National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environmental Monitoring & Modelling Research Group

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[Some] Updates on Research into Fire Radiative Power & Energy

Presented by Martin Wooster

(Kings College London, UK)

Slide contributions from many others…

Environmental Monitoring and Modelling Research Group, Dept. of Geography, King's College London, UK.

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MODIS FRP to FRE

[problem is MODIS only provides a few observations per day]

Vermote (2009): MODIS FRP to FRE

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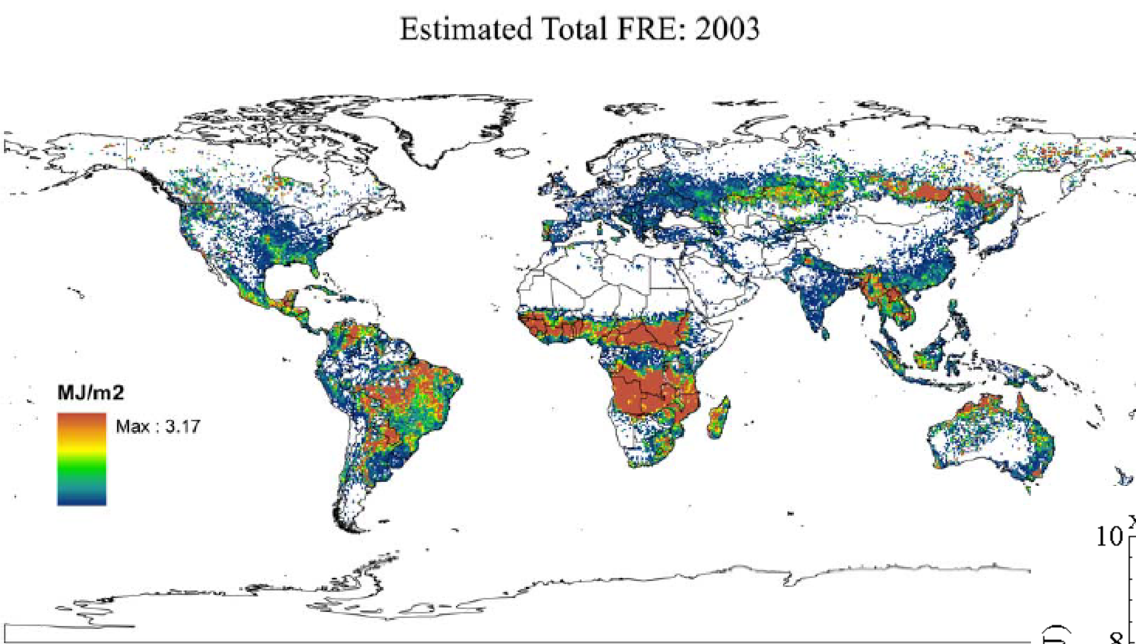
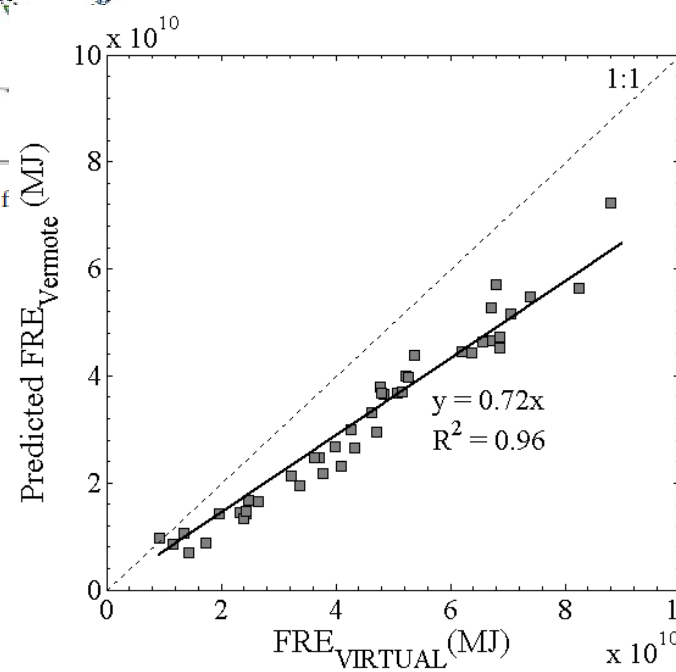
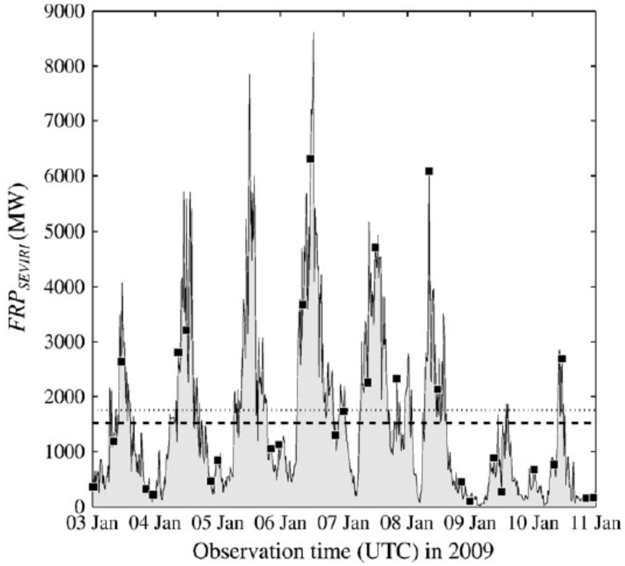
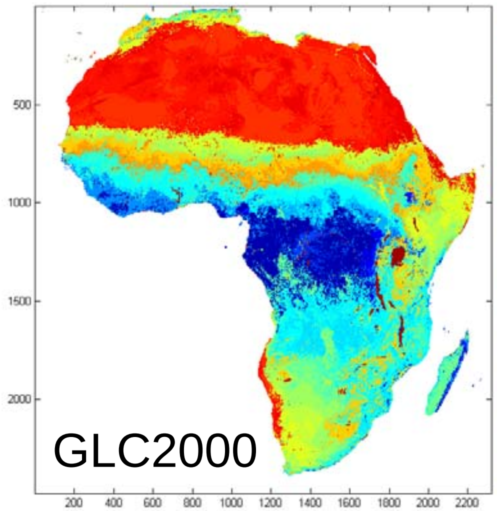


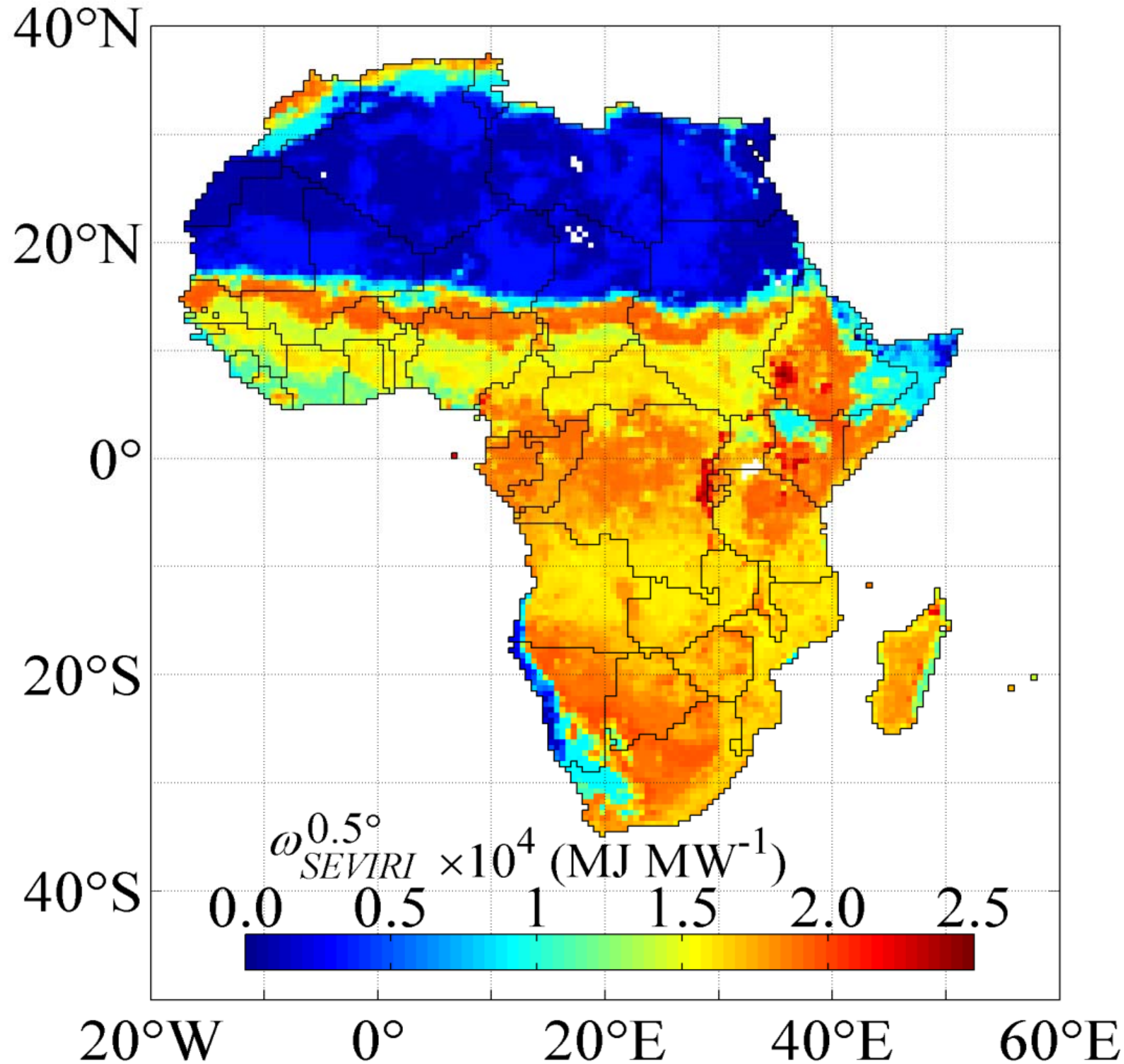
Figure 6. Estimated 2003 FRE (MJ/m^2) from Aqua MODIS. Integrated energy was calculated f
FRP (MW) values derived from a Gaussian function using modeled parameters.

MODIS FRE – 8 day
0.5° resolution
[but apparently
underestimated
compared to
geostationary]









Freeborn et al. (2011) Addressing the spatiotemporal sampling design of MODIS to provide estimates of the fire radiative energy emitted from Africa, RSE.

