All Hazards Application of RCM in BC Part III

BC Wildfire Service, University of Alicante, Indian Institute of Technology, University of Stirling, Natural Resources Canada

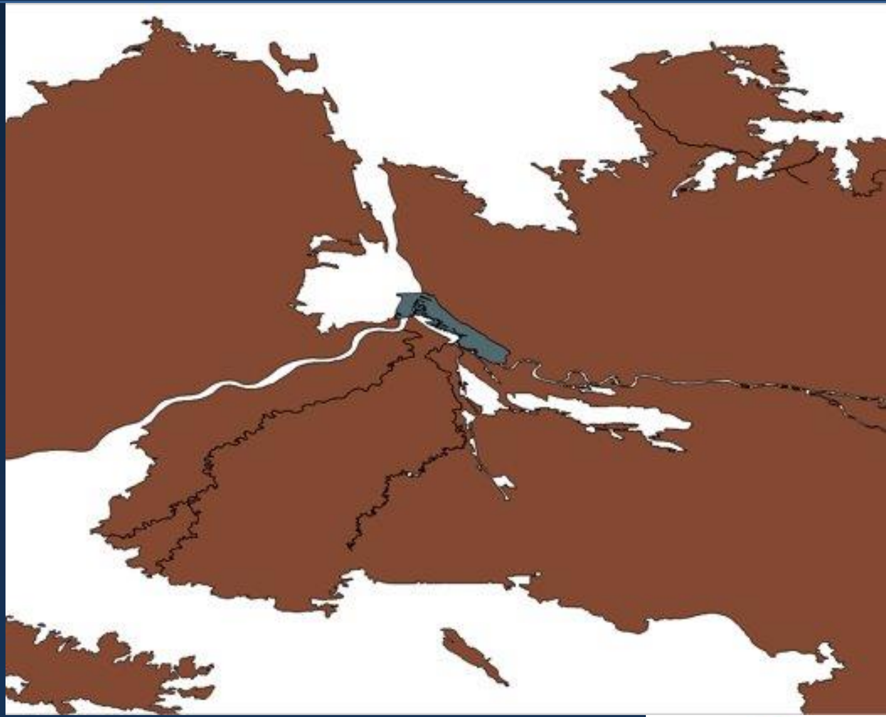
Canadian Space Agency RCM Users Forum Nov 23, 2022

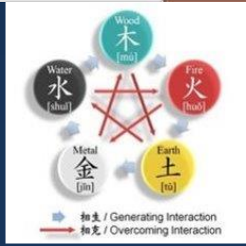
Thanks

- CSA for
  - Great meetings + Hi-Quality data + More missions coming
  - health applications in their EO strategy document (Jan 2022)
  - fire monitoring noted at ESA 2nd Workshop on SAR Coordination (Sep 2022)
- JAXA for collaboration EORA-3 agreement
- CFS for WildFireSat team for KE participation
  - unique engagement approach
- H Chen and L Mascolo for data analysis
- NRCAN EGS + GSDI for data engineering support
- Forest Inventory and BCWS Geospatial Services team for support
- BC MoF or the nice internal news release (Nov 2022)
- Ridha Touzi for expert advice
- R Saper and C Jackson (NOAA) for advice on SAR wind measurement
- Dr. E Whitman for sharing burn severity data!
- DRDC for interesting connections
- Saeid H for RS advice
- SNAP team for software
- Many others..

All hazards

- Here to collaborate! Work w the group for best outcomes
- Promote SAR and RS applications for situational awareness
  - Explore new uses of existing data
- Priorities of connecting re: RS / Geomatics:
  - **Operational RS**
    - Align w others oriented to produce new info quickly!
  - **Operationalization**
  - **Operationalizable R&D**, end user oriented
- Hoping for interdisciplinary learning w other hazard areas!
  - People, hardware, software and data
  - Knowledge transfer across different applications?
  - Patterns in Matrix of hazards? E.g. Extreme fire 2016 in Fort McMurray, then 2020 flood (4 years). Extreme fire 2017-18 in BC then flood 2021 (4 years).





Predictive Services Unit

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What we do:

- Gather information and analysis using best available science, technology & human expertise
- Assist risk-based decision making for wildfire prevention, preparedness, response & recovery

Who we are: 3 prongs

1. Fire Weather Forecasters,
2. Fire Behavior Specialists, and
3. IT and Data Scientists

JAXA L-band SAR Project Info

Research Agreement: The 3rd Earth Observation Research Announcement (EORA-3) Collaborative Research Agreement (Non-Funded) between the Japan Aerospace Exploration Agency (JAXA) and the Research Organization (RO)

Project Title: BC Wildfire Service -- Predictive Services Unit -- Fuel Type Layer Project

Principal Investigator: Ashlin Richardson, Senior Scientist, BC Wildfire Service

Co-Investigators:
Hao Chen, Canadian Forest Service
Dr. Subhadip Dey, Indian Institute of Technology
Dr. Armando Marino, University of Stirling
Dr. Lucio Mascolo, University of Alicante

Partners and collaborators

BC Wildfire Service

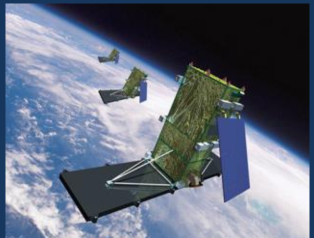
- Hopefully you?
- All feedback / input welcome!

RPAS

Sentinel1

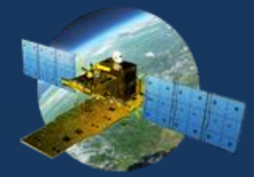
Sentinel2

RCM

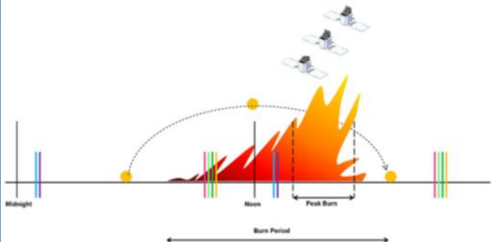


NiSAR (2023)

JAXA PALSAR-2



WILDFIRESAT



Sentinel-2 fire mapping BCWS operational trial 2022

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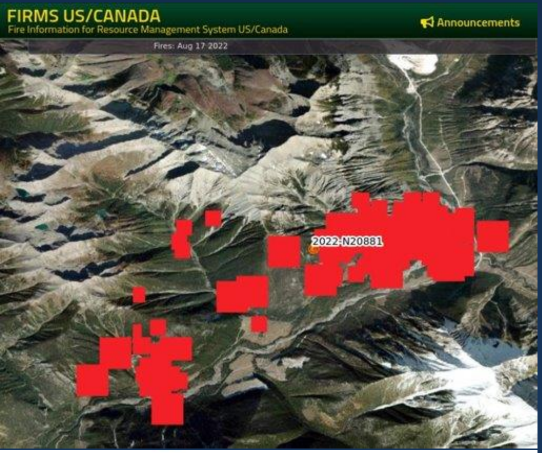
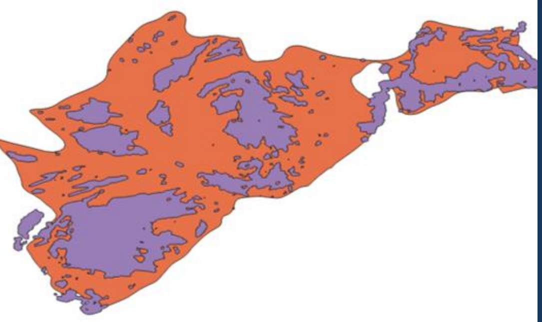
- Not a retrospective pre/post veg comparison
- Single-date fixed-threshold method (fast)
- NBR / dNBR, Thermal IR, NIR not used
- Special ***3-band SWIR combination***
- Not hotspot detection, can catch transient fires

Comparison with FIRMS product



NASA Firms (MODIS and VIIRS) detection Aug 17



Purple – Sentinel-2 detection Aug. 17th
Orange – public perimeter as of 20220819

1. Prepare Sentinel2/Landsat data
   - Download, extract, band selection, crop
   - Copernicus faster than SentinelHub
   - Save ~2h by downloading L1 & process to L2

2. Binary fire classification
   - Two classes: Fire vs NA
   - Usually simple thresholding but occasionally (NN, KNN, or KGC) to help cope with atmospheric effects / illumination irregularities

3. Scrub false positives (using GIMP)
   - E.g. Water

4. Convert to Polygon (kml)
   - ***Record GeoTiff raster for QC/QA and analysis***
   - Wompare w public perimeter data in QGIS

5. Submit to BCWS Geospatial Services team
   - SME review (+ Post processing)

Sentinel-2 fire mapping BCWS operational trial 2022

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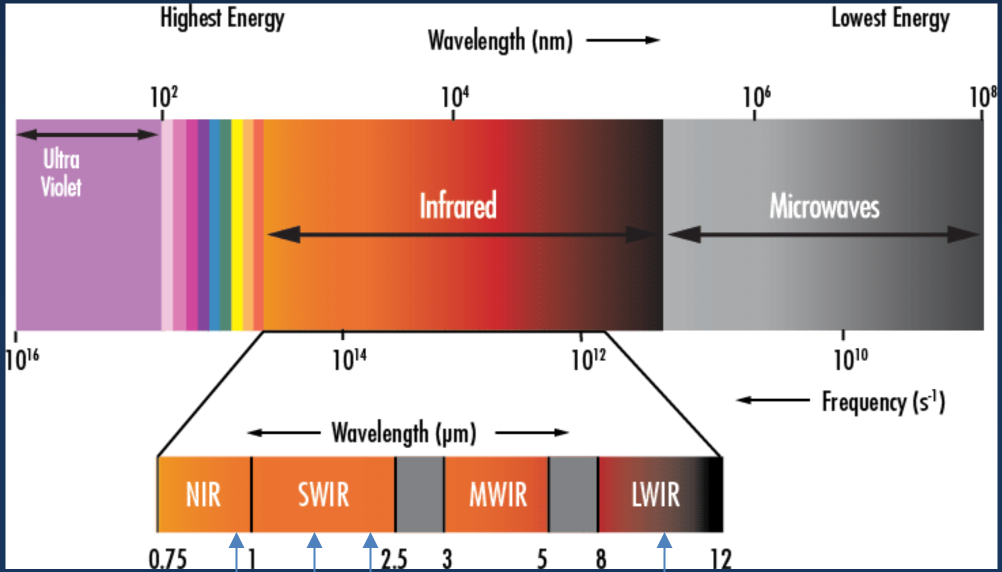
- Color encoding to generate map at right:
  - Red: "B12" 2190 nm = 2.2 µm
  - Green: "B11" 1610 nm = 1.6 µm
  - Blue: "B9" 945 nm = 0.95 µm

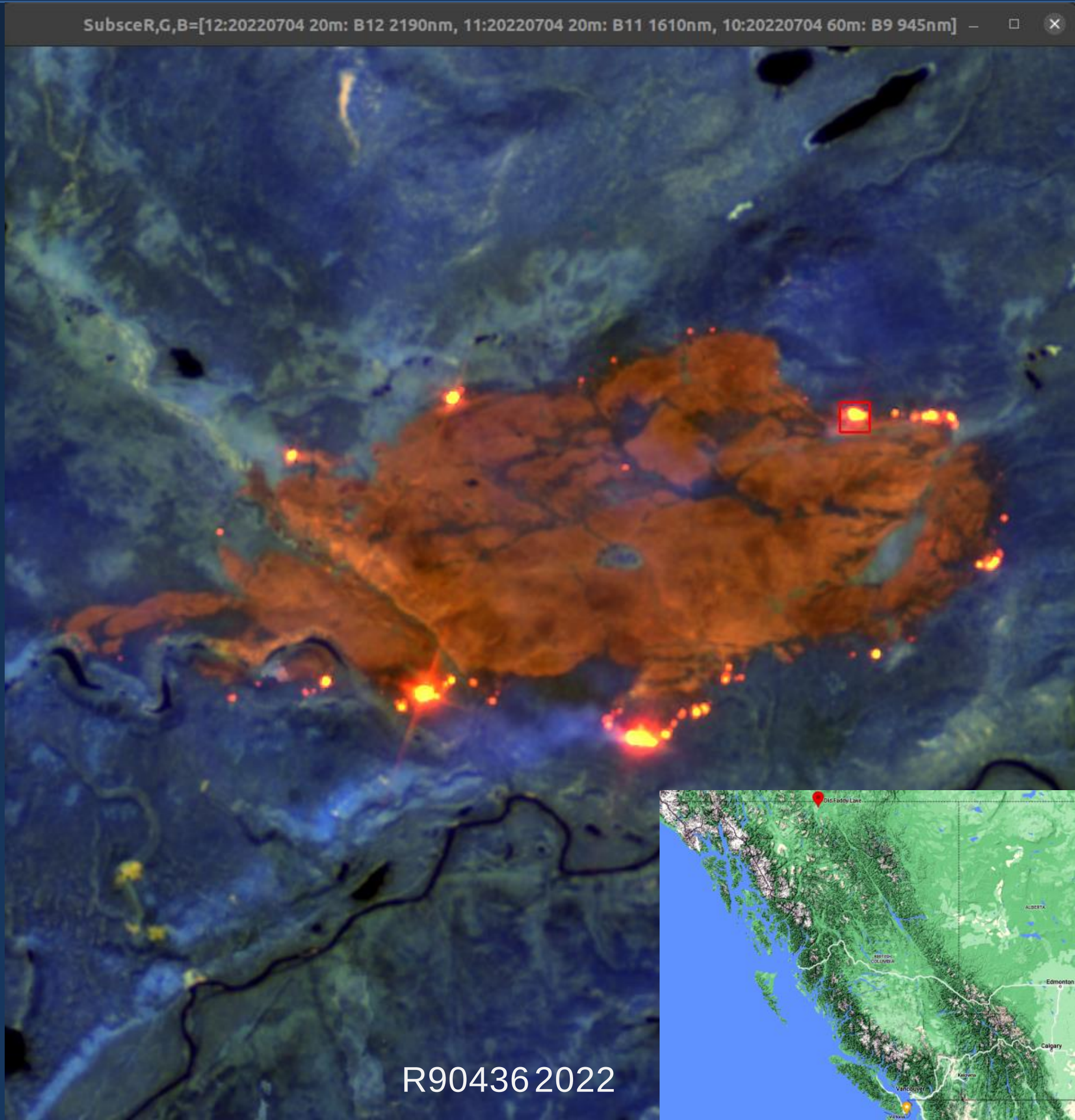
I.e. The B12, B11 and B9 are respectively plotted as Red, Green and Blue on the screen
  - Vegetation is blue
  - Hotspots are red
  - Burned areas are orange



B9 B11 B12

"True" Thermal

"Somewhere between visible and thermal"



Sentinel-2 fire mapping BCWS operational trial 2022

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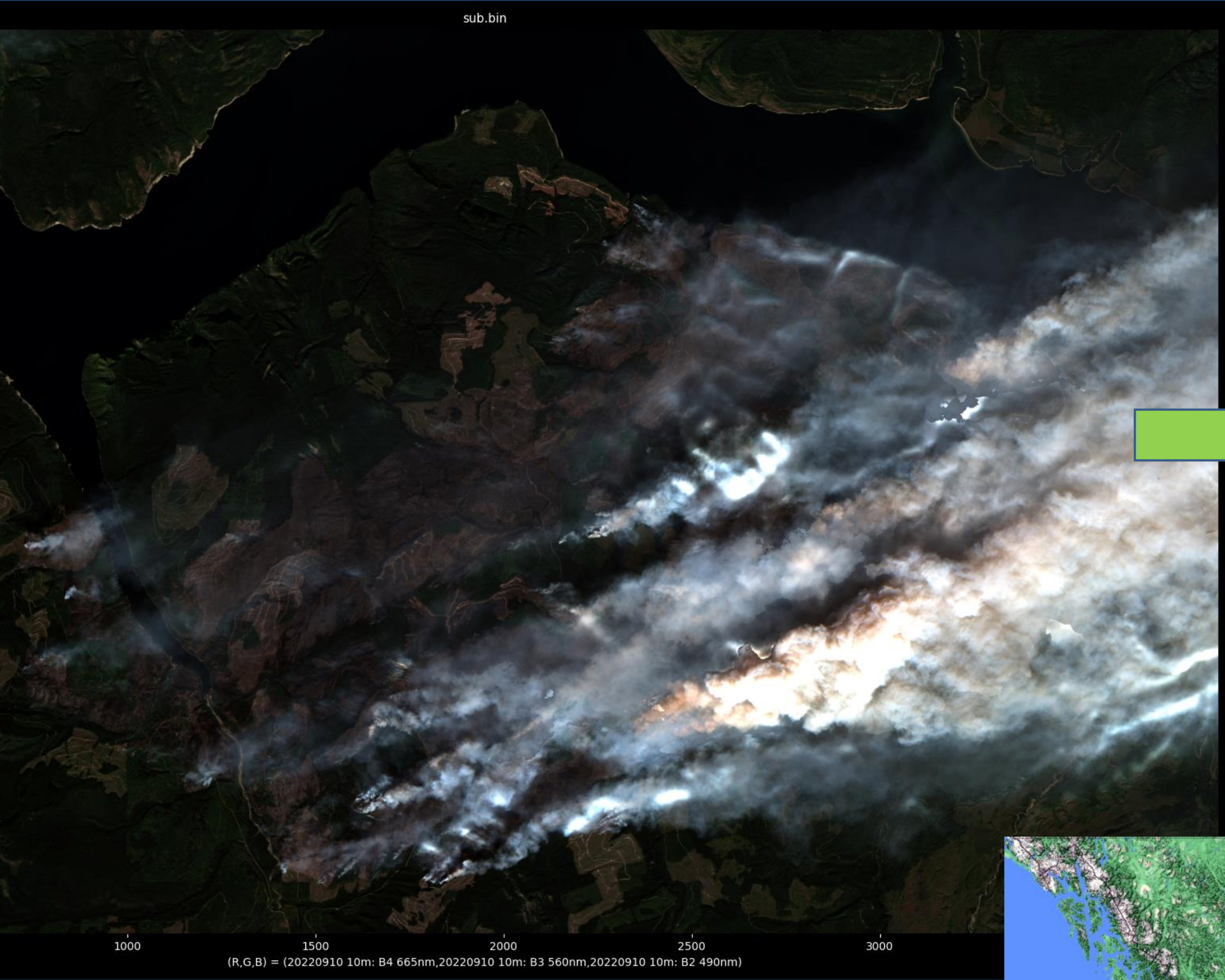

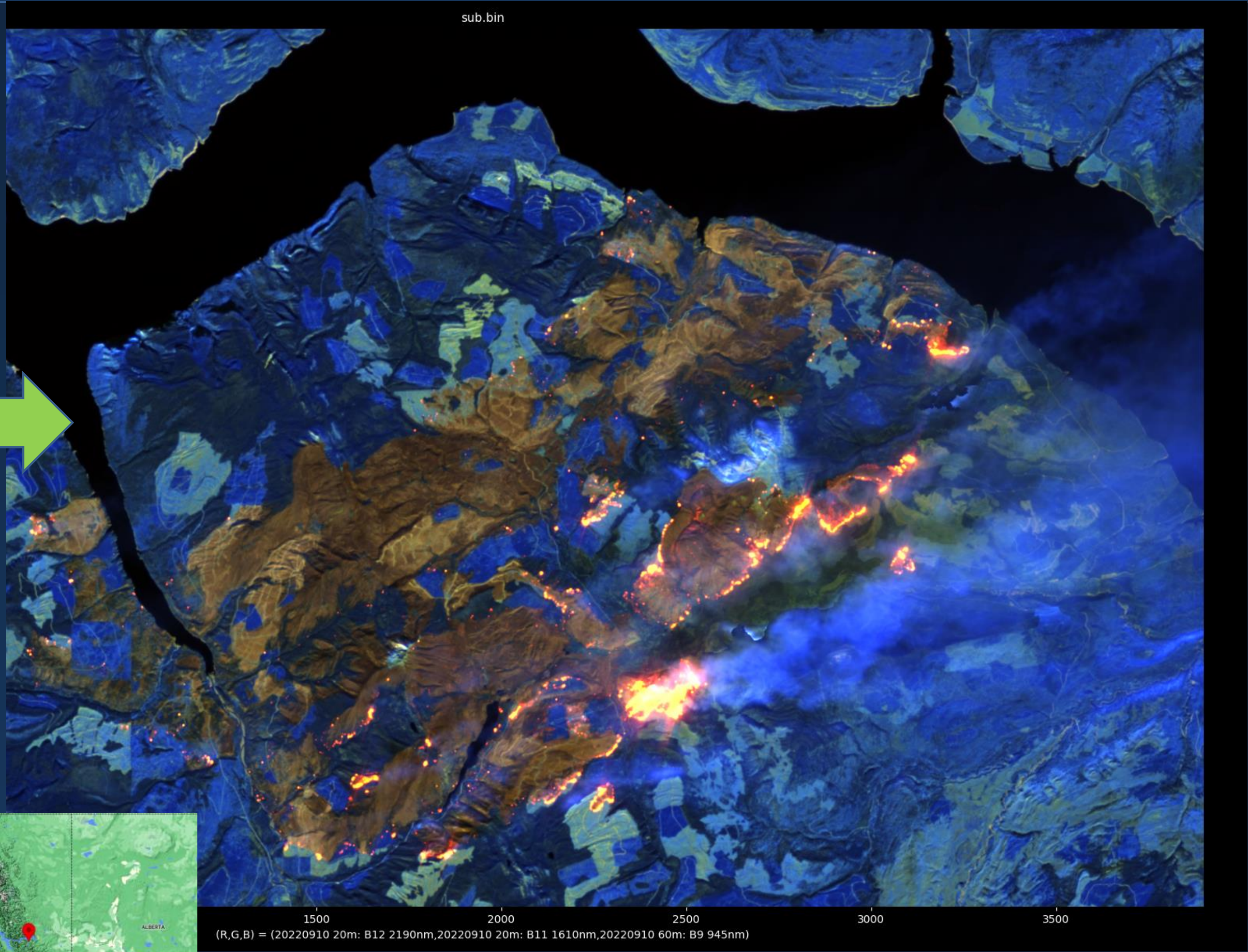

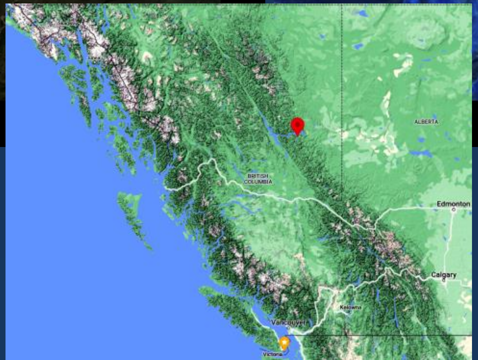

Battleship mountain (G72150) 20220910

Sentinel-2 fire mapping BCWS operational trial 2022

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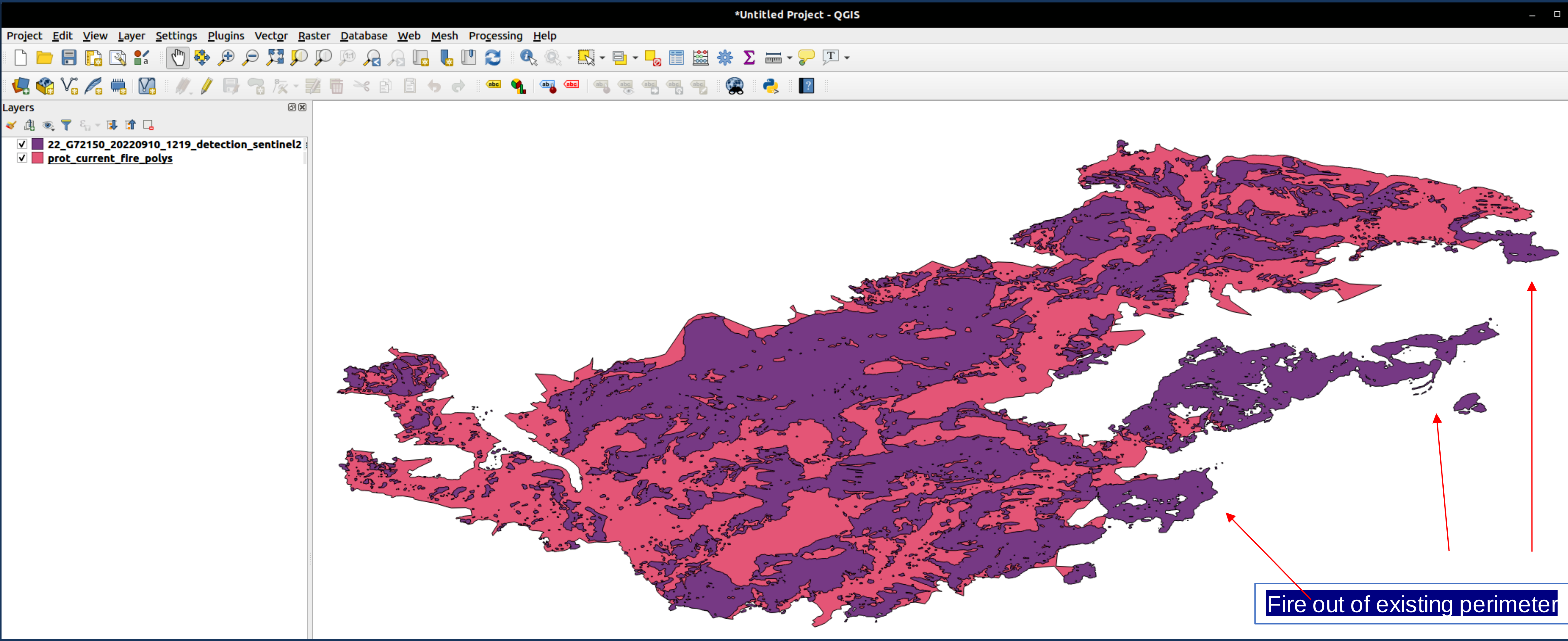

Battleship mountain (G72150) 20220910 Poly data 2022091021 (9-10pm)

Note: 12 Sep 2022 poly to boots on ground in 4h24m from image capture (approx noon)

Wins + Next steps

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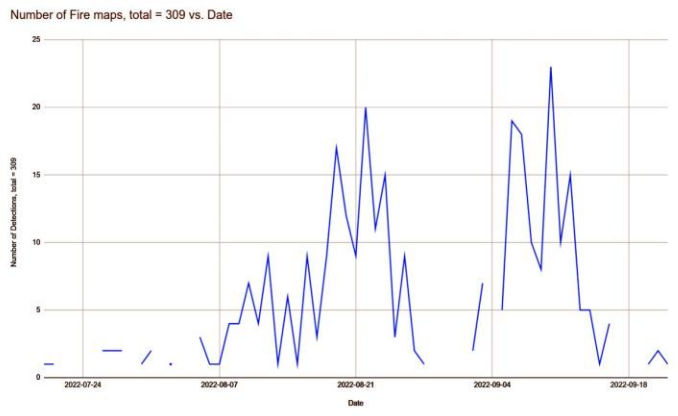
- Approx 310 "low latency" fire maps generated (S2 and L8-9)
  - Total latency 4.5-12h (5min DL, 5-10min processing)
- Mapped small or unknown fires + fires under smoke cover + haze
- Increasing number of front-line requests from incidents
- To automate: Exploring energy modelling w WildfireSat KE team
- Scale up: working with EGS/GSDI on NRT access



2022 JAXA project results

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- Project info
  - Purpose & Targets
- Data and Results
  - Monte Lake, BC
  - Fort Simpson, NWT
    - Explore DP parameters
  - Fort McMurray, AB
    - T3 matrix elements
    - **Dual-pol parameters and interpretation**
    - Freeman parameters
    - Improved ground-ref
    - QP/DP comparison
  - Sparks Lake BC
- Next steps

