Fire Emission Monitoring in MACC-II

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

GOFC-Gold Fire IT
Wageningen, April 2013

Significance for Atmosphere Modelling: Biomass Burning (BB) Emissions …

AIR QUALITY:

- … can dominate local and regional air quality with poisonous smoke
- … can elevate background of atmospheric pollutant after long range transport [Stohl et al. 2001, Forster et al. 2001, Andreae et al. 2001]

POLLUTION CONTROL:

- … significantly contributes to global budgets of several gases
  - Kyoto, CLRTAP, …

WEATHER: (absorbing aerosols)

- … influences the radiative energy budget [Konzelmann et al., JGR 1996]
- … provides cloud condensation nuclei [Andreae et al., Science 2004]
- Heat release accelerates deep convection. [Damoah et al., ACP 2006]

REMOTE SENSING:

- … affects essential a priori information for remote sensing (AOD, profiles)

MACC-II?

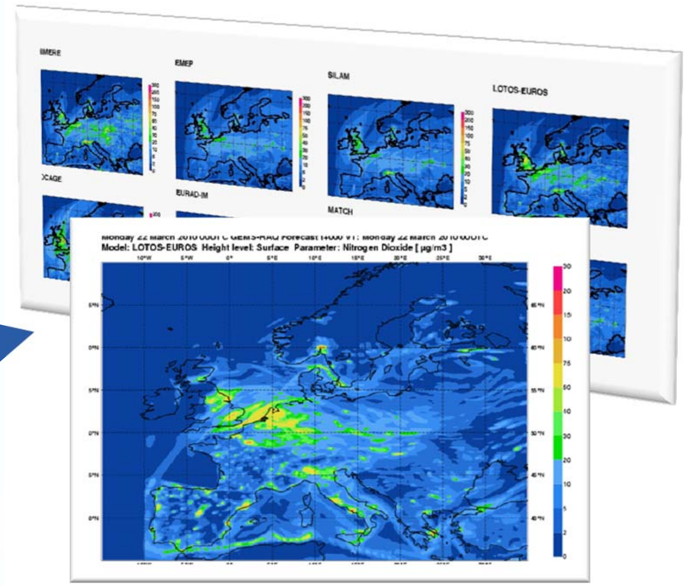
It delivers GMES Atmosphere Services.

(here: Near-Real-Time Service Provision)

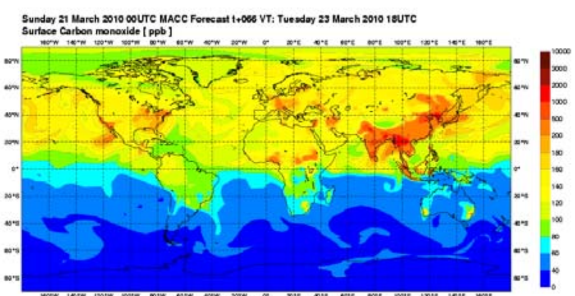
They will become EU-funded operational Copernicus Atmosphere Services in 2014.

http://gmes-atmosphere.eu

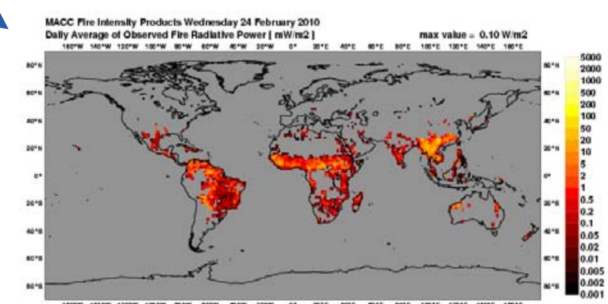
European Air Quality



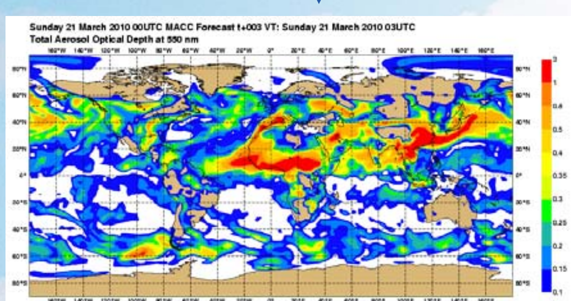
Global Pollution



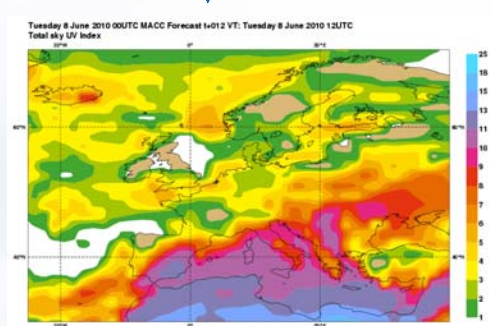
Emissions



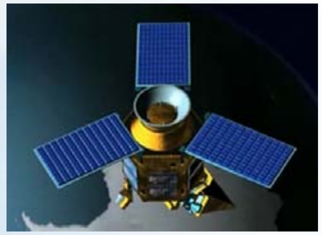
Aerosol



Radiation



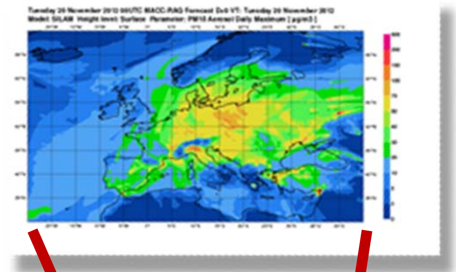
MACC-II in a nut shell – for example CO

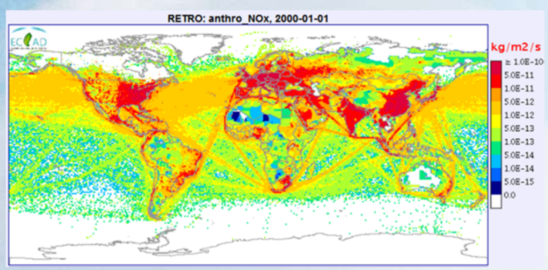


IASI, MOPITT, and Sentinel missions

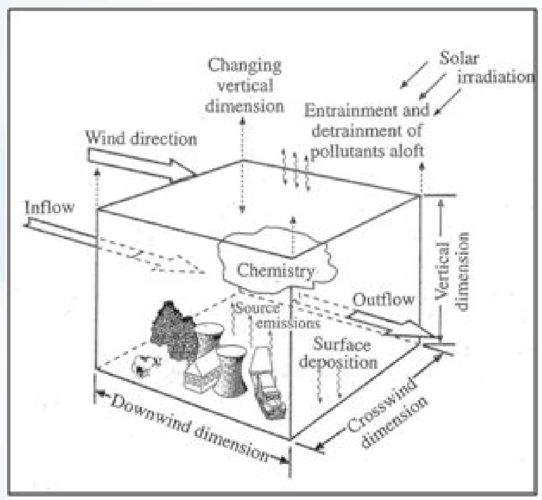
In-situ observations

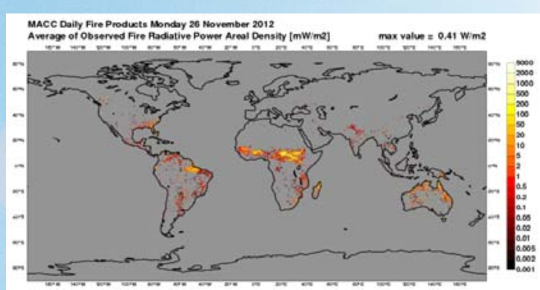
European air quality forecasts





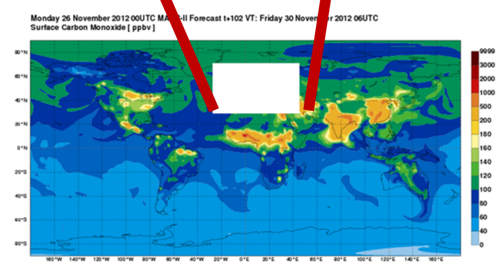
MACCity anthropogenic emissions



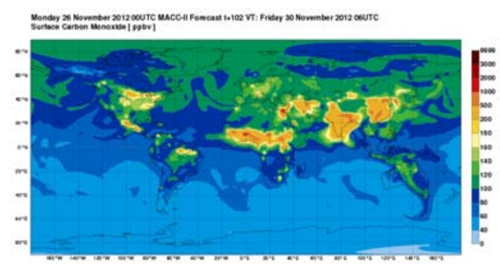


GFAS fire emissions

Global and regional models



Boundary conditions



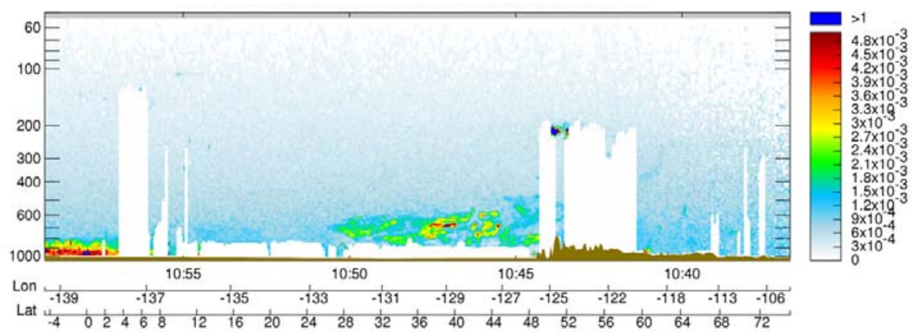
Global atmospheric composition forecasts

Forecast example:

