Landsat-8 Sentinel-2 global burned area product Prototyping (Type II) to Production (Type 1)

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Sally Archibald, University of the Witwatersrand, Johannesburg, South Africa

Shawn Levick, Charles Darwin University, Darwin, NT, Australia

LCLUC Spring Science Team Meeting,
3-5 April 2018, Gaithersburg Marriott
Washingtonian Center (Rio), Maryland

Landsat-8 and Sentinel-2 global burned area product Protocol (Type II) to Product (Type 1)

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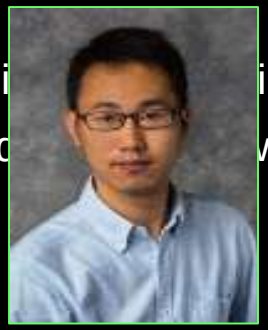

Geospatial Scienc Excell n Dak ni ings, SD 57007

[2] Department esourc ety, U Id , ID 83843

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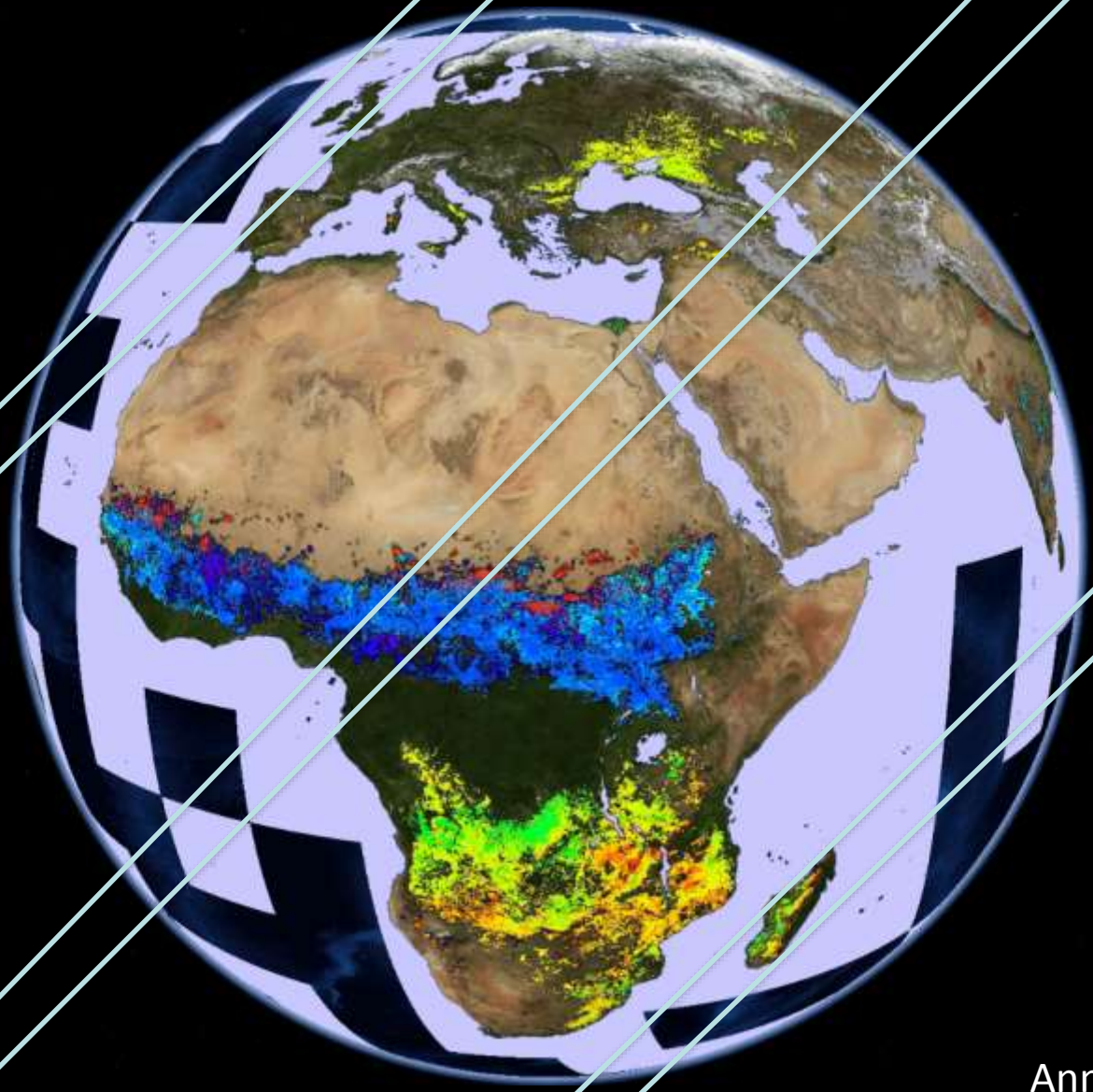
Landsat-8 Sentinel-2 global burned area product Prototyping (Type II) to Production (Type 1)

Overview

- Product rationale
- Pre-Processing
- Burned area mapping algorithm
- Example 30 m burned area results
- Production plans

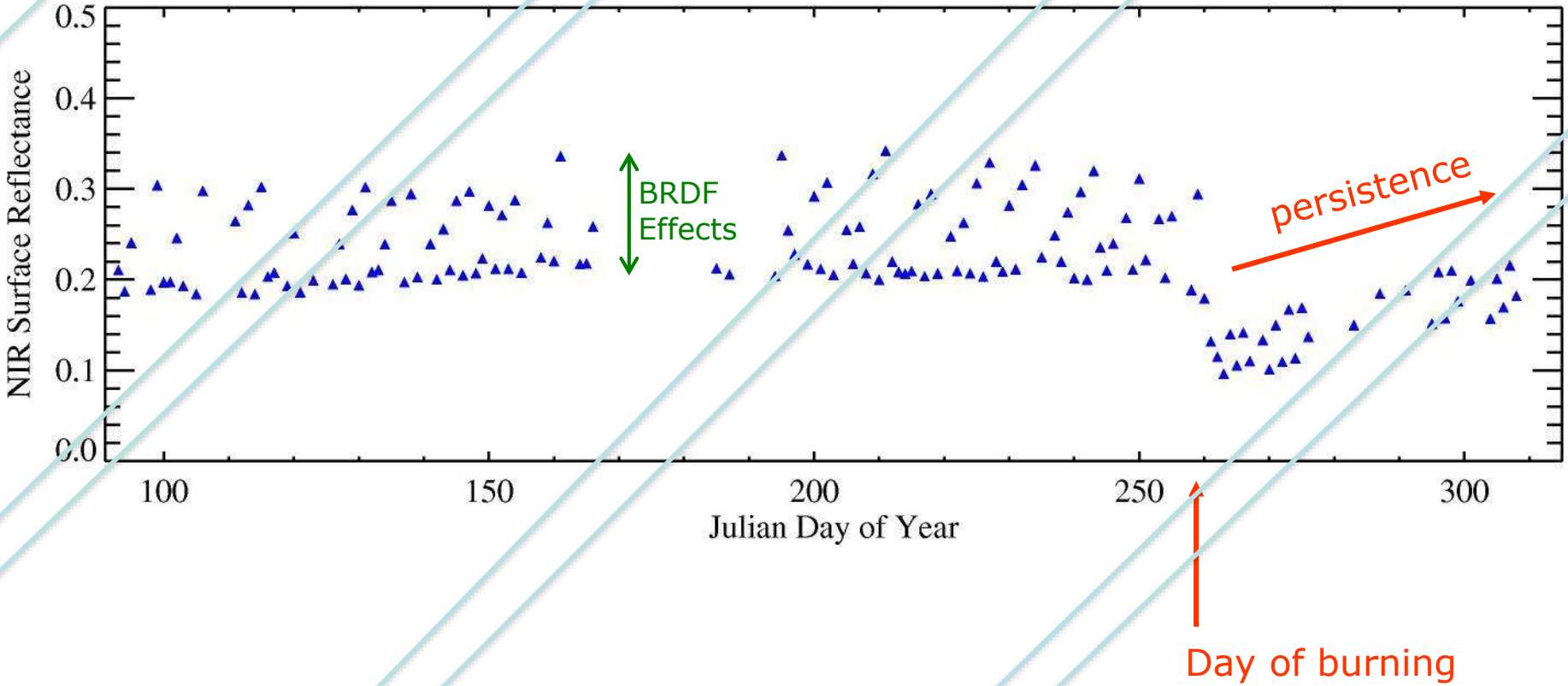
18 years of NASA systematically generated global MODIS 500 m burned area product



Annual 2001

MODIS burned area product algorithms based on moving window change detection

Example single pixel 500m NIR surface reflectance time series



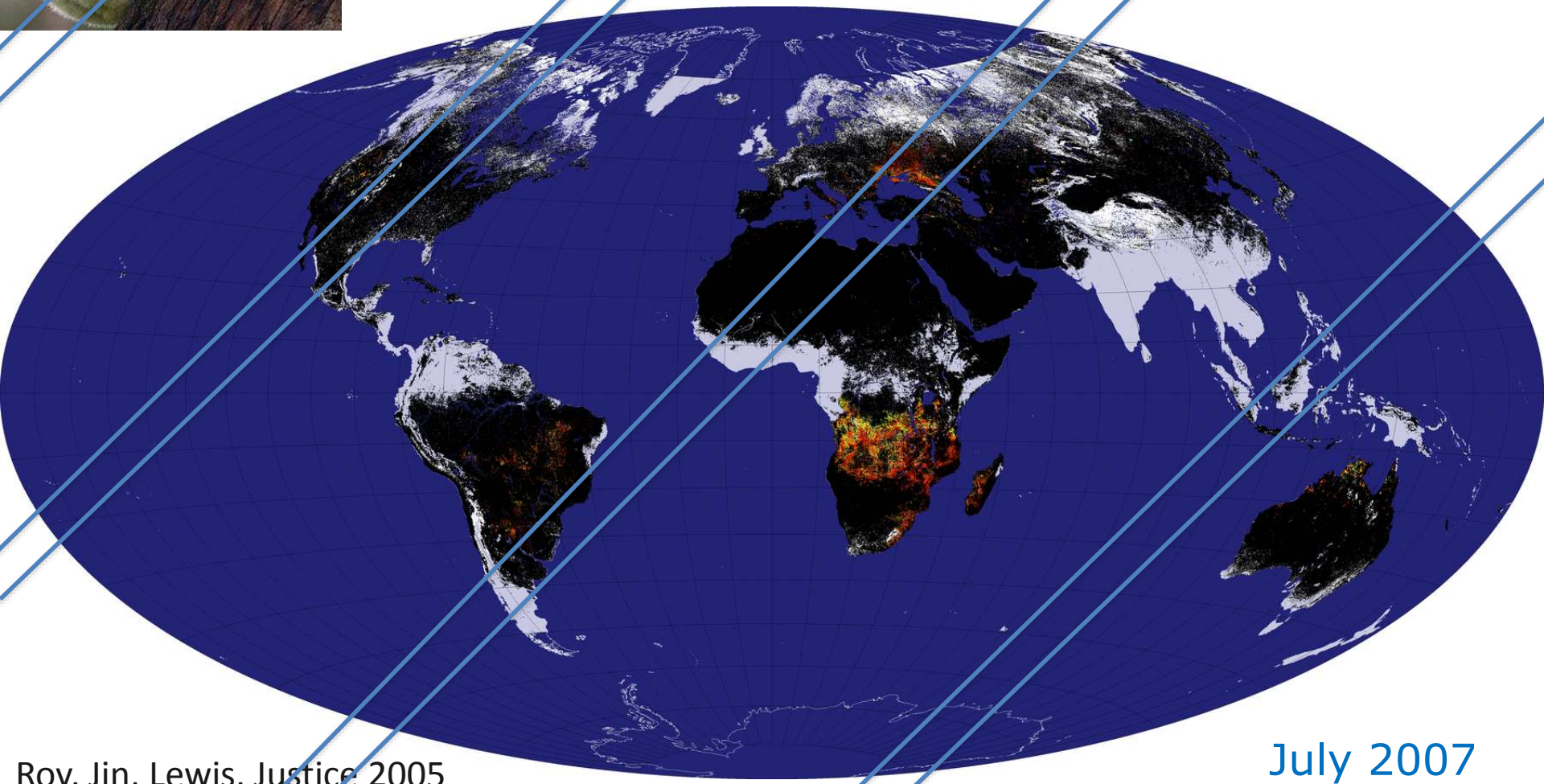
MCD45
(Collection 5.1)

Multi-temporal BRDF based

Multi-temporal VI based
+ Active fire detections

MCD64
(Collection 5.1,
Collection 6)

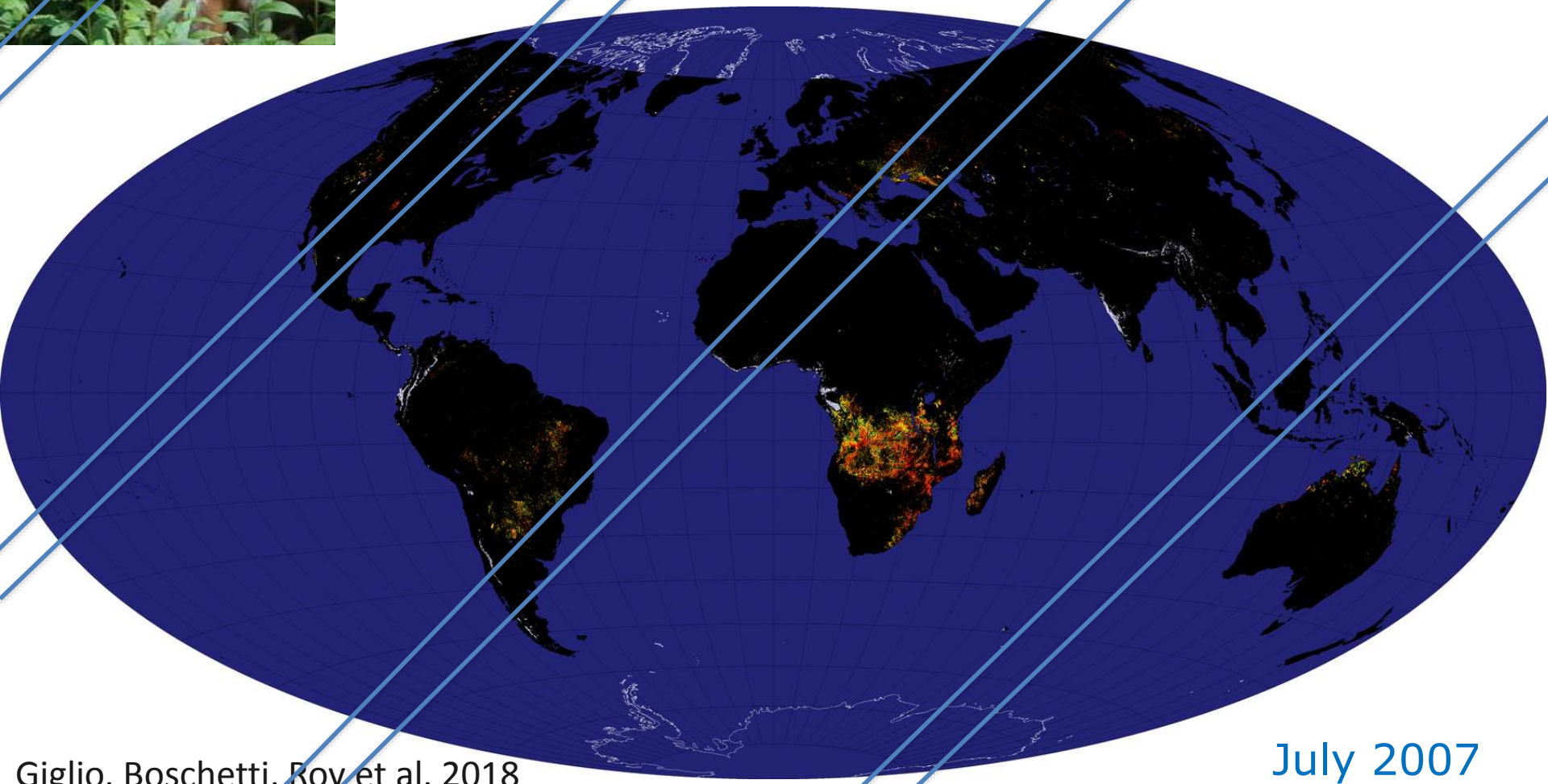
MODIS 500m burned area C5 MCD45A1 (BRDF "Koala")



Roy, Jin, Lewis, Justice 2005

July 2007

MODIS 500m burned area C6 MCD64A1 (“Goat”)



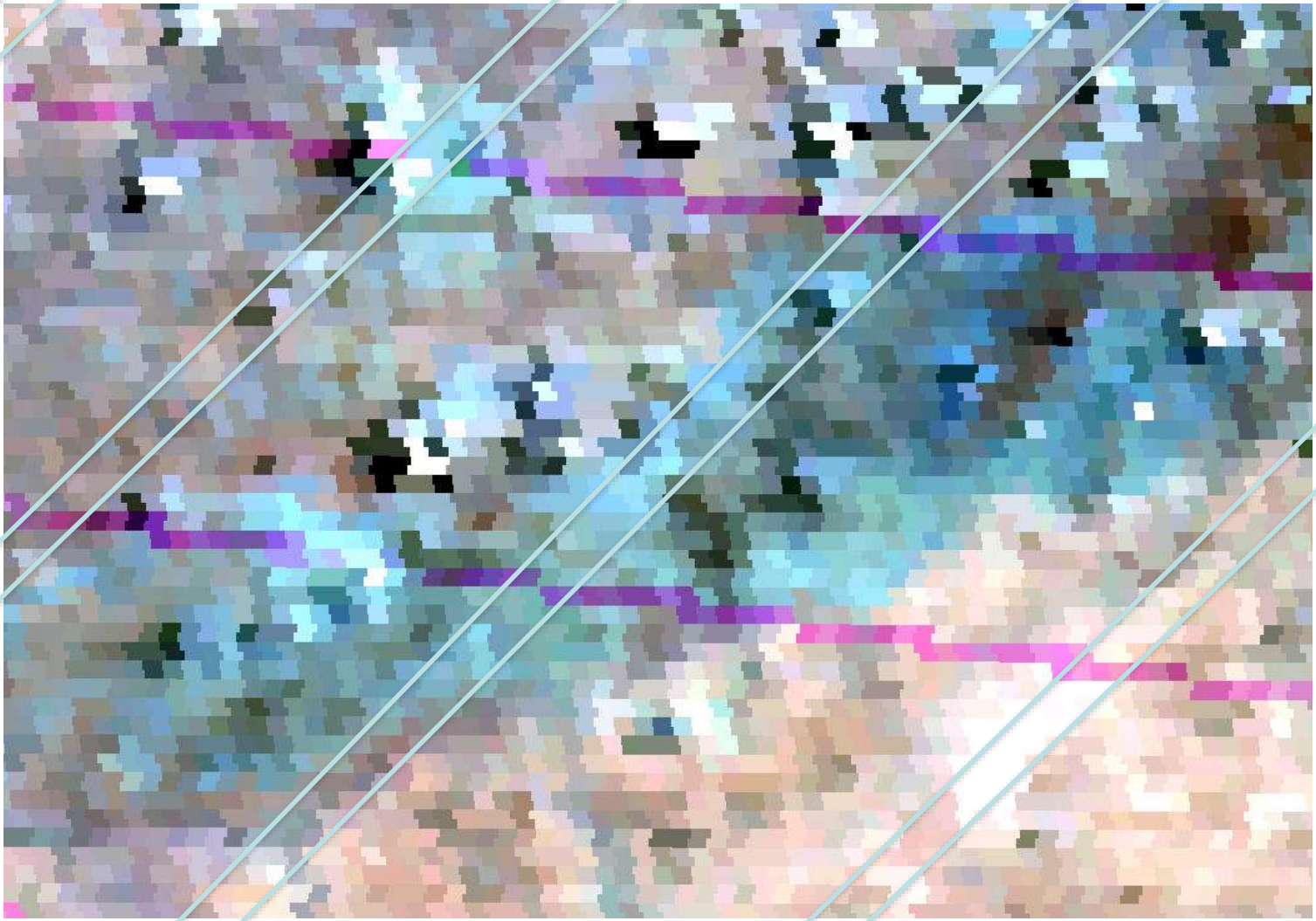
Giglio, Boschetti, Roy et al. 2018

July 2007

MODIS 500 m pixels

bands 6 (1.65 μm), 5 (1.24 μm), 2 (0.86 μm)

September 26th 2001



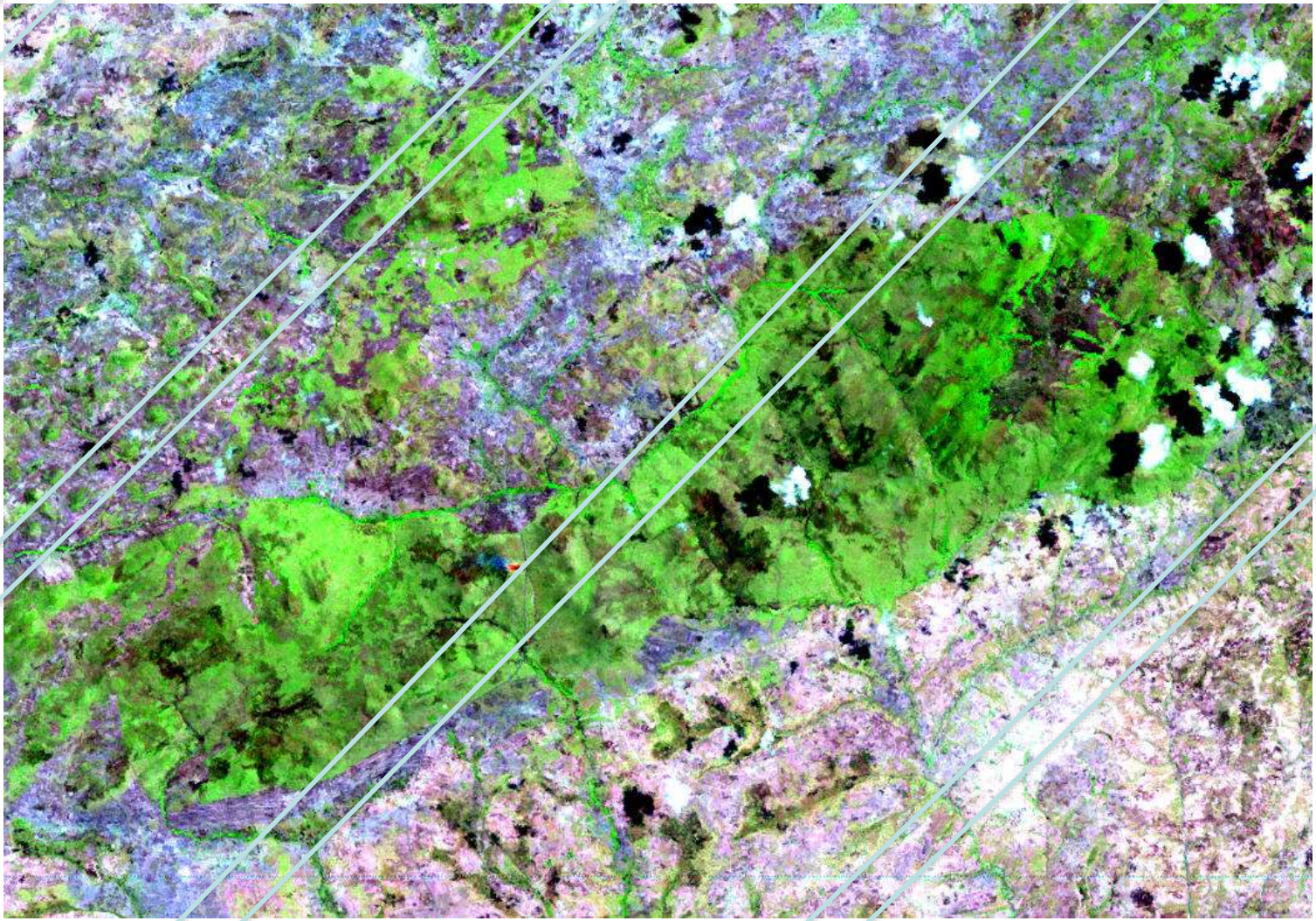
31km x 23km

Chimaliro forest reserve, Malawi

Landsat 30m pixels

bands 5 (1.65 μm), 4 (0.82 μm), 3 (0.66 μm)

September 26th 2001



31km x 23km

Chimaliro forest reserve, Malawi

JOURNAL OF GEOPHYSICAL RESEARCH
Biogeosciences
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JGR

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Global burned area and biomass burning emissions from small fires

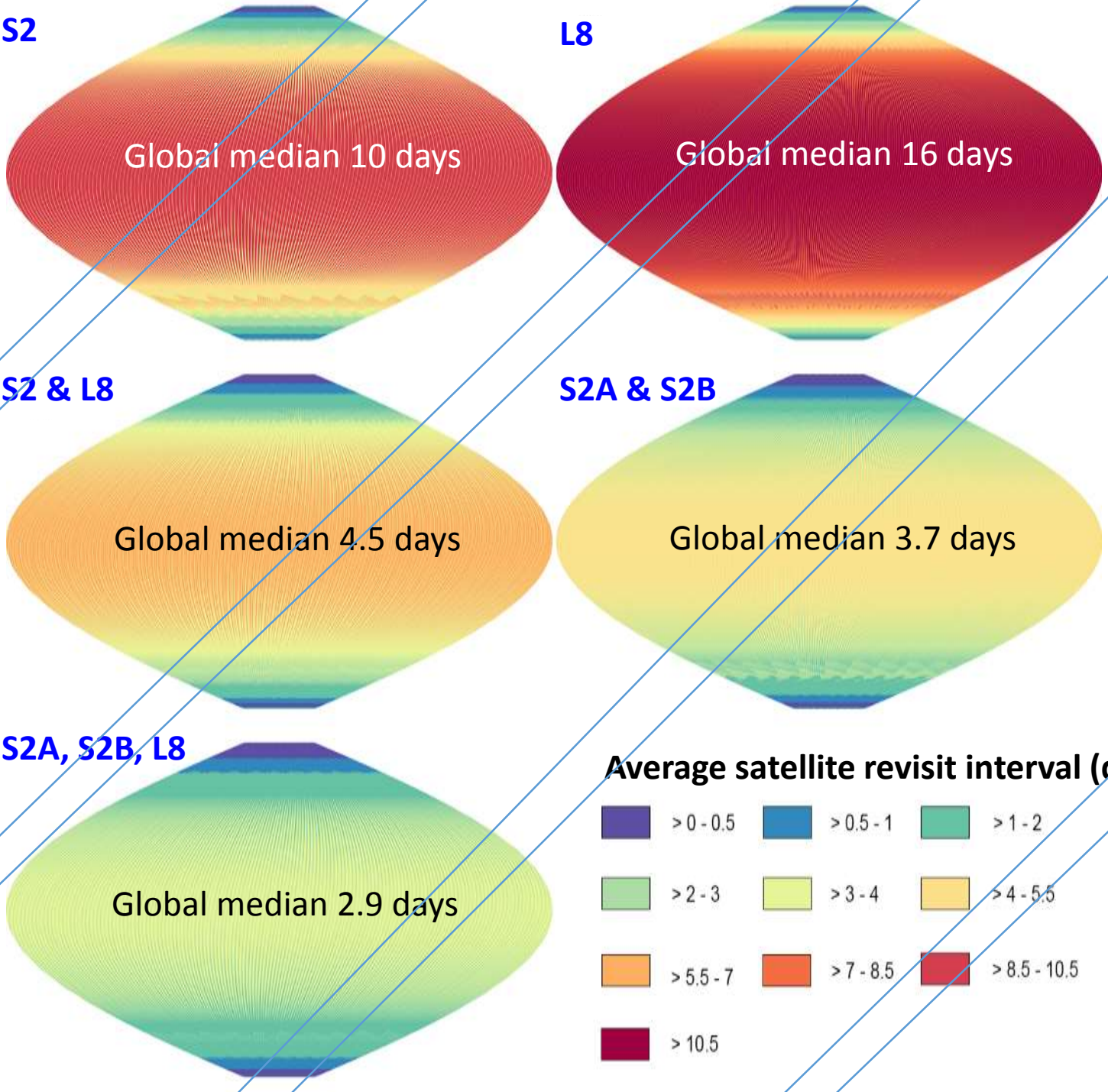
J. T. Randerson ✉, Y. Chen, G. R. van der Werf, B. M. Rogers, D. C. Morton

First published: 11 December 2012 Full publication history

DOI: 10.1029/2012JG002128 View/save citation

Accounting for small fires increased total global burned area by ~35%, from 345 Mha/yr to 464 Mha/yr

"A formal quantification of uncertainties was not possible …"



