All Hazards Application of RCM in BC part 2

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Canadian Space Agency (CSA) Radarsat Constellation Mission (RCM) Users' Forum (May 18th, 2022)

Overview

- **Purpose**
  - **Here to build relationships w CSA and partners!**
- Team context
  - BC Wildfire does fire. Moving to all-hazards...
    - Multi-sector role: bridge geospatial vs admin (or other seemingly disparate) data
      - On loan from Citizens' Services (Chief informatics Office) AKA Integrated Data Division..
        - EL SME RS/AI/HPC
- **Multispectral / hyperspectral / Radar project context**
  - **Fire progression:** Immediate operational emphasis
    - Reference data to support RCM fire monitoring analysis
  - Stepping-stone to continuous forest mapping (province wide NRT)
- Synergy!
  - Partnerships, cooperation, collaboration (local to international)
  - Value in open, reusable, modular systems, data or processing?
- **Today: Image translation as a metaphor for collaboration**

BCWS Predictive Services Unit

- Report to Deputy Director, Wildfire Ops
  - Meteorology
  - Fire Behavior + Agile Software Engineering
  - Data Science: enhancing operational use of RS
    - Also promoting continuously-updating geo-intelligence. Reproducible transparent methods

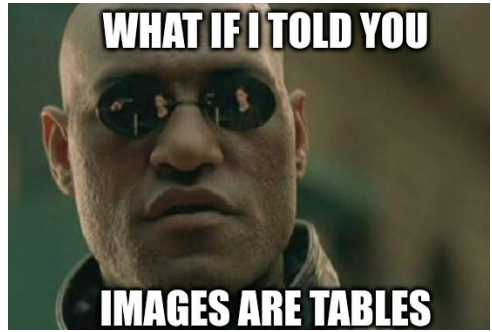
Mandate:

- Daily and increasingly-proactive situational awareness to support Prevention, Preparedness, Response, Recovery

Recent communications/
timeline

- Fire mapping with Shortwave Infrared, BC Government Remote Sensing CoP, Apr 13 2022
- Fire mapping with Sentinel-2, BCWS Geomatics CoP, Mar 16 2022
- Longitudinal encounter histories as text: Using natural language processing and graph machine learning methods to locate patient voices within constituencies, Putting Patients First, March 10 2022
- Remote Sensing and Pattern Recognition in BCWS Predictive Services Unit, BCWS Priorities Forum, Jan 6 2022
- Field Observations and Remote Sensing of Wildland Fuels: A Case Study, Bulkley Valley Research Centre, Oct 8 2021 2021 (*)
- All Hazards Application of RCM in BC, CSA RCM Users Group Meeting, Nov 25 2021

(*) non composite / use all acquisitions. 3d from 2d?



"Trajectory methods"

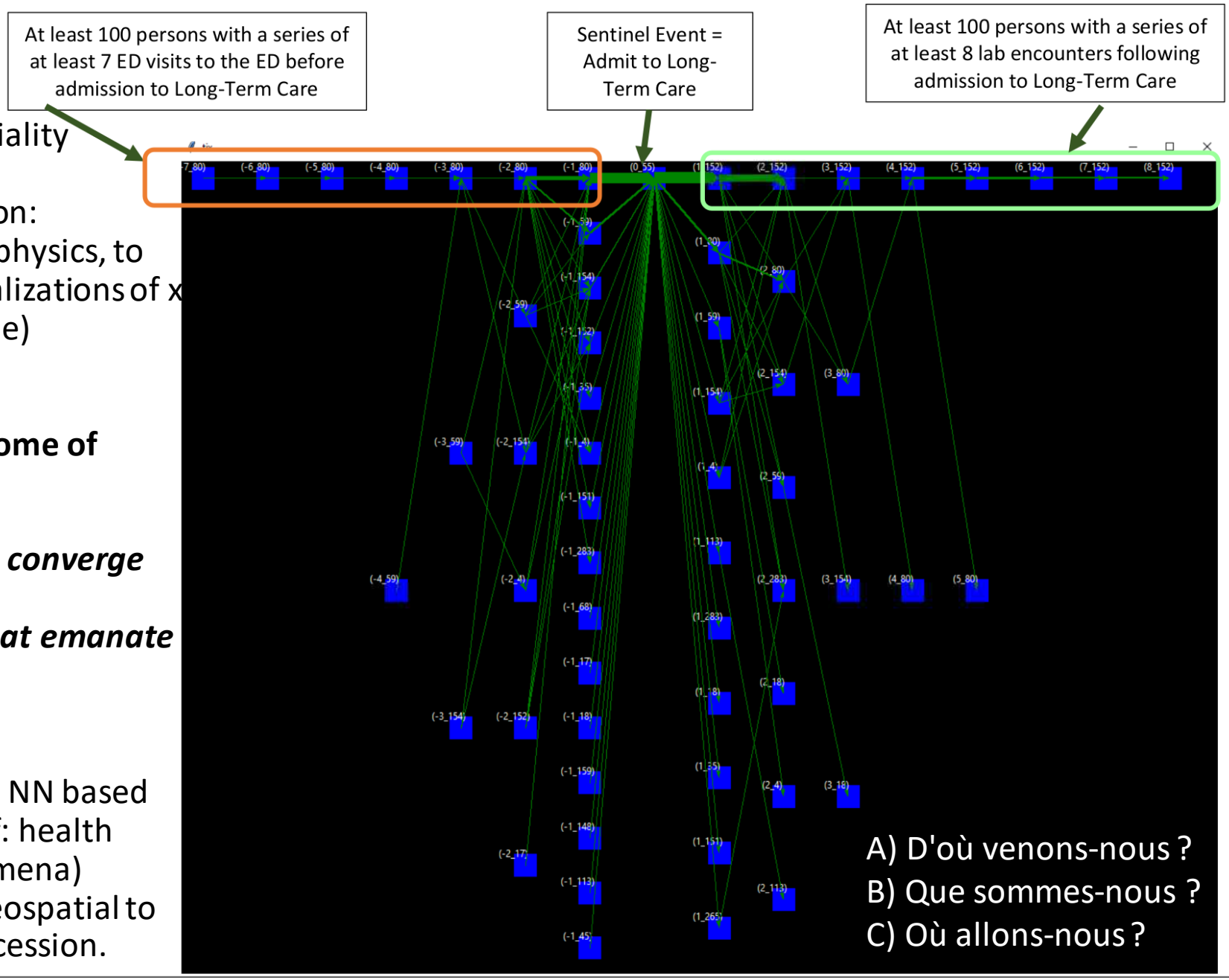
- I.e. considering relationships, & event sequentiality

- Hourglass implementation: inspired by the "light cone" of physics, to bring time and space into visualizations of x actional data (Thanks Dr. Cloude)

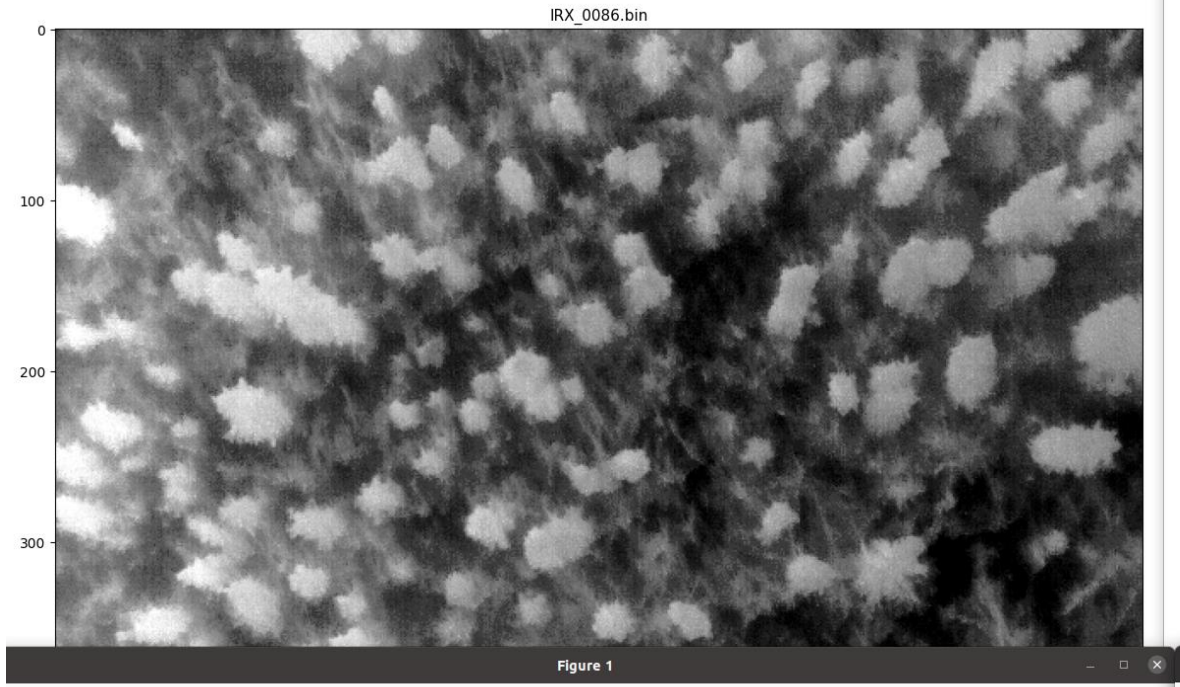
- **Input: "tabular data"**
  - **Set "X" to any outcome of interest**
- ***Result:***
  - ***past outcomes that converge towards X***
  - ***Future outcomes that emanate from X***

- Event aggregation: not ML / NN based
- Determinants and effects of: health conditions (or other phenomena)
- **Next:** bring this back into geospatial to understand forest / eco succession.

X. Hourglass Tool – Sequences of Service Encounters Leading Up To/Following Sentinel Event



At least 100 persons for every encounter sequence in this figure. In the live version, you mouse over a box to see the service class associated with that box.


