



1st Arctic and High-Latitude Products Evolution and Validation Workshop

12-13 November 2014, Ottawa, Canada

PROGRAMME



Table of Contents

<i>Forward</i>	<i>i</i>
<i>Introduction</i>	<i>ii</i>
<i>Organization committee</i>	<i>ii</i>
1 SESSION 1: USER'S PERSPECTIVES	1
1.1 <i>EO challenges in high-latitudes and the workshop objectives Purpose of this document. Bojan Bojkov, ESA, Italy.</i>	1
1.2 <i>Downstream EO Products and Services for the Arctic: CSA Support for Canadian Governmental Organizations, Industry & Academia Purpose of this document, Guy Aubé. CSA, Canada.</i>	2
1.3 <i>The Growing Importance of Remote Sensing Derived Information to Northern Commercial Activities. Dennis Nazarenko and Bill Jefferies, LOOKNorth, Canada.</i>	3
1.4 <i>Using Arctic and high-latitude observational data for process studies and model evaluation at the Swedish Meteorological and Hydrological Institute (SMHI). Ulrika Willen, SMHI, Sweden.</i>	4
1.5 <i>Use of remote sensing in WWF's Rapid Assessment of Circum-Arctic Ecosystem Resilience (RACER) tool for conservation planning in a rapidly changing Arctic. Marcel Babin, Takuvik Joint International Laboratory, Canada.</i>	6
2 SESSION: LAND	7
2.1 <i>Remote Sensing of Northern Forest Tree Species Products and Validation using Spectral Mixture Analysis and Multi-Temporal Satellite Imagery, Northwest Territories, Canada. Derek Peddle, ATIC, Canada.</i>	7
2.2 <i>Detecting Landscape Changes in High Latitude Environments using Landsat Trend Analysis: 1. Visualization. Robert H. Fraser, CCMEQ, NRCAN, Canada.</i>	8
2.3 <i>Detecting Landscape Changes in High Latitude Environments using Landsat Trend Analysis: 2. Classification. Ian Olthof, CCMEQ, NRCAN, Canada.</i>	9
2.4 <i>Hyperspectral Simulation of an Arctic Landscape with ISDASv2. Peter White, CCRS, NRCAN, Canada.</i>	10
2.5 <i>Using VIIRS to extend MODIS long-term clear-sky composites over Canada. Alexander Trishchenko, CCRS, NRCAN, Canada.</i>	11
2.6 <i>CHARS as a Science Partner for Coordinated Northern EO/RS, Donald McLennan/ Katherine Wilson, CHARS, Canada.</i>	12
2.7 <i>Object-based land cover classification of Torngat Caribou Habitat in Quebec and Labrador, Canada using SPOT imagery and DTM data. Bahram Salehi, C-CORE, Canada.</i>	13
2.8 <i>Challenges in monitoring Arctic plant growth and phenology using long-term remote datasets. Wenjun Chen, CCRS, NRCAN, Canada.</i>	15
2.9 <i>Spaceborne Remote Sensing Requirements for the Arctic-Boreal Vulnerability Experiment (ABOVE). Elizabeth Hoy, NASA, US.</i>	17
3 SESSION: CRYOSPHERE	19
3.1 <i>Validation needs for microwave derived terrestrial cryosphere products. Chris Derksen, EC, Canada.</i>	19
3.2 <i>CAL-VAL Opportunities for Terrestrial Cryosphere Products at the Sodankylä Supersite, Northern Finland. Kari Luojus, FMI, Finland.</i>	21
3.3 <i>Error estimation in snow density sampling and its effect on validation of remotely sensed snow cover products. Pia Eriksson, Stockholm University, Sweden.</i>	22
3.4 <i>From hemispheric snow cover products towards an integrated view on the land cryosphere" - Remote sensing & snow & carbon cycle. Jouni Pulliainen, FMI, Finland.</i>	23

3.5	<i>The Satellite Snow Product Intercomparison and Evaluation Experiment – SnowPEX. Thomas Nagler, ENVEO, Austria.</i>	24
3.6	<i>Global Cryosphere Watch(GCW): A Contribution to Arctic Products Validation and Evolution (APVE). Barry Goodison, GCW Steering Group, Canada.</i>	26
3.7	<i>Canadian Ice Service Satellite-based Ice Monitoring: Optical Data Applications. Yi Luo, CSI, EC.</i>	28
3.8	<i>Characterization of Hazardous Ice using Spaceborne SAR and Ice Profiling Sonar: Preliminary Results. Kaan Ersahin, ASL Environmental Sciences Inc., Canada.</i>	30
3.9	<i>Validation of DInSAR displacement measurements in permafrost environments. Naomi Short, CCRS, NRCAN, Canada.</i>	31

4 SESSION: LAKE AND COASTAL 33

4.1	<i>Arctic Lake Ice Algorithms and Products: Progress and Prospects. Claude Duguay, University of Waterloo, Canada.</i>	33
4.2	<i>Pan-Arctic Land and lake surface temperature from AATSR and MODIS: Products development and evaluation. Homa Kheyrollah, University of Waterloo, Canada.</i>	34
4.3	<i>Multi-sensor monitoring of ice regimes of High Arctic Lakes. Cristina Surdu, University of Waterloo, Canada.</i>	35
4.4	<i>Improvement of MODIS snow products for Arctic lake ice. Kyung-Kuk (Kevin) Kang, University of Waterloo, Canada.</i>	36
4.5	<i>Ocean color remote sensing for the study of Arctic marine ecosystems: II - Algorithm development and data processing platforms Emmanuel Devred, Takuvik, Joint International Laboratory, Canada.</i>	37
4.6	<i>On the Validation of Earth Observation Data for snow covered sea ice: Challenges and Opportunities, David Barber/Kerri Ann Warner, University of Manitoba, Canada.</i>	38

5 SESSION: ATMOSPHERE 39

5.1	<i>Validation Capacity in the Canadian High Arctic: The Polar Environment Atmospheric Research Laboratory (PEARL), James R. Drummond/Kaley Walker, Dalhousie University, Canada/University of Toronto.</i>	39
5.2	<i>Observing CO₂ from a highly elliptical orbit for studies of the carbon cycle in the Arctic and boreal regions. Ray Nassar, EC, Canada.</i>	40
5.3	<i>Balloon demonstrator Imaging Fourier Transform Spectrometer for the measurement of methane and carbon dioxide over the Arctic. Zahra Vaziri, York University, Canada.</i>	41
5.4	<i>Validation/Verification of the microphysical and dynamic characteristics of Arctic Cloud systems: what infrastructure is required to meet the challenge? Stella Melo, EC, Canada.</i>	42
5.5	<i>Measuring high-latitude precipitation and falling snow from space. Ralf Bennartz, University of Wisconsin, US. Ralf Bennartz</i>	43

ANNEX: APVE WORKSHOP PROGRAMME 45

<i>Programme: Day 1</i>	45
<i>Programme: Day 2</i>	47

Forward

The Arctic Products Validation and Evolution (APVE) will address the development, assessment and improvement of the broad spectrum of capabilities offered by Space-based Earth observation technology in response to high-latitude and Arctic stakeholders information needs; addressing National, Regional, and International interests and, focusing on existing agency data, and others in support of future capabilities (evolution) such as pooling resources (systems, programs, audience, etc.) and better operation support/amplified impact.

Introduction

In response to strategic priorities common to all high-latitude and Arctic Nations and most of which are Member States of the European Space Agency (ESA); ESA, in collaboration with LOOKNorth and the Canadian Space Agency (CSA) is organising a Workshop on Arctic Products Validation and Evolution (APVE). The APVE will foster the development, assessment and improvement of the broad spectrum of capabilities offered by Space-based Earth observation technology in response to high-latitude and Arctic stakeholders information needs addressing National, Regional, and International interests. The focus of the first of three international workshops will be on existing agency data, and others in support of future capabilities (evolution). Scientists and validation experts are provided with the opportunity to present latest results from their on-going research, including the evolution of products, the development of validation, the inter-comparison methodologies and the evolution of algorithms. The workshop will focus on optical imaging sensors with some elements of radar, from ESA missions and national missions.

Organization committee

Bojan Bojkov, ESA (Italy)
Dennis Nazarenko, LOOKNorth (Canada)
Yves Crevier, CSA (Canada)
Guy Aubé, CSA (Canada)
Françoise Labonté, FLC (Canada)
Alessandro Burini, ESA (Italy)

1 SESSION 1: USER'S PERSPECTIVES

1.1 EO challenges in high latitudes and the workshop objectives Purpose of this document. Bojan Bojkov, ESA, Italy.

In spite of the tremendous societal and technological advances of the last century, the high-latitude and Arctic areas remain some of the least understood and most challenging environments to monitor on our planet. In recent decades, the higher latitudes have also been undergoing considerable changes ranging from increasing development and exploration, to an extended growing season and increasingly ice-free seas. Understanding the state of this remote and sparsely inhabited environment is important to governments, the private sector and the scientific community, and requires a cost effective, efficient and accurate observation and monitoring system to address the evolving Local, Regional, National, and International stakeholder information needs.

Over the past decades, space-based Earth Observation (EO) has effectively demonstrated the operational potential of radar sensors in monitoring snow and ice, yet other EO optical measurement techniques, mainly optical addressing the biosphere or coastal zones have lagged in comparison to the microwave systems due to the complexity of the measurement environment ranging from the challenging illumination conditions, to cloud or snow interference, to the availability of few ground-based reference measurement datasets.

In this presentation, a summary of the challenges faced by space-borne Earth Observation will be presented and discussed.

1.2 Downstream EO Products and Services for the Arctic: CSA Support for Canadian Governmental Organizations, Industry & Academia Purpose of this document, Guy Aubé. CSA, Canada.

Guy Aubé, Yves Crevier, Paul Briand, Earth Observation Applications and Utilizations, CSA

Today, we see an ever-increasing number of demands on Arctic lands, coastal zones and ocean and their resources. While traditional fishing and marine transportation continue to be of prime importance, they are now joined by other uses, such as oil and gas exploration, aquaculture, eco-tourism, search and rescue operations, etc. With over \$20 billion in annual economic activity, Canada's coastal zones and their resources are significant contributors to the overall Canadian economy. Our need for tools to predict and monitor short and long-term environmental changes, especially in the Canadian Arctic, has never been greater. Improved, up-to-date environmental data is needed to plan for environmentally and economically sound growth and to develop more sustainable practices and solutions to protect our waters and lands. Space-based Earth Observation (EO), including the series of EO sensors and technologies (SAR, Optical, Altimeter, LIDAR, etc.), provides Canadians scientists with unique and essential information to understand how our northern environments work, allowing, for instance, reporting on biodiversity and wildlife, improving the understanding, modelling and prediction of weather, refining the techniques for the delivery of ecosystem services, predicting potential hazards on infrastructures, mapping of renewable energy potential, detecting new vector born diseases, measuring water quality and quantity, identifying shorelines and ecosystems at risk in preparation of emergencies, reporting on coastal glaciers and ice melting, measuring water quality and quantity, etc. Canada is among the world leaders in EO applications and utilizations. Since 2000, the Canadian Space Agency (CSA) EO Applications and Utilization Division has managed over 200 projects in partnership with Canadian OGDs, industry and universities. The presentation will be a review of CSA past & on-going EO initiatives and applications support to Canadian departments, industry and academia related to Arctic. Based on our experience, this paper will also provide some insight on the elements required to “travel the last mile” towards the more confident assimilation and fluid accessibility of EO-derived products and services.

