OPERATIONAL WILDFIRE MAPPING WITH SENTINEL2 AND LANDSAT IN BRITISH COLUMBIA

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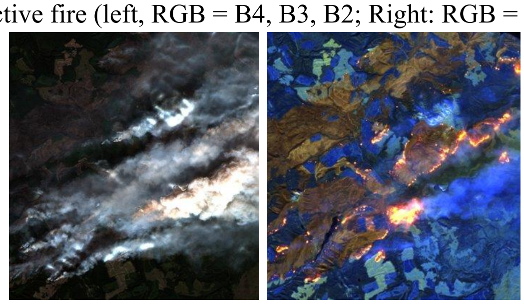
ABSTRACT

We outline an operational trial of satellite fire perimeter mapping in the 2022 fire season in British Columbia using ESA Sentinel-2 data, supplemented by NASA Landsat data. Over three hundred "low latency" fire polygon updates were generated by BCWS's Predictive Services Unit and vetted by BCWS's Geospatial Services Team, demonstrating: Sentinel-2 for timely (delivery in under twelve hours from capture) fire mapping even of small or unknown fires, and mapping fires under smoke cover. The products' value was recognized by front-line staff on high-profile incidents in 2022. The increased potential for extreme weather events (White et al, 2023) highlights the need for improved situational awareness offered by increased exploitation of Remote Sensing.

In 2022 the BC Wildfire Service took the opportunity of using Sentinel-2 spaceborne multispectral data from ESA to monitor the progression of remote fires where active suppression was not occurring and to improve situational awareness. Moreover, frequency and fidelity of fire mapping updates were improved, including for fires being actively suppressed. A non-thermal infrared method (Wooster et al, 2021) was used, illustrated here with 20220910 imagery of the Battleship Mountain wildfire (G72150).

1. Prepare Sentinel-2 (bands B12, B11 and B9) or Landsat data (spectrally interpolated to Sentinel-2 bands B12, B11 and B9). Sentinel-2's three longest wavelengths are selected for cloud-penetration and sensitivity to active fire (left, RGB = B4, B3, B2; Right: RGB = B12, B11, B9):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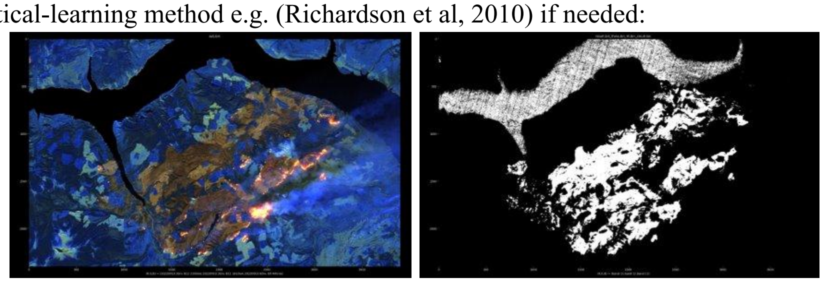
2. Classify fire with a simple rule-based method (B12 > B11 && B12 > B9) or a rudimentary statistical-learning method e.g. (Richardson et al, 2010) if needed: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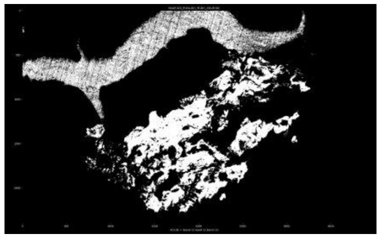
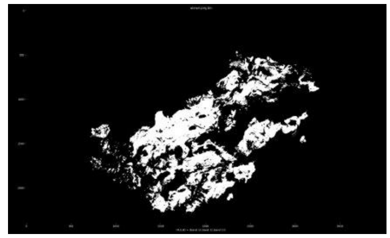
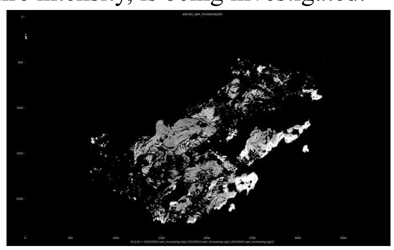
3. Scrub false positives:

  .

