

The potential of commercial high resolution satellite data for detailed burned area mapping

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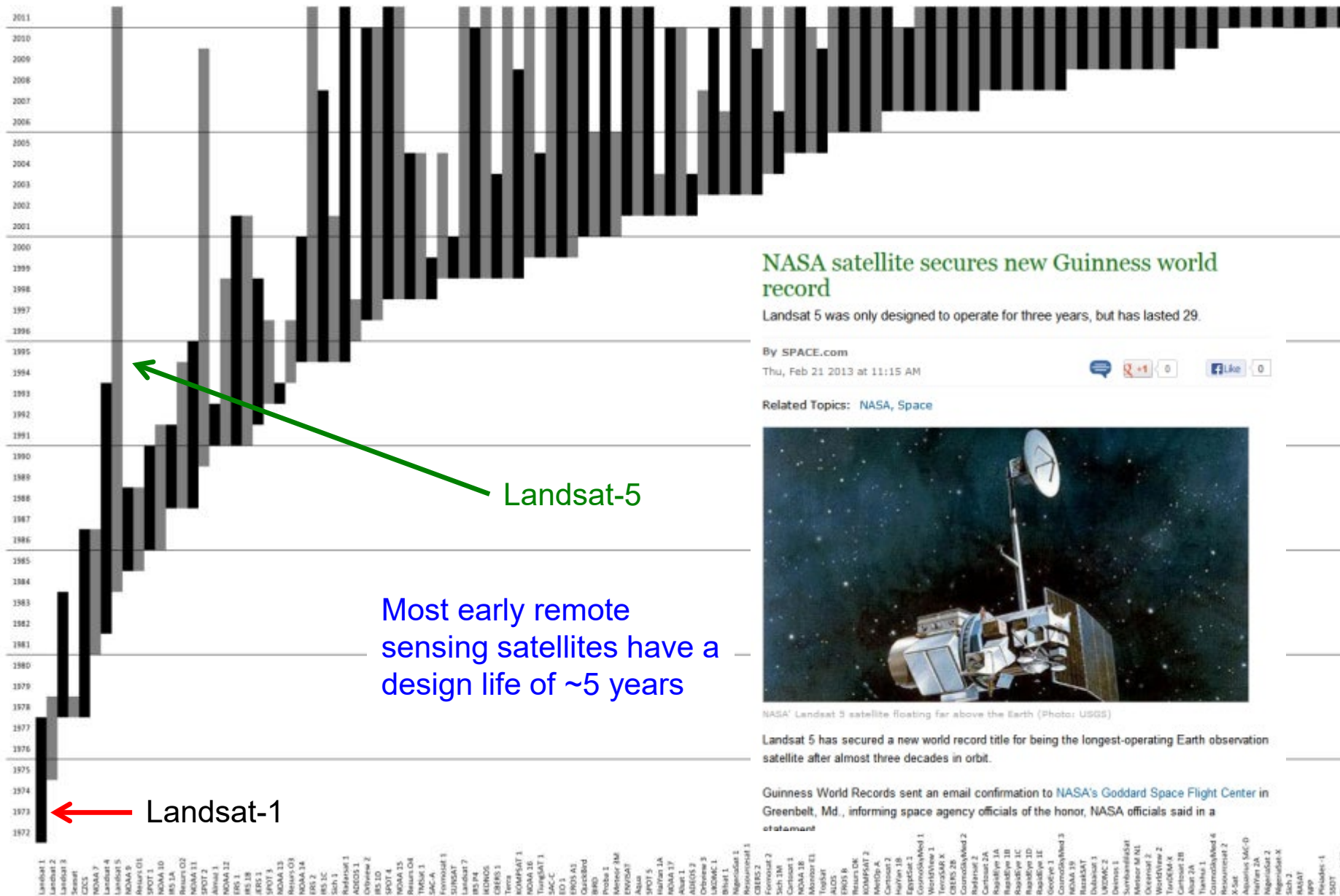
5th Global Wildfire Information System (GWIS) and GOFC Fire Implementation Team meeting
June 21-23 2022, Stresa VB, Italy



Department of Geography,
Environment, and Spatial Sciences
MICHIGAN STATE UNIVERSITY



Lots of Remote Sensing Systems launched since 1972



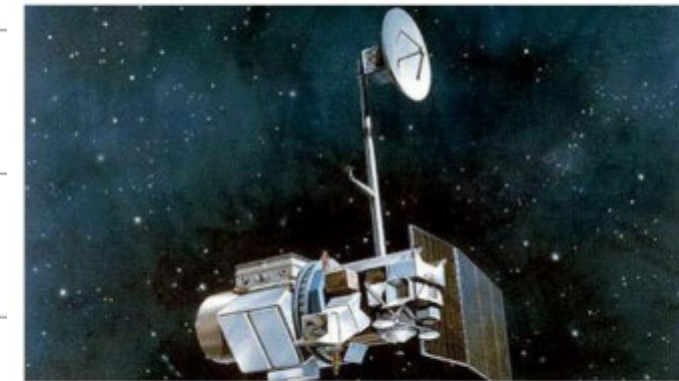
NASA satellite secures new Guinness world record

Landsat 5 was only designed to operate for three years, but has lasted 29.

By SPACE.com

Thu, Feb 21 2013 at 11:15 AM

Related Topics: NASA, Space



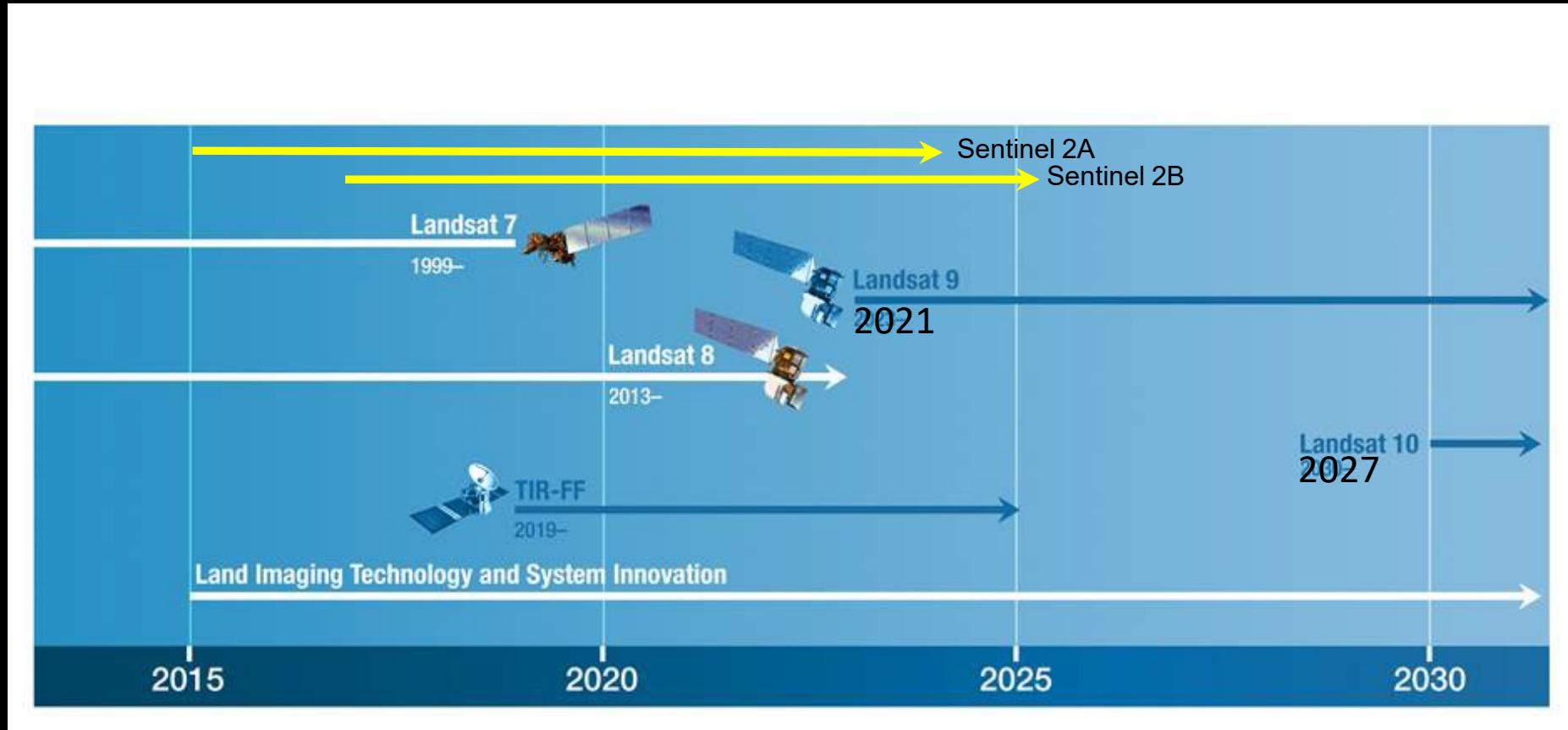
NASA's Landsat 5 satellite floating far above the Earth (Photo: USGS)

Landsat 5 has secured a new world record title for being the longest-operating Earth observation satellite after almost three decades in orbit.

Guinness World Records sent an email confirmation to NASA's Goddard Space Flight Center in Greenbelt, Md., informing space agency officials of the honor, NASA officials said in a statement

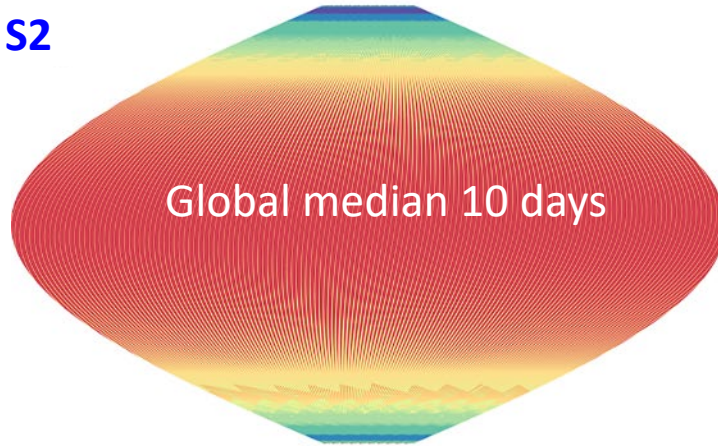
New Global moderate resolution era

Landsat 8, 9, Next

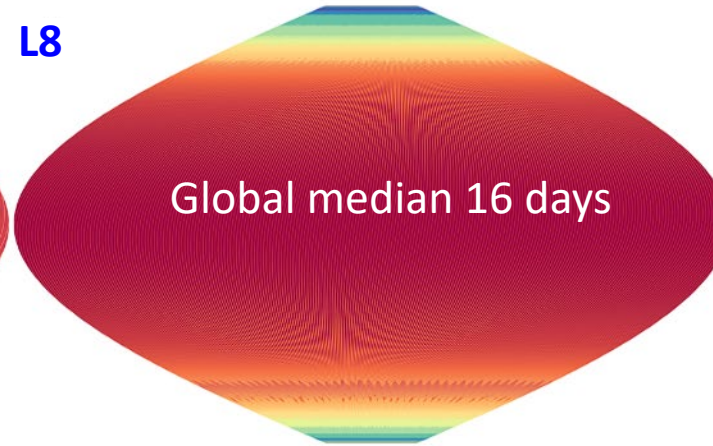


ESA Sentinel 2A & 2B

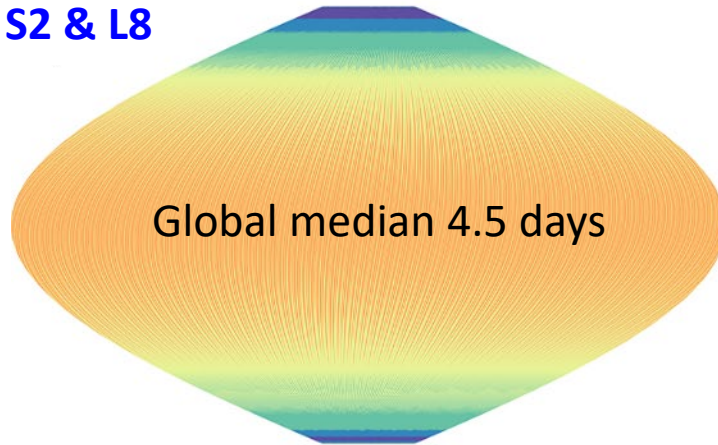
S2



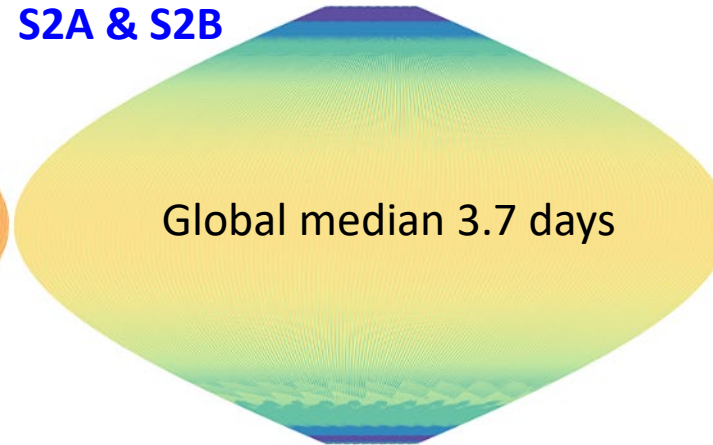
L8



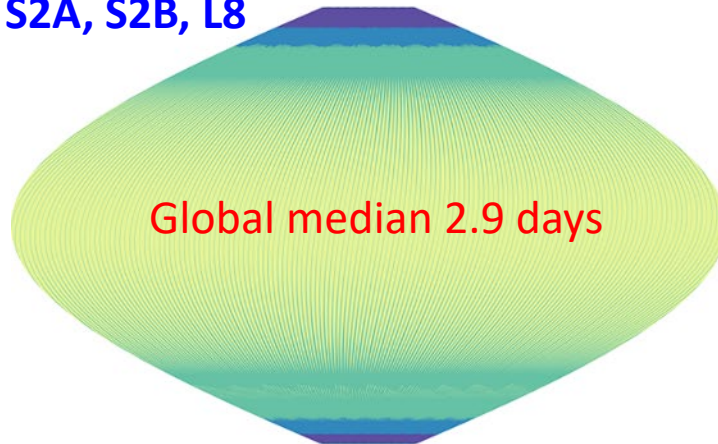
S2 & L8



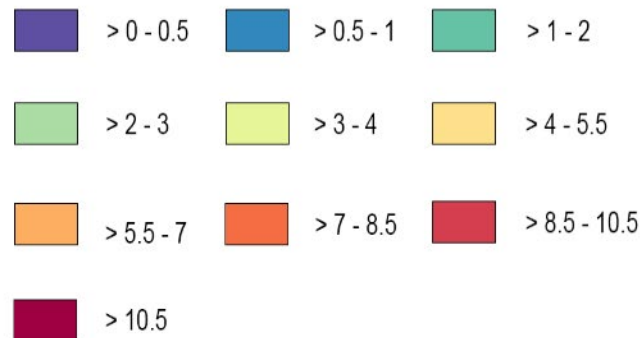
S2A & S2B



S2A, S2B, L8



Average satellite revisit interval (days)



Li and Roy, 2017
A global analysis of
Sentinel-2A,
Sentinel-2B
and
Landsat-8
data revisit
intervals
and implications
for terrestrial
monitoring,
Remote Sensing,
9,902.

Landsat 9 successful launch

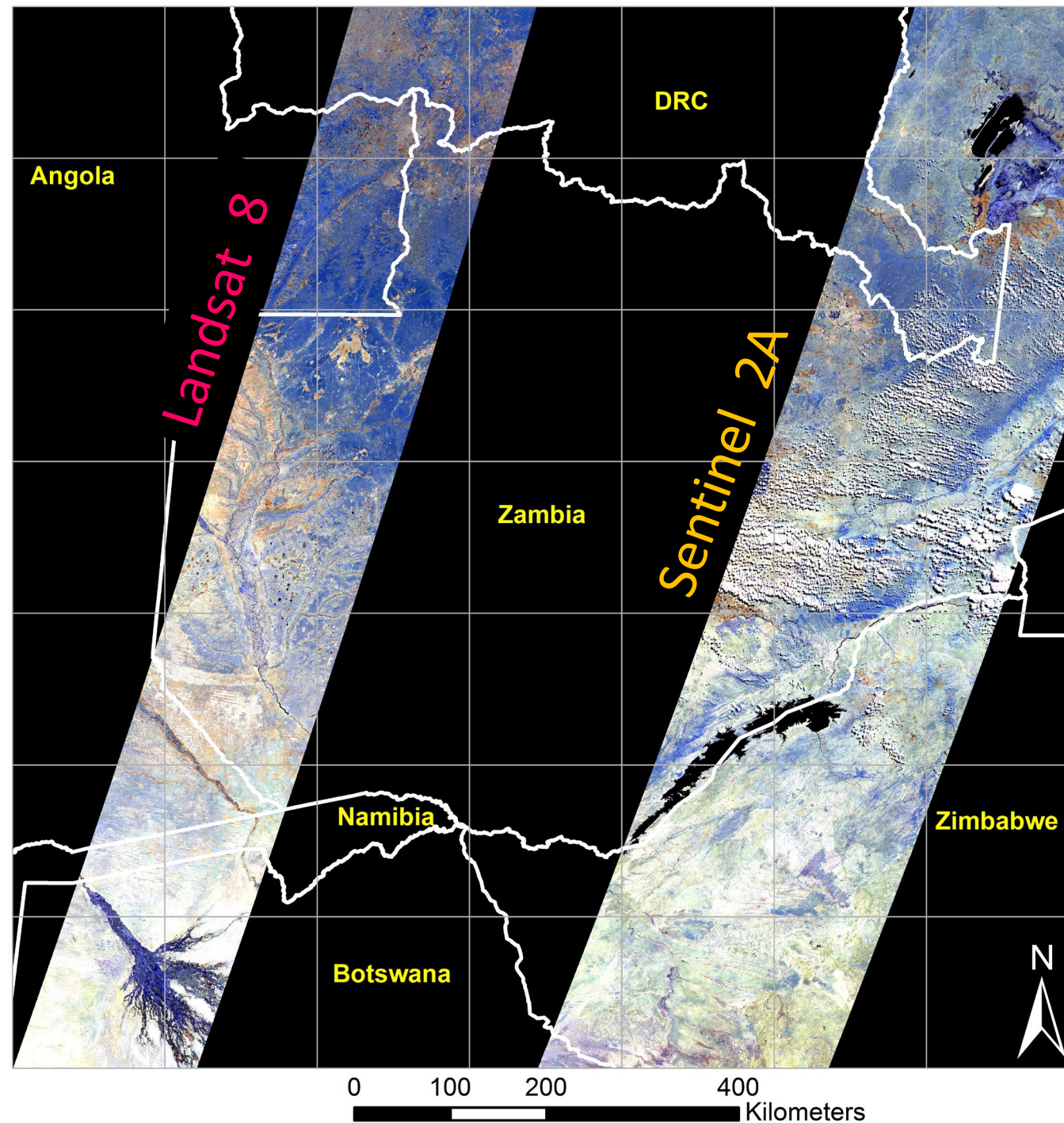
11:12 am September 27 2021



Vandenberg Space Force Base, California

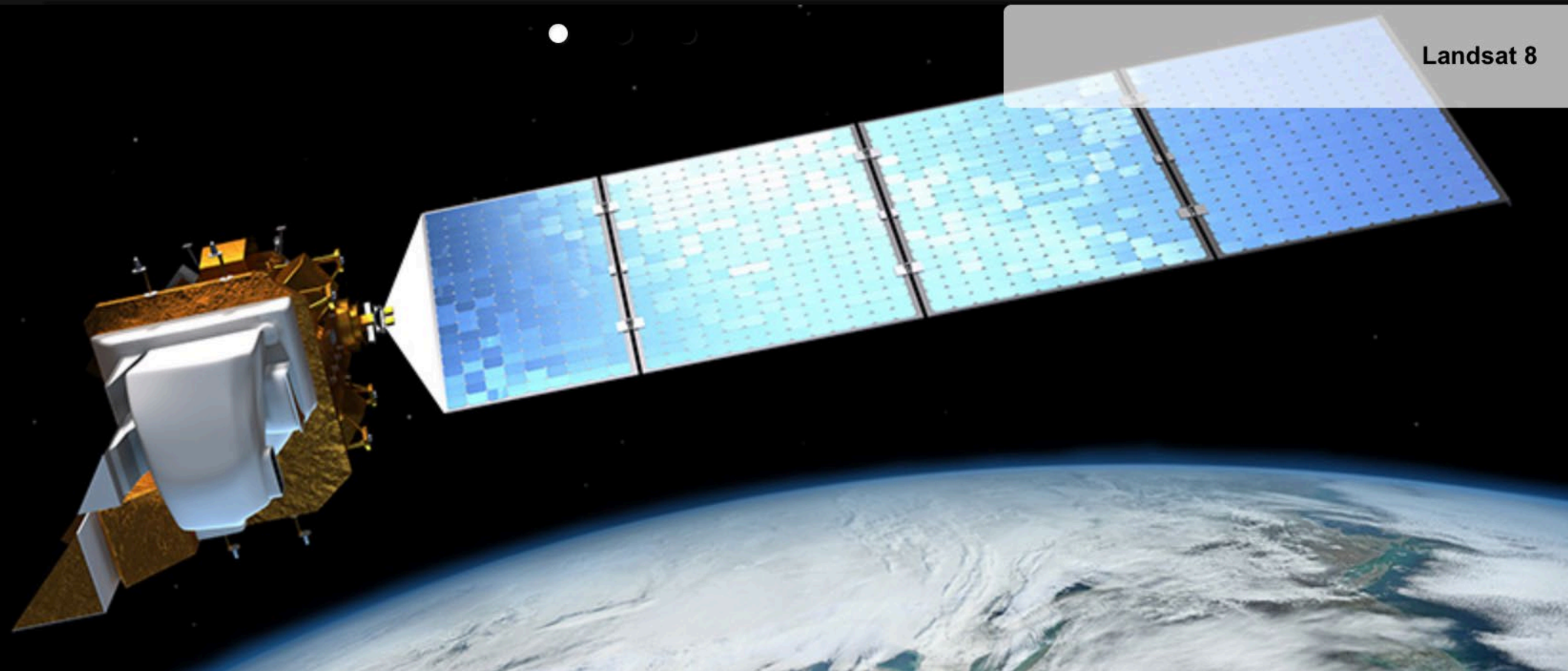
1112 x 1112 km

MODIS tile h20v10





Harmonized Landsat Sentinel-2

[Home](#)[Algorithms](#)[Products Description](#)[Test Sites](#)[Data](#)[QA](#)[Documents](#)[News](#)

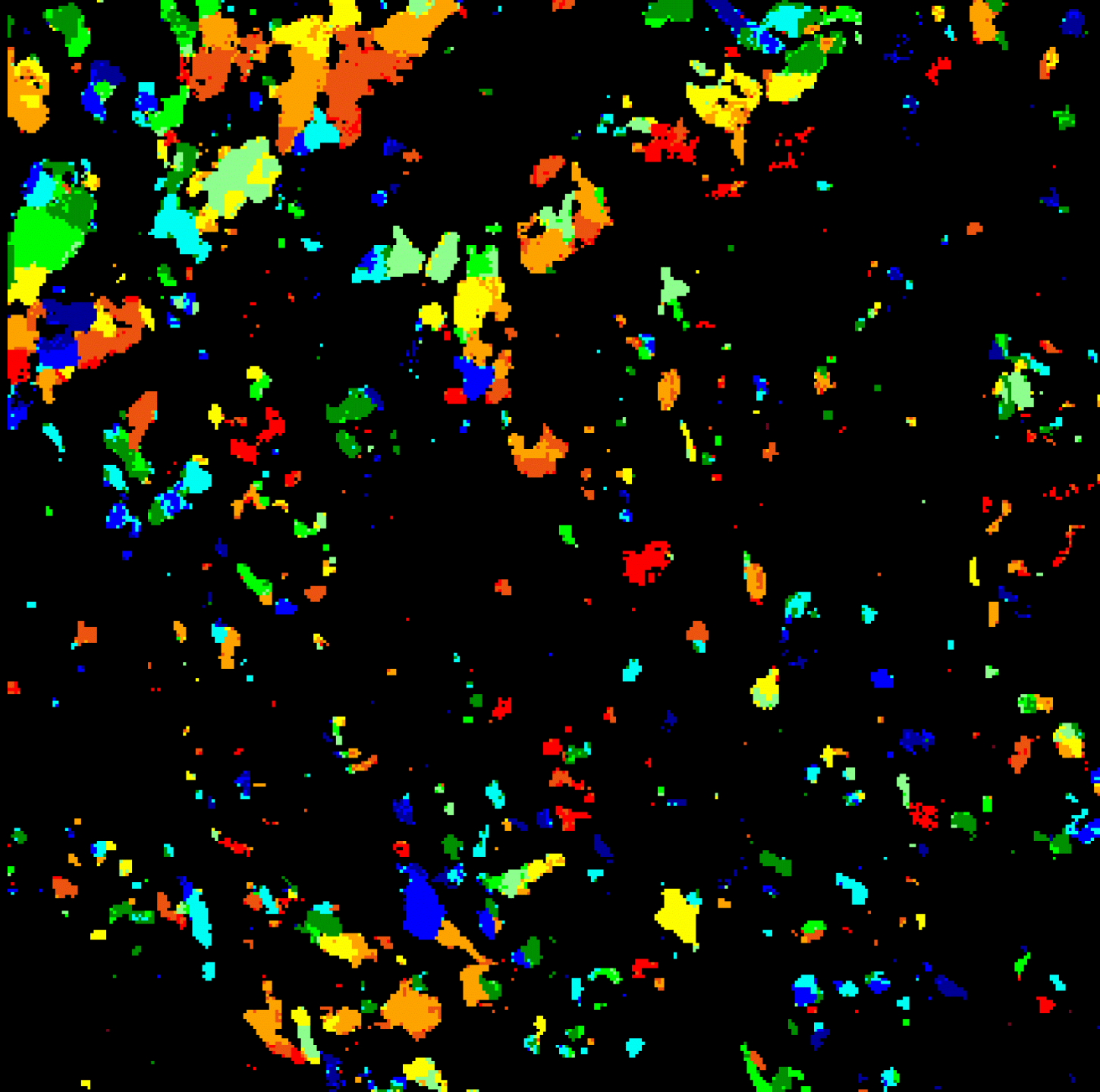
Landsat 8

Day of burning
MODIS
500m MCD64
July 2016

0-2
3-5
6-8
9-11
12-14
15-17
18-20
21-23
24-27
28-31

Angola,
Lunda Sul
Province

159 x 159 km

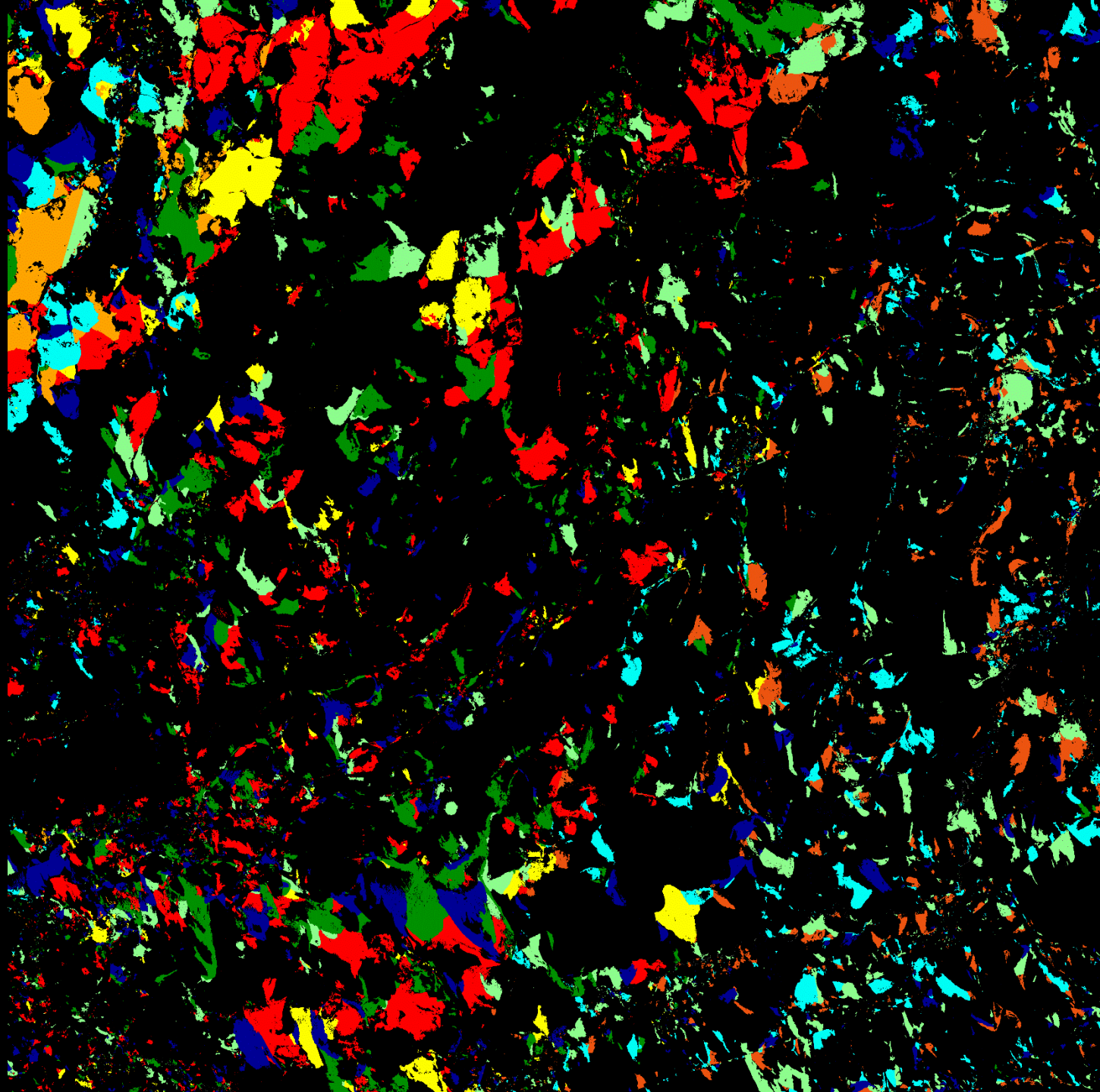


Day of burning
30m Sentinel-2
Landsat-8
July 2016

0-2
3-5
6-8
9-11
12-14
15-17
18-20
21-23
24-27
28-31

Angola,
Lunda Sul
Province

159 x 159 km

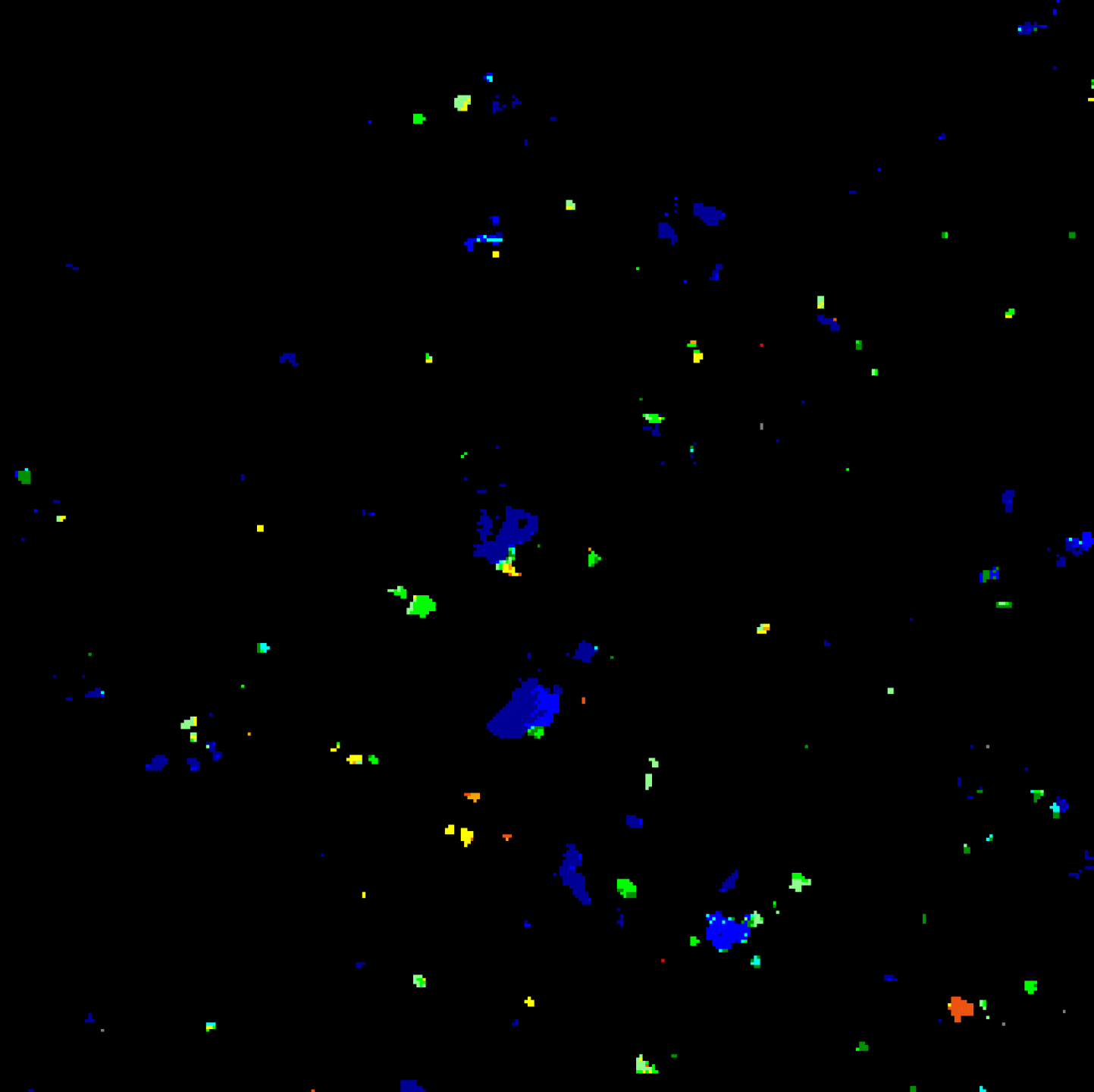


Day of burning
MODIS
500m MCD64 C6
Sept. 2016

0-2
3-5
6-8
9-11
12-14
15-17
18-20
21-23
24-27
28-31

Angola,
Lunda Sul
Province

159 x 159 km

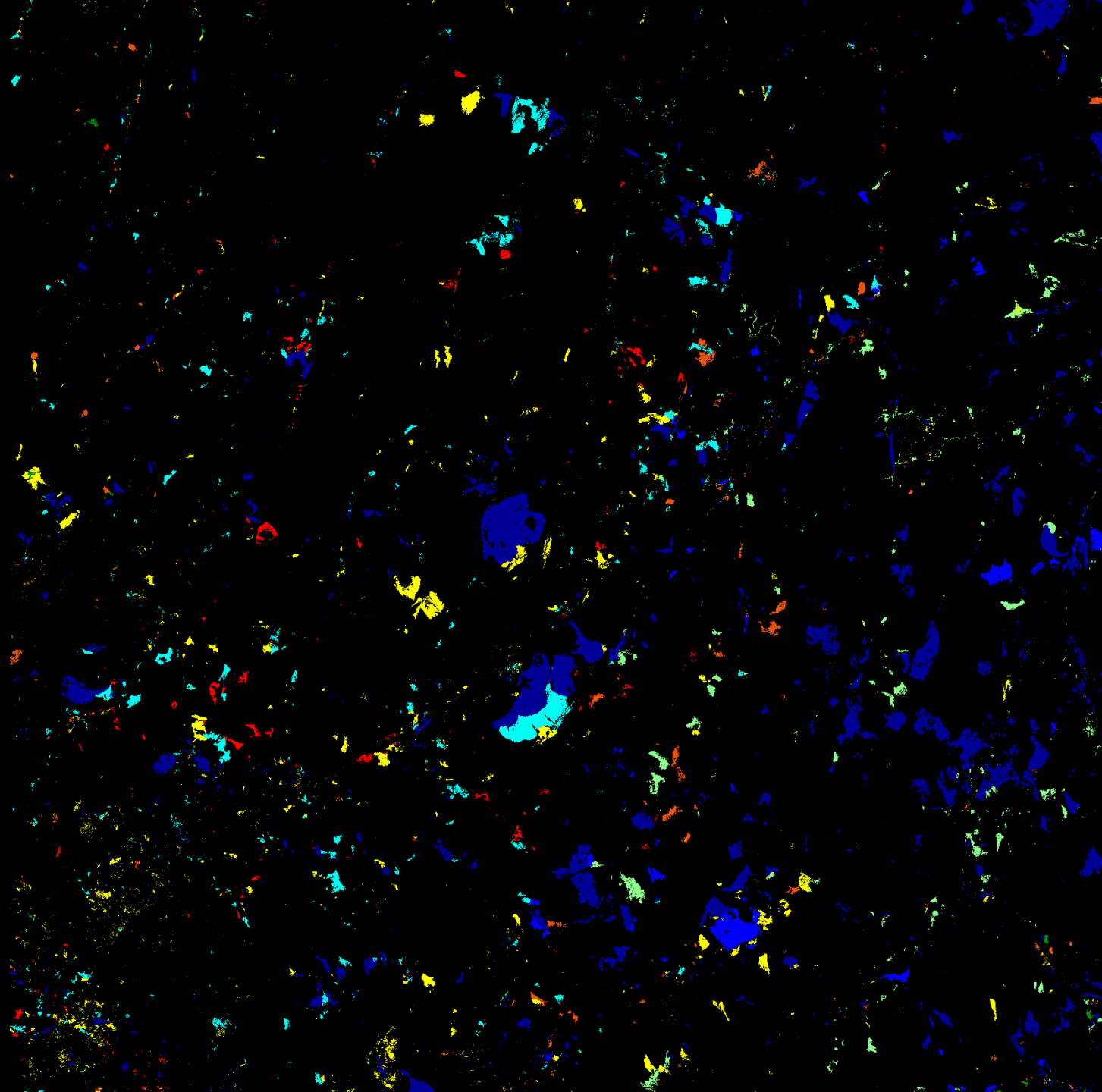


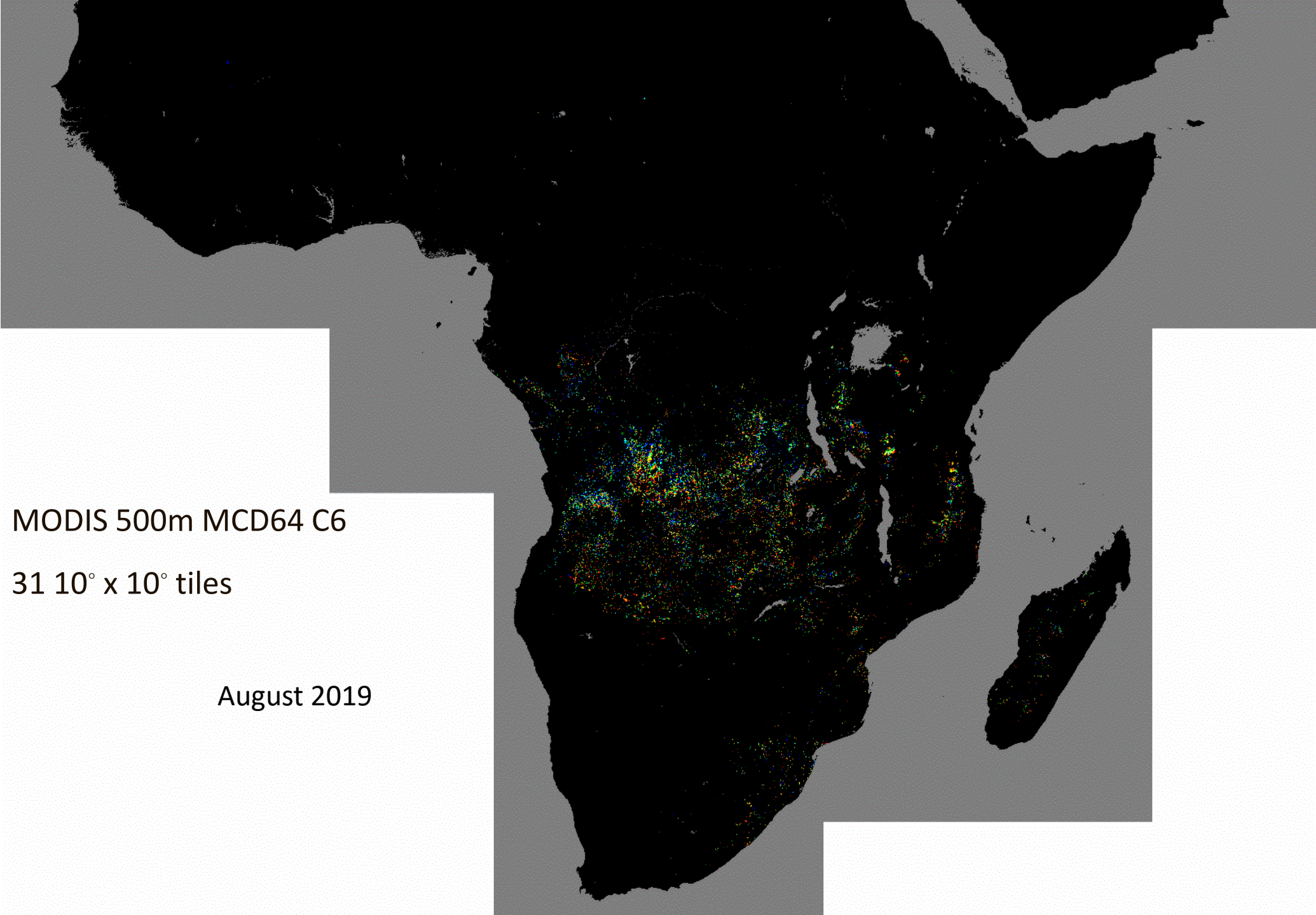
Day of burning
30m Sentinel-2
Landsat-8
Sept. 2016

