Natural Resources Canada | Ressources naturelles Canada

GEOMATICS CANADA
OPEN FILE 18

Earth Observation for Improved Regulatory Decision Making in Alberta – Workshop Report

R. De Abreu, S. Patterson, T. Shipman and C. Powter

2015

Canada

GEOMATICS CANADA
OPEN FILE 18

Earth Observation for Improved Regulatory Decision Making in Alberta – Workshop Report

R. De Abreu[1], S. Patterson[2], T. Shipman[3] , C. Powter[4]

[1] Natural Resources Canada – Canada Centre for Mapping and Earth Observation, Ottawa, Ontario.
[2] Government of Alberta -- Innovation and Advanced Education, Edmonton, Alberta.
[3] Alberta Energy Regulator – Alberta Geological Survey, Edmonton, Alberta.
[4] Enviro Q&A Services, Edmonton, Alberta.

2015

©Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources Canada, 2015

doi:10.4095/296799

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

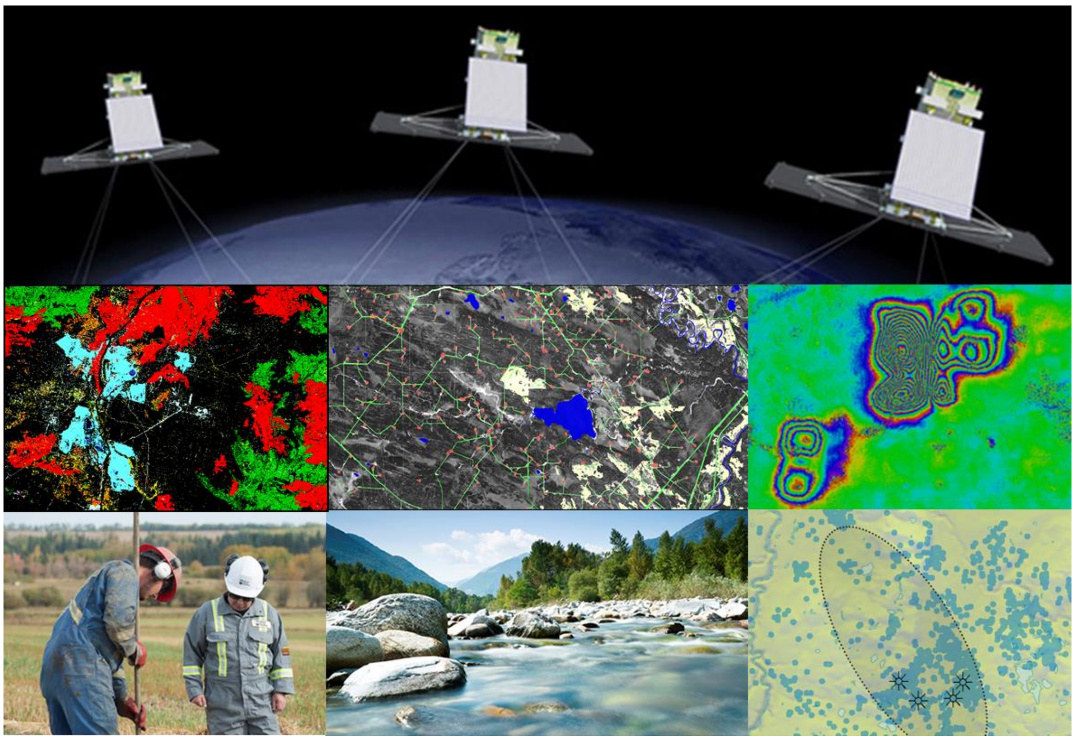
Recommended citation
De Abreu, R., Patterson, S., Shipman, T., and Powter, C., 2015. Earth Observation for Improved Regulatory Decision Making in Alberta – Workshop Report; Geomatics Canada, Open File 18, 178 p. doi:10.4095/296799

Publications in this series have not been edited; they are released as submitted by the author.

EARTH OBSERVATION FOR IMPROVED REGULATORY DECISION MAKING IN ALBERTA

WORKSHOP REPORT

March 2015



Workshop Sponsors:

Alberta Energy Regulator (AER)
Alberta Environment and Sustainable Resource Development
Alberta Innovation Advanced Education
Canadian Space Agency
Natural Resources Canada

Report Prepared for Natural Resources Canada by Enviro Q&A Services

Natural Resources Canada
Ressources naturelles Canada

Canada

ACKNOWLEDGEMENTS

Canadian Space Agency supported the facilitation of the workshop and creation of this report through Government Related Initiatives Program funding to the Canada Centre for Remote Sensing.

The following members of the Workshop Steering Committee helped scope the project, the survey and the workshop:

Roger De Abreu	Canada Center for Mapping and Earth Observation / Canada Centre for Remote Sensing
Shane Patterson	Government of Alberta, Innovation and Advanced Education
Todd Shipman	Alberta Energy Regulator – Alberta Geological Survey
Bob Sleep	Government of Alberta, Environment and Sustainable Resource Development

Enviro Q&A Services is grateful to Shelagh Pyper, Fuse Consulting Ltd., for summarizing the presentations and discussion sessions on Day 1.

REPORT CITATION

This report may be cited as:

De Abreu, R., Patterson, S., Shipman, T., and Powter, C., 2015. Earth Observation for Improved Regulatory Decision Making in Alberta – Workshop Report; Geomatics Canada, Open File 18, 178 p. doi:10.4095/296799

COVER PAGE GRAPHIC SOURCES

Top: Canadian Space Agency.

Middle: Natural Resources Canada

Bottom: Alberta Energy Regulator

TABLE OF CONTENTS

EXECUTIVE SUMMARY

On February 26, 2015, scientists from Natural Resources Canada's Canada Centre for Remote Sensing presented their research related to the use of Earth observation (EO) technology for more effective regulation of resource development activities in the province of Alberta, with a strong focus on the oil sands region. The workshop was attended by 57 people from the federal government, Government of Alberta, academia, resource industry and the Earth observation service and products industry. This EO research involved various collaborations within and between federal (NRCan, Canadian Space Agency, Environment Canada) and provincial departments/agencies (Alberta Energy Regulator – Alberta Geological Survey, Government of Alberta - Environment and Sustainable Resource Development, Government of Alberta - Innovation and Advanced Education) and academia (U. Victoria, U. Lethbridge, U. Calgary). Also included in the workshop were presentations from the Canadian Forest Service related to their current and planned research activities in the region. Presentations were also given that articulated provincial and federal priorities around the responsible development of resources and the larger needs for environmental monitoring and data management in Alberta. Further perspectives on the use of EO within Alberta were also gathered via a pre-workshop survey.

The NRCan pilot projects spanned high resolution monitoring of production activities (i.e. land disturbance and in-situ related ground deformation) to regional change monitoring of vegetation, water and freshwater ice. Each clearly demonstrated the potential of EO to support key Alberta environmental initiatives, including: energy industry regulation, environmental monitoring, regional planning, and emergency management. Together, the 2011 and 2015 workshops, survey and pilot projects point to the conclusions and recommendations briefly described below. Each of these is further expanded upon within this report.

1) The pilot science projects have proven that EO can provide relevant and valuable information to inform and enhance monitoring in support of Alberta's management and regulatory frameworks. An example being AER's move to Play-Based Regulation. This will require, continued collaboration with scientists to understand the role of EO in the monitoring and regulation of rapidly expanding unconventional oil and gas extraction within Alberta is a priority.

2) Further development of the concept of operations and business case for integration of EO into the management and regulatory frameworks is required before EO can play a formal role in integrated resource management in Alberta. The success of these pilot projects has launched this development within the AER.

3) The transition of these and other techniques into operational management and regulatory frameworks will require further user investment in highly qualified people and/or services. Opportunities exist to leverage support from innovation funds and commercial service providers.
4) Future activities to move EO science and technology further down the value chain and into operational use should be supported by multi-sector teams (govt., commercial, academia) from the beginning to ensure good business focus is being combined with the best science and the road to implementation is understood and ready.
5) Given the significant national and international investment in constellations of EO satellites (e.g. RCM, Sentinels) and the ever increasing availability of open EO data, further investments by stakeholders in moving EO science into Alberta's management and regulatory should be considered timely, strategic and given priority.
6) The successful implementation and use of EO science and technology in Alberta's Integrated Resource Management System (IRMS) depends strongly on the existence of a sophisticated spatial data infrastructure (such as GeoDiscover Alberta at the provincial level, and the Federal Geospatial Platform at the federal level) that will enable the smart integration and use of EO information demonstrated in these pilots.

A 5-year roadmap, guided largely by the results of the pilot projects and the activities over the last four years, has been developed to identify which regulator business needs could be met by EO information and on what timescale (i.e. <2, 2-3, 4-5 years).

Finally, beyond the science, the workshops and pilot projects have resulted in an effective dialog between sectors that must be sustained to ensure the full impact of these activities over the last four years are realized. While there remains much work to do transitioning this research and development into operational workflows, the stage has been set to help ensure EO contributes at its fullest potential to the shared priority of responsible resource development in the oil sands.

1 INTRODUCTION

A workshop on Earth Observation (EO)[1] Monitoring of the Oil Sands was held in Edmonton, Alberta in 2011. Fifty-two participants from provincial and federal government agencies and academia attended the workshop, and discussed issues and opportunities surrounding EO monitoring in Alberta, specifically, the oil sands (Ryerson 2011).

The 2011 workshop had six objectives:

1. To better understand the monitoring and surveillance requirements of the regulatory agencies with responsibilities in the oil sands in terms amenable to remote sensing and Earth observation science;
2. To review the current capabilities of remote sensing and Earth observation technologies as they relate to the oil sands environment;
3. To better understand the potential for remote sensing science and technology in the monitoring and surveillance of oil sands environmental performance;
4. To identify existing and proven technologies that can meet the regulatory information requirements now;
5. To develop concepts for potential operational projects, validation or demonstration projects, and research projects; and,
6. Identify the gaps in information and the research and development needed to develop and demonstrate remote sensing and Earth observation technologies in the future to, where possible, fill these gaps.

On February 26, 2015 researchers from the Canada Centre for Remote Sensing (CCRS) (Natural Resources Canada -- NRCan) presented their research related to earth observation technology in a workshop. This was attended by 57 participants from the federal government, Government of Alberta, academia, resource industry and the Earth observation service and products industry. Many of these projects were developed as a result of the 2011 workshop in which several project themes were identified; these themes, in turn, led to the development of several pilot projects that were implemented to demonstrate the application of earth observation technologies (Figure 1). Over the last three years, this work, supported by funding

[1] While it is recognized that the term Earth Observation can refer to the holistic collection of terrestrial, airborne and space-borne measurements, for the purposes of this report the term refers only to the airborne and spaceborne collection of remote sensing data.

from the Canadian Space Agency and Natural Resources Canada, involved various levels of collaboration with the Government of Canada, Government of Alberta, and academia.

The intent of the 2015 workshop was to:

- Communicate the results of the collaborative work completed since 2011;
- Present on invited topics such as future earth observation missions, hyperspectral data, and the geospatial infrastructure in Alberta;
- Gain insight into the operational role that earth observation technologies can play in Alberta; and,
- Identify gaps and opportunities in the area of earth observation as they might apply to Alberta.

In addition to the workshop, a pre-workshop survey was conducted to document participant experiences with conducting EO projects. This report summarizes the results of the survey and workshop, and provides recommendations for moving forward.

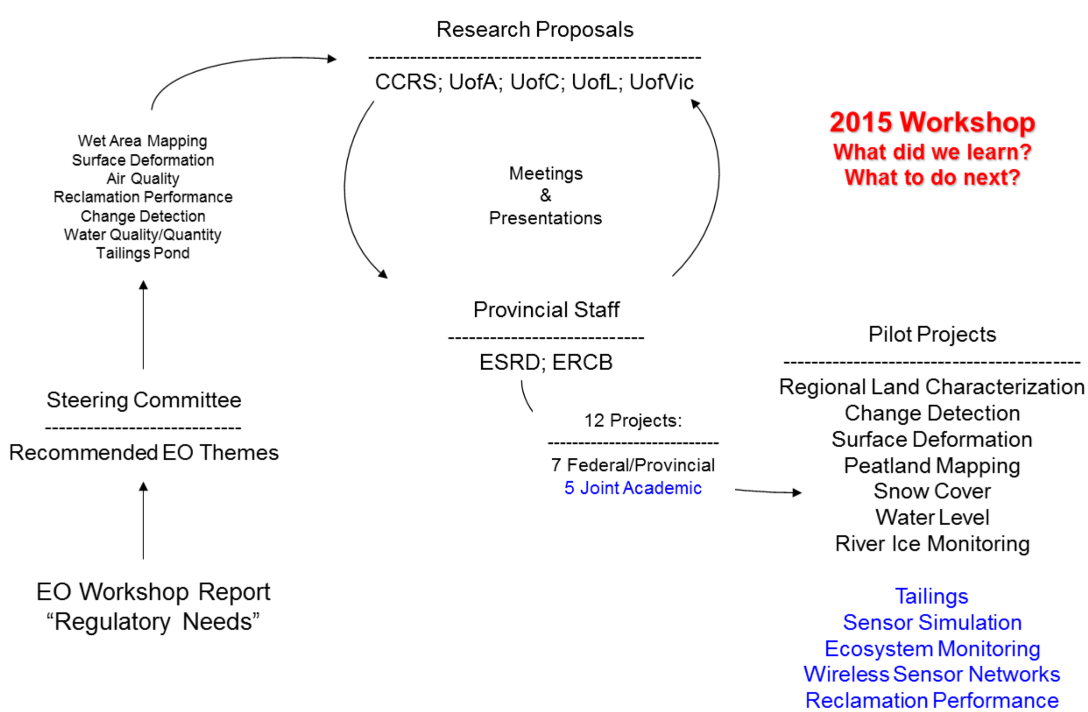


Figure 1. Activities undertaken between the 2011 Workshop and the 2015 Workshop.

1.1 WORKSHOP FORMAT

The Workshop structure was developed by a provincial and federal government Steering Committee. A total of 57 people from provincial and federal government, academia, resource industry and the EO service and products industry attended the Workshop held in Edmonton on February 26 and 27, 2015 (Appendix 1). The final Workshop Agenda (Appendix 2) was a combination of presentations about the pilot projects undertaken since 2011 (Appendix 3) followed by groups discussions.

1.2 SURVEY PROCESS

Discussions amongst Steering Committee members, and with the people carrying out the pilot projects, identified a number of positive and negative learnings arising from the pilot project experiences. The Steering Committee decided to capture these learnings through a pre-Workshop survey (Appendix 4) that was distributed by e-mail to the people on the Workshop invitation list. The survey was sent on February 4 with a request to complete it by February 19; additional time was allowed after the Workshop for participants to submit responses.

2 DAY 1 – WORKSHOP PRESENTATIONS AND DISCUSSIONS

Copies of all of the presentations are available in Appendix 3. A link is provided in each of the sections below to the speaker's presentation. Key points from each presentation are listed along with a summary of the Q&A session that followed.

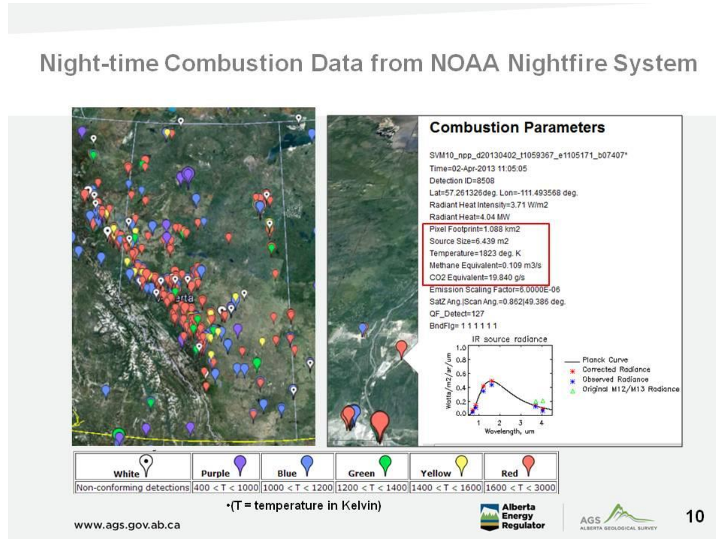
2.1 AGS/AER AND CCRS COLLABORATIONS

Andrew Beaton, Alberta Energy Regulator – Alberta Geological Survey

Key points from the presentation were:

- The AER wanted to demonstrate application of EO technology for monitoring, regulatory support and risk identification
- EO technology is suitable for monitoring and assessing a variety of issues of interest to the AER – e.g., flaring, geohazards, pipeline spills

- The AGS-CCRS collaboration has resulted in technology transfer and development of in-house expertise in a wide range of EO applications.
- We have demonstrated the utility of these applications within AER/GoA for monitoring and risk assessment to support land use stewardship and regulatory processes



2.2 EARTH OBSERVATION FOR RESOURCE DEVELOPMENT

Yvan Desy, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:

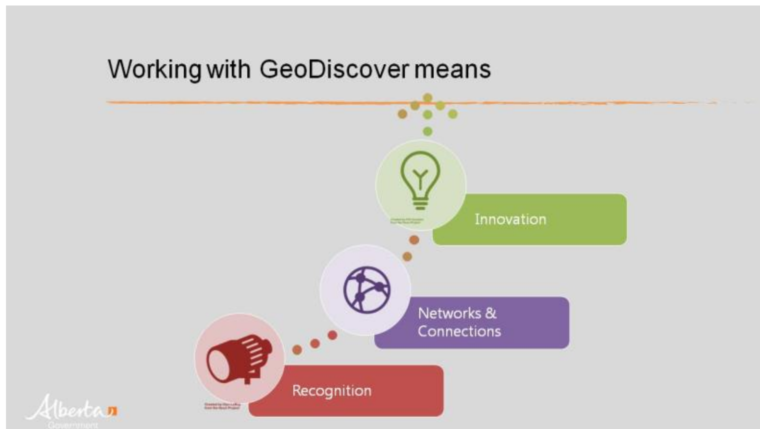
- Canada Centre for Mapping and Earth Observation (CCMEO) created June 2013 as a result of a merger of Canada Centre for Remote Sensing (CCRS) and Mapping Information Branch (MIB)
- CCMEO provides the GoC access to valued earth observation and geomatic data streams along with value-added products and expertise
- Canada invests significantly in Earth Observation – it has tremendous potential to monitor and understand environmental impacts
- Overall objective of the pilot projects was to ensure the full value of EO is understood and applied by regulators (and industry) in support of the responsible management of the oil sands resource

- In the future, CCMEO is targeting greater integration of EO and cartography, and development of a service-oriented Geomatics and EO infrastructure
- CCRS would like to see operationalization of the extensive research undertaken to date

2.3 GOVERNMENT OF ALBERTA REMOTE SENSING INITIATIVE

Daryl McEwan, Environment and Sustainable Resource Development (ESRD), GeoDiscover Alberta

Key points from the presentation were:



- GeoDiscover is accountable to ensure the interoperability, effective management, and broad availability of foundational geospatial data across the Government of Alberta and to Albertans.
- GeoDiscover uses national standards for interoperability and data management, and ensures foundational data assets are collected, catalogued, and maintained in an open and interoperable manner[2]
- By show of hands the majority of people in the Workshop were aware of GeoDiscover
- Data sharing is two-way – data comes in from partners, is housed in the portal and is available to other users; the portal connects users with the owners/creators of data
- GeoDiscover accesses other portals rather than trying to recreate them

Q: Could you comment on the national standards you mentioned? What level of collaboration do you have with the federal government?

A: We've adopted all the standards working with the geospatial groups. As we move forward we're closely connected to ensure inter-operability.

Participants can e-mail Daryl McEwan directly or through the GeoDiscover portal with more questions.

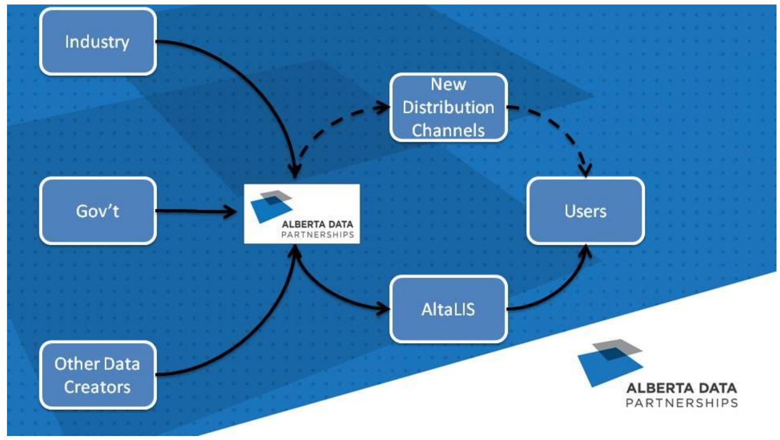
---

[2] See CEOS Data Policy for examples of data policies, data access portals and interoperability protocols – http://www.ceos-datapolicy.org/

2.4 GEOSPATIAL DATA ACCESS IN ALBERTA

Erik Holmlund, Alberta Data Partnerships

Key points from the presentation were:



- Alberta Data Partnerships formed in 1996 to take over digital mapping activities, at that time primarily Cadastral Mapping
- AltaLIS selected as private sector operator in 1998 to complete Cadastral Mapping and has continued to produce and distribute other mapping products under license to ADP
- High level technical working groups help develop a product from idea to operations; External Advisory Groups focused on specific products meet to provide advice to ADP; true engagement that is working
- Stakeholder engagement is an important tool allowing ADP to improve services and delivery – a Stakeholder Forum in 2000 produced a list of recommended upgrades that were subsequently completed; further Stakeholder Forums held in 2006 and 2012
- Two datasets are needed to enhance Alberta's base mapping; a complete map of interests on the land, and Human or Anthropogenic Footprint
- Open to new opportunities and working with new companies who could act as a distribution channel; also actively looking for new data sets
- Municipalities and GoA are embracing open data, but industry would prefer to pay so there is more 'accountability' from their perspective; ADP is working to increase understanding of open data

Q: With open data and data becoming free and available to the public your revenue will decrease over time; in the future will you join the GeoDiscover team?

A: In terms of future business model we think more open data for us is good, it takes some of the data that were considered 'value added' in the past and this becomes foundational data and then other new data comes in to fill that gap and people will pay for the new data. There will always be new data that wasn't available before and people will pay for those data.

Comment: The government should pay for this new data.

A: Not everyone thinks government should pay.

Comment: These assets are infrastructure for our society (paying for data is like toll roads, the government should build the data infrastructure just like they build roads).

A: I agree the infrastructure is for public good but how do you pay for this infrastructure? There are lots of perspectives on this and we would love to discuss further.

Q: You mentioned there are needs for new mapping – one map layer you didn't mention was classification by ecological system – ecosites, this is key.

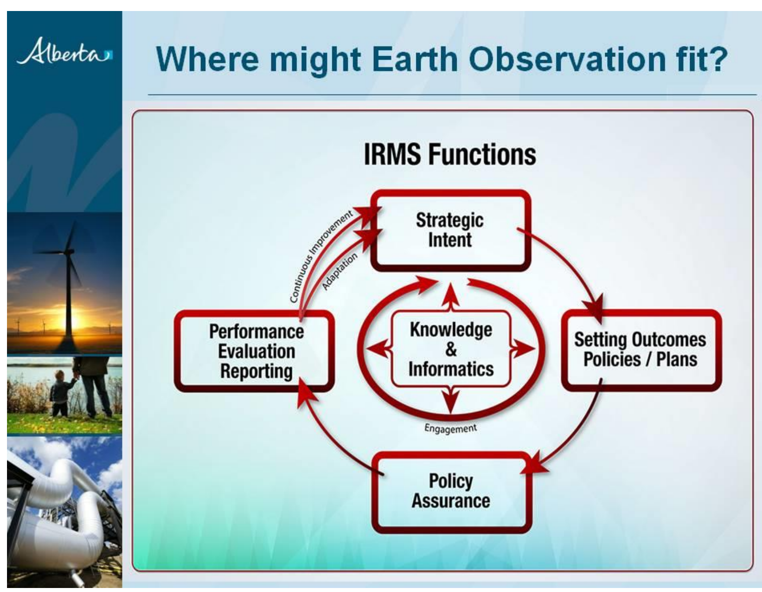
A: Some people think of this as part of the base of the human footprint map. The final workshop proceedings (from the stakeholder workshop described in the slides) are available and ecological mapping was listed as a priority there, but most stakeholders are more concerned about what helps them get their work done – but yes this is important.

Q: Products seem to be mostly vector type data, do you serve imagery. Is it your plan to make imagery available in addition to vectors?

A: We serve up imagery in a couple products – some delivered to GoA for their exclusive use. The stakeholder group hasn't shown an appetite for province-wide imagery data; doesn't mean we aren't interested but we take direction from stakeholder group. We have had discussions about making imagery data more widely accessible.

2.5 ROLE FOR EO IN AN INTEGRATED RESOURCE MANAGEMENT SYSTEM

Ken Greenway, Environment and Sustainable Resource Development, Integrated Resource Management System (IRMS) Office



Key points from the presentation were:

- Integrated Resource Management System is the means by which Alberta will achieve responsible resource development (balancing social, economic & environmental outcomes).
- A key outcome of IRMS is open and accessible data for multiple uses and users; viewed as an asset to be shared

- Roles for EO in IRMS include: data to support cumulative impact understanding and decisions; and, detecting natural and anthropogenic change (and subsequent recovery)
- EO provides information at multiple scales and over time and data that supports a wide range of user needs
- Using data for a single use is no longer of value – everyone needs to be able to access each others' data

Q: If you were looking at changes (how, when, where and why) and that information lies with AER, how does that relate to what you're doing – you have five players, that's where the substance lies (the spatial data, info, etc.) – where do you fit into that? Are you the executive summary of all of that?

A: IRMS is about interactions across multiples scales (AER has some data, as well as four other players) and there are constant interactions between them. We say "Here's what's happening here and this feeds into a local management plan (for example) and then flows back and forth. If there were five things all stacked up into silos that would be a mistake; the five all need to communicate consistently so everyone knows what everyone knows all at the same time. The idea is that there is constant information flow back and forth.

Q: To be sure I understand, you're managing the relationships between these agencies, so IRMS is a management of relationships rather than the management of the data and the infrastructure for exchanging the data?

A: We are an office that supports the systems. Where we can strengthen relationships that's great, but we can also help build systems for data integration. So yes, fundamentally relationships but also building processes for interaction of data.

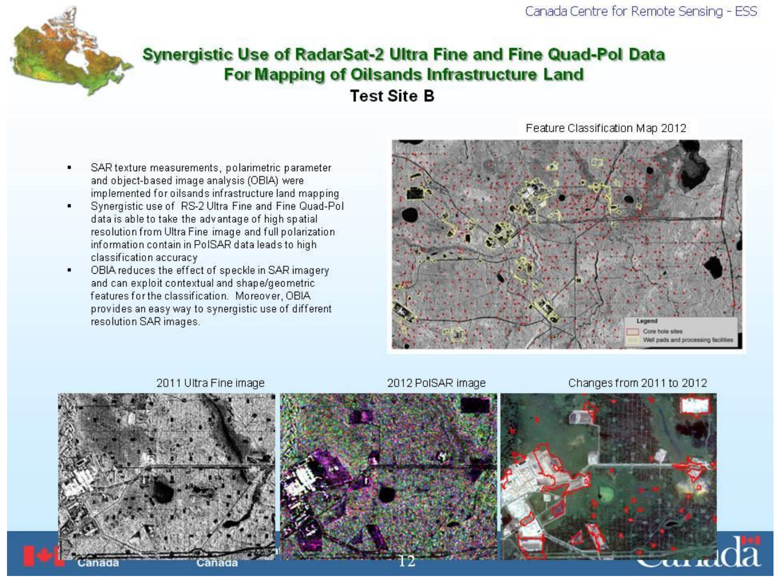
2.6 INFRASTRUCTURE MONITORING WITH EO

Ying Zhang, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:

- Sensor selection and assessment must be based on the trade-off between cost and information potential.
- Methodologies developed were assessed for oil sands mining, in-situ oil sands and upstream oil and gas sites using SPOT5, RapidEye, RadarSat2 and Pleiades platforms

- Confidence in the ability of the technology to accurately represent the attribute being measured is critical to successful implementation
- Object-based Accuracy Assessment is currently very time consuming, improvement of the assessment efficiency is needed.
- The project demonstrated that the methodologies can provide enhanced information to support regulatory monitoring activities



Q: What was the benefit of combining optical and radar?

A: Radar imagery is not affected by clouds, we have to use radar data when no cloud-free optical data is available. The change detection using optical and radar (but not radar only) data increases accuracy because the preprocessing of radar data reduces the resolution, use of optical data increases the sharpness of the result.

Q: Purchasing the two together – what is the ratio of increased cost?

A: Optical with reasonable resolution costs less so the total cost is actually less.

Clarification: Using Landsat and Sentinel data are free, so if you can use data from these two platforms with no data cost and also radar cuts through clouds, so if you want to revisit a site over time you may need to move to radar.

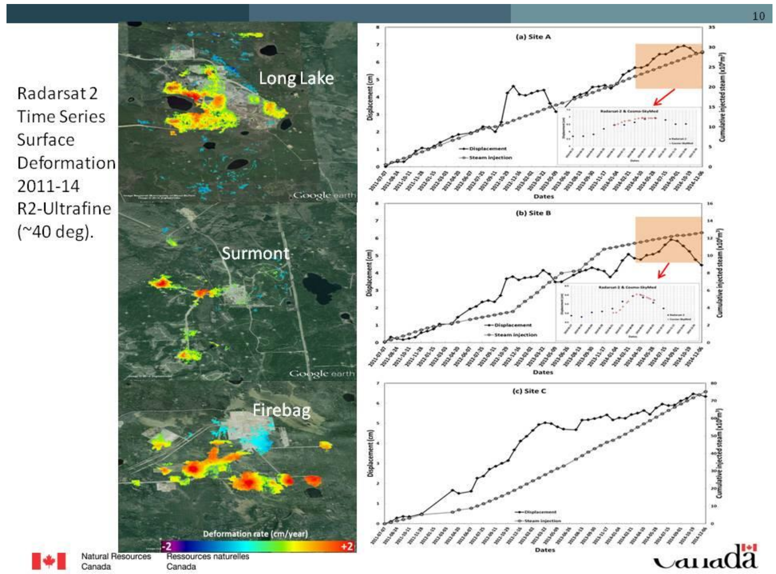
2.7 MONITORING STEAM-ASSISTED EXTRACTION WITH INSAR

Vern Singhroy, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:

- InSAR was used to evaluate surface heave at four SAGD and CSS sites
- Heave at SAGD sites was considerably less than at CSS sites (2 cm/yr vs. 450 cm/yr, respectively)
- Assessed 8 scenes from Fox Creek in an attempt to identify heave from recent seismic activity; trees created problems with coherence

Q: I would have thought that the more frequent visitation would be more important for CSS, can you explain why you did more frequent visitation for SAGD?



A: We were not focused on Cold Lake originally; we went there when they had the spill. We didn't realize it was swelling that much.

Clarification: Initially our plan was to have cyclic steaming as part of it, but we became more realistic after doing site visits and decided to look at SAGD. But we are still looking at cyclic steaming. InSAR are great measurements but the question is So What? Is it important? Does rapid movement lead to failure in the sub-surface?

A: What's critical is that the remote sensing imagery is allowing us to refine our modelling on the steam expansion side. AER is revising their models based on our measurements in SAGD.

Clarification: I think the frequent revisiting will be helpful in cyclic steaming. SAGD is where we went first and CSS is where we could go next.

Q: From a geotechnical perspective, is the heave more important or the settling back later on?

A: Luigi is looking at that – we tend to have/expect settlement but we're seeing expansion. What's the geology of that specific site? What's the depth? One doesn't fit all, I don't know if heave is more important than sag.

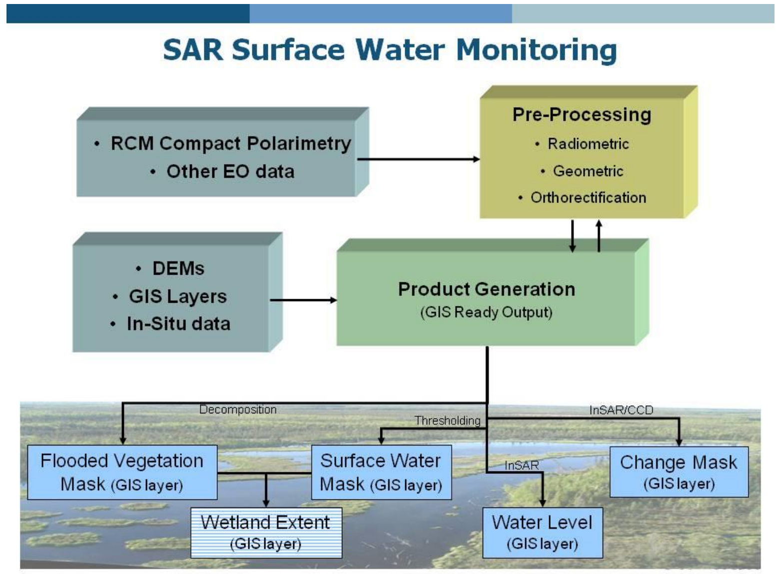
2.8 SURFACE WATER MAPPING IN THE AOSR WITH SAR

Brian Brisco, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:

- There is no accurate map layer for surface water for the PAD or for many other areas in Canada
- InSAR can produce water level changes with sub-cm accuracy given the right conditions; we can use coherence to identify ephemeral and seasonally flooded vegetation
- EO provides spatial data vs. point data for hydrometric stations

- Many project partners are interested in temporal surface water extent products
- Can convert the product to a GIS map
- 24 day repeat for InSAR allowed “monthly” products during the ice-free season
- RCM rapid revisit will generate “weekly” products with 3 to 5 m resolution

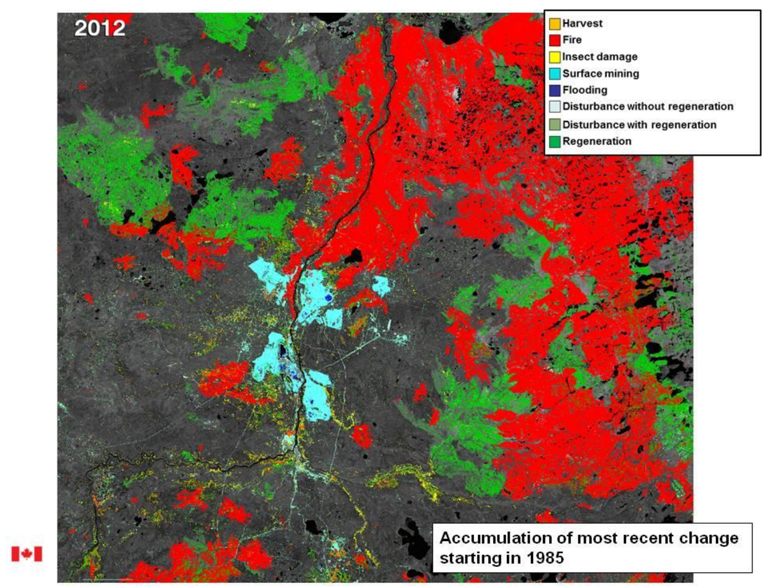


2.9 VEGETATION AND LAND USE CHANGE IN THE AOSR

Darren Pouliot, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:

- Long term satellite earth observation time series are a form of big data that federal and provincial governments need to effectively handle. Future satellite missions will amplify this requirement. In response CCRS has developed a research software platform to process and manipulate remote sensing big data.



- The project contributes to cumulative environmental impact assessment in two ways: (1) Passive monitoring of land surface conditions (Leaf Area, land cover, phenology); and (2) Active approach by integrating models with remote sensing inputs.
- Remote sensing and geospatial information technologies have the ability to monitor how human activities impact the environment on local, regional, national, and global

scales. Changes can be attributed to causes such as fire, harvest, flood, insect damage, etc. as well as more basic categories such as gradual or abrupt change events.

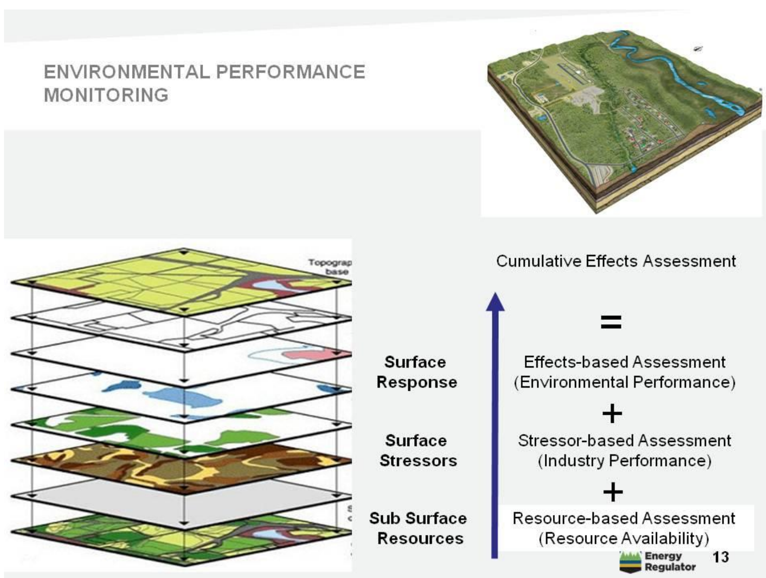
- Results are supporting impact assessment, air quality monitoring, carbon modeling, and phenology information requirements.

2.10 POTENTIAL FOR EO FOR AER OPERATIONS

Monique Dube, Alberta Energy Regulator (AER)

Key points from the presentation were:

- The opportunity for EO and remote sensing is significant but the innovation needs to be directed by the business needs; think we have the technology but don't understand how it plugs into business
- Storage and integration of data is so critical it should be the first thing to be achieved and the last thing taken off the resource plate, but this goal has not been achieved and we are in catch up mode
- AER wants to
    - Monitor environmental performance – Linking environmental performance to industry performance monitoring through performance metrics, triggers, and thresholds
    - Track environmental state – Linking subsurface to surface, existing state assessment linked to future environmental state assessment based on predictive resource development forecasts
    - Implement trans-disciplinary environmental issues coordination and integration – Issues that span across sectors, multiple environmental disciplines or applications
    - Support Government of Alberta policy development



- AER could use EO for:
    - Authorizations: what exists now on the land? How close are we to the stressor & response lines? Will this project proposal put us over? Can we justify the level of monitoring requested in the approval based upon the environmental condition?
    - Enforcement & Compliance: Are there changes occurring that relate to complaints? What level of investigation is required if the environment is stable?
    - AGS: Are there areas where resource development can be accelerated as environmental risk is low and the environment is stable?
    - Strategy & Regulatory: What are the environmental changes that have occurred? Is regulatory revision required?
- Data management is a big factor in the success of environmental management

Q: Given we [scientists] have worked on these projects and have some gold nuggets, what I would like to see (since we started the conversation 5 years ago) is for regulators to take the technologies and move them further – I'd like to see AER have an action item to start using this tool. One stumbling block is governance (rules, industry participation, regulations; you are a model organization for Alberta and Canada to try this. You have the data, the regulation, industry, etc. so make the data an integral part of the governance structure.

A: I need you to communicate back to me my business structure so I know you understand our objectives and mandate and we can move our needs forward. I keep feeling there's a gap. I need to know how this technology (the bridge you're trying to sell me) is going to advance our business decisions. Is the technology put in the context of protecting the environment?

Q: We have the gold nuggets and bridges to sell, what I'm saying as an academic is we need to pick the gold nuggets, take the geomatics and make it a PanCanadian strategy. The Alberta model could be a case study.

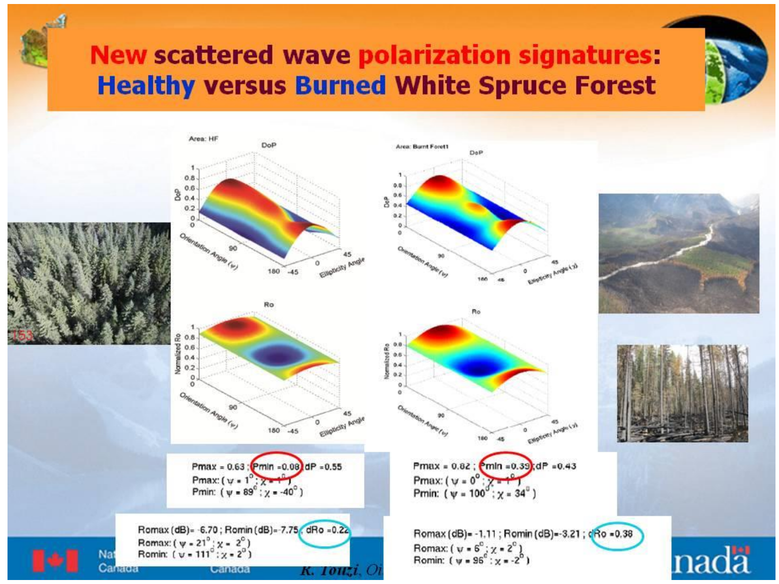
A: We're trying to get IRMS partners working with a team of folks where we can agree on the framework and who is best to do each piece. We have the technology, the vendors, and the scientists so plug it in.

Comment: We need a strategy.

2.11 MONITORING PEATLAND TRANSFORMATION WITH SAR

Ridha Touzi, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:



- An improved wetland inventory in Alberta's northern boreal forest would support advances in wildfire management planning and strategic wildfire suppression
- Optical sensors don't do an adequate job of discriminating peatland types (e.g., bog vs. fen) when water is below the vegetation/soil interface; Landsat combined with polarimetric L-band ALOS produces accurate peatland inventory
- Archived Polarimetric Satellite L-band SAR provides a cost-effective source of information for long-term monitoring of peatland changes

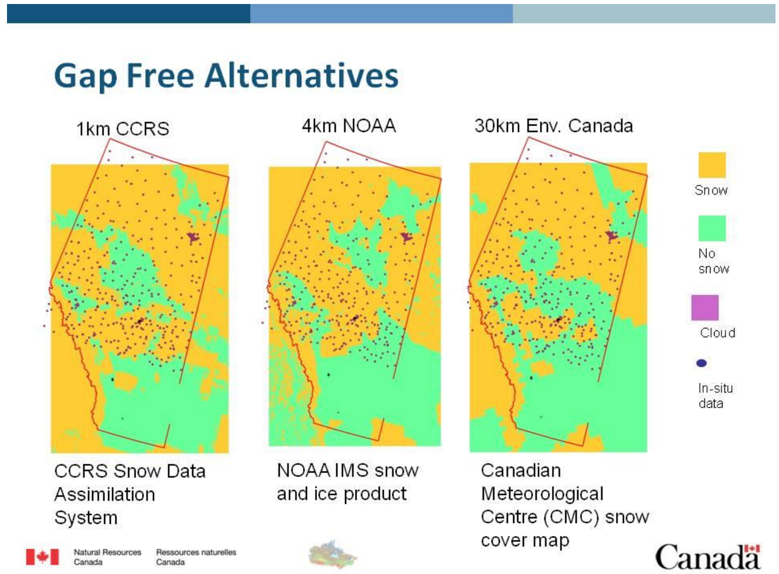
2.12 SNOW COVER MAPPING IN THE AOSR

Richard Fernandes, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:

- Between 1,000 and 2,000 wildfires per year; over half occur in May – snow melt over frozen ground leaves dry organic layer with high fire danger; therefore snow cover time series required to map fire danger.
- AESRD snow cover maps based on 500 m resolution MODIS daily snow cover maps (4 day moving window composites)
- CCRS Snow Data Assimilation System offers 100% coverage vs. 25% cloud-cover gaps for AESRD; both systems show similar uncertainty in melt date prediction (7 to 8 days)
- Inexpensive drone data acquisition for small areas produces useful information that can be used to validate other data sources

Q: On the figures comparing ground-truthed and satellite information, there's a huge amount of variability (2 months).

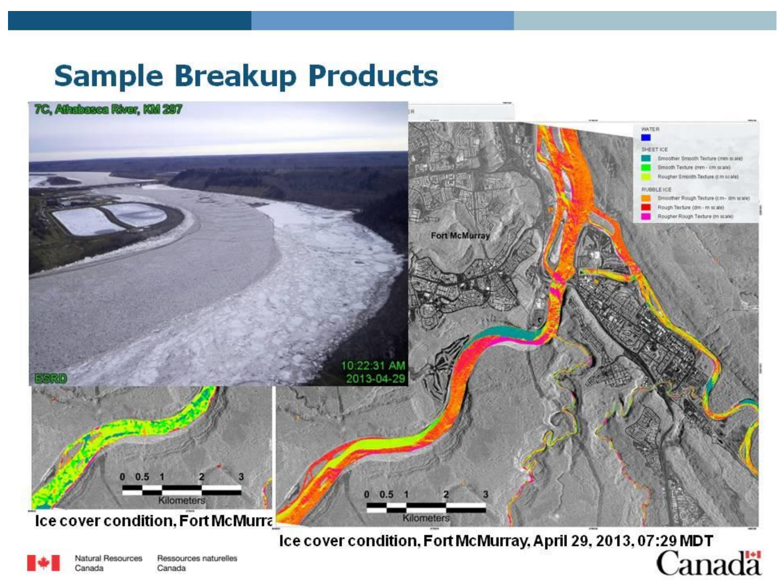


A: Those are different sites at different locations where the snow melts much earlier or much later, focus on the 1:1 ratio of each. We went and followed up and what happens is in a clearing snow melts faster than in a forest producing a systematic bias, but even removing the bias an error of 5 to 7 days is not great.

2.13 MONITORING ATHABASCA RIVER ICE DYNAMICS

Roger De Abreu (for Joost van der Sanden), Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:



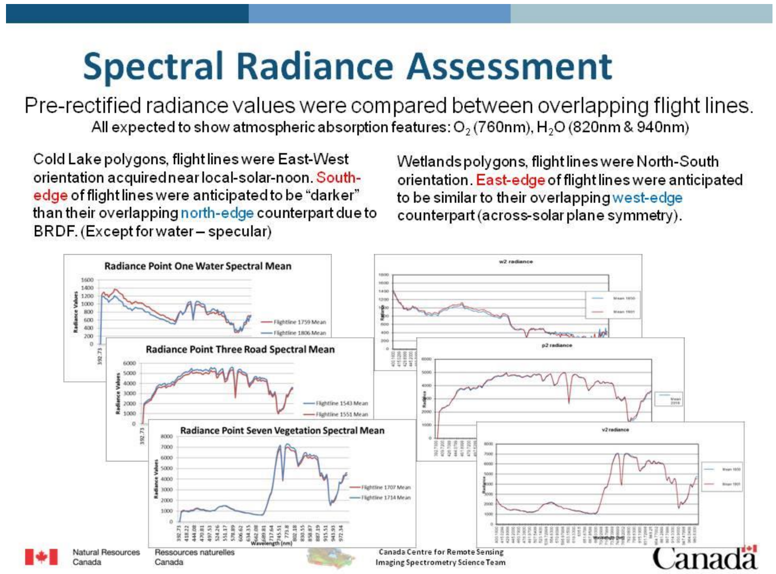
- CCRS has been studying the use of SAR for river ice dynamics under a variety of contexts: climate change, flooding, ice road integrity and now river management in the AOSR.
- EO and on-site cameras used to monitor freeze-up and breakup of the Athabasca River. Peace R. studied as well in Peace Athabasca Delta
- RADARSAT can systematically monitor the presence of river ice, its freeze-up and break-up – all relevant to understanding hydrology and management of the regional rivers.
- Ice-off is easier to detect than freeze-up with SAR

2.14 THE AOSR HYPERSPECTRAL DATASET: STATUS AND OPPORTUNITIES

Peter White, Natural Resources Canada – Canada Centre for Remote Sensing

Key points from the presentation were:

- EO outputs need to be processed, validated and corrected when anomalies are identified
- Flight-line orientation leads to "shadow" effects that must be adjusted; prefer to fly towards the sun or away from the sun
- Space-borne sensors can be used to help direct airborne or field assessments



Q: You have a lot of good data here – I'm sure you'll be able to squeeze a lot of stuff out of it. Remind me, did you collect field data at the time of overpass?

A: Some was done at time of overpass, some of it wasn't. The Cold Lake was done by UofL during overpass, for Fort McMurray there was a mix.

Q: Have you seen any interesting results that could be published?

A: Conference publications on vegetation cover, species types. Active research on things like tailings ponds spectral with no result yet. UofL has the most results to date. UofA did some good work on tailings ponds spectra.

Q: You said in ten years you'll have weekly data rates, will that be drones or space borne? How will these faster revisit rates help with monitoring?

A: Some changes that might occur on the ground might be overnight or seasonal events, like water quality in the case of spills – maybe should have said 20 years not 10 years. Referring to space borne, there are lots of upcoming missions – Canada has proposed several missions in the next twenty years, Italy has proposed some also. I prefer hyperspectral work but there are some spectrally intense missions. Once all these things get flying it's going to be hard not to get data.

Q: Are you thinking of developing a spectral library for your study sites?

A: A spectral library is extremely important, there are ones that exist now. We attempted to use a spectral library produced in Arizona, the chemistry is the same but spectral imagery is different here and we couldn't use their library.

Q: Paul Budkewitsch walked around the Yukon (and other northern landscapes) gathering all these spectra, also my students gathered lots of data but I've never seen it completed. There were certainly a large number of spectral data gathered but they are in an unusable format.

A: Yes there have been lots collected. It's great to report on what data you have and what person reported it, but when the person retires you need to analyze the metadata. Some data have been lost because the idea of metadata and availability is a challenge but getting it in a usable form is a priority.

Q: Sometimes the criteria for collecting data in your model are so stringent we can't put any data into it, so maybe we just need to "drain the swamp" and start adding data.

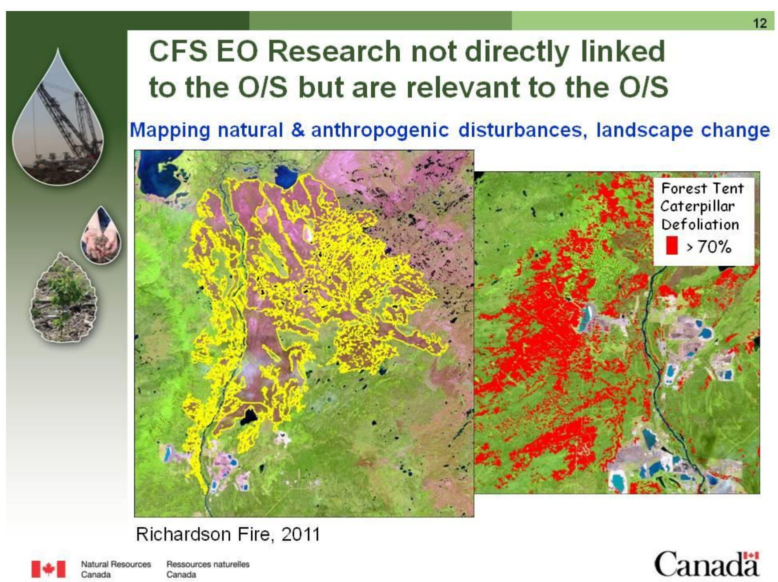
Comment: Before Paul left it was almost done, any chance in reinvigoration the data?

A: We are currently negotiating with NRCan library on how best to get that distributed so there is an NRCan spectral library similar to the one done in the southern US (referring to Arizona).

2.15 CFS ACTIVITIES IN THE OIL SANDS

Brad Pinno and Ron Hall, Natural Resources Canada – Canadian Forest Service, (NRCan-CFS)

Key points from the presentation were:



- The CFS Land Reclamation Project aims to improve environmental performance of Canada's natural resource sectors by creating and mobilizing knowledge and tools to enable a systems approach to integrated resource development thereby mitigating impact on forest ecosystems and informing land reclamation policies and practices
- Most of these projects are field-based data gathering efforts but it is clear that EO technologies have the potential

to supplement the field data gathered (collaboration opportunity); the key is – How do we scale from field to landscape perspective and how can EO help?

- CFS also undertakes EO work related to mapping natural & anthropogenic disturbances and landscape change

Q: I want to point out – I'd suggest on slide 3 you have more roles to add – collaboration or partnership should be one of your objectives, you're moving into a place where people have been doing reclamation for a long time. There is already lots of money being invested into land reclamation research before you were on the scene, I've listened to lots of this work that's been done in the last 20 years. CEMA's been doing similar work (N deposition and stand development and composition), also government was working on landform design over five years ago and similar things before that. When you present it's important to emphasize how what you're doing is different from what's been done before (but still indicate awareness of previous work).

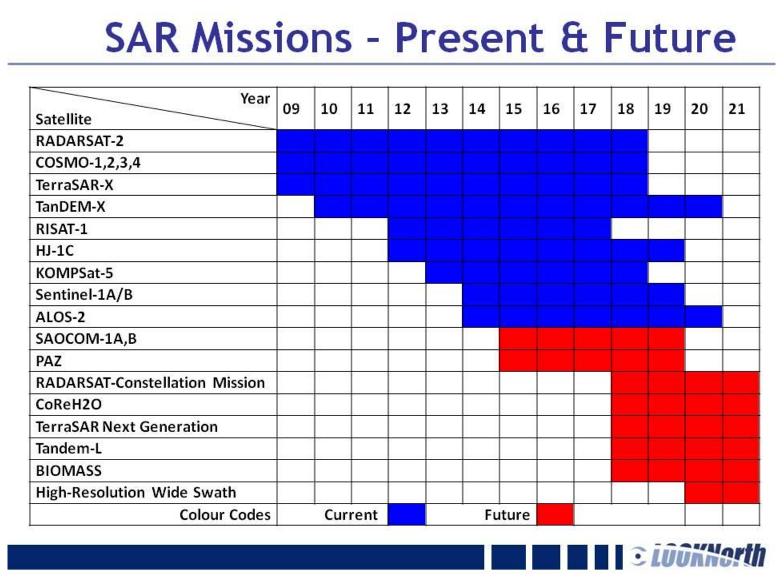
A: Yes, I realize it's important to make it clear how what CFS is bringing to the table is different.

Comment: To be clear, there is no doubt you have a wealth of knowledge to contribute.

2.16 FUTURE EO MISSIONS

Bill Jeffries, LOOKNorthLOOKNorth

Key points from the presentation were:



- Leading Operational Observations and Knowledge for the North (LOOKNorth) is one of 21 Canadian Centres of Excellence for Commercialization & Research (CECR); its role is to validate and commercialize Remote Sensing technologies to support safe and sustainable development of northern natural resources
- There is a broad range of application domains for EO
- An additional 360 EO satellites are to

be launched in the next decade, adding to the already crowded space; Probably won't see more large, complex satellites – now we'll see smaller, more specialized and optimized new satellites with targeted applications like RCM

- Data policies in a number of countries are moving to free and open access with near real time capability; we will see more small start up knowledge transfer companies who can reformat and sell this data.
- Effective EO must meet the 3R's – regular, reliable and repeatable; Constellations give more repeat pass data, with less time between monitoring, and redundancy makes data source more reliable (if one satellite breaks)
- You don't want data users processing radar imagery, it should be processed centrally and then delivered for user-application (this will only work if users trust the data source and processor)
- In Canada we have 50 years of satellite data archived – great continuity of data for monitoring/change detection.
- UAV technology is advancing in a number of applications (e.g., pipeline monitoring, tailings pond emissions, tactical ship navigation

Q: How to change the reality, get the optical people and radar people to talk to each other. Need to combine the sets of information, each person thinks their field is the best. How to overcome challenge of people wanting acquisition free but also today!

A: Google as an example, lots of layers of info and we are adept as users at using the layers of information. We don't care about where the info came from. As EO we need some creative thinking so we come in a say "You are an expert in Polaris, go do it and we'll trust it and incorporate it." Not worrying about the details.

