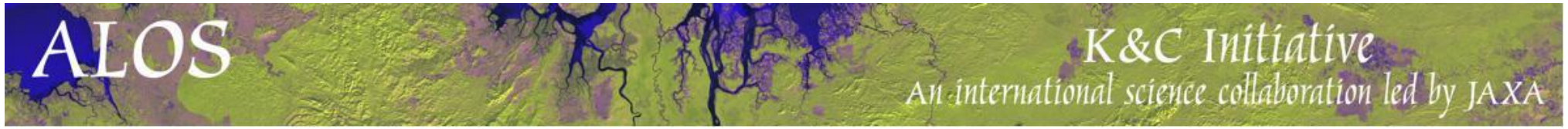


KC#27 Project Report

Wildfire Predictive Services -- Fuel Type Layers

Ashlin Richardson
BC Wildfire Service
Predictive Services Unit
Province of British Columbia

Hao Chen *- CFS/NRCAN*
Andre Beaudoin *– CFS/NRCAN*
Lucio Mascolo *– Global Change Unit, U. Valencia*
Subhadip Dey *– Indian Institute of Technology, Kharagpur*

K&C Science Team meeting #27
Tokyo, Japan, September 9-10, 2023

EORA3 Project Team

Co-I:

Hao Chen – CFS (Canada)
Andre Beaudoin – CFS (Canada)
Armando Marino – Uni. Stirling (UK)
Subhadip Dey – IIT Kharagpur (India)
Lucio Mascolo – Uni. Valencia (Spain)

Project outline and objectives

Project objectives

Project area(s) – its geographic location(s) and special characteristics.

Indicate how the project aims to supported one or more of *the 4 K&C thematic drivers* (**C**arbon cycle science, **C**limate Change, International **C**onventions, Environmental **C**onservation)

Project objectives: w L-band JAXA SAR

1. **Immediate goal: Improve situational Awareness**
- NRT fire perimeter/extent mapping w Quad-pol SAR
- Fire behaviour simulations need accurate, current fire extent
- Moisture / Drought Code ("DC") and other Fire weather data req'd
- Improve safety & effectiveness

2. **Intermediary: Help Predict where fires will go next**
- Fire behaviour simulations require "Fuel Type" maps (plus with topography, fire weather, etc.) as inputs
- E.g. Canadian Forest Fire Behaviour Prediction System (FBP) Fuel-type classes! (O= grass, C=conifer, D=deciduous etc)
- More general: Forest Inventory classes, continuous forest attributes
- I.e. continuously updating inputs for Canadian FBP system!

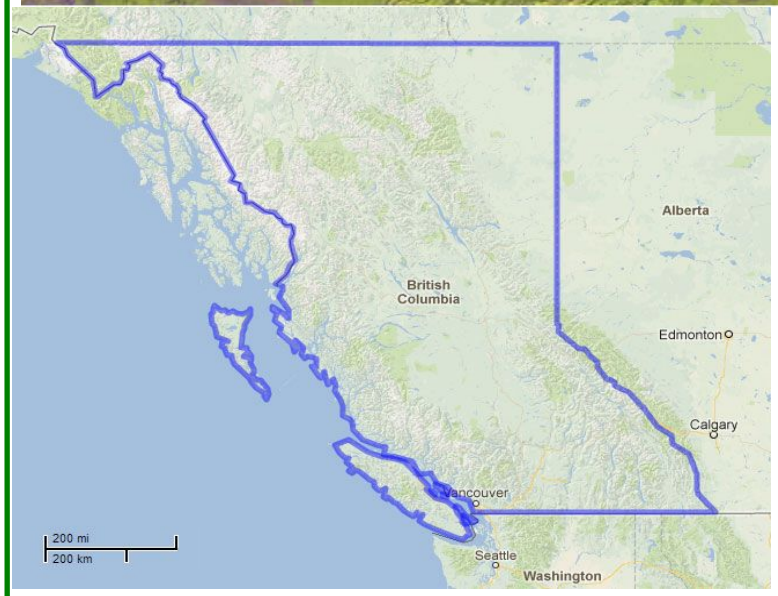
3. **General/ long-term:**
- Anticipate risk areas/ forest fires before they start
- Technical: move towards full "time-series PolInSAR" approach
- Co-supervise PhD student

K&C Thematic Drivers

- **Carbon cycle science**
  - Burn severity currently under investigation by CFS partners
  - Preferred data (Time-series L-band fully polarimetric data) can support biomass/carbon change accounting updates as well
- **Climate Change:** continuous mapping to support improving
  - mitigation,
  - preparedness/prevention,
  - response,
  - and recovery

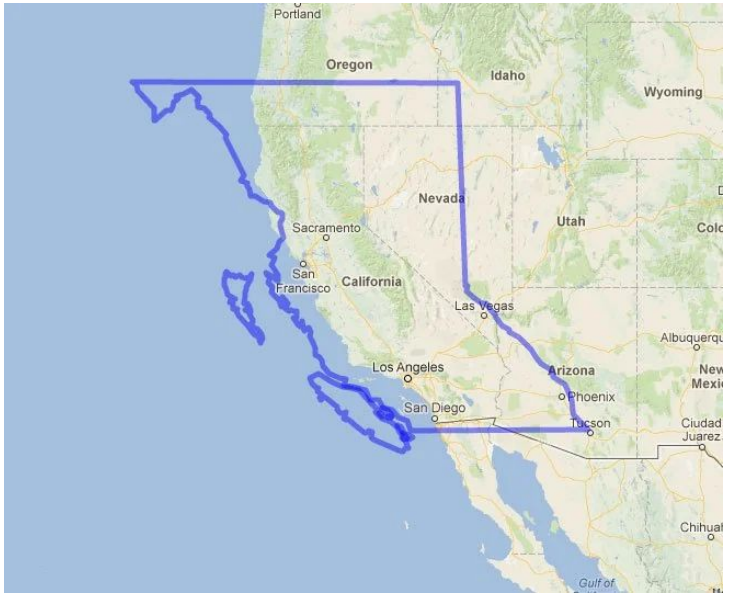
Use satellite to extend Fire Weather data from points to landscape!

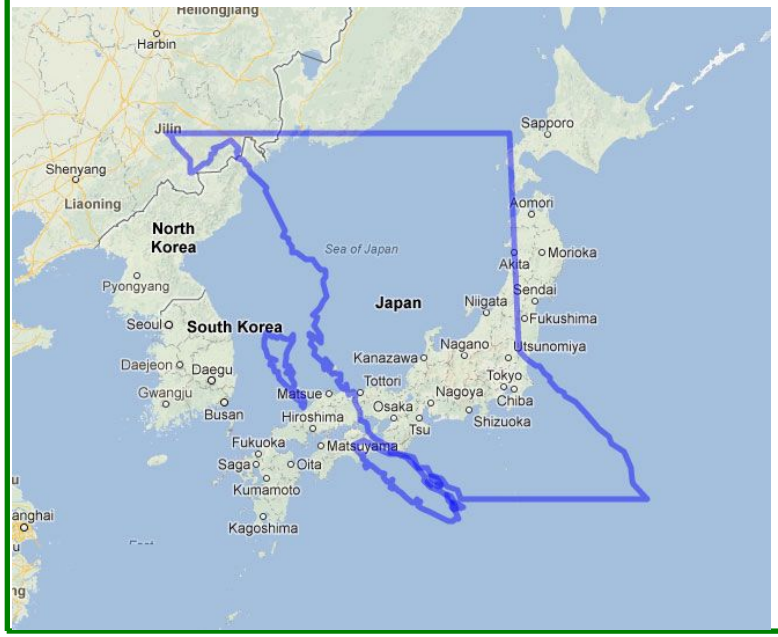
- **International Conventions**
  - UNFCCC / Land Use, Land-Use Change and Forestry (LULUCF)
- **Environmental Conservation**
  - Forest change/ parameters supportive of more conservative NRM decisions



Project area & context

- Province of British Columbia (BC)
- And/or where fully-polarimetric JAXA L-band SAR data are available E.g.:
  - Alberta (AB)
  - North West Territories (NWT)
- 2023 fire season
  - unprecented

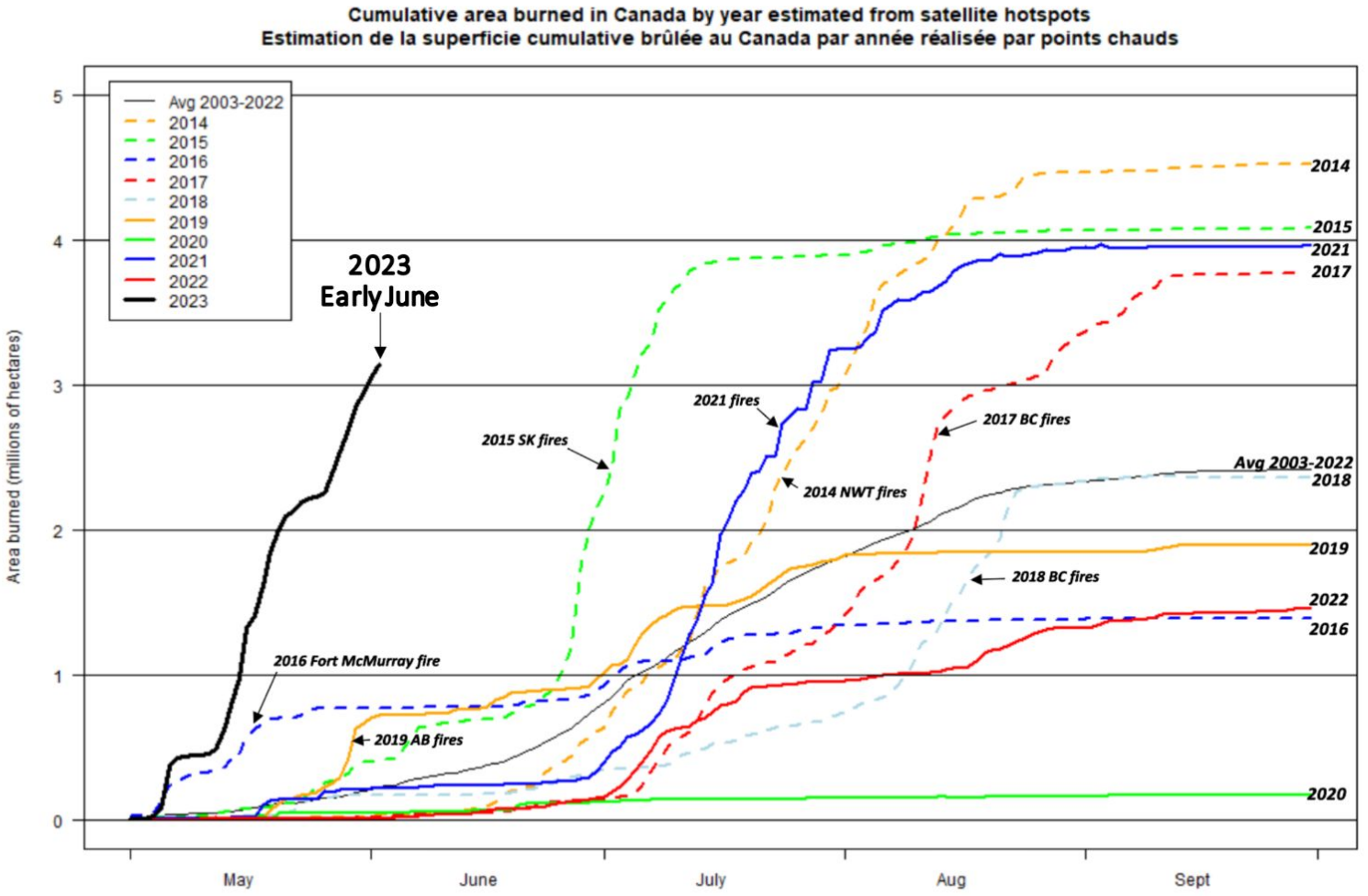




2023 Area burned Canada

Area burned

- Canada is experiencing an unprecedented amount of fire activity for this early in the wildfire season.
- The rate of increase of area burned to date is high.
- If this rate continues, we could exceed the largest total ever recorded in Canada.

