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National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Centre for Wildfires, Environment and Society

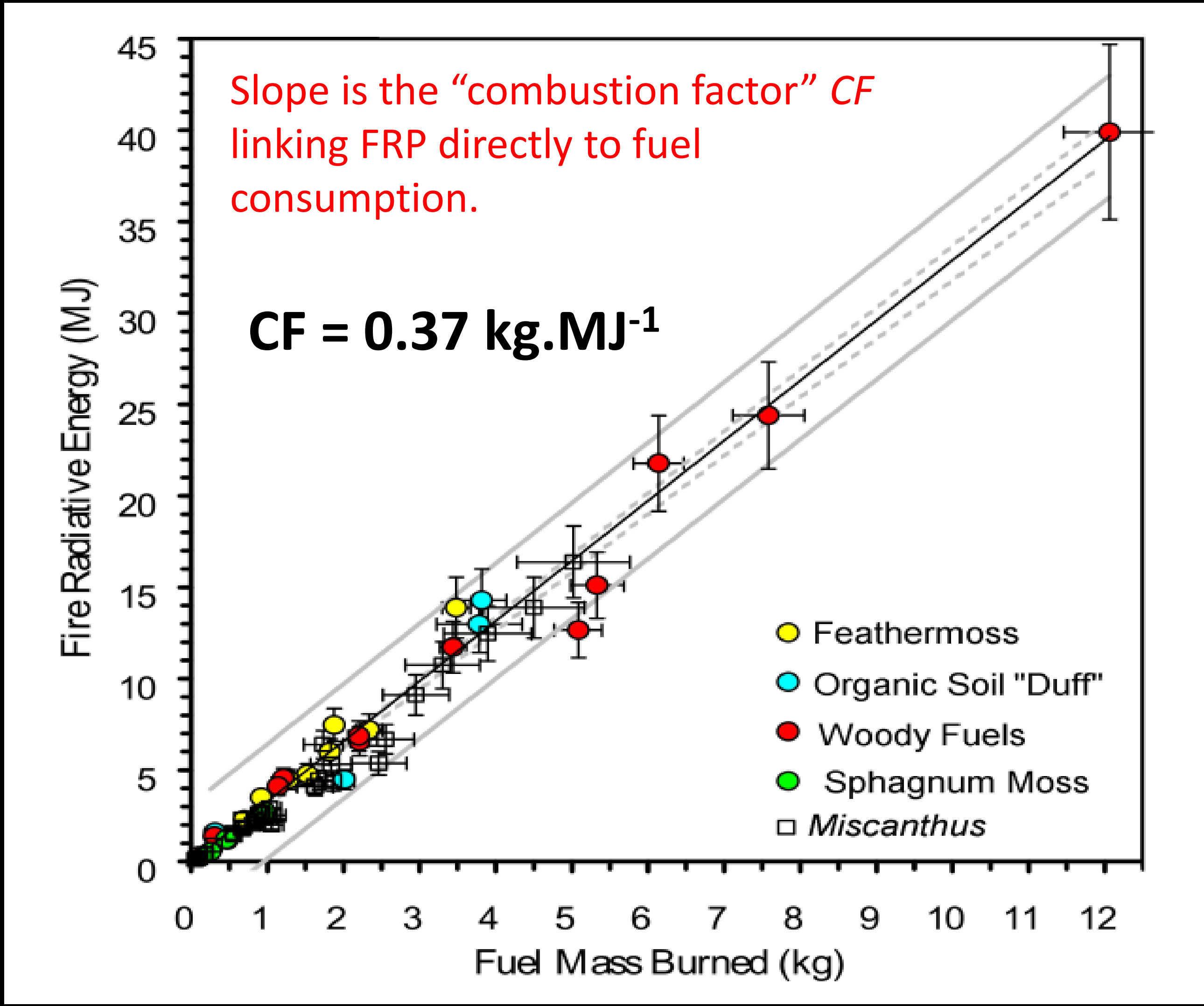
# New AF Developments of European Satellites

Wooster, M., Xu, W., Nguyen, H., He, J., Roberts, G., Johnston, J., Strydome, T.,

# Structure

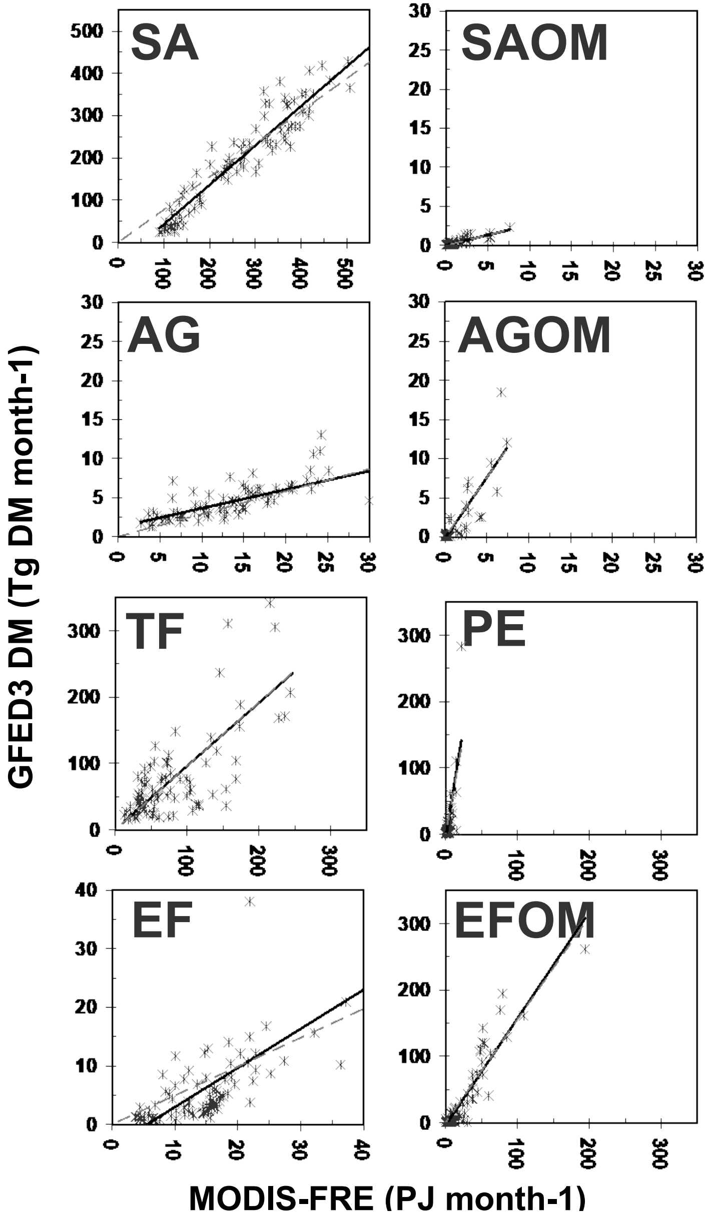
- Fire Radiative Energy eMissions (FREM) Products from Geostationary Satellites
- Sentinel-3 Polar Orbiting SLSTR Active Fire and FRP Products

# Fire Radiative Energy & Fuel Consumption

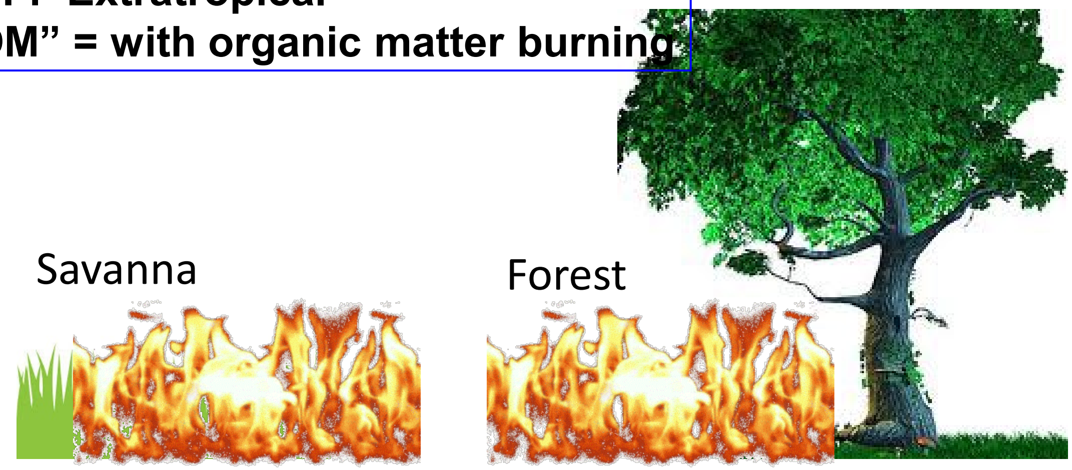



***Fuel Consumption = ΣFRP × CF*** → **Theoretically ~ constant**

# GFAS MODIS-estimated FRE to GFED3.1 Fuel Consumption




**SA: Savanna AG: Agricultural**
**DF: Tropical PE: Peat**
**EF: Extratropical**
**"OM" = with organic matter burning**



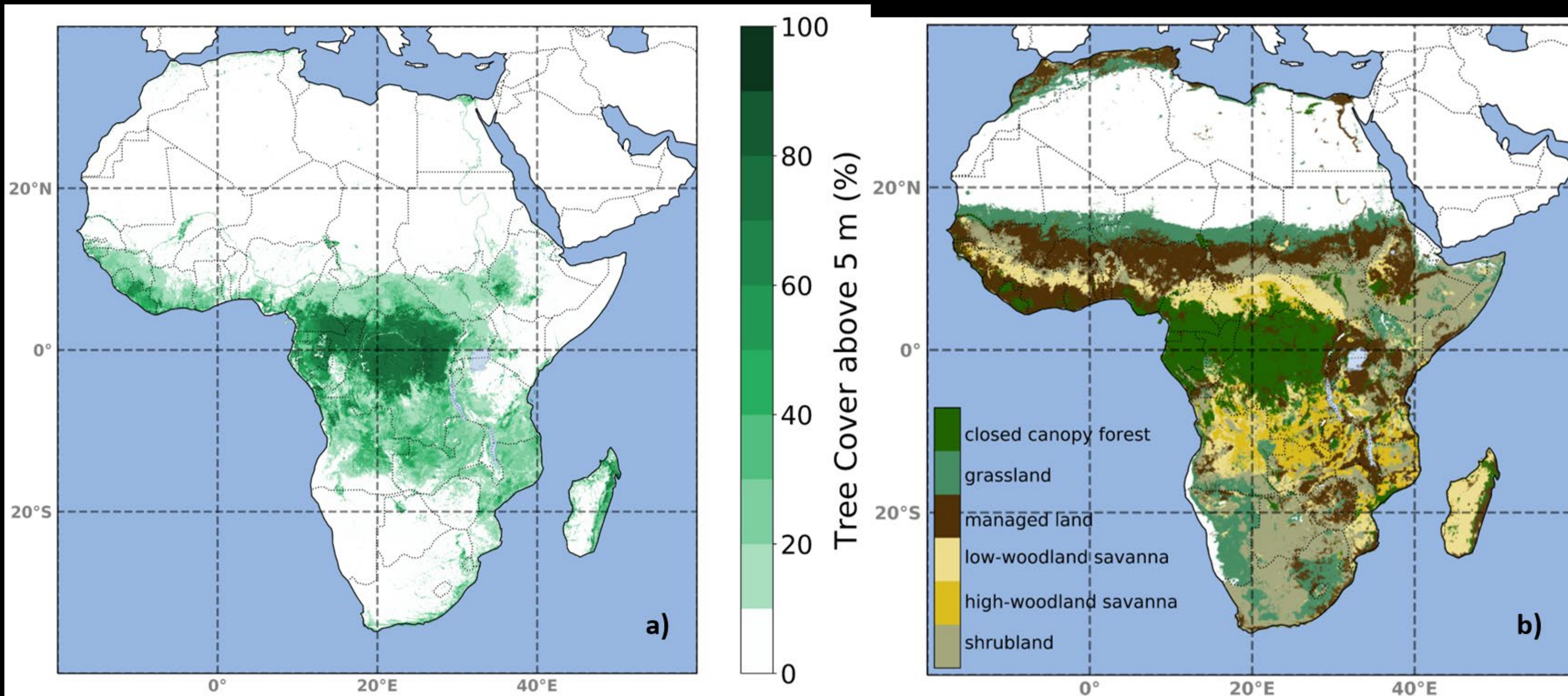

Derivation of conversion factors (CF) from linearly regressing monthly GFED3.1 DM with GFAS1.0 FRE

| | Predominant Fuel Class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Linear Regres.** | **SA** | **AG** | **DF** | **EF** | **SAOM** | **AGOM** | **PEAT** | **EFOM** | **ALL** |
| **$R^2$** | 86% | 58% | 55% | 50% | 77% | 54% | 57% | 86% | 74% |
| **Slope [g $kJ^{-1}$]** | **0.78** | **0.29** | **0.96** | **0.49** | **0.26** | **0.13** | **5.87** | **1.55** | **0.85** |

