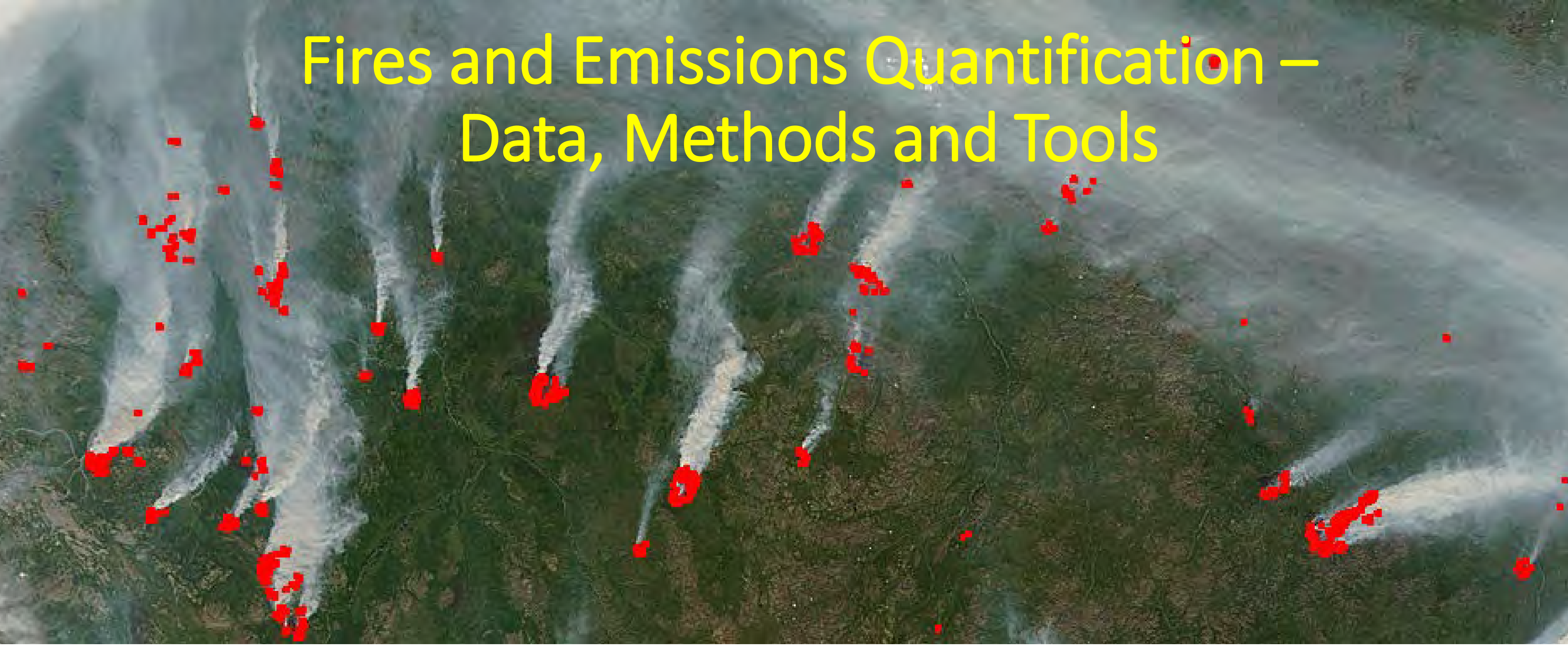
Fires and Emissions Quantification – Data, Methods and Tools



Krishna Vadrevu, NASA Marshall Space Flight Center, USA

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Marshall Space Flight Center

GOFC-GOLD

Global Observations of Forest Cover and Land Use Dynamics

UNIVERSITY OF MARYLAND

Contents

Land Use Fire: Tropical Deforestation and Pasture Maintenance, Brazil

Justice, 2021

Fire is an Interdisciplinary Subject

Fire is an important and poorly understood Earth System process

- **Land Use and Land Cover Change**
  - Fire is a major cause of surface change and occurs in most vegetation zones across the world.
  - A widespread land management tool – tropical deforestation, agricultural waste burning, rangeland management
- **Ecology**
  - fire disturbance as negative and positive ecological effects
  - US ecosystem management - moving from total fire suppression to recognizing fire as an important and natural process – fuel management
- **Hydrology**
  - impact on burned watersheds - erosion and water quality
- **Climate Change**
  - emissions of greenhouse gases and aerosols, smoke and clouds
  - Impacts of global warming on fire regimes
- **Atmospheric Composition**
  - emissions of gases and pollutants – greenhouse gases – dry and wet deposition
- **Air Quality**
  - particulates – health/respiratory problems, at risk citizens – trans boundary transport
- **Coupled Systems**
  - More people, more land use pressure (intensification and extensification), more sources of ignition, warmer drier climates, more fires, more greenhouse gases, (more smoke), feedback loops ?
- **Human hazard / cost / risk**
  - uncontrolled wildfires are a hazard at the wildland/urban interface
  - impact on protected areas / biodiversity

Vegetation Fires and Emissions Estimation

Seiler and Crutzen (1980) – Emissions Estimation Approach

M (quantity of gas emitted) = Area x Biomass Density x Burning Efficiency x Emission Factor

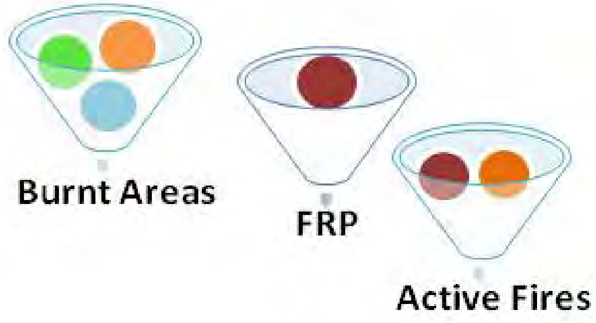
- Area – Satellite based mapping;
- Biomass density/fuel loading – (vegetation type mapping);
- Burning or combustion efficiency - (most uncertain - field measurements);
- Emission factors (field or lab based) - satellite based surrogate measures combined with Inverse modeling

Satellite Fire Products

Satellites	VIS	NIR	SWIR	MIR	TIR	Spatial
Disaster Monitoring Constellation	●	●				32m
ENVISAT-MERIS	●	●				300m
DMSP-OLS	●	●				2-3km
TRMM VIRS	●	●	●			2km
SPOT-VGT	●	●	●			1km
Bird		●		●	●	185-370m
ERS-2 ATSR ENVISAT-2 AATSR	●	●	●	●	●	1km
TERRA/AQUA/MODIS	●	●	●	●	●	250-1km
NOAA/METOP/AVHRR	●	●	●	●	●	1km
GMES-Sentinel-SLST	●	●	●	●	●	500-1km
NPP/NPOESS VIIRS	●	●	●	●	●	375-250
LDCM	●	●	●	●	●	30m

Sentinel Missions with various combinations of bands

-Burnt Areas, Visible and SWIR
-Active Fires: Thermal + MIR
-Fire Radiative Power Products - MIR



Burned Area Products and Emissions

M (quantity of gas emitted) = Area x Biomass Density x Burning Efficiency x Emission Factor

India – Forest Biomass (t/ha)

	Place name	Forest type	Tree density (ha)	Total basal area (m2/ha)	ABG Biomass (t/ha)
1	Garhwal Himalayas	Pine-Oak forest	889	75.12	8
2	Shoolpaneshwar wildlife sanc	Tropical dry deciduous	NA	NA	88
3	Bilaspur circle of Korba, Chattisgarh	Tropical dry forest	306	20.2	155
4	Tehri Garhwal,	Mixed deciduous forest	NA	NA	130
5	Garo Hills, NEAST-1	Shorea robusta (60 year old growth)	570	54.9	259.8
6	Garo Hills, NEAST-2	60 year old plantation	608	54	255.96
7	Garo Hills, NEAST-3	Mixed Sal forest - 60 yr	688	58	272.83
8	Garo Hills, NEAST-4	Mixed Sal natural forest 50 yr	640	42.67	204.15
9	Garo Hills, NEAST-5	As above	690	49.21	233.25
10	Garo Hills, NEAST-6	Primary forest undisturbed	846	67.18	314.02
11	Himalayas, Kashmir	Coniferous	120	NA	90
12	Kashmir Himalayas	Himalayan temperate forest	210	NA	150
13	Kolli forests, Eastern Ghats	Tropical Evergreen forest	1946	NA	336
14	Chikaldhara hill station	Tropical mixed forest	NA	NA	49
15	Banthra, Lucknow	Tropical dry deciduous	554	29.9	30
16	Northern Haryana	Tropical Mixed deciduous	564	27	132
17	Assam Gibbon	Evergreen forest	286	90.29	135.3
18	Assam Kholahat	Evergreen forest	416	62.49	146.42
19	Bhuban Hills, Assam-1	Evergreen forest	396	16.96	NA
20	Bhuban Hills, Assam-2	Evergreen forest	590	21.14	NA
21	Bhuban Hills, Assam-3	Evergreen forest	344	17.21	NA
22	Bhuban Hills, Assam-4	Evergreen forest	614	38.44	NA
23	Bhuban Hills, Assam-5	Evergreen forest	718	42.54	NA
24	Bhuban Hills, Assam-6	Evergreen forest	794	45.07	NA
25	Uttara Kanara	Wet semi-evergreen forest	414	25.62	249.67
26	Ekkambi	Wet semi-evergreen forest	1087	43	417
27	Hosur	Wet semi-evergreen forest	1409	42.95	417
28	Malgi	Wet semi-evergreen forest	928	34.1	344
29	Togralli	Wet semi-evergreen forest	1647	36.19	361
30	Malgi	Wet semi-evergreen forest	468	33.67	340
31	Ananthnag District, Kashmir	Low lying temperate forests	NA	NA	NA
32	Ananthnag District, Kashmir-2	Juglans regia	1201	36.1	204
33	Ananthnag District, Kashmir-3	Populus deltoides	220	38.5	157
34	Ananthnag District, Kashmir-4	Salix sp.	195	43.6	284
35	Ananthnag District, Kashmir-5	Pinus wallichiana	199	44.9	272
36	Ananthnag District, Kashmir-6	Cedrus deodara	196	46.7	276
37	Ananthnag District, Kashmir-7	Abies pindrow	197	51.9	294
38	Ananthnag District, Kashmir-8	Betula utilis	103	19.4	100.8

Typical biomass densities can be obtained through literature review or through field surveys.

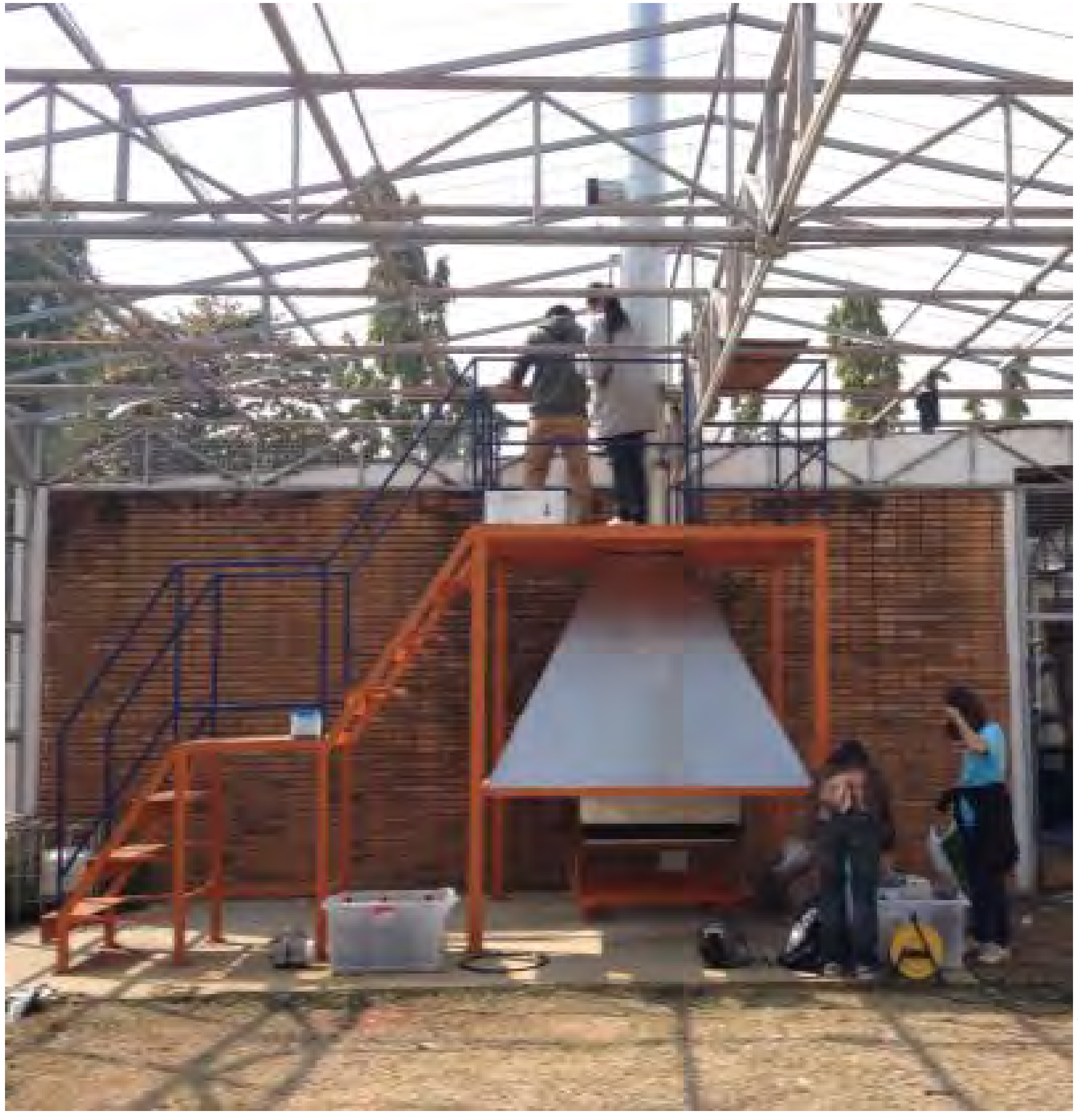
Taking girth measurements of trees and then using allometric equations linking girth with the Biomass. Per unit area measurements can be obtained through averaging the trees per plot.

M (quantity of gas emitted) = Area x Biomass Density x Burning Efficiency x Emission Factor

-Burning or combustion efficiency is the hardest and have highest uncertainties
-Also called combustion completeness (how much of actual biomass is burnt in field)
-Measurements before and after fire and accounting for moisture content

-Forest biomass – only 30% burnt
-Ag. Residues – 70-80% burnt

M (quantity of gas emitted) = Area x Biomass Density x Burning Efficiency x Emission Factor



Source: Dr. Somporn Chantara, Chiang Mai University

Combustion Chamber Experiment for Trace Gases

Biomass Burning Field Campaigns

Bamboo

Cleared Patches

Slashed BAMBOO

Burnt Bamboo

Hill Tops

Secondary Growth

Dry Deciduous Forests

Multi-Wavelength Radiometer

Multi-Filter Rotating Shadow-Band Radiometer (MFRSR)

PREDE Sky Radiometer

Portable Trace Gas Analyzers
CO, CO_2, NOx, SO_2

NRSC - ISRO

SUV & UVA Meter

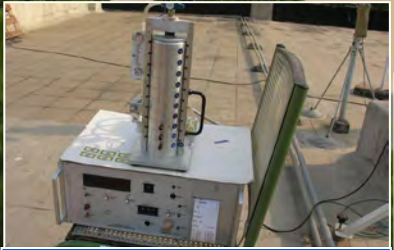
CO Analyser

Automatic Weather Station

UV Multi-Filter Rotating Shadow Band Radiometer

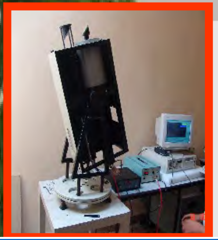
Microtops II Sun Photometer

Portable Aerosol Spectrometer (GRIMM)



Quartz Crystal Micro balance (QCM) Cascade Impactor

Aethalometer



Micro-pulse LIDAR

Forest Fire Mapping and Monitoring, Evergreen Forests, Northeast India









M (quantity of gas emitted) = Area x Biomass Density x Burning Efficiency x Emission Factor

