# Fire Radiative Energy eMissions Methodology (FREM) for Fire Emissions Estimation

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Australian Fires (photographed at night from the ISS)

# Emissions Methodologies

## GFED [ currently MODIS BA Based, non NRT ]

- Based on observations insensitive to observation time ✓
- Based on very long-term datasets, so long-time series ✓
- Potential biases in burned area measures ?
- Fuel loads & combustion completeness may have large uncertainties ?

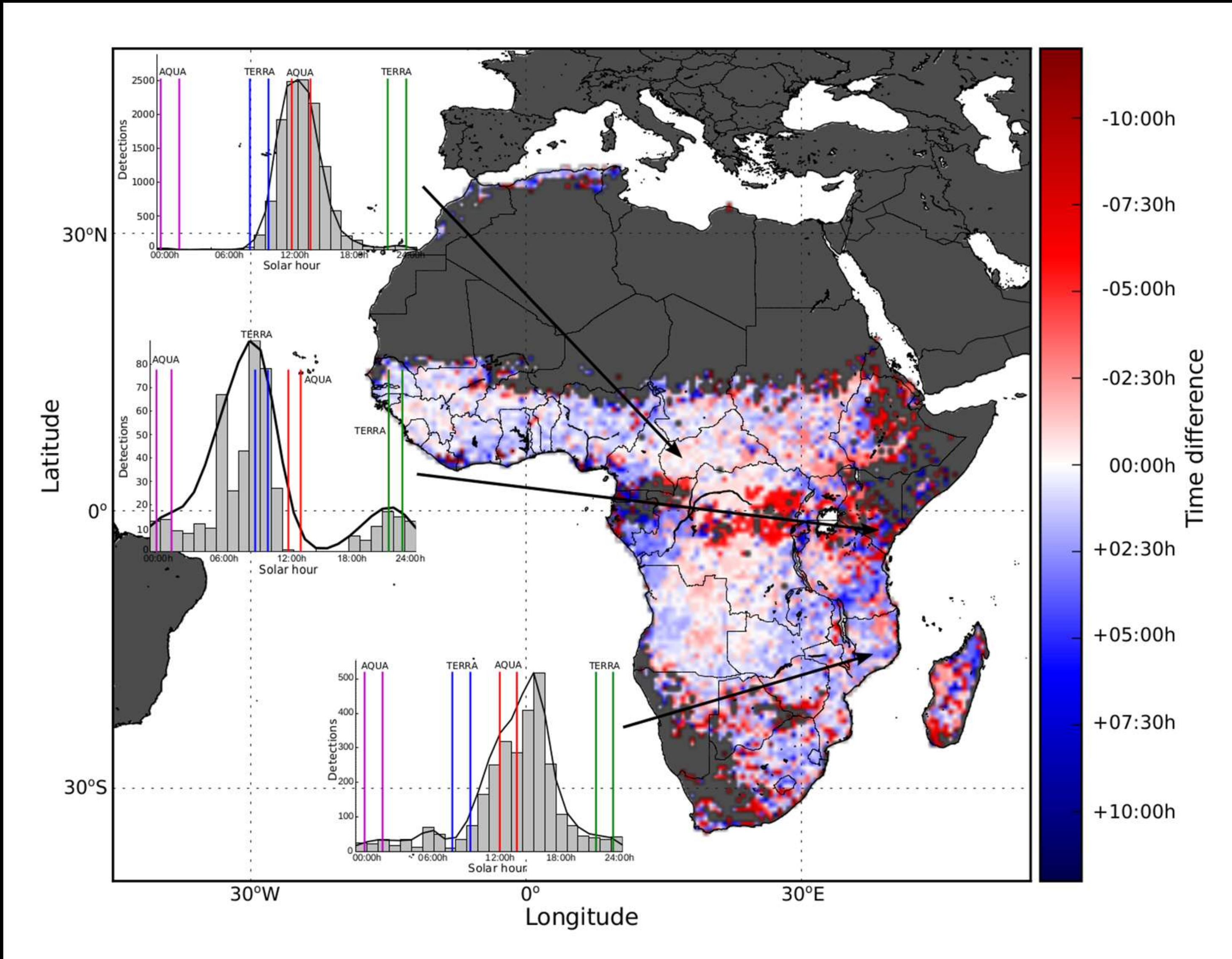
## Geostationary [ NRT & FRP Based- though not @ high lats ]

- Avoids need for fuel loads & combustion completeness ✓
- Semi-continuous observations - insensitive to observation times (and less to cloud) ✓
- Assumes fixed relationship between FRP and biomass combustion rate ?
- Misses more low FRP fires than with polar-orbiters ?

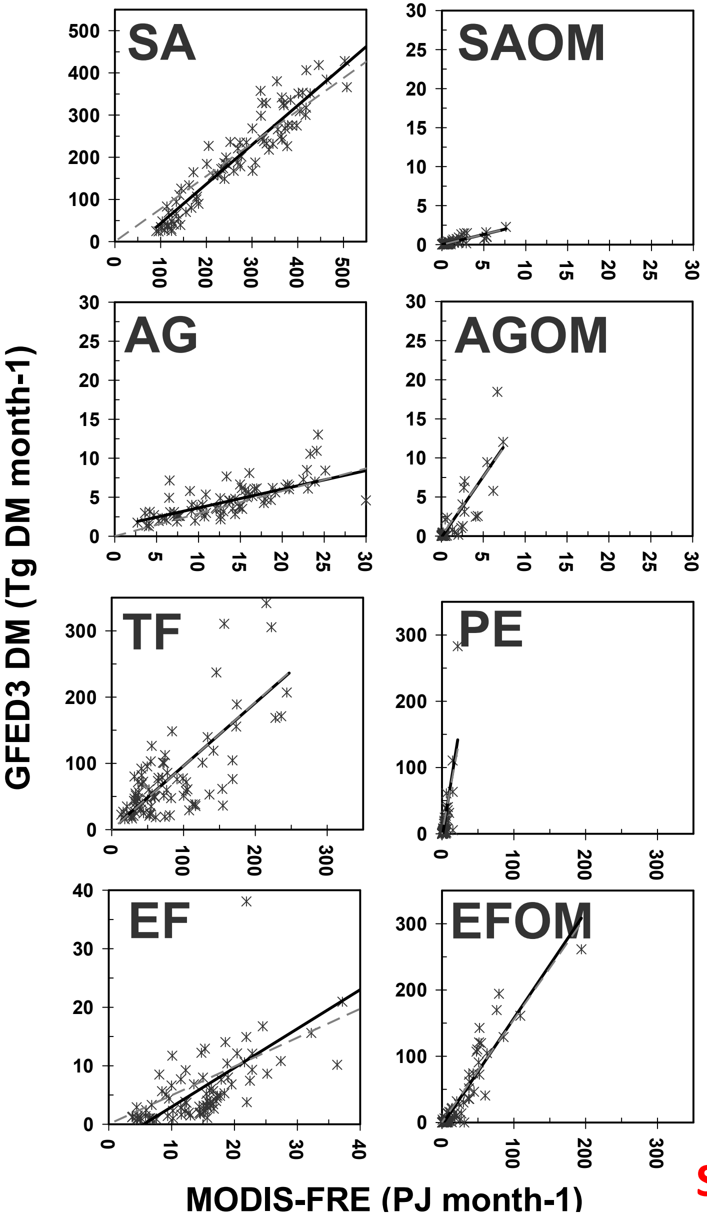
## GFAS [ currently MODIS FRP Based ]

- Avoids need for fuel loads & combustion completeness ✓
- Sensitive to MODIS overpass time in relation to diurnal cycle (and cloud) ?
- Hard to know how to convert FRP to emissions rate – so calibrated to GFED ?