IRX_0086.bin
0
100
200
300
Figure 1

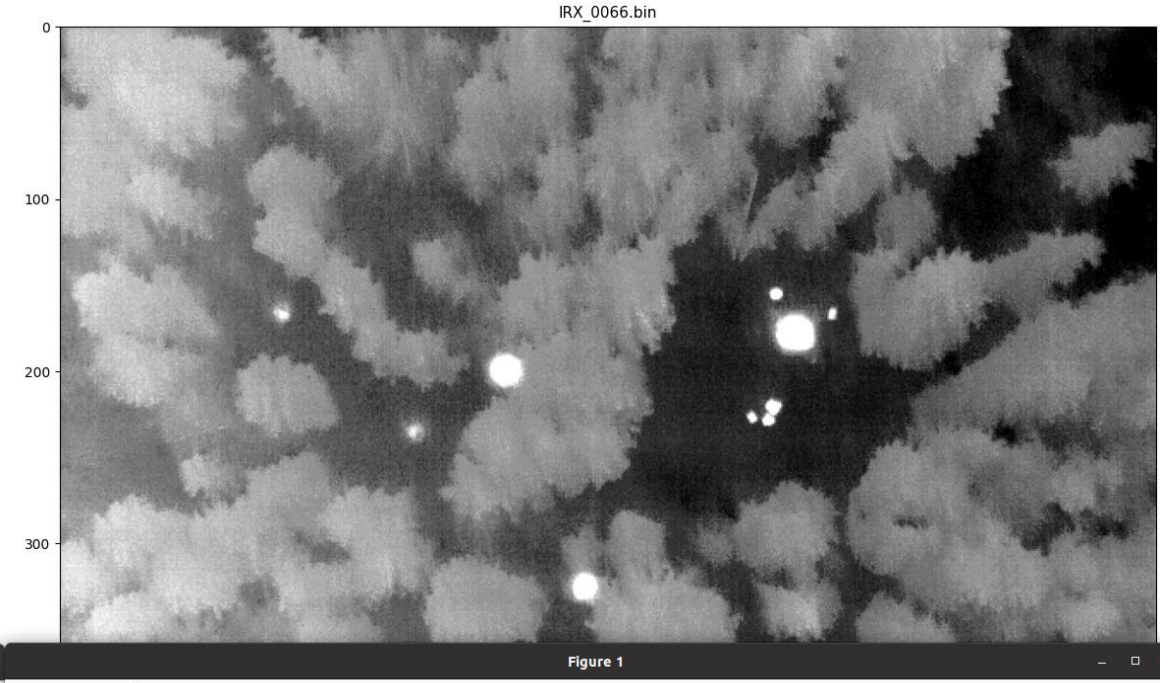

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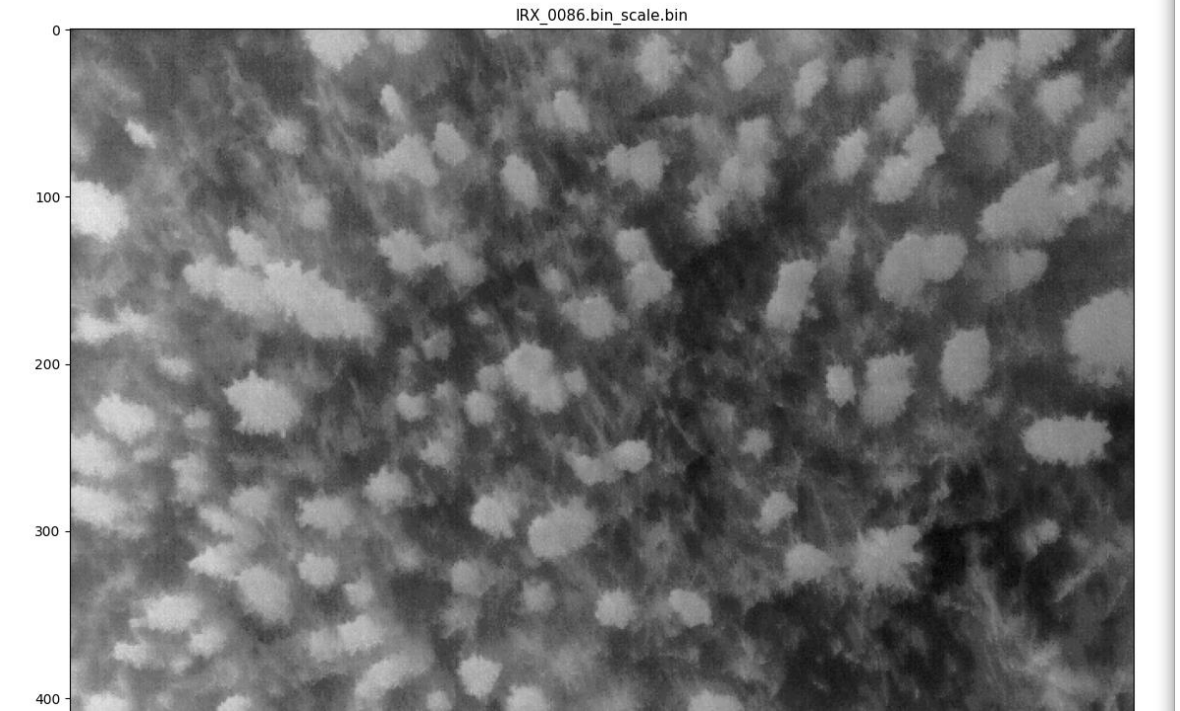
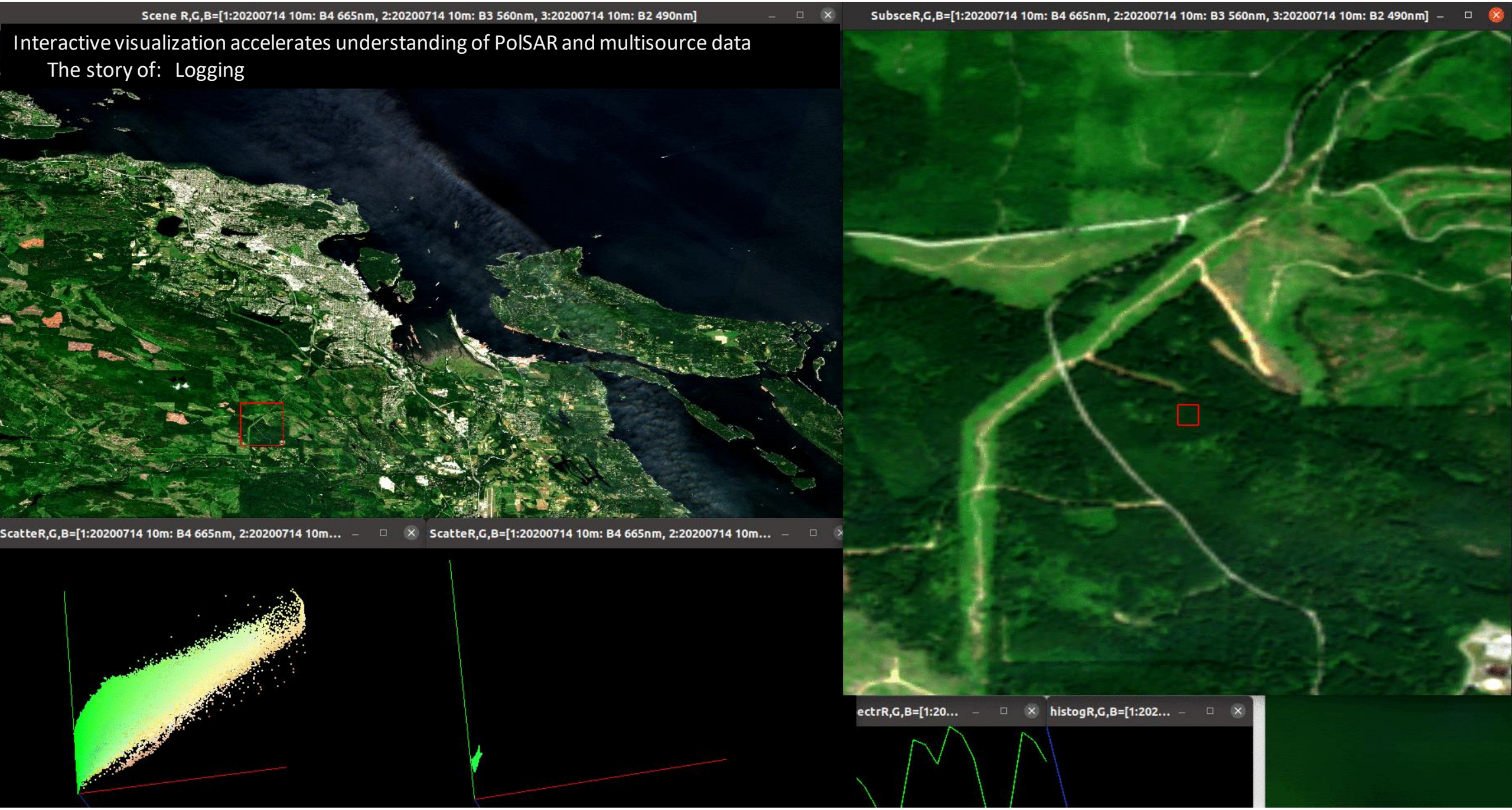
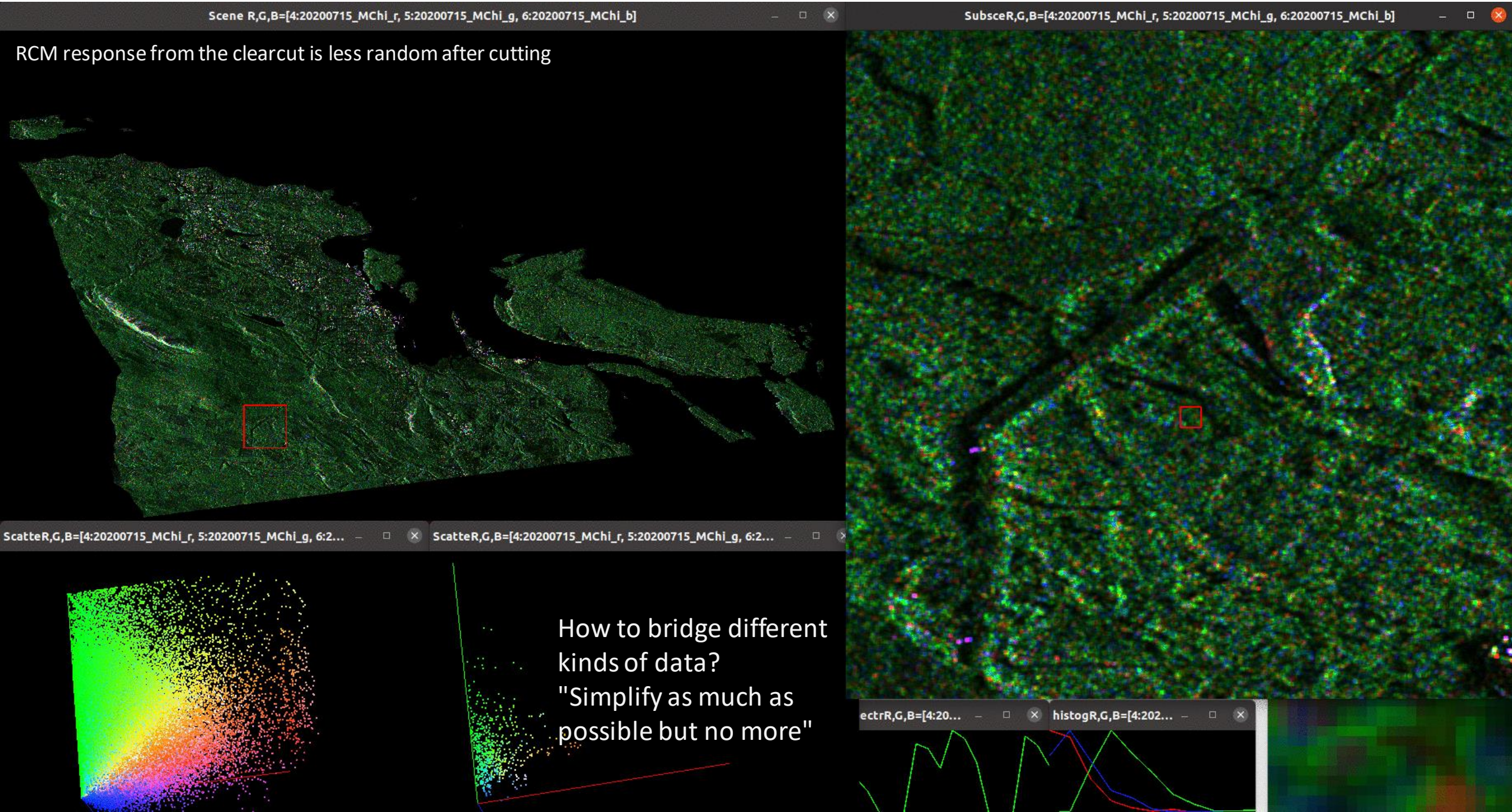
Figure 1

