Current and Emerging Methods for Satellite Monitoring of the Oil Sands

Oil Sands Monitoring Program
Technical Report Series 4.0

Canada

Alberta

AEP-ECCC Workshop on Current and Emerging Methods for Satellite Monitoring of the Oil Sands

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Recommended citation:
Sioris, C., McLinden, C., Dawson, J., Brisco, B., Fu, L., and Nunifu, T. 2018. AEP-ECCC Workshop on Current and Emerging Methods for Satellite Monitoring of the Oil Sands. Oil Sands Monitoring Program Technical Report Series No. 4. 19 p. ISBN: 978-1-4601-4195-3.

ISBN: 978-1-4601-4195-3 (PDF)
Posted October, 2018

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Foreword

Since February 2012, the governments of Alberta and Canada have worked in partnership to implement an environmental monitoring program for the oil sands region. In December 2017 both governments renewed their commitment to working together with Indigenous communities in the region by the signing the *Alberta-Canada Memorandum of Understanding (MOU) Respecting Environmental Monitoring in the Oil Sands Region*. The MOU establishes the foundation for an adaptive and inclusive approach to program implementation ensuring that the program is responsive to emerging priorities, information, knowledge, and input from key stakeholders and Indigenous peoples in the region.

The Oil Sands Monitoring Program is designed to enhance the understanding of the state of the environment and cumulate environmental effects as a result of oil sands development in the region though monitoring and publically reporting on the status and trends of air, water, land and biodiversity. Its vision is to integrate Indigenous knowledge and wisdom with western science to design, interpret, assess, report and govern the program.

Canada and Alberta have provided leadership to strengthen program delivery, and ensure that necessary monitoring and scientific activities meet program commitments and objectives. The oil sands industry provides funding support for the program under the Oil Sands Environmental Regulation (Alberta Regulation 226/2013). Key findings and results from the program inform regional resource management decisions and importantly, are considered as an objective source of scientific interpretation of credible environmental data.

A mandated cornerstone of the program is the public reporting of data, status and trends of environmental impacts caused by development of oil sands resources. The Oil Sands Monitoring Program *Technical Report Series* provides an objective, and timely, evaluation and interpretation of monitoring data and information collected across environmental media of the program. This includes reporting and evaluation of emission/release sources, fate, effects and transport of contaminants, landscape disturbance and responses across theme areas including atmospheric, aquatic, biotic, wetlands, and community based monitoring.

Executive Summary

The AEP-ECCC Workshop on Current and Emerging Methods for Satellite Monitoring of the Oil Sands was held from March 8 to 9, 2017 in Toronto, Ontario at the Environment and Climate Change Canada building at 4905 Dufferin Street. As the workshop name suggests, the event was jointly hosted by Alberta Environment and Parks (AEP) and Environment and Climate Change Canada (ECCC). The workshop agenda, list of participants, and presentations are provided in Appendices.

Purpose

The purpose of the workshop was to bring together developers, scientific experts, users, and potential clients of satellite remote sensing products to discuss how satellite remote sensing can contribute to monitoring of the Alberta oil sands region (AOSR) on three environmental themes, with focus on both current and emerging space-based capabilities: (1) Wetlands, (2) Greenhouse gases (GHGs), and (3) Air Quality (AQ).

Workshop presentations, grouped by theme and spanning the first day and a half, were designed to address how various satellite products could be used to improve the confidence and scientific value of monitoring in the AOSR. In complement, the discussion phase, held during the afternoon of the second day, was designed to identify common and overlapping goals and needs between these themes, how one community might assist another, and to identify potential future collaborations that ideally cut across multiple themes.

Outcomes

Workshop attendees were from a broad range of backgrounds, including satellite remote sensing experts and researchers, data providers, and data users from multiple levels of government, academia, and industry. Presentations in each theme covered the state-of-the-science technology and applications, both current and that expected over the next five years. In this regard, the workshop was able to bring together the right people and cover the right material.