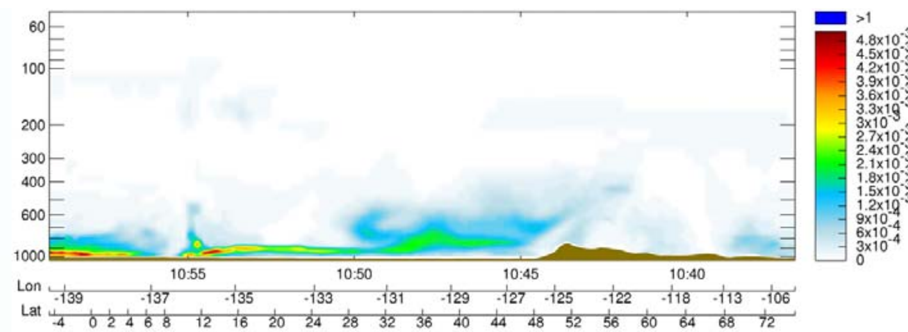
Seattle haze

July 2012

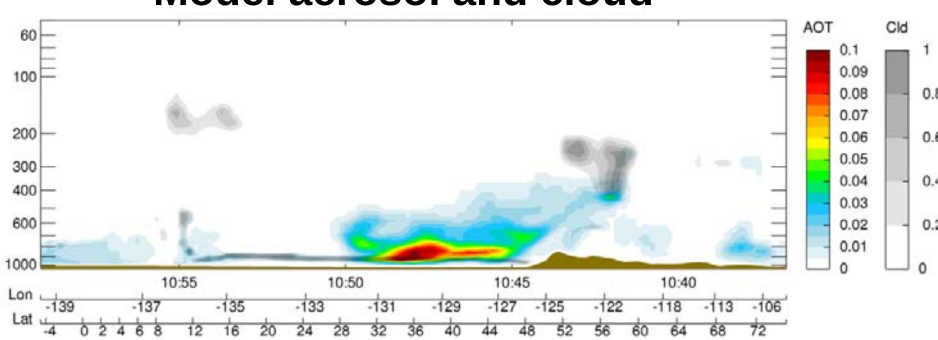
CALIPSO backscatter



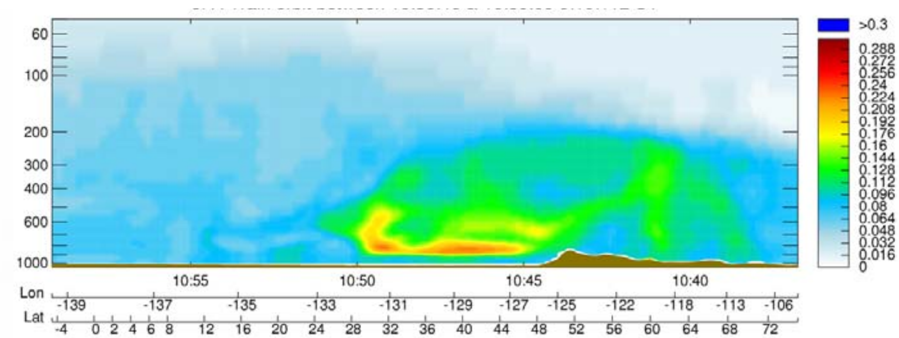
Model backscatter



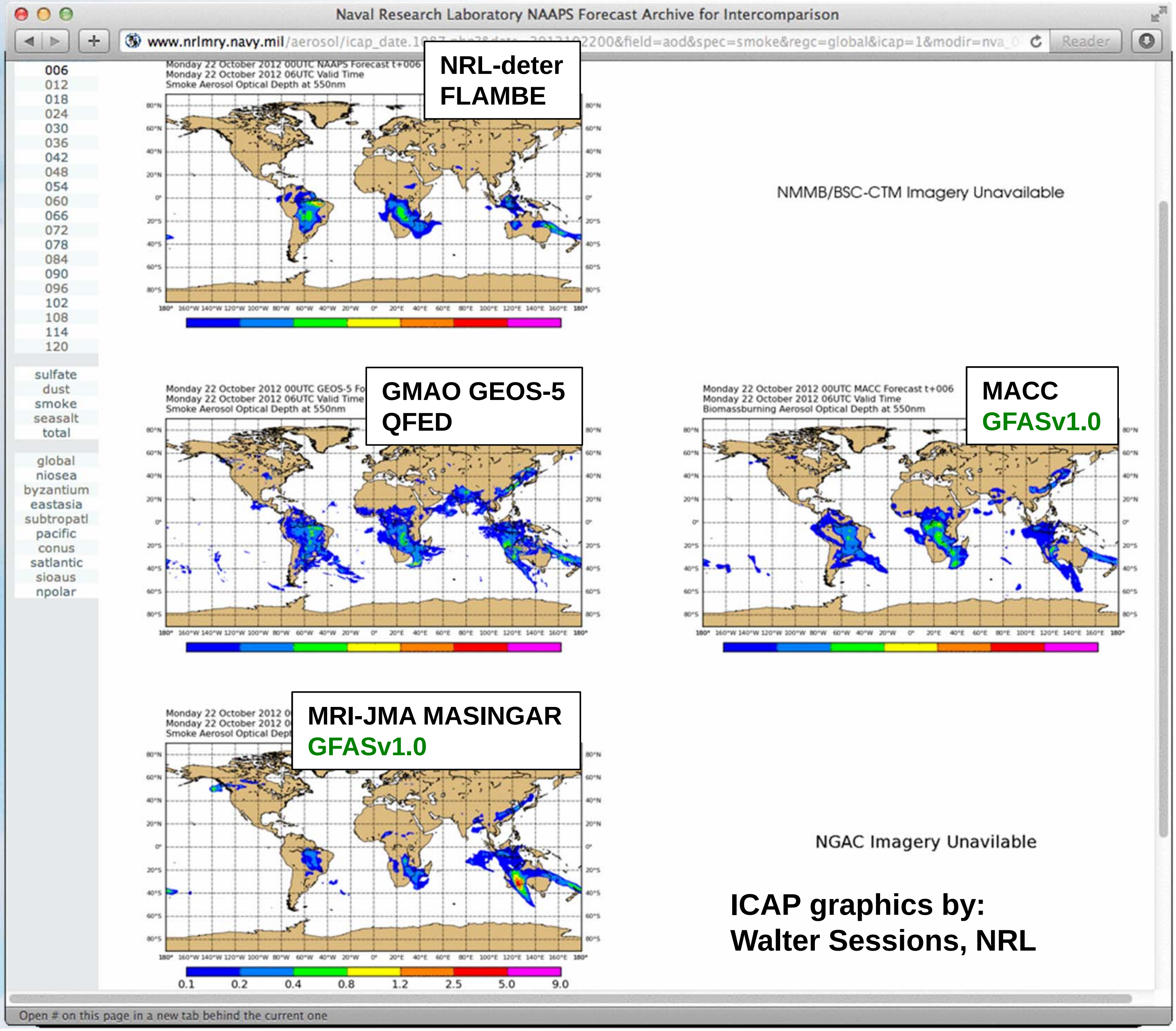
Model aerosol and cloud



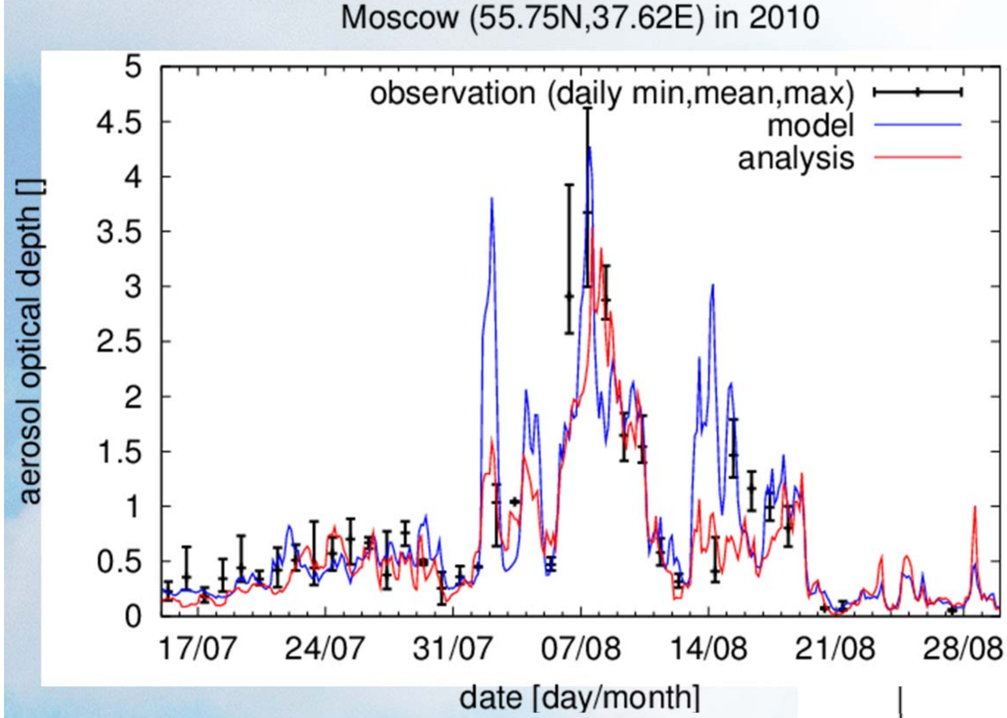
Model CO



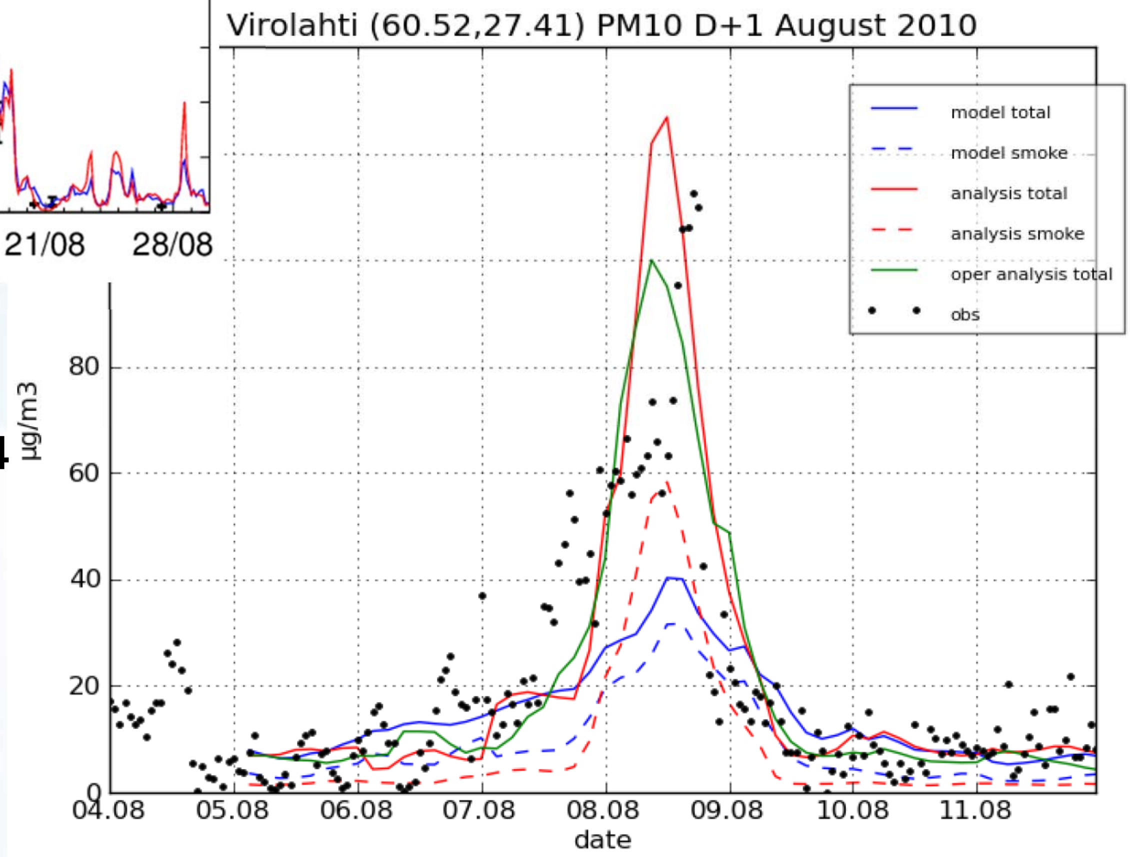
Use of daily global BB emissions around the world



Russia 2010: Validation of aerosol emissions



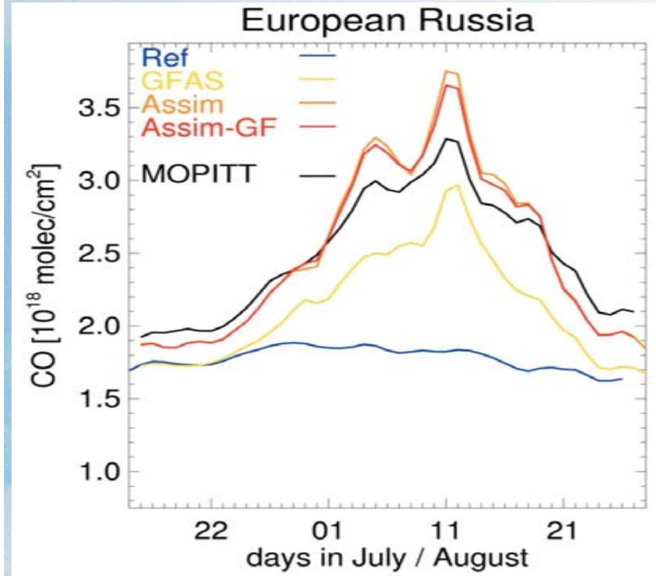
simulated aerosol load vs. observed PM10

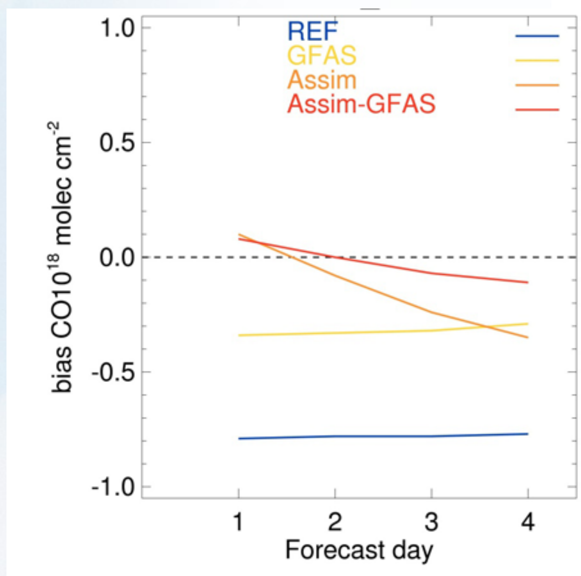


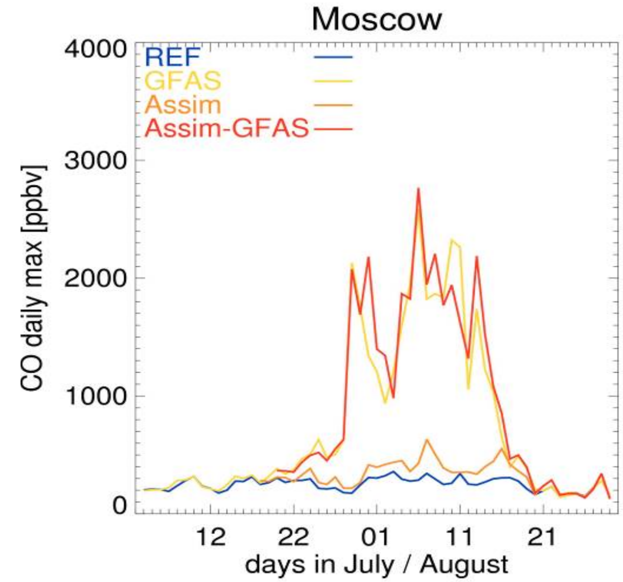
- **model using GFASv1.0 and globally derived scaling by 3.4**
- **analysis additionally assimilates MODIS AOD**

(adapted from Kaiser et al. 2011)

CO Simulations with IFS-TM5







- Much of the signal in CO column is captured by **either** emissions or assimilation.
- Accurate column forecasts require **both**.
- Surface concentrations are dominated by emissions.
- Forecasts suffer from poor fire predictions.

Model, with climatological emissions

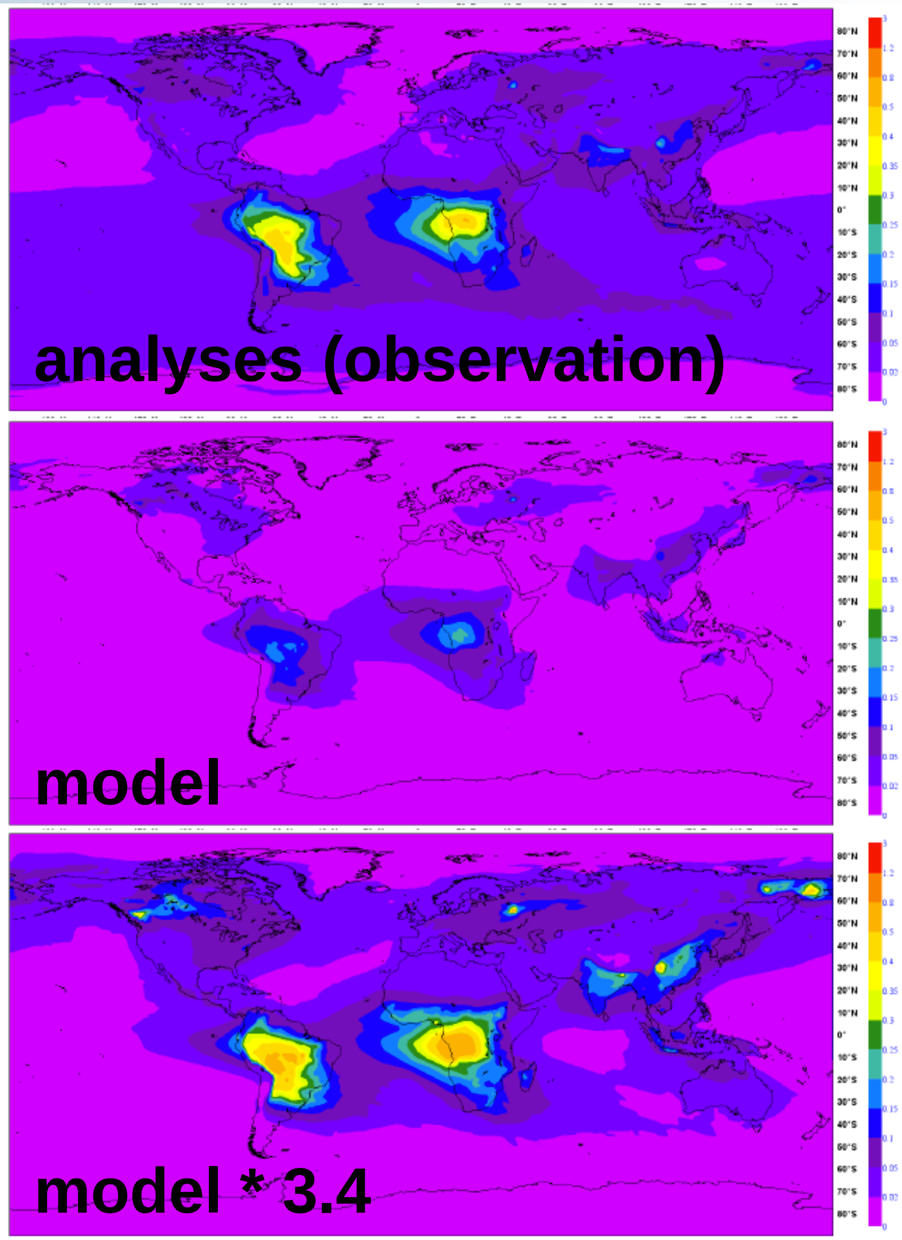
Model, with analysed emissions

Assimilation of IASI CO, with climatological emissions

Assimilation of IASI CO, with analysed emissions

[Huijnen et al. 2012]