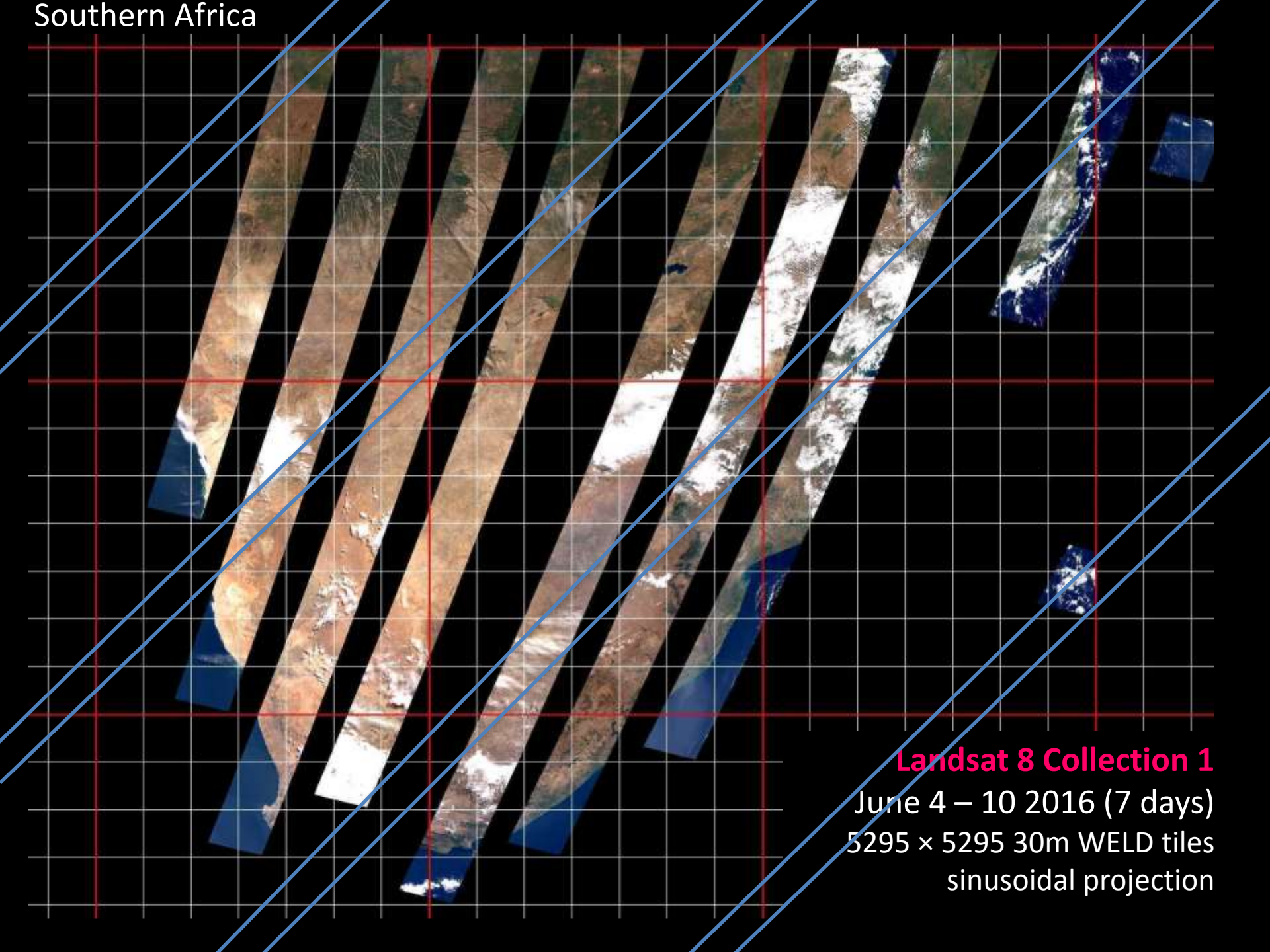
Li, J and Roy, D.P. 2017

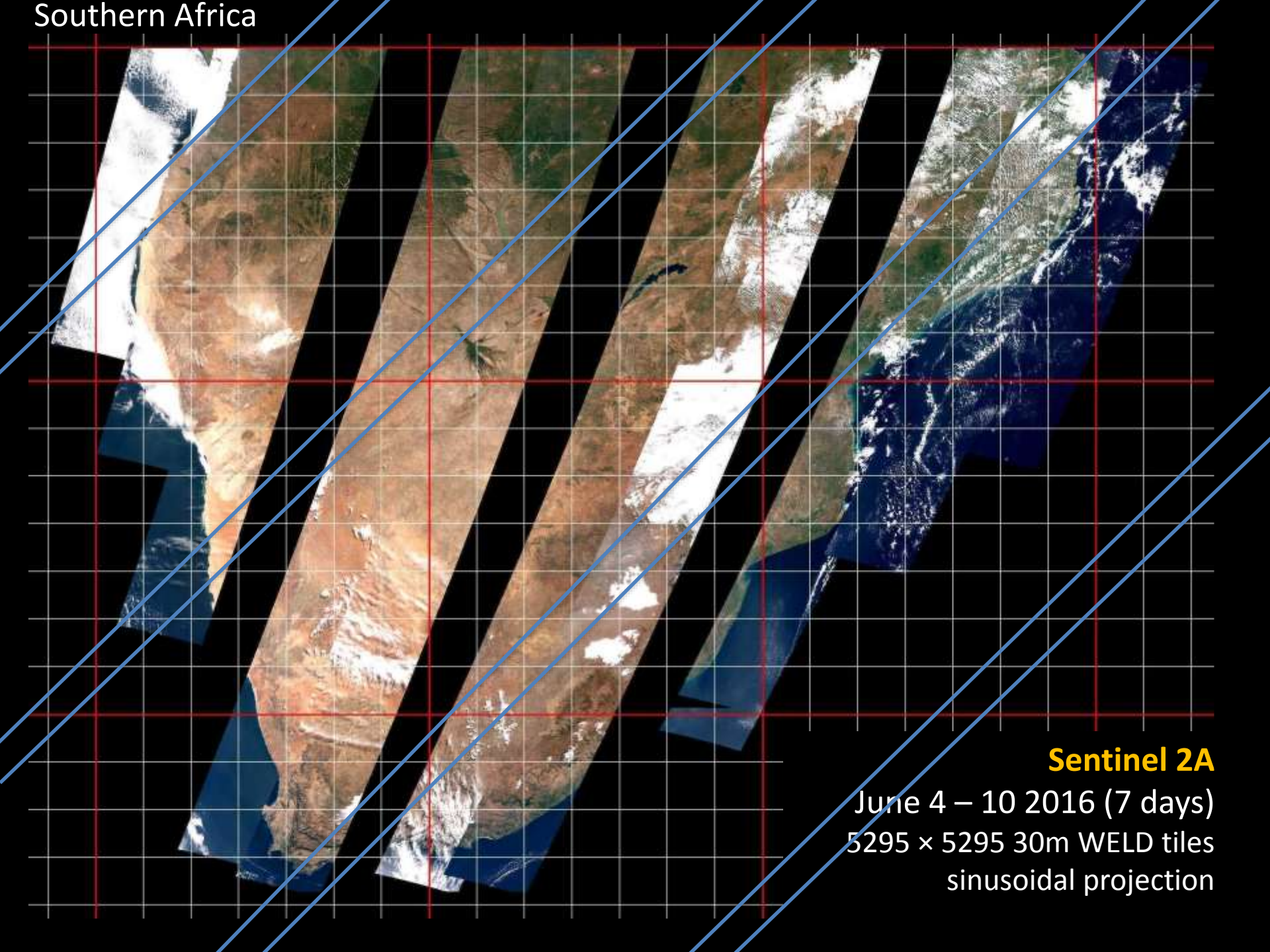
A global analysis of Sentinel-2A, Sentinel-2B and Landsat-8 data revisit intervals and implications for terrestrial monitoring,

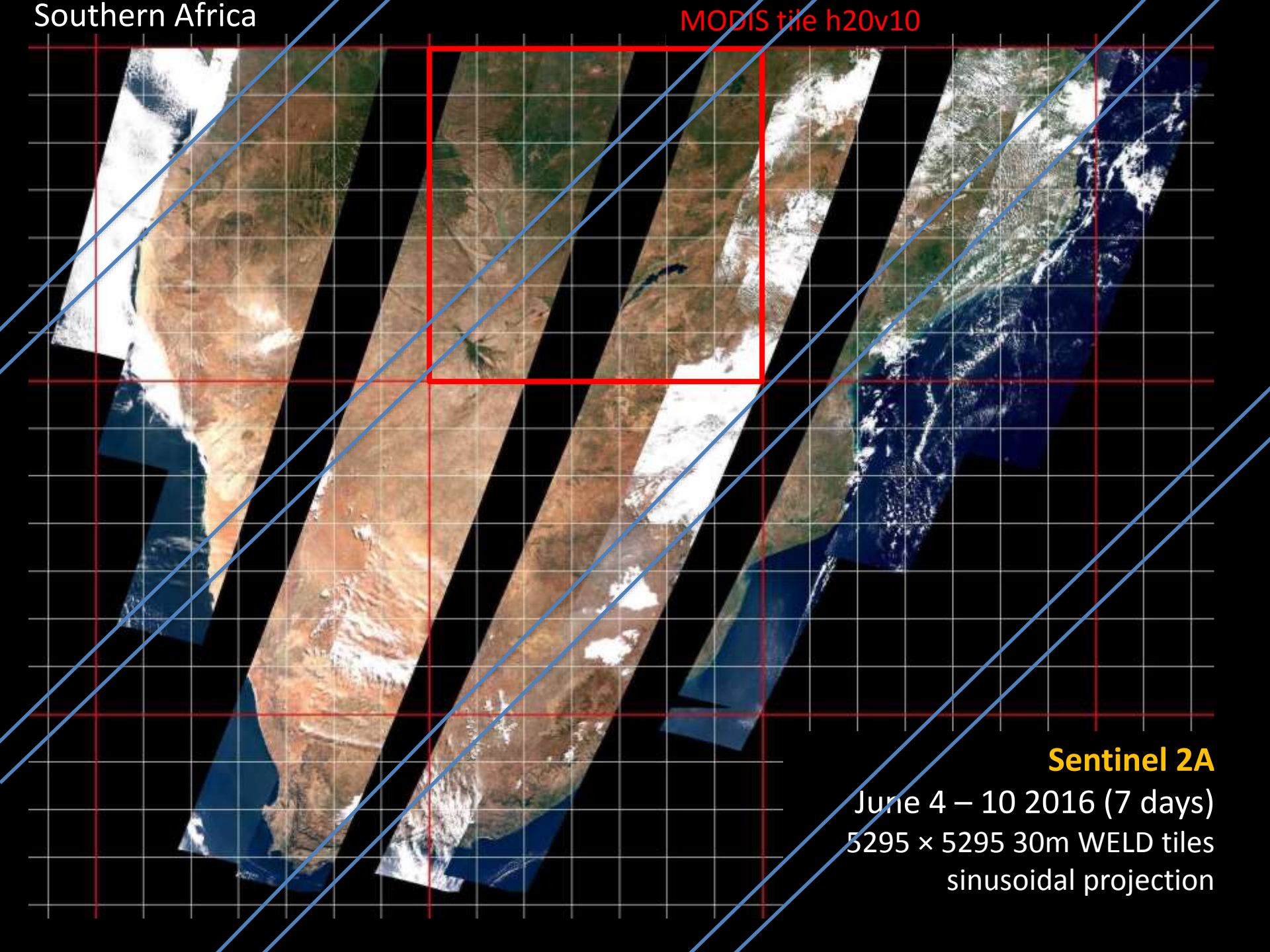
Remote Sensing, 9, 902

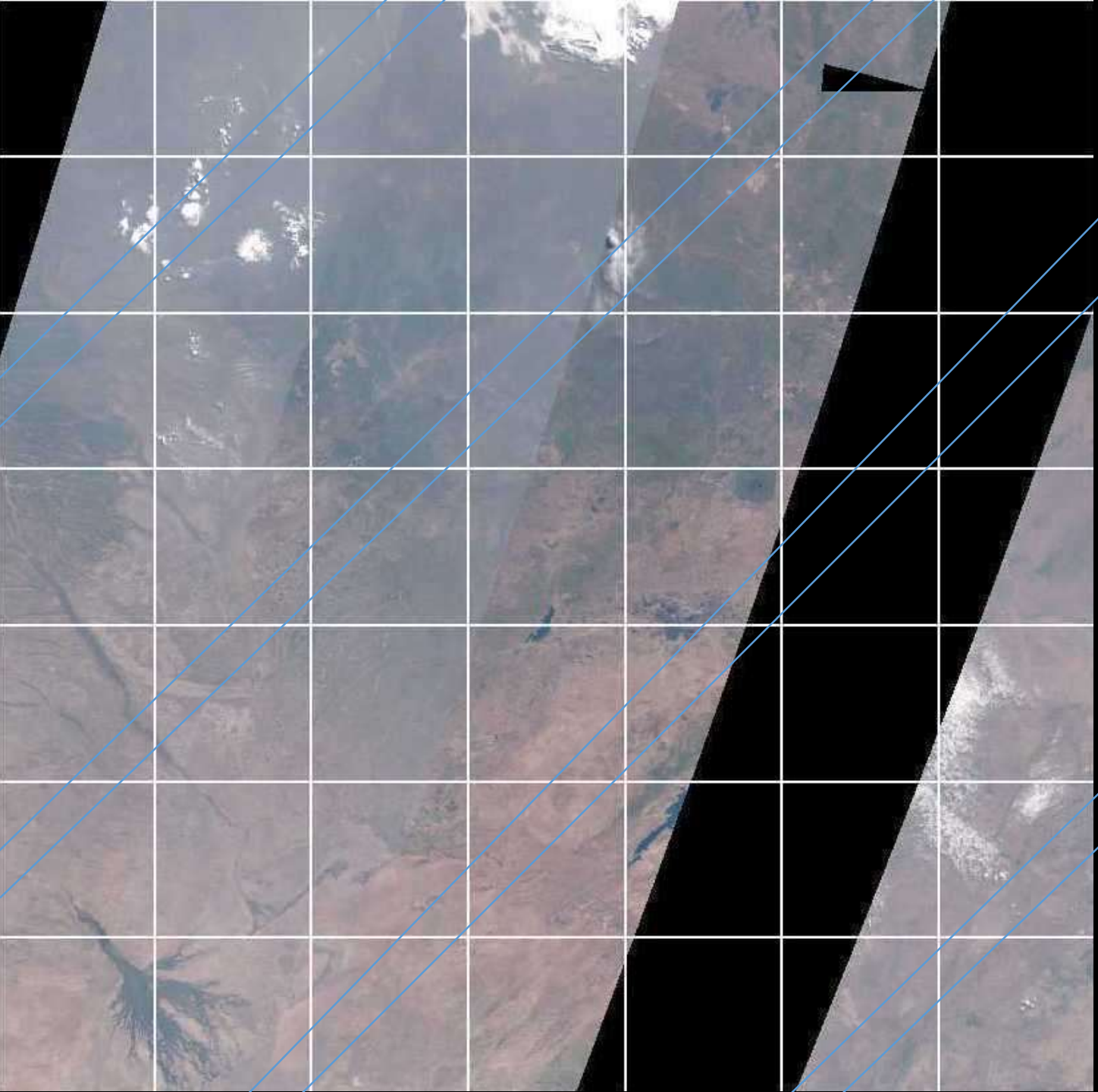
Sentinel-2 Landsat-8 Pre-Processing

- Global WELD processing framework
  - Tiling into MODIS sinusoidal grid
  - Sentinel-2A to Landsat-8 registration
  - Sentinel-2A to Sentinel-2A registration
- Atmospheric correction (LaSRC)
- Nadir BRDF-adjusted reflectance (NBAR) (MODIS c-factor)
- Masking
  - cloud (Landsat 8 Collection 1 & Sen2Cor)
  - no masking of shadow (!)
  - ephemeral water masking issues


Southern Africa
Landsat 8 Collection 1
June 4 – 10 2016 (7 days)
5295 × 5295 30m WELD tiles
sinusoidal projection


Southern Africa
Sentinel 2A
June 4 – 10 2016 (7 days)
5295 × 5295 30m WELD tiles
sinusoidal projection


Southern Africa
MODIS tile h20v10
Sentinel 2A
June 4 – 10 2016 (7 days)
5295 × 5295 30m WELD tiles
sinusoidal projection



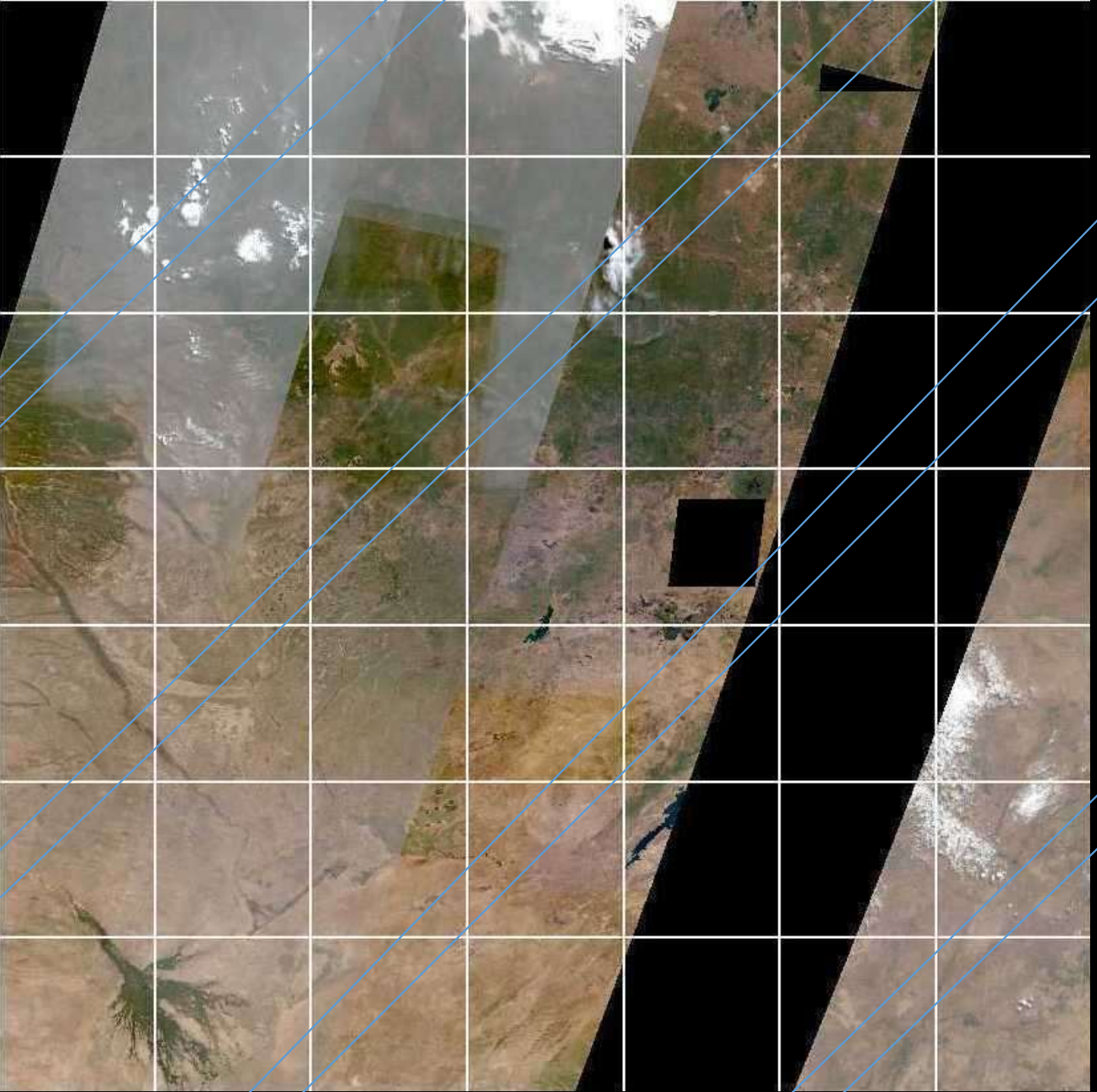
Sentinel 2A
TOA
reflectance

week 30
Jul. 22-28 2016

7 x 7 WELD tiles

1112 x 1112 km

MODIS tile
h20v10



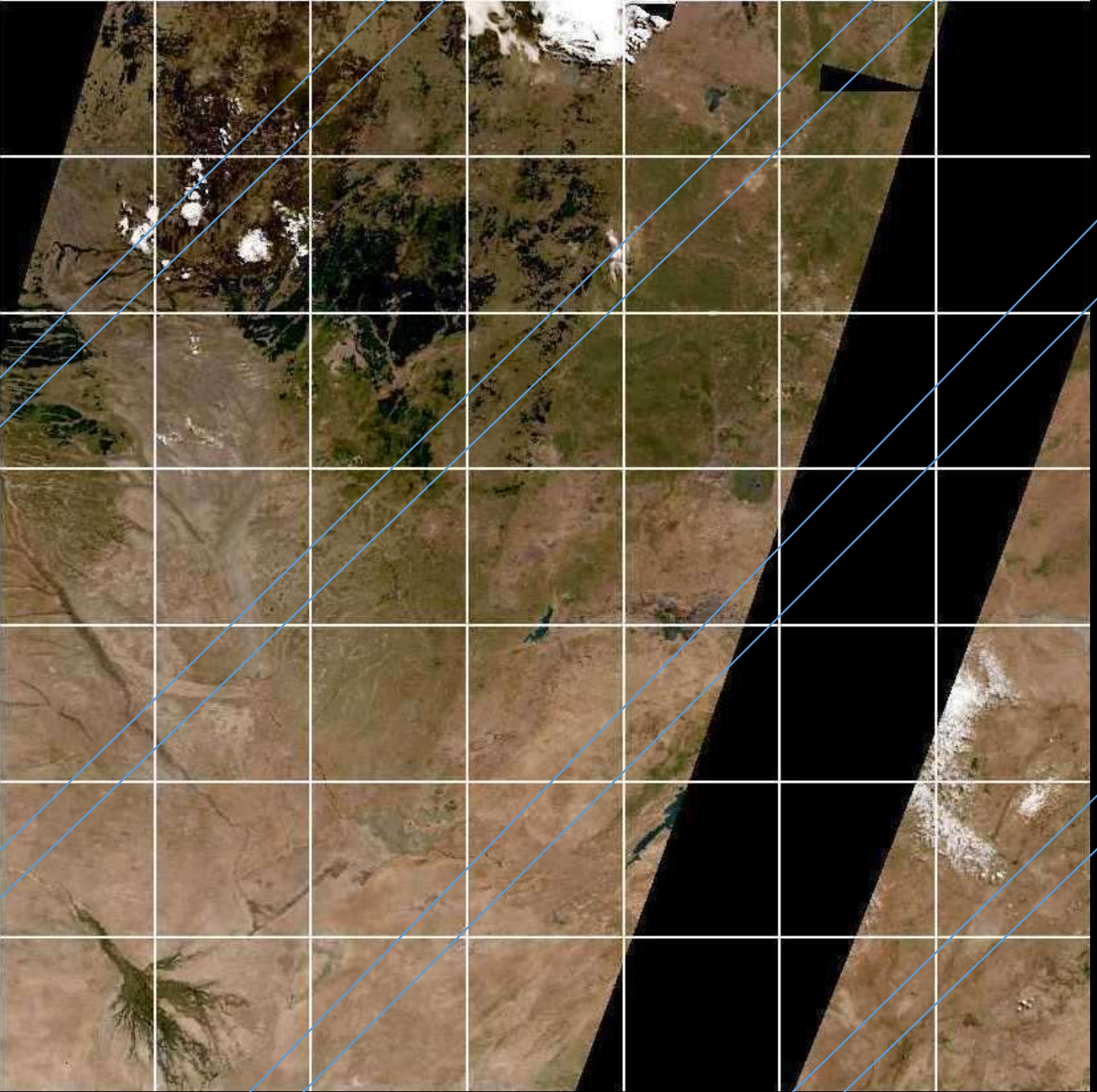
Sentinel 2A
V2.3.1
Sen2Cor
surface
reflectance

week 30
Jul. 22-28 2016

7 x 7 WELD tiles

1112 x 1112 km

MODIS tile
h20v10



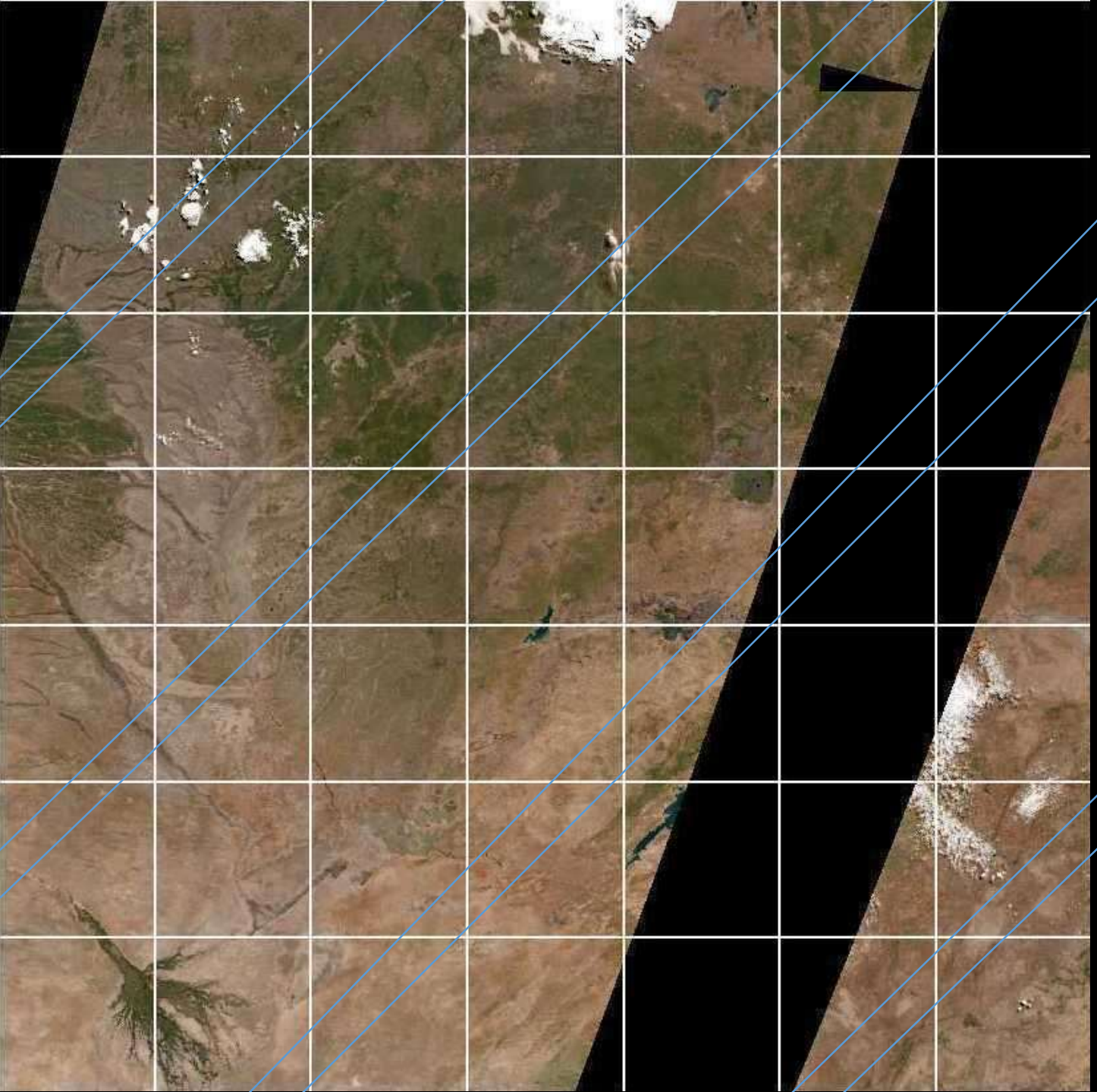
Sentinel 2A
V3.5.3
LaSRC
surface
reflectance

week 30
Jul. 22-28 2016

7 x 7 WELD tiles

1112 x 1112 km

MODIS tile
h20v10



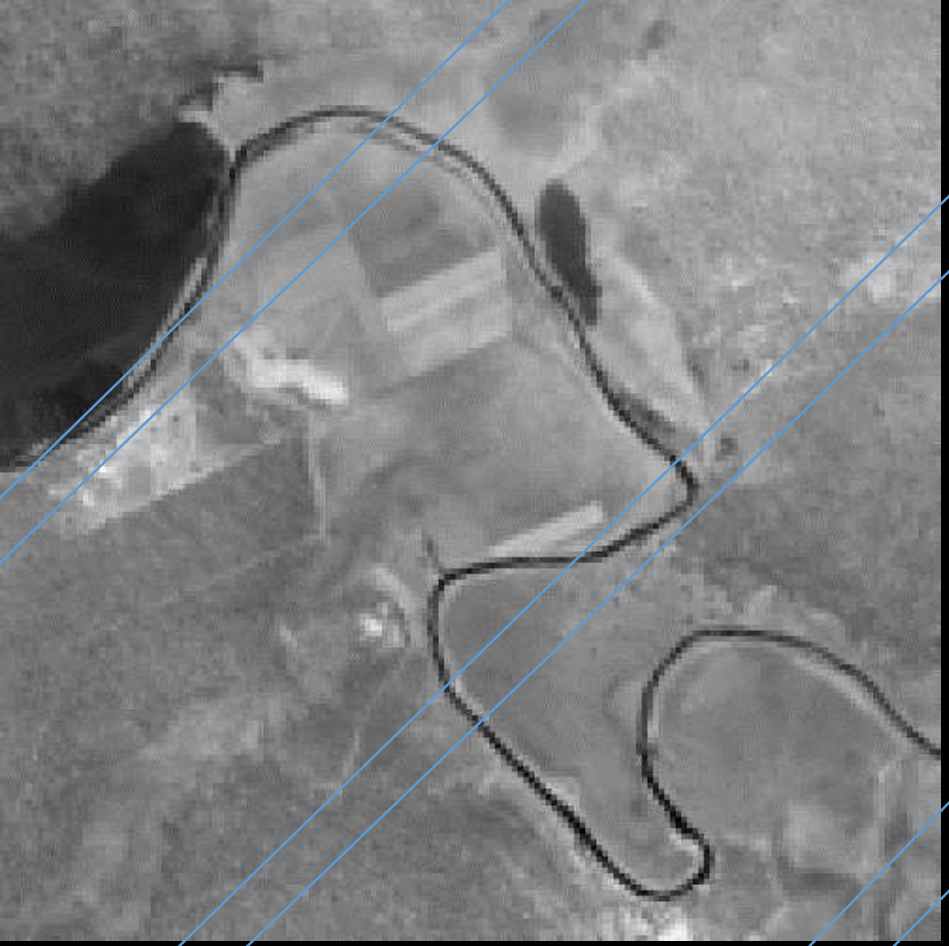
Sentinel 2A
V3.5.5
LaSRC
surface
reflectance

