Fire Science Algorithms and Products Update for Low Latency Applications/Users

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NASA Direct Readout Conference Webinar

29 May 2018

Applications Discussed

- Active fire detection and characterization
  - Can be performed in Direct Readout environment in essentially NRT
  - Bulk of presentation
- Burned area mapping
  - Much more challenging in NRT
  - To do reliably requires very large data volumes

Sensors Discussed

- Terra and Aqua MODIS
  - Launched 1999 and 2002
- S-NPP and NOAA-20 VIIRS
  - Launched October 2011 and November 2017
- Landsat-8 OLI (Operational Land Imager)
  - February 2013 launch
- Sentinel-2 MSI (Multi-Spectral Instrument)
  - Sentinel-2A: June 2015 launch
  - Sentinel-2B: March 2017 launch

MODIS

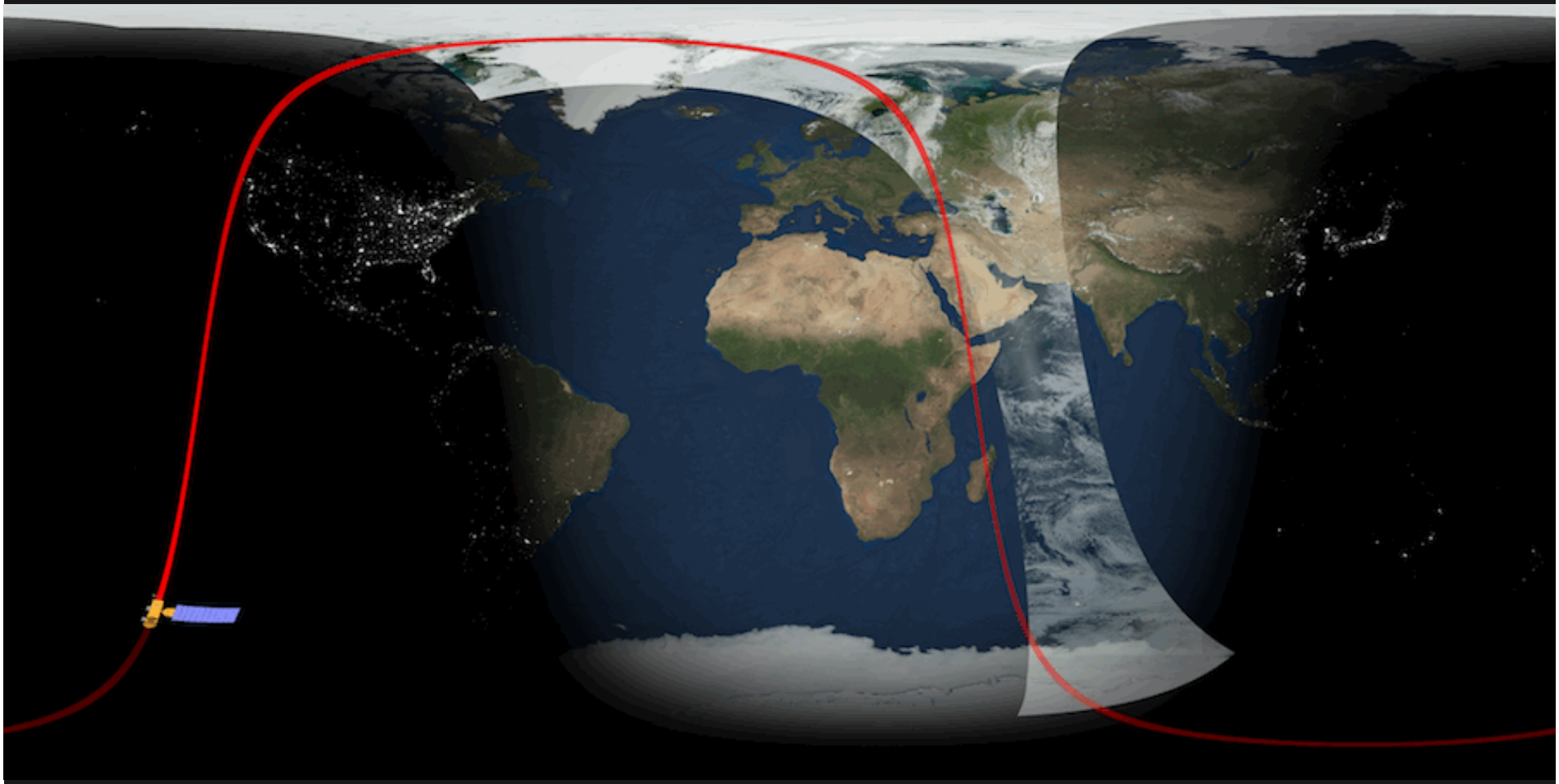
- One of the few Earth Observation sensors built with fire observation capabilities
  - Spectral bands
    - specifically for observing active fires
    - useful for observing burned areas
  - Accurate and reliable calibration & geolocation
- Dedicated 1 km fire bands
  - Channel 21: 3.96 µm, ≈ 500 K saturation
  - Channel 22: 3.96 µm, ≈ 330 K sat. (multi-purpose)
  - Channel 31: 11.0 µm, ≈ 400 K saturation

NASA's MODIS Active Fire Products

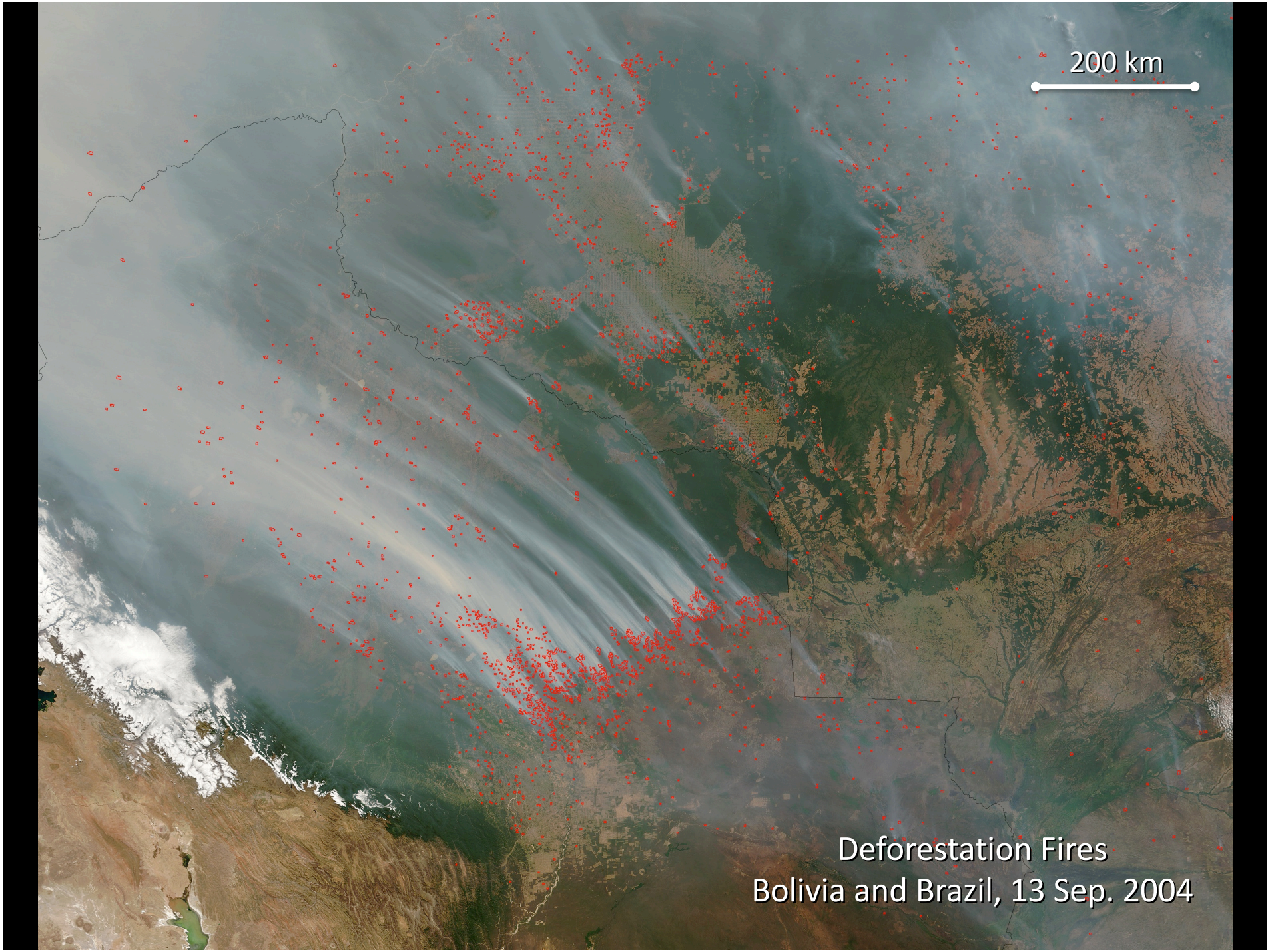
MOD14/MYD14	1-km Swath L2
MOD14A1/MYD14A1	1-km Daily Composite L3
MOD14A2/MYD14A2	1-km 8-Day Composite L3
MOD14C8H/MYD14C8H	0.5° 8-Day CMG
MOD14CMH/MYD14CMH	0.5° Monthly CMG
MCD14ML	Monthly fire locations + attributes

Direct broadcast version available (stand-alone and IPOPP MOD14_SPA)

MODIS Swath



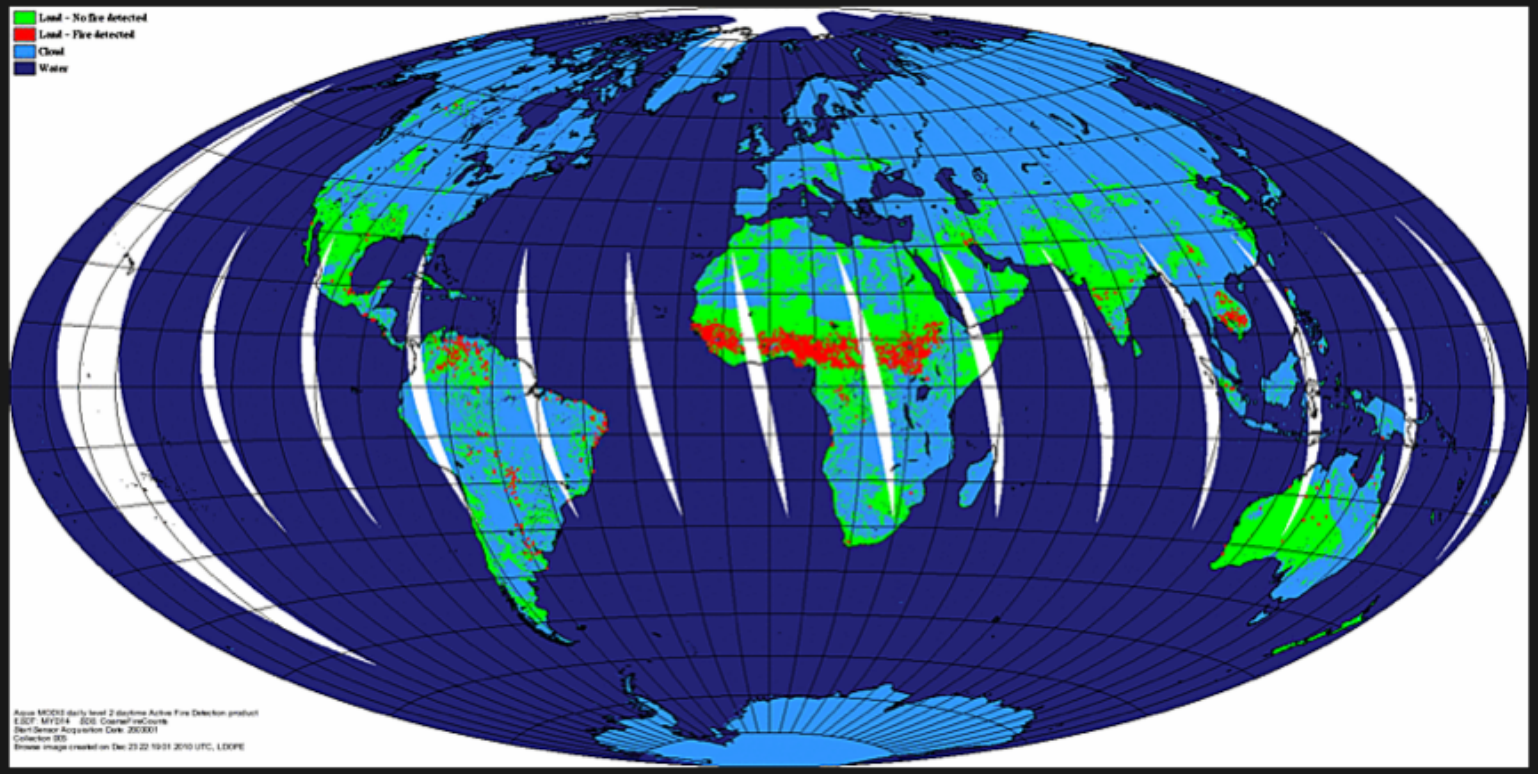
NASA Scientific Visualization Studio


200 km
Deforestation Fires
Bolivia and Brazil, 13 Sep. 2004

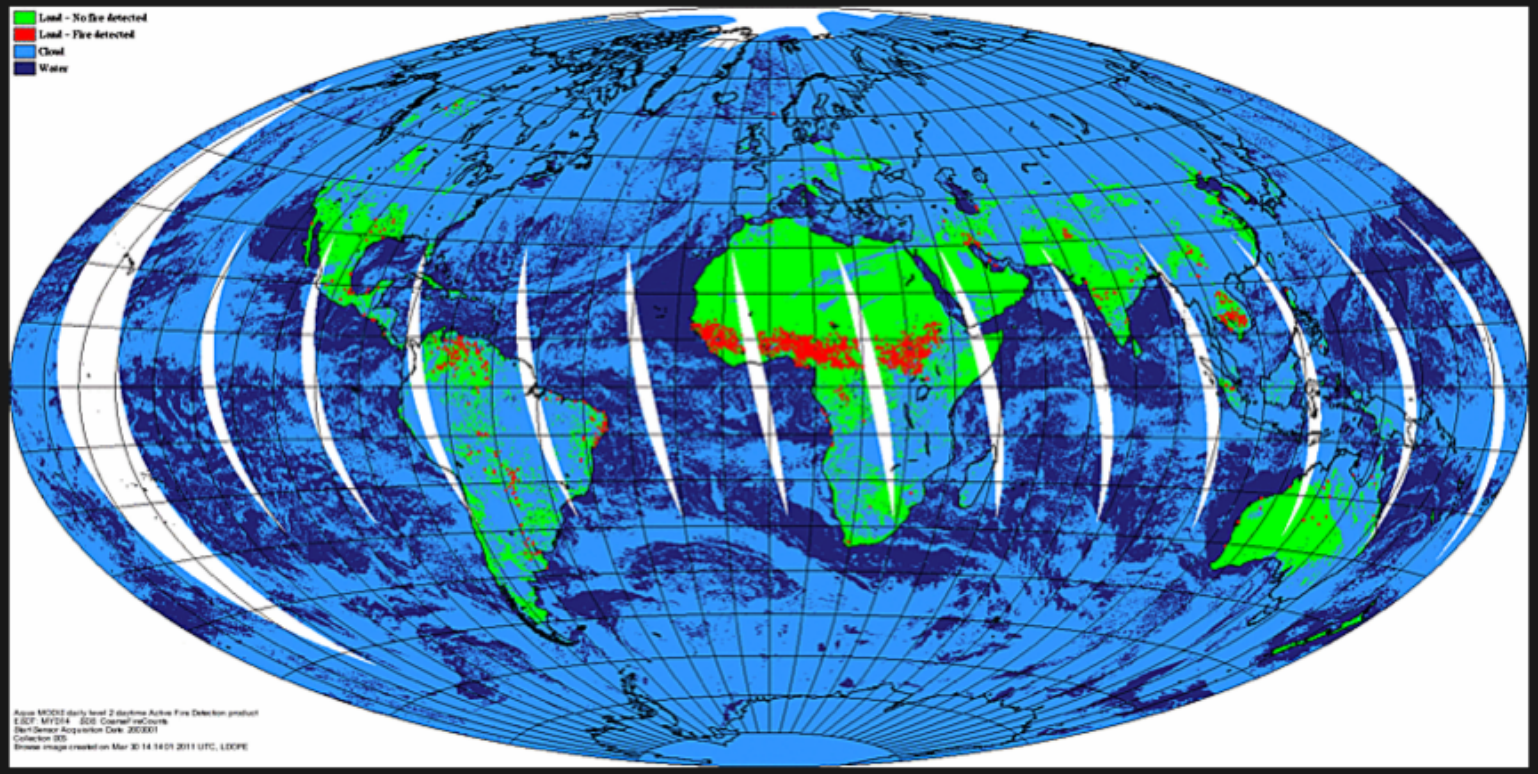
Collection 6 Algorithm Refinements

- Processing extended to water
  - Detect off-shore gas flaring
  - Can be disabled for DR use
- Improved cloud mask
- Reduce false alarms in Amazon caused by small forest clearings
- Adjust potential fire thresholds dynamically
  - Detect smaller fires
- Improved fire radiative power (FRP) retrieval