Facilitated discussion on opportunities and applications for satellite monitoring in the oil sands resulted in the identification of common areas of interest for potential future collaborations. These included satellite validation field campaigns, data infrastructure and emissions, specifically the need for new and better measurements of atmospheric methane, and a common interest in better quantifying fluxes of pollutants from the atmosphere to the surface. Participants concurred that emissions should be a priority. There are several species of common interest, including methane, ammonia, nitrogen products and climate forcers. Opportunity for a joint project could be framed around one or more of these species.

The GHG and AQ communities were already in close contact since their interests lie in many of the same satellite data products and satellite instruments. In contrast, there has been limited interaction between the atmospheric and wetland communities. Hence, this workshop provided the first real opportunity for engagement and directed discussion on priorities and needs across the three communities.

Recommendations

As an outcome of the presentations and facilitated discussion, a series of recommendations are proposed for consideration in future satellite monitoring and related activities within the oil sands.

1. Integrating deposition estimates from atmospheric and wetlands monitoring, to inform both science communities, and towards reducing uncertainty in emission inventories. In spring 2018, there will be a significant atmospheric measurement field campaign in the AOSR where emissions from point sources will be quantified. Wetlands scientists should be engaged before summer 2017 to explore potential collaborations for the spring 2018 campaign. In the longer-term a validation campaign should be considered focusing on species of common interest across the atmospheric and wetland science communities.

2. Methane was a species of common interest across all three themes. The TropOMI (Tropospheric Monitoring Instrument) satellite instrument, scheduled for launch in Q3/Q4 of 2017 with first data expected by early 2018, will be the first satellite to provide daily methane maps across the AOSR. Experts in the AQ and GHG communities should make it a priority to obtain and analyze these data to understand its strengths and limitations, and in particular its potential for quantifying methane emissions and fluxes. The wetlands community, based on this assessment, should then discern what they want or need from these new CH_4 observations and together with the atmospheric community to consider linkages with ongoing activities (e.g., OSM wetlands program) and communication of methane status over the AOSR.

3. There are opportunities to leverage expertise and capacity across the relatively small Canadian satellite science community. An example is the need for a coordinated approach to satellite data management as the ever-increasing volume of new data cannot continue to be managed in an ad hoc manner. Within OSM, there may be scope to identify, demonstrate and apply tangible improvements towards satellite data management across the science communities.

4. It is recommended that another workshop be considered in 2 to 3 years' time to enable continued dialogue and cross-collaboration.

Summary of Presentations

The summaries are provided here in the same order as they were presented.

Update from the Canadian Space Agency

Robert Saint-Jean and Marcus Dejmek, Canadian Space Agency

The presentation by Canadian Space Agency (CSA) addressed current and future missions of relevance to this workshop. Radarsat-2 and SMAP (Soil Moisture Active Passive) are the current instruments of relevance for wetlands monitoring. The main upcoming mission for space-based wetlands monitoring is Radarsat Constellation Mission (RCM), scheduled for launch in July 2018. It will be capable of measuring oil on the surface of inland water bodies, which could be particularly relevant for the AOSR. Surface Water Ocean Topography (SWOT) and CIWI (formerly COCI and WaterSat) were also mentioned as future missions. SWOT is scheduled for launch in 2021 whereas CIWI (Coastal and Inland Waters Imager) is a possible mission. The sensors used for atmospheric remote sensing include MOPITT (Measurements of Pollution in the Troposphere) and OSIRIS (Optical Spectrograph and Infrared Imager System). A future mission concept possibly involving a highly elliptical orbit to increase high-latitude coverage was also discussed. The Canadian-led Raven mission, proposed in response to the European Space Agency's Earth Explorer 9 announcement, was also highlighted.

