Top-Down Biomass-Burning Aerosol Emissions hold great promise for Global and Regional Modeling

Charles Ichoku, Luke Ellison

Climate & Radiation Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD

Collaborators:

Jun Wang
Johannes Kaiser
Edward Hyer
Arlindo da Silva
Anton Darmenov
Mian Chin
Ralph Kahn
Mariya Petrenko
Cynthia Randles
Huisheng Bian

West Fork Complex fire, CO, captured by Astronaut picture aboard the ISS on 19 June 2013. (Image: Courtesy of NASA Earth Observatory)

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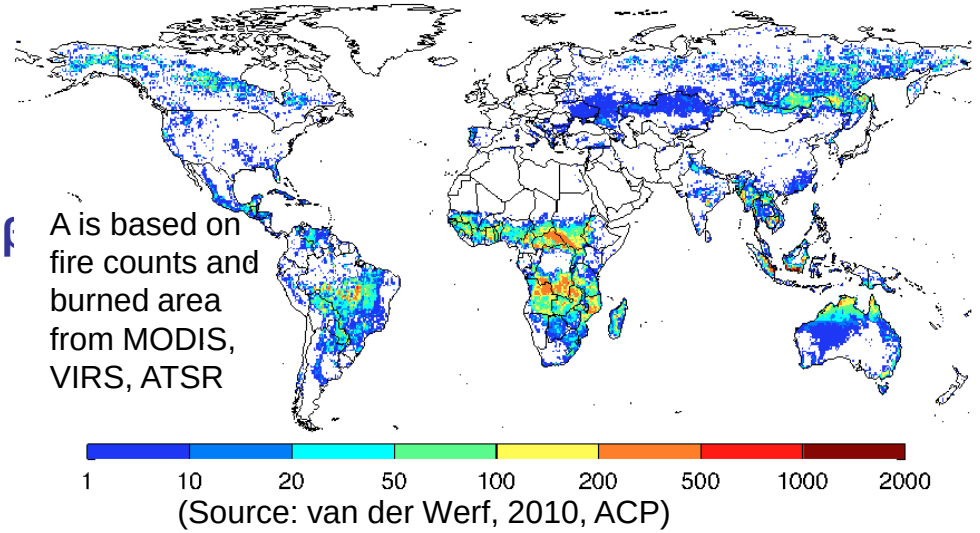
Smoke Emissions Estimation Approaches

Traditional Emissions Calculations

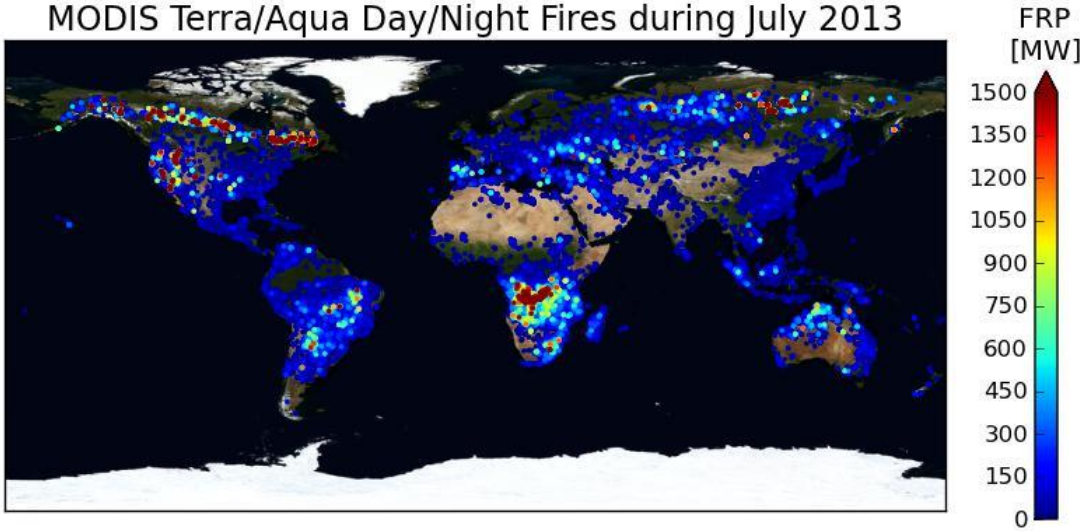
Emissions = EF × BM

EF = Emission Factor
BM = Biomass Dry Mass = A × B × α × β
Where:
A=Area burned,
B=Biomass density,
α=Above ground biomass proportion,
β=Combustion Completeness

GFED Annual Avg. Carbon Emissions (1997-2009)



(Source: van der Werf, 2010, ACP)

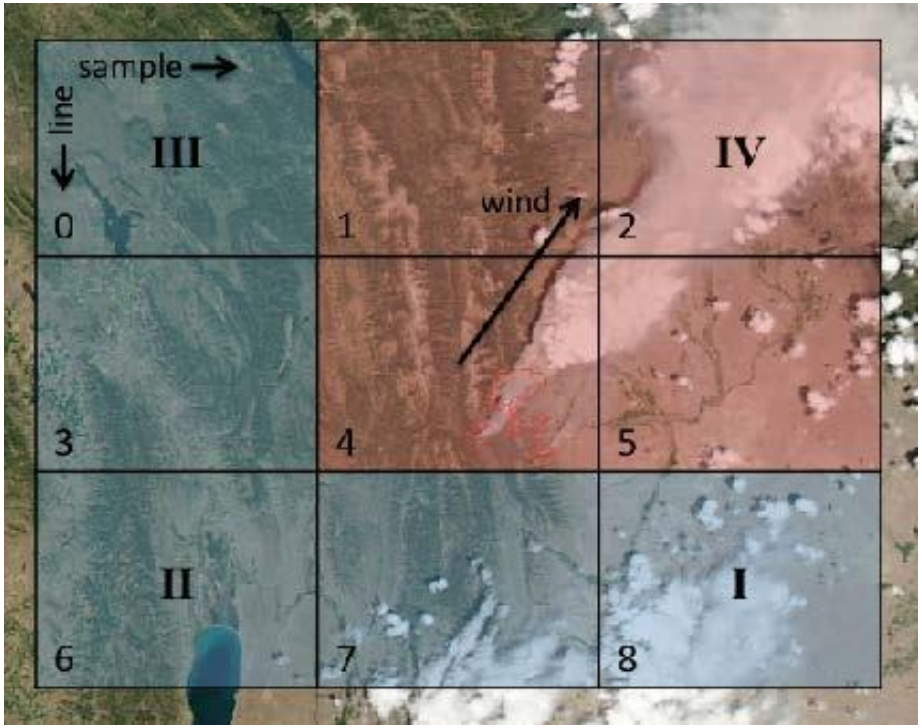


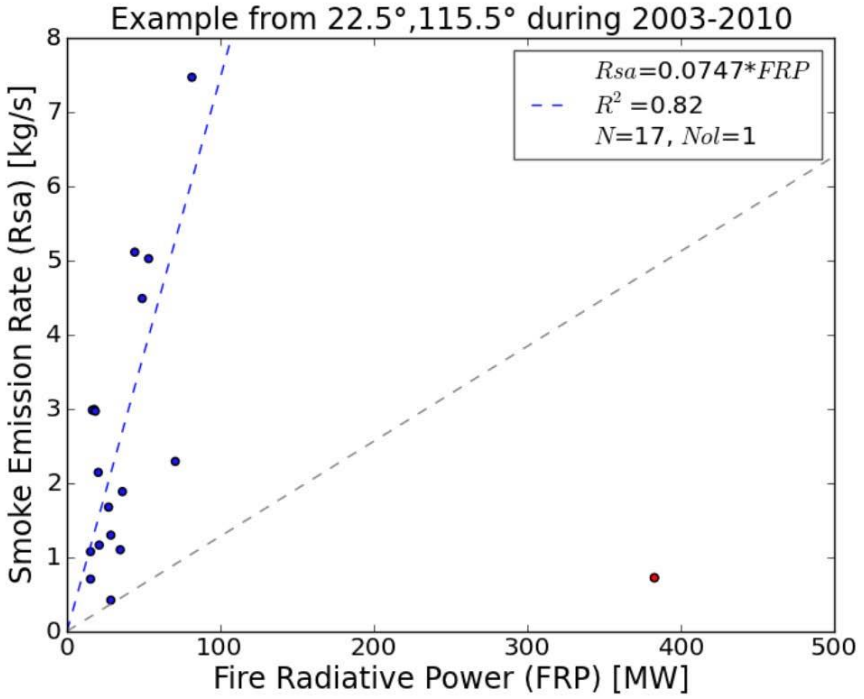
Use Satellite Fire Radiative Power/Energy (FRP/FRE)

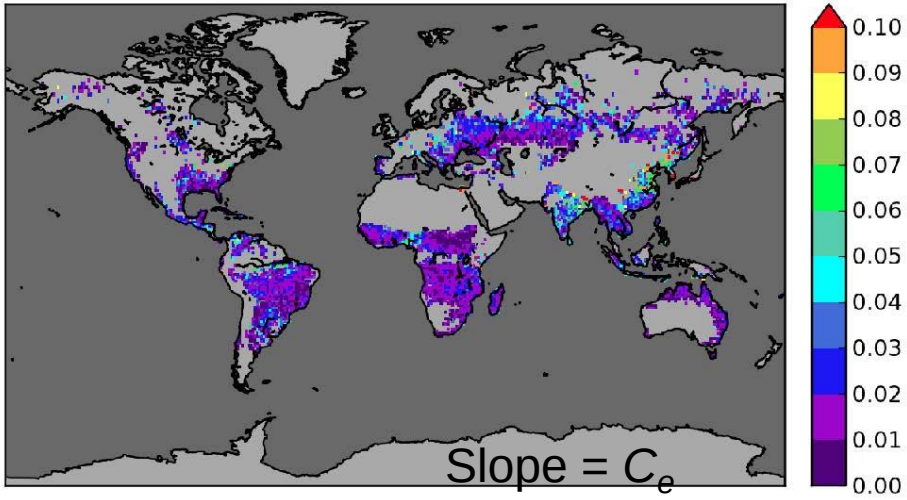
(1) **Emissions = EF × BM (from FRE)** ***[Wooster]*** **=> GFAS.v1**