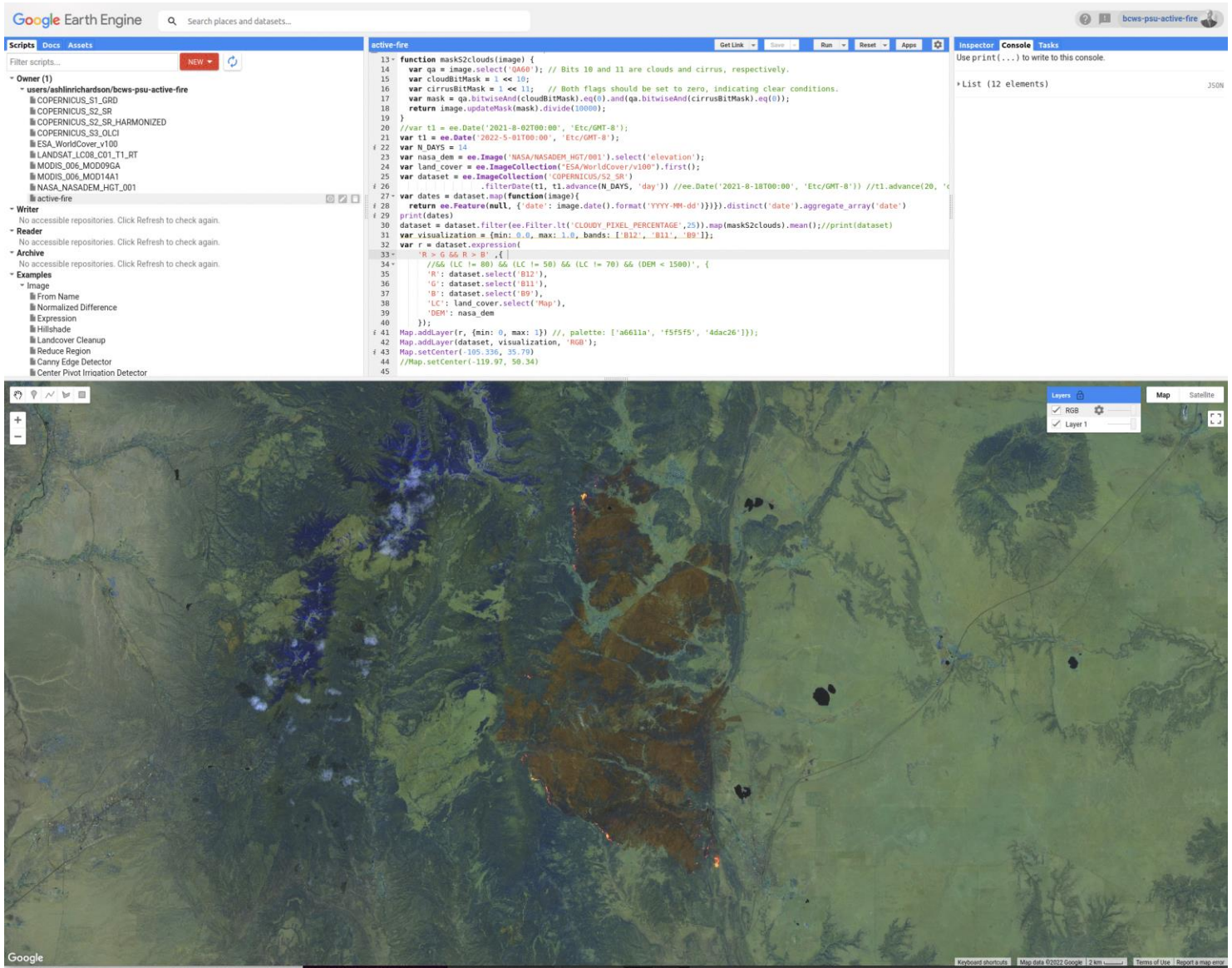

IRX_0086.bin_scale.bin
0
100
200
300
400


IRX_0066.bin_scale.bin
UAV
hotspot
detection +
geolocation
0
100
200
300
400


Scene R,G,B=[1:20200714 10m: B4 665nm, 2:20200714 10m: B3 560nm, 3:20200714 10m: B2 490nm]
Interactive visualization accelerates understanding of PolSAR and multisource data
The story of: Logging
SubsceR,G,B=[1:20200714 10m: B4 665nm, 2:20200714 10m: B3 560nm, 3:20200714 10m: B2 490nm]
ScatteR,G,B=[1:20200714 10m: B4 665nm, 2:20200714 10m...
ScatteR,G,B=[1:20200714 10m: B4 665nm, 2:20200714 10m...
ectrR,G,B=[1:20...
histogR,G,B=[1:202...


Scene R,G,B=[4:20200715_MChi_r, 5:20200715_MChi_g, 6:20200715_MChi_b]
RCM response from the clearcut is less random after cutting
SubsceR,G,B=[4:20200715_MChi_r, 5:20200715_MChi_g, 6:20200715_MChi_b]
ScatteR,G,B=[4:20200715_MChi_r, 5:20200715_MChi_g, 6:2...
ScatteR,G,B=[4:20200715_MChi_r, 5:20200715_MChi_g, 6:2...
How to bridge different kinds of data?
"Simplify as much as possible but no more"
ectrR,G,B=[4:20...
histogR,G,B=[4:202...

How to map fires in Sentinel2? B12 > B11

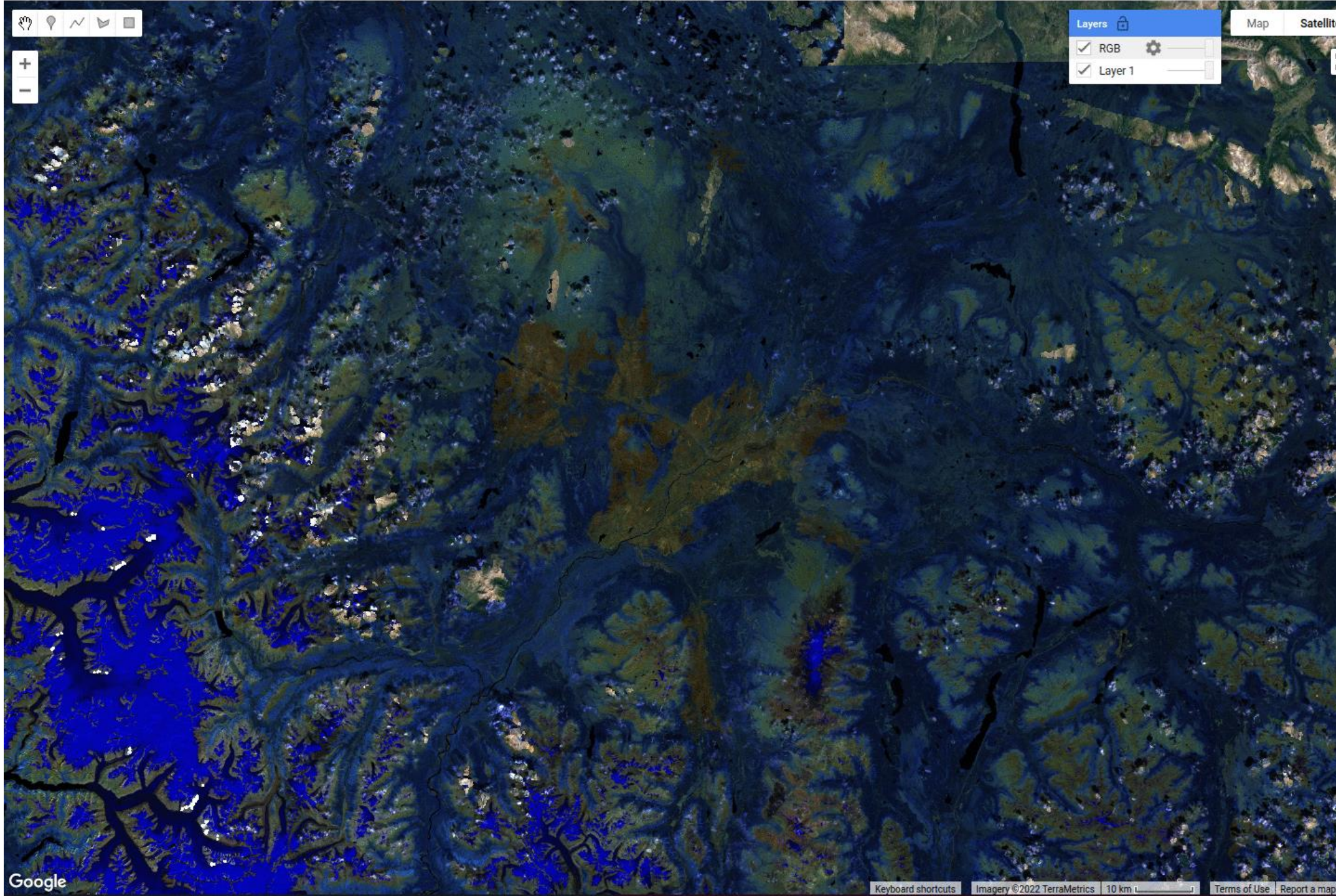


Need to mask out:

- water
- High elevations

Telegraph Creek area fires (BC) 2019

Have a 3rd iteration of a field study underway in the area this year



White Rock Lake Fire 2021 BC (12 updates, Landsat 7,8 and Sentinel2)

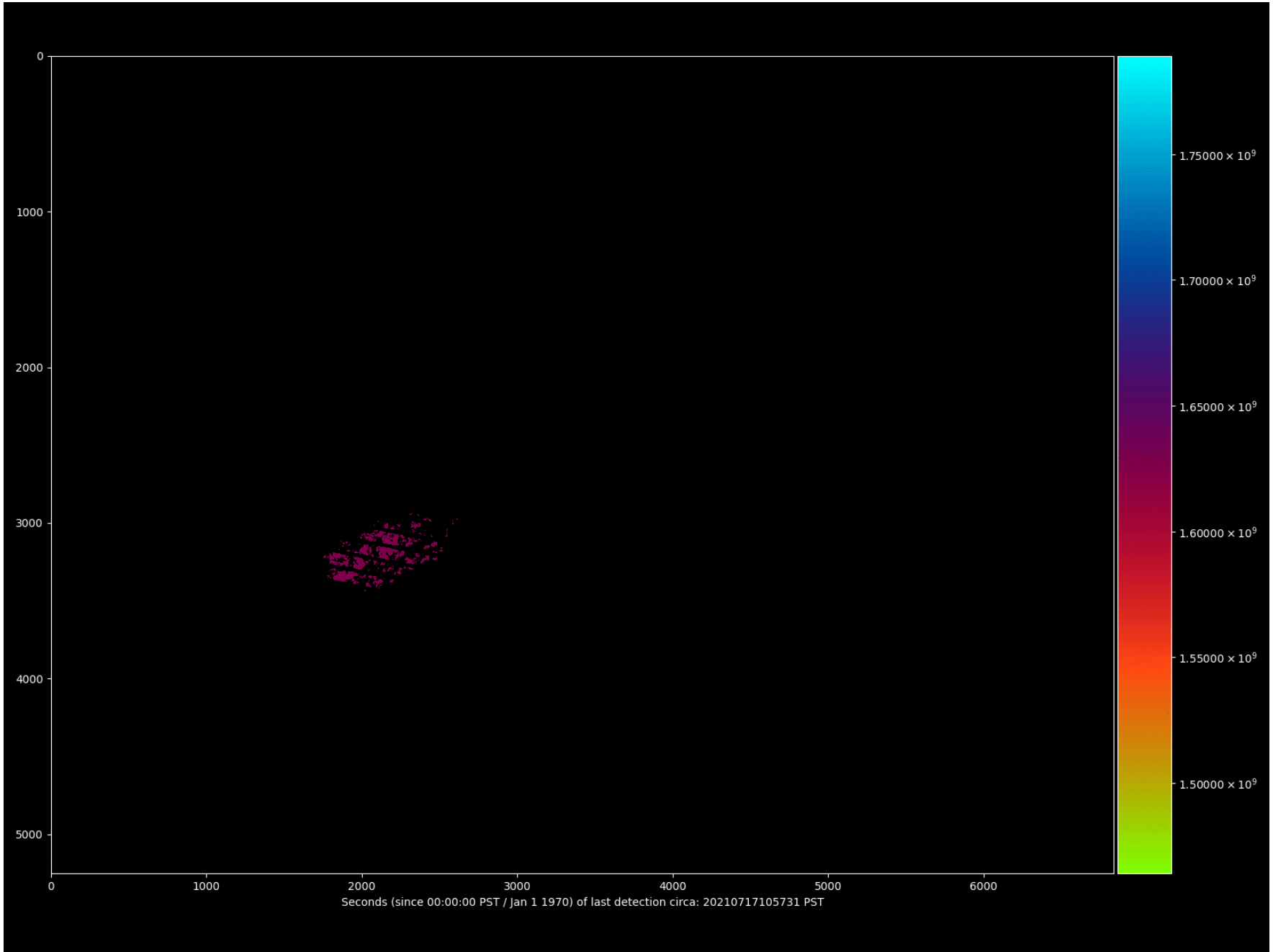
Simple Classification Rule generalizes Across sensors By "spectral Interpolation"