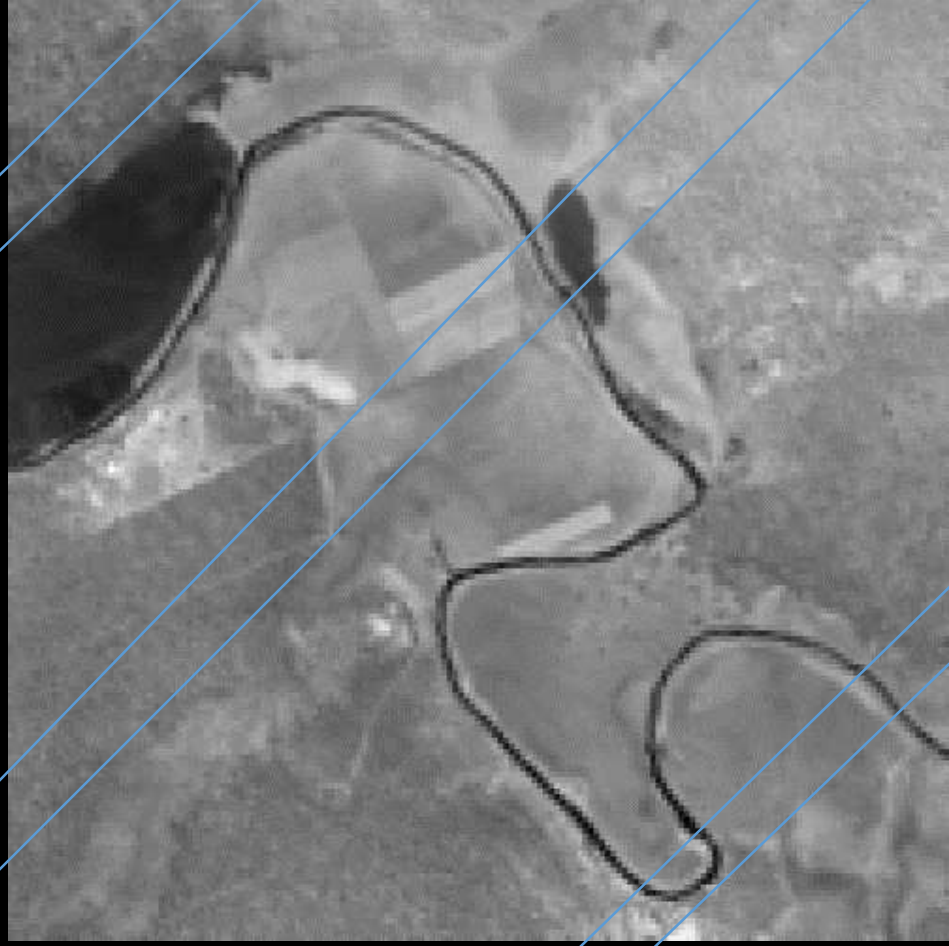
week 30
Jul. 22-28 2016

7 x 7 WELD tiles

1112 x 1112 km

MODIS tile
h20v10





Original

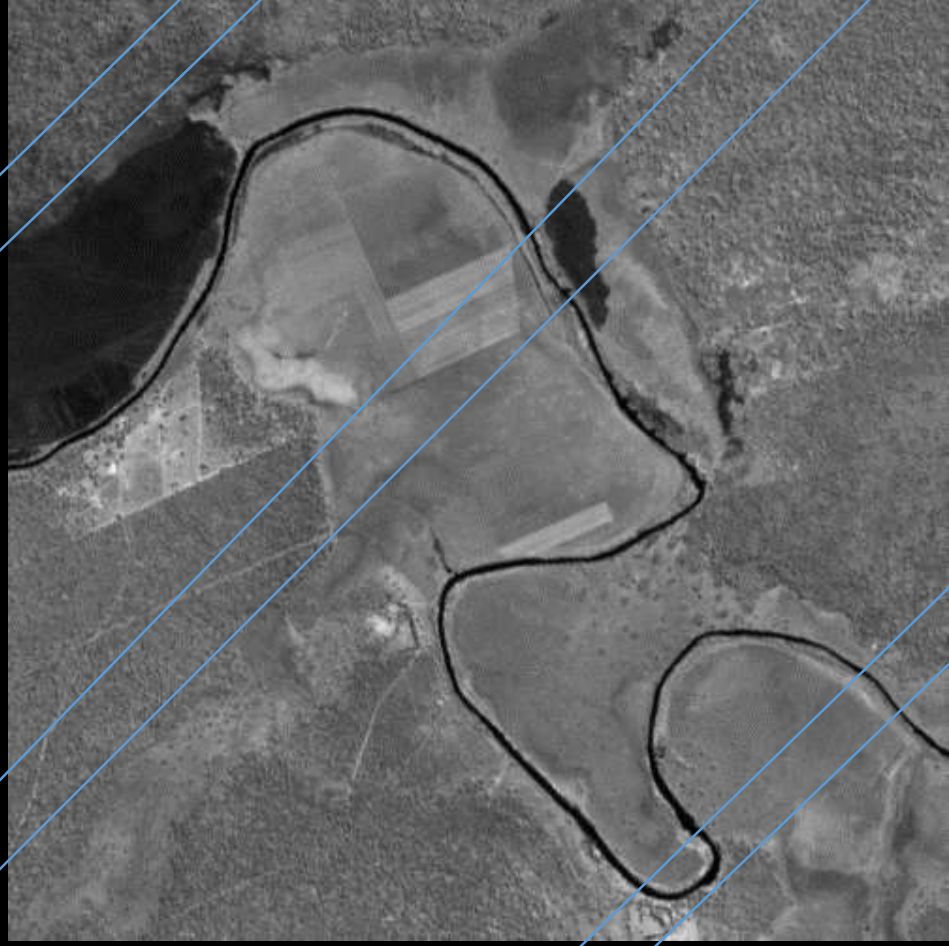
Registered

Landsat 8 Collection 1

July 21 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR



Original

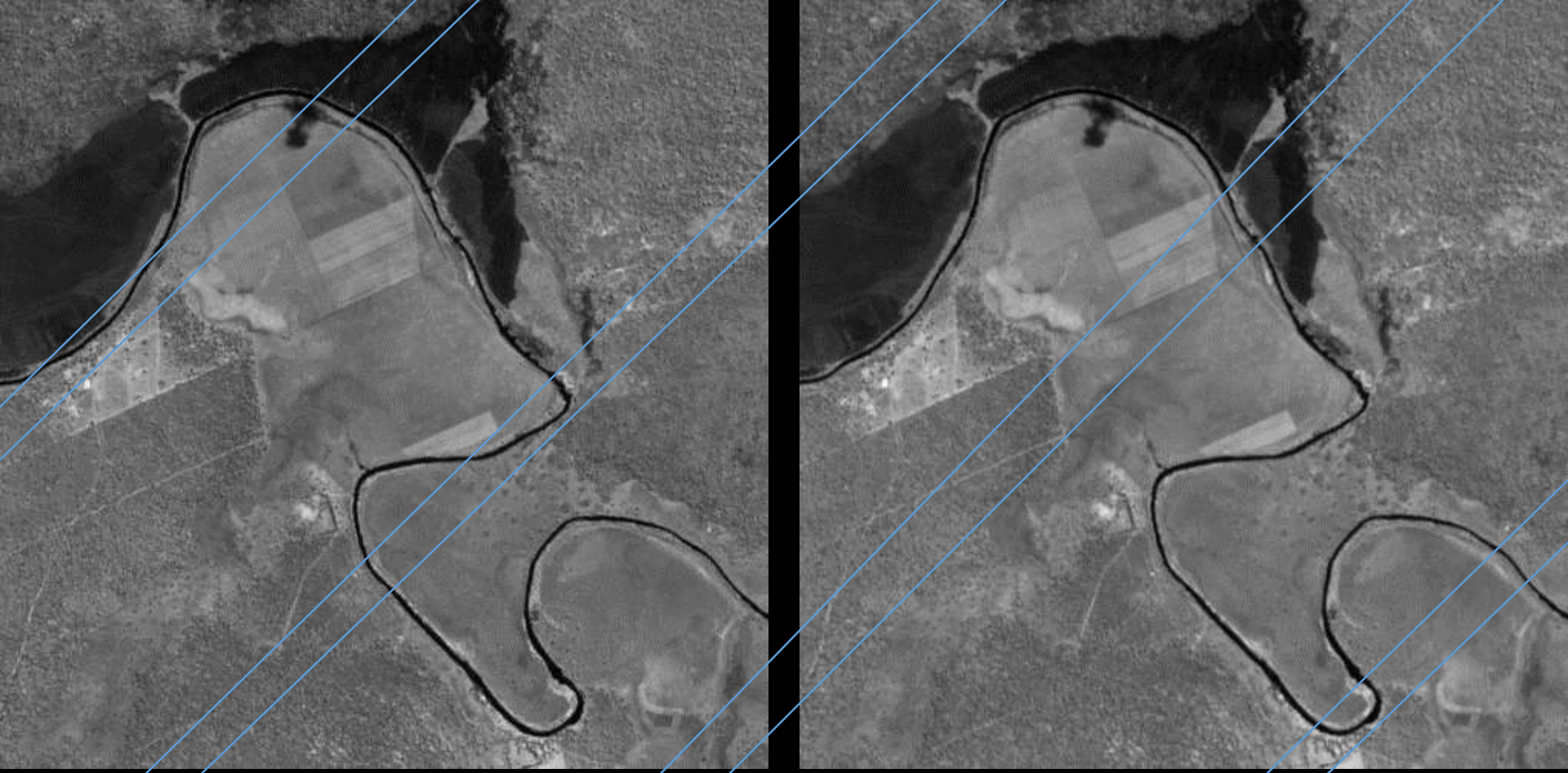
Registered

Sentinel 2A

July 22 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR



Original

Registered

Sentinel 2A

August 1 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR

Original

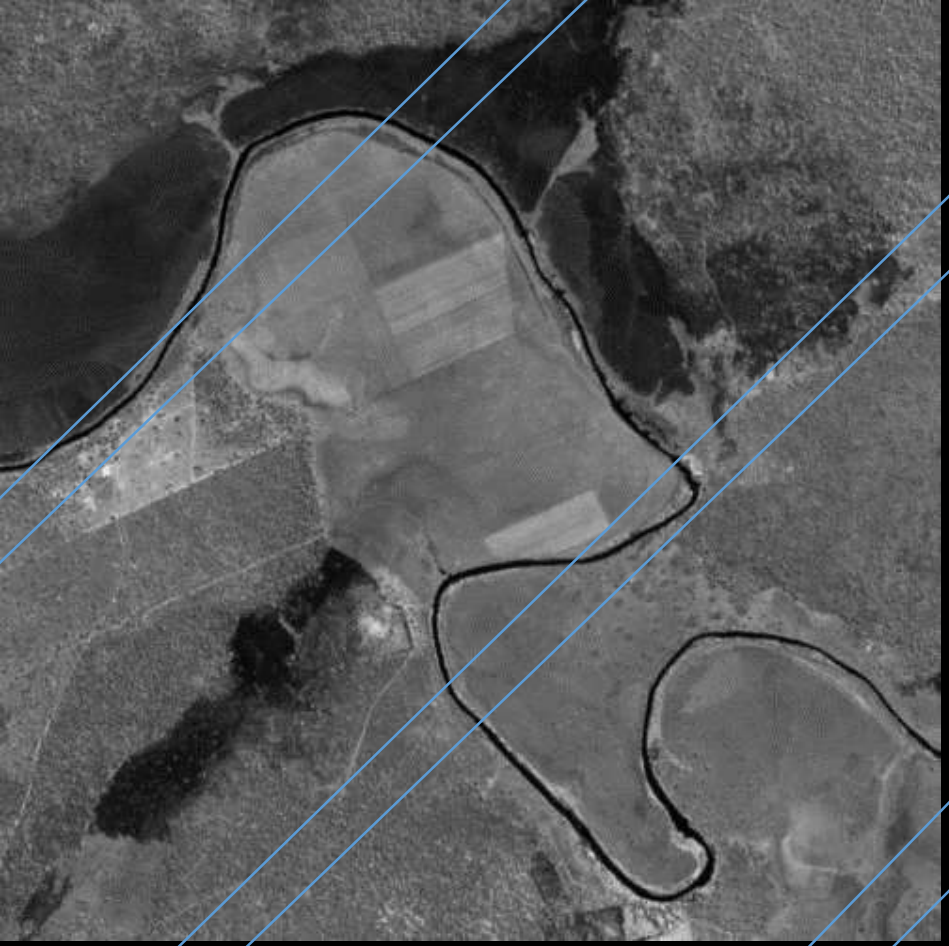
Registered

Landsat 8 Collection 1

August 6 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR



Original

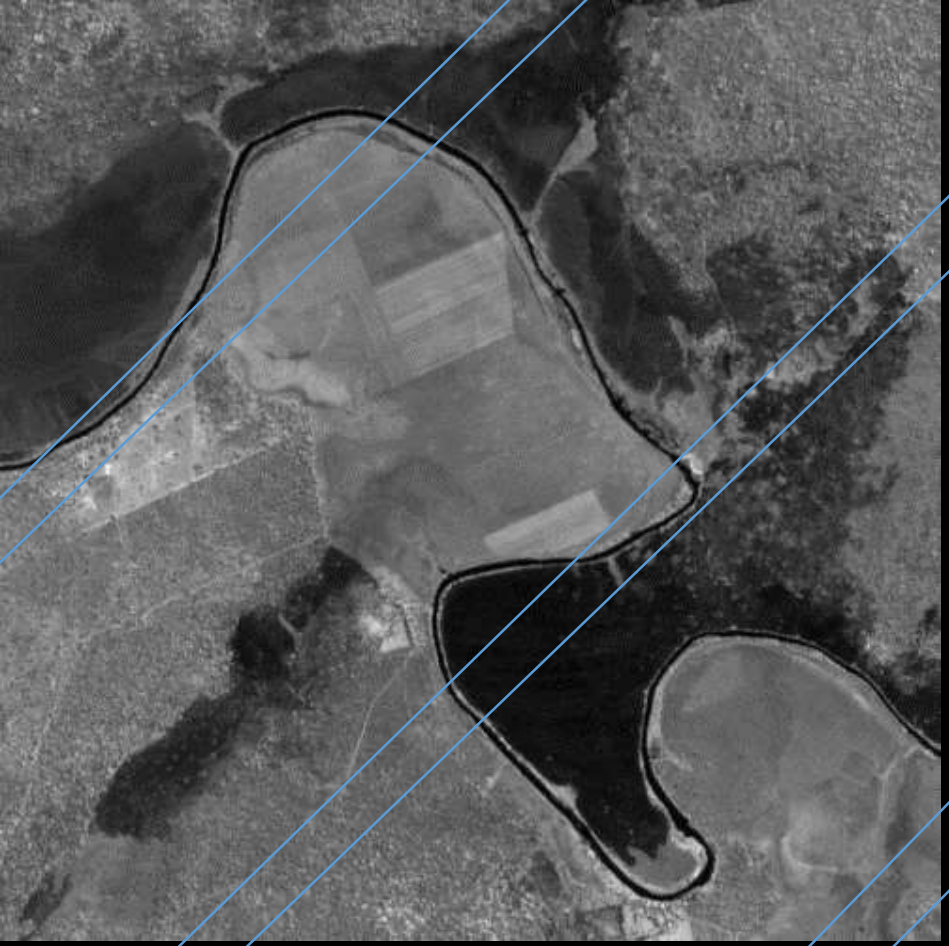
Registered

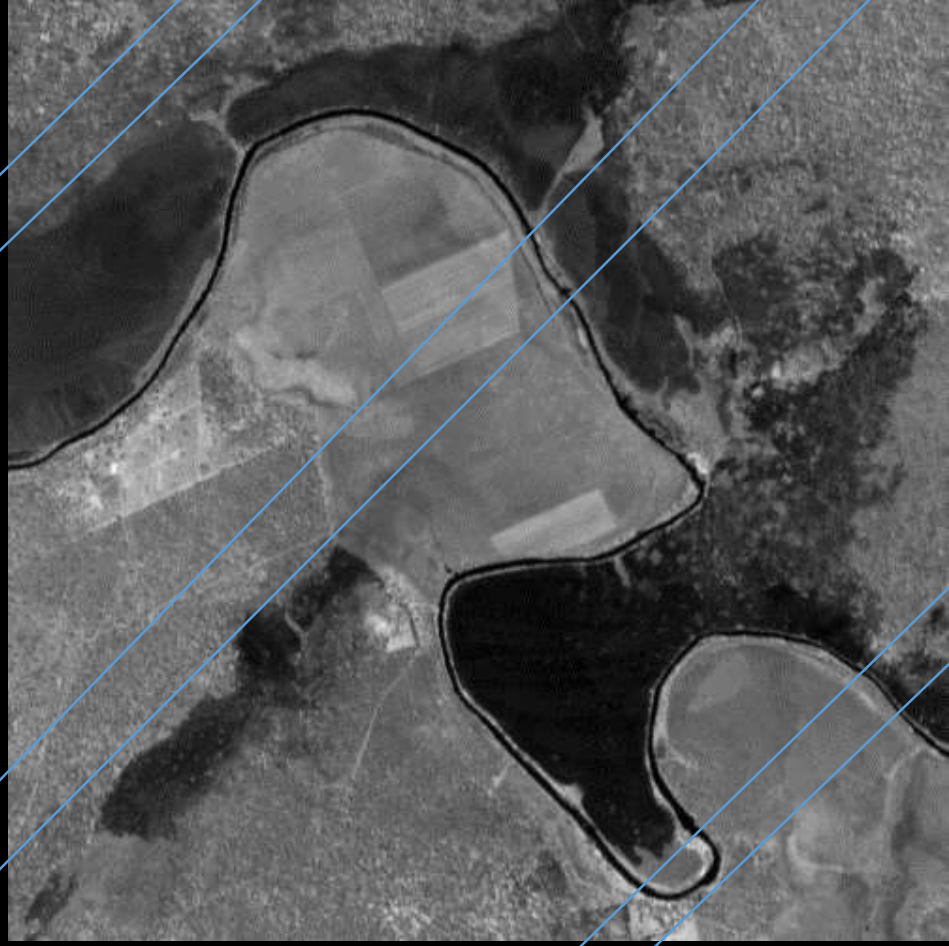
Sentinel 2A

August 11 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR





Original

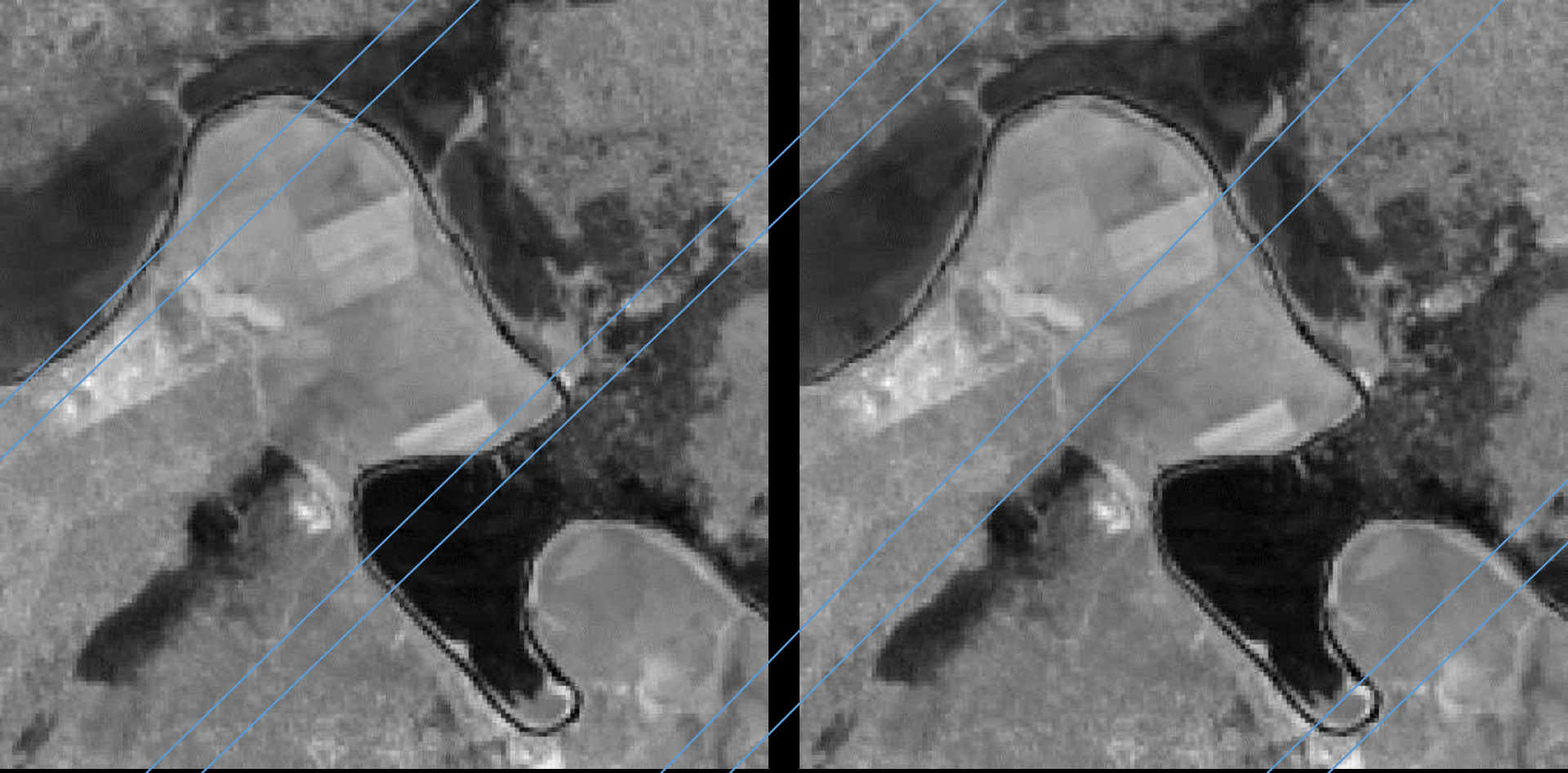
Registered

Sentinel 2A

August 21 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR



Original

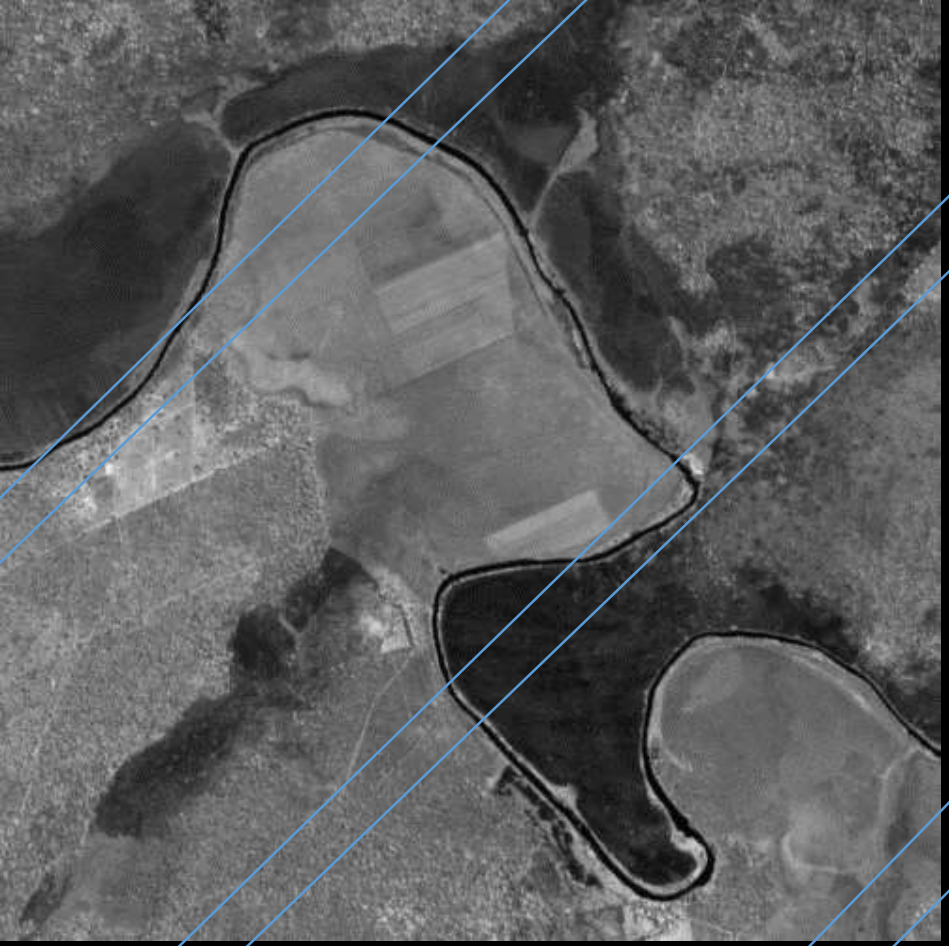
Registered

Landsat 8 Collection 1

August 22 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR



Original

Registered

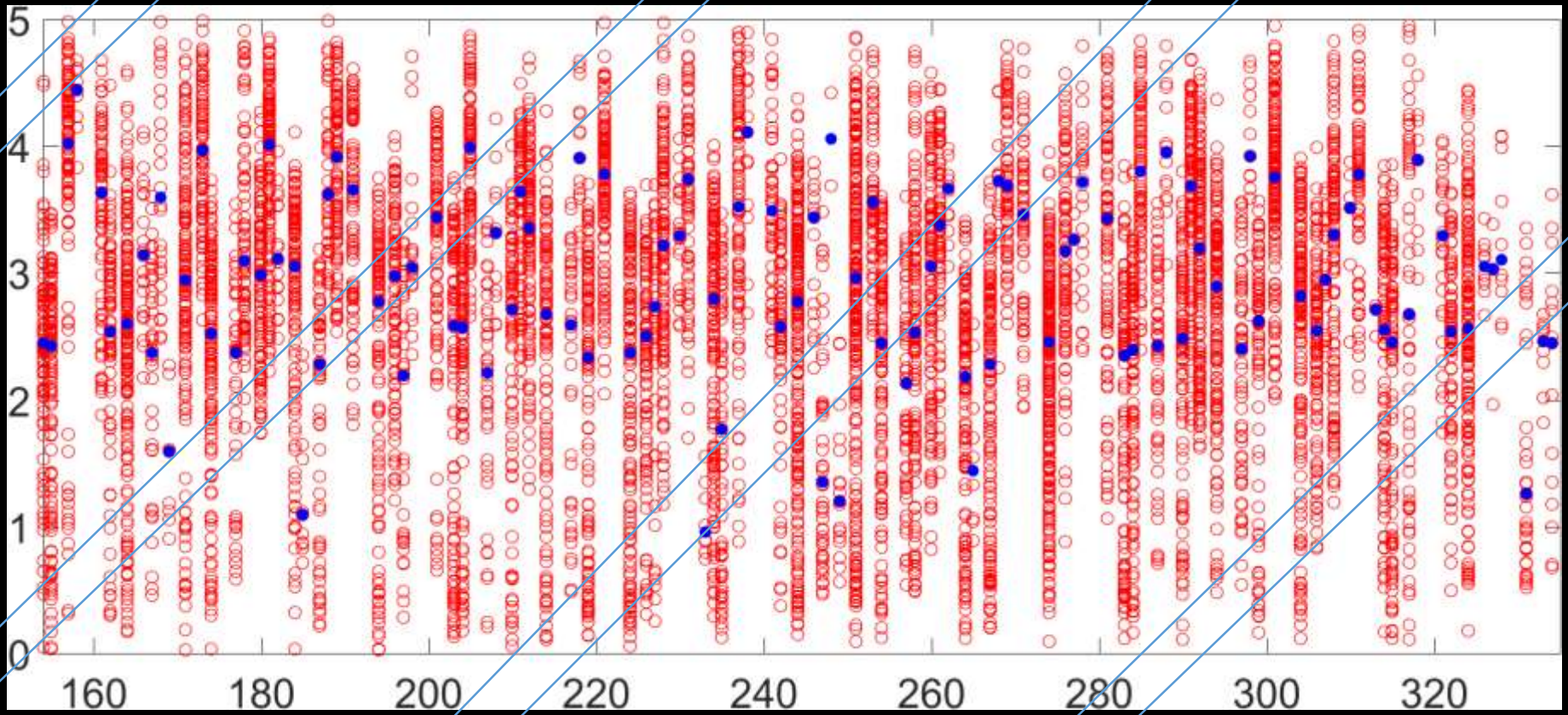
Sentinel 2A

August 31 2016

Copperbelt Provence, Zambia

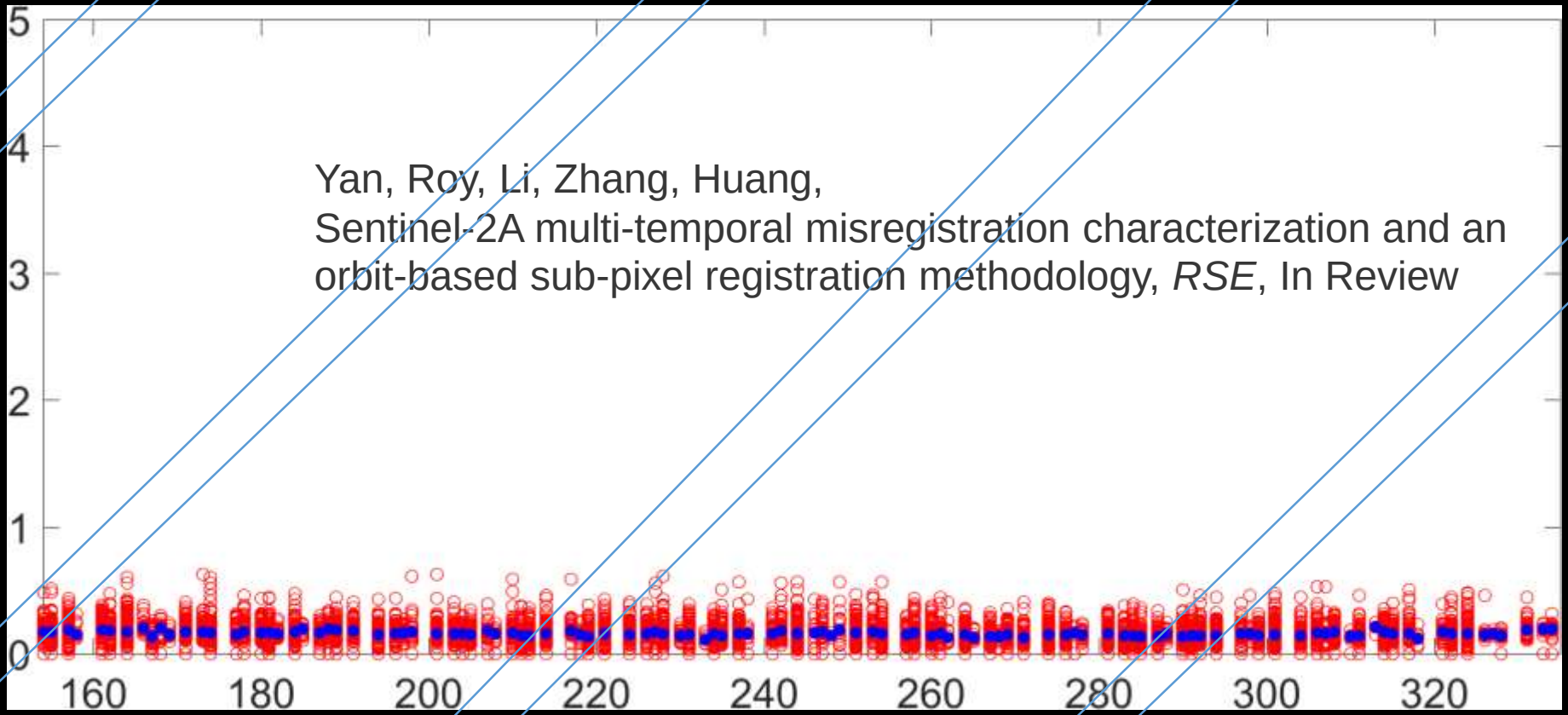
500 × 500 10 m pixels, NIR

Landsat 8 <-> Sentinel 2
misregistration characterization (10m), UTM 35



μ = 2.761, σ = 1.075, max = 4.990 (10m pixels) (4,574 matched image pairs)