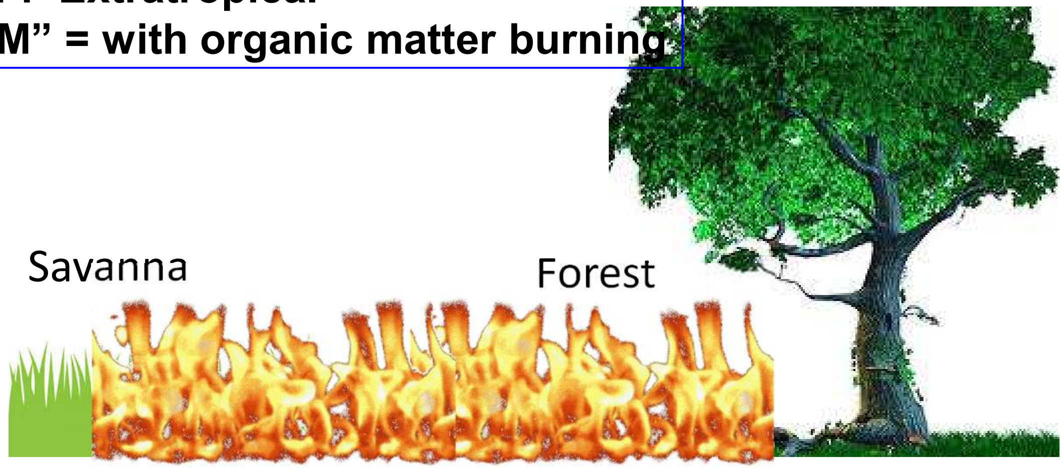
# Time Difference between Peak Burn Time and Aqua MODIS Overpass



# 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** |

**Slide and Data taken from Kaiser *et al.* (2012) *Biogeosciences***

$$Cf_{small\ scale} = 0.37\ g\ kJ^{-1}$$ Wooster *et al.* (2005) JGR

# Fire Radiative Energy eMissions (FREM)

- Geostationary FRP to get FRE
  - insensitive to observation times
- Exploit atmospheric observations to derive Conversion Factors
  - link FRP directly to smoke emission rate

(similar to C. Ichoku MODIS-FRP based FEER approach)

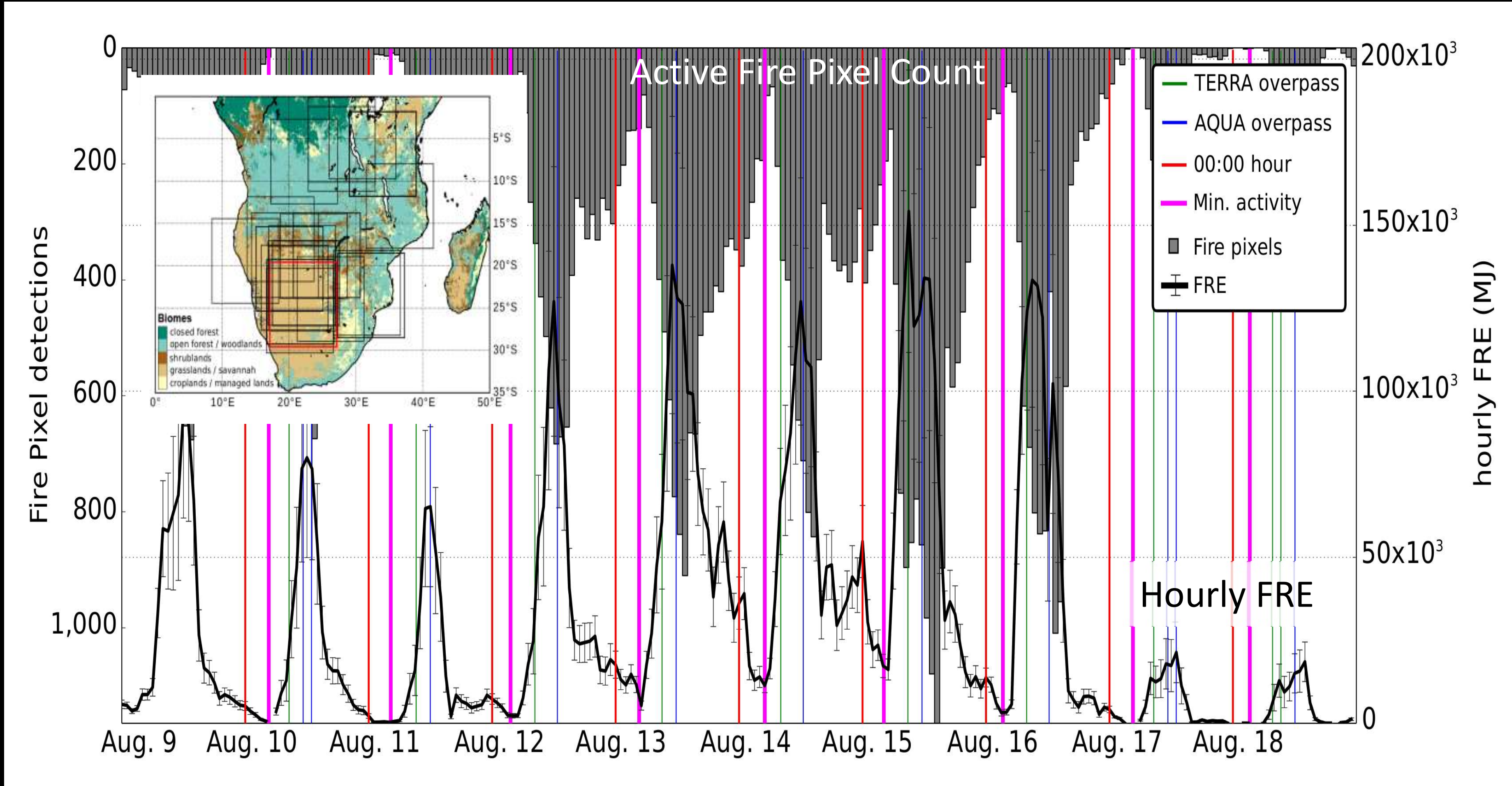
- Subsequently use relations to estimate fuel consumption as a final step (including fuel consumption per unit area)
  - remove bottom-up estimation of fuel consumption

PILOTED IN SOUTHERN AFRICA USING
15 mins METEOSAT FRP-PIXEL PRODUCT

*Currently Under Review in RSE*

# Meteosat SEVIRI Hourly FRE

Five biomes based on reclassification of 300 m Globcover (incl multiple "savanna")




August 2011 Hourly FRE time-series for a 500 km × 500 km region – mostly grassland savannah

# Per-Fire Smoke Plume Delineation

[small(ish) subset of fires used to obtained conversion coeffs]

