Global Fire Emission Monitoring with Fire Radiative Power in the MACC Project

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M.J. Wooster, W. Xu, more MACC partners and Gareth Roberts

Russia, August 2010

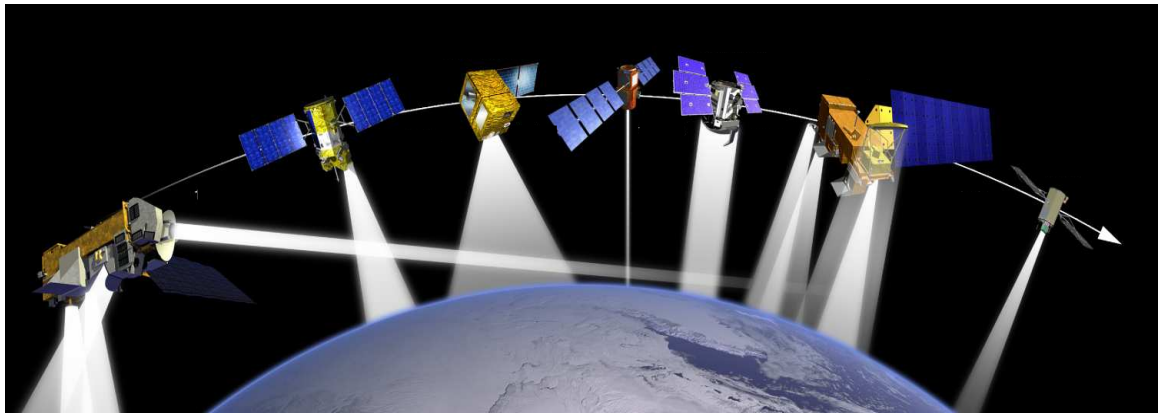
GMES Atmosphere Component Service

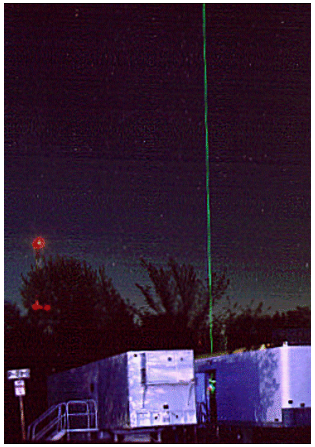
- Part of Europe's Global Monitoring for Environment and Security initiative

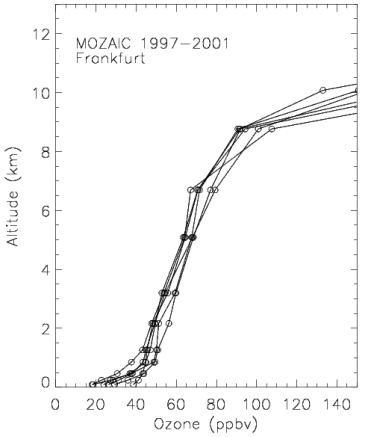
  - development of operational space-based observation
  - strengthening of complementary in-situ observing systems
  - development and operation of associated data and information services, based on core integrated assimilation and forecasting
    - Three environmental services for Land, Ocean and Atmosphere

- A 48-partner EC-funded project called MACC:
  - provides pilot GMES Atmosphere Component Service
  - succeeds earlier projects GEMS and PROMOTE
  - coordinated by ECMWF

MACC data use & modelling



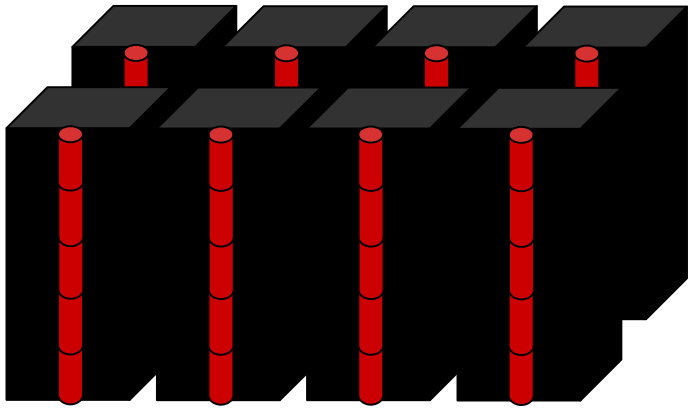




validation

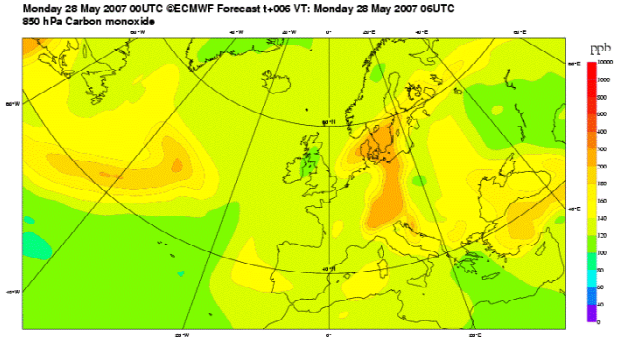
data assimilation

meteo data,
CO_2, CH_4, CO, O_3,
NO_2, SO_2, aerosol



analysis & forecast

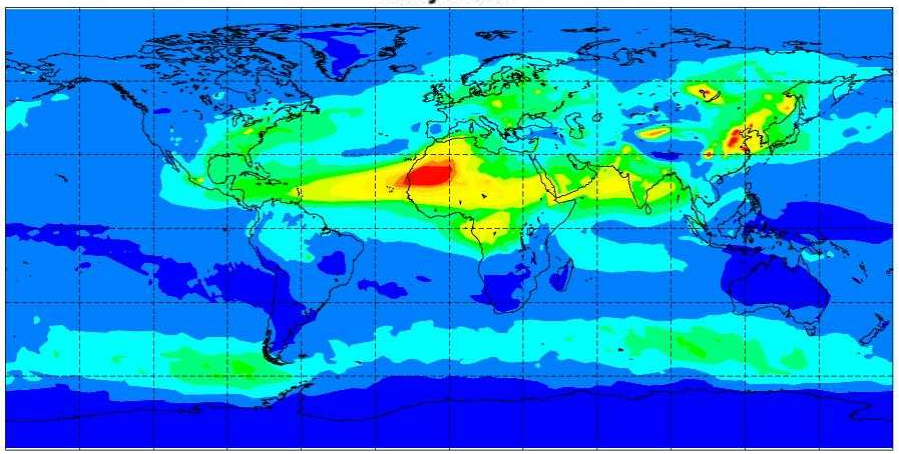
global and regional data and web products



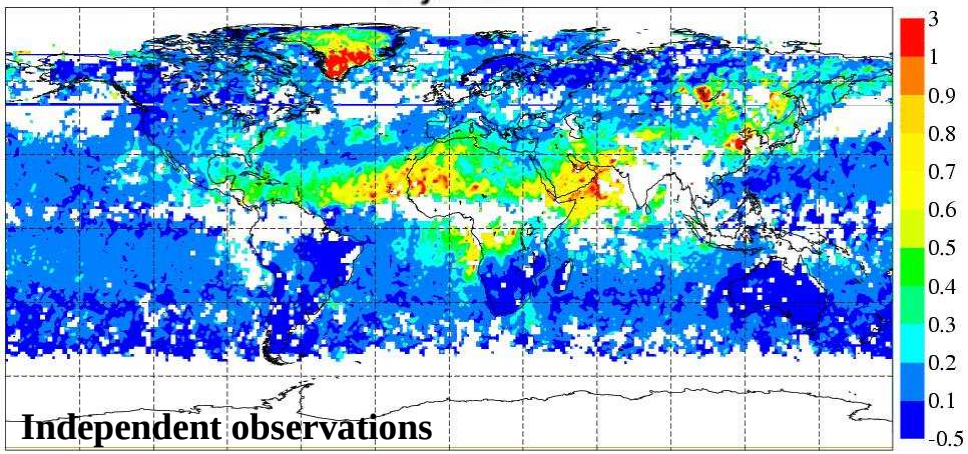
CO

Comparison of GEMS simulated and analysed aerosol optical depth with MODIS and MISR for July 2003

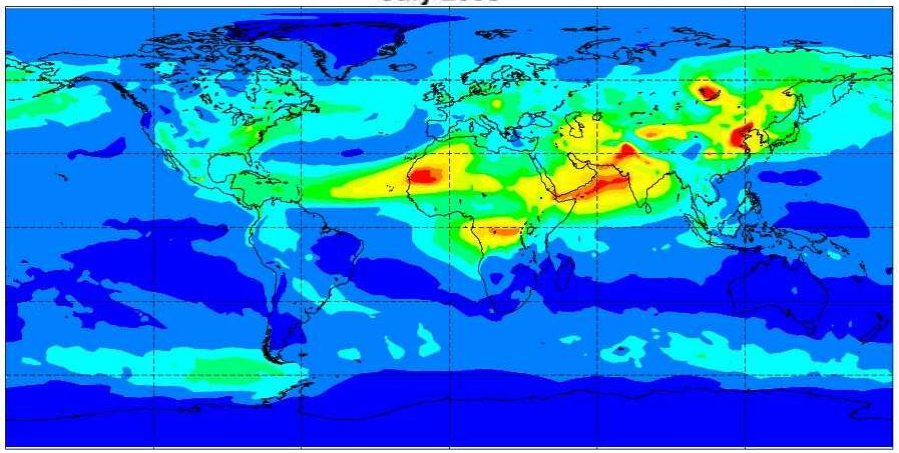
Aerosol Optical Depth at 550 nm from Unconstrained Model Run
July 2003



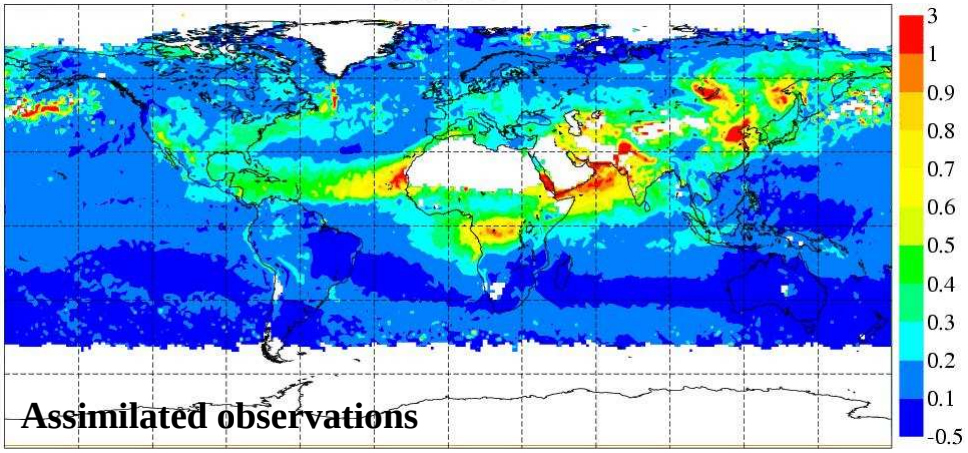
MISR Terra Aerosol Optical Depth at 557.5 nm [unitless]
July 2003