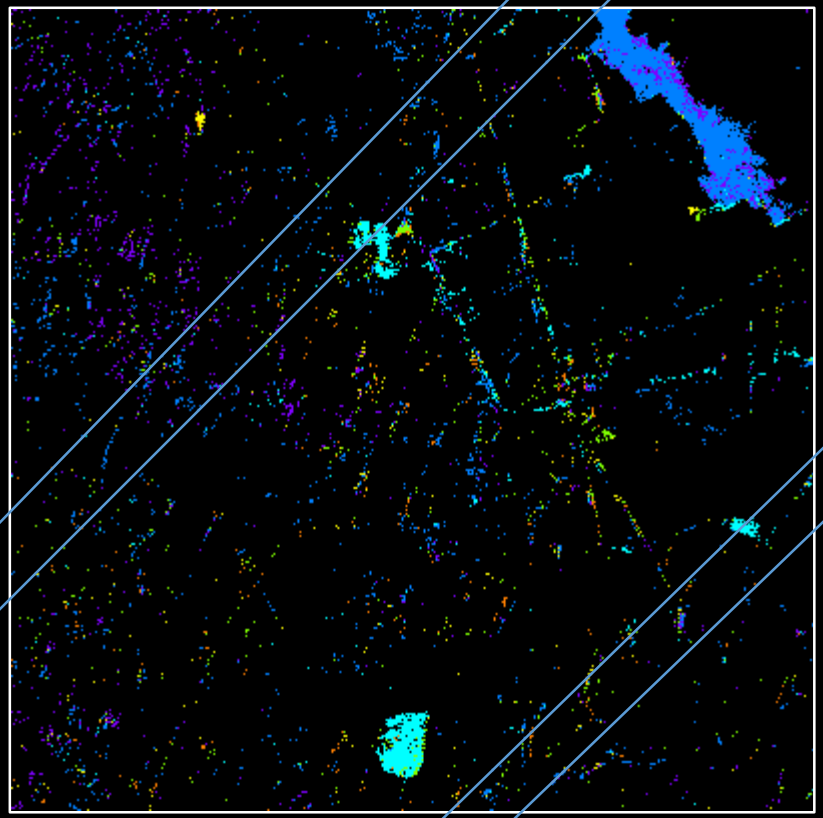
Landsat 8 <-> Sentinel 2
misregistration characterization (10m), UTM 35
after partial-orbit based registration



μ = 0.161, σ = 0.076, max = 0.624 (10m pixels) (4,574 matched image pairs)

Example burned areas & date of burning

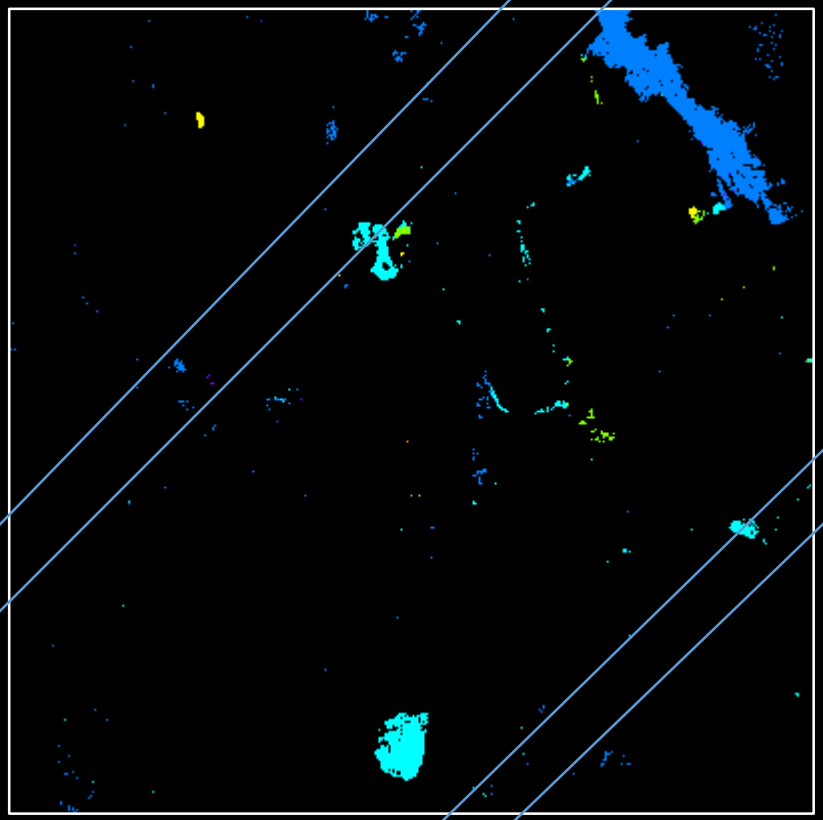
Derived from
tile-based
registered data



400 x 400 30 m pixels
Zimbabwe

Example burned areas & date of burning

Derived from
partial-orbit based
registered data



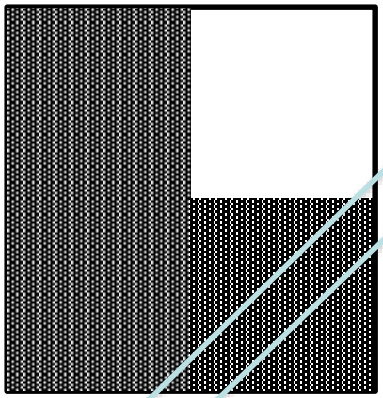
400 x 400 30 m pixels
Zimbabwe

Landsat-8 Sentinel-2 global 30 m burned area product generation algorithm

Then some Example Results

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

Linear Spectral Mixture Model



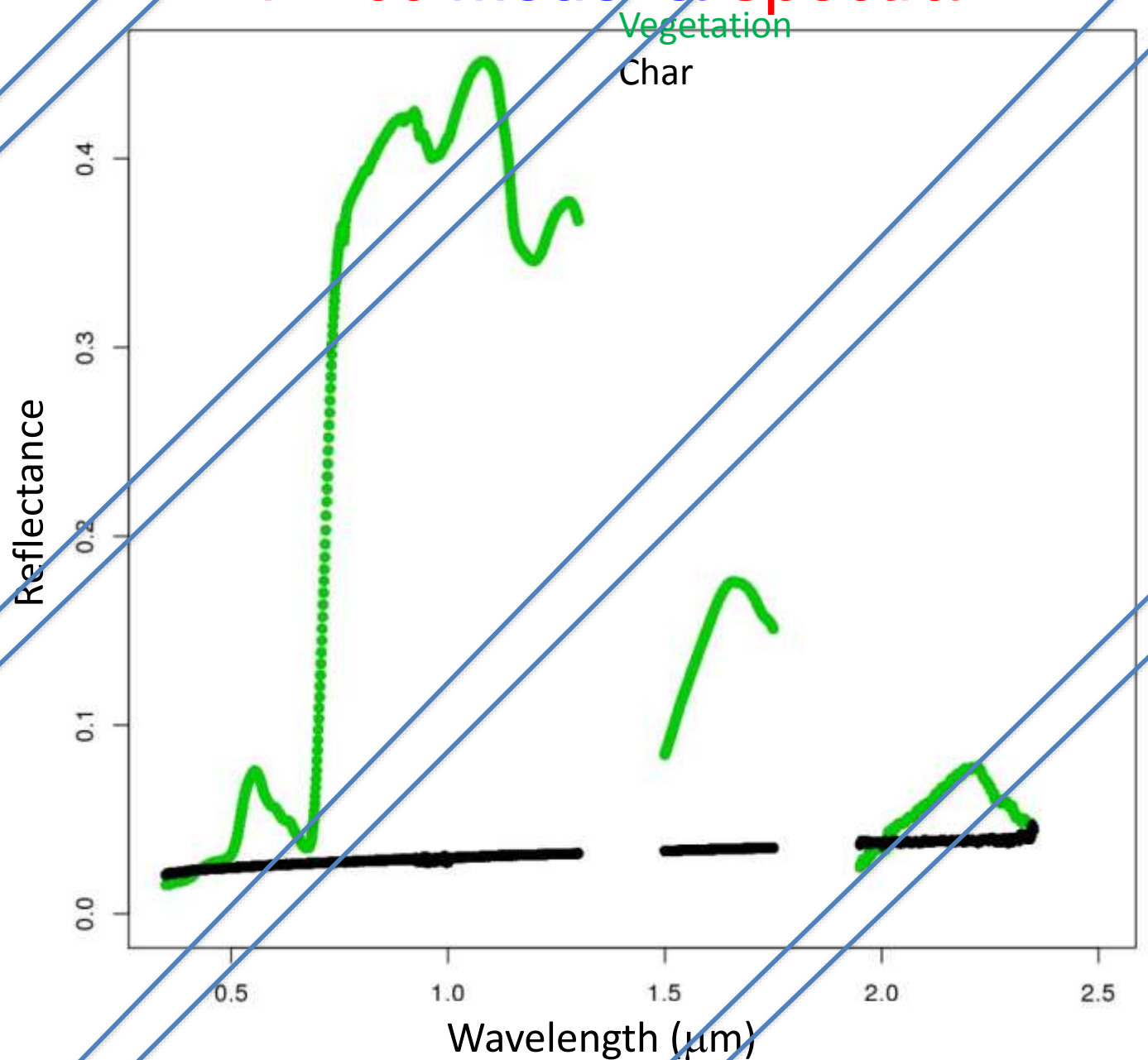
f = 0.75
cc = 0.3

Reflectance of a pixel with fraction of area burned f combustion completeness cc

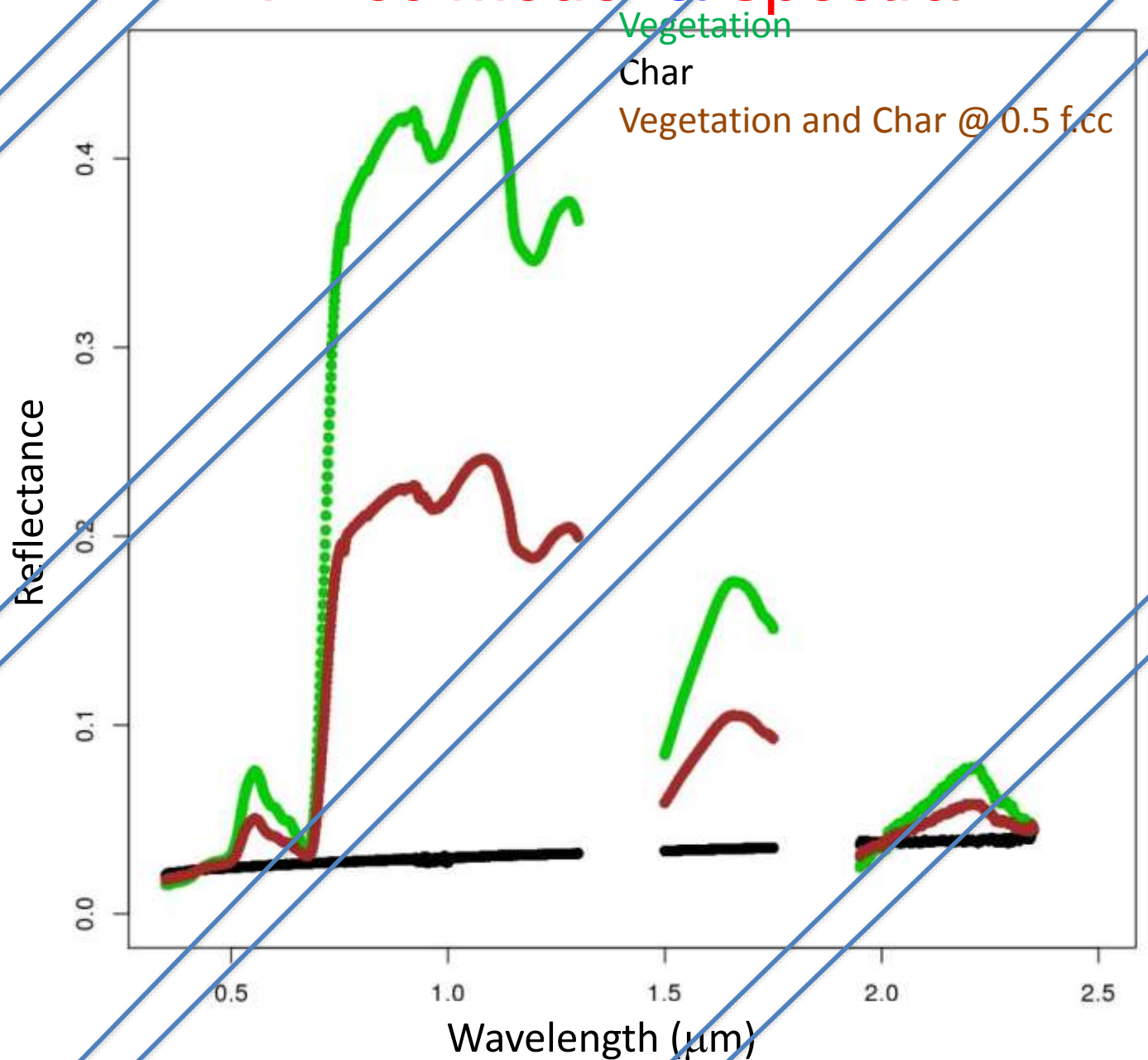
$$\rho = (1 - f\,cc)\,\rho_{unburned} + f\,cc\,\rho_{burned}$$

Roy, D, Landmann, T (2005) Characterizing the surface heterogeneity of fire effects using multi-temporal reflective wavelength data. *International Journal of Remote Sensing* 26, 4197-4218.

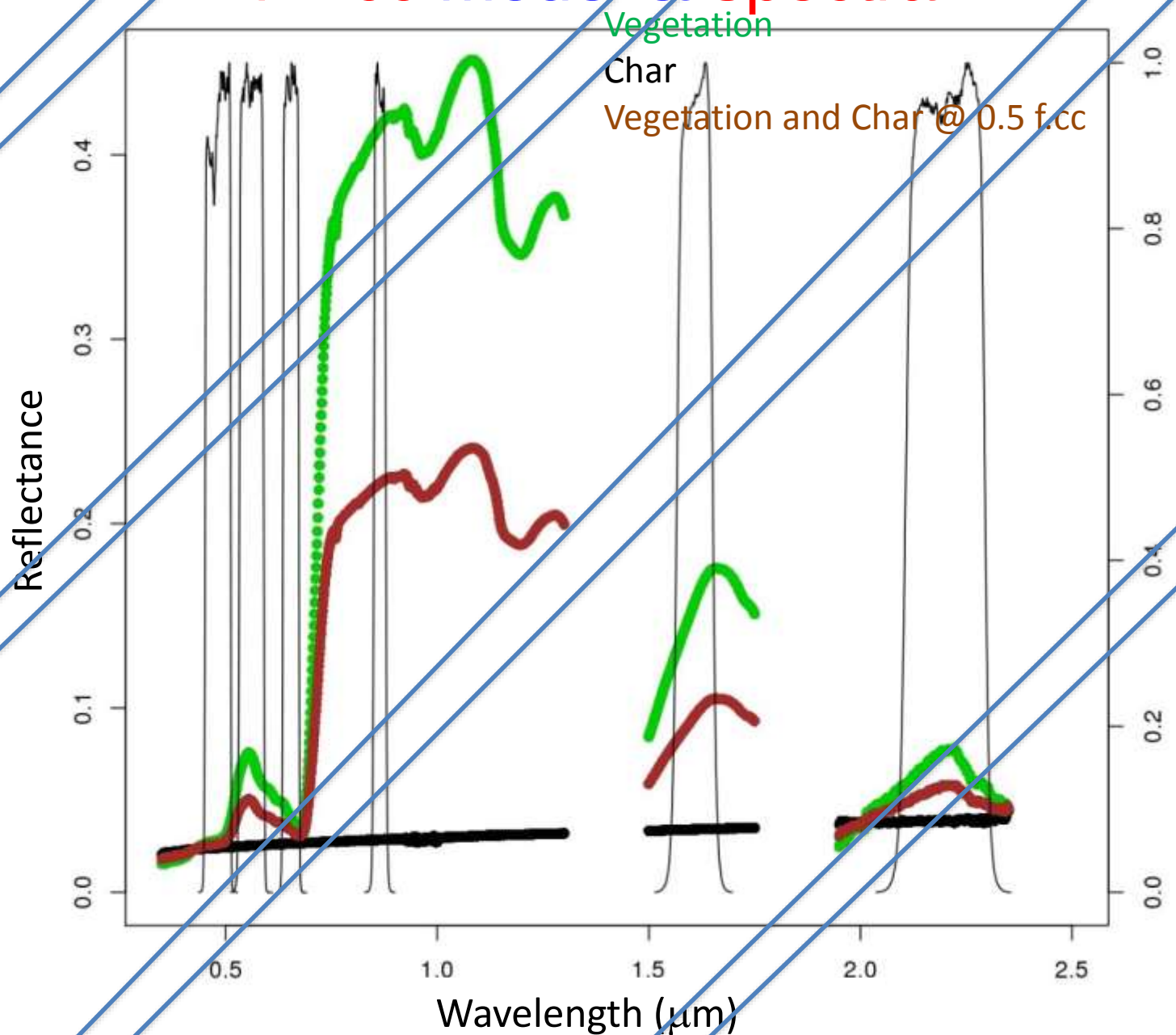
Derive synthetic training data using f × cc model & spectra

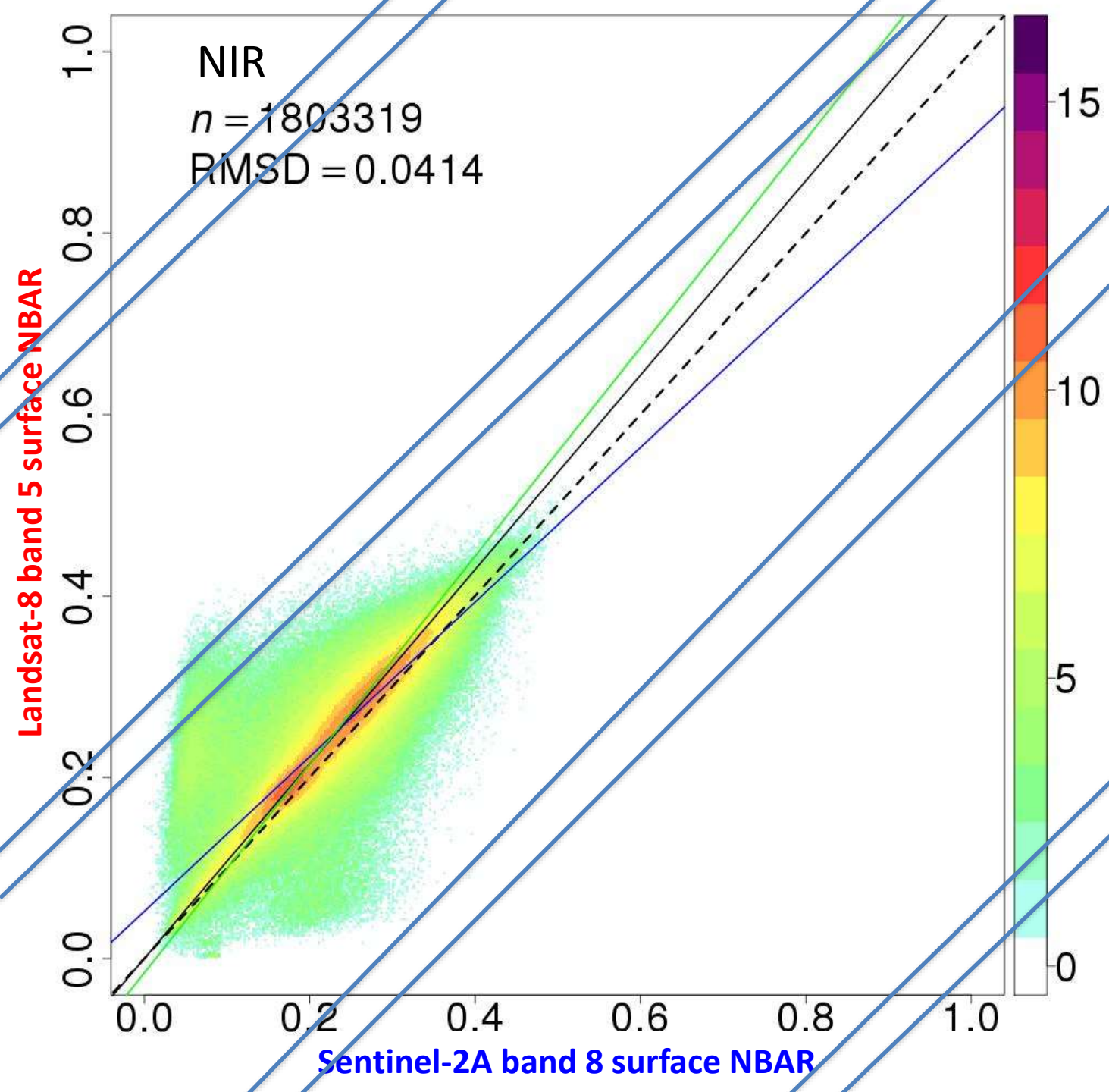


Derive synthetic training data using f × cc model & spectra



Derive synthetic training data using f × cc model & spectra





Apply **Landsat-8** **Sentinel-2A** band statistical calibration

Zhang, Roy, Yan, Li, Huang, Vermote, Skakun, Roger,

Characterization of Sentinel-2A and Landsat-8 top of atmosphere, surface, nadir BRDF adjusted reflectance and NDVI differences,

RSE, in review

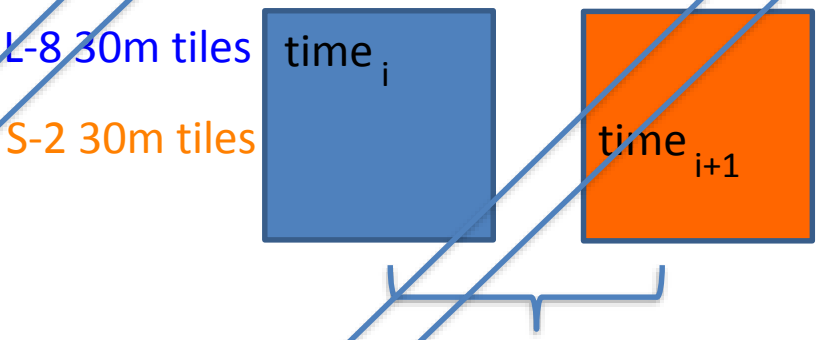
Synthetic training data
spectral library
f. cc model

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

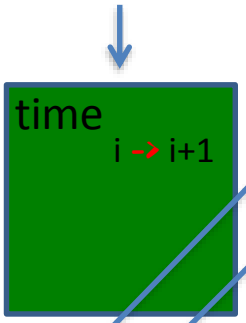
Landsat-8 & Sentinel-2
Spectral Response Functions