Emission factors (g/kg) Akagi et al., 2011

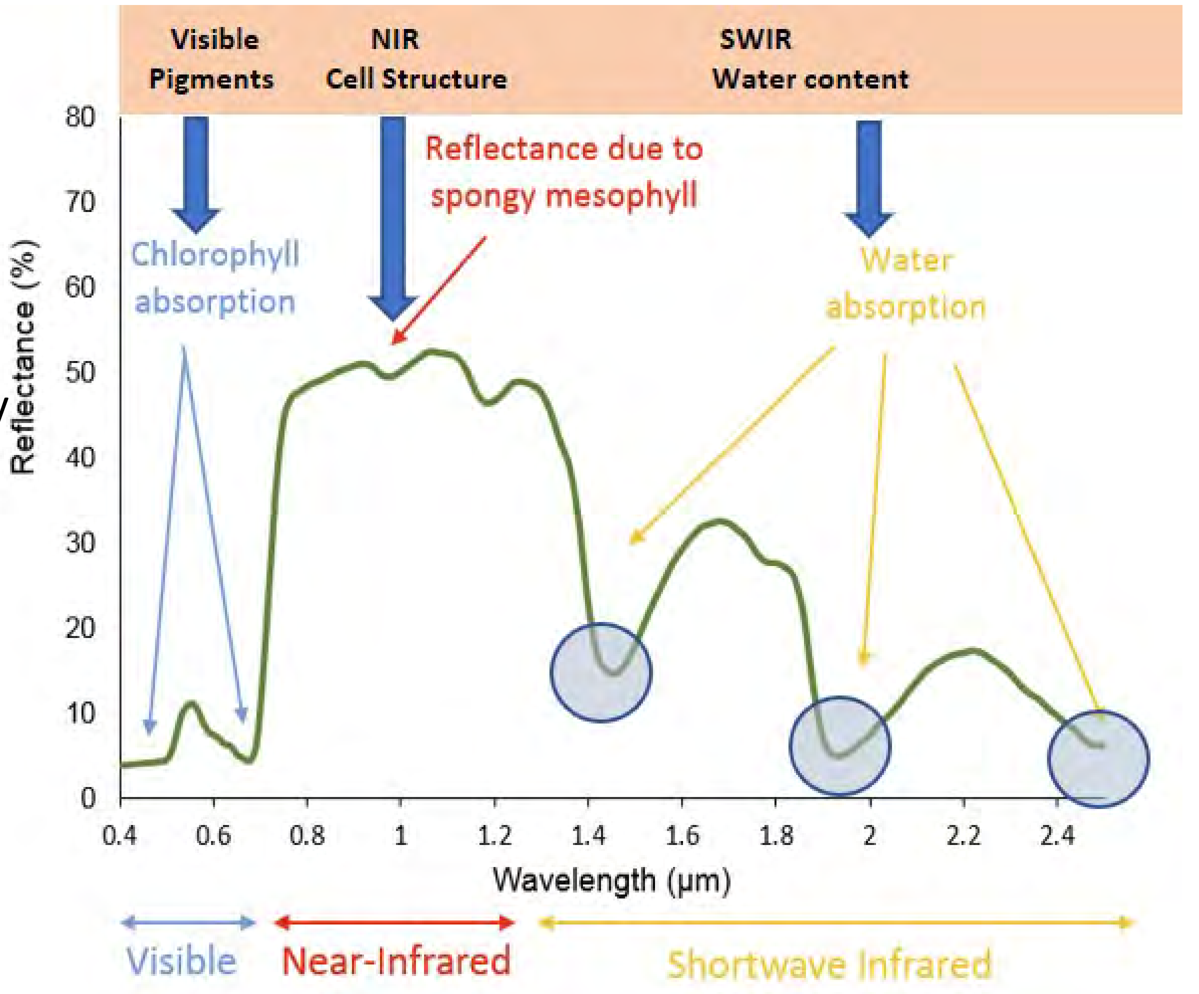
Compound	Peatland	Chaparral	Open Cooking	Patsari Stoves	Charcoal Making[a]	Charcoal Burning[b]	Dung Burning	Garbage Burning
Carbon Dioxide (CO_2)	1563 (65)	1703 (38)	1548 (125)	1610 (114)	1626 (244)	2385	859 (15)	1453 (69)
Carbon Monoxide (CO)	182 (60)	71 (13)	77 (26)	42 (19)	255 (52)	189 (36)	105 (10)	38 (19)
Methane (CH_4)	11.8 (7.8)	2.74 (0.74)	4.86 (2.73)	2.32 (1.38)	39.6 (11.4)	5.29 (2.42)	11.0 (3.3)	3.66 (4.39)
Acetylene (C_2H_2)	0.14 (0.093)	0.20 (0.08)	0.97 (0.50)	0.28 (0.01)	0.21 (0.02)	0.42	–	0.40 (0.28)
Ethylene (C_2H_4)	1.79 (0.72)	0.81 (0.18)	1.53 (0.66)	0.46 (0.12)	3.80 (1.15)	0.44 (0.23)	1.12 (0.23)	1.26 (1.04)
Ethane (C_2H_6)	–	0.36 (0.11)	1.50 (0.50)	–	12.2 (9.3)	0.41 (0.13)	–	–
Propylene (C_3H_6)	2.3 (0.74)	0.41 (0.13)	0.57 (0.34)	0.03	4.12 (1.89)	–	1.89 (0.42)	1.26 (1.42)
Propane (C_3H_8)	–	0.19 (0.09)	–	–	–	–	–	–
Butane (C_4H_{10})	–	0.14 (0.07)	–	–	–	–	–	–
Isoprene (C_5H_8)	1.07 (0.44)	–	–	–	–	–	–	–
Toluene ($C_6H_5CH_3$)	1.21 (0.69)	–	–	–	–	–	–	–
Benzene (C_6H_6)	2.46 (1.21)	–	–	–	–	–	–	–
Methanol (CH_3OH)	5.36 (3.27)	0.91 (0.29)	2.26 (1.27)	0.39 (0.39)	54.9 (27.9)	1.01	4.14 (0.88)	0.94 (1.25)
Acetol ($C_3H_6O_2$)	3.43 (0.36)	–	–	–	21.6 (35.3)	–	9.60 (2.38)	–
Phenol (C_6H_5OH)	4.36 (5.06)	0.44 (0.08)	3.32	–	10.4 (6.6)	–	2.16 (0.36)	–
Furan (C_4H_4O)	1.51 (0.37)	0.22 (0.09)	0.40	–	3.94 (2.30)	–	0.95 (0.22)	–
Formaldehyde (HCHO)	1.69 (1.62)	0.88 (0.27)	2.08 (0.86)	0.37 (0.40)	3.62 (2.42)	0.60	–	0.62 (0.13)
Glycolaldehyde ($C_2H_4O_2$)	1.22 (1.95)	0.06 (0.19)	0.66	–	–	–	–	–
Acetaldehyde (CH_3CHO)	2.81 (1.36)	–	–	–	–	–	–	–
Carbonyl Sulfide (OCS)	1.20 (2.21)	–	–	–	–	–	–	–
Acetic Acid (CH_3COOH)	7.08 (3.40)	1.32 (0.45)	4.97 (3.32)	0.34	44.8 (27.3)	2.62	11.7 (5.08)	2.42 (3.32)
Formic Acid (HCOOH)	0.54 (0.71)	0.06 (0.03)	0.22 (0.17)	0.0048	0.68 (0.20)	0.063	0.46 (0.31)	0.18 (0.12)
Acetone (C_3H_6O)	1.08 (0.29)	–	–	–	–	–	–	–
Hydrogen Cyanide (HCN)	5.00 (4.93)	0.46 (0.11)	–	–	0.21 (0.17)	–	0.53 (0.30)	0.47
Methyl Ethyl Ketone (C_4H_8O)	–	–	–	–	–	–	–	–
Hydrogen Chloride (HCl)	–	0.17 (0.14)	–	–	–	–	–	3.61 (3.27)
Methyl Vinyl Ether (C_3H_6O)	0.85	–	–	–	–	–	–	–
Acetonitrile (CH_3CN)	3.70 (0.90)	–	–	–	–	–	–	–
Sulfur Dioxide (SO_2)	–	0.68 (0.13)	–	–	–	–	0.06	0.5
Hydrogen (H_2)	–	–	–	–	–	–	–	0.091
Ammonia (NH_3)	10.8 (12.4)	1.26 (0.62)	0.87 (0.40)	0.03	1.24 (1.44)	0.79	4.75 (1.00)	0.94 (1.02)
Nitrogen Oxides (NO_x as NO)	–	3.29 (1.02)	1.42 (0.72)	–	0.22 (0.22)	1.41	0.5	3.74 (1.48)
Nitrous Oxide (N_2O)	–	0.25 (0.18)	–	–	–	0.24	–	–

- M (quantity of gas emitted) = Area x Biomass Density x Burning Efficiency x Emission Factor

Burnt Areas from Satellites

Typical Vegetation Reflectance and Burnt Areas

- In the visible region of the spectrum (400-700 nm; 1 micrometer (µm) = 1000 nanometers), Pigments dominate reflectance. Chlorophyll (a and b) selectively absorbs blue (400–500 nm) and red (600–700 nm) light for photosynthesis and absorbs less over the green wavelengths (500–600 nm) and thus the green appearance of healthy vegetation.
- In the near-infrared region (NIR) region (700-1400nm), the spongy mesophyll and cellular structure of the leaves dominate reflectance.
- In the shortwave infrared (SWIR) region, the water absorption dominates in the 1450nm, 1950nm, and 1250nm. The overall reflectance in SWIR is governed by internal vegetation structure and water absorption.
- Typical healthy vegetation shows ***very high reflectance in the NIR and low reflectance in the SWIR region***.
- Burnt areas: **A decrease in NIR and an increase in SWIR**; such differences can be used to distinguish burnt areas from the healthy vegetation.

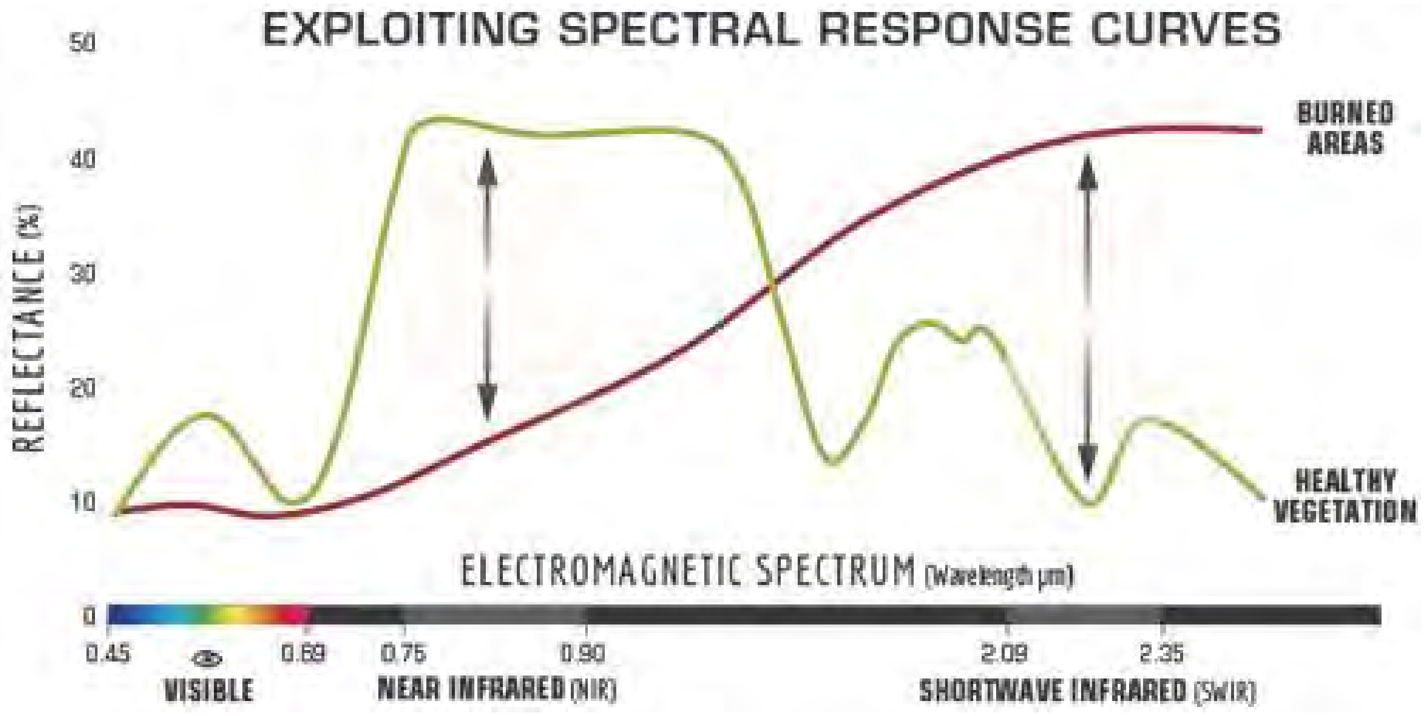


Burnt Area Signal

Burned areas are characterized by: **Removal of vegetation, alteration of vegetation structure and deposits of charcoal and ash, and alteration of the vegetation structure (Pereira et al.,1997, Roy et al., 1999).**

The MODIS burned area mapping algorithm takes advantage of these spectral, temporal, and structural changes.

The algorithm detects the approximate date of burning at a spatial resolution of 500 m by locating the occurrence of rapid changes in daily surface reflectance time series data.



Source: UNSPIDER.org

Also, Burnt Vegetation Indices such as Normalized Burnt Ratio = NIR-SWIR / NIR+SWIR

-High NBR = Healthy Vegetation
-Low NBR = bare ground and recently burnt areas

Status of MODIS Burned Area Product

MODIS Burned Area Products

Collection 6: (released 2017)

- •MCD64A1: Monthly L3 500 m SIN Grid
- •MCD64CMH: Monthly CMG

Status and Updates:

- Widely used mature product
- Stage-3 validation complete

Known Issues:

- None

Recent Publications:

- Yu et al., 2020, Quantifying the drivers and predictability of se changes in African fire. Nature Communications, 11:2893.
- Humber, M., Boschetti, L., and Giglio, L., 2019, Assessing the accuracy of coarse resolution burned area identifications. *IEE Transactions on Geoscience and Remote Sensing*, 58:1-11.

nature COMMUNICATIONS

ARTICLE

Check for updates

https://doi.org/10.1038/s41467-020-16692-w OPEN

Quantifying the drivers and predictability of seasonal changes in African fire

Yan Yu [1,7], Jiafu Mao [2,7], Peter E. Thornton [2], Michael Notaro[3], Stan D. Wullschleger[2], Xiaoying Shi[2], Forrest M. Hoffman [4,5] & Yaoping Wang [6]

Geophysical Research Letters

RESEARCH LETTER

10.1029/2019GL083469

Changes in Fire Activity in Africa from 2002 to 2016 and Their Potential Drivers

Maria Zubkova[1], Luigi Boschetti[1], John T. Abatzoglou[2], and Louis Giglio[3]

[1]Department of Natural Resources and Society, University of Idaho, Moscow, ID, USA, [2]Department of Geography, University of Idaho, Moscow, ID, USA, [3]Department of Geographical Sciences, University of Maryland, College Park, MD, USA

Key Points:

- Burned area in Africa declined by 18.5% (51.9 Mha) from 2002-2016
- The majority of the decline (35.4 Mha) occurred in noncropland areas
- 71.2% of the decline in noncropland burned area can be explained by changes in effective rainfall

Supporting Information:

- Supporting Information S1
- Table S1
- Table S5
- Table S6

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Abstract While several studies have reported a recent decline in area burned in Africa, the causes of this decline are still not well understood. In this study, we found that from 2002 to 2016 burned area in Africa declined by 18.5%, with the strongest decline (80% of the area) in the Northern Hemisphere. One third of the reduction in burned area occurred in croplands, suggesting that changes in agricultural practices (including cropland expansion) are not the predominant factor behind recent changes in fire extent. Linear models that considered interannual variability in climate factors directly related to biomass productivity and aridity explained about 70% of the decline in burned area in natural land cover. Our results provide evidence that despite the fact that most fires are human-caused in Africa, increased terrestrial moisture during 2002–2016 facilitated declines in fire activity in Africa.

https://modis-fire.umd.edu/

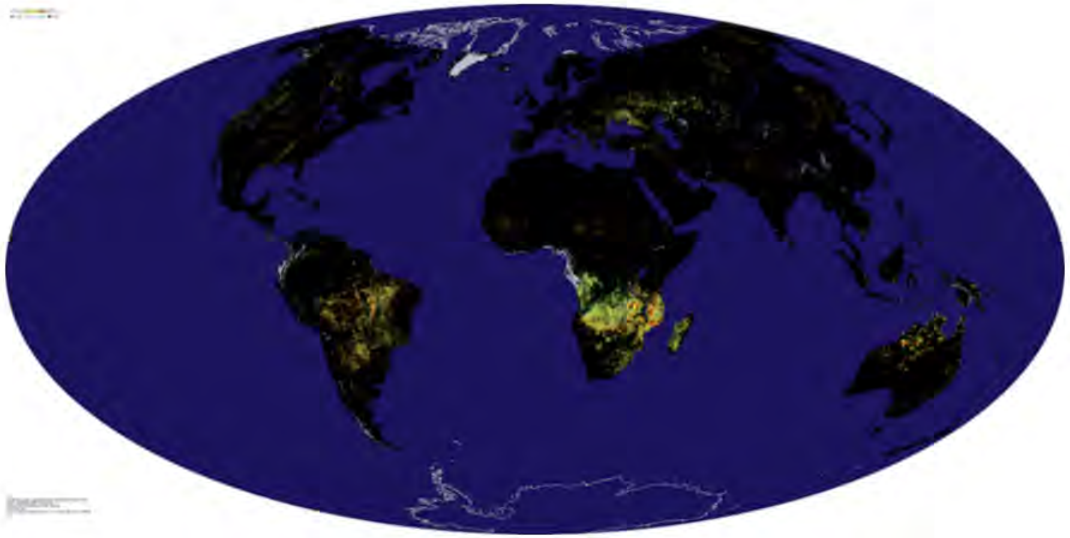
MODIS ACTIVE FIRE AND BURNED AREA PRODUCTS

Burned Area Products

Burned areas are characterized by deposits of charcoal and ash, removal of vegetation, and alteration of the vegetation structure (Pereira et al.,1997, Roy et al., 1999). The MODIS burned area mapping algorithm takes advantage of these spectral, temporal, and structural changes. It detects the approximate date of burning at a spatial resolution of 500 m by locating the occurrence of rapid changes in daily surface reflectance time series data. The algorithm maps the spatial extent of recent fires and not of fires that occurred in previous seasons or years.

The latest version (Collection 6) of the MODIS Global Burned Area Product was released in 2017. The new product (MCD64A1) supersedes the heritage Collection 5.1 (C5.1) MCD64A1 and MCD45A1 products whose use is deprecated. The new algorithm is designed to be extremely tolerant of cloud and aerosol contamination, which affected the Collection 5.1 MCD45A1 product. As a consequence, the Collection 6 MCD64A1 product has significantly better detection of small burns, a modest reduction in burn-date temporal uncertainty, and a large reduction in the extent of unmapped areas compared to the C5.1 products.

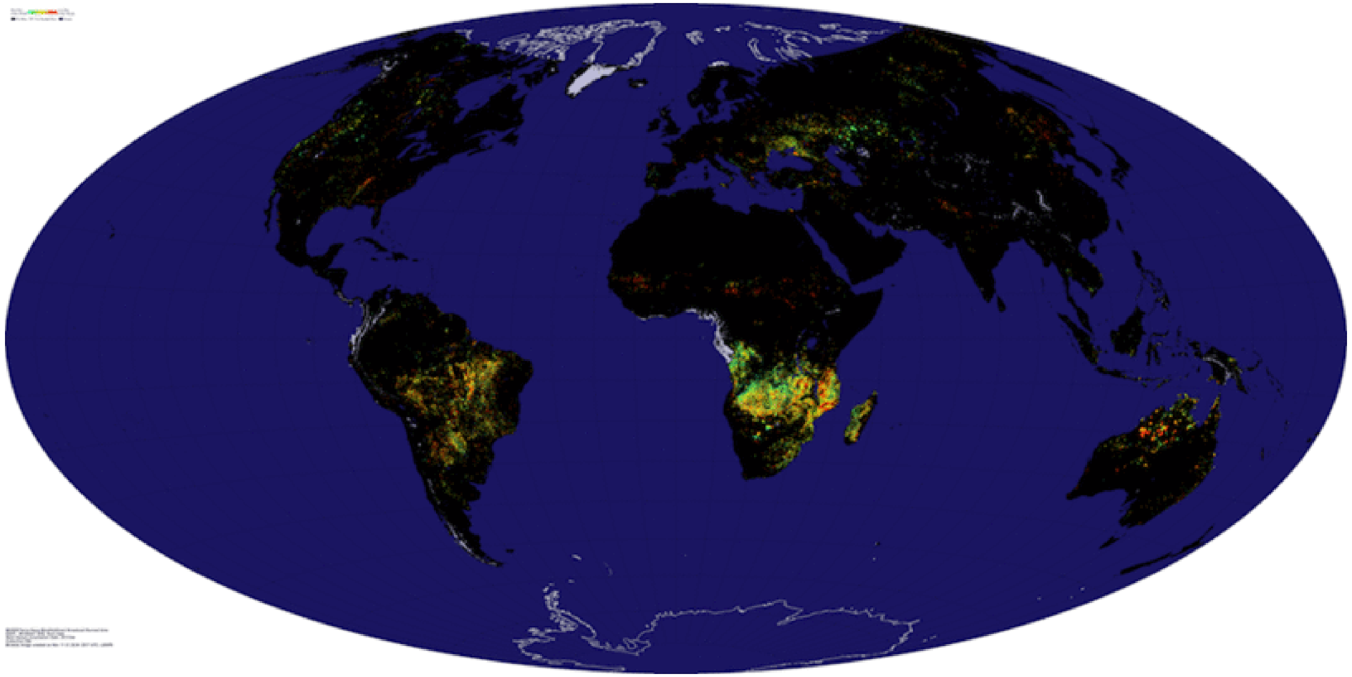
Please see the MODIS Burned Area Product User's Guide for detailed information about the MODIS burned area product suite. The entire product archive is available in a variety of formats (HDF, GeoTIFF, Shapefile). Instructions for downloading the data may be found in Section 4 of the User's Guide.



