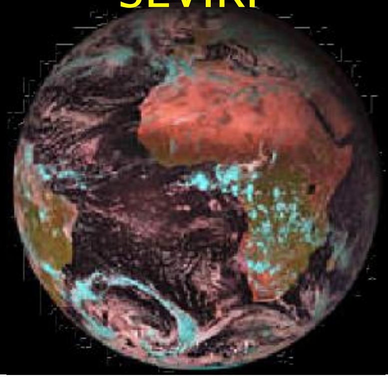
LSA SAF Fire Radiative Power Product

Martin J. Wooster, Weidong Xu, Gareth Roberts, Johannes kaiser and Jiangping He

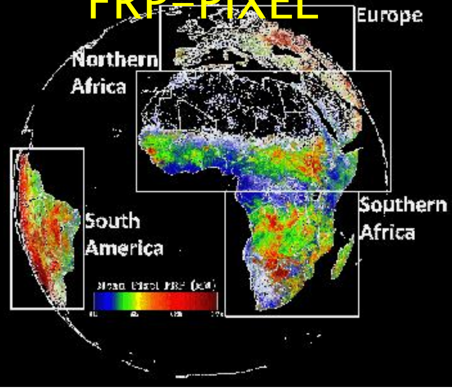
SALGEE workshop 1 Sept 2015

Background

SEVIRI

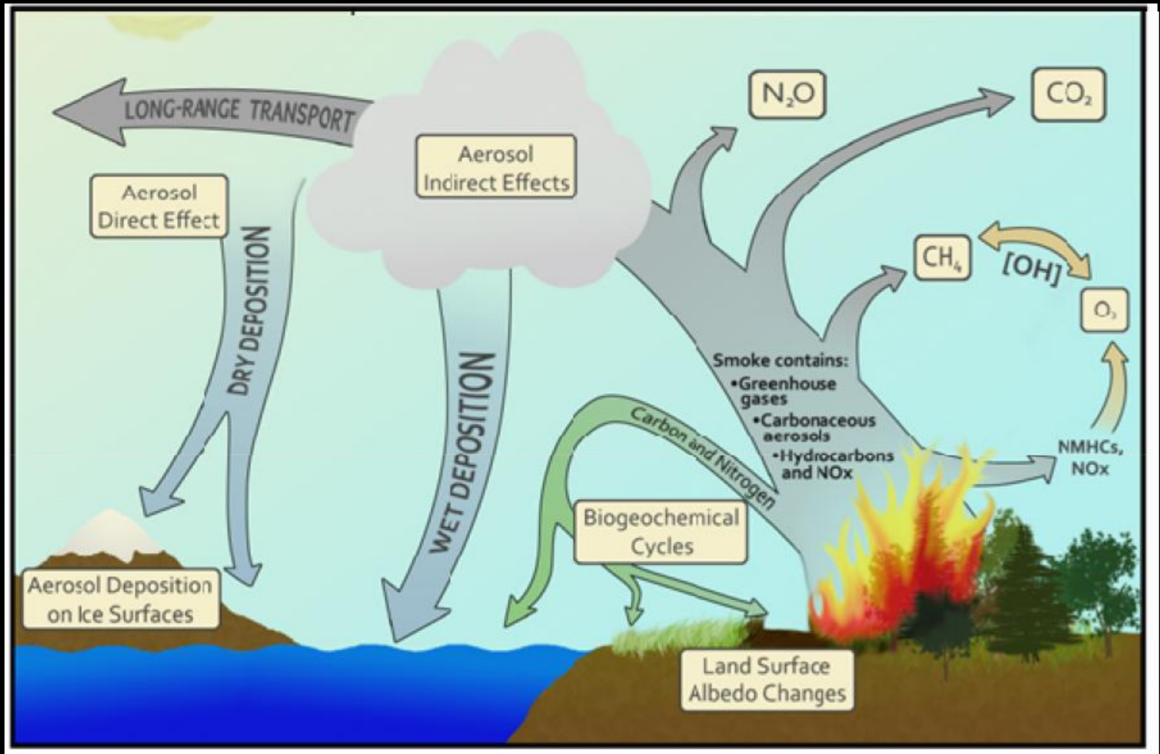


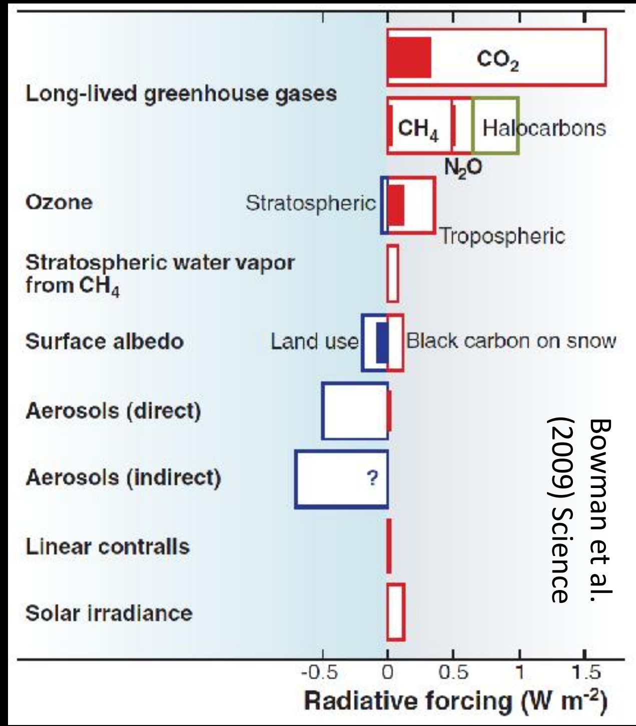
FRP-PIXEL



Inputs to Models

Biomass Burning Impacts

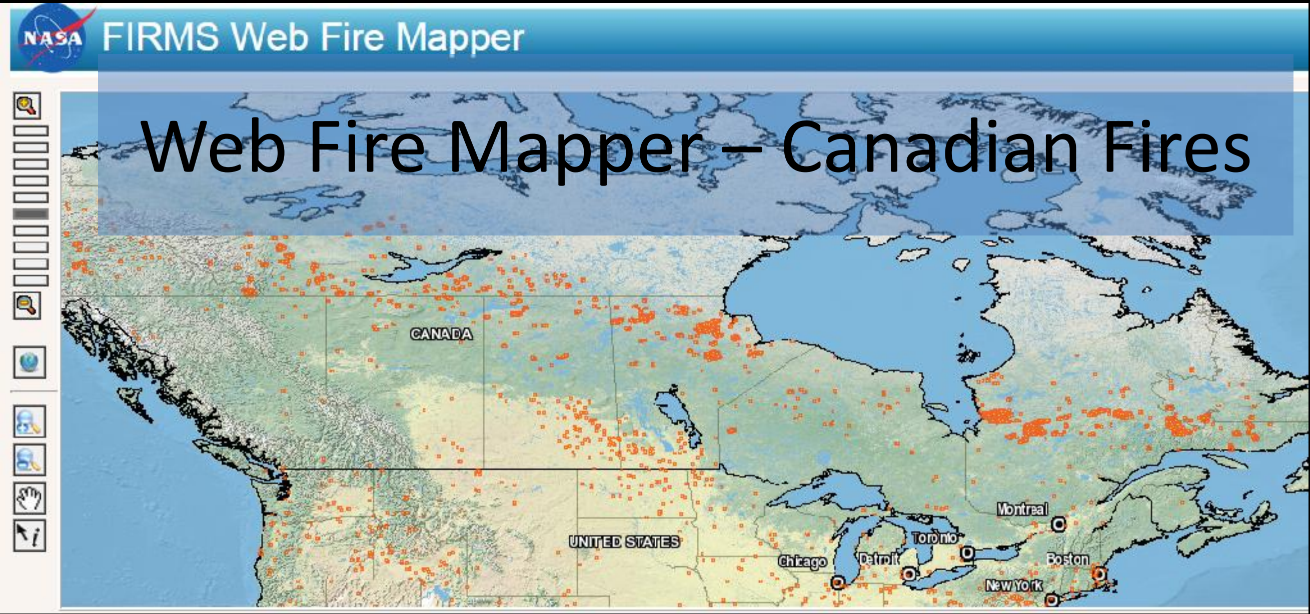




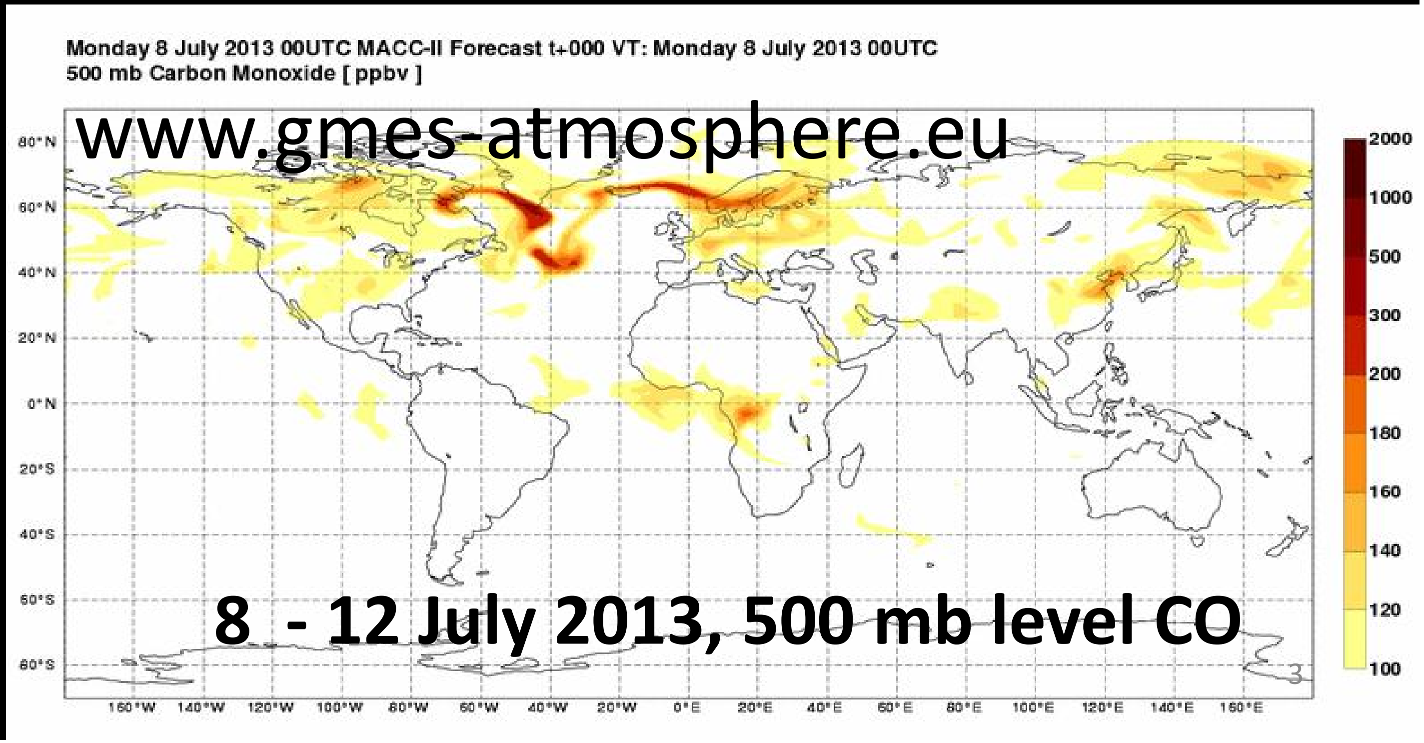
- Fire contribution (warming)
- Fire contribution (cooling)
- Total contribution (warming)
- Total contribution (cooling)

- Fires play an important role in the natural equilibrium climate, and that perturbed by humans.
- They need to be considered in future climate projections (Ward et al., 2012)
- And also in UNFCC Sponsored REDD+ Programmes.

Web Fire Mapper – Canadian Fires



June-July 2014

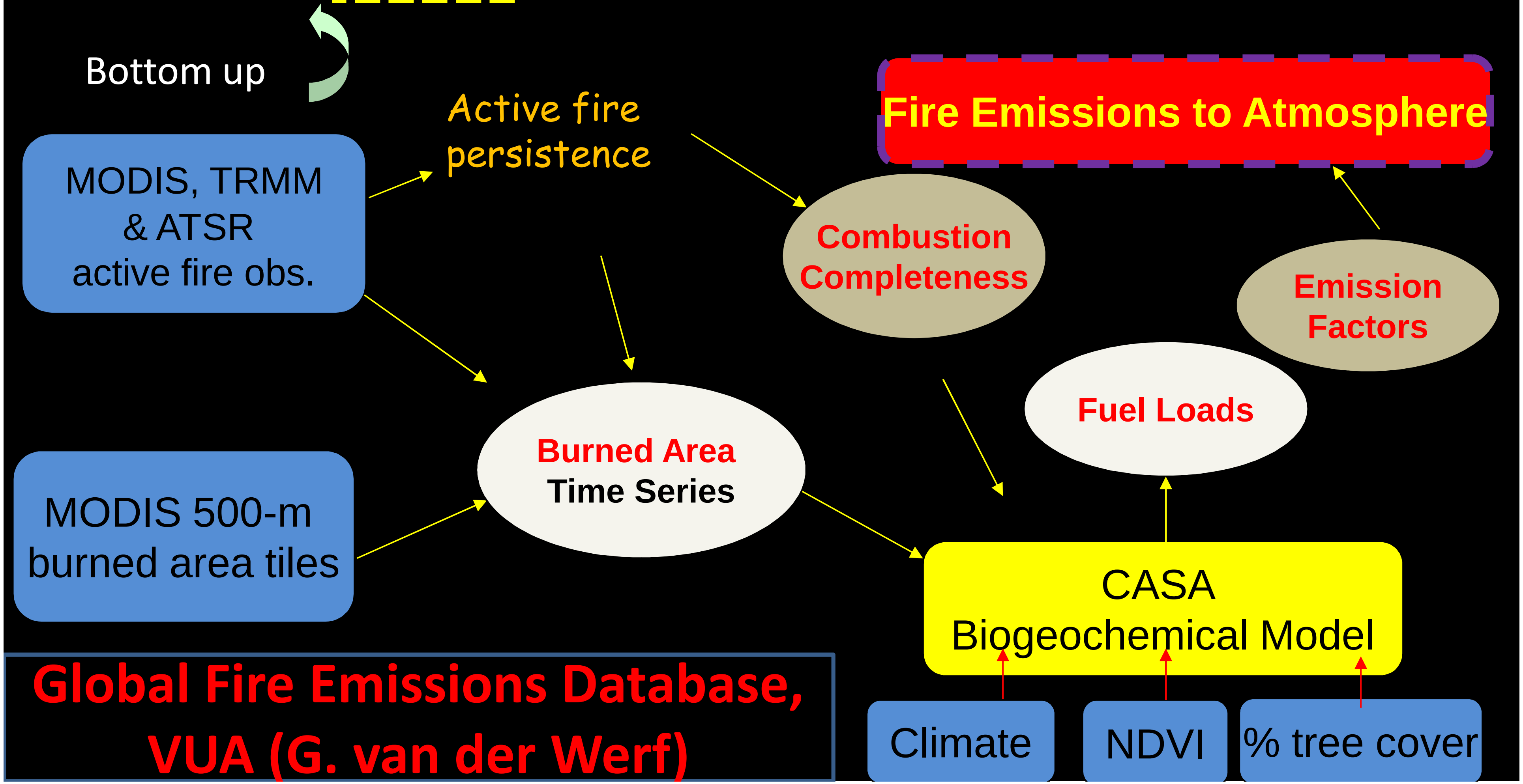


www.gmes-atmosphere.eu

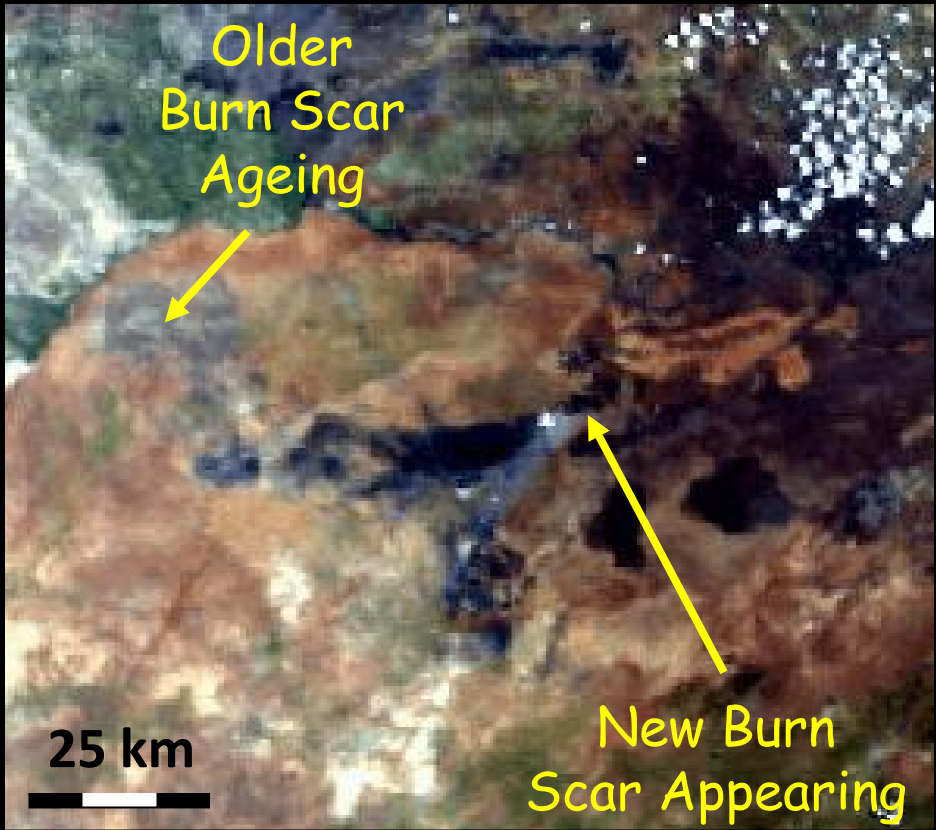
8 - 12 July 2013, 500 mb level CO

Quantification & Limitations

$$\text{Emissions}_{\text{Species}} = \boxed{\text{Burned Area}} \times \overbrace{\text{Fuel Load} \times \text{Combustion Completeness}}^{\text{Fuel Mass Burned}} \times \text{EF}_{\text{Species}}$$

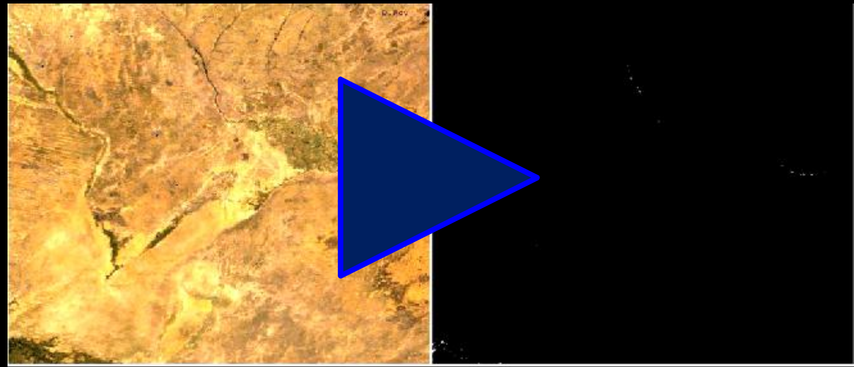


MODIS Burned Area Mapping



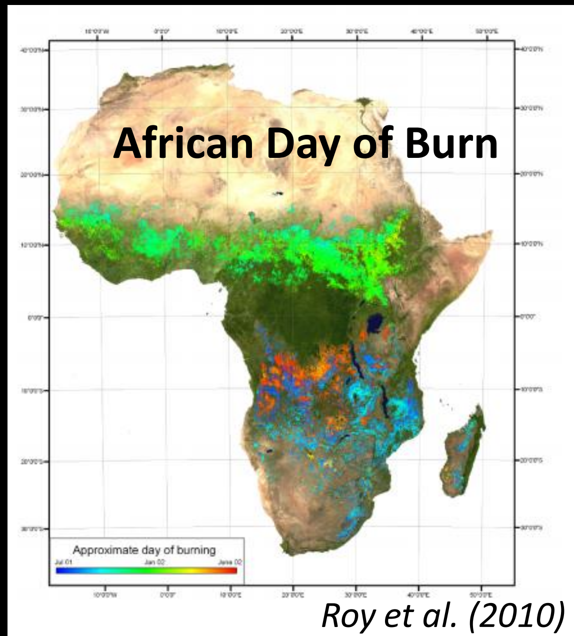
MODIS True Colour Image Pair

17th & 24th Oct 2001



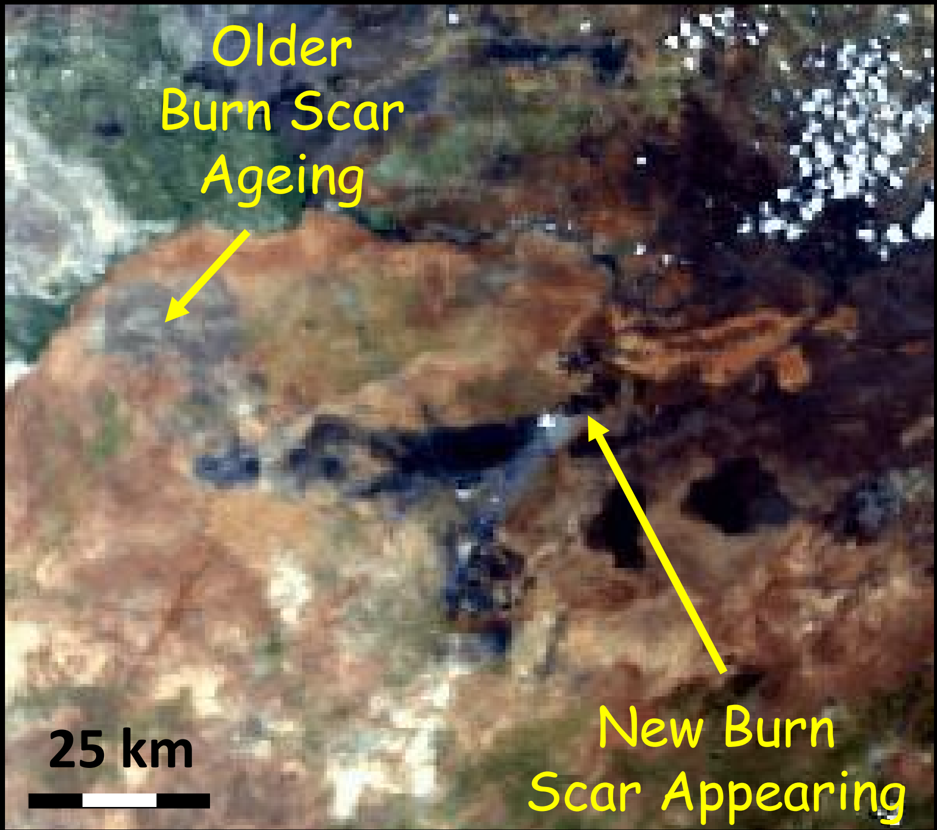
MODIS True Colour Timeseries

MODIS Burned Area Timeseries



Roy et al. (2010)

