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Generation of Global Biomass Burning Emissions Product Using Fire Radiative Power Retrieved from Multiple Geostationary and Polar-orbiting Satellites

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Outlines

1. Biomass burning emissions from geostationary satellites (GBBEP-Geo)
2. Biomass burning emissions from MODIS fire detections
3. Biomass burning emissions from VIIRS fires
4. Blended global biomass burning emissions product (GBBEPx)
5. Summary

Biomass Burning Emissions from Fire Radiative Power

- **Biomass Burning Emissions = Burned Area × Fuel Loading × Combustion Completeness × Emission Factor**

- Fire Radiative Power (FRP) is theoretically a function of fire size and fire temperature which is closely related to brightness temperature observed from satellite thermal bands (Wooster, 2002).
- Fire radiative energy (FRE) is an integration of FRP during a certain time period of biomass burning. It represents the dry fuel mass combusted within a given burned area or a fire pixel.

$$E = \beta \times FRE \times F$$

Biomass burning emissions (kg)

Combustion rate per unit energy released

Fire radiative energy (MJ)

Emission factors

$$FRE = \int_{t1}^{t2} FRP\,dt$$

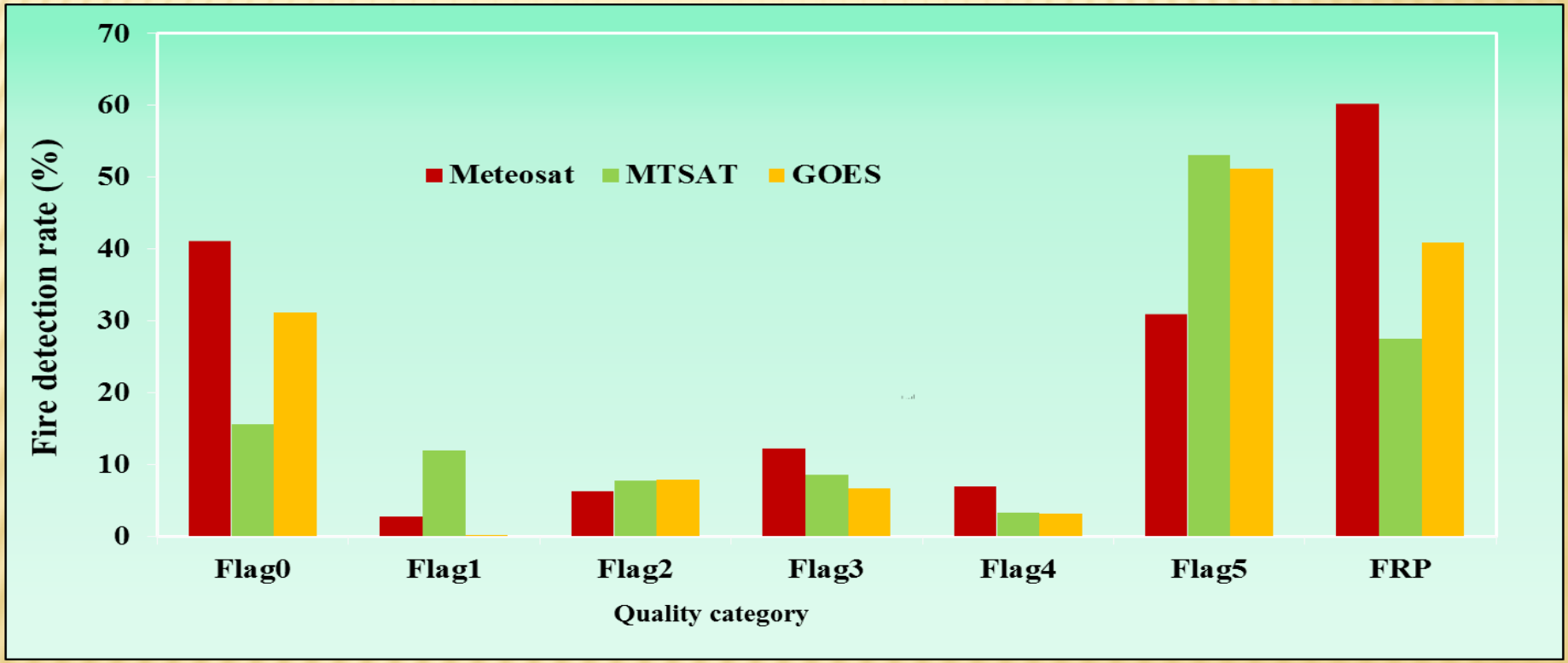
Time of fire end

Time of fire start

Fire radiative power (MW)

Global Biomass Burning Emission Product from Geostationary Satellites (GBBEP-Geo)

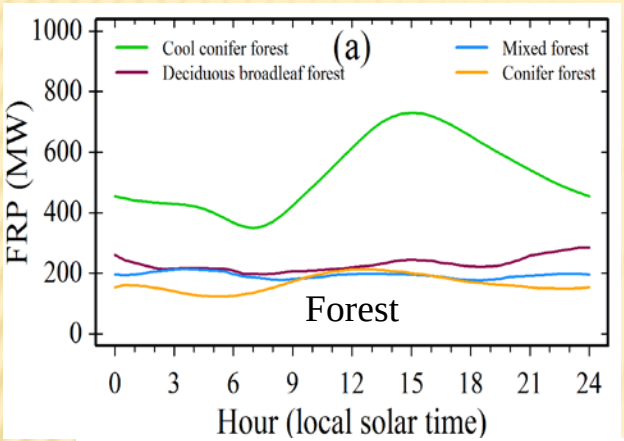
Wildfire Detections from Geostationary Satellites Using Wildfire Automated Biomass Burning Algorithm (WF_ABBA)

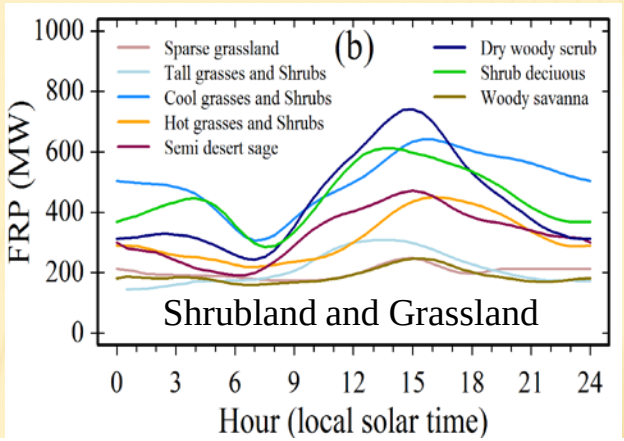


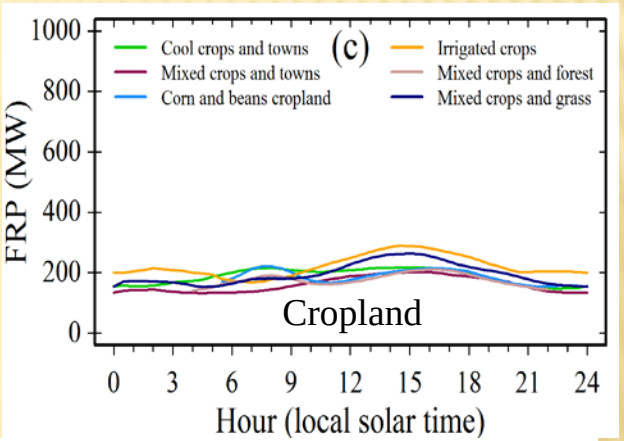
Flag0-- good quality fire pixel
Flag1-- saturated fire pixel
Flag2--cloud contaminated fire pixel
Flag3-- high-probability fire pixel
Flag4-- medium-probability fire pixel
Flag5-- low-probability fire pixel

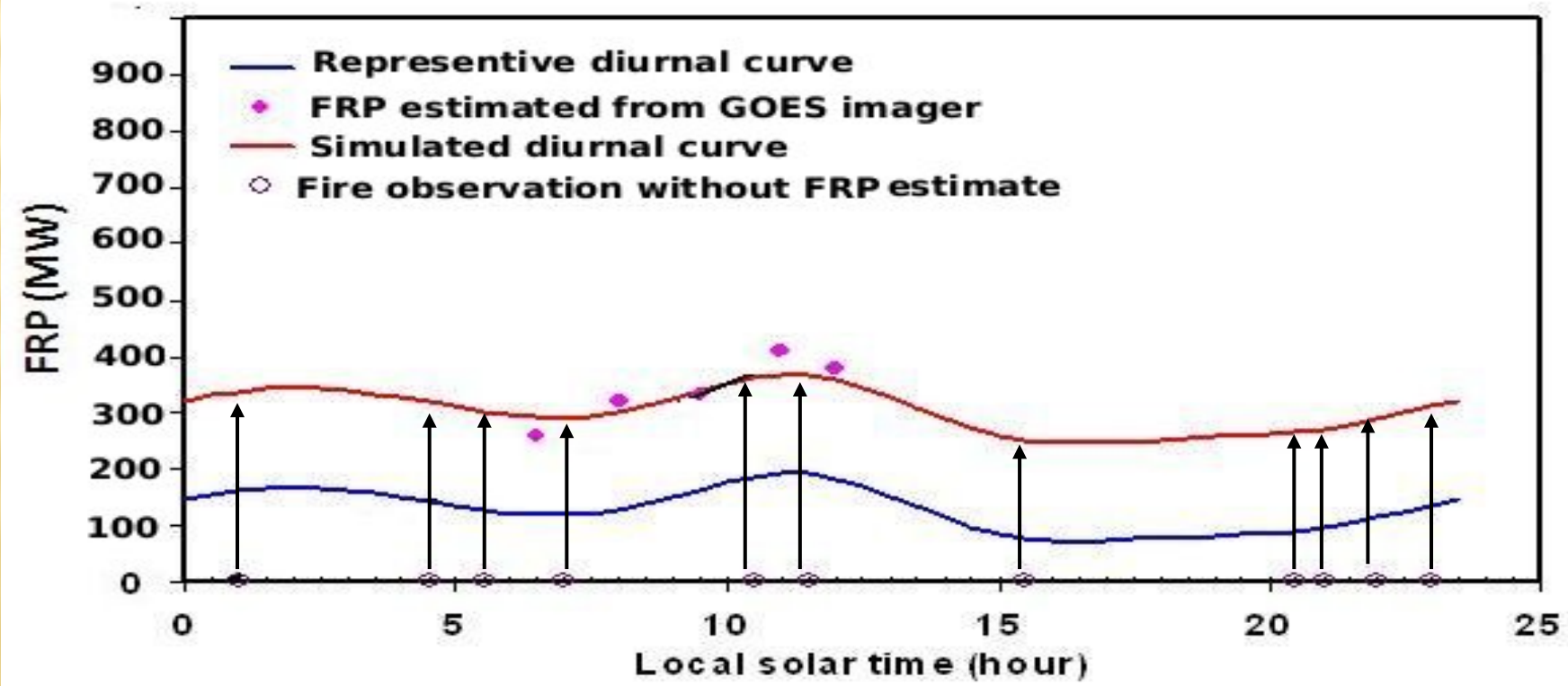
FRE from Reconstructed Diurnal FRP in a Fire Pixel