Wetlands

Earth observation applications for wetlands in the AOSR

Danielle Cobbaert, Alberta Environment and Parks

This presentation provided a useful introduction to wetlands. Danielle Cobbaert discussed a three year program that is being developed under the Oil Sands Monitoring. The Canadian Wildlife Classification System was presented. The five wetland classes are fens, bogs, marsh, swamp, and shallow (<2 m) open water. Bogs and fens make up the majority of the AOSR. Distinguishing between similar classes is difficult. Bogs are hydrated from the top down whereas fens are hydrated from above and below. Shallow water represents ≤1/4 of the AOSR. Wetlands are important area for indigenous people (e.g., berry picking). As also mentioned in subsequent talks, evapotranspiration tends to exceed precipitation in this region. Glacial meltwater plays a role in the boreal plains: deep (20-200m) heterogeneous glacial deposits result in complex subsurface hydrology that underlies the landscape of forests and peatlands. Danielle's presentation was the first of many to point out the interannual variability of the local wetlands. Biological indicators are used to detect changes in structure, composition, and condition of the vegetation community. One of the cross-discipline (i.e., air and wetland) links was made when the presenter commented on eutrophication of the wetlands by increase in nitrogen from atmospheric emissions (including air pollution). The Human Footprint Inventory was discussed. It provides coverage over all of Alberta and will be "refreshed" soon. Ducks Unlimited is investigating the productivity of ducks in relation to human disturbances. The three-phase response of Sphagnum moss to changes in nitrogen deposition was presented. As nitrogen deposition increases, the sphagnum moss thrives initially, but then taller plants (e.g. trees) shade out the moss. Reclamation can be evaluated using satellite remote sensing.

Wetland delineation and monitoring in the AOSR with SAR

Valentin Poncas, Kepler Space

The presentation illustrated the difference between optical and radar remote sensing of a river. The river is slightly wider than indicated by the optical measurements (possibly due to vegetation at the river banks). The radar, being able to see through thin vegetation, can accurately delineate the water body.

Remote sensing and water quality in the AOSR

Peter White, NRCan

This presentation detailed the expansion of techniques for mapping water extent changes in wetlands using Radarsat-2 SAR (Synthetic Apeture Radar) data. The presenter used the example of how a ground-based sensor missed a tailings pond breach to illustrate how satellite remote sensing could complement monitoring of such a water body. Remote sensing is an important component of mine and tailings pond remediation. There are issues with low reflectance from water in the shortwave. ISDAS version 2 software was discussed. The software can process water vapour and determine its spatial variability. Indices for groundwater depth were discussed. The indices performed well for natural water bodies but tailings ponds tend to be shallow and have bright sediment at the base. Both factors make bathymetry challenging.

Alberta Water Portal: implications for wetlands in the AOSR

Chris Hopkinson, University of Lethbridge

Chris Hopkinson discussed the Alberta Water Portal that is being developed and is expected to be ready by the time of the launch of the RCM. The portal can be queried on a spatial, temporal or attribute basis. GIS-based software is being developed to allow for maps of wetland attributes. Fusion of LIDAR and SAR (synthetic aperture radar) is being developed to create more comprehensive wetland classification. As mentioned in other presentations, for SAR, specular reflection is desired; double bounces complicate the analysis (i.e., source of bias). SAR data is analyzed to retrieve wetland information when snow and ice are not present. One of the principles of radar remote sensing is that the areas with low variance in terms of radar signal are water bodies. As an example, six views of the same target area are taken, typically a few weeks apart. If the target location appears inundated 6 out of 6 times, it is categorized as a permanent water body. If, according to the radar, a scene is inundated only once out of 6 times, it is classified as “shallow water or a saturated surface”. This presentation also emphasized the interannual variability (contrasting 2013 to 2014-15).

Multi-temporal monitoring of wetlands using polarimetric SAR data

Brian Brisco, NRCan

Brian Brisco discussed Radarsat-2 measurements in ‘fine-quad’ mode (four polarization combinations and 5 m spatial resolution). Brisco presented the hierarchy of polarization measurements (single, dual, compact, and fine). Similar to earlier presentations, the presenter commented on the temporal variability of wetlands and the low utility of a static wetlands map. The compact polarization (CP) data in medium resolution mode can spatially resolve areas 16 metres in length whereas the ‘fine-quad’ mode resolution is ~10 m. The CP mode is qualitative (e.g., marsh or no marsh), whereas with the full polarization and fine spatial resolution, many more changes could be observed. Perched basins contribute to the variability of wetlands in the AOSR. Wetlands types such as bogs and fens have a highly variable radar signal, more so than exposed rock.