4. Convert to Polygon and compare with existing publicly available BCWS perimeter data, in QGIS.
5. Submit polygon in KMZ format for SME review by BCWS's Geospatial Services Team.

Currently a new rule: "(B12 / B9 > 1.1) * B12" reducing false positives due to cloud cover and ice, and scaled by B12 to correspond with fire intensity, is being investigated:

 .

Acquisition frequency and data latency were the most significant issues. The authors are grateful for infrastructure support provisioned by NRCan's Emergency Geomatics Service team, which is anticipated to improve this application's latency to less than five hours for use in the 2023 fire season. Continued development of this initiative will contribute towards Knowledge Exchange (KE) and agency readiness for Canada's upcoming WildfireSat mission (McFayden et al 2023).

Keywords**—** Fire Mapping, Sentinel-2, Landsat, SWIR, Fire intelligence, Situational awareness

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INVESTIGATING SPACEBORNE L-BAND POLARIMETRIC SAR FOR OPERATIONAL WILDFIRE MAPPING IN BC

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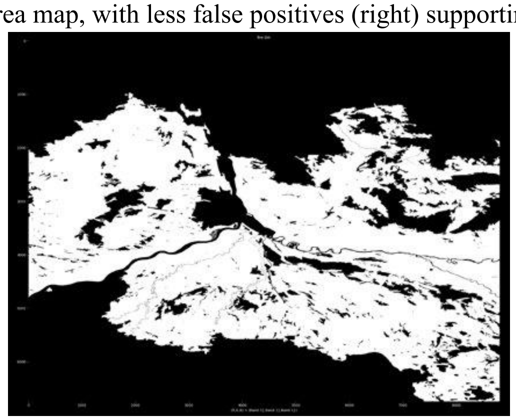
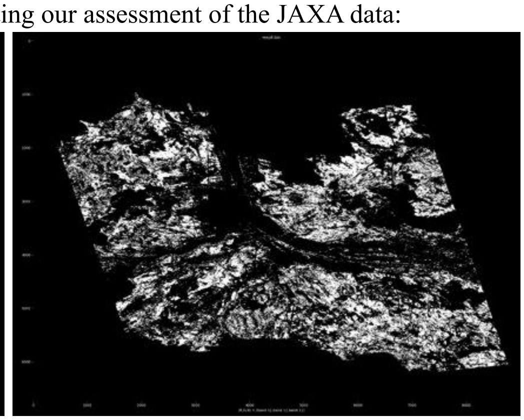
ABSTRACT