MODIS FRP to FRE (compared to Vermote [2009])

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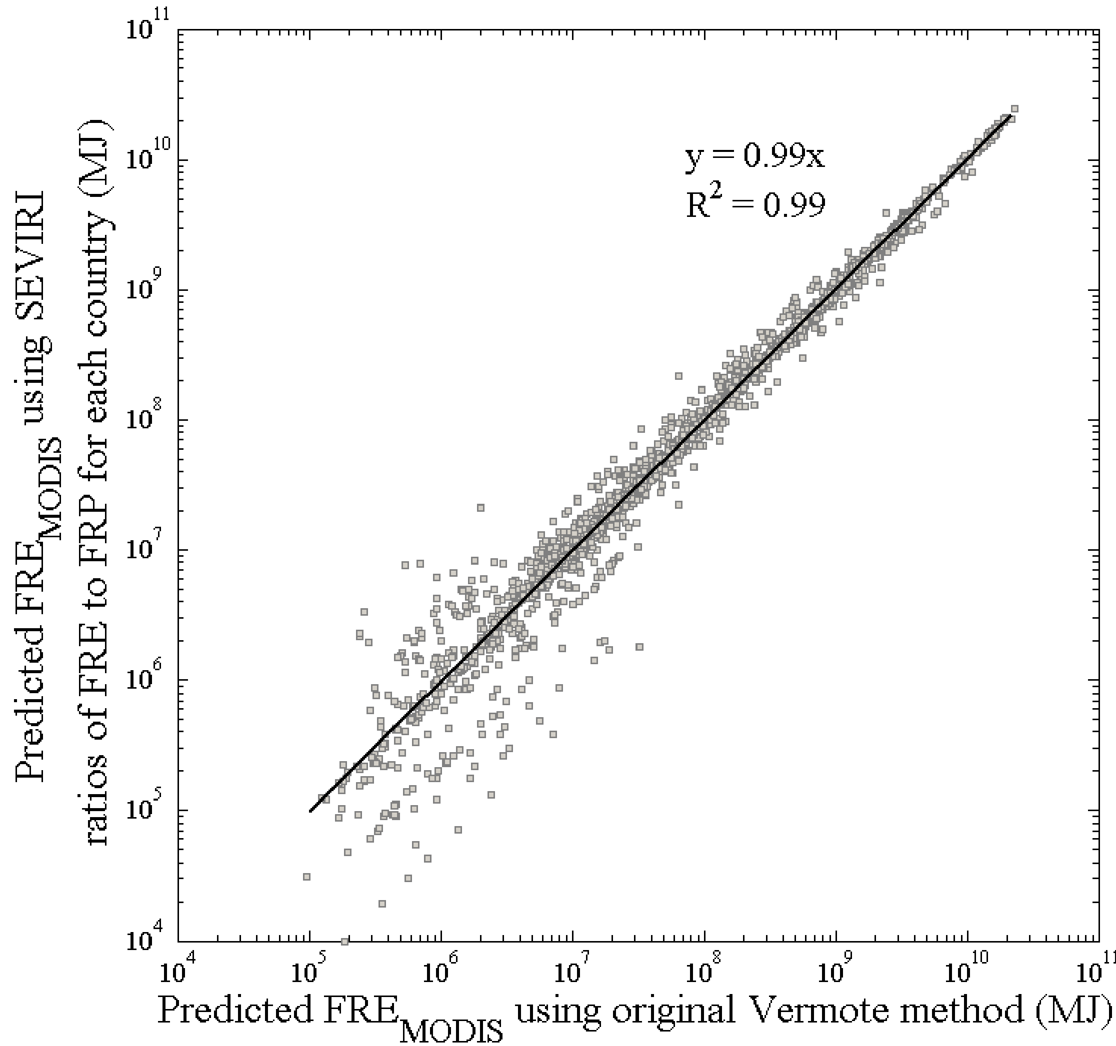
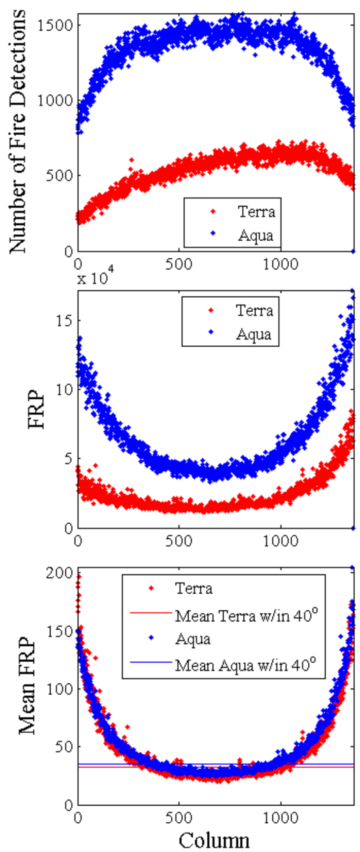
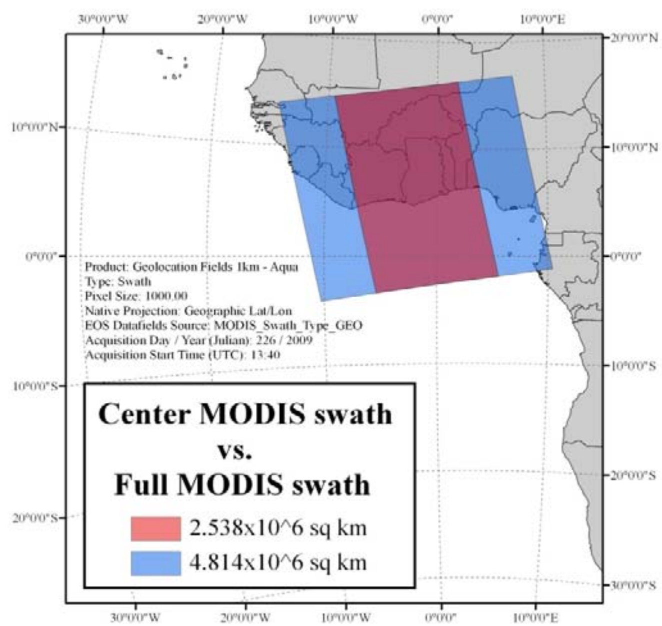


Use MODIS CMG FRP Product

MODIS CMG (8-day / 0.5 deg)

Raw MODIS Data





$$A_{Full} = 1.897 \times A_{\pm 40°}$$

1. Retrieve FRP in centre of MODIS swath
2. Retrieve area in centre of MODIS swath
3. Calculate the FRP per unit area in centre of MODIS swath:

$$\phi_{\pm 40°} = \frac{FRP_{\pm 40°}}{A_{\pm 40°}}$$

4. Multiply FRP per unit area in centre of swath by the total area of the swath:

$$FRP_{Full} = A_{Full} \times \phi_{\pm 40°}$$

$$FRP_{Full} = FRP_{\pm 40°} \times \frac{A_{Full}}{A_{\pm 40°}}$$

$$FRP_{Full} = 1.897 \times FRP_{\pm 40°}$$

Freeborn et al (2011)

Recommend that the sum of FRP measured within ±∠40° of nadir is made available in MODIS Collection 6 CMG fire product (to aid bow tie adjustment).

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Geostationary FRP

Zhang et al. (2012) GEOSTATIONARY FRP

- Uses all current FRP capable geostationary sats except FY (China)
- WFABBA based fire detection algorithm.
- FRP calculated using MIR radiance method (linear fn).
- Applied to network of geostationary (GOES E/ W, Meteosat, MTSAT)
- Many fire pixel records have non-detections or saturation – and gaps due to cloud cover. Reconstruction of full diurnal cycle using defaults.

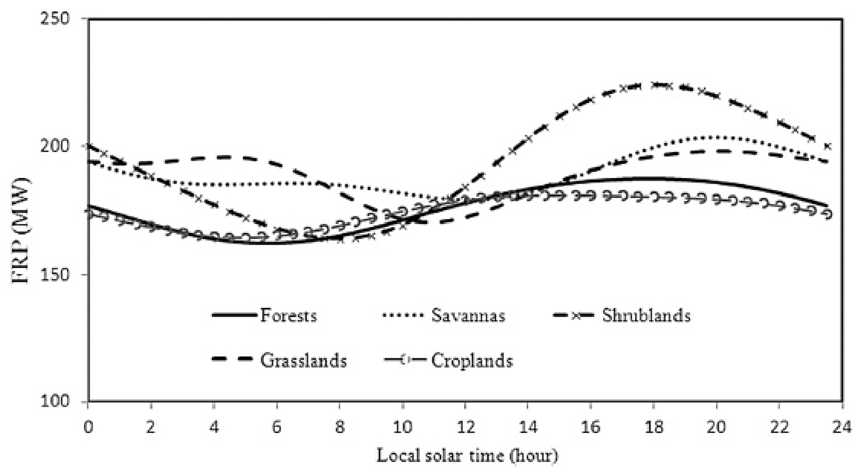
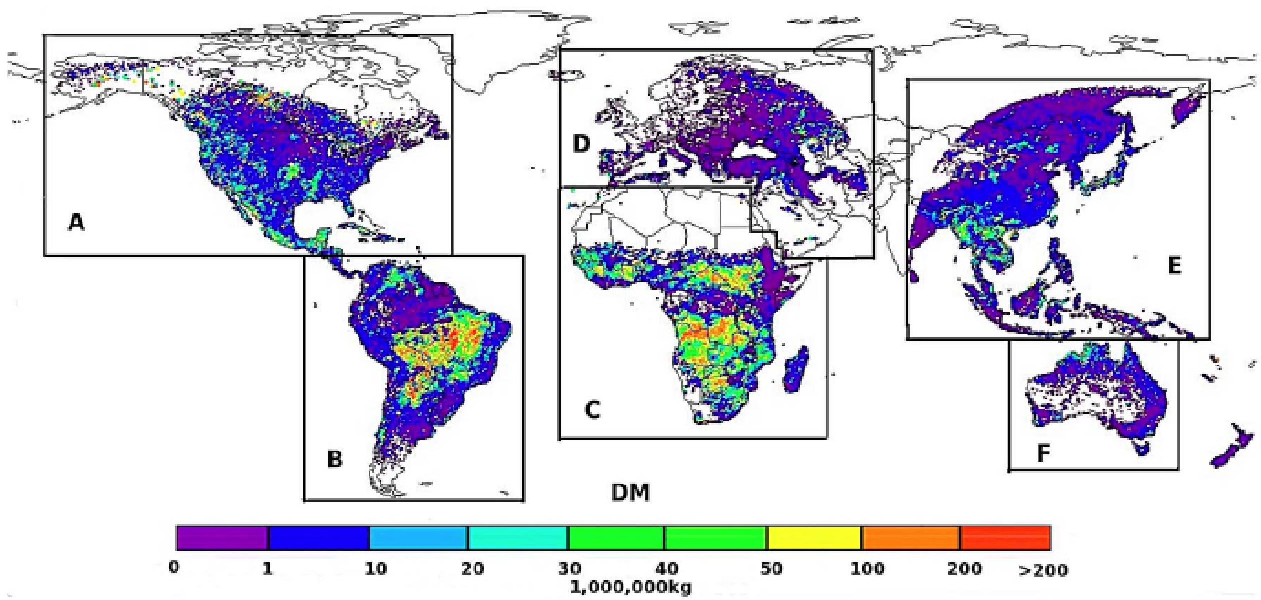