Q: What's your take on UAV – disruptive and proliferating – is there play space for satellite EO and UAV?

A: I think they're strongly complimentary. Great value in easily deployed, cheap UAVs, that can go back and forth and get images from different angles, but if we're looking at mapping all of Alberta you'll need something else – satellite gives a broad perspective. Once you've identified something of interest, go back with UAV. UAV's are great for tactical application: "I know there are these ice conditions over there and I want to know what's up on this ridge. UAV are great at this tactical stuff but satellites have big coverage and repeat passes.

Q: LOOKNorth operating model – you listed many challenges on EO domain, do you have an operating model to facilitate transition [all these new sensors]? Every time a new sensor comes down the pipe it brings new requirements for R&D capabilities of sensors, how to process data, how to use with applications, and then how to integrate with other geospatial data sets in an operating model. Operating model has to change every time new sensor comes down. With all the new capabilities we have a situation where the technology to make a sensor is ahead of our ability to deal with the data, (e.g., shaded pixels, spatial variability that our software can't process). We're constantly catching up on how to deal with new data. Where turn-key application was once there, now a new sensor is going up that will enhance what we have but not fit with this old application.

A: Well said.

Comment: That's why GoC needs national centre for EO. At CCRS there is a struggle to stay within mandate and address issues; at the same time, operational groups don't have capacity to do forward looking R&D. We went wrong putting it in a department because it's difficult to address non-department challenges/needs.

Q: I'm a lay person looking at things on horizon and how they might derail strategies and current opportunities. I'm glad you picked up on idea that Google's map service became free to everyone, I like that you picked up on the change Google has produced in EO. At a conference a person from Google Maps spoke about how to make things user friendly and how an icon would be perceived differently by different cultures. There's lots of interesting info but when it comes to an environmental compliance officer, what I'm not seeing is that level of user interface design and when you look at the map and have this requirement of what it needs to be will the average person know how to deal with that? Is there a push to make this use friendly as it moves to operational stage?

A: You hit the nail on the head. Part of the problem as EO scientists is we like what we do. We're proud of the technology we've got, we have the instinct to show our technology, the problem is we're not thinking how the regulators think. What do you need? Do you care how I came up with it? Or do you just need to know I'm confident in this measurement I can get this climate change indicator reliably and can repeat it later. When the Macondo oil spill happened it was quite the episode from an EO point of view. Everyone was collecting everything. But what do you do with all of this? It turned out Radarsat was a baseline they measured everything else to. Massive problem in putting all the data together. Nobody was thinking about it from the regulatory point of view. What came out of it was a Presidential decree that there was going to be a Lessons Learned report. The report identified a need to develop common operating platform so people could sit down and digest all this data. Need to be able to assemble it and it makes sense to the people who need it. How do you visualize it? Hugely important.

Q: One of the things we looked at, why we developed ISDAS, is because lots of products are based on sensors; highlighted by presentation at a conference about getting Landsat 5 to work with Landsat 7 algorithms. This is not right, so got into ISDAS. One of the things with reliable and regular and all these different sensors is variability and delineation of products, sensors will have different accuracy and you need to understand that to have continuity. We want to understand why different info products are different and provide different accuracy in different realms. How many sensors next decade?

A: 360 in next decade.

Comment: If we don't understand why each sensor gives us different data we'll be lost.

Comment: Add one R – Required. What's required of this data? Why are you collecting the data?

3 DAY 2 – GROUP DISCUSSIONS ON FUTURE ACTIONS

On Day 2 Workshop participants were assigned to two groups: one to discuss project management and funding, and the second to discuss project/program ideas, with the aim of moving the technology from research to operations. The following is a synthesis of the key themes and discussion points that were brought forward that morning.

3.1 KEY COMPONENTS FOR TRANSITION OF RESEARCH TO OPERATIONS

The following components were identified by the break-out groups as being necessary to facilitate a successful transition of these pilots and other EO research into regulatory operations:

- It is hoped that through these pilots, AER and other provincial users can now identify specifically where EO has the potential to intersect and add value. This will help define the various paths to operations and related gates. However, transition to operations of these piloted projects (and other science) cannot begin until there is a clearer targeted operational framework and related workflow. With a clearer understanding of desired operational products, there will be a need to validate technology through more targeted studies with industry and the Regulator so that there is clear definition of product accuracies.
    - For example, will it be used within a threshold/trigger system? If so, regarding what indicators? Will it feed certain predictive models?
- A strong business case will be the accelerant that moves this science down the value chain to operational use. An understanding of how EO could reduce regulatory costs (and by how much) and/or support regulatory outcomes is required. Ultimately adoption of EO should lead to reduction, removal or improvement of traditional data collection methods. This knowledge will drive the business case that underpins

operational implementation – *"I need to know how this technology (the bridge you're trying to sell me) is going to advance our business decisions"*.

- As soon as they are ready, regulators need to make a clear statement regarding their expected investment and use of operational EO. This will serve to spur investment in further research and development and commercial services – all of which is important for the transition of EO into operations. Operational transitions required special skillsets. Multi-sectoral teams, i.e. operational users, EO researchers, commercial service providers, are best positioned to support the operational transition of science. Researchers are needed to support the transition by providing scientific expertise when issues arise. The development of highly qualified personnel who can implement and sustain EO technology is important. Commercial service providers and producers should be engaged and participating in the transition where they can add value.
- EO is but one tool in a regulatory tool chest – it is unlikely to be the decision-maker, rather it will be used for support and confirmation. It must be understood where EO fits into the regulatory system and amongst the various observation technologies already employed within the technology box, i.e. satellite, airborne (i.e., UAVs), Ground Sensors; Spatial Data Infrastructure; Data & Data Management.
- The monitoring landscape (e.g. technologies, mandates) and associated requirements are changing continually in Alberta. Since the start of these pilots, new monitoring needs have likely arisen from the implementation of IRMS, and stand-up of AEMERA and the AER. The development of a matrix that matches needs with technology options to allow easier visualization and communication of options is suggested.
- While there was good support for the focus on operational deployment of the EO science there still exists a need for continued research and development for new technology and science within the context of new resource development (e.g., shale gas, pipelines)in Alberta to move science to higher technology readiness levels.

3.2 OTHER POINTS OF NOTE

- Data Management: EO produces vast quantities of data. These need to be stored, managed, accessed, and transformed into useful products. Data must be efficiently shared between users – historically a problem in government with individual departments purchasing the same data. The push to more open data models will enhance sharing within and outside government. For example, the US National Pipeline

Mapping System (NPMS) is used extensively for industry planning but is also open to the public.

- Although regulatory requirements are the central driver for further operational adoption in Alberta, it is important to recognize the power of other requirements, especially environmental monitoring and emergency management. Free and open access to EO products can also increase larger social awareness of issues and provide stakeholders and ENGOs with authoritative information to support their objectives.
- The group identified the following needs that further encourage the operational deployment of EO in Alberta:
    - Description of the current state of environment (baseline)
    - Systematic monitoring, including the need for early warning of events
    - Change detection and trend identification/prediction
    - Providing critical observational data for downstream predictive models to support improved management and policy decisions
    - Support development of management strategies and standards
- Operational Standards: Combining the needs with the frequency and precision will allow development of operational standards for EO products. With the certainty provided by standards it will become easier to develop a business case for EO deployment. It will also allow the Regulator to incorporate the standard into regulatory requirements which is necessary to drive industry adoption. There was some discussion of the value of certification of people and products as a means of showing value and reliability (e.g., ASPRS certification program).
- Participants acknowledged the value of this workshop but noted that it only focused on NRCan studies – many other EO related studies have been done in the province. They stressed the need for ongoing opportunities to share information across the whole EO/regulator/industry community. Groups such as PTAC, Environmental Services Association of Alberta, LOOKNorth and TECTERRA provide opportunities for knowledge exchange and outreach. Academic institutions are also excellent venues for engaging future researchers and knowledge workers. Examples of user groups were noted in Alberta, British Columbia, NWT and Yukon that allowed for input on product needs and feedback allowing improvement of existing products.
- To inform on EO transition into regulatory environments, Alberta should learn from other users (e.g. forestry, agriculture) who have successfully transitioned EO in this context.
- The following The following funding sources for future work were identified:

- National:
  - Canadian Space Agency (CSA; e.g., EOADP, GRIP, SOAR, etc.).
- Provincial:
  - Government of Alberta: International Technology Partnerships (e.g., Mexico, Germany); Industry Memorandum of Understanding (e.g., GE, Lockheed Martin).
  - Alberta's Innovation System: Alberta Innovates – Energy and Environment Solutions (AI-EES); Alberta Innovates – Technology Futures (AITF) for technology development; and Alberta Innovates Biosolutions (AI-Bio);
  - Organizations such as TECTERRA and LOOKNorth that focus on small and medium enterprises;
- Industry:
  - Canadian Oil Sands Innovation Alliance (COSIA; Land, Water and/or Monitoring EPAs),
  - Petroleum Technology Alliance of Canada (PTAC).

- Establishing a related Centre of Excellence for EO was discussed. Such a provincial centre could fit into one or more of the existing research networks in Alberta. The centre would focus on how to transition EO science and technology into regulatory processes. The Centre of Excellence concept requires a focus on longer-term strategic work rather than short-term focused research. Various regulators and industry would be the clients of the Centre and thus focus its agenda.

4 SURVEY RESULTS

Nine surveys were completed: five government, two industry, one consultant and one from academia. Appendix 5 contains the detailed results, including projects that respondents are working on that they felt would be of interest to the EO/RS community.

Common themes arising from the survey comments include:

- Technology capability and awareness is expanding rapidly but this creates even greater need for products that non-specialists can use and understand; collecting data is but one step, interpreting the data is where the value arises.

- Need for practical applications of technology, related to government-directed requirements; this must be combined with government acceptance of technology-derived data/information in place of “traditional” monitoring.
- Better understanding of the cost-benefit equation could lead to more investment.
- Change detection (especially status and progress of reclamation) was frequently mentioned as a desired application of the technology.
- Scale of measurement must be related to the land management decision(s) required – do we need 1 m resolution when the management tool will be applied at a scale of 10’s to 100’s of metres?
- The most frequently cited impediment to uptake is a lack of awareness/understanding about what EO can do. The next most frequently mentioned impediment – how to use the data – is also an awareness issue.

5 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE ACTIONS

5.1 CONCLUSIONS AND RECOMMENDATIONS

Together, the 2011 and 2015 workshops, survey and pilot projects point to the following conclusions and recommendations:

1. EO has been shown to provide relevant and valuable information to inform and enhance monitoring in support of Alberta’s management and regulatory frameworks.
    a. AER has begun to invest in EO capacity to further their understanding and use of this technology and it is estimated that most can be implemented operationally in less than two years. Continued collaboration with scientists to understand the role of EO in the monitoring and regulation of rapidly expanding unconventional oil and gas extraction (e.g. fracking) within Alberta is a priority and should fit well into Alberta’s new Play-Based Regulation approach.
2. Further development of the concept of operations and business case for integration of EO into the management and regulatory frameworks in Alberta is required before EO can play a formal role in integrated resource management (*The success of these pilot projects has launched this discussion within the AER*).
    a. This will require comparing the value and costs of EO approaches (as shown in these pilot projects) against current methods; and,

b. Understanding the value of EO-based information within various business contexts.

3. Even after a clear understanding of how EO information fits within regulatory workflows / frameworks and a business case is established for investment, there remain significant steps to formally implement these techniques.

   a. Highly Qualified Personnel Development: It was recognized that Alberta will have to invest in highly qualified EO personnel and/or services and related systems to advance operational deployment.

   b. Commercialization and Funding: As well, programs like LOOKNorth, CSA EOADP and Alberta Innovates represent important opportunities for clients to move these techniques downstream towards operational use with the assistance of small-medium enterprises.

   c. Operational Delivery: Commercial remote sensing companies are in place to work with downstream users to assist in the further operationalization and deployment of these techniques and methods.

4. It was agreed that putting EO technology on the value chain and moving it down to operational implementation and use requires a wide variety of skills and competencies, none of which exclusively exist in one sector, be it government, academia or commercial. As such, it was recognized that future activities should be supported by multi-sector teams from the beginning to ensure good business focus is being combined with the best science and the road to implementation is understood and ready. This will require unique integrated funding frameworks that allow resources to move easily between government, academia and commercial project partners.

5. National and international investment in constellations of EO satellites (e.g. RCM, Sentinels) continues to be significant as the number of EO platforms are expected to double each decade. Data policies are moving to cheaper, open data models and coverage is becoming more frequent and reliable. Given this, further investments by stakeholders in moving EO science into Alberta's management and regulatory frameworks should be considered timely, strategic and given priority.

6. It was made clear that potential for EO to have impact on Alberta's management and regulatory frameworks hinges strongly on the province's ability to efficiently and effectively gather, store, integrate and disseminate relevant geospatial information. It was recognized that Alberta's IRMS is an important spatial data infrastructure that will enable the integration and use of EO information demonstrated in these pilots. The strong focus on change detection will place further emphasis on the efficient storage and smart integration of *big* EO data.

5.2 FUTURE STEPS

The research projects clearly demonstrated the potential of EO to support key Alberta environmental initiatives, including energy industry regulation, environmental monitoring, regional planning, and emergency management. The workshop and ensuing discussions indicated that the transitioning of these and other EO techniques into regular, systematic use by regulators will require broader based activity teams working within a clear strategic plan or roadmap.

5-YR ROADMAP FOR THE USE OF EO WITHIN ALBERTA'S REGULATORY FRAMEWORKS

To this end, based on the discussions at the Workshop and considering the apparent needs and interest of Alberta regulatory agencies, the following *5-yr Roadmap for the Use of EO within Management and Regulatory Frameworks* was developed and is recommended (Figure 2[3]).

Each of the bars in figure 2 represents a transition from the current state where technology is used on a case-by-case basis to a future state in which technology is routinely used. Of note is that those business needs that were addressed by the pilot projects are now positioned to be deployed in less than two years with further transitioning support.

KNOWLEDGE EXCHANGE

Finally, workshop participants recognized that since the initiation of the pilot projects in 2012, the regulatory and environmental monitoring landscape has changed dramatically in Alberta and in this timeframe, important and relevant EO research and development has also occurred within other government and industrial activities in the province and beyond. It was agreed that future steps should be taken to ensure continued dialogue with a broader suite of participants to enhance understanding of the significant role EO can play in environmental management –including supporting regulatory functions, industrial and ambient monitoring, and policy development. In support of this, consideration should be given to arranging a conference on the Enhancing Environmental Performance through Earth Observation. Sponsors could include Alberta Energy Regulator, Alberta Environment and Sustainable Resource Development, Alberta Innovation and Advanced Education, COSIA (Monitoring EPA), PTAC, TECTERRA, LOOKNorth, Environmental Services Association of Alberta and possibly the

---

[3] Recent reports have identified flood mapping and dam safety monitoring deficiencies (Auditor General of Alberta 2015) and oil sands tailings monitoring requirements (Government of Alberta 2015) – these could be addressed within this proposed Roadmap.

Canadian Space Agency. In addition to paper presentations (and associated conference proceedings), there should be opportunities for service providers to demonstrate capabilities.

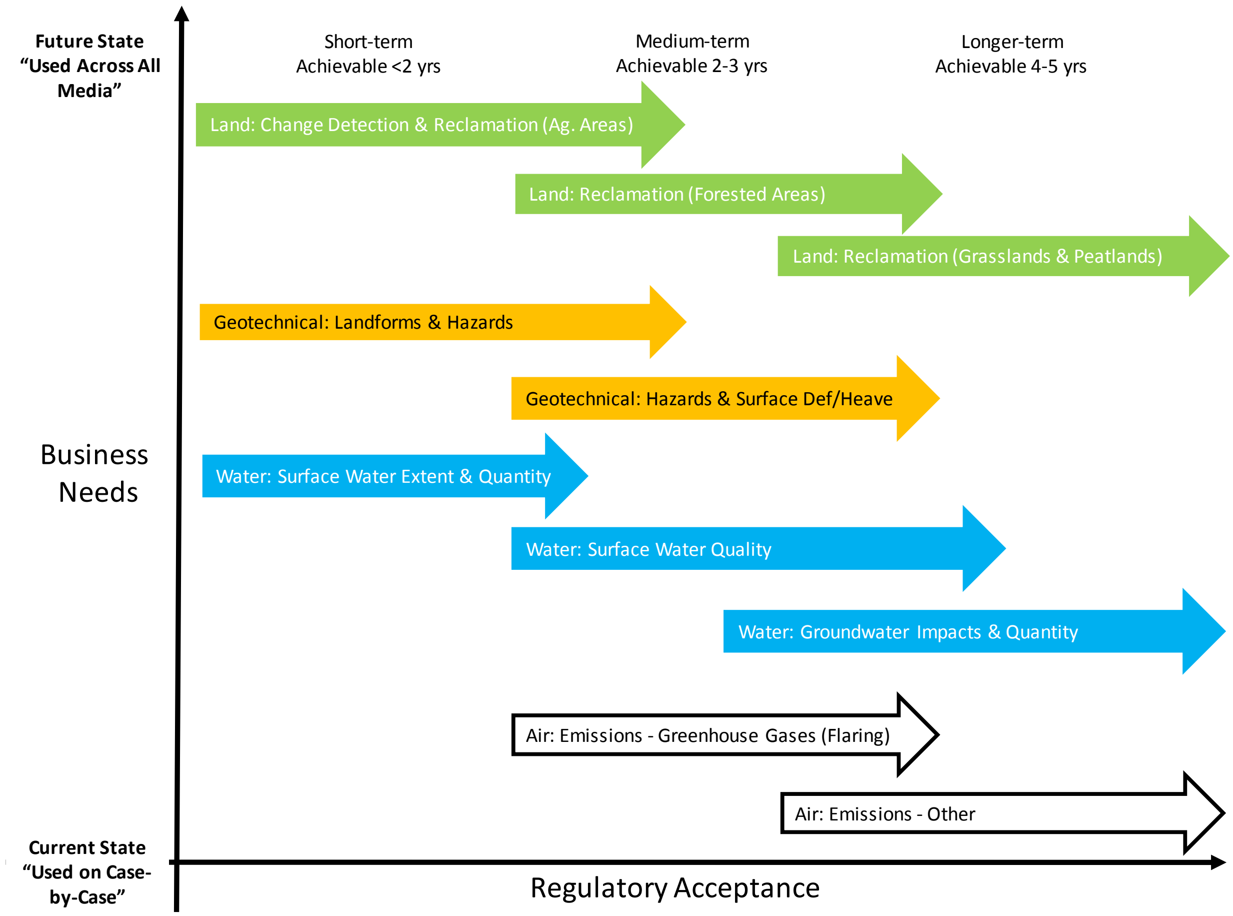


Figure 2. 5-yr Roadmap for the Use of EO within Alberta's Regulatory Frameworks.

6 REFERENCES

Auditor General of Alberta, 2015. Report of the Auditor General of Alberta – March 2015. Office of the Auditor General of Alberta, Edmonton, Alberta. 128 pp. http://www.oag.ab.ca/webfiles/reports/OAG%20March%202015%20Report.pdf

Government of Alberta, 2015. Lower Athabasca Region Tailings Management Framework for the Mineable Athabasca Oil Sands. Alberta Environment and Sustainable Resource Development, Edmonton, Alberta. 52 pp. http://esrd.alberta.ca/focus/cumulative-effects/cumulative-effects-management/management-frameworks/documents/LARP-TailingsMgtAthabascaOilsands-Mar2015.pdf

Ryerson, R.A., 2011. Earth Observation Monitoring of the Oil Sands in Alberta: Report on a Workshop. Prepared by Kim Geomatics Corporation, Manotick, Ontario for Alberta Geological Survey, Energy Resources Conservation Board, Edmonton, Alberta. 69 pp.

Suggested Reading

Akbar, T.A., Q. K. Hassan and G. Acharia, 2010. A Remote Sensing Based Framework for Predicting Water Quality of Different Source Waters. International Society for Photogrammetry and Remote Sensing, Canadian Geomatics Conference, Calgary, Alberta. Paper #117. 4 pp. http://www.isprs.org/proceedings/XXXVIII/part1/02/02_02_Paper_117.pdf

Aubé, G., V. Singhroy, C. Froese and P. Briand, 2009. New Disasters Earth Observation Monitoring Initiative in Canada: Assessment and Mitigation of Active Geohazard Sites. Earthzine 2009/01/13. http://earthzine.org/2009/01/13/new-disasters-earth-observation-monitoring-initiative-in-canada-assessment-and-mitigation-of-active-geohazard-sites/

Baines, P.J., 2007. Canadian Commercial Remote Sensing Data Policy – The Remote Sensing Space Systems Act Remote Sensing Space Systems Act. Foreign Affairs and International trade Canada. Presentation. http://www.nesdis.noaa.gov/CRSRA/files/CSA_Public_Presentation_Sept07.pdf

Bampfylde, C.J., S. Hughes, D. Page, B.G. Purdy, S. Stanley and A. Syed, 2010. Compiling a geospatial database of existing oil sands industrial features for Alberta Environment. International Society for Photogrammetry and Remote Sensing, Canadian Geomatics Conference, Calgary, Alberta. Paper #171. 5 pp. http://www.isprs.org/proceedings/XXXVIII/part1/02/02_02_Paper_171.pdf

Chien, W., 2012. Remote Sensing of Alberta Oil Sands. UCLA Geography 169 paper. http://remotesensing-oilsands.tumblr.com/

Howell, S.G., A.D. Clarke, S. Freitag, C.S. McNaughton, V. Kapustin, V. Brekovskikh, J-L. Jimenez and M.J. Cubison, 2014. An airborne assessment of atmospheric particulate emissions from the processing of Athabasca oil sands. Atmospheric Chemistry and Physics 14: 5073-5087. http://www.atmos-chem-phys.net/14/5073/2014/acp-14-5073-2014.pdf

Janzen, D., 2012. Canada Centre for Remote Sensing: Activities in Alberta's Oil Sands Region (AOSR). Petroleum Technology Alliance of Canada 2012 Resource Access and Ecological Issues Forum presentation (pdf copy). http://www.google.ca/url?url=http://www.ptac.org/attachments/550/download&rct=j&frm=1&q=&esrc=s&sa=U&ei=R0LnVM7TC4HZggSdpoKwDA&ved=0CEUQFjAF&usg=AFQjCNFh25g9s0HoF3C_v3Rqlid-eKEoHw

Katsuris, D. and B. Wanless, 2013. Application of UAV Technology for Environmental Lifecycle Monitoring. RemTech 2013 presentation. http://www.esaa-events.com/proceedings/remtech/2013/pdf/13-Katsuris.pdf

Latifovic, R., D. Pouliot and R. Fernandes, 2011. Earth Observation Technique and its Applications on Alberta Oil Sands. Alberta Oil Sands: Environmental Challenges and Solutions CPANS 2011 Fall Technical Conference presentation. http://www.cpans.org/assets/Uploads/Presentations/2011-Fall-Conference/Session-8-Presentations/Session-82.pdf

Lewis, G., 2012. Applications of Unmanned Air Vehicle (UAV) Systems for Remediation Projects. RemTech 2012 presentation. http://www.esaa-events.com/proceedings/remtech/2012/pdf/12-Lewis.pdf

McLinden, C.A., V. Fioletov, K.F. Boersma, N. Krotkov, C.E. Sioris, J.P. Veefkind and K. Yang, 2012. Air quality over the Canadian oil sands: A first assessment using satellite observations. Geophysical Research Letters 39(4). 8 pp. http://onlinelibrary.wiley.com/doi/10.1029/2011GL050273/pdf

Natural Resources Canada, 2010. Earth Sciences Sector Basic Infrastructure Evaluation.

Parks, K.P. and E. Grunsky, 2002. RADARSAT imagery: A new way to help map discharge and recharge, Athabasca oil sands area. IN: Canadian Society of Petroleum Geologists Annual Meeting – 2002. Canadian Society of Petroleum Geologists, Calgary, Alberta. 1 pp. http://www.cspg.org/cspg/documents/Conventions/Archives/Annual/2002/247S0125.pdf

Patterson, S., 2013. Investigation of New Monitoring Technologies and Capabilities. PTAC/LOOKNorth – Remote Sensing & Monitoring Forum, May 27, 2013 presentation. https://www.LOOKNorth.org/cms_content/files/files/New%20Technologies%20for%20Environmental%20Monitoring%201%28RSTAP%202013%29.pdf

Shammi Akther, M. and Q.K. Hassan, 2010. Spatio-Temporal Dynamics of Surface Wetness Conditions Using Remote Sensing Data. International Society for Photogrammetry and Remote Sensing, Canadian Geomatics Conference, Calgary, Alberta. Paper #100. 5 pp. http://www.isprs.org/proceedings/XXXVIII/part1/02/02_03_Paper_100.pdf

Shipman, T., B. White and S. Patterson, 2012. Earth Observation and Remote Sensing for Environmental Monitoring. Alberta Institute of Agrologists presentation. http://www.albertaagrologists.ca/files/2012%20-%20Alberta%20Soils%20Network%20v2%203_Handouts%20Remote%20Sensing.pdf

Wood, J.E., M.D. Gillis, D.G. Goodenough, R.J. Hall, D.G. Leckie, J. E. Luther and M.A. Wulder, 2002. Earth Observation for Sustainable Development of Forests (EOSD): Project Overview. Canadian Forest Service, Victoria, British Columbia. 4 pp. http://www.cfs.nrcan.gc.ca/pubwarehouse/pdfs/20541.pdf

Historical Documents

These documents provide a sense for how far EO/RS science and practice has come.

Aronoff, S., G.A. Ross and W.A. Ross, 1978. The application of remote sensing to environmental monitoring of the AOSERP study area. Volume 1. Alberta Oil Sands Environmental Research Program, Edmonton, Alberta. AOSERP Project TF 6.3. 274 pp. http://hdl.handle.net/10402/era.22985

Aronoff, S., G.A. Ross and W.A. Ross, 1978. The application of remote sensing to environmental monitoring of the AOSERP study area. Volume 2. Alberta Oil Sands Environmental Research Program, Edmonton, Alberta. AOSERP Project TF 6.3. 161 pp. http://hdl.handle.net/10402/era.22986

Cheng, L., A. Davis, E. Peake and D. Rogers, 1987. The use of aircraft measurements to determine transport, dispersion and transformation rates of pollutants emitted from oil sands extraction plants in Alberta. Alberta Environment, Research Management Division, Edmonton, Alberta. AOSERP Report 133. 128 pp. http://hdl.handle.net/10402/era.26681

Fanaki, F., R. Hoff, L. Barrie, R. Mickle, M. Lusis, K. Anlauf, A. Gallant, J. Kovalick, F. Froude, J. Markes, J. Arnold, S. Melnichuk, D. Brymer, A. Gaudenzi, A. Moser and D. Bagg, 1979. Air system summer field study in the AOSERP study area, June 1977. Alberta Oil Sands Environmental Research Program, Edmonton, Alberta. AOSERP Project AS 1.5.3 and AS 3.5.2. 265 pp. http://hdl.handle.net/10402/era.26689

Harrington, R.A., 1982. Modelling the circulation and sediment distribution in the Athabasca Delta area. Alberta Environment, Research Management Division, Edmonton, Alberta. Report No. RMD 81-23. 124 pp. plus appendix. http://hdl.handle.net/10402/era.23611

Mercer, J.M. and R.B. Charlton, 1977. Very high resolution meteorological satellite study of oil sands weather "A feasibility study". Alberta Oil Sands Environmental Research Program, Edmonton, Alberta. AOSERP Project ME 1.7. 50 pp. http://hdl.handle.net/10402/era.27305

Neill, C.R., B.J. Evans and A.W. Lipsett, 1981. Circulation of water and sediment in the Athabasca Delta area. Alberta Oil Sands Environmental Research Program, Edmonton, Alberta. AOSERP Project WS 3.3.1. 182 pp. http://hdl.handle.net/10402/era.28967

Syncrude Canada Ltd., 1974. Remote sensing and the Athabasca tar sands: An overview. Syncrude Canada Ltd., Edmonton, Alberta. Environmental Research Monograph 1974-1. http://hdl.handle.net/10402/era.40291

Thompson, M.D., M.C. Wride and M.E. Kirby, 1978. Ecological habitat mapping of the AOSERP study area: Phase I. Alberta Oil Sands Environmental Research Program, Edmonton, Alberta. AOSERP Project VE 2.3. 203 pp. http://hdl.handle.net/10402/era.25513

Web Sources

Alberta Biodiversity Monitoring Institute Remote Sensing Group – University of Calgary

Alberta Environment and Sustainable Resource Development – LiDAR

Alberta Environment and Sustainable Resource Development – Reconnaissance and Remote Sensing Unit

Alberta Geological Survey – Remote sensing reports

Alberta Terrestrial Imaging Centre (ATIC) – University of Lethbridge

AltaLIS (Alberta Data Partnerships)

American Society for Photogrammetry and Remote Sensing (ASPRS)

Canadian Council on Geomatics

Canadian Remote Sensing Society (CRSS)

Canadian Space Agency (CSA)

Centre for Earth Observation Sciences (CEOS) – University of Alberta

Committee on Earth Observation Satellites (CEOS)

Earth Observation Application Development Program (CSA)

Earth Observation for Environment Laboratory – University of Calgary

European Space Agency (ESA)

Foothills Facility for Remote Sensing and GIScience – University of Calgary

GEOBIA: GEO-Object-Based Image Analysis (Wiki)

Government of Alberta – GeoDiscover

Government of Canada, 2005. Remote Sensing Space Systems Act

LOOKNorth

Natural Resources Canada – Remote Sensing

Natural Resources Canada – Satellite Imagery and Air Photos

Observing Systems Capability Analysis and Review Tool (OSCAR)

Petroleum Technology Alliance of Canada – 2014 Geospatial Monitoring and Analytics Forum (presentations)

Science and Operational Applications Research (CSA)

TECTERRA

WORKSHOP ACRONYMS

This section contains acronyms relevant to this workshop only. Appendix 6 contains definitions and acronyms that could be used as the basis for an Alberta-focused glossary of EO/RS monitoring-related terminology.

ABMI	Alberta Biodiversity Monitoring Institute
ACO	Aboriginal Consultation Office
ADP	Alberta Data Partnerships
AEMERA	Alberta Environmental Monitoring, Reporting and Evaluation Agency
AER	Alberta Energy Regulator
AESRD	Alberta Environment and Sustainable Resource Development
AGCC	Alberta Ground Cover Classification
AGS	Alberta Geological Survey
AIAE	Alberta Innovation and Advanced Education
AI-EES	Alberta Innovates – Energy and Environment Solutions
AOSR	Athabasca Oil Sands Region
AR	(Alberta) Aboriginal Relations
AWI	Alberta Wetland Inventory
BAP	Best Available Pixel
CCMEO	Canada Centre for Mapping and Earth Observation
CCOG	Canadian Council on Geomatics

CCS	Cyclic Steam Stimulation
CECR	(Canadian) Centres of Excellence for Commercialization & Research
CEMA	Cumulative Environmental Management Association
CFS	Canadian Forest Service
COSIA	Canada's Oil Sands Innovation Alliance
CSS	Cyclic Steam Stimulation
DLR	German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt
DoE	(Alberta) Department of Energy
DUAP	Data Utilization and Plan
EC	Environment Canada
ECOP	Environmental Communities of Practice
EIA	Environmental Impact Assessment
ESS	Earth Sciences Sector
ET	Evapotranspiration
G&C	Grants & Contributions
GoA	Government of Alberta
GoC	Government of Canada
GRIP	Government Related Initiatives Program
IRMS	Integrated Resource Management System
JPL	Jet Propulsion Lab
JV	Joint Venture
LAI	Leaf Area Index
LARP	Lower Athabasca Regional Plan
LOOKNorth	Leading Operational Observations and Knowledge for the North
MIB	Mapping Information Branch
MTRI	Michigan Technology Research Institute

NAIT	Northern Alberta Institute of Technology
NBAC	National Burned Area Composite
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen Oxides
NP	National Park
NPP	Net Primary Productivity
NRT	Near Real Time
NTEMS	National Terrestrial Ecosystem Monitoring System
NRC	National Research Council
O&G	Oil and Gas
O/S	Oil Sands
OPA	Office of Public Affairs (AER)
OSWG	Oil Sands Wetlands Working Group
PAD	Peace-Athabasca Delta
PBR	Play Based Regulation
PCA	Parks Canada Agency
PMO	Project Management Office
PTAC	Petroleum Technology Alliance of Canada
Q/A	Quality Assurance
R&D	Research and Development
REDA	*Responsible Energy Development Act*
RSS	Remote Sensing Science
SAGD	Steam-Assisted Gravity Drainage
SDW	Spatial Data Warehouse
SEEDS	Seed Enhanced Ecological Delivery System
SGR	Stakeholder and Government Relations (AER)
SME	Small-Medium Enterprises
SOx	Sulphur Oxides
UM	University Miami

UofL	University of Lethbridge
VOC	Volatile Organic Compounds
WSC	Water Survey of Canada
WST	Water Science and Technology

7 APPENDICES

7.1 APPENDIX 1: LIST OF WORKSHOP PARTICIPANTS

Workshop Attendees

Name	Organization	Name	Organization
Caroline Bampfylde	AESRD	Jahan Kariyeva	ABMI
Chris Bater	AESRD	Shauna Kryba	AESRD
Andrew Beaton	AER – AGS	Edwardo Loos	ASL Environmental Sciences
Brian Brisco	CCRS	Rene Lapointe	CFS
Zvonko Burkus	AESRD	Brian Makowecki	AESRD
Guillermo Castilla	CFS	Daryl McEwan	GeoDiscover Alberta
Daphne Cheel	AIAE	Murali Pai	NAIT
Tom Churchill	AESRD	Chad Pankewitz	AIAE
Roger De Abreu	CCRS	Shane Patterson	AIAE
Andy Dean	Hatfield	Brad Pinno	CFS
Yvan Désy	CCMEO	Valentin Poncos	Kepler-Space
Monique Dube	AER	Darren Pouliot	CCRS
Kaan Ersahin	ASL Environmental Sciences	Brett Purdy	AI-EES
Richard Gorecki	TECTERRA	Peter Rose	AESRD
Erin Grass	AESRD	Todd Shipman	AER – AGS
Ken Greenway	AESRD	Vern Singhroy	CCRS
Ron Hall	CFS	Bob Sleep	AESRD
Lorna Harron	Enbridge	Karl Staenz	UofL
Erik Holmlund	ADP	Ridha Touzi	CCRS
Chris Hopkinson	UofL	Cassidy VanRensen	AESRD
Jane Humberstone	AIAE	Chris VanTighem	AIAE

Darren Janzen	CCRS	Peter White	CCRS
Bill Jeffries	LOOKNorth	Jinkai Zhang	AESRD
Mark Kapfer	LOOKNorth	Ying Zhang	CCRS

A1B Online Workshop Participants

On Day 1 of the Workshop several people participated remotely via conference call:

Name	Organization	Name	Organization
Robert Albricht	Conoco	Richard Fernandes	CCRS
Guy Aube	Canadian Space Agency	Sam Lieff	Blackbridge
Erin Baird	Suncor	Farrah McFadden	AESRD
Meridith Ball	Husky	Bin Xu	NAIT
Jenna Dunlop	COSIA		

7.2 APPENDIX 2: WORKSHOP AGENDA

Day 1 – Agenda

7:30 – 8:00	Registration	
8:00 – 8:10	Welcome	Chris Powter Enviro Q&A Services
8:10 – 8:25	Opening Remarks from AER-AGS	Andrew Beaton Alberta Energy Regulator – Alberta Geological Survey (AER – AGS)
8:25 – 8:40	Earth Observation for Resource Development	Yvan Desy Natural Resources Canada – Canada Centre for Remote Sensing (NRCan-CCRS)
8:40 – 9:00	GoA Remote Sensing Initiative	Daryl McEwan Environment and Sustainable Resource Development (ESRD), GeoDiscover Alberta
9:00 – 9:20	Geospatial Data Access in Alberta	Erik Holmlund Alberta Data Partnerships
09:20 – 9:40	Role for EO in an Integrated Resource Management System	Ken Greenway ESRD, Integrated Resource Management System (IRMS) Office
9:40 – 10:00	Role for EO in for Environmental Monitoring	TBD AEMERA.ORG

10:00 – 10:30	Coffee Break	

10:30 – 10:50	Infrastructure Monitoring with EO	Ying Zhang NRCan-CCRS
10:50 – 11:10	Monitoring Steam-Assisted Extraction with InSAR	Vern Singhroy NRCan-CCRS
11:10 – 11:30	Surface Water Mapping in the AOSR with SAR	Brian Brisco NRCan-CCRS
11:30 – 11:50	Vegetation and Land Use Change in the AOSR	Darren Pouliot NRCan-CCRS

11:50 – 12:10	Potential for EO for AER Operations	Monique Dube Alberta Energy Regulator (AER)

12:10 – 13:00	Lunch	

13:00 – 13:20	Monitoring Peatland Transformation with SAR	Ridha Touzi NRCan-CCRS
13:20 – 13:40	Snow Cover Mapping in the AOSR	Richard Fernandes NRCan-CCRS
13:40 – 14:00	Monitoring Athabasca River Ice Dynamics	Roger De Abreu (for Joost van der Sanden) NRCan-CCRS
14:00 – 14:30	The AOSR Hyperspectral Dataset: Status and Opportunities	Peter White NRCan-CCRS

14:30 – 14:50	Coffee Break	

14:50 – 15:20	CFS Activities in the Oil Sands	Brad Pinno, Natural Resources Canada – Canadian Forest Service, (NRCan-CFS)
15:20 – 15:50	Future EO Missions	Bill Jeffries LOOKNorth
15:50 – 16:30	Discussion for Day 2, Wrap up	Chris Powter Enviro Q&A Services

Day 2 – Agenda

8:00 – 8:20	Opening	Chris Powter
8:20 – 10:00	Break-out discussion	Breakout groups

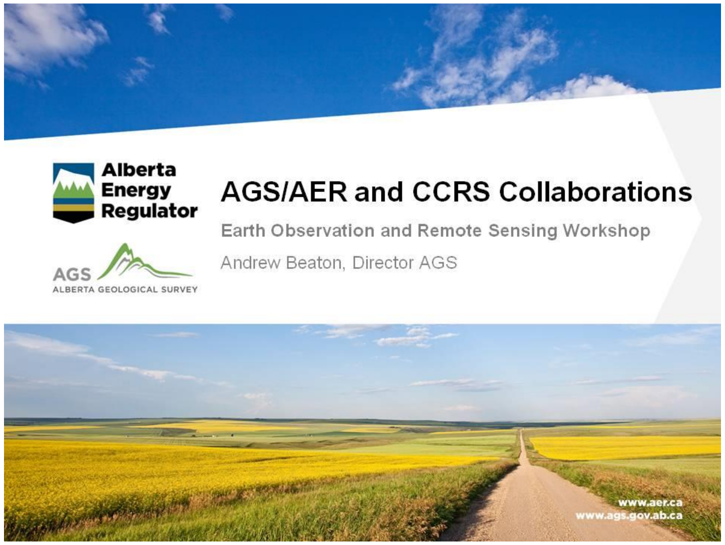
10:00 – 10:30	Coffee Break / Networking Break	

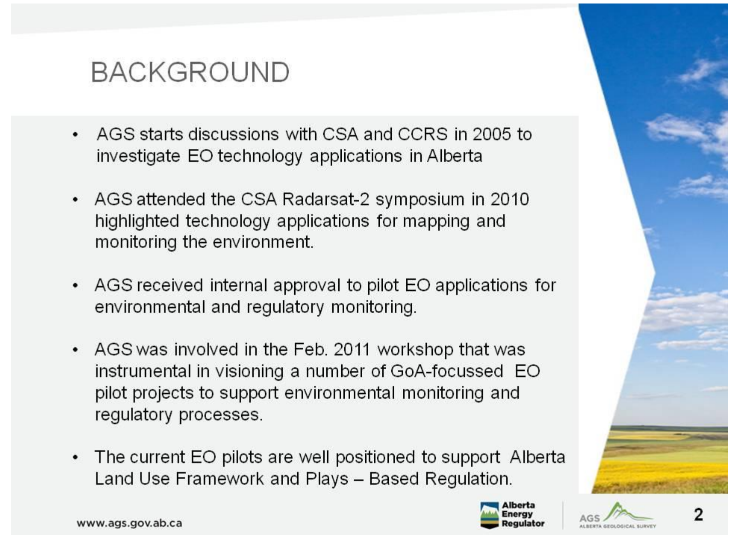
10:30 – 11:30	Discussion on Breakout Group Findings	Chris Powter
11:30 – 12:00	Wrap-up / Final Remarks	Chris Powter

7.3 APPENDIX 3: WORKSHOP PRESENTATIONS

AGS/AER and CCRS Collaborations	Andrew Beaton, Alberta Energy Regulator – Alberta Geological Survey
Earth Observation for Resource Development	Yvan Desy, Natural Resources Canada – Canada Centre for Remote Sensing (NRCan-CCRS)
GoA Remote Sensing Initiative	Daryl McEwan, Environment and Sustainable Resource Development (ESRD), GeoDiscover Alberta
Geospatial Data Access in Alberta	Erik Holmlund, Alberta Data Partnerships
Role for EO in an Integrated Resource Management System	Ken Greenway, ESRD, Integrated Resource Management System (IRMS) Office
Infrastructure Monitoring with EO	Ying Zhang, NRCan-CCRS
Monitoring Steam-Assisted Extraction with InSAR	Vern Singhroy, NRCan-CCRS
Surface Water Mapping in the AOSR with SAR	Brian Brisco, NRCan-CCRS
Vegetation and Land Use Change in the AOSR	Darren Pouliot, NRCan-CCRS
Potential for EO for AER Operations	Monique Dube, Alberta Energy Regulator (AER)
Monitoring Peatland Transformation with SAR	Ridha Touzi, NRCan-CCRS
Snow Cover Mapping in the AOSR	Richard Fernandes, NRCan-CCRS
Monitoring Athabasca River Ice Dynamics	Roger De Abreu (for Joost van der Sanden), NRCan-CCRS
The AOSR Hyperspectral Dataset: Status and Opportunities	Peter White, NRCan-CCRS
CFS Activities in the Oil Sands	Brad Pinno, Natural Resources Canada – Canadian Forest Service, (NRCan-CFS)
Future EO Missions	Bill Jeffries, LOOKNorth

AGS/AER and CCRS Collaborations, Andrew Beaton, Alberta Energy Regulator – Alberta Geological Survey





AGS - CCRS Collaborations

Two joint CCRS/AGS projects were initiated:

1) CCRS provided InSAR (data and training) to investigate geotechnical risk associated with in-situ oil sands development.

2) CCRS provided training to initiate change detection monitoring for critical areas of energy development in Alberta

AGS is now collaborating with CCRS in new projects and continues to develop our in-house expertise to provide risk and change detection to support GoA processes.

www.ags.gov.ab.ca Alberta Energy Regulator AGS Alberta Geological Survey 3

Project Summary 1 – InSitu Operations

- AGS has been working with CCRS in using InSAR technology to monitor oilsands extraction activities in Alberta since 2010.
- Early stage of the project also involved CSA and MDA in feasibility studies of using InSAR for in situ oilsands recovery activities monitoring (including surface deformation).
- Pilot evaluated 4 SAGD and 1 CCS sites. CCRS and AGS are jointly doing the data processing and evaluations.

www.ags.gov.ab.ca Alberta Energy Regulator AGS Alberta Geological Survey

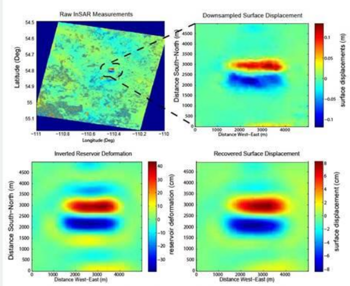
Why Monitor Surface Heave?

- Surface heave is a form of expression of reservoir expansion and dilation, which is directly related with subsurface heavy oil reservoir development
- By assessing the surface heave, we can estimate the deformation of caprock and induced shear/tensile plasticity
- Heave provides a way of calibrating geomechanical models. Key geomechanical parameters can be estimated by comparing forward modelling results and surface measurements.
- Ultimate use is risk identification (caprock integrity) and risk mitigation.

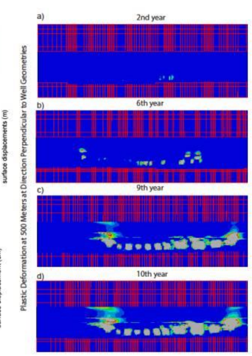
www.ags.gov.ab.ca Alberta Energy Regulator AGS Alberta Geological Survey

Geomechanical simulation of operational risk

Model deformation and failure associated with In-Situ processes

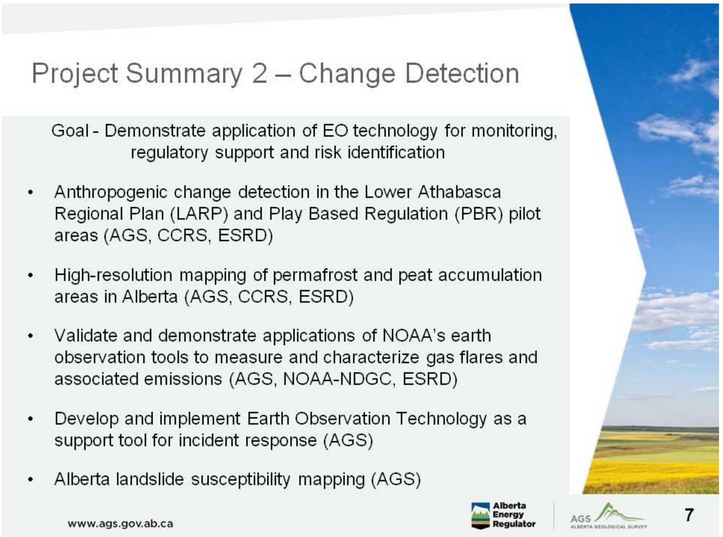


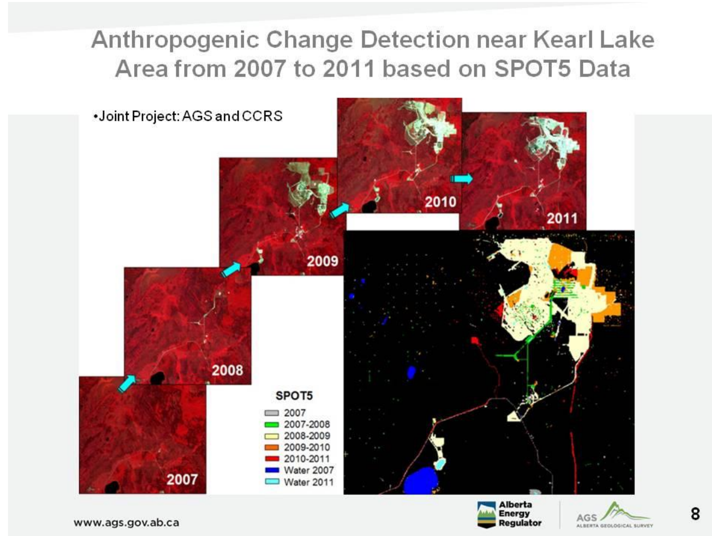
Ground movement

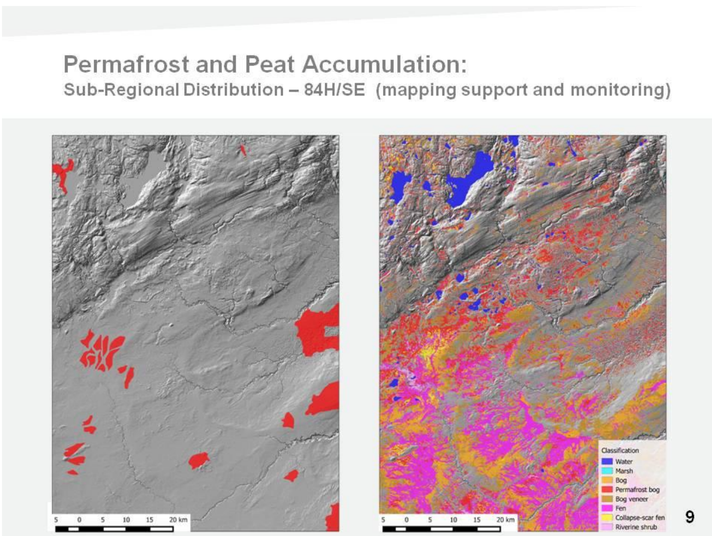


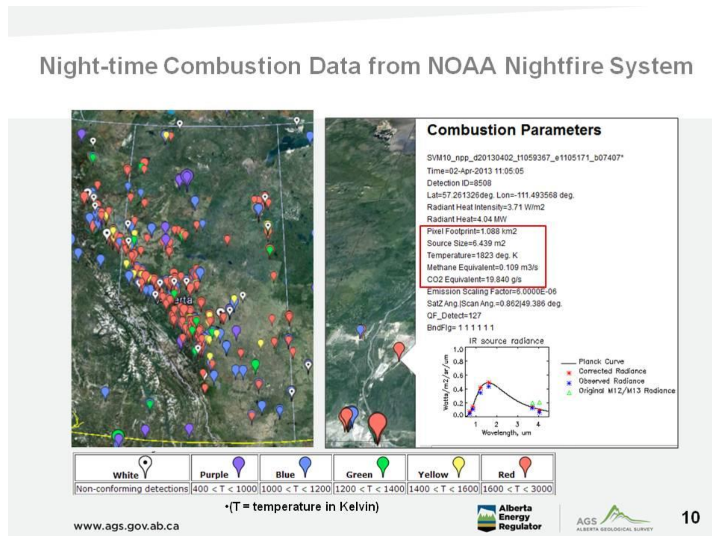
Fracture/breakthrough risk

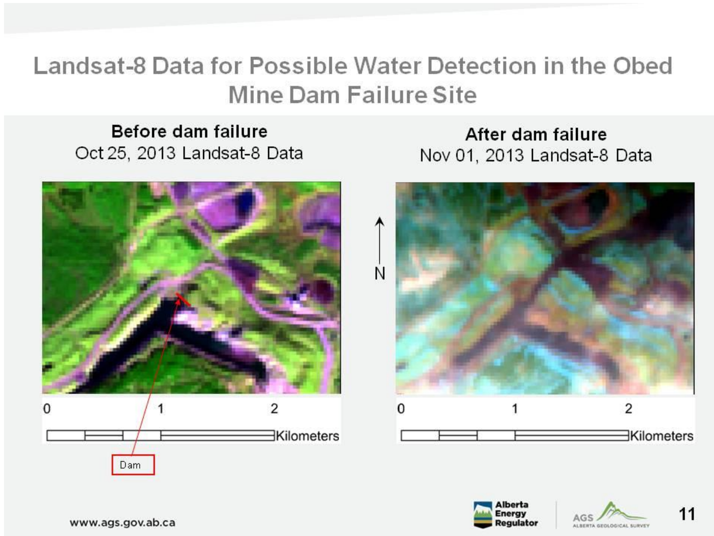
www.ags.gov.ab.ca Alberta Energy Regulator AGS Alberta Geological Survey


Project Summary 2 – Change Detection
Goal - Demonstrate application of EO technology for monitoring, regulatory support and risk identification
• Anthropogenic change detection in the Lower Athabasca Regional Plan (LARP) and Play Based Regulation (PBR) pilot areas (AGS, CCRS, ESRD)
• High-resolution mapping of permafrost and peat accumulation areas in Alberta (AGS, CCRS, ESRD)
• Validate and demonstrate applications of NOAA's earth observation tools to measure and characterize gas flares and associated emissions (AGS, NOAA-NDGC, ESRD)
• Develop and implement Earth Observation Technology as a support tool for incident response (AGS)
• Alberta landslide susceptibility mapping (AGS)
www.ags.gov.ab.ca
Alberta Energy Regulator
AGS
7

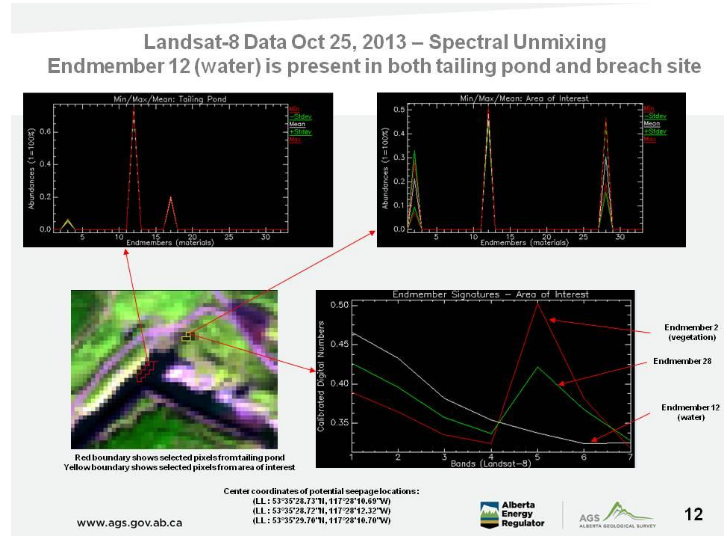

Anthropogenic Change Detection near Kearl Lake Area from 2007 to 2011 based on SPOT5 Data
•Joint Project: AGS and CCRS
2007
2008
2009
2010
2011
SPOT5
2007
2007-2008
2008-2009
2009-2010
2010-2011
Water 2007
Water 2011
www.ags.gov.ab.ca
Alberta Energy Regulator
AGS
8


Permafrost and Peat Accumulation:
Sub-Regional Distribution – 84H/SE (mapping support and monitoring)
Classification
Water
Marsh
Bog
Permafrost bog
Bog veneer
Fen
Collapse-scar fen
Riverine shrub
9

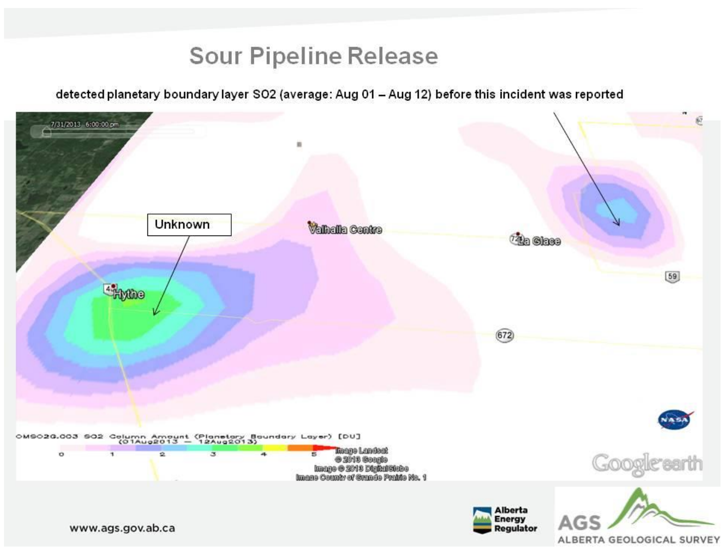

Night-time Combustion Data from NOAA Nightfire System
Combustion Parameters
SVM10_npp_d20130402_t1059367_e1105171_b07407*
Time=02-Apr-2013 11:05:05
Detection ID=8508
Lat=57.261326deg. Lon=-111.493568 deg.
Radiant Heat Intensity=3.71 W/m2
Radiant Heat=4.04 MW
Pixel Footprint=1.088 km2
Source Size=6.439 m2
Temperature=1823 deg. K
Methane Equivalent=0.109 m3/s
CO2 Equivalent=19.840 g/s
Emission Scaling Factor=6.0000E-06
SatZ Ang.|Scan Ang.=0.862|49.386 deg.
QF_Detect=127
BndFlg= 1 1 1 1 1 1
IR source radiance
Watts/m2/sr/um
Wavelength, um
Planck Curve
Corrected Radiance
Observed Radiance
Original M12/M13 Radiance
White
Purple
Blue
Green
Yellow
Red
Non-conforming detections
400 < T < 1000
1000 < T < 1200
1200 < T < 1400
1400 < T < 1600
1600 < T < 3000
•(T = temperature in Kelvin)
www.ags.gov.ab.ca
Alberta Energy Regulator
AGS
10



Landsat-8 Data for Possible Water Detection in the Obed Mine Dam Failure Site
Before dam failure
Oct 25, 2013 Landsat-8 Data
After dam failure
Nov 01, 2013 Landsat-8 Data
N
0 1 2 Kilometers
Dam
www.ags.gov.ab.ca
Alberta Energy Regulator
AGS
11



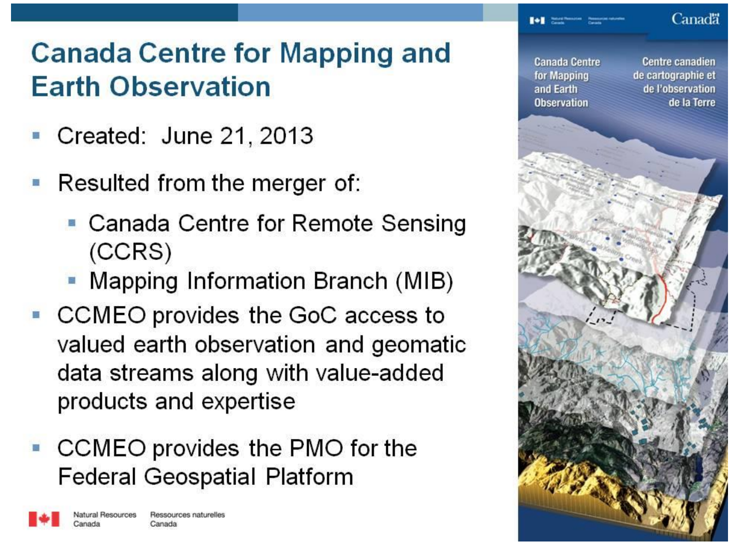
Landsat-8 Data Oct 25, 2013 – Spectral Unmixing
Endmember 12 (water) is present in both tailing pond and breach site
Min/Max/Mean: Tailing Pond
Min/Max/Mean: Area of Interest
Endmembers (materials)
Endmember Signatures – Area of Interest
Calibrated Digital Numbers
Bands (Landsat-8)
Endmember 2 (vegetation)
Endmember 28
Endmember 12 (water)
Red boundary shows selected pixels from tailing pond
Yellow boundary shows selected pixels from area of interest
Center coordinates of potential seepage locations:
(LL: 53°35'28.73"N, 117°28'10.69"W)
(LL: 53°35'28.72"N, 117°28'12.32"W)
(LL: 53°35'29.70"N, 117°28'10.70"W)
www.ags.gov.ab.ca
Alberta Energy Regulator
AGS Alberta Geological Survey
12



Sour Pipeline Release
detected planetary boundary layer SO2 (average: Aug 01 – Aug 12) before this incident was reported
Unknown
Valhalla Centre
La Glace
Hythe
Google earth
www.ags.gov.ab.ca
Alberta Energy Regulator
AGS
ALBERTA GEOLOGICAL SURVEY

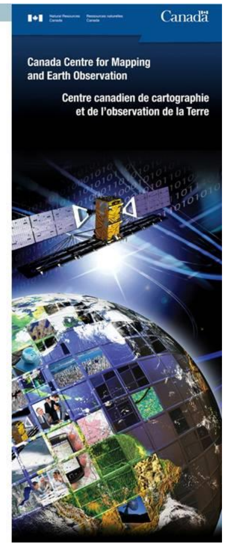
The AGS-CCRS collaboration has resulted in technology transfer and development of in-house expertise in a wide range of EO applications.
We have demonstrated the utility of these applications within AER/GoA for monitoring and risk assessment to support land use stewardship and regulatory processes.
www.ags.gov.ab.ca
Alberta Energy Regulator
AGS
14

Earth Observation for Resource Development, Yvan Desy, Natural Resources Canada - Canada Centre for Remote Sensing (NRCan-CCRS)



Canada Centre for Remote Sensing

- A Government of Canada centre of excellence in the exploitation of EO data.
- Current focus areas are:
  - **EO for Responsible Resource Development – Oilsands**
  - Landcover change and infrastructure monitoring in the North
  - Emergency Geomatics Services (e.g. Floods and flood plain mapping)
  - Value-Added Product Development (e.g. LTSDRs)



Natural Resources Canada / Ressources naturelles Canada

Government of Canada Strategic Context

Natural Resource Sectors and Consumers are Environmentally Responsible

↳ Responsible Natural Resource Management

↳ Earth Observation for Responsible Development of Natural Resources

- Expected Outcome -- Governments, regulatory bodies and industry have access to sound Earth observation scientific information (i.e., value-added datasets and publications) to support responsible resource development

Activity Background

- Responsible development of the Alberta oilsands resource is a high federal priority
- Canada invests significantly in Earth Observation – tremendous potential to monitor and understand
- 2011 workshop with AER and others was important for us to understand information needs and how our scientific expertise and EO technology could address any gaps.