**$Cf_{small\ scale} = 0.37\ g\ kJ^{-1}$**

Kaiser et al. (2012) *Biogeosciences*

# "Fire Radiative Energy eMissions" [FREM] Approach – "Fire Biome Map"

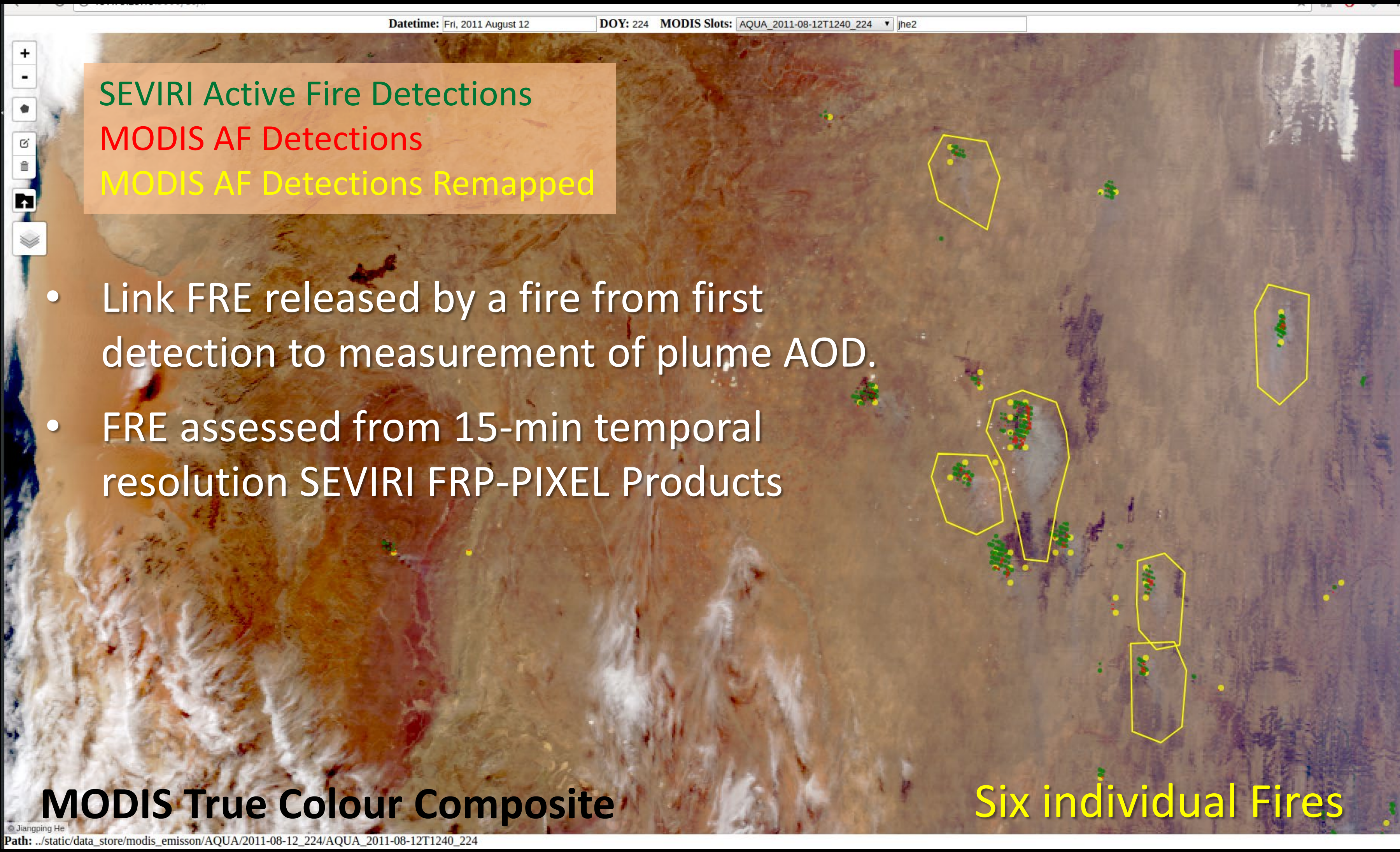



% tree cover > 5 m tall using 30 m Landsat 2015 Vegetation Continuous fields (VCF) product.

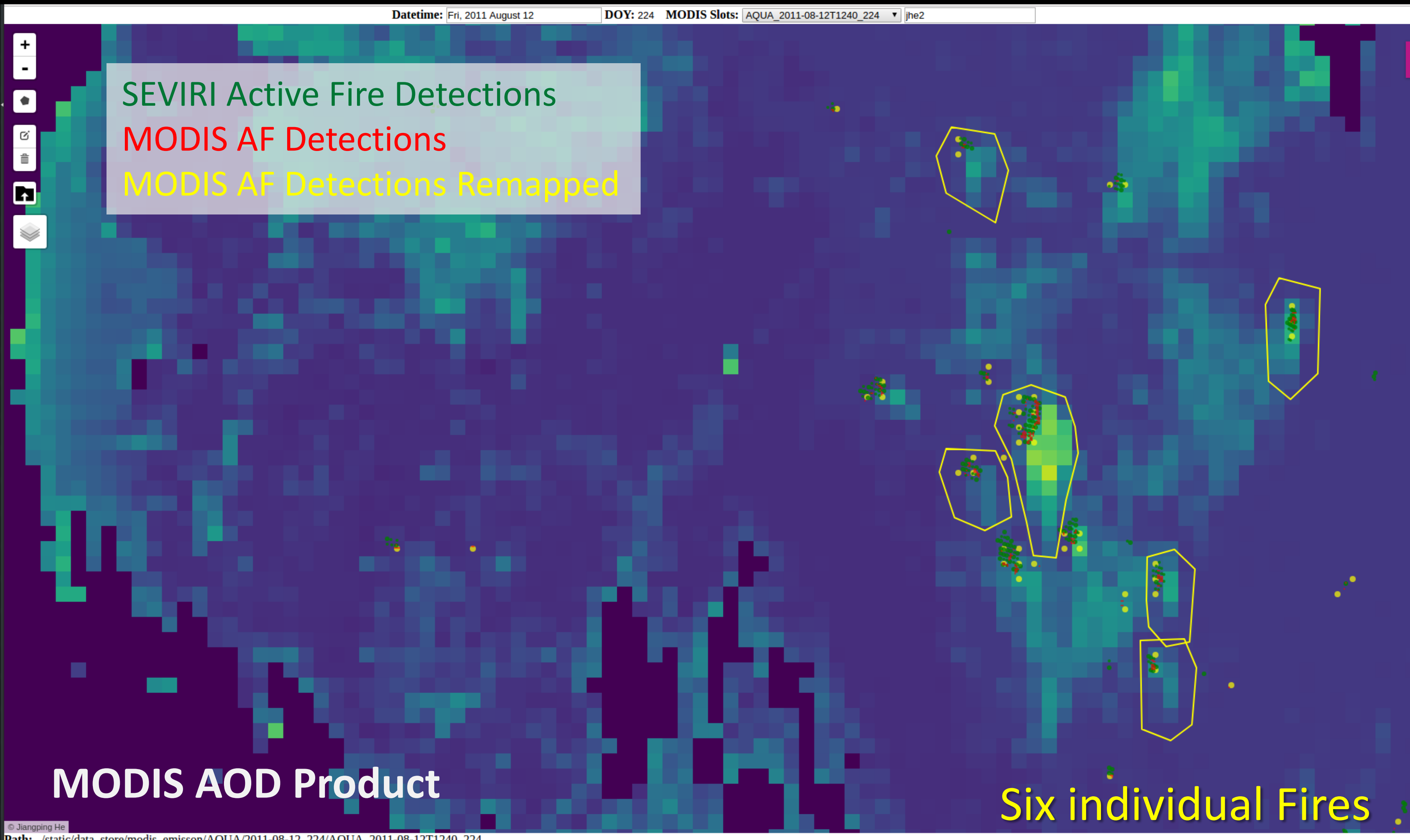
FREMv2 African biome map using 300 m ESA CCI Landcover map (2015). Two woodland savanna biomes were separated into low and high % tree cover using the VCF product.

# Smoke Plume Delineation

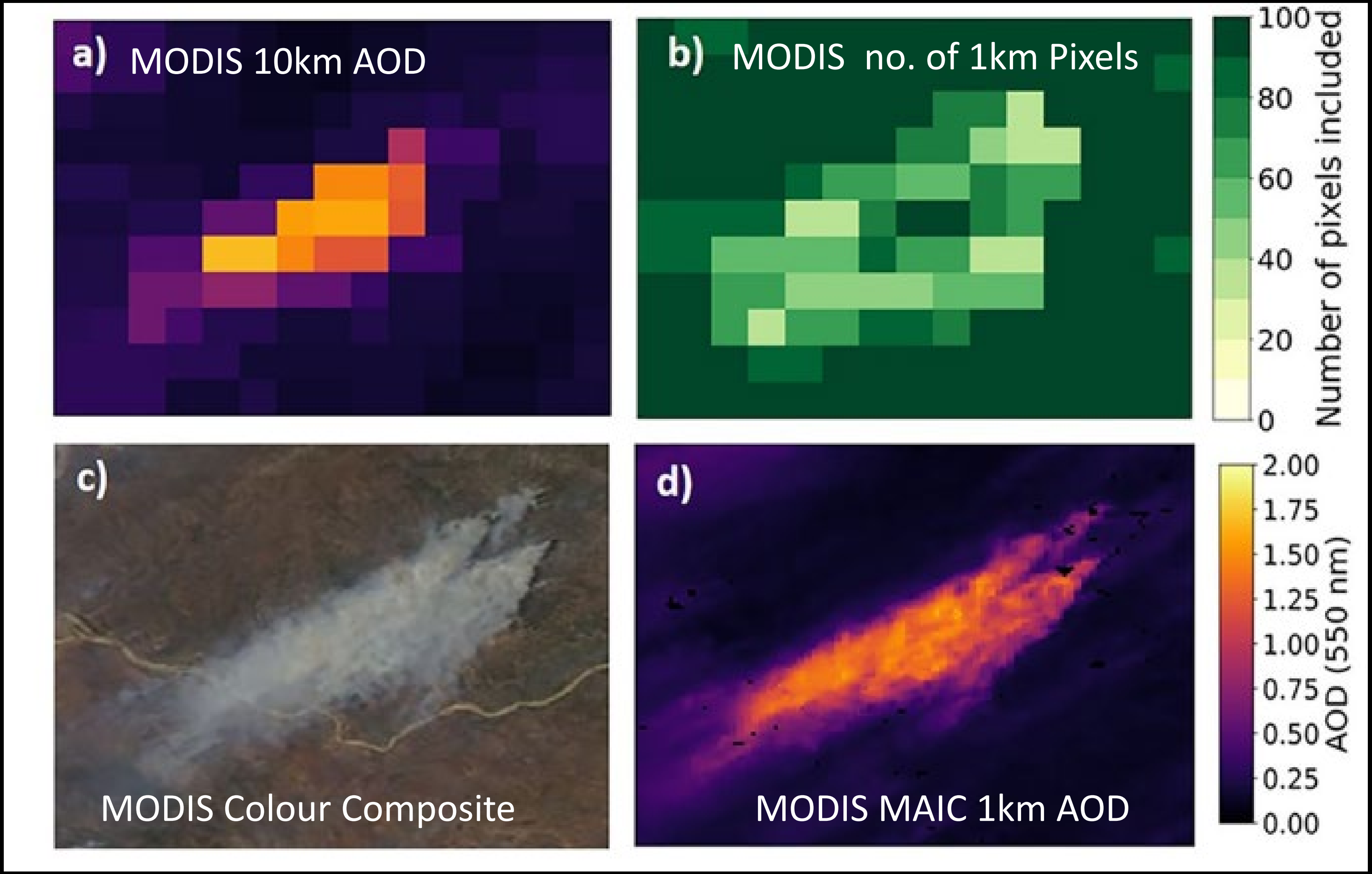
- Link FRE released by a fire from first detection to measurement of plume AOD.
- FRE assessed from 15-min temporal resolution SEVIRI FRP-PIXEL Products



