Data Fusion: When and How Is It Useful?

Megan Gallagher

Solutions Engineer, L3Harris Geospatial

Megan.Gallagher@L3Harris.com

SPECTRAL

SESSIONS

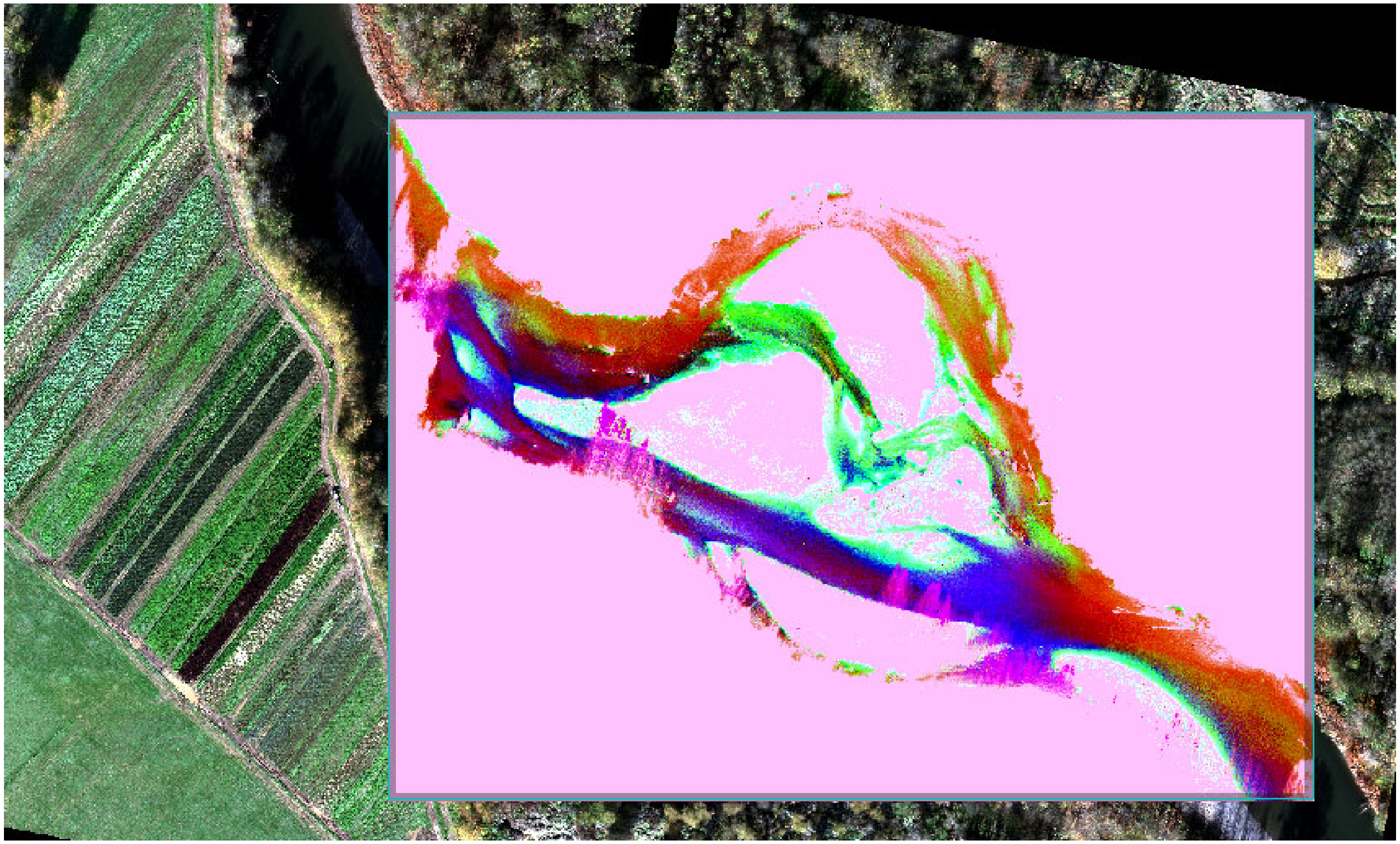
What is data fusion?

- A combination of data (in our case, mainly imagery) that comes from disparate sources.
- “Fusion” is the product of these combined sources; this can either be a band stack of information, a colorized point cloud, or even using the sources together in a process.

SPECTRAL SESSIONS

When do I want to use data fusion?

- Resolution
  - Spatial
  - Spectral
  - Temporal
- Specific Information
- Modeling



SPECTRAL SESSIONS

The necessities

- Data must be geo located and registered, it must have proper overlap and be exactly where it is supposed to be.
- Data must be comparable; the scaling must be close enough to be compared to each other (for example comparing an exponentially scaling data set to a linear one is not great)
- Rigorous comparison and testing may be necessary.

SPECTRAL SESSIONS

Optical to optical data

- One of the most common practices of data fusion is using different sources of optical data together.
- This can be because of temporal, spatial, and spectral resolution, as well as for modelling purposes.
- For example: If you had a sensor that was working from 2010-2020, and then a new sensor from 2020-present, if you are doing a long-term process you need to fuse the data to hopefully be comparable.
- Another example: Combining sources of different resolutions, such as satellite information to UAV, or even ground stations.

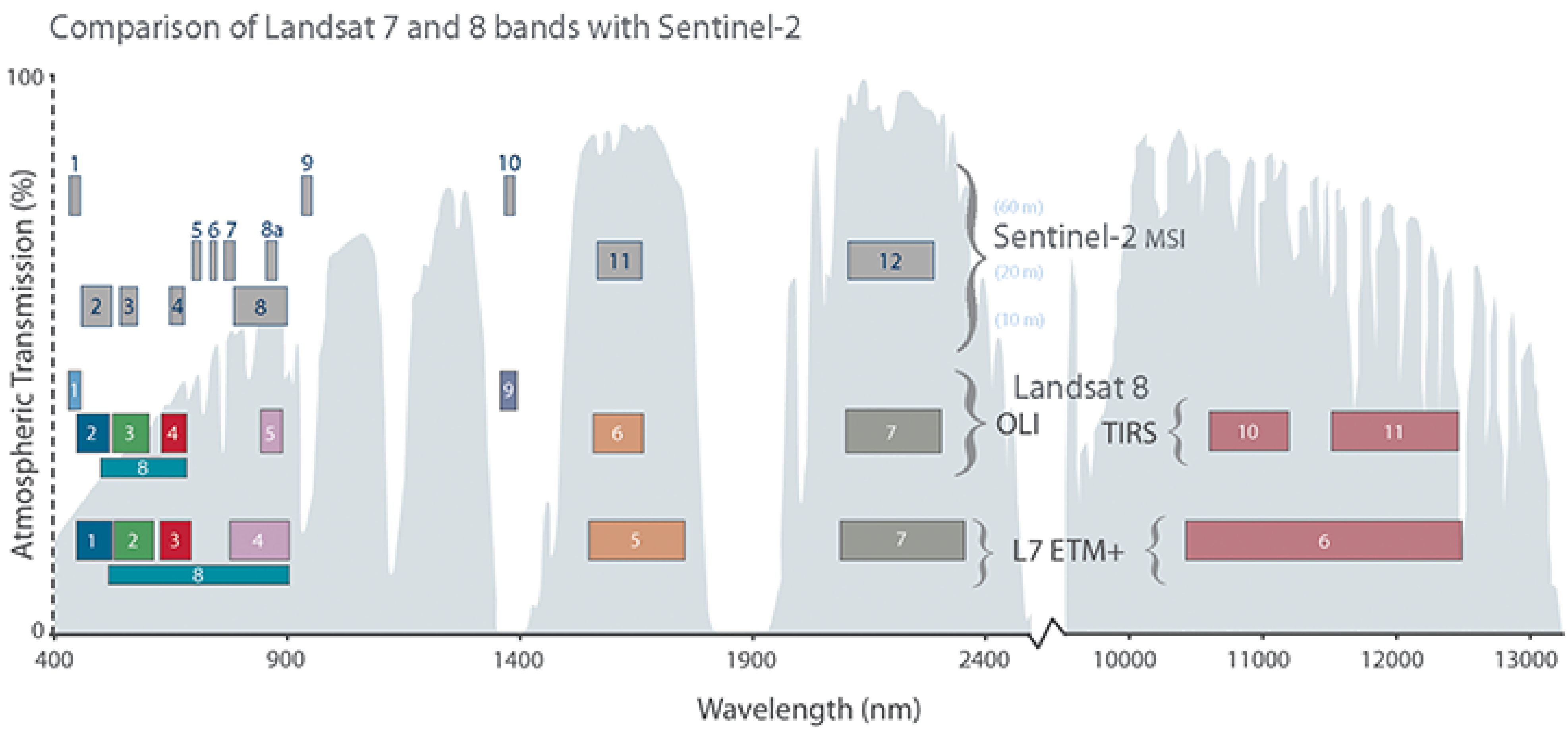
SPECTRAL SESSIONS

How to prep the data

- The most important part of data fusion!
- Must be in reflectance and comparable, better with actual band overlap, if there isn’t any you may have to mathematically split or combine bands for better matching.
- MUST be geolocated correctly, pixels should line up as best as possible.
- Resolution is tricky. If things can be put into the same gridding they should be.