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

5295 × 5295 30m registered WELD tiles



Random Forest Classification



30m f × cc

Landsat 8

Kafue
National park,
Zambia

Day 155 2016

false color surface
NBAR

2000 x 2000 30m pixels

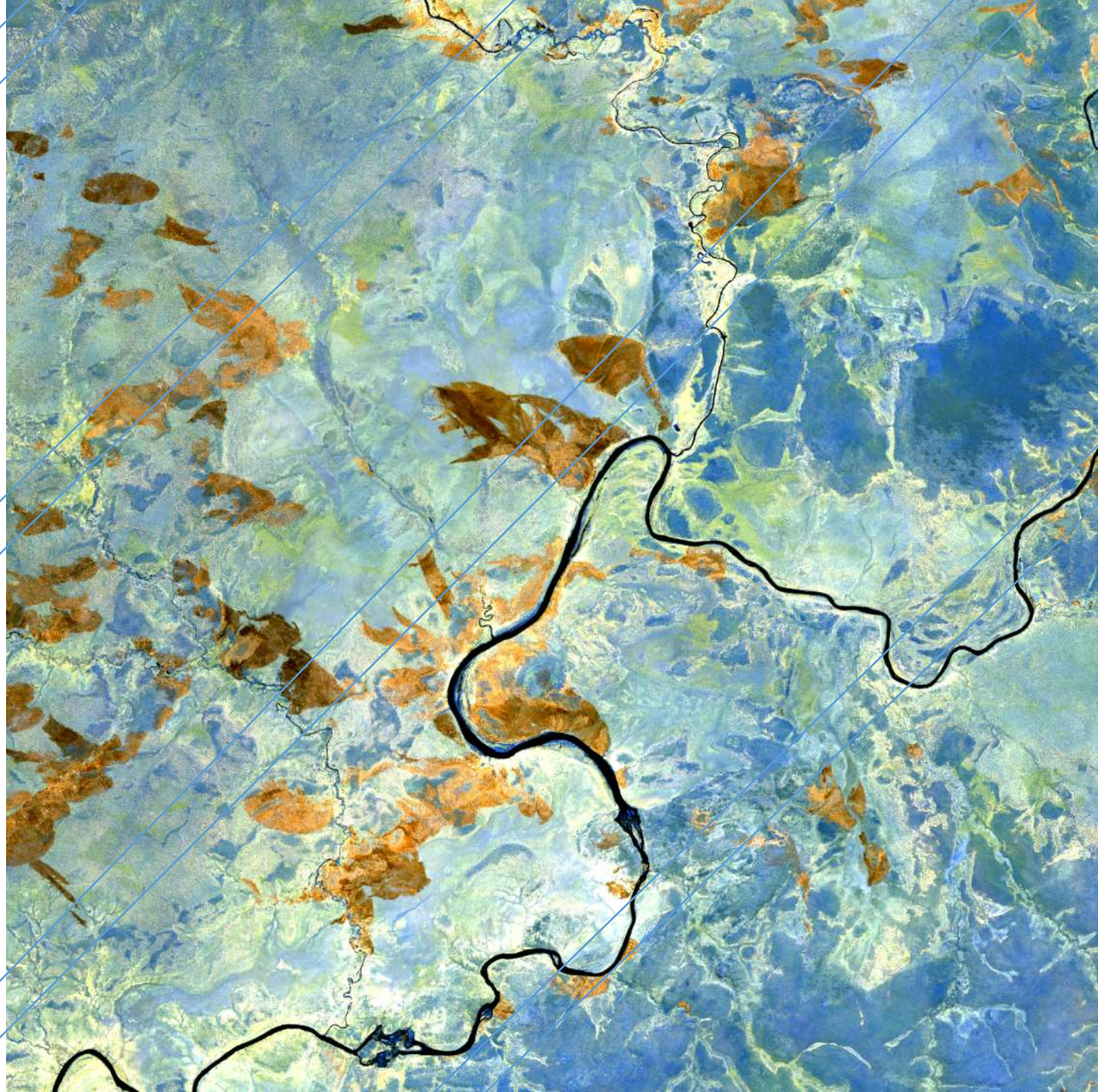
Sentinel 2A

Kafue
National park,
Zambia

Day 164 2016

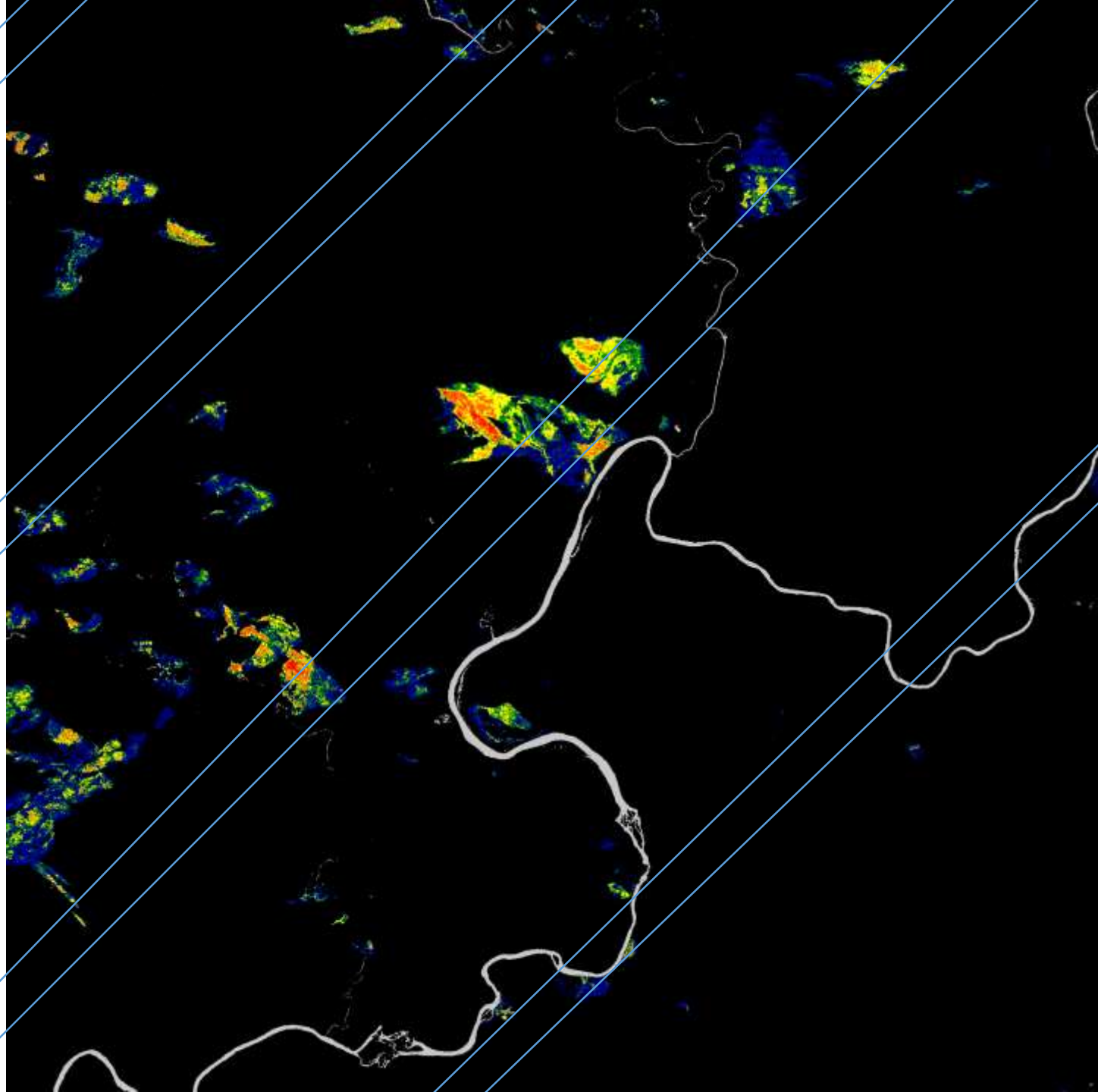
false color surface
NBAR

2000 x 2000 30m pixels

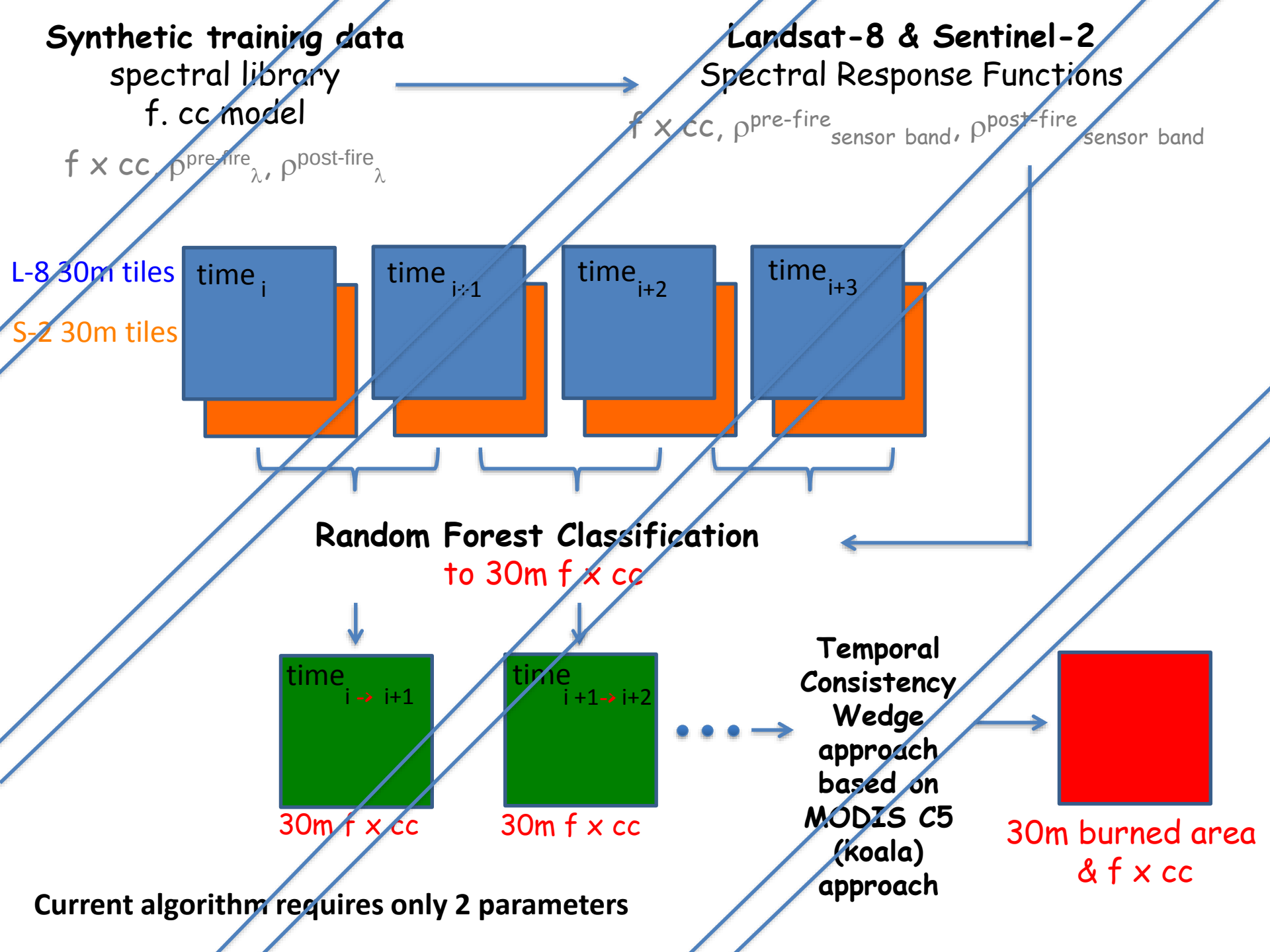


f x cc

day 155 -> 164



2000 x 2000 30m pixels

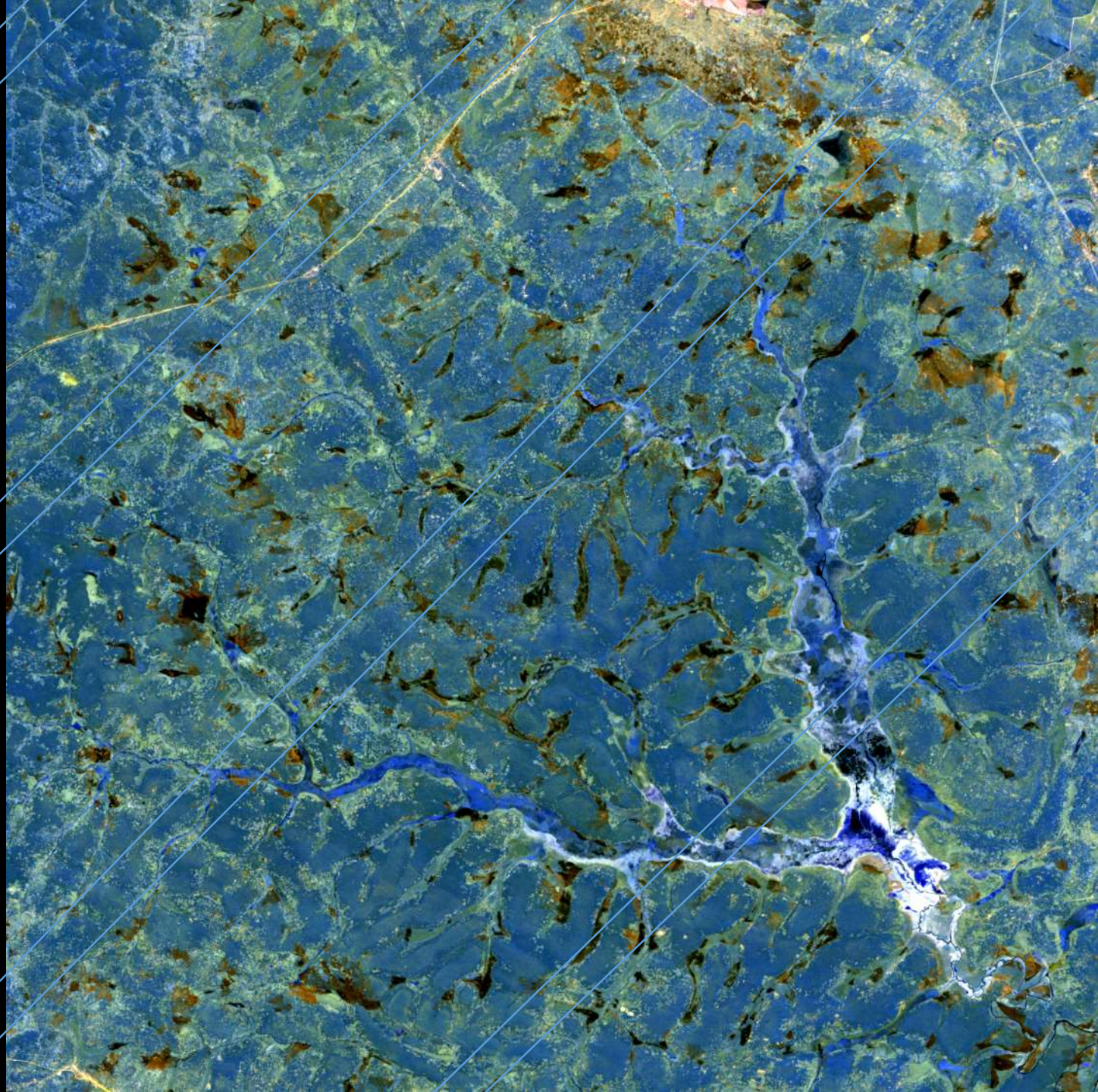

Synthetic training data
spectral library
f. cc model
f x cc, ρ pre-fire λ, ρ post-fire λ
Landsat-8 & Sentinel-2
Spectral Response Functions
f x cc, ρ pre-fire sensor band, ρ post-fire sensor band
L-8 30m tiles
S-2 30m tiles
time i
time i+1
time i+2
time i+3
Random Forest Classification
to 30m f x cc
time i -> i+1
time i +1-> i+2
30m f x cc
30m f x cc
Temporal Consistency Wedge approach based on MODIS C5 (koala) approach
30m burned area & f x cc
Current algorithm requires only 2 parameters

Landsat 8

collection 1

Day 171 2016

2200 nm
1600 nm
865 nm



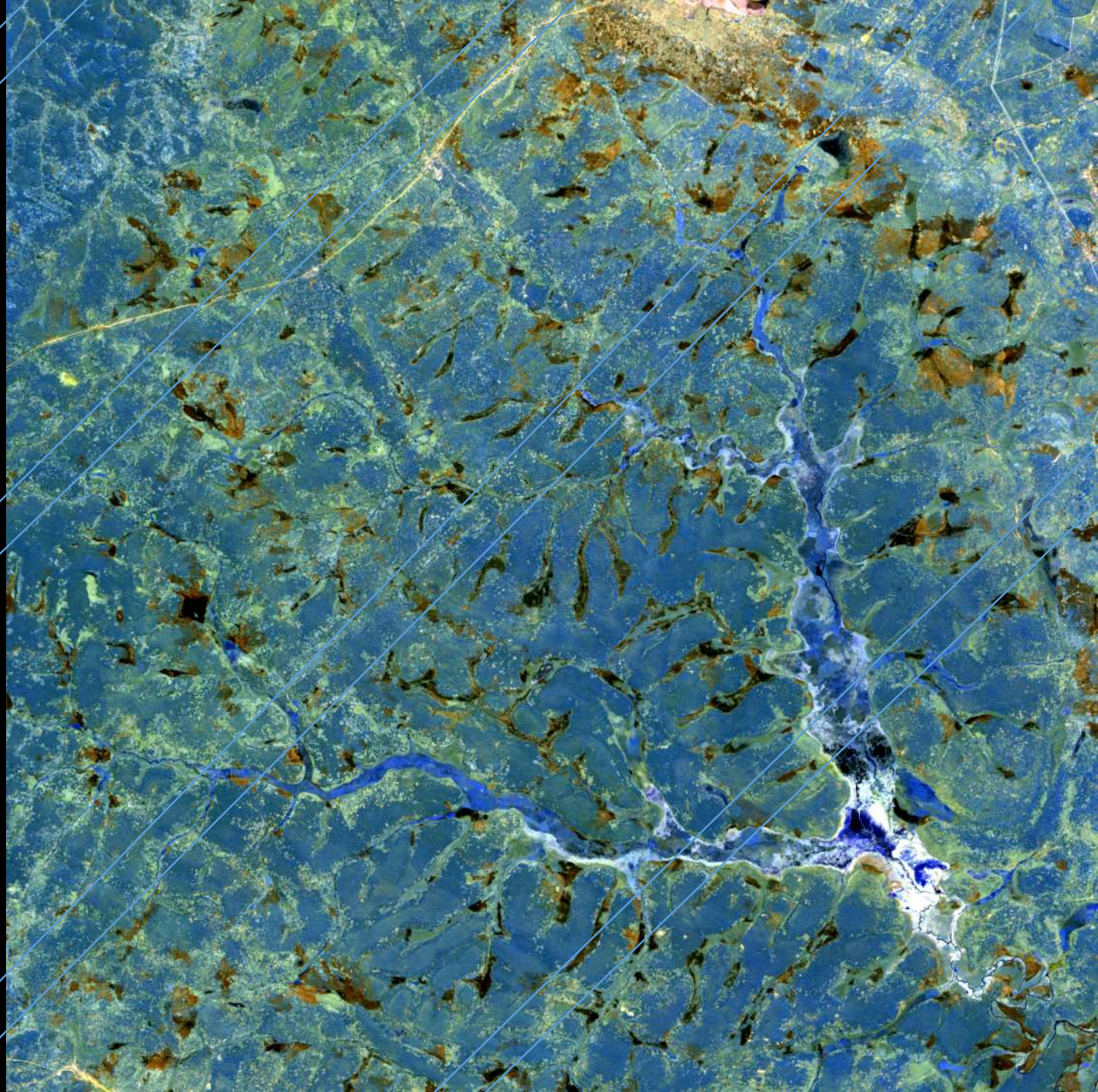
Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels

Sentinel 2A

Day 174 2016

2190 nm
1610 nm
865 nm



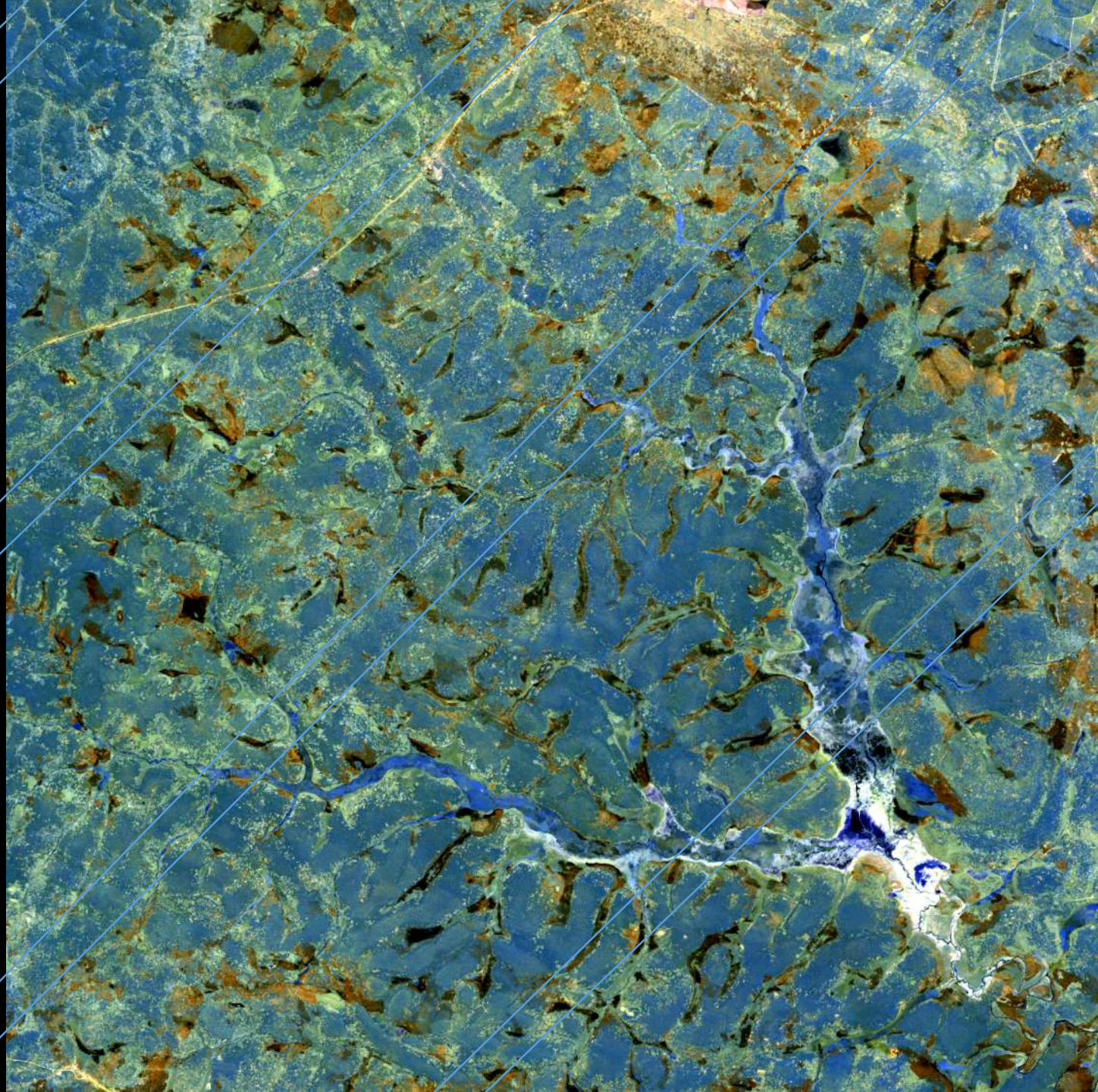
Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels

Sentinel 2A

Day 184 2016

2190 nm
1610 nm
865 nm



Zambia,
Copperbelt
Provence

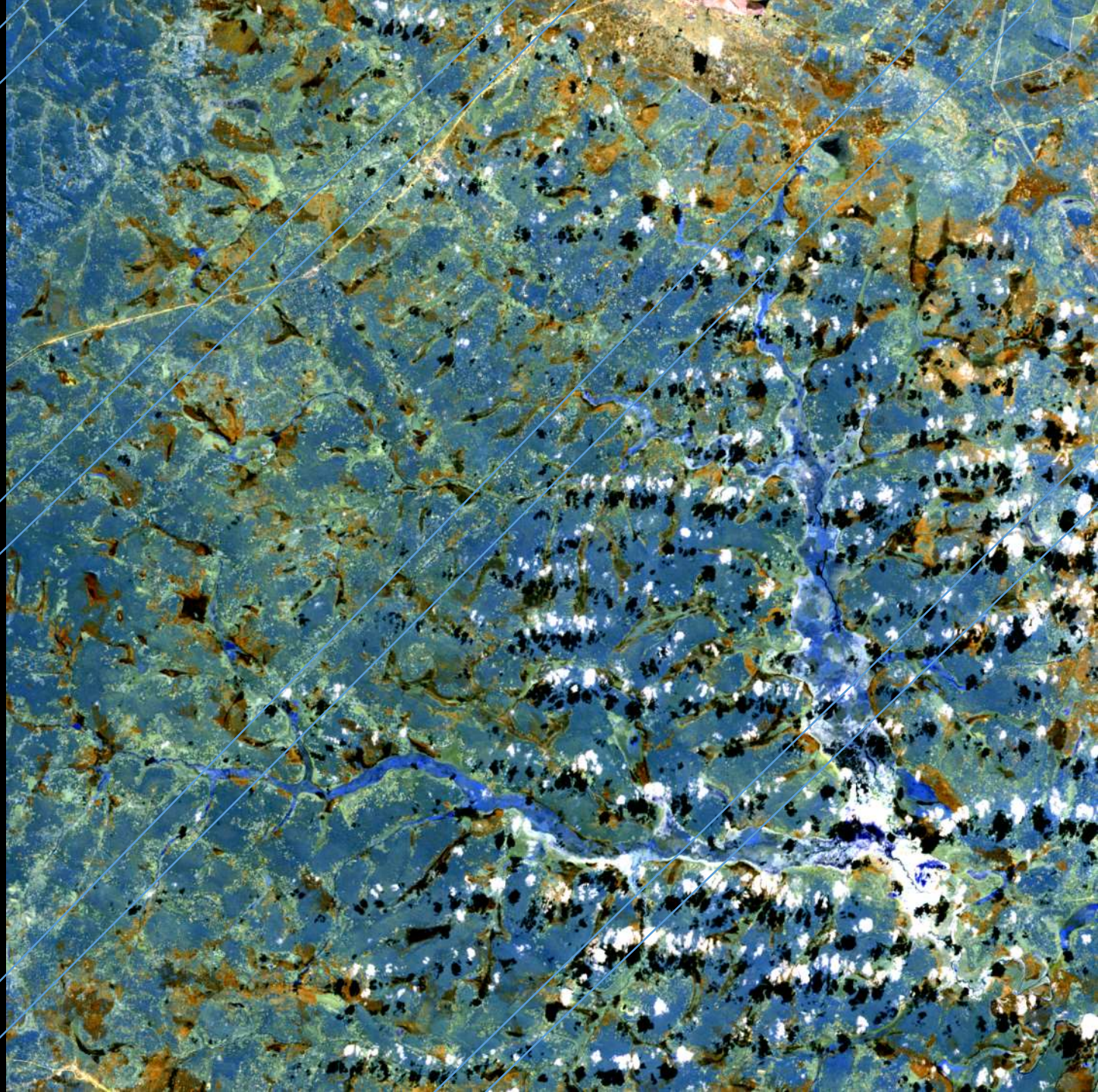
2000 x 2000 30 m pixels

Landsat 8

collection 1

Day 187 2016

2200 nm
1600 nm
865 nm



Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels

Sentinel 2A

Day 194 2016

2190 nm
1610 nm
865 nm

Zambia,
Copperbelt
Provence

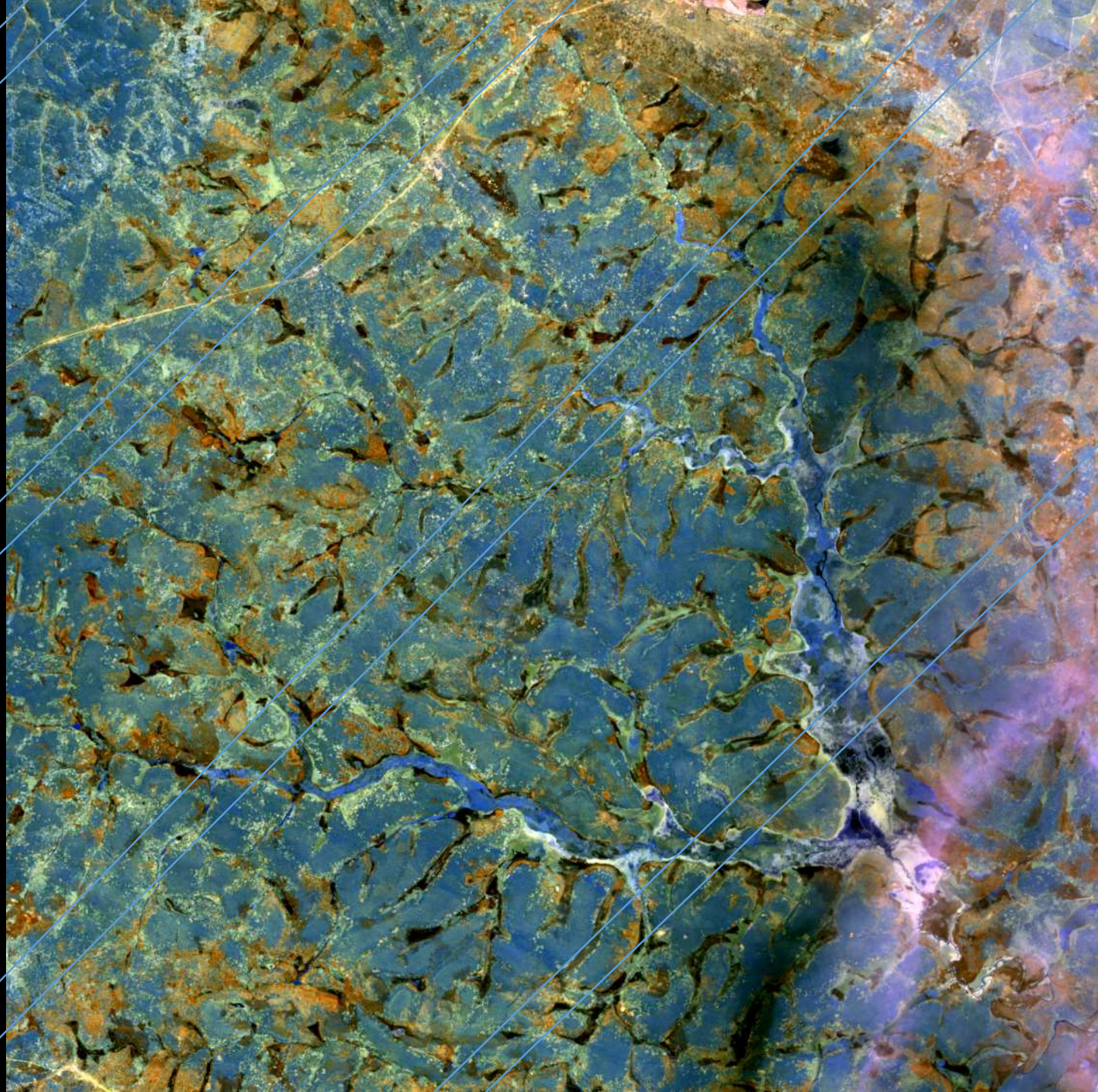
2000 x 2000 30 m pixels

Landsat 8

collection 1

Day 203 2016

2200 nm
1600 nm
865 nm



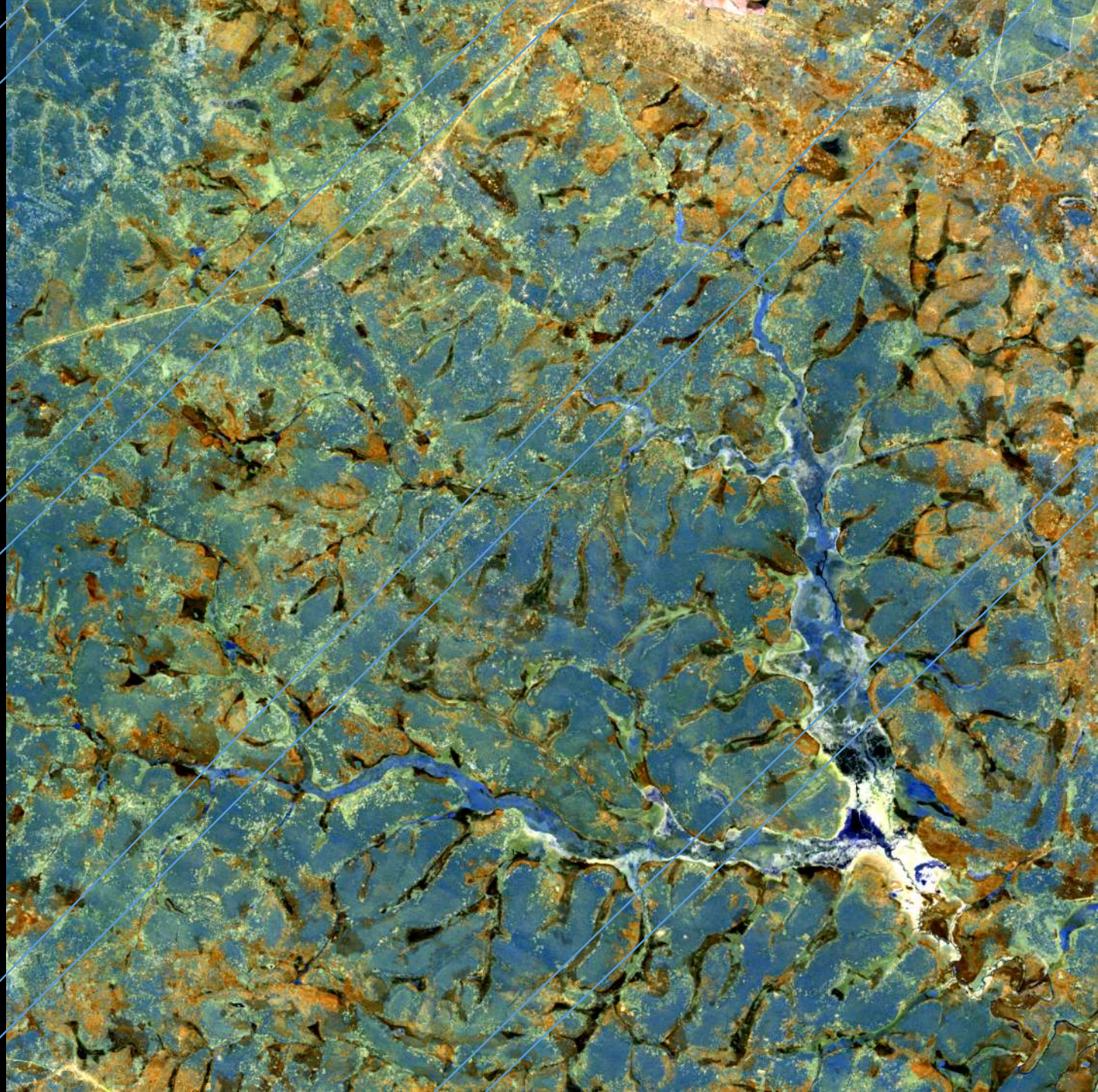
Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels

