Global Fire Data-sets for Model Input

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Thanks to Niels Andela, Angelika Heil, Ronan Paugam, Martin G. Schultz, Guido R. van der Werf, Martin J. Wooster, Jean-Jacques Morcrette, Angela Benedetti and Samuel Remy!

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Monitoring atmospheric composition & climate – II

AeroCom Workshop, Hamburg
25 September 2013

KING'S College LONDON

ECMWF

MAX-PLANCK-INSTITUT FÜR CHEMIE

MAX-PLANCK-GESELLSCHAFT

SEVENTH FRAMEWORK PROGRAMME

European Commission

GMES

Observing our planet for a safer world

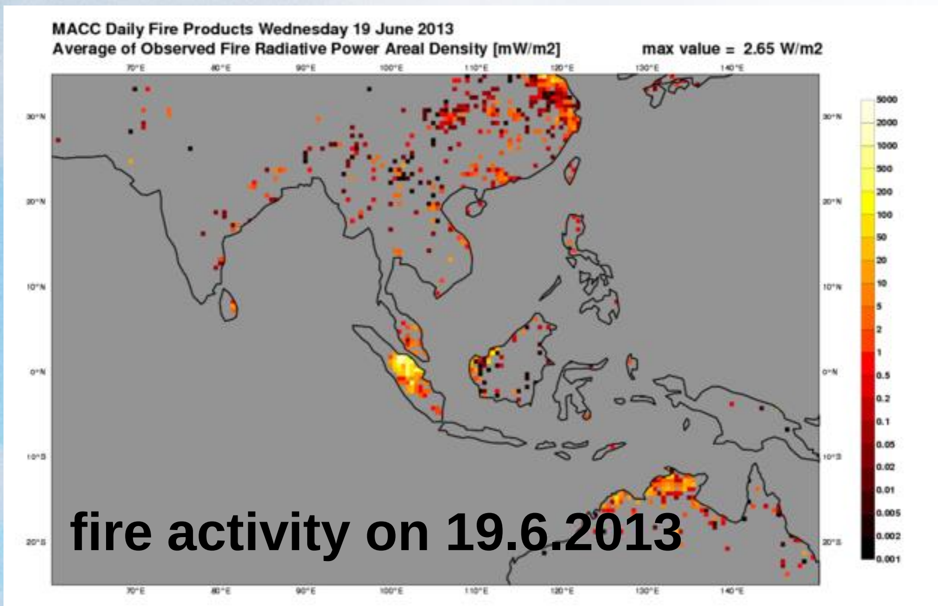
copernicus

Smoke from Sumatran fires in Singapore in June 2013

AQ measurements at 12am on 21.6.2013 from http://app2.nea.gov.sg

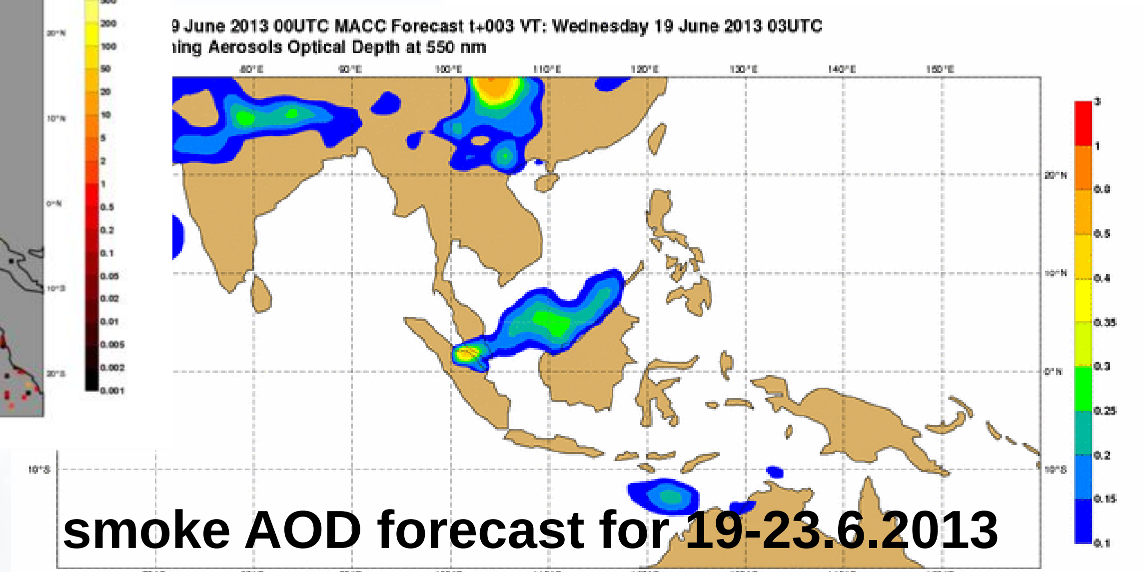
PM2.5 Concentration (µg/m³)

North	South	East	West	Central	Overall Singapore
273	302	273	263	242	242-302



fire activity on 19.6.2013

graphics from http://www.copernicus-atmosphere.eu



smoke AOD forecast for 19-23.6.2013

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Bottom-Up Estimation of Fire Emissions

promising best accuracy: MACC real time

sat. obs. ~ const. land cover map

$$E_i = FRE \times CF \times EF_i$$ (Wooster et al. 2003/5)

$$E_i = BA \times AFL \times CC \times EF_i$$ (Seiler & Crutzen 1980)

burnt biomass

"key uncertainty"

(e.g. Reid et al. 2009)

(dynamic) vegetation model

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

Ei = emission of species i [kg(species i)]

BA = burnt area [m2]

AFL = available fuel load [kg(biomass) / m2]

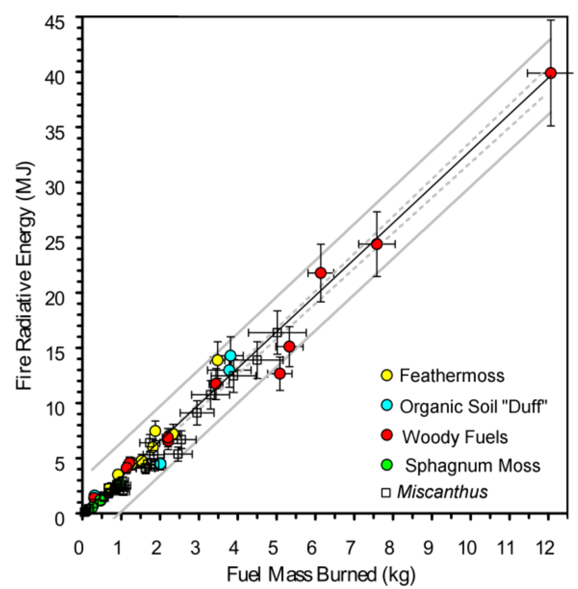
CC = combustion completeness [kg(burnt fuel) / kg (available fuel)]

EFi = emission factor for species i [kg(species i) / kg(biomass)]

FRP = fire radiative power [W]

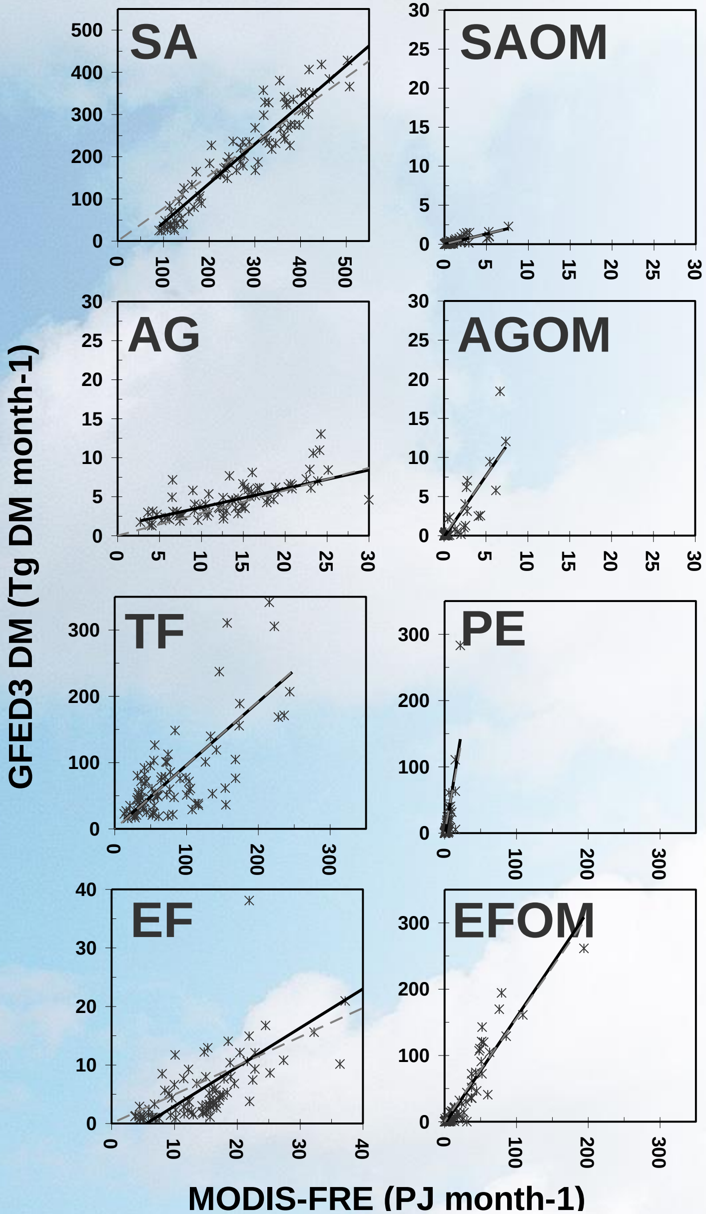
FRE = fire radiative energy [J] = ∫ FRP(t) dt