SPECTRAL SESSIONS

An Example of Overlap



Harmonized Sentinel-2 and Landsat

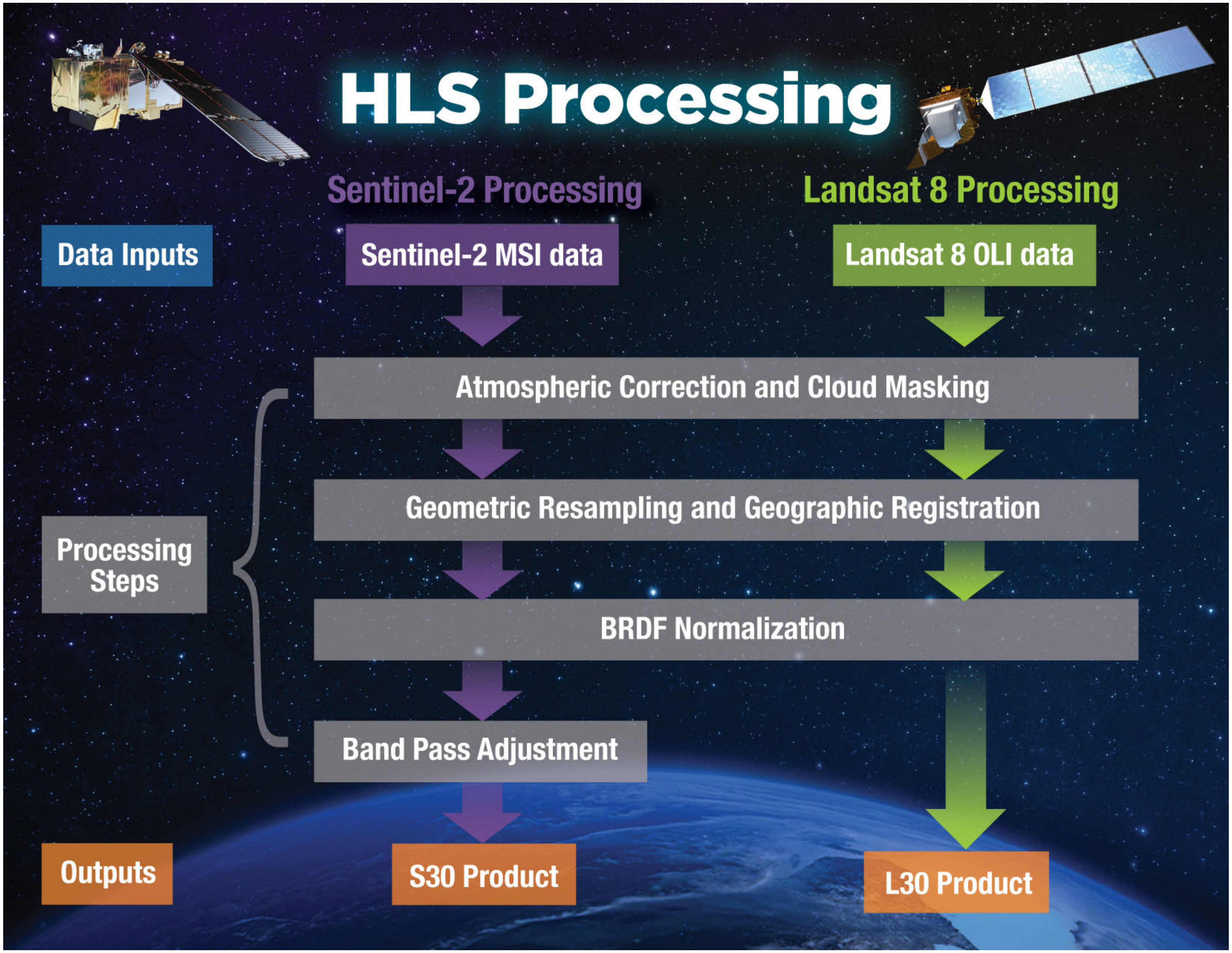
“A Harmonized Surface Reflectance Product”

Landsat and Sentinel-2 data represent the most widely accessible moderate-to-high spatial resolution multispectral satellite measurement. Following the launch of the two Sentinel-2 satellites in 2015 and 2017, the potential for synergistic use of Landsat and Sentinel-2 data creates unprecedented opportunities for timely and accurate observation of Earth status and dynamics. Harmonization of the Landsat and Sentinel-2 data is of paramount importance for the scientific community. This research project prototypes the harmonization for the entire North America and other globally distributed test sites. Technical details of harmonization can be found in the following paper and the User Guide in the Documents section.

https://hls.gsfc.nasa.gov/

SPECTRAL SESSIONS

Claverie, M., Ju, J., Masek, J. G., Dungan, J. L., Vermote, E. F., Roger, J.-C., Skakun, S. V., & Justice, C. (2018). The Harmonized Landsat and Sentinel-2 surface reflectance data set. *Remote Sensing of Environment*, 219, 145-161.



SPECTRAL SESSIONS

Modis to Landsat fusion using STARFM

- Purpose: Daily 30 m resolution imagery over a dryland ecosystem for monitoring Cheat grass and shrub brush changes due to fire.
- Why was fusion used: Dryland ecosystems make it very difficult to separate brown grass from other brown grass unless using a good time scale.

Utilizing Satellite Fusion Methods to Assess Vegetation Phenology in a Semi-Arid Ecosystem

SPECTRAL SESSIONS

Gallagher, Megan, "Utilizing Satellite Fusion Methods to Assess Vegetation Phenology in a Semi-Arid Ecosystem" (2018). *Boise State University Theses and Dissertations*. 1425. 10.18122/td/1425/boisestate

STARFM

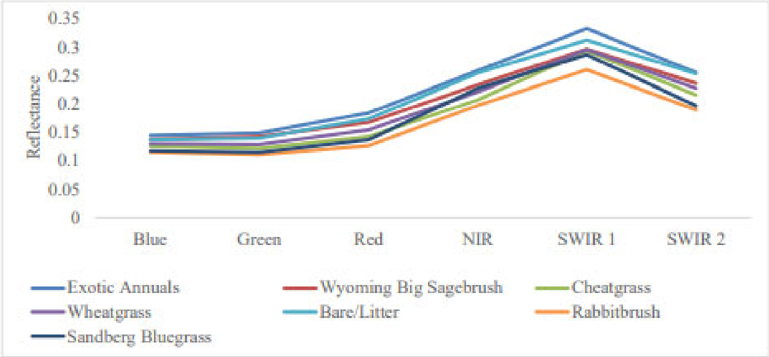
- STARFM – an algorithm created by NASA Goddard for the combination of Landsat and Modis to create fusion products in between the Landsat dates. https://data.nal.usda.gov/dataset/starfm

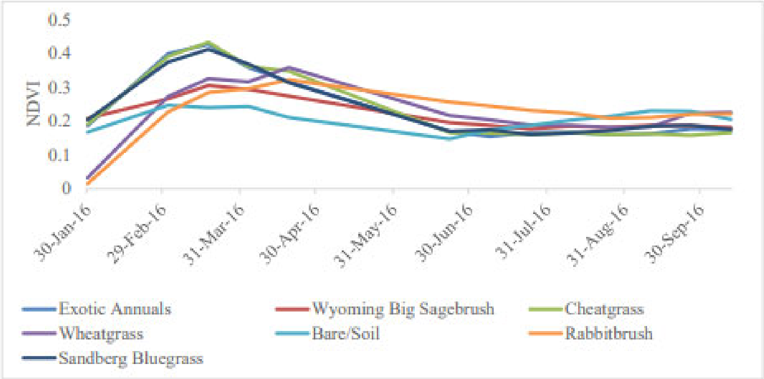
	Landsat 8	Wavelength (nm)	MODIS	Wavelength(nm)
Blue	2	450-510	3	459-479
Green	3	530-590	4	545-565
Red	4	640-670	1	620-670
NIR	5	850-880	2	841-876
SWIR 1	6	1570-1650	6	1628-1652
SWIR 2	7	2110-2290	7	2105-2155

SPECTRAL SESSIONS

Why was data fusion used?

- Dryland environments have immediate green ups after rain, and then spend the rest of the season ranging in colors of brown and dried out.
- This makes it spectrally difficult to separate out plants.
- High temporal resolution time series are better able to separate out species.
- Landsat has a 30 m pixel size, but a revisit period of 16 days, and MODIS has a resolution of 250 -1000 m daily.