Surface hydrology and remote sensing in the AOSR

Daniel Peters, ECCC

Daniel Peters discussed the impact of hydroelectric projects of wetlands in the Peace Athabasca Delta (PAD). The construction of the one of the dams in 1968 decreased the flow rate of the Peace River significantly. As a mitigation measure, weirs were installed on an outflow channel in 1975-76 to partially compensate for decreased Peace River flows. The PAD is one of the largest freshwater deltas in the world. Hydrometric height data from in-situ gauges and aerial datasets are recent. Peters mentioned the aerial LIDAR surveys in 2012/2013 which provided 2 m spatial resolution and centimeter-scale resolution in the elevation dimension. He illustrated how the flow of the Peace River is highly dependent on the water volume. The direction of the flow can reverse at higher volumes (back toward Lake Athabasca). Also, the impact of an ice jam was shown as a time-lapse video. The ice jam led to water spilling into the surrounding area. In 1996, flow was regulated by another dam. ECCC (Water Survey of Canada) provides operational data products based on 40 in-situ monitors, which includes a three-tier classification of areas: open water, flooded and non-flooded. It was pointed out that relating water extent to elevation is challenging. Besides hydroelectric projects, climate change is one of the stressors of wetlands. Further, it was noted that flooding tends to occur where the river bends (i.e., spillage over the river banks). One of the key topics of the presentation was that of connectivity. The frequency of connections between different water bodies is obtained from the gauges.

Hyperspectral imaging spectroscopy and LiDAR

Olaf Niemann, University of Victoria (presentation delivered by Daniel Peters)

The theme of high spatial resolution resurfaced in this presentation: 5 x 5 m^2 spatial resolution was insufficient to detect water connectivity episodes; 2 x 2 m^2 resolution was achieved but 1 x 1 m^2 resolution was not possible. It was noted that changes in ground water tend to propagate westward. The main conclusion was that LIDAR and passive optical hyperspectral data represent powerful tools to assess wetland dynamics.

Terrain Morphology and Vegetation Structure Classification for Wetlands of the Boreal Plains, Alberta using LiDAR

Laura Chasmer, University of Lethbridge

Laura Chasmer illustrated that northeastern Alberta is clearly drying up over the 30 years due to increased evapotranspiration and wetlands are shrinking at a staggering rate. A long record of optical imagery is available: 40 years for Landsat and even longer for aerial imagery. At Utikama Lake (central Alberta), there are forests found on plateaus that are underlain by permafrost that is rapidly thawing. The edges of the plateaus are converting more quickly into wetland, and the tree mortality at these edges lags the rate of permafrost thaw (i.e., the trees die due to inundation and fall into the water). A decision-based classification has been developed whereby characteristics representing the different land covers are accumulated into indices although there are fuzzy transitional edges. The scheme takes only a couple of hours for a ~1300 km^2 area whereas manually delineation of wetlands would take days to weeks. Vegetation was shown to expand in the area surrounding wetlands as the area dries out (i.e., shrub encroachment or 'shrubification'). Data fusion, mentioned in many talks, was also discussed here. Specifically, data fusion of LIDAR and passive optical imagery was discussed in this presentation, while LIDAR/radar data fusion was discussed in Hopkinson's presentation. Chasmer showed that such fused data was leading to better agreement with validation data in terms of land cover.