1.3 The Growing Importance of Remote Sensing Derived Information to Northern Commercial Activities. Dennis Nazarenko and Bill Jefferies, LOOKNorth, anada.

The Canadian North is receiving attention from many directions locally, nationally and from abroad - and for many reasons, not the least of which are commercial in nature. None of these interests are new but many factors dictate that close attention needs to be afforded to the plans, benefits and impacts of these activities. Accelerated environmental change, increased global demand and advances in resource extraction technology all have an impact on commercial activities in the North. The application of remote sensing technology and products in support of commercial interests in the North is not new. However within a frontier environment and as new technological capabilities emerge, there is a challenge to bridge the gap between research and technology development and operational implementation. LOOKNorth is a Canadian National Centre of Excellence program focused on migrating pre-commercial remote sensing solutions to northern development issues with the objective of achieving sustainable development in the North. The program works closely with government and industry, remote sensing experts and commercial service providers to broaden and accelerate the operational adoption of advanced technologies. In many cases the nature of Northern environments, infrastructure limitations and economic realities present unique challenges for remote sensing product development, delivery and implementation.

1.4 Using Arctic and high latitude observational data for process studies and model evaluation at the Swedish Meteorological and Hydrological Institute (SMHI). Ulrika Willén, SMHI, Sweden.

Ulrika Willén, Torben Königk, David Gustafsson, Lars Axell, Joakim Lagner, Magnus Lindskog and Abhay Devastahle, Swedish Meteorological and Hydrological Institute, Sweden

Understanding and monitoring climate changes in the Arctic and high latitudes are important from scientific, environmental, societal and economical perspectives. There is a need for more and consistent observational data sets for the Arctic and improvements of climate models failing to capture the rapid changes. Interactions between the Arctic sea-ice, surface fluxes, and atmospheric transports of heat and moisture are not well understood. There is a need for the observing and modelling communities to interact as well. Confronting the models with observations but also confronting the observations with models, pin-pointing where and what observations are most urgent, and use models for testing and evaluation of satellite retrievals. The co-dependence of reanalysis data and satellite data is also important to address over the Arctic.

The SMHI research department consists of six groups; climate, hydrology, oceanography, air quality, numerical weather prediction and remote sensing. All groups are involved in research projects for the Arctic or high latitude regions using earth observations for monitoring, model evaluation, calibration and data assimilation. The combination of satellite experts and modellers from different disciplines offer unique opportunities for tackling some of the important Arctic scientific questions. Descriptions of the different group's research activities and models follow here and results from some of the studies will be presented at the APVE workshop.

The climate research group use observations to evaluate global and regional climate models and use observations as initial conditions for seasonal and decadal predictions. Most climate models fail to predict the recently observed sea-ice decline, to understand the rapid changes and help to improve the models more observations are needed also during the polar night. Clouds, surface radiation and heat fluxes and oceanic sub-surface variables are of importance as well as atmospheric profiles of temperature, humidity and cloud condensate. A changing Arctic has implications on the predictability of the atmosphere ocean system, better initial conditions of SST and sea-ice, including sea-ice thickness, can also benefit the predictions.

The hydrological research group works to develop hydrological forecasting and scenario tools, describe the hydrological consequences of climate change, modelling nutrient in rivers and biogeochemical processes in lakes. For the Arctic the group perform short term forecasts, long-term hind casts and climate change impacts and predictions in ungauged basins with an Arctic multi-basin large scale hydrological model (Arctic-HYPE). Meteorological forcing data, land and soil characteristics are used as input, and other datasets, evaporation, snow, glacier, surface water distribution are used for calibration and

evaluation. Other important data sets for hydrology are lake and river, temperature, sea-ice and river morphology.

The ocean groups main research topics are environmental oceanography, ocean and sea ice forecasts, biogeochemical and sea-ice modelling. Data assimilation system based on ensemble or variational methods are used for different domains including the Baltic Sea and the North Atlantic. Ice edge data, sea-ice concentration and SST are used for operational forecasting. Future plans include using satellite ocean colour data for comparison with the biogeochemical model. The air quality group use satellite data for climate and air quality studies, including space based monitoring of atmospheric composition over the Nordic countries. Satellite data is also used for validation and improvement of models, for estimating climate effects of aerosols and greenhouse gases, and for improved boundary conditions for regional chemical transport models. Satellite measured trace gases are used to address the following scientific questions. How do different atmospheric weather states affect the distribution of pollutants? What is their relative importance? What role does atmospheric stability play in regulating pollutant concentrations?

1.5 Use of remote sensing in WWF's Rapid Assessment of Circum Arctic Ecosystem Resilience (RACER) tool for conservation planning in a rapidly changing Arctic. Marcel Babin, Takuvik Joint International Laboratory, Canada.

Climate change has triggered major changes in Arctic Ecosystems. The 40% decrease in the summer extent of the icepack over the last three decades is the most spectacular of such changes. The impact on marine life is expected to be huge as sea ice controls the amount of light-sustaining sunlight that penetrates into the ocean, and constrains the air-sea interactions that drive nutrient dynamics. In this context, the use of ocean color remote sensing has abruptly expanded because it allows monitoring marine ecosystems from space in this hardly accessible and harsh environment. Major research initiatives for studying Arctic marine ecosystems using ocean color remote sensing have recently emerged, including the France-Canada-USA Malina (2008-2012) and Green Edge projects (2014-2018). These two projects strongly contribute to improving the way we use ocean color remote sensing, and in fact remote sensing in general, to study Arctic marine ecosystems. I will present examples of achievements made on developing new ocean color algorithms for the Arctic Ocean, and some major scientific results obtained using this technique in the frame of Malina, and plans for new research avenues in the frame of Green Edge.

2 SESSION: LAND

2.1 Remote Sensing of Northern Forest Tree Species Products and Validation using Spectral Mixture Analysis and Multi Temporal Satellite Imagery, Northwest Territories, Canada. Derek Peddle, ATIC, Canada.

D.R. Peddle¹, J. Van der Sluijs¹, R.J. Hall^{2,1} and S. Schwarz³

*(1) Department of Geography and Alberta Terrestrial Imaging Centre (ATIC)
University of Lethbridge, Lethbridge, AB., Canada*

(2) Natural Resources Canada, Canadian Forest Service, Edmonton AB., Canada

(3) Government of the Northwest Territories, NWT Centre for Geomatics, Yellowknife NT, Canada

Natural resource management in circumpolar subarctic forests in northern Canada requires land cover and tree species identification for improved decision making for sustainable resource development. For example, in the Northwest Territories (NWT) of Canada, the Biomass Energy Strategy and the Boreal Woodland Caribou Action Plan require detailed forest resources information, from which resource inventory and maps of wildlife habitat, landscape disturbance, and vegetation cover can be produced. These are important for industry sectors through policy compliance and for obtaining permits for exploration, and also for government for resource monitoring programs and inventories. However, the acquisition of forest information is often time-consuming and expensive due to the large areas involved in remote, inaccessible northern forest terrain. Therefore, satellite-based remote sensing is increasingly used to derive these products over large areas. Although information regarding the distribution of tree species has been obtained using remote sensing in forest regions in southern Canada, these approaches are either unsuitable or have not been tested in these higher- latitude, more sparse forest stands of the NWT. In this lower density, open forest stands, satellite spectral response patterns (pixel signals) are highly mixed due to the presence of tree shadows and understory cover together with the trees of interest. To resolve this and obtain information about the trees only (essentially factoring out the other non-tree parts of the signal), spectral mixture analysis (SMA) was used to obtain information at sub-pixel scales for sunlit canopy (trees), sunlit background (forest understory) and shadow. SMA, and specifically multiple end-member SMA (MESMA), was investigated as a method to obtain tree species information represented as the leading or dominant species of a forest stand using Landsat Thematic Mapper imagery. Furthermore, the performance of multi-temporal imagery was investigated for its potential to improve forest leading-species discrimination accuracies. Results showed that improvements of over 30% at the 95% confidence level were achieved using multi-temporal imagery (overall accuracy = 79 %, Kappa = 0.67) compared with individual (single-date) mid-summer imagery. This was based on four coniferous and deciduous tree species with validation obtained at 48 ground plots. Recommendations for future work include expanding the scope of the study to other areas, assessing additional northern boreal forest types in the NWT, and the integration of this derived information into a polygon-based forest inventory system used for operational management through the enumeration of leading species composition at the pixel scale.

2.2 Detecting Landscape Changes in High Latitude Environments using Landsat Trend Analysis: 1. Visualization. Robert H. Fraser, CCMEQ, NRCAN, Canada.

Robert H. Fraser¹, Ian Olthof¹, Steven V. Kokelj², Trevor C. Lantz³, Denis Lacelle⁴, Alexander Brooker⁴, Stephen Wolfe⁵ and Steve Schwarz⁶

(1) Canada Centre for Mapping and Earth Observation (CCMEQ), Natural Resources Canada, Ottawa, ON

(2) Northwest Territories Geoscience Office, Yellowknife, NT

(3) School of Environmental Studies, University of Victoria, Victoria, BC

(4) Department of Geography, University of Ottawa, Ottawa, ON

(5) Geological Survey of Canada, Natural Resources Canada, Ottawa

(6) NWT Centre for Geomatics, Yellowknife, NWT

(In review for Remote Sensing special issue on “Remote Sensing of Changing Northern High Latitude Ecosystems”)

Satellite remote sensing is a promising technology for monitoring natural and anthropogenic changes occurring in remote, northern environments. It offers the potential to scale-up ground-based, local environmental monitoring efforts to document disturbance types, and characterize their extents and frequencies at regional scales. Here we present a simple, but effective means of visually assessing landscape disturbances in northern environments using trend analysis of Landsat satellite image stacks. Linear trends of the Tasseled Cap brightness, greenness, and wetness indices, when composited into an RGB image, effectively distinguish a diversity of landscape changes based on additive color logic. Using a variety of reference datasets within Northwest Territories, Canada, we show that the trend composites are effective for identifying wildfire regeneration, tundra greening, fluvial dynamics, thermokarst processes including lake surface area changes and retrogressive thaw slumps, and the footprint of resource development operations and municipal development. Interpretation of the trend composites are aided by a color wheel legend and contextual information related to the size, shape, and location of change features. A companion study (Olthof and Fraser) focuses on quantitative methods for classifying these changes.