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

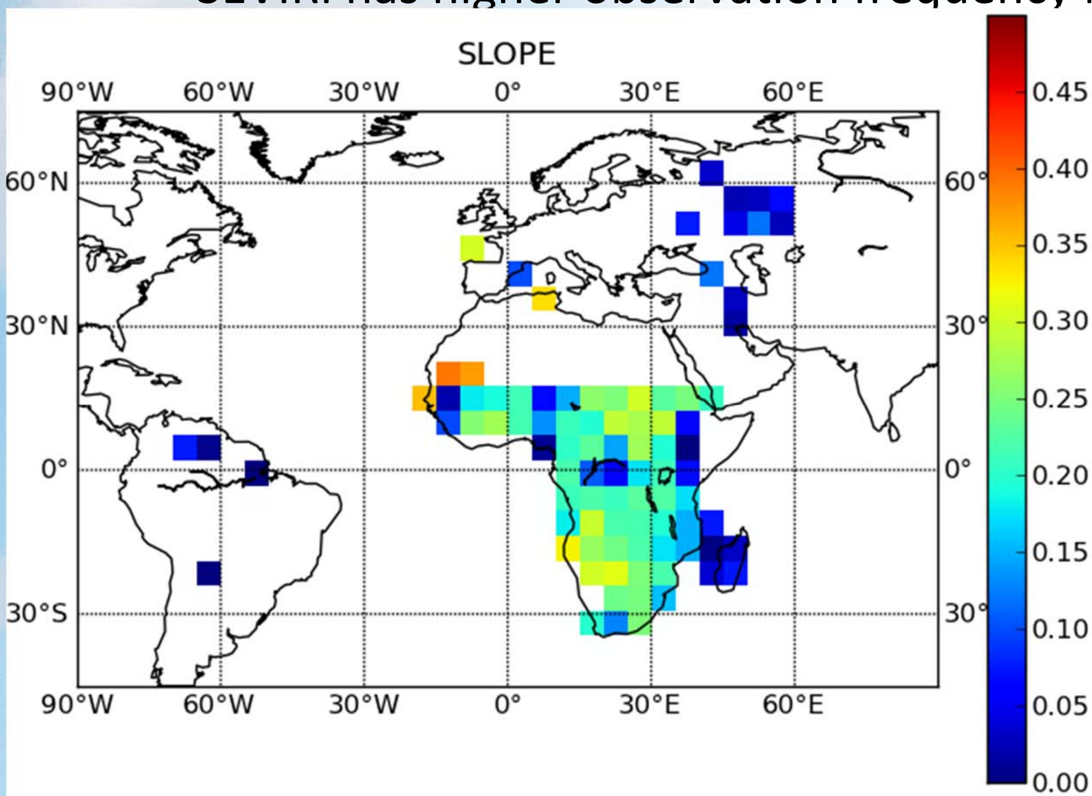


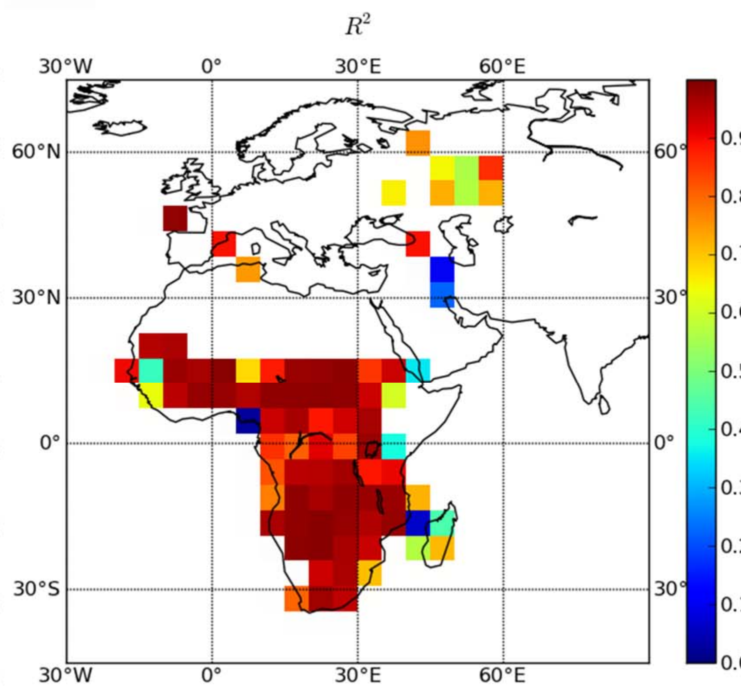
[Kaiser et al. 2012]

- assimilation of MODIS AOD
  - active: “analyses”
  - passive: “model”
- average of 15 Jul – 31 Dec 2010
- AOD (OM+BC) low by factor 3.4
  - similar to other top-down estimates:
    - NASA (GFED2.2)
    - NRL (Reid et al. 2009)
    - LSCE (N. Huneeus et al. 2012)
    - FMI (Sofiev et al. 2009)
    - AMMABB (Liousse et al. 2010)
  - inconsistent with bottom-up estimates:
    - GFED2/3 (van der Werf et al. 2006/10)
    - published emission factors (e.g. Andreae &

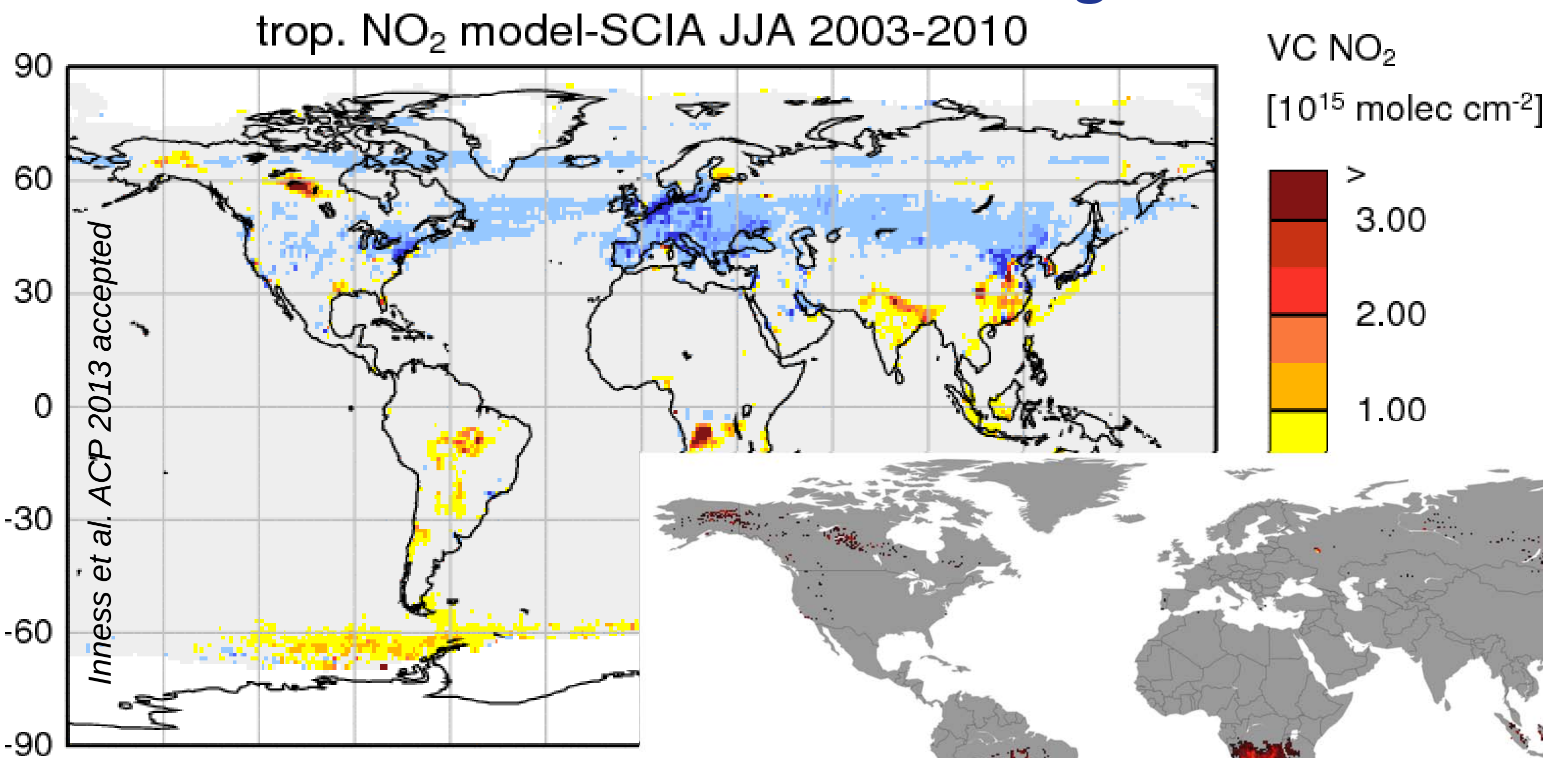
Why not SEVIRI?

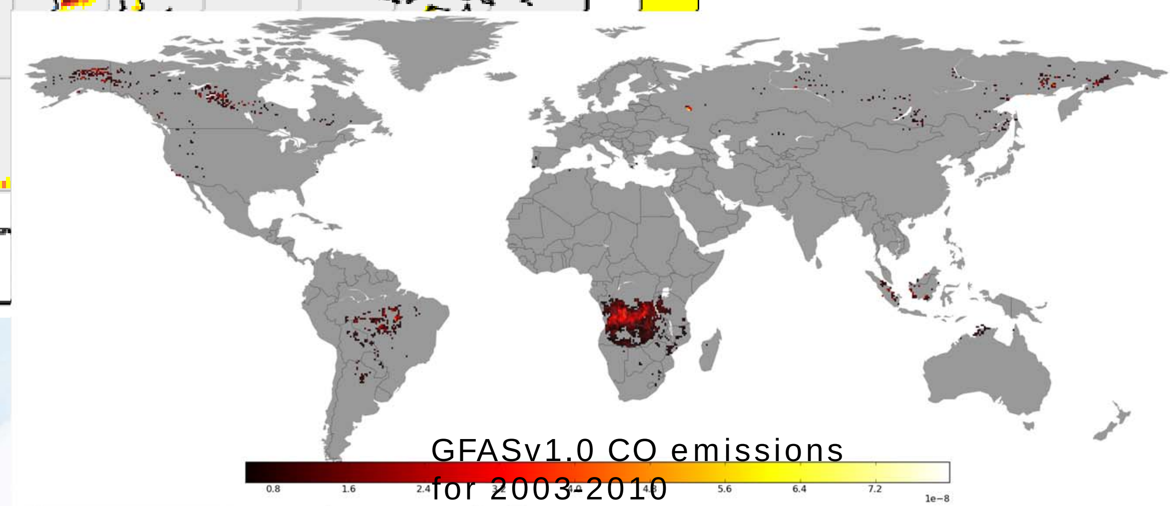
- regression of daily gridded FRP observations for 2010
- data produced by LandSAF (SEVIRI) and NASA (MODIS)
- SEVIRI has higher observation frequency but lower detection threshold





Bottom-up aerosol emissions are too low. Are NO2 emission estimates too high?





- Overestimation of NO2 near boreal forests
- → improve emission factors with large-scale validation ☺
- U Thessaloniki find underestimation of NH3, CH3OH compared to Coheur et al. 2009 (Greece 2007)

Conclusions on Atmospheric Systems

- Fire observations are used in NRT and retrospectively for applications in
  - air quality monitoring & forecasting
  - numerical weather prediction (in the future: CO2, aerosols)
  - feedback from plume observations
- Observations requirements:
  - real time: with ~ 3hours
  - resolution ~5km, ~1hour
  - emission estimates of aerosol species, greenhouse gases, reactive gases
  - observation error characterisation
  - gas flare observations
- Some challenges:
  - bias of geostationary FRP observations
  - undetected small fires, even form LEO
  - low accuracy of conversion to emissions
  - injection height
  - observations gaps due to clouds, insufficient satellites

What is "IBBI"?

IBBI is the new research initiative "Interdisciplinary Biomass Burning Initiative". It is jointly sponsored by

- IGAC (International Global Atmospheric Chemistry),
- iLEAPS (Integrated Land Ecosystem-Atmosphere Processes Study) and
- WMO (World Meteorological Organization).

IBBI is co-chaired by Melita Keywood and Johannes Kaiser.

IBBI has emerged from two past workshops:

- European Science Foundation (ESF) Exploratory Workshop in 2009
- Joint IGAC-iLEAPS-WMO workshop in Geneva in 2012

Goals

IBBI will **foster international and interdisciplinary collaboration of research activities** dealing with vegetation fires and will lead to improved

- understanding of all processes influencing vegetation fires
- scientific and operational fire monitoring and forecasting based on physical models and the latest earth observations.
- air quality forecasts
- assessments of global air pollution transport patterns
- observations and predictions of climate change
- guidance for managing large-scale fire situations

Key contribution could be from the

- quantification of the relationships between emission factors and physical parameters that are available from remote sensing or operational modelling system,
- derivation of estimates for fuel consumption, fire spread, fire intensity, change in vegetation, etc.
- integration of biogeochemical fire science with socioeconomic research to describe driving parameters (e.g. population density, GDP, land ownership, land management)
- widespread calibration of global models and systems with a large number of field campaigns

Activities

IBBI workshops

2nd IBBI mini-workshop on 12 April 2013
3rd IBBI workshop for 3 days during April 2014, Germany

Sessions at conferences

*** EGU, Apr 2013, Vienna, Austria: “Fire in the Earth System”**
*** AsiaFlux, Aug 2013, Seoul, Korea: “IBBI –Asian Perspective”b (http://asiaflux.net/asiafluxws2013)**
*** iLEAPS Science Conference, May 2014, Nanjing, China (http://www.ileaps-sc2014.org)**

New directions paper on advances and challenges in research of biomass burning

Open mailing list with announcements of

*** meetings**
*** field campaigns**
*** announce opportunities for collaboration**
(subscription on web page)

IBBI web page at http://www.mpic.de/projekte/ibbi.html

Invitation

If you work on any aspect of biomass burning please join our discussions in the IBBI community

- on our mailing list at http://www.mpic.de/projekte/ibbi.html

- at our 3rd workshop planned for
  23-26 April 2014 on Schloss Ringberg in Germany

You are also welcome to contact
Melita Keywood <Melita.Keywood@csiro.au> or
Johannes Kaiser <j.kaiser@ecmwf.int>.

