KING'S College LONDON
University of London

LEVERHULME
Centre for **Wildfires, Environment** and **Society**

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

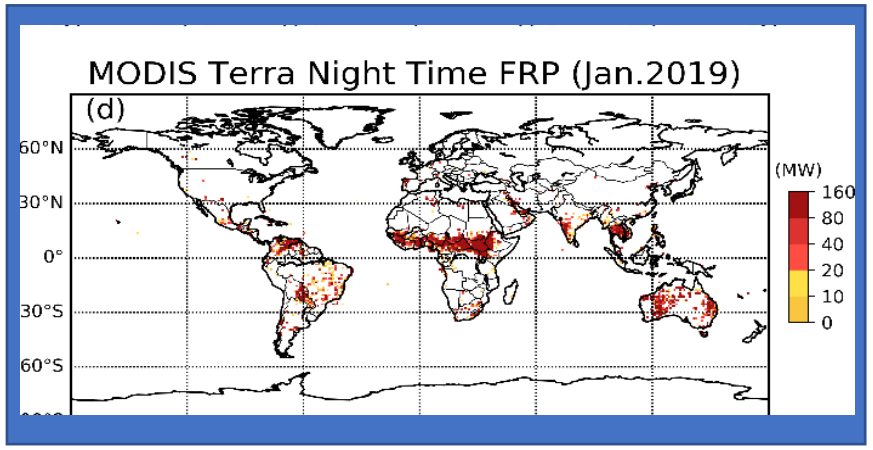
# Global & Continental Active Fire Products – Qualities, Issues & Developments

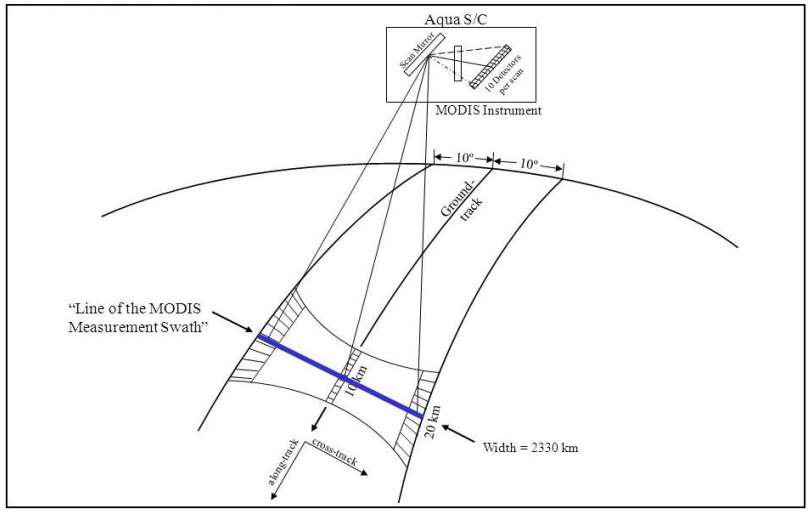

Presented by
Martin Wooster
[Slides from many others]

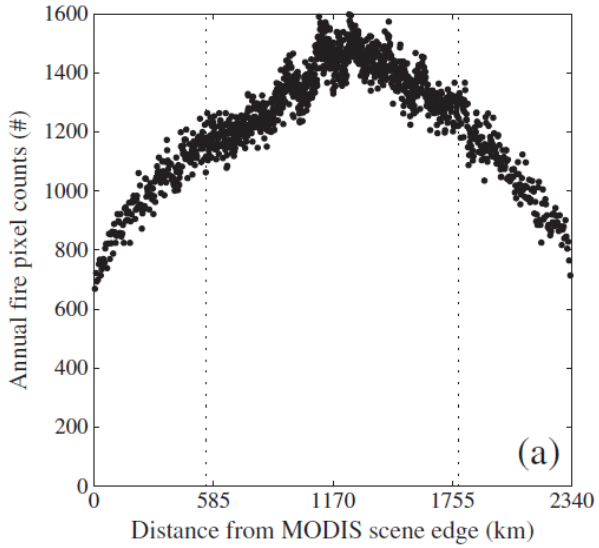


Wooster, M.J., Roberts, G.J., Giglio, L., Roy, D.P., Freeborn, P.H., Boschetti, L., Justice, C., Ichoku, C., Schroeder, W., Davies, D. and Smith, A.M., 2021. Satellite remote sensing of active fires: History and current status, applications and future requirements. *Remote Sensing of Environment*, *267*, p.112694.

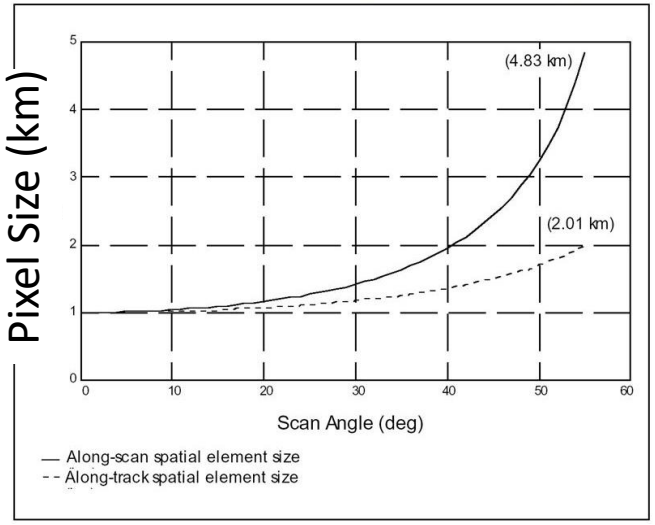
# MODIS Scan Angle Impacts on AF Detection