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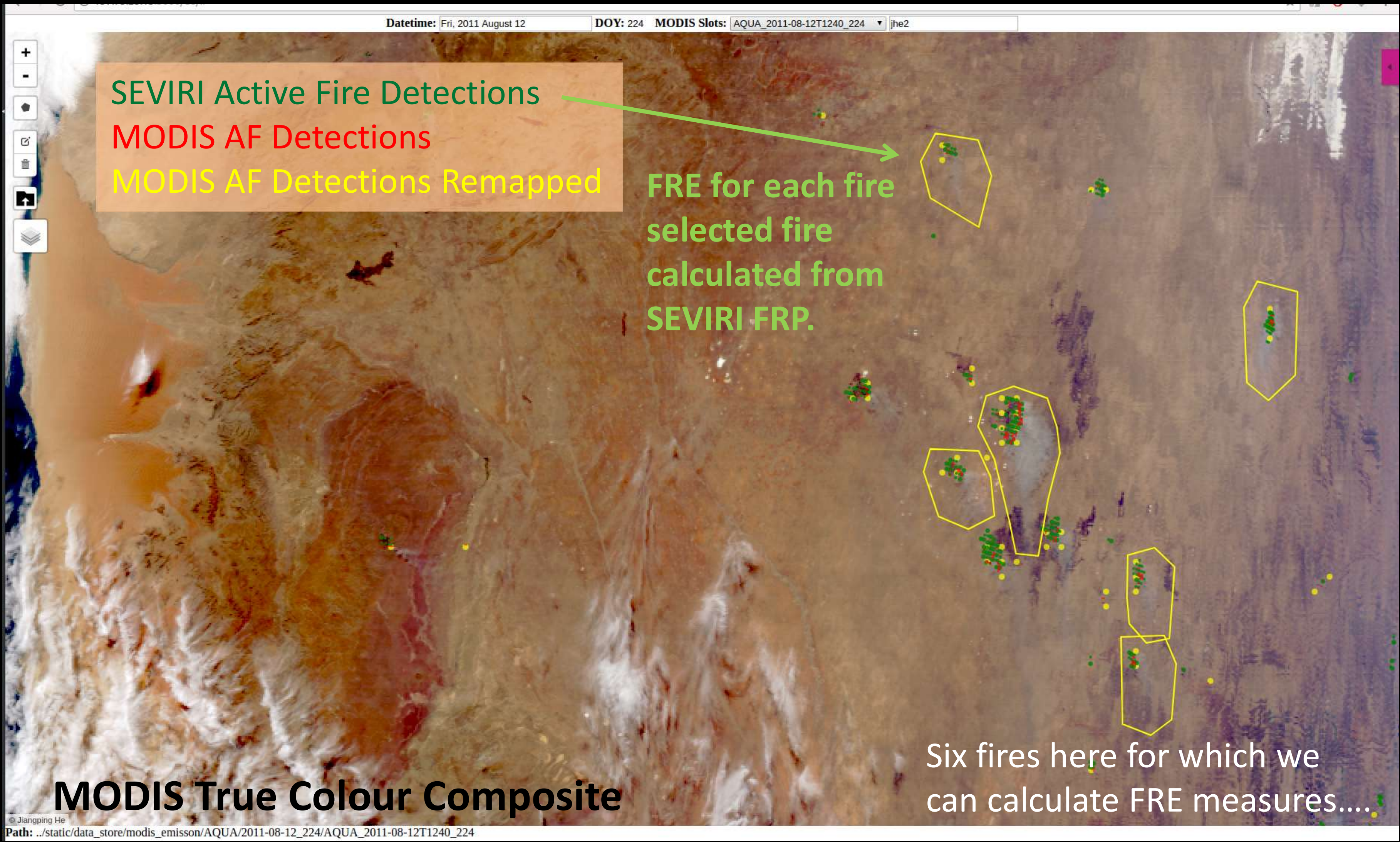
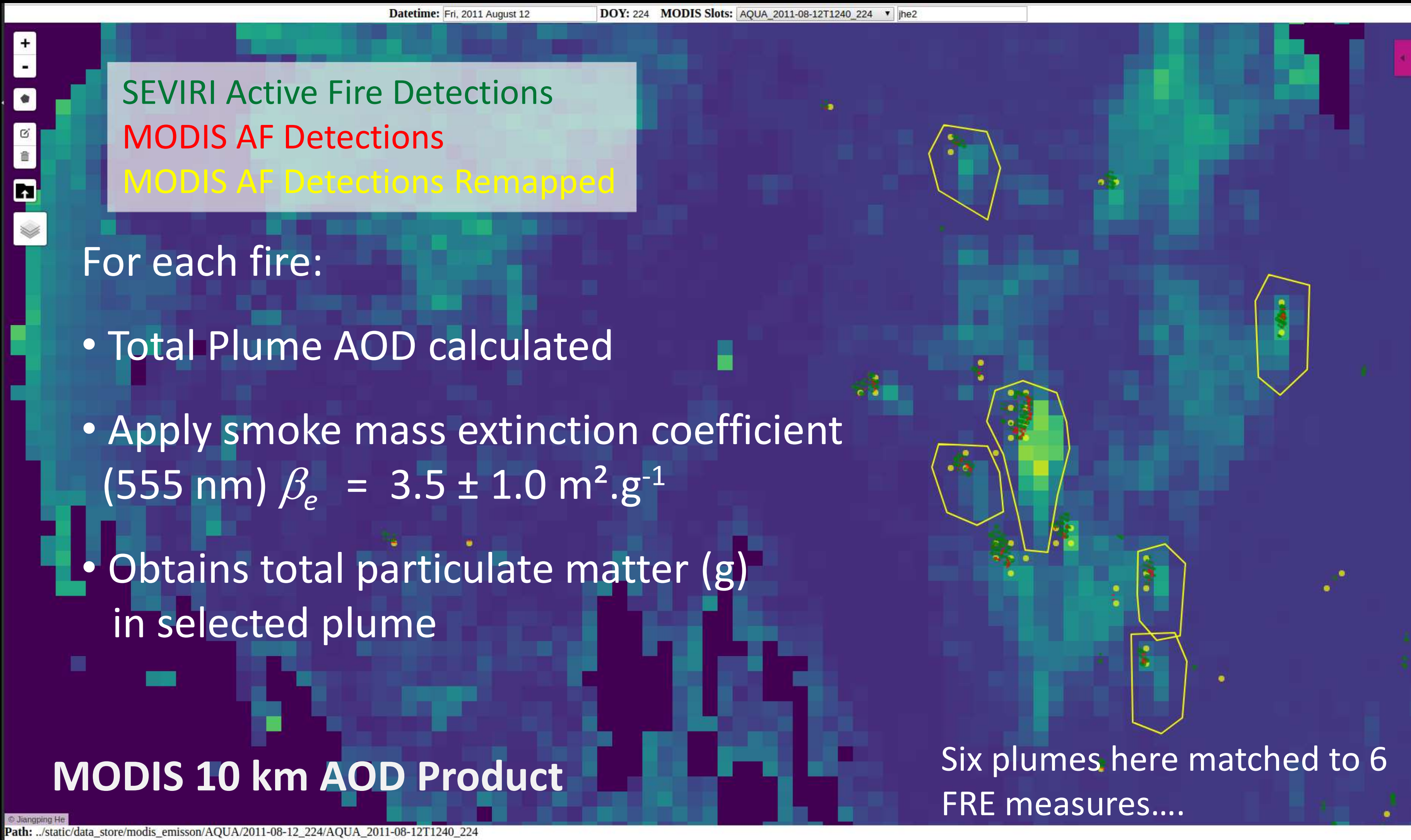


# Pre-Fire Smoke Plume Delineation



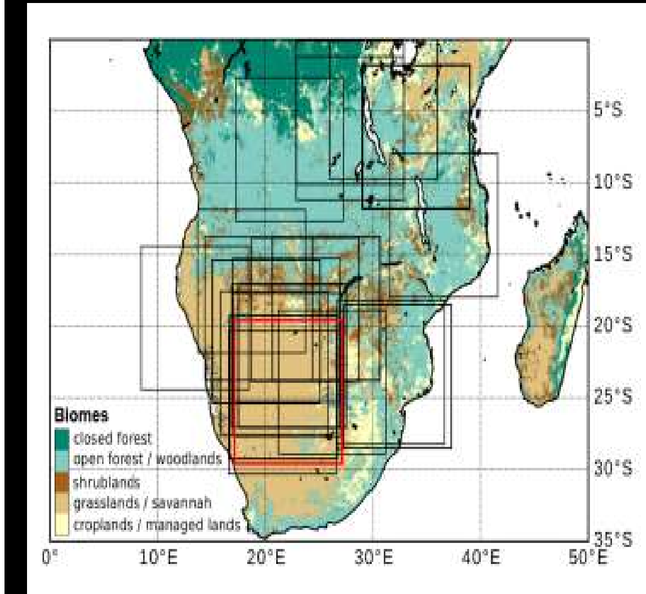

For each fire:

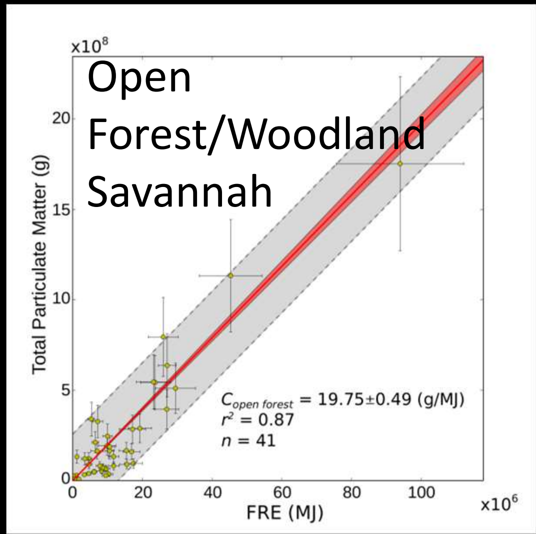
- Total Plume AOD calculated
- Apply smoke mass extinction coefficient (555 nm) $\beta_e$ = $3.5 \pm 1.0\ m^2.g^{-1}$
- Obtains total particulate matter (g) in selected plume