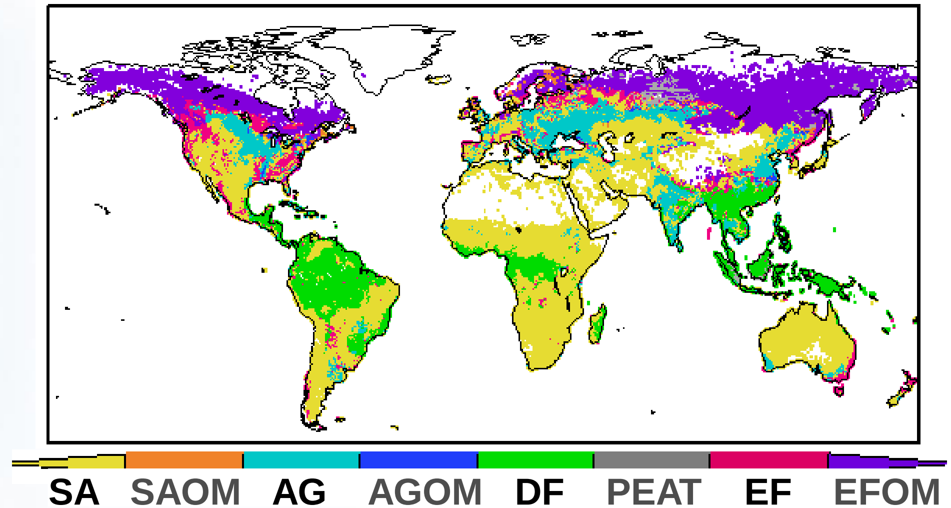
CF = conversion factor [kg(biomass) / W(FRE)]



graphics by M. Wooster

FRP conversion factor analysis against GFEDv3





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

Conversion factor depends on dominant fire type!

(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

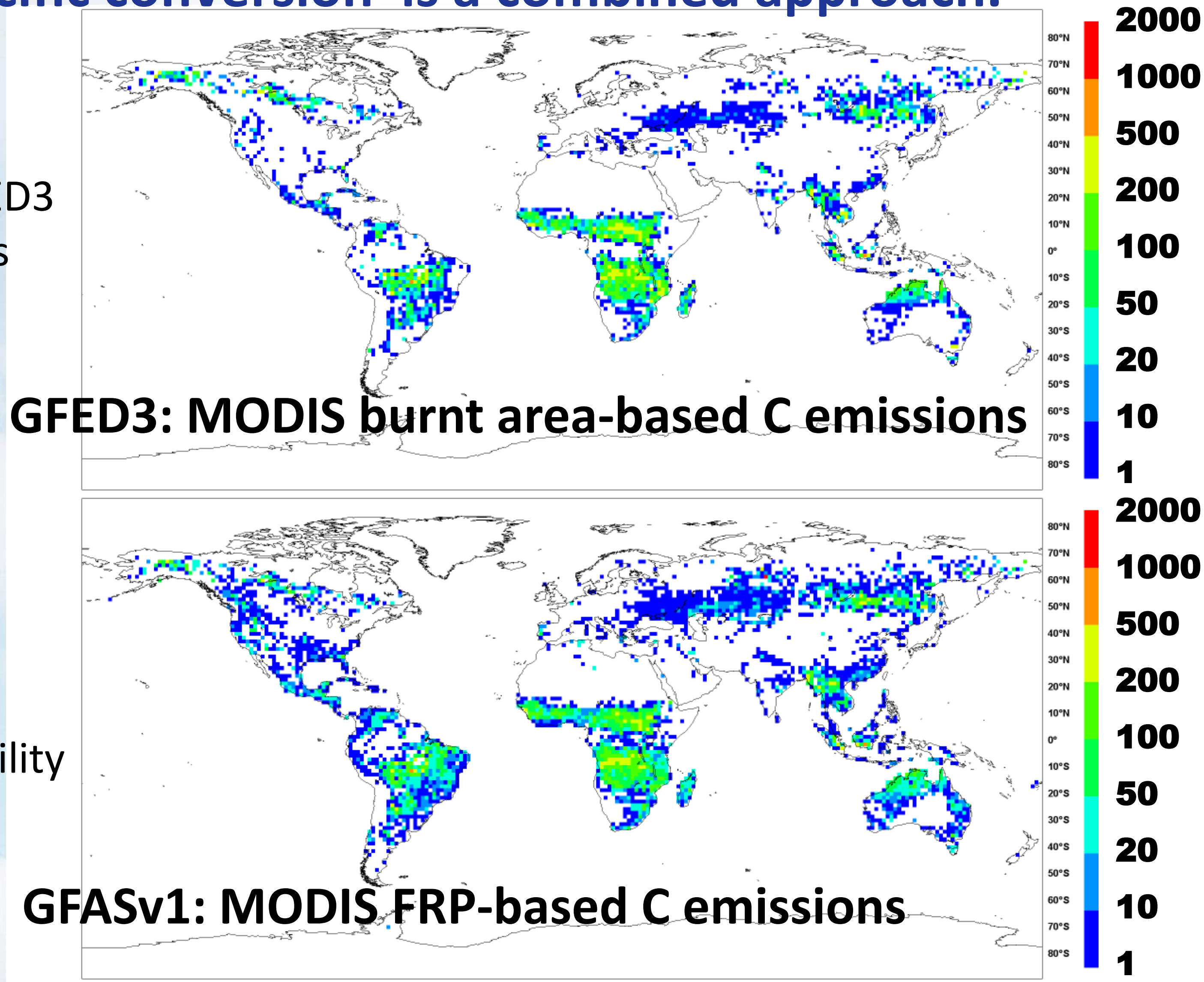
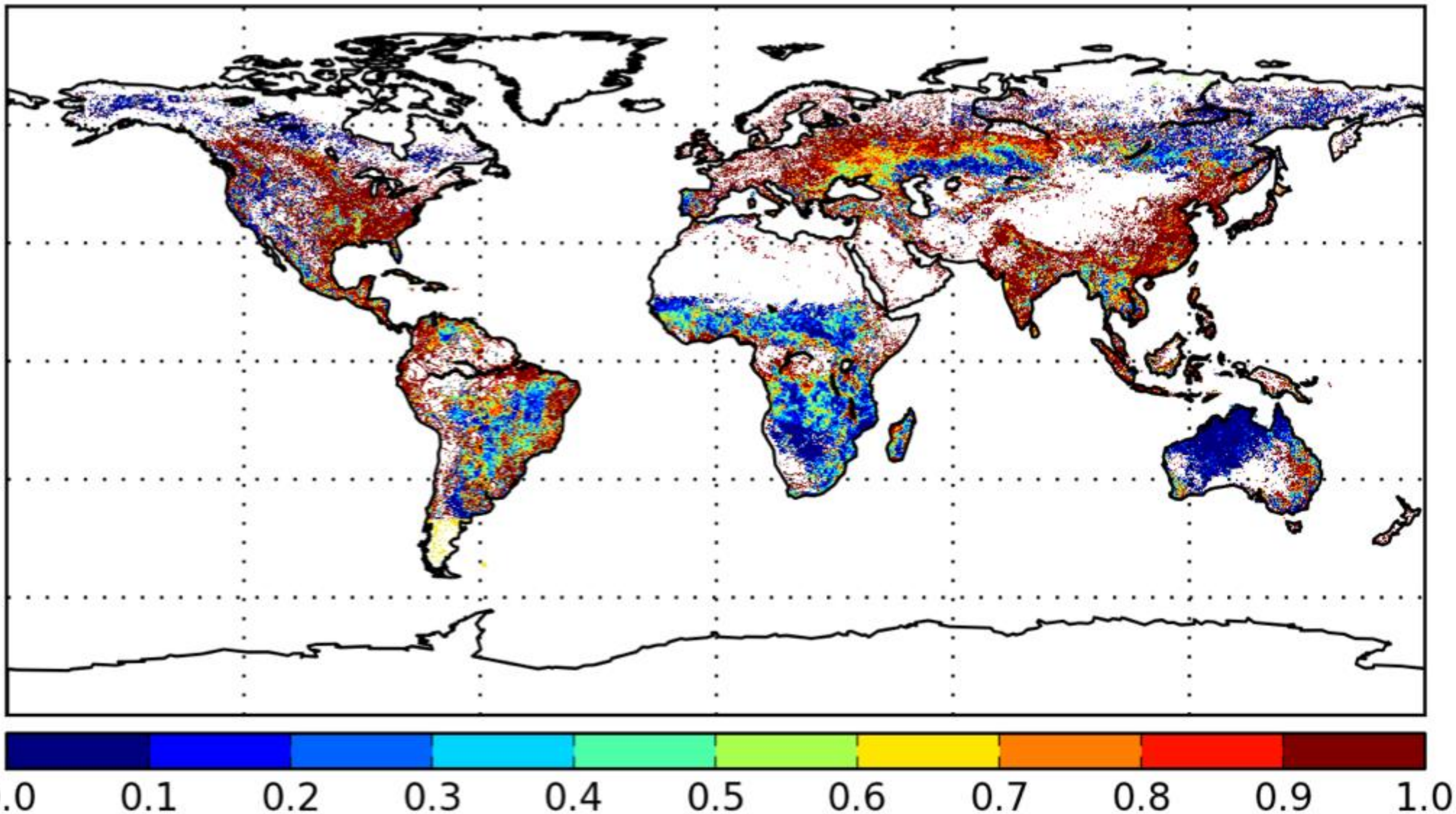


Fig. 5. Average distribution of carbon combustion [g(C) a^{-1} m^{-2}] during 2003–2008 in GFED3.1 (top) and GFASv1.0 (bottom).