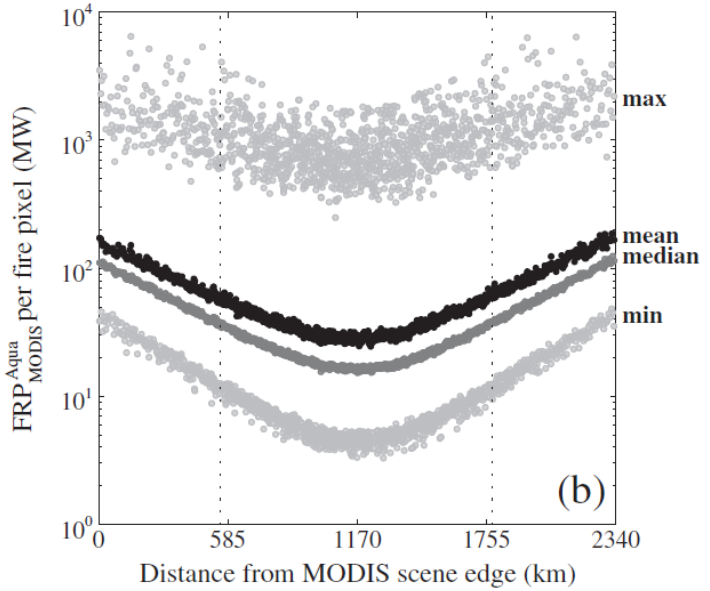


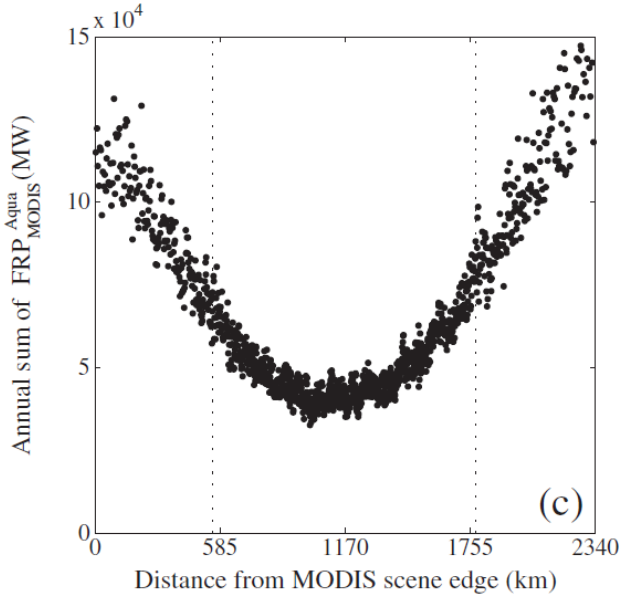



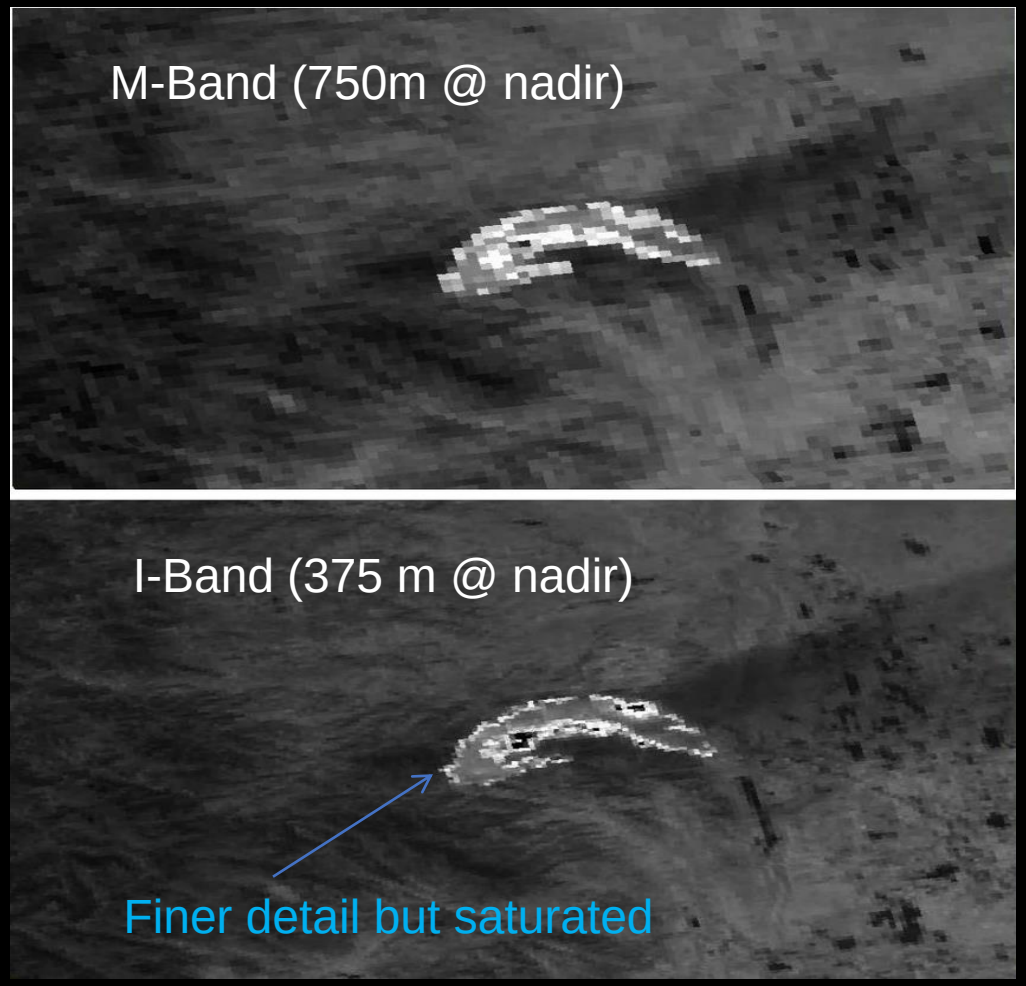

MWIR (3.9 μm) Band



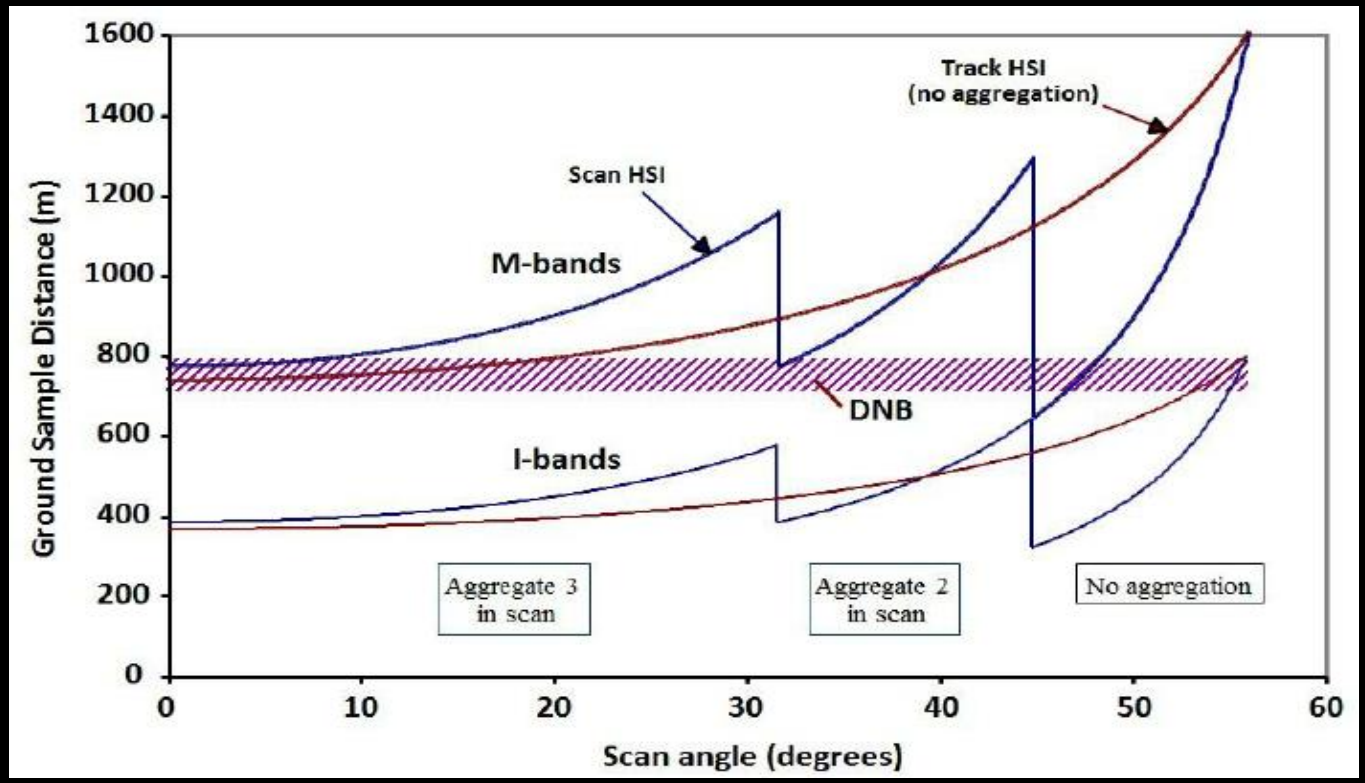



# VIIRS I-Band & M-Band Improvements




McCathy et al. (2013) Proceedings of SPIE

## Along-Scan Pixel Aggregation




Cao *et al.* (2013) VIIRS User's Guide

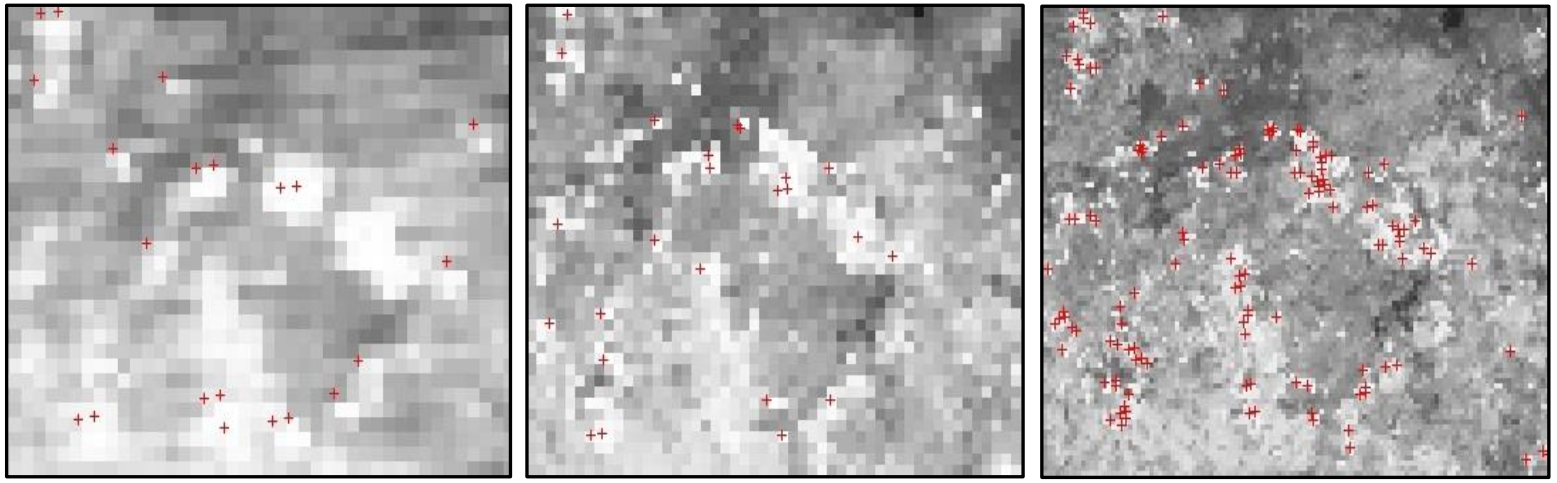
# Aqua MODIS Transition to VIIRS

Aqua MODIS (1000 m)

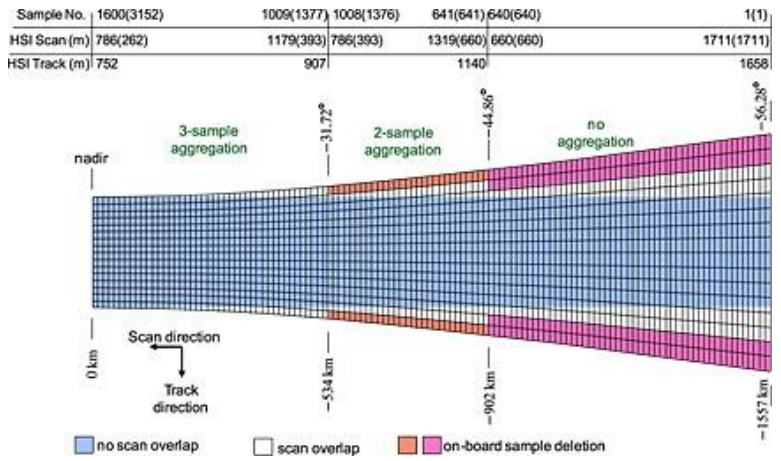
VIIRS-M band (750 m)

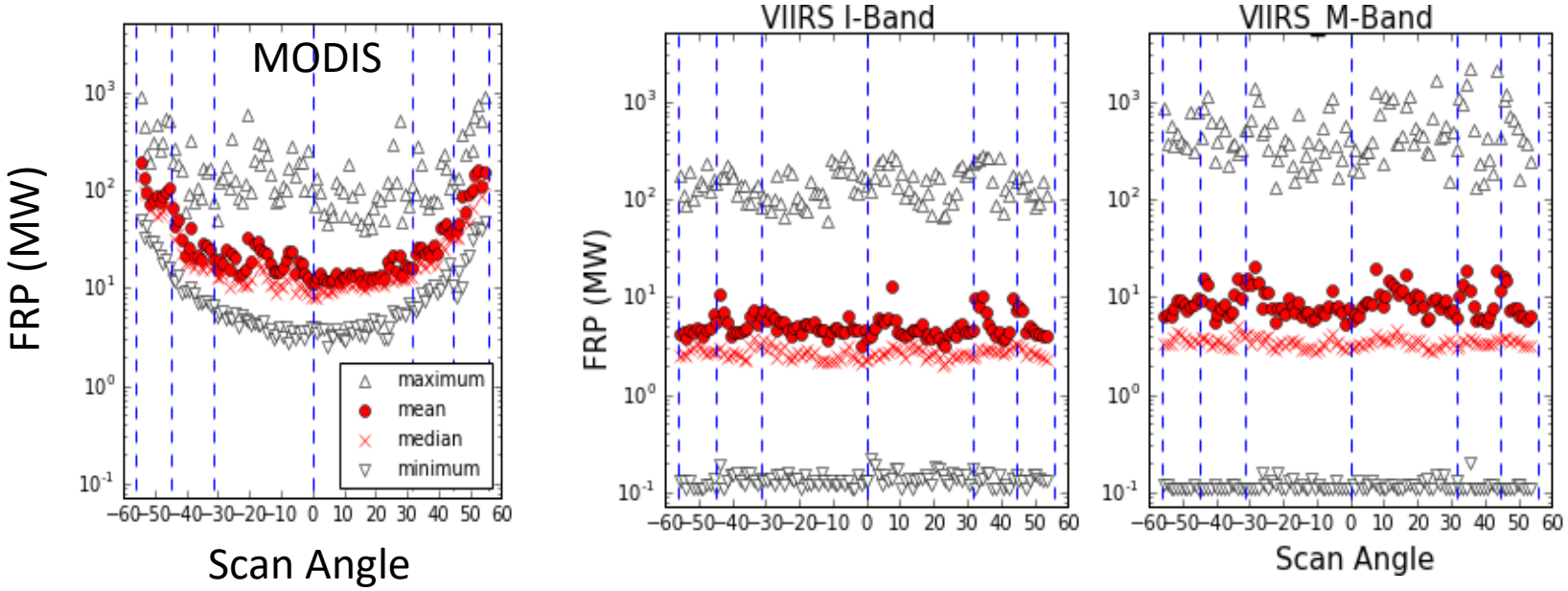
VIIRS-I band (375 m)