2.3 Detecting Landscape Changes in High Latitude Environments using Landsat Trend Analysis: 2. Classification. Ian Olthof, CCMEQ, NRCAN, Canada.

Ian Olthof and Robert H. Fraser. *Canada Centre for Mapping and Earth Observation (CCMEQ), Natural Resources Canada, Ottawa, ON*

(In review for Remote Sensing special issue on “Remote Sensing of Changing Northern High Latitude Ecosystems”)

Mapping landscape dynamics is necessary to assess cumulative impacts due to climate change and development in Arctic regions. Landscape changes produce a range of temporal reflectance trajectories that can be obtained from remote sensing image time-series. Mapping these changes assumes that their trajectories are unique and can be characterized by magnitude and shape. A companion study describes a trajectory visualization method for assessing a range of landscape disturbances (Fraser et al.). This paper focusses on generating a change map using a time-series of calibrated Landsat Tasseled Cap indices from 1985–2011. A reference change database covering the Mackenzie Delta region was created using a number of ancillary datasets to delineate polygons describing 21 natural and human-induced disturbances. Two approaches were tested to classify the Landsat time-series and generate change maps. The first involved profile matching based on trajectory shape and distance, while the second quantified profile shape with regression coefficients that were input to a decision tree classifier. Results indicate that classification of robust linear trend coefficients performed best. A final change map was assessed using bootstrapping and cross-validation, producing an overall accuracy of 82.8 % at the level of 21 change classes and 87.3 % when collapsed to eight underlying change processes.

2.4 Hyperspectral Simulation of an Arctic Landscape with ISDASv2. Peter White, CCRS, NRCAN, Canada.

H. Peter White, Lixin Sun, Matthew Maloley, Canada Centre for Remote Sensing, Natural Resources Canada

Abstract: The landscape of Canada's arctic is a complex mixture of exposed rock, lichen and tundra vegetation. Being illuminated by a low elevation sun and snow-free for short periods annually make it a challenging region to map with traditional remote sensing technologies. Yet imaging spectrometry (hyperspectral remote sensing) has been shown useful in exploiting the spectral features associated with select mineral and biota as indicators in this environment, demonstrating applicability in geological exploration and habitat monitoring. Advancing methodologies to exploit hyperspectral imaging as one tool in arctic exploration is now required to prepare for the upcoming suite of space borne hyperspectral sensors that will soon regularly acquire imagery of this region.

To aid in the evaluation of space borne hyperspectral imagery for northern environments, the Imaging Spectrometry Data Analysis System (ISDASv2) can be used. ISDASv2 provides a robust system allowing for the simulation of space borne imagery from airborne or field data, including known sensor characteristics (spectral/spatial resolutions, spectral curvature, keystone, noise, etc.) and atmospheric influences. Once derived, simulated imagery can be independently processed to at-surface reflectance and methodologies for information extraction can be evaluated. In this short demonstration study, an arctic environment scene is simulated for various existing and proposed sensors and the potential for detection of spectral features associated with select surficial constituents is evaluated.

2.5 Using VIIRS to extend MODIS long term clear sky composites over Canada. Alexander Trishchenko, CCRS, NRCAN, Canada.

The Canada Centre for Remote Sensing produces long-term clear-sky composites from Moderate Resolution Imaging Spectroradiometer (MODIS) over Canada since early 2000. MODIS time series in turn continue data records generated from the Advanced Very High Resolution Radiometer (AVHRR) onboard the NOAA satellites. These data serve as input for several high-level products, such as albedo, fPAR, landcover etc. With the launch of Visible Infrared Imaging Radiometer Suite (VIIRS) onboard Suomi National Polar-orbiting Partnership (SNPP) satellite, the work has started at CCRS to continue MODIS time series with the data available from VIIRS which becomes a new operational moderate resolution imager operated by NOAA. In this presentation the processing techniques for generating clear-sky composites over Canada for land applications from VIIRS onboard SNPP satellite will be described. The CCRS VIIRS processing system is based on principles developed for MODIS (Khlopenkov and Trishchenko, 2008, Luo et al, 2008, Trishchenko et al., 2009). It also includes several enhancements, particularly related to the cloud detection scheme over the Northern latitudes and the extended set of multi-scale output layers. The processing system also contains quality assurance (QA) procedures for automated assessment of the geolocation accuracy as well as scene identification. The CCRS VIIRS data processing system uses VIIRS SDRs and some EDR as input and generates output products as Canada-wide composites in Lambert Conformal Conic (LCC) projection at two spatial resolutions depending on spatial resolution of input imagery (I or M-bands). The re-projection is accomplished using concurrent gradient search, the fast algorithm adopted from CCRS MODIS processing (Khlopenkov and Trishchenko, 2008). This work constitutes part of CCRS project on production of the Long-Term Satellite Data Records (LTSDR) over Canada.

References

- Khlopenkov K.V., A.P.Trishchenko, 2008: Implementation and evaluation of concurrent gradient search method for re-projection of MODIS level 1B imagery. IEEE TGRS, 46 (7), art. no. 4538199, pp. 2016-2027
- Luo, Y., A.P.Trishchenko, K.V. Khlopenkov, 2008: Developing clear-sky, cloud and cloud shadow mask for producing clear-sky composites at 250 m spatial resolution for seven MODIS land bands over Canada and North America. Rem. Sens.Environ., 112 (12), pp. 4167-4185.
- Trishchenko, A.P., Y.Luo, K. Khlopenkov, W.M.Park, S.Wang, 2009: Arctic circumpolar mosaic at 250m spatial resolution for IPY by fusion of MODIS/TERRA land bands B1–B7. IJRS, 30, 1635-1641.

2.6 CHARS as a Science Partner for Coordinated Northern EO/RS, Donald McLennan/ Katherine Wilson, CHARS, Canada.

Donald S. McLennan, Katherine Wilson, Mike Gill, Canadian High Arctic Research Station, Arctic Science Policy Integration Branch, Aboriginal Affairs and Northern Development Canada.

The mission of the Canadian High Arctic Research Station (CHARS) is to be a world-class research centre in Canada's Arctic that is on the cutting edge of Arctic issues, anchoring a strong research presence that serves Canada and the world, while advancing knowledge of the Arctic in order to improve economic opportunities, environmental stewardship, and the quality of life of Northerners and all Canadians. The domain over which CHARS operates is vast, so that achieving the establishment of CHARS' cross-cutting activities and its 5 year science priorities will require the use and application of remote sensing approaches - approaches that will need to be validated by coordinated and strategic ground observations. This presentation will outline how CHARS will operate to deliver on its mandate, provide a summary of EO/RS needs to meet CHARS' obligations to identified priorities, describe evolving partnerships directly relevant to arctic EO/RS, e.g., NASA ABoVE, and provide examples of useful EO/RS approaches. As for other fields of arctic science, the key to success will be an approach that includes federal, territorial and Aboriginal governments, academics, NGOs, industry and communities in a coordinated EO/RS strategy focused on common goals.

2.7 Object based land cover classification of Torngat Caribou Habitat in Quebec and Labrador, Canada using SPOT imagery and DTM data. Bahram Salehi, C CORE, Canada.

Bahram Salehi, Bill Jefferies, and Dennis Nazarenko, LOOKNorth

The Torngat Caribou has always been important for the Inuit regionally in Quebec and Labrador both for food and as part of their culture. In recent years, there have been some concerns expressed by Inuit in the decline of the Torngat Caribou herd. Monitoring the Torngat Mountain Caribou herd is challenging due to its rugged arctic location. Using remote sensing technologies allows monitoring of the herd, its habitat, and the factors that are impacting its survival. To monitor the caribou herd, an accurate and up-to-date land cover map covering the whole habitat of the Torngat Caribou with sufficient detailed ground cover types, particularly important for caribou monitoring, is required. Such a land cover map combined with additional information such as seasonal movement and distribution of the caribou herd (i.e. using GPS collar telemetry) would be used to monitor the caribou herd and its habitat.

A standard method for classification of satellite image data is using pixel-based classification. However, pixel-based classification produces a very noisy map (isolated pixels) especially in the Torngat area because of the heterogeneity of land cover types. Furthermore, pixel-based approaches use only the spectral information of the satellite imagery which is not sufficient for differentiating similar land cover types (e.g. sparse vs. dense shrub). Because of the sparse structure of vegetation in high latitudes, in general, and the high topographical (elevation) variation in Torngat mountainous area, in particular, standard pixel-based approaches do not provide promising results for classification such areas. In this project, we are investigating an innovative land cover mapping method based on the concept of the object-based image analysis (OBIA) using medium resolution SPOT imagery (10m). OBIA take into consideration not only the spectral information of the image, but also textural and contextual information of groups of neighbouring pixels. Therefore, spectrally similar land cover types can be differentiated based on their spatial pattern and texture and also the resultant map is more homogenous (less noisy). The proposed methodology consists of 3 major steps: image segmentation, feature extraction, and supervised object-based classification. The input dataset include 21 scenes of cloud-free SPOT 4 and 5 data acquired over the period of 2007-2010, digital terrain model (DTM) of the area, and photographs taken in the field as reference data.

The developed methodology is applicable to a broad range of land cover classification applications such as wildlife habitat and environmental mapping/monitoring, wetland classification, and vegetation type mapping in high latitude regions. Also, the method has a high potential for using radar imagery (e.g. Radarsat-2 polarimetry data) for similar applications where the clear optical imagery is hardly acquired. In addition, there is a high potential to improve the result of classification by using the upcoming Sentinel-2 imagery because of its higher spectral, spatial, and temporal (shorter revisit) resolutions.

2.8 Challenges in monitoring Arctic plant growth and phenology using long term remote datasets. Wenjun Chen, CCRS, NRCAN, Canada.

Wenjun Chen, Canada Centre for Remote Sensing, Natural Resources Canada

Long-term high temporal satellite remote sensing datasets (e.g., AVHRR, MODIS, SPOT-VGT, and SeaWiFS) have been used widely for monitoring plant growth and phenology over the Arctic. However, many challenges continue to prevent the realization of their full potentials. In this presentation, I will review and discuss some of the challenges.

(1) How to account for the influence of high percentages of shade and bare surface on remote sensing signals and vegetation indices when monitoring plant growth and phenology over the Arctic? One unique feature of the polar region is low solar zenith angle and high proportion of shade, especially towards the end of growing season. Another one is the high percentage of bare surface, especially in the high Arctic.

(2) How to explain and reconcile the difference in plant productivity trend over a same tempo-spatial domain when different remote sensing datasets are used? For example, Guay et al. (2014) reported that over the at naturally vegetated areas north of 50°N during 2002–2008, the values of annual mean NDVI increased by 0.0060 per year when using AVHRR GIMMS_g, 0.0051 per year when using AVHRR GIMMS_{3g}, 0.0040 per year when using SeaWiFS, 0.0362 when using SPOT, but decreased by -0.0049 per year when using MODIS.