FRP diurnal climatology for different ecosystems

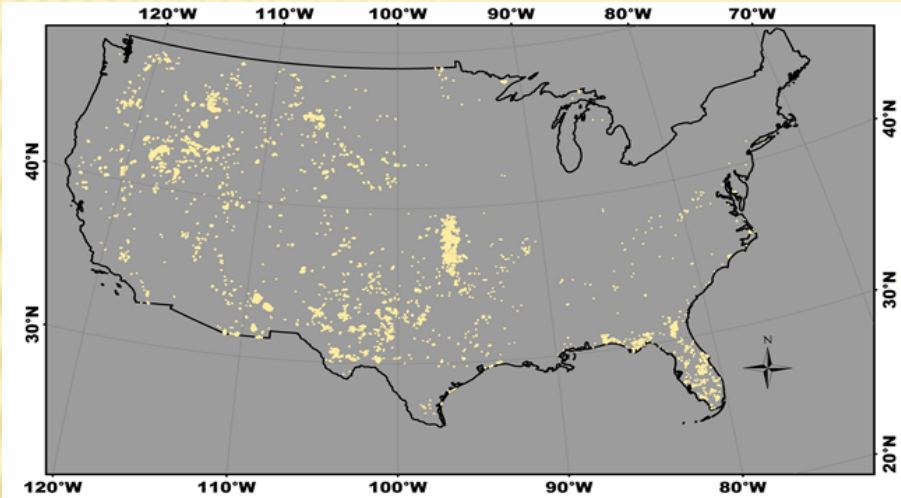




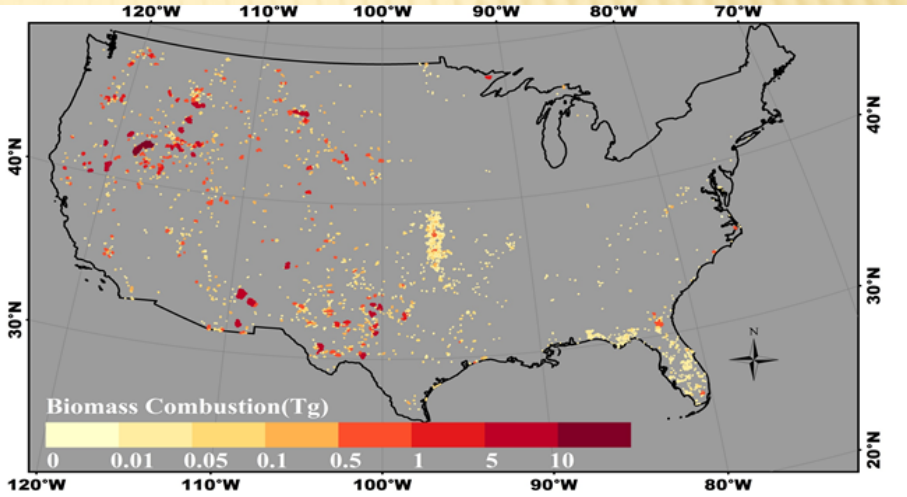




Biomass Combustion Rate (β) – Determined from GOES FRE and Biomass Combusted in ETM+/TM Burn Scars

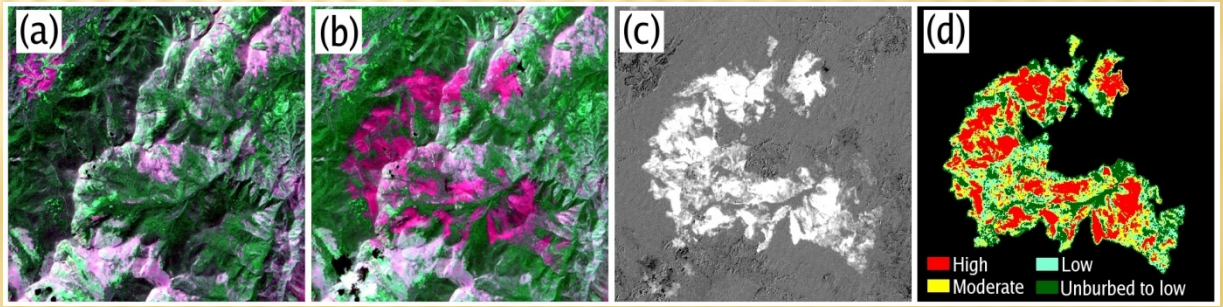


Landsat TM/ETM+ Burn Scars (2616) in 2011-2012 Wildfires.

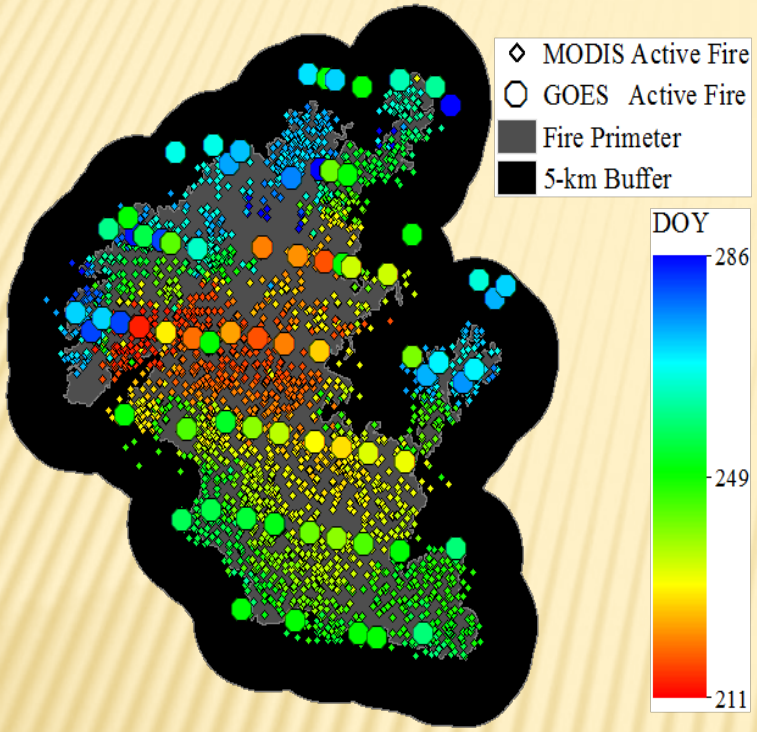


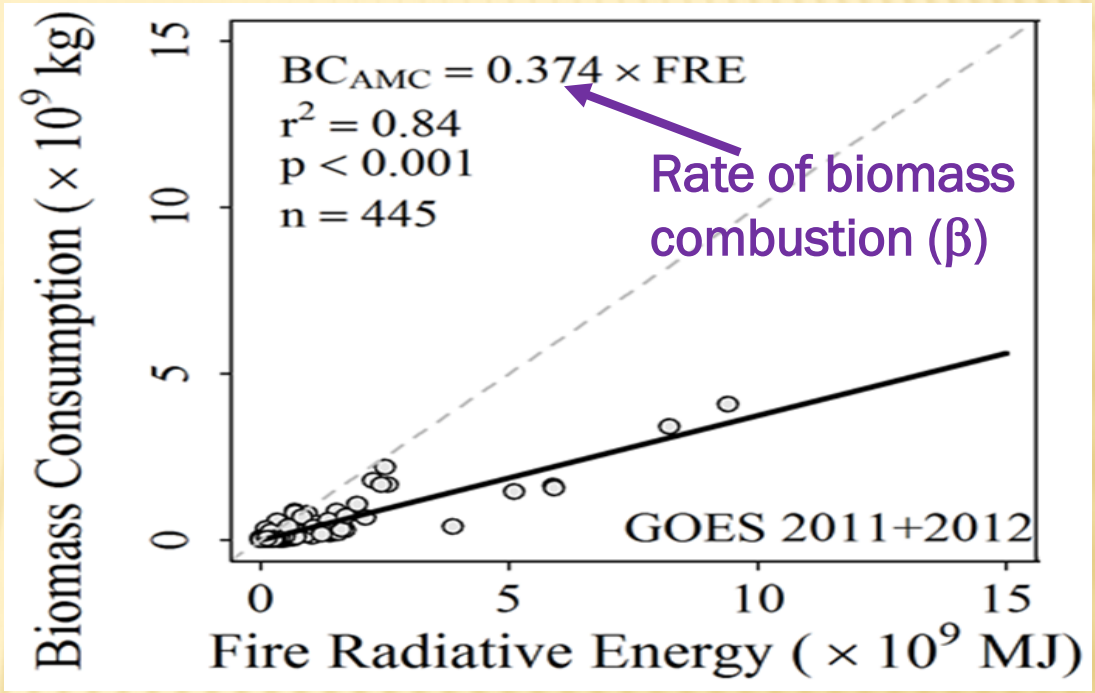
Biomass combustion ($BC_{TM/ETM+}$, unite: Tg = 10^{12} g) at individual burn scars.