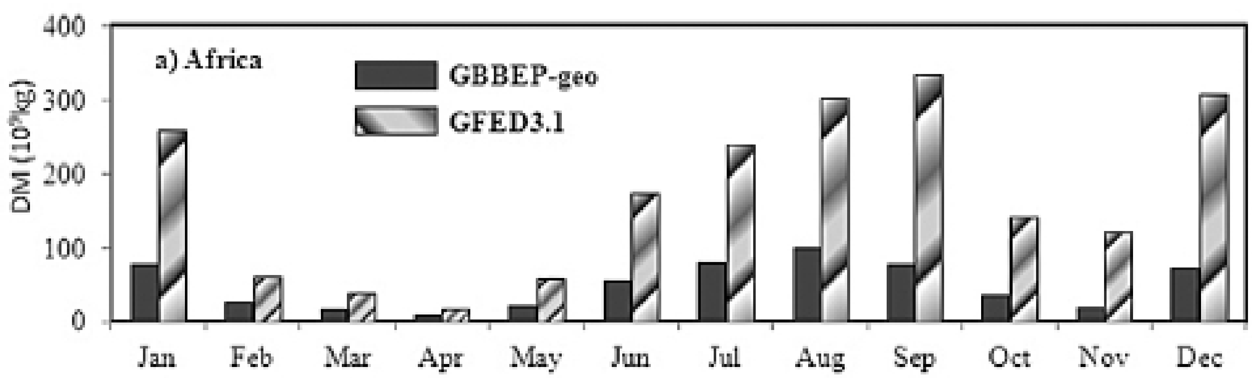
Figure 2. Climatological diurnal FRP (average data from 2002 to 2005) fitted using the discrete Fourier transform model for various ecosystems in North America.

Zhang et al (2012) Near-real-time global biomass burning emissions product from geostationary satellite constellation, JGR.

Zhang et al. (2012) GEOSTATIONARY FRP



Fuel Mass Combusted
(0.25 deg grid cells)



Comparison to GFEDv3.1
(Africa)

Effect of Errors of Omission

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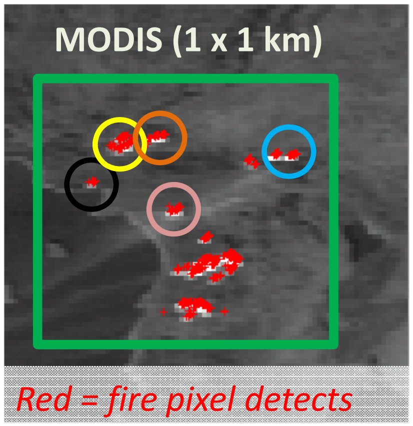
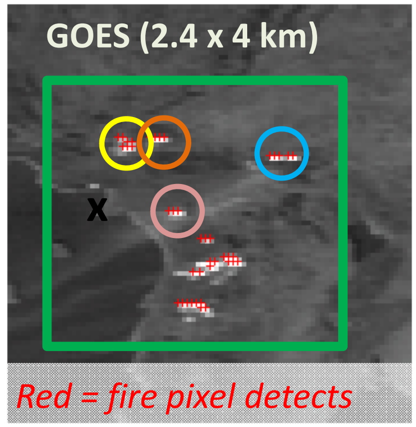
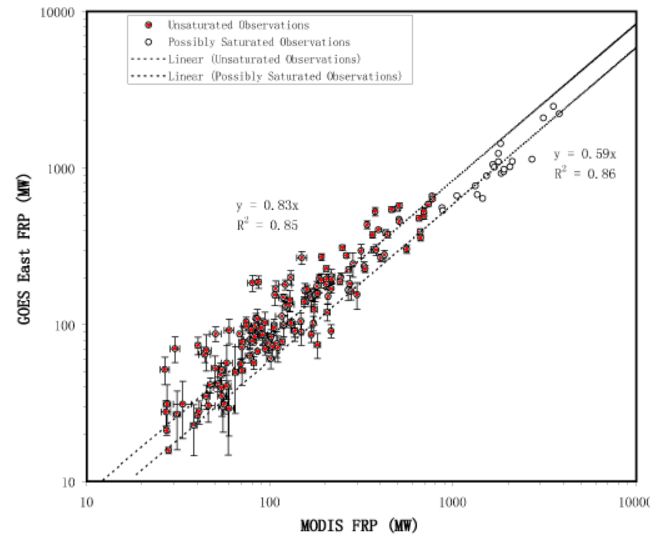
On "per fire" basis Geosat FRP close to MODIS FRP



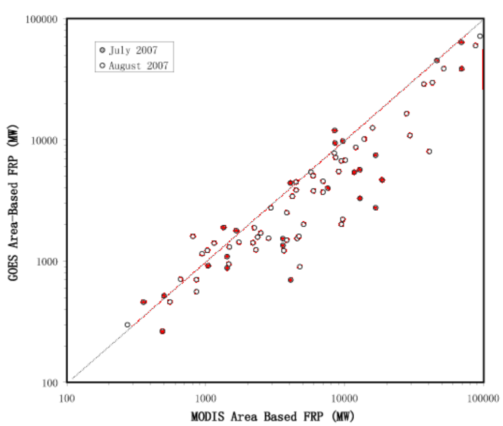
MODIS Californai Fires 20:55 UTC



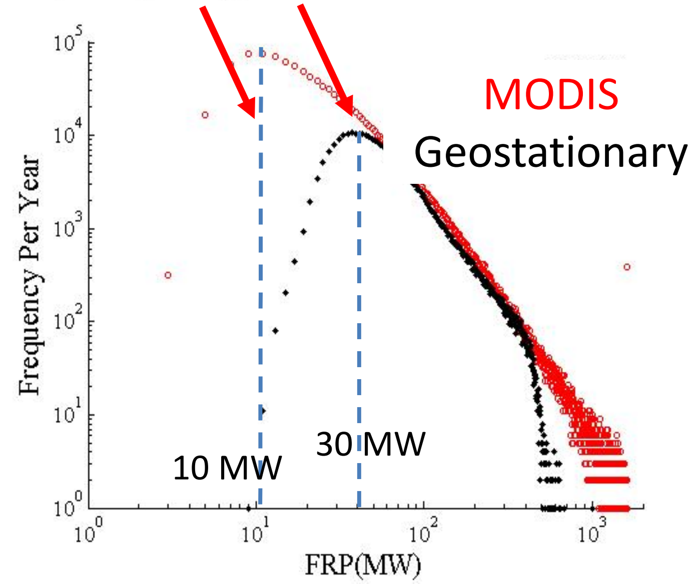
GOES California Fires 20:45 UTC



On "per region" basis Geosat FRP underestimates polar-orbiting (MODIS) FRP



Non-detection of low FRP Fires



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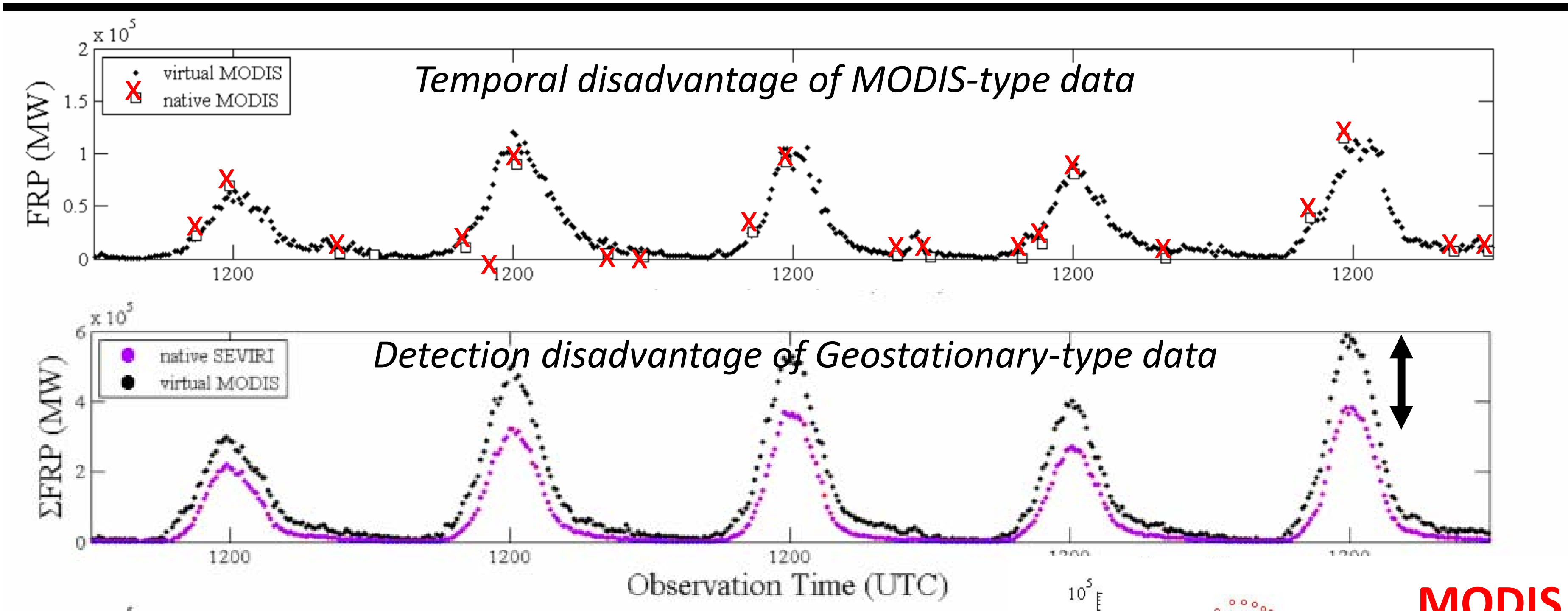
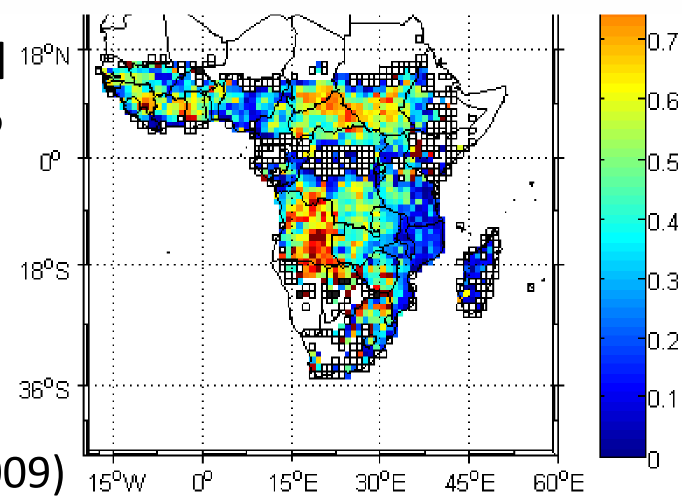
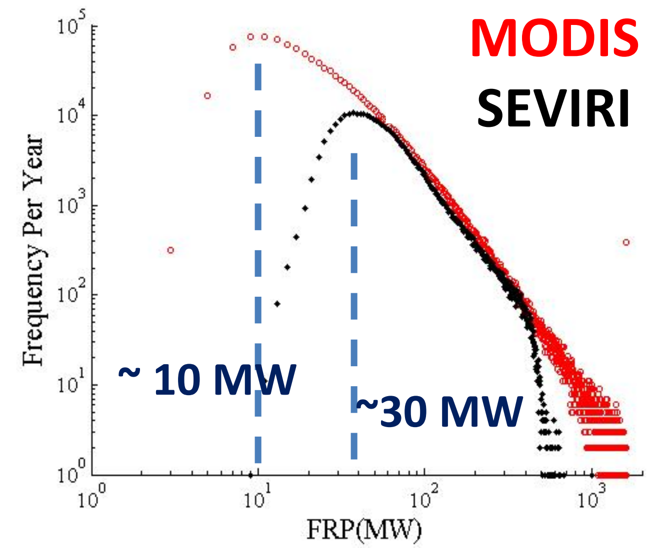
GEO to LEO Merging