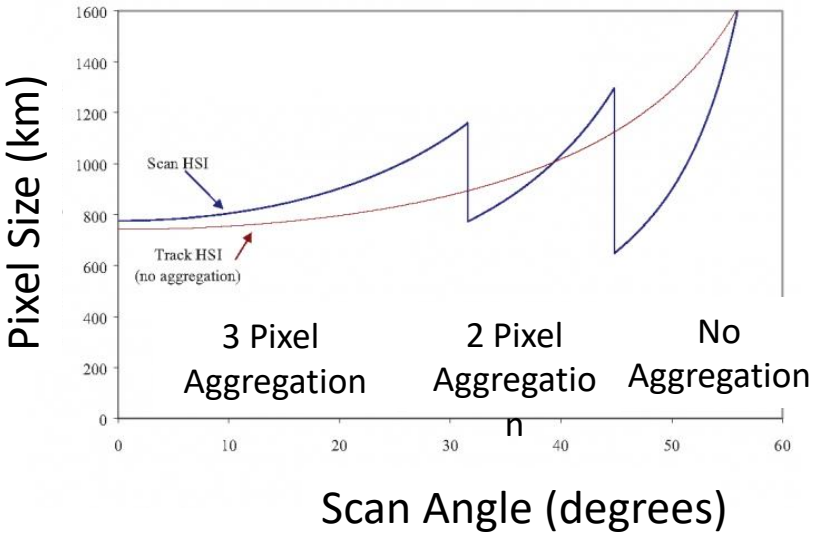
red = AF detection



VIIRS Across Scan Pixel Growth

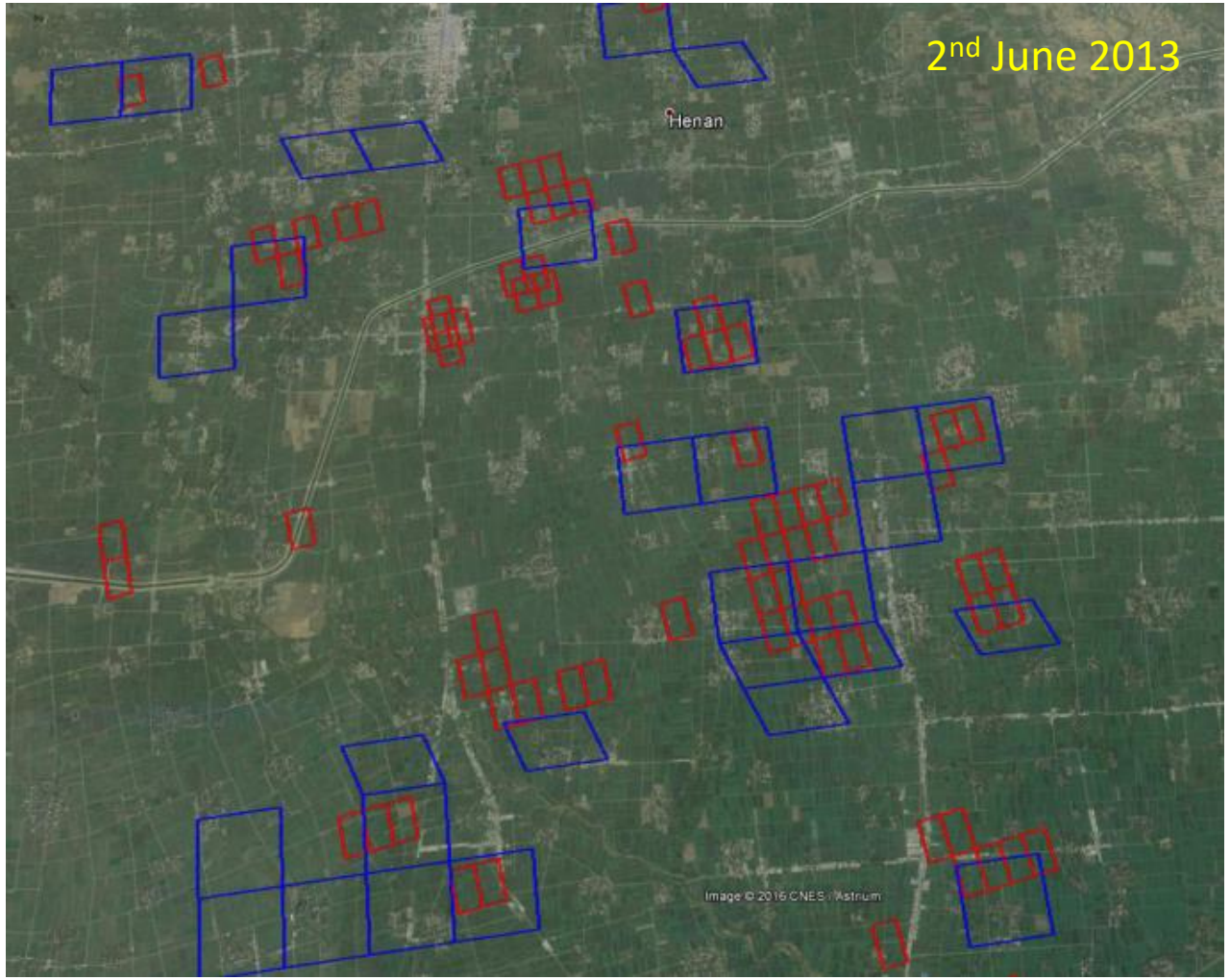


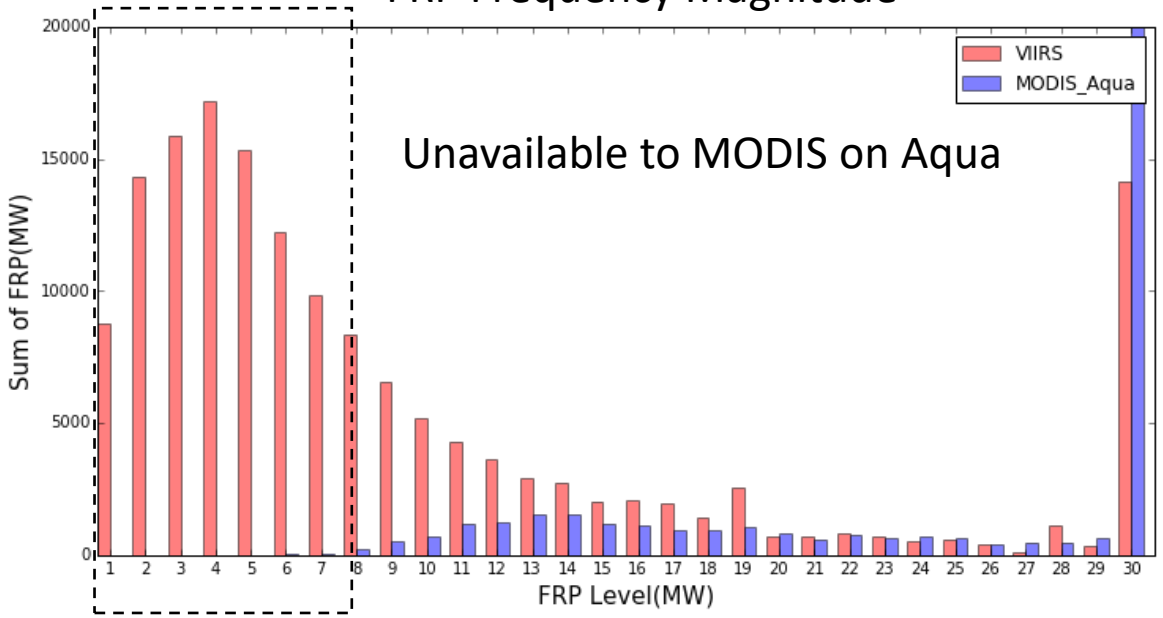
# VIIRS Benefits for Small Fires – Agr. Residue Burning (China)

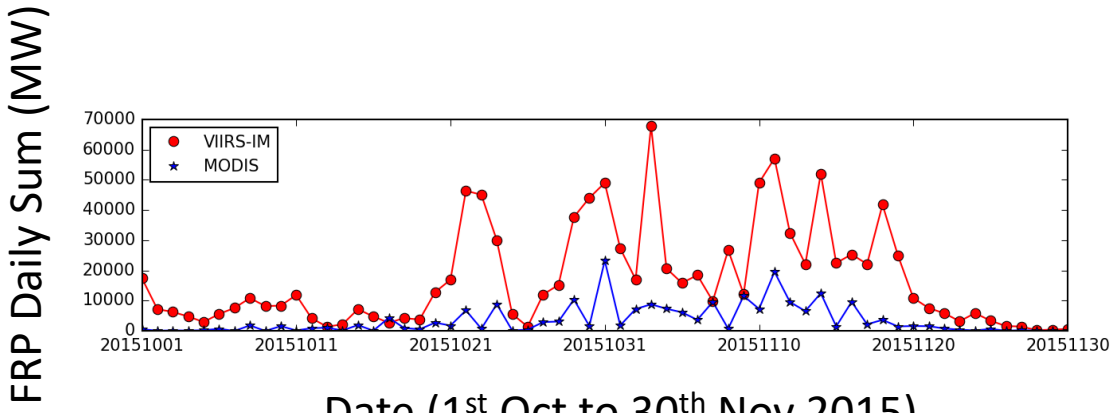
## Active Fire Detections




MODIS (blue) and VIIRS-I band (red)

FRP Frequency Magnitude



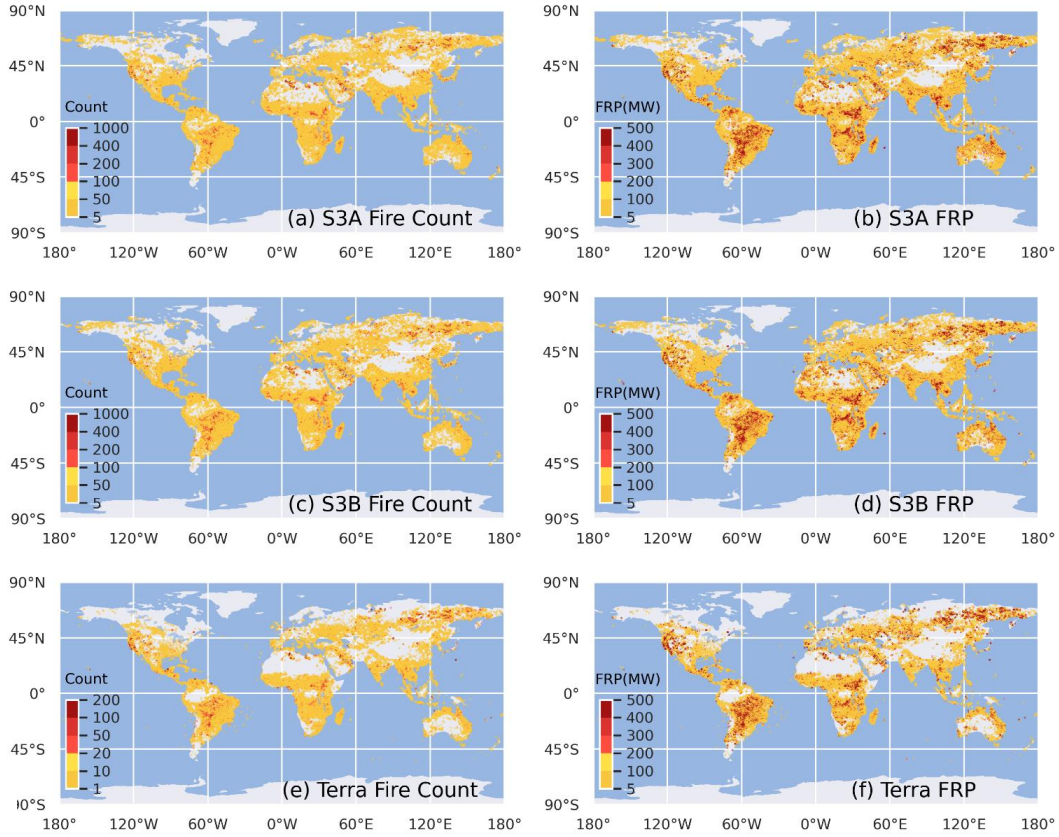



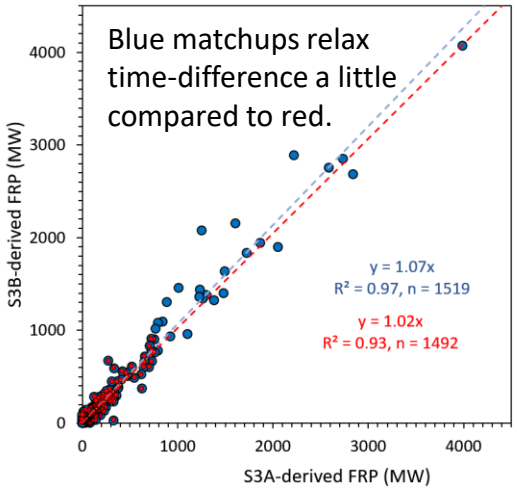

Date (1st Oct to 30th Nov 2015)