MODIS Burned Area Mapping



MODIS True Colour Image Pair

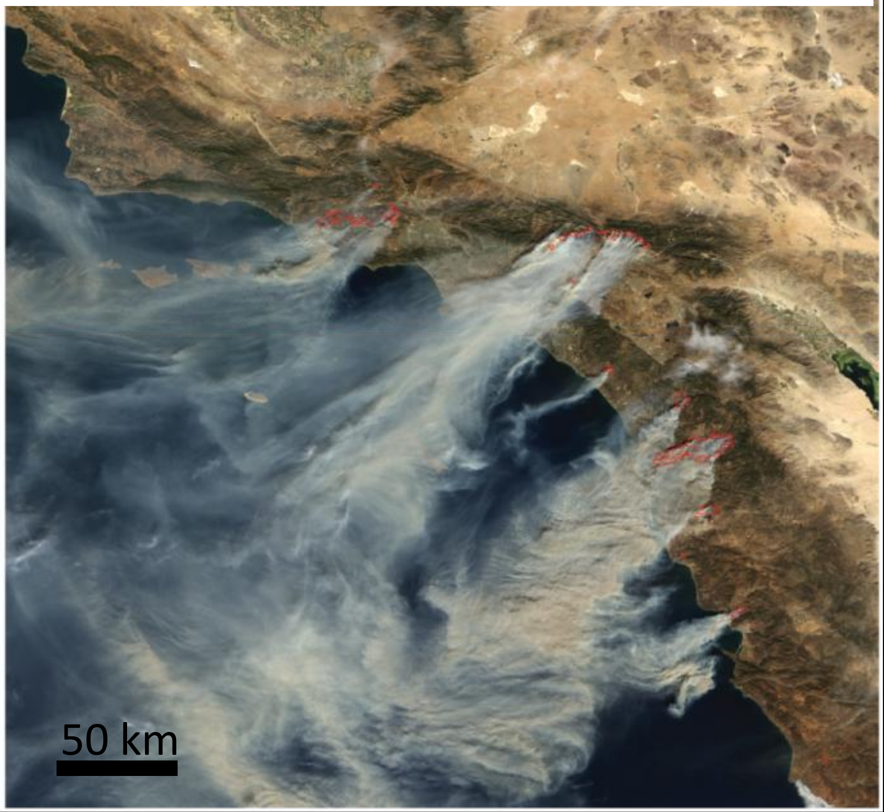
17th & 24th Oct 2001

MODIS Thermal Band

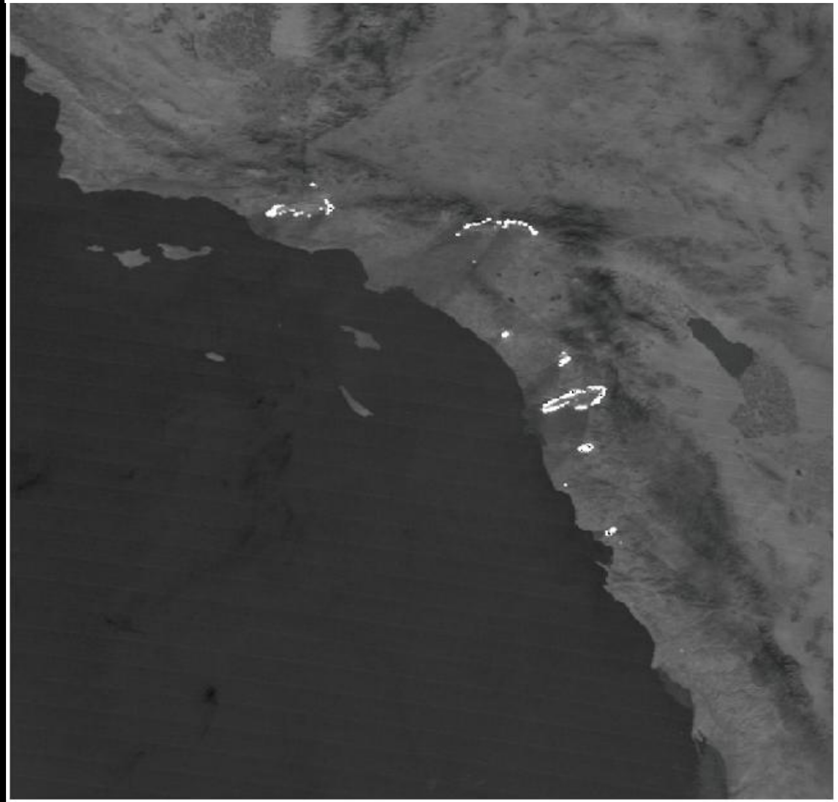
24th Oct 2001

MODIS 1 km Fire Observations

True Colour Composite



Middle IR Wavelength (3.96 µm)

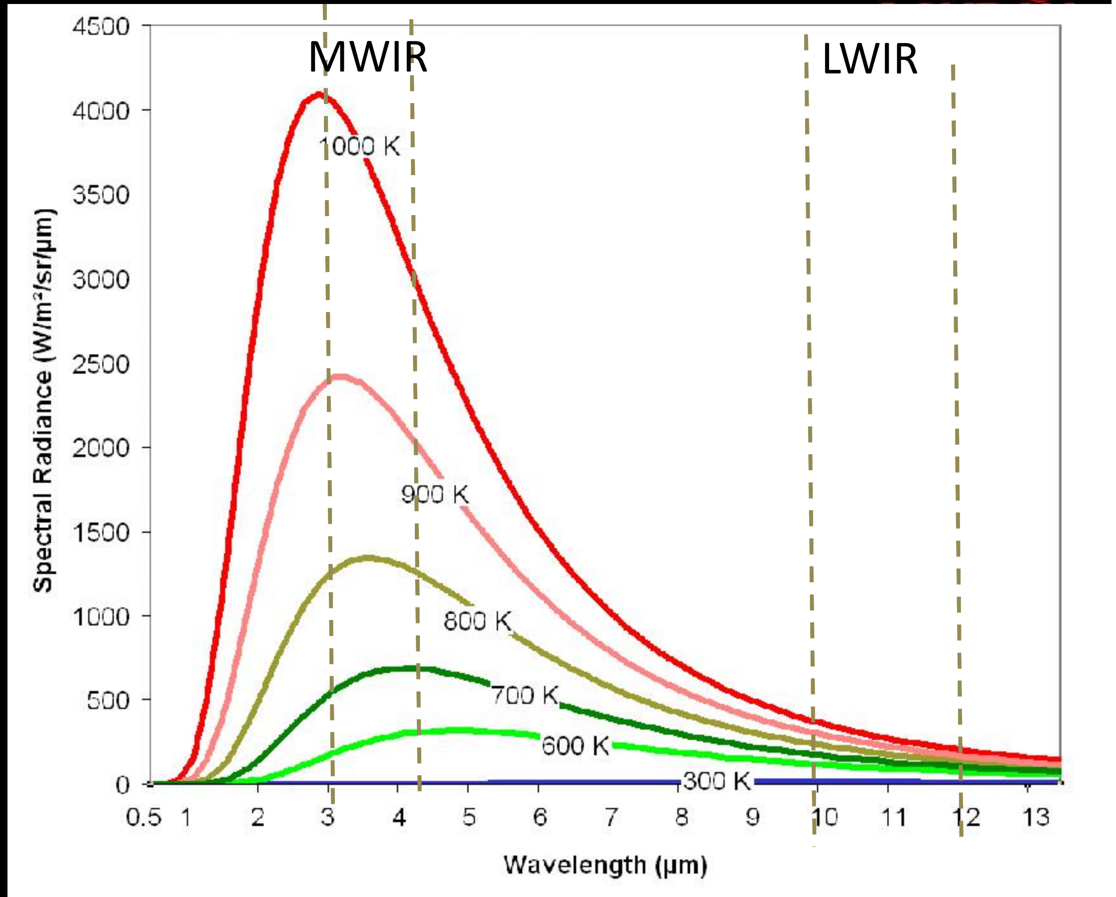


Basic Physics of Active Fire Detection

Planck Radiation Law

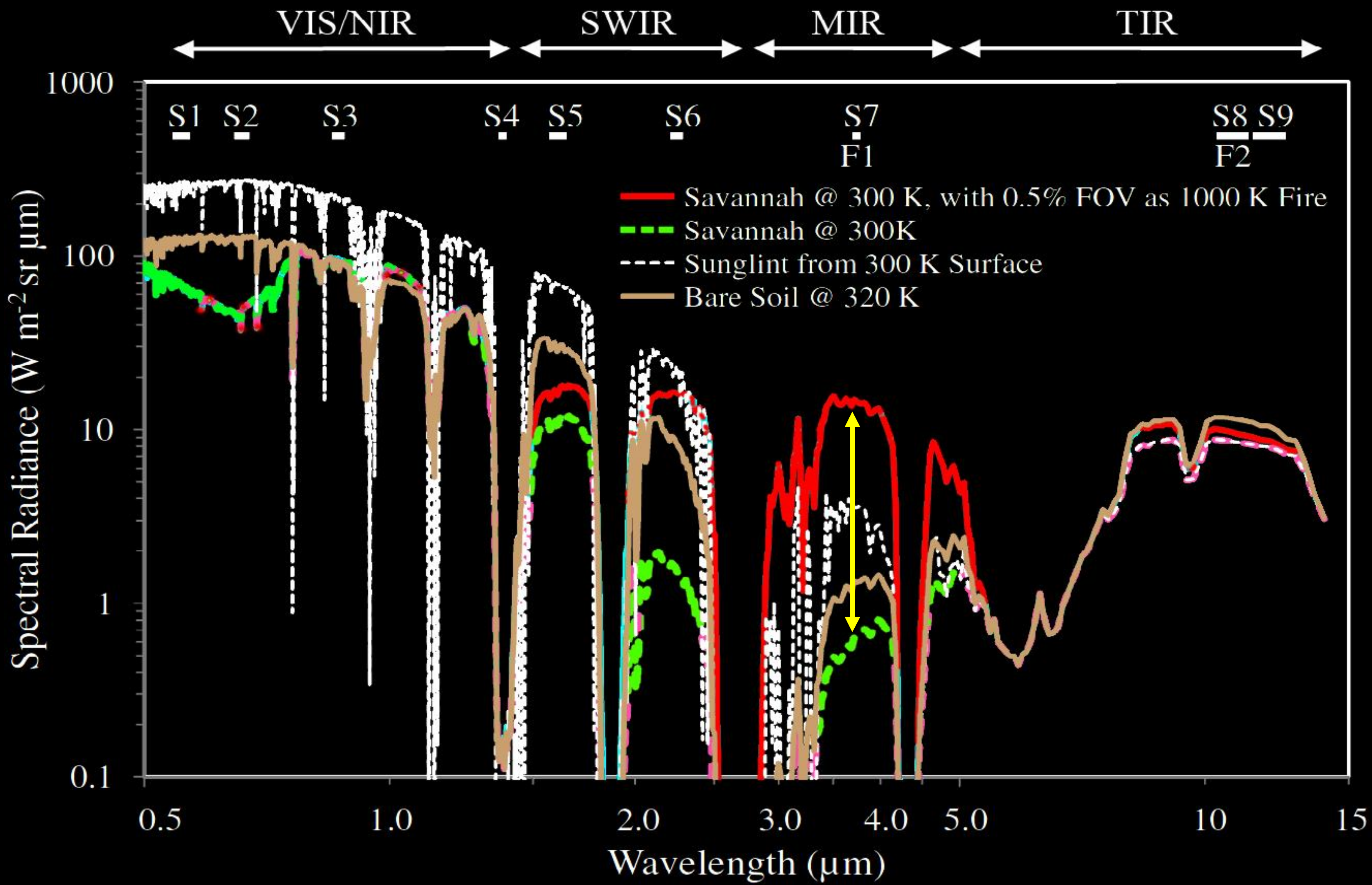
$$L(a,T)=\frac{C_1}{a^5(\exp(\frac{C_2}{aT})-1)}$$

l wavelength (m)
T temperature (K)
L spectral radiance ($Wm^{-2}\ sr^{-1}m^{-1}$)
$C_1 = 2\pi hc^2$ W.m^2
$C_2 = hc/k$ m.K



Thermal emission peaks in the MIR (3-5 μm) region for fire temperatures ranging from ~ 650 K (weak smouldering) to ~ 1400 K (strong flaming).

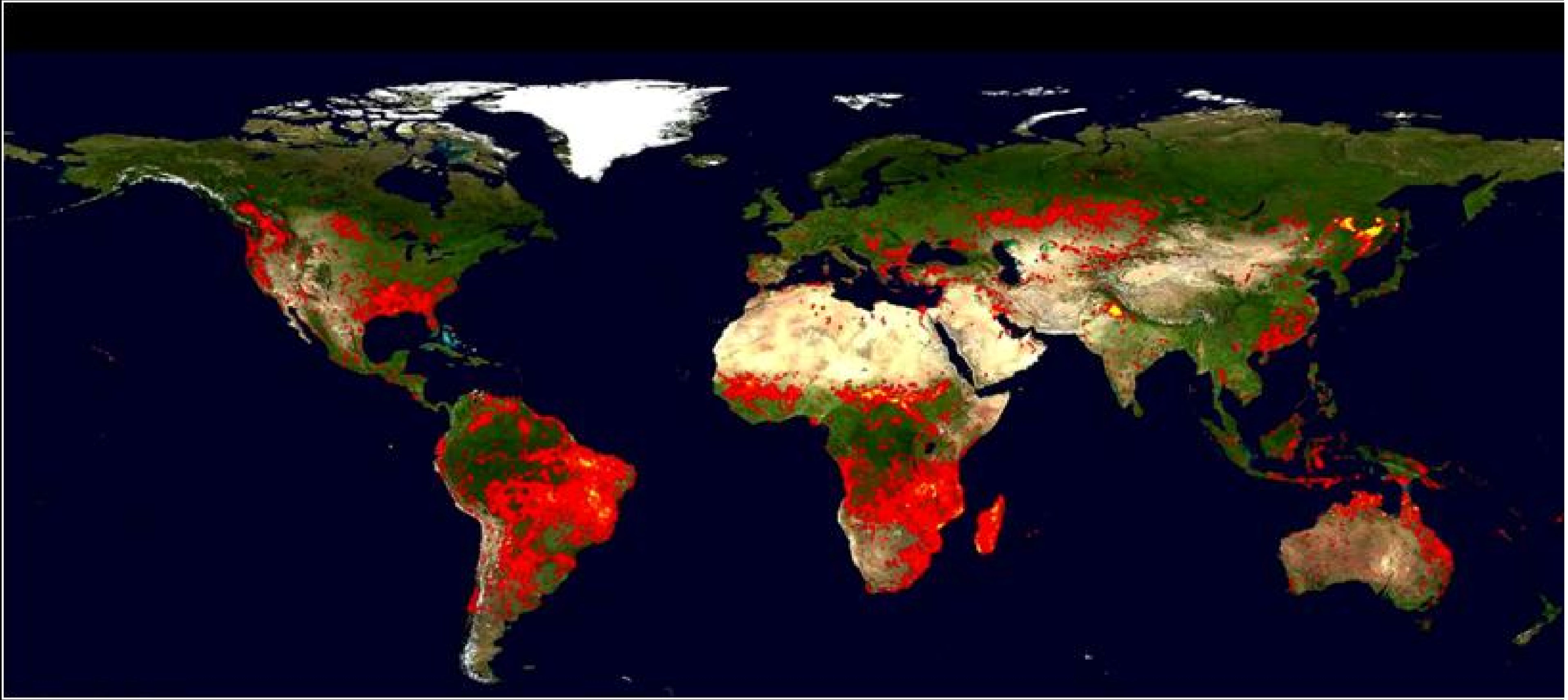
Radiative Transfer of Active Fire Detection



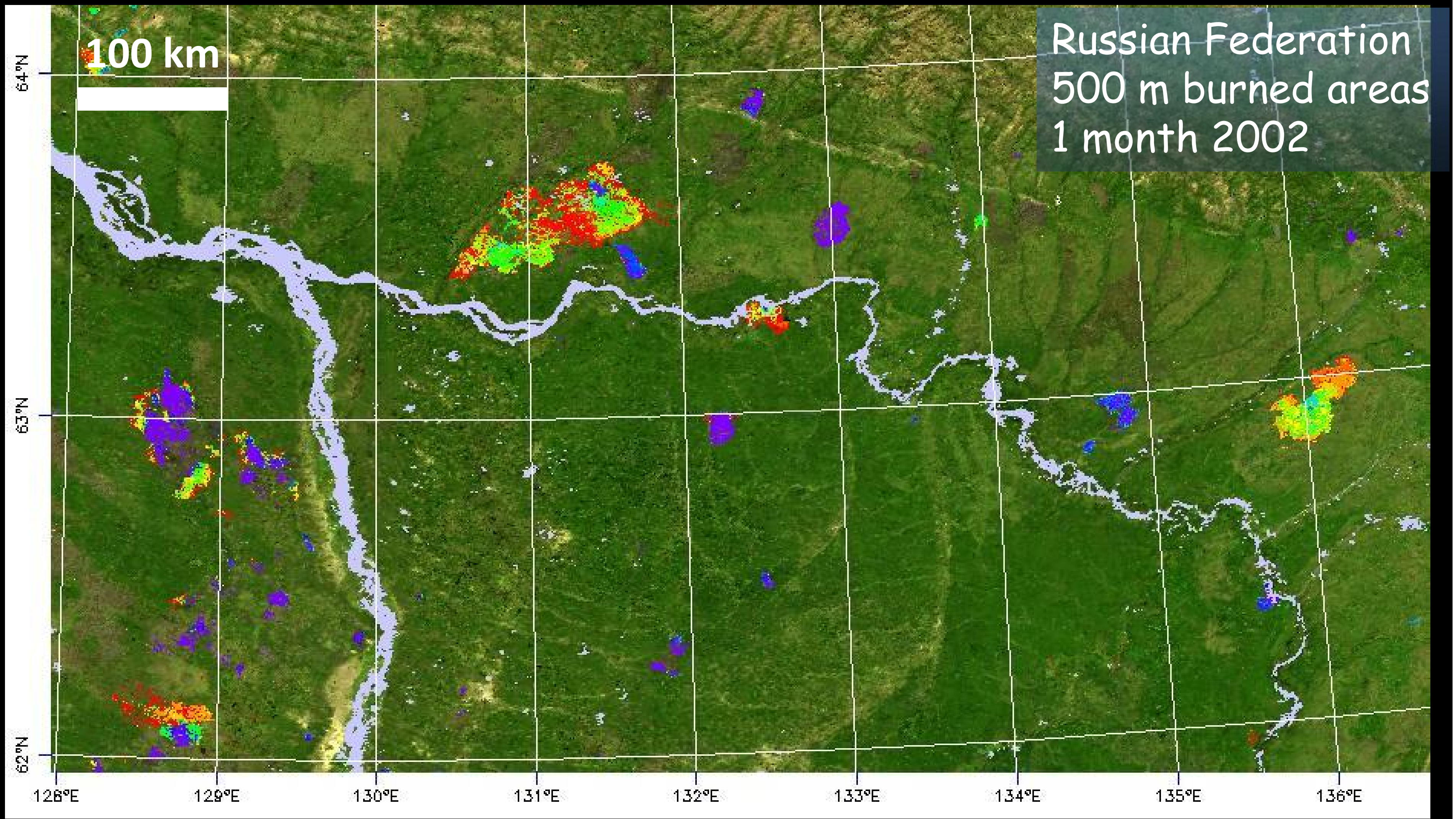
Global Fires from MODIS

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

KING'S College LONDON

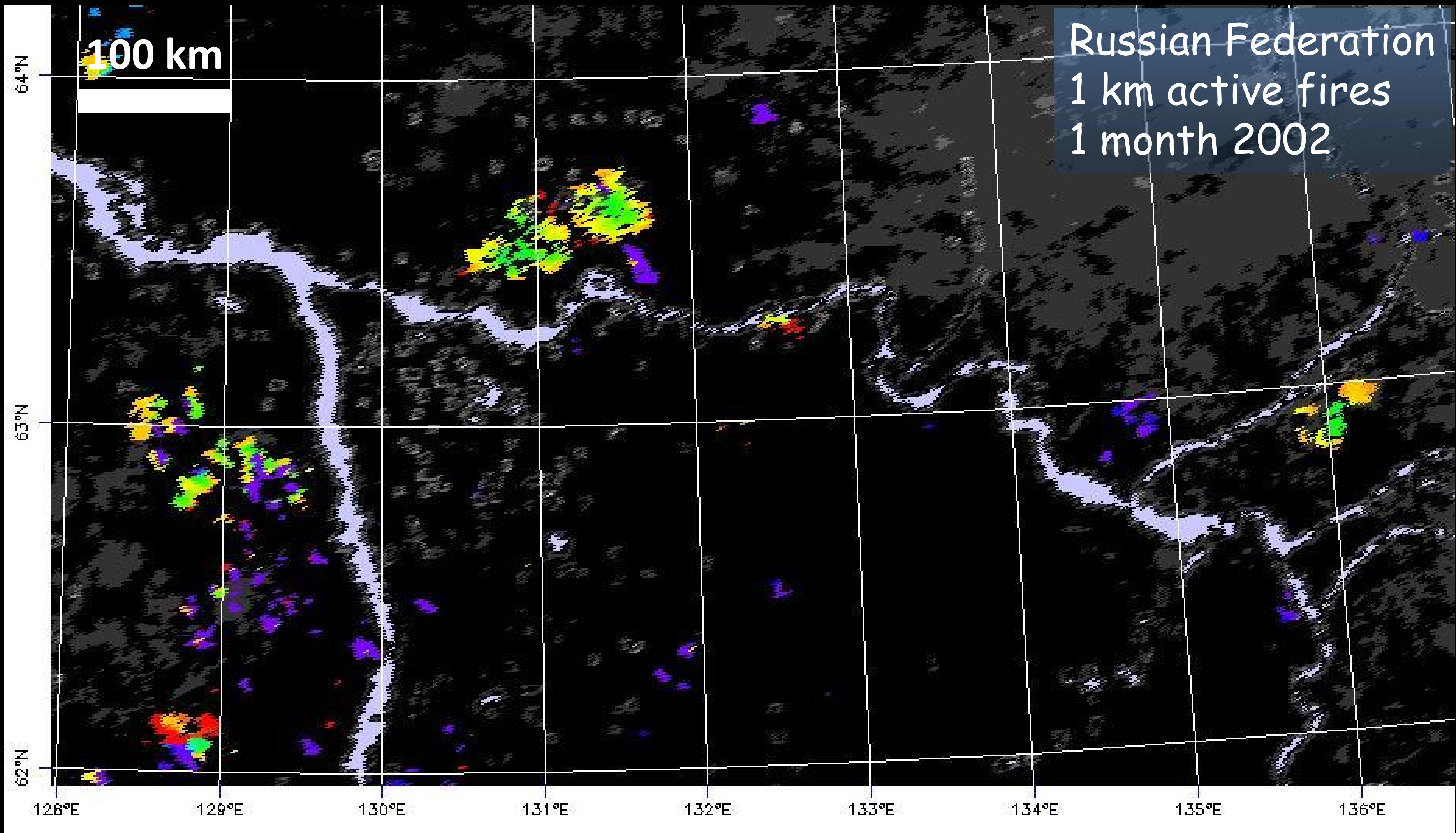


- 1 km resolution – very sensitive to fires with ~ 4 passes per day.
- Global database – useful for evaluation of other products.
- Fires temporally variable - diurnal cycle - so geostationary very useful.