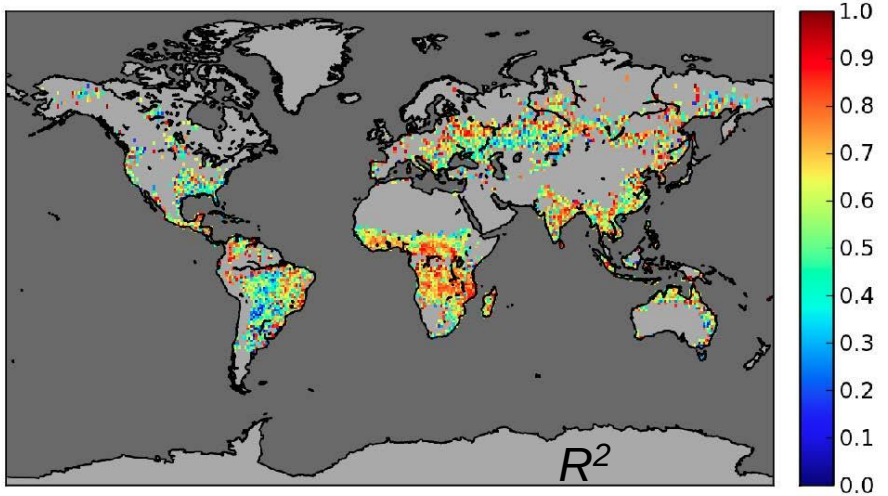
(2) **Emissions = Emission Coeff. (C_e) × (FRP or FRE)** ***[Ichoku]*** **=> FEER.v1**

Generation of FEER.v1 Gridded Emission Coeffs. (C_e)