# Sentinel-3 Active Fire & FRP Product

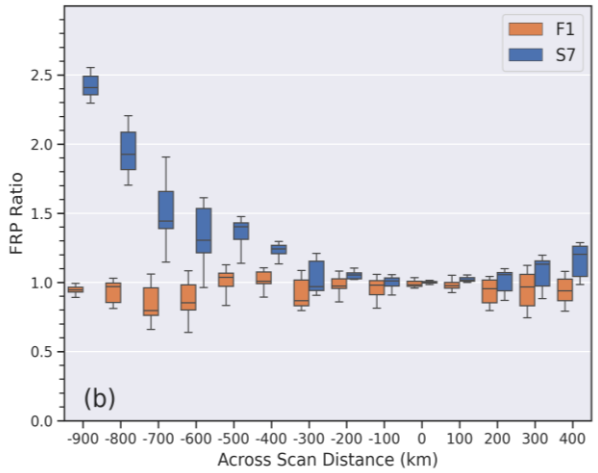

- Two Sentinel-3 (S3A & S3B) satellites each carry an SLSTR imaging radiometer overpassing at times similar to Terra MODIS and with two MWIR bands (S7 & F1) for AF detection and FRP retrieval.
- Daily global night- and day-time products, generated using slightly different band combinations/algs (due to sensor characteristics).
- Night-time S3 product detects more low FRP fires than Terra MODIS, and regionally a higher FRP. Daytime the reverse.
- Product Access: https://scihub.copernicus.eu/dhus/#/home
  NRT version - https://metis.eumetsat.int/frp/index.html

## Example Comparison to Terra MODIS (similar equator crossing time)




Early Sentinel-3 "Tandem mode" data used to compare S3A & S3B FRP estimates of the same fire taken near concurrently, with good agreement.




"F1" band provides FRP data that do not depend much on fires location in the Earth scan, unlike if S7 used. A welcome characteristic - different to MODIS, but similar to VIIRS.

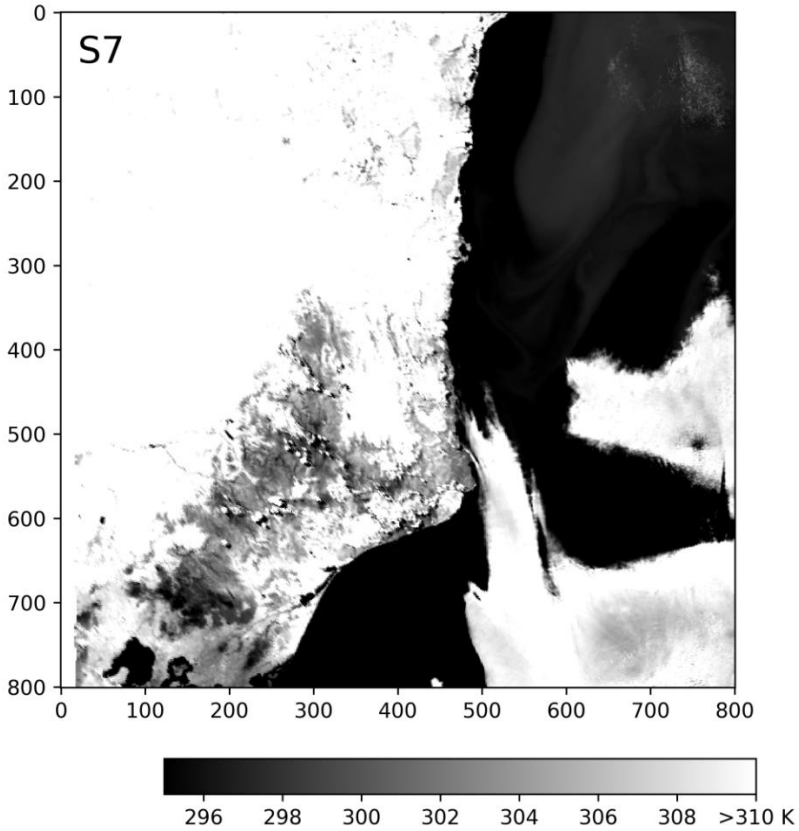
**Further information:**

https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-3-slstr

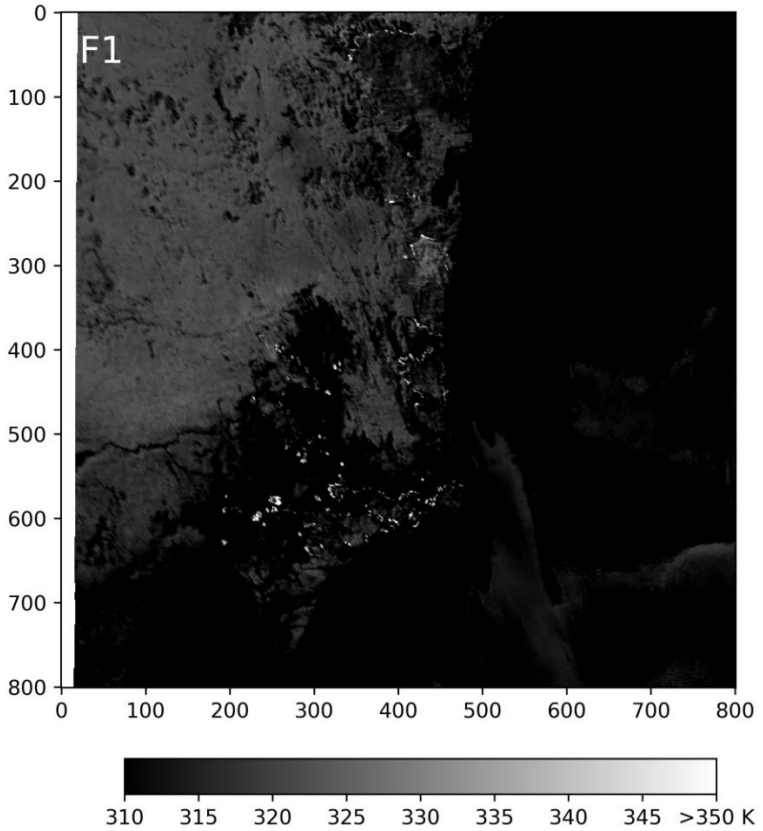

Xu, W., Wooster, M.J. et al. (2020) First study of Sentinel-3 SLSTR active fire detection and FRP retrieval…. *Remote Sens. Environ*, *248*, p.111947.

Xu, W., Wooster, M.J., et al. (2021) Sentinel-3 AF detection and FRP product performance…. *Remote Sens. Environ*, *261*, p.112460.

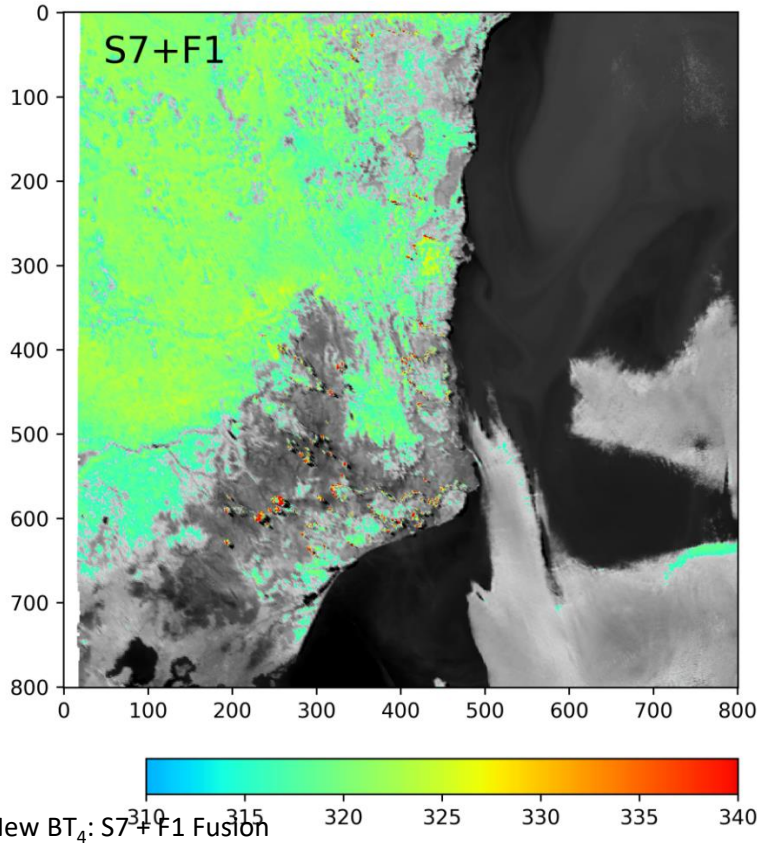
# S3 NTC Daytime Active Fire Detection And FRP Retrieval Algorithm




Half of S7 pixels in this scene in Australia are saturated (BT > 311 K) during the Jan. 2020 extreme temperature & fire season. AF pixels can't be detected using S7.