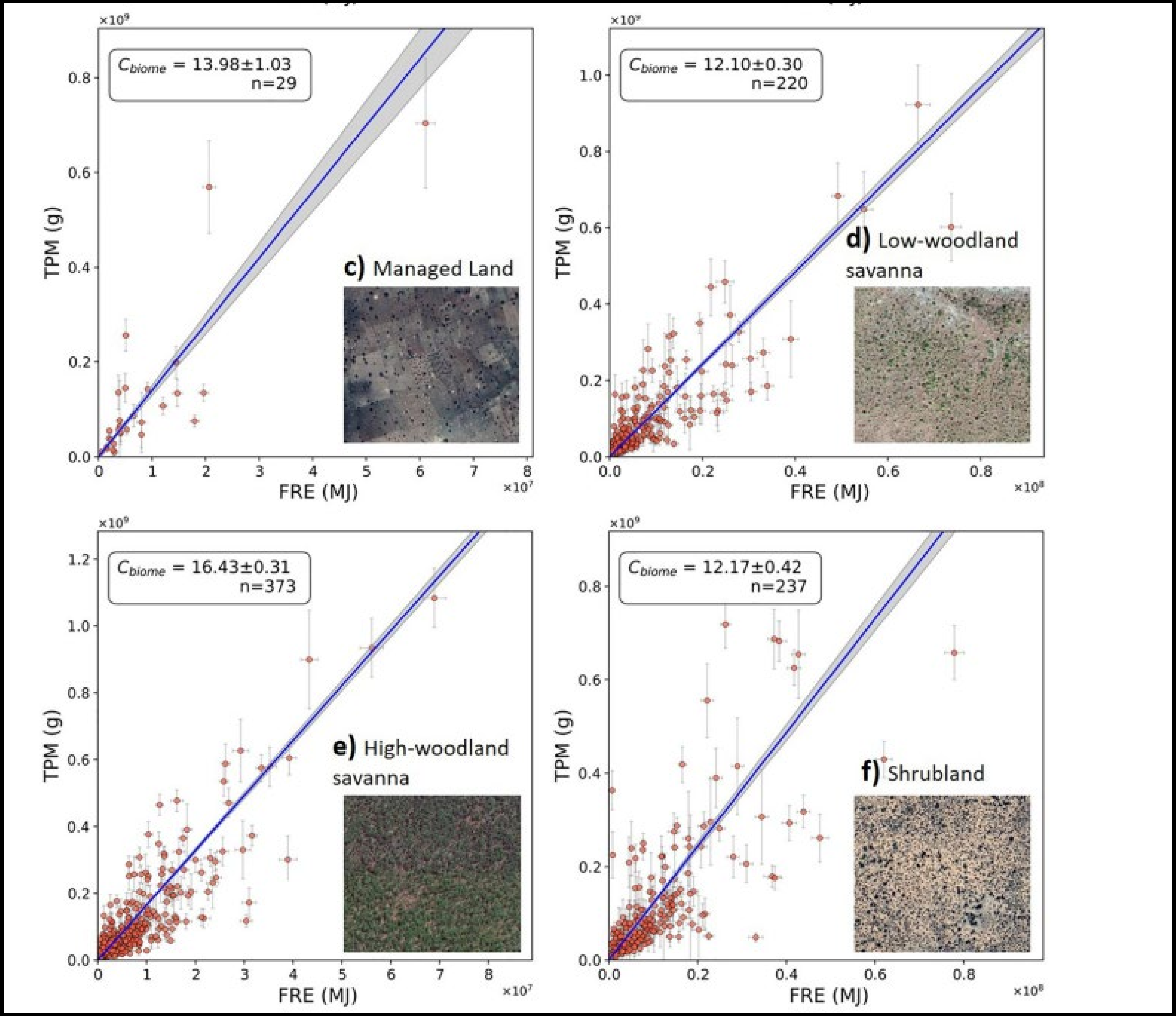
# Smoke Plume Delineation



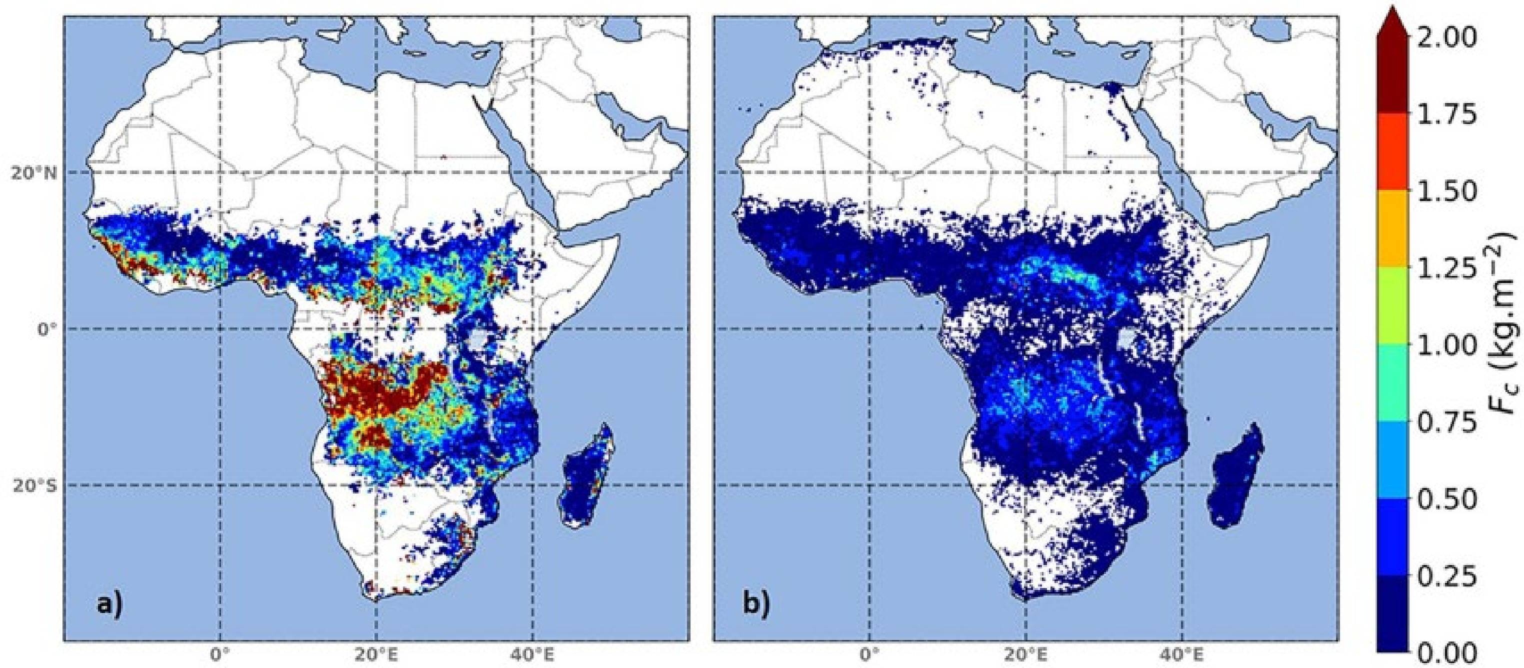
# New Developments in FREMv2

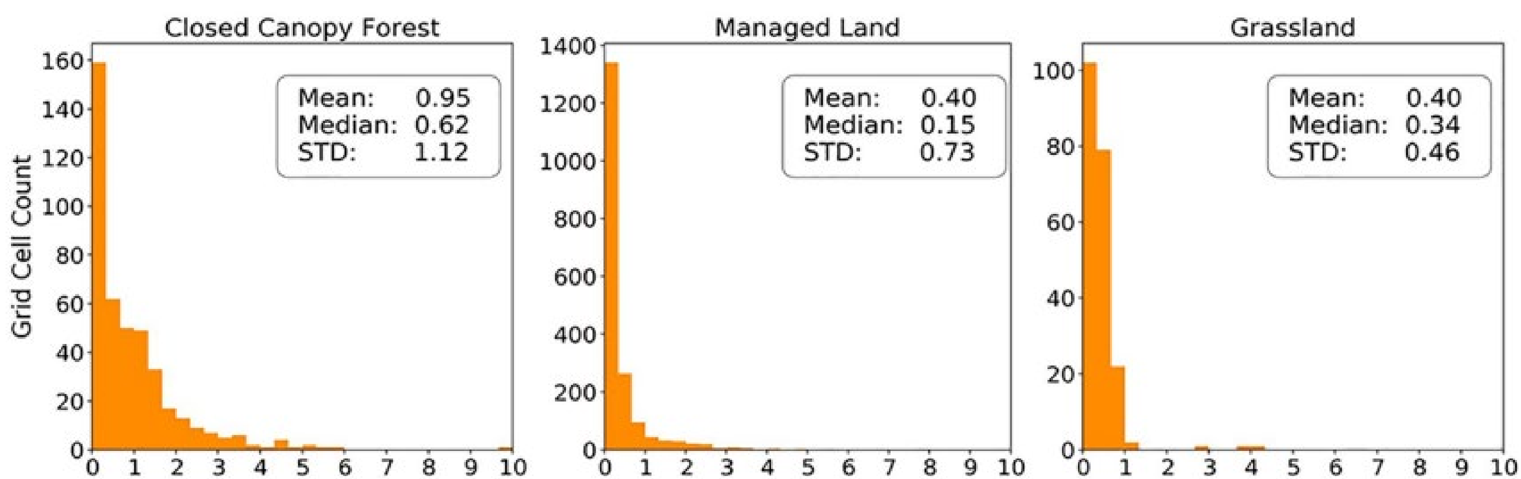


# Coefficient Derivation



# Fuel Consumption Per $m^2$ of Burned Area



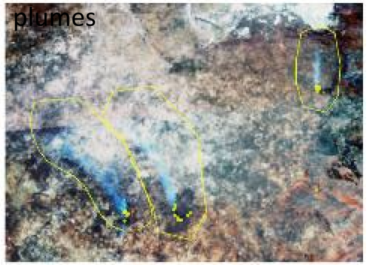



# Extension to use Trace Gas Observations from S5P

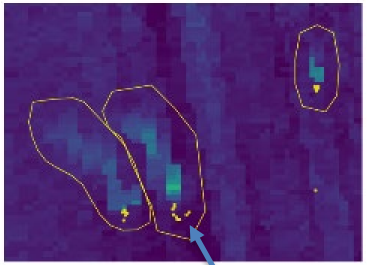
Emissions are derived from coefficients linking Meteosat-derived Fire Radiative Energy (FRE) totals to atmospheric species (CO) for different biomes - Nguyen et al. (*ACPD*)