Collection 5

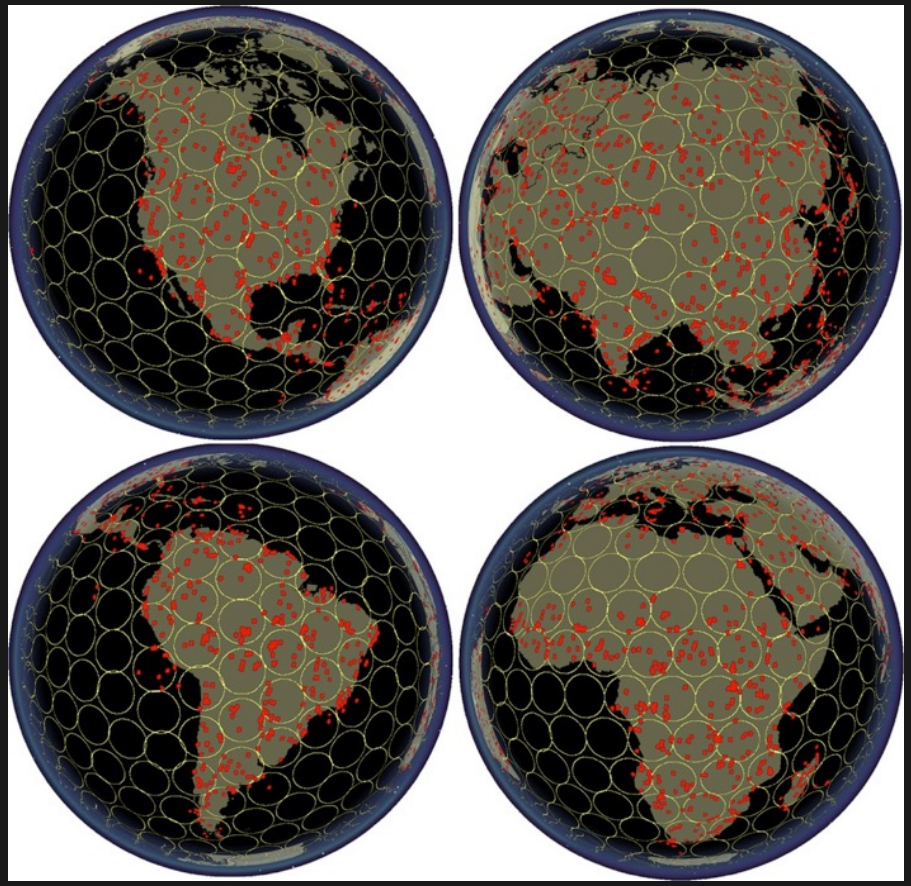


Collection 6

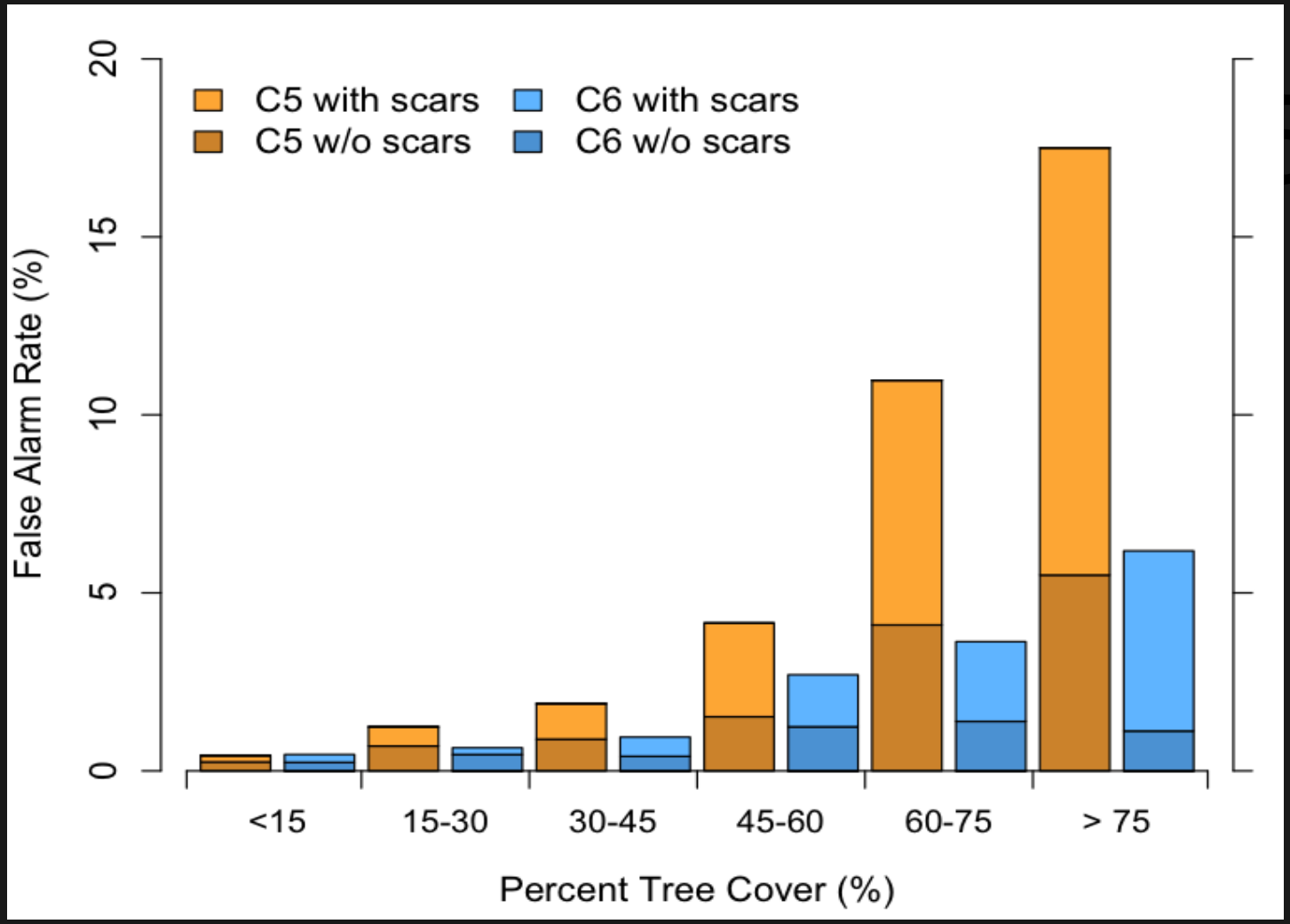


C6 Validation

- Use swath (L2) product
- Compare Terra MODIS fire masks to 30-m ASTER fire masks
- > 2300 ASTER scenes

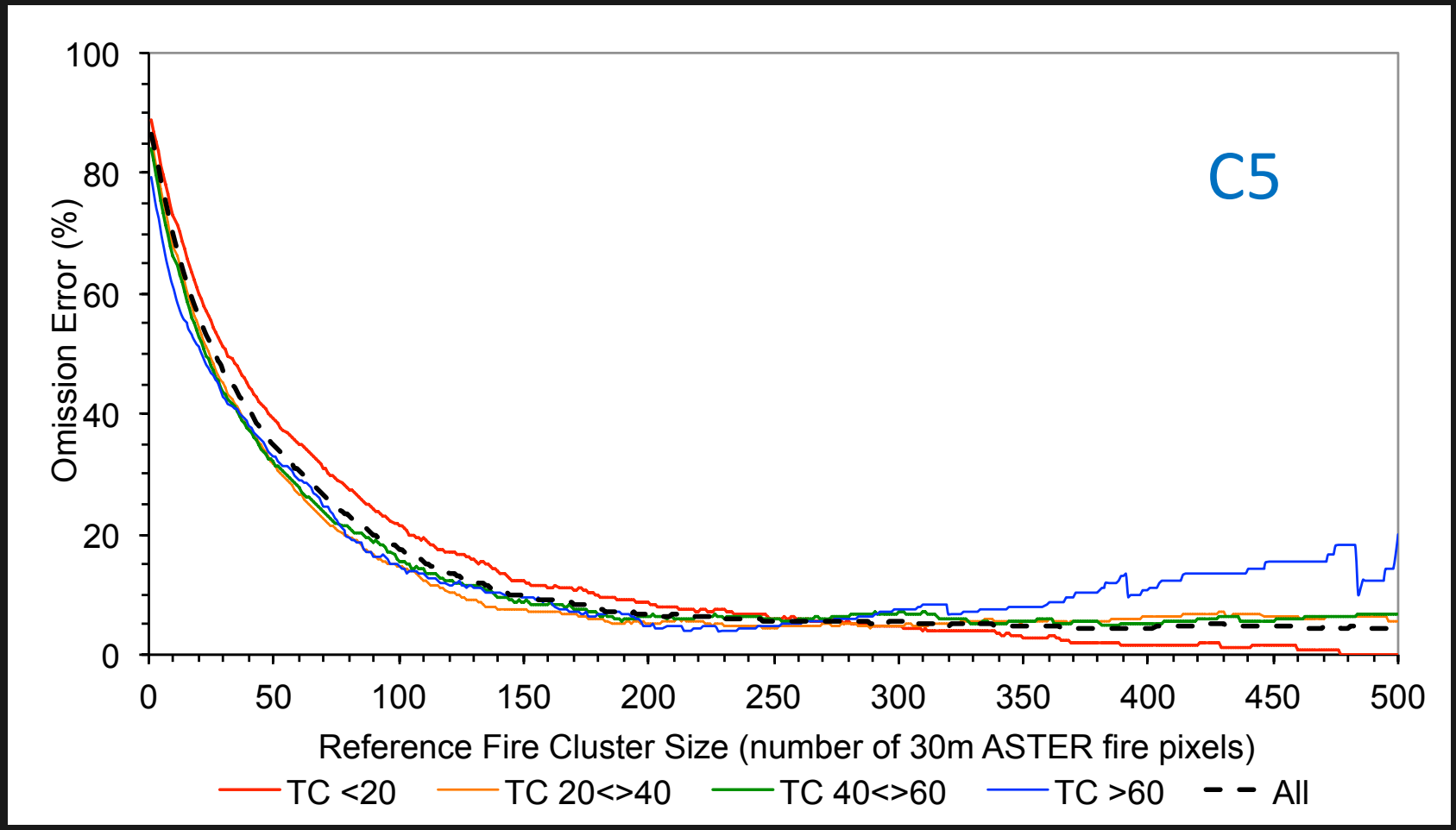


Terra MODIS Fire Product Validation

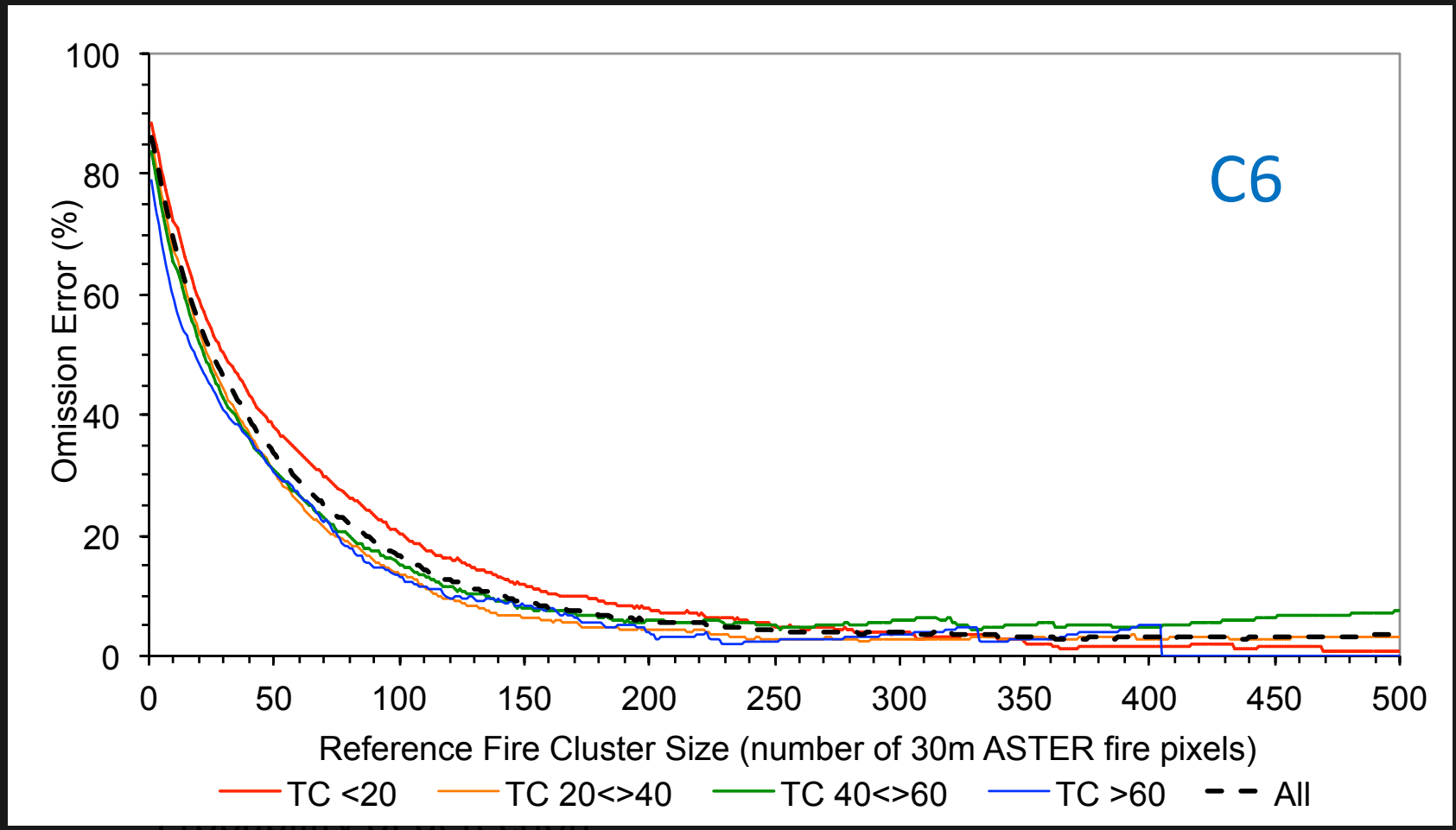


Giglio et al. (2016)

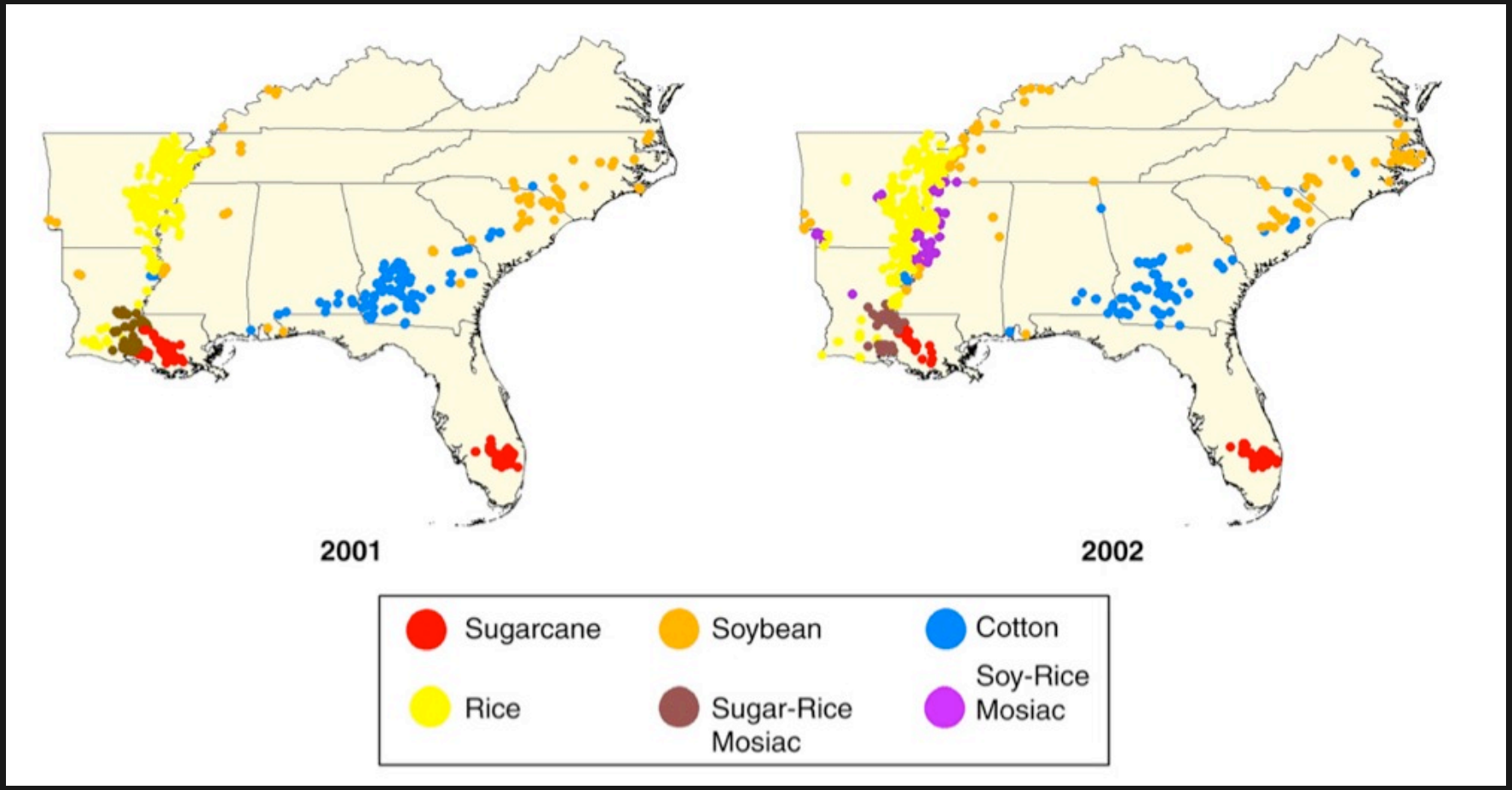
Terra MODIS Fire Product Validation



Terra MODIS Fire Product Validation



as a function of fire size

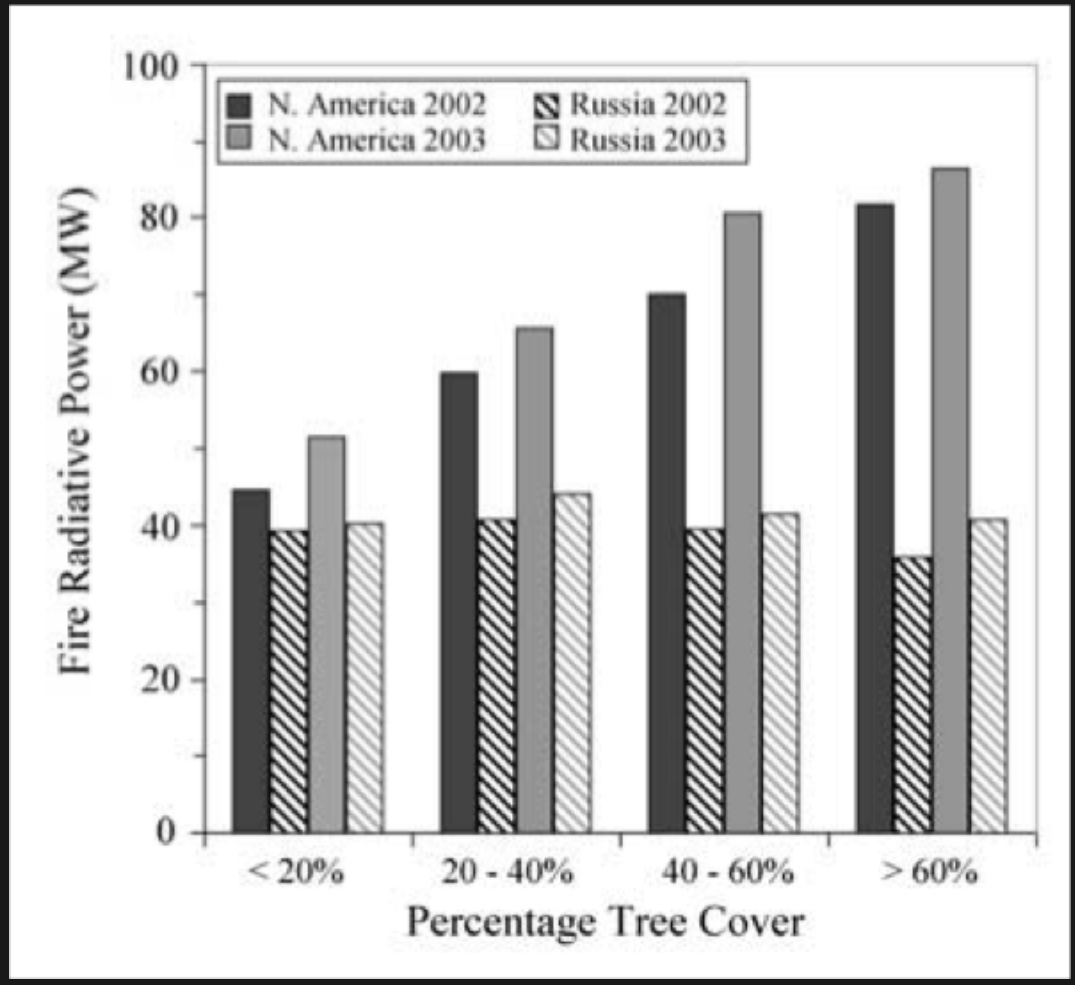


McCarty et al. (2007)