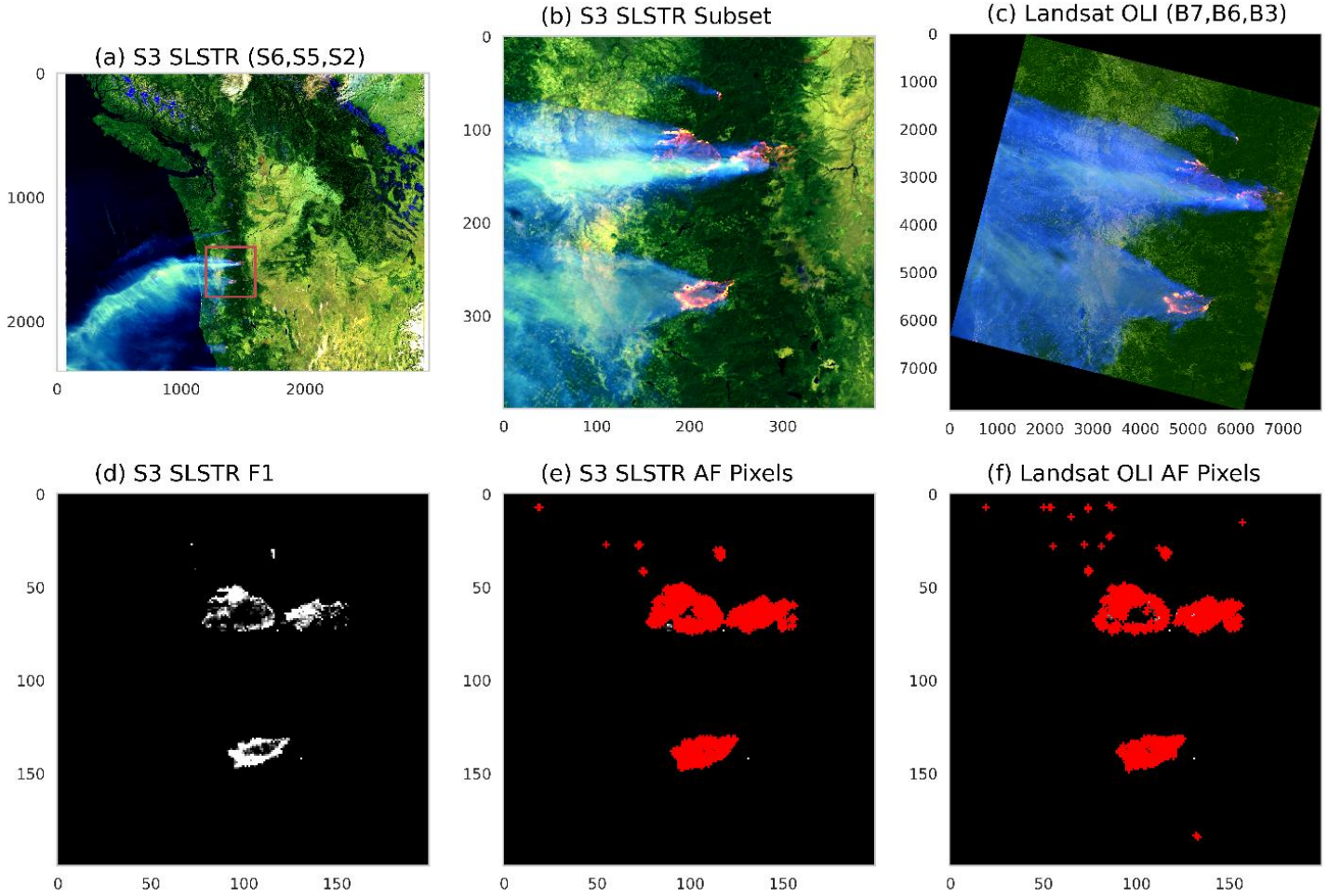

AF pixels are seen on F1, but with a spatial offset to S7 and S8 and a down-scan anomaly (lowered BTs) on F1.




New $BT_4$: S7 + F1 Fusion
(Background BT from S7, Fire BT from F1):

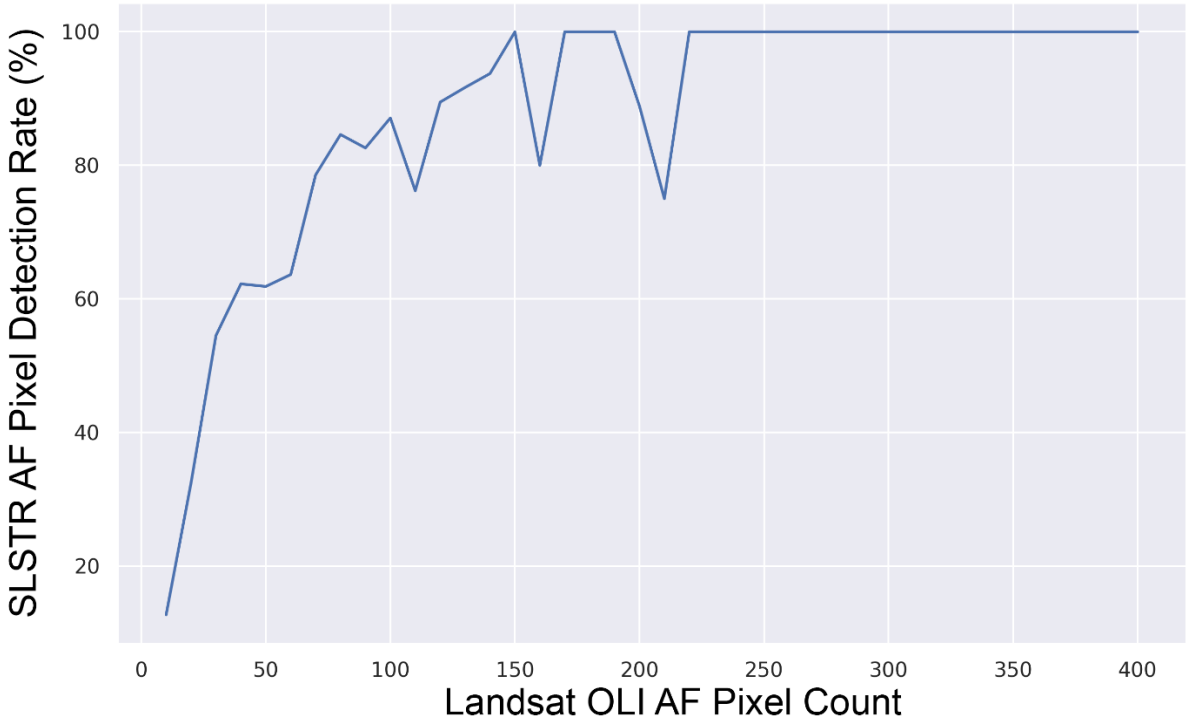
1. S7: S7 < 311 K (Gray)
2. F1: S7 > 311 K (Colour)
    1. plus 11×11 surrounding window S7 > 300K
    2. Exclude background F1 downscan anomaly

# Validation of SLSTR NTC Daytime Active Fire Detection with Landsat OLI




- (a). SLSTR colour composite with S6,S5 and S2 bands.
- (b). 200 KM by 200 KM SLSTR subset image highlighted in the red rectangle in (a).
- (c). Landsat-8 OLI composite with B7, B6 and B3 covered same area as (b).
- (d). SLSTR MIR Brightness Temperature (BT) image calculated using F1 channel data, and where higher BT are depicted as brighter pixels.
- (e). Same as (d) but with the SLSTR AF detections overlain with a one pixel offset for clarity.
- (f). the same as (d) but with near-simultaneous OLI AF detections.

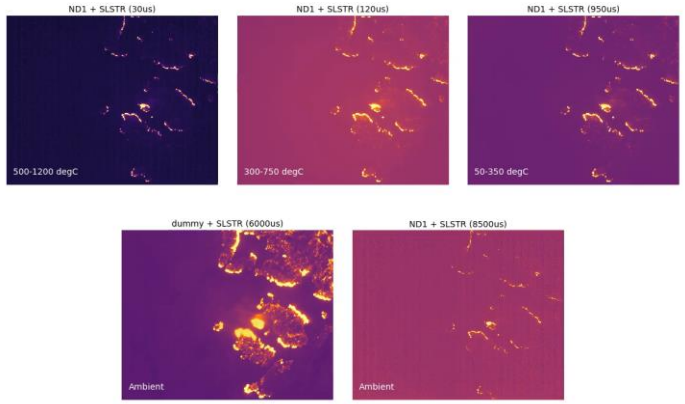
# Validation of SLSTR NTC Daytime Active Fire Detection with Landsat OLI

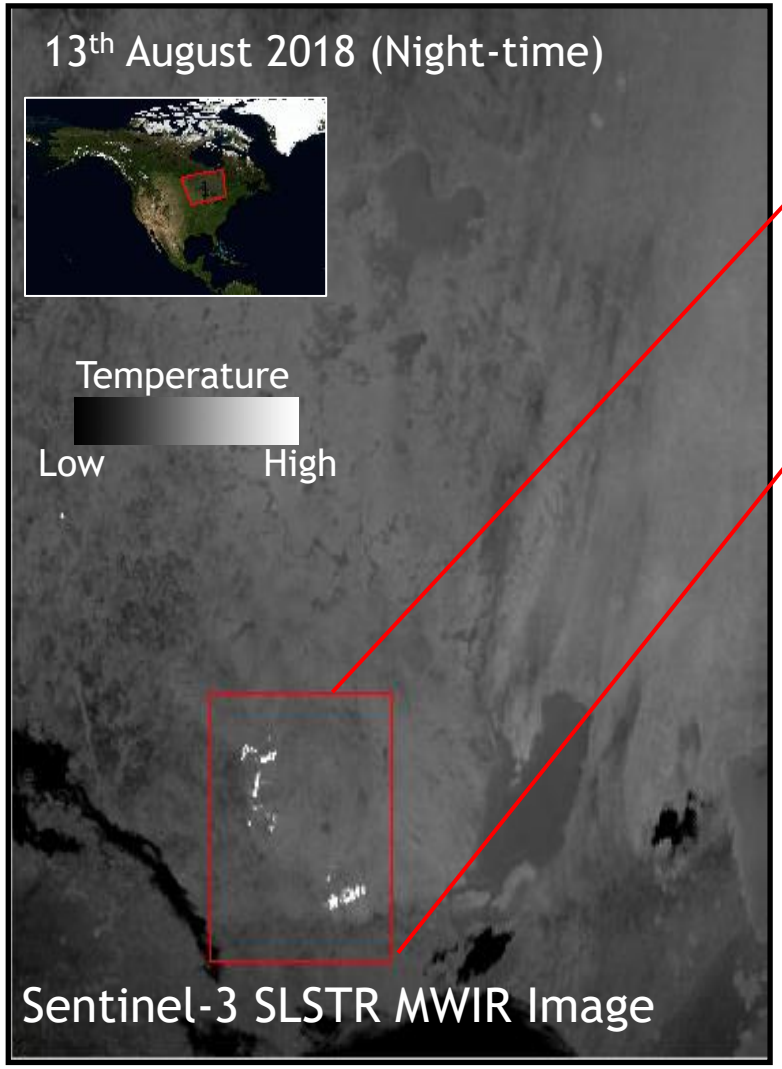


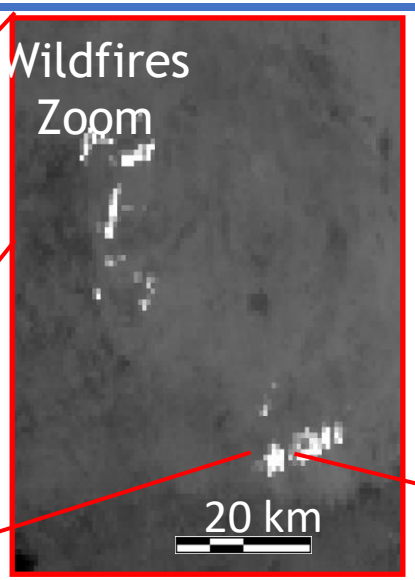

- The SLSTR detection rate starts with ~10% if there are 10 OLI pixels (~1%) in one SLSTR pixel.
- Increases to 60% if 50 pixels in SLSTR pixel (5%) .
- Increases to ~100% if 150 Landsat pixels (15%).
- The False alarm is ~5%.

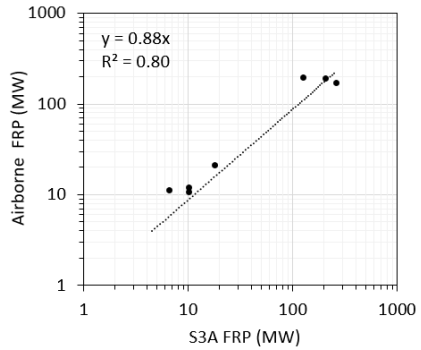
*Note that OLI itself is seeing largely sub-pixel fires.