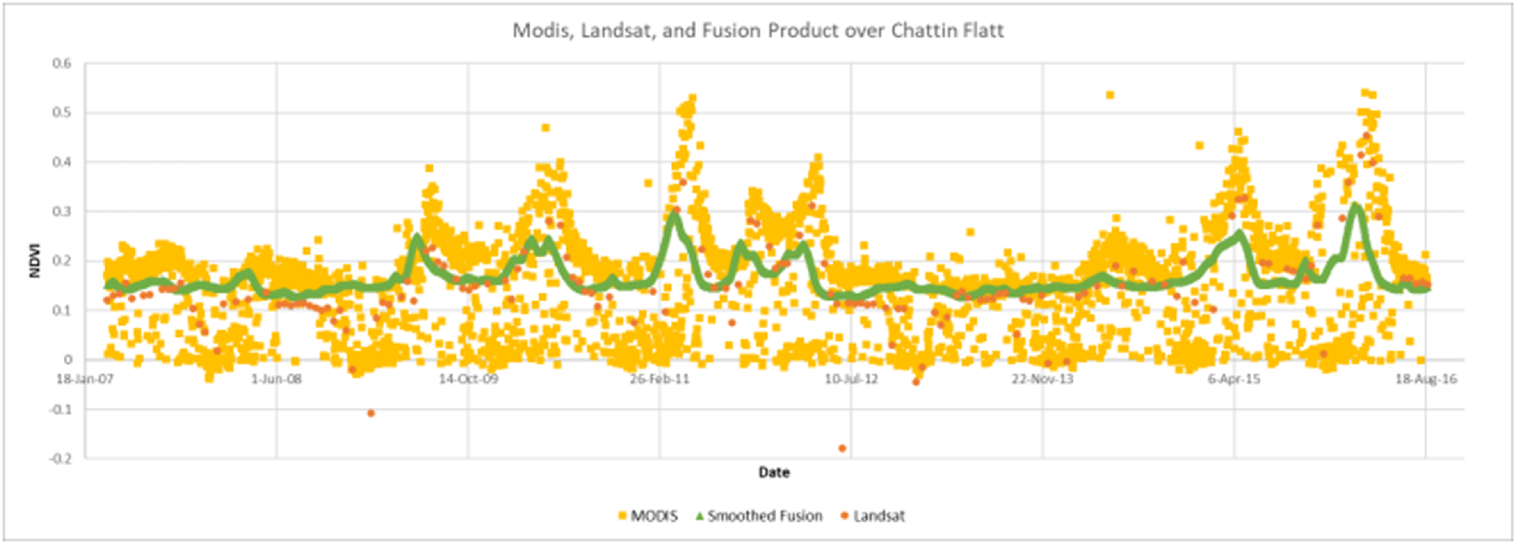




SPECTRAL SESSIONS

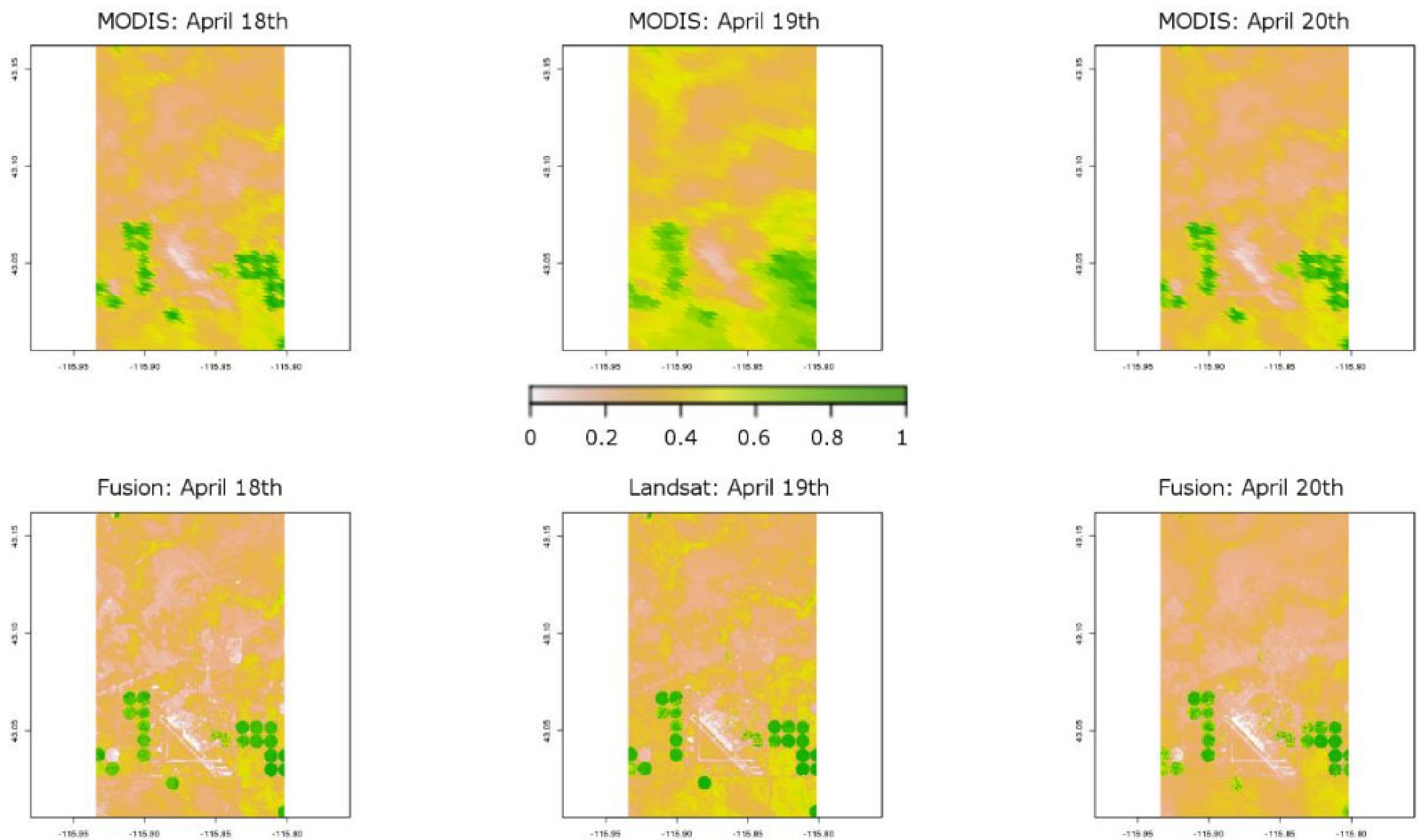
How does it work?

- Uses Landsat dates and compares to MODIS imagery at the same date to create an interpolation of the daily MODIS data down to the 30 m Landsat scale.



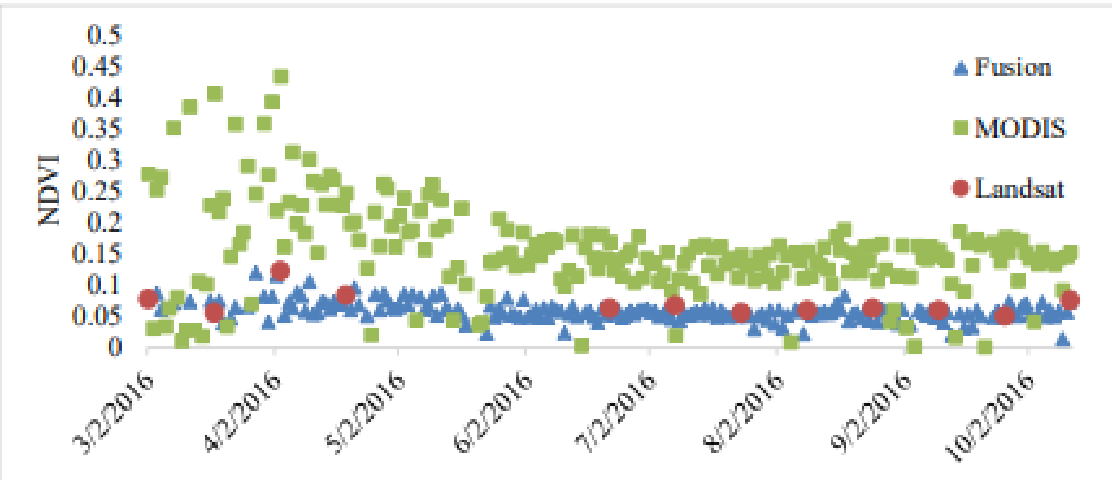
SPECTRAL SESSIONS

What the fusion outputs look like



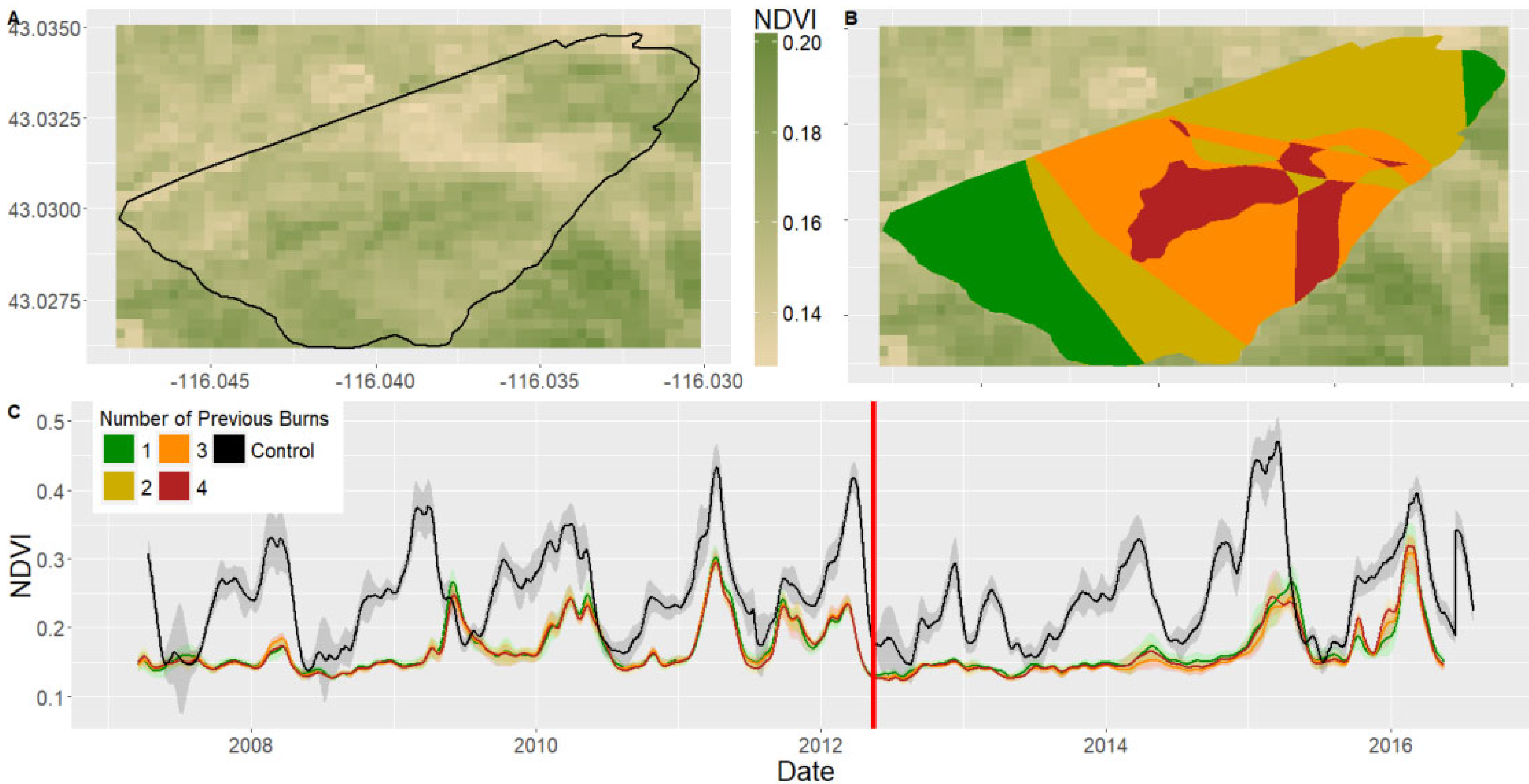
NDVI of MODIS compared to NDVI of Landsat and the Fusion product

Always check your data



	Mean	STD	Min	Max	25th	Median	75th
Landsat	0.0684	0.0195	0.0494	0.1215	0.0565	0.0619	0.0756
MODIS	0.1503	0.0765	0.0078	0.4326	0.1144	0.1459	0.1788
Fusion	**0.0587**	**0.0158**	**0.0136**	**0.1224**	**0.0510**	**0.0571**	**0.0640**

Left: Chart of NDVI responses by MODIS, Landsat, and the fusion product over a pixel of black asphalt
Top: Statistics of the three products over the asphalt pixel