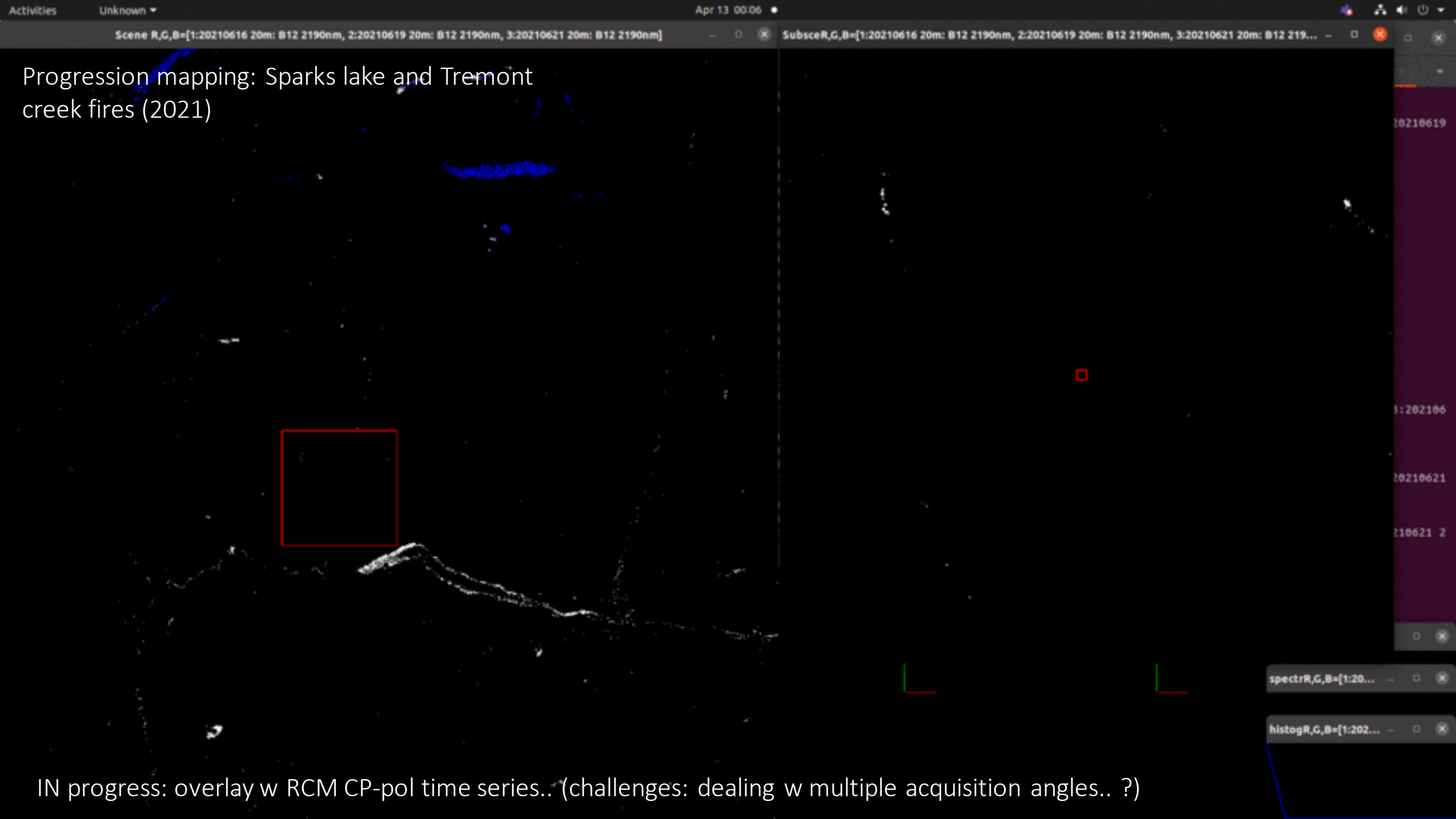
Not perfect..

..Accessible!

Tested it on

- Sentinel2
- Landsat 7, 8
- ASI Prisma




Activities
Unknown
Apr 13 00:06
Scene R,G,B=[1:20210616 20m: B12 2190nm, 2:20210619 20m: B12 2190nm, 3:20210621 20m: B12 2190nm]
SubsceR,G,B=[1:20210616 20m: B12 2190nm, 2:20210619 20m: B12 2190nm, 3:20210621 20m: B12 219...
Progression mapping: Sparks lake and Tremont creek fires (2021)
spectrR,G,B=[1:20...
histogR,G,B=[1:202...
IN progress: overlay w RCM CP-pol time series.. (challenges: dealing w multiple acquisition angles.. ?)

New algorithm: ABCD method!

- For A, B, C (input) images(*), an answer to the question:

A is to B, as C is to what?

Of course, the answer is..

..D!

Inspired by this meeting!

- Conceptual solution to ***Image translation problem*** (thanks S.N.) by "Local non-linear embedding".
- Is a supervised classifier, esp. if training labels are propagated (todo)
  - Stuff training data chips into A, B (predictor, response).. Vegetation or fire mapping! Other uses: simulating day images fro m night vision system
- Image compression

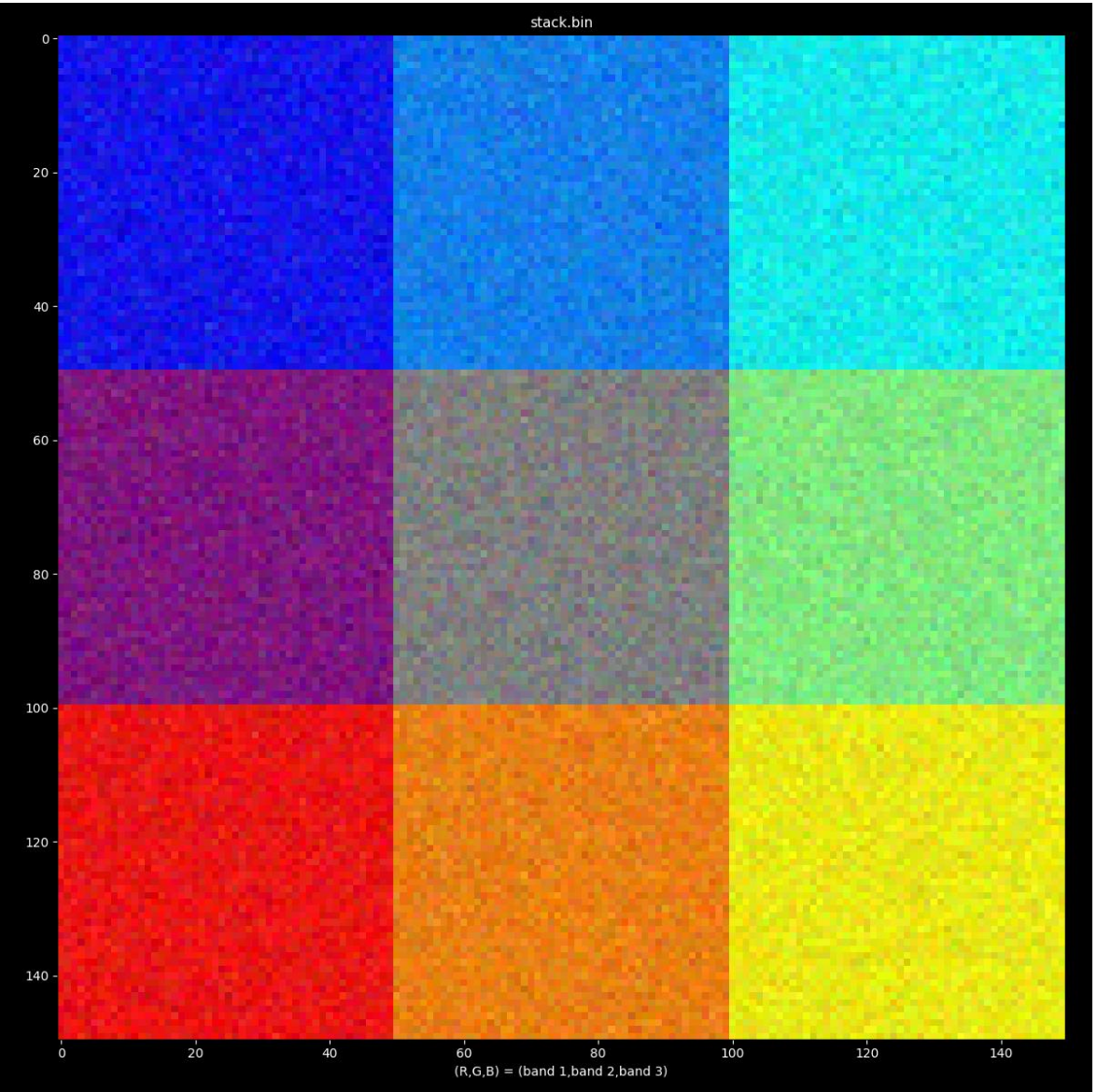
- Only one parameter:
  Fraction of data in A, B to use
  - "skip factor" (use every nth pixel) 1= 100% 10 = 10% etc..

  • Self-contained, "no" dependencies. No neural networks!
  •(*) A,B assumed to be the same shape, but possibly different numbers of bands. C and A are assumed to have the same number of bands (they need not be the same shape)

https://github.com/bcgov/bcws-psu-research/blob/master/cpp/abcd.cpp

A is to A, as A is to __ ? (A=B=C) --> (D)

