Fire Product Validation
Status and Methods

Luigi Boschetti, Kevin Tansey, David Roy, Chris Justice, Steve Stehman, Emilio Chuvieco, Marc Padilla, Wilfrid Shroeder, Louis Giglio

http://modis-fire.umd.edu/MCD45A1.asp

Satellite products

- Active fire products

TRMM VIRS fire product (NASA)

ftp://disc2.nascom.nasa.gov/data/TRMM/VIRS_Fire/data/

FIRMS: Fire Information for Resource Management System (University of Maryland /NASA/UN FAO), distribution of MODIS fire products

http://lance-modis.eosdis.nasa.gov/

World Fire Atlas (ESA)

http://dup.esrin.esa.int/ionia/wfa/index.asp

TRMM VIRS fire product (NASA)

ftp://disc2.nascom.nasa.gov/data/TRMM/VIRS_Fire/data/

MODIS active fires VIIRS active fires (University of Maryland /NASA / NOAA)

http://modis-fire.umd.edu

Experimental Wildfire Automated Biomass Burning Algorithm: GOES WF-ABBA

http://cimss.ssec.wisc.edu/goes/burn/wfabba.html

Satellite products

- Burned Area products

  Global burnt areas 2000-2007: L3JRC (EC Joint Research Center)

  http://bioval.jrc.ec.europa.eu/products/burnt_areas_L3JRC/GlobalBurntAreas2000-2007.php

  MODIS burned areas (University of Maryland /NASA / NOAA)

  http://modis-fire.umd.edu

  Globcarbon products (ESA)

  http://www.fao.org/gtos/tcopjs4.html

  Wide Area Monitoring Information System (*WAMIS*) portal –Advanced Fire information System

  (CSIR, Meraka Institute South Africa)

  http://www.wamis.co.za/

  Fire CCI (forthcoming)

- Emissions

  Global Fire Emissions Database (GFED3) - multi-year burned area and emissions

  http://ess1.ess.uci.edu/%7Ejranders/data/GFED3/

Burned areas

- Systematic QA is essential (remember – ill posed problem)
- Active fires for temporal validation to stage 4
- Spatial Validation to stage 2 with Landsat TM
- Stage 3 requires sampling in time and space
- Data availability issues
- How good is the Landsat classification, anyway?

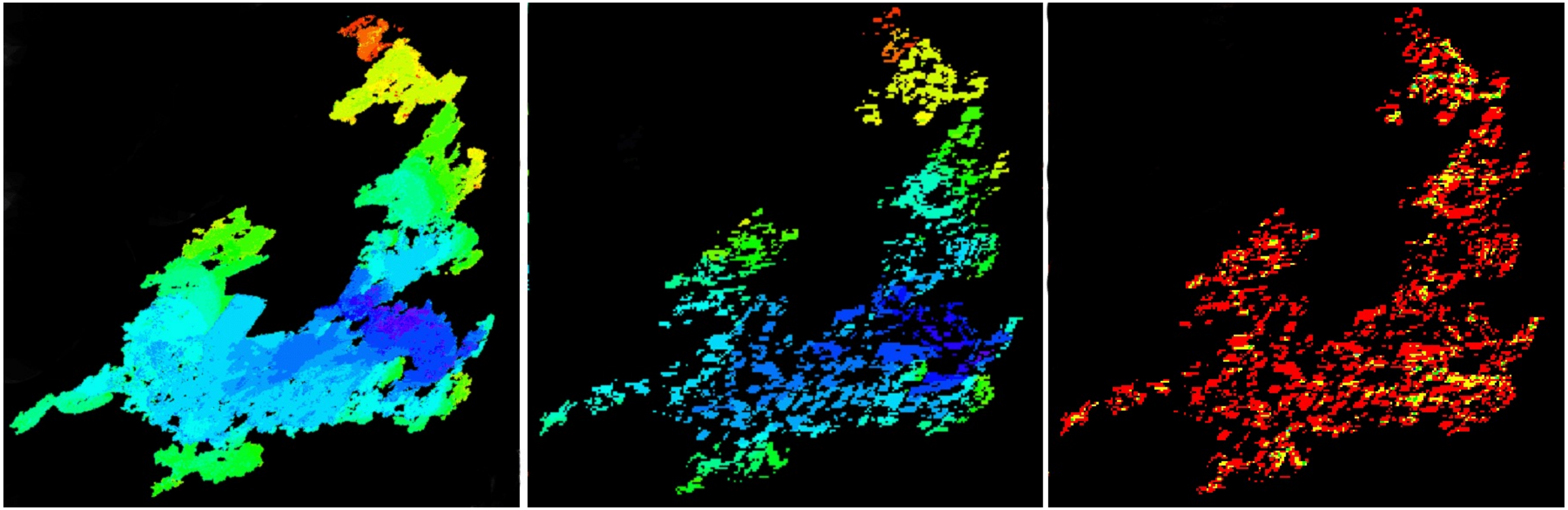
Example of Quality Assessment: Comparison with polygons by the European Forest Fire Service

Boschetti et al, 2008

Validation of Burned Area Product

Temporal Reporting Accuracy

- To date we have concentrated on product spatial reporting accuracy
- The product also reports the ~day of detection
- The nominal uncertainty due to the daily rolling BRDF inversion window is 8 days
- Temporal product accuracy increasingly relevant to user community
  - near real time air quality
  - atm. transport models (weather on day of burn, plume injection height)
  - some regional assessment applications (nat. resource, disaster management)



Burned Area

Active Fire

Active Fire Detections

Red=1, Yellow= 2

- MODIS active fire product
  - validated to stage 3
  - very low commission error
  - date & time of active fire detection defined by orbit overpass

MODIS Burned Area Temporal Reporting Validation Approach

Comparison at all global locations where there is a burned area detection and an active fire detection

- Active Fire (Terra or Aqua)
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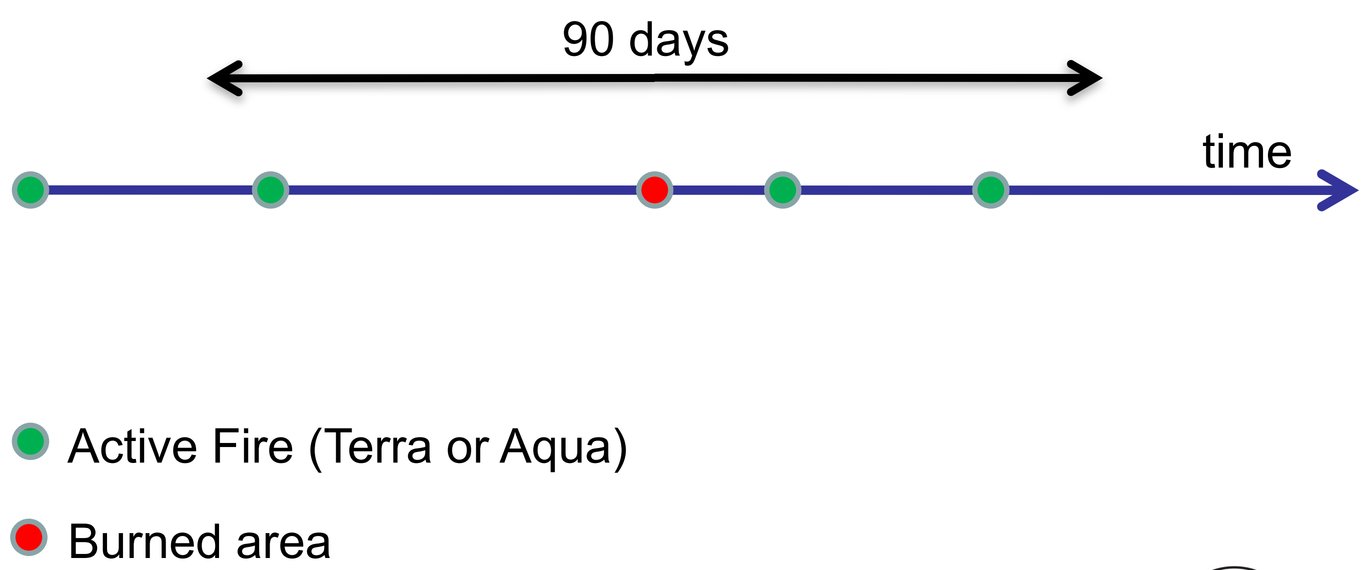

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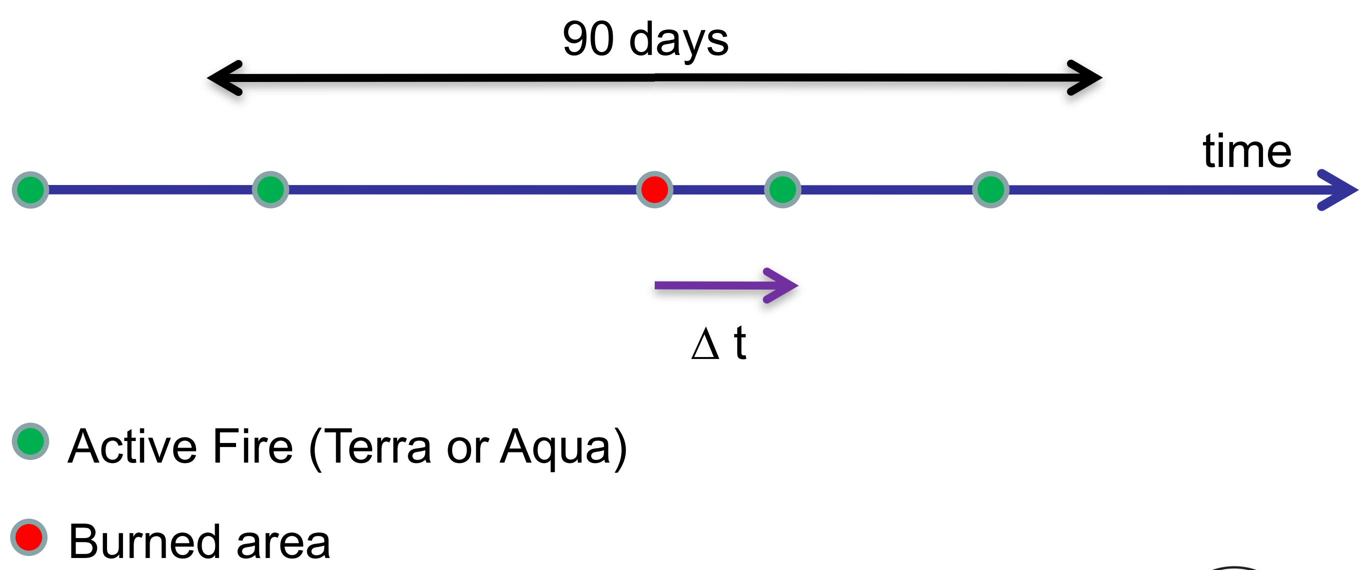
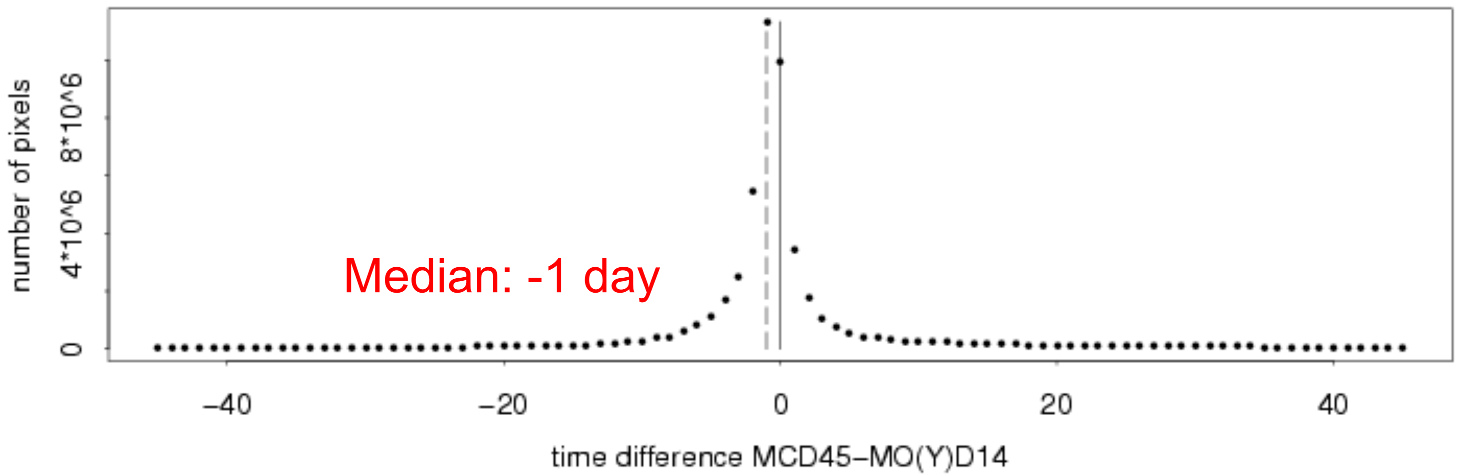
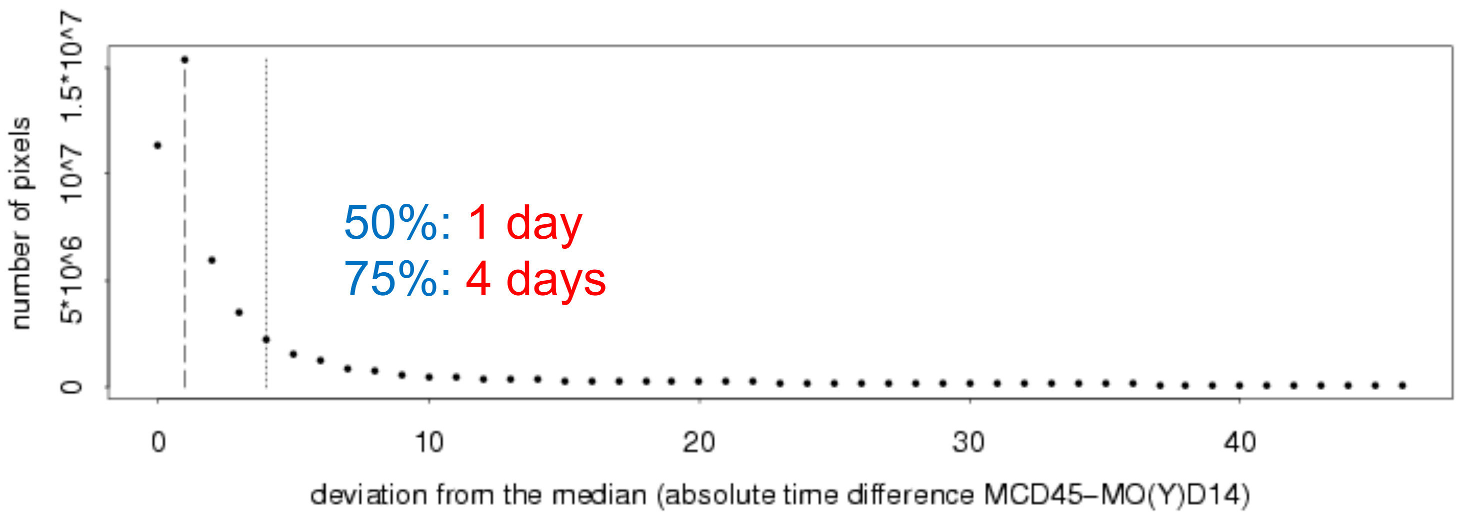
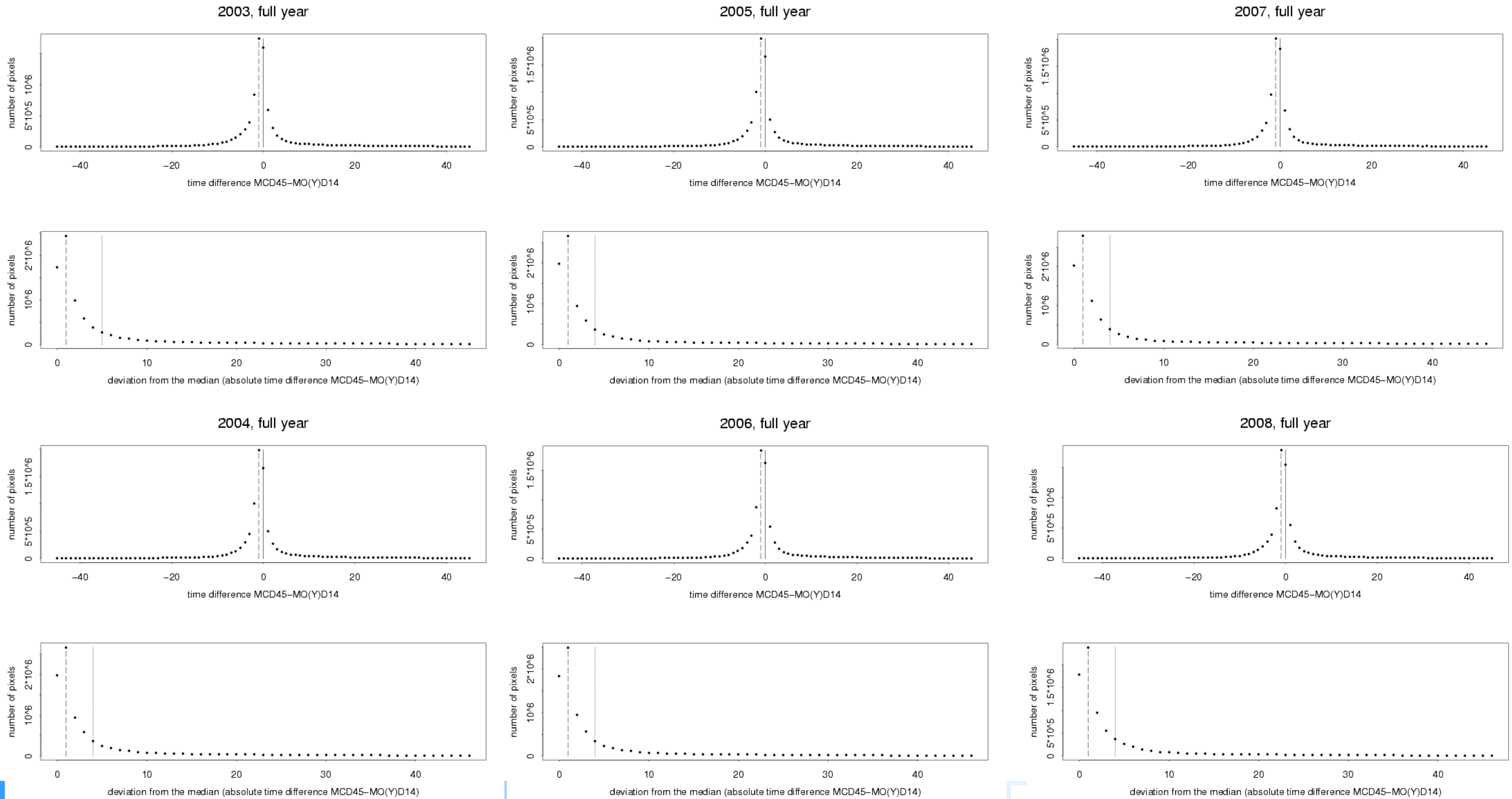


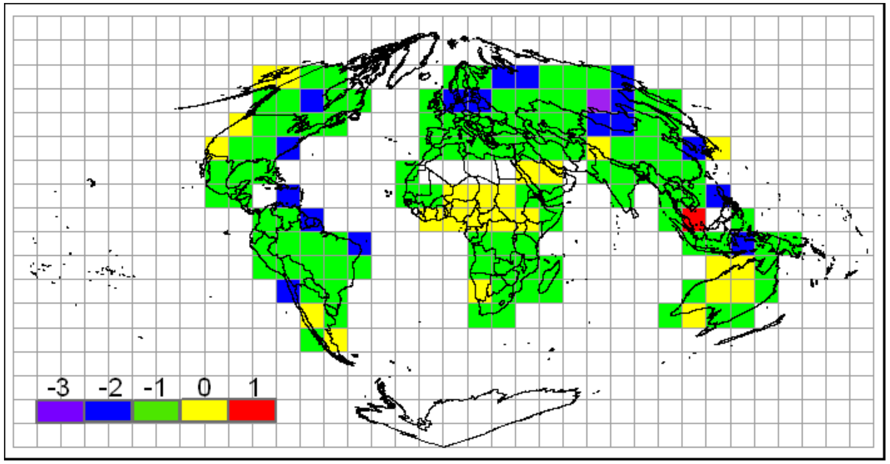
Time difference analysis global, 6 years



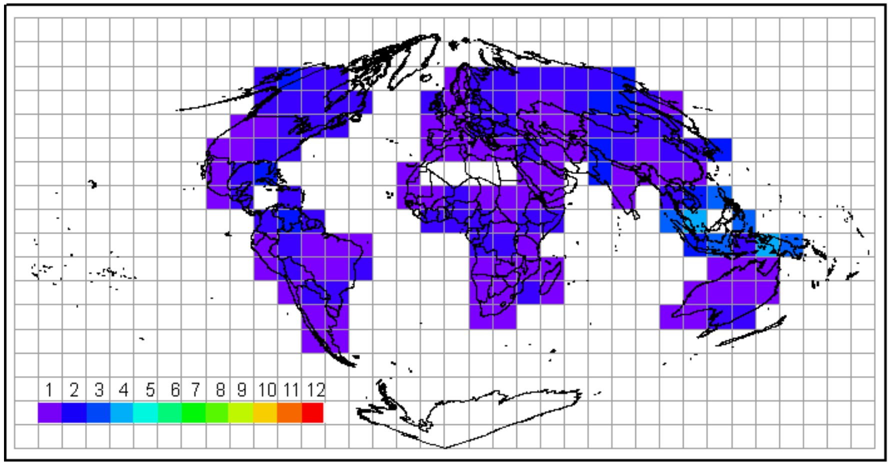


Consistent annual results

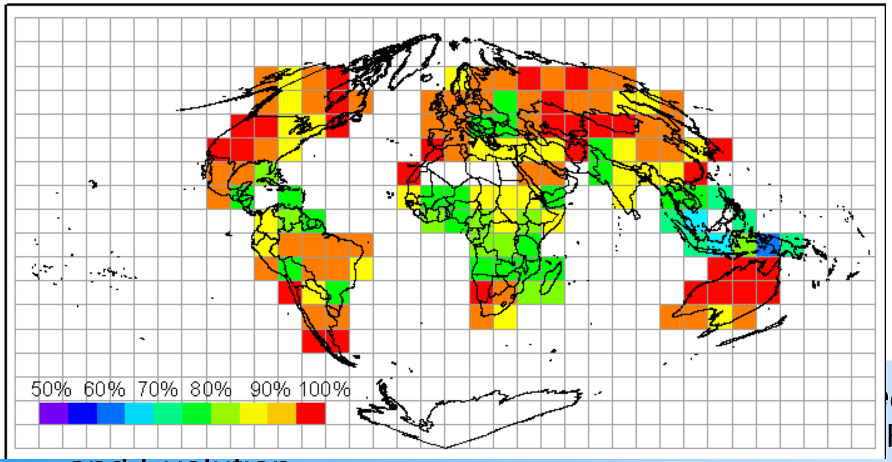




Median difference



50% of deviation from the median



% of pixels within the nominal 8 day uncertainty

Boschetti et al, 2010

Spatial Validation Protocol

- Landsat-based validation protocol
  - Developed in SAFARI2000 with SAFNet
  - Expanded to other GOFC-GOLD regional networks
  - Protocol advocated & now adopted by the CEOS Cal/Val program
- Multi-temporal Landsat data
  - interpreted by regional experts
  - map the area burned between acquisitions
  - generate independent reference data set

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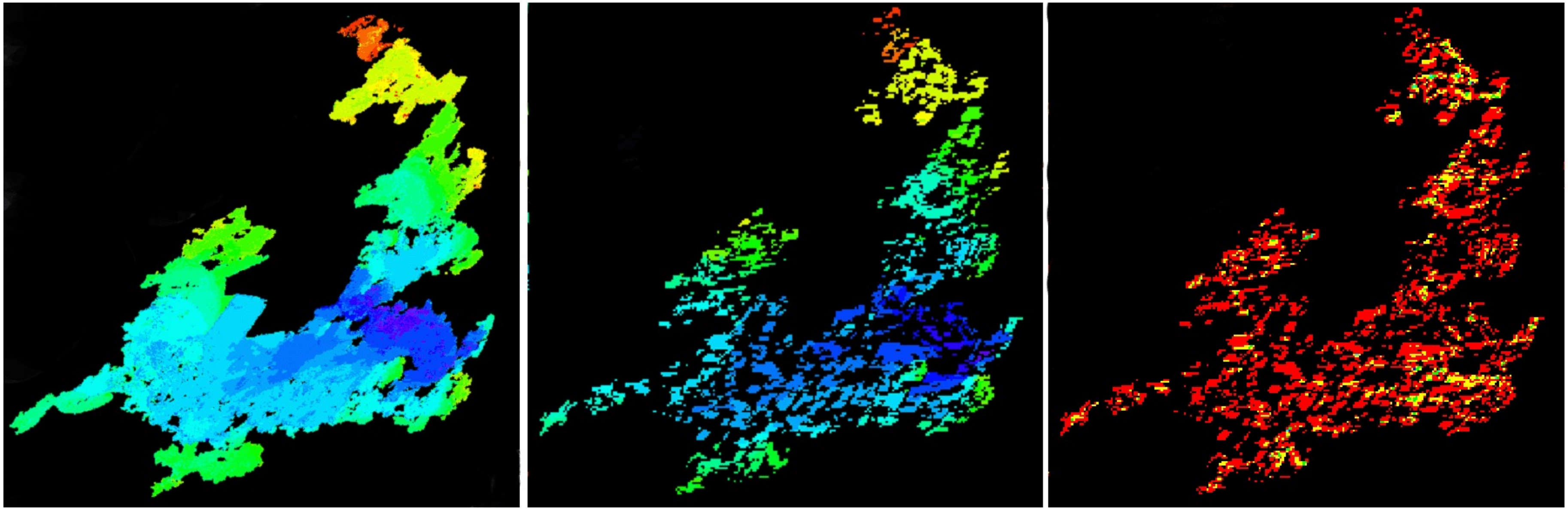

Burned Area | Active Fire | # Active Fire Detections Red=1, Yellow= 2

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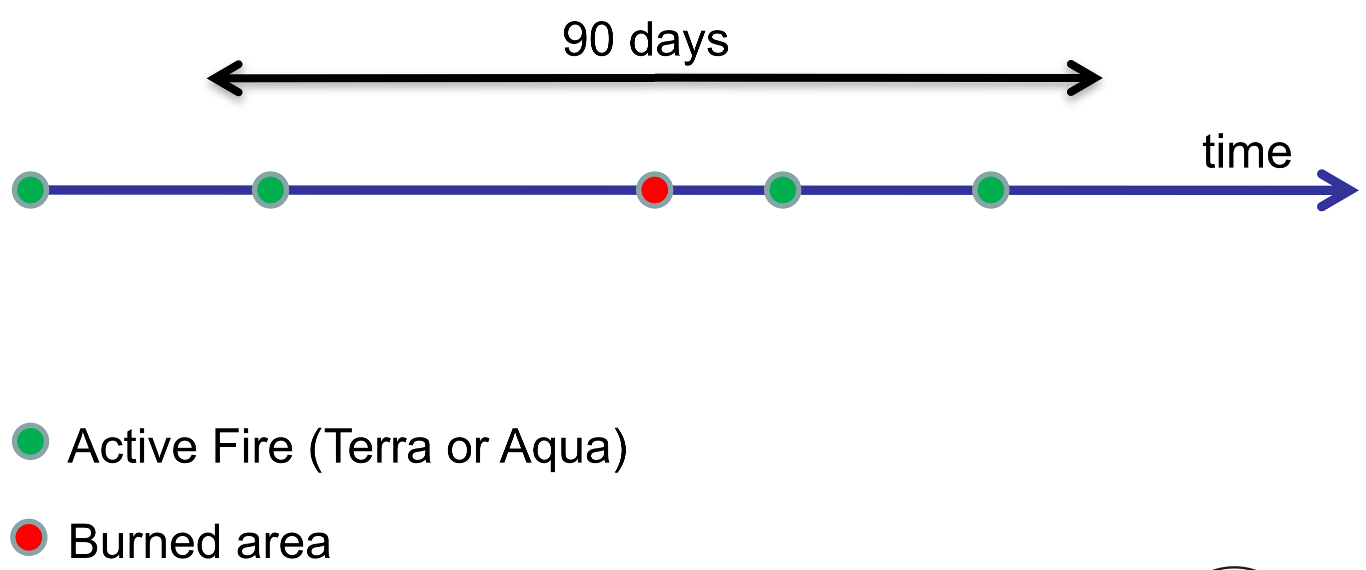