Sentinel 2A

Day 204 2016

2190 nm
1610 nm
865 nm



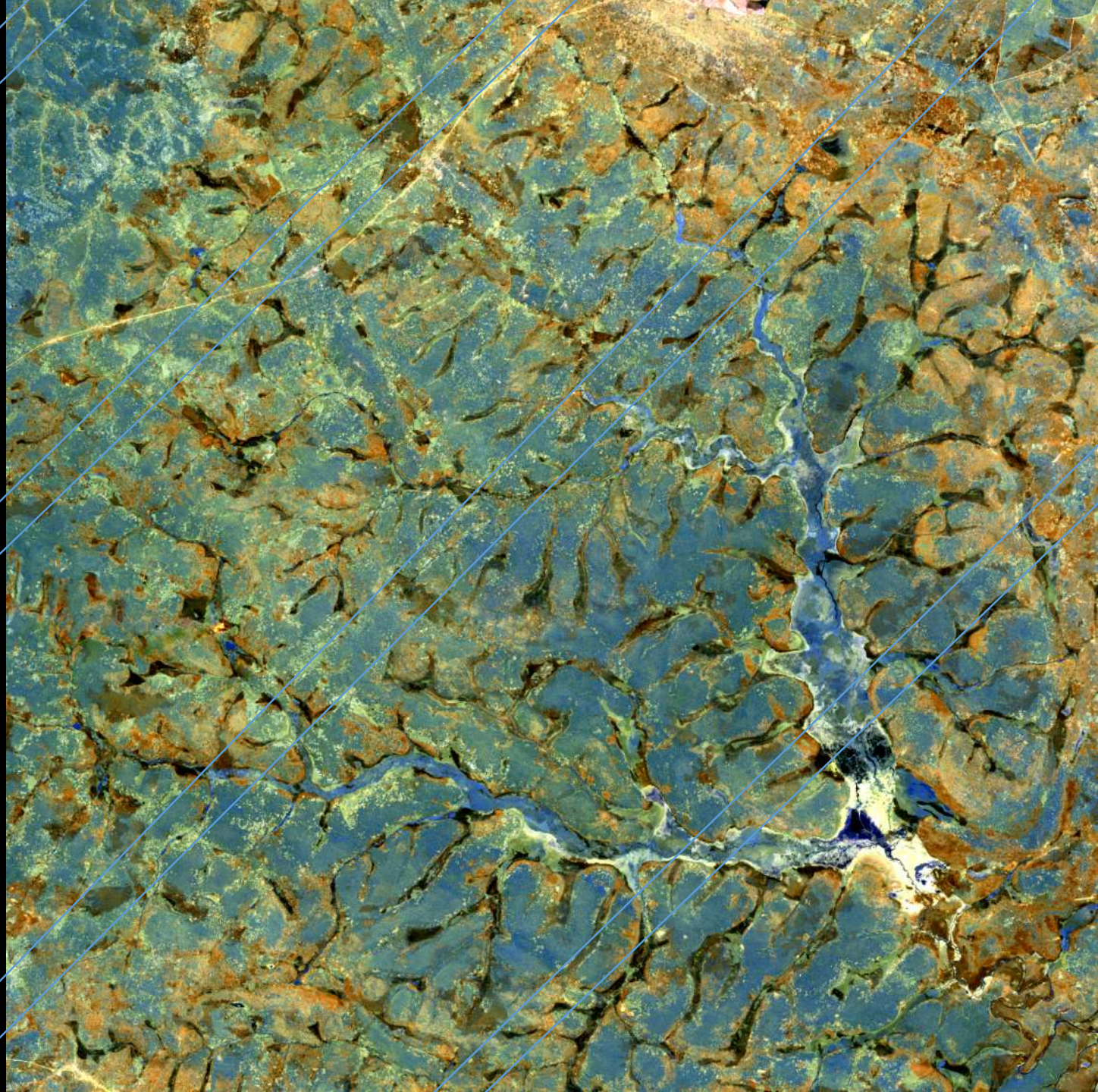
Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels

Sentinel-2A

Day 214 2016

2190 nm
1610 nm
865 nm



Zambia,
Copperbelt
Provence

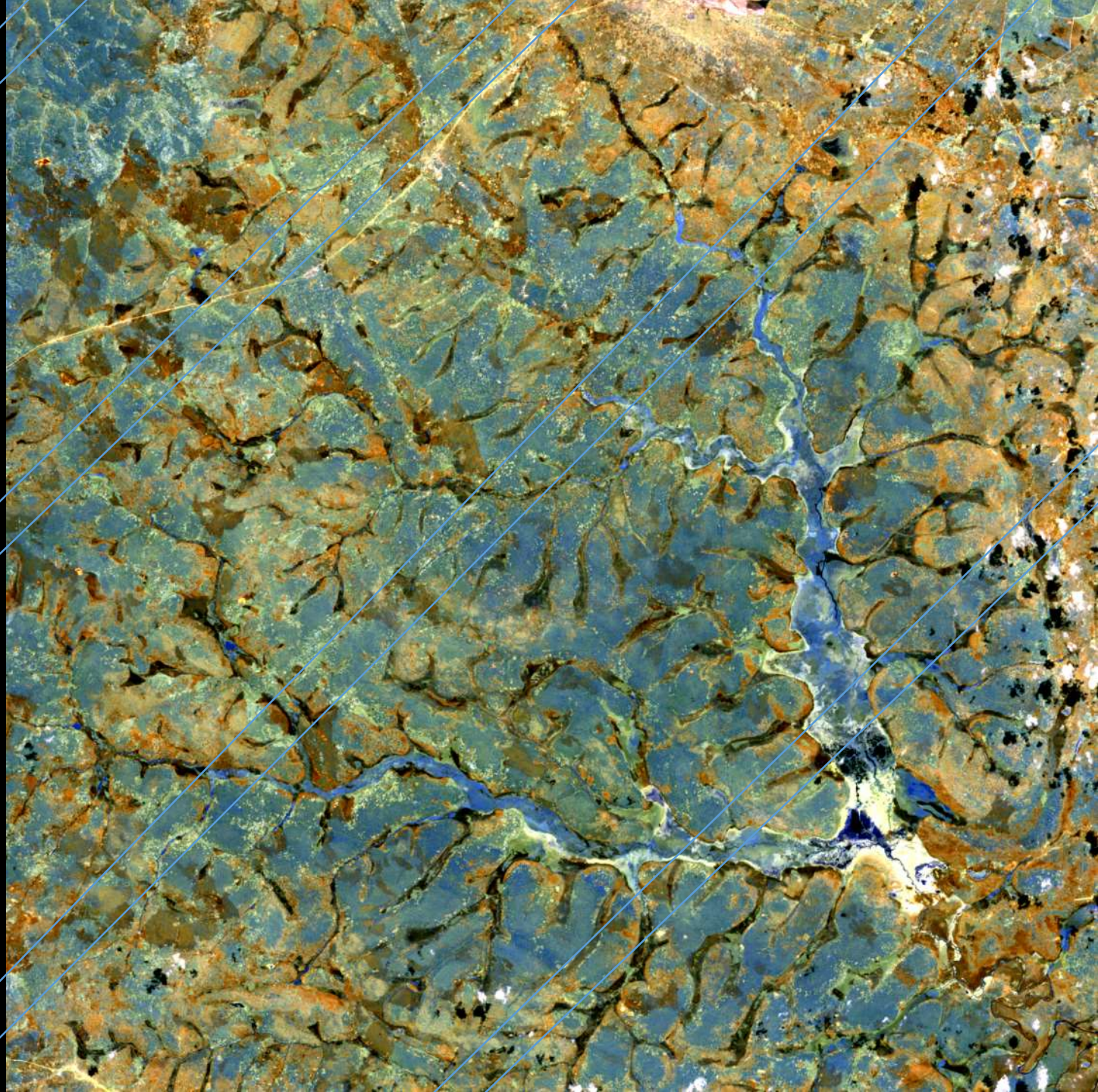
2000 x 2000 30 m pixels

Landsat 8

collection 1

Day 219 2016

2200 nm
1600 nm
865 nm



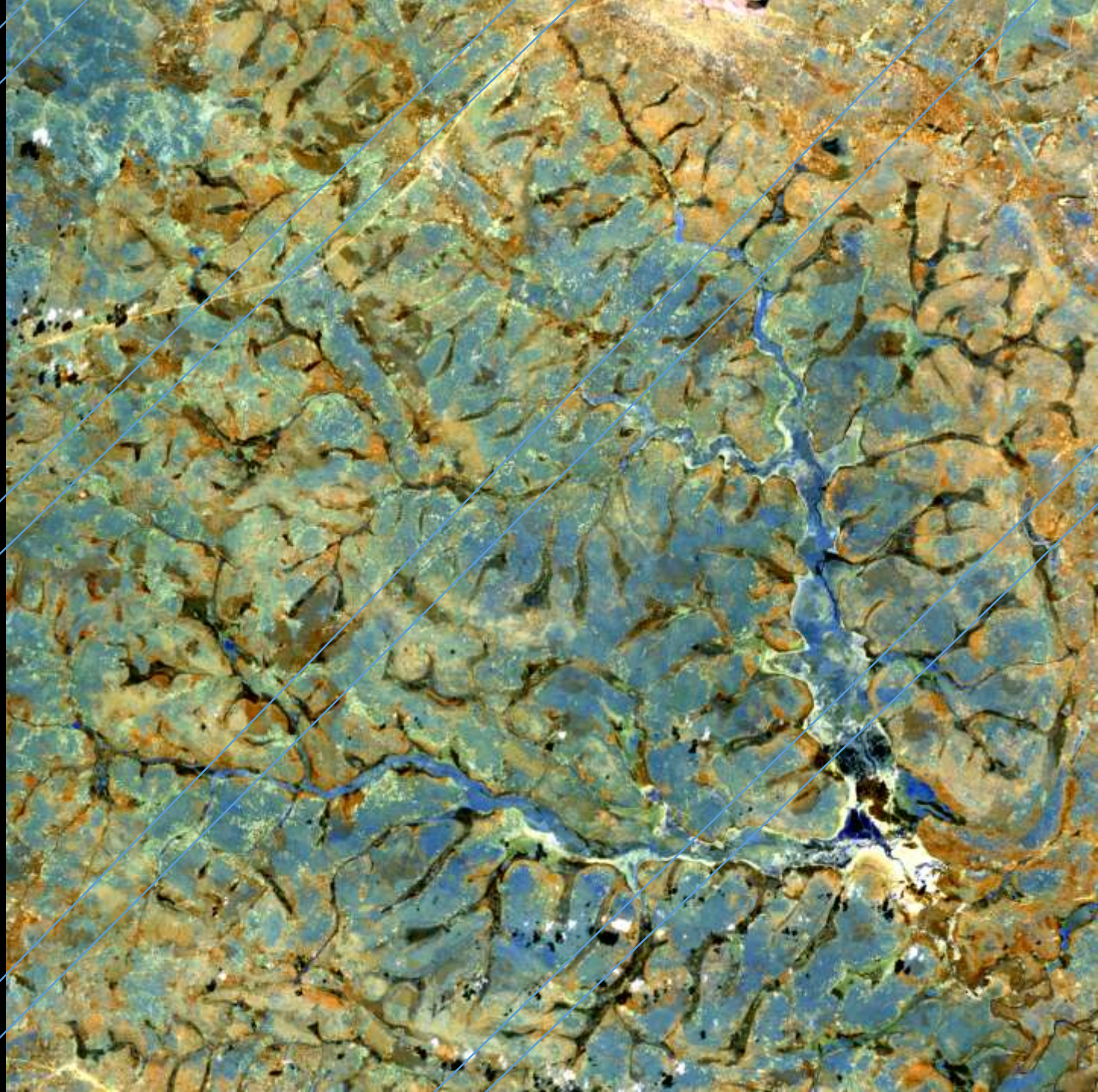
Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels

Sentinel 2A

Day 224 2016

2190 nm
1610 nm
865 nm



Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels

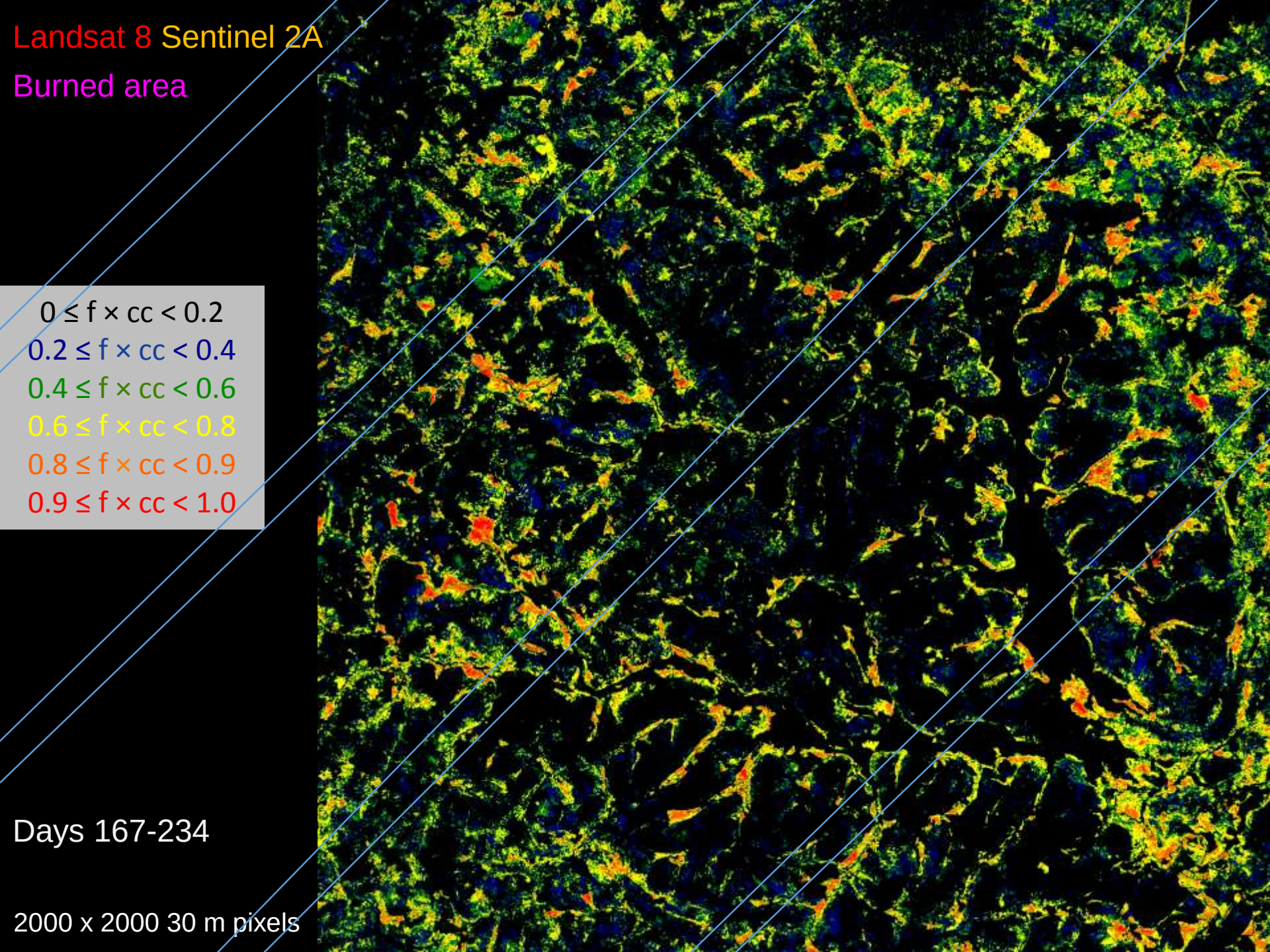
Sentinel 2A

Day 234 2016

2190 nm
1610 nm
865 nm

Zambia,
Copperbelt
Provence

2000 x 2000 30 m pixels


Landsat 8 Sentinel 2A
Burned area
0 ≤ f × cc < 0.2
0.2 ≤ f × cc < 0.4
0.4 ≤ f × cc < 0.6
0.6 ≤ f × cc < 0.8
0.8 ≤ f × cc < 0.9
0.9 ≤ f × cc < 1.0
Days 167-234
2000 x 2000 30 m pixels

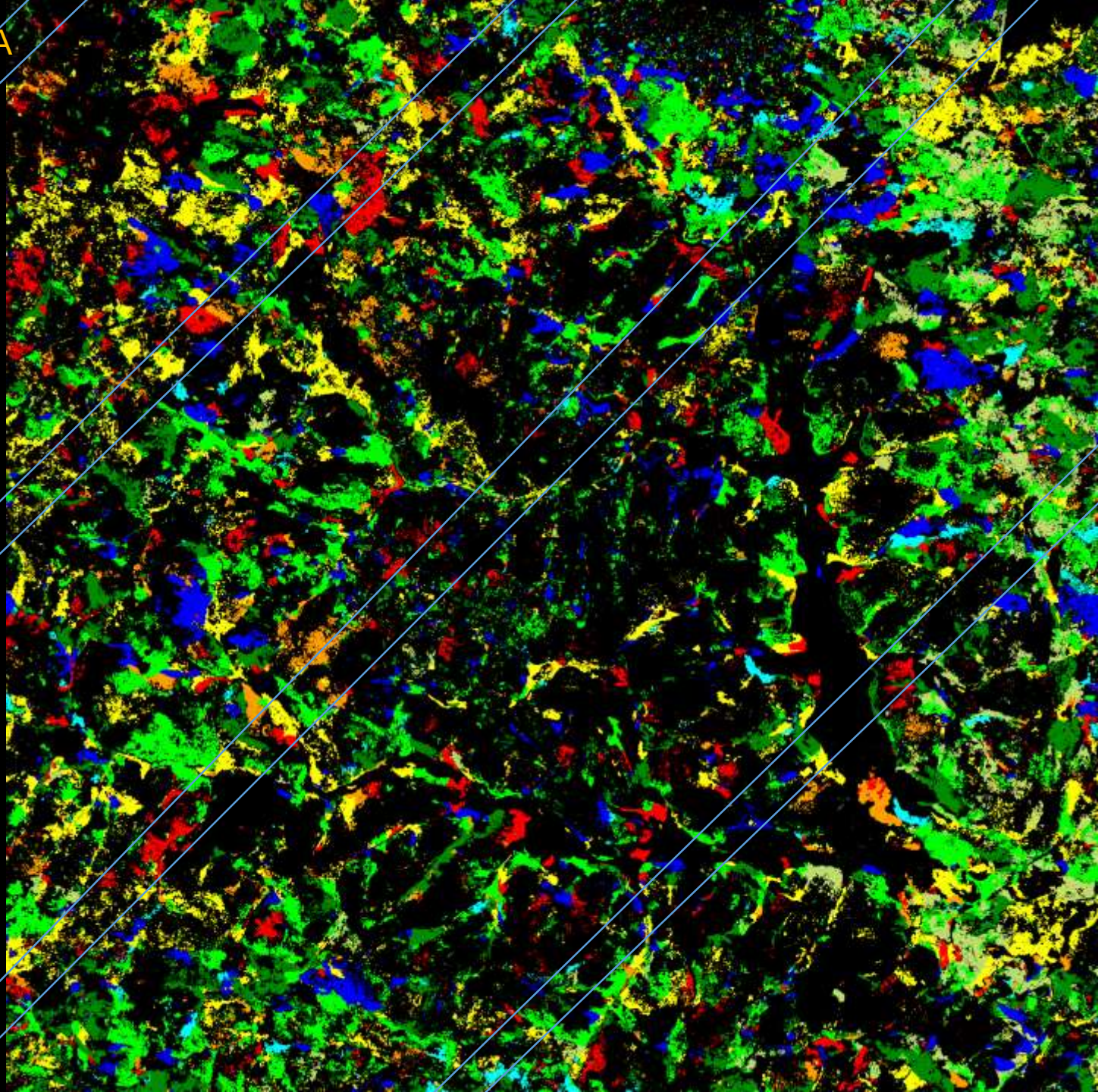
Landsat 8 Sentinel 2A

Burned area

Day of burning

(minus 167)

0 ≤ days < 10
10 ≤ days < 20
20 ≤ days < 30
30 ≤ days < 40
40 ≤ days < 50
50 ≤ days < 60
60 ≤ days < 70
70 ≤ days < 80
80 ≤ days < 90
90 ≤ days < 100