Natural Resources Canada / Ressources naturelles Canada — Canada

Activity Background

- In 2012, seven projects kicked off led by CCRS scientists and partnered with Alberta and federal regulators and scientists.
- $500K G&C support also provided to a western academic consortium focused on hyperspectral EO over the oil sands.
- Overall objective is to ensure the full value of EO is understood and applied by regulators (and industry) in support of the responsible management of the oil sands resource.

Natural Resources Canada / Ressources naturelles Canada — Canada

Remote Sensing Oilsands Activities (2012-2015)

- 2 Projects Focused on Development Sites
  - Infrastructure Monitoring (buildings, roads, ponds, etc) (Zhang)
  - InSAR for Injection-Related Ground Deformation (Singhroy)
- 5 Projects Focused on the Surrounding Environment
  - Long-Term Land Surface Characterization (Latisovic)
  - Peatland Characterization (Touzi)
  - Relative Water Level (Brisco)
  - Fresh Water Ice Characteristics (van der Sanden)
  - Snow Cover (Fernandes)
- Projects leveraged existing expertise and projects

Natural Resources Canada Ressources naturelles Canada Canada

Remote Sensing Oilsands Activities

- Activity Funding
  - ADM Direct Funding ($600k two years 12/13-13/14)
  - CSA GRIP Funding ($859k two years 13/14-15/16)
  - Leveraged ongoing CSA DUAP Science projects
- Planned initially as 3 year projects
  - Most started in 2012-2013
  - 2014-2015 final year of this phase
  - 2015-2016 some projects may be extended
- Further work to be determined

Natural Resources Canada Ressources naturelles Canada Canada

Earth Observation and Remote Sensing: Technologies and Approaches for Informing Policy and Regulatory Decision Making -- Edmonton Feb. 27-28, 2015

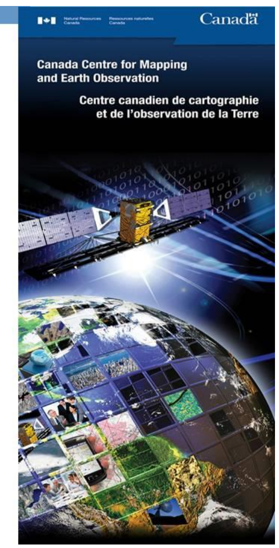
NRCan Workshop Objectives:

- Present to regulatory stakeholders the final scientific results of seven NRCan research activities
- Discuss issues/strategies and methods for transitioning these techniques into regulatory operations
- Increase visibility of this NRCan research project and its related results to industry, academia and other government agencies not directly involved in the project.
- Discuss potential for further research and development collaborations on the use of EO technology within the AOSR.

Natural Resources Canada Ressources naturelles Canada Canada

On the horizon

- Greater integration of EO and Cartography
- Development of a service-oriented Geomatics and EO infrastructure
- New technologies
  - **RCM**
  - **"Digital Commons"**
  - **Drones - UAVs**

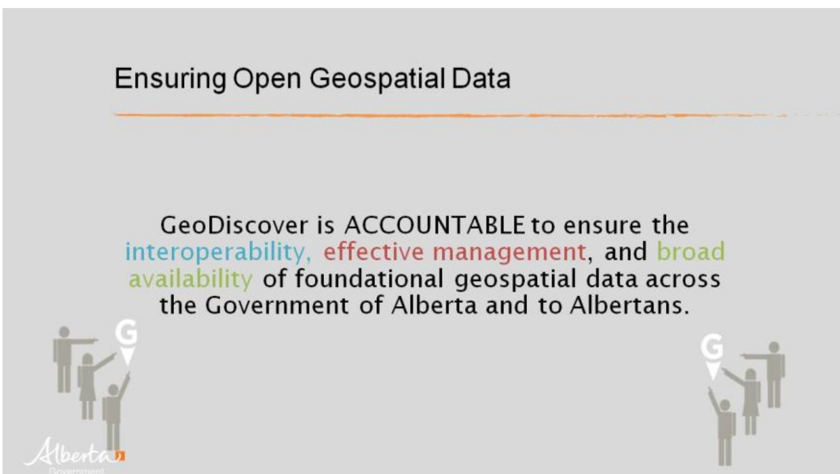


Natural Resources Canada Ressources naturelles Canada

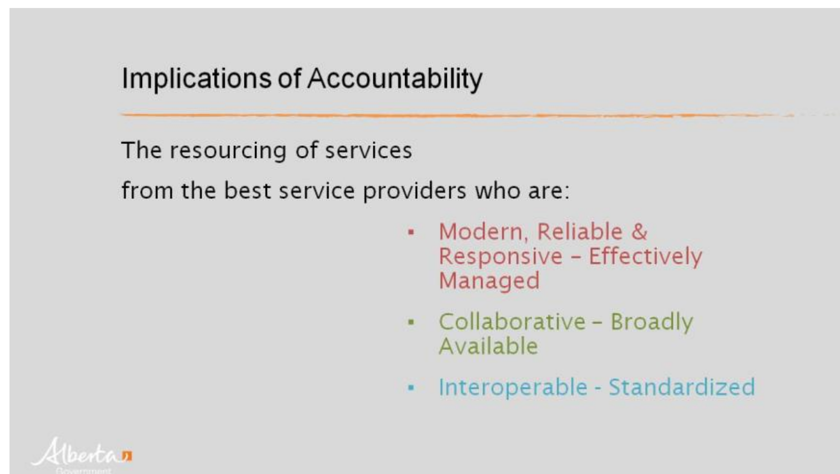
GoA Remote Sensing Initiative, Daryl McEwan, Environment and Sustainable Resource Development (ESRD), GeoDiscover Alberta

7.3.1.1.1.1.1.1

7.3.1.1.1.1.1.2

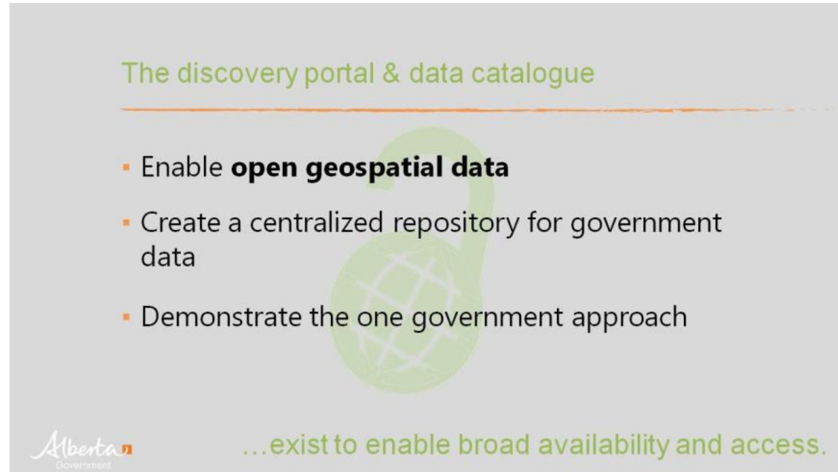


7.3.1.1.1.1.1.3

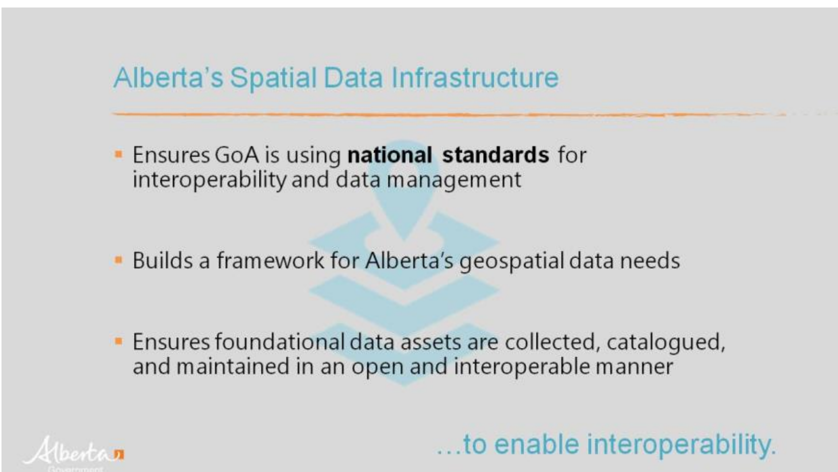


7.3.1.1.1.1.1.4

7.3.1.1.1.1.1.5

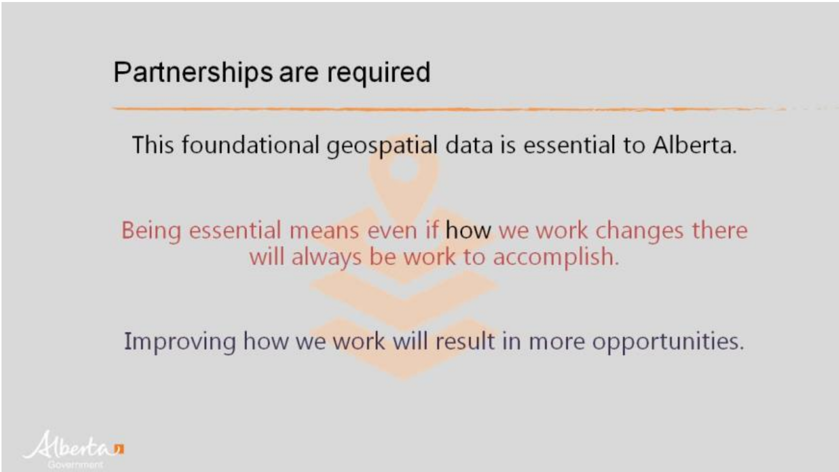


7.3.1.1.1.1.1.6



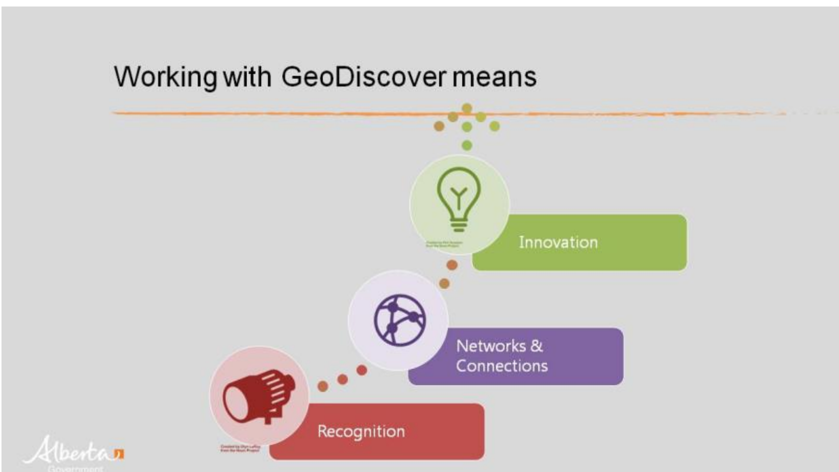
7.3.1.1.1.1.1.7

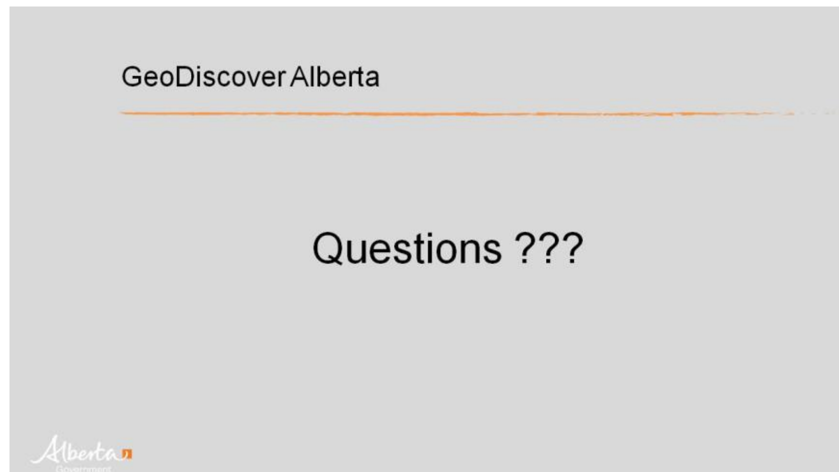
7.3.1.1.1.1.1.8



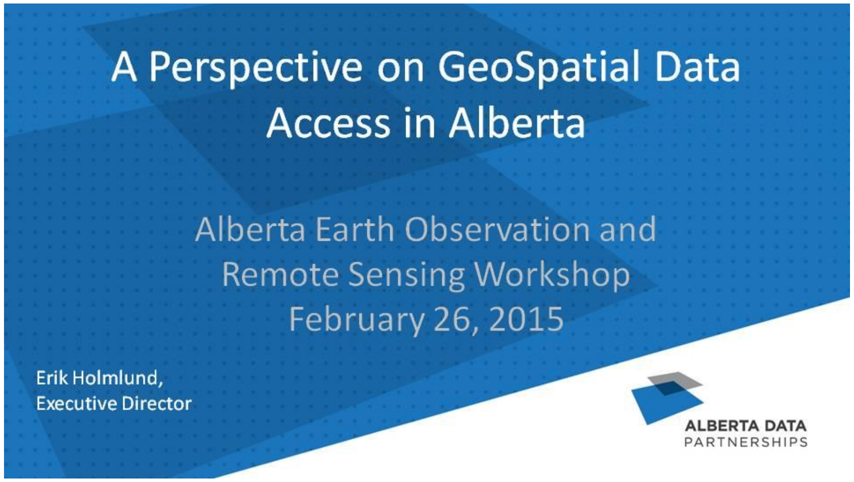
7.3.1.1.1.1.1.9

7.3.1.1.1.1.1.10

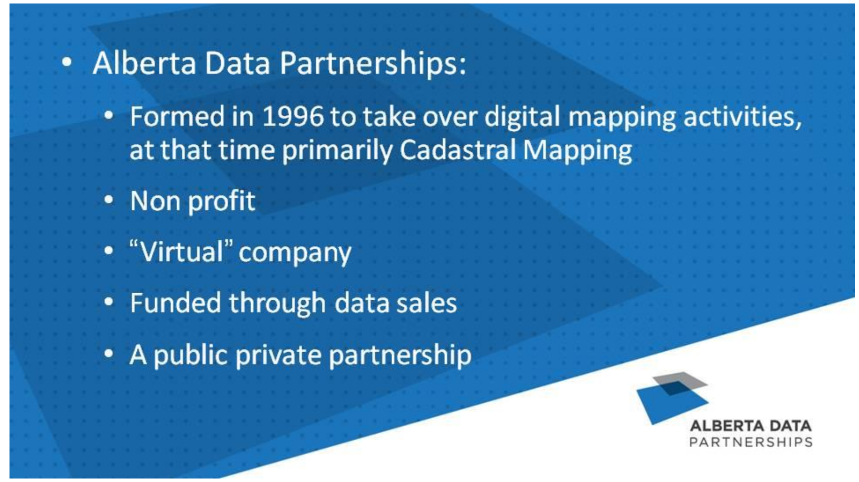




Geospatial Data Access in Alberta, Erik Holmlund, Alberta Data Partnerships



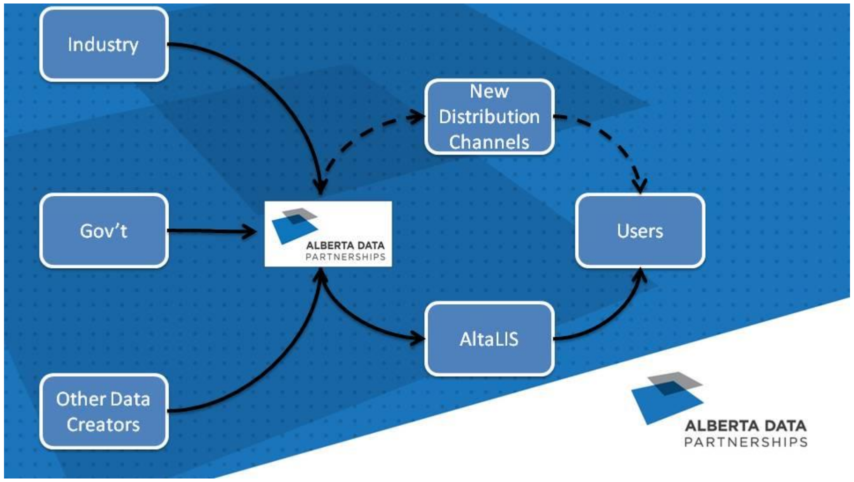
7.3.1.1.1.1.1.11



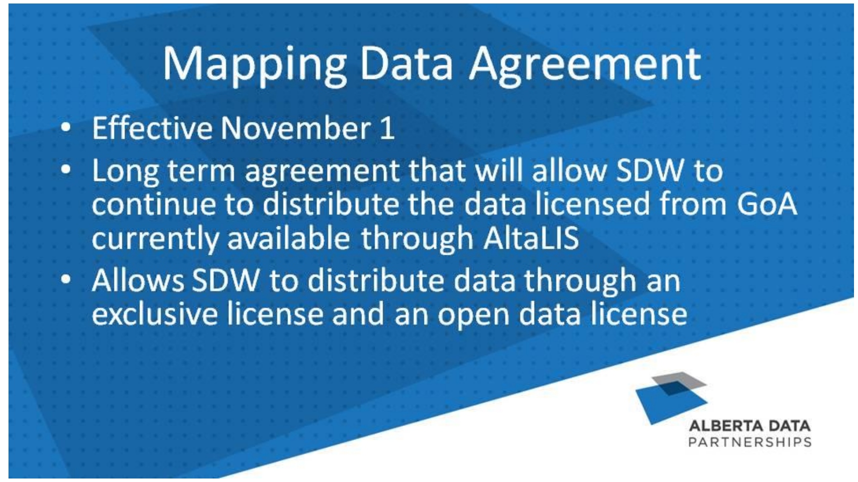
7.3.1.1.1.1.1.12

7.3.1.1.1.1.1.13

7.3.1.1.1.1.1.14

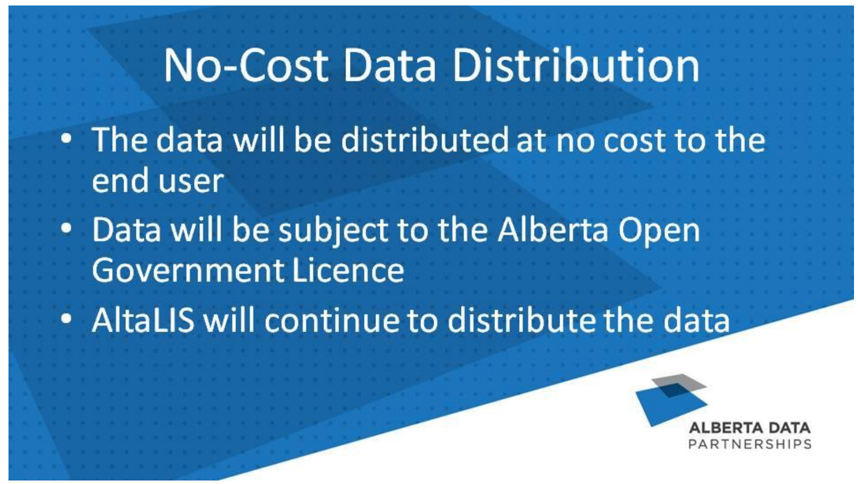


7.3.1.1.1.1.1.15

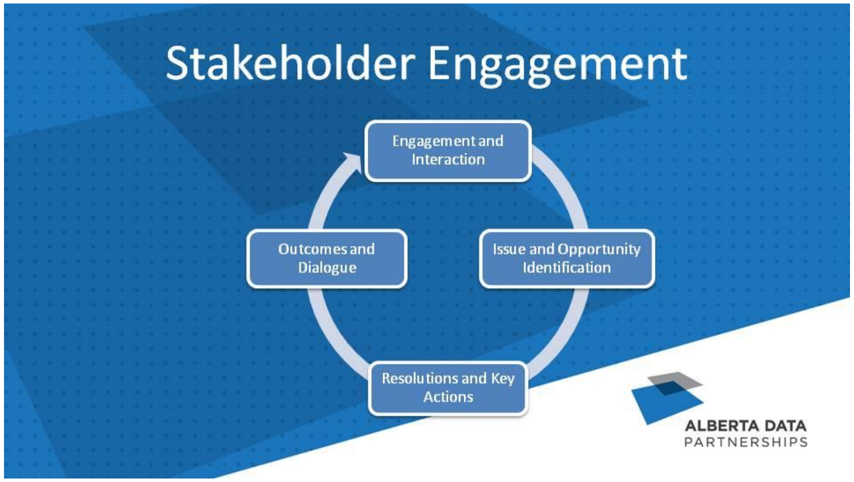


7.3.1.1.1.1.1.16

7.3.1.1.1.1.1.17



7.3.1.1.1.1.1.18

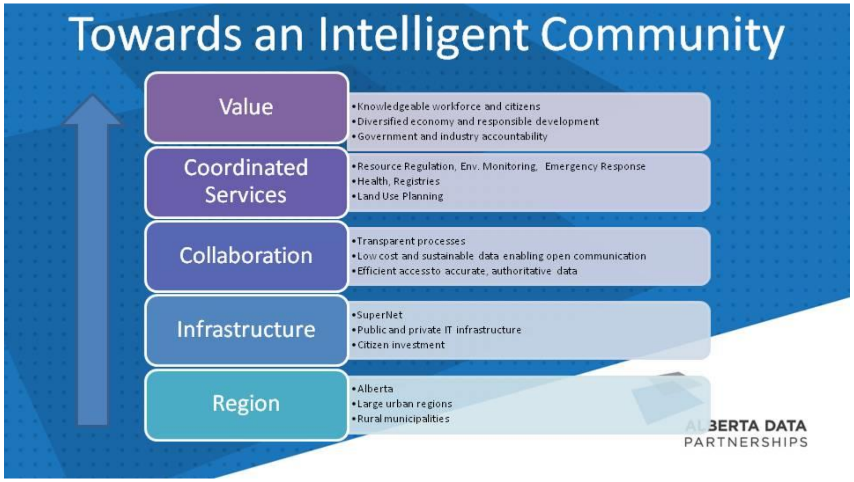


7.3.1.1.1.1.1.19

7.3.1.1.1.1.1.20

7.3.1.1.1.1.1.21

7.3.1.1.1.1.1.22


Towards an Intelligent Community
Value
•Knowledgeable workforce and citizens
•Diversified economy and responsible development
•Government and industry accountability
Coordinated Services
•Resource Regulation, Env. Monitoring, Emergency Response
•Health, Registries
•Land Use Planning
Collaboration
•Transparent processes
•Low cost and sustainable data enabling open communication
•Efficient access to accurate, authoritative data
Infrastructure
•SuperNet
•Public and private IT infrastructure
•Citizen investment
Region
•Alberta
•Large urban regions
•Rural municipalities
ALBERTA DATA PARTNERSHIPS

7.3.1.1.1.1.1.23

Role for EO in an Integrated Resource Management System, Ken Greenway, ESRD, Integrated Resource Management System (IRMS) Office

IRMS Principles:

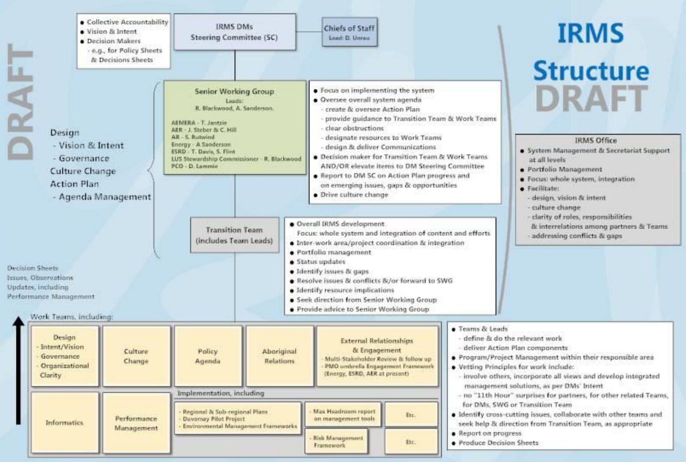
How we work together in the System:

- Ensure role clarity throughout the system
- Engage early and often to be successful; failure to engage is failure
- Not about winning or losing; operating as a coherent and comprehensive system
- We will make mistakes and learn our way forward; be reflective
- We are collectively responsible – focus on how the system functions, rather than "owning" a part
- Failure of one component of the system is failure of the system
- Trust in each other and that the system is working

"Central" Players

- Aboriginal Relations, Aboriginal Consultation Office (AR - ACO).
- Alberta Energy Regulator (AER)
- Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA)
- Department of Energy (Energy, DoE)
- Alberta Environment and Sustainable Resource Development (ESRD)

IRMS Governance



IRMS Office

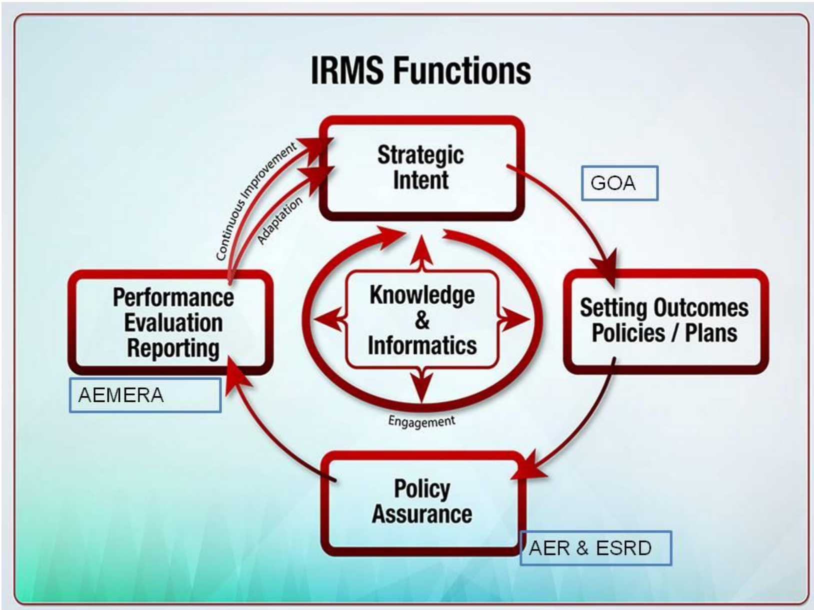
TRANSITIONAL ROLE

- **IRMS Design/Advancement**
  - shaping system components
  - clarifying roles, responsibilities, relationships
  - developing business processes
- **Portfolio Management**
  - coordinating & tracking issues
  - progress reporting
  - facilitating process to confirm direction and priorities
  - communicating direction and decisions
- **Communication and Engagement**
  - promoting awareness and understanding
  - change management

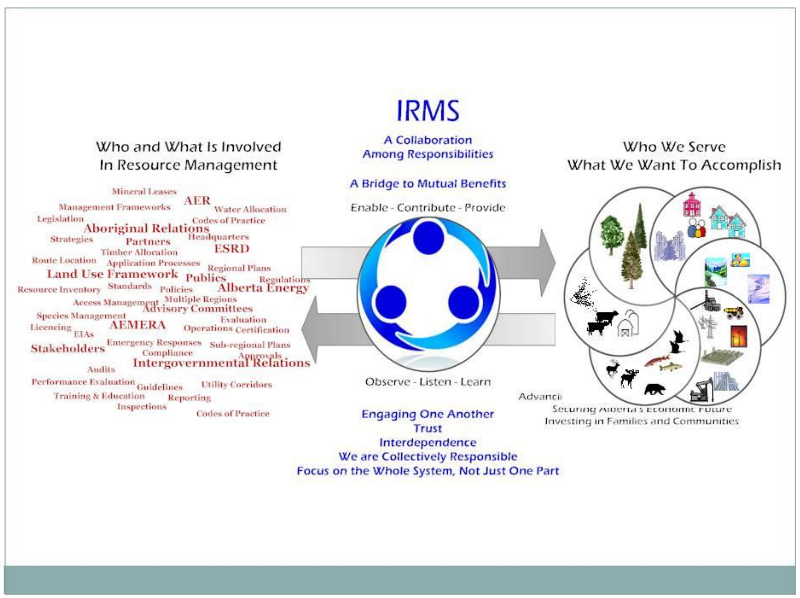
OPERATIONAL ROLE

- **System Management**
  - connector, convener
  - issues identification and resolution enabler
  - stimulating continuous improvement
  - triggering adaptation
- **Performance Reporting**
  - 'state of' system reporting
  - identification of gaps and opportunities
- **Communication and Engagement**
  - promoting understanding, literacy

+ Provide secretariat support for IRMS SC/SWG/TT


IRMS Functions
Strategic Intent
GOA
Continuous Improvement
Adaptation
Performance Evaluation Reporting
AEMERA
Knowledge & Informatics
Setting Outcomes Policies / Plans
Engagement
Policy Assurance
AER & ESRD

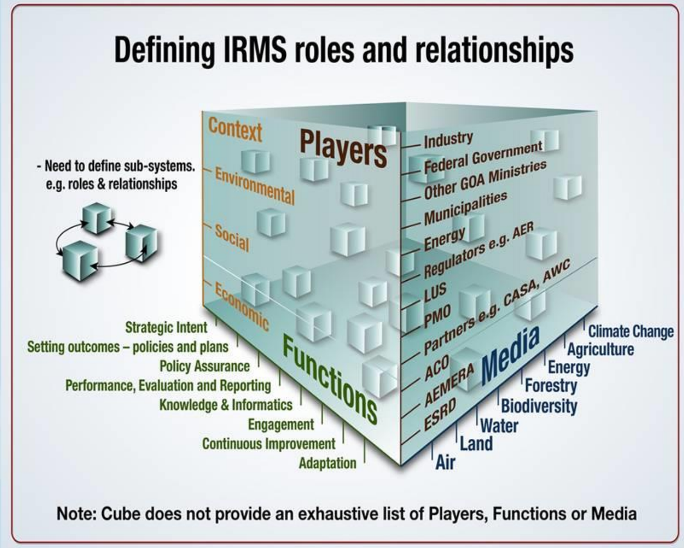

Integrated Resource Management
Why pursue IRMS?
✓ Continued economic and population growth
✓ Need to manage cumulative effects
✓ Heightened need for integration and resource optimization
✓ Growing expectations of public and stakeholders


IRMS
A Collaboration Among Responsibilities
A Bridge to Mutual Benefits
Enable - Contribute - Provide
Who and What Is Involved In Resource Management
Who We Serve What We Want To Accomplish
AER
Aboriginal Relations
ESRD
Land Use Framework
Alberta Energy
AEMERA
Stakeholders
Intergovernmental Relations
Observe - Listen - Learn
Engaging One Another
Trust
Interdependence
We are Collectively Responsible
Focus on the Whole System, Not Just One Part


Some IRM Basics
Integrated resource management recognizes:
• Use & enjoyment of a natural resource or environment for one purpose affects:
– others who may want to use resource/environment for the same or other purposes.
– use/enjoyment of other natural resources.
• There are cumulative effects and limits.
• The environment, the economy & society are each complex & dynamic and interact with one another.

Previous Approach	Fully Functional IRMS
Alberta Advantage fuelled by resource development	Social Licence required to develop resources
Some fragmented systems	Connected system with clear accountabilities
Independent action to produce outputs	Collective action to achieve outcomes
View some resources as abundant	Recognize finite capacity of resources
Management of incremental impacts on an activity-by-activity basis	Management of cumulative (and interactive) impacts of all activities
Policy assured through prescriptive, 'cookie-cutter' regulation	Outcomes-based management through a suite of regulatory and non-regulatory tools tailored to meet place-based circumstances
Management response often reactive	Proactive management of risks and opportunities
Data collected for single use and user; viewed as evidence to be stored	Data is open and accessible for multiple uses and users; viewed as asset to be shared
Some tendency to report good news	All news is reported

It's not pretty…



IRMS -- Who are the participants?

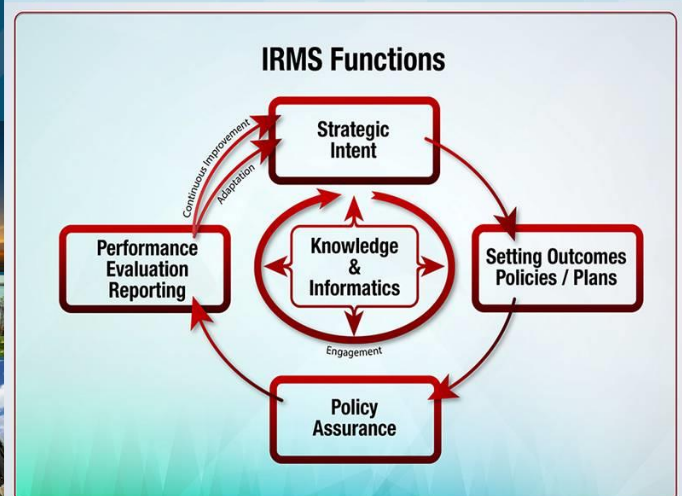
Those responsible for management of the various natural resources and the environment.

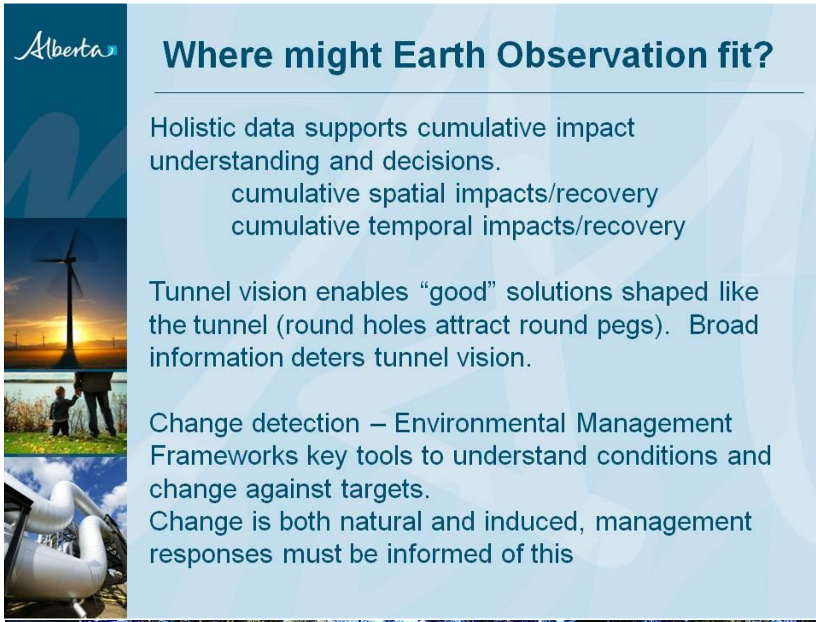
Those who are accountable, consulted or informed by/about resource management and environmental conditions.

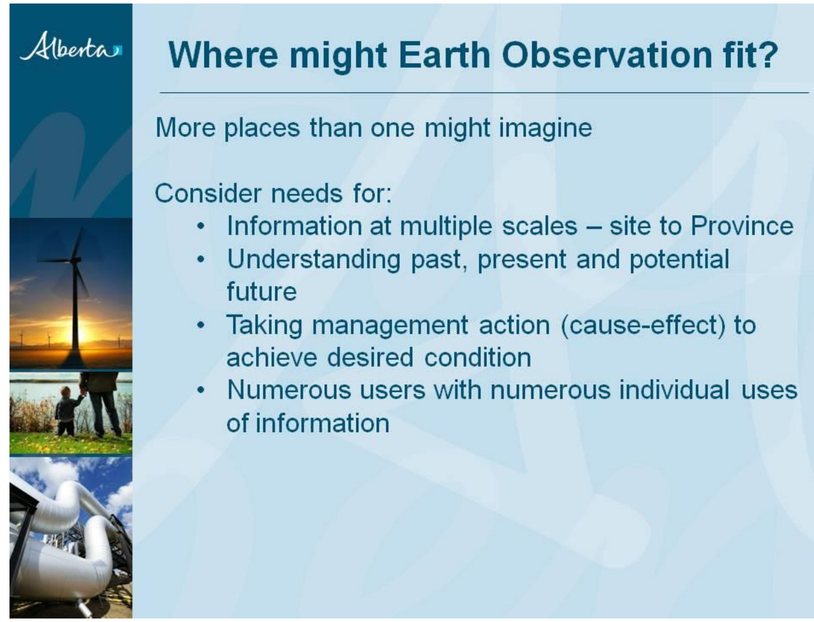
Those that support or enable resource management & integration.

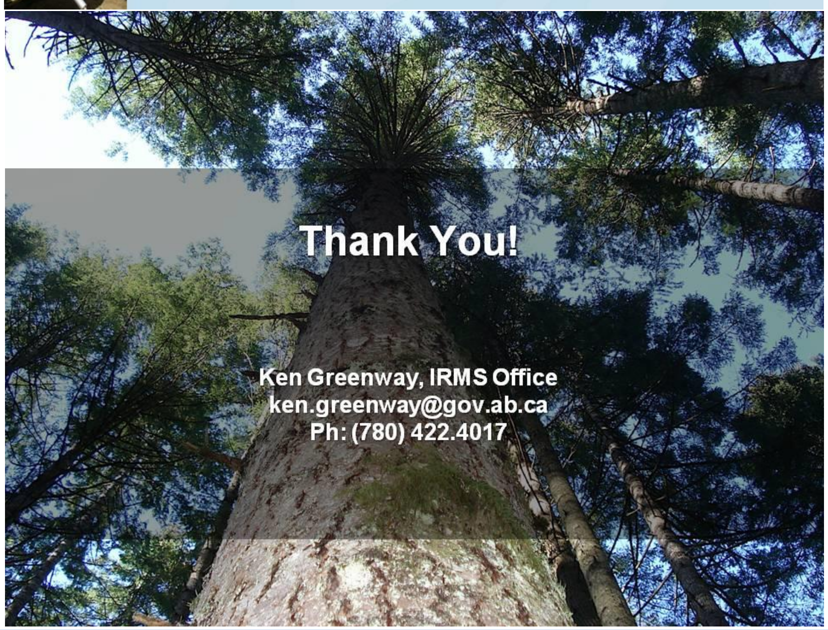
Those parties, even if they are not part of the formal System, that see themselves in the above.

Where might Earth Observation fit?

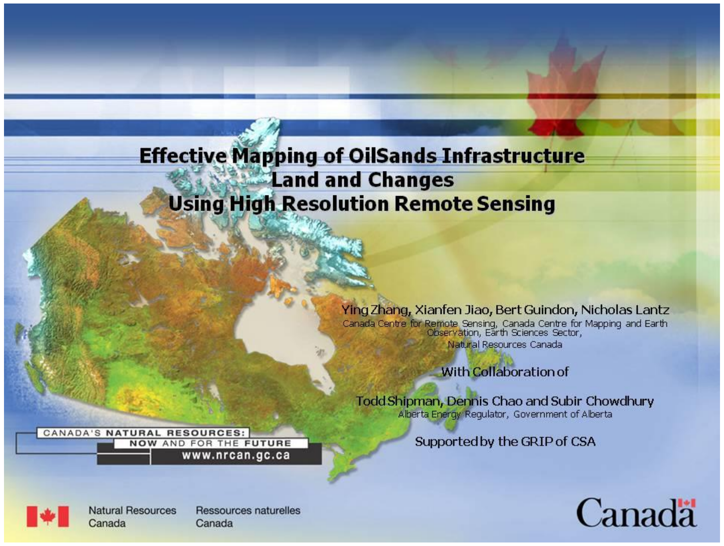



Alberta
Where might Earth Observation fit?
Holistic data supports cumulative impact understanding and decisions.
cumulative spatial impacts/recovery
cumulative temporal impacts/recovery
Tunnel vision enables "good" solutions shaped like the tunnel (round holes attract round pegs). Broad information deters tunnel vision.
Change detection – Environmental Management Frameworks key tools to understand conditions and change against targets.
Change is both natural and induced, management responses must be informed of this


Alberta
Where might Earth Observation fit?
More places than one might imagine
Consider needs for:
• Information at multiple scales – site to Province
• Understanding past, present and potential future
• Taking management action (cause-effect) to achieve desired condition
• Numerous users with numerous individual uses of information


Thank You!
Ken Greenway, IRMS Office
ken.greenway@gov.ab.ca
Ph: (780) 422.4017

Infrastructure Monitoring with EO, Ying Zhang, NRCan-CCRS



7.3.1.1.1.1.1.24

7.3.1.1.1.1.1.25

Canada Centre for Remote Sensing - ESS

Mapping Infrastructure Features and Changes

Requirements:

- **Image Targets**: Infrastructure features and changes associated with relevant production, exploration and transportation activities (i.e. well sites, well pads, drilling pads, roads, pipelines etc.)
- **Methodologies**: Effective target detection and precise mapping with potential for operational use.
- **Products**: GIS-based maps of relevant land features and their changes

Project Objectives:

- Develop methodologies for quantifying infrastructure footprints and changes.
- Assess the relevant information content of high resolution (<10m) satellite imagery as it pertains to man-made features of interest.
- Assess the compatibility of different sensors, both optical and radar, for integrated change monitoring.
- Evaluate the cost effectiveness of various satellite image sources for operational monitoring purposes.

Natural Resources Canada Ressources naturelles Canada 3 Canada

7.3.1.1.1.1.1.26

Canada Centre for Remote Sensing - ESS

High Resolution Remote Sensing Data

Sensor selection and assessment based on the trade-off between cost and information potential.

❖High (5-10m) resolution data (SPOT5, RapidEye and RadarSat2) for synoptic monitoring.

❖Very high resolution (<5m) imagery (Pleiades and WorldView2) for selected target areas and for validation.

SPOT5, 10m

RapidEye, 5m

WorldView2, 2m

Natural Resources Canada Ressources naturelles Canada 4 Canada

7.3.1.1.1.1.1.27

Canada Centre for Remote Sensing - ESS

Strategy for Targeted Information Extraction

Technology Challenging Level →

Test Site	A. Open Pit Oilsands	B. In-Situ Oilsands	C. In-Situ Oil and Gas	D. In-Situ Oil and Gas	E. In-Situ Oil and Gas
Background	Forest	Forest	Forest	Agriculture	Agriculture
Size (km²)	1017.3	625	625	625	360
Sensor	SPOT5 (10m)	SPOT5 (10m), RapiEye (5m), RadarSat2 (various)	RapidEye (5m)	RapidEye (5m)	RapidEye (5m) Pleiades (2m)

Natural Resources Canada Ressources naturelles Canada 5 Canada

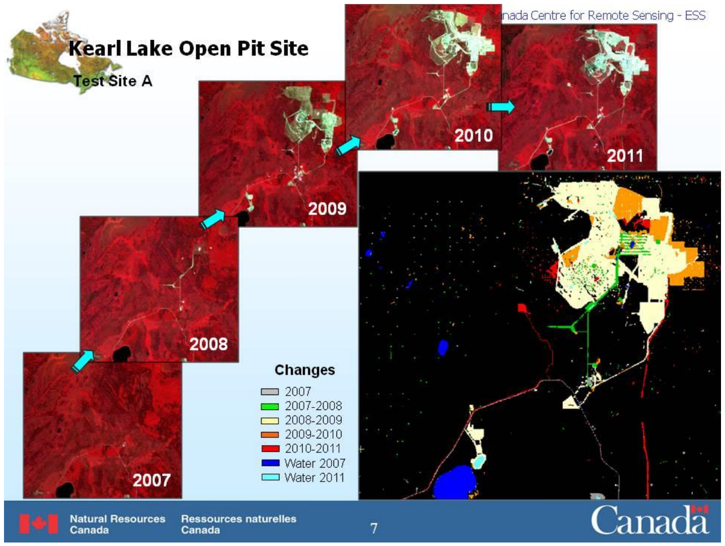
7.3.1.1.1.1.1.28

Canada Centre for Remote Sensing - ESS

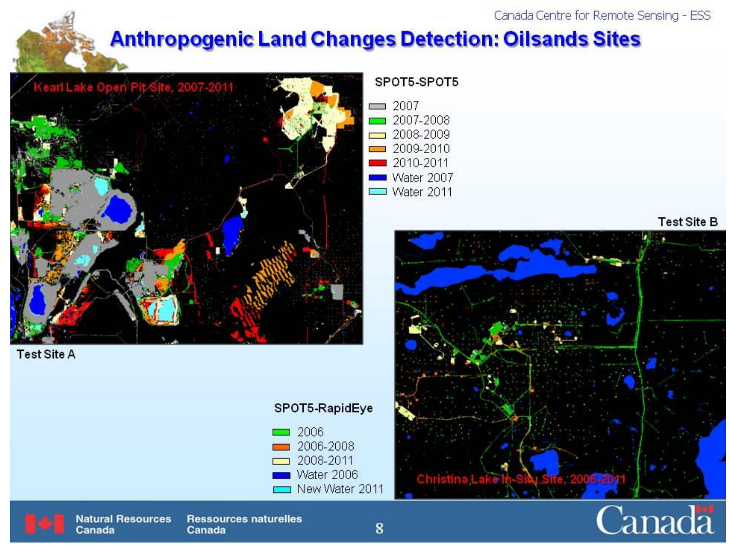
Oilsands Resources Development in Northern Alberta

Natural Resources Canada Ressources naturelles Canada 6 Canada

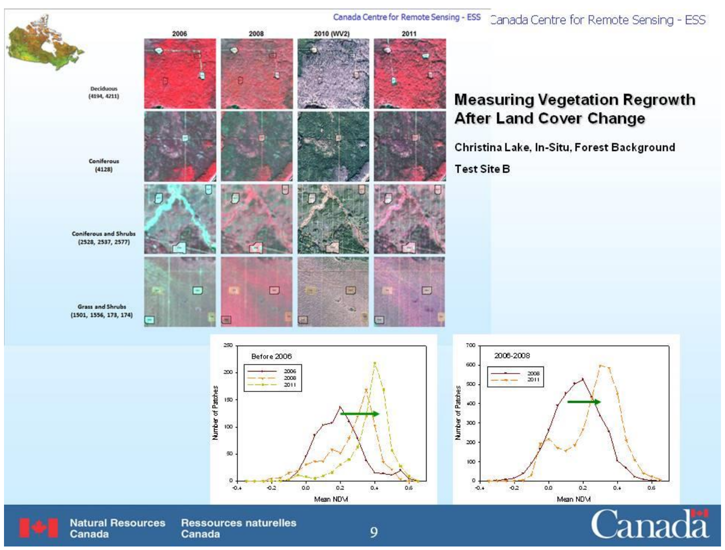
7.3.1.1.1.1.1.29



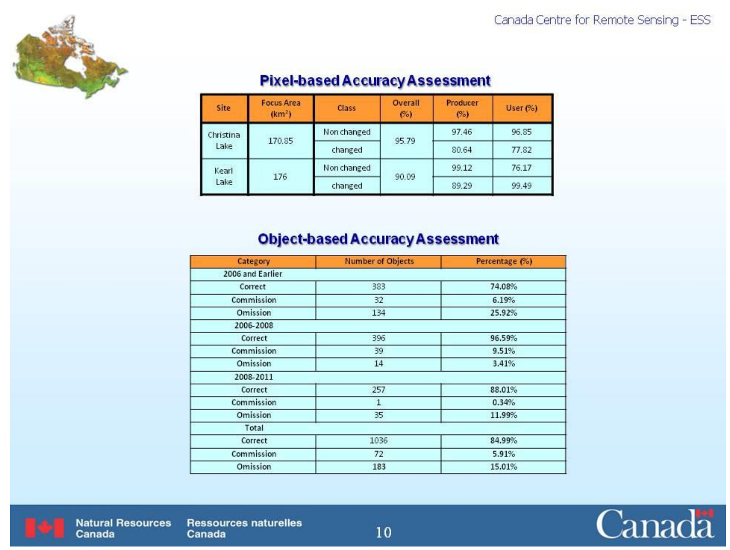
7.3.1.1.1.1.1.30



7.3.1.1.1.1.1.31



7.3.1.1.1.1.1.32



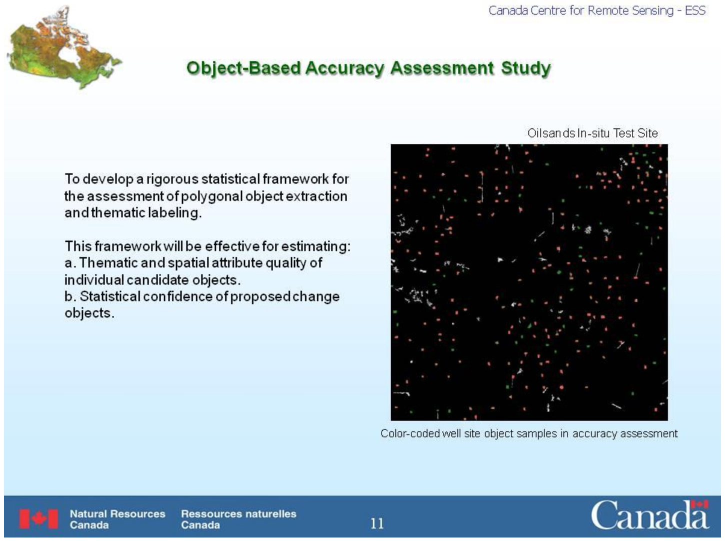
Pixel-based Accuracy Assessment

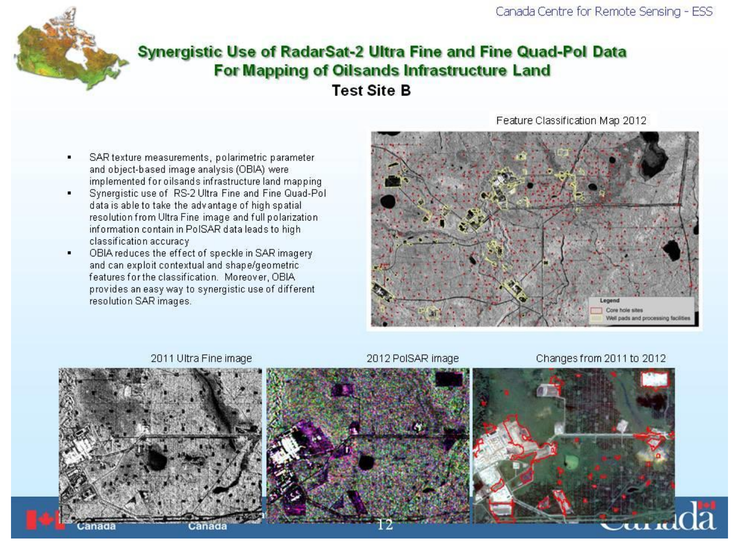
Site	Focus Area (km²)	Class	Overall (%)	Producer (%)	User (%)
Christina Lake	170.85	Non changed	95.79	97.46	96.85
		changed		80.64	77.82
Kearl Lake	176	Non changed	90.09	99.12	76.17
		changed		89.29	99.49

