validated algorithm for medium resolution mapping based on hypertemporal ASAR Wide-Swath and Global Monitoring data for Central Siberia, Canada and Sweden.

4. FIRST RESULTS AND DISCUSSION

We have analyzed the signatures of C-band and L-band backscatter intensities and tandem as well as long-term repeat-pass coherence of forests. The results suggest that long-term ERS and ASAR winter coherence can be used reliably for forest/non-forest mapping and detecting forest cover changes as well as estimation of a data-dependent number of growing stock volume classes.

In China, we followed a different approach due to limited forest inventory information. We developed a new approach that allows the training of a semi-empirical model on a frame-by-frame basis using the MODIS Vegetation Continuous Field product without further need of ground data. A comparison of the new approach with the traditional regression-based and ground-data dependent model training procedure using the Siberian data and the application of the new approach to a multi-seasonal and multi-baseline ERS-1/2 tandem coherence dataset are presented.

Envisat ASAR's additional multi-angle, multi-polarisation, multi-resolution capabilities add new dimensions to the forest product generation and a series of recently advanced parameter retrieval results are

being presented. This sensor operates at C-band and in the Wide Swath mode has the possibility to acquire data over large swaths (400 km) with a relatively good resolution for forestry (75 m). Because of the large swath, neighbouring swaths present a certain overlap which in turn means that multi-temporal datasets of backscatter values become available even on short time intervals. We have utilized the full ENVISAT ASAR Wide Swath dataset acquired between spring 2003 and summer 2004 over the SIBERIA-II project transect. More than 500 Wide Swath frames have been processed and geocoded using an automated chain and a spatial database approach. The spatial distribution of the forest biomass retrieved from ASAR Wide Swath images shows remarkable agreement with inventory-based estimates available for the whole region. This is far beyond what is commonly expected from C-band SAR backscatter and is an extremely relevant finding for SENTINEL-1 applications. In addition, for remote areas where inventory data have in the meantime become obsolete, ENVISAT ASAR can provide a valid update of the biomass.

5. CONCLUSIONS

The comparison of the ASAR Global Monitoring and Wide-Swath biomass maps with existing global biomass or carbon stock maps clearly indicated the relevance of the ASAR biomass product [1]. The main conclusions that can be drawn are:

- The comparison of the ASAR and VCF biomass maps confirmed the assumption that the ASAR maps are sensitive to biomass changes beyond the point of canopy closure. Although the canopy cover represents a major predictor for forest biomass, a VCF-based biomass retrieval leads to an underestimation of biomass in dense forests since biomass changes beyond canopy closure cannot be identified.
- The biomass maps that were produced by extrapolating default biome mean values of biomass to large forest areas are prone to high uncertainty. A well known problem of this approach is that compilations of typical biome average biomass values often reflect few ground measurements in mostly undisturbed forests. The values given in these maps, e.g. the Olson map, thus rather reflect the 'potential' biomass or carbon stocks as they hardly consider constraints imposed on forest growth, e.g. human influence, topography, land use history or poor site quality.
- Even though the use of biome mean values commonly leads to an overestimation of biomass, the analysis of the Tier-1 map revealed the opposite. The observed underestimation should not have been due to too low default biomass values in the IPCC guidelines but a result of considerable uncertainties in assigning the appropriate values when the only available information about the forest resources is a global land cover map.
- The comparison of the ASAR biomass maps with the LPJ-DGVM biomass simulation results pointed out the potential of the ASAR product to improve the model simulations. The ASAR biomass maps may aid tuning the model to better describe 1) the overall level of carbon sequestration in the biomass of forests and 2) the heterogeneity of the forest distribution resulting from disturbance or inferior site quality.

ALOS PALSAR data proved having great potential for forest stem volume estimation in Siberia [2]. Winter FBS coherence is the most powerful measure. Summer FBD coherence can provide additional information (e.g. for forest cover mapping), but the temporal baseline must be enlarged to increase temporal decorrelation of forest. However, this approach is very susceptible to variable environmental conditions. The computation of coherence based on FBS (winter) and FBD (summer) images is technically feasible but not very useful; it might - if at all - be used to support forest cover mapping.

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Role of landscape position and permafrost thawing on seasonal variations of methane emissions and soil concentrations in four ecoregions in Mackenzie Valley, region of Canada

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Methane concentration in soil and its surface emission were measured in four northern ecoregions of Mackenzie Valley over two years in 2008-09 using surface chambers and aspiration of soil air or water-dissolved methane from pre-determined depth. Sites were selected to represent upland, oligotrophic bog, and collapsed peatland locations.
The collapsed parts of landscape accounted for most or all of the methane that ended up in the atmosphere with emission reaching 14, 86, 9, and 5 g m^{-2} y^{-1} in midboreal region, in high boreal, in low subarctic, and in high subarctic, respectively. Increased methane emissions apparently associated with recent thawing of permafrost as the flux in Fort Simpson was several times greater than those found at the permafrost-free southern sites and at the northern sites, where permafrost is still persistent. Significant spatial variability of methane flux indicated presence of relatively stable pathways through the soil.
The link between soil methane and its surface emission was not always obvious: elevated dissolved methane in inundated horizons of peat plateaus did not manifest itself in emission while there is a substantial evidence of it being oxidized before reaching the surface. The emission has peaked at 40 mg/m2/day July in high boreal region while the dynamics of soil concentration has a bi-modal pattern with two peaks of 10 000 ppm recorded at 50cm depth in June and September.

The effect of daily climate variability on the Canadian boreal forest

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The importance of climate variability when simulating forest succession using process-based models of stand development has not been widely studied. This study will report an assessment of the predictive capability of a modified version of the FORSKA-2V model (Price et al., 1999a) when forced with daily climate data compared to monthly mean data and long-term monthly averages and applied at a series of sites crossing the boreal forest regions of central Canada, including the aspen-parkland and forest-tundra transition zones. The study tests the hypothesis that high frequency climatic variability (i.e., observed at daily time-scales) is an important determinant of boreal composition and productivity, particularly at forest ecotones where many species are at the limits of their present natural ranges. The results suggest that the daily variability associated with future change in mean climate may be an important determinant of changes in forest composition and productivity.

Influence of environmental variation on tree growth and climate interactions at the western Canadian subarctic treeline

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Recent studies conducted at high latitudes have shown increasingly instable relationships between climate and tree growth. However, these changes are not likely to be universal or common to all northern treeline sites. Here, we used dendrochronology as a tool to observe tree growth variation in relation to important climatic variables that occur across multiple environmental gradients in the western Canadian arctic. Two adjacent regions in the Yukon and Northwest Territories which harbour distinct climatic, geologic, and ecologic environments were considered. In the Yukon, site slope gradient was found to be a key contributor to growth variation, and may be an important determinant of the climate factors most important to tree growth. In the Northwest Territories, a larger-scale effect was found based on more general landscape differences and ecoregion classification. This study serves to underlie the importance of environmental variation regarding climate/tree growth studies, and indentifies the key climatic factors associated with the various environmental factors and contexts found at the subarctic treeline in western Canada.

Detecting the undetectable: A new dendroecological method for dealing with low-level disturbance at treeline

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Large-scale disturbances, such as fire and insect outbreaks are commonplace throughout the boreal forest. At large spatial scales, dendrochronological signatures of disturbance are left behind with low variability, resulting in high levels of detectability at the individuals and stand level. Conversely, patterns of small-scale disturbance are difficult to detect at the individuals and stand level, and may therefore be underemphasized in the literature. Traditional dendrochronological detection of insect disturbance is accomplished by comparing the radial growth patterns of an affected tree species (host) to a non-affected tree species (non-host). This approach assumes that the different species respond the same to landscape and climate features, making it rarely appropriate to use. More recent approaches have used geographically separated conspecifics for host and non-host designations, assuming there is no site-level variability in response. Our novel approach allows us to classify periods within an individual series as disturbed or non-disturbed. Results of this approach are two chronologies for each site, with the possibility of an individual tree having regions of its series in both disturbed and non-disturbed chronologies. For example, an individual could be affected during one insect outbreak but not in the next. With many studies in the eastern Canadian sub-Arctic showing diverging patterns of climate warming and tree radial growth, this new technique will help improve the resolution by removing low-level disturbance, which until now, has been overlooked. Furthermore, this approach draws attention to the importance of low-level disturbance for persistence and potential response of treeline to climate change.

Assessing present and past lakewater balance conditions in the Old Crow Flats, Yukon Territory

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The Old Crow Flats (OCF) comprises approximately 2700 shallow thermokarst lakes. This wetland of international significance is a wildlife refuge, which supports the traditional lifestyle of the Vuntut Gwitchin First Nation. Thermokarst lakes, which occupy vast northern regions, are greatly influenced by climate conditions. Though there is widespread concern that thermokarst lake processes, including lake expansion and drainage, are accelerating as a result of ongoing climate change, there are few studies that have investigated current and past variability of climate – lake hydrology interactions at the landscape scale.

As part of a Government of Canada International Polar Year multidisciplinary project, the present and past hydrology of lakes in the OCF are being investigated using water isotope tracers and paleolimnological approaches. Water samples obtained from 57 lakes three times over three ice-free seasons (2007-09) were analyzed for oxygen and hydrogen isotope composition. We identified snowmelt-dominated, rainfall-dominated, groundwater-influenced, evaporation-dominated and drained lake types. Relationships between the diverse water balance conditions and lake physical and land cover characteristics were investigated through spatial analysis. Precipitation during the three-year study was highly variable and was the main driver of interannual change in water balances. Knowledge of modern water balance variability provides the basis for interpretation of past hydrological conditions, which are being determined from ongoing multi-proxy analyses of lake sediment cores. Approaches used in this study are readily transferable to other thermokarst lake systems, which would provide further insight into landscape-scale responses to ongoing climate change.

Analysis of vegetation, fire and lake change on pan-arctic and local scale within the ESA Data User Element Permafrost

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Boreal-tundra ecosystems in the northern hemisphere are highly affected by global climate change including a measureable impact on permafrost dynamics. The transformation of existing landforms in permafrost regions lead to great changes in areas of thaw settlement which altered the terrain (thermokarst effects), hydrology and vegetation.
This study presents [1] results from pan-arctic land cover and fire monitoring by the use of coarse resolution Earth observation products as well as [2] the analysis of fine scale vegetation and lake change phenomena utilizing very high resolution satellite data as part of the ESA Data User Element (DUE) Permafrost.

The pan-arctic land cover monitoring and fire assessment is connected to the requirements defined by the user and modeling community. One aim is the extraction of cover percentage information for vegetation physiognomy and barren areas by a synergetic combination of global land cover products. Another major goal is the analysis of burned area products according to similarities and inconsistencies.

At the local scale the generation and development of a high resolution vegetation and water body map using historical and recent high resolution remote sensing data will be carried out by using object based classification approaches. The final land cover product should provide a high resolution map, which shows the distribution and structure of vegetation units under potential permafrost degradation scenarios. The water body change product offers lake area changes and also structural water body changes (e.g. water area, lake object border index, lake object elliptical fit).