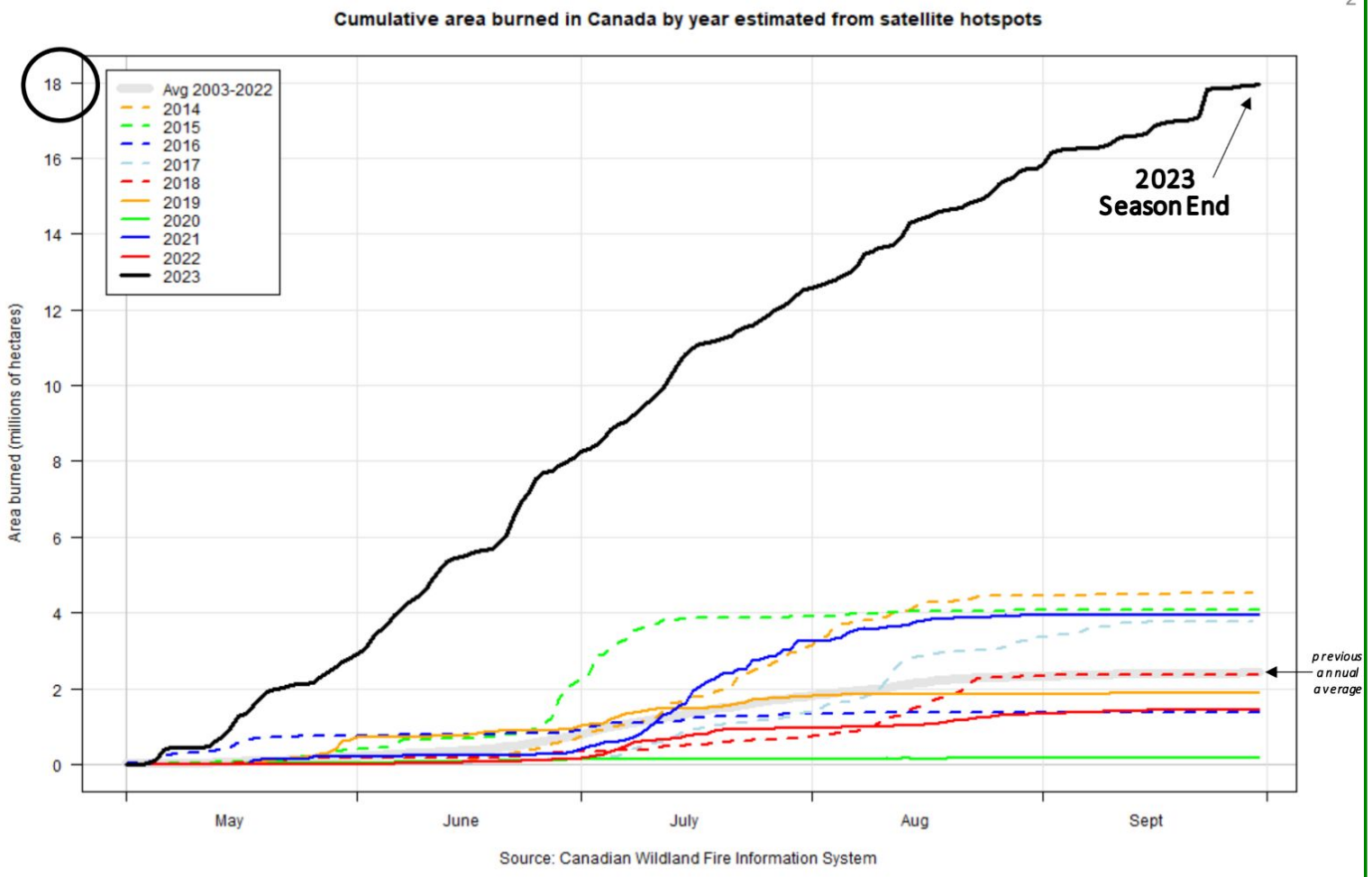


Source: Canadian Wildland Fire Information System / Système canadien d'information sur les feux de végétation

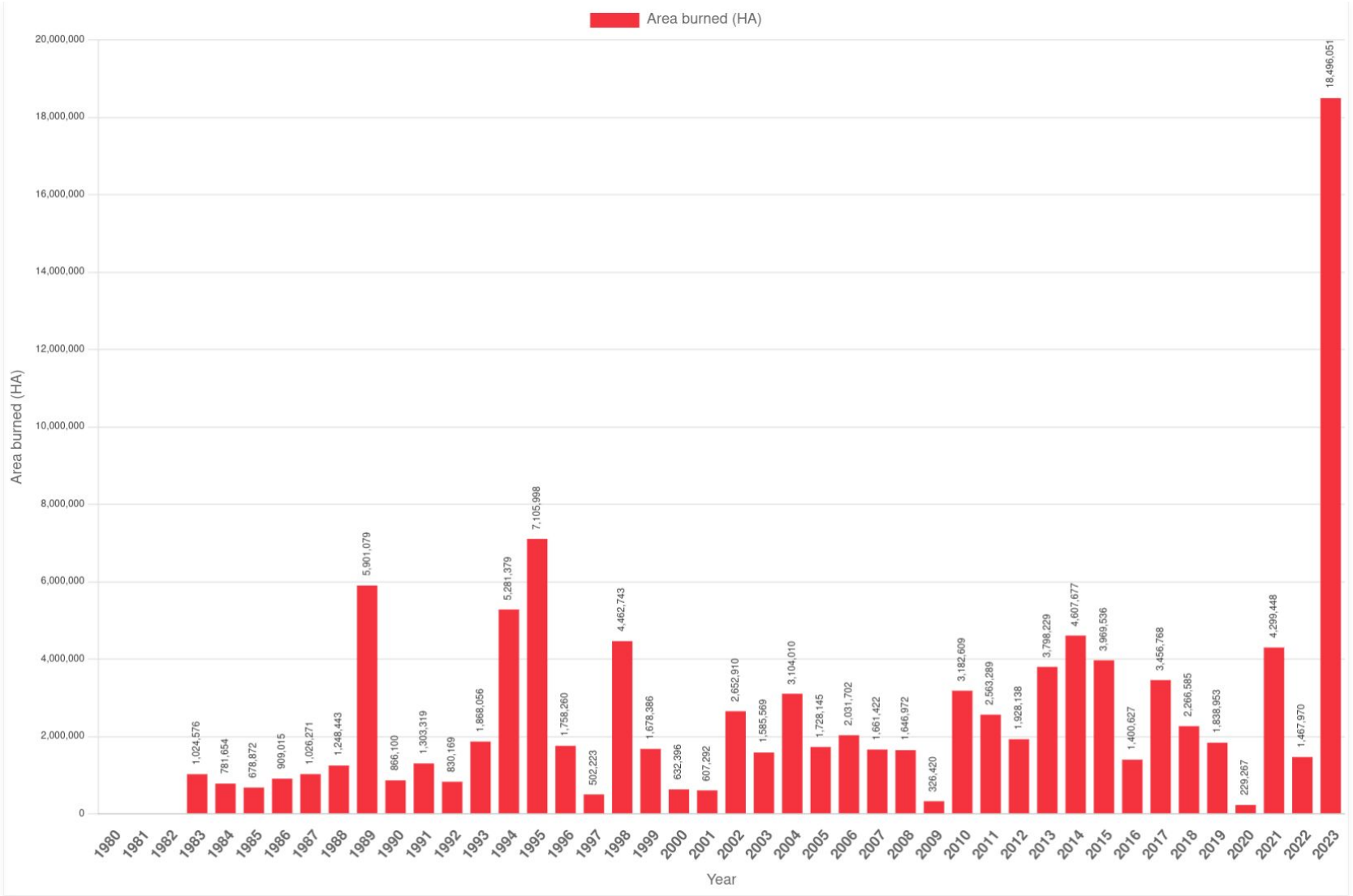
2023 Area burned Canada

Area burned

- Canada experienced an unprecedented amount of fire activity this wildfire season.
- The spring fire season started out notably early and began to break records for area burned, large fires, evacuations, and smoke impacts.
- Total area burned reached a record 18 million hectares (more than half the size of Europe).



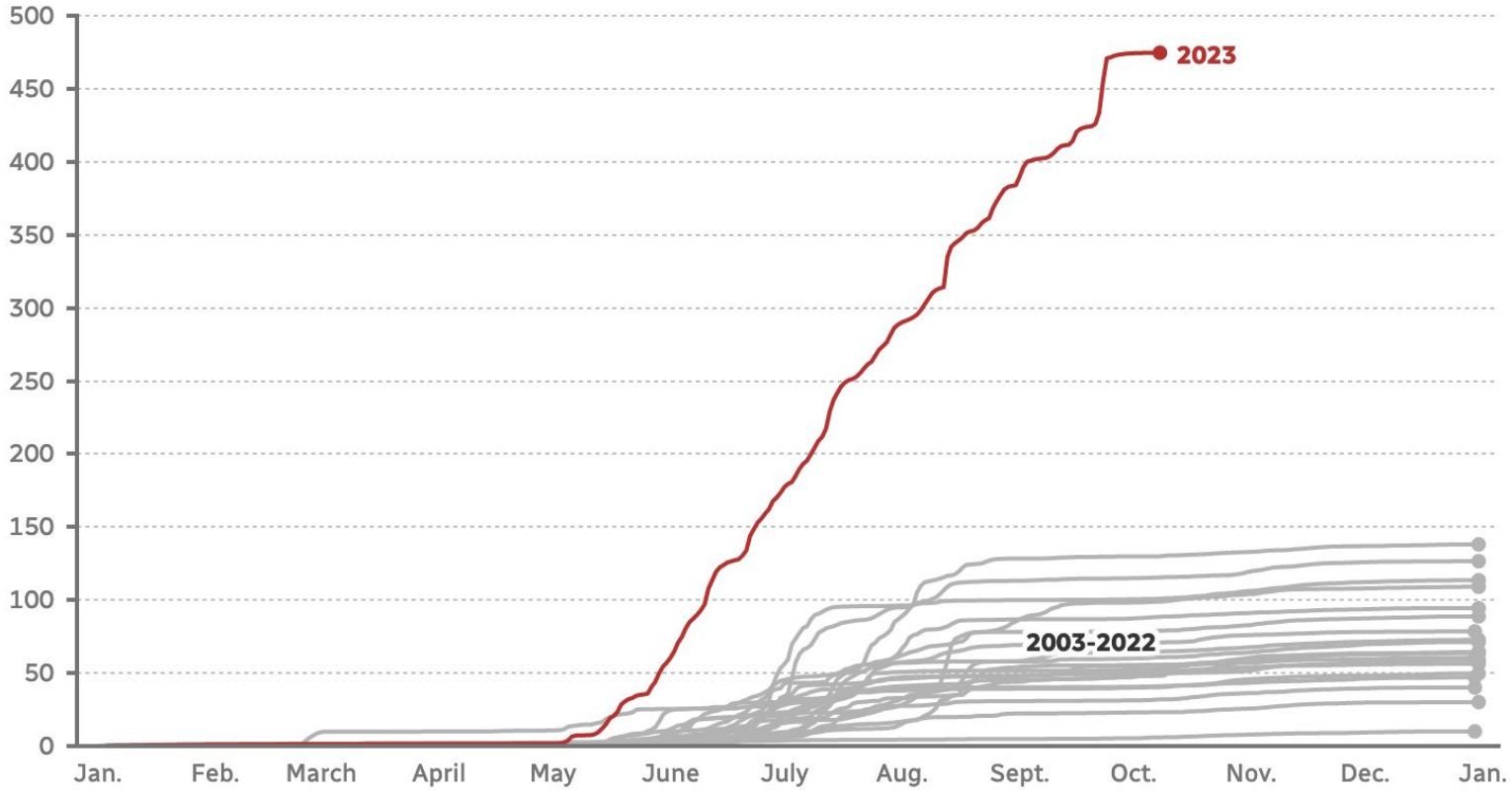
Annual burned area in Canada



Carbon emissions

The amount of emissions from wildfires this year is close to triple the previous annual record

Cumulative amount of carbon emissions from wildfires in Canada (megatonnes)



Source: Copernicus Atmosphere Monitoring Service (Graeme Bruce/CBC)

Workplace fatalities

B.C. wildfire fighter, 19, died after being hit by falling tree while responding to blaze: RCMP

Devyn Gale was clearing brush with her team when tree fell, police say

Rhianna Schmunk · CBC News · Posted: Jul 14, 2023 11:09 AM PDT | Last Updated: July 14

4 B.C. wildfire fighters dead in Hwy 1 crash west of Kamloops: police

Subcontractors were driving home from fighting fires when their pickup hit a semi near Walhachin, B.C.

Karin Larsen · CBC News · Posted: Sep 20, 2023 1:40 PM PDT | Last Updated: September 20

British Columbia

25-year-old from Ontario identified as wildfire fighter killed in B.C.