**Example for Three Fires**

VIIRS RGB Image showing plumes

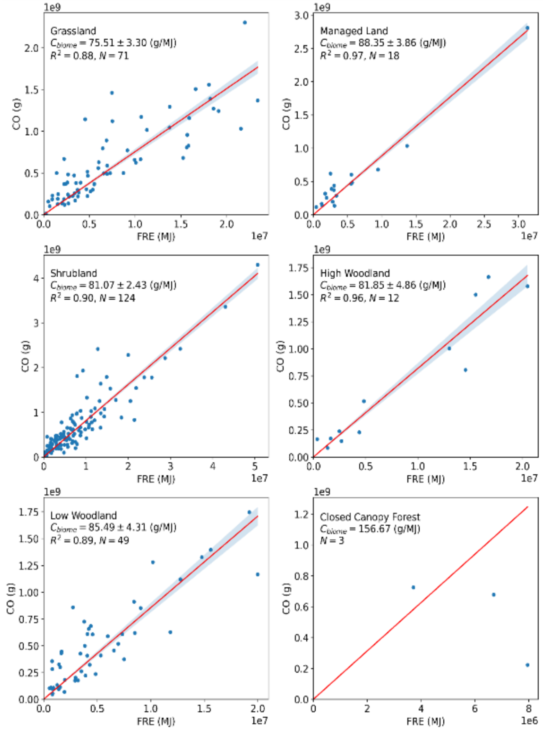


Sentinel-5P Total Column CO

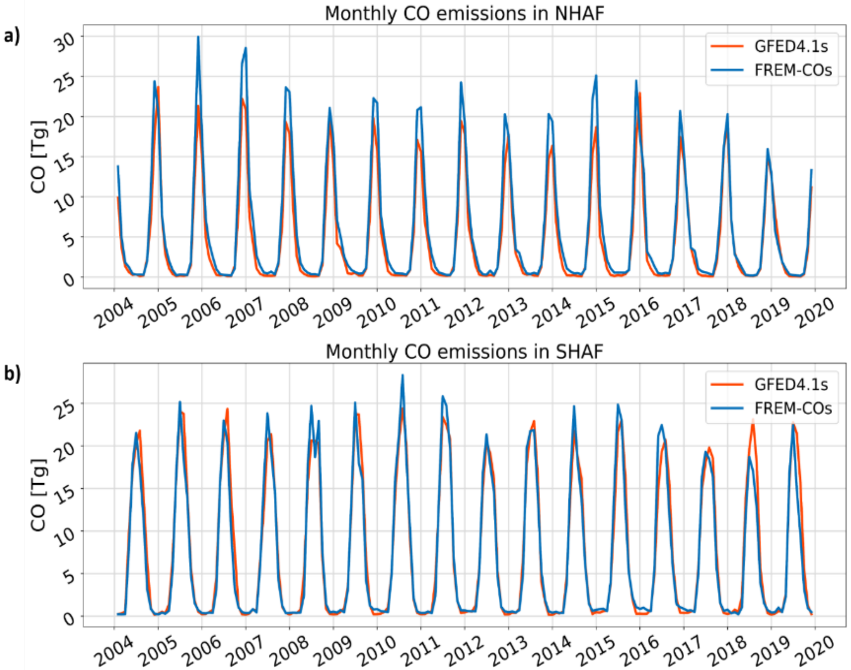


Meteosat Active Fire pixels from which FRE is derived

**Coeffs for Six different "fire biomes"**

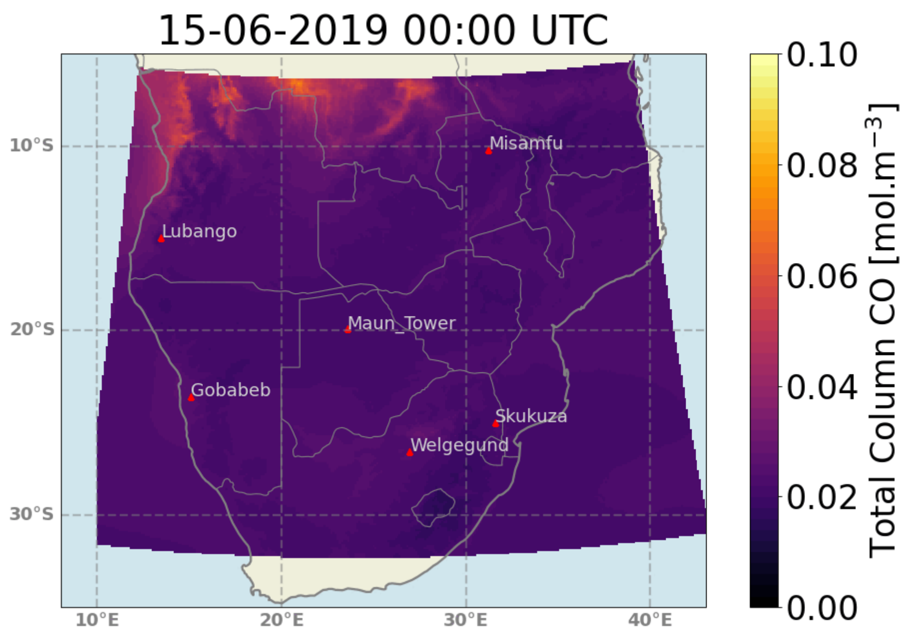


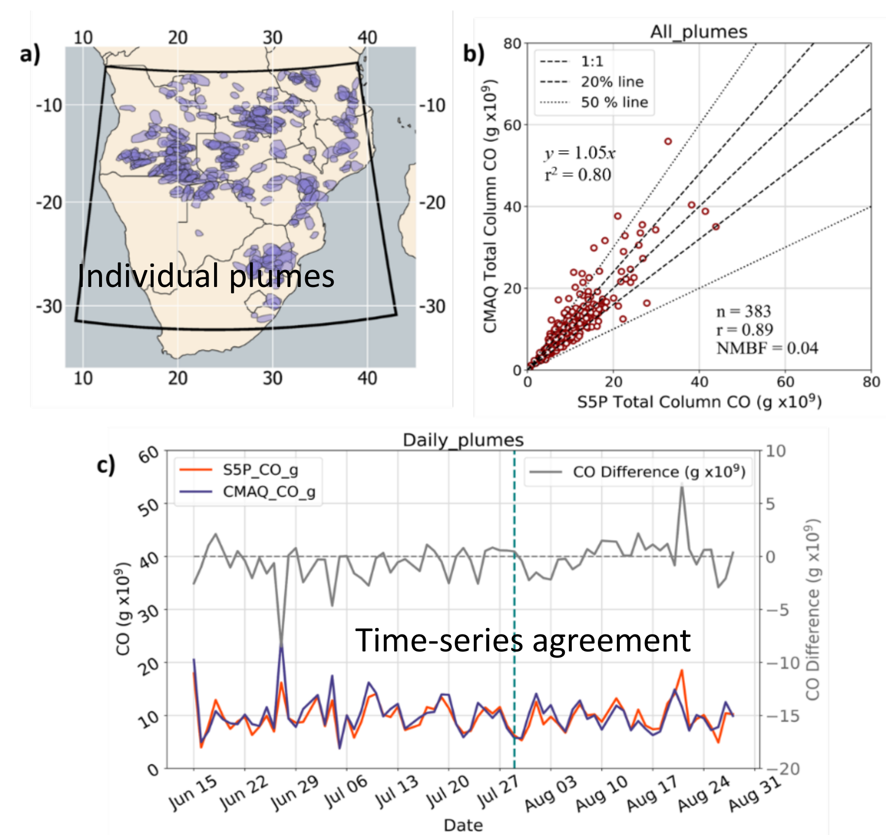

- Applied to LSA SAF FRP-PIXEL record (2004-2019) across whole Africa (NH and SH)
- CO emissions very close to GFED4.1s - derived using completely different datasets and methods



# Meteosat / S5P Fire Emissions Product Evaluation

Emissions validation using emissions + WRF-CMAQ compared to independent Sentinel-5P CO observations




Any other species, $x$, can be estimated via emission factor ratios:

$$C_e^x\,[g.MJ^{-1}] = \frac{EF_x\,[g.kg^{-1}]}{EF_{reference}\,[g.kg^{-1}]} \cdot C_e^{reference}\,[g.MJ^{-1}]$$

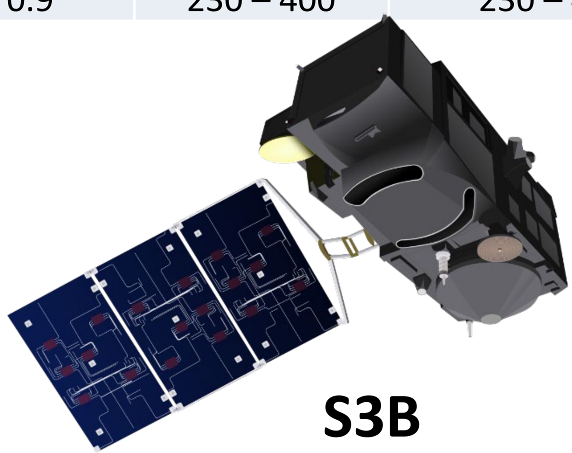
***Where reference species is CO***

# Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR)

| SLSTR Channel | Band center (µm) | Bandwidth (µm) | Albedo range (%) | Reference albedo (%) | SNR at reference |
|---|---|---|---|---|---|
| **S1** | 0.555 | 0.020 | 0 – 100 | 0.5 – 30 | 25 – 570 |
| **S2** | 0.659 | 0.020 | 0 – 100 | 0.5 – 30 | 25 – 570 |
| **S3** | 0.865 | 0.020 | 0 – 100 | 0.5 – 30 | 21 – 630 |
| **S4** | 1.375 | 0.015 | 0 – 100 | 0.5 – 5 | 25 – 162 |
| **S5** | 1.610 | 0.060 | 0 – 100 | 0.5 – 50 | 37 – 900 |
| **S6** | 2.250 | 0.050 | 0 – 100 | 0.5 – 4 | 27 – 142 |
| | | | **BT range (K)** | **Reference BT (K)** | **NEdT at reference (mK)** |
| **S7** | 3.74 | 0.38 | 200 – 311 | 270 | 56 |
| **S8** | 10.85 | 0.9 | 200 – 321 | 270 | 29 |
| **S9** | 12 | 1.0 | 200 – 318 | 270 | 21 |
| **F1** | 3.74 | 0.38 | 285 – 450 | 285 – 450 | 680 – 16 |
| **F2** | 10.85 | 0.9 | 230 – 400 | 230 – 400 | 79 – 35 |

Non-aligned

**S3A**

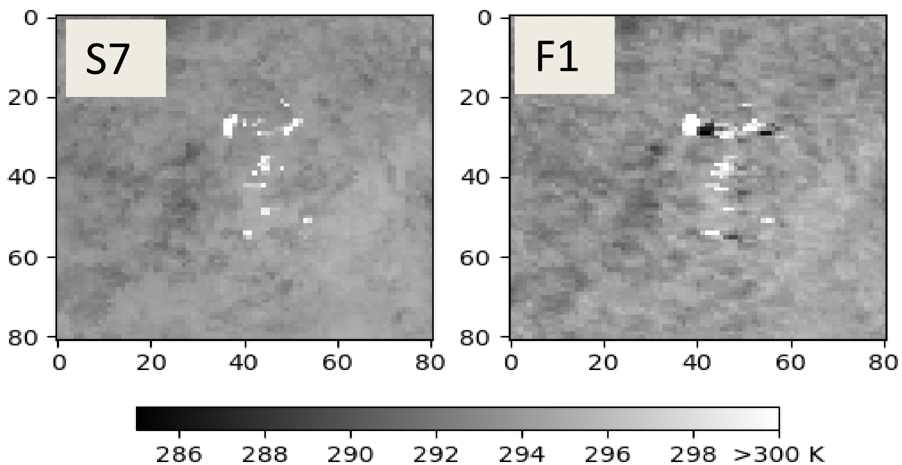


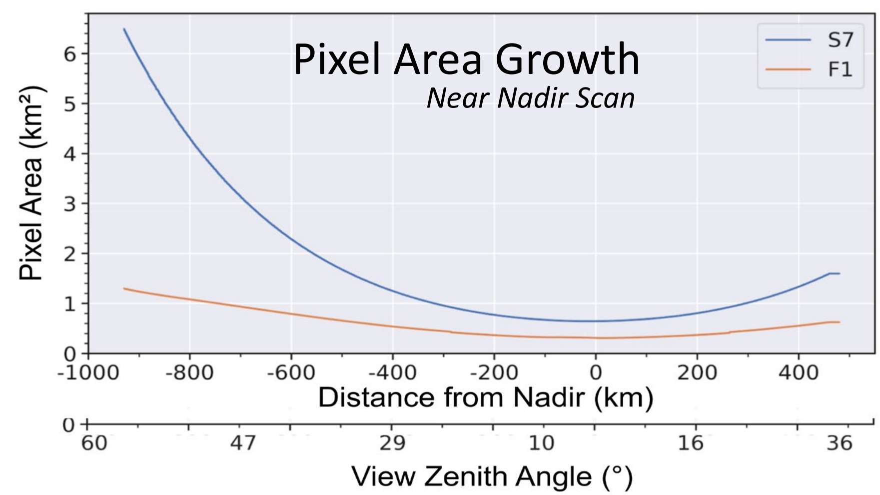
**S3B**

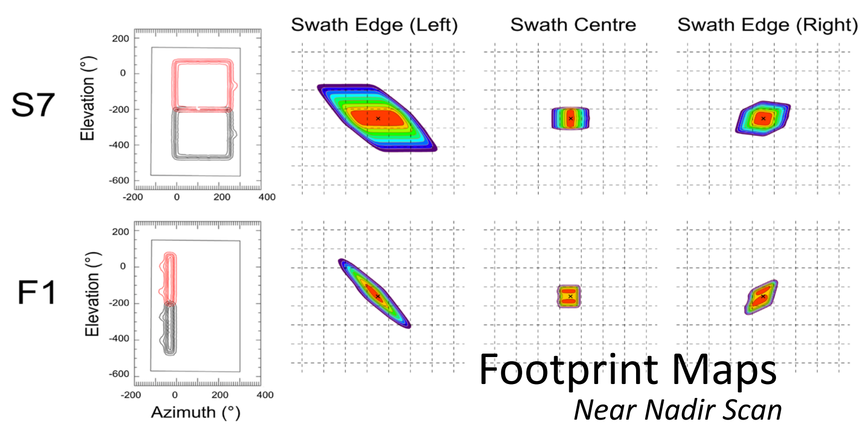
- Two operational satellites
- Global Daily Data
- @ ~ Terra overpass times

# S3 SLSTR Data Intricacies

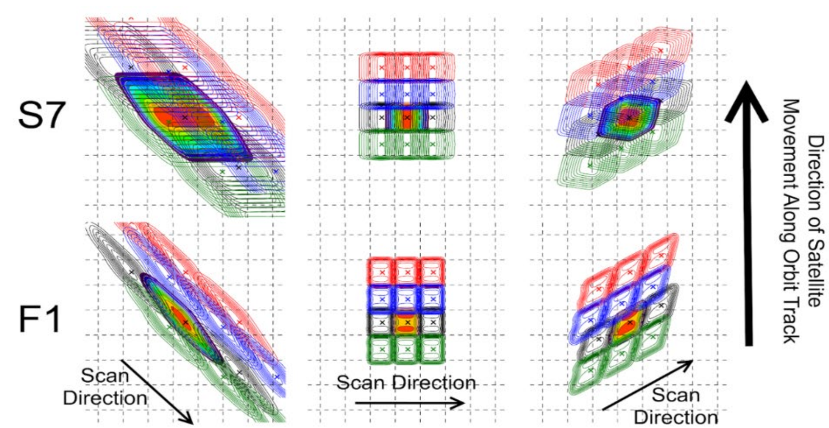
*Boreal Forest Fire Example (N. Canada)*