Merging GEO and LEO Datasets



Varying SEVIRI to MODIS FRP Ratio





Freeborn *et al.* (2009)

Merging GEO and LEO Datasets

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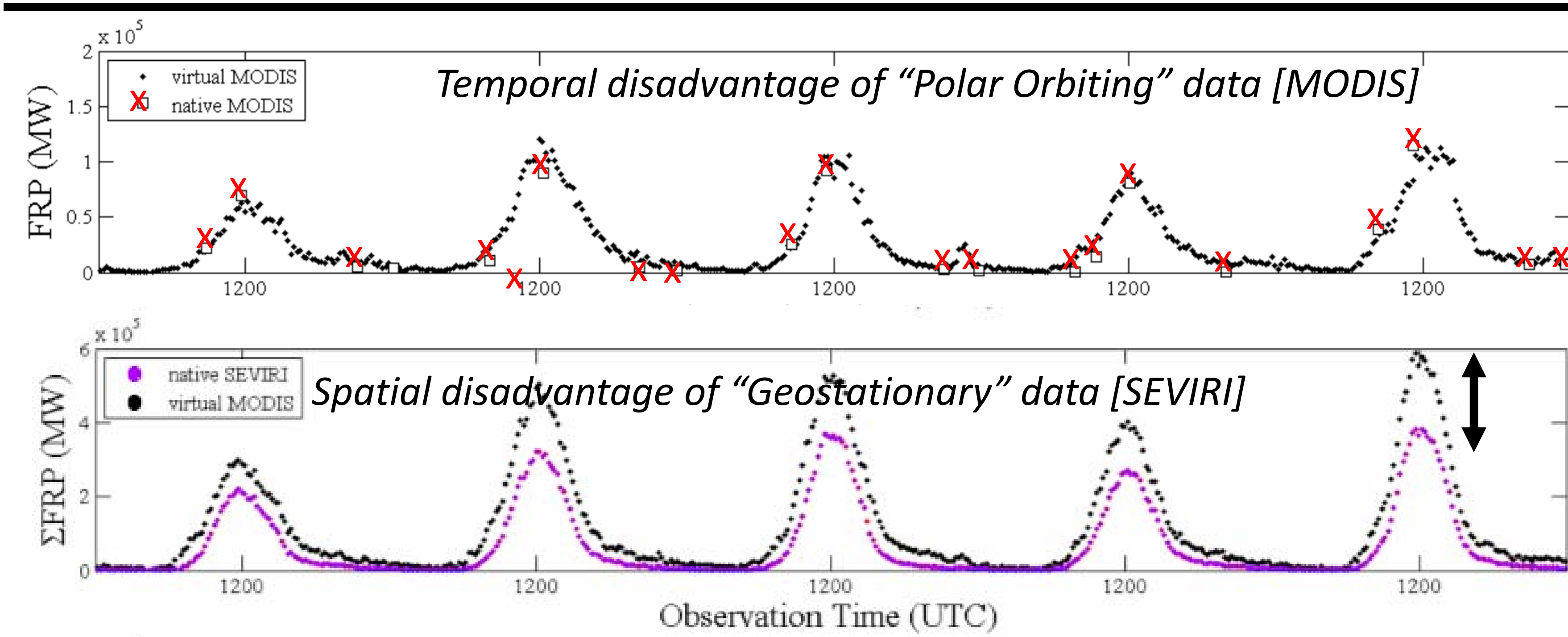
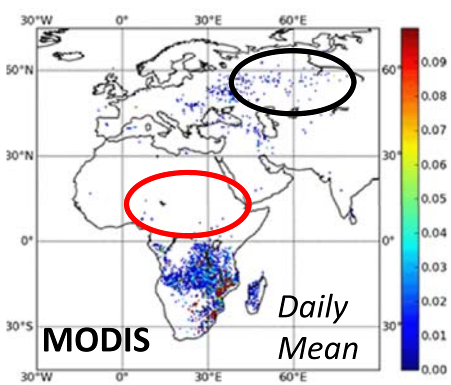
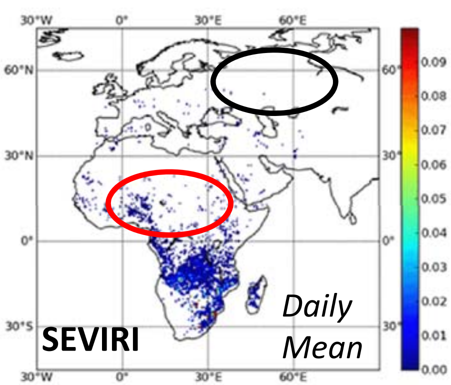
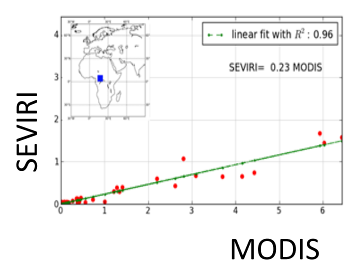




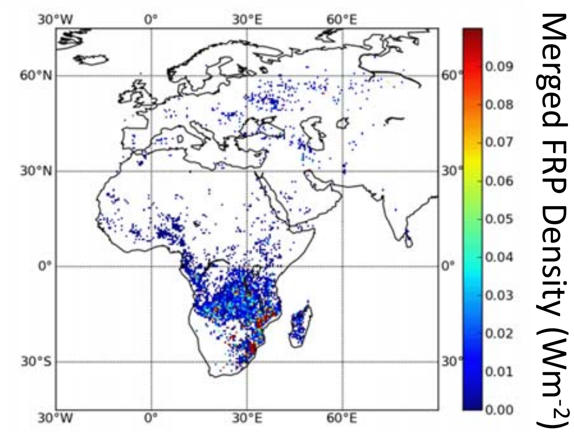
FRP density (Wm^{-2})



FRP Density (Wm^{-2})



transfer fn.



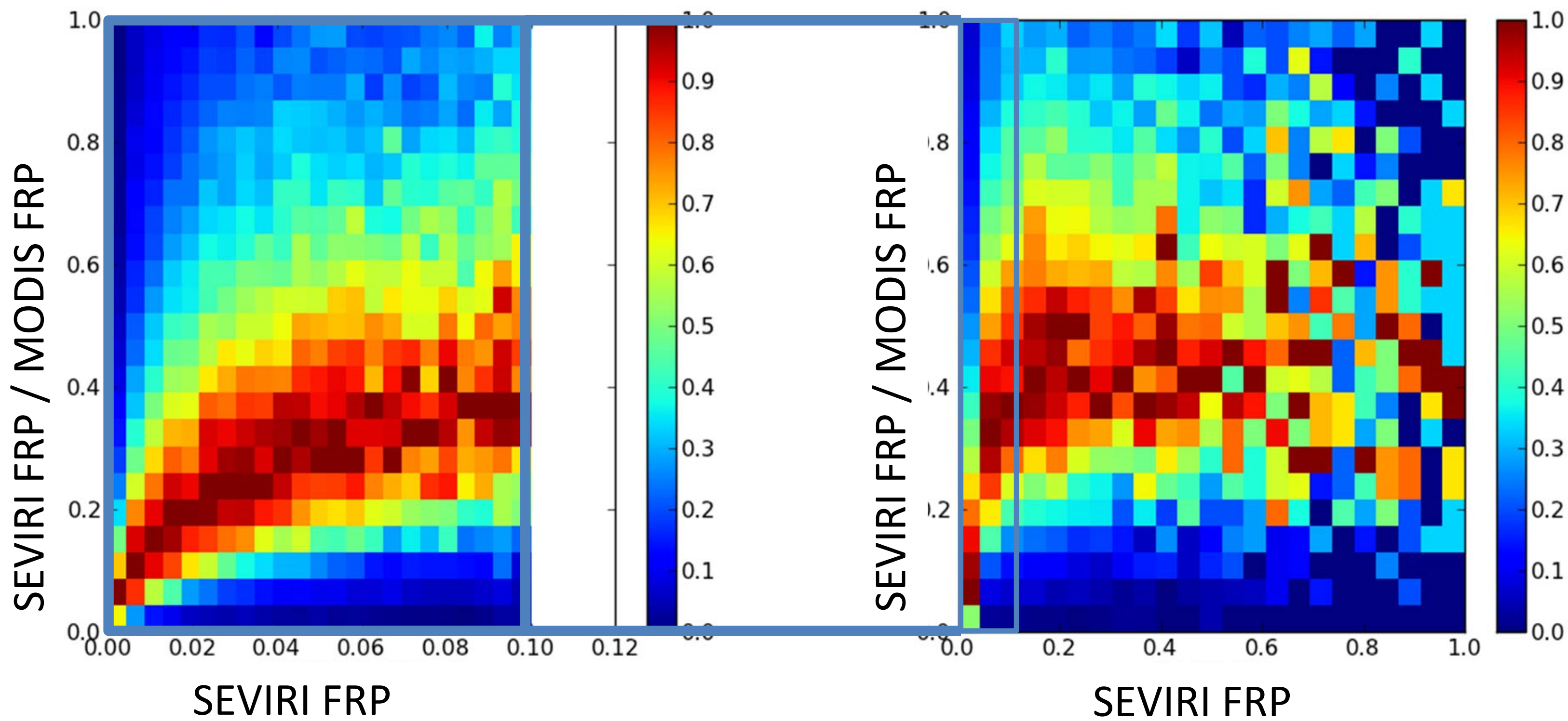
Merged & Bias-Corrected

FRP merging of GEO & LEO

- Scientifically not yet solved
  - based on GFAS-gridded observations
  - characterisation of bias (GEO FRP, view angle, local time)
  - prediction of bias from previous co-located observations

Also new paper by Heyer et al (2013) Atmospheric Res. Usig MODIS & MTSAT

Conditional PDF (Jun2010-Jul2012)