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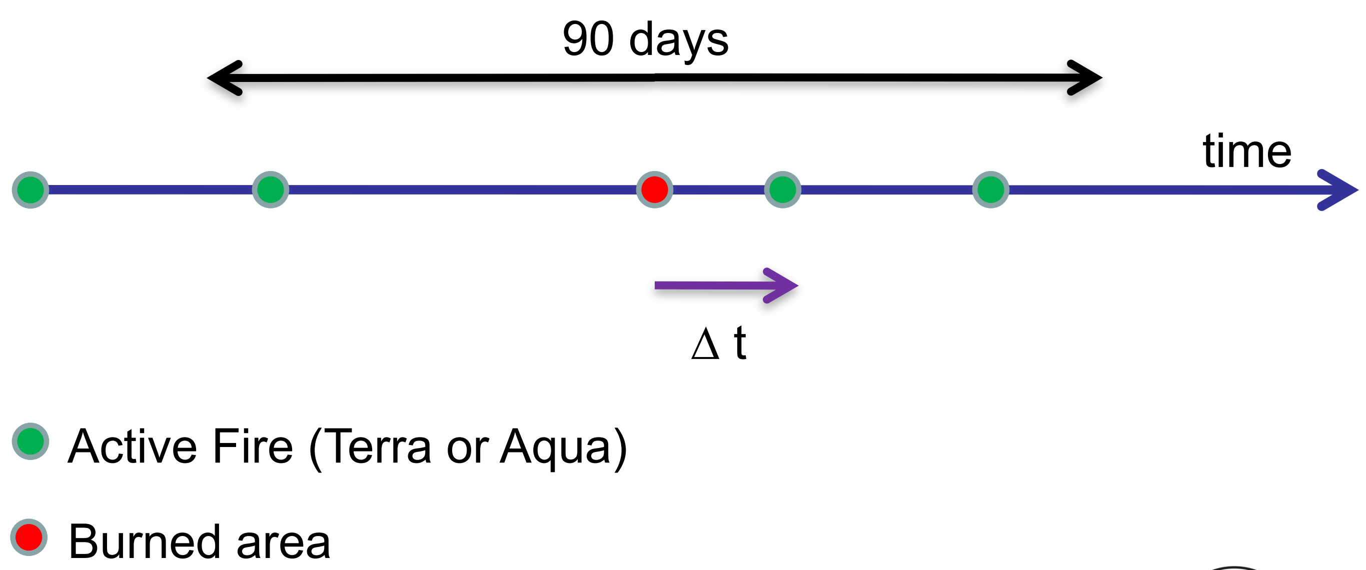
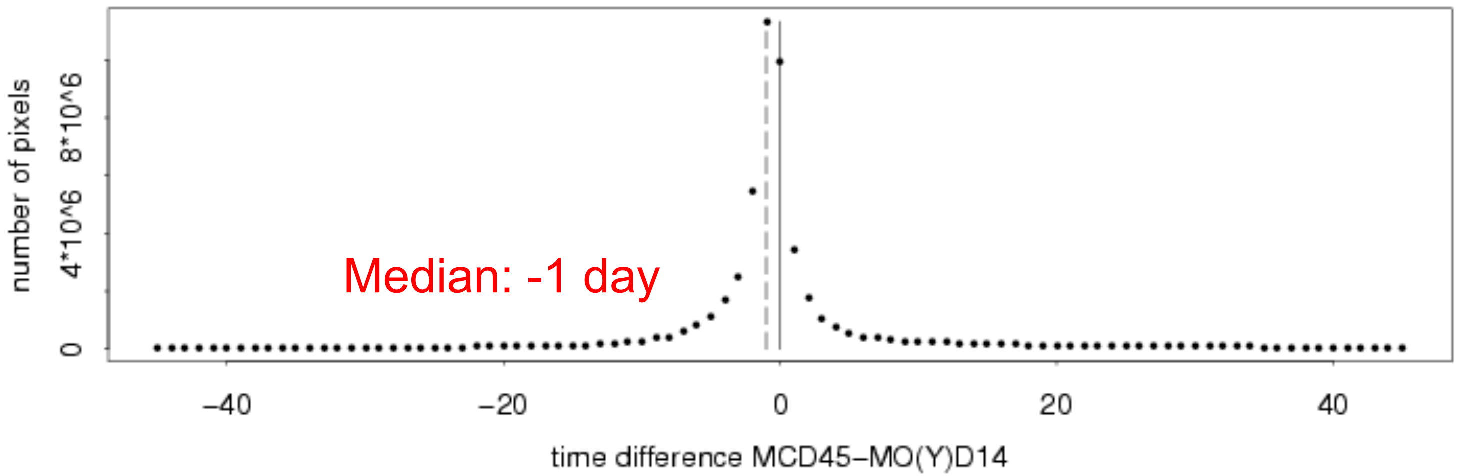
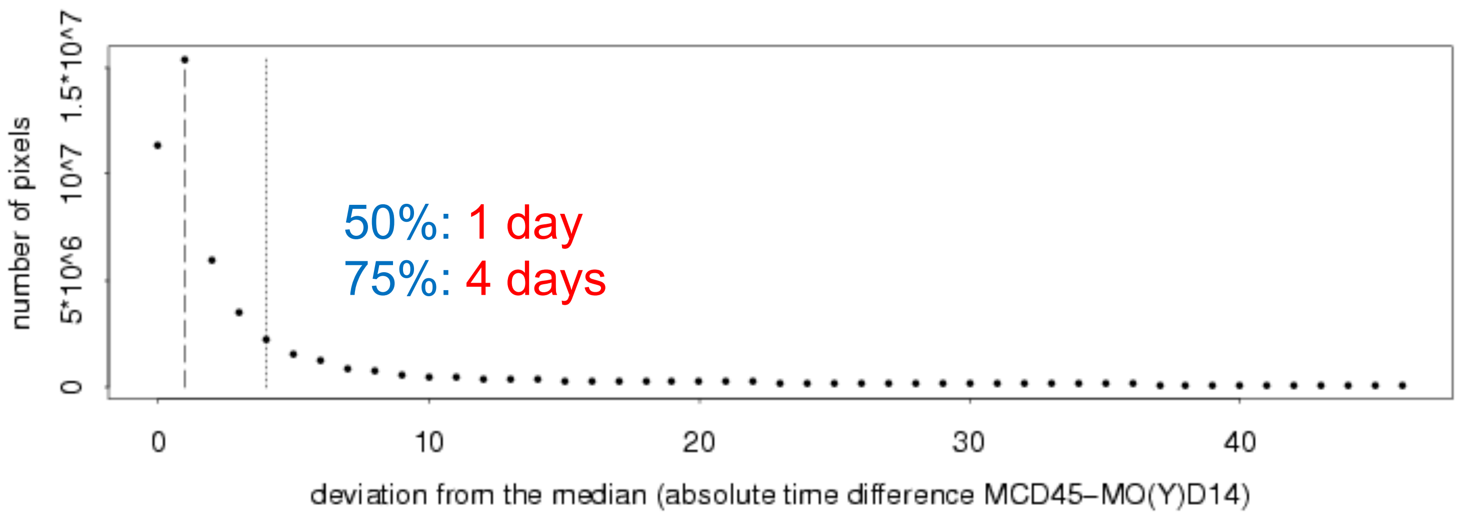


Time difference analysis
global, 6 years





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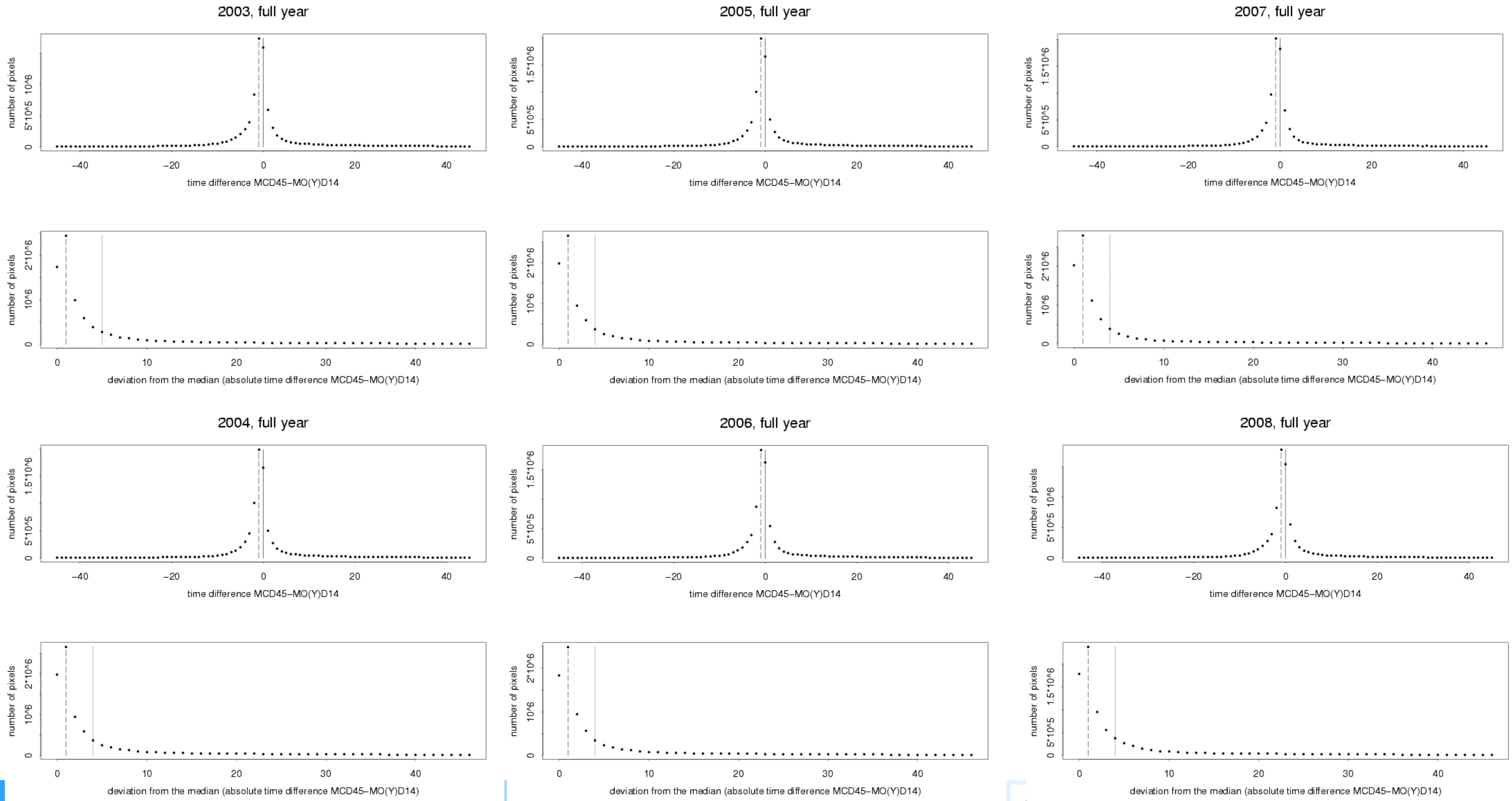
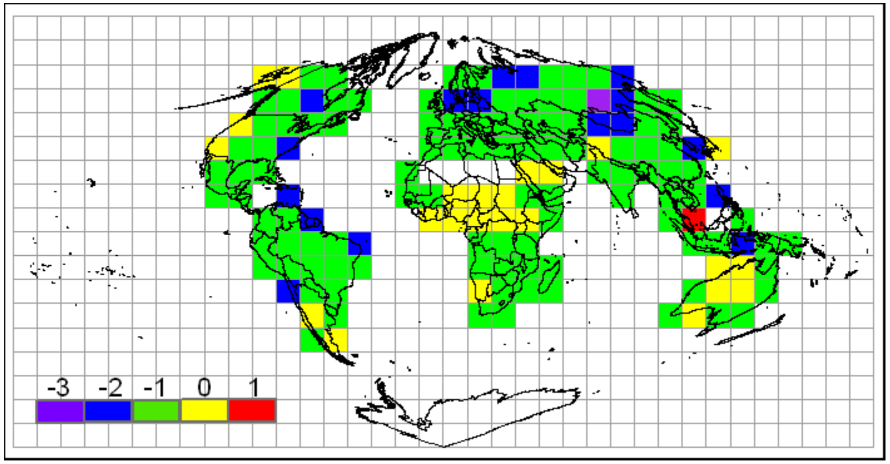
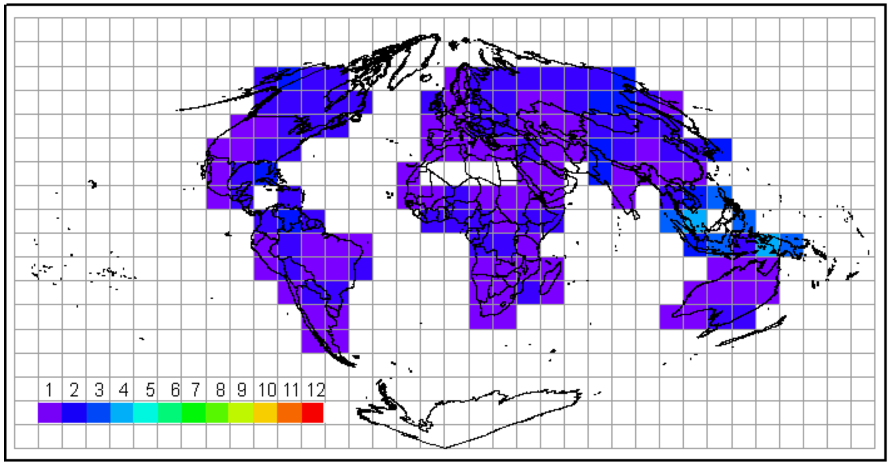




Median difference



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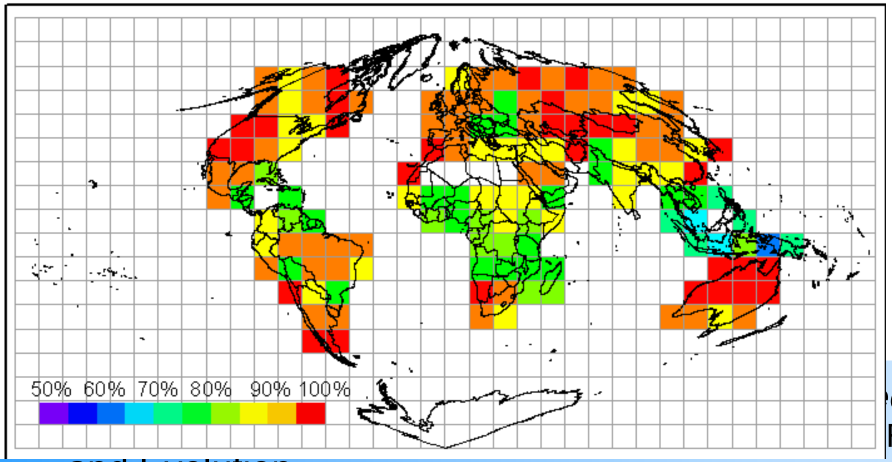


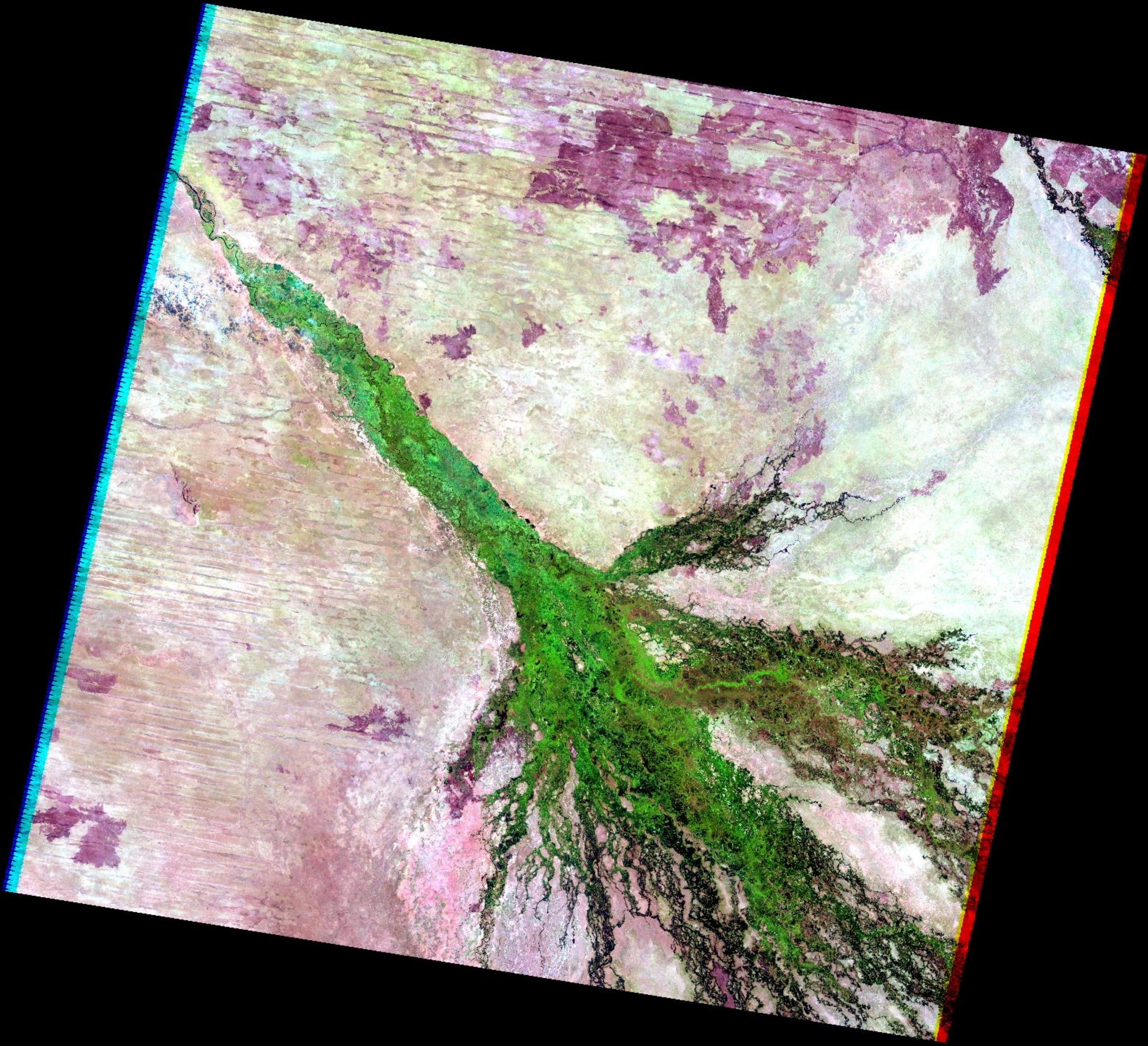
% of pixels within the nominal 8 day uncertainty

Boschetti et al, 2010

Time 1:

Landsat ETM+

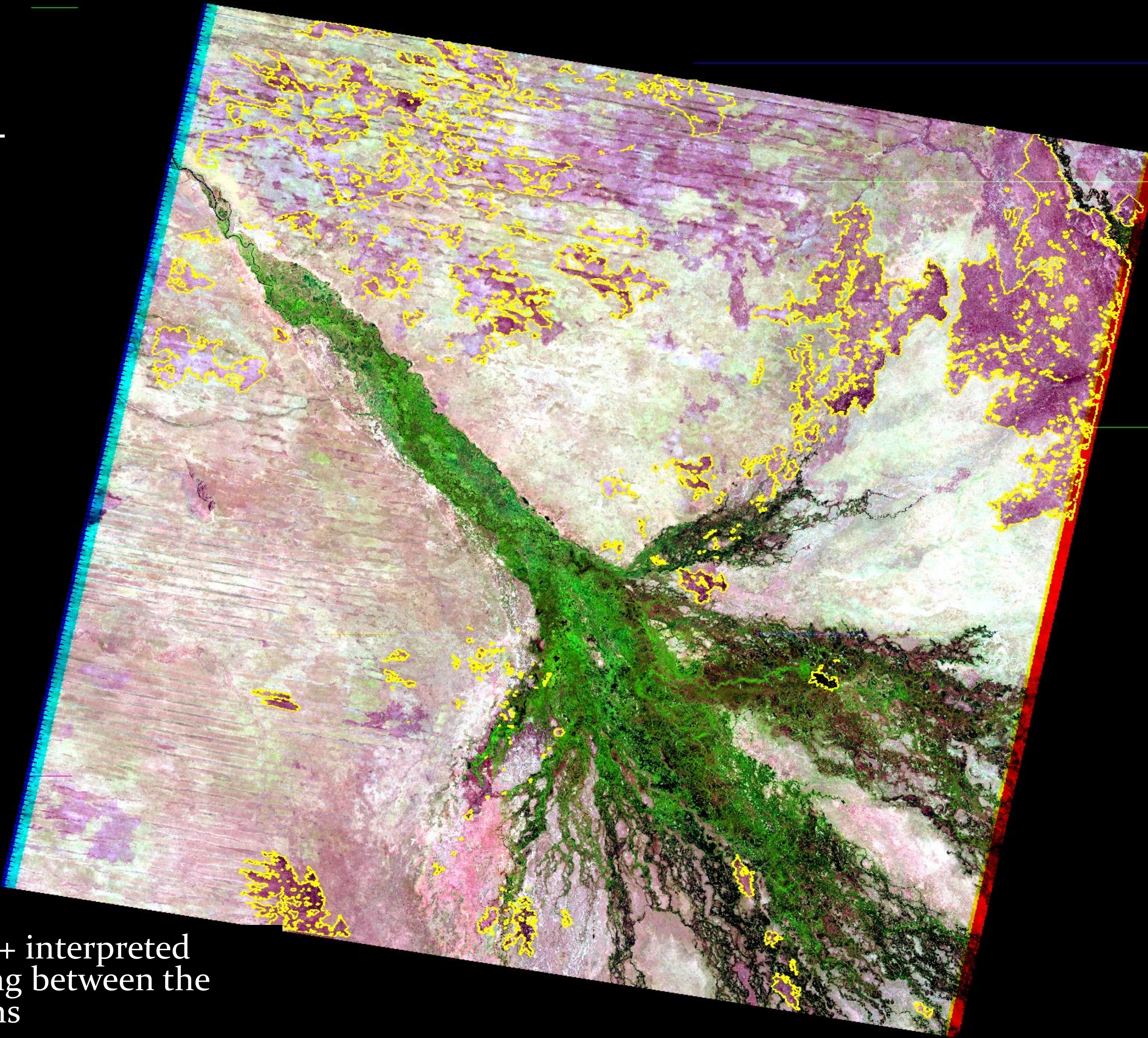
Sept. 4th



Time 2:

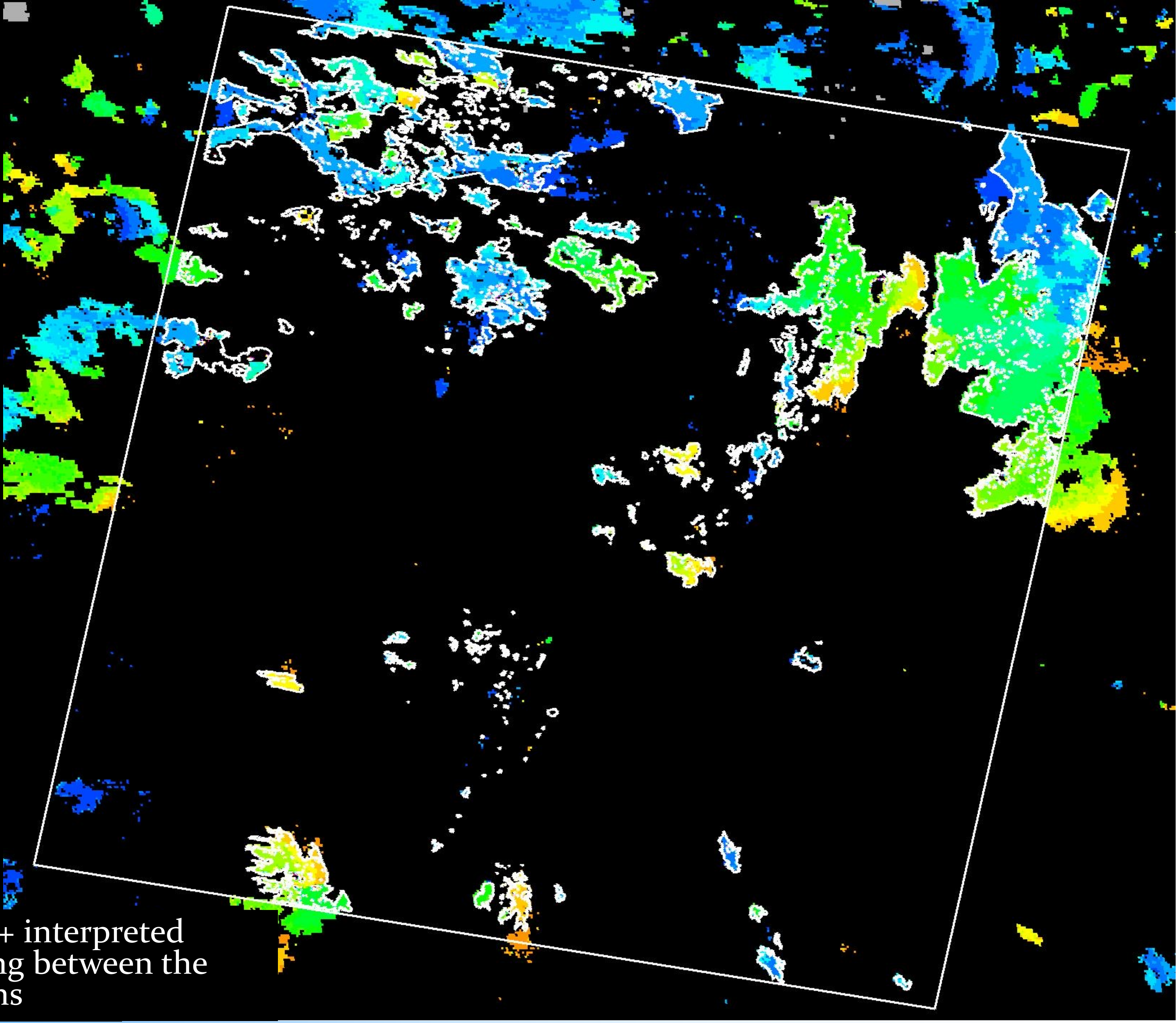
Landsat ETM+

Oct 6th



Yellow vectors = ETM+ interpreted burned areas occurring between the two ETM+ acquisitions

MODIS 500m Burned Areas

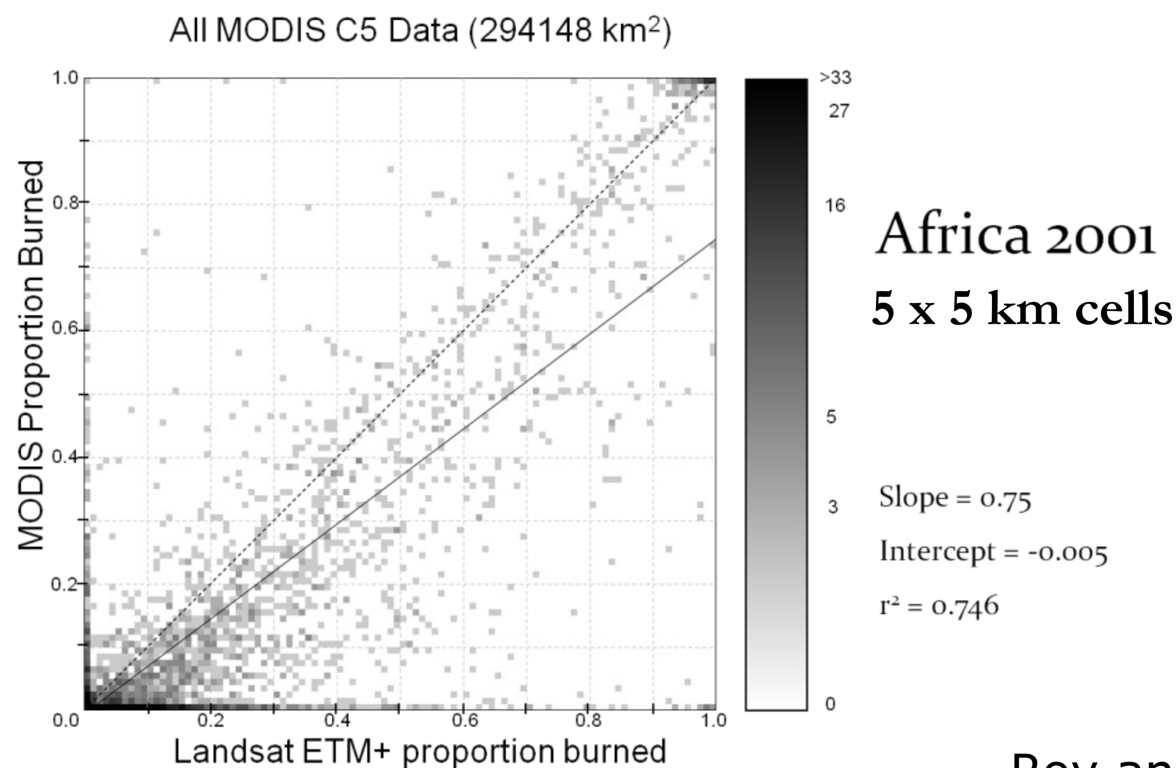


Time 1 Sept. 4
to
Time 2 Oct. 6

White vectors = ETM+ interpreted burned areas occurring between the two ETM+ acquisitions

Validation Metrics

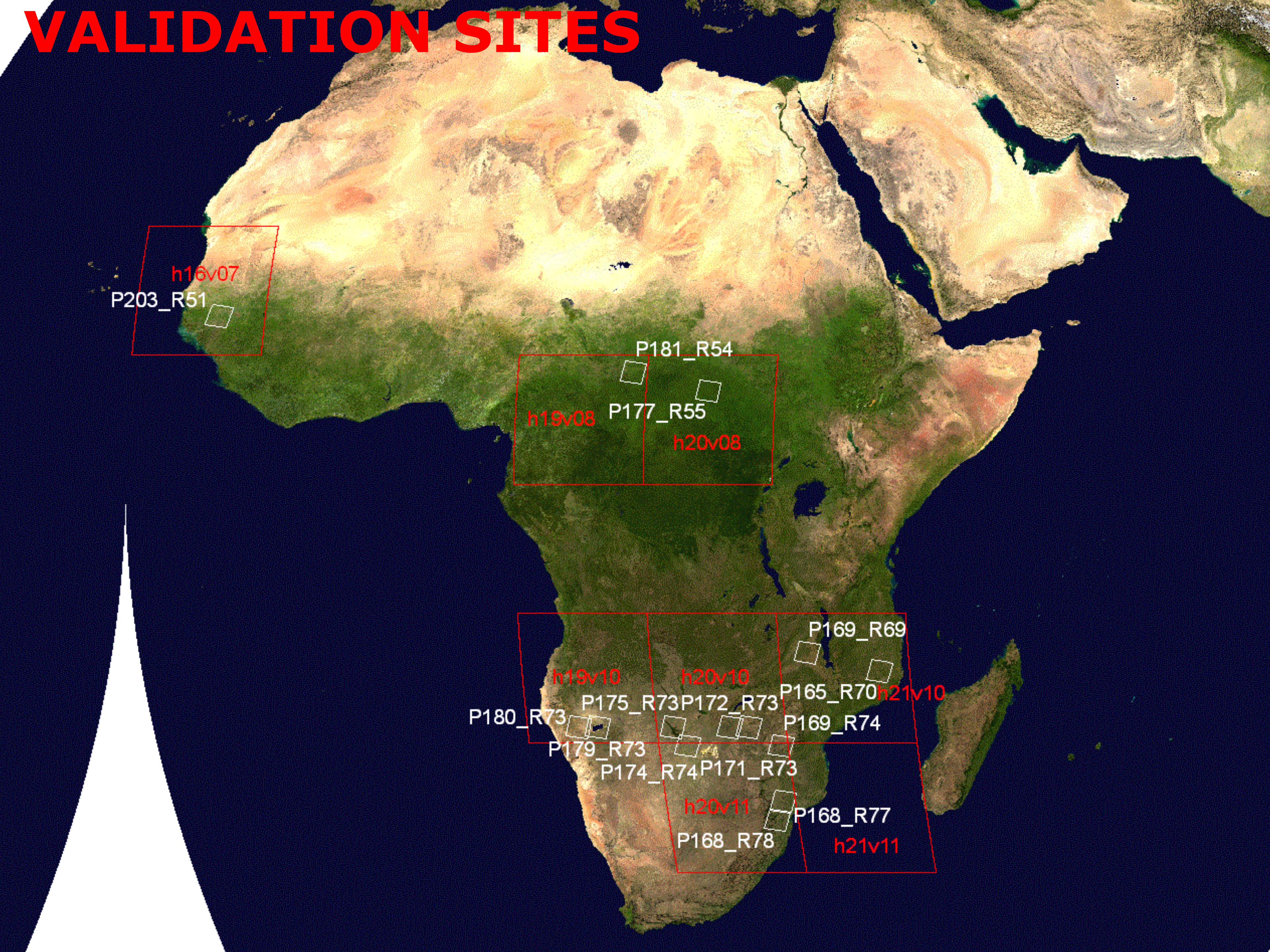
- Regression – accuracy and precision at coarser scale (this is what should be the ECV requirement!)