Landsat ETM+/TM →fuel loading → burn scars → burned area and burn severity → biomass combustion



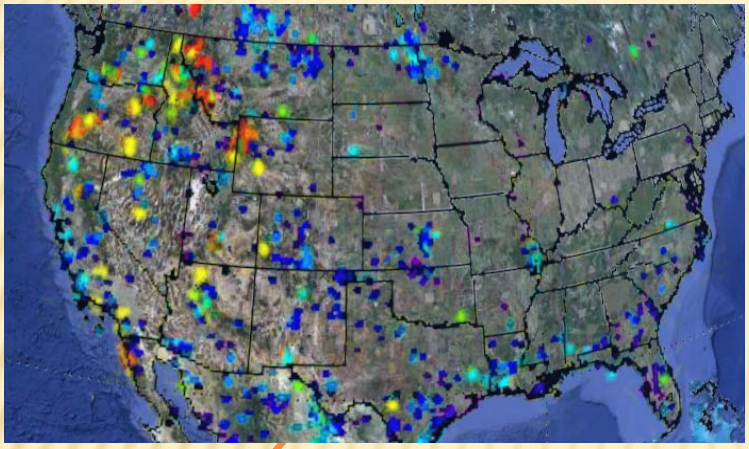
Biomass Combustion Rate (β) –Determined from GOES FRE and Biomass Combusted within TM Burn Scars

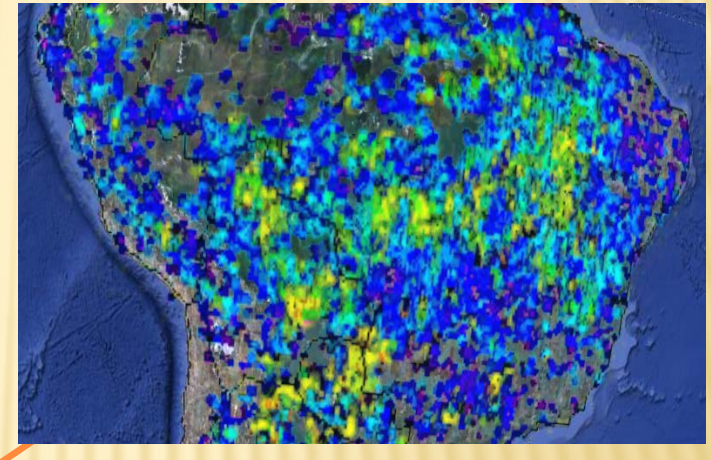


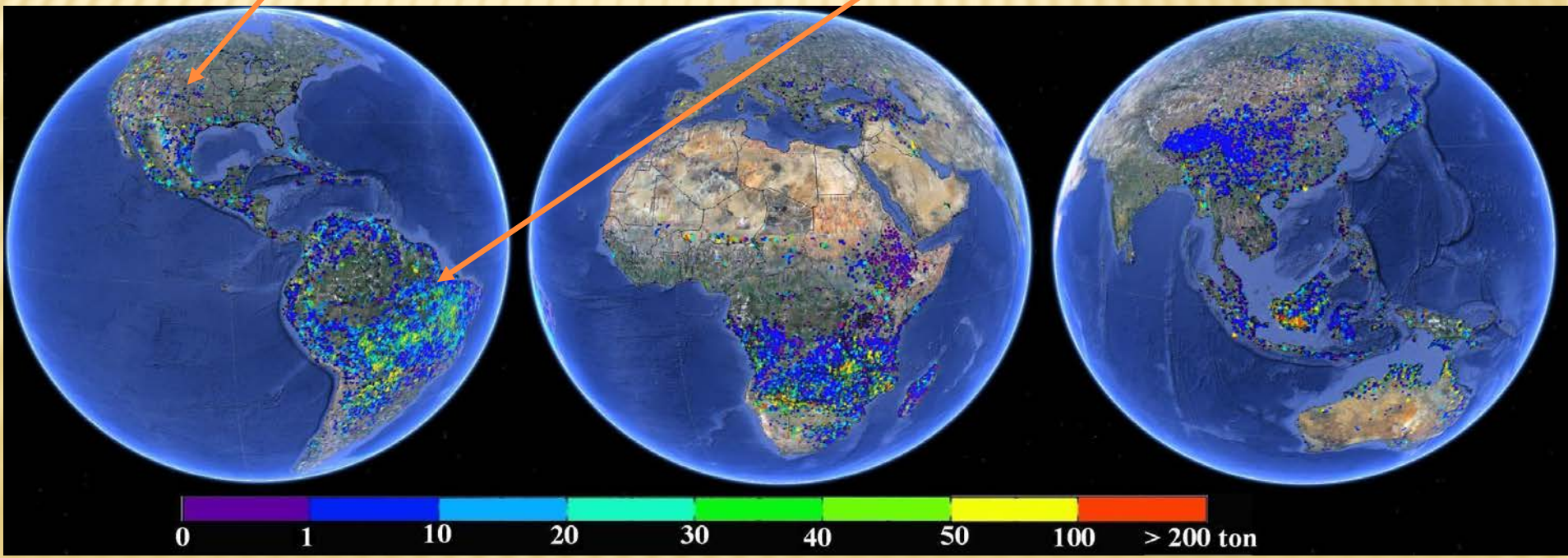


- Each pair of sample indicates the GOES FRE and burn- severity-based biomass combustion within a burn scar detected from TM imagery.
- The relationship between FRE and biomass combustion is used to determine the rate of biomass combustion (β) for the FRE released.
- Our result is similar to the β value of 0.368±0.015 kg/MJ (Wooster et al., 2005)

Estimates of Global Biomass Burning from FRP (GBBEP-Geo) –– PM2.5 in Sept. 15-30, 2009