0-2
3-5
6-8
9-11
12-14
15-17
18-20
21-23
24-27
28-31

Angola,
Lunda Sul
Province

159 x 159 km





MODIS 500m MCD64 C6

31 10° x 10° tiles

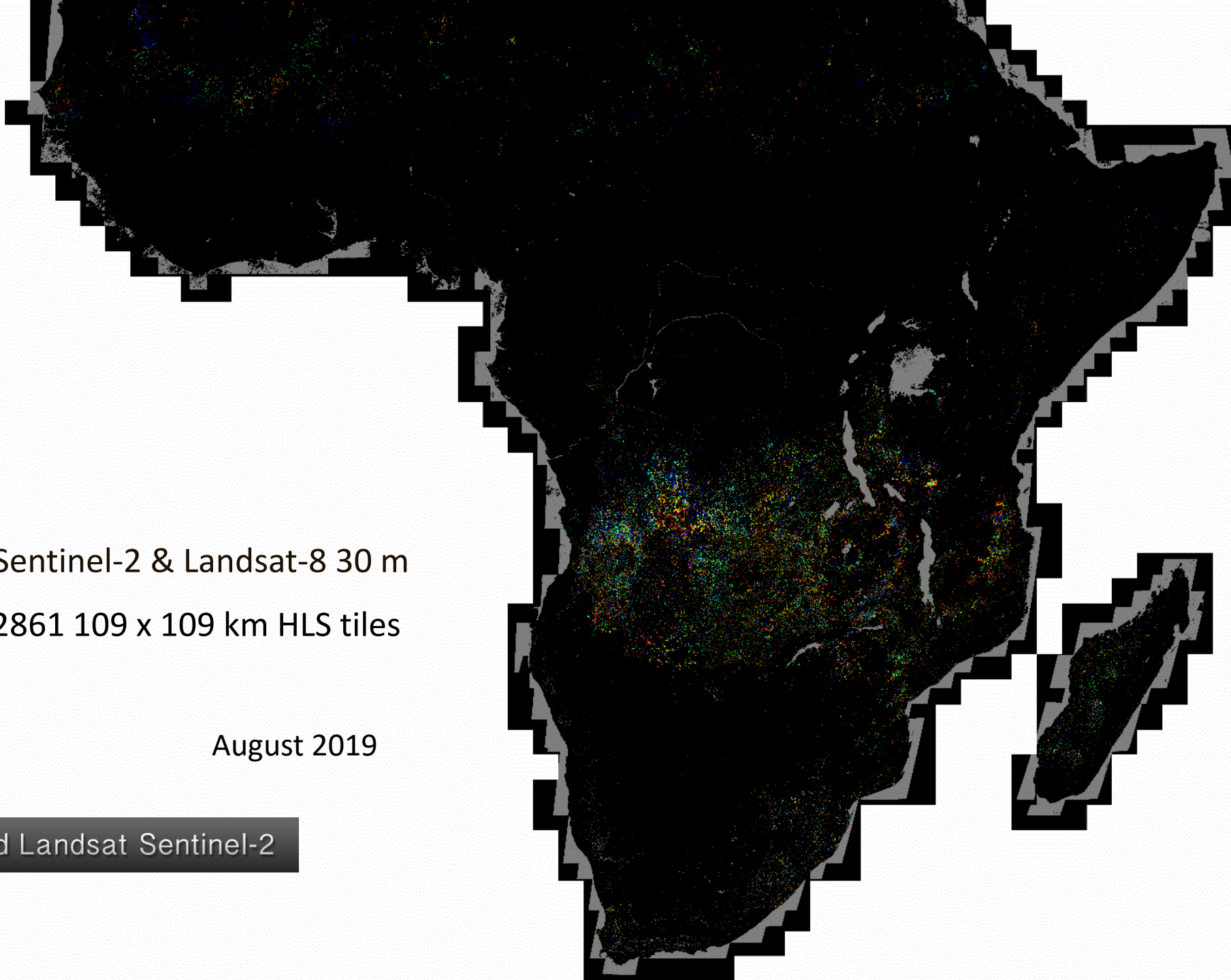
August 2019

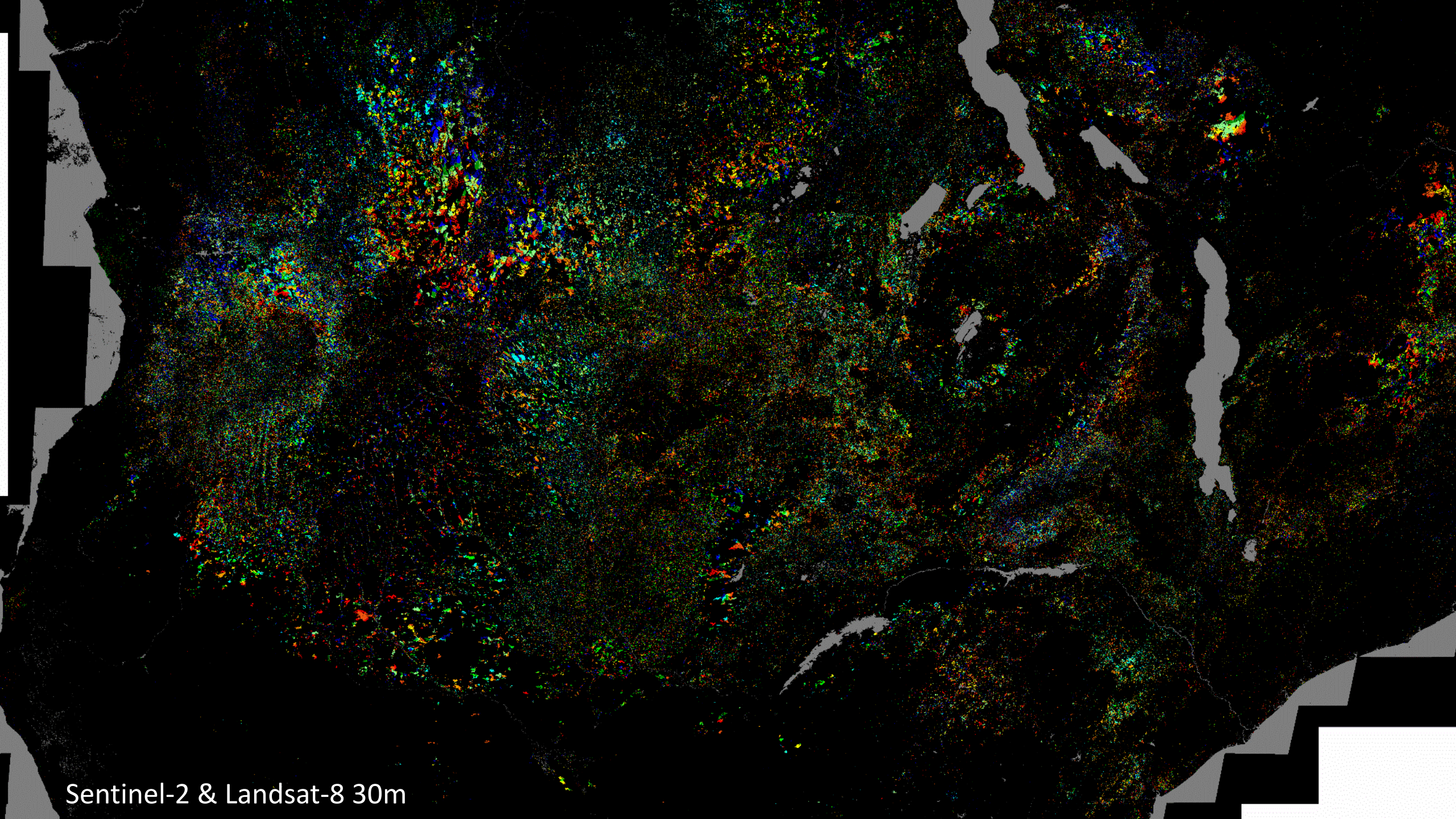
Sentinel-2 & Landsat-8 30 m
2861 109 x 109 km HLS tiles

August 2019



Harmonized Landsat Sentinel-2

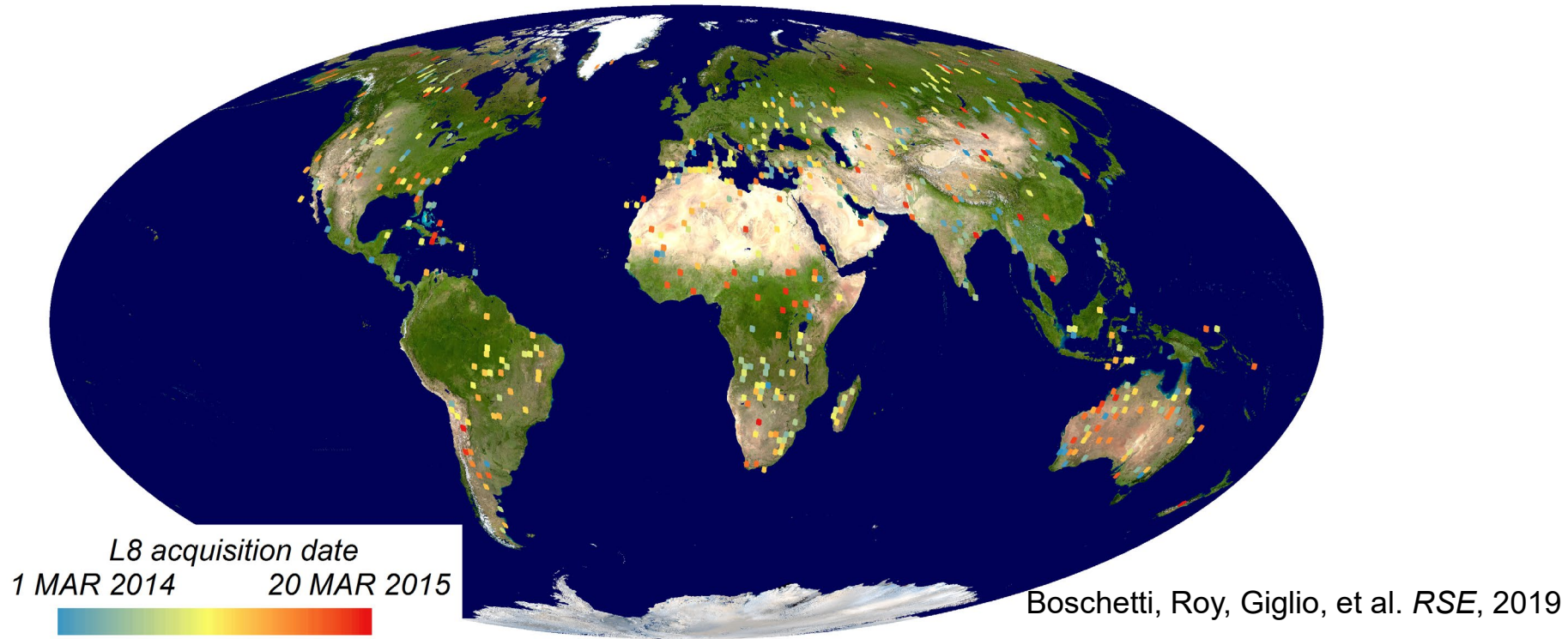




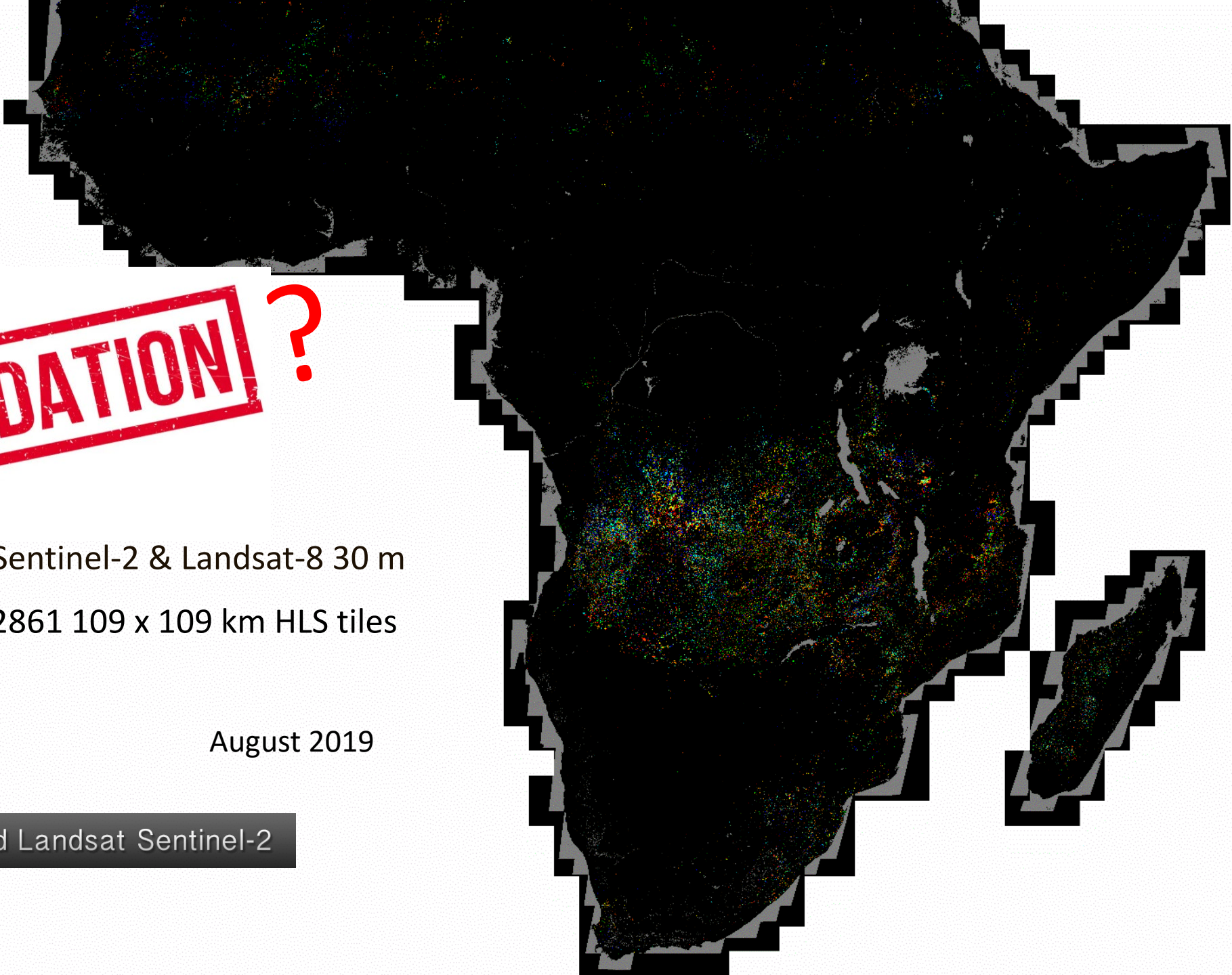
Sentinel-2 & Landsat-8 30m

NASA MODIS 500m Burned Area Product

Stage 3 Validation by comparison with higher spatial resolution
30m Landsat derived independent reference data



Locations of 558 two date Landsat image pairs **selected by stratified random sampling in space and time**; pairs were visually interpreted into burned, unburned, and unmapped classes



VALIDATION?

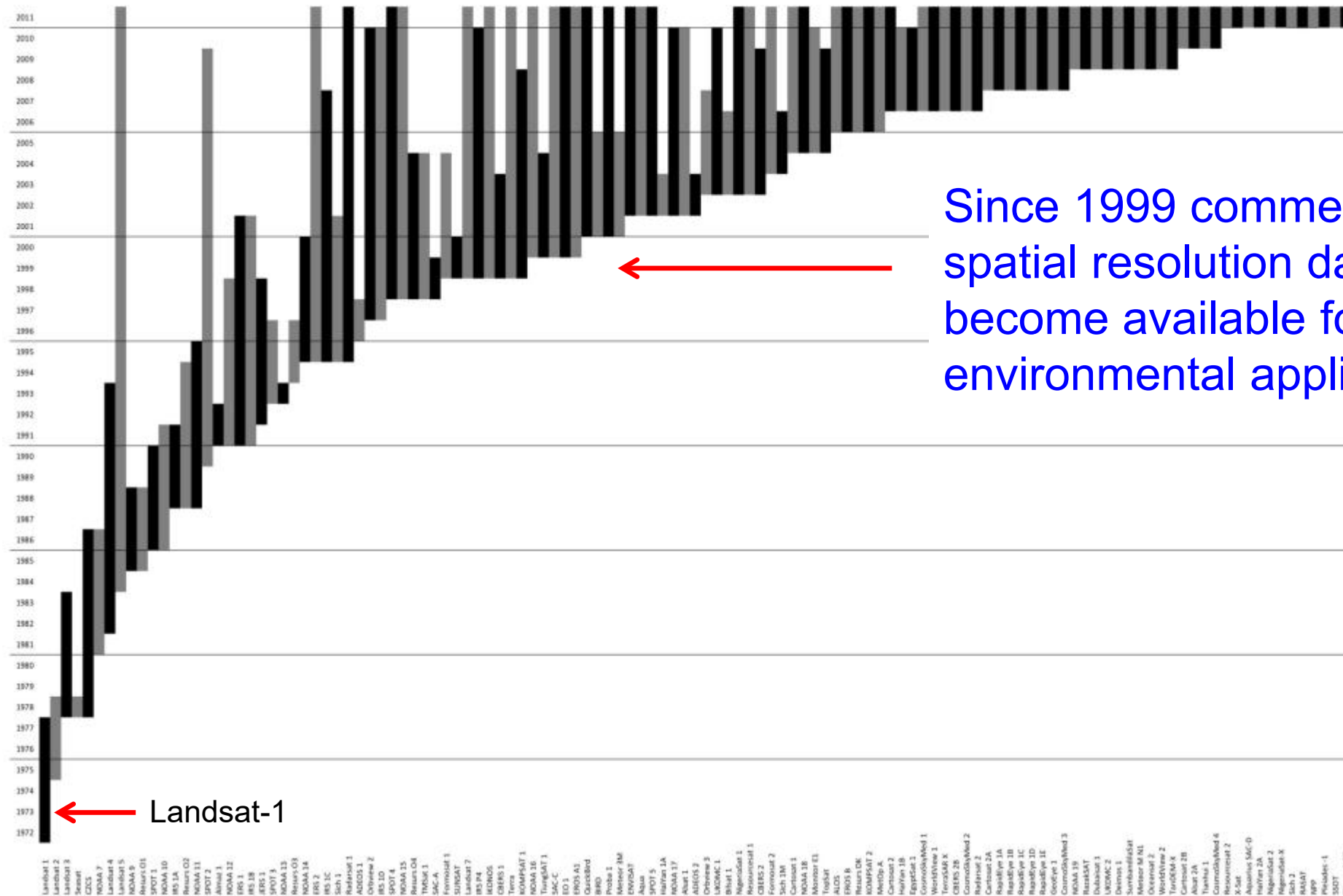
Sentinel-2 & Landsat-8 30 m
2861 109 x 109 km HLS tiles

August 2019



Harmonized Landsat Sentinel-2

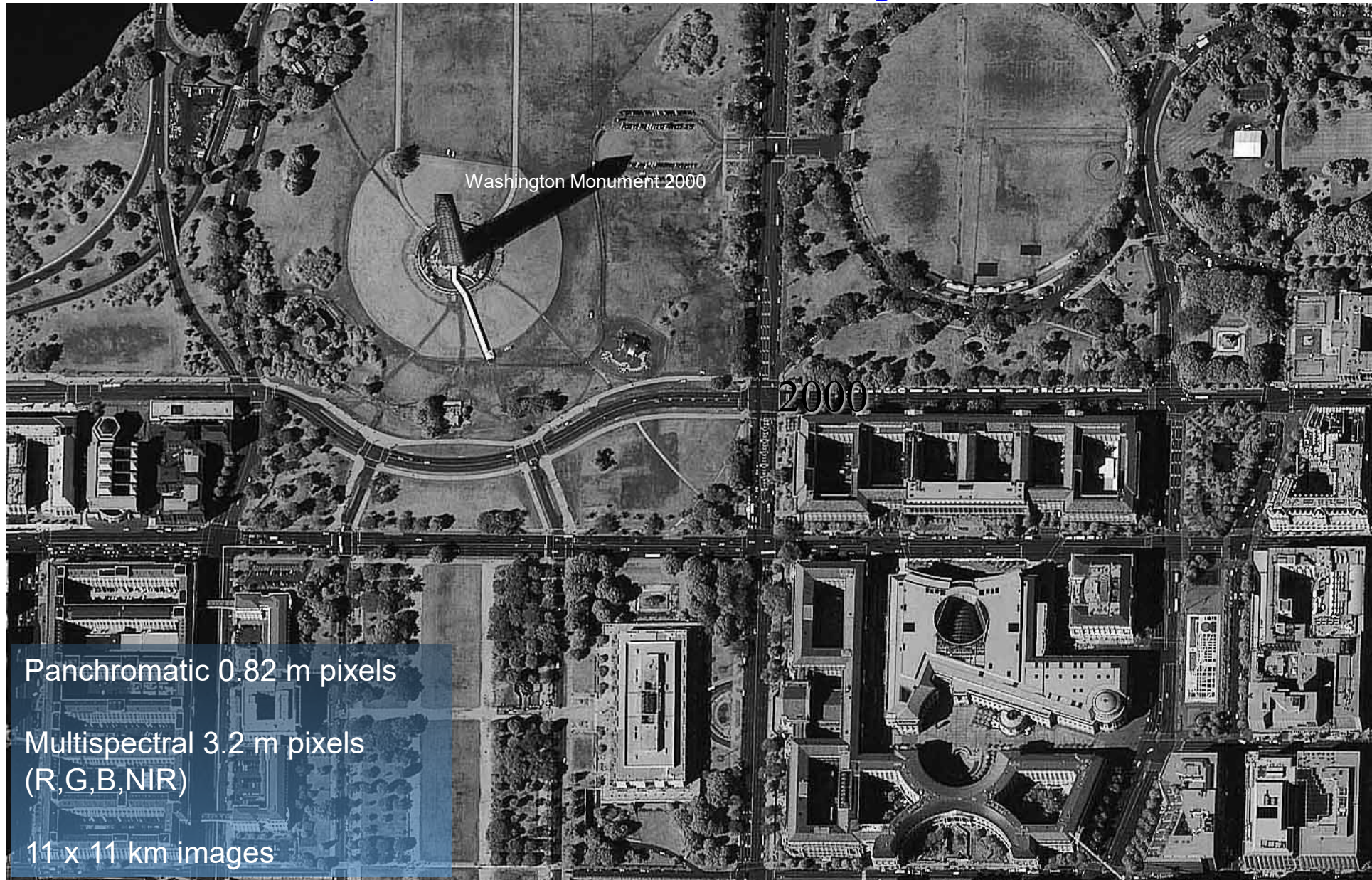
Lots of Remote Sensing Systems launched since 1972



Since 1999 commercial high spatial resolution data have become available for environmental applications

IKONOS (1999, US Company)

the first of a series of **commercial satellites** launched and operated by private companies sometimes on behalf of governments



Panchromatic 0.82 m pixels

Multispectral 3.2 m pixels
(R,G,B,NIR)

11 x 11 km images

RapidEye (2008)

five satellite constellation

Standard Image Product Specification

	Specification	
Spectral Bands	Blue	440-510 nm
	Green	520-590 nm
	Red	630-685 nm
	Red Edge	690-730 nm
	NIR	760-850 nm
Ground Sampling Distance (Nadir)	6.5 m	
Pixel Size (orthorectified)	5 m	
Swath Width	77 km	
Revisit Time	DAILY	
Equator crossing time	11:00 a.m. (approximately)	
Image Capture Capacity	4 Million km ² DAILY	



GeoEye-1 (2008)

High spatial
resolution commercial satellite sensor
(financed in part by a \$500-million
NextView contract with the National
Geospatial-Intelligence Agency)

Panchromatic 0.41 x 0.41 m

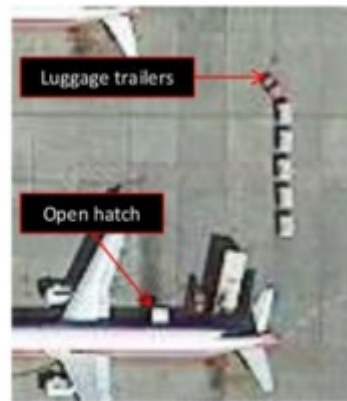
Multispectral 1.64 x 1.6 m
(R,G,B,NIR)

GeoEye-1 can “revisit” any point
on the globe every three days or
sooner, depending upon the
required look angle

GOOGLE has exclusive rights
among online mapping sites to
GeoEye-1 imagery



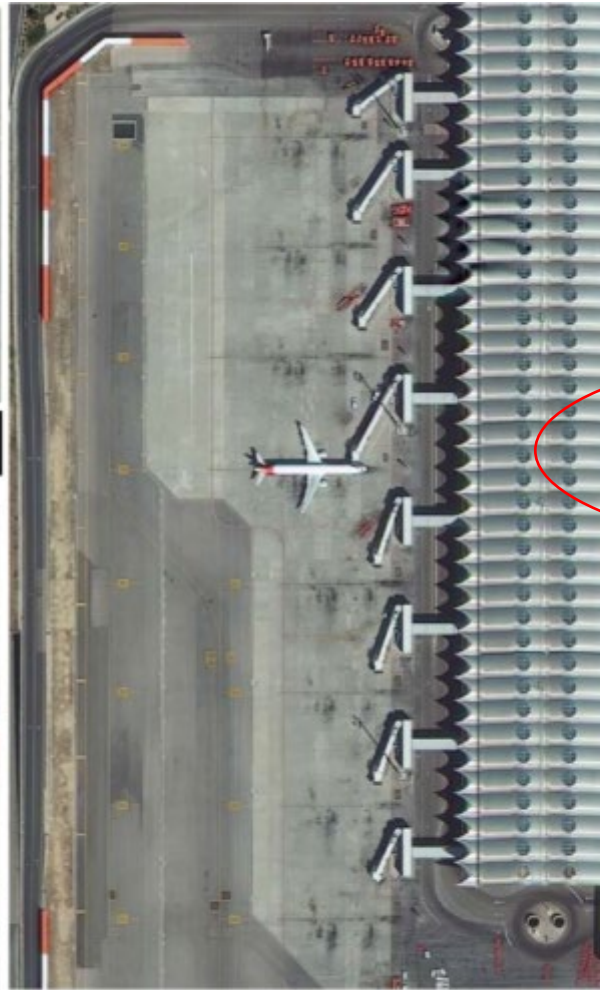
13 August 2014 Last updated at 15:01 ET



Additional activity is identifiable such as aircraft loading/unloading activity.



Refueling and maintenance activity is



WV-3 image collected at 30cm resampled to 40cm

DigitalGlobe launches super-sharp WorldView-3 Earth imager

COMMENTS (51)



About 60% of DigitalGlobe's business is with the US government - for both military and civil applications

The most powerful commercial imaging satellite ever built has just gone into orbit from California, US.

DigitalGlobe's WorldView-3 spacecraft will return pictures of the Earth's surface down to a resolution of 31cm.

Until recently, the company was restricted to selling images sharper than 50cm only to the US government.

DigitalGlobe's products will be familiar to anyone using Google or Bing maps - both run on views captured by the firm's satellites.

But its pictures also find wide application in areas such as **scientific investigations**, urban planning, forestry and agricultural monitoring, and in mineral exploration.

WorldView-3 is an important moment for the Longmont, Colorado-based company, however.

The market place for commercial Earth imagery is getting increasingly competitive, and being able to go to sub-0.5m resolutions gives DigitalGlobe a stand-out advantage over its rivals.

"It's important for them to be able to differentiate themselves by being able to say, 'we have the most high-resolution and highest-accuracy data available'," commented Adam Keith, the director of space and Earth observation at **industry-watchers Euroconsult**.

More from Jonathan

Rosetta: 'Spuds in space'

Ariane 6: Customers call the shots

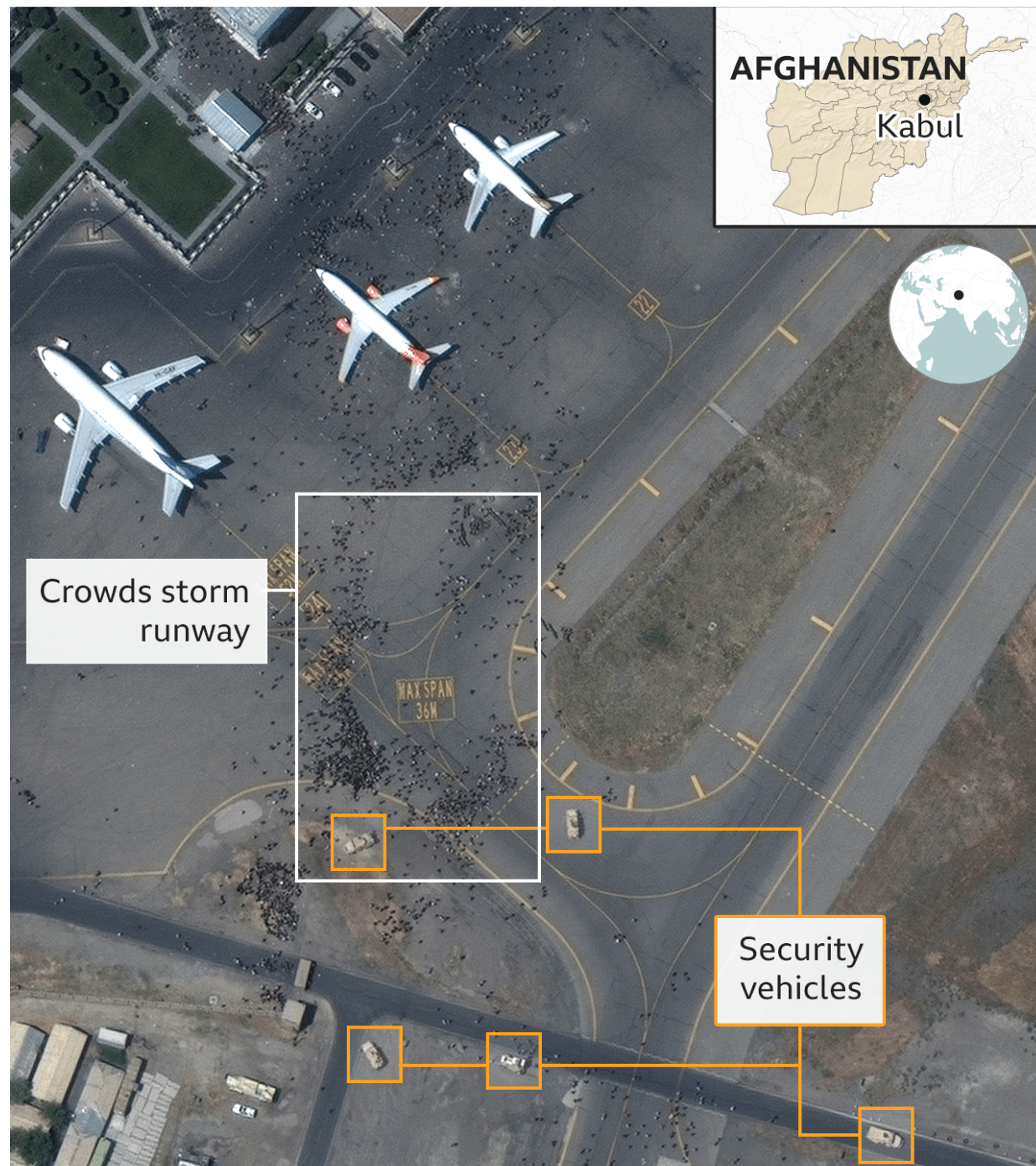
Rosetta edges towards Comet 67P

MH370: Refined analysis drives new search area

High spatial
resolution
commercial
satellite
data
used
to infer

human
activities

19 August 2021



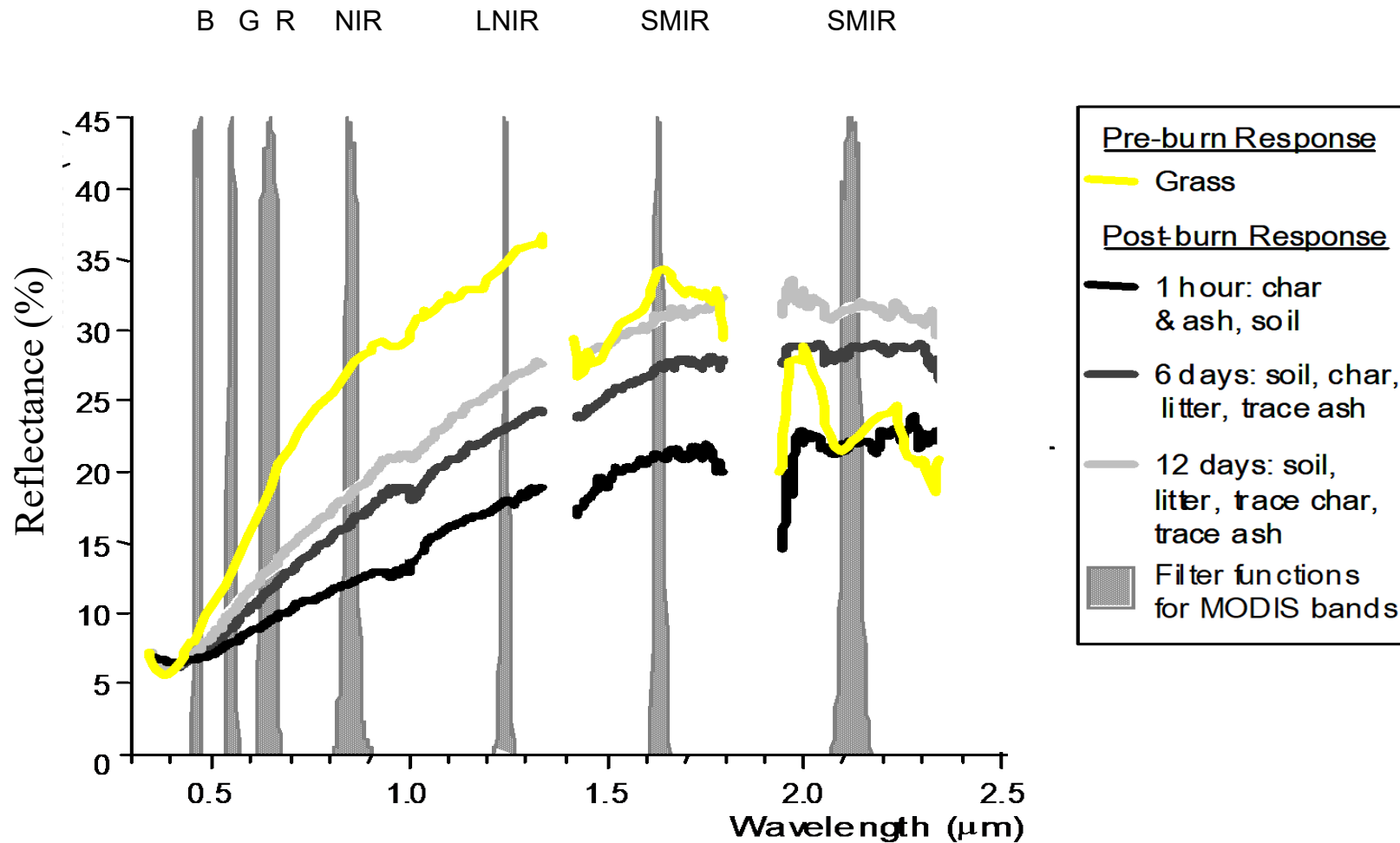
Satellite image ©2021 Maxar Technologies

BBC

High spatial resolution commercial satellite data potential to resolve small and spatially fragmented burned areas



But **high temporal** resolution also needed to capture many burns
spectra of a pre-burn & burned grass fuel 1 hour, 6 days, 12 days after burning