Aerosol Optical Depth at 550 nm for Reanalysis using MODIS AOD
July 2003

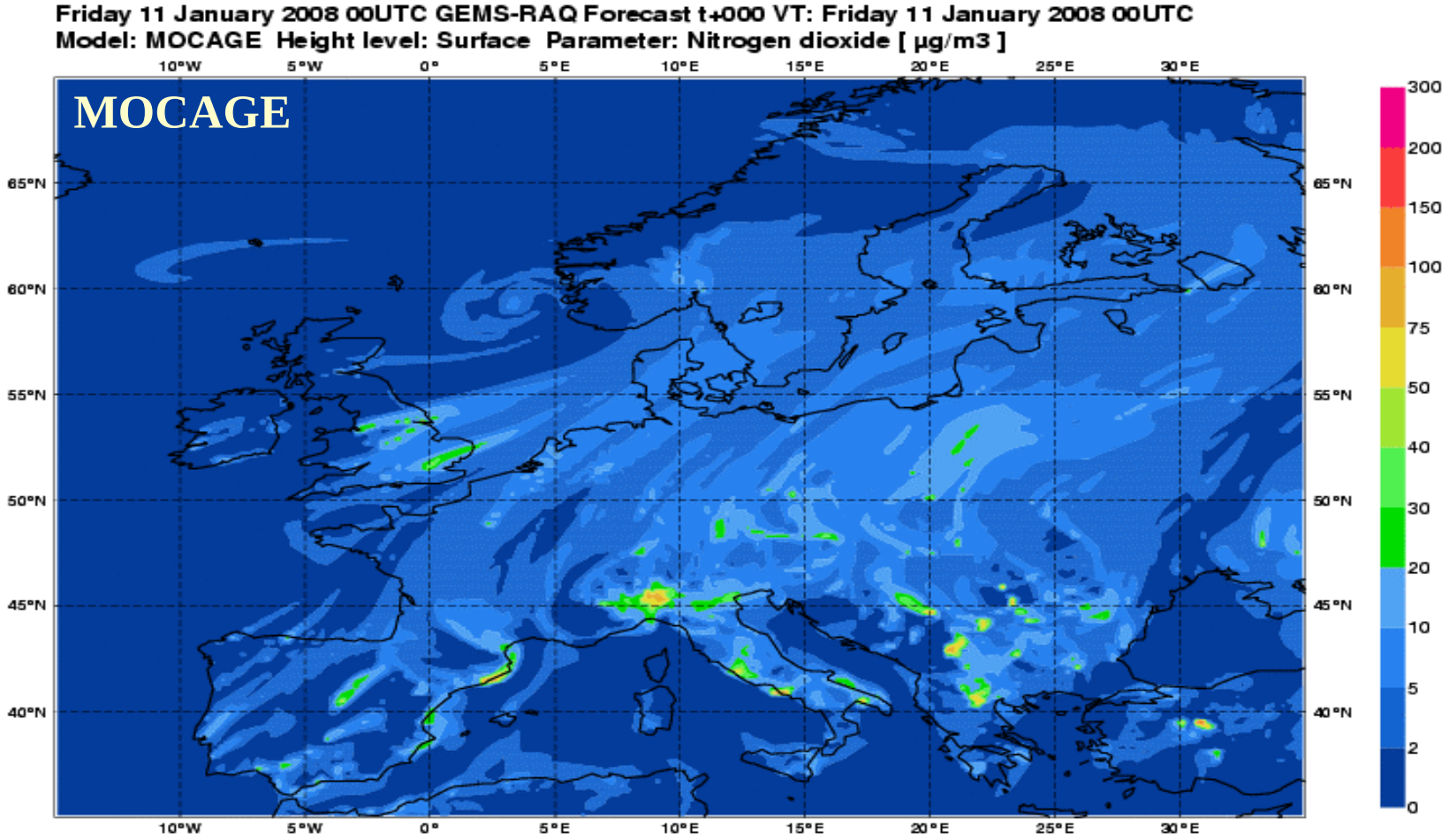


MODIS Terra MOD08-M3.005 Aerosol Optical Depth at 550 nm [unitless]
July 2003



Instrument	Satellite	Provider	Version	Species	Type	Period	Status
GOME	ERS-2	RAL		O3	Profiles	20030101-20030531	Active
MIPAS	Envisat	ESA		O3	Profiles	20030127-20040326	Active
MLS	AURA	NASA	V02	O3	Profiles	20040808 -	Active
OMI	AURA	NASA	V003	O3	Total column	20041001 -	Active
SBUV	NOAA-16	NOAA	V8	O3	6 layer profiles	20040101 -	Active
SBUV	NOAA-17	NOAA	V8	O3	6 layer profiles	20030101 -	Active
SBUV	NOAA-18	NOAA	V8	O3	6 layer profiles	20050604 -	Active
SCIAMACHY	Envisat	KNMI		O3	Total column	20030101 -	Active
GOME-2	METOP	EUMETSAT		O3	Total column/profile	20070101 -	Passive
MOPITT	TERRA	NCAR	V4	CO	Total column	20030101 -	Active
IASI	METOP	LATMOS		CO	Total column	20070101 -	Active
OMI	AURA	KNMI	Col. 3	NO2	Tropospheric column	20041001 -	Passive
SCIAMACHY	Envisat	KNMI	V1.1	NO2	Tropospheric column	20030101 -	Active
OMI	AURA	NASA	V003	SO2	Total column	20040817 -	Passive
SCIAMACHY	Envisat	BIRA		SO2	Total column	20040104 -	Passive
OMI	AURA	NASA	V003	HCHO	Total column	20040827 -	Passive
SCIAMACHY	Envisat	BIRA	V2	HCHO	Total column	20030101 -	Passive
MODIS	AQUA	NASA		AOD	Total column	20030101 -	Active
MODIS	TERRA	NASA		AOD	Total column	20030101 -	Active
SCIAMACHY	ENVISAT	SRON		CH4	Total column	20030101 -	Active
TANSO	GOSAT	JAXA		CH4	Total column	20090601 -	Passive
AIRS	AQUA	NASA		CO2	Radiances	20030101 -	Active
IASI	METOP	EUMETSAT		CO2	Radiances	20070101 -	Active
TANSO	GOSAT	JAXA		CO2	Total column	20090601 -	Passive

3-day European Air Quality Forecast: NO2 (single member of the ensemble shown)

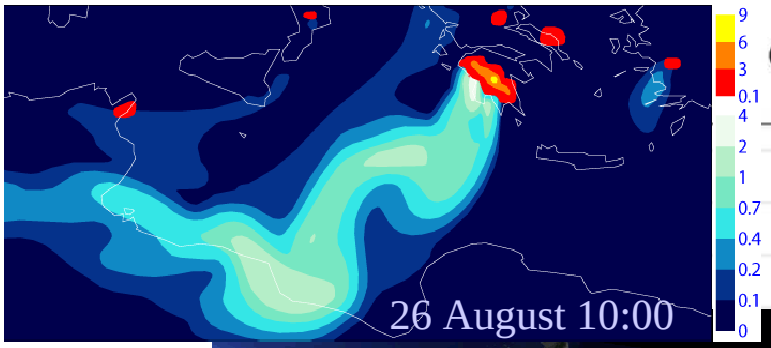


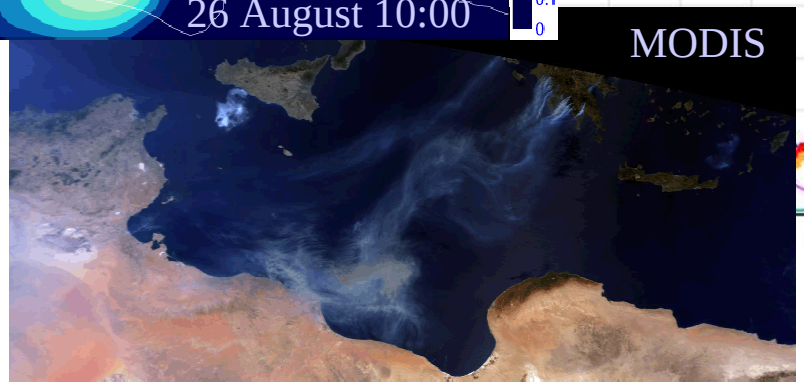
Modelled AOD of Greek Fire Plumes, August 2007

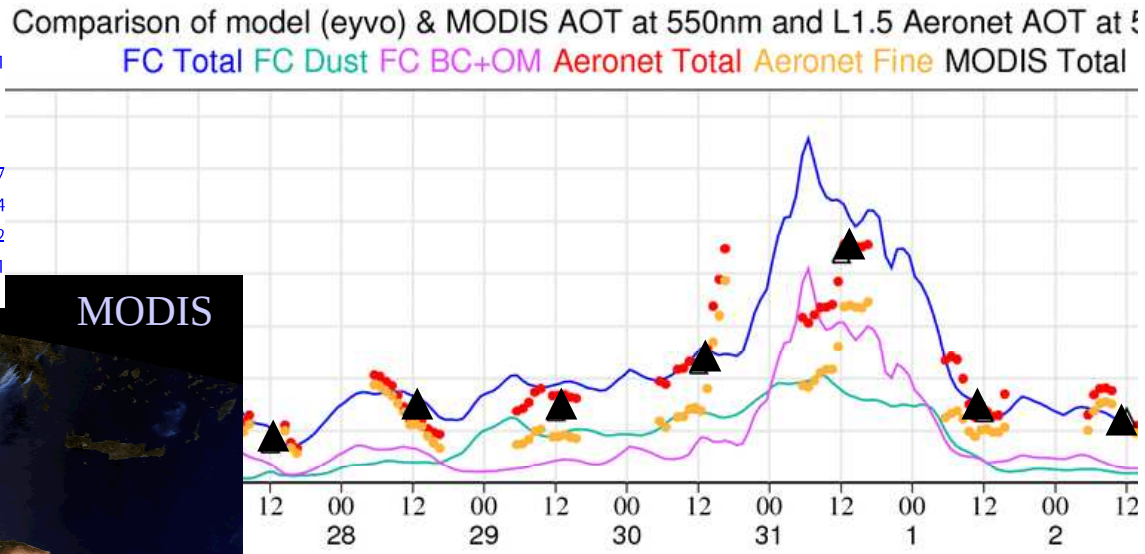
Emissions calculated from Fire Radiative Power observed by SEVIRI on Meteosat.

Emission factors from *Andreae & Merlet 2001* and *Ichoku & Kaufman 2005*.

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







Bottom-Up Estimation of Fire Emissions

promising best accuracy: MACC real time

sat. obs.

~ const.

land cover map

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

burnt biomass

"key uncertainty" (Reid et al. 2009)

(dynamic) vegetation model

most established, in particular GFED *(van der Werf et al. 2006)*: MACC retrospective

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

BA = burnt area [m2]

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

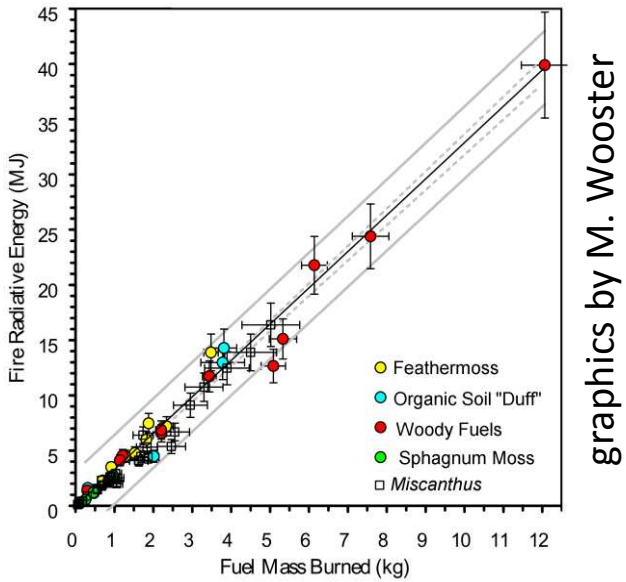
CC = combustion completeness [kg(burnt fuel) / kg (available fuel)]

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

FRP = fire radiative power [W]

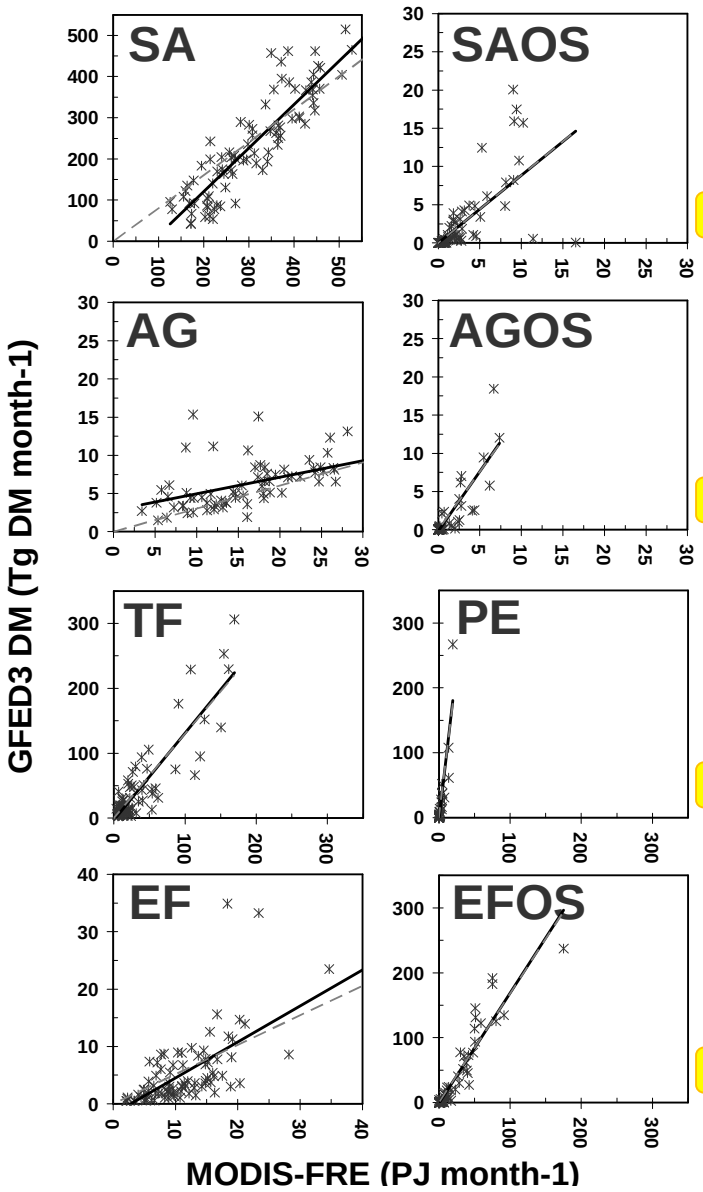
FRE = fire radiative energy [J] = $\int$ FRP(t) dt