(3) How to avoid the ambiguity and large uncertainties in determining plant phenology using satellite remote sensing data? For example, despite selection of the best day within a 10-day period through compositing techniques and other pre-processing efforts, the remnant cloud contamination and aerosol effect could still result in an up to 40% noise:signal ratio in AVHRR-derived vegetation indices over its 1 km by 1 km spatial resolution pixel, which is often larger than the real changes to be detected. Various smoothing/filtering techniques (e.g., line-smoothing, polynomial fitting, double logistic, piecewise logistic, and Asymmetric Gaussian) and thresholds of start and end of growing season (e.g., a fixed value of vegetation index, a fixed ratio of vegetation index to its maximum, and max curvature point) have been used subjectively. Consequently, when various methods were compared using over a common tempo-spatial domain with the same dataset, the difference in growing season length was found to be > 60 days.

(4) How to make satellite remotely sensed information relevant to decision making about key issues in the North? While remote sensing products of plant growth and phenology are of great scientific values, it remains a challenge to ensure the information being up-taken by decision makers in the north. There are many priority issues identified by northern governments and communities in Canada. One of issues is how to optimally balance resource development and protection of environment (including water, land, and wildlife, which are critically important to the way of life and economy of many aboriginal people).

These challenges could easily erode the confidence and interest of users in remote sensing products. Therefore, there is an urgent need for remote sensing community to pay attention to these challenges and find ways to resolving them in a timely manner.

2.9 Spaceborne Remote Sensing Requirements for the Arctic Boreal Vulnerability Experiment (ABOVE). Elizabeth Hoy, NASA, US.

*Elizabeth E. Hoy, Diane E. Wickland, Eric S. Kasischke, Peter C. Griffith, Elisabeth K. Larson
U. S. National Aeronautics and Space Administration (NASA)*

In 2015, the U.S. NASA Terrestrial Ecology Program will initiate its next major field campaign, named the Arctic-Boreal Vulnerability Experiment (ABOVE). ABOVE will be a large-scale study of changes to terrestrial and freshwater ecosystems in the Arctic and boreal regions of western North America and the implications of these changes for local, regional, and global social-ecological systems. Research for ABOVE will address questions in six thematic areas: society, disturbance, permafrost, hydrology, flora/fauna, and carbon biogeochemistry. Satellite and airborne remote sensing data will play a key role in addressing these thematic questions, as the data will be critical to the spatial and temporal scaling of observations made from field studies across the Study Domain, and will provide the basis for addressing societal needs and improving terrestrial biosphere models. In this presentation, we will discuss the requirements for using satellite remote sensing data to address the research questions and objectives that have been defined for ABOVE. We will discuss those products that require additional development, refinement, and validation, including products that would be derived from CSA and ESA missions as well as U.S. missions.

3 SESSION: CRYOSPHERE

3.1 Validation needs for microwave derived terrestrial cryosphere products. Chris Derksen, EC, Canada.

C. Derksen¹, L. Mudryk¹, R. Brown¹, K. Luojus², A. Colliander³, X. Xu³, S. Dunbar³

(1) Climate Research Division, Environment Canada, Toronto

(2) Arctic Research Centre, Finnish Meteorological Institute, Helsinki

(3) Jet Propulsion Laboratory, Pasadena

The validation of satellite derived terrestrial cryosphere products is hampered across the Arctic by a lack of conventional observing networks, and the high cost and logistical complexity of mounting dedicated field campaigns. The need for well constrained error budgets for satellite products is increasing, however, as applications such as land surface data assimilation are becoming more mature and sophisticated. This presentation will provide an overview of the current state and challenges related to the validation of satellite derived terrestrial snow water equivalent (SWE) and freeze/thaw (FT) products.

There is a long heritage of passive microwave derived SWE products, including standalone satellite retrievals (such as the NASA SWE product derived from the Advanced Microwave Scanning Radiometer -AMSR-E) and methods which combine satellite measurements, radiometric modeling, and in situ snow observations (i.e. the ESA GlobSnow product). A coordinated effort to assess gridded SWE products (including reanalysis derived estimates) is underway through the Satellite Snow Product Intercomparison and Evaluation Exercise (SnowPEX). The coarse spatial resolution (25 x 25 km for satellite products, up to 1 degree x 1 degree for reanalysis) of these products demands multiple sub-grid reference measurements for meaningful validation. Preliminary analysis conducted for SnowPEX shows a large inter-product spread nearly equal to the interannual variability in climatological SWE. Suitable networks of high quality reference measurements are sparse, but show retrieval errors at individual grid cells can reach 50% of the seasonal pre-melt maximum SWE.

The upcoming NASA Soil Moisture Active/Passive (SMAP) mission, scheduled for launch in early 2015, will provide 3 km resolution estimates of daily landscape freeze/thaw status across northern hemisphere land areas north of 45N using L-band radar measurements. Evaluation of a pre-launch FT product (derived from Aquarius measurements) using the SMAP cal/val network has identified the importance of reference measurements of the vertical continuum of soil, snow, vegetation, and near surface air temperature in order to determine the radar response to seasonal transitions in surface properties. The fall freeze-up signal is concurrent to the soil temperature transition to below freezing conditions; the spring thaw signal is strongly related to air temperature independent of soil conditions which means wet snow cover has a strong influence on the radar signal.

While evaluation of terrestrial products across the Arctic is possible with current networks, these activities would benefit greatly from enhanced coordination between agencies and

initiatives (for example, through GCW CryoNet), which must continue to facilitate improved observational capabilities of the terrestrial cryosphere across the Arctic.

3.2 CAL VAL Opportunities for Terrestrial Cryosphere Products at the Sodankylä Supersite, Northern Finland. Kari Luojus, FMI, Finland.

Kari Luojus, Jouni Pulliainen, Juha Lemmetyinen, Timo Ryyppö and Matias Takala, *Finnish Meteorological Institute (FMI), Finland*

Intensive campaign activities for the remote sensing of snow cover and soil processes have been carried out in the Sodankylä region since 2006. The objective has been to investigate the feasibility of space-borne instruments operating at optical and microwave regions for the monitoring of snow and soil processes in boreal forest and sub-arctic environment. The Sodankylä *in situ* observations also facilitate the analysis of the effect of snow and soil processes to carbon cycling. The Sodankylä site is equipped with tower-based reference instruments of present and planned cryosphere-observing satellites. The systems provide time-series of reference observations on a continuous basis. They include multi-channel microwave radiometers, the L-band ESA Elbara-II microwave radiometer and VIS/NIR spectroradiometer (since 2006; reference to AATSR, MODIS, VIIRS, Sentinel-2 and -3 etc.). An essential part in experimental activities has been the production of comprehensive *in situ* reference data sets from automatic sensor networks, including a full set of atmospheric profile observations, and from regular manual observations (e.g. snow pit observations).

Sodankylä experiments have enabled the development and validation of modeling approaches to describe space-borne microwave and optical observations. In general, the parameterization of models has been investigated concerning the influence of soil, snowpack, and forest canopy characteristics.

The available data sets range from point-wise monitoring observations to regionally distributed information. The data sets are relevant for space-borne remote sensing instruments with a high or coarse spatial resolution, as well as for atmosphere or surface monitoring instruments. The available reference data also enables the analyses of mixed pixel effects that are highly relevant for the utilization of satellite observations with a coarse spatial resolution.

The Sodankylä-Pallas satellite calibration and validation site activities are related e.g. to the Global Atmosphere Watch (GAW) and Global Cryosphere Watch (GCW) networks of WMO and the GCOS Reference Upper Air Network (GRUAN), the Global Energy and Water Cycle Experiment (GEWEX), the Network for the Detection of Atmospheric Composition Change (NDACC), the EU-ESFRI Integrated Carbon Observation System (ICOS), the network of ground-based Fourier Transform Spectrometers recording direct solar spectra in the near-infrared spectral region (TCCON, Total Carbon Column Observing Network), Climate databases and near-real-time services for hemispheric snow mapping (ESA GlobSnow and EUMETSAT H-SAF), and reference systems and measurements, e.g. for ESA SMOS, ESA CoReH2O, NASA AURA, NASA/Jaxa AMSR-E, NASA MODIS, and ESA AATSR.

3.3 Error estimation in snow density sampling and its effect on validation of remotely sensed snow cover products. Pia Eriksson, Stockholm University, Sweden.

Andrew Mercer, Susanne Ingvander, Ian Brown and Pia Eriksson and the affiliation is Stockholm University, Sweden

Snow density is a key parameter when analyzing a snow pack, seasonal or perennial. Correct estimation of the snow water equivalent (SWE) is crucial for calculating snowmelt's contribution to the hydrological system. In order to improve the reliability in the SWE estimation, we hereby review the accuracy of snow density measurements as well as the error induced by up scaling and generalizing such measurements. Snow density measurements are generally performed by intrusive methods that alter the material according to the method and instrumentation used.

The review covers snow on glacier/permafrost and on noncryotic ground as the sub surface has a strong effect on the behavior of the overlying snow pack. We investigate the seasonal and spatial variability and different methods used and how these factors introduce errors into the density measurements. Finally we review snowpack sampling for satellite product validation and propose appropriate sampling methodologies to optimize validation accuracy and sampling efficiency with reference to the geographic setting of the site.

3.4 From hemispheric snow cover products towards an integrated view on the land cryosphere" Remote sensing & snow & carbon cycle. Jouni Pulliainen, FMI, Finland.

Kari Luojus⁽¹⁾, Jouni Pulliainen⁽¹⁾, Sari Metsämäki⁽²⁾, Kimmo Rautiainen⁽¹⁾, Juha Lemmetyinen⁽¹⁾, Timo Ryyppö⁽¹⁾ and Matias Takala⁽¹⁾

(1) Finnish Meteorological Institute (FMI), Finland

(2) Finnish Environment Institute (SYKE), Finland

The efforts of the European Space Agency (ESA) Data User Element (DUE) funded GlobSnow project has resulted in two hemispherical-scale records of snow parameters intended for climate research purposes. The datasets contain satellite-retrieved information on snow extent (SE) and snow water equivalent (SWE) extending more than 17 and 35 years respectively. The dataset on snow extent is based on optical data of Envisat AATSR and ERS-2 ATSR-2 sensors covering Northern Hemisphere between years 1995 to 2012. The record on snow water equivalent is produced using a combination of passive microwave radiometer and ground-based weather station data. Recent efforts within the GlobSnow project include a thorough evaluation of the long term datasets and further development of the optical SE retrieval methodology for NPP Suomi VIIRS data and preparation for Sentinel-3 OLCI & SLSTR utilization. Additionally, the combination of the optical SE and the passive microwave SWE products has been investigated.

At the northern latitudes, the carbon cycle is strongly related to the annual temperature behavior, snow cover and distribution of the daylight. SMOS provides observations that are indirectly related to phenomena important for the carbon exchange processes (soil temperature, soil freezing). Finnish Meteorological Institute is conducting multiple studies related to these behaviors. One such is the development of a SMOS based product for detection of soil freeze/thaw. The first prototype product has been produced that uses SMOS data as an input to categorize the soil state to three classes; frozen, partially frozen, and non-frozen. Further studies to enhance the product are carried out at the moment.