Linking fire frequency and seed production in northern black spruce (*Picea mariana*) forests

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Self-replacing black spruce (*Picea mariana*) forests dominate the landscape of the northern boreal forest of Canada and Alaska. At these latitudes climate conditions limit growth rates and cone production of conifer forests. As global climate change alters environmental conditions, we expect a shift in the natural fire regime. With the predicted shortened fire interval, black spruce stands may be vulnerable to regeneration failures after fire because of the long time required to reach reproductive maturity. The main objective of this research is to assess the relationship between age and seed productivity of black spruce in northern Yukon Territory and central Alaska. Fire history maps were used to select sites of various stand ages, including those that would occur in a short fire return interval (less than 80 years) versus longer fire intervals (up to 350 years). At each site, stand density and basal area were measured and 10 black spruce trees were randomly selected for cone surveys and age analysis. A subset of five trees were also selected for detailed analyses of cone and seed production within yearly cohorts. Viability and germination tests were performed on a sub-sample of seeds extracted from the collected cones. These data can be used to estimate the minimum age at which northern black spruce trees start producing cones, and the age at which reliable seed production occurs. In turn, we will be able to estimate the range of fire return intervals where post-fire spruce recruitment may be limited by seed availability.

Social science perspectives in developing synthesis activities in PPS Arctic beyond the IPY

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Both social and natural investigations undertaken within IPY PPS Arctic project have registered considerable changes happening nowadays in terrestrial, atmospheric and human environments. In order to move forward in projecting and responding to these changes we need to develop synthesis approaches. For this it is suggested:

1. to advance solution-driven science that can provide scientific knowledge that can be translated into strategies for coping with change for the benefit of different stakeholders and society.
2. to establish dialogue and new partnerships among all scientific disciplines and with diverse northern communities, decision-makers, funding agencies, all stakeholders to effectively develop adaptation and mitigation strategies from local to circumpolar scales.

Multi-Disciplinary PPS Arctic Observing Network construction is seen as a productive instrument for synthesis activities implementation. The Northern Socially-oriented Observation Network (NOSON) launched by PPS Arctic in the Russian North funded by the Research Council of Norway, as well as Russian Academy of Sciences can be viewed as one of possible synthesis approaches in building Multi-Disciplinary PPS Arctic Observing Network. First results of NOSON show that changes in human capital (depopulation, unemployment, lack of sufficient education, marginalization etc.) are becoming the major driving force effecting land use changes and overall sustainability. Changes in climate and biota (ice melting, tundra shrubs getting taller and more numerous, etc.) have become an add factor in accelerating or influencing social changes. In relation to the future sustainability in nature and society it is northern communities, their adaptive capacities and creativity that are decisive.

Processes controlling the watershed-scale carbon balance of high-Arctic ecosystems at Cape bounty, Melville Island, Nunavut

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Seasonal eddy covariance measurements of the carbon balance of mid-moisture, High Arctic tundra ecosystems suggest that these systems are a small carbon sink. At Cape Bounty, Melville Island, Nunavut, eddy covariance measurements during the growing season in 2008 suggest that these high-Arctic ecosystem are accumulating about -7 g C m^{-2} over the approximately three month growing season. While these results indicate that these High Arctic ecosystems are carbon sinks, they do not include other processes that could alter the annual carbon balance at the watershed scale. These processes include losses of both dissolved and particulate organic carbon and dissolved inorganic carbon in stream water and losses of other gases (e.g. methane) from the soil to the atmosphere. We used measurements of catchment-scale sediment and dissolved carbon fluxes in stream water, and static chamber measurements of soil carbon dioxide fluxes and methane fluxes in a variety of plant community types, to constrain the carbon balance of a small (18 ha) watershed at Cape Bounty. River-based dissolved carbon losses (DIC and DOC) were about 1 g C m^{-2}, and particulate losses were about three orders of magnitude lower. Carbon losses through methane emissions were about 0.03 g C m^{-2}. When added together, for 2008 an undisturbed watershed was accumulating roughly 6 g C m^{-2} over the growing season. Future work will explore the role of permafrost disruption on the net carbon balance of whole watersheds in the high Arctic.

Trace gas fluxes from three high-Arctic plant communities along a soil moisture gradient

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Greenhouse gases (GHG's) are critical components of global climate forcing. The most important GHG is CO_2, but CH_4 and N_2O also play important roles in warming earth's climate. High latitude environments are expected to undergo the most pronounced warming and increases in precipitation. Warmer and wetter soils with deeper active layers, could lead to changes in emissions of all of these greenhouse gases. Their impact, however, may not be uniform across the landscape, where different vegetation types are distributed across moisture gradients. Despite the potential importance of GHG fluxes in arctic environments, little research has explored spatial variability in GHG emissions from high-arctic landscapes.

In 2008 and 2009, we measured CO_2, CH_4 and N_2O fluxes using static chamber techniques at Cape Bounty, Melville Island, Nunavut, in three major plant community types: polar desert, mid-moisture tundra and wet sedge meadow.

In both years, wet sedge meadow had the highest rates of GHG emissions, followed by mid-moisture tundra. Polar desert soils were usually sequestering CH_4 (around –4 ng C m^{-2} s^{-1}). These differences relate to both CH_4 emissions and respiration being negatively correlated with soil moisture, with warmer soils tending to emit less, or even sequestrate CH_4. Overall, emissions of CH_4 and N_2O, as well as respiration, tended to be higher in the warmer year 2008. On a given land area, and depending on the climate of a given year, CH_4 flux can result either in carbon emissions or sequestration (2.68×10^{-3} g C m^{-2} in 2008 vs. -15.71×10^{-3} g C m^{-2} in 2009 for the entire study area).

The reproduction, establishment, and growth of white spruce at its northern range limit in Canada

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Climate is considered one of the most important factors controlling treeline dynamics and as temperatures increase, the treeline is expected to shift northwards. The main objective of this research is to assess the reproduction, establishment, and growth of white spruce throughout the forest-tundra ecotone and determine if these dynamics have changed since they were last examined 15 years ago. Four forest stand sites and eight tree island sites were located and re-examined in the summer of 2009. Cone production has increased since the early 1990s and cone production decreases northward across the forest-tundra. Germination rates also decrease with increasing latitude but have not significantly changed since they were last examined 15 years ago. In June 1994 seedlings were transplanted at three tree island sites. Survivorship of these seedlings ranged from 3 to 20%. An age structure of white spruce individuals throughout the forest tundra was developed and results indicate that establishment coincides with decades classified as cool and wet. The yearly diameter growth of each tree was determined and two tree ring chronologies were built, one for forest stands and one for tree islands. These chronologies were correlated to climate data. In general, growth is negatively correlated to previous growing season temperature and positively correlated to current season temperature. Results of increased cone production, no change in seed viability, the survivorship of transplanted seedlings, and temperature being the primary factor limiting growth indicates that a lack of viable seed is the limiting factor to treeline expansion in a warming climate.

The greening valleys of the Lewis Glacier and Isortoq River, north central Baffin Island, Nunavut, Canada

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Recent repeat sampling, after 46 years, shows significant vegetation change in these landscapes. The area is free of direct human disturbance and the surfaces have been available for plant colonization for up to 600y. Two matched data sets from terrestrial cryptogamic and vascular vegetation with good surface age control were compared. Icecap and glacier margins are retreating at 3 times the rate from 1948 to 1963 and in 2009 reached 60 m y^{-1}. Perennial snow banks have disappeared. On valley sides and bottoms the frequency of rare species, characteristic of milder regions, has increased as has productivity and plant cover. Many of the plant community changes can be attributed to autogenic succession, however, changes on the older (c. 500y), mesic surfaces may be attributed to climate warming linked to the decline of sea and land ice (Bhatt, U. S. et al., 2010 Earth Interactions 14(8): 1-20). In the 1960s the zonal vegetation conformed to Bioclimate Subzone B with a dominance of prostrate shrubs and general impoverishment. Increased plant cover, shrub stature, extent of sedge communities and diversity indicates a biome shift to Subzone C. Recently similar responses have been reported. Nevertheless, note that the diversity of circumpolar Arctic ecosystems, the increasing direct impact of human activities and the genetic and ecotypic variation in wide ranging species will lead to varied responses across the Arctic. This is a contribution to the International Polar Year Back to the Future project.

Critical Inuit studies and the EU seal ban

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What is the status of 'critical Inuit studies' (Stern and Stevenson 2006) particularly when it comes to the analysis of specific, contemporary social and political disagreements? Today, critical study of Inuit ways of adapting to changing sea ice conditions, climate change narratives more generally, and ongoing processes of globalization has become much more than a mere cottage industry. Inuit culture with its small population of approximately 150,000 in Alaska, the Canadian Arctic, Greenland/ Denmark and Russia, although it varies across these different national scenes, is amongst the most intensely studied indigenous cultures in the world, and this is surely connected to ongoing speculation about the opening of the Arctic because of resource extraction and the expanding influence of science as a consequence of climate change discourses. In this paper I investigate several of the cultural implications of the European Union's long-standing and more recently publicized ban on the importation of seal products to Europe. I seek to investigate the political stakes of such events and ask what effects the disagreement between the EU and Inuit political leaders have had on questions of Inuit identity in the current context, as well as to review some of the European justifications for the ban.

Investigating potential impacts of shrub encroachment on arctic ground squirrel behaviour and density

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Recent climatic warming is linked to rapid shrub encroachment in arctic and alpine tundra. Shrub encroachment may cause a decrease in visual openness, which many alpine and northern mammals rely on vigilance for predator detection. Consequently, some species may be negatively affected by these changes.

Arctic ground squirrels have a widespread and locally abundant distribution across the north. As such, they have the potential to substantially influence northern ecosystems. Populations occur in northern and alpine tundra, shrub, and boreal habitats; however population dynamics differ between these habitats. Certain, more visually closed habitats appear to be 'sink' populations, where birth rates are insufficient to sustain the population without immigration from other areas. In tundra habitats, an increase in shrub density and resulting decrease in the ability to detect predators at distance could have serious negative consequences for these populations. This could be the result of either a direct increase in mortality via predation or a reduction in foraging efficiency as a result of increased predator sensitive behaviour.

This study examines how foraging behaviour differs between shrub and tundra populations. Results of experiments examining the effect of local visibility upon giving up density will be presented. In addition, characteristics of individual foragers active at different sites will be examined. Links between behaviours characteristic of different landscapes will be made to population dynamics observed in both shrub and tundra. These data should help highlight potential responses of this species to the changing landscape.

Characterization of GHG distribution and processes in peatlands along a permafrost climatic gradient using stable isotopes

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Thawing permafrost peatlands substantially influence northern ecosystems by: 1) changing the regional hydrology and 2) mobilizing the vast carbon (C) reserves that results in increased greenhouse gas (GHGs) emissions to the atmosphere. With permafrost distribution controlled largely by topography and climate, our IPY study intensively monitored the local C cycling processes and GHG fluxes associated with different hydrologic and permafrost environments at 4 sites along a climatic gradient extending from the Isolated Patches Permafrost Zone (northern Alberta), to the Continuous Permafrost Zone (Inuvik, NWT). Each site encompasses a local gradient from upland forest and peat plateau to collapse scar.

Our multi-year measurements of peatland profiles and flux chambers for CH_4 and CO_2 concentrations and stable carbon and hydrogen isotope ratios indicate a range in processes that control the distribution of these GHGs, including methanogenesis, methanotrophy, transport and emission. These relationships are modulated by fluctuating local soil water and corresponding ecosystem conditions. The gas geochemistry shows that significant surface CH_4 production occurs by both hydrogenotrophic and methyl-fermentative methanogenesis in submerged, anaerobic peats, e.g., collapse scars, whereas methane oxidation is restricted to aerobic, drier environments, e.g., upland sites and/or peat-atmosphere interface. The most active methanogenesis and emissions are in areas of actively thawing permafrost contrasting with sites under continuous permafrost. This degree of methanogenesis is being amplified by the increased rate of Arctic warming and the rapid retreat of Permafrost in Canada's Arctic (ca. 2.5 km yr^{-1}).

For context, the present situation is compared with the Younger Dryas-Preboreal transition.