(Kaiser et al. 2012)

Small fire fraction of total area burned



See Randerson et al. (2012) JGR-Biogeosciences

Increase in burned area and emissions due to small fires

Region	Burned area	Emissions
Europe	111%	98%
CONUS	75%	81%
Indonesia	157%	55%
Australia	7%	9%
Globe	*35%*	*35%*

Emissions based on the Global Fire Emissions Database (GFED) framework

Extreme Cases: Large Tundra and Peaty Soil Fires

- 2007 Anaktuvu River fire
  - Mack et al. 2011
  - 1039 km^2 of tundra burnt
  - 2.1 ± 0.4 Tg C burnt
  - ~annual net sink of Arctic tundra
- GFASv1.0
  - 1.7 Tg C burnt

- CO, Western Russia 2012

Table 1. Prior and Posterior Emissions. Emissions are given in Tg CO and have been integrated from 16 July 2010 up to 17 August 2010. Region R1 is defined from 35° E to 45° E, and from 53° N to 58° N, see Fig. 3 and Konovalov et al. (2011). Region R2 is defined from 30° E to 70° E, and from 46° N to 70° N, see Fig. 3.

Simulation	Prior R1	Poste R1	Prior R2	Poste R2
MERGED	1.06	6.82	6.5	26.6
MERIS	0.86	7.29	3.9	24.0
GFAS	10.52	9.93	12.4	22.0
GFED3	0.63	10.06	2.0	22.3
MERGED-CLIM	1.06	5.26	6.5	22.6
MERGED-DAILY	1.06	5.98	6.5	25.1
MERGED-DIURNAL	1.06	6.62	6.5	26.9
MERGED-INFLATE	1.06	6.98	6.5	26.8

  - Krol et al. 2013

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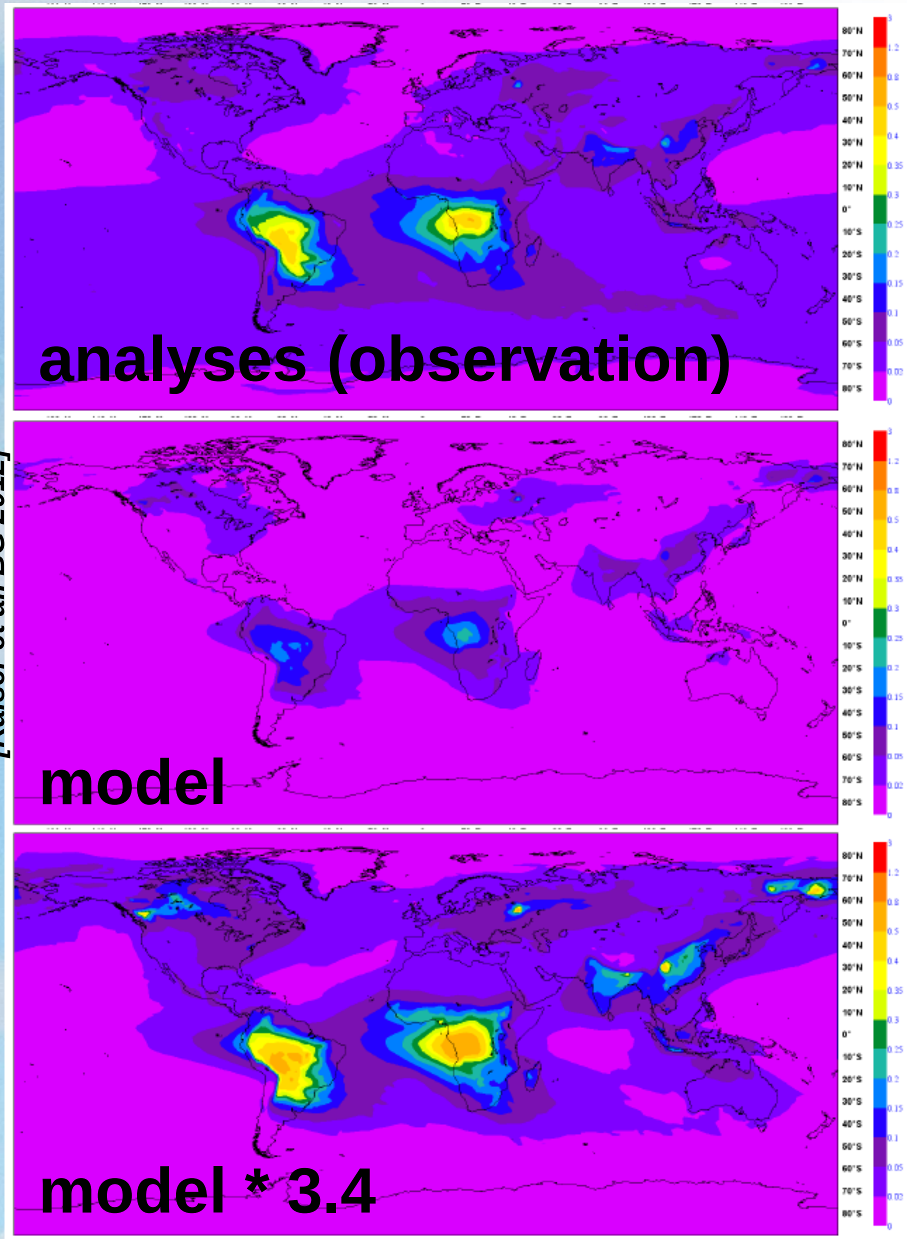
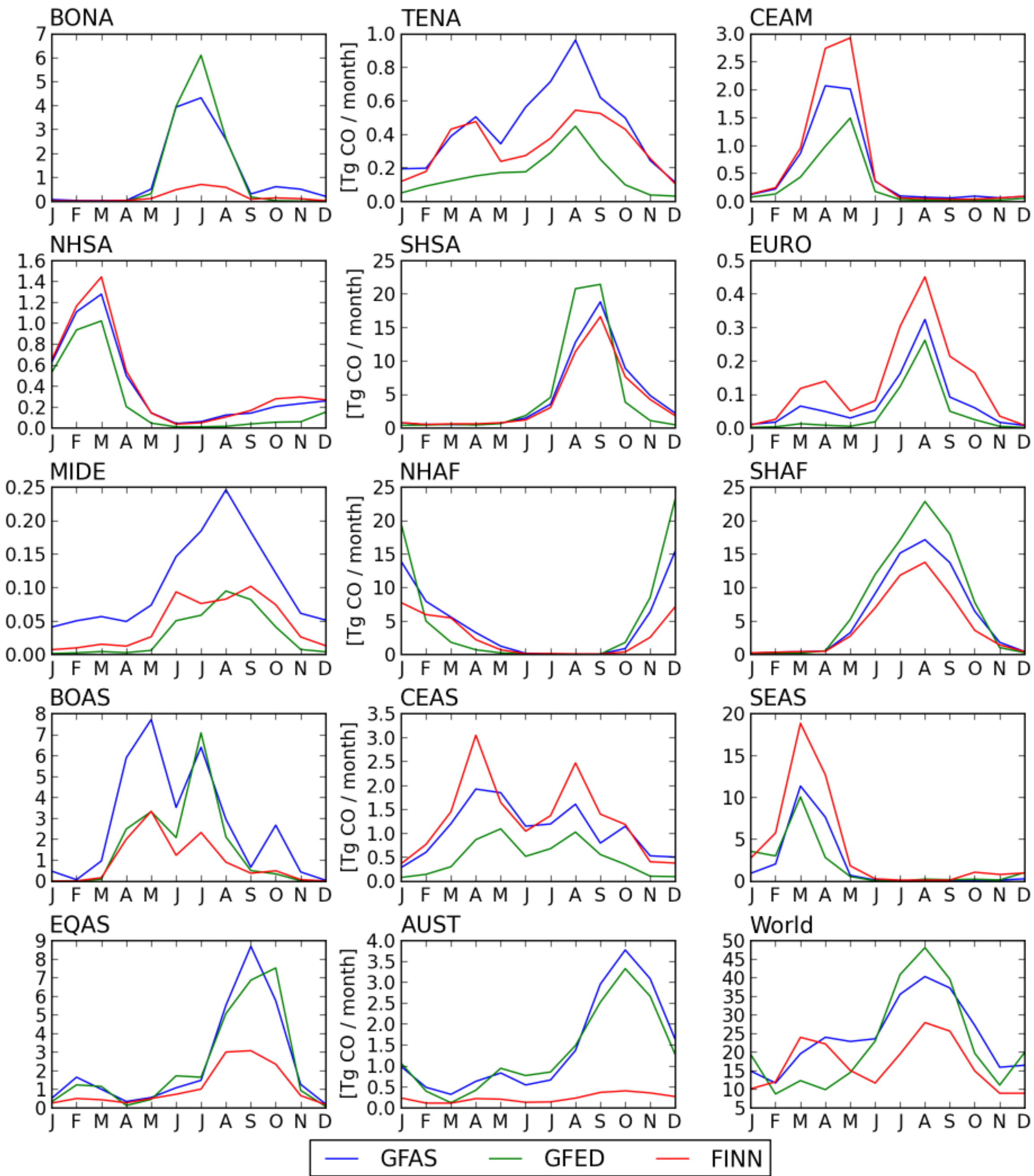
Validation of Aerosol Emissions: AOD(OM) + AOD(BC)

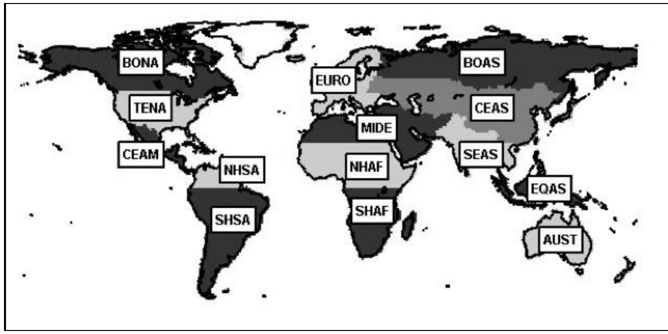


[Kaiser et al. BG 2012]

- assimilation of MODIS AOD
  - active: "analyses"
  - passive: "model"
- average of 15 Jul – 31 Dec 2010
- AOD (OM+BC) low by mean factor 3.4
  - similar to other top-down estimates:
    - NASA (GFED2.2)
    - NRL (Reid et al. 2009)
    - aerosol inversions (Huneeus et al. 2012)
  - inconsistent with bottom-up estimates:
    - GFED2/3 (van der Werf et al. 2006/10)
    - published emission factors (e.g. Andreae & Merlet 2001)
    - INPE/CPTEC (Freitas et al. 2005)
- Petrenko et al. 2012: regional variability
- recommendations:
  - correct emissions by factor 3.4
  - do multi-parameter analysis