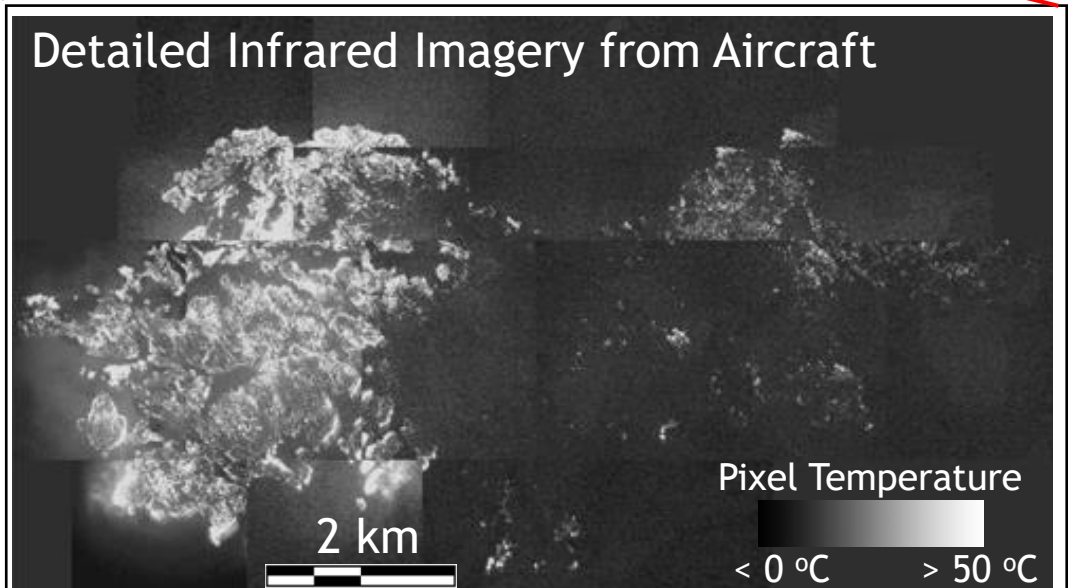
# Sentinel-3 SLSTR Satellite Instrument

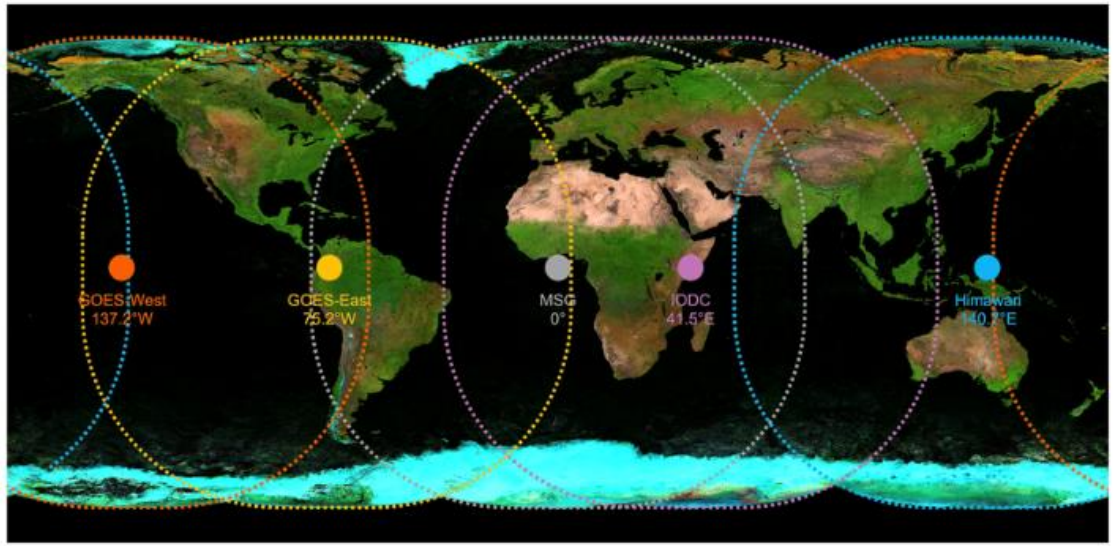



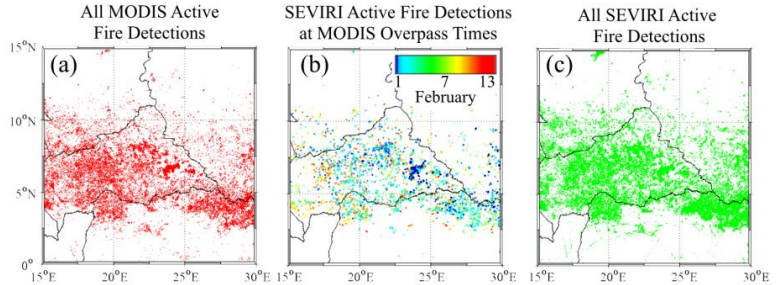



# Geostationary Active Fire & FRP Products

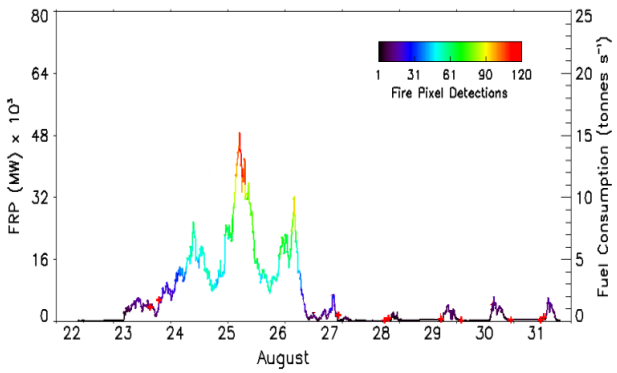
- Five geostationary satellites have their data processed with the same “Fire Thermal Anomaly” [FTA] AF detection and FRP retrieval algorithm originally designed for MSG.
- “FRP-PIXEL” products generated across the full disk, full temporal resolution (10 or 15 mins). Product contains a LIST file (small size) and a QUALITY PRODYCT map (large size).
- Cloud free conditions provide semi-continuous fire observations, though misses the lowest FRP component of a regions fire regime.

## Global Geostationary Five Satellite Network

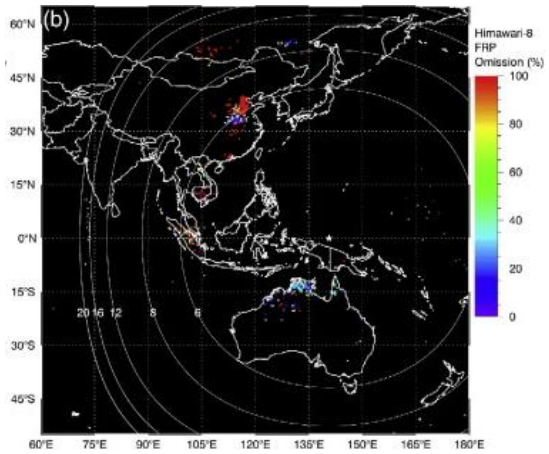



AF pixels across Central Africa in February 2004 from (a) MODIS, (b) MSG SEVIRI at same time as MODIS, and (c) all SEVIRI data. In (b), the detected active fire pixels are coloured by day of detection.




Example of MSG-derived FRP time-series of Greek fire burning severely four days and then continuing in a deduced manner for another four. Coloured by the number of AF pixel detections making up the fire. The equivalent fuel consumption is shown on the rhs y-axis.




% of FRP missed by Himawari compared to MODIS due to the non-detection of low FRP active fire pixels. Calculated at 0.5 degree grid cell resolution. Higher % missed in China due to higher latitude (larger pixels) and typically small agricultural fires (low FRP).

Geostationary FRP Access:
https://landsaf.ipma.pt/en/
or email
martin.wooster:@kcl.ac.uk

**Further information:**

https://landsaf.ipma.pt/en/products/fire-products/frppixel/


Wooster, M.J., Roberts, et al (2015). Meteosat SEVIRI Fire Radiative Power (FRP) products from the LSA SAF - Part 1. *Atm Chem Phys*, *15*(22), pp.13217-13239

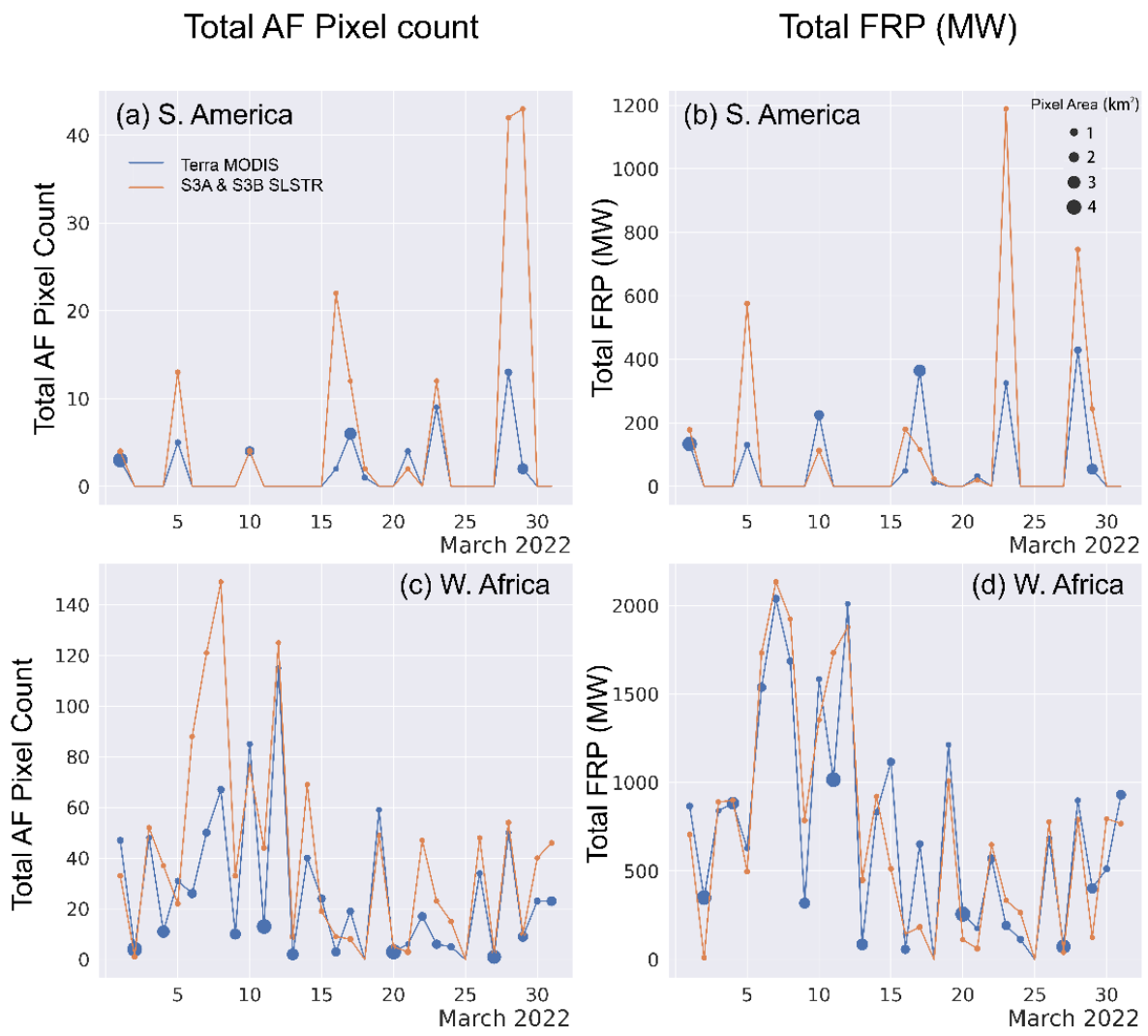
Roberts, G., Wooster, M.J. (2015). LSA SAF Meteosat FRP products–Part 2:. *Atm Chem Phys*, *15*(22), pp.13241-13267.