Evaluating the quality of clear-sky MODIS Terra daytime Land Surface Temperatures (LST) using ground based meteorology station observations

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In this study, we compare MODIS (MOD11A1 – Version 5) Terra clear sky daytime Land Surface Temperatures (LST) to temporally matched Environment Canada meteorological station air temperatures, collected on the hour, at four stations in the southwest Yukon. Using qualitative ground based sky condition observations and co-incident MODIS quality flag information available at two stations we further refine the MODIS LST to air temperature relationships. The results of our study indicated that air temperature observed at a variety of discrete spatial locations is highly correlated with MODIS LST (collected at 1 km grid spacing). A slight seasonal bias in MODIS LST was detected, where LST plotted against air temperature showed a steeper response (slope > 1) when air temperature was greater than zero, than when air temperature was less than zero (slope < 1). The relationships constrained by ground observations of clear sky conditions showed less variability and positive y-intercepts; the relationships found under mainly clear and mostly cloudy sky conditions showed more variability and negative y-intercepts. The trend of an increasing cloudy sky decreasing the LST to air temperature y-intercept is largely consistent with the MODIS LST quality flag information. The clear sky LST to air temperature relationship provided here could be used to provide further cloud discrimination at ground based meteorology stations where surface air temperature is recorded. Lastly, the trends reported here suggest residual quality issues in the MODIS Version 5 products.

POSTERS (alphabetical by first author)

Comparison of sea ice thickness measurements in the Fram Strait region

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Sea ice strongly affects the global climate system through modification of the albedo of polar regions. Sea ice is also extremely important to northern communities, people, fauna ,and stakeholders as a platform for travel, hunting and habitat. Satellite records of sea ice extent in the Arctic Ocean show a decreasing trend since 1979 of approximately 11% per decade. However, while sea ice extent can be accurately monitored from satellite data, sea ice thickness remains poorly parameterized. Sea ice thickness measurements are urgently required to improve the knowledge and modeling of sea ice mass balance in climate models, and to provide for safe maritime operations in ice filled waters. While the recently launched CryoSat-2 is a major step in providing accurate operational sea ice thickness information, this radar altimeter measures the height of the ice surface above the water, a property which can be dramatically affected by the overlying snow and condition of the ice, leading to errors in the estimated sea ice thickness. Airborne electromagnetic induction measurements of sea ice thickness provide a logistically simple method of acquiring accurate sea ice thickness measurements over large transects. A comparison between airborne electromagnetic induction measurements (HEM) of sea ice thickness in the region of the Svalbard and Fram Strait from September 2010 and previous measurements over the past decade will be presented

Effects of long-term experimental warming on phenotypic and phenological traits of *Papaver radicatum* on Ellesmere Island, Nunavut, Canada

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Climatic changes due to anthropogenic activity are predicted to have profound effects on Arctic ecosystems. Passive warming experiments at Alexandra Fiord (part of the International Tundra Experiment (ITEX) on Ellesmere Island), provide an ideal model for how future climatic changes are likely to affect Arctic plant species. Experimental open-topped warming chambers were established in 1992, and since then both phenological (e.g. leaf-out and flowering time) and quantitative (e.g. weight of seeds and size of leaves) variables have been recorded in every growing season. We analyze this long-term dataset to determine the effects of warming on one species, *Papaver radicatum* (Arctic poppy). Preliminary results suggest that some but not all of the traits measured have responded to warming. Interestingly, the phenotypic and phenological differences between individuals in different habitats may be greater than the differences between warmed and non-warmed individuals within the same habitat. This result could indicate that environmental factors other than temperature play an important role in the phenotypic and phenological characteristics of this species.

Assessing the impact of climate change on tundra vegetation through experimental warming and fertilization

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Warming at high latitudes will likely result in increased nutrient (specifically nitrogen) availability due to increased mineralization rates. The incorporation of warming and fertilization treatments provides the opportunity to observe and analyze plant response to a warmer, nutrient enhanced environment. These studies are an essential part of understanding what is currently happening in this rapidly changing environment, as well as what degree of change can be expected in the future.

The fertilizer study site at Alexandra Fiord, Ellesmere Island consists of 40 randomly located plots, each assigned a warming and a fertilization factor in a fully crossed factorial design. The warming factor consists of two levels: warming and control. The fertilization factor consists of four levels: high, low, water only and none. The water only fertilization treatment is included as a control, in order to isolate the effect of the watering itself. Eight treatments are applied across the experimental plots, with five replications of each treatment occurring.

Species composition and abundance data within all 40 experimental plots was measured using a standardized point frame method. The data for the 2010 field season was collected at peak season, which corresponded with the time of maximum aboveground biomass.

Multivariate analysis of variance (MANOVA) was used to assess the impact of warming and fertilization treatments on species abundance. It was anticipated that the majority of plant species would respond strongly to the experimental treatments. Preliminary results suggest that species response is variable among treatments.

Combining dendrochronology and aerial photography to document ecotone change in southwest Yukon

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Ecotones are naturally dynamic landscape features that may respond gradually or rapidly to acute or chronic forcings, including natural disturbances or long term climate change. Because they represent boundaries between vegetation types, their structure and location is frequently used as an indicator of more widespread vegetation change. This is increasingly the case with respect to climate change. Appropriate methods for identifying recent ecotone change are therefore necessary for characterizing their dynamics and attributing causal mechanisms of change. We highlight results of a study that examined the dynamics of the alpine treeline ecotone in southwest Yukon by combining dendrochronology and sequential aerial photography. The combination of the two approaches permitted detailed analysis of stand dynamics at a fine scale, but also allowed for broader analysis at the landscape scale. The methodology is now being applied to the study of forest-grassland boundaries and pond margins, which represent two other ecologically important ecotones in the region. We illustrate the general transferability of the approach to these two other ecotones as well as challenges associated with its application to different ecotone structures. These include difficulties dating the establishment of highly clonal species such as Salix sp., interpreting small-scale aerial photography, and inferring mechanisms of change in the absence of complete data.

Hydrothermal response impact of climate change on permafrost within the South Mackenzie Plain, Northwest Territories, Canada.

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A hydrothermal forest hydrology model, ForHyM, was used to discern likely depth and duration of frost penetration into the soil for select upland/wetland conditions pertinent to the South Mackenzie Plain, based on daily weather information, from 1963 to 2010. It was found that forested upland soils would experience deep frost and thawing cycles each year, but no permafrost, with two exceptions of two-year durations. In contrast, water-saturated wetland soils with limited drainage should still develop a permafrost layer starting from a hypothetical no-frost condition in 1963. In all cases, the depth of soil frost including permafrost would be affected by extent of thermal insulation afforded to the soil and its substrate at the ground surface, by way of forest litter layers, as well as the local peat, moss and snow accumulations. Variations in snow depth were calculated to influence the depth of frost penetration the most on a year-to-year basis in a major way. These results were used to hypothesize likely permafrost distribution patterns within the study area, based on local flow patterns, likely depth-to-water from the soil surface, vegetative cover and landforms, including ice roads. It was also noted that recent increases in air-temperature changes (more so in winter than in summer) are consistent with fairly sudden permafrost loss in areas where the originally stabilized permafrost layers are thinning to a critically low depth.

The quantity and quality of soil organic matter in three Canadian Cryosols

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Soils in the circumpolar permafrost zone are estimated to contain 50% (1672 Pg C) of global belowground organic carbon (OC) stores, with 88% being perennially frozen and largely protected from microbial degradation. Predicted warming of up to 7-8º C in permafrost areas by the end of the 21st century will result in a significant release of perennially frozen stores of soil organic matter (SOM). Though an increase in the size of the SOM pool is expected, the bioavailability of the thawed stores is poorly known. In this exploratory investigation, we characterize the quantity and quality of SOM in genetic horizons in three Cryosols sampled in the Northwest Territories using chemical (sequential cold- and hot-water extraction), physical (size) and biological (100-d bioassay for mineralizable C) methods. Stores of OC and total nitrogen (TN) ranged from 15-46 kg OC/m2 and 1.3-3.1 kg N/m2, with perennially frozen storage accounting for 4-86% of both TOC and TN. Concentrations of OC and TN in the whole soil and all fractions typically declined with depth. The proportions of soluble OC and TN relative to total OC and TN for both water extractions also declined with depth but mineralizable C did not. The contribution of perennially frozen OC and TN to total storage in each fraction was generally higher than that observed in the whole soil. These preliminary findings indicate that perennially frozen stores of SOM are at least as labile and biodegradable as those in the active layer.

Photos and plants through time: Sharing knowledge - building adaptation

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Morgan Ip, McMaster University
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Within International Polar Year research, PPS Arctic Canada has held a unique place because of its multi-method approach incorporating biological, ecological, and climatic measures of the impacts of a changing treeline and social, cultural and economic aspects as experienced by northern communities. Within PPS Arctic, the Photos and Plants Through Time project encouraged the sharing of science and community based knowledge and brought human experience of impacts of environmental change within communities into focus. Sharing knowledge as a process has intrinsic adaptive properties itself, as we found during our reporting back throughout the past year. In this paper we offer some of the strategies and methods that proved useful and discuss some examples.

Above-ground biomass, CO_2 flux and species composition in three Arctic plant communities: response to experimental warming along a soil moisture gradient

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Arctic plant communities are expected to show varying responses to increasing atmospheric temperatures. Changes in CO_2 flux and above ground biomass have implications for carbon release and storage, as well as feedbacks to local temperatures and vegetation change. This study investigates the differences in CO2 flux and above ground biomass between dry, mesic, and wet plant communities in the High Arctic. Experimentally warmed plots set up in 1992 use open top chambers to heat 1m sq sections of tundra. CO_2 flux was measured using a custom made chamber to calculate rates of ecosystem photosynthesis and respiration. Above ground biomass was estimated using a handheld, multispectral camera to calculate plot-level NDVI. A point-intercept technique was also used to record the number of live hits of all species within each plot. Live hits were used to calculate species composition and above-ground biomass. Preliminary results indicate increases in gross ecosystem photosynthesis, ecosystem respiration and above ground biomass as a result of warming, but no change in species composition. Community level results will be linked to the wider landscape using maps of environmental variables and above ground biomass. Maps of surface air temperature, soil moisture, elevation and NDVI will be created using field data collected at peak season across an 8km sq grid. Differences in above ground biomass at the community scale are expected to be replicated at the landscape scale provided that NDVI values are not significantly affected by changes in community composition.

The influence of climatic gradient and landscape position on Carbon stock trends along the Mackenzie Valley region of Canada's Northwest Territories

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With northern ecosystem carbon (C) an integral part of the global C cycle, it is not only important to quantify these northern C stocks, but to also understand how these stocks may be impacted by a warming climate. The Mackenzie Valley region of Canada presents a unique opportunity to examine northern ecosystem carbon stocks in a region rich in peat deposits, spanning a climatic gradient of 10˚C mean annual temperature and 227mm annual precipitation, in what is predicted to be one of the most sensitive areas to climate warming in Canada.

This study examines the influence of climate, topography, and associated permafrost conditions on both above- and below-ground carbon stocks along a climatic gradient extending from the Mid-Boreal Ecoregion in the south to the High Subarctic environments near the arctic tree line at Inuvik. At each of 25 sites, plots were established in areas of permafrost-affected peatlands (peat plateaux), internal areas of permafrost thaw (collapse scars), and adjacent forest environments occurring on mineral soils (upland forests). A total of 69 plots distributed throughout the Mackenzie Valley region were examined and data from numerous published sources was also compiled to better place these plots within a regional context.