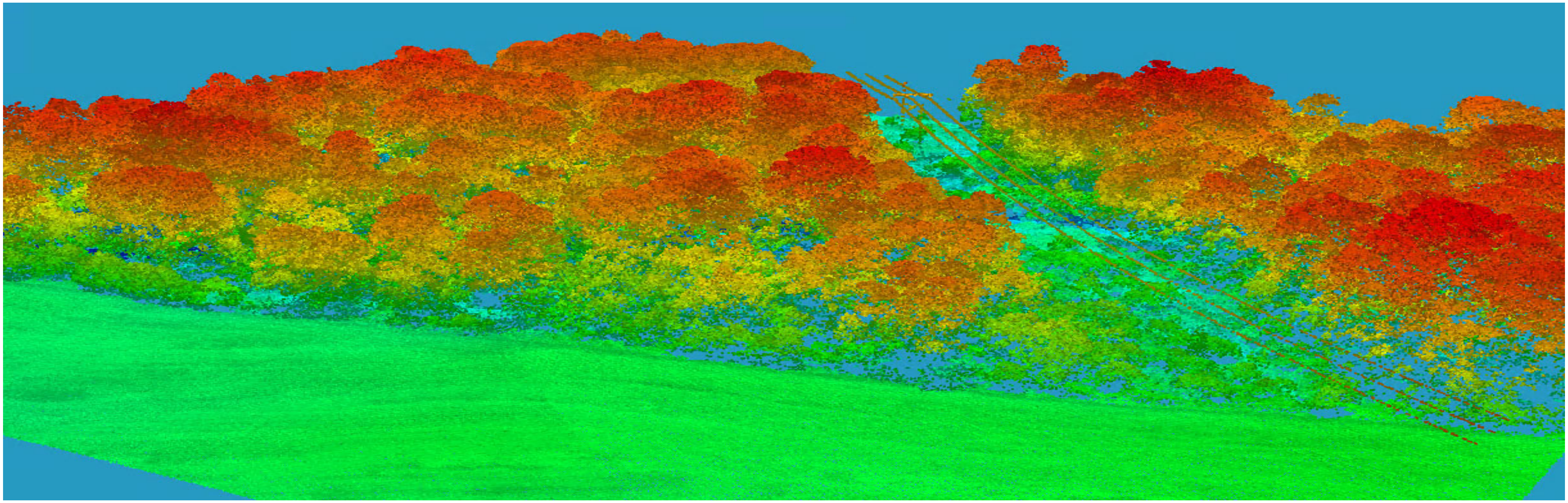
Chattin Flatt Fire

Optical to Lidar

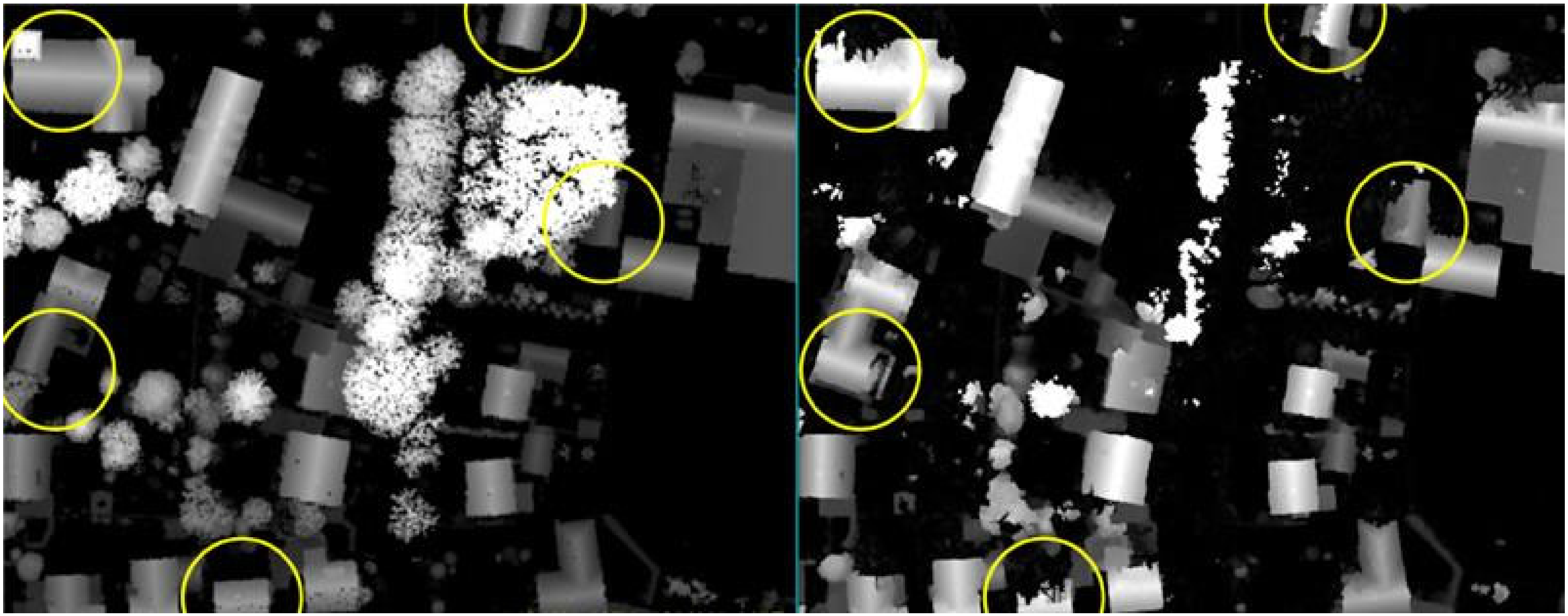
- Optical and Lidar are commonly fused for extra information and modelling purposes.
- One of the most common fusion techniques, some sensors automatically colorize point clouds with built in cameras.
- Another common use of Lidar is to use the output DEM and DSM products to highlight height features for differentiation.

How to prep the data

- All preprocessing of optical should be done like normal.
- Lidar products should be changed to nDEM or nDSM, looking solely at the height and height change rather than the whole product.
- Make sure that the products are orthorectified and aligned.



Lidar compared to Photogrammetric Lidar



SPECTRAL
SESSIONS

Road Network Extraction

Nearmap
35cm, 3 band

SPECTRAL SESSIONS

Road Network – LiDAR Derived Input

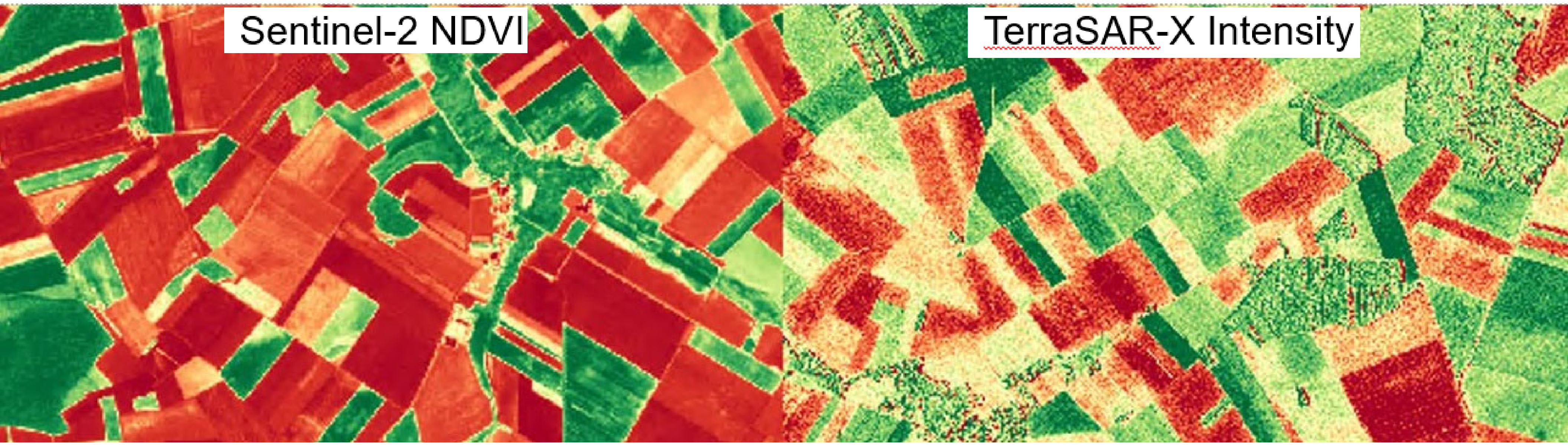
Height, intensity, and shaded relief

Results

SPECTRAL SESSIONS

Optical and SAR

- Optical can be fused with SAR data to increase temporal and spectral resolution, as well as increase in extra information that is not available from just optical data.
- Commonly used for time series monitoring, or areas where texture and dielectric response are necessary for separation of features.

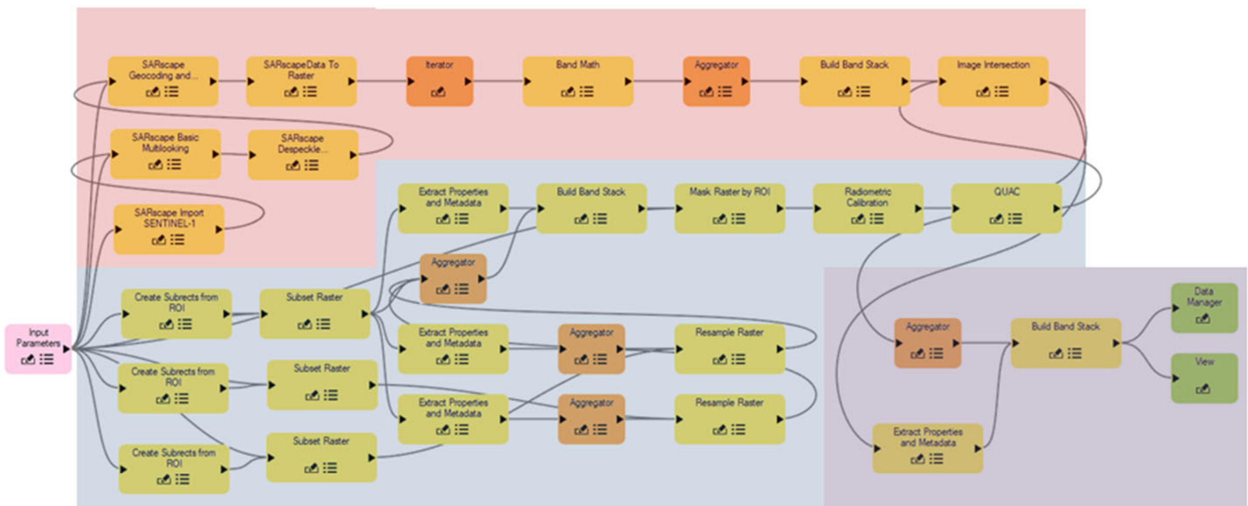


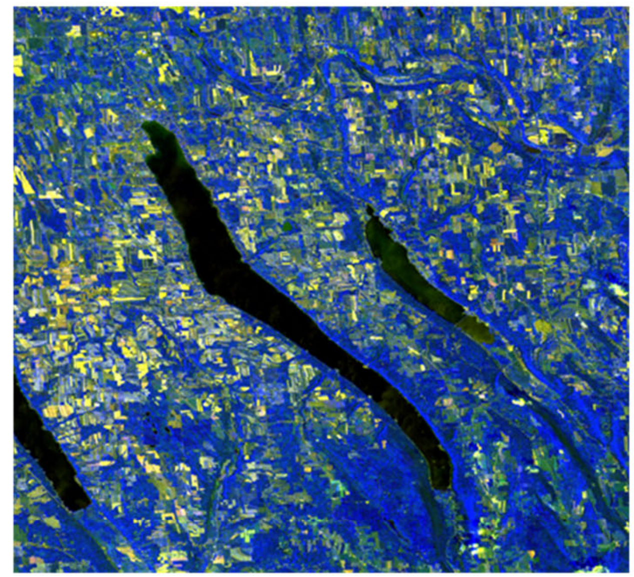
How to prep the data

- Optical – normal preprocessing, reflectance and orthorectification are necessary.
- SAR – preprocessing for product needed, whether this is getting a SAR reflectance product or generating a DEM/change map. SAR outputs should be put into a Linear scale when compared to optical for classification, otherwise the dB scale can skew the results.
- dB scaling can be used when comparing outputs.