Object-based Accuracy Assessment

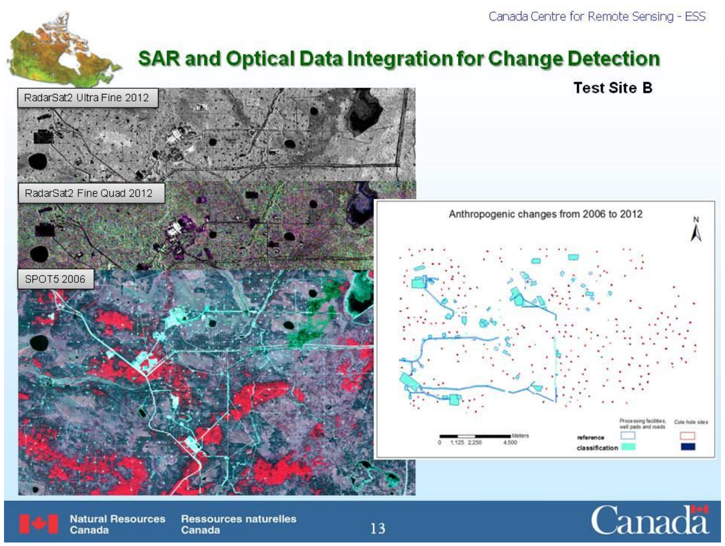
Category	Number of Objects	Percentage (%)
2006 and Earlier		
Correct	383	74.08%
Commission	32	6.19%
Omission	134	25.92%
2006-2008		
Correct	396	96.59%
Commission	39	9.51%
Omission	14	3.41%
2008-2011		
Correct	257	88.01%
Commission	1	0.34%
Omission	35	11.99%
Total		
Correct	1036	84.99%
Commission	72	5.91%
Omission	183	15.01%

7.3.1.1.1.1.1.33

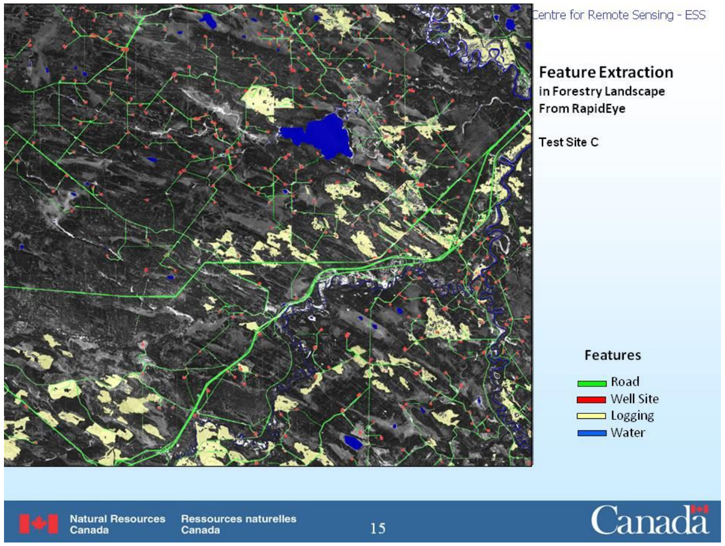


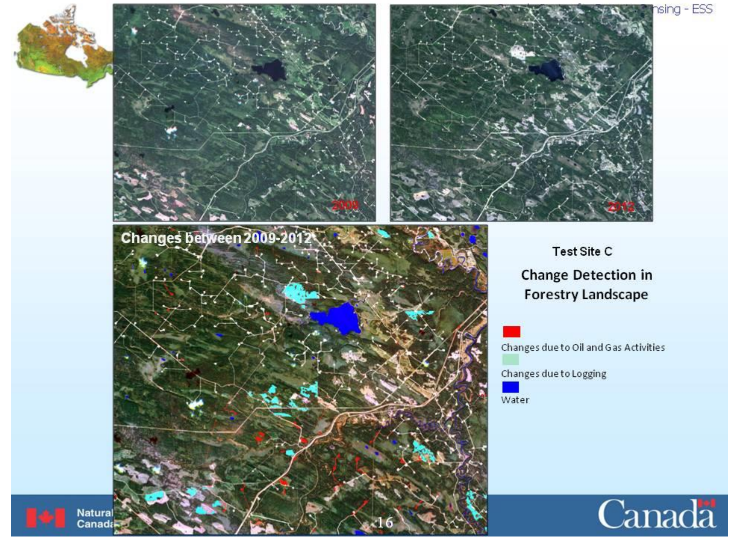


7.3.1.1.1.1.1.34

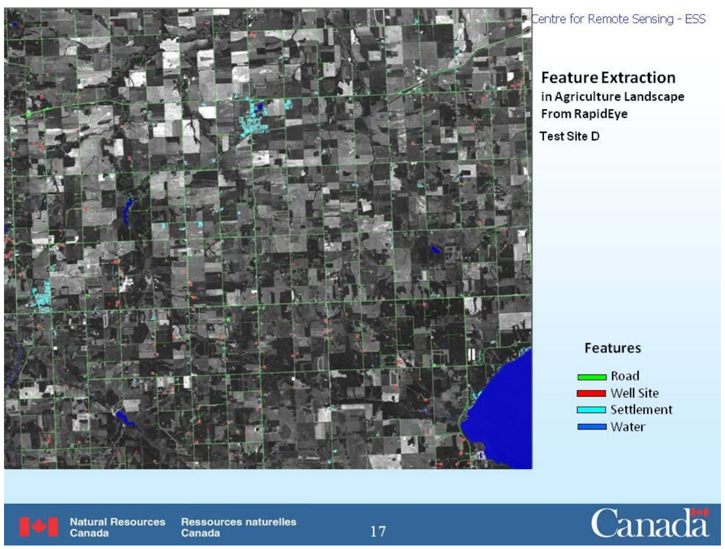


7.3.1.1.1.1.1.35

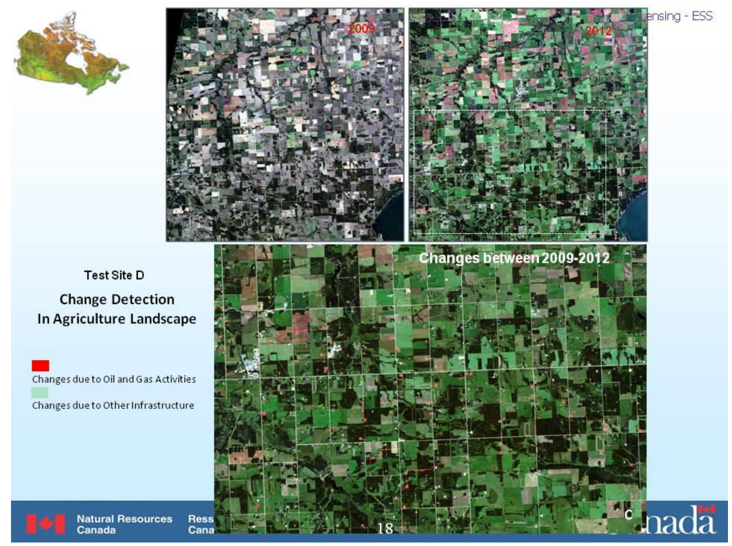




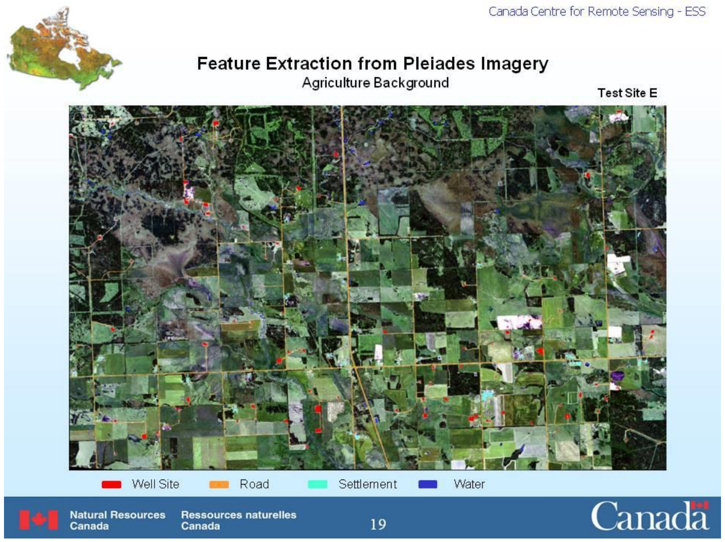
7.3.1.1.1.1.1.36

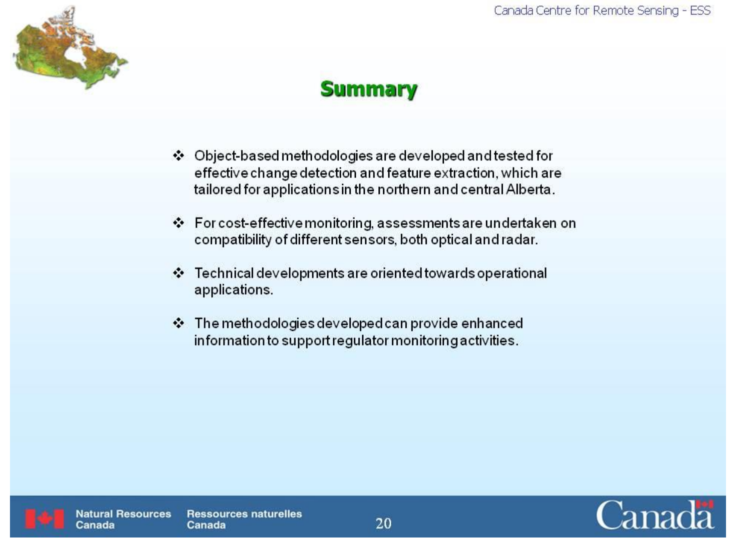


7.3.1.1.1.1.1.37



7.3.1.1.1.1.1.38

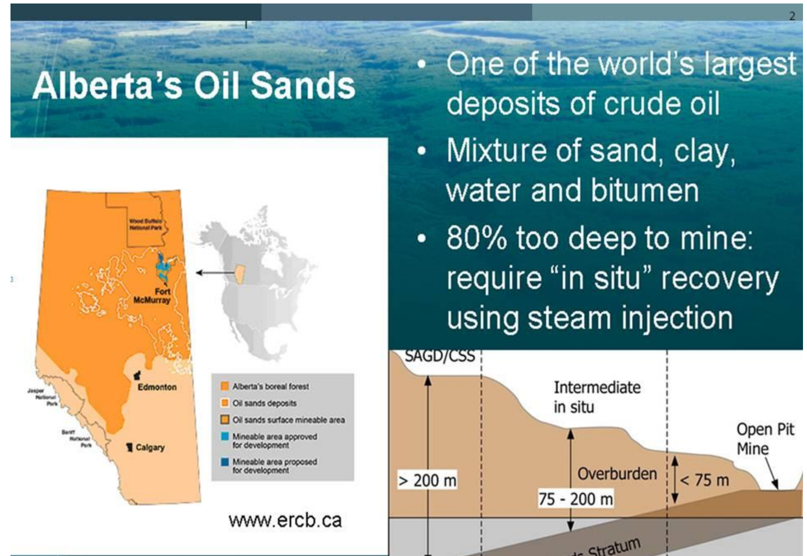


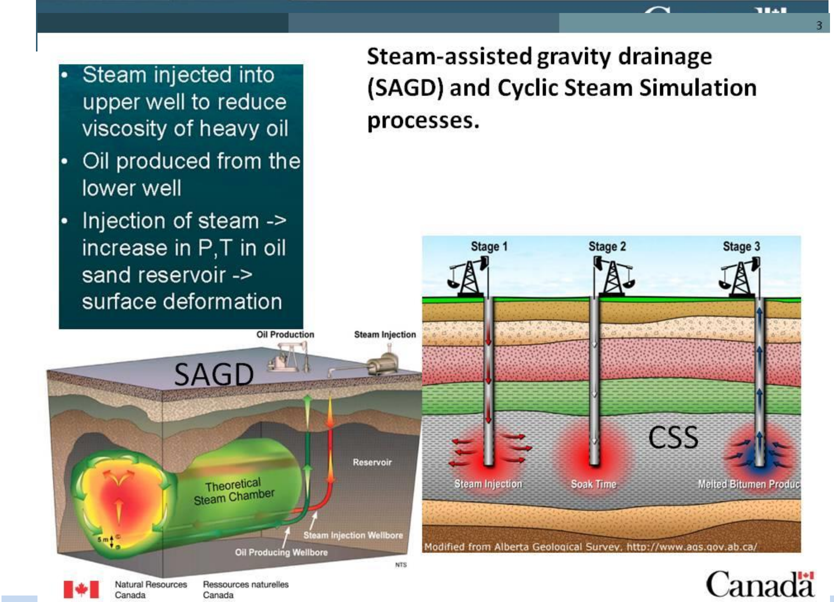


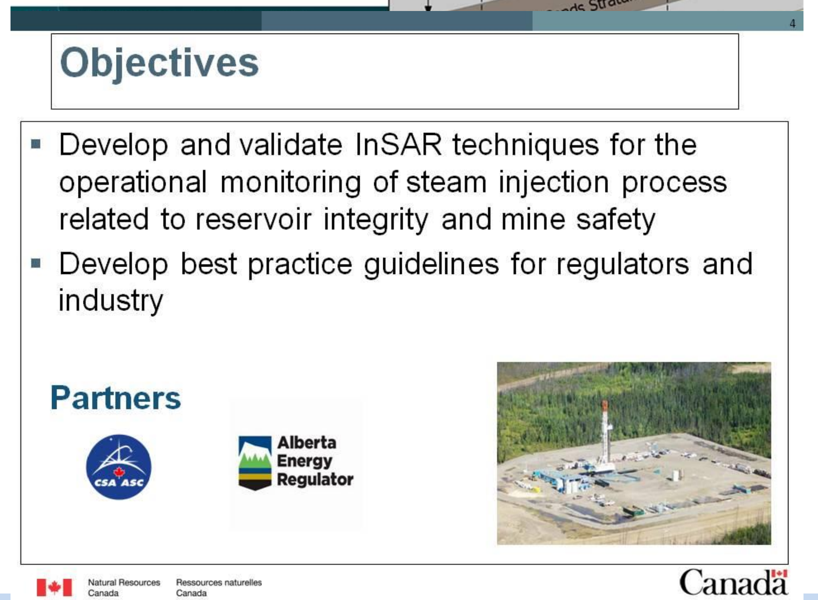
7.3.1.1.1.1.1.39

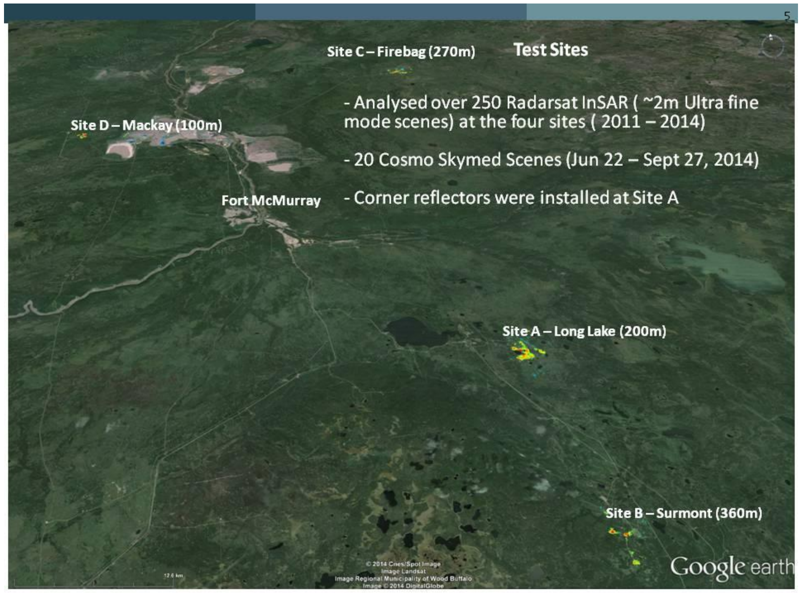
7.3.1.1.1.1.1.40


NATURAL RESOURCES CANADA - INVENTIVE BY NATURE
INSAR MONITORING OF SURFACE DEFORMATION INDUCED BY
STEAM INJECTION AT THE ATHABASCA OIL SANDS
V. Singhroy [1], J. Li [1], S. Samsonov [1], L. Shen [2],
[1]Canada Center for Remote Sensing, Ottawa, Canada.
[2] Alberta Geological Survey, Edmonton, Alberta, Canada.


2
Alberta's Oil Sands
• One of the world's largest deposits of crude oil
• Mixture of sand, clay, water and bitumen
• 80% too deep to mine: require "in situ" recovery using steam injection
Fort McMurray
Edmonton
Calgary
Alberta's boreal forest
Oil sands deposits
Oil sands surface mineable area
Mineable area approved for development
Mineable area proposed for development
www.ercb.ca
SAGD/CSS
Intermediate in situ
Open Pit Mine
> 200 m
Overburden
75 - 200 m
< 75 m


3
• Steam injected into upper well to reduce viscosity of heavy oil
• Oil produced from the lower well
• Injection of steam -> increase in P,T in oil sand reservoir -> surface deformation
Steam-assisted gravity drainage (SAGD) and Cyclic Steam Simulation processes.
Oil Production
Steam Injection
SAGD
Reservoir
Theoretical Steam Chamber
Steam Injection Wellbore
Oil Producing Wellbore
Stage 1
Stage 2
Stage 3
CSS
Steam Injection
Soak Time
Modified from Alberta Geological Survey, http://www.ags.gov.ab.ca/
Natural Resources Canada
Ressources naturelles Canada
Canada


4
Objectives
▪ Develop and validate InSAR techniques for the operational monitoring of steam injection process related to reservoir integrity and mine safety
▪ Develop best practice guidelines for regulators and industry
Partners
CSA ASC
Alberta Energy Regulator
Natural Resources Canada
Ressources naturelles Canada
Canada



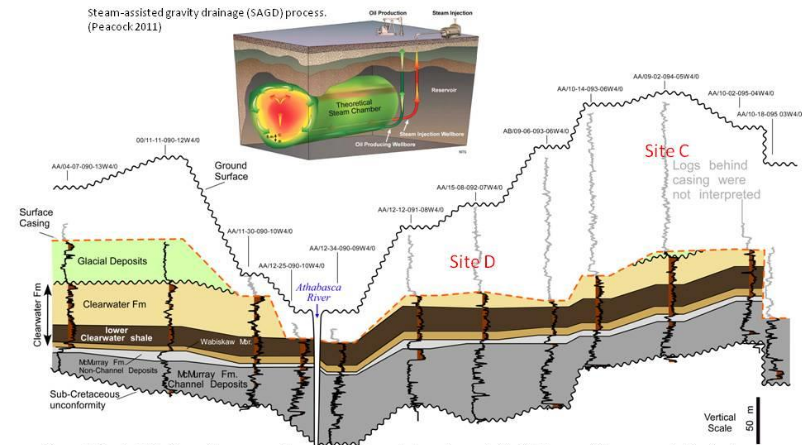


Figure 1: Typical stratigraphic cross section of the oil sands showing variable thickness of the reservoir lithologies

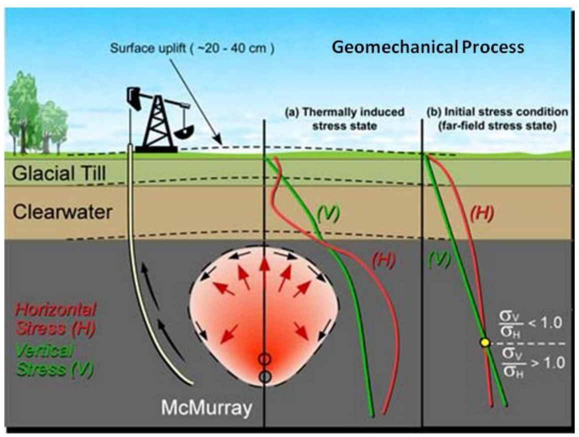
Potential risks for caprock integrity are:

1:buried channels cutting into the Clearwater Formation creating pathways for steam to escape.

2: Complete absence and thinning of the Clearwater Formation.

3: Fracturing and faulting of the caprock due to post depositional deformation. (Haug et al. 2013)

Natural Resources Canada Ressources naturelles Canada Canada



In the overburden directly above the steam chamber, there may be a slight increase in vertical stress and a decrease in horizontal stress

Haug, K.M. Greene, P. Schneider, C.L. Mei, S. 2013 Geological and Geomechanical Characterization of In situ Oil Sands Caprock in the Athabasca Oil Sands Area, Alberta, Canada *Alberta Geological Survey, Edmonton, Alberta, Canada:* 47th US Rock Mechanics / Geomechanics Symposium held in San Francisco

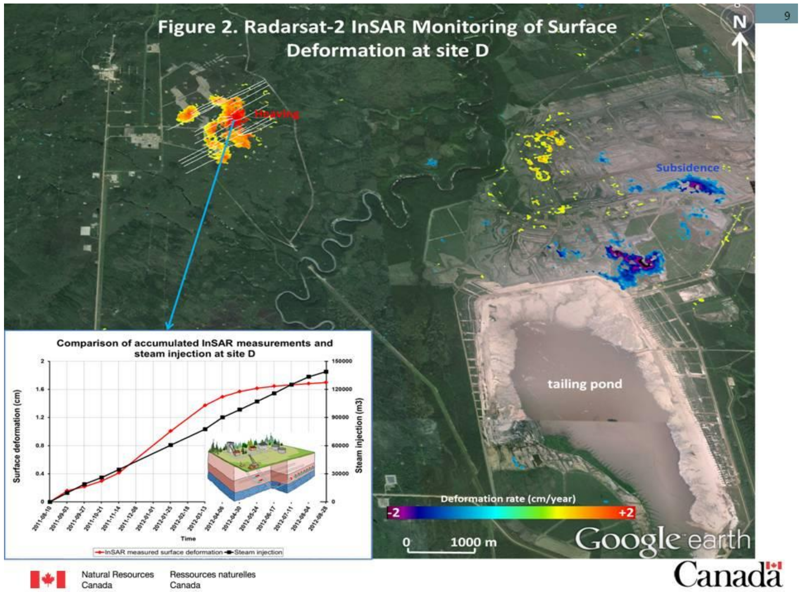
Natural Resources Canada Ressources naturelles Canada Canada

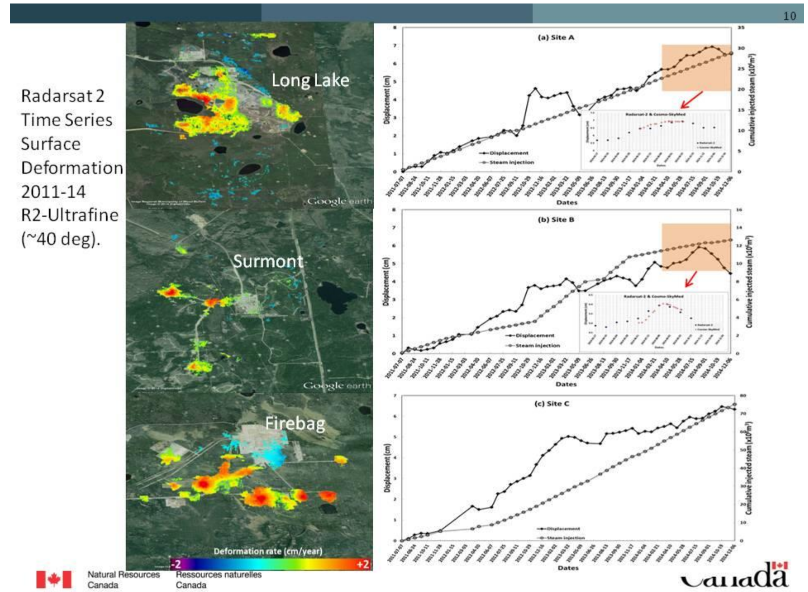
8

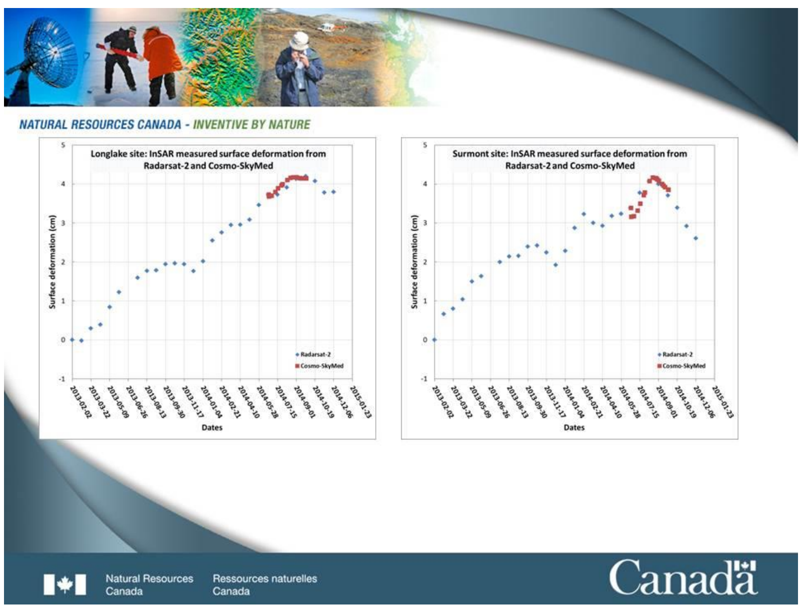
Methods:

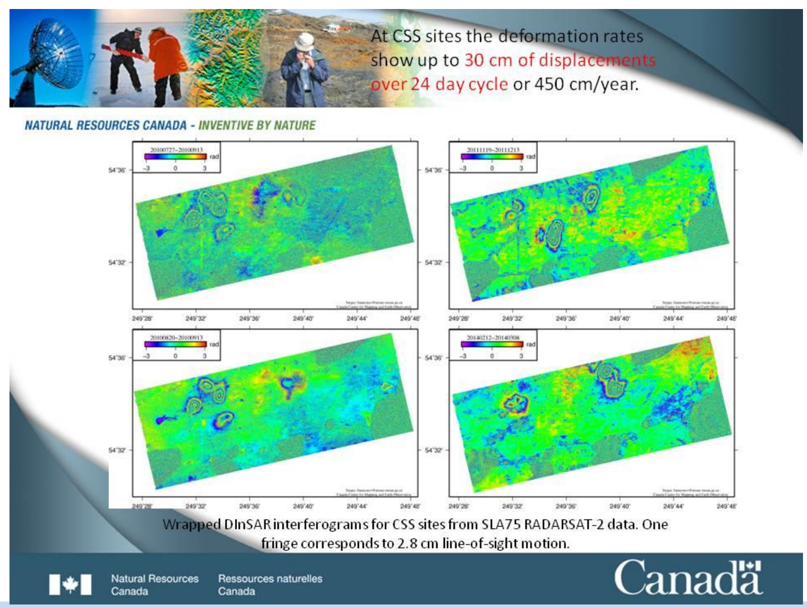
- Our InSAR processing method uses an improved SBAS (Small Baseline Subset) algorithm which minimizes the effects of the atmosphere and inaccuracies in the DEM on the accuracy of InSAR measurements.
- The method produces nonlinear time series of deformation over a long period of time using interferograms with short time spans, which are usually more coherent- Cosmo-SkyMed/ RCM.
- A high-pass filtering was applied to remove the residual orbital and long wavelength atmospheric signals.
- A Singular Value Decomposition (SVD) inversion was applied to simultaneously solve for the individual deformation rates and the residual topographic error.

Natural Resources Canada Ressources naturelles Canada Canada

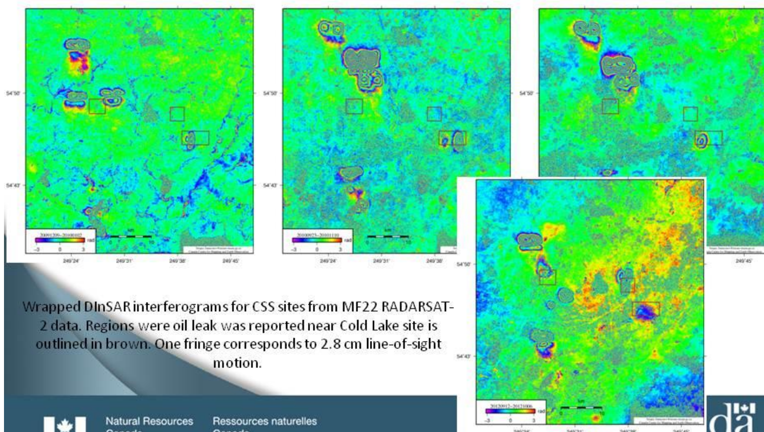

9
Figure 2. Radarsat-2 InSAR Monitoring of Surface Deformation at site D
N
Subsidence
tailing pond
Comparison of accumulated InSAR measurements and steam injection at site D
Surface deformation (cm)
Steam injection (m3)
Time
InSAR measured surface deformation
Steam injection
Deformation rate (cm/year)
-2
+2
0
1000 m
Google earth
Natural Resources Canada
Ressources naturelles Canada
Canada


10
Radarsat 2 Time Series Surface Deformation 2011-14 R2-Ultrafine (~40 deg).
Long Lake
Surmont
Firebag
Deformation rate (cm/year)
-2
+2
(a) Site A
(b) Site B
(c) Site C
Displacement (cm)
Dates
Displacement
Steam injection
Radarsat-2 & Cosmo-SkyMed
Natural Resources Canada
Ressources naturelles Canada
Canada


NATURAL RESOURCES CANADA - INVENTIVE BY NATURE
Longlake site: InSAR measured surface deformation from Radarsat-2 and Cosmo-SkyMed
Surmont site: InSAR measured surface deformation from Radarsat-2 and Cosmo-SkyMed
Surface deformation (cm)
Dates
Radarsat-2
Cosmo-SkyMed
Natural Resources Canada
Ressources naturelles Canada
Canada


At CSS sites the deformation rates show up to 30 cm of displacements over 24 day cycle or 450 cm/year.
NATURAL RESOURCES CANADA - INVENTIVE BY NATURE
Wrapped DInSAR interferograms for CSS sites from SLA75 RADARSAT-2 data. One fringe corresponds to 2.8 cm line-of-sight motion.
Natural Resources Canada
Ressources naturelles Canada
Canada

NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

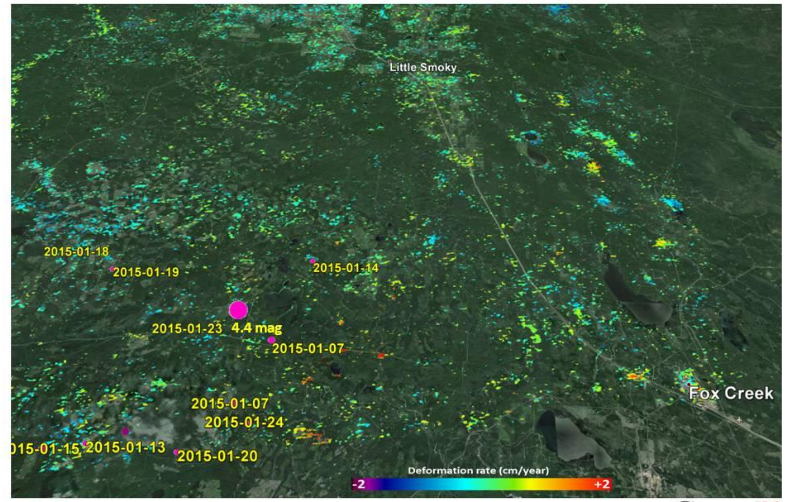


Wrapped DInSAR interferograms for CSS sites from MF22 RADARSAT-2 data. Regions were oil leak was reported near Cold Lake site is outlined in brown. One fringe corresponds to 2.8 cm line-of-sight motion.

Natural Resources Canada Ressources naturelles Canada

14

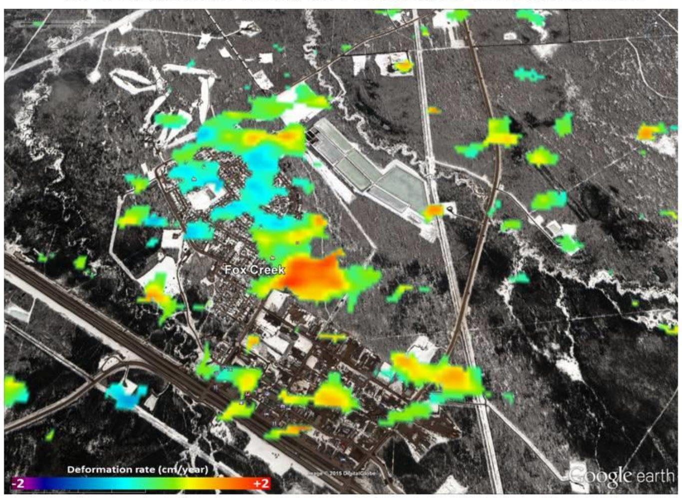
Fox Creek: Radarsat-2 InSAR (F0W2, 8 scenes): 2014-06-21 to 2015-01-23



Natural Resources Canada Ressources naturelles Canada Canada

15

Fox Creek: Radarsat-2 InSAR (F0W2, 8 scenes): 2014-06-21 to 2015-01-23



Natural Resources Canada Ressources naturelles Canada Canada

16

Publications to date.

- Singhroy, V., Li. J., S. Samsonov, L. Shen and J. Pearse, J. (2014), InSAR monitoring of surface deformation induced by steam injection in the Athabasca oil sands. *Proceedings*, ***IEEE-IGARSS* Quebec**, pp.4796-4799.
- Pearse, J., V. Singhroy, S. Samsonov, and J. Li (2014), Anomalous surface heave induced by enhanced oil recovery in northern Alberta: InSAR observations and numerical modeling, ***J. Geophys. Res. Solid Earth,*** 119, doi:10.1002/2013JB010885
- L.Shen, R. Dokht, D.Schmitt, S.Samsonov, V. Singhroy, T.Shipman (2015) Geomechanical Modelling of Cyclic Steaming Induced Surface Deformation. **2015 SPE Heavy Oil Conference-Canada.**
- L.Shen, D.Schmitt, V.Singhroy, S.Samsonov, T.Shipman (2015). Numerical Assessment of SAGD Subsurface Integrity and Induced Heave. **2015 World Heavy Oil Congress**.
- L.Shen, V. Singhroy, S. Samsanov (2014). Forward modeling of SAGD Induced Heave and Caprock Integrity analysis. **2014 SPE Heavy Oil Conference-Canada**.
- Samsonov, S., Czarnogorska, M. (2014). Ground deformation due to steam assisted gravity drainage and cyclic steam stimulation observed from RADARSAT2 in Alberta's oil sands. *Proceedings*, ***IEEE-IGARSS* Quebec**, pp.883-885.

Natural Resources Canada Ressources naturelles Canada Canada

Conclusions

We provide examples of InSAR monitoring over four SAGD sites with different overburden thickness. Our results show:

SAGD

- The uplift rates above the horizontal injector wells are strongly correlated with rates of steam injection.
- The cumulative overburden thickness is not influencing the amount of surface heave. Shallow reservoir (100 m) shows the same heave of about 2 cm/year compared to the area with thicker overburden (> 300 m).
- Local seasonal freeze-thaw cycles are producing seasonal variability in surface deformation.
- The more rapid revisit Cosmo SkyMed acquisitions are providing more frequent InSAR heave results to monitor the complex geomechanical dilation process of reservoir. The future application of a similar satellite constellation, such as the Radar Constellation Mission (RCM), will be significant in monitoring surface deformation. This is the focus of our current investigation

CSS

- At CSS sites the deformation rates show up to 30 cm of displacements over 24 day cycle or 450 cm/year.

Fox Creek –(Fracking)

- InSAR results from June 2014- Jan 2015 show the area has poor coherence due to the dense vegetation (the need for corner reflectors).
- We have seen some minor motion at Fox Creek. We plan to continue our investigation.

Natural Resources Canada Ressources naturelles Canada

Canada

Surface Water Mapping in the AOSR with SAR, Brian Brisco, NRCan-CCRS

Monitoring Terrestrial Wetlands and Watershed Basins with RCM Rapid Revisit and CCD Mode

Canada Centre for Remote Sensing
CCMEO/ESS/NRCan
Brian.Brisco@NRCan.gc.ca

Natural Resources Canada | Ressources naturelles Canada | Canada

Project Team

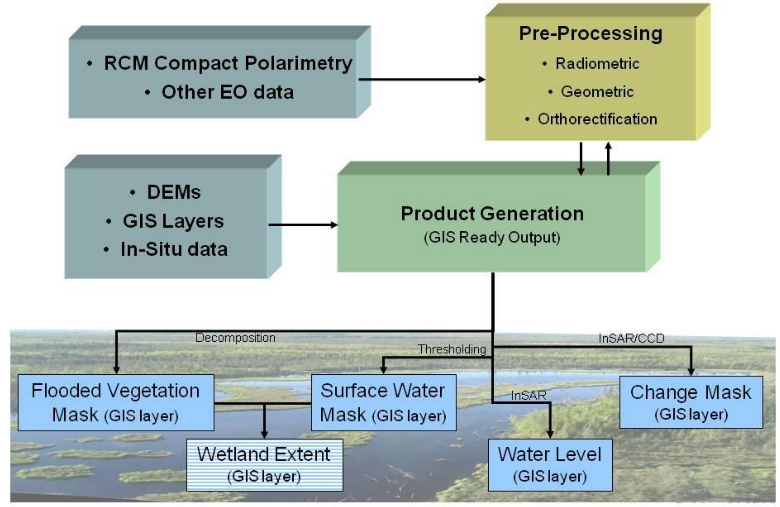
- Project Lead
  - Brian Brisco
- Research Associates
  - Kevin Murnaghan, Lori White, Alexander Chichagov
- Collaborations
  - EC – Al Pietroniro and Daniel Peters
  - AB – Shane Patterson
  - UM – Shimon Wdowinski
  - MTRI – Don Atwood
  - DLR – Andreas Schmitt
  - JPL- Seungbum Kim

Natural Resources Canada | Ressources naturelles Canada | Canada

Outline

- Project Background
- Coherence
  - Wetland parameters
  - Temporal point monitoring
  - Seasonal area product
- Interferometry
  - Relative water level
  - Absolute water level
- Surface Water Extent
- Towards RCM

SAR Surface Water Monitoring



RCM-CCD Project

- Project initially started in RSS program at CCRS (5K)
- Funding provided by RCM-CCD through CSA for 2 years
- Oil Sands GRIP for 2 years

Objectives

- 1) to evaluate wetland vegetation and hydrology characteristics that generate high coherence to allow for InSAR estimation of water level;
- 2) to develop new geo-spatial techniques for the extraction of water level information from freshwater wetlands using InSAR and ancillary data sources; and
- 3) to prepare a plan for the operational implementation of the techniques developed for implementation with future SAR systems including the RCM.

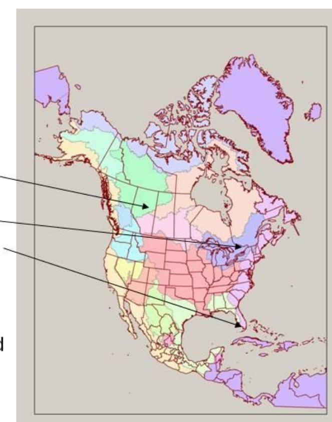
RCM-CCD Test Sites

Study Sites

•Peace Athabasca Delta, Alberta

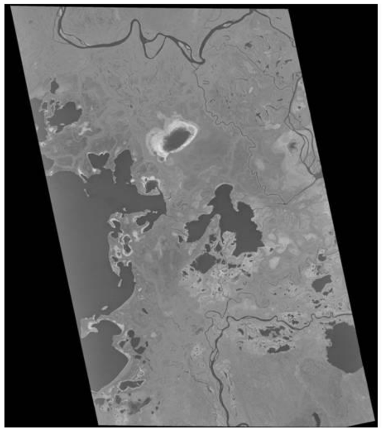
•Lake Clear, Ontario

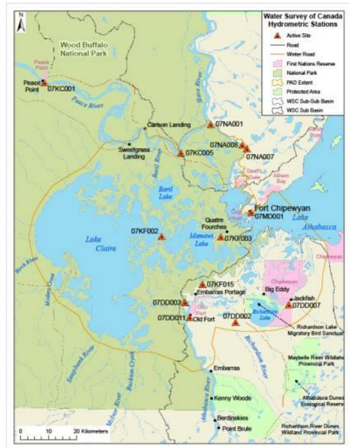
•Everglades National Park, Florida



Note: Calgary and Edmonton added for future work

PAD Hydrometric Sites





Natural Resources Canada Ressources naturelles Canada

Canada

RADAR Reflector Configurations

Up

Triple Bounce

Wet

Triple Bounce

Down

Quintuple Bounce

Water level logger

Natural Resources Canada Ressources naturelles Canada

Canada

SAR Coherence

Coherence is related to the degree to which surfaces are identical, it is measured on a scale of 0 (low) to 1 (high).

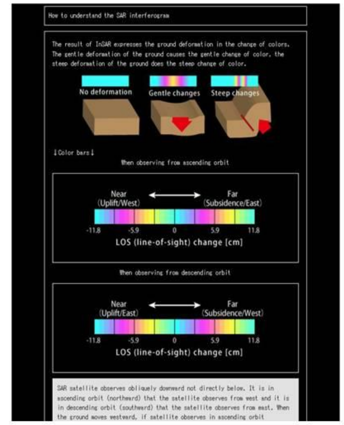
Low	→ usually water (unusable)
Moderate	→ often growing or moving vegetation (sometimes usable)
High	→ desert, rock, infrastructure (usable)

- Most swamps and marshes as well as some open wetlands are coherent for the spring to fall time-period due to double bounce scattering mechanism.
- Interferograms can be generated and water level changes determined with coherence values greater than **.4**

Natural Resources Canada / Ressources naturelles Canada — Canada

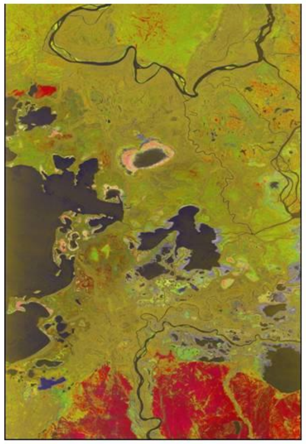
Interferograms

Appendix I. [1]How to understand the SAR interferogram.

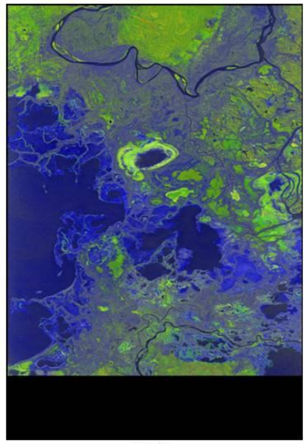


Natural Resources Canada / Ressources naturelles Canada — Canada

Example: PAD U2W2



2012



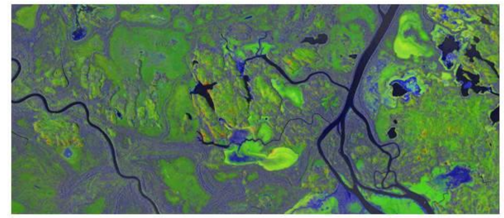
2013

2014

Natural Resources Canada Ressources naturelles Canada

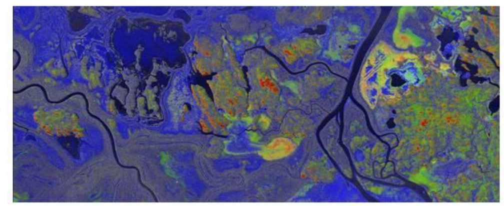
Canada

Example: PAD SLA12



2013

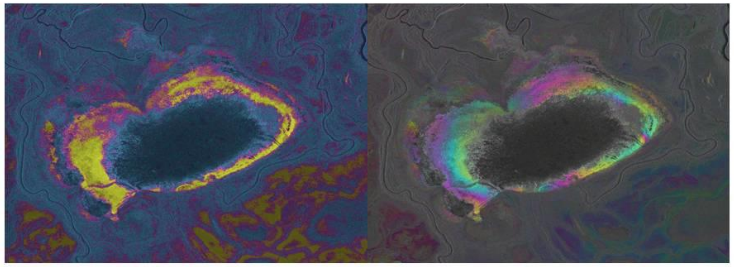
2014



Natural Resources Canada Ressources naturelles Canada

Canada

PAD – Barril Lake 2012 Animation

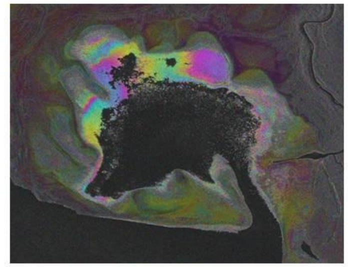


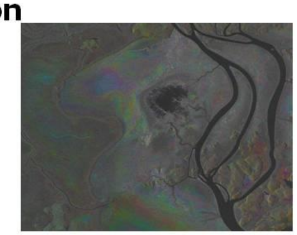
Coherence Interferogram

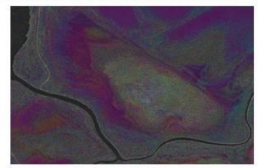
Natural Resources Canada Ressources naturelles Canada

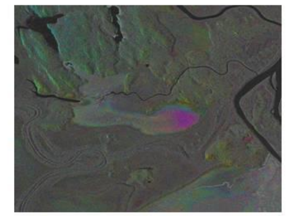
Canada

PAD Remaining Sites Interferogram Animation



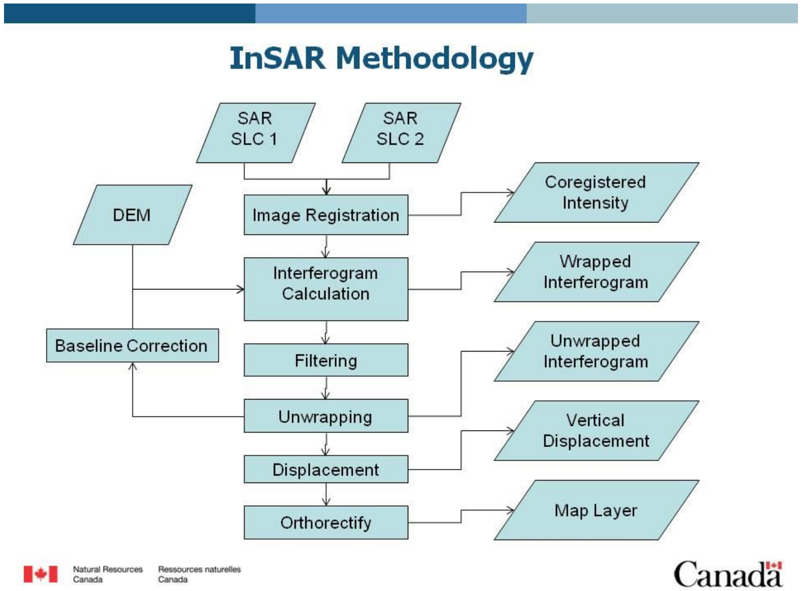


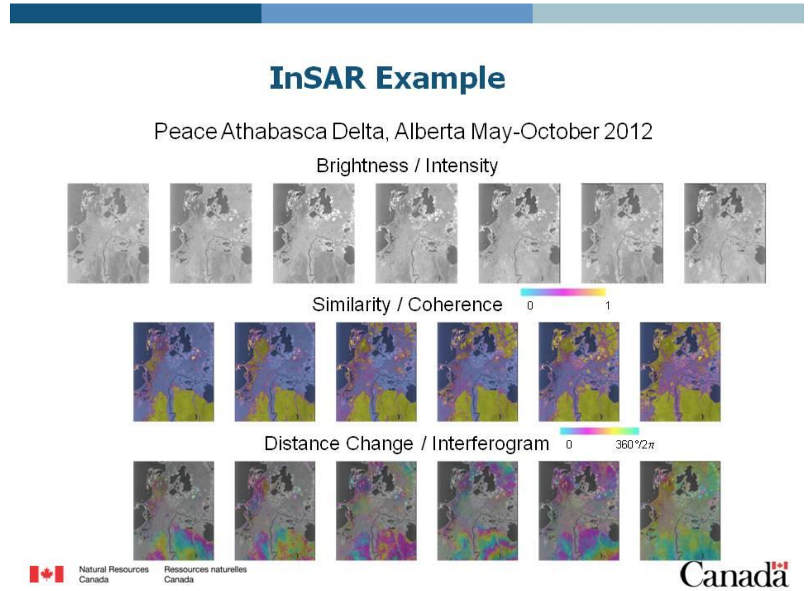




Natural Resources Canada Ressources naturelles Canada

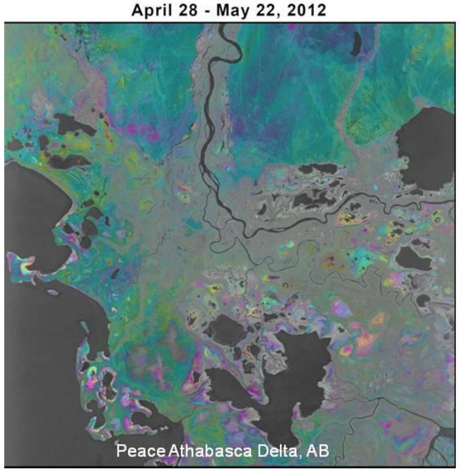
Canada


InSAR Methodology
SAR SLC 1
SAR SLC 2
DEM
Image Registration
Coregistered Intensity
Interferogram Calculation
Wrapped Interferogram
Baseline Correction
Filtering
Unwrapped Interferogram
Unwrapping
Vertical Displacement
Displacement
Orthorectify
Map Layer
Natural Resources Canada
Ressources naturelles Canada
Canada


InSAR Example
Peace Athabasca Delta, Alberta May-October 2012
Brightness / Intensity
Similarity / Coherence
0
1
Distance Change / Interferogram
0
360°/2π
Natural Resources Canada
Ressources naturelles Canada
Canada

Interferogram

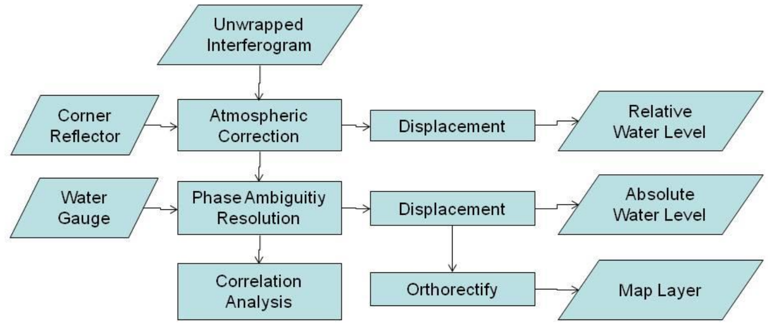
April 28 - May 22, 2012



Natural Resources Canada Ressources naturelles Canada

Canadä

Water Level Methodology



Natural Resources Canada Ressources naturelles Canada

Canadä

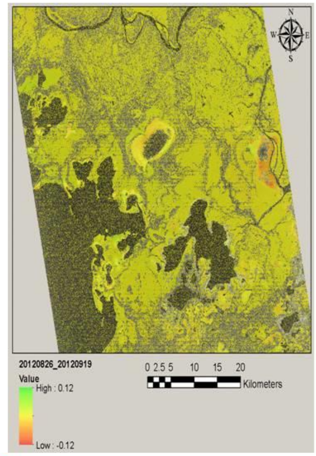
Water Level Products

- Relative water level products
  - Relative change in cm between image acquisitions with no solution for phase ambiguity
  - N-1 products for each season
  - Temporal and spatial variation
  - Flow direction
- Absolute water level products
  - Absolute change in cm between acquisitions
  - Phase ambiguity resolved with water loggers
  - N-1 products for season
  - Can determine volume with DEM or surface water polygons

Natural Resources Canada Ressources naturelles Canada

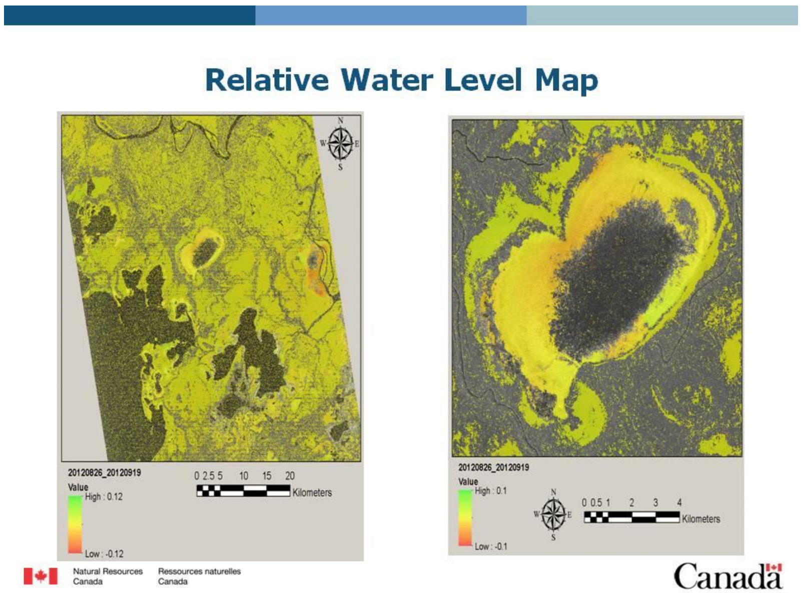
Canada

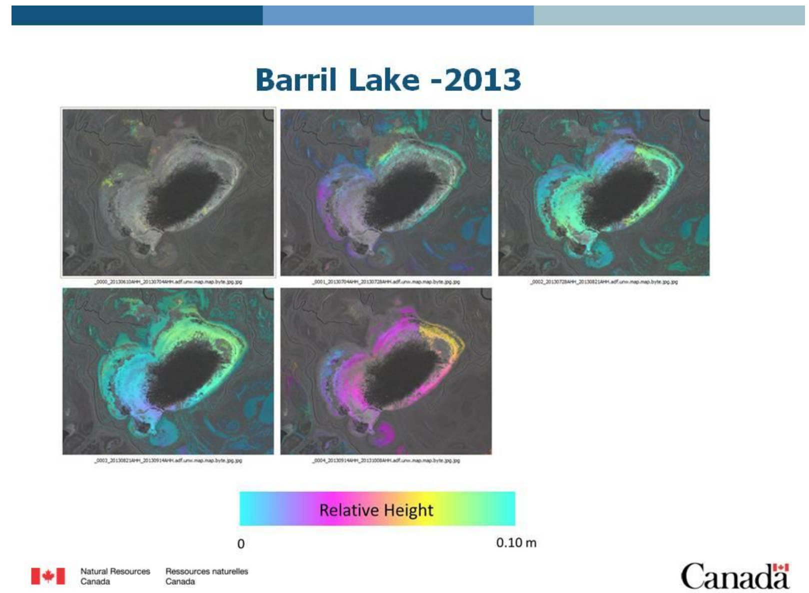
Relative Water Level Map



Natural Resources Canada Ressources naturelles Canada

Canada


Relative Water Level Map
20120826_20120919
Value
High : 0.12
Low : -0.12
0 2.5 5 10 15 20
Kilometers
20120826_20120919
Value
High : 0.1
Low : -0.1
0 0.5 1 2 3 4
Kilometers
Natural Resources Canada
Ressources naturelles Canada
Canada


Barril Lake -2013
Relative Height
0
0.10 m
Natural Resources Canada
Ressources naturelles Canada
Canada

Surface Water Extent

- Many project partners interested in temporal surface water extent products
- 24 day repeat for InSAR allowed "monthly" products during the ice-free season
- RCM rapid revisit will generate "weekly" products
- Traditional approach implemented in GAMMA and PCI
- Explored temporal filters as well

Natural Resources Canada   Ressources naturelles Canada

Canada

PAD 2012/13 Surface Water

Natural Resources Canada   Ressources naturelles Canada

Canada

RCM Operational Implementation

- Wetlands with flooded vegetation have suitable coherence
- InSAR can produce water level change with sub-cm accuracy given right conditions
  - Suitable atmospheric conditions
  - Extended wetlands with coherence
  - Water level change less than 2.5 cm between acquisitions or in-situ capacity for solving phase ambiguity (level loggers or CR)
  - Multi-frequency could also solve phase ambiguity
- 3-5 m resolution with ~ 300 km swath and twice weekly coverage possible with RCM

Natural Resources Canada Ressources naturelles Canada

Canada

Summary

- Temporal surface water masks produced
- Temporal filter useful
- Coherence of flooded wetlands suitable for InSAR estimation of water level
- Relative water level changes can be monitored
- In-situ for phase ambiguity – absolute changes
- End-user evaluation needed
- PAD – dynamic and changing
- Dynamic surface water monitoring possible with RCM

Natural Resources Canada Ressources naturelles Canada

Canada

Vegetation and Land Use Change in the AOSR, Darren Pouliot, NRCan-CCRS

Systematic Regional Land Surface Characterization From High Quality Long Term Satellite Data Records

Project lead: Darren Pouliot
Scientific Authorities: Rasim Latifovic, Richard Fernandes
Research Associates: Matt Maloley, Will Parkinson, Sivasathivel Kandasamy

Edmonton, Alberta, Canada
February, 26-27, 2015

Natural Resources Canada · Ressources naturelles Canada · Canada

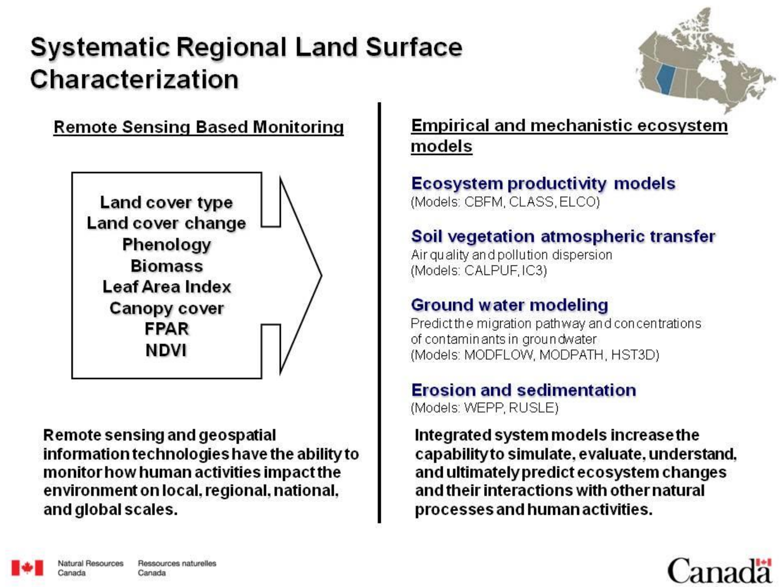
Systematic Regional Land Surface Characterization From High Quality Long Term Satellite Data Records

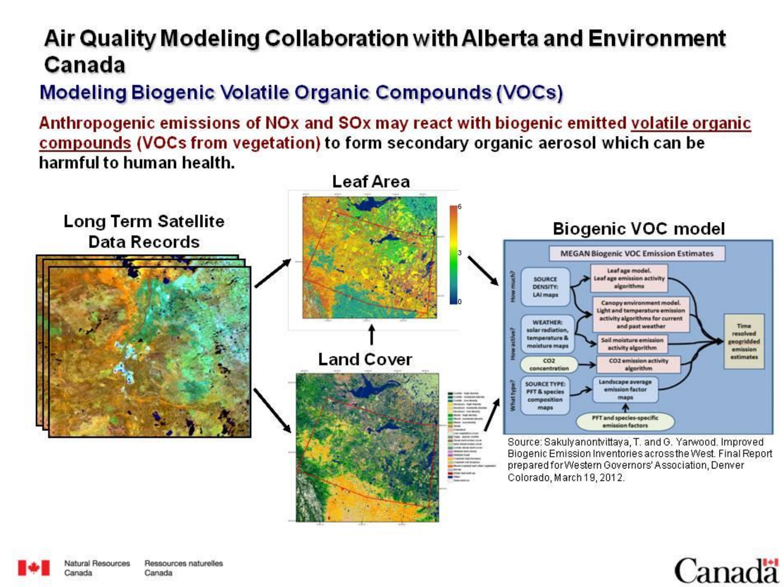
Project Objectives:

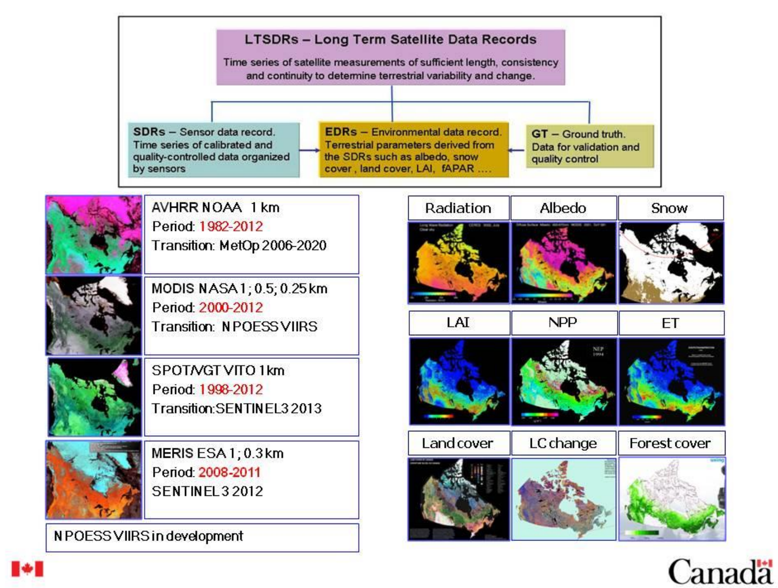
- Generate regionally consistent multi-sensor long term satellite data records at coarse (250m-1km) and moderate (~30m) spatial resolution.
- Derive land surface information (land cover, land cover change, phenology, leaf area, surface temperature etc.) to establish baselines, analyze change/trends, and support modeling for assessment of land surface/water/air processes.