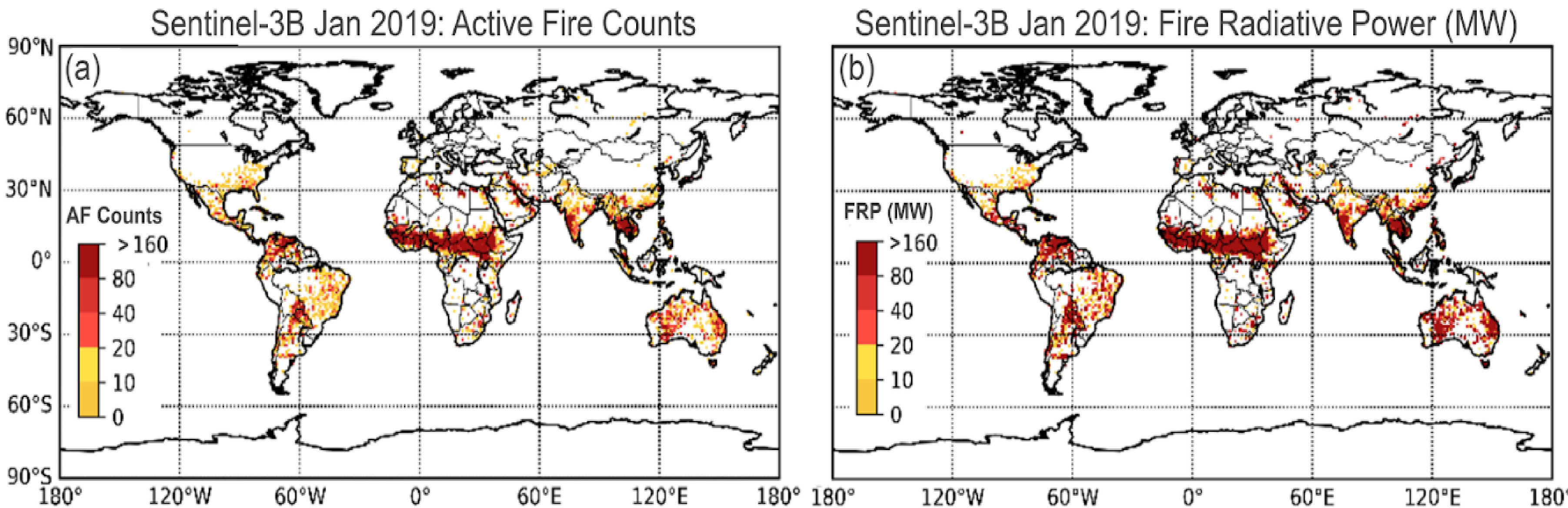




Footprint Maps
*Near Nadir Scan*



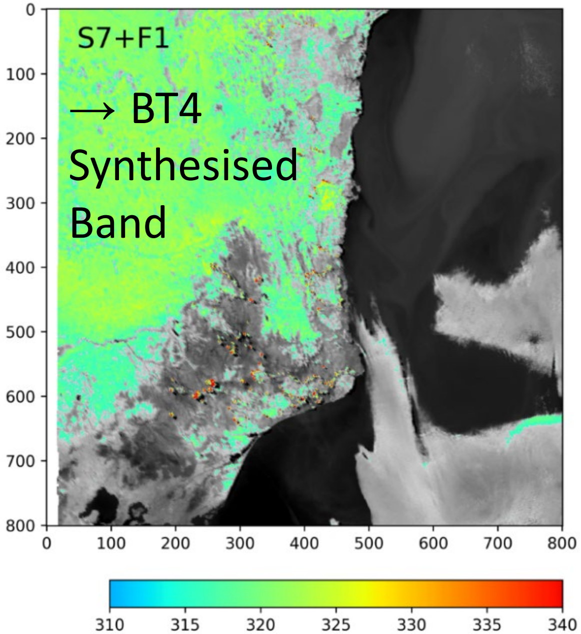

Footprint Overlap
*Near Nadir Scan*

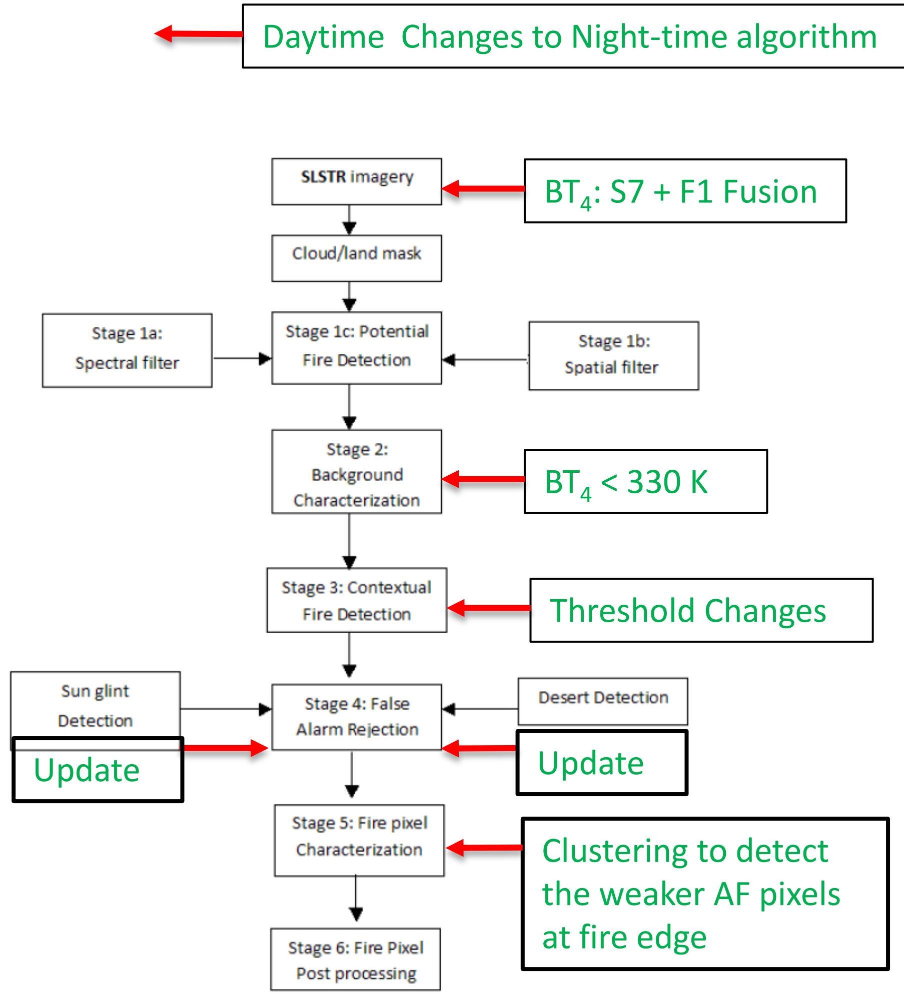
# Operational S3 AF Detection & FRP Products




- Global daily active fire (AF) counts and FRP retrievals from S3A and S3B.
- SLSTR has S7 and F1 MIR channels
- S7 often saturates by day (starting at BTs > 311 K) so day and night products are different

# S3 SLSTR AF Detection Alg. Structure



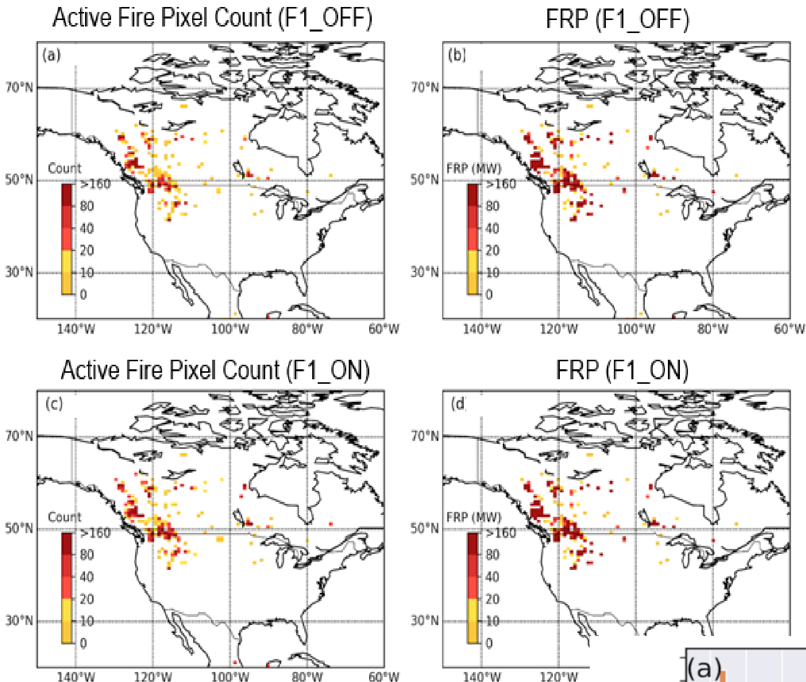




## Some Key Points

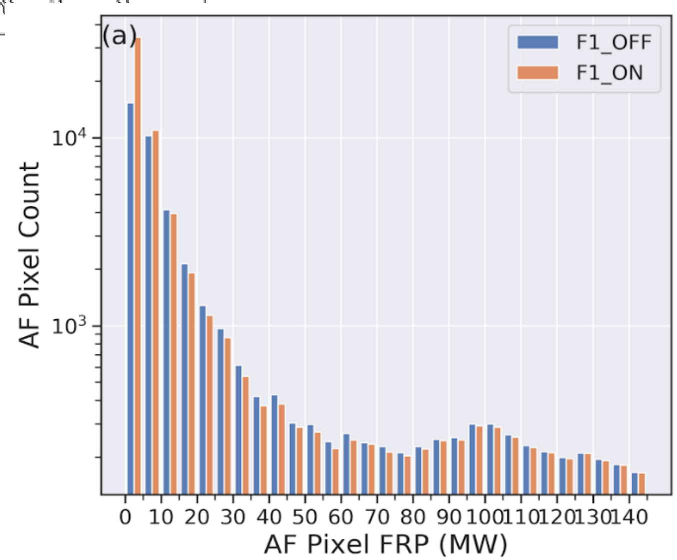
- Daytime synthesised "$BT_4$" channel - combing S7 & F1
- Background characterisation uses $BT_4 < 330$ K
- Contextual AF pixel detection thresholds increased compared to the night-time version.
- Sun-glint & desert detection thresholds further optimised.
- AF pixel clustering used to detect weak AF pixels at AF cluster edge

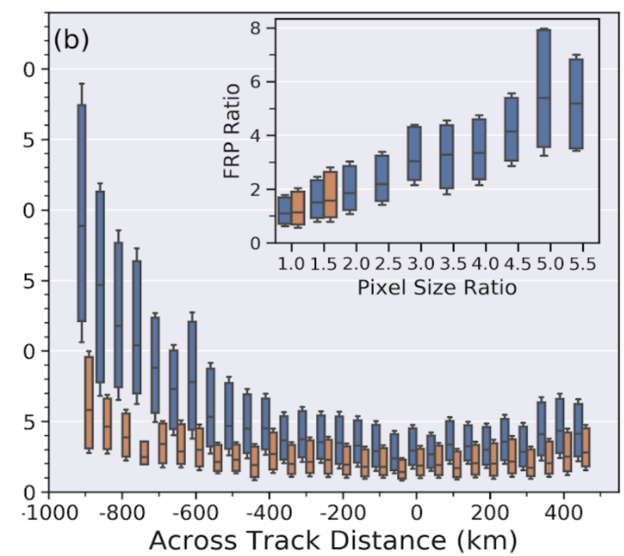
- **Use S7 where possible for initial AF pixel detection.**
- **Always use F1 for FRP retrieval or not?**

# F1_ON and F1_OFF Comparison

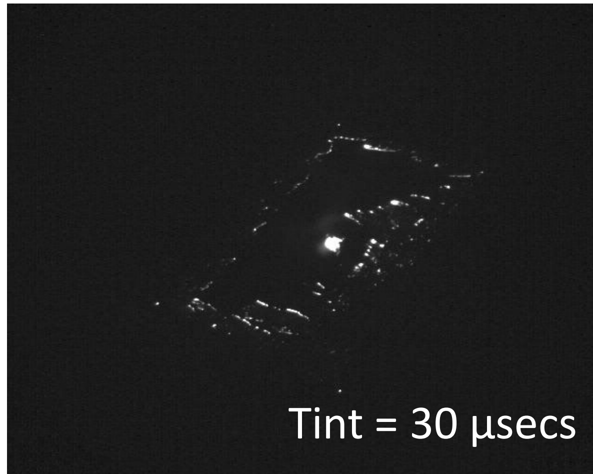


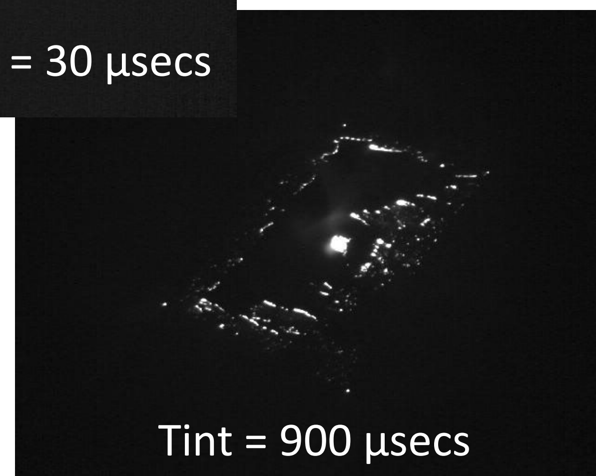

- Each fire has cluster of AF pixels in S7 and F1 (each imperfectly co-registered)
- F1_OFF - any fire without saturation S7 is processed using the S7 data (lower noise, more sensitive).
- F1_ON – means that such fires are anyway processed with F1 (smaller pixels)