Roy and Boschetti 2009

- Confusion matrix statistics (overall, user's & producer's accuracy) – pixel level accuracy assessment

VALIDATION SITES



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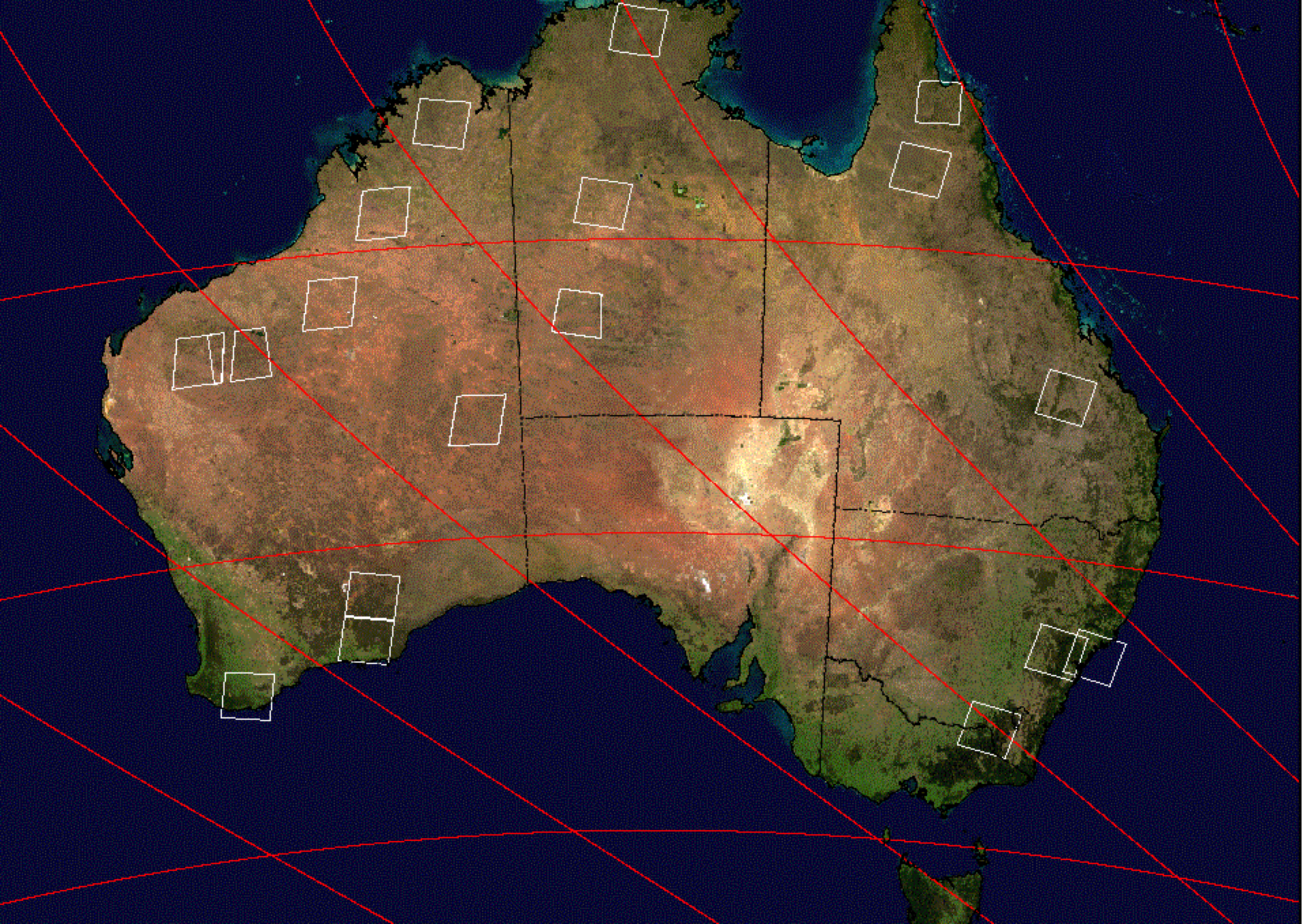



VALIDATION SITES
P32_R43
P31_R44
P28_R47
h08v07
P5_R55
P4_R55
P5_R56
h11v08
h13v09
P220_R66
P231_R70
P228_R70
h11v10
P224_R70
h12v10
P224_R71
P220_R75
h13v11
h12v12
P229_R85
P230_R84
P230_R85

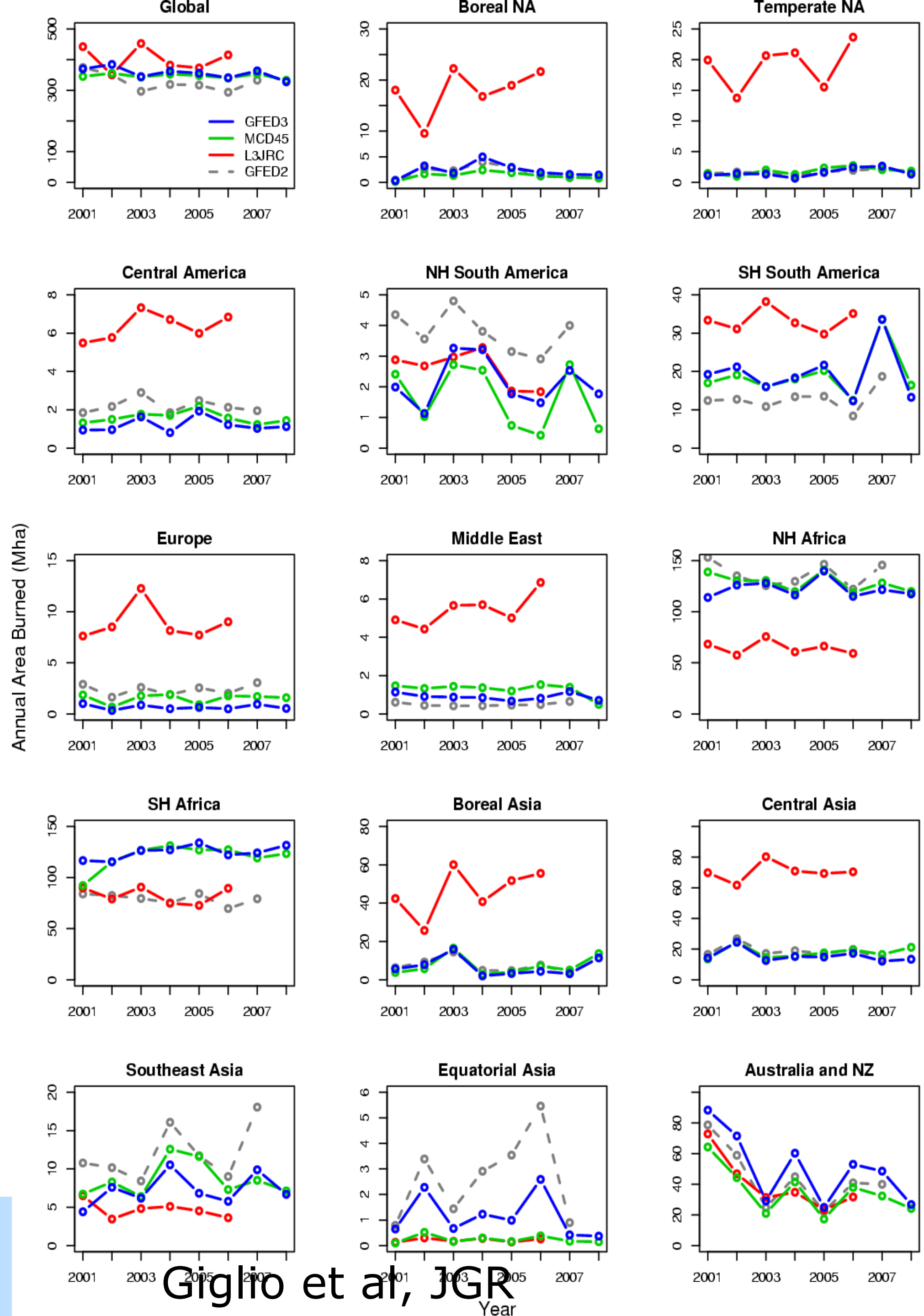
VALIDATION SITES


VALIDATION SITES

The case for CEOS stage 3 and stage 4 validation

Intercomparisons

- Shed light of difference and similarity
- Limited usefulness in understanding which product is correct…



Giglio et al, JGR

VALIDATION SITES
h17v04
h18v04
h19v04
h20v04
h17v05
h19v05
177026
189029
187030
183030
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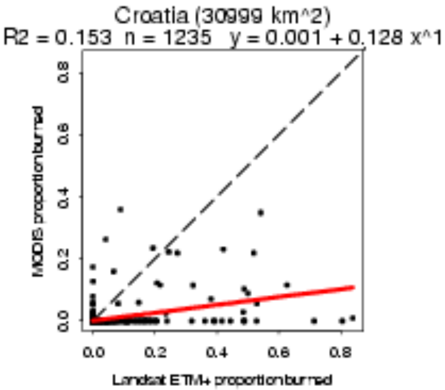
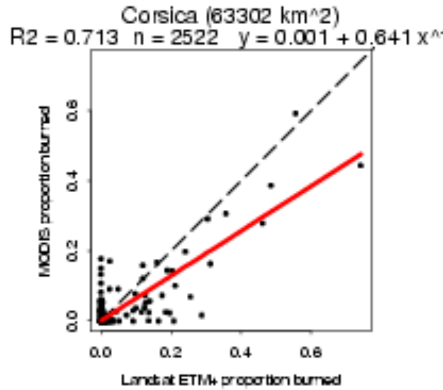
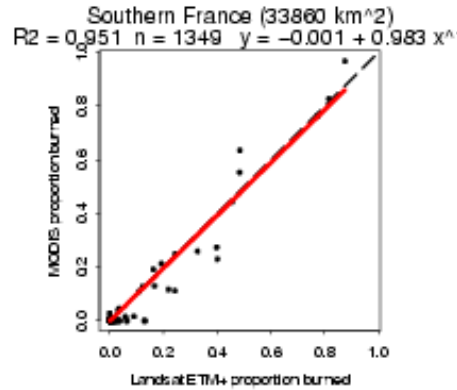
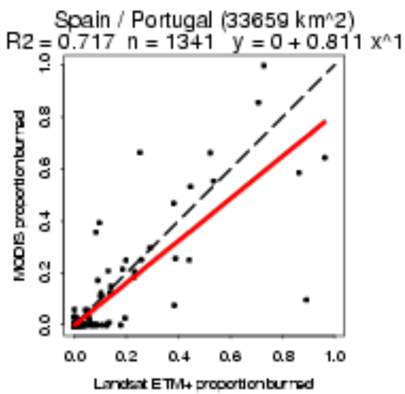
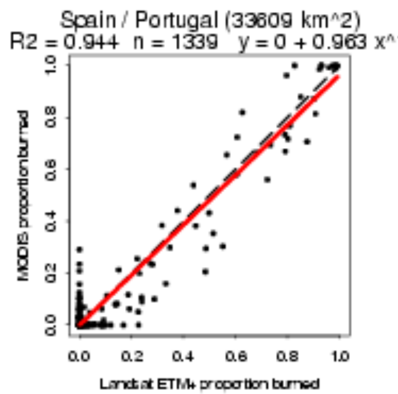
203034
188033
188034

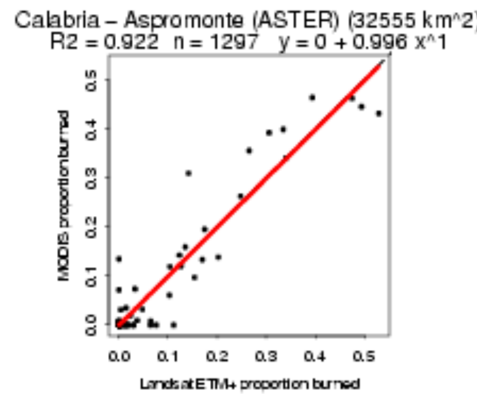


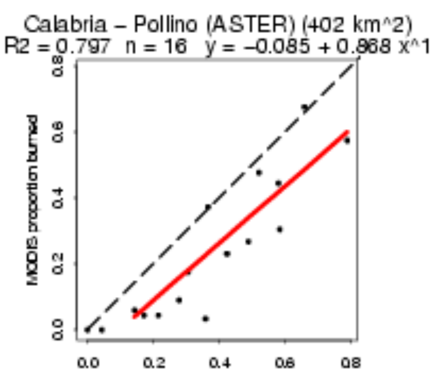






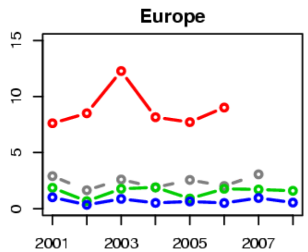






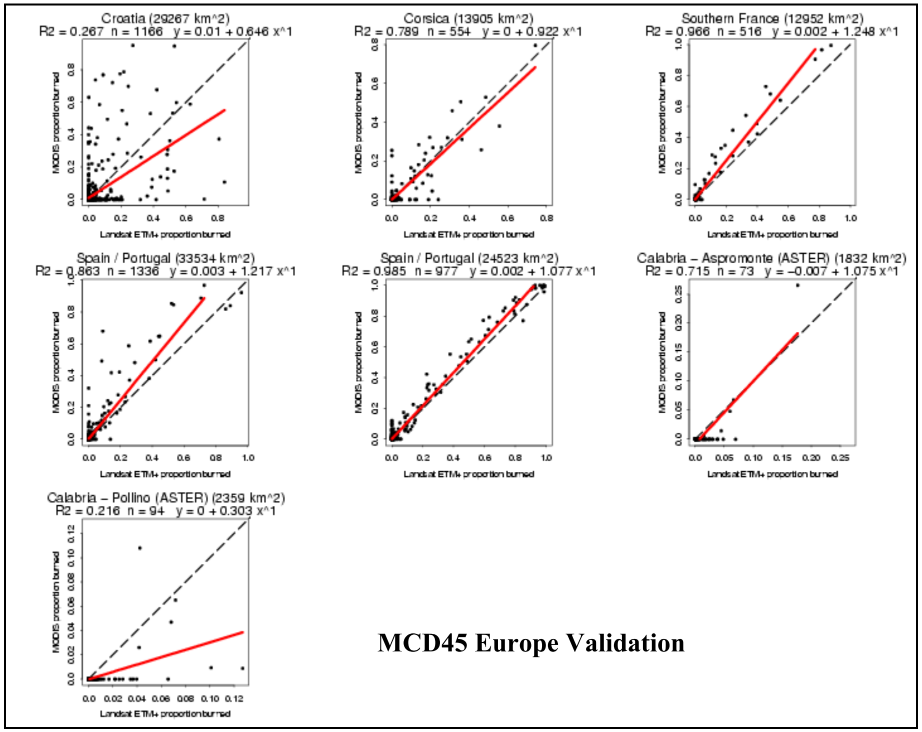
2003 VALIDATION: L3JRC REGRESSION OVER 5KM X 5KM CELLS

- L3JRC performs very well on MODIS Europe validation dataset.
- Intercomparison: Giglio et al 2010, shows that L3JRC detects more than MCD45, GFED 2 and GFED 3 in Europe



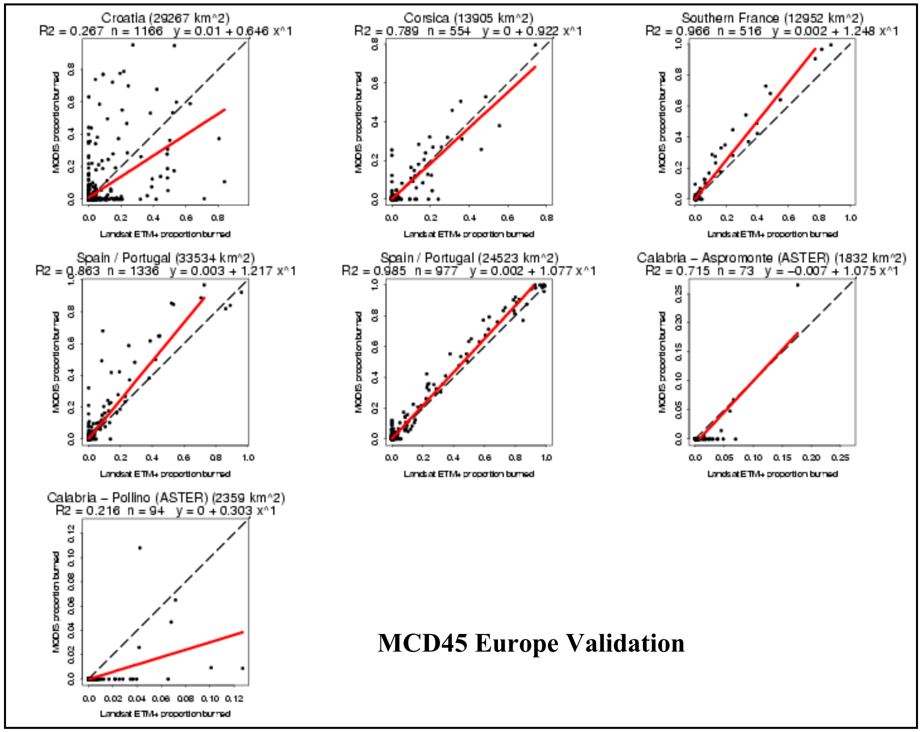
- Is the Stage 2 dataset enough to conclude that L3JRC is a correct estimate?

- MCD45 also performs well on Stage 2 dataset!



- Stage 3 needed to characterize fully the variability! (sampling in space and time)

- To reinforce the point: with Stage 2 datasets we can get a set of plots



- But Stage 3 is needed to put them together! The sampling probability is required to correctly estimate continental and global precision and accuracy

In the meantime…

Can we generate a Landsat burned area product?

Test case on US

(Boschetti, Roy, Justice, Baraldi, Humber)

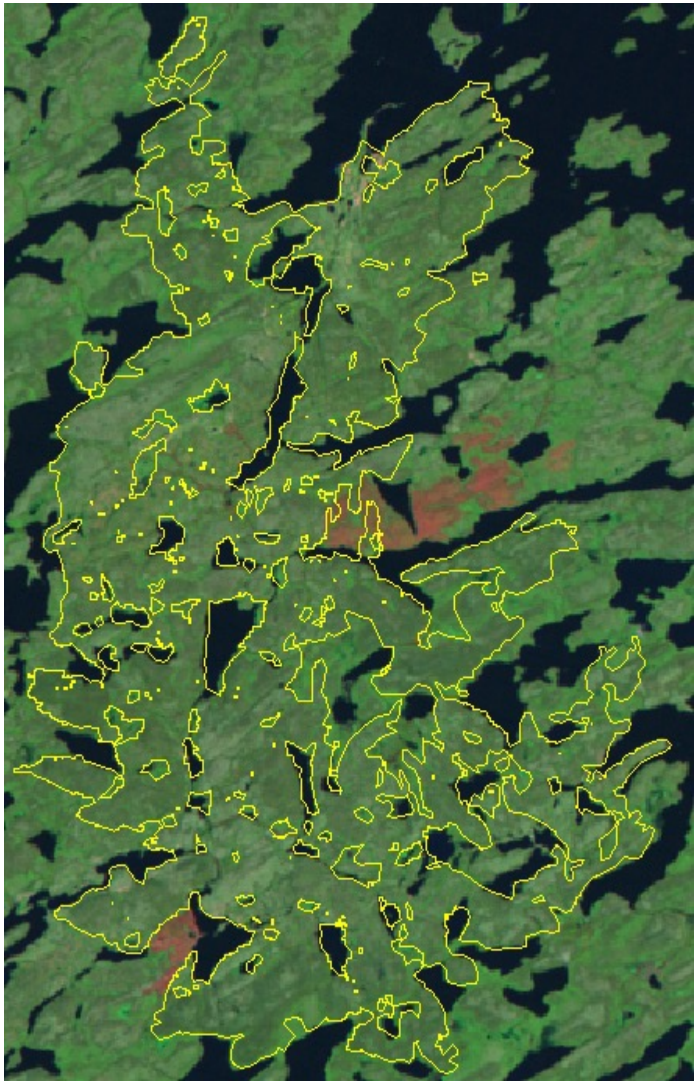
Validation approaches for the ESA Fire_CCI project

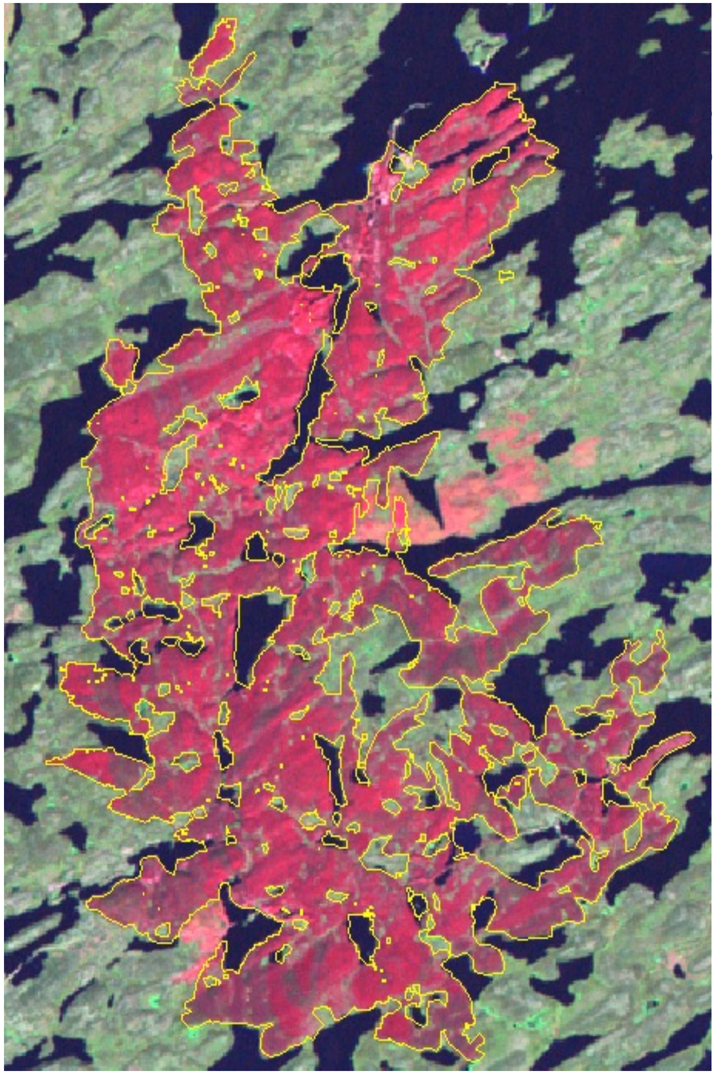
Marc Padilla and Emilio Chuvieco

Validation of fire_cci BA products

- A new full dataset of fire perimeters was derived from multitemporal pairs of Landsat TM/ETM+ data.
  - A total of 242 Pairs of Landsat TM/ETM+ images have been processed.
  - They include 147.994 fire perimeters and 126.180 hectareas of burned area.
- All files are documented following standard CEOS Cal-Val guidelines.

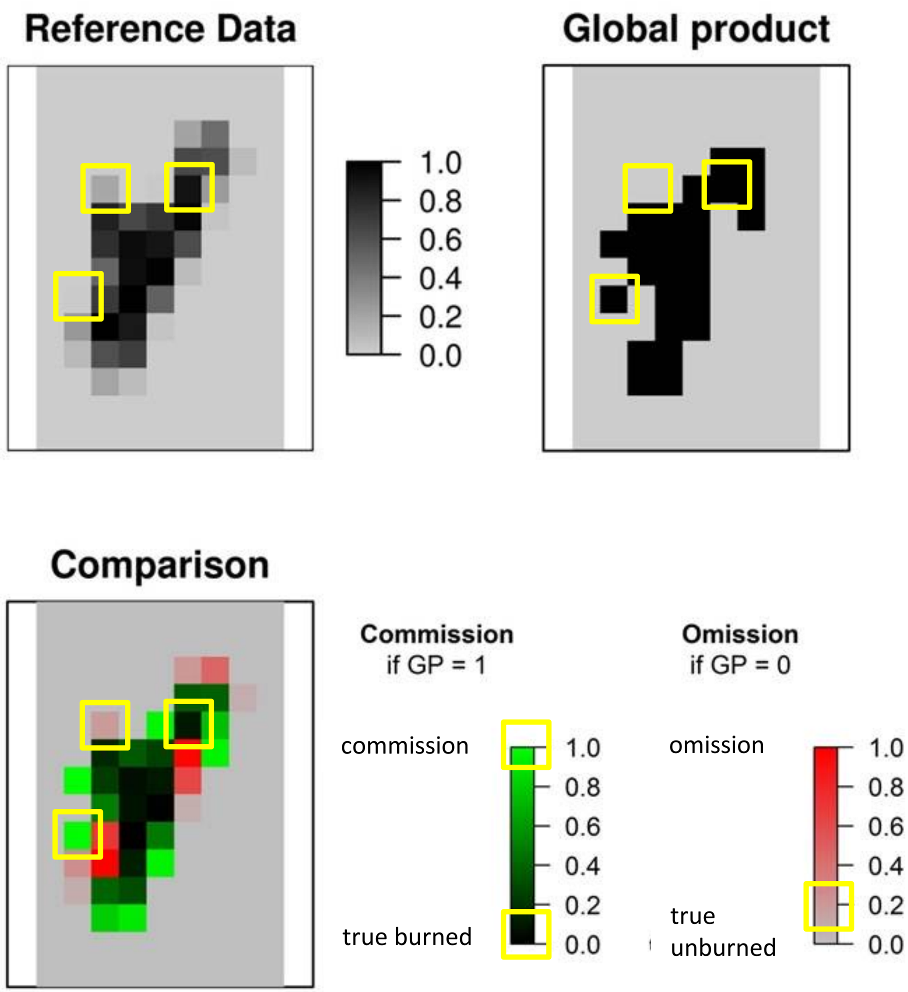
Fire reference data





anada

Validation was based on error matrix



Error matrix

Global product	Reference data: Burned	Reference data: Unburned	Global total
Burned	p_{11}	p_{12}	p_{1+}
Unburned	p_{21}	p_{22}	p_{2+}
Reference Total	p_{+1}	p_{+2}	$p=1$

Validation aspects / metrics

- Global accuracy:
  - Overall Accuracy
  - Dice coefficient (DC)
  - Commission and Omission Errors:
- Error balance:
  - Error bias (B)
  - Relative bias (relB).
- Temporal stability:
  - b slope of the accuracy and time relationship
  - Friedman test
  - Wilcoxon signed-rank test between multitemporal pairs of error matrices.