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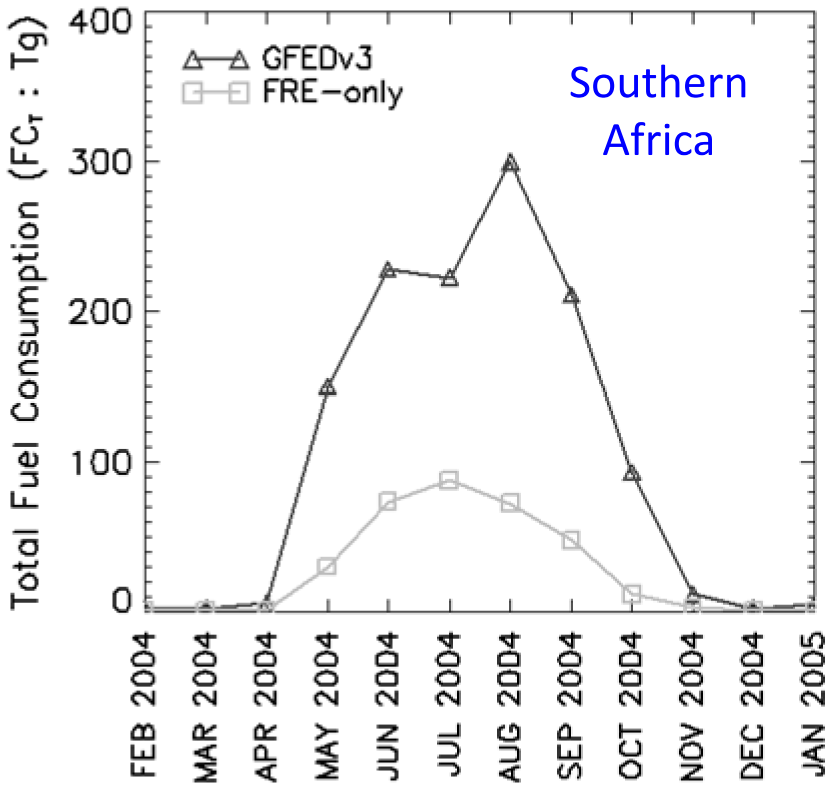
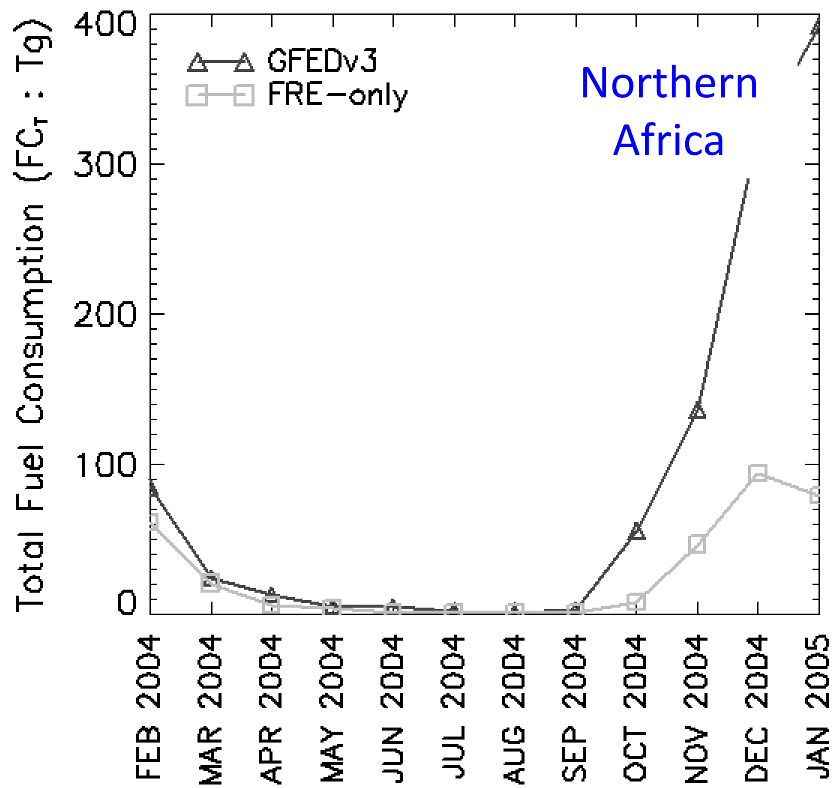
Potential to "Merge" with Burned Area Products

Fire Radiative Energy *vs.* Global Fire Emissions Database (v3)

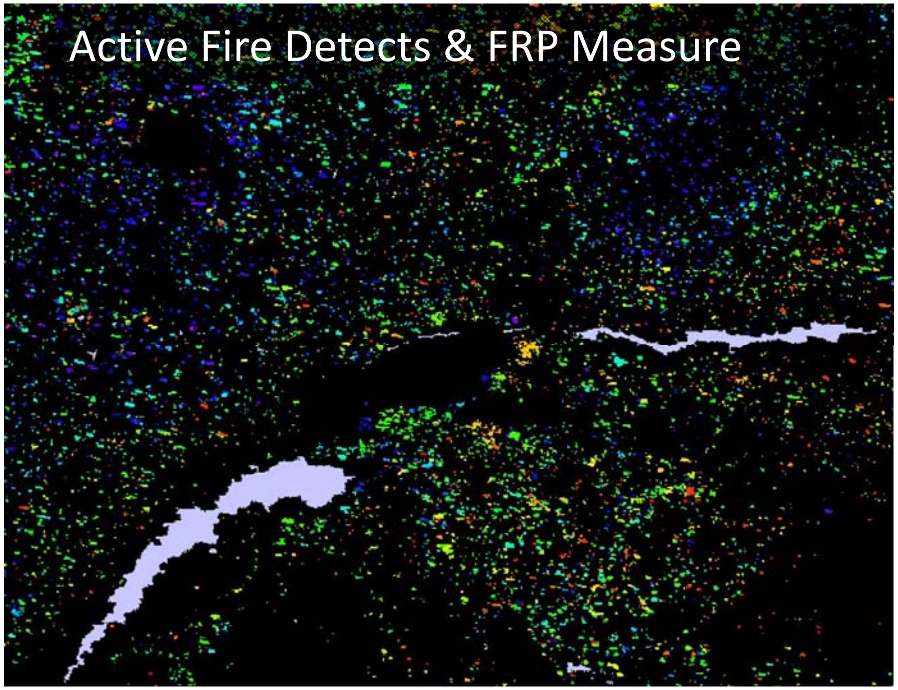
Feb 2004 – Jan 2005 Fuel Consumption Totals (Southern and Northern Hemisphere Africa)

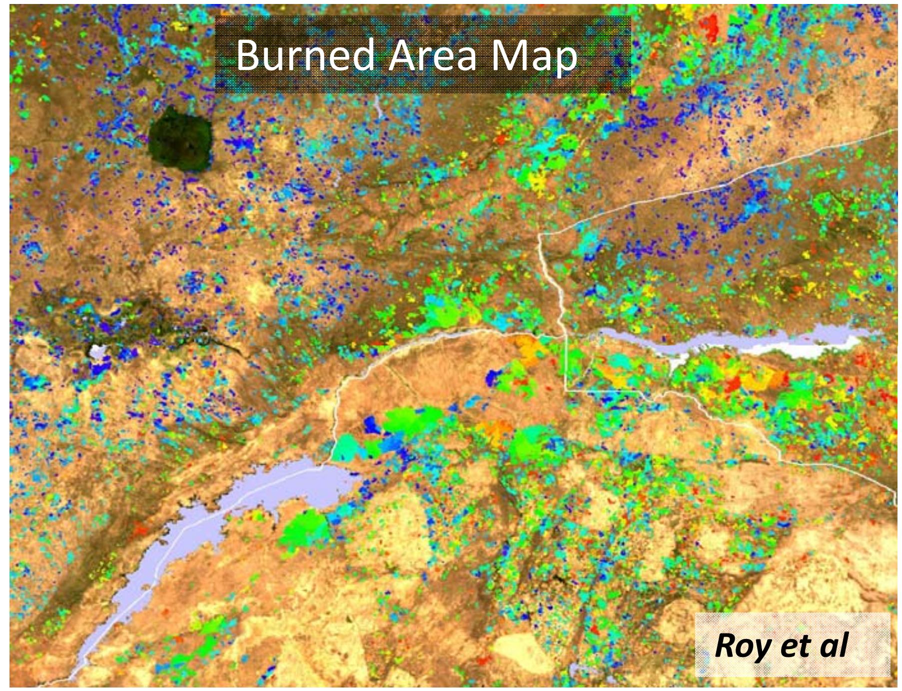




Large discrepancies between GFED and “raw” FRE-derived emissions....

Solution: Combine FRE & Burned Area





- Advantages
  - Well observed fires → measure of energy/total fuel consumption
- Disadvantages:
  - Missing fires occurring between views.
  - Missing data due to cloud cover.
  - Missing data due to low FRP" fires below active fire detection limit.

- Advantages
  - More "complete" coverage (wait for cloud to clear and for overpass)
- Disadvantages:
  - Requires additional "hard to obtain" information on fuel load in order to estimate fuel consumption.

Fuel Consumption (g /m²)