A = Synthetic hyperspectral checkerboard with noise



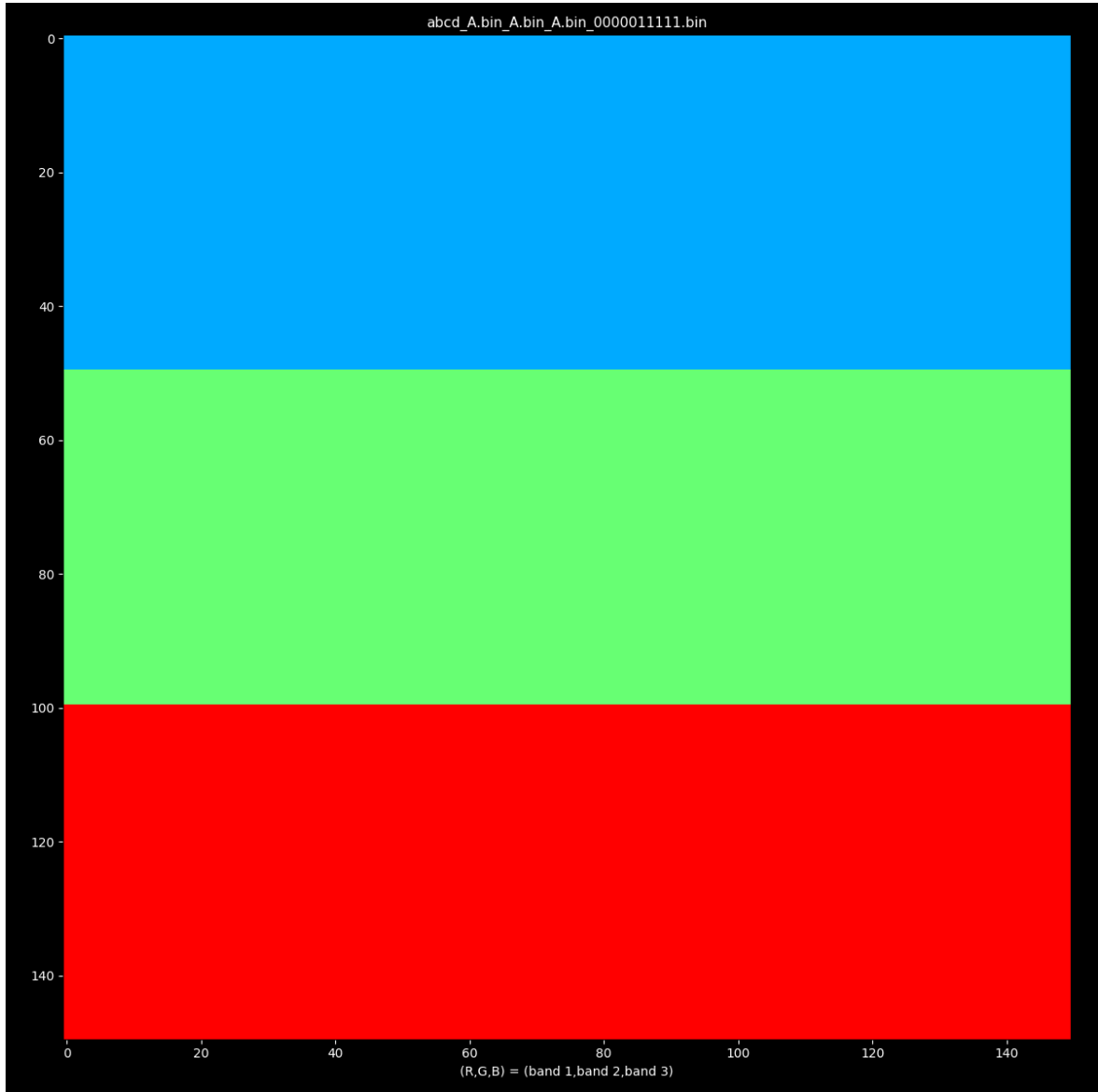


Image translation

https://github.com/bcgov/bcws-psu-research/blob/master/cpp/abcd.cpp

```
+ #include"misc.h"
+ static size_t nr[3], nc[3], nb[3], skip_f;
+ static int * bp, * bp2;  // bad px: {A,B}, C
+ static float * y[3], *x; // {A, B, C}, D
+ static size_t np, np2;  // npix A, C
+ static float *A, *B, *C;
+ static size_t m;  // tmp band-ix
+ static float t; // tmp float
+
+ void status(size_t i){
+   cprint(to_string(100.* ((float)(i+1) / (float)np2)) + str(" % ") + to_string(i) + str(" / ") + to_string(np2));
+ }
+
+ void job(size_t i){
+   if(bp2[i]) return; // skip bad
+   float d, e, md = FLT_MAX;
+   size_t j, k, mi = 0;
+   size_t nb_0 = nb[0];
+
+   for(j = 0; j < np; j += skip_f){
+     d = 0;
+     if(bp[j]) continue;
+     for0(k, nb_0){
+       e = A[np * k + j] - C[np2 * k + i];
+       d += e * e;
+     }
+     if(d < md){
+       md = d;
+       mi = j;
+     }
+   }
+   for0(k, nb[2])
+     x[np2 * k + i] = B[np * k + mi];
+
+   if(i % 100000 == 0) status(i);
+ }
+
+ inline int is_bad(float * dat, size_t i, size_t n_b){
+   int zero = true;
+   for0(m, n_b){  // find bad/empty pix
+     t = dat[np * m + i];
+     if(isnan(t) || isinf(t)) return true;
+     if(t != 0) zero = false;
+   }
+   return zero;
+ }
```

```
+ int main(int argc, char** argv){
+   size_t i, n_bad = 0;
+   if(argc < 5)
+     err("view_as [img1 (n band)] [img2 (m band)] [img3 (n band)] [skip]\n");
+   skip_f = (size_t) atol(argv[4]);
+
+   for0(i, 3)
+     hread(hdr_fn(argv[1 + i]), nr[i], nc[i], nb[i]);
+
+   if(nr[0] != nr[1] || nc[0] != nc[1]) err("A.shape != B.shape");
+   if(nb[0] != nb[2]) err("A.n_bands != C.n_bands");
+
+   x = falloc(nr[2] * nc[2] * nb[2]); // out buf
+   for0(i, 3) y[i] = bread(str(argv[i + 1]), nr[i], nc[i], nb[i]);
+   np = nr[0] * nc[0];
+   np2 = nr[2] * nc[2];
+
+   n_bad = 0;
+   bp = ialloc(np);  // bad pix
+   for0(i, np){
+     bp[i] = is_bad(y[0], i, nb[0]) || is_bad(y[1], i, nb[1]);
+     if(bp[i]) n_bad ++;
+   }
+   if(n_bad == np) err("no good pix: AxB");
+
+   n_bad = 0;
+   bp2 = ialloc(np2);
+   for0(i, np2){
+     bp2[i] = is_bad(y[2], i, nb[2]);
+     if(bp2[i]) n_bad ++;
+   }
+   if(n_bad == np2) err("no good pix: C");
+
+   A = y[0];  B = y[1]; C = y[2];
+   parfor(0, np2, job);  // for each output pix
+
+   str pre(str("view_as_") +
+       str(argv[1]) + str("_") + str(argv[2]) + str("_") +
+       str(argv[3]) + str("_") + str(argv[4]));
+   bwrite(x, pre + str(".bin"), nr[2], nc[2], nb[1]);
+   hwrite(pre + str(".hdr"), nr[2], nc[2], nb[1]);
+   system((str("python3 ~/GitHub/bcws-psu-research/py/raster_plot.py ") +
+      pre + str(".bin 1 2 3 1")).c_str());
+   return 0;
+ }
```

"Tiny AI" challenge < 100 lines

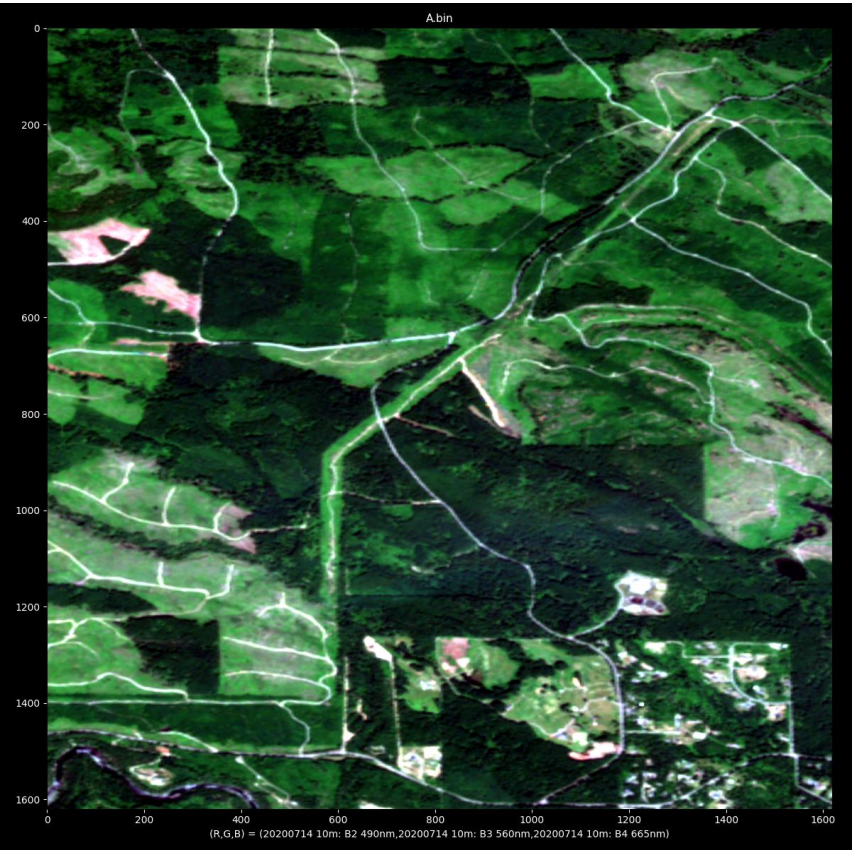
A is to B as A is to D

Simulating RCM from Sentinel-2

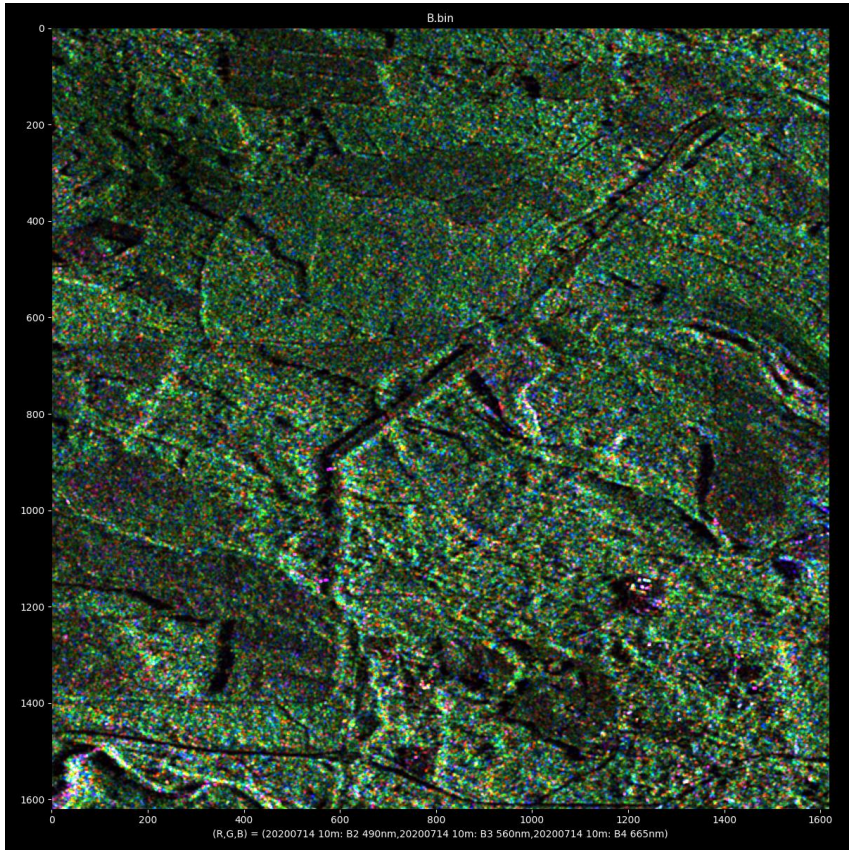
Nanaimo BC, 2020

- Would be interesting to include terrain geometry variables and try this again!
- **Would get better results with higher-dimensional imagery / more bands**
- Also, bsq2bip -> binary_sort -> bip2bsq method to improve sampling

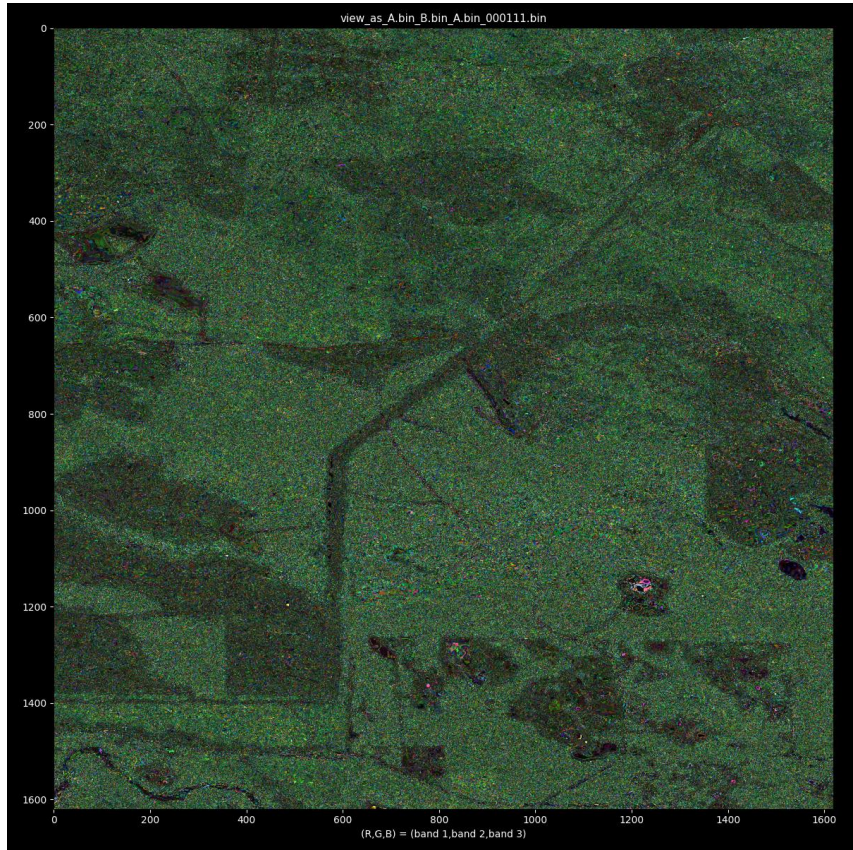
A (Sentinel-2)