Validation metrics: global accuracy

- Overall accuracy $OA = p_{11} + p_{22}$
- Commission error $Ce = p_{12} / p_{1+}$
- Omission error $Oe = p_{21} / p_{+1}$
- Dice coefficient

$$DC = \frac{2p_{11}}{2p_{11} + p_{12} + p_{21}} = \frac{(1 - Ce) \cdot p_{1+} + (1 - Oe) \cdot p_{+1}}{p_{1+} + p_{+1}}$$

(a)	Ref		
Map	B	UB	
B	0.30	0.15	
UB	0.15	0.40	

DC = 0.66
OA = 0.70
Ce = 0.33
Oe = 0.33

(b)	Ref		
Map	B	UB	
B	0.10	0.10	
UB	0.10	0.70	

DC = 0.50
OA = 0.80
Ce = 0.50
Oe = 0.50

Validation metrics

- Error balance: Bias (B) = $p_{1+} - p_{1+} = p_{12} - p_{21}$
  - Named Quantity Disagreement in Pontius (2011)
- Temporal stability: based on metrics insensitive to BA prevalence.
  - Relative bias (relB) = $(p_{1+} - p_{1+}) / p_{1+}$

(a)	Ref		
Map	B	UB	
B	0.10	0.05	B = -0-1
UB	0.15	0.70	relB = -0.4

(b)	Ref		
Map	B	UB	
B	0.20	0.15	B = -0-1
UB	0.25	0.40	relB = -0.22

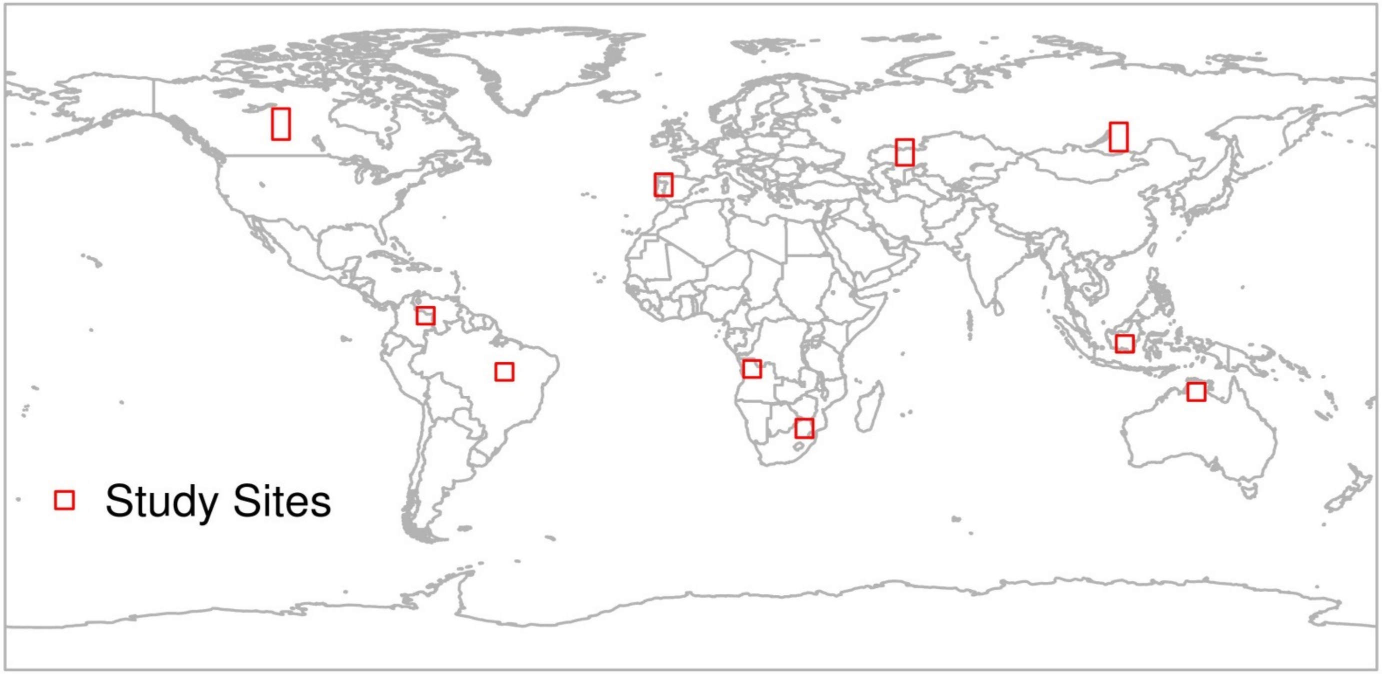
Table a) has the same B, but much less BA in the reference data, and therefore it has worse relB than table b)

Validation approaches

- Study sites sampling:
  - Spatial representativity is low.
  - Temporal representativity is high (temporal trends can be measured).
- Global sampling:
  - Statistically selected.

Study Sites

- Reference fire perimetres are derived from 1 pair of Landsat images on each study site and year, from 1995 to 2009



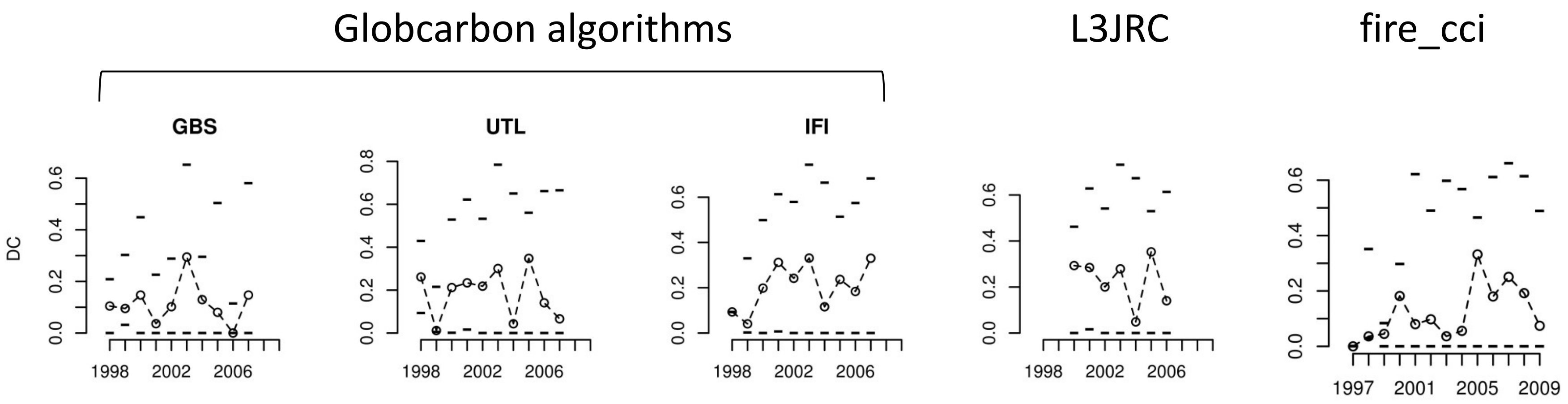
1. Validation at the Study Sites

- Overall results from 10 sites and 12 years (1997-2009):
  - MERIS is significantly better than all other ESA products in DC, better than two in OA and better than 4 in B

	BA product	DC	OA	B
a	fire_cci_MERIS	0.412[bcdef]	0.968[cd]	-0.008[bcef]
b	fire_cci_VGT	0.332	0.964[cd]	-0.012
c	fire_cci_AATSR	0.263	0.927	0.032
d	fire_cci	0.393[bce]	0.948	0.022[c]
e	GBS	0.208	0.969[cdg]	-0.023
f	UTL	0.422[bce]	0.970[abcdg]	-0.011[c]
G	IFI	0.336[bce]	0.962[c]	-0.005[c]
	Friedman test (p-value)	<0.001	0.002	<0.001

Note: All fire_cci results are still a draft

Temporal trends of accuracy



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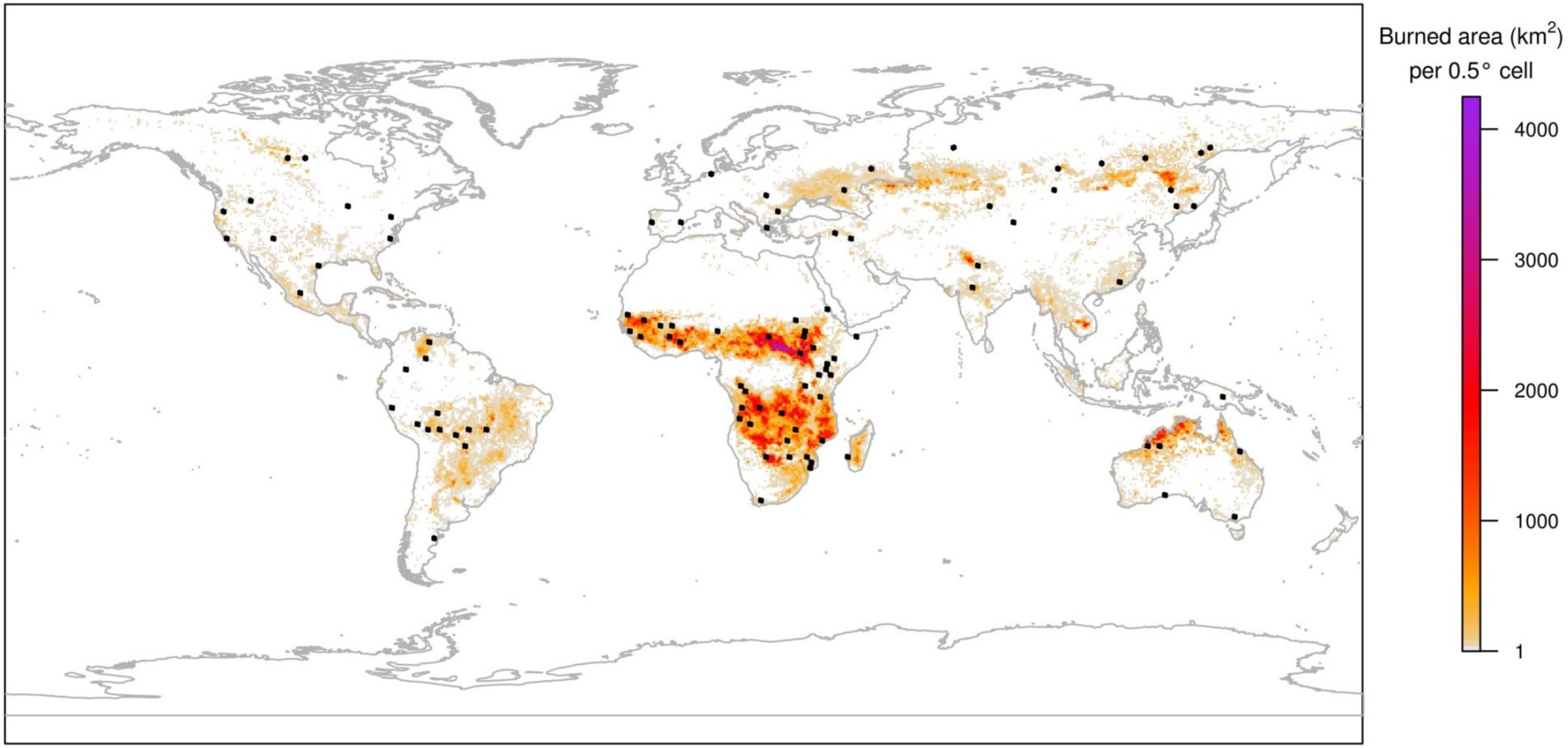
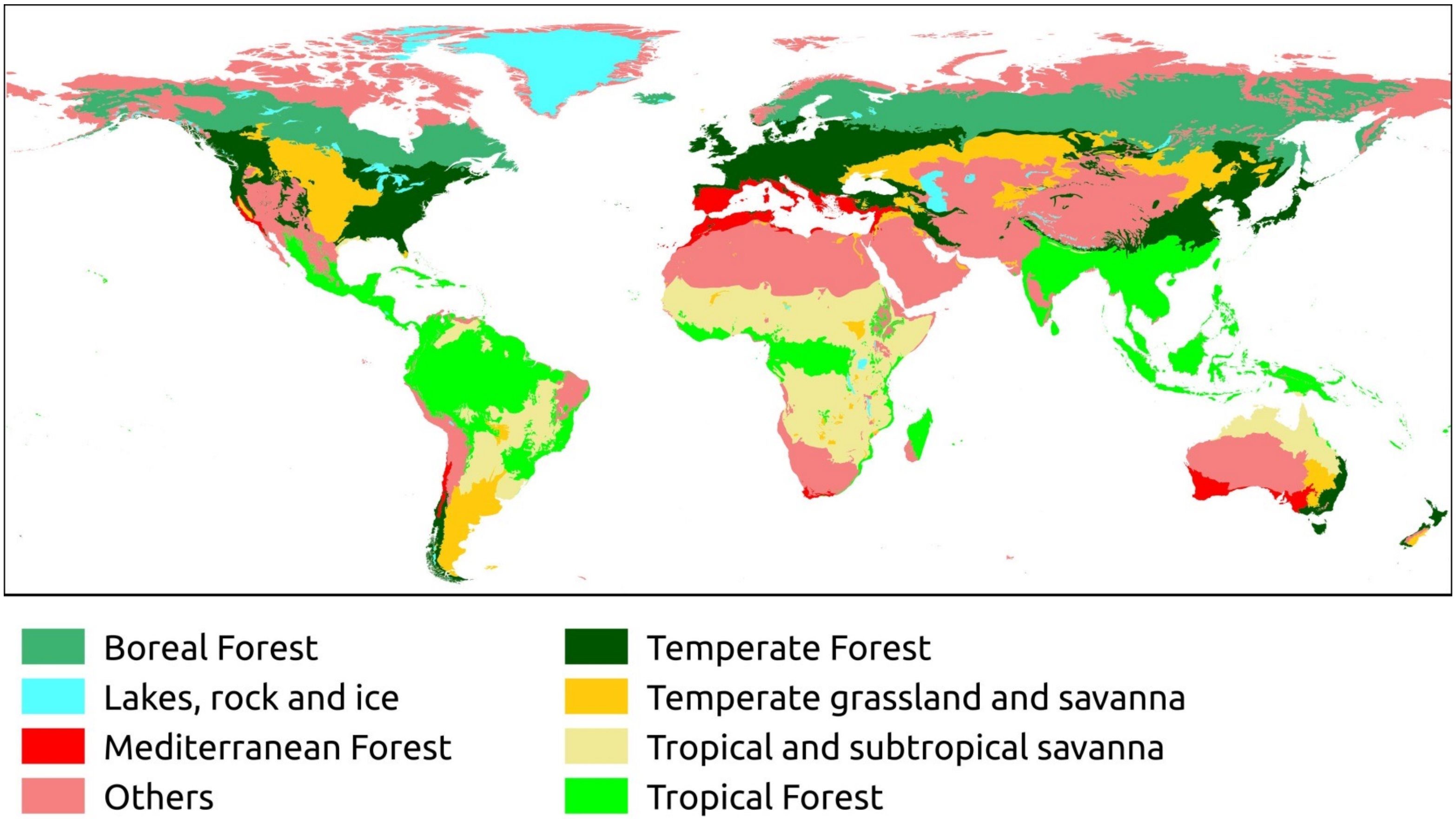
2. Validation at the Global Sample

- Reference fire perimetres are derived from 105 pairs of images

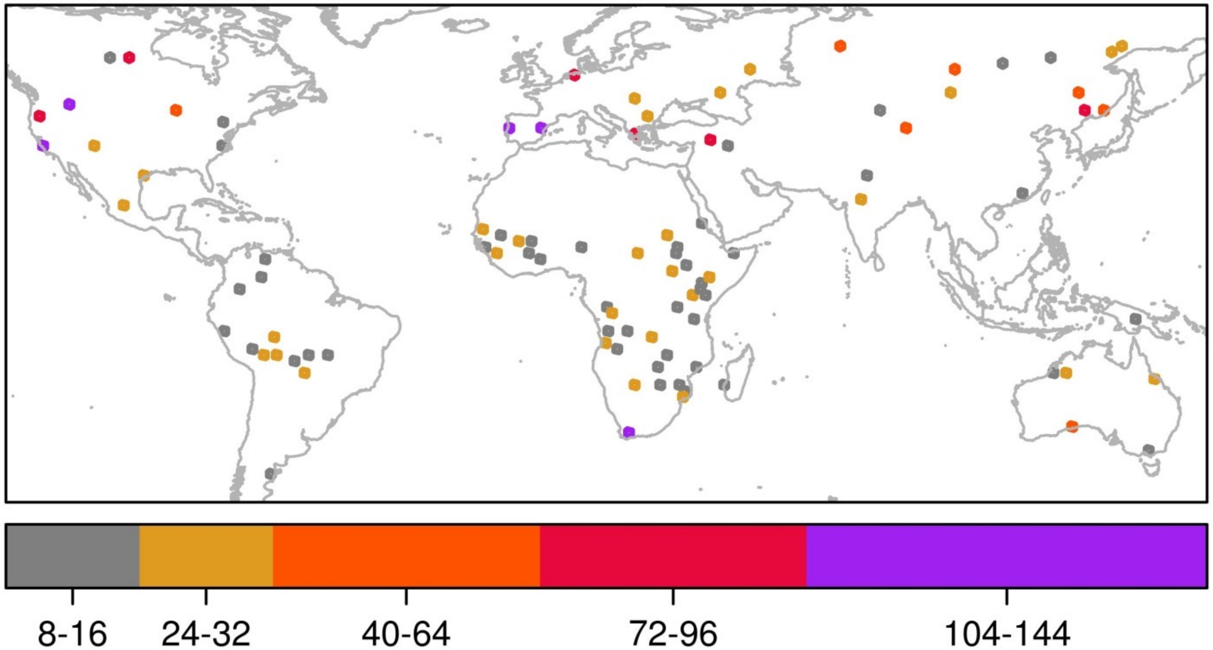


Sampling strata



Reference Data - #Days between image-pairs

- Separated by < 32 days in 83 of the 105 sampled pairs
- Longer than 32 days only in Boreal, Mediterranean or Temperate Forests
- Maximum 144 days



(b) #Days

Per-biome and global description of accuracy

- Stratified combined ratio estimates (Cochran 1977; Stehman et al. 2007)

$$\hat{R} = \frac{\sum_{h=1}^{H} K_h \bar{y}_h}{\sum_{h=1}^{H} K_h \bar{x}_h} \qquad \hat{V}(\hat{R}) = \frac{1}{\hat{X}^2} \sum_{h=1}^{H} K_h^2 (1 - k_h / K_h)(s_{yh}^2 + \hat{R}^2 s_{xh}^2 - 2\hat{R} s_{xyh}) / k_h$$

  - $\bar{y}_h$ and $\bar{x}_h$ are the sample means of y_t and x_t for each stratum *h*
  - *K* and *k* are the total number and the sampled Landsat frames selected for each stratum
- For example, for OA

$$OA_t = \frac{\sum_t (e_{11,t} + e_{22,t})}{\sum_t n_t} = \frac{\sum_t y_t}{\sum_t x_t} = R$$

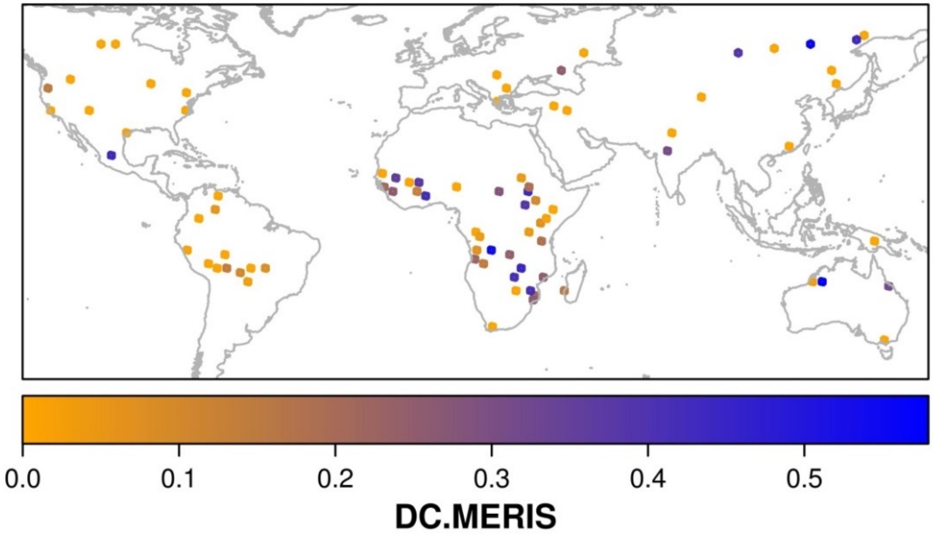
Global validation metrics

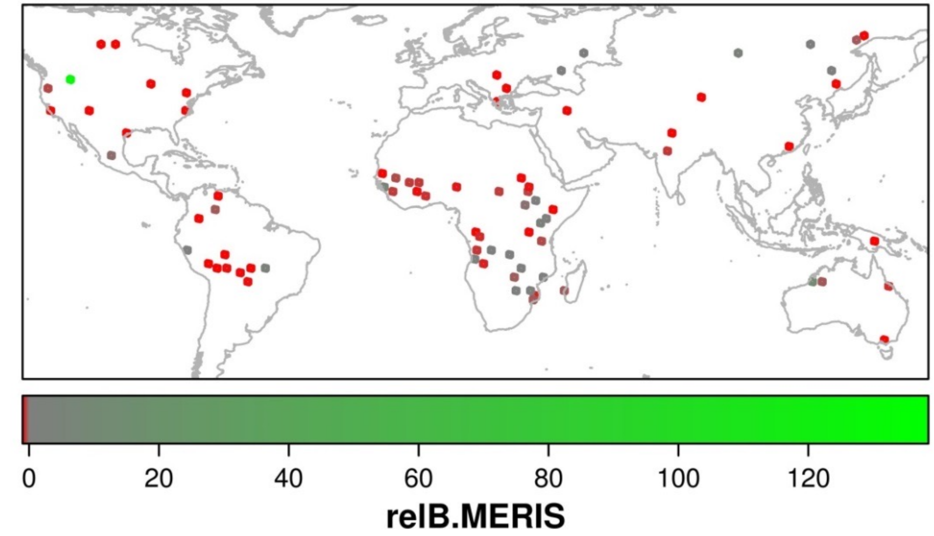
- Again MERIS is significantly better than Geoland, VGT and ATSR products

	BA product	Ce(%)	Oe(%)	OA(%)	B(%)	relB(%)
c	Geoland2	73.85 (9.29)ef	91.50 (3.82)	99.60 (0.07)ef	-0.23 (0.07)	-67.50 (9.71)
d	MERIS	68.36 (4.17)ef	72.29 (5.46)cef	99.54 (0.09)ef	-0.04 (0.04)abc	-12.43 (12.79)
e	VGT	91.60 (3.19)f	92.21 (2.59)	99.35 (0.11)	-0.03 (0.11)ac	-7.32 (29.73)bc
f	AATSR	96.03 (2.18)	94.26 (2.52)	99.17 (0.2)	0.16 (0.2)	44.62 (60.92)

Note: All fire_cci results are still a draft

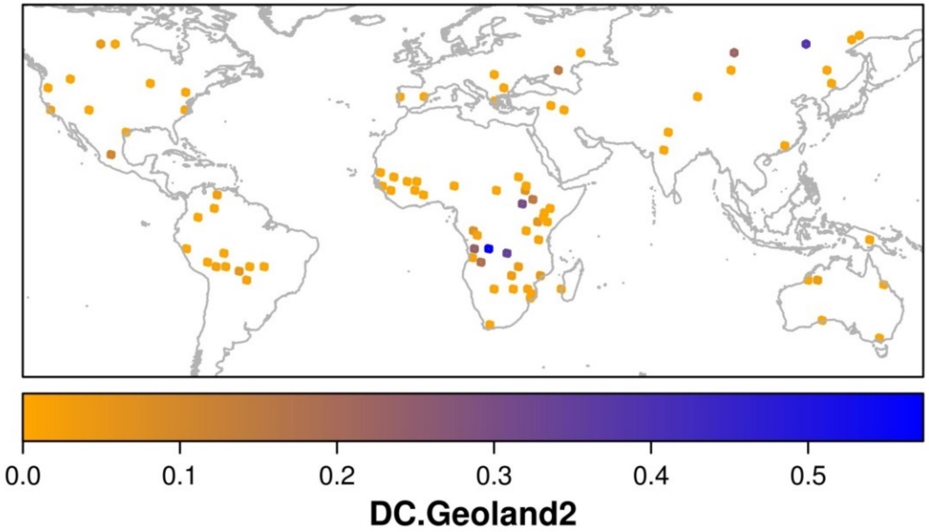
Spatial variation of accuracy

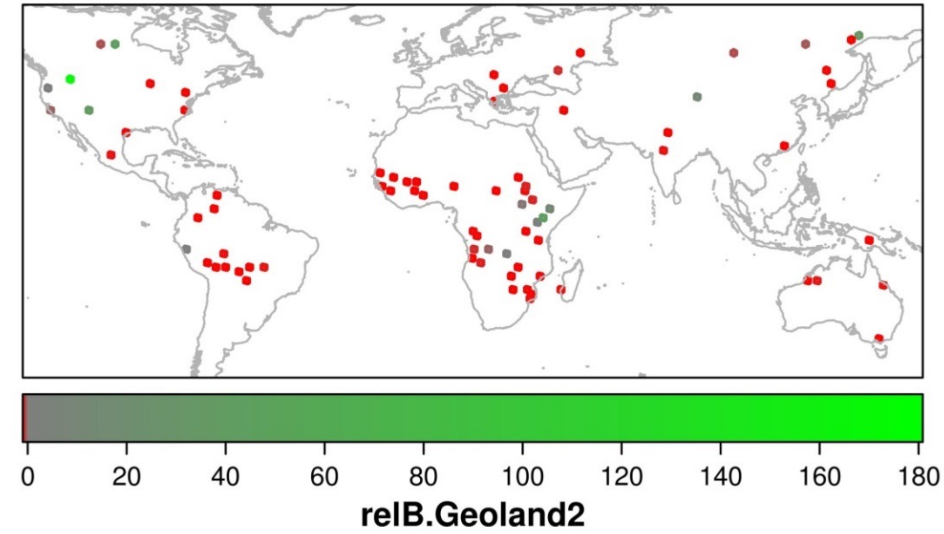




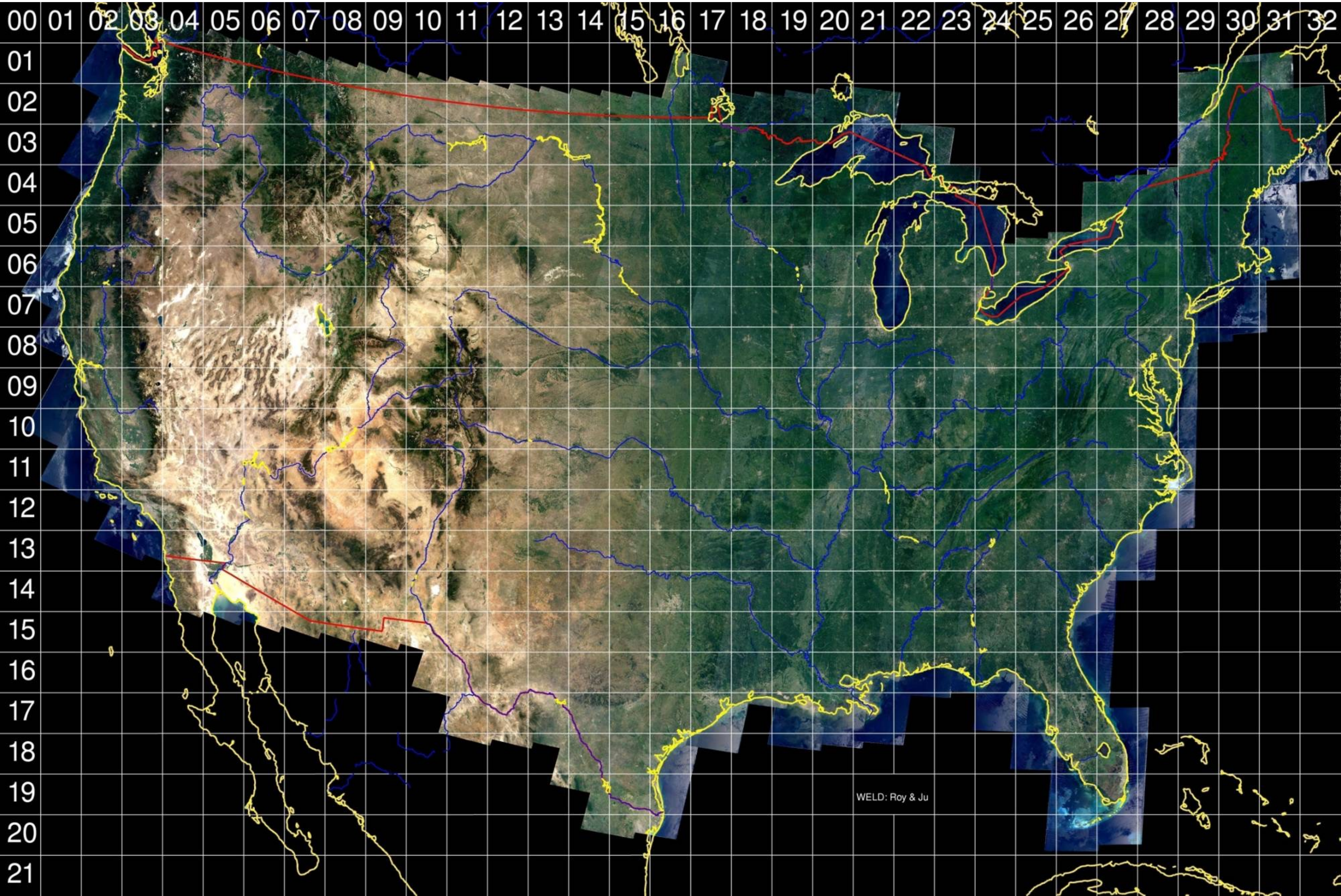
Note: All fire_cci results are still a draft

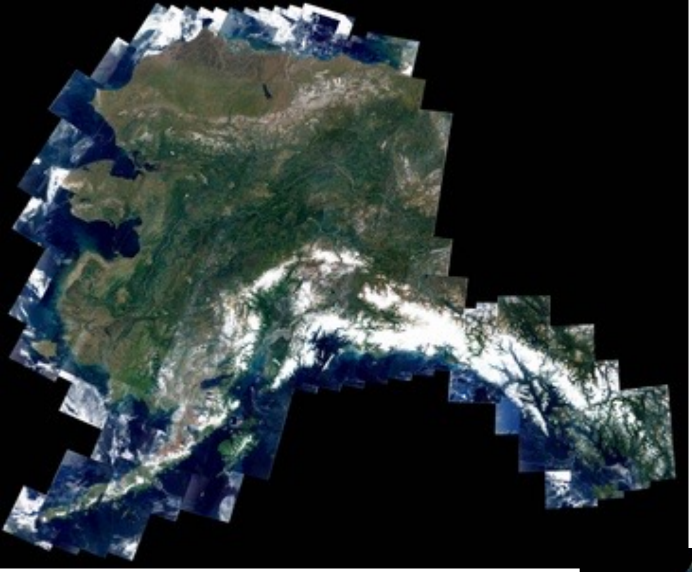
Spatial variation of accuracy





WELD Tile Map (CONUS has 501 5000x5000 30m pixel tiles in Albers)