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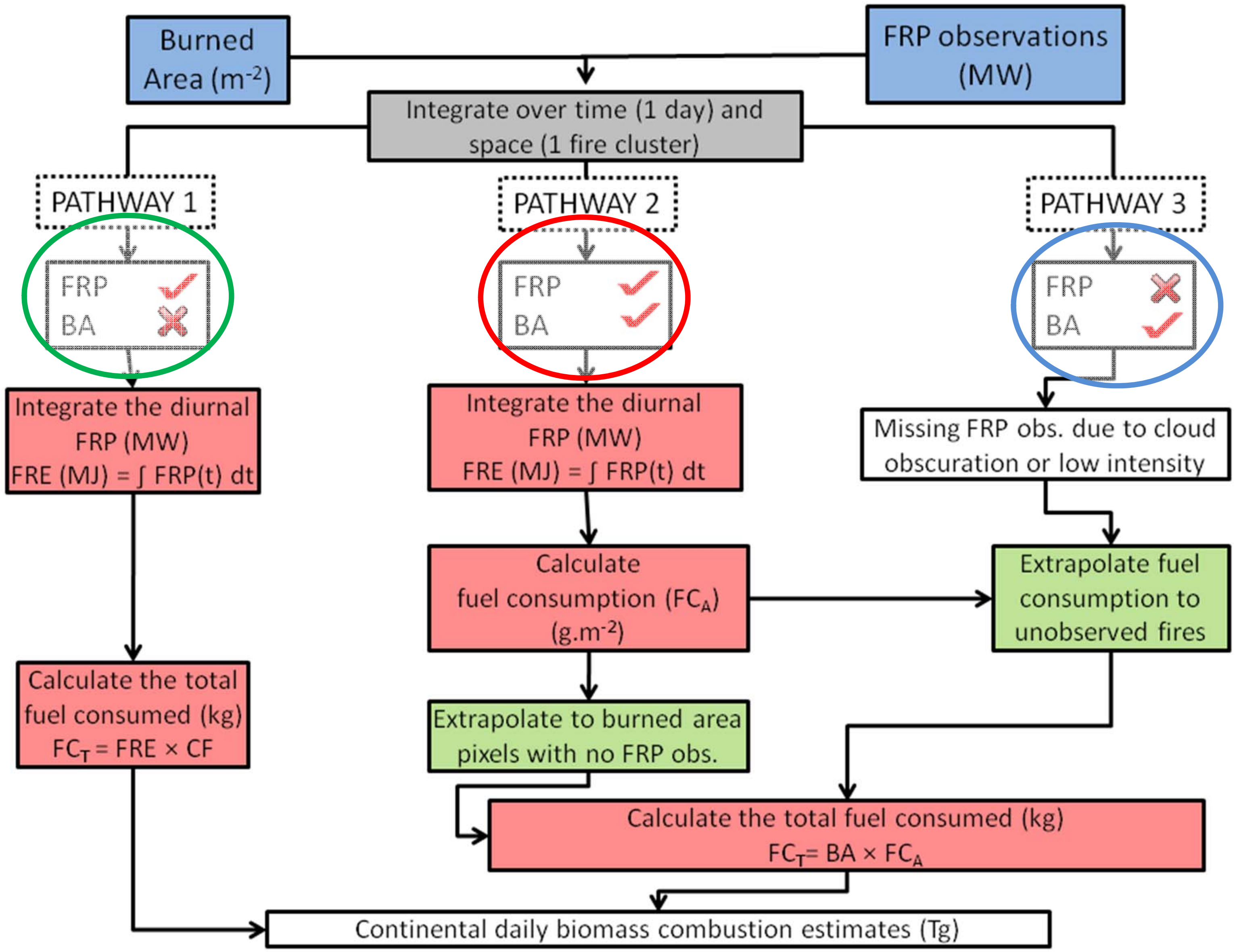
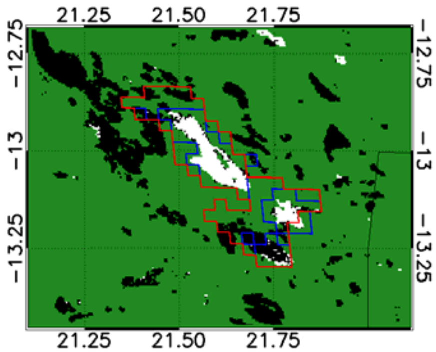
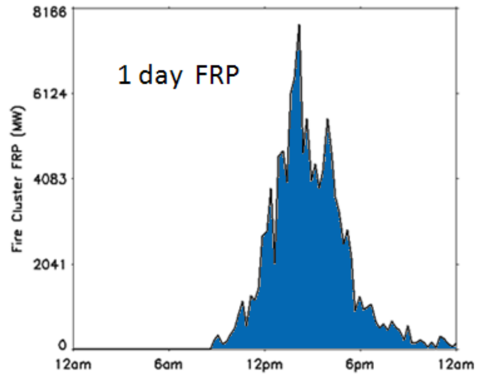


Fuel Consumption (g /m²)



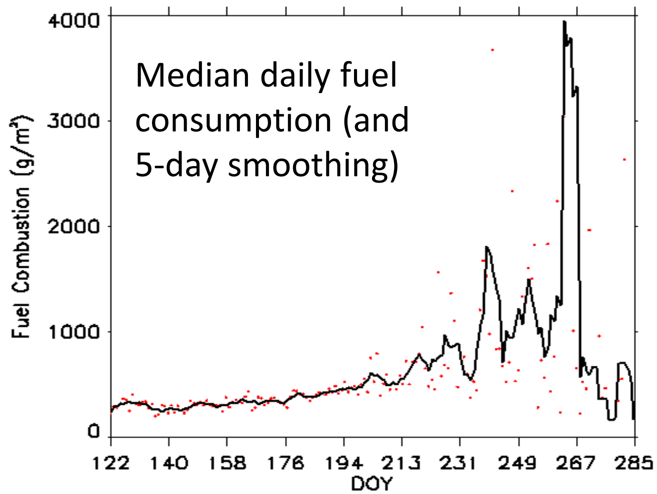
+

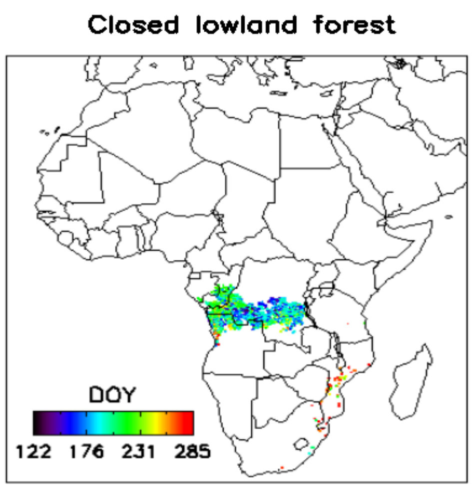


500 m MODIS burned area data (white is day of interest)

- FRE = 1.1×10^8 MJ
- Total Fuel Burned = 39 ktonnes
- Burned area = 40.8 km²

⇒ Fuel Consumption ~ 1.0 $kg.m^{-2}$





- Repeat for all "well observed" fires detected by SEVIRI
- Extrapolate using burned area for "poorly observed" fires

Fire Radiative Energy *vs.* Global Fire Emissions Database (v3)

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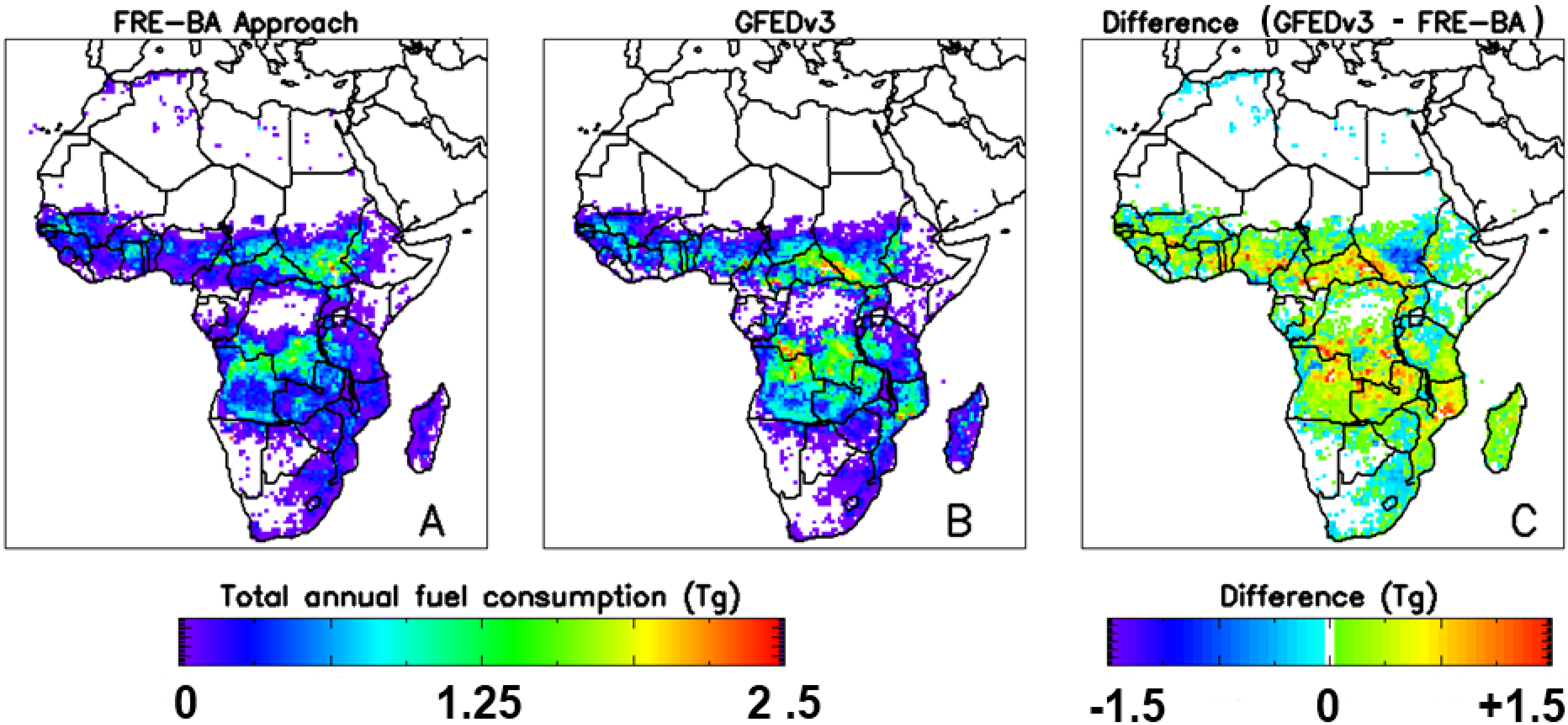
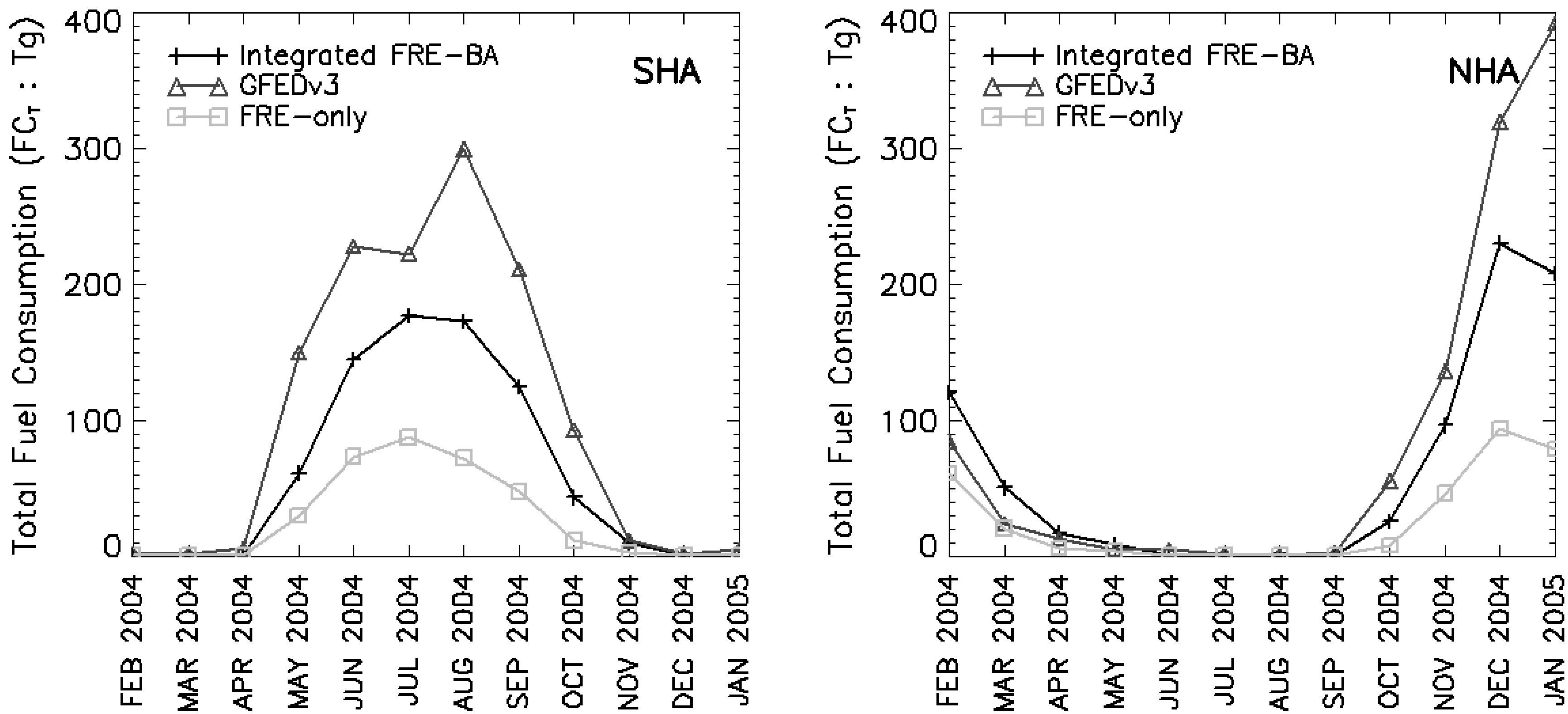
Feb 2004 – Jan 2005 Fuel Consumption Totals (0.5°cells)