Zak Muise was from Waterford and called a vital member of his crew in online tribute

The Canadian Press · Posted: Aug 01, 2023 9:08 PM PDT | Last Updated: August 2

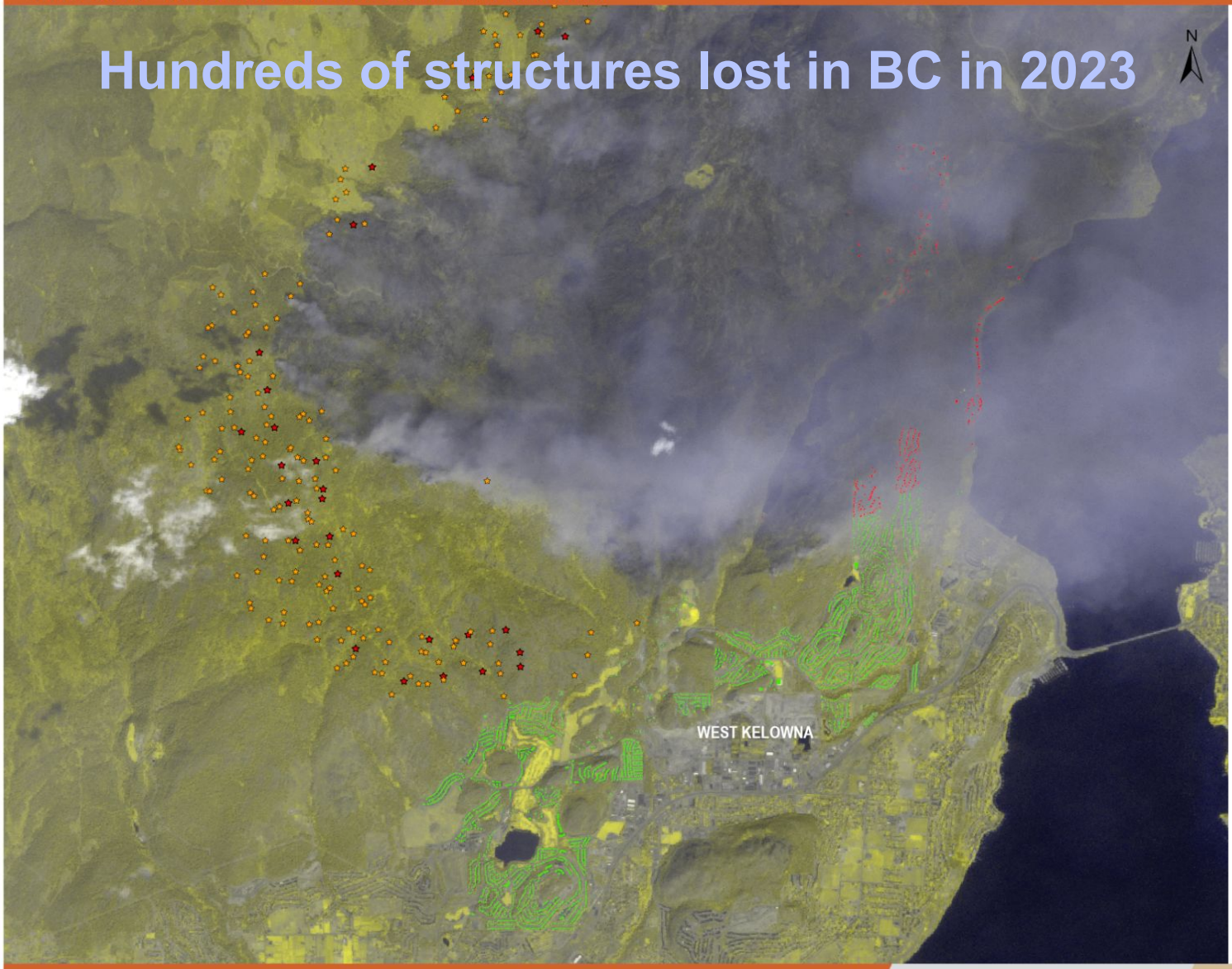
Wildfire damage assessment - McDougall Creek Wildfire
Évaluation des dommages d'incendies – Incendie McDougall Creek

PEACHLAND, CA-BC
NTS / SNRC 082E13

2023-08-18 18:42:49 UTC / 2023-08-18 11:42:49 Local

119° 34' 54" W / 49° 52' 39" N

Hundreds of structures lost in BC in 2023



Hotspots last 24 hrs /
Foyers d'incendie des dernières 24 heures.

- 0 to/à 6 h
- 6 to/à 12 h
- 12 to/à 24 h

Building footprint affected / Empreinte de bâtiment touchée.

- Yes / Oui
- No / Non

+500 building footprints potentially affected /
+500 empreintes de bâtiments potentiellement touchées.

0 2 4 km

Produced by the Canada Centre for Mapping and Earth Observation, Natural Resources Canada, August 20, 2023. Damage assessment derived from PlanetScope imagery with systems developed and operated by the Department of Natural Resources Canada. © All rights reserved.

Produit par le Centre canadien de cartographie et d'observation de la Terre, Ressources naturelles Canada, le 20 août 2023. Les produits d'évaluation des dommages d'incendies sont réalisés à partir d'images PlanetScope, à l'aide d'un système mis au point et exploité par le Ministère des Ressources naturelles du Canada. © Tous droits réservés.

Building footprints obtained from the City of West Kelowna. / Empreintes de bâtiments obtenues de la Ville de West Kelowna.

Natural Resources Canada Ressources naturelles Canada

Canada

PlanetScope 3m

Results and significant findings

Describe project outcomes and significant findings
(several slides OK!)

Comments and suggestions to JAXA (if any)

CSA ASAR MEETING Nov 2023

BENEFITS OF L-BAND PALSAR-2 QUAD-POL INDICES VS. BACKSCATTER FOR MAPPING FOREST STRUCTURAL ATTRIBUTES IN NORTHWEST TERRITORIES, CANADA

André Beaudoin[1], *Hao Chen*[2], *David Correia*[1], *Ash Richardson*[3]

[1] Natural Resources Canada, Canadian Forest Service (NRCan/CFS) – Laurentian Forestry Centre
[2] Natural Resources Canada, Canadian Forest Service (NRCan/CFS) – Pacific Forestry Centre
[3] Province of British Columbia – BC Wildfire Service (BCWS)

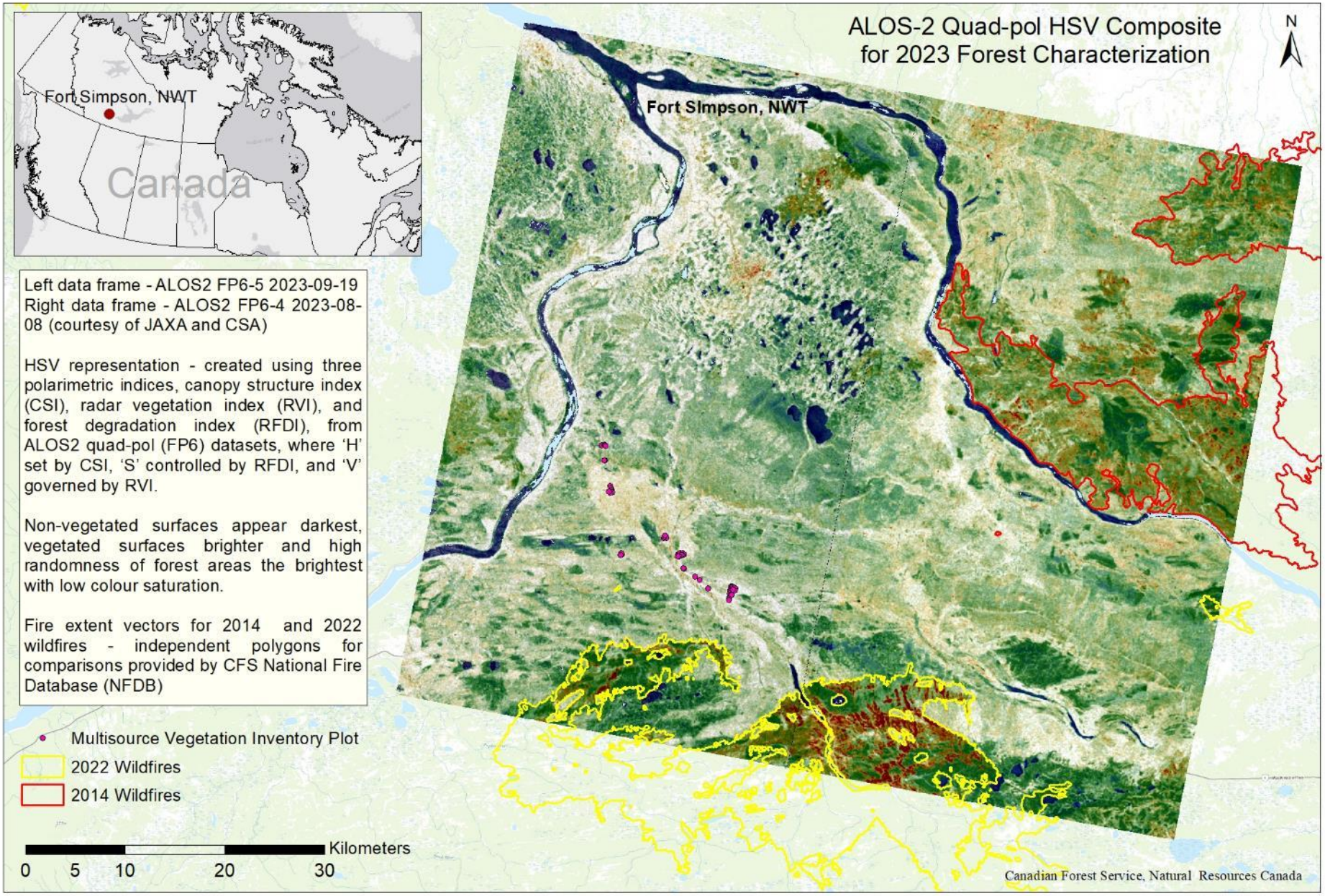
ABSTRACT

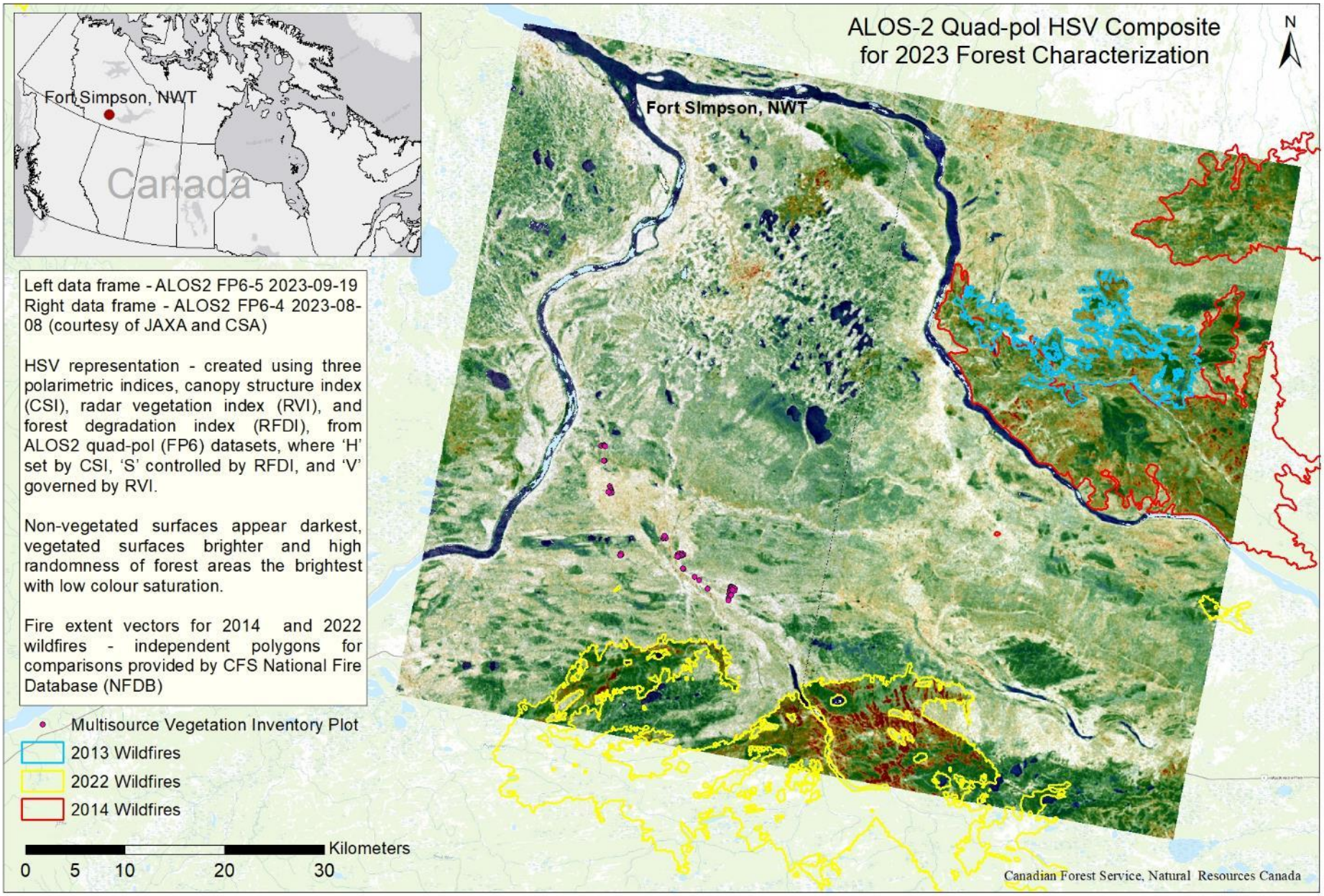
Remote sensing datasets are required to map vast and sparsely inventoried taiga forests of Northwest Territories (NWT). 30-m resolution forest inventory (FI) maps of five forest structural attributes for circa 2010 were produced over ~50% of NWT via the CFS Multisource Vegetation Inventory (MVI 1.0) project. This project demonstrated the substantial prediction improvements stemming from the combination of PALSAR-1 L-band dual-pol terrain-corrected backscatter ($DP\gamma^0$) with Landsat multispectral summer mosaics. On-going MVI 2.0 project aims at improving and updating this mapping to year 2022 and across all NWT mainland for a broad suite of forest attributes, including i) four FI attributes: crown closure, height, aboveground biomass (AGB) and percent conifer and ii) three fuel attributes: crown base height and crown fuel loads (branch and foliage AGB). MVI 2.0 is designed to use cloud-based large-area temporal compositing of Sentinel-2 (S-2) and PALSAR-2 (P-2) $DP\gamma^0$ providing predictors in machine/deep learning models trained by airborne LiDAR plots.