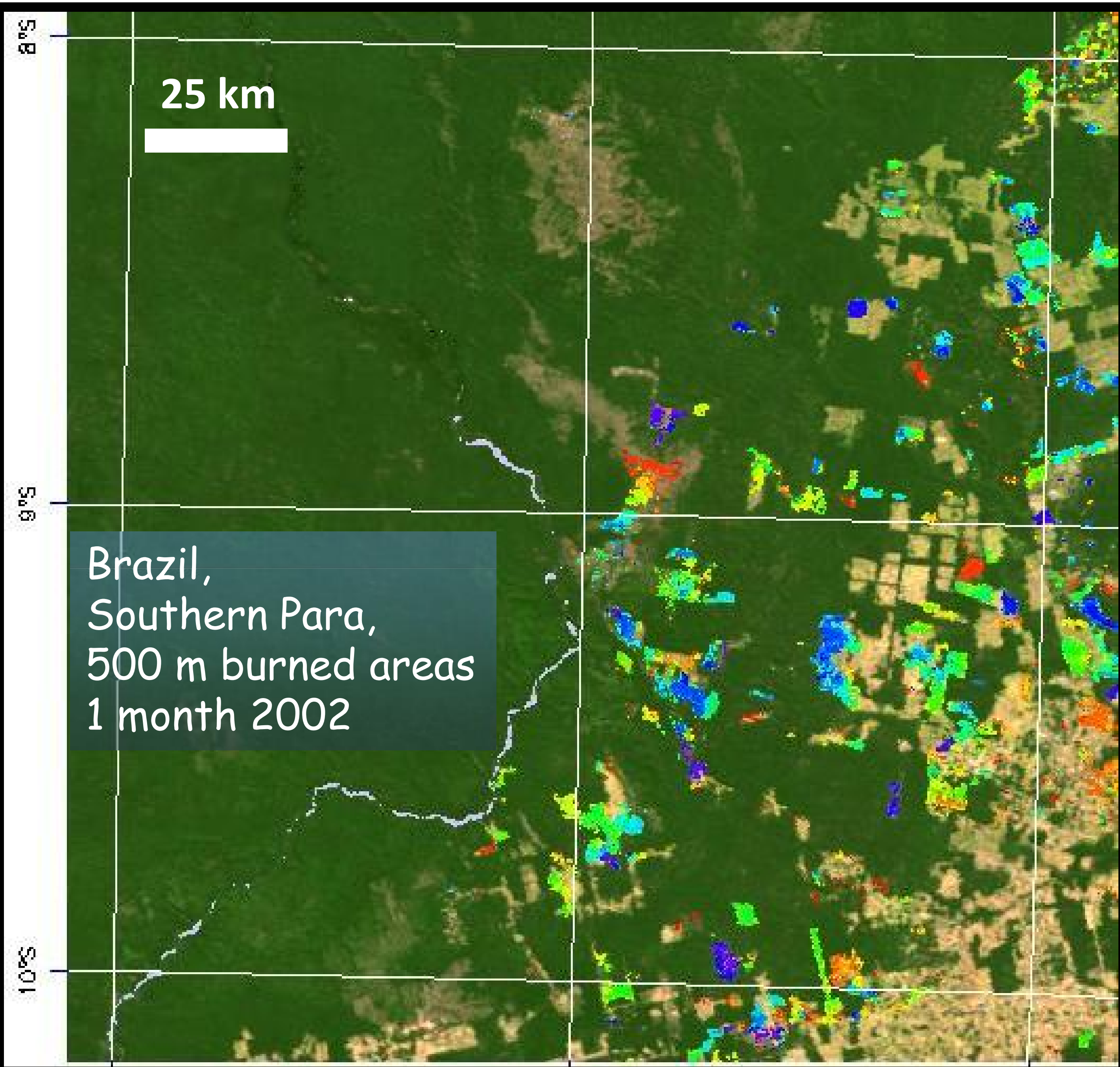
Burned Area (Reflectance)

Roy et al. (2010)



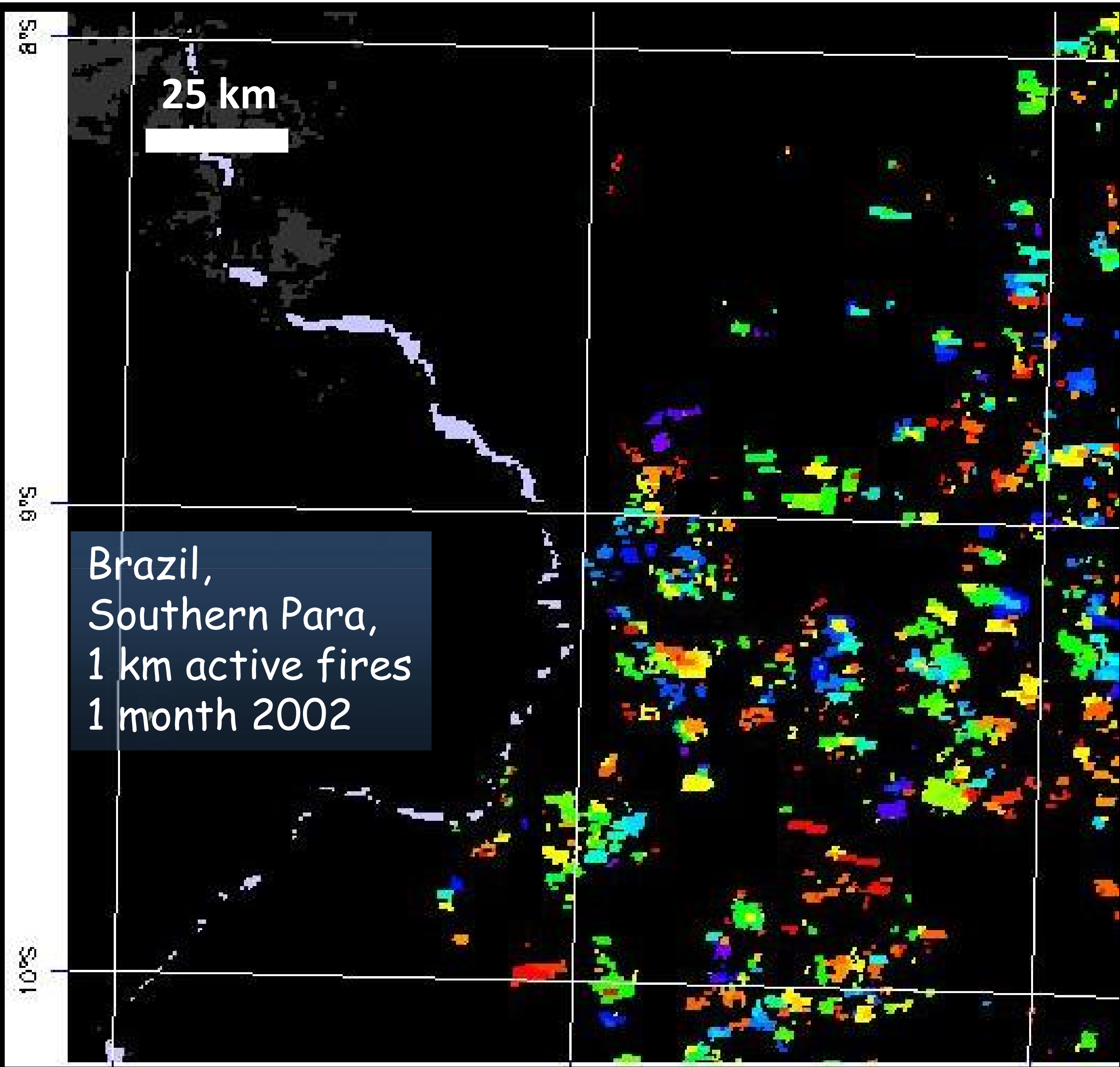
Hotspot Map (Thermal)

Roy et al. (2010)



Burned Area (Reflectance)

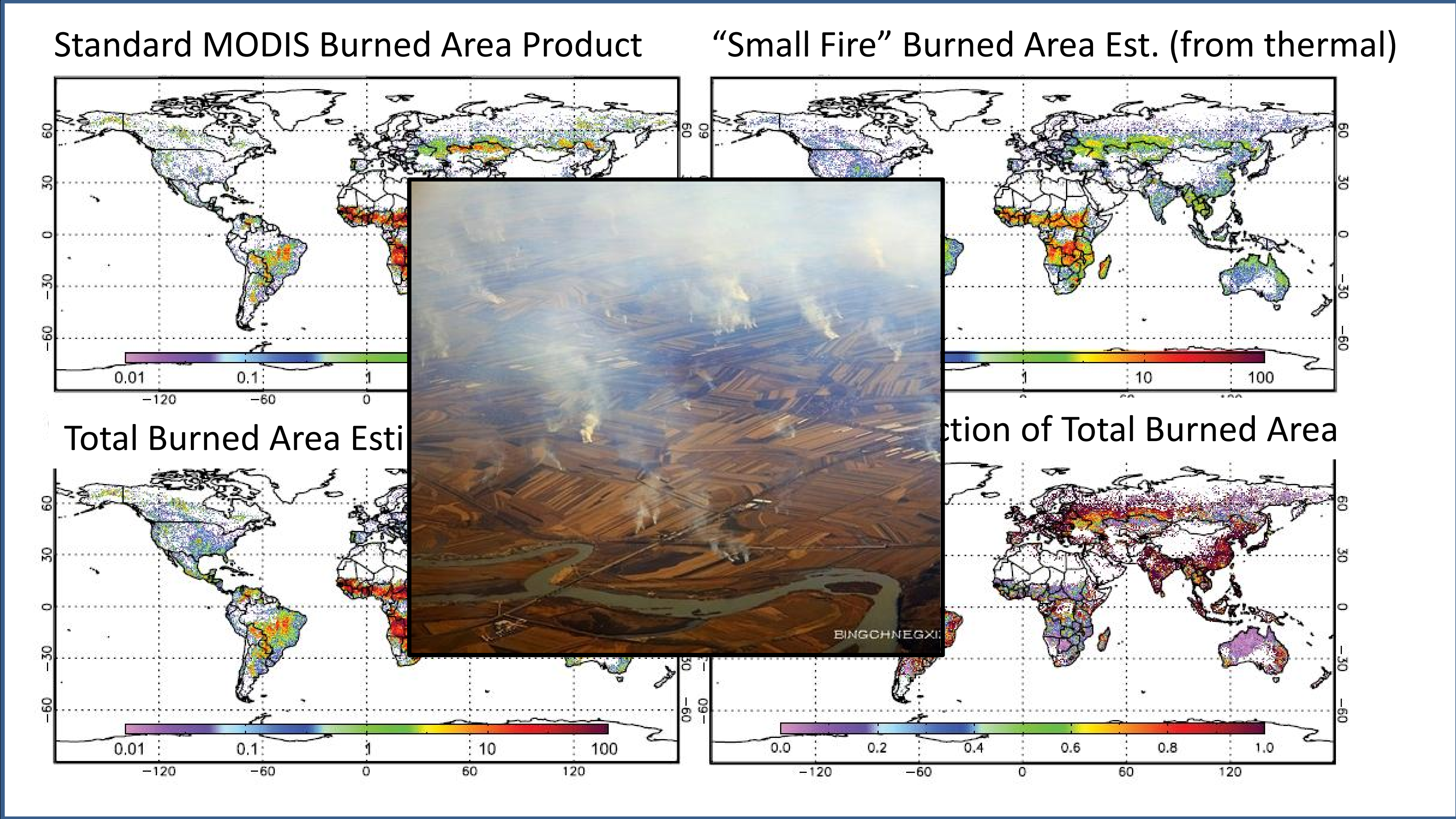
Roy et al. (2010)



Hotspot Map (Thermal)

Roy et al. (2010)

Global Burned Area & “Small Fire” Problem



Randerson et al., (2012)

Fuel Consumption Estimation

- Plants store 0.02% of solar energy across Earth 10^{21} J yr^{-1}.
- Release ~ 20 kJ kg^{-1} when they burn.
- Much as thermal radiation.

Fuel Burned = BA x FL x CC

Fuel Burned = ΣFRP x CF

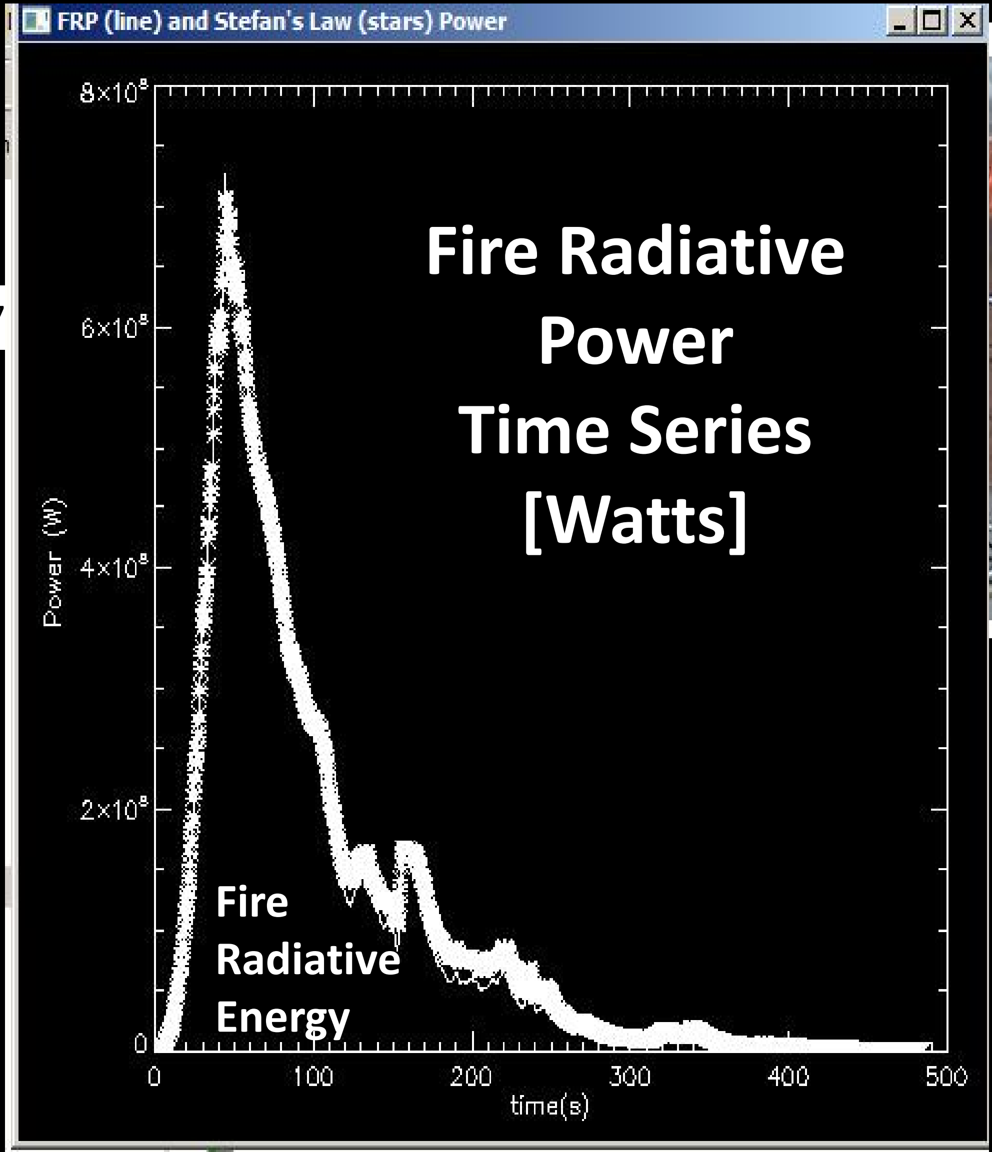
Where FRP = Fire Radiative Power (Watts)

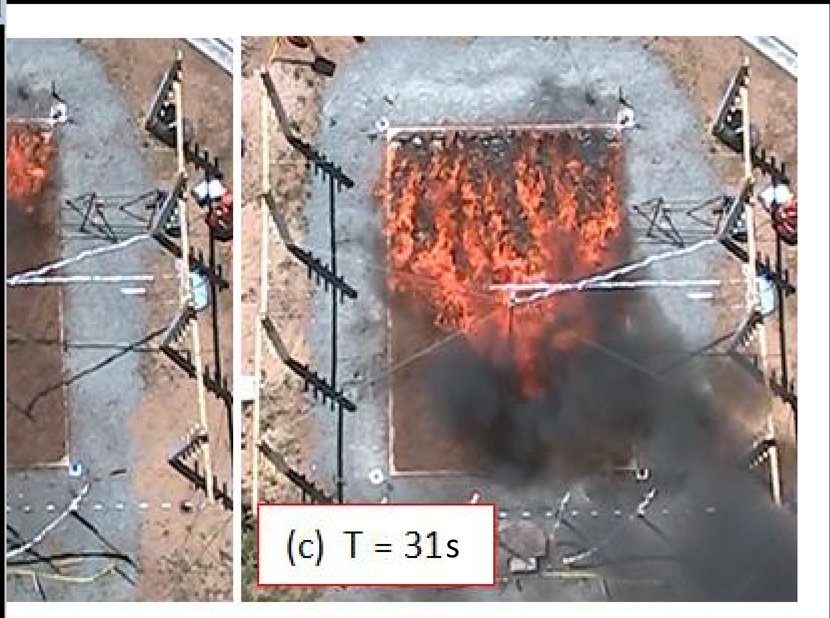
ΣFRP = Fire Radiative Energy (Joules)

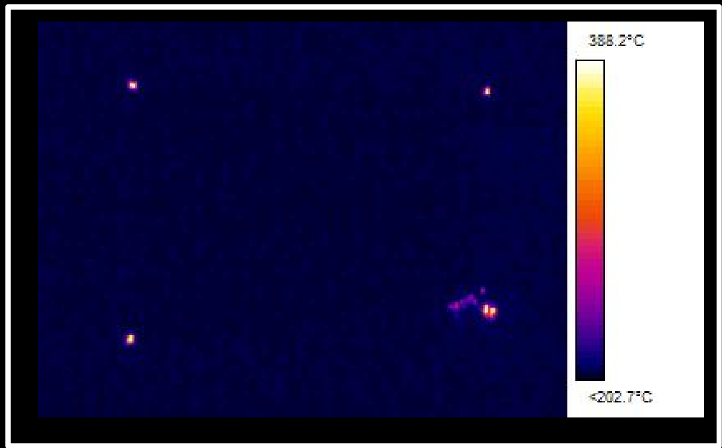
CF = Consumption Factor (J kg^{-1})

[amount of energy radiated per kg]

Testing ΣFRP → Fuel Consumption







Fuel Consumption Estimation

- Plants store 0.02% of solar energy across Earth 10^{21} J yr^{-1}.
- Release ~ 20 kJ kg^{-1} when they burn.
- Much as thermal radiation.

