Estimating Biomass Burning Organic and Black Carbon Particulate Matter Emissions Using Fire Radiative Power

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Project Goals

Estimate biomass burning emissions of organic and black carbon particulate matter (OCBC) using the fire radiative power (FRP) released during combustion.

Fire Radiative Energy

Estimating fire emissions using the integrated fire radiative power (FRP), or fire radiative energy (FRE), was first developed by Kaufman et al. (1996) and later refined by Wooster et al. (2002, 2005). FRE can be used to estimate the total fuel combusted (Fig. 2) and, given an emission coefficient (E_c), the total emissions released (Eq. 1).

$$Emission = E_c \int FRP\, dt \qquad \text{(Eq. 1)}$$

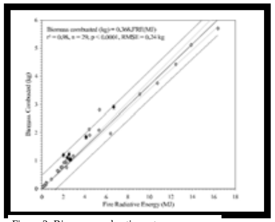

Figure 2: Biomass combustion rate

OCBC Emission Data

To retrieve organic and black carbon particulate matter emissions from biomass burning a combination of satellite and ground-based observations, along with chemical transport modeling, was used in concert with forward and inverse modeling (Dubovik et al., 2007). This data was used to estimate the emission coefficient using FRP retrievals.

MODIS: Global observations of ambient aerosol

AERONET: Semi-Global accurate observations of aerosol

GOCART: Global aerosol simulations
- assimilated meteorology
- advection and convection
- removal processes

Synergy of Observation and Modeling:
Retrieved sources (location and strength) provided best agreement between observations of MODIS /AERONET and GOCART simulations

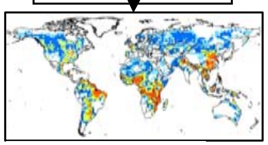

Figure 1: OCBC 2001

Estimating FRP Diurnal Cycle

Curve fitting of SEVIRI geostationary FRP retrievals* with a Gaussian function (Eq. 2) was used to calculate parameters to account for MODIS FRP diurnal cycle. 15 minute FRP observations made by SEVIRI were placed in hourly bins for the month and normalized by the number of days contributing to each hour (0-23). Figure 3 is for a 10°x10° site centered at 5°N 15°E (n ~ 2.5E+05)

$$FRP(t) = a\left(d + e^{-\frac{(t-b)^2}{2c^2}}\right) \qquad \text{(Eq. 2)}$$

Where t is time, d is the lower boundary of FRP retrievals, a is the maximum FRP value, b is the hour corresponding with a, and c is the sigma, or full width at half maximum (FWHM).

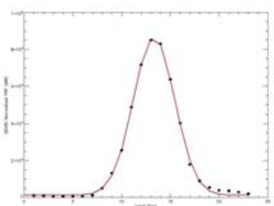

Figure 3: SEVIRI observations, binned in hourly increments, fitted using Gaussian function.

Figure 4 shows an example of the Terra/Aqua monthly FRP observations (2003-2006) from the same site as Figure 3. The relationship between Terra/Aqua ratios and each parameter (b, c, & d) from SEVIRI curves was calculated for multiple test sites (e.g. Fig. 5-7). Modeled parameters were used to estimate the diurnal cycle of FRP for Terra using Equation 2 and FRP values for each site were then integrated to retrieve FRE (Fig. 8).

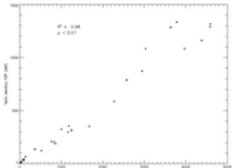

Figure 4: Terra & Aqua FRP for 48 months

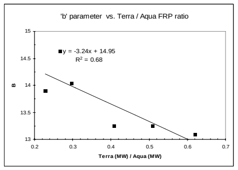

Figure 5: b parameter vs. T/A ratio

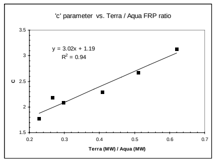

Figure 6: c parameter vs. T/A ratio

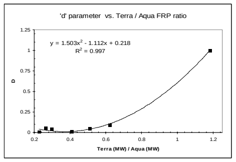

Figure 7: d parameter vs. T/A ratio

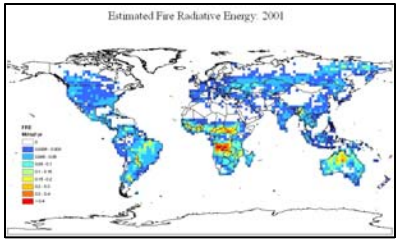

Figure 8: FRE (MJ/m²/year) total for 2001.