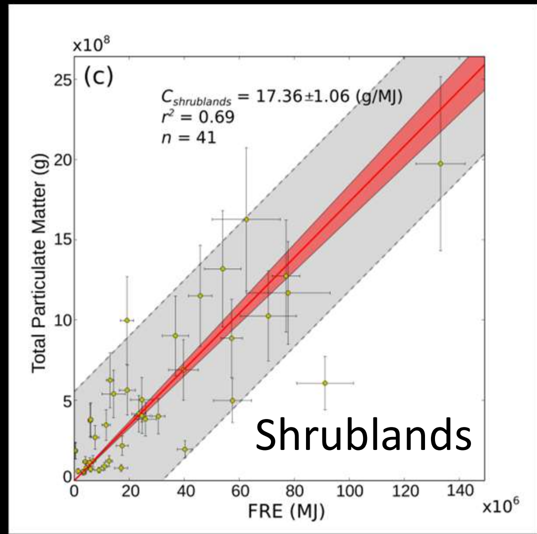
**MODIS 10 km AOD Product**

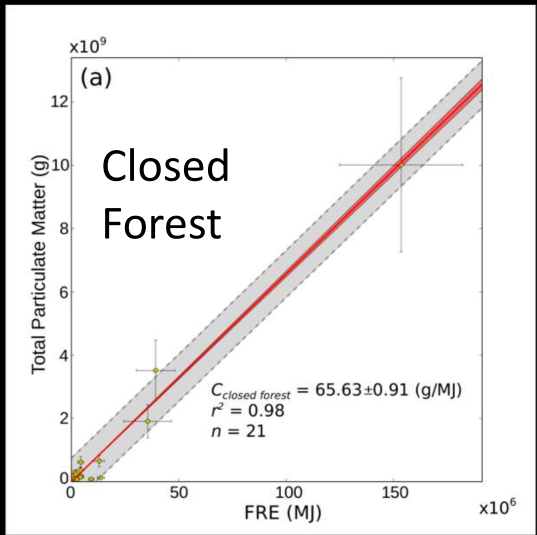
Six plumes here matched to 6 FRE measures….

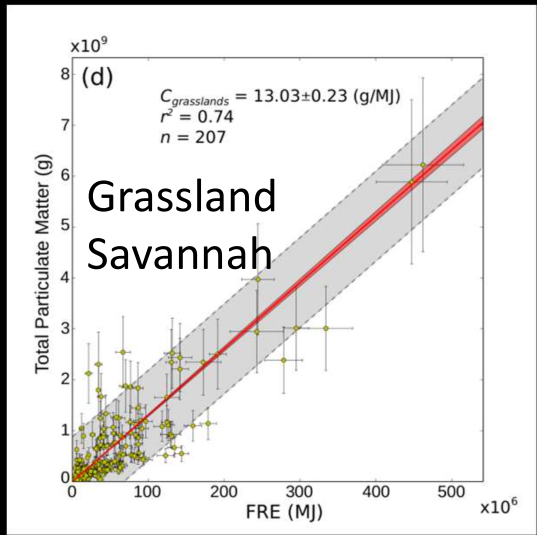
# Smoke Emissions Coefficients, $C_e$ [g.MJ$^{-1}$]