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



graphics by M. Wooster

Conversion Factor Validation against GFEDv3



SA
LR:
y=1.06x-90.7
R^2=0.81
LR0:
y=0.80x
R^2=0.76

SAOS
LR:
y=0.88x+0.02
R^2=0.47
LR0:
y=0.89x
R^2=0.47

AG
LR:
y=0.2x+2.8
R^2=0.54
LR0:
y=0.30x
R^2=0.41

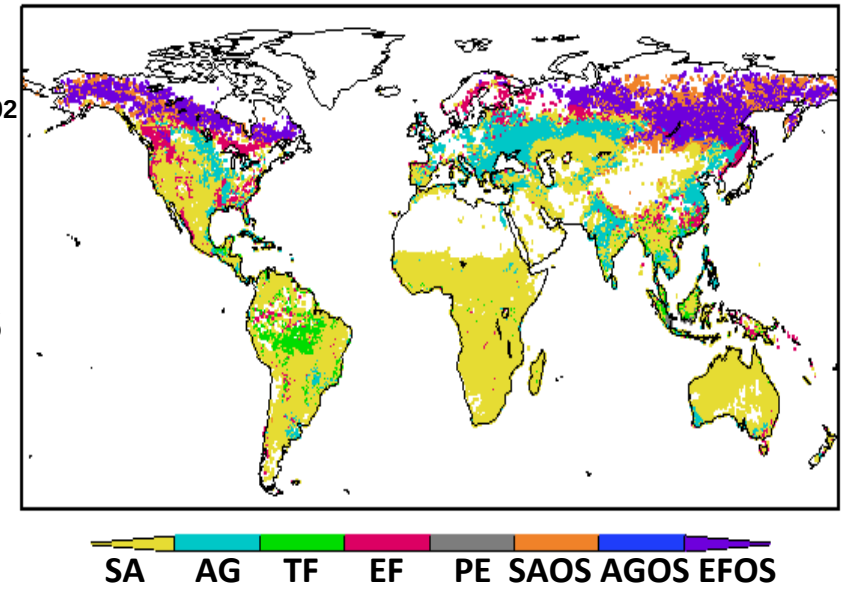
AGOS
LR:
y=1.6x-0.16
R^2=0.76
LR0:
y=1.51x
R^2=0.76

TF
LR:
y=1.3x-3.2
R^2=0.78
LR0:
y=1.30x
R^2=0.78

PE
LR:
y=9.4x-2.9
R^2=0.82
LR0:
y=9.04x
R^2=0.82

EF
LR:
y=0.6x-1.8
R^2=0.44
LR0:
y=0.51x
R^2=0.43

EFOS
LR:
y=1.7x-1.1
R^2=0.88
LR0:
y=1.68x
R^2=0.88



- Conversion factor depends on land cover!
- **FRP observations can reproduce GFED within its accuracy.**

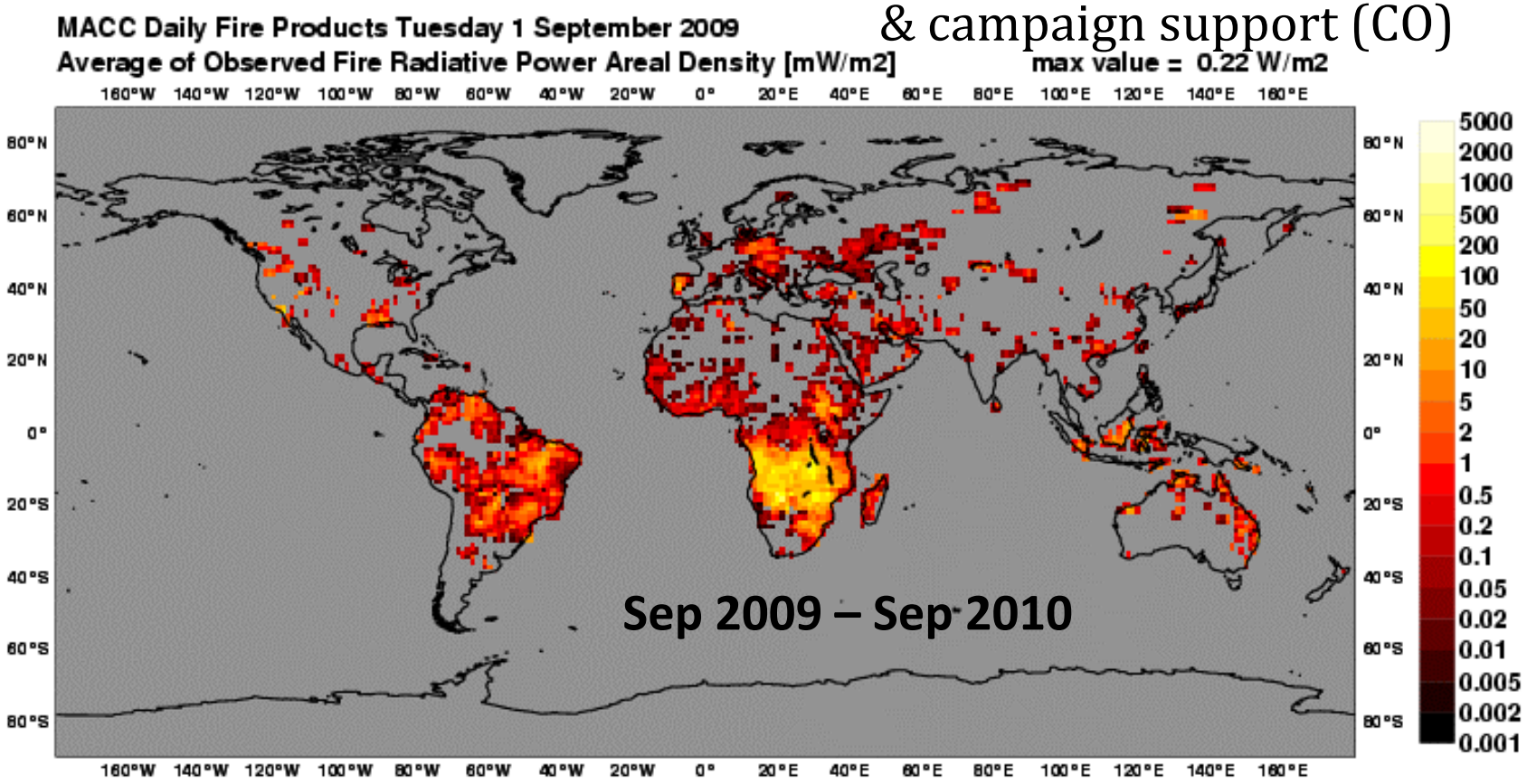
- lab: 0.368 kg DM / MJ
- GFASv0: 1.37 kg DM / MJ

Heil et al. ECMWF 2010

Global Fire Assimilation System (GFASv0)

- real-time production of fire emissions
  - using FRP ≥ 0 observation by MODIS & SEVIRI
- list of species:

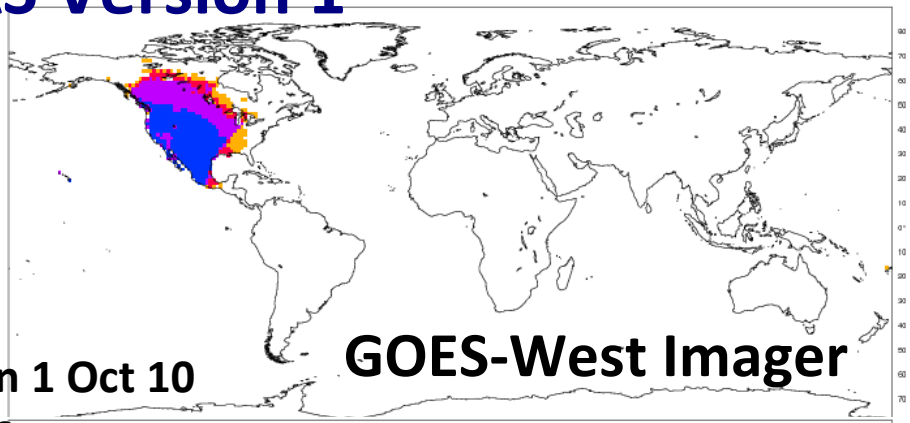
  C, TPM, PM2.5, BC, OC, CO2, CH4, CO, SO2, NOx, NMHC
- used in MACC NRT production system: aerosols & greenhouse gases & campaign support (CO)

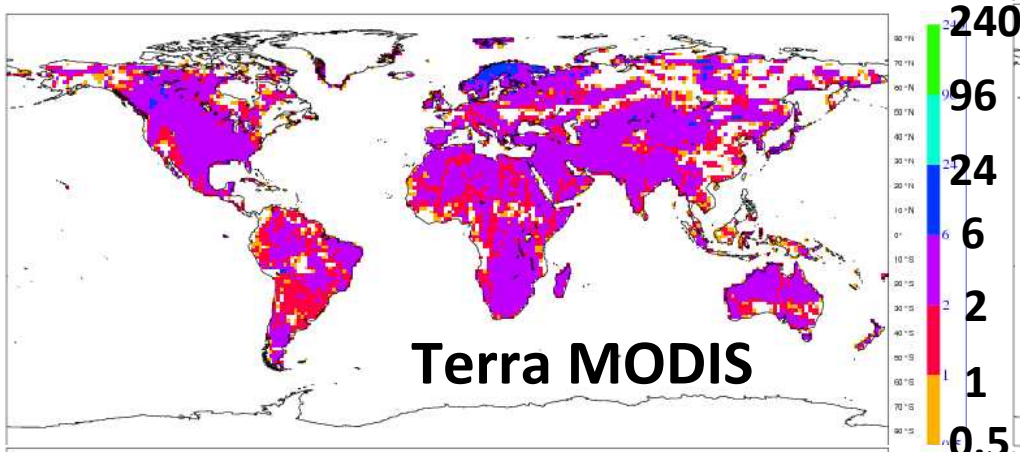


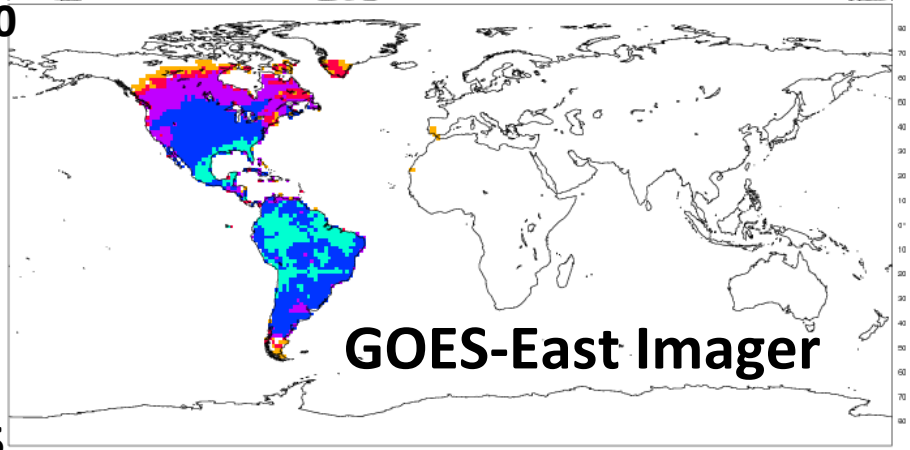
Upcoming GFAS Version 1

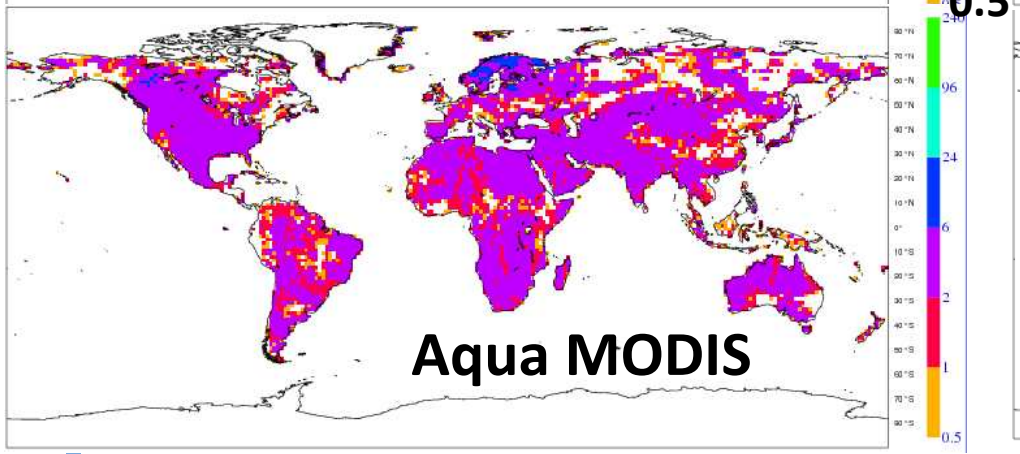
- observation gap filling with data assimilation
- land-cover specific FRP conversion
- 0.5 deg resolution
- GOES observations