Trends in the above-ground C were largely dominated by trends in tree biomass and results indicate significant (α=0.05) changes in above-ground C stocks along both the climatic and topographic gradients examined. The interaction between topographic and climatic factors was evident, with greatest above-ground C in the Boreal uplands, but with Subarctic uplands having comparable biomass to the Boreal peat plateaux. In turn, Subarctic peat plateaux were seen to have very low above-ground C, comparable to that found in collapse scars from all regions. Above-ground stocks ranged from 10-40 t C ha^{-1} (upland forest), 2-10 t C ha^{-1} (peat plateau), and 0.4-0.9 t C ha^{-1} (collapse scars). Below ground C stocks dominated the total ecosystem C stocks and also showed significant (α=0.05) differences between topographic position. Organic soil C stocks averaged approximately 1500 t C ha^{-1}, with only approximately 200 t C ha^{-1} in the mineral soils of upland forests. Regional, we estimate approximately 4.2 Pg of C stored in the Mackenzie Valley peatlands, although variability in the peat thickness obscured any North to South climatic trends in these peat C stocks.

Aeolian deposition in natural and disturbed arctic treeline habitats near Churchill, Manitoba

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Wind erosion and deposition are important factors in cold climates because of the open space and low height vegetation. In addition, aeolian literature has indicated that particle movement can and does take place on frozen and exposed surfaces during the winter period. This study examines wind deposition of material in seven habitats (disturbed (natural and anthropogenic) and undisturbed natural conditions) located across the arctic treeline transition zone near Churchill, Manitoba. Samples of windblown material were collected in 33 cm x 66 cm traps flush with the surrounding surface and subsequently dried and weighed to determine aeolian deposition. Collections of the traps were made in the spring and fall of each year from 2003 to 2010 to examine annual variations in deposition in a subarctic environment. Significantly higher values (180 g $year^{-1}$ $trap^{-1}$) were collected from sites where natural disturbance had occurred with lesser amounts (10- 100 g $year^{-1}$ $trap^{-1}$) in areas of anthropogenic disturbance. The undisturbed environments sampled; tundra, peatlands and forest environments, had <5 g $year^{-1}$ $trap^{-1}$ with no significant annual variation between 2003 and 2010. Disturbance appears to cause increased amounts of material to be available for transport that is deposited locally. The highest deposition of windblown material occurred in an area where forest fire had occurred in an open woodland forest of the arctic transition zone. Over the seven years of this study (2003-2010) there was no significant variation in the annual deposition of windblown material at the disturbed and undisturbed locations.

Canada's IPY Northern Coordination Offices: Generating northern community involvement

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Given the immensity of Canada's North, its geographic and cultural diversity, and its political complexity, it has been essential to have key contacts in Northern Canada play an active role in the overall coordination of the Canadian IPY Program. In February 2006, the Canadian IPY Program Office established "IPY Northern Coordination Offices" (NCOs), hosted within established research-oriented organizations in Canada's three territories (Yukon, Northwest Territories, Nunavut) and in northern Québec (Nunavik). This presentation will assess the strengths and challenges of the NCOs and examine their structure and role as a model for future research and science outreach programs and initiatives.

With their existing contacts, networks and experience working with both the communities in their region and the broader research community, the NCOs are trusted local sources of information about IPY, and northern science matters in general. Working in partnership with the Canadian IPY Program Office, the NCOs have served as regional points of contact for IPY, coordinated IPY activities on a regional and community level, provided guidance and support to scientists carrying out IPY research, facilitated the involvement of Northerners and northern communities in IPY activities, and informed and educated the public about IPY, creating enthusiasm across the North about the overall IPY initiative.

The NCOs are a model for ensuring meaningful involvement of Aboriginal and northern peoples in future Arctic science programs in Canada and internationally, and an effective "tool" for broad dissemination of information and awareness-raising of scientific news and issues across northern Canada.

The dynamic of the tree line under pollution impact in the Kola Peninsula

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The use of biomarkers is becoming more significant in the diagnosis of ecosystems' states and environmental risk assessment. But there are a lot of questions in this area and the methodology requires a new point of view. In our research we developed an integrated approach to the diagnosis of ecosystems' states, based on the response of the vascular plants to anthropogenic impact, which can be expressed on molecular, cellular, physiological and suborganisminal levels. Such an approach allows evaluation of all aspects of the modifications and adaptations of organisms to the environment.
Field studies were carried out in the impact zone of a metallurgical complex in Northern European boreal ecosystems.
Results:
1. The main diagnostic criteria for the assessment of ecosystem state under pollution impact are parameters at different levels of plants organization.
The system of biomarkers includes:
- On the molecular and physiological level: the intensity of oxidation processes in chloroplast membranes, the ratio between chlorophyll a and b content, the photosynthetic activity.
- On the cellular level: the ultrastructure of chloroplasts and the structure of cells of the assimilation parenchyma.
- On the level of the organs: morphology of leaves.
- On the level of the population: the number and the structure of the population.
- On the suborganismal level: parameters of floristic and phytocenotic structure.

2. Three models of responses of vascular plants to the impacts of pollution were created for slightly, moderately, and severely damaged ecosystems and technogenic barrens.

Mercury input to the Beaufort Sea from the Mackenzie River

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Concentrations of toxic monomethyl mercury (MeHg) in the tissues of marine mammals living in Canada's Beaufort Sea (Arctic Ocean) can be above those recommended for human consumption. Several factors likely contribute to MeHg contamination of these mammals, however the large volume of sediment-rich water delivered by the Mackenzie River cannot be overlooked as a potential source of mercury (Hg) contamination to this region. Currently, it is not known how much Hg is delivered from the Mackenzie River each year and therefore the river remains an important, yet unmeasured, source of Hg to the Beaufort Sea. We have been sampling surface waters from the lower Mackenzie River and its delta channels for total Hg (THg; all forms of Hg in a sample) and MeHg since 2004 to help establish a long-term dataset of Hg delivery from the Mackenzie River. There are two overarching goals of our ongoing research and monitoring program. First, we will accurately measure the amount of THg and MeHg delivered annually by the Mackenzie River to the Beaufort Sea using a dynamic ice-jam flow model through a partnership with the International Polar Year Project Study of Canadian Arctic River-delta Fluxes (IPY-SCARF). Secondly, we will quantify the influence of the ecologically-rich, yet rapidly changing, floodplain of the Mackenzie River Delta (MRD) on the delivery of Hg from the Mackenzie River. Here we present preliminary results from our sampling program including multi-year THg and MeHg concentrations from several locations throughout the MRD.

Mobilizing knowledge and capacity: Education and outreach activities of "Photographs and Plants Through Time"

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This presentation reports on IPY education and outreach activities in three Nunavut communities. It also illustrates how the legacy of IPY subsists not only in the documentation and distribution of research outcomes, but also through innovative procedural dimensions and the training of new northern researchers.

The work emerges from Photos and Plants Through Time (PPTT), a community-based project examining the impacts of a changing tree line on the health and well-being of northerners through participatory action research processes that emphasizes qualitative methods, visual approaches, and a range of knowledge sources, including western science and local knowledge. From 2007 to 2010, in partnership with Sanikiluaq and Kinngait (Cape Dorset), local landscape photographs and plants were collected and interpreted by local residents and southern researchers. Data was documented and stored in digital and hard copy formats. Education and outreach involves sharing the information gathered with community members using various formats, such as information packages distributed to schools, interactive community workshops, and a multi-day on-the-land camp. These methods of "reporting" followed significantly from the recommendations of community partners. In Qamani'tuaq (Baker Lake), IPY outreach involves sharing and distributing PPTT information, resources, and equipment so that residents might engage in a similar, self-directed process of collecting and identifying local plant specimens and landscape photographs. In addition, the first author has modeled his PhD research methodology after the innovative visual approaches used in PPTT. The presentation thus highlights how the environmental knowledge mobilized through PPTT generates capacity within and between communities, researchers, and institutions.

At the front of forest expansion into tundra: the structure of tree islands within the forest-tundra ecotone

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With climate change, tree islands located at the northern edge of the forest-tundra ecotone in Canada would be at the front of forest expansion into tundra. Our objectives were to assess whether tree islands are expanding, to compare their structure between leeward and windward sides and to determine the variation in plant species composition across tree islands. We recorded height and cover of twelve tree islands in Churchill, Manitoba, and twelve more in the Mealy Mountains, Labrador. We also sampled other plant species at all tree islands and the surrounding tundra at both sites, and mapped all trees within tree islands in Churchill. We found some evidence of expansion of 8-15 m wide, 3-7 m tall tree islands in Churchill including the presence of <15 cm tall saplings at the edges. Tree island shape was variable and not affected by predominant wind direction as expected. Sampled tree islands in Labrador were 4-9 m wide krummholz patches <70 cm tall (except one) with no signs of expansion. In Churchill, moss, *Vaccinium uliginosum* and *V. vitis-idaea* were more abundant and lichen, *Dryas integrifolia* and *Rhododendron lapponicum* were less abundant within tree islands compared to tundra. In Labrador, lichen and *V. vitis-idaea* were more abundant and moss, total herb cover and *Arctostaphylos alpina* were less abundant in tree islands compared to tundra. Possible expansion of tree islands is expected to result in site-specific changes in plant species composition at the edges of tree islands.

Investigation of temperatures across a Subarctic Alpine treeline

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Temperature is a limiting factor for plant growth in higher latitudes. An increase in growing season temperature over time will cause the forest to advance at the expense of tundra, assuming soil and moisture conditions are suitable. To predict the effect of future climate warming, it is necessary to have a detailed picture of the current temperature environment across the current forest-tundra ecotone.

In the central Mealy Mountains, Labrador (N 53.6º, W 58.6º) treeline, as defined by the upper limit of stands of erect conifers > 3 m in height, is about 600 m a.s.l., though, smaller, but long-lived erect conifers and krummholz are found to an elevation of nearly 800 m. This indicates that there is a broad altitudinal zone where thermal conditions are suitable for tree growth.

To better characterize temperatures across this ecotone, we carried out long-term (2001-2009) observations at three sites between 570 m and 995 m a.s.l., supplemented by short-term measurements within the study area. At the coarse scale of the upper and low stations, the summer (JJA) gradient of mean daily surface temperature averaged about - 0.6ºC 100 m^{-1}. Short-term measurements at a finer scale showed a broad zone between 570 and 700 m where differences in temperature were less than the instrumental uncertainty of ca. 0.4ºC. These results and related measurements of soil temperatures show the complexity of quantifying temperature fields across the forest–tundra transition zone.

Long term dynamics of earthworms in forest-tundra ecotones in the Khibiny Mountains, Kola peninsula, Russia

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The population of earthworms in the Khibiny Mountains is characterized by relatively high species diversity and abundance for polar regions. Our study was based on 23-year dynamics of the earthworm population in the forest-tundra ecotone. Investigations were carried out at the Vudyavrchorr mountain (N 67°38'39" E33°39'48"). Earthworms were collected by hand-sorting of soil samples (25x25 cm) at the tundra, forest-tundra and forest sites in August of 1986 and 2009.

The earthworm species include epigeic and anaceic forms. *Lumbricus rubellus* and *Dendrobaena octaedra* were widespread, and *Dendrodrilus rubudus* and *Nicodrilus caliginosus* were also recorded. Most species inhabit in forests growing in mountain valleys.

The density of earthworms increased from tundra to forests and reached 250 individuals m^{-2} in 2009. Their activities resulted in the development of organic -mineral humus horizon in mountain forests. The density and biomass of earthworms increased over 23-year period. Compared to 1986, in 2009 the density of earthworms in the forest sites was higher by as much as 1.5-2 times. In 2009 epigeic earthworms were recorded in lichen tundra.