Franken-model

Automate and batch process your data in the ENVI modeler with SARscape tasks





Full preprocessing and fusion of Sentinel-1 (all bands) and Sentinel-2

Skaneateles Lake, NY

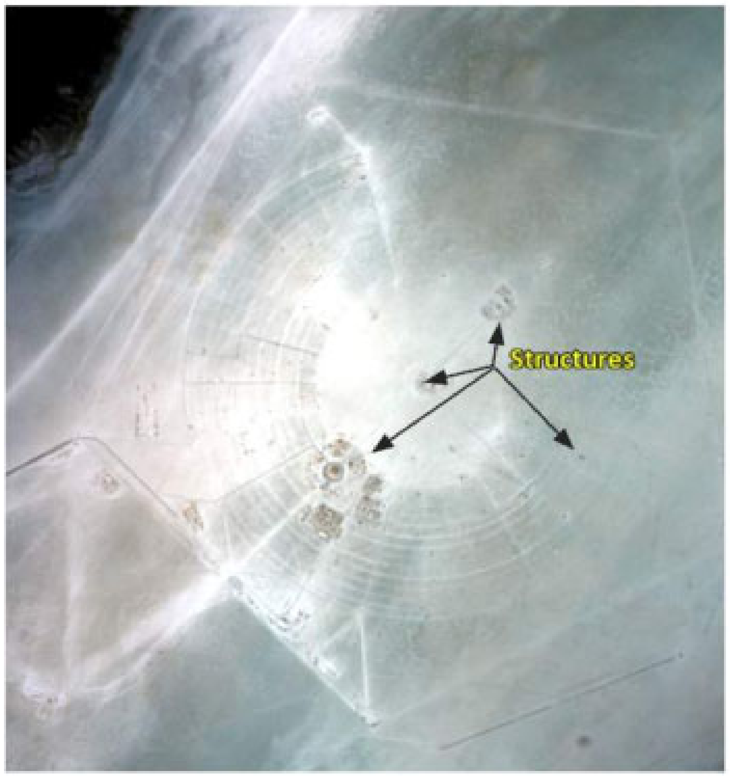
Red- Red (Sentinel-2)

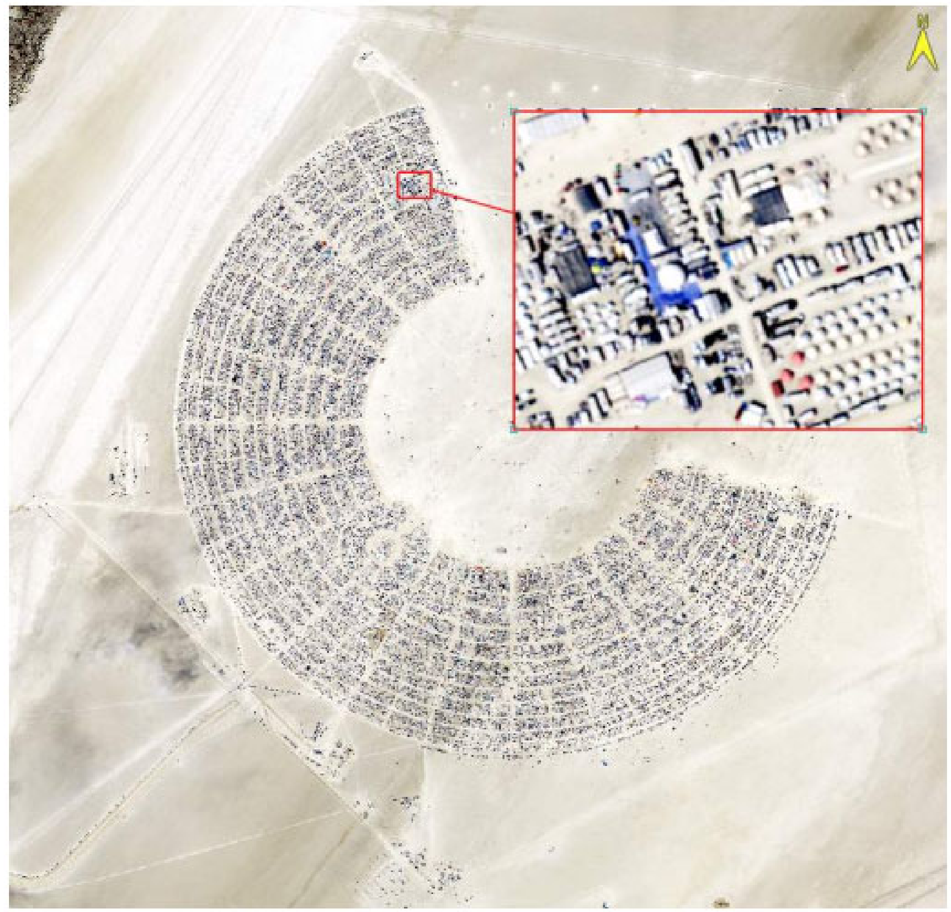
Green- Green (Sentinel-2)

Blue- VV (Sentinel-1)

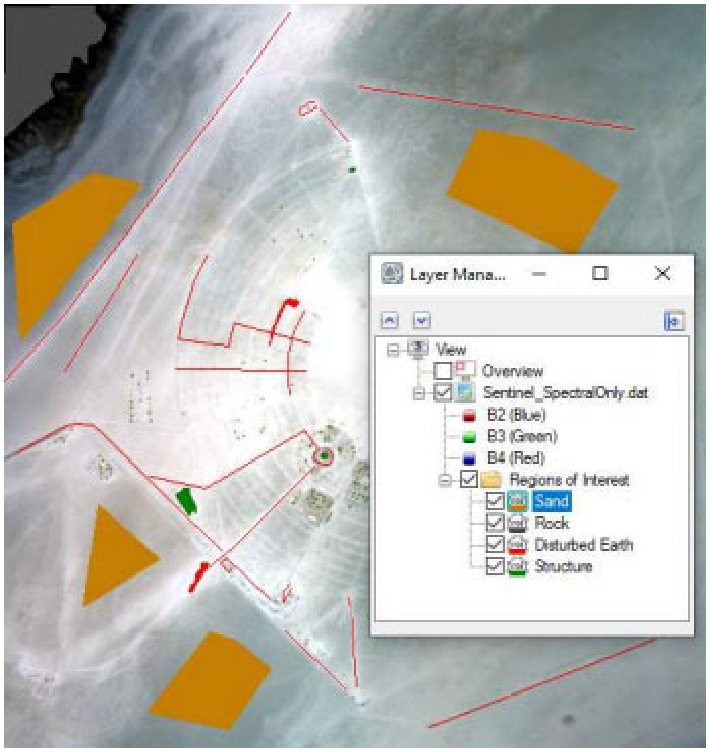
SPECTRAL SESSIONS

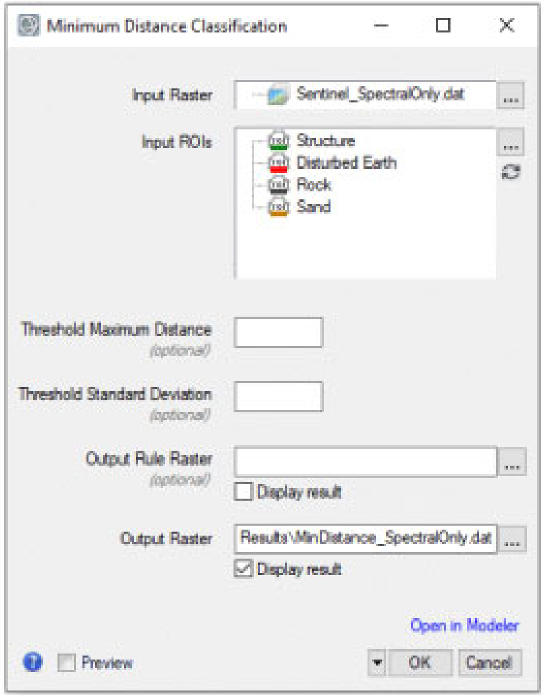
Burning Man classification with Sentinel-1 and 2





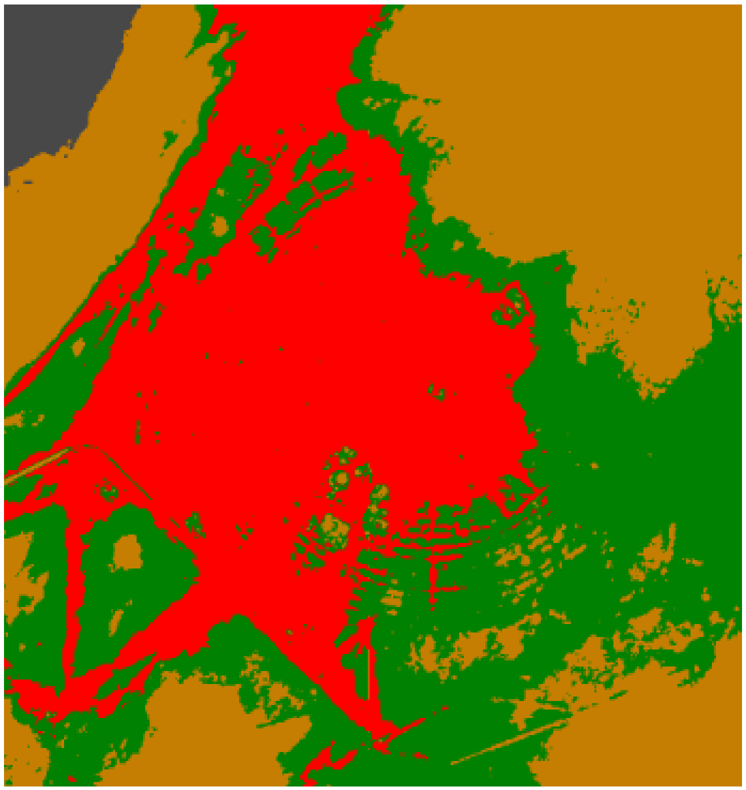
Training data and classification





SPECTRAL SESSIONS

Classification output and accuracy



Overall Accuracy = (21740/27648) 78.6314%
Kappa Coefficient = 0.5937

Ground Truth (Pixels)

Class	Structure	Disturbed Ear	Rock	Sand	Total
Unclassified	0	0	0	0	0
Structure	286	193	0	5158	5637
Disturbed Ear	99	1400	0	0	1499
Rock	0	0	4326	0	4326
Sand	88	370	0	15728	16186
Total	473	1963	4326	20886	27648

Ground Truth (Percent)

Class	Structure	Disturbed Ear	Rock	Sand	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
Structure	60.47	9.83	0.00	24.70	20.39
Disturbed Ear	20.93	71.32	0.00	0.00	5.42
Rock	0.00	0.00	100.00	0.00	15.65
Sand	18.60	18.85	0.00	75.30	58.54
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Structure	94.93	39.53	5351/5637	187/473
Disturbed Ear	6.60	28.68	99/1499	563/1963
Rock	0.00	0.00	0/4326	0/4326
Sand	2.83	24.70	458/16186	5158/20886