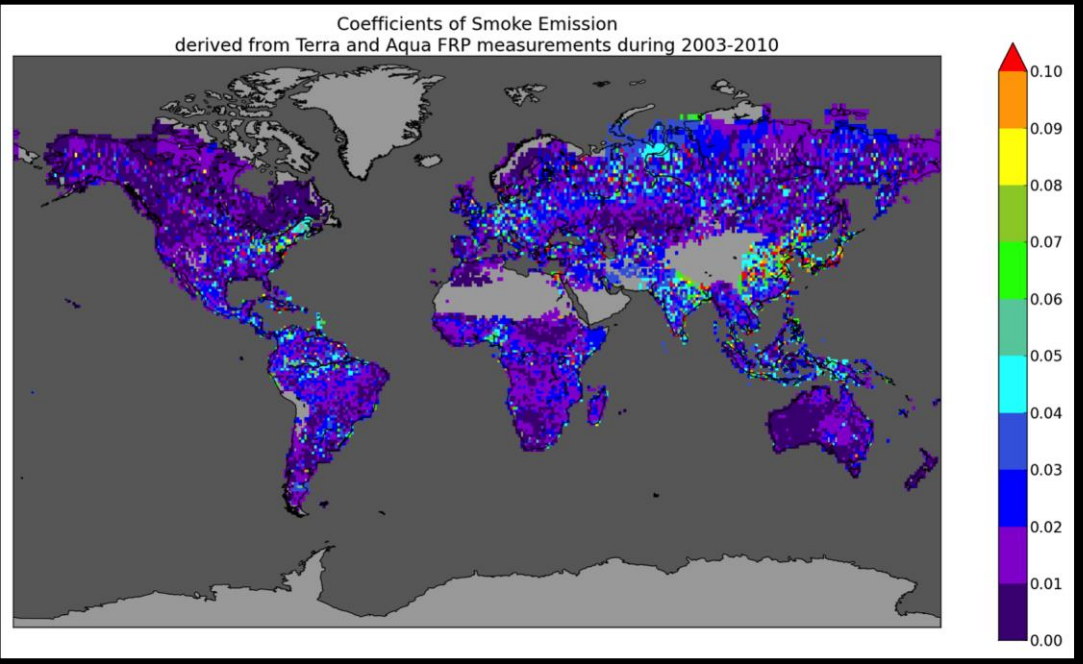


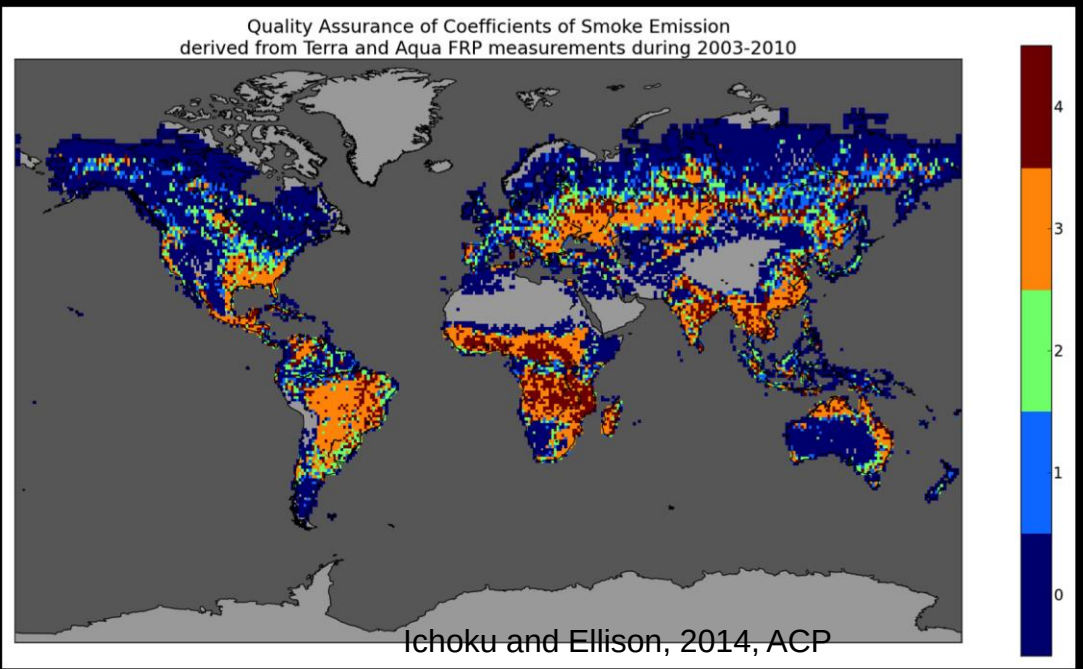


FEER = Fire Energetics and Emissions Research

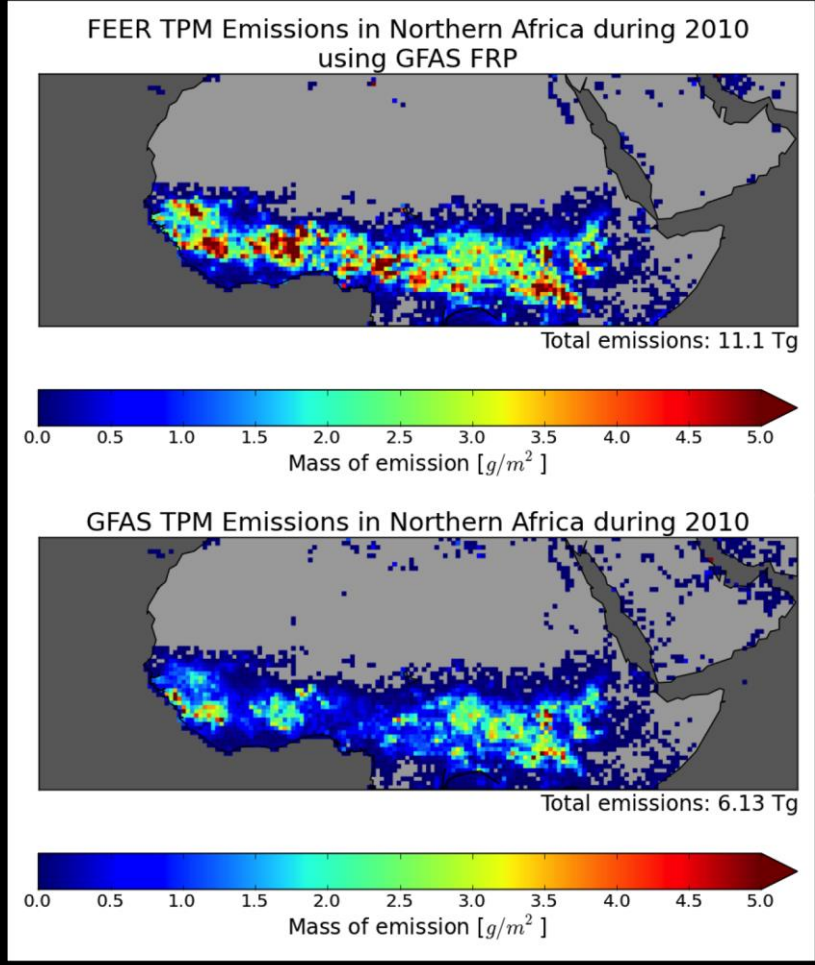
Ichoku and Ellison, 2014, ACP

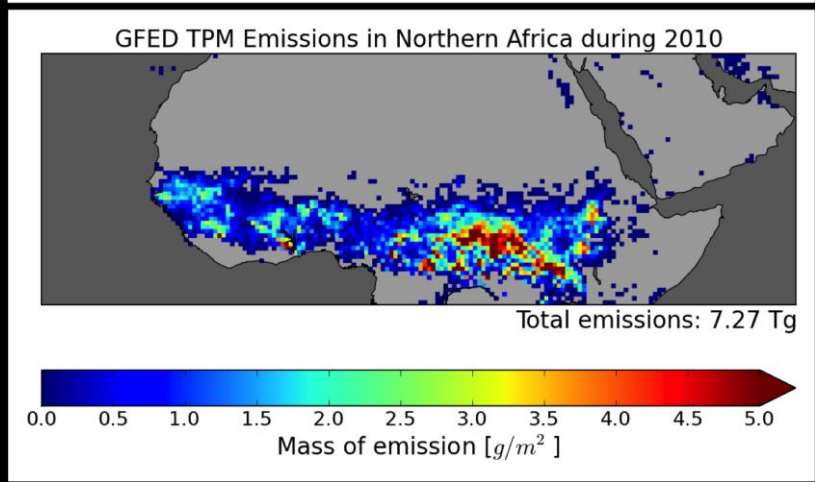
Smoke Emission Estimates and Evaluation



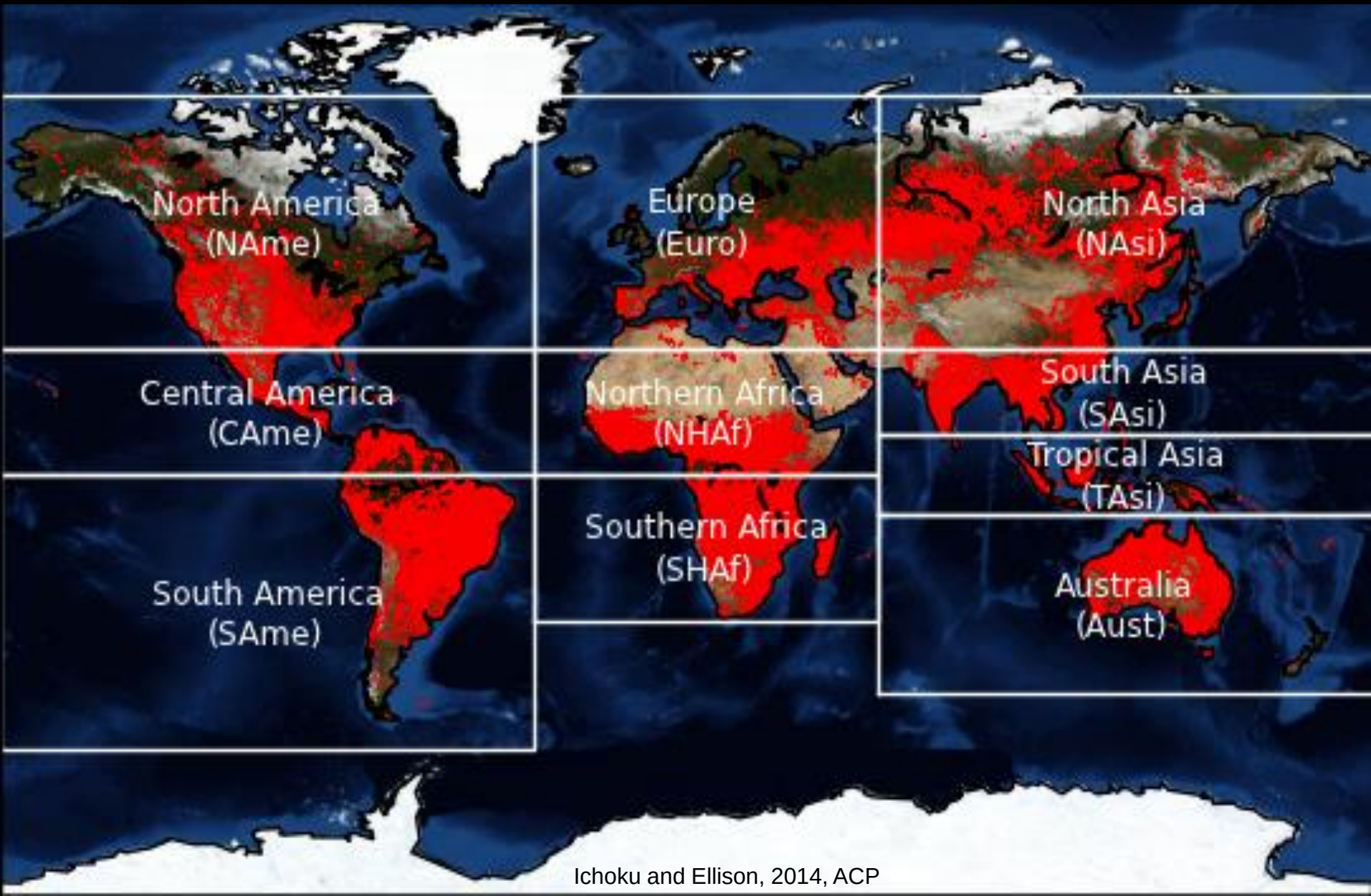


Ichoku and Ellison, 2014, ACP



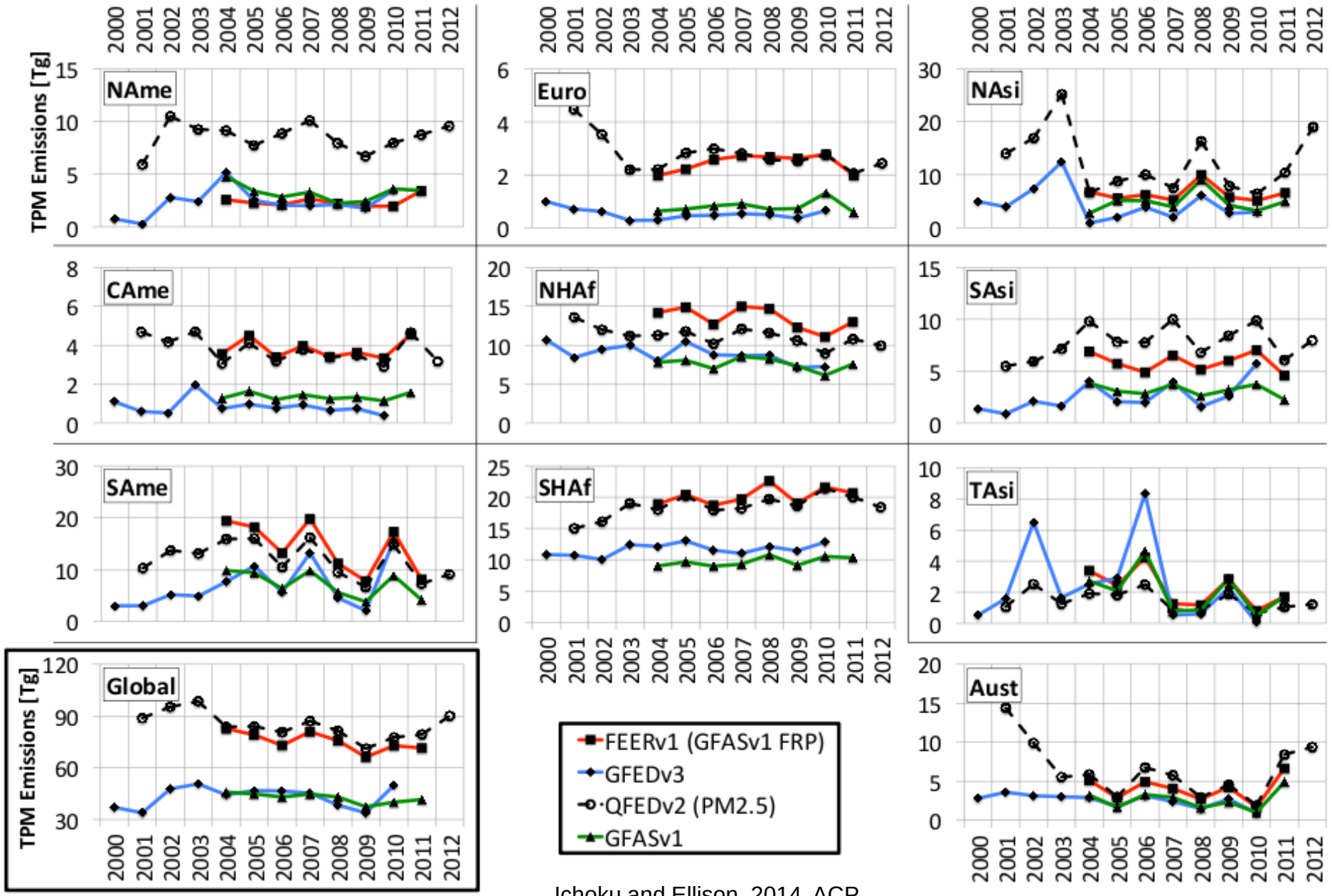


Regional partitions as defined in Kaiser et al. (2012)
Showing Terra- and Aqua-MODIS 2012 fire detections