Scientific Challenges

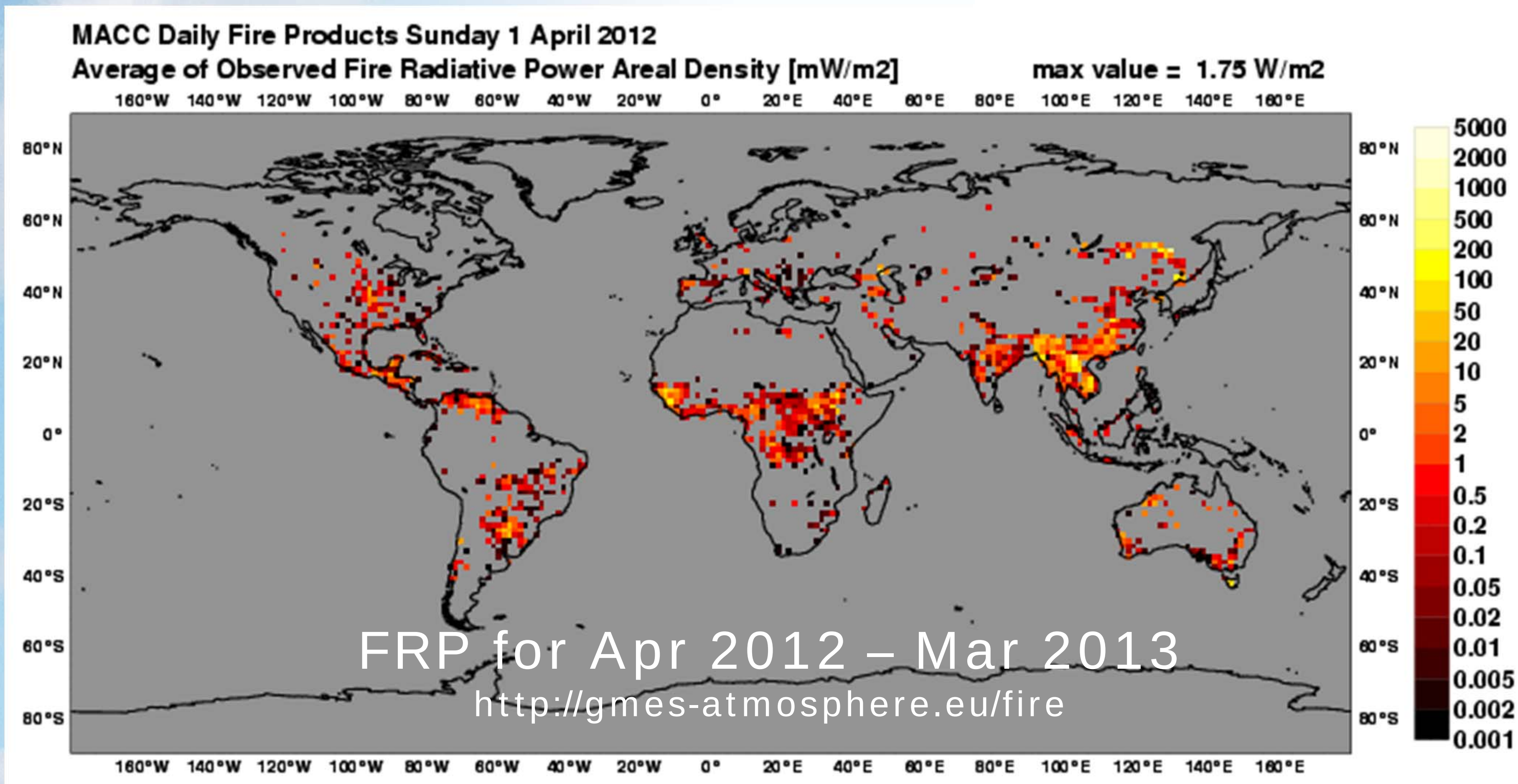
Despite all the recent advances, many scientific challenges must be overcome before the role of fire in all aspects of the earth system can be understood and simulated. Most challenges relate to the many different types of vegetation fire that exist and each fire has its individual properties. Some of the challenges are:

- Species emission factors vary with meteorological and fuel condition, e.g. moisture
- A discrepancy between bottom-up and top-down estimates of fire emissions has been observed. Even the relatively well-observed emissions of aerosols disagree by up to a factor 4. This links to a poor understanding of the smoke evolution during the first hour after the emission.
- Generally, observations of many emission factors are sparse and not globally representative.
- Combustion efficiency is only poorly known.
- Up-scaling to global estimates is challenging.
- There appears to be a shift between fires and CO plumes in Southern Africa.
- Emissions from open burning and other sources cannot be distinguished from atmospheric observations.
- Multi-species source inversion for smoke constituents have not been achieved yet.
- Timeliness and resolution of the global operational fire monitoring system are still not sufficient for emergency response applications.

- A new initiative jointly sponsored by IGAC, iLEAPS & WMO
- IBBI will address the open issue through improve physical understanding and modelling of biomass burning by improved interdisciplinary collaboration.
- poster G24 today
- mini-workshop in room R10 on Friday, 10-16hrs
- 3-day workshop in Schloss Ringberg in April 2014
- http://www.mpic.de/projekte/ibbi.html
- co-chaired by Melita Keywood & Johannes Kaiser

NRT production of daily FRP and Emissions

- GFASv1.0
  - MODIS FRP assimilation
  - ~50 km resolution
  - 1 Jan 2008—yesterday
- GFASv1.1
  - MODIS FRP assimilation
  - ~10 km resolution
  - 1 Jan 2003—yesterday

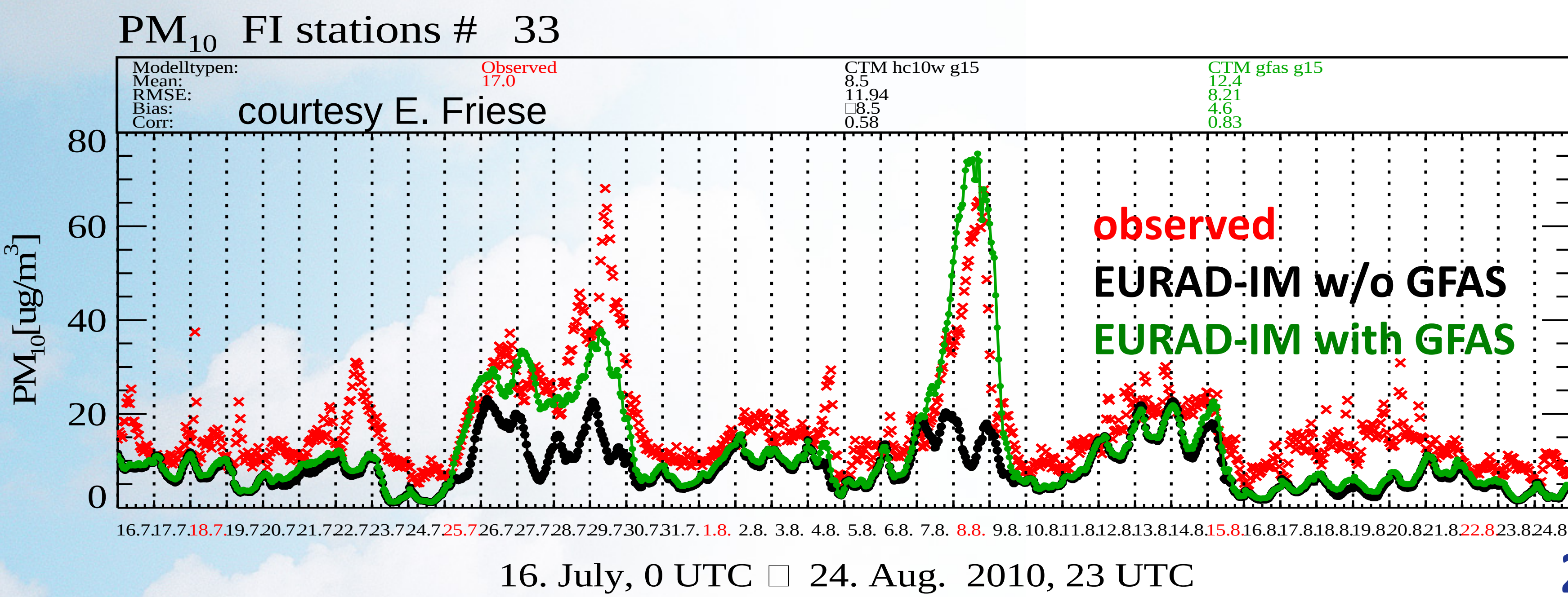


Use of GFAS in MACC-II, cont.

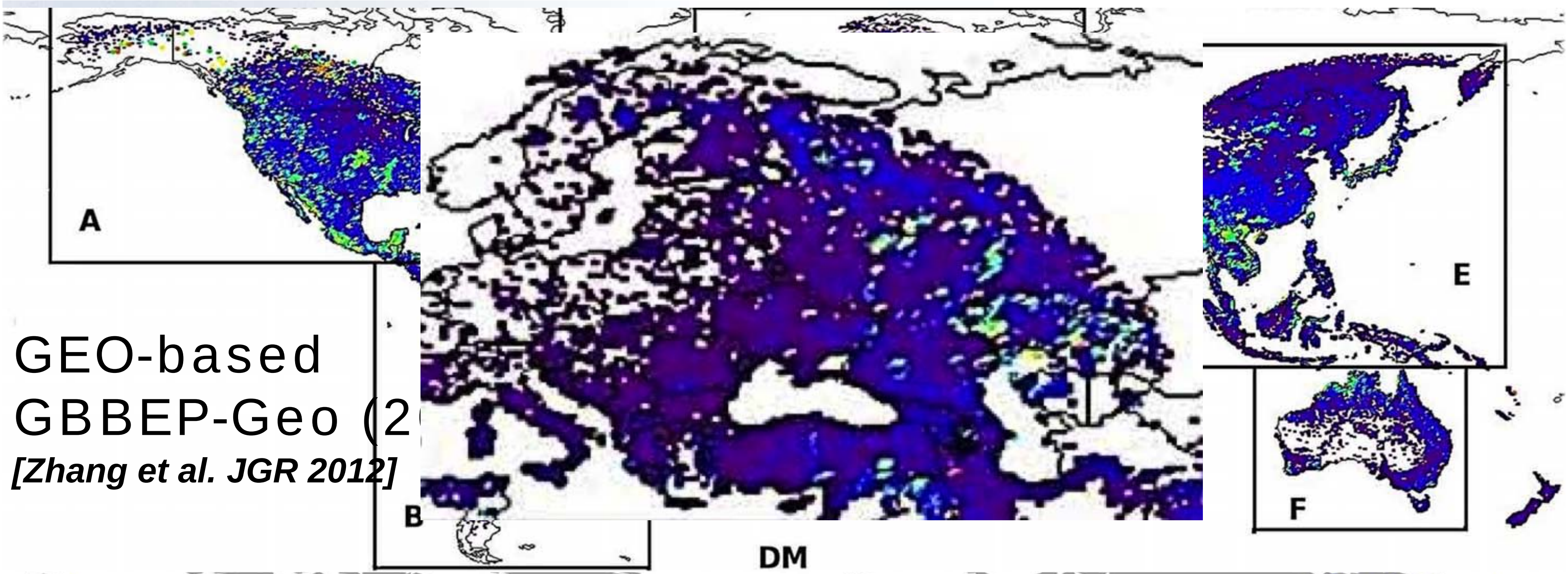
GFASv1.1

- daily 0.1deg resolution
- used in hi-res studies and campaign support
- being implemented in four regional AQ systems
  - EURAD-IM, MATCH, CHIMERE, SILAM

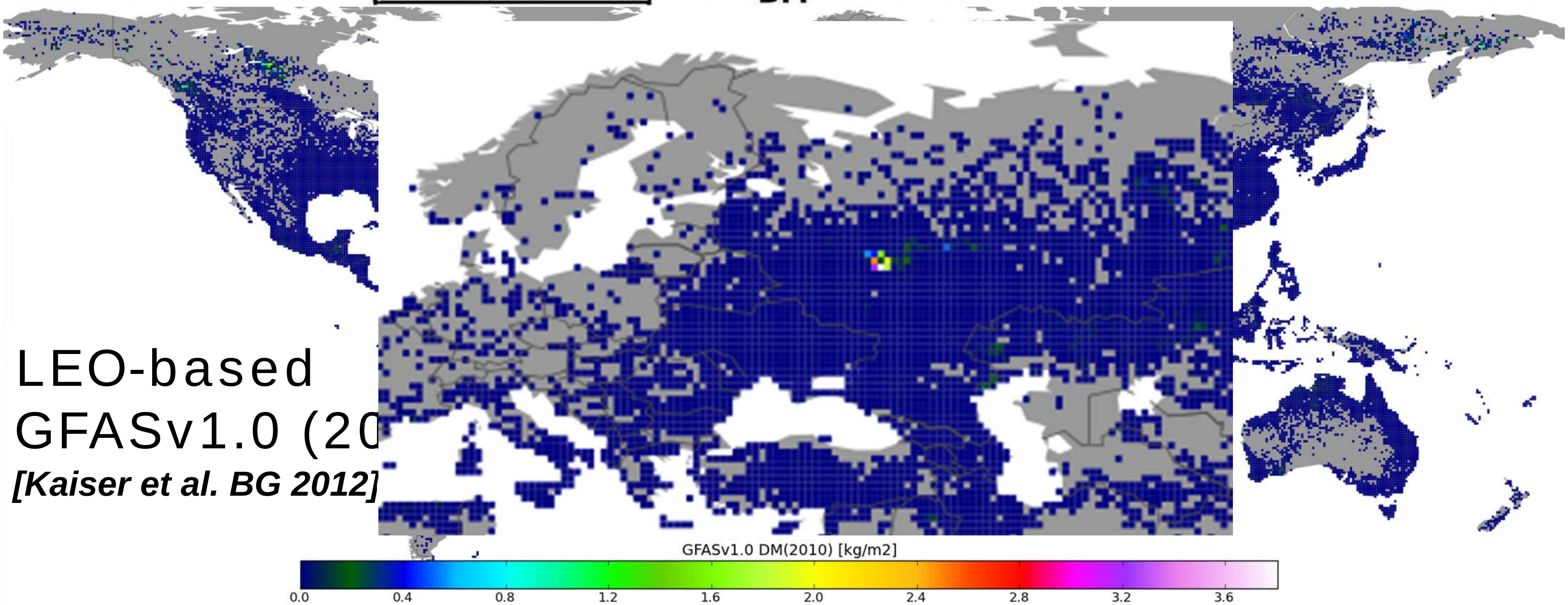
- SILAM uses IS4FIRES emissions (MODIS FRP)