Xu, W., Wooster, M.J. et al (2021) Improvements in high-temporal resolution active fire detection and FRP retrieval over the Americas using GOES-16 ABI with the geostationary Fire Thermal Anomaly (FTA) algorithm. *Science of Remote Sens*, *3*, p.100016.

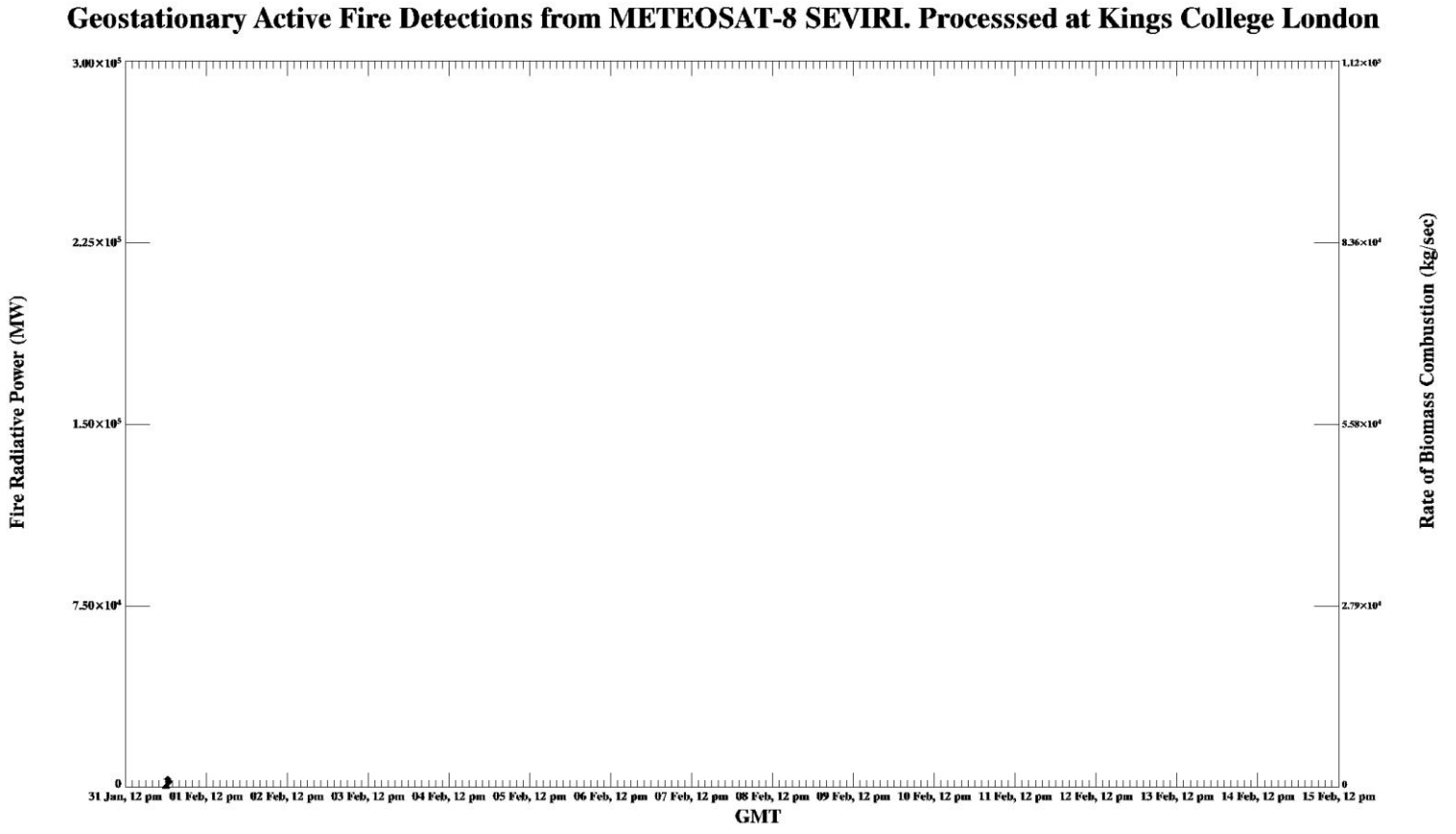
Xu, W., Wooster, M.J. et al (2017). Major advances in geostationary fire radiative power (FRP) retrieval over Asia and Australia stemming from use of Himarawi-8 AHI. *Remote Sens Environ*, *193*, pp.138-149.

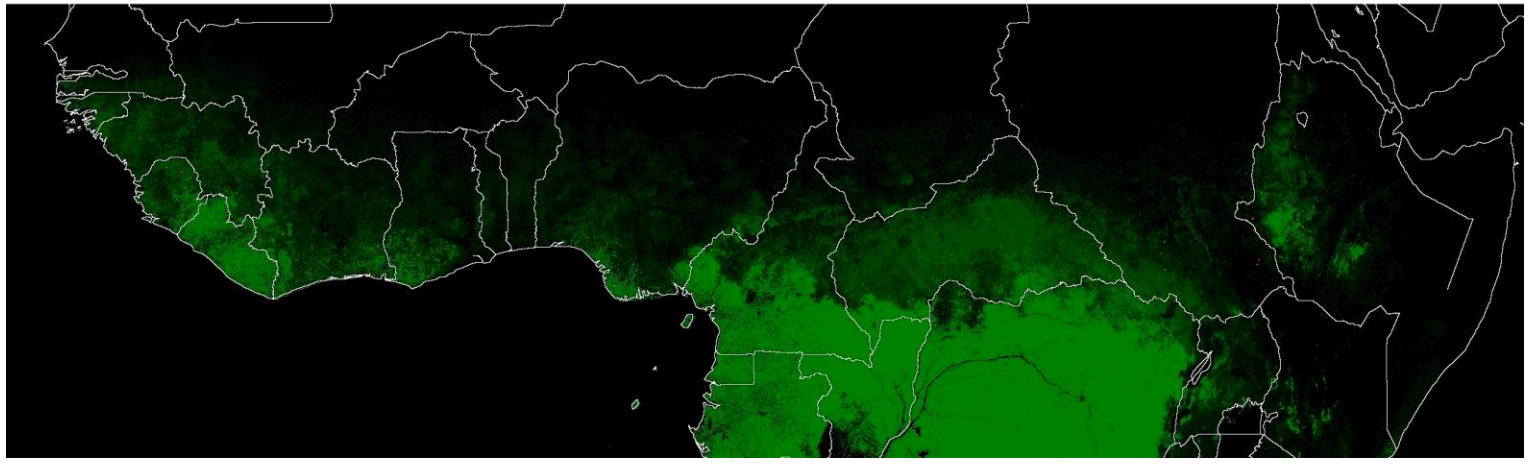
# S3 SLSTR NTC Daytime AF & FRP Time Series

- Time series of active fire (AF) counts and FRP retrievals from S3A & S3B and MODIS Terra.
- S3 has a similar fire pattern (fire count and FRP) with MODIS Terra.
- The time series pattern of other regions like East Africa and Asia also look similar between SLSTR and MODIS.