Landsat 8

Kafue
National park,
Zambia

Day 155 2016

2000 x 2000 30m
pixels

false color surface
NBAR



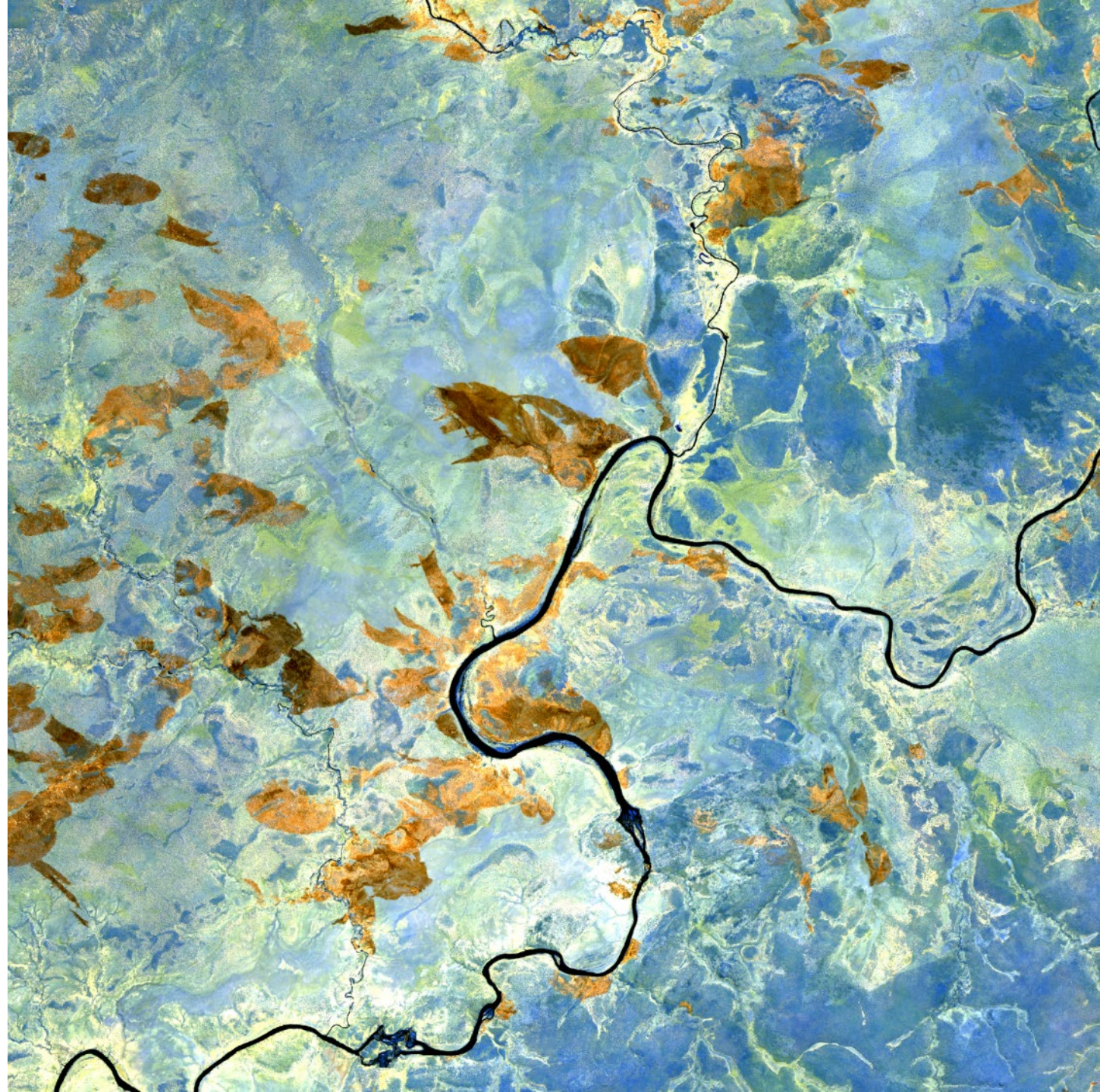
Sentinel 2A

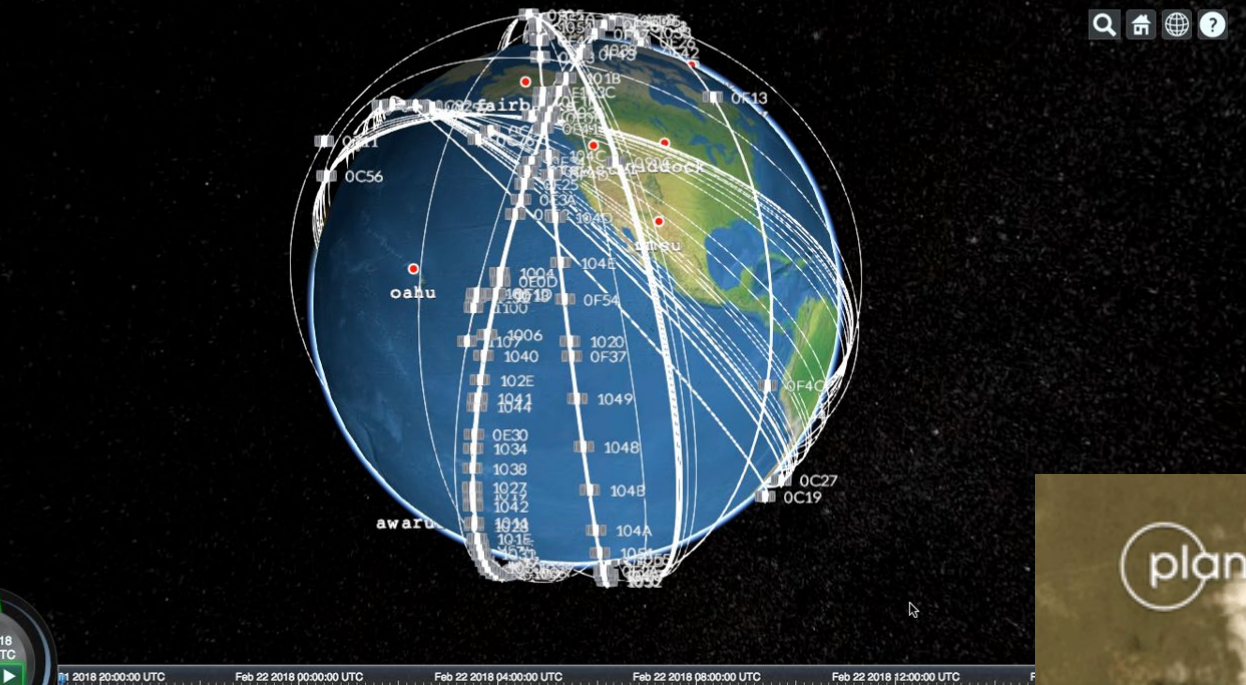
Kafue
National park,
Zambia

Day 164 2016

2000 x 2000 30m
pixels

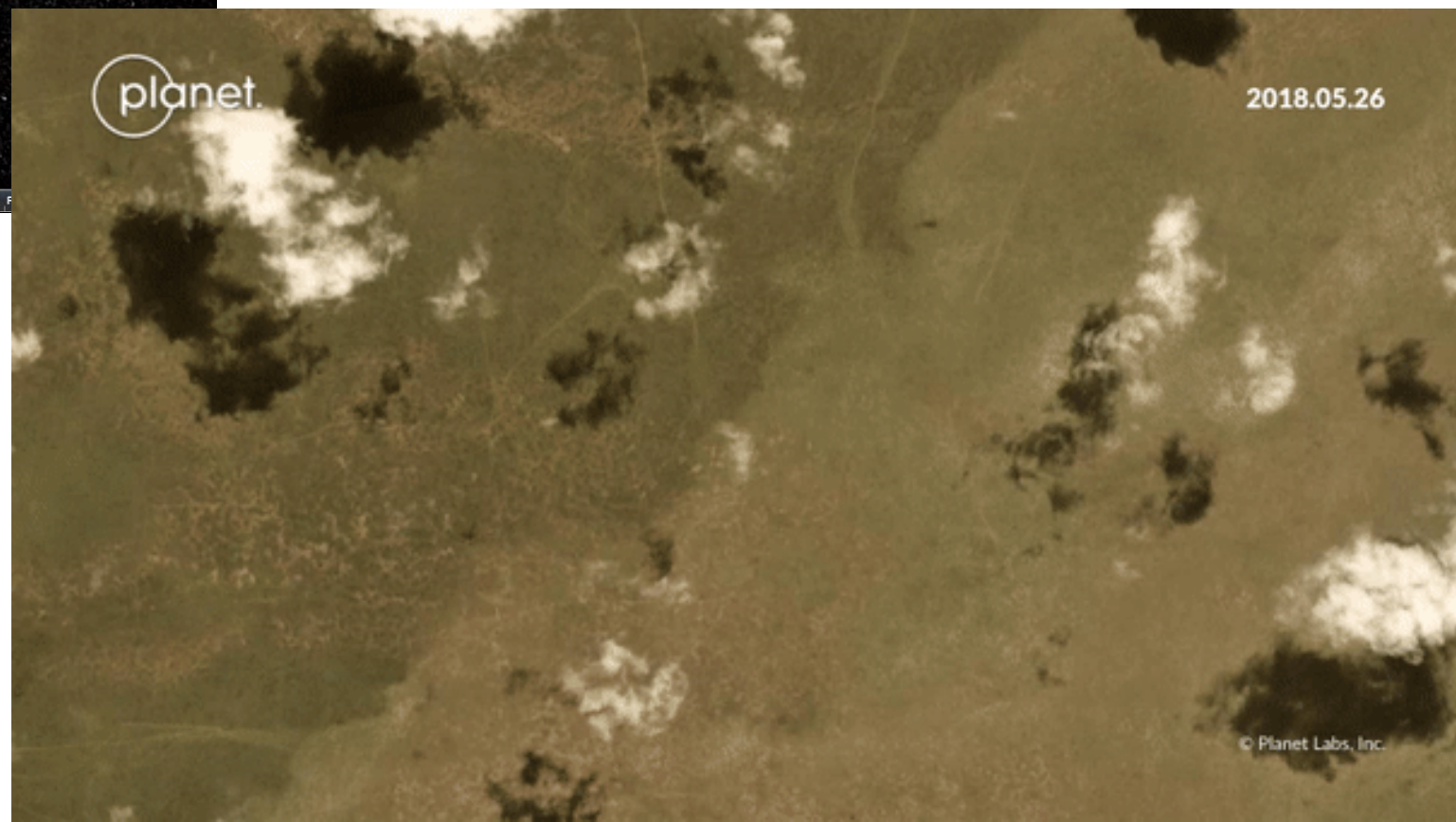
false color surface
NBAR





PlanetScope constellation

- ~200 sensors
- 461- 594 km altitude
- 3 - 4 m
- B / G / R / NIR λ



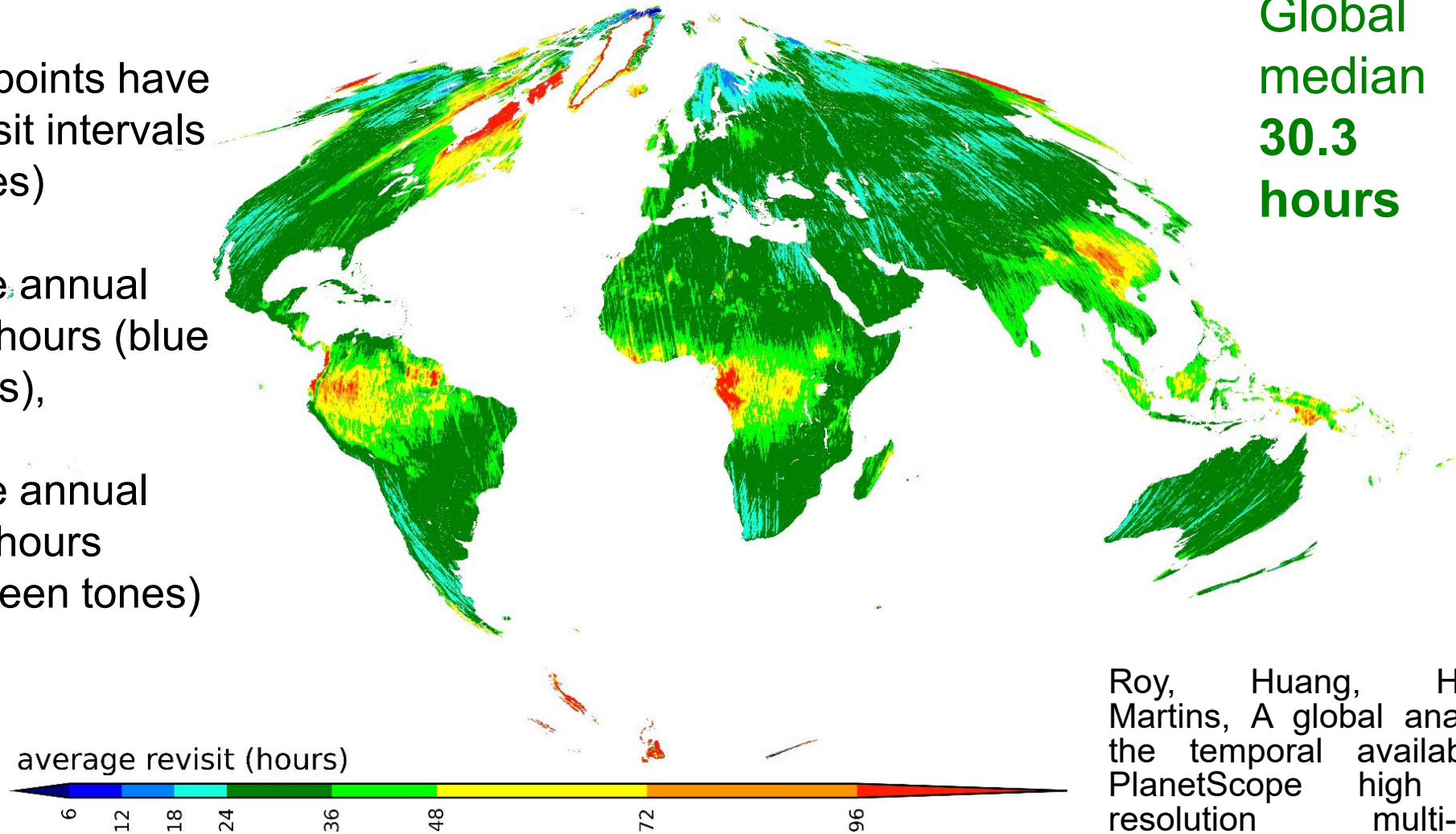
PlanetScope average revisit interval December 2019 – November 2020

9.6% of global land points have average annual revisit intervals <24 hours (blue tones)

71.8% have average annual revisit intervals <36 hours (blue and dark green tones),

88.4% have average annual revisit intervals <48 hours (blue, dark & light green tones)

Global
median
**30.3
hours**



Roy, Huang, Houborg, Martins, A global analysis of the temporal availability of PlanetScope high spatial resolution multi-spectral imagery, *RSE*, 2021.



BlackSky Data Catalog



BlackSky has a constellation of 14, L3 Harris/Excellis SpaceView-24 satellites, 2 blocks of builds

- 0.7-1.3 [m] RGB and Pan
- 500-600 km orbit
- ~3 yr life
- Payload mass: <10 kg

The evaluation will target basic image products.

Data Archive Coverage



Basic Image Products

AVAILABLE IMAGERY
PRODUCTS (Q2 '21)

Single-Frame Collection	Standard Non-Ortho Image		Standard Ortho Image	
	Spectral Bands		Pan, RGB	
	Estimated NIIRS		≤ 4 (Minimum GSD: 0.83 m)	
	Geolocation Accuracy		< 20 m CE90	

Constellation Details

Launched	2018+ (Global) https://space.skyrocket.de/doc_sdat/blacksky-global.htm
Orbit	Polar & Mid-inclination
Repeat period	14 observations per day (constellation)
GSD	Varies between satellite & orbit

BlackSky's First To Know Insights



SEVEN COLLECTS IN SEVEN HOURS

Sensor: Sentinel 2A
Spatial Resolution: 10 m
Date: 2021/12/27
Time: 16:17:01 UTC
Solar Elevation: 49°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
300 x 300



Sensor: Landsat 9
Spatial Resolution: 30 m
Date: 2021/12/27
Time: 16:18:37 UTC
Solar Elevation: 46°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
100 x 100



Sensor: Planetscope
Spatial Resolution: 3 m
Date: 2021/12/28
Time: 15:33:44 UTC
Solar Elevation: 39°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

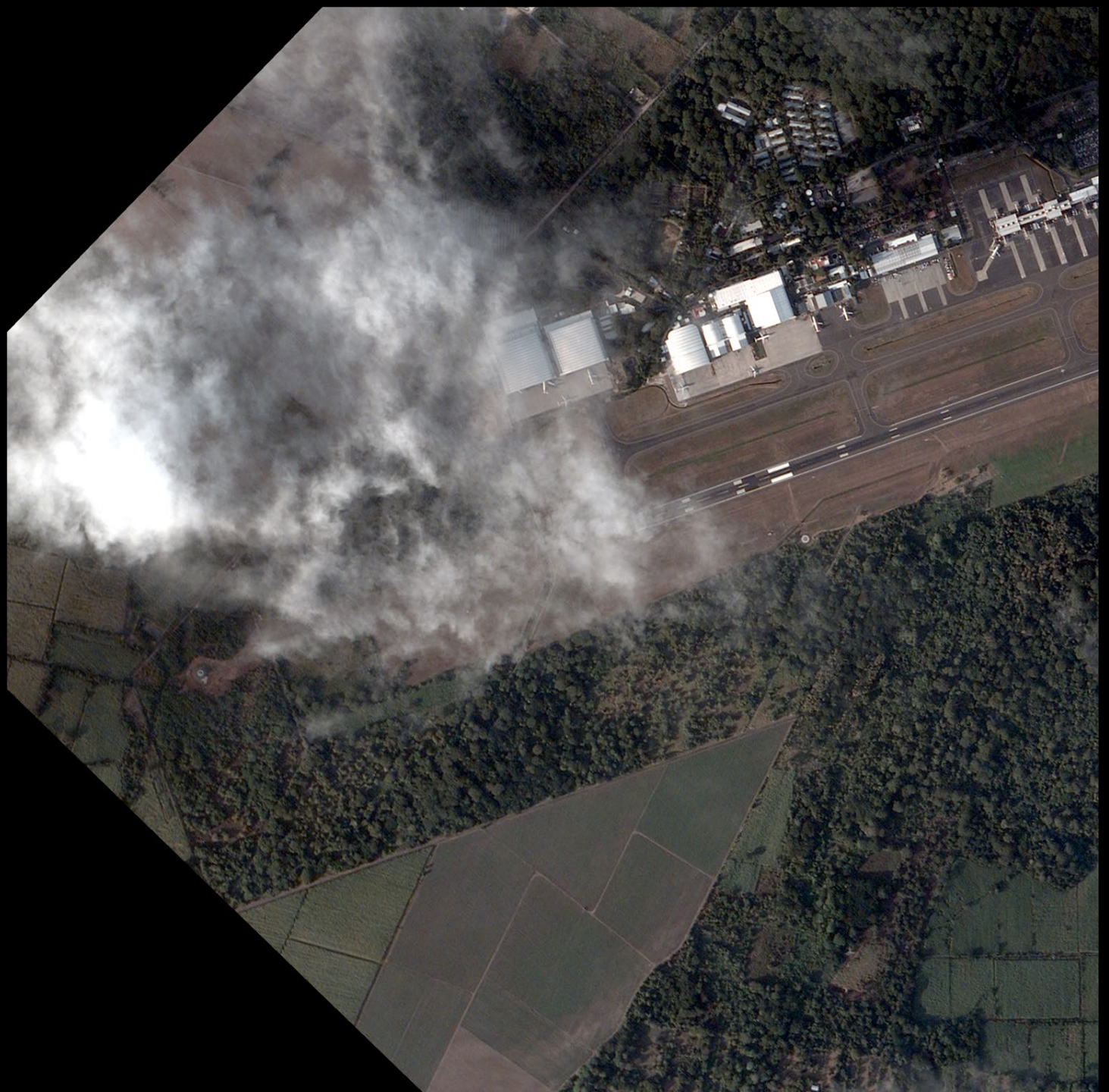
Dimension:
1000 x 1000



Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2021/12/28
Time: 22:25:50 UTC
Solar Elevation: 15°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
3000 x 3000



Sensor: Sentinel 2A
Spatial Resolution: 10 m
Date: 2021/12/30
Time: 16:27:01 UTC
Solar Elevation: 49°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
300 x 300



Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2021/12/30
Time: 16:29:02 UTC
Solar Elevation: 47°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

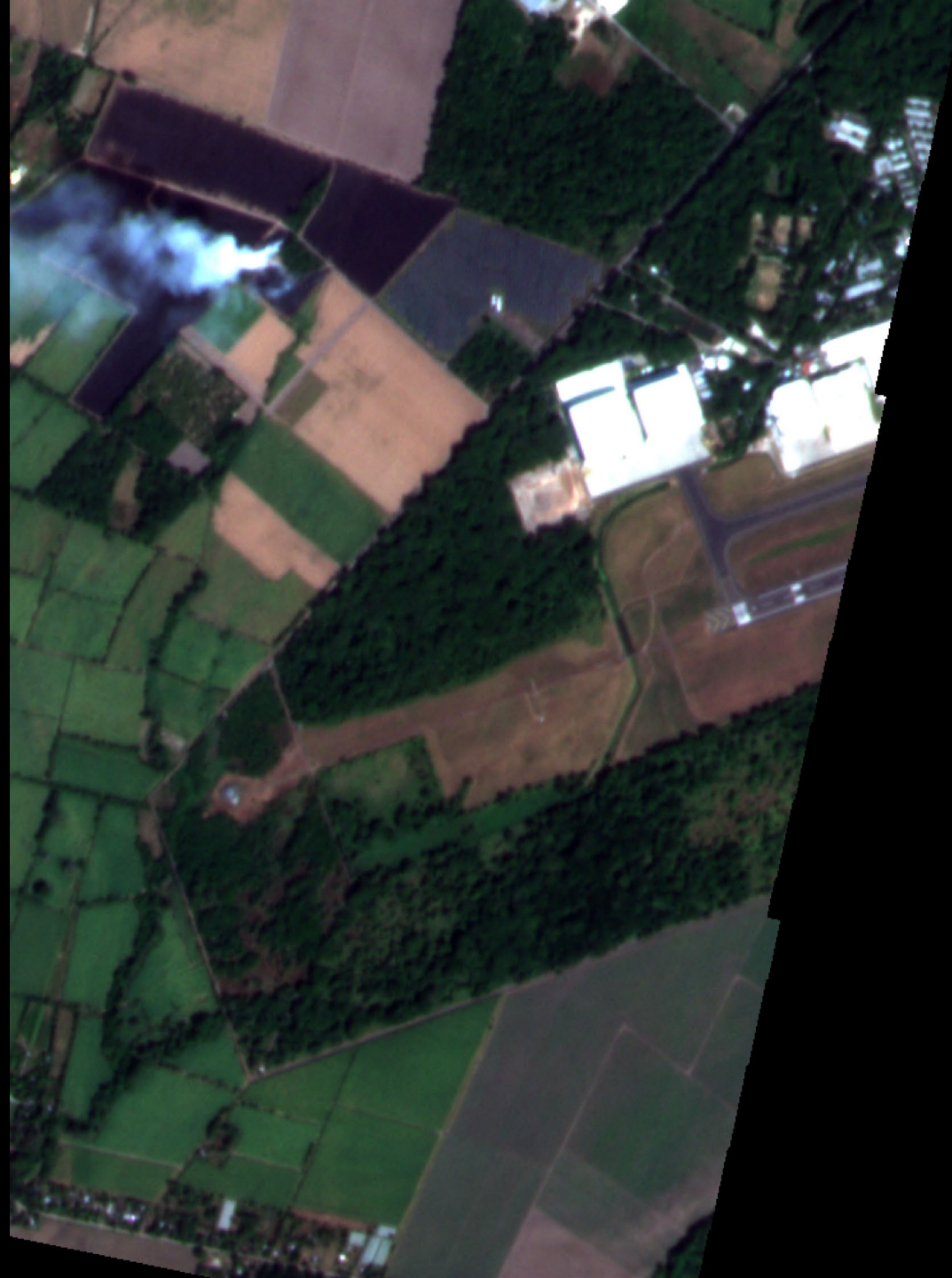
Dimension:
3000 x 3000



Sensor: Planetscope
Spatial Resolution: 3 m
Date: 2021/12/31
Time: 15:32:57 UTC
Solar Elevation: 39°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
1000 x 1000



Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2021/12/31
Time: 22:04:40 UTC
Solar Elevation: 20°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
3000 x 3000



Sensor: Planetscope
Spatial Resolution: 3 m
Date: 2022/01/01
Time: 15:34:37 UTC
Solar Elevation: 39°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
1000 x 1000



Sensor: Sentinel 2B
Spatial Resolution: 10 m
Date: 2022/01/01
Time: 16:16:49 UTC
Solar Elevation: 48°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

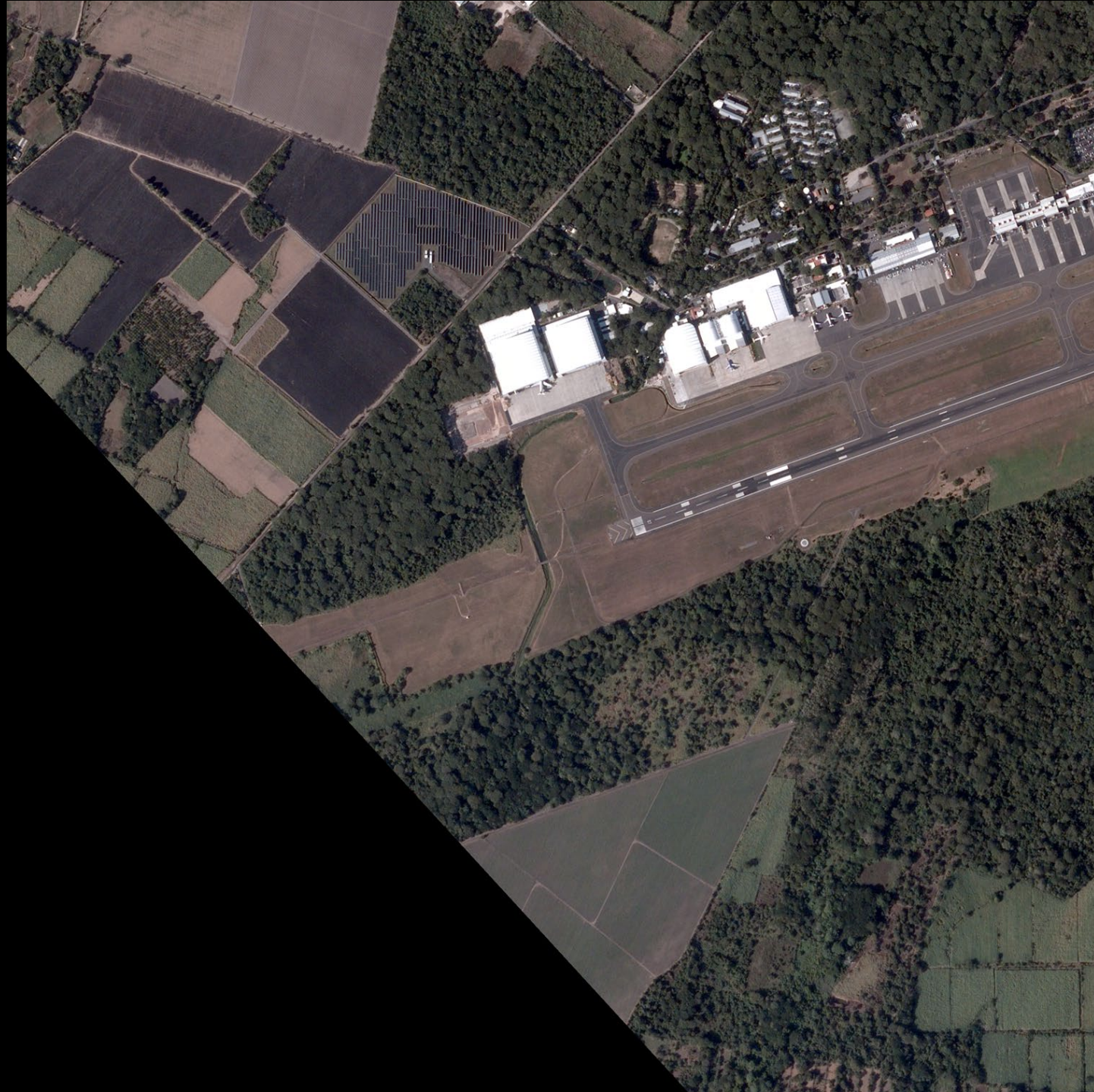
Dimension:
300 x 300



Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2022/01/01
Time: 21:25:39 UTC
Solar Elevation: 28°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
3000 x 3000



Sensor: Planetscope
Spatial Resolution: 3 m
Date: 2022/01/02
Time: 16:10:53 UTC
Solar Elevation: 45°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
1000 x 1000



Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2022/01/03
Time: 21:25:59 UTC
Solar Elevation: 28°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
3000 x 3000



Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2022/01/05
Time: 16:03:37 UTC
Solar Elevation: 44°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
3000 x 3000



Sensor: Planetscope
Spatial Resolution: 3 m
Date: 2022/01/05
Time: 17:01:25 UTC
Solar Elevation: 51°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
1000 x 1000



Sensor: Planetscope
Spatial Resolution: 3 m
Date: 2022/01/06
Time: 16:21:16 UTC
Solar Elevation: 46°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
1000 x 1000



Sensor: Sentinel 2A
Spatial Resolution: 10 m
Date: 2022/01/06
Time: 16:27:53 UTC
Solar Elevation: 48°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
300 x 300



Sensor: BlackSky
Spatial Resolution: 1 m
Date: 2022/01/06
Time: 18:38:37 UTC
Solar Elevation: 53°

Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

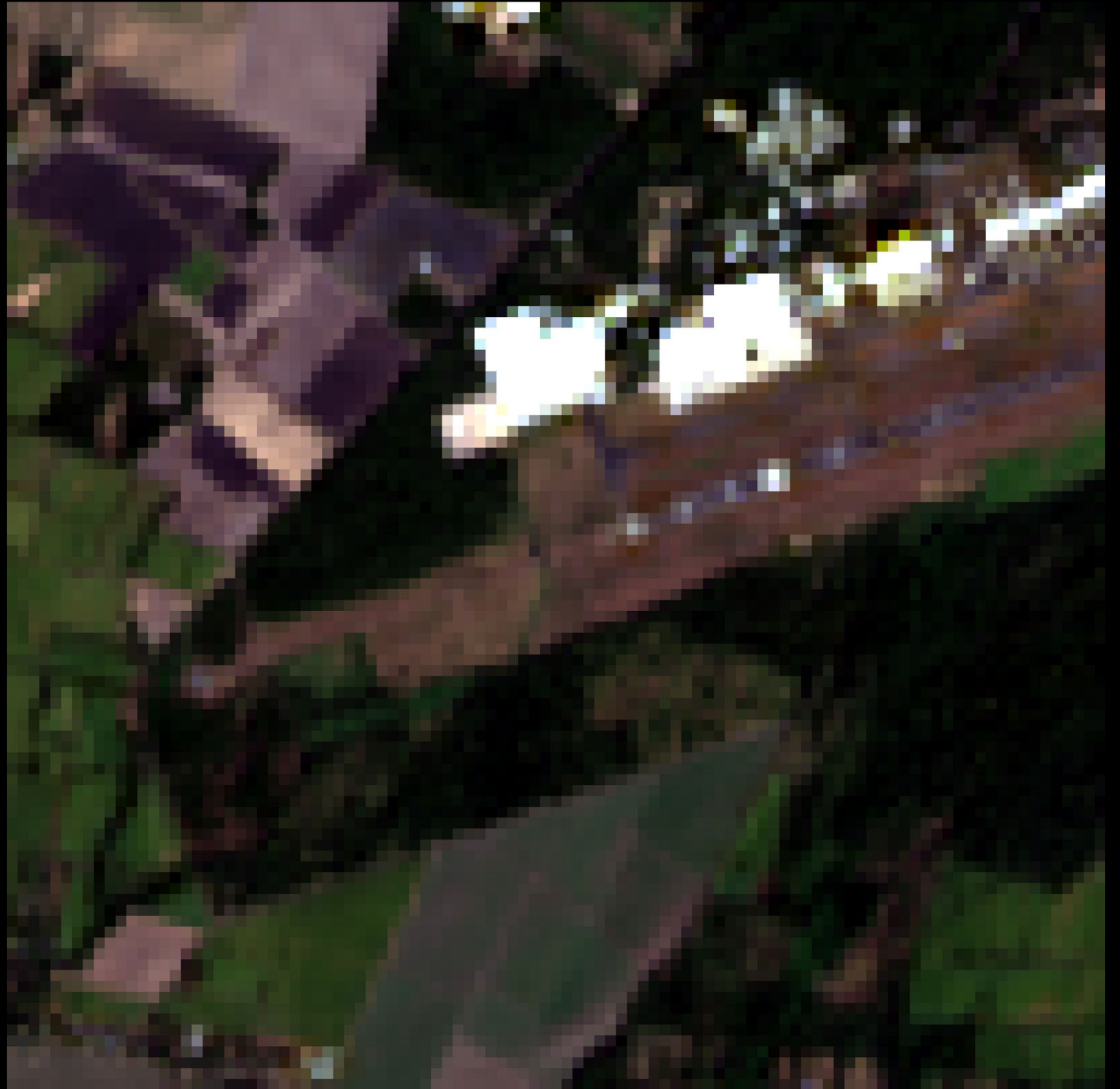
Dimension:
3000 x 3000



Sensor: Landsat 9
Spatial Resolution: 30 m
Date: 2022/01/12
Time: 16:18:34 UTC
Solar Elevation: 46°

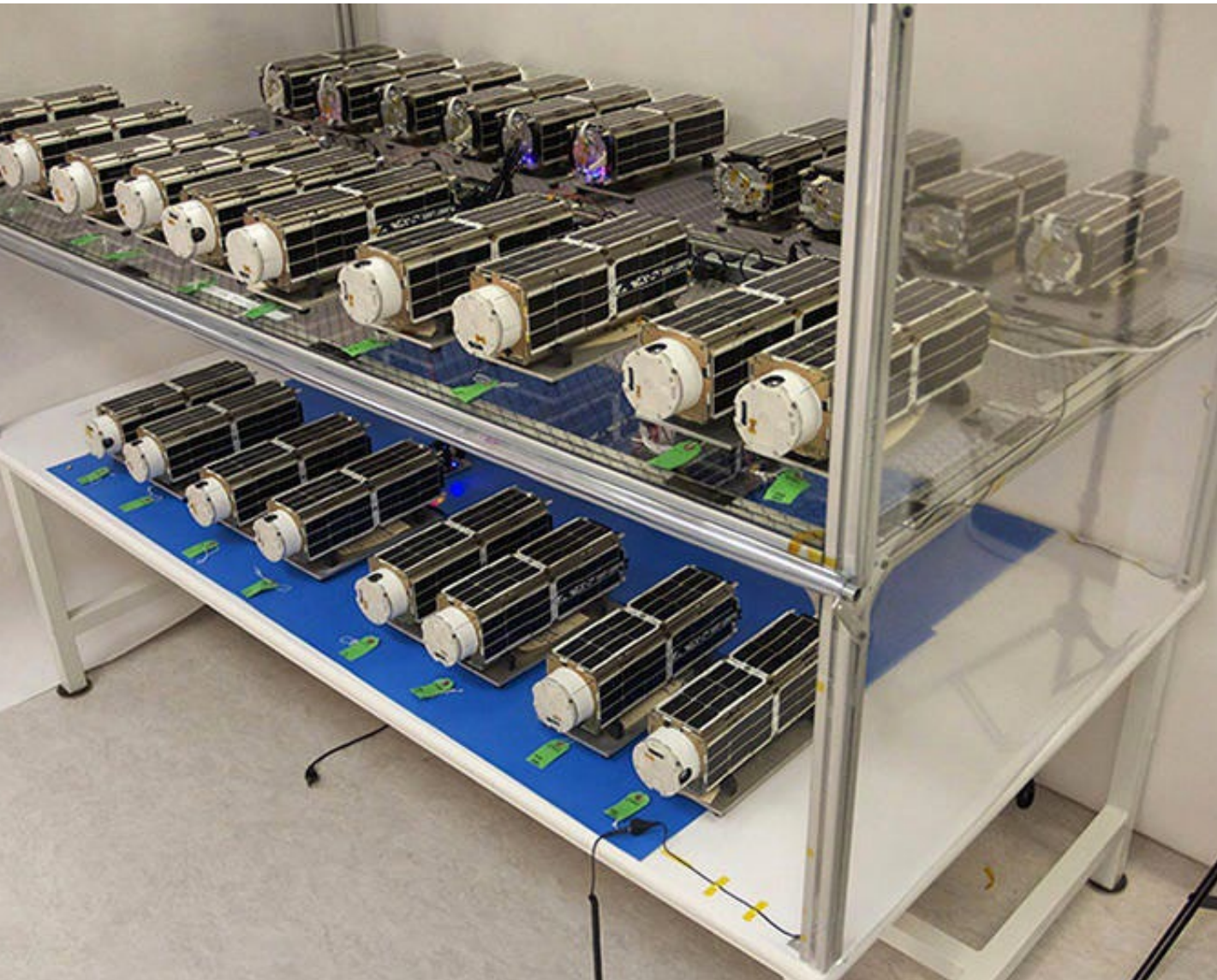
Location: SAL Airport, San Luis Talpa,
La Paz, El Salvador

Dimension:
100 x 100

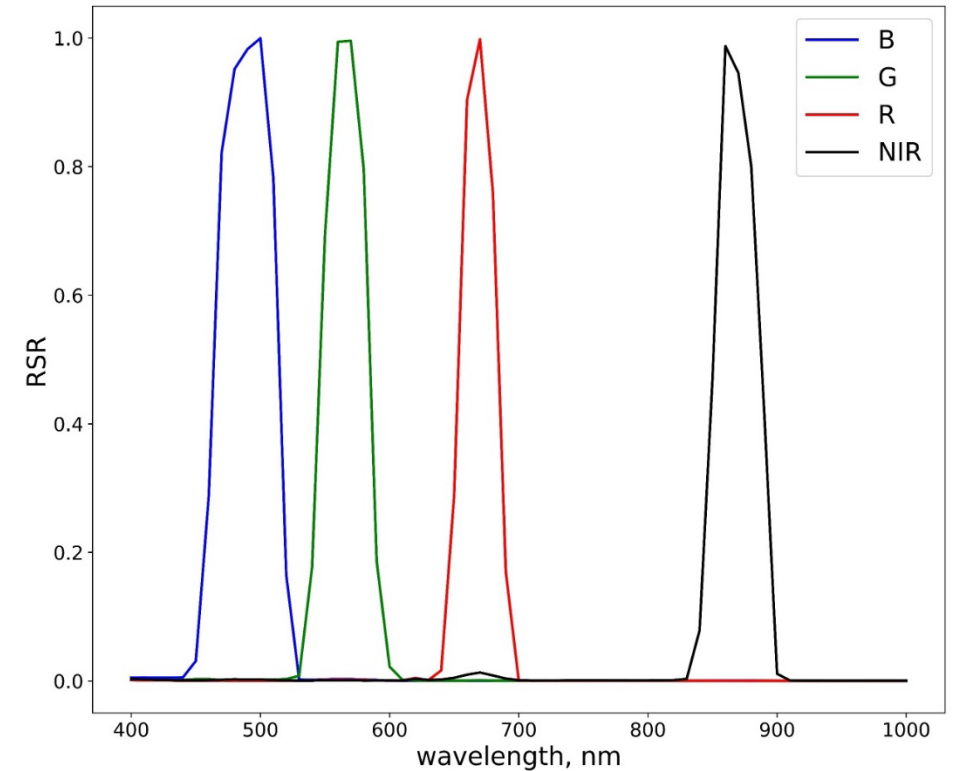


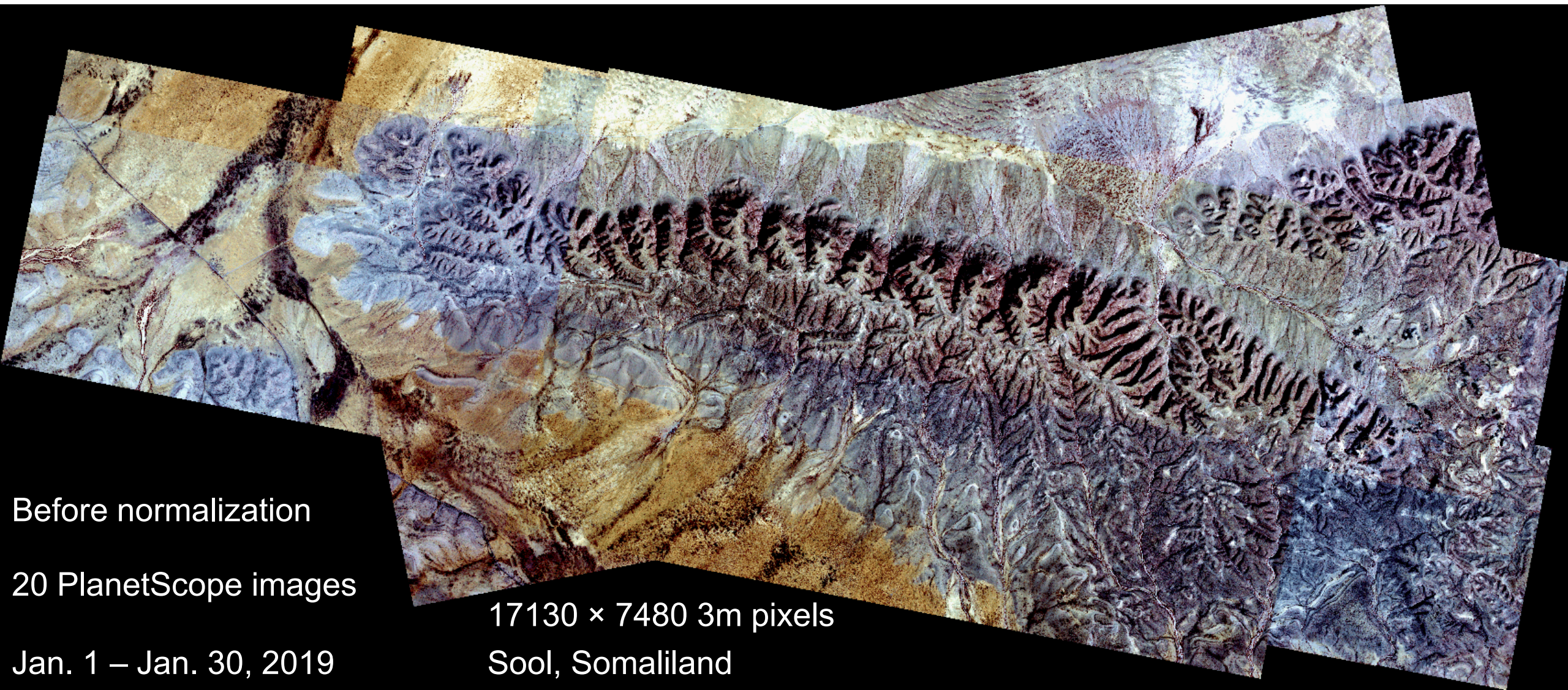
3 Planet generations:

- Planetscope-0
- Planetscope-1
- Planetscope-2



Planetscope-1





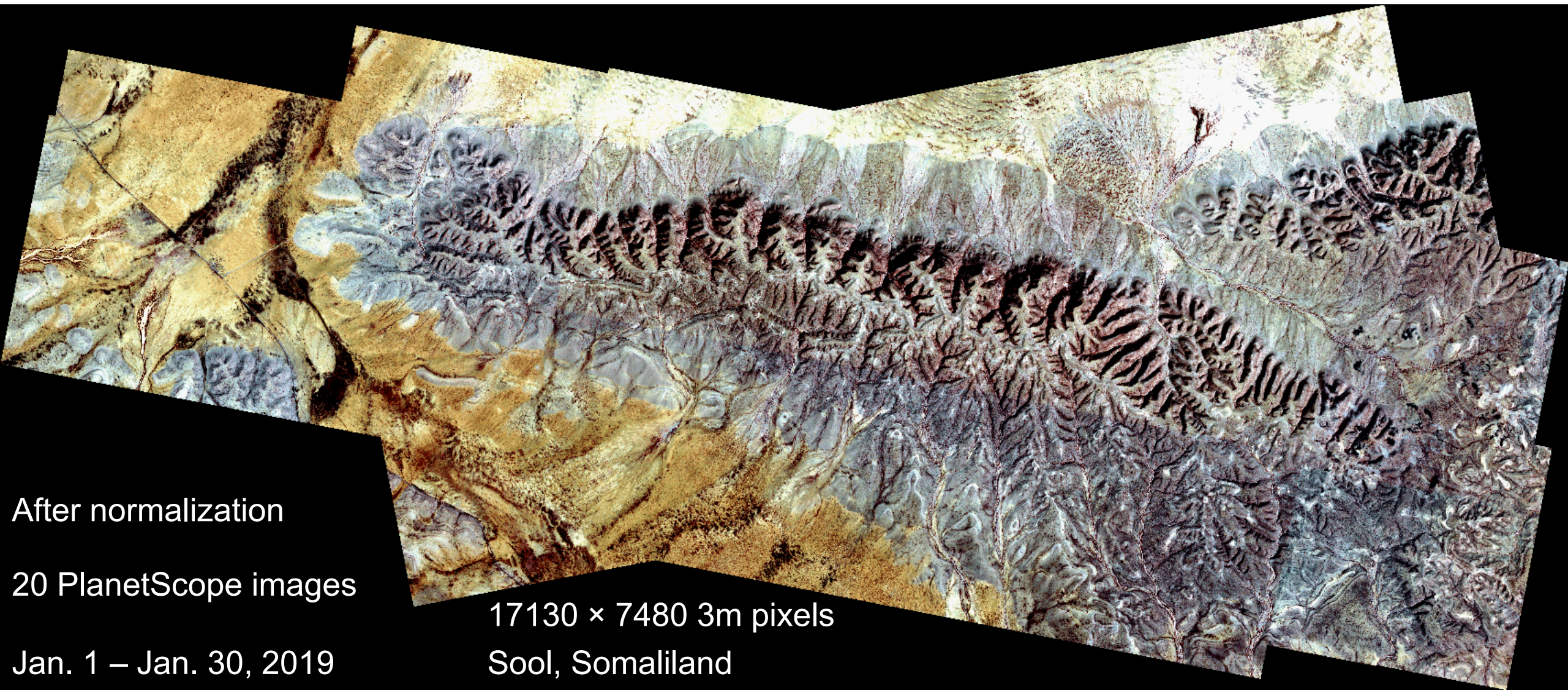
Before normalization

20 PlanetScope images

Jan. 1 – Jan. 30, 2019

17130 × 7480 3m pixels

Sool, Somaliland



After normalization

20 PlanetScope images

Jan. 1 — Jan. 30, 2019

17130 × 7480 3m pixels

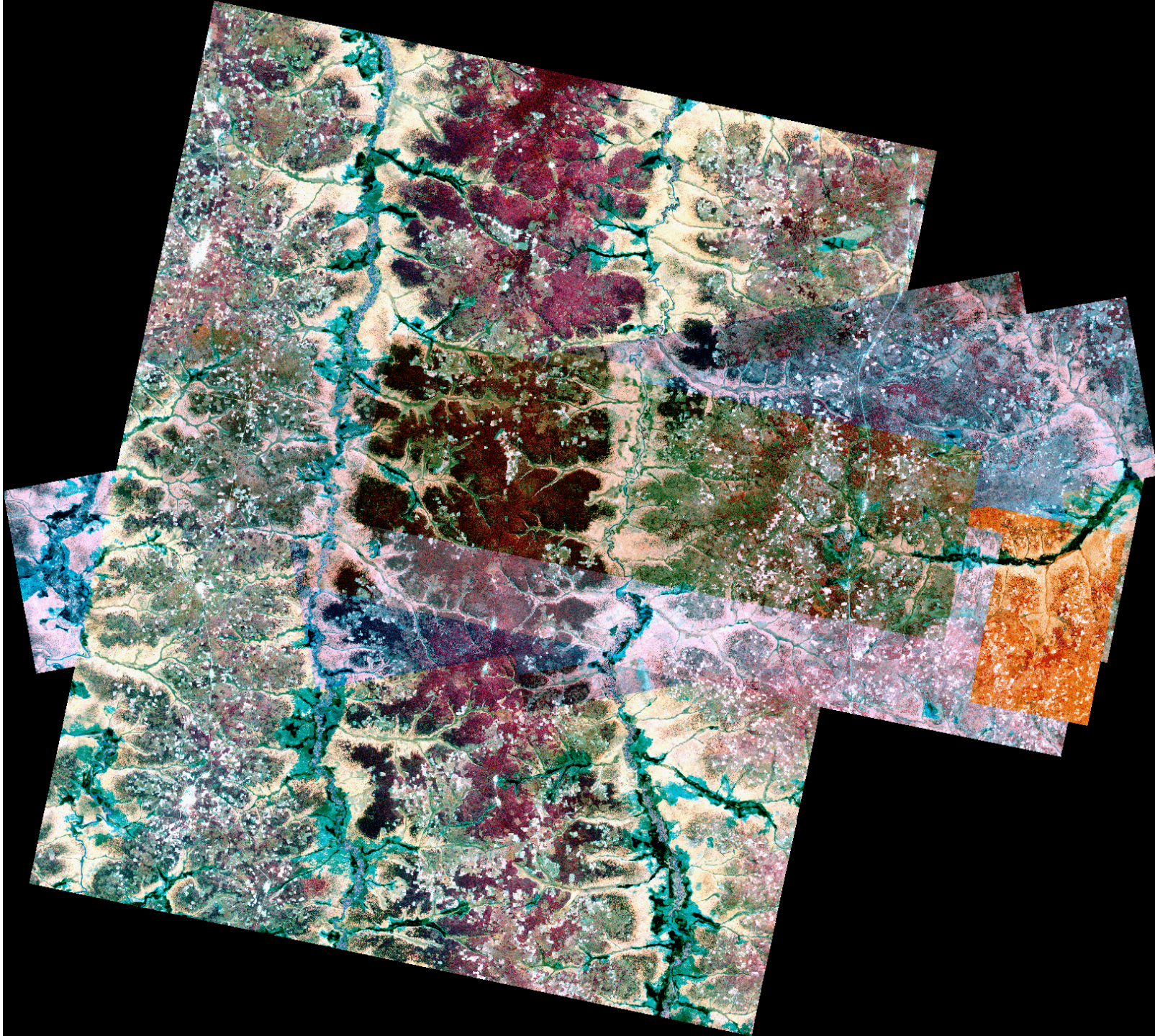
Sool, Somaliland

Before
normalization

False-color
mosaic
(NIR, red, green)

15 PlanetScope
images

June 3 – June 29,
2019



16250 × 14570
3m pixels

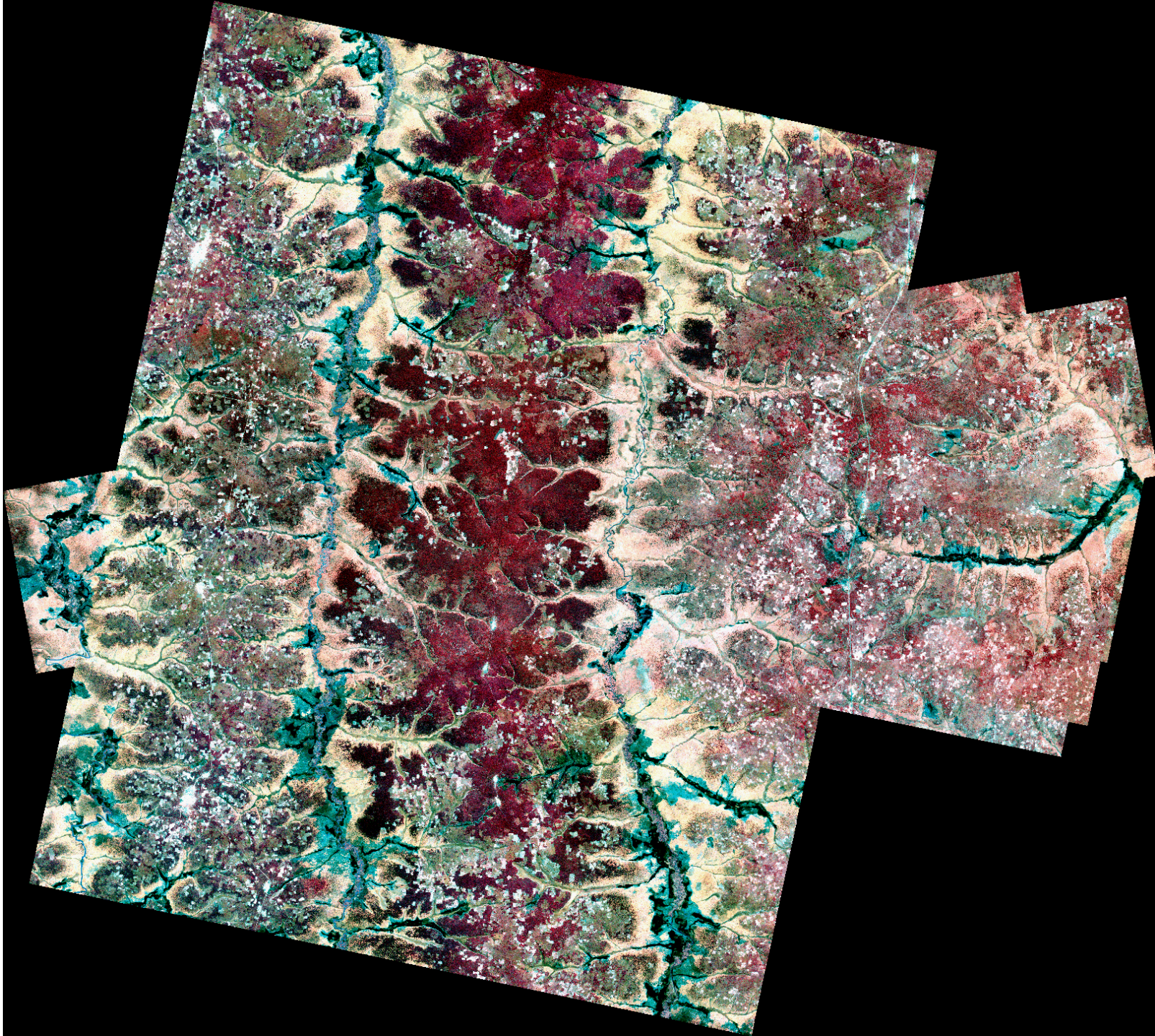
Benguela,
Angola

After
normalization

False-color
mosaic
(NIR, red, green)

15 PlanetScope
images

June 3 – June 29,
2019



16250 × 14570
3m pixels

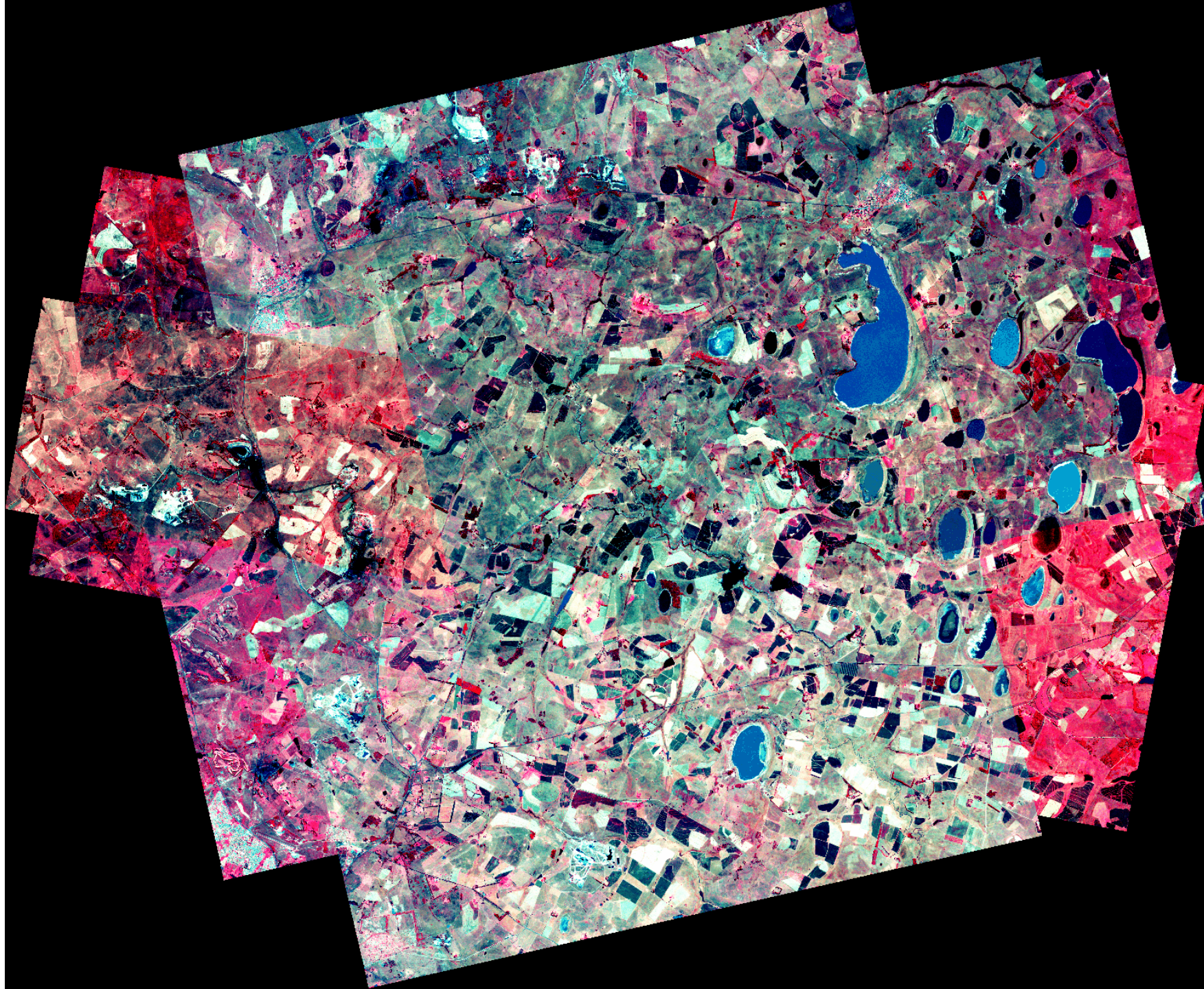
Benguela,
Angola

Before
normalization

False-color
mosaic (NIR,
red, green)

15 PlanetScope
images

May 1 – May 25,
2019



15480 × 12670
3m pixels

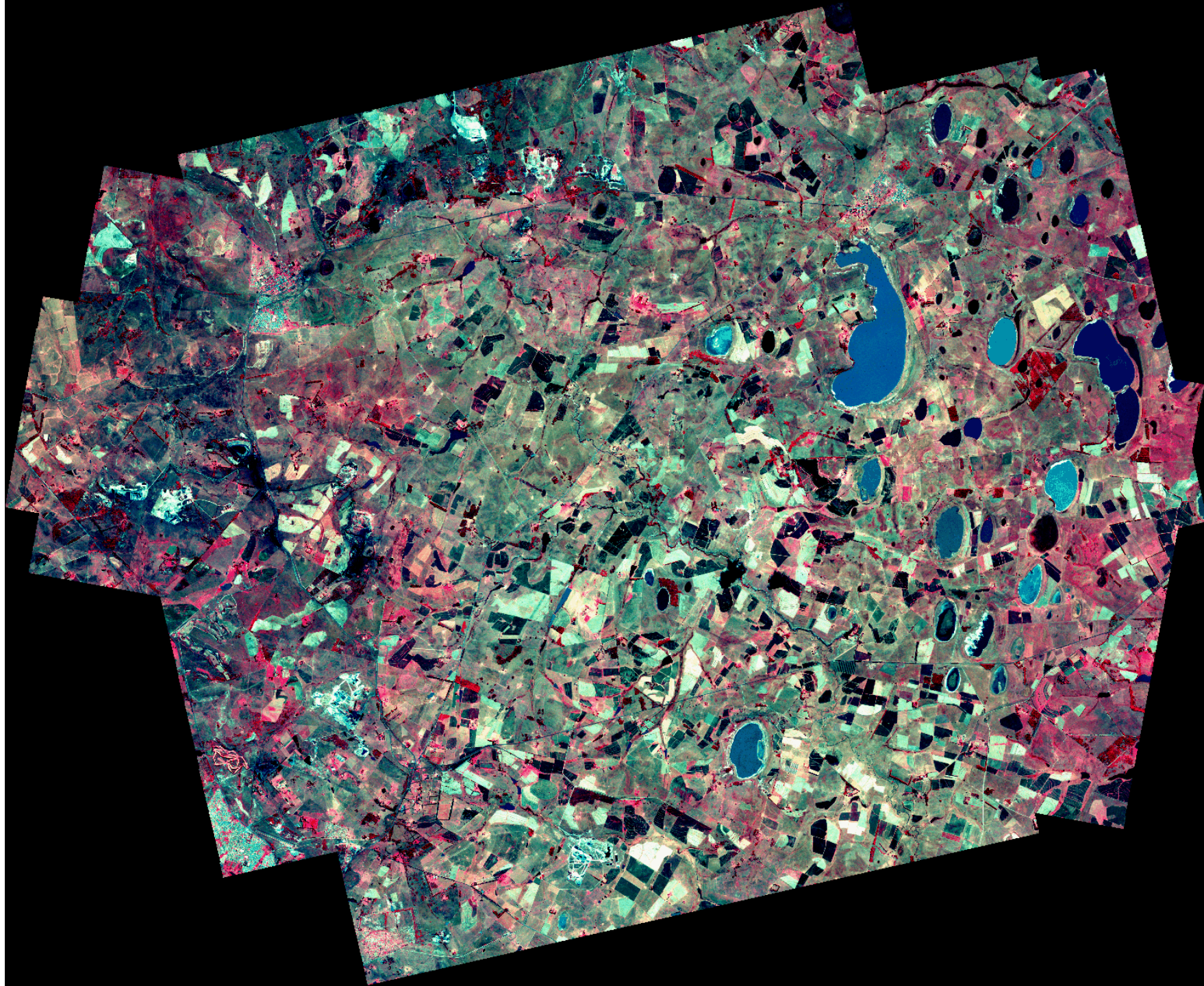
Mpumalanga,
South Africa

After
normalization

False-color
mosaic (NIR,
red, green)

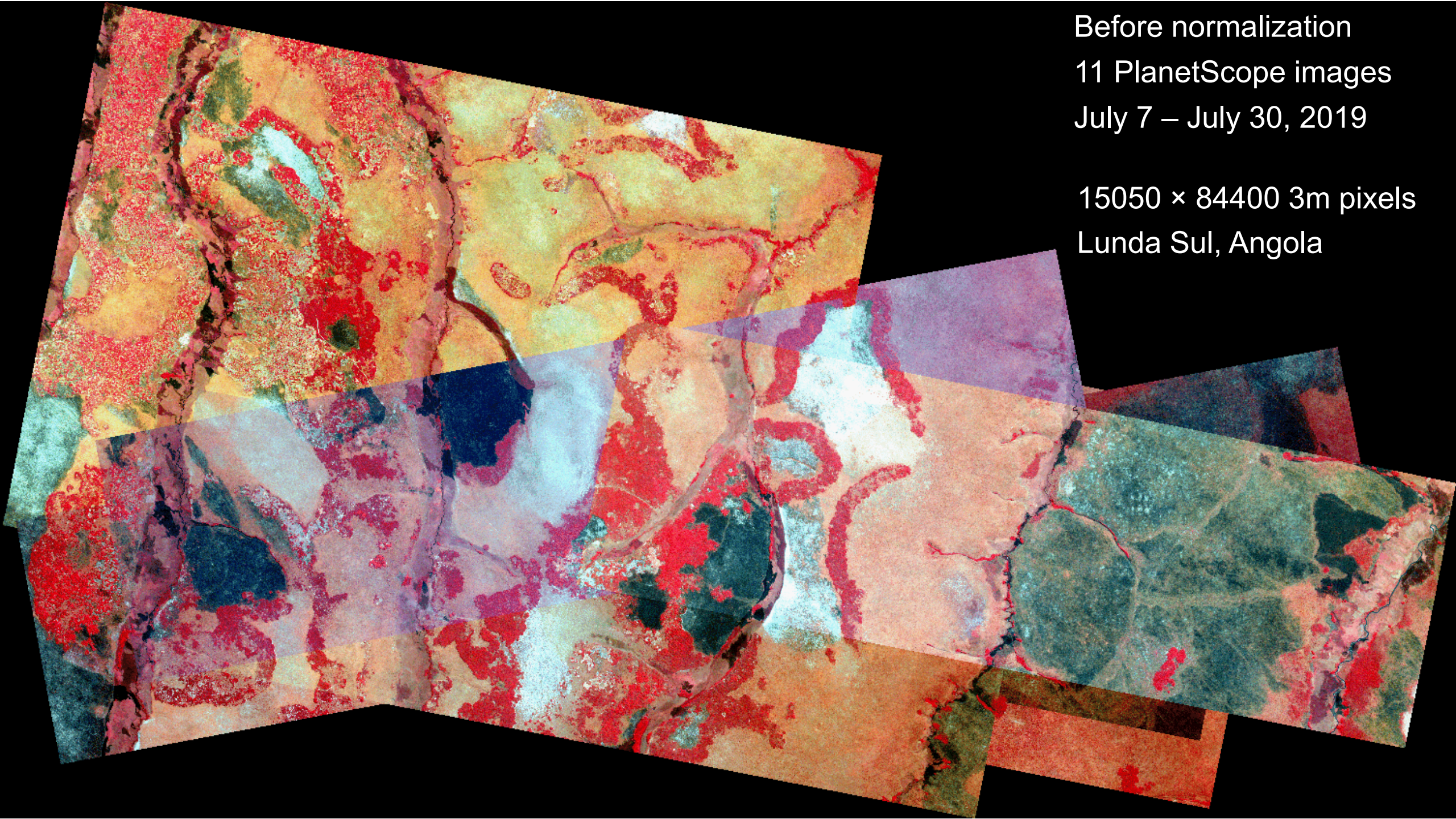
15 PlanetScope
images

May 1 – May 25,
2019



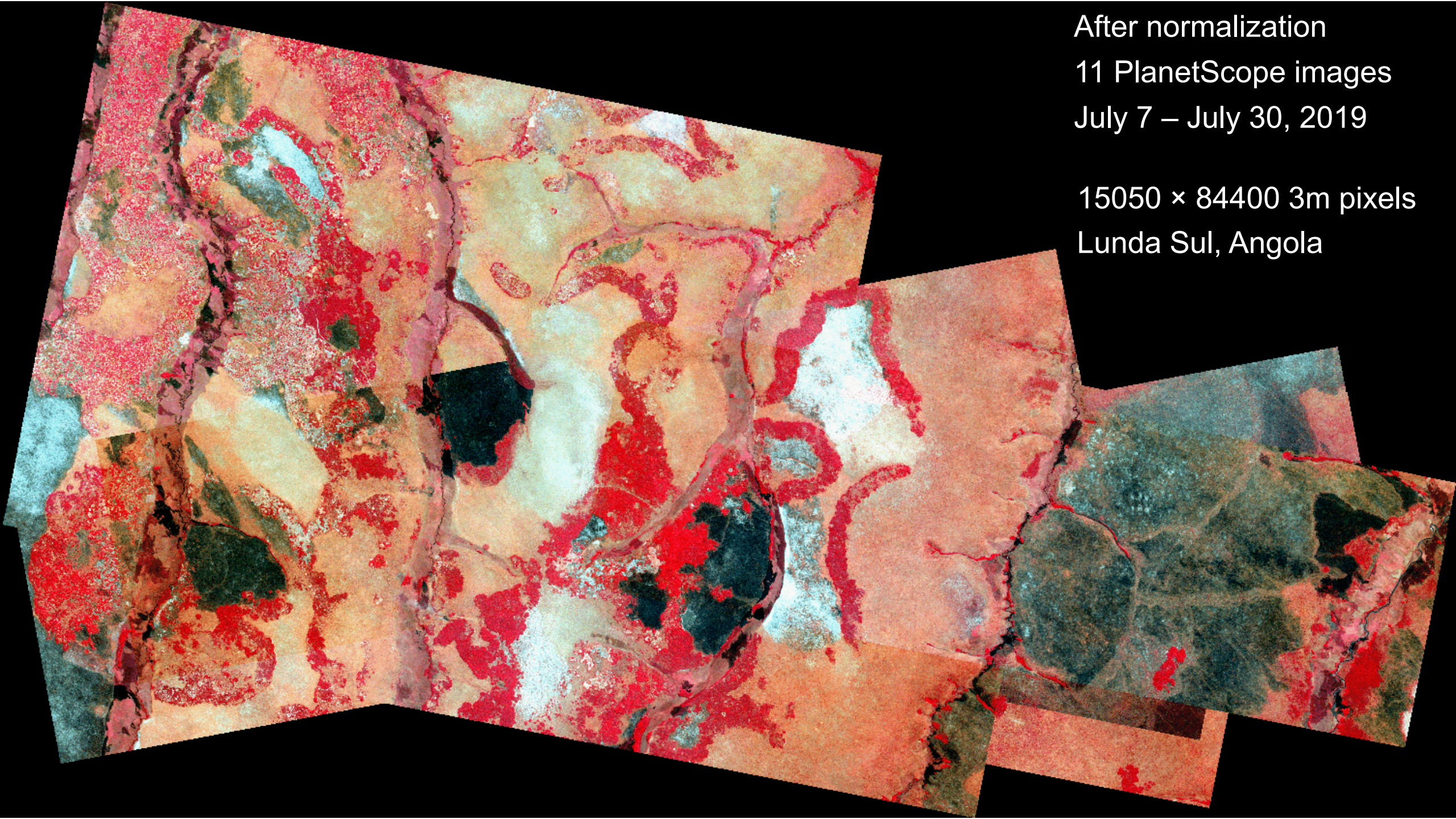
15480 × 12670
3m pixels

Mpumalanga,
South Africa



Before normalization
11 PlanetScope images
July 7 – July 30, 2019

15050 × 84400 3m pixels
Lunda Sul, Angola

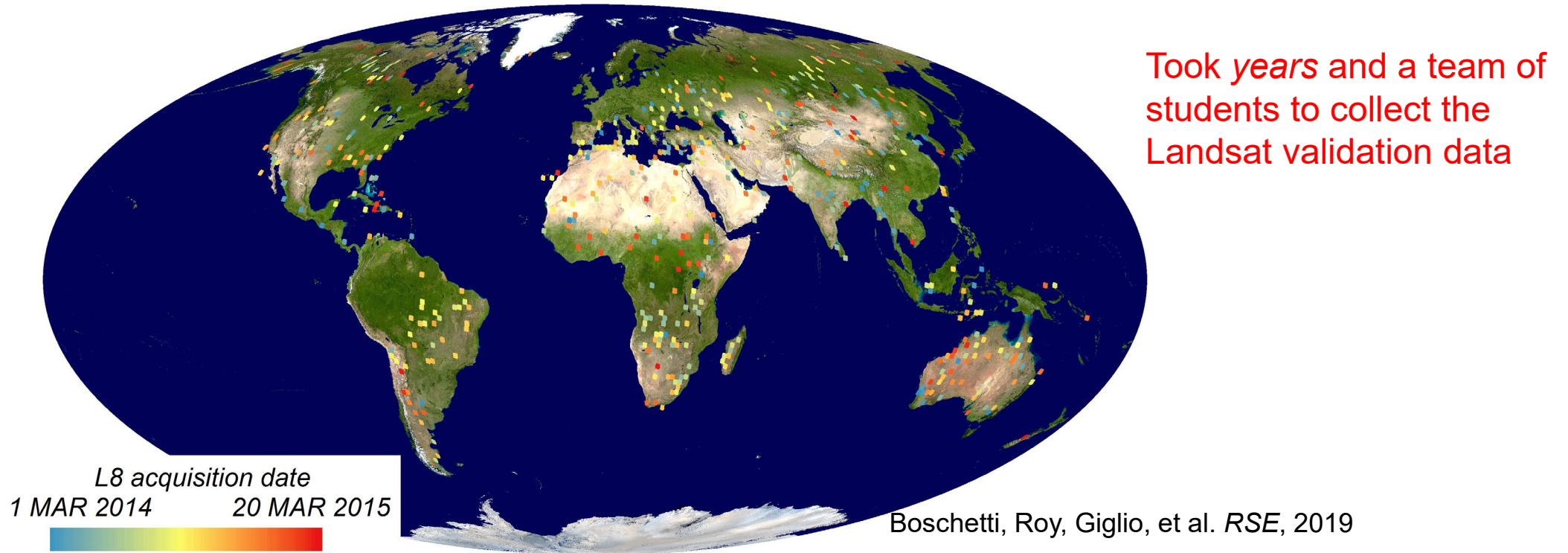


After normalization
11 PlanetScope images
July 7 – July 30, 2019

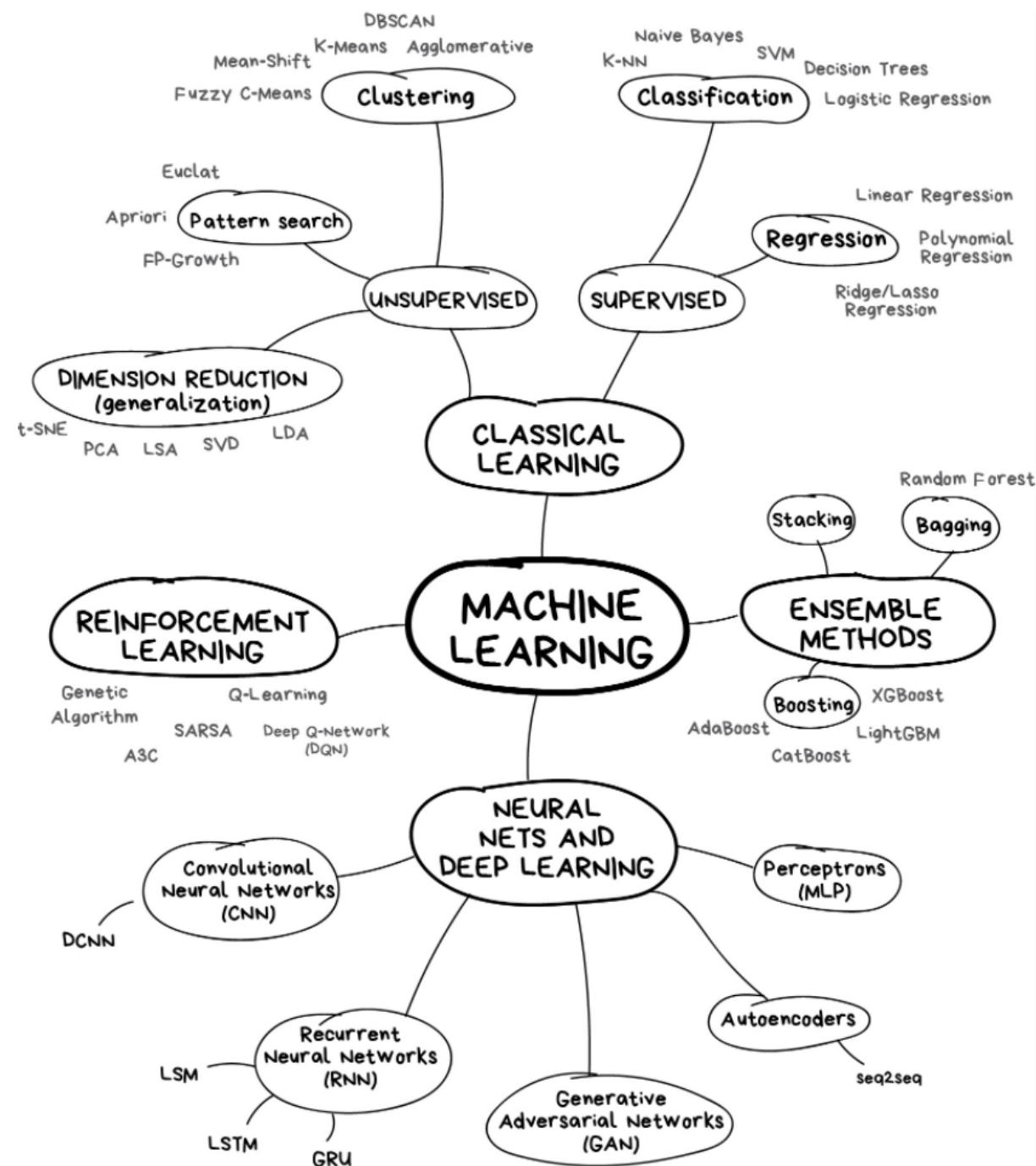
15050 × 84400 3m pixels
Lunda Sul, Angola

NASA MODIS 500m Burned Area Product

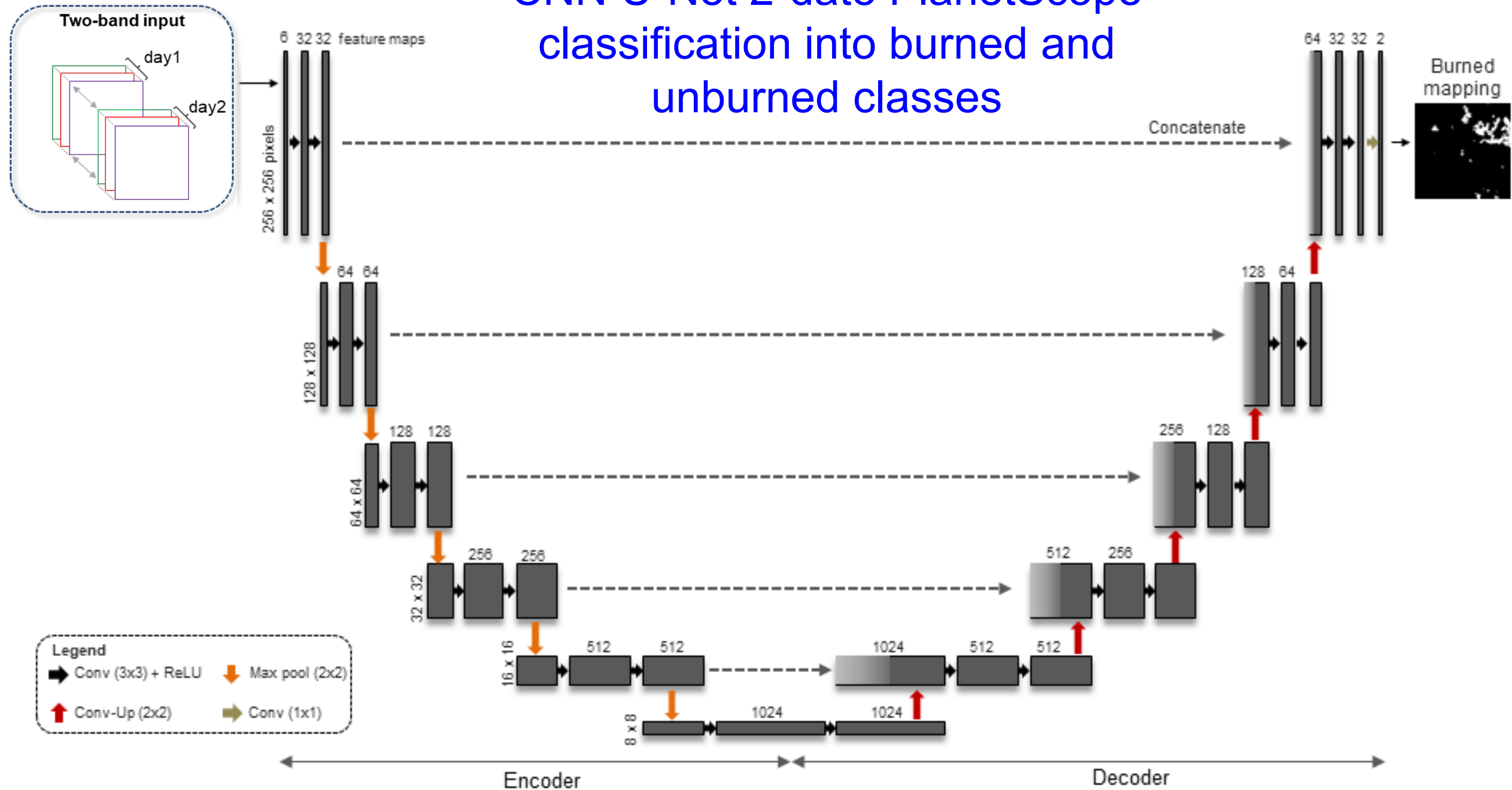
Stage 3 Validation by comparison with higher spatial resolution 30m Landsat derived independent reference data



Locations of 558 two date Landsat image pairs **selected by stratified random sampling in space and time**; pairs were visually interpreted into burned, unburned, and unmapped classes

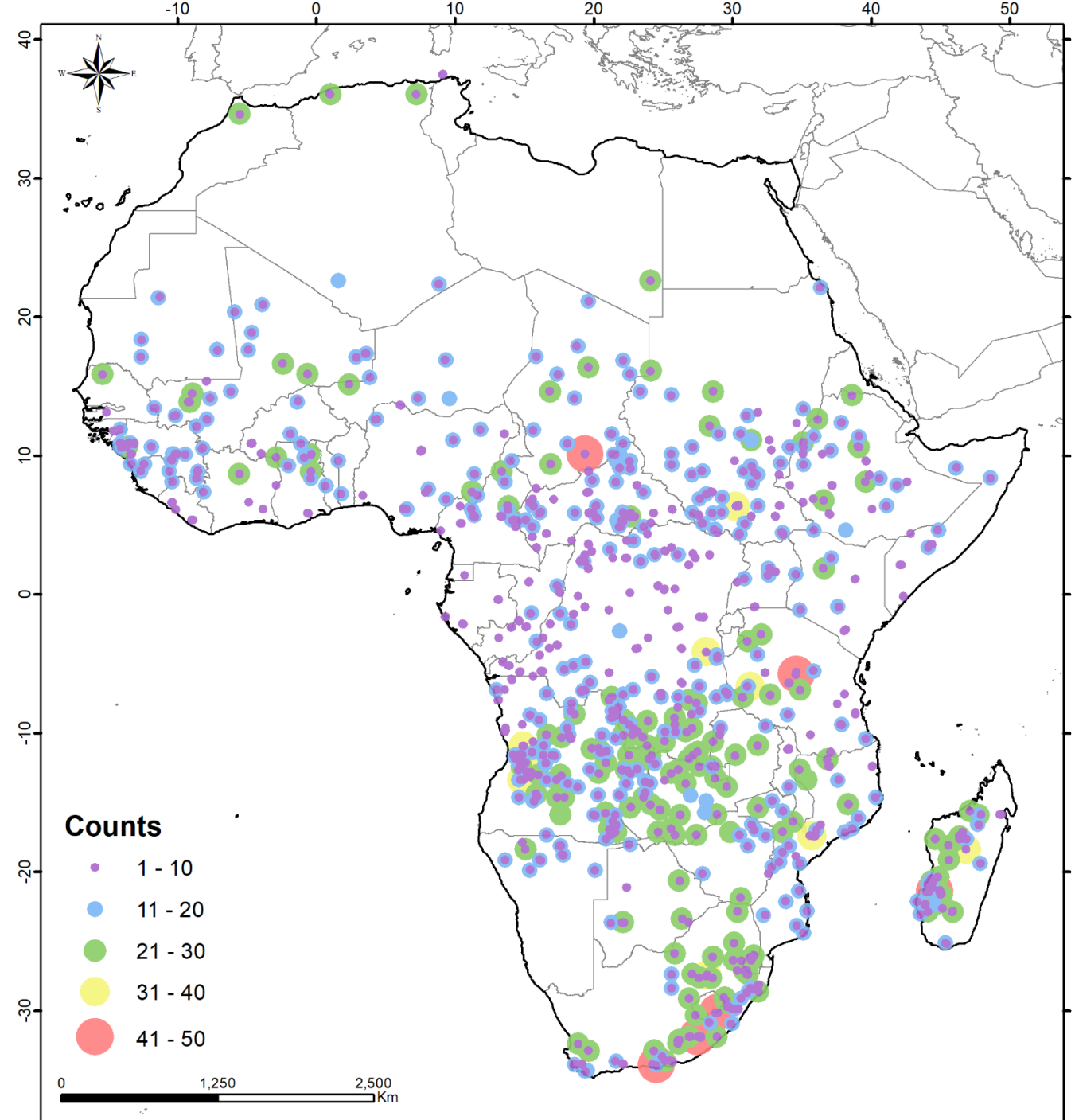


CNN U-Net 2-date PlanetScope classification into burned and unburned classes



Fast prototyping with the NASA Landsat burned area training data

Total: 12,497 Planetscope images
(2019-2020)
all with cloud cover <30%



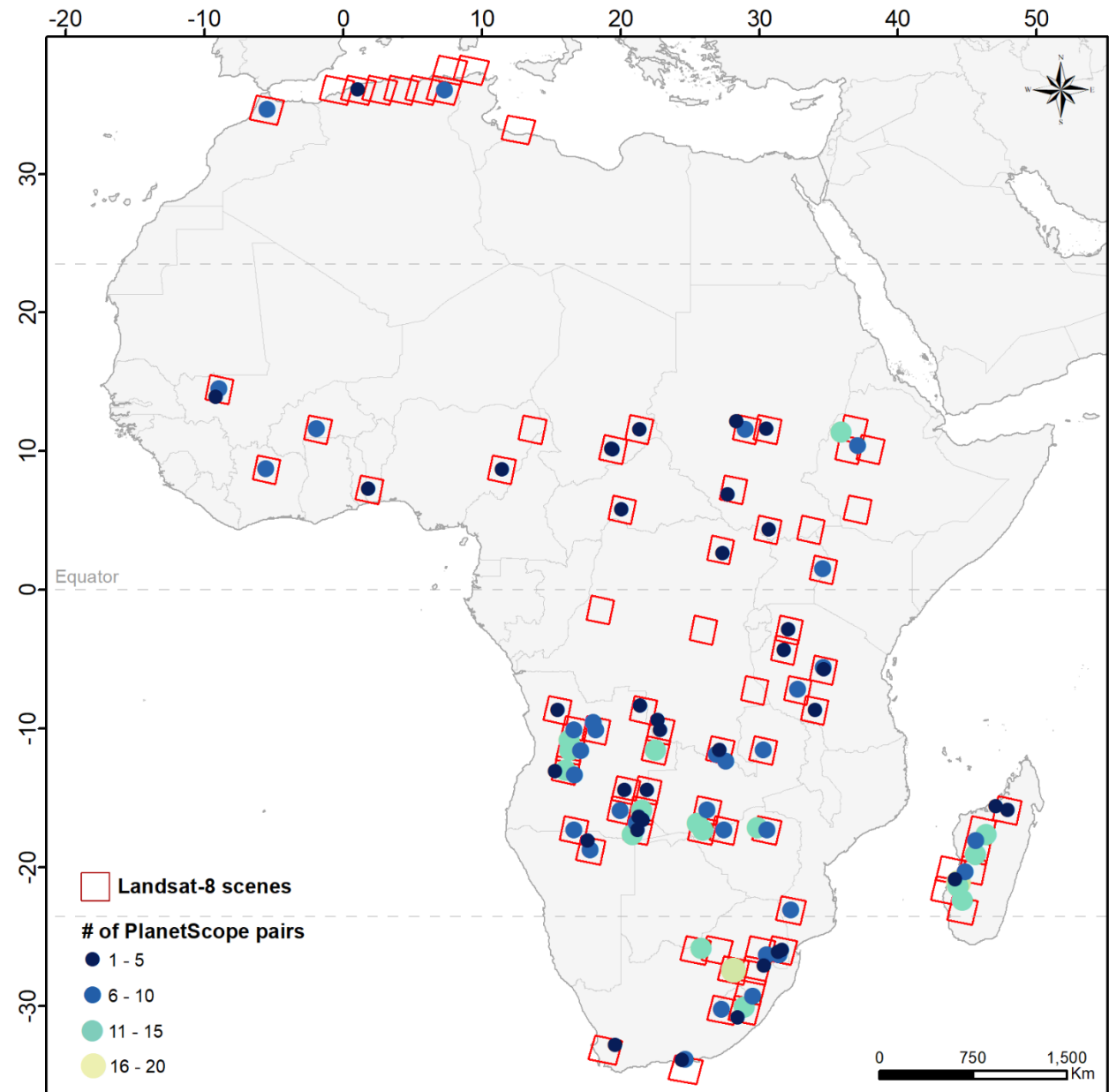
Deep Learning high resolution burned area mapping by transfer learning from Landsat-8 to PlanetScope

