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Evaluation of the FEERv1.0 Global Top-Down Biomass Burning Emissions Inventory over Africa

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FEER Version 1.0 Emissions Product in Africa

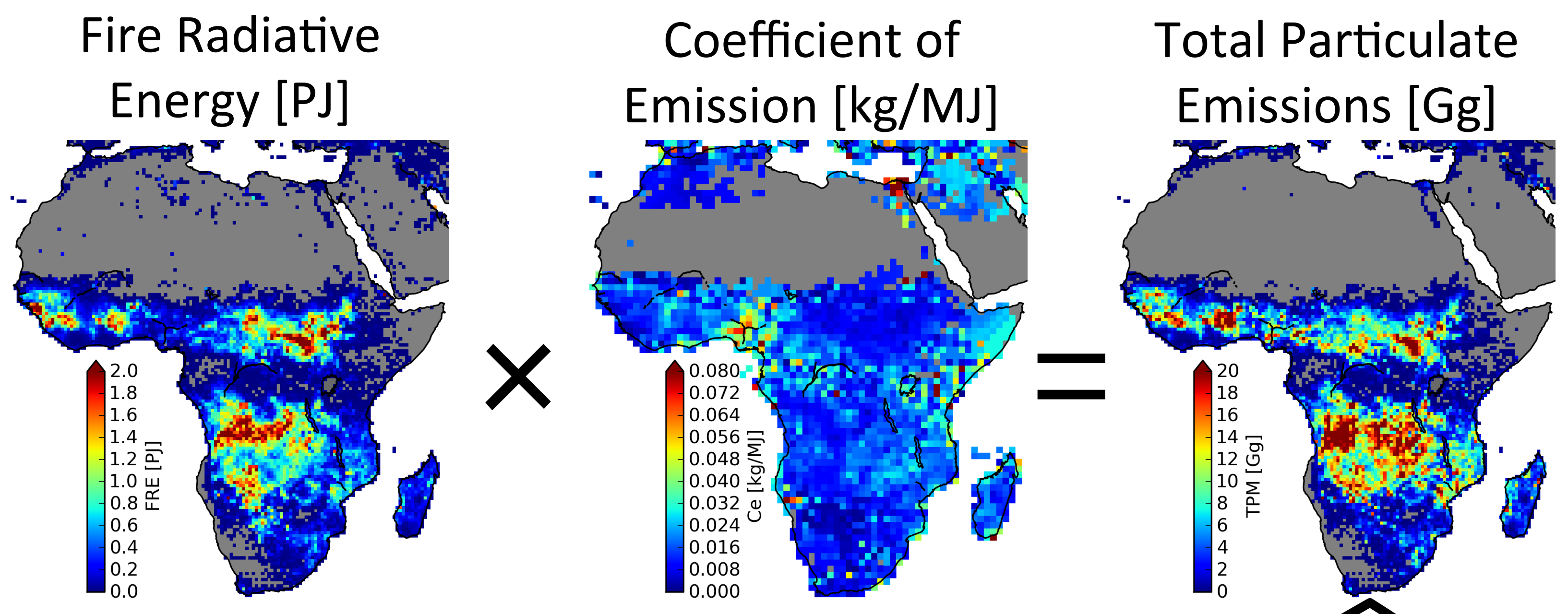
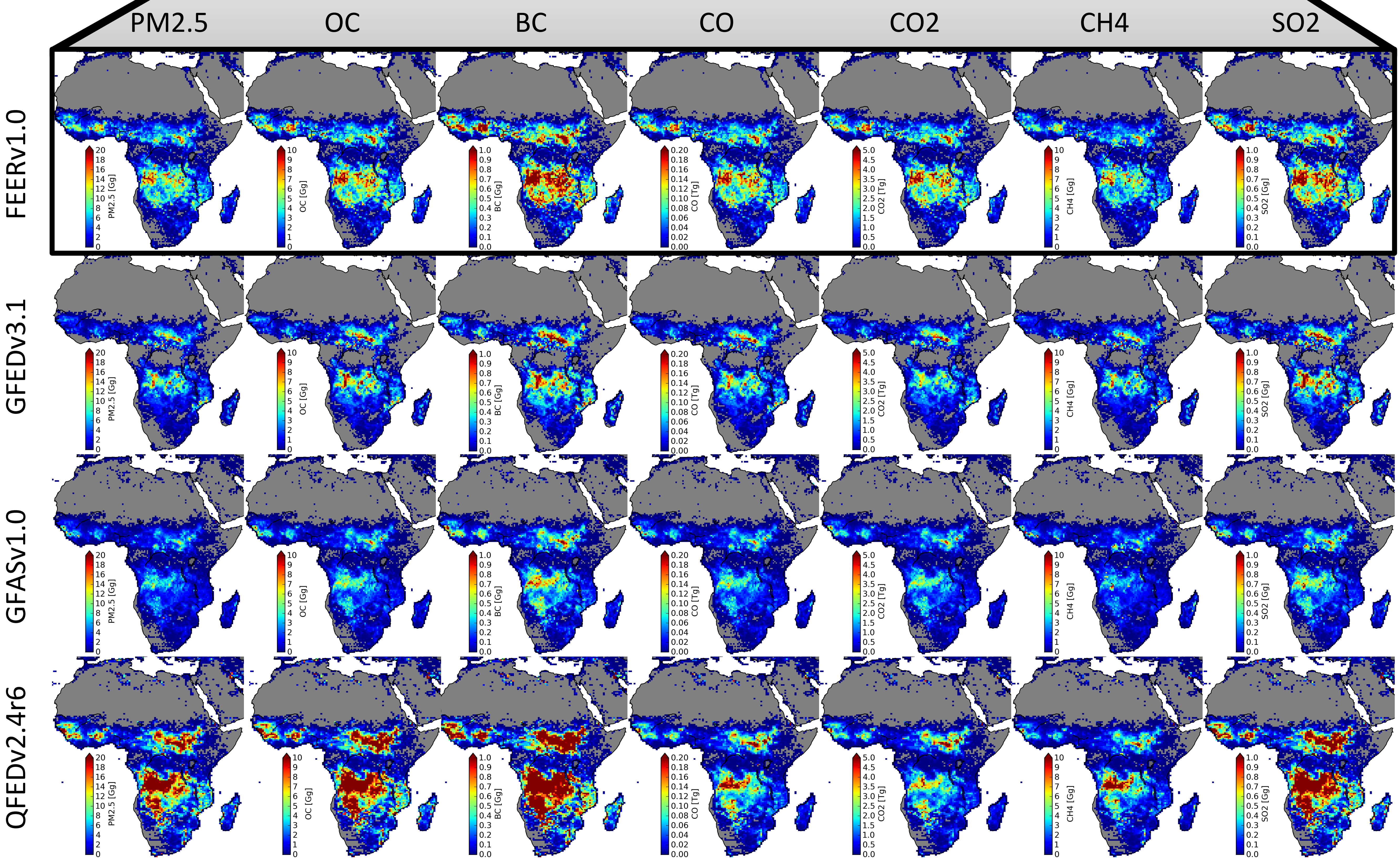