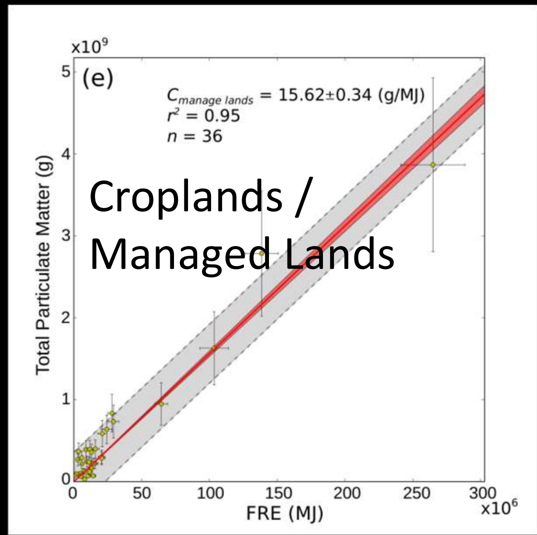


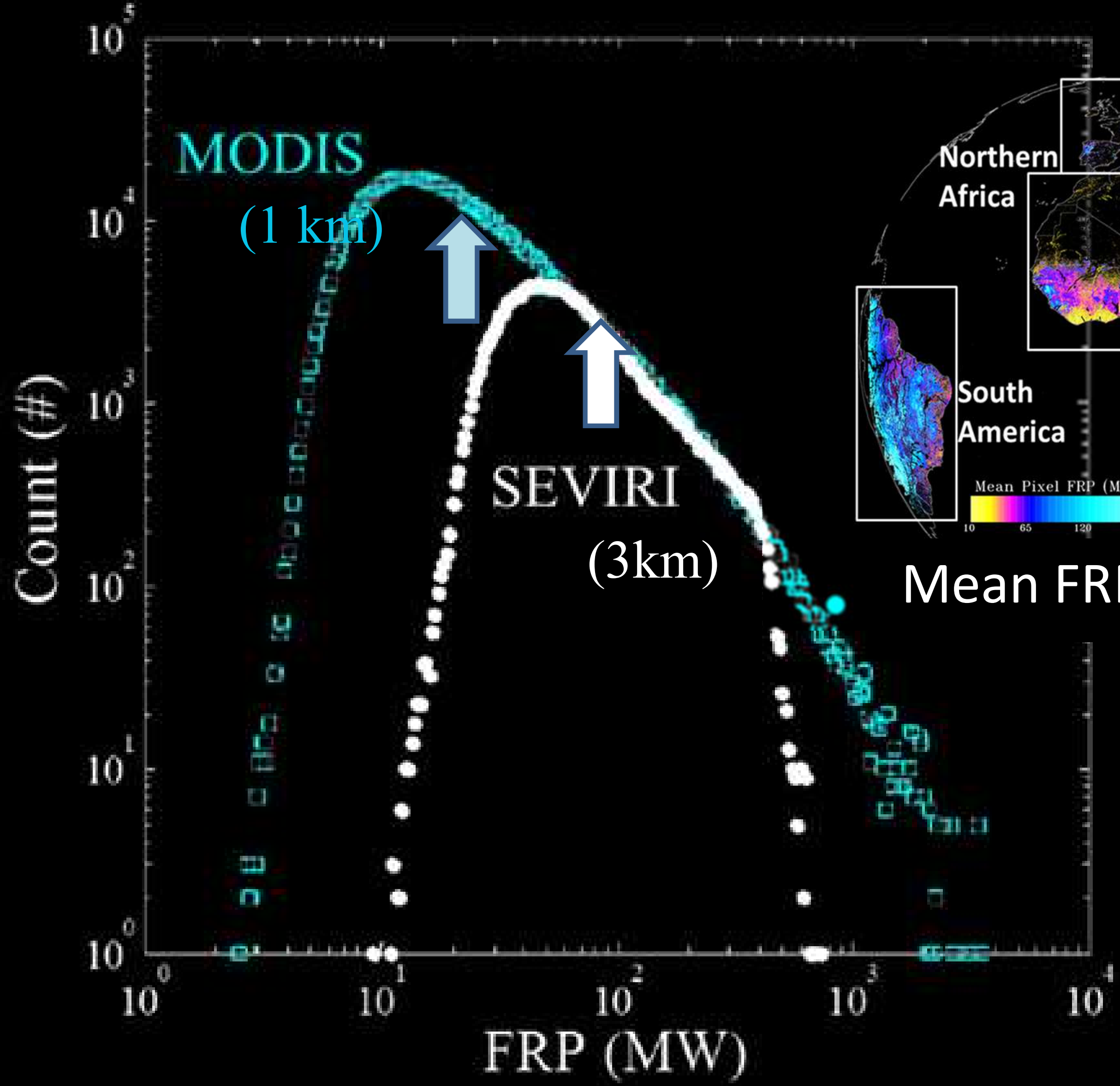



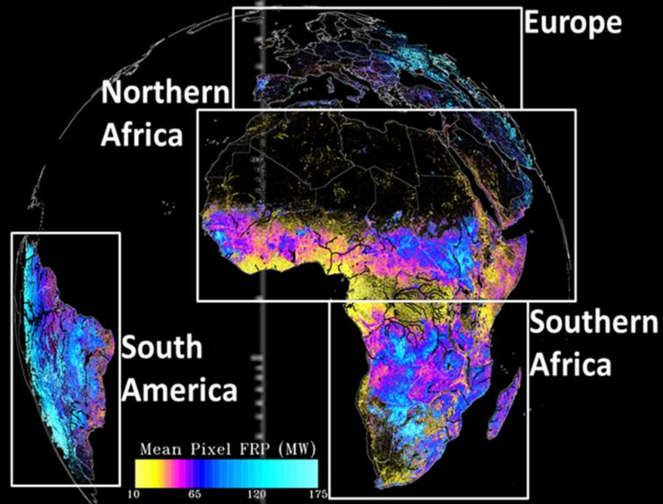



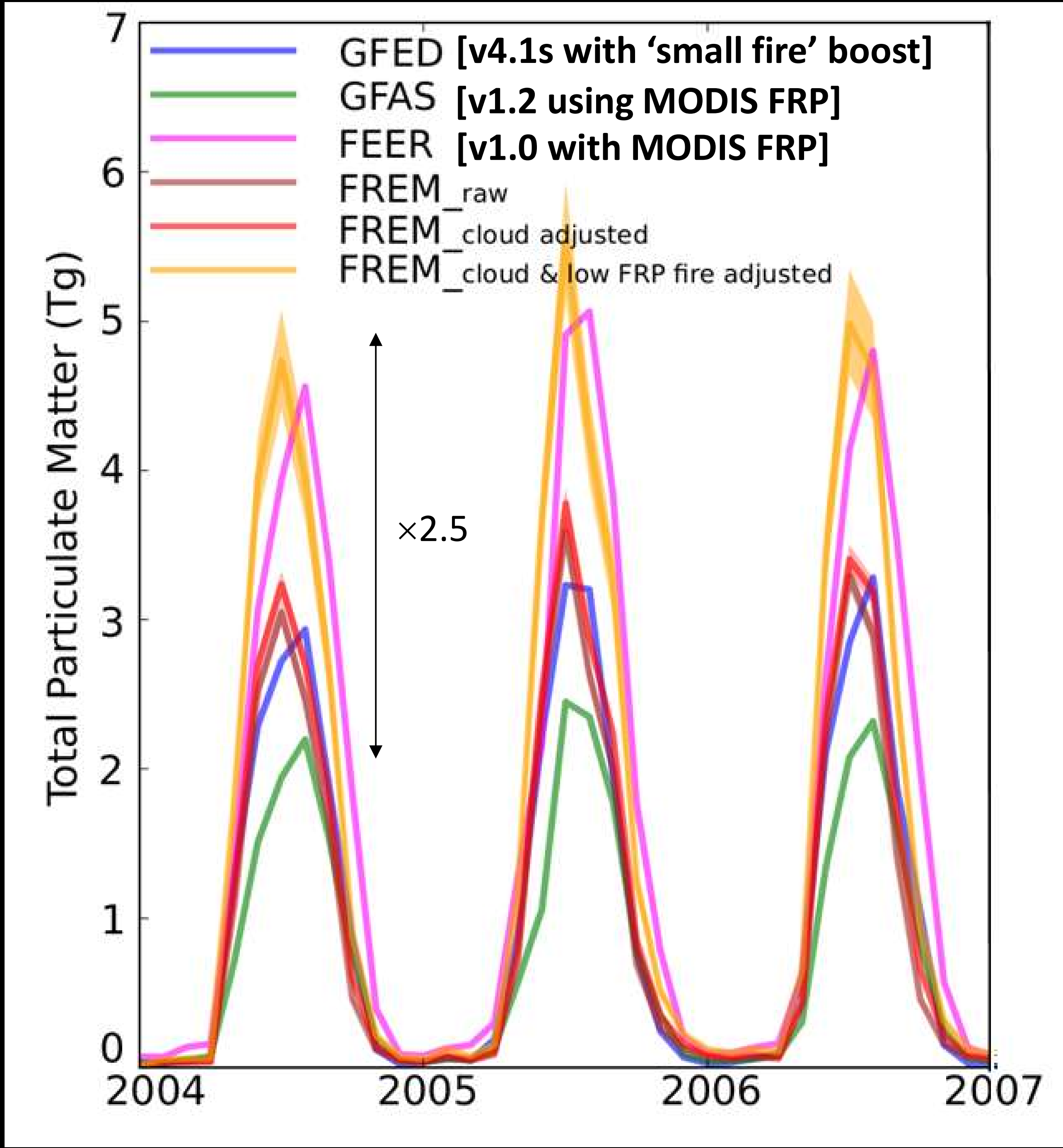
# But - Geostationary Data Miss low FRP Fires




Mean FRP ($MW.pixel^{-1}$)

Monthly Total Particulate Matter Emissions [Tg.month$^{-1}$]