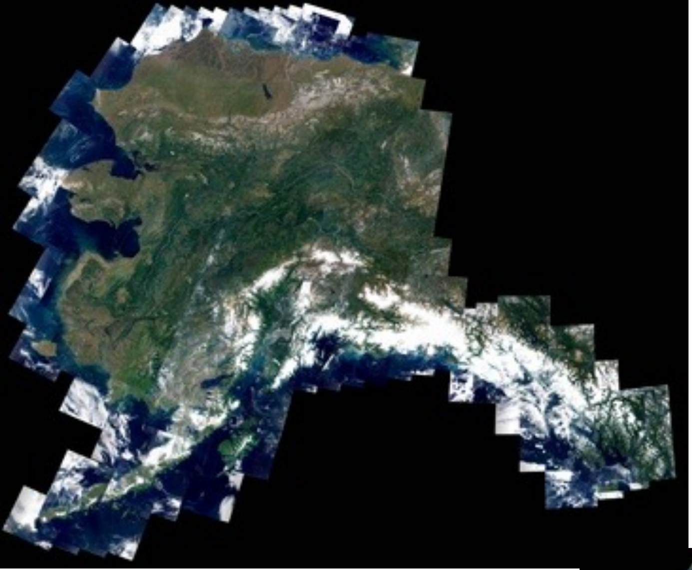


Annual

(December 2009 – November 2008)

Alaska ~ 1,700 L1T acquisitions / year

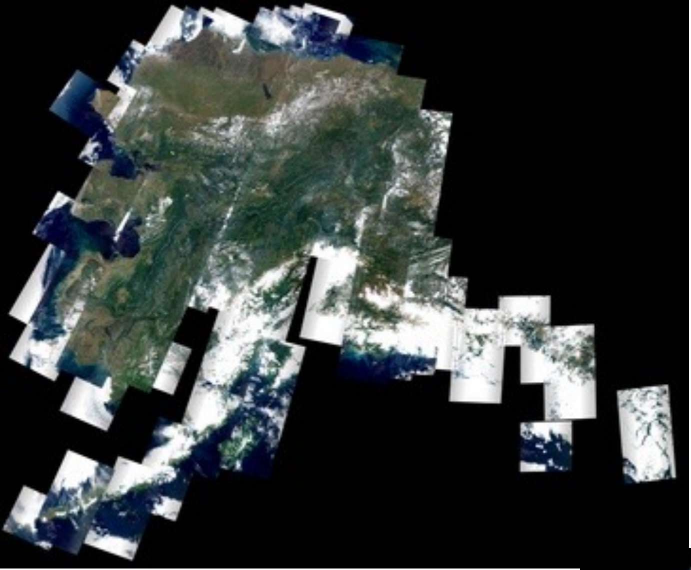
CONUS ~ 8,000 L1T acquisitions / year

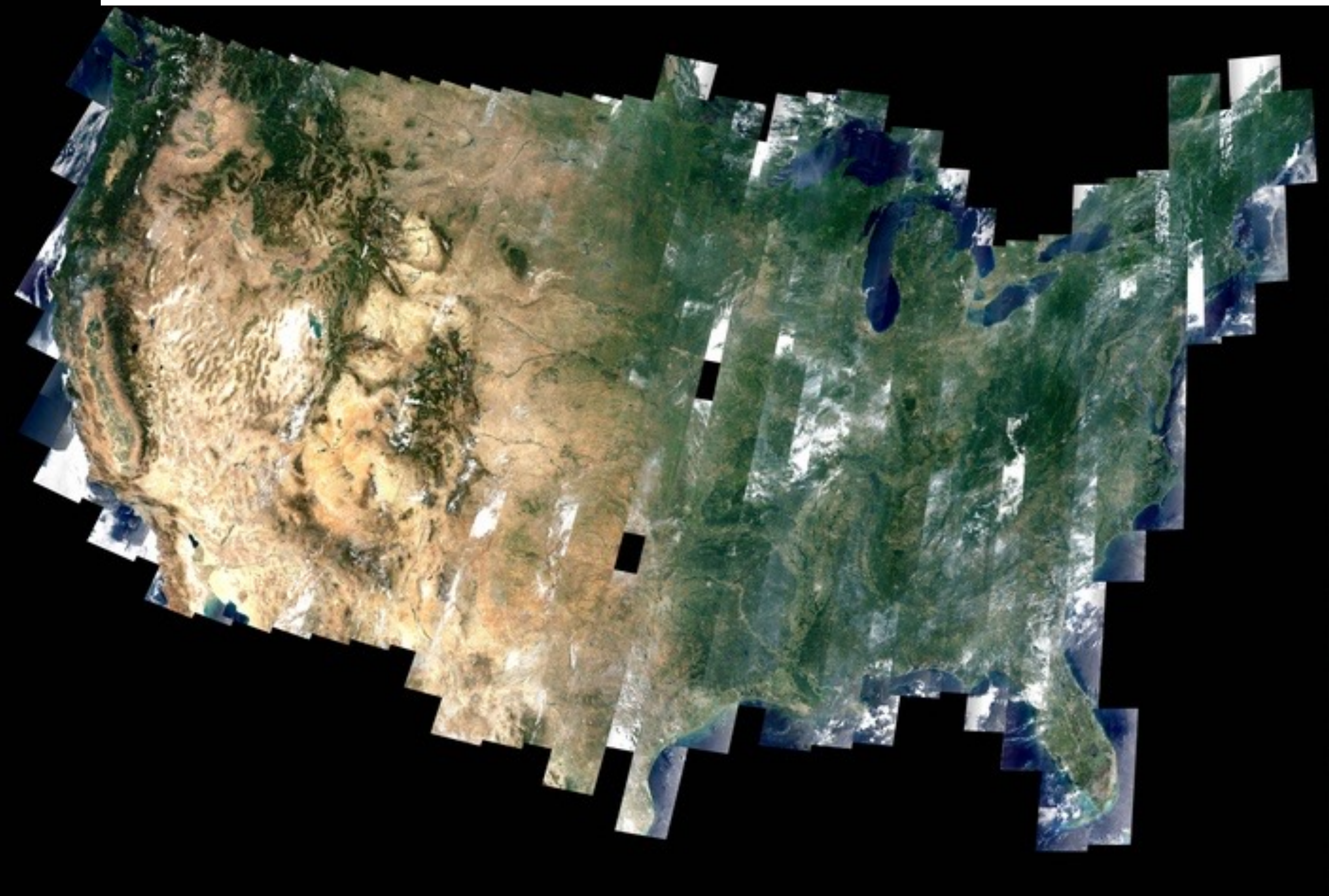


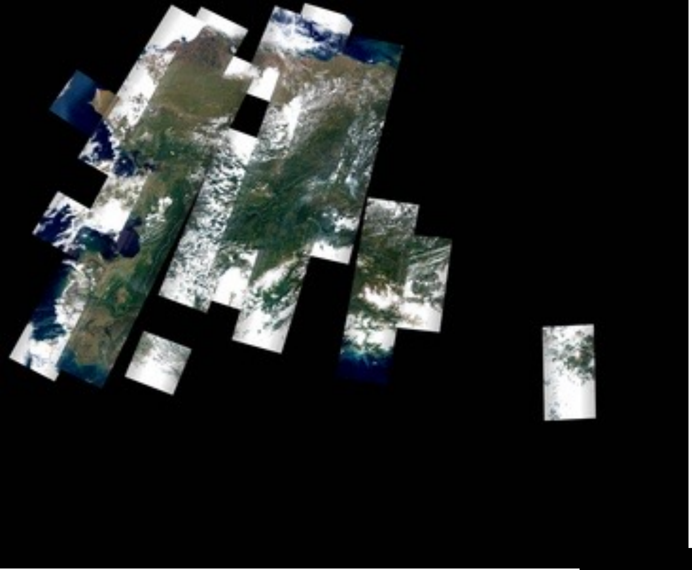
Summer

(June, July, August) 2008

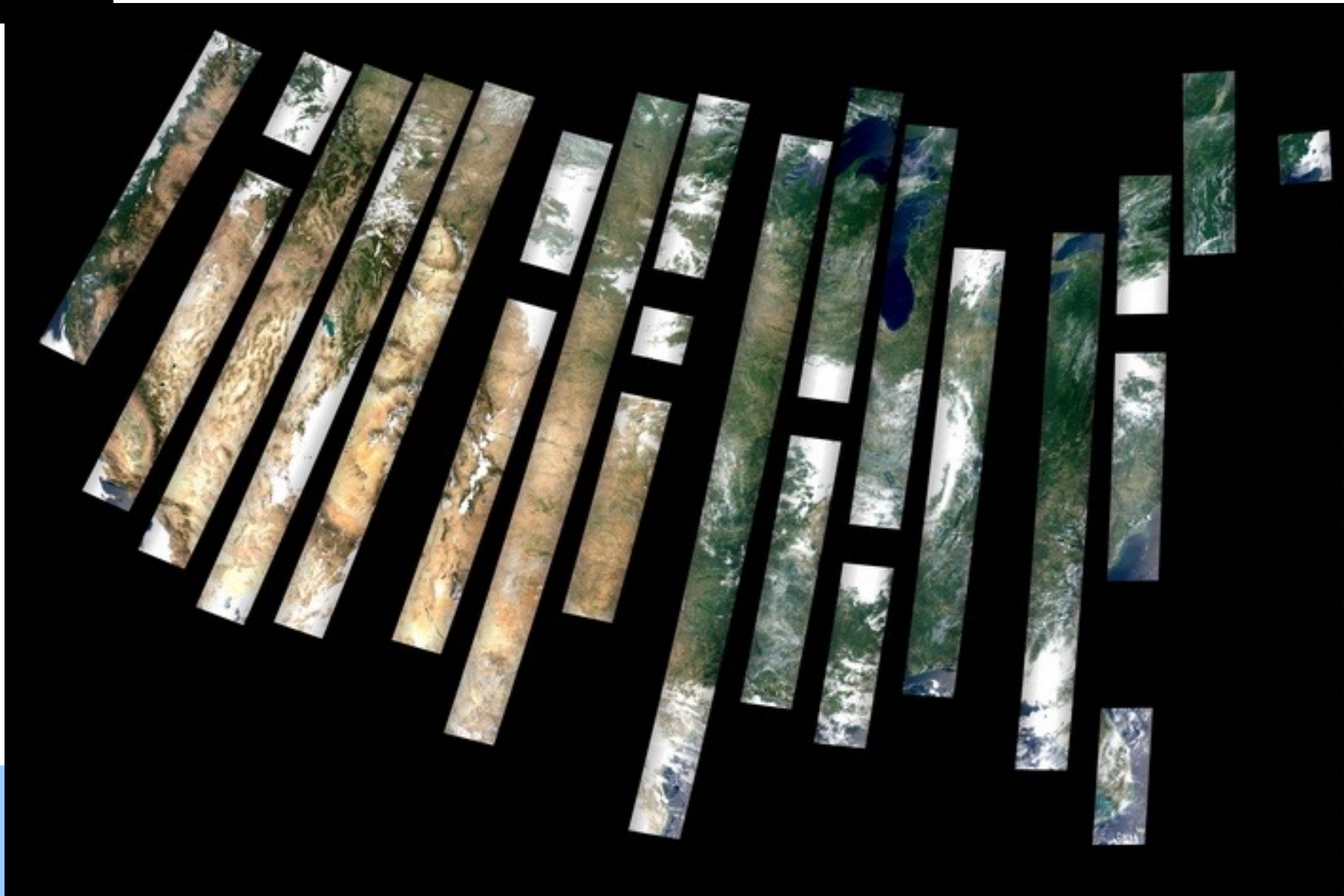
July 2008

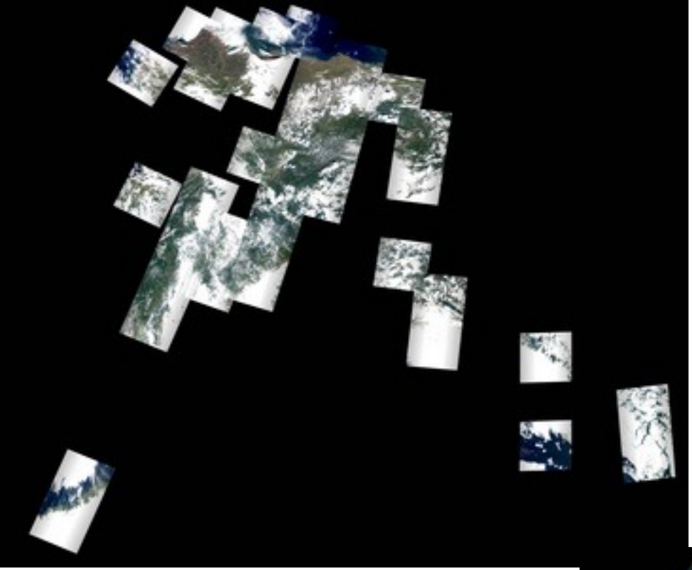




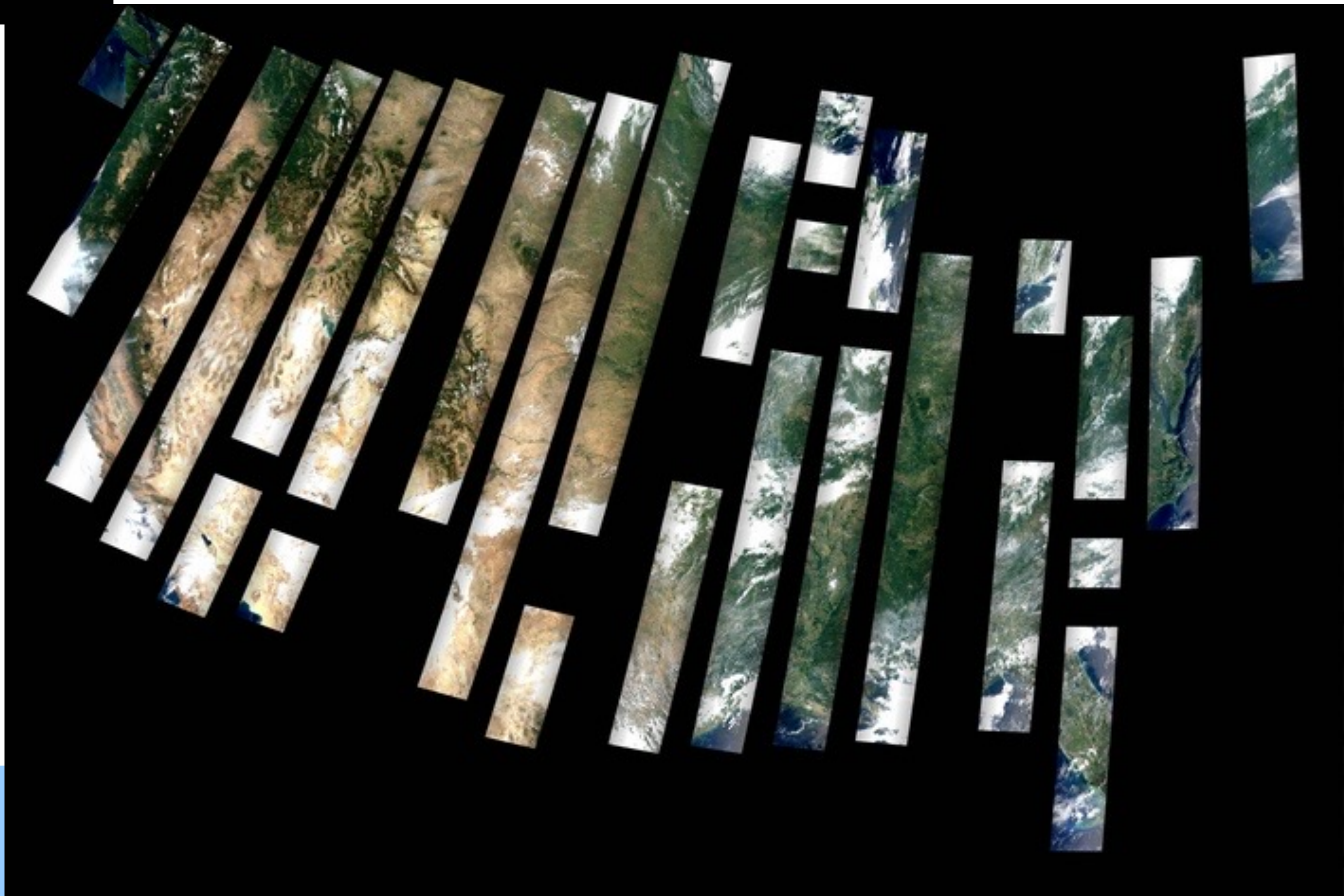


Week 27: July 8 - 14 2008

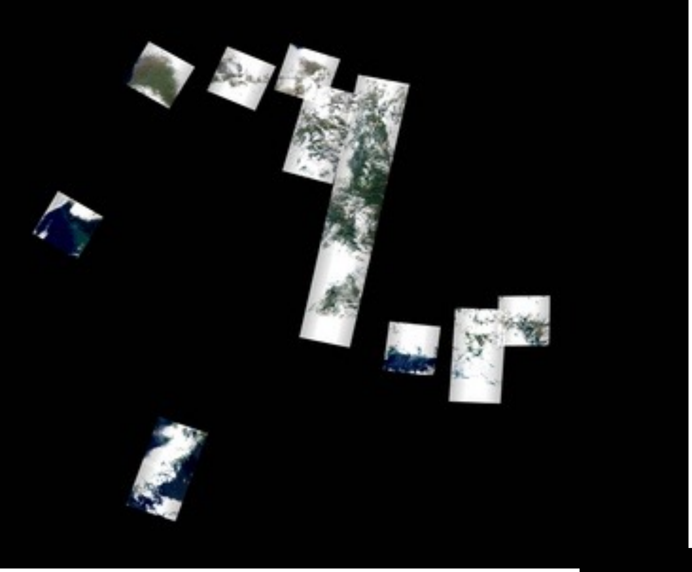


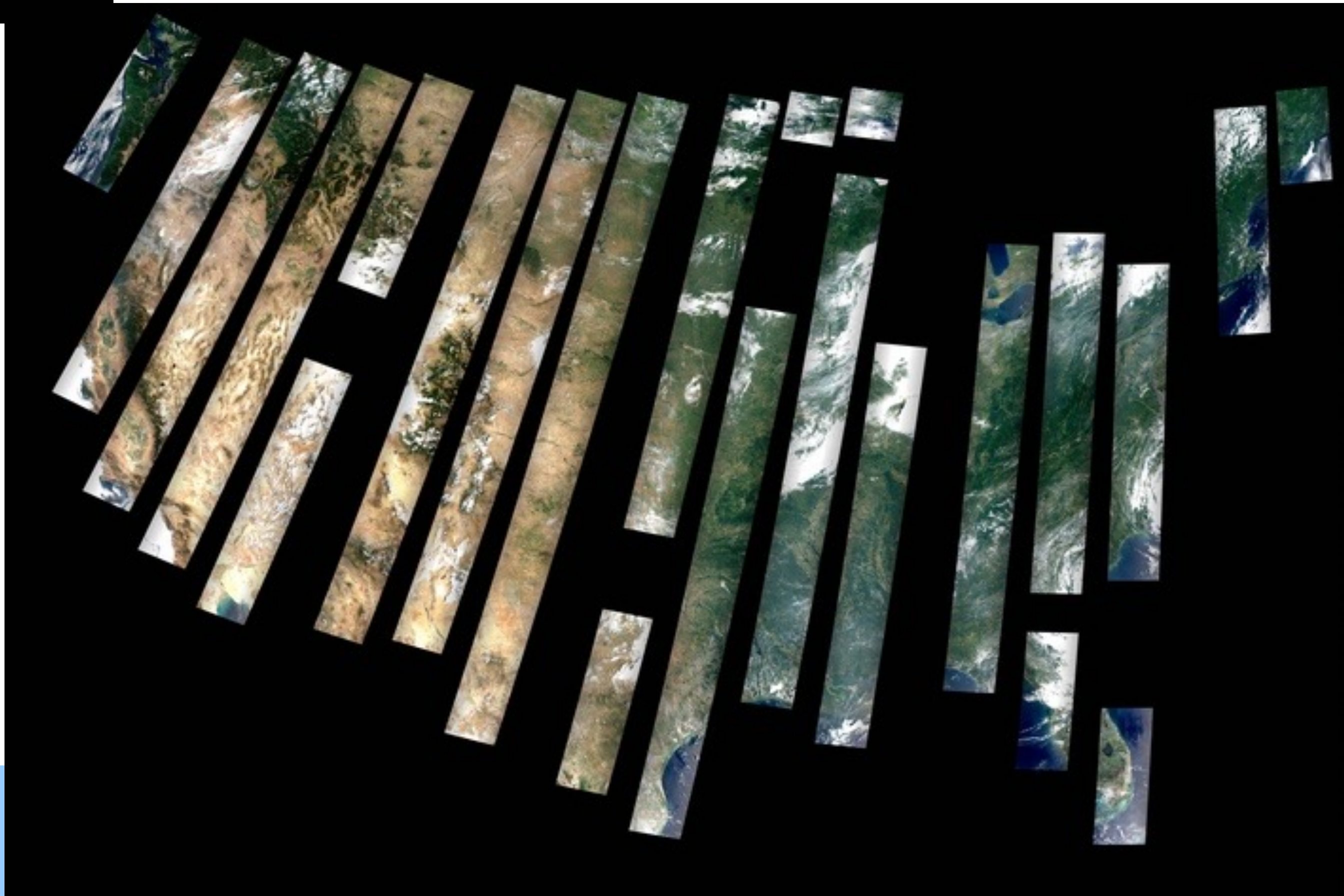


Week 28: July 8 - 14 2008

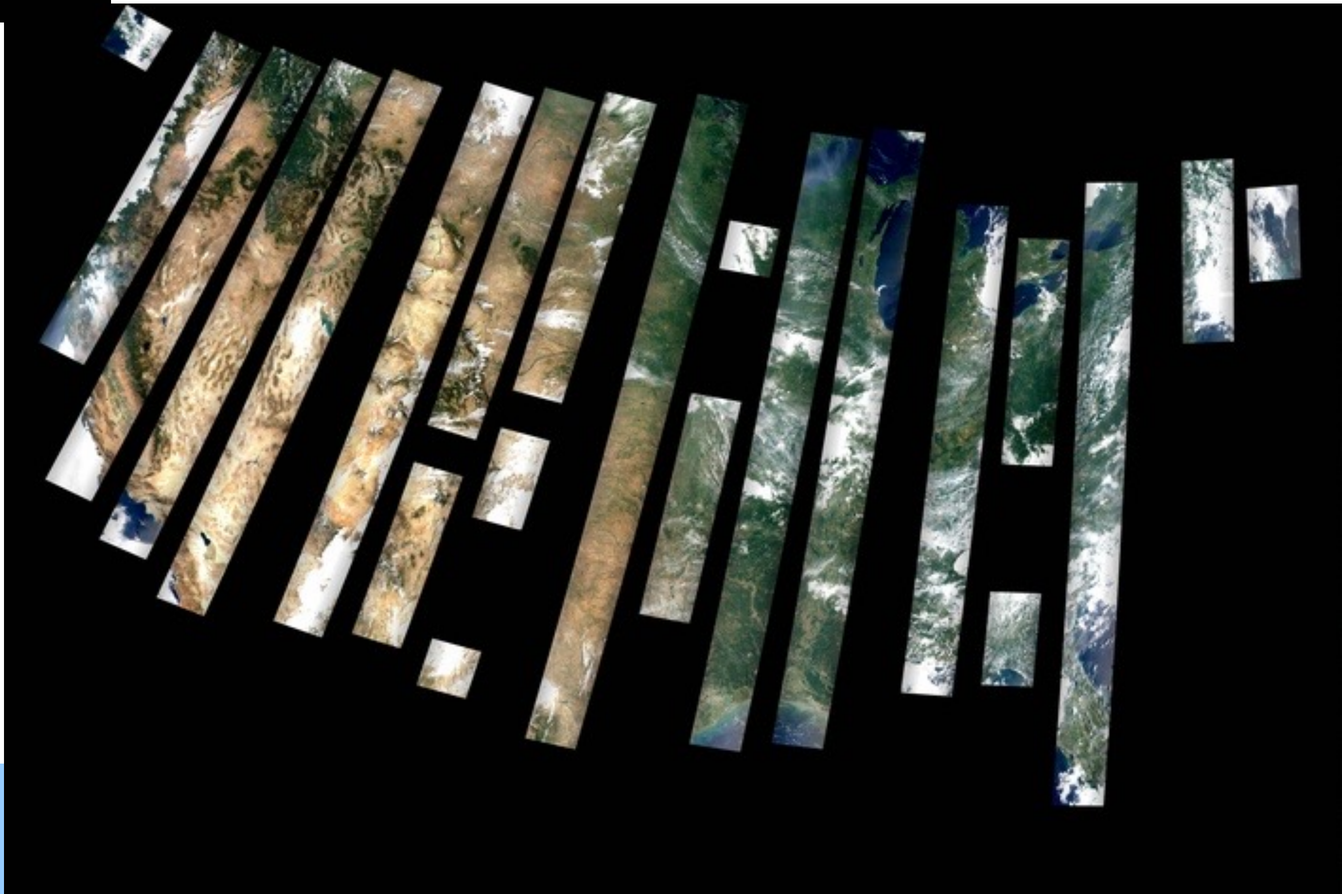


Week 29: July 15 - 21 2008





Week 30: July 22 – 28 2008



The methodology

FIRST PASS: PIXEL BASED SEMANTIC CHANGE DETECTION

•The weekly WELD products are classified using the SIAM™ automatic classifier into 96 spectral categories (Baraldi et al. 2010). SIAM™ is a physical model-based, fully automatic (no training) decision-tree classifier based on prior spectral knowledge of surface types observed from space.

•The 52 SIAM™ classified weekly products per WELD tile enables the adoption of a change detection strategy based on semantics applied to the SIAM™ spectral categories: a set of explicit rules applied to the spectral category time series, detecting all the transitions between categories that are compatible with burning, while avoiding potentially spurious changes, is developed.

- The changes considered compatible with burning are:

  Vegetation → Soil

  Vegetation with high LAI → Vegetation with low LAI

  Vegetation → Charcoal

  Light Soil → Dark Soil

SECOND PASS: SEGMENT BASED DATA FUSION

The candidate burned areas detected by temporal analysis of the SIAM spectral categories are segmented using an approach based on their proximity in space and time, and integrated with the MODIS active fire product.