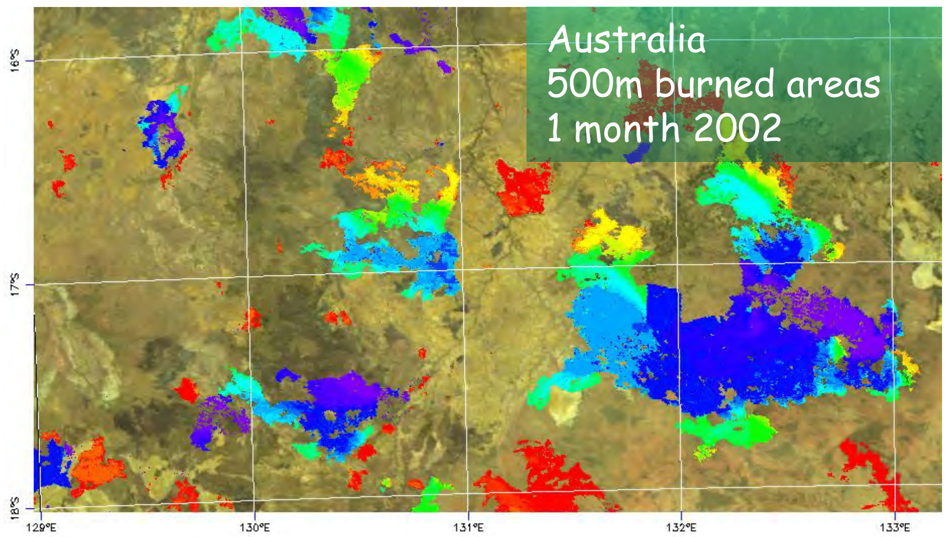
MODIS Burned Area Product 500m

Latest collection: MCD64A1

The hybrid algorithm applies dynamic thresholds to composite imagery generated from a burn-sensitive vegetation index (VI) derived from MODIS short-wave infrared channels 5 and 7, and a measure of temporal texture. Active fires are used to guide the selection of burned and unburned training samples and to guide the specification of prior probabilities. Regional thresholds.



September 2017 MCD64A1 global burned area map. Rainbow color spectrum encodes the day of burn during the calendar month. Unburned land is shown in black. Unmapped areas are shown in white.

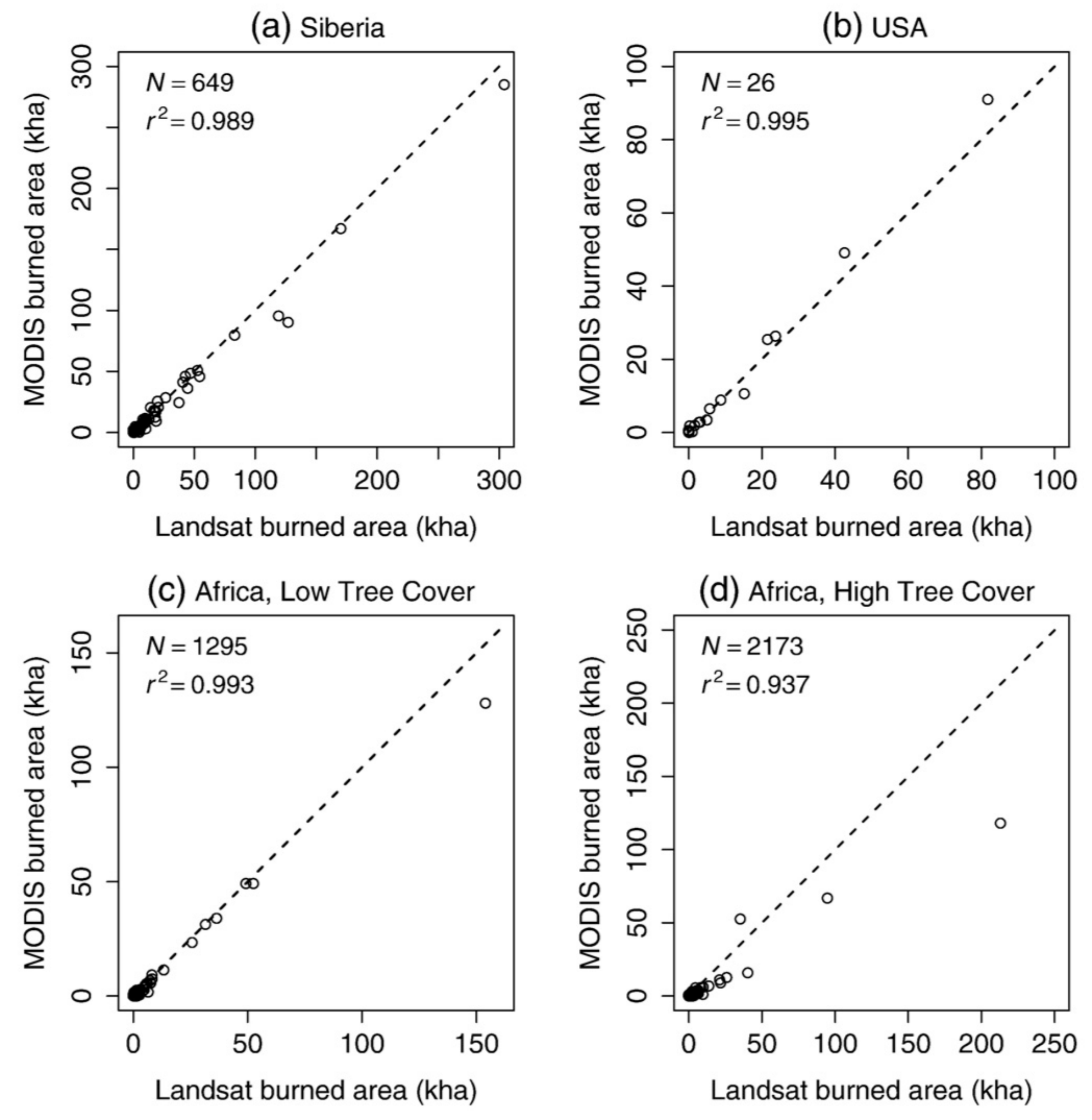


Roy et al. 2002

Burnt Areas - HDF, GeoTIFF, Shape Files

https://modis-fire.umd.edu/

Validation of 500-m Burned Area Maps



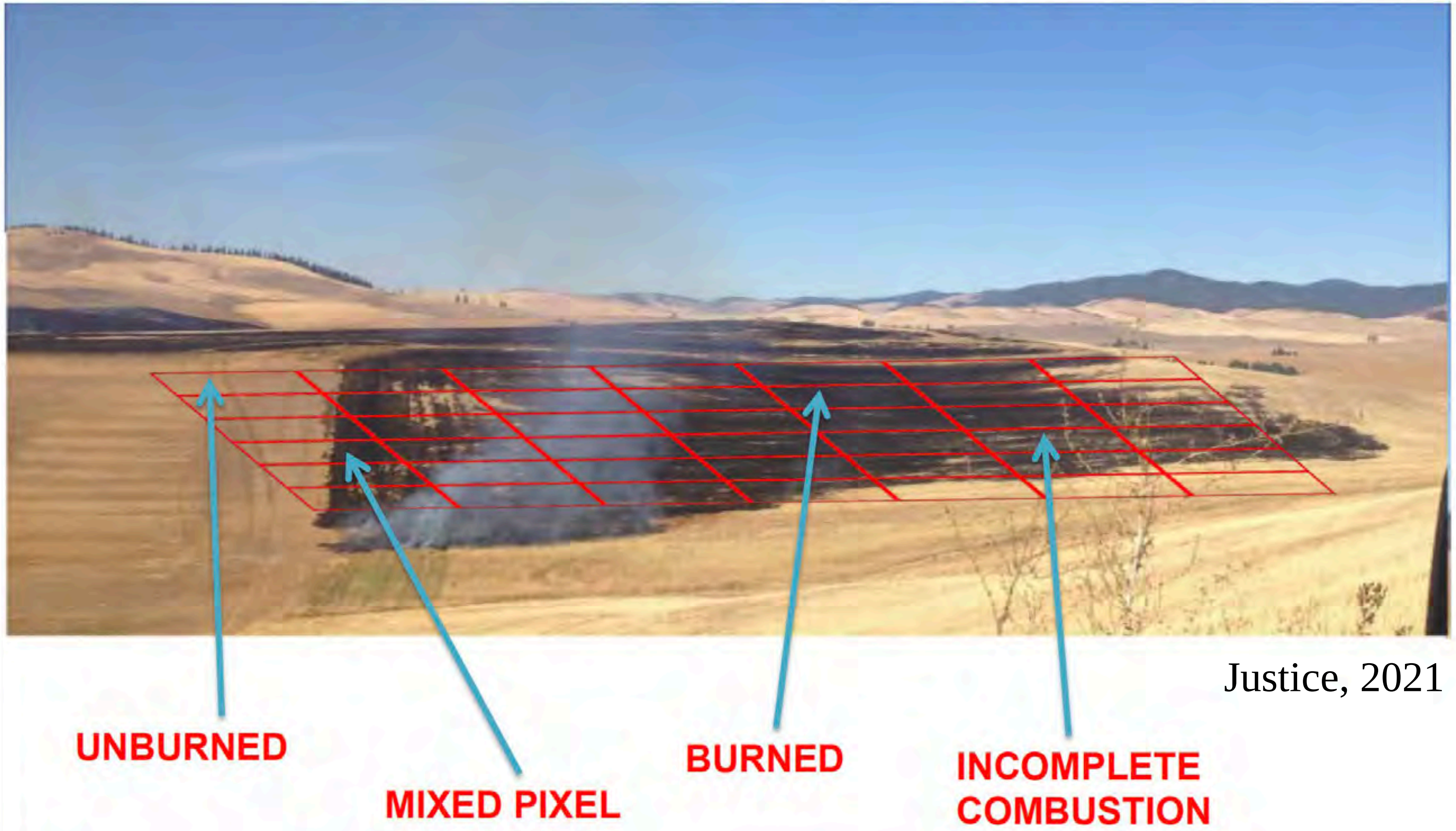
Validation using high-resolution burn scar maps manually produced from Landsat imagery.

~40 Landsat scene pairs

Giglio et al. (2009)

Validation is important as complexities can arise due to different burnt area signal variations

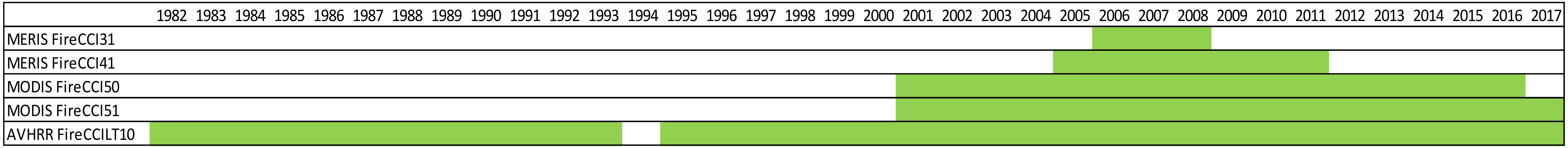
To first order the change in reflectance due to burning is dependent on the fraction of area burned *f* and combustion completeness *cc*



Justice, 2021

European Space Agency, Current Fire BA CCI Products – PI: Emilio Chuvieco (www.esa-fire-cci.org)

- MERIS FireCCI41: 2005-2011, 300 m.
- MODIS FireCCI50: 2001-2016, 250 m.
- MODIS FireCCI51: 2001-2017, 250 m
- AVHRR FireCCILT10: 1982-2017, 5 km.
- MSI FireCCISFD11: 2016, 20m (Africa).
- SAR FireCCIS1: 2016, 40m (Africa, Indonesia, SAmerica).

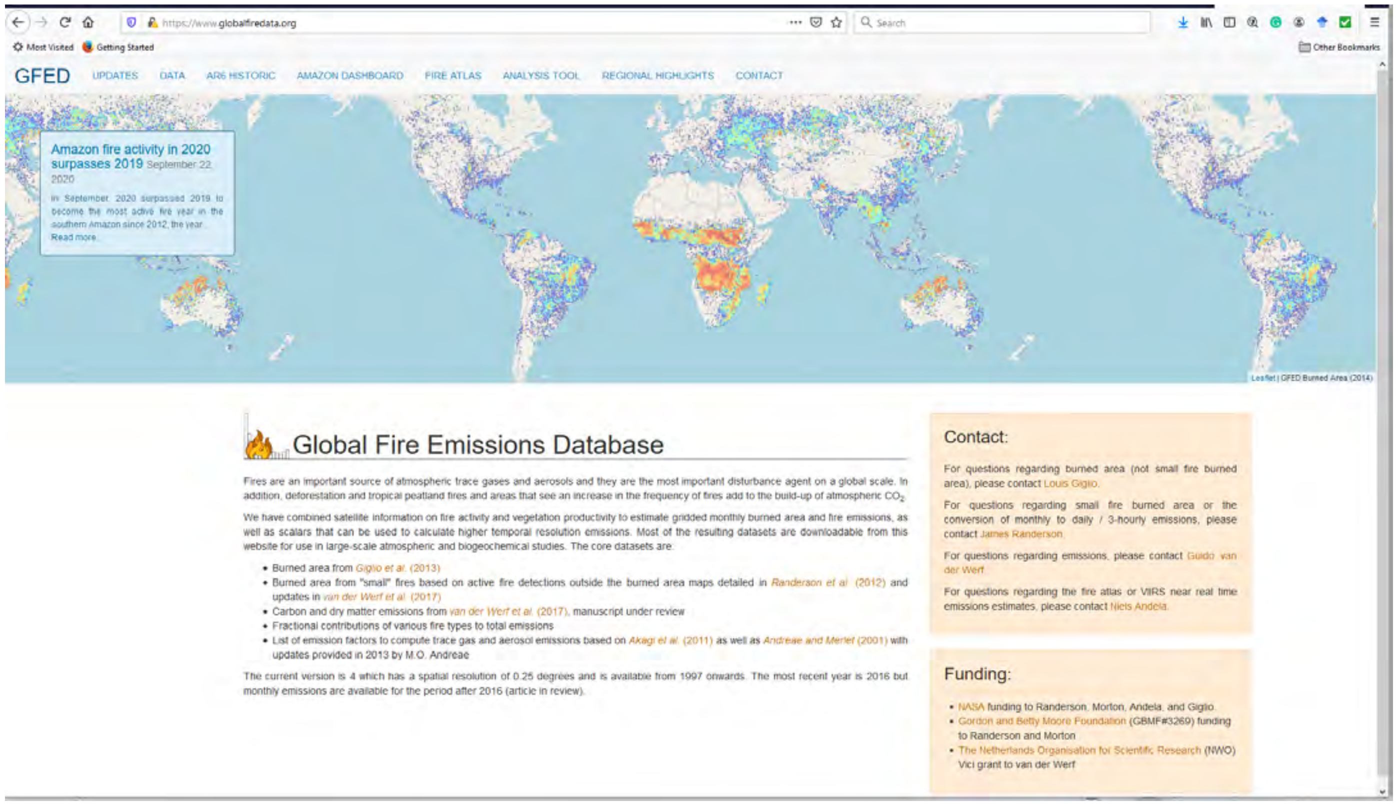


Product Downloads

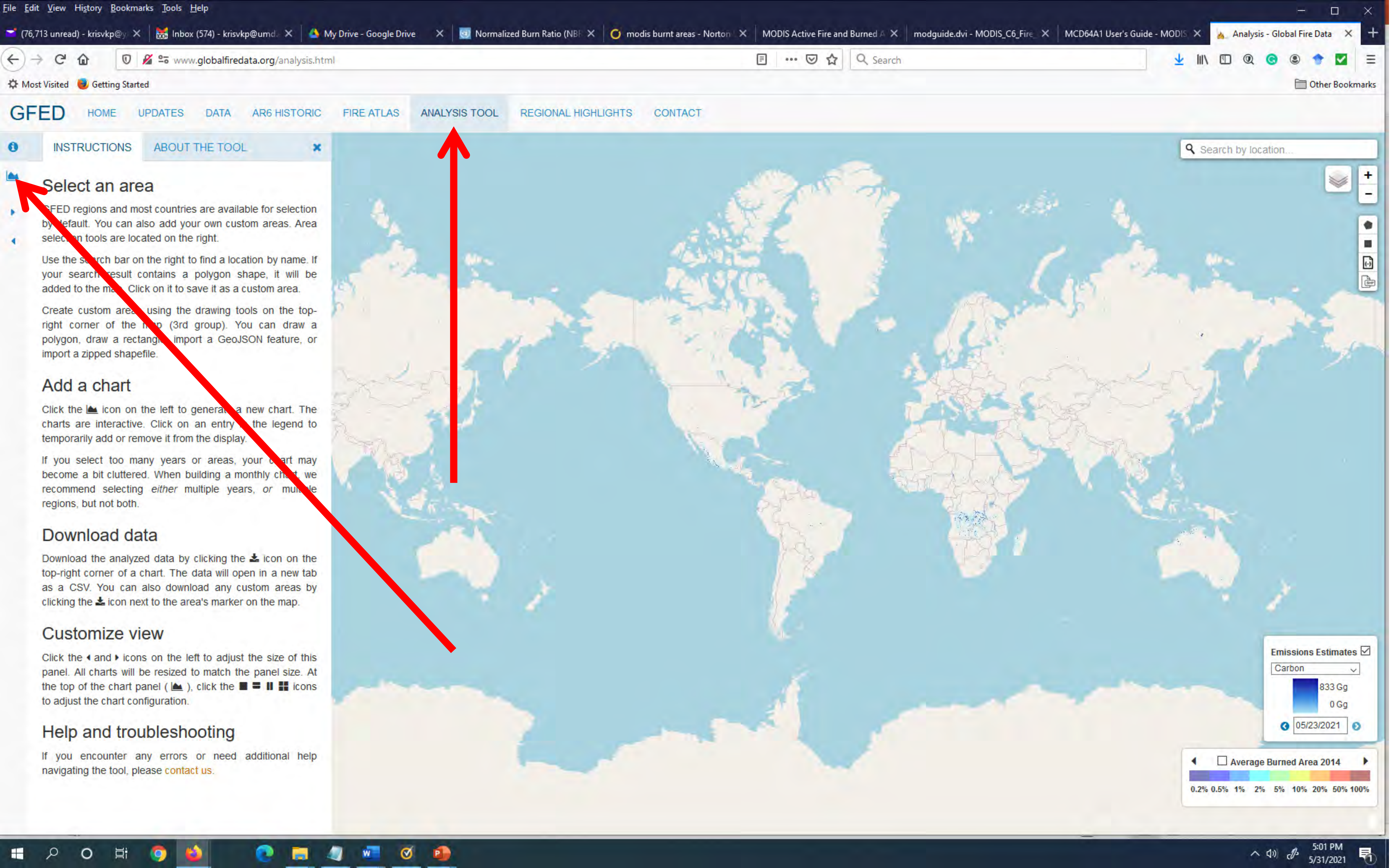
	Pixel	Grid	Release
MERIS FireCCI31	37	51	Oct. 2014
MERIS FireCCI41	168	161	Jul. 2016
MODIS FireCCI50	156	127	Feb. 2018
MODIS FireCCI51	198	103	Nov. 2018
AVHRR FireCCILT10	-	37	March 2019
S2 FireCCISFD11	64	26	Nov. 2018
Total	**623**	**505**	**1128**