Figure 1 *[above]*: The FEERv1.0 algorithm for deriving emissions from the FEER Coefficient of Emission (*Ce*) product is simply Fire Radiative Energy (FRE) multiplied by *Ce* (*Ichoku & Ellison, 2014; Ichoku & Kaufman, 2005*). FRE is obtained in this case from the GFASv1.0 (*Kaiser et al., 2012, 2009*).

All figures of FRE and emissions are the annual total for 2011.

Calculate other emitted species using Emission Ratios against Total Particulate Matter derived from Emission Factors from Andreae & Merlet (2001), with updated values from email correspondence.

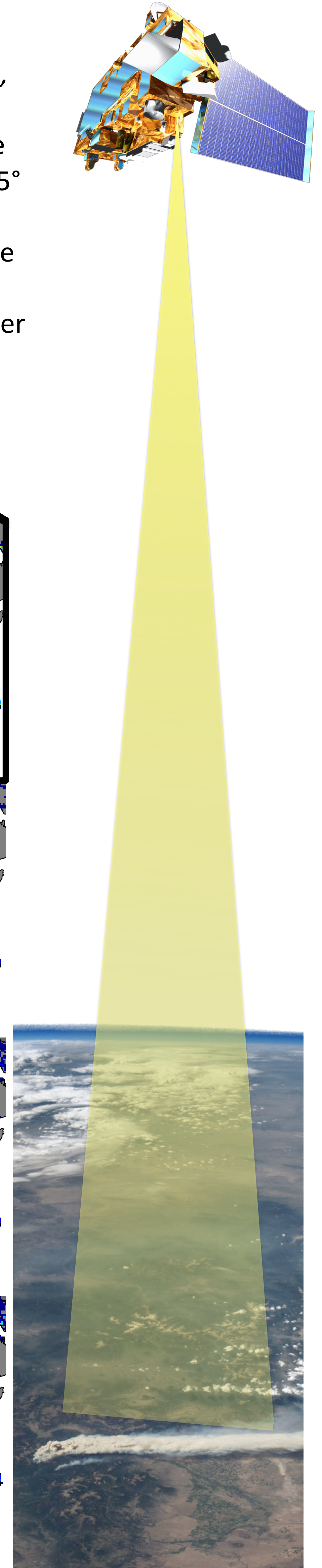
Figure 2 *[below]*: Emissions of various species for FEERv1.0 (*Ichoku & Ellison, 2014*), GFEDv3.1 (*Van der Werf et al., 2010*), GFASv1.0 (*Kaiser et al. 2012, 2009*) and QFEDv2.4r6 (*Darmenov & da Silva, 2013*). The spatial resolutions are plotted at 0.5°×0.5° except for QFED which is plotted at 0.5°×0.625° (lat×lon), and whose emissions values are consequently 25% larger in this figure.



Abstract

With the advent of the Fire Energetics and Emissions Research (FEER) global top-down biomass burning emissions product from NASA Goddard Space Flight Center, a subsequent effort to analyze and evaluate some of the main (particulate and gaseous) constituents of this emissions inventory against other biomass burning emissions inventories over the African continent is shown here. There is consistent and continual burning during the dry seasons in Africa of many small agricultural fires that, though they individually may be relatively small, collectively contribute 20-25% of the global total carbon emissions from biomass burning. As a top-down method of estimating biomass-burning emissions, FEERv1.0 is able to yield higher and more realistic emissions than previously obtainable using bottom-up methods. This effort is carried out in conjunction with a NASA-funded interdisciplinary research project investigating the effects of biomass burning on the regional climate system in Africa, particularly in Northern Sub-Saharan Africa (NSSA). Essentially, the project aims to determine how fires may have affected the severe droughts that plagued the NSSA region in recent history. Therefore, it is imperative that the biomass burning emissions input data over Africa be as accurate as possible in order to obtain a confident understanding of their interactions and feedbacks with the hydrological cycle in NSSA. A first-cut at estimating the overall uncertainty in FEERv1.0 emissions reveals that there is still room for improvement in this algorithm.

Variable	Description
τ_f	Aerosol Optical Depth (AOD) contributable to a fire.
A_T	MODIS AOD pixel size.
WS	Wind Speed.
β_e	Smoke aerosol mass extinction efficiency.
FRP	Fire Radiative Power.
L	Length of the plume from its source to the MODIS AOD pixel edge.
C_e	Coefficient of emission.
M_x	Mass of smoke emitted species.
EF_x	Emission Factor.