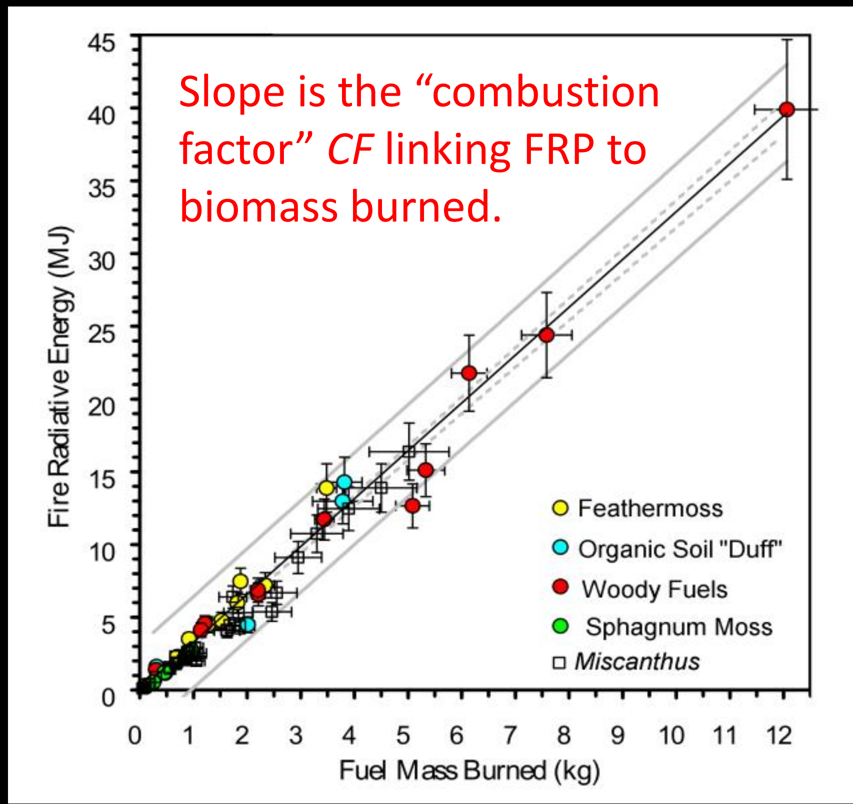
Fuel Burned = *BA* x *FL* x *CC*

Fuel Burned* = p *FRP* x *CF

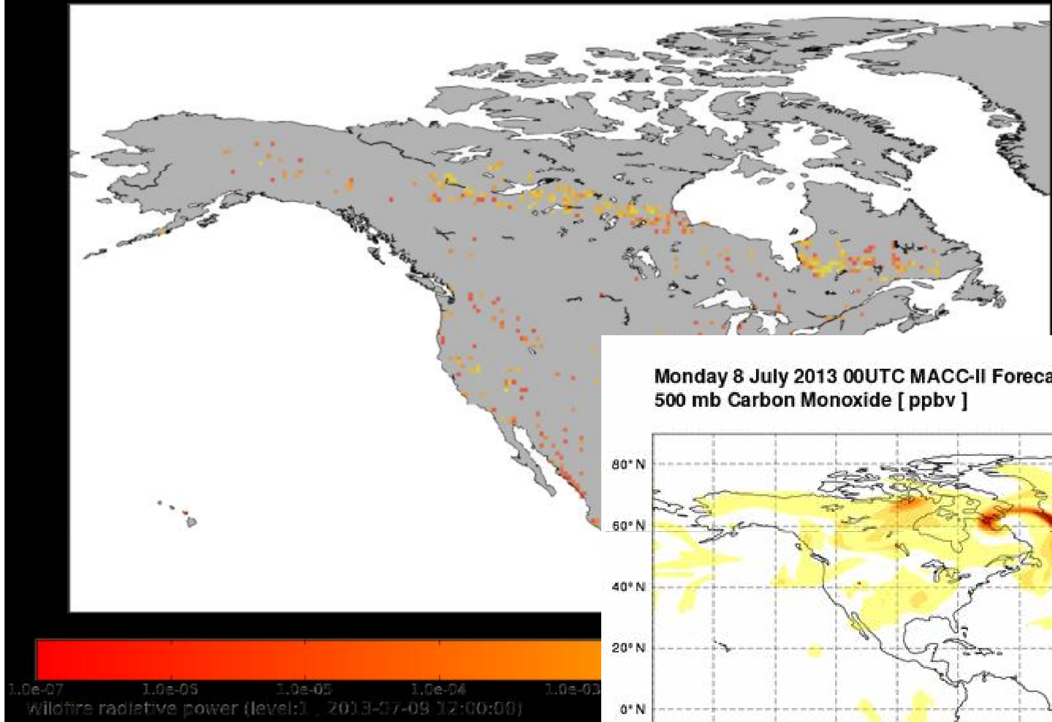
Appears theoretically ~ constant

FRP now part of the Global Climate Observing System Essential Climate Variables

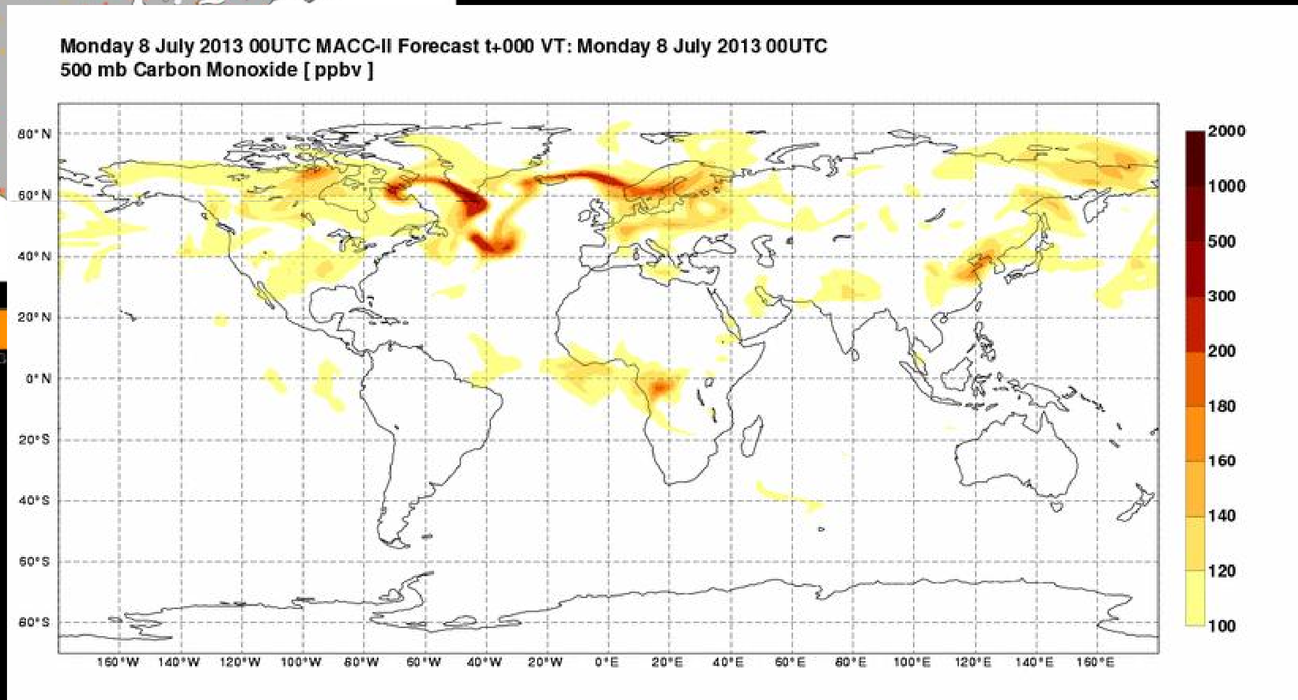
p ***FRP vs. Fuel Mass Burned***



www.gmes-atmosphere.eu



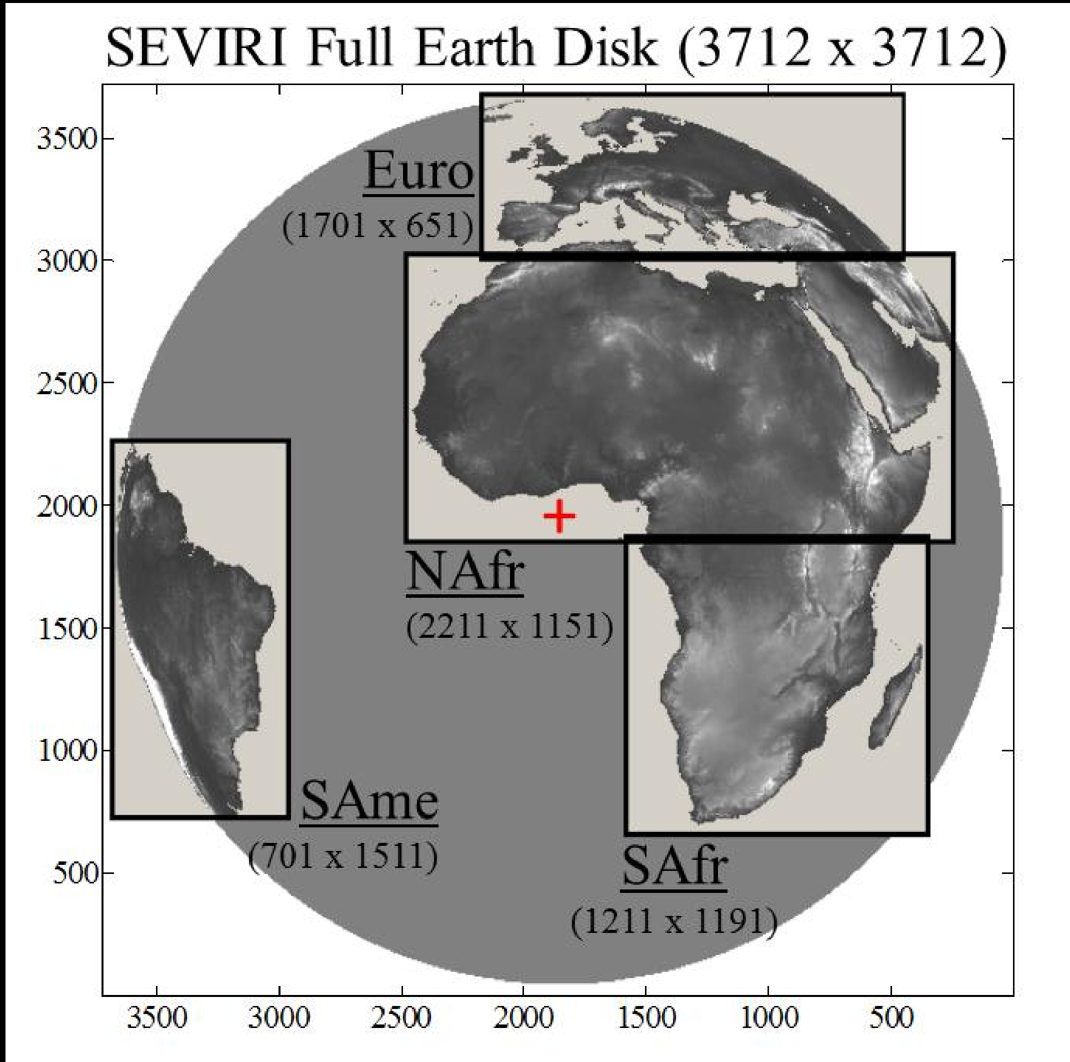
MACC Fire Radiative Power Density



- ECMWF
- VU Amsterdam.
- Jülich, Germany
- Max-Planck Chemie
- Instituto de Met. Portugal.
- King's College London, UK

8 - 12 July 2013, 500 mb level CO

SEVIRI FULL DISK



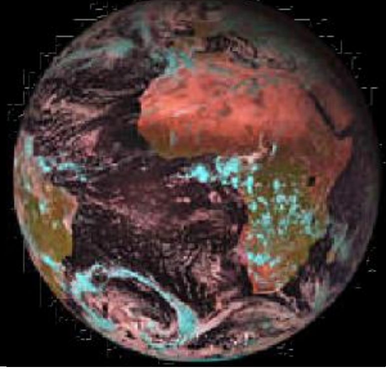
LSA SAF Fire Radiative Power Product - Part 2

Martin J. Wooster, Weidong Xu, Gareth Roberts, Daniel Fisher and Jiangping He

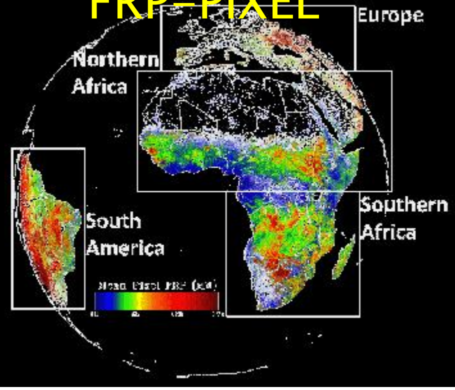
SALGEE workshop 1 Sept 2015

Background

SEVIRI



FRP-PIXEL

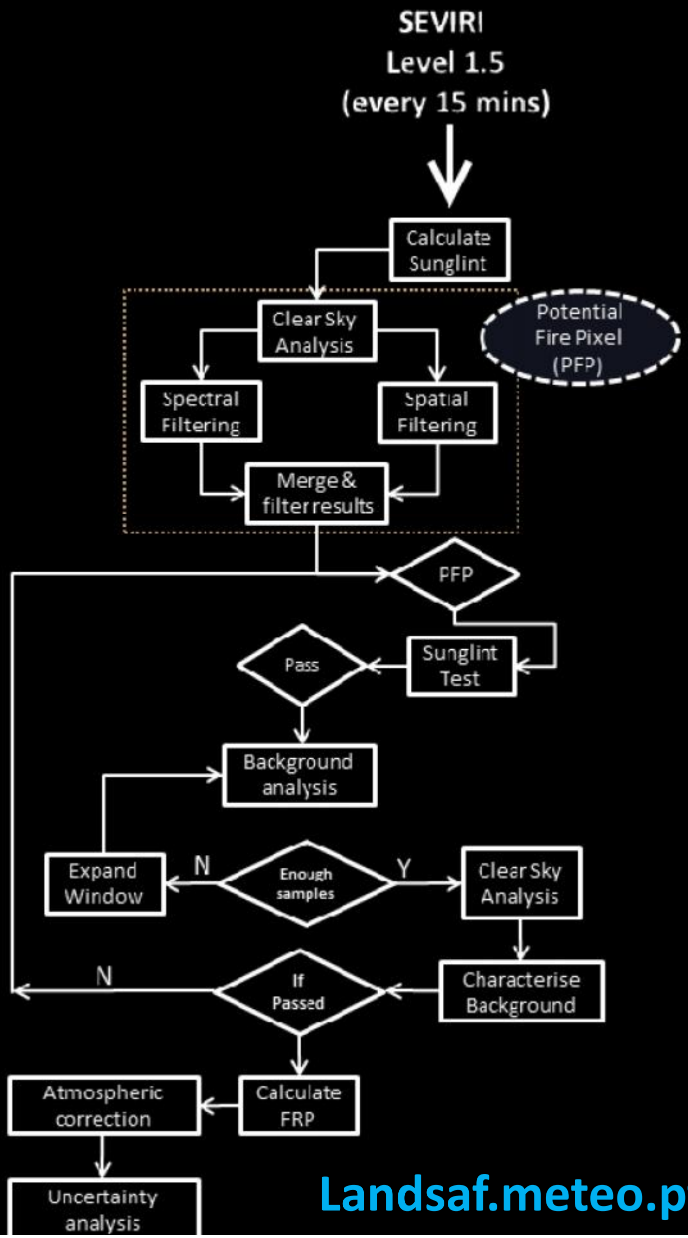


Inputs to Models

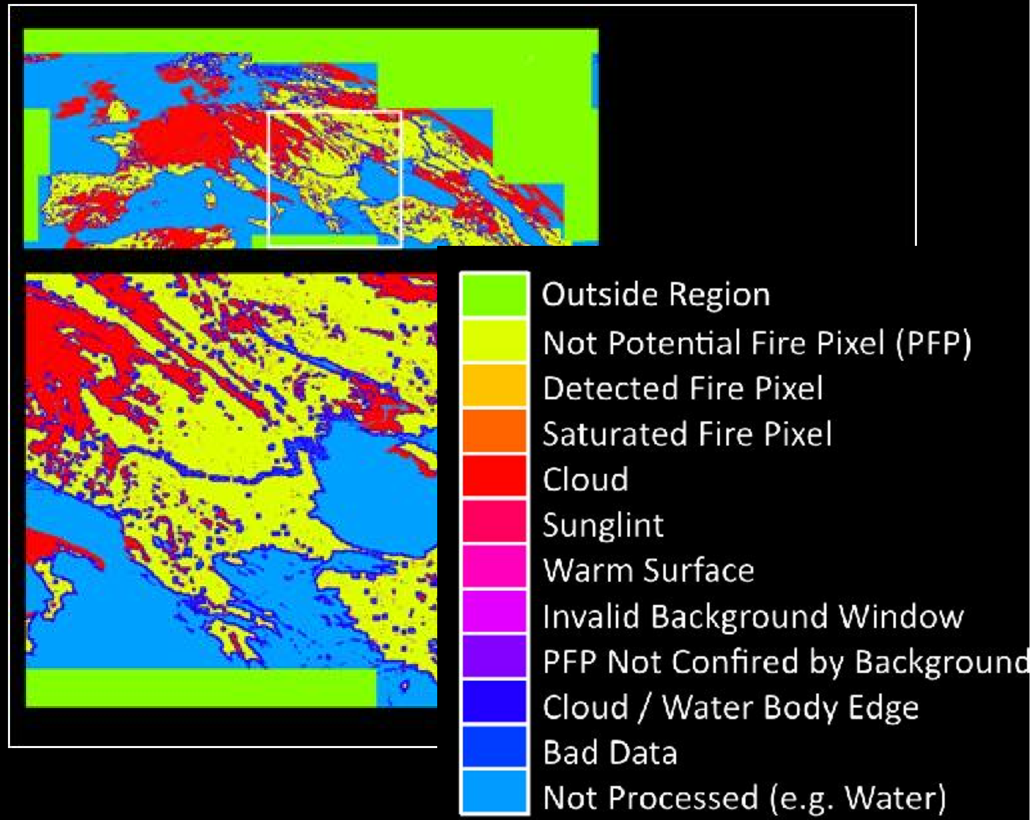
LSA SAF FRP Products from Meteosat SEVIRI

SEVIRI MWIR Band (5 mins)

Operational SEVIRI FRP-PIXEL Product

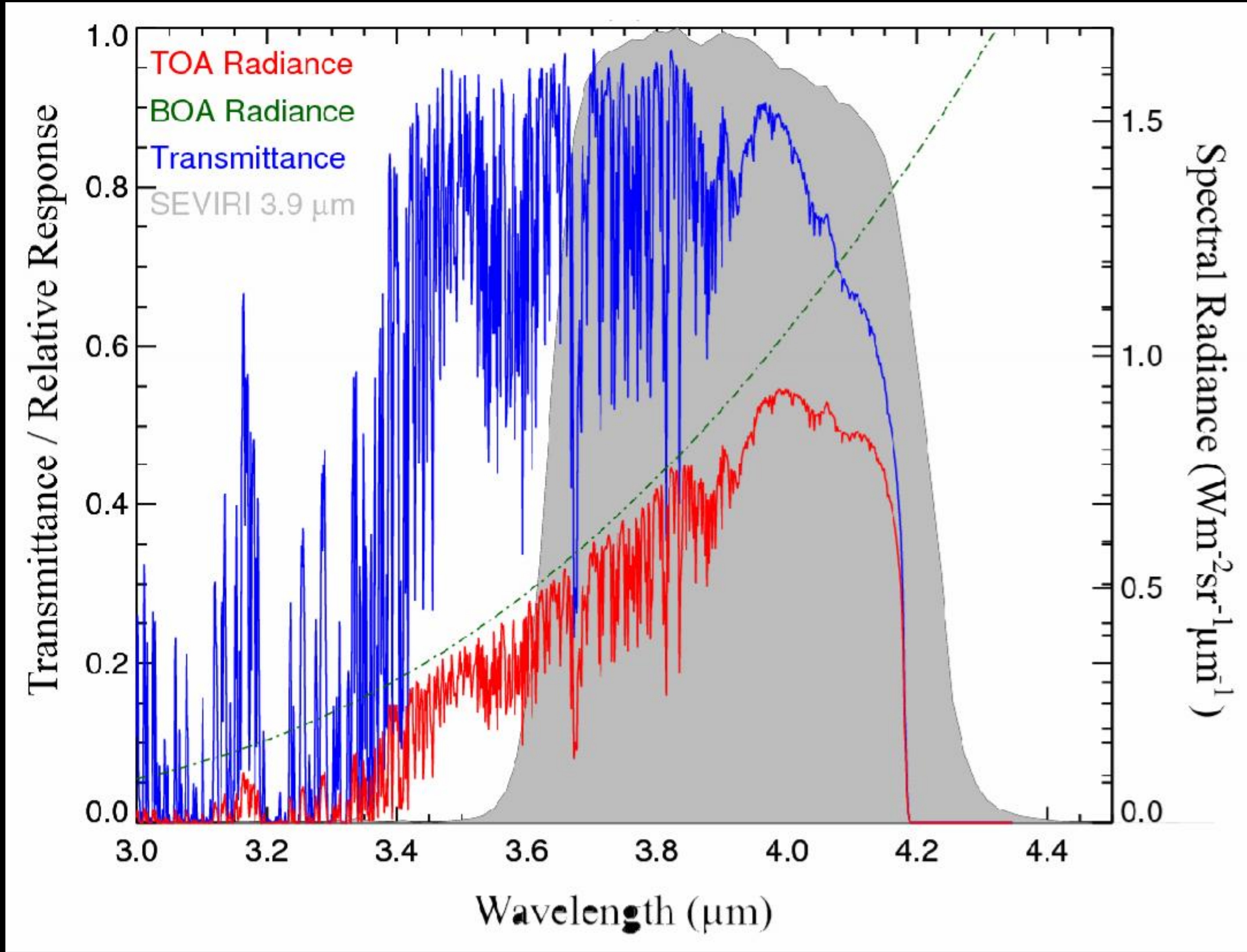


Landsaf.meteo.pt/



Delivered operationally (high timeliness and high reliability) as part of EUMETSAT Land Surface Analysis Satellite Applications Facility (LSA SAF).