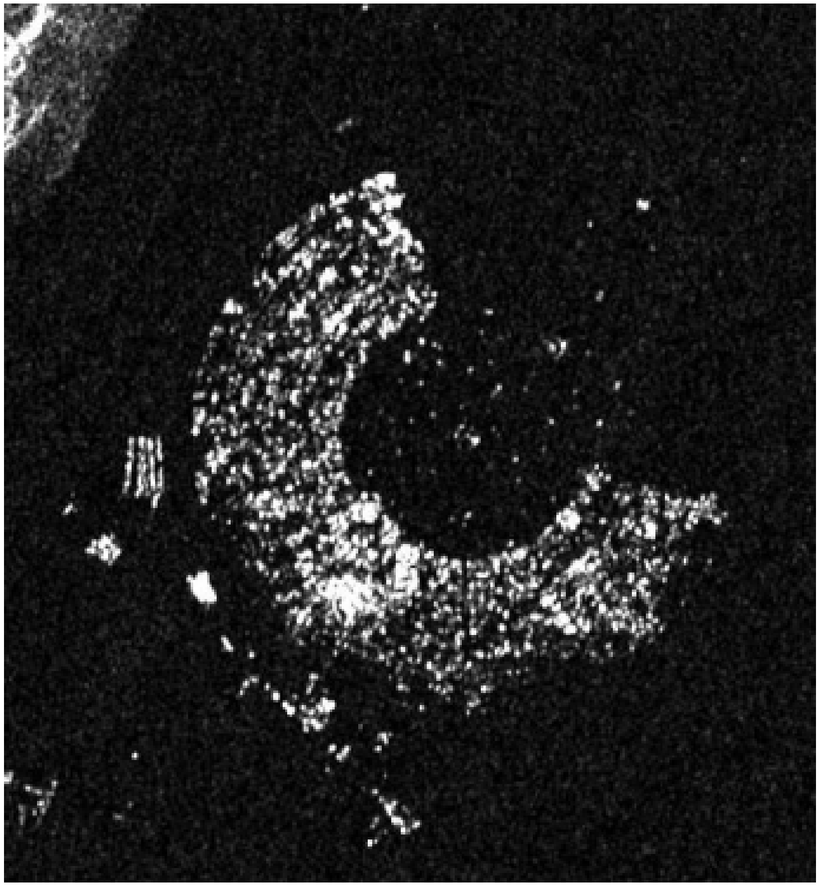
Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Structure	60.47	5.07	286/473	286/5637
Disturbed Ear	71.32	93.40	1400/1963	1400/1499
Rock	100.00	100.00	4326/4326	4326/4326
Sand	75.30	97.17	15728/20886	15728/16186

SPECTRAL
SESSIONS

Sentinel-1 data reflectance

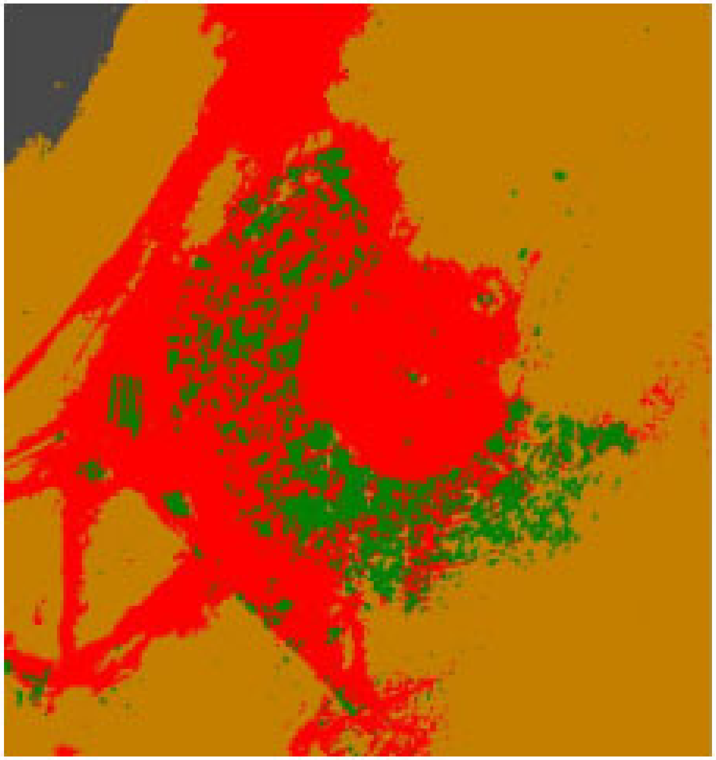
Left – VH

Right - VV



SPECTRAL SESSIONS

Combined classification and accuracy



Overall Accuracy = (26453/27648) 95.6778%
Kappa Coefficient = 0.8887

Ground Truth (Pixels)

Class	Structure	Disturbed Ear	Rock	Sand	Total
Unclassified	0	0	0	0	0
Structure	127	240	0	131	498
Disturbed Ear	146	1282	0	35	1463
Rock	13	2	4326	2	4343
Sand	187	439	0	20718	21344
Total	473	1963	4326	20886	27648

Ground Truth (Percent)

Class	Structure	Disturbed Ear	Rock	Sand	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
Structure	26.85	12.23	0.00	0.63	1.80
Disturbed Ear	30.87	65.31	0.00	0.17	5.29
Rock	2.75	0.10	100.00	0.01	15.71
Sand	39.53	22.36	0.00	99.20	77.20
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
Structure	74.50	73.15	371/498	346/473
Disturbed Ear	12.37	34.69	181/1463	681/1963
Rock	0.39	0.00	17/4343	0/4326
Sand	2.93	0.80	626/21344	168/20886

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
Structure	26.85	25.50	127/473	127/498
Disturbed Ear	65.31	87.63	1282/1963	1282/1463
Rock	100.00	99.61	4326/4326	4326/4343
Sand	99.20	97.07	20718/20886	20718/21344

SPECTRAL
SESSIONS

Sentinel-1 and Sentinel-2 over the Amazon

- A common reason to combine optical and SAR is to get information from areas when optical can not receive any, such as when an area is covered in clouds.
- This is commonly the case in the Amazon, which is monitored to track illegal deforestation.

Climate data for Porto Velho (1961–1990) [hide]

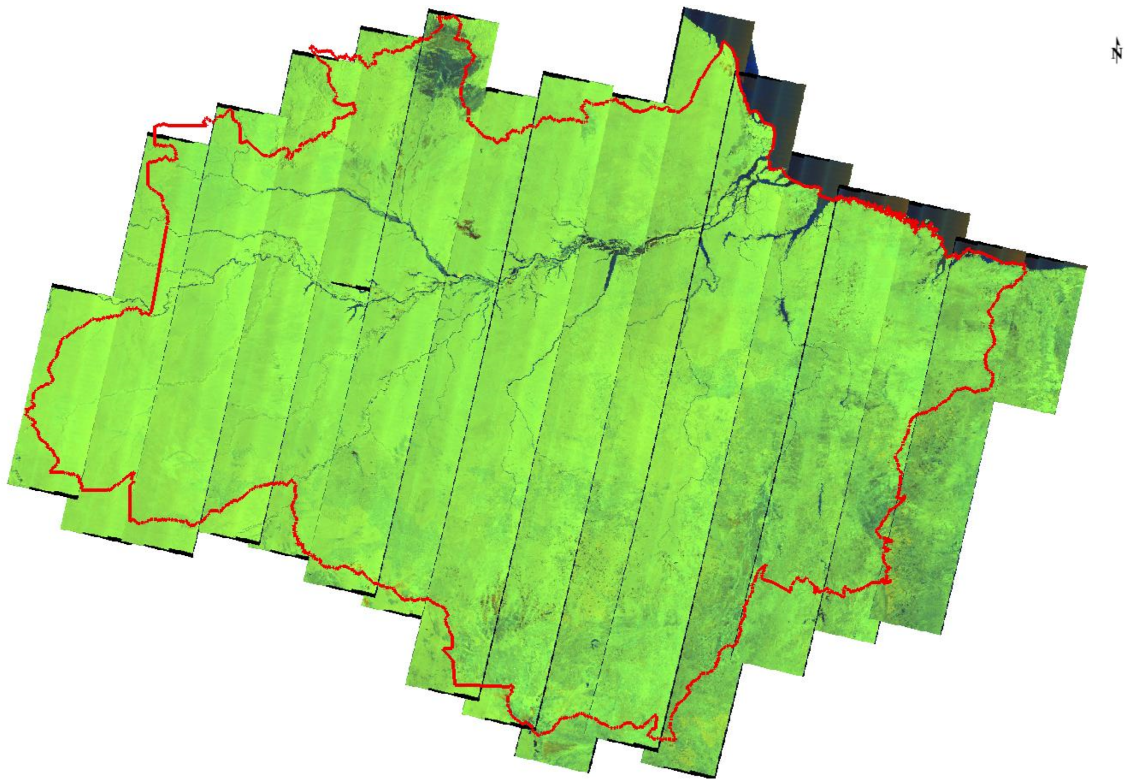
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	37.2 (99)	36.4 (97.5)	38.7 (101.7)	37.1 (98.8)	36.8 (98.2)	38.8 (101.8)	37.9 (100.2)	40.9 (105.6)	39.4 (102.9)	40.0 (104)	39.7 (103.5)	38.0 (100.4)	40.9 (105.6)
Average high °C (°F)	31.3 (88.3)	31.5 (88.7)	31.7 (89.1)	31.6 (88.9)	31.6 (88.9)	31.7 (89.1)	32.7 (90.9)	34.3 (93.7)	34.0 (93.2)	33.3 (91.9)	32.6 (90.7)	31.6 (88.9)	32.3 (90.1)
Daily mean °C (°F)	25.5 (77.9)	25.5 (77.9)	25.6 (78.1)	25.7 (78.3)	25.3 (77.5)	24.7 (76.5)	24.6 (76.3)	25.9 (78.6)	26.2 (79.2)	26.1 (79)	26.0 (78.8)	25.5 (77.9)	25.6 (78.1)
Average low °C (°F)	21.7 (71.1)	21.8 (71.2)	21.8 (71.2)	21.9 (71.4)	21.0 (69.8)	19.2 (66.6)	18.3 (64.9)	19.0 (66.2)	20.8 (69.4)	21.8 (71.2)	22.0 (71.6)	22.0 (71.6)	20.9 (69.6)
Record low °C (°F)	14.4 (57.9)	15.4 (59.7)	12.0 (53.6)	12.8 (55)	12.0 (53.6)	11.8 ([illegible])	7.4 ([illegible])	10.0 ([illegible])	12.1 (53.8)	17.7 (63.9)	18.1 (64.6)	11.0 (51.8)	7.4 (45.3)
Average rainfall mm (inches)	320.9 (12.634)	316.0 (12.441)	273.9 (10.783)	251.0 (9.882)	126.6 (4.984)	49.2 (1.937)	24.2 (0.953)	36.4 (1.433)	119.9 (4.72)	192.7 (7.587)	225.2 (8.866)	319.1 (12.563)	2,255.1 (88.783)
Average rainy days (≥ 1.0 mm)	19	19	20	17	11	4	3	4	11	13	16	19	156
Average relative humidity (%)	89	88	89.1	89	86	[illegible]	[illegible]	[illegible]	84	86	87	88.7	86.1
Mean monthly sunshine hours	107.1	98.3	124.0	140.1	183.7	226.7	259.7	234.0	186.8	166.7	137.1	124.2	1,988.4