Martins, V.S.^a, Roy, D.P.^{a,b,*}, Huang, H.^a, et al.,
Remote Sensing of Environment, In Review

Down-selected 12,497 PlanetScope images to 607 two-date image pairs:

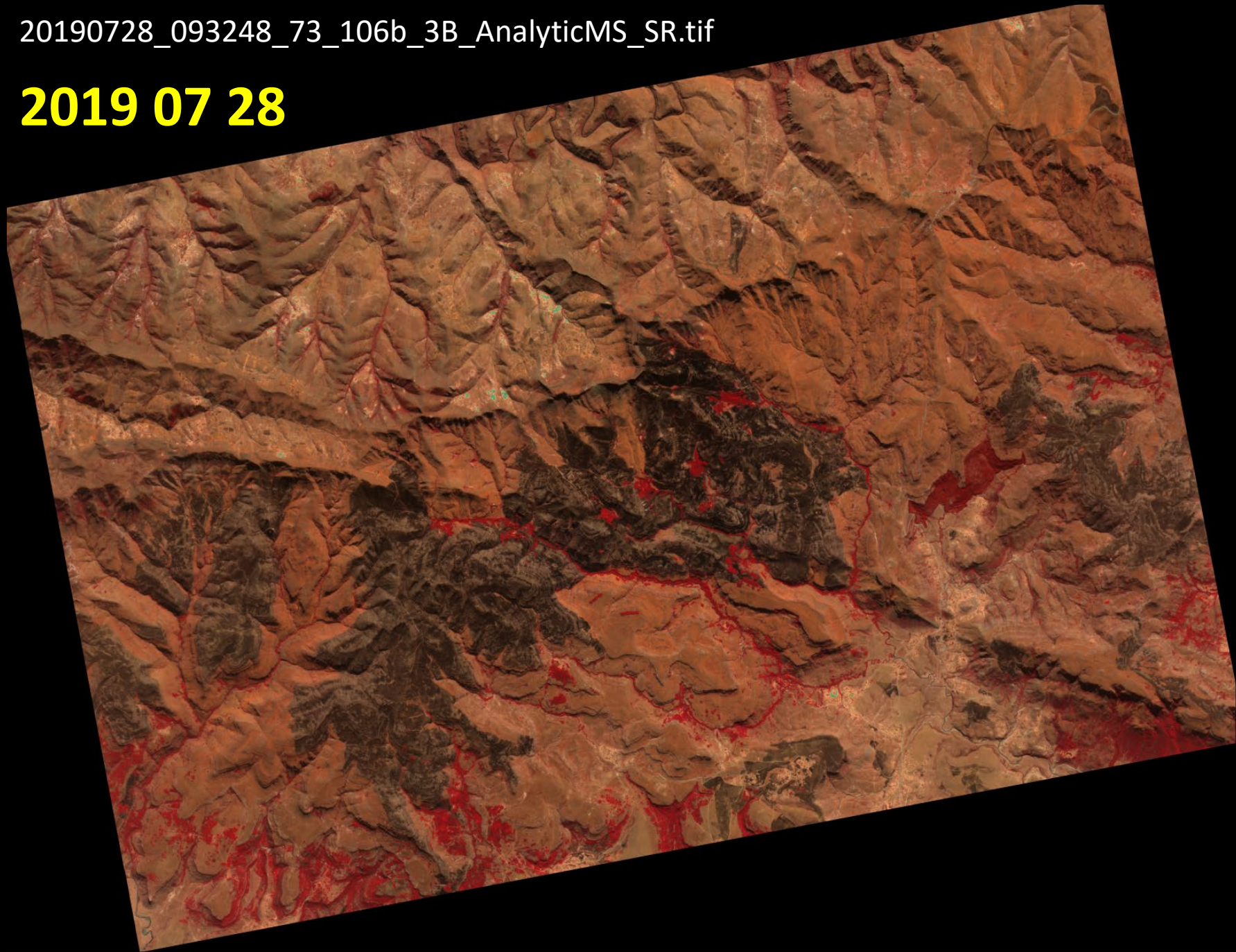
- images acquired one day apart
- $\geq 25 \text{ km}^2$ overlapping spatial area that was $\geq 75\%$ cloud- and shadow-free in both images
- solar zenith angle differences between images $< 5^\circ$
- fell within or intersected the 30 m Landsat burned area reference mapped areas

Set aside 20 two-date image pairs and interpreted them into burned/unburned for validation.



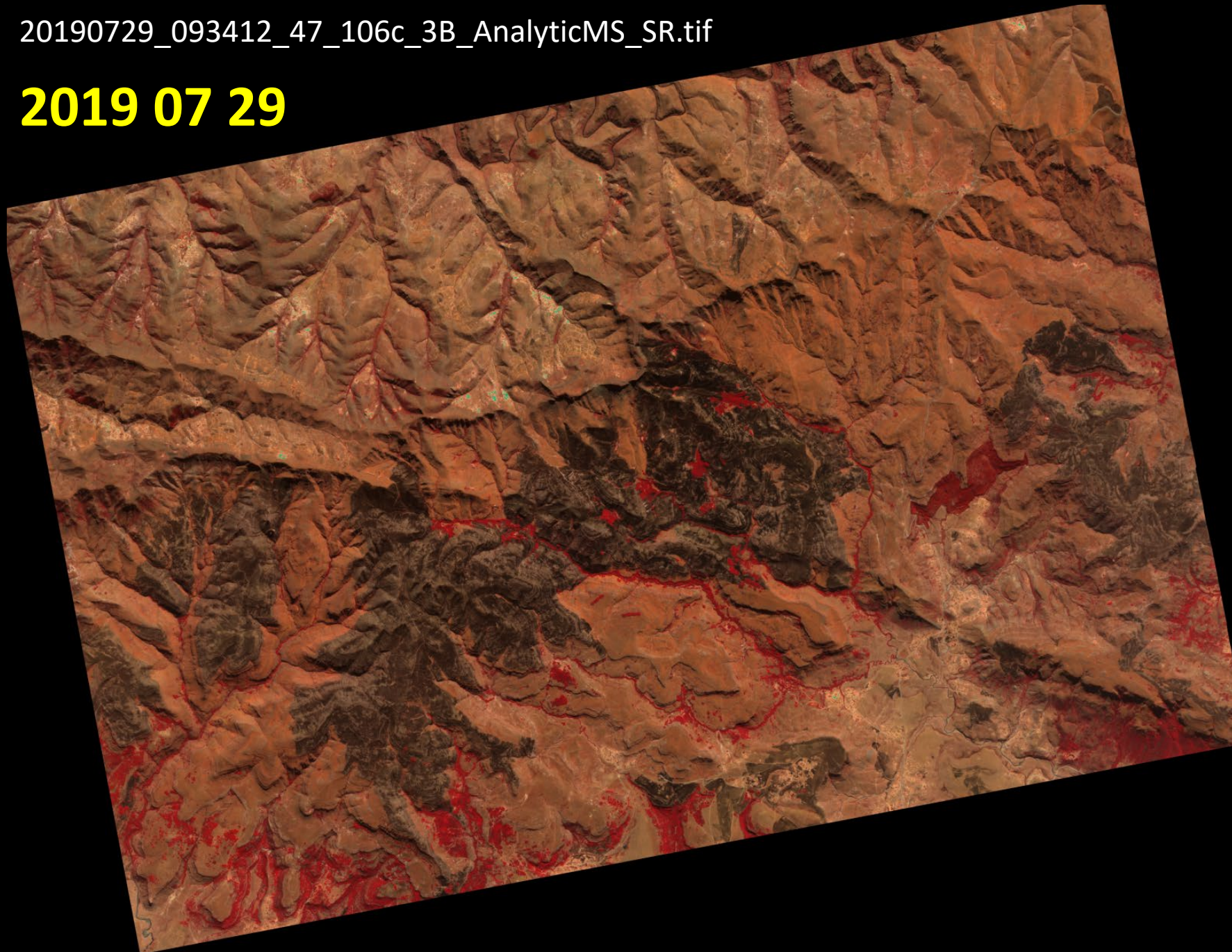
20190728_093248_73_106b_3B_AnalyticMS_SR.tif

2019 07 28

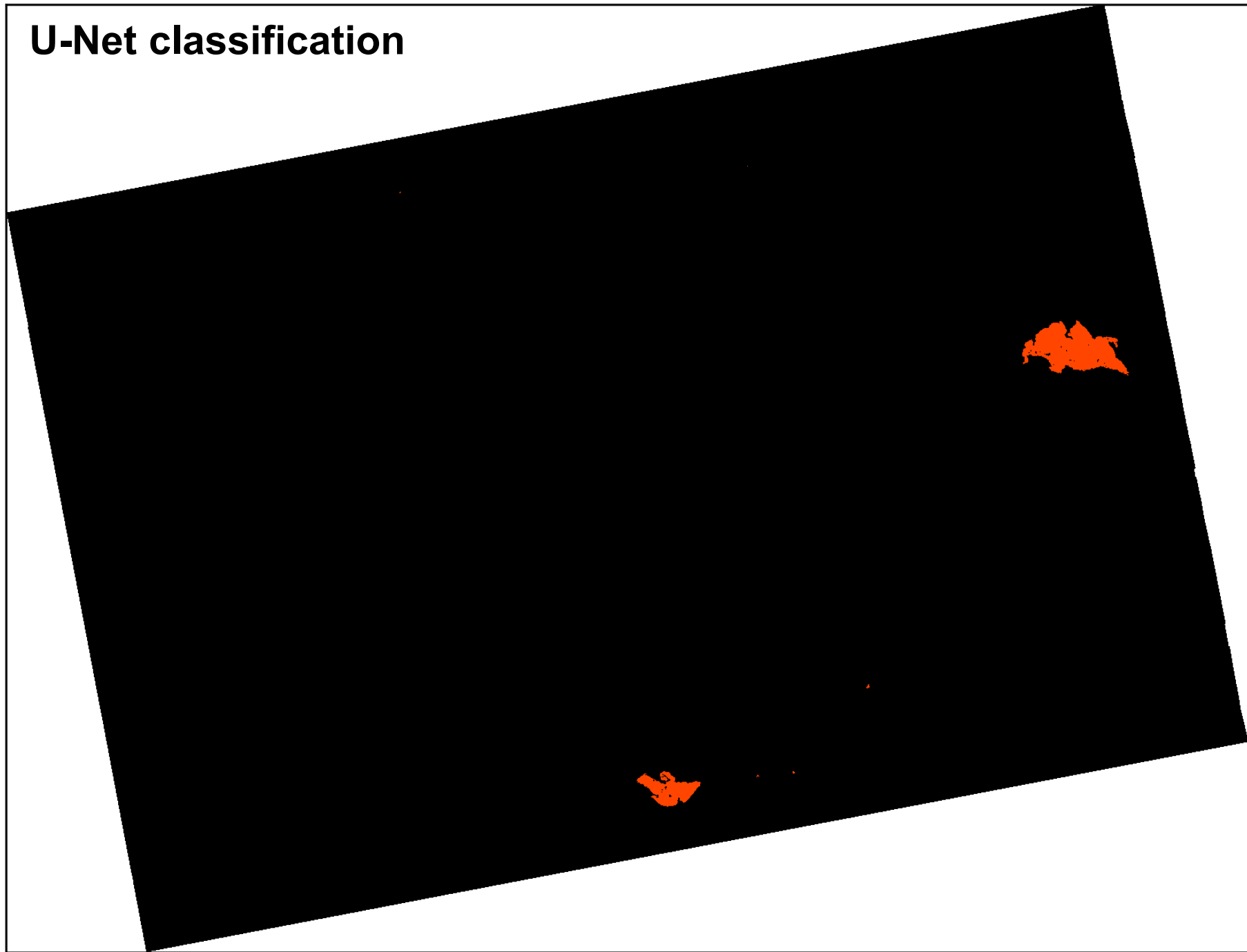


20190729_093412_47_106c_3B_AnalyticMS_SR.tif

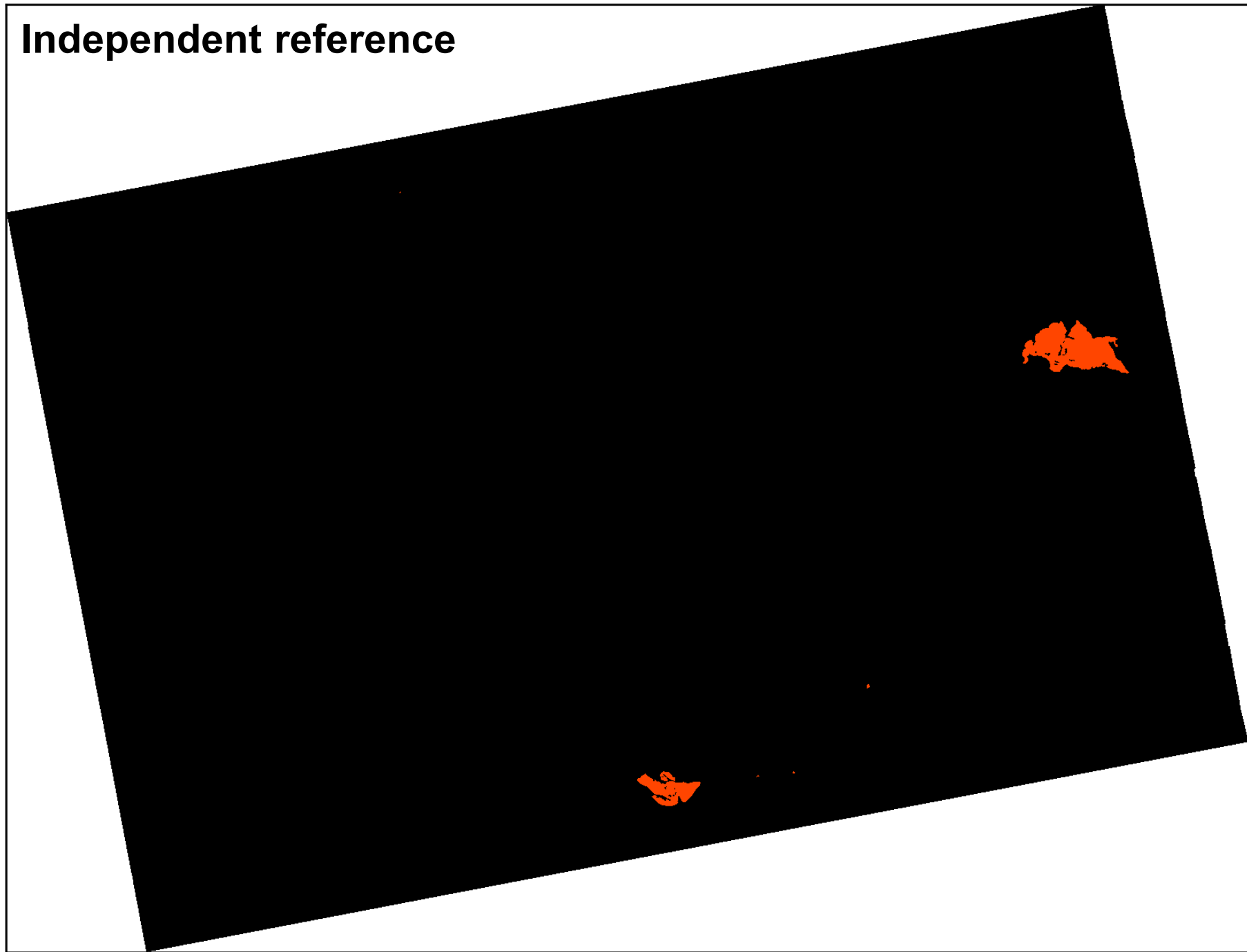
2019 07 29



U-Net classification

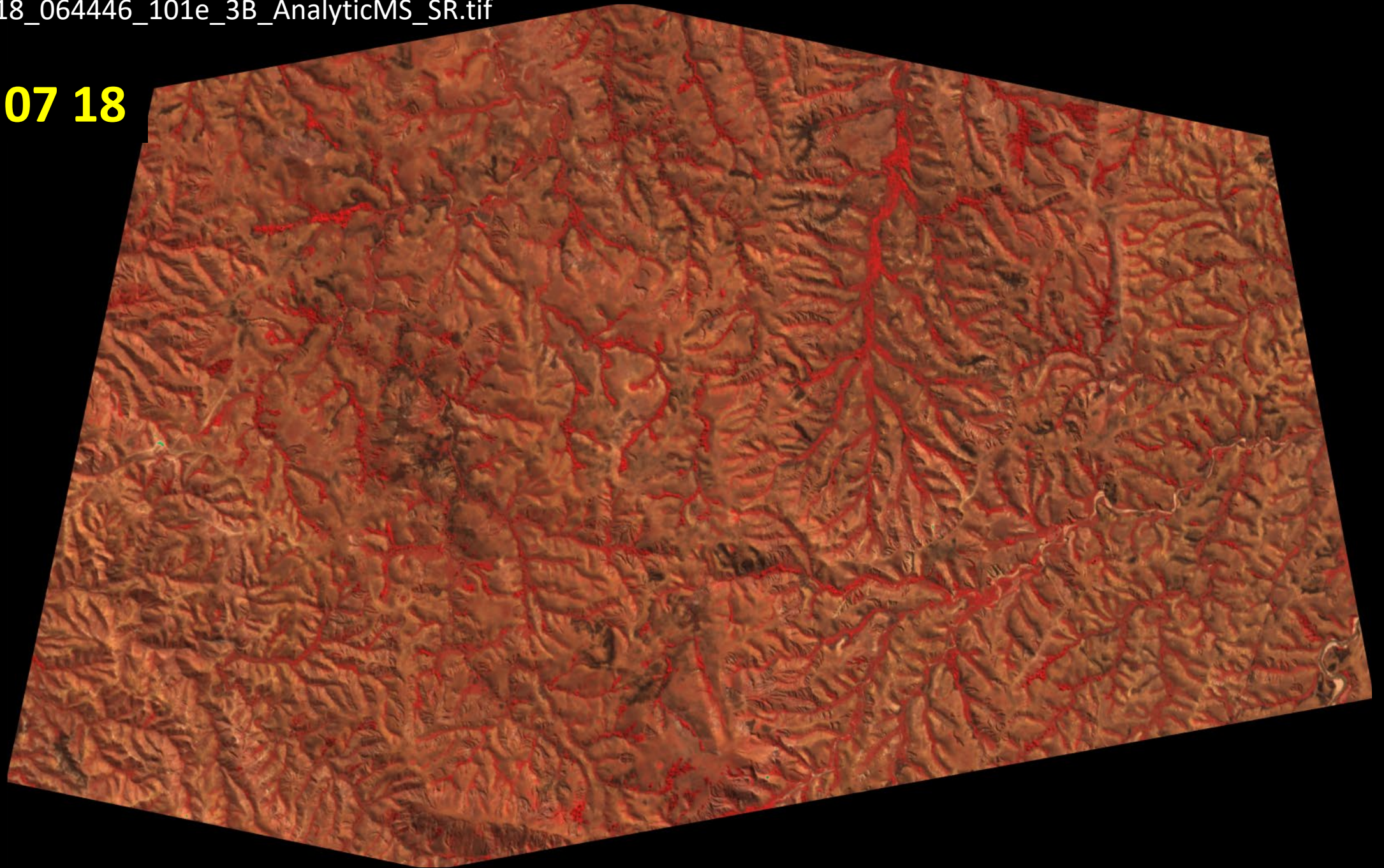


Independent reference



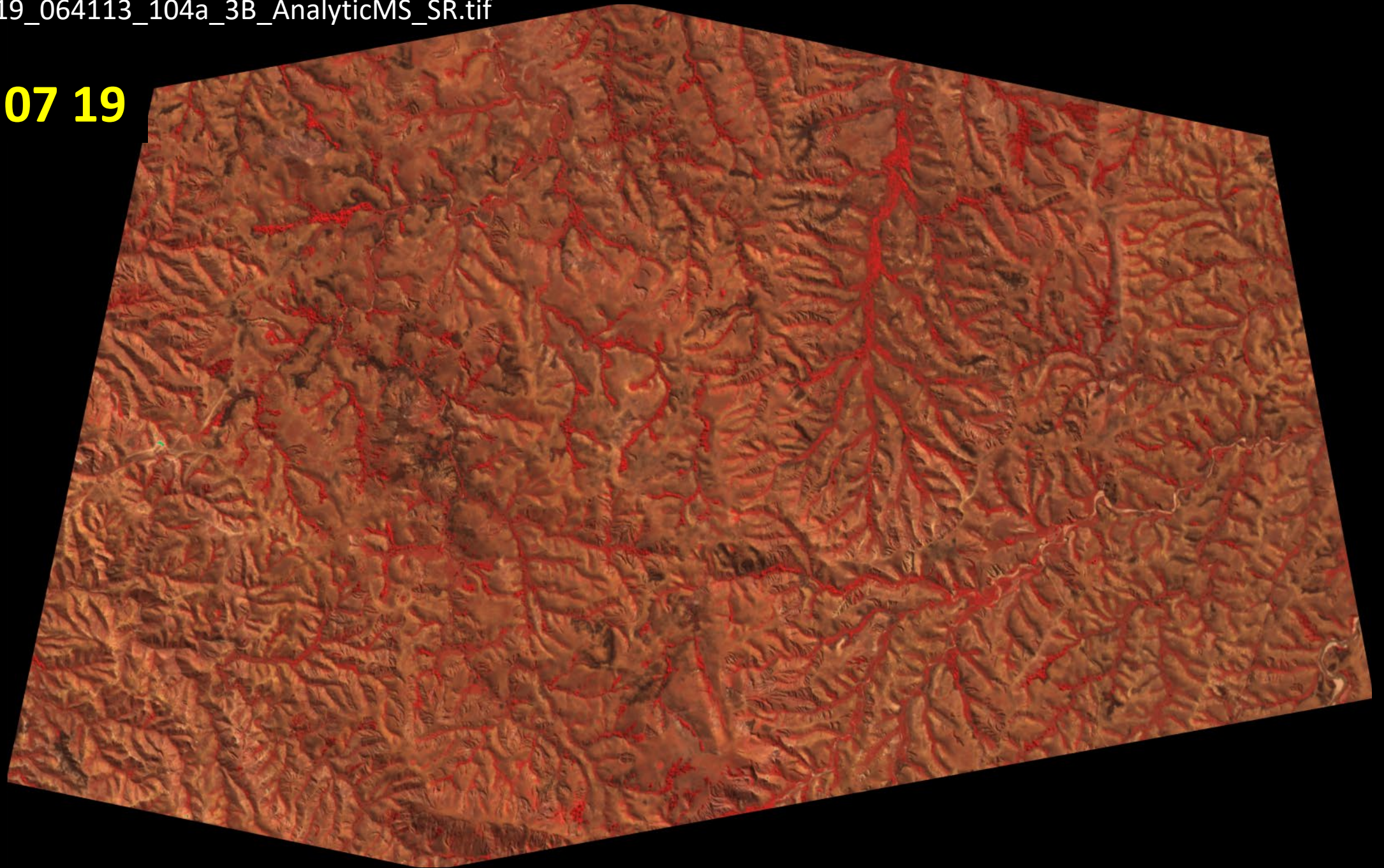
20190718_064446_101e_3B_AnalyticMS_SR.tif

2019 07 18

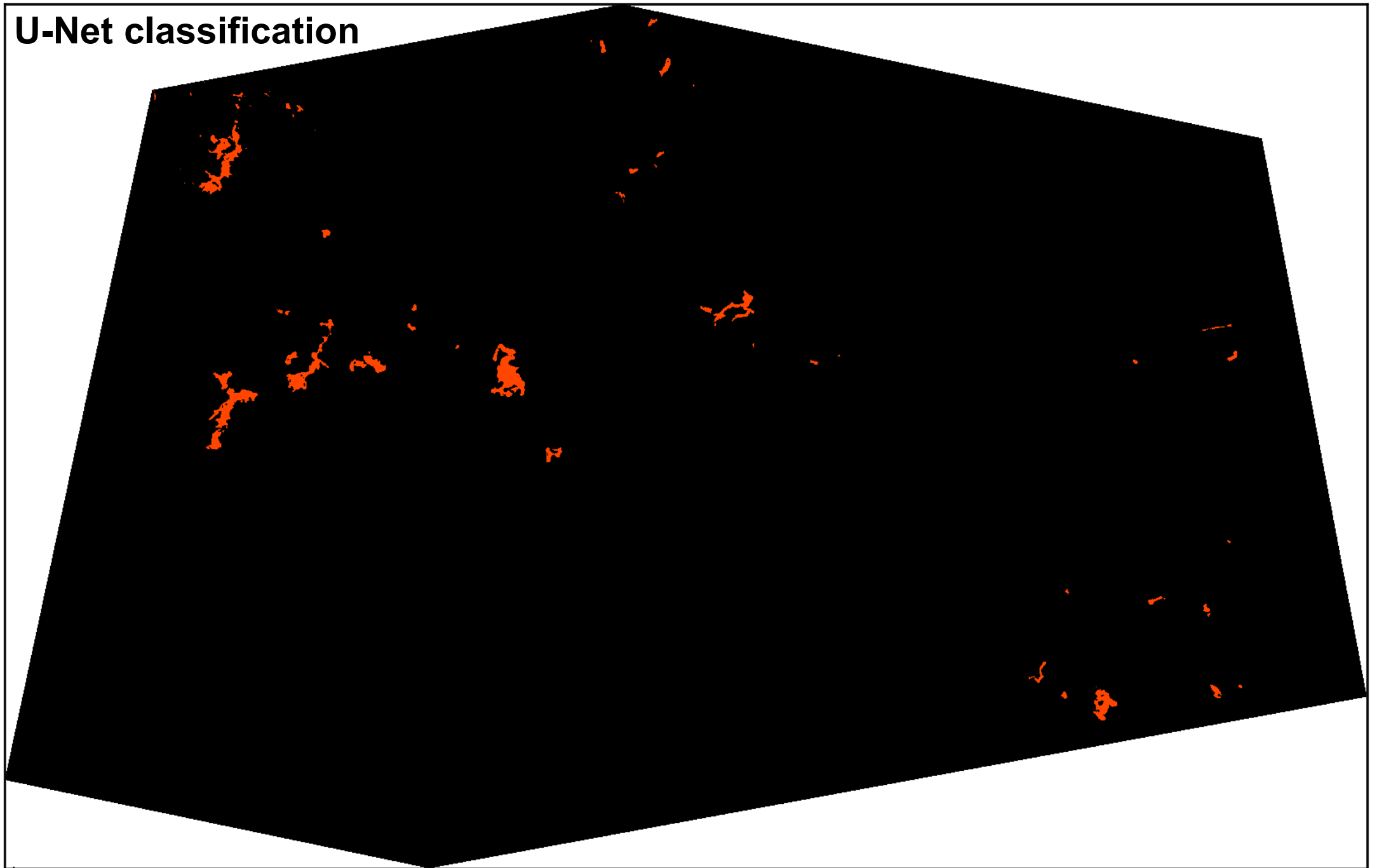


20190719_064113_104a_3B_AnalyticMS_SR.tif

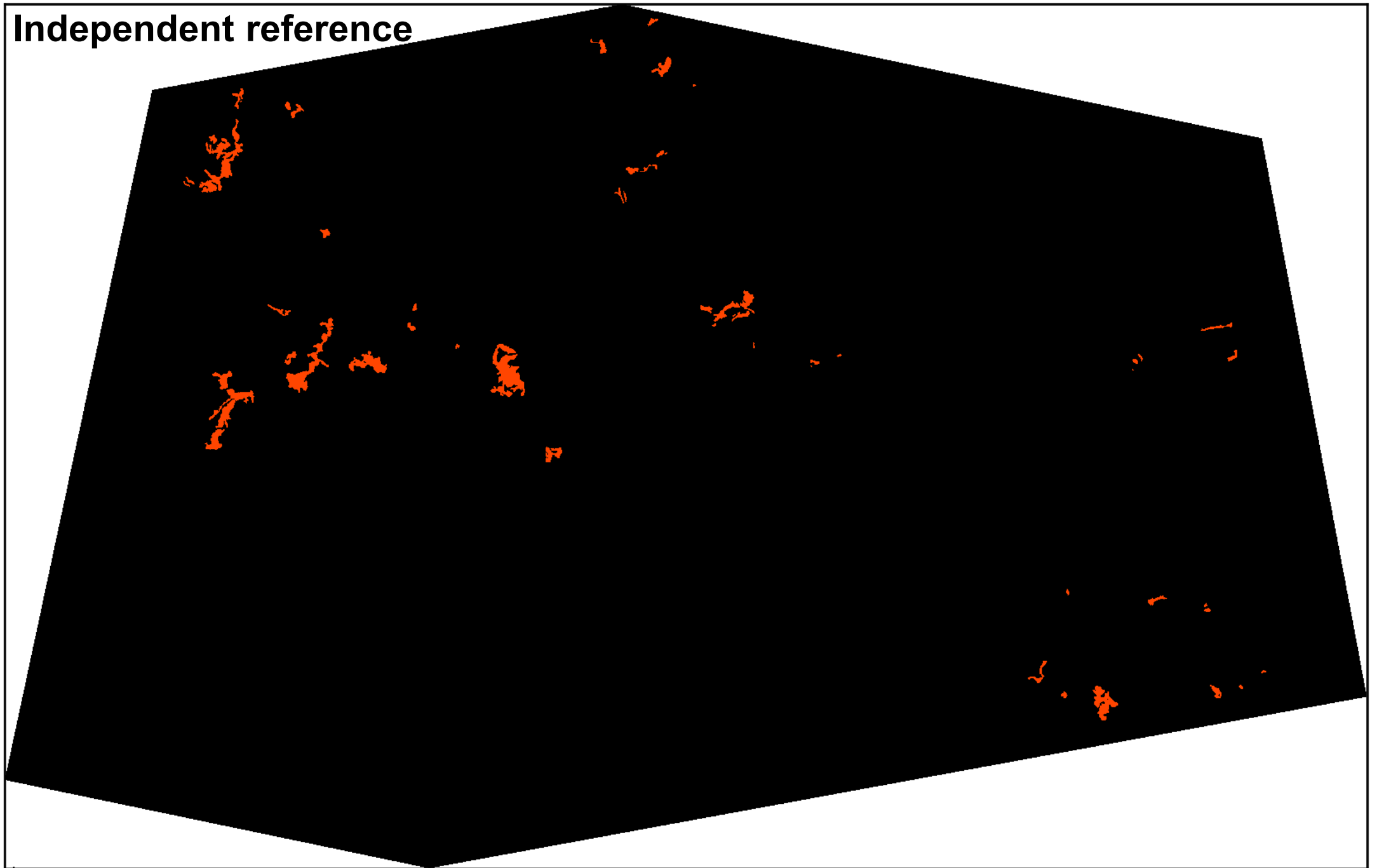
2019 07 19



U-Net classification

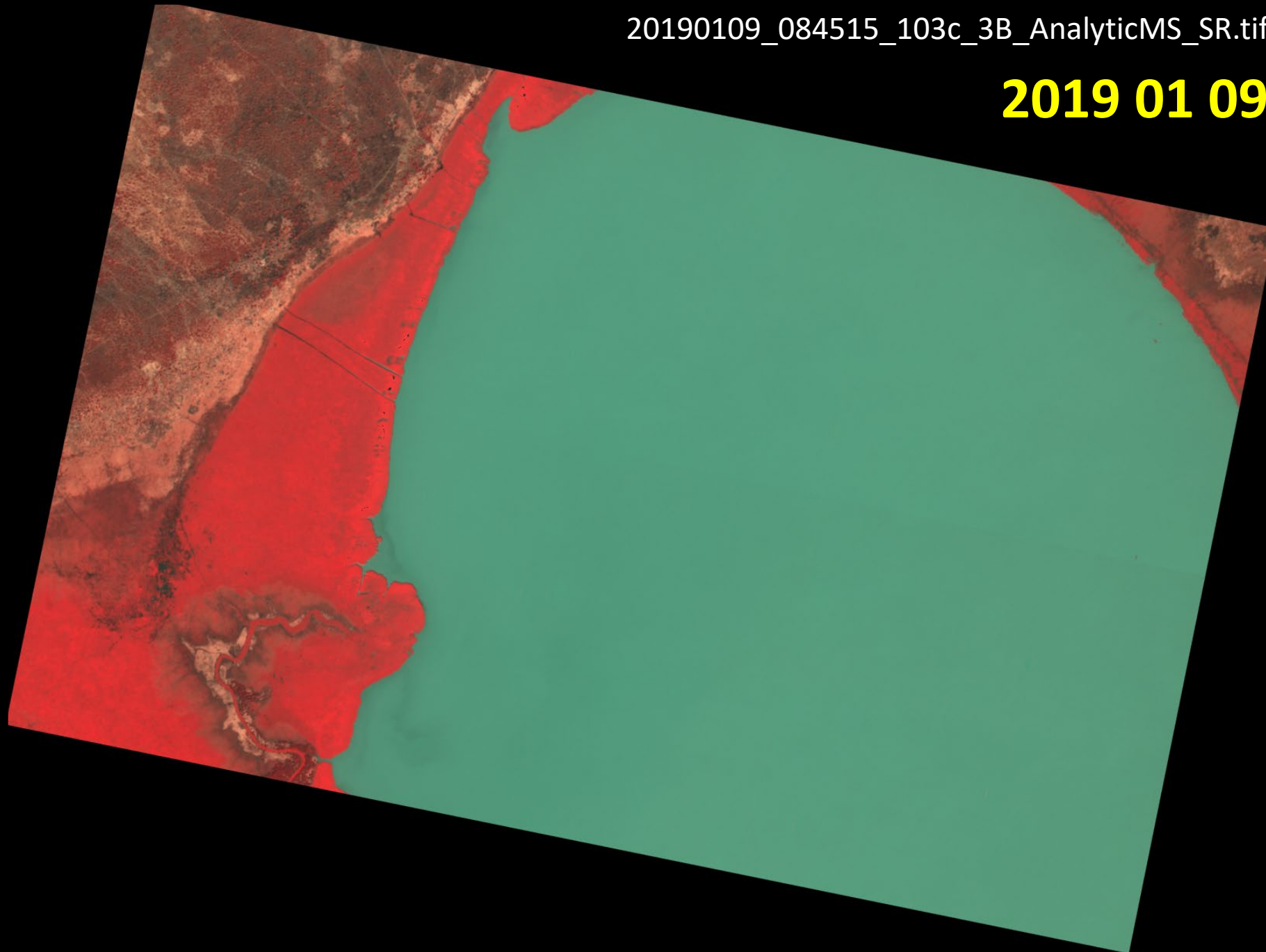


Independent reference



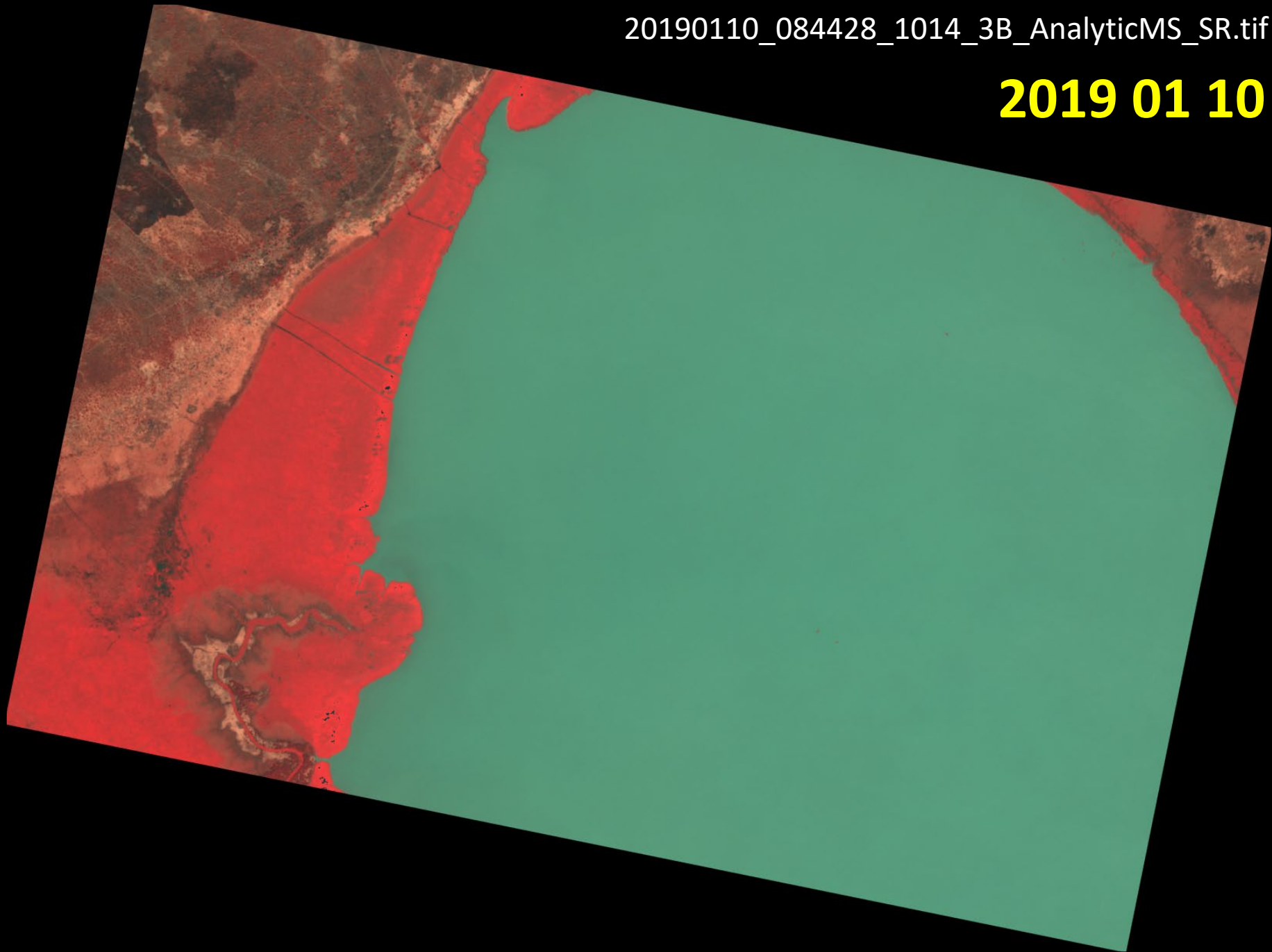
20190109_084515_103c_3B_AnalyticMS_SR.tif