B (RCM m-chi)

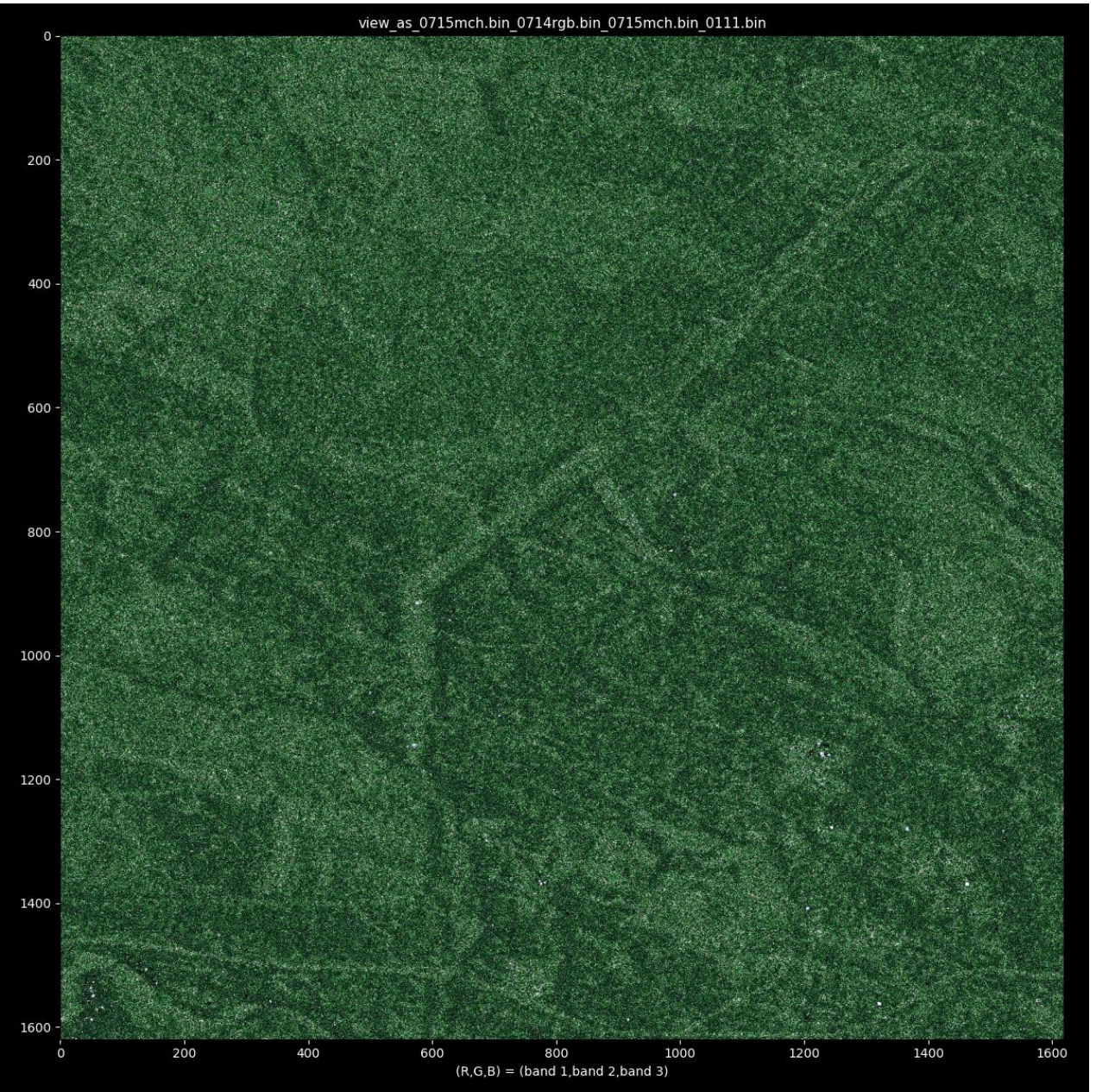


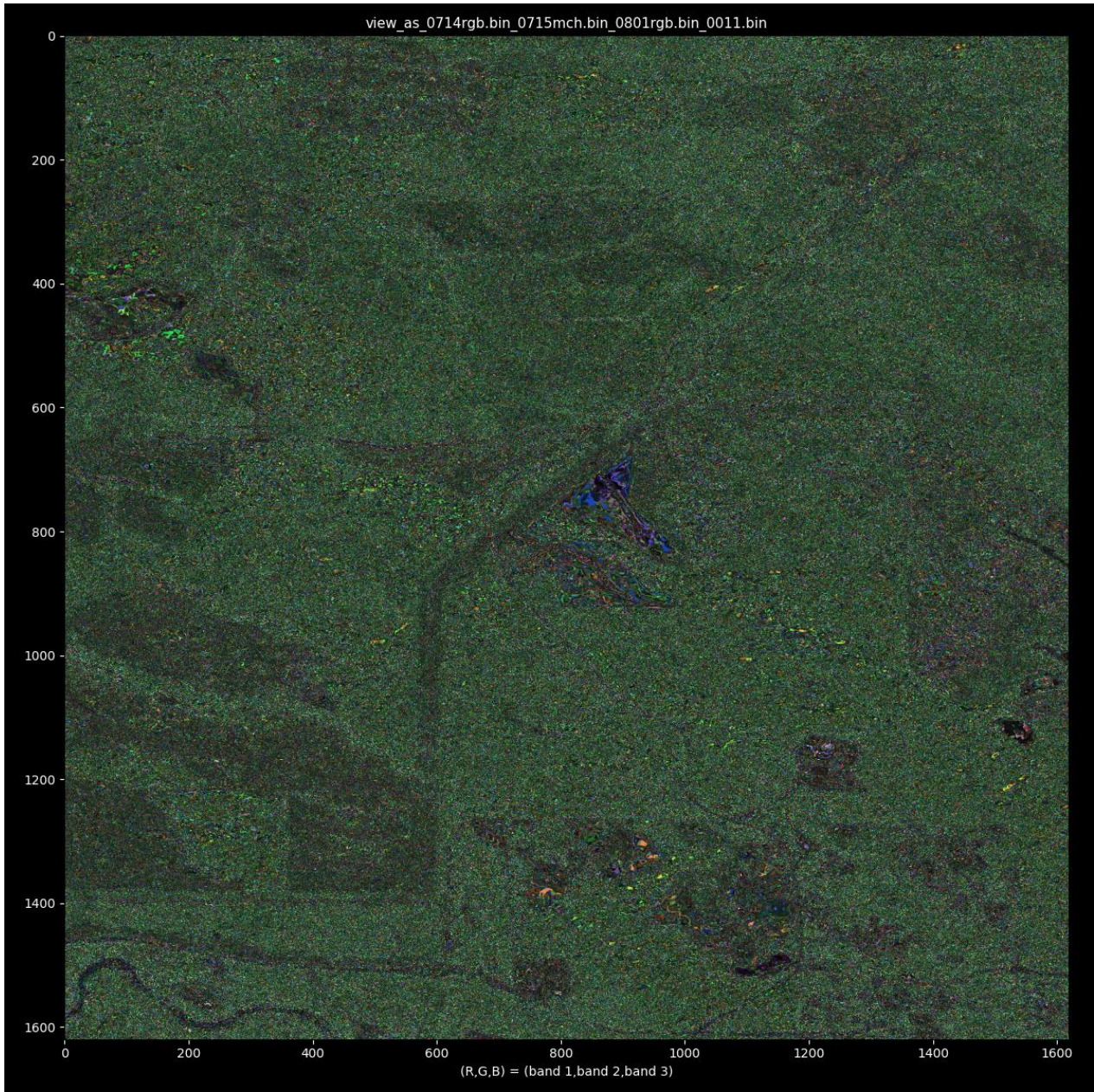
D



Infer RCM from Sentinel-2 (present, future)

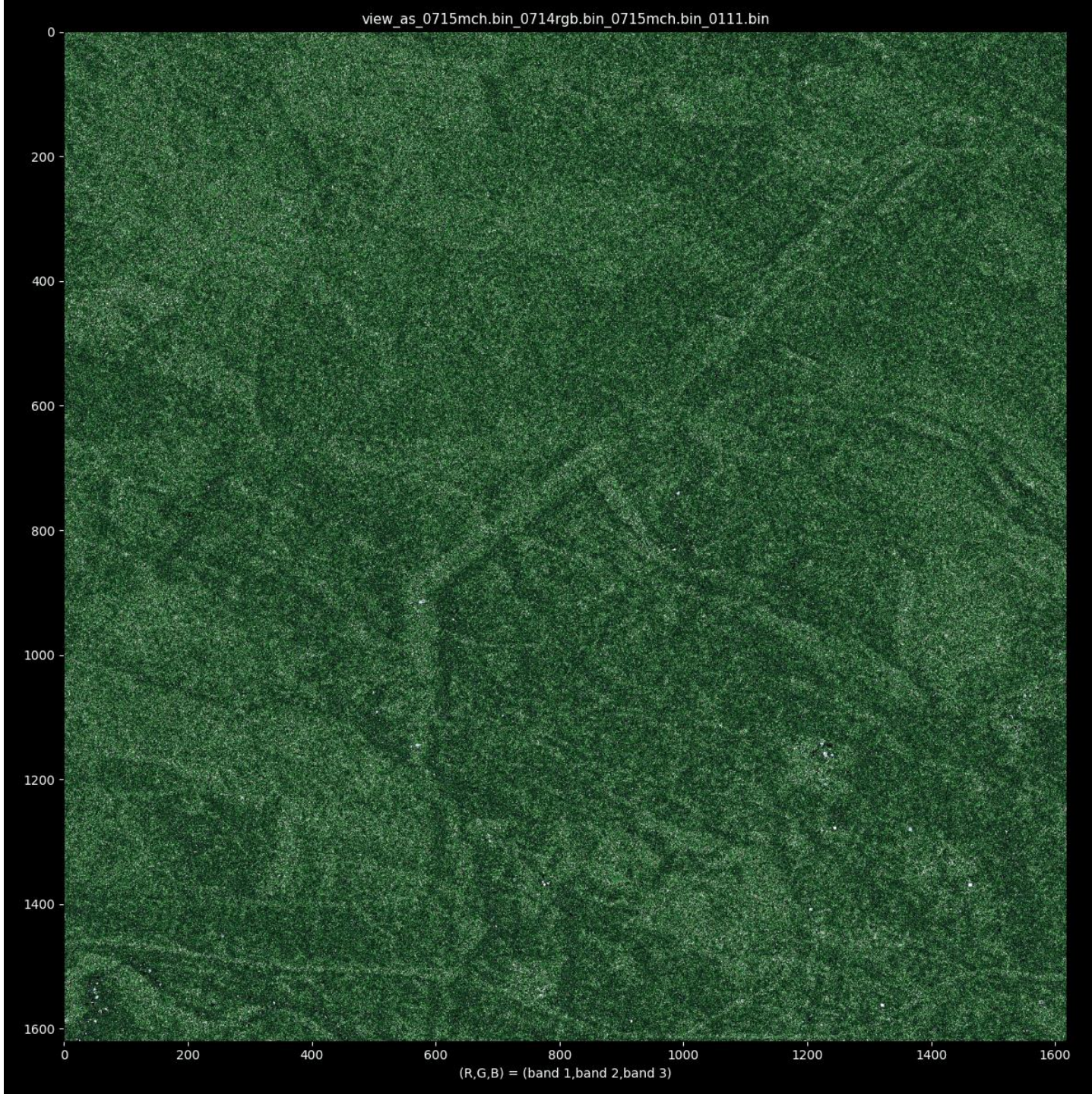
Sentinel-2 predicts Surface scattering in clearcut





Predict S2 from RCM

- Sentinel-2 seemed more capable in an obvious sense (excepting the obvious.. Clouds)
- The forest change is again apparent from RCM
- *Value in doing more with what we have*



abcd_0715mch.bin_0714rgb.bin_0715mch.bin_0111.bin_1_2_3_rgb.png
abcd_0715mch.bin_0714rgb.bin_0731mch.bin_0111.bin_1_2_3_rgb.png

What happens if we "skip" most of the "training" data?