Greenhouse Gases

Quantifying fossil fuel CO_2 emissions from space-based observations: Current capabilities and future opportunities

Ray Nassar, ECCC

Ray Nassar presented an overview of current and future space-based greenhouse gas observing missions, complemented by details on quantified CO_2 emissions from individual overpasses by Orbiting Carbon Observatory 2 (OCO-2). The samples over Alberta were at Wolf Lake and Cold Lake where 2.7 and 4.0 Mt/year of CO_2 are emitted from the local oil sands project, respectively, according to bottom-up emissions. The top-down (i.e., satellite-based) method for measuring emissions developed by Nassar is currently being applied to sources >10 Mt/year of CO_2. Thin cirrus was shown to be a source of bias in the retrieved CO2. The across-track swath of OCO-2 is very narrow and future sensors will be better in this regard. Significant volume mixing ratio enhancements were observed at many sites, with the largest so far of ~12 ppm from the Sasan Ultra Mega plant (India), which translate to 3% enhancements relative to the background. A couple of OCO-2 maps during overpasses near the Athabasca oil sands were presented but anthropogenic emissions could not be estimated in either case, due to the unfavorable wind direction and biomass burning, respectively. Nassar suggested international partnership could be used to make a highly-elliptical orbital mission a reality. Such a mission would provide imaging measurements over northern Canada multiple times per day.

GHGSat

Jean-Francois Gauthier, GHGSat

Jean-François Gauthier presented some imagery from the orbiting Claire satellite. The retrieval algorithm was described as being in a “research and development phase”. According to Gauthier, the accuracy of 1% is a more reasonable goal for methane as opposed to CO_2 due to the wavelength range of the instrument. With future satellites, GHGSat may monitor NO_x and SO_x. The measurements from Claire are not expected to be unbiased, but the goal is to measure relative spatial differences for the purpose of estimating emissions. The partnership with the University of Toronto Institute for Aerospace Studies (UTIAS) Space Flight Laboratory (SFL) will continue with the upcoming two satellites (expected launches in 2018 and 2019). Competitive surveys are among the services that will be provided by GHGSat. This entails comparing the emissions from two or more sources. A Gaussian plume model and the CALPUFF dispersion model are among the tools to be used to estimate emissions. One instrumental issue was shown: a ghost image of a flare, spatially shifted from the actual flare location. In terms of validation of methane, the controlled release method may be used.

Integration and Application of Satellite Remote Sensing for GHG and Air Quality

Long Fu, AEP

Long Fu showed annual mean methane time series (2003-13) from the AIRS satellite for four quadrants of Alberta (northeast, northwest, etc.). The 2010 decrease in all four quadrants of Alberta was attributed to economic recession. Fu mentioned the acquisition of a tunable LIDAR for CO_2 and CH_4. Also mentioned was the flux chamber, which can be used to estimate emissions of both of these greenhouse gases from tailings ponds. The derived CH_4 and CO_2 emissions show a maximum at the same time. A paper on this topic has been accepted by J. Air Waste Management Assoc.

Air Quality

Overview of current and planning air quality satellite monitoring activities at ECCC

Chris McLinden, ECCC

Chris McLinden presented an overview of current and future air quality sensors. Ozone Monitoring Instrument (OMI) was one of the featured instruments. The conclusion was that satellite-based instruments have proven to be important oil sands monitors. Many applications such as emissions and surface-level concentrations require combining measurements with models.

Estimation of SO_2 emissions using satellite data

Vitali Fioletov, ECCC

Vitali Fioletov showed that satellite measurements can be used to detect sources and estimate emissions for them. Existing emission inventories can be verified, information about missing sources can be provided, and emission trends can be analyzed. Emission estimates will be more accurate and more sensitive when the next generation of satellite instruments will be in orbit. This presentation focused on SO_2, but the methods can be applied to other pollutants, including NO_x, ammonia, and aerosols.

Satellite observations of ammonia

Mark Shephard, ECCC

Mark Shephard presented ammonia (NH_3) retrieved from CriS (Cross-track Infrared Sounder) infrared spectra. Results show that forest fires dominate the ammonia budget in the warm season. Further, Shepherd showed a comparison with a model that accounts for bi-directional fluxes, which is an important process for NH_3. Ammonia deposition maps were presented and a possible, related collaboration with wetlands scientists was highlighted. Regarding the validation, comparisons with AMON (Ammonia Monitoring Network) showed that CriS NH_3 tended to be biased high at low concentrations, consistent with the FTIR (Fourier Transform InfraRed) validation.