Comparison of FRE estimates between MODIS and SEVIRI over southern Africa were quite close: 893x10^9 MJ versus 921x10^9 MJ, respectively.

*SEVIRI data courtesy of Gareth Roberts, Kings College, UK

OCBC Emission Coefficient

Emission coefficients (E_c, grams OCBC emitted/MJ FRE) were calculated using a power function. First the relationship between FRE and the OCBC product was examined for multiple test sites (e.g. Fig. 9). The emission coefficient (slope) for each site was then plotted against the mean annual FRP within the site (Table 1), yielding the power function (Fig. 10). Plotting the power function-predicted E_c against the observed E_c demonstrates the strength of the function (Fig 11). Figure 12 shows a map of the calculated emission coefficients.

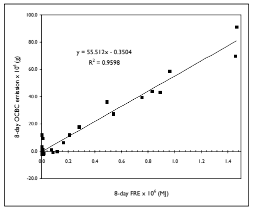

Figure 9: Analysis of relationship within Asian test site (10x10) between FRE (MJ) and OCBC (g)

row	column	R²	Emission (g/MJ)	Mean FRP (MW)	Zone/Description
132	551	0.9797	55.5119	25.5047	Asia
146	178	0.9635	55.1725	25.7758	Central America
160	218	0.9060	27.5989	31.1236	South America
166	414	0.9364	5.9228	41.6958	Africa
193	249	0.9736	14.3189	35.9265	South America
197	415	0.9509	16.9889	32.3648	Africa
199	235	0.9473	39.7331	30.0110	South America
195	422	0.9341	24.4022	29.3505	Africa
213	235	0.9601	11.5231	48.0504	South America

Table 1: Relationship between emission coefficients from preliminary analysis and mean FRP within spatially distributed test sites.

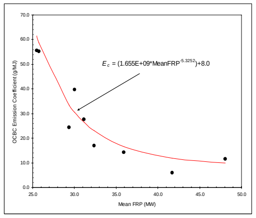

Figure 10: Modeled power function based on relationship between mean FRP and E_c. The latter was retrieved from analysis of relationship between FRE and OCBC within each site.

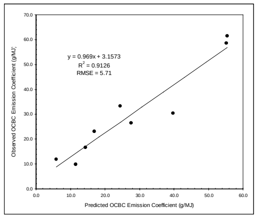

Figure 11: Predicted versus Observed emission coefficients. Observed E_c were retrieved from the slope of the relationship between estimated FRE and the OCBC inversion product for several test sites.

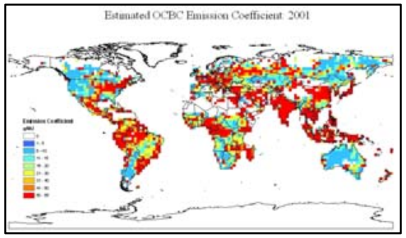

Figure 12: OCBC emission coefficients calculated using power function and mean annual FRP.

Results

OCBC emission from biomass burning was calculated using Equation 1.

We calculated 72.6Tg globally for 2001, which is close to the 63Tg reported by Chin et al. (2007) , but well above van der Werf et al.'s (2006) estimate of 23Tg.

Comparison of the temporal cycle of emissions between our estimate and the OCBC inversion product were very close (e.g. Fig. 14)

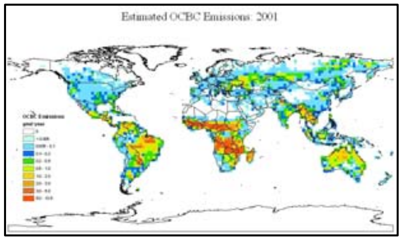

Figure 13: Total OCBC emissions estimated from fire for 2001.

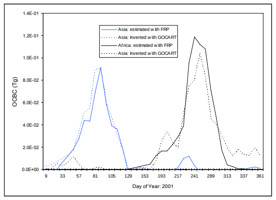

Figure 14: Weekly emission trajectory comparisons for 2 sample test sites between FRE estimated OCBC and OCBC inversion estimates using GOCART.

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