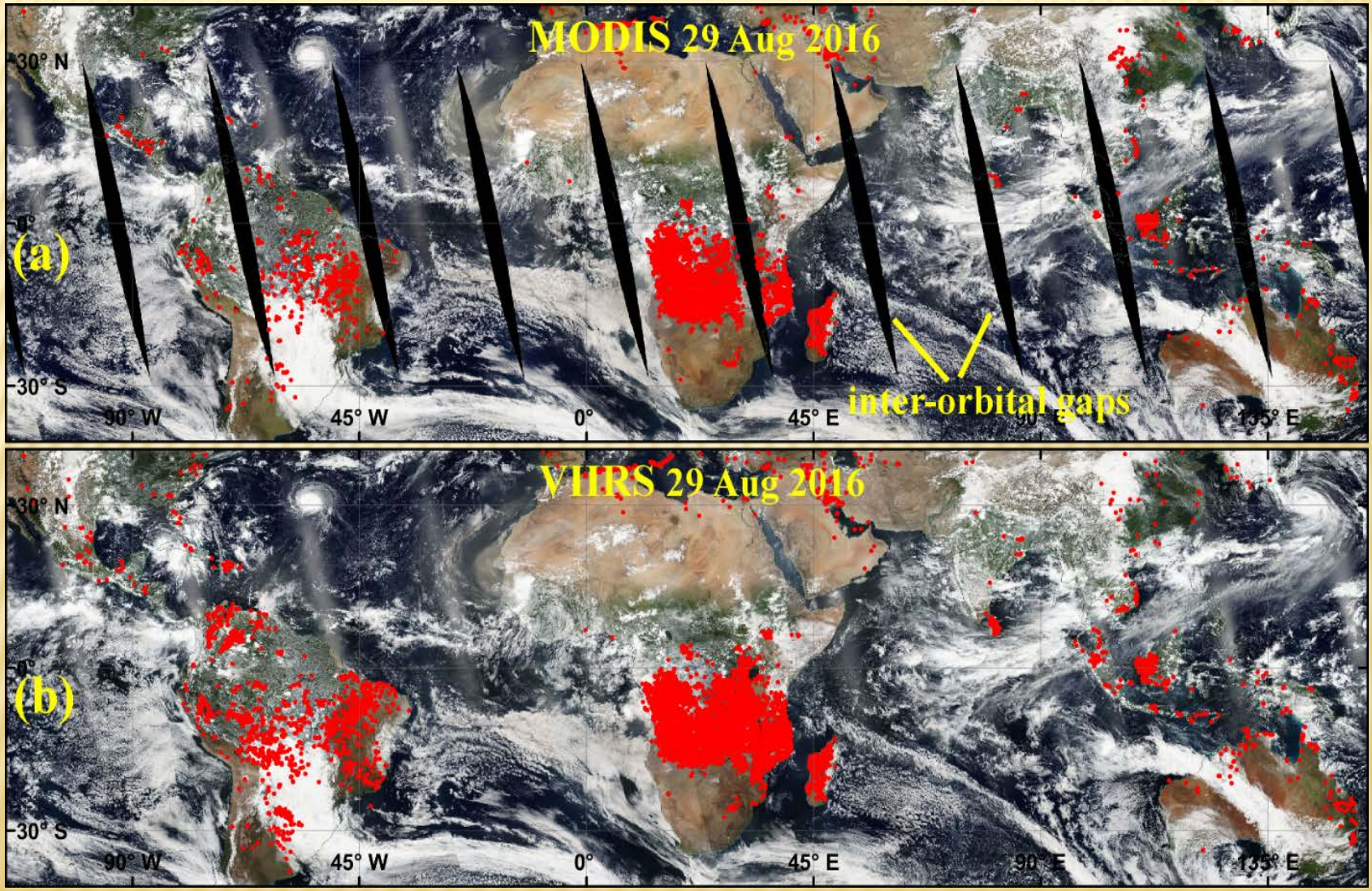


Quick Fire Emission Dataset (QFED) from MODIS Fire Data

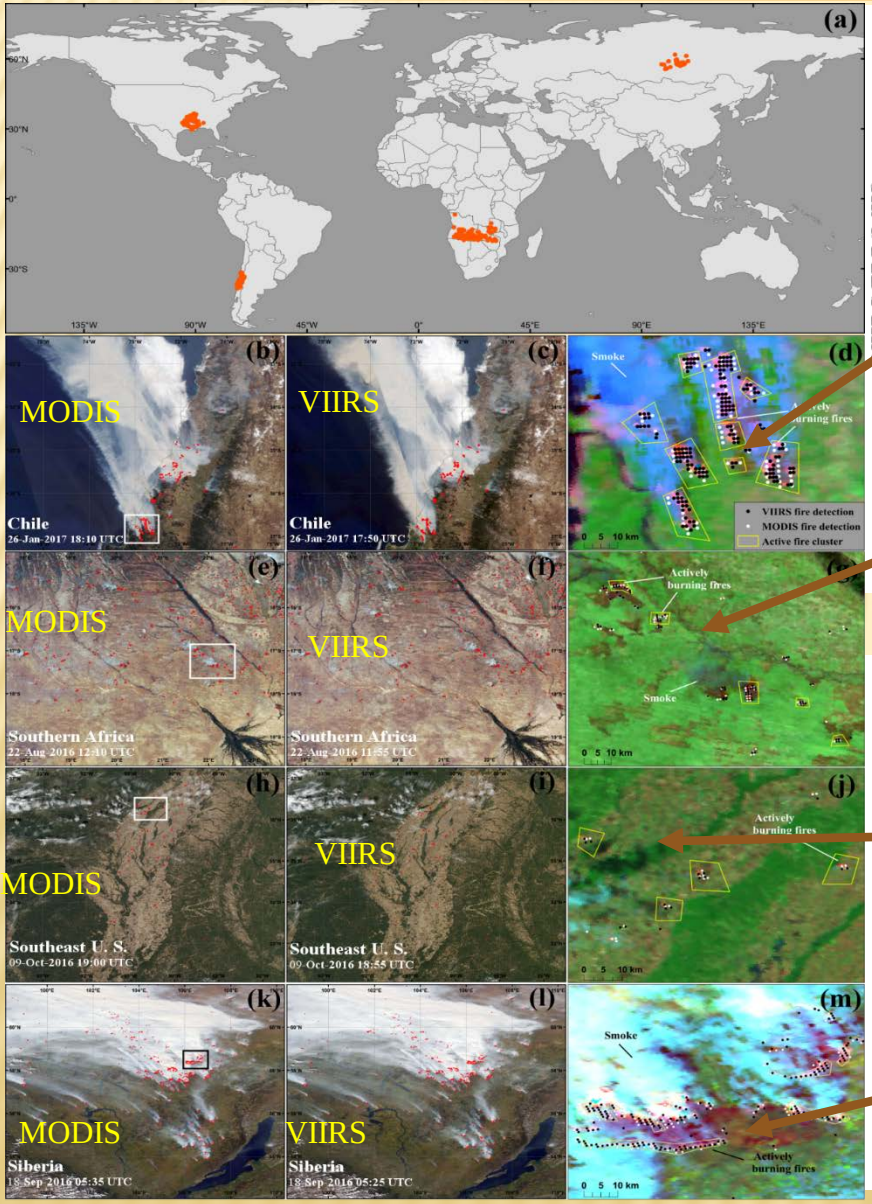
- QFEDv2:
  - MODIS FRP for various biome types
  - Combustion factors obtained by comparing with GFED product
  - Fire emissions are calculated from FRP flux and combustion factors
  - Fire emissions scaling factors are calculated by comparing GFS-GOCART-modeled AOD (Fire emissions as input) with MODIS observed AOD.
- Emissions are then tuned using scaling factors respectively for Terra MODIS and Aqua MODIS, which are then combined to produce daily global emissions.
- Finally, QFED product at 0.25x0.3125 degree is merged from Terra and Aqua daily fire emissions of BC, OC, SO2, CO, CO2, PM2.5

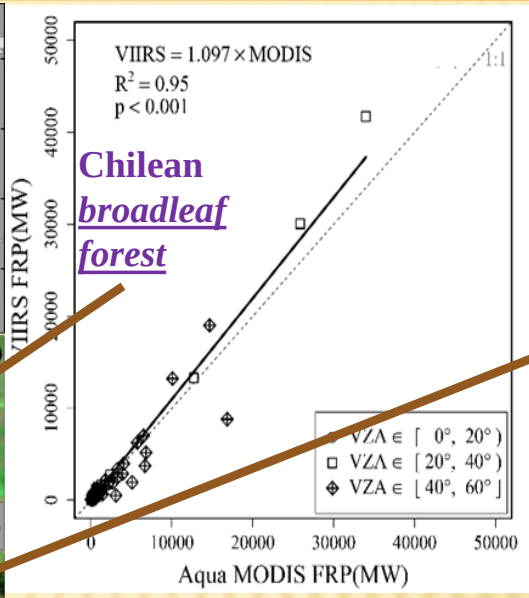
Darmenov, A., and da Silva, A. 2013, The Quick Fire Emissions Dataset (QFED) - Documentation of versions 2.1, 2.2 and 2.4, In M. J. Suarez (Editor), *Technical Report Series on Global Modeling and Data Assimilation*, Volume 32.

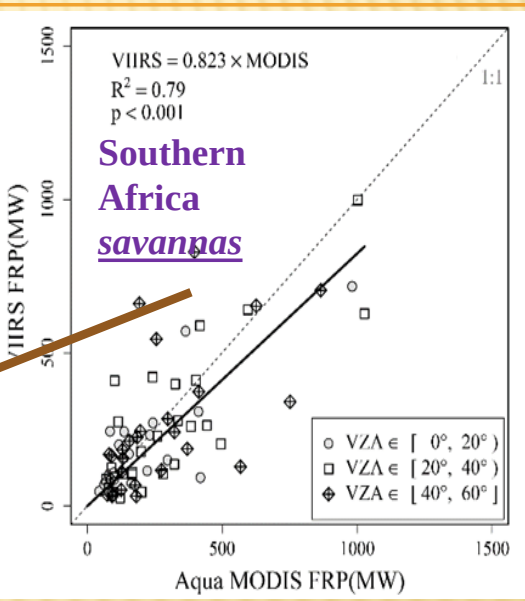
Fire Emissions from VIIRS: Spatial Comparisons between MODIS and VIIRS FRP

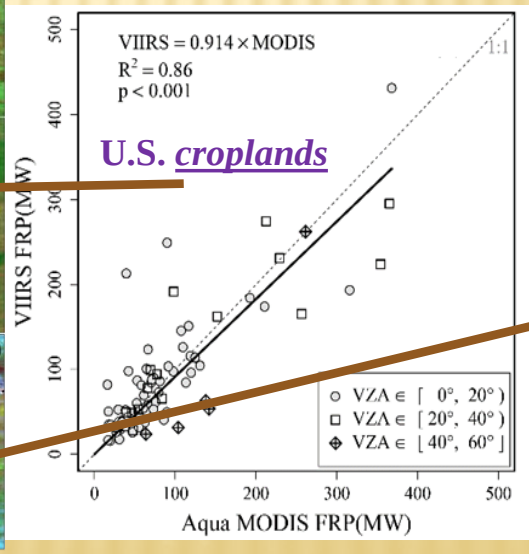


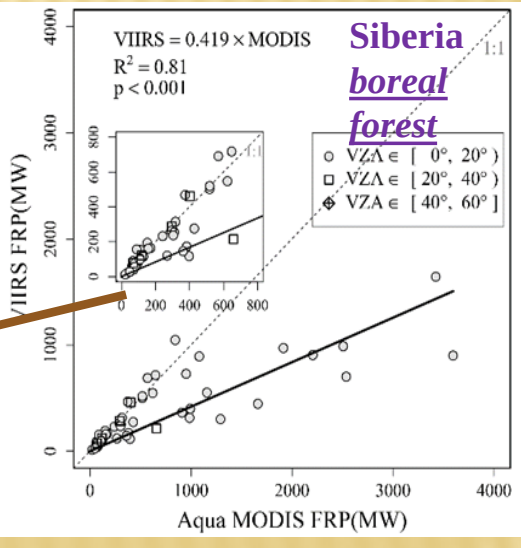
Comparison between FRP Observations from MODIS and VIIRS