2019 01 09

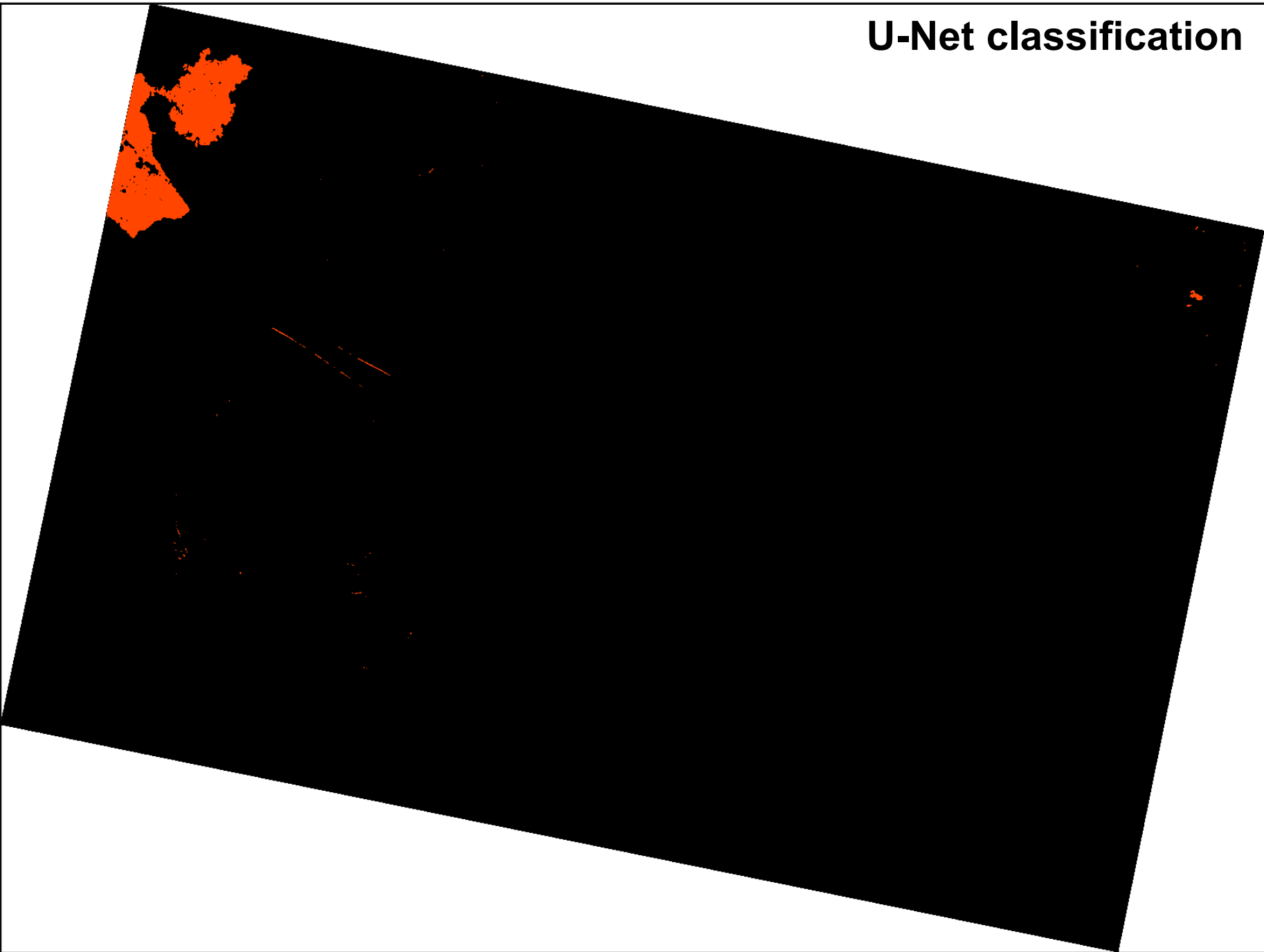


20190110_084428_1014_3B_AnalyticMS_SR.tif

2019 01 10



U-Net classification

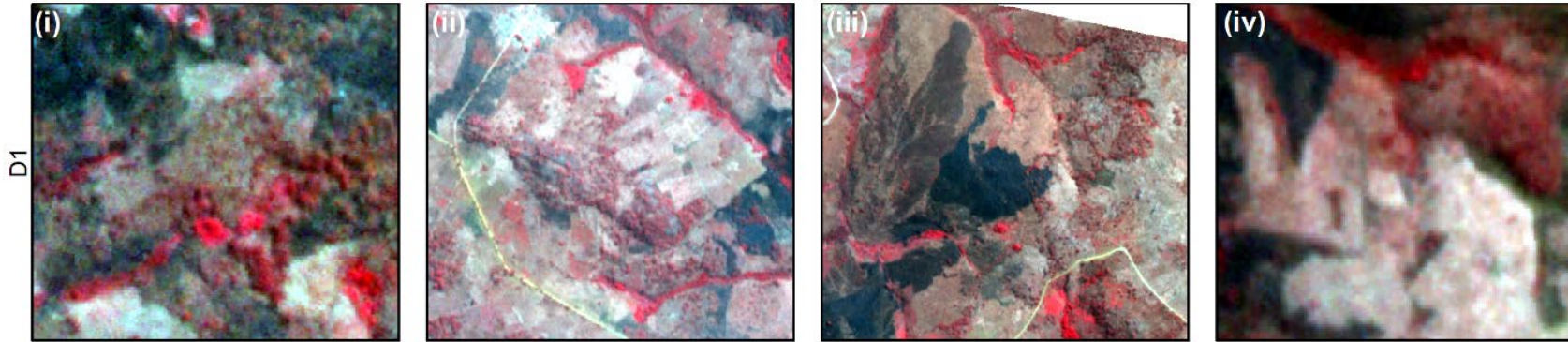


Independent reference



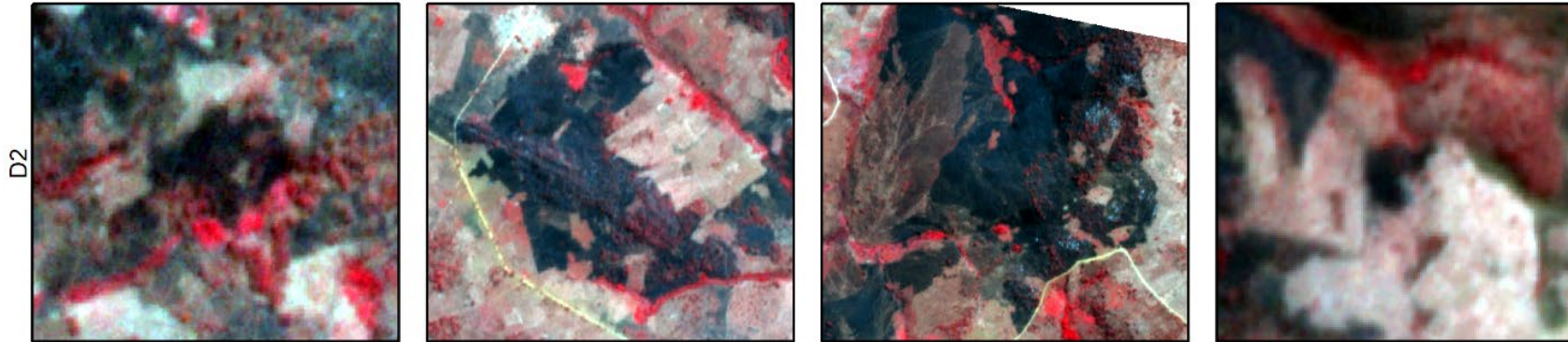
Analysis of different sizes of burned area

July 24

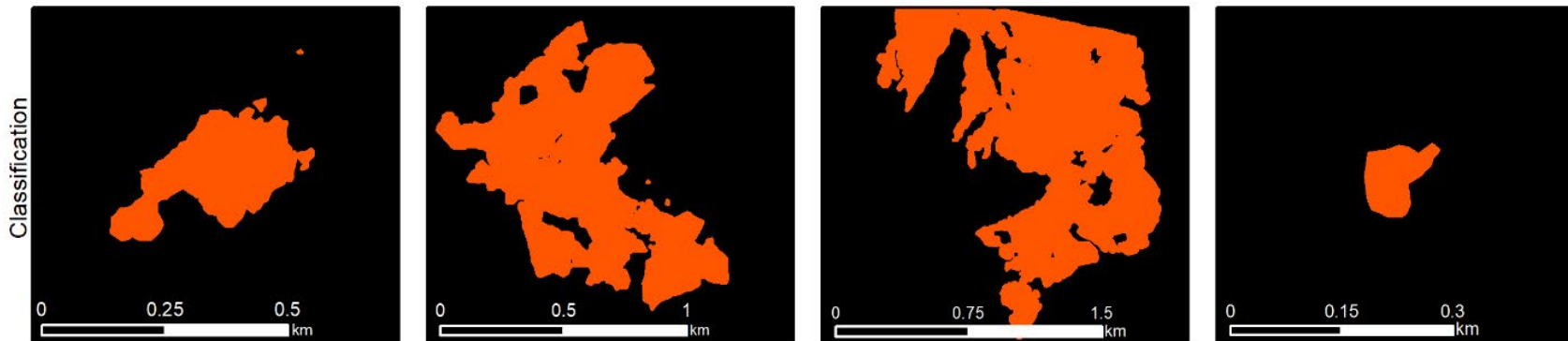


PlanetScope
3 m
false color
(NIR/R/G)

July 25



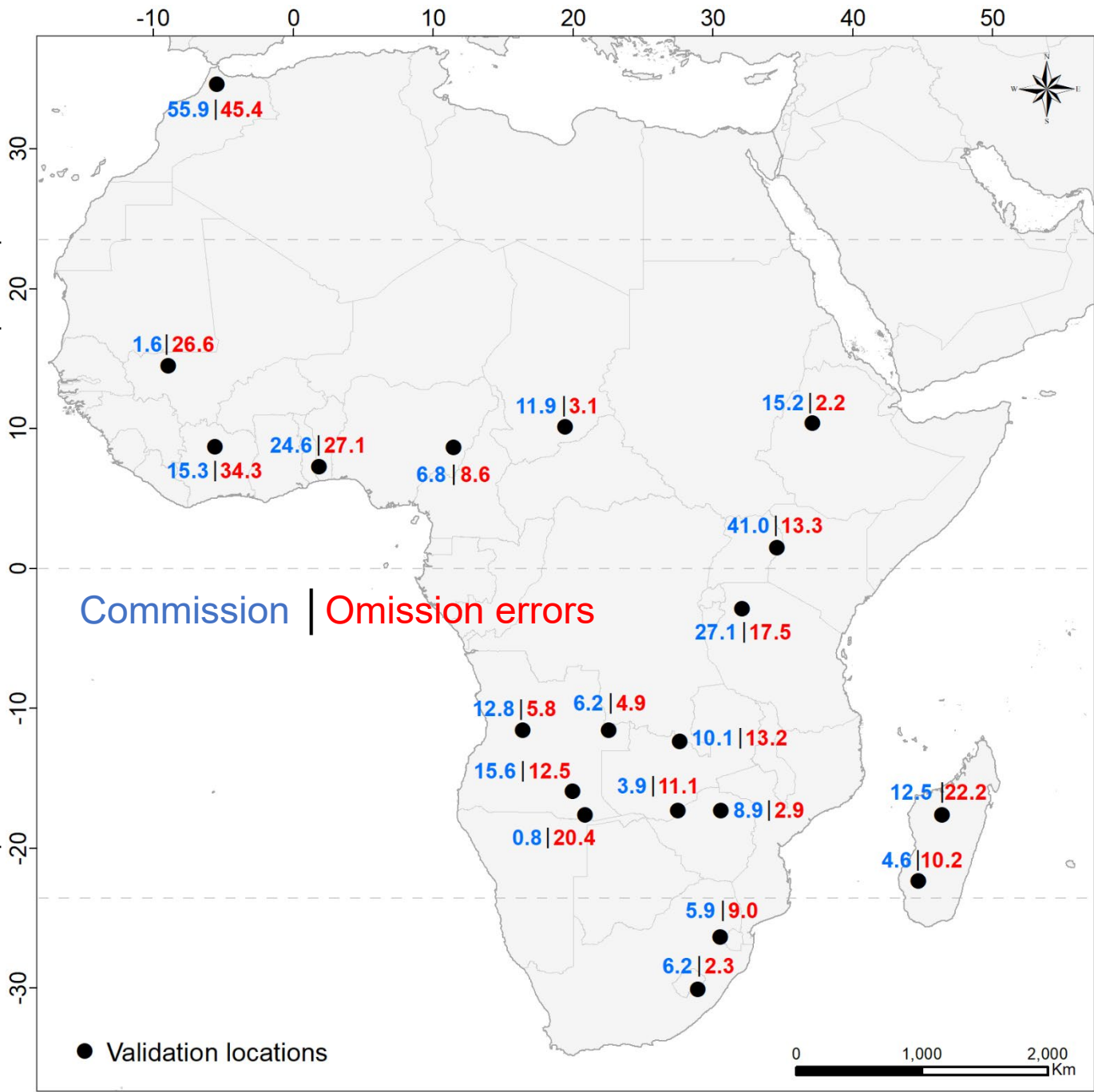
Cuanza Sul,
Angola



Validation results considering 20 manually interpreted Planetscope image pairs

Classified	Reference		
	Burned [pixels]	Unburned [pixels]	Total [pixels]
Burned [pixels]	1,383,404	136,572	1,519,976
Unburned [pixels]	136,060	337,737,527	337,873,587
Total [pixels]	1,519,464	337,874,099	339,393,563

Overall:
Commission error = 8.98%
Omission error = 8.95%



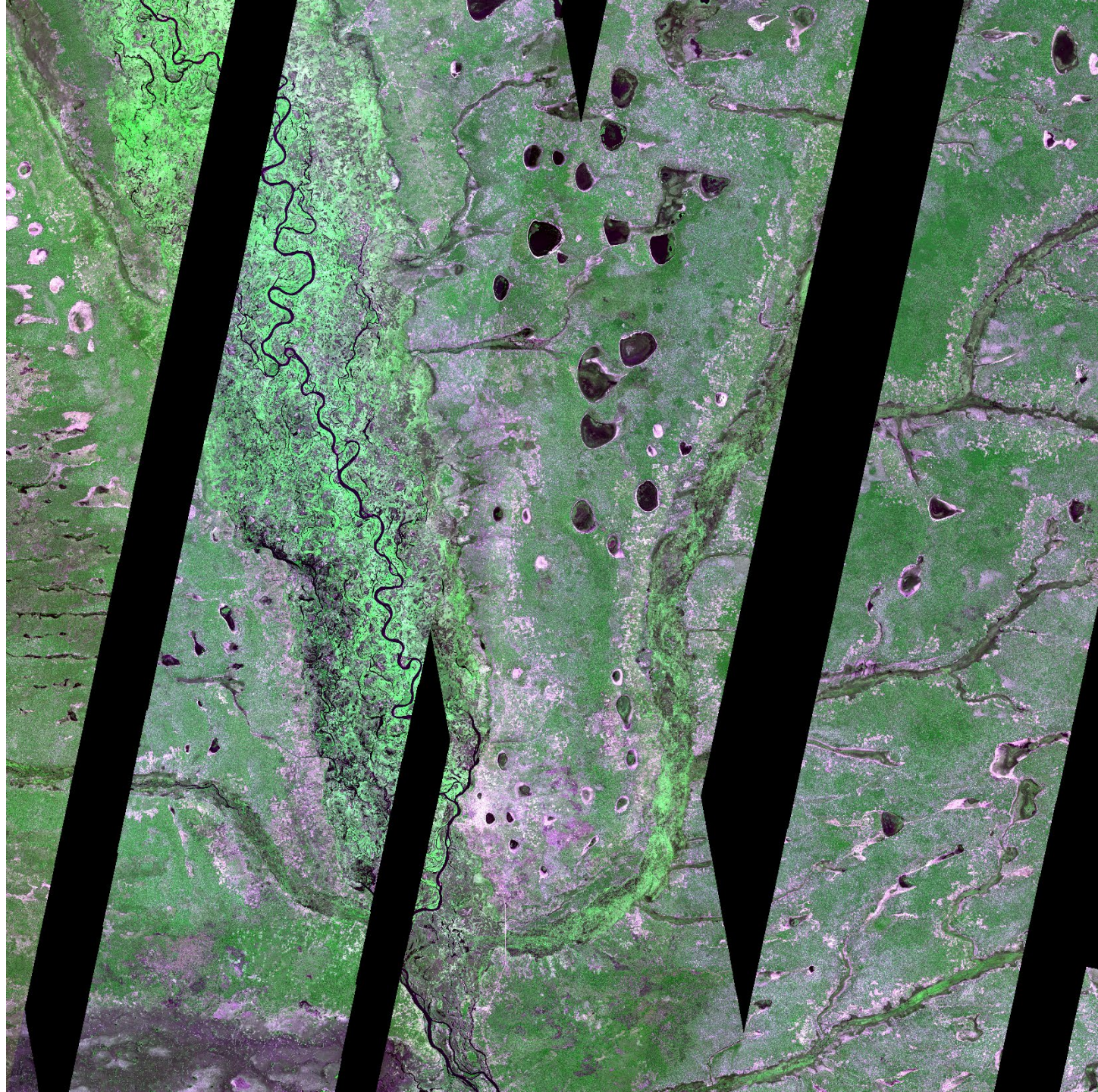
Summary

- Medium resolution Sentinel-2 and Landsat-8 data enable mapping of
 - small (~30 m) spatially fragmented burns
 - low combustion completeness burns
- Landsat Next and next generation Sentinel-2 will continue the medium global resolution record
- Commercial high spatial & high temporal resolution data
 - new potential for automated burned area mapping of small (<5 m) burns
 - issues with low sensor calibration, band pass differences, geolocation
 - deep learning has real potential

PlanetScope

July 3rd

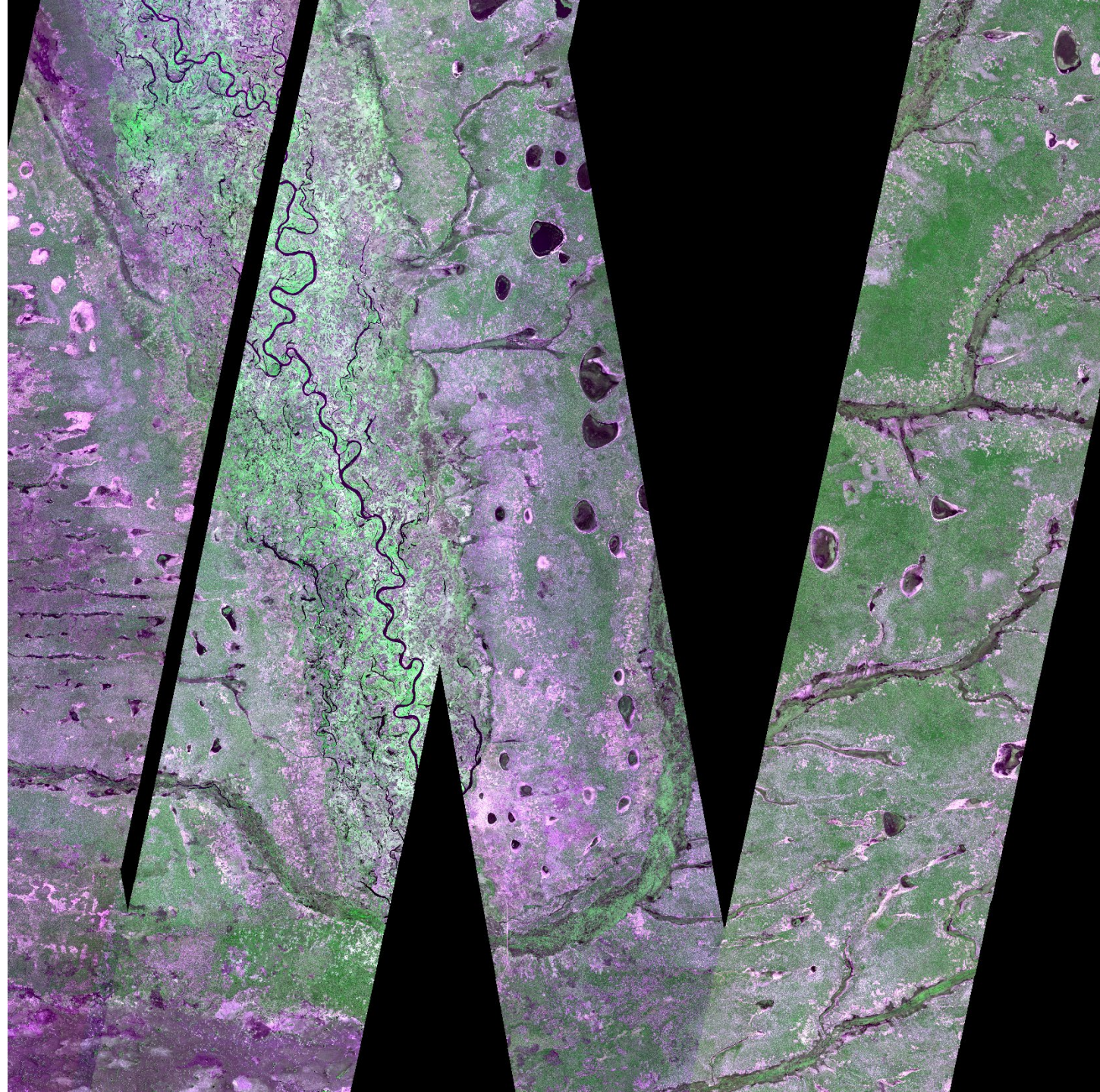
Preliminary
Example
validation



PlanetScope

July 31st

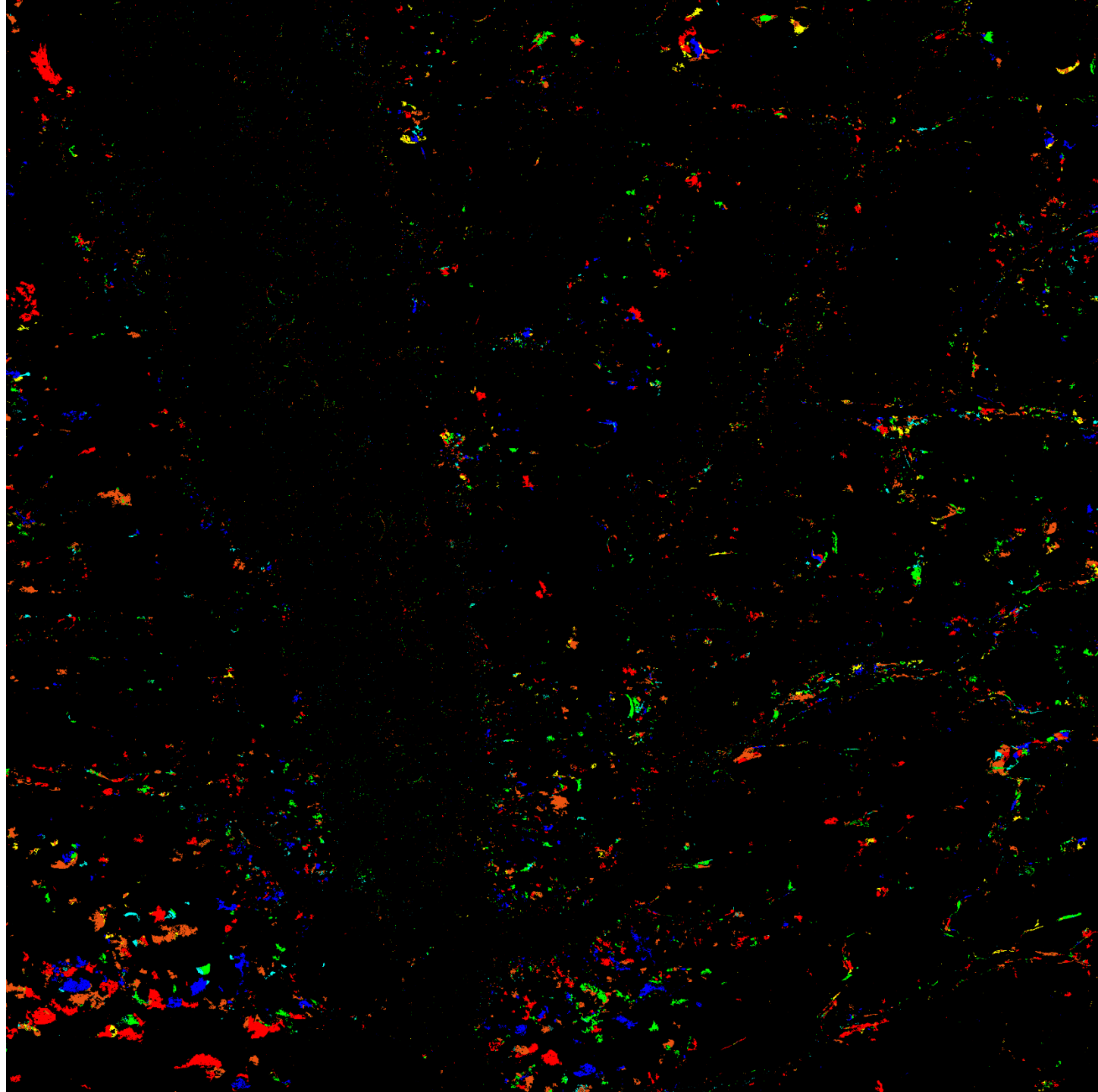
Preliminary
Example
validation



Sentinel-2A/2B
Landsat-8

Preliminary
Example
validation

0-2
3-5
6-8
9-11
12-14
15-17
18-20
21-23
24-27
28-31



Harmonized Landsat Sentinel-2

Comparison of July burned proportions mapped by 3 m PLANET reference and 30 m Landsat-8 & Sentinel-2

8093.4 km ² compared		PLANET reference (assumed to be truth)		
		Burned [km ²]	Unburned [km ²]	Row total [km ²]
Landsat-8 & Sentinel-2	Burned [km ²]	83.7	56.4	140.7
	Unburned [km ²]	173.6	7780.3	7953.7
	Column total [km ²]	257.0	7836.7	8093.4