Source: Brazilian National Institute of Meteorology (INMET).[2][6][7][3][8][9][10][5][4]

SPECTRAL SESSIONS

sarmap your information gateway

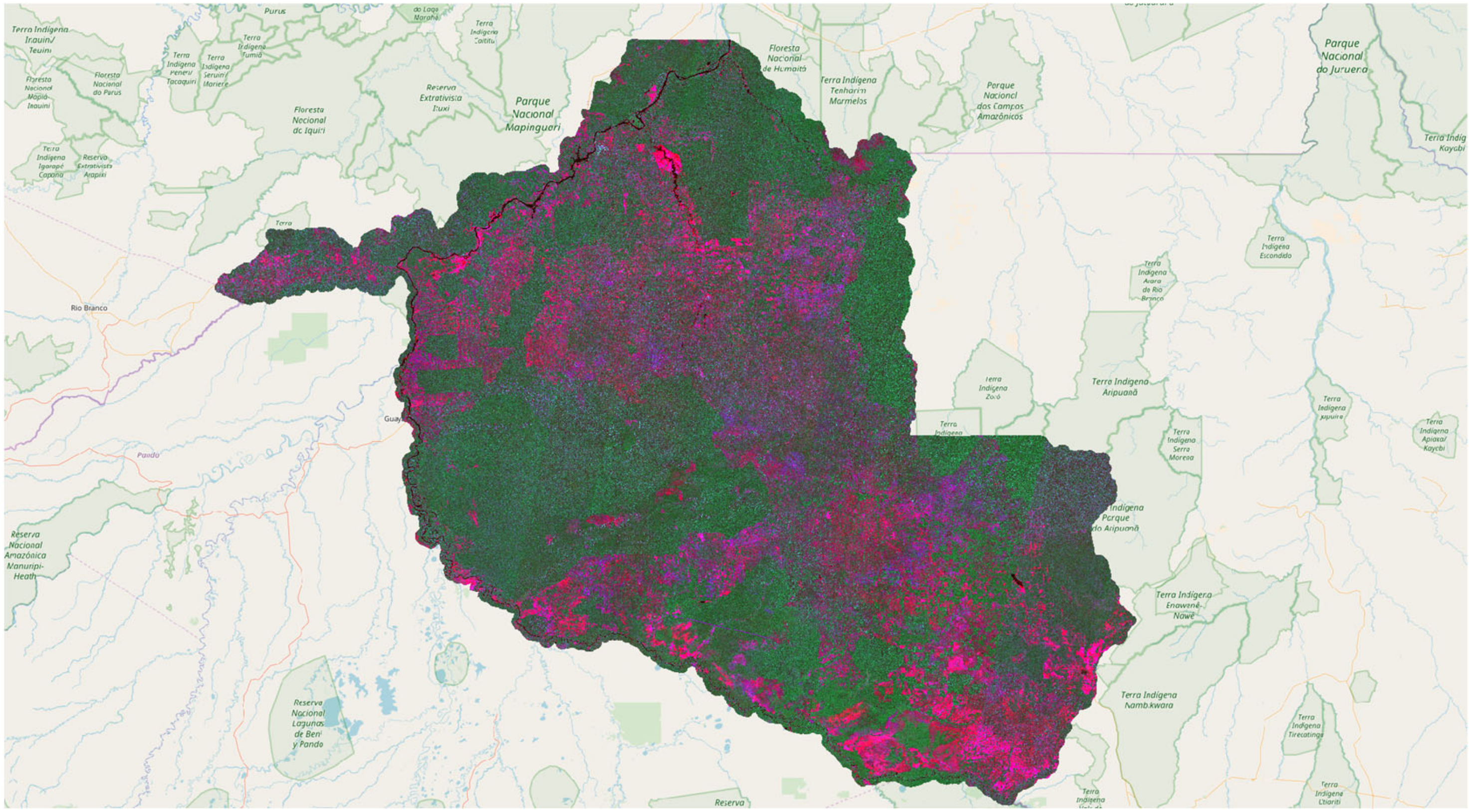
1 cycle of Sentinel-1 over the Amazon, 9/2016 to 8/2017