# Airborne Data Collection Over African Fires



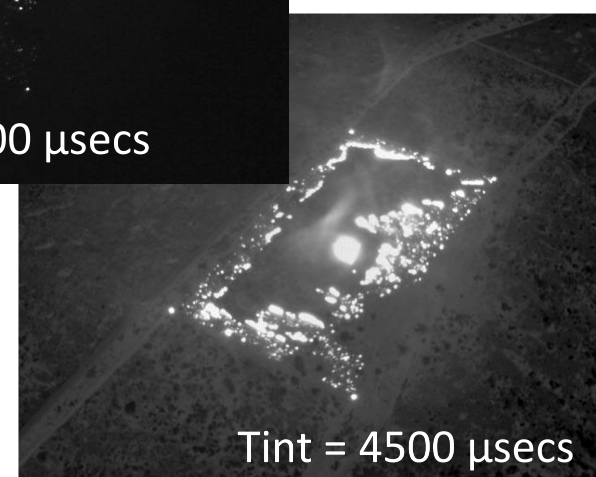
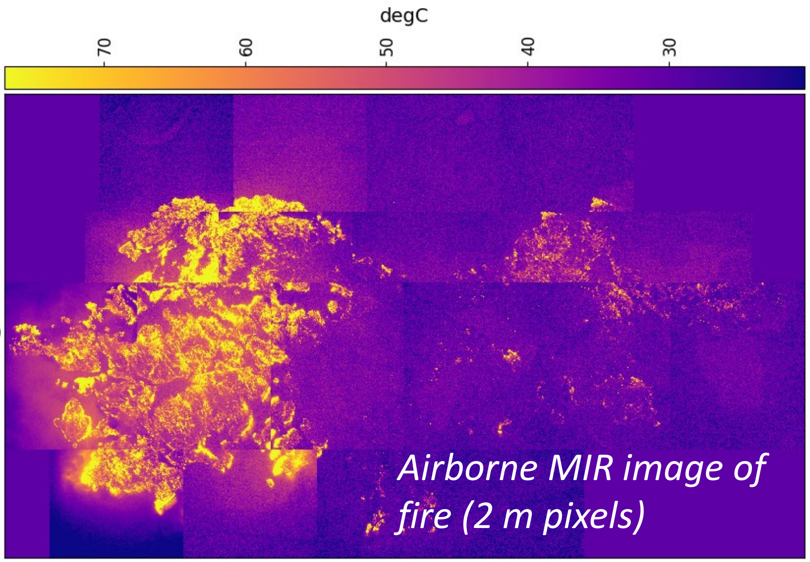
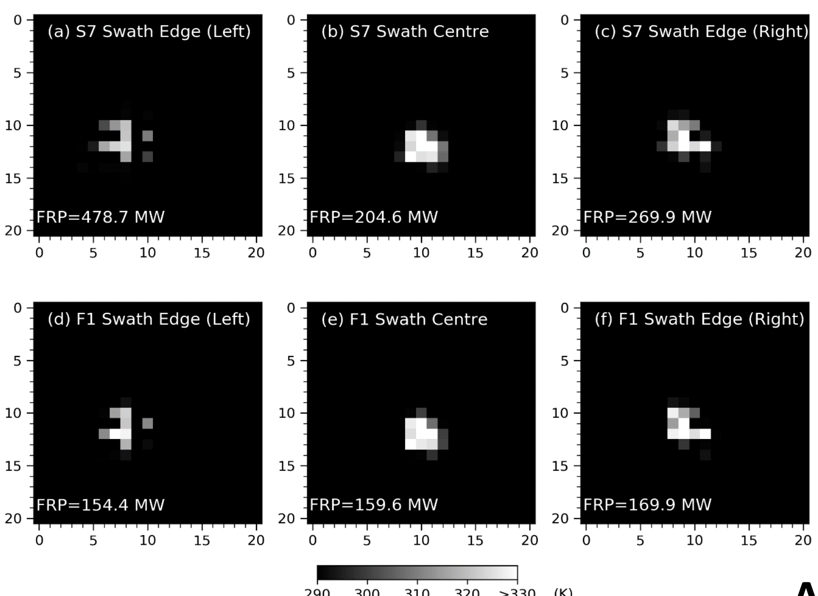



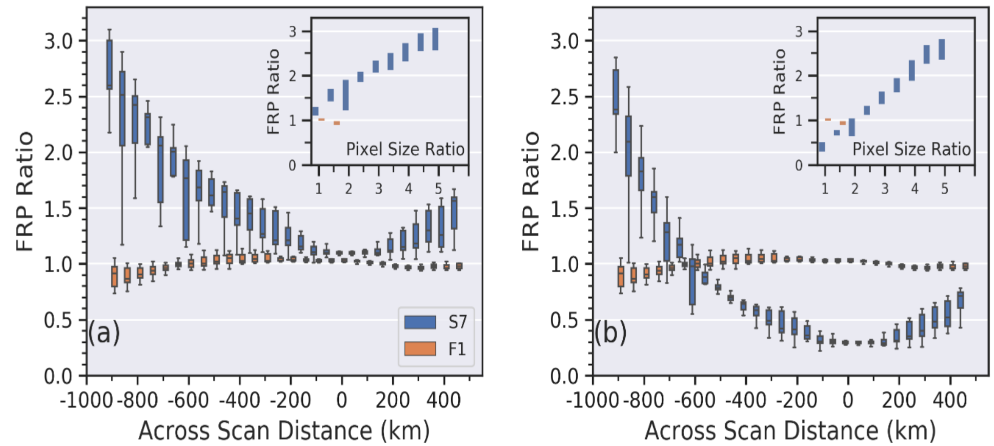

Image:
kruger0830.xvi_nuc_000424_tint_06000

# Simulation of SLSTR F1_ON & F1_OFF Observations

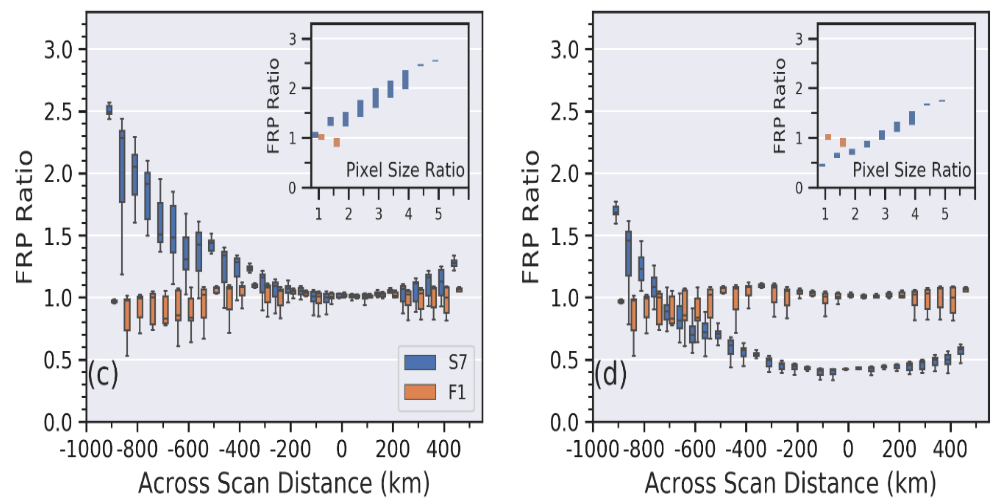



*Assuming no S7 Saturation*

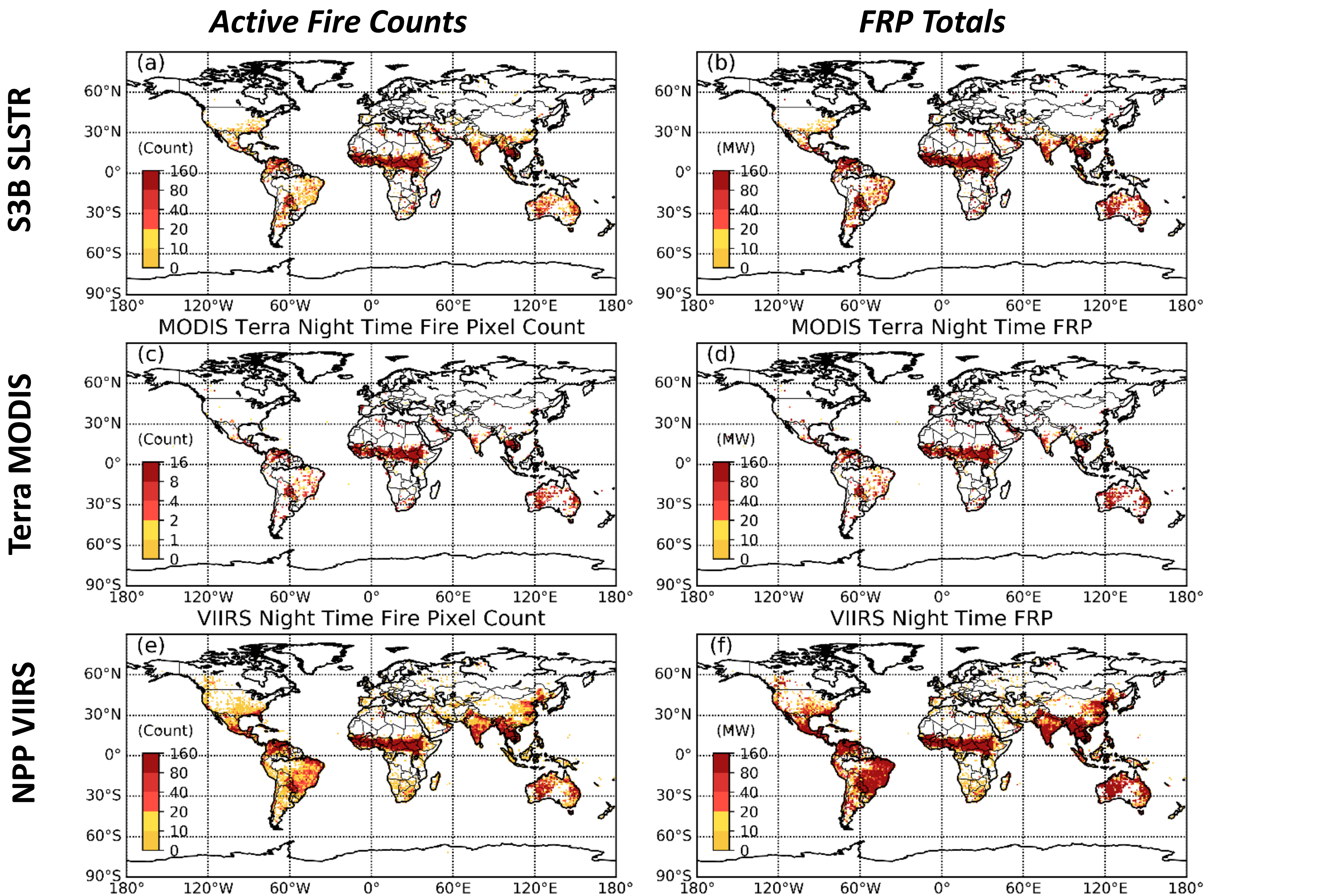



*With simulated S7 Saturation*



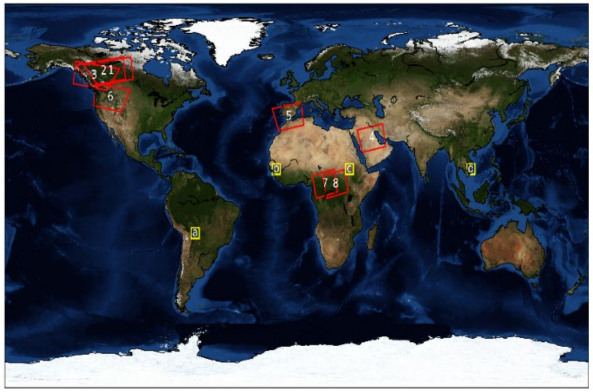

**Always use F1 for 2nd Pass AF detection & FRP retrieval**

# Global <u>Nighttime</u> SLSTR AF & FRP Example Comparison

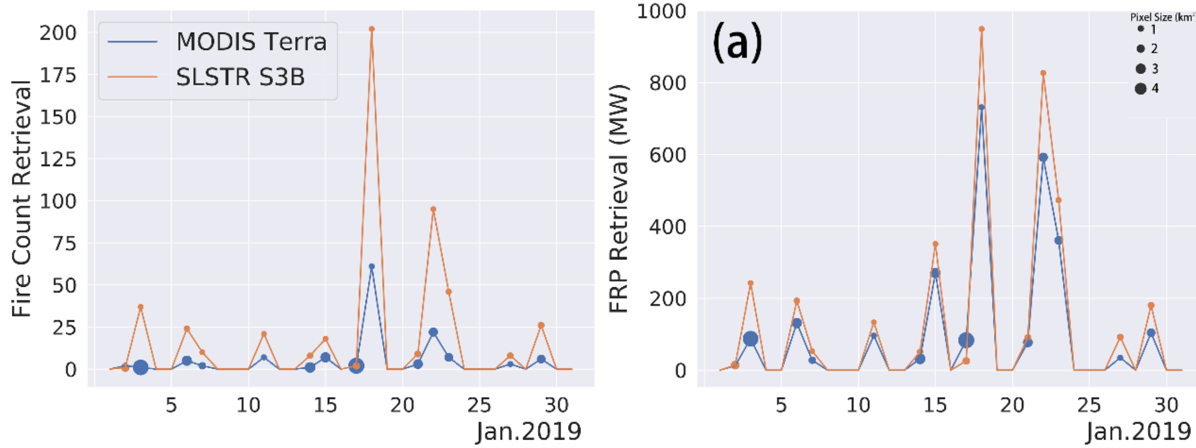



Night-time S3 detects more AF pixels than MODIS, but less than VIIRS. FRP totals less different