Comparison to other inventories: Monthly CO emissions

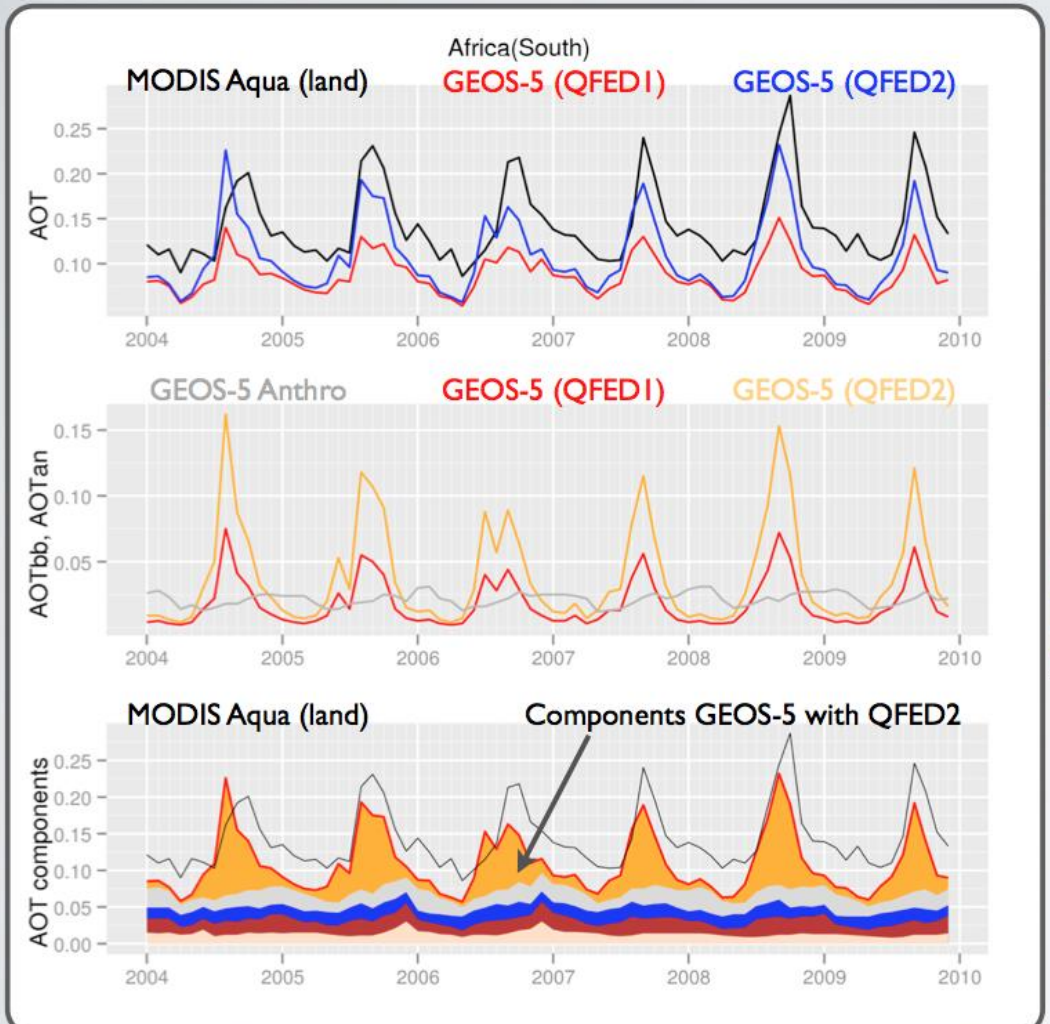




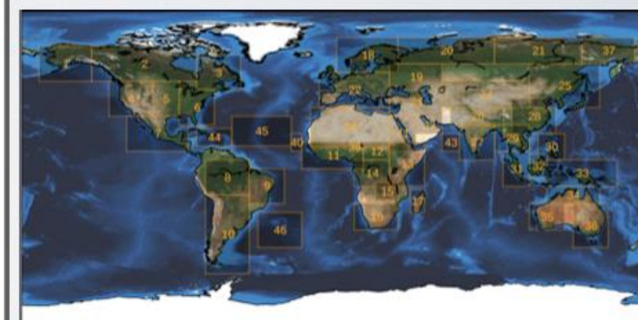
by Niels Andela

Derive enhancement factor geographically dependently:

QFED Tuning



- GFED emissions led to anemic biomass burning AOT in model
- QFED1 had global (per species) tuning of satellite fire product to GFED emissions; also led to low AOT in model
- QFED2 is tuned per biome and species via simulations w/ and w/out specific biome biomass burning emissions and analyzed regionally



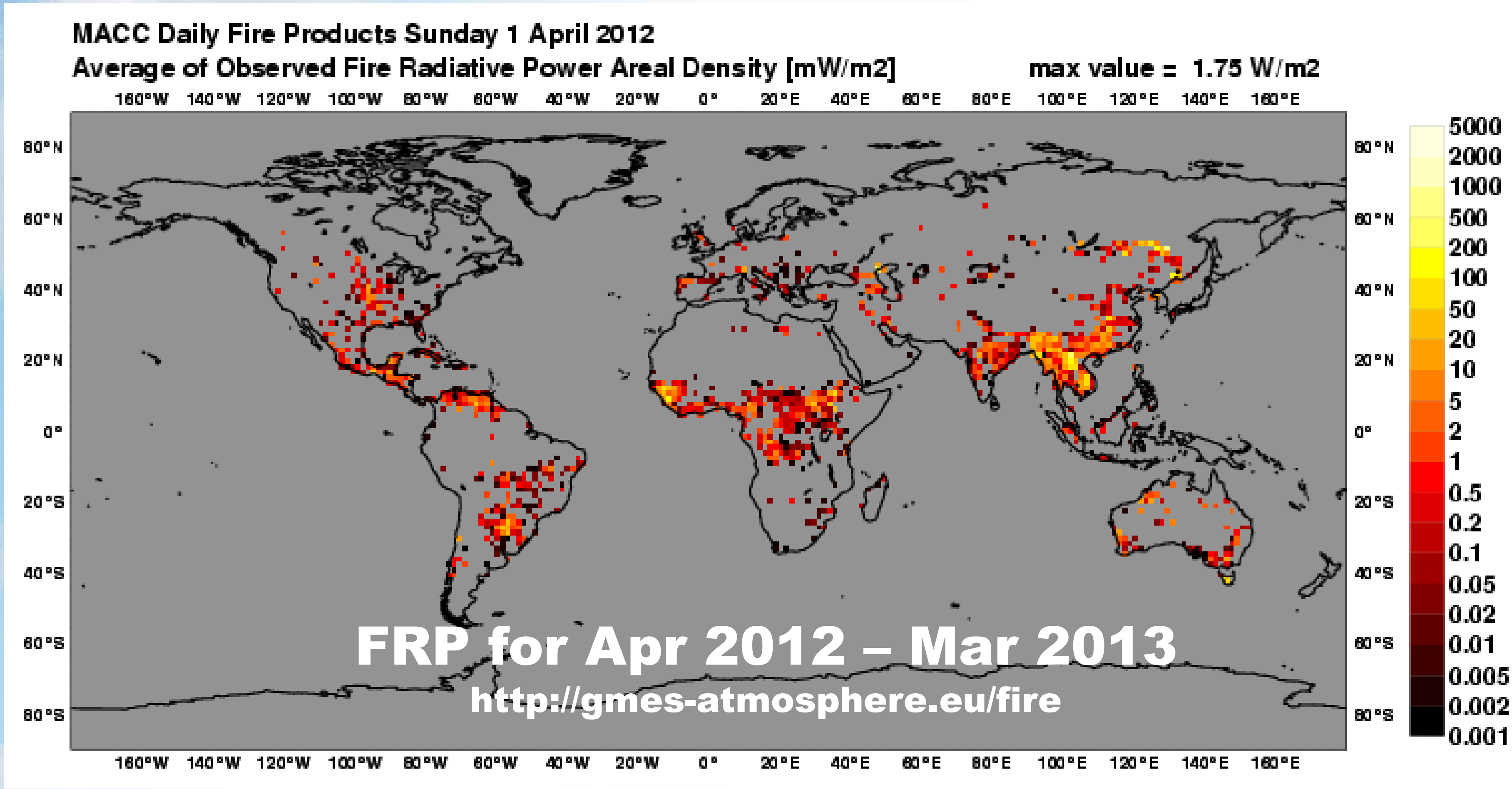
Biome	C
Tropical Forest	2.5
xTropical Forest	4.5
Savanna	1.8
Grassland	1.8