Earlier the stability of earthworm populations in the Khibiny Mountains was explained by thick snowpack on the non-freezing soil. According to measurements of the Centre of Avalanche Safety in the Khibiny Mountains, winter temperature increased and amount of snow precipitation decreased in the period of 1962-2006. The next step in our study is to check if there are any correlations between earthworm density and soil temperatures measured by iButton temperature loggers.

Vegetation change on Herschel Island and the Coastal Plain of Ivvavik National Park

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Significant increases in the cover of vascular plant species have been recorded on Herschel Island, situated in the Beaufort Sea and the nearby coastal plain of Ivvavik National Park, between 1985 and 2001. In particular, polargrass (*Arctagrostis latifolia*), a native grass species has shown a dramatic increase in both percent cover and occurrence.

Significant changes have also been shown in the increase in lupines (*Lupinus arcticus*) and netted willow (*Salix reticulata*), with significant decreases in bare ground (e.g. frost boils) and lichen cover during the same time period.

In a short time span, the character of the vegetation over a large proportion of Herschel Island has changed from a forb/low shrub dominated tundra to a graminoid dominated tundra.

On the coastal plain of Ivvavik, a significant increase in polargrass was recorded on exposed coastal sites and headlands. Changes in vegetation cover were not as dramatic as Herschel Island , but exhibited similar trends.

The vegetation changes observed may be related to the many environmental changes observed in recent years by residents in communities across the north. A significant change in vegetation cover may have implications for wildlife and birds.

Two years of IPY in the context of 20 years of permafrost monitoring in the discontinuous permafrost zone, Northwestern Canada

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Monitoring of permafrost landforms (palsas and peat plateaus) in the Mackenzie Mountains NWT began in 1990. Palsas and peat plateaus were instrumented to measure near-surface permafrost temperature (-150 cm). A active layer probe grids were established on each of the eight study sites in the study area. The probe grid was monitored annually. Permafrost temperatures for the first 18 years rose between ~0.75 and 1.25 C° to temperatures close to thawing. Over the past few years they have cooled by ~0.75 C°. The recent permafrost cooling paralleled a drop in mean annual air temperatures (MAAT) by ~2 C°. The long-term MAAT varied from -6 to -5 °C with warmer temperatures prevailing at the higher elevations. Active layer thickness on the top of one feature doubled over the 20 years while it shrunk in area by 90% over the past 65 years. At this site 65% of the thaw monitoring sites established in 1990 were lost as the permafrost degraded. At the remaining sites the thaw depth varied little over the record period although all features lost sampling sites around their perimeters due to permafrost degradation. These conditions illustrate the relatively rapid response of permafrost features in the discontinuous permafrost zone to changes in MAAT. The peat depth on the palsas and peat plateaus varies from 2.5 to >5 m. As permafrost degradation continues the hydrology and carbon budgets of these peatlands can be expected to undergo significant changes.

What is going to happen with the mosses? A baseline study to determinate the impact of climate change on tundra vegetation

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Information on how climate change will affect terrestrial ecosystems of northern Labrador is limited. A systematic baseline data on the terrestrial ecosystems including mosses are needed to asses any potential impacts. Mosses contribute 30% to the vegetation cover of the tundra and they play an important role in the biogeochemistry processes of the boreal and arctic ecosystems through carbon and nitrogen fixation, soil production, and habitat services for animals and vascular plants. This project yielded baseline data on wet and dry moss communities and also complement work was done on vascular plant communities of the same low arctic alpine study area (Torngat Mountains, Labrador). A spatial data base was created for the present mosses (2008, 2010) in order to detect any changes to the community structure after five, or more, years of warming experiments (open top chambers) using the IPY-CiCAT protocol. Species richness and abundance was measured using a point framing method. Significant differences observed between assemblages associated with wet and dry sites. Species diversity was higher in the wet habitat. Most of the wet sites were dominated with *Sphagnum* and *Drepanoclaudus* spp. and most of the dry sites were typified by *Polytrichum* and *Pogonatum* spp. All species were recorded from Labrador and the species richness and diversity relative to the study area are similar to those found in other alpine tundra areas. The data base can, in the future, be used to assess the consequence of climate change on the tundra vegetation including mosses.

Allocation between reproduction mechanisms did not change along environmental gradients of the moss Polytrichum juniperinum in the low arctic

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Numerous plants reproduce through both sexual and asexual mechanisms. However, the evolutional and ecological factors influencing allocation among the two reproductive strategies are little understood. In general studies have shown that as resources decrease (such as along environmental stress gradients) the rate of sexual reproduction also decreases among many vascular and bryophyte species. However, little is known about the allocation of sexual vs. asexual reproduction within species. Our goal was to observe the link between the spatial genetic structure and sexual vs. asexual reproductive allocation along an altitudinal and a moisture gradient of the moss *Polytrichum juniperinum*. Sampling sites were established in the Torngat Mountains National Park (Labrador) low arctic area; in a low elevation valley, along a mid elevation slope (wet, mesic, dry sites), and at a high elevation summit. Within each site population structure (density, sex ratio, reproduction effort, and diaspore bank) and genetic composition (variability of five polymorphic allozymes in female, male shoots and sporophytes) were assessed. We found no difference in the level of allocation for sexual vs. asexual reproduction of *P. juniperinum* along the gradients. Sexual reproduction was depressed at all sites, compare to a random mating population which might have been due to macro-regional climate or biological effects. Sporophytes were produced at all sites, however frequently by inter-gametophyte self fertilization. Future studies using more allozymes or examining a wider environmental range might detect allocation between reproduction strategies

Micromosaic structure of vegetation cover in forest-tundra ecotone

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Vegetation cover in forest-tundra ecotone has mosaic structure. Spatially similar, elementary vegetation cover units can be determined in this structure. We call them plant compartments (microgroups), as delineated by distribution of predominant plant species.

The aim of this study is to characterize the species and structure diversity of forest-tundra ecotones for relatively small areas through field mapping of vegetation micro-mosaic structures (scale 1:100) and for larger areas using high resolution satellite imagery (0.5m) to investigate the dynamics of treeline change.

Vegetation cover has been studied in two ecotones in north-west Russia: the Khibiny Mountains (Tuliok N67.70139, E33,78825) reflect altitudinal change of vegetation cover and Lake Kanentiavr surroundings (N68.88811, E34.26546) reflect latitudinal gradient, Russia.

Vascular plant species diversity in the Kanentiavr was higher than that of the Tuliok: the number of species varied from 52 to 35 correspondingly. Total number of compartments in the Kanentiavr was 175, and in the Tuliok – 94, only 15% of them contributed significantly to the total area (not less than 5 % of each). About 20% of these were common for tundra, forest-tundra and forests. Using very high resolution images we could identify 8 predominant landscape structures reflecting predominant compartments.

Structural diversity of the Kanentiavr site was significantly higher than of the Tuliok site: the Shannon index was 2.74 and 2.48 correspondingly. On the level of individual compartments, the index values in the Tuliok were, on the contrary, higher (2.0…2.9 against 1.4…1.8) which is related to higher fragmentation of compartments in the Khibiny Mountains.

Representation of forest-tundra ecotone at multi-resolution satellite images: from QuickBird to Landsat

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This study was conducted by the Laboratory of Aerospace Methods, Faculty of Geography MSU, within the PPS Arctic project. Images from Landsat satellites available over the last three decades, with a resolution of 30 m were not sufficient for clear representation of sparse northern forests. Therefore it was necessary to know what dominates inside the 30x30 m pixel area? We addressed this issue by analyzing a high resolution QuickBird image.
The study area was in the northern part of the Kola Peninsula, Russia. We compared interpretations of ETM+/Landsat, ASTER/Terra, and QuickBird images. After fieldwork in 2009 a vegetation map was created by visually interpreting the QuickBird image, which was used as a quasi ground truth. Comparison of this map with ETM+/Landsat and ASTER/Terra images confirmed that 8 ecosystem types discernible in the QuickBird image could be merged into 3 on coarser resolution images. Forests with dwarfshrub understorey merged with dwarfshrub tundra (which can be with groups of trees, with single trees and without trees). Therefore forest line and tree line disappear from the image. This analysis helped to explain the disappearance of forest boundaries in Landsat TM images and proved to be an optimal method for change detection.

Community turnover across the forest-tundra ecotone in the Mealy Mountains, Labrador

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Changes in ecological community patterns have been measured across treelines, but usually with a focus on one vegetation layer. We present an analysis of community patterns for the all vegetation layers (trees, shrubs, field, and ground) across the forest-tundra ecozone in the Mealy Mountains, the dominant highlands of southern Labrador. Along an elevational gradient through forest, forest-tundra ecotone, and alpine-tundra zones, we established two, four, and two transects respectively of 50 or 100 m. Soil nutrient-flux probes and miniature soil temperature loggers were placed at plots within each zone. Climate stations operated in the forest-tundra ecotone and alpine tundra to establish altitudinal temperature gradients. Trees structure and density were recorded for all sites along with information on herbivory and cone production. Along each transect, contiguous 1 x 1 m plots were used to record the amount of cover by species for each vegetation layer: tree, shrub (individuals >25 cm tall), field and ground (e.g., percentage cover of dwarf shrubs, mosses, lichens, graminoids etc and bare ground; see variables in Section 2). We used the following cover classes: 0%,1-5%, 5-25%, 26-50%, 51-75%, 76-100%. We used NMDS with fitted vectors to explore how community patterns change across the treeline and the potential allelopathic or facilitative effects on species composition.

Mid-winter snowpack characteristics and feedbacks with Arctic treeline dynamics

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Winter conditions dominate the year at the Arctic treeline. Snowpack characteristics, distribution and duration can affect meso- and micro-scale processes. Studies at Churchill over two winters confirm significant differences in snowpack characteristic along transects from forest through the forest-tundra ecotone into tundra. Mid-winter snowpack depth, density and snow water equivalent (SWE) were different between the two sampling years - 2008 and 2009. There was significantly deeper and denser snow with higher SWE in all three zones (except density in the tundra) during 2009. The 2-year mean snow depth on the tundra was 14.8 cm while in the forest and forest-tundra ecotone it was, respectively, 5.6 and 4.1 times deeper. SWE was 6.2 and 4.9 times higher on the forest and ecotone respectively over the tundra where it was 34 mm. The difference in depth and density resulted in heat flux potential that was ~3 to 6 times greater than the tundra. Surveys for conifer seedlings located greater numbers in the ecotone and forest compared with tundra. This reflects proximity to seed source and protective winter/spring snowpack. There are feedbacks between stand and snowpack characteristics whereby stems trap snow which facilitates seedling survival which leads to higher stem density and expansion of the forest into the ecotone and seedlings into the tundra.

Analogous tree growth pattern in contrary climate regions along the Arctic margin

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The northern distribution limit of Scots pine is predominantly controlled by climate and as temperature increase, a northward shift and more vigorous growth is expected. Implications of changed forest cover include changed carbon sequestration, changed land-atmosphere energy balance and ecosystem changes. Understanding of climate related height- and diameter-growth patterns across geographical regions is therefore essential. The study focuses climate-growth relationship for pine during last decades, along longitudinal and coast-inland gradients in Northern Norway and Kola Peninsula; by analyzing i) how height and diameter growth at the northern distribution margin have responded to climate variability; ii) if growth responses differ between climatic regions; and iii) if short-term height and diameter growth-climate relations are useful predictors for forest cover change. Six pine woodland sites along the forest-tundra zone were analyzed for annual height growth (saplings, i.e. <2m) and diameter growth (adult trees) and compared with local climate data. Height growth correlated strongly among all sites while diameter growth showed limited correlation among sites. However, an inter-annual pattern with common growth peaks among sites is evident for both height and diameter growth. Although summer temperature is the most important factor(s) to both height growth (Julyt-1) and diameter growth (Julyt-1, Junet, Julyt), winter (November-February) and late non-growing season (April-May) temperature and precipitation showed significant. The results highlight the importance of generally overseen precipitation and non-growing season factors to growth at northern distribution limits. Such detailed data on climate-growth relations is essential to feed models for forest cover change.