Ichoku and Ellison, 2014, ACP

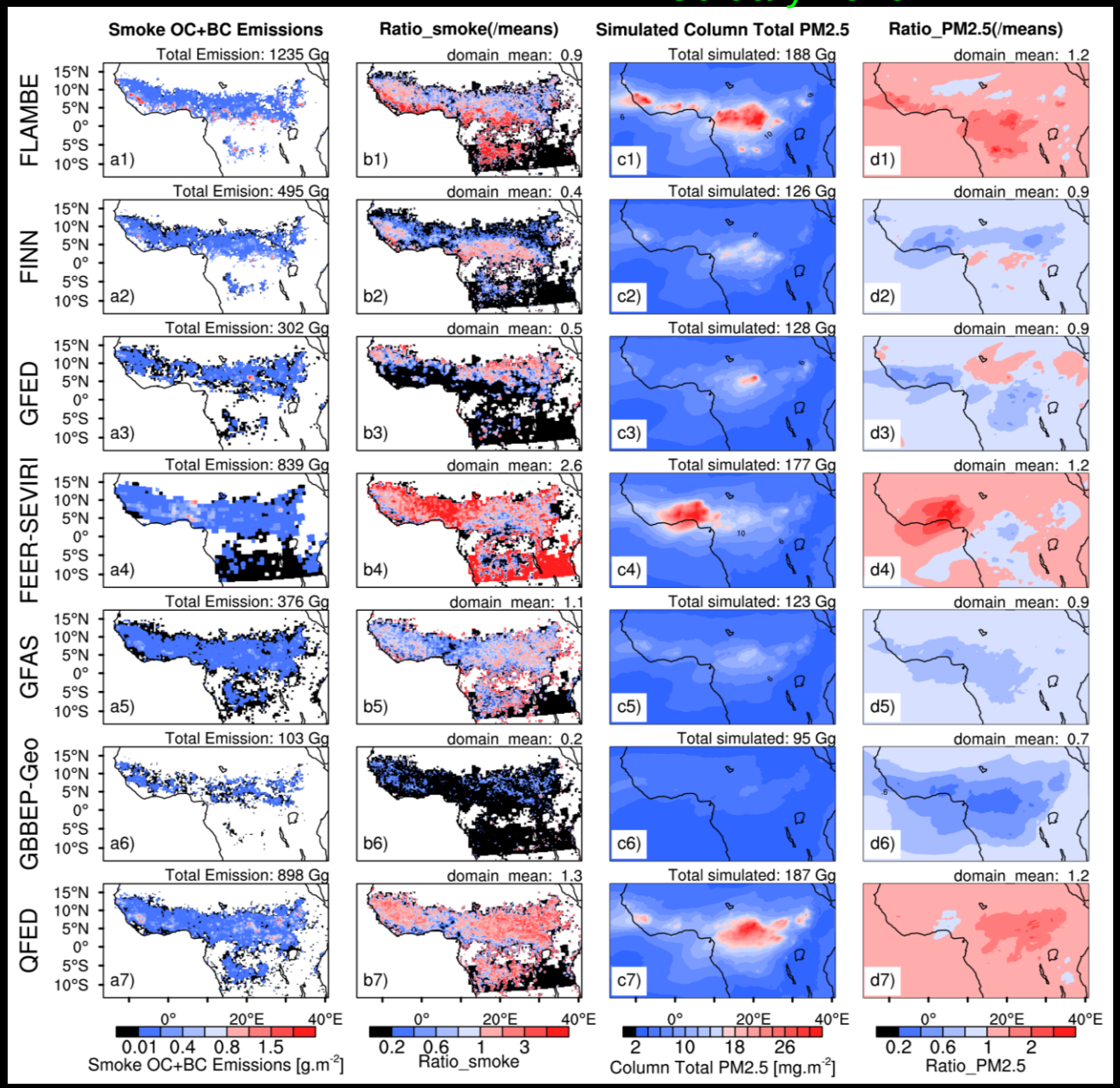
Comparison of PM Emissions Inventories



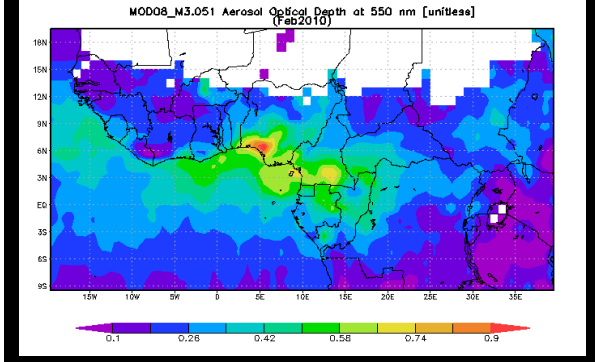
Ichoku and Ellison, 2014, ACP

Comparison of WRF-Chem simulations using 7 Emissions

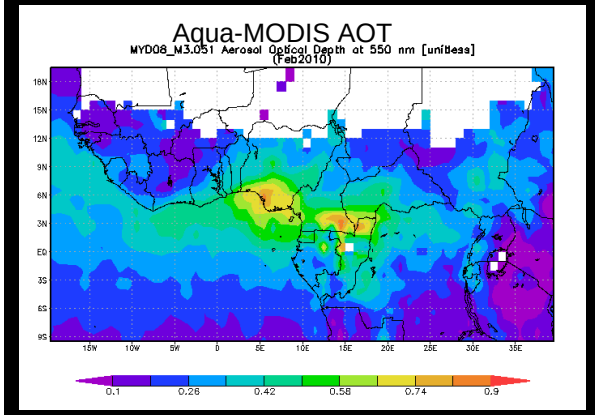
February 2010



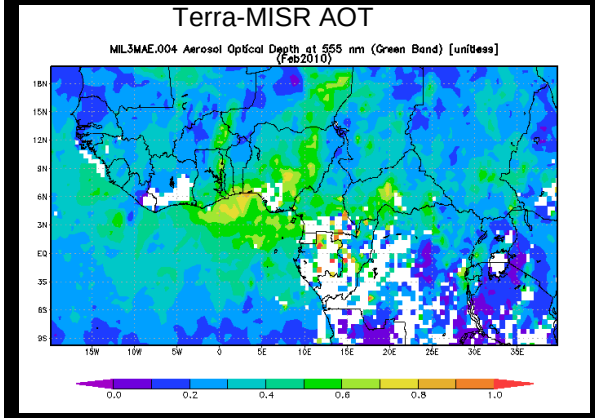
Terra-MODIS AOT



Aqua-MODIS AOT

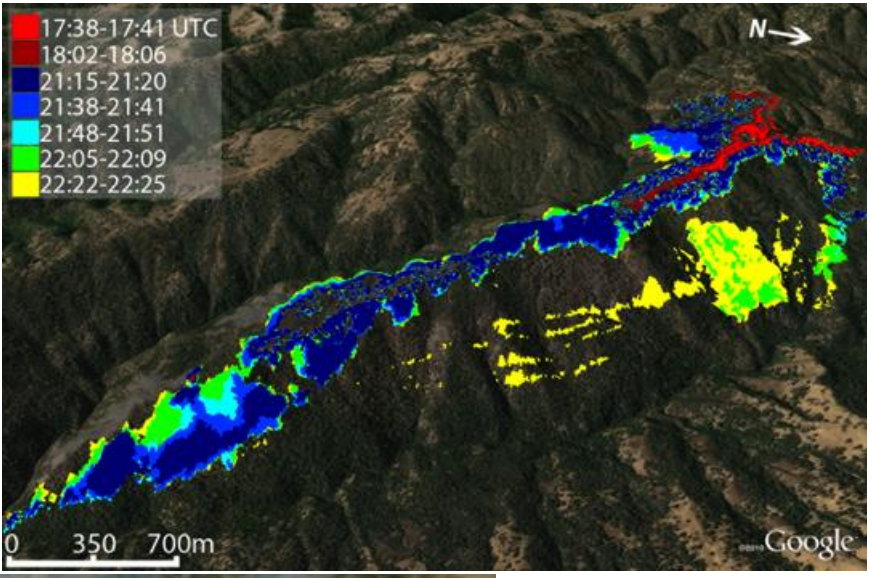


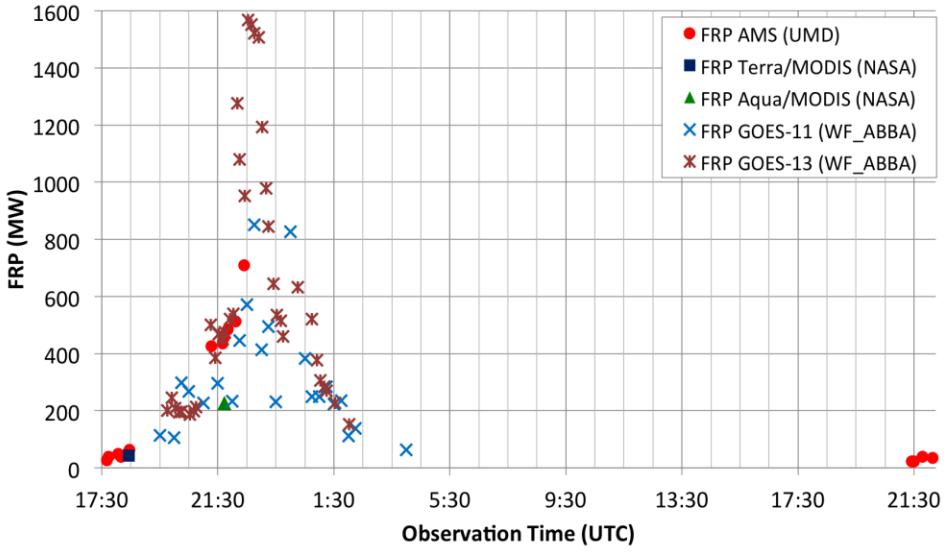
Terra-MISR AOT

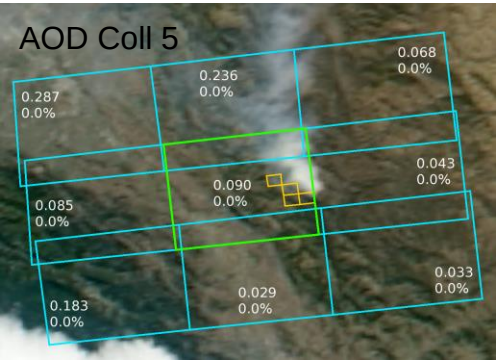


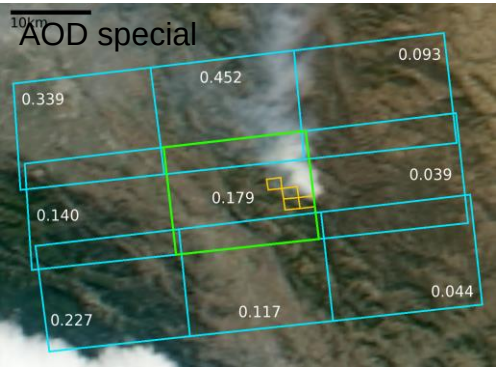
Zhang et al., 2014, ERL

Controlled burn at the Henry Coe State Park, CA (18-Oct-2011)