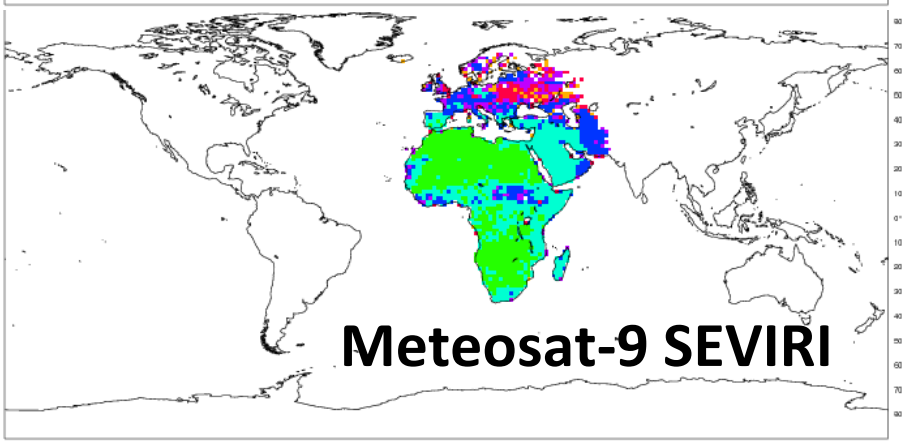
 # observations on 1 Oct 10





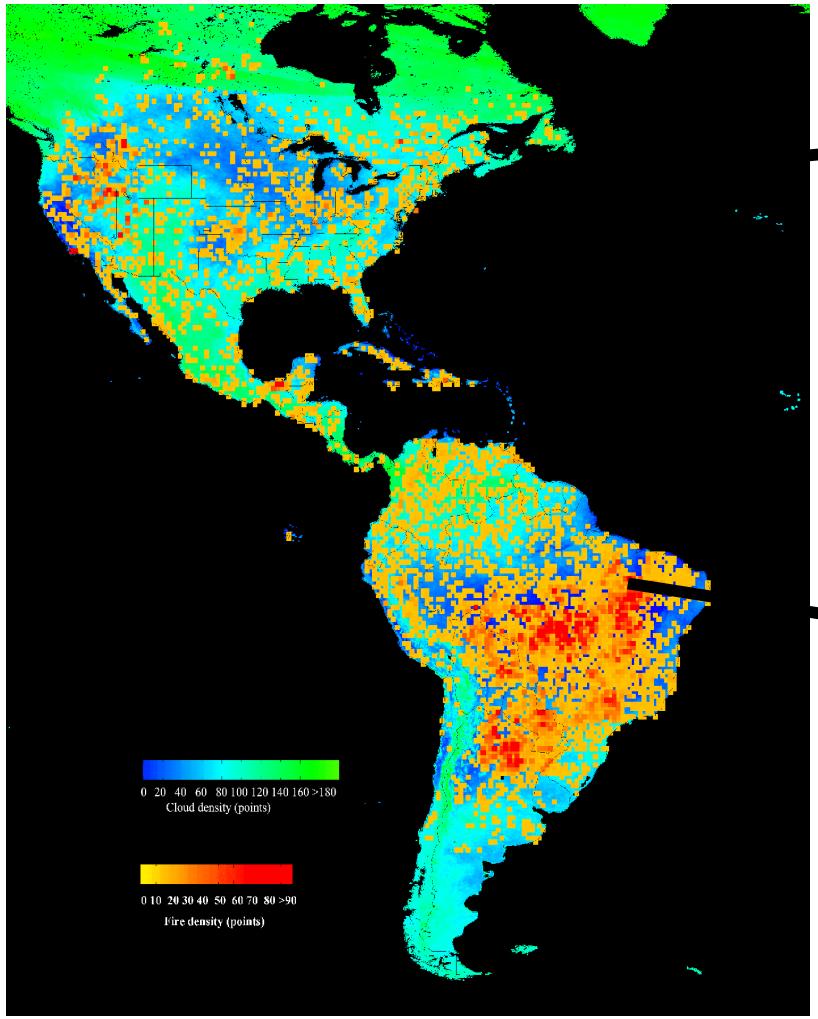


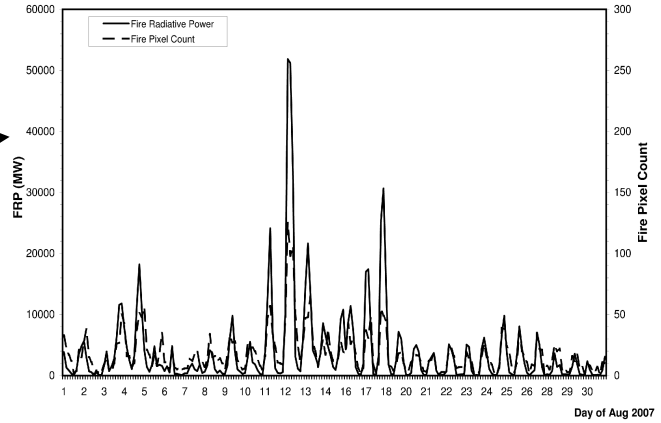


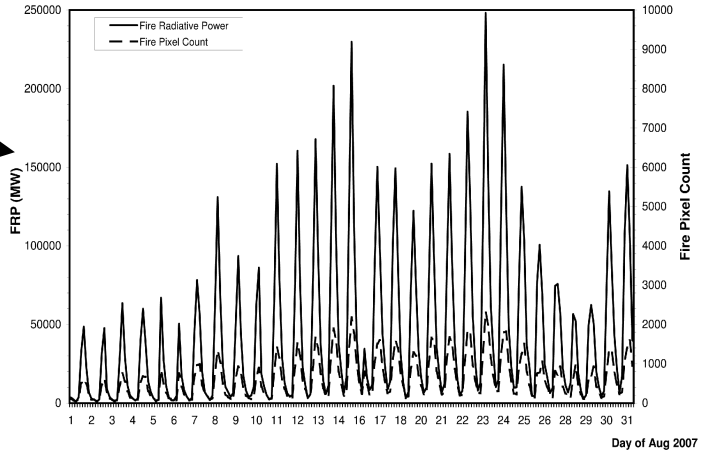


240
96
24
6
2
1
0.5

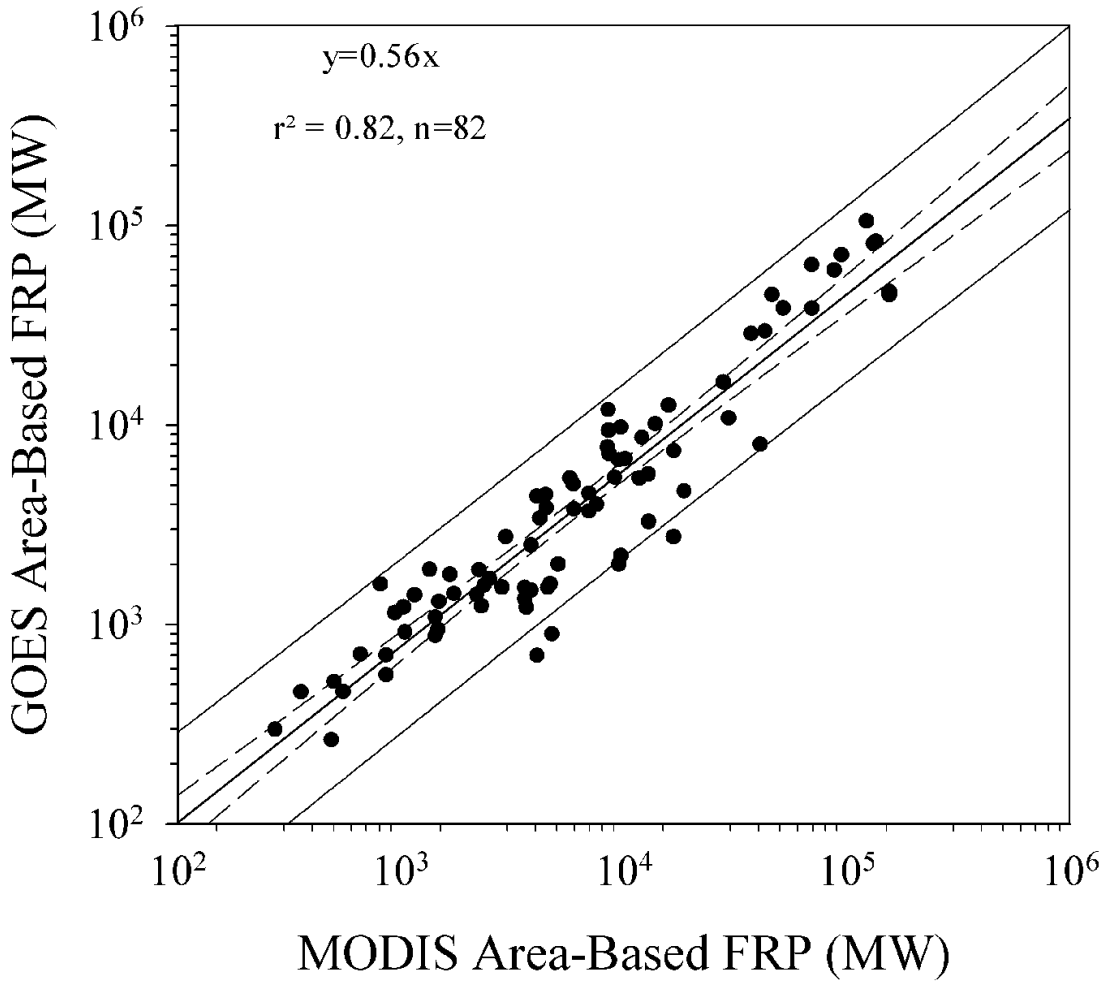
Fires Diurnal Cycle in Americas



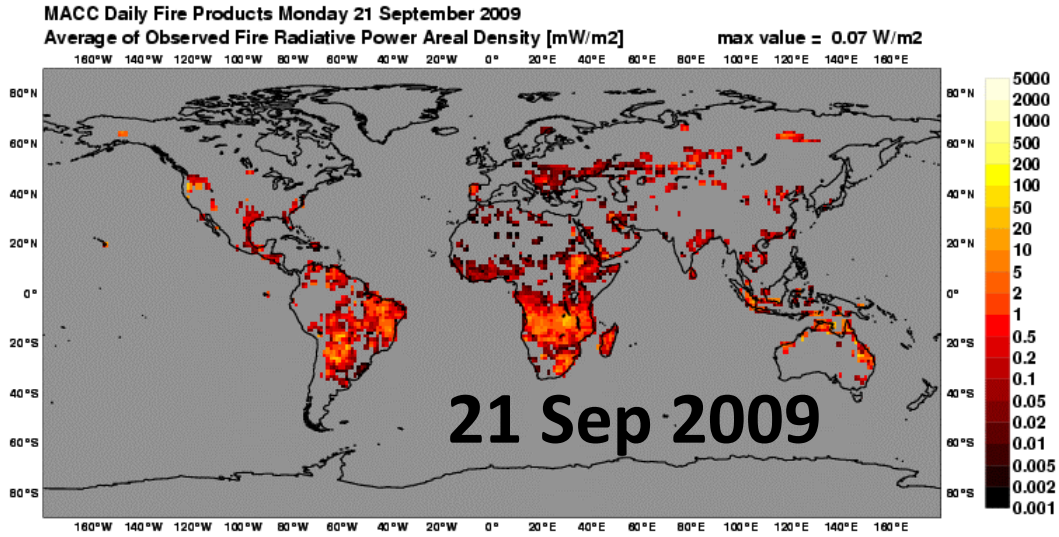


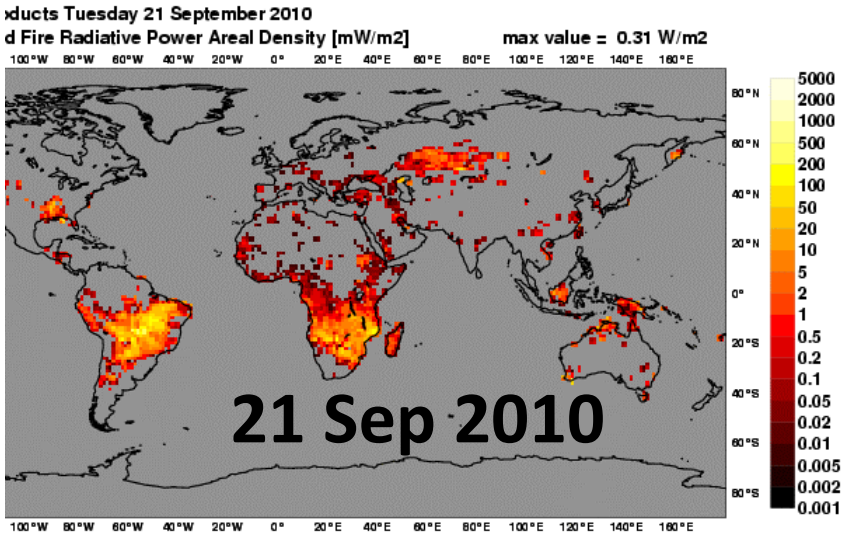


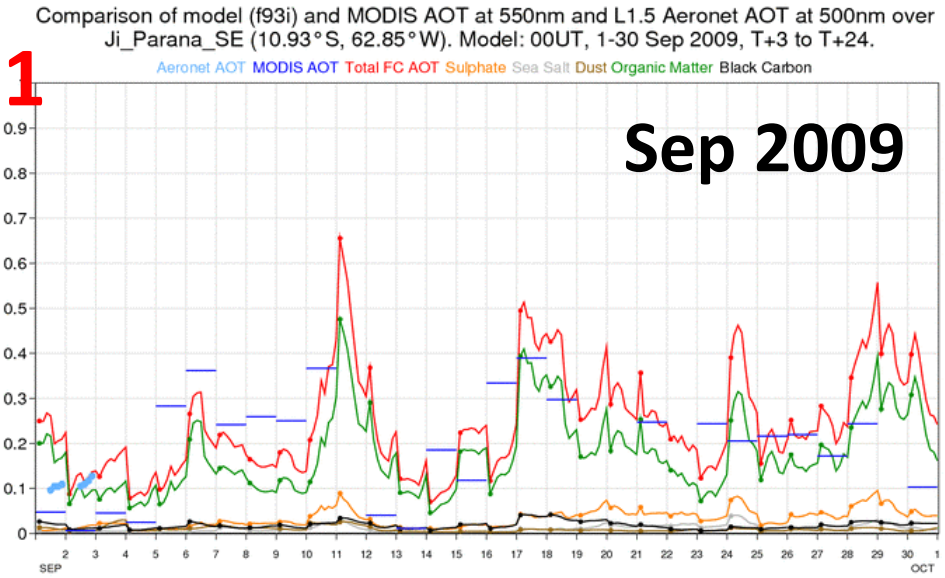
GOES vs. MODIS Grid Based FRP Comparison