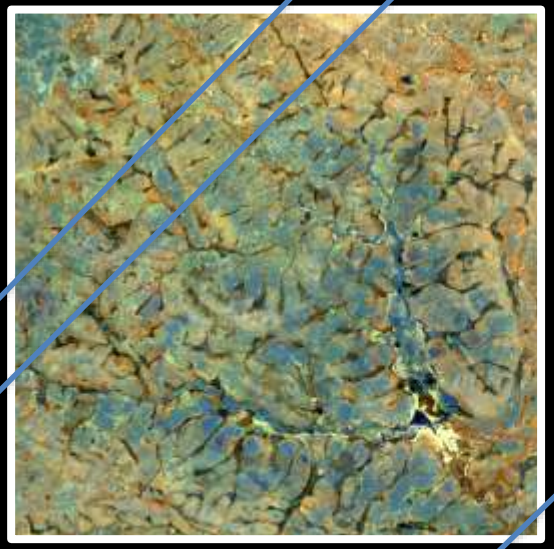
Days 167-234

2000 x 2000 30 m pixels

Sentinel-2A

Day 234 2016

2190 nm
1610 nm
865 nm



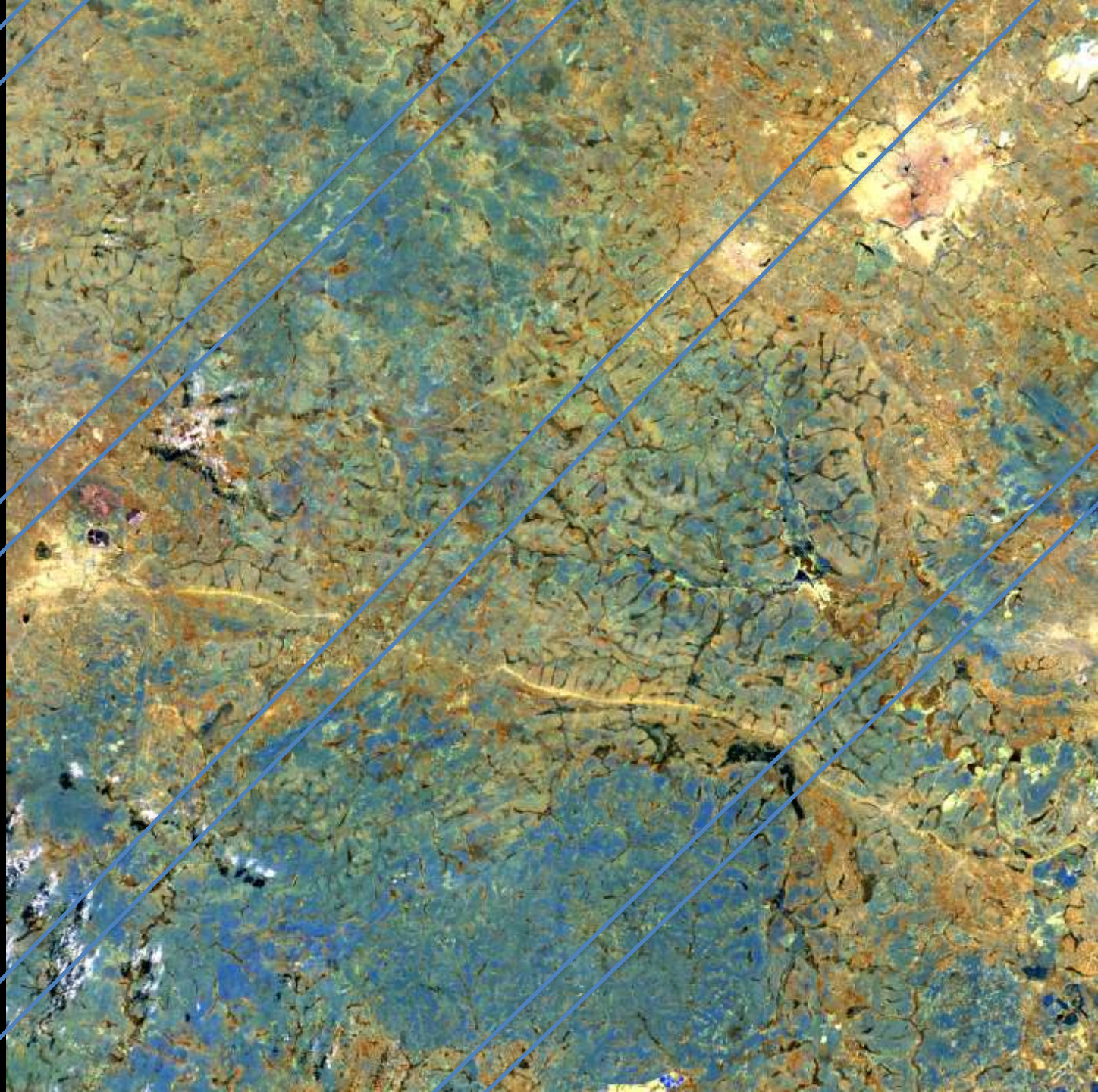
60 x 60 km
2000 x 2000 30 m pixels

Zambia,
Copperbelt
Provence

Sentinel-2A

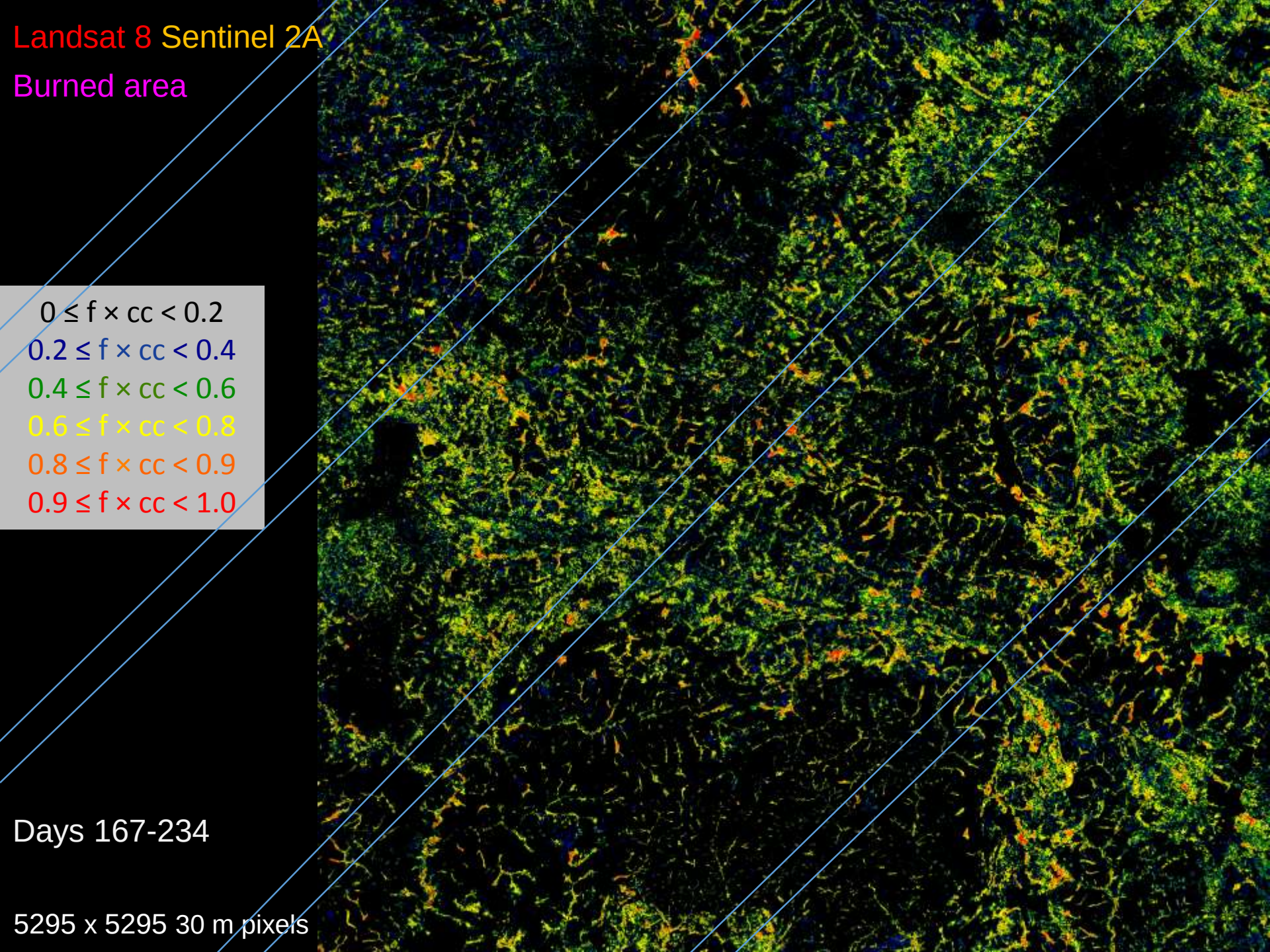
Day 234 2016

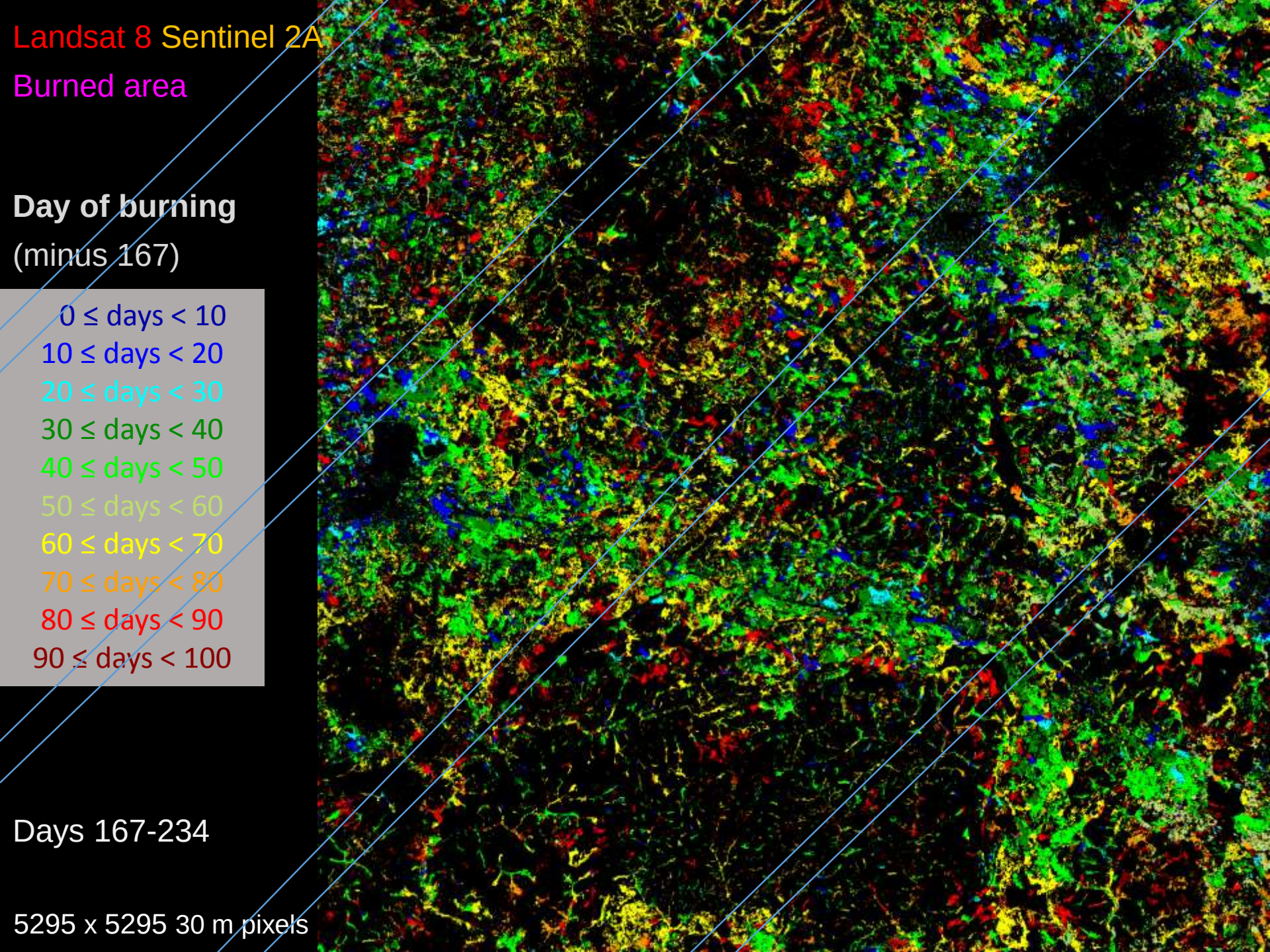
2190 nm
1610 nm
865 nm



Zambia,
Copperbelt
Provence

159 x 159 km
5295 x 5295 30 m pixels

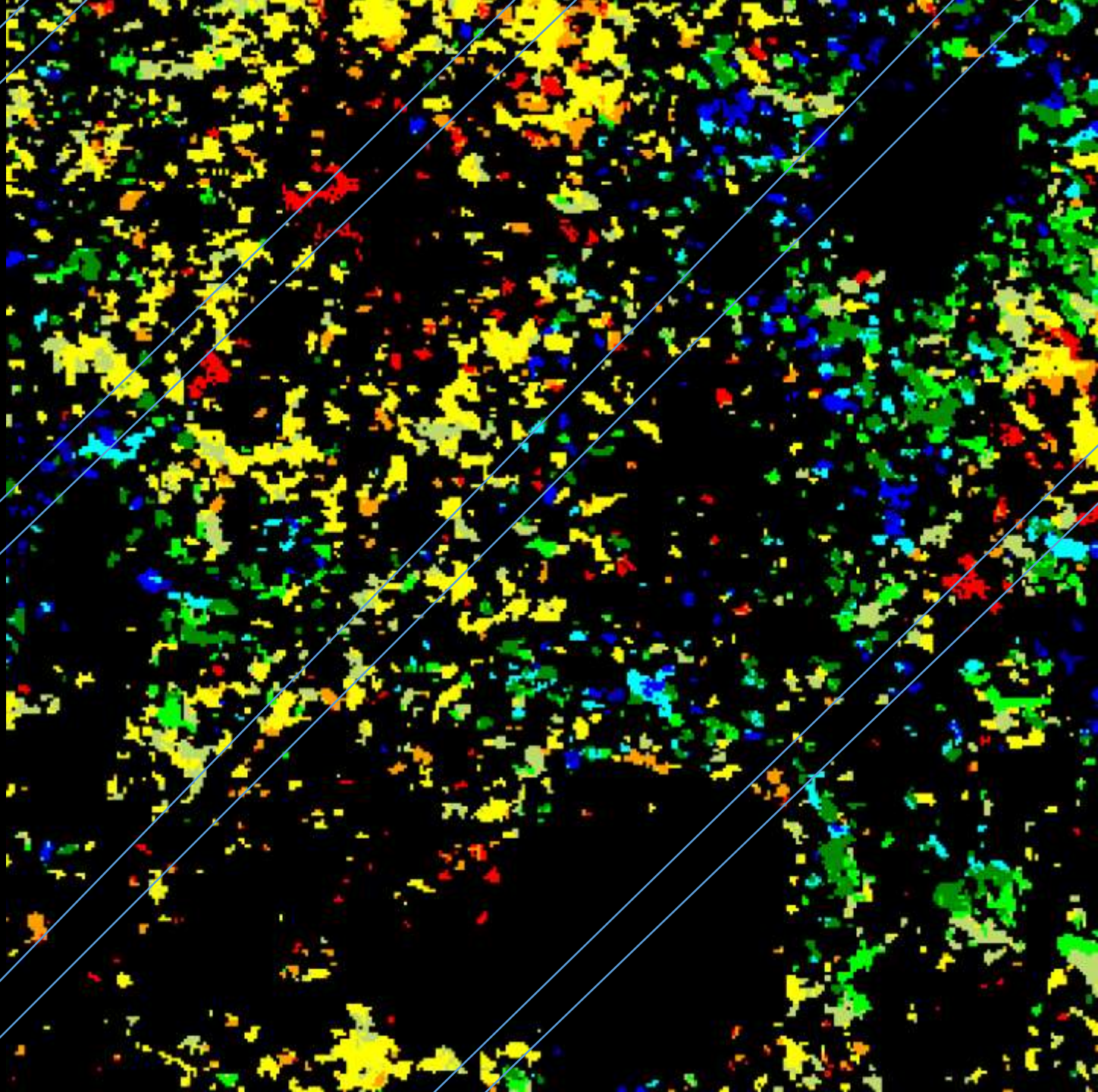

Landsat 8 Sentinel 2A
Burned area
0 ≤ f × cc < 0.2
0.2 ≤ f × cc < 0.4
0.4 ≤ f × cc < 0.6
0.6 ≤ f × cc < 0.8
0.8 ≤ f × cc < 0.9
0.9 ≤ f × cc < 1.0
Days 167-234
5295 x 5295 30 m pixels


Landsat 8 Sentinel 2A
Burned area
Day of burning
(minus 167)
0 ≤ days < 10
10 ≤ days < 20
20 ≤ days < 30
30 ≤ days < 40
40 ≤ days < 50
50 ≤ days < 60
60 ≤ days < 70
70 ≤ days < 80
80 ≤ days < 90
90 ≤ days < 100
Days 167-234
5295 x 5295 30 m pixels

MODIS 500 m
Burned area
(MCD64 C6)

Day of burning
(minus 167)

0 ≤ days < 10
10 ≤ days < 20
20 ≤ days < 30
30 ≤ days < 40
40 ≤ days < 50
50 ≤ days < 60
60 ≤ days < 70
70 ≤ days < 80
80 ≤ days < 90
90 ≤ days < 100



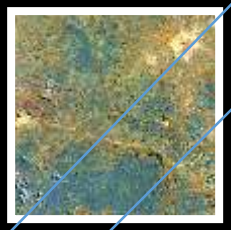
Days 167-234

318 x 318 500 m pixels

Sentinel 2A

Day 234 2016

2190 nm
1610 nm
865 nm



159 x 159 km

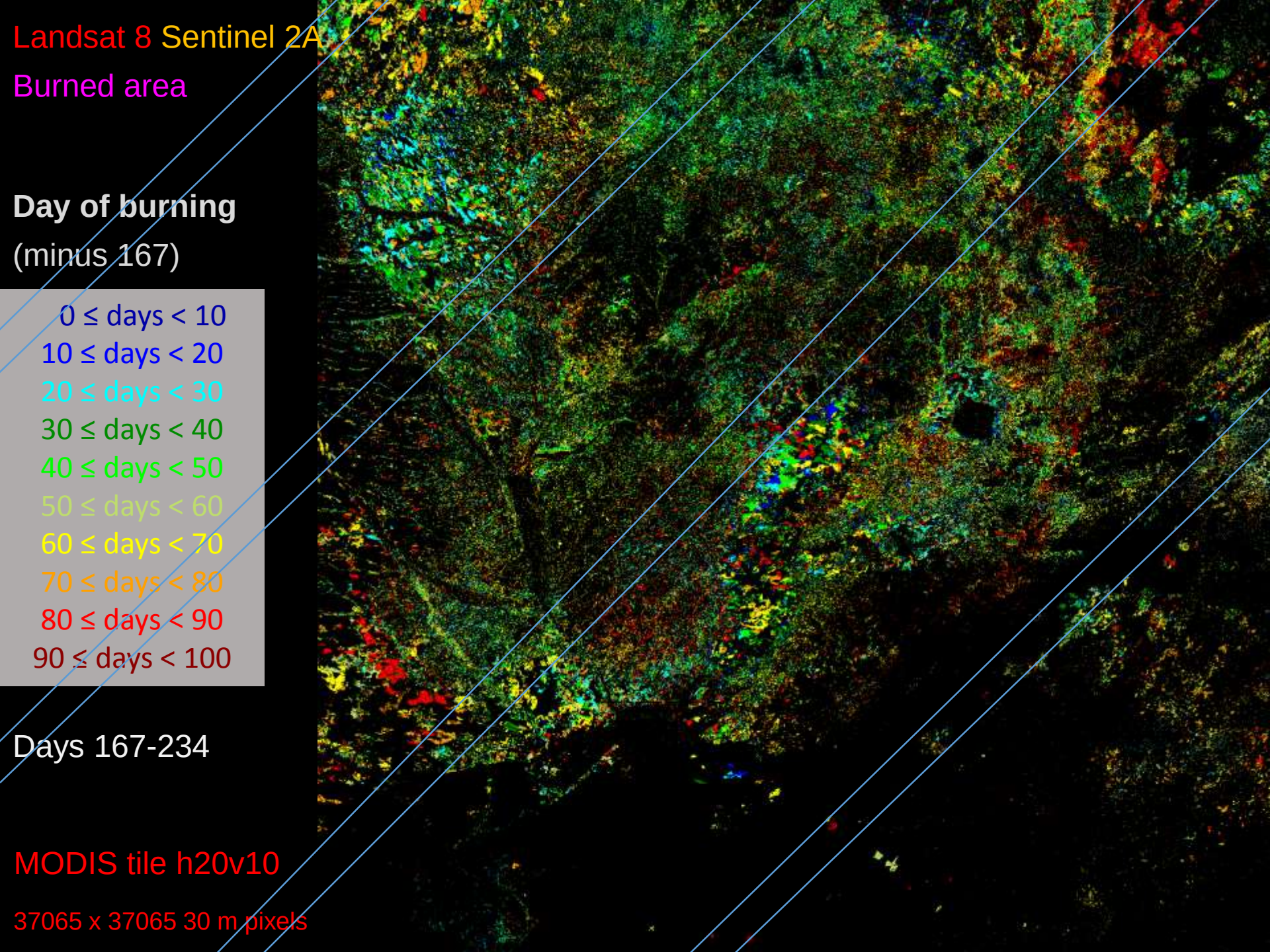
Sentinel 2A

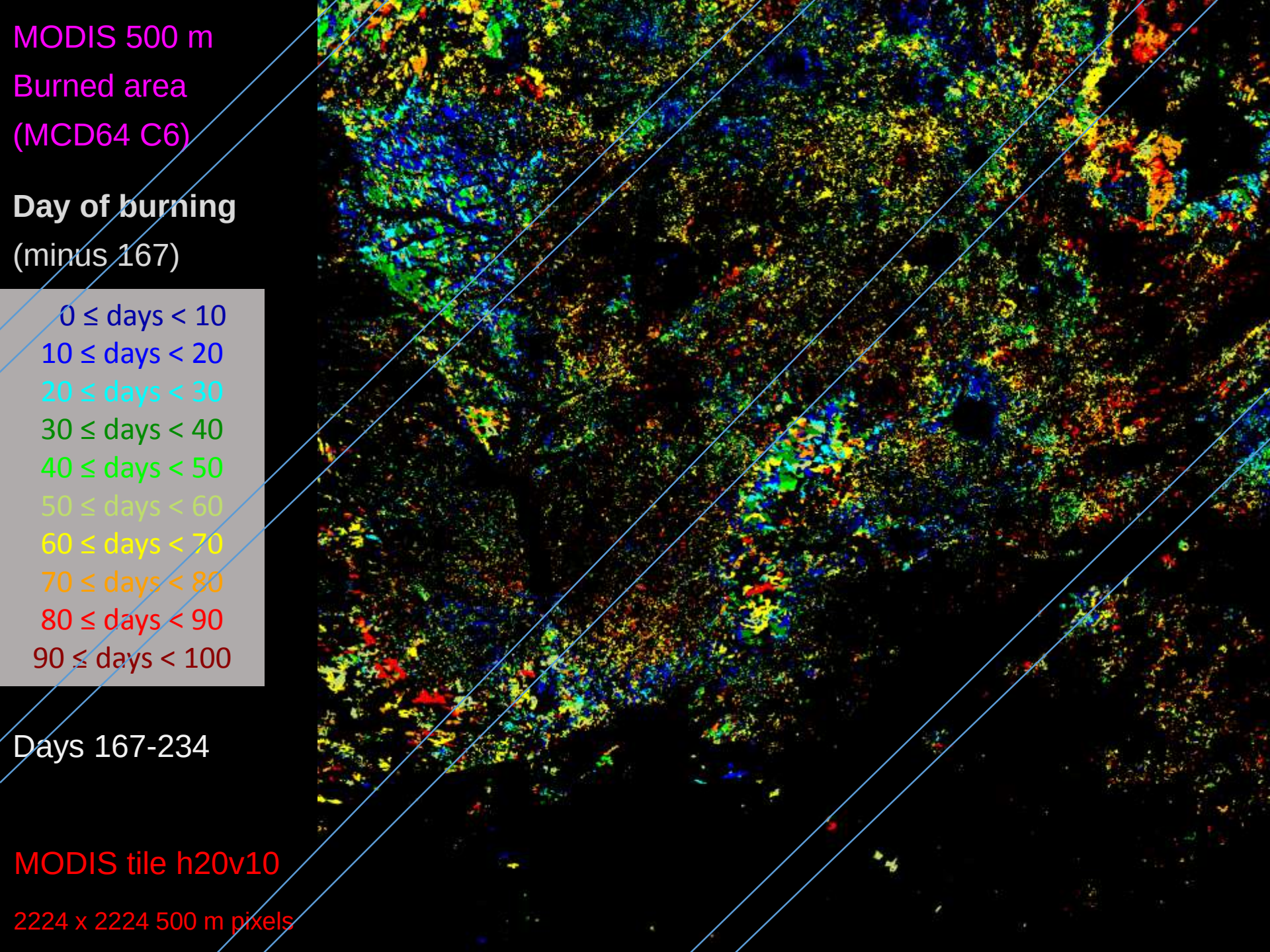
Day 234 2016

2190 nm
1610 nm
865 nm

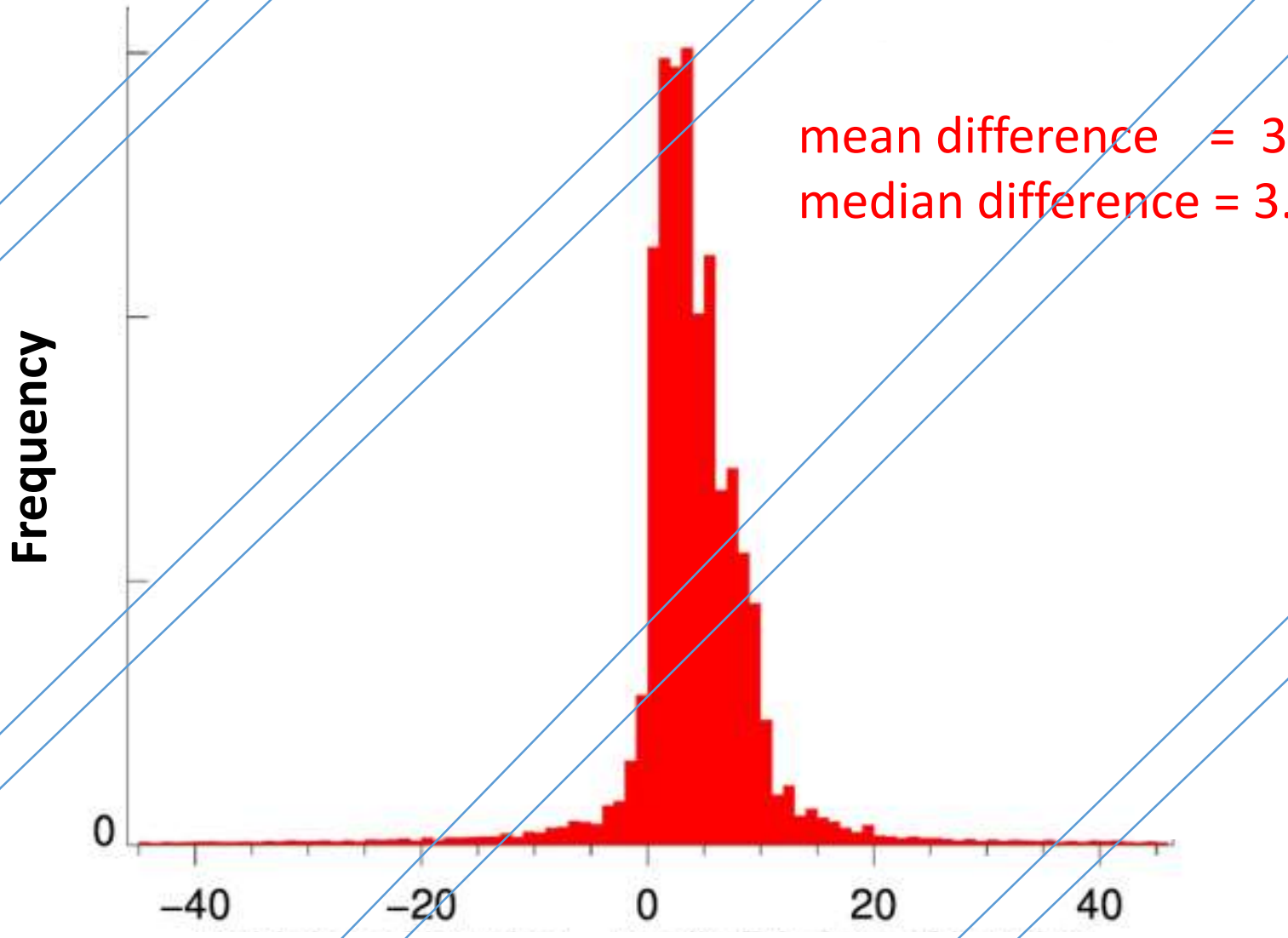
MODIS tile h20v10

37065 x 37065 30 m pixels


Landsat 8 Sentinel 2A
Burned area
Day of burning
(minus 167)
0 ≤ days < 10
10 ≤ days < 20
20 ≤ days < 30
30 ≤ days < 40
40 ≤ days < 50
50 ≤ days < 60
60 ≤ days < 70
70 ≤ days < 80
80 ≤ days < 90
90 ≤ days < 100
Days 167-234
MODIS tile h20v10
37065 x 37065 30 m pixels


MODIS 500 m
Burned area
(MCD64 C6)
Day of burning
(minus 167)
0 ≤ days < 10
10 ≤ days < 20
20 ≤ days < 30
30 ≤ days < 40
40 ≤ days < 50
50 ≤ days < 60
60 ≤ days < 70
70 ≤ days < 80
80 ≤ days < 90
90 ≤ days < 100
Days 167-234
MODIS tile h20v10
2224 x 2224 500 m pixels

Temporal product reporting difference (days)



Planned Production - all of Africa, including Madagascar, south of the Tropic of Cancer (23.44° N)

1041
Landsat-8 Collection 1
WRS-2 path/rows (UTM)

2829
Sentinel-2
L1C tiles (UTM)

33
MODIS
Tiles (sinusoidal)

1255
WELD
tiles

Planned Production – 3 years

Input number files (volume)

	2017	2018	2019	3-year total
Landsat-8 Collection 1	23,747 (21.8 TB)	23,747 (21.8 TB)	23,747 (21.8 TB)	71,241 (65.4 TB)
Sentinel-2A L1C	103,258 (46.5 TB)	103,258 (46.5 TB)	103,258 (46.5 TB)	309,774 (139.5 TB)
Sentinel-2B L1C		103,258 (46.5 TB)	103,258 (46.5 TB)	206,516 (93.0 TB)
	127,005 (68.3 TB)	230,263 (114.8 TB)	230,263 (114.8 TB)	**587,531 (297.9 TB)**

298 TB

Input Landsat 8 Sentinel 2 data

Planned Production – 3 years

Output number files (volume)

Output	2017	2018	2019	3-year total
Annual total	15,060 (3.19 TB)	15,060 (3.19 TB)	15,060 (3.19 TB)	**45,180 (9.57 TB)**