Overall Uncertainty Estimations of FEER Version 1.0

An effort was made to estimate the overall uncertainty in FEER emissions using rough estimates for uncertainties of the contributing variables: first from the literature, if available; otherwise, estimated from our data and relevant equations. Assuming zero covariance between all involved variables, the uncertainty calculated from the propagation of error is given in the equation to the right. This equation is applied to the FEER equations below, along with the values in the tables below, to estimate FEER uncertainty (see Fig. 3).

$$\delta f(x_{i=1,n}) = \sqrt{\sum_{i=1}^{n} \left(\frac{\partial f(x_i)}{\partial x_i}\right)^2 \delta {x_i}^2}$$

Coefficient of Emission

$$C_e = \frac{\sum R_{sa}}{\sum FRP} = \frac{\tau_f \cdot A_T \cdot WS}{\beta_e \cdot FRP \cdot L} \qquad \frac{\delta C_e}{C_e} = \sqrt{\left(\frac{\delta\tau_f}{\tau_f}\right)^2 + \left(\frac{\delta A_T}{A_T}\right)^2 + \left(\frac{\delta WS}{WS}\right)^2 + \left(\frac{\delta\beta_e}{-\beta_e}\right)^2 + \left(\frac{\delta FRP}{-FRP}\right)^2 + \left(\frac{\delta L}{-L}\right)^2}$$

Emissions of Total Particulate Matter

$$M_{TPM} = C_e \cdot FRP \qquad \frac{\delta M_{TPM}}{M_{TPM}} = \sqrt{\left(\frac{\delta C_e}{C_e}\right)^2 + \left(\frac{\delta FRP}{FRP}\right)^2}$$