In this context, a data exchange agreement between CSA and JAXA as well as a research agreement between BCWS and JAXA has allowed CFS to obtain and test P-2 quad-pol (QP) datasets relative to the on-going use of P-2 DPγ^0 composite and S-2. The objective, therefore, was to assess prediction improvements of seven forest attributes when i) using multitemporal P-2 QP polarimetric indices compared to P-2 QP backscatter (QPγ^0) and to current P-2 DPγ^0 composite and ii) combining P-2 QP and S-2 composites.

We derived plot-level estimates of seven forest attributes from ~140 MVI 2.0 FI plot measurements across four NWT test-sites. We then processed temporal stacks of 11 P-2 QP images spanning multiple seasons from 2015 to 2023 to produce four QPγ^0 (HH/HV/VH/VV) and three polarimetric indices, RVI, CSI and RFDI. We summarized outputs of QP temporal stacks using temporal statistics and carried out trend analysis between P-2 QP and DP candidate predictors and forest attributes along with biophysical interpretation. Finally, we performed univariate variable selection and attribute prediction from random forest modelling using all P-2 QP and DP predictors and then combined with S-2 predictors.

Preliminary results indicated that QP RVI and RFDI indices provided for most of the time better trends and attribute predictions for five biomass-related attributes (height, total and branch AGB, percent conifer, crown base height) than any other QPγ^0 or DPγ^0 predictors. Furthermore, temporal statistics of QP indices often provided further improved predictions compared to single-date QP data. However, both QP and DP data were usually poorer predictors of foliage biomass and crown closure due to L-band high penetration depth along with vegetation scattering mostly generated from attributes related to woody biomass. When combined with S-2 data, P-2 QP indices were usually found among the best predictors for random forest predictions of biomass-related attributes, whereas a good fit was achieved with all forest attributes ($r^2 > 0.7$). These preliminary encouraging results suggest that multi-temporal ALOS-4/PALSAR-3 quad-pol acquisitions across northern boreal forests of Canada would be highly valuable in combination with multispectral S-2 and/or Landsat composites for the purpose of generating the most accurate possible maps of key forest structural attributes.


ALOS-2 Quad-pol HSV Composite
for 2023 Forest Characterization
N
Fort Simpson, NWT
Fort Simpson, NWT
Canada
Left data frame - ALOS2 FP6-5 2023-09-19
Right data frame - ALOS2 FP6-4 2023-08-08 (courtesy of JAXA and CSA)
HSV representation - created using three polarimetric indices, canopy structure index (CSI), radar vegetation index (RVI), and forest degradation index (RFDI), from ALOS2 quad-pol (FP6) datasets, where 'H' set by CSI, 'S' controlled by RFDI, and 'V' governed by RVI.
Non-vegetated surfaces appear darkest, vegetated surfaces brighter and high randomness of forest areas the brightest with low colour saturation.
Fire extent vectors for 2014 and 2022 wildfires - independent polygons for comparisons provided by CFS National Fire Database (NFDB)
Multisource Vegetation Inventory Plot
2022 Wildfires
2014 Wildfires
Kilometers
0 5 10 20 30
Canadian Forest Service, Natural Resources Canada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2013 Wildfires
2022 Wildfires
2014 Wildfires
Kilometers
0 5 10 20 30
Canadian Forest Service, Natural Resources Canada

Results and significant findings

ALOS2 FP6-4 HSV Composite 2022-08-23

High gray scale: undisturbed canopies

ALOS2 FP6-4 HSV Composite 2023-08-08

New wildfire occurred

ALOS2 FP6-4 RFDI Ratio: 20230808 / 20220823

High RFDI Ratio

Deliverables and other output

Describe planned output of your project.

- Project deliverables
- Peer-reviewed publications
  - Submit first peer-reviewed article: Feb 24 2024
- Non-peer-reviewed publications (conference papers, reports etc.)
- Other results

Non-peer reviewed comms supported

1. Wildfire Predictive Services -- Fuel Type Layers, The Joint PI Meeting of JAXA Earth Observation Missions FY2023, Tokyo, Japan, Nov 10, 2023
2. Operational Wildfire Mapping in British Columbia with Sentinel-2, Landsat & PRISMA, Ororatech International Wildfire Conference 2023, Landsberg am Lech, Germany, October 2-3, 2023
3. Operational Wildfire Mapping with Sentinel-2 and Landsat in British Columbia, 44th Canadian Symposium on Remote Sensing (CSRS), Yellowknife, Jun 22, 2023
4. Investigating Spaceborne L-Band Polarimetric SAR for Operational Wildfire Mapping in BC, 44th Canadian Symposium on Remote Sensing (CSRS), Yellowknife, Jun 22, 2023
5. Knowledge Exchange and Assessing Wildfire Management Agency Readiness for WildFireSat, 44th Canadian Symposium on Remote Sensing (CSRS), Yellowknife, Jun 22, 2023
6. Burned Area Mapping Using Scattering Spectrum Information From Full Polarimetric ALOS-2 SAR Data, ESA PolInSAR & Biomass 2023, Tolouse, France Jun 21, 2023
7. Remote Sensing Show and Tell, WildfireSat Mission Knowledge Exchange (KE) Group Meeting, Nov 29, 2022
8. All Hazards Application of RCM in BC Part 3, CSA RCM Users Forum, Nov 23, 2022
9. Mapping Forest Fires and Fuels in Canada with ALOS-2 SAR data, Joint PI Meeting of JAXA Earth Observation Missions FY2022, Nov 7-11, 2022
10. Fuel Type Mapping with Remote Sensing and Machine Learning, Wildland Fire Canada Conference, Nov 1, 2022
11. A.I. Fire Perimeter Mapping, CIFFC Geomatics Working Group meeting, Oct 12, 2022
12. All Hazards Application of RCM in BC Part 2, CSA RCM Users Forum, May 18, 2022

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

S. Dey[1], A. Richardson[2], A. Bhattacharya[3]

[1]Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur

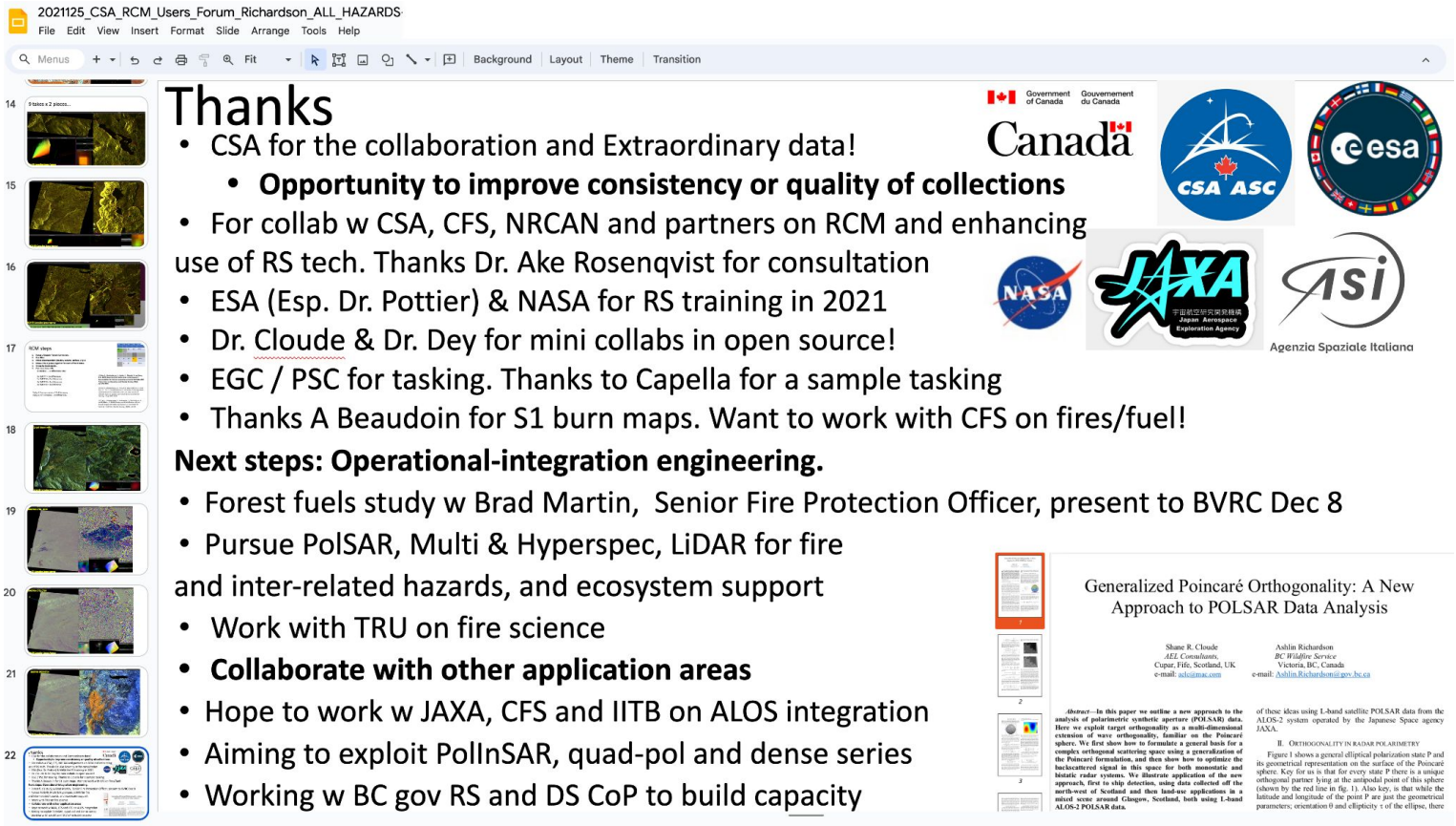
[2]British Columbia Wildfire Service, Canada

[3]MRSLab, CSRE, Indian Institute of Technology Bombay, Mumbai, India

CSA RCM Users Forum #1 20211125

Thursday, 25 November
09h00 – Opening
Users' presentations

1. Wesley Van Wychen, University of Waterloo
2. Jennifer Nafziger, Government of Alberta
3. Corey Froese, BGC Engineering
4. Robert Brewer, CGI
5. Christopher Jackson, NOAA NESDIS STAR
6. Ashlin Richardson, Government of British Columbia



CSA RCM User's Forum #2 20220518

GC users' presentations

1. Agriculture and Agri-Food Canada, Heather McNairn – *RCM applications to Agricultural Monitoring*
2. Environment and Climate Change Canada, Benjamin Deschamps – *ECCC Use of RCM Data*
3. Public Safety Canada, Cameron Bouchard – *Coordinating RCM for Emergency Management*
4. Fisheries and Oceans Canada/Environment and Climate Change Canada, William Perrie/ Mohammed Amine Bessar – *SWOT*

Users' presentations

1. Government of British Columbia, Ashlin Richardson – *All Hazards Application of RCM in BC part 2*
2. C-CORE, Sherry Warren – Icebergs, Ice and Slicks – *Near Real Time RCM Services offered by C-CORE*
3. Dromadaire Géo Innovations, Stéphane Hardy – *DGI : un utilisateur de RCM !*
4. Skywatch, Luis Veci – *SNAP Demonstration*

International partners presentations

1. European Space Agency, Ciro Manzo – *Radarsat Constellation Mission support to Earth Observation activities of the EU Space Programme*
2. Japan Aerospace Exploration Agency, Sobue Shin-ichi
3. NASA Goddard Space Flight Center, James B. Garvin – *Monitoring the evolution and destruction of a small volcanic island in Tonga from Radarsat:*
4. NOAA National Environmental Satellite, Data, and Information Service, Christopher Jackson – *Great Lakes Ice and Red River Flooding*

PALSAR/PALSAR-2 data access

Please list the PALSAR/PALSAR-2 data you have

(1) requested and (2) obtained.