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

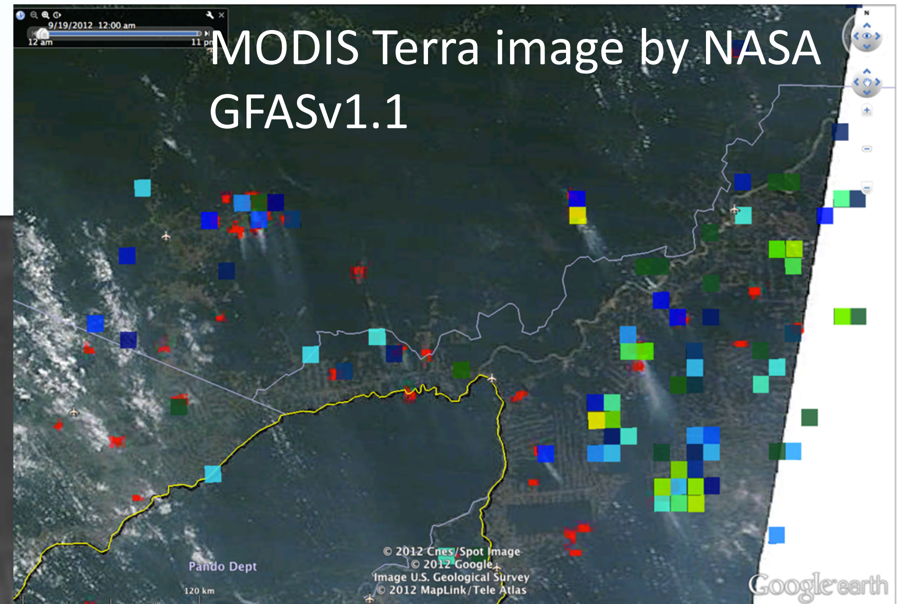


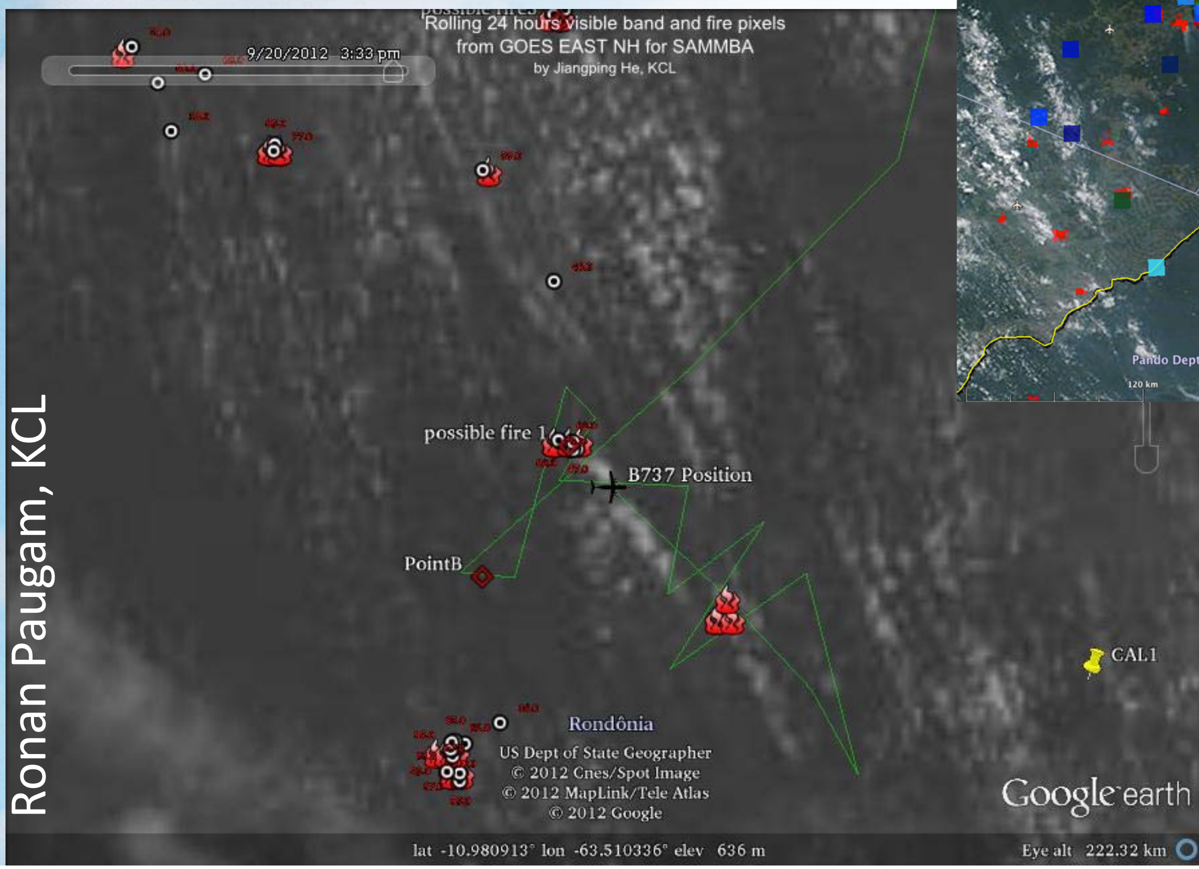
LEO-based
GFASv1.0 (20
[Kaiser et al. BG 2012]



Science campaign support, here: SAMBBA

- AOD & CO forecasts
- GFAS emissions for UK Metoffice LAM forecasts
- GFASv1.1 fire activity
- GFAS hourly GOES FRP
- native resolution GOES FRP
- native resolution GOES hot spots
  - from 2 hours after observation





Ronan Paugam, KCL

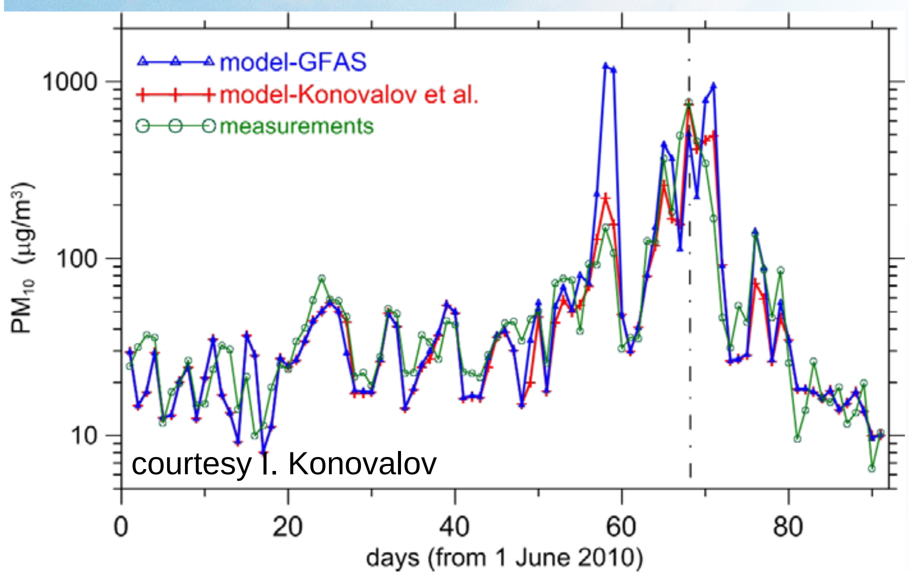
Scientific Studies: Russia revisited

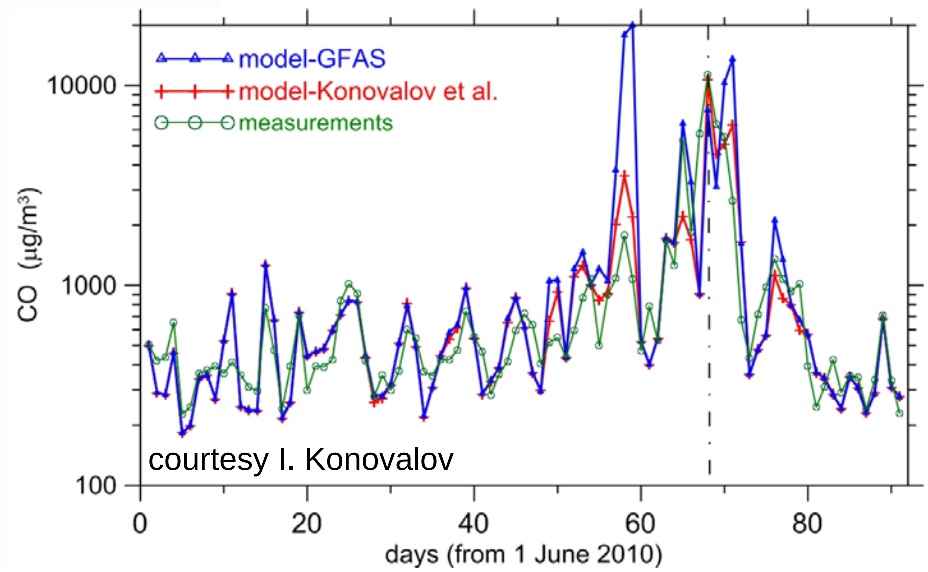
- ESA ALANIS Smoke Plumes:
  - CO vs. IASI
  - Krol et al. ACPD 2012

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.

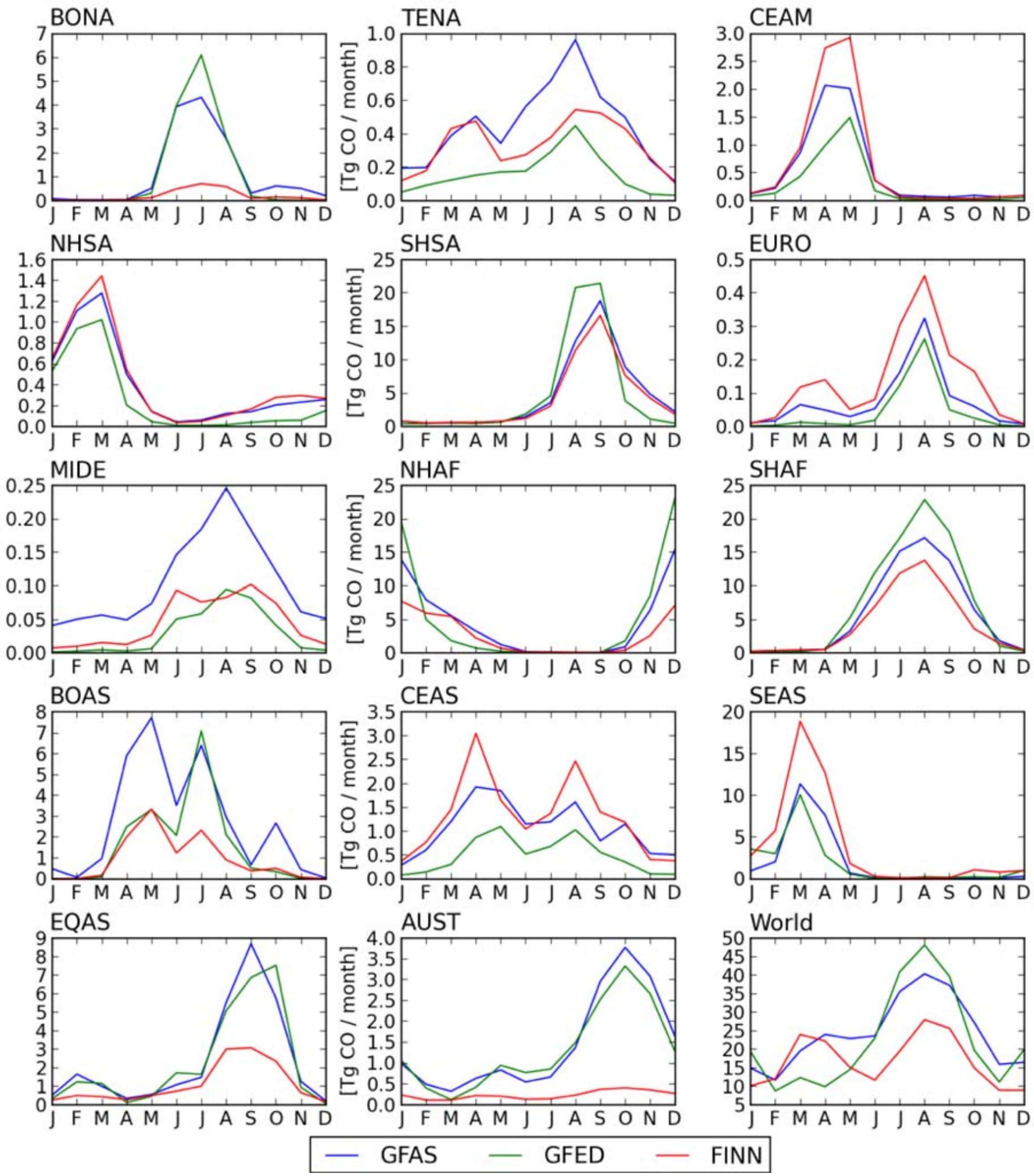
Simulation	Prior R1	Poste R1	Prior R2	Poste R2
MERGED	1.06	6.82	6.5	26.6
MERIS	0.86	7.29	3.9	24.0
GFAS	10.52	9.93	12.4	22.0
GFED3	0.63	10.06	2.0	22.3
MERGED-CLIM	1.06	5.26	6.5	22.6
MERGED-DAILY	1.06	5.98	6.5	25.1
MERGED-DIURNAL	1.06	6.62	6.5	26.9

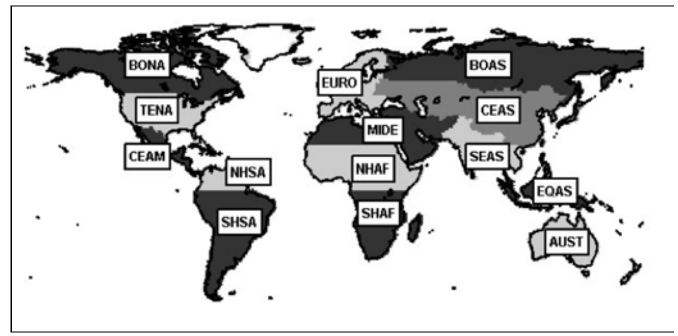
- Russian Academy of Science: CO, PM10… vs. Moscow in-situ





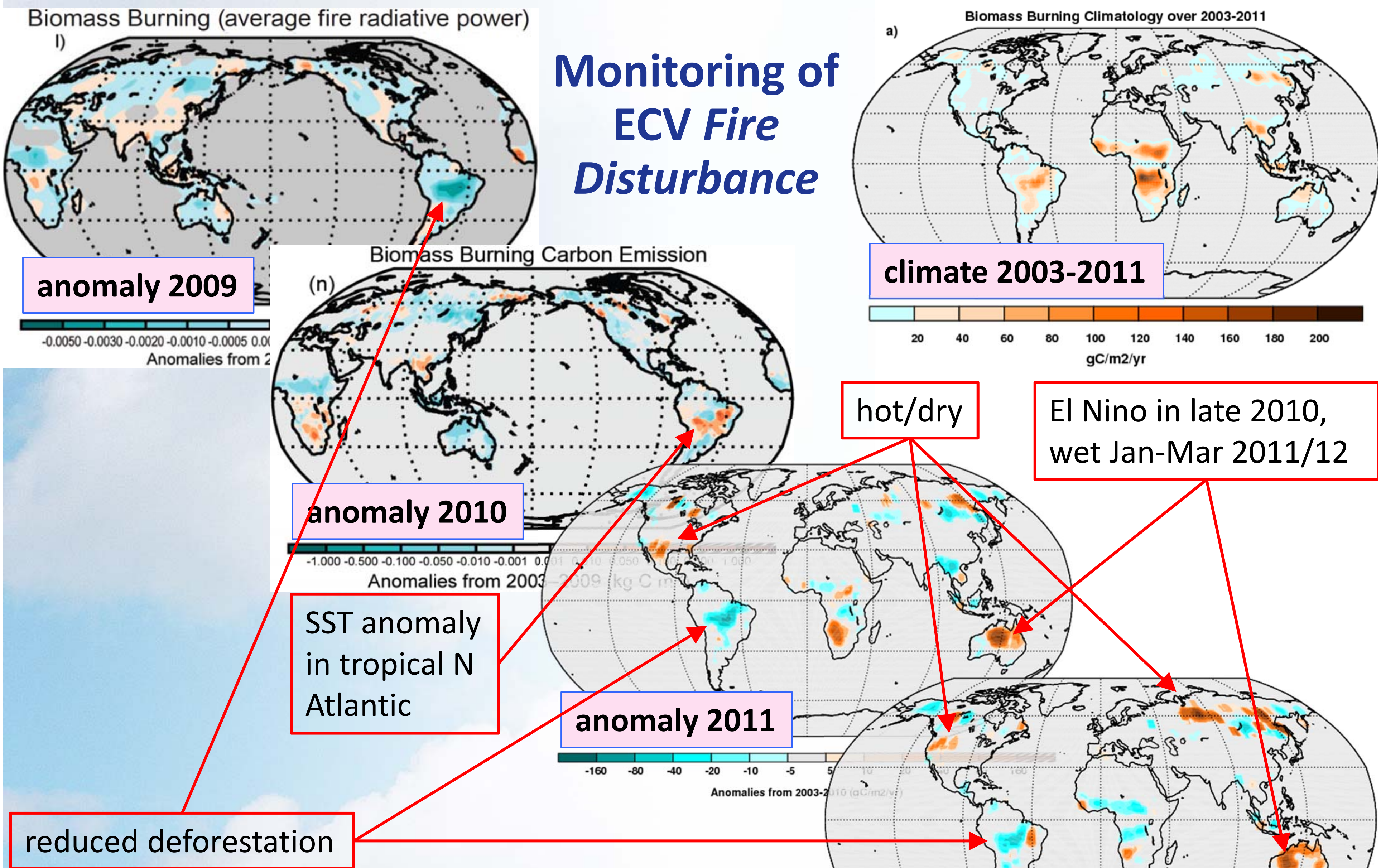
Comparison to other inventories: Monthly CO emissions