Global Fires Emissions Database (GFED)

https://www.globalfiredata.org/



- Burned area from MODIS burnt areas *Giglio et al.* (2013)
- Burned area from "small" fires based on active fire detections outside the burned area maps detailed in *Randerson et al.* (2012) and updates in *van der Werf et al.* (2017)
- Carbon and dry matter emissions from *van der Werf et al.* (2017) – NASA CASA Model
- Fractional contributions of various fire types to total emissions
- List of emission factors to compute trace gas and aerosol emissions based on *Akagi et al.* (2011) as well as *Andreae and Merlet* (2001) with updates provided in 2013 by M.O. Andreae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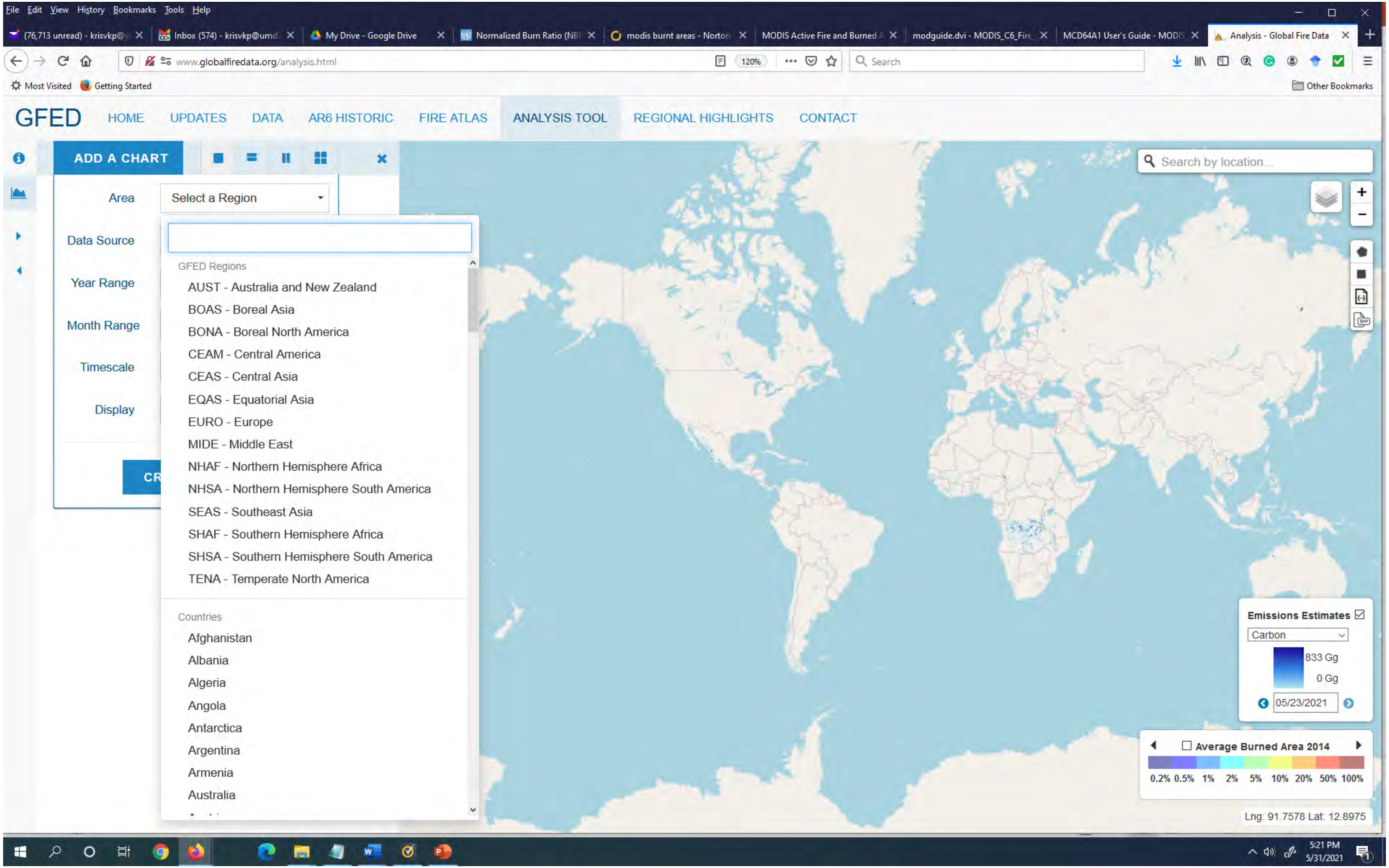
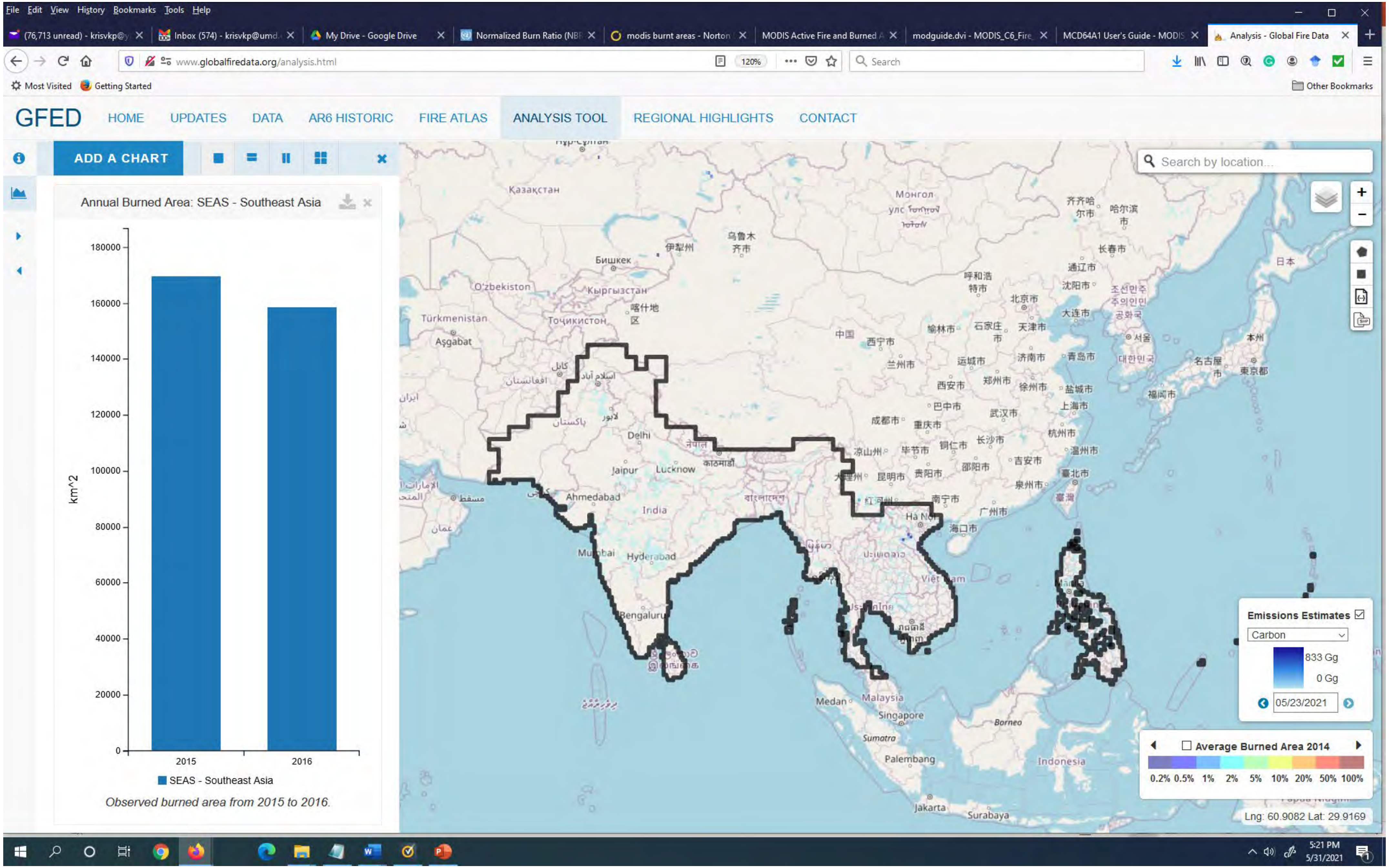
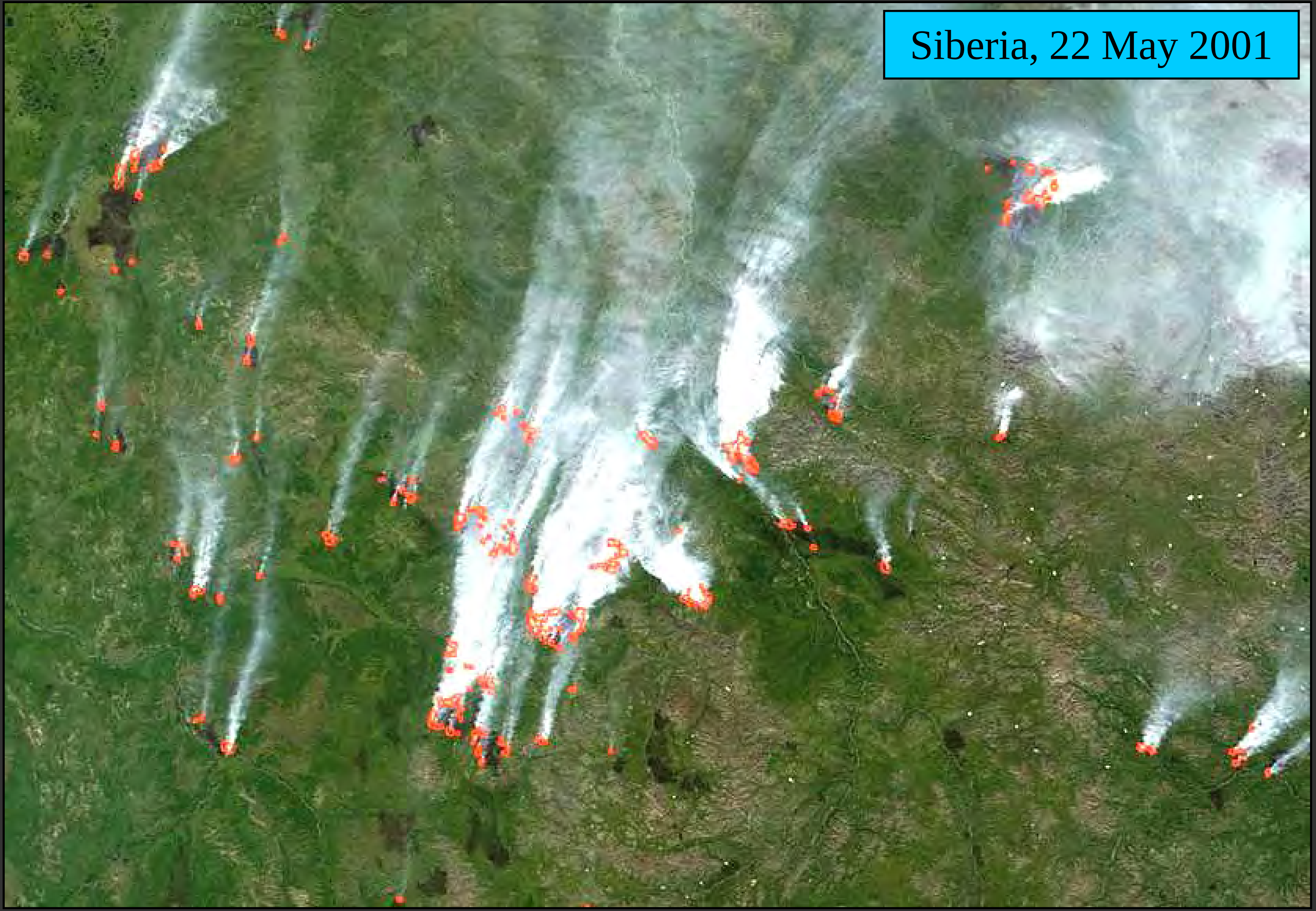
ABOUT THE TOOL
Select an area
GFED regions and most countries are available for selection by default. You can also add your own custom areas. Area selection tools are located on the right.
Use the search bar on the right to find a location by name. If your search result contains a polygon shape, it will be added to the map. Click on it to save it as a custom area.
Create custom areas using the drawing tools on the top-right corner of the map (3rd group). You can draw a polygon, draw a rectangle, import a GeoJSON feature, or import a zipped shapefile.
Add a chart
Click the icon on the left to generate a new chart. The charts are interactive. Click on an entry in the legend to temporarily add or remove it from the display.
If you select too many years or areas, your chart may become a bit cluttered. When building a monthly chart, we recommend selecting either multiple years, or multiple regions, but not both.
Download data
Download the analyzed data by clicking the icon on the top-right corner of a chart. The data will open in a new tab as a CSV. You can also download any custom areas by clicking the icon next to the area's marker on the map.
Customize view
Click the and icons on the left to adjust the size of this panel. All charts will be resized to match the panel size. At the top of the chart panel ( ), click the icons to adjust the chart configuration.
Help and troubleshooting
If you encounter any errors or need additional help navigating the tool, please contact us.
Search by location...
Emissions Estimates
Carbon
833 Gg
0 Gg
05/23/2021
Average Burned Area 2014
0.2% 0.5% 1% 2% 5% 10% 20% 50% 100%


File Edit View History Bookmarks Tools Help
(76,713 unread) - krisvkp@
Inbox (574) - krisvkp@umd
My Drive - Google Drive
Normalized Burn Ratio (NB
modis burnt areas - Norton
MODIS Active Fire and Burned A
modguide.dvi - MODIS_C6_Fire
MCD64A1 User's Guide - MODIS
Analysis - Global Fire Data
www.globalfiredata.org/analysis.html
120%
Search
Most Visited
Getting Started
Other Bookmarks
GFED
HOME
UPDATES
DATA
AR6 HISTORIC
FIRE ATLAS
ANALYSIS TOOL
REGIONAL HIGHLIGHTS
CONTACT
ADD A CHART
Area
Select a Region
Data Source
Year Range
Month Range
Timescale
Display
CR
GFED Regions
AUST - Australia and New Zealand
BOAS - Boreal Asia
BONA - Boreal North America
CEAM - Central America
CEAS - Central Asia
EQAS - Equatorial Asia
EURO - Europe
MIDE - Middle East
NHAF - Northern Hemisphere Africa
NHSA - Northern Hemisphere South America
SEAS - Southeast Asia
SHAF - Southern Hemisphere Africa
SHSA - Southern Hemisphere South America
TENA - Temperate North America
Countries
Afghanistan
Albania
Algeria
Angola
Antarctica
Argentina
Armenia
Australia
Search by location...
Emissions Estimates
Carbon
833 Gg
0 Gg
05/23/2021
Average Burned Area 2014
0.2% 0.5% 1% 2% 5% 10% 20% 50% 100%
Lng: 91.7578 Lat: 12.8975
5:21 PM
5/31/2021

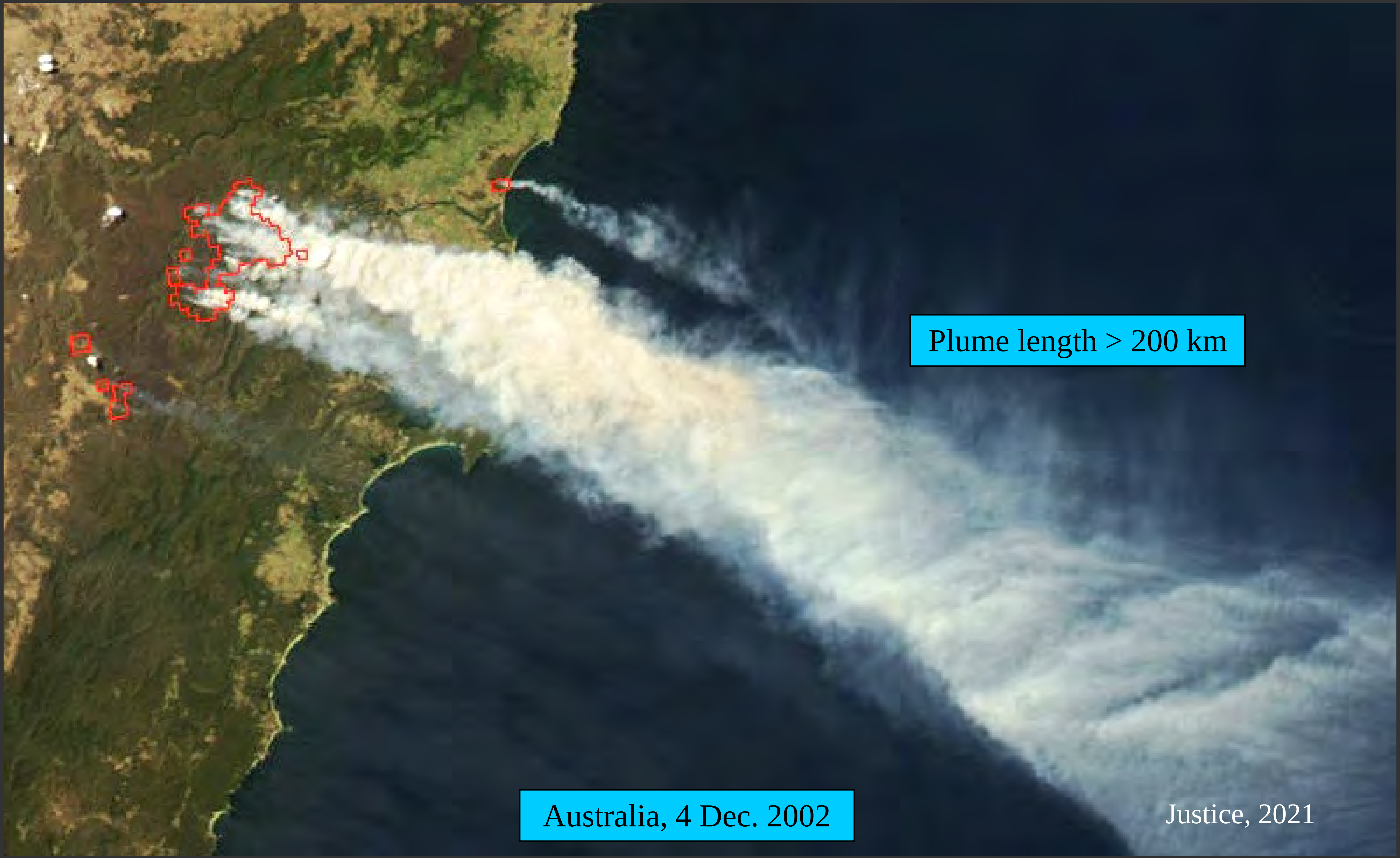

File Edit View History Bookmarks Tools Help
www.globalfiredata.org/analysis.html
GFED
HOME
UPDATES
DATA
AR6 HISTORIC
FIRE ATLAS
ANALYSIS TOOL
REGIONAL HIGHLIGHTS
CONTACT
ADD A CHART
Annual Burned Area: SEAS - Southeast Asia
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
km^2
2015
2016
SEAS - Southeast Asia
Observed burned area from 2015 to 2016.
Search by location...
Emissions Estimates
Carbon
833 Gg
0 Gg
05/23/2021
Average Burned Area 2014
0.2% 0.5% 1% 2% 5% 10% 20% 50% 100%
Lng: 60.9082 Lat: 29.9169
5:21 PM
5/31/2021