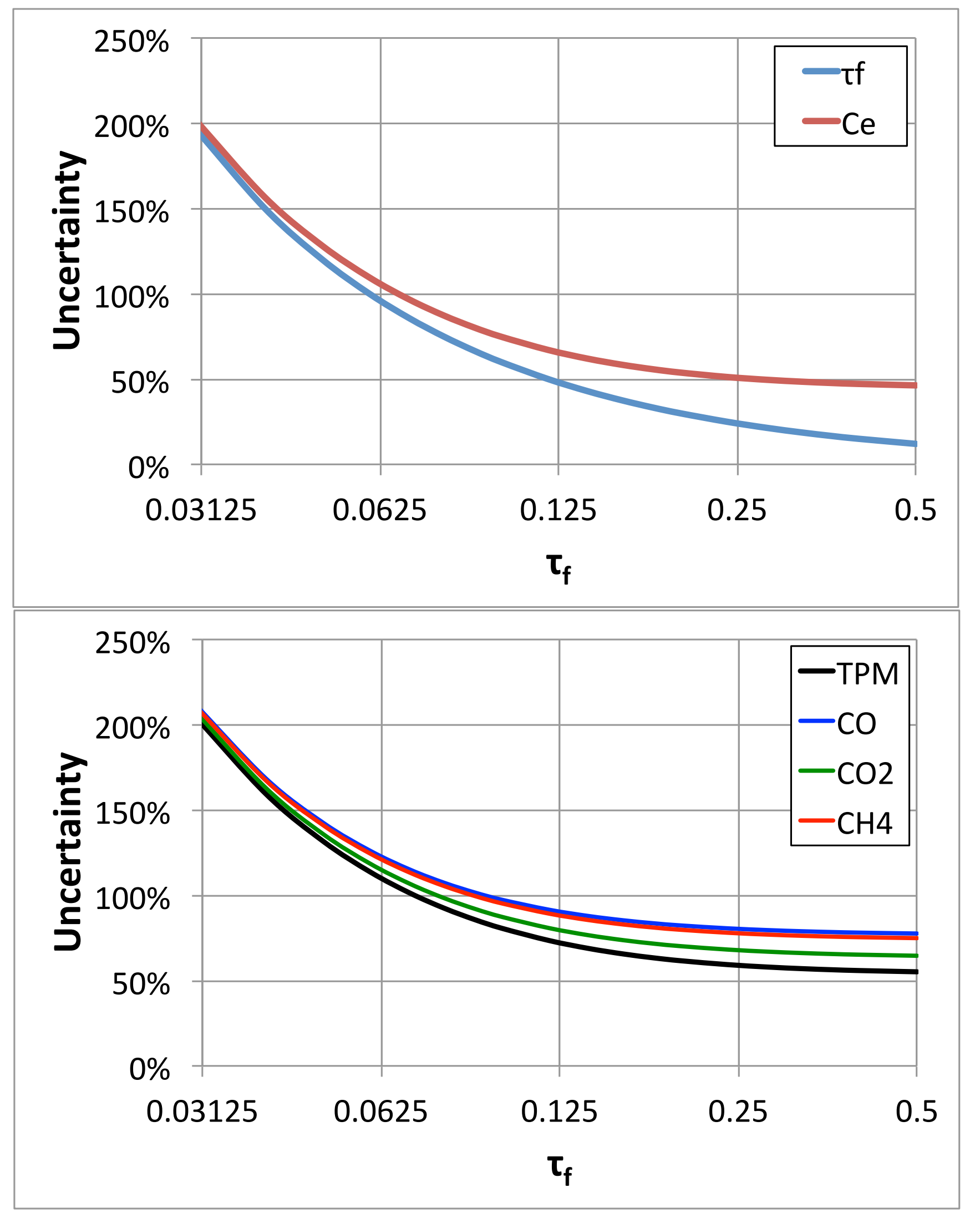
Emissions of other species

$$M_x = M_{TPM}\frac{EF_x}{EF_{TPM}} \qquad \frac{\delta M_x}{M_x} = \sqrt{\left(\frac{\delta M_{TPM}}{M_{TPM}}\right)^2 + \left(\frac{\delta EF_x}{EF_x}\right)^2 + \left(\frac{\delta EF_{TPM}}{-EF_{TPM}}\right)^2}$$

Variable	δx/x	δx	Source
τ_f	–	0.06	Estimated from the Δτ=±0.05±0.15τ relationship in Levy et al. (2010) for a background τ≈0.2 (global average) and a range of τ≈[0.2,0.4] which fits the African fire domain according to Figure 9 in Petrenko et al. (2012).
A_T	0.001%	–	Estimated as the minimum difference in areas (i.e. at nadir) between adjacent pixels.
WS	30%	–	Estimated from the RMSE distribution as shown in Figure 5 in Decker et al. (2012).
β_e	10%	–	Estimated from Table 5 in Reid et al. (2005).
FRP	30%	–	e.g. Kaufman et al. (1998), Wooster (2003), Zhukov et al. (2006), Roberts & Wooster (2008, 2014), Peterson et al. (2013), Peterson & Wang (2013)
L	10%	–	Independent estimation based off of the PDF found from validation against digitized smoke plumes of May 2003 Siberian fires from the MISR satellite (Nelson et al., 2008, 2013), and using an average wind speed.

(mean values)	CO	CO_2	CH_4	TPM
EF *[g/kg]*	92.00	1569	4.125	11.85
σ_{EF} *[g/kg]*	40.3	123	1.60	3.87
σ_{EF}/EF	44%	8%	39%	33%

Figure 3. Relationships of uncertainties of different FEER *Ce* and emissions variables based on varying values of AOD from fire using a global AOD background average of 0.2.



References

Ichoku, C., & Ellison, L. (2014). Global top-down smoke-aerosol emissions estimation using satellite fire radiative power measurements. Atmospheric Chemistry and Physics, 14(13), 6643–6667. doi:10.5194/acp-14-6643-2014.

** Please see the attached document for a list of all articles referenced on this poster.

Terra satellite and fire plume images courtesy of NASA.