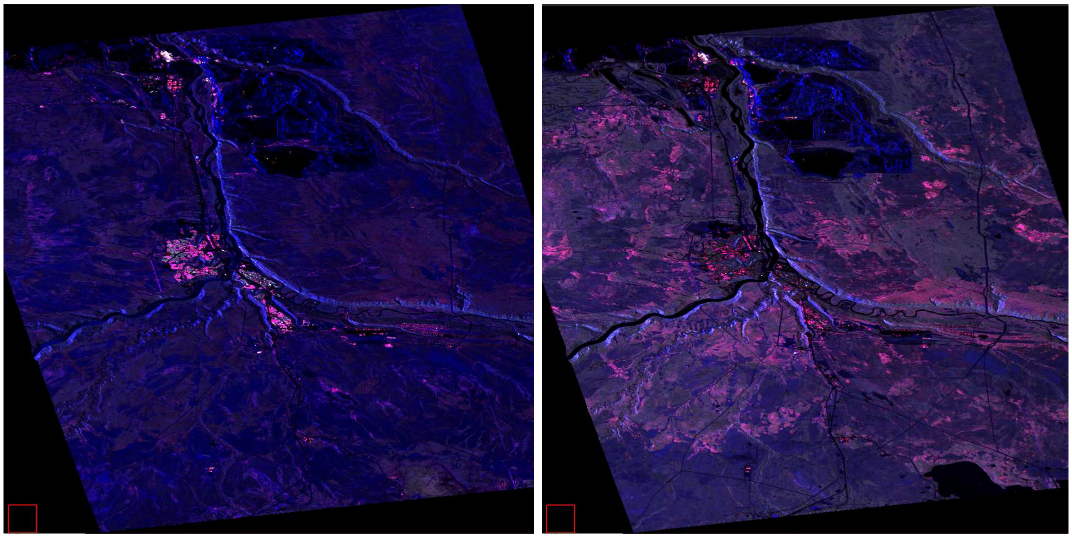
This paper continues investigating L-band Polarimetric Synthetic Aperture Radar (PolSAR) applications, to support optical fire progression and burn severity mapping (Tanase et al, 2015) when clouds are in the way (Goodenough et al, 2011). Due to scarcity of ALOS-2/PALSAR-2 data over British Columbia in the Quad-Pol (QP) mode, we chose the 2016 Horse River fire affecting Fort McMurray, Alberta Canada for assessing operational potential of L-band QP SAR using several methods. Moreover ALOS-2 QP data are available over Fort McMurray in two time series, with overlapping but distinct footprints. Whereas (JAXA, 2016) and (Plank et al 2019) analyse dates from a series where Fort McMurray appears slightly East of the footprint centre, we analyse dates from the other series in which Fort McMurray appears closer to the footprint centre (and classify burned area) to help prepare for using L-band NISAR, ALOS-4/PALSAR3, ROSE-L missions in operational fire mapping scenarios in BC. Finally, as L-band SAR missions aren't guaranteed to provide large coverage in QP mode, we hedge our bets and apply Dual-Pol (DP) methods of (Mascolo et al, 2021) providing physical polarimetric interpretation accessible from both DP and QP acquisition modes.

Because fire perimeter data are operationally oriented, classification of October 3, 2016 Landsat data was used in conjunction with the existing CNFDB fire perimeter data (left) to create a reference burned-area map, with less false positives (right) supporting our assessment of the JAXA data:

 .

Next we performed a preliminary classification on 20150404 (pre) and 20160528 (post) dates, with the Nearest Neighbour classifier (i.e., the simplest version of *k*NN with *k*=1) and an unreasonably small number of identified positive and negative samples (only N=20 pixels for training to classify a raster with millions of pixels). Using the T22 channel only as in (JAXA, 2016) 77% overall accuracy was obtained. For T11, T22, and T33 channels 80% accuracy was obtained. Moreover, 75% accuracy was reported using the T22 channel only using only the post date. Finally, 75% accuracy was also produced by classifying the

DP parameters (Mascolo et al, 2021) for the post date only. Accordingly, we expect to report classification accuracy close to 90% in the full paper after using a contemporary Machine Learning (ML) classification algorithm, as well as a more substantial number of training samples. Finally, additional info will be gained from the other five images available over the same footprint, such as coherent change detection as in (Lehrbass et al, 2018). The 20150404 (left) and 20160528 (right) dates: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Thanks to JAXA for providing ALOS-2/PALSAR-2 data under the EORA3 opportunity “BC Wildfire Service – Predictive Services Unit – Fuel Type Layer Project”.