(1) “Dense” Quad-pol sequence

(2) Various one offs/ before + after pairs (Canada: BC, AB, NWT)

One “sparse” sequence (Fort Mac): old, not the right ecosystem type, already analyzed

Have you had sufficient data to complete your research (according to your K&C agreement)?

If not, which key data sets are missing? **Very little recent Quad-pol**

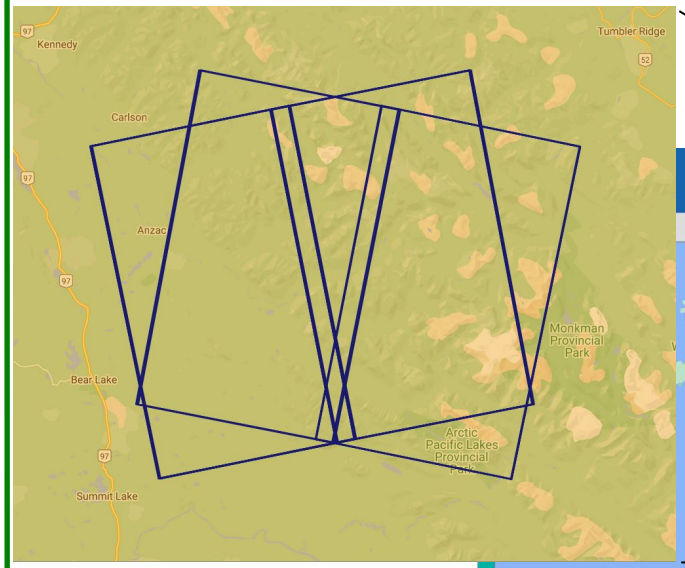
(1) “Dense” Quad-pol time series over fire / fire prone area

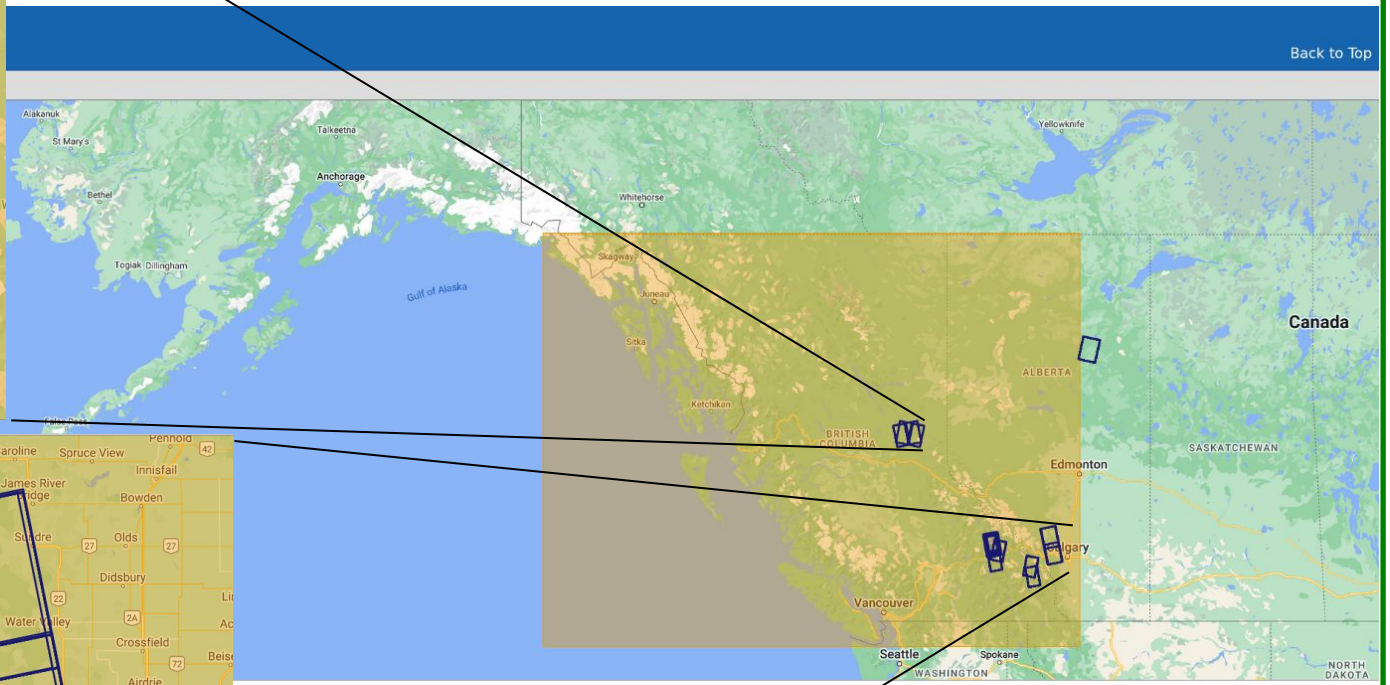
E.g. 24-48 frames? Preferred spring/summer/fall + InSAR compatible

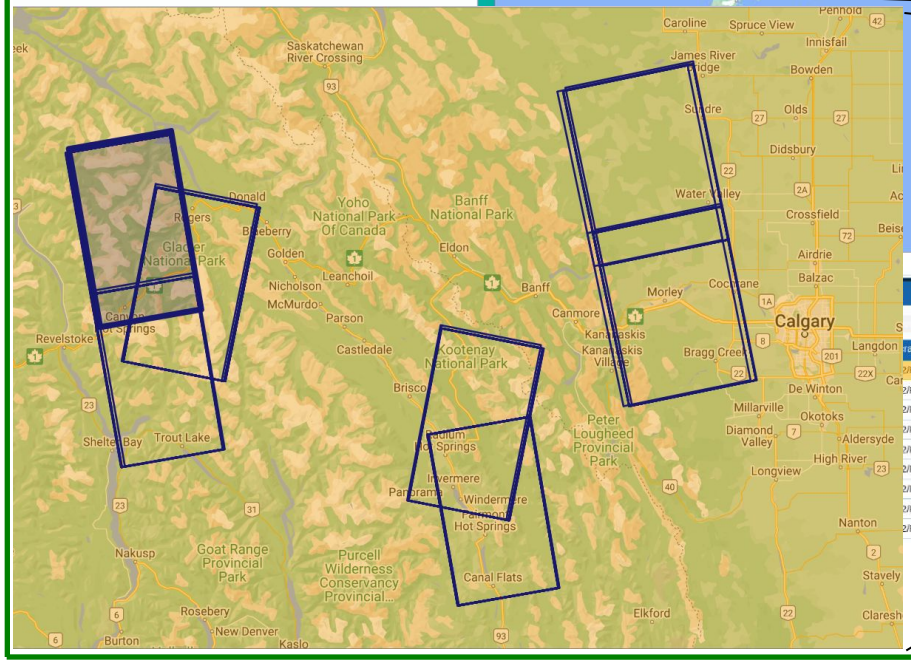
ALOS

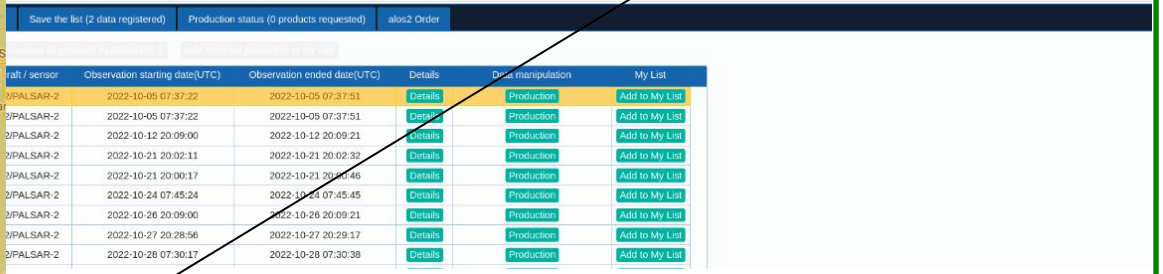
K&C Initiative
An international science collaboration led by JAXA

QP coverage 20220101 - 20231102









Save the list (2 data registered) | Production status (0 products requested) | alos2 Order

raft / sensor	Observation starting date(UTC)	Observation ended date(UTC)	Details	Data manipulation	My List
2/PALSAR-2	2022-10-05 07:37:22	2022-10-05 07:37:51	Details	Production	Add to My List
2/PALSAR-2	2022-10-05 07:37:22	2022-10-05 07:37:51	Details	Production	Add to My List
2/PALSAR-2	2022-10-12 20:09:00	2022-10-12 20:09:21	Details	Production	Add to My List
2/PALSAR-2	2022-10-21 20:02:11	2022-10-21 20:02:32	Details	Production	Add to My List
2/PALSAR-2	2022-10-21 20:00:17	2022-10-21 20:00:46	Details	Production	Add to My List
2/PALSAR-2	2022-10-24 07:45:24	2022-10-24 07:45:45	Details	Production	Add to My List
2/PALSAR-2	2022-10-26 20:09:00	2022-10-26 20:09:21	Details	Production	Add to My List
2/PALSAR-2	2022-10-27 20:28:56	2022-10-27 20:29:17	Details	Production	Add to My List
2/PALSAR-2	2022-10-28 07:30:17	2022-10-28 07:30:38	Details	Production	Add to My List

Where to collect future QP data?

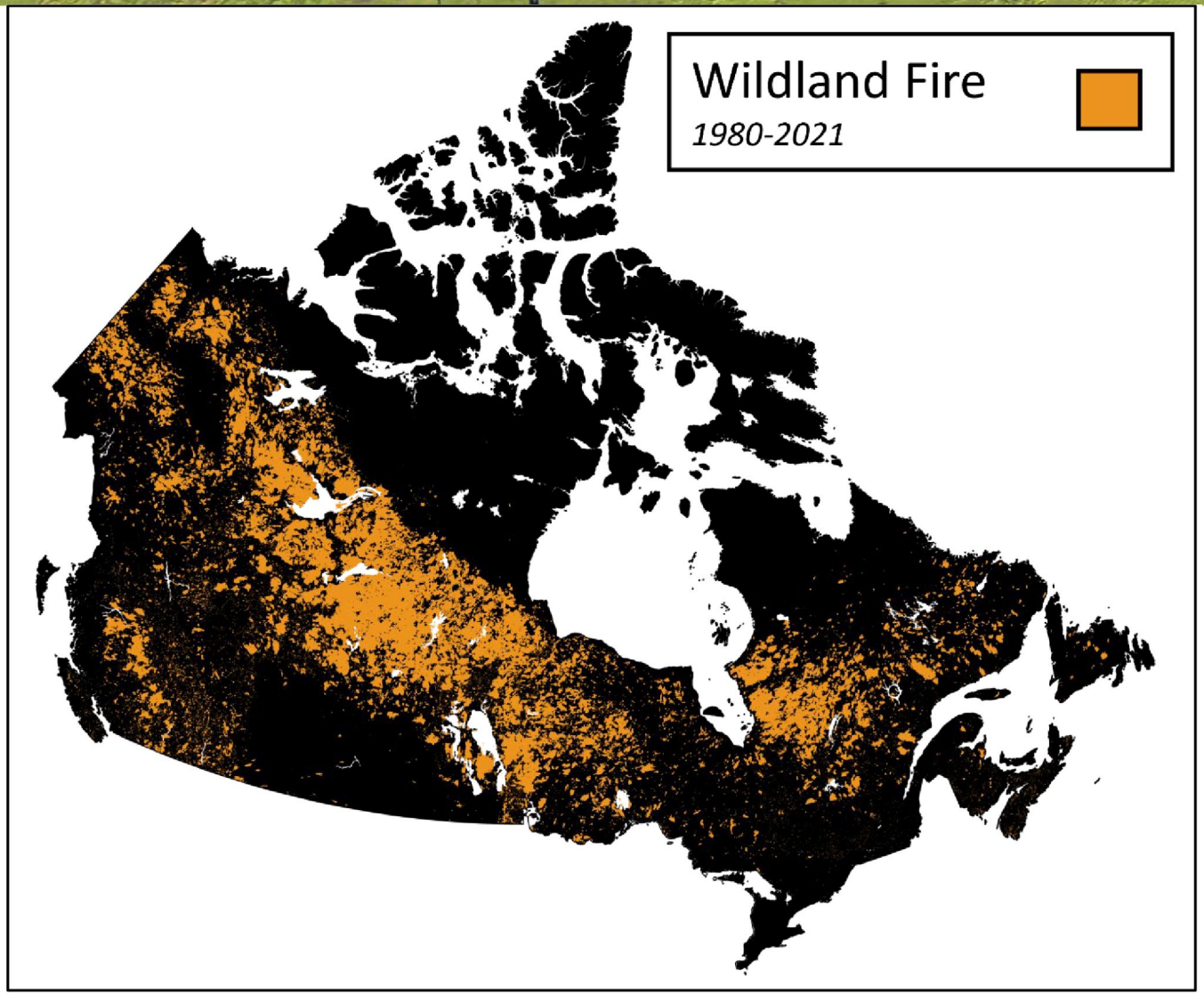


Figure 3. The area burned in Canada between 1980 and 2021; data from the National Fire Database (Canadian Forest Service 2021a) and the National Burned Area Composite (Canadian Forest Service 2021b).