Overall accuracy = 97% Omission error [0-1] = 0.40 Commission error [0-1] = 0.67

Preliminary
example
validation
results



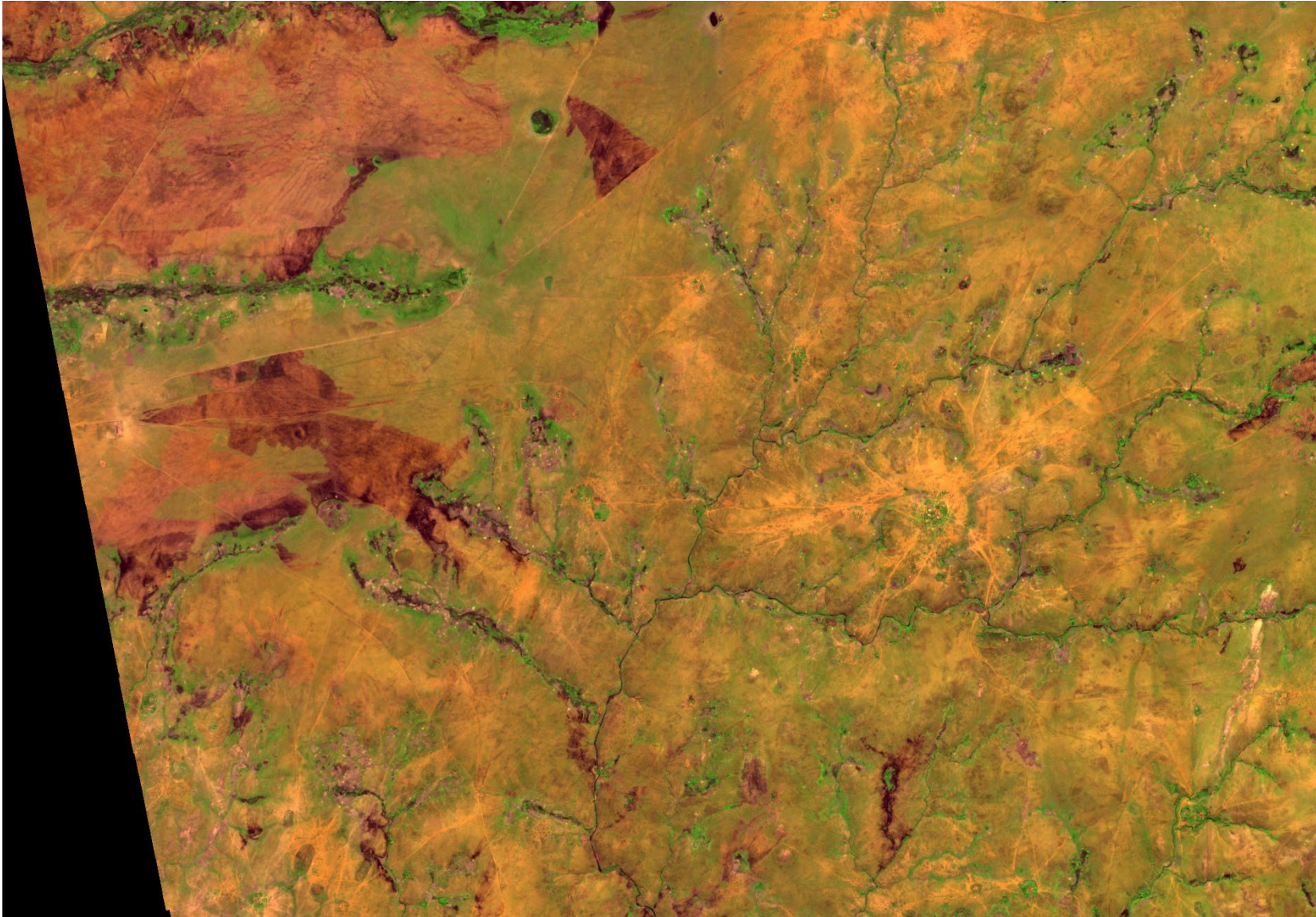
Dove-R

July 12nd 2019

630 nm
820 nm
545 nm
surface reflectance

Isalo National Park
Madagascar

15.4 × 10.7 km
5134 × 3568 3 m pixels

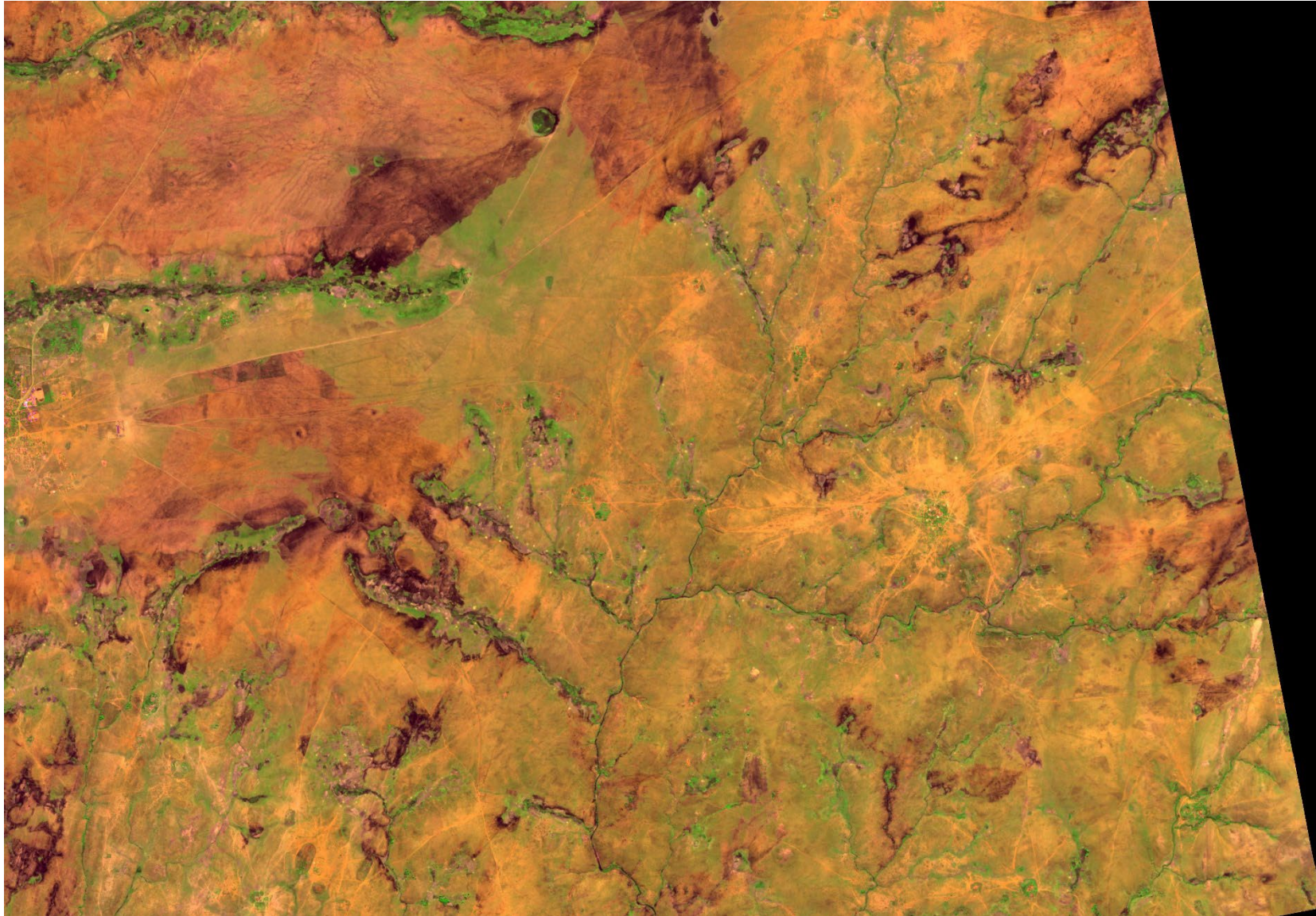




630 nm
820 nm
545 nm
surface reflectance

Isalo National Park
Madagascar

15.4 × 10.7 km
5134 × 3568 3 m pixels



Dove-R

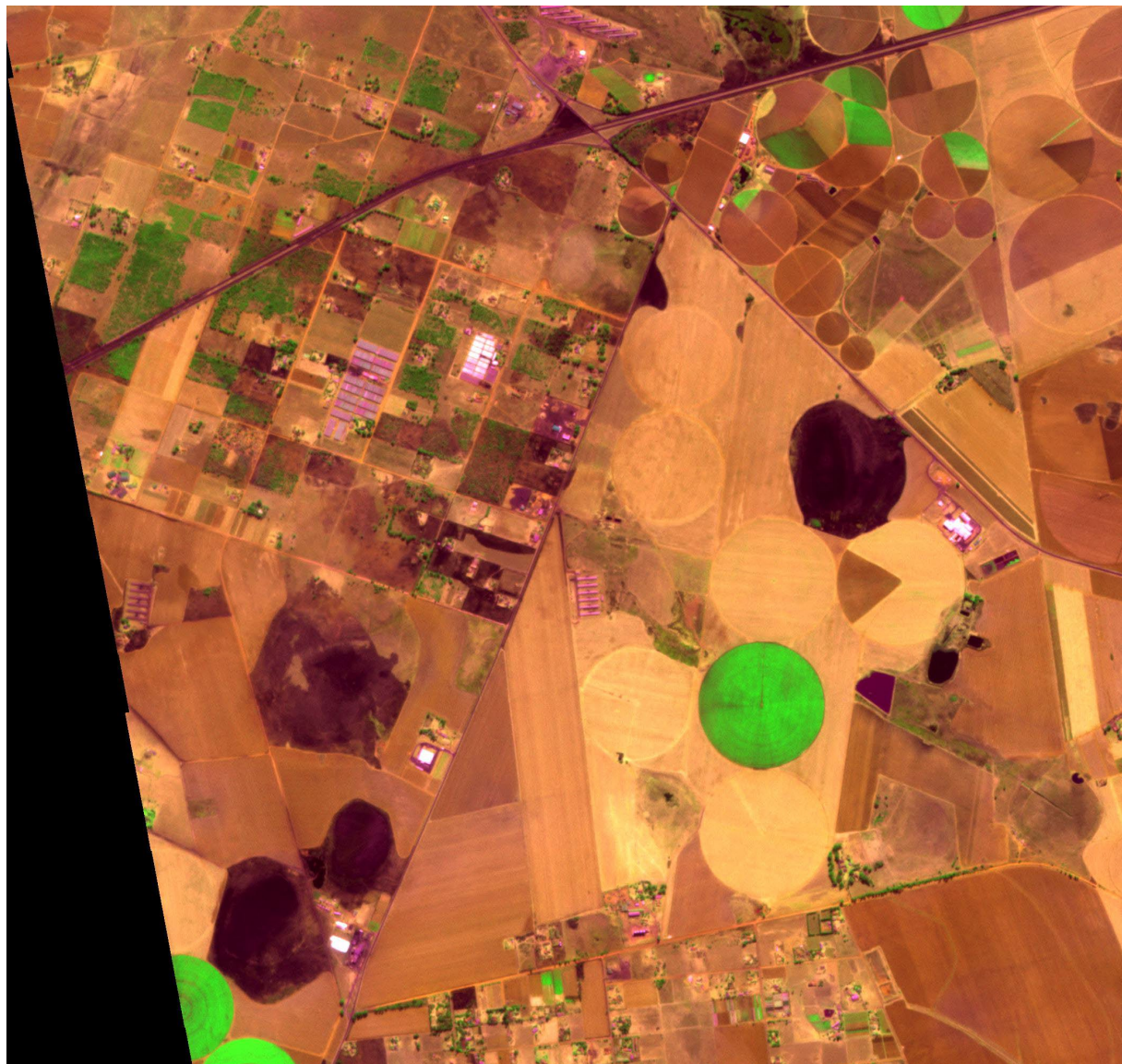
July 16th 2019



630 nm
820 nm
545 nm
surface reflectance

Near Johannesburg,
South Africa

6.4 × 6.0 km
2123 × 1997 3 m pixels



Dove-R

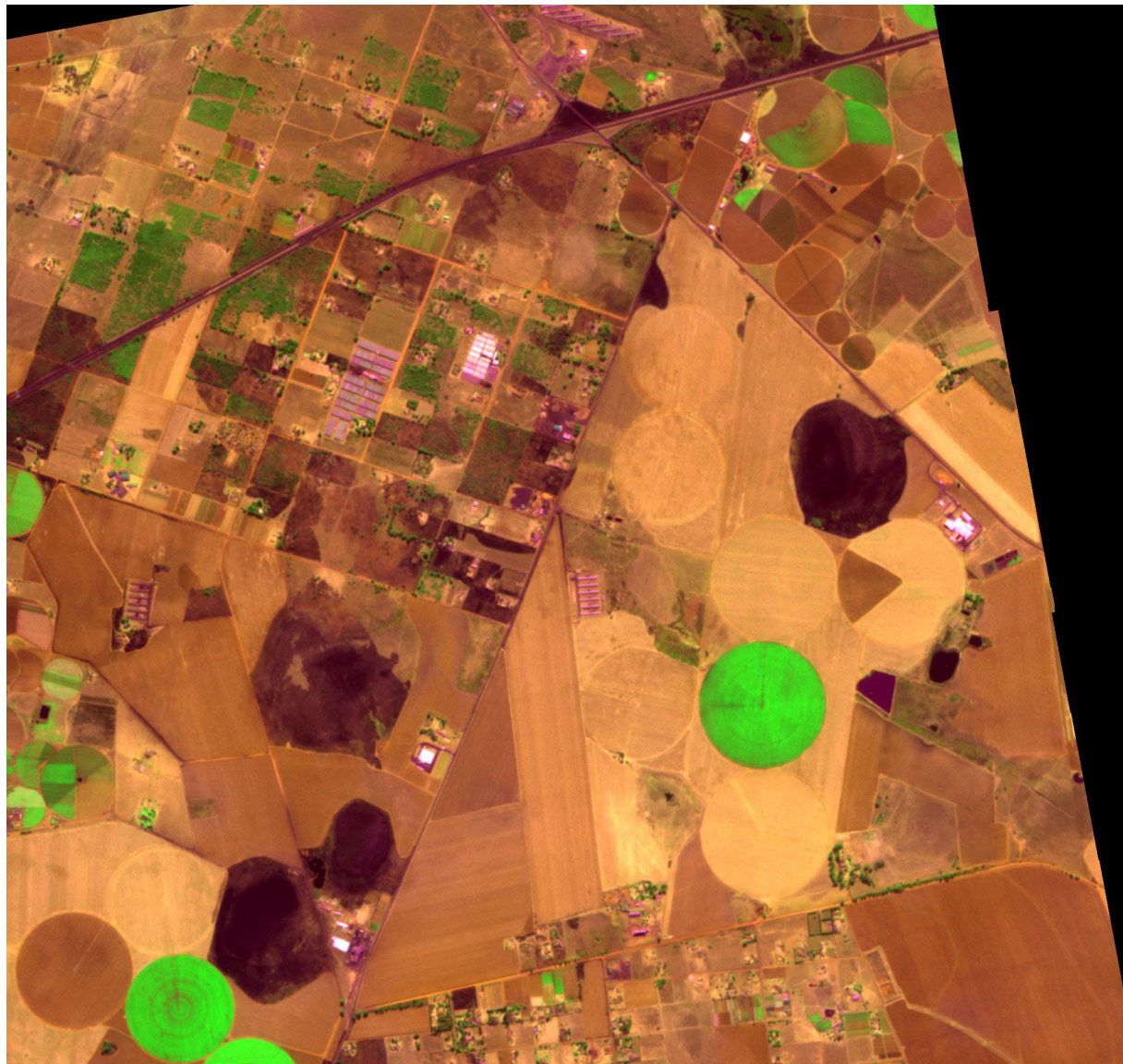
July 25th 2019



630 nm
820 nm
545 nm
surface reflectance

Near Johannesburg,
South Africa

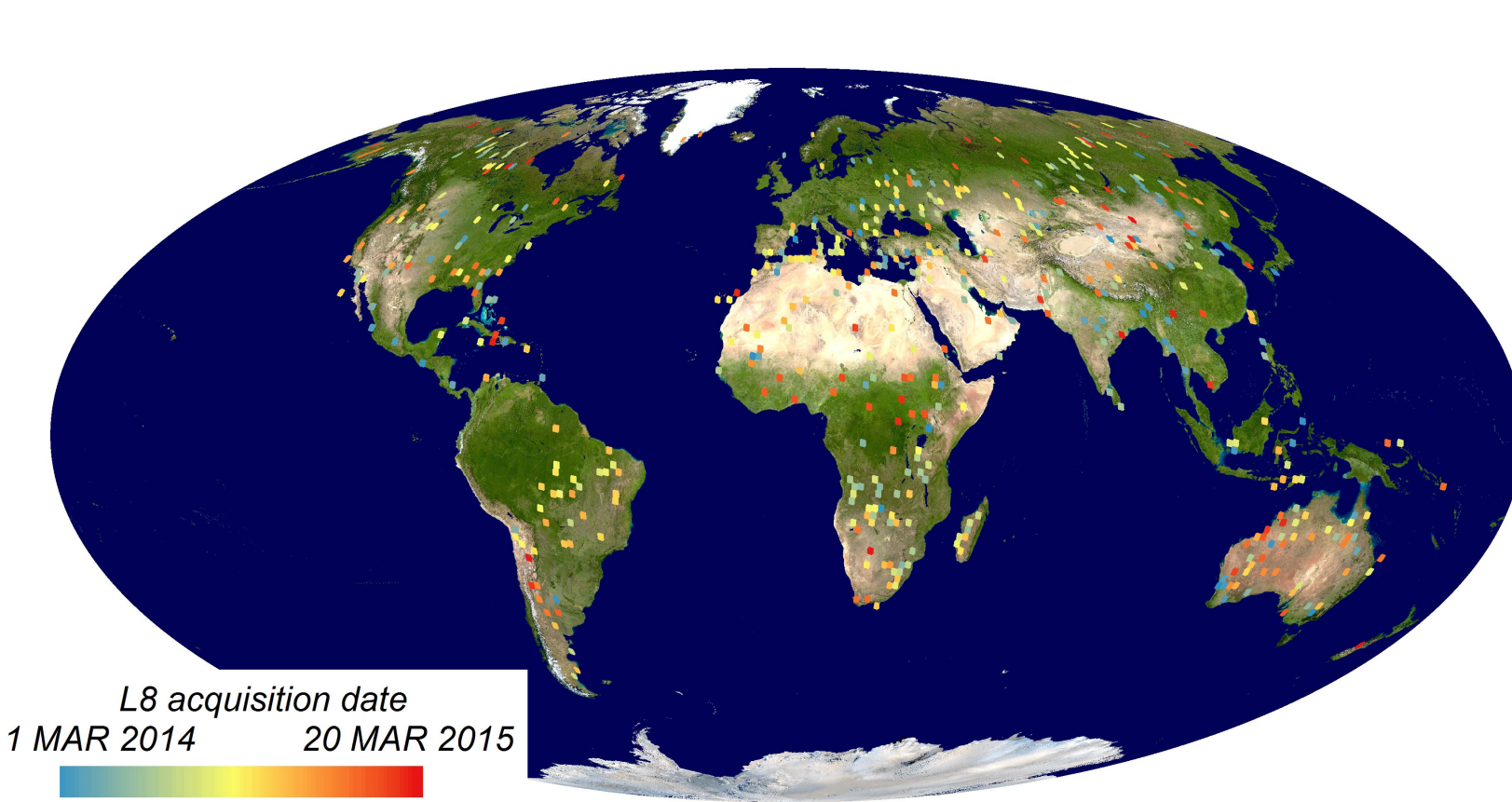
6.4 × 6.0 km
2123 × 1997 3 m pixels



Dove-R

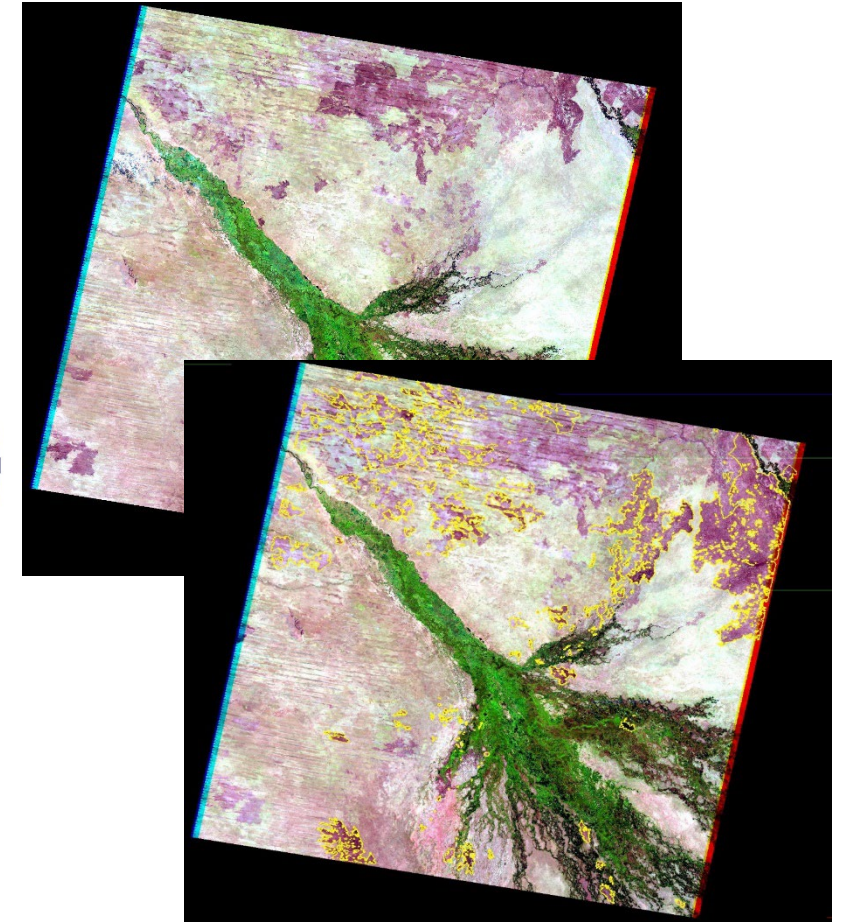
July 30th 2019

Fast prototyping - use the previously collected Africa Landsat 30m 2-date training data to derive a U-Net and investigate its utility (i.e., transfer learning) for 2-date PlanetScope classification into burned and unburned classes



Locations of 558 Landsat-8 two date image pairs interpreted into burned, unburned, and unmapped classes

roydavi1@msu.edu



Yellow vectors = Interpreted burned areas occurring between the two Landsat images sensed 16-days apart

PlanetScope

July 3rd

630nm

820 nm

545 nm

Preliminary
Example
validation

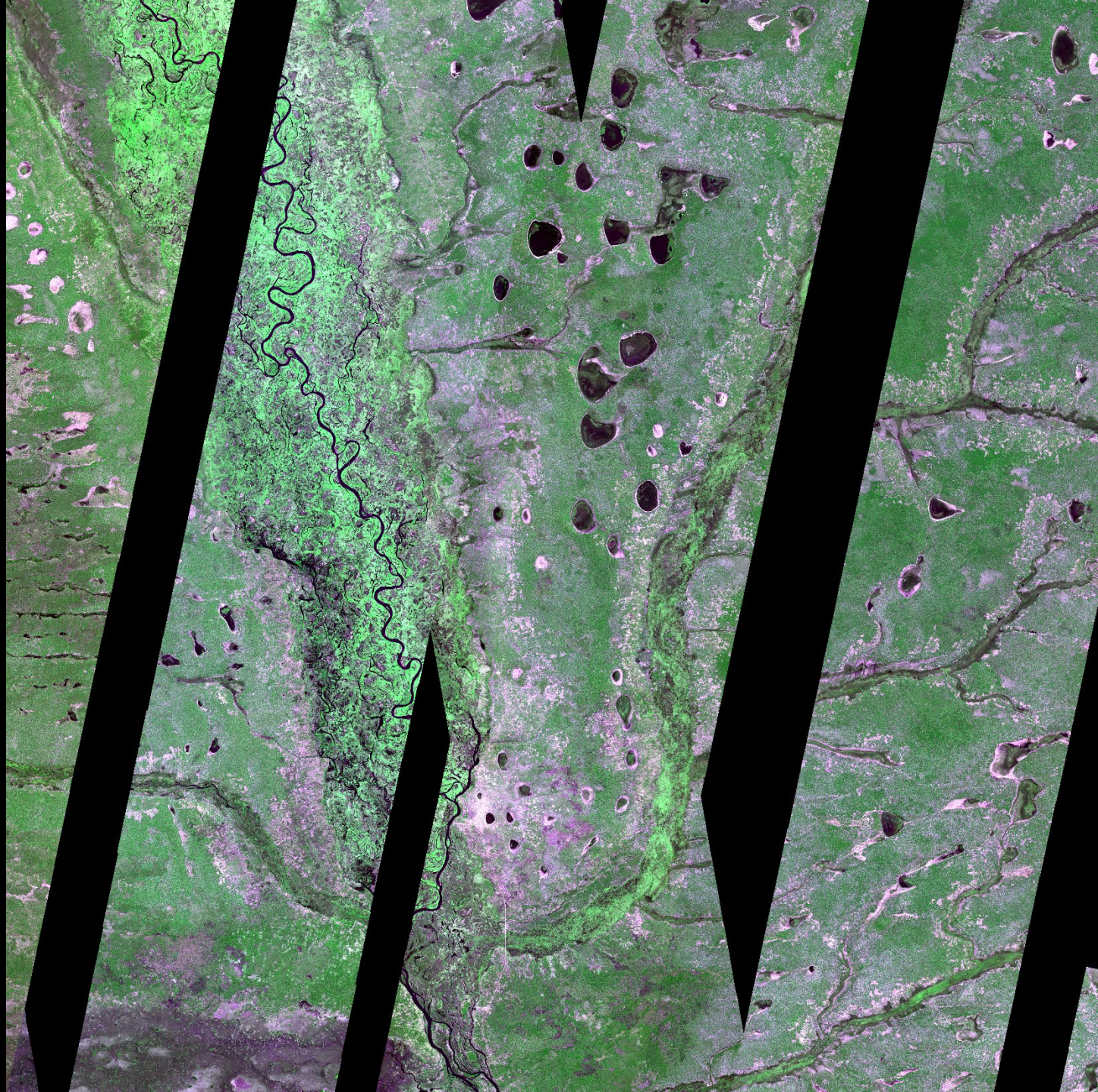
Zambia

Western Province

110 x 110 km

36600 x 36600 3m pixels

planet.



PlanetScope

July 31st

630nm

820 nm

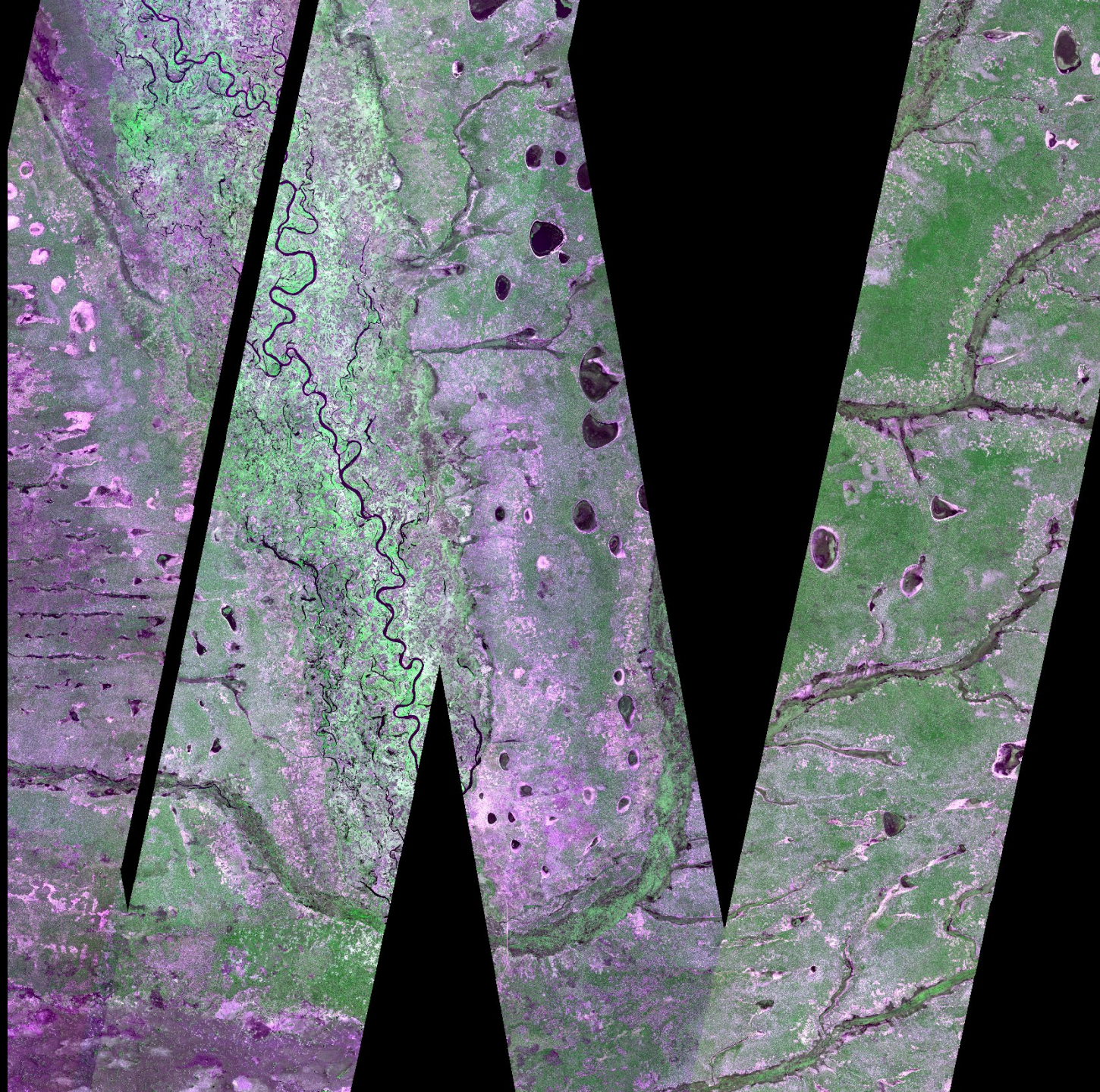
545 nm

Preliminary
Example
validation

Zambia
Western Province

110 x 110 km
36600 x 36600 3m pixels

planet.



Day of burning
July

Sentinel-2A/2B

Landsat-8

Preliminary
Example
validation

0-2

3-5

6-8

9-11

12-14

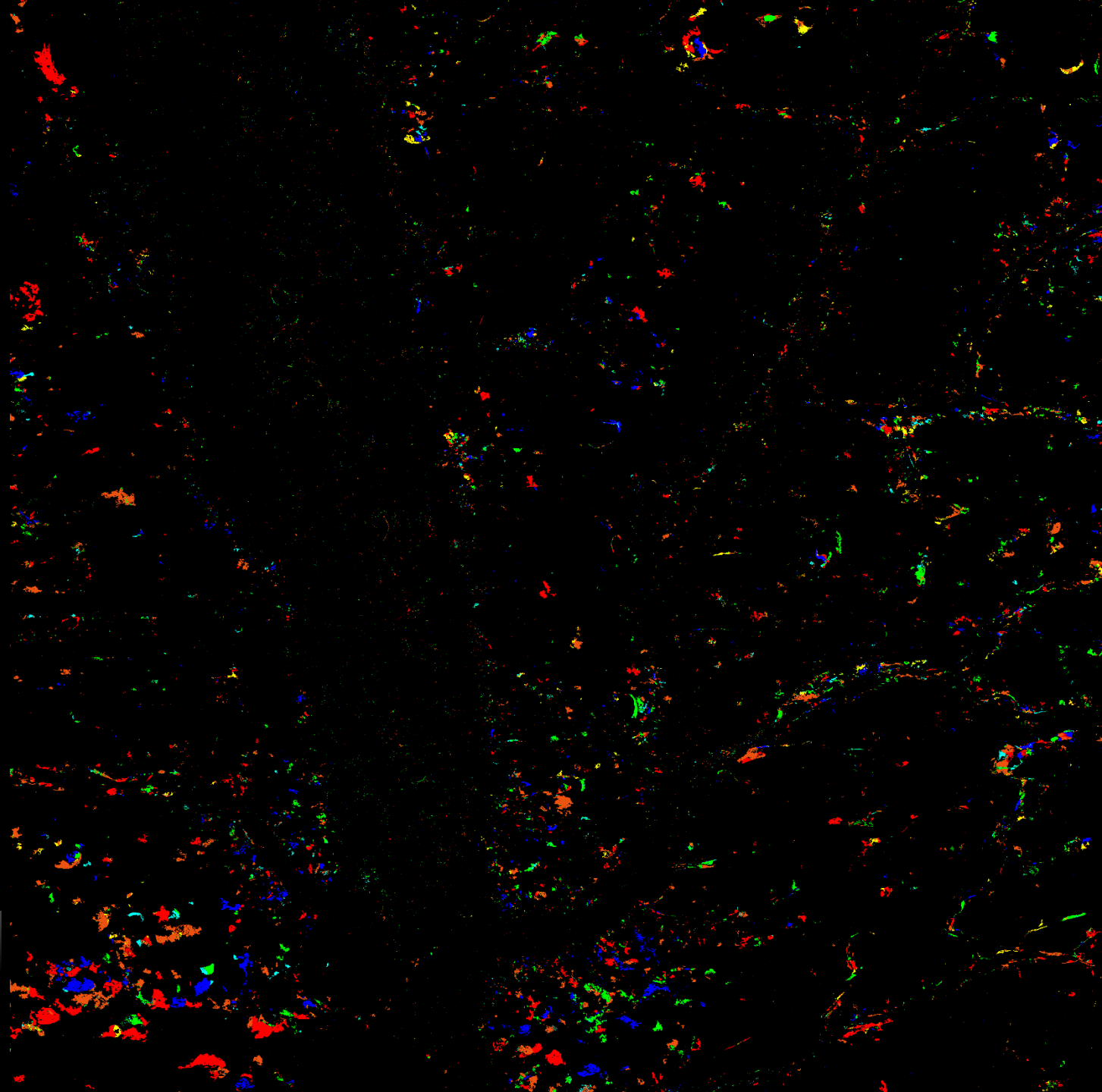
15-17

18-20

21-23

24-27

28-31



Harmonized Landsat Sentinel-2

110 x 110 km

3660 x 3660 30m pixels

Comparison of July burned proportions mapped by 3 m PLANET reference and 30 m Landsat-8 & Sentinel-2

8093.4 km ² compared		PLANET reference (assumed to be truth)		
		Burned [km ²]	Unburned [km ²]	Row total [km ²]
Landsat-8 & Sentinel-2	Burned [km ²]	83.7	56.4	140.7
	Unburned [km ²]	173.6	7780.3	7953.7
	Column total [km ²]	257.0	7836.7	8093.4

Overall accuracy = 97% Omission error [0-1] = 0.40 Commission error [0-1] = 0.67

Preliminary
example
validation
results

Burned Areas Characterized by

- deposits of charcoal and ash
- removal of vegetation
- alteration of vegetation structure
- exposure of underlying material



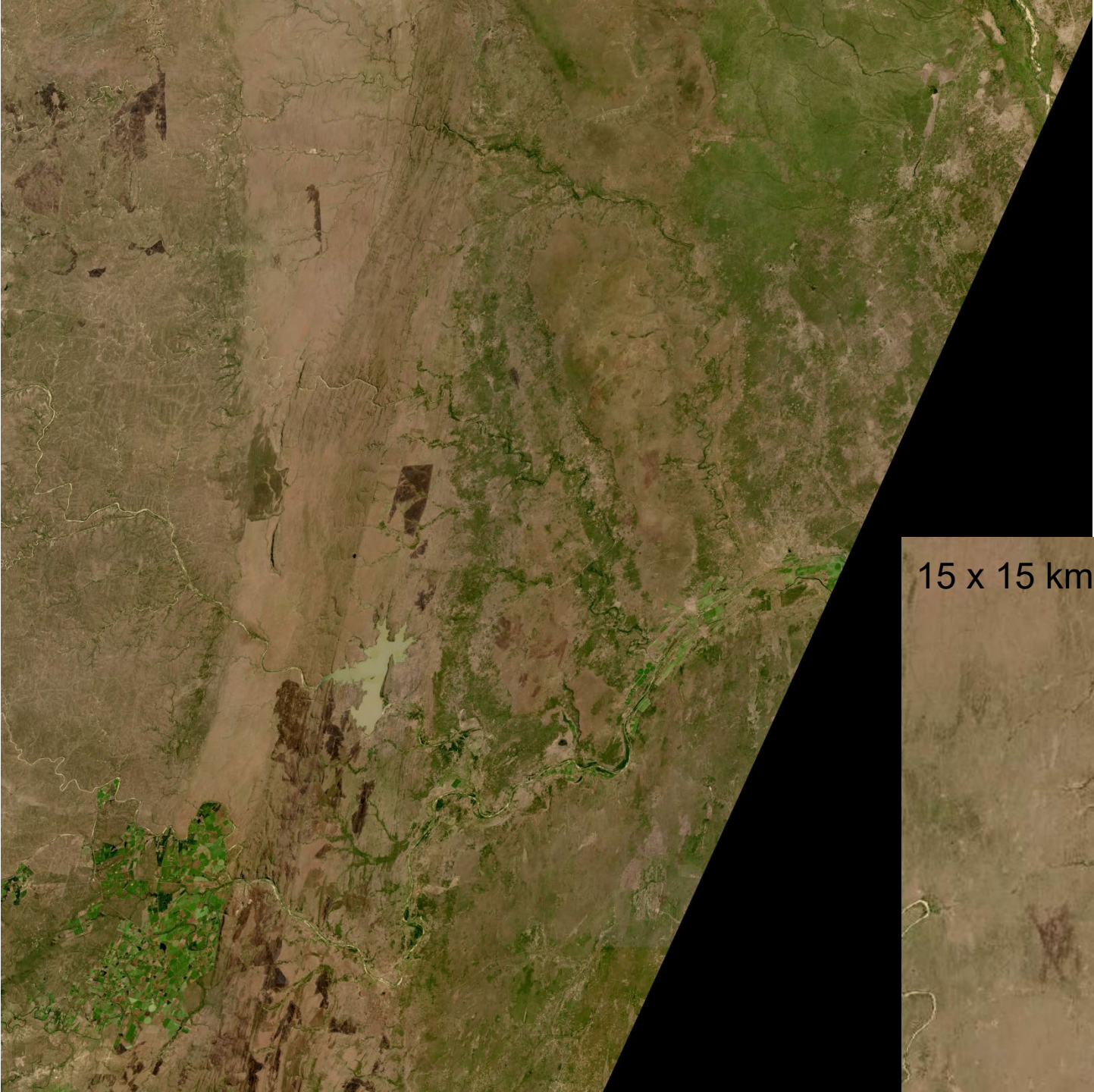
Erik Boren
Idaho



Cheikh Mbow,
Senegal

Burned pixel is a mix of burned and unburned stuff
AND the burned stuff has different reflectance



A satellite image of a landscape, likely a savanna or woodland, showing a mix of green vegetation and brown, bare soil. A prominent diagonal line runs from the top right to the bottom left, separating the image into two distinct regions. The region to the upper left of this line is predominantly brown and textured, indicating a burned area. The region to the lower right is predominantly green, indicating unburned vegetation. The boundary between the two is irregular, following natural features like rivers and ridges.

The effects of
burned areas
may persist on
the landscape

Landsat 8,
30m true color,
Week 23 2014
South Africa/Moz.

15 x 15 km

A zoomed-in satellite image of a 15 x 15 km area, showing a detailed view of the landscape. The image is dominated by brown, bare soil, with some green vegetation visible along the edges. The texture is highly irregular, with many small, dark, irregular patches scattered throughout, which are likely remnants of burned vegetation or charred soil. The overall appearance is one of a severely degraded or burned landscape.

The effects of
burned areas
may persist on
the landscape

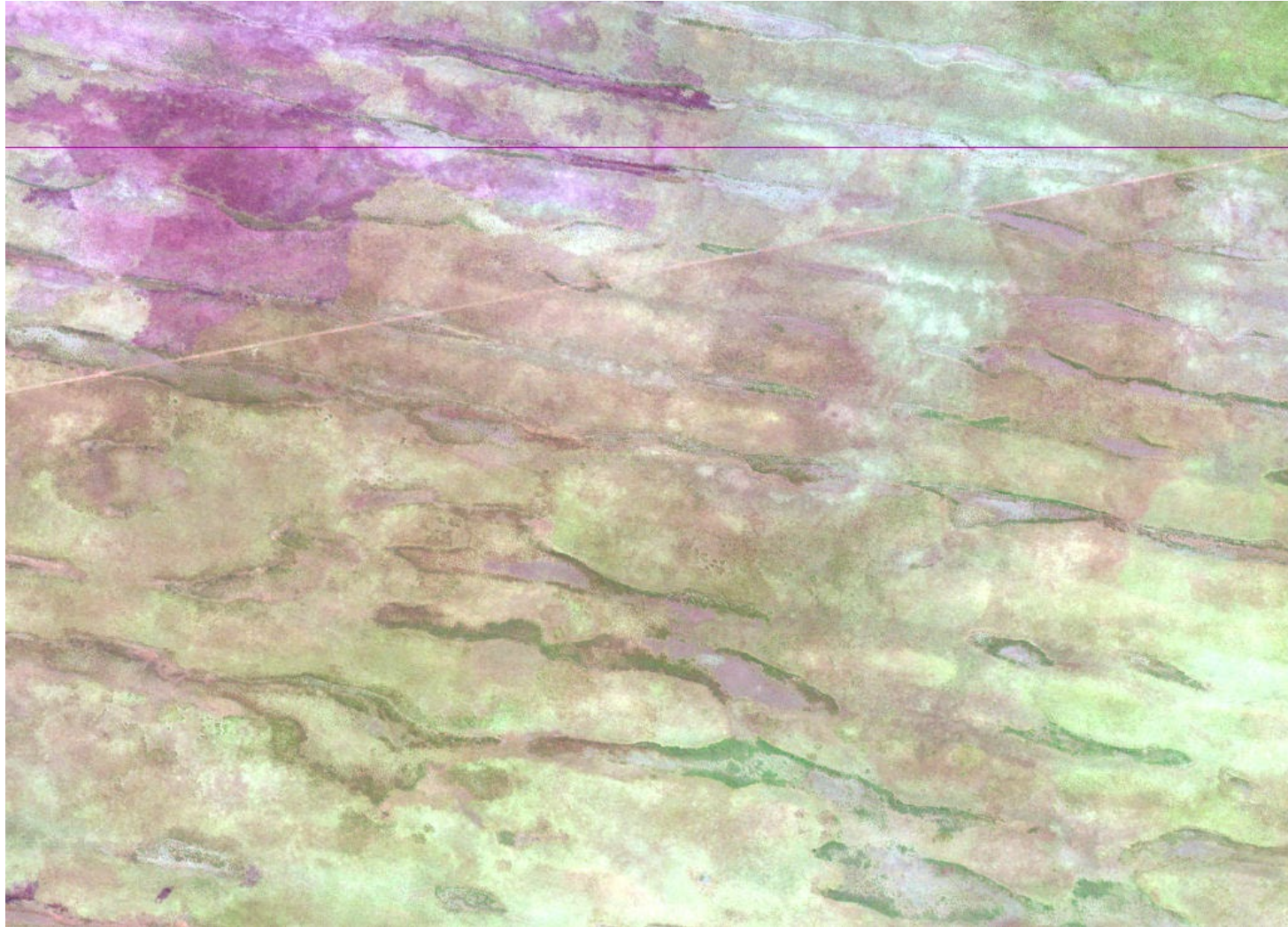
Landsat 8,
30m true color,
Week 25 2014
South Africa/Moz.

15 x 15 km

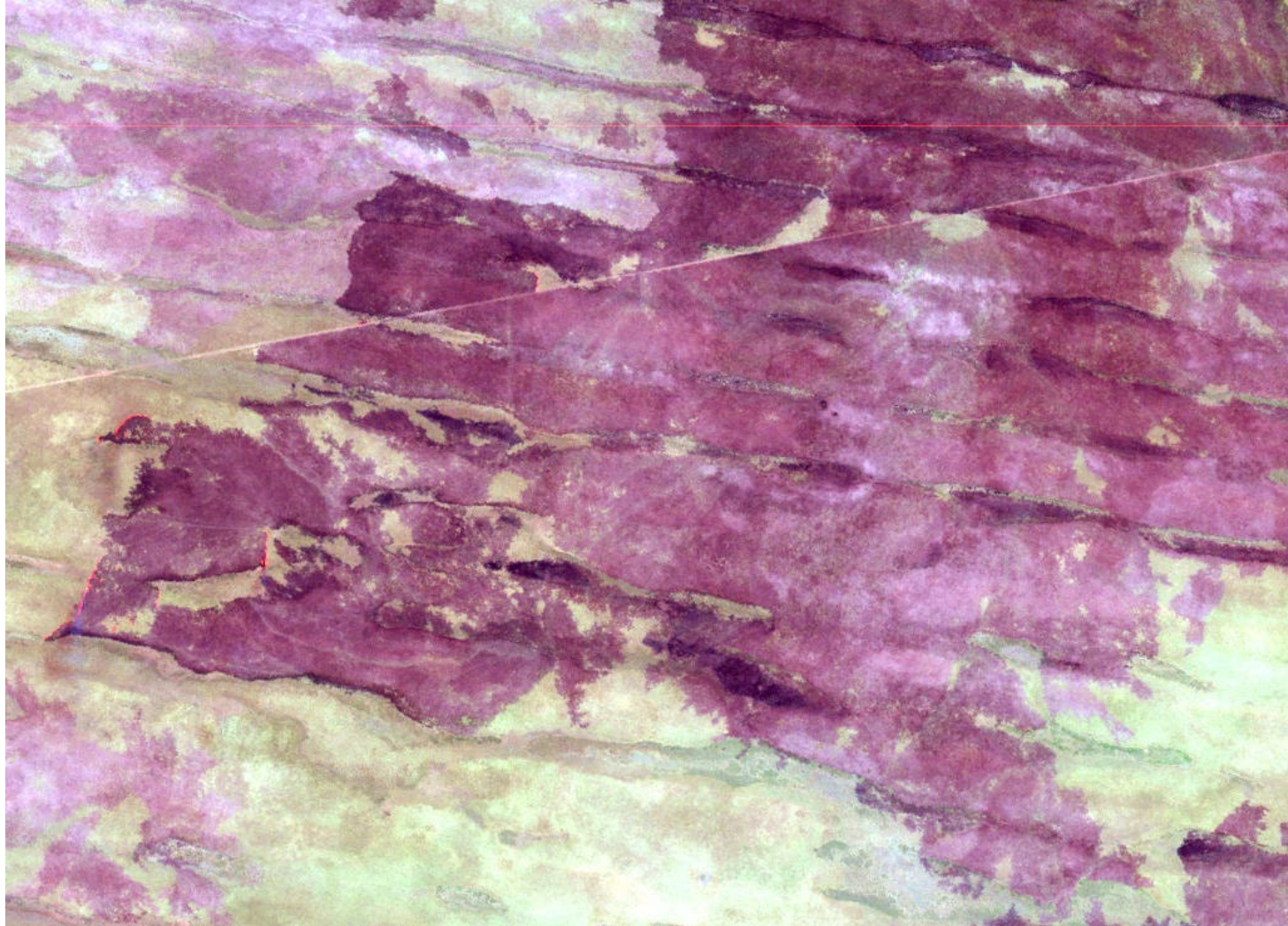


August 19th 2001, Botswana

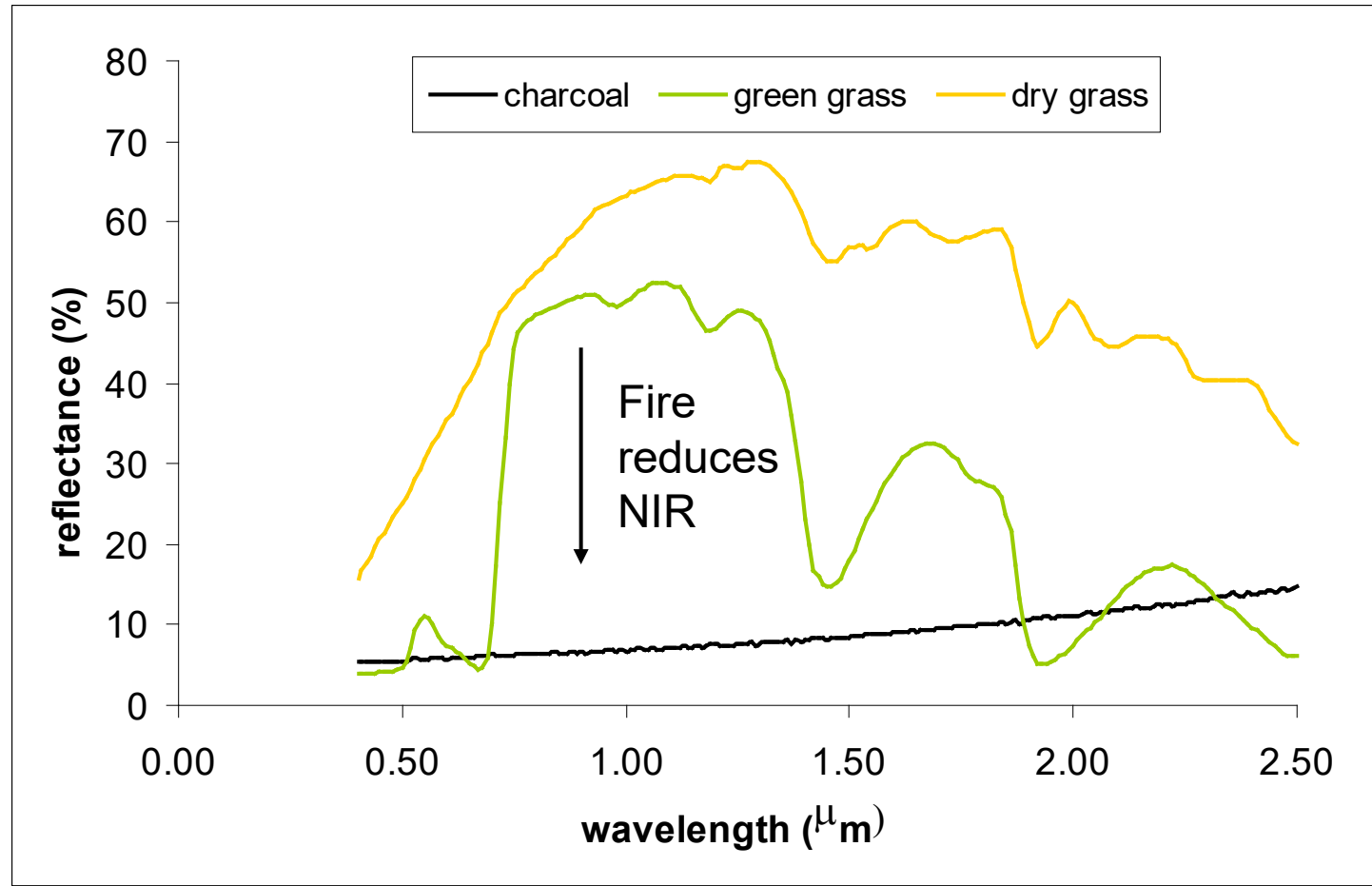
open savanna grassland, fossil dune system, bright Kalahari Sand
Landsat 30m pixels, bands 5 (1.65 μ m), 4 (0.82 μ m), 3 (0.66 μ m)



September 4th 2001, Botswana
open savanna grassland, fossil dune system, bright Kalahari Sand
Landsat 30m pixels, bands 5 (1.65 μ m), 4 (0.82 μ m), 3 (0.66 μ m)

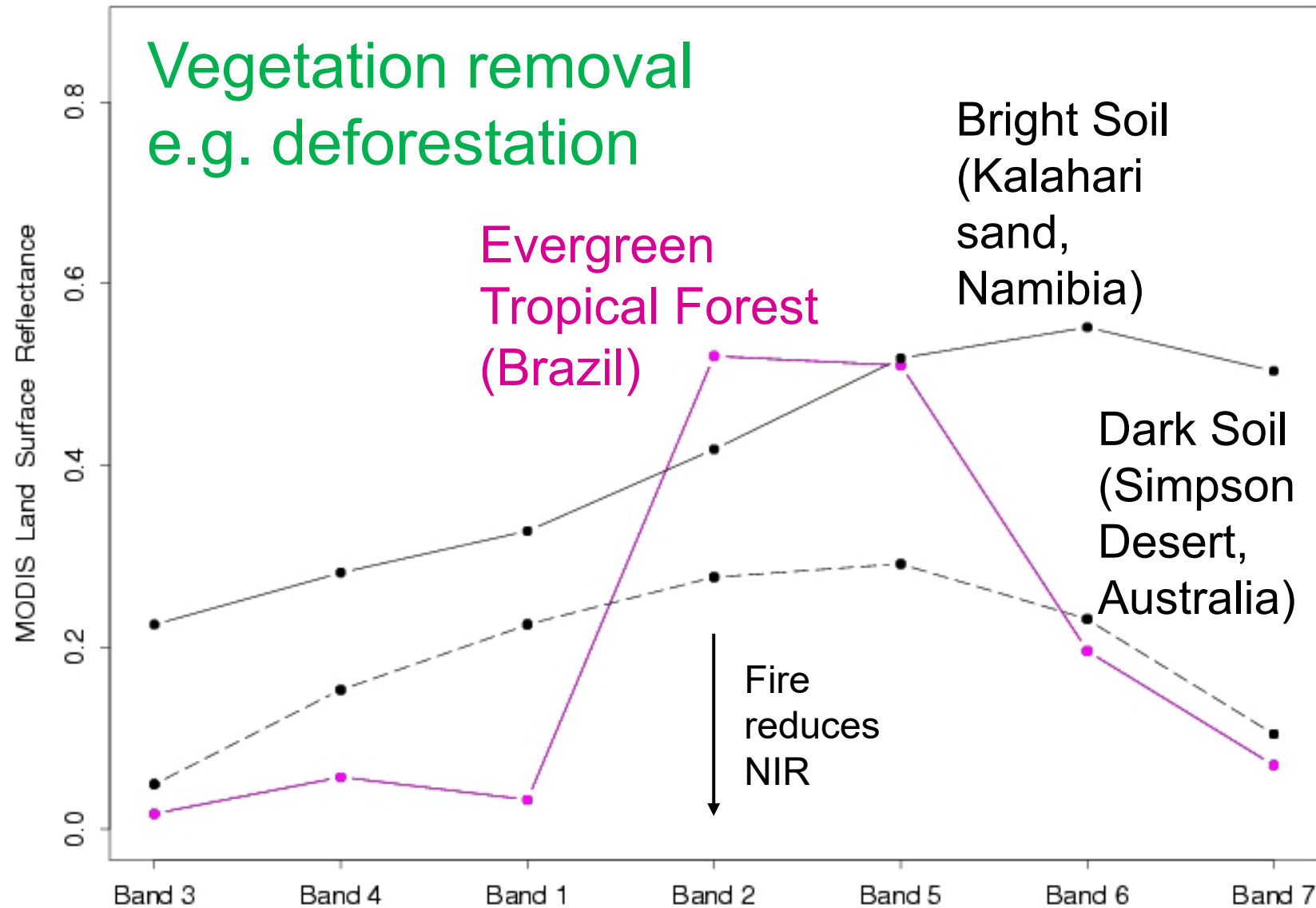


“Typical” spectral reflectance of charcoal (immediately post-fire), green & dry grass