Purpose of Research for Wildfire

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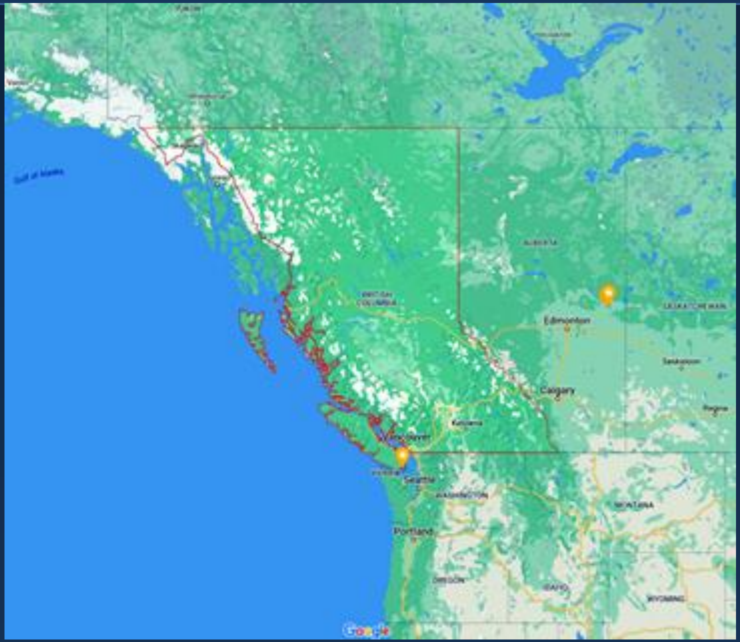
- Wildfire: significant intra-jurisdictional climate issue:
  hard to map & predict
- Continuous vegetation info updates needed on wide areas:
  - e.g. **> 900,000 km² in BC**
- JAXA's weather-resilient, L-band SAR systems are ***uniquely sensitive to vegetation***
- Collaborate to push the envelope on RS info to support wildfire prevention, preparedness, response & recovery
- **Assess operational potential of Polarimetric L-band SAR technology**
  - **engage front-line operations personnel in value-added product R&D**
- Support disaster management by applying Polarimetric L-band SAR technology
  - **better situational awareness for firefighters & first responders**



Research target

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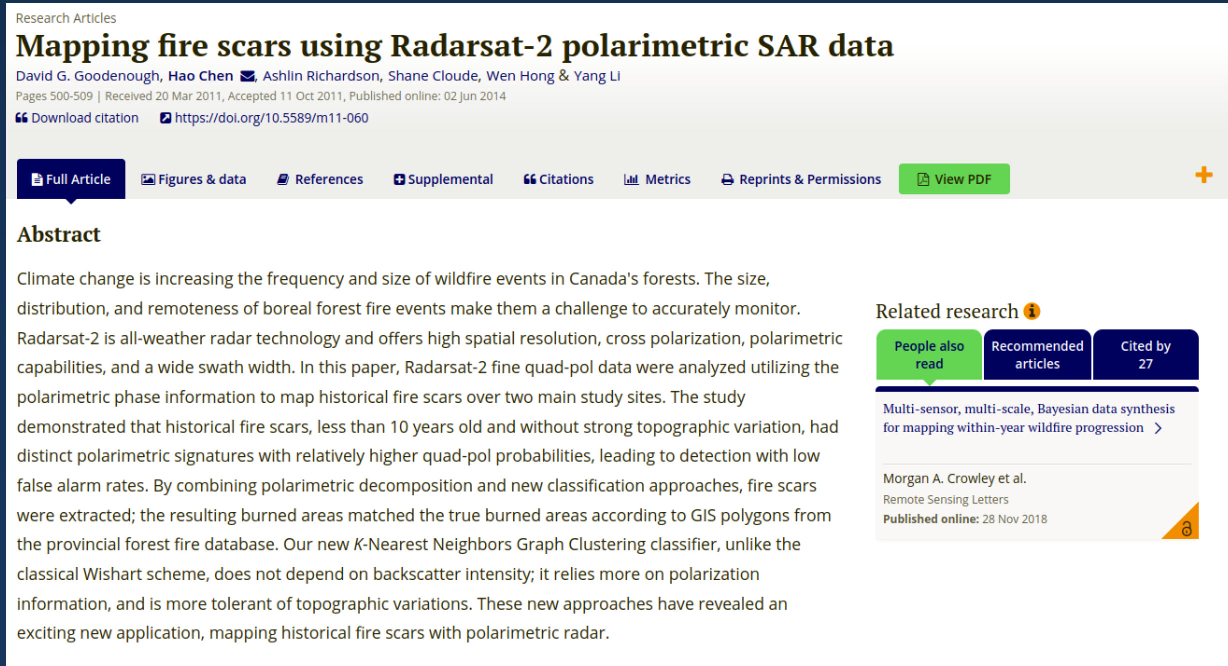
- Leverage advanced JAXA satellite tech in synergy
  - w novel combinations of **physical info retrieval methods being developed & evolved by the research partners**
- Develop terrestrial situational awareness in **three iterations of:**
  1. Reference data curation
  2. Analysis Ready Data (ARD) production
  3. **Added-value products generation**
  4. Refereed publication
- Forest attributes determination, change detection, physical decomposition, pol-SAR interferometry
- Machine learning (ML) inference of
  1. Forest Structure and
  2. Forest fire hazards Present, historical or anticipated
- **Expand situational Awareness & decision support product options for emergency geomatics applications**

Related work

(2021) Parker et al “Survey of Transverse Range Fire Scars in 10 Years of UAVSAR Polarimetry”
(2021) Wildfire today "NASA uses UAVs and satellites equipped with radar to monitor recovery from vegetation fires"
(2018) C. Raines “Detection of Fire Burn Scars by UAVSAR: Immediate, Short-term, and Multi-year Observations and Applications”
(2018) Plank et al “Burn Scar Detection Using Polarimetric ALOS-2 Data”
(2018) Touzi et al “Scattered and Received Wave Polarization Optimization for Enhanced Peatland Classification and Fire Damage Assessment Using Polarimetric PALSAR”
(2017) Hatfield Consultants "Rapid Radar Mapping to Support Wildfire Response and Recovery Operations"
(2016) JAXA “ALOS-2/PALSAR-2 Observation Results on Wildfire in Canada”
(2013) Polychronaki et al “Evaluation of ALOS PALSAR Imagery for Burned Area Mapping in Greece Using Object-Based Classification”
(2015) Heo et al “Airborne synthetic aperture radar for near-real-time wildfire monitoring using NASA’s UAVSAR instrument”
(2011) Goodenough et al “Mapping Fire Scars Using Radarsat-2 Polarimetric SAR Data”
(2011) Cloude et al "Radar Polarimetry for Forestry Applications: ALOS and Radarsat-2 studies in Canada" ForestSat 2010


Research Articles

Mapping fire scars using Radarsat-2 polarimetric SAR data

David G. Goodenough, Hao Chen, Ashlin Richardson, Shane Cloude, Wen Hong & Yang Li

Pages 500-509 | Received 20 Mar 2011, Accepted 11 Oct 2011, Published online: 02 Jun 2014

Download citation https://doi.org/10.5589/m11-060

Full Article | Figures & data | References | Supplemental | Citations | Metrics | Reprints & Permissions | View PDF

Abstract

Climate change is increasing the frequency and size of wildfire events in Canada's forests. The size, distribution, and remoteness of boreal forest fire events make them a challenge to accurately monitor. Radarsat-2 is all-weather radar technology and offers high spatial resolution, cross polarization, polarimetric capabilities, and a wide swath width. In this paper, Radarsat-2 fine quad-pol data were analyzed utilizing the polarimetric phase information to map historical fire scars over two main study sites. The study demonstrated that historical fire scars, less than 10 years old and without strong topographic variation, had distinct polarimetric signatures with relatively higher quad-pol probabilities, leading to detection with low false alarm rates. By combining polarimetric decomposition and new classification approaches, fire scars were extracted; the resulting burned areas matched the true burned areas according to GIS polygons from the provincial forest fire database. Our new *K*-Nearest Neighbors Graph Clustering classifier, unlike the classical Wishart scheme, does not depend on backscatter intensity; it relies more on polarization information, and is more tolerant of topographic variations. These new approaches have revealed an exciting new application, mapping historical fire scars with polarimetric radar.

Related research

People also read | Recommended articles | Cited by 27

Multi-sensor, multi-scale, Bayesian data synthesis for mapping within-year wildfire progression

Morgan A. Crowley et al.
Remote Sensing Letters
Published online: 28 Nov 2018

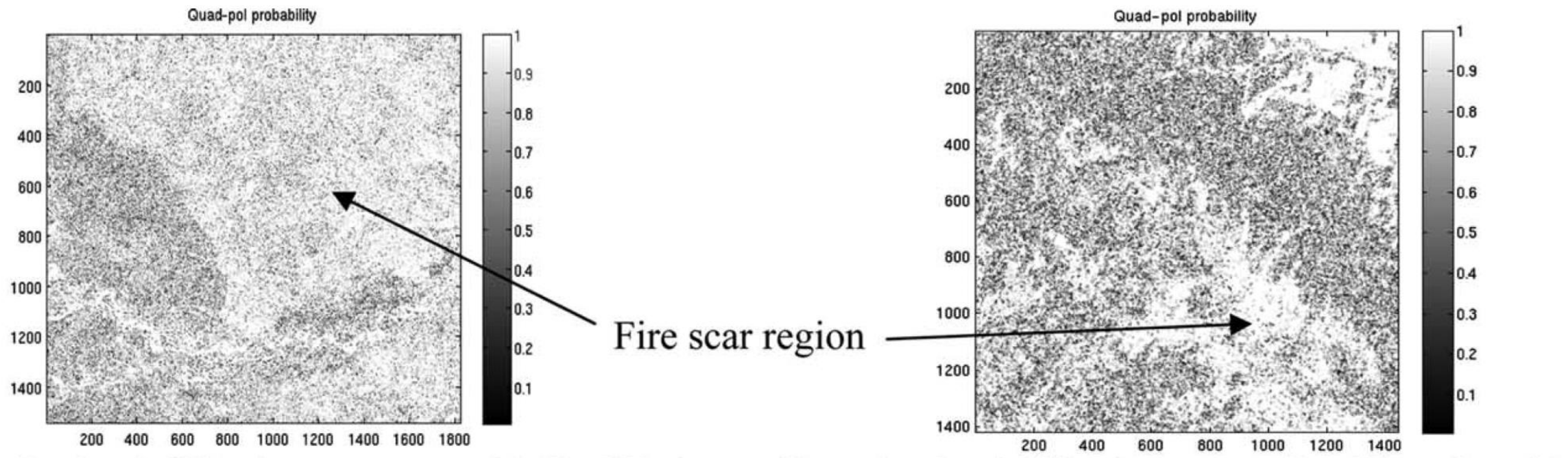
Related work

BRITISH COLUMBIA BC Wildfire Service

(2011) Goodenough et al "Mapping Fire Scars Using Radarsat-2 Polarimetric SAR Data"

burned regions show relatively higher quad-pol probabilities (Cloude 2009), suggesting burned areas have a distinct (fully) polarimetric signature

$$p(\Delta\alpha) = \frac{\Delta\alpha}{\sigma^2} \exp\left(-\frac{\Delta\alpha^2}{2\sigma^2}\right) \quad (5)$$



(a) quad-pol probability (18 October 2009, Ta-He, China) (b) quad-pol probability (2 July 2010, Keg River, Canada)

Figure 2. Quad-pol probabilities of Radarsat-2 quad-pol data (imagery dimension: 29 km × 27 km).

My opinion: comparisons of DP vs QP need: better geo-location than is available currently

White Rock Lake (2021 fire, British Columbia) Visual POC for differencing (Dual-pol)

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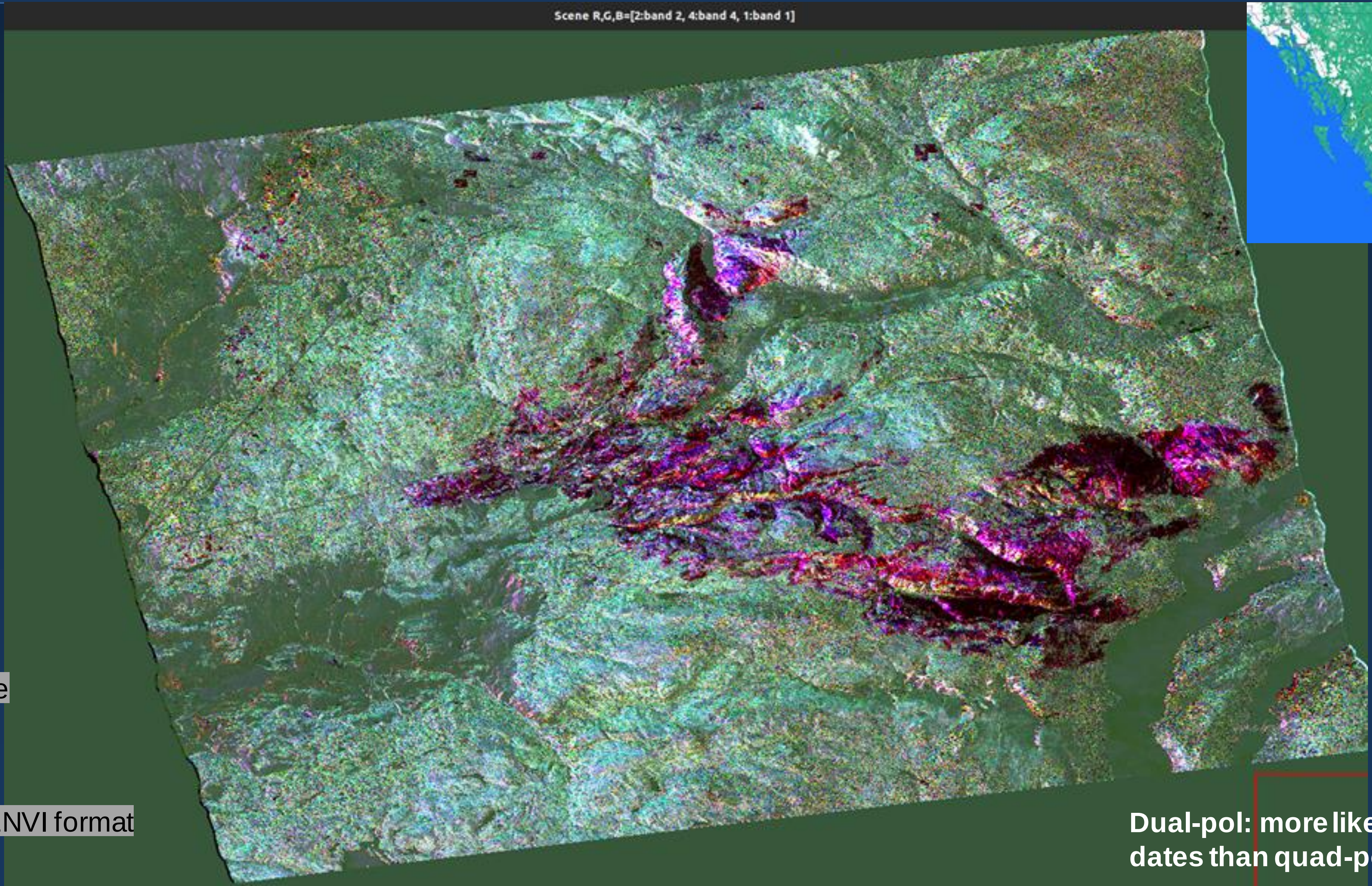
JAXA L-band dual-pol

Shown: Difference: (2022 - 2021) of

Re(C12) (red)
C22 (green)
C11 (blue)

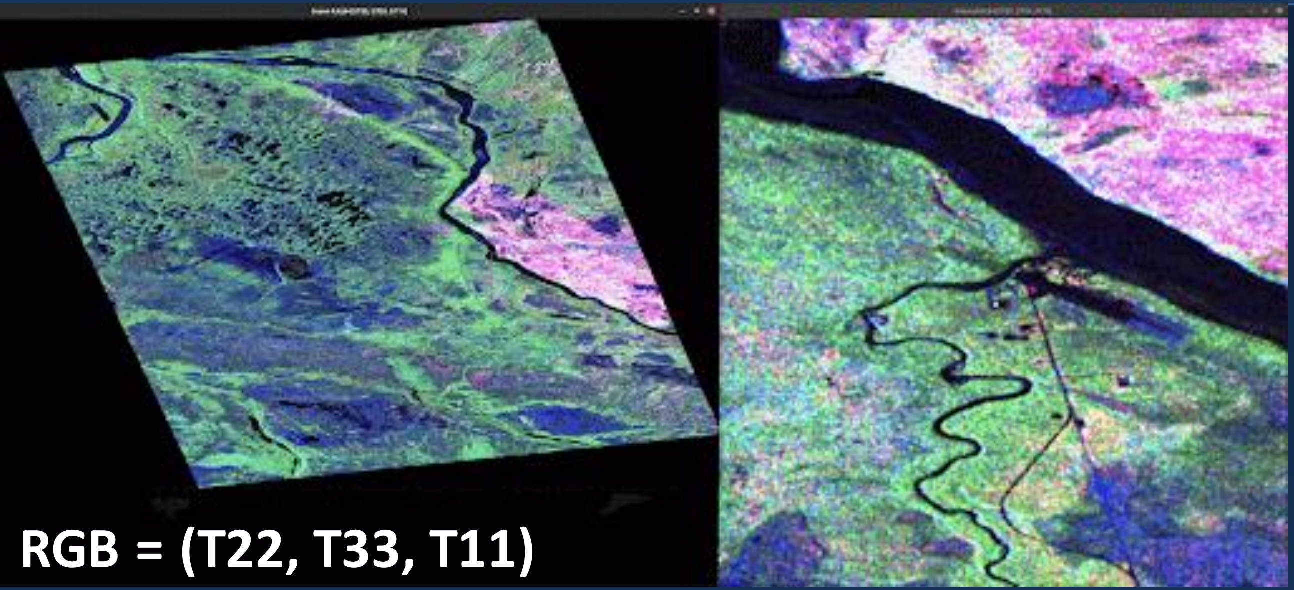
Burned area is the big pink/purple Pattern!



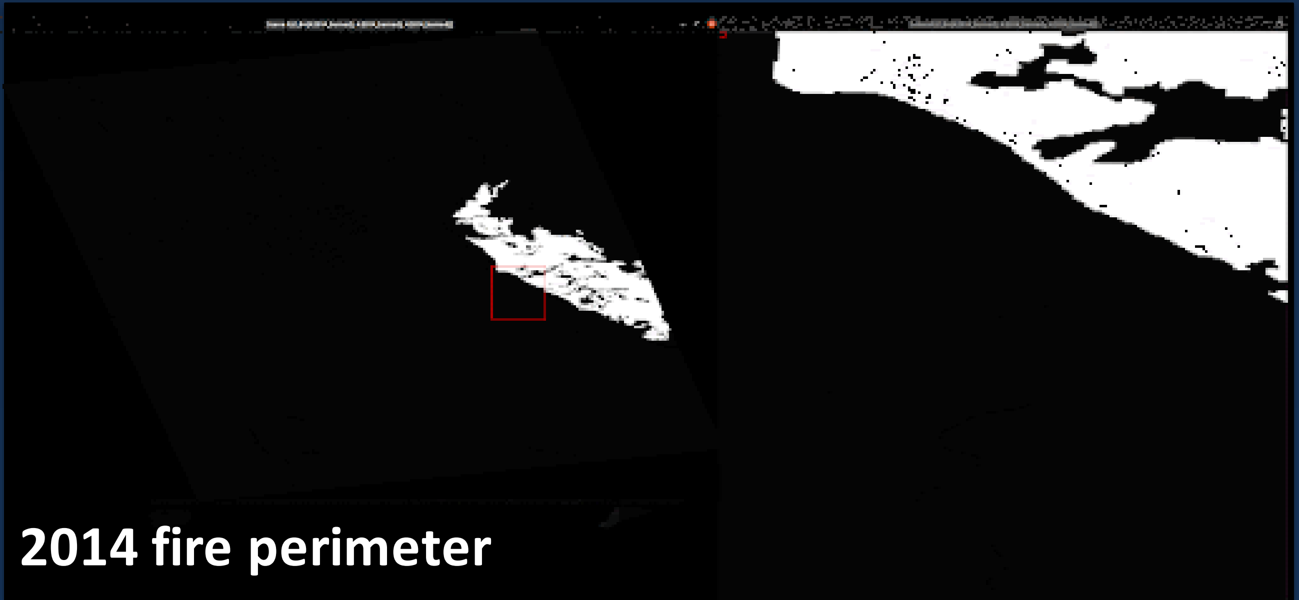
Processing steps (SNAP):
1) Radiometric calibration
2) Multilook to approx square
3) 5x5 box filter
4) Range-Doppler TC (Copernicus 30m dem)
5) Convert to PolSARPro / ENVI format
6) Co-locate with GDAL

Dual-pol: more likely need >1 dates than quad-pol

Fort Simpson, NWT, Canada (20150424)



RGB = (T22, T33, T11)



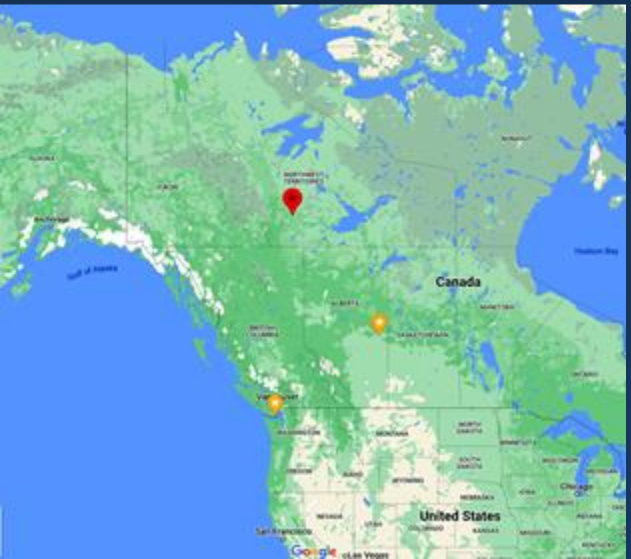
2014 fire perimeter

Burned area is visible. Could use the Span parameter?

Fort Simpson, NWT, Canada (20150424)

- Standard Forest Parameters
  - Provided by Hao Chen (CFS, NRCAN)
  - Present CFS work: Compact-pol versions of these to be introduced!
- Affected area is clearly visible

- Next slide: emulated Dual Pol (DP)



Simulation of Dual-pol (DP) parameters

1) Obtain C3 from T3

$$[C_{3A}] = \frac{1}{2}\begin{bmatrix}1 & 1 & 0\\ 0 & 0 & \sqrt{2}\\ 1 & -1 & 0\end{bmatrix}[T_{3A}]\begin{bmatrix}1 & 0 & 1\\ 1 & 0 & -1\\ 0 & \sqrt{2} & 0\end{bmatrix}. \quad (21)$$

- Cloude: "A review of Target decomposition theorems in radar polarimetry"
- Pottier & Lee: "Polarimetric radar imaging: from basics to applications"

2) Obtain C2 from C3, by considering sub-matrices of C3.

A. (HH-HV)

$$\boldsymbol{C}_3 = \langle \underline{\Omega} \cdot \underline{\Omega}^{*T} \rangle = \left\langle \begin{bmatrix} |\Omega_1|^2 & \Omega_1\Omega_2^* & \Omega_1\Omega_3^* \\ \Omega_2\Omega_1^* & |\Omega_2|^2 & \Omega_2\Omega_3^* \\ \Omega_3\Omega_1^* & \Omega_3\Omega_2^* & |\Omega_3|^2 \end{bmatrix} \right\rangle = \begin{bmatrix} \boxed{\begin{matrix} \langle |S_{XX}|^2 \rangle & \sqrt{2}\langle S_{XX}S_{XY}^* \rangle \\ \sqrt{2}\langle S_{XY}S_{XX}^* \rangle & 2\langle |S_{XY}|^2 \rangle \end{matrix}} & \begin{matrix} \langle S_{XX}S_{YY}^* \rangle \\ \sqrt{2}\langle S_{XY}S_{YY}^* \rangle \end{matrix} \\ \begin{matrix} \langle S_{YY}S_{XX}^* \rangle & \sqrt{2}\langle S_{YY}S_{XY}^* \rangle \end{matrix} & \langle |S_{YY}|^2 \rangle \end{bmatrix} \quad (3.39)$$

B. (VH-VV)

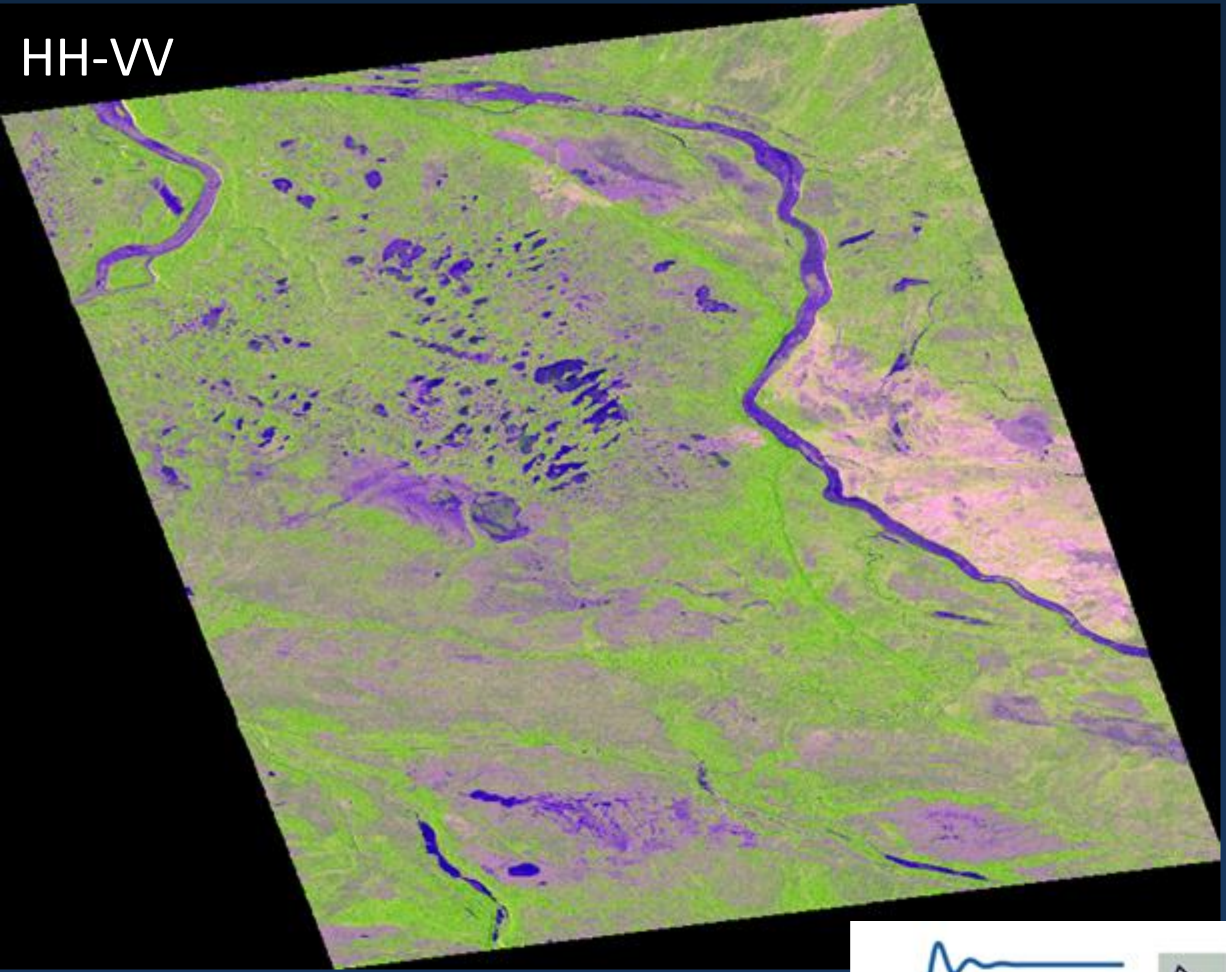
$$\boldsymbol{C}_3 = \langle \underline{\Omega} \cdot \underline{\Omega}^{*T} \rangle = \left\langle \begin{bmatrix} |\Omega_1|^2 & \Omega_1\Omega_2^* & \Omega_1\Omega_3^* \\ \Omega_2\Omega_1^* & |\Omega_2|^2 & \Omega_2\Omega_3^* \\ \Omega_3\Omega_1^* & \Omega_3\Omega_2^* & |\Omega_3|^2 \end{bmatrix} \right\rangle = \begin{bmatrix} \langle |S_{XX}|^2 \rangle & \begin{matrix} \sqrt{2}\langle S_{XX}S_{XY}^* \rangle & \langle S_{XX}S_{YY}^* \rangle \end{matrix} \\ \begin{matrix} \sqrt{2}\langle S_{XY}S_{XX}^* \rangle \\ \langle S_{YY}S_{XX}^* \rangle \end{matrix} & \boxed{\begin{matrix} 2\langle |S_{XY}|^2 \rangle & \sqrt{2}\langle S_{XY}S_{YY}^* \rangle \\ \sqrt{2}\langle S_{YY}S_{XY}^* \rangle & \langle |S_{YY}|^2 \rangle \end{matrix}} \end{bmatrix} \quad (3.39)$$