SEVERI MWIR Band

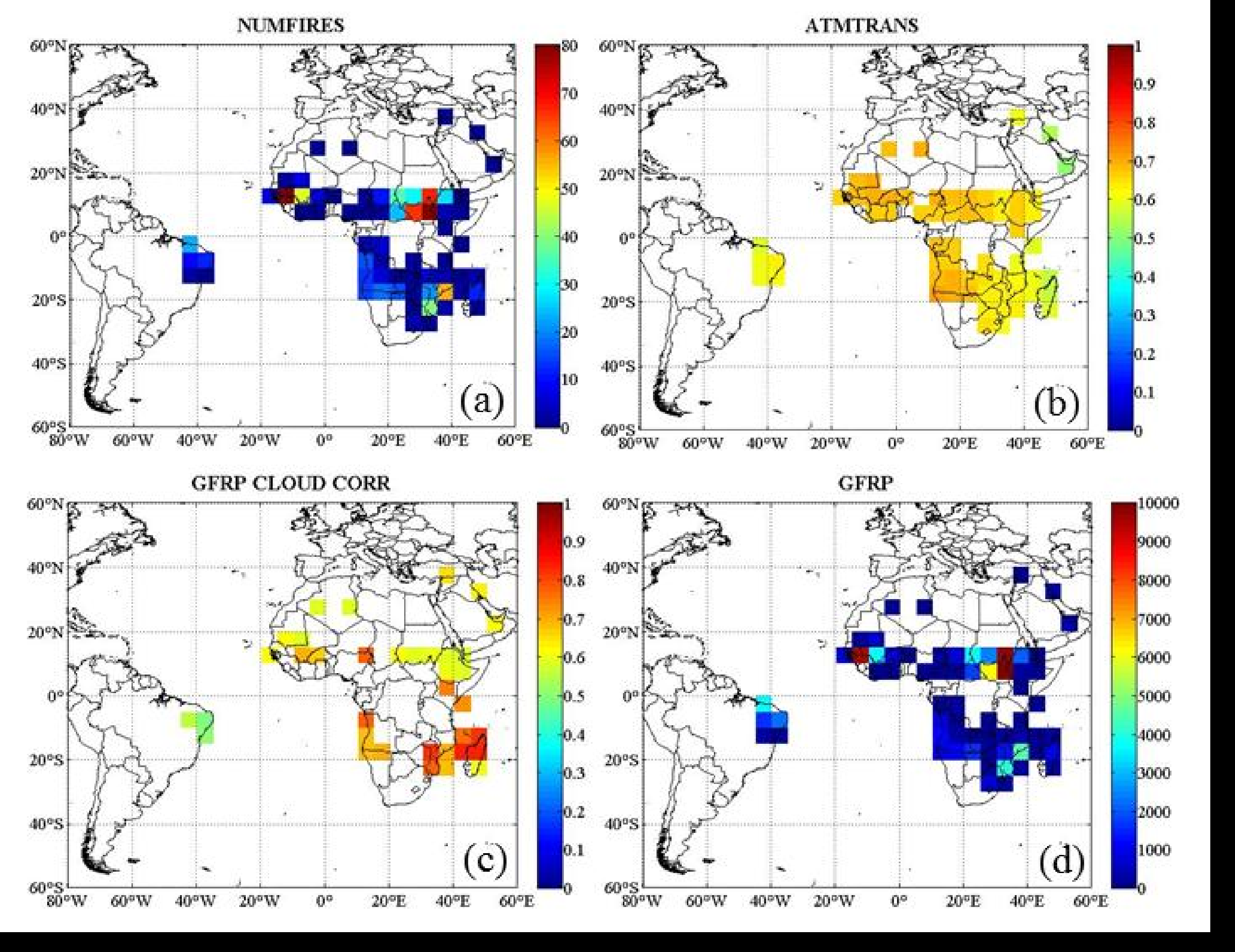


Product includes atmospheric correction and per-pixel FRP uncertainty analysis.

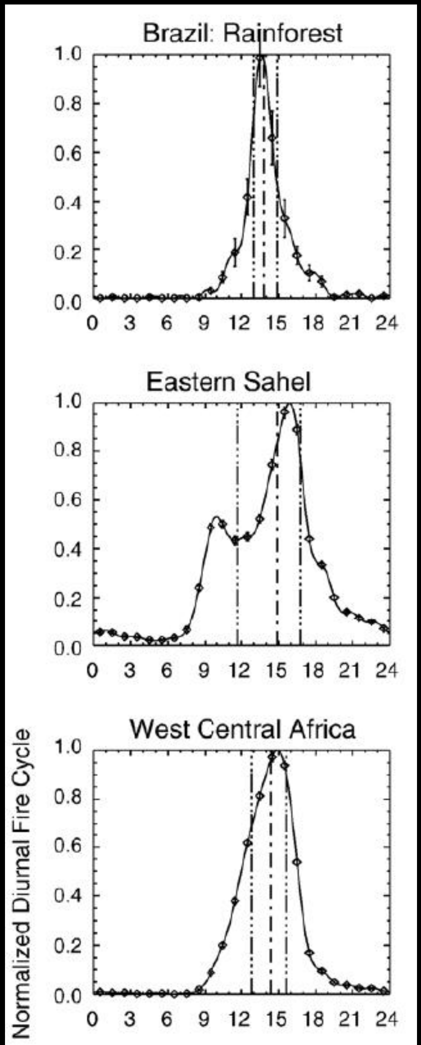
FRP-PIXEL LIST & Quality Products

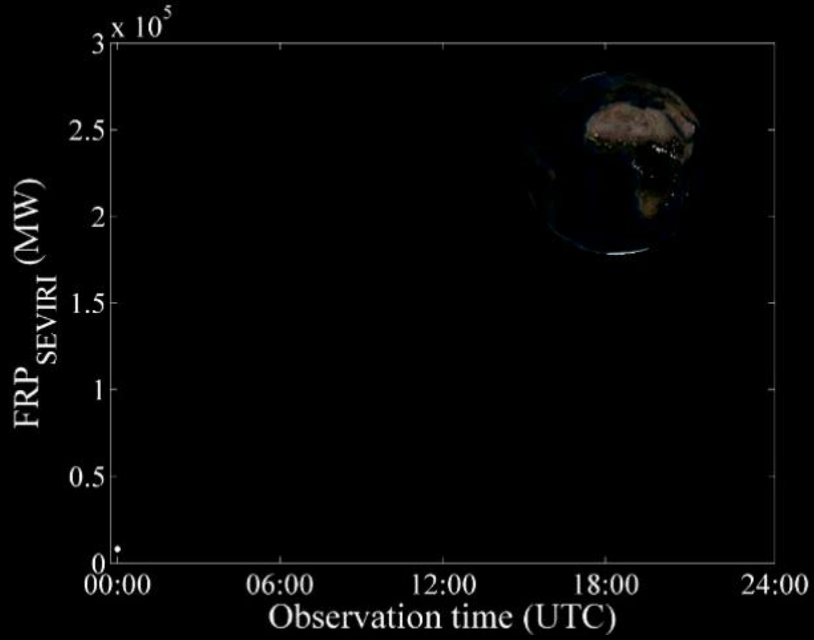
NAME	VALUE	CLASS	REASON
FRP_OUTSIDE_ROIS	-1	FRP NOT Estimated	Pixels that are in the LSA SAF regions (Euro, NAfr, SAfr, SAme) but not in the internal windows considered for processing
FRP_APL_NOTPOT	0	FRP NOT Estimated	Not classed as a potential fire pixel (see Section 3.2).
FRP_APL_FRP	1	FRP Estimated	Successful active fire pixel detection confirmed, with FRP estimation derived from unsaturated 3.9 μm signal .
FRP_APL_FRP_SAT	2	FRP Estimated (but saturated IR3.9 pixel)	Successful active fire pixel detection confirmed, with FRP estimation derived with a saturated 3.9 μm

LSA SAF FRP Grid Product

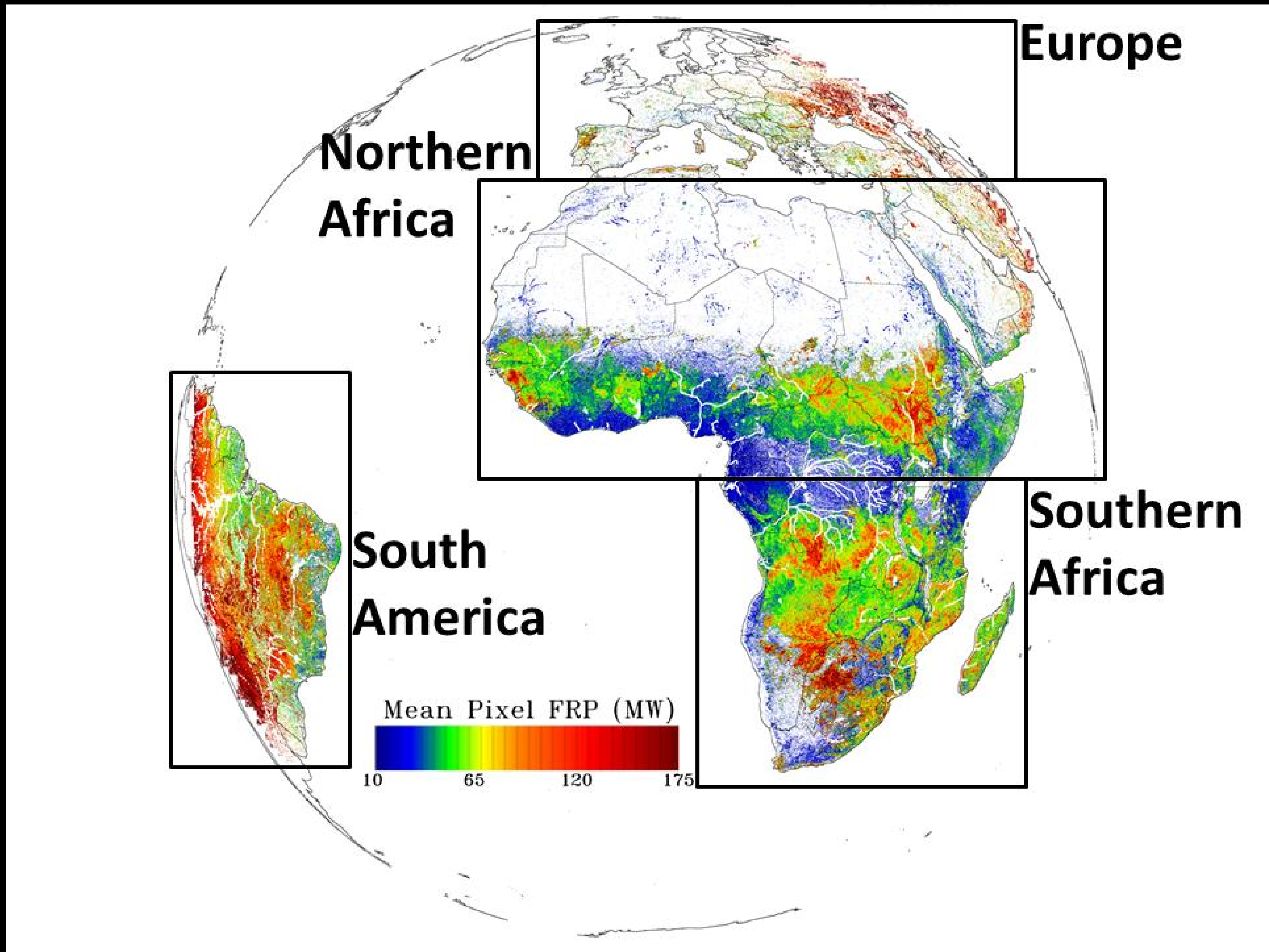


SEVIRI – FRP-Pixel Fire Diurnal Cycle



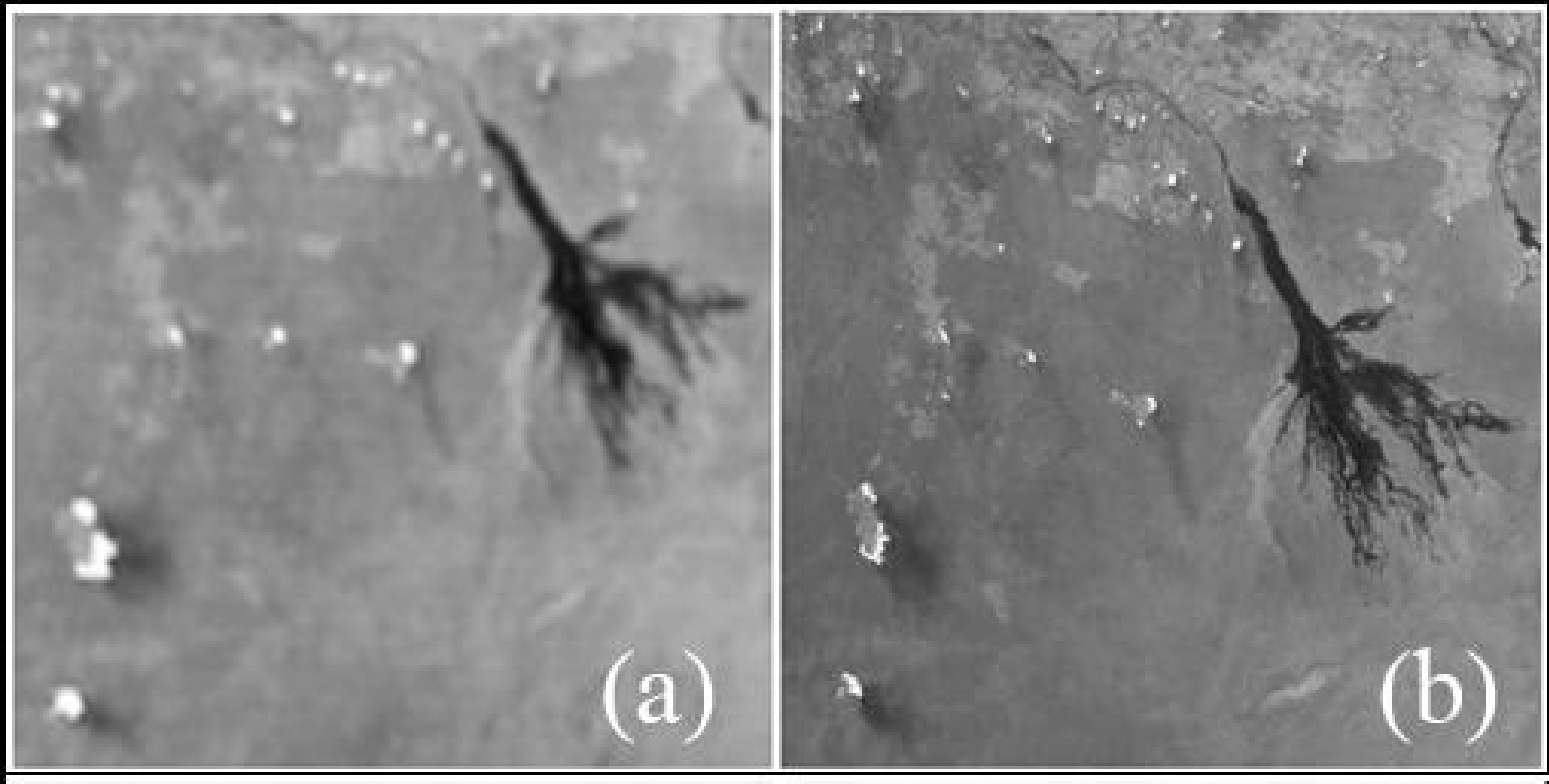


LSA SAF FRP Product Mean FRP



Comparison to MODIS Active Fires

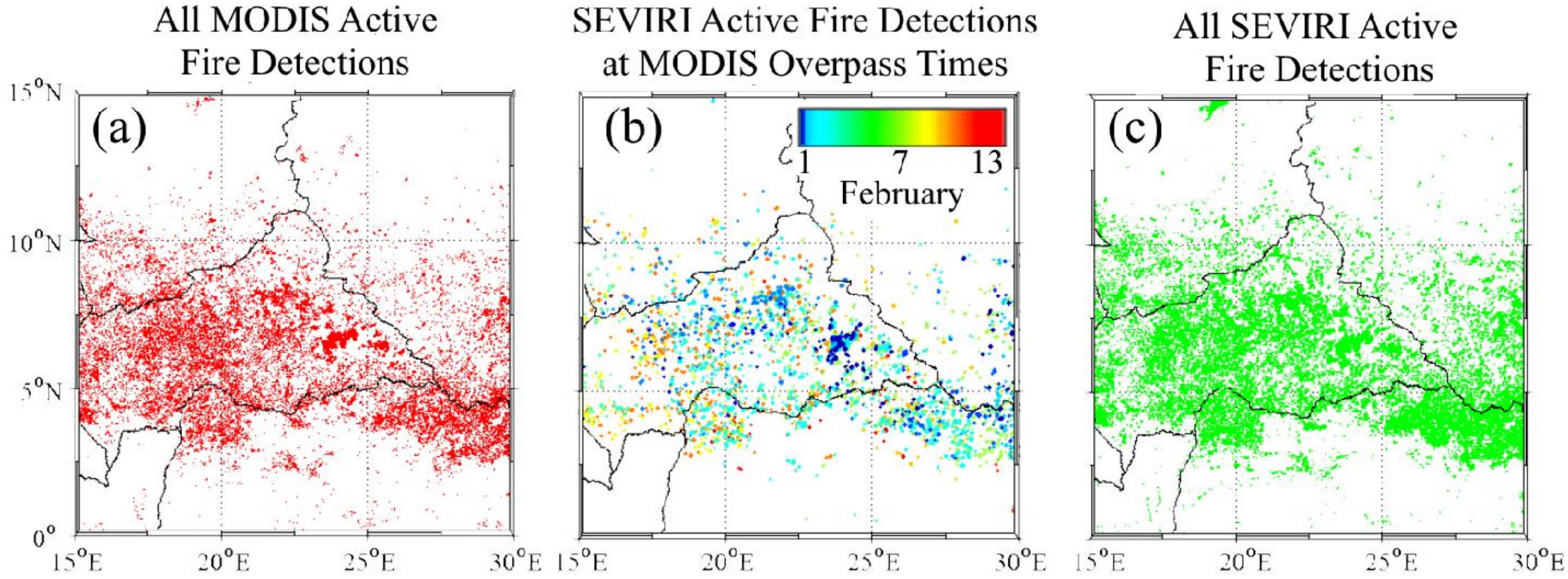
SEVIRI & MODIS Fire Observations



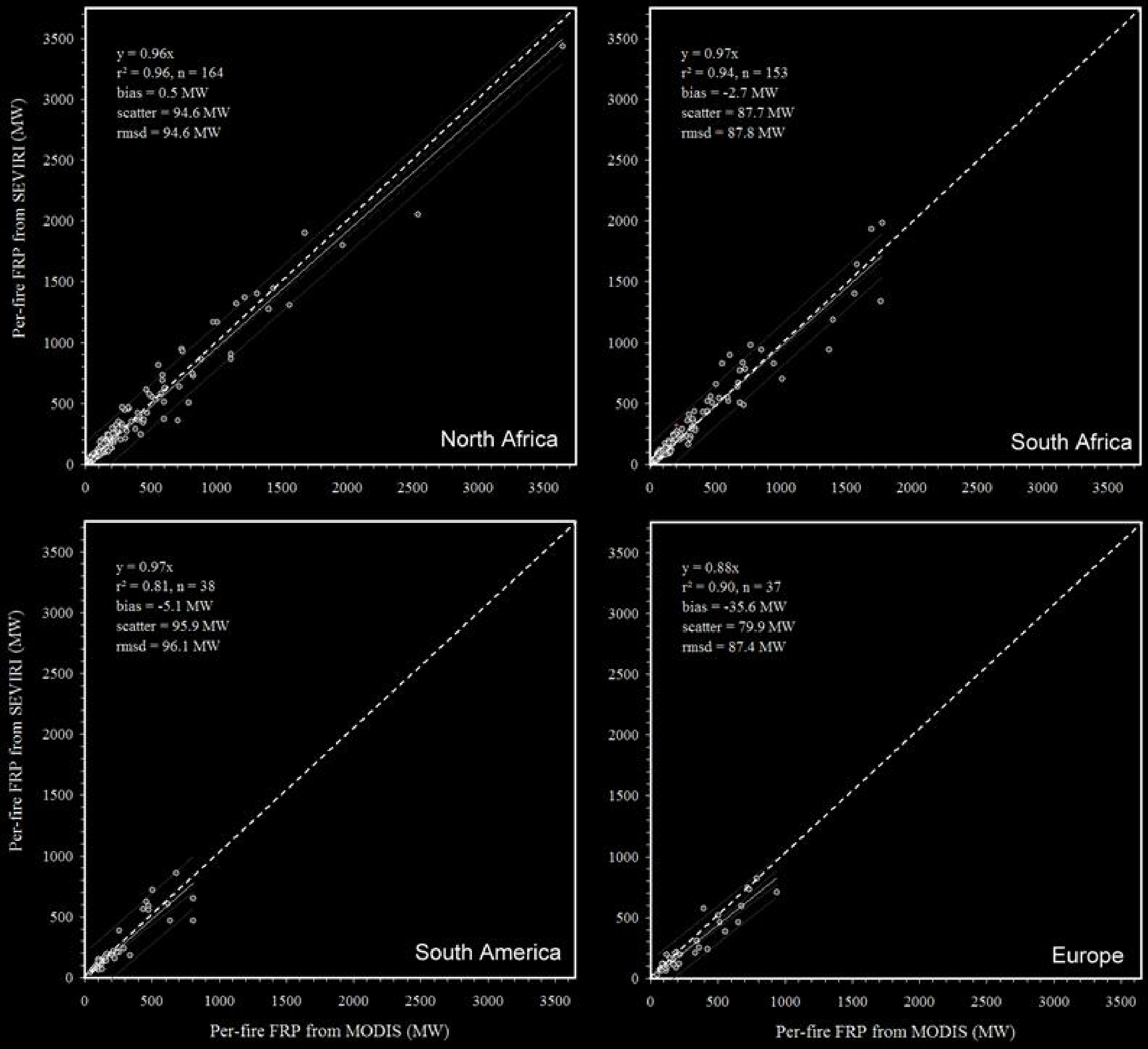
SEVIRI MWIR Band

MODIS MWIR Band

SEVIRI FRP-Pixel and MODIS Fire Detects



Fire Pixel “Cluster” FRP Comparison
(FRP-PIXEL *vs.* MODIS)

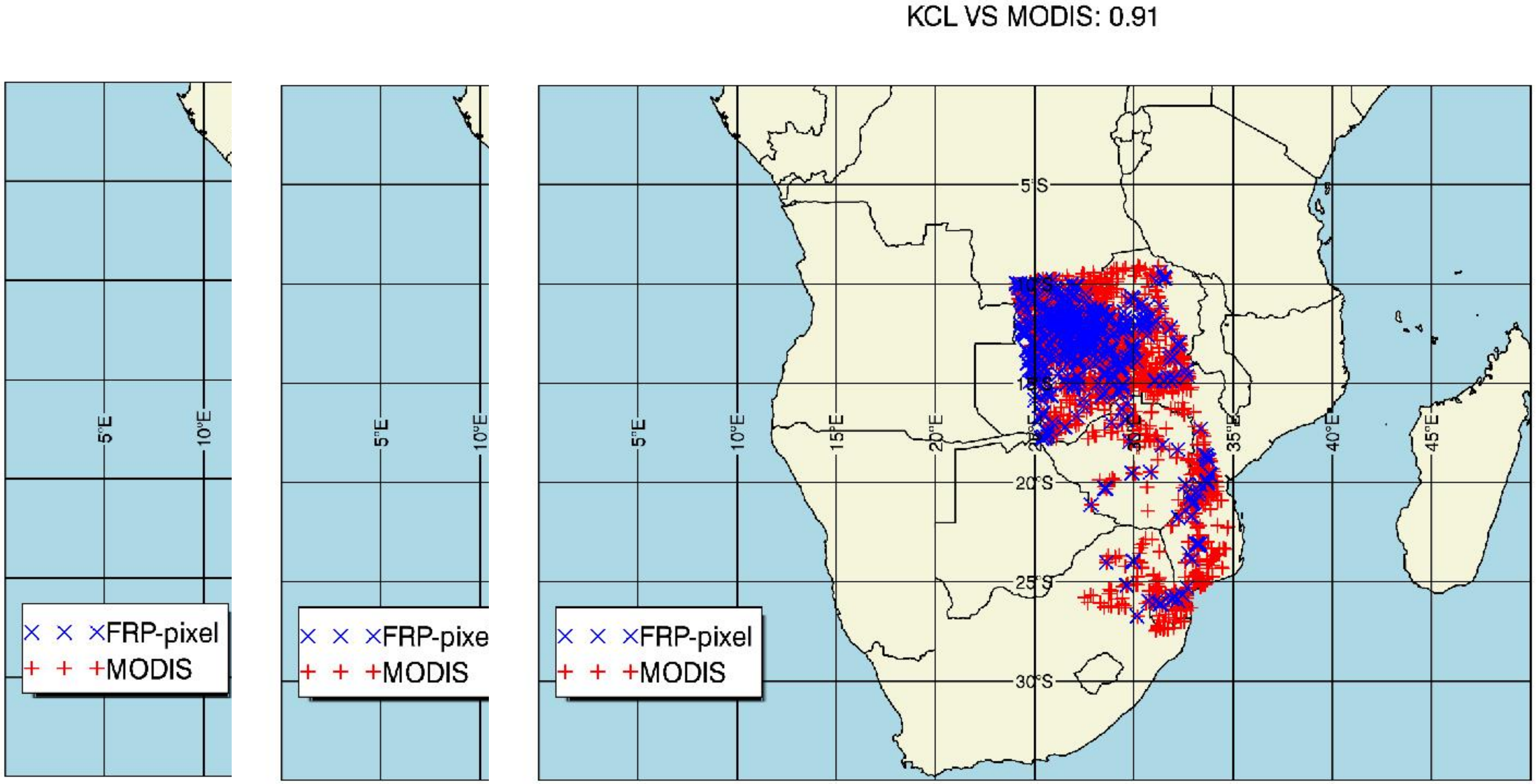


Slopes: 0.88-0.97
r^2: 0.81-0.96
Scatter: 79.9-95.9
RMSD : 87.4-96.1

Conclusion

When SEVIRI and MODIS detect the same fires, the retrieved FRP shows excellent agreement in all four LSA SAF regions.