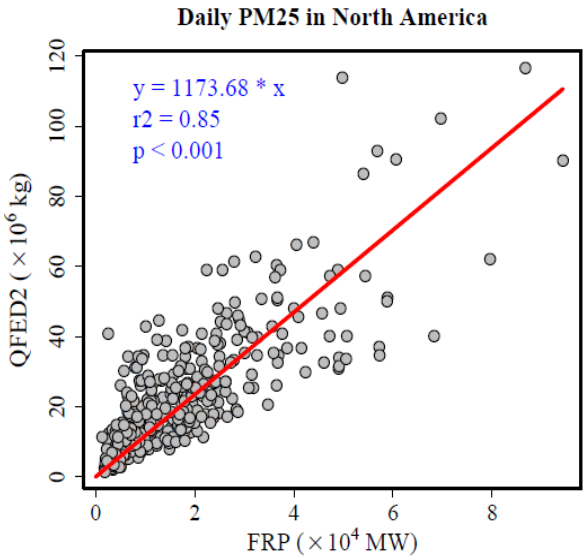


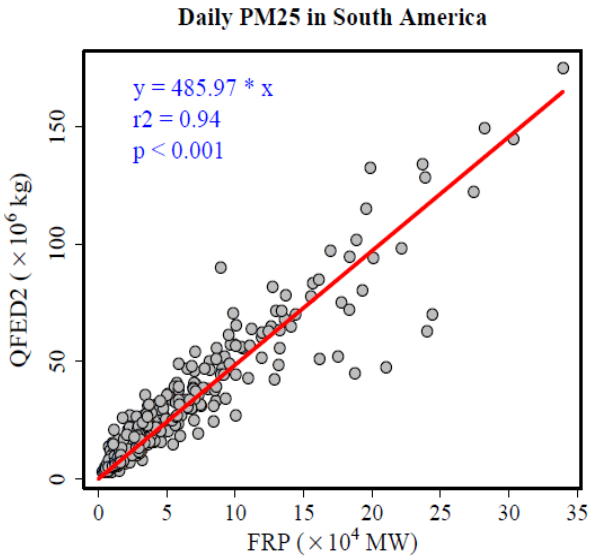


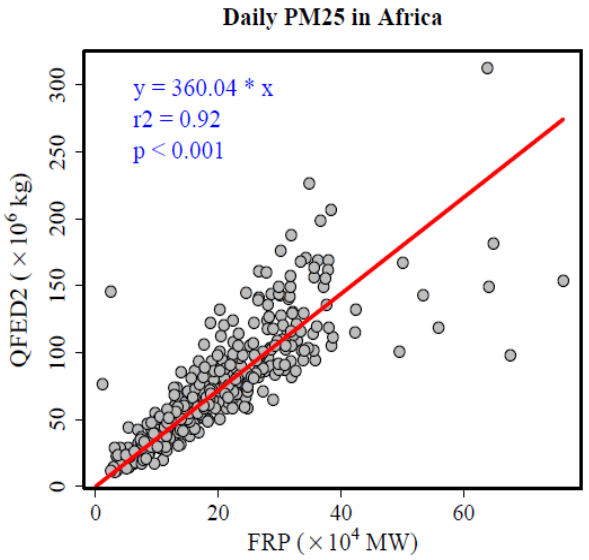


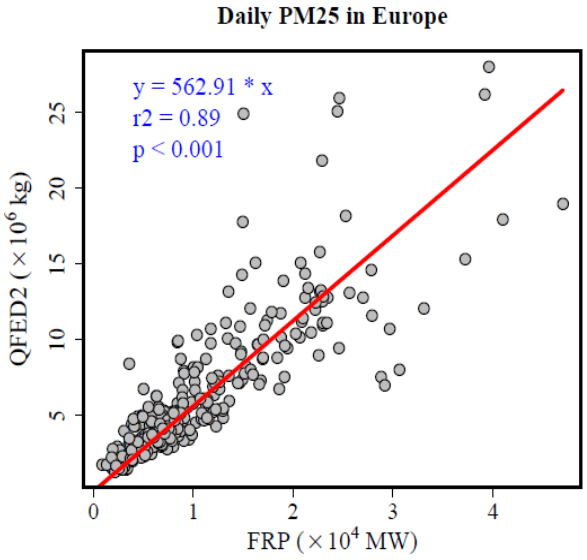


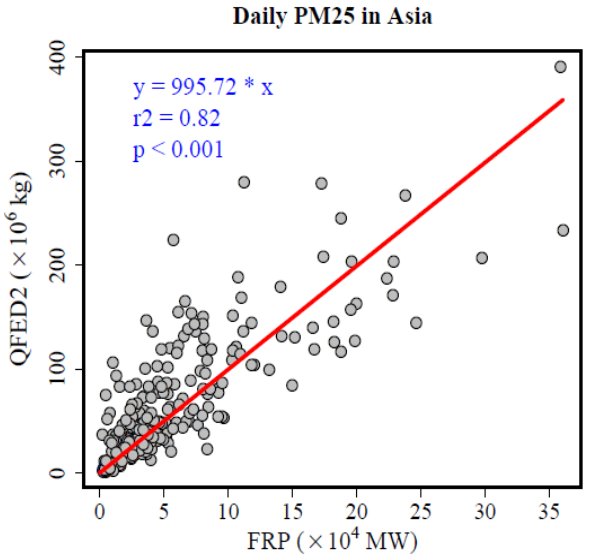
Correlation Model between VIIRS 750m FRP and Fire Emissions from QFED (*April 2016 - March 2017)*