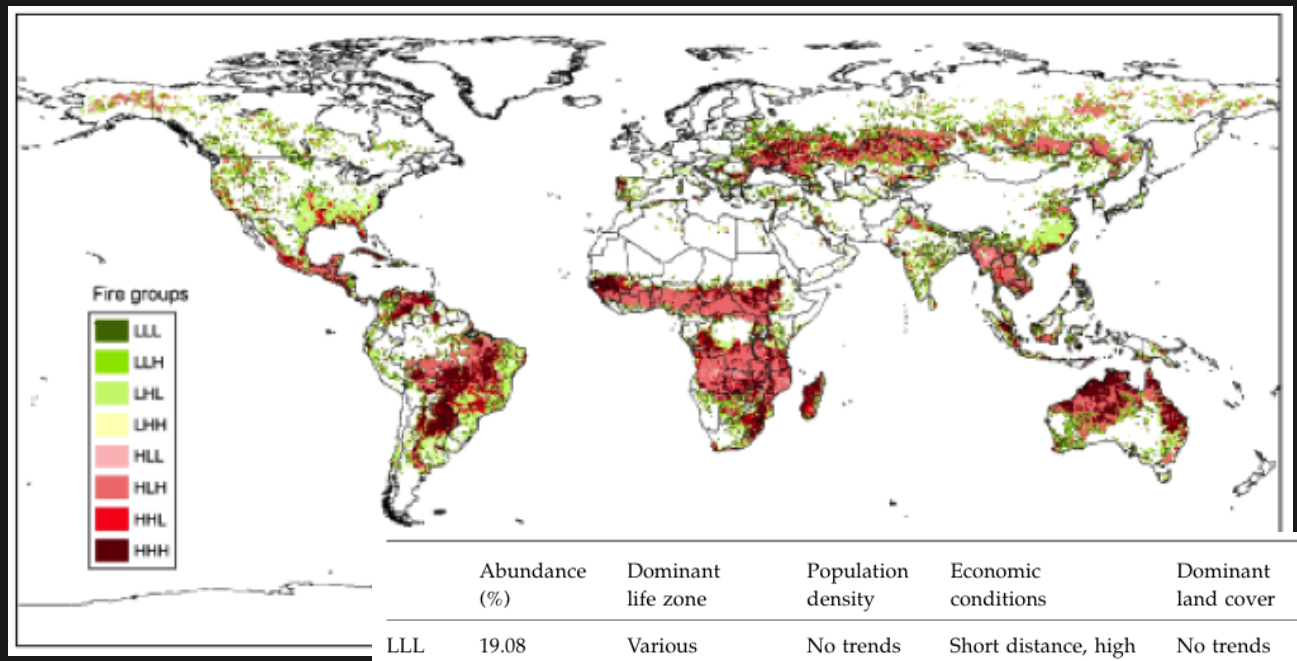
Boreal forest fires burn less intensely in Russia than in North America

M. J. Wooster[1] and Y. H. Zhang[1,2]

Received 22 June 2004; revised 18 August 2004; accepted 10 September 2004; published 26 October 2004.



Global Fire Regimes



	Abundance (%)	Dominant life zone	Population density	Economic conditions	Dominant land cover	Interpretation
LLL	19.08	Various	No trends	Short distance, high investment	No trends	Various fires in developed regions
LLH	6.16	Boreal	Low density	Long distance, low investment	Low crops Low grass	Boreal fires
LHL	20.64	Temperate and tropical wet	High density	Short distance, high investment	High crop	Agricultural fires in developed regions
LHH	1.27	Temperate	No trends	No trends	No trends	Various temperate
HLL	3.16	Various	No trends	No trends	No trends	Residual
HLH	24.17	Boreal and tropical	Lower densities	Long distance, low investment	Low crops, high grass	Boreal and savannas fires in low developed regions
HHL	5.98	Tropical wet	Higher densities	No trends	High crops and grass	Periodic tropical fires, agricultural and savannas
HHH	19.54	Tropical dry	Various	Long distance, low investment	High grass	Savannas and deforestation fires

Chuvieco et al. (2008)

VIIRS

- Visible Infrared Imaging Radiometer Suite (VIIRS)
- On Suomi-NPP and JPSS satellites
  - S-NPP launch 25 October 2011
- 22 bands
  - 750 m and 375 m spatial resolution
- Multi-agency JPSS legacy
  - $$$
  - complicated development and uptake of products

NASA's VIIRS Active Fire Products

VNP14	750-m Swath L2
VNP14IMG	375-m Swath L2
VNP14A1	1-km Daily Composite L3
VNP14ML	Monthly fire locations + attributes
VNP14IMGML	Monthly fire locations + attributes

Direct broadcast versions available (stand-alone and IPOPP VIIRS-AF and VFIRE375 SPAs)

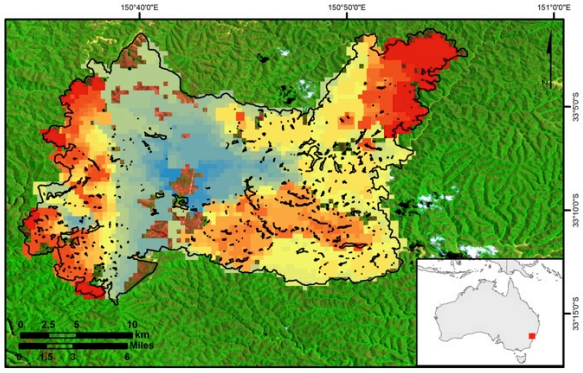
VIIRS Active Fire Product Status

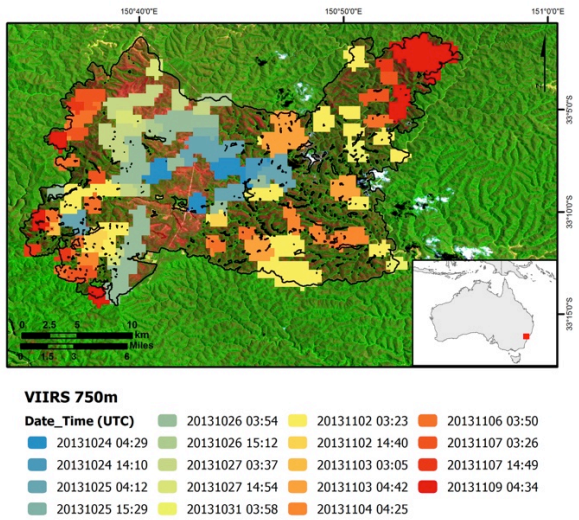
- Baseline 750-m active fire product
  - Built on MODIS C6 algorithm
  - Small adjustments performed to account for unique L1B data (plenty of reactive maintenance)
  - Fire detection + FRP
  - Output format supporting MODIS-VIIRS data continuity
- Alternative 375-m active fire product
  - Developed by Wilfrid Schroeder (now at NOAA)
  - Hybrid algorithm optimizes use of 375-m MIR channel I4 (frequent saturation, folding) + 750-m MIR channel M13
  - First version produced fire detections only
  - Latest version providing fire detection + FRP
  - Output format supporting MODIS-VIIRS data continuity

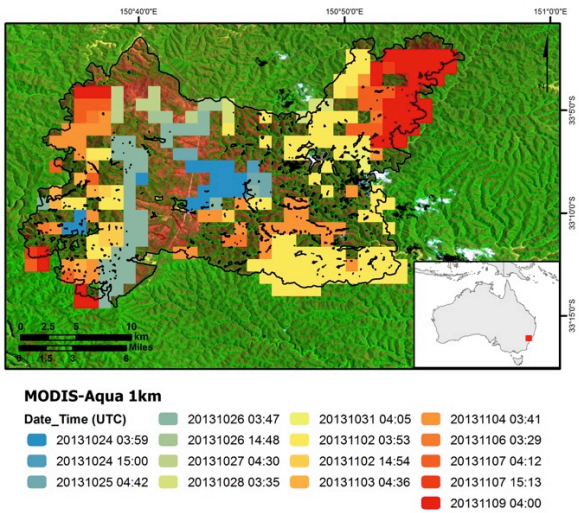
VIIRS Active Fire Product Status

- NASA 750m swath product (**VNP14**)
  - Running at Land SIPS (≈12h latency), incomplete/inconsistent record due to changes in input data and data retention
  - Also available from NOAA (**AF_v1r0_npp** product)
  - Production code available through DRL IPOPP direct readout data processing package (VIIRS-AF_SPA)
- NASA 375m swath product (**VNP14IMG**)
  - Running at Land SIPS (≈12h latency), incomplete/inconsistent archive due to changes in input data and data retention
  - Running at LANCE, feeding FIRMS/Worldview since Dec 2015
  - Production code available through DRL IPOPP direct readout data processing package (VFIRE375_SPA)
- Data reprocessing being implemented at NASA and NOAA
  - Should provide complete/consistent data record

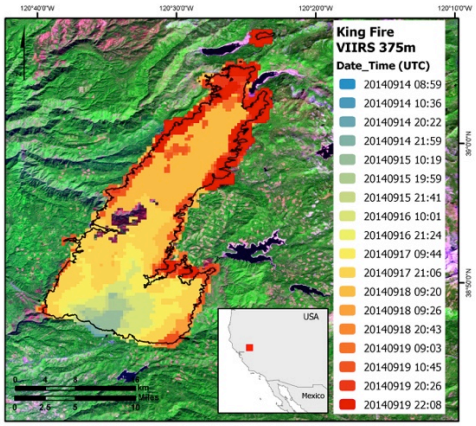
S-NPP/VIIRS 375 x 750m x Aqua/MODIS 1km Fire Detection Data Quick Comparison