Degree-day prediction of first flowering in subarctic Manitoba, Canada

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Date of first flowering was recorded from 2001 to 2009 for seven subarctic angiosperm species around Churchill. At the same sites, mean daily temperatures were determined for monitoring on 5-minute intervals at heights relative to the soil surface of 150 cm, 0 cm, -5 cm and -10 cm. Degree days for first-flowering were calculated using threshold temperatures of 2ºC, 0ºC, and -5ºC. Using coefficient of variation (cv) for means across years, degree-day scores (DS) were considered less variable than numeric scores for calendar dates (NS) when cvDS/cvNS was <0.9 for a combination of species and site. Irrespective of threshold, degree days offered considerable advantage over calendar date to predict flowering when temperature was recorded at 150 cm height for *Dryas integrifolia, Ledum palustre ssp. decumbens, Ledum groenlandicum*, and *Vaccinium vitis-idaea*. For these species, other heights for temperature monitoring were less reliable predictors of flowering. In contrast, either 150 cm or 0 cm above soil surface was equally effective for *Saxifraga oppositifolia*, but a threshold of -5ºC was essential to predict flowering for this species. Degree days offered no advantage over calendar date to predict flowering for *Arctostaphylos rubra* and *Salix reticulata*. Degree-day values were site specific where multiple sites were investigated, indicating that environmental factors in addition to day length and temperature contribute to flower initiation for *L. palustre* ssp. *decumbens, L. groenlandicum*, and *Vaccinium vitis-idaea*. The utility of degree days to predict flowering suggests that temporal patterns of flowering will be modified across the subarctic as climate warming proceeds.

Linear spectral mixture modelling of arctic vegetation using ground spectroradiometer

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The main purpose of this study within PPS Arctic/Benefits project is to describe how the reflectance of mixture of vegetation and non-vegetation objects is formed, on the basis of ground-level data. We aim to answer whether it is
a linear or non-linear sum of reflectances, to find out whether we can use the linear mixture model to upscale from detailed imagery of arctic vegetation to coarser imagery, and define the accuracy of such modelling.

In our experiment we used a SkyInstruments SpectroSense2+ ground spectroradiometer with the following spectral bands: 450-500 nm, 500-600 nm, 650-700 nm, 750-900 nm (NIR). Mixtures of typical arctic landscape components such as: white lichen (*Cetraria nivalis*), birch (*Betula ortuosa*), dwarf shrubs (*Empetrum nigrum* and *Betula nana*), spruce (*Picea* sp.) and stones were constructed in the field and their reflectance factors were measured (about 400 samples in total).
The obtained spectral data has shown that the general spectrum of a mixture is indeed the linear sum of
spectra of the constituent samples multiplied by their area. Adding vegetation into a mixture causes considerable changes in the visible range when the vegetation occupies one third of the sample area. In the NIR band the values smoothly grow as vegetation is added. We also created a software for spectra visualisation and mixture modelling. The inputs for the analysis are measured reflectance factor values, codes, describing combinations of samples, real abundances for each sample class.

Update on Mackenzie Delta hydraulic model and 2008 river breakup progression mapping as Part of IPY-SCARF Project

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The Mackenzie Delta, located in Canada's western arctic, contains over 45,000 interconnected lakes and channels that flow through a permafrost-influenced sand-silt plain. This area is biologically productive, supporting diverse populations of plant, fish, wildlife and waterfowl. River ice processes, particularly at spring break-up, are critical controls on delta lake ecosystems as they result in the peak yearly water levels which replenish nutrients and freshwater to lakes normally perched above river level. Furthermore, the impact of oil and gas development and climate change on river ice jamming and other hydraulic processes are not well understood. This poster reports on the development and application of a hydrodynamic model of river flows in the Mackenzie Delta that as part of the Canadian International Polar Year (IPY) project entitled "Study of Canadian Arctic River-delta Fluxes (IPY-SCARF)," which aims to better understand the transport of freshwater and nutrients to the Arctic Ocean. The model will be used to simulate hydraulic conditions in the Delta to provide a better understanding of current delta channel processes and the possible effects of global change on these processes. Additionally, maps showing the extent and type of ice cover illustrating the progression of the 2008 river ice breakup will be presented. These maps were prepared from air photos and remotely-sensed data from the 2008 International Polar Year and will be used for model verification and simulation of actual ice and water conditions in the Delta.

Long term monitoring of the Arctic tree line using Radarsat-2

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Temporal changes within the, arctic tree line, or tundra-taiga interface (TTI), can be monitored using a visible and infrared band-derived 'normalized difference vegetation index' (NDVI) image. However, the limited temporal resolution of fixed nadir view imagery, worsened by its sensitivity to cloud cover, causes difficulties in collecting data that would inform on the spatially continuous and temporally significant characteristics of the tree line in Arctic regions.

As a cloud alternative, this project proposes the use of synthetic aperture radar (SAR) images from the Canadian Space Agency's RADARSAT-2 satellite to derive an image product representing vegetation cover within the TTI region of Labrador. The methodological objective of this project is to extract texture and backscatter information from radar imagery in order to represent vegetation cover. The operational objective is to create a radar-derived vegetation variable that correlates highly with 'normalized difference vegetation index' (NDVI) images.

The creation of a radar derived vegetation variable will allow for more extensive and reliable spatiotemporal analysis of tree line dynamics in Labrador, and the Arctic region as a whole. The derived product will be useful for quantitative and qualitative studies relating to the taiga-tundra boundary including land cover change, tree stand type and structure identification, and forecast modeling. For Labrador, this will mean a greater understanding of the TTI ecosystem and the impacts of ecological changes on local hydrology, soil characteristics, climate, wildlife and people living in northern communities.

Ecological impacts of shrub expansion in alpine and Arctic tundra in the Yukon

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The arctic is experiencing a change in vegetation boundaries, particularly the spread of tall shrubs into tundra ecosystems. Growing evidence indicates an expansion of canopy-forming woody shrubs up mountain slopes and northward into Arctic tundra. The correlation between warming and greening has been used to link climate change with shrub expansion; however, the exact mechanisms driving observed increases in canopy-forming shrubs are probably more complex. Shrub expansion that results in a change in canopy cover may modify the ecology of tundra ecosystems by changing understory plant composition, soil thermal dynamics, surface albedo, nutrient turnover times and carbon storage. And, enhanced nutrient cycling associated with warmer winter soil conditions may provide a positive feedback mechanism that could promote further expansion of shrubs in the arctic. We have surveyed shrub abundance in the mountains of the Kluane Region and on the Arctic Coast of the Yukon, and found evidence of shrub expansion including younger age distributions of shrubs at higher elevations and expansion of individual willow patches identified in historic photographs. Here, we present estimates of willow expansion at our Yukon study sites, and experimental quantifications of the ecosystem level impacts of greater shrub canopy cover on snow depths and soil temperatures. Understanding both the rate of change in canopy forming woody shrubs and the impacts of this change on ecosystem function will improve circumpolar estimates of future carbon storage, wildlife habitat and permafrost integrity in tundra ecosystems.

Quantification and modelling of patch-scale vegetation dynamics in the Alaskan Arctic

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Shrub expansion over the course of the 20th century in the Alaskan Arctic has been documented from experimental plot data and broad-scale satellite remote sensing. There is, however, a lack of knowledge regarding expansion at the intermediate patch-scale. Analysis of repeat oblique aerial photography from two dates (late 1940s and late 1990s) in the Colville River basin identified significant expansion (3-80% increase). While it has been proposed that this expansion follows a simple logistic growth model, its precise nature in the interim period is largely unknown. Building on this work, this study aims to more explicitly quantify and model the manner in which shrub expansion has occurred in the Colville basin and other sites throughout the North Slope. From compilation and georectification of historic vertical aerial photos of these sites, along with associated high-resolution orthorectified QuickBird imagery, we will map shrub patches in a GIS. We will calculate pattern metrics of these maps using FRAGSTATS to pinpoint potential variability in spatial patterns. Additionally, we will develop and implement a stochastic cellular model that simulates shrub expansion and incorporates environmental heterogeneity (e.g., topography and hydrology) and biological processes (e.g., clonal expansion, seed dispersal). Analysis of the model output using FRAGSTATS, MANOVA, and Principal Components Analysis (PCA) will allow us to determine what environmental parameters best explain the observed pattern of expansion. This methodology can then be used to refine hypotheses about the processes controlling shrub expansion, and can also help to predict future expansion in Alaska and throughout the Arctic.

High resolution modeling of flow channels, wet area and cartographic depth to water modelling and mapping for arctic and subarctic areas in Canada.

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A GIS-based process was developed to determine flow channels, wet-area regimes and cartographic depth-to-water (DTW) for about 1,000,000 ha sections (i) in the Fort Simpson area, (ii) east of the Great Bear Lake, and (iii) Bathurst Island in the Arctic. This process combines digital elevation modeling (DEM) with other surface information including satellite surface images to delineate and classify uplands and lowlands and related vegetation zonations. The process also assists in delineating watershed borders, the extent of wet area per watershed including sinks (collapse scars) and depressions, all at high geospatial resolution (at least 10 m, with 1 m resolution possibility for LiDAR (Light Detection and Ranging) deterived DEMS and images. The presentations illustrates the principles involved, and provides examples of how the resulting information can be used within the management and planning contexts, with emphasis on the evaluation of hydrothermal risks as these would pertain to already existing or contemplated regional and local development plans. Examples deal with trail, road and pipeline layout, and related infrastructure requirements. The results also serve environmental, ecological and engineering research interests in terms of understanding hydrothermal processes and impacts on soil, vegetation and water at the local scale as they would be affected by land-use interests and structures in particular, and climate change in general.

Application of different VHR satellite images for detailed mapping of forest spatial structure properties in the forest-tundra ecotone

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Tree height as well as crown coverage and distances between individual trees are among the criteria for definition of forest, forest-tundra and tundra zones in the forest-tundra ecotone. Estimation of these parameters requires very high resolution (VHR) remotely-sensed data (satellite or airborne multispectral images), because coarser imagery cannot provide the necessary detail.

The goal of this study is apply a local-focal object interpretation method for extraction of detailed information on spatial structure of forest, position of forest line and tree line in forest-tundra ecotone from the very high resolution (VHR) satellite imagery, using Quickbird, IKONOS and GeoEye images acquired in summer seasons in 2006-2009 for central and northern Kola Peninsula, Putorana Plateau and south-eastern Taimyr Peninsula, Russia.Using our method we delineated single trees and shrubs in sparse forest in forest-tundra ecotone with an accuracy over 80%, as proved by detailed visual interpretation of validation transects. Tree heights have been calculated with 1.0 – 1.5 m accuracy using the shape-from-shadow technique. Tree line and forest line have been delineated. Tree canopy cover and distances between individuals have been calculated for various grid sizes, for further comparison with coarser imagery and development of multi-scale mapping approaches.

The study revealed that QuickBird satellite images is more suitable for detailed mapping of forest spatial structure properties than IKONOS or GeoEye images, due to a combination of good radiomatric properties and spatial detail.