by Niels Andela

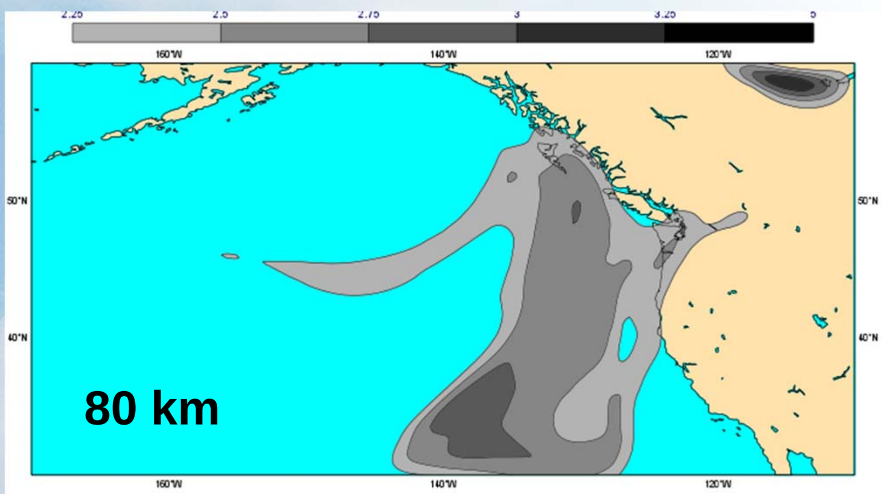
Monitoring of ECV *Fire Disturbance*

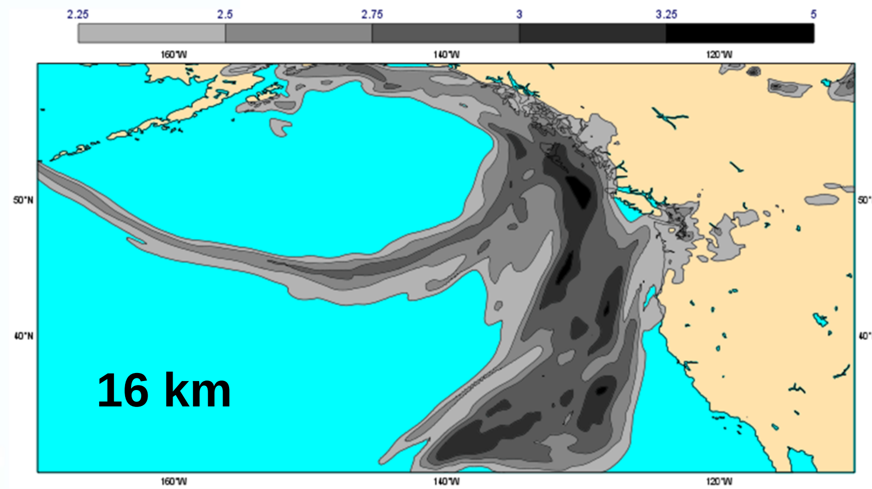


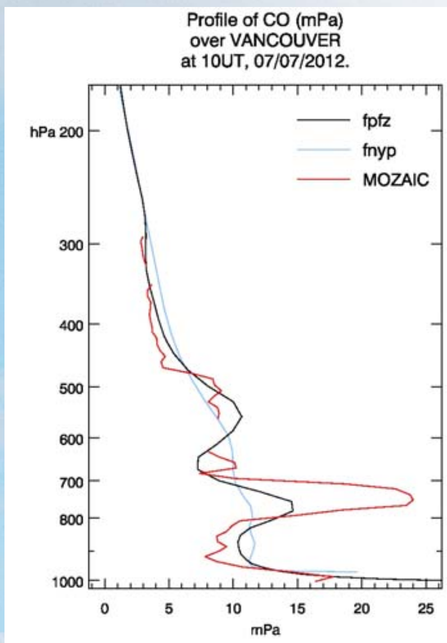
Annual fire anomalies in NOAA's *State of the Climate* reports.

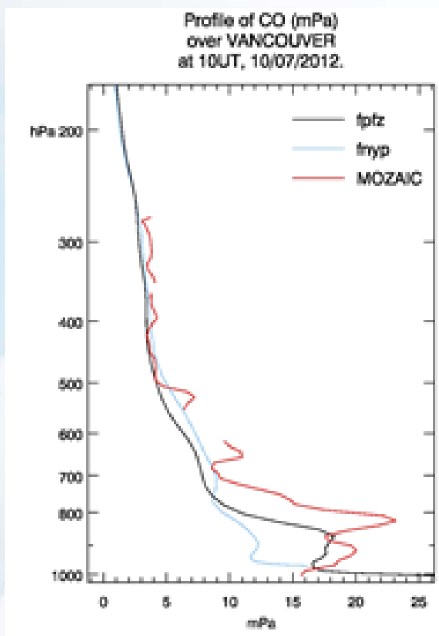
[Kaiser et al. *BAMS* 2010, 2011, 2012, 2013]

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

Use of GFAS in MACC, cont.

GFASv1.1

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- being implemented in four regional AQ systems
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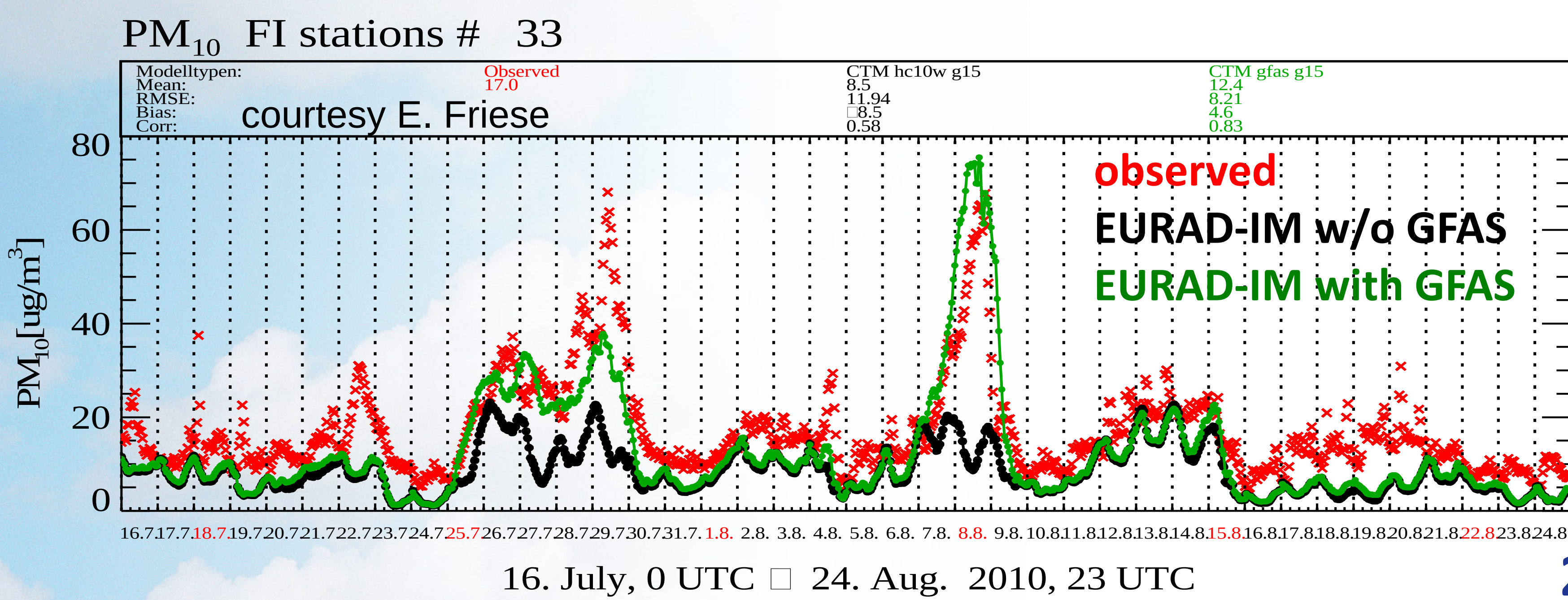

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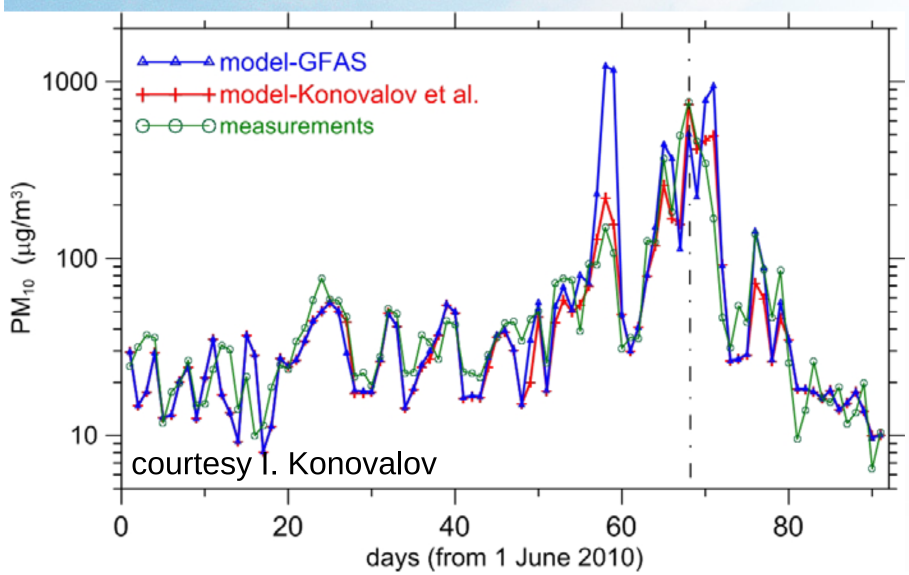
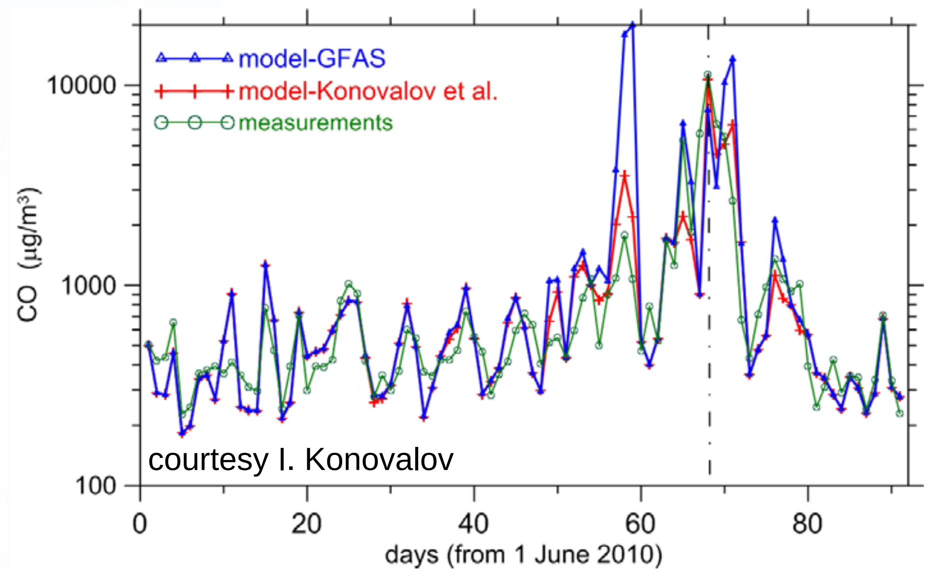
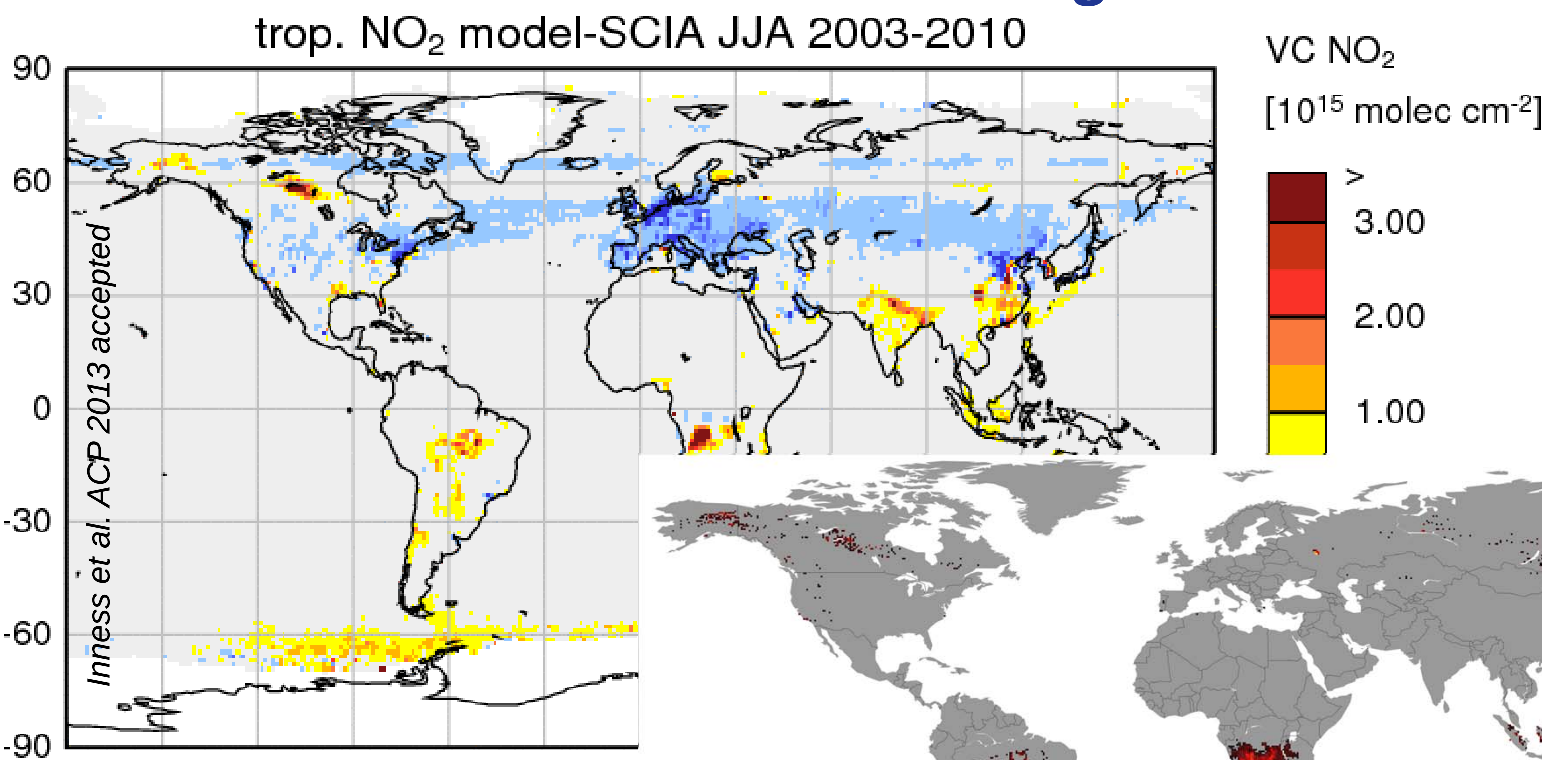
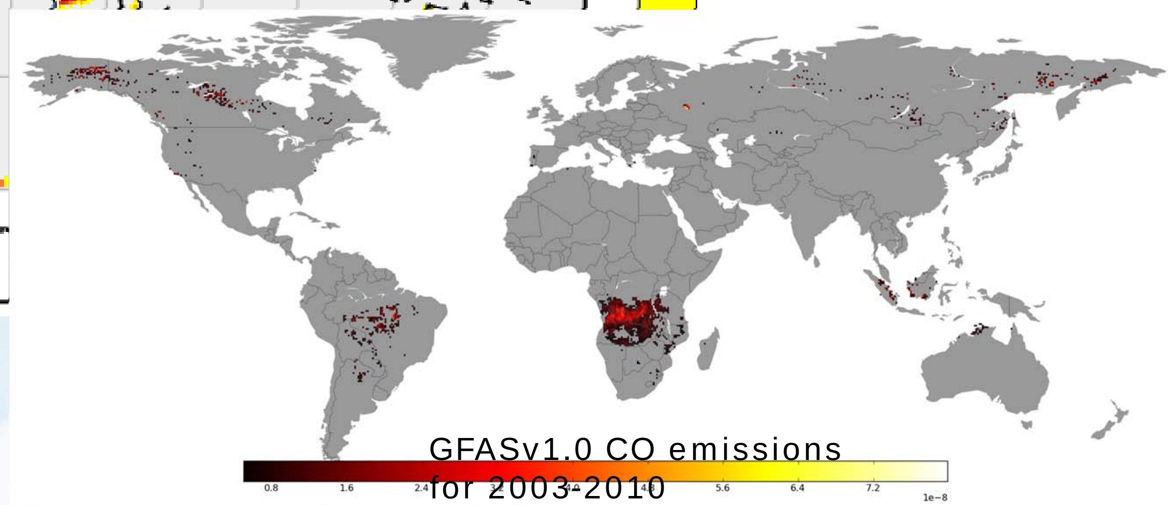