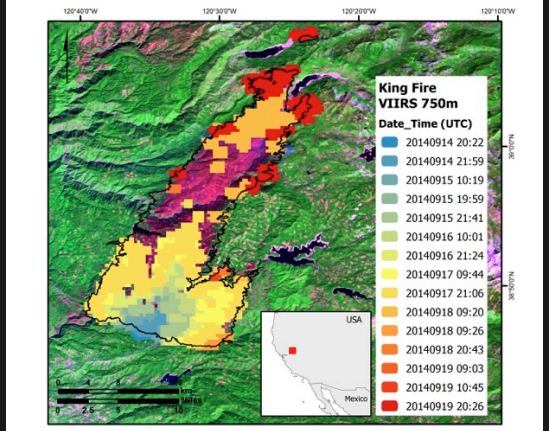




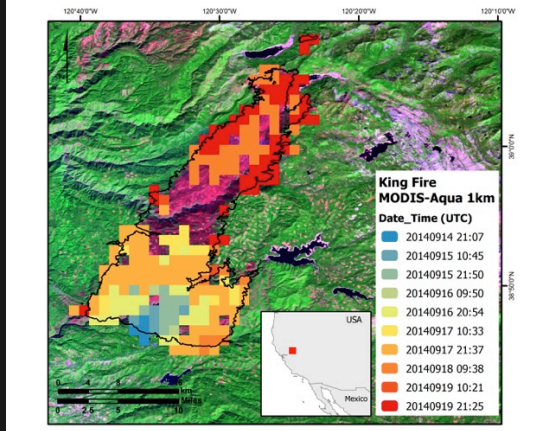
S-NPP/VIIRS 375 m



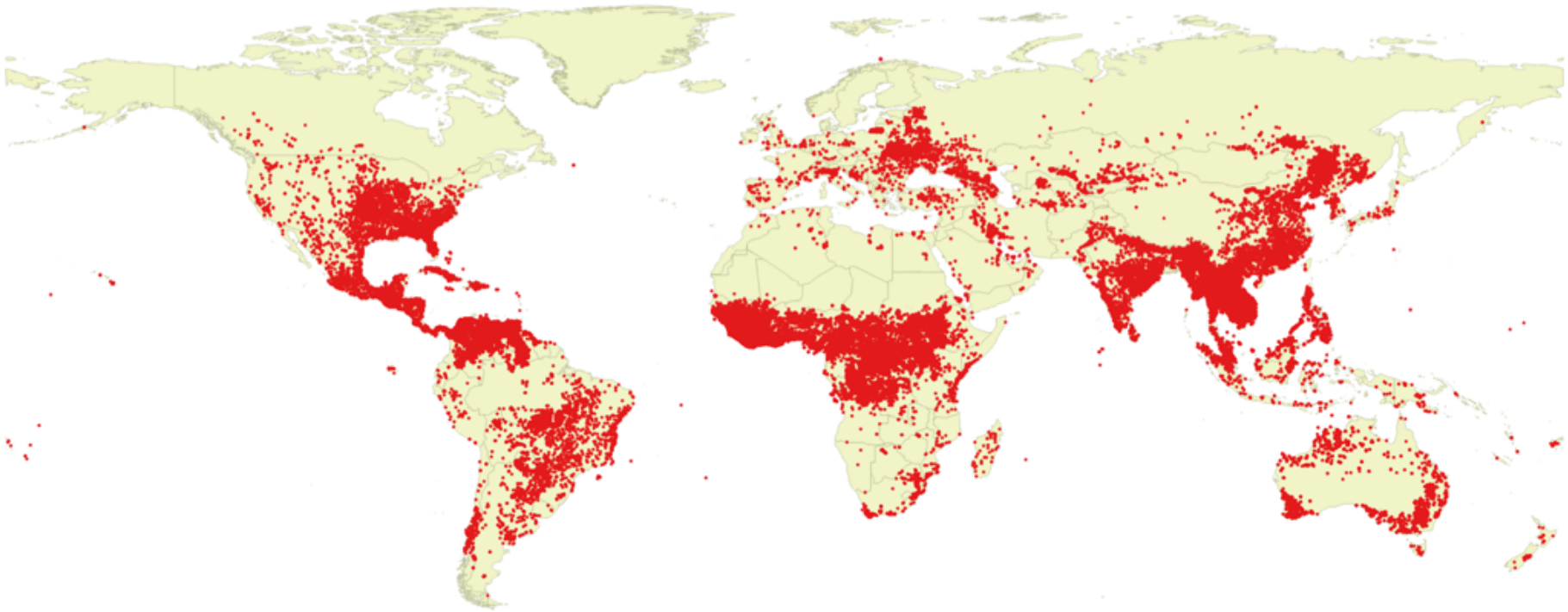
S-NPP/VIIRS 750 m



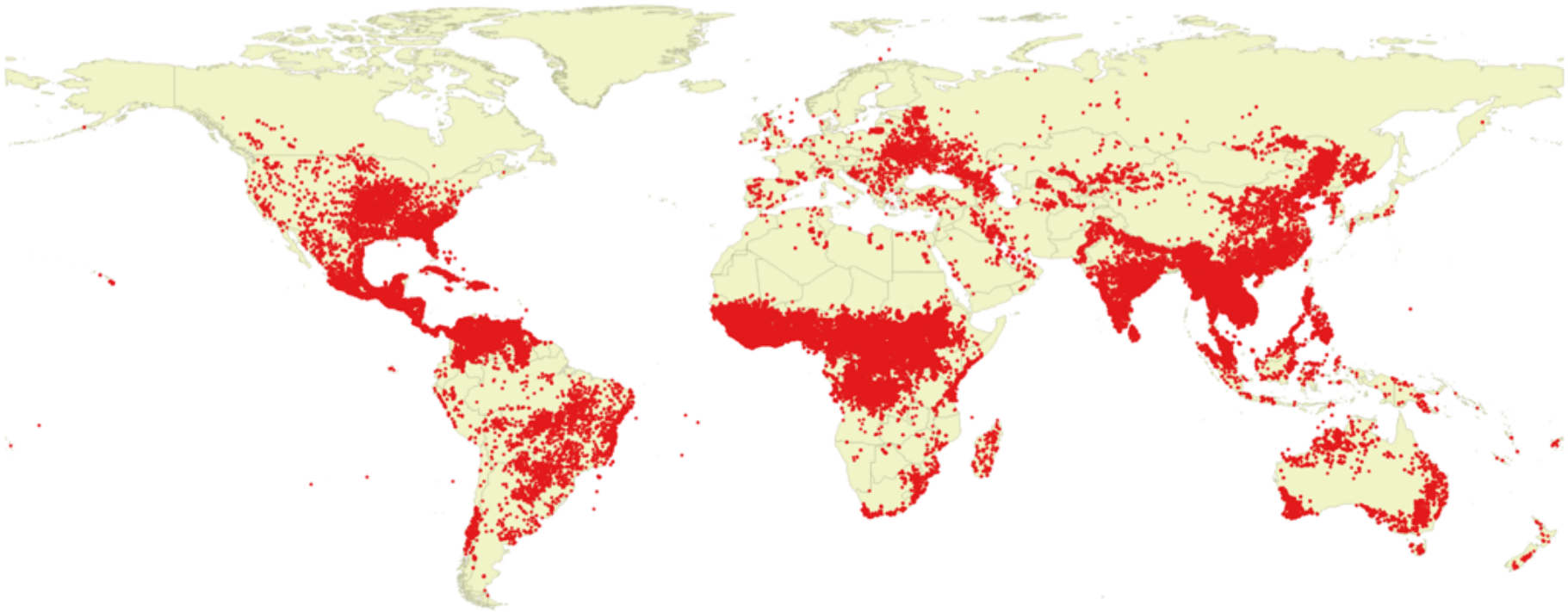
Aqua/MODIS 1 km



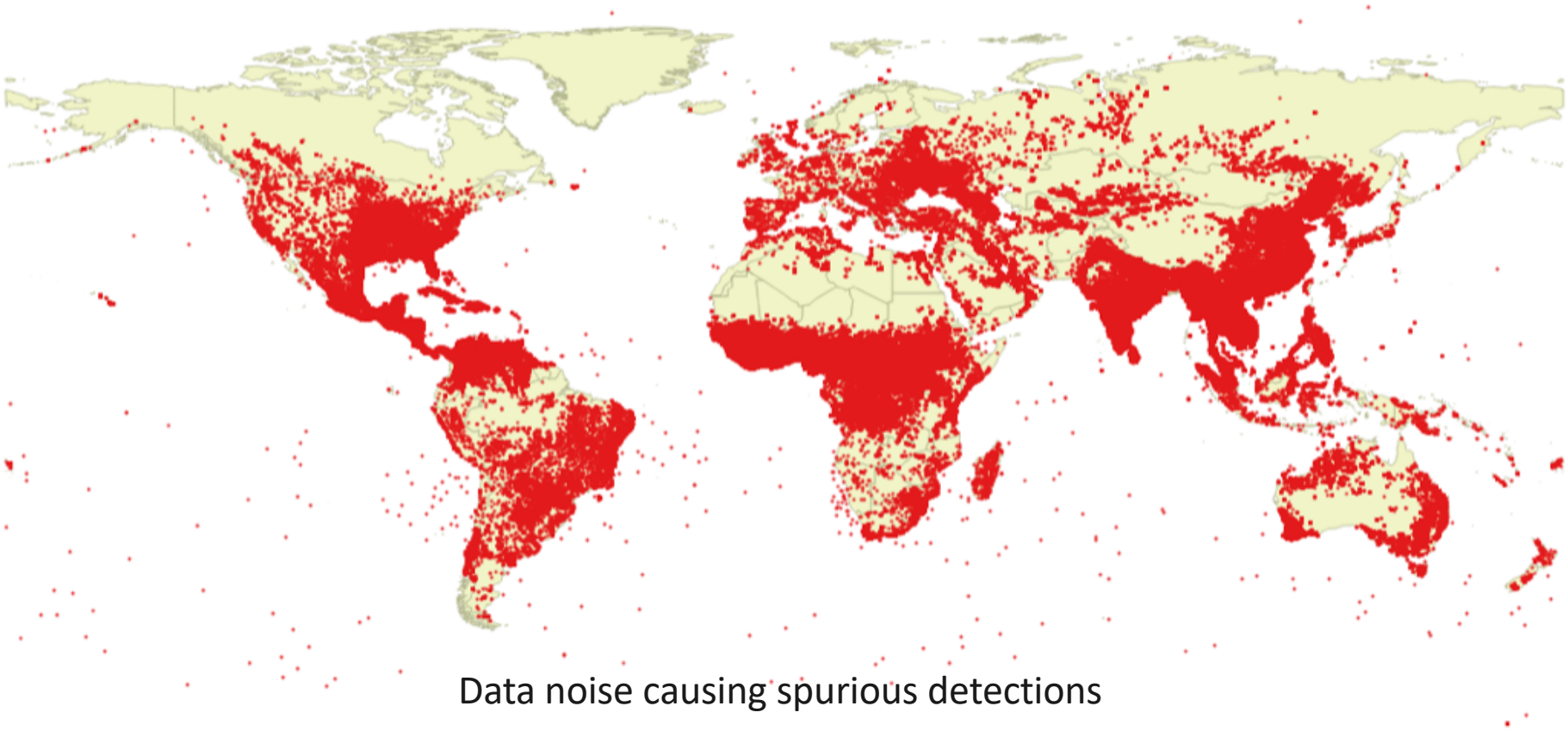
MYD14 Fire Pixels (March 2016)
Collection 6



VIIRS 750 m Fire Pixels (March 2016)

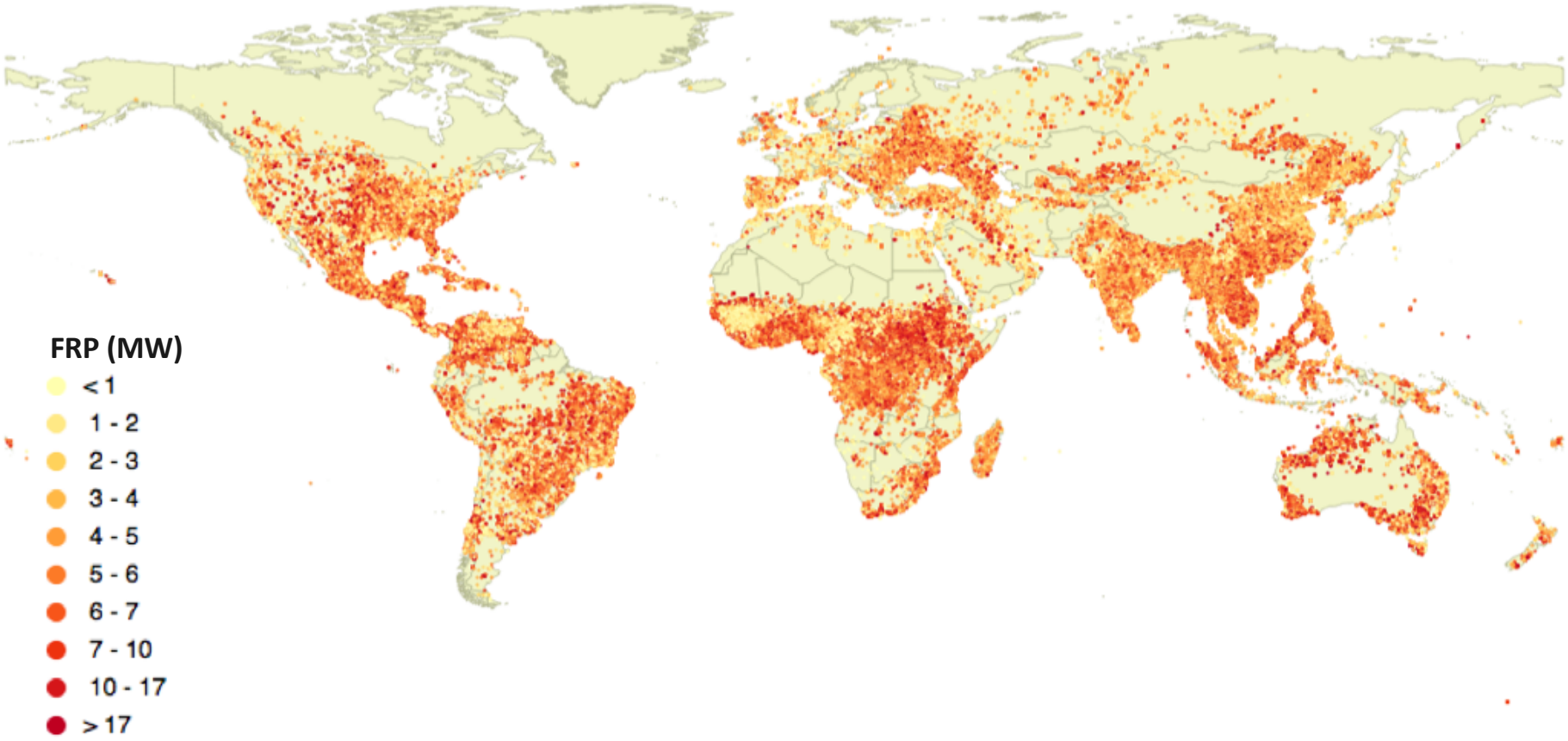


VIIRS 375-m Fire Pixels (March 2016)
"Collection 1"

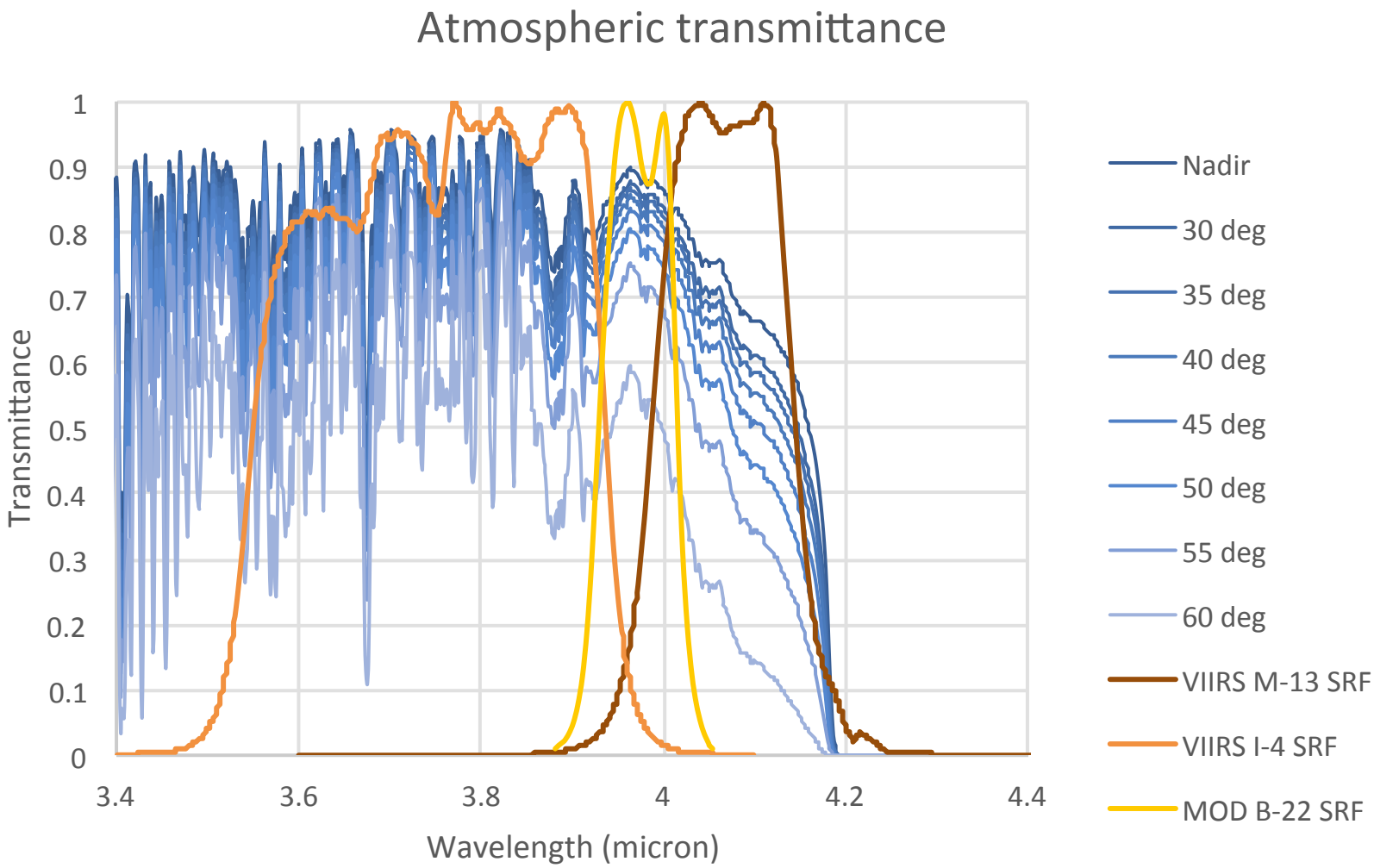


Data noise causing spurious detections

VIIRS 375-m Fire Pixels (March 2016)
"Collection 2"



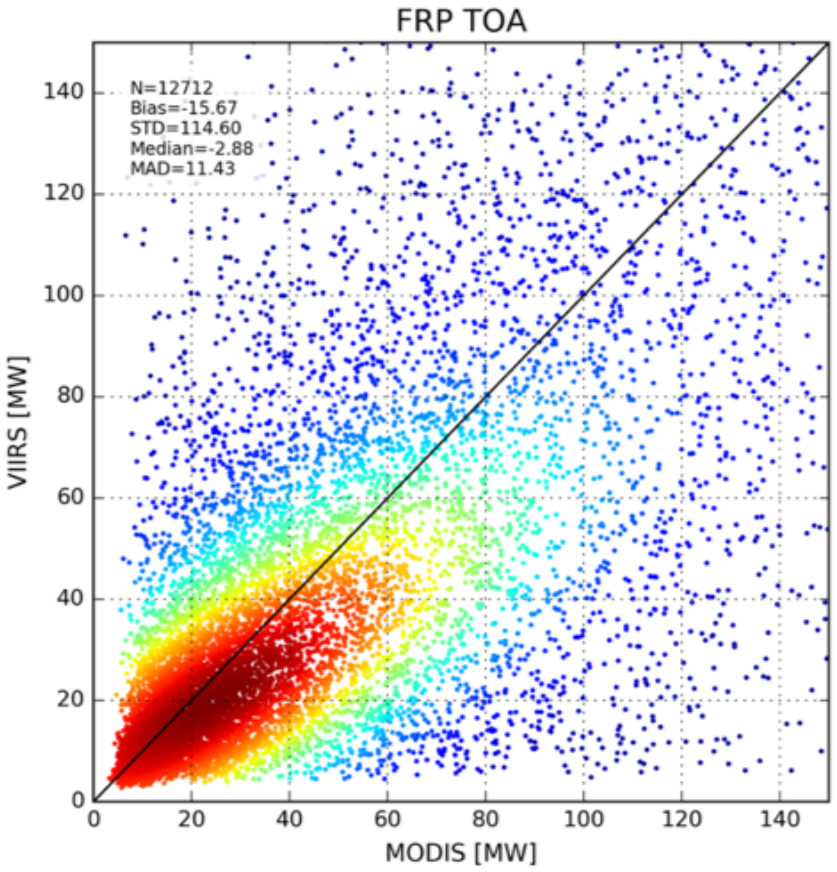
MODIS x VIIRS Mid-IR
Spectral Responses & Atmospheric Transmittance



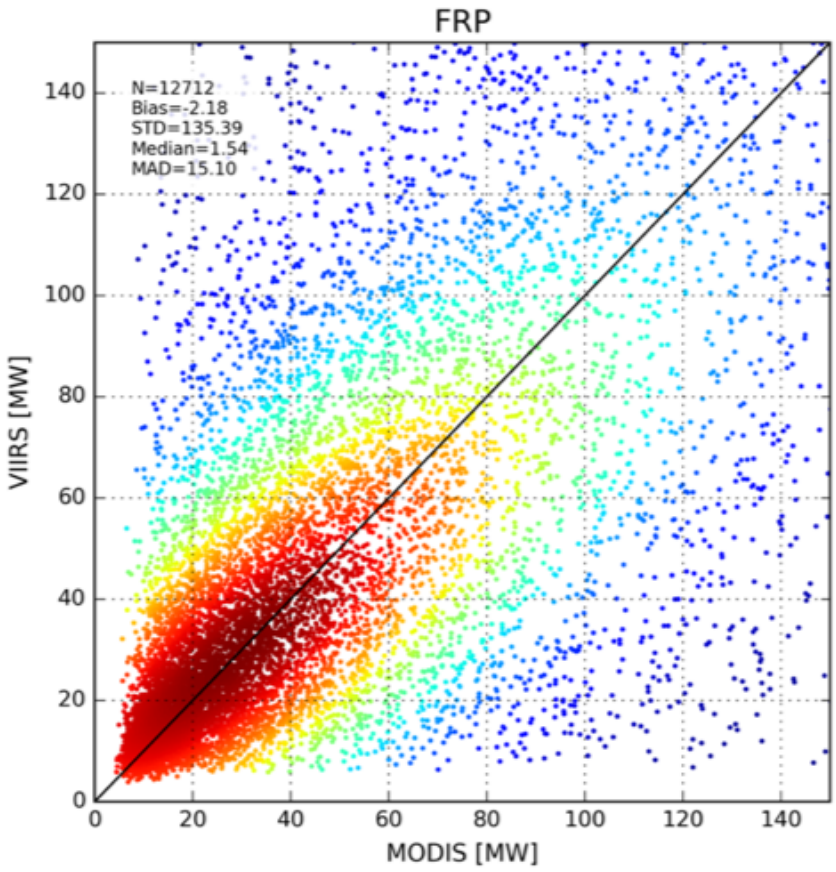
W. Schroeder

Atmospheric Correction of MODIS and VIIRS

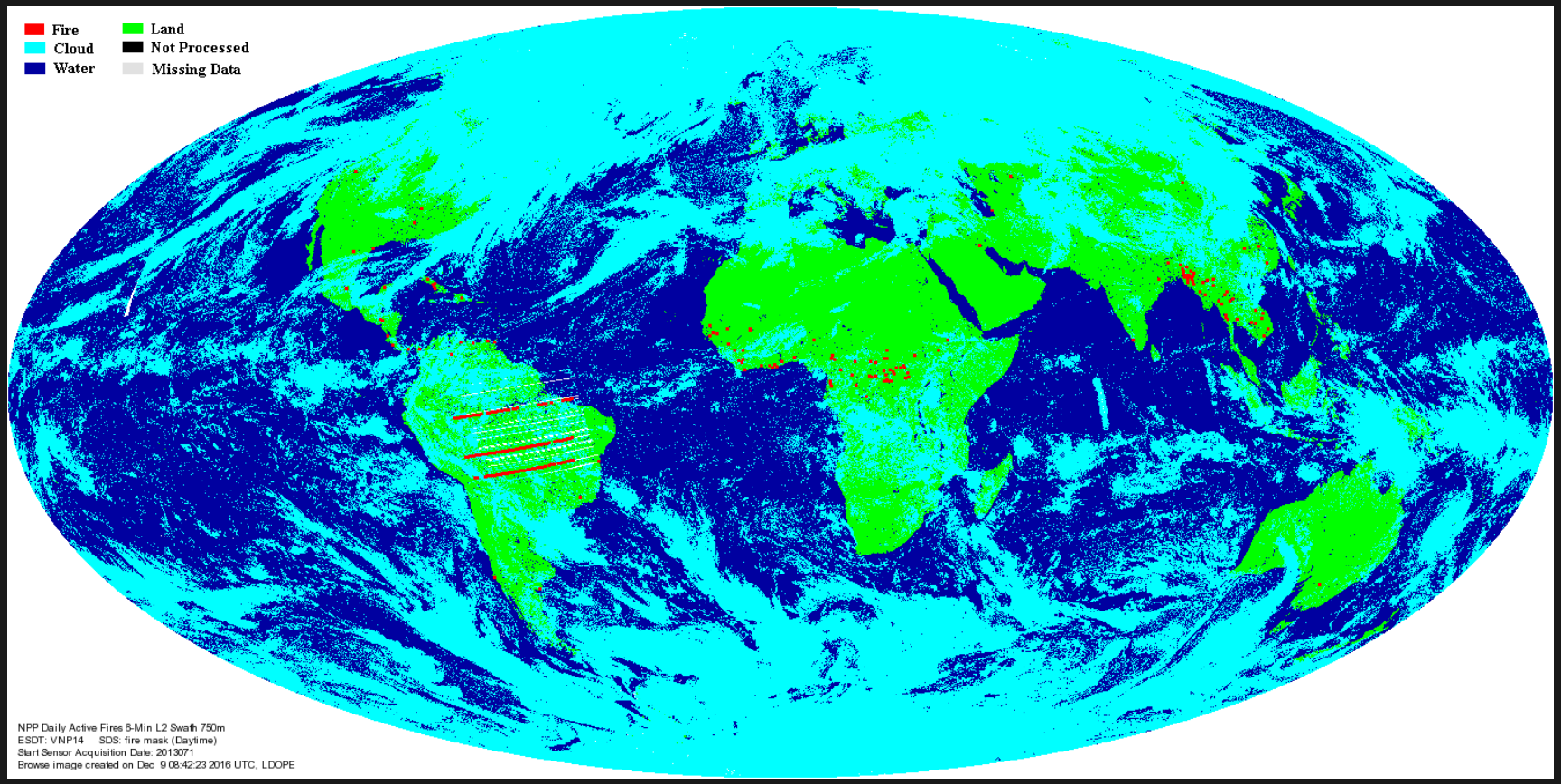
Implementing approach to correct Level 2 , 3, 4 products in support of data continuity
Currently running MODTRAN + MERRA-2 (0.625° x 0.5°)