- Get an unusual looking result v quickly. Still a pattern hidden in the chaos..

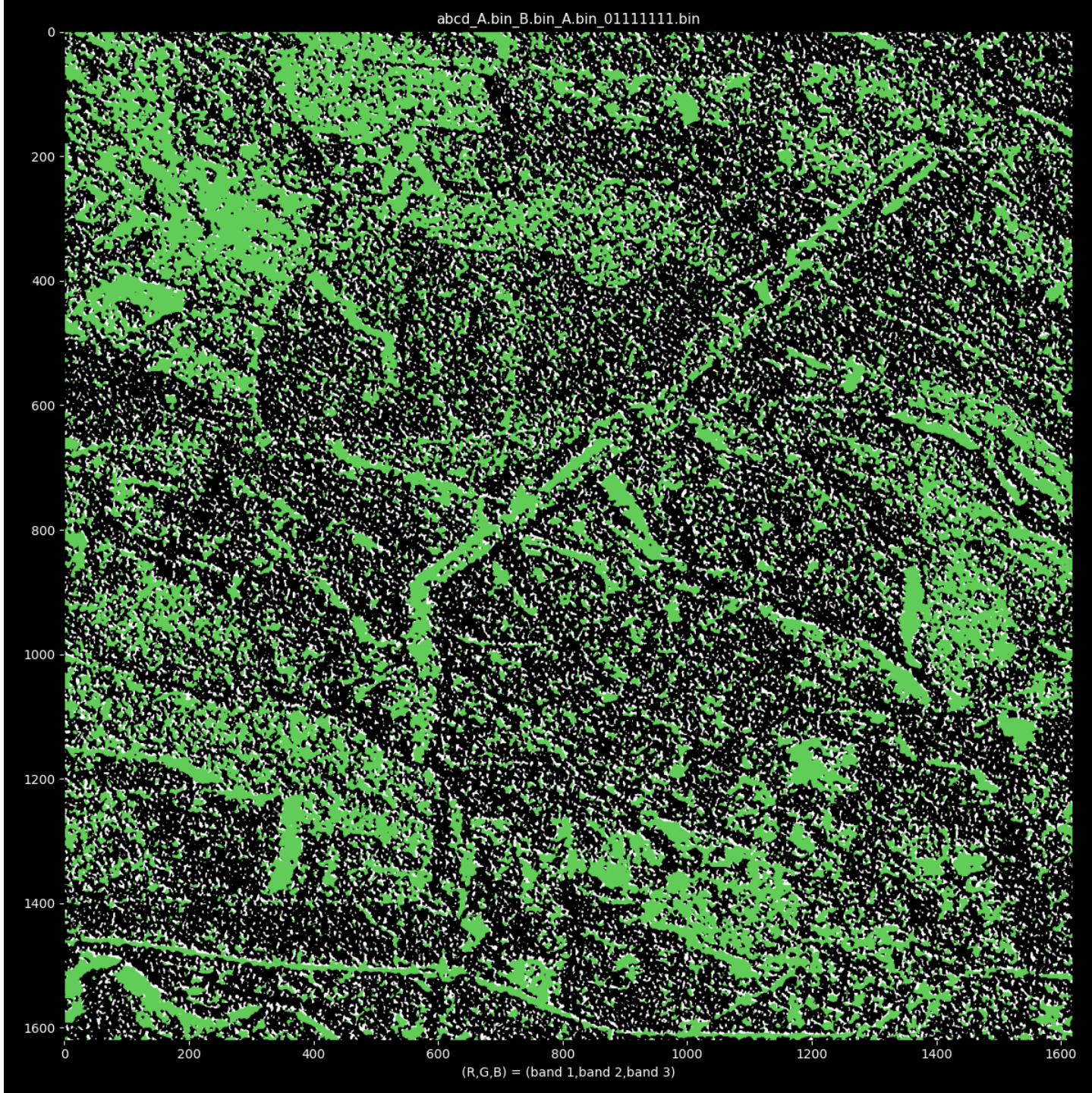
How to outline a noisy blob? Possible solutions:

- "Optimal Transport problem" (*)
- Clustering algorithms (e.g. KGC-2010 with (i,j) coordinates added to distance function)
- Fourier transform?

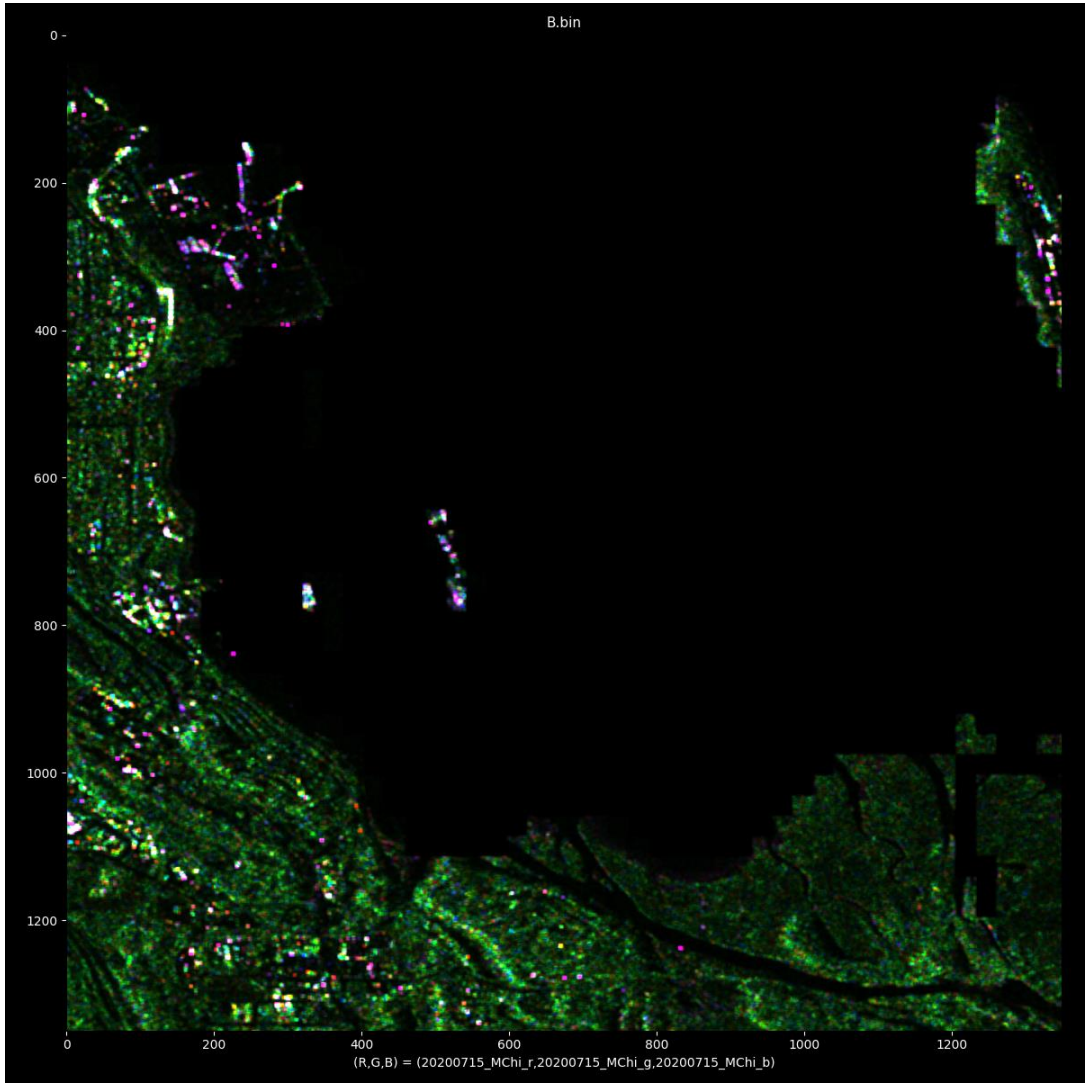
(*) An efficient numerical algorithm for the L2 optimal transport problem with applications to image processing (Saumier Demers, L.P):

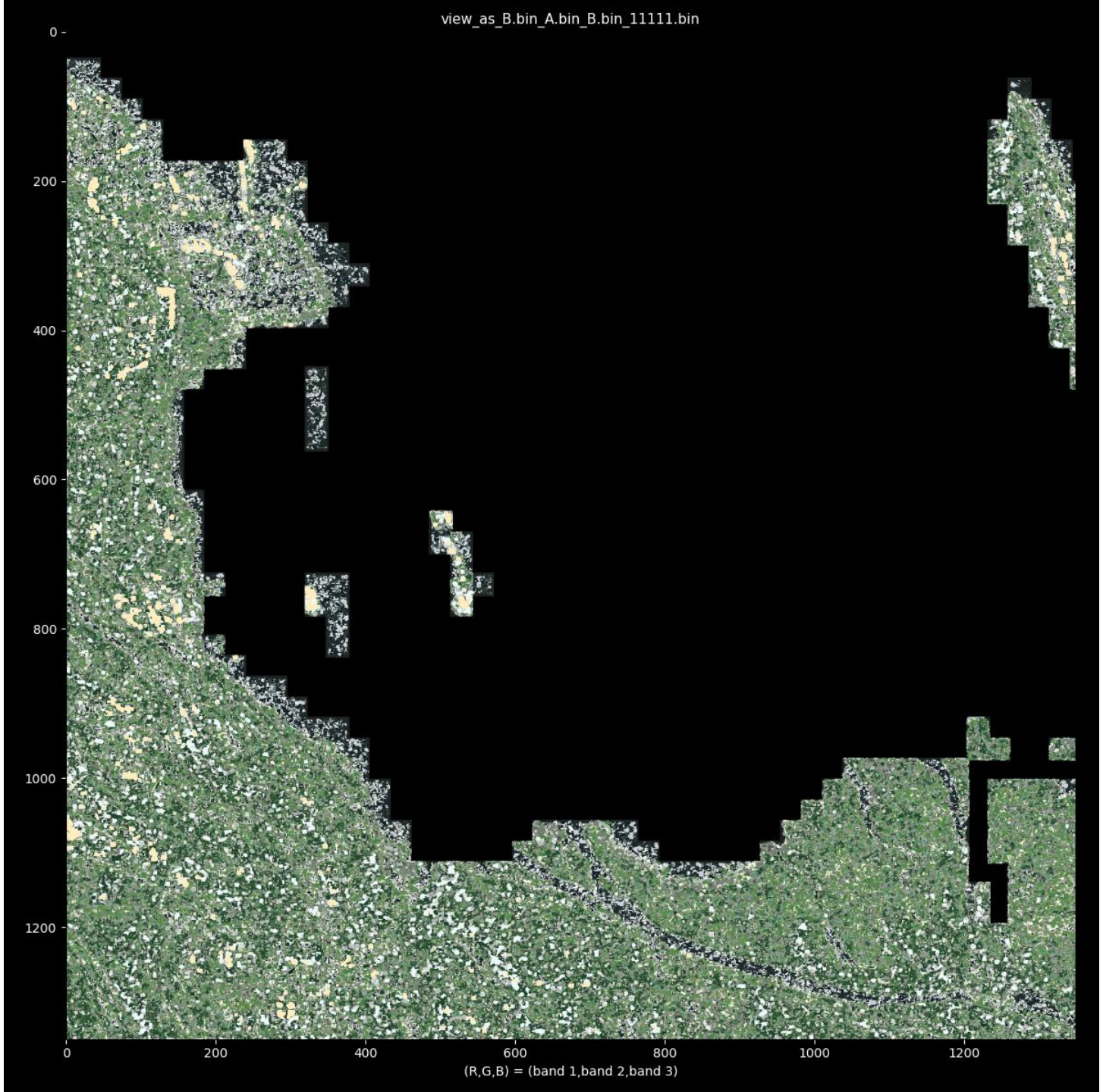
- https://dspace.library.uvic.ca/handle/1828/3157

- http://ashlinrichardson.com/talks/20210526_character_recognition.pdf
- (more continuity of affected area, seen in the difference)



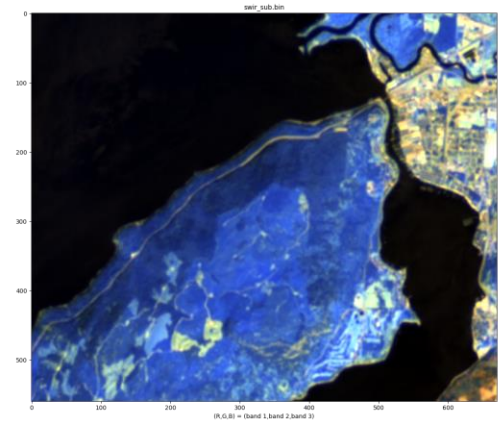
Can we morph RCM into S2?