Active Fire Pixel Comparison: FRP-PIXEL & MODIS

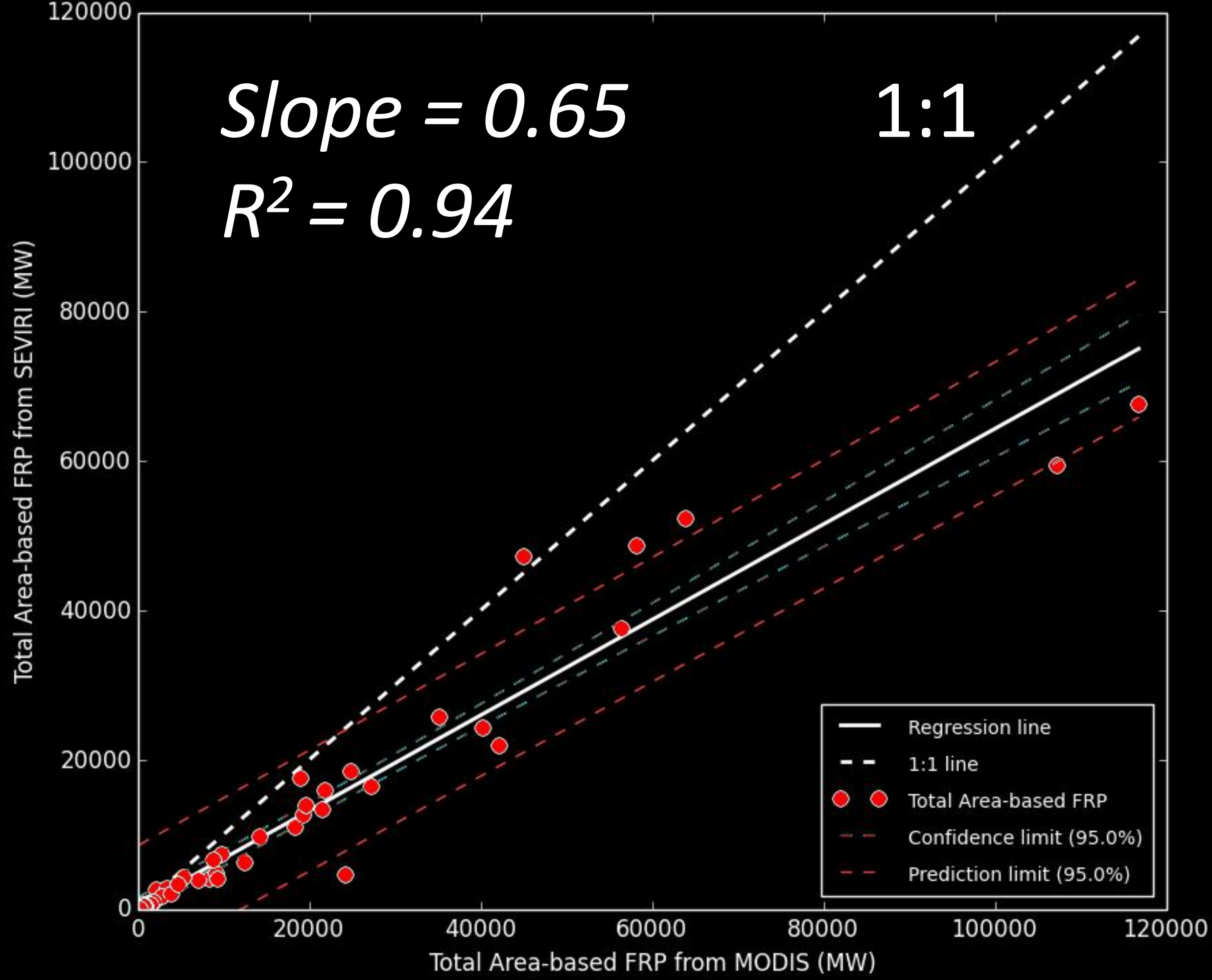


- + MODIS Active Fire Pixels in MODIS Swath
- × SEVIRI FRP-PIXEL Detections at Same Time & Within Same "Swath"

Regional Scale FRP Comparison (FRP-PIXEL *vs.* MODIS)

National Centre for Earth Observation

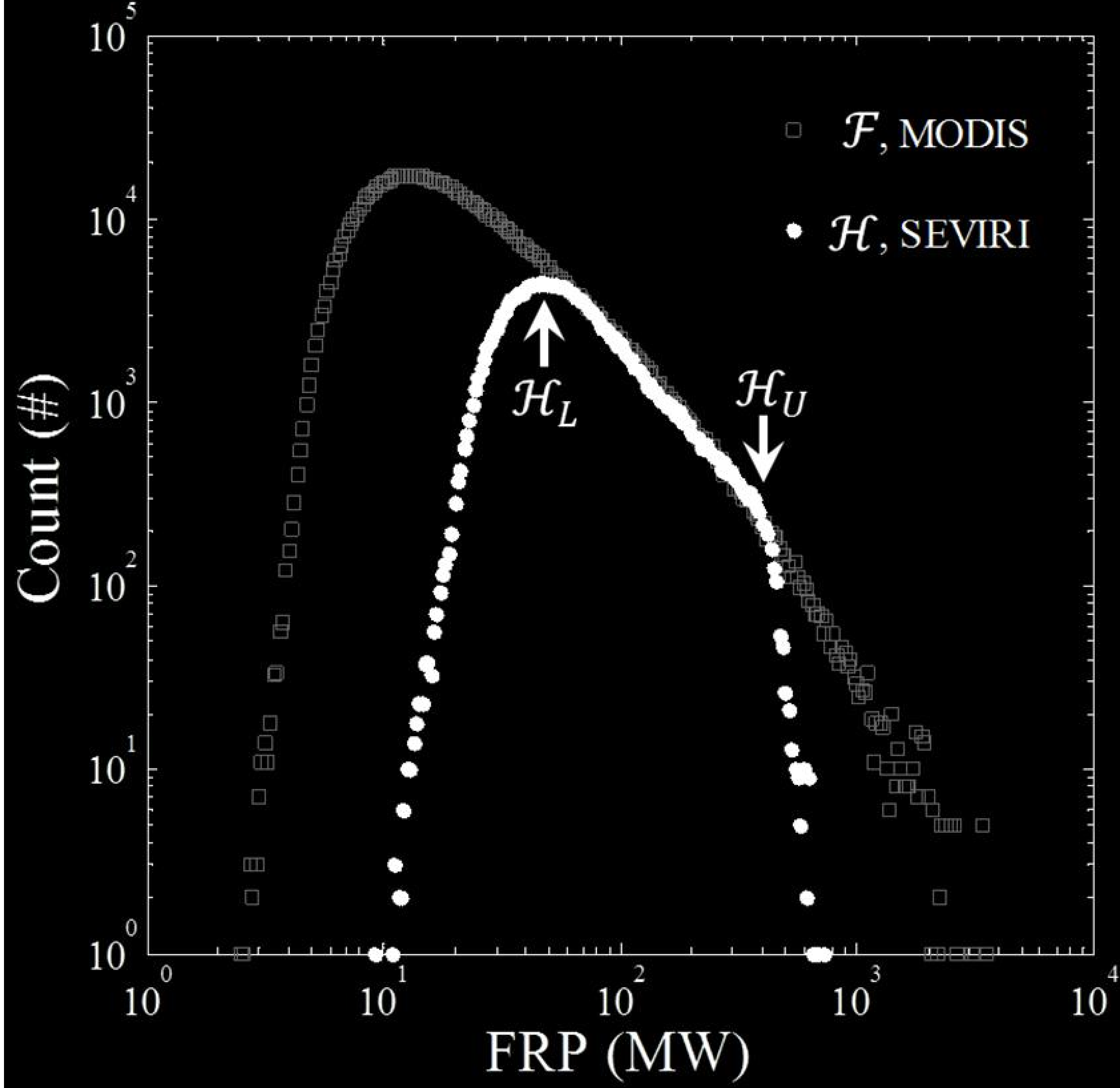
KING'S College LONDON



Conclusion

When SEVIRI and MODIS observe the same region, the FRP-PIXEL product tends to underestimate total regional-scale FRP, due to missing "small fire" which can be detected by MODIS.