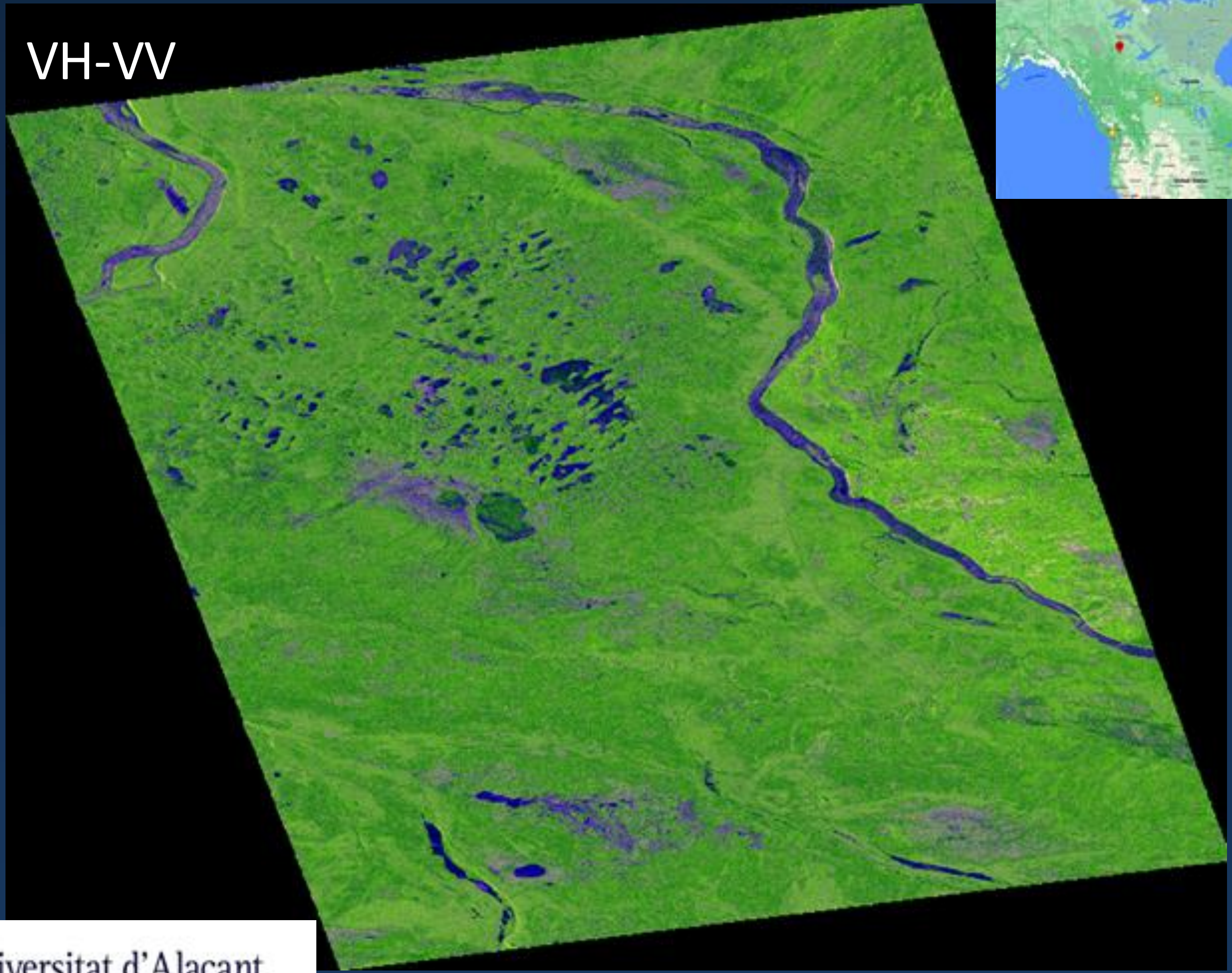
- Divide XY element by 2, so that the SPAN of emulated DP element equals XX+XY (for HH-HV case) or XY+YY (VH-VV case)
- Divide the off-diagonal elements by sqrt(2), so that the correlation between cross-and copolar channels equals XX*conj(XY) or XY*conj(YY)
  - In the (HH-HV and VH-VV cases, respectively)

Fort Simpson, NWT, Canada (20150424)

- RGB: from emulated dual-pol params (will explain later)

[1] Mascolo et al "Model-based decomposition of dual-pol SAR data: application to Sentinel-1" Transactions on Geoscience and Remote Sensing



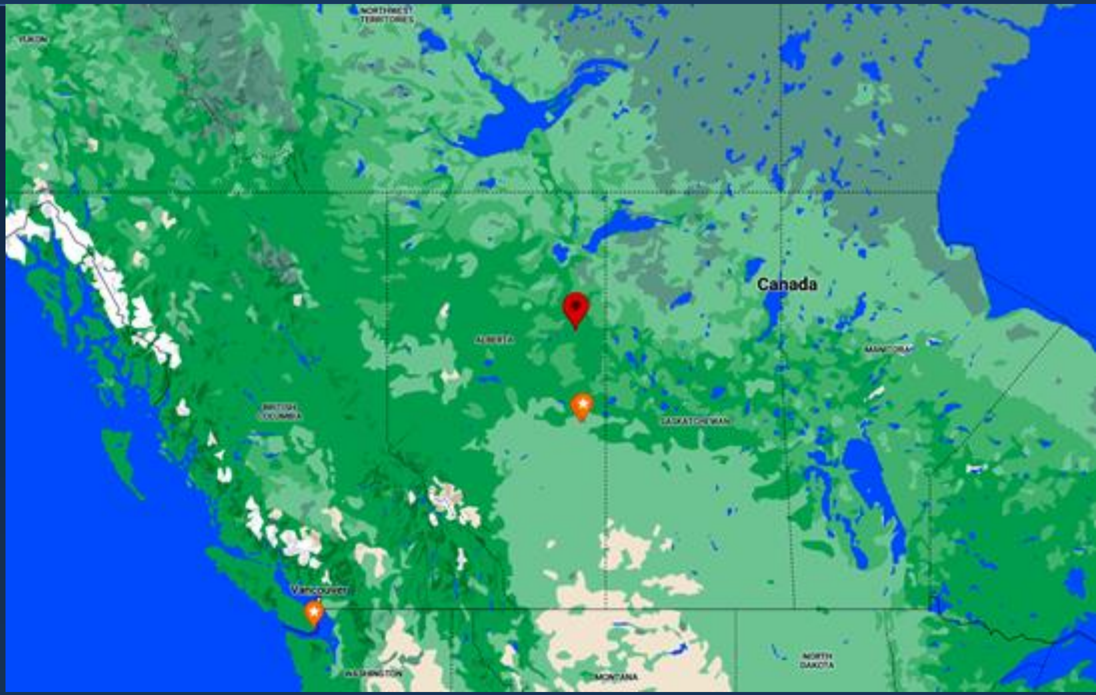


Results: Fort MacMurray (2016)

BC Wildfire Service

Quad-pol processing steps

1. Radiometric calibration
2. Faraday rotation correction (Default option)
3. Multilook (2x2)
4. T4 matrix generation
5. Box filter 7x7
6. Range doppler terrain correction (Copernicus 30m dem)
7. Convert to PolSARPro format, use NAN in no-data areas, co-locate ground-reference, assign no-data areas (where the image pair not overlapping)
8. Multilook x2



References

- https://www.eorc.jaxa.jp/ALOS-2/en/img_up/dis_pal2_can-forest_fire_20160509.htm
- https://ieeexplore.ieee.org/document/8517822
- https://www.alberta.ca/assets/documents/Wildfire-MNP-Report.pdf

Physical polarimetric interpretation

BC Wildfire Service

A First step: PolSAR analysis: Fire event →

- Vegetation destruction (volume scattering changes)
- Decreased soil moisture / water content

Diagonal elements of T matrix: Ratio between the first two diagonals should be sensitive to soil moisture [1]

$$\frac{T_{22} + T_{33}}{T_{11}} = \frac{|R_S - R_P|^2}{|R_S + R_P|^2} \qquad (22)$$

[1] "Inversion of Surface Parameters From Polarimetric SAR" Hajnsek et al, 2003

Further studies: study physical interpretation for detailed land-cover classes (e.g. fuel types)

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Fort McMurray 2016 (Horse River fire) radar

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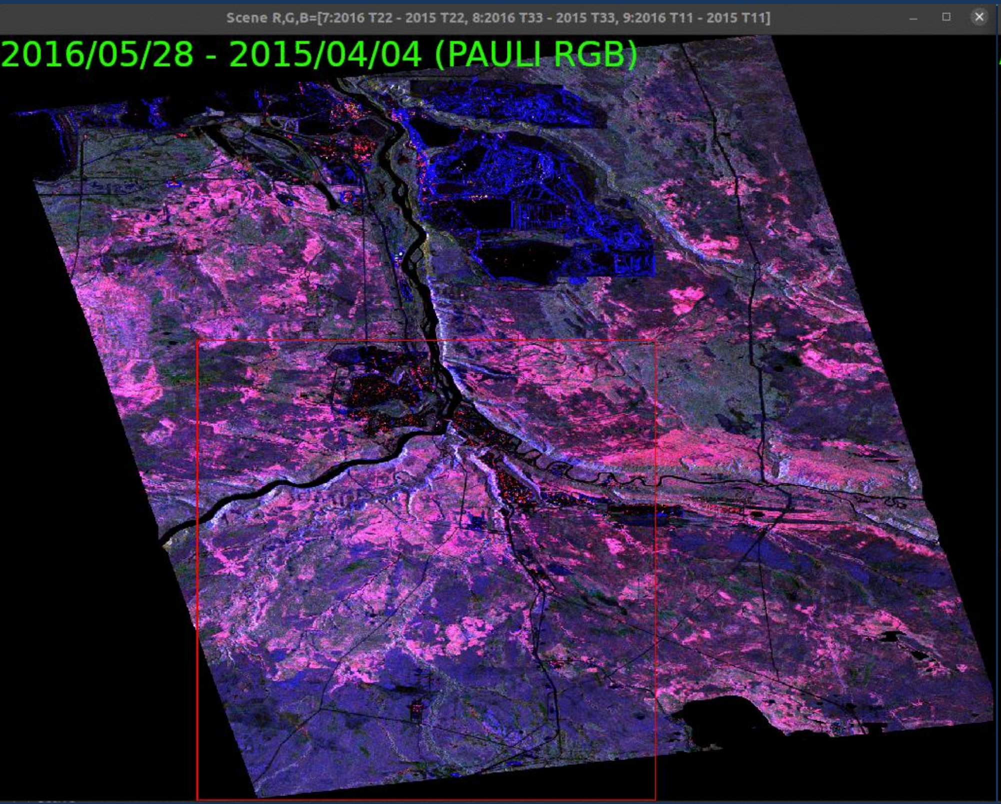


JAXA Quad-pol L-band SAR data

National Fire Polygon Database Extent

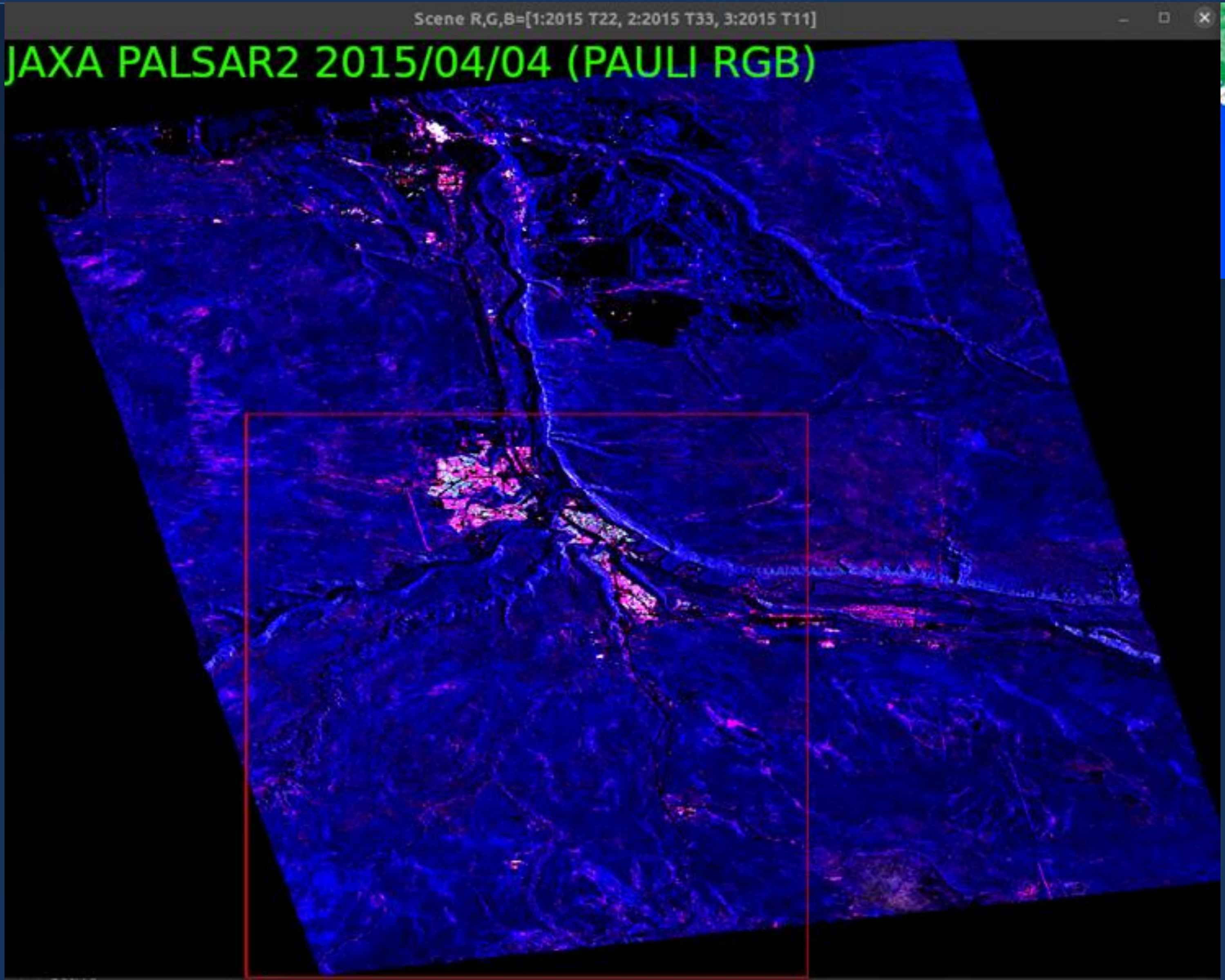
Quad-pol processing steps

1. Radiometric calibration
2. Faraday rotation correction (Default option)
3. Multilook (2x2)
4. T4 matrix generation
5. Box filter 7x7
6. Range doppler terrain correction (Copernicus 30m dem)
7. Convert to PolSARPro format, use NAN in no-data areas, project ground-reference on top, assign no-data areas (where no image overlap)

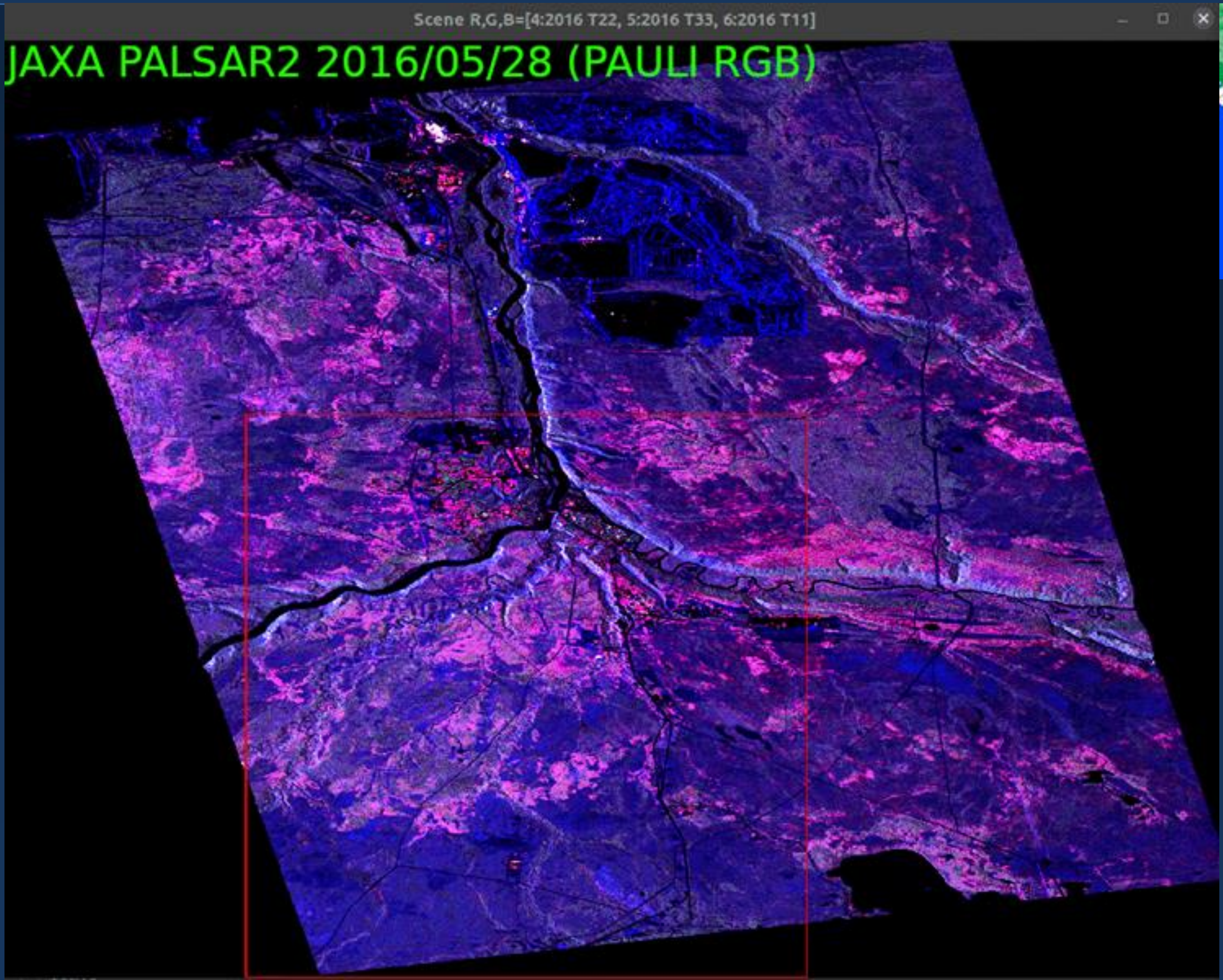
References
• https://www.eorc.jaxa.jp/ALOS-2/en/img_up/dis_pal2_can-forest_fire_20160509.htm
• https://ieeexplore.ieee.org/document/8517822

Need better ground reference data! Fire locations and other forest attributes. Working on it!

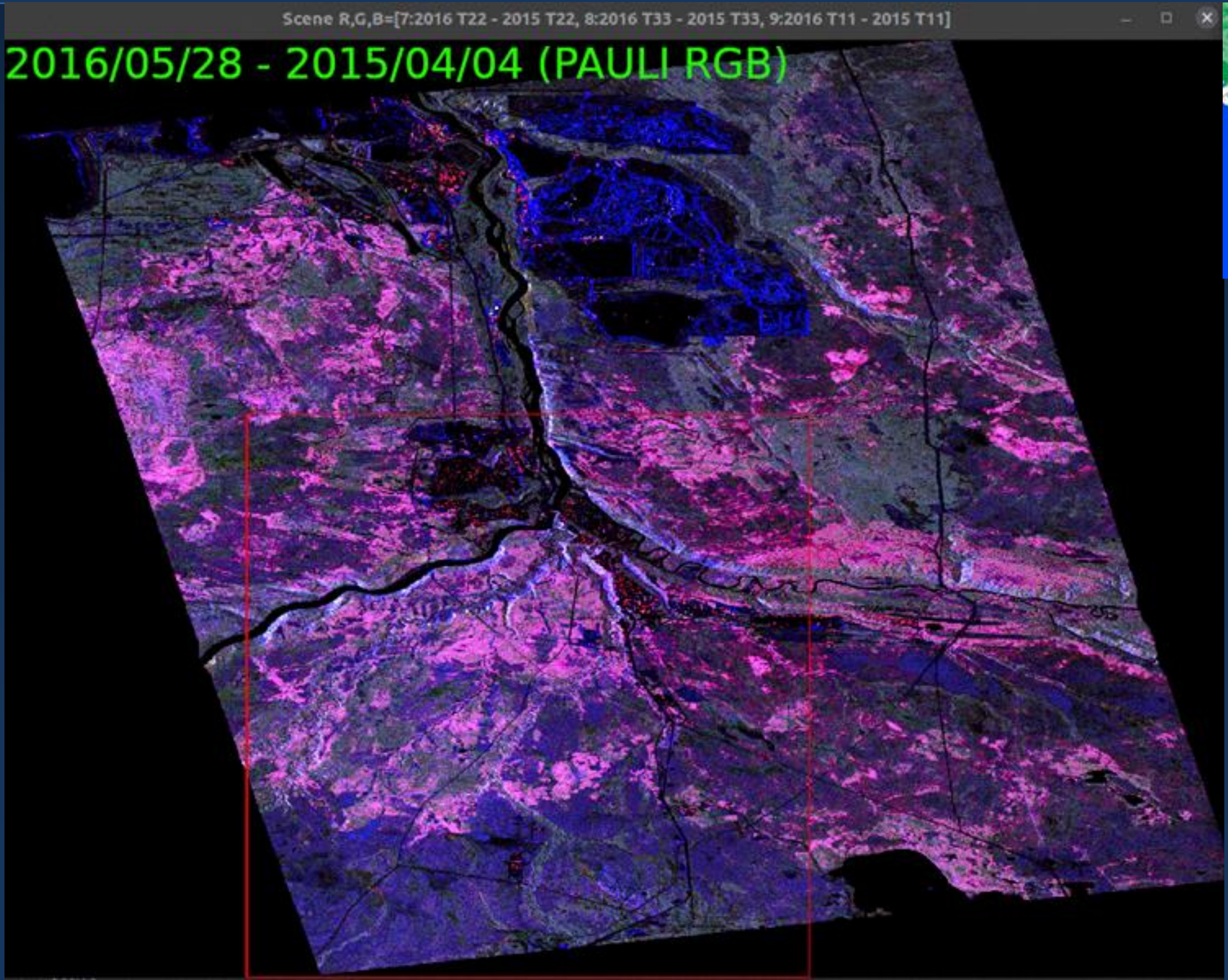
Results: Fort MacMurray (2016) T-matrix



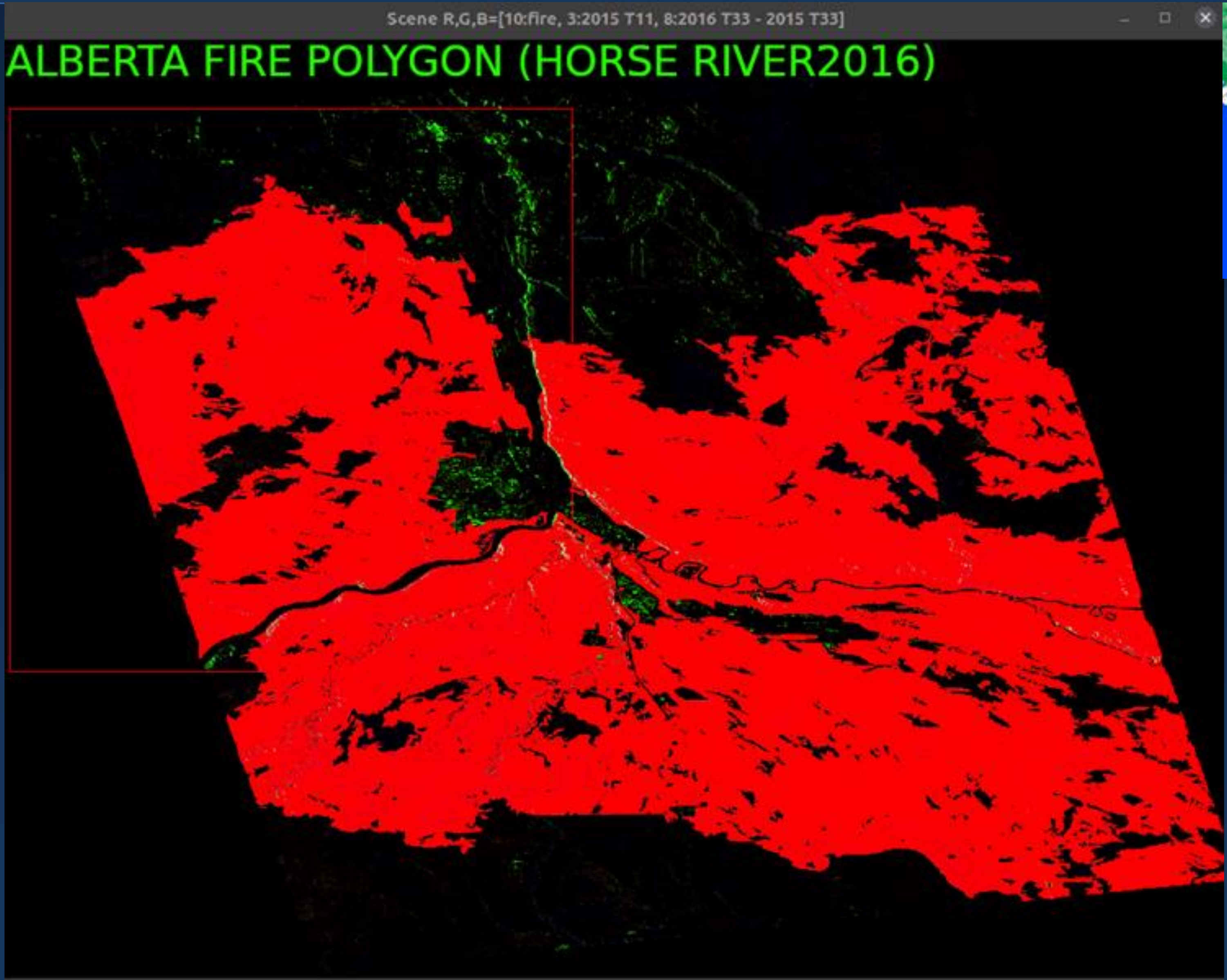
Results: Fort MacMurray (2016) T-matrix



Results: Fort MacMurray (2016) T-matrix



Results: Fort MacMurray (2016) Ground-ref



What if we only have dual-pol?