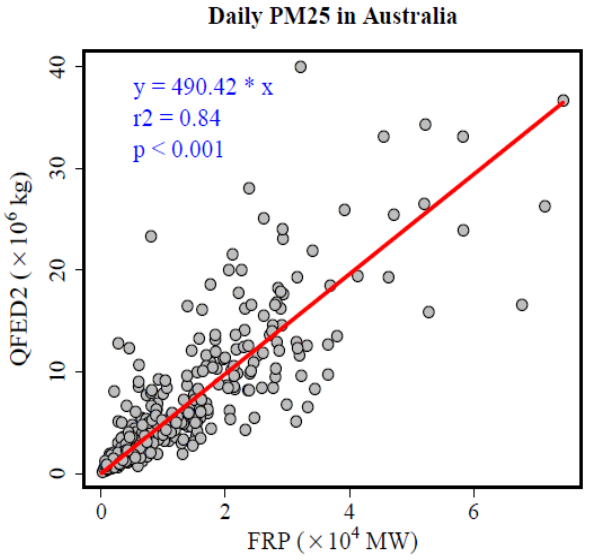




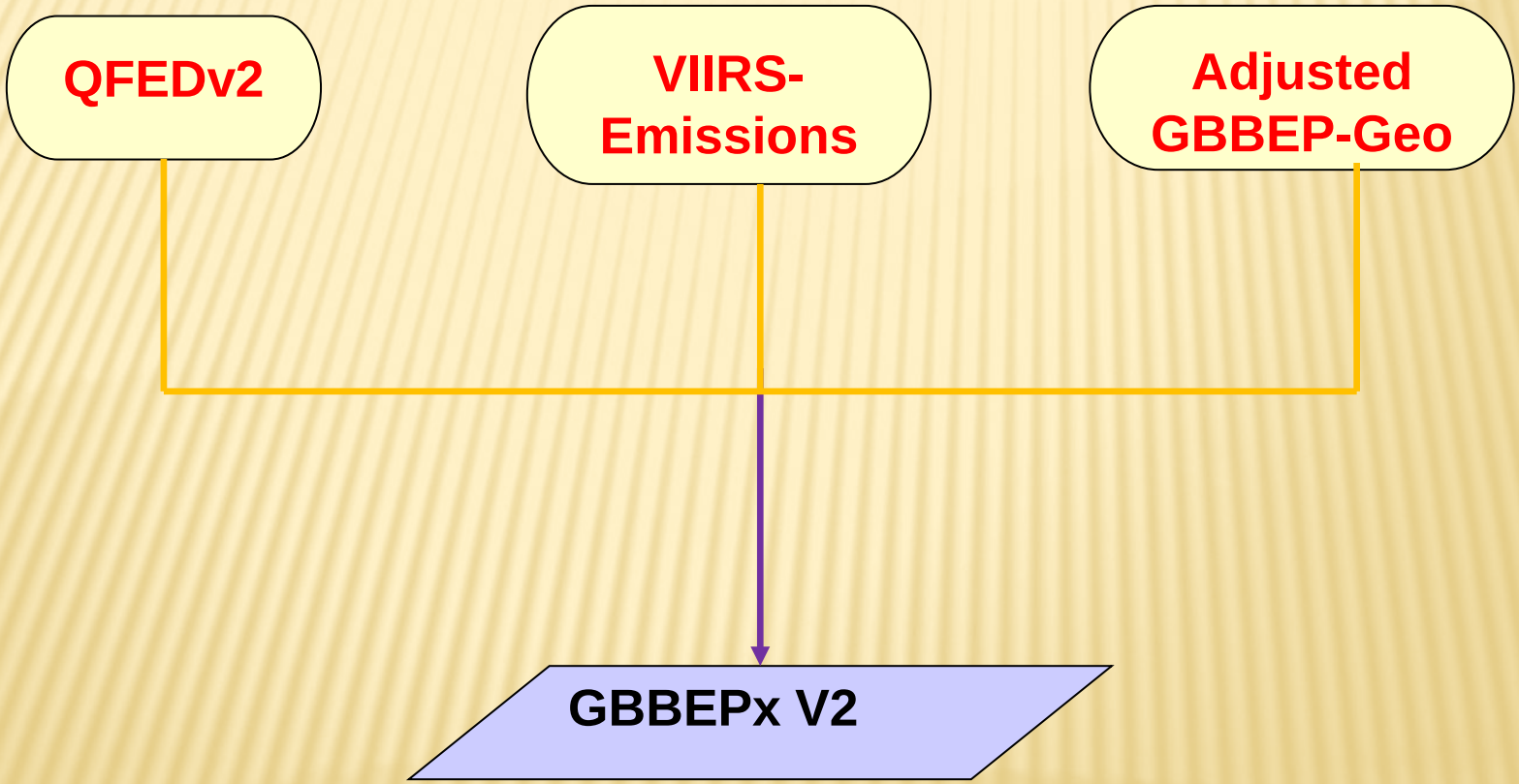




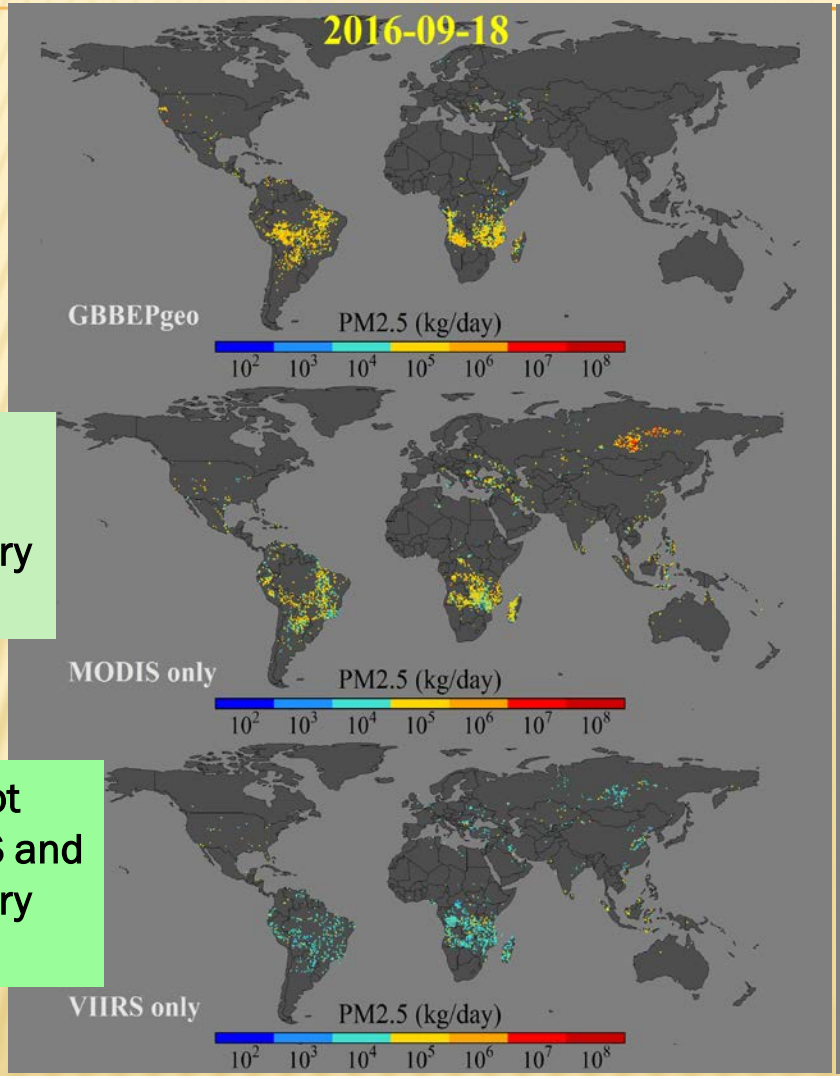


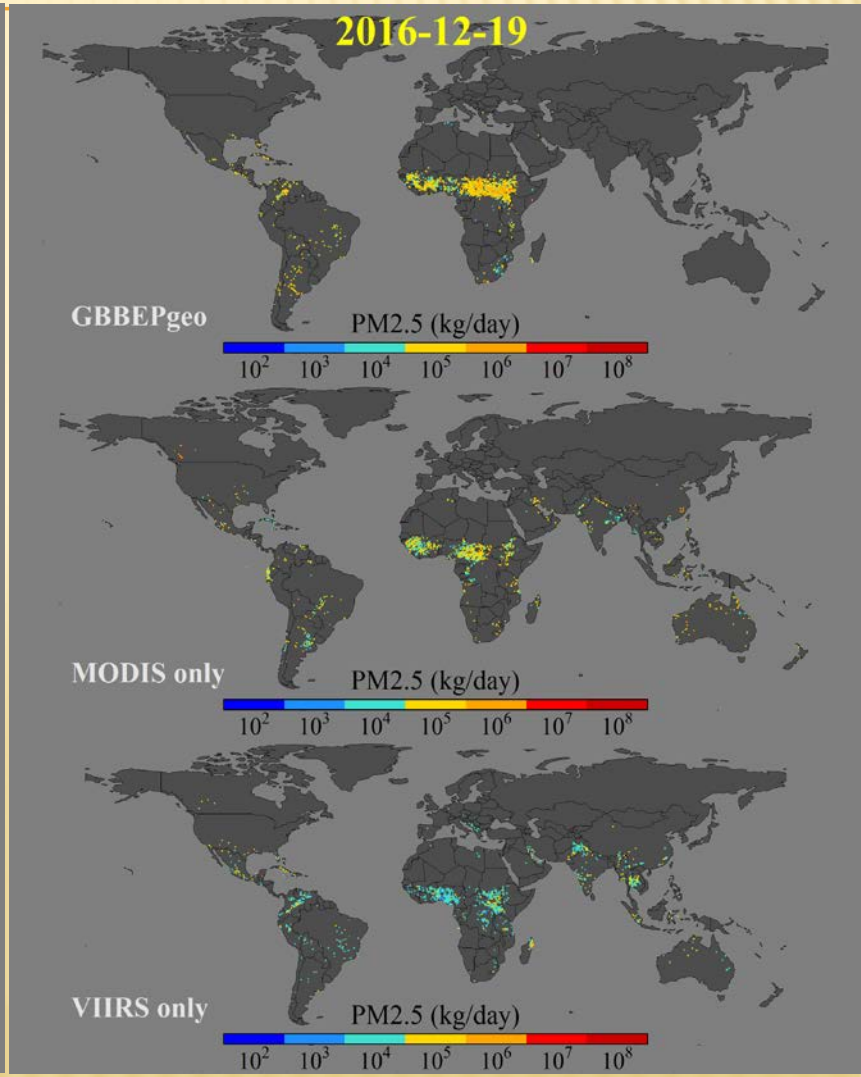


GBBEPx V2: Integrating QFED, GBBEP-Geo, and VIIRS Fire Emissions



Emissions: GBBEPgeo vs. GBBEPx vs. GBBEPx (VIIRS)





MODIS but not from geostationary satellites

VIIRS but not from MODIS and geostationary satellites

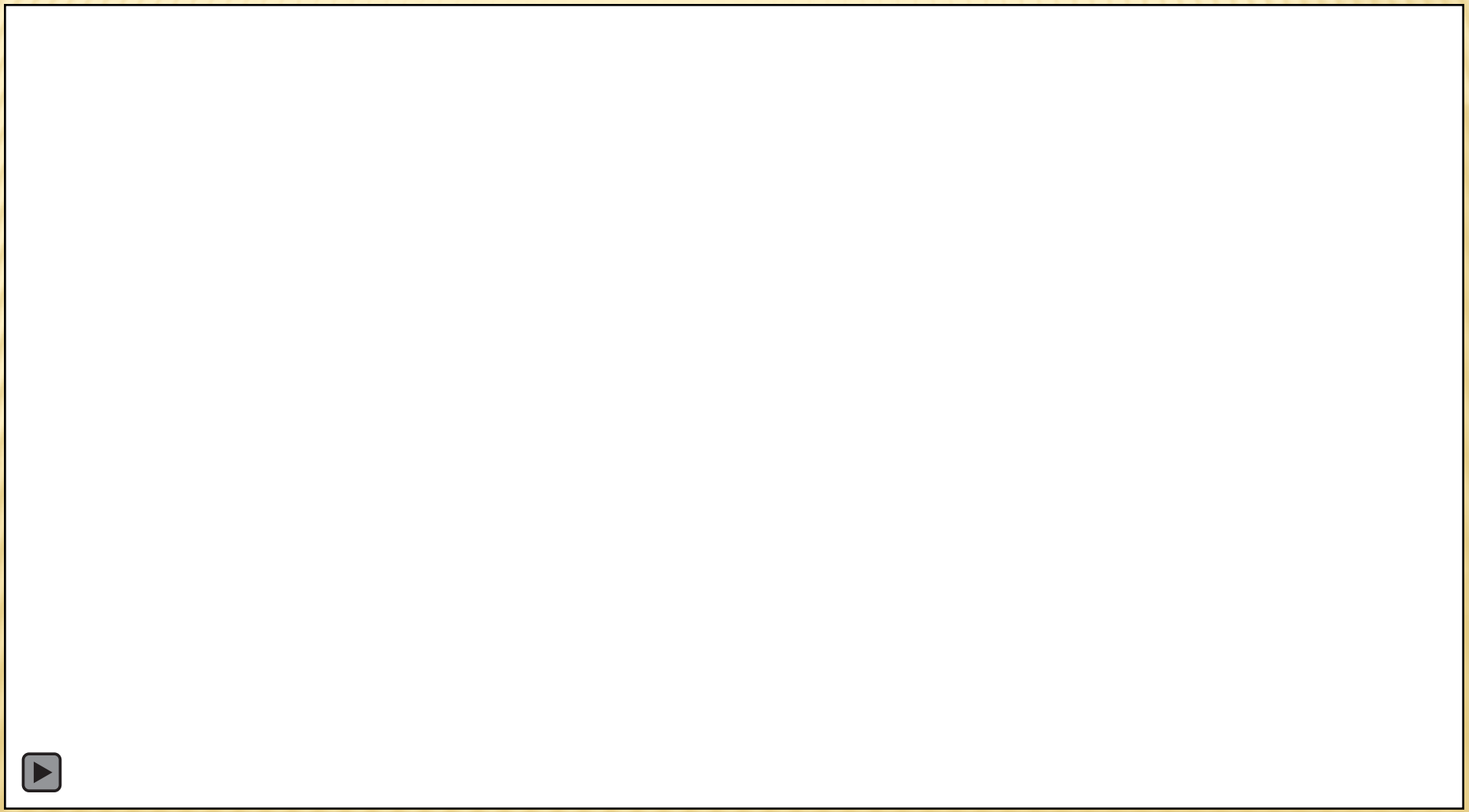
VIIRS is capable of detecting some small and cool fire emissions that cannot be detected from both MODIS and Geostationary satellite observations