Bottom-up aerosol emissions are too low. Are NO2 emission estimates too high?





- Overestimation of NO2 near boreal forests
- → improve emission factors with large-scale validation ☺
- U Thessaloniki find underestimation of NH3, CH3OH compared to Coheur et al. 2009 (Greece 2007)

IBBI | Interdisciplinary Biomass Burning Initiative

- A new initiative jointly sponsored by IGAC, iLEAPS & WMO

- IBBI will address the open issue through improve physical understanding and modelling of biomass burning by improved interdisciplinary collaboration.
- poster G24 today
- mini-workshop in room R10 on Friday, 10-16hrs
- 3-day workshop in Schloss Ringberg in April 2014
- http://www.mpic.de/projekte/ibbi.html

- co-chaired by Melita Keywood & Johannes Kaiser

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:

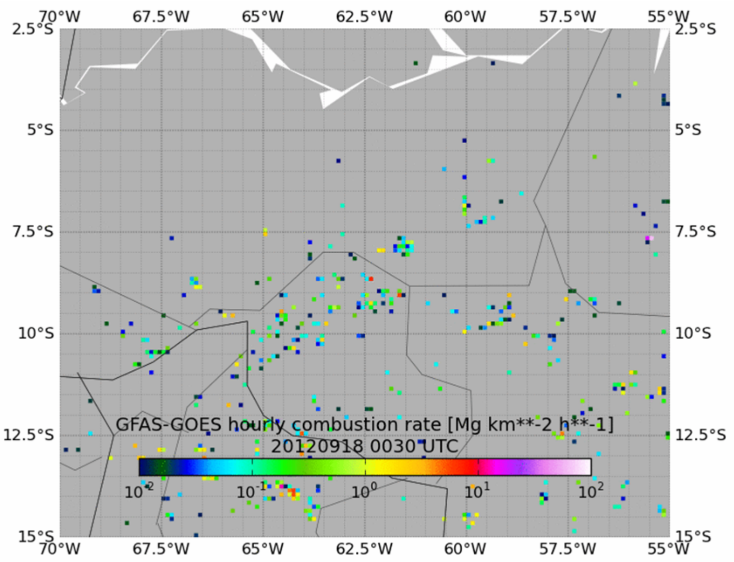
- OGC web server

GEIA **archive**:

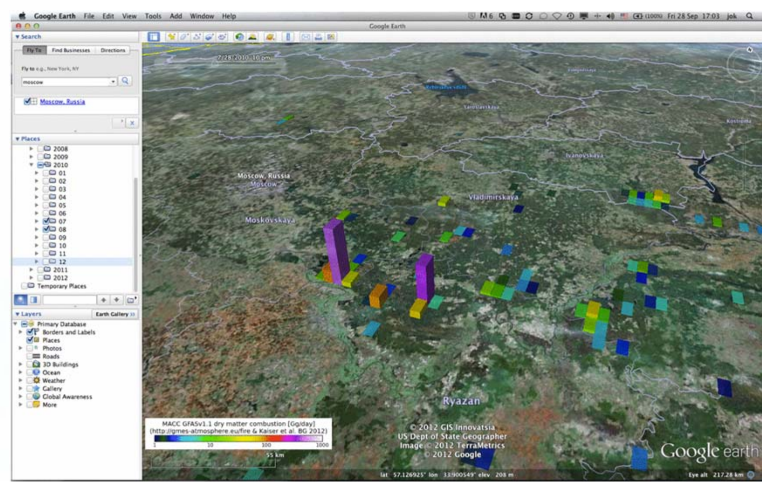
- OGC web server

USERS

Conclusions



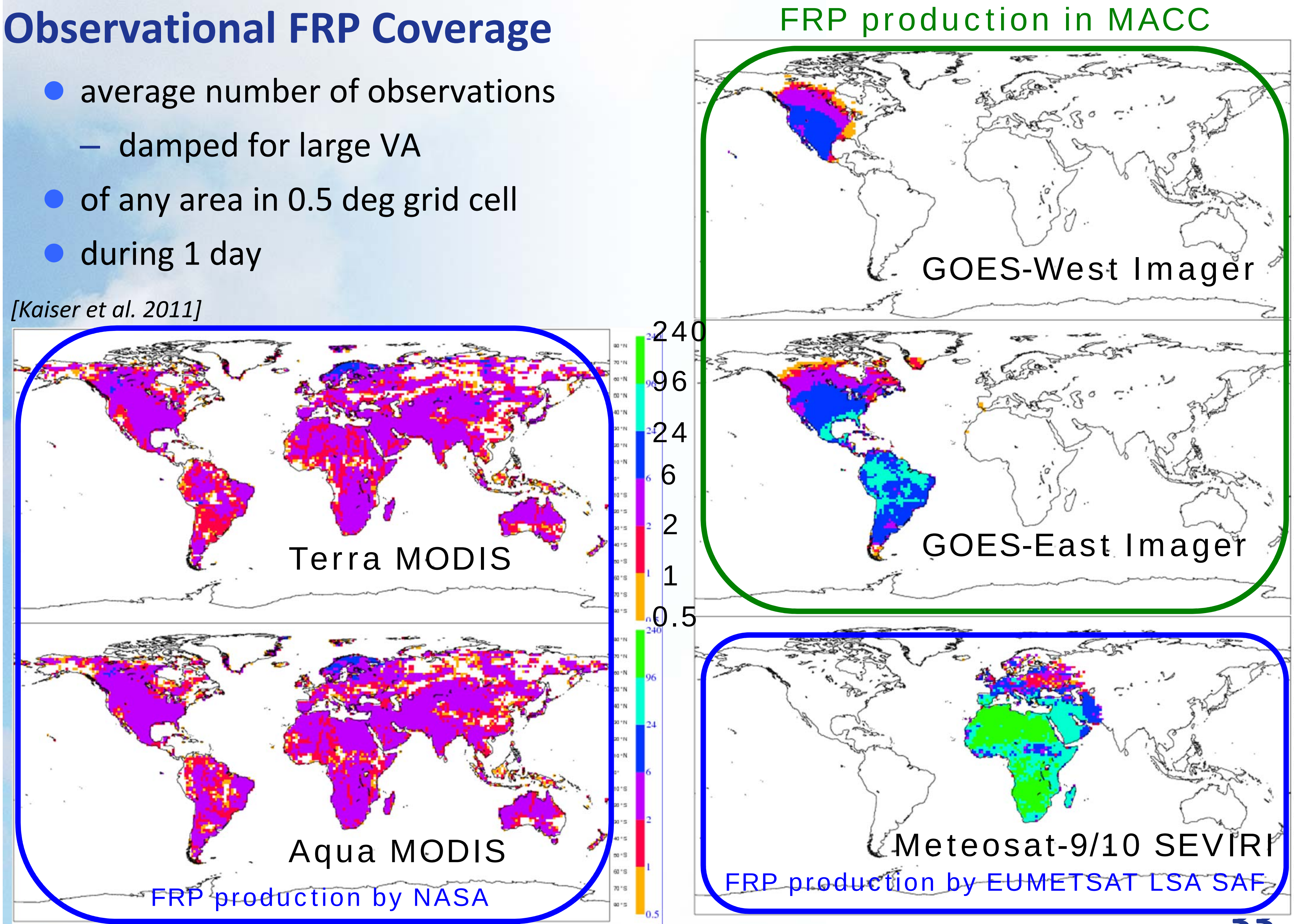
- MACC GFAS is producing
  daily biomass burning estimates
  - for 40 smoke constituents
  - in real time
  - publicly available
- All global MACC systems consistently use GFAS emissions.
- More and more regional air quality systems use GFAS.
- GFAS compares well with other inventories.
- Feedback from 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

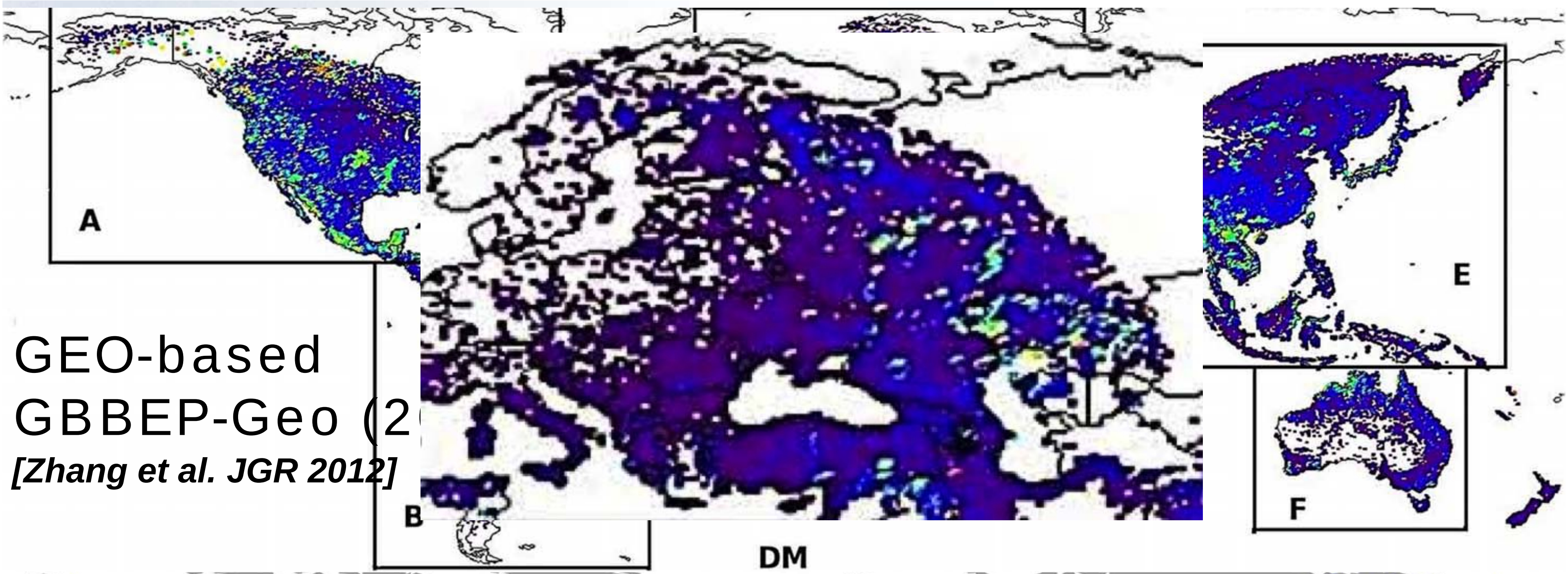
- average number of observations
  - damped for large VA
- of any area in 0.5 deg grid cell
- during 1 day

[Kaiser et al. 2011]



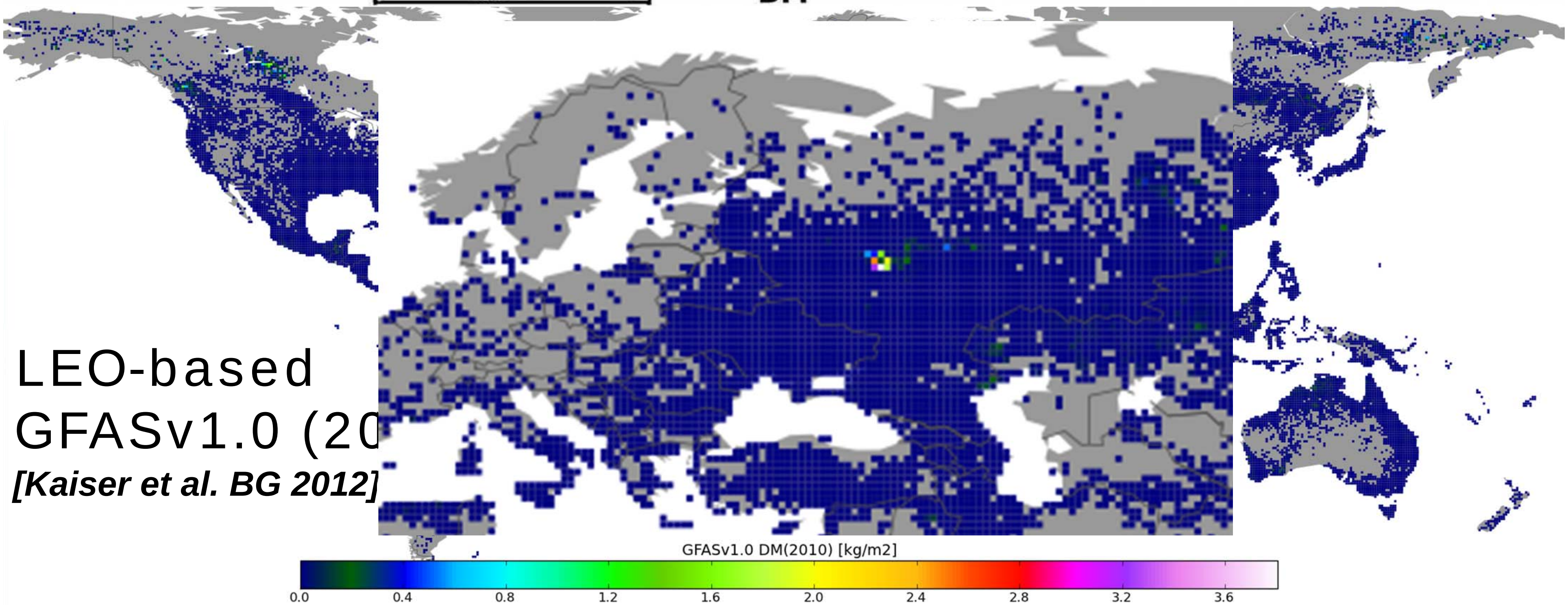
GEO-based
GBBEP-Geo (2

[Zhang et al. JGR 2012]