Tuning relative to QFED1

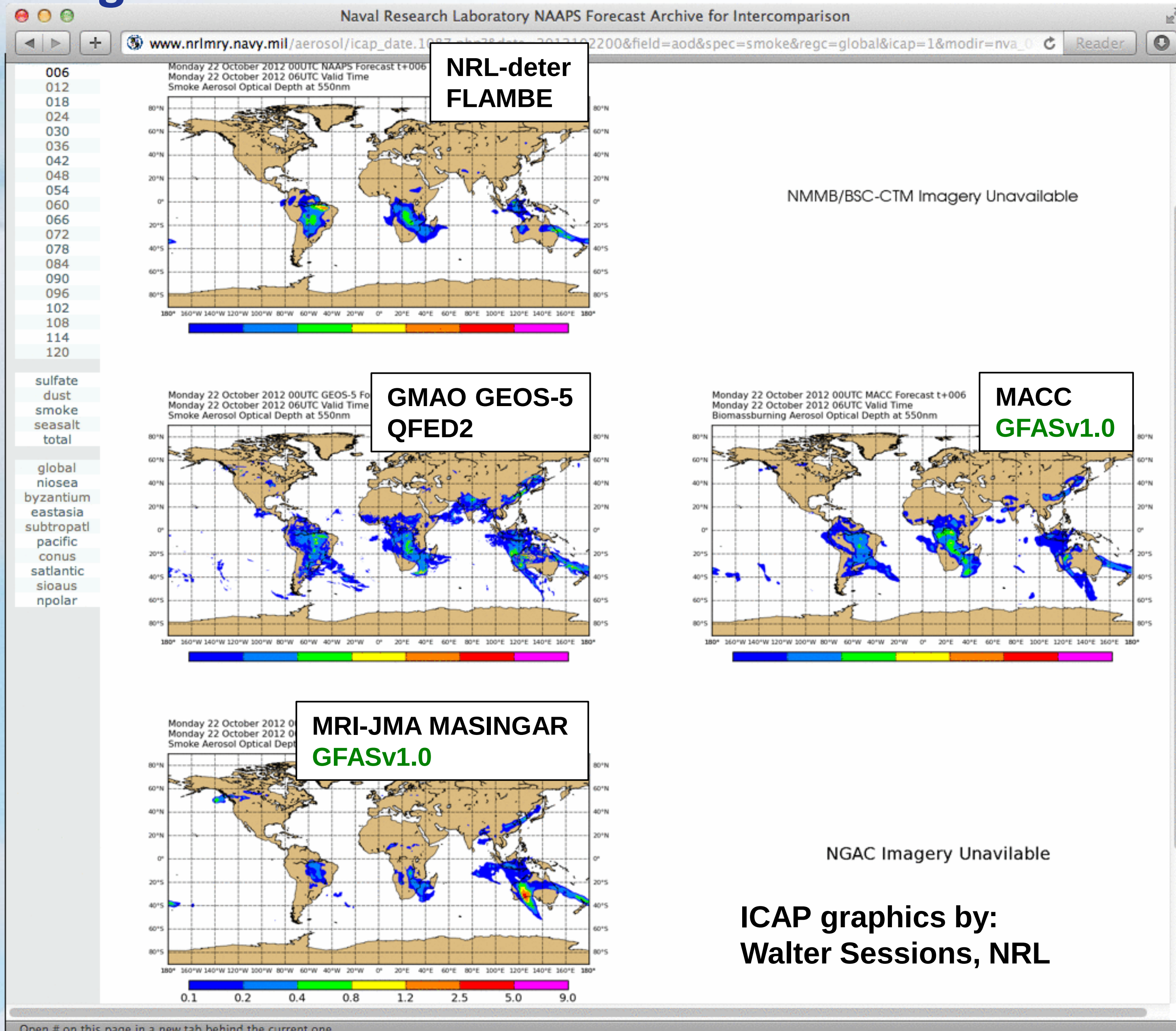
P. Colarco, MACC Assembly, May 25, 2011, Antropia, the Netherlands

NRT production of daily FRP and Emissions

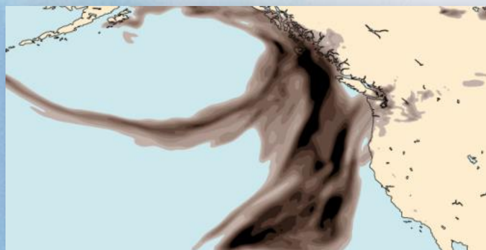
- GFASv1.0
  - MODIS FRP assimilation
  - ~50 km resolution
  - 1 Jan 2003—yesterday
- GFASv1.1
  - MODIS FRP assimilation
  - ~10 km resolution
  - 1 Jan 2005—yesterday



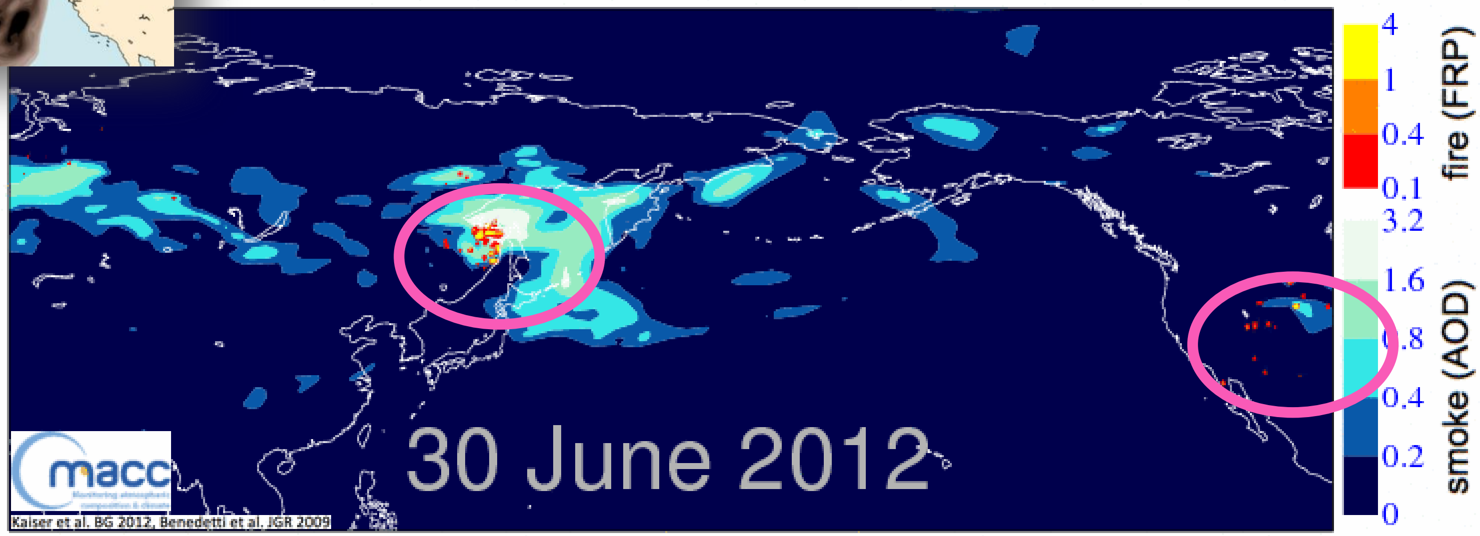
Daily GFAS used by blobal pre-operational smoke aerosol forecasting in MACC and at MRI-JMA



Where is the July 2012 Seattle haze coming from?

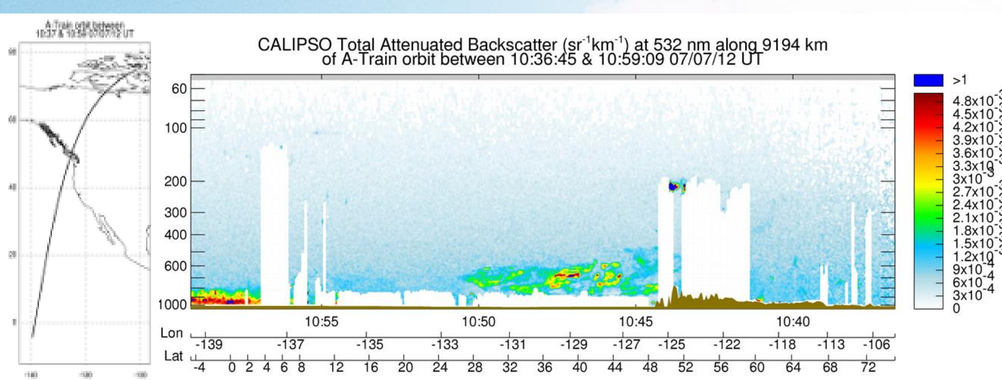


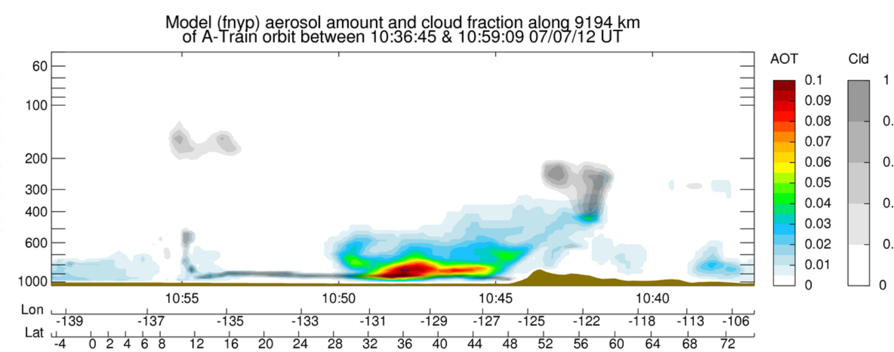
MACC-II has estimated that the global amount of biomass burnt last June was the highest of the past decade, with wildfires particularly acute in boreal forests in North-America and Asia.



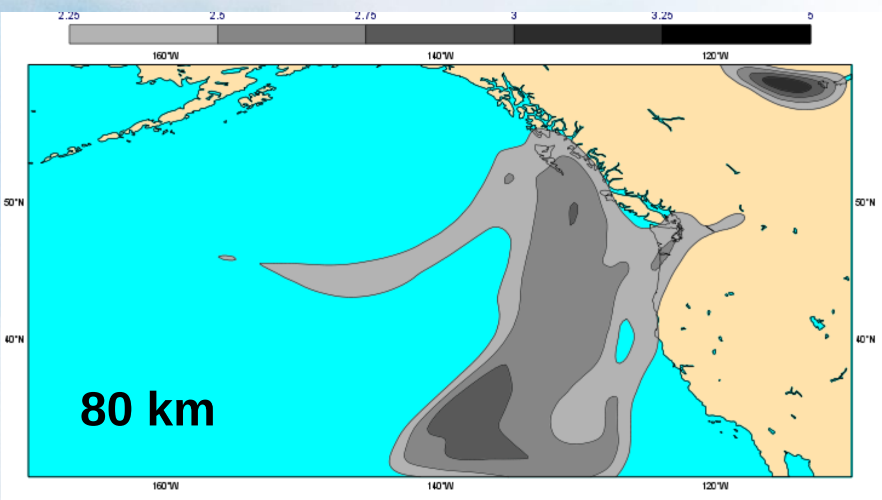
Ubiquitous sources!