Dual pol parameters [1]

1. From the full-pol data we extract dual-pol (reduced polarimetric info) to “emulate” dual-pol products in: **HH-HV and VH-VV** modes

   (*) From Quad-pol T3 matrix, **extract C2 matrices** for both:

   HH-HV and VH-VV dual-pol products

1. Apply model-based decomposition for dual-pol data [1] for both HH-HV and VH-VV to get:

   m_p: completely polarized power AKA “polarized contribution to the backscattered wave”. Contribution from polarized targets in the scene!

   m_v: partially polarized power (“random-dipoles cloud” used as volume model, as in the Freeman Durden decom.) AKA “partially polarized contribution”. From “random volume” targets in the scene! e.g. Forests

1. Visualize as: (R, G, B) = (m_p, m_v, m_p)

[1]: 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.

Polarimetric interpretation of colors!

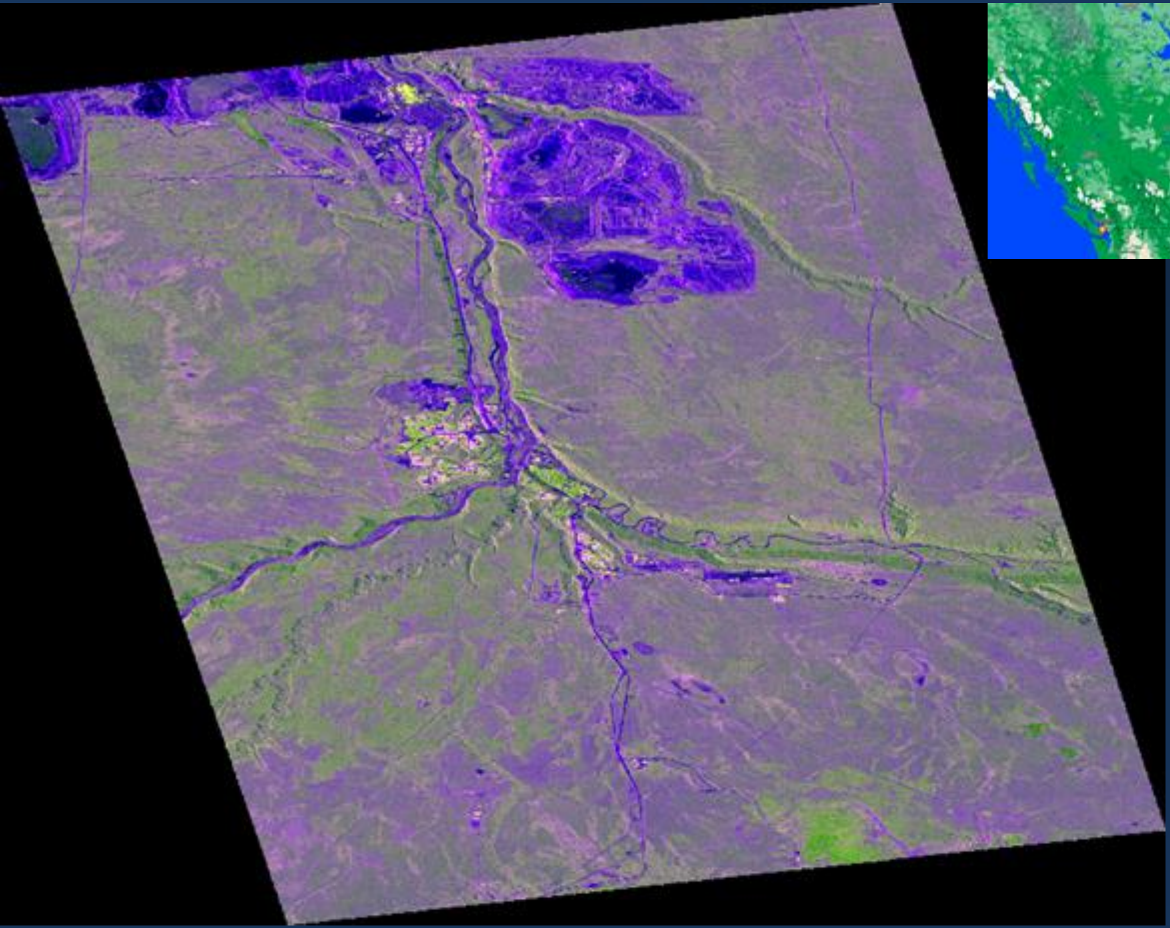
(R, G, B) = (m_p, m_v, m_p) (*)

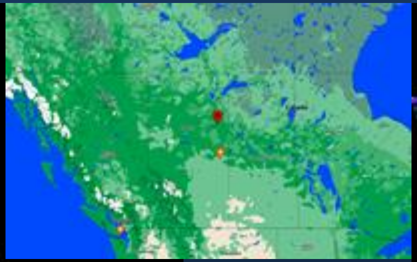
Note: unlike the conventional dual-pol-RGB often seen in the literature:
(i.e., (R,G,B) = (VV power, G: VH power, B:, VH/VV)

- this RGB representation (*) is more grounded in the physics of polarimetry
    - Colors are associated w polarized and partially polarized contributions of the reflected waves, not w simple received powers

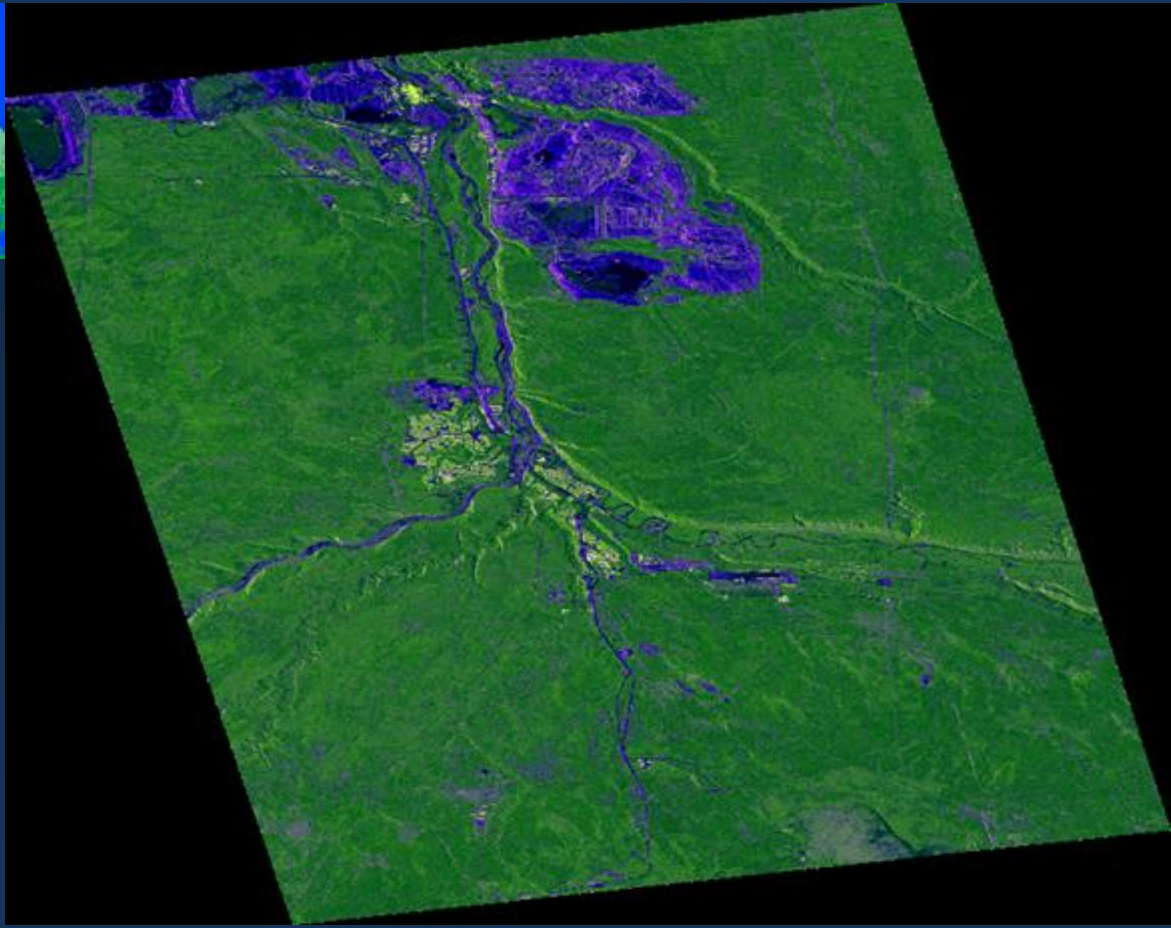
Dual pol parameters 20150404

HH/HV case





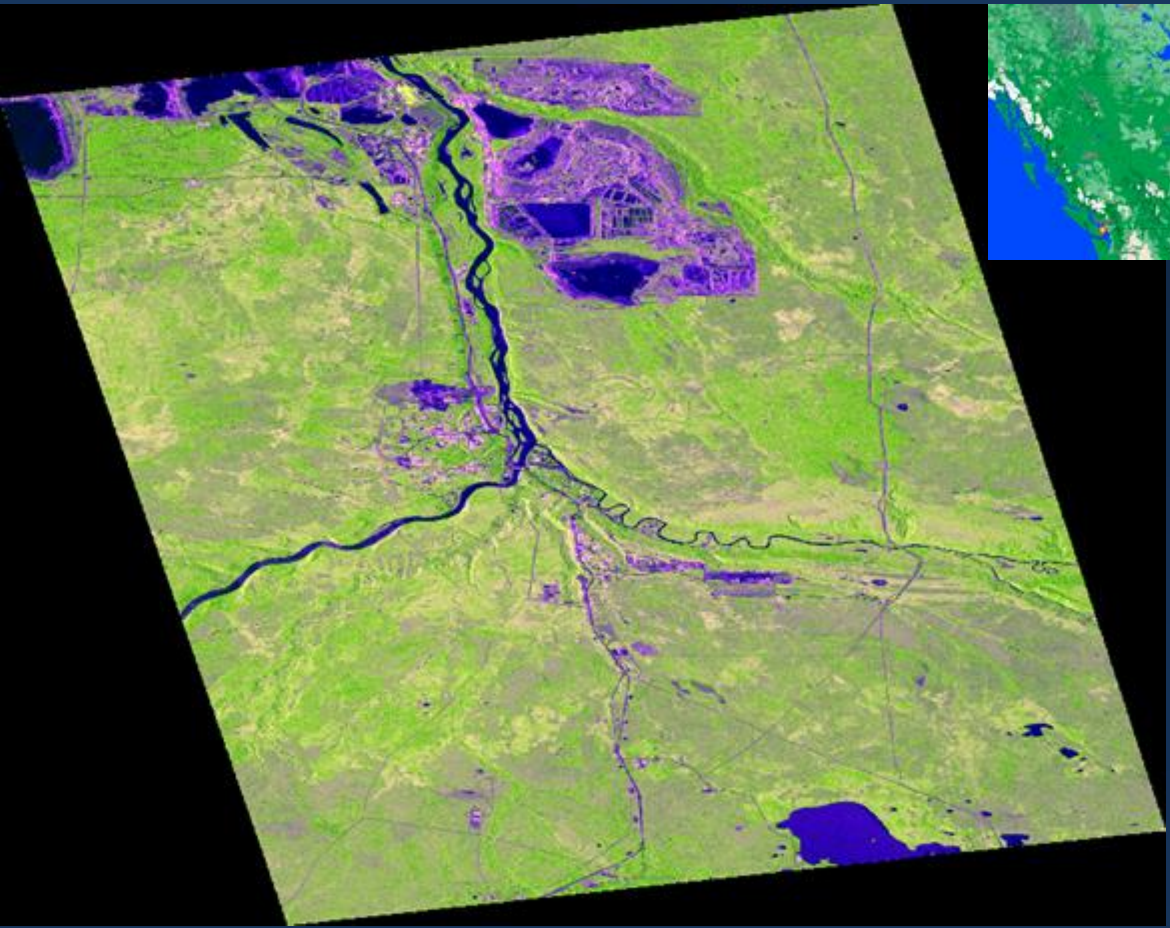
VH/VV case



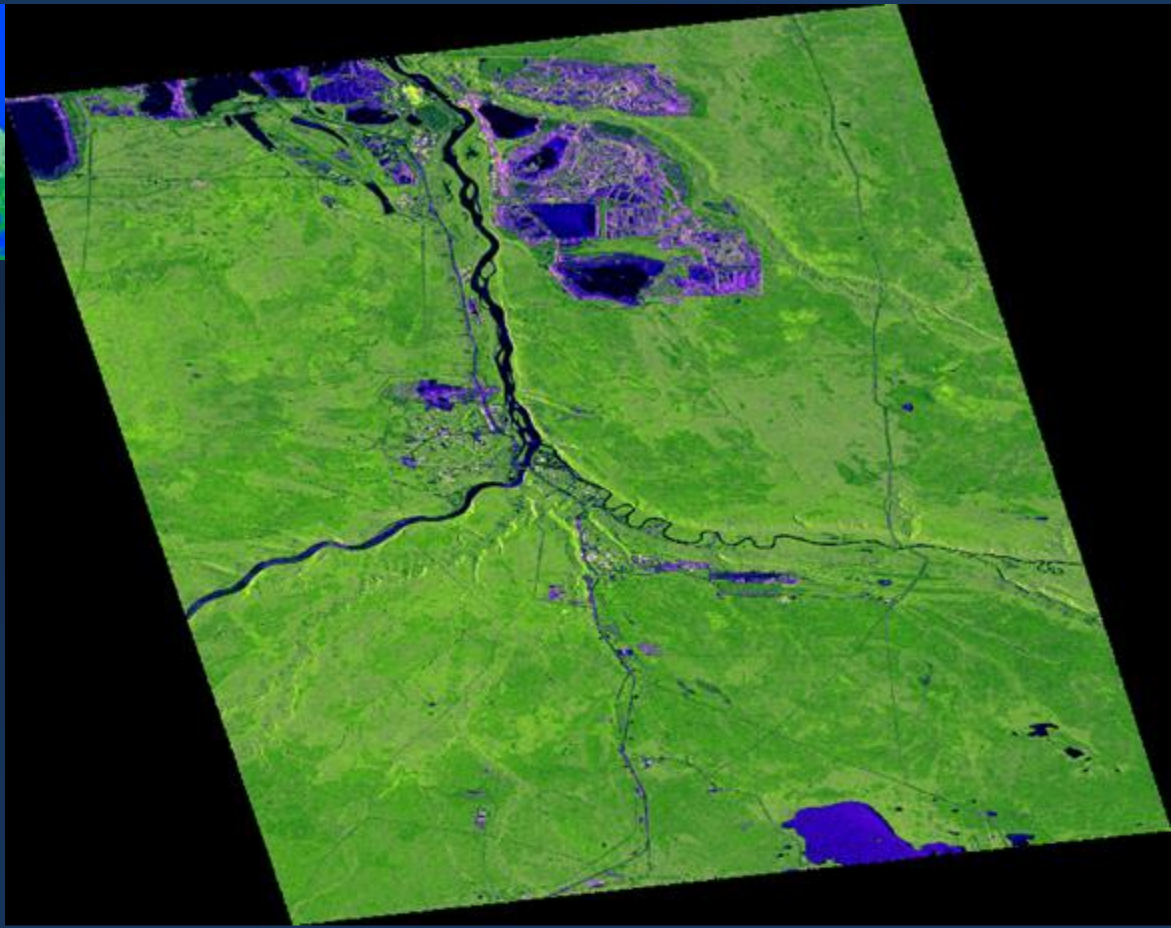
- Much more volume contribution in VH-VV than in HH-HV case.
- Possible explanation: sensitivity of L-band to long elements such as stems.
- Vertical stems attenuate V-polarized waves: m_p << m_v hence we see more green!
- HH-HV case: H-polarized waves are less attenuated: less volume scattering, hence we see less green

Dual pol parameters 20160528

HH/HV case



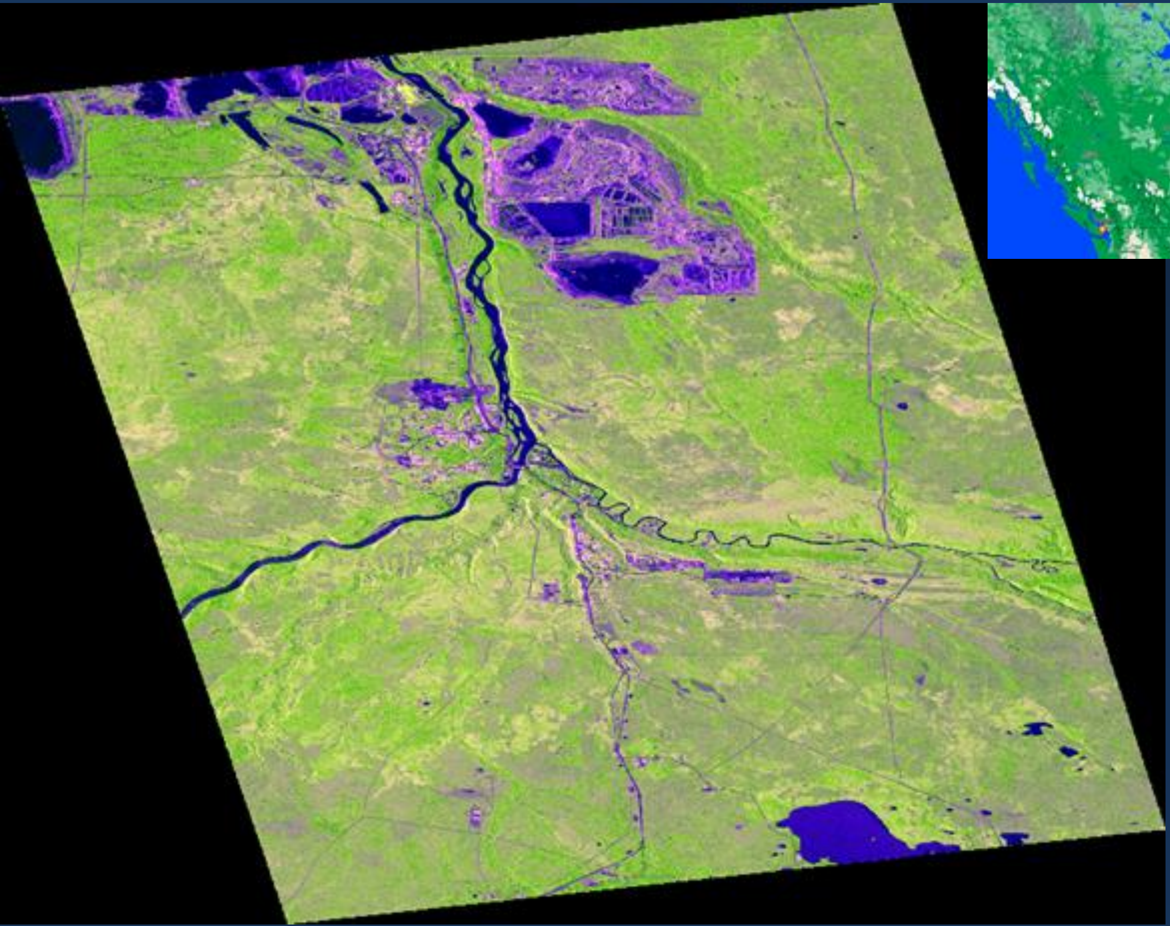
VH/VV case



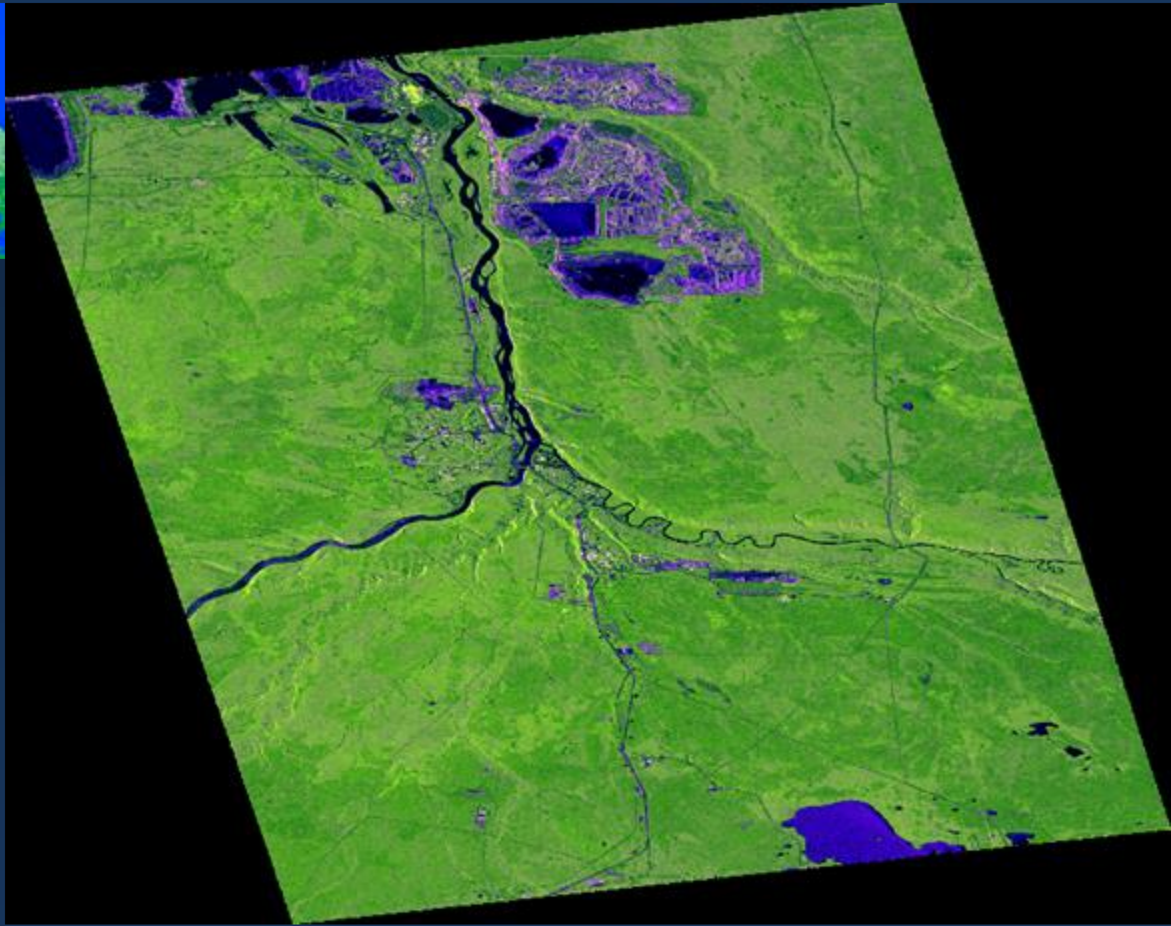
- Compared to the pre-fire images, the **volume component of the backscattered wave increases for both modes**
- **However, the increase is more significant for the HH-HV mode.**
- **Possible explanation: Stems partially collapse after the fire.** The remainder of the stem is vertically oriented, the collapsed portion is random

Dual pol parameters 20160528 cont'd (1/2)

HH/HV case



VH/VV case



- Possible explanation (1, cont'd): Hence, the **collapsed portion of the stem increase the volume contribution. This increase is more prominent for HH-HV case**: H-polarized waves see mainly the random collapsed matter.
- On the other hand, the **m_v increase is less visible for VH-VV,** since here we are **more sensitive to the remaining vertical elements,** and less sensitive to the random collapsed material

Dual pol parameters 20160528 cont'd (2/2)

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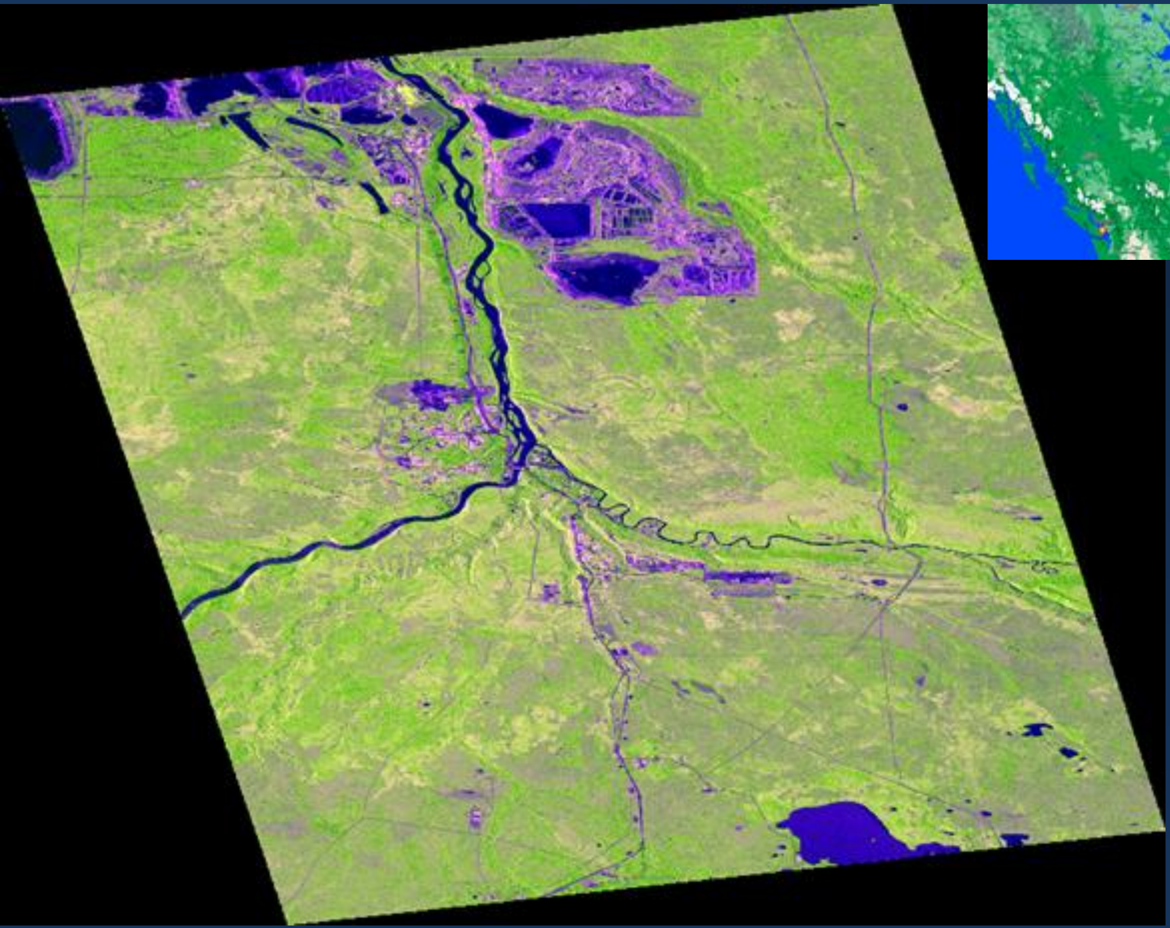
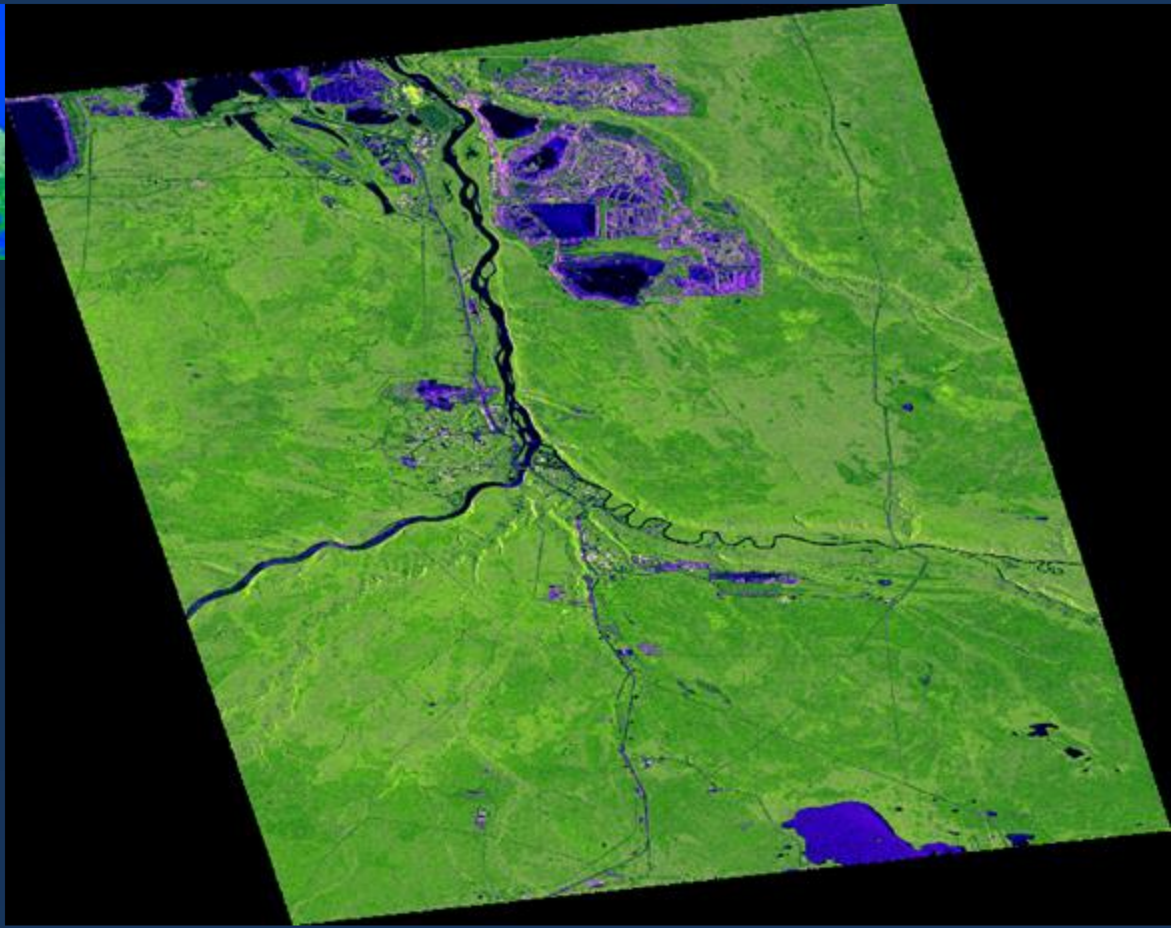
HH/HV case