GBBEPx V2 Product

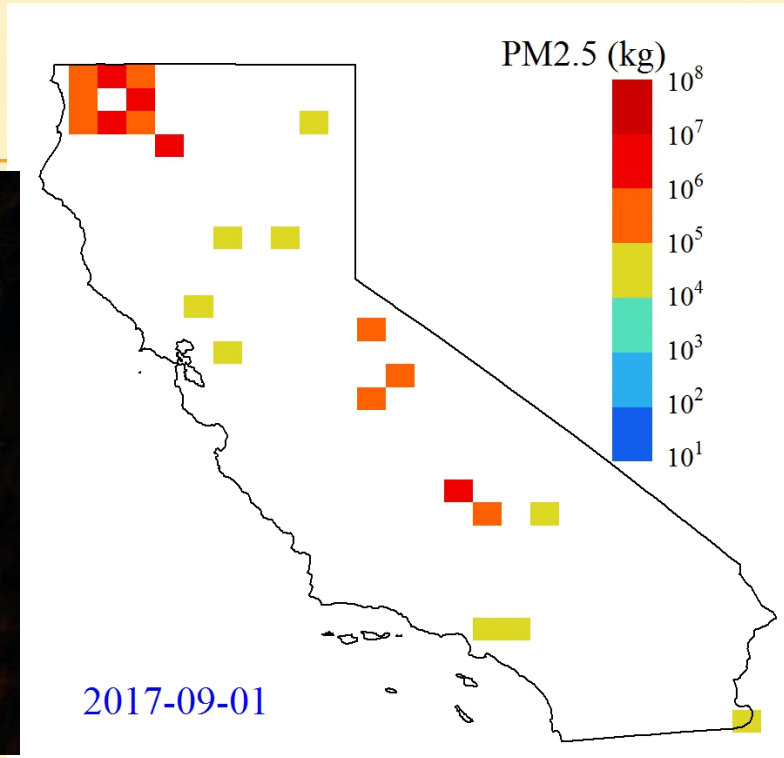
GBBEP-Geo_QFED=(GBBEP-Geo + QFED)/2 if both products available
GBBEP-Geo_QFED=GBBEP-Geo if QFED not available
GBBEP-Geo_QFED=QFED if GBBEP-Geo not available

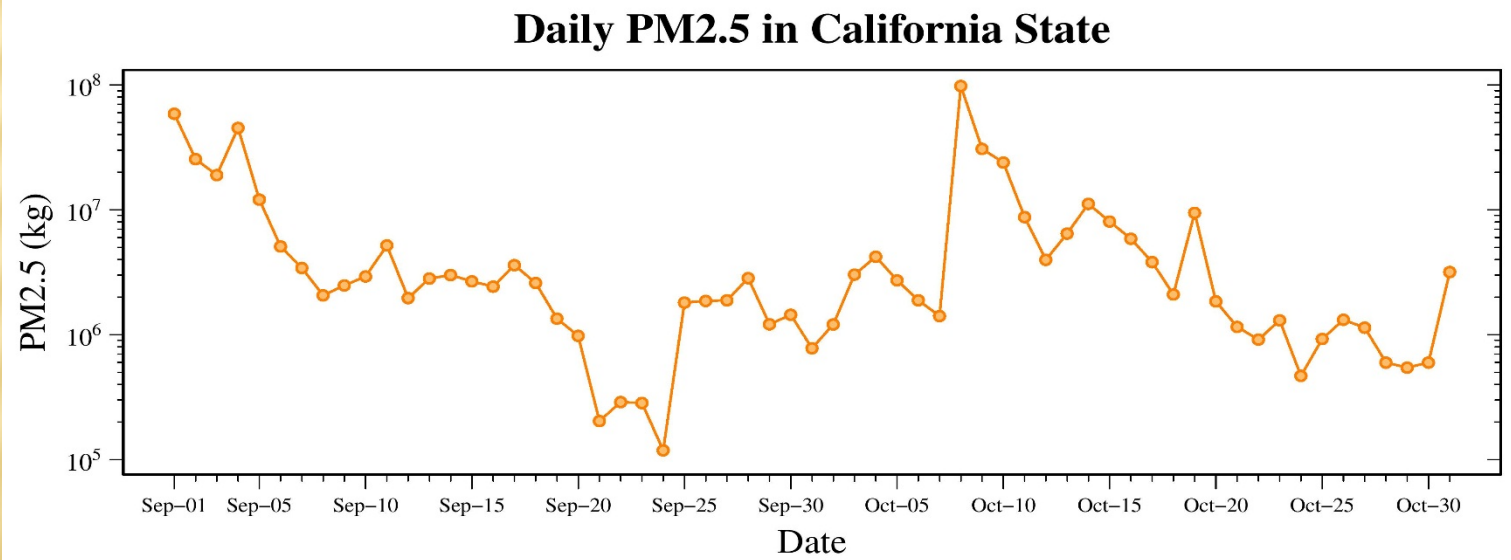
Name	Type	Description	Dimension
BC	Daily output	Emission flux (kg s-1 m-2)	0.25°x0.3125° grid globally
OC	Daily output	Emission flux (kg s-1 m-2)	0.25°x0.3125° grid globally
SO2	Daily output	Emission flux (kg s-1 m-2)	0.25°x0.3125° grid globally
CO	Daily output	Emission flux (kg s-1 m-2)	0.25°x0.3125° grid globally
PM2.5	Daily output	Emission flux (kg s-1 m-2)	0.25°x0.3125° grid globally
CO2	Daily output	Emission flux (kg s-1 m-2)	0.25°x0.3125° grid globally