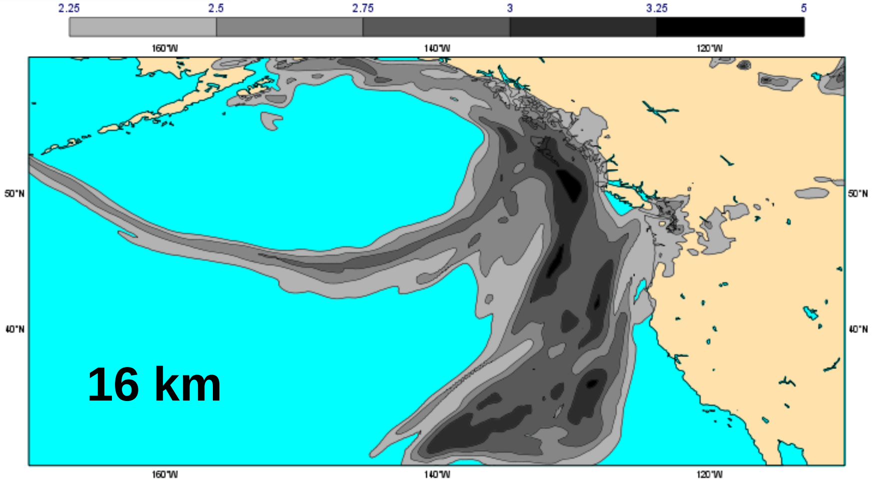
Independent validation against CALIPSO

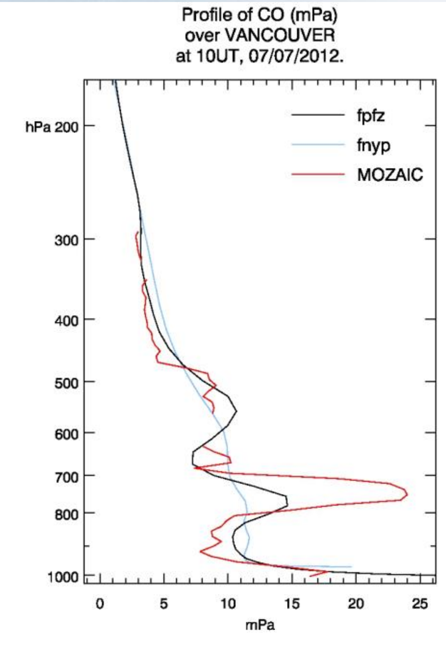


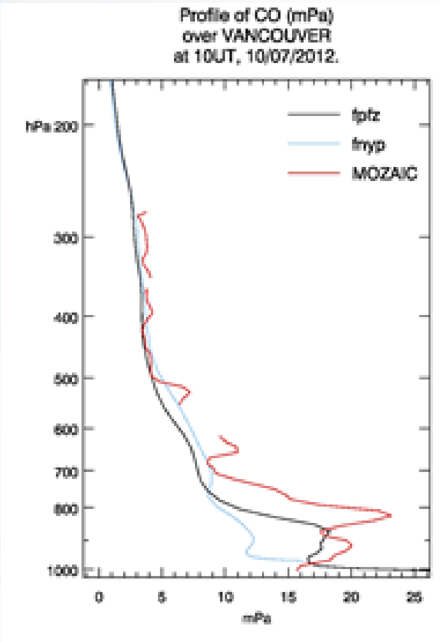


Benefit of high resolution









MACC already runs forecasts at high resolution with simplified chemistry for CO. This provides better forecasts in areas with complicated orography.

IAGOS observations

Low resolution model

High resolution model

IBBI | Interdisciplinary Biomass Burning Initiative

IGAC ileaps WMO

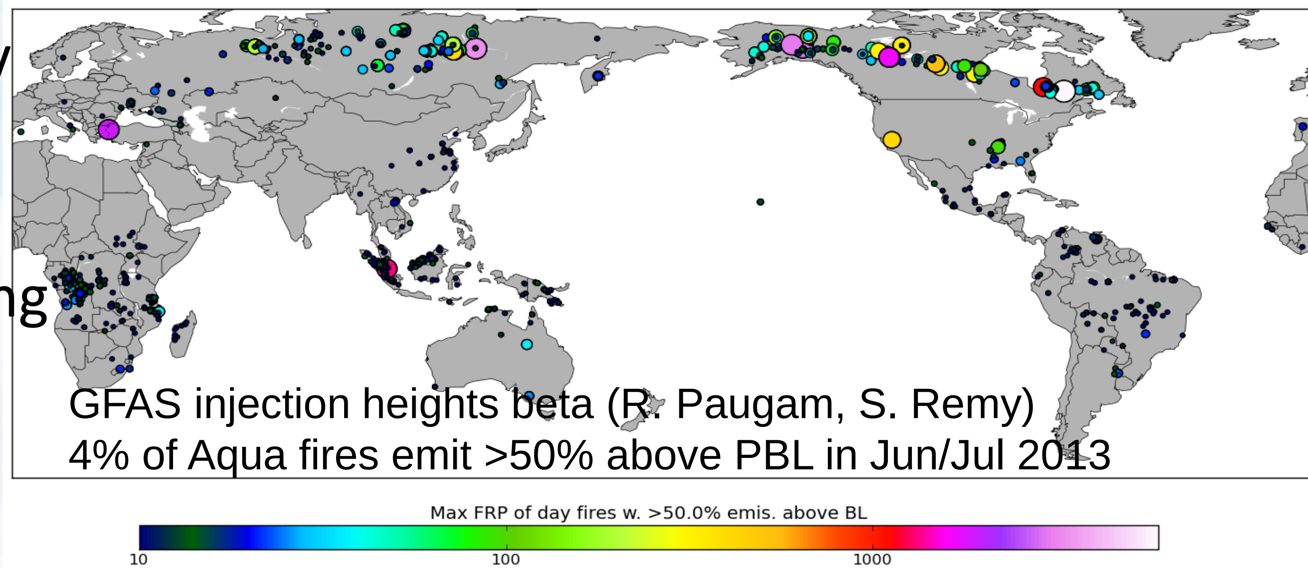
- Workshops in 2009 and 2012 (ESF and IGAC-iLEAPS-WMO) found **advances** in biomass burning research **since** the 1990s and **BIBEX**:
  - modelling: fire spread, plume rise, global operations
  - satellite observations of fires and atmospheric smoke plumes

  But **research** has also become **fragmented**.
- **New IBBI** aims to bring the various communities and new developments together to the improve physical understanding and modelling capabilities of biomass burning.

- next workshop in Schloss Ringberg on 23–26 April 2014
- Atm. Env. plans special issue with IBBI.
- co-chaired by Melita Keywood & Johannes Kaiser
- *http://www.mpic.de/projekte/ibbi.html*

Some Conclusions

- FRP-based BB emissions as mature as any other
  - and more sensitive to small fires than BA-based ones.
  - GFAS is freely available 2003 – real time.
- Bottom-up aerosol emission inventories need enhancement.
  - I don't know why.
  - The BB comparison is very timely!
- Other research topics
  - Injection heights
  - diurnal variability
  - resolution
  - gas flaring
  - residential burning
  - CCN
  - BC-OC

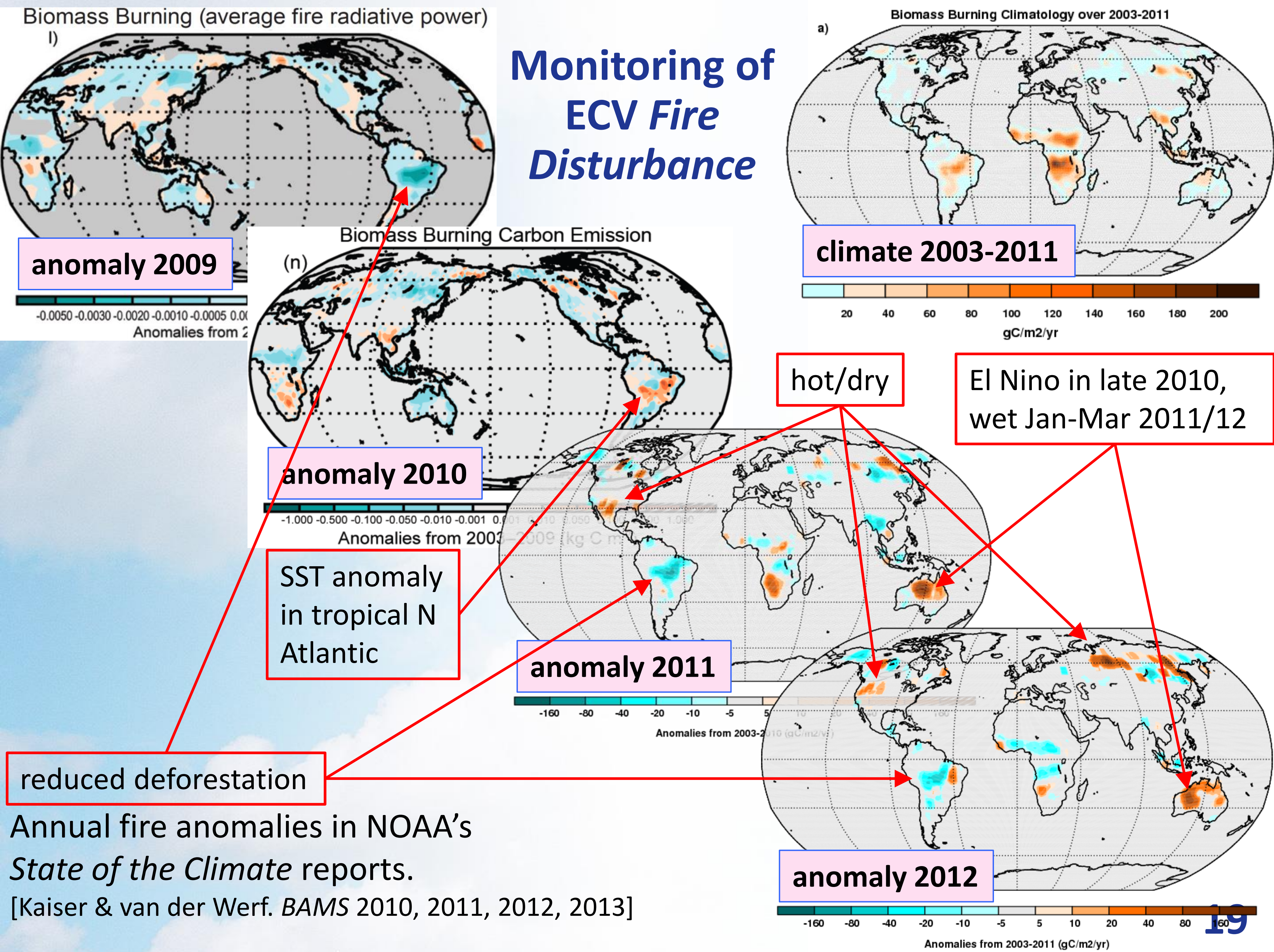


GFAS injection heights beta (R. Paugam, S. Remy)
4% of Aqua fires emit >50% above PBL in Jun/Jul 2013