Collaborators: AESRD, EC, CFS, CSA, and universities.

Natural Resources Canada · Ressources naturelles Canada · Canada


Systematic Regional Land Surface Characterization
Remote Sensing Based Monitoring
Land cover type
Land cover change
Phenology
Biomass
Leaf Area Index
Canopy cover
FPAR
NDVI
Remote sensing and geospatial information technologies have the ability to monitor how human activities impact the environment on local, regional, national, and global scales.
Empirical and mechanistic ecosystem models
Ecosystem productivity models
(Models: CBFM, CLASS, ELCO)
Soil vegetation atmospheric transfer
Air quality and pollution dispersion
(Models: CALPUF, IC3)
Ground water modeling
Predict the migration pathway and concentrations of contaminants in groundwater
(Models: MODFLOW, MODPATH, HST3D)
Erosion and sedimentation
(Models: WEPP, RUSLE)
Integrated system models increase the capability to simulate, evaluate, understand, and ultimately predict ecosystem changes and their interactions with other natural processes and human activities.
Natural Resources Canada
Ressources naturelles Canada
Canada

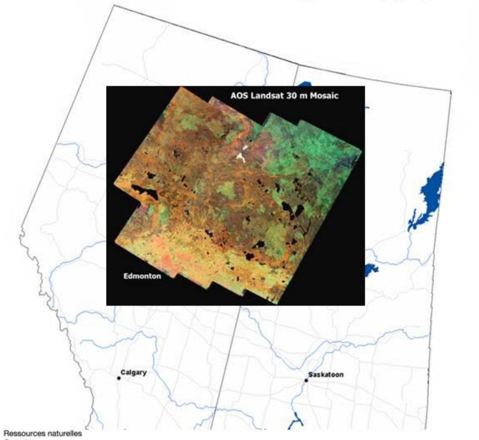

Air Quality Modeling Collaboration with Alberta and Environment Canada
Modeling Biogenic Volatile Organic Compounds (VOCs)
Anthropogenic emissions of NOx and SOx may react with biogenic emitted volatile organic compounds (VOCs from vegetation) to form secondary organic aerosol which can be harmful to human health.
Long Term Satellite Data Records
Leaf Area
Land Cover
Biogenic VOC model
MEGAN Biogenic VOC Emission Estimates
Source: Sakulyanontvittaya, T. and G. Yarwood. Improved Biogenic Emission Inventories across the West. Final Report prepared for Western Governors' Association, Denver Colorado, March 19, 2012.
Natural Resources Canada
Ressources naturelles Canada
Canada


LTSDRs – Long Term Satellite Data Records
Time series of satellite measurements of sufficient length, consistency and continuity to determine terrestrial variability and change.
SDRs – Sensor data record. Time series of calibrated and quality-controlled data organized by sensors
EDRs – Environmental data record. Terrestrial parameters derived from the SDRs such as albedo, snow cover, land cover, LAI, fAPAR ....
GT – Ground truth. Data for validation and quality control
AVHRR NOAA 1 km
Period: 1982-2012
Transition: MetOp 2006-2020
MODIS NASA 1; 0.5; 0.25 km
Period: 2000-2012
Transition: NPOESS VIIRS
SPOT/VGT VITO 1 km
Period: 1998-2012
Transition: SENTINEL3 2013
MERIS ESA 1; 0.3 km
Period: 2008-2011
SENTINEL3 2012
NPOESS VIIRS in development
Radiation
Albedo
Snow
LAI
NPP
ET
Land cover
LC change
Forest cover
Canada


Natural Resources Canada
Canada
National Earth Observation Data Framework Catalogue
CCRS Thematic Data Sets
Long Term Satellite Data Records
Landcover
Biophysical Indicators
National Image Composites
AVHRR 10-day composite time series of Canada 1985-01-01 - 2013-12-31
MODIS 10-day composite time series of Canada 2000-02-21 - 2015-01-31
return to Thematic Data Sets section
https://neodf.nrcan.gc.ca/neodf_cat3/
Natural Resources Canada
Ressources naturelles Canada
Canada

Moderate Resolution Long Term Satellite Data Record

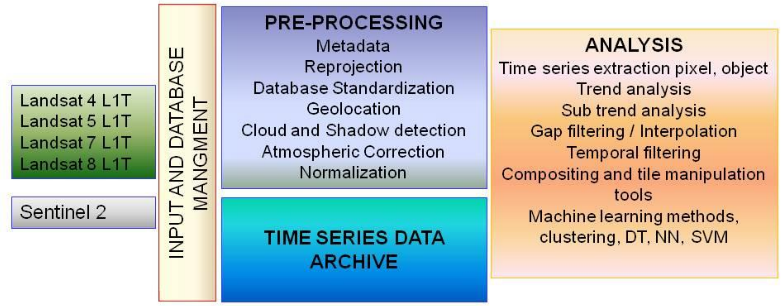
Establishment of uniform Landsat data record (~9000 scenes) with consistent data format, metadata, cloud/shadow screening, and map projection.



Natural Resources Canada Ressources naturelles Canada

Canada

Research Software Platform
Time Series Data Management and Analysis (TSDMA)



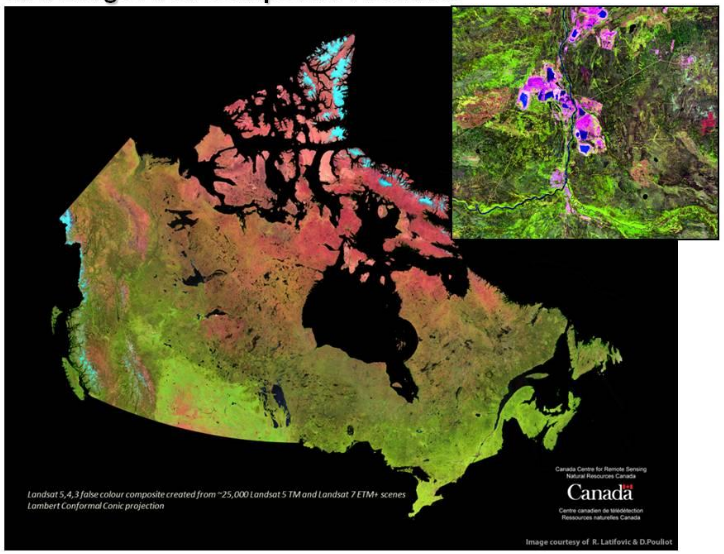
Object based, developed in C++

Latifovic, R., Pouliot, D., Sun, L., Schwarz, J., and Parkinson, W. (2015). Moderate Resolution Time Series Data Management and Analysis: Automated Large Area Mosaicking and Quality; Canada Center for Mapping and Earth Observation, Open File.

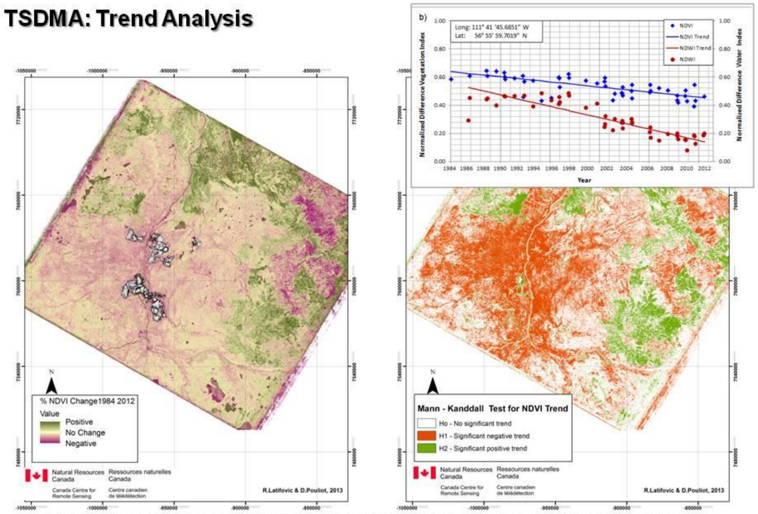
Natural Resources Canada Ressources naturelles Canada

Canada

TSDMA: Large Area Composite Products



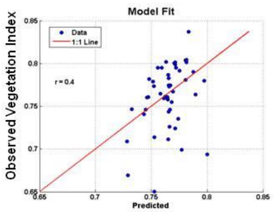
TSDMA: Trend Analysis



Latifovic, R.; Pouliot, D. (2014). Monitoring Cumulative Long-Term Vegetation Changes Over the Athabasca Oil Sands Region, Selected Topics in Applied Earth Observation and Remote Sensing, IEEE Journal of , no.99, pp.1,13

TSDMA: Trend Climate Normalization

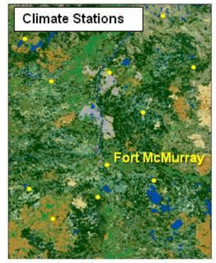
Predicted Vegetation Index= *c1*avtmp+avprc+…………+avtmp5+avprc5+c0*

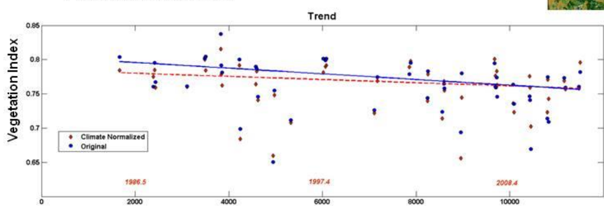


avtmp = average temperature starting in may up to the date of the satellite observation.

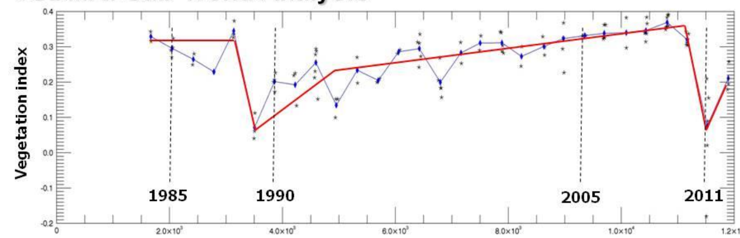
avprc = average precipitation starting in may up to the date of the satellite observation.

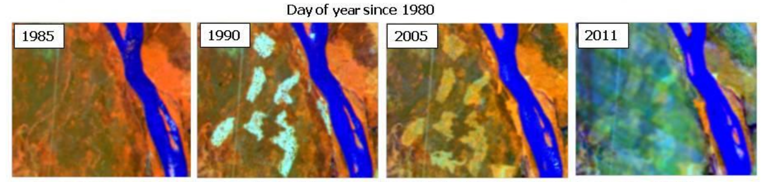
Numeric postfix indicates lag in days.





TSDMA: Sub Trend Analysis

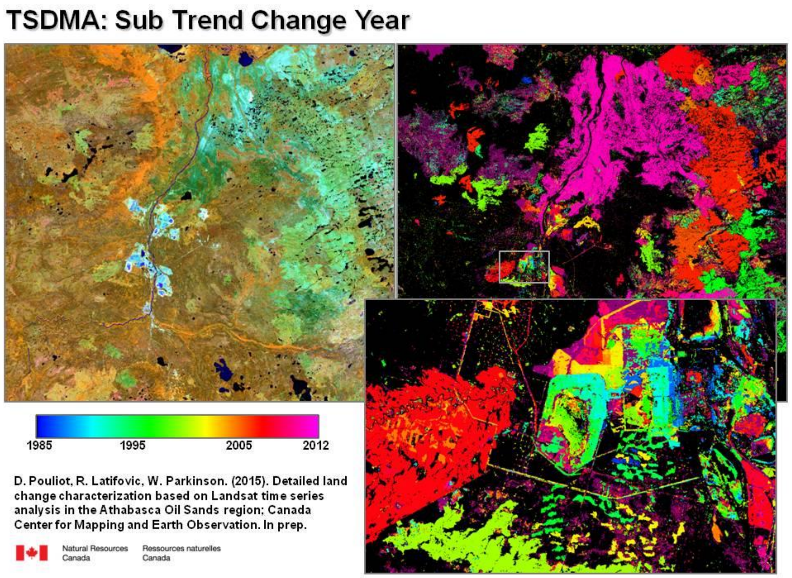


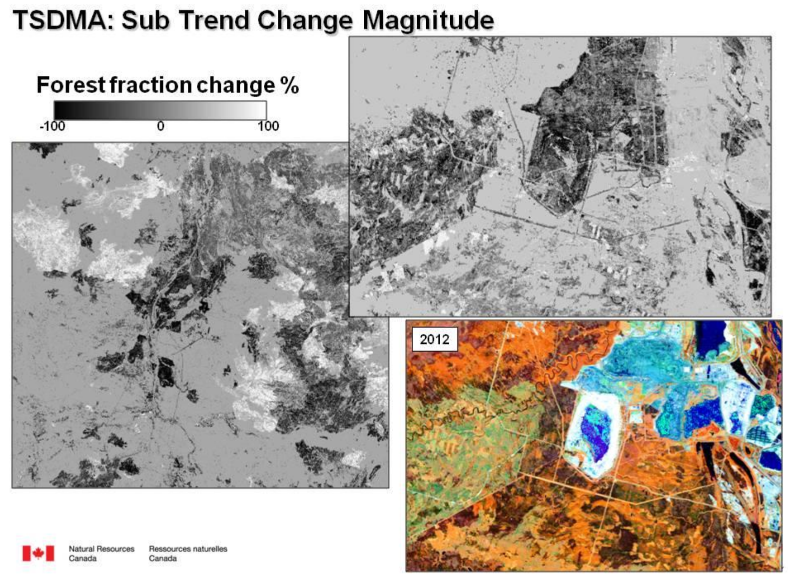


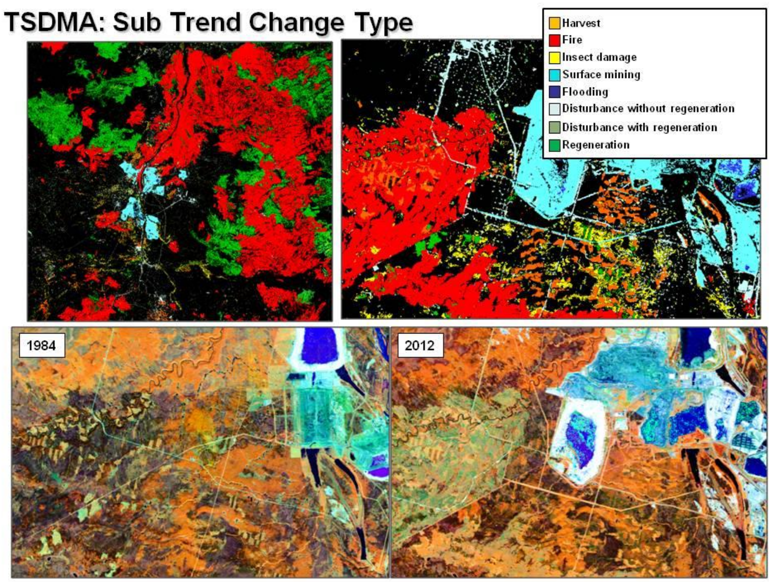
- **Better understand trends and temporal-spatial change dynamics in the AOS.**
- **Contribute to detailed change information for CFS carbon modeling research.**

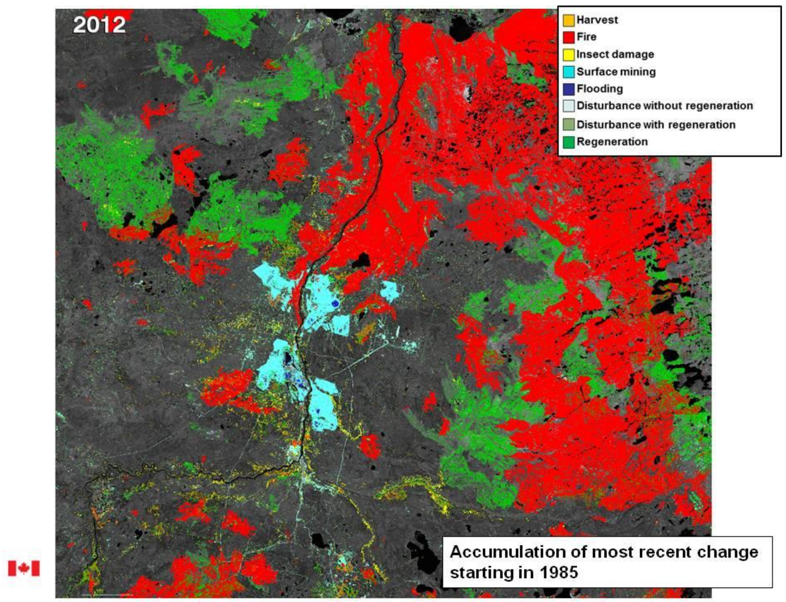
Natural Resources Canada Ressources naturelles Canada

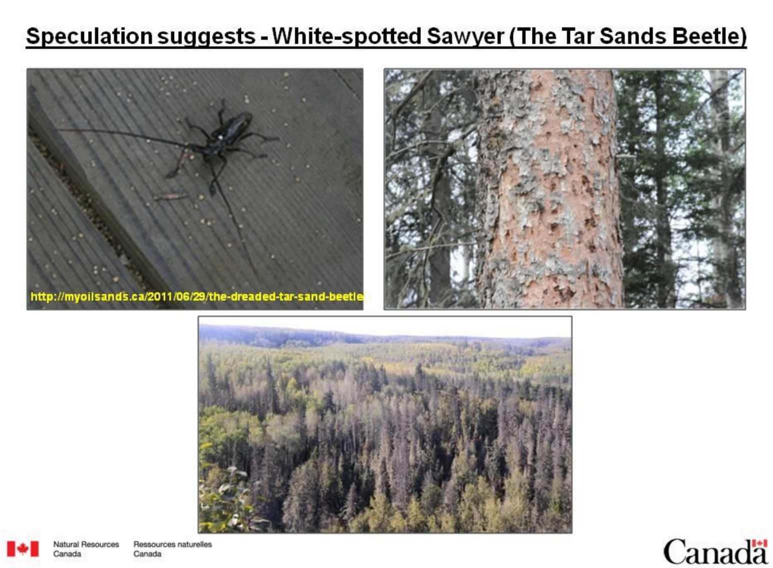
Canada

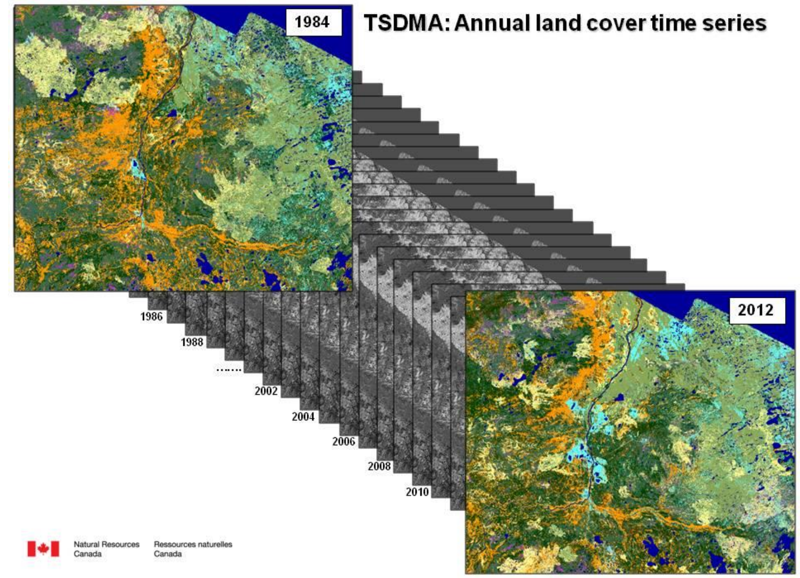

TSDMA: Sub Trend Change Year
1985
1995
2005
2012
D. Pouliot, R. Latifovic, W. Parkinson. (2015). Detailed land change characterization based on Landsat time series analysis in the Athabasca Oil Sands region; Canada Center for Mapping and Earth Observation. In prep.
Natural Resources Canada
Ressources naturelles Canada


TSDMA: Sub Trend Change Magnitude
Forest fraction change %
-100
0
100
2012
Natural Resources Canada
Ressources naturelles Canada


TSDMA: Sub Trend Change Type
Harvest
Fire
Insect damage
Surface mining
Flooding
Disturbance without regeneration
Disturbance with regeneration
Regeneration
1984
2012


2012
Harvest
Fire
Insect damage
Surface mining
Flooding
Disturbance without regeneration
Disturbance with regeneration
Regeneration
Accumulation of most recent change starting in 1985

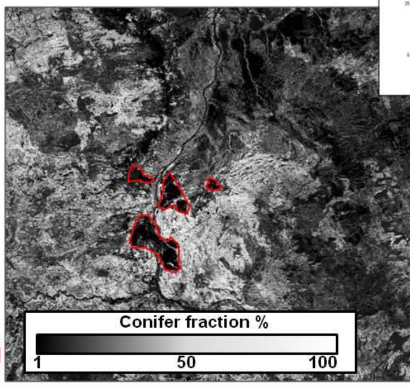

Speculation suggests - White-spotted Sawyer (The Tar Sands Beetle)
http://myoilsands.ca/2011/06/29/the-dreaded-tar-sand-beetle
Natural Resources Canada
Ressources naturelles Canada
Canada

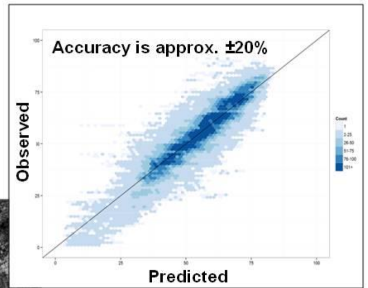

TSDMA: Annual land cover time series
1984
1986
1988
……
2002
2004
2006
2008
2010
2012
Natural Resources Canada
Ressources naturelles Canada

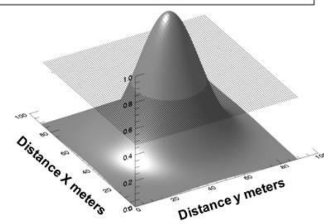
Fractional Land Cover Mapping

% Ground cover within a 30m pixel of:

- *Conifer forest*
- *Deciduous forest*
- *Shrub*
- *Herbaceous*
- *Bare*
- *Water*

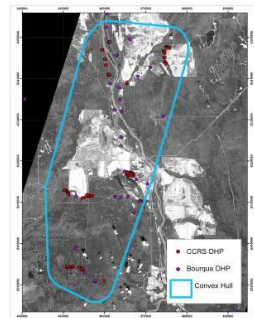


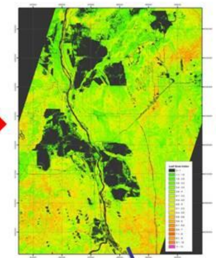


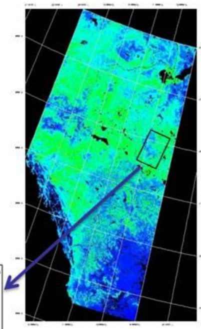


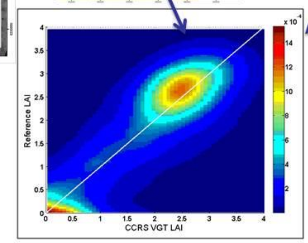
D. Pouliot, W. Parkinson, R. Latifovic. 2015. Evaluation of Landsat Based Fractional Land Cover Mapping in the Alberta Oil Sands Region; Canada Center for Mapping and Earth Observation, Open File.

Leaf Area Index Scaling/Validation





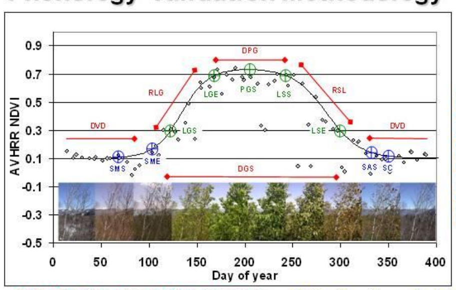


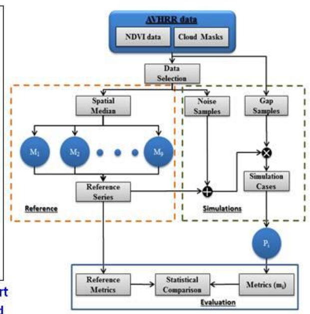


Maloley, M. and Fernandes, R. (2013). Validation of Systematically Derived Leaf Area Index of the Canadian Oil Sands Region. 34th Canadian Symposium on Remote Sensing, Victoria, British Columbia, Canada, August 27-29.

Natural Resources Canada Ressources naturelles Canada Canada

Phenology Validation Methodology





- •DVD – Duration of vegetation dormancy
- •RLG – Rate of leaf growth
- •DPG – Duration of peak growing season
- •DGS – Duration of the growing season
- •RLS – Rate of leaf senescence
- •LGS – Leaf growth start
- •LGE – Leaf growth end
- •PGS – Peak of growing season
- •LSS - Leaf senescence start
- •LSE - Leaf senescence end

- •SMS – Snowlice melt start
- •SME – Snowlice melt end
- •SAS – Snowlice accumulation start
- •SC – Snow covered

Kandsamy, S. and Fernandes, R. (2014). Assessment of satellite based vegetation land surface phenology algorithms with application to a 20 year NOAA AVHRR record over Canada and Northern USA. Proceedings of IEEE Geoscience and Remote Sensing Symposium.

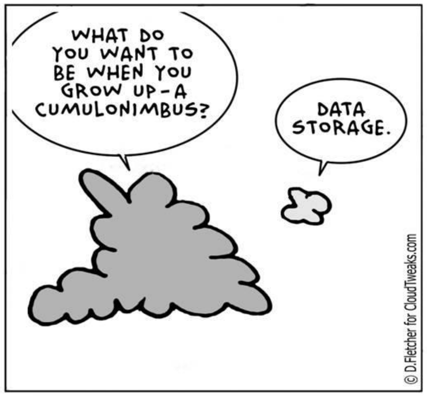
Natural Resources Canada Ressources naturelles Canada Canada

Project Future

- Continue collaboration with the CFS to investigate remote sensing based change characterization for enhancing carbon modeling in the region.
- Continue investigation of trends and trend drivers in the region for understanding landscape change and its effect on environmental processes.
- Contribute to land cover mapping requirements for biodiversity and wildlife habitat evaluation in collaboration with ABMI and the University of Calgary.
- Continued development and evaluation of phenology protocols and evaluation in fire and ecological applications with AESRD.
- Potential contribution of moderate resolution time series analysis for pipeline monitoring and wetland inventory mapping.
- Support knowledge transfer for interested partners.

Natural Resources Canada Ressources naturelles Canada Canada

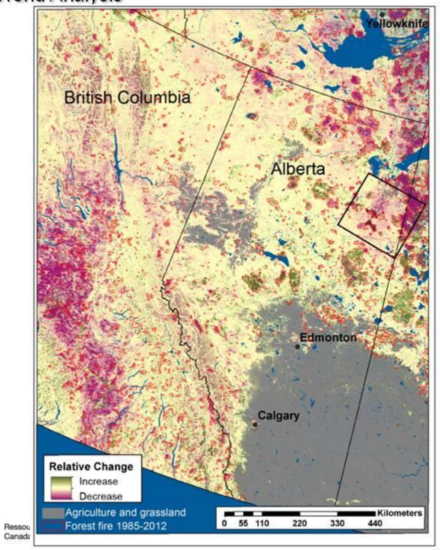
Thank you



Natural Resources Canada Ressources naturelles Canada

Canada

Regional Trend Analysis



Natural Resources Canada

Canada

Potential for EO for AER Operations, Monique Dube, Alberta Energy Regulator (AER)

THE AER and the ENVIRONMENT

1) About the AER
2) The AER's Enhanced Environmental Role
3) AER's New Strategic Environment Team
4) Innovation and Technology - AER Environment
5) Potential Uses of Earth Observation Technology
6) Questions

AER 2

ABOUT THE ALBERTA ENERGY REGULATOR

- The AER was established in June 2013
  - Amalgamation of the old ERCB and the regulatory functions from the old Alberta Environment and Sustainable Resource Departments
- In setting up the AER, a "lift and shift" model was used whereby all regulatory functions were moved but not changed
  - The AER is moving into transformation now that the transition is complete
- The AER hired a "Chief Environmental Scientist" in September of 2014 to determine how the regulator will manage its enhanced environmental mandate

AER 3

Monique Dube, PhD

- BSc (UBC), MSc (U of S), PhD (UNB)
- Environmental toxicologist
- BC Environment (EIA biologist, inspector)
- Environment Canada (Research Scientist; NWRI)
- U of S (Canada Research Chair, Professor)
- Oil and Gas Industry (Environment Team Lead)
- Principle, Consulting Company
- Chief Environmental Scientist (AER)
- UN, UNEP, NCASI Science Advisory Panel, Oil Sands panels, etc
- NSERC Synergy Award, Canadian Geographic Scientist of the Year, YWCA Woman of Distinction in Science and Technology)

AER

THE AER'S ENHANCED ENVIRONMENTAL ROLE MANDATE & SCOPE

Under REDA and the Specified Enactments, AER is responsible:

- To provide for the efficient, safe, orderly and **environmentally responsible development** of energy resources in Alberta through the Regulator's regulatory activities, and
- In respect of **energy resource activities**, to regulate
  - (i) the disposition and management of public lands,
  - (ii) the protection of the environment, and
  - (iii) the conservation and management of water, including the wise allocation of water,

AER 4

ENVIRONMENT MANDATE & SCOPE: ESRD, AER & AEMERA

	ESRD	AER	AEMERA
Policy	Development & Analysis All Sectors	Support & Assurance Energy Sector	Support All Sectors
Powers, duties and functions under the Specified Enactments	Non-Energy Sector[1]	Energy Sector[1]	None
Sector-specific monitoring in approvals	Non-Energy Sector	Energy Sector	Need clarity (see next slide)
Multi-sector, regional cumulative effects monitoring	Support Non-Energy Sector	Support Energy Sector Need clarity (see next slide)	Need clarity (see next slide)

[1] Subject to the Jurisdiction Regulation.

AER 5

ENVIRONMENT MANDATE & SCOPE: AER & AEMERA

	AER	AEMERA
CURRENT STATE	Environmental monitoring in respect of energy resource activities under approvals.	Funding for environmental monitoring from operators who hold EPEA approvals in respect of an "oil sands mine", "oil sands processing plant" and "enhanced recovery in-situ oil sands or heavy oil processing plant".
DESIRED STATE	Site specific and local ambient monitoring in respect of energy resource activities.	Regional cumulative effects monitoring in respect of all energy resource activities and all other sectors.

AER 6

AER's New Strategic Environment Team

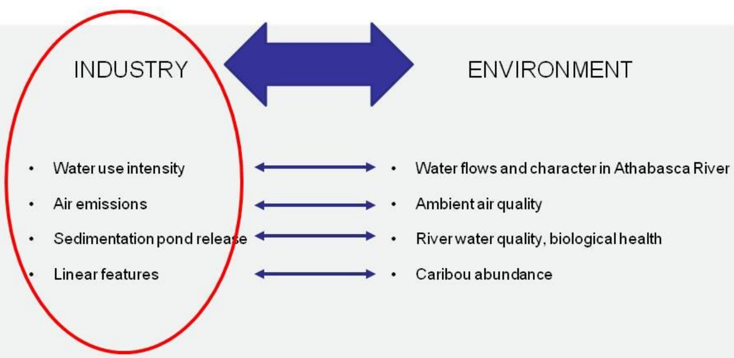
Advance the following 5 areas:

1. Monitor environmental performance
   - Linking environmental performance to industry performance monitoring through performance metrics, triggers, and thresholds
2. Track environmental state
   - Linking subsurface to surface, existing state assessment linked to future environmental state assessment based on predictive resource development forecasts
3. Develop strategic intelligence on emerging environment issues
   - identification of top environment priorities and AER position statements.
4. Implement trans-disciplinary environmental issues coordination and integration
   - Issues that span across sectors, multiple environmental disciplines or applications
5. Support Government of Alberta (GoA) policy development

Environmental Communities of Practice (ECOPs)
Lead by our Strategic Environment Team

AER 7

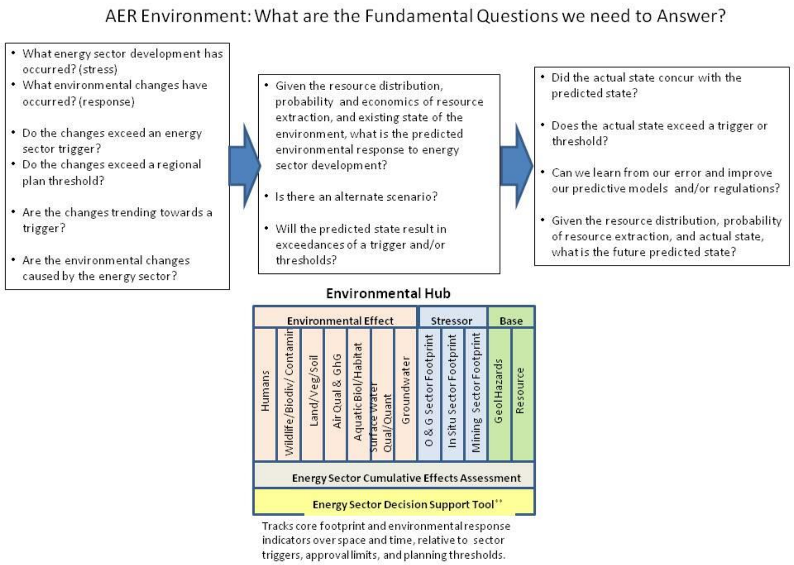
MEASURING INDUSTRY PERFORMANCE IN THE CONTEXT OF ENVIRONMENTAL PERFORMANCE



While industry performance is important to demonstrate, in the absence of linking industry performance to environmental performance, there is not context.

Alberta Energy Regulator 9

INDUSTRY PERFORMANCE	ENVIRONMENT PERFORMANCE	RESULT
—	↓	Compliant, not protective
—	↑	Compliant, room to grow
↑	—	Cost burden to industry
↓	—	Non compliant but contained (context)
— ↑ ↓	No data or inadequate reporting of data	Uncertainty increases risk and decreases credibility
↑	↑	Win/Win
↓	↓	Lose/Lose



How would AER use it?

Authorizations: what exists now on the land? How close are we to the stressor & response lines? Will this project proposal put us over? Can we justify the level of monitoring requested in the approval based upon the environmental condition?

EIA: What exists now on the land? How close are we to the stressor & response lines? Will this project proposal put us over? Can we fast-track a development and illustrate no harm?

Enforcement & Compliance: Are there changes occurring that relate to complaints? What level of investigation is required if the environment is stable?

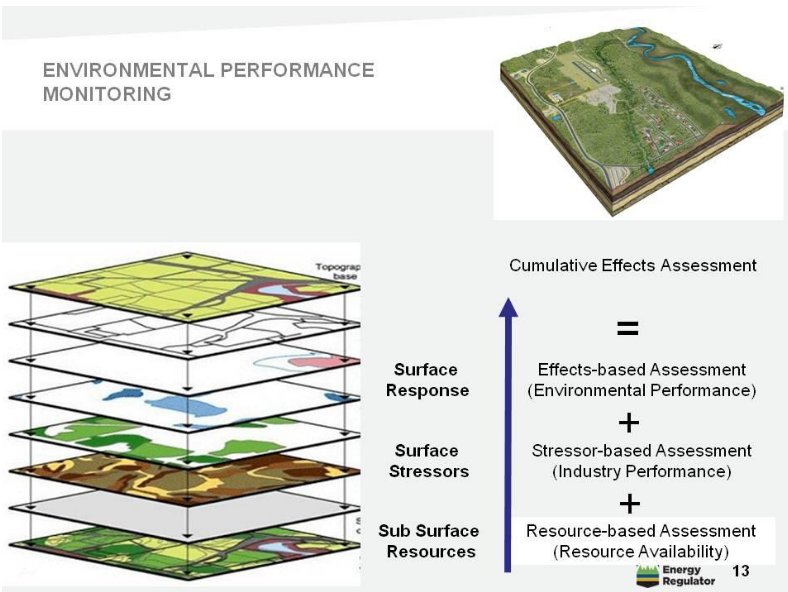
AGS: are there areas where resource development can be accelerated as environmental risk is low and the environment is stable?

Hearing Support; OPA
Justification for decisions. Access to information, rapid response to information requests

Strategy & Regulatory: What are the environmental changes that have occurred? Is regulatory revision required?

SGR: Does this complaint have a strong basis given the environmental condition? Has anything in the area changed that may be resulting in the complaint?

Alberta Energy Regulator 12



Earth Observation and Remote Sensing

- Part of the Strategic Environment Team's goal is to develop an integrated environmental decision support tool in concert with IRMS partners
- The AER's Subject Matter Experts, IT and IM are working on the vision
- The opportunity for EO and remote sensing is significant but the innovation needs to be directed by the business needs
  - All things monitoring; real time tracking environmental performance and industry performance; predictive risk algorithms relating resource extraction projections to surface environmental assessments

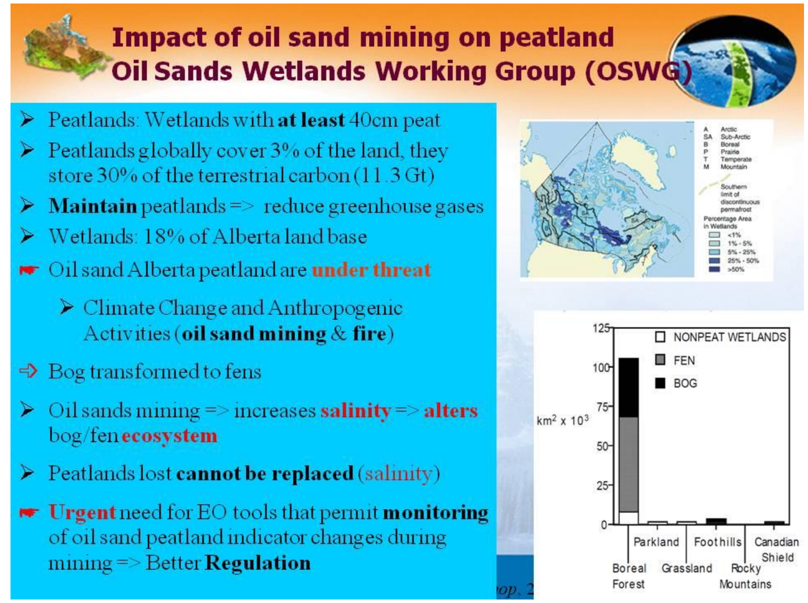
AER 9

AER Technology & Innovation Themes

- Technology "pilot" industry / vendors / innovators to AER.
- AER's use of new technology e.g. satellite surveillance, pipeline drones, IT
- Interaction with science / technology organizations
- Global innovation trends
- Clearing house for technology / science research

AER

Monitoring Peatland Transformation with SAR, Ridha Touzi, NRCan-CCRS



Anthropogenic Activities Athabasca Oil sand Exploration Region

Richardson Fire 2011

White spruce forest

Oil sand exploration site

Treed Bog

Natural Resources Canada Ressources naturelles Canada 3 *R. Touzi, Oil Sand Workshop, 27 Feb. 2015* Canada

Polarimetric SAR for Oil Sand Peatland Monitoring

- **Objective: Investigation of the polarimetric and Pol-InSAR L-band ALOS, and C-band Radarsat2 information for enhanced mapping and monitoring of oil sand peatlands**
- Lead scientist: Ridha Touzi
- CCRS: K. Omari, D. Raymond, S. Nedelcu , P. Wilson, G.Gosselin
- Partners:
  - ESRD (B. Sleep, B. Stankovic)
  - ERCB/AGS (T. Shipman, S. Pawley)
  - CSA (GRIP funding FY13-FY15)
  - JAXA: ALOS1&2 data under ALOS2-PI agreement
- ESRD (3 year project, B. Sleep): ERCB/AGS and CCRS

Polarimetric SAR for Oil Sand Peatland Monitoring: Outputs and Outcomes

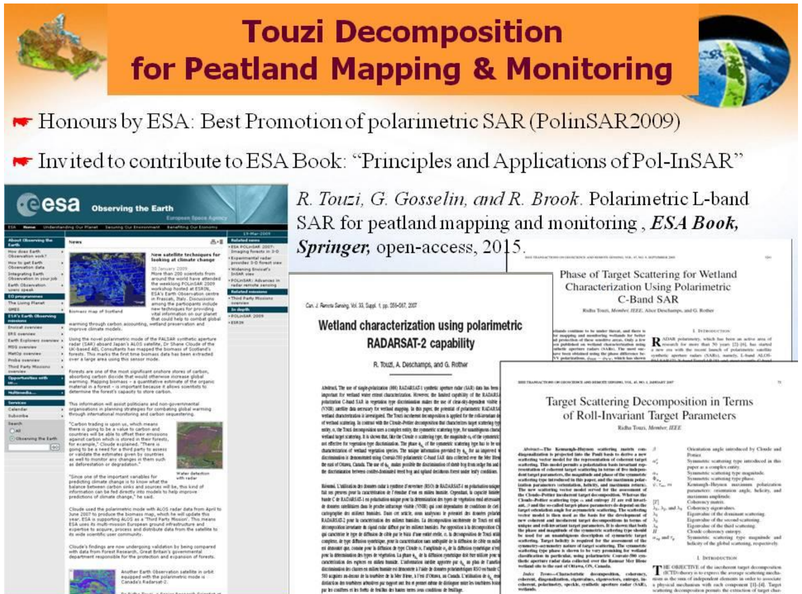
- **Polarimetric** Satellite SAR ➪ **Cost-effective** source of information for long-term monitoring of oil sand peatland changes
- Outputs:
  - New Polarimetric and Pol-inSAR methodology for peatlands classification & long term monitoring bog-fen transformation
  - Validation with the Clients => **improved** peatland **inventory**
- Accurate monitoring of peatland **subsurface** water flow.
- Long term monitoring of the global wetland hydrology, which is among the **vital** indicator of wetlands
- Better **monitoring** bog-fen transformations => Better **regulation**
- Determination of the **cause** for the change in the wetland whether it has been caused by **climate change or** by **anthropogenic** activities.
- An **improved wetland inventory** in Alberta's northern boreal forest would support advances in wildfire management planning and strategic wildfire suppression

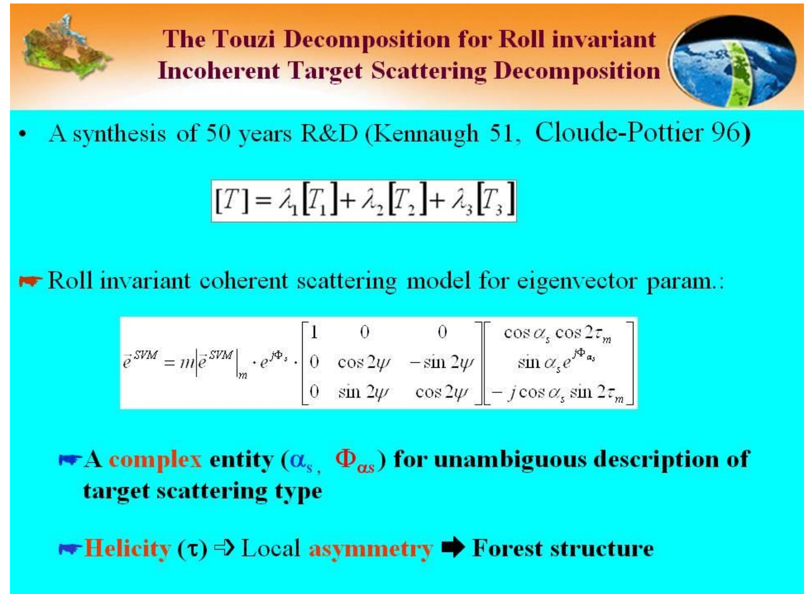
Why Polarimetric SAR for Peatland monitoring?

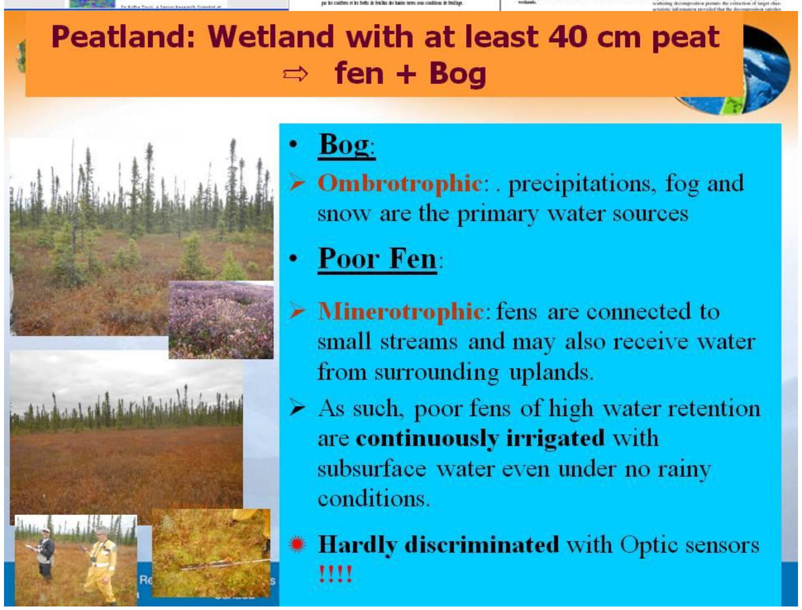
RADARSAT2

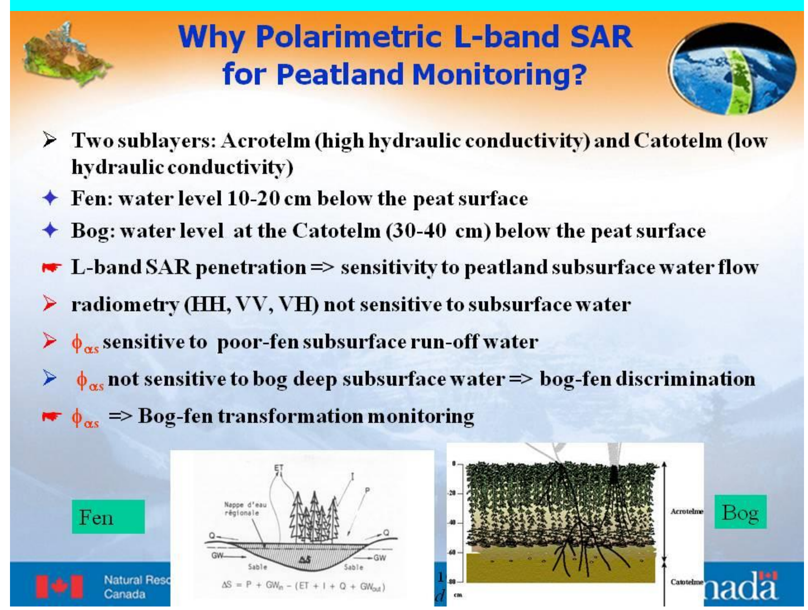
ALOS / PALSAR JAXA / JAROS (J)

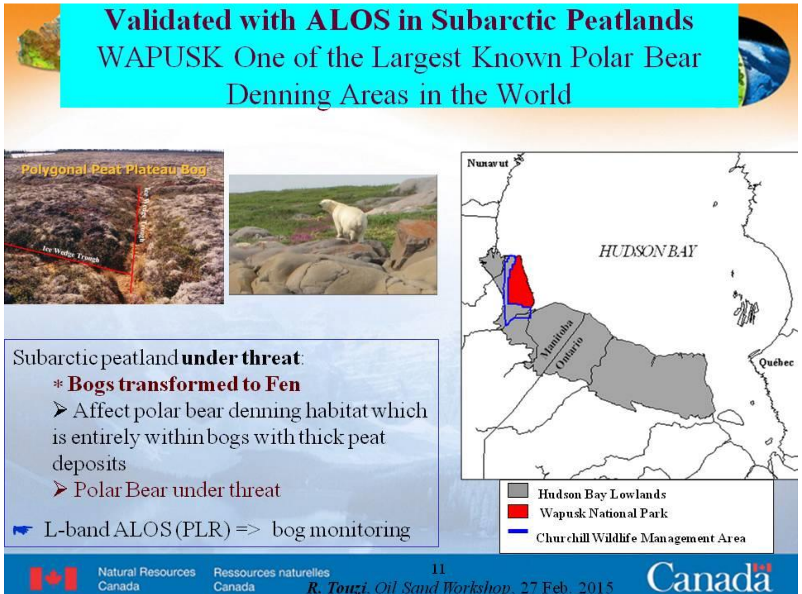
- **Bog- (poor)-Fen classification** and **monitoring** not accurate with conventional Optic and SAR Sensors
- Polarimetric SAR ➪ Scattering mechanisms and target **structure**
- **Polarimetric** L-ALOS: large **penetration** (23cm)
  - **Peatland subsurface water flow monitoring**
  - **Bog-fen discrimination & transformation monitoring**
  - **Validated over Boreal & Subarctic peatlands**
- **Polarimetric** C- RADARSAT-2 (5cm):
  - Enhanced vegetation species discrimination provided by target scattering information
  - Enhanced wetland (surface) hydrology monitoring

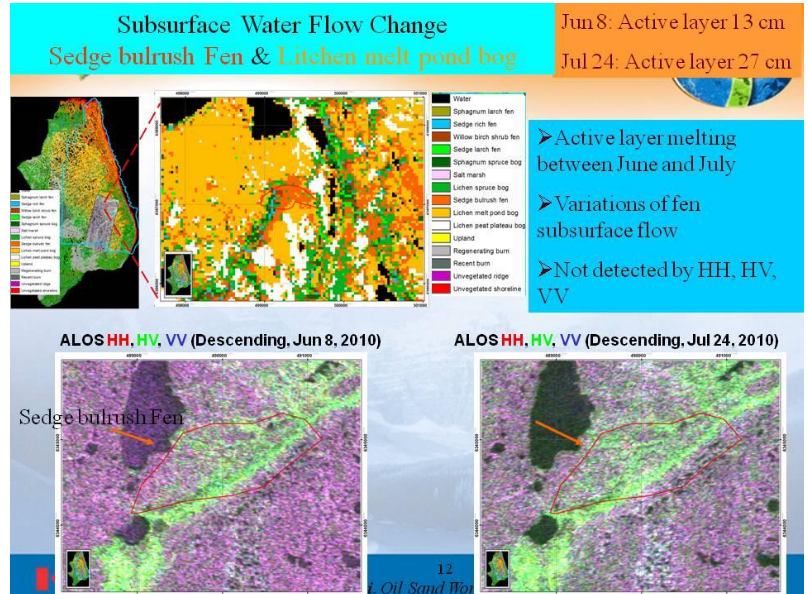

Touzi Decomposition
for Peatland Mapping & Monitoring
Honours by ESA: Best Promotion of polarimetric SAR (PolinSAR2009)
Invited to contribute to ESA Book: "Principles and Applications of Pol-InSAR"
esa
R. Touzi, G. Gosselin, and R. Brook. Polarimetric L-band SAR for peatland mapping and monitoring , ESA Book, Springer, open-access, 2015.
Phase of Target Scattering for Wetland Characterization Using Polarimetric C-Band SAR
Wetland characterization using polarimetric RADARSAT-2 capability
Target Scattering Decomposition in Terms of Roll-Invariant Target Parameters

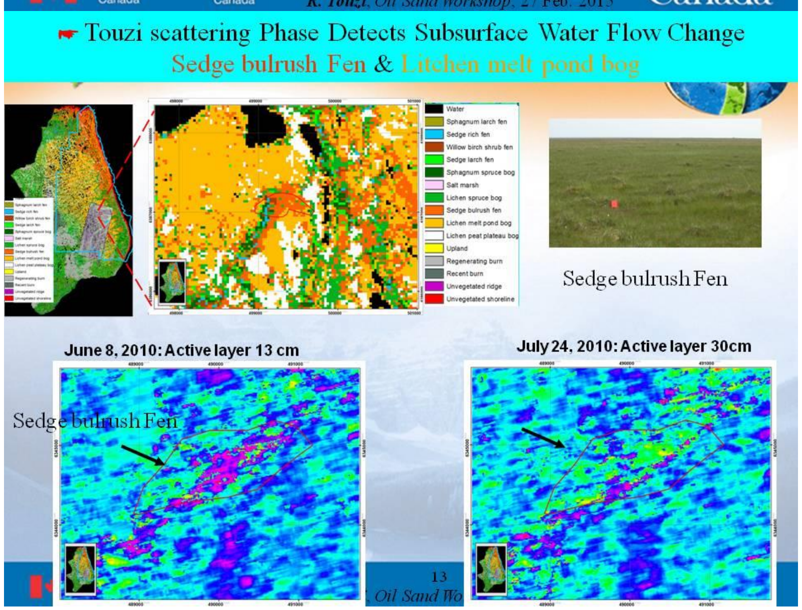

The Touzi Decomposition for Roll invariant
Incoherent Target Scattering Decomposition
A synthesis of 50 years R&D (Kennaugh 51, Cloude-Pottier 96)
$[T] = \lambda_1[T_1] + \lambda_2[T_2] + \lambda_3[T_3]$
Roll invariant coherent scattering model for eigenvector param.:
$\vec{e}^{SVM} = m|\vec{e}^{SVM}|_m \cdot e^{j\Phi_s} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 2\psi & -\sin 2\psi \\ 0 & \sin 2\psi & \cos 2\psi \end{bmatrix} \begin{bmatrix} \cos\alpha_s \cos 2\tau_m \\ \sin\alpha_s e^{j\Phi_{\alpha_s}} \\ -j\cos\alpha_s \sin 2\tau_m \end{bmatrix}$
A complex entity (α_s, $\Phi_{\alpha s}$) for unambiguous description of target scattering type
Helicity (τ) ⇨ Local asymmetry ➡ Forest structure


Peatland: Wetland with at least 40 cm peat
⇨ fen + Bog
Bog:
Ombrotrophic: . precipitations, fog and snow are the primary water sources
Poor Fen:
Minerotrophic: fens are connected to small streams and may also receive water from surrounding uplands.
As such, poor fens of high water retention are continuously irrigated with subsurface water even under no rainy conditions.
Hardly discriminated with Optic sensors !!!!