Fire Radiative Energy *vs.* Global Fire Emissions Database (v3)

Feb 2004 – Jan 2005 Fuel Consumption Totals (Southern and Northern Hemisphere Africa)

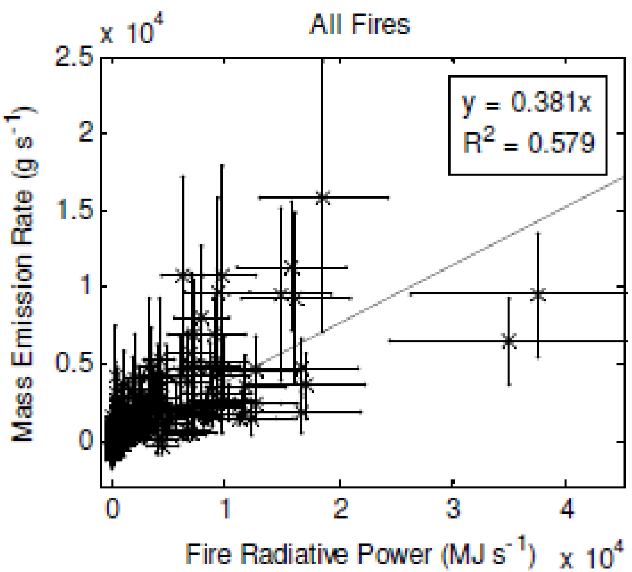


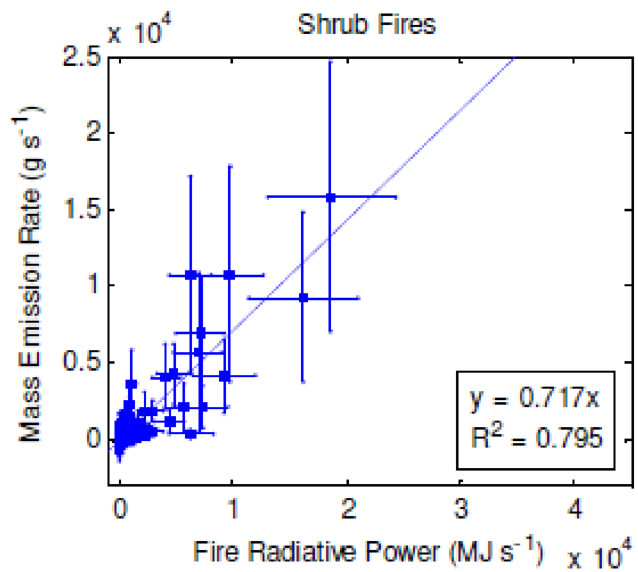
Roberts et al. (2011) Integration of geostationary FRP and polar-orbiter burned area datasets for enhanced biomass burning inventory, ***Remote Sensing Environ.****, 115.*

Direct Relationship to Trace Gas Emission

Mebust et al. (2011) FRP and NO_2

- Derive emissions factors (grammes of NO_2 emitted per kg of fuel burned) from combination of MODIS FRP and GOME NO_2 columns.
- Based on Ichoku and Kaufman (2005) approach previously used for aerosols rather than trace gases.





EFs vary in the expected way, but are lower than previous measures. Underestimated contribution from smouldering previously?

Field Based FRP Studies

Remote Determination of Emissions Factors (EF_x)

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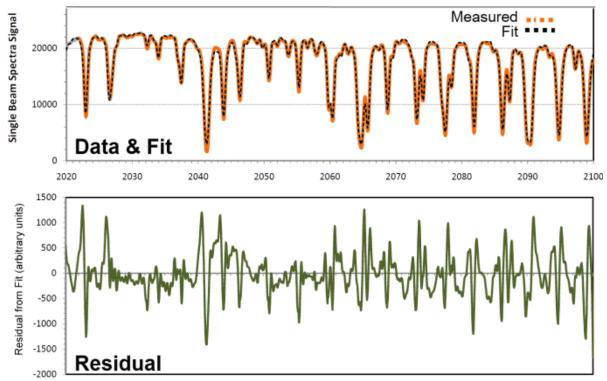
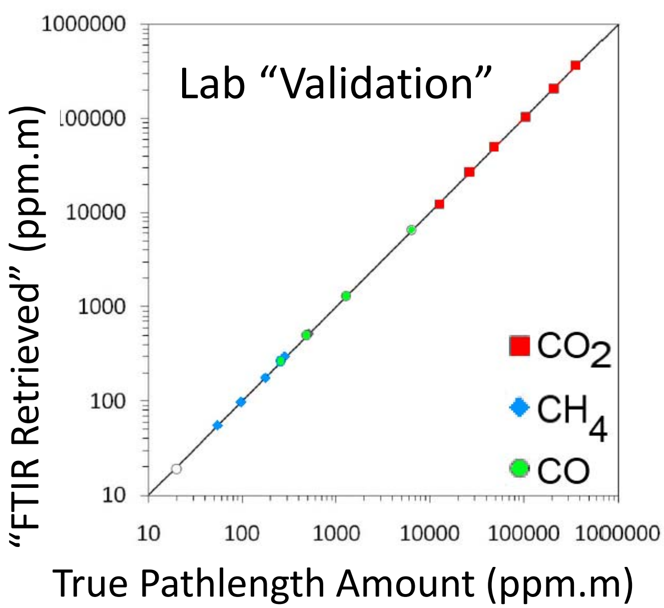
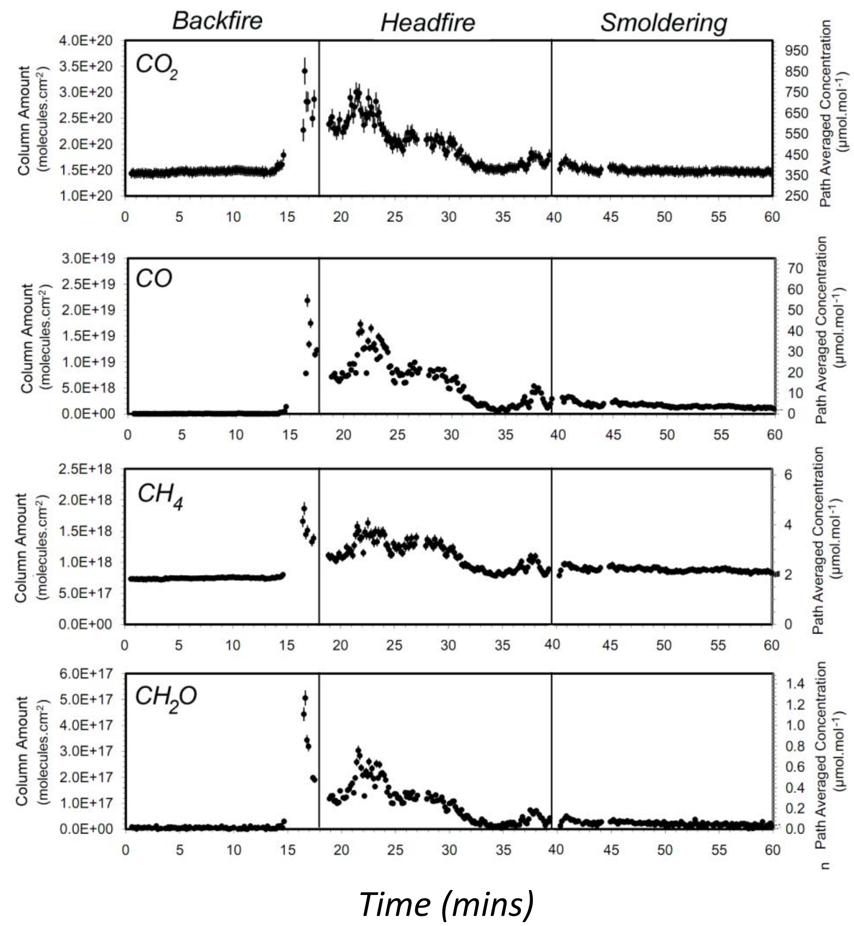
Field Portable Open Path FTIR Spectrometry





Gas Concentration Time Series



- *Wooster et al. (2011)* Field determination of biomass burning emission ratios and factors via open-path FTIR spectroscopy, *Atmos. Chem. Physics, 11, 11591-11615.*
- *Smith, Wooster et al. (2011)* Absolute accuracy and sensitivity analysis of OP-FTIR retrievals, *Atmospheric Measurement Techniques,* 4, 97-116.