Some global biomass burning inventories

Name	Ref.	satellite era	real time	BA-based	hot spot-based	FRP-based	retrospectively	reports	fire/veg. modelling
GFED3	van der Werf et al. 2010	1997-		yes					
GFED4		1997-		yes	yes				
FLAMBE	Freitas et al. 2005		yes		yes				
FINN	Wiedinmyer et al. 2010	2005-	yes		yes				
QFED2			yes			yes			
GFAS1	Kaiser et al. 2009/2012	2003-	yes			yes			
IS4FIRES	Sofiev et al. 2009		yes			yes			
GICC	Mieville et al. 2010				yes		1900-2005	yes	
RETRO	Schultz et al. 2008						1960-2000		yes
	Ito & Penner 2005						1870-2000		

Monitoring of ECV *Fire Disturbance*



Annual fire anomalies in NOAA's *State of the Climate* reports.

[Kaiser & van der Werf. *BAMS* 2010, 2011, 2012, 2013]

- BA-based
  - no cloud cover
  - high spatial resolution
  - hybrids using hot spots
    - high temporal resolution
    - small fires
  - both consistent

- FRP-based
  - small fires
  - real time
  - diurnal cycle
  - stability for extreme events (Tundra, Russia, Greece)
  - gas flares

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IBBI Interdisciplinary Biomass Burning Initiative

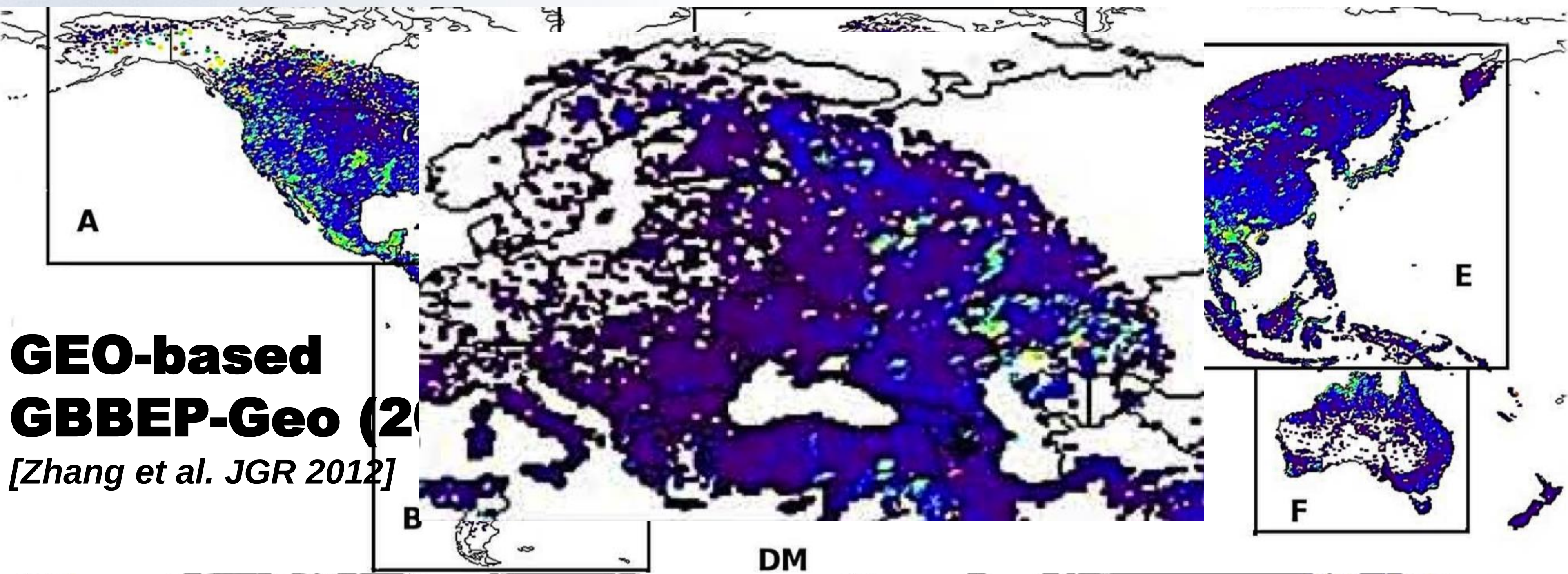
IGAC ileaps WMO

Some scientific challenges

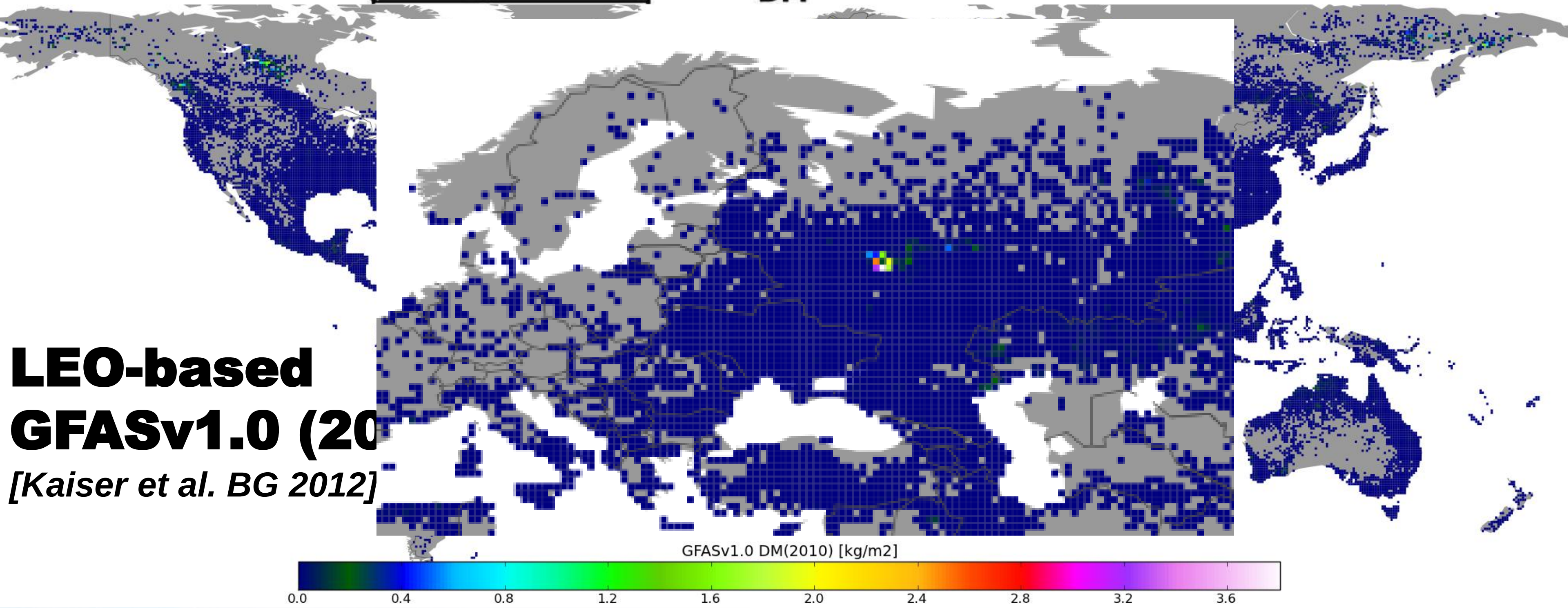
- discrepancy between top-down and bottom-up aerosol emission estimates
- multi-species inversions
- combining information from comprehensive fire and smoke observations

- variability of emission factors
- injection heights, pyro-convection, in-plume chemistry

GEO-based
GBBEP-Geo (2
[Zhang et al. JGR 2012]