Investigation of carbon monoxide emissions and aerosol dynamics using space-based observations

Heba Marey, U of Alberta

Heba Marey emphasized synergism between different satellite instruments. Marey found only minor differences between the current version of MOPITT carbon monoxide and the version she used in her publication of CO over Alberta. She showed that MOPITT CO has a peak at the surface at Fort McMurray in August that is not observed at Edmonton and Calgary. However there is not a hotspot in the AOSR. Further, Marey showed that MOPITT CO is consistent with ground-based measurements in terms of the long-term trend. CO is decreasing over Edmonton and Calgary but is relatively constant versus time at Fort McMurray. Another conclusion, supported by MODIS (Moderate Resolution Imaging Spectroradiometer) smoke plume images and HYSPLIT forward trajectories, is that satellite and ground measurements indicate that biomass burning and its transport have significant influence for the tropospheric CO distribution in northern Alberta.

Space-based aerosol observations in the AOSR

Chris Sioris, ECCC

Chris Sioris presented the spatial distribution of aerosol optical depth over the oil sands from six satellite data products. The Alberta oil sands are an aerosol source region, but aerosol optical depths (AODs) are only moderately enhanced relative to the background. The enhancement is visible in all of the data products but there are some differences in the spatial pattern. The enhancement relative to the background is <2. Satellite and AEROCAN AODs were shown to have good agreement in absolute terms and with respect to temporal correlation. MODIS and VIIRS (Visible Infrared Imaging Radiometer Suite) have some data confidence issues in the aerosol hotspots (e.g., Syncrude Mildred Lake facility), while MISR (Multi-angle Imaging SpectroRadiometer) has limited spatial resolution.

Opportunities and applications for satellite monitoring of the oil sands

Workshop participants had the opportunity to participate in a facilitated discussion of opportunities and applications for satellite monitoring of the oil sands. Discussion was first focused by thematic groups—air quality and wetlands—around the following questions. The main discussion points of this facilitated discussion are summarized below by theme, and reflected in this report's recommendations.

Where are we and where are we going?

- » Are we going to be able to make measurements with satellites in a few years such that we could diminish surface monitoring?
- » Are there species we should be measuring from the ground that we are not currently?

What applications might be valuable to consider in the next few years?

- » Where will investments have the most impact?

Where does collaboration make sense?

- » Where could these collaborations lead?
- » How can we be ready for new and upcoming missions?

Air Quality

There are opportunities to collaborate on linkages.

- Methane also arose as a common linkage, which should result in broad interest in the new space-based CH_4 observations expected this year (but that will need to be validated). Satellite measurements will become extremely important in complement to reported emissions. A question to be addressed is what does the wetlands community want or need from the new CH_4 observations. While the atmospheric community should communicate on the status of these species; conversely, the wetlands community needs to advise on how concentrations in these gases could change.
- Specific to nitrogen deposition, the wetland community could use nitrogen deposition derived using satellite information rather than relying solely on model estimates.

There are opportunities to leverage expertise and capacity across a relatively small Canadian satellite science community.

- Cross-validate satellites to reconcile measurements, where the investment would be in the use of satellite data to develop programs for policy and management. The Canadian satellite science community is relatively small—there should be more sharing of algorithms.
- Invest in emission inventory improvements that are based on satellite data. However, it was questioned if current capacity can facilitate this work in the short-term (i.e., 3 years).
- A common issue between air quality and greenhouse gas data is the lack of data in winter and over snow covered surfaces. There are issues with retrievals, but the signal-to-noise ratio of those measurements is higher for those data in some cases; this is a potential area to focus improvement.
- There is a critical need for a coordinated approach to satellite data management as the volume of new data increases it cannot continue to be managed in an ad hoc manner. There is a need to identify and demonstrate a new technique that could be applied.

There are opportunities to collaborate on validation (e.g., using ground-based monitoring to validate satellite information).