GBBEPx V2
Daily PM2.5 from June 15th to August 15th in 2017

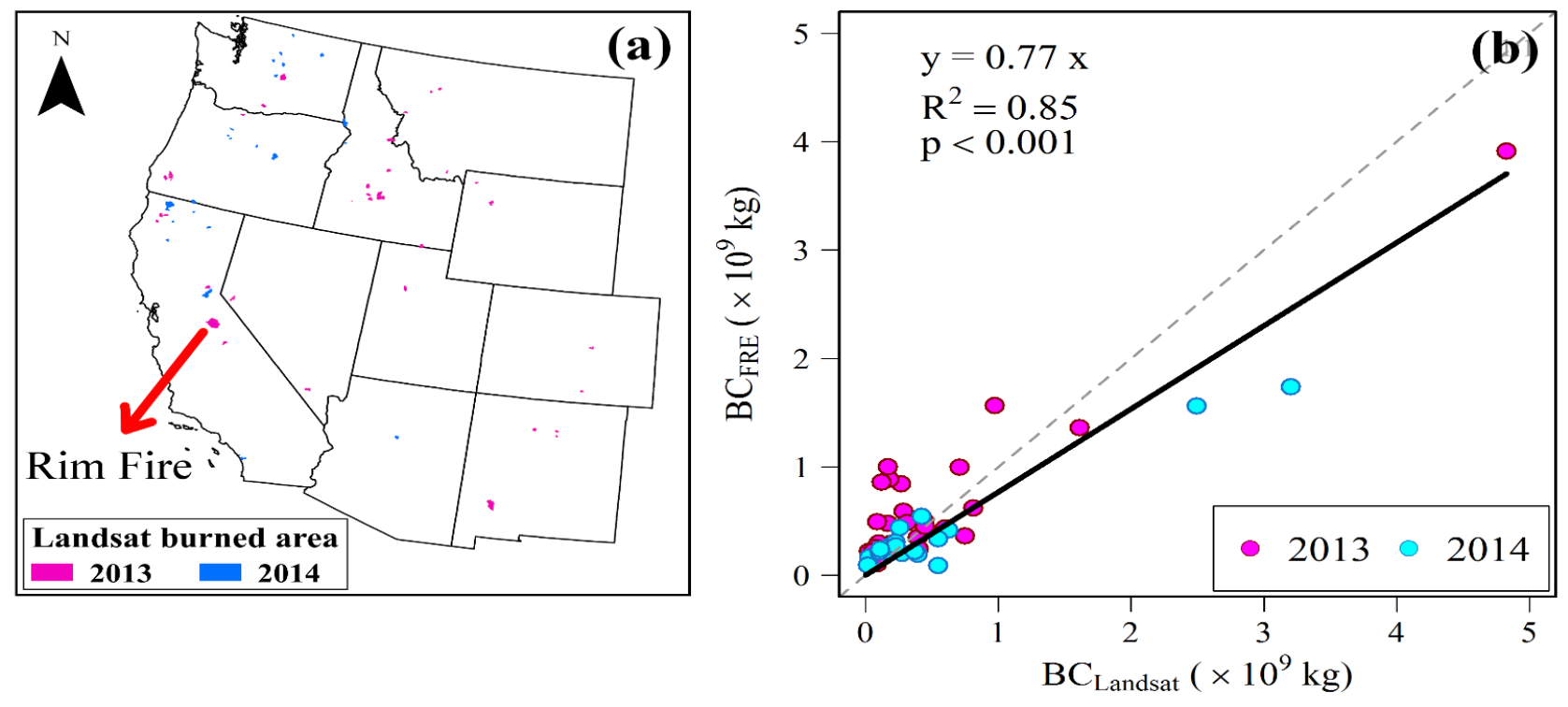


Biomass Burning Emissions in California



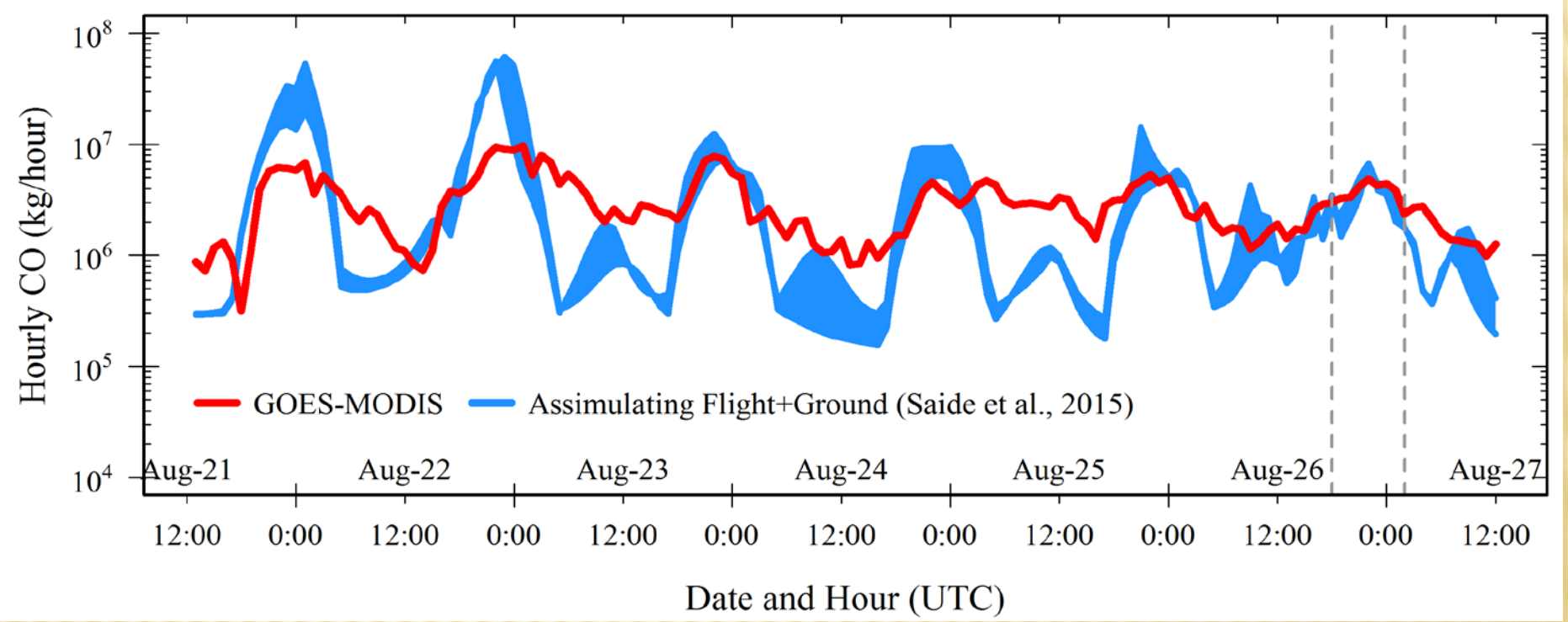


Validation/Evaluation: Using Biomass Consumption in Landsat Burn Scars



Comparison between the GOES-MODIS-FRE (GBBEP) based total biomass consumption (BC_{FRE}) and the Landsat-burned-area-based total biomass consumption ($BC_{Landsat}$) across the west CONUS. (a) Distribution of the 47 selected fire events from 2013 to 2014. (b) Scatterplot of BC_{FRE} against $BC_{Landsat}$. Overall difference: 23%.

Validation/Evaluation: Using Modeled Emissions



Comparison of hourly CO emissions in the Rim Fire. The red lines is the GOES-MODIS CO estimates, and the light blue area represents the estimates simulated by the WRF-Chem model.

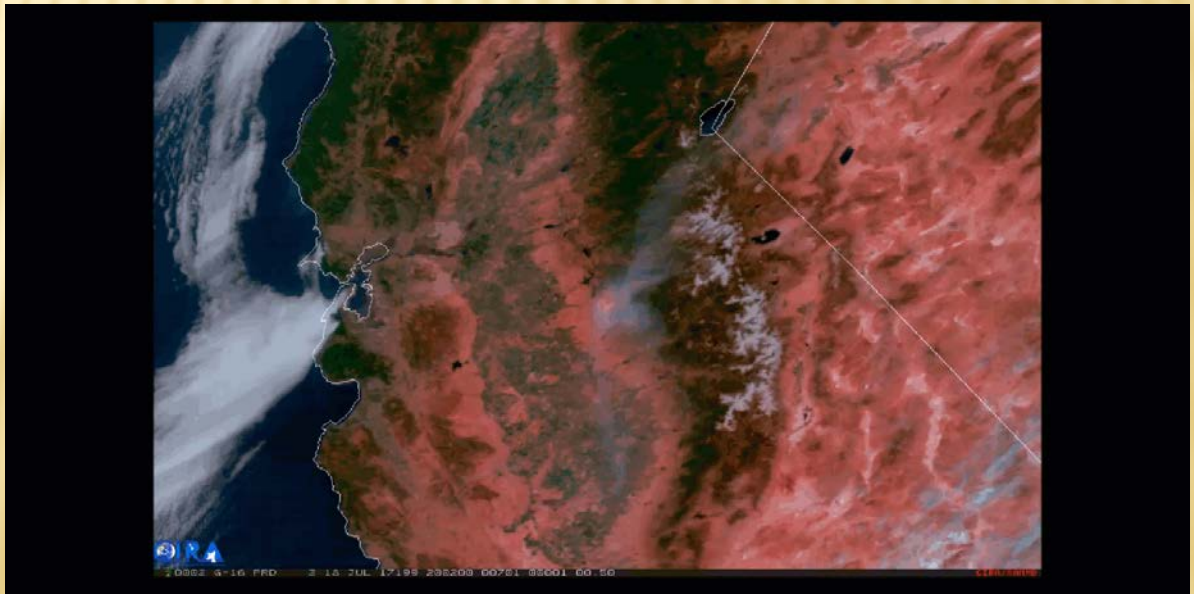
Uncertainty comparing with CO simulation from WRF-Chem model based on ground observations (21-27 August): 30%

Uncertainty comparing with CO simulation from WRF-Chem model based on both ground- and airborne-based observations (18:00 UTC on 26 to 02:00 UTC on 27 August): 13%

Summary

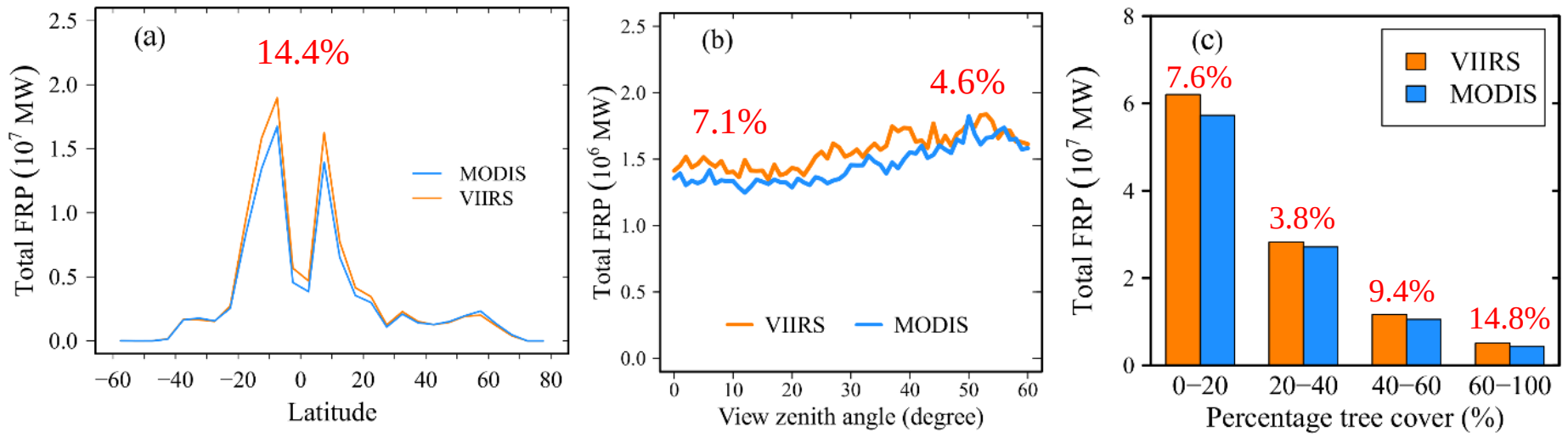
- GBBEP-Geo is developed using diurnal patterns of FRP from geostationary satellites, which reduces impacts of missing fire observations caused by cloud cover, sensor saturation, etc.
- QFEDv2 is calibrated by taking MODIS AOD as a reference and GBBEP-Geo is then calibrated using QFEDv2.
- VIIRS fire emissions conclude emissions from some small and cool fires and inter-orbit-gap fires missed from MODIS.
- These three datasets are blended to generate a global biomass burning emissions product (GBBEPx), which is expected to meet well the requirement of global aerosol forecasting (NEMS-GFS-GOCART).

- Our next step is to estimate biomass burning emissions using observations from Himawari AHI and GOES-16 ABI. It is expected that the GBBEPx could be improved greatly.



PRELIMINARY RESULTS: HYPOTHESIS #4

FRP OBSERVATIONS OF MODIS AND VIIRS ARE COMPARABLE AT CONTINENTAL AND GLOBAL SCALES.



Variations of annual total FRP with latitude, satellite view zenith angles, and percent tree cover.

Annual total FRP from MODIS and VIIRS at 1°×1° grid resolution