VH/VV case

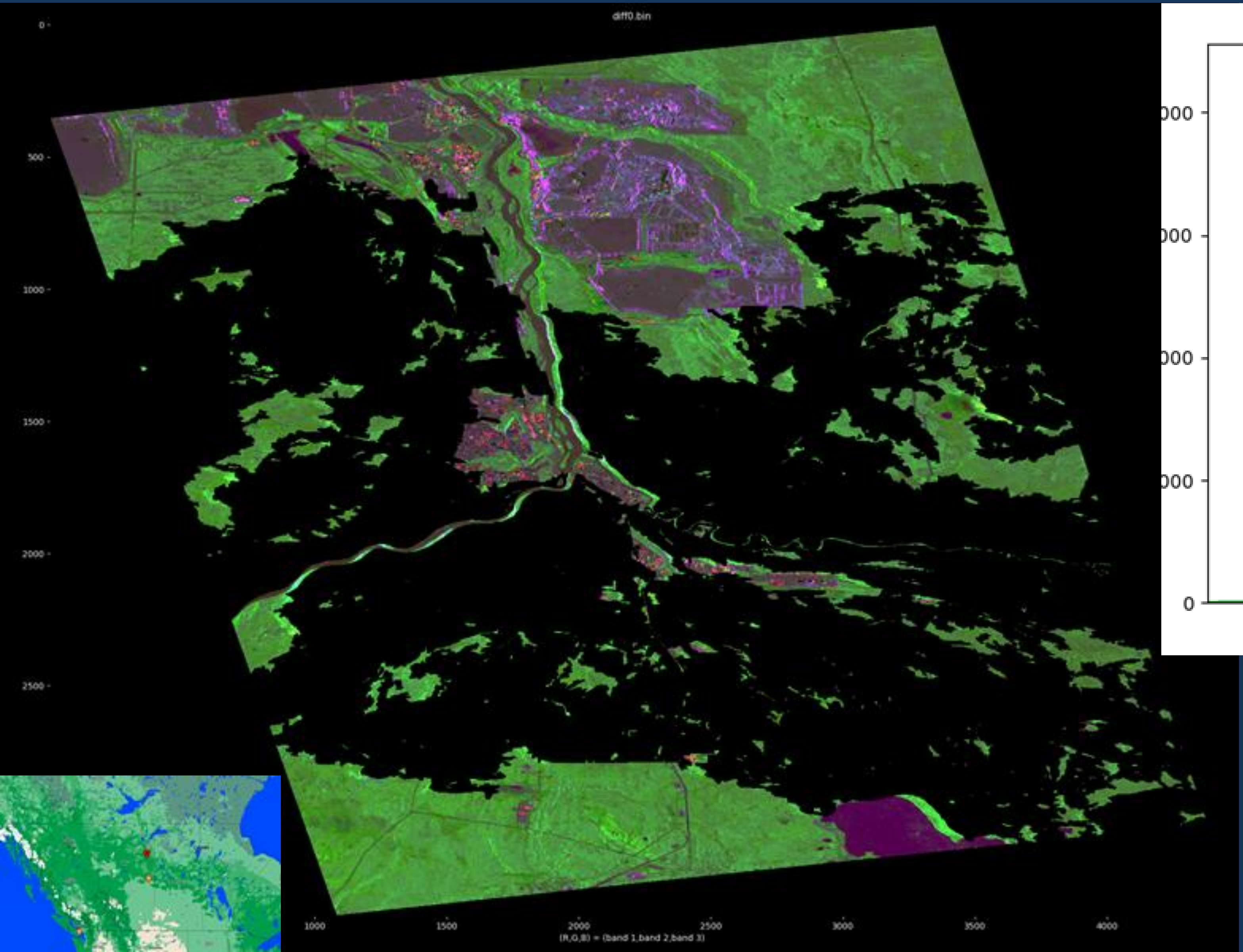


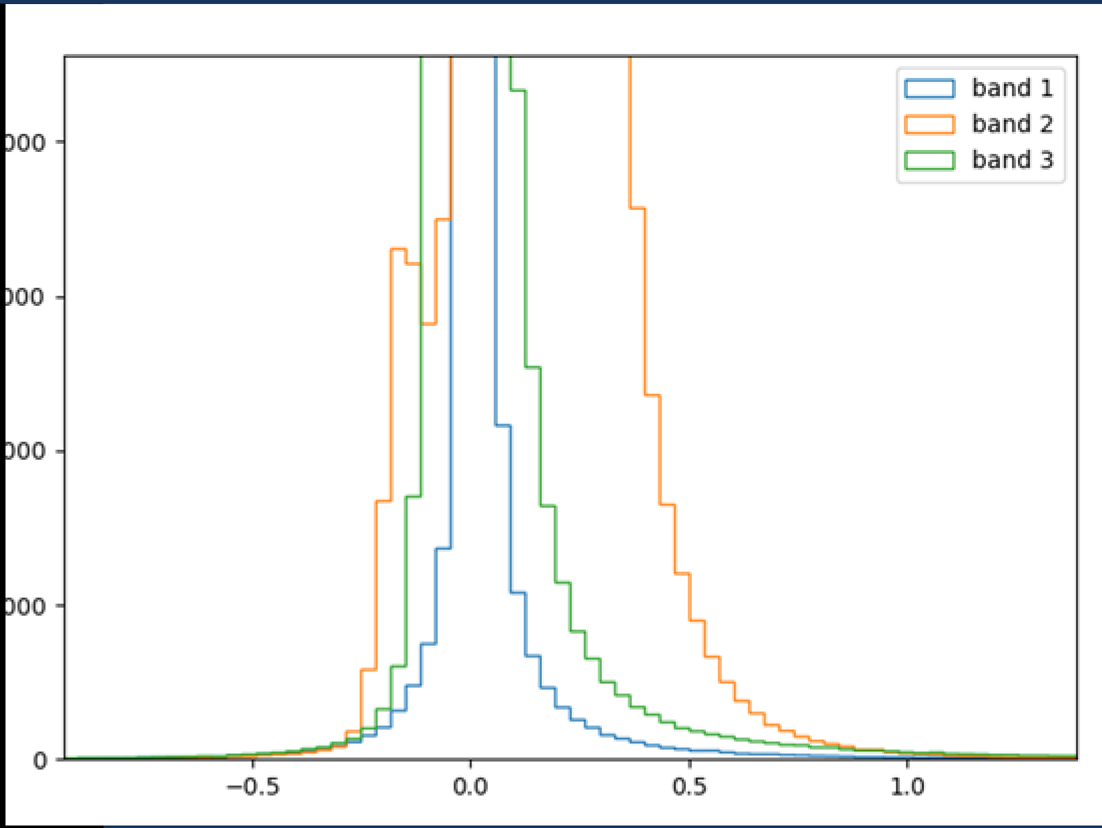
- Possible explanation 2) the observations could be related to water content of the stems, which could be high on May 26, as noted in (2018) Plank et al

Check DP interpretation by using Freeman parameters

1. Calc. freeman 3-component decom for 2015 & 2016 dates
2. Calc. the difference: 2016 - 2015 (for the three Freeman params)
3. Partition the data into unburned and burned portions (according the national fire database polygon)
4. Plot histograms for each fraction, see if they move

Freeman decom (difference 2016-2015): unburned area





- No conclusive bias observed
- Should stratify by land-cover types to understand more

Freeman decom (difference 2016-2015): burned area

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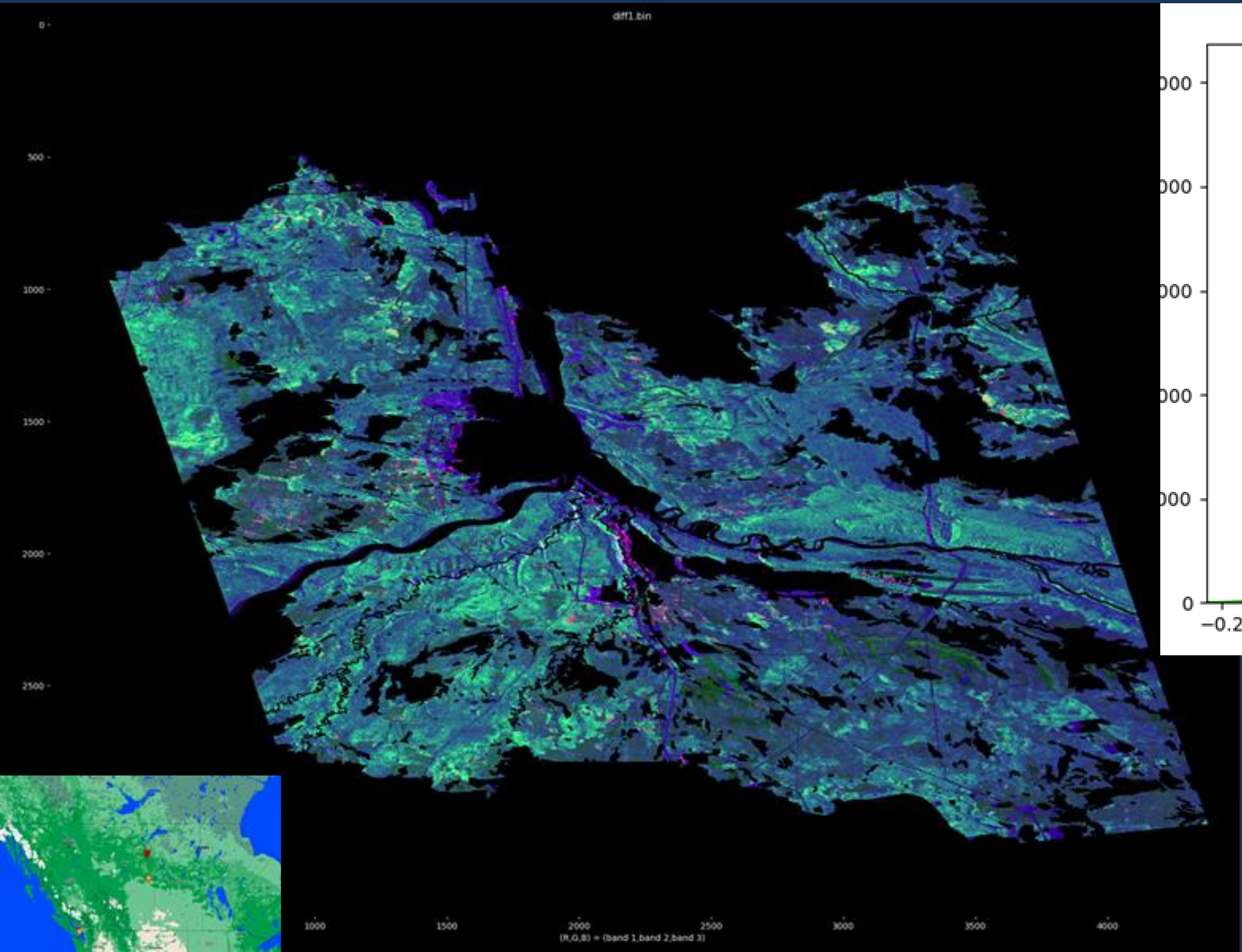

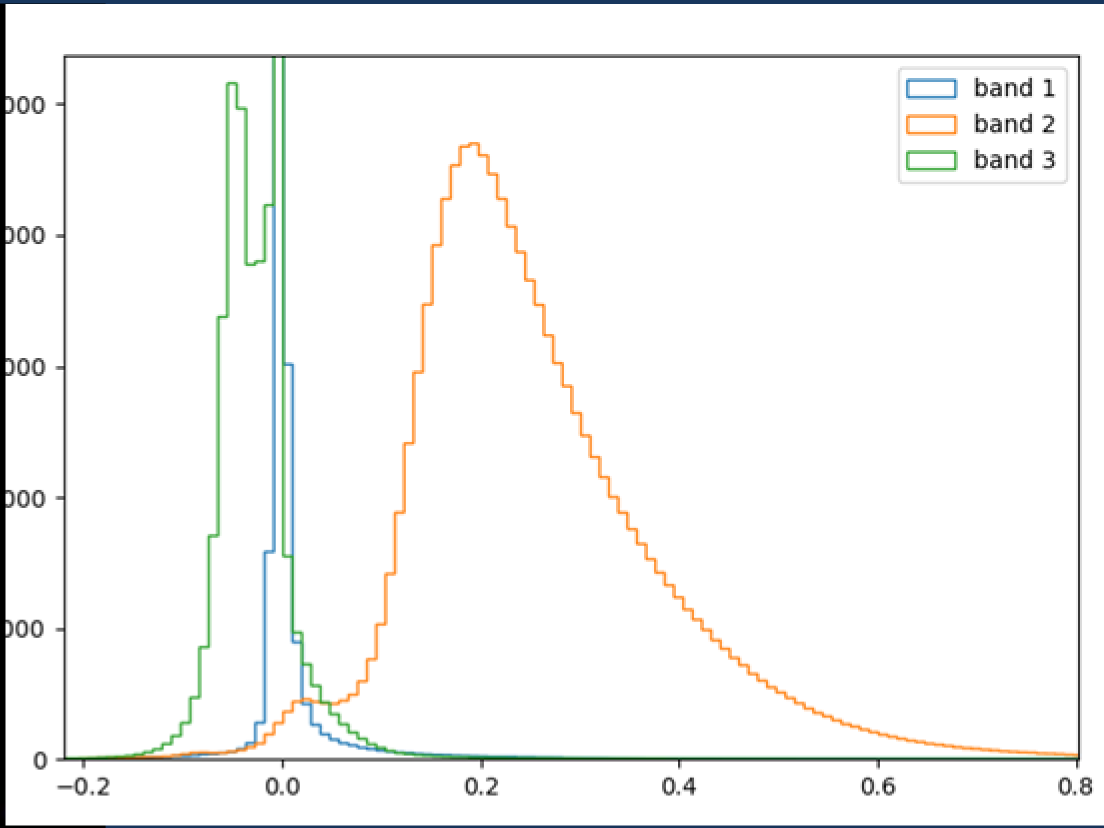

- Clear bias observed
- The histograms moved!
- Volume-scattering changes observed!

Better: DP/QP comparison: create a “new” ground-ref (less false positives)

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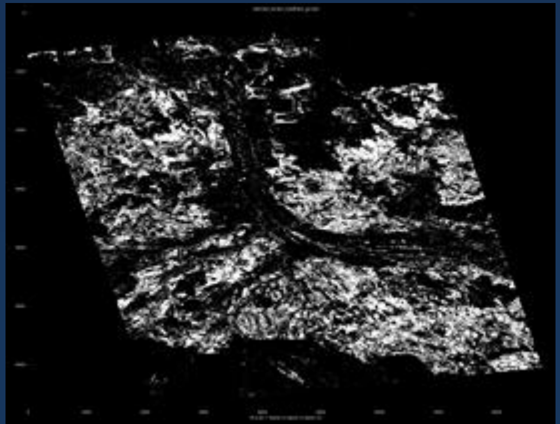
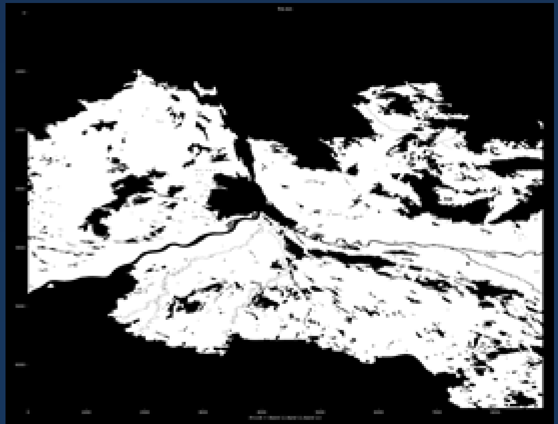
Chainsaw math approach

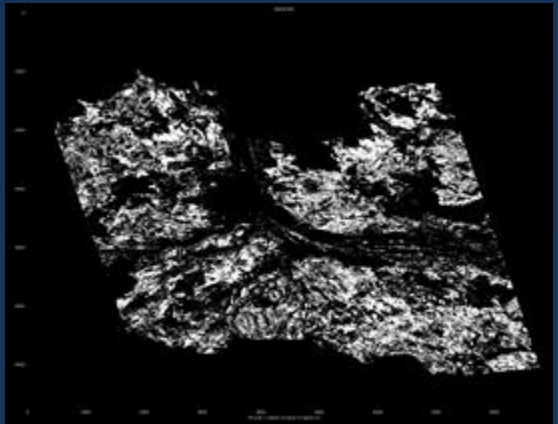
1. Download two landsat frames:
   a. LC08_L2SP_042021_20161003_20200906_02_T1.tar
   b. LC08_L2SP_042020_20161003_20200906_02_T1.tar
2. Merge using **gdal_merge.py**
3. Use **gdal_translate** to project onto ARD radar data
4. Use spectral interpolation to **emulate Sentinel2 bands: B12, B11, B9** (resilient to atmosphere)
5. **Histogram trim 1%** each channel and **scale each band to range [0, 1]**
6. Apply channel-wise **histogram mode filter** to reduce the number of values
   a. https://github.com/bcgov/wps-research/blob/master/cpp/modf.cpp
7. Use simple NN binary classifier (trained on manually selected pixels) to produce a **burned mask (LEFT)**
   a. https://github.com/bcgov/wps-research/blob/master/cpp/pn.cpp
8. Multiply by the **National Fire Database polygon data (MIDDLE)**
   a. https://cwfis.cfs.nrcan.gc.ca/downloads/nfdb/fire_poly/current_version/NFDB_poly_large_fires.zip
9. Result: a **more conservative estimate of burned area extent, with less false positives included (RIGHT)**



*



=



Detail of step 7 (last slide): select N=36 points
Quick and dirty selection, first attempt

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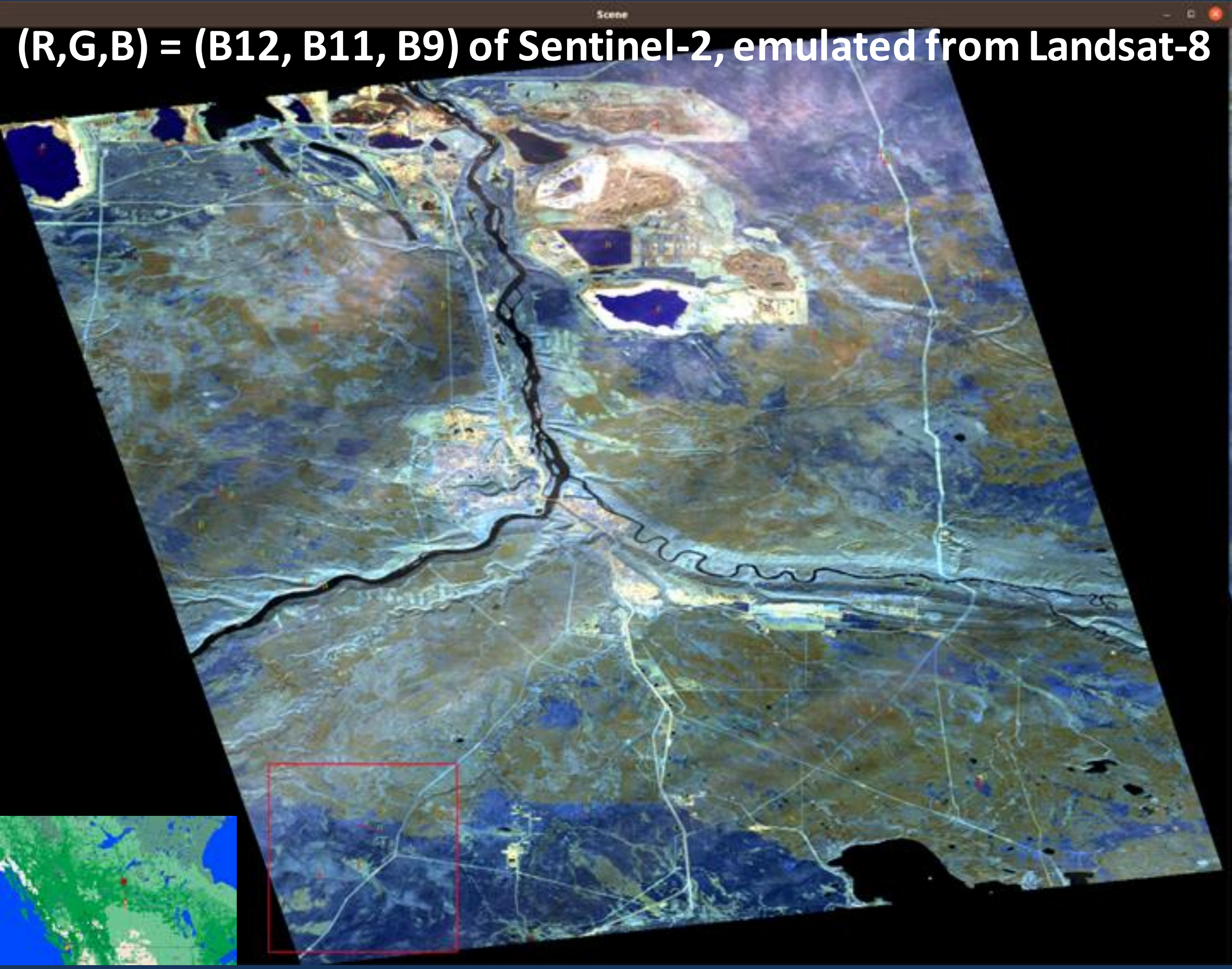

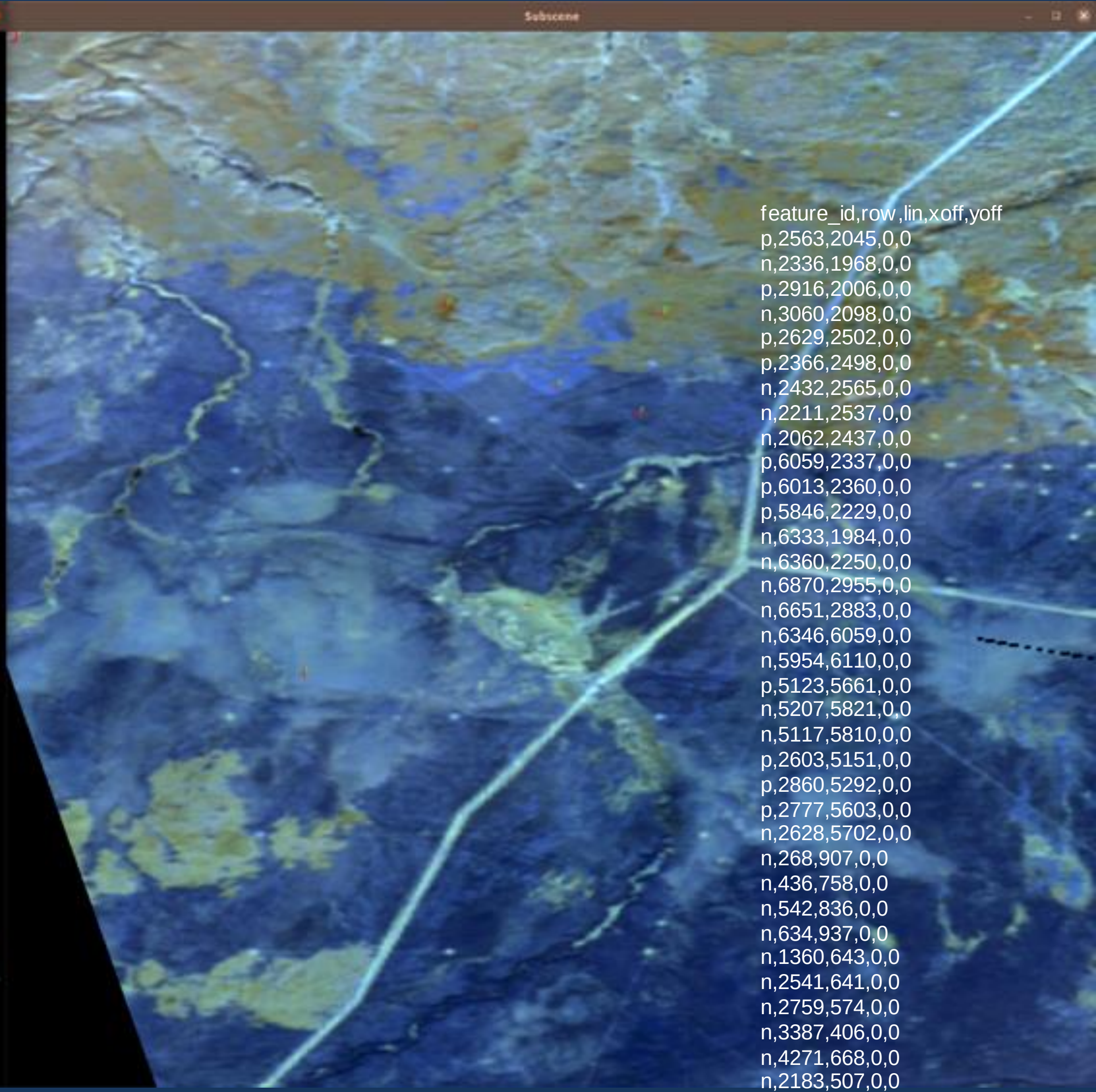


```
feature_id,row,lin,xoff,yoff
p,2563,2045,0,0
n,2336,1968,0,0
p,2916,2006,0,0
n,3060,2098,0,0
p,2629,2502,0,0
p,2366,2498,0,0
n,2432,2565,0,0
n,2211,2537,0,0
n,2062,2437,0,0
p,6059,2337,0,0
p,6013,2360,0,0
p,5846,2229,0,0
n,6333,1984,0,0
n,6360,2250,0,0
n,6870,2955,0,0
n,6651,2883,0,0
n,6346,6059,0,0
n,5954,6110,0,0
p,5123,5661,0,0
n,5207,5821,0,0
n,5117,5810,0,0
p,2603,5151,0,0
p,2860,5292,0,0
p,2777,5603,0,0
n,2628,5702,0,0
n,268,907,0,0
n,436,758,0,0
n,542,836,0,0
n,634,937,0,0
n,1360,643,0,0
n,2541,641,0,0
n,2759,574,0,0
n,3387,406,0,0
n,4271,668,0,0
n,2183,507,0,0
n,1013,603,0,0
```

Radar classification: annotate small # of training pixels (n=20)
Then apply NN classifier again (T22 channels only!)