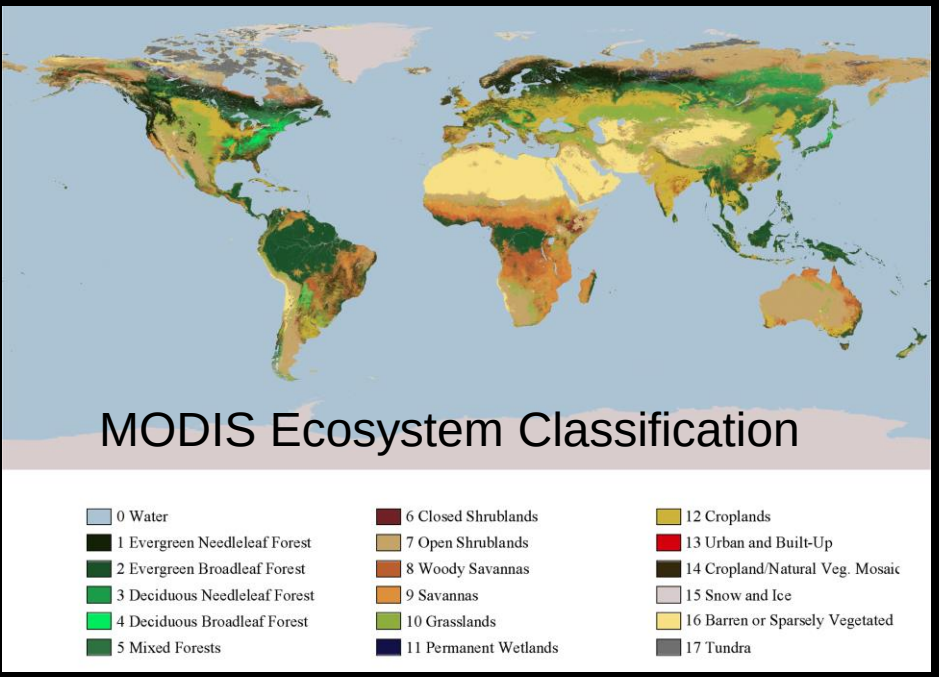
Parameters	E=FRE*CF*EF	E=FRE*EC	E=FRE*Ce
FRE	14.5e+06 MJ		
CF	0.261 kg MJ^{-1}		–
EC		0.0025 kg MJ^{-1}	
Ce	–		0.00612 kg MJ^{-1}
Species (EF g kg^{-1})*			
TPM (8.3)	3.1e+04 kg	7.6e+04 kg	8.9e+04 kg
PM2.5 (5.4)	2.0e+04 kg	5.0e+04 kg	5.8e+04 kg
TC (3.7)	1.4e+04 kg	3.4e+04 kg	3.9e+04 kg
OC (3.4)	1.3e+04 kg	3.1e+04 kg	3.6e+04 kg
BC (0.48)	1.8e+03 kg	4.4e+03 kg	5.1e+03 kg
OCBC	1.5e+04 kg	3.6e+04 kg	4.1e+04 kg
C	1.7e+06 kg	4.0e+04 kg	4.7e+06 kg
CO_2 (1613)	6.1e+06 kg	14.8e+06	17.2e+06 kg

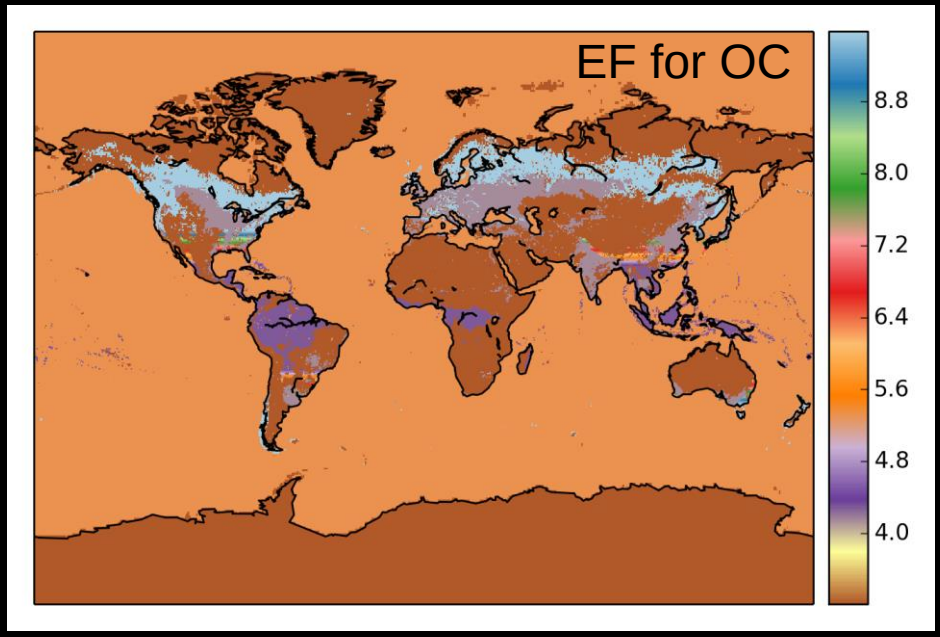
Schroeder et al., 2014, RSE

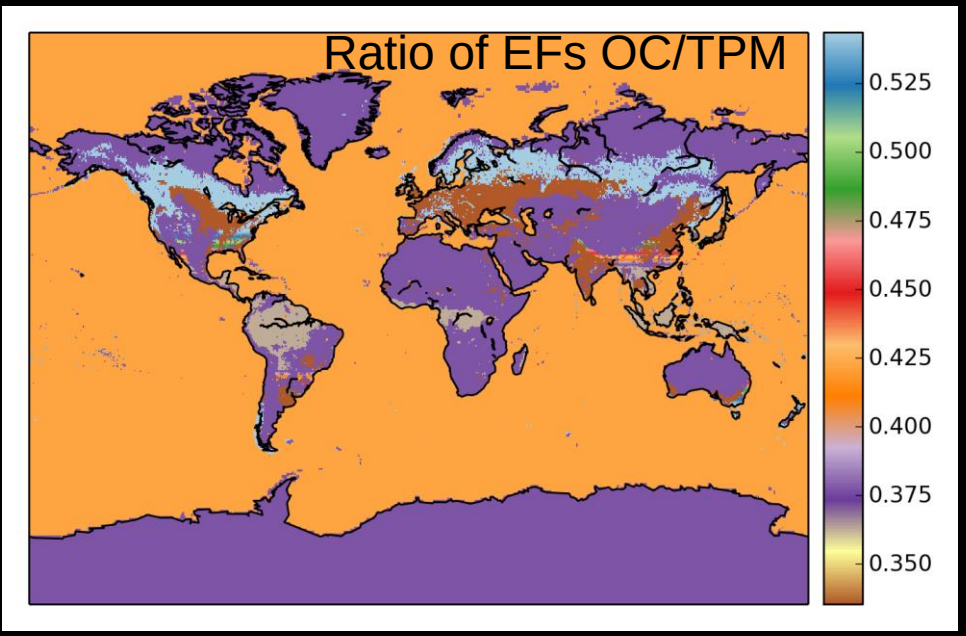
Updated Emission Factors from Andreae (2014)