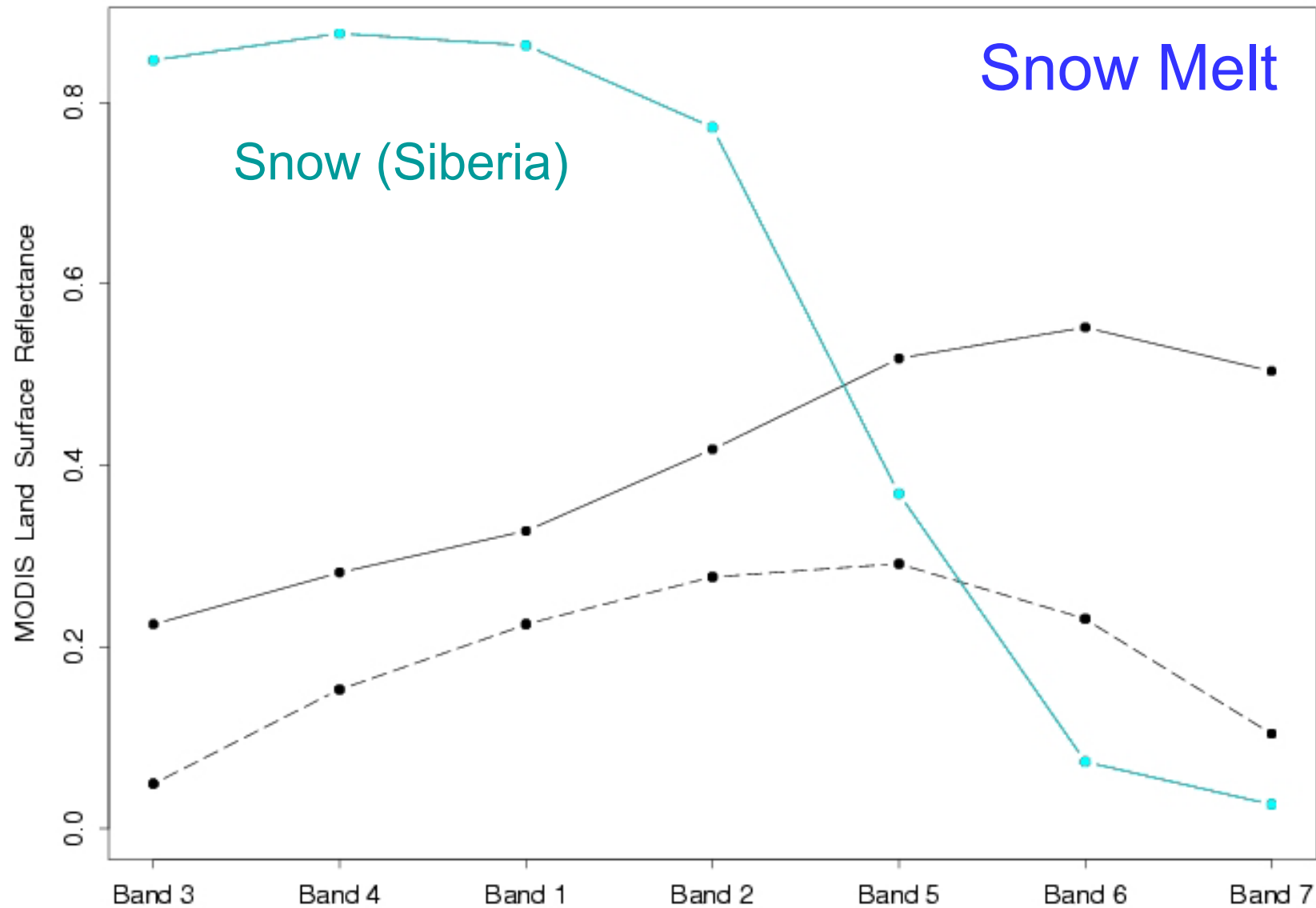


i.e. burning reduces reflectance at reflective wavelengths

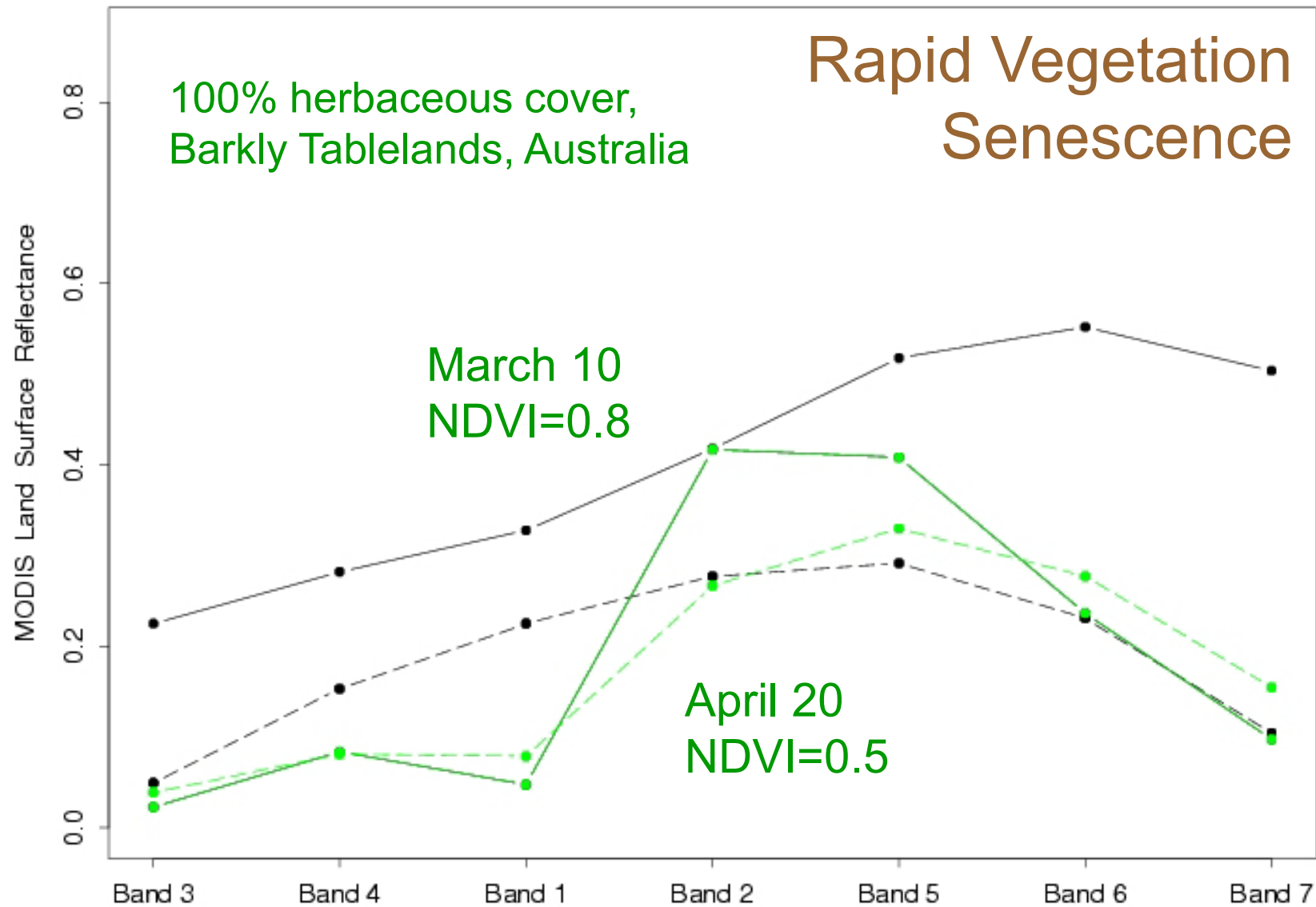
Must account for spectrally confusing land cover changes i.e.,
that look like burning but are not



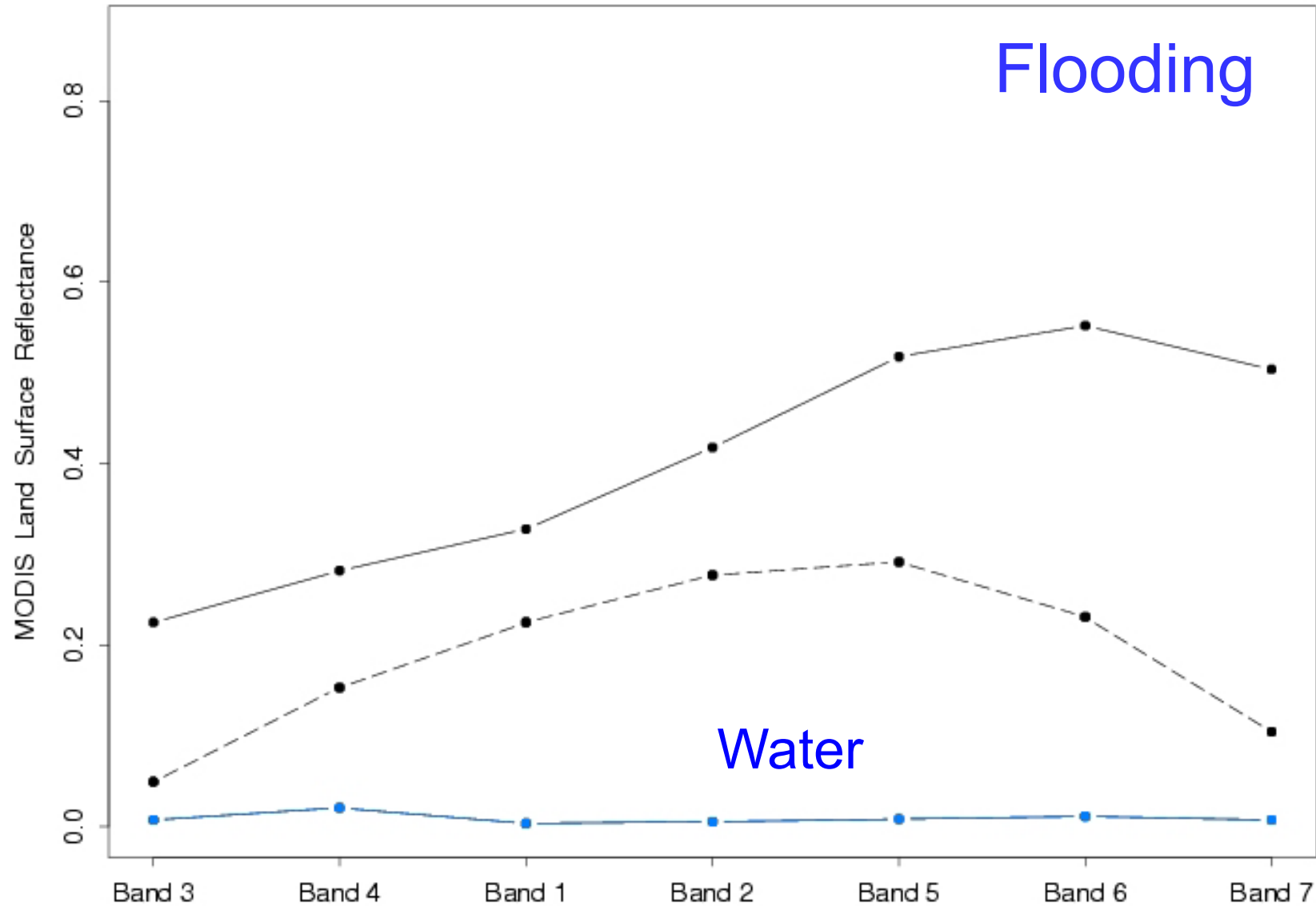
Must account for spectrally confusing land cover changes i.e.,
that look like burning but are not



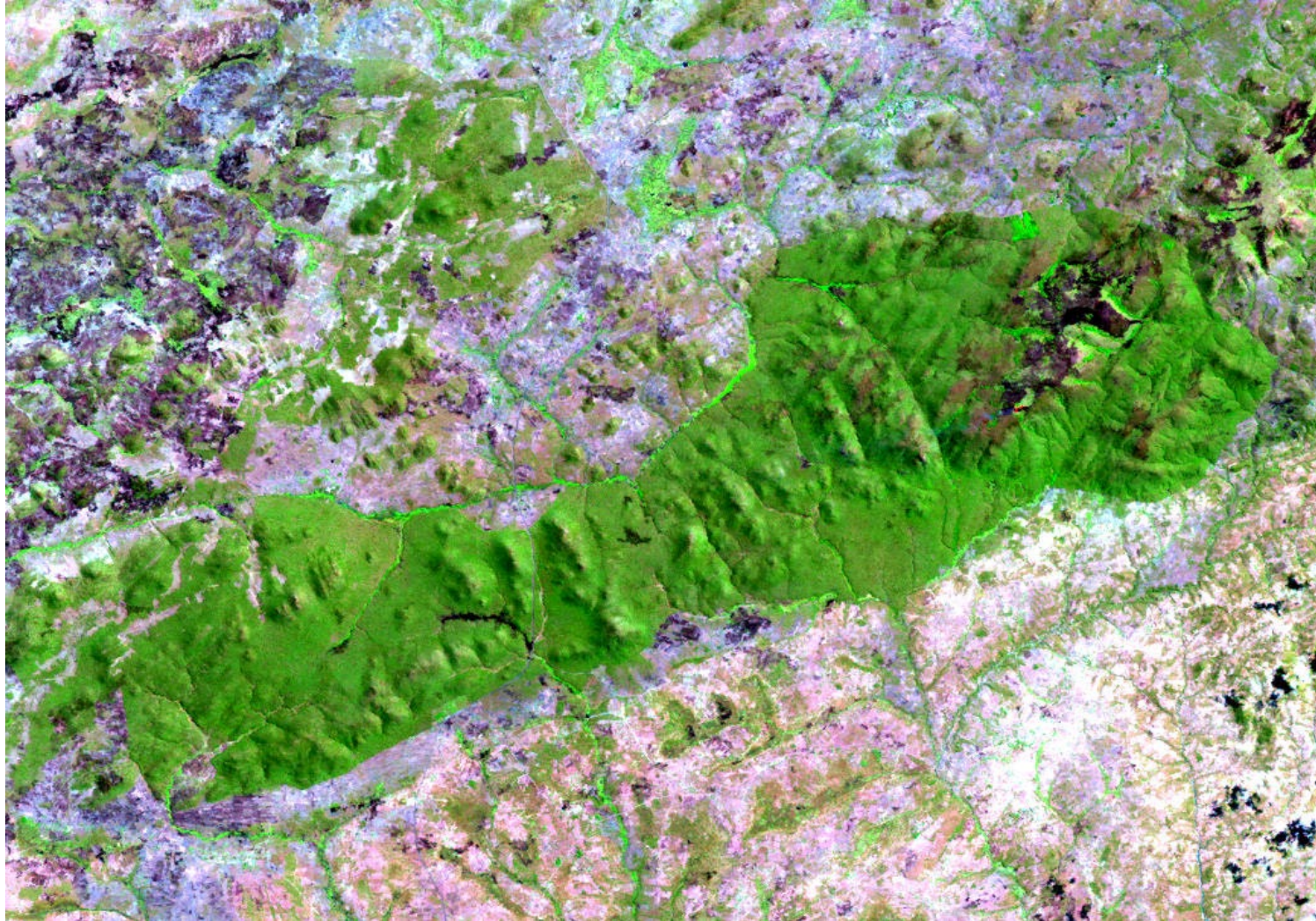
Must account for spectrally confusing land cover changes i.e.,
that look like burning but are not



Must account for spectrally confusing land cover changes i.e.,
that look like burning but are not

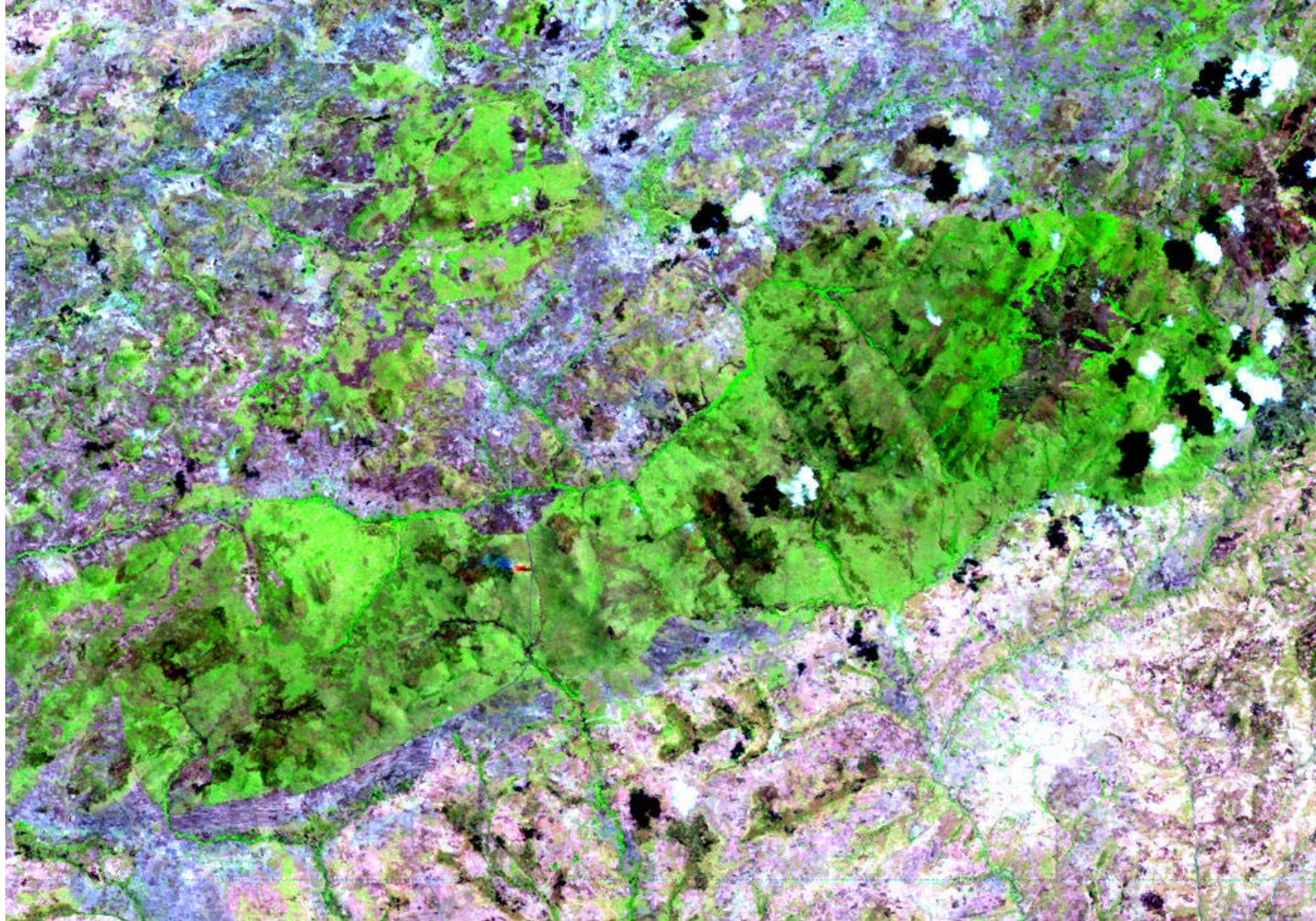


Must account for spectrally confusing land cover changes i.e.,
that look like burning but are not



Must account for spectrally confusing land cover changes i.e.,
that look like burning but are not

Cloud
shadows
and
burned
areas look
similar in
this image



To first order the change in reflectance due to burning is dependent on the fraction of area burned f and combustion completeness cc



UNBURNED

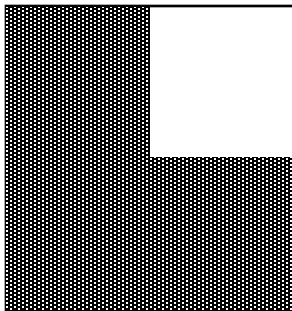
MIXED PIXEL

BURNED

INCOMPLETE
COMBUSTION

Linear Spectral Mixture Model

Two linear mixture equations



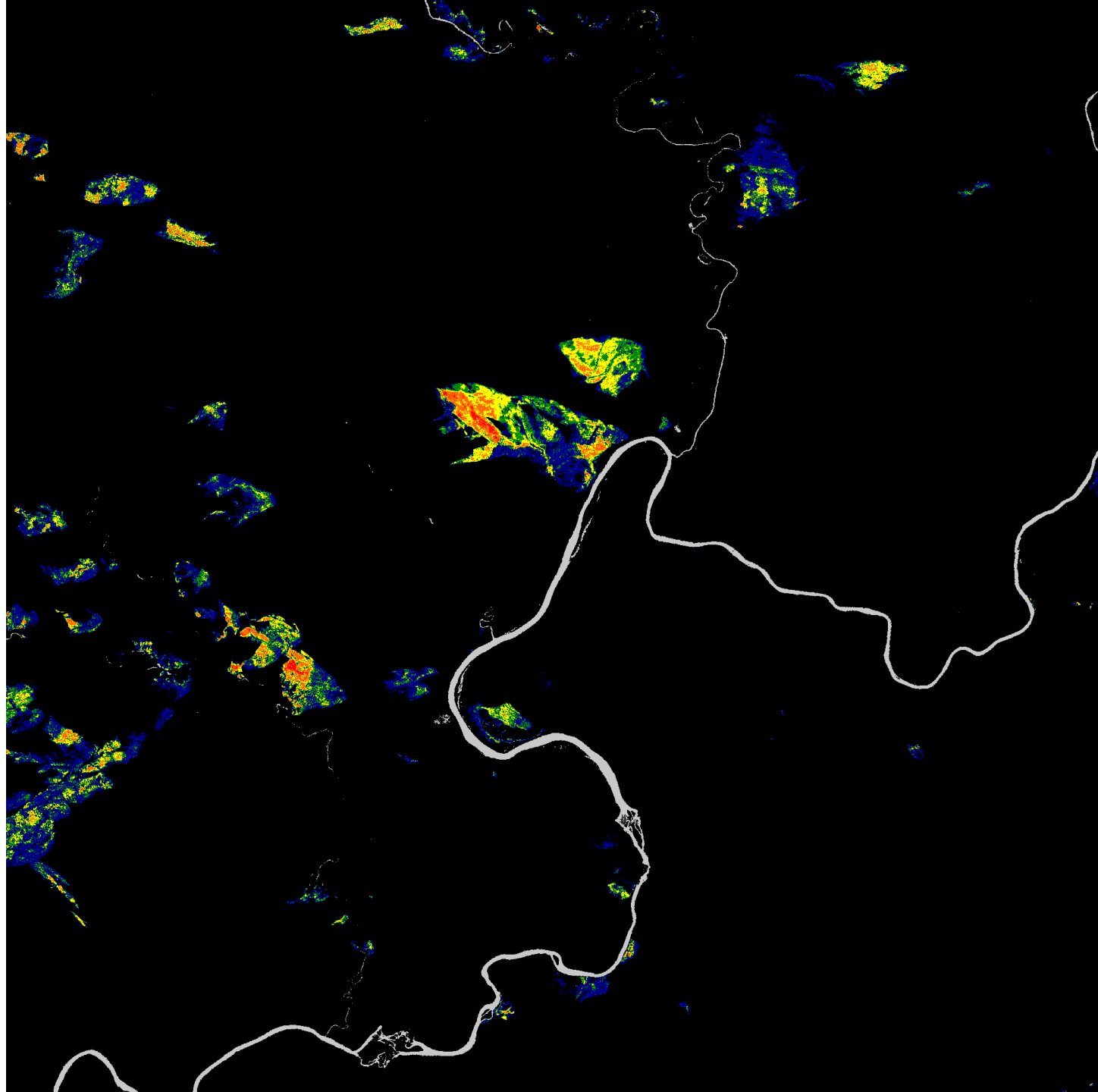
*a pixel with fraction of area burned f
and combustion completeness cc :*

$$\rho = (1 - f \, cc) \, \rho_{\underline{UB}} + f \, cc \, \rho_{\underline{B}}$$

$f \times cc$

day 155 -> 164

2000 x 2000 30m pixels

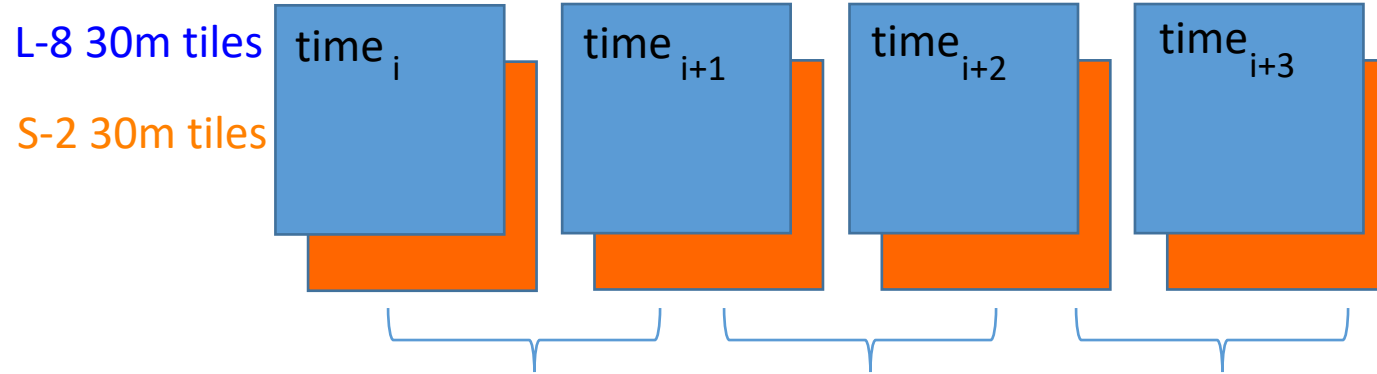


Synthetic training data
spectral library
f. cc model

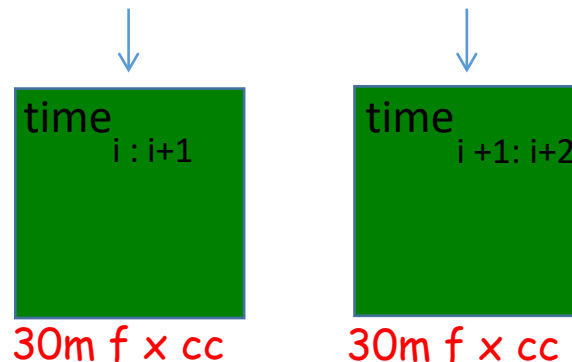
$f \times cc, \rho^{\text{pre-fire}}_{\lambda}, \rho^{\text{post-fire}}_{\lambda}$

Landsat-8 & Sentinel-2
Spectral Response Functions

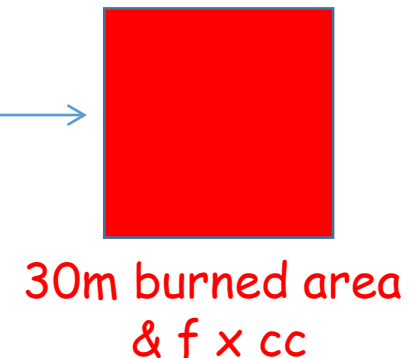
$f \times cc, \rho^{\text{pre-fire}}_{\text{sensor band}}, \rho^{\text{post-fire}}_{\text{sensor band}}$



Random Forest Classification
to 30m $f \times cc$

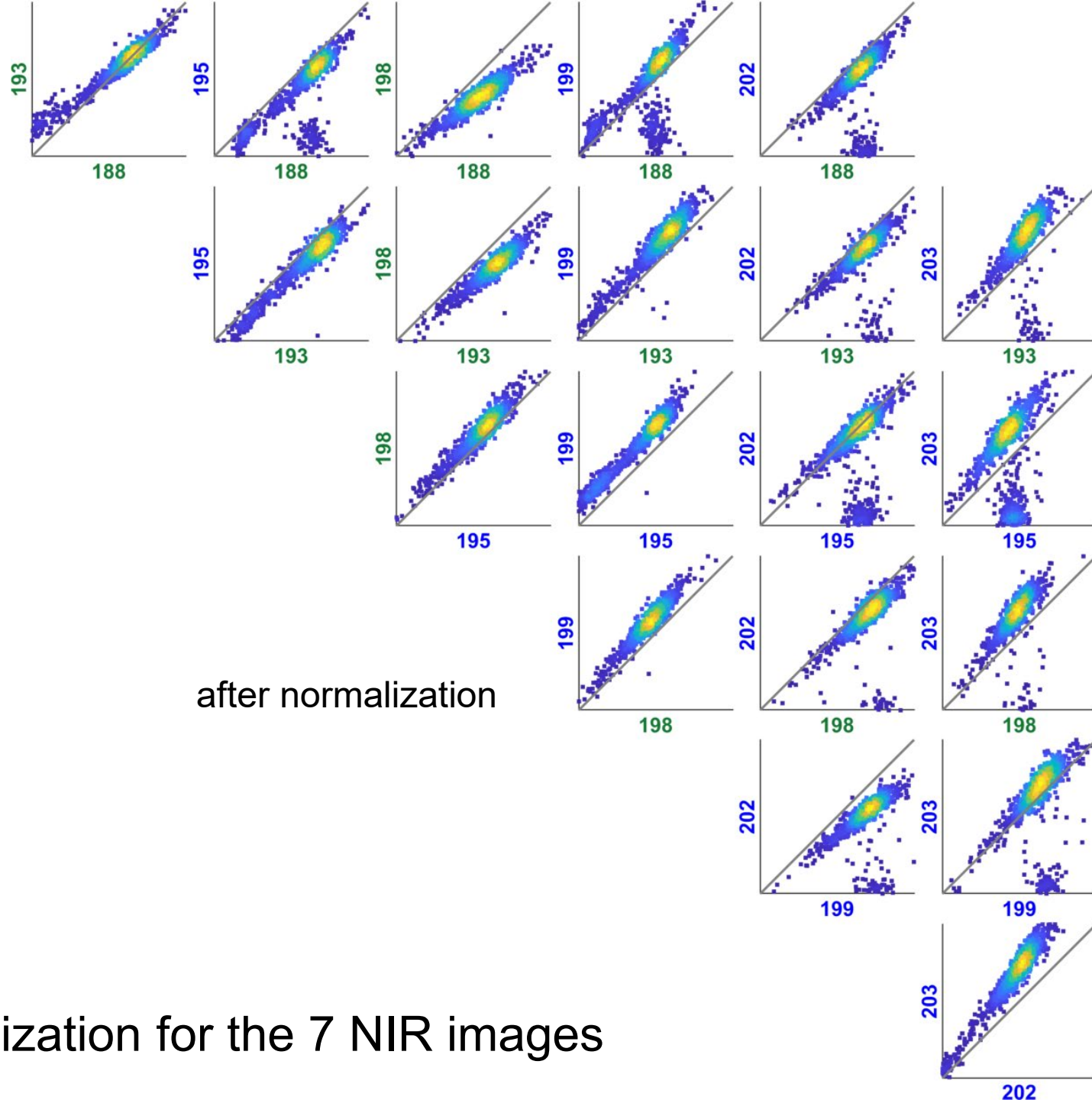


Temporal
Consistency
Wedge
approach
based on
MODIS C5.1
(koala)
approach

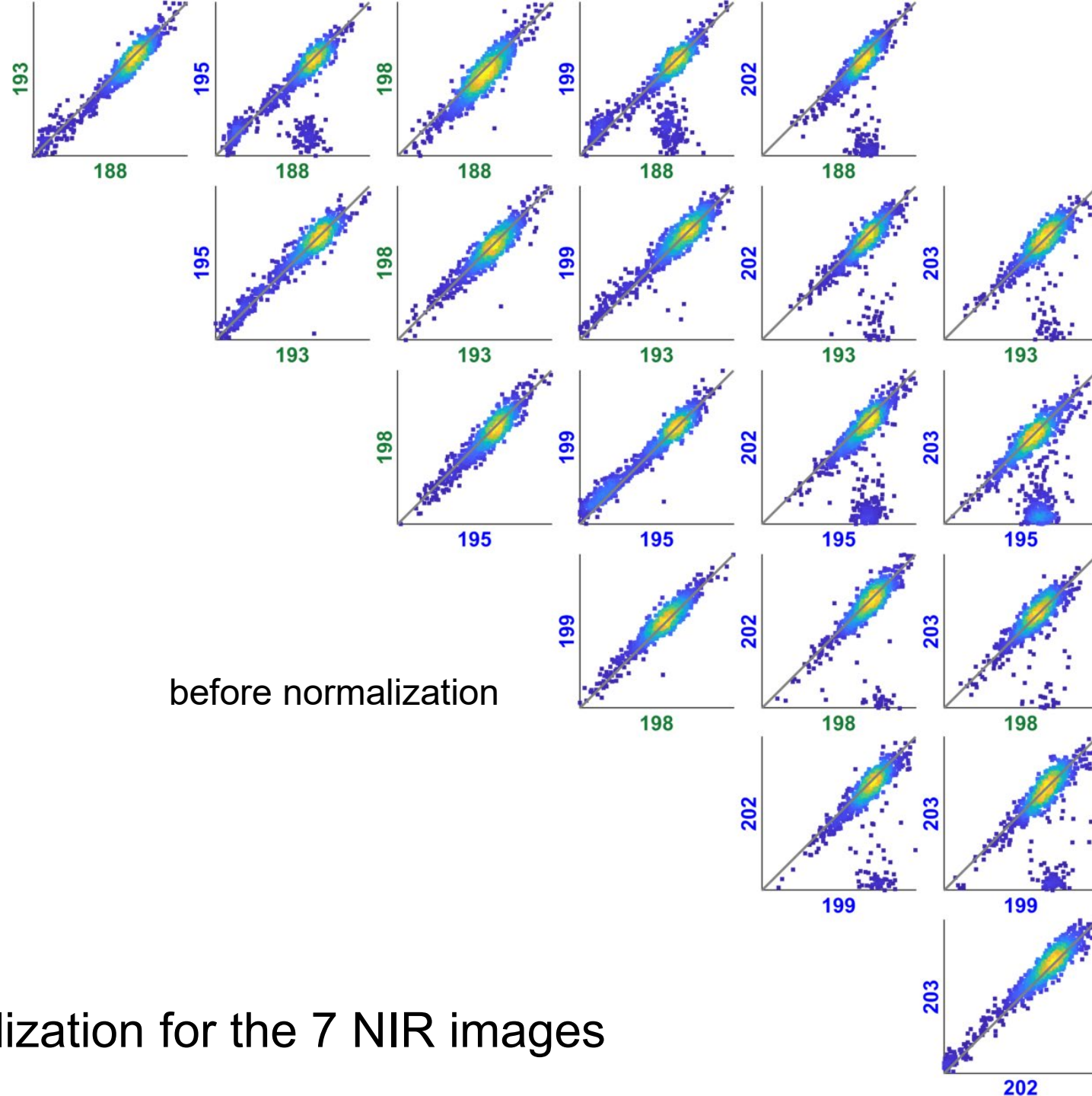


Roy, Huang, Boschetti, Giglio,
Yan, Zhang, Li, 2019, Landsat-8
and Sentinel-2 burned area
mapping - a combined sensor
multi-temporal change
detection approach, RSE, 231,
111254.

Current algorithm requires only 3 parameters

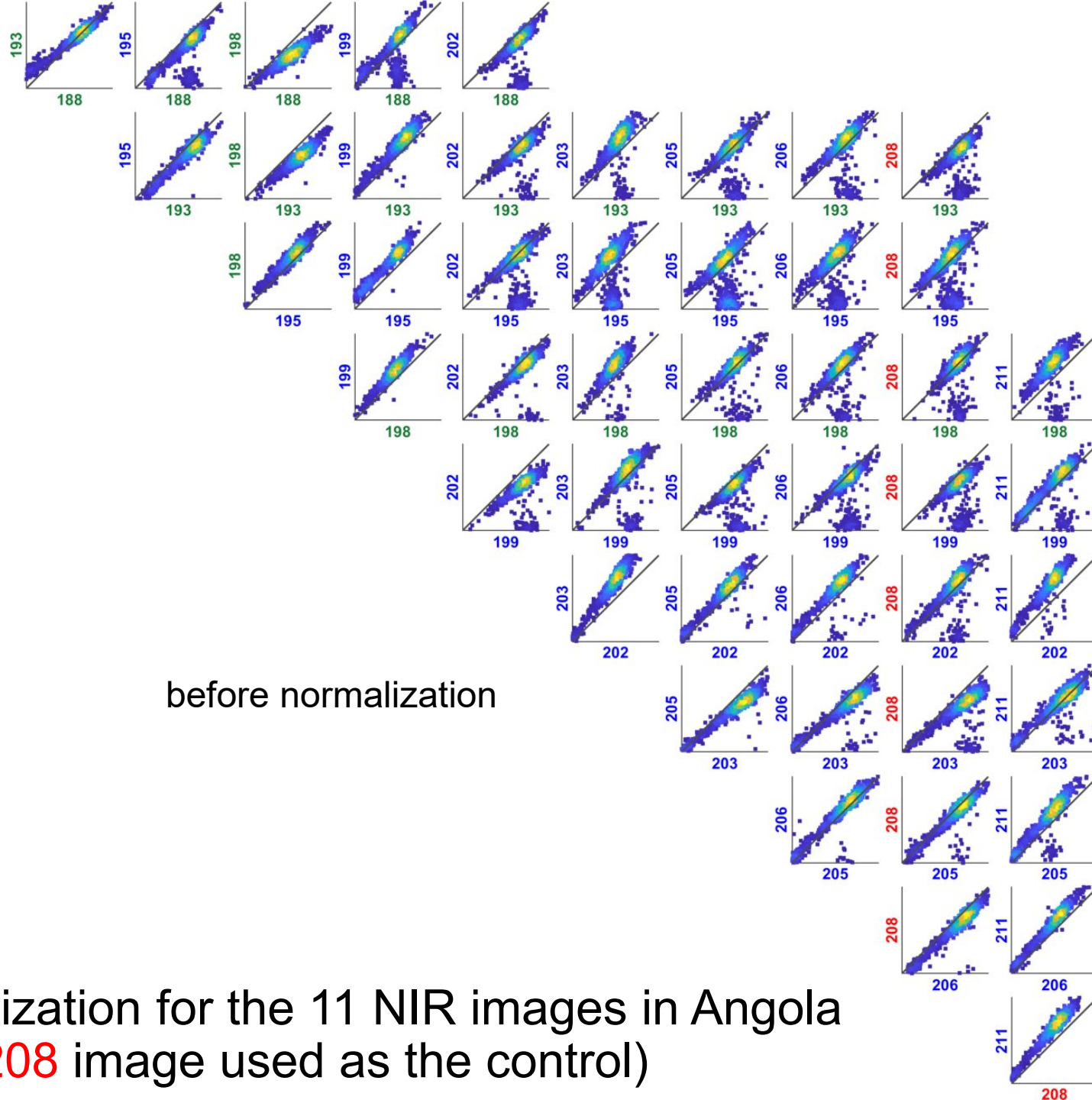


Normalization for the 7 NIR images

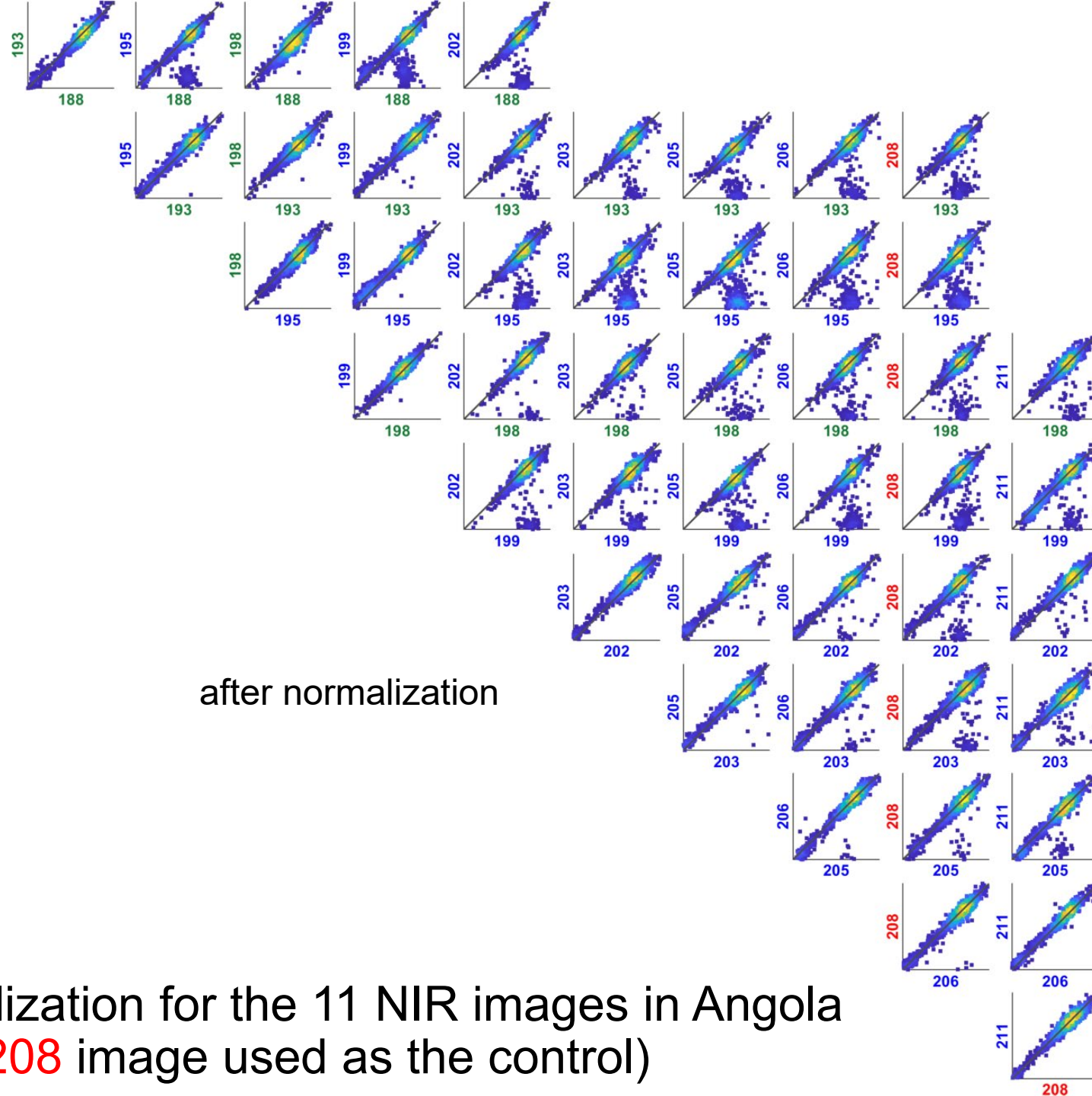


before normalization

Normalization for the 7 NIR images



Normalization for the 11 NIR images in Angola
(DOY-208 image used as the control)



Normalization for the 11 NIR images in Angola
(DOY-208 image used as the control)