# Night-time FRP Time-Series SLSTR *vs.* MODIS



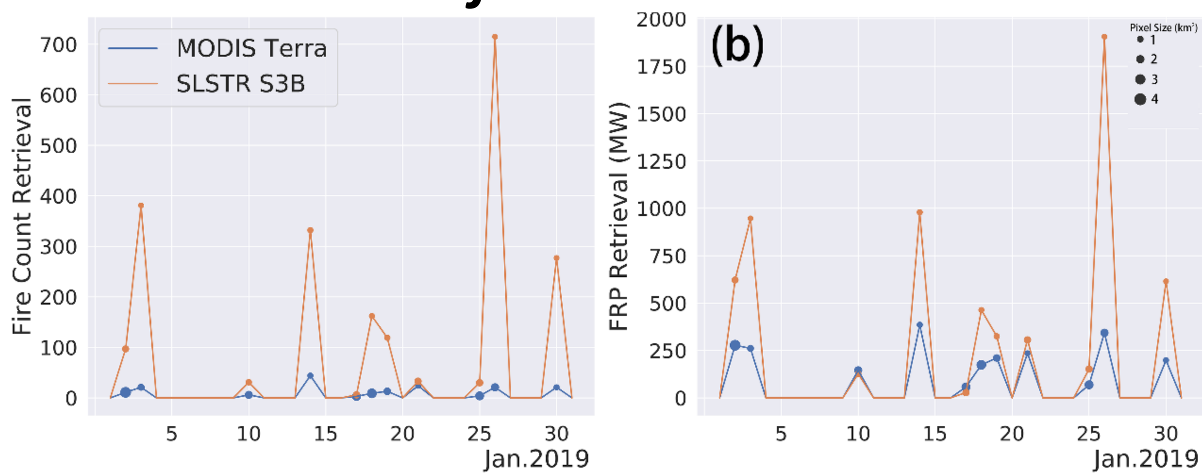

## *South America*




- Active fire pixel counts are higher for SLSTR than for MODIS.

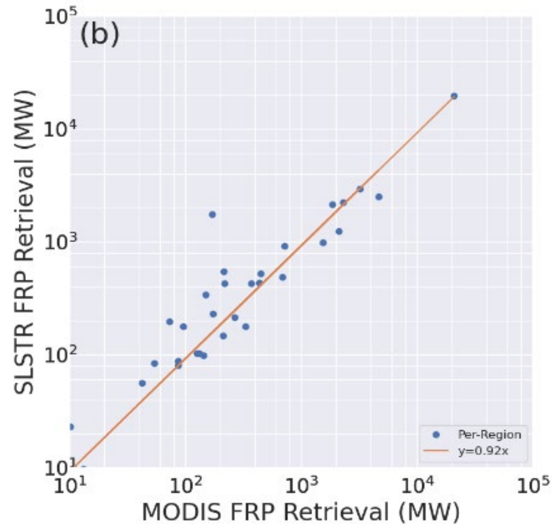
- FRP values are far more similar.

