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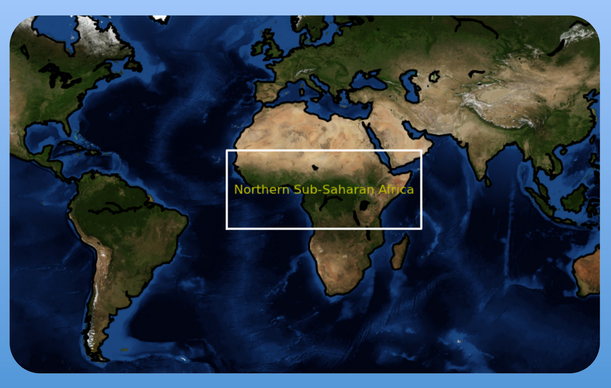
Derivation of a New Smoke Emissions Inventory using Remote Sensing, and Its Implications for Near Real-Time Air Quality Applications

A new emissions inventory of particulate matter (PM) is being derived mainly from remote sensing data using fire radiative power (FRP) and aerosol optical depth (AOD) retrievals from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, as well as wind data from the Modern Era Retrospective-Analysis for Research and Applications (MERRA) reanalysis dataset, which spans the satellite era. This product is generated using a coefficient of emission, C_e, that has been produced on a 1×1° global grid such that, when it is multiplied with satellite measurements of FRP or its time-integrated equivalent fire radiative energy (FRE) retrieved over a given area and time period, the corresponding PM emissions are estimated. This methodology of using C_e to derive PM emissions is relatively new and advantageous for near real-time air quality applications compared to current methods based on post-fire burned area that may not provide emissions in a timely manner. Furthermore, by using FRP to characterize a fire's output, it will represent better accuracy than the use of raw fire pixel counts, since fires in individual pixels can differ in size and strength by orders of magnitude, resulting in similar differences in emission rates. Here we show examples of this effect and how this new emission inventory can properly account for the differing emission rates from fires of varying strengths. We also describe the characteristics of the new emissions inventory, and propose the process chain of incorporating it into models for air quality applications.

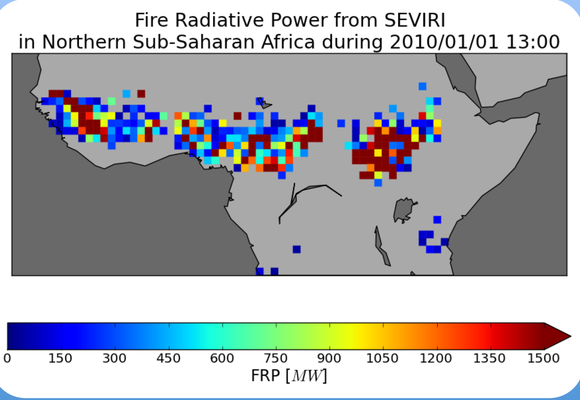
Definitions of Acronyms

C_e – coefficient of emission [kg/MJ], linearly relates emissions to fire radiative energy
FRP – fire radiative power [Watts], rate of radiant energy output from a fire
FRE – fire radiative energy [Joules], radiant energy output from a fire and is the temporally integrated FRP curve
R_{sa} – rate of emission of smoke aerosol [kg/s]
M_{sa} – mass of emitted smoke aerosol [kg]
ROI – region of interest
GEO – geostationary earth orbit (satellites), where regular and frequent FRP measurements are possible over the same region of earth