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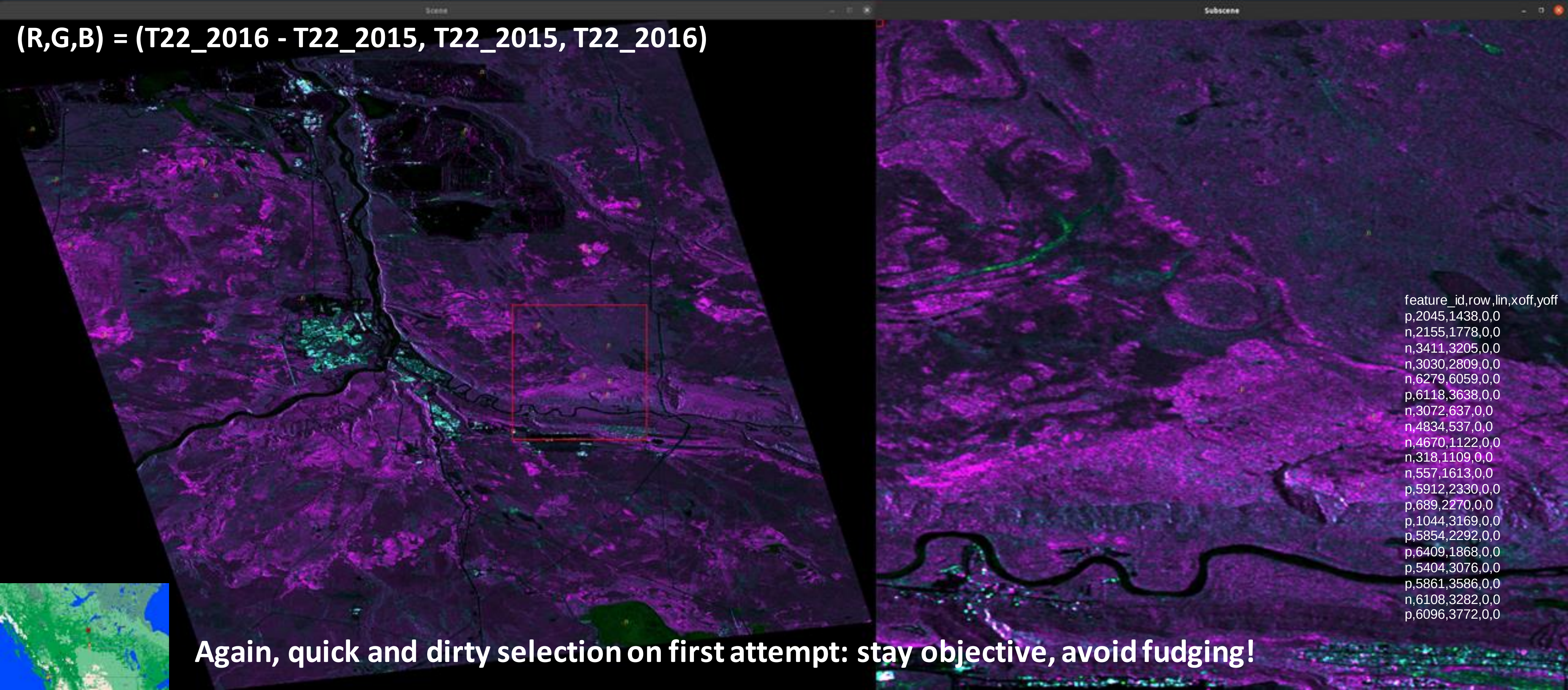
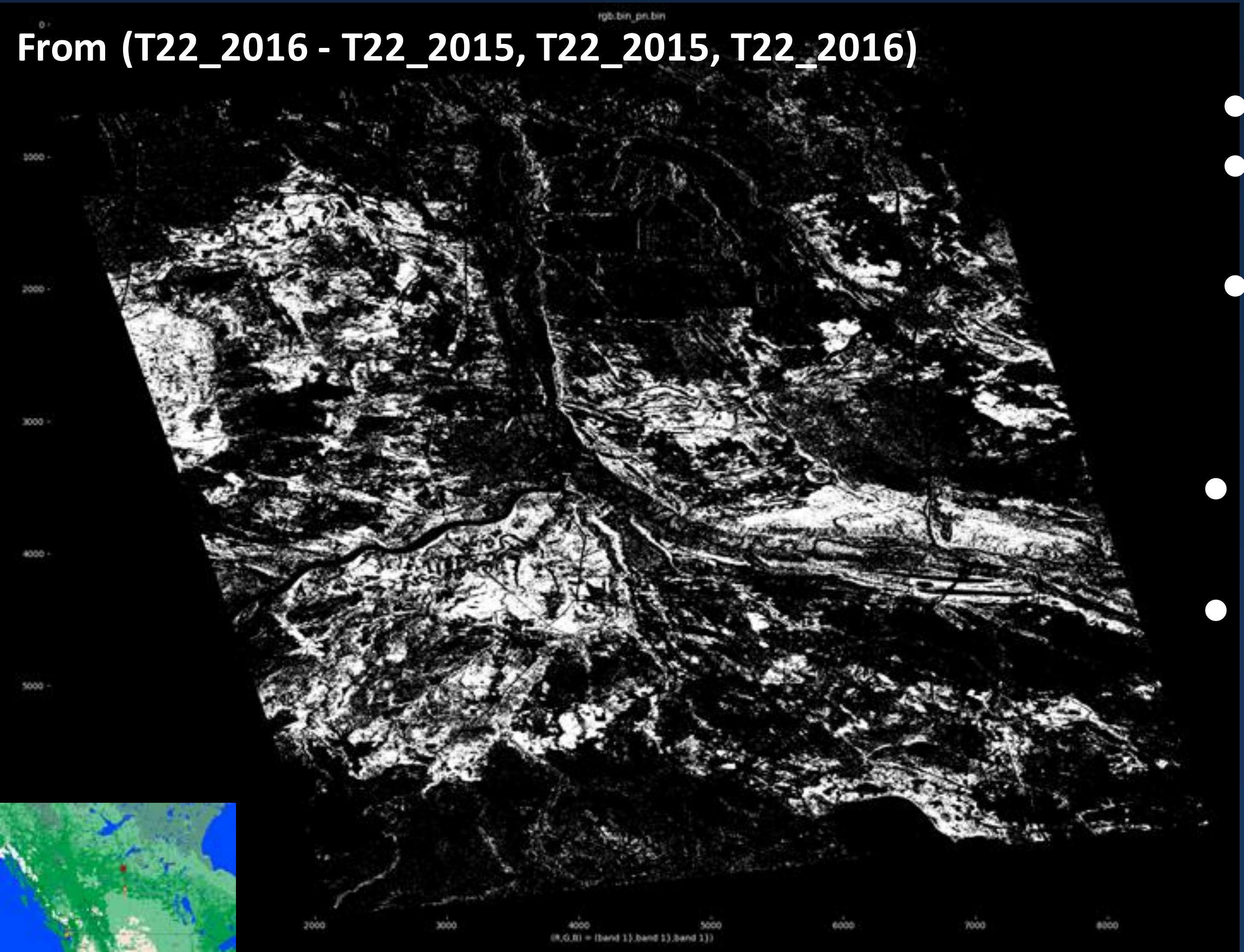


Again, quick and dirty selection on first attempt: stay objective, avoid fudging!

T22 only result (two dates): 77% Accuracy (N_train=20)



- Got 71% Accuracy from using the original (simple) fire polygon data
- **+ 6% accuracy from the improved GR**
- **Later improve this using the active fire detection method**
- Got 80% accuracy by using T22, T33, T11 for both years (6 bands) with histogram trim (1% each side)

- Used basic “chainsaw science” to show the potential
- More sophisticated stats would improve the results

class_map,ground_ref,P%,N%,TP%,TN%,FP%,FN%,TPR,TNR,PPV,NPV,FNR,FPR,FDR,FOR,PLR,NLR,**ACC**,BA,F1,BM,MK
rgb.bin_pn.bin,mask.bin,14.041385,28.255510,4.254117,28.255510,9.670004,9.787269,0.302970,1.000000,0.305521,0.742730,0.697030,0.342234,0.694479,0.257270,0.885270,0.697030,**0.768606**,0.651485,0.304240,2.302970,0.048251

feature_id,row,lin,xoff,yoff
p,2045,1438,0,0
n,2155,1778,0,0
n,3411,3205,0,0
n,3030,2809,0,0
n,6279,6059,0,0
p,6118,3638,0,0
n,3072,637,0,0
n,4834,537,0,0
n,4670,1122,0,0
n,318,1109,0,0
n,557,1613,0,0
p,5912,2330,0,0
p,689,2270,0,0
p,1044,3169,0,0
p,5854,2292,0,0
p,6409,1868,0,0
p,5404,3076,0,0
p,5861,3586,0,0
n,6108,3282,0,0
p,6096,3772,0,0

Single date, one channel only (2016_T22)
75% Accuracy

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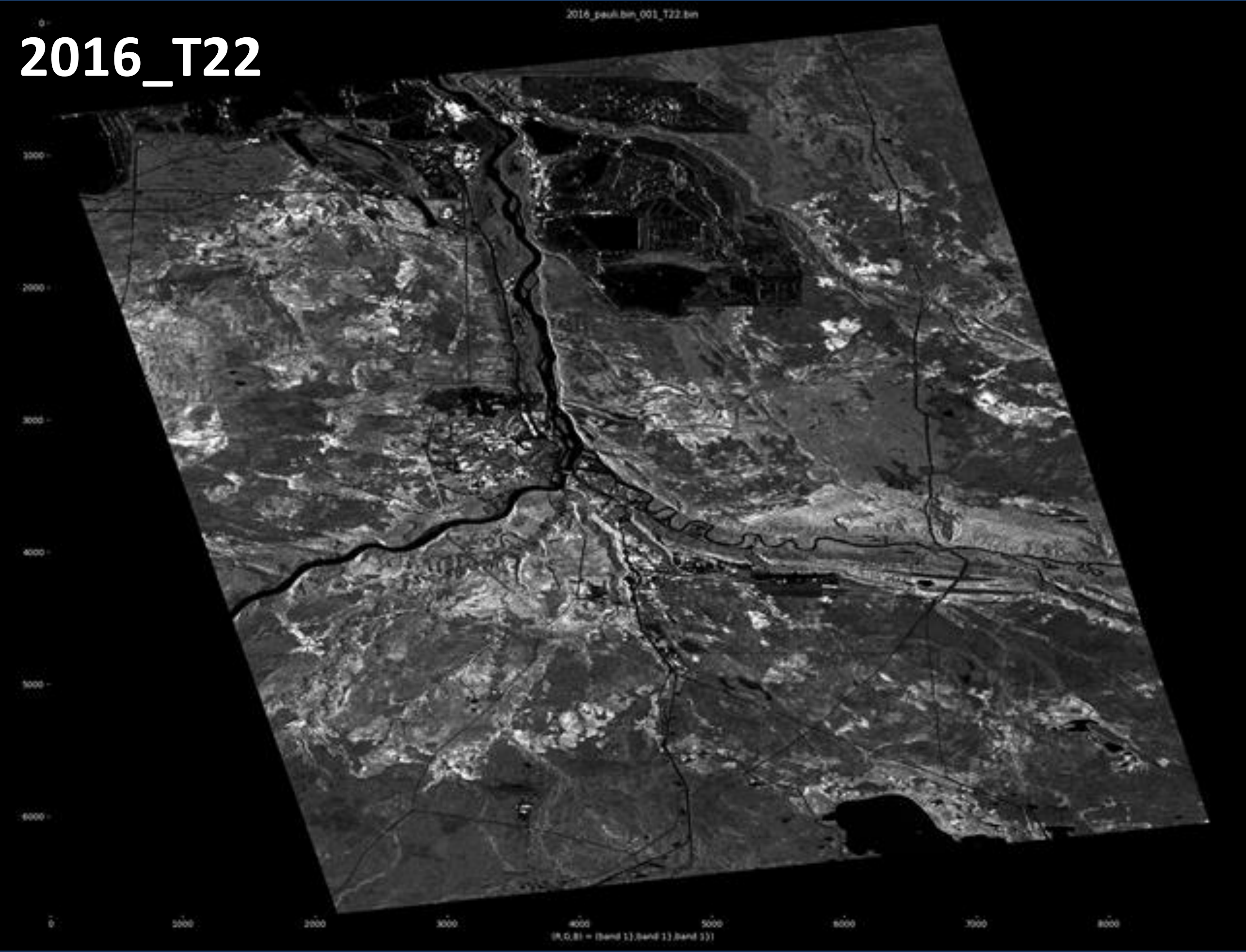
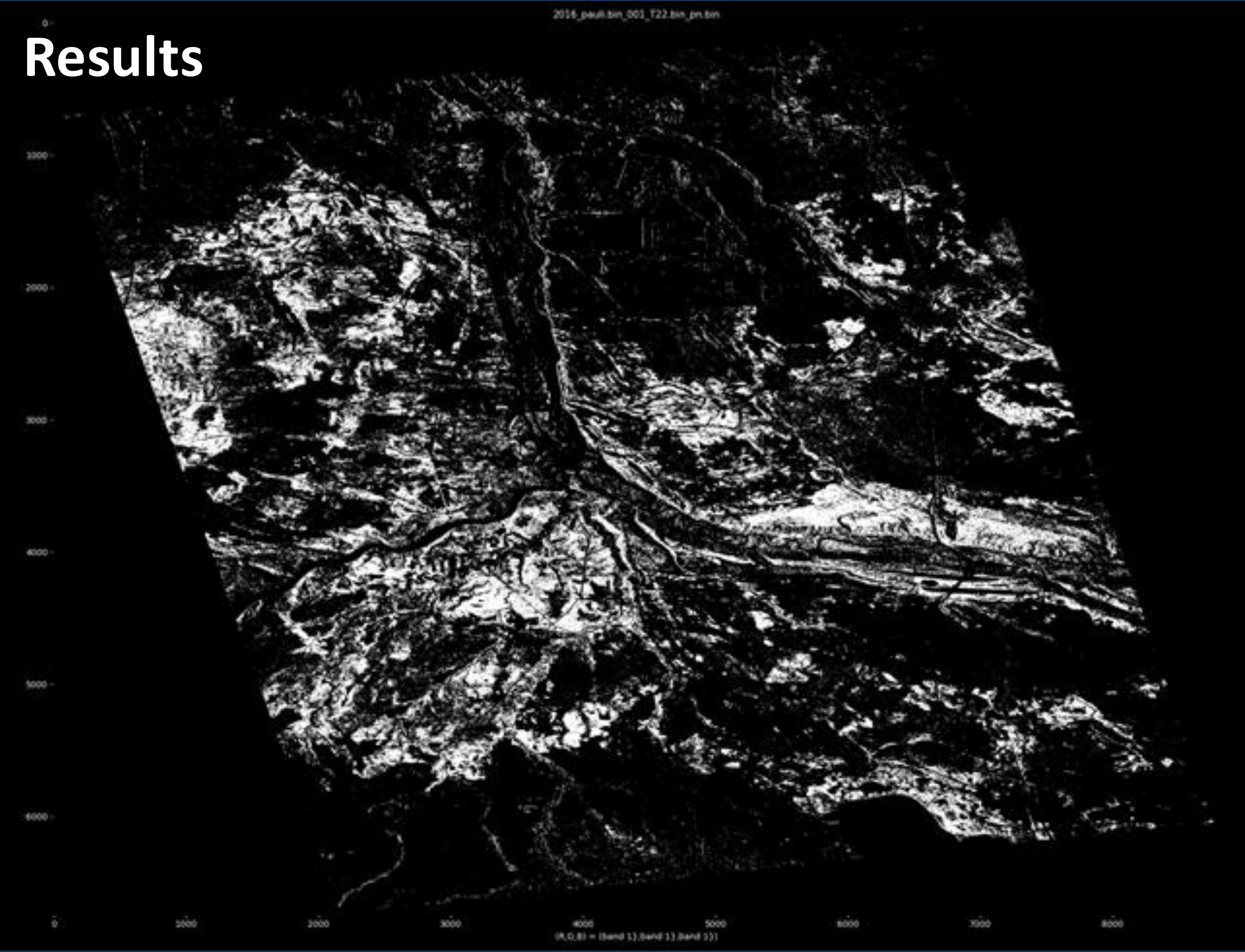
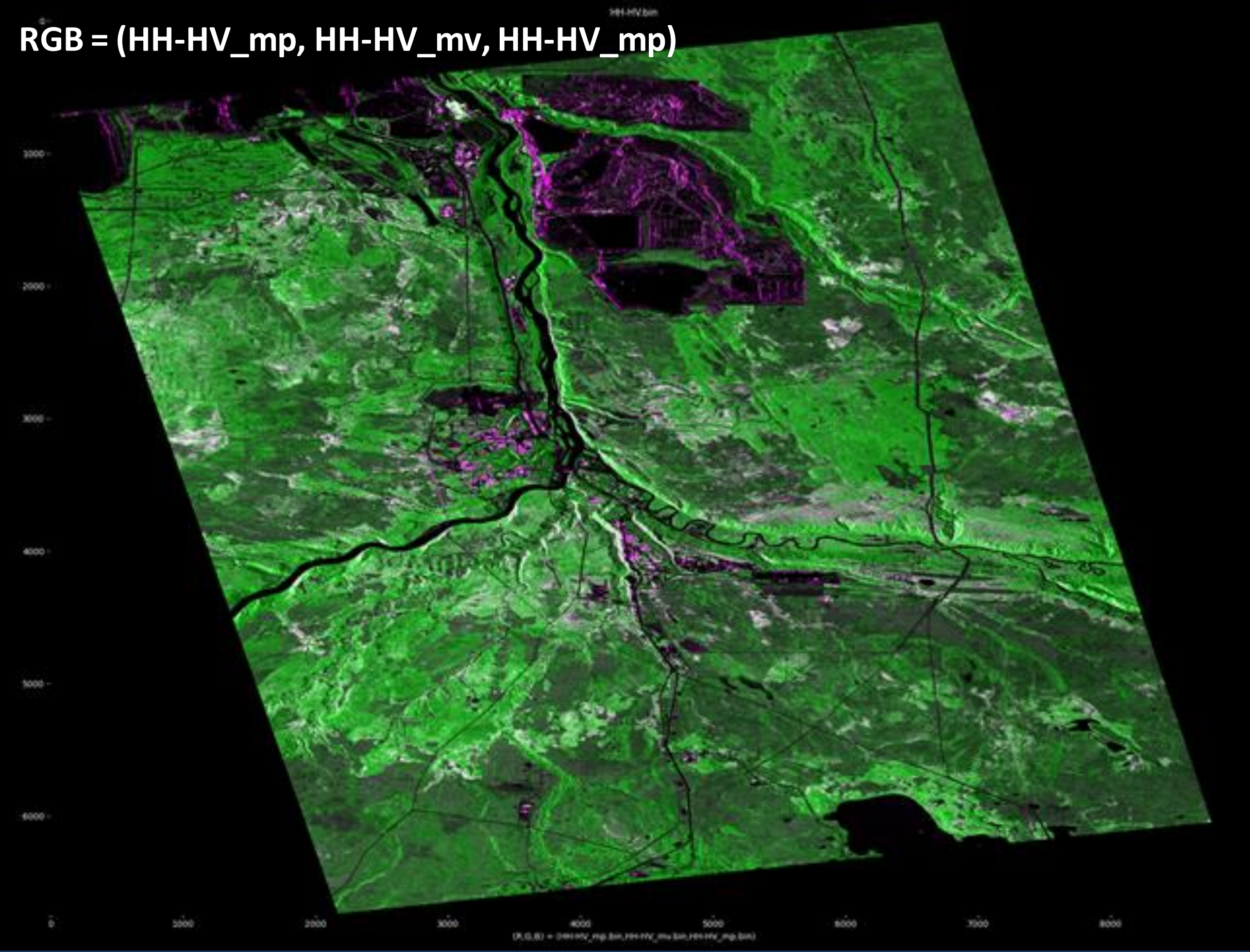


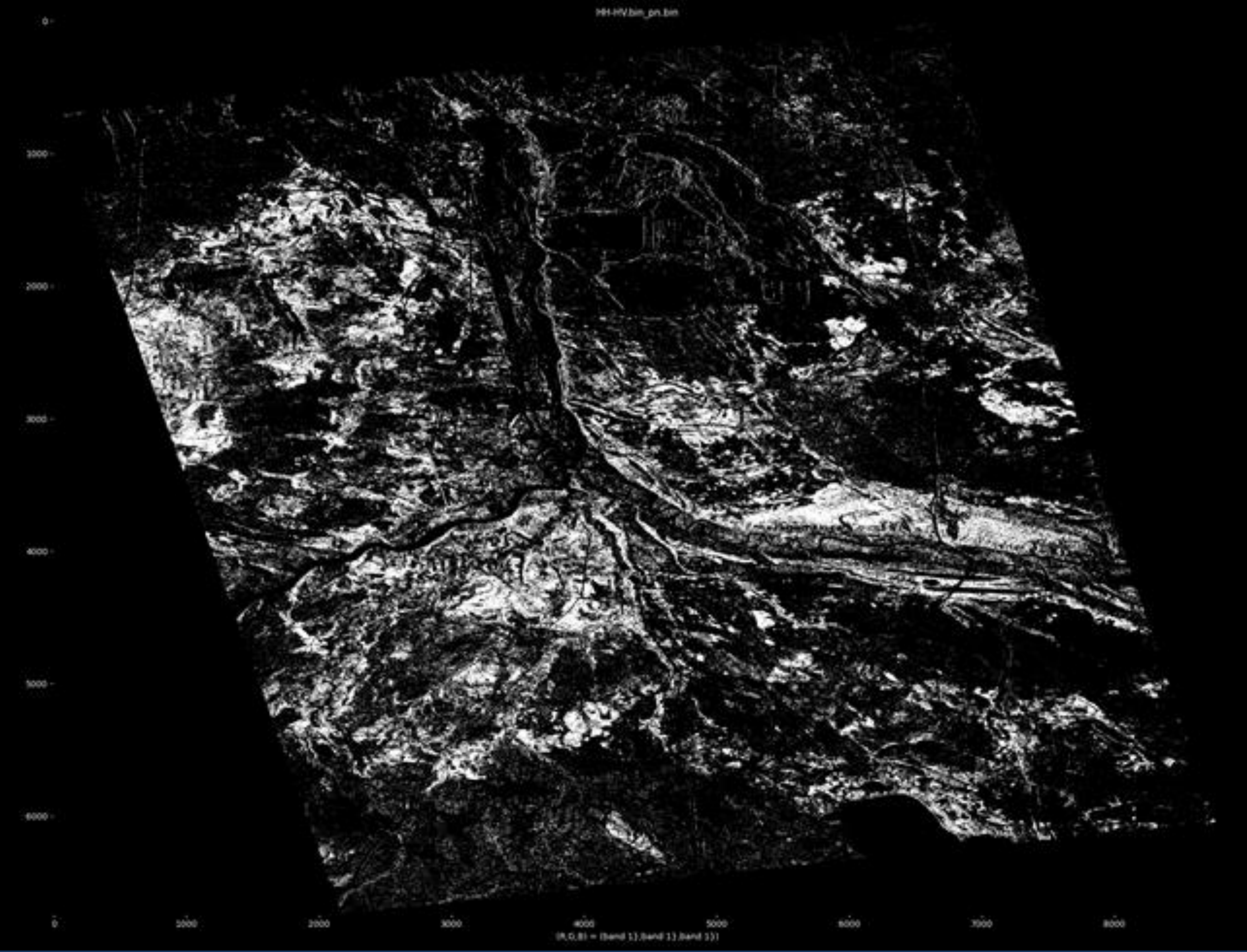


class_map,ground_ref,P%,N%,TP%,TN%,FP%,FN%,TPR,TNR,PPV,NPV,FNR,FPR,FDR,FOR,PLR,N
LR,ACC,BA,F1,BM,MK
2016_pauli.bin_001_T22.bin_pn.bin,mask.bin,14.041385,28.255510,3.442727,28.255510,8.167476,10
.598658,0.245184,1.000000,0.296526,0.727220,0.754816,0.289058,0.703474,0.272780,0.848219,0.7
54816,**0.749422**,0.622592,0.268422,2.245184,0.023746

2016 Dual-pol: (HH-HV_mp, HH-HV_mv) parameters: 75% Accuracy

RGB = (HH-HV_mp, HH-HV_mv, HH-HV_mp)