Why Polarimetric L-band SAR
for Peatland Monitoring?
Two sublayers: Acrotelm (high hydraulic conductivity) and Catotelm (low hydraulic conductivity)
Fen: water level 10-20 cm below the peat surface
Bog: water level at the Catotelm (30-40 cm) below the peat surface
L-band SAR penetration => sensitivity to peatland subsurface water flow
radiometry (HH, VV, VH) not sensitive to subsurface water
$\phi_{\alpha s}$ sensitive to poor-fen subsurface run-off water
$\phi_{\alpha s}$ not sensitive to bog deep subsurface water => bog-fen discrimination
$\phi_{\alpha s}$ => Bog-fen transformation monitoring
Fen
Bog
Nappe d'eau régionale
Sable
Acrotelme
Catotelme
Natural Resources Canada

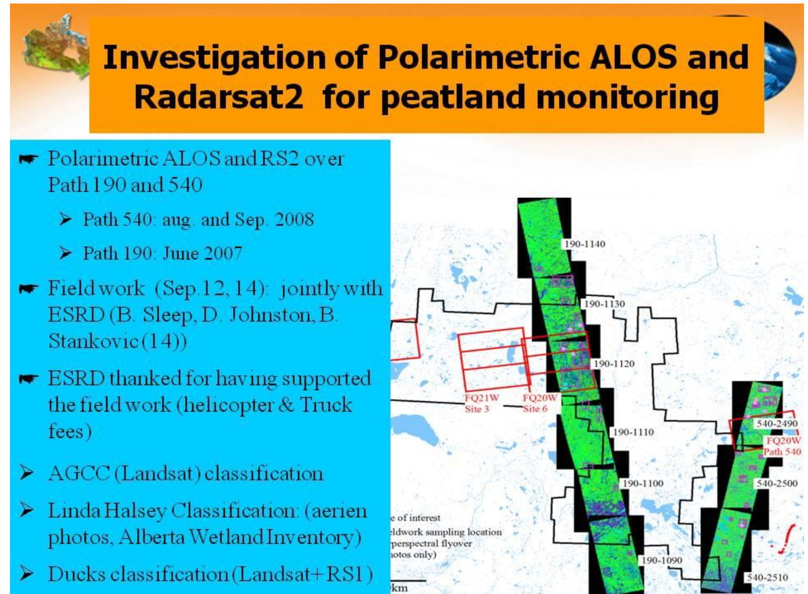

Validated with ALOS in Subarctic Peatlands
WAPUSK One of the Largest Known Polar Bear Denning Areas in the World
Polygonal Peat Plateau Bog
Nunavut
HUDSON BAY
Manitoba
Ontario
Québec
Subarctic peatland under threat:
* Bogs transformed to Fen
➢ Affect polar bear denning habitat which is entirely within bogs with thick peat deposits
➢ Polar Bear under threat
L-band ALOS (PLR) => bog monitoring
Hudson Bay Lowlands
Wapusk National Park
Churchill Wildlife Management Area
Natural Resources Canada
Ressources naturelles Canada
11
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

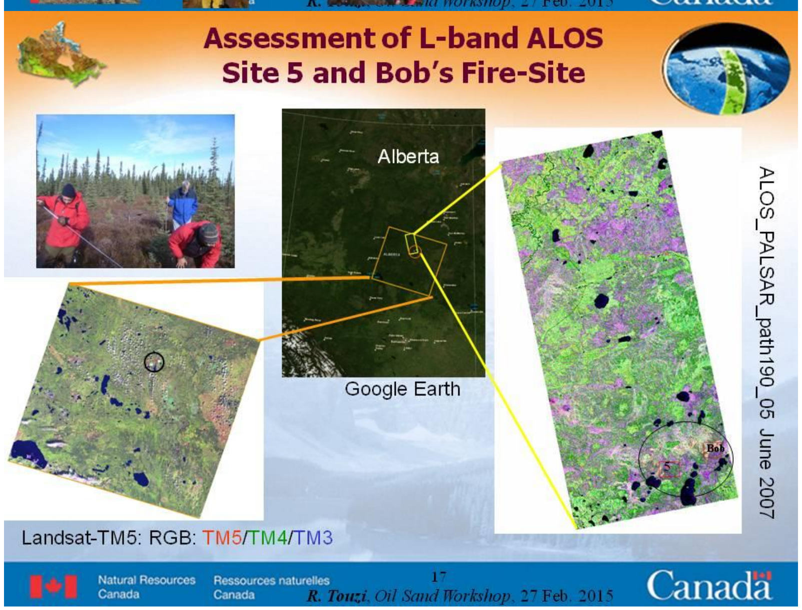

Subsurface Water Flow Change
Sedge bulrush Fen & Litchen melt pond bog
Jun 8: Active layer 13 cm
Jul 24: Active layer 27 cm
➢Active layer melting between June and July
➢Variations of fen subsurface flow
➢Not detected by HH, HV, VV
ALOS HH, HV, VV (Descending, Jun 8, 2010)
ALOS HH, HV, VV (Descending, Jul 24, 2010)
Sedge bulrush Fen
12


Touzi scattering Phase Detects Subsurface Water Flow Change
Sedge bulrush Fen & Litchen melt pond bog
Sedge bulrush Fen
June 8, 2010: Active layer 13 cm
July 24, 2010: Active layer 30cm
Sedge bulrush Fen
13

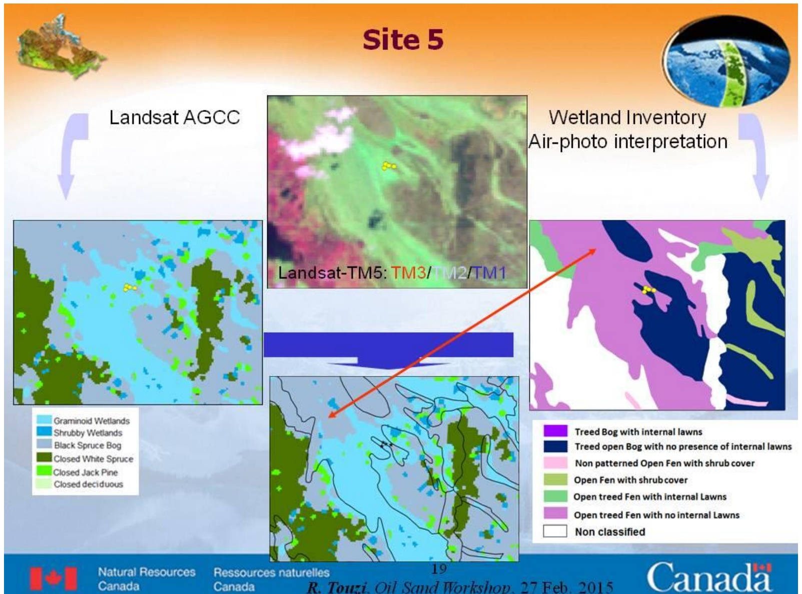

Validated In Collaboration with Parks Canada (July 6, 2012)
Active layer (20cm)
Sedge bulrush Fen
Litchen melt pond Bog
Water 13 cm under peat fen surface
No water under peat bog surface
14
R. Touzi, Oil Sand Workshop, 2

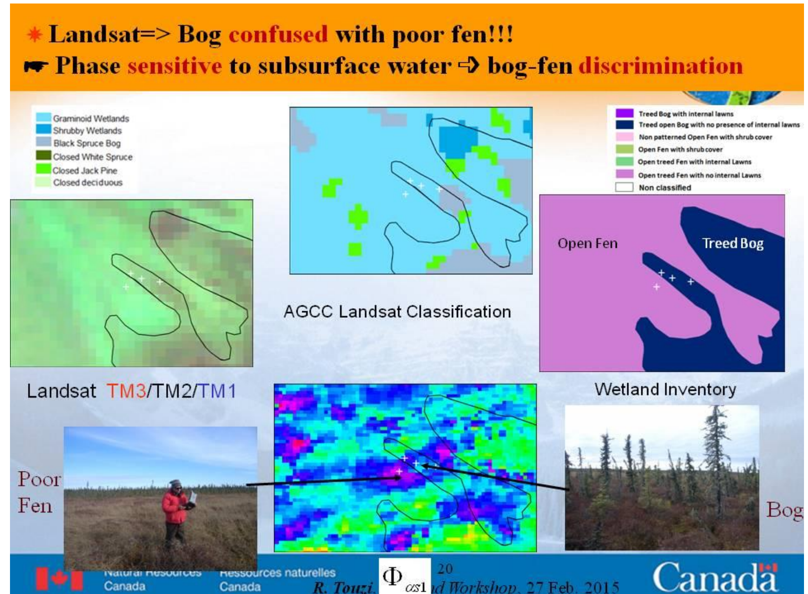

Investigation of the
Touzi Decomposition & Scattered Wave Optimization
for Peatland Classification using
polarimetric L-band ALOS and C-band Radarsat2
R. Touzi, K. Omari and G. Gosselin
Canada Centre for Remote Sensing
Natural Resource of Canada
Bob Sleep
ESRD
Acknowledgment
D. Johnston and B. Stankovic (ESRD)
Canadian Space Agency for their support (GRIP)
15
Canada


Investigation of Polarimetric ALOS and Radarsat2 for peatland monitoring
Polarimetric ALOS and RS2 over Path 190 and 540
Path 540: aug. and Sep. 2008
Path 190: June 2007
Field work (Sep 12, 14): jointly with ESRD (B. Sleep, D. Johnston, B. Stankovic (14))
ESRD thanked for having supported the field work (helicopter & Truck fees)
AGCC (Landsat) classification
Linda Halsey Classification: (aerien photos, Alberta Wetland Inventory)
Ducks classification (Landsat+RS1)
190-1140
190-1130
190-1120
190-1110
190-1100
190-1090
540-2490
540-2500
540-2510
FQ21W Site 3
FQ20W Site 6
FQ20W Path 540

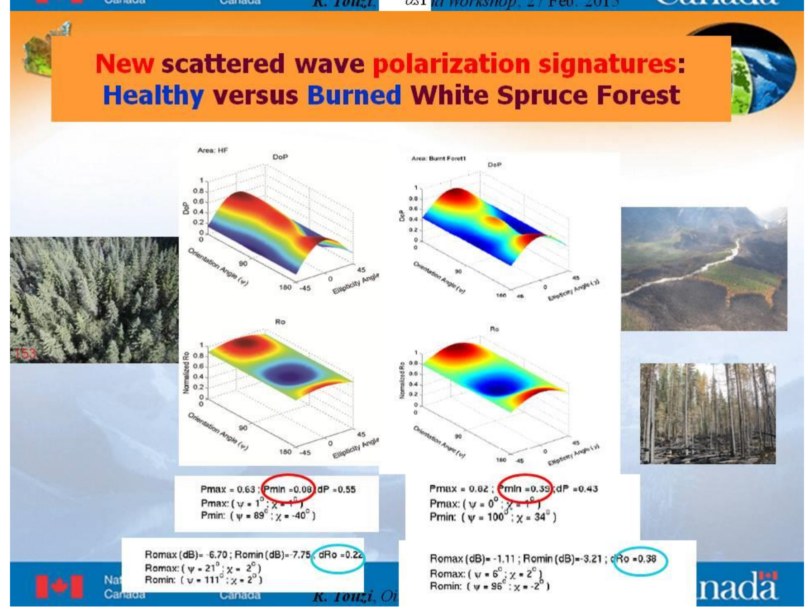

Assessment of L-band ALOS
Site 5 and Bob's Fire-Site
Alberta
Google Earth
ALOS_PALSAR_path190_05 June 2007
Landsat-TM5: RGB: TM5/TM4/TM3
Natural Resources Canada
Ressources naturelles Canada
17
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

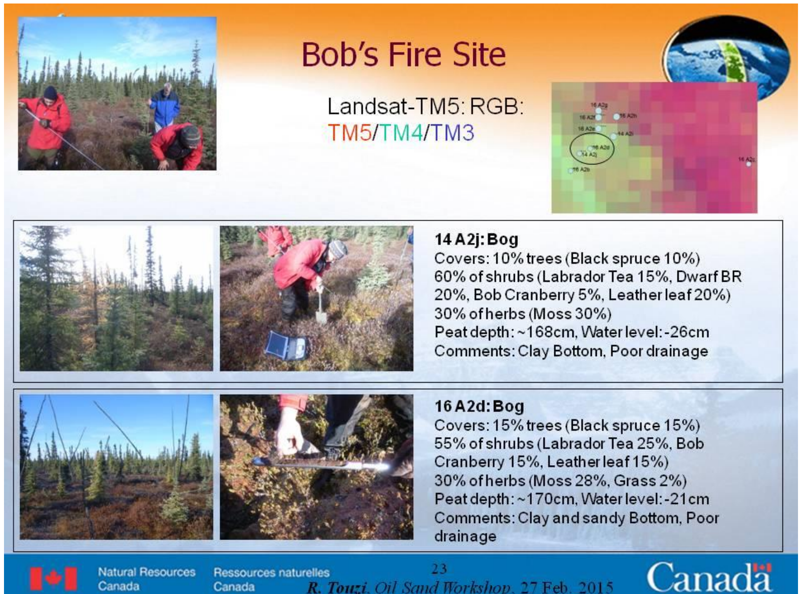

Site 5: Bog & poor fens
Landsat-TM5: RGB: TM3/TM2/TM1
5A6b: (Poor) Fen
Covers: 5% trees (Bog Birch 5%)
5% of shrubs (Leather leaf 5%)
90% of herbs (Moss 50%, Grass 40%)
Peat depth: ~124cm, Water level: -9cm
Comments: Poor drainage
5A6c: Bog
Covers: 5% trees (Black spruce 5%)
69% of shrubs (Labrador Tea 15%, Dwarf BR 25%, Cloud Berry 4%, Leather leaf 15%, Bog Rosemary Leaved FSS 5%)
31% of herbs (Moss 31%)
Peat depth: ~155cm, Water level: -20cm
Comments: Clay Bottom, Poor drainage
5A6d: Bog
Covers: 5% trees (Black spruce 5%)
70% of shrubs (Labrador Tea 5%, Dwarf BR 30%, Leather leaf 30%, Leaved FSS 5%)
45% of herbs (Moss 40%, Grass 5%) (120% of cover !)
Peat depth: ~131cm, Water level: -20cm
Comments: Poor drainage
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

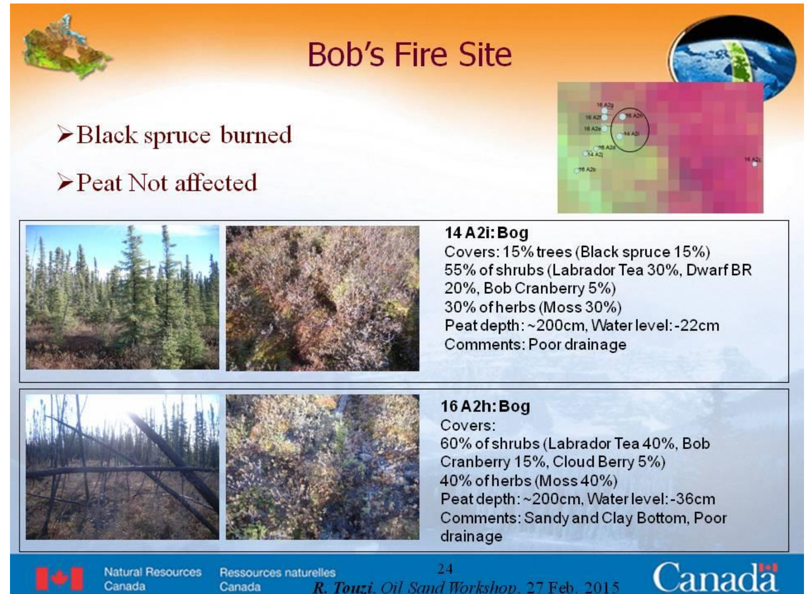

Site 5
Landsat AGCC
Wetland Inventory
Air-photo interpretation
Landsat-TM5: TM3/TM2/TM1
Graminoid Wetlands
Shrubby Wetlands
Black Spruce Bog
Closed White Spruce
Closed Jack Pine
Closed deciduous
Treed Bog with internal lawns
Treed open Bog with no presence of internal lawns
Non patterned Open Fen with shrub cover
Open Fen with shrub cover
Open treed Fen with internal Lawns
Open treed Fen with no internal Lawns
Non classified
Natural Resources Canada
Ressources naturelles Canada
19
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

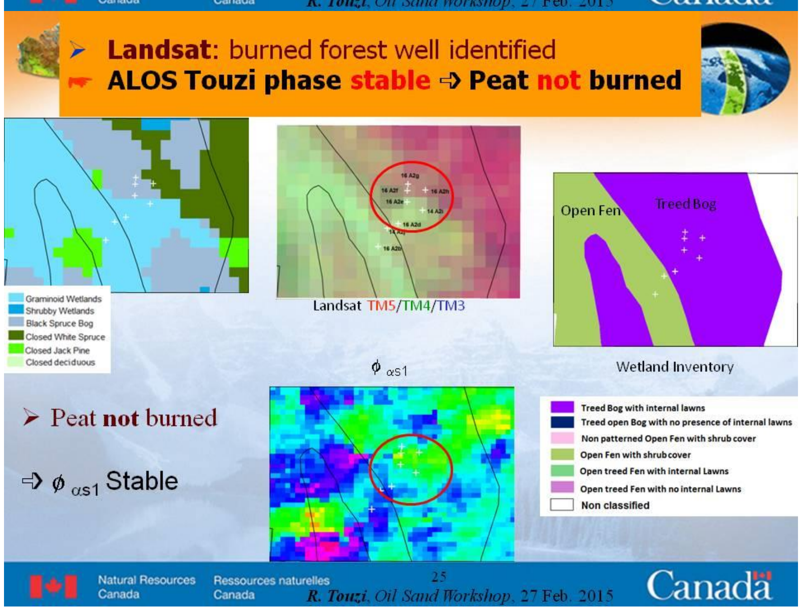

Landsat=> Bog confused with poor fen!!!
Phase sensitive to subsurface water ⇨ bog-fen discrimination
Graminoid Wetlands
Shrubby Wetlands
Black Spruce Bog
Closed White Spruce
Closed Jack Pine
Closed deciduous
Treed Bog with internal lawns
Treed open Bog with no presence of internal lawns
Non patterned Open Fen with shrub cover
Open Fen with shrub cover
Open treed Fen with internal Lawns
Open treed Fen with no internal Lawns
Non classified
Open Fen
Treed Bog
AGCC Landsat Classification
Landsat TM3/TM2/TM1
Wetland Inventory
Poor Fen
Bog
20
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

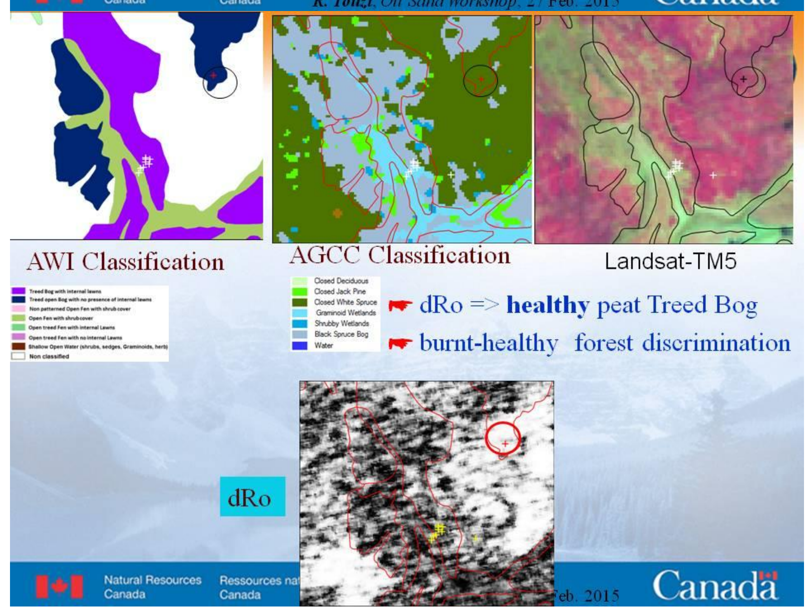

Investigation of the
Touzi Decomposition & Scattered Wave Optimization
for Peatland & Forest Fire Damage
Richardson Fire 2011
Bob's
Treed Bog Fire Site
Natural Resources Canada
Ressources naturelles Canada
21
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

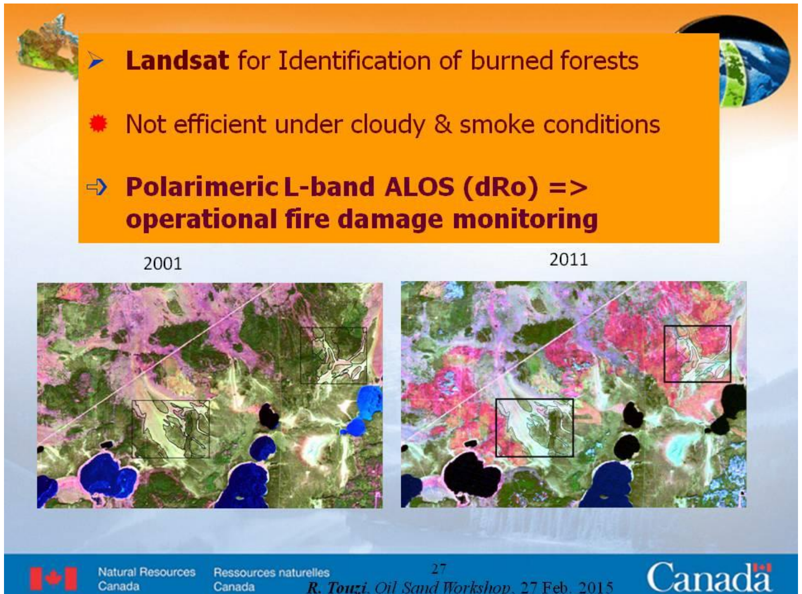

New scattered wave polarization signatures:
Healthy versus Burned White Spruce Forest
Area: HF
DoP
Area: Burnt Foret1
Ro
Orientation Angle (ψ)
Ellipticity Angle
Pmax = 0.63 ; Pmin = 0.08 ; dP = 0.55
Pmax = 0.82 ; Pmin = 0.39 ; dP = 0.43
Romax (dB)= -6.70 ; Romin (dB)= -7.75 ; dRo = 0.22
Romax (dB)= -1.11 ; Romin (dB)= -3.21 ; dRo = 0.38

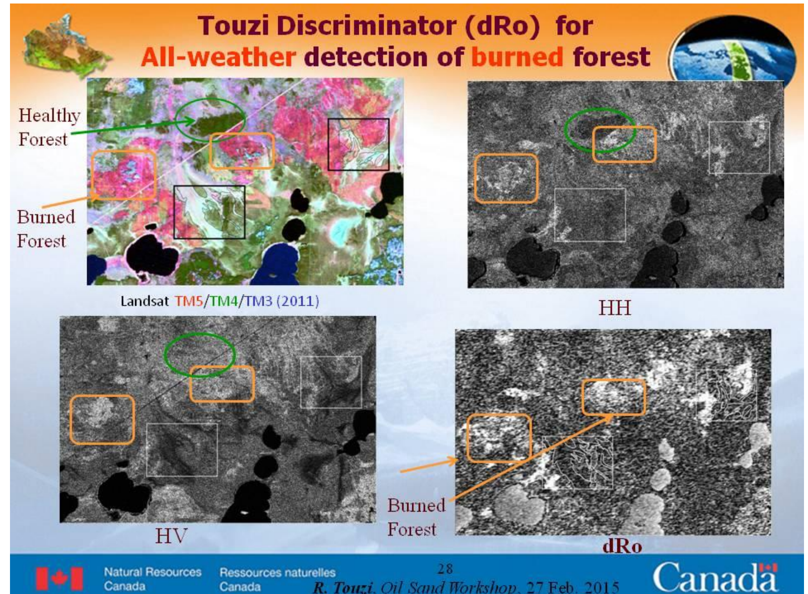

Bob's Fire Site
Landsat-TM5: RGB:
TM5/TM4/TM3
14 A2j: Bog
Covers: 10% trees (Black spruce 10%)
60% of shrubs (Labrador Tea 15%, Dwarf BR 20%, Bob Cranberry 5%, Leather leaf 20%)
30% of herbs (Moss 30%)
Peat depth: ~168cm, Water level: -26cm
Comments: Clay Bottom, Poor drainage
16 A2d: Bog
Covers: 15% trees (Black spruce 15%)
55% of shrubs (Labrador Tea 25%, Bob Cranberry 15%, Leather leaf 15%)
30% of herbs (Moss 28%, Grass 2%)
Peat depth: ~170cm, Water level: -21cm
Comments: Clay and sandy Bottom, Poor drainage
Natural Resources Canada
Ressources naturelles Canada
23
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

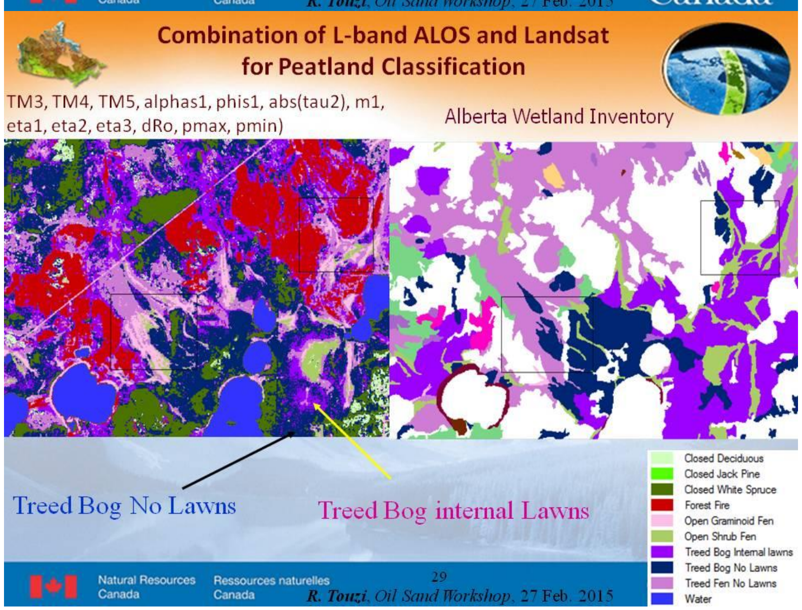

Bob's Fire Site
➢Black spruce burned
➢Peat Not affected
14 A2i: Bog
Covers: 15% trees (Black spruce 15%)
55% of shrubs (Labrador Tea 30%, Dwarf BR 20%, Bob Cranberry 5%)
30% of herbs (Moss 30%)
Peat depth: ~200cm, Water level: -22cm
Comments: Poor drainage
16 A2h: Bog
Covers:
60% of shrubs (Labrador Tea 40%, Bob Cranberry 15%, Cloud Berry 5%)
40% of herbs (Moss 40%)
Peat depth: ~200cm, Water level: -36cm
Comments: Sandy and Clay Bottom, Poor drainage
Natural Resources Canada
Ressources naturelles Canada
24
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

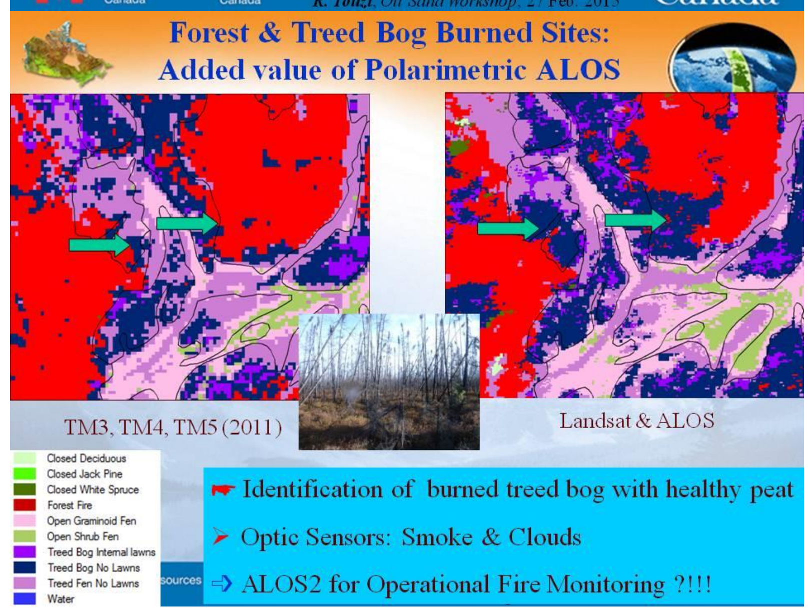

Landsat: burned forest well identified
ALOS Touzi phase stable ➩ Peat not burned
Graminoid Wetlands
Shrubby Wetlands
Black Spruce Bog
Closed White Spruce
Closed Jack Pine
Closed deciduous
Landsat TM5/TM4/TM3
Open Fen
Treed Bog
Wetland Inventory
$\phi_{\alpha s1}$
➢ Peat not burned
➩ $\phi_{\alpha s1}$ Stable
Treed Bog with internal lawns
Treed open Bog with no presence of internal lawns
Non patterned Open Fen with shrub cover
Open Fen with shrub cover
Open treed Fen with internal Lawns
Open treed Fen with no internal Lawns
Non classified
Natural Resources Canada
Ressources naturelles Canada
25
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

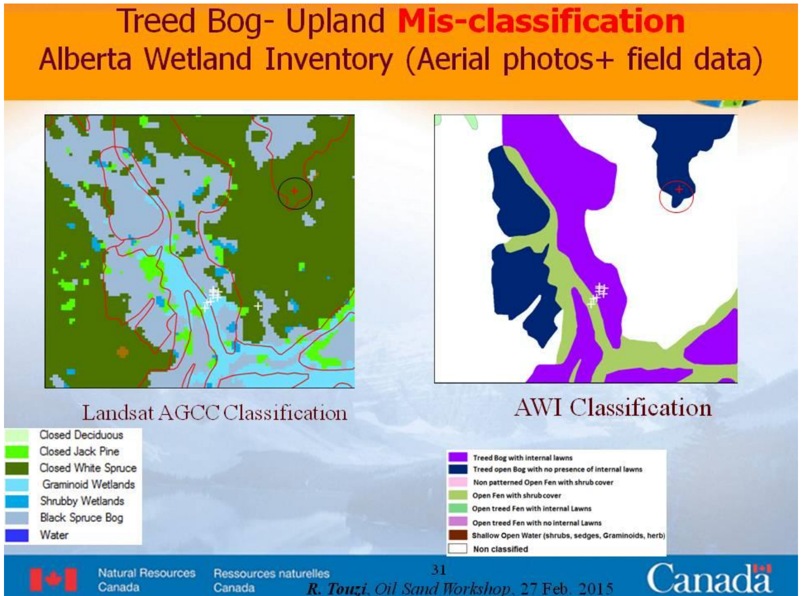

AWI Classification
AGCC Classification
Landsat-TM5
Closed Deciduous
Closed Jack Pine
Closed White Spruce
Graminoid Wetlands
Shrubby Wetlands
Black Spruce Bog
Water
dRo => healthy peat Treed Bog
burnt-healthy forest discrimination
dRo
Natural Resources Canada
Ressources na
eb. 2015
Canada


Landsat for Identification of burned forests
Not efficient under cloudy & smoke conditions
Polarimeric L-band ALOS (dRo) => operational fire damage monitoring
2001
2011
Natural Resources Canada
Ressources naturelles Canada
27
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada


Touzi Discriminator (dRo) for
All-weather detection of burned forest
Healthy Forest
Burned Forest
Landsat TM5/TM4/TM3 (2011)
HH
HV
Burned Forest
dRo
Natural Resources Canada
Ressources naturelles Canada
28
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

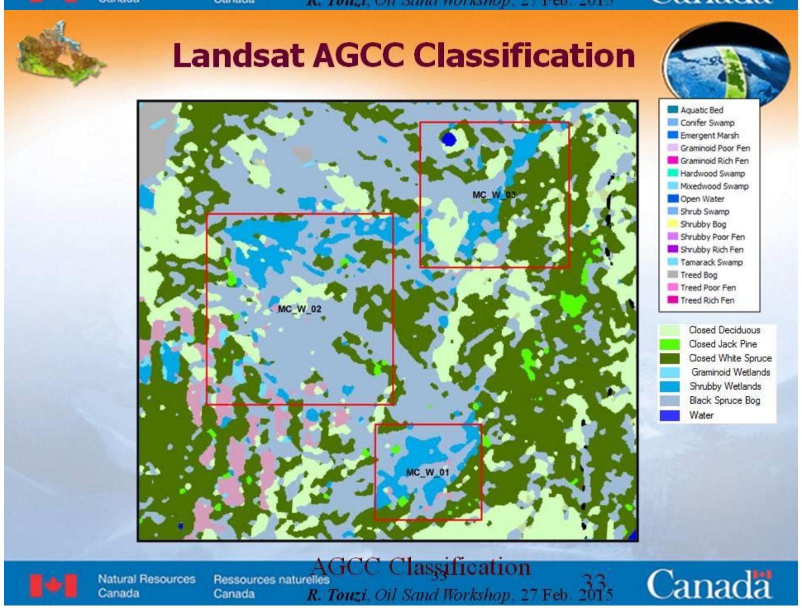

Combination of L-band ALOS and Landsat
for Peatland Classification
TM3, TM4, TM5, alphas1, phis1, abs(tau2), m1, eta1, eta2, eta3, dRo, pmax, pmin)
Alberta Wetland Inventory
Treed Bog No Lawns
Treed Bog internal Lawns
Closed Deciduous
Closed Jack Pine
Closed White Spruce
Forest Fire
Open Graminoid Fen
Open Shrub Fen
Treed Bog Internal lawns
Treed Bog No Lawns
Treed Fen No Lawns
Water
Natural Resources Canada
Ressources naturelles Canada
29
R. Touzi, Oil Sand Workshop, 27 Feb. 2015


Forest & Treed Bog Burned Sites:
Added value of Polarimetric ALOS
TM3, TM4, TM5 (2011)
Landsat & ALOS
Closed Deciduous
Closed Jack Pine
Closed White Spruce
Forest Fire
Open Graminoid Fen
Open Shrub Fen
Treed Bog Internal lawns
Treed Bog No Lawns
Treed Fen No Lawns
Water
Identification of burned treed bog with healthy peat
Optic Sensors: Smoke & Clouds
ALOS2 for Operational Fire Monitoring ?!!!

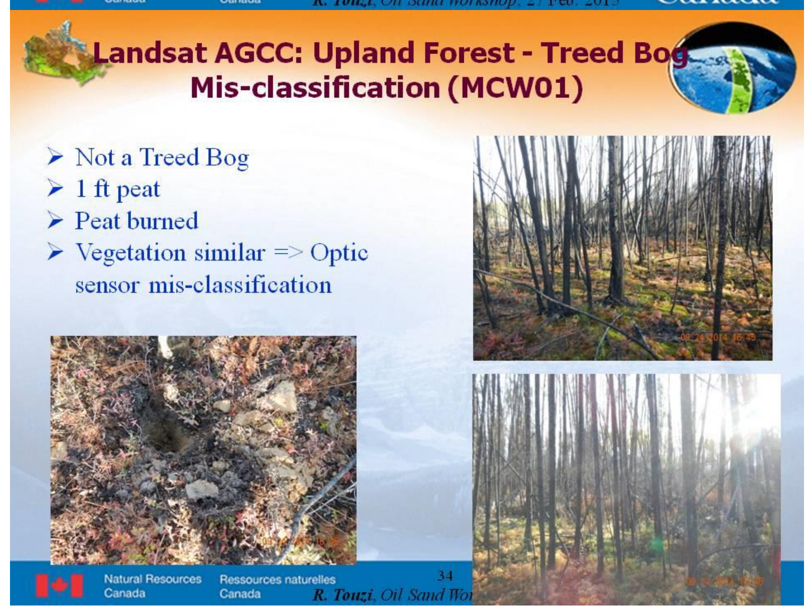


Treed Bog- Upland Mis-classification
Alberta Wetland Inventory (Aerial photos+ field data)
Landsat AGCC Classification
AWI Classification
Closed Deciduous
Closed Jack Pine
Closed White Spruce
Graminoid Wetlands
Shrubby Wetlands
Black Spruce Bog
Water
Treed Bog with internal lawns
Treed open Bog with no presence of internal lawns
Non patterned Open Fen with shrub cover
Open Fen with shrub cover
Open treed Fen with internal Lawns
Open treed Fen with no internal Lawns
Shallow Open Water (shrubs, sedges, Graminoids, herb)
Non classified
Natural Resources Canada
Ressources naturelles Canada
31
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

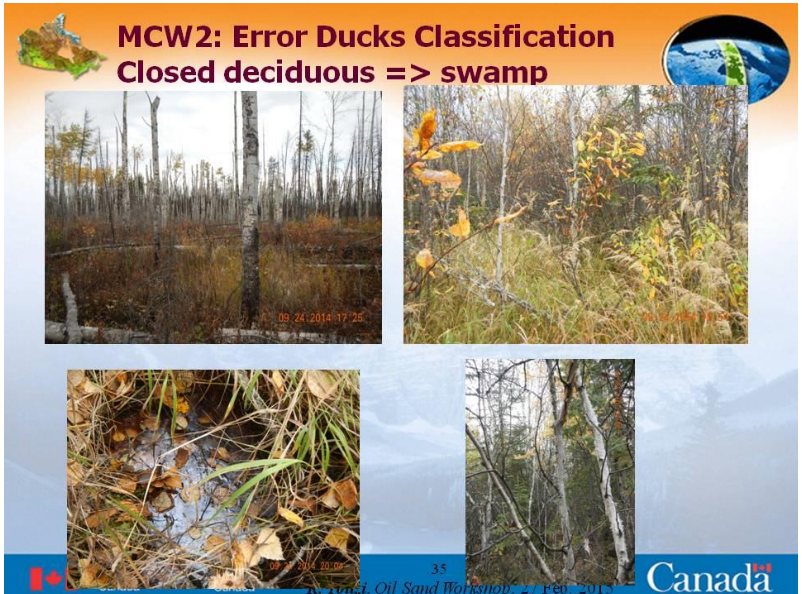
Upland Forest- mis-classified as a Treed Bog (AWI)
Not a Treed Bog
1 ft peat
Peat burned
Vegetation similar => Optic sensor mis-classification
Natural Resources Canada
Ressources naturelles Canada
32
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

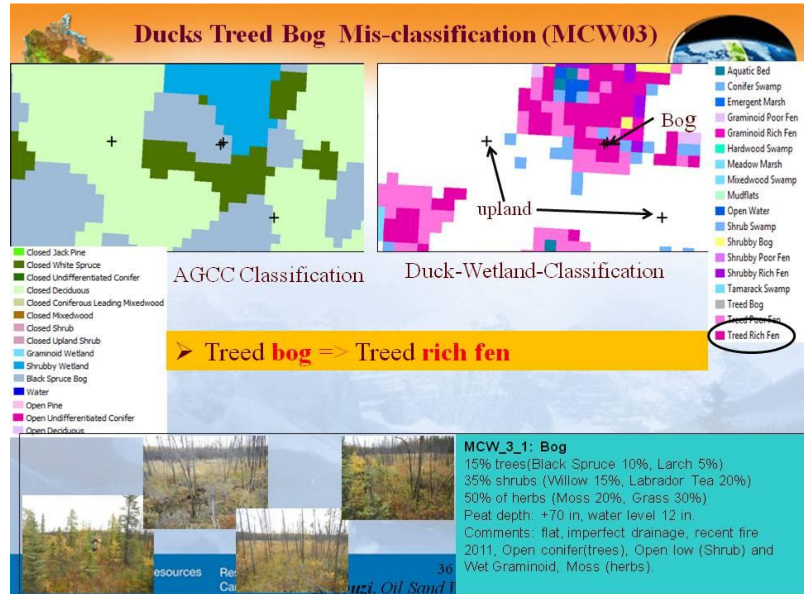


Landsat AGCC Classification
MC_W_03
MC_W_02
MC_W_01
Aquatic Bed
Conifer Swamp
Emergent Marsh
Graminoid Poor Fen
Graminoid Rich Fen
Hardwood Swamp
Mixedwood Swamp
Open Water
Shrub Swamp
Shrubby Bog
Shrubby Poor Fen
Shrubby Rich Fen
Tamarack Swamp
Treed Bog
Treed Poor Fen
Treed Rich Fen
Closed Deciduous
Closed Jack Pine
Closed White Spruce
Graminoid Wetlands
Shrubby Wetlands
Black Spruce Bog
Water
AGCC Classification
Natural Resources Canada
Ressources naturelles Canada
33
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada

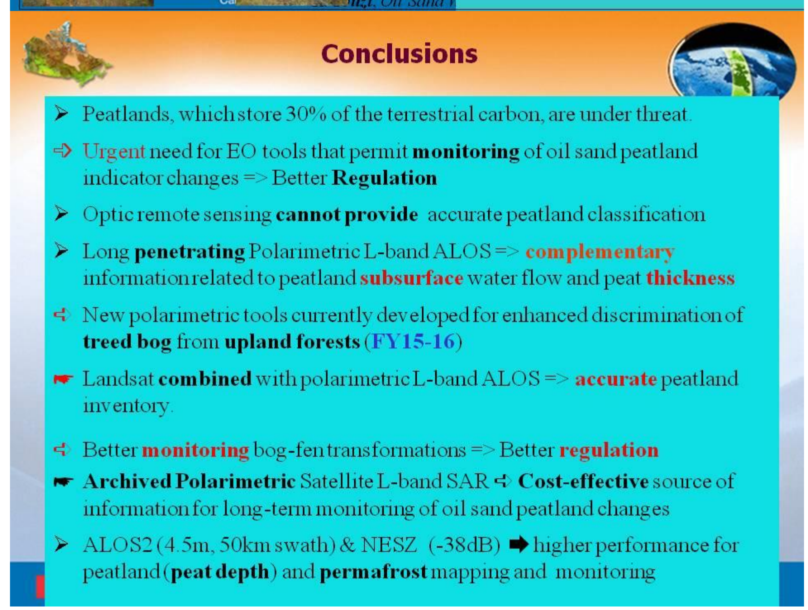


Landsat AGCC: Upland Forest - Treed Bog Mis-classification (MCW01)
Not a Treed Bog
1 ft peat
Peat burned
Vegetation similar => Optic sensor mis-classification
Natural Resources Canada
Ressources naturelles Canada
34


MCW2: Error Ducks Classification
Closed deciduous => swamp
35
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada


Ducks Treed Bog Mis-classification (MCW03)
Closed Jack Pine
Closed White Spruce
Closed Undifferentiated Conifer
Closed Deciduous
Closed Coniferous Leading Mixedwood
Closed Mixedwood
Closed Shrub
Closed Upland Shrub
Graminoid Wetland
Shrubby Wetland
Black Spruce Bog
Water
Open Pine
Open Undifferentiated Conifer
AGCC Classification
Bog
upland
Duck-Wetland-Classification
Aquatic Bed
Conifer Swamp
Emergent Marsh
Graminoid Poor Fen
Graminoid Rich Fen
Hardwood Swamp
Meadow Marsh
Mixedwood Swamp
Mudflats
Open Water
Shrub Swamp
Shrubby Bog
Shrubby Poor Fen
Shrubby Rich Fen
Tamarack Swamp
Treed Bog
Treed Rich Fen
➢ Treed bog => Treed rich fen
MCW_3_1: Bog
15% trees(Black Spruce 10%, Larch 5%)
35% shrubs (Willow 15%, Labrador Tea 20%)
50% of herbs (Moss 20%, Grass 30%)
Peat depth: +70 in, water level 12 in.
Comments: flat, imperfect drainage, recent fire 2011, Open conifer(trees), Open low (Shrub) and Wet Graminoid, Moss (herbs).
36


Future Challenges (FY 15-16)
Treed-Bog versus upland Classification
Optic sensors & Aerial photos => Mis-classification
Polarimetric L-band ALOS2
Wave penetration => accurate treed-bog & upland forest classification
Pol-inSAR ALOS2 (13 days repeat-pass)
Will be validated jointly with ESRD& AER
Natural Resources Canada
Ressources naturelles Canada
37
R. Touzi, Oil Sand Workshop, 27 Feb. 2015
Canada


Conclusions
➢ Peatlands, which store 30% of the terrestrial carbon, are under threat.
Urgent need for EO tools that permit monitoring of oil sand peatland indicator changes => Better Regulation
➢ Optic remote sensing cannot provide accurate peatland classification
➢ Long penetrating Polarimetric L-band ALOS => complementary information related to peatland subsurface water flow and peat thickness
New polarimetric tools currently developed for enhanced discrimination of treed bog from upland forests (FY15-16)
Landsat combined with polarimetric L-band ALOS => accurate peatland inventory.
Better monitoring bog-fen transformations => Better regulation
Archived Polarimetric Satellite L-band SAR Cost-effective source of information for long-term monitoring of oil sand peatland changes
➢ ALOS2 (4.5m, 50km swath) & NESZ (-38dB) higher performance for peatland (peat depth) and permafrost mapping and monitoring

Snow Cover Mapping in the AOSR, Richard Fernandes, NRCan-CCRS

Motivation

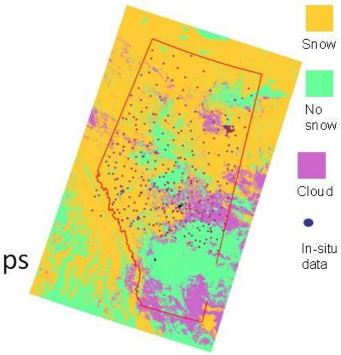
- Between 1000 and 2000 wildfires per year.
- Over half occur in May.
- Snow melt over frozen ground leaves dry organic layer with high fire danger.
- Snow cover time series required to map fire danger.

Natural Resources Canada Ressources naturelles Canada

Canada

AESRD Snow Cover Maps

- Based on 500m resolution MODIS daily snow cover maps.
- ~75% cloud cover
- 4 day moving window composites
- How accurate are these maps for snow melt?

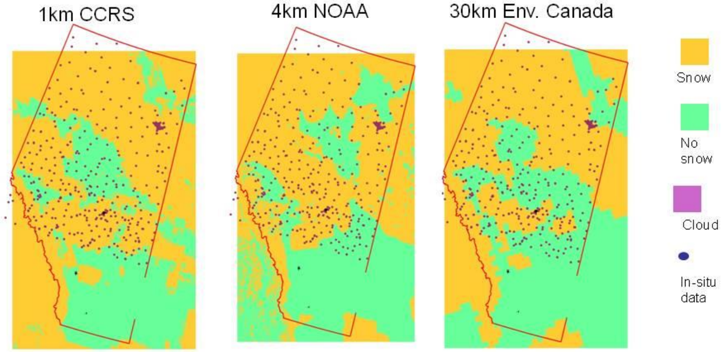


Natural Resources Canada Ressources naturelles Canada

Canada

Gap Free Alternatives

1km CCRS | 4km NOAA | 30km Env. Canada



CCRS Snow Data Assimilation System

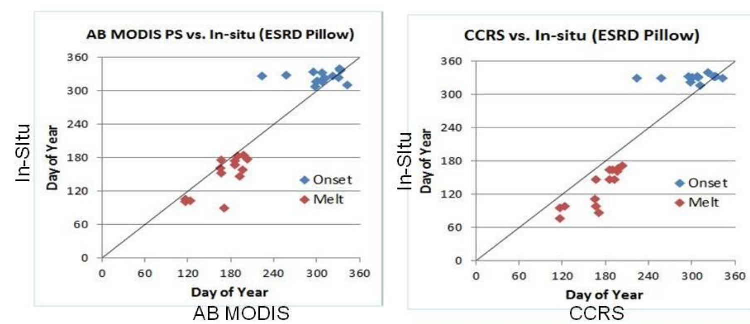
NOAA IMS snow and ice product

Canadian Meteorological Centre (CMC) snow cover map

Natural Resources Canada Ressources naturelles Canada

Canada

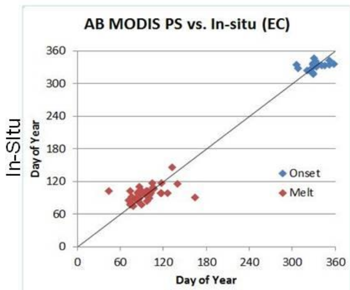
vs. AESRD Melt/Onset Date



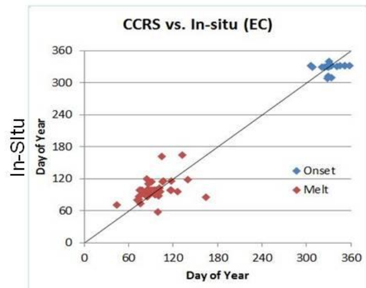
Natural Resources Canada Ressources naturelles Canada

Canada

vs . EC Melt/Onset Date



AB Modis



CCRS

Natural Resources Canada Ressources naturelles Canada

Canada

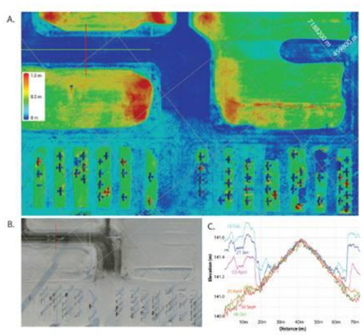
Conclusions

- CCRS and AB MODIS show similar uncertainty
  - Melt error of 7-8 days
  - Late bias due to snow cover in forests vs. in-situ sites
- CCRS offers:
  - 100% coverage vs. 25% gaps for AB MODIS
  - snow depth and uncertainty estimates
  - Better linearity with AESRD pillows
- Issue with comparing in-situ point vs. >=500m pixels
- Look for intermediate scale mapping using UAVs

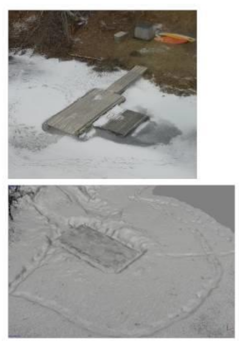
Natural Resources Canada Ressources naturelles Canada

Canada

Snow Depth from Air Photos



Airborne Digital System, Nolan et al. 2015

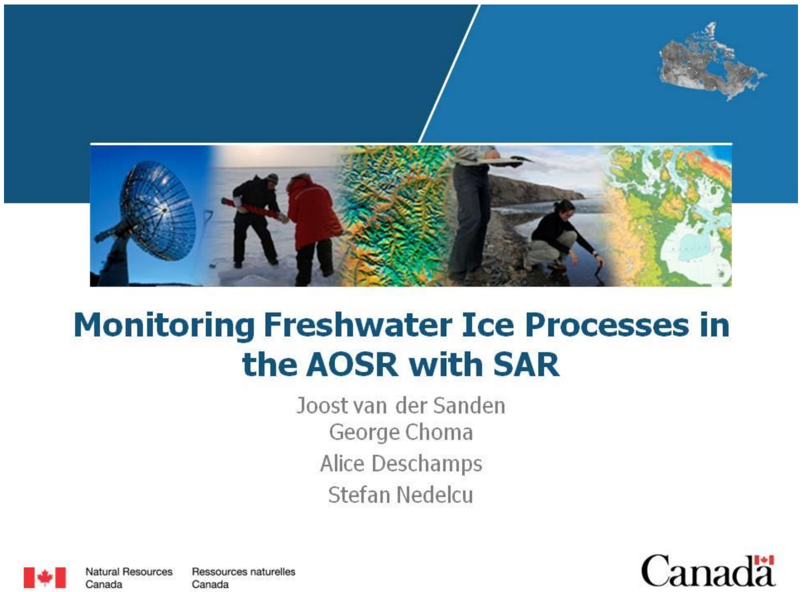


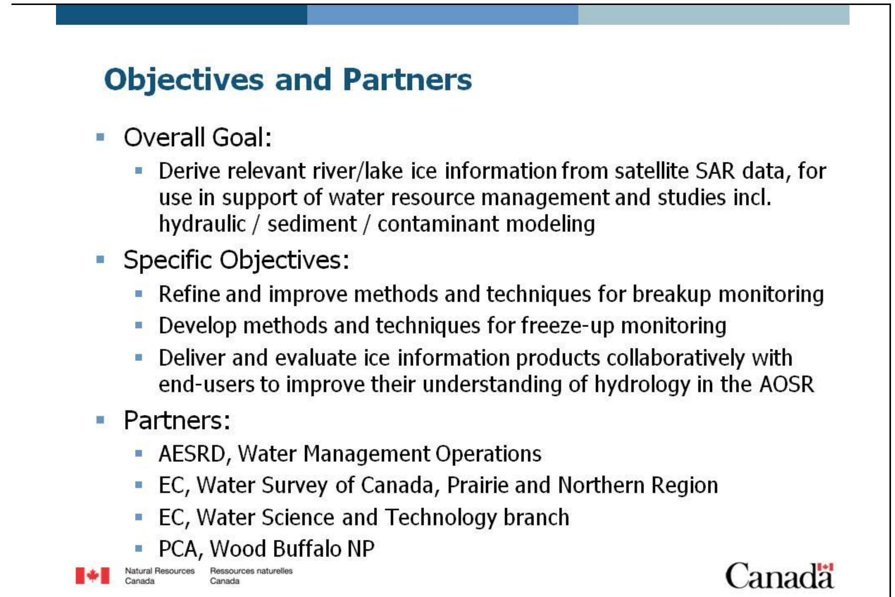
Hobby grade UAV, Fraser. 2015

Natural Resources Canada Ressources naturelles Canada

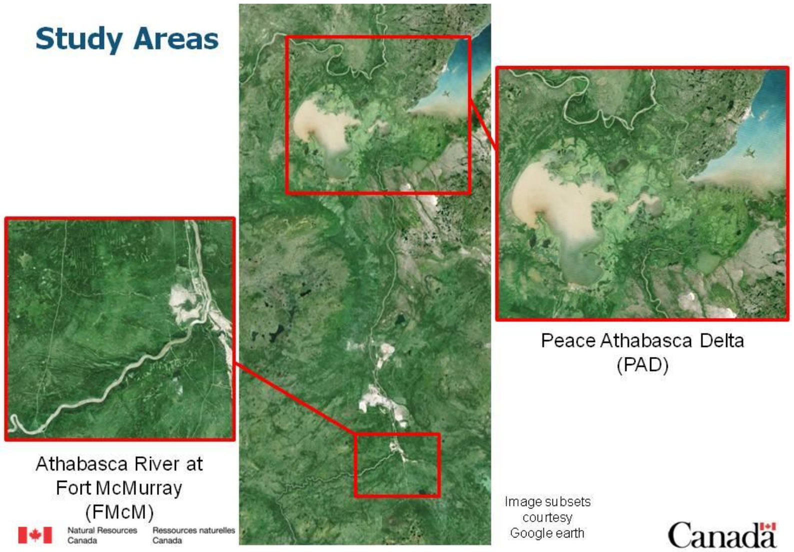
Canada

Monitoring Athabasca River Ice Dynamics, Roger De Abreu (for Joost van der Sanden), NRCan-CCRS





Study Areas



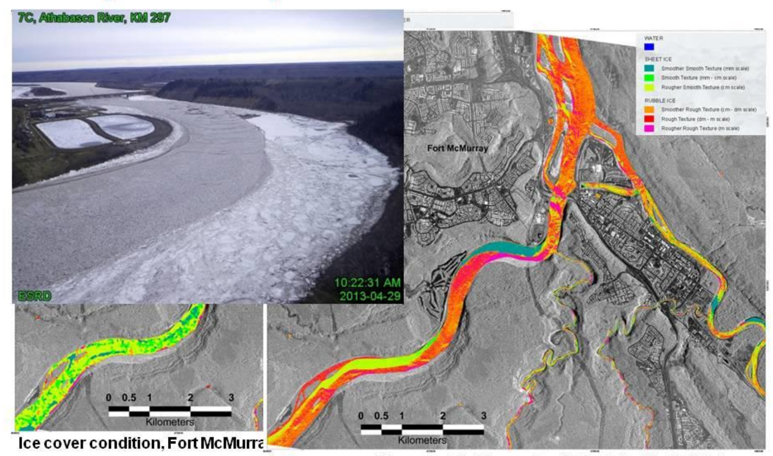
Breakup Monitoring: 2013 and 2014

- Automated processing workflow; developed Google Earth compatible product format
- Scheduled RSAT2 acquisitions (2013: 42 dates in Apr-Jun; 2014: 44 dates in Apr-Jun)
- Generated and distributed products in NRT:
  - 2013
    - 16 ice cover products (April 1st – May 19th: FMcM 12, PAD 4)
    - 1 flood product (May 9th: FMcM 0, PAD 1)
  - 2014
    - 15 ice cover products (April 17th – May 18th: FMcM 4, PAD 11)
    - 10 flood products (April 24th – May 21st: FMcM 0, PAD 10)
- Products downloaded by: Gov Alberta (Public Works, Forestry/Lands/Wildlife), EC, PCA, CSA, Municipality of Wood Buffalo, BC Hydro, UoAlberta, and UoSask.