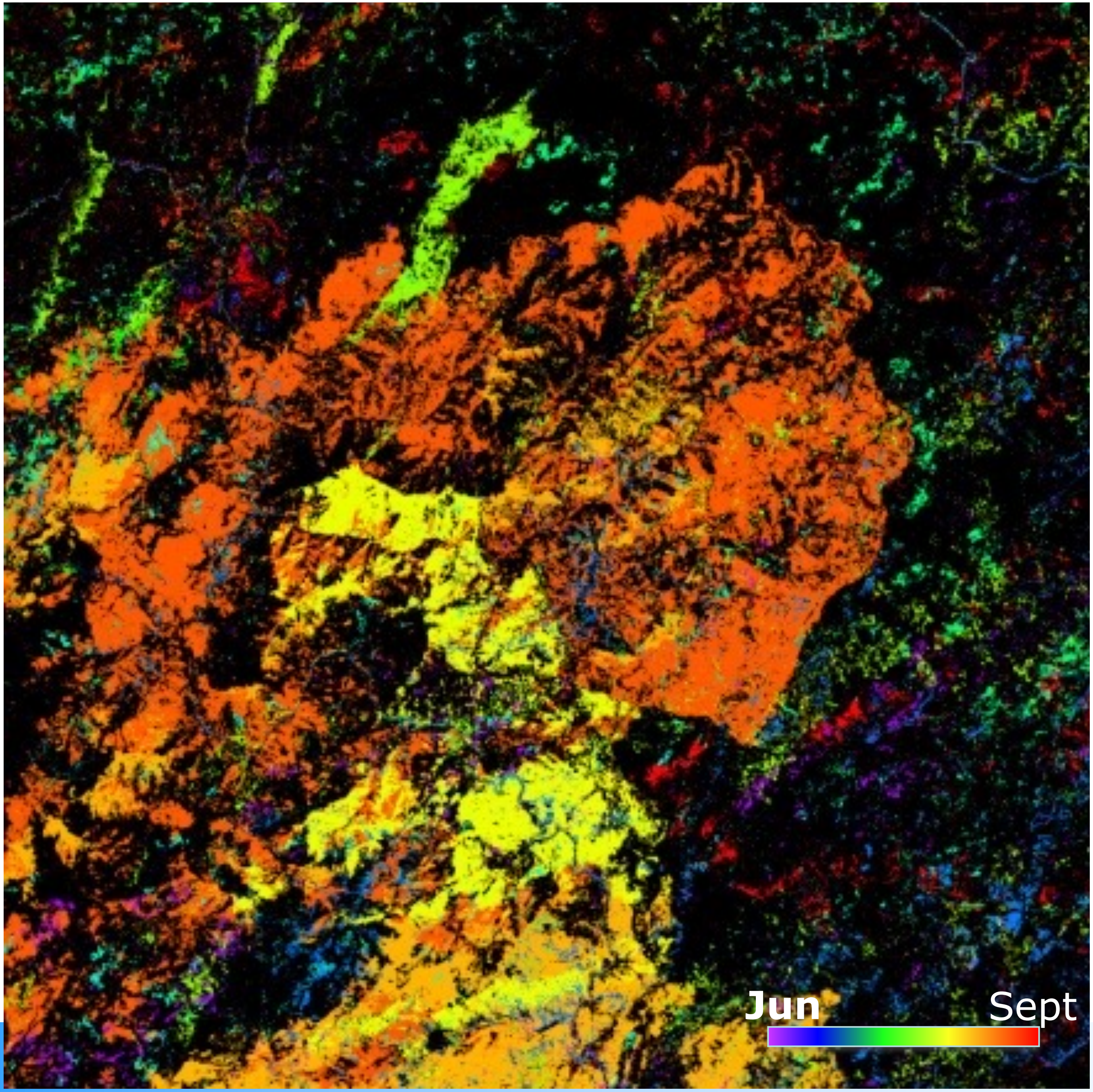
A burned area segment is confidently detected if:

a) it contains a MODIS active fire detection in the same temporal interval of the spectral changes

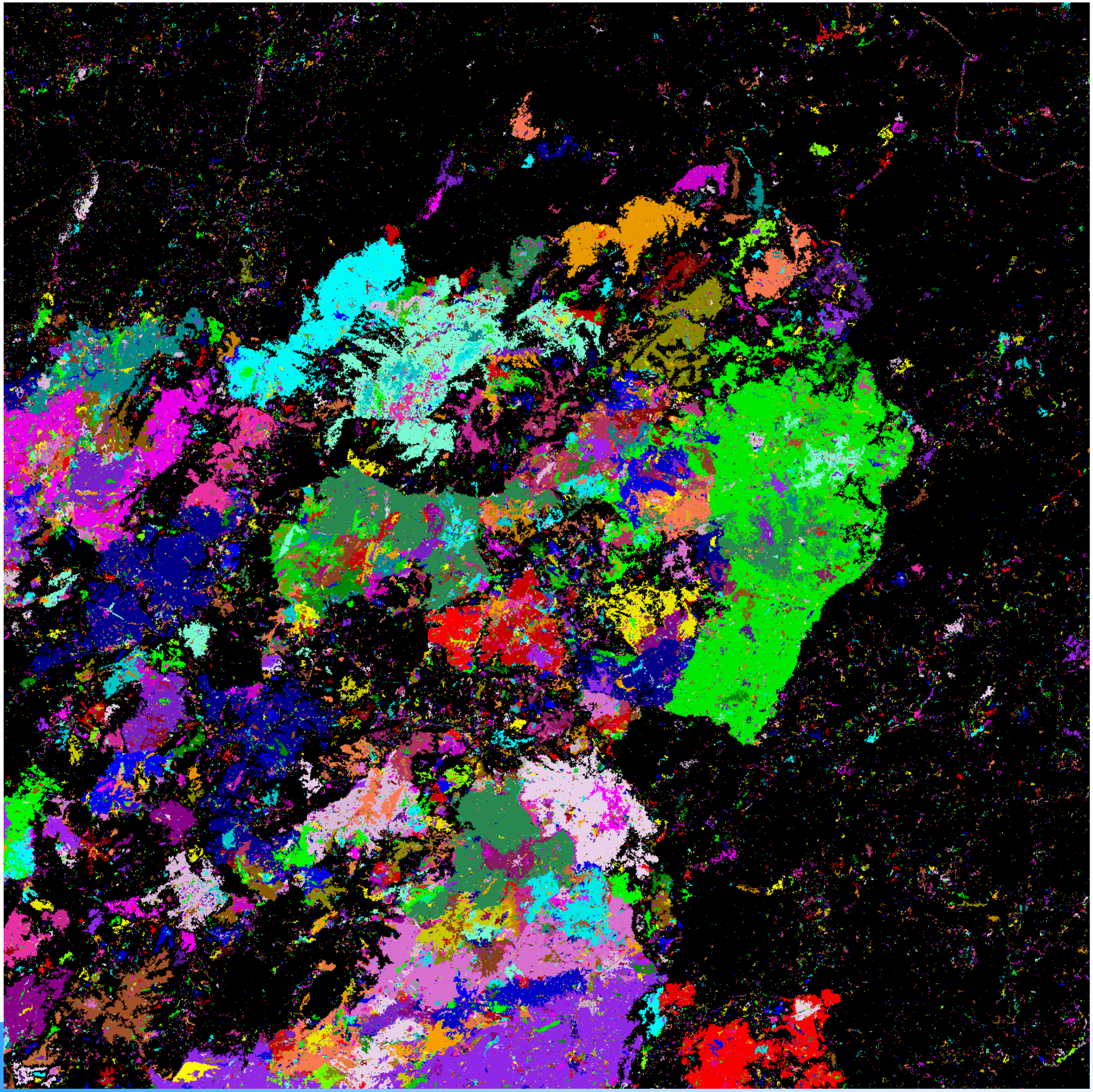
OR

b) it is adjacent to a segment already confirmed as confident, and the spectral changes in the two segments are detected in the same temporal interval.

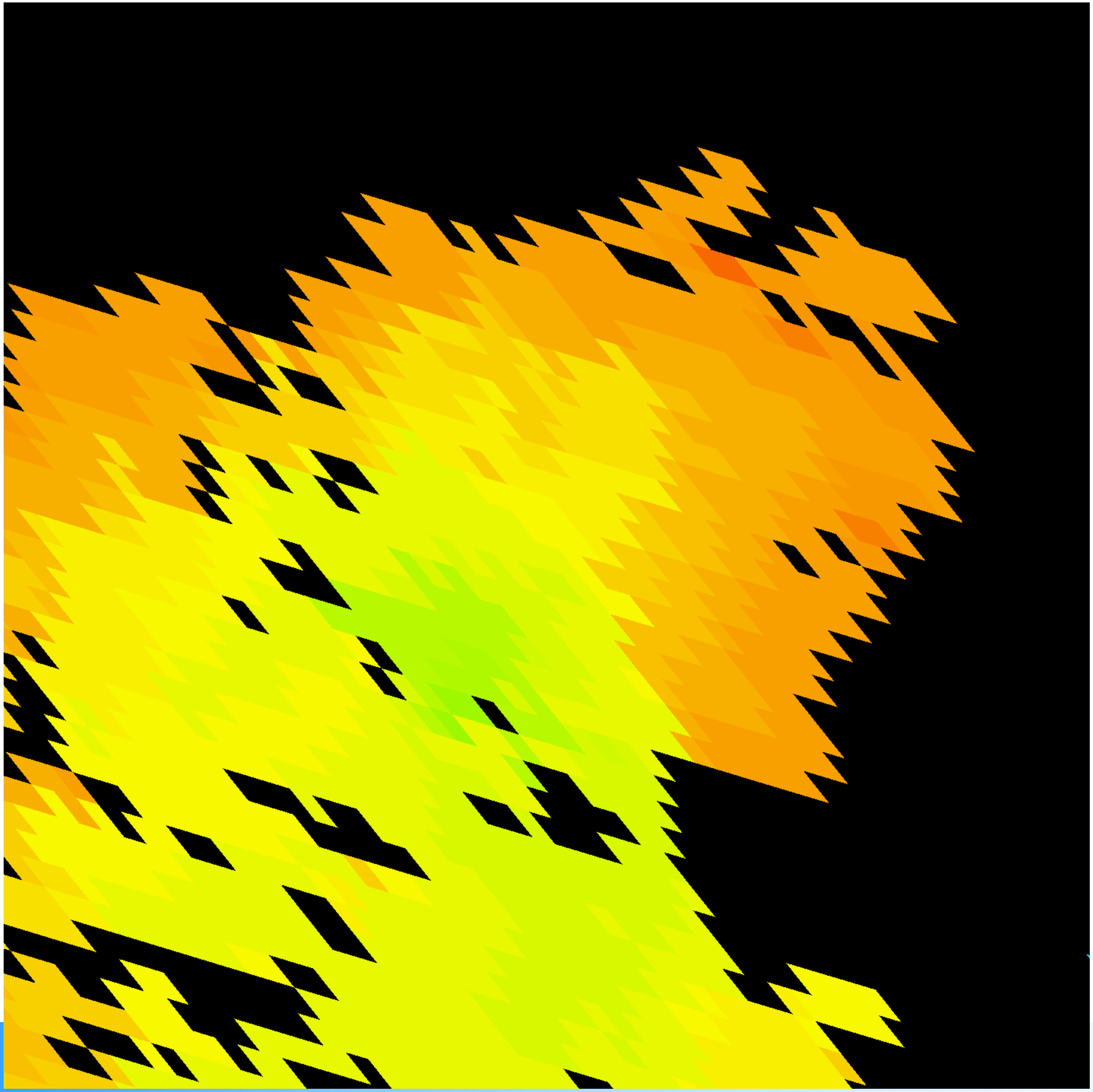
The contextual analysis is iterated until no new segments are identified as confidently burned.



potential burns with day of detection

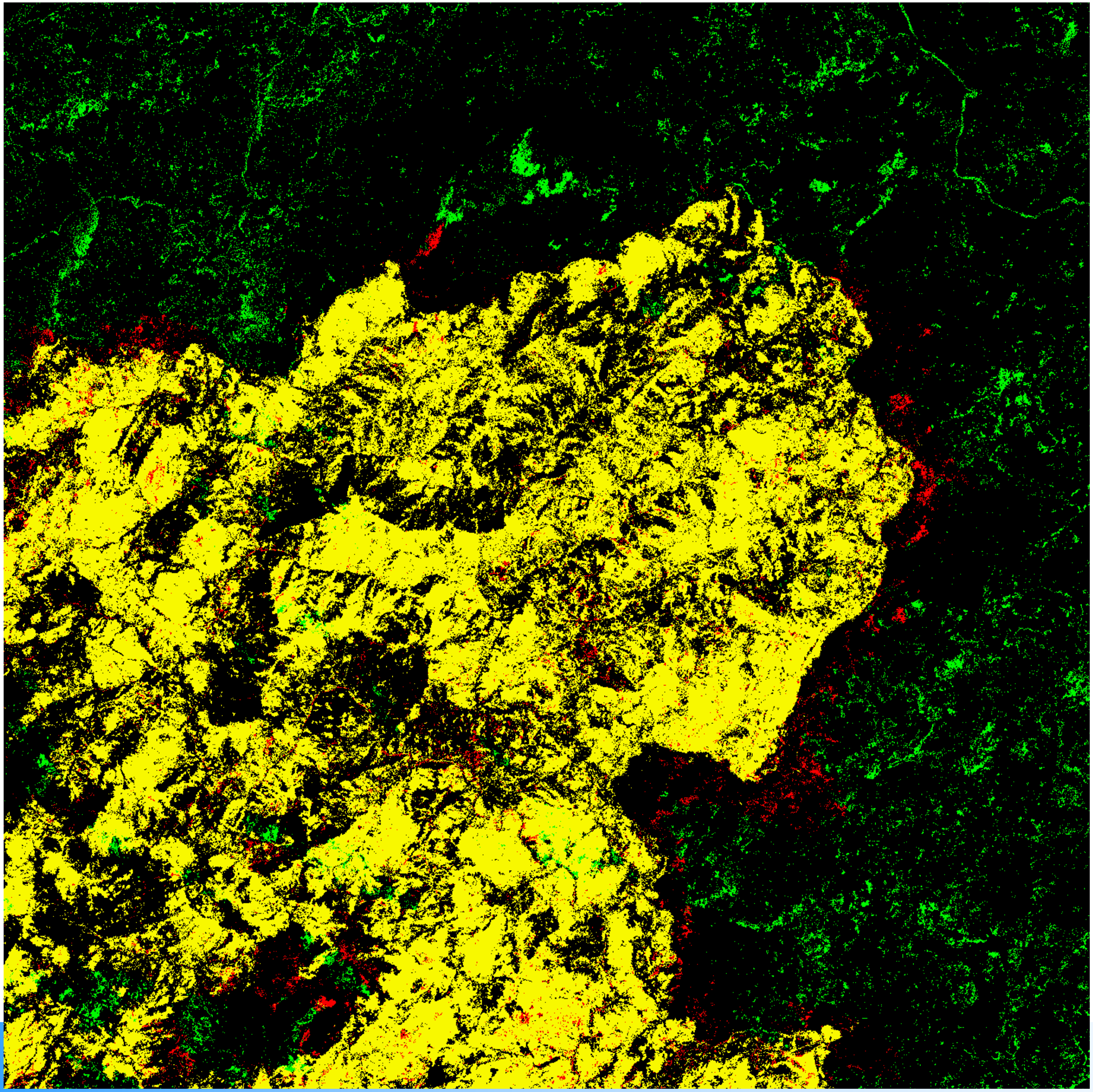


Segmentation

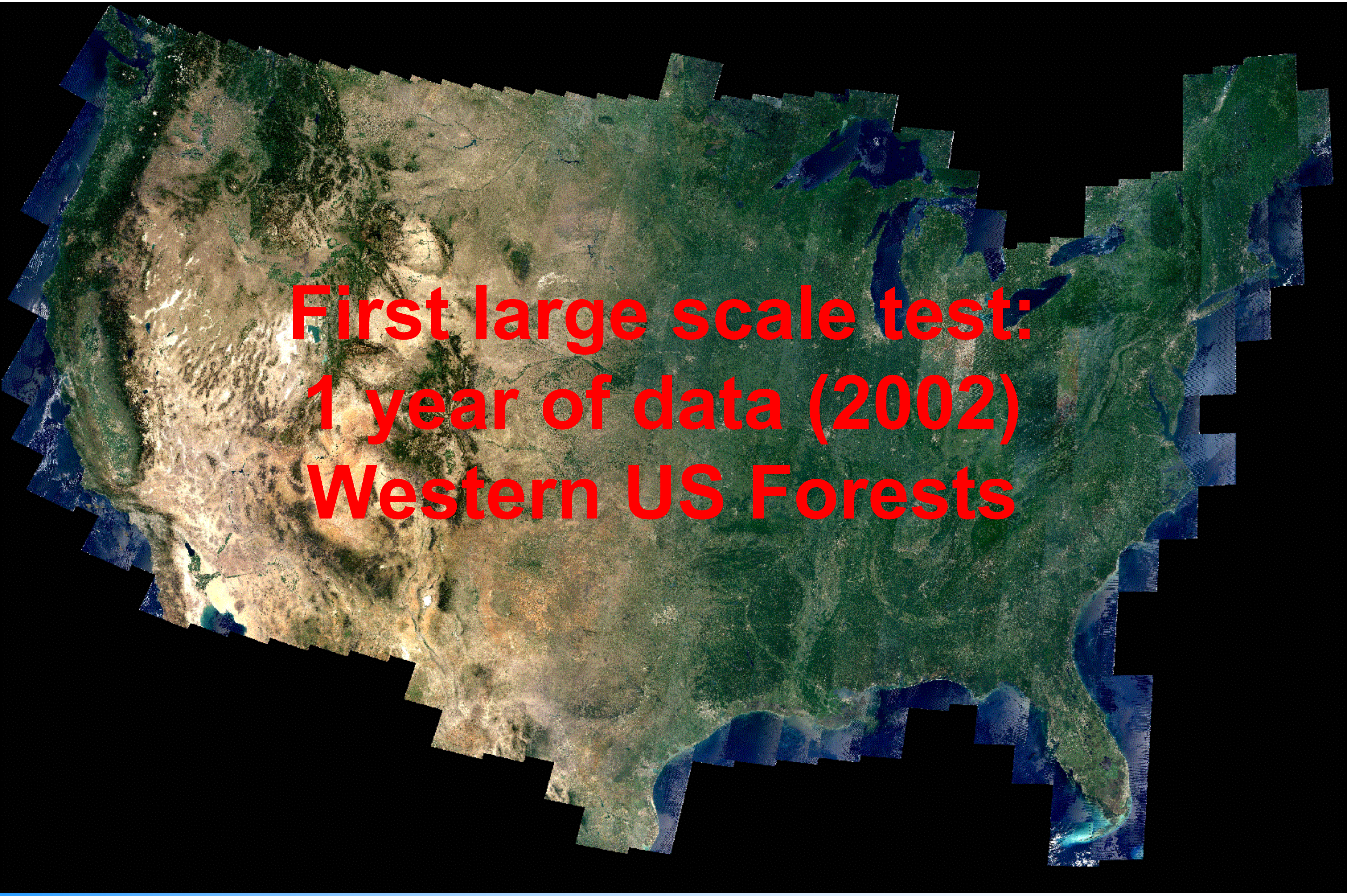


MOD14 Active fires (day of detection)

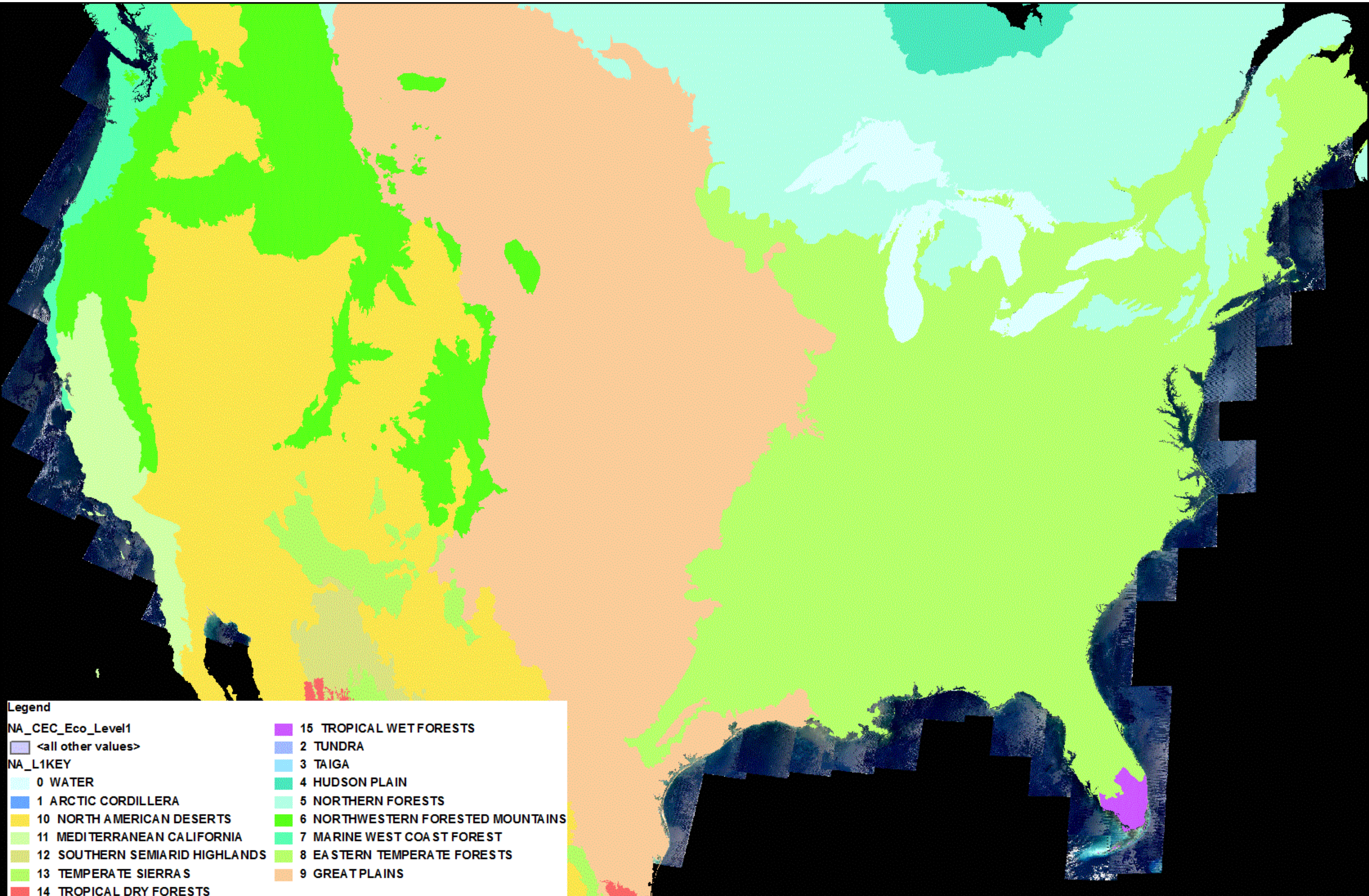
Result of the contextual analysis



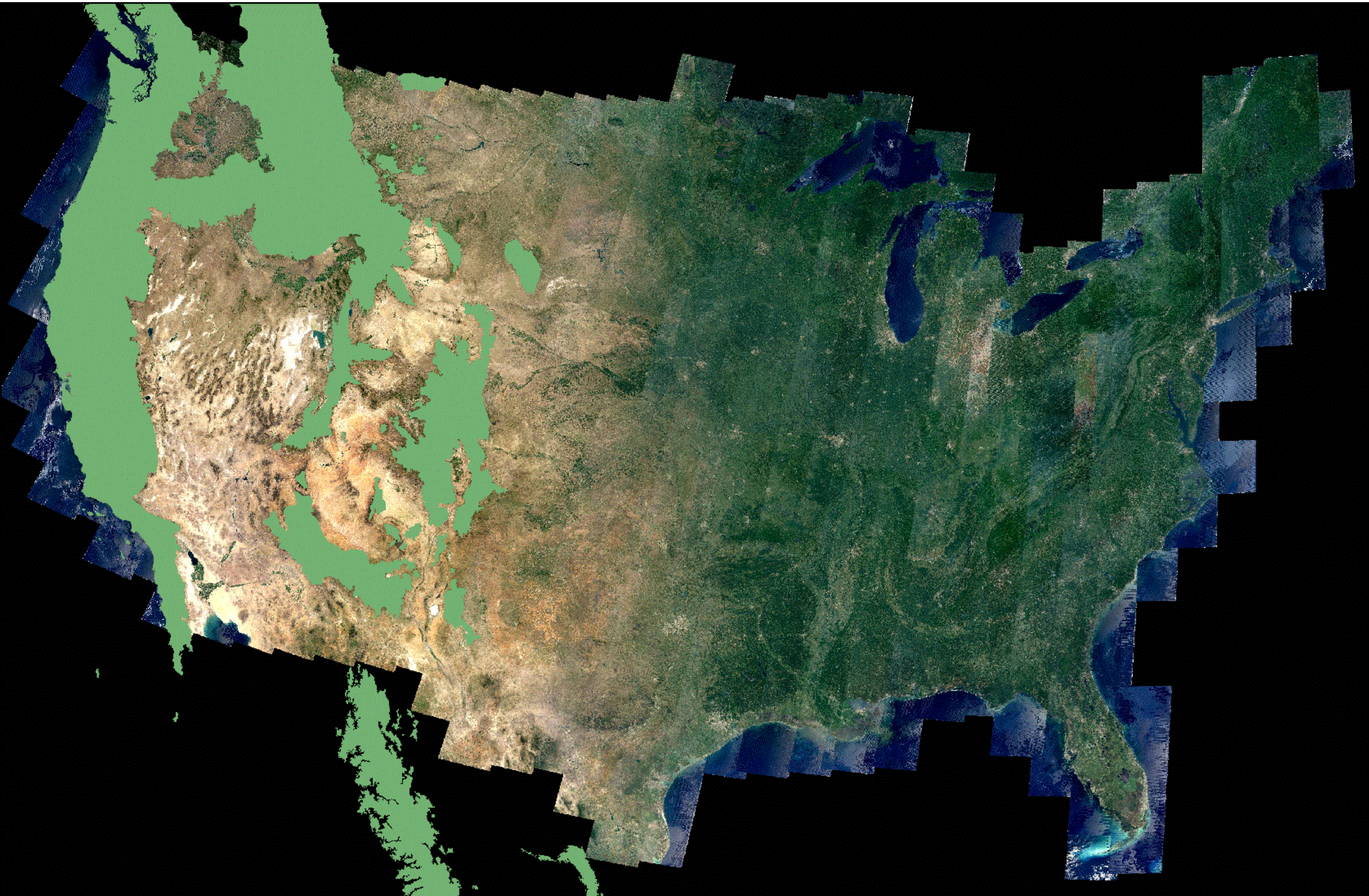
- Burned area
- Not a burn
- Not a burn (active fire in incompatible period)