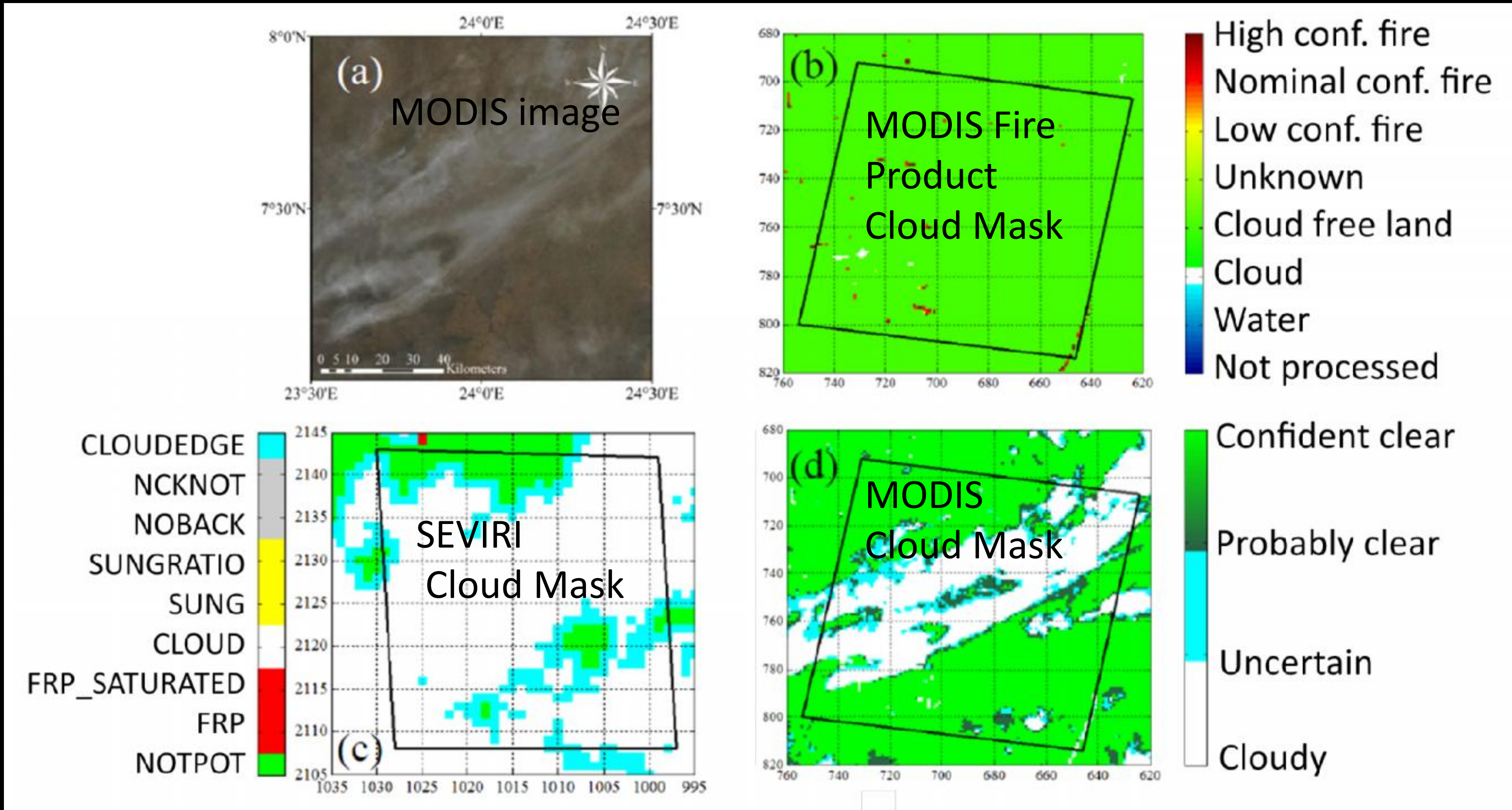
FRP Frequency Distribution



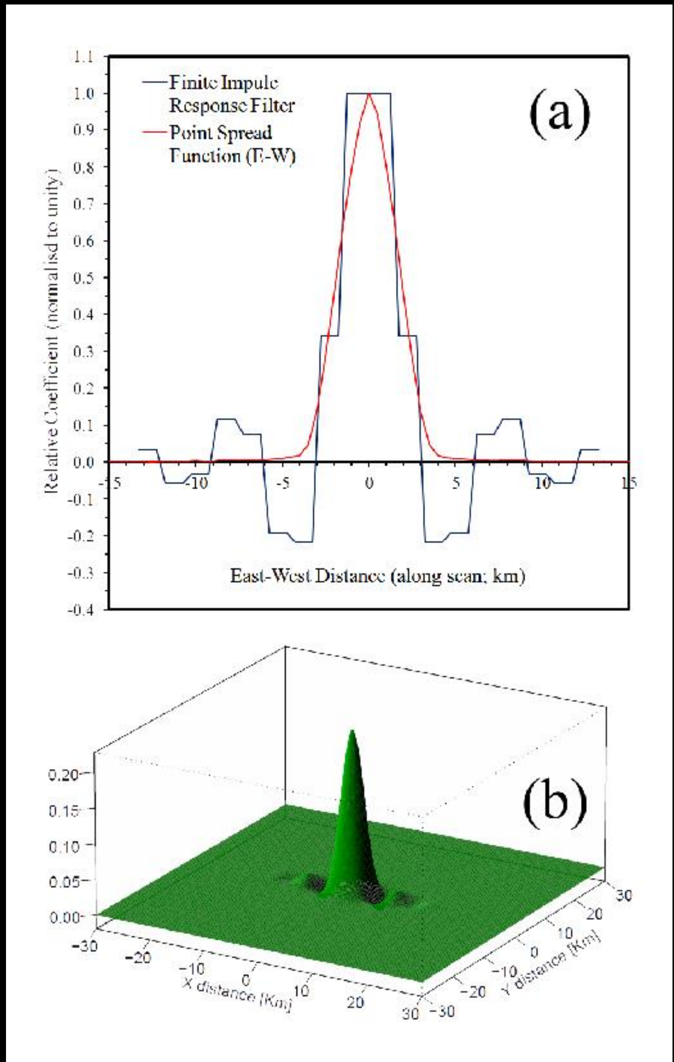
"Rollover" Thresholds

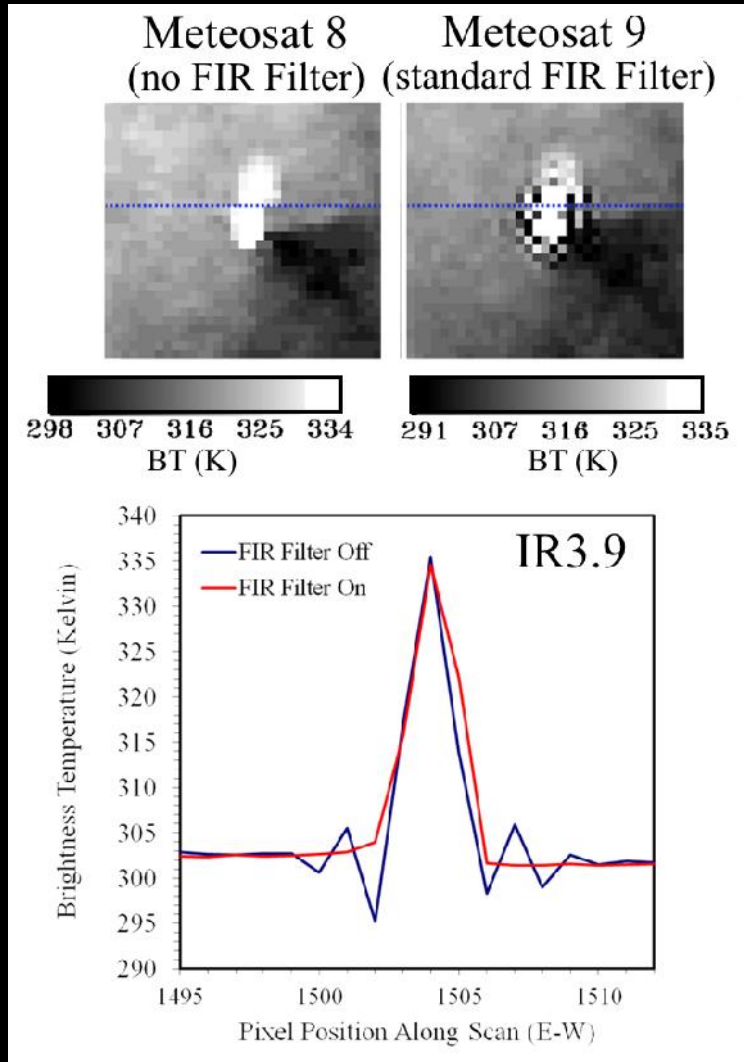
MODIS: ~10 MW
SEVIRI: ~ 40 MW

SEVIRI NWC-SAF Cloud Mask

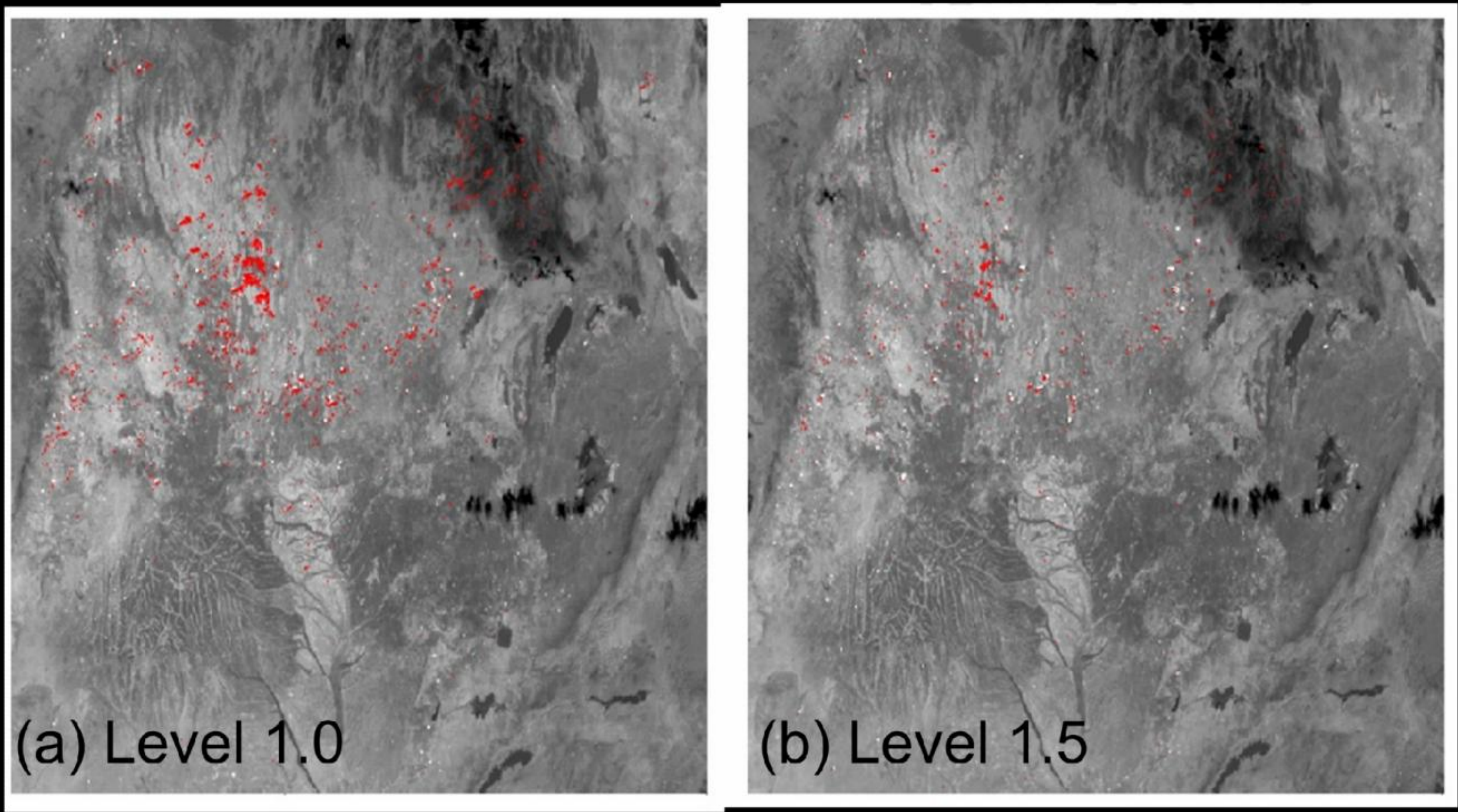


SEVIRI Level 1.0 to Level 1.5 Fire Observation

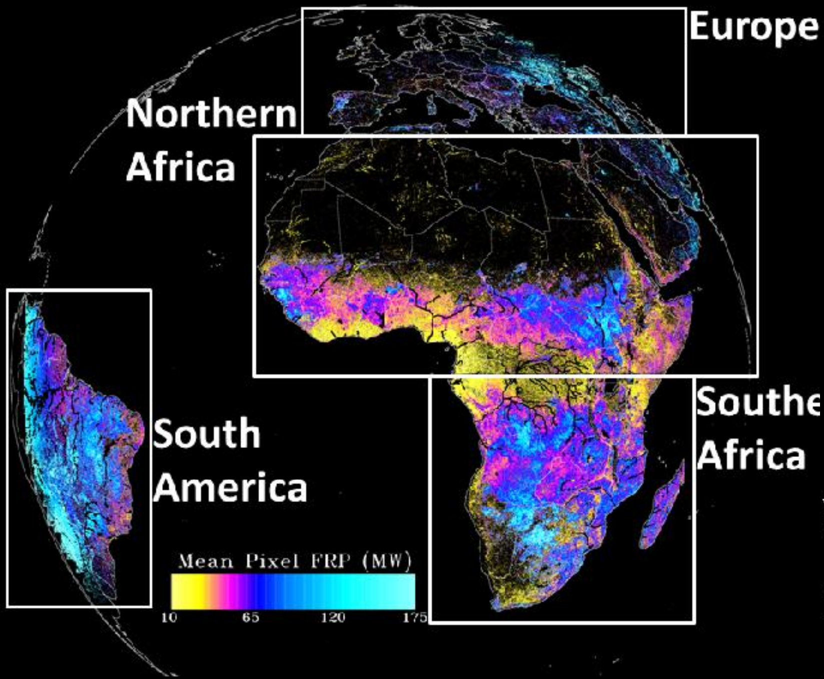




SEVIRI Level 1.0 *vs.* Level 1.5 Fires

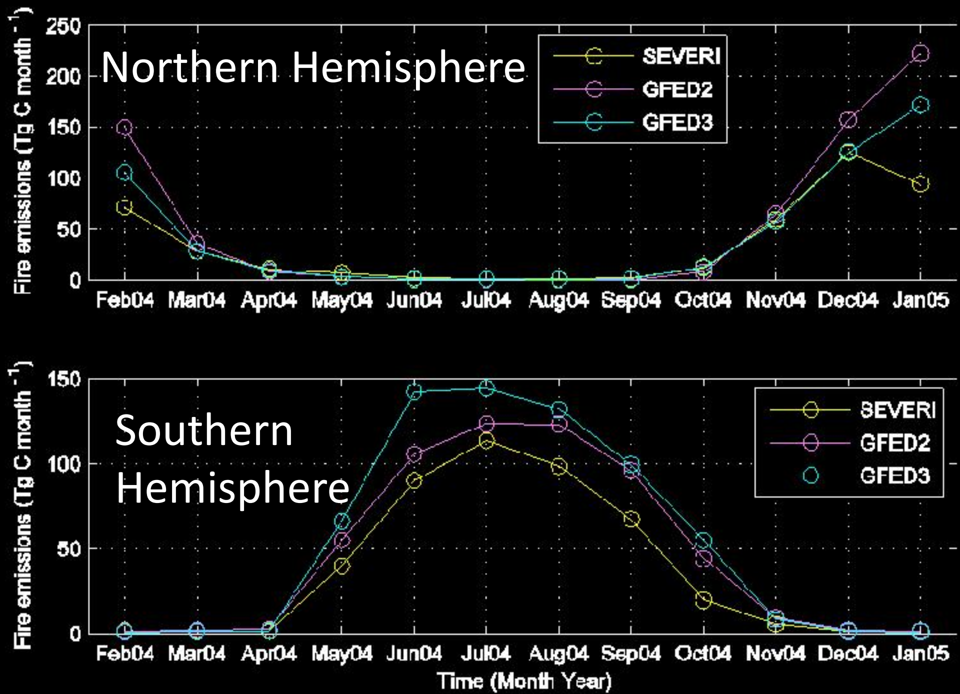


LSA SAF African Fire Radiative Power



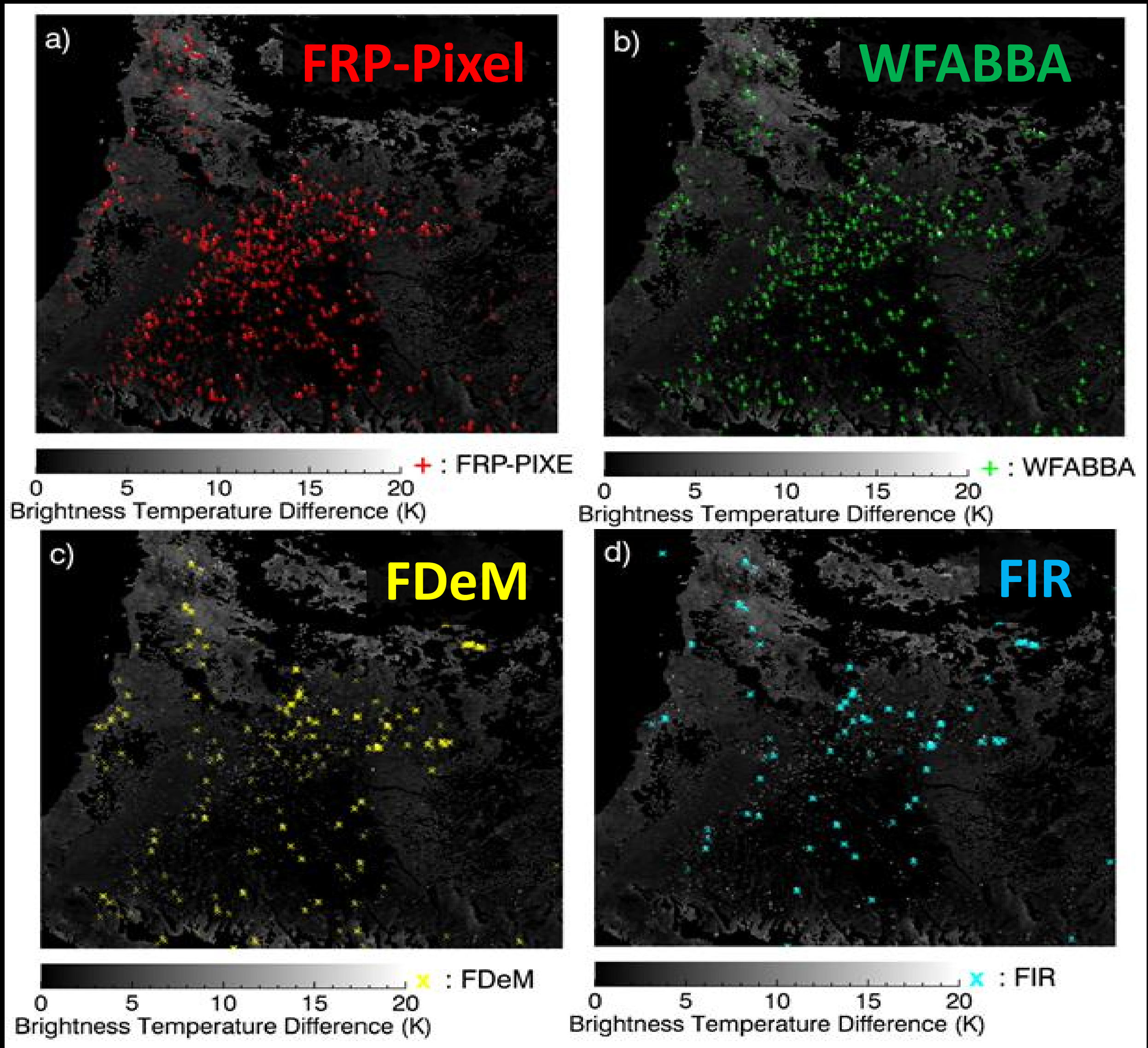
Mean FRP per Pixel (MW)

Bias Adjusted SEVIRI Annual Carbon Emissions Timeseries Compared to GFED



Comparison to other SEVIRI Active Fire Products available "operationally"

FRP-Pixel: Comparison to Alternative SEVIRI Active Fire Products – 21 Aug 2014

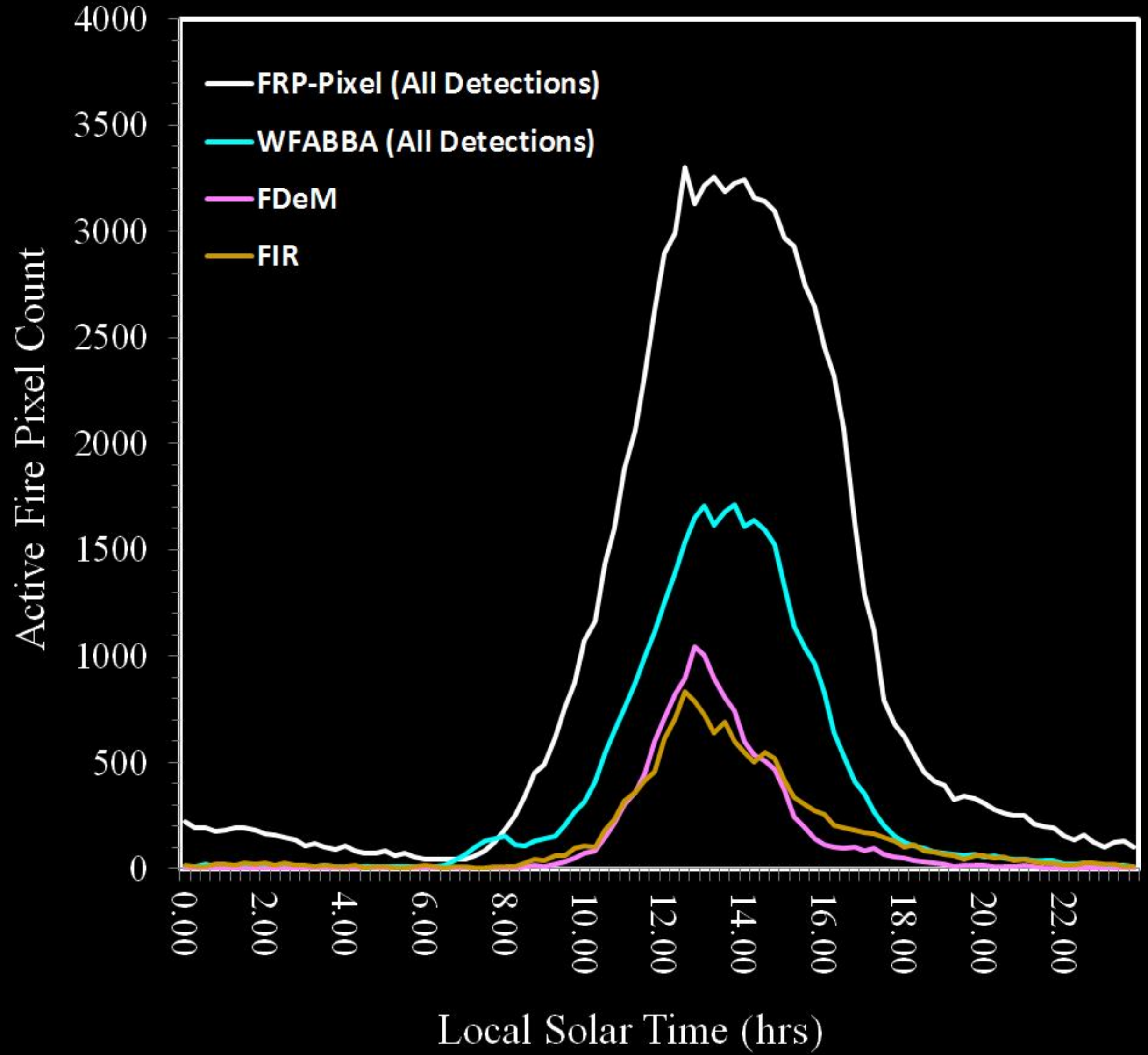


Active Fire Pixel Counts

FRP-PIXEL : 1249
WFABBA : 686
FDeM : 346
FIR : 312

Southern Africa
All @ 13:15 UTC

Fire Diurnal Cycle of SEVIRI Active Fire Products



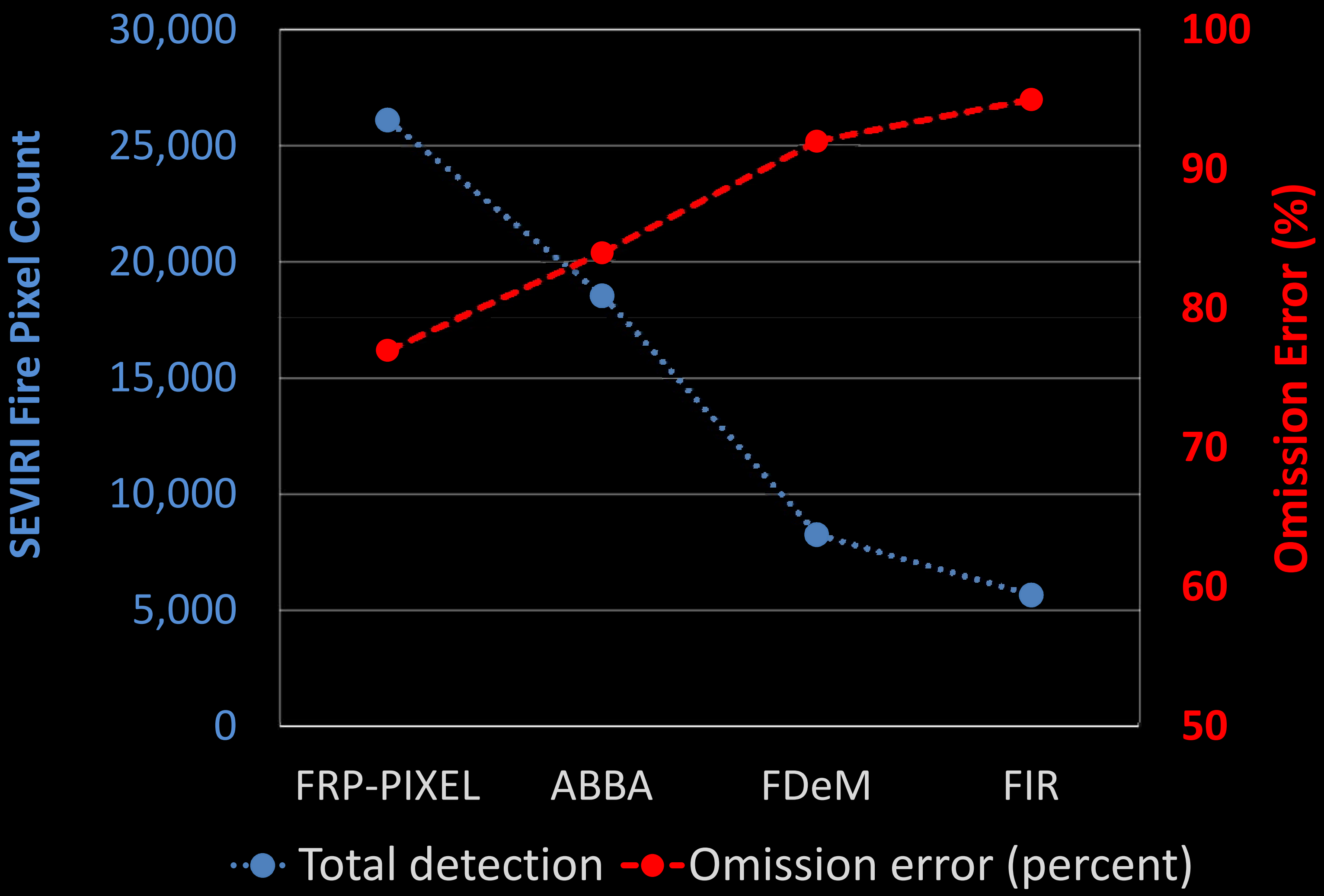
Daily Active Fire Pixel Count

FRP-PIXEL : 89,781
WFABBA : 35,759
FDeM : 13,477
FIR : 14,645

All on 30 Aug 2014

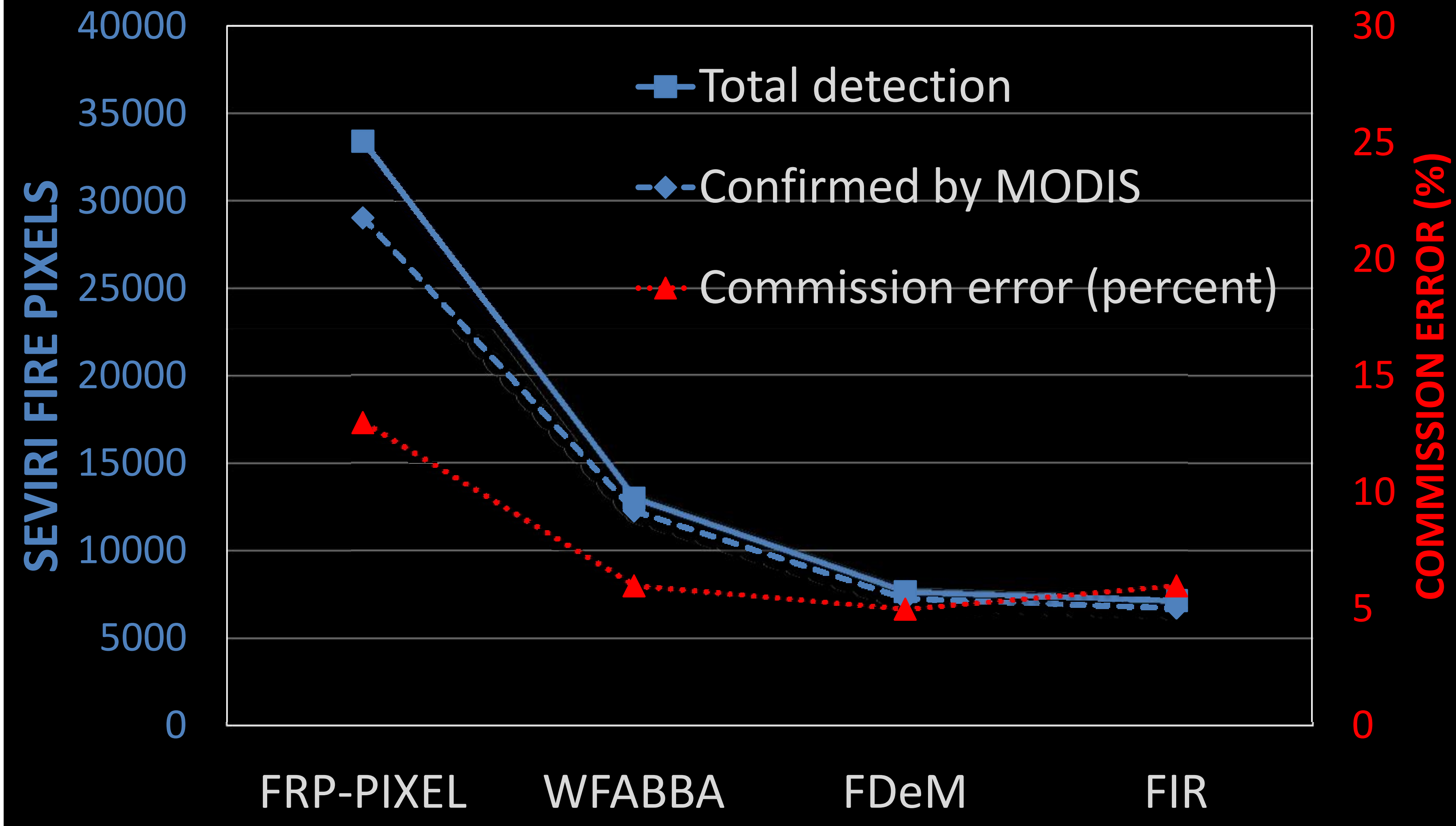
Active Fire Detection Performance : SEVIRI Fire Products *vs.* MODIS