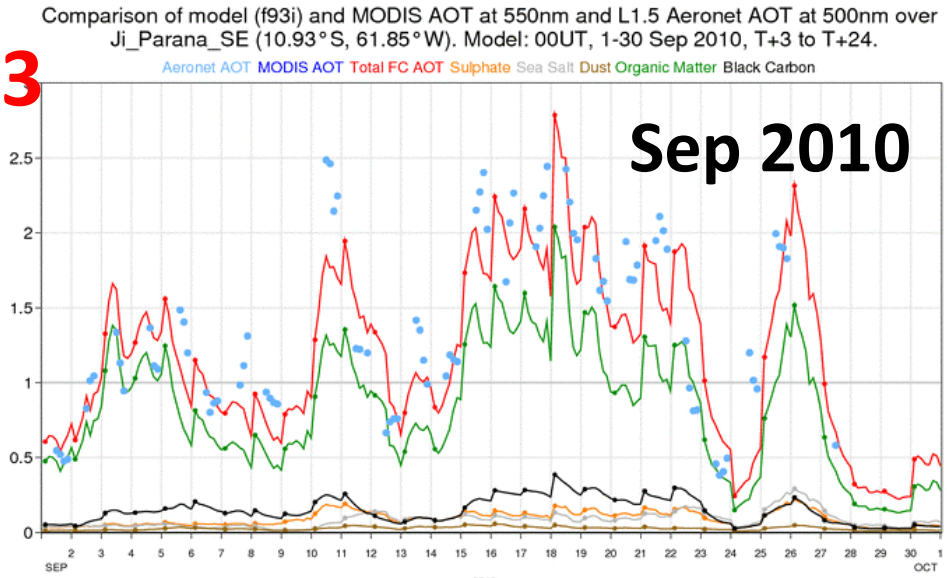


More “NRT” FRP and AOD







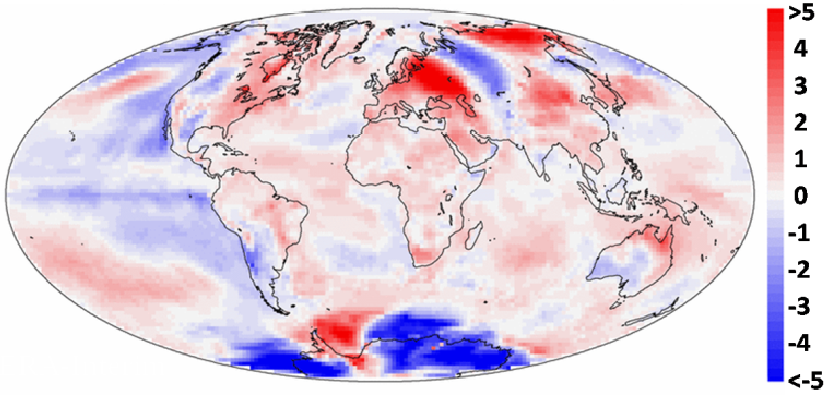


SH American fire activity strongly enhanced in 2010

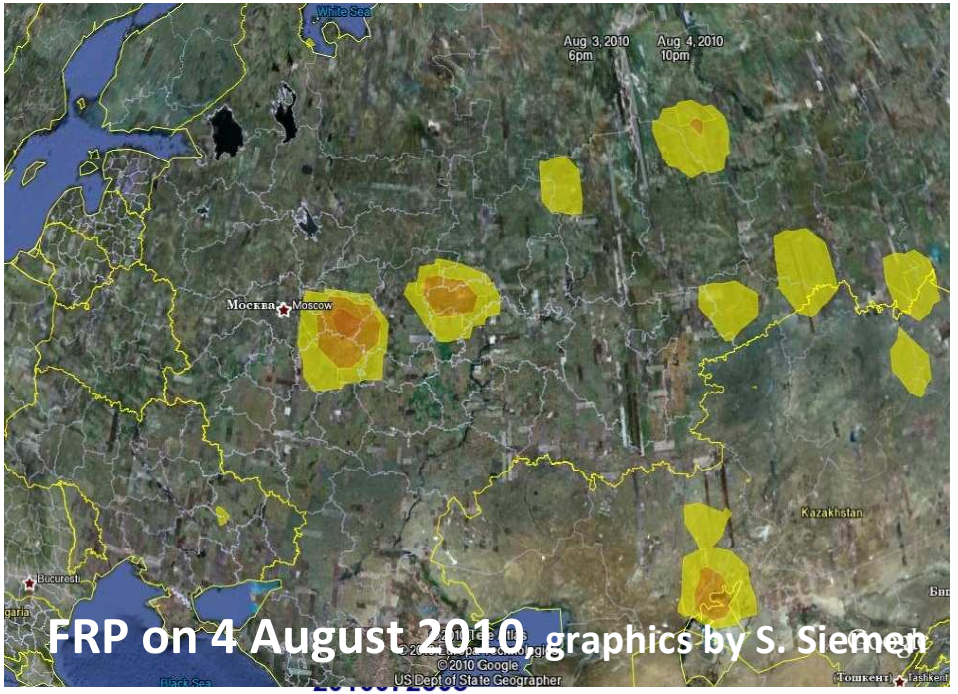
(smoke) aerosols enhanced by factor ~3

2010 Fires in Russia

2m temperature anomaly (K) for July 2010

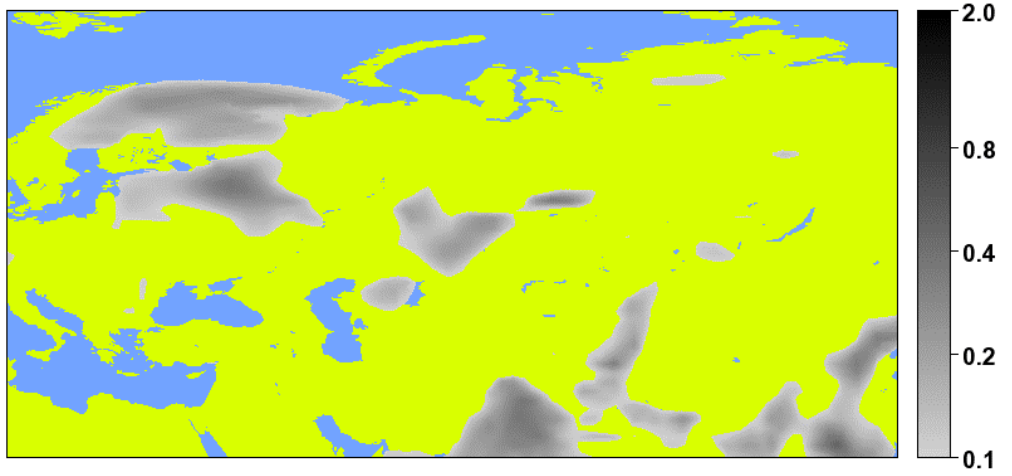


graphics by A. Simmons



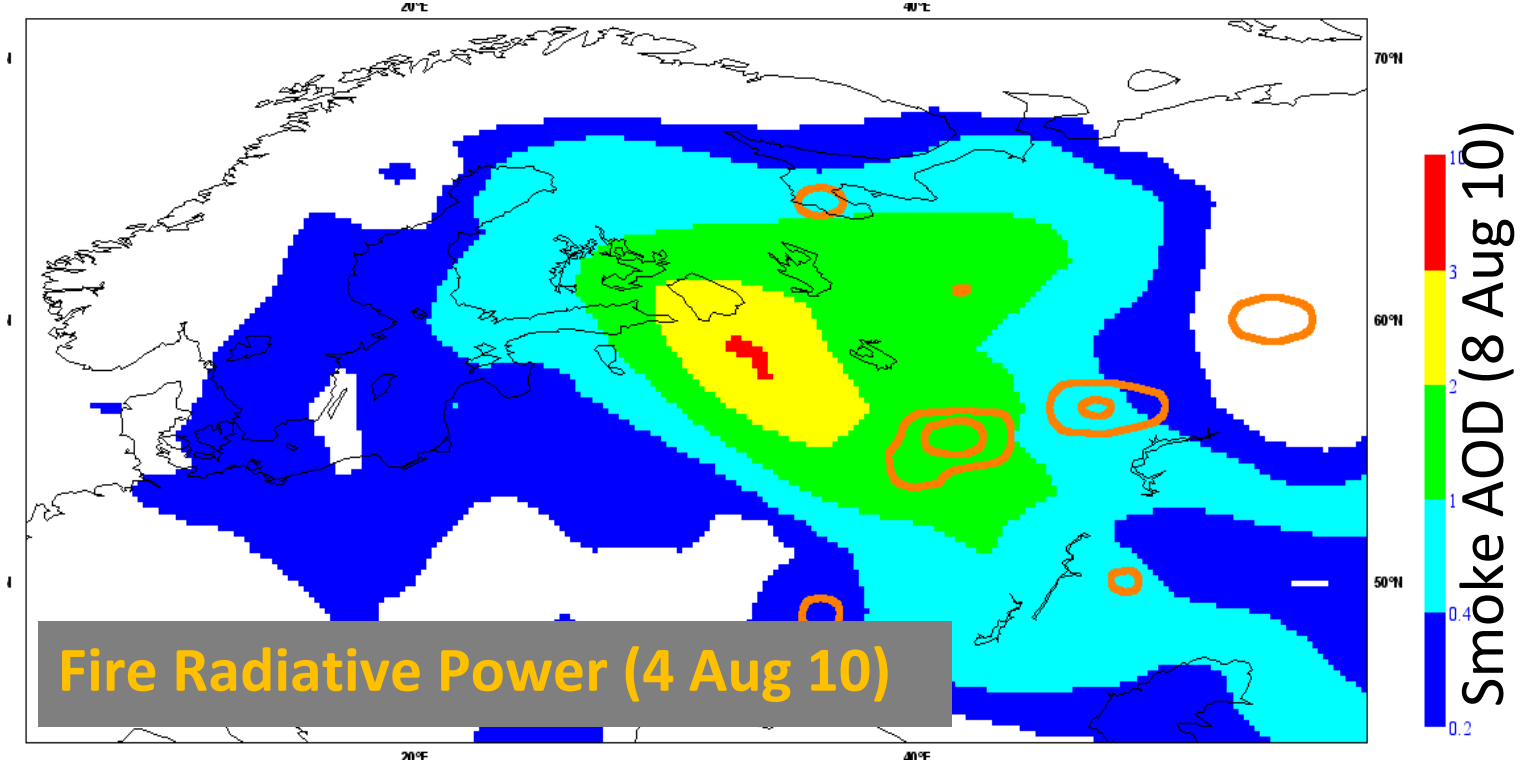
FRP on 4 August 2010, graphics by S. Siemen