Breakup Monitoring: 2013 and 2014 cont.

- Monitored 2014 breakup of the Athabasca River at FMcM with time-lapse cameras (5 locations, every 15 minutes)
- Received ground reference data from AESRD, PCA, EC, and Municipality of Wood Buffalo for product validation and refinement

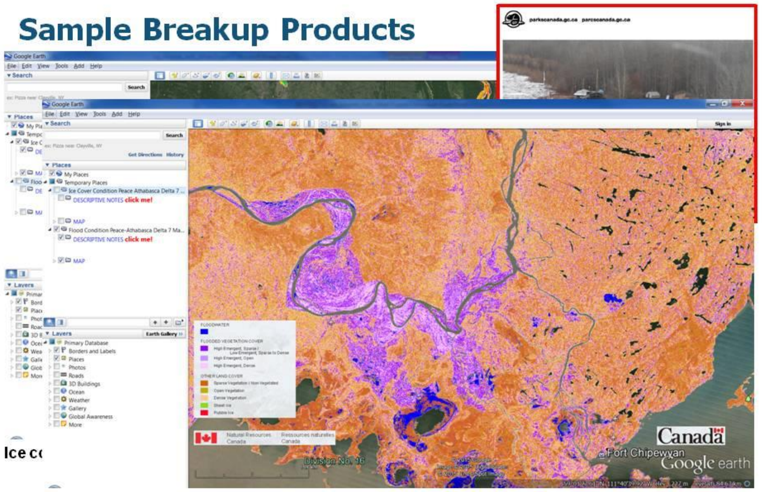
Sample Breakup Products



Ice cover condition, Fort McMurra

Ice cover condition, Fort McMurray, April 29, 2013, 07:29 MDT

Sample Breakup Products



Flood condition, Peace Athabasca Delta, May 7, 2014, 07:49 MDT

Natural Resources Canada | Ressources naturelles Canada
Canada

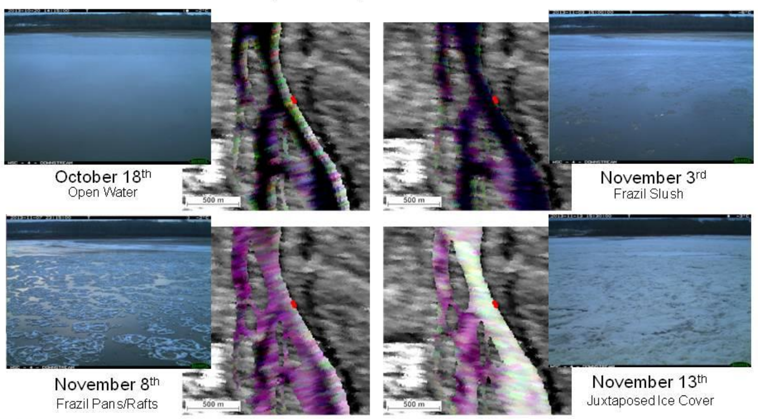
Freeze-up Monitoring: 2013 and 2014

- Scheduled RSAT2 acquisitions (2013: 30 dates in Oct-Nov; 2014: 26 dates in Oct-Nov)
- Monitored 2013 and 2014 freeze-up of the Athabasca River at FMcM with time-lapse cameras (5 locations, every 15 minutes)
- Initiated analysis of full polarimetric and simulated compact polarimetric data

Natural Resources Canada | Ressources naturelles Canada
Canada

Preliminary Freeze-up Monitoring Results

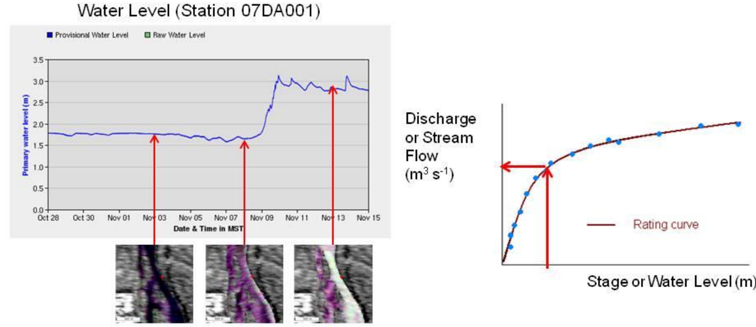
Athabasca River at Fort McMurray: Freeze-up 2013



Natural Resources Canada | Ressources naturelles Canada
Canada

Ice cover, Water Level and Stream Flow

Water Level (Station 07DA001)



- Ice cover formation increases the water level (hampers flow)
- Hydrometric stations measure water level
- Water level readings are used to estimate discharge (using 'rating curve')
- Rating curves do not typically account for ice cover effects
- Estimation of discharge in the presence of ice cover is problematic
- Freeze-up monitoring supports the validation/correction of discharge estimates

Natural Resources Canada | Ressources naturelles Canada
Canada

Conclusions and Future Activities

- RADARSAT can systematically monitor the presence of river ice, its freeze-up and break-up – all relevant to understanding hydrology and management of the regional rivers.
- Continue to develop method for the classification of ice cover conditions during freeze-up (using traditional and compact polarizations)
- Monitor 2015 breakup with time lapse cameras but will refocus from product demo to R&D aimed at developing utility of RCM-type compact polarimetry data
- Continue to gather feedback of utility of this type of information
- Further disseminate results in presentations, reports, and papers

Natural Resources Canada Ressources naturelles Canada Canada

Acknowledgements

- Government Related Initiatives Program (GRIP) of the CSA
- AESRD: Bernard Trevor and Andun Jevne
- EC/WSC: Brian Wiens and Dwayne Mayell
- Regional Municipality of Wood Buffalo: Travis Kendel
- Fort McMurray Golf Club: Jeff Hacior
- PCA: Jean Poitevin, Stuart MacMillan, Dawn Andrews, and David Campbell
- EC/WST: Spyros Beltaos, Charles Talbot, and Tom Carter

- Please note:

  - RADARSAT-2 Data and Products © MacDONALD, DETTWILER AND ASSOCIATES LTD. 2013/14 – All Rights Reserved
  - RADARSAT is an official mark of the Canadian Space Agency

Natural Resources Canada Ressources naturelles Canada Canada

The AOSR Hyperspectral Dataset: Status and Opportunities, Peter White, NRCan-CCRS

Overview

- 2012: University of Victoria was the successful recipient of a Dept. Natural Resources Departmental Class Grants and Contributions Program (G&C)
  - Based on a diversity of studies planned and ongoing related to environmental monitoring in the Oil Sands region, the University of Victoria brought together several stakeholders, identified supporting airborne remote sensing, and put forward the proposal.
  - *"… to develop and refine remote sensing techniques to better monitor possible environmental impacts of the Alberta Oil Sands. It will do this through the acquisition and preprocessing of multisensory airborne data (hyperspectral, LiDAR, aerial and INS - Inertial Navigation System) for selected areas of the Alberta Oil Sands region of interest."*
  - Sites were selected and flown in 2012 (Cold Lake/Sandy Lake Regions) and 2013 (Fort McMurray Region)

Natural Resources Canada Ressources naturelles Canada
Canada Centre for Remote Sensing Imaging Spectrometry Science Team
Canada

Overview

- CCRS Role
  - Scientific Advisor on the G&C
  - Provide support for the site selection, acquisition and data quality assessment to facilitate development of environmental monitoring applications exploiting multisensor remote sensing pertaining to oil sands extraction, related processing activities, and remediation initiatives in northern Alberta.
- Key Partnerships
  - University of Victoria and Terra Remote Sensing Inc.
  - Government of Alberta - AER
  - Campus Alberta (Uni. Lethbridge, Uni. Alberta-Edmonton, Uni. Calgary)
  - CCRS Projects and Activities

Natural Resources Canada Ressources naturelles Canada
Canada Centre for Remote Sensing Imaging Spectrometry Science Team
Canada

Data Acquisitions

- Summer 2012
  - $560km^2$ acquired
    - Cold Lake[v]
    - Cold Lake Wetlands[d]
    - Sandy Lake[v]
  - Field data (all partners)
- Fall/Winter 2012/13
  - Revision of ROI selection for 2013 acquisitions.
- Spring/Summer 2013
  - Data delivery (2012)

v: AISA Eaglet (VNIR) d: AISA Dual (VNIR+SWIR)

Natural Resources Canada Ressources naturelles Canada
Canada Centre for Remote Sensing Imaging Spectrometry Science Team
Canada

2012 Polygons

Wetlands CL
11-August-2012
VNIR+SWIR(400-2500nm) | 2m

In Situ N

In Situ S
12-August-2012
VNIR (400-1000nm) | 1.3m

Wetlands SL
7-Sept.-2012
VNIR (400-1000nm) | 1.3m

Natural Resources Canada Ressources naturelles Canada
Canada Centre for Remote Sensing Imaging Spectrometry Science Team
Canada

Data Acquisitions

- Summer/Winter 2013/14
  - Q/A of data
- Summer 2013
  - 1290km^2 acquired
    - Shell Muskeg[v]
    - South Bisonhills[v]
    - McClelland[v]
    - Stoney Long Lake[d]
  - Field data (all partners)
- Summer/Winter 2015
  - Data delivery and Q/A (2013)

[v]: AISA Eaglet (VNIR) [d]: AISA Dual (VNIR+SWIR)

Natural Resources Canada | Ressources naturelles Canada | Canada Centre for Remote Sensing Imaging Spectrometry Science Team | Canada

2013 Polygons

South Bison Hills
10 & 17-Aug-2013
VNIR+SWIR(400-2500nm) | 2m

McClelland
19-Aug-2013
VNIR (400-1000nm) | 2m

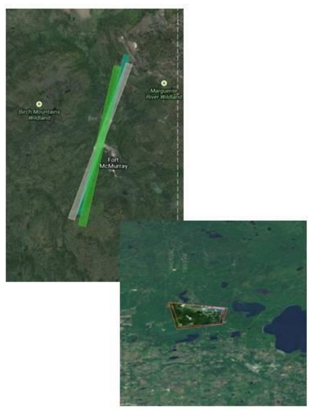
Shell Muskeg
8 & 10-Aug-2013
VNIR (400-1000nm) | 2m

Stoney Long Lake
23-Aug-2013
VNIR (400-1000nm) | 2.25m

Natural Resources Canada | Ressources naturelles Canada | Canada Centre for Remote Sensing Imaging Spectrometry Science Team | Canada

Data Acquisitions

- Complimented with EO-1 Hyperion acquisitions
  - 28-Aug-2014
  - 27-July-2009
  - 26-July-2009
- And CHRIS-Proba acquisitions
  - 20-July-2012
  - 09-July-2013
  - 01-August-2013

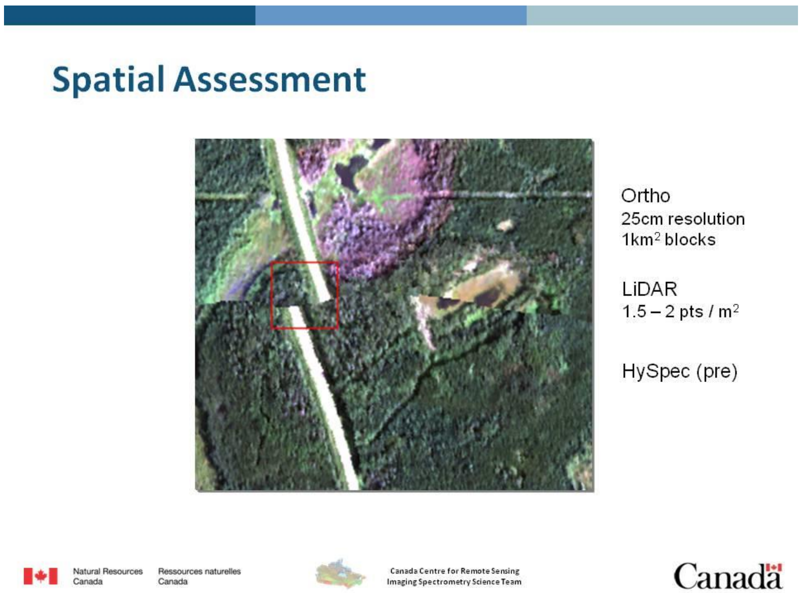


Natural Resources Canada | Ressources naturelles Canada | Canada Centre for Remote Sensing Imaging Spectrometry Science Team | Canada

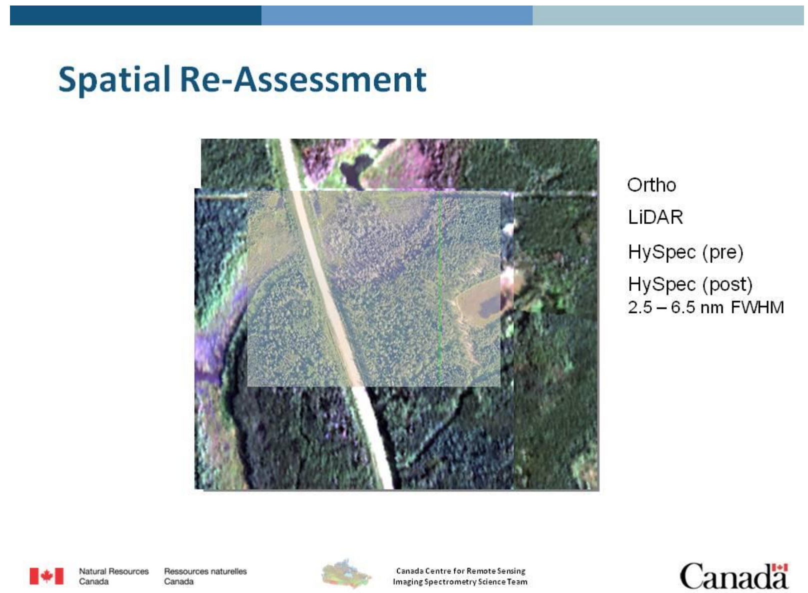
Spatial Assessment

- Terra Remote Sensing performed spatial cal/val using field located targets. Reported accuracies were ±2 pixels (HS) and ±25cm horizontal, ±10cm vertical (LiDAR).
  - All data were spatially tied to an RTK ground reference base station placed within a 60 km radius of the survey polygon to yield a positional accuracy of ±25 cm in the horizontal and ±10 cm in the vertical domains.
- CCRS independent validation agreed with LiDAR assessment, but identified a small subset of data with ±25 pixel offset. These flight lines were reported to, and reprocessed by, the data provider.
  - Now assess to be within reported accuracies.
- Additional cross-validation determined flight lines were within the reported relative accuracies with neighbouring flight lines and with LiDAR and orthophotos.

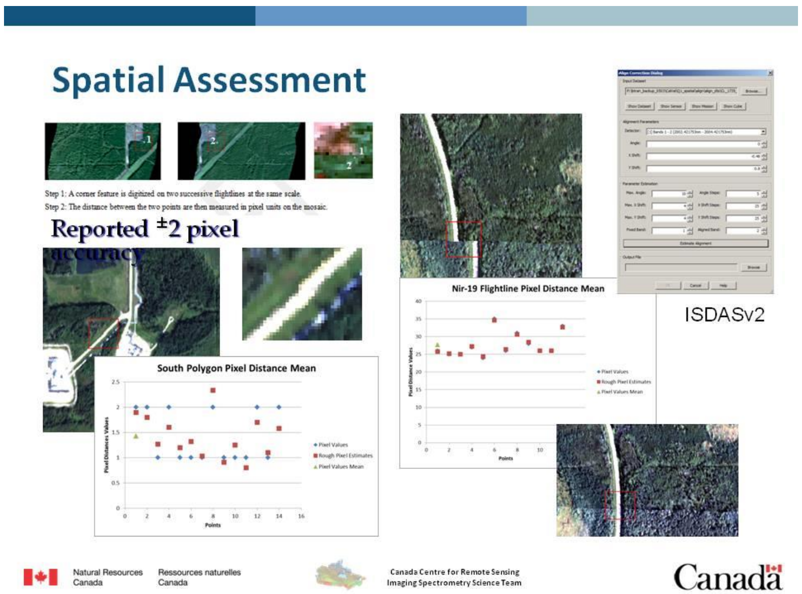
Natural Resources Canada | Ressources naturelles Canada | Canada Centre for Remote Sensing Imaging Spectrometry Science Team | Canada



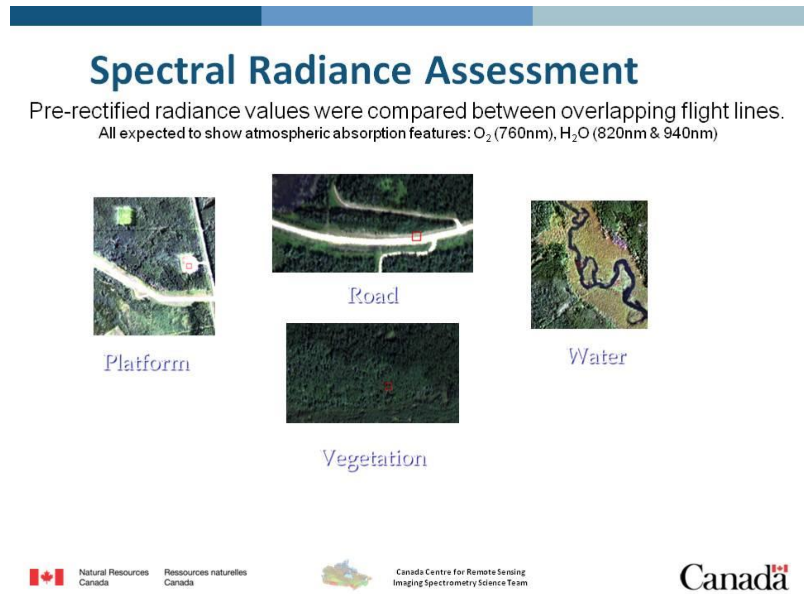
Spatial Assessment
Ortho
25cm resolution
1km² blocks
LiDAR
1.5 – 2 pts / m²
HySpec (pre)
Natural Resources Canada
Ressources naturelles Canada
Canada Centre for Remote Sensing
Imaging Spectrometry Science Team
Canada



Spatial Re-Assessment
Ortho
LiDAR
HySpec (pre)
HySpec (post)
2.5 – 6.5 nm FWHM
Natural Resources Canada
Ressources naturelles Canada
Canada Centre for Remote Sensing
Imaging Spectrometry Science Team
Canada



Spatial Assessment
Step 1: A corner feature is digitized on two successive flightlines at the same scale.
Step 2: The distance between the two points are then measured in pixel units on the mosaic.
Reported ±2 pixel accuracy
South Polygon Pixel Distance Mean
Nir-19 Flightline Pixel Distance Mean
ISDASv2
Natural Resources Canada
Ressources naturelles Canada
Canada Centre for Remote Sensing
Imaging Spectrometry Science Team
Canada



Spectral Radiance Assessment
Pre-rectified radiance values were compared between overlapping flight lines.
All expected to show atmospheric absorption features: O2 (760nm), H2O (820nm & 940nm)
Platform
Road
Vegetation
Water
Natural Resources Canada
Ressources naturelles Canada
Canada Centre for Remote Sensing
Imaging Spectrometry Science Team
Canada

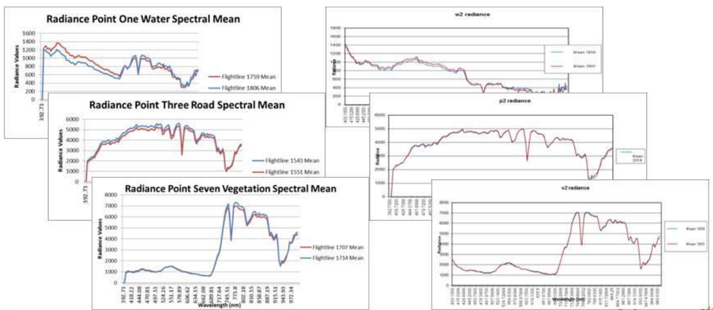
Spectral Radiance Assessment

Pre-rectified radiance values were compared between overlapping flight lines.

All expected to show atmospheric absorption features: O_2 (760nm), H_2O (820nm & 940nm)

Cold Lake polygons, flight lines were East-West orientation acquired near local-solar-noon. South-edge of flight lines were anticipated to be "darker" than their overlapping north-edge counterpart due to BRDF. (Except for water – specular)

Wetlands polygons, flight lines were North-South orientation. East-edge of flight lines were anticipated to be similar to their overlapping west-edge counterpart (across-solar plane symmetry).

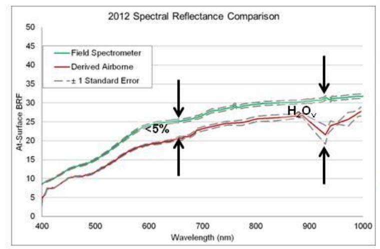


Natural Resources Canada / Ressources naturelles Canada / Canada Centre for Remote Sensing Imaging Spectrometry Science Team / Canada

Spectral At-Surface BRF Assessment

At-surface BRF (Bidirectional Reflectance Factor) was compared between the airborne derived values and field validation data.

Neither *should* show atmospheric absorption features: O_2 (760nm), H_2O (820nm & 940nm)



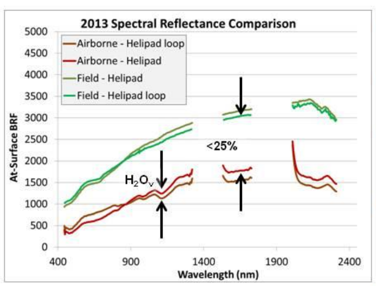
- Airborne data has a uniform atmospheric normalization.
- 2012 data shows reflectance offsets of a few percentage.
- The stronger atmospheric absorption features have not been completely removed.
- Spectral curvature noted (up to 2nm)

Natural Resources Canada / Ressources naturelles Canada / Canada Centre for Remote Sensing Imaging Spectrometry Science Team / Canada

Spectral At-Surface BRF Assessment

At-surface BRF (Bidirectional Reflectance Factor) was compared between the airborne derived values and field validation data.

Neither *should* show atmospheric absorption features: O_2 (760nm), H_2O (820nm, 940nm, 1130nm), etc.



- Airborne data has a uniform atmospheric normalization.
- 2013 data shows more significant reflectance offsets.
- The stronger atmospheric absorption features have not been completely removed.
- Spectral curvature noted (up to 2nm)
- *Still being followed-up.*

Natural Resources Canada / Ressources naturelles Canada / Canada Centre for Remote Sensing Imaging Spectrometry Science Team / Canada

Items

- Flight lines with spectral-spatial issues identified and reprocessed.
- UVic processing to at-surface reflectance items of note:
  - Normalized to a "clear dry sky". (standard commercial product)
  - No evaluation of smile / keystone.

Natural Resources Canada / Ressources naturelles Canada / Canada Centre for Remote Sensing Imaging Spectrometry Science Team / Canada

Current/Planned Sample Project

- University of Victoria:
  - Reclaimed Oil Sands tailings vegetation assessment;
  - Wetlands characterization and flow path analysis;
  - Pre--‐mining vegetation structure assessment.
- University of Alberta:
  - Oils sands tailings assessment.
- CCMEO/CCRS
  - *See today's presentations*
- University of Calgary:
  - Biodiversity mapping.
- University of Lethbridge:
  - Monitoring Procedures for Reclamation in Alberta;
  - Assessment of reclaimed Areas Using Hyperspectral Data;
  - A Web--‐Based Monitoring System for Enhancing the Provincial Mapping and Monitoring Capability.
  - Hyperspectral/LiDAR tree species mapping.

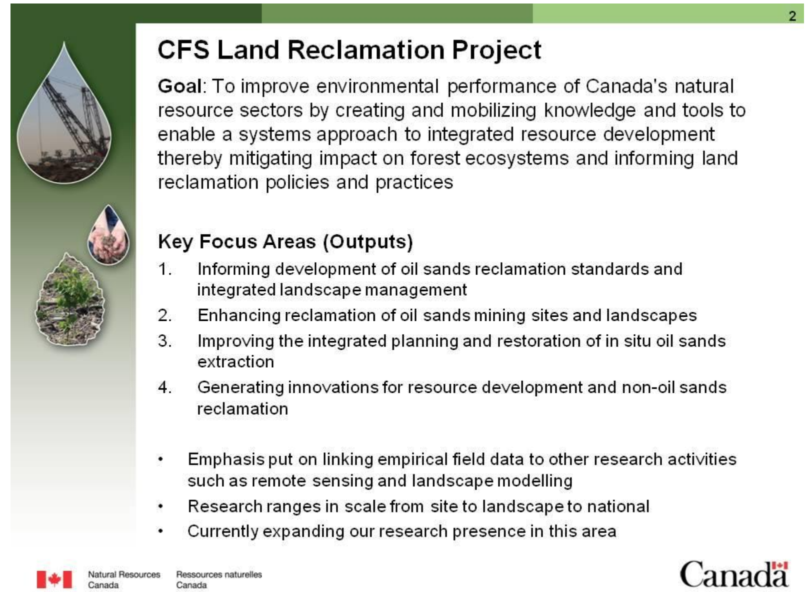
Natural Resources Canada / Ressources naturelles Canada — Canada Centre for Remote Sensing Imaging Spectrometry Science Team — Canada

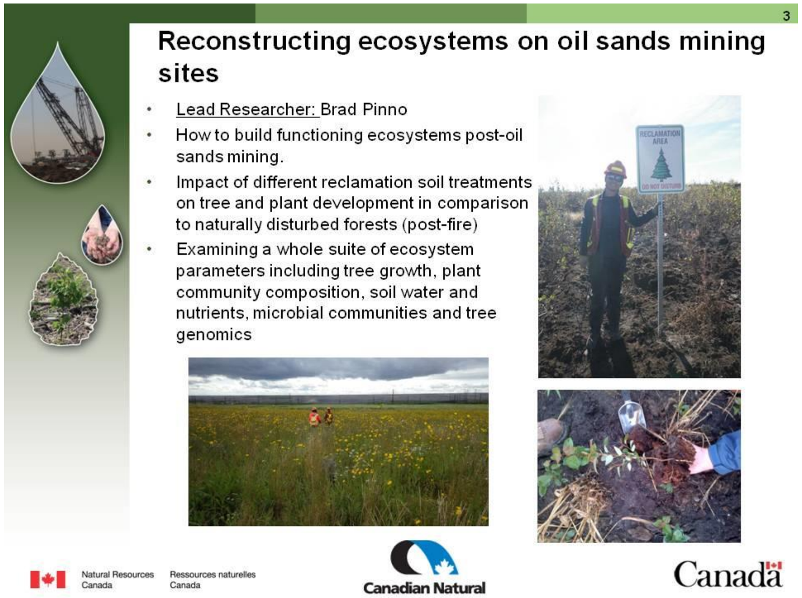
Longer term targets

- How to further support research/application initiatives in this region? What extra science technology innovations could be pursued?
  - Reprocess at-surface reflectance using physical modelling of sensor artefacts and atmospheric contributions (ISDASv2).
  - Use of LiDAR to match with Hyperspectral for enhanced environmental indicators.
  - Simulation of space-borne systems (EnMAP, Sentinel, Landsat, etc.)
  - Evaluation/engagement of physical models for vegetation and water (emphasis, how to use spaceborne to direct airborne and field deployments).
    - Radiative Transfer Models (proFLAIR) for canopy parameters.
    - Water column reflectance modelling (hyperspectral bathymetry) for tailings ponds and impacted water bodies.

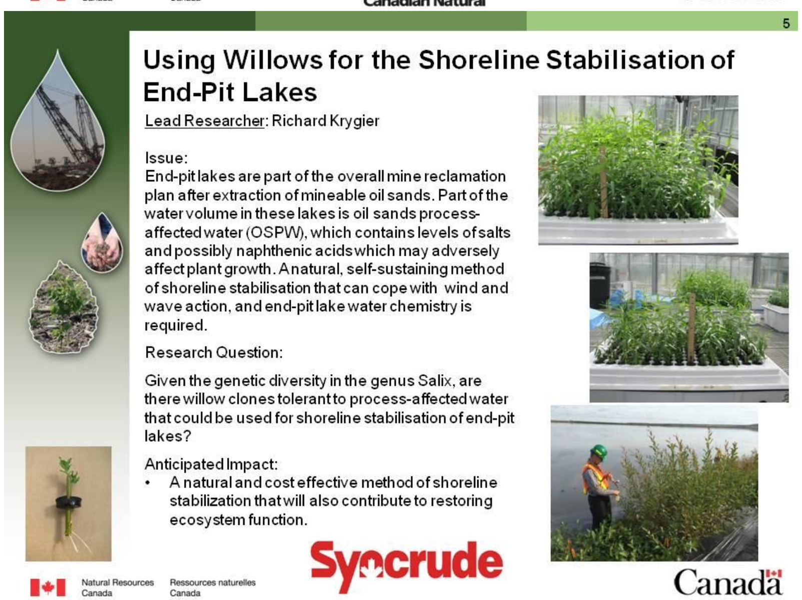
Natural Resources Canada / Ressources naturelles Canada — Canada Centre for Remote Sensing Imaging Spectrometry Science Team — Canada

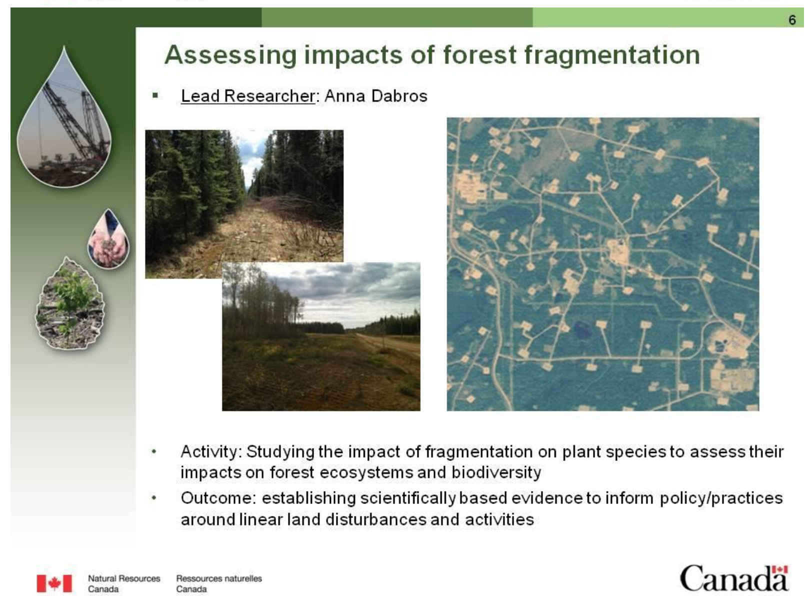
CFS Activities in the Oil Sands, Brad Pinno, Natural Resources Canada – Canadian Forest Service, (NRCan-CFS)

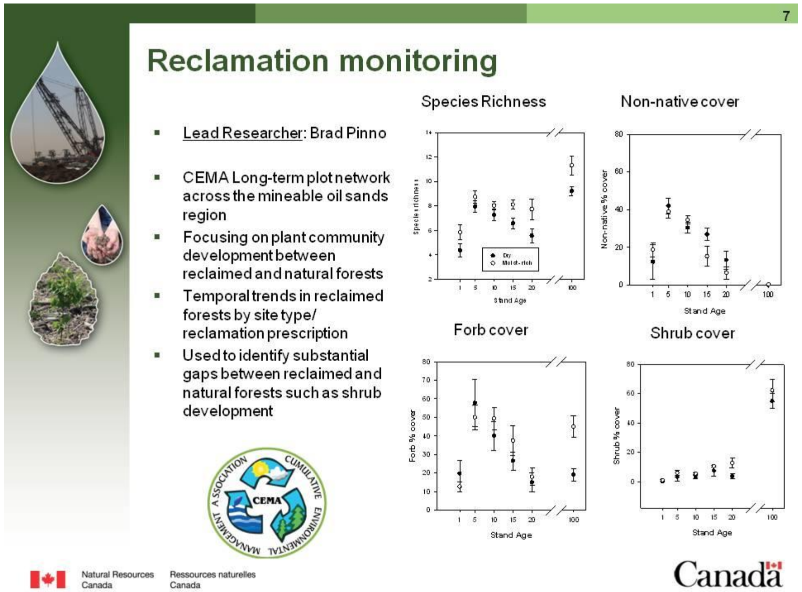


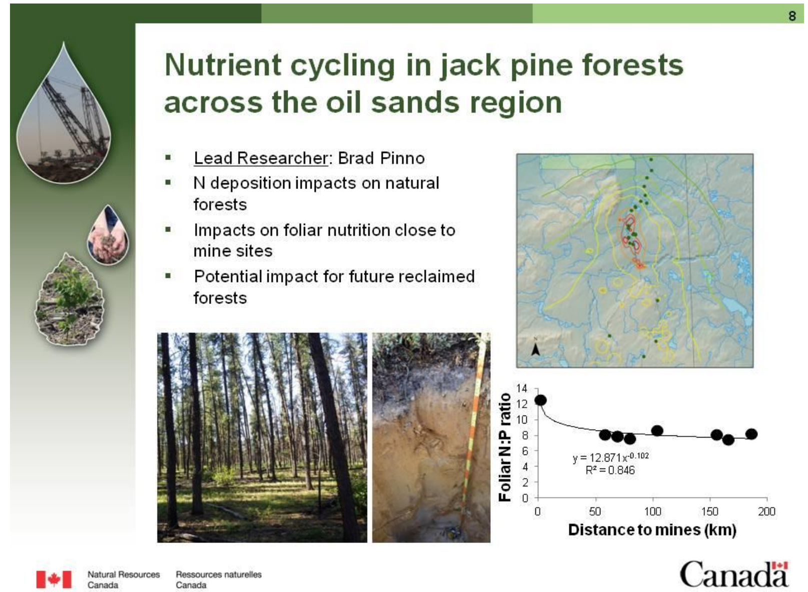

3
Reconstructing ecosystems on oil sands mining sites
• Lead Researcher: Brad Pinno
• How to build functioning ecosystems post-oil sands mining.
• Impact of different reclamation soil treatments on tree and plant development in comparison to naturally disturbed forests (post-fire)
• Examining a whole suite of ecosystem parameters including tree growth, plant community composition, soil water and nutrients, microbial communities and tree genomics
Natural Resources Canada
Ressources naturelles Canada
Canadian Natural
Canada

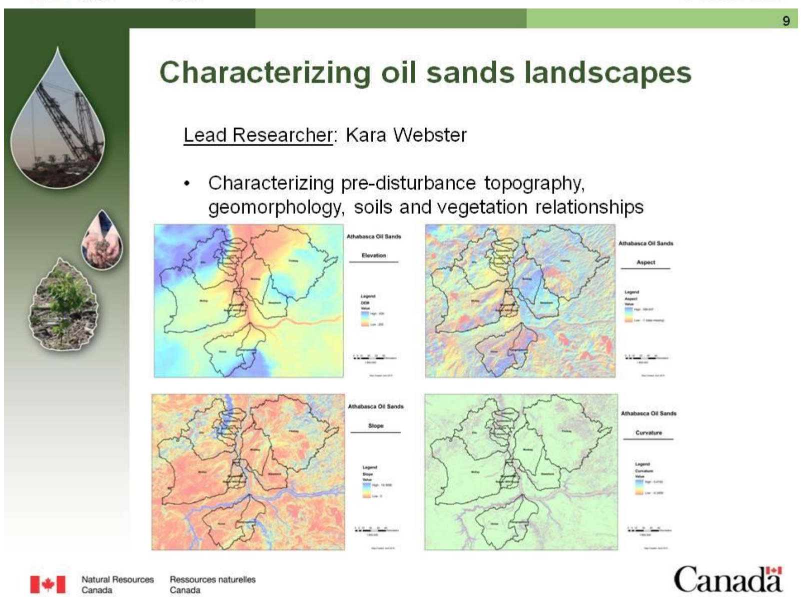

4
Seed Enhanced Ecological Delivery System (SEEDS)
Lead Researcher: Richard Krygier
Issue:
• Reclamation of linear disturbances and widely dispersed well sites with shrubs and forbs is costly and not always successful using traditional planting and seeding systems
Research Objectives:
Develop and test a novel seed delivery system to enable the effective and efficient re-establishment of native plants on disturbed forest sites
Anticipated Impact:
• Companies will save significant time and money on the re-establishment of native plants on in situ reclamation sites
nexen
Natural Resources Canada
Ressources naturelles Canada
Canada

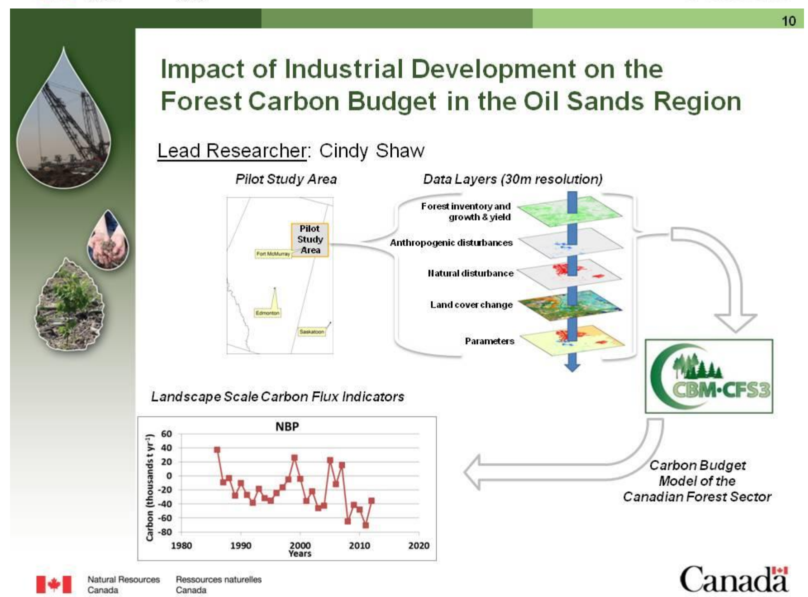

5
Using Willows for the Shoreline Stabilisation of End-Pit Lakes
Lead Researcher: Richard Krygier
Issue:
End-pit lakes are part of the overall mine reclamation plan after extraction of mineable oil sands. Part of the water volume in these lakes is oil sands process-affected water (OSPW), which contains levels of salts and possibly naphthenic acids which may adversely affect plant growth. A natural, self-sustaining method of shoreline stabilisation that can cope with wind and wave action, and end-pit lake water chemistry is required.
Research Question:
Given the genetic diversity in the genus Salix, are there willow clones tolerant to process-affected water that could be used for shoreline stabilisation of end-pit lakes?
Anticipated Impact:
• A natural and cost effective method of shoreline stabilization that will also contribute to restoring ecosystem function.
Syncrude
Natural Resources Canada
Ressources naturelles Canada
Canada


6
Assessing impacts of forest fragmentation
▪ Lead Researcher: Anna Dabros
• Activity: Studying the impact of fragmentation on plant species to assess their impacts on forest ecosystems and biodiversity
• Outcome: establishing scientifically based evidence to inform policy/practices around linear land disturbances and activities
Natural Resources Canada
Ressources naturelles Canada
Canada


7
Reclamation monitoring
Lead Researcher: Brad Pinno
CEMA Long-term plot network across the mineable oil sands region
Focusing on plant community development between reclaimed and natural forests
Temporal trends in reclaimed forests by site type/ reclamation prescription
Used to identify substantial gaps between reclaimed and natural forests such as shrub development
Species Richness
Non-native cover
Forb cover
Shrub cover
Stand Age
CEMA
CUMULATIVE ENVIRONMENTAL MANAGEMENT ASSOCIATION
Natural Resources Canada
Ressources naturelles Canada
Canada


8
Nutrient cycling in jack pine forests across the oil sands region
Lead Researcher: Brad Pinno
N deposition impacts on natural forests
Impacts on foliar nutrition close to mine sites
Potential impact for future reclaimed forests
Foliar N:P ratio
y = 12.871x-0.102
R² = 0.846
Distance to mines (km)
Natural Resources Canada
Ressources naturelles Canada
Canada


9
Characterizing oil sands landscapes
Lead Researcher: Kara Webster
Characterizing pre-disturbance topography, geomorphology, soils and vegetation relationships
Athabasca Oil Sands
Elevation
Aspect
Slope
Curvature
Natural Resources Canada
Ressources naturelles Canada
Canada


10
Impact of Industrial Development on the Forest Carbon Budget in the Oil Sands Region
Lead Researcher: Cindy Shaw
Pilot Study Area
Data Layers (30m resolution)
Pilot Study Area
Fort McMurray
Edmonton
Saskatoon
Forest inventory and growth & yield
Anthropogenic disturbances
Natural disturbance
Land cover change
Parameters
CBM-CFS3
Carbon Budget Model of the Canadian Forest Sector
Landscape Scale Carbon Flux Indicators
NBP
Carbon (thousands t yr⁻¹)
Years
Natural Resources Canada
Ressources naturelles Canada
Canada

11

Other CFS research activities

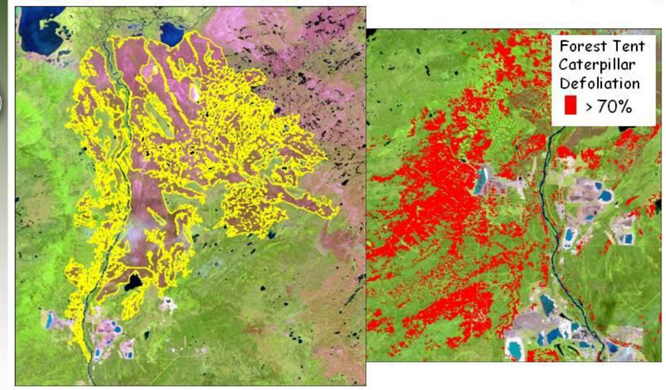
- Modelling forest stand and landscape trajectories under climate change scenarios
- Application of historical silvicultural research to current reclamation
- Assessing wildland fire risk to habitat and infrastructure
- Nursery science to improve seedling survival and growth
- Evaluating forest re-establishment using remote sensing

Natural Resources Canada | Ressources naturelles Canada | Canada

12

CFS EO Research not directly linked to the O/S but are relevant to the O/S

Mapping natural & anthropogenic disturbances, landscape change



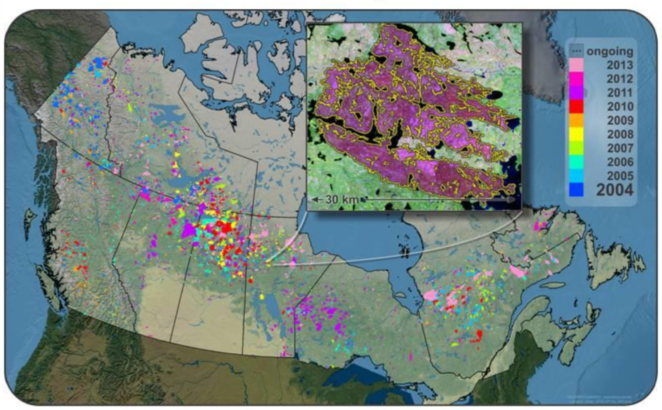
Richardson Fire, 2011

Natural Resources Canada | Ressources naturelles Canada | Canada

13

Mapping of Burned Areas: National Burned Area Composite (NBAC)

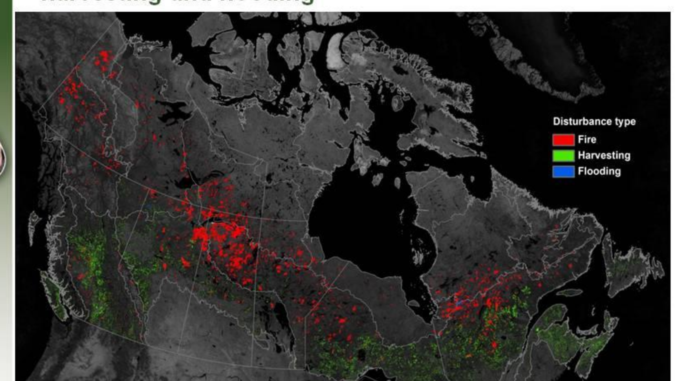
Lead: Ron Hall, Rob Skakun, Rob Landry



Natural Resources Canada | Ressources naturelles Canada | Canada

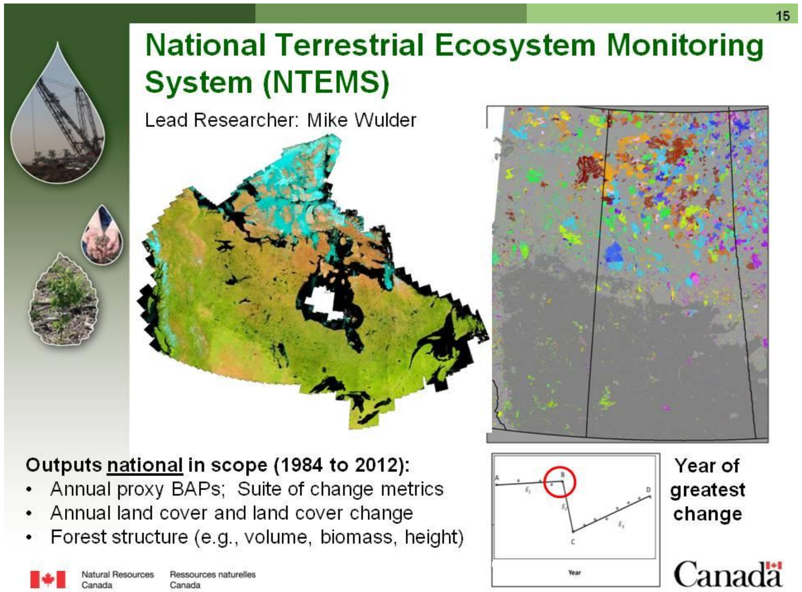
14

Cumulative 2000-2011 Map of yearly detection of fire, harvesting and flooding



Annual mapping of large forest disturbances across Canada's forests using 250 m MODIS imagery from 2000 to 2011
L. Guindon, P.Y. Bernier, A. Beaudoin, D. Pouliot, P. Villemaire, R.J. Hall, R. Latifovic, and R. St-Amant (published in CJFR 2014)

Natural Resources Canada | Ressources naturelles Canada | Canada


15
National Terrestrial Ecosystem Monitoring System (NTEMS)
Lead Researcher: Mike Wulder
Outputs national in scope (1984 to 2012):
• Annual proxy BAPs; Suite of change metrics
• Annual land cover and land cover change
• Forest structure (e.g., volume, biomass, height)
Year of greatest change
Natural Resources Canada
Ressources naturelles Canada
Canada

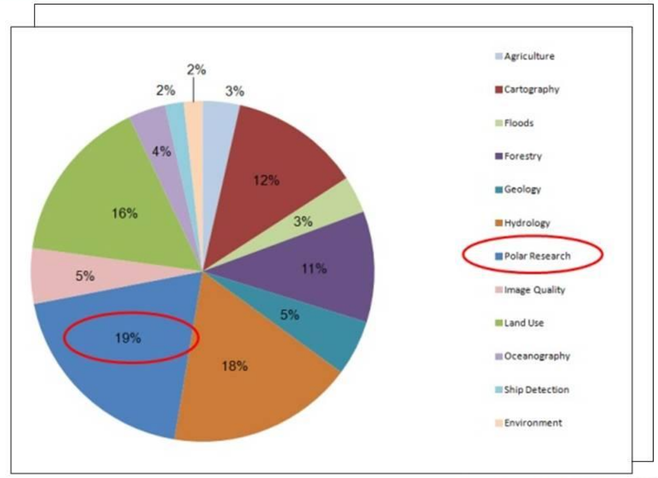
Future EO Missions, Bill Jeffries, LOOKNorth

LOOKNorth Objectives

- Identify needs and technology gaps for Northern resource development
- Develop opportunities for Canadian small-medium enterprises (SME) and researchers by creating the business case and co-funding technology validations as a precursor to long-term implementation;
- Guide research and development (R&D) and technology commercialization where gaps presently exist;
- Enable transfer of relevant technologies from international research to Canada; and,
- Facilitate information sharing amongst stakeholders in Northern development including industry.