# TPM Emissions Density [g.m$^{-2}$]

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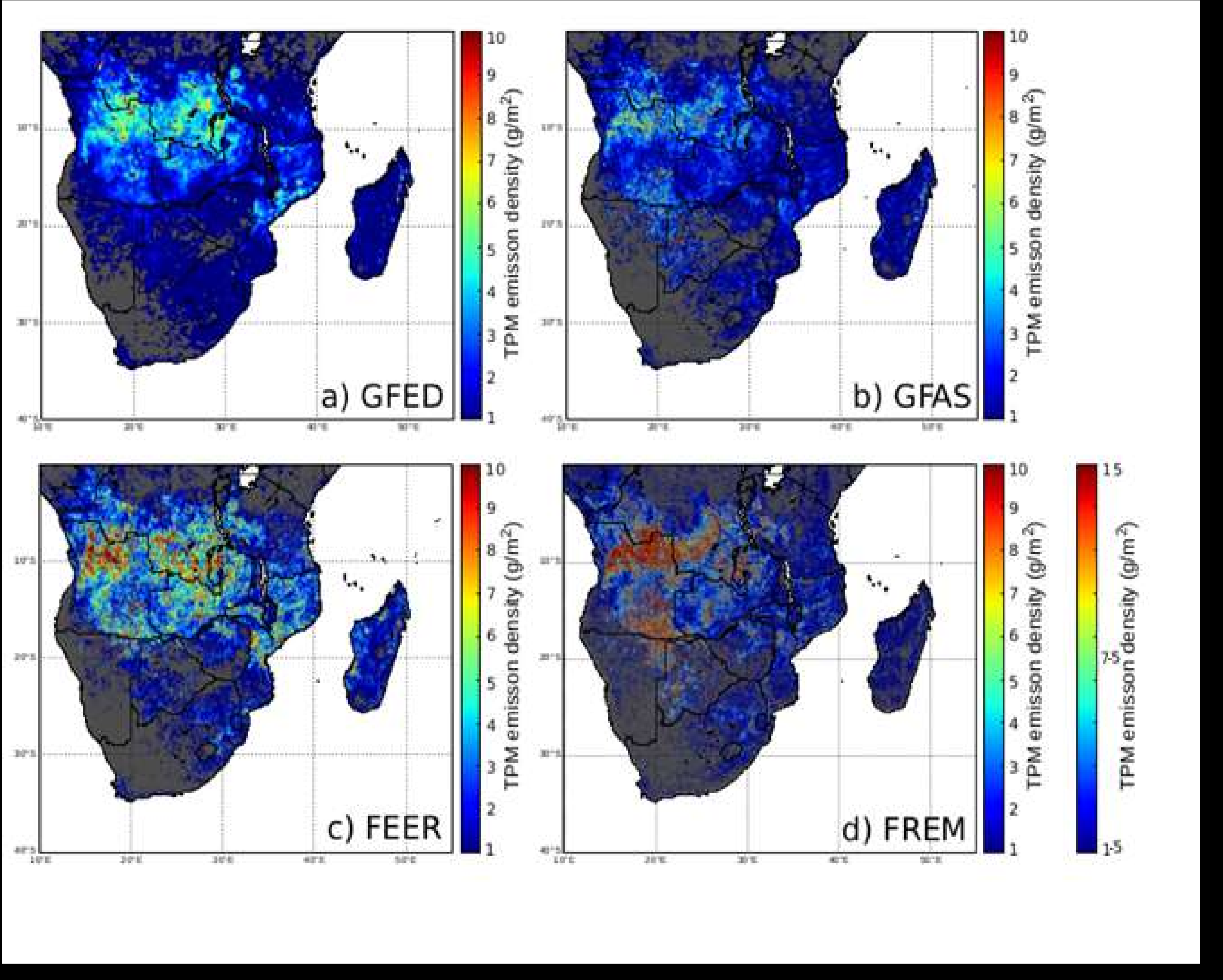
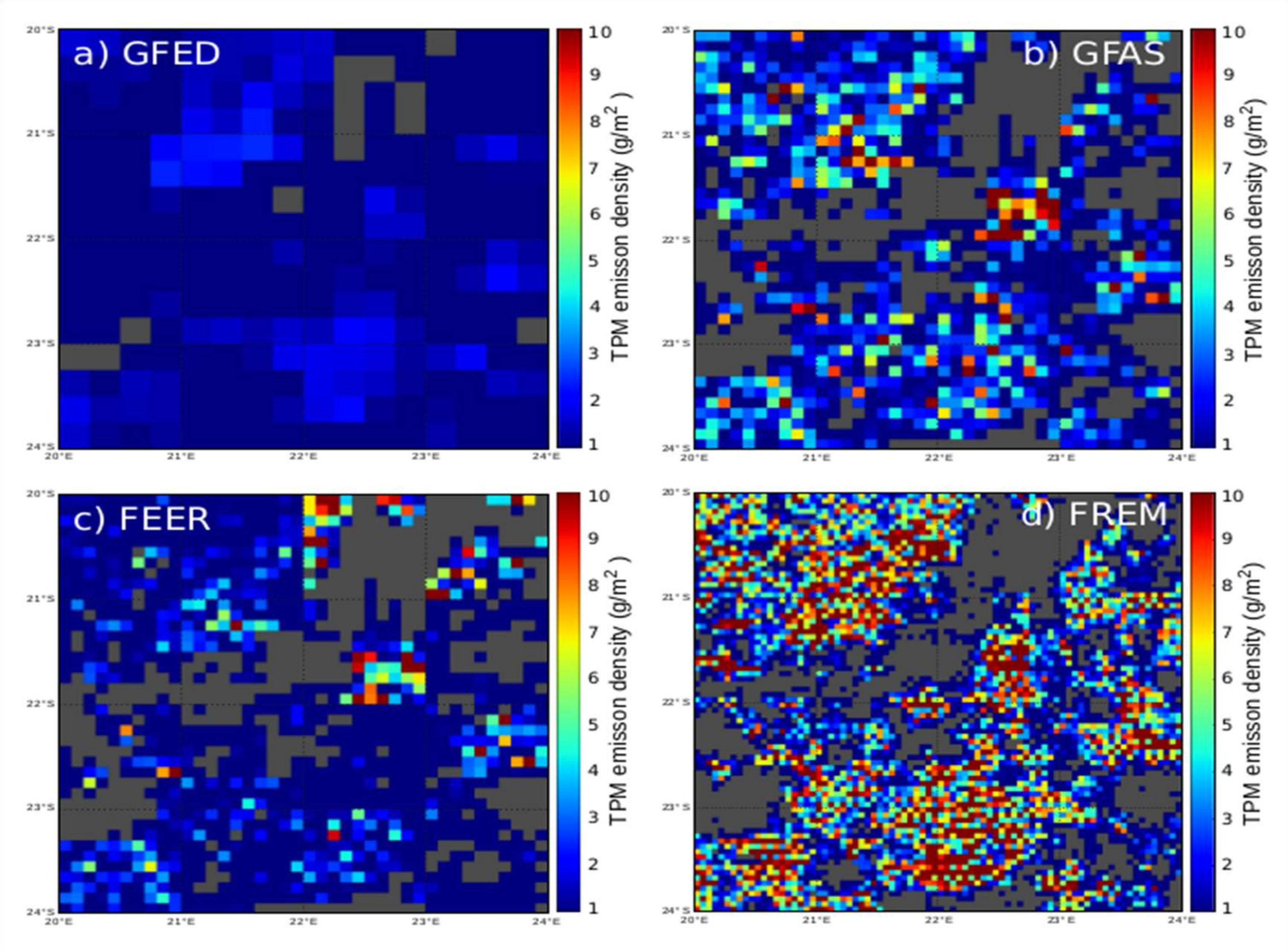
Varying Grid Cell Resolutions




Emissions per grid cell

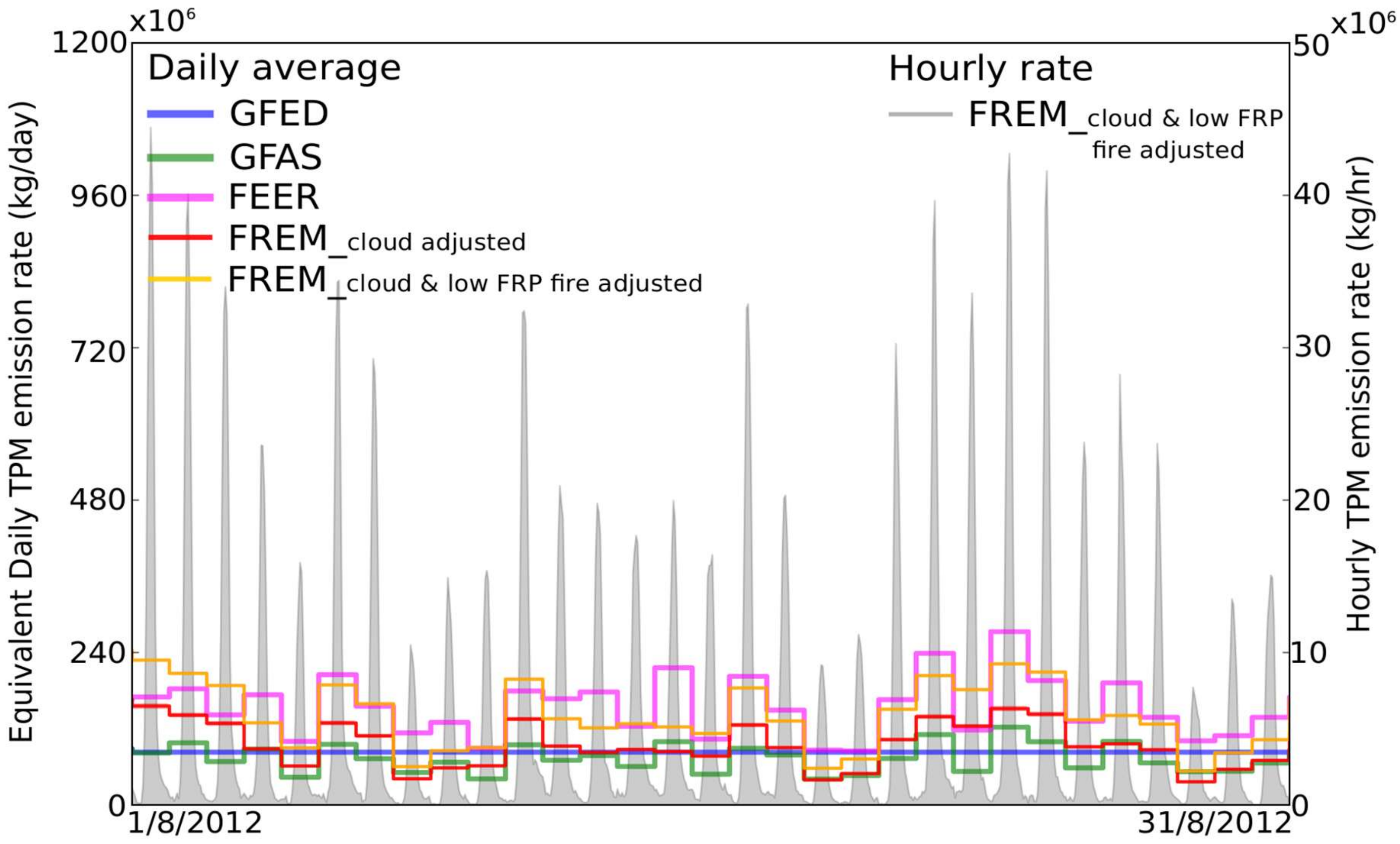
3 g.m$^{-2}$ TPM emissions ≅ FC of 350 g.m$^{-2}$ (Shea et al., 1996) with $EF_{TPM}$ 8.5 g.kg$^{-1}$ (A&M, 2001)