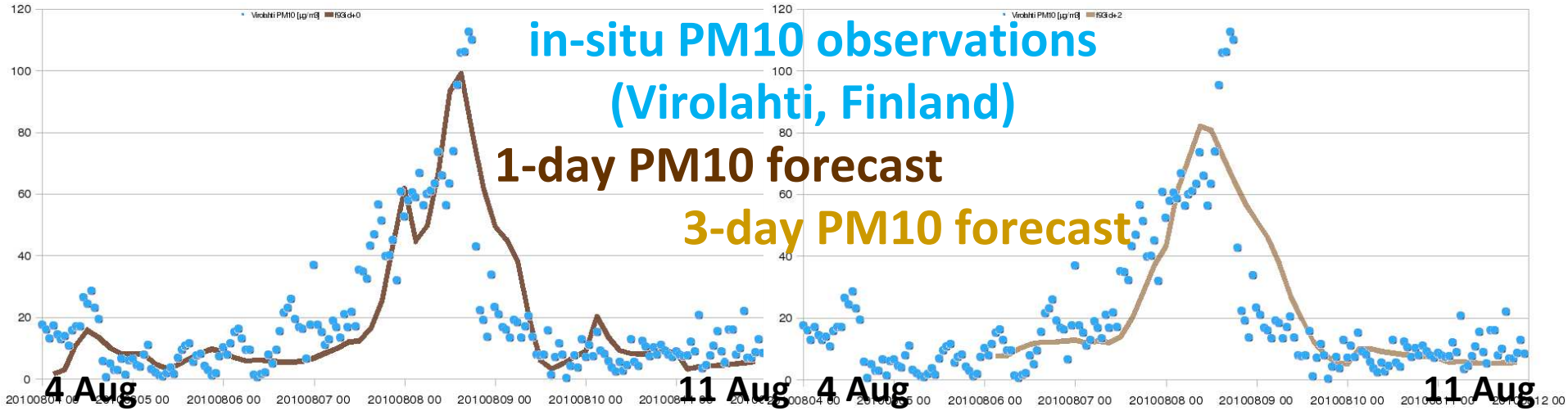
Aerosol optical depth due to black carbon and organic matter



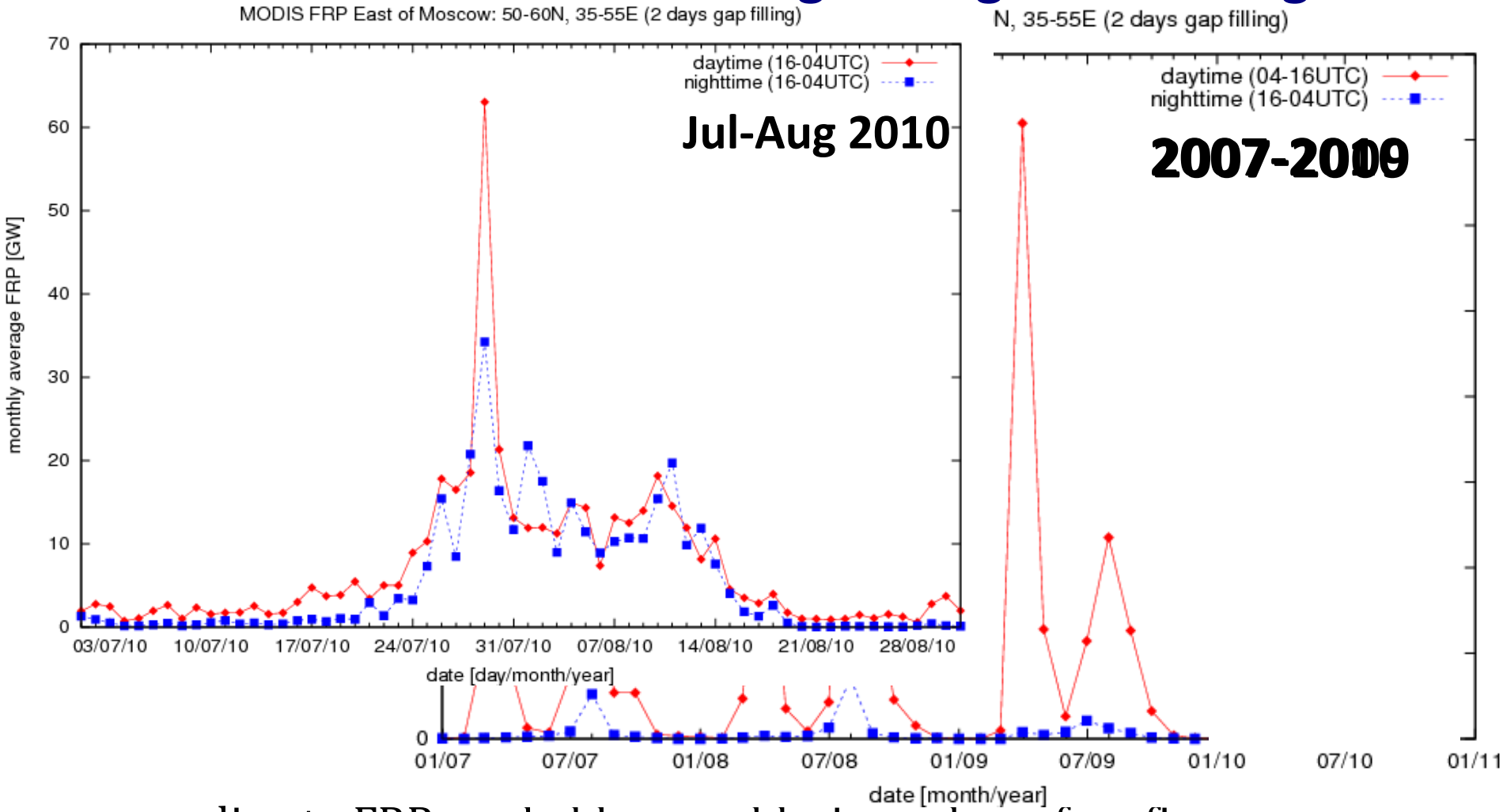
The daily jump in the modeled smoke distribution is due to the assimilation of satellite information on the fires

Russian Smoke Plume in Finland well Predicted





2010 Fires in Russia: Burning throughout the Night!

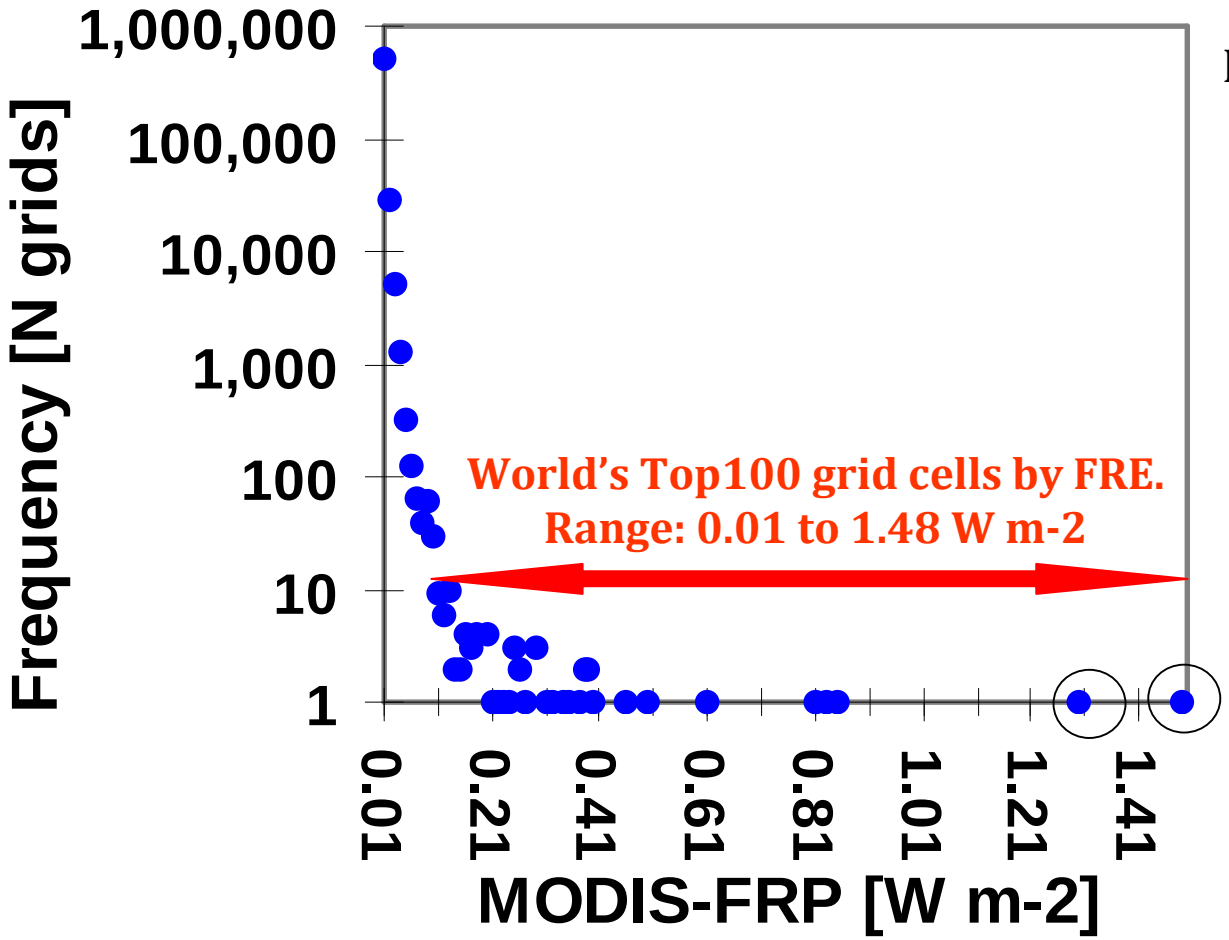


- according to FRP, probably smouldering sub-surface fires
- Conversion and emission factors need to be adapted dynamically.
  - 80% peat fires 20% forest fires explain the CO and NO2 observations.