The burial of organic carbon by cryoturbation in soils at two Canadian Arctic sites

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Changes in the global climate system have stimulated a recent scientific focus on the size and interrelationships of carbon pools. Soils are an important reservoir of carbon, and arctic soils in particular contain vast amounts of organic carbon. This carbon is believed to be sensitive to climate change, and regional warming could allow the release of large amounts of soil organic carbon to the atmosphere as carbon dioxide and methane.

There has been much work done to investigate the size of carbon pools in northern regions, but relatively little work has been done on the role that soil mixing by cryoturbation plays in the preservation of organic carbon. There is evidence indicating that cryoturbation moves soil organic carbon to greater depth in the soil profile where it is less likely to decompose and be released to the atmosphere as a greenhouse gas, but more work is needed to examine the burial of organic carbon in soils subject affected by cryoturbation.

The objective of this study was to compare the depth distribution of soil organic carbon in arctic soils subject to cryoturbation and those not subject to cryoturbation. Soil units were examined in cross section and GIS techniques were used to compare area-weighted averages of organic carbon density by depth class. Results indicate that mixing driven by cryoturbation plays an important role in the redistribution of organic carbon in some arctic soils.

Remote sensing methods for mapping the above-ground phytomass of plants in the forest-tundra ecotone

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The goals of this study are to: i) establish relations between phytomass values and structure, and spectral reflectance, derived from ground research; and ii) upscale from ground data to QuickBird satellite imagery to compile maps of above-ground phytomass for key sites.

This research is part of PPS Arctic, the IPY project which investigates current status and past changes in the circum-arctic treeline zone, as well as associated social and natural factors, including climate change. Vegetation changes due to climate would be mostly reflected in the changing structure of phytomass.

The field research focused on two sites in the central and northern parts of the Kola Peninsula, Russia. Over 50 vegetation samples were measured with a Skye Instruments 4-channel radiometer, geobotanically described, separated by species and plant parts, dried at 105oC, and weighed.

These data were compared to derive relationships between reflectance, phytomass values and structure. The ground radiometry data were upscaled to QuickBird imagery of the study sites using spectral unmixing techniques. Finally above-ground phytomass maps of the key sites were compiled from QuickBird imagery.

Mapping the above-ground phytomass in tundra and forest-tundra can be used to predict changes in phytomass structure due to climate change. In future we plan to develop our results to include relations between soil nutritional status and vegetation composition.

Permafrost thaw in peatlands of the Mackenzie Valley: Towards an integrated drainage network and changes in carbon sequestration.

Stephen D. Robinson, Champlain College Dublin, Dublin, Ireland.

This poster examines and quantifies the impacts and magnitude of recent warming upon permafrost stability in peatlands of the upper Mackenzie Valley. Permafrost has a significant impact upon carbon storage in peatlands, with frozen peatlands generally accumulating carbon at lower rates than unfrozen peatlands. We used a time-series of aerial photographs and high-resolution satellite images spanning the years 1947-2000 to quantify thaw at four locations (total 6 sites) ranging in latitude from 60 to 64^{o}N.

Significant thaw of permafrost has occurred at all sites over the past 50 years, ranging from a 33.9 to 79.2% increase in unfrozen peatland area. On average, the amount of thawed peatland increases by 1% per year in this region. There is a trend of lesser increases in thawed area with increasing latitude.

Mean lateral thaw (the lateral movement of the frozen – unfrozen boundary) range from 18.6 to 7.0 m over the time period of study. There are also locations at the Liard site where very large peat plateaus, up to 200 x 225 m have completely thawed in the 53 years between images. Of course there are many locations that appear to be stable (not thawing), or in rare cases permafrost may be aggrading.

One of the most interesting results of this study is the recognition that many of the thawed areas at the Liard River sites are becoming more and more interconnected and contiguous over time, resulting in improved drainage and a decrease in the dominance of permafrost. In contrast, sites other than the Liard River area are still permafrost-dominated, although the trend is certainly towards ongoing thaw, the coalescence of thaw features, the development of an integrated drainage basin, and a landscape becoming more dominated by unfrozen peatlands. A result of the dominance of unfrozen peatlands and improved drainage is the establishment of drier, shrub and tree dominated peatlands that have higher carbon accumulation rates than permafrost-dominated sites.

Differentiating clonal and non-clonal Yukon black spruce trees by microsatellite DNA analysis

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We investigated the prevalent concept that asexual reproduction serves to maintain populations of black spruce (*Picea mariana*) at the treeline. Microsatellite DNA markers of the black spruce nuclear genome enabled genetic affinity in four black spruce populations of the Western Yukon Plateau to be resolved. Sixty individual trees from each population were genotyped by priming for eight simple sequence repeats followed by PCR and electrophoresis. Microsatellite polymorphs were visualized, and genotypic differences were assessed by determining the number of multiple-locus genotypes within and between each of the four sampled sites. Every individual within three montane black spruce populations growing on flat terrain provided a unique multi-locus signature, indicating absence of clonal structure. However, in a never-disturbed climax community on a northwest-facing slope near Mount Nansen, the majority of sampled subalpine individuals belonged to eight genetically distinct clones (genets), the dominant genet being nearest timberline. The results indicate that black spruce reproduction in this region is adaptive, primarily sexual in low-elevation fire-disturbed montane populations but mixed vegetative-sexual in fire-exempted upland subalpine populations. The explanation for the difference evidently resides in the depth of accumulated tundra vegetation available in support of lower branch layering. Acknowledgements: This research was a product under the IPY core project PPS Arctic as part of International Polar Year 2007-2008 sponsored by the International Council for Science and the World Meteorological Organization. Funding from the Government of Canada Program for International Polar Year was to PPS Arctic Canada.

Pearson's correlations of dendrochronological variation in subalpine Yukon white spruce

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Our objective was to determine if changing widths of annual rings in mature, open-grown, full-crowned white spruce (*Picea glauca*) trees growing at timberline on permafrost on the Western Yukon Plateau could serve toward deducing past climate change. Our null hypothesis, based on dendroclimatology, was: If year-to-year climatic variation is the primary factor determining the magnitude of yearly cambial growth, then between-tree dendrochronological comparisons at the same trunk height should generate Pearson product-moment correlation coefficients (PMCC) near a value of 1. A secondary hypothesis was that PMCC values near 1 should exist when comparing different trunk heights within a tree. The vertical trunks of 12 mature trees on a southwest slope within a timberline ecotone were felled; disks were cut from each at successive meter intervals, transferred to the laboratory and sanded; ring widths were measured to the nearest 0.1 mm across each cardinal direction using WinDendro. Within-disk (4 cardinal directions), within-tree (all trunk heights, 4 cardinal directions, and averages for the 4 cardinal directions), and between-tree (all trunk heights, averages of 4 cardinal directions) PMCC's were calculated. Within-disk PMCC values for cardinal direction comparisons spanned a broad range, indicating the existence of major uncertainty should only cores be extracted from trunks and analyzed. Within-tree PMCC values were rarely > 0.8 and showed a general tendency to decline with each additional meter separation between two trunk positions. Between-tree PMCC values were low, often near zero, invalidating the null hypothesis.

Vegetation change after 2-year experimental warming in wet and dry tundra ecosystems of Torngat Mountains National Park, Northern Labrador

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Monitoring and experimental manipulation of tundra vegetation and climate are underway in Torngat Mountains National Park (TMNP) to predict future vegetation change. Our study area is located north of Saglek Fiord, adjacent to Nakvak Brook. In 2007-2008, we established 20 open-top warming chambers (OTCs) paired with control plots and a network of ground temperature sensors to predict the impacts of warming on wet and dry tundra vegetation. Pre-warming vegetation data were collected using the ITEX pin drop protocol and sampling was repeated after 2 years warming (summer 2010). Pre-warming trends in vegetation data show that wet sites are dominated by taller and more abundant graminoids, deciduous woody shrubs and mosses while dry sites are dominated by shorter, less abundant sub-shrubs and lichens. After 2-years warming, the OTC's appeared to support greater shoot elongation of dwarf birch in dry sites and greater height growth of some willow species in wet sites. However, we did not detect significant warming effects on the abundance and height of vegetation/lifeforms within wet or dry site types (using MRPP and NMS ordination). Our analysis depicted greater variation in vegetation abundance and height between OTC and control treatments in wet sites rather than dry sites; this may suggest that graminoids and woody deciduous shrubs (i.e. willows) in wet sites are responding quicker to warming than the sub-shrubs and lichens characteristic of dry sites. Further investigations of ground temperature patterns in relation to vegetation change are underway.

Influence of climate, landscape position and permafrost thawing on net ecosystem exchange and soil respiration along the Mackenzie Valley, Canada.

Natalia A. Startsev, Northern Forestry Centre
Jagtar S. Bhatti, Northern Forestry Centre

Rates of net ecosystem exchange (NEE) and CO_2 emissions were studied in relation to landscape position across different ecoregions (mid boreal, high boreal, low subarctic and high subarctic) along the Mackenzie Valley of Canada. Measurements were conducted for a period of over three years in upland, peat plateau and collapse scars. NEE was measured using automatic CO_2 chambers; CO_2 emissions through CO_2 sensors (CarboCaps™); spatial variability of NEE and respiration rates were assessed monthly using a portable PP system.

Both NEE and respiration rate of the soil surface were primarily controlled by soil temperature. Soil respiration rate varied from 583 to 214 g of CO_2 m^{-2} $year^{-1}$ for upland locations of mid-boreal and high subarctic zones, respectively. Annual soil respiration in upland forest sites was double that of peat plateaus and collapsed areas in all study sites. Almost 60% of surface CO_2 emissions were generated by the upper 5 cm layer composed of live bryophytes and fibric material. Our results suggest that respiration was the main determinant of C balance. Bryophyte assimilation rates were greatest in the continuously wet collapsed areas and negligible in the upland sites. Overall, upland forest soils were sources of CO_2 (64g C m^{-2} $year^{-1}$ in the high subarctic to 588 g m^{-2} $year^{-1}$ in the mid boreal site); collapsed peatlands were sinks of C especially in the high subarctic (from 27 g m^{-2} $year^{-1}$ in the mid boreal site to 86 g m^{-2} $year^{-1}$ in the high subarctic) and peat plateau were intermediate sources (from 153 g m^{-2} $year^{-1}$ in the mid-boreal to 6 g m^{-2} $year^{-1}$ in the subarctic).

Influence of climate, vegetation and landform on the soil thermal regime along the Mackenzie Valley, Northwest Territories, Canada.

Natalia A. Startsev, Northern Forestry Centre
Jagtar S. Bhatti, Northern Forestry Centre

Water and temperature regime of the rhizosphere provides important insight for plant ecology and survival in northern ecoregions. In this study we investigated effects of climate and landscape positions on the soil microclimate at a range of locations in Alberta and NWT. Research sites varied in tree cover, peat layer, and permafrost characteristics affecting the soil profile. Soil and air temperatures were continuously measured for three years in uplands, peat plateau and collapsed areas of four climatically different sites in mid boreal, high boreal, low and high subarctic ecoregions. Depth to the water-saturated layer and frozen horizon were measured regularly during the year at all the locations. There is a clear relationship between soil temperature and climatic parameters as well as landforms. Results show that soil temperature at 5 cm depth in the peat plateau tended to be 3 to 7°C warmer during the winter than in the upland forest due to the thick peat layer effecting latent heat transfer. The presence of a water-saturated layer had a significant effect on the soil microclimate in collapsed areas as soil temperature remained close to zero throughout the winter even in the high subarctic site. The length of the thawed period increased by as much as 46 days in the collapsed area soils as compared to uplands forested sites. Soil temperature changes throughout the year followed distinct patterns driven by type of vegetation, water content, thickness of surface organic layer and permafrost presence on the site.