# TPM Emissions Density [$g.m^{-2}$]

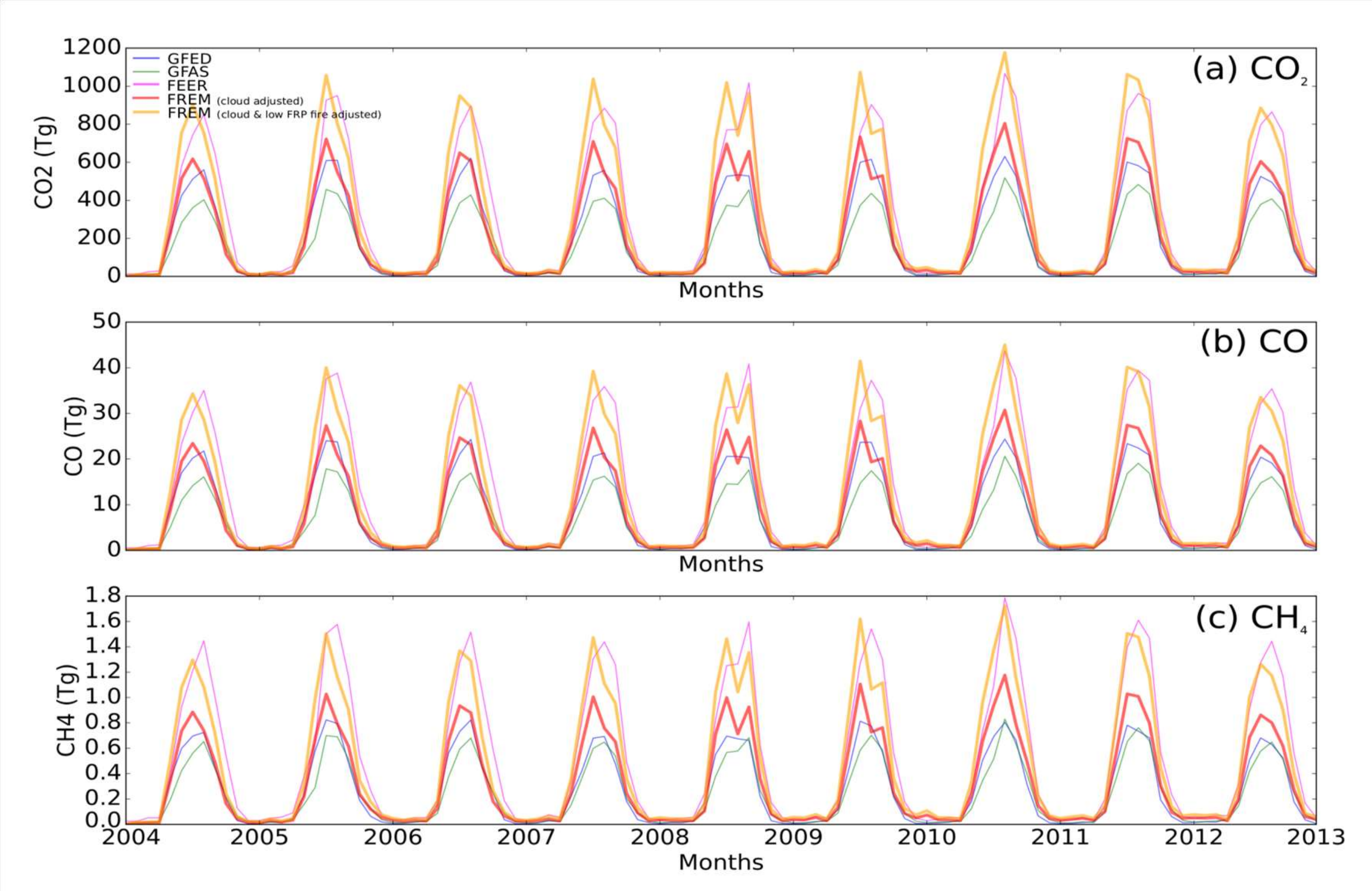



3 $g.m^{-2}$ TPM emissions ≅ FC of 350 $g.m^{-2}$ (Shea et al., 1996) with $EF_{TPM}$ 8.5 $g.kg^{-1}$ (A&M, 2001)