***Keywords*—** Radar, Polarimetric SAR, Fire mapping, ALOS-2, Wildfire, Fort McMurray

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KNOWLEDGE EXCHANGE AND ASSESSING WILDFIRE MANAGEMENT AGENCY READINESS FOR WILDFIRESAT

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ABSTRACT

Responding to the many challenges wildland fire managers face, the Government of Canada is designing and launching a new wildfire monitoring satellite system, WildFireSat. WildFireSat is the only public satellite monitoring system ever created to respond directly to the needs of, and in conjunction with, front line fire managers in Canada (Johnston et al., 2020). The data products from WildFireSat are anticipated to be transformational for operational situational awareness and decision-making. WildFireSat will provide unprecedented, daily, near real-time strategic intelligence on all active wildfires across the country. The resulting intelligence products will be timed to provide agencies with the information needed to make critical decisions at key points during the planning process. Experience tells us that solely having new information available does not mean there will be uptake (McFayden et al., 2022). Preparing ahead of launch will allow fire management agencies to better position themselves to benefit from WildFireSat. In this presentation we discuss (1) knowledge exchange in fire management (2) an assessment of the readiness of Canadian fire management agencies to integrate WildFireSat and (3) guidance for reducing readiness gaps. This will be a joint presentation with presenters from the WildFireSat mission team and the Government of the Northwest Territories.

Keywords— satellite, wildfire, forest fire, fire management, smoke forecasting, air quality, situational awareness, suppression, fire intelligence.

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BURNED AREA MAPPING USING SCATTERING SPECTRUM INFORMATION FROM FULL POLARIMETRIC ALOS-2 SAR DATA

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Proposed topic for the paper: SAR Polarimetry
Presentation preference: Oral

The world has witnessed many devastating wildfires in recent years due to human-induced climate change [1]. According to the National Wildland Fire Situation Report, there were 5,449 forest fires in Canada, with a 10-year average of 5,900 annually. The total burned area recorded by the Canadian Interagency Forest Fire Centre was 1,610,216 ha in 2022. Identification of fire location and extent, especially with SAR's unique weather-resilient ability, offers unique potential to support firefighting operations including prevention, preparedness, response and recovery. Moreover, information on the progression of burnt areas supports enhanced decision making for wildfire emergency response, by improving situational awareness. In this regard, optical sensors such as MODIS, VIIRS, Sentinel-2, and Landsat are often used for preliminary mapping and boundary identification of burned areas [2]. However, dense cloud cover over forests freqeuntly makes it impossible to get information about conditions on the ground. As a result, Synthetic Aperture Radar (SAR) data are used in wildfire mapping [3]. Tanase et al. [4] investigated the sensitivity of multifrequency X-, C- and L-band SAR data for burn severity estimation. Later different orthonormal projections of covariance information obtained from SAR data were utilized to reduce target characterization ambiguities [5, 6]. Dey et al., [7] have proposed a spectrum analysis of the target scattering parameter by projecting the coherency matrix onto different non-orthogonal scattering mechanism bases. This polarimetric spectrum is sensitive to the geometry of the targets and can be a highly effective technique for target characterization and classification. This study utilizes this polarimetric spectrum to detect burned forest areas using ALOS-2 full polarimetric L-band data captured on May 28, 2016 over Fort McMurray, Province of Alberta, Canada which burned in 2015. The random forest classifier produced $85\,\%$ overall accuracy, which is $10\,\%$ higher than using the only three eigenvalues of the coherency matrix ($\mathbf{T}_3$). The classified map using the polarimetric spectrum after a post-processing step and the ground truth map are shown in Fig. 1.