Before atmospheric correction



After atmospheric correction

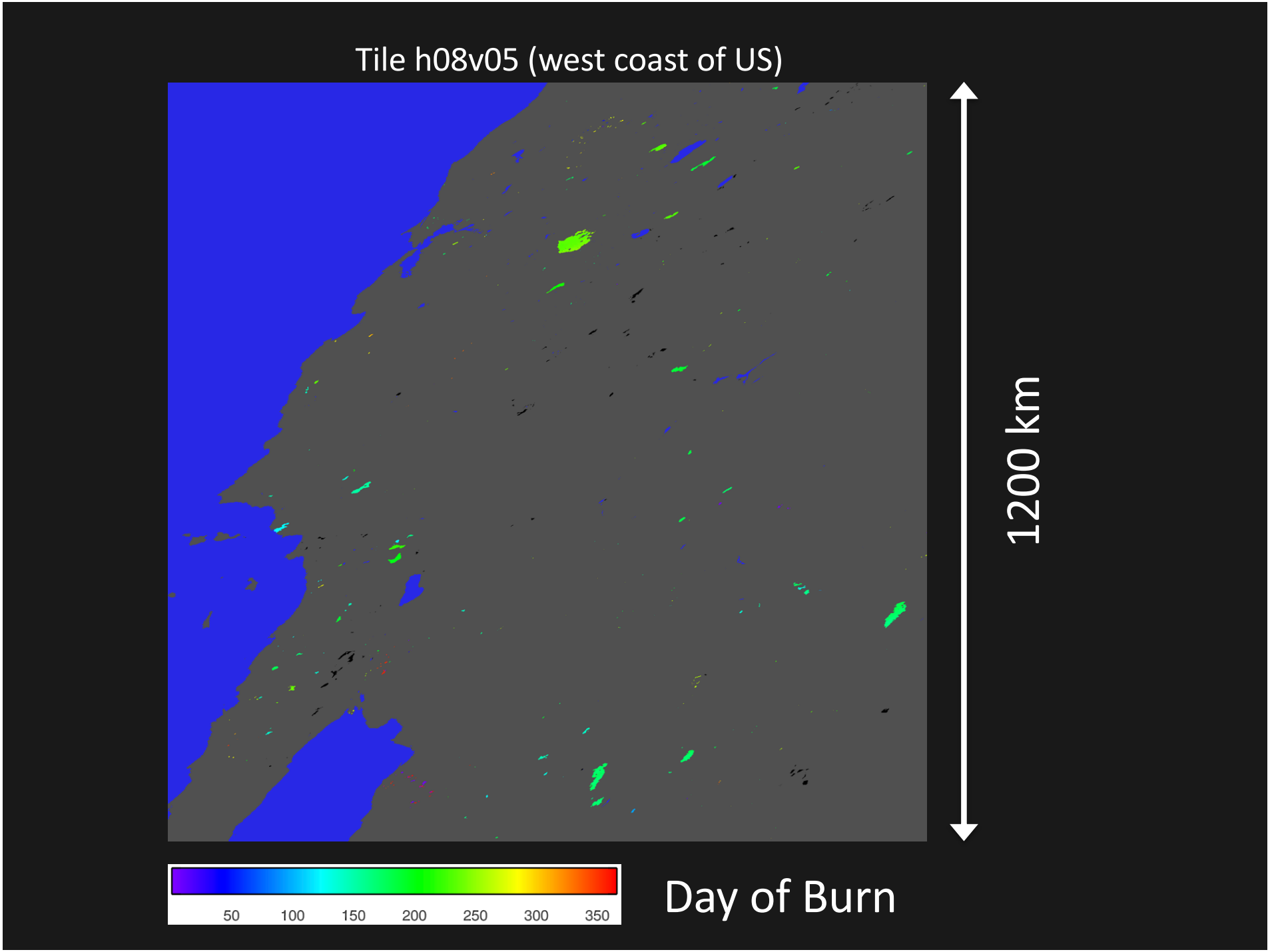


750-m VIIRS VNP14 active fire product
12 March 2013
Arcs of false fire pixels caused by spurious M13 scans.

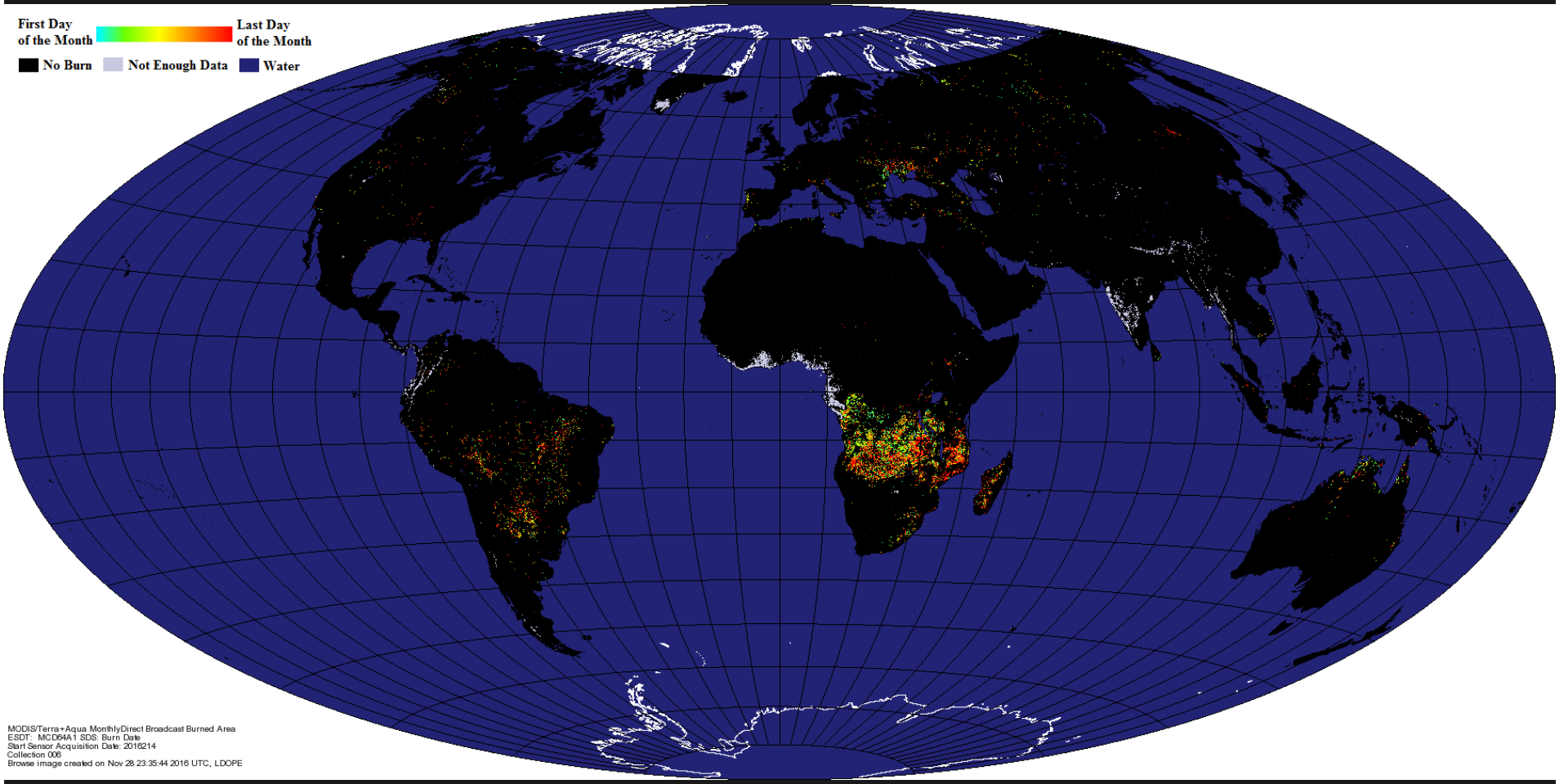
NASA MODIS Burned Area Products

MCD64A1	500-m Monthly
MCD64A1-based GIS Products (SCF)	Shapefiles + 500-m GeoTIFF
MCD64CMQ (SCF)	0.25° Monthly

In A1 product burning is mapped to the nearest day.


Tile h08v05 (west coast of US)
1200 km
50
100
150
200
250
300
350
Day of Burn

August 2016 C6 MCD64A1 Global Browse



http://landweb.nascom.nasa.gov/cgi-bin/browse/browseMODIS.cgi

Remote Sensing of Environment 113 (2009) 408–420

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

An active-fire based burned area mapping algorithm for the MODIS sensor

Louis Giglio [a,b,*], Tatiana Loboda [b], David P. Roy [c], Brad Quayle [d], Christopher O. Justice [b]

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[b] Department of Geography, University of Maryland, College Park, Maryland, USA
[c] Geographic Information Science Center of Excellence, South Dakota State University, Brookings, South Dakota, USA
[d] USDA Forest Service Remote Sensing Applications Center, Salt Lake City, Utah, USA

Original algorithm published in 2009 (C5) and updated in 2011 (C5.1) and 2016 (C6). Product known by various names ("Direct Broadcast Burned Area Product"), but ultimately "MCD64".

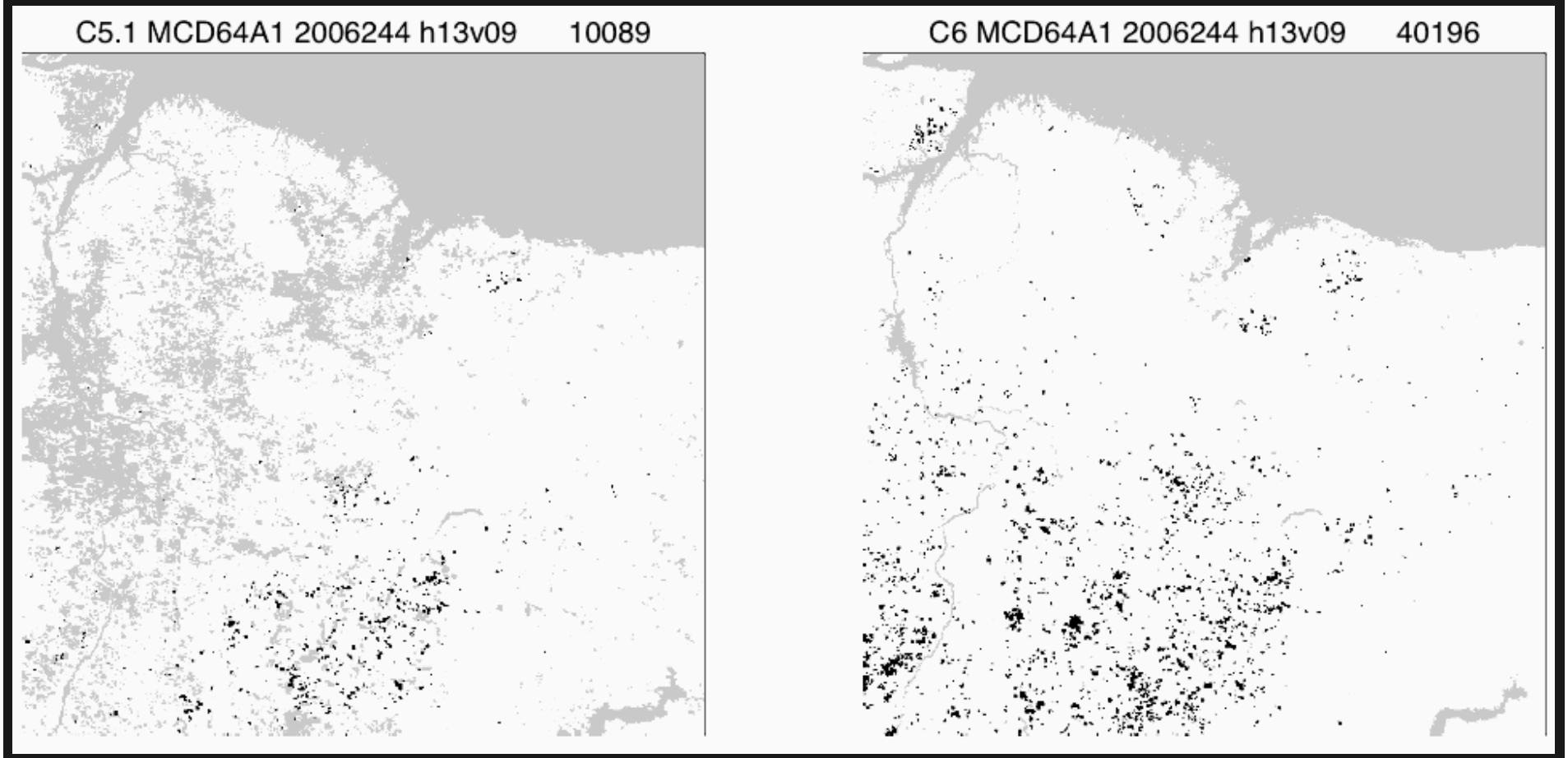
Current (C6) Input Requirements

- Daily 500-m gridded surface reflectance
  - Bands 1, 2, 5, and 7 from MODHDFSR/MYDHDFSR products
  - Terra and/or Aqua MODIS
- Daily 1-km gridded active fire maps
  - Preferably Terra + Aqua MODIS
- Land cover map
  - C5.1 MODIS MOD12Q1 product
- All input data co-registered in MODIS sinusoidal projection & partitioned into standard MODIS tiles

2008 MCD64A1 DB Implementation

- IPOPP burned area SPA
- Ingests daily corrected reflectance + daily Terra/Aqua MODIS fire-mask composites
- Input data coregistered in MODIS sinusoidal projection
- Some quality traded to reduce nominal one-month production lag to ~2 weeks
- Now obsolete
  - 108 code updates since last release in 2010!

September 2006, MODIS tile h13v09 (eastern Brazil)



C5.1 MCD64A1

C6 MCD64A1

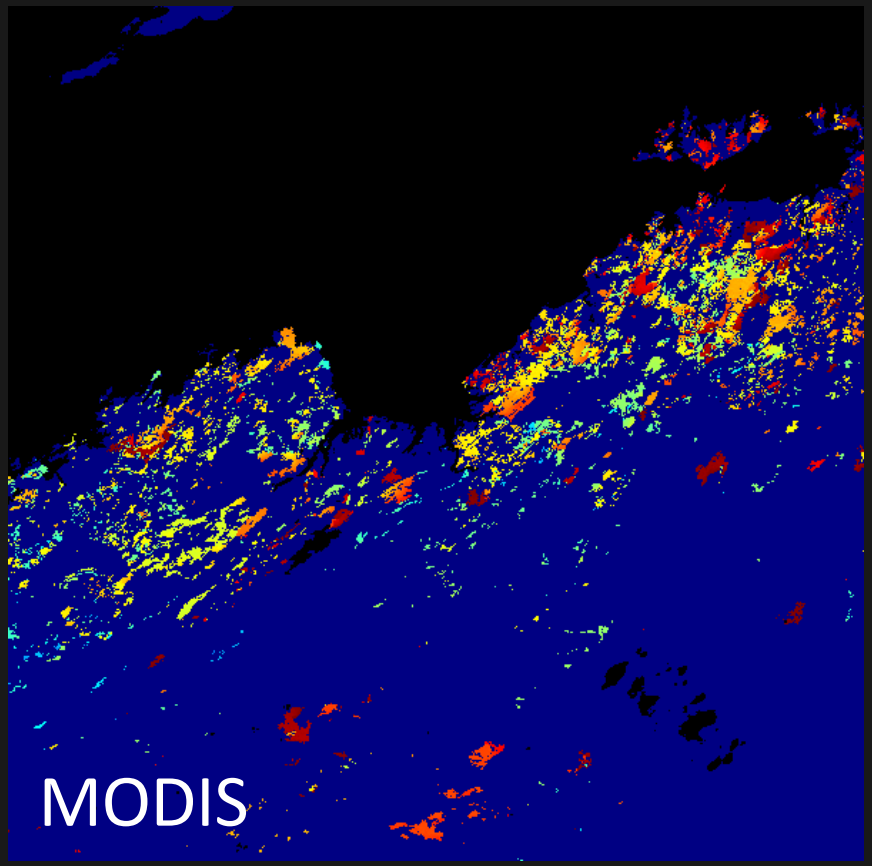
VIIRS Burned Area Products

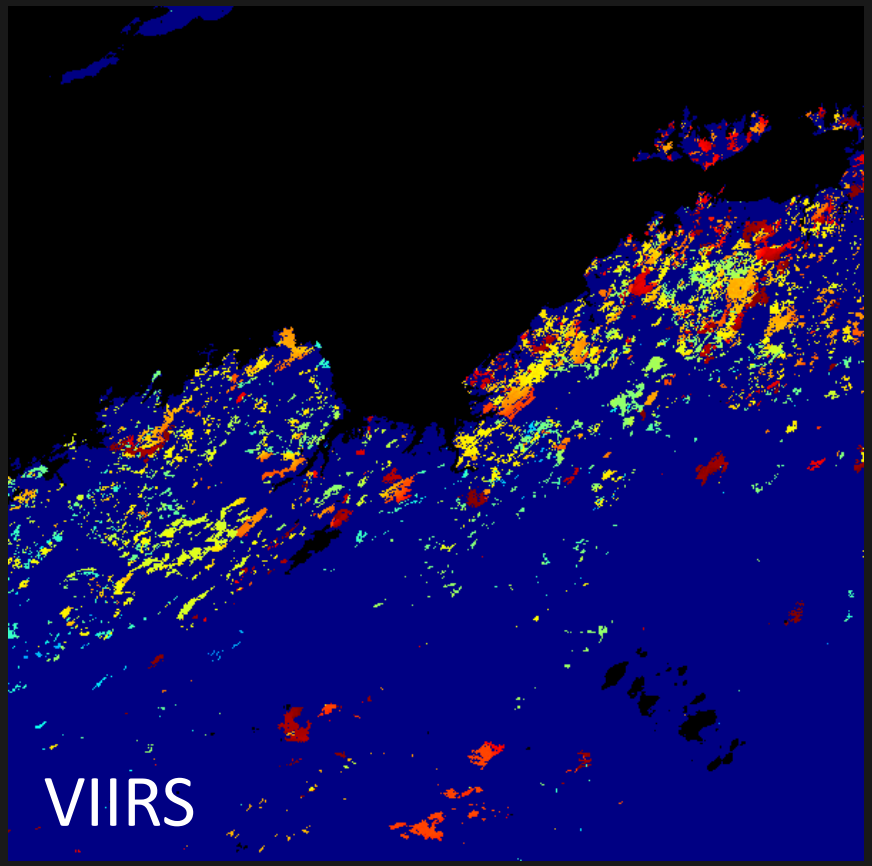
VNP64A1	500-m Monthly
VNP64A1-based GIS Products (SCF)	Shapefiles + 500-m GeoTIFF
VNP64CMQ (SCF)	0.25° Monthly

MCD64A1 mapping algorithm ported to VIIRS.