1 Month Active Fire Error of Omission



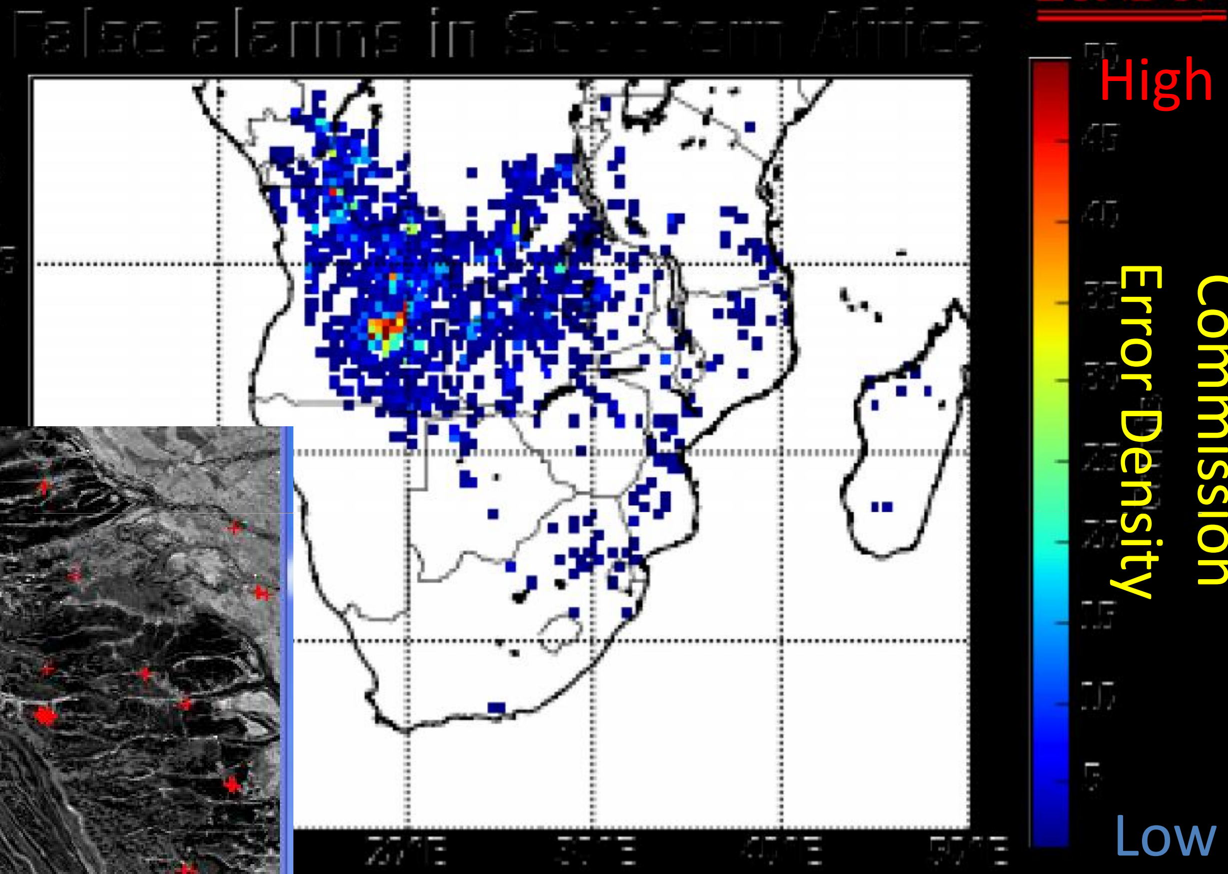
Active Fire Detection Performance : SEVIRI Fire Products *vs.* MODIS

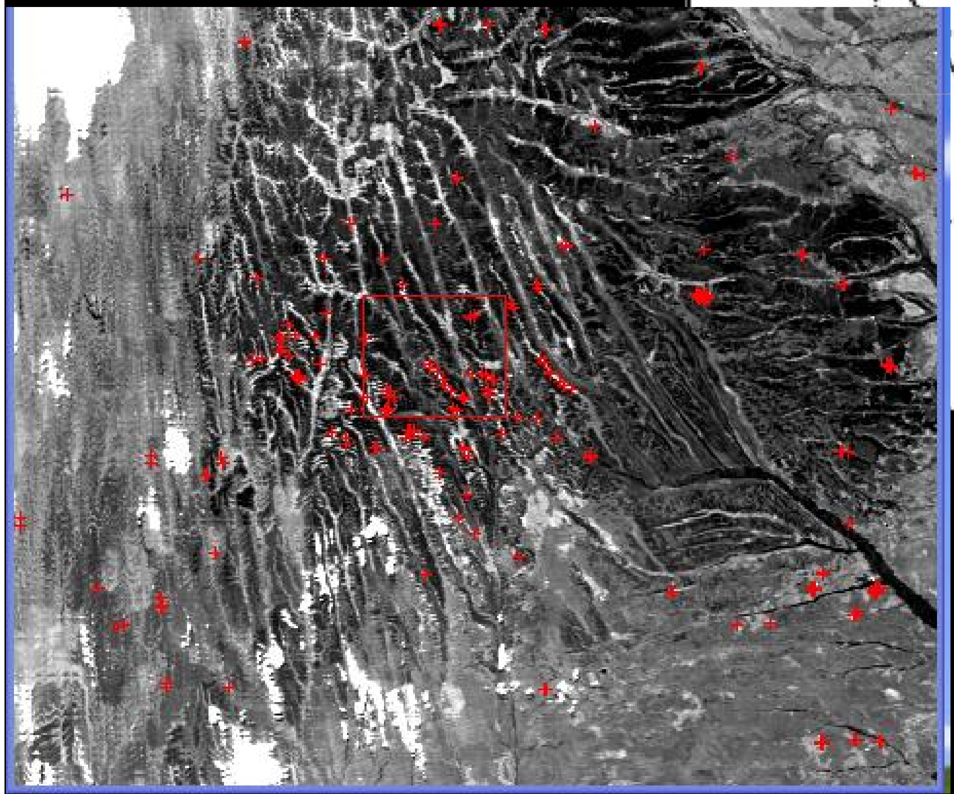
1 Month Active Fire Error of Commission



Active Fire Detection Commission Error Mapping

~28% (1247 of 4415 pixels) of false detections in FRP-Pixel Product from “solar heated warm slopes” in Angola.

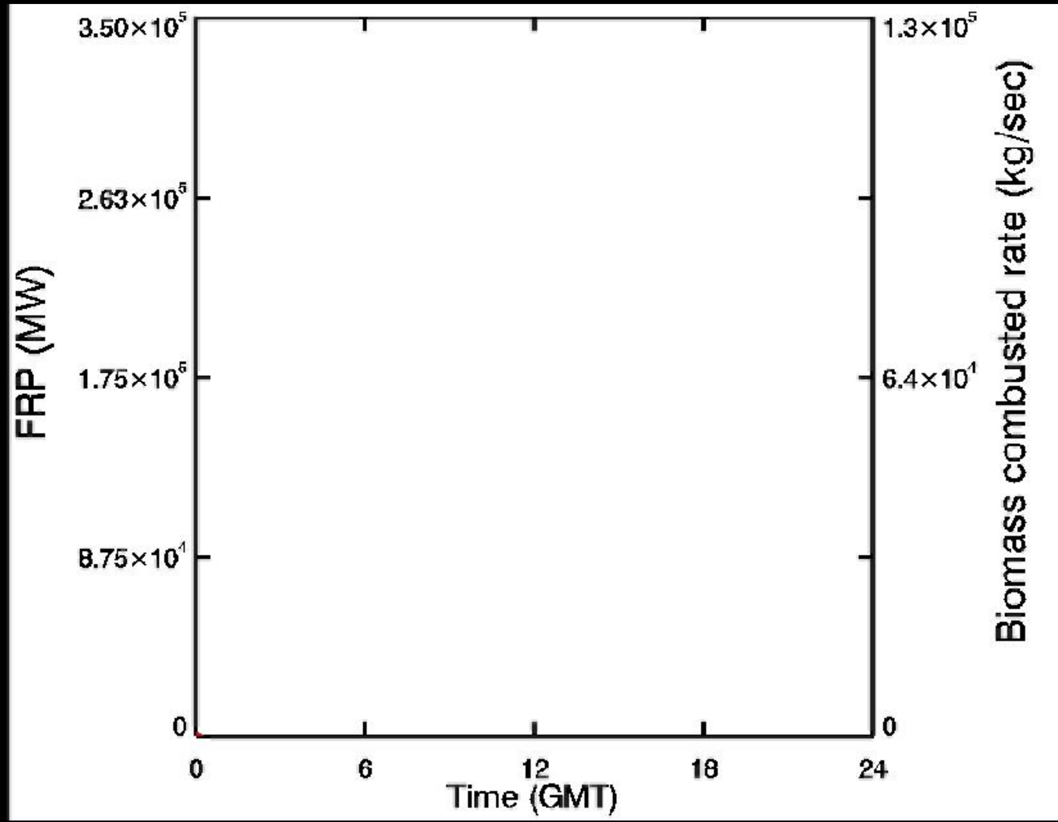




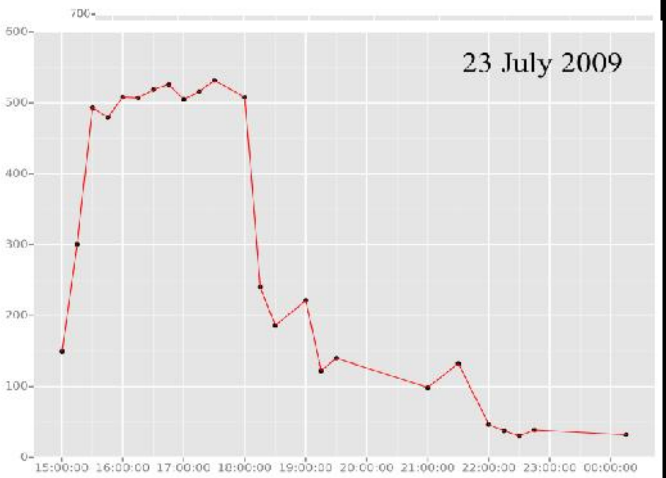
- Caused by Alg. “Spatial filter” using static minimum threshold to save processing time.
- Reduces to < 10% using dynamic spatial filter (mean of all clear pixels).

Use of SEVIRI FRP-Pixel Product

Southern African 7-Days FRP

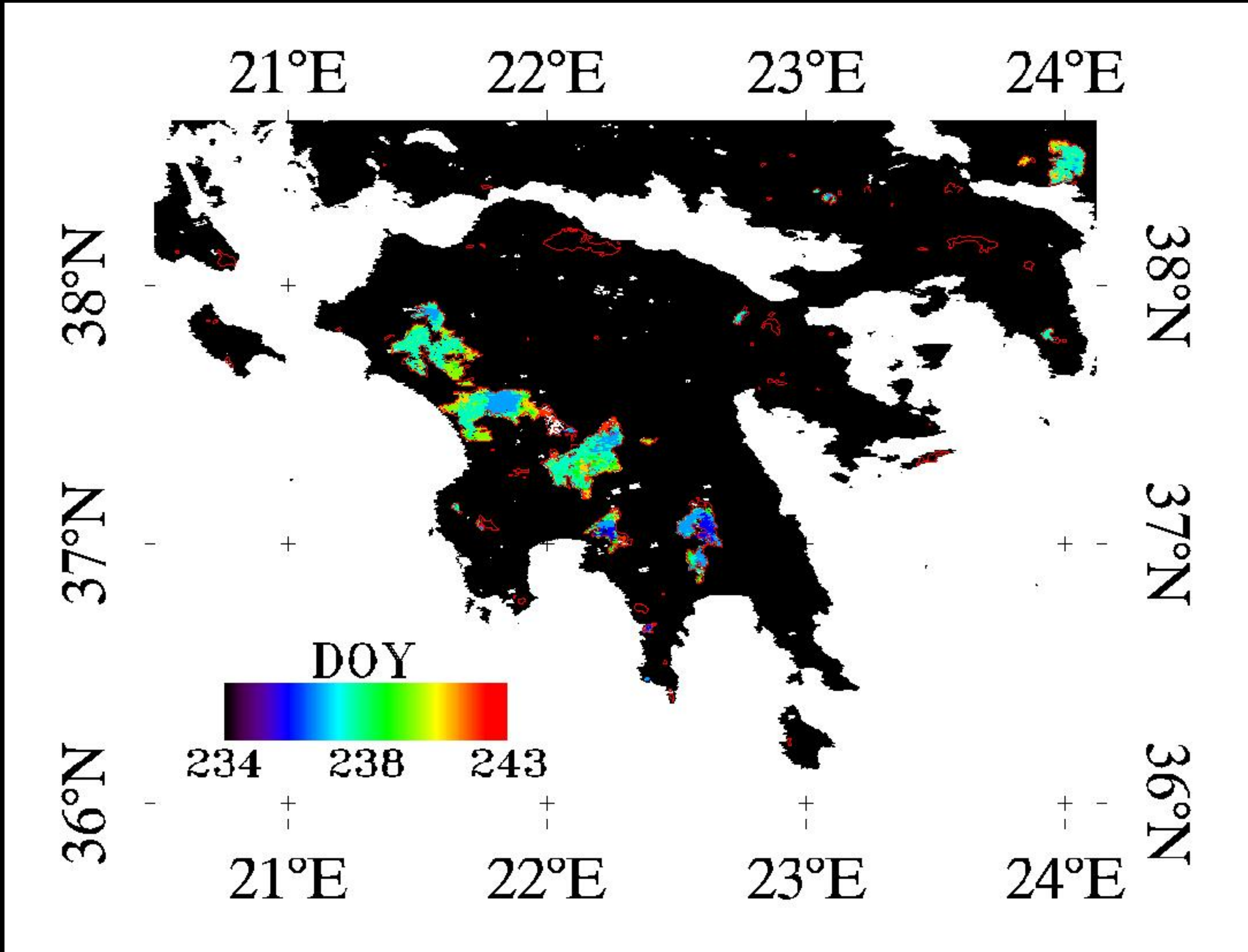


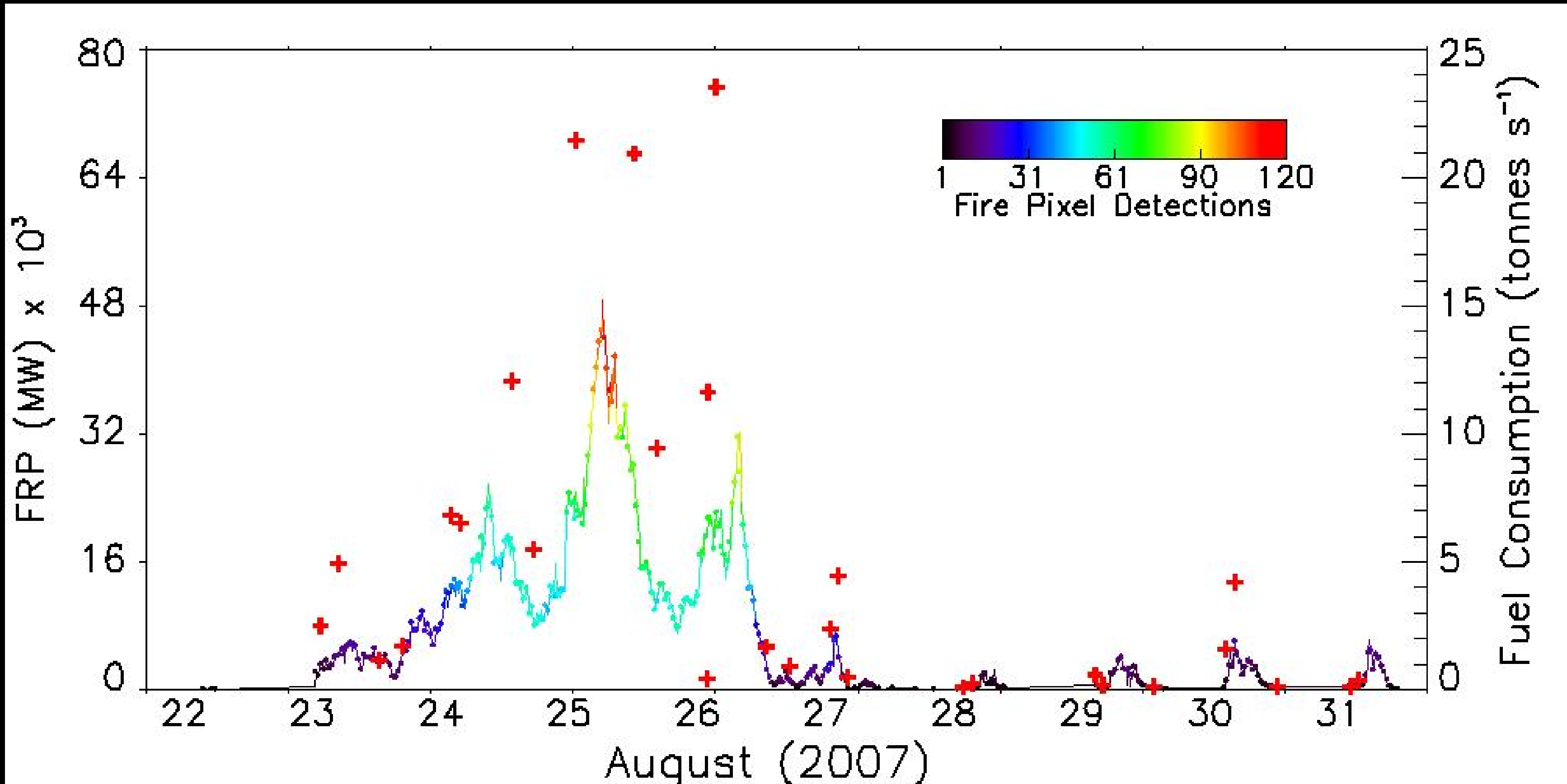
Example Wildfire - July '09 Spain

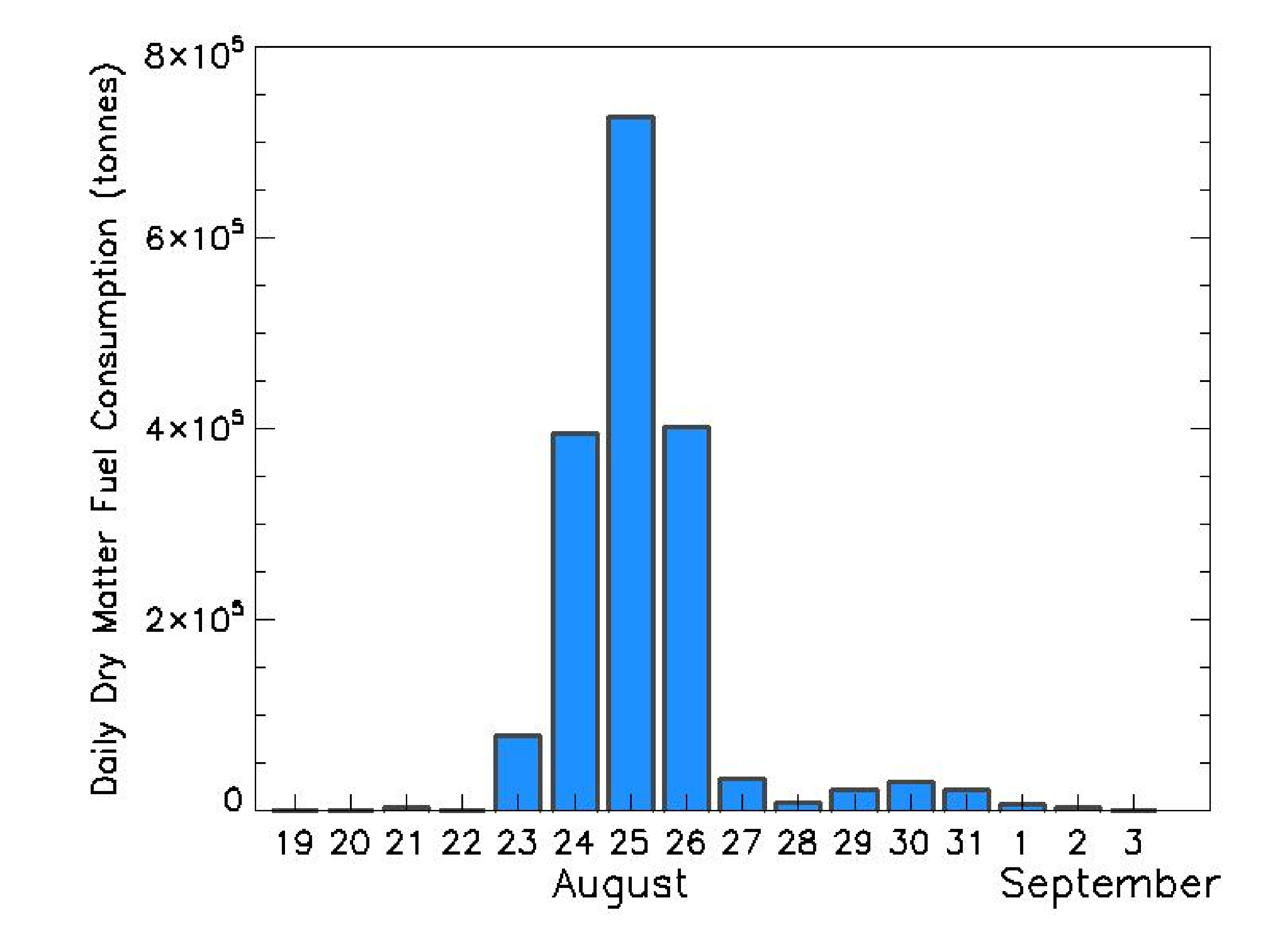


- Fire expanded & burned initially exactly matching News reports.
- Fire flared again on 23rd July, as illustrated in FRP-PIXEL product.

2007 Greek Fires

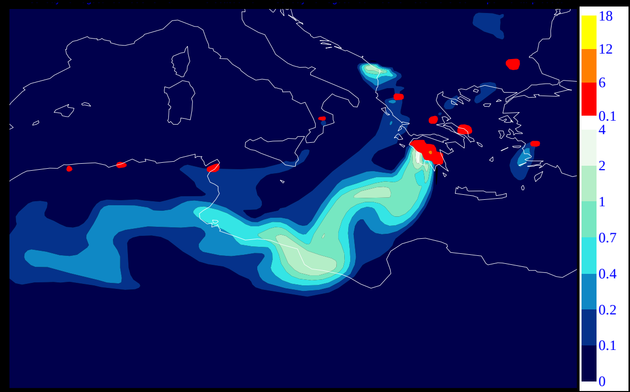



National Centre for Earth Observation
KING'S College LONDON
80
64
48
32
16
0
FRP (MW) x 10^3
25
20
15
10
5
0
Fuel Consumption (tonnes s^{-1})
1 31 61 90 120
Fire Pixel Detections
22 23 24 25 26 27 28 29 30 31
August (2007)



Daily Dry Matter Fuel Consumption (tonnes)
8×10^5
6×10^5
4×10^5
2×10^5
0
19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3
August
September

August 2007 Greek Fires
Copernicus Atmosphere Service



MODIS - 26th Aug (09:35 UTC)

Modeling performed under EU MACC Project

Courtesy by Morcrette, J., Jones, L, Benedetti, A. and Kaiser, J