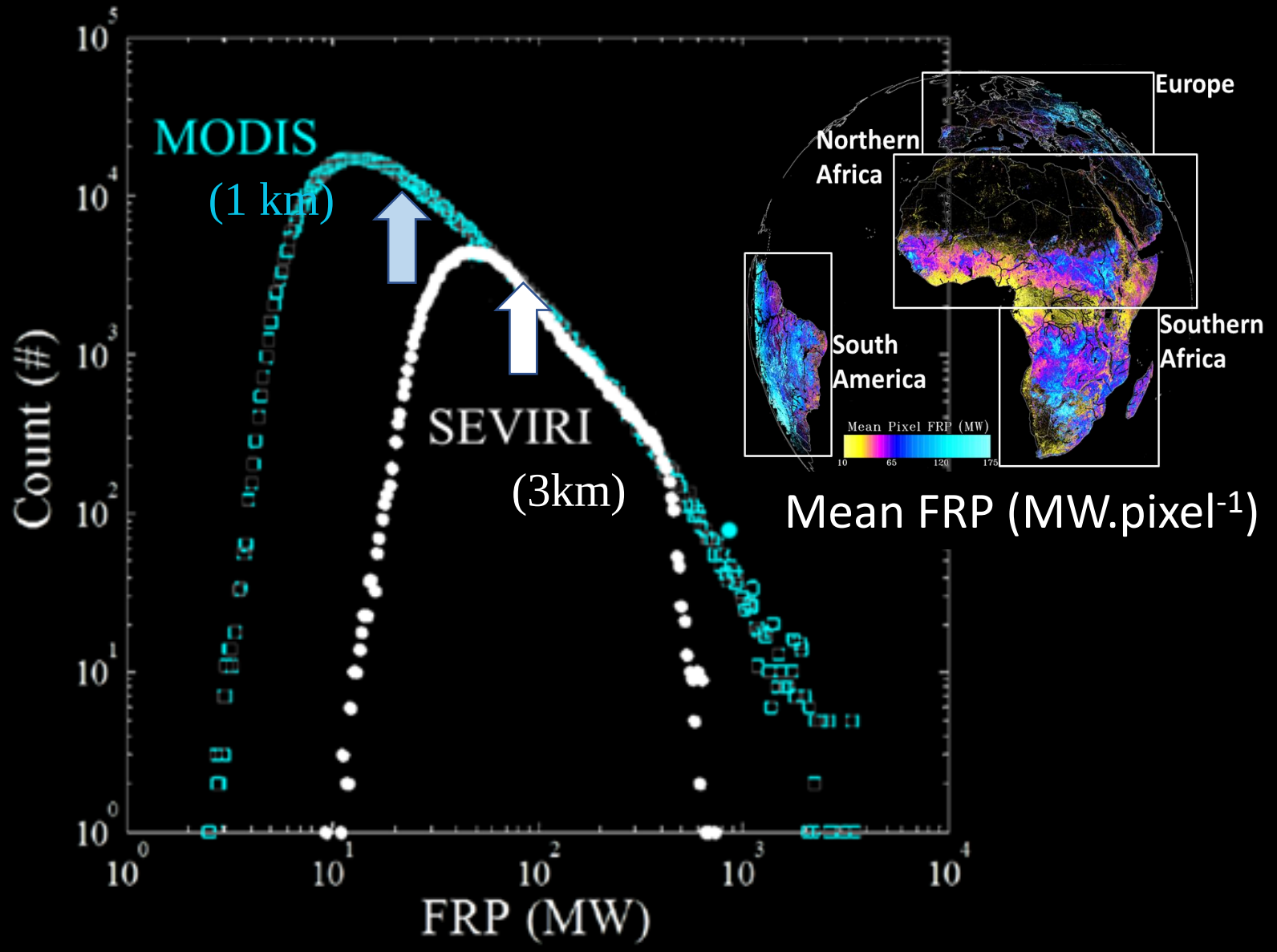


# Geostationary FRP Observations

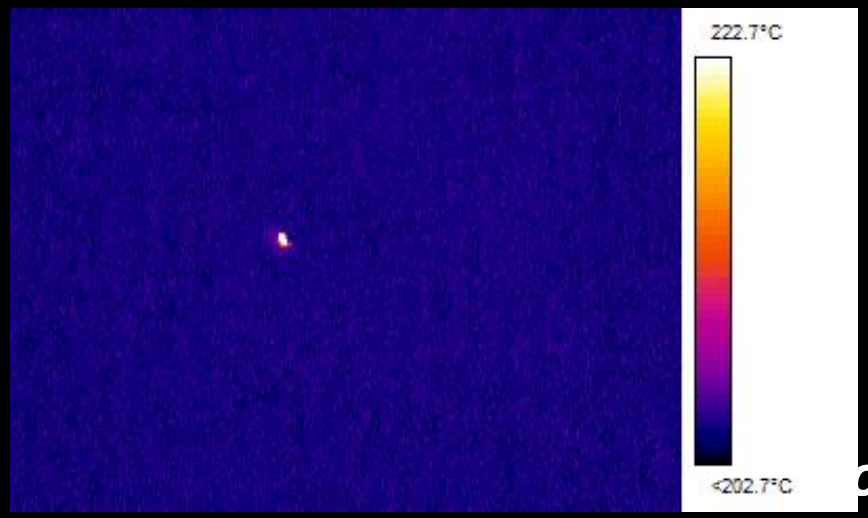


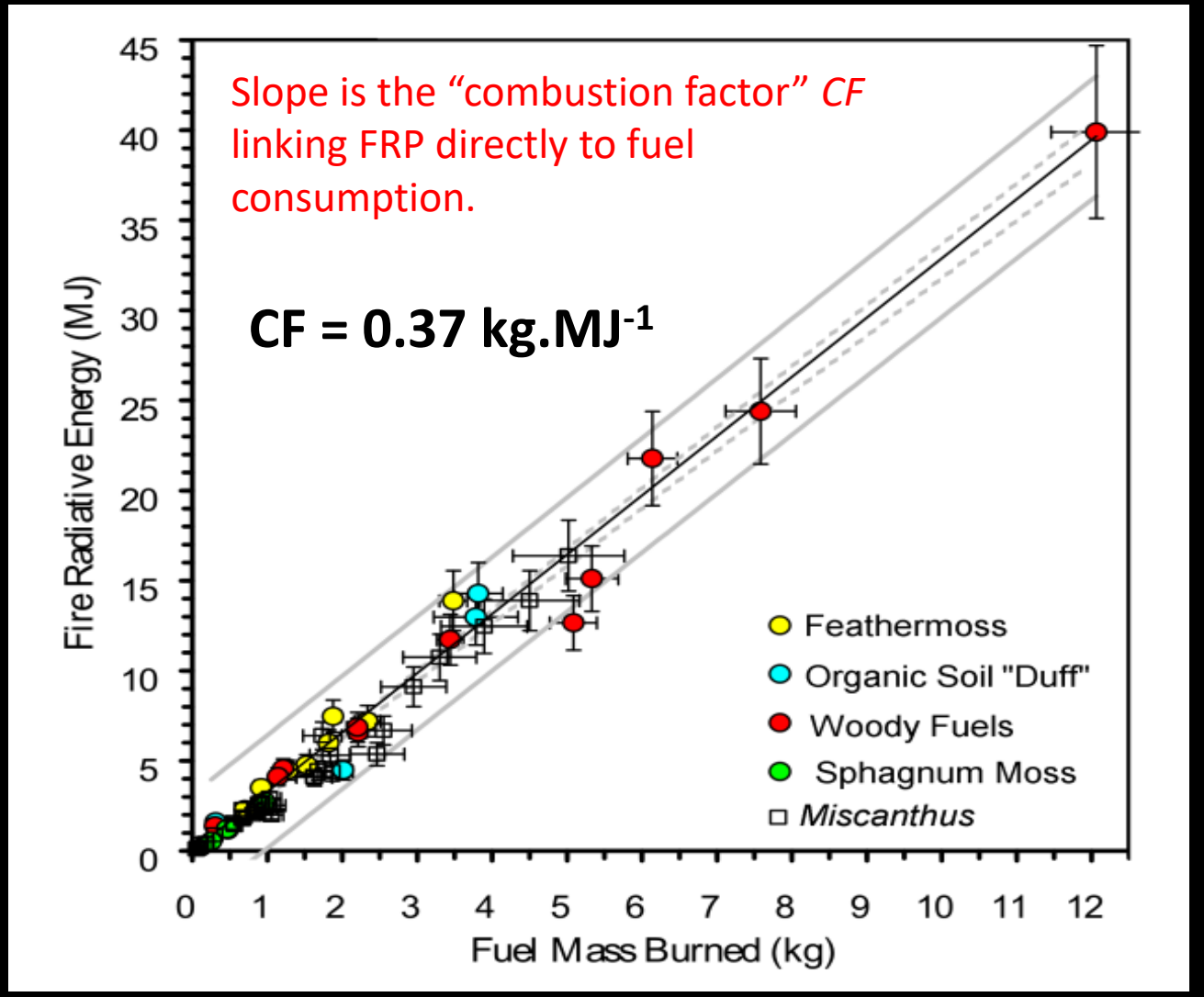



# But - Geostationary Data Tend to Miss low FRP Fires



# Relationship Between Fire Radiative Energy & Fuel Consumption




***onsumption = Σ FRP × CF*** → **Theoretically ~ constant**

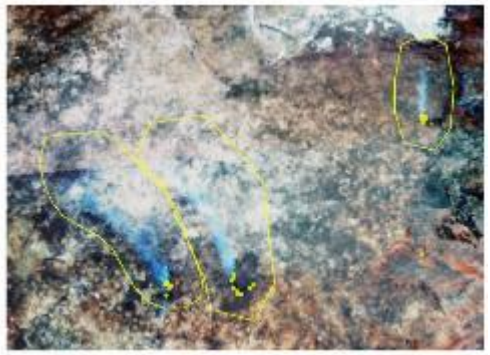
# Geostationary FRP & Sentinel-5P CO Complementarity

Fire emissions are derived from coefficients linking geostatoinary Fire Radiative Energy (FRE) totals to atmospheric species (CO) in different biomes.

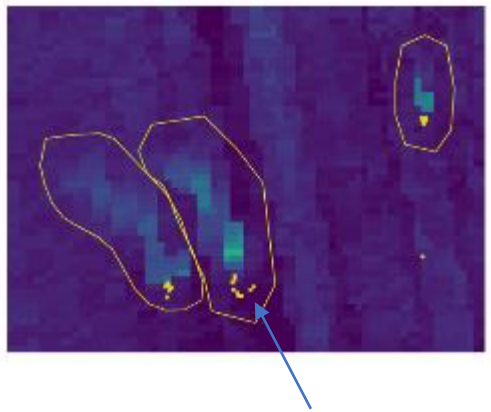
- Applied to Meteosat FRP record (2004-2019) across whole Africa (NH and SH)
- CO emissions very close to GFED4.1s - derived using completely different datasets and methods

## Example for Three Fires

VIIRS RGB Image showing plumes

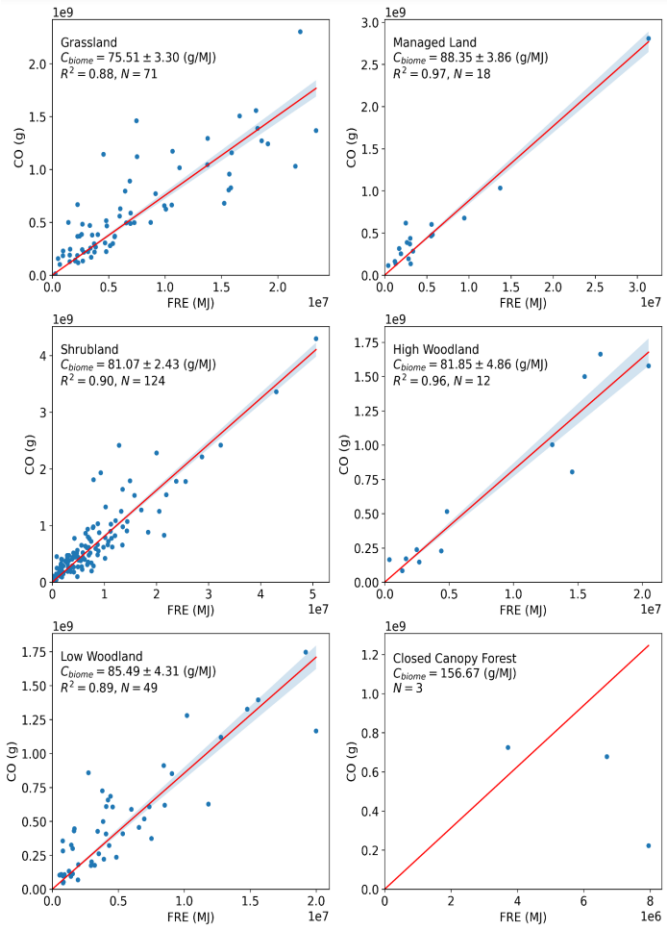


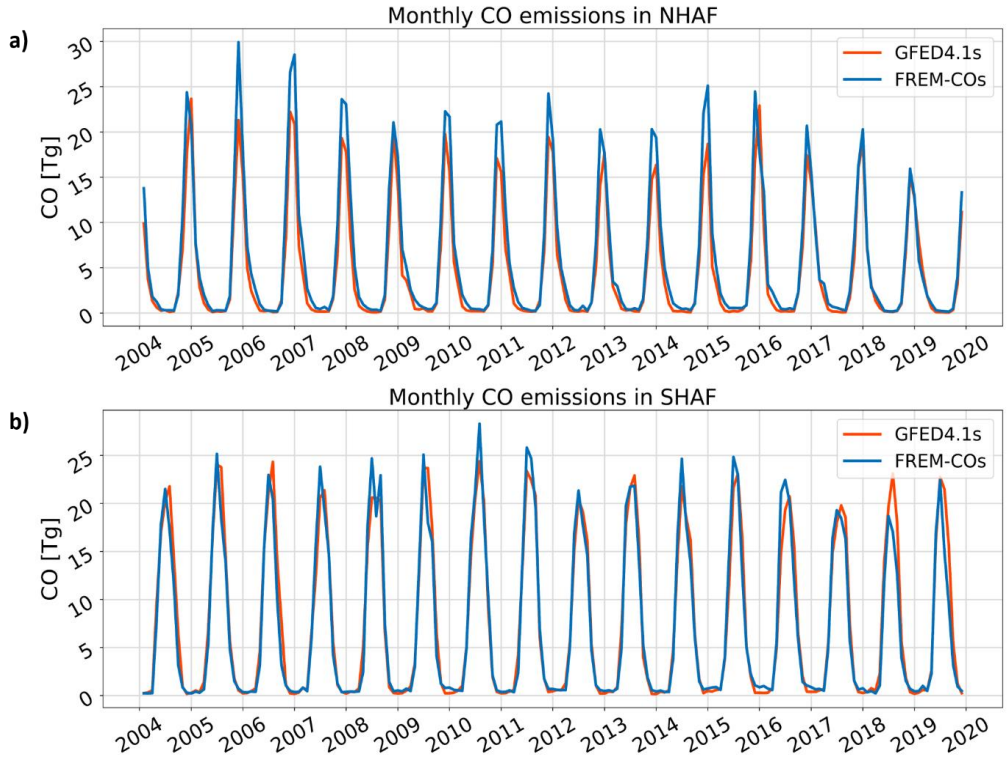
Sentinel-5P Total Column CO



Meteosat Active Fire pixels from which FRE is derived

## Coeffs for Six different "fire biomes"



# Geostationary FRP & Sentinel-5P CO Complementarity