First large scale test:
1 year of data (2002)
Western US Forests

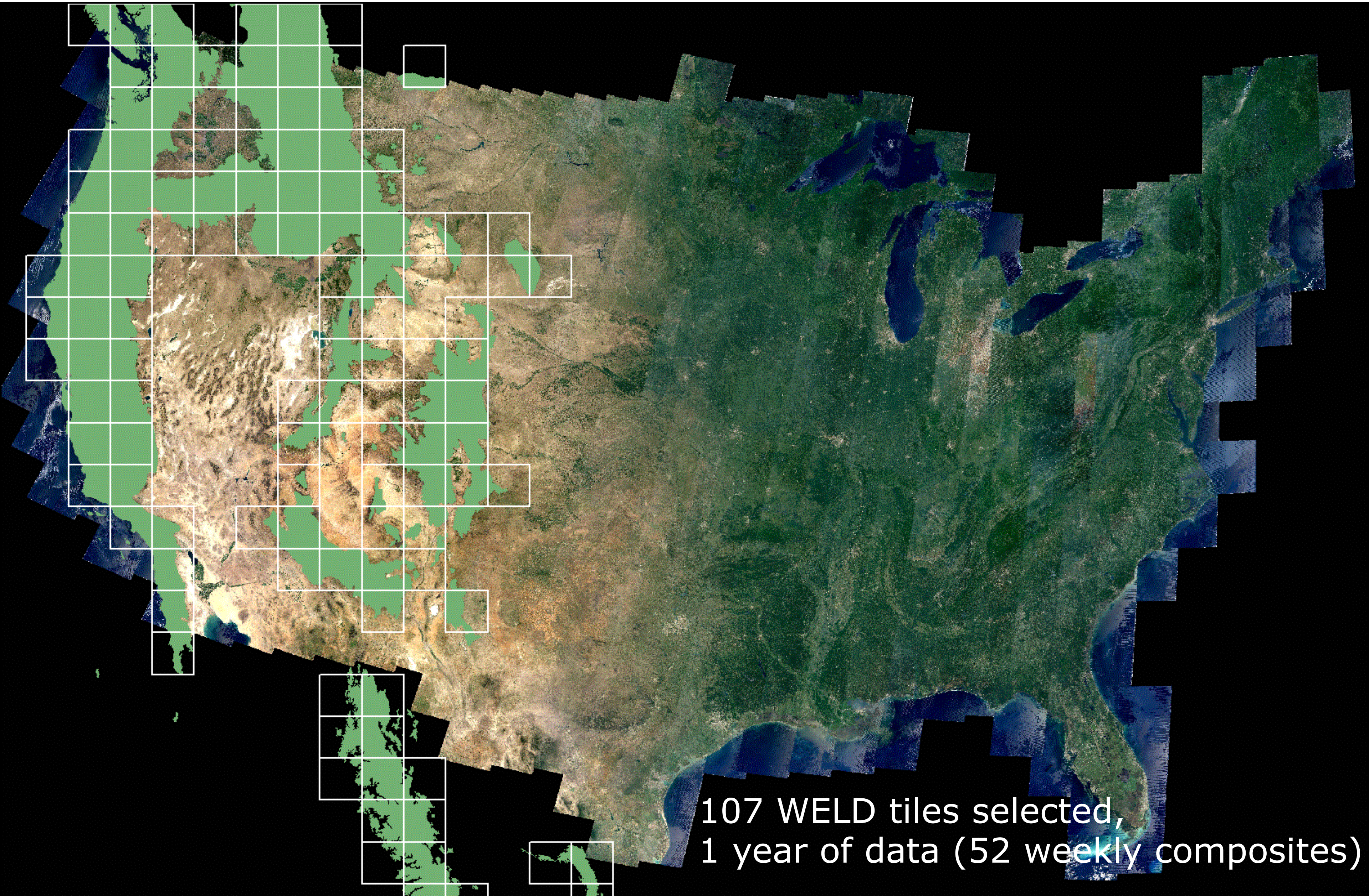
US Ecoregions

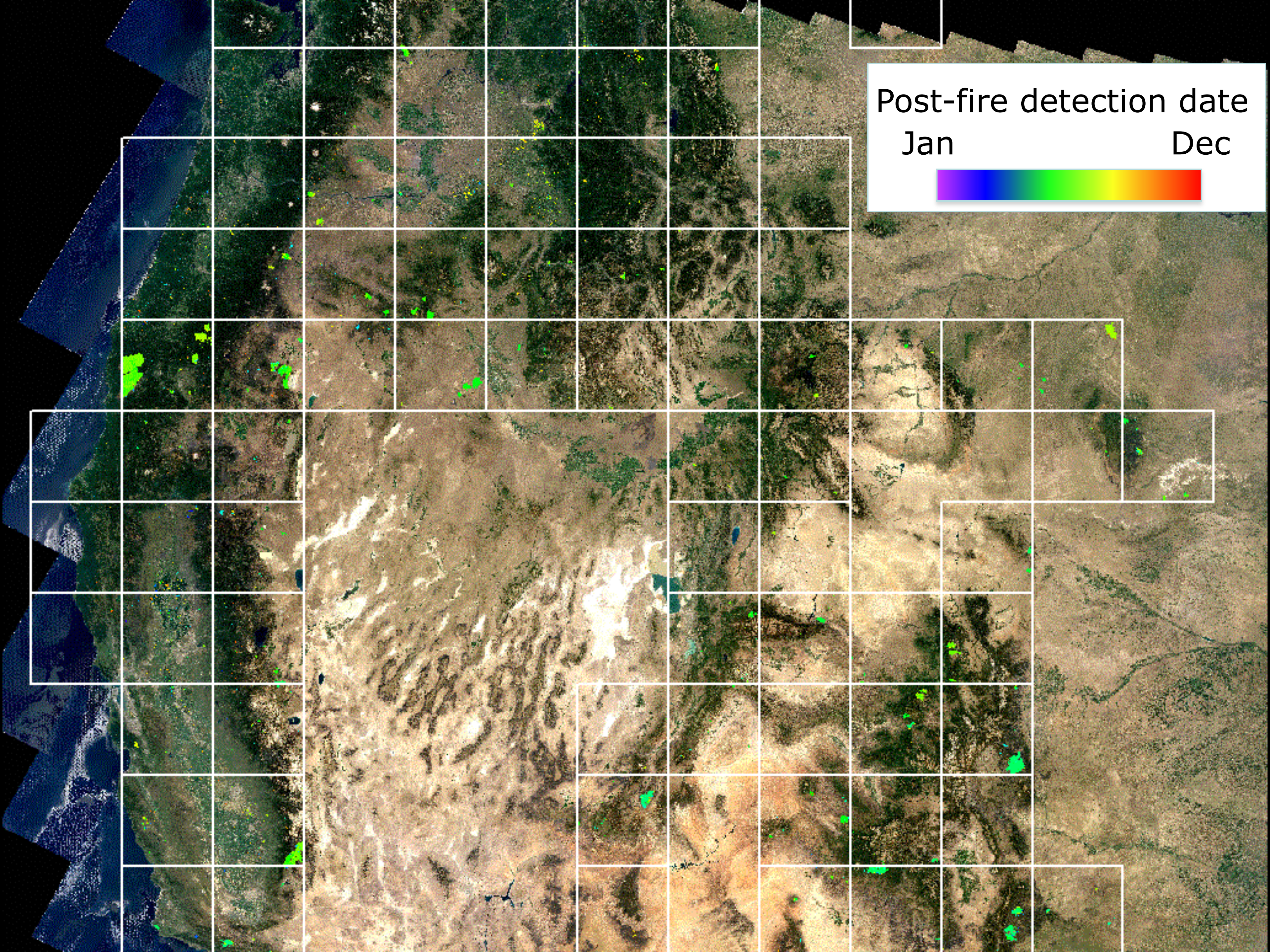


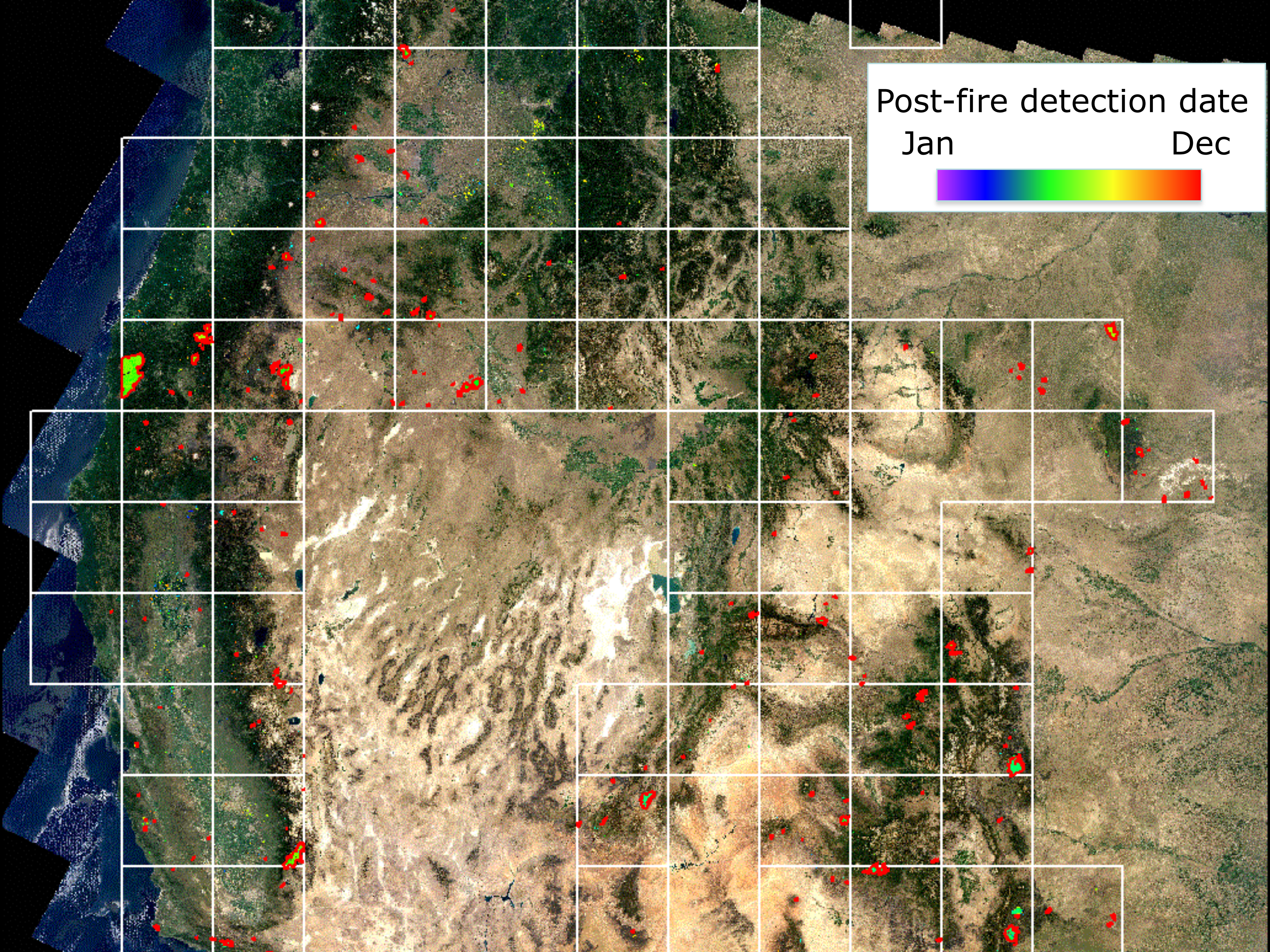
Western US Forests

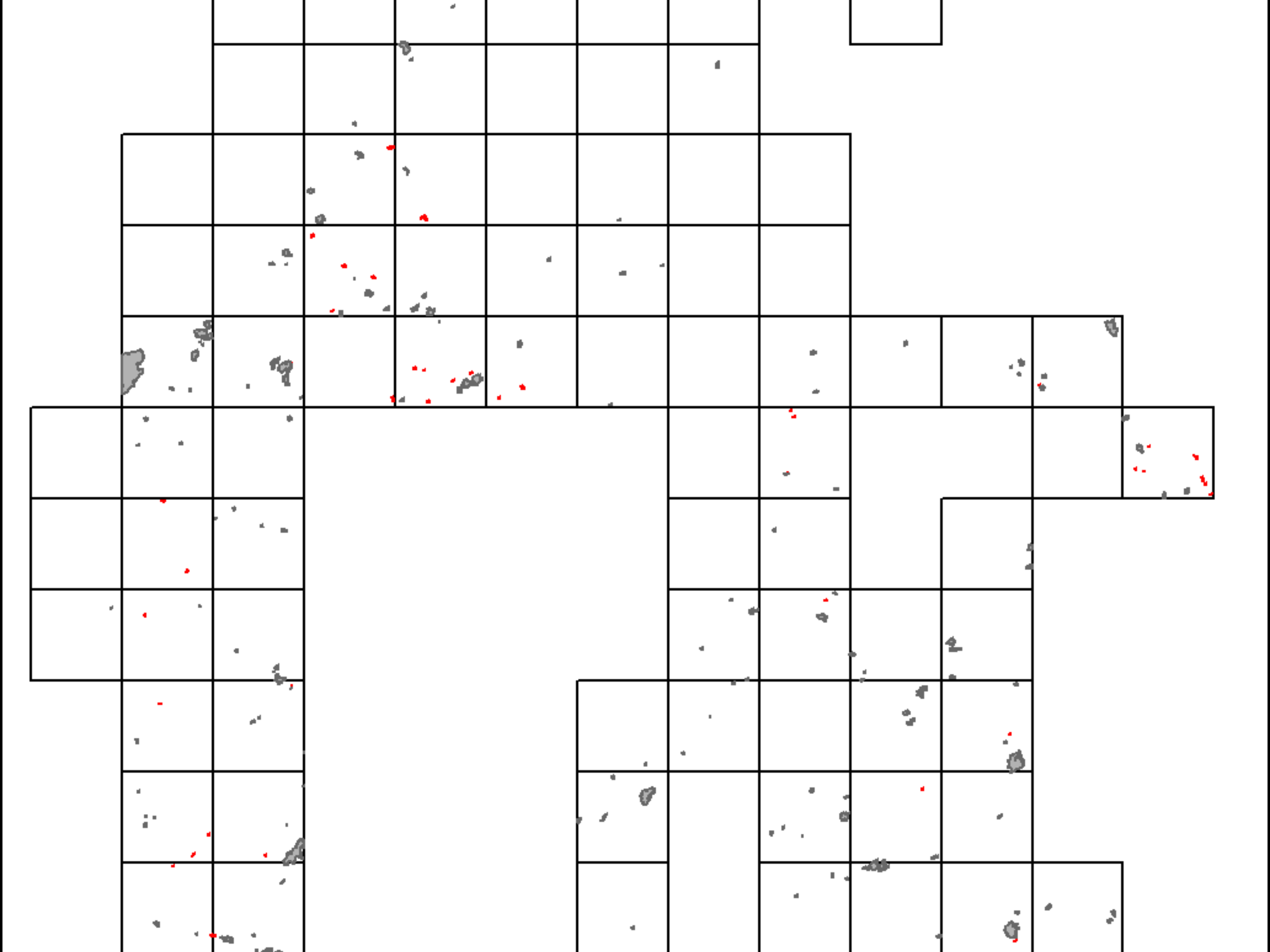


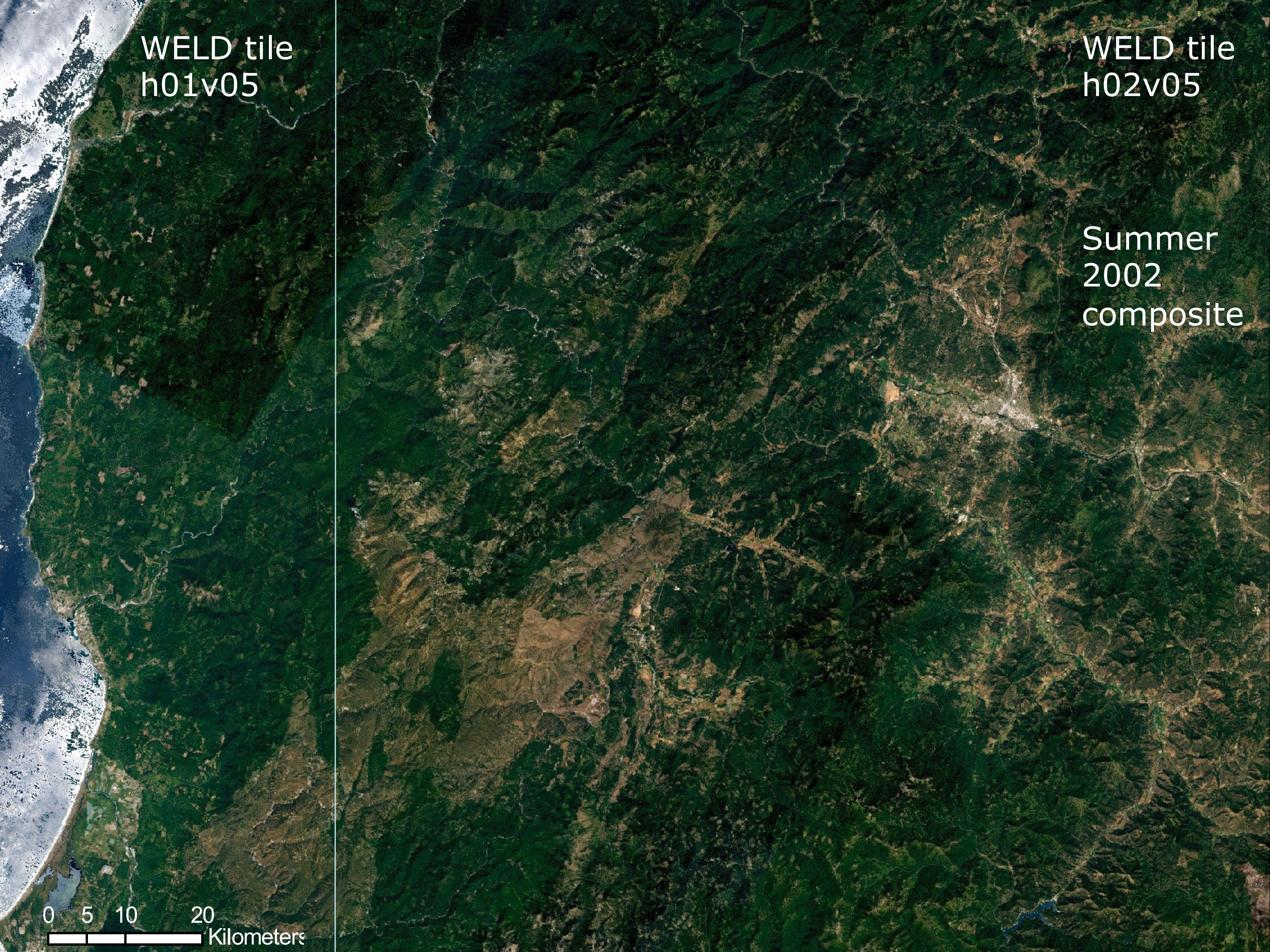
Western US Forests

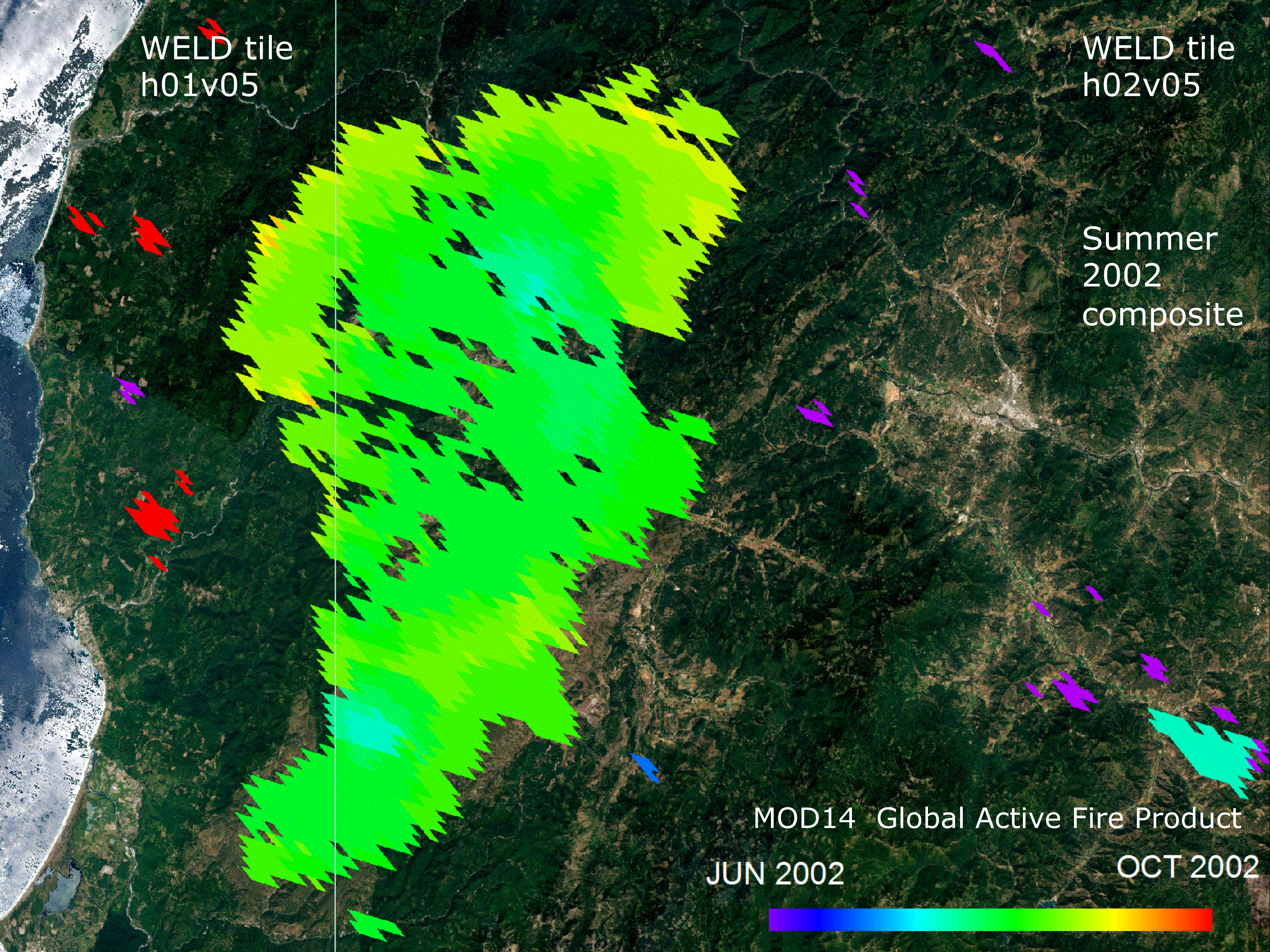


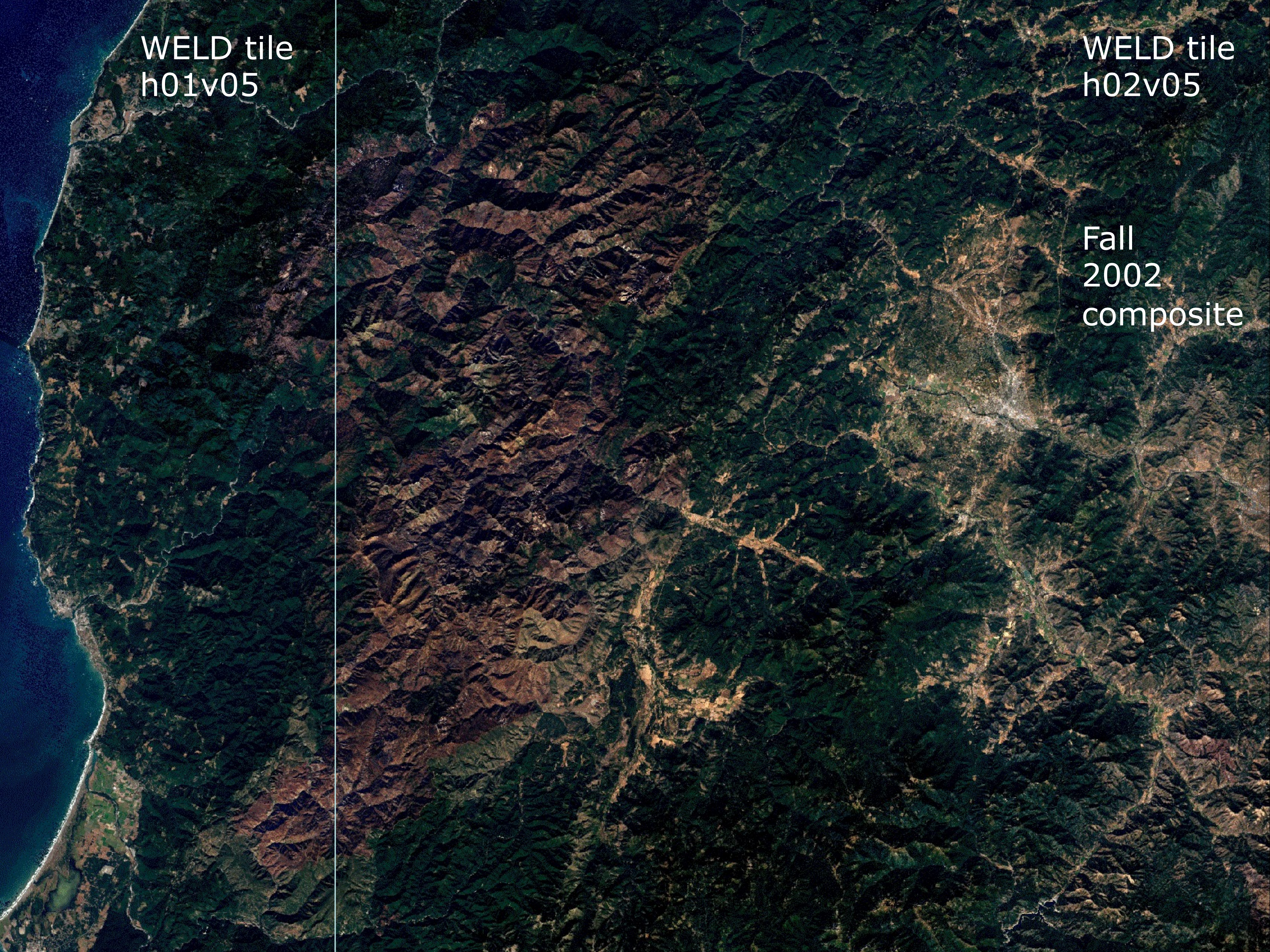

Post-fire detection date
Jan
Dec

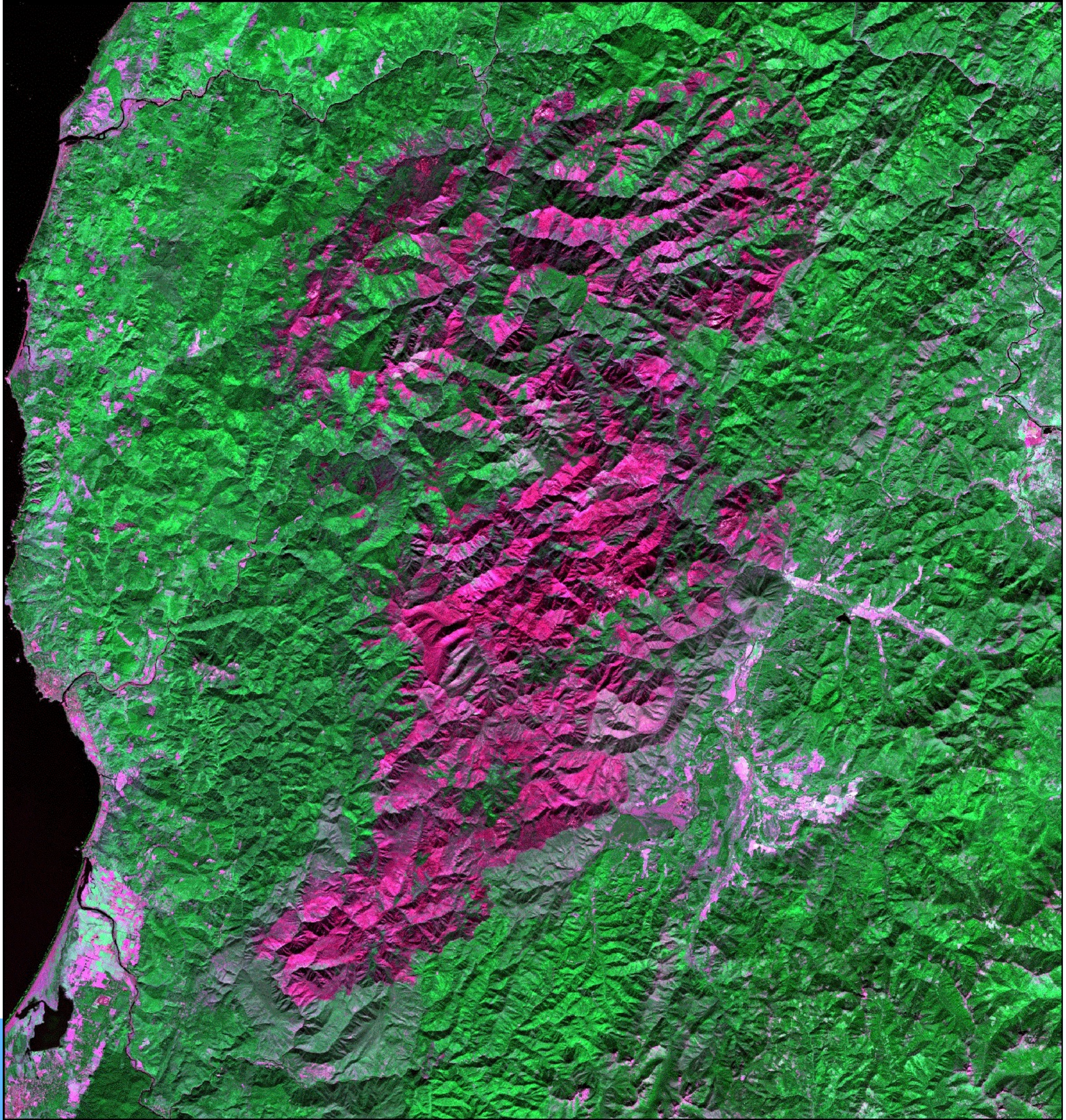

Post-fire detection date
Jan
Dec

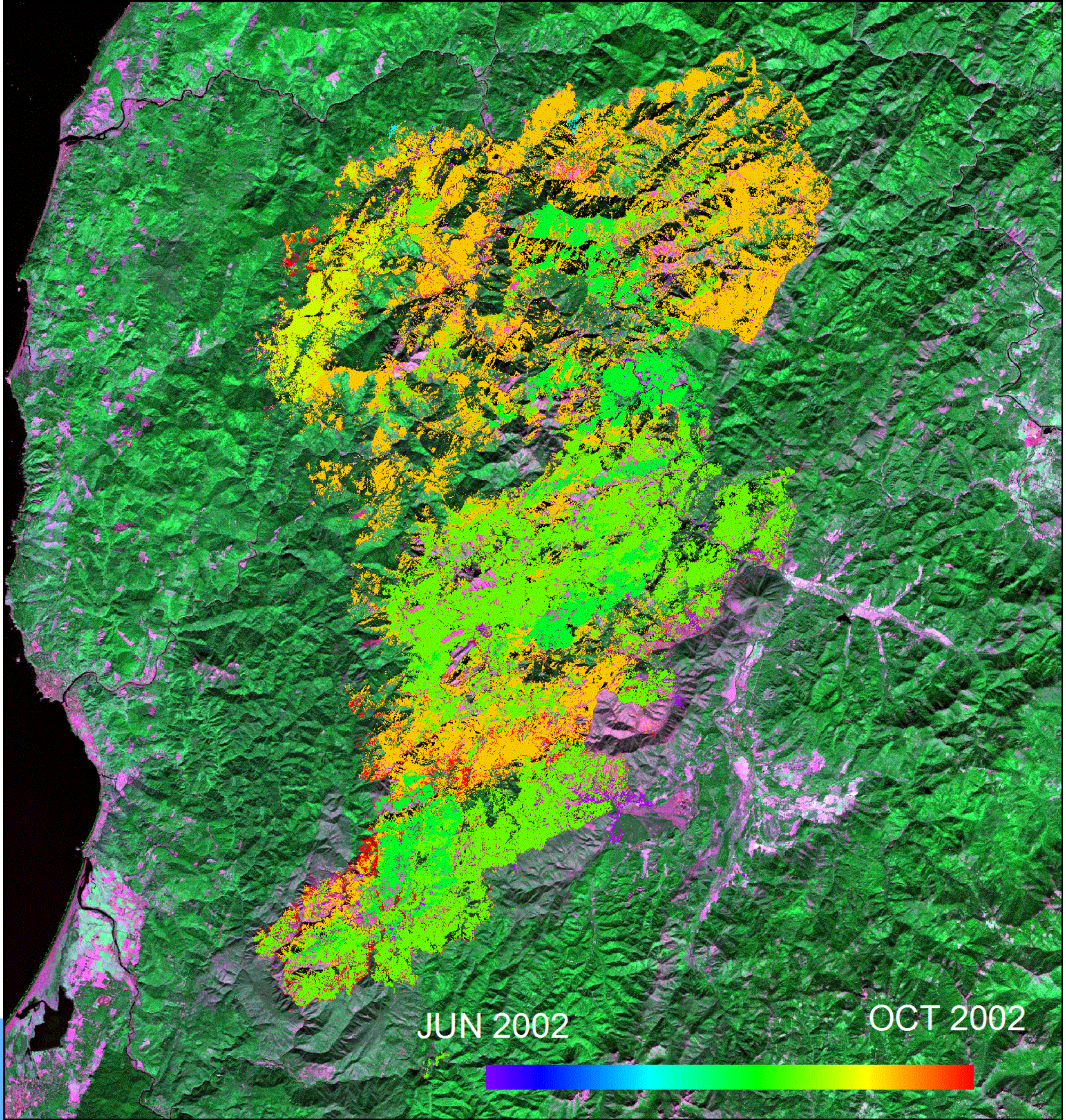


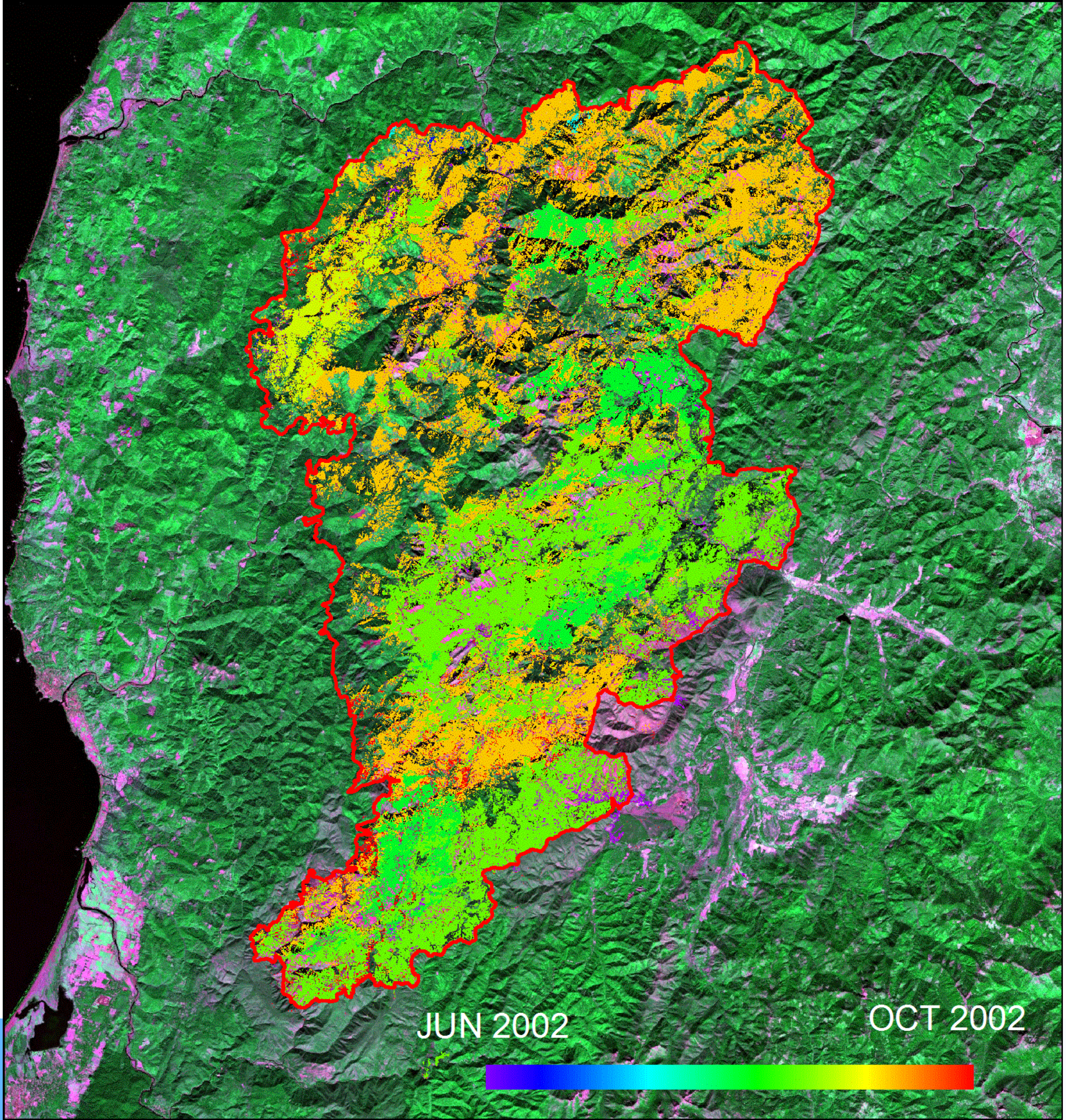

WELD tile h01v05
WELD tile h02v05
Summer 2002 composite
0 5 10 20
Kilometers

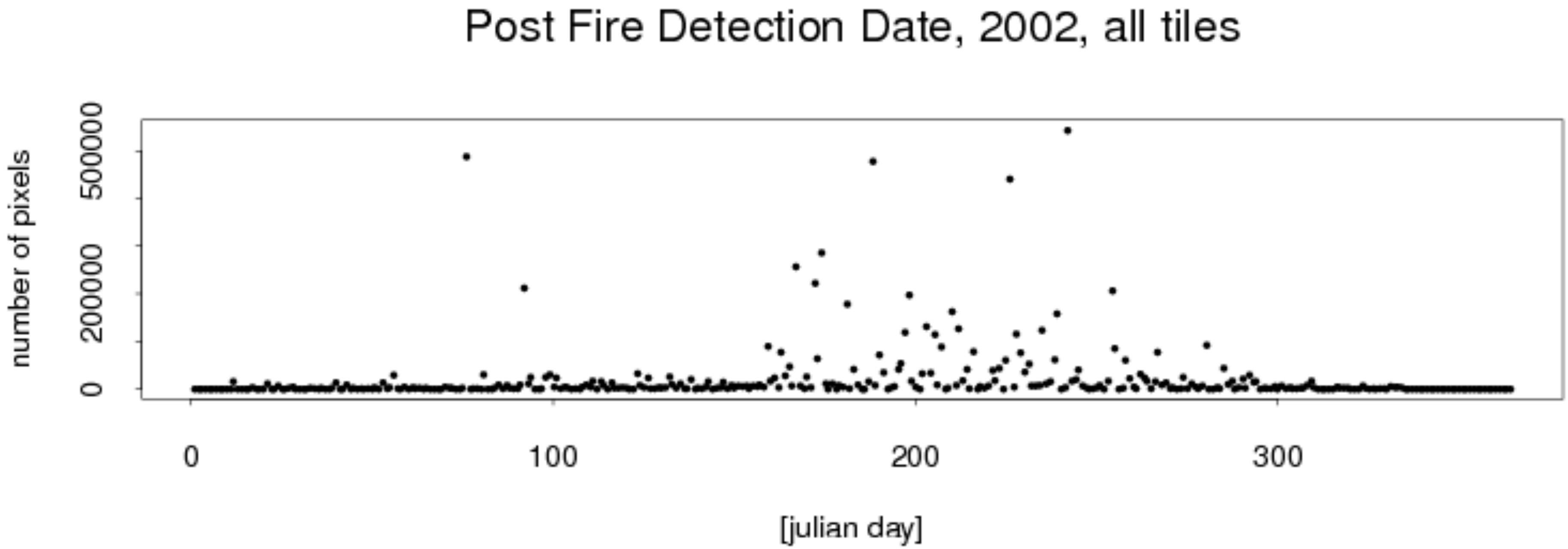

WELD tile
h01v05
WELD tile
h02v05
Summer
2002
composite
MOD14 Global Active Fire Product
JUN 2002
OCT 2002


WELD tile
h01v05
WELD tile
h02v05
Fall
2002
composite

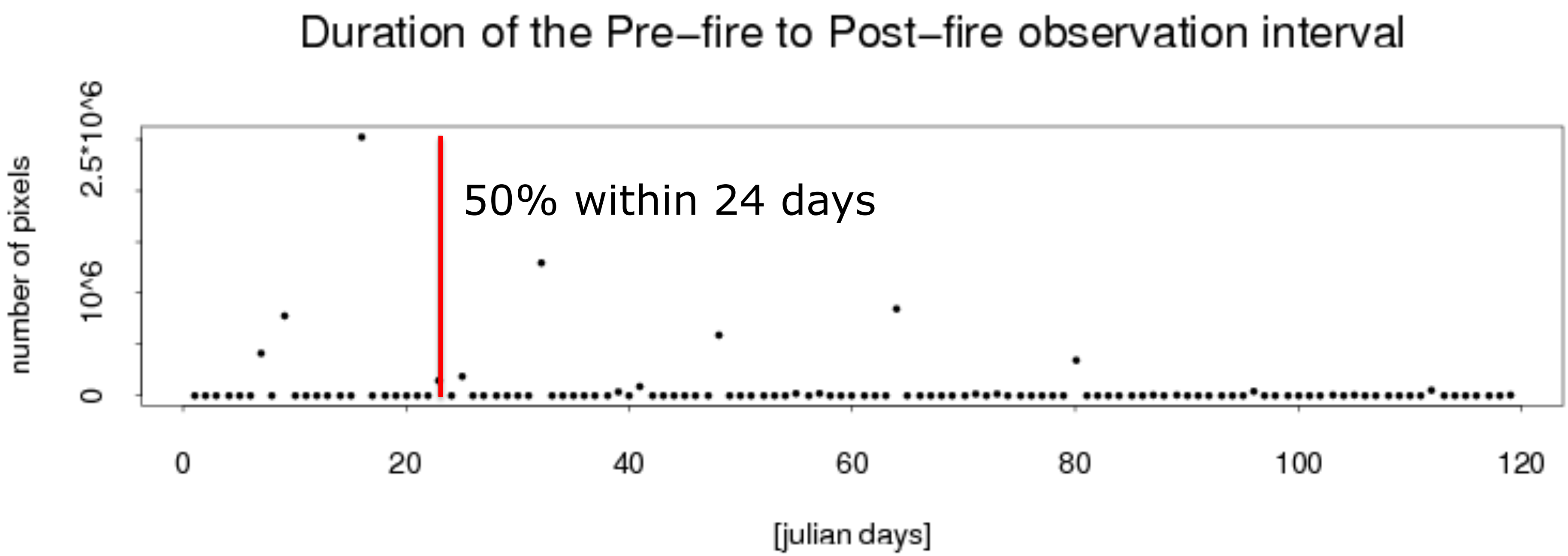



JUN 2002
OCT 2002


JUN 2002
OCT 2002



Post Fire Detection Date, 2002, all tiles
number of pixels
0
200000
500000
0
100
200
300
[julian day]



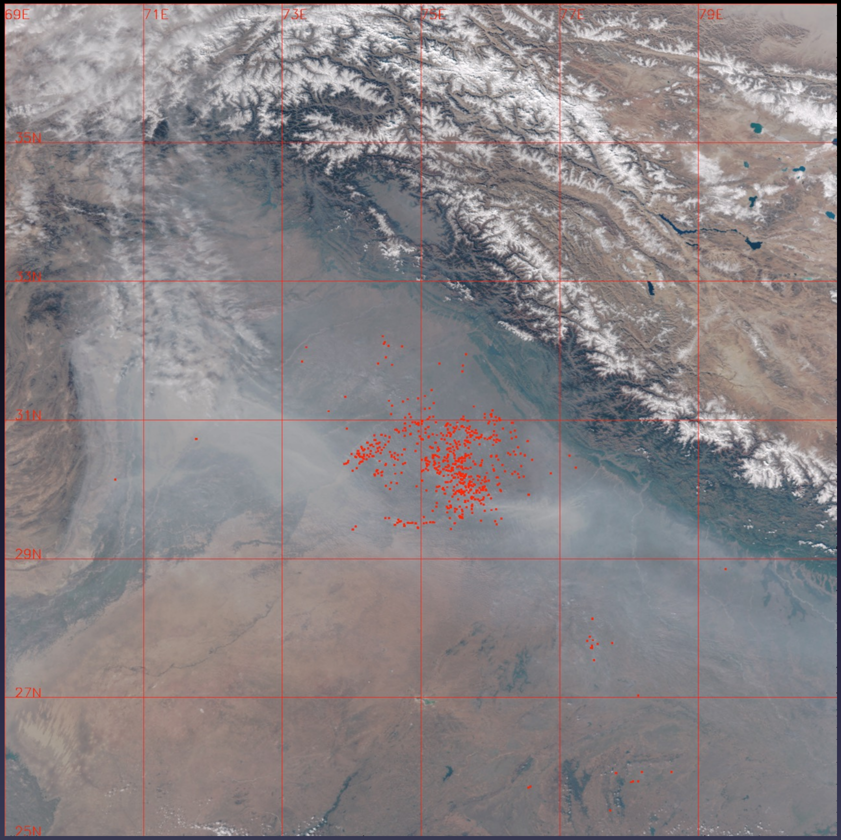
Duration of the Pre–fire to Post–fire observation interval
number of pixels
0
10^6
2.5*10^6
50% within 24 days
0
20
40
60
80
100
120
[julian days]

How are we going to validate this???

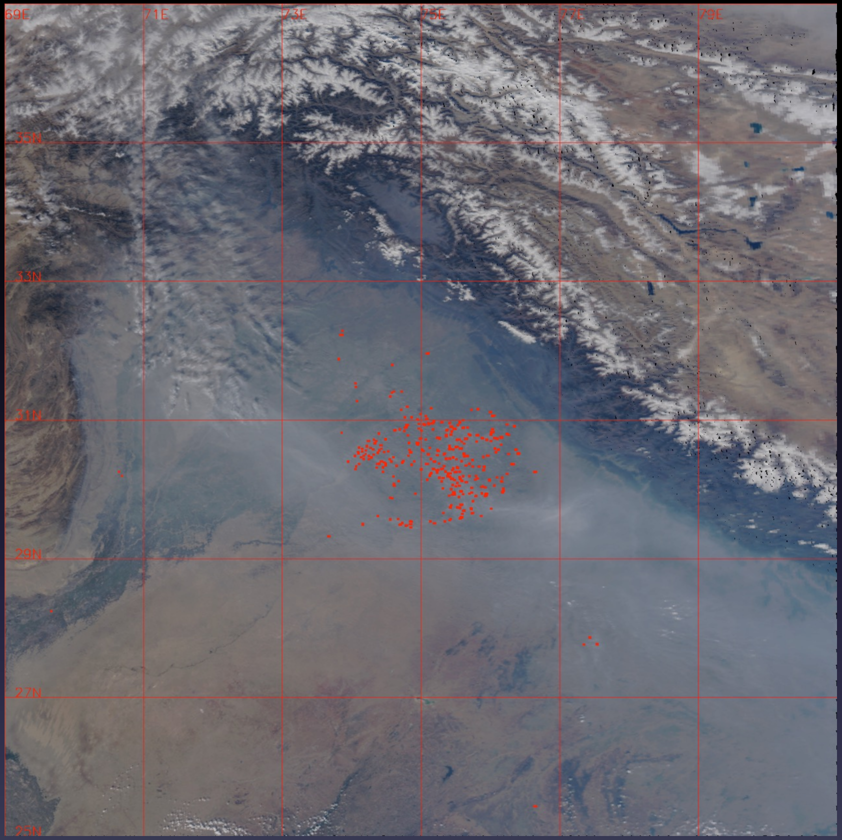
And now for something completely different:
Active Fire Validation

Sensor Inter-comparison
Near-Coincident Acquisition with EOS-MODIS

November 12, 2012 at approximately 0800 UTC (1330 local time) over the Punjab region



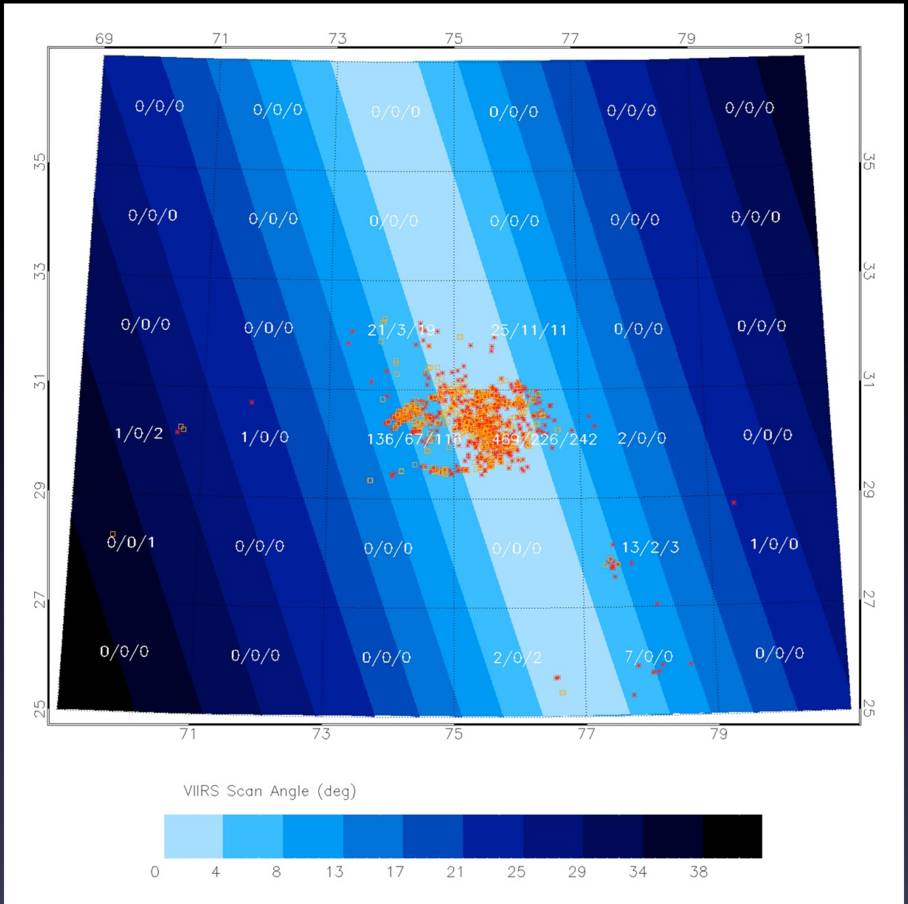
S-NPP/VIIRS 750 m Fire Product



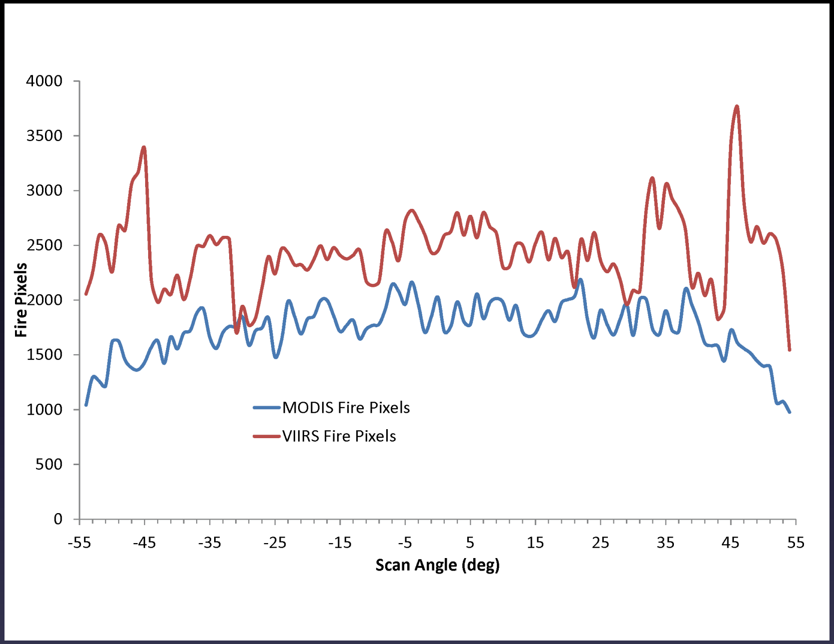
Aqua/MODIS 1 km Fire Product

Provide semi-quantitative fire detection performance estimates

Sensor Inter-comparison
Near-Coincident Acquisition with EOS-MODIS

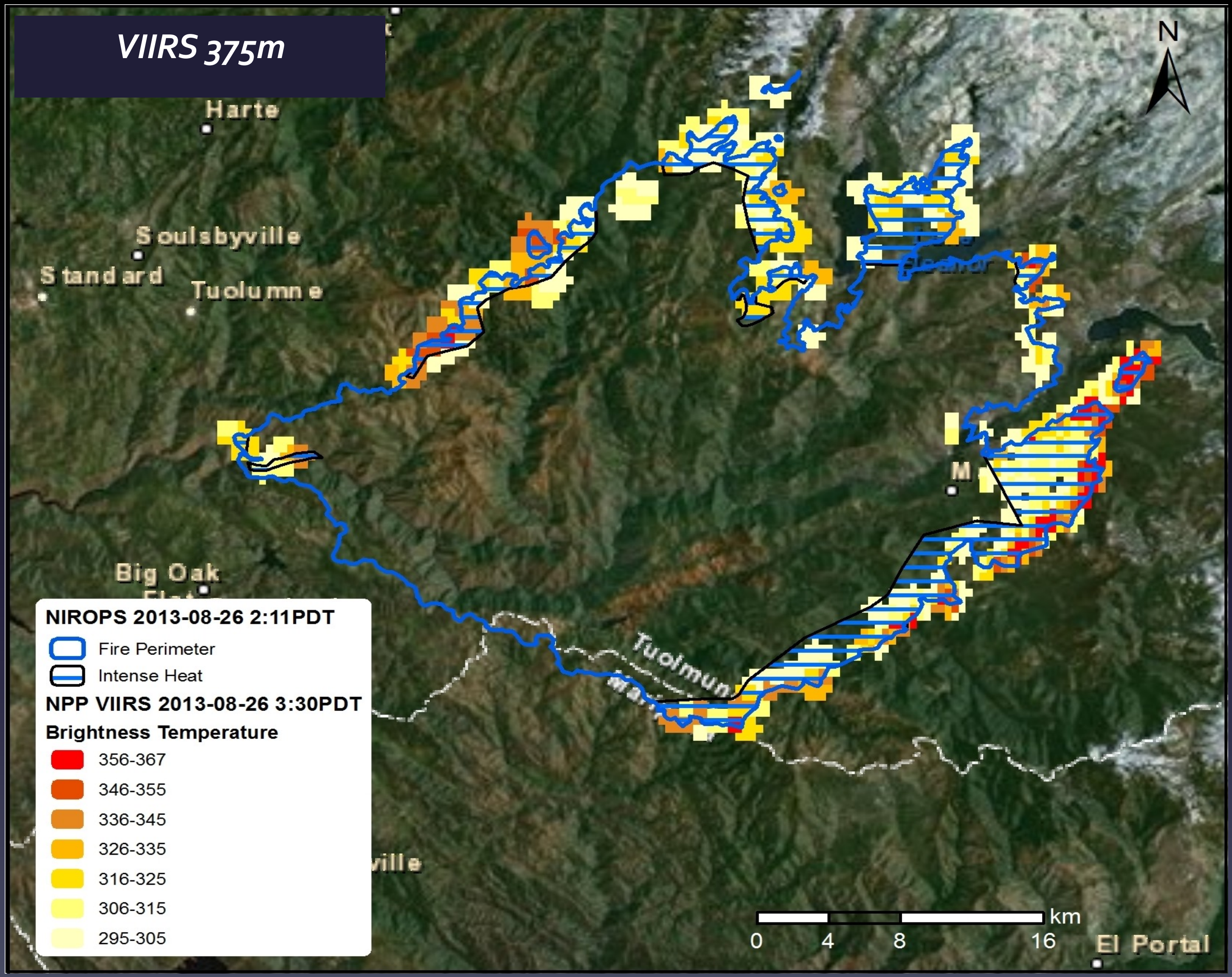


Gridded Fire Detection Statistics
(image subset – previous slide)



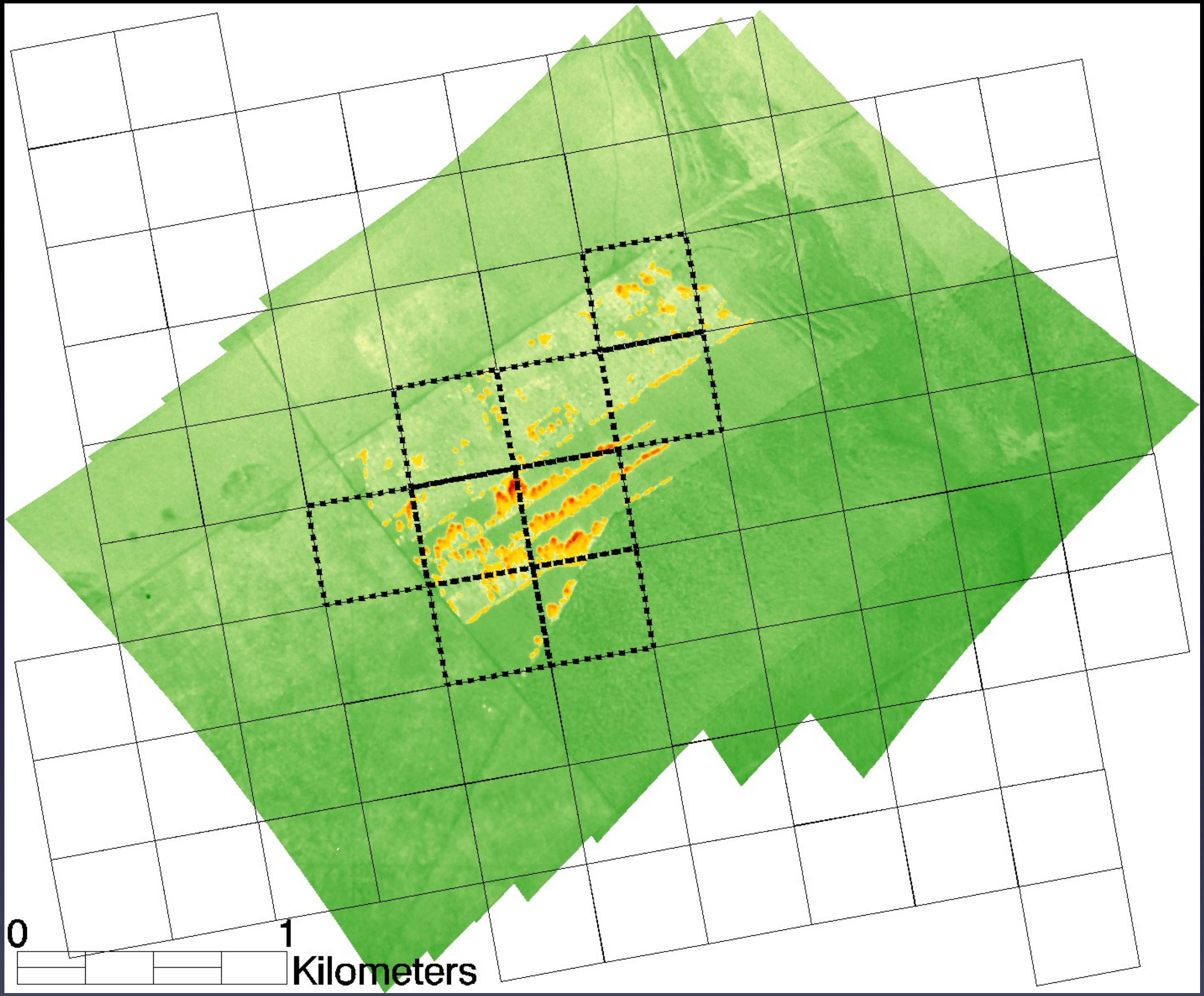