Where to collect future QP data?

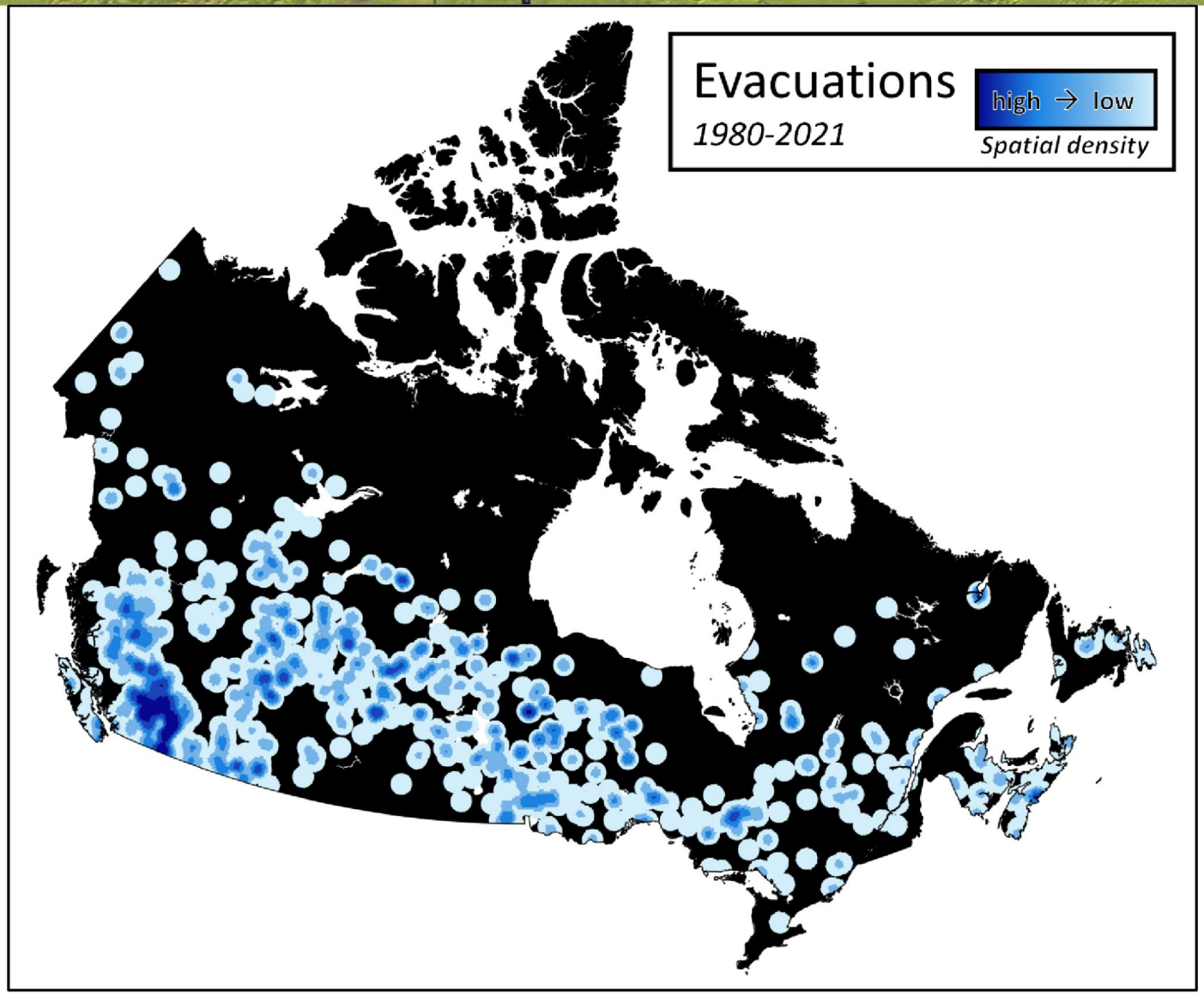


Figure 5. Location of evacuations due to wildland fire between 1980 and 2021, with darker blue indicating more evacuations in that area (data from Canadian Forest Service 2021c).

Comments to JAXA: Data Collection

- DP is baseline dependent: Quad-pol much less dependent on baseline!
- Very little QP coverage in BC since the first few years mission?
  - More data required to verify scaling of methods
- Unsure if existing data is appropriate use of Quota
  - Have requested CSA access to the L-band data JAXA is sharing to CSA (the portion over British Columbia) thank you Shinichi-san
  - If we get access from CSA, we can query this data from Canada's EODMS system

- Hope JAXA can increase Quad-pol collection to continue their setting a higher standard for data
  - JAXA can be the unique go-to "reference data" for NISAR, etc
  - DP too low-dimensional for synergy with Optical / multispectral
  - Fewer modes the better: more quad-pol?
  - Foresters and other "boots on the ground" will be discouraged from Radar until Quad-pol is the new "normal"

General comment

- Canada has 10% of the world's forests; Top 5 / Top 3 w.r.t. forest cover
- Extreme fire activity suggests forestry in Canada is neither renewable, nor sustainable at present?
- Why are Canadian forests not internationally observed to the same standard as Tropical forests?

Country	1990	2000	2010	2020
Russia	808,950	809,269	815,136	815,312
Brazil	588,898	551,089	511,581	496,620
Canada	348,273	347,802	347,322	346,928
United States	302,450	303,536	308,720	309,795
China	157,141	177,001	200,610	219,978
Australia	133,882	131,814	129,546	134,005
Democratic Republic of the Congo	150,629	143,899	137,169	126,155
Indonesia	118,545	101,280	99,659	92,133
Peru	76,449	75,298	74,050	72,330
India	63,938	67,591	69,496	72,160

B.C. timber industry in throes of change, as premier warns of 'exhausted forests'

By The Canadian Press
Dec 22, 2022

B.C. government looking to "get serious" about sustainability of timber supply

Debris is cleaned up in the forest near the Penticton Indian Band in southern B.C. Photo: APTN file

British Columbia's forest sector has "never been under greater stress," Premier David Eby says.

There is an "inescapable recognition that change is needed to ensure our forest industry is sustainable," he writes in his mandate letter for the new forests minister, Bruce Ralston.

Eby's letter to the minister of water, land and resource stewardship, Nathan Cullen, meanwhile, says "short-term thinking" in land management has led to "exhausted forests."

The new premier's pointed language to his ministers highlights how British Columbia's forests sector is in the throes of change, as the province embarks on plans to "modernize" how forests are managed amid ecological concerns, fluctuating lumber prices and dwindling supply of trees for harvesting.

Bob Simpson, who served as mayor of Quesnel, B.C., a longtime forestry community, between 2014 and 2022, said the province's forest sector is "stuck in a time warp," carrying on with clear-cutting and exporting raw logs and lumber at a pace ecosystems and the timber supply cannot maintain.

Comments to JAXA: data Engineering

- Future need: Wish to learn about latency for direct/ programmatic access for use by Wildfire Operations in Near-real Time (NRT)

- Now: Need to Programmatically query the archive!
  - To cross reference existing data with known fire locations etc.

- Web portal crashes if too many results. Big data analyses:
  - large query support required otherwise too manual / can't generalize

The searching issue might be solved if CSA approves the request made on Nov 9 (thank you for the advice Shinichi-san)

Lucio Mascolo is a senior researcher in radar remote sensing at the University of Valencia, Spain.

https://www.linkedin.com/in/lucio-mascolo-86b894110/

https://orcid.org/0000-0002-1989-592X

https://www.researchgate.net/profile/Lucio-Mascolo

His interests include the polarimetric modeling of Synthetic Aperture Radar (SAR) data and its application to key Earth Observation (EO) topics, such as agriculture monitoring, wild-fire monitoring, etc.

Since 2022, he is the owner of the Linkedin group Polarization in Remote Sensing (https://www.linkedin.com/groups/2529322/), which now counts nearly 2000 members.

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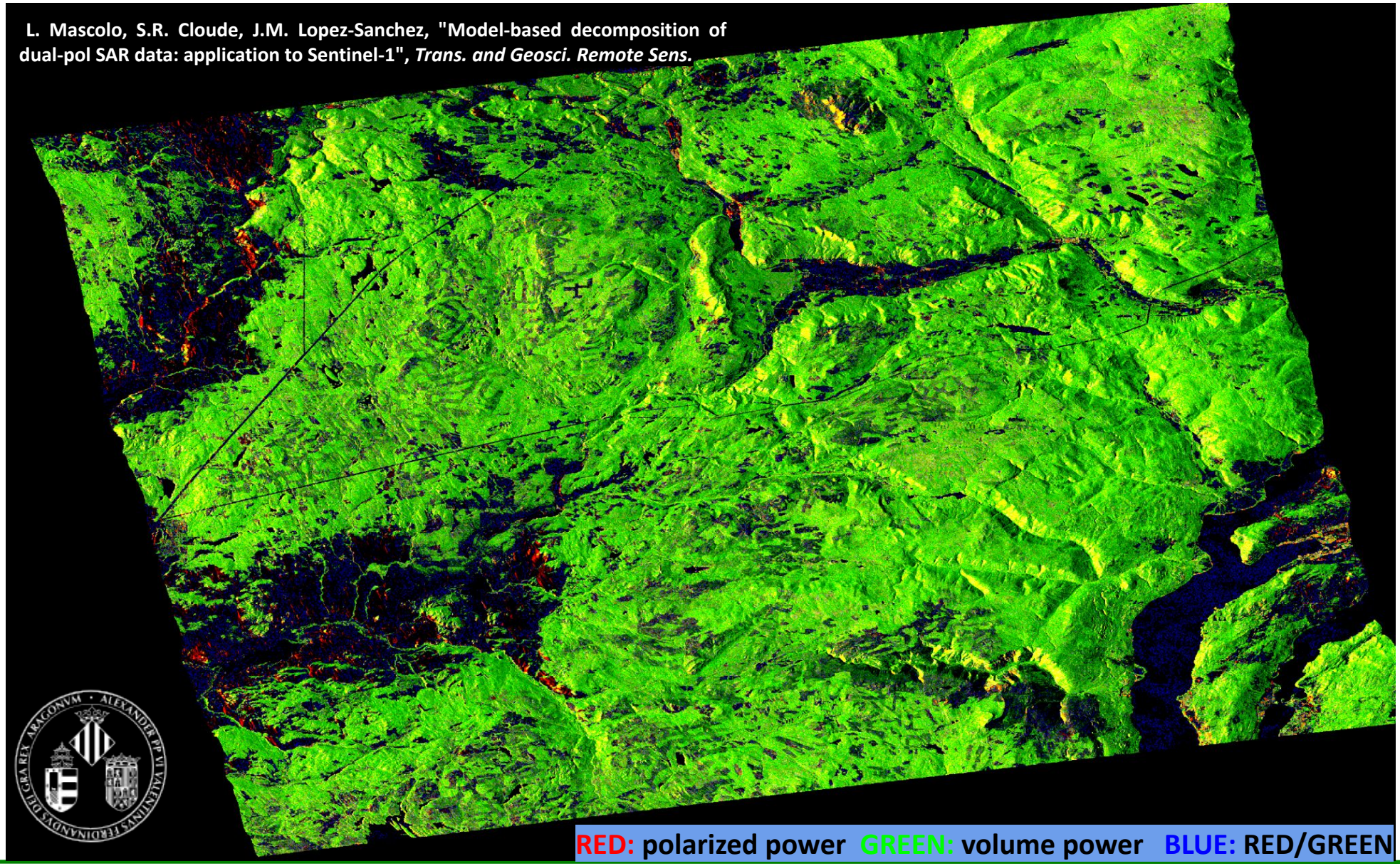
L. Mascolo, S.R. Cloude, J.M. Lopez-Sanchez, "Model-based decomposition of dual-pol SAR data: application to Sentinel-1", *Trans. and Geosci. Remote Sens.*