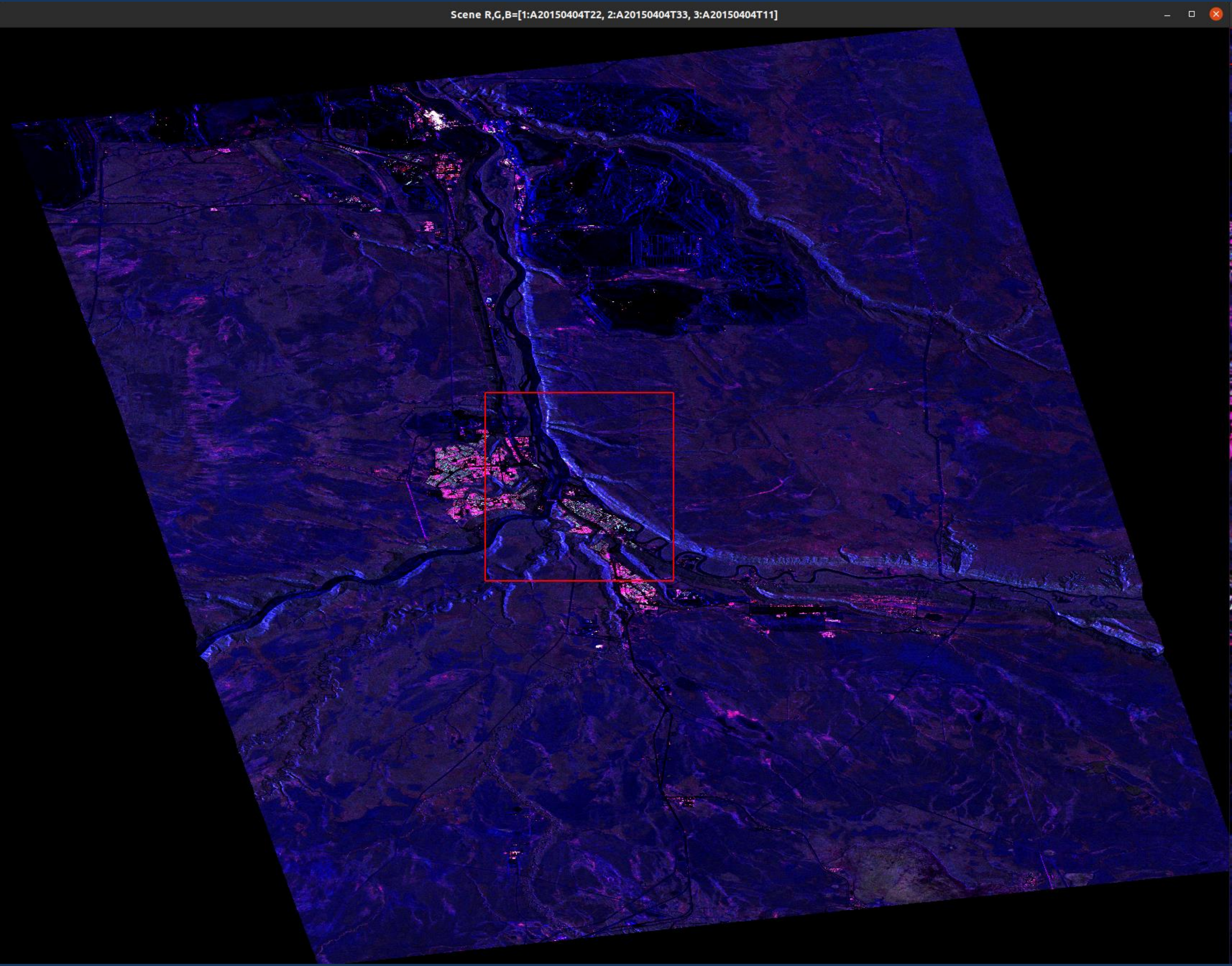


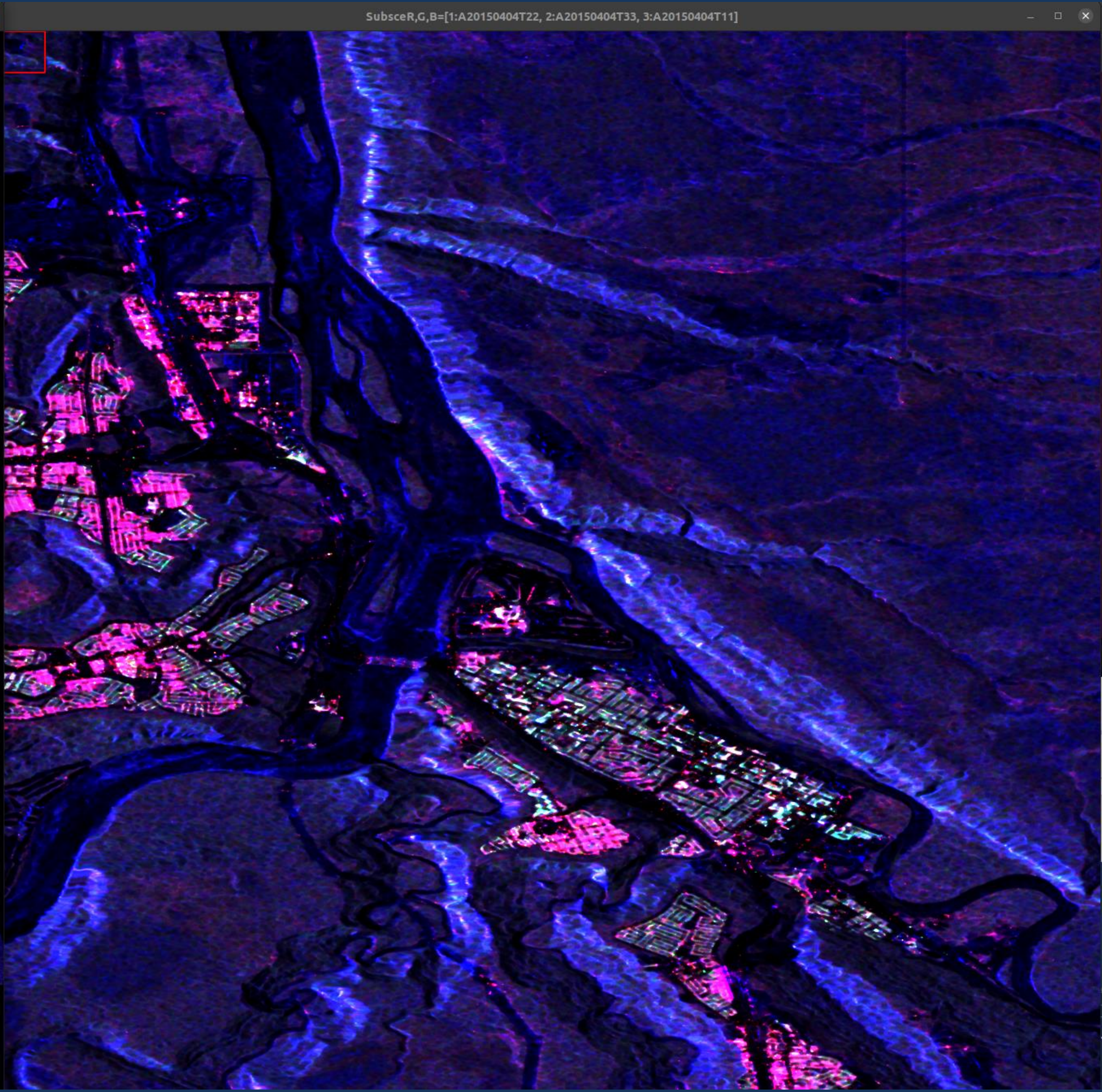


Better geolocation needed (SAR vs Optical registration) to make an objective assessment between all the modes!

Compare with C band

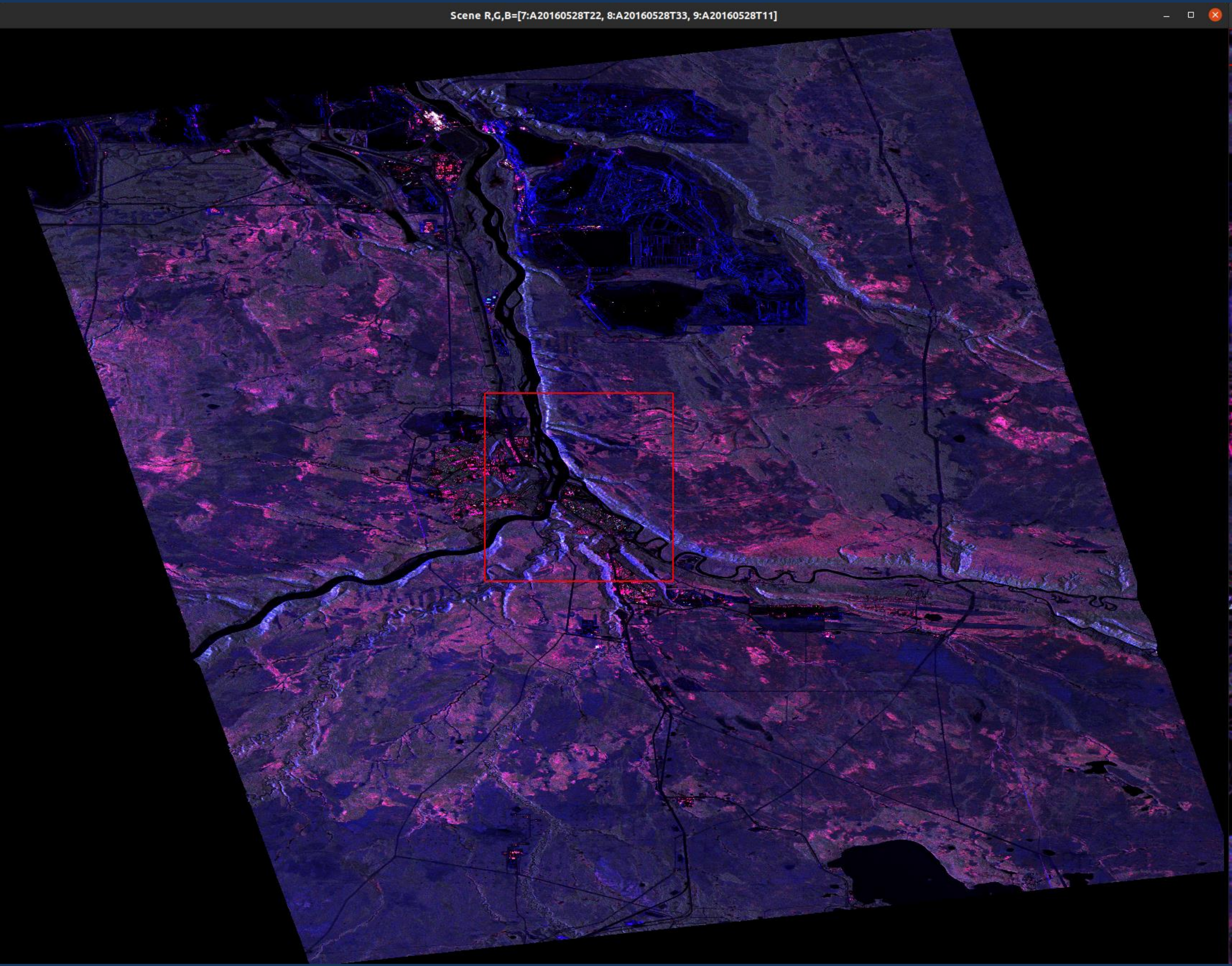
AP2 20150404 T22, T33, T11 pre (L-band)

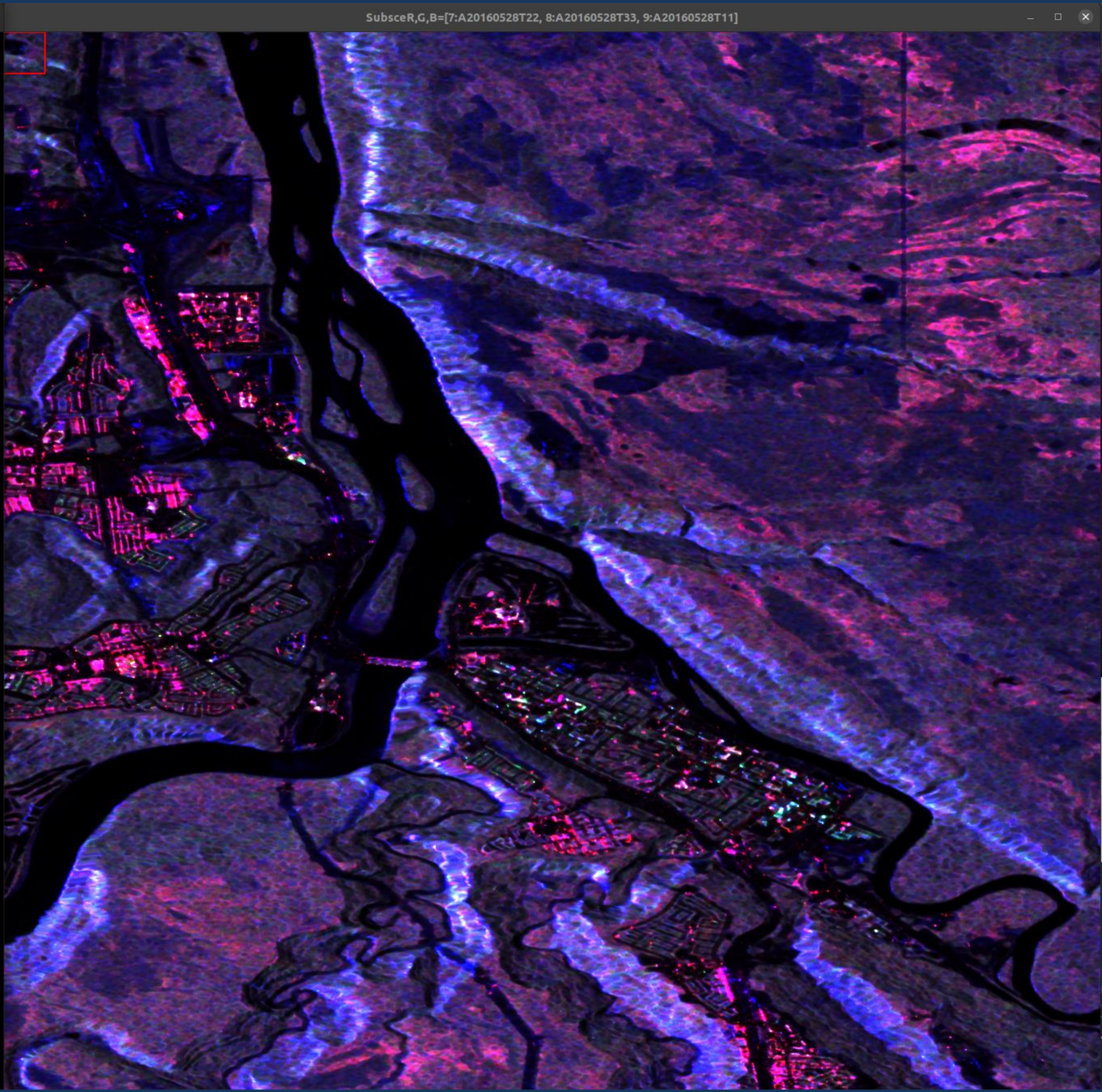




Compare with C band

AP2 20160528 T22, T33, T11 post (L-band)





Compare with C band

RS2 20160409 T22, T33, T11 pre (C band)

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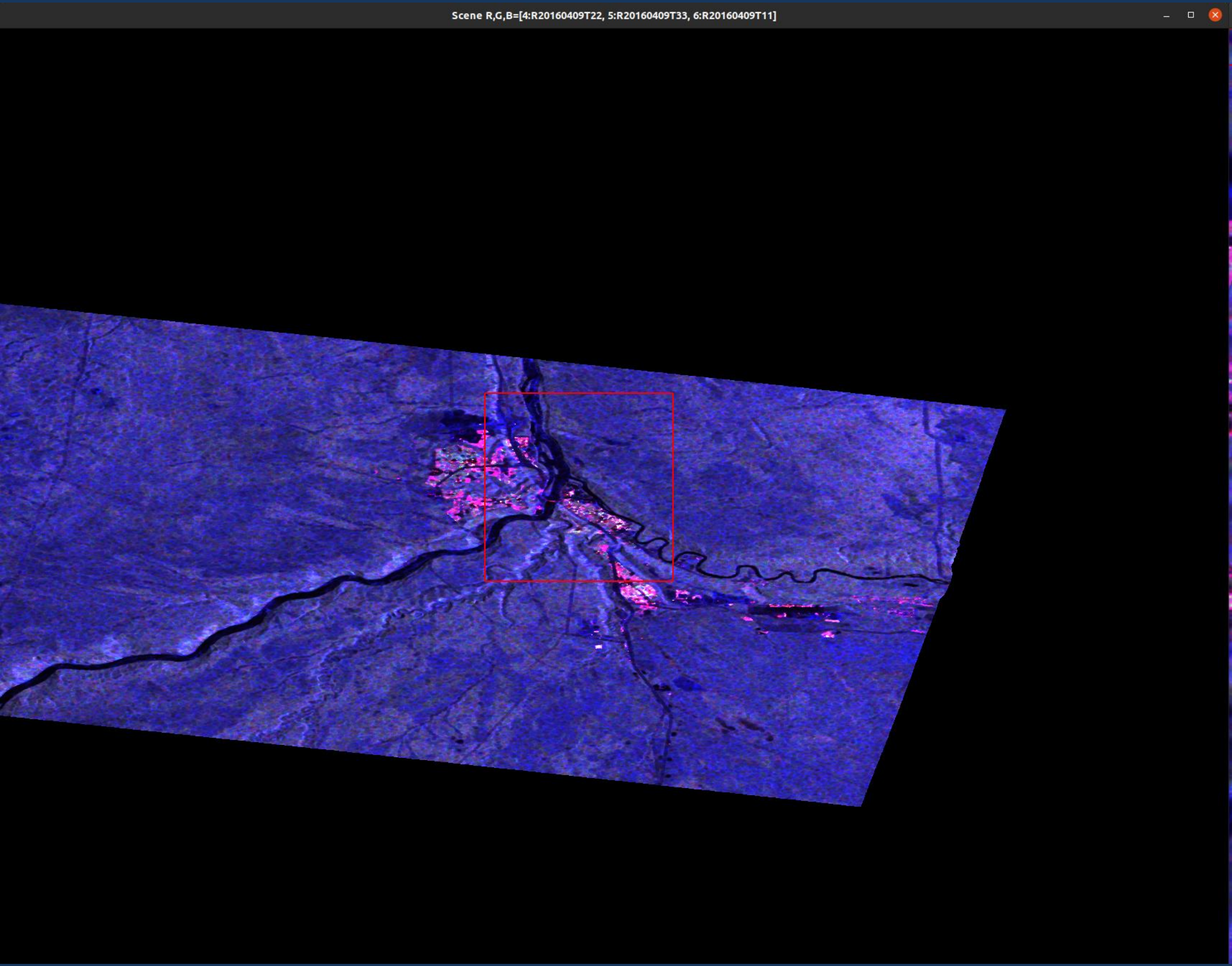

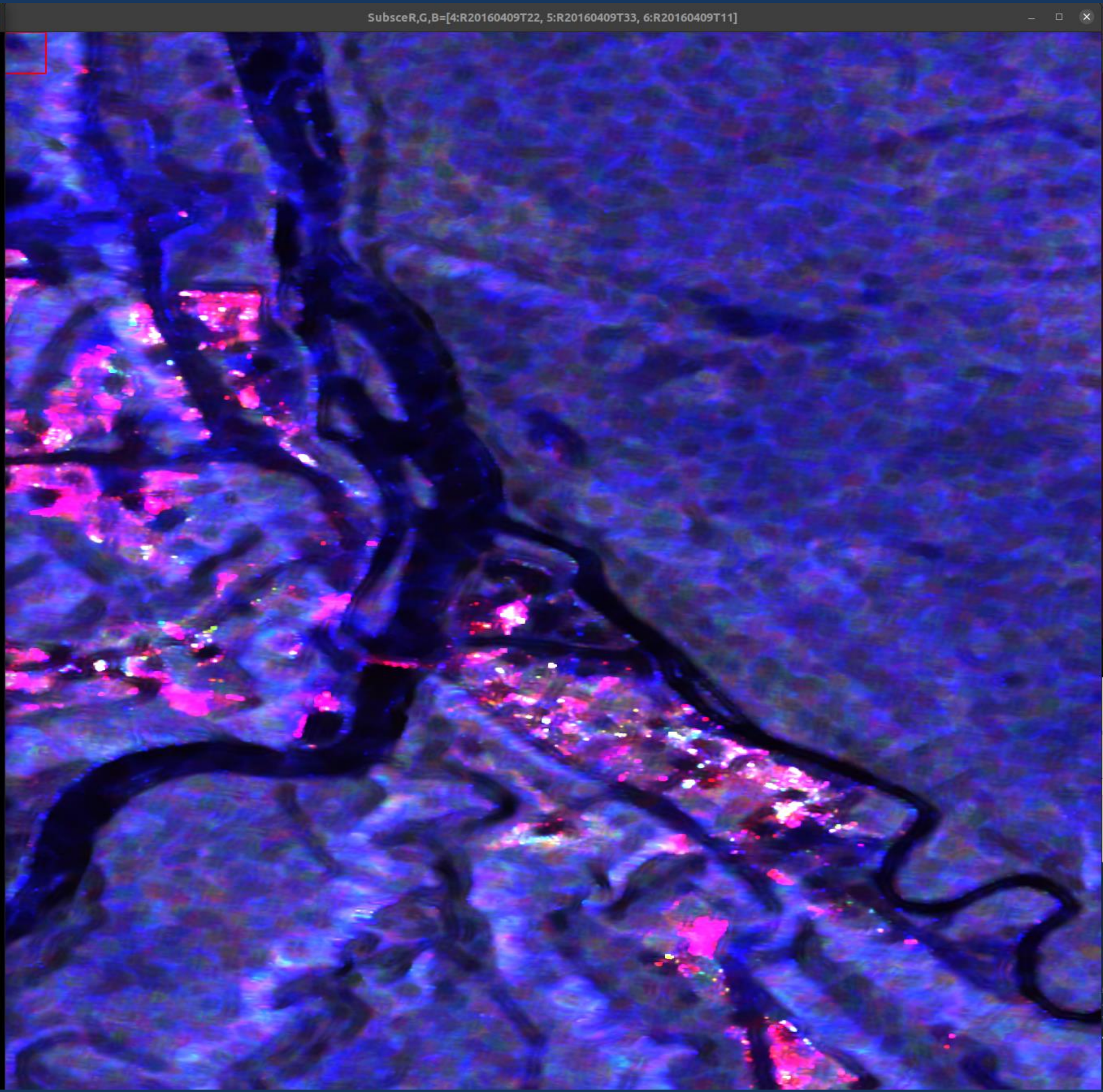

AP2 20161018 T22, T33, T11 post (C-band)

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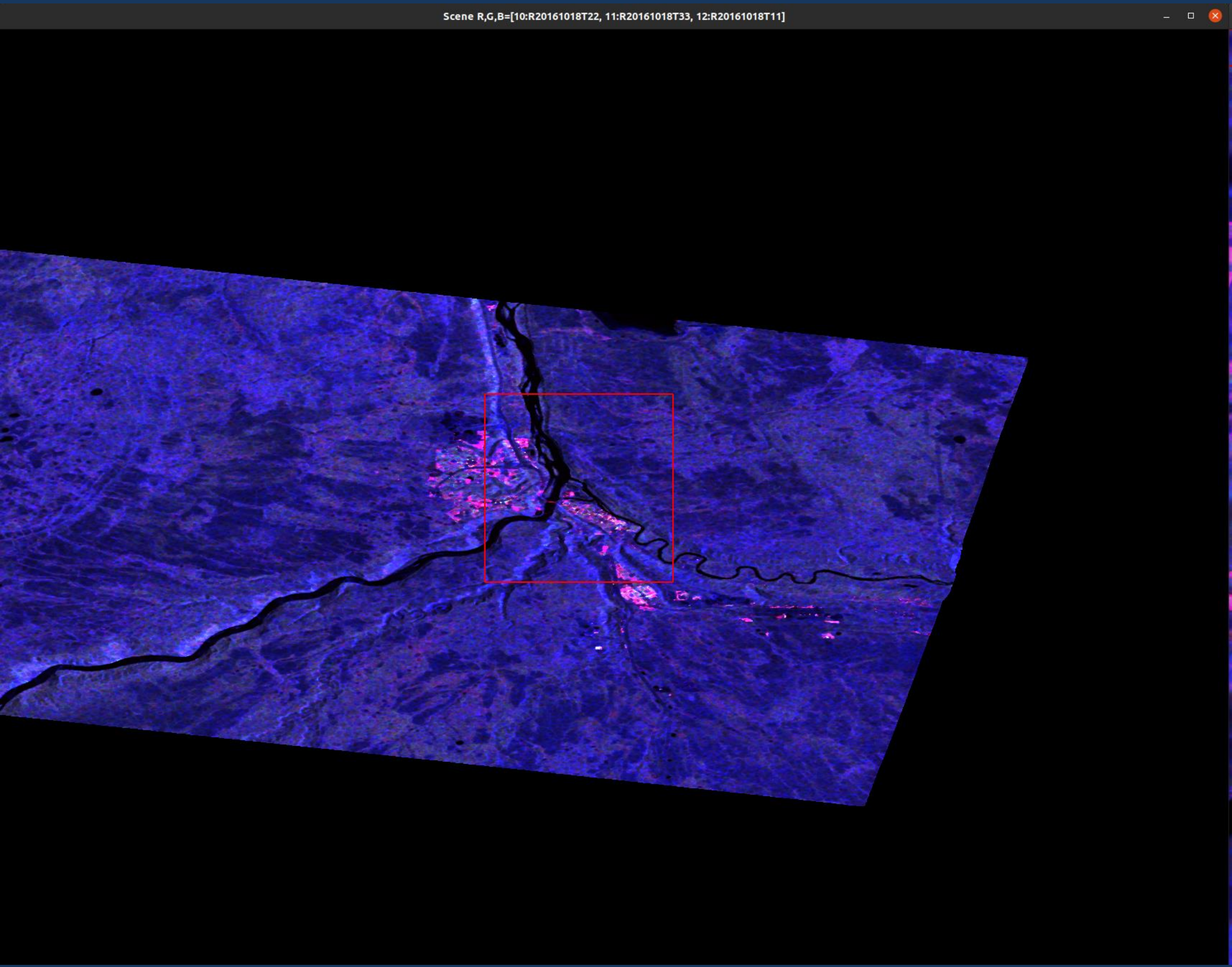
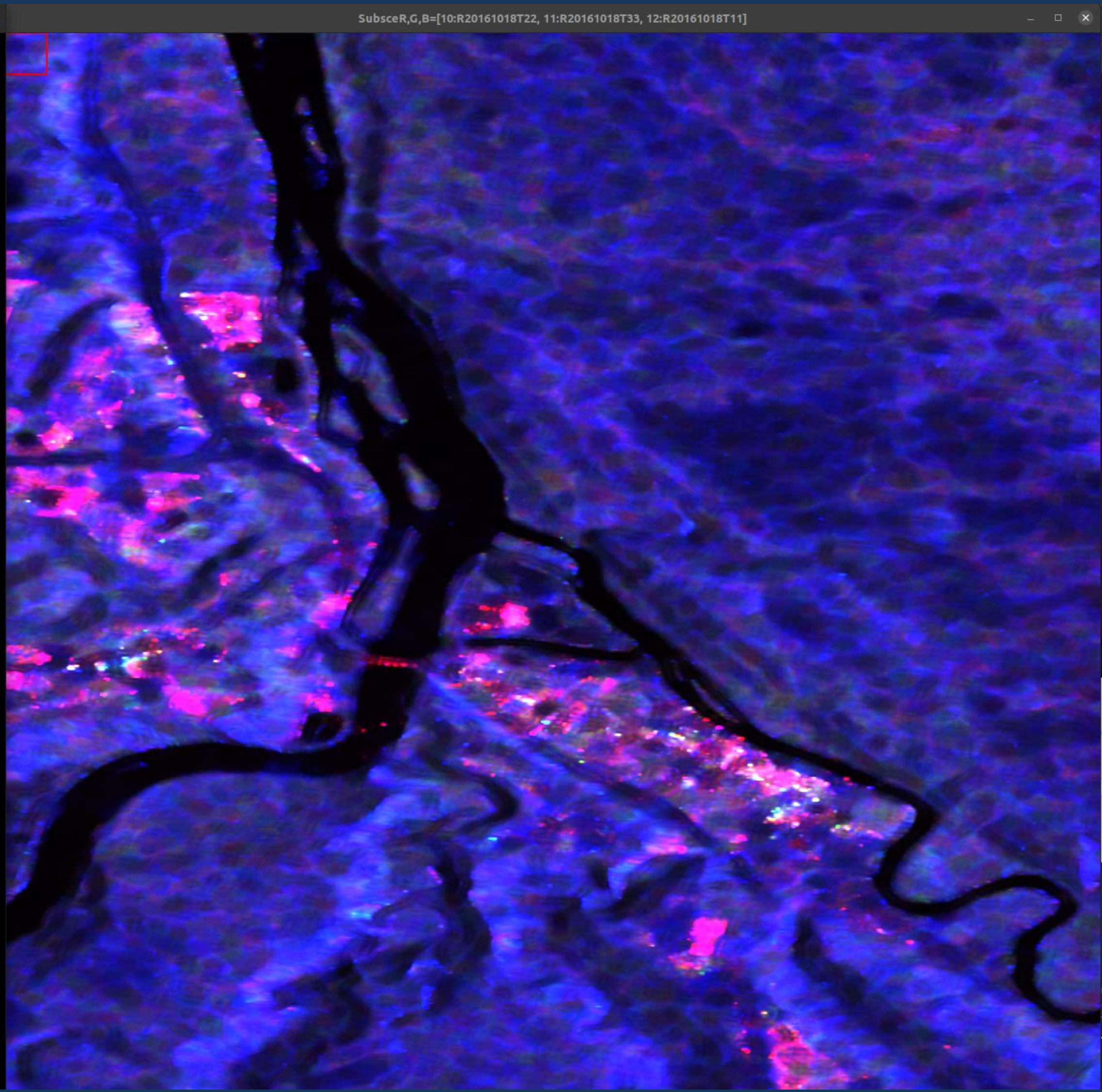