Remote Determination of Emissions Factors (EF_x)

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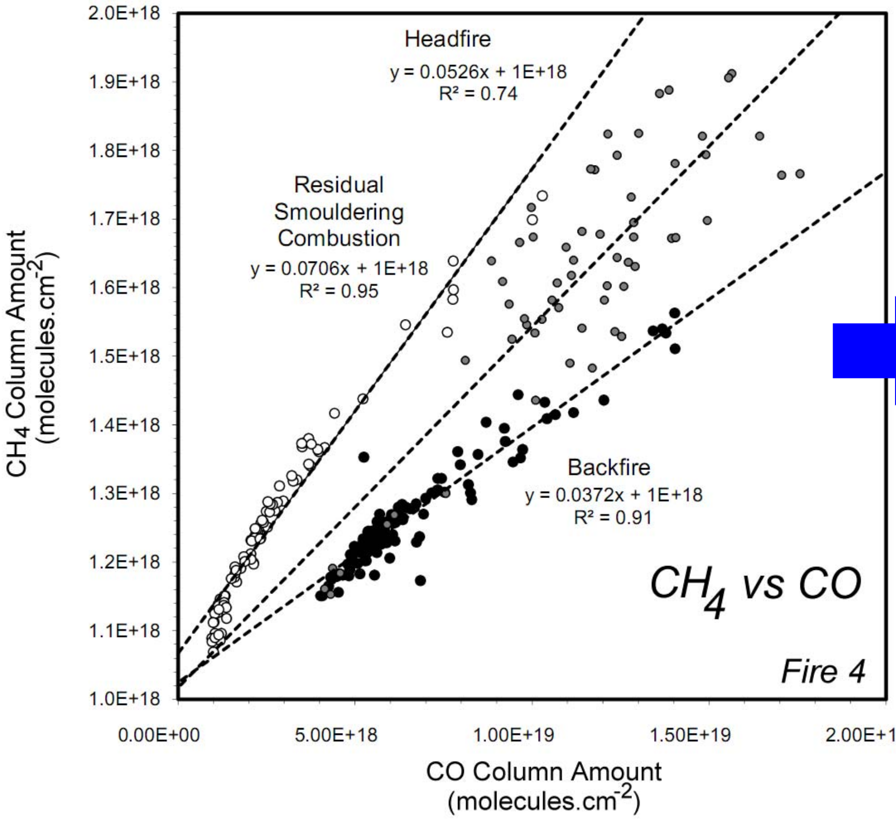
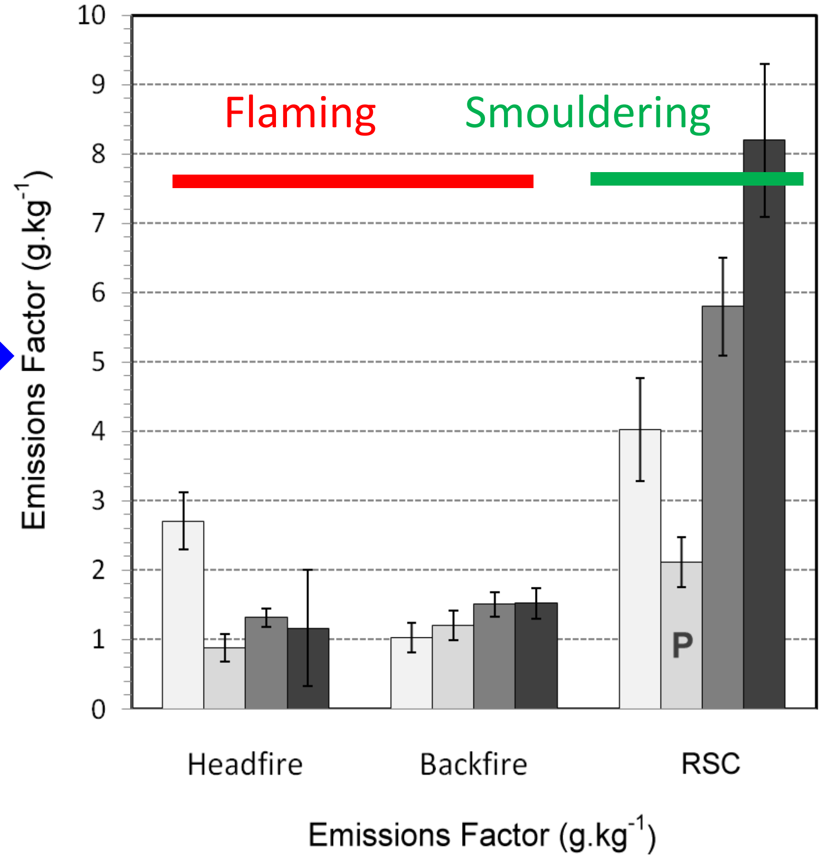
Emissions Ratio ($mol.mol^{-1}$)



Emissions Factor ($g.m^{-2}$)



- Used to provide environment & time specific EF_x parameters
- FRE recorded simultaneously from aircraft used to weight the components to calculate weighted mean EFs

Controls on MODIS FRP in Alaska

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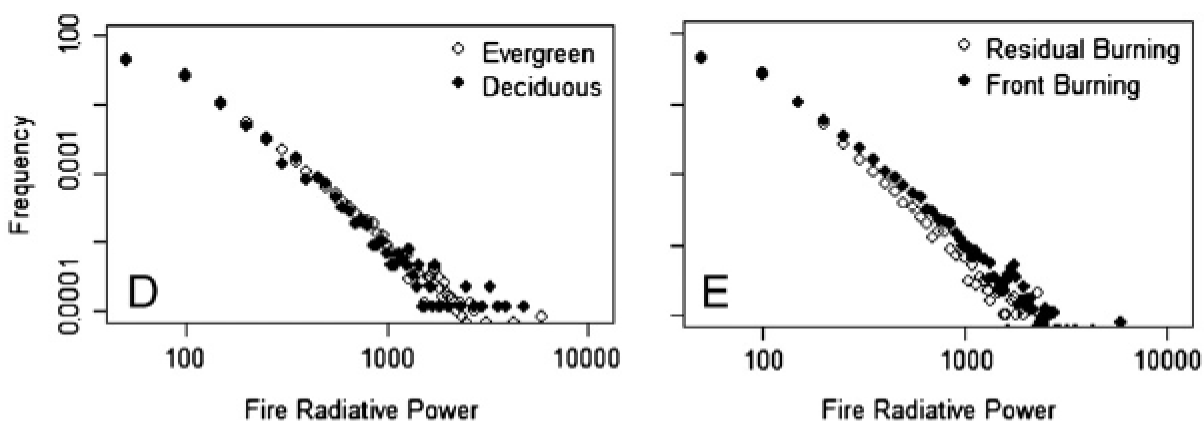
• Used MODIS FRP observations of Alaskan forests to determine the controls of FRP (forest type, "large fire year", fire front or residual burning etc)



• Periods of high fire activity in the Alaskan boreal forest are characterized by a higher proportion of residual burning…which may ultimately impact tree mortality and species makeup.

Barrett and Kasischke (2012) Controls on variations in MODIS FRP in Alaskan boreal forests: Implications for fire severity conditions

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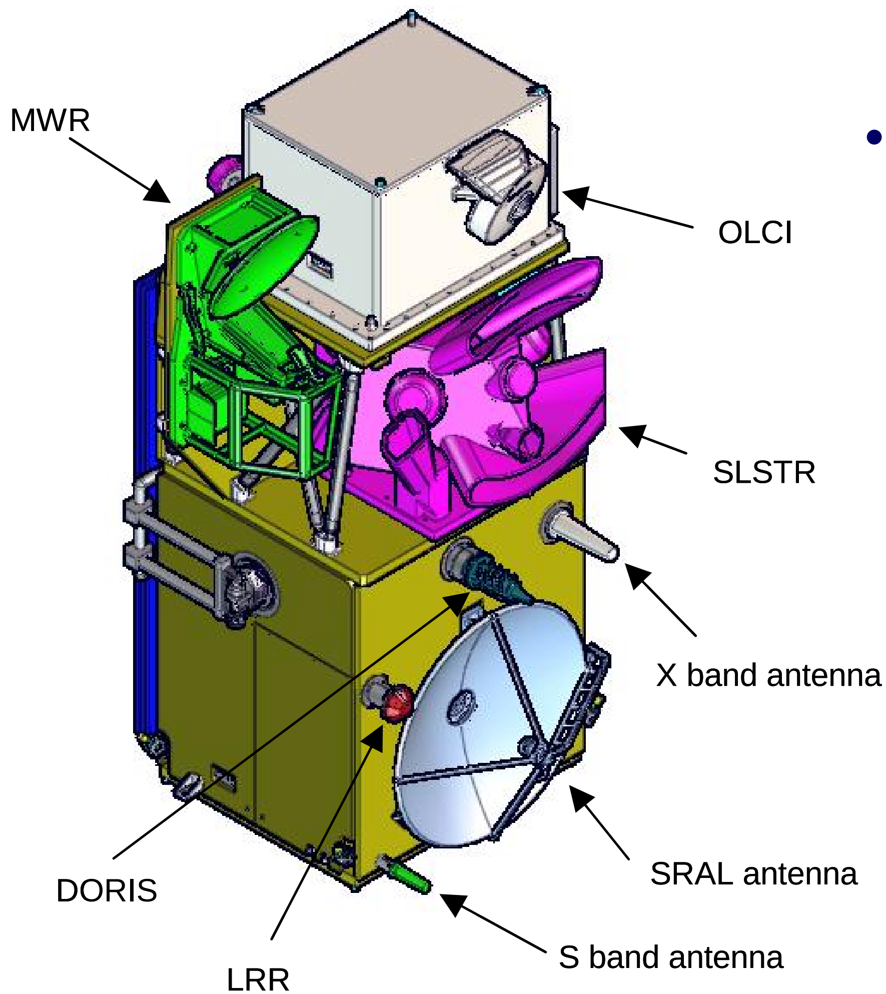
New FRP Products

- NPP VIIRS
- SENTINEL3 SLSTR

Sentinel-3 Satellite Overview



- Payload
  - Colour Instrument: OLCI
  - **Surface Temperature Instrument : SLSTR**
  - Radar Altimeter: SRAL
  - Micro Wave Radiometer: MWR
  - GPS receiver: GNSS
  - Laser Retro Reflector: LRR
  - Doris instrument

Sentinel-3 SLSTR ~ 2013/14

SLSTR Spectral Bands

Band #	Centre λ_{centre} μm	Spectral Width $\Delta\lambda$ μm	Lmin/Tmin	Lref/Tref	Lmax/Tmax	SNR/NEDT	Radiometric Accuracy	Ref SSD
			mWm^{-2}sr^{-1}nm^{-1}/K			@Lref		
S1	0.555	0.02	2.92	2.92	585	20	2%	0.5km
S2	0.659	0.02	2.43	2.43	475	20	2%	0.5km
S3	0.865	0.02	1.53	1.53	295	20	2%	0.5km
S4	1.375	0.15	0.58	0.58	113.1	20	2%	0.5km
S5	1.61	0.06	0.39	0.39	74.0	20	2%	0.5km
S6	2.25	0.05	0.13	0.13	24.3	20	2%	0.5km
S7	3.74	0.38	200K	270K	323K	0.08K	0.2K (0.1K goal)	1km
S8	10.85	0.9	200K	270K	321K	0.05K	0.2K (0.1K goal)	1km
S9	12.0	1.0	200K	270K	318K	0.05K	0.2K (0.1K goal)	1km
F1	3.74	0.38	350K		500K (634K Goal)	1K	3K	1km
F2	10.85	0.9	330K		400K	0.5K	3K	1km

Note:

- New spectral bands at 1.375um and 2.25um
- VIS/SWIR Spatial Resolution at Nadir of 0.5km
- Fire channels at 3.74 and 10.85um
- Radiometric accuracy requirement of 0.2K with goal of 0.1K

Algorithm for active fire detection and FRP assessment should be in ESA ground station