Efforts to combine observations of soil moisture, soil freeze/thaw state and snow cover, from snow accumulation to eventual spring snow melting are underway with an ultimate goal to provide an integrated view on land cryosphere over the annual cycle. This information can be utilized e.g. for soil and vegetation process studies including tracking and estimation of carbon balance over high latitudes through the annual cycle. This information combined with long term records of cryosphere can be further utilized to understand the long term changes in terrestrial cryosphere their relation to carbon cycle.

The ultimate objective of these efforts are to globally estimate and map the carbon sinks and sources in the high latitude zones by combining different satellite products, such as information on soil state (SMOS), snow water equivalent and snow extent (GlobSnow), and growing season (Modis) and all available relevant in situ observations (CO₂ fluxes, soil temperatures).

3.5 The Satellite Snow Product Intercomparison and Evaluation Experiment – SnowPEX. Thomas Nagler, ENVEO, Austria.

Thomas Nagler, Gabriele Bippus, Elisabeth Ripper¹, Chris Derksen², Richard Fernandes³, Kari Luojus⁴, Sari Metsämäki⁵, Rune Solberg⁶, Bojan Bojkov, Alessandro Burini⁷

(1) ENVEO IT Gmb

(2) Environmental Canada

(3) CCRS

(4) Finish Meteorological Institute

(5) Finish Environment Institute, (6) Norwegian Computing Center

(7) ESA

Seasonal snow is a main element of the global water cycle and climate system. Due to its strong influence on the radiation and energy balance, changes in snow extent tend to amplify climate fluctuations. Terrestrial snow covers up to 50 million km² of the Northern Hemisphere in winter. It is characterized by high spatial and temporal variability. Therefore satellite observations provide the only means for timely and complete observations of the global snow cover. The recently published *2013 IPCC Working Group 1* report identified seasonal snow as significantly decreasing in the recent decades.

SnowPEX is an ESA funded project contributing to WMO Global Cryosphere Watch (GCW) and WRCP CliC programs. In SnowPEX the quality of the current satellite based snow products derived from Earth Observation satellite data will be assessed, starting with the definition of a framework for validation and intercomparison of EO based data sets. Based on the outcome, guidelines for improvements of the products will be elaborated. Furthermore, the analysis of the climatic trends in the seasonal snow extent and mass will be consolidated. In July 2014 the first international workshop on satellite snow product intercomparison was held at NOAA in Washington DC, with about 50 attending scientists working in the field of satellite based snow mapping.

SnowPEX focuses on two parameters of the seasonal snow pack, the snow extent from medium resolution optical satellite data (e.g. MODIS, AVHRR, VIIRS, etc.) and the snow water equivalent (SWE) from passive microwave data (SSM/I, AMS-R, etc.). Overall about 14 continental to global snow extent products (including fractional snow cover products) and about five SWE products will be evaluated in the intercomparison and validation experiment, with test areas spread over different environments and climate zones. The validation of snow extent products will be based on snow maps from high resolution optical data such as Landsat TM and ETM+ generated by various algorithms. The snow extent uncertainty of these reference data will also be assessed. Networks of in-situ measurements of snow pack are assisting in the local validation of the products.

For SWE products only dense networks of in-situ measurements will be used for validation. To study the spatial pattern of the differences, the snow products are intercompared pixel – by – pixel, which requires the conversion to a common digital coding of the products and to the same map projection. Prototype protocols for intercomparison and validation of the

products will be presented in order to prepare for joint elaboration of consolidated validation procedures. Examples for snow extent validation with Landsat based snow maps and first intercomparison results of various hemispheric snow products will be shown.

3.6 Global Cryosphere Watch(GCW): A Contribution to Arctic Products Validation and Evolution (APVE). Barry Goodison, GCW Steering Group, Canada.

Barry Goodison¹, Jeffrey Key², Wolfgang Schöner³, Øystein Godøy⁴

(1) Vice-Chair, GCW Steering Group, Canada

(2) National Oceanic and Atmospheric Administration (NOAA), Madison, Wisconsin, USA,

(3) Zentralanstalt für Meteorologie und Geodynamik (ZAMG), Vienna, Austria

(4) Norwegian Meteorological Institute, Oslo, Norway

(On behalf of GCW Steering Group, World Meteorological Organization)

There is now an unprecedented demand for authoritative information on the past, present and future state of the world's snow and ice resources. The cryosphere is one of the most useful indicators of climate and environmental change, yet is one of the most under-sampled domains in the climate system, particularly in remote regions, such as the Arctic. The World Meteorological Organization (WMO) recognized that there was an urgent need for a sustained, robust, end-to-end cryosphere observing and monitoring system, not only for polar and alpine regions, but globally, and with its partners is now developing and implementing an operational Global Cryosphere Watch (GCW). Improved cryospheric monitoring, integration of information across cryospheric domains and the provision of data and service-oriented information are essential for use in real time, for risk management and to fully assess, predict, and adapt to the variability and change which we now witness in weather, climate, water and other environmental sectors. Such a system must be a combination of ground-based measurements, satellite remote sensing, aircraft measurements, modeling, and data management. Satellite information is, and will continue to be, vital in filling this void.

Important for current and future cryosphere monitoring and satellite validation is the initiation of a surface-based cryosphere observing network called "CryoNet", which will build on existing efforts and provide sustained surface observations based on best practices and guidelines for cryospheric measurement for compatible observations from all GCW constituent observing and monitoring systems. Such practices are an important aspect in all evaluation and validation activities for Earth Observation and model outputs. CryoNet Reference and Integrated Sites will provide long-term data for calibration and validation of satellite products, for the assessment of long-term changes of the cryosphere and for verification of cryospheric processes in weather, climate, and hydrological models. Eight of the first 14 global CryoNet sites that were recently approved for initial development and implementation are in the Arctic and will provide data and information for all possible cryosphere components at each site. All of the initial sites are part of WMO's Integrated Global Observing System, the Global Atmosphere Watch (GAW) or the IASOA network. This combination provides an extremely valuable integration of environmental measurements for assessment and validation of satellite products into the future. GCW is working with the satellite community to ensure the appropriate measurement program is implemented at these sites.

GCW promotes the intercomparison of satellite products as a step toward providing authoritative information. GCW *Snow Watch*, a GCW Products Team activity, has identified critical issues affecting the ability to provide authoritative information on the current state of snow cover, and has initiated projects to address priority areas. These include improving the real time flow and access to in-situ snow measurements; initiating a satellite snow products evaluation and intercomparison activity; developing hemispheric "snow anomaly trackers" for snow extent and snow water equivalent; and, developing an inventory of existing snow datasets. The *Snow Watch* efforts to improve the real-time flow and access to in-situ measurements are critical to continuing development of regional and global satellite snow products. This team is already working with ESA's SnowPEX on an international satellite snow product intercomparison and evaluation experiment, including an intercomparison of algorithms, products, and generation of a reference data set for validation of snow products. The need to develop intercomparison protocols was identified and will be critical for APVE.

Improved data exchange and provision of authoritative products and information are critical to the success of GCW. The GCW Data Portal (gcw.met.no) will provide the ability to exchange data and information among a distributed network of providers. The "Watch" is provided through the GCW website (globalcryospherewatch.org) and will provide authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere to meet the needs of WMO Members and partners. GCW offers a valuable contribution to well planned, and executed, validation of EO products. The presentation will further define the linkages between GCW and its activities in the context of APVE.

3.7 Canadian Ice Service Satellite based Ice Monitoring: Optical Data Applications. Yi Luo, CSI, EC.

Yi Luo, Matt Arkett, Leah Braithwaite, and Tom Carrieres, Canadian Ice Service, Environment Canada

The Canadian Ice Service (CIS) relies on a variety of EO datasets to operationally monitor ice and other marine conditions in Canadian waters. Although Synthetic Aperture Radar (SAR) data are the primary source for daily analysis of ice conditions, optical data including visible and infrared provide an excellent complement. In fact in some situations, optical data may be the only information source. Advantages of optical sensors include: (1) multiple band observations (e.g. MODIS 36 bands) providing significant surface target detail allowing easier ice boundary identification and ice-type classification; (2) much wider imaging swath (e.g. VIIRS 3040km) and therefore a more frequent revisit (multiple times a day) for the same area; (3) longer historical data archive (e.g. AVHRR back to 1979); and (4) much higher spatial resolution (e.g. Landsat 15/30m). In addition to using high-quality (calibrated, geo-referenced) near real-time images operationally to create navigational sea ice charts, several value-added products are also produced including: (1) a MODIS multi-day clear-sky Arctic composite; (2) animations of optical imagery for enhanced visualizations and (3) data assimilation of optical data.

This presentation will discuss: (1) the development of MODIS clear-sky composites to provide representative views of ice conditions over a variety of periods. Additionally, based on these composite products, a MODIS Arctic sea ice extent map can be created that appears to have (a) reduced land contamination in coastal zones, (b) improved accuracy in detecting thin and melting ice and (c) more realistic extent values due to high resolution data in comparison to conventional passive microwave-based assessments; (2) the generation of animations from a series of normalized optical images to provide excellent visualization tools demonstrating the dynamic changes in sea ice conditions and drift to enhance short-term forecasts and predictions of sea ice status; and (3) the assimilation of optical satellite data in models used to predict sea ice concentration. Specifically, calibrated and corrected AVHRR data used in sea ice data assimilation are yielding promising results. Not only do well-calibrated, consistent optical data provide quantitative information about a variety of environmental parameters, these data can also be used for both operational ice monitoring and detection of long-term changes in the sea ice environment.

The Regional Ice Prediction System (RIPS) version 2.1. Lynn Pogson, CSI, EC.

The Regional Ice Prediction System (RIPS) version 2.1 has recently been implemented experimentally at Environment Canada. This system provides ice information for the waters surrounding Canada 4 times daily. It is comprised of an analysis component, derived from 3dvar data assimilation techniques, and a forecast component, derived from the CICE4 sea ice model. Version 2.1 of the analysis includes the assimilation of observational data from SSM/I, SSM/IS, ASCAT, and CIS daily charts and RADARSAT2 image analyses.

Development is underway for upcoming versions of the system, including the assimilation of AVHRR, AMSR-2, and RADARSAT2 data. An overview of RIPS, and an update of the work on SAR data assimilation will be presented.

3.8 Characterization of Hazardous Ice using Spaceborne SAR and Ice Profiling Sonar: Preliminary Results. Kaan Ersahin, ASL Environmental Sciences Inc., Canada.

Kaan Ersahin, Leslie Brown, Michael Henley, Edward Ross, Keath Borg, and David Fissel ASL Environmental Sciences Inc., Victoria, BC, Canada

Ice can pose hazard for operations (e.g., transportation, shipping, surveillance, offshore oil and gas exploration) and for infrastructure (e.g., bridges, ports, pipelines, offshore structures). There is an increasing need for fine scale characterization of hazardous ice conditions. This information is of interest to many stakeholders including government departments and agencies, and the oil and gas industry.