Active Fire Products and Emissions



https://worldview.earthdata.nasa.gov/

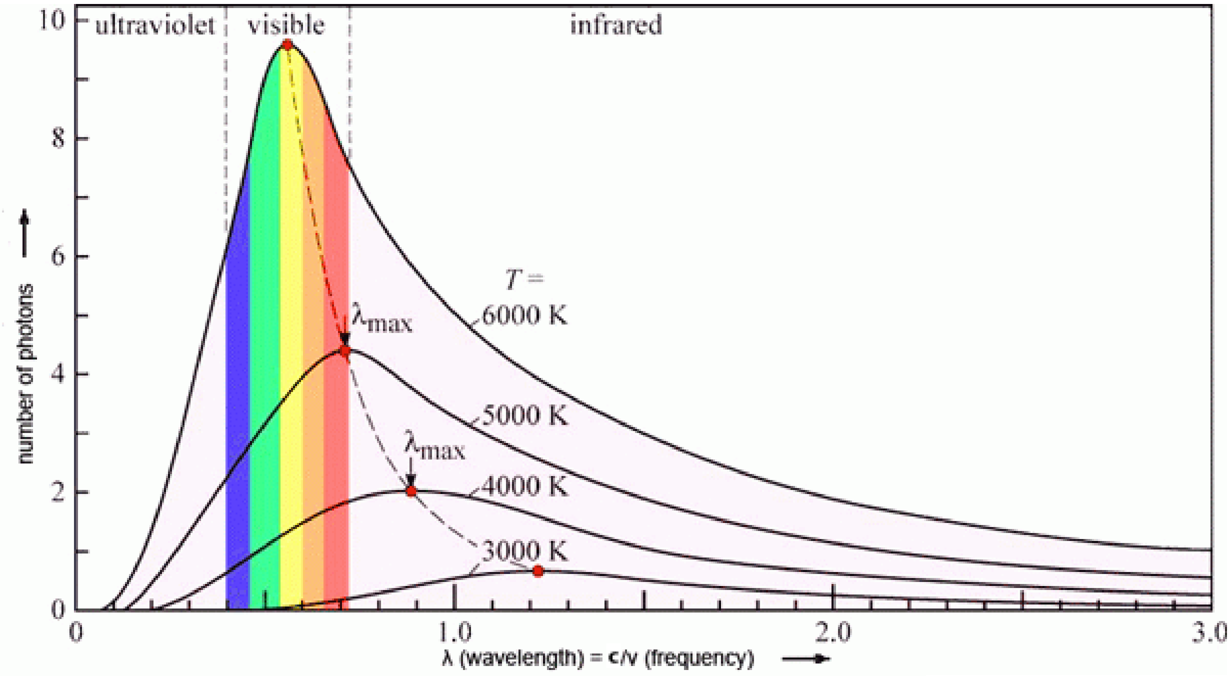
Justice, 2021


Plume length > 200 km
Australia, 4 Dec. 2002
Justice, 2021

NASA EOS Moderate Resolution Imaging Spectroradiometer

- MODIS Data Record 2000 – present
  - Terra 10:30 & 22:30 local overpass
  - Aqua 01:30 & 13:30 local overpass
- 36 spectral bands covering 0.4 to 14.4 micrometers
  - Dedicated 1 km Fire bands (sub-pixel fire detection)
    - Channel 21: 3.96 μm, ≈ 500 K saturation (high range)
    - Channel 22: 3.96 μm, ≈ 330 K saturation (low range)
    - Channel 31: 11.0 μm, ≈ 400 K saturation (Cloud masking)
- Active fire Algorithm
  - Look for elevated signal at 4 μm; use 11 μm channel to help exclude warm, non-fire surfaces
  - Adaptive thresholds based on local statistics so algorithm can be applied globally
  - Use additional channels to help reject false alarms
    - Small convective clouds, sun glint, land cover/vegetation boundaries, coastline, desert and other hot/reflective surfaces, urban areas

The basis for satellite active fire detection



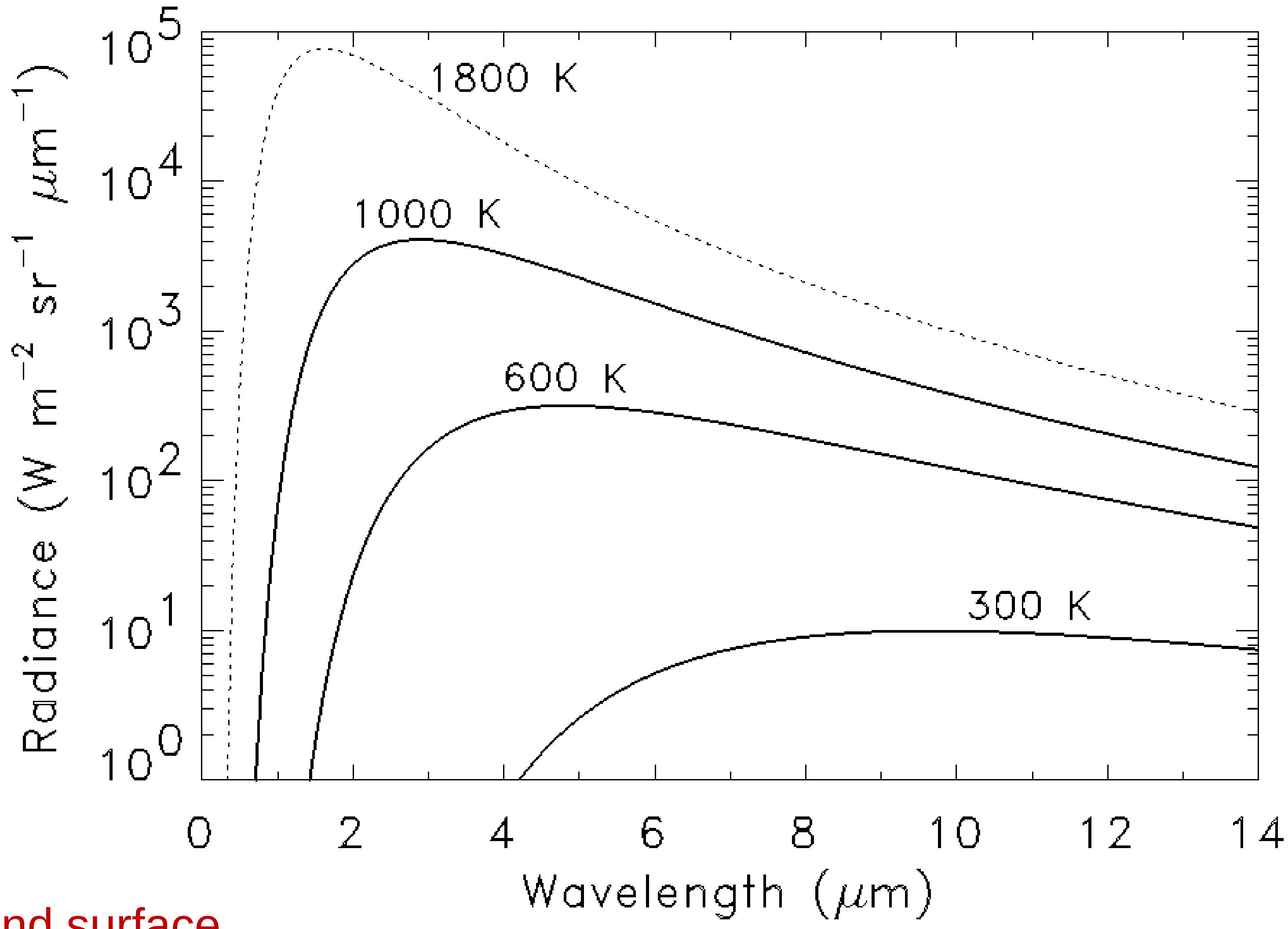
Weins displacement Law

As temperature increases, the peak in the blackbody spectrum shifts progressively to shorter wavelengths (high frequencies).

Wien's displacement law

$$T\lambda_{max} = \frac{hc}{4.965k} = 2.898 \times 10^{-3}\ \text{m-K}$$

Suggested reading: Giglio et al. 2008. Remote Sensing of the Environment, 112, 3055-3063



300K – typical land surface
600K – typical smoldering
1000K – typical flaming

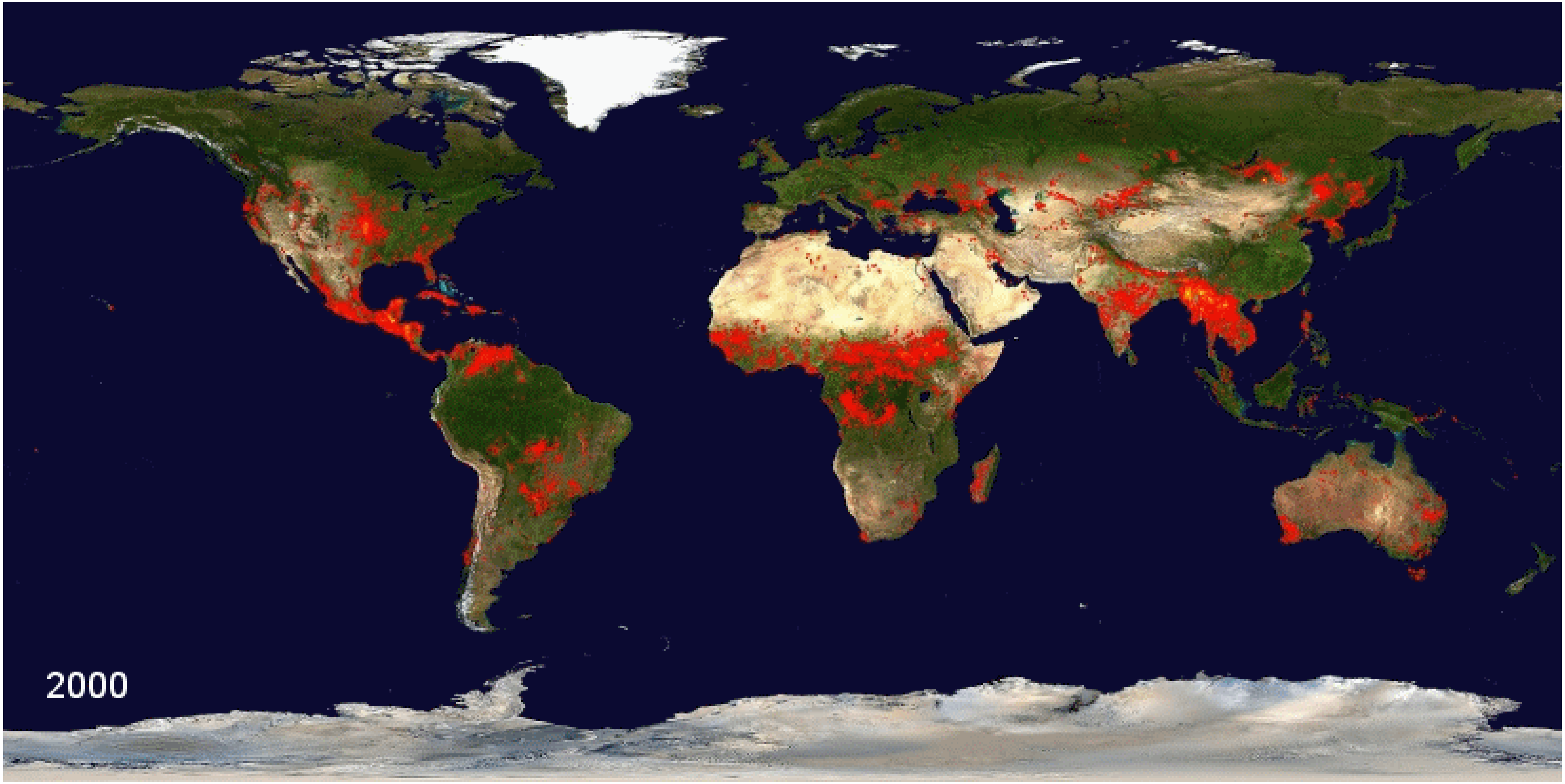
Justice, 2021

Factors Affecting Detection

- Fire size
- Fire temperature
- Biome
- Season
- Surface temperature
- Cloudiness
- Types of clouds
- Position of sun
- Viewing geometry
- Characteristics of smoke
- Instrument issues
- Other

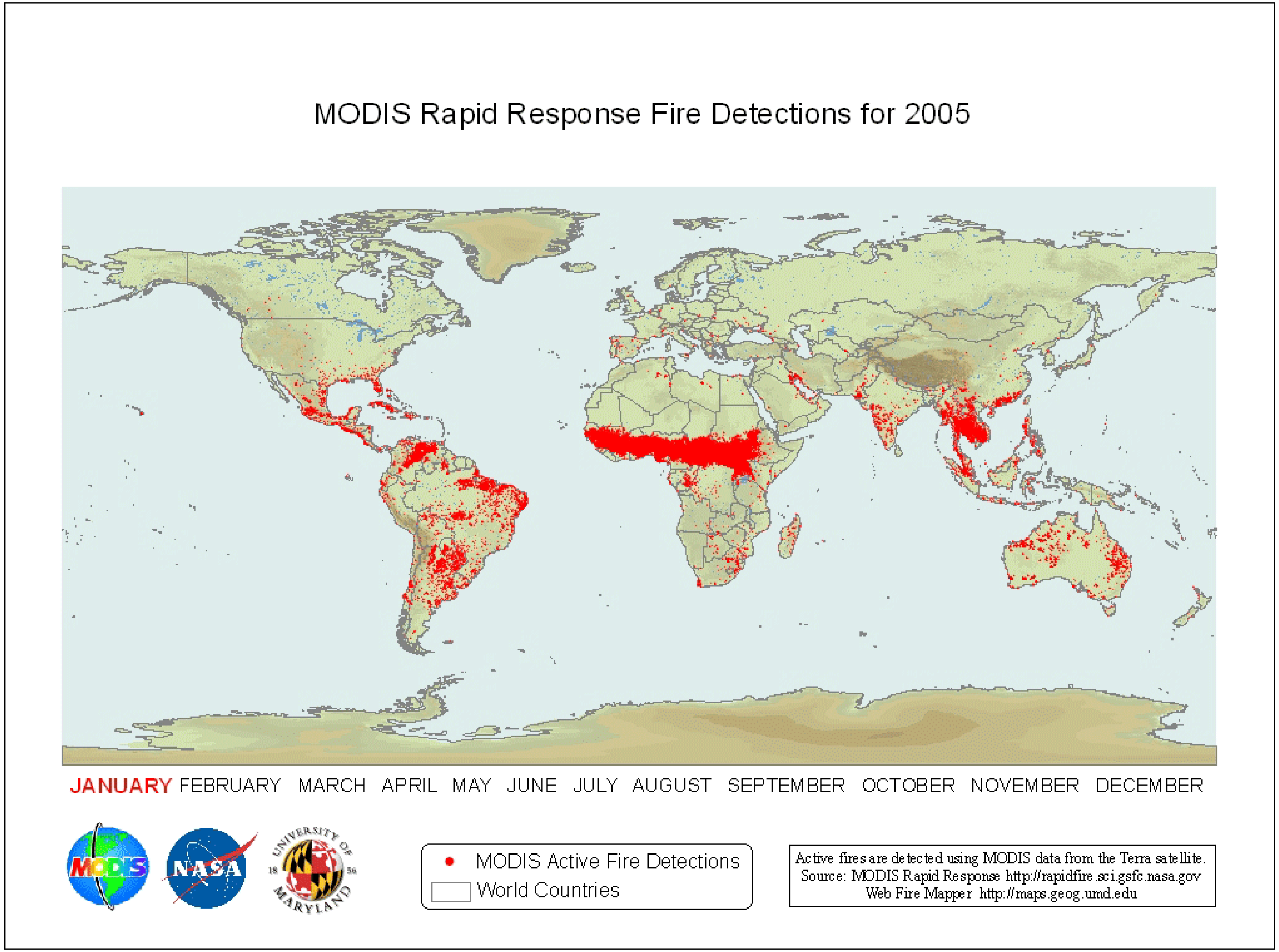
Justice, 2021

Interannual variability: April-May



https://firms.modaps.eosdis.nasa.gov/

Seasonal Variability (2005)



Status of MODIS Active Fire Product

MODIS Active Fire Products

Collection 6: (released 2015)

- MOD14/MYD14: Terra/Aqua L2 Swath
- MOD14A1/MYD14A1: L3 Daily 500-m SIN Grid
- MOD14A2/MYD14A2: L3 8-day 500 m SIN Grid
- MCD14ML: Monthly fire locations

Status and Updates:

- Widely used mature product
- Stage-2 validated

Known Issues:

- None

Recent Publications:

- Vadrevu, K. P., Lasko, K., Giglio, L., Schroeder, W., Biswas, S., and Justice, C. O., 2019, Trends in vegetation fires in south and southeast Asian countries. *Scientific Reports*, 9:7422, 1-13.
- Pereira, J. M. C., et al., 2019, Anthromes displaying evidence of weekly cycles in active fire data cover 70% of the global land surface, *Scientific Reports*, 9:11424.