Gas Flaring

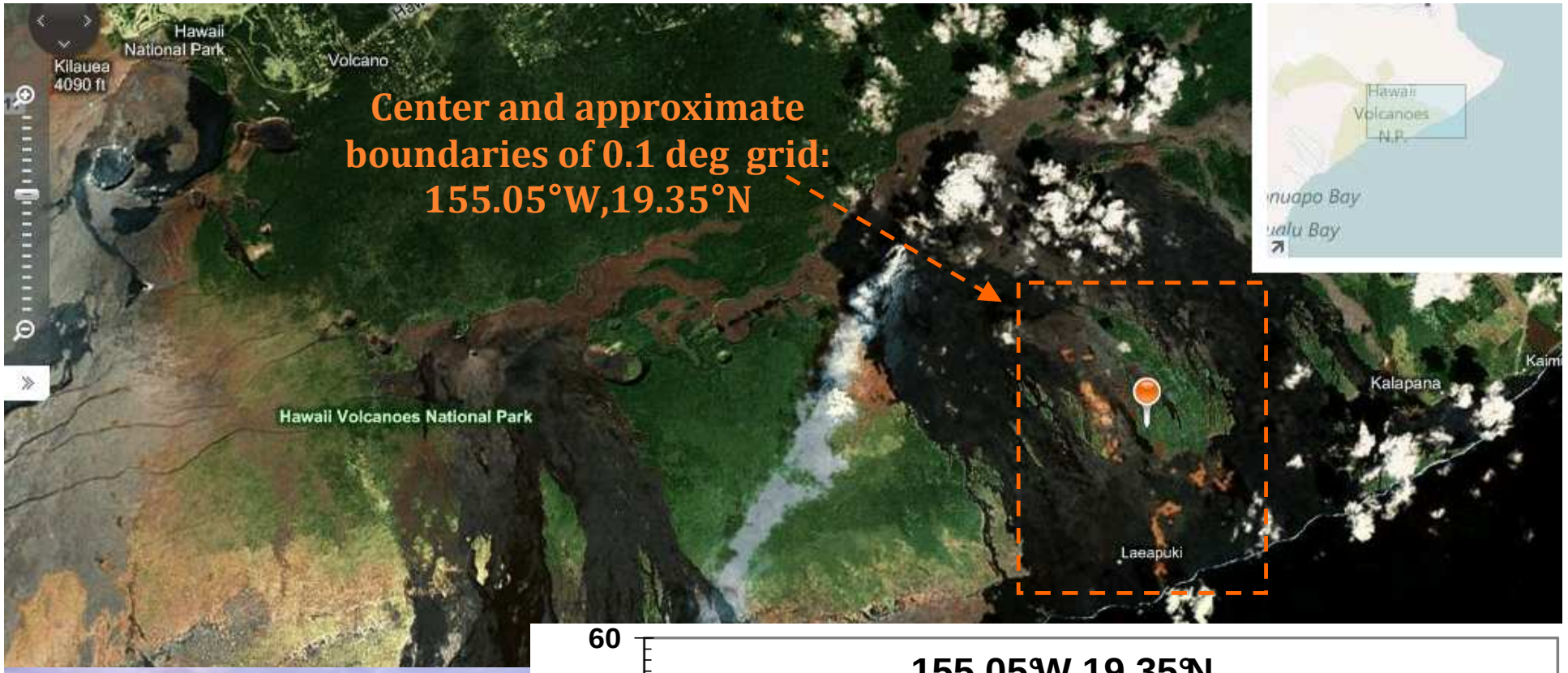
Analysis of daily "NRT" MODIS-FRP data at 0.1 deg covering 2003 to 2009

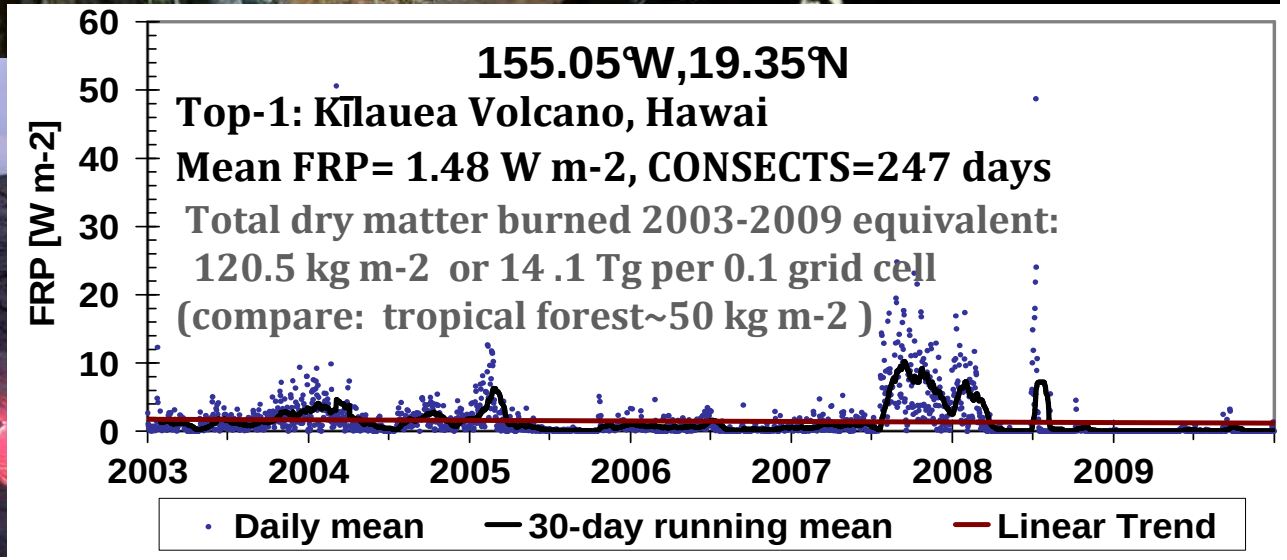
Source identification based on the analysis of the stationarity and/or magnitude of the FRP signal, visual inspection using GoogleEarth /Bing Maps,



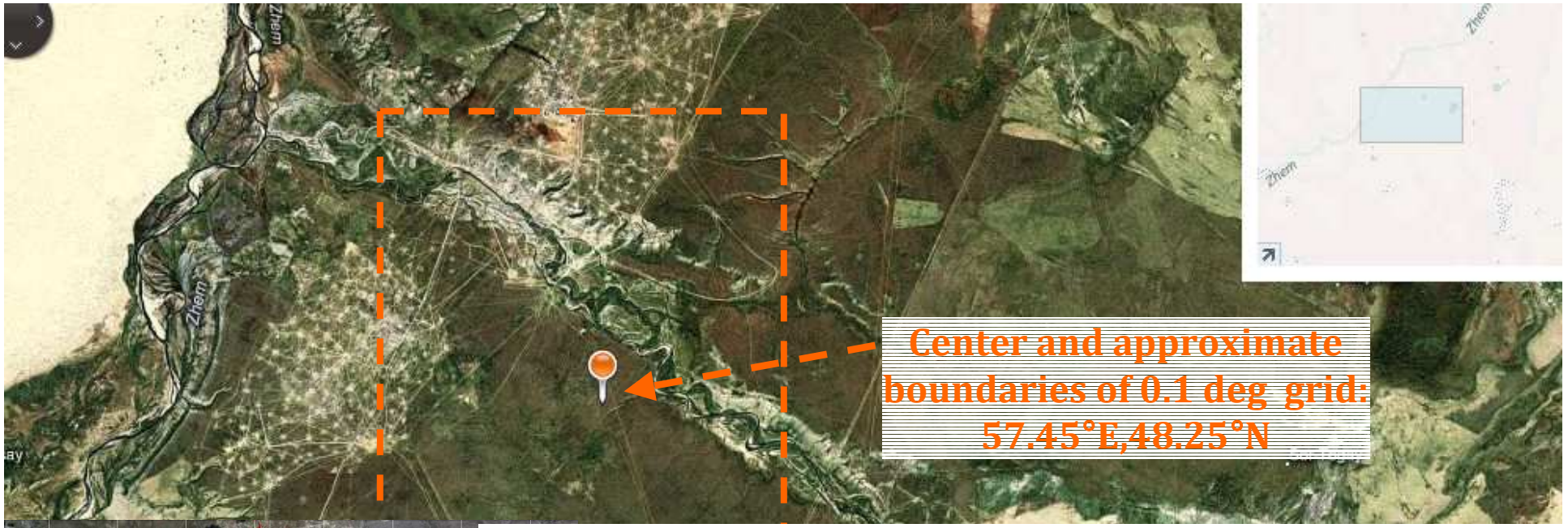
Histogram of time-averaged MODIS-FRP grids (in 0.01 Wm-2 bins) (r3600x1800≙ 6,480,000 grid cells)