Behind schedule due to major delays in availability of upstream VIIRS input products.

MCD64A1 Burn Date
Australia (h30v10), 1 March – 31 August 2014





Goal: True NRT Burned Area Mapping

- Rapid production
  - Cumulative map through day *N* available on day *N*
  - Map is refined as additional days are acquired
- Sacrifice mapping of smallest burns for NRT
- Leverage active fire data more heavily
  - MCD64 prior probabilities

USDA U.S. FOREST SERVICE
Caring for the land and serving people
United State Department of Agriculture

Fire, Fuel, Smoke Science Program
Rocky Mountain Research Station

Home

Near Real-Time Burned Area Mapping with VIIRS

Wildland fires emit significant amounts of greenhouse gases, particulate matter, and ozone precursors which have significant negative effects on public health at multiple scales. In order to mitigate these impacts, state agencies require daily air quality forecasts to minimize exposure risk. Air quality analyses are also necessary to quantify the contribution of fires to regional air pollution and thereby support the development of effective and efficient emission controls for industrial, power generation, and transportation sources. In addition to air quality forecasting and analyses, burned area maps are invaluable tools used by emergency response teams, which often include hydrologists, wildlife biologists, soils scientists, geologists, ecologists, engineers, foresters, botanists, and GIS specialists, and which assess threats to life, property, and natural resources in the days and weeks immediately following a fire. The availability of timely, comprehensive, and consistent burned area estimates can improve fire and forest management decisions and lead to better fire emission estimates and subsequent air quality forecasts and air regulatory strategies.

Currently, the MODIS sensor on the polar-orbiting Terra and Aqua satellites provides burned area products (the satellites' orbits provide two local overpasses each day - one nighttime and one afternoon). However, the aging MODIS sensors have exceeded their expected lifetime and a longer-lasting data solution is needed. The Visible Infrared Imaging Radiometer Suite (VIIRS) sensor onboard the Suomi-National Polar-orbiting Partnership satellite (S-NPP) is the first of the next generation of sensors that will replace MODIS. To address this need a near real-time burned area detection algorithm has been developed for the VIIRS sensor. The algorithm combines VIIRS

Search

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- Corley, Rachel

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- Carl Albury
- Brenna Schwert

Funding Contributor(s):

US Forest Service, USFS Rocky Mountain Research Station

Program Focus Area(s):

Smoke Emissions and Dispersion

Project Status:

2014-2017

https://www.firelab.org/project/near-real-time-burned-area-mapping-viirs

Landsat-8 and Sentinel-2 Active Fire Mapping

- No mid-infrared channel
- NIR+SWIR ratio/differencing approach
- Saturation/folding artifacts
- Temporal signal analysis to avoid false alarms
- Stand-alone C code also available as wrapped IPOPP module

Most of the slides to follow were provided by Wilfrid Schroeder (now at NOAA).

Remote Sensing of Environment 112 (2008) 3055-3063

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

Active fire detection and characterization with the advanced spaceborne thermal emission and reflection radiometer (ASTER)

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ARTICLE INFO

Article history:
Received 16 October 2007
Received in revised form 26 February
Accepted 1 March 2008

Remote Sensing of Environment 185 (2016) 210–220

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

Active fire detection using Landsat-8/OLI data

Wilfrid Schroeder [a,*], Patricia Oliva [a], Louis Giglio [a], Brad Quayle [b], Eckehard Lorenz [c], Fabiano Morelli [d]

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ARTICLE INFO

Article history:
Received 6 April 2015
Received in revised form 10 August 2015
Accepted 31 August 2015
Available online 9 September 2015

ABSTRACT

The gradual increase in Landsat-class data availability creates new opportunities for fire science and management applications that require higher-fidelity information about biomass burning, improving upon existing coarser spatial resolution (≥1 km) satellite active fire data sets. Targeting those enhanced capabilities we describe an active fire detection algorithm for use with Landsat-8 Operational Land Imager (OLI) daytime and nighttime data. The approach builds on the fire-sensitive short-wave infrared channel 7 complemented by visible and

Landsat-class Active Fire Detection

Pros:
>150x more information per unit area than VIIRS 375 m
>1000x more information per unit area than MODIS 1km

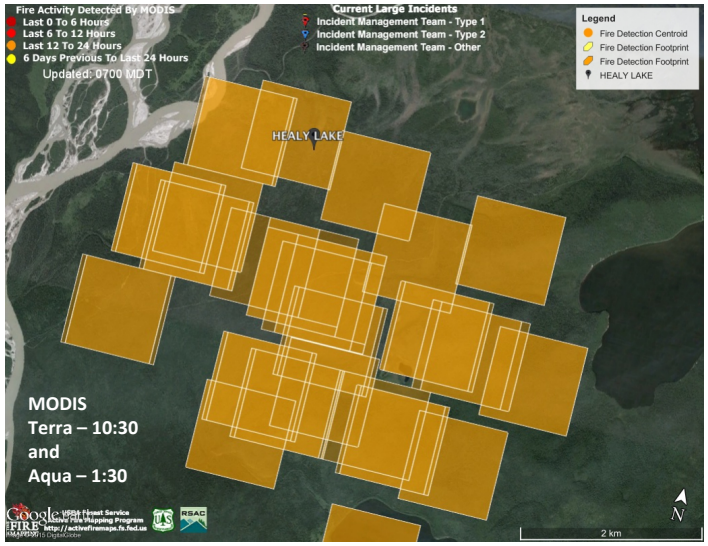
Cons:
Limited coverage/infrequent data

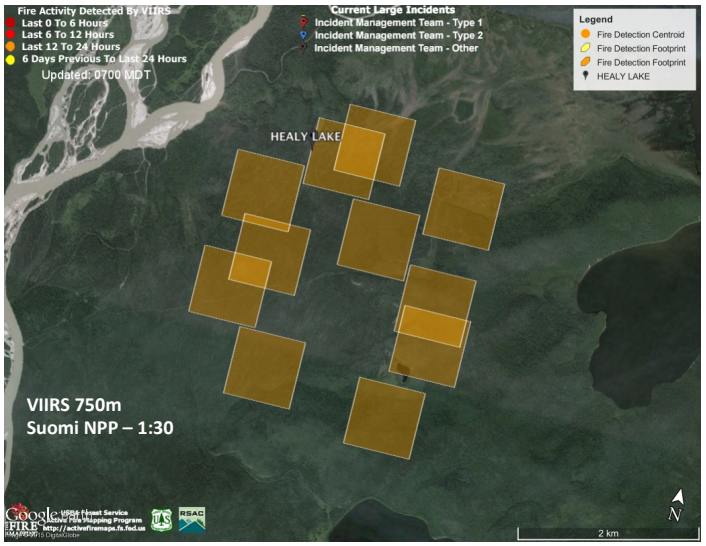
Potential:
Detecting primarily flaming fires on daytime scenes; detection of lower temperature (e.g., smoldering) targets possible with nighttime scenes
Launch of similar sensors increasing data availability

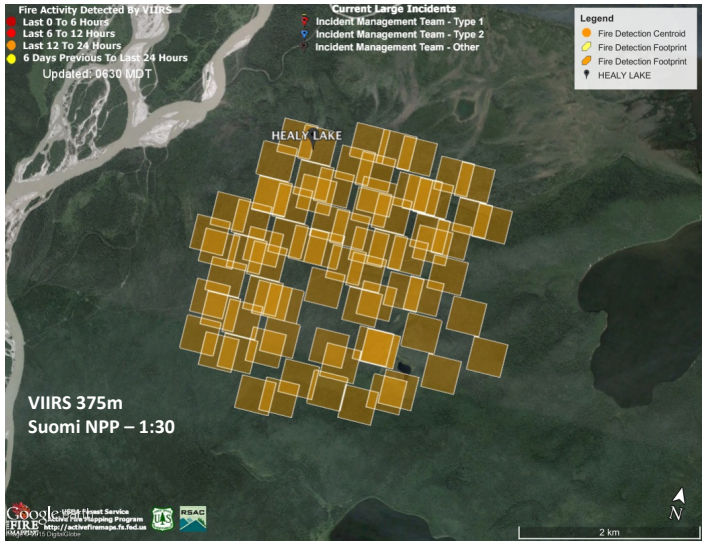
- Landsat-8, Sentinel-2A/2B

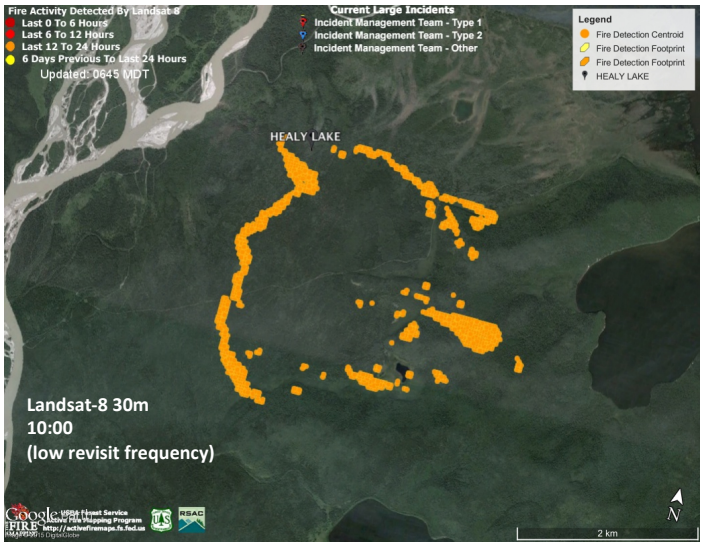
Near real-time data processing/distribution possible under certain conditions

Comparing Landsat-8 (30 m), VIIRS (375, 750), & MODIS (1km)







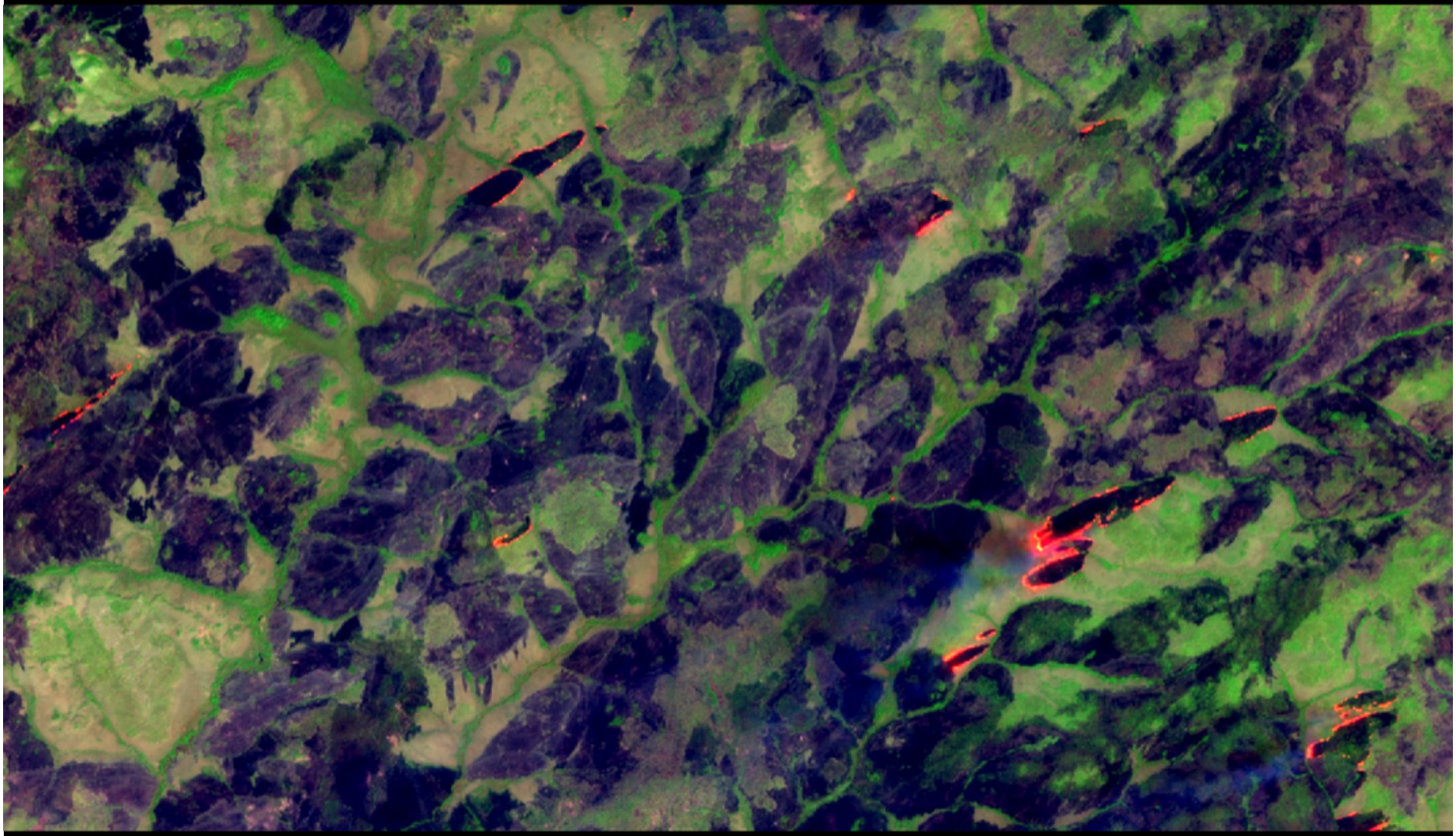


Spatial resolution

X

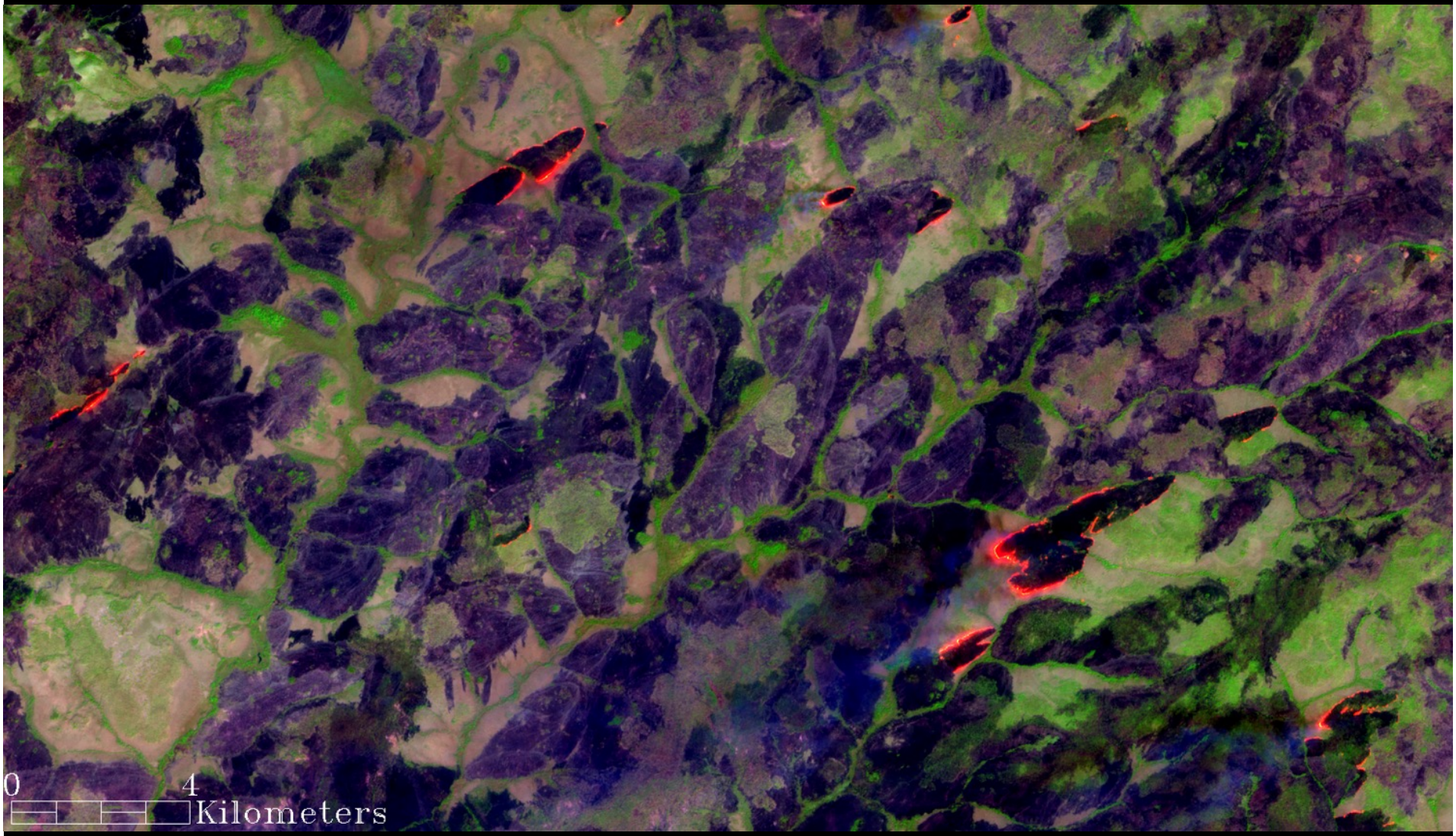
Temporal resolution (revisit cycle)