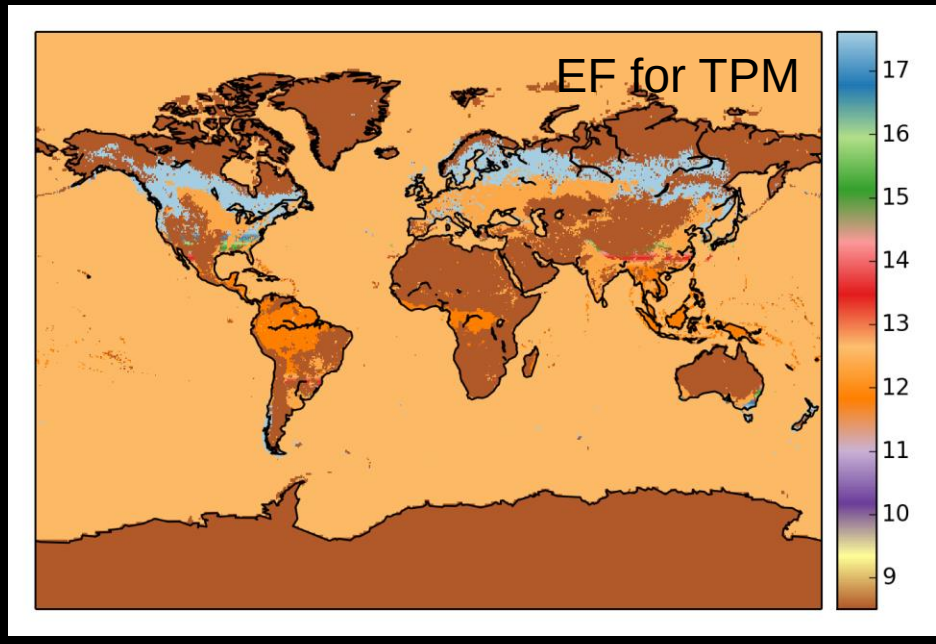
Species	ID	Description	Savanna and grassland	Tropical Forest	Extratropical Forest	Agricultural Burning
C	C	Total Carbon				
CO_2	CO2	Carbon Dioxide				
CO	CO	Carbon Monoxide				
CH_4	CH4	Methane (CH4)				
Total VOC	TVOC	Total Volatile Organic Compounds				
C_2H_2	C2H2	Acetylene (C2H2)				
C_2H_6	C2H6	Ethane (C2H6)				
C_3H_6	C3H6	Propene (C3H6)				
C_3H_8	C3H8	Propane (C3H8)				
n-Butane	nBut	Butane (C4H10)				
i-Butane	iBut	Isobutane (C4H10)				
Methanol	CH4O	Methanol (CH4O)				
Formaldehyde	CH2O	Formaldehyde (CH2O)				
Acetaldehyde	MeCHO	Acetaldehyde (C2H4O)				
Acetone	Acet	Acetone (C3H6O)				
2-Butanone	MEK	Methyl Ethyl Ketone (C4H8O)				
Formic acid	CH2O2	Formic acid (CH2O2)				
Acetic acid	AcOH	Acetic acid (C2H4O2)				
H_2	H2	Hydrogen				
NO_x	NOx	Mono-Nitrogen Oxides				
N_2O	N2O	Nitrous Oxide				
NH_3	NH3	Ammonia (NH3)				
HCN	HCN	Hydrogen Cyanide				
SO_2	SO2	Sulfur dioxide				
COS	COS	Carbonyl Sulfide				
$PM_{2.5}$	PM2.5	Particulate Matter under 2.5 micrometers				
TPM	TPM	Total Particulate Matter				
TC	TC	Total Particulate Carbon				
OC	OC	Organic Carbon				
BC	BC	Black Carbon				