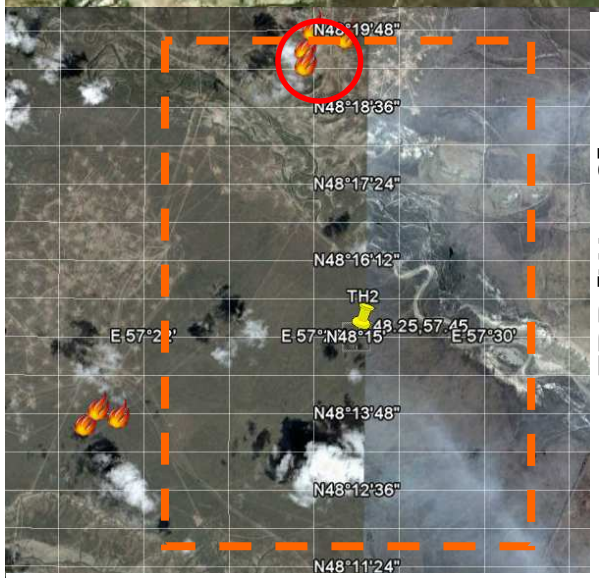
Contamination of MODIS-FRP by Volcanoes



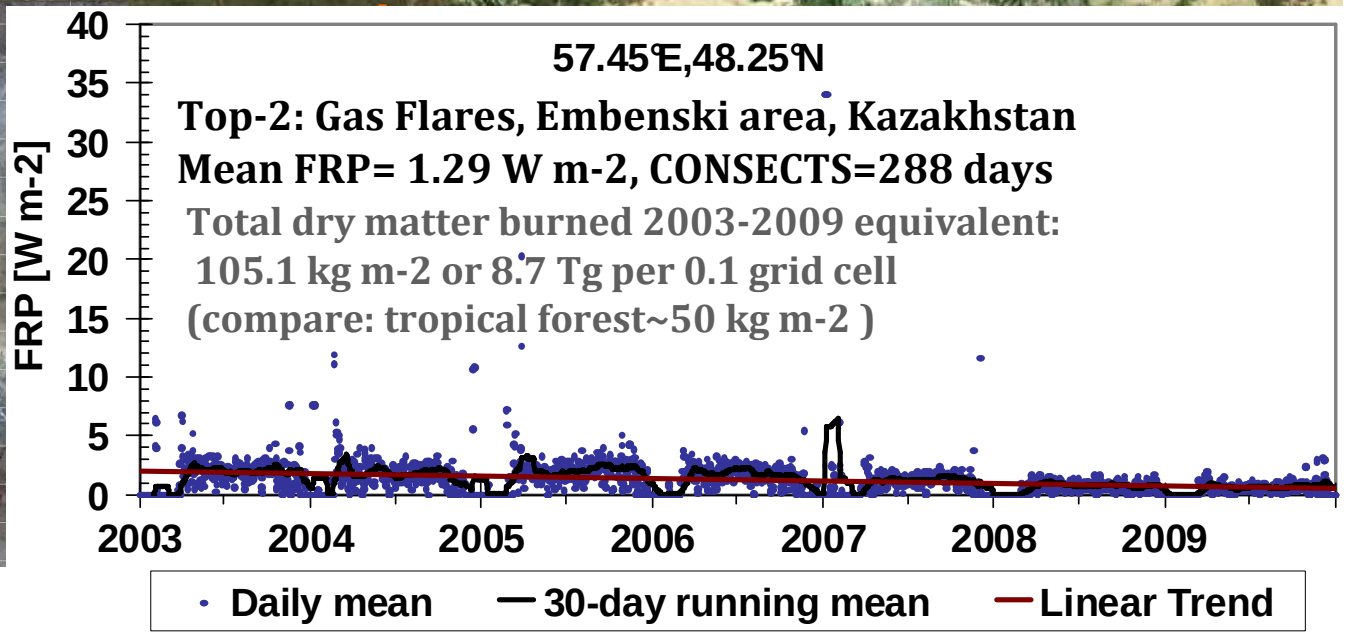


Contamination of MODIS-FRP by Gas Flares





MODIS FIRMS last 48h

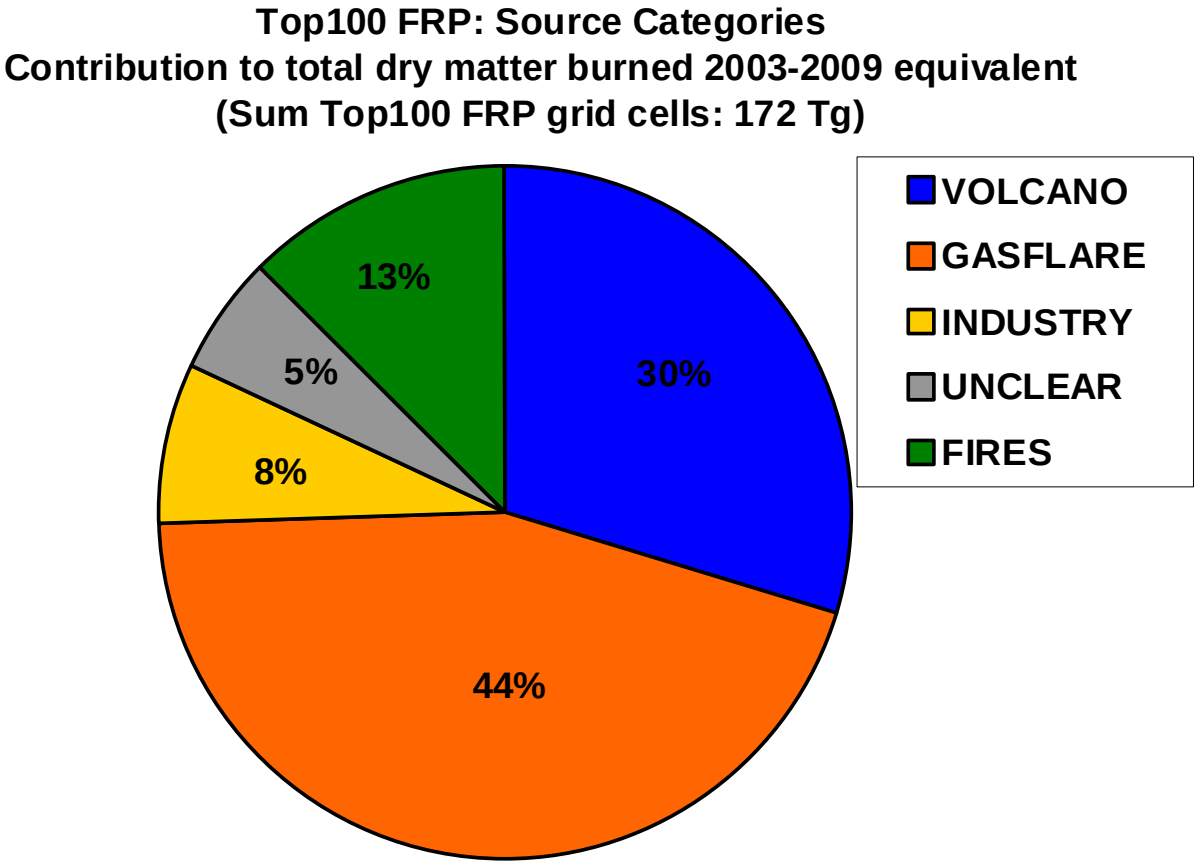


Contamination of MODIS-FRP by Gas Flares

Total dry matter burned 2003-2009 equivalent

Global: 12800 Tg

Top 100 by FRP: 172 Tg (~1.3% of global)



→ **Identification and Masking Out of Non-Biomass Burning MODIS FRP signals in Future**

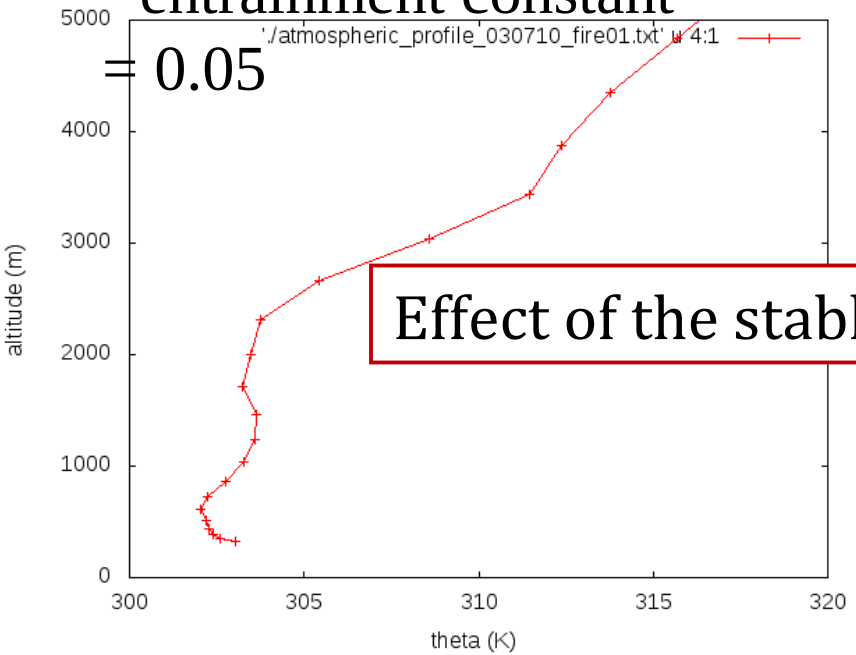
Parameterization of Injection Height

Freitas 1D Plume Model : validation

Fire in Siberia July 2003

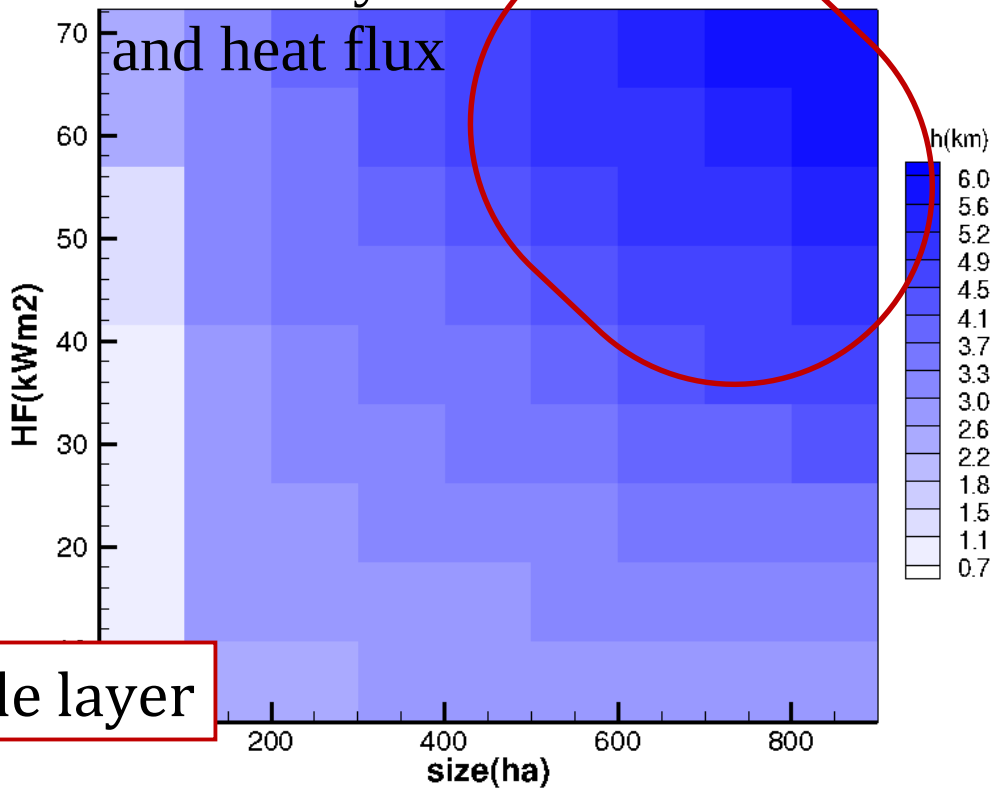
-Fire radius = 3ha

- FRP = 419 MW
- moisture = 10 %
- entrainment constant = 0.05



Effect of the stable layer

Sensitivity test to fire radius and heat flux



Height above the terrain

Plume Model	2.7 km
MISR	2.1 km

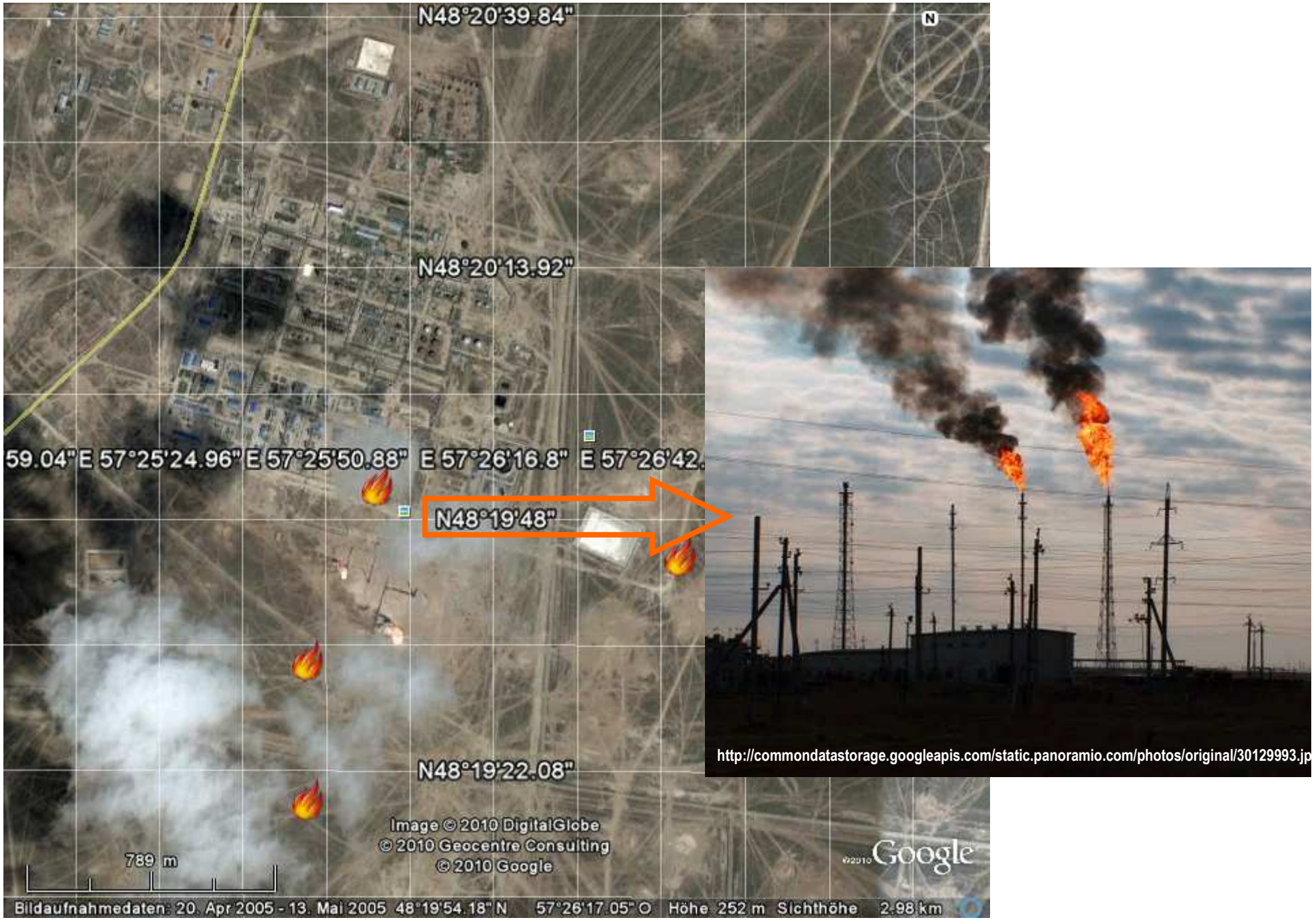
Conclusions

- MACC atmospheric and fire products publicly available
  - starting 2003
  - NRT, as operational GMES service in 2014
  - observation gap filling with data assimilation

- global MACC services use fire emission products since January (aerosols) and April (greenhouse gases) 2010

- real-time fire emission rates critically depend on availability and quality of FRP products
  - LandSAF: SEVIRI
  - KCL: GOES-E/-W (to be moved to IM Lisbon in MACC II)
  - NOAA/NASA: MODIS
  - in the future: MTSAT, FY2C, Sentinel-3, NPP VIIRS

http://www.gmes-atmosphere.eu/fire


N48°20'39.84"
N48°20'13.92"
59.04" E 57°25'24.96" E 57°25'50.88" E 57°26'16.8" E 57°26'42.
N48°19'48"
N48°19'22.08"
http://commondatastorage.googleapis.com/static.panoramio.com/photos/original/30129993.jp
Image © 2010 DigitalGlobe
© 2010 Geocentre Consulting
© 2010 Google
789 m
Google
Bildaufnahmedaten: 20. Apr 2005 - 13. Mai 2005 48°19'54.18" N 57°26'17.05" O Höhe 252 m Sichthöhe 2.98 km

Contamination of MODIS-FRP by Gas Flares

Pipe CNPC

In Google Earth Teilen auf:

von **Solo Tiberian**

Dieses Foto wurde für Google Earth ausgewählt [?] - ID: 30130005

in Aktobe, Kasachstan

48° 18' 28.50" N 57° 23' 38.53" E

Falsch platziert? Bessere Platzierung vorschlagen

More “NRT” MODIS FRP over SH America

- observation gap filling with Kalman smoother in 5-day window
- fire enhancement consistent with aerosol one
- associated with transition from El Nino to La Nina