RED: polarized power **GREEN:** volume power **BLUE:** RED/GREEN

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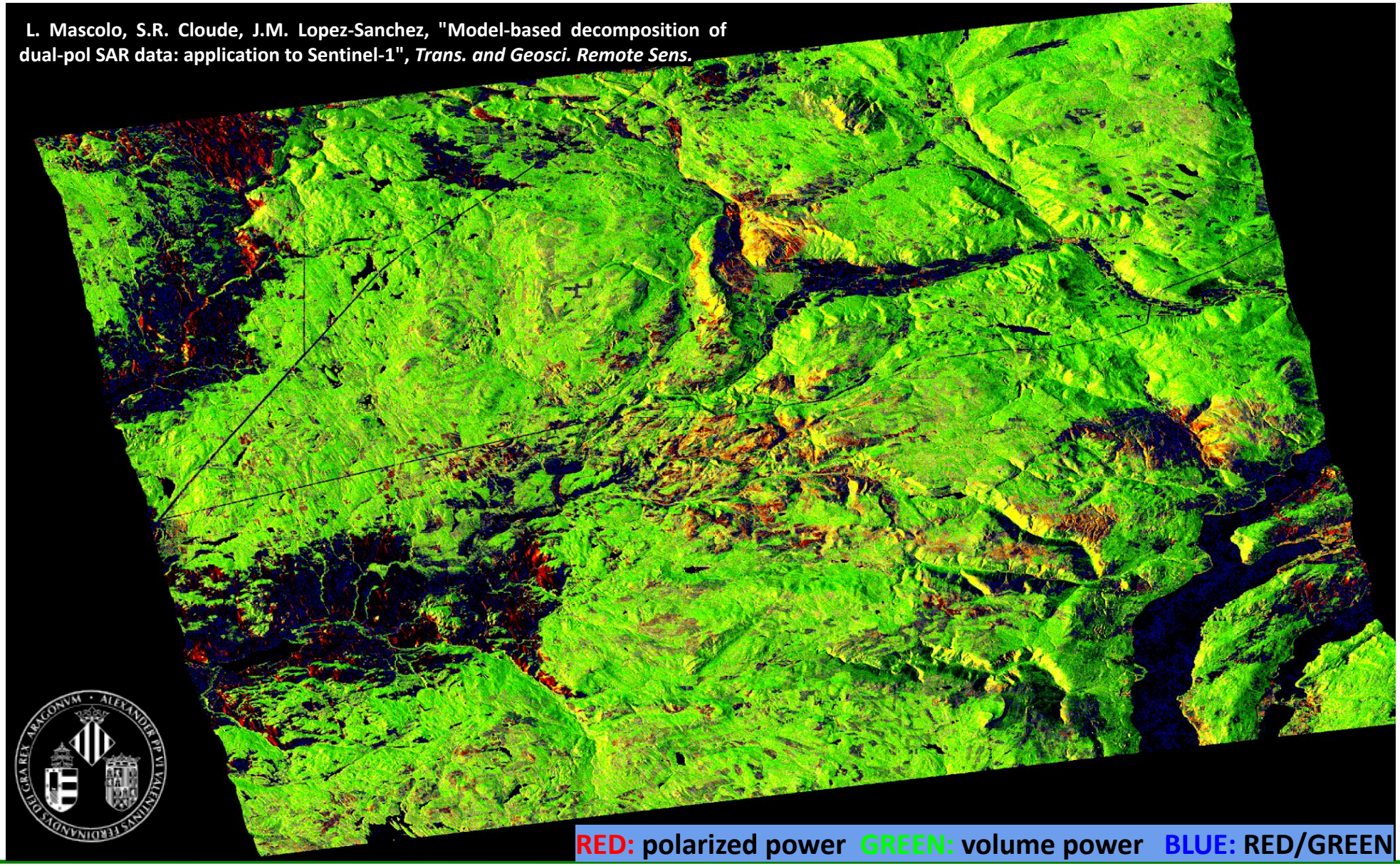
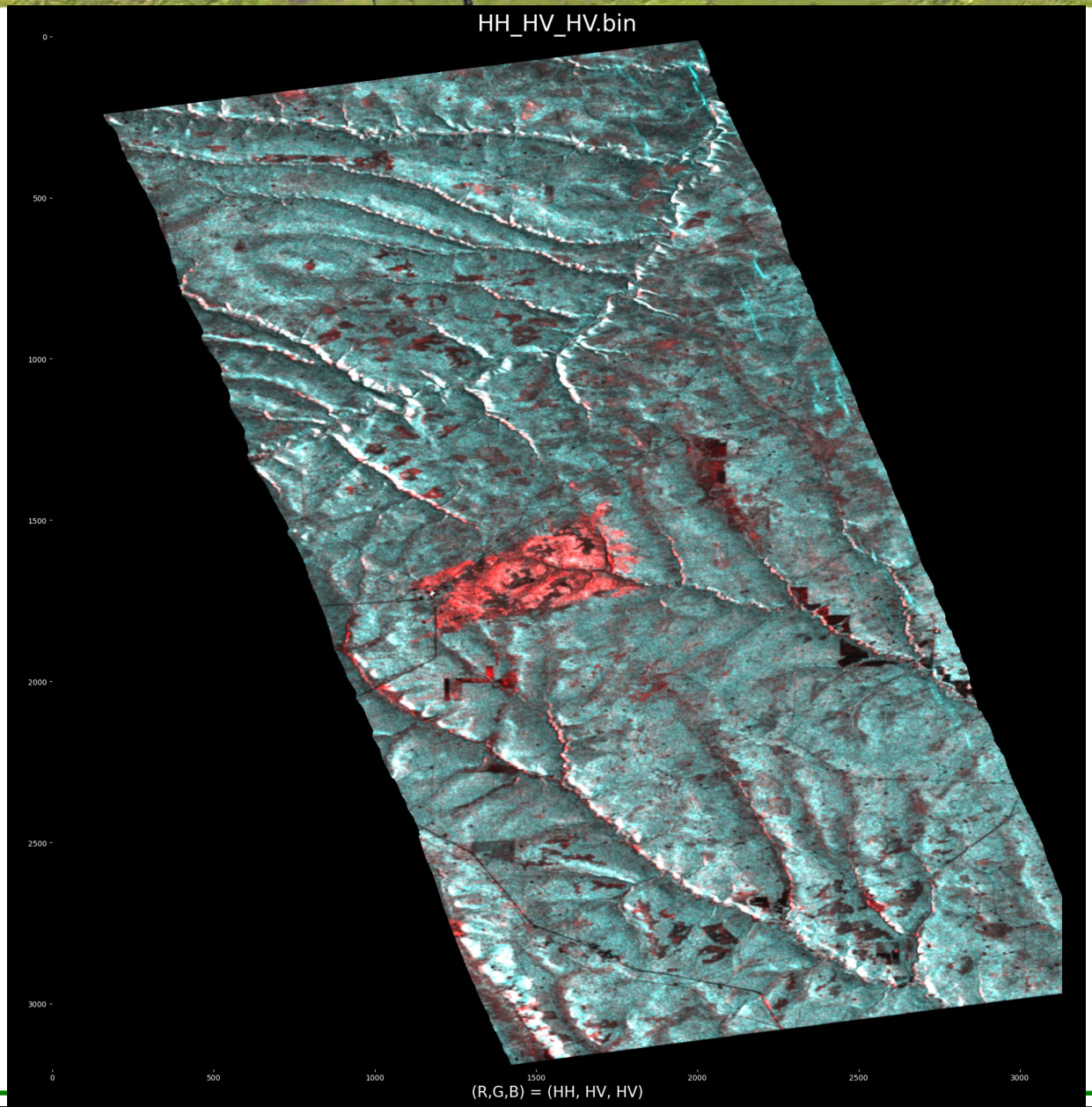


RED: polarized power GREEN: volume power BLUE: RED/GREEN

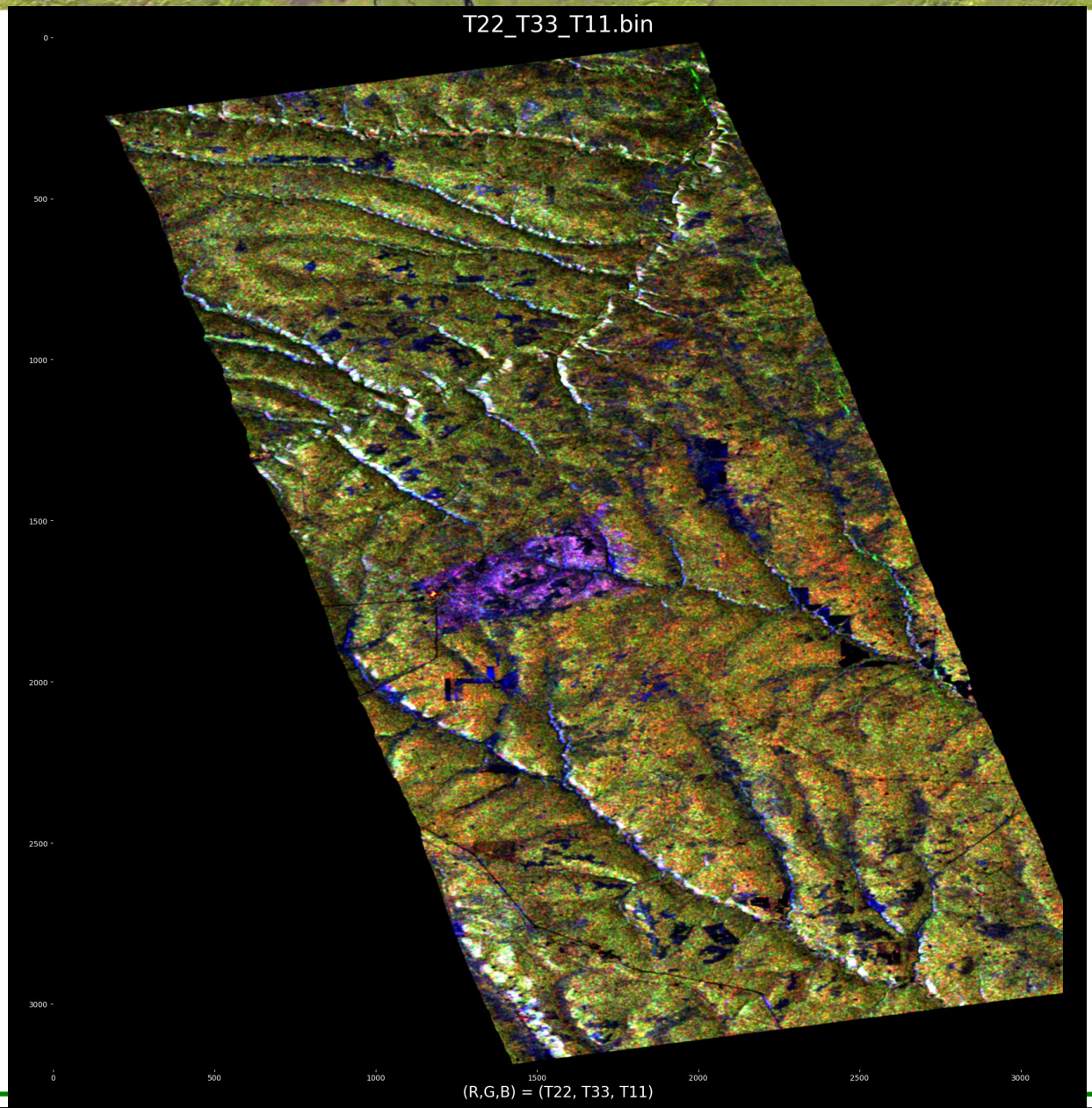
DP vs QP Comparison:

Dual Pol RGB:= (|HH|, |HV|, |HV|)



DP vs QP Comparison:

Quad-pol RGB:= (T22, T33, T11)



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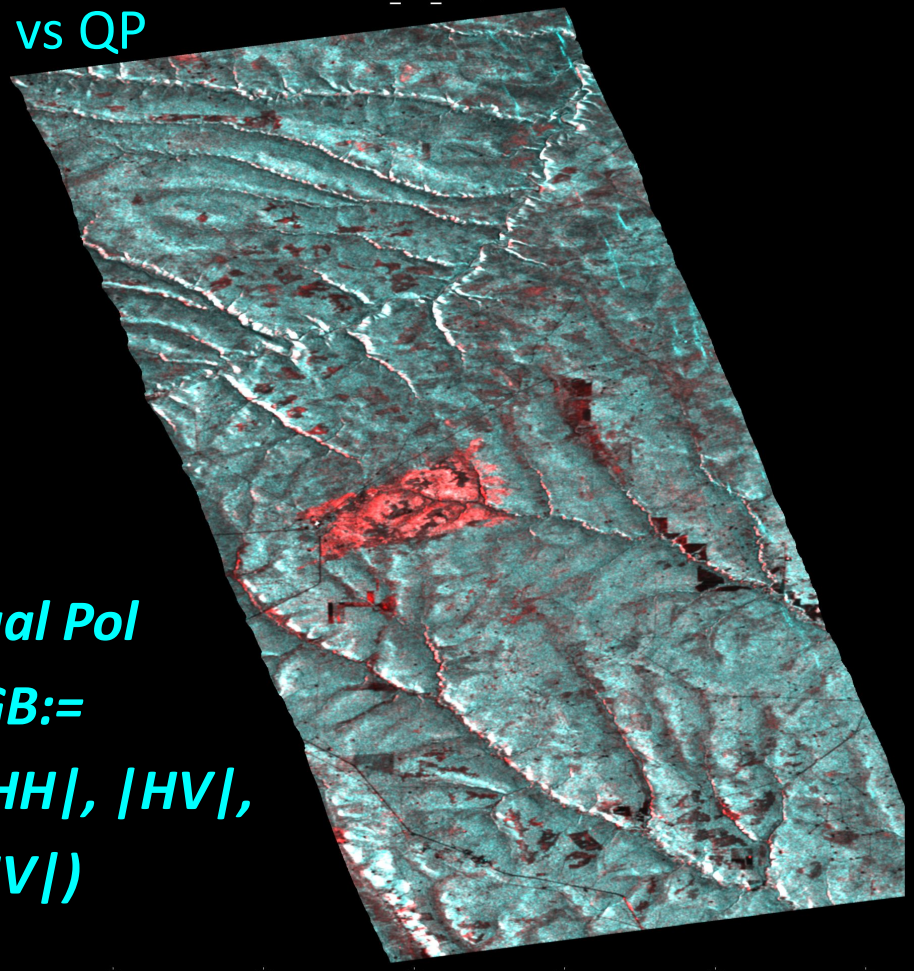
HH_HV_HV.bin