OC/TPM Emission Ratios based on Andreae (2014) EFs





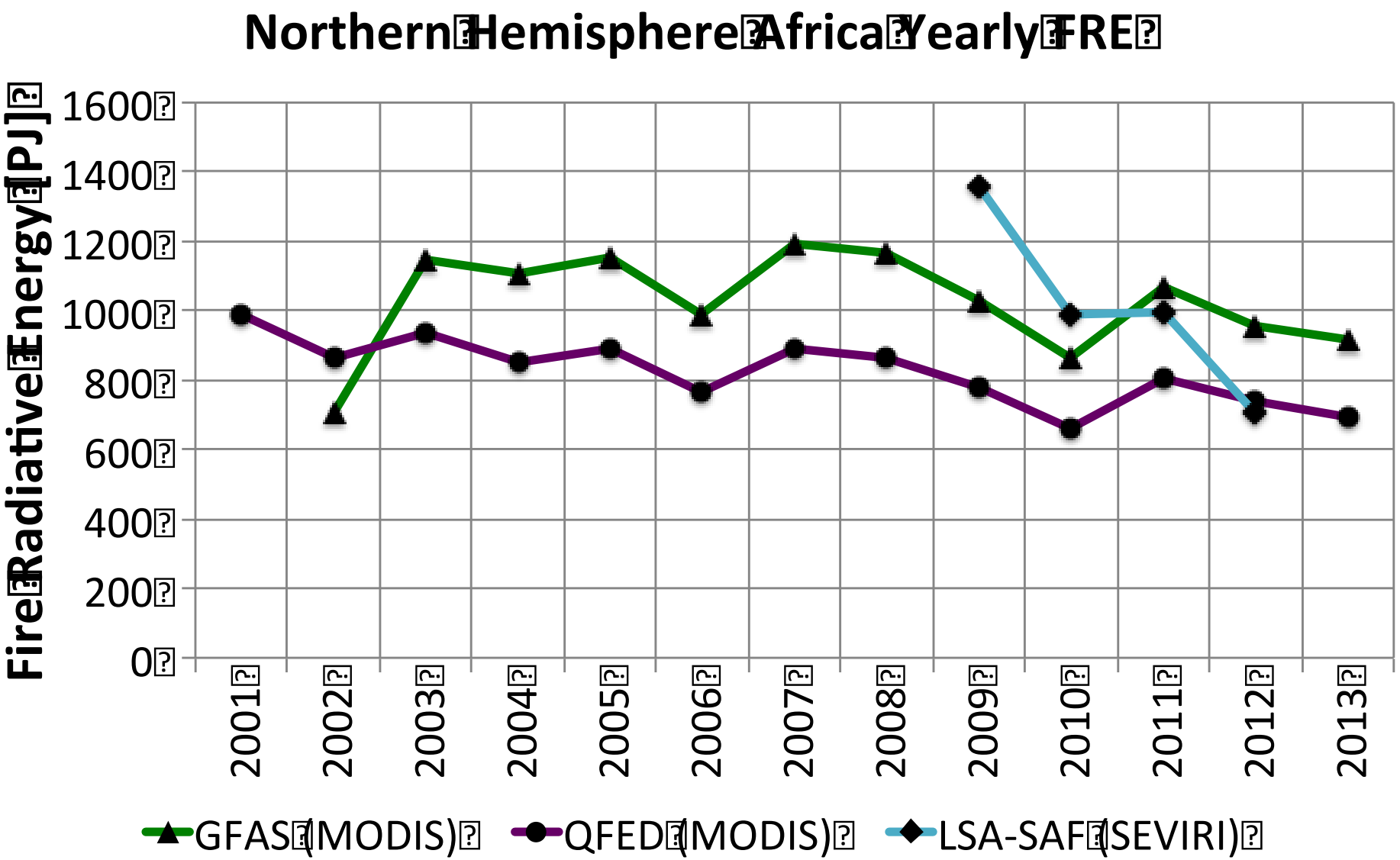




Data Resources

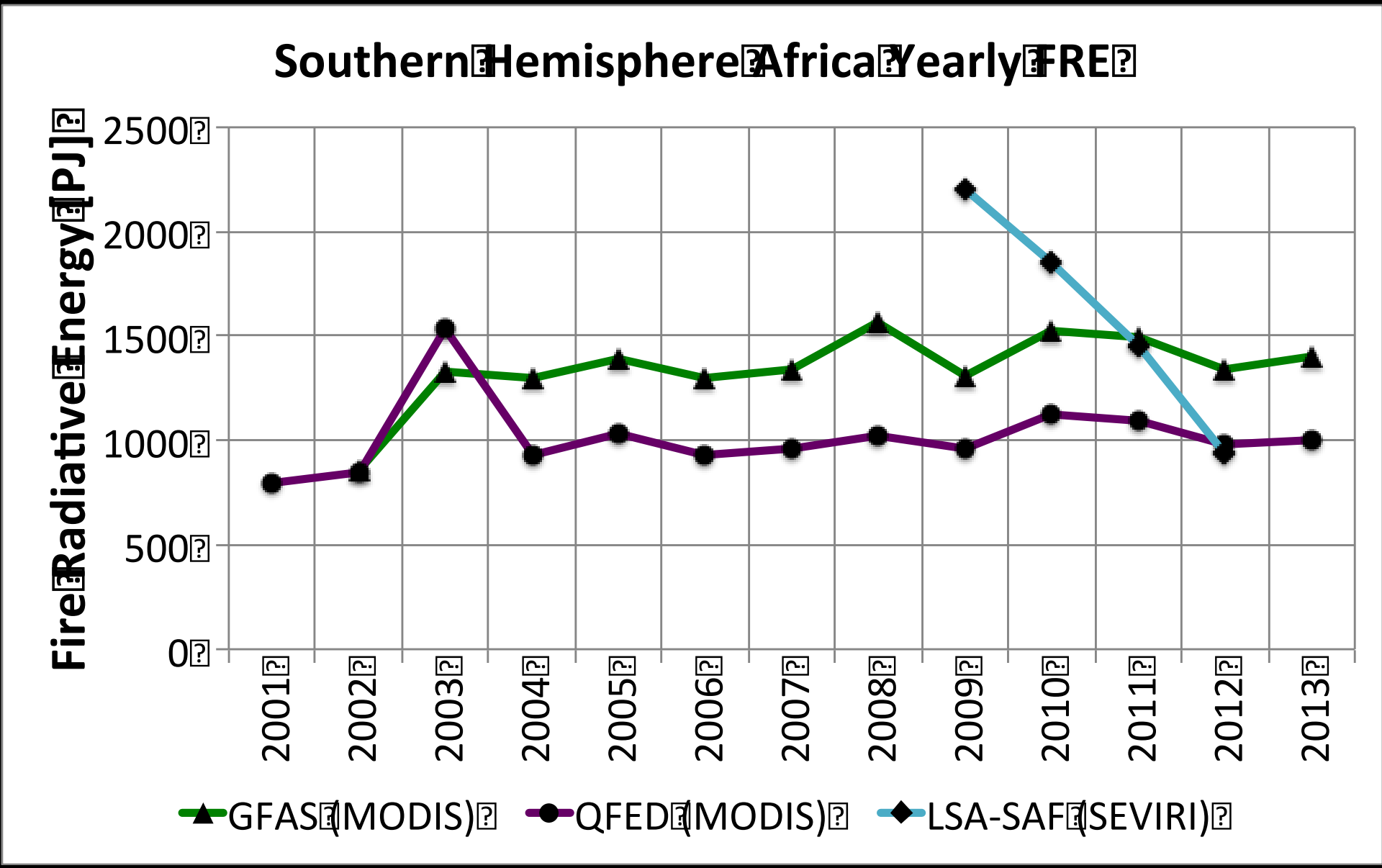
http://feer.gsfc.nasa.gov/data/

Comparison of Fire Radiative Energy Data



Differences still being investigated

Comparison of Fire Radiative Energy Data



Differences still being investigated

Proposed Augmentation to AeroCOM Biomass Burning Emissions Experiment (ABBEX)

Held a Meeting at GSFC between: Charles Ichoku, Luke Ellison, Mariya Petrenko, Mian Chin, Ralph Kahn, Arlindo da Silva, Anton Darmenov, Cynthia Randles

(1) Run FEERv1 on GOCART to compare with QFED and GFED

(2) Make comparisons with observations at current ABBEX boxes

(3) Based on the outcome of (1) and (2), explore what to do at the AEROCOM level

References

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Schroeder, W., E. Ellicott, **C. Ichoku,** L. Ellison, M. Dickinson, R. Ottmar, C. Clements, D. Hall, V. Ambrosia, and R. Kremens, (2014), Integrated active fire retrievals and biomass burning emissions using complementary near-coincident ground, airborne and spaceborne sensor data. *Remote Sens. Environ.*, 140 (2014) 719–730.

van der Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Mu, M., Kasibhatla, P. S., Morton, D. C., DeFries, R. S., Jin, Y., and van Leeuwen, T. T.: Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009), Atmos. Chem. Phys., 10, 11707-11735, 2010. doi:10.5194/acp-10-11707-2010

Zhang, Feng, Jun Wang, Charles Ichoku, Edward J. Hyer, Zhifeng Yang, Cui Ge, Shenjian Su et al. "Sensitivity of mesoscale modeling of smoke direct radiative effect to the emission inventory: a case study in northern sub-Saharan African region." Environmental Research Letters 9, no. 7 (2014): 075002.

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We highly appreciate:

- Funding by NASA through ACMAP and IDS

- Data products from:
  - MODIS (aerosol and fire) teams
  - MISR/MINX team (for MISR plume heights)
  - GMAO (for MERRA wind fields)

- Updated emission factors from Andi Andreae

Conclusions

The FEER.v1 smoke TPM emission coefficients (C_e) product:

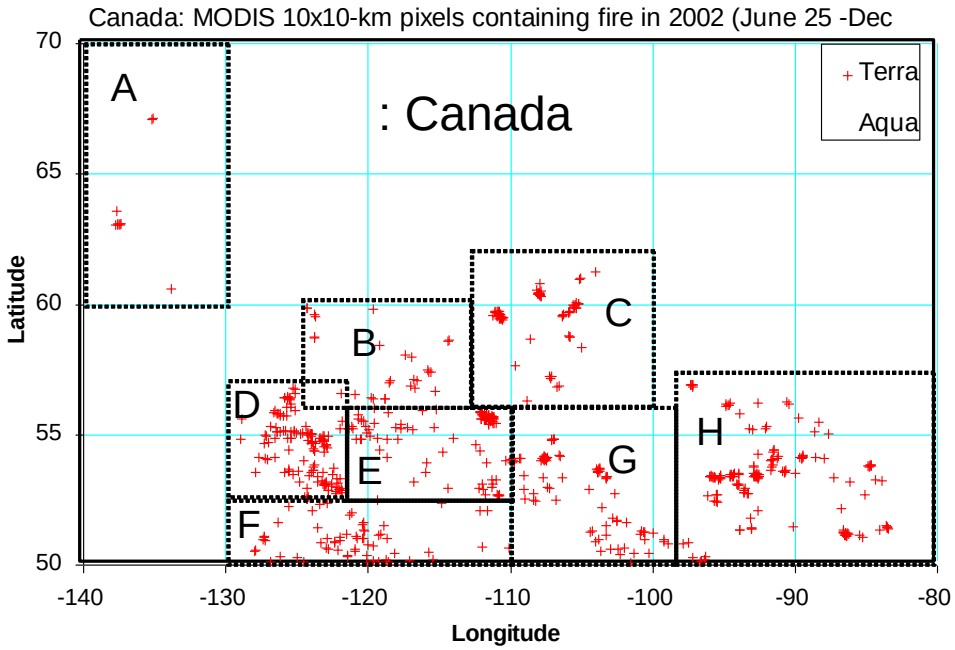
(1) is the first global gridded product in the family of "emission factors" (easy to validate), whereas existing products specify one value per ecosystem type (not possible to validate)

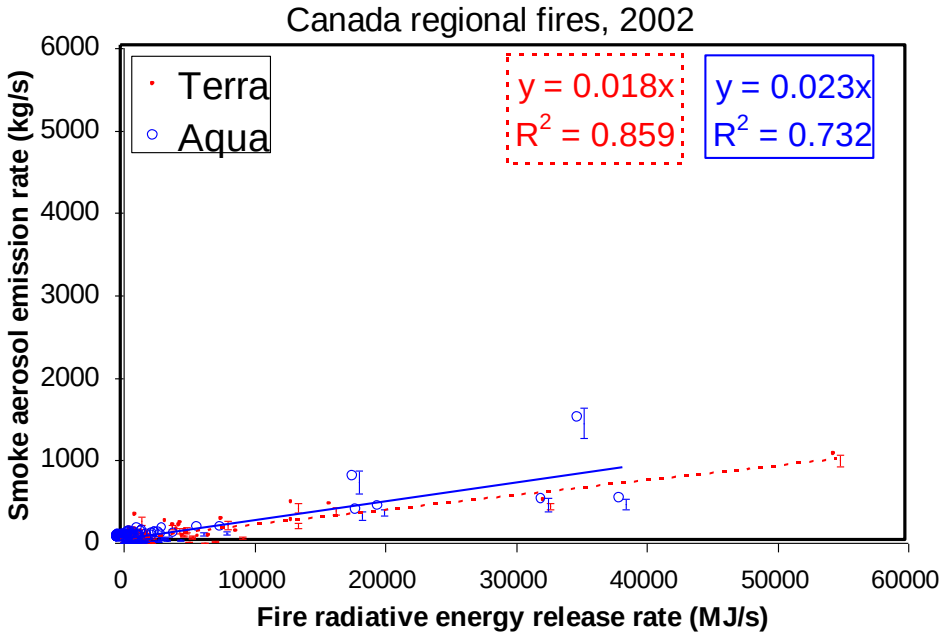
(2) requires only direct satellite measurements of FRP or its time-integrated FRE to generate emission rates or totals, respectively, whereas regular EF values require estimation of burned biomass using intricate processes that are time-consuming and increase uncertainty

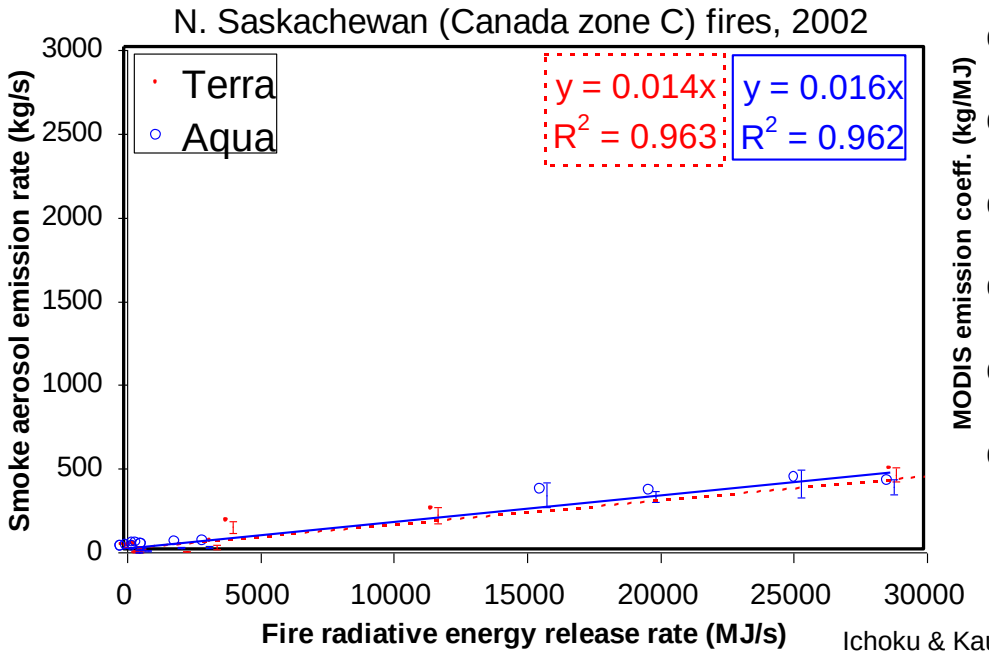
(3) is the only variable in the family of "emission factors" that does not require pre-determination of the ecosystem type of an actively burning fire to evaluate its emission rate in near real time (essential for operational activities such as air quality monitoring and forecasting).