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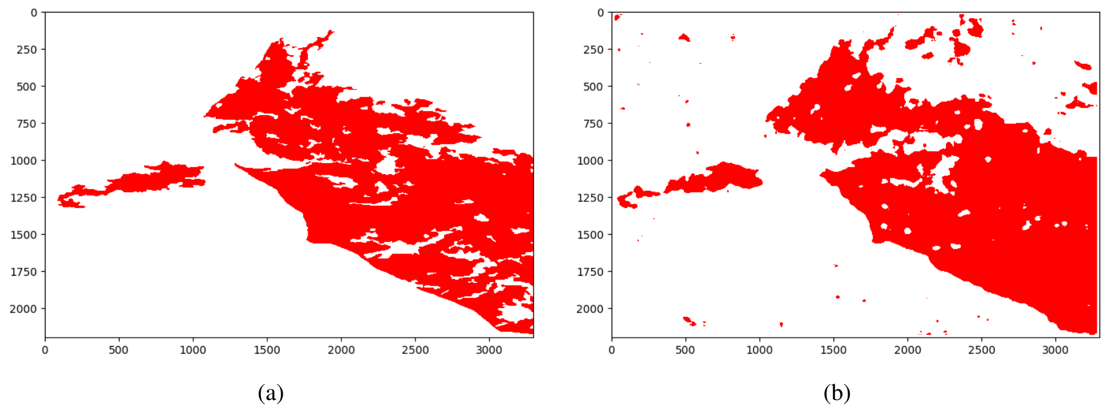

Fig. 1: (a) Ground truth image and (b) The classified image of the burnt area using the polarimetric spectrum. The red pixels depict the burnt area.

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B.C. MINISTRY OF FORESTS – USING REMOTE SENSING TO IMPROVE PROVINCIAL HARVEST MONITORING

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ABSTRACT

The Forest Analysis and Inventory Branch (FAIB) of British Columbia's Ministry of Forests is responsible for the inventory and continuous monitoring for growth and disturbance of nearly 60 million ha of forested lands. The standard forest inventory program - vegetation resources inventory (VRI) predominately uses aerial photography and ground sampling to estimate forest cover attributes such as height, species composition, diameter at breast height (dbh), volume, and trees per ha. Since the VRI is used to inform annual allowable cut determinations made by the province's Chief Forester, it is necessary to project annual forest growth and make annual updates to the VRI to account for stand replacing disturbances (i.e. harvest and wildfire). When it comes to harvest monitoring, the province relies heavily on licensee reporting of harvest activities. However, these data can be temporally imprecise, with reported disturbance start and end dates not always representative of when harvest activities took place. Additionally, the submission and integration of the information into the provincial database can be delayed by up to 18 months due to the large of volume of data and submission deadlines.

Traditionally, FAIB has relied on two-date change detection during the summer season to identify harvested areas throughout the province. However, this approach can be data intensive and provides an incomplete picture of harvest activity because individual scenes are used, with any missed harvest captured in the following year. Annual time-series methods that leverage cloud-based data and algorithms such Landtrendr (Kennedy et al., 2010) have shown considerable improvement, capturing more harvest area than two-date change detection. However, similarly to the two-date change detection, harvest activity that occurred in the late fall/winter months is assigned to the subsequent year (i.e. harvest that occurred in November 2021 will be assigned a harvest year of 2022). Though this is acceptable for updating the VRI, as we are more interested in harvest extent than exact timing, recently it has become apparent that timely and accurate disturbance dates are necessary for supporting forest management decision making. As a result, we investigated a number of sub-annual, time-series change detection methods including Continuous Change Detection and Classification (CCDC), Breaks for Additive Season and Trend (BFAST), and simple tracking of spectral indices within individual forested areas of interest (Verbesselt et al., 2010; Zhu & Woodcock, 2014). Using, CCDC and provincial permit data we have successfully produced quarterly harvest maps, allowing us to improve our understanding of harvest timing throughout the province.

This work serves as an update on the harvest monitoring activities of the Forest Analysis and Inventory Branch of British Columbia's Ministry of Forests. With the wider availability of cloud-based data and tools such as Google Earth Engine, introduction of new sensors (e.g. Landsat-9), combined with increased need for sub-annual monitoring, substantial gains have been made in the uptake of satellite multispectral imagery and time-series algorithms for forest inventory. However, harvest tracking in near real-

time remains a priority for the organization, and we will discuss opportunities and potential challenges for this work.

Keywords— forest inventory, British Columbia, multispectral, time-series, disturbance, change detection

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