10 TB
output 30 m burned area product

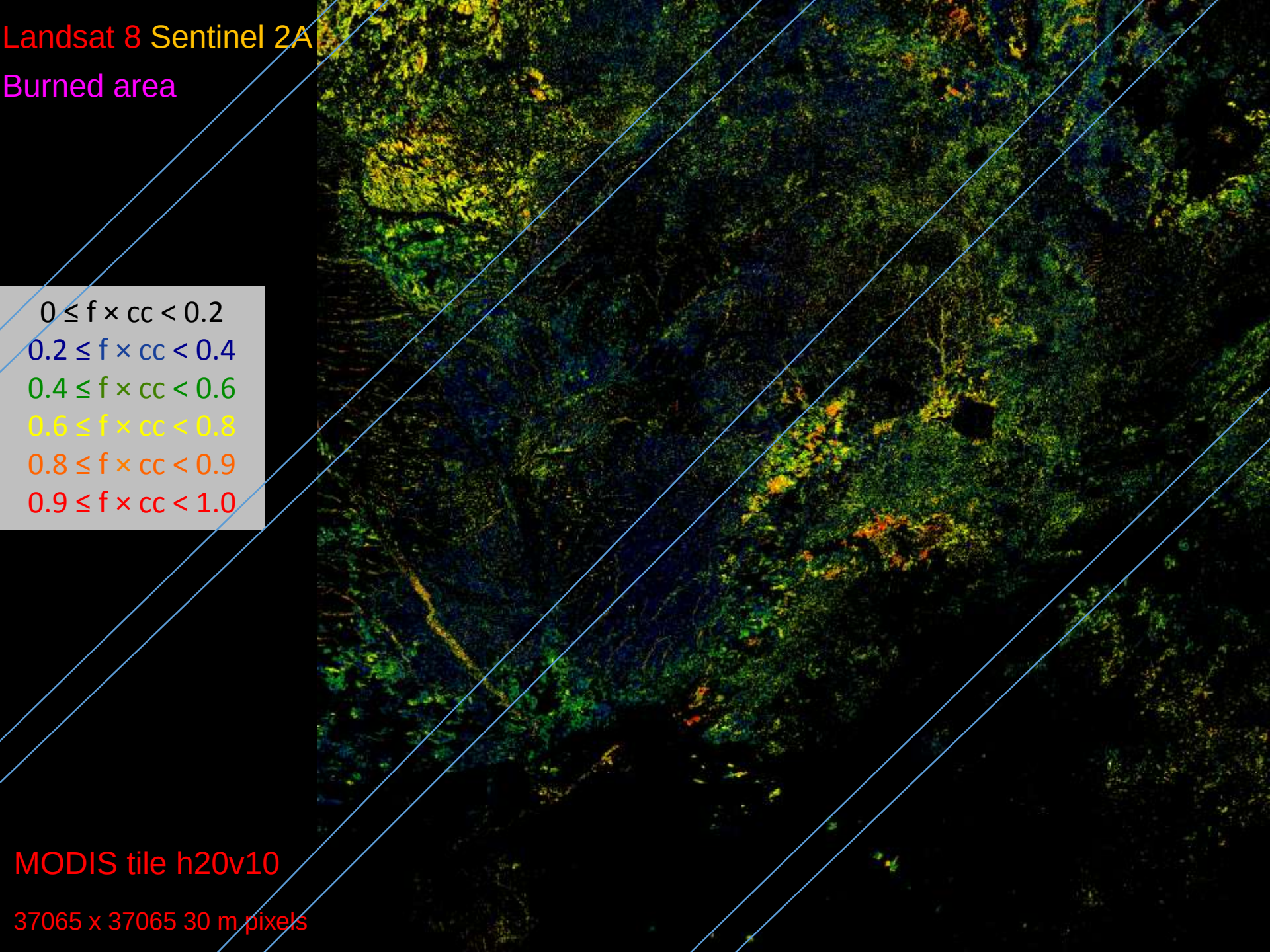
Output per-pixel

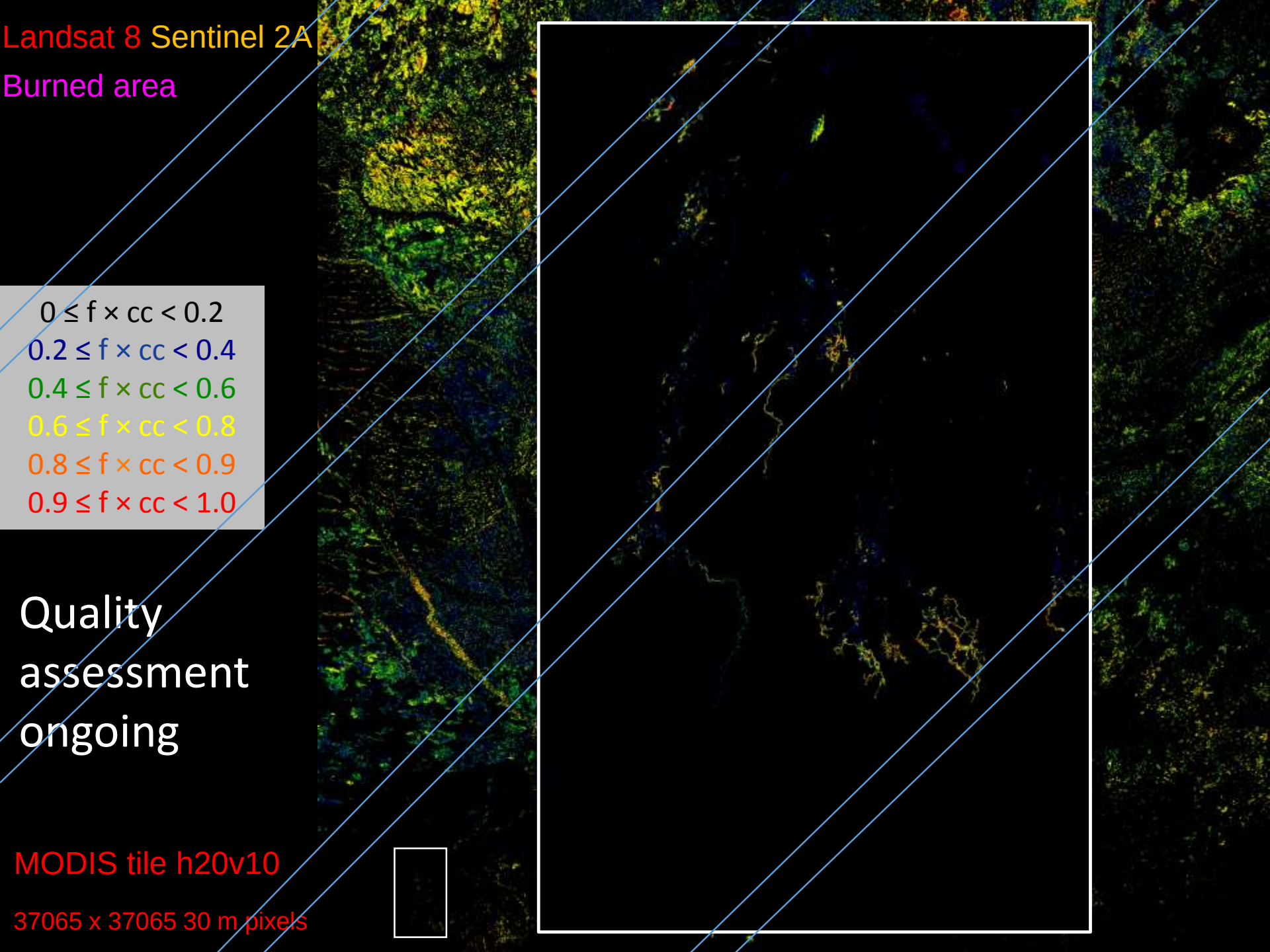
(i) pre-change date (day of year, or 0 if no detection) [2 Bytes]
(ii) post-change date (number of days since pre-change date, or 0) [1 Byte]
(iii) f × cc [0, 1 … 100], or water [200], unobserved [201], permanently cloudy [202], etc. [1 Byte]
(iv) number of valid (non-cloudy, observed) Landsat-8 observations [1 Byte]
(v) number of valid Sentinel-2A and -2B observations [1 Byte]
(vi) internal algorithm QA pathway code [1 Byte]

Planned Production

Quality Assessment

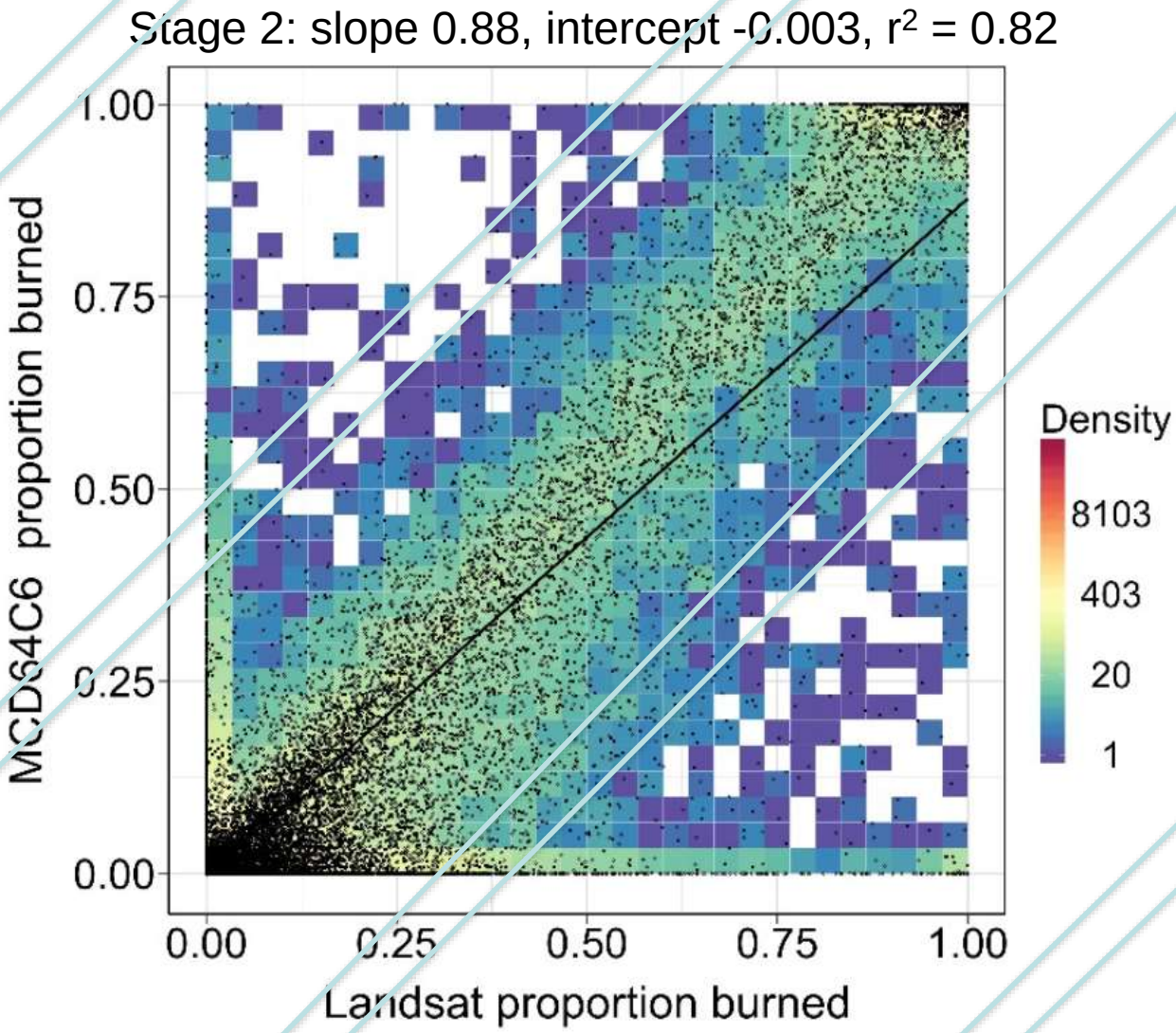
Validation


Landsat 8 Sentinel 2A
Burned area
0 ≤ f × cc < 0.2
0.2 ≤ f × cc < 0.4
0.4 ≤ f × cc < 0.6
0.6 ≤ f × cc < 0.8
0.8 ≤ f × cc < 0.9
0.9 ≤ f × cc < 1.0
MODIS tile h20v10
37065 x 37065 30 m pixels


Landsat 8 Sentinel 2A
Burned area
0 ≤ f × cc < 0.2
0.2 ≤ f × cc < 0.4
0.4 ≤ f × cc < 0.6
0.6 ≤ f × cc < 0.8
0.8 ≤ f × cc < 0.9
0.9 ≤ f × cc < 1.0
Quality assessment ongoing
MODIS tile h20v10
37065 x 37065 30 m pixels

Validation

Previously MODIS 500 m burned area validation by comparison with 2-date 30 m Landsat interpreted burned maps

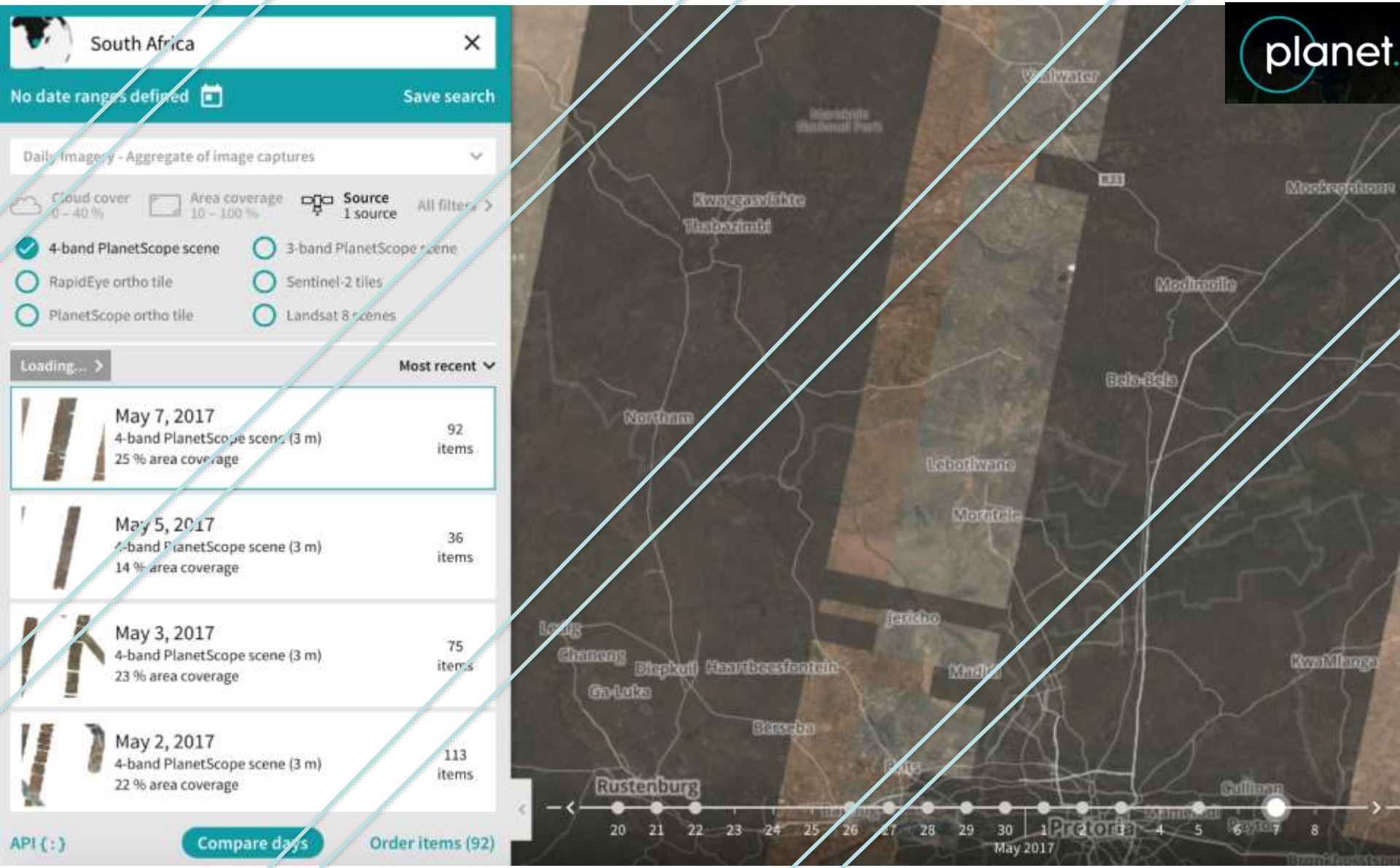


Giglio, Boschetti, Roy, Humber, Justice

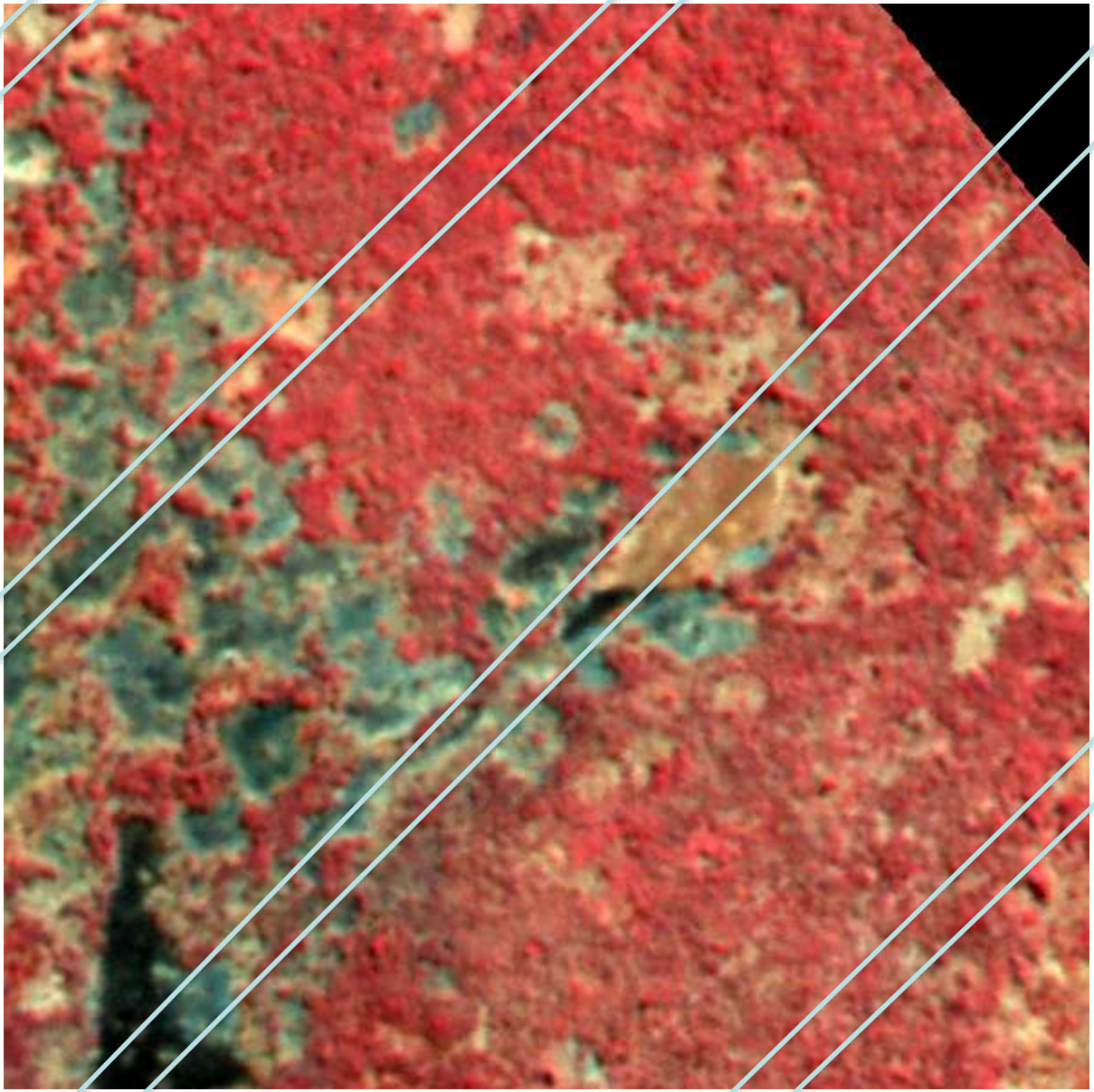
The Collection 6 MODIS Burned Area Mapping Algorithm and Product,

RSE, In review

Validate 30m Landsat-8 Sentinel-2 burned area & f using commercial multi-date interpreted high resolution data



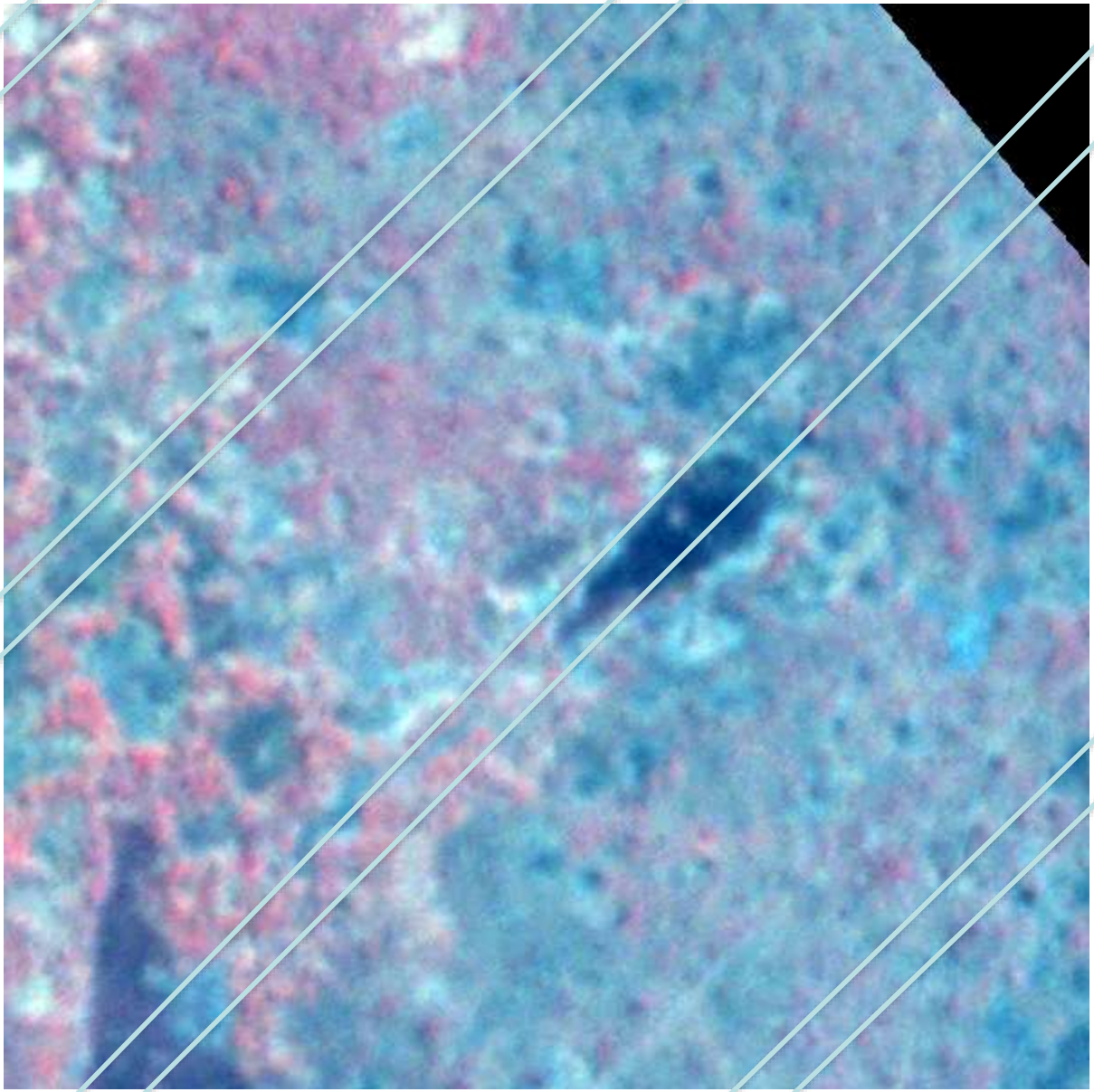
600 × 600 3 m pixels (1.8 km × 1.8 km)



Somewhere in Zambia

July 18th 2016

600 × 600 3 m pixels (1.8 km × 1.8 km)



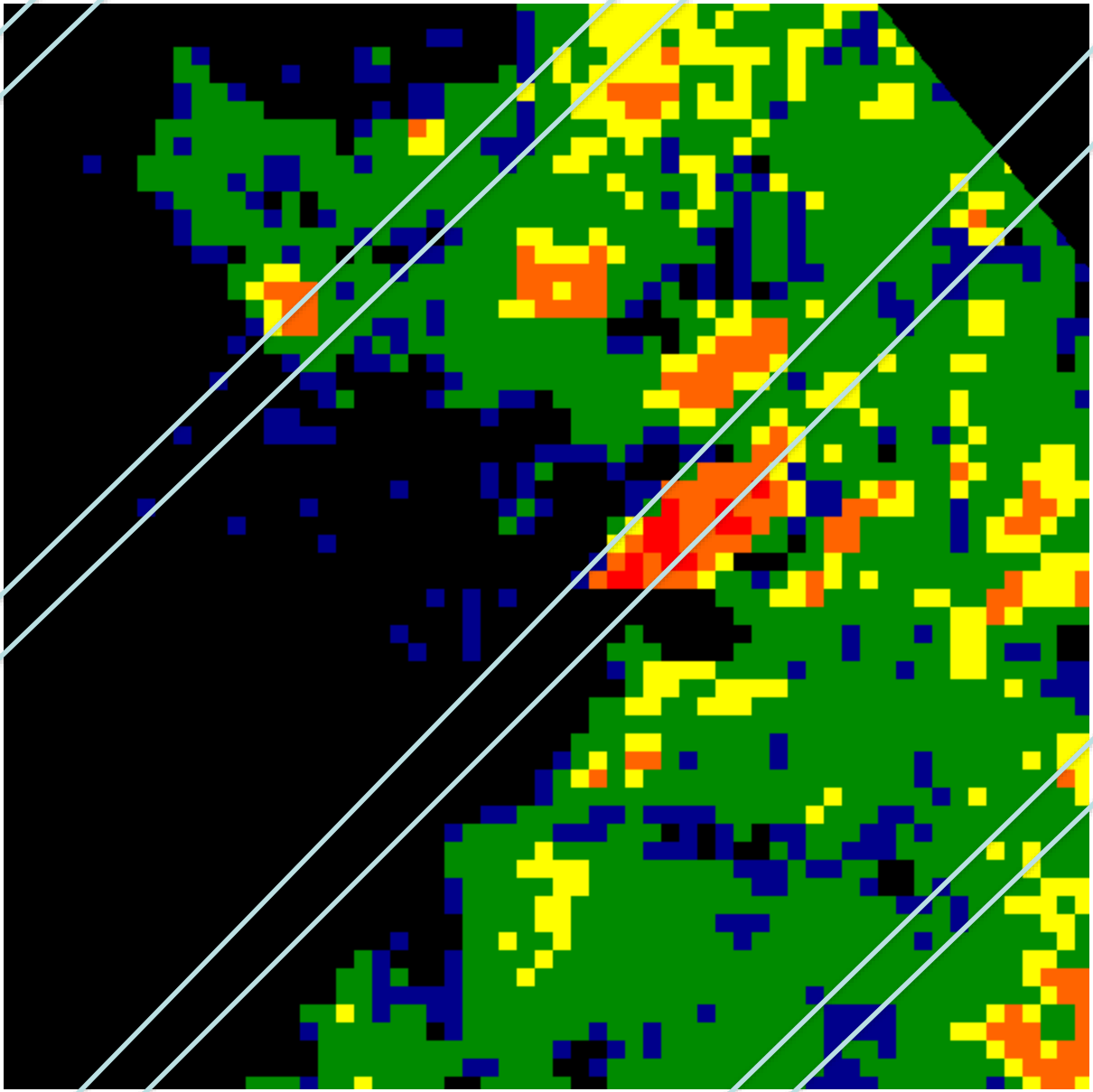
Somewhere in Zambia

August 18th 2016

60 × 60 30 m pixels (1.8 km × 1.8 km)

S2A/L8

f x cc

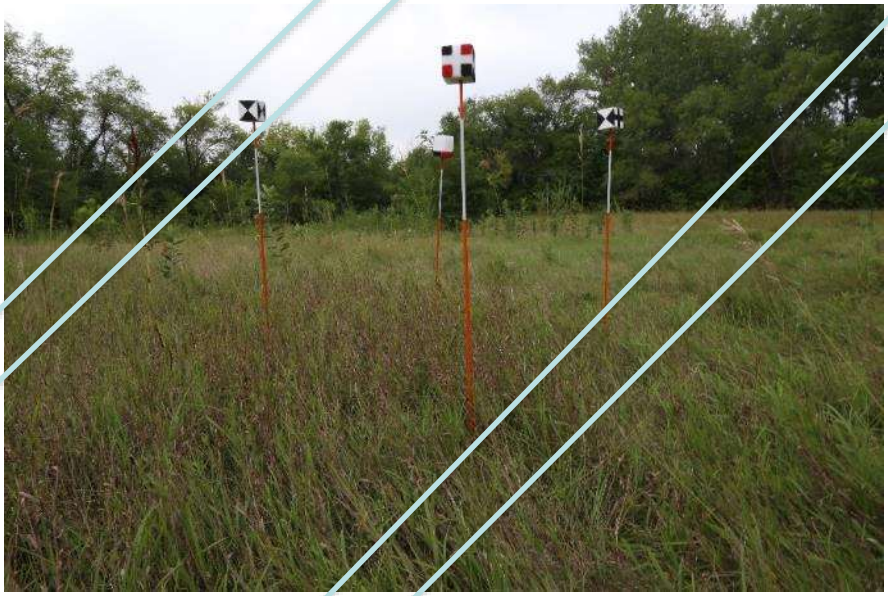


Somewhere in Zambia

July – August 18th 2016

CC estimation by *in situ* biomass measurement pre and post fire very time consuming

Validate *cc* using high speed, low-cost, highly portable Terrestrial Laser Scanner



Cooper, Roy, Schaaf, Paynter, 2017, Examination of the potential of Terrestrial Laser Scanning and Structure-from-Motion photogrammetry for rapid nondestructive field measurement of grass biomass, *Remote Sensing*. *9* (6), 531.

Field work next week with international collaborators

SAFNet

GOFC-GOLD Global Observation of Forest and Land Cover Dynamics

South African National Parks

INTERNATIONAL START SECRETARIAT

IHDP • IGBP • WCRP

10th Southern African Fire Network (SAFNet) Meeting

17th - 19th April 2018

Venue: Kruger National Park, Skukuza, South Africa

Collaborative fire information, resource sharing, training and research in support of Integrated Fire Management in Southern African countries

Summary

- New moderate resolution data will provide global burned area mapping capability
  - Exciting
  - Improved reporting of small and spatially fragmented burned areas
- Major R&D effort on Sentinel-2 and Landsat-8 pre-processing
  - Many papers from group please see http://globalmonitoring.sdstate.edu/faculty/roy/roy.html
- Automated burned area algorithm protoyped
  - applied to NBAR surface reflectance gridded WELD tile time series
  - only 2 parameters
  - map 30m burned area + sub-pixel fraction (f) x combustion completeness (cc)
- Planned production
  - all of Africa, including Madagascar, south of the Tropic of Cancer
  - 2017 (S2A & L8), 2018 (S2A, S2B, L8), 2018 (S2A, SB, L8)
- Validation
  - Commercial data (burned area, f) & perhaps *in situ* Terrestrial Laser Scanner (cc)