Since the early 1990s, space-borne SAR sensors have demonstrated the viability and cost-effectiveness of near-real-time monitoring of the regional ice conditions. Recently, improved data products were developed for dual-polarized ScanSAR data. Satellite derived sea ice information products typically rely on the interpretation of ice analysts or in some cases semi-automated techniques. However, validation of data products is challenging due to limited or no ground-truth.

This work aims to develop improved ice data products from spaceborne SAR through calibration and validation of algorithms using continuous in situ measurements obtained from bottom mounted Upward Looking Sonar (ULS) instruments. The ASL Ice Profiling Sonar (IPS) is an upward looking sonar device designed for very high resolution ice draft measurements. The Acoustic Doppler Current Profilers (ADCP) measure ice velocity, when used in conjunction with IPS provides information about feature widths and ice floe position at a sub hour time interval. Since the mid-1990s, these instruments provided ice draft and velocity measurements in support of research and oil and gas exploration programs in the Arctic Ocean and marginal ice zones. Analysis of ULS datasets allow us to make inferences regarding the ice conditions that are used as input to the engineering design of offshore platforms and the development of operational support programs.

We have recently developed analytical methods for processing ice draft and velocity information to characterize highly deformed sea ice features, e.g., large individual keels and segments of large hummocky (rubbled) ice. Our ongoing work (2013-2015) funded by the Canadian Space Agency is focusing on the development of techniques to characterize hazardous ice using quad-polarized RADARSAT-2 and ULS datasets.

The expected results include:

- (1) Paired space-borne SAR and ULS datasets to allow algorithm calibration and validation.
- (2) ULS data overlays on satellite imagery for visualization, interpretation and analysis.
- (3) Refined methods to extract hazardous ice information from ULS data.
- (4) Validated algorithms for characterization of potentially hazardous ice from spaceborne SAR.

This paper will present the project overview and preliminary results obtained to date.

3.9 Validation of DInSAR displacement measurements in permafrost environments. Naomi Short, CCRS, NRCAN, Canada.

*Canada Centre for Remote Sensing, Natural Resources/Geological Survey of Canada,
Natural Resources, Canada*

Space-borne Differential Interferometric Synthetic Aperture Radar (DInSAR) is rapidly gaining acceptance as a source of terrain stability information for permafrost regions. Qualitative and quantitative validation of this new data source is challenging though, due to the remote and harsh nature of the environment and large area coverage. This paper describes efforts to validate DInSAR products from both continuous and discontinuous permafrost environments. A number of different strategies are used: field observations, in-situ instrumentation, ground electrical resistivity measurements, surficial geology maps and borehole data. These methods provide insights into permafrost conditions and these conditions can be correlated with patterns in the DInSAR products. Yellowknife in the Northwest Territories and Iqaluit in Nunavut are the discontinuous and continuous permafrost study sites respectively. The results show that DInSAR can provide significant information about permafrost conditions and that this information is useful for infrastructure planning and management.

3.10 Polar View – Lessons Learned for the Validation and Evaluation of Operational Arctic Monitoring Services. Thomas Puestow, C CORE/Polar View, Canada.

Initially funded under ESA's GMES Services Element (GSE) initiative, Polar View has become an international collaborative network of service providers, government agencies, research institutions and user organizations from 17 countries. Throughout its operation under GSE, Polar View has been an efficient catalyst for cooperation (e.g. international, public-private partnerships), for the use of Earth Observation (EO) technology, and for the dissemination of knowledge and information related to EO and polar issues.

In order to carry forward the significant momentum generated by Polar View and facilitate the continued collaboration of its members within a formalized network, Polar View was formally incorporated in the UK in 2011. It is the continuing mission of Polar View to provide, through its members, efficient and effective operational monitoring services of the world's Polar Regions and other areas affected by snow and ice, and supply decision makers with critical information pertaining to the environment, the economy and safety. Because of the size and remoteness of the targeted areas, Polar View services are primarily relying on EO technologies.

Users are central to the success of Polar View, and the continued expansion of the Polar View network since its inception is a direct result of the high level of user engagement achieved and a worldwide growing interest of users in Polar View services. Core users of Polar View services include predominantly governmental organizations with international, national, regional and local responsibilities, as well as a smaller number of commercial and not-for-profit private sector organizations. These core user bodies represent a much larger group of end users (i.e. 1000s) that benefit directly from the services (e.g. ships, hunters moving on the ice).

Due to the network's growing reputation among polar stakeholders, Polar View is playing an increasingly important role in defining and promoting standardization and best practices across all components of its service portfolio. To this end, Polar View established a service validation protocol applicable to any precursor or future products or services provided by Polar View. As the validation is conducted, the protocol is tailored to each individual product and service. The validation principles provided are universally applicable to all products and services in a format that is understandable by all members of Polar View, including Polar View's end user community.

4 SESSION: LAKE AND COASTAL

4.1 Arctic Lake Ice Algorithms and Products: Progress and Prospects. Claude Duguay, University of Waterloo, Canada.

Claude R. Duguay, Kyung-Kuk (Kevin) Kang, Homa Kheyrollah Pour, and Cristina Surdu, Department of Geography & Environmental Management and Interdisciplinary Centre on Climate Change, University of Waterloo, Waterloo, Canada

Lakes are sensitive indicators of climate variability and change. They also play an important role in the energy and water balance at local and regional scales, influencing climate and weather. One of the key variables that is sensitive to climate conditions and that influences lake-atmosphere interactions in high-latitude environments is ice cover. Its presence/absence and duration as well as its thickness have wide ranging impacts from the magnitude of energy/heat exchanges with the overlying atmosphere to winter (ice road) transportation and food security. Ground-based observations and lake ice models are useful for studying the response and role of lake ice cover. Satellite remote sensing is, however, a necessary complement to these approaches as it provides the spatial coverage not captured by ground-based observational networks and ice models.

This presentation will provide an overview of recent progress in the development of lake ice products and their evaluation, and provide an outlook for remote sensing of Arctic lake ice. Algorithms and products on lake ice cover extent and concentration, ice thickness, floating and grounded ice, and ice/snow albedo and temperature from optical and microwave sensors will be presented. The talk will conclude with prospects for lake ice product developments in light of the upcoming satellite missions of the European Space Agency (ESA) and the Canadian Space Agency (CSA).

4.2 Pan Arctic Land and lake surface temperature from AATSR and MODIS: Products development and evaluation. Homa Kheyrollah, University of Waterloo, Canada.

Homa Kheyrollah Pour and Claude R. Duguay, Department of Geography and Environmental Management, University of Waterloo, Waterloo, Canada

Temperature is the most direct indicator of Arctic environmental changes and has wide-ranging impacts, including permafrost thermal state and the temperature and ice regimes of lakes. To monitor and assess these changes in the Arctic region with respect to climate change, we developed novel EASE-grid Level 3 (L3) land surface temperature (LST) and lake surface water temperature (LSWT) products from AATSR and MODIS data in order to provide the scientific community with daily, weekly, monthly and annual LST/LSWT means over the pan-Arctic domain at various grid resolutions (1–25 km) from 2000–onward.

LST (land) products are generated from Level 2 (L2) AATSR (ATS_NR_2P) and MODIS collection 5, L2 acquired by both the Terra (MOD11_L2) and Aqua (MYD11_L2) satellites. Products have been evaluated through inter-comparison with existing surface and near-surface temperature products such as meteorological station measurements, Advanced Microwave Scanning Radiometer (AMSR-E), the Special Sensor Microwave/Imager (SSM/I), and North American Regional Reanalysis (NARR). Results show a close correspondence between AATSR and MODIS monthly products with a mean difference (MD) of -1.1°C . Comparing L3 products with NARR indicates a close agreement in summer and a systematic bias in winter, which is entirely negative with respect to MODIS L3 (MD: -3.6 , Min: -6.8 , Max: -1°C). Comparing monthly averaged MODIS L3 to NARR clear-sky to quantify over-representing clear-sky days indicates a decrease of winter and an increase of summer differences compared to NARR all-sky.

LSWT (lake) products are generated from Level 1B (L1B) AATSR and both MODIS-Terra/Aqua (collection 5, L2) satellites. Products have been evaluated against in-situ measurements during the open-water season for the Great Bear and Great Slave Lakes, NWT, Canada, as well as 22 Finnish lakes. MODIS-derived products show a strong agreement with in-situ measurements, yielding a mean bias (MB) of less than 1°C when skin water temperature data were available. The bias was higher when data were evaluated against water temperature measurements taken at 20 cm below the water surface (MB = -1.13°C). We have also implemented two retrieval algorithms applied to AATSR data: one based on Key et al. (1997) and the other on Prata (2002) with a finer resolution water mask than used in the creation of the AATSR-L2 product distributed by ESA. The accuracies of LSWT retrievals are improved with the Key and Prata algorithms with MB of 0.79 and -0.12°C , respectively, compared to the original AATSR-L2 product (3.19°C).

4.3 Multi sensor monitoring of ice regimes of High Arctic Lakes. Cristina Surdu, University of Waterloo, Canada.

Cristina Surdu, Claude R. Duguay, and Diego Fernández Prieto, Department of Geography and Environmental Management, University of Waterloo, Waterloo, Canada

The lake ice cover – a robust indicator of climate variability and change – is expected to continue reducing in both, duration and extent, following warmer climate conditions. Lake ice regime shifts have been identified across the Arctic but considering the limited availability of resources to monitor High Arctic lakes, past and ongoing changes within these lakes have not yet been comprehensively documented.

A 14-year time series of RADARSAT-1/2, ENVISAT ASAR wide-swath synthetic aperture radar (SAR) and Landsat acquisitions was analyzed to detect the response of ice cover on lakes in the Canadian Arctic Archipelago to recent climate conditions. With an algorithm that limits the backscattering intensity to set intervals for class allocation and that is flexible to varying ice conditions during the ice season, K-means image segmentation was used to discriminate between open water and ice. When available, Landsat imagery was also used for either improving the existing temporal resolution or evaluating the SAR observations.

Preliminary results indicate that the ice cover of lakes situated in a typical polar desert environment as well as that of lakes in a milder polar oasis climate may be transitioning from a perennial to a seasonal ice regime, with earlier ice off dates consequent to the loss of perennial ice, and an overall deficit in ice duration. Analysis of the available SAR and Landsat data from 1997 to 2011 indicates that the start of ice break-up is occurring by 14-36 days earlier ($\alpha > 0.1$) for polar-oasis lakes and eight days or less ($\alpha > 0.1$) for polar-desert lakes. Changes were also observed in the summer ice minimum, with ice generally disappearing earlier on all lakes (by 4-22 days, $\alpha > 0.1$). During the 14-year period of analysis, perennial ice cover was only present during a few years for two polar-oasis lakes – on Devon Island (1999, 2001, 2003 and 2004) and Lake Hazen (2004 and 2009) while being non-existent on lakes in polar desert environments.

