FRP Emissions

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Bottom-Up Estimation of Fire Emissions

promising best accuracy: MACC real time

sat. obs. ~ const. land cover map

E_i = BA x AFL x CC x EFi (Seiler & Crutzen 1980)

most established, in particular GFED (van der Werf et al. 2010): MACC retrospective

Ei = emission of species i [kg(species i)]
BA = burnt area [m2]
AFL = available fuel load [kg(biomass) / m2]
CC = combustion completeness [kg(burnt fuel) / kg (available fuel)]
EFi = emission factor for species i [kg(species i) / kg(biomass)]
FRP = fire radiative power [W]
FRE = fire radiative energy [J] = \int FRP(t) dt
CF = conversion factor [kg(biomass) / W(FRE)]
Qualitative Comparison of MODIS-derived Emission Coefficients and Literature Emission Factors from Andreae and Merlet, 2001

Ichoku and Kaufman (2005), TGARS
Why Fire Radiative Power (FRP)?

**Atmospheric CO Concentration and Fire Observations in Northeast India**

[Vadrevu et al. *Atmospheric Environment* 2012]

Advantages of FRP

- real time availability, low detection threshold (compared to burnt area)
- use quantitative observations, avoid assumptions on
  - available fuel load
  - combustion completeness (compared to fire counts)
- proven suitability for Air Quality applications
Modelled AOD of Greek Fire Plumes, August 2007

Emissions calculated from Fire Radiative Power observed by SEVIRI on Meteosat.


Run at 25km global resolution, which is typical for regional models.

Comparison of model (eyvo) & MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm
Global Fire Assimilation System (GFASv1.0)

1. FRP observation input:
   • MODIS Aqua/Terra
2. gridding on global 0.5/0.1 deg grid
   • including FRP ≥ 0 corrects partial cloud cover
3. merging in 1-day slots
4. removal of spurious observations, e.g. gas flares
5. quality control
6. observation gap filling with Kalman filter, assuming
   • variance according to representativity error
   • errors spatially uncorrelated
   • fire persistence
7. fire type-dependent conversion to combustion rate
8. emission calculation
   • 40 gaseous & particulate species
World’s Top 100 Grid Cells by FRE: ~1.3% of Total
masked in GFASv1

Top100 FRP: Source Categories
Contribution to total dry matter burned 2003-2009 equivalent
(Sum Top100 FRP grid cells: 172 Tg)

- VOLCANO: 30%
- GASFLARE: 44%
- INDUSTRY: 8%
- UNCLEAR: 5%
- FIRES: 13%

Contribution to total dry matter burned 2003-2009 equivalent
(Sum Top100 FRP grid cells: 172 Tg)

Frequency [N grids]

MODIS-FRP [W m⁻²]

World’s Top100 grid cells by FRE.
Range: 0.01 to 1.48 W m⁻²
Quality Control: Threshold for Daily FRP Fields
Conversion factor depends on dominant fire type!

SA: savannah fires
SAOM: SA with potential OM burning
AG: agricultural fires
AGOM: AG with potential OM burning
DF: tropical fires
PEAT: peat burning
EF: extra-tropical fires
EFOM: EF with potential OM burning

(adapted from Heil et al., ECMWF TM628, 2010)
Land-cover specific conversion is a combined approach.

- consistent with GFED3 inventory (within its accuracy)
- advantages
  - quantitative information
  - low detection threshold
  - real-time availability

GFED3: MODIS burnt area-based C emissions

GFASv1: MODIS FRP-based C emissions

Fig. 5. Average distribution of carbon combustion [g(C) a⁻¹ m⁻²] during 2003–2008 in GFED3.1 (top) and GFASv1.0 (bottom).

(Kaiser et al. 2002)
Comparison to other inventories: Monthly CO emissions

by Niels Andela
Black Carbon Cross-validation

- **GFASv1.0** (with aerosol enhancement) compares well with NASA’s **QFEDv2.2**.