- If models are a validation tool, is there value to focus on one model? There are many currently in use. There has not been an inter-model validation completed for OSM specifically. There are very different sophistication levels for the different models; there would need to be reconciliation between the varying models.
- A validation campaign would be useful, with an aircraft to "flesh out" the full satellite pixel. The Canadian niche is validation in the winter season and the far north, whereas American validation campaigns tend to focus on tropical and subtropical conditions. Aircraft campaigns are most important for species retrieved from the ultraviolet for which the shape of the concentration profile is most important. In order to link remote sensing data to ground-based in-situ data there is a requirement for aircraft profiles to probe the profile variability. CH_4 and CO_2 is where we might want to focus for most value, as well as aerosols or pollutants that affect the radiative balance. If framed around SLCPS (short-lived climate pollutants), there would be an impact for Canada and the OSM link is there with wetlands and ecosystems.

There are opportunities to improve emissions inventories using satellite remote sensing.

- Inventories currently used have missing sources over the boreal forests and wetlands. We are not accounting for the fact that these sources could be emitting tonnes of ammonia. More information here could improve our understanding of the climate aspects. Further, we do not know what is happening 100 km away from the source. A fusion method would facilitate improved understanding.
- We need improved emissions inventories and data assimilation technology. Chemistry in the atmosphere adds complexity. GEM-MACH–FIREWORK is an example where using MODIS NRT fire measurements as input to the model, as well as Mark Shephard's ammonia retrieval to model temporal and spatial distribution of ammonia.

- We would benefit from reducing the uncertainties of emissions of various species. Currently, there are factors of 2 or 3 in uncertainty. This could be incorporated into one of these validation activities. With TropOMI methane, we could improve emission uncertainty given the satellite coverage. Methane links well with above comment of where we could have value and impact.

Wetlands

Remote sensing data are leading us to an improved understanding of hydrology and vegetation / land cover. Hydrology is the critical driver of wetland class and is reflected in the vegetation. There is a need to integrate improvements and technologies, as listed below, into a long-term monitoring program for the Alberta oil sands region.

- Regarding ecosystem functions such as carbon storage, there is a need to develop site-based infrastructure and develop models from there.
- We need more field-based measurements, particularly where measurements cannot be made remotely.
- Validation of remote sensing products is required, as is the need to develop scaled-up products from surface monitoring.
- Regarding overlap with air quality, chemical deposition from the atmosphere crosses over between themes.
- In the future, there is a need for improved wetland inventory based on remotely-sensed land cover information, and better consistency in methodology.
- Regarding ammonia, we could be assessing remote sensing measurements with ground-based within the wetlands, and similarly for other species such as CH_4, CO_2, NO_2, etc.
- Regarding technologies that are planned or anticipated, we are preparing for validation. For example, with SAR, we can detect open water extent/depth of water.
- There may be larger wetland areas where you could target remote sensing to characterize the CO_2 regime. As part of the new wetlands OSM program, there will be CO_2 and CH_4 measurements at reference and disturbed sites. The current focus is on bogs, which tend to be the most sensitive and to have the lowest nitrogen levels. There may be opportunity for validation with the air quality community.

Linkages between Air Quality and Wetland Themes

In summary, the potential areas for cross-collaboration to consider are a validation campaign, data infrastructure, and emissions. Participants concurred that emissions should be a priority. In spring 2018, there will be a measurement field campaign in the AOSR where emissions from point sources will be quantified. Wetlands scientists should be engaged before summer 2017 to explore potential collaborations for the spring 2018 campaign.

There are several species of common interest, including methane, ammonia, nitrogen products and climate forcers. Opportunity for a joint project could be framed around one or more of these species.

Finally, there are currently limited linkages between the air quality and wetland satellite remote sensing communities. This workshop and future collaborative initiatives will serve to improve these linkages.