SPECTRAL SESSIONS

sarmap
your information gateway

Sentinel-1 change over the Amazon



- Coefficient of variation
- Mean
- Gradient

SPECTRAL SESSIONS

sarmap your information gateway

Sentinel-1 and Sentinel-2 imagery

Sentinel-2 8/2016

Sentinel-2 8/2017

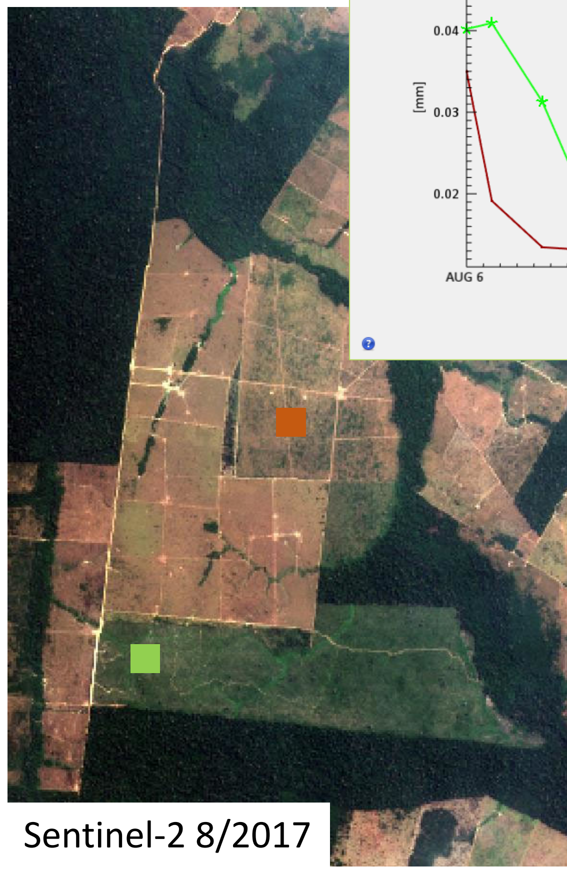
Sentinel-1 8/16 – 4/17

SPECTRAL SESSIONS

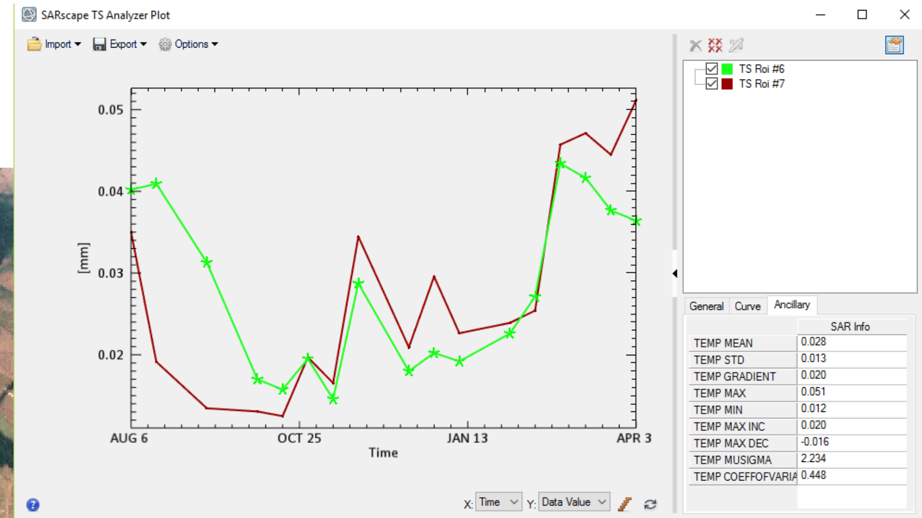
sarmap
your information gateway

Sentinel-1 and Sentinel-2

Sentinel-2 8/2016



Sentinel-2 8/2017

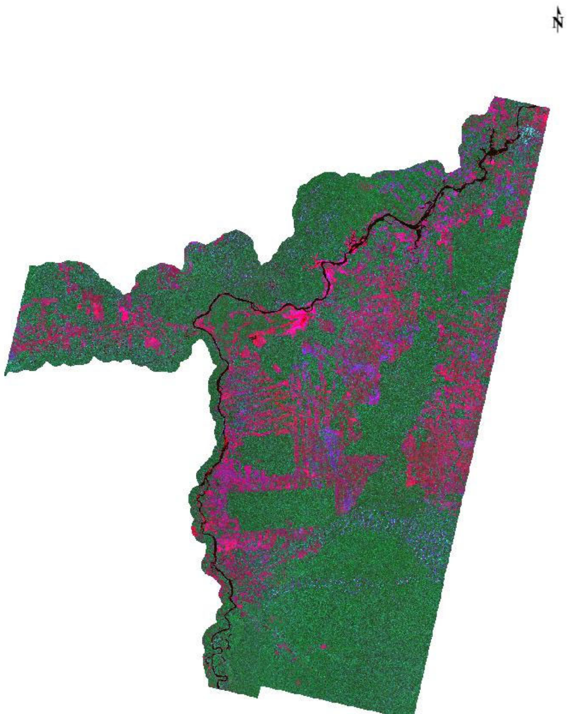


Sentinel-1 8/16 – 4/17

SPECTRAL SESSIONS

sarmap your information gateway

Sentinel-1 and Sentinel-2 imagery comparison



Sentinel-1 8/16 – 4/17

Sentinel-2 8/2016

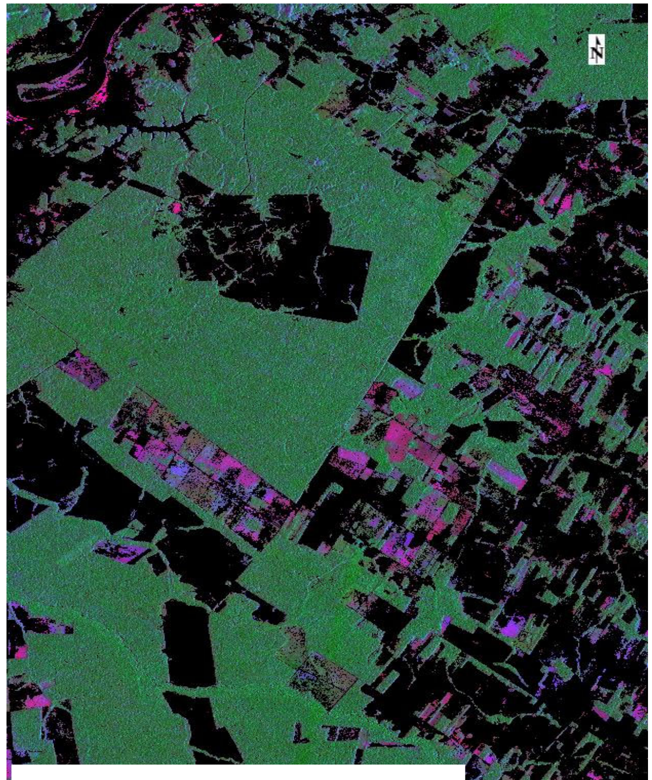
Sentinel-2 NDVI 8/2016

SPECTRAL
SESSIONS

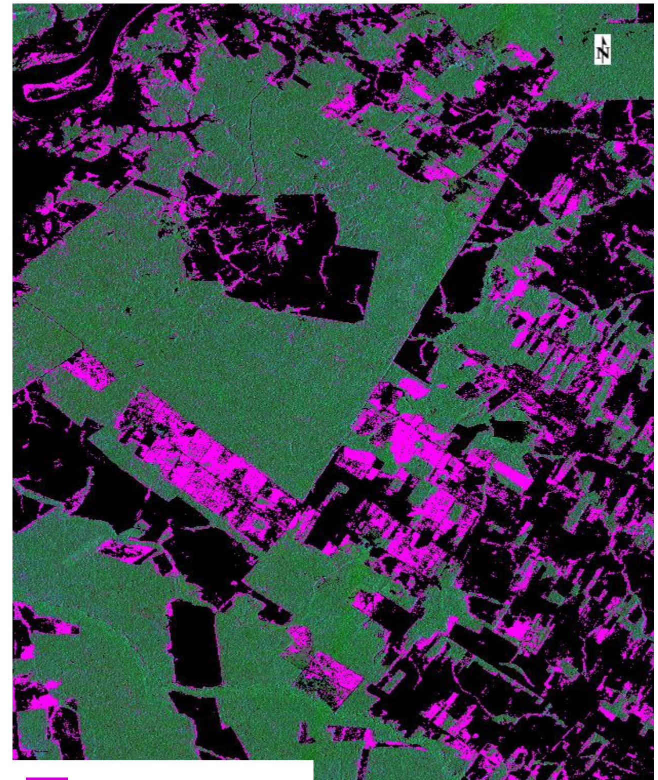
sarmap
your information gateway

Separating forest from agriculture

Sentinel-1 8/16 – 4/17



Non-forest from NDVI

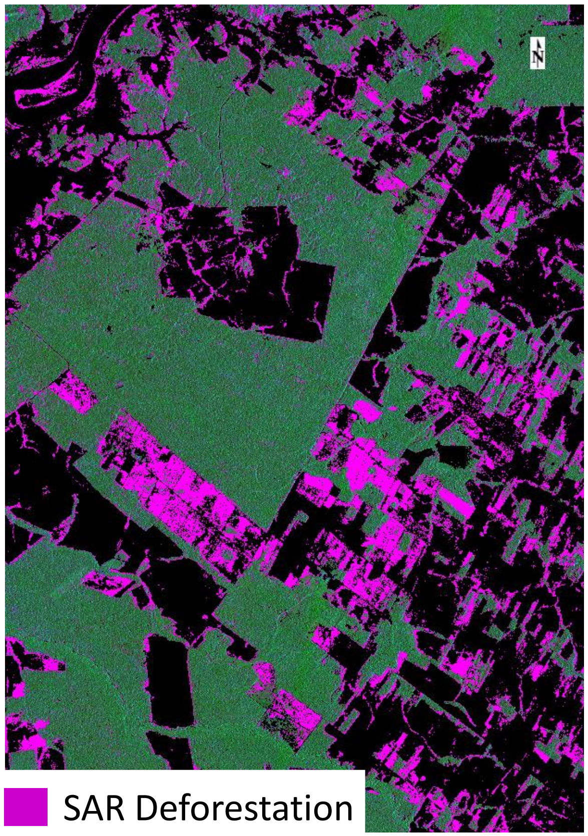


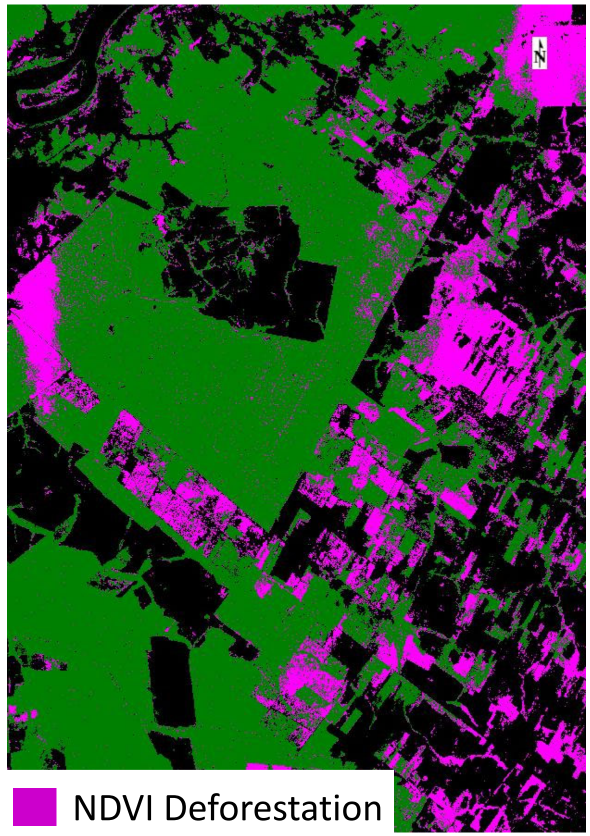
Deforestation

SPECTRAL
SESSIONS

sarmap
your information gateway

Deforestation

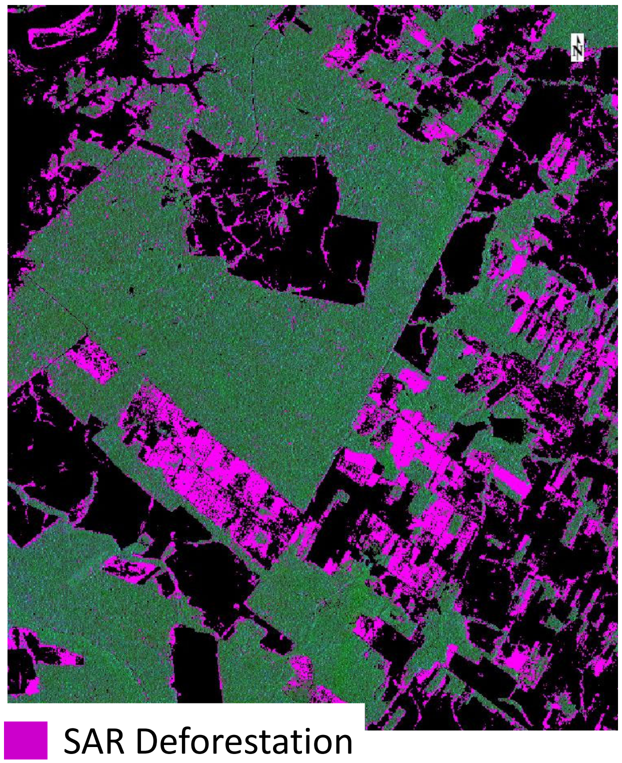




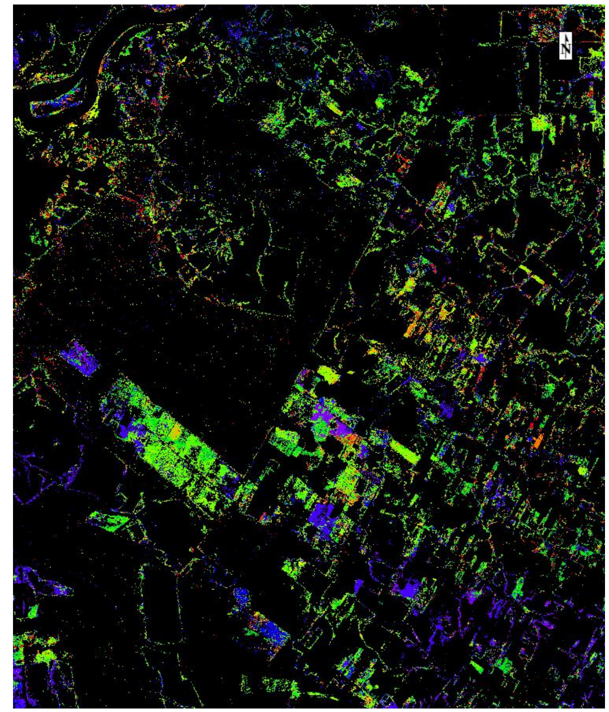
SPECTRAL SESSIONS

sarmap
your information gateway

Sentinel-1 dates of change



0: Unclassified
1: 18-AUG-2016 — '06-AUG-2016
2: 11-SEP-2016 — 18-AUG-2016
3: 05-OCT-2016 — 11-SEP-2016
4: 17-OCT-2016 — 05-OCT-2016
5: 29-OCT-2016 — 17-OCT-2016
6: 10-NOV-2016 — 29-OCT-2016
7: 22-NOV-2016 — 10-NOV-2016
8: 16-DEC-2016 — 22-NOV-2016
9: 28-DEC-2016 — 16-DEC-2016
10: 09-JAN-2017 — '28-DEC-2016
11: 02-FEB-2017 — '09-JAN-2017
12: 14-FEB-2017 — '02-FEB-2017
13: 26-FEB-2017 — '14-FEB-2017
14: 10-MAR-2017 — '26-FEB-2017
15: 22-MAR-2017 — '10-MAR-2017
16: 03-APR-2017 — '22-MAR-2017



SPECTRAL SESSIONS

sarmap your information gateway

End points

- We went over when and how to use data fusion with many examples of different kinds of use cases.
- Always make sure your data is preprocessed and overlaps correctly, be it spectral, temporal, and especially spatial.
- Make sure the data can viably work together.

- **Make sure data fusion is necessary for your process**

SPECTRAL
SESSIONS

Questions?

Megan Gallagher

Solutions Engineer

Megan.Gallagher@l3harris.com

L3Harris Geospatial

www.l3harrisgeospatial.com
geospatialinfo@l3harris.com
303-786-9900

SPECTRAL SESSIONS