The combination of spaceborne SAR and visible imagery enables an adequate assessment of ice conditions for Arctic lakes, limited by spatial or temporal resolution of the sensors. The recent launch of Sentinel-1a combined with that of the upcoming Sentinel-2a/b, and that of the Radarsat constellation will significantly improve the frequency of observations at high latitudes and will provide a valuable data set, through cross- monitoring and high-temporal observations of Arctic lakes.

4.4 Improvement of MODIS snow products for Arctic lake ice. Kyung Kuk (Kevin) Kang, University of Waterloo, Canada.

Kyung-Kuk (Kevin) Kang and Claude R. Duguay, Department of Geography & Environmental Management and Interdisciplinary Centre on Climate Change, University of Waterloo, Waterloo, Canada

Observations of lake ice coverage is important for studying the role of lakes in high-latitude weather and climate since the presence/absence of seasonal floating ice has an effect on heat and energy transfers across the lake-atmosphere boundary. Shortening of the ice cover season in many regions of the Northern Hemisphere over recent decades has been shown to significantly influence the thermal regime of lakes. In this respect, spaceborne remote sensing instruments are providing invaluable measurements for monitoring changes in timing of ice phenological events on large northern lakes.

The objective of this study was to evaluate and refine the existing NASA MODIS (Aqua and Terra) snow products for lake ice monitoring during freeze-up and break-up periods. MODIS data acquired over four large high-latitude lakes (Great Bear Lake and Great Slave Lake in Canada; Lake Ladoga and Lake Onega in Russia) from 2003-2012 were used for analysis. MODIS/Aqua (Terra) 500 m snow products (i.e. MYD10_L2 and MOD10_L2, version 5) and refined products for lake ice were evaluated against optical imagery from MODIS/Aqua (Terra) Calibrated Radiances 5-Min L1B Swath 500m V005 (MYD02HKM and MOD02HKM). The main improvement of the new refined algorithm is that it can discriminate more clearly lake ice from cloud cover compared to the original MODIS snow algorithm. It also detects better disintegrating ice-cover during the break-up period. In general, the new algorithm provides a significant improvement for operational monitoring of ice cover on the large northern lakes analyzed in this study as well as on lakes of smaller size (~1 km² or larger) over the pan-Arctic domain on a regular basis.

4.5 Ocean color remote sensing for the study of Arctic marine ecosystems: II Algorithm development and data processing platforms Emmanuel Devred, Takuvik, *Joint International Laboratory, Canada.*

Satellite observations of the Arctic Ocean present a number of advantages that cannot be matched by other means of observation, notably their spatial and temporal coverage. In particular, ocean-colour remote sensing provides information on phytoplankton and suspended particulate matter (SPM) over the last 17 years over the entire Arctic Ocean, a period of observation sufficient to observe the response of the marine ecosystem to the warming of the Arctic and the decrease in sea-ice extent. However, interpretation of the remote sensing signal require a fine tuning of bio-optical algorithms and the use of ancillary data to account for the specificities of the Arctic Ocean. Here we present two examples of state-of-the-art models to 1) compute primary production and 2) derive suspended particulate matter concentration in the delta and plume of the Mackenzie River. The primary production model integrates the most recent regionally-tuned bio-optical models, which are integrated in a processing chain that includes, in addition to ocean colour, satellite information on cloud cover, sea-ice concentration. The primary production model also includes original research on phytoplankton vertical distribution, a known limitation of current model that can lead to large bias in PP estimates. Satellite observations of SPM in the Mackenzie river delta and plume, using an original procedure to remove the atmospheric signal over turbid waters, showed a significant increase of sediment transport towards the Beaufort Shelf in relation to an increase in river flow and precipitation during the last decade. These studies, that complement the in situ and laboratory worked performed at Takuvik, reflect the important effort undertaken to monitor the Arctic marine ecosystem.

4.6 On the Validation of Earth Observation Data for snow covered sea ice: Challenges and Opportunities, David Barber/Kerri Ann Warner, University of Manitoba, Canada.

D. G. Barber, K. Warner, A. Komarov, N. Firoosy, D. Babb, M. Shields, University of Manitoba, Canada

Earth Observation data are a key measurement approach to understand high latitude cryospheric processes. We review approaches available to estimate both the geophysical and thermodynamic state and evolution of snow covered sea ice relative to space based measurements of these climactic states. In this talk we provide an overview of sea ice validation opportunities in the Arctic using field camps, mesocosm studies, automated observatories, and ice breaker based sampling. We introduce the reader to the Sea Ice Environmental Research Facility (SERF) and studies linking sea ice to fluxes of gas and energy. We show how automated observatories can be used to provide key validation variables for various optical and microwave EO validation and how instrumentation aboard the Canadian Research Icebreaker Amundsen can provide extensive validation of various sea ice related products. We conclude with an overview of a new multimillion dollar proposal known as the Churchill Marine Observatory (CMO) which will be a technology test-bed and incubation centre and near real time supersite for EO validation.

5 SESSION: ATMOSPHERE

5.1 Validation Capacity in the Canadian High Arctic: The Polar Environment Atmospheric Research Laboratory (PEARL), James R. Drummond/Kaley Walker, Dalhousie University, Canada/University of Toronto.

James R. Drummond, Pierre F. Fogal², Kaley A. Walker², and the CANDAC/PAHA Science Team

(1) Department of Physics and Atmospheric Physics, Dalhousie University, Halifax, NS, Canada

(2) Department of Physics, University of Toronto, Toronto, ON, Canada

The Polar Environment Atmospheric Research Laboratory (PEARL) is a research facility near Eureka, Nunavut, Canada (80 N, 86 W). Its goal is to characterize the atmosphere of the high Arctic from the surface to 100 km through measurements by active and passive instruments. PEARL has been operated since 2005 by the Canadian Network for Detection of Atmospheric Change (CANDAC). However some measurements, by Environment Canada and their collaborators, go back as far as 1993.

There are three components to the PEARL site: the Ridge Laboratory, the Zero Altitude PEARL Auxiliary Laboratory (OPAL), and the Surface and Atmospheric Flux and Irradiance Extension site (SAFIRE). Trace gases are measured using Fourier transform infrared instruments using solar absorption and emitted radiation, UV-visible grating and Brewer spectrometers and lidars. These measurements include columns and/or profiles of gases such as O₃, NO, NO₂, HNO₃, N₂O₅, NO₃, N₂O, ClONO₂, HCl, OCIO, BrO, HF, CFCs, CH₄, H₂O, CO, and OCS. Aerosols are measured via lidar, sun photometer and star photometer instrumentation. Longwave and shortwave radiation are measured using Baseline Surface Radiation Network (BSRN) type instrumentation. In addition, there are upper atmospheric wind and temperature measurements, cloud and wind radars and a 10-m flux tower. Processed data from these instruments are supplied to several international databases.

PEARL is located in a "sweet spot" for validation of sun-synchronous polar-orbiting satellites. The 80 N latitude of the station provides a very high frequency of satellite overpasses and it is one of few stations located in the high Arctic. PEARL in Eureka provides unique opportunities for validating space instrumentation used for atmospheric studies in the Arctic. Because the site is permanent, validation measurements can span a large time frame and can also be anchored in very reliable ground calibrations. Over the past decade, regular and campaign validation measurements have been made at PEARL for a number of satellites including the Canadian SCISAT/ACE and Odin/OSIRIS missions, ESA's ENVISAT mission and the NASA CloudSat and Aura missions. Most recently, PEARL measurements of CO₂ are part of the initial validation for NASA's OCO-2 mission, launched in July 2014.

5.2 Observing CO₂ from a highly elliptical orbit for studies of the carbon cycle in the Arctic and boreal regions. Ray Nassar, EC, Canada.

Ray Nassar¹, Chris E. Sioris², Dylan B.A. Jones³, Kaley A. Walker³, Chris McLinden¹, C. Tom McElroy⁴

(1) Environment Canada

(2) University of Saskatchewan

(3) University of Toronto

(4) York University

Arctic permafrost holds approximately twice the amount of carbon in the global atmosphere, thus the potential emission of some fraction of this carbon could impact global climate. One method for quantifying emissions of CO₂ or CH₄ is through the assimilation of atmospheric CO₂ or CH₄ measurements (in situ or satellite) with transport models. A highly elliptical orbit (HEO) offers the potential for quasi-geostationary observations of CO₂ and CH₄ in the Arctic and boreal regions, which could help to quantify emissions of these gases. Canada's proposed Polar Communications and Weather (PCW) mission would consist of two satellites in a HEO configuration, optimized for observing northern high latitudes (~50-90°N). Although the primary mission drivers are Arctic weather and communications, a mission enhancement consisting of an imaging Fourier transform spectrometer (FTS) operating in the thermal infrared (TIR) to shortwave-infrared (SWIR) is also under consideration. CO₂ and CH₄ bands in the 1.60-1.67 micron region and the O₂ A band at 0.760-0.766 micron would enable retrieval of column-averaged volume mixing ratios of CO₂ and CH₄. Such observations are more challenging at high latitudes than at lower latitudes due to large solar zenith angles and reduced albedo over snow in the 1.6 micron band. Regardless of these challenges, our studies with simulated CO₂ demonstrate that HEO observations would yield improved constraints when compared with a Low Earth Orbit (LEO) mission for regional-scale Arctic and boreal CO₂ fluxes, where permafrost and other components of the carbon cycle will be important to monitor over the coming years. Potential methods of improving high latitude validation capabilities for column CO₂ and CH₄ mixing ratios to meet the needs of such a mission will also be discussed.

5.3 Balloon demonstrator Imaging Fourier Transform Spectrometer for the measurement of methane and carbon dioxide over the Arctic. Zahra Vaziri, York University, Canada.

Z. Vaziri¹, C.T. McElroy¹, K.-H. Feng¹, K.A. Walker², P.F. Foga²,
R.V. Martin³, R. Nassar⁴ and F.J. Grandmont⁵

(1) York University, Toronto, Canada

(2) University of Toronto, Toronto, Canada

(3) Dalhousie University, Halifax, Canada

(4) Environment Canada, Toronto, Canada

(5) ABB Inc., Quebec City, Canada

In the Arctic, multi-year ice cover is disappearing more rapidly than climate models estimate and the arctic climate is changing. With declining ice cover, the Arctic Ocean will be subject to increased shipping traffic and exploration activity for natural resources with a concomitant increase in air pollution. There is a multifaceted need to monitor the polar region. Canadian government departments, led by the Canadian Space Agency (CSA) and the Department of National Defence (DND), are proposing the Polar Communications and Weather (PCW) mission to provide improved communications and critically important meteorological and air quality information for the Arctic using an operational meteorological imager. Two satellites in highly eccentric orbits with apogees at ~ 40,000 km over the Arctic would provide quasi-geostationary viewing over the Arctic with 24-7 coverage in the IR and measurements using solar reflected light in the summertime. The planned operational meteorological instrument is a 21-channel spectral imager with UV, visible, NIR and MIR channels similar to MODIS and ABI. This presentation will focus on the development of an Imaging Fourier Transform Spectrometer (IFTS) to be flown on a high-altitude balloon to demonstrate the capacity to monitor methane and carbon dioxide in the Arctic as part of the PHEOS-WCA (Polar Highly Elliptical Science - Weather, Climate and Air quality) mission, a science complement to the PCW mission.