Subarctic dendroecology using *Betula glandulosa* Michx. (dwarf birch)

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Arctic shrub expansion is likely a response to warmer summer temperatures. Paleobotanical data from Alaska suggests warm periods are characterized by high fire frequency shrub dominated tundra. Air photos, artificial warming experiments and some newly emerging shrub ring studies also support warming induced shrub expansion. As shrubs proliferate they can exert controls on albedo, nutrient and fire regimes, and therefore plant community composition.

Betula glandulosa Michx. is a gregarious shrub found in wet and dry subarcitc and alpine sites. Challenges associated with dating shrubs include their small size, young age, branching structure, and high degree of missing/false rings. Sampling and ring counting aside, shrubs are abundant, can be cross-sectioned (as opposed to bored) and are sensitive to climate parameters.

The results of this study are three-fold:

- Developed thin-sectioning methods to accurately resolve *B. glandulosa* annual rings, and characterized and documented the number and nature of missing/false rings,
- 142 shrub root collars were collected from 2 aspects along an elevation gradient in a Subarctic, alpine site (Macmillan Pass, NWT) to determine shrub history and status. Ages ranged from 19-91 yrs with an average age of 57 yrs. Two pulses of establishment occurred during the 1930's and 1950's. Ring width growth trends support continued shrub expansion in response to warmer summer temperatures,
- Used shrub ring-widths and regional and microclimate data to determine potential for ring-width climate correlations using COFECHA.

Habitat preferences of the grey-sided vole in mountainous northern Sweden

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Given the important role small mammals such as voles play in terrestrial Arctic and sub-Arctic ecosystems, it is imperative that habitat assessment studies are performed now to create a baseline to reference how species are coping with change. This study attempts to identify habitat components of the grey-sided vole in northern Sweden. Trapping occurred in two different locations (Helags and Ritsem) in mountainous Arctic and sub-Arctic regions. Traps were checked twice a day, and left out for two days. Vegetation at each station was classified into functional groups. Trap data from Helags was converted into a successful (1) or non-successful (0) trapping event for each line, while vole abundance in Ritsem was converted to a 100-trap night index. Principal Component Analysis (PCA) was used to create new uncorrelated groups based on the 11 vegetation categories. The first five principal components (PCs) explained 85% of the total variation, and were included in a generalized linear model to determine their importance to grey-sided vole abundance. The presence of grey-sided voles in Helags was significantly linked to a food rich habitat, in addition to rocky, forested areas. Conversely, at the Ritsem site, grey-sided voles were significantly absent from grassland areas and were linked to habitats abundant with boulders, either above treeline or in a mesic forest. These results suggest that risk of predation and intraspecific competition may be a more important factor in habitat selection in Ritsem, whereas food abundance and interspecific competition plays a greater role in Helags.

Advancement of the northern forest lines in northern Norway in the period 1914 – 2007

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The interface between the boreal forest and the arctic tundra is the Earth's largest vegetation transition zone and climate change as well as change in land use can alter its position. In order to detect changes in the arctic forest lines of birch and pine in northern Norway, we used old and new forest maps, topographic maps and remote sensing based imagery and maps. For the latter data we used both traditional spectral classification and "spectral unmixing" on imageries from Landsat and Quickbird for detection of forest lines. Comparison of the birch forest lines from 1914 and 2007 revealed a north-ward advancement of up to 11 km in the western part of the study area, 22 km in the middle parts, and 12 km in the eastern part. The advancement for the period 1980 to 2007 was less than 1 km in northern direction for most of the area. The analysis revealed only minor changes in the position of the pine forests for most of the study area and the period 1914-2007, except in the eastern part where it was up to 4-5 km over the study period. The changes in the position of the northernmost birch forest line are considered to be a combined effect of reduced grazing (reindeer, goats and sheep) and climate change. The recorded slower forest cover change rate seen for pine is, hypothetically, both related to species-specific response patterns and exploitation of the pine forests during World War II and the following decades.

Use of remote sensing methods and ground data to define tundra-taiga ecotone changes in key sites in the Russian Arctic

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Remotely-sensed images help to identify ecotone features and processes, and highlight tendencies of ecosystem change over large territories. High-resolution images enable to delineate ecotone boundaries and find their links with factors on the ground, in order to create a model of ecotone change. Such model is validated by comparing spectral properties of vegetation in situ and in the images, and by field measurements of other parameters. After validation some parameters may be inferred through image analysis. We realised this approach in three years (2008-2010) of the BENEFITS project of the IPY PPS Arctic in Kola Peninsula, Taimyr Peninsula and Putorana Plateau, Russia.
The results include:
1. Significant negative correlations were found between above-groung phytomass and ground-radiometry NDVI of lichen-dominated samples, suggesting possible mapping of lichen tundra phytomass over wide areas.
2. Visual change detection at forest line and treeline was performed , using airphoto and satellite imagery and DEM.
3. Tree locations, heights and derivative properties have been automatically interpreted from very high resolution multispectral satellite data and validated in situ.
4. Analysis of subpixel spectral components of Landsat ETM+ and Terra ASTER pixels has been performed by comparison with QuickBird images. Currently ETM+ and ASTER images are not suitable for accurate mapping by spectral unmixing due to many spectrally similar components of the tundra-taiga ecotone.
5. Forest line in NW Russia is being mapped from relatively high resolution multispectral imagery (10-30 m).
Integration of ground and remote sensing research enabled to validate the developed models.

Small-scale remote sensing mapping of geosystems in Taymyr–Putoran Region

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The aim of this research which is part of the international IPY PPS Arctic project is to study the modern state of vegetation, as well as geosystems in general, in a large part of north-central Siberia, including the Taymyr Peninsula and southward territories (66º00'- 77º43'N, 85º00'- 115º00'E) by way of compiling a small-scale (1:2,500,000) map of geosystems. The map will include such components of geosystems as vegetation, relief, and geocryological features. The resulting map should become the basis for large-scale field investigations of treeline ecotone in the region. Monthly MODIS composite images (spatial resolution 250 m) of 2005, processed and refined by the Space Research Institute (Russian Academy of Sciences) serve as the main source of up-to-date environmental information. Several thematic maps, including the Circumpolar Arctic Vegetation Map (2003, 1:7,500,000), the Vegetation Map of USSR (1990, 1:4,000,000), the Geocryological Map of USSR (1996, 1:2,500,000) are being used used to recognize different types of geosystems in satellite images. Map compilation is based on visual interpretation of MODIS images and DEMs (VMAP0, GTOPO30) to match borders of geosystems with natural orographic boundaries. Field validation of the map is planned for summer 2010.

This research is being carried out at the Laboratory of Aerospace Methods, Department of Cartography and Geoinformatics at the Faculty of Geography, Lomonosov Moscow State University, and financially supported by the Benefits Russo-Norwegian project of the Norwegian Research Council (OST 185023/S50).

A cellular automata-Markov chain approach to modelling vegetation change in the Torngat Mountains National Park Reserve, Labrador

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Changes in vegetation distribution due to climate change are a concern in alpine tundra ecosystems. Past vegetation change was assessed and a cellular automata-Markov chain (CA-Markov) model was used to predict future land cover scenarios in the Torngat Mountains National Park Reserve (Labrador, Canada). Post-classification image comparison was applied to classified, multi-temporal satellite imagery to detect changes in vegetation patterns since 1985. Deciduous shrubs had an increase in areal coverage whereas heath experienced a decrease in coverage. Transition matrices were developed from these observed changes, and were used in the Markov chain component of the model. Topographic variables were classified, and used as prior information to calculate Bayesian probabilities (BP). The BP's describe suitable areas of growth based on known patterns and were used as a suitability map in the cellular automata component of the model. The CA-Markov model was initially used to predict a known vegetation pattern for 2008, using classified imagery from 1985 and 2001. The model predicted the 2008 land cover with 70.7% accuracy and was subsequently used to predict scenarios for 2018, 2028, and 2038. Results of the CA-Markov simulations show that deciduous shrubs will increase in area by 7.7% but heath will decrease by 14.4%. The results indicate that deciduous shrubs have a tendency to move into higher elevations over an extended period of time.

Effects of high latitude climate change and permafrost dynamics on forest growth in the Mackenzie River basin in northern Canada

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The Mackenzie valley watershed of northwestern Canada is a worldwide hotspot of climate change, having experienced an unprecedented greater than 2.0°C increase in annual temperature over the last century. Given a continuation of this trend, permafrost is expected to diminish significantly over large portions of the region in near future. The effects on forest growth could be both positive (e.g., increased rates of photosynthesis and increased water use efficiency) or negative (decreased water availability, higher rates of respiration) depending upon factors which vary considerably within the valley: latitude, species, soils and topography.
The authors used tree rings to quantify historical forest growth in sites along a 1400 km transect extending from the mid-boreal at Anzac, Alberta to the sub-arctic forests near Inuvik, NWT. Forest productivity was observed to increase significantly in the mineral soil upland sites: between 30% and 100% over 30 years, with the largest increases in the southern end of the transect. Comparison with climate data suggests that this is largely due to an extended annual growing period, but is also augmented by an increase in precipitation and warmer summer temperatures, particularly in the boreal region. In contrast, forested peatland sites decreased in productivity by as much as 30% over the same period, particularly in the more southern sites. The suggested cause is a decrease in water availability in the rooting zone of mid-boreal peat soils during the increasingly warmer summer months.

Using clear-sky MODIS Terra daytime Land Surface Temperatures (LST) to calculate mean daily surface temperature

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We use MODIS (MOD11A1 – Version 5) Terra clear sky daytime Land Surface Temperatures (LST) temporally matched to Environment Canada meteorological station air temperatures, at four stations in the southwest Yukon, to provide the basis to model mean daily surface temperatures (MDST) from temporally discrete MODIS LST. Ground based climate data in the arctic is often interpolated from sparse and heterogeneously situated meteorology stations, thus introducing error. The model presented here exploits the daily MODIS LST coverage, in 1 km grid cells, of the whole arctic. Furthermore the model is predicated on the spatial interpolation of diurnal temperature curve shape rather than interpolation of air temperature directly. The results of our study indicated that air temperature observed at the Environment Canada meteorological stations is highly correlated with MODIS LST. The modelled MDST was compared to daily mean air temperatures recorded at three independent locations consisting of differing tundra land cover and elevation; these signals were strongly correlated. These results indicate that reliable measurements of mean daily surface temperature can be achieved using a simple Thiessen polygon nearest neighbour normalization scheme that does not rely on intensive spatial interpolation. The MDST model is likely a better descriptor than air temperature for processes that are strongly linked to the ground surface such as low stature arctic vegetation growth, permafrost dynamics and gas fluxes.

Dendroclimatic relationships and possible implications for mountain birch and Scots pine at treeline in northern Sweden through the 21st century

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Changing climate in the Arctic is expected to have significant effects on the pattern and distribution of terrestrial vegetation. Species characteristic of specific zones in the mountains of northern Sweden have been shown to migrate up and downslope with changes in climate over the Holocene. This study evaluates the potential for Scots pine (*Pinus sylvestris*) to become a treeline dominant at Fennoscandian treelines replacing mountain birch (*Betula pubescens* ssp. *czeropanovii*). Data from paired mountain birch and Scots pine tree-ring chronologies for 8 locations in northern Sweden are used to develop climate tree-ring width index (RWI) relationships. Modeled climate RWI relationships are then used to predict the relative RWI values of the two species under a suite of climate forcing scenarios using an ensemble of three global climate models. Results indicate that birch and pine RWI are both correlated with summer temperatures, but pine is more likely than birch to be influenced by moisture conditions. Predictions of RWI under future climate conditions indicate that mountain birch is unlikely to be replaced by Scots pine within the next century.