SCIENTIFIC REPORTS

natureresearch

Anthromes displaying evidence of weekly cycles in active fire data cover 70% of the global land surface

J. M. C. Pereira[1], M. A. Amaral Turkman[2], K. F. Turkman[2] & D. Oom[1]

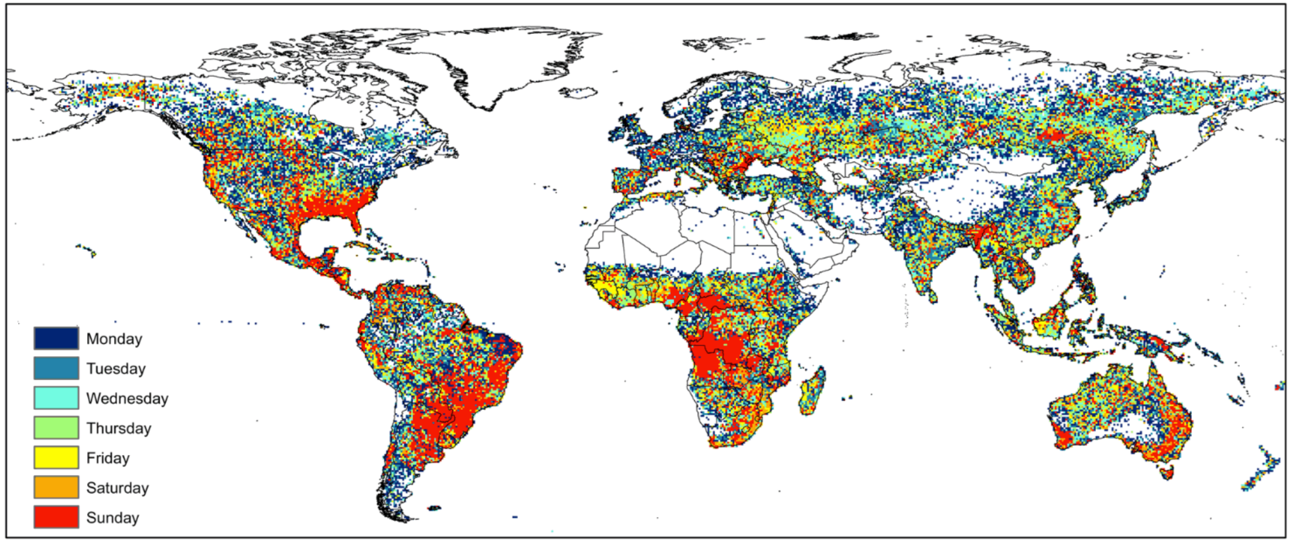
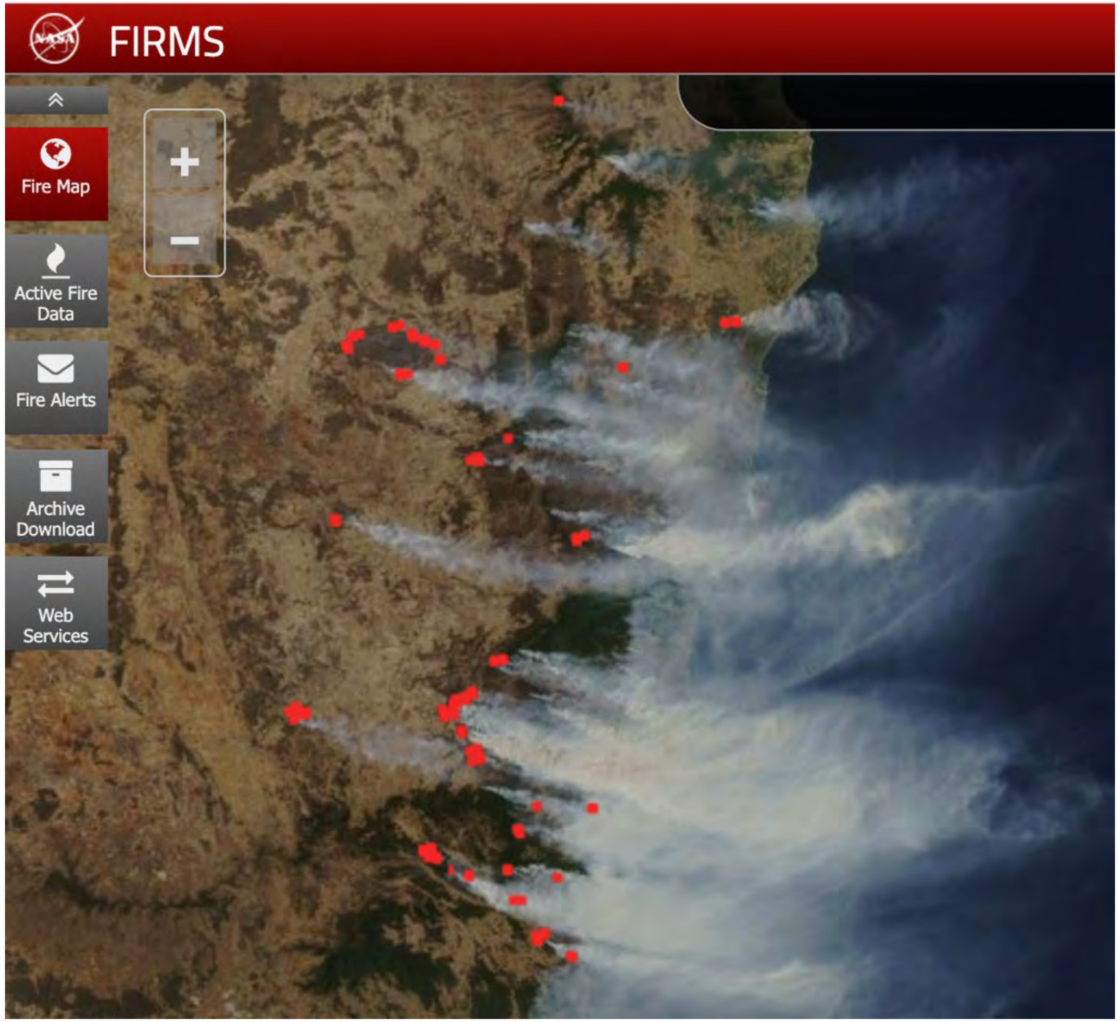


Figure 2. Weekday with the fewest fire counts, 2002–2012.

Fire Information for Resource Management System (FIRMS)



FIRMS provides global NRT active fire/thermal anomaly data from MODIS and VIIRS.

Originally developed at the University of Maryland in partnership with the United Nations (UN) Food and Agriculture Organization (FAO), in 2012 FIRMS became part of LANCE

Users can:

- view data and imagery in FIRMS Fire Map
- receive email Fire Alerts
- download data in easy to use formats

Approximately 240,000 FIRMS alerts (including daily, rapid and weekly alerts) are sent to users in more than 160 countries.

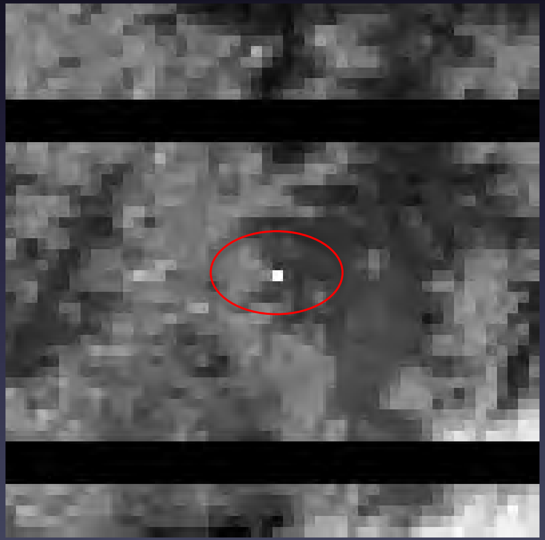
Left: FIRMS Fire Map showing active fires in New South Wales, Australia. The fires, overlaid in red, are on a corrected reflectance true color image from VIIRS SNPP from 11/13/ 19

https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms

VIIRS Heritage: MODIS and AVHRR

VIIRS			MODIS Equivalent			AVHRR-3 Equivalent			OLS Equivalent		
Band	Range (um)	HSR (m)	Band	Range	HSR	Band	Range	HSR	Band	Range	HSR
DNB	0.500 - 0.900								HRD PMT	0.580 - 0.910 0.510 - 0.860	550 2700
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000						
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000						
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000						
M4	0.545 - 0.565	750	4 12	0.545 - 0.565 0.546 - 0.556	500 1000						
I1	0.600 - 0.680	375	1	0.620 - 0.670	250	1	0.572 - 0.703	1100			
M5	0.662 - 0.682	750	13 14	0.662 - 0.672 0.673 - 0.683	1000 1000	1	0.572 - 0.703	1100			
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000						
I2	0.846 - 0.885	375	2	0.841 - 0.876	250	2	0.720 - 1.000	1100			
M7	0.846 - 0.885	750	16	0.862 - 0.877	1000	2	0.720 - 1.000	1100			
M8	1.230 - 1.250	750	5	SAME	500						
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000						
I3	1.580 - 1.640	375	6	1.628 - 1.652	500						
M10	1.580 - 1.640	750	6	1.628 - 1.652	500	3a	SAME	1100			
M11	2.225 - 2.275	750	7	2.105 - 2.155	500						
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000	3b	SAME	1100			
M12	3.660 - 3.840	750	20	SAME	1000	3b	3.550 - 3.930	1100			
M13	3.973 - 4.128	750	21 22 23	3.929 - 3.989 3.929 - 3.989 4.020 - 4.080	1000 1000 1000						
M14	8.400 - 8.700	750	29	SAME	1000						
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000	4	10.300 - 11.300	1100			
I5	10.500 - 12.400	375	31 32	10.780 - 11.280 11.770 - 12.270	1000 1000	4 5	10.300 - 11.300 11.500 - 12.500	1100 1100	HRD	10.300 - 12.900	550
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000	5	11.500 - 12.500	1100			

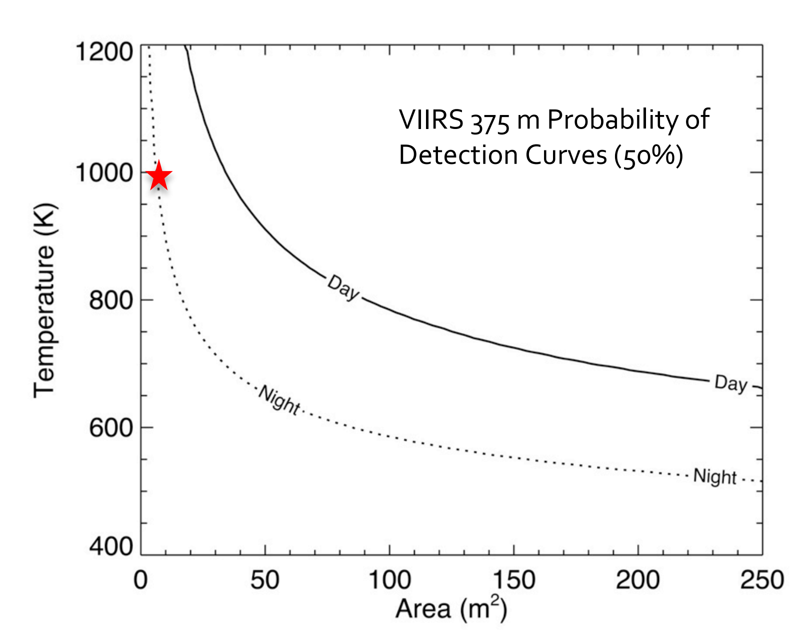
Small Fire Validation
VIIRS 375 m nighttime example in Rio de Janeiro/Brazil



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

2.5 m diameter
experimental bonfire

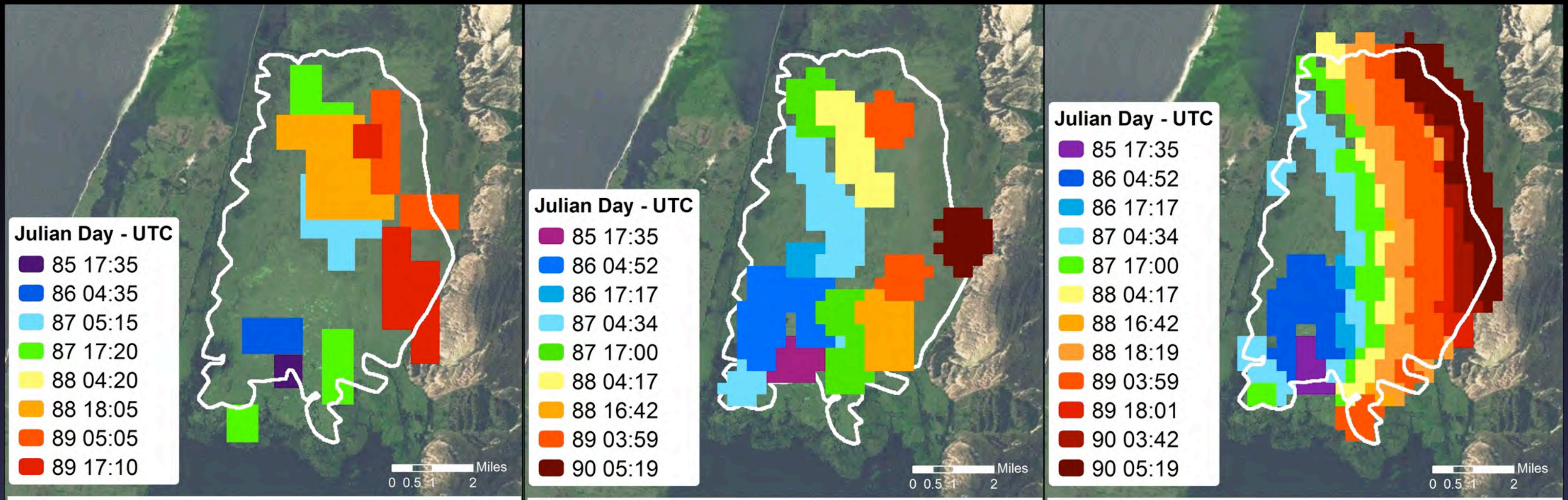
Single pixel detection
Pixel fraction containing
active fire: **0.004%**



Schroeder

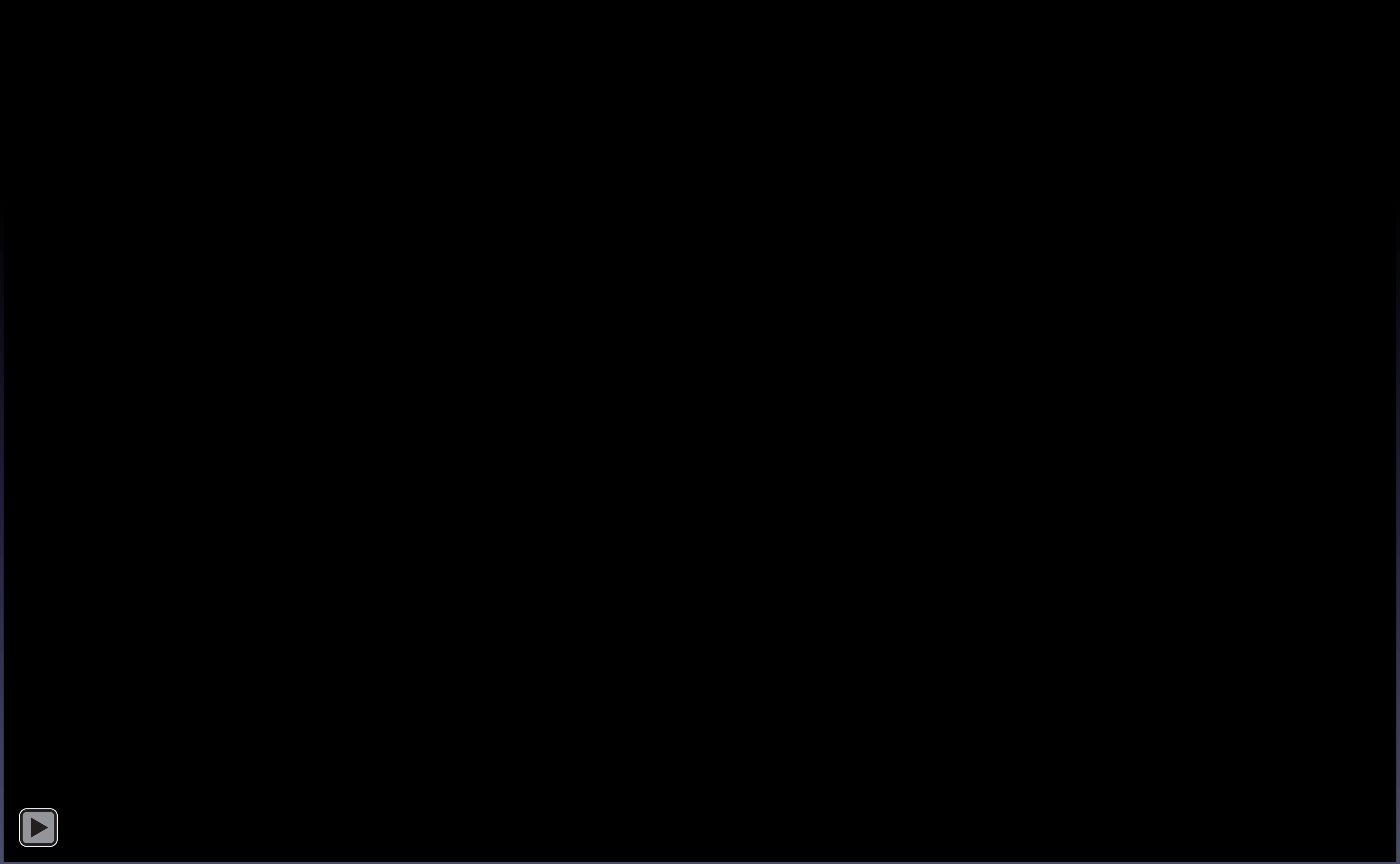
MODIS 1 km × VIIRS 750 m × VIIRS 375 m
Fire Data Intercomparison

Taim Ecological Reserve, Southern Brazil (March 2013)



Aqua/MODIS 1 km	NPP/VIIRS 750 m	NPP/VIIRS 375 m
Pixel Area 1<>10 km²	Pixel Area 0.56<>2.5 km²	Pixel Area 0.14<>0.625 km²
Image Swath 2330 km	Image Swath 3000 km	Image Swath 3000 km

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



Active Fire Validation

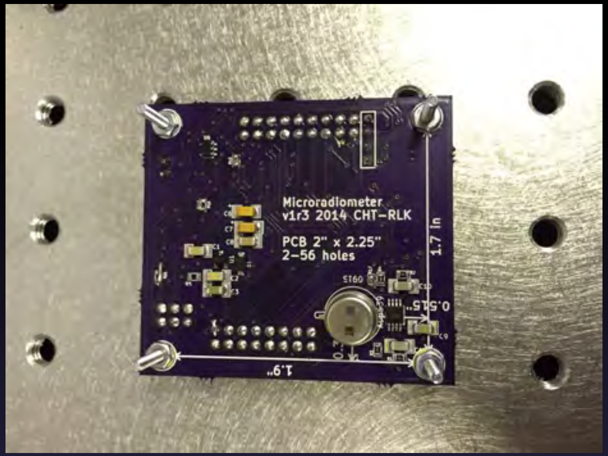
- *Use of Landsat-class data to validate VIIRS is not an option due to prohibitively large time separation between same-day acquisitions*
- *Use of prescribed fires (easy/accessible)*
- *Coincident ground, airborne, spaceborne data acquisitions*
- *Community-organized (reduce spending, maximize output)*