1. Select ROI



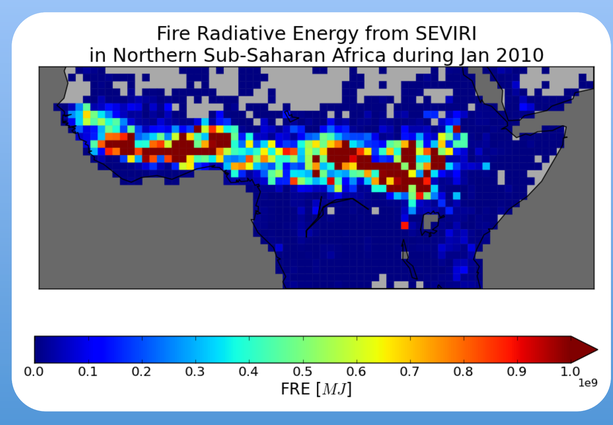
2a. Get FRP from satellite overpass



$\int dt$

2b. Calculate FRE

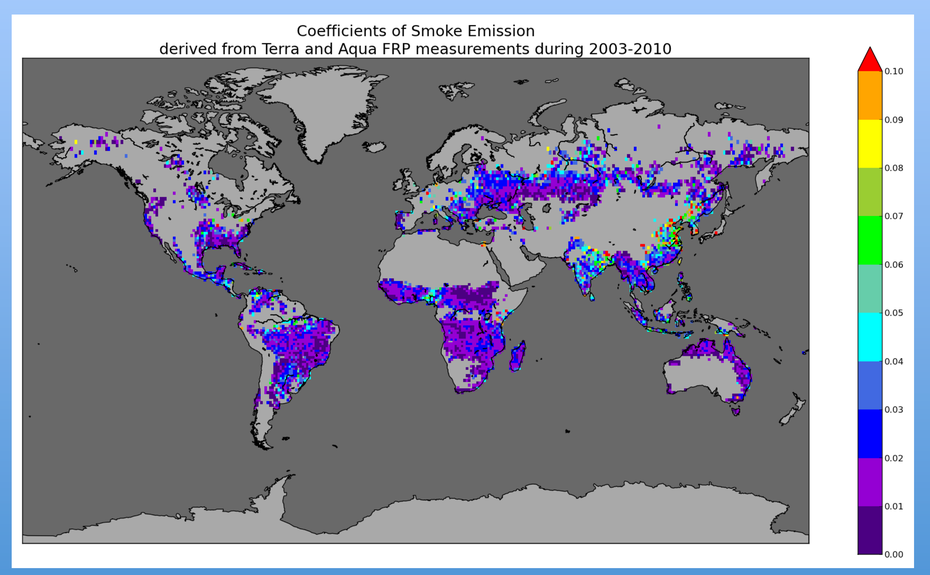
Generate FRE from multiple FRP measurements



$$FRE = \int FRP(t)\,dt$$

What in the world is a coefficient of emission?
It has been empirically shown that FRE is linearly related to total biomass burned.[2,10] This, coupled with the knowledge that the amount of smoke aerosol released varies linearly with the total biomass burned, results in the linear relationship between R_{sa} and FRP (or M_{sa} and FRE) and a coefficient of emission to relate the two such that $R_{sa}=C_e$*FRP (or $M_{sa}=C_e$*FRE). This coefficient can then be used to calculate regional PM emissions knowing the FRE output.[5]

3. Upload C_e grid



Where can I get my hands on all this wonderful work?
The C_e and emissions products will be made publically available at http://feer.gsfc.nasa.gov.

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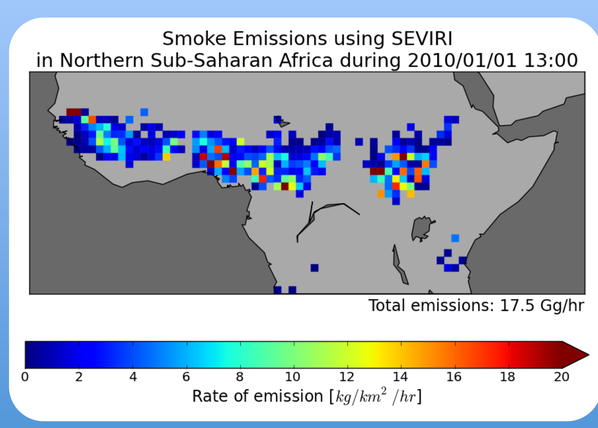
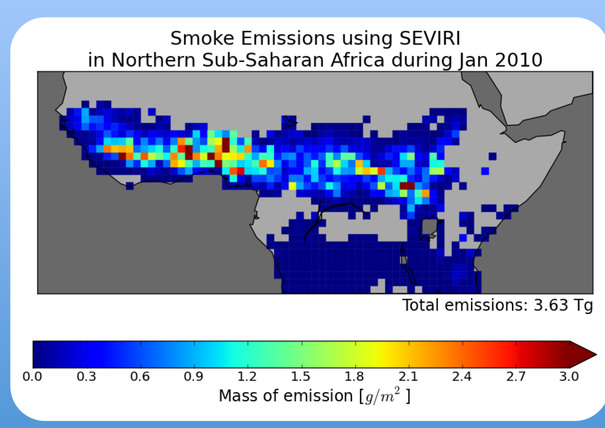
4. Generate emissions

Emission Rates from FRP



$R_{sa}=C_e \cdot FRP$

Emissions from FRE



$M_{sa}=C_e \cdot FRE$

5. Input emissions into atmospheric models (AQ or CTM)

6. Use output for monitoring or forecasting

How did you generate the gridded C_e map?
Having established the relationship that $R_{sa}=C_e$*FRP, estimates for R_{sa} and FRP were obtained and the slope of the trend line relating the two at each grid cell was its C_e value[5]. FRP was obtained directly from the MODIS MOD14 product[3,6]. R_{sa} was estimated using smoke aerosol mass derived from differences between total and background AOD retrievals from the MODIS MOD04_L2 aerosol product[7,8] and using winds from MERRA's inst3_3d_asm_Cp product[1,9].

Are you deriving C_e and/or emissions products for different trace gases and aerosols?
Yes, although currently the only product available is for total particulate matter.

Are you generating a global emissions product?
Yes! Although some initial results have been shown over Africa using SEVIRI FRP data,[4] work is currently being done to extend this emissions product to the entire globe using the suite of GEO satellites.

How fast will this process be when I implement it into my model?
This process can be near real-time, limited only by the time it takes to obtain the FRP measurements. This remarkable turn around time is made possible due to fact that the only other parameter in generating emissions is C_e, which is pre-determined and already provided in a 1×1° grid.

How do your emission results compare with other smoke emission databases?
Extensive comparisons between this product and others like GFED, GFAS, FLAMBE, etc. have not yet been completed, though initial comparisons over northern sub-Saharan Africa from Nov. 2009 to Dec. 2010 indicate that our product generates somewhat higher emissions than the "standard" GFED.

References

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