Funding from the CSA FAST (Fights for the Advancement of Science and Technology) program is in place to develop the demonstrator IFTS to show that images of methane and carbon dioxide can be collected from space. The characteristics of the instrument and plans for the balloon flight will be discussed and details of the full PCW mission and PHEOS-WCA component will be presented. The authors acknowledge the support of the PHEOS-WCA science team.

5.4 Validation/Verification of the microphysical and dynamic characteristics of Arctic Cloud systems: what infrastructure is required to meet the challenge? Stella Melo, EC, Canada.

Stella Melo, Paul Joe, David Hudak, Ismail Gultepe, Institution: Environment Canada, ASTD, Cloud Physics and Severe Weather Section

Provision of accurate meteorological predictions over the Arctic is a pressing need which is increasing with the expansion of activities in this region. Satellite retrieval of meteorological data is essential to provide the required spatial and temporal coverage. Satellite data nor in-situ ground based data can meet the needs. Rather, an observing system which conceptually integrates satellite and ground-based measurements and appropriate infrastructure is required. A major challenge is the need for merging data with different spatial and temporal characteristics. Quality is also intrinsically dependent on the user application and therefore diverse in terms of requirements. Different users require different level of data characterization and validation. For example, data products for weather, for data assimilation have different requirements than products for climate analysis or for process studies.

Validation/characterization activities, both statistical and physically based, need to be conceived and integrated at the system design level to include measurements from different sensing technology, different platforms and to the different user applications which the data products serve.

Environment Canada's Cloud Physics and Severe Weather research group has strong heritage in satellite data validation over Canada, including during cold seasons. We are currently working on our view of this integrated observing system which would meet the needs for meteorological data for Canada. We will review our past and current activities. We will then discuss our plans to expand measurement capabilities over the Arctic with the goal to integrate data from different platforms. This effort will require an international and a collaborative approach to assure efficiency. We would like to take this opportunity to motivate discussions around possible collaborations.

5.5 Measuring high latitude precipitation and falling snow from space. Ralf Bennartz, University of Wisconsin, US. Ralf Bennartz

EES, Vanderbilt University/SSEC, University of Wisconsin

Over the last years our capabilities to remotely sense high-latitude precipitation have increased. Significant progress has been made in particular in three areas. Firstly, new in-situ and ground-based remote sensing techniques allow us to better specify snowfall size distribution, fall speed, and particle shapes. Secondly, our understanding of basic interactions between non-spherical frozen particles and the radiation field has advanced considerably. Thirdly, with the advent of space-borne radars and improved radiometers it has become feasible to study snowfall globally from space. While initial studies show very promising results, many retrieval techniques are still in their infancy.

Based on the outcome of the Fourth International Workshop on Space-based Remote Sensing of Snowfall (IWSSM-4: <http://www.ssec.wisc.edu/meetings/iwssm/2013/>) this presentation will review the current state-of-the-art of high latitude precipitation remote sensing and highlight recent advances in the different research areas listed above.

ANNEX: APVE WORKSHOP PROGRAMME

Programme: Day 1

Day 1: Wednesday, 12 November 2014			
	Introduction		
8:30	Yves Crevier	CSA, Canada	Welcome and introduction
8:40	Bojan Bojkov	ESA, Italy	(1.1) EO challenges in high-latitudes and the workshop objectives
9:00	Guy Aubé	CSA, Canada	(1.2) Downstream EO Products and Services for the Arctic: CSA Support for Canadian Governmental Organizations, Industry & Academia
	User Perspectives Chair: T. Puestow		
9:15	Dennis Nazarenko/ Bill Jefferies	LOOKNorth, Canada	(1.3) The Growing Importance of Remote Sensing Derived Information to Northern Commercial Activities.
9:35	Ulrika Willen	SMHI, Sweden	(1.4) Using Arctic and high-latitude observational data for process studies and model evaluation at the Swedish Meteorological and Hydrological Institute (SMHI)
9:50	James Snider	WWF, Canada	(1.5) Use of remote sensing in WWF's Rapid Assessment of Circum-Arctic Ecosystem Resilience (RACER) tool for conservation planning in a rapidly changing Arctic
10:05	Marcel Babin	Takuvik, Canada	(1.6) Ocean color remote sensing for the study of Arctic marine ecosystems: I- Major research initiatives and scientific results
10:20	Discussion		
10:45 11:00	Coffee Break		
	Land Session (1/2) Chair: D. Peddle		
11:00	Derek Peddle	ATIC, U.Lethbridge, Canada	(2.1) Remote Sensing of Northern Forest Tree Species Products and Validation using Spectral Mixture Analysis and Multi-Temporal Satellite Imagery, Northwest Territories, Canada
11:30	Robert H. Fraser	CCMEO, NRCAN, Canada	(2.2) Detecting Landscape Changes in High Latitude Environments using Landsat Trend Analysis: 1. Visualization
11:50	Ian Olthof	CCMEO, NRCAN, Canada	(2.3) Detecting Landscape Changes in High Latitude Environments using Landsat Trend Analysis: 2. Classification
12:10	Peter White	CCRS, NRCAN, Canada	(2.4) Hyperspectral Simulation of an Arctic Landscape with ISDASv2
12:30	Discussion		
13:00 14:00	Lunch		

Day 1: Wednesday, 12 November 2014			
	Cryosphere Session (1/2) Chair: B. Goodison		
14:00	Chris Derksen	Environment Canada	(3.1) Validation needs for microwave derived terrestrial cryosphere products
14:20	Kari Luojus	Finnish Meteorological Institute, Finland	(3.2) CAL-VAL Opportunities for Terrestrial Cryosphere Products at the Sodankylä Supersite, Northern Finland
14:40	Pia Eriksson	Stockholm University, Sweden.	(3.3) Error estimation in snow density sampling and its effect on validation of remotely sensed snow cover products
15:00	Jouni Pulliainen	Finnish Meteorological Institute, Finland	(3.4) From hemispheric snow cover products towards an integrated view on the land cryosphere" - Remote sensing & snow & carbon cycle
15:20	Thomas Nagler	ENVEO, Austria	(3.5) The Satellite Snow Product Intercomparison and Evaluation Experiment – SNOWPEX
15:40	Discussion		
15:50	Coffee Break		
16:05	Lake and Coastal Session Chair: C. Duguay		
16:05	Claude Duguay	University of Waterloo, Canada	(4.1) Arctic Lake Ice Algorithms and Products: Progress and Prospects
16:35	Homa Kheyrollah Cristina Surdu Kyung-Kuk (Kevin) Kang	University of Waterloo, Canada	(4.2) Pan-Arctic Land and lake surface temperature from AATSR and MODIS: Products development and evaluation (4.3) Multi-sensor monitoring of ice regimes of High Arctic Lakes (4.4) Improvement of MODIS snow products for Arctic lake ice
17:20	Emmanuel Devred	Takuvik, Canada	(4.5) Ocean color remote sensing for the study of Arctic marine ecosystems: II - Algorithm development and data processing platforms
17:40	David Barber/Kerri Ann Warner	University of Manitoba, Canada	(4.6) On the Validation of Earth Observation Data for snow covered sea ice: Challenges and Opportunities
18:00	Discussion		
18:30	End of day 1		
20:00	Optional dinner: At the Mills St. Pub		

Programme: Day 2

Day 2: Thursday, 13 November 2014			
	Land Session (2/2) Chair: A. Trishchenko		
8:45	Alexander Trishchenko	CCRS, NRCAN, Canada	(2.5) Using VIIRS to extend MODIS long-term clear-sky composites over Canada
9:15	Donald McLennan/ Katherine Wilson	CHARS, Canada	(2.6) CHARS as a Science Partner for Coordinated Northern EO/RS
9:35	Bahram Salehi	C-Core, Canada	(2.7) Object-based land cover classification of Torngat Caribou Habitat in Quebec and Labrador, Canada using SPOT imagery and DTM data
9:55	Wenjun Chen	CCRS, NRCAN, Canada	(2.8) Challenges in monitoring Arctic plant growth and phenology using long-term remote datasets
10:10	Elizabeth Hoy	NASA, US	(2.9) Spaceborne Remote Sensing Requirements for the Arctic-Boreal Vulnerability Experiment (ABOVE)
10:30	Discussion		
10:45 11:00	Coffee Break		
	Atmosphere Session Chairs: J. Drummond / K. Walker		
11:00	James R. Drummond/ Kaley Walker	Dalhousie University, Canada/University of Toronto	(5.1) Validation Capacity in the Canadian High Arctic: The Polar Environment Atmospheric Research Laboratory (PEARL)
11:30	Ray Nassar	Environment Canada	(5.2) Observing CO ₂ from a highly elliptical orbit for studies of the carbon cycle in the Arctic and boreal regions
11:50	Zahra Vaziri	York University, Canada	(5.3) Balloon demonstrator Imaging Fourier Transform Spectrometer for the measurement of methane and carbon dioxide over the Arctic
12:10	Stella Melo	Environment Canada	(5.4) Validation/Verification of the microphysical and dynamic characteristics of Arctic Cloud systems: what infrastructure is required to meet the challenge?
12:30	Ralf Bennartz	University of Wisconsin, US	(5.5) Measuring high-latitude precipitation and falling snow from space
12:50	Discussion		
13:00 14:00	Lunch		
	Cryosphere Session (2/2) Chair: C. Derksen		
14:00	Barry Goodison	GCW Steering Group, Canada	(3.6) Global Cryosphere Watch (GCW): A Contribution to Arctic Products Validation and Evolution (APVE)

Day 2: Thursday, 13 November 2014			
14:30	Yi Luo/Lynn Pogson	Canadian Ice Service, Environment Canada	(3.7) Canadian Ice Service Satellite-based Ice Monitoring: Optical Data Applications/ The Regional Ice Prediction System (RIPS) version 2.1
14:50	Kaan Ersahin	ASL Environmental Sciences Inc., Canada	(3.8) Characterization of Hazardous Ice using Spaceborne SAR and Ice Profiling Sonar: Preliminary Results
15:10	Naomi Short	CCRS, NRCAN, Canada	(3.9) Validation of DInSAR displacement measurements in permafrost environments
15:20	Thomas Puestow	C-CORE, Canada	(3.10) Polar View – Lessons Learned for the Validation and Evaluation of Operational Arctic Monitoring Services
15:50	Discussion		
16:00 16:15	Coffee Break		
16:45	Conclusions and recommendations – Way forward Chairs: B. Bojkov and Y. Crevier		
18:00	End		

NOTES

NOTES