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

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

Presented at the International AEROCOM Workshop, Steamboat Springs, CO, Sep 29 – Oct 2, 2014
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

Fire releases Heat Energy and emits Smoke

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


A is based on fire counts and burned area from MODIS, VIRS, ATSR

MODIS Terra/Aqua Day/Night Fires during July 2013

(Source: van der Werf, 2010, ACP)
Generation of FEER.v1 Gridded Emission Coeffs. ($C_e$)

FEER = Fire Energetics and Emissions Research
Smoke Emission Estimates and Evaluation

Coefficients of Smoke Emission
derived from Terra and Aqua FRP measurements during 2003-2010

FEER TPM Emissions in Northern Africa during 2010
using GFAS FRP
Total emissions: 11.1 Tg

GFAS TPM Emissions in Northern Africa during 2010
Total emissions: 6.13 Tg

Quality Assurance of Coefficients of Smoke Emission
derived from Terra and Aqua FRP measurements during 2003-2010

GFED TPM Emissions in Northern Africa during 2010
Total emissions: 7.27 Tg

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, 2013, ACP, SUBMITTED

ICHOKU AND ELLISON, 2014, ACP
Comparison of PM Emissions Inventories

Ichoku and Ellison, 2014, ACP
Comparison of WRF-Chem simulations using 7 Emissions

Zhang et al., 2014, ERL

Terra-MODIS AOT

Aqua-MODIS AOT

Terra-MISR AOT

Ichoku and Ellison, 2013, ACP, submitted
Controlled burn at the Henry Coe State Park, CA (18-Oct-2011)

AOD Coll 5

Parameters | $E = F_R E \cdot C_F \cdot O_F$ | $E = F_R E \cdot C_E$ | $E = F_R E \cdot C_e$
---|---|---|---
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$^{-1}$)*

| Species | $E = F_R E \cdot C_F \cdot O_F$ | $E = F_R E \cdot C_E$ | $E = F_R E \cdot C_e$
---|---|---|---
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)

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<th>Species</th>
<th>ID</th>
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</table>
OC/TPM Emission Ratios based on Andreae (2014) EFs

MODIS Ecosystem Classification

Ratio of EFs OC/TPM

EF for OC

EF for TPM
Data Resources
http://feer.gsfc.nasa.gov/data/
Comparison of Fire Radiative Energy Data

Northern Hemisphere Africa Yearly FRE

Differences still being investigated
Comparison of Fire Radiative Energy Data

Southern Hemisphere Africa Yearly FRE

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


Acknowledgement

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

Canada: MODIS 10x10-km pixels containing fire in 2002 (June 25 -Dec

A

B

C

D

E

F

G

H

Canada: MODIS 10x10-km pixels containing fire in 2002 (June 25 -Dec

Terra

Aqua

Canada regional fires, 2002

\[ y = 0.018x \]

\[ R^2 = 0.859 \]

\[ y = 0.023x \]

\[ R^2 = 0.732 \]

N. Saskachewan (Canada zone C) fires, 2002

\[ y = 0.014x \]

\[ R^2 = 0.963 \]

\[ y = 0.016x \]

\[ R^2 = 0.962 \]

MODIS emission coeff. (kg/MJ)

Literature Emission Factors (g/kg)

Ce_(850mb winds)

Ce_(925mb winds)

Ce_(700mb winds)

Regions or Zones

Unclassif.

Tropical

Forest

Savanna and

Grassland

Agricultural 

Residue

Extra-Trop. F.

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