LEO-based
GFASv1.0 (20

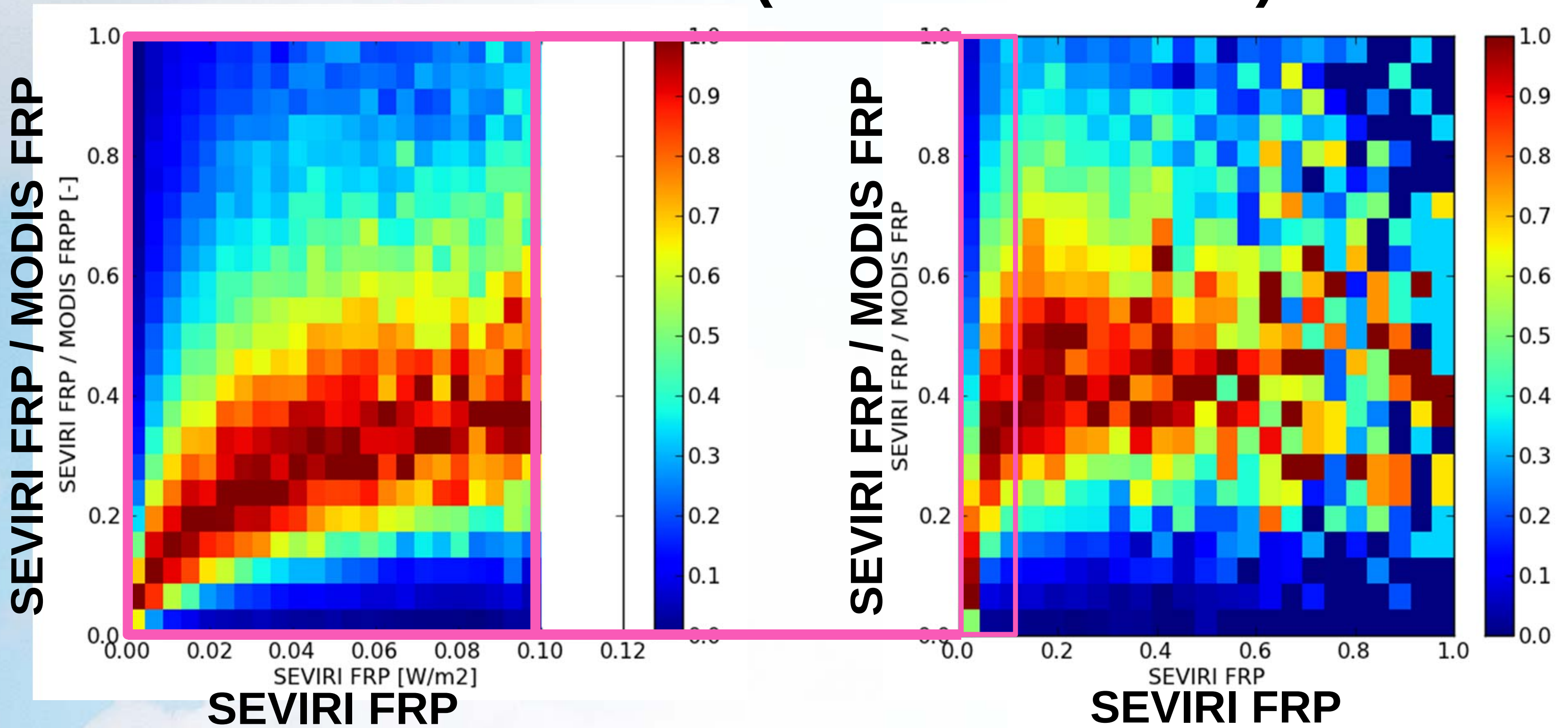
[Kaiser et al. BG 2012]

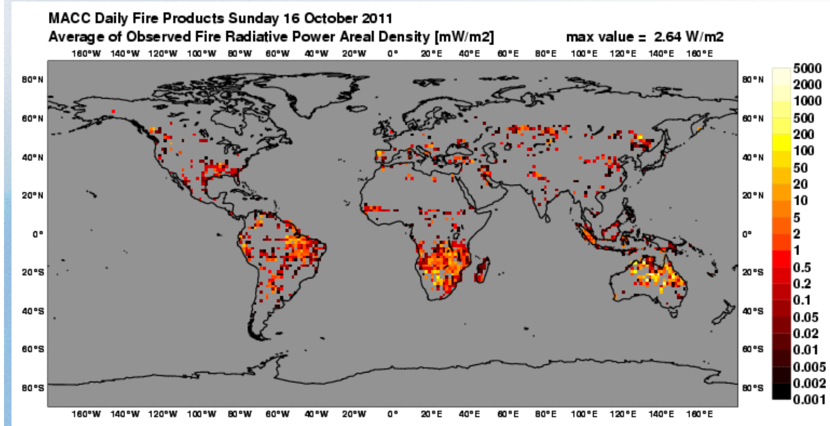


FIR Developments: FRP merging of GEO and LEO observations

- 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

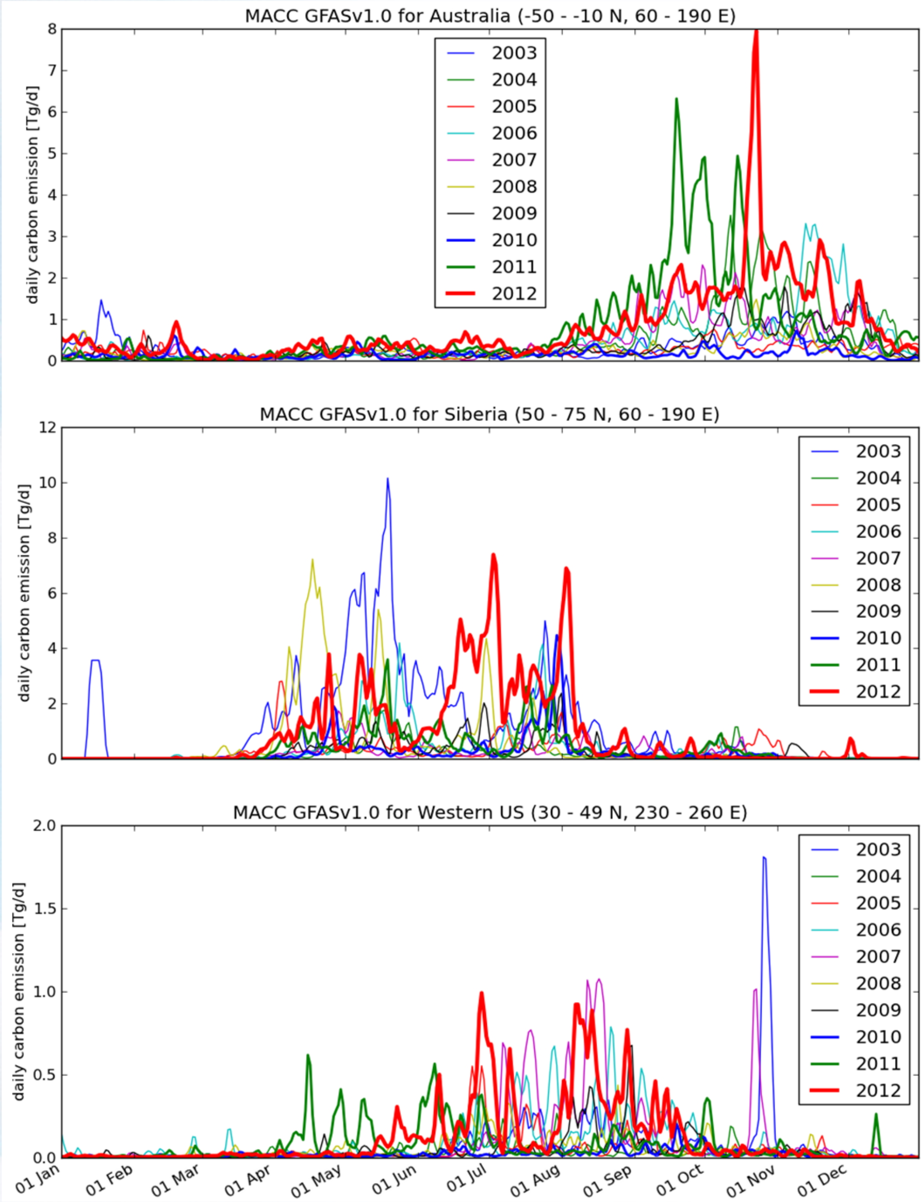
conditional PDF (Jun2010-Jul2012)



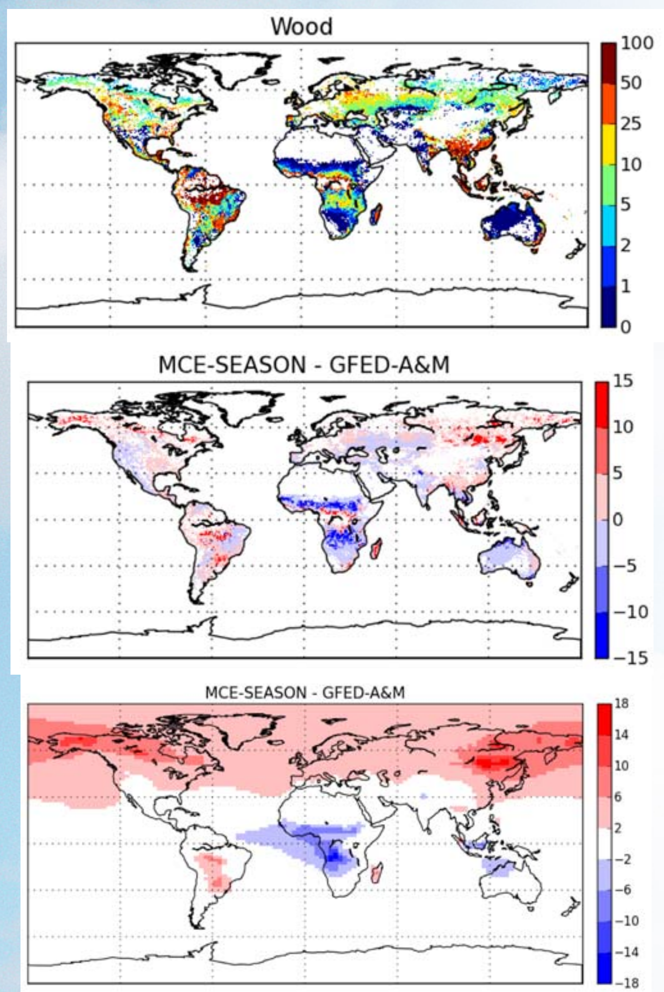


GFAS Emissions in MACC Systems

- global production
  - aerosols
  - reactive gases
  - greenhouse gases
- reanalysis (2009-10)
- CO-tracer forecasts
- EURAD regional forecasts


MACC GFASv1.0 for Australia (-50 - -10 N, 60 - 190 E)
daily carbon emission [Tg/d]
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
MACC GFASv1.0 for Siberia (50 - 75 N, 60 - 190 E)
daily carbon emission [Tg/d]
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
MACC GFASv1.0 for Western US (30 - 49 N, 230 - 260 E)
daily carbon emission [Tg/d]
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
01 Jan
01 Feb
01 Mar
01 Apr
01 May
01 Jun
01 Jul
01 Aug
01 Sep
01 Oct
01 Nov
01 Dec

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

van Leeuwen, VUA

Plume Rise Model Development

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

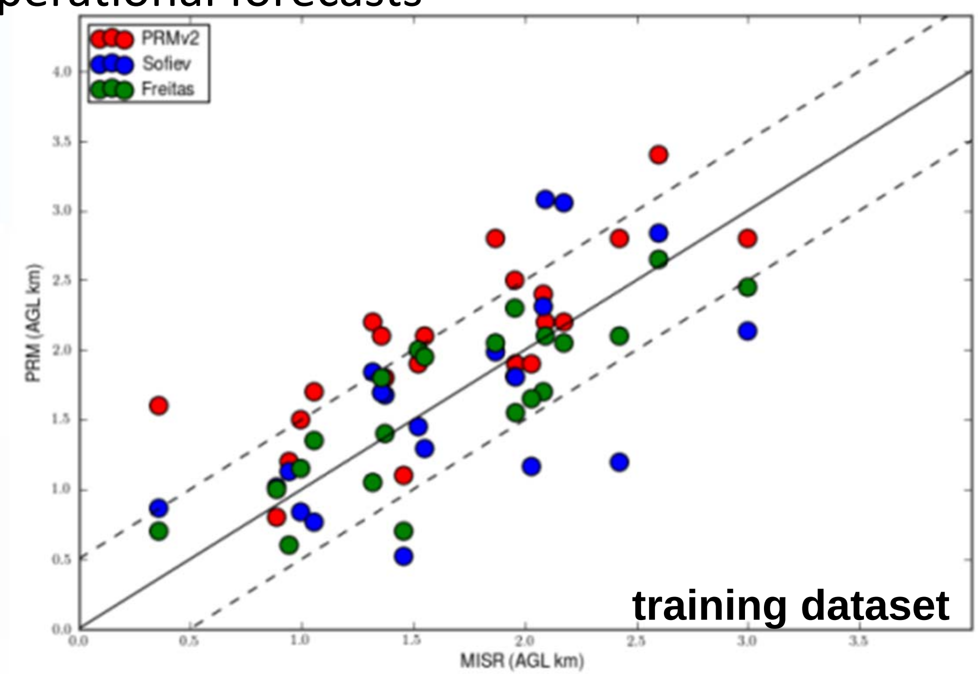
Improve Physics ⇨ Validation and optimization on well characterised fire event ⇨ Introduce more time dependence with an Implementation on-line

mass conservation
new entrainment scheme

MISR + MODIS FRP
+ Atmospheric Profile

validation on large regional scale simulation with CALIOP product