Appendices

Appendix A

AEP-ECCC Workshop on Current and Emerging Methods for Satellite Monitoring of the Oil Sands - Conference Room 3, ECCC-Downsview, Toronto - March 8-9, 2017

Workshop Program

March 8, 2017		
TIME	**SPEAKER**	**PRESENTATION**
0900 – 0920	Welcome, Announcements, and Introductions	
0920 - 0940	Marcus Dejmuk and Robert Saint-Jean, CSA	Update from the Canadian Space Agency
	Chair: Daniel Peters	
0940 – 1010	Danielle Cobbaert, AEP	Earth observation applications for wetlands in the AOSR
1010 – 1040	Valentin Poncas, Kepler Space	Wetland delineation and monitoring in the AOSR with SAR
1040 – 1100	Health Break	
1100 – 1130	Peter White, NRCan	Optical water mapping algorithms review for ponds in the Oil Sands region
1130 – 1200	Chris Hopkinson, University of Lethbridge	Alberta Water Portal: implications for wetlands in the AOSR
1200 – 1230	Brian Brisco, NRCan	Multi-temporal monitoring of wetlands using polarimetric SAR data
1230 – 1330	Lunch & Posters	
	Chair: Brian Brisco	
1330 – 1400	Daniel Peters, ECCC	Surface hydrology and remote sensing in the AOSR
1400 – 1430	Olaf Niemann, University of Victoria (talk given by Daniel Peters)	Hyperspectral imaging spectroscopy and LiDAR
1430 – 1500	Laura Chasmer, University of Lethbridge	Terrain Morphology and Vegetation Structure Classification for Wetlands of the Boreal Plains, Alberta using LiDAR
1500 – 1515	Health Break	
	Chair: Chris Sioris	
1515 – 1600	Ray Nassar, ECCC	Quantifying fossil fuel CO2 emissions from space-based observations: Current capabilities and future opportunities
1600 – 1630	Jean-Francois Gauthier, GHGSat	GHGSat
1630 – 1700	Long Fu, AEP	Integration and Application of Satellite Remote Sensing for GHG and Air Quality

March 9, 2017		
TIME	**SPEAKER**	**PRESENTATION**
0900 - 0915	Welcome and Announcements	
	Chair: Shailesh Kharol	
0915 – 1000	Chris McLinden, ECCC	Overview of current and planning air quality satellite monitoring activities at ECCC
1000 – 1030	Vitali Fioletov, ECCC	Estimation of SO_2 emissions using satellite data
1030 – 1050	Health Break	
1050 – 1120	Mark Shephard, ECCC	Satellite observations of ammonia
1120 – 1150	Heba Marey, U of Alberta	Investigation of carbon monoxide emissions and aerosol dynamics using space-based observations
1150 – 1220	Chris Sioris, ECCC	Space-based aerosol observations in the AOSR
1220 – 1330	Lunch & Posters	
1330 – 1600	Facilitated Discussion: Opportunities and applications for satellite monitoring of the oil sands	

Appendix B

Workshop Participants

(in person and by WebEx)

1. Stewart Cober
2. Ray Nassar
3. J-F Gauthier
4. Thompson Nunifu
5. Jon Pasher
6. Jakob Siemens
7. Tim Hill
8. Alex Bush
9. Danielle Cobbaert
10. Kelly Munkittrick
11. Heba Marey
12. Long Fu
13. Laura Chasmer
14. Chris Sioris
15. Brian Brisco
16. Chris Hopkinson
17. Peter White
18. Shailesh Kharol
19. Dan Sayek
20. Valentin Poncas
21. Vitali Fioletev
22. Anne Walker
23. Jaime Dawson
24. Daniel Peters
25. Prit Kotecha
26. Marjorie Shepherd
27. Carrie Taylor
28. Shailesh Kharol
29. Michael Sitwell
30. Alex Lupu
31. Saroja Polavarapu
32. Mike Moran
33. Robert Saint-Jean (webex)
34. Sandra Bolanos (webex)
35. Karen Holwas (webex)
36. Kim Strong (webex)
37. Mourad (webex)
38. Marcus Dejmek (webex)
39. Jeremy Reid (webex)
40. Daniel Burt (webex)
41. James Beck (webex)
42. Rory Heffel (webex)
43. Shari Hayne (webex)
44. Todd White (webex)
45. Yan Liu (webex)

*List is not comprehensive of all participants who joined by WebEx