## *West Central Africa*

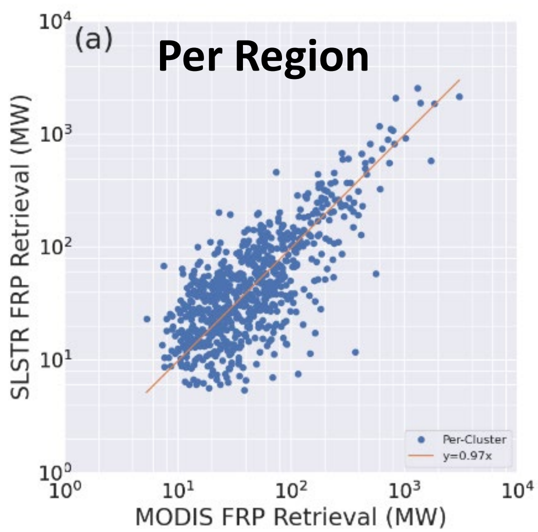


# S3B FRP Product Performance Compared to MODIS

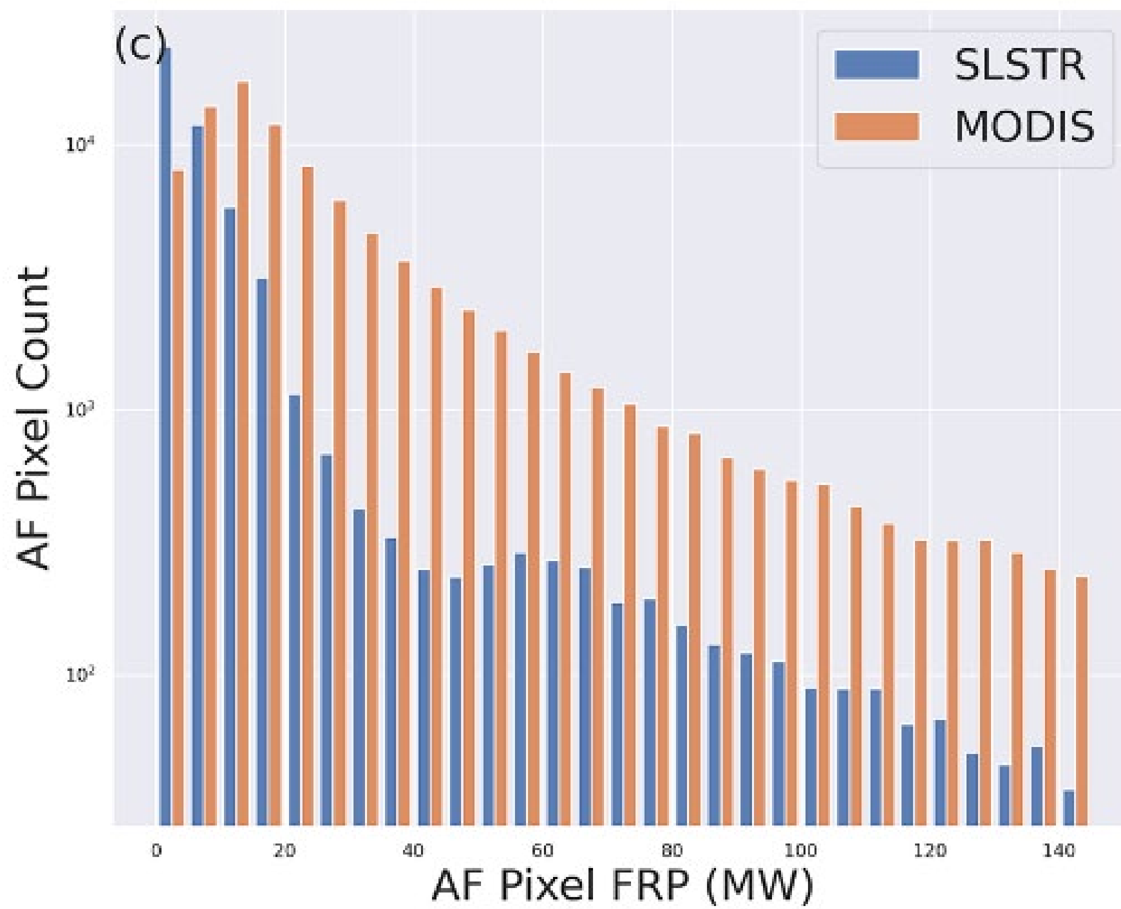
## Per Fire Cluster



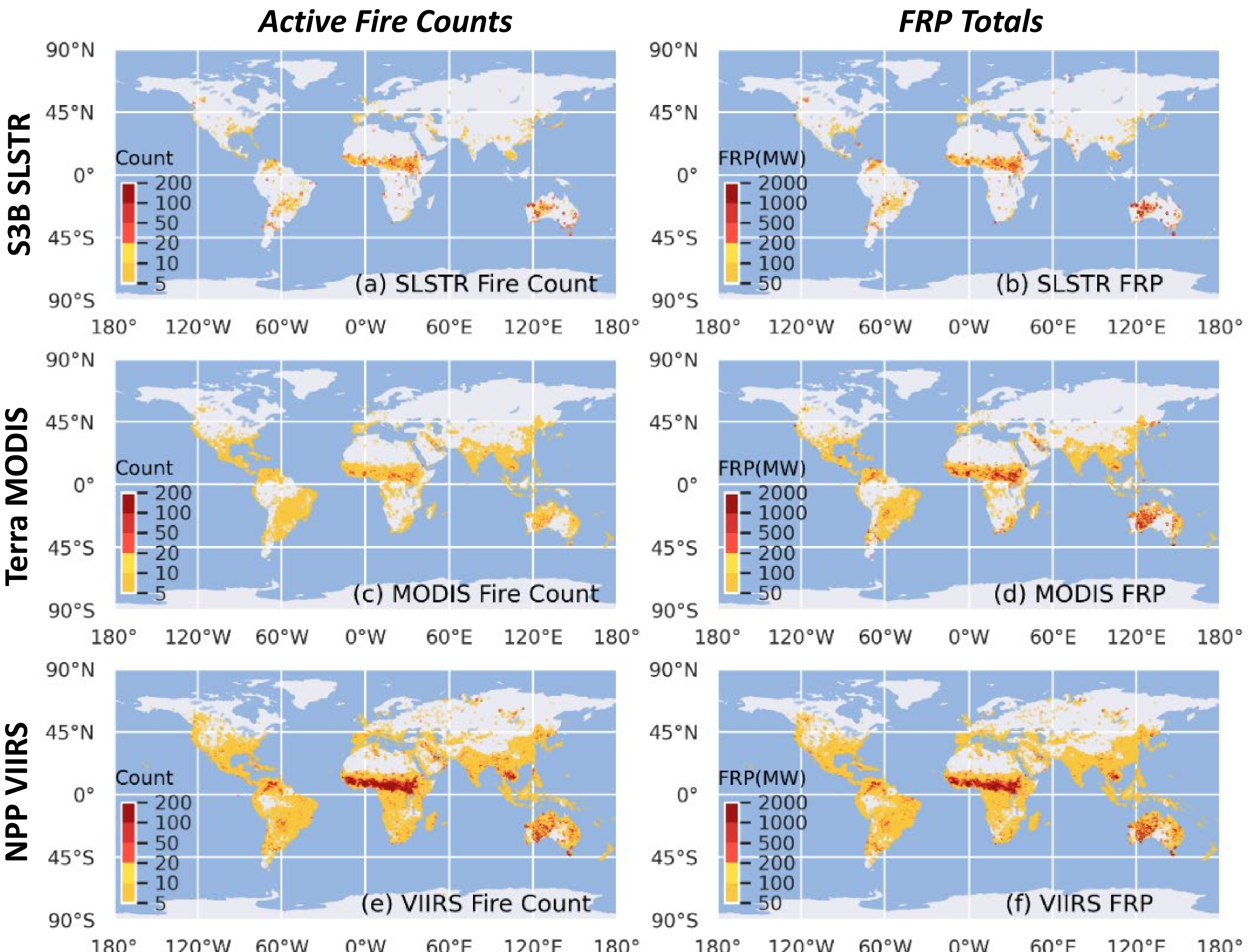

## Per Region



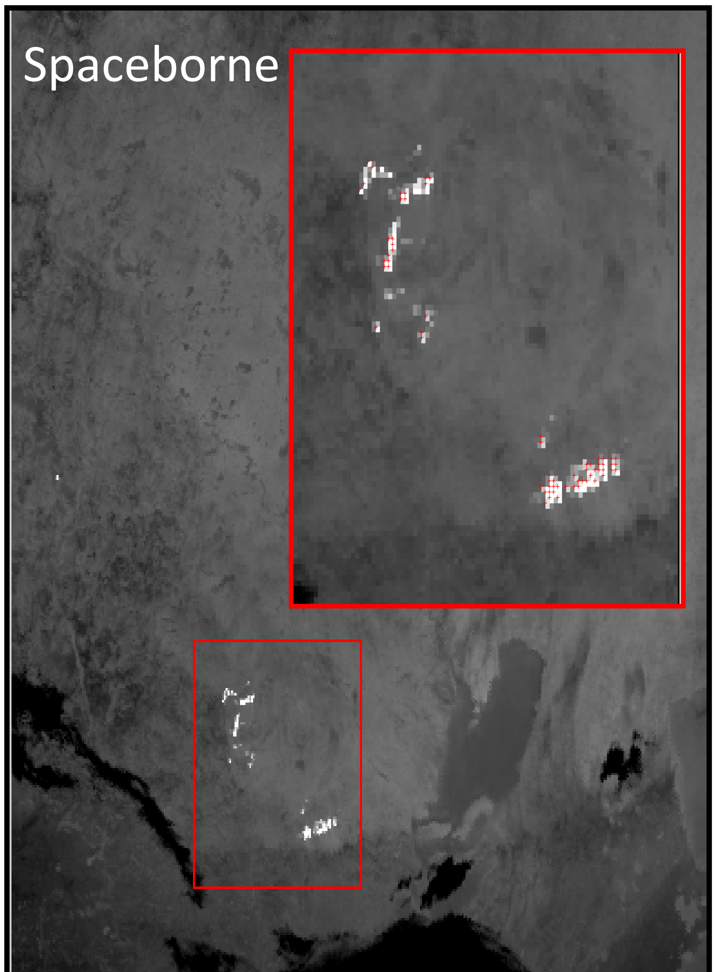

## Per Pixel FRP Freq. Distribution

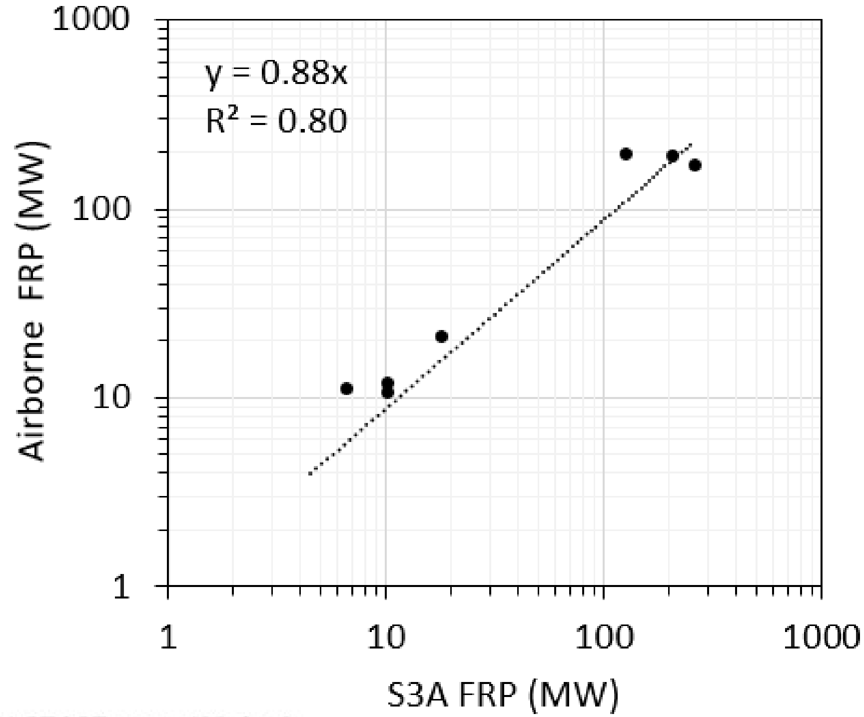


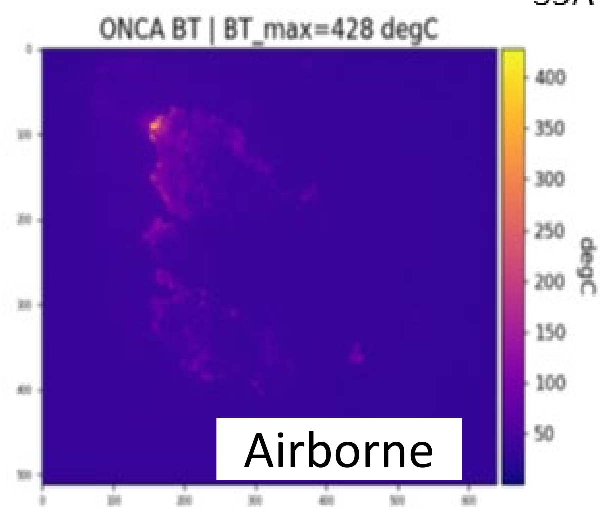
# Global <u>Daytime</u> SLSTR AF & FRP Example Comparison



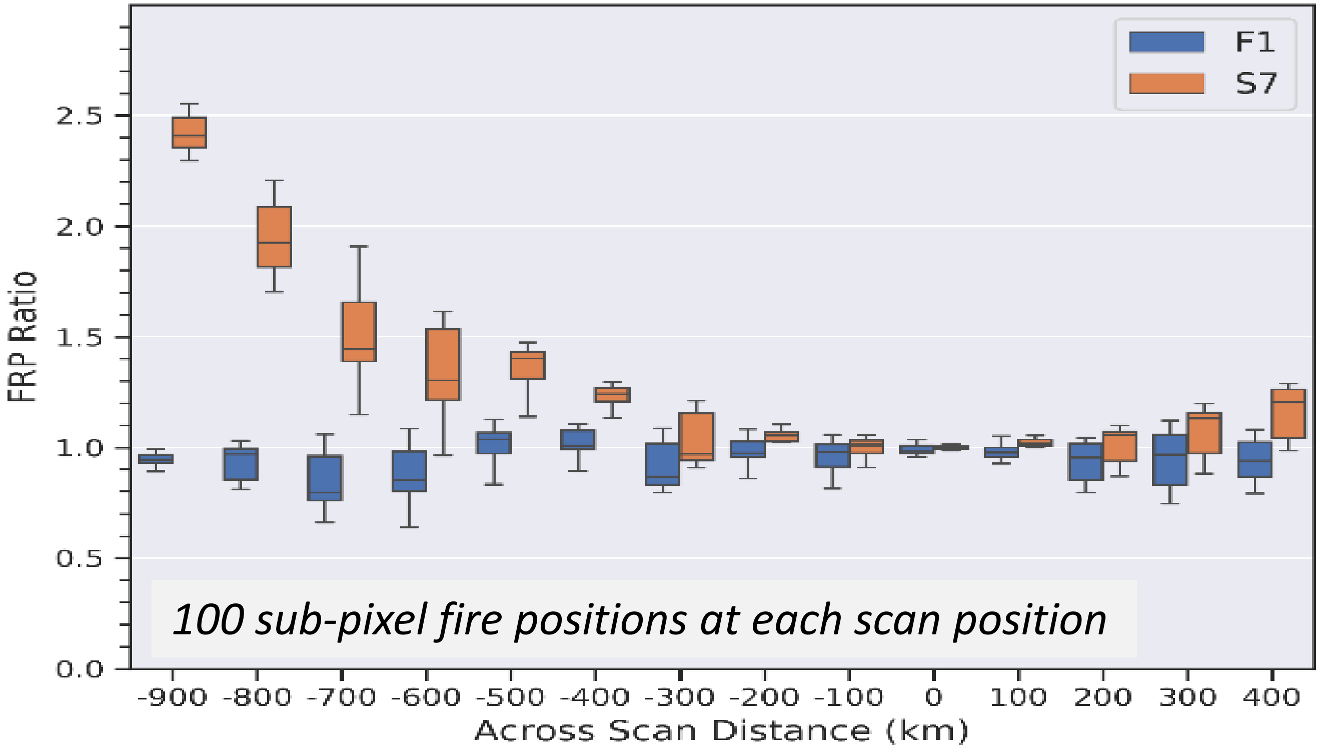
# Final S3 Spaceborne to Airborne FRP Dataset



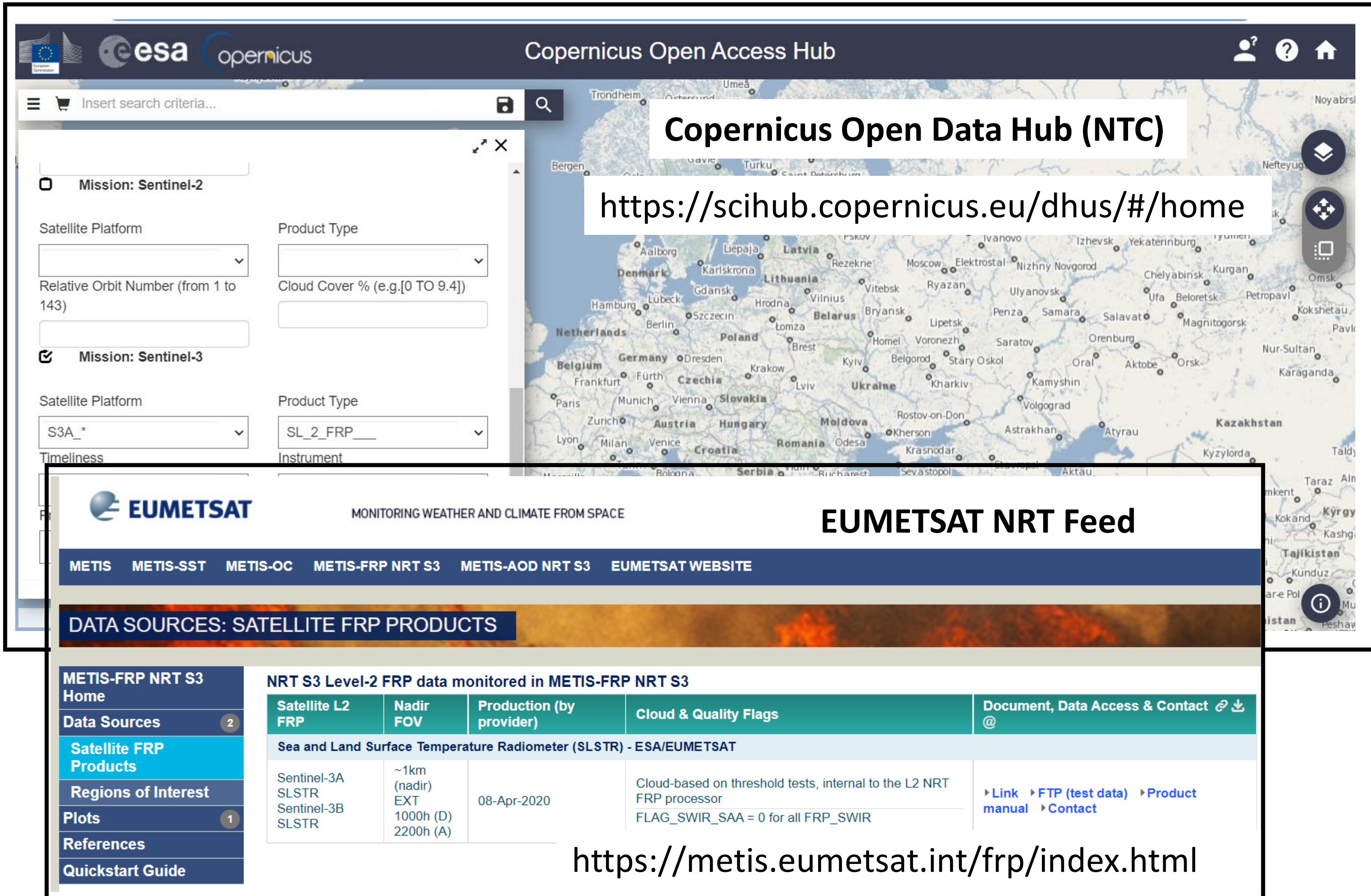



# Retrieved FRP Uncertainty & Sub-Pixel Fire Position




- F1 channel shows benefits compared to S7 channel, despite higher noise.
- Even with F1_ON, FRP can vary by up to ~ x2 depending on fire sub-pixel position.
- Comparison to airborne shows all but one fire to be within ~ x2, and most far closer.
- F1_ON confirmed as a far better option.
- F1_ON now used in NTC products available from Sentinel Data Hub.

# Obtaining S3 AF Detection & FRP Products – Two Sources




[FIRMS Integration probably coming]

Sentinel-3 A SLSTR - Standard FRP MWIR [MW] - Night - 2.0 deg resolution - 19.06.2022

Total number 1 km hot-spots = 2635

FRP 1 km: Total = 18793.0 [MW] - Avg. = 7.1±14.7 [MW] - Min = 0.2 [MW] - Max = 308.4 [MW]