Landsat-8 + Sentinel-2A



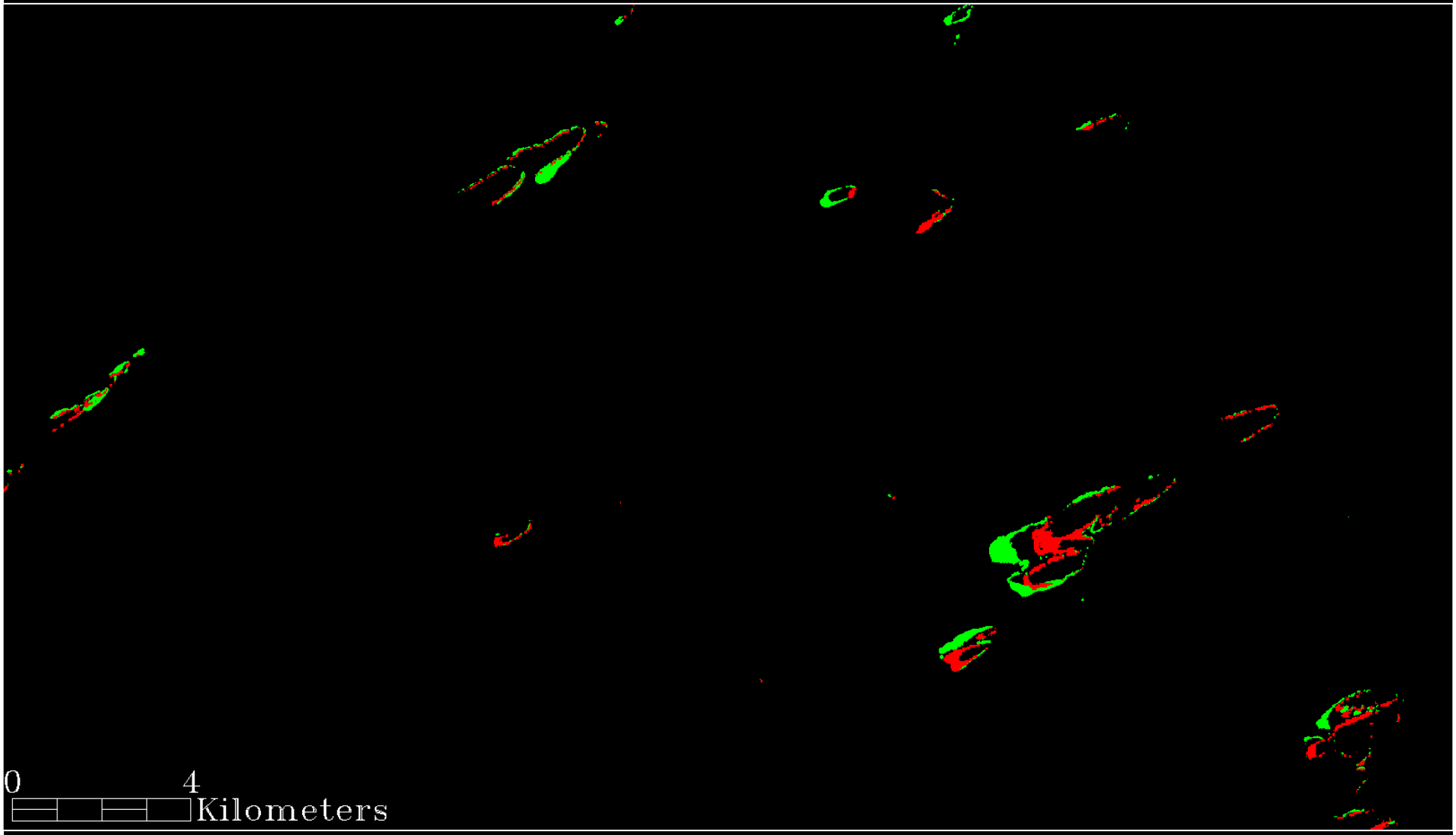
Landsat-8 (30 m)

Landsat-8 + Sentinel-2A



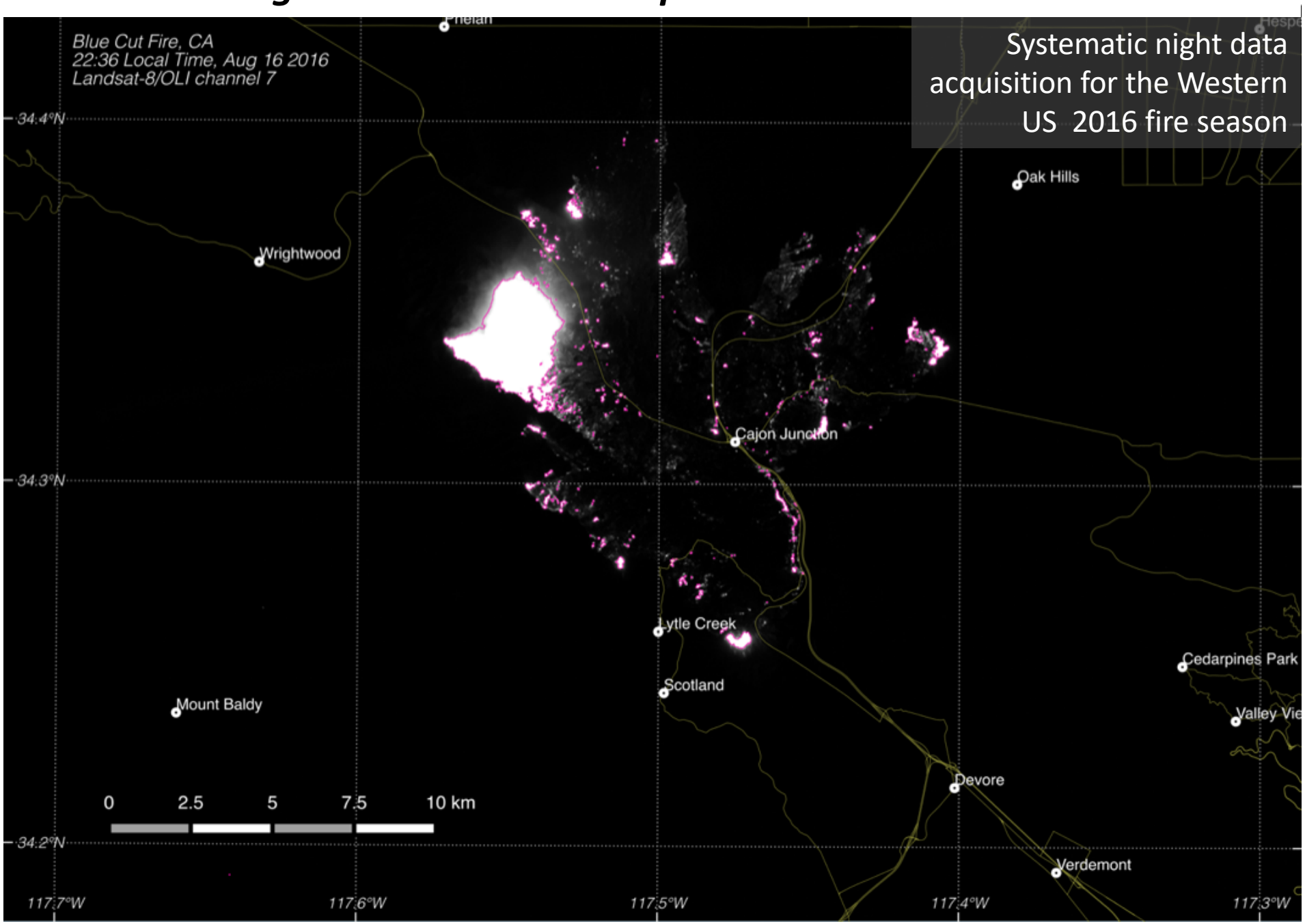
ESA/Sentinel-2A (20 m)
16 min later

Landsat-8 + Sentinel-2A

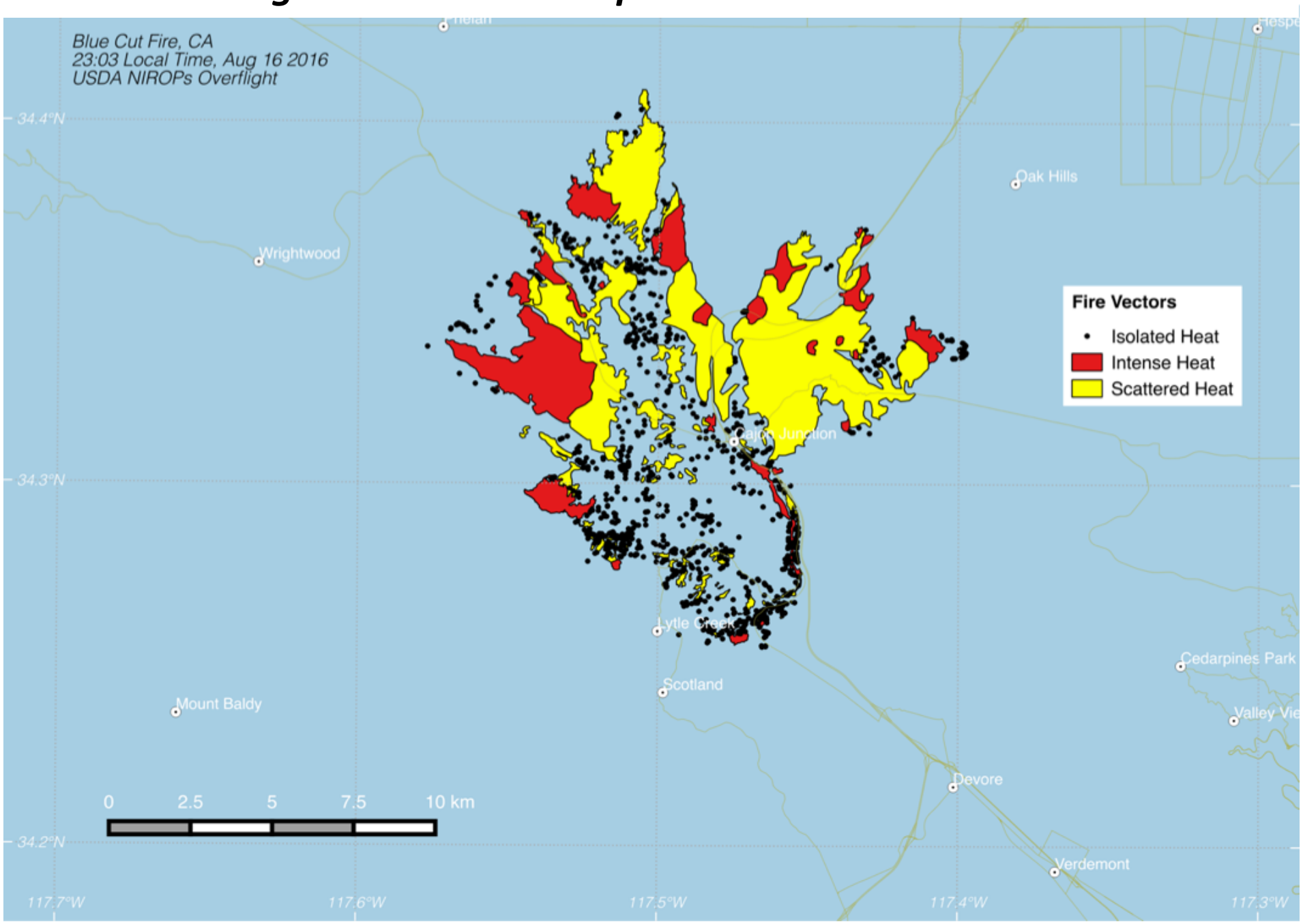


Landsat-8 fire mask: red
Sentinel-2A fire mask: green

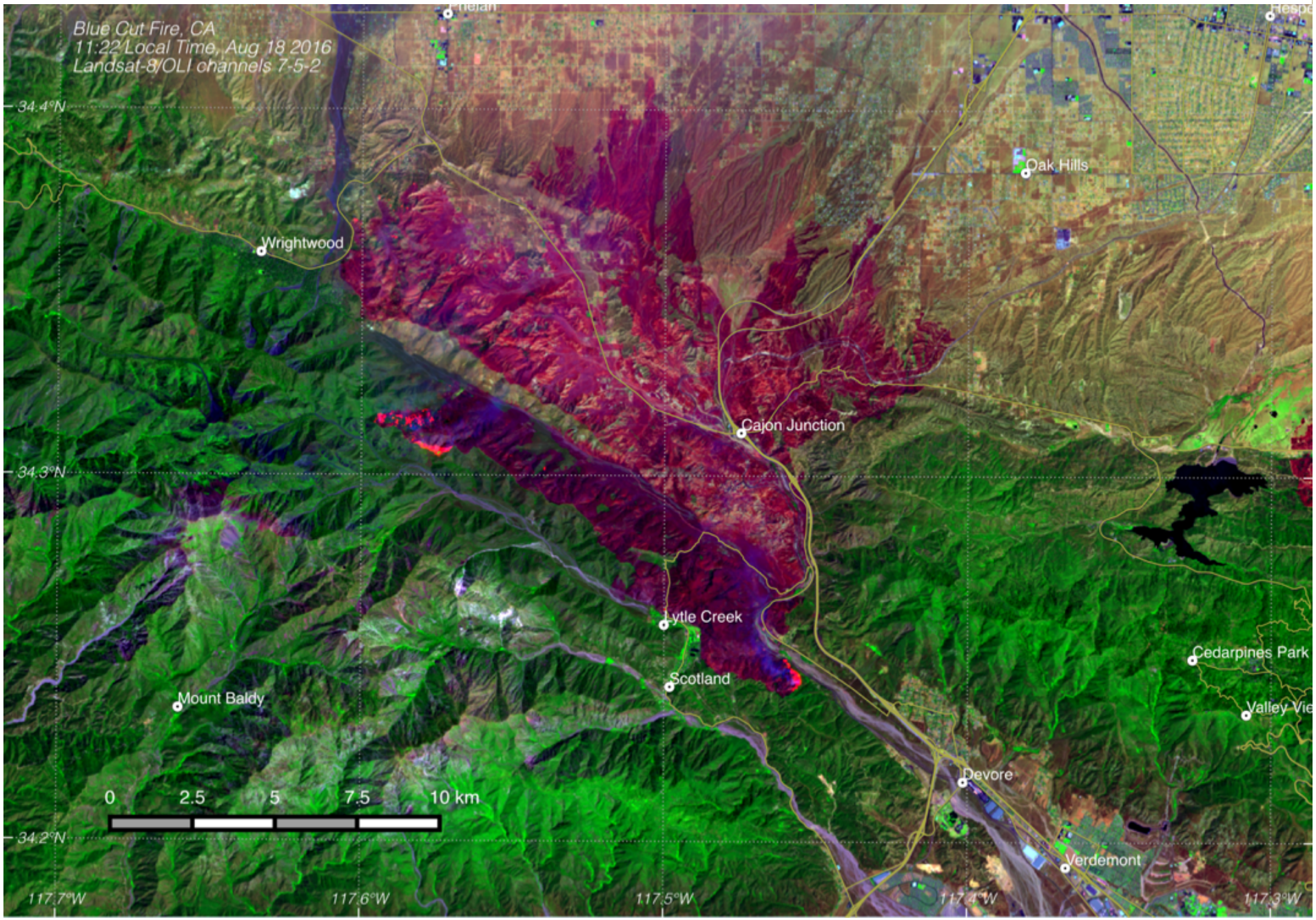
On-demand nighttime Landsat-8 acquisition



On-demand nighttime NIROPs acquisition

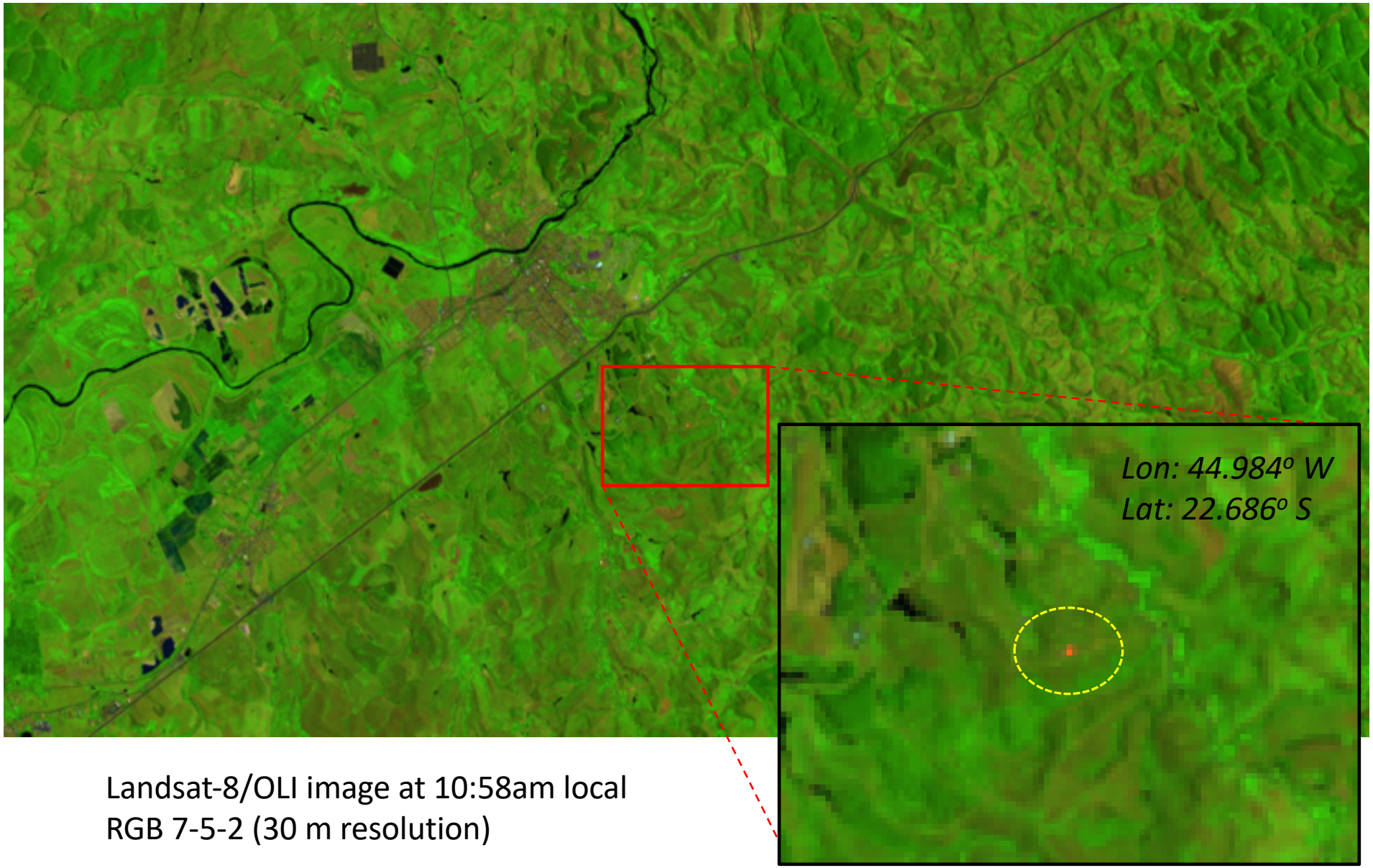


Routine daytime Landsat-8 acquisition



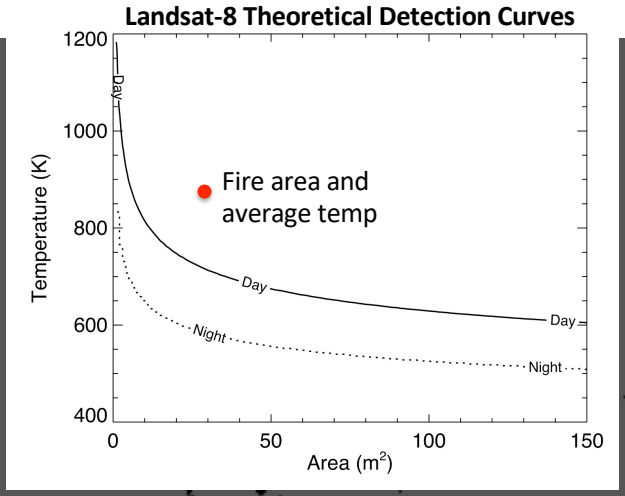
Small Fire Validation
Landsat-8 and VIIRS 375 m example in Cachoeira Paulista, Brazil