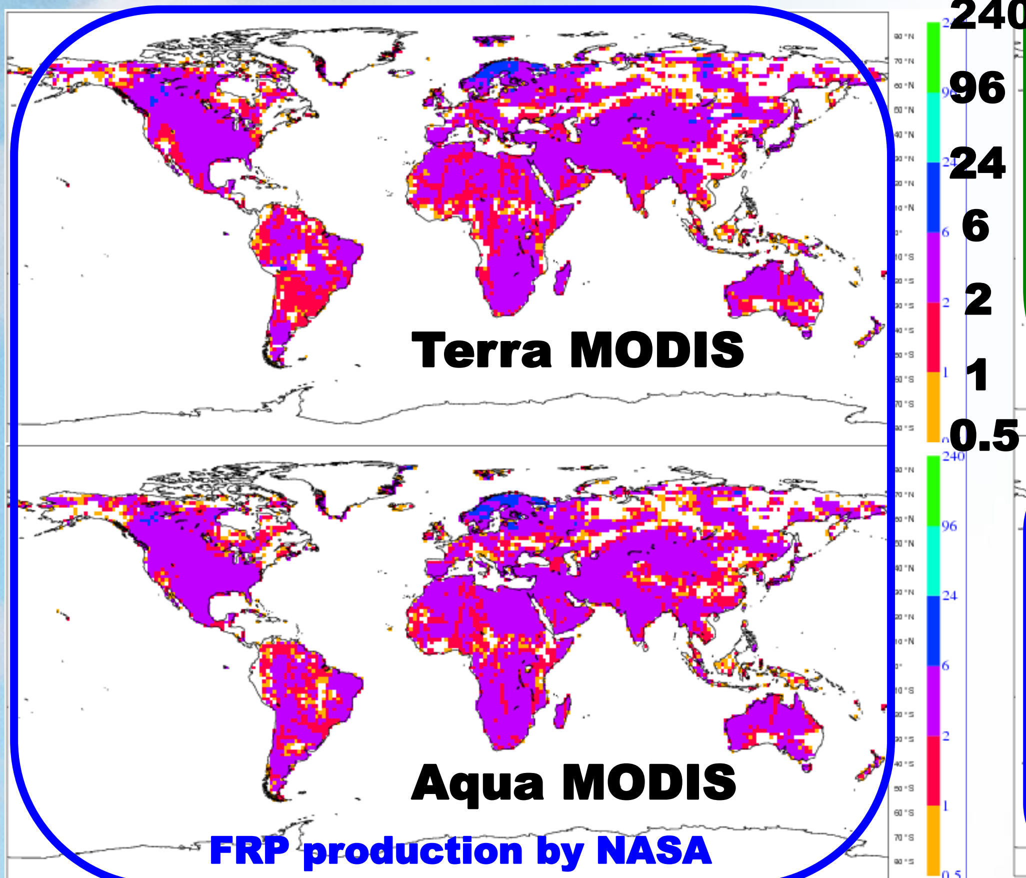
LEO-based
GFASv1.0 (20
[Kaiser et al. BG 2012]



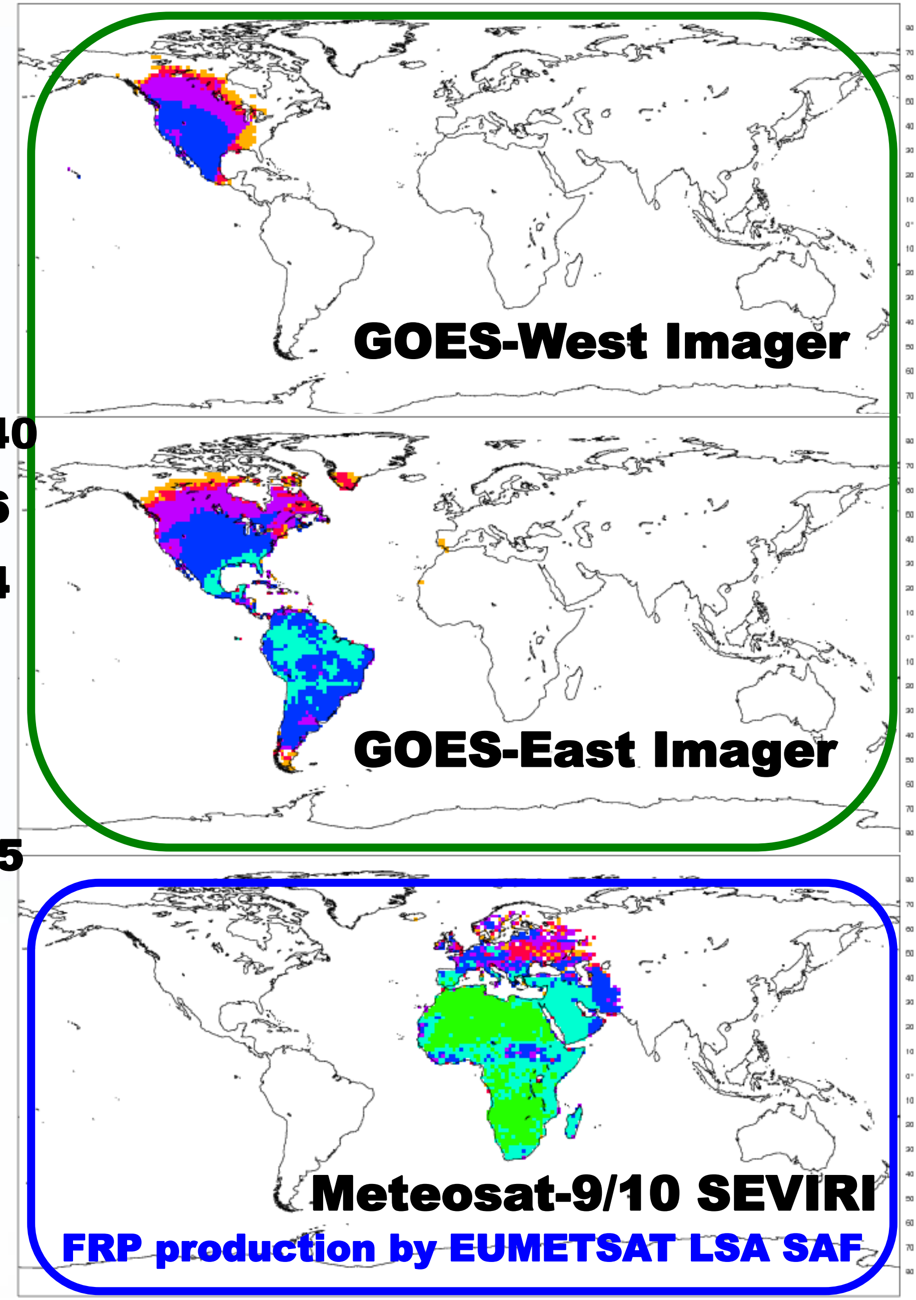
Observational FRP Coverage

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

[Kaiser et al. 2011]



FRP production in MACC



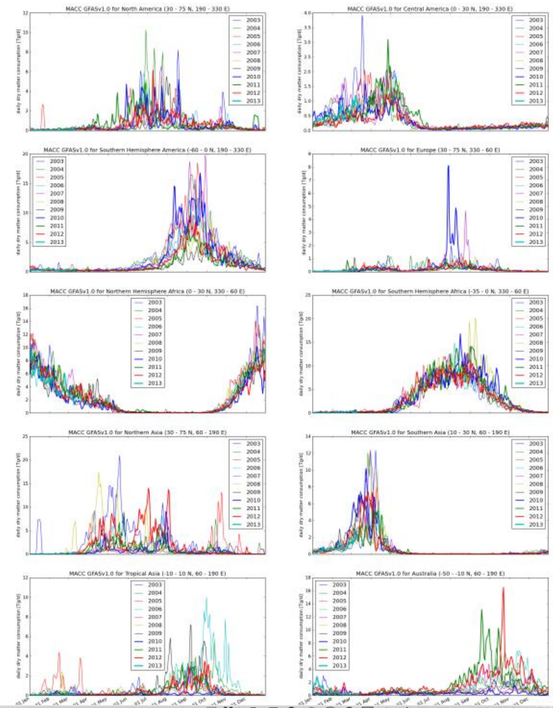
Key Features

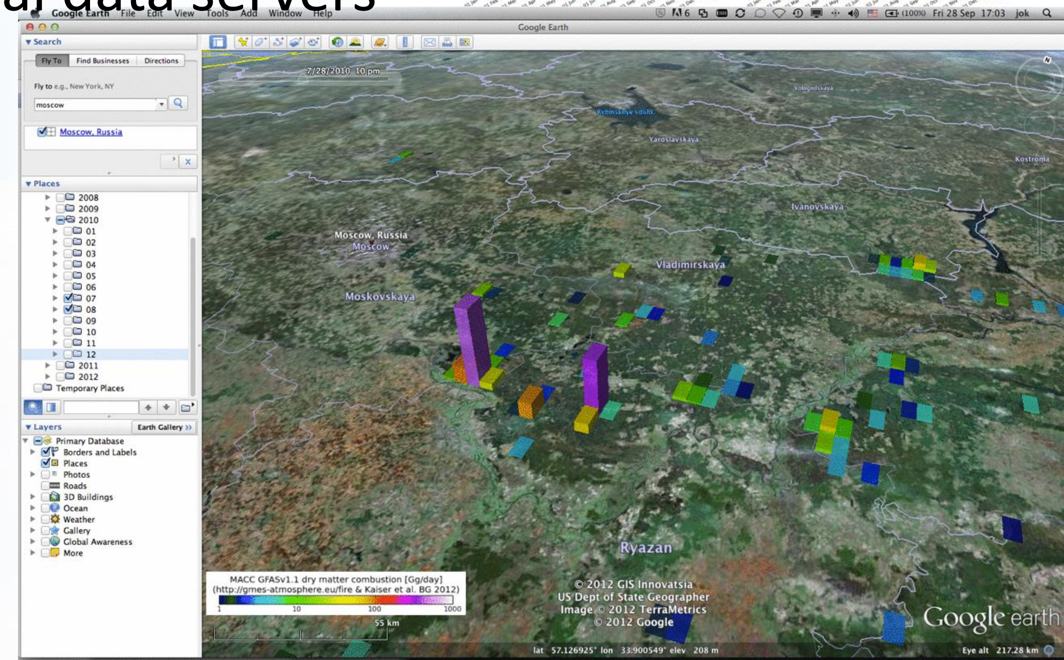
satellite-based FRP assimilation :

- 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

Various types

- Bottom-up (from satellite obs. of fires)
  - burnt area or fire radiative power
  - real time or retrospectively
- Top-down (inversion)
  - inversion of observed PM or AOD
  - inversion of CO
  - combine with bottom-up
- emission factors
- diurnal cycle, injection height
- residential burning, gas flares, daily resolution, CCN