(courtesy A. da Silva)
Two approaches, with consistent results:

Ichoku, da Silva, Sofiev

- scale FRP empirically to emissions as observed in plumes
- geographical dependence
- possibly extend to other species with relative emission factors

Wooster, Kaiser

- scale FRP to DM as prescribed in GFED
- fire type dependence
- adjust single species emission factors to atmospheric observations
- Without CO2 observations, the parameters remain underdetermined 😞
Monthly C emission up to September 2011

- Global
- Europe
- S. Hem. America
- Australia
Monitoring of ECV Fire Disturbance

Annual fire anomalies in NOAA’s *State of the Climate* reports.
Key Features

satellite-based FRP assimilation:
- global coverage
- NRT availability
- daily resolution (tests: hourly)
- similar maturity as BA approach

MACC-GFAS:
- publicly available in several data servers
- various product formats:
  - GRIB
  - NetCDF
  - GIF map
  - PNG spaghetti plot
  - KML

http://gmes-atmosphere.eu/fire
Real-time Supply Chain

**Data providers:** (acquired by OBS)
- NASA: MODIS FRP
- EUMETSAT LSASAF: SEVIRI FRP
  - UCAR: GOES-E/-W rad.
  - ECMWF: met. forecasts

**MACC FRP processing:**
- KCL (IM): GOES-E/-W FRP

**MACC GFAS processing:**
- GFAS @ ECMWF
  - assimilated FRP
  - combustion rate
  - emissions
  - (injection heights)

**archives @ ECMWF:**
- ECFS
- MARS

**archive @ FZJ:**
- OGC web server

**GEIA archive:**
- OGC web server

**users**
Conclusions

- MACC GFAS is producing daily biomass burning estimates
  - for 40 smoke constituents
  - in real time
  - publicly available
- All global MACC systems consistently use GFAS emissions.
- More and more regional air quality systems use GFAS.
- GFAS compares well with other inventories.
- Feedback from atmospheric validation is becoming more widely available.
- Many uncertainties remain. Current developments focus on
  - plume rise model
  - merging of geostationary FRP observations
  - 5-day fire evolution prediction
  - improved emission factor formulation
- http://gmes-atmosphere.eu/fire
Observational FRP Coverage

- average number of observations
  - damped for large VA
- of any area in 0.5 deg grid cell
- during 1 day

[Kaiser et al. 2011]
GEO-based
GBBEP-Geo (2010)
[Zhang et al. JGR 2012]

LEO-based
GFASv1.0 (2010)
[Kaiser et al. BG 2012]
FIR Developments: FRP merging of GEO and LEO observations

- scientifically not solved anywhere
- We follow two approaches
  - based on GFAS-gridded observations
  - characterisation of bias (GEO FRP, view angle, local time)
  - prediction of bias from previous co-located observations

conditional PDF (Jun2010-Jul2012)
GFAS Emissions in MACC Systems

- global production
  - aerosols
  - reactive gases
  - greenhouse gases
- reanalysis (2009-10)
- CO-tracer forecasts
- EURAD regional forecasts
FIR Developments: Dynamic Emission factors

Top: partition fuel sources contributing to emissions (shown here the fraction wood)

Each fuel source gets a MCE range based on literature (MCE = Modified Combustion Efficiency = CO2 / (CO+CO2))

Meteorology used to scale within the range

MCE relates (reasonably) well with EFs of other trace gases and aerosols

Middle: emissions difference between MCE run and standard GFED run (Gg CO / year)

Bottom: atmospheric concentration (ppb / month) for lower atmosphere (up to 800 hPa)

Next step: build into GFAS
Plume Rise Model Development

Objective: Improvement and Validation of a new PRM based on the Freitas Model

- MISR reference dataset of observed FRP and plume top height created (N America)
- PRM by Freitas et al. 2007 implemented and optimised
  - input data stream from ECMWF operational forecasts
- Sofiev et al. 2012 implemented
- PRMv1 delivered to ECMWF
  - for implementation in GFAS

Ronan Paugam, KCL
GFAS test version with 1 hour time resolution implemented

- assimilation of GOES FRP products
- 1-hour forecast based on corresponding 5 hour window of past 24 hours
- provided for SAMBBA campaign in real time
- evaluation to follow
Key Features

- satellite-based FRP assimilation:
  - global coverage
  - NRT availability
  - daily resolution (tests: hourly)
  - well documented
  - publicly available in several data servers
  - various product formats:
    - GRIB
    - NetCDF
    - GIF map
    - PNG spaghetti plot
    - KML

http://gmes-atmosphere.eu/fire
2012 is most interesting: Siberia, Western US & Australia!
FRP Example: Russia 2010

carbon combustion rate on 4 August (g d\(^{-1}\) m\(^{-2}\))
2010 fires over Russia

Fire radiative power from MODIS, east of Moscow (50-60N, 35-

Large night-time values are indicative of peat fires

Modelled emissions were those appropriate to woodland fires
User statistics: GEIA ECCAD

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