Global Summary Statistics
(Feb-May 2012)

Qualitative Assessment Using Airborne Reference Data



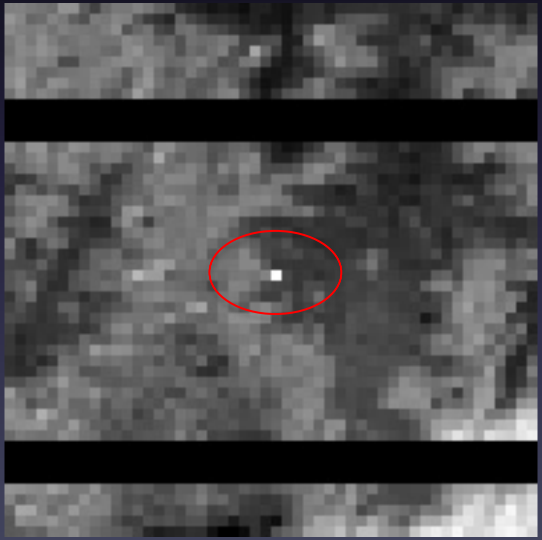
August 26, 2012 - Rim Fire/CA

Semi-Quantitative Assessment Using Airborne Reference Data



S-NPP/VIIRS 375 m Fire Detection Pixels (dashed lines) Mapped to 3.5 m Resolution Airborne IR Data of Prescribed Fire

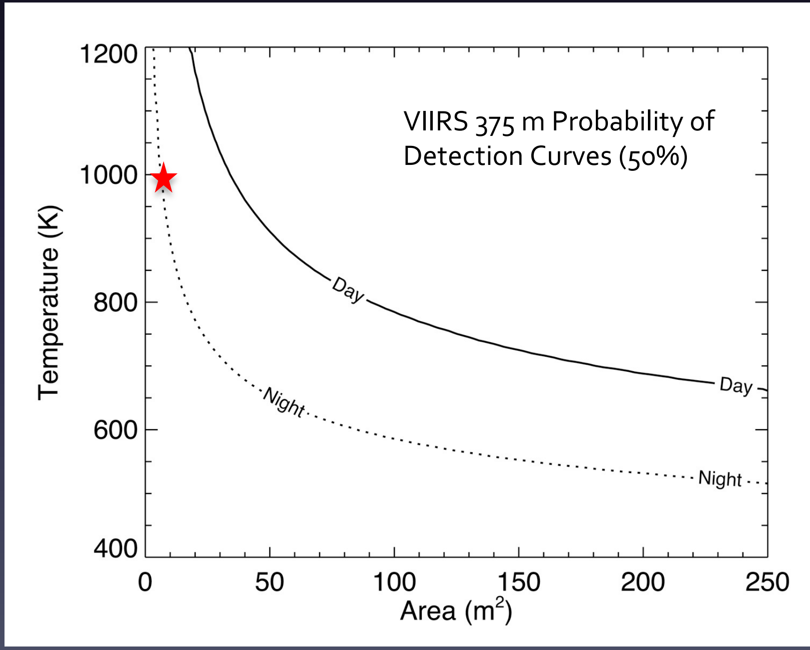
Use of Small Experimental Fires
To Verify Simulated Probability of Detection Curves



Subset of VIIRS L1B data
08 July 2013 4:23 UTC (1:23am local)
Coinciding with <u>bonfire</u>

2.5 m diameter
experimental bonfire

Single pixel detection
Pixel fraction containing
active fire: **0.004%**



VIIRS Publications and User Information

AGU PUBLICATIONS
JGR
Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE
10.1002/2013JD020453

Special Section:
Suomi NPP Calibration and Validation Scientific Results

Active fires from the Suomi NPP Visible Infrared Imaging Radiometer Suite: Product status and first evaluation results

Ivan Csiszar[1], Wilfrid Schroeder[2], Louis Giglio[2], Evan Ellicott[2], Krishna P. Vadrevu[2], Christopher O. Justice[2], and Brad Wind[3]

[1]NOAA/NESDIS Center for Satellite Applications and Research, College Park, Maryland, USA, [2]Department of Geographical Sciences, University of Maryland, College Park, Maryland, USA, [3]Enterprise Information Solutions, Inc., Columbia, Maryland, USA

University of Maryland VIIRS Fire Website: http://viirsfire.geog.umd.edu/

Remote Sensing of Environment 143 (2014) 85–96

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journal homepage: www.elsevier.com/locate/rse

The New VIIRS 375 m active fire detection data product: Algorithm description and initial assessment

CrossMark

Wilfrid Schroeder [a,*], Patricia Oliva [a], Louis Giglio [a], Ivan A. Csiszar [b]

[a] *Department of Geographical Sciences, University of Maryland, College Park, MD, United States*
[b] *NOAA/NESDIS Center for Satellite Applications and Research, College Park, MD, United States*