Data Validation

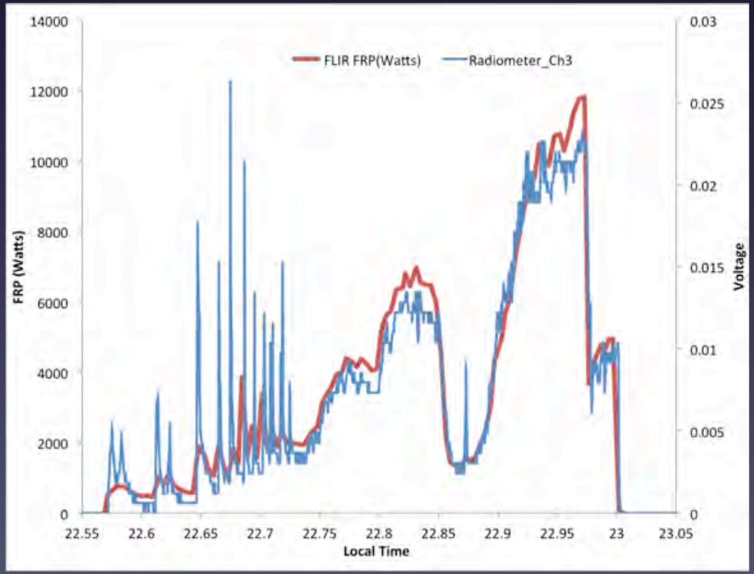
Experimenting new/inexpensive ways of collecting reference data in support of algorithm validation

- Use of relatively low-cost drones
- Use of relatively low-cost instrumentation

Dual-band radiometer ($)

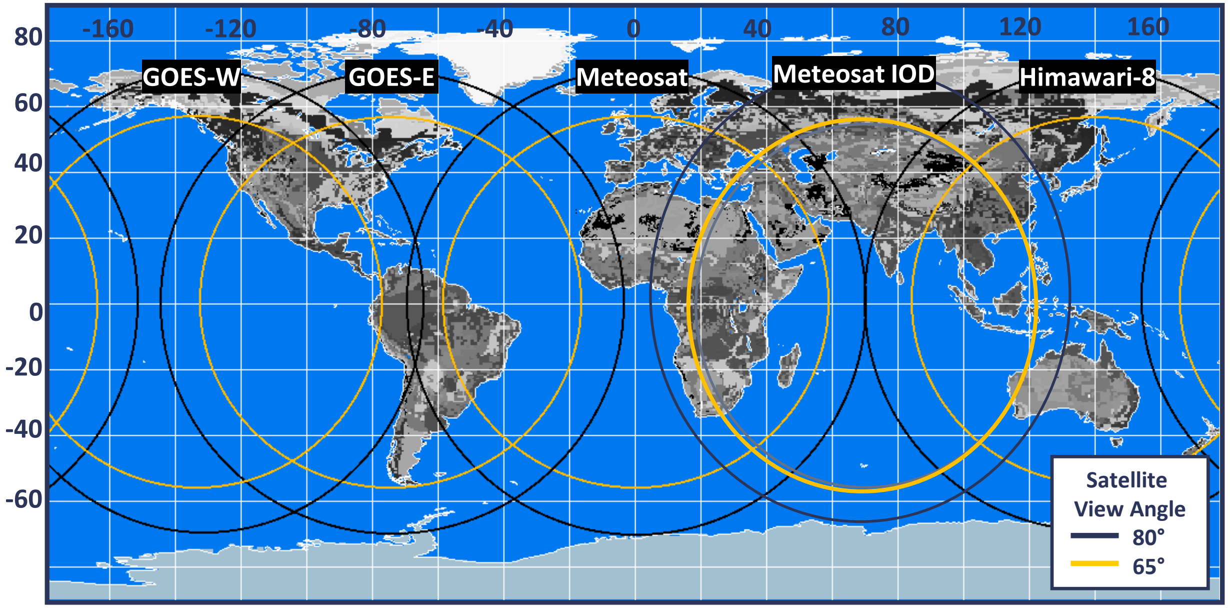


Hexacopter + FLIR camera ($$)



Global Geostationary Network using Fire Thermal Anamoly Algorithm – In process (PI: Martin Wooster, Kings College London)

- **2km spatial resolution**
- **Data every 10 to 15 mins**
- Processed using single algorithm with some adaptations to each sensor.
- NRT delivery
- Fully operational specifications (24/7 service, 95% data availability)



National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

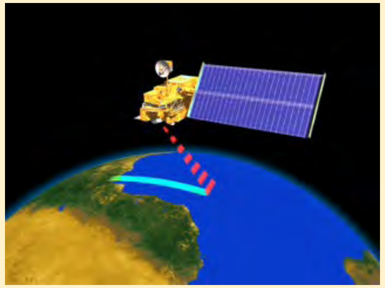
Active Fire Products

Instrument	Spatial resolution of active fire data	Geographic coverage	Satellite Orbit	Satellite / Agency	
MODIS	**1 km**	**Global**	**LEO**	**Terra, Aqua/ NASA**	
GOES ABI	**2 km**	**75.2 ° W: North and South America** **135 ° W:** **Pacific Ocean, Hawaii, North and South America**	**Geostationary**	**GOES-E and -W /NOAA**	
Himawari AHI	**2 km**	**140.7 ° E: East Asia, Australia, Pacific Ocean**	**Geostationary**	**Advanced Himawari Imager (AHI), JAXA and JMA**	
GCOM-C SGLI	**500 m**	**Global**	**LEO**	**Second-generation GLobal Imager (SGLI) JAXA**	
Meteosat SEVIRI	**3 km**	**0 °: Europe, Africa, 41.5 E**	**Geostationary**	**Eumetsat**	
VIIRS	**375 m, 750 m**	**Global**	**LEO**	**S-NPP, JPSS1/NOAA 20 NASA/NOAA~~20~~**	
NOAA AVHRR	**1 km**	**Global**	**LEO**	**POES / NOAA** **METOP / Eumetsat**	
(A)ATSR	**1 km**	**Global (but only nighttime AF product)**	**LEO**	**ERS-2* and ENVISAT**	
SLSTR	**1 km**	**Global**	**LEO**	**Sentinel-3/ Eumetsat and ESA**	
Bird	**350 m**	**Global (but on demand products)**	**LEO**	**Firebird Constellation / DLR**	

Source: Wooster et al., (RSE, In Preparation)

Emissions Quantification

Burned area × fuel load × combustion completeness × emission factor



Average fuel loads, Biogeochemical models, Satellite derived estimates of Net Primary Production, empirical relations for fuel types allocation

Average values, Field based parameterizations based on fuel types and fuel moisture

Average values, Field based parameterizations based on fuel types and fuel moisture

A). Can we minimize uncertainties relating to fuel loads and combustion completeness?

B). Can we do real-time or near-real time emissions instead of using burned area estimates?

Fire Radiative Power Products and Emissions

Fire Radiative Power (FRP) Products and Emissions

- Fire Radiative Power (FRP) is the rate of fire energy released per unit time, measured in megawatts [Wooster et al., (2003; 2005). Derived from the mid-infrared channel.

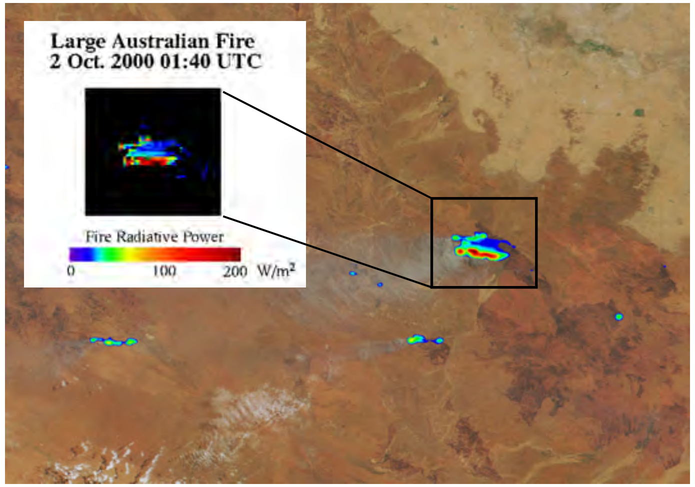
- Fire radiative energy (FRE) is therefore, FRP integrated over time and space with units in mega joules.

- FRP measurements have been previously related to the amount of biomass burnt (Wooster et al., 2003) the strength of fires (Wooster et al., 2004) and ***aerosol emissions (Ichoku and Kauffman, 2005;*** Vermote et al., 2009; Pereira et al., 2009; Ichoku et al., 2014; Vadrevu et al., 2012; 2018; Wooster et al., 2019, 2020)

- The FRE based emission coefficients for quantifying the gas and aerosol emissions from biomass burning have been developed by (Wooster et al., 2003) from field experiments and by (Freeborn et al., 2008) from laboratory measurements.

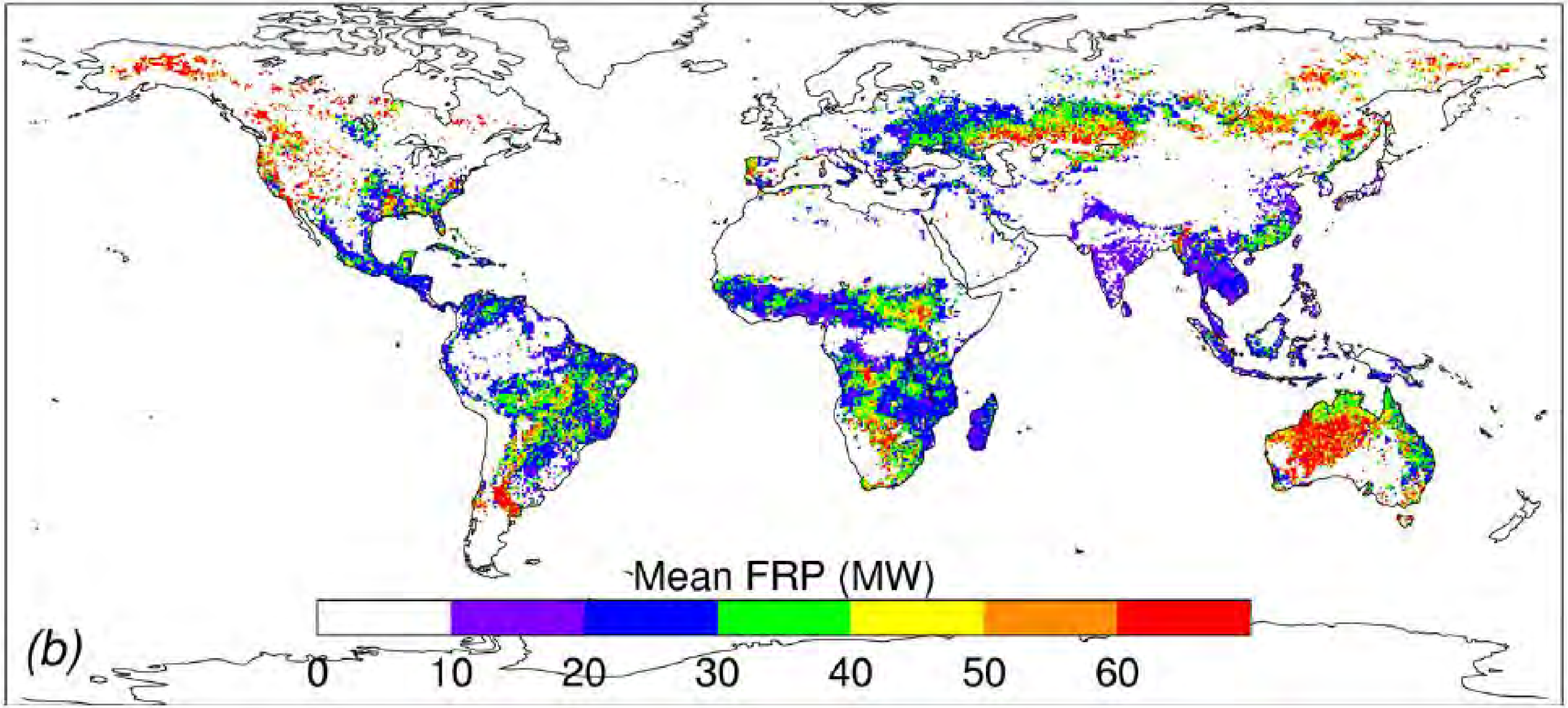
- Mass of smoke aerosol released from biomass burning can be linearly related to FRE. Coefficients to multiply with FRE to get Smoke emissions.

Giglio et al., 2008



Emitted Fire Radiative Power
Related to biomass combusted and trace gas emissions

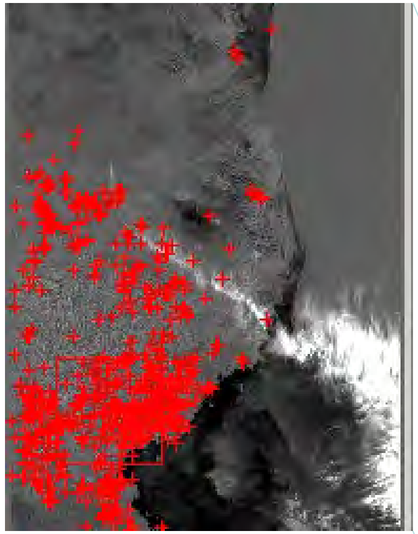
Fire radiative power from MODIS active fires (2000-2005)



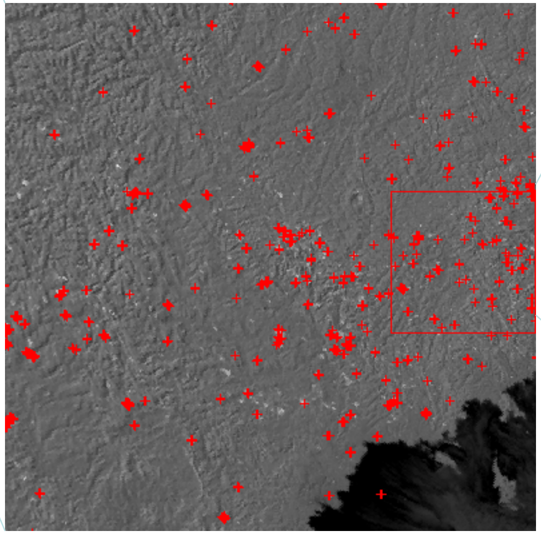
Giglio et al., 2006, JGR

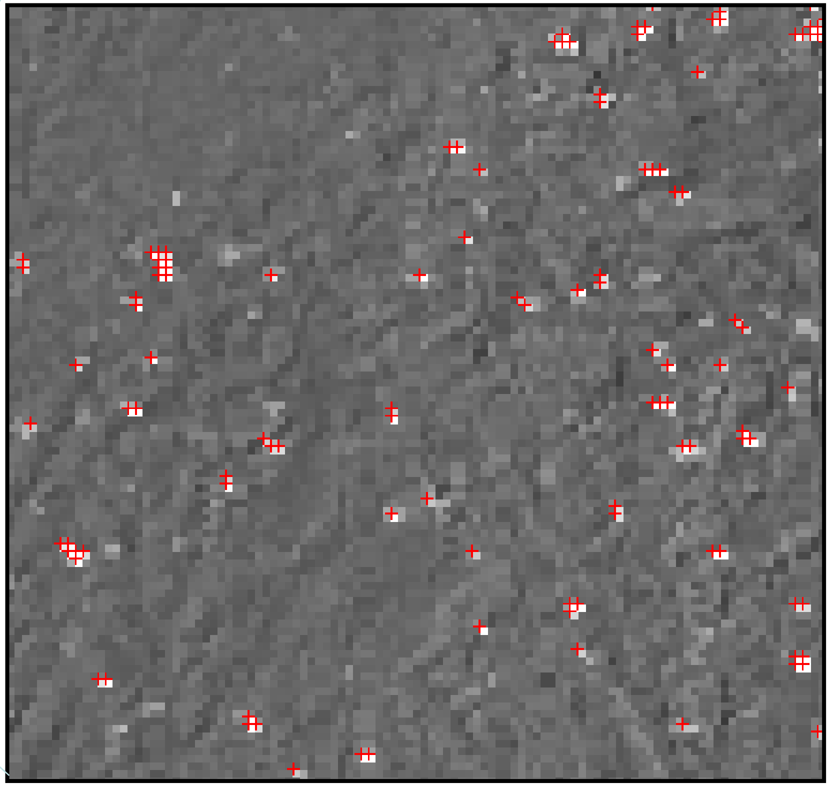
Sentinel-3 SLSTR Active Fire & FRP Product

- **Two satellites now in orbit – Sentinel-3A and Sentinel-3B**
- **Product Processor Completed for ESA – Similar to Terra MODIS Overpass Time**