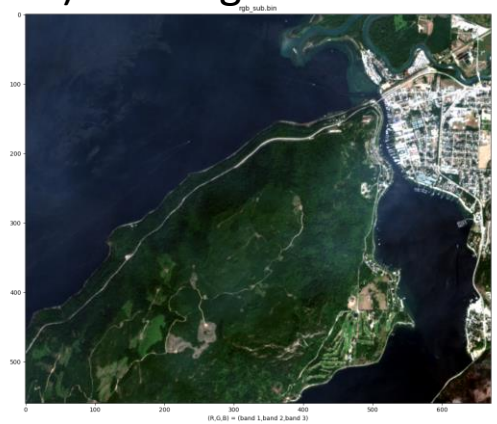

view_as_B.bin_A.bin_B.bin_11111.bin
0
200
400
600
800
1000
1200
0
200
400
600
800
1000
1200
(R,G,B) = (band 1,band 2,band 3)

Sicamous BC, 2021. Can we view SWIR in optical?

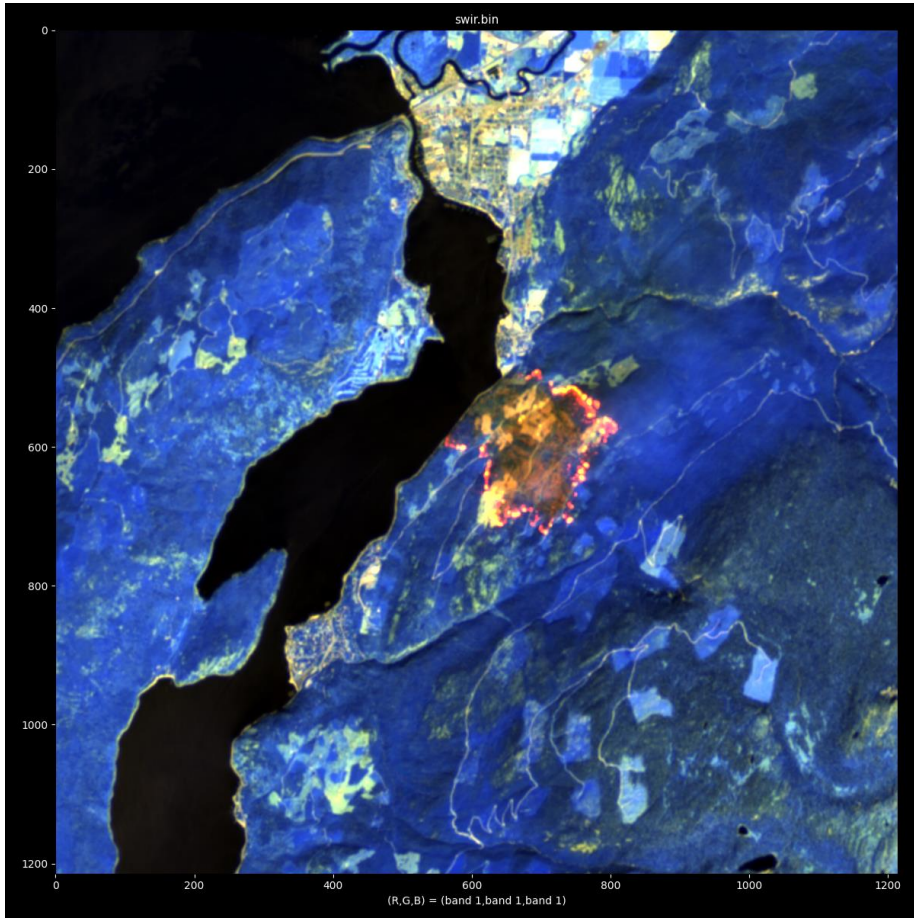
A) training



B) training



C) input



D) prediction

Dimensionality of L-band / Quad-pol

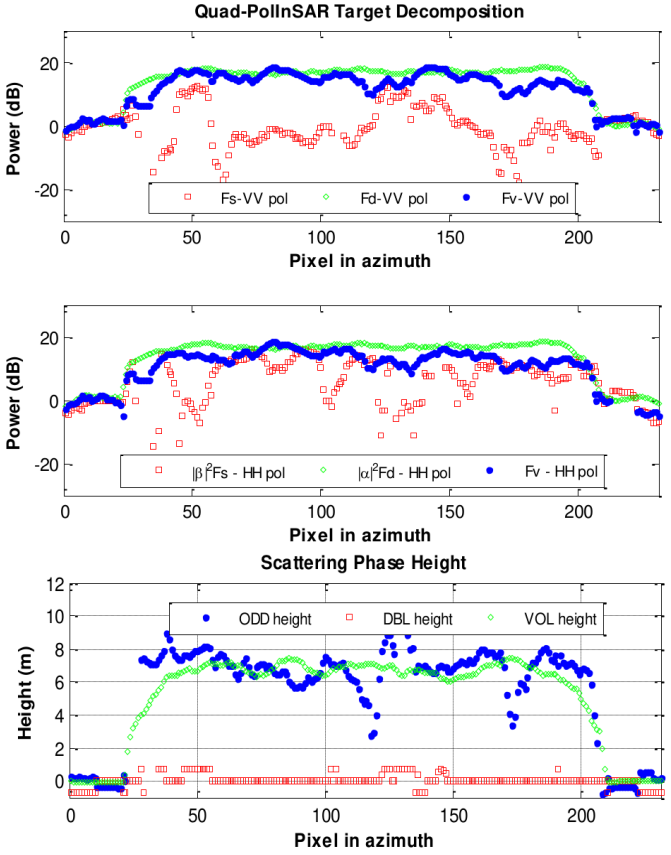
Can delineate harvest / fire events with a single frame (right)
Detect and compensate for ionosphere effects, still model scattering mechanisms
2 or more takes --> inSAR or tomography approach (vertical density of scattering contributions)
Inherently contains 3d info to help correct for topography (Europe/China Dragon cooperation)

Simulated Test Dataset Description

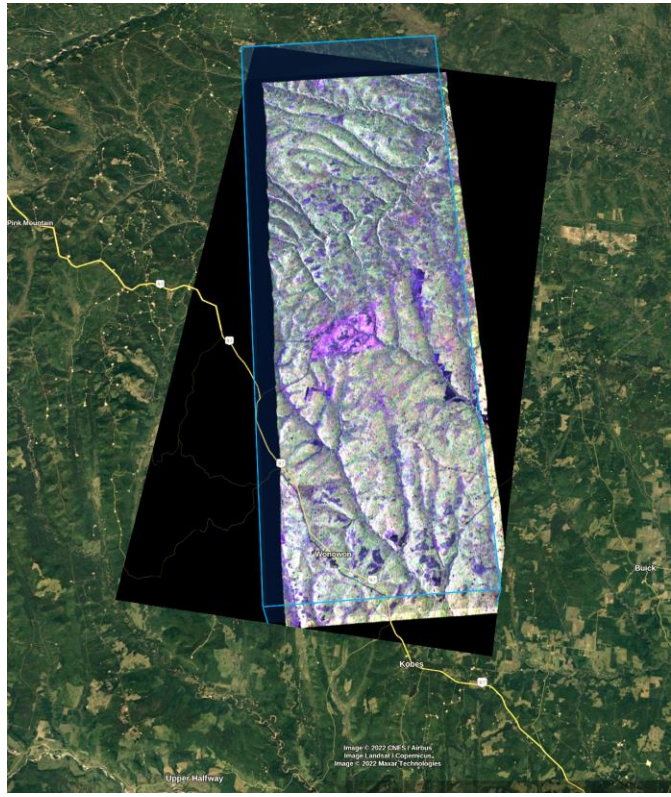
- For testing the decomposition algorithm, a simulated PolInSAR forest dataset was generated (using the PolSARProSim software) with the following parameters:
  - Tree height: 10m. Tree type: *hedge*.
  - Frequency: L-band. Baseline: 10m (horizontal), 1m (vertical).
  - Resolution (Azimuth x Range): 0.69m x 0.975m. Data size: 131x219.

|HH+VV|, |HH-VV|, |HV|

12



Quad-PolInSAR decomposition 15



[Applying the Freeman Durden Decomposition to Compact polarimetric SAR Interferometry, IEEE IGARSS, Québec City, Canada, July 2014]

Next steps

- **More international cooperation will be key!**
  - **Continue to develop relationships**
  - **Task me? Open to your feedback**

Operational-integration engineering (prototype operational products)

  - **Fire mapping (this year)**
  - **Fuel type layer challenge (next)**

Use ABCD method

- as supervised classifier (categorical land cover)
- For communication / accessibility
  - Explanatory visualization to share technical CCD/inSAR/polSAR choicesand trade-offs..
    - Compare CP vs QP and avail. parameters /decoms
    - Reconstruction metrics to compare heterogeneous imaging modes
    - Understand relationships between Prisma, Sentinel2 and RCM data over Sparks Lake Fire
    - Find synergy with Compact-pol in-SAR decomposition, compact and Quad-pol change detection techniques being advanced by colleagues!

- **Next reporting:** applying to present, (Oct) Wildfire 2022 conference on:
  - Fuels mapping Ground study (3rd iteration underway)
  - Fire mapping (currently being examined by dev team)
  - Fuels mapping province-wide pilot (first iteration)
- **Background missions**
  - Use trajectory analysis for consistent representation to integrate (disparate) data streams!
  - Pursue PolSAR, Multi & Hyperspec, LiDAR for fire and inter-related hazards, and ecosystem support

Thanks

- CSA for collab & extraordinary data.
- Emmanuelle, Daniel, Cédric, Guennadi & team for the inspiring session!
- Public Safety Canada for RCM tasking during fire, flood/slide seasons
  - Analysis in progress (3 sets). Thanks Cameron
- BC Wildfire, Brent, Predictive Services Unit, & BC Stats / DSP program
- JAXA for accepting BCWS L-band access application. Grateful for the opportunity!
- A. Rosenqvist for collab & data feasibility study
- H. Chen for cooperation on RCM
- ASI for Prisma hyperspectral data
- NASA for ARSET training
- S. Nasonova & BC Forest Inventory program
- A. Bevington & BCGov R.S. CoP
- C. Froese for sharing with our CoP
- ESA for Sentinel-2 and Dr. Pottier for PolSARPro!
- L. Veci & team, and ESA for SNAP software
- B Martin for field data collection. M Sakals and J Nicholas for RPAS collection
- DLR for initial connection
- CFS / NRCAN, TRU, and other partners
- D Goodenough, D Bancroft, S Cloude, A Marino, S Dey for consultations!

Thanks for your collaboration any thoughts / feedback / direction you can share!