# TPM Emission Rate [Gg.day$^{-1}$]
# Southern Africa August 2012 Detail

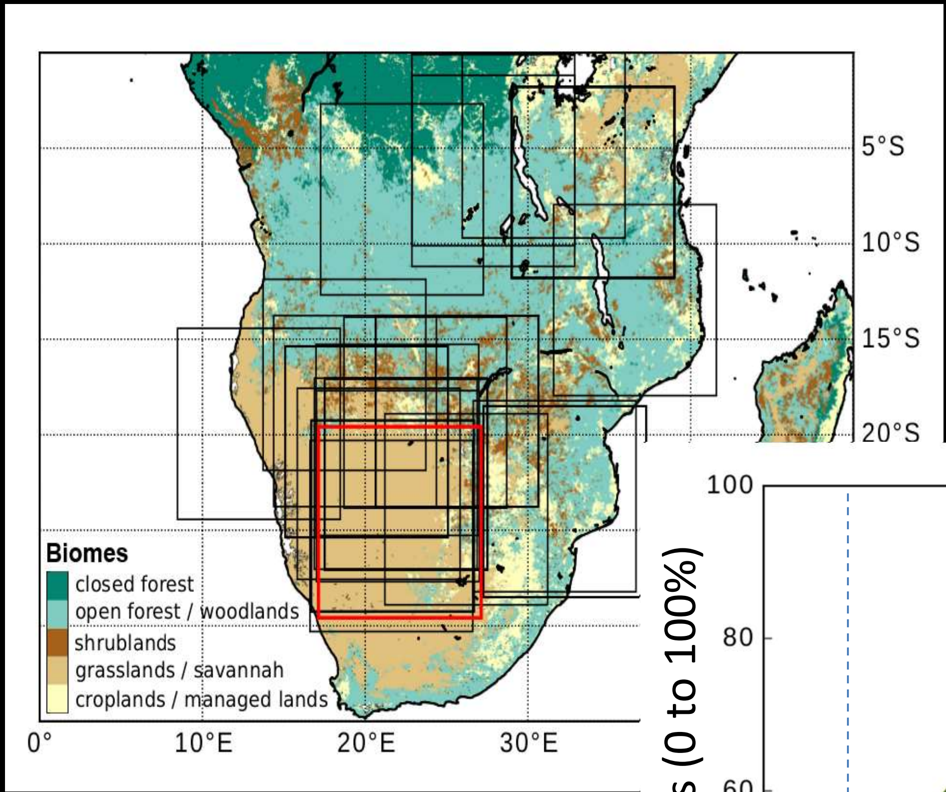


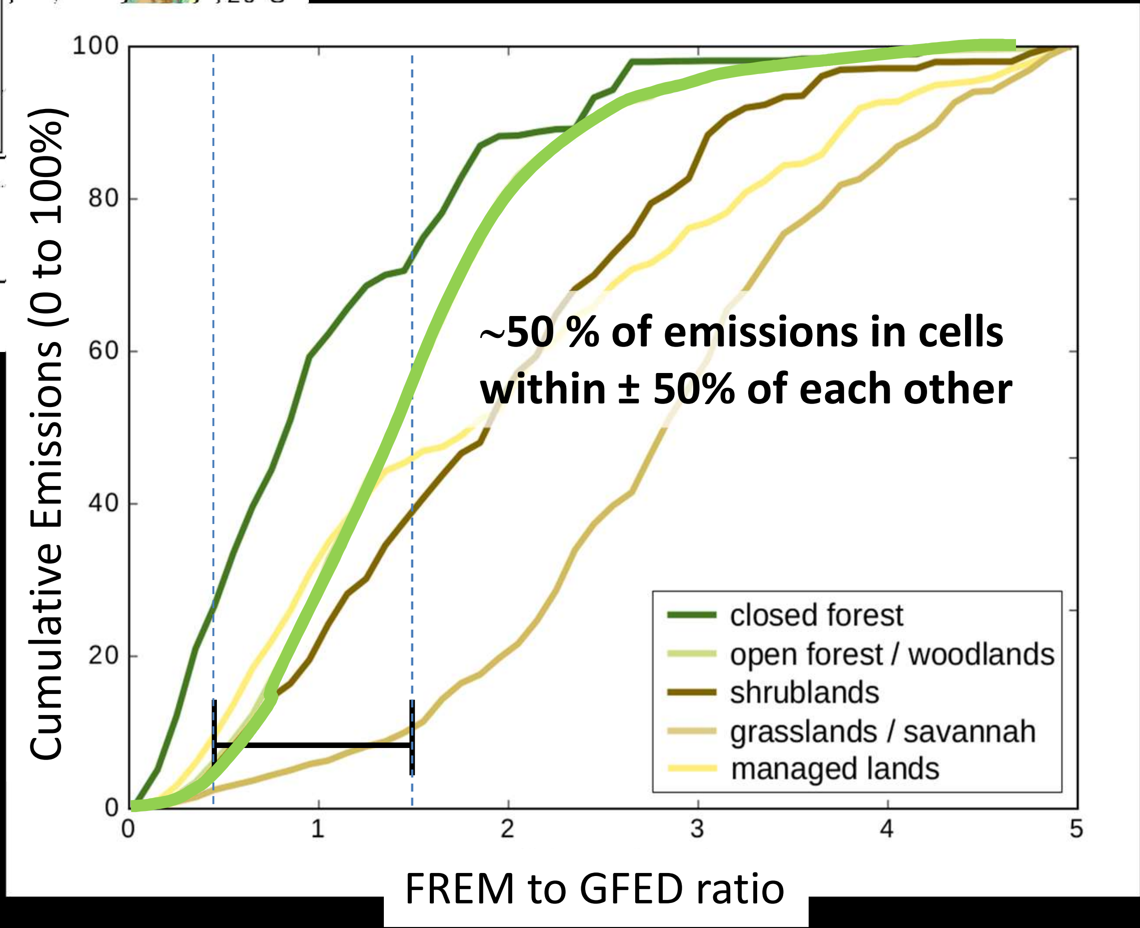
# Extension to Gases [Tg.month$^{-1}$]



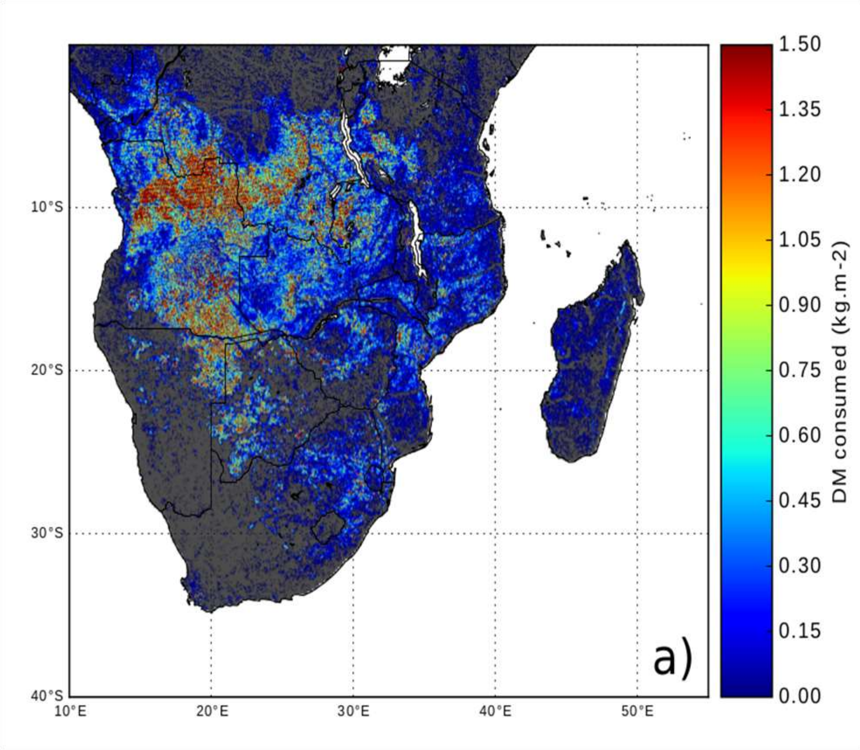

Emission of species X = TPM Emissions . $EF_x$ / $EF_{TPM}$

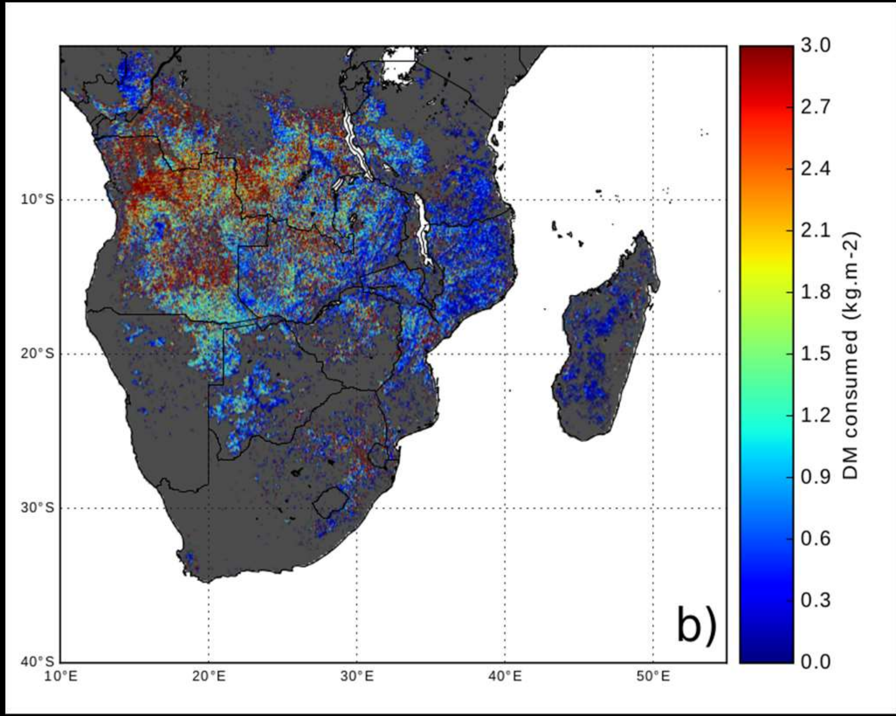
# FREM TPM Emissions to GFED4.1s



# Fuel Consumption per $m^2$




$$\text{Fuel Consumption (kg per grid cell)} = \frac{\text{TPM Emissions (g)}}{\text{TPM Emissions Factor (g.kg}^{-1}\text{)}}$$

# Conclusions, Adv & Limitations

- "FREM" approach delivers emissions at very high spatio-temporal resolutions and in NRT.
- TPM emissions appear in line with atmospheric observations.
- Emissions broadly agree with NASA FEER inventory, and are higher than GFAS and (less so) higher than GFED.
- Fuel consumptions (inc per unit area) can be derived via inverse of emissions factors (and use of BA data).

BUT

- Extent of need for low FRP fire correction currently uncertain.
- FREM not usable at v. high latitudes, and extent to which "undetected" fires needs adjusting for remains uncertain.
- Future work needs a focus on $EF_{TPM}$ & AOD specification.
- Interest in 30 m resolution burned area dataset for FC per $m^2$.