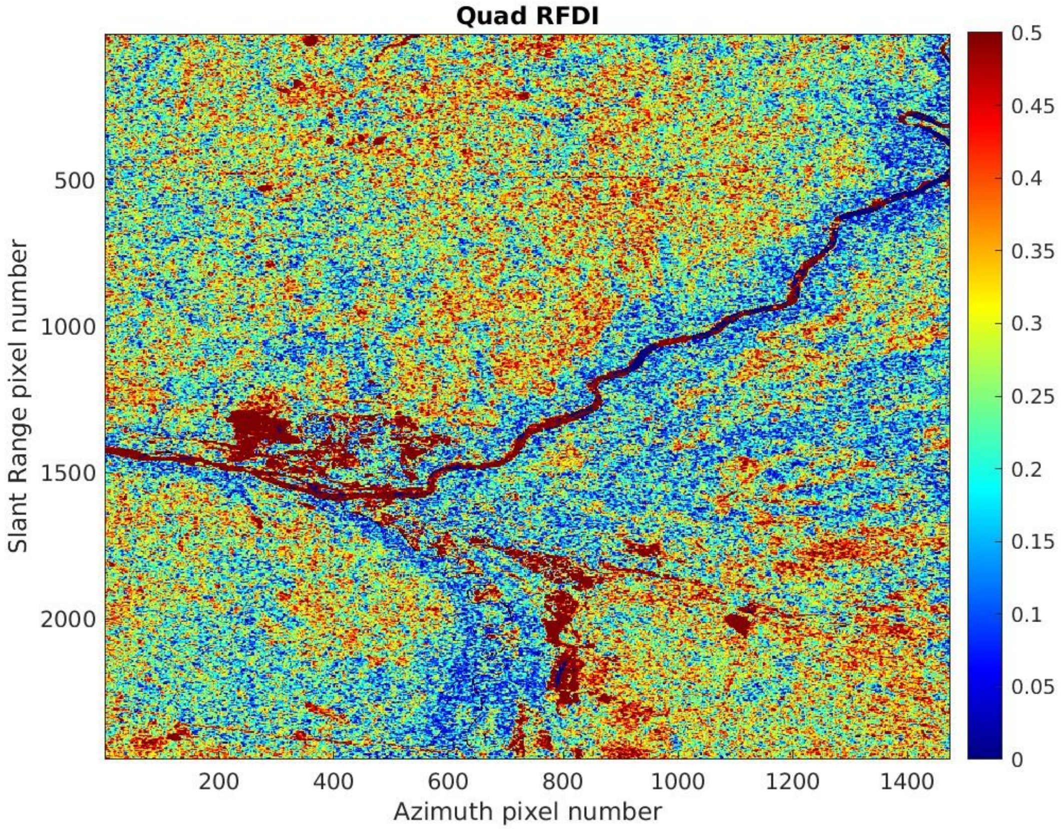
Changes are harder to see in C-band: But they are still there! Physics-based models needed

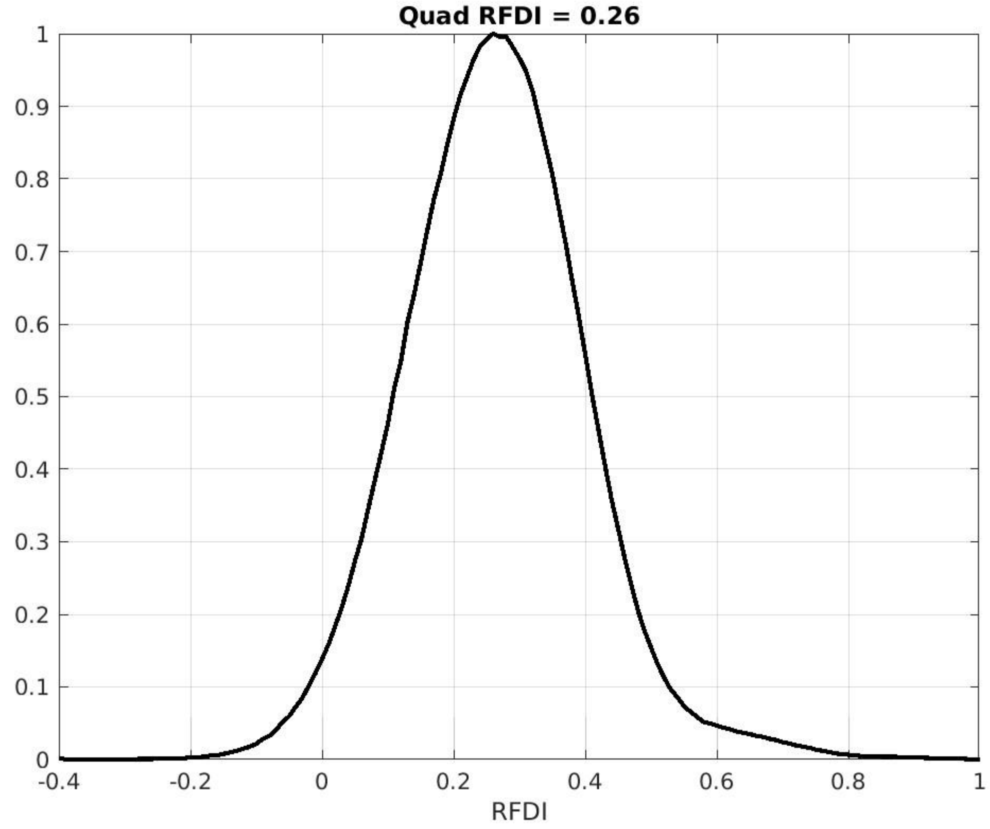
Radarsat-2 SQW and HSV Specs

- SQ16W
  - Beam mode: Wide Standard Quad-Pol
  - Product: SLC
  - Pixel spacing: 11.8 (rng) x 5.5 (az)
  - Nominal resolution: 13.5 (rng) x 7.6 (az)

- HSV (CSI / RFDI / RVI)
  - Multilook: 1 x 4
  - Boxcar: 5 x 5
  - ENL: 63
  - Resolution: 30 m

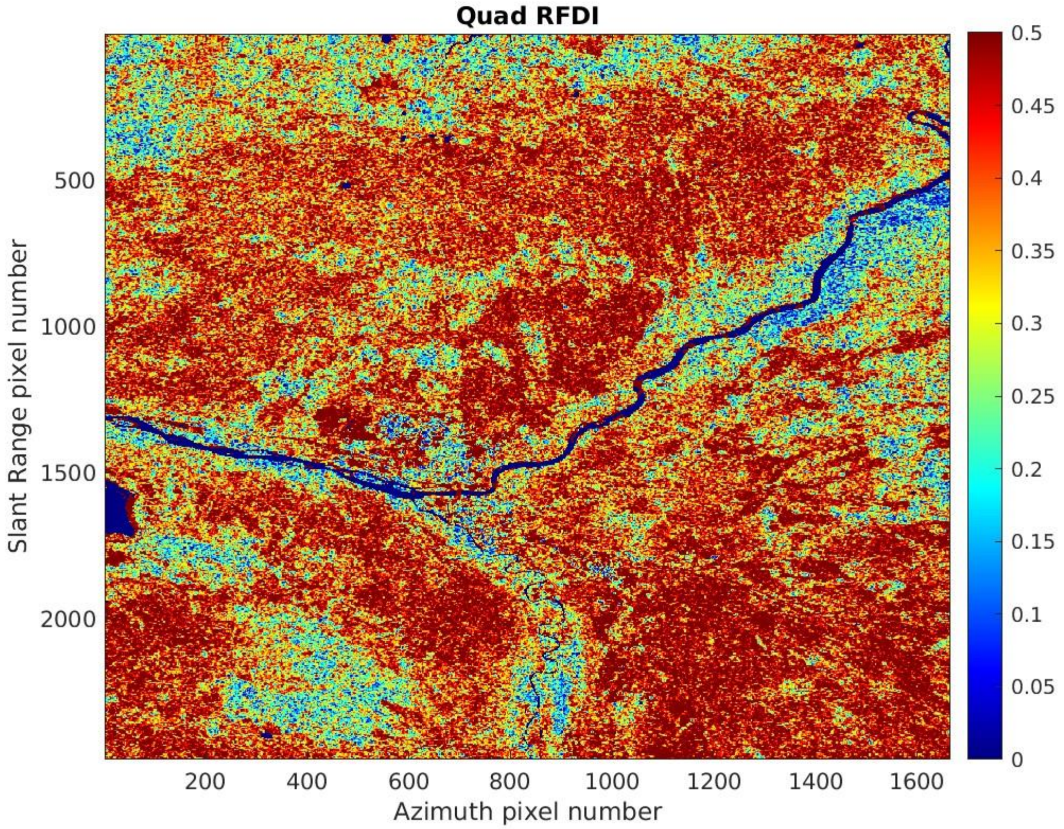
RFDI – Pre-fire 2016-04-09 (radar domain)

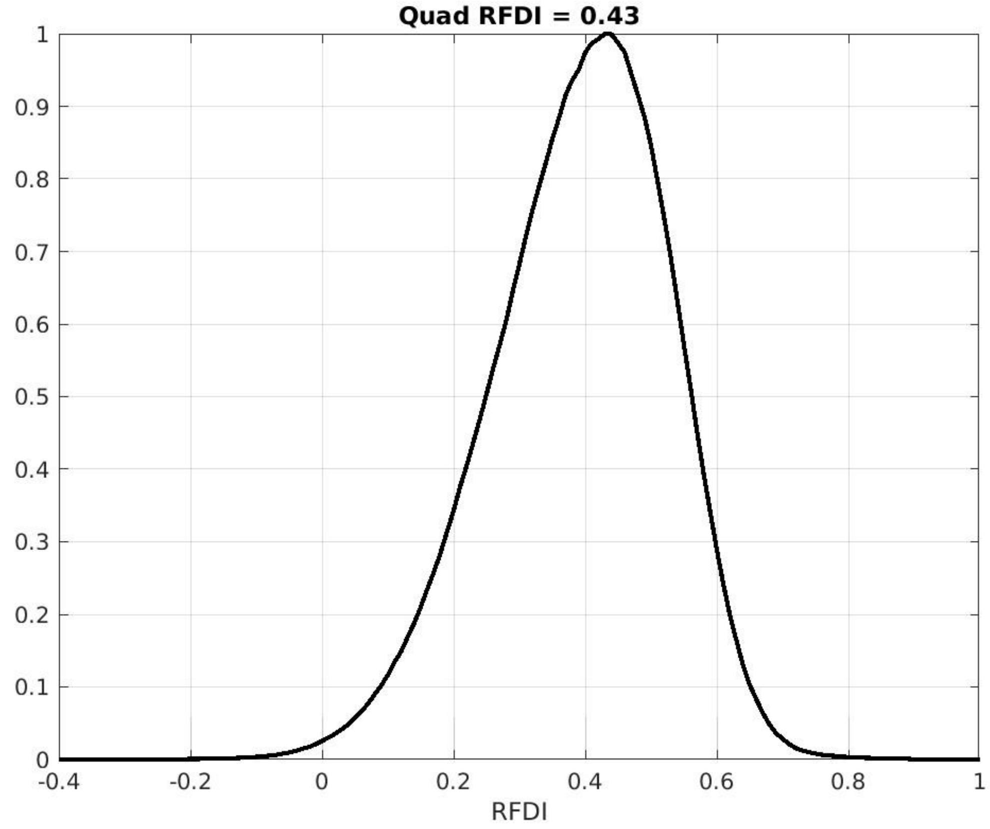


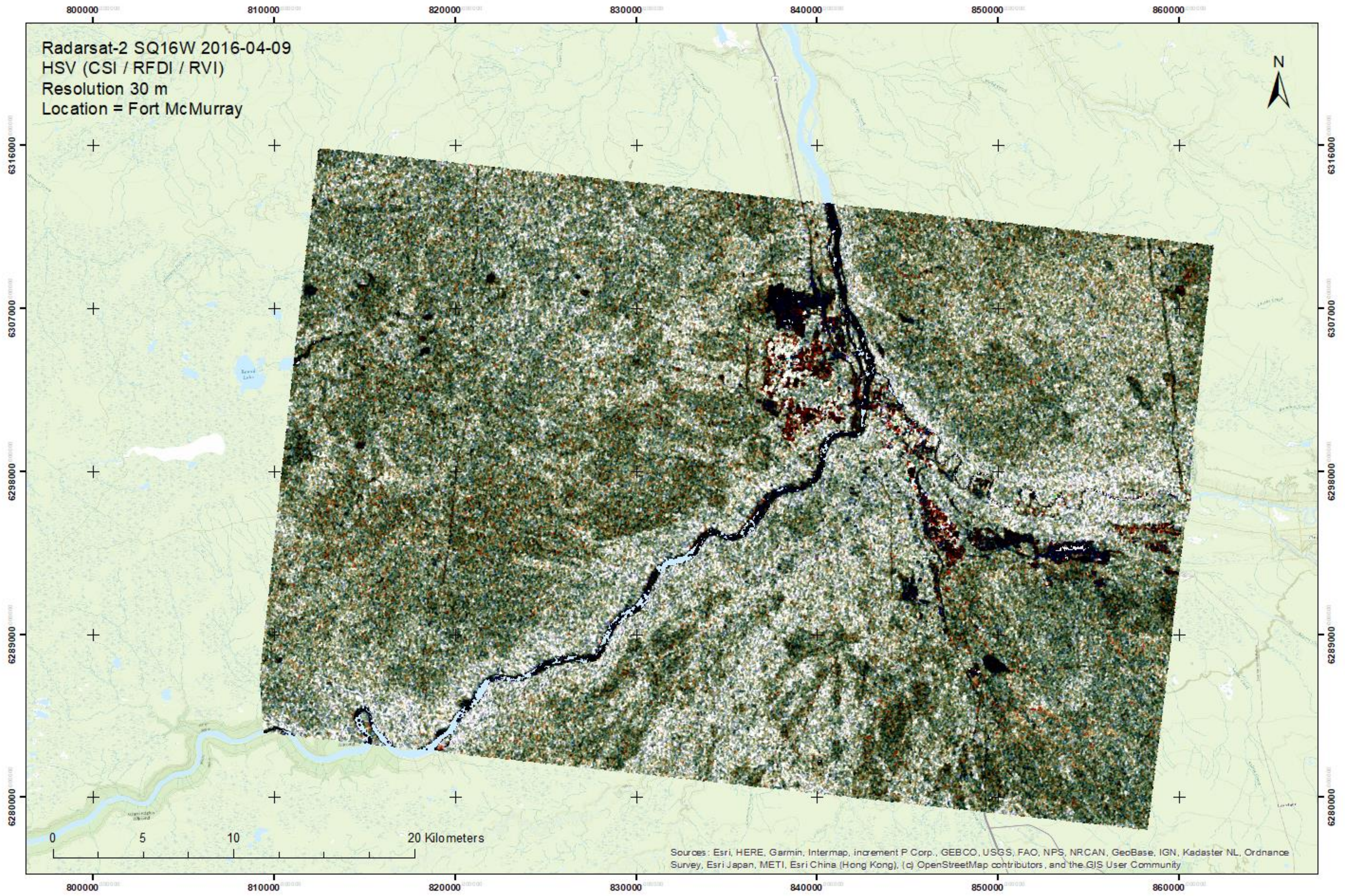


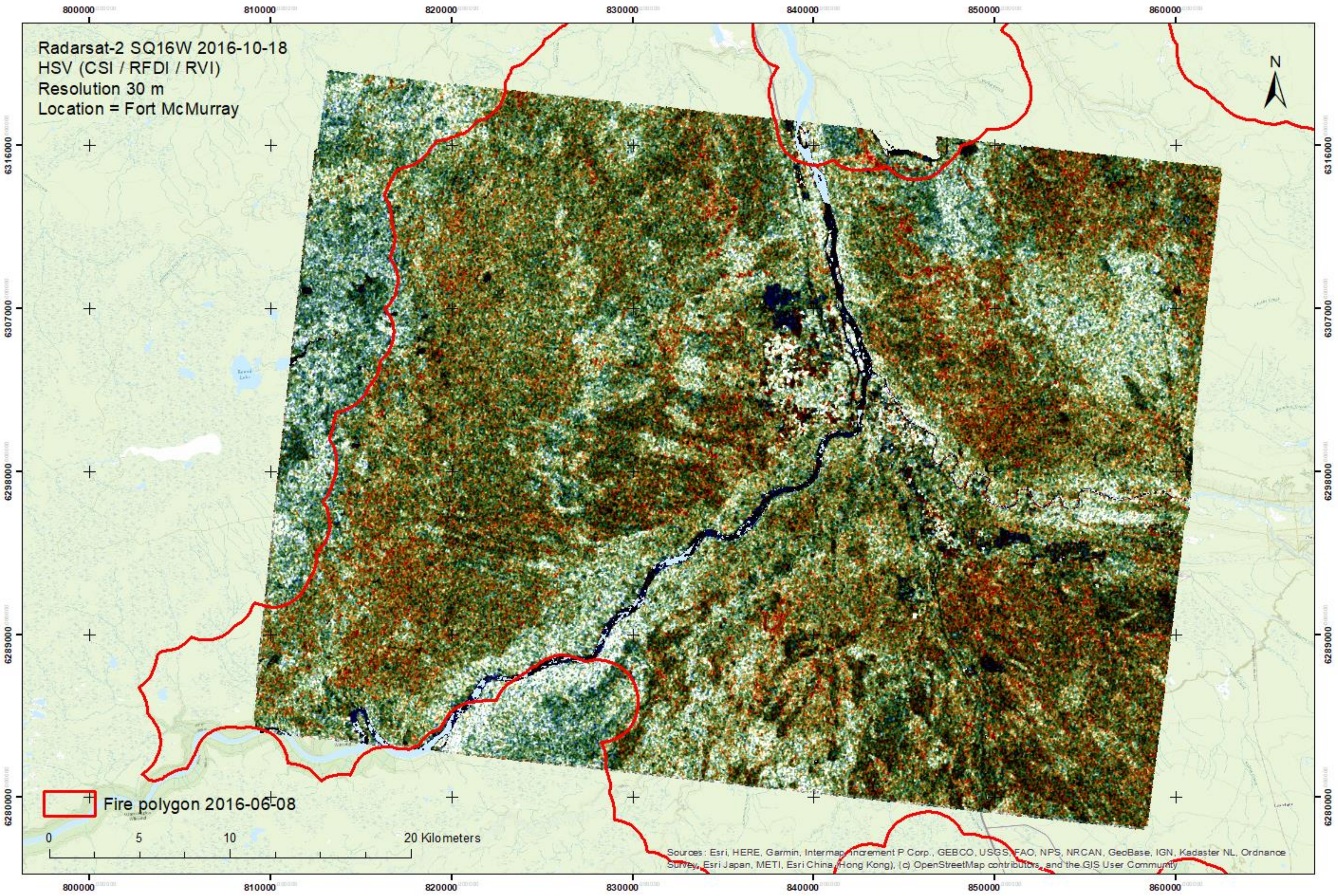
RFDI – Post-fire 2016-10-18 (radar domain)

- An effective indicator for fire degraded forest structures






Radarsat-2 SQ16W 2016-04-09
HSV (CSI / RFDI / RVI)
Resolution 30 m
Location = Fort McMurray
N
800000
810000
820000
830000
840000
850000
860000
6316000
6307000
6298000
6289000
6280000
0
5
10
20 Kilometers
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



Hao Chen's group are extending these parameters to Compact-pol mode!

Sparks Lake (2021) L-band pre

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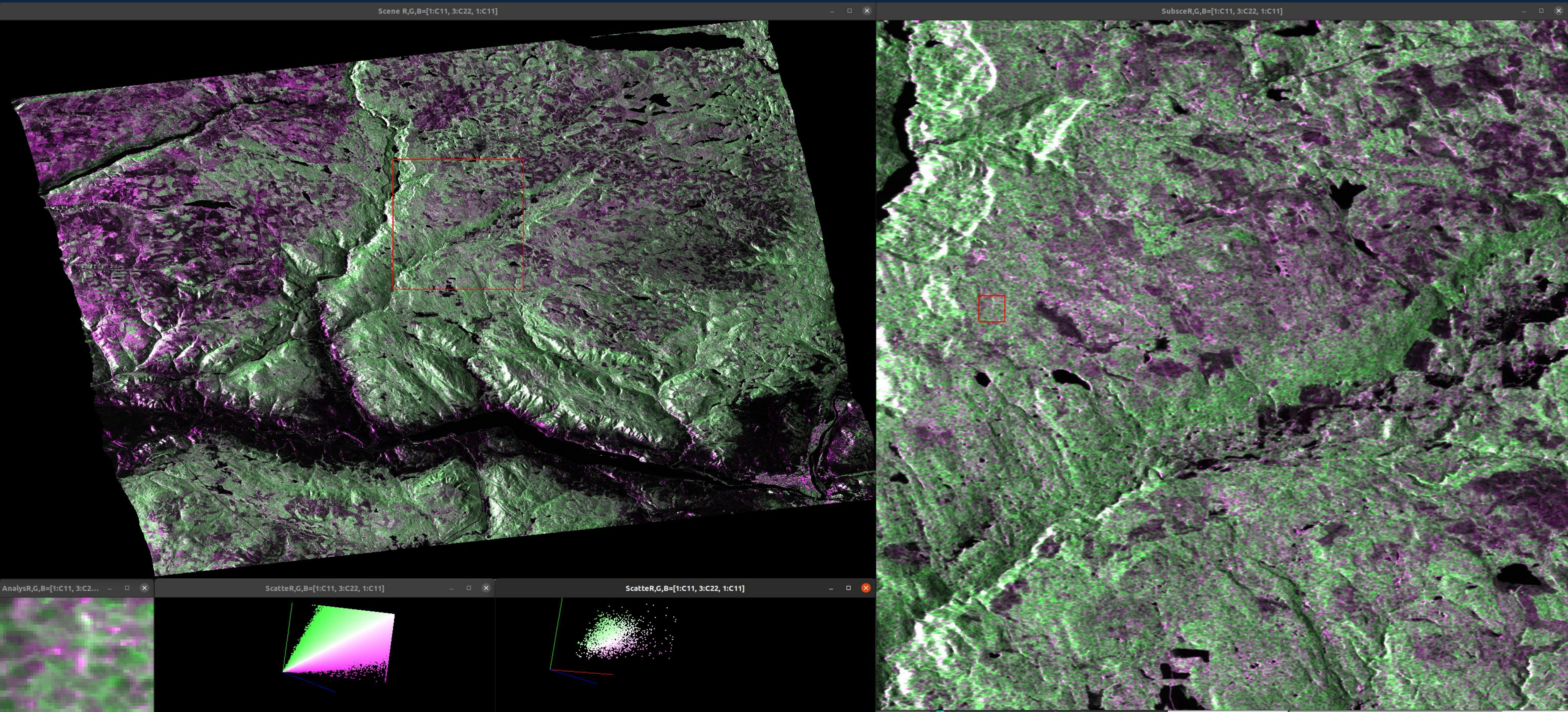
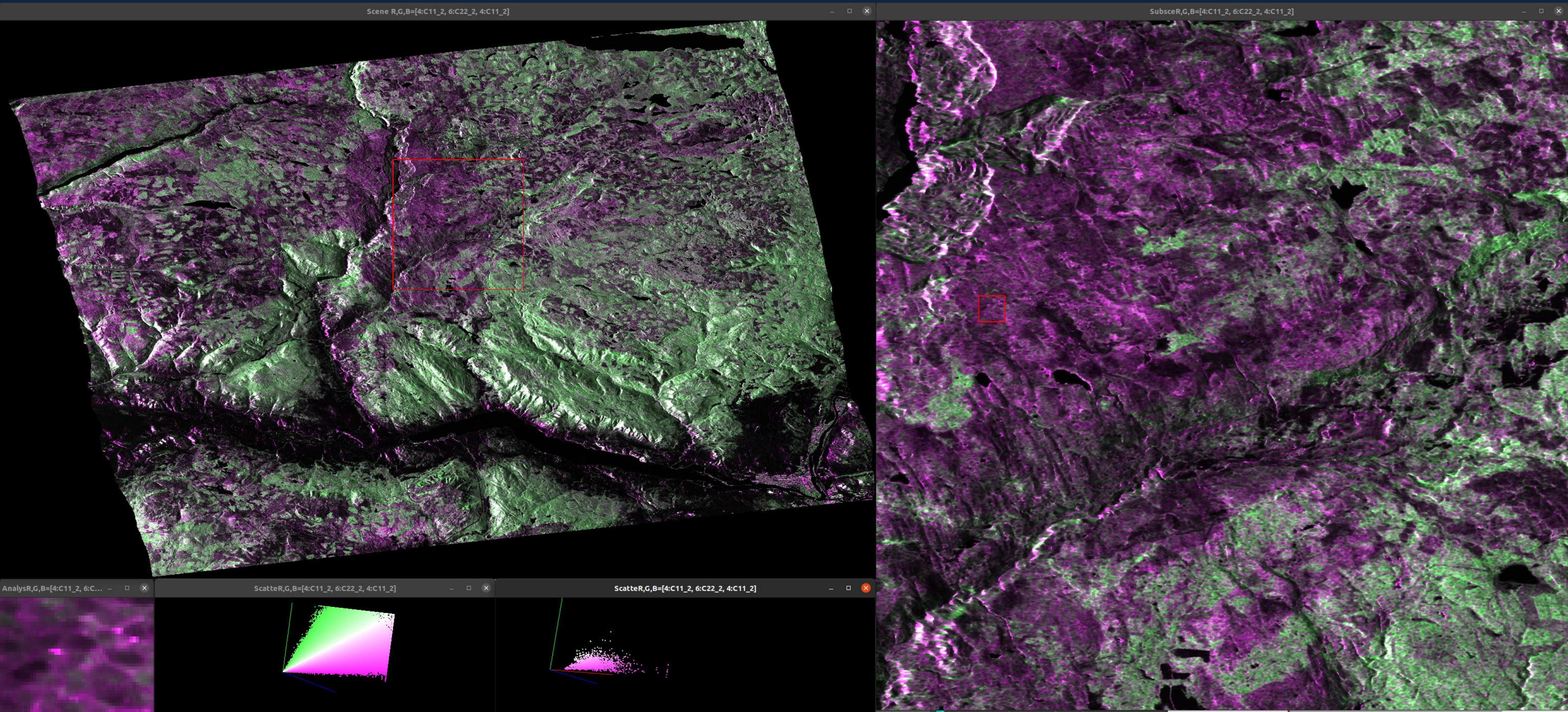


Sparks Lake (2021) L-band post



Results and next steps

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- Operational potential for fire mapping with L-band SAR
  - In both Quad-pol (QP) and Dual-pol (DP) modes
  - Dual-pol more likely needs pre+ post!
- Initial comparison of QP w emulated DP shows DP could give similar results
  - Need to verify that emulation from corrected T3 matrix (QP) approach does not overstate DP results
  - DP results may be harder to extend to other incidents?

Actions:

- Confirm over more fire incidents in BC!
- Coherence modelling / CCD + Region-based approach
- **Improve geo-location, then upgrade ground-ref to burn severity, and fuel types / Land Cover**
- RCM, ALOS-2, PRISMA, Sentinel-2 data to be compared over Sparks Lake fire 2021 (compact, dual physical parameters and more- automatic ML)

- **Applications we want to operationalize for RCM:**
- **Snow cover**
- **Moisture monitoring**

Closing remarks

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- Polarimetry (and multispectral) changes reflect land cover, topography and weather
  - **Detailed, continuous land-cover mapping needed to interpret SAR + optical data changes automatically and correctly**
  - Extending from NRT to retrospective approach w Phenology / process based approach to land cover
  - Increase intel for operations through multiple sources

- Better operational fire maps become ground-ref for SAR analysis & fire science downstream
  - Sensor-specific physical modelling
  - + Transferrable pattern approaches

- ***Better geo-referencing needed for improved classification***
  - Could we cheat with stereo or monocular vision for 3-d estimation?
  - Do we need national wall to wall LiDAR value of SAR data?
  - Or can we just use InSAR and iterate?
- Other synergy between hazard areas? Open to collaborate

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