DP vs QP



Dual Pol

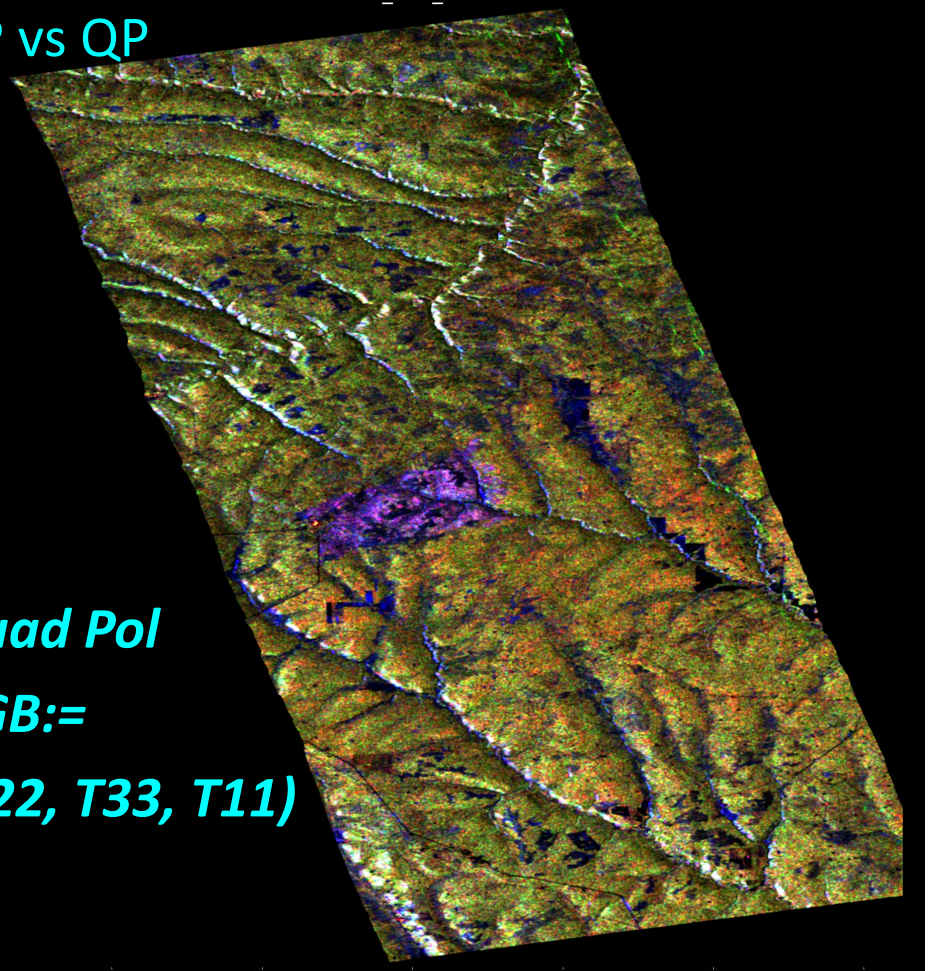
RGB:=

(|HH|, |HV|, |HV|)

(R,G,B) = (HH, HV, HV)

T22_T33_T11.bin

DP vs QP



Quad Pol

RGB:=

(T22, T33, T11)

(R,G,B) = (T22, T33, T11)

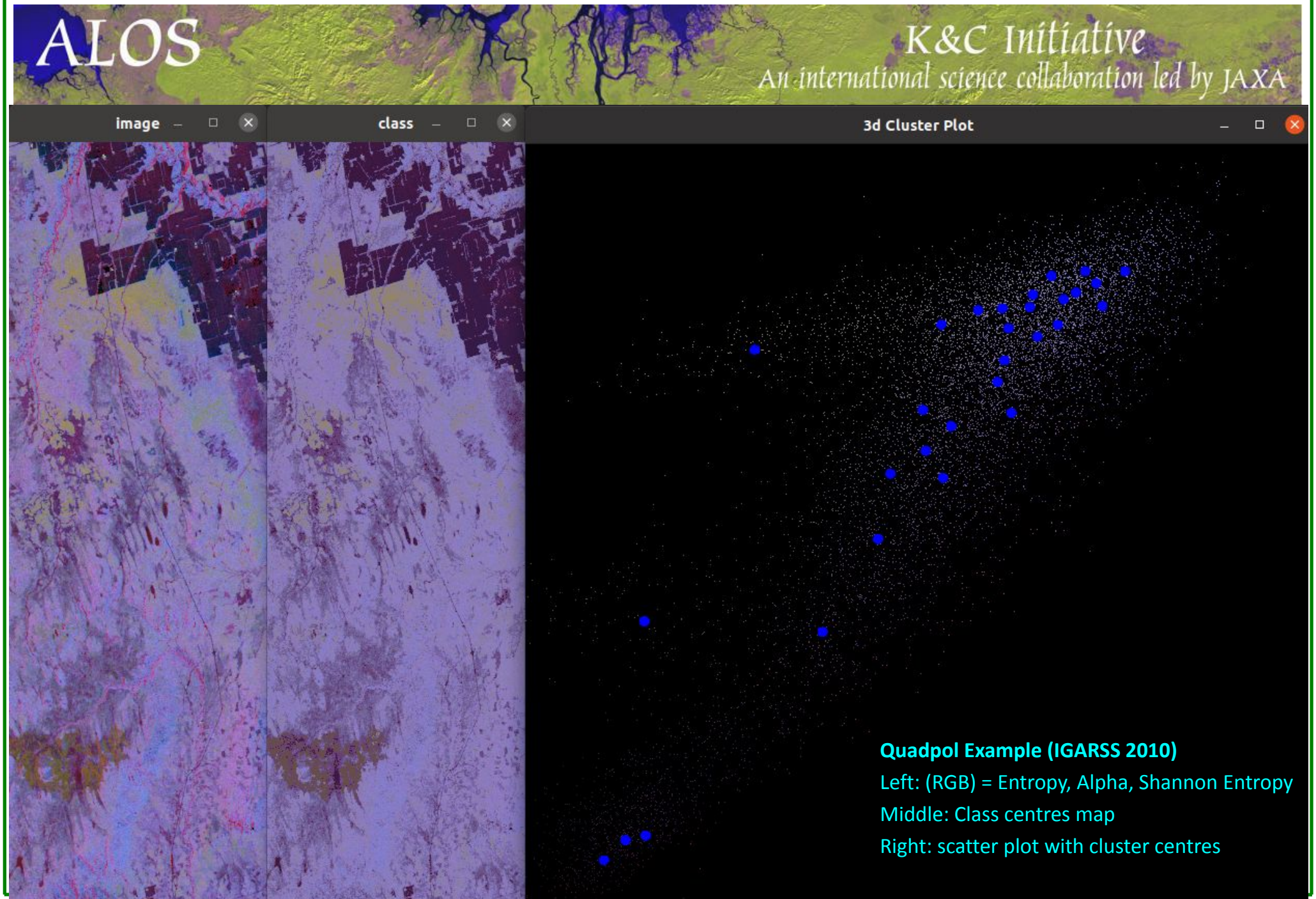

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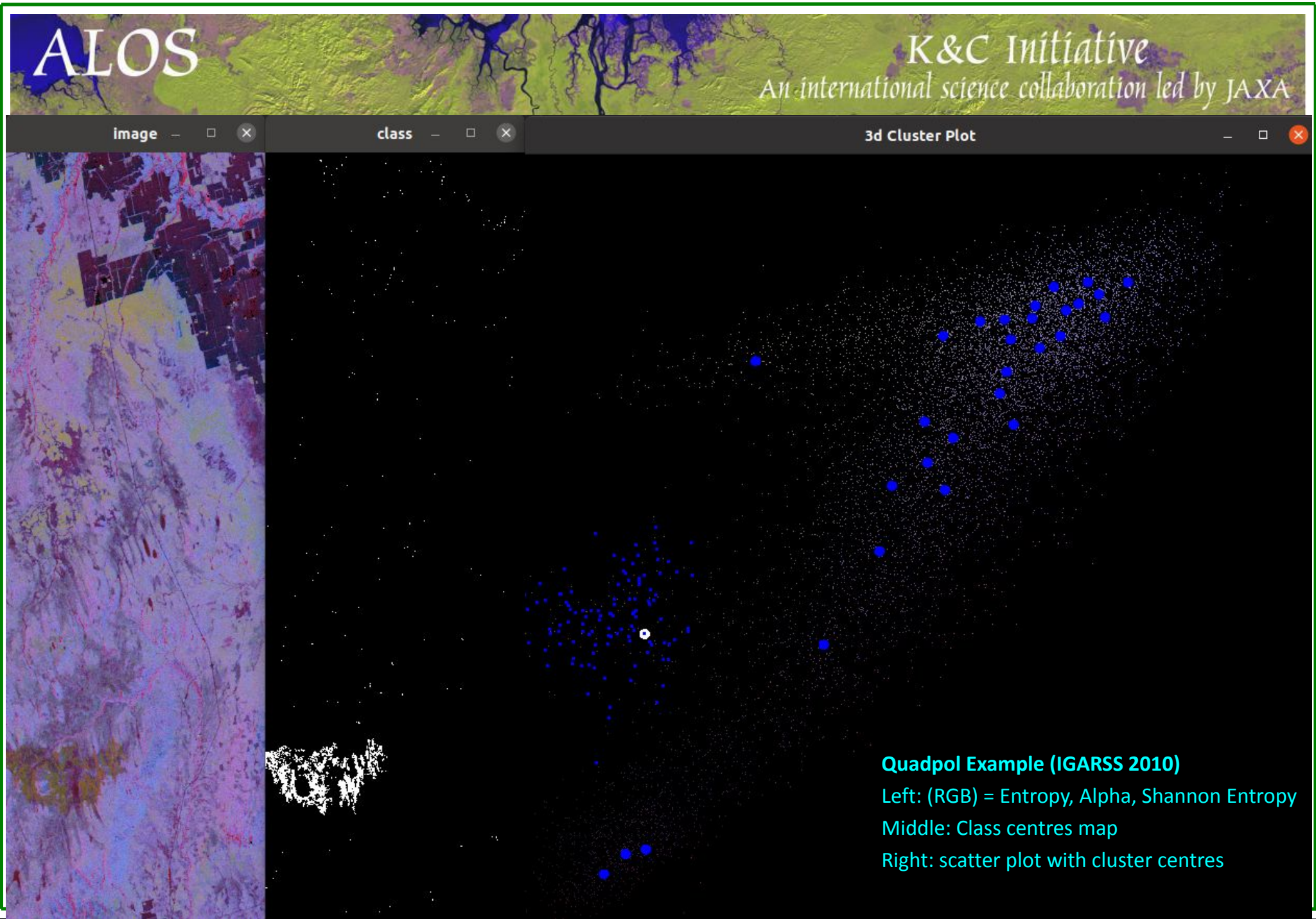
image
class
3d Cluster Plot
Quadpol Example (IGARSS 2010)
Left: (RGB) = Entropy, Alpha, Shannon Entropy
Middle: Class centres map
Right: scatter plot with cluster centres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Acknowledgements

Thank you:

- JAXA for the collaboration, data & wonderful meeting!
- JAXA for leading the way globally on L-band Ecosystem mapping for so many years
- Thank you to NASA and ESA for following JAXA's lead!

Thanks to partners incl.

- CSA, ESA, NASA, ASI, CFS/NRCAN, WildfireSat Team
- MDA, ICEEYE and CSA for the special fire tasking in 2023
- BC Wildfire Geospatial Services, BC Forest Inventory, GeoBC
- NASA and U. Waterloo for investigating possible airborne mission
- Ake-san and the whole K&C team, hope to deepen/extend collaboration with you and JAXA!