Southern Angola



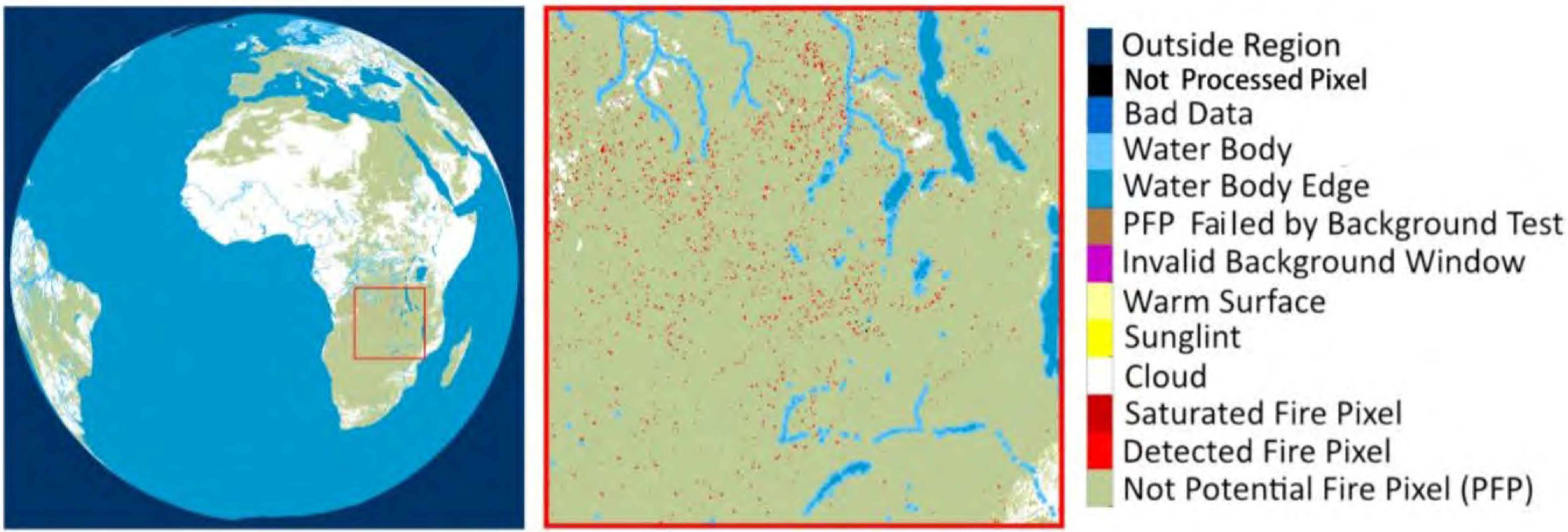


S7 (3.7 μm) – S8 (10.8 μm) BT Difference

Relevant Bands
S6 - 2.25 μm
S7 - 3.7 μm
S8 - 10.8 μm

F1 - 3.7 μm
but low gain

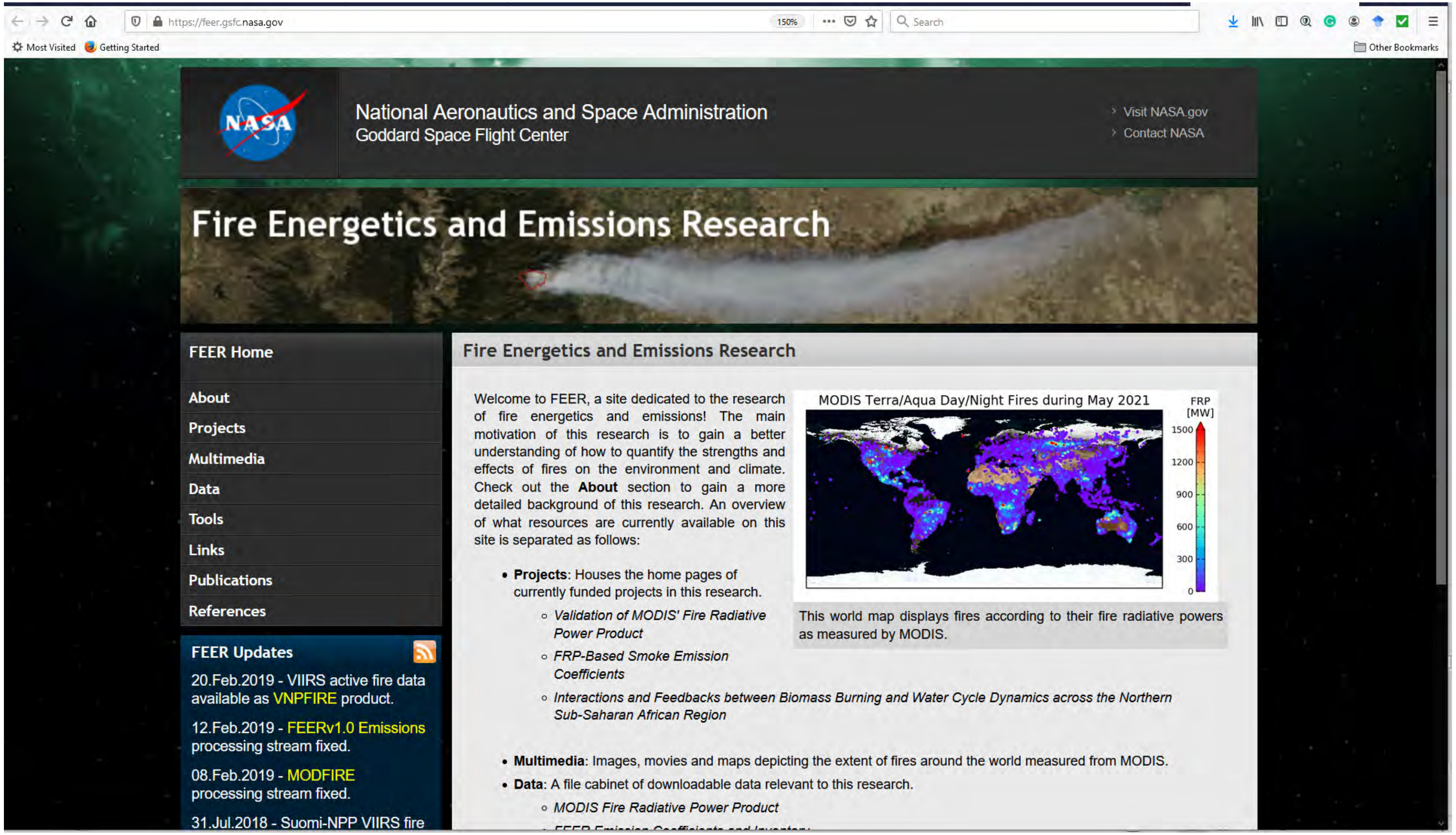
Meteosat FRP-PIXEL Product Produced at EUMETSAT LSA SAF – OPERATIONAL NOW



Available at the EUMETSAT LSA SAF (https://landsaf.ipma.pt/en/products/fire-products/frppixel/

Fire Energetics and Emissions Research (FEER product)

PI: Charles Ichoku



FRP based Global smoke Emissions (Both MODIS and VIIRS Products)

Emission Coefficients linking FRP and Smoke Emissions
Ichoku and Ellison, 2014. Atmos. Chem. Phys., 14, 6643–6667.

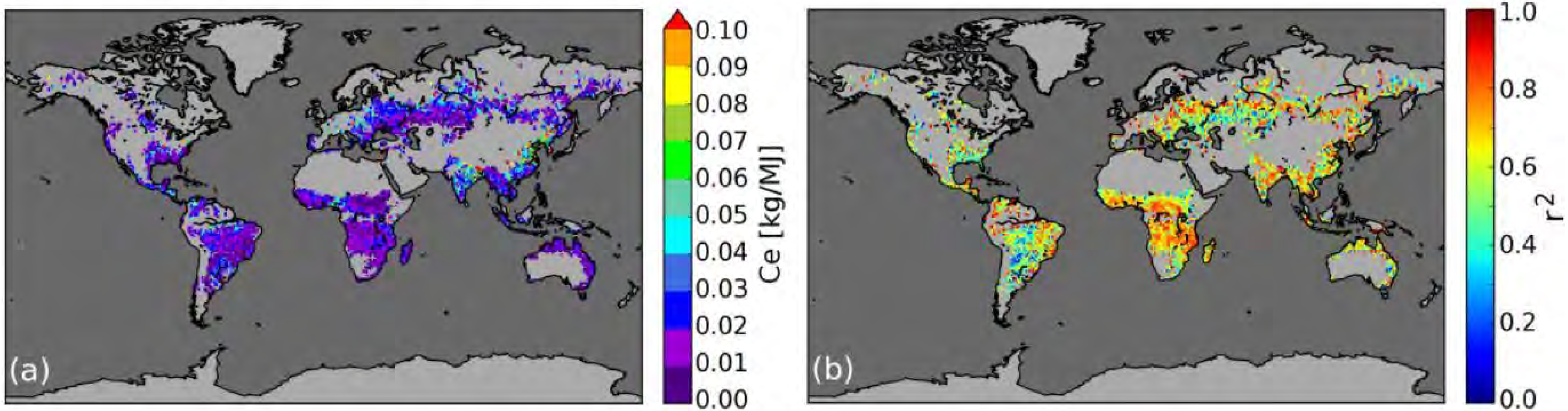


Figure 7. (a) The coefficient of emission (C_e) product based on MODIS 2003–2010 FRP and AOT observations from Terra and Aqua, after applying the 11 300 filter setting (Table 2) and outlier removal processing steps described in Sects. 4.3 and 4.4., respectively, and **(b)** the corresponding coefficient of determination (r^2) map.

Other Emission Products

- FINN - *Wiedinmyer et al., 2011*
  https://www2.acom.ucar.edu/modeling/finn-fire-inventory-ncar

- FLAMBE (ARCTAS) - *Reid et al., 2009*

- GBBEPx_v2 – Zhang et al., 2012
  http://www.ospo.noaa.gov/Products/land/gbbepx/

- GFAS_v1.2 - *Kaiser et al., 2017*
  https://www.ecmwf.int/en/forecasts/dataset/global-fire-assimilation-system

- IS4Fires_v2.0 – Sofiev et al., 2009;
  http://is4fires.fmi.fi

- QFED_2.5 – Darmenov and Da Silva, 2015

http://wiki.seas.harvard.edu/geos-chem/index.php/QFED_biomass_burning_emissions

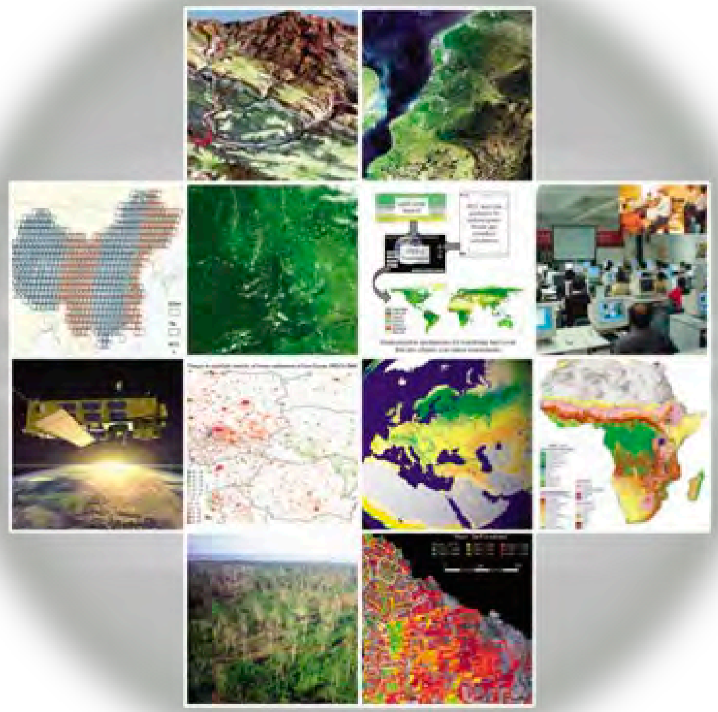
GOFC-GOLD

Global Observations of Forest Cover and Land Use Dynamics

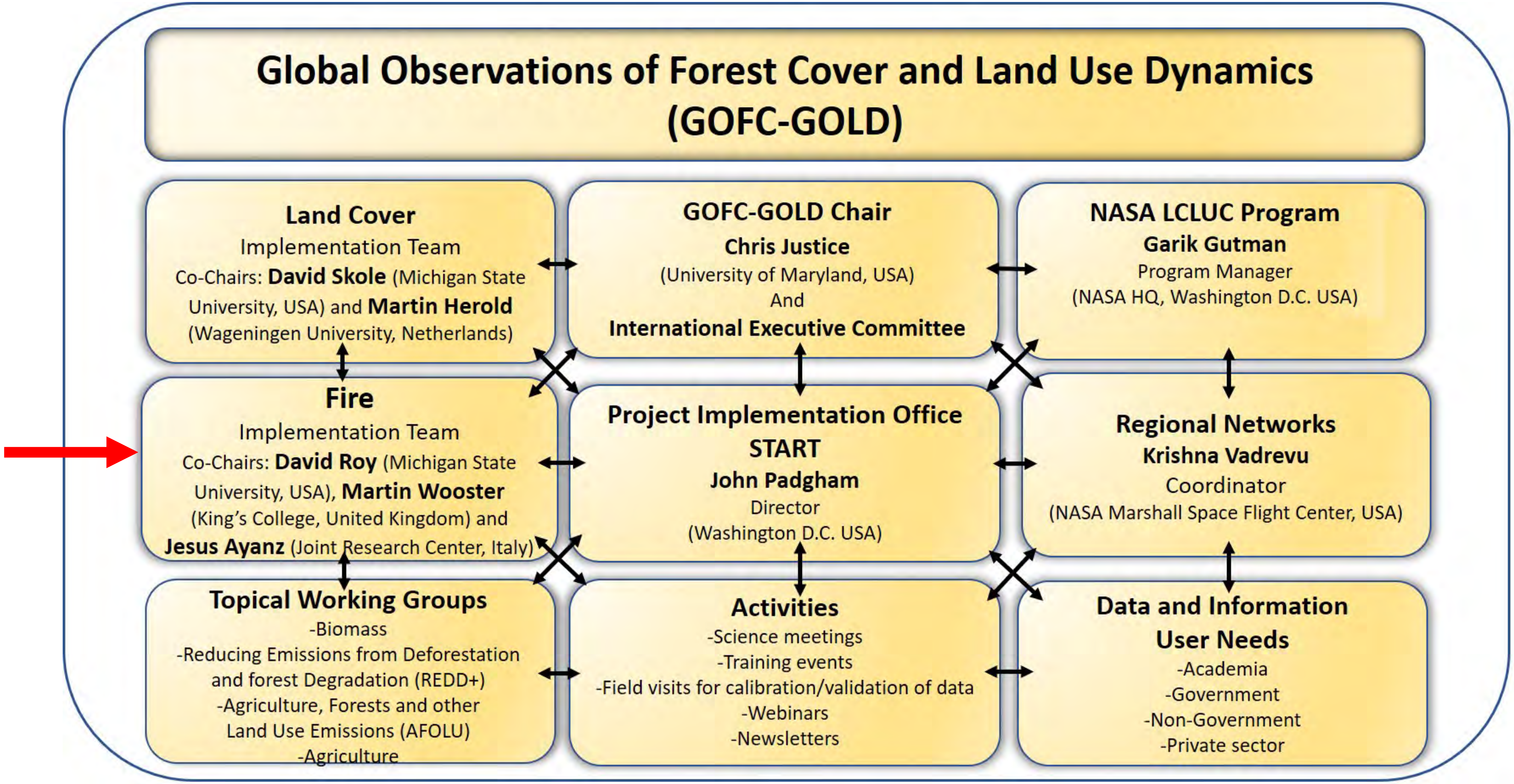
Program Focus

- Coordination of Spaceborne and In-Situ Measurements of Land cover change and Fire
- Derived Data and Information Products
- Data Availability and Access
- Assistance for Improved Data Utilization through Regional Science Networks (with the START Program)
- Communication between Science and Decision Makers
- Coordination with other programs – e.g. UN REDD+, GCOS ECVs, CEOS LPV, GEOGFOI, GEOGLAM, etc.

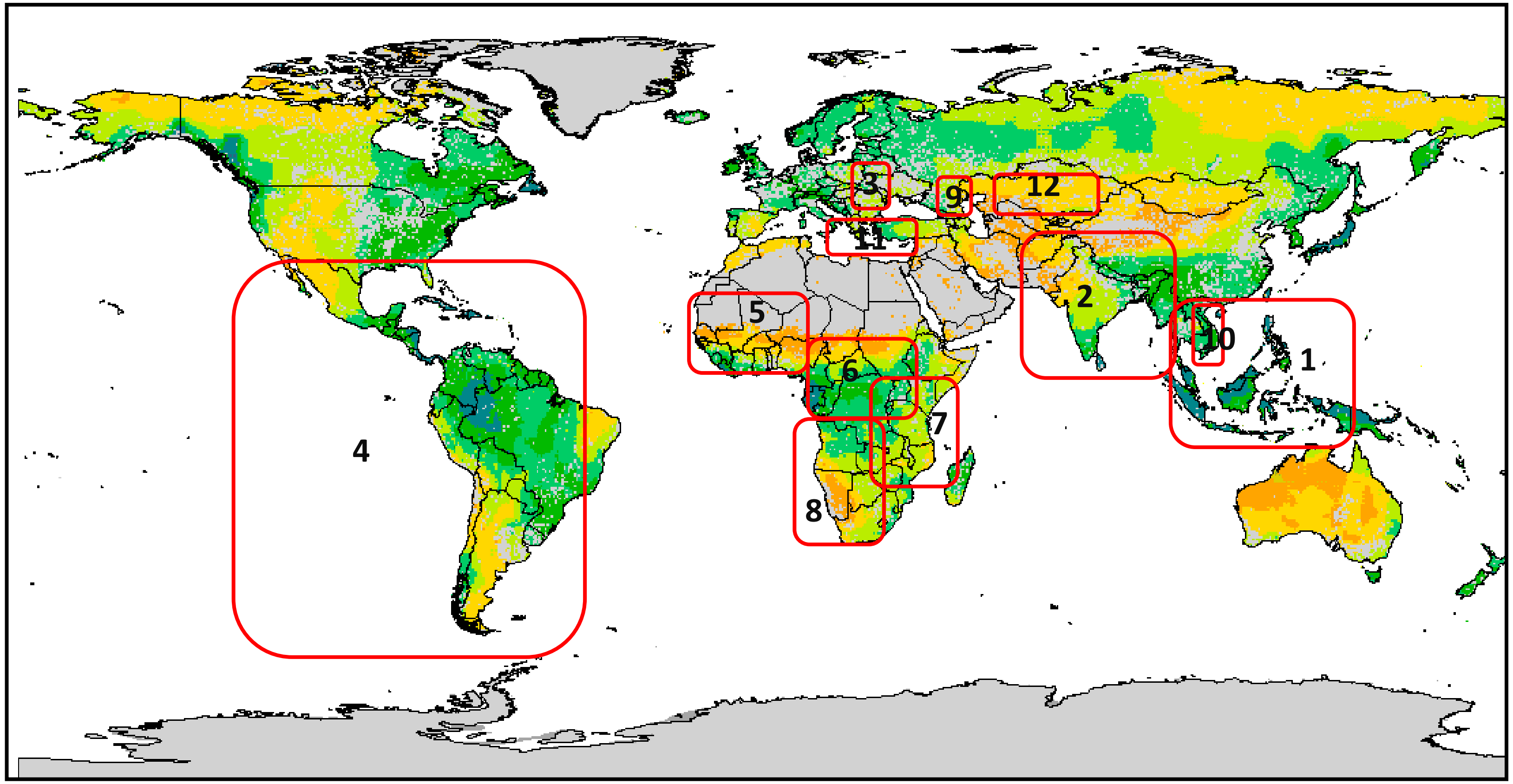
An international forum for coordination concerning Earth Observations



GOFC-GOLD Structure



GOFC-GOLD Regional Networks



Currently active GOFC-GOLD regional networks. 1.Southeast Asia Regional Research and Information Network (SEARRIN); 2. South Asia Regional Information Network (SARIN); 3. South Central European Regional International Network (SCERIN); 4. Red Latinoamerica de Teledeteccion e Incendios Forestales (RedLaTIF); 5. West African Regional Network (WARN); 6. Observatoire Satellital des Forets d'Afrique Central (OSFAC); 7. Miombo Network (MIOMBO); 8. Southern Africa Fire Network (SAFNET); 9.Caucasus Regional Information Network (CaucRIN); 10.Mekong Regional Information Network (MekRIN); 11. Mediterranean Regional Network (MedRIN); 12. Central Asia Regional Information Network (CARIN)

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- **Thank you for your attention**