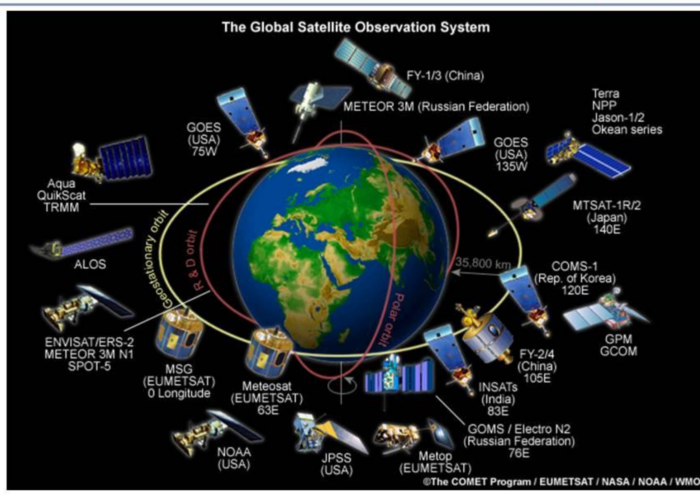
LOOKNorth

Application domains for Canada



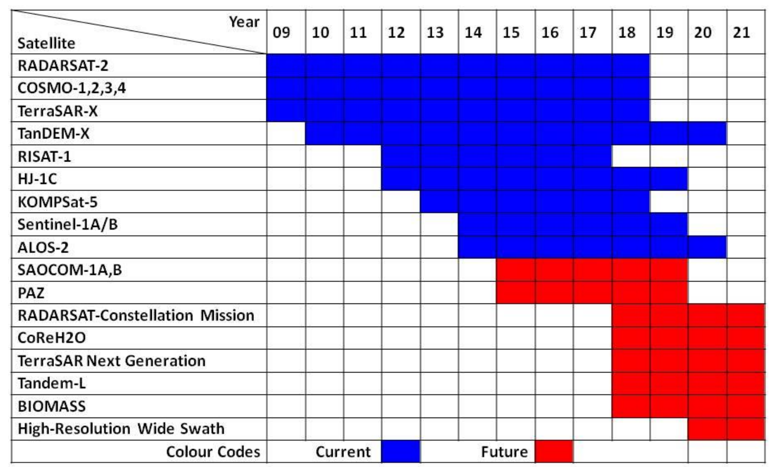
LOOKNorth

Crowded Space



LOOKNorth

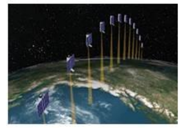
SAR Missions - Present & Future

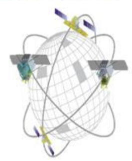


LOOKNorth

Trends in EO Missions (1)

- EO satellites – 360 to be launched in the next decade
  - *Number to double from one decade to the next*
  - *Forecast in 2010 was 267*
- Tightening national budgets favor the increase of lower-cost and more responsive missions
- EU, Canadian data policy mimicking US
  - *Free and open with near real time capability*
- New operators question the existing business model
  - *Skybox Imaging, UrtheCast*
  - *Planet Labs*
  - *Gazprom's SMOTR, dedicated to O&G operations*

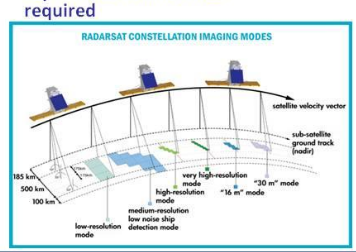


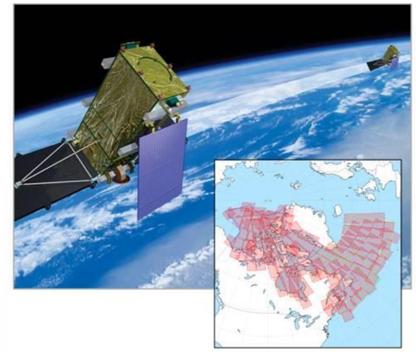


RADARSAT Constellation Mission (RCM)

The next generation SAR mission consisting of 3 spacecraft and providing quick revisit, very high collection capacity, and frequent coverage

- Daily Coverage of North America
- Polar Orbit: ~2 passes per hour over the arctic
- Rapid satellite tasking and very rapid data / information distribution to end customer
- Enhanced polarization capabilities as and when required





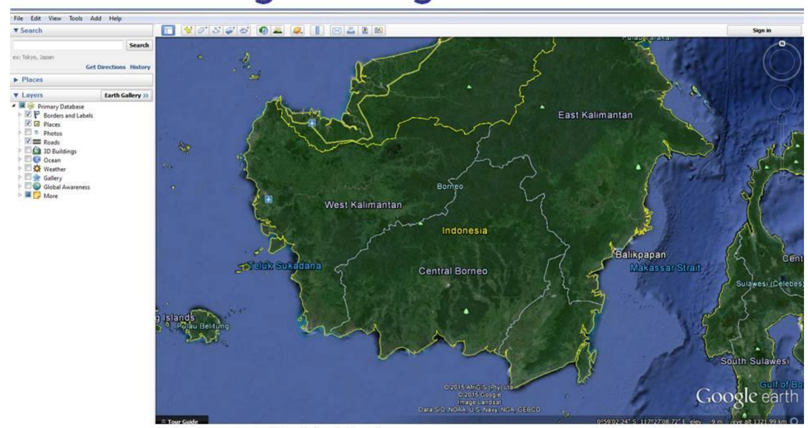
Example daily coverage over DND East Maritime AOI

Trends in EO Missions (2)

- Constellations
- High resolution
- Hyper spectral
- Multi polarization/multi frequency
- Complex data
- Cloud Computing

Sentinel 1-5

How Google Changed the EO World



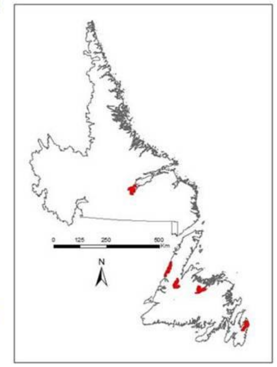
- Worldwide data
- Consumer level familiarity
- Easy exploitation

Issues for EO Missions

- Earth observation now emphasizes monitoring and change detection;
- To be effective missions must address:
  - 3 Rs - Regular, Reliable, Repeatable
  - Calibration
  - Formats
  - Mission planning
  - Ground support network
  - Data Delivery & Toolboxes
  - Cost
  - Cost Model ($/pixel)
  - Continuity of Mission
  - Interoperability of missions
  - Archives
  - Legislation restrictions

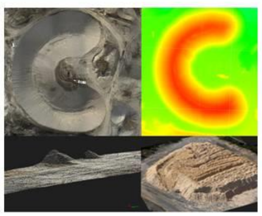
ESA Calibration/Validation Project

- Purpose is to use Canadian northern sites for advising ESA on calibration/validation methodologies and requirements for Sentinel-2 with respect to high latitude application requirements
- Two phased program:
  - *Summer 2015 – proof of concept (Ottawa region)*
  - *Summer 2016 – multiple validation sites (Northern Canada)*
- Current project team:
  - *LOOKNorth, NRC, CCRS*
  - *Others to support field aspects of the 2015 project (McGill University, Agriculture and Agrifood Canada, Jim Freemantle-atmospheric consultant)*
- ESA Investment:
  - *2015 - $500K (estimate $150K through LOOKNorth for internal support, McGill University)*
  - *2016 – tbd*

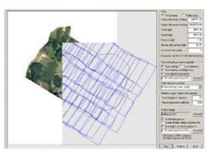


3/1/2015 Presentation Title

UAV Programs



UAV and remote sensing technologies for
- Pipeline monitoring
- Tailings pond emissions
- Tactical ship navigation



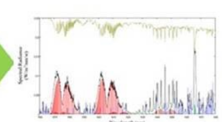
GHG Sat

In 2015 GHGSat, is planning to launch a nano-satellite capable of measuring air quality and greenhouse gas emissions from industrial sites.

Monitoring

Illustration of planned GHGSat orbit

Data Processing



Data Retrievals
Instrument measures absorption spectrum (upper curve) in targeted spectral bands (in this case, CO_2 and CH_4 in NIR)

Service Delivery

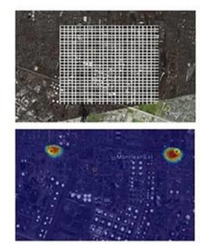
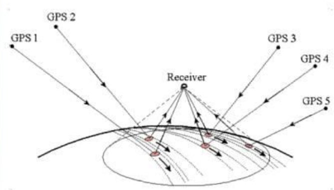


Illustration of GHGSat spatial resolution and data products for industrial emitter (e.g. Montreal East Refinery)

WatSat Project

Performing GNSS Reflectometry from a Cubesat to Measure Arctic Sea Ice Thickness



Other potential applications include soil moisture, snow water equivalent

LOOKNorth

If EO is to be useful for Policy and Regulatory Decision Making, it must be:

- Regular
- Reliable
- Repeatable

Courtesy of ING Robotics

LOOKNorth is a non-profit organization that identifies, evaluates, manages and accelerates the development of remote sensing technologies that support sustainable natural resource development to create wealth in Canada

LOOKNorth

Thank-you!

LOOKNorth

Email: bill.jefferies@looknorth.org
Website: www.looknorth.org
Phone: +1-613-698-9690

7.4 APPENDIX 4: PRE-WORKSHOP SURVE

We would like to gather information prior to the workshop on February 26-27 session, please take some time to fill in this questionnaire.

1. Please provide the following

Name	Organization

2. What sector are you representing?

Academia ● **Government ●** **Regulator ●** **Industry ●** **Consultant ●**

Please explain your role:

____

3. Will you be attending the workshop on February 26-27 in Edmonton? **Yes ●** **No** ●

a. If yes, would you participate in a Post-Workshop Survey? **Yes ●** **No** ●

4. Prior to this event:

a. Were you aware of the 2011 Earth Observation Workshop? **Yes ●** **No** ●

b. Did you attend the 2011 Earth Observation Workshop? **Yes ●** **No** ●

c. Have you read the 2011 EO Workshop Report? **Yes ●** **No** ●

d. Were you aware of any EO projects that the Canada Centre for Remote Sensing was conducting in Alberta? **Yes ●** **No** ●

e. Were/are you involved in any projects that originated from the 2011 Earth Observation Workshop? **Yes** • **No**

•

5. From your organization's perspective, please complete the following as it applies to your sector:

a. In the last 5 years, has there *been, or have you observed, an increase in the use of earth observation technologies in Alberta?* **Yes** • **No**

•

If yes, what do you believe are the top 5 drivers behind the increase in use?

#1	
#2	
#3	
#4	
#5	

b. What are the top 5 key questions / knowledge gaps related to EO that need to be addressed in the short-term (≤3 yrs)?

#1	
#2	
#3	
#4	
#5	

c. What are the top 5 key questions / knowledge gaps related to EO that need to be addressed in long-term (>3 yrs)?

#1	
#2	

#3	
#4	
#5	

d. What are the 3 additional key questions / knowledge gaps related to EO that you feel are important and need to be included. Please identify whether these would be short- or long-term.

#1		**Short ●** **Long ●**
#2		**Short ●** **Long ●**
#3		**Short ●** **Long ●**
#4		**Short ●** **Long ●**
#5		**Short ●** **Long ●**

e. What are the top 3 key things that are restricting and/or preventing the uptake of EO technologies?

#1	
#2	
#3	
#4	
#5	

6. Prior to this event:

a. Were you aware of the 2011 Earth Observation Workshop? **Yes ●** **No ●**

b. Did you attend the 2011 Earth Observation Workshop? **Yes ●** **No ●**

c. Were you aware of the NRCan-led research projects whose results will be reported within the workshop? **Yes ●** **No ●**

d. Are there projects that involve Earth Observation you are with that you feel would be of interest? **Yes** • **No**

•

If yes, please complete the following. Please add additional pages if necessary.

	Project Title:		
	Lead Organization:	**Name:**	
		E-mail:	
	Funding Organization(s):		
	Collaborator(s):		
	Abstract (150 words max)		

	Project Title:		
	Lead Organization:	**Name:**	
		E-mail:	
	Funding Organization(s):		
	Collaborator(s):		
	Abstract (150 words max)		

	Project Title:		
	Lead Organization:	**Name:**	
		E-mail:	
	Funding Organization(s):		
	Collaborator(s):		
	Abstract (150 words max)		

7. Please describe, from the perspective of your organization, your desired outcomes for this workshop:

____

____

____

____

____

____

8. General Comments:

a. Was there something important you feel that was missed in the questions above?

Comments:

____

____

____

7.5 APPENDIX 5: SURVEY RESULTS

Drivers for Increased Use of EO/RS

Survey respondents identified the following drivers for an increase in the use of earth observation technologies in Alberta:

- I think the technology is perceived to be more robust now and more and more people are aware of it.
- Increasing familiarity of people with the products.
- Acceptance of technology increasing at management/regulatory levels.
- Active interest in multi-disciplinary activities (industry/government/academic).
- Knowledge (increase of) – has become part of daily life.
- More awareness of the capability of these types of technologies (presentations, etc.).
- Improved knowledge of remote sensing applications.
- Knowledge & appreciation for what EO can do.
- Technology availability: capability of software.
- Improved ability to work with data as software becomes more accessible & functional.
- Availability of suitable low cost data.
- Easier access to data through online searches and download.
- Technology improvements (IT user side and EO sensor capabilities).
- Availability.
- Increased efficiency.
- Increased availability and decreased cost in acquisition and application of EO data.
- Realization that EO monitoring can reduce operational costs if implemented wisely.
- Increase funding opportunities for relevant remote sensing projects.
- New technologies/data sets have more use at the scale of our development.
- Major projects like oil sands that make the economics work for purchasing data.
- From my perspective there appears to be more companies selling the idea of using remote sensing.
- Products delivered in a way that non-experts can actually use them.

- Increasing information needs: e.g., Requirements for reporting to respond to legislated mandate and public perception regarding sustainability of Canada's forests. Growing importance of landscape scale changes.
- Need for efficiency in environmental regulatory framework as industrial / societal pressure on the land increases.
- Demonstrated value proposition associated with using the products.
- Growth of LiDAR.
- Landsat free data policy.
- Increasing use of softcopy photogrammetry.
- Increased awareness of cumulative impacts and challenges with assessment.
- Increased need to monitor.
- Oil sands monitoring.
- Reclamation monitoring.
- Environmental monitoring.
- Climate change assessment.
- Pollutants transport assessment.

Short-Term Questions / Knowledge Gaps

Respondents listed the following questions / knowledge gaps related to EO that need to be addressed in the short-term (≤3 yrs):

- Where are new anthropogenic disturbances occurring? How much, how fast?
- From a wildlife habitat perspective: When are disturbances no longer disturbances?
- What are the ecosystem service impacts from oil sands operations and what is the response from reclamation? Are these indicators of equivalent land capability?
- Oil sands impact on environment.
- Disturbance assessment.
- Land use/land cover changes (e.g., along pipelines).
- Linking EO and field data for land surface functional assessment; i.e. move beyond simple classification.
- Wetlands assessment.

- Vegetation inventory, health assessment.
- Linking EO to resource inventory such as forest, minerals
- Linking EO to monitoring policy such as wetland, water and land reclamation.
- What are the monitoring requirements (e.g., metric, scale, resolution?) and how will the information be used?
- Policy and decision making under uncertainty and partial knowledge provided by remote sensing.
- Accuracy resolution compromises for specific applications.
- Temporal consistency/stability of methods for monitoring.
- Evaluation and testing of new algorithms to understand advantages/limitations.
- How the data can be applied at an operational level – to what purpose.
- Better understanding of how to use/interpret the data – training?
- Linking field data to EO.
- Increase quantitative and sensitivity relationships to ground parameters.
- Better define ground parameters from a “view-from-above” perspective.
- Acceptability as a replacement for on-site or ground-level data gathering.
- I think we need to give greater emphasis on identifying the needs of the customer, so these needs can in turn drive what we spend our R&D $s on.
- Decision makers need to be convinced of merits & then resource the users / managers to implement.
- Return on investment. Cost to acquire versus applications.
- Data storage/access – EO data assets currently at risk of being lost, duplicated, under-utilized if not properly managed.
- Data management not properly funded/resourced.
- Processing automation for big data.
- Skills required to turn data into actionable information is still lacking in many sectors.

Long-Term Questions / Knowledge Gaps

Respondents identified the following questions / knowledge gaps related to EO that need to be addressed in the long-term (>3 yrs):

- To have any kind of significant impact, I think it would help to identify a couple of key challenges that we want to solve in the next 5 years. These challenges should be audacious, but doable.
- What are the operational requirements currently challenging industry/government that EO could serve?
- Defining the applicability of EO technology?
- Needs coordination among user groups.
- Technology transfer specialist to liaise between users and producers of remote sensing data.
- Development of automation / push button EO routines so it is no longer the domain of experts.
- What can local sites do to on the ground to better exploit/integrate this data source?
- Increased availability in spectral, spatial, radiometric quality is coming in the next 5 to 10 years.
- Continuity and mission failure alternatives.
- What are the indicators of reclamation success from field and landscape perspectives and how does that change at different yearly time intervals following reclamation?
- To what extent can EO contribute to measureable indicators of reclamation success and how does that vary between surface mining and in-situ operations?
- Are those disturbed sites that are no longer in use recovering?
- Recovery monitoring.
- Ecosystem disturbance monitoring.
- Assessment of cumulative impacts (land, water).
- Water quality (eutrophication, suspended sediments, organic matter, productivity).
- Snow/ ice cover, accumulation, distribution.
- What can modelling do (such as radiative transfer models, spectral detection models, water quality models) to exploit these data sources to direct managers in monitoring and risk assessment.

- Effective methods for data scaling.
- Data reduction methods and tradeoffs.
- Online tools for EO information extraction to support gaps above.
- Online comprehensive EO data access; one stop shop accessible to all.
- Active RS (LiDAR and radar) skills need to be taught in mainstream curriculum. Currently this is very specialized and even grads in RS programs often do not access these skill sets. Same could be said for hyperspectral but commercial / operational uses are an order of magnitude smaller for HS than active RS so need is much reduced.

Additional Key Questions / Knowledge Gaps

Respondents noted the following additional key questions / knowledge gaps to be addressed by EO/RS:

- At what data quality / spectral resolution can stresses in vegetation / reduced water quality be detected from airborne/satellite systems (not identifying the cause of the stress, just that the target area is more stressed than previous years or than the surroundings.
- How can reclamation success be assessed using RS? (short- and long-term need).
- How does this measure change at different stages of vegetation response/succession and how does that look like from RS? (long-term need).
- (Wildlife) Habitat monitoring.
- Mine characterization and monitoring.
- Surface water run-off monitoring.
- Need to develop provincial / national protocols for EO use in hazard assessment, planning and risk mitigation (floods, fires, slope stability, severe weather).
- Need to develop uses of EO in support of alternative energies (wind, hydro, solar, biomass).
- Need to develop EO uses in energy conservation (e.g. bldg. / community efficiency – thermal).
- Municipalities often lack capability in EO, yet EO is a great tool to aid in urban planning, to monitor development or assess local risks. Provincial (federal) governments could support municipal development by providing online data and processing resources that can be used at municipal level.

Impediments to Uptake of EO/RS

When asked what were the top 3 key things that are restricting and/or preventing the uptake of EO technologies, respondents said:

- There is an overwhelming amount of information and people flogging it.
- Highly qualified personnel with appropriate knowledge and training.
- Lack of skilled HR & the high skill level requirement to enter EO field.
- Education. Can we get a minimal EO certification requirement to Environmental Regulators and Monitors.
- Universities and colleges are usually way behind industry in terms of technology knowledge and use so students rarely get access to cutting edge aerial or satellite EO data and procedures.
- Lack of pilot studies which go beyond the academic lab for the purposes of enterprise deployment.
- Not operational; still in "research phase".
- In recent years, Alberta has been fiscally successful by unsustainably drawing on its natural capital. This emphasis on 'easy' money has, in some cases, proven a detriment to innovation (e.g., many companies are generating handsome profits by maintaining the status quo so, in some sectors, there might be little need to adapt or innovate). Conversely, the economic surplus this has generated has led to the support of much R&D and the collection / archival of data at an unprecedented rate compared to other provinces in Canada. Consequently, there appears to be more innovation on exploration and resource inventory / management, while innovation aimed at recognition and quantification of ecosystem services may be some way behind.
- While we need to fund academic research to advance the state of the art, there needs to be a greater focus on moving such research into enterprise level deployment by developing value proposition, marketing the product(s) to get support of customers, and then making it operational.
- Some of the EO layers products are hard for non-experts to use. As an example, RADAR data is very hard for non-experts to understand or use. Are there ways to make it easier to use?
- Ease of use – once you have the data how do you use/interpret it?
- What do EO results mean in terms of applied land management issues?

- Familiarity with data.
- Data access.
- Handling of large datasets.
- Uncertainty in datasets.
- Knowledge of datasets and limitations.
- Don't fully understand what it can be used for.
- Uncertainty over what it can do.
- Knowledge of what can be achieved using EO data and technology.
- Lack of desire to change existing process.
- Familiar 'standard' (old) procedures often prevent users from exploring new procedures that may be more cost effective – especially if users are not equipped or trained to take advantage of new EO techniques.
- Translating EO observations to meaningful indicators that can support land management decisions.
- Relating ground observations to results of EO observations.
- Field data standards / availability. Minimal water level monitoring, webcam monitoring of vegetation/water sites, AEROCan sun photometer stations. All are minimal cost, but certifying a company to deploy/maintain them and requiring companies to see them deployed and maintained, and seeing a regulator receive/disseminate such data would have quick tie-ins to EO initiatives (existing and projected).
- Cost to acquire data source.
- Cost of data is perceived to be a barrier in some fields.
- Cost.
- Cost benefit ratio.

Desired Workshop Outcomes

Respondents indicated the following desired outcomes for the Workshop:

- Learn more about issues in Alberta related to EO utilization and potential new applications of remote sensing methods.
- Learn about user needs and communicate how remote sensing can contribute to environmental monitoring.

- A recognition through discussion of the potential contributions and limitations that EO and Remote Sensing brings as a new and complimentary data source.
- More funding for EO / web GIS / cloud dissemination services workflow development. Both to industry and academia.
- The field of earth observation is moving ahead quite rapidly – which is good. However, that makes it hard to keep track of both the latest and greatest advances, and also makes it difficult to ensure that one is pursuing approaches which are robust and will stand the test of time. Thus, I hope what comes out of this workshop is some consensus at a strategic level on how we in Alberta should move forward, where we should invest, what technologies we should develop, and also which technologies we should simply buy "off the shelf". I hope that we see the beginning of Programs, not simply collections of projects.
- Meet with Alberta stakeholders and showcase MARA and ASL projects and capabilities in general.
- Establish partnerships for developing or entering EO research proposals/projects in the Athabasca Oil Sands Region.
- Industry and universities to work more closely in tackling EO challenges. This already happens but there needs to be better mechanisms to facilitate closer integration; e.g., more opportunity for student interns or industry / university research chairs.
- Greater recognition and support for universities to play a key role in transferring EO skills and capacity to current and future personnel in the EO field.
- A well-resourced university lab in Alberta dedicated to aerial EO with emphasis on active sensing (LiDAR and radar); i.e., a lab that manages its own aerial logistics in support of public and industry sector applied R&D.
- Recognition that universities can only do this in so far as they are resourced to educate and research using cutting edge technologies. Old or demo datasets and canned labs don't cut it in this fast moving field.
- Promote awareness of CFS initiatives in the Athabasca Oil Sands Region through informal exchanges in the breaks (suggestion: make room for networking opportunities).

General Comments

Respondents were given the opportunity to provide additional observations not addressed in the main survey questions.

- A paragraph or two providing context for this survey and workshop would have been helpful.
- Remote sensing is often not sufficient for regulation or monitoring on its own. It needs to be integrated into a larger framework where it serves to identify where field or other resources should be allocated to investigate regulatory or environmental problems.
- One of the most important issues I find while trying to help find a practical use for remote sensing in our company is sorting through all the academics to find and do something useful. What I am looking for is information about best practices and recommended workflows for certain applications. I find the academic nature of the technology is constantly giving industry too much information and jargon. The important thing to understand is industry does not have a lot of remote sensing specialists in house and therefore the people making a lot of the decisions have no idea what all the chatter is about. Some find themselves trying to sort through the literature on their own but this can almost be more dangerous.
  What industry needs is some good information aimed at simple questions such as "vegetation change" and come up with some ball park sensors and prices and examples to show people exactly what to expect. Same goes for surface water. Rather than inundating people with the details of SAR and all the combinations, it would be nice to start with a simple report about the costs and results and accuracy of simply mapping surface water. Then get into the details of going beyond the surface. Repeatability is a big one for me. I think it is easy to say we can compare year over year but normalizing images for different vegetation stages and atmospheric conditions can be tricky and it would be good to have some practical information about the potential struggles with this. One concern I have with the technology is it seems people would like to jump on the Hyperspectral bandwagon however I am not exactly sure how necessary it is to practically answer questions we are needing answers too and I have concerns we will end up with hundreds of bands of information when 7 would have been fine. Of course scale is always an issue however when you ask people with no experience in this and perhaps a background in reclamation what scale they need the tendency is to say "the best" however yet again we are putting that onto people who actually might not understand the difference between 10 cm and 10 m when it comes to results such as a change in an indice. Of course the other piece of information we need is what the regulators will accept and translating the requirements into products from remote sensing. I have been working in industry for 10 years and have attempted to get remote sensing used more and done many presentations and communication sessions with people on what RS can do and applications and it is difficult to get buy in. I have moved

careers to something else now but I still get called in regularly when a company has come in selling some sort of RS solution.
So that's quite a bit of ranting but I guess in my opinion what needs to happen is the information needs to be made practical with simple proven concepts and ball park costs to make it viable and something decision makers would like to put money into. I look to EO to help industry with best practices and to curb and help industry sort through the mass of information and people selling their services. I don't know if this is not realistic but from my perspective it would be useful.
From my experience industry does not want to be part of the leading edge in this economy but is looking for practical, logistical, cost effective solutions to common reclamation and mapping solutions. Once those become more common place and people start to see the benefits, then the new and exciting science will be easier to fund with industry dollars.

- Questions seemed focused on EO rather than on the application/info need. Think more of: What are the knowledge gaps that EO can help resolve?

Additional EO/RS Projects

Survey respondents provided the following information on current projects that they are working on that may be of interest to the broader EO/RS community.

Project Title:	Impact of Industrial Development in a Part of the Oil Sands Region (1984 – 2012): A Pilot Study	
Lead Organization:	**Name:**	Canadian Forest Service
	E-mail:	cshaw@nrcan.gc.ca
Funding Organization(s):	Canadian Forest Service	
Collaborator(s):	Rasim Latifovic, Darren Pouliot (Canadian Centre for Remote Sensing) Bin Xu, Amanda Schoonmaker (Boreal Research Institute) Shari Hayne (Environment Canada)	
Abstract	Regulators and policy makers seek to understand the cumulative effects of industrial activities at the landscape scale in the Oil Sands region of Alberta. This pilot project aims at assessing the impact of industrial development on the forest carbon budget in a part of the Athabasca Oil	

	Sands region. The project is in the early stages of development. We are using Landsat-derived land cover and disturbance times-series to generate inputs to the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) to create a spatially-explicit (30 m resolution) representation of annual carbon flux indicators over the period from 1984 to 2012. Spatial forest inventory for the pilot are being provided by ALPAC. Collaborators from the Boreal Research Institute and Environment Canada are providing knowledge to define disturbance types and impacts for the modeling framework.

<table>
<tr><td>Project Title:</td><td colspan="2">Multi-sensor Assessment of Reclaimed Areas (MARA)</td></tr>
<tr><td rowspan="2">Lead Organization:</td><td>Name:</td><td>ASL Environmental Sciences</td></tr>
<tr><td>E-mail:</td><td>eloos@aslenv.com</td></tr>
<tr><td>Funding Organization(s):</td><td colspan="2">Canadian Space Agency</td></tr>
<tr><td>Collaborator(s):</td><td colspan="2">University of Lethbridge, Polster Environmental Services</td></tr>
<tr><td>Abstract</td><td colspan="2">We present methods to help monitor reclamation at the very large number of small remote disturbances, but to also help better characterize large sites like mines that cannot be adequately sampled. Our approach involves:
• providing new information by combining measures of plant pigments and vegetation structure not now in use in the reclamation context,
○ being applicable at distant, isolated sites and across wide areas, greatly extending the monitoring effort possible,
○ regular monitoring at regular intervals across wide areas possible, and
○ being available at relatively low cost.
This will not replace existing information sources, but greatly expand on them by providing continuous maps of new and different information not currently available or practically impossible to acquire.</td></tr>
</table>

	Detailed ground knowledge of local and regional plant ecology will still be required but experience shows that the required level of effort may be less when remote sensing data are added. The objectives of the project involve: 1. assessment of optical and RADAR remote sensing techniques for characterization of early stage reclamation of disturbed areas; 2. comparison and integration of information gained from optical and RADAR data analyses for different sites; 3. development of strategies for remote sensing-based reclamation monitoring, based on site properties (location, size, vegetation community). As such these techniques will have potential for operational, long-term and widespread utilization in both industry and government agencies.

Project Title:	Monitoring Procedure for Reclamation in Alberta (MOPRA) (2011-2014)	
Lead Organization:	Name:	University of Lethbridge, Alberta Terrestrial Imaging Center (ATIC)
	E-mail:	Karl.staenz@imaingcenter.ca; nadia.rochdi@uleth.ca
Funding Organization(s):	TECTERRA, Environment and Sustainable Resource Development (ESRD), Oil Sands Research and Information Network (OSRIN), and Alberta Innovates – Energy and Environment Solutions	
Collaborator(s):	Alberta Energy Regulator (AER)	
Abstract	The scope of the *Monitoring Procedure for Reclamation in Alberta (MOPRA)* project was to develop a geomatics-based monitoring system to support the Government of Alberta's efforts for monitoring reclamation success. This software will support the decision making process to screen almost all oil and gas wellsites and prioritize those that require immediate intervention allowing an efficient allocation of government resources. Using remote sensing technologies, the following three types of information were pursued: • Baseline maps of the pre-disturbance condition of sites,	

	• Vegetation condition related to species, and canopy structure, and vegetation productivity, and • Temporal change of land condition in reclaimed areas. The project provided the opportunity to assess remote sensing technologies including optical multispectral, hyperspectral and LiDAR, for monitoring vegetation condition in reclaimed wellsites and mine areas. Three study areas were assessed, sampling both wellsites and a coal mine areas, which cover different landscapes including forested, and agricultural areas. A set of land products were developed within this project, including baseline land cover, land-cover change, canopy height, fractional cover, tree species and canopy leaf area index (LAI). In addition, multi-year profiles of vegetation index data were examined to assess vegetation regrowth in wellsites in comparison to undisturbed reference areas. Canopy structure attributes, derived from LiDAR data such as canopy height and fractional cover, were also examined to assess differences in vegetation structure between reclaimed wellsites and regenerated burnt/clear-cut areas. In addition, a reclamation monitoring system, composed of a *Remote Sensing Data Processing Toolbox* and *A Stand-Alone Assessment Tool,* was developed. Results of the work are available: Rochdi, N., J. Zhang, K. Staenz, X. Yang, D. Rolfson, J. Banting, C. King and R. Doherty, 2014. Monitoring Procedures for Wellsite, In-Situ Oil Sands and Coal Mine Reclamation in Alberta – December 2014 Update. OSRIN Report No. TR-47. 167 pp. http://hdl.handle.net/10402/era.38742 The land products derived from remote sensing data provide information related to some of the landscape and vegetation assessment parameters adopted within the 2010 reclamation criteria document (Alberta Environment and Sustainable Resource Development 2013), such as bare areas, vegetation species, land-use change, canopy height, percent canopy cover and vegetation quantity/quality. The achievements of the MOPRA project have highlighted the benefits that remote sensing technologies can provide in support of reclamation monitoring efforts. Having access to a synoptic view of reclaimed lands at the landscape and regional level is of value for assessing land-use cumulative effects and making decisions in line with an integrated

	resource management system. While the MOPRA outcomes have shown promise in this direction, there is still a need to test and validate the information extraction approaches adopted as well as the monitoring system developed on various landscapes, such as wetlands, rangelands, agriculture and forested areas. Although, this project has focused on reclaimed wellsites and reclaimed areas within coal mines, the work undertaken can be applicable to natural areas as well as reclaimed lands that have been disturbed by other activities, such as transportation corridors, wind energy, sand and gravel operations, oil sands mines as well as pipelines. To move towards an integration of remote sensing technologies as an operational monitoring tool, the MOPRA monitoring system would require further testing, involving consultants, industry (e.g., oil and gas, coal mine, wind energy farms), and monitoring organizations (Alberta Environmental Monitoring, Evaluation and Reporting Agency – AEMERA) and regulatory agencies (e.g., AER, ESRD).

Project Title:	Assessment of Reclaimed Areas near Cold Lake Using Hyperspectral Data	
Lead Organization:	Name:	Nadia Rochdi, Alberta Terrestrial Imaging Centre - University of Lethbridge
	E-mail:	nadia.rochdi@uleth.ca
Funding Organization(s):	Oil Sands Research and Information Network Alberta Innovates – Energy and Environment Solutions	
Collaborator(s):	ESRD	
Abstract	The project investigates the use of airborne hyperspectral data for mapping tree species in reclaimed well sites. The AISA airborne hyperspectral, the Alberta Vegetation Inventory as well as ground-reference data collected in the Cold Lake study area are used to conduct this assessment.	

Project Title:	Geospatial Technologies for Monitoring Vegetation Recovery on Human Disturbance Features in Alberta's Boreal Forest	
Lead Organization:	Name:	Greg McDermid, University of Calgary
	E-mail:	mcdermid@ucalgary.ca
Funding Organization(s):	NSERC CRD (Al-Pac, Cenovus, ConocoPhillips industry partners)	
Collaborator(s):	Guillermo Castilla, Canadian Forest Service Steve Liang, University of Calgary Erin Bayne, University of Alberta Scott Nielsen, University of Alberta Steven Franklin, Trent University	
Abstract	The goal of this research program is to use cutting-edge geospatial technologies and advanced modelling techniques to aid in the process of measuring, monitoring, and predicting the recovery of vegetation on non-permanent (i.e., to-be reclaimed) human-footprint features in the Boreal forest. Within this broad goal, our project will address five specific research objectives: (i) mapping human-footprint features with advanced remote-sensing devices, (ii) assigning descriptive attributes to human-footprint features that can be tracked through time in a monitoring program, (iii) developing low-cost ground-senor networks that can track the physical condition and human/animal use of human-footprint features, (iv) developing statistical models that can predict the rate of vegetation recovery in human-footprint features across the boreal forest, and (v) delivering a rapid-verification protocol designed to assess the reclamation status of human-disturbed areas. The work is designed to help resource-extraction companies and government regulators reduce the impact of industrial development on boreal ecosystems, and is well-integrated with other complementary research projects currently planned or underway.	

Project Title:	Hyperspectral/LiDAR Vegetation Environmental Indicators

Lead Organization:	Name:	H. Peter White
	E-mail:	HPWhite@NRCan.gc.ca
Funding Organization(s):	TBD	
Collaborator(s):	TBD	
Abstract	The effect of stress or vigour on vegetation can be expressed in a variety of ways, from decreased leaf volume, increased clumping of branches, to shifts in spectral absorption features. A combined hyperspectral/LiDAR data set can provide the data required to exploit the potential of detecting these effects through modelling (such as radiative transfer models such as the CCRS developed proFLAIR model).	

Project Title:	Remote Sensing of Plant Phenophases and Pulsed Ecosystem Dynamics for Wildlife Ecological Applications	
Lead Organization:	Name:	Greg McDermid, University of Calgary
	E-mail:	mcdermid@ucalgary.ca
Funding Organization(s):	NSERC	
Collaborator(s):		
Abstract	This research is designed to generate the tools and processing strategies necessary to help scientists observe phenological patterns – periodically recurrent events such as spring budburst, berry emergence, or autumn senescence - over very large areas using regular observations from earth-orbiting satellites. Specific challenges to be addressed include (i) determining the cumulative temperature thresholds beyond which key wildlife food plants reach various stages of phenological development;	

	(ii) establishing field sites to observe the progression of annual plant development cycles on the ground; (iii) developing the digital-image-processing strategies that will allow technicians to extract phenological measurements from noisy satellite data; (iv) calibrating and validating statistical models that enable us to predict the phenology of specific plants underneath the forest canopy using remote sensing; and (v) investigating how wildlife such as grizzly bear, elk, and caribou respond to changing patterns of food plant distribution throughout the growing season. The results of this work will contribute to management and conservation of wildlife, and is intended to assist anyone dealing with remote sensing technology in an ecological context.

Project Title:	Peace River Environmental Monitoring Super Site (PR-EMSS)	
Lead Organization:	Name:	Arturo Sanchez-Azofeifa
	E-mail:	Arturo.sanchez@ualberta.ca
Funding Organization(s):	Canada Foundation for Innovation	
Collaborator(s):	Petr Musilek, Mike MacGregor, Martin Sharp, Jim Witt (DMI)	
Abstract	The PR-EMSS is a state of the art carbon-flux site where intensive near surface, airborne, and space borne remote sensing studies are conducted in Alberta. The site consist of over 200 wireless sensor network nodes and 600 sensors distributed over 3 km^2. The site conducts intensive research on ground LiDAR systems and also on bioacoustics research. The site will be a forthcoming Sentinel 2 calibration/validation site.	

Project Title:	Remote Sensing for Biodiversity Monitoring	
Lead Organization:	Name:	Greg McDermid, University of Calgary
	E-mail:	mcdermid@ucalgary.ca

Funding Organization(s):	Alberta Biodiversity Monitoring Institute
Collaborator(s):	
Abstract	Use of remote sensing for various issues related to landscape and biodiversity monitoring, including rangeland condition assessment, human footprint mapping, time-series remote-sensing analysis, and Unmanned Aerial Vehicles.

Project Title:	SAR / Hyperspectral Wetlands Modelling	
Lead Organization:	Name:	H. Peter White
	E-mail:	HPWhite@NRCan.gc.ca
Funding Organization(s):	TBD	
Collaborator(s):	TBD	
Abstract	While SAR is one leading technology being researched to characterize indicators of subsurface water levels in peatlands and wetlands, hyperspectral provides the potential to delineate the vegetation indicators related to these land cover types. When vegetation cover characteristics are not found to align with the subsurface water, then this provides the prospect to highlight regions undergoing a transition to changing hydrology (either natural or anthropogenic).	

Project Title:	Hyperspectral Water Quality Indicators	
Lead Organization:	Name:	H. Peter White
	E-mail:	HPWhite@NRCan.gc.ca
Funding Organization(s):	TBD	
Collaborator(s):	TBD	

Abstract	The use of spectral reflectance from water bodies is well understood for large deep water (oceans). Science technology innovation in hyperspectral bathymetry is just now advancing in the area of water quality and shallow fresh water bodies. Measured spectral reflectance becomes a function of both water column penetration (which is itself a function of wavelength observed and water clarity) and the spectral reflectance characteristics of the lake/pond bottom (related to sediment composition). Implications on the monitoring of natural water bodies and tailing ponds can be evaluated.

Project Title:	A Remote Sensing-Based Operational Water Monitoring Portal for Alberta	
Lead Organization:	**Name:**	Dr. Chris Hopkinson, University of Lethbridge, Alberta Terrestrial Imaging Center (ATIC)
	E-mail:	c.hopkinson@uleth.ca
Funding Organization(s):	Environment and Sustainable Resource Development (AESRD) Innovation and Advanced Education (AIAE) University of Lethbridge	
Collaborator(s):	Keplar-Space Natural Resources Canada - Canada Center for Mapping and Earth Observation PCI Geomatics CYBERA Optech International Granduke Geomatics Airborne Imaging	
Abstract	The remote sensing-based water monitoring portal will provide a web-GIS framework for integration of LiDAR and radar datasets to support headwater snowpack volumetric sampling as well as lowland and floodplain water inundation mapping. During winter and spring time, snowpack depth and distribution can be sampled using repeat LiDAR digital elevation model data over headwater locations to provide an inventory of snow volumes. During spring and summer, repeat synthetic	

	aperture radar (SAR) satellite imagery will be collected and merged with the provincial LiDAR DEM database available throughout Alberta to monitor water level, extent and volume. This is an academic, private and public sector partnership to support Alberta water monitoring priorities.

Project Title:	Surface Reflectance Re-Processing	
Lead Organization:	**Name:**	H. Peter White
	E-mail:	HPWhite@NRCan.gc.ca
Funding Organization(s):	TBD	
Collaborator(s):	TBD	
Abstract	CCRS has developed algorithms to perform a higher level of data quality assessment and atmospheric correction than currently exists commercially. The existing suite of optical airborne and optical satellite data could be reprocessed to better define sensor artefact impacts and to perform atmospheric correction to provide improved at-surface reflectance data products.	

Project Title:	Space borne Sensor Simulations	
Lead Organization:	Name:	H. Peter White
	E-mail:	HPWhite@NRCan.gc.ca
Funding	TBD	

Organization(s):	
Collaborator(s):	TBD
Abstract	Through advancing research in hyperspectral data quality, the CCRS developed ISDASv2 system now has the capacity to simulate existing and upcoming sensors. Determining the sensitivity of environmental indicators to each satellite system will prepare both managers and regulators to develop confidence in the application of such data sources on the reporting of these indicators. This also promotes a quantitative understanding of how these indicators evolve as old systems get transitioned to new systems (data continuity).

Project Title:	Wet Area Mapping (WAM)	
Lead Organization:	Name:	University of New Brunswick, Alberta Environment and Sustainable Resource Development
	E-mail:	ESRD.WetAreasMapping@gov.ab.ca
Funding Organization(s):	Alberta Environment and Sustainable Resource Development	
Collaborator(s):		
Abstract	Since 2008 the Government of Alberta has acquired in excess of 30 million hectares of airborne lidar data, largely across the province's forested landscapes, and the dataset continues to grow. Initially driven by operational planning needs resulting from the mountain pine beetle epidemic, the data have proven valuable well beyond the forestry sector. To date the largest user of the province's lidar holdings has been the wet areas mapping program. The initiative, recently honoured for innovation and environmental excellence by both the Alberta Science and Technology Foundation and the Alberta Emerald Foundation, is lead by Alberta Environment and Sustainable Resource Development in partnership with researchers at the University of New Brunswick. Spatially explicit datasets predict the location of: (1) small water bodies, such as ephemeral stream channels, often as narrow as 10 cm in width; and (2) wet, saturated soils, which may not be known to resource planners, but which may be especially sensitive to disturbance. Significant efforts are underway to explore additional opportunities for	

	lidar to influence public policy and operational practices within both the forestry and energy sectors. For example, in parallel to the wet areas mapping initiative, separate software tools for predicting optimal trail layout and spill routing are under development. Despite Alberta's success in lidar acquisition and tool development, significant challenges remain. Opportunities for further innovation are thought to be significant.

7.6 APPENDIX 6: GLOSSARY OF TERMS AND ACRONYMS USED IN EARTH OBSERVATION AND REMOTE SENSING

A6.1 Terms

Active Remote Sensing

A system that emits its own radiation from the active remote sensors and detects back-scattered radiation from the target.

Aggregator

A part of network which aggregates the data from other nodes and sends the collected data to the end user.

Airborne Sensing

Remote sensing from an airplane.

Atmospheric Correction

Process of correcting the at-sensor radiance data to remove the atmosphere contribution to the signal and derive the surface reflectance.

Backscattering

Energy, when hitting a target, can be scattered in many directions. The part of the energy that is scattered back in the exact direction where it came from, is "backscattered".

C-Band

The 4 to 8 GHz range of the radio spectrum.

Change-Detection Images

A difference image prepared by digitally comparing images acquired at different times. The gray tones or colors of each pixel record the amount of difference between the corresponding pixels of the original images.

Classification

When image pixels are the same colour, or nearly the same colour, an image "classification" computer program can recognize this and group such pixels together. Such a grouping is called a "class" and the process of doing the grouping is called "classification". The remote sensing researcher then has the challenge of identifying just what each "class" represents in the real environment (pine trees? pavement? shallow water? dry grass?).

Classifier

A technique based on pattern recognition principles used in remote sensing to classify the image data into a number of categorical classes (e.g., land-cover, land-use, species …).

Coherence

The degree to which surfaces are identical, measured on a scale of 0 (low) to 1 (high).

Composite Image

We can make a "composite" image by selecting the most appropriate parts of other images. For instance, we could take only the cloud-free parts of many images to make a "composite" image of all of Canada showing no clouds at all. It would not be a realistic scene, since we always have some clouds, but it would show all of Canada without allowing cloud cover to mask parts of it.

Distributed Data Collection

Act of collecting data from sensor nodes in a distributed fashion.

Earth Observation

Looking down at the Earth from aircraft and satellites using various sensors which make images that are afterwards used to study what is happening on or near the Earth's surface.

Geomatics

The branch of science which addresses the collection, analysis, and interpretation of spatial data relating to the earth's surface.

Geometric Correction/Geo-rectification/Ortho-rectification

Image data acquired by airborne and spaceborne sensors containing geometric errors due to the Earth's curvature and terrain relief. These errors can be corrected by matching coordinates of physical features in the image to the geographic coordinates of these features in an existing map or collected using global positioning system (GPS).

Geospatial

Relating to or denoting data that is associated with a particular location.

Ground Track

The path on the earth's surface below an aircraft, or satellite.

Ground Truthing

Remote sensing analysts must be sure that their image analysis is accurate. This is done by field where they go out to the actual places shown in the images and confirm that what they think they see on the image is actually true.

Heterogeneous Network

A network that includes different devices and computers and connecting these devices with different operating systems.

Hyperspectral Image

A remote sensing image acquired in narrow contiguous (using a large number) bands (> 20) across the electromagnetic spectrum.

Image Registration

The process of matching two different remote sensing images pixel by pixel.

Inclination Angle

The angle between the equatorial plane and the orbital plane.

Interferogram

SAR interferometry makes use of the phase shift information by subtracting the phase value from one SAR data acquisition from that of another, for the same point on the ground. The resulting phase difference, represented by interferometric fringes, is directly related to topographic height. The result is an interferogram.

L-Band

The 1 to 2 GHz range of the radio spectrum.

Limb Geometry

In this geometry light scattered from the Earth's edge is analysed by sampling the atmosphere tangentially.

Laser Return

A portion of the laser light energy which is sent back towards the LiDAR system after having an interaction with a given target (e.g., top of tree, ground).

Mosaic

A big image made by combining smaller images. For example, to get an image of a whole province in Canada, we must combine many images. This is tricky because the images were probably taken at different times and possibly in different seasons so they could look different in colour or brightness.

Multi-hop Network

A network consisting of multiple segments separated by routers; every time you cross a router it's a 'hop' from one network segment to another. *Multi-hop* would indicate you have crossed several routers to reach your destination.

Multispectral Image

A remote sensing image acquired in a small number of spectral bands ranging between 3 and 20.

Nadir Geometry

Refers to atmospheric volume observations directly beneath the instrument (i.e., the spacecraft).

Node

In networks system a node is a point of each device that communicates each other.

Occultation

A system of observing the light of the rising or setting sun, moon, or stars through the atmosphere at different tangent altitudes.

Passive Remote Sensing

A system that measures the reflected and emitted electromagnetic radiation that is coming from naturally available passive sensors (e.g., the sun), after it has passed through the atmosphere.

Pixel

The smallest unit in a remote sensing image.

Platform

This is what carries a sensor – usually a satellite or an airplane. But a remote sensing platform could also be a hot-air balloon, a tall tower, etc.

Point Cloud Data

A set of data points defined by *X*, *Y*, and *Z* coordinates, which correspond to the locations where laser pulses emitted by a LiDAR system had an interaction with an object.

Polar Orbit

An orbit that has an inclination near 90 degrees, so a satellite passes over both poles of the body being orbited on every revolution.

Pre-processing

A series of processes which consist of applying radiometric, atmospheric and geometric correction to remote sensing data to improve data quality and extract information with higher accuracy.

Producer Accuracy

The probability that a given land-cover class on the ground was correctly represented in the classification map.

Radiometric Correction

Process of correcting for radiometric errors (e.g., noise) caused by failure or mis-calibration of the sensor, as well as atmospheric and topographic effects, which affect the actual brightness value of the imaged surface.

Red-edge Region

A spectral region between 680 nm and 730 nm where a rapid change in vegetation reflectance is observed.

Remote Sensing

Remote sensing is the action of collecting images or other forms of data about the surface of the Earth, from measurements made at some distance above the Earth, processing these data and analyzing them.

Sensor

A device that measures detects and responds to some physical input such as motion, light, heat, pressure, moisture, or other environmental features.

Sensor Node

In a wireless sensor network is a node that performs some process and collects the data sensory and connects with other nodes in the network.

Sink Node

The sink is the node that access to the entire network and all the information which is collected by the sensor nodes are sending to sink node to proses and performs.

Solar Back Scatter

The process by which electromagnetic radiation interacts with and is redirected by the molecules of the atmosphere, ocean, or land surface.

Spatial Resolution

The smallest area on the ground (pixel) that can be resolved by satellite sensor.

Spectral Band

A spectral range defined by the spectral response function, where a remote sensor acquires data.

Spectral Region

Refers to a finite segment of wavelengths in the electromagnetic spectrum.

Sun-synchronous

Describes the orbit of a satellite that crosses the equator and each latitude at a fixed local time each day.

Swath Width

The width of the area observed by a satellite as it orbits the Earth.

Synthetic-Aperture Radar

Radar system in which high azimuth resolution is achieved by storing and processing data on the Doppler shift of multiple return pulses in such a way as to give the effect of a much longer antenna.

Temporal Resolution

Refers to the time needed to revisit and acquire data for the exact same location.

Thematic Mapper

A cross-track scanner deployed on Landsat that records seven bands of data from the visible through the thermal IR regions.

Time Curtain

The contour plot that has x axis as time, y axis as an altitude, and z axis as the measured quantity.

User Accuracy

The probability that pixels for a given class of the land-cover map have been correctly classified.

Wireless Sensor Network

Is a network that comprises of spatially distributed separate sensors to monitor environmental conditions such as temperature, moisture, pressure, etc.

A6.2 Acronyms

AATSR	Advanced Along-Track Scanning Radiometer
ADEOS	Advanced Earth Observation System
AERONET	Aerosol Robotic Network
AGCC	Alberta Ground Cover Characterization
AIRS	Atmospheric Infrared Sounder

AIS	Airborne Imaging Spectrometer
AISA	Airborne Imaging Hyperspectral Systems
ALOS	Advanced Land Observing Satellite
ANGEL	Airborne Natural Gas Emission LiDAR
ARCTAS	Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARVI	Atmospherically Resistant Vegetation Index
ATIC	Alberta Terrestrial Imaging Centre (University of Lethbridge)
ATCOR3	Atmospheric and Topographic Correction
AVI	Alberta Vegetation Inventory
AVIRIS	Airborne Visible And Infrared Imaging Spectrometer
AVHRR	Advanced Very High Resolution Radiometer
BRF	Bidirectional Reflectance Factor
BUV	Backscattered Ultraviolet
CALIOP	Cloud-Aerosol LiDAR with Orthogonal Polarization
CALIPSO	Cloud Aerosol LiDAR and Infrared Pathfinder Satellite Observations
CCRS	Canada Centre for Remote Sensing (NRCan)
CEOS	Centre for Earth Observation Sciences (University of Alberta)
CEOS	Committee on Earth Observation Satellites
CHRIS	Compact High Resolution Imaging Spectrometer
CMC	Canadian Meteorological Centre
CSA	Canadian Space Agency
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DIAL	Differential Absorption LiDAR
ENVI	ENvironment for Visualizing Images
ENVISAT	Environmental Satellite

EO	Earth Observation
EO-ADP	Earth Observation Application Development Program (CSA)
EO/RS	Earth Observation / Remote Sensing
EOS	Earth Observing System
EROS	Earth Resources Observation System
ERS	European Remote Sensing Satellite
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
ETM	Enhanced Transverse Mercator
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EVI	Enhanced Vegetation Index
FLAASH	Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes
FPAR	Fraction of Photosynthetically Active Radiation
GDAS	Global Data Assimilation System
GEO	Geo-Stationary Orbits
GEO-CAPE	Geostationary Coastal and Air Pollution Events
GIS	Geographical Information System
GMES	Global Monitoring for Environment and Security
GOME	Global Ozone Monitoring Experiment
GOSAT	Greenhouse Gas Observing Satellite
GPS	Global Positioning System
GSM	Global System for Mobile
HIRDLS	High Resolution Dynamics Limb Sounder
HRV	High Resolution Visible
HRVIR	High Resolution Visible Infra-Red
IAGOS	In service Aircraft for Global Observing System

IASI	Infrared Atmospheric Sounding Interferometer
IMS	Interactive Multisensor Snow and Ice Mapping System
InSAR	Interferometric Synthetic Aperture Radar
IRMS	Integrated Resource Management System
ISDAS	Imaging Spectrometer Data Analysis System
ISR	Infrared Simple Ratio
KARI	Korea Aerospace Research Institute
LAI	Leaf Area Index
LANCE	Land Atmosphere Near-real time Capability for EOS
LEO	Low Earth Orbits
LiDAR	Light Detection and Ranging
LTSDR	Long-Term Satellite Data Record
MAPS	Measurements of Atmospheric Pollution from Satellites
MDA	MacDonald, Dettwiler and Associates
MISR	Multi-angle Imaging SpectroRadiometer
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging SpectroRadiometer
MOPITT	Measurement of Pollution in the Troposphere
MOPRA	Monitoring Procedures for Reclamation in Alberta
MSS	Multi Spectral Scanner
MWIR	Medium Wavelength Infrared
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NFI	National Forest Inventory
NGDC	National Geophysical Data Center (NOAA)
NIR	Near-Infrared
NOAA	National Oceanic and Atmospheric Administration
NRCan	Natural Resources Canada
OBIA	Object-Based Image Analysis

ORS	Optical Remote Sensing
ORS-RPM	Optical Remote Sensing Radial Plume Mapping
PAI	Plant Area Index
PAR	Photosynthetically Active Radiation
PARASOL	Polarization & Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a LiDAR
PBL	Planetary Boundary Layer
POLDER	Polarization and Directionality of the Earth's Reflectances
RCM	RADARSAT Constellation Mission
ROI	Region of Interest
SAR	Synthetic Aperture Radar
SAVI	Soil Adjusted Vegetation Index
SBAS	Small Baseline Subset
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SERS	Second European Research Satellite
SMOS	Soil Moisture and Ocean Salinity
SOAR	Science and Operational Applications Research (CSA)
SOF	Solar Occultation Flux
SPEAR	Spectral Processing Exploitation and Analysis Resource
SPOT	Satellite Pour l'Observation de la Terre
SR	Simple Ratio
SRI	Simple Ratio Index
SRTM	Shuttle Radar Topography Mission
SVD	Singular Value Decomposition
SVM	Support Vector Machine
SWIR	Short-Wave-Infrared
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TES	Tropospheric Emission Spectrometer

TIR	Thermal Infrared
TM	Transverse Mercator
TOMS	Total Ozone Mapping Spectrometer
TROPOMI	TROPOspheric Monitoring Instrument
TSDMA	Time Series Data Management and Analysis
UAV	Unmanned Aerial Vehicle
VALERI	Validation of Land European Remote Sensing Instruments
VI	Vegetation Index
VIS	Visible
VNIR	Visible and Near-InfraRed
WINSOC	Wireless Sensor Networks with Self Organization Capabilities
WISC	Wireless In-field Sensing and Control
WSN	Wireless Sensor Network
WUSN	Wireless Underground Sensor Network

A6.3 Glossary Sources

Columbia University, 1998. Remote Sensing Glossary. Columbia University, New York, New York. http://www.ldeo.columbia.edu/res/fac/rsvlab/glossary.html

European Space Agency. Earth Online. Glossary. https://earth.esa.int/web/guest/glossary

Hashisho, Z., C.C. Small and G. Morshed, 2012. Review of Technologies for the Characterization and Monitoring of VOCs, Reduced Sulphur Compounds and CH_4. OSRIN Report No. TR-19. Oil Sands Research and Information Network, School of Energy and the Environment, University of Alberta, Edmonton, Alberta. 93 pp. http://hdl.handle.net/10402/era.25522

Marey, H.S., Z. Hashisho and L. Fu, 2014. Satellite Remote Sensing of Air Quality in the Oil Sands Region. OSRIN Report No. TR-49. Oil Sands Research and Information Network, School of Energy and the Environment, University of Alberta, Edmonton, Alberta. 104 pp. http://hdl.handle.net/10402/era.38882

Natural Resources Canada. Glossary of Remote Sensing Terms. http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9483

Rochdi, N., J. Zhang, K. Staenz, X. Yang, D. Rolfson, J. Banting, C. King and R. Doherty, 2014. Monitoring Procedures for Wellsite, In-Situ Oil Sands and Coal Mine Reclamation in Alberta –

December 2014 Update. Oil Sands Research and Information Network, School of Energy and the Environment, University of Alberta, Edmonton, Alberta. OSRIN Report No. TR-47. 167 pp. http://hdl.handle.net/10402/era.38742

7.7 APPENDIX 7. WORKSHOP FACILITATOR'S OBSERVATIONS

I made the following observations based on the Day 1 presentations and questions being asked:

- The data being collected, stored and distributed are gathered from scientists and technicians involved in EO/RS projects and operations. There is a growing interest in less technical sources of information collected through citizen science initiatives, aboriginal knowledge and the activities of non-profit environmental management organizations. There may be merit in evaluating the role of such data in the larger EO/RS umbrella.
- As shown in the presentations, EO/RS generates vast amounts of data that are often presented as "photos". Since it is critical that users of these products understand what they are trying to convey there may be merit in engaging graphic artists and others who are knowledgeable in presenting information to non-technical people to ensure the messages are clear (note that the Committee on Earth Observation Satellites has made available a suite of tools for visualizing actual and potential satellite sensor coverage).
- As noted in the 2011 Workshop, and again in the Day 1 presentations, the EO/RS world is filled with technical terms and acronyms that hinder clear communication with non-technical users. To that end the beginnings of a Glossary of Terms and Acronyms is proposed in Appendix 6.