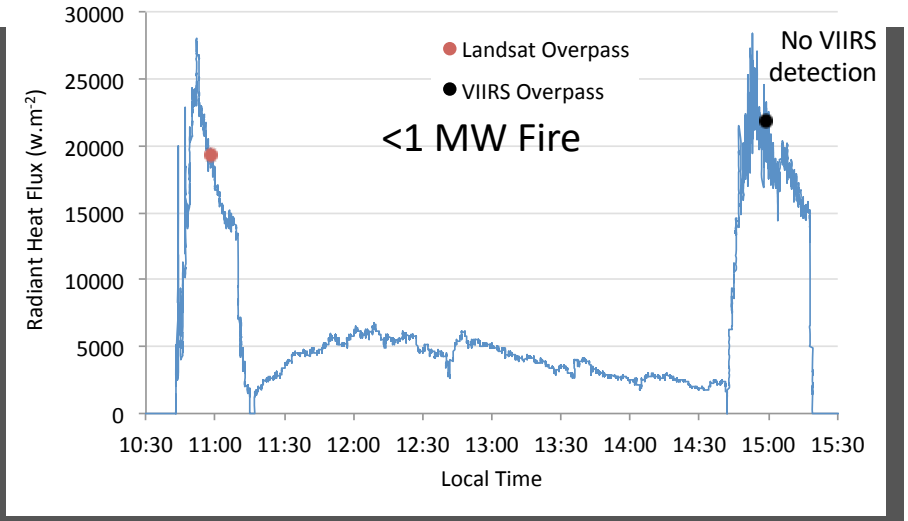
Small Fire Validation
Landsat-8 and VIIRS 375 m example in Cachoeira Paulista, Brazil



Landsat-8/OLI image at 10:58am local
RGB 7-5-2 (30 m resolution)

Small Fire Validation
Landsat-8 and VIIRS 375 m example in Cachoeira Paulista, Brazil





Fire mask (30 m resolution)

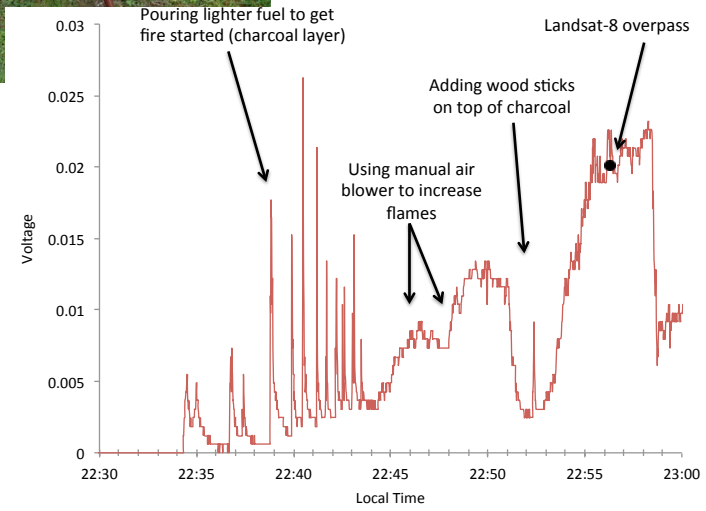
Very Small Fire Validation
Landsat-8 nighttime example in Greenbelt, MD

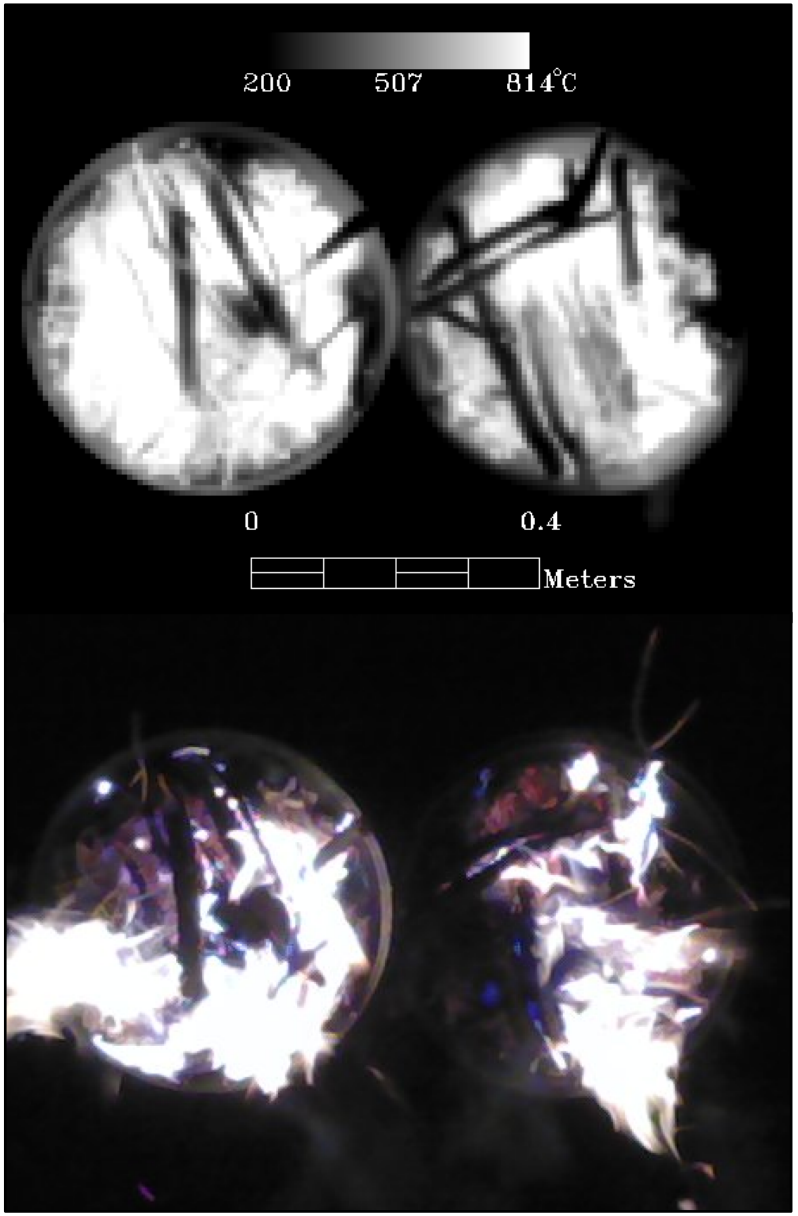
04 April 2015
10:56pm local

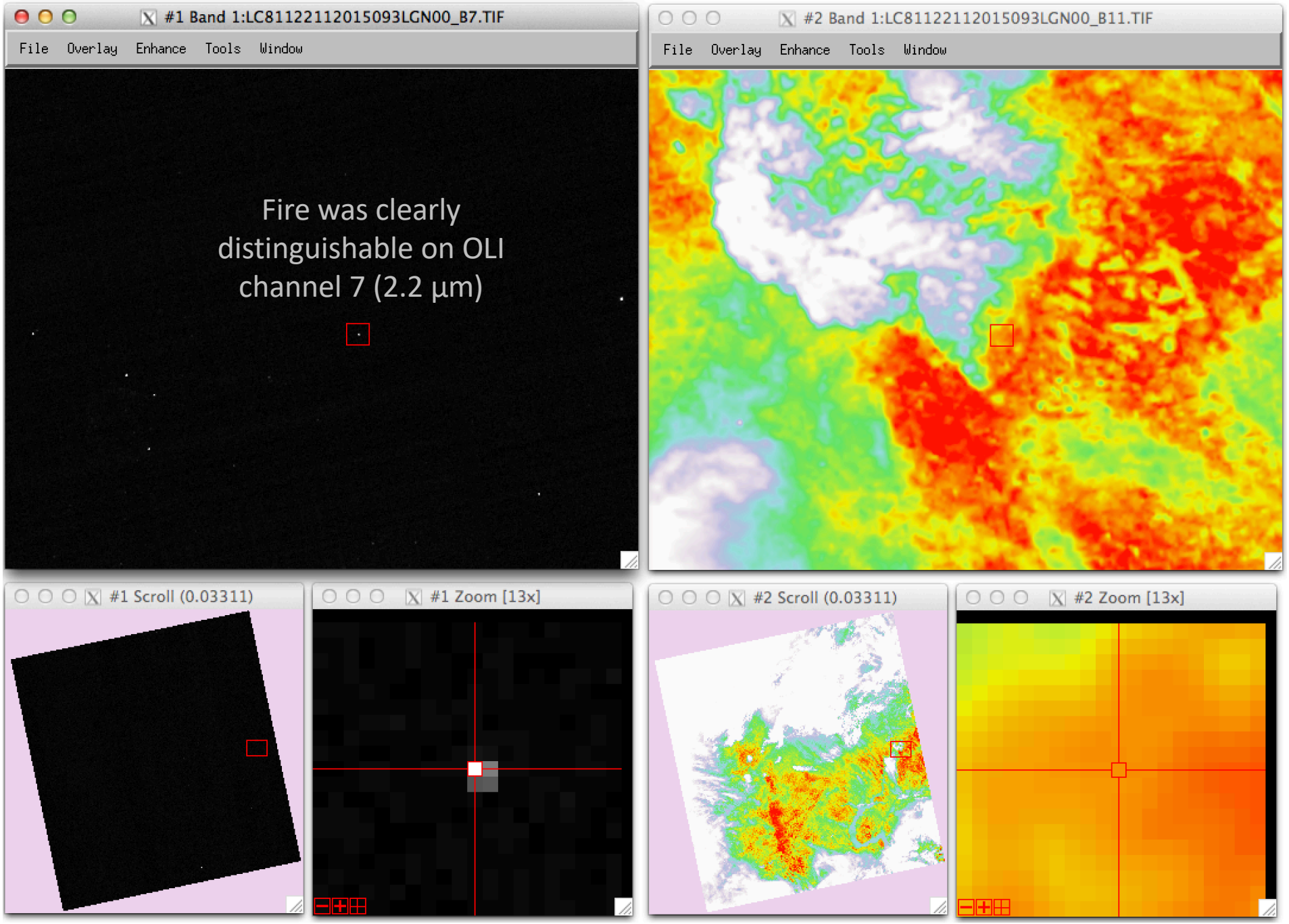
FLIR camera and dual-band radiometer mounted to 5 m telescoping tower overlooking grill fire

Effective area (combined): 0.5 m^2

Lon: 76.870° W
Lat: 39.009° N






#1 Band 1:LC81122112015093LGN00_B7.TIF
File Overlay Enhance Tools Window
Fire was clearly distinguishable on OLI channel 7 (2.2 µm)
#2 Band 1:LC81122112015093LGN00_B11.TIF
File Overlay Enhance Tools Window
#1 Scroll (0.03311)
#1 Zoom [13x]
#2 Scroll (0.03311)
#2 Zoom [13x]

Very Small Fire Validation
Landsat-8 nighttime example in Greenbelt/USA

- Fire radiative power output at overpass time (using IR camera data):

  0.01 MW

- Simulated channel 7 fire radiance (using IR camera data):

  0.453 W/m^2.sr.µm

  - Surface-equivalent (no atmosphere)

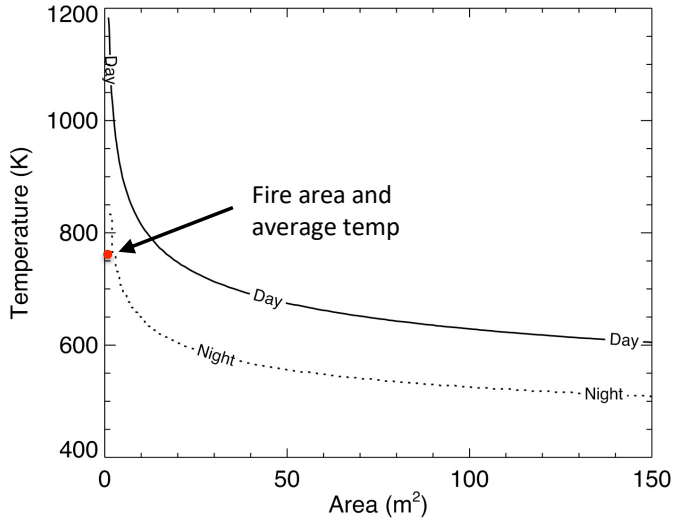
  - Assuming rectangular spatial response function and no data smearing

- Actual channel 7 top-of-atmosphere pixel radiance:

  0.229 W/m^2.sr.µm

- Single fixed threshold proposed for nighttime fire algorithm:

  1 W/m^2.sr.µm

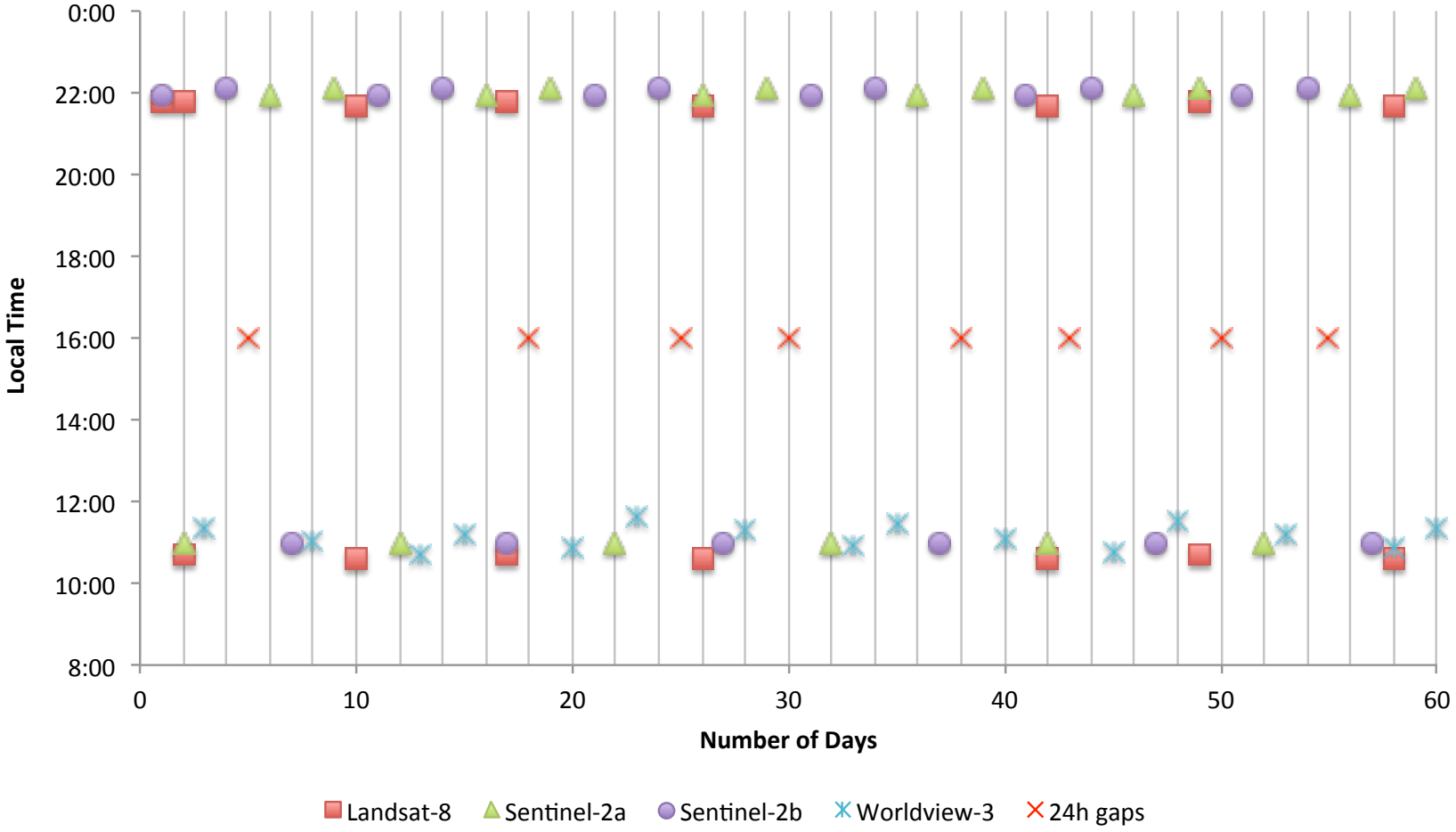


Current nighttime algorithm settings are made intentionally conservative in order to avoid large number of recreational and/or urban-related thermal anomalies!

Landsat-Class Data Coverage Potential

Expansion of sensor network and data acquisition capabilities resulting in gradual increase in observation frequency

Hypothetical coverage scenario @ 40°N including nighttime acquisitions



Landsat-8 and Sentinel-2 Burned Area Mapping

- Numerous papers/presentations/announcements on this topic during the past several years
- Most approaches employ change-in-NBR ("dNBR") thresholding
- Classification via machine learning becoming wildly popular
- Many (most?) products and/or approaches not suitable for NRT use
  - Use, e.g., Google Earth Engine

Thanks!