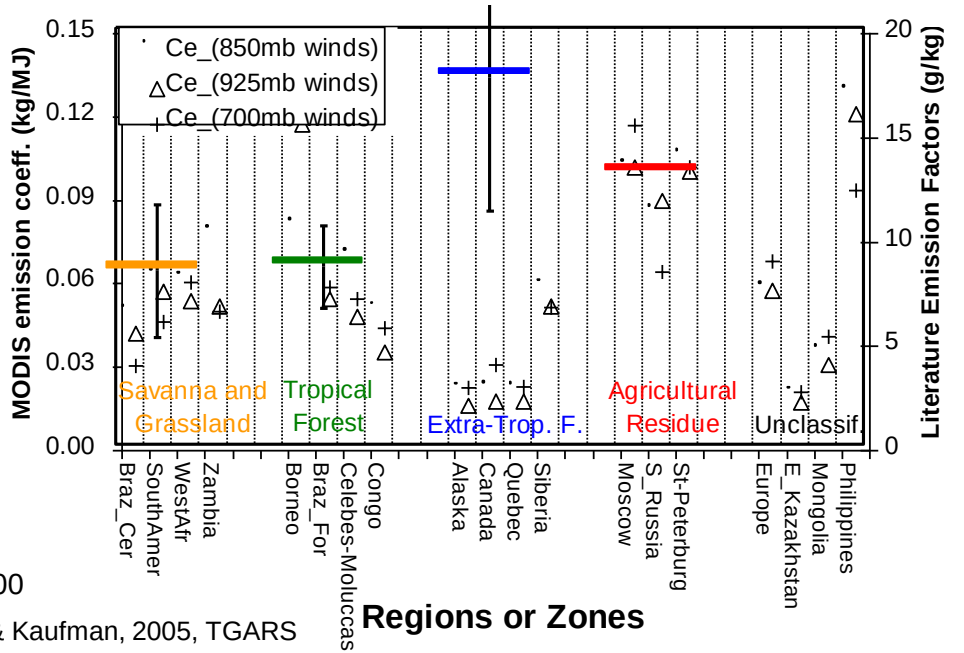
Backup Slides

Smoke Emissions from MODIS Fire Radiative Power and Aerosol



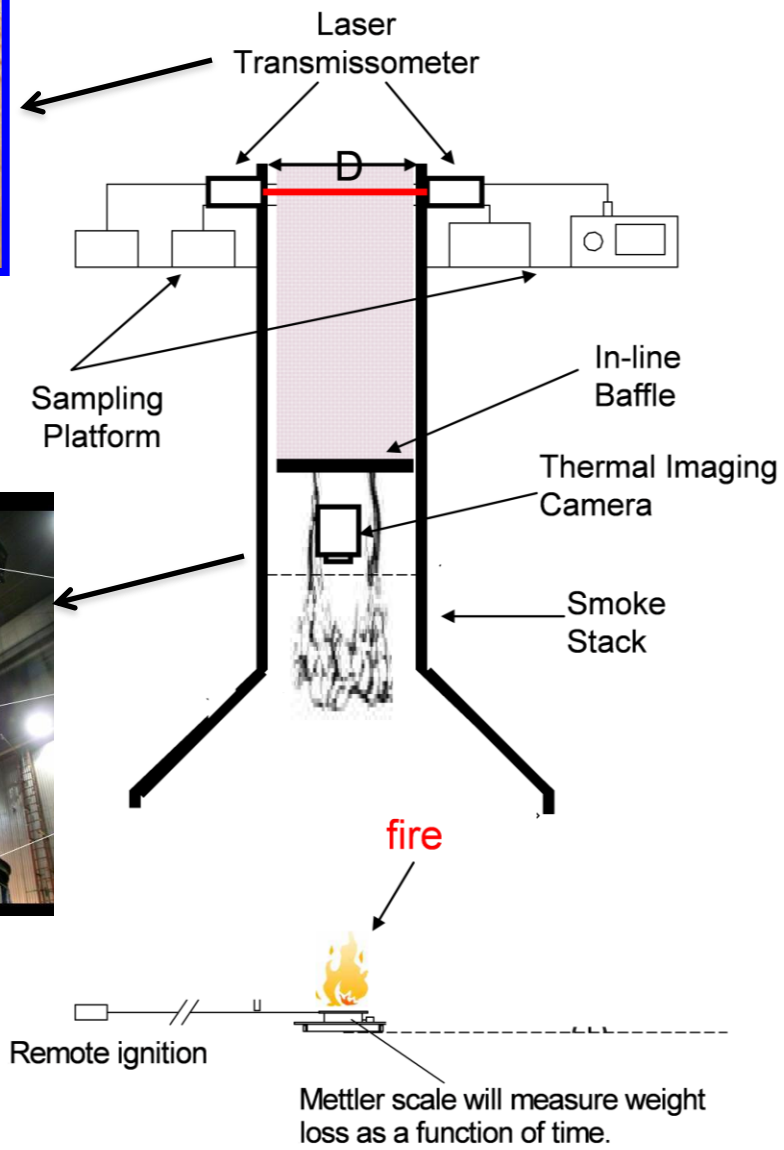


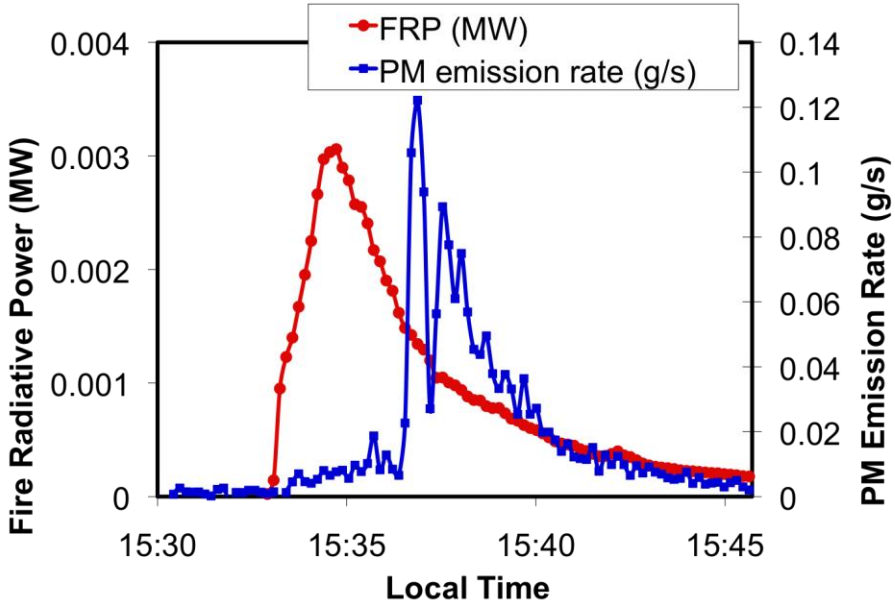


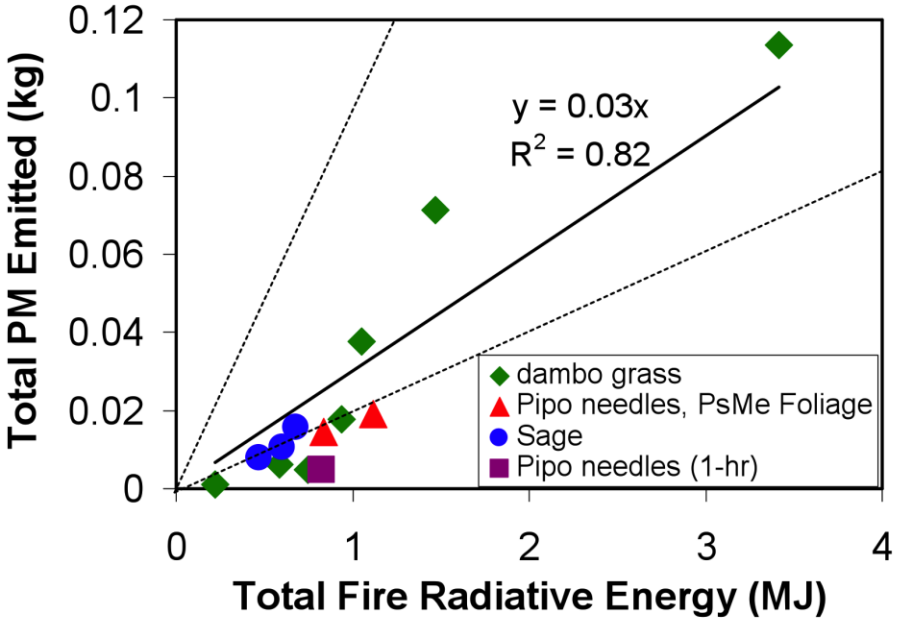


Ichoku & Kaufman, 2005, TGARS

Controlled burns conducted inside the Burn Chamber of the Fire Sciences Lab., USFS, Missoula, MT, Nov. 2003







Ichoku et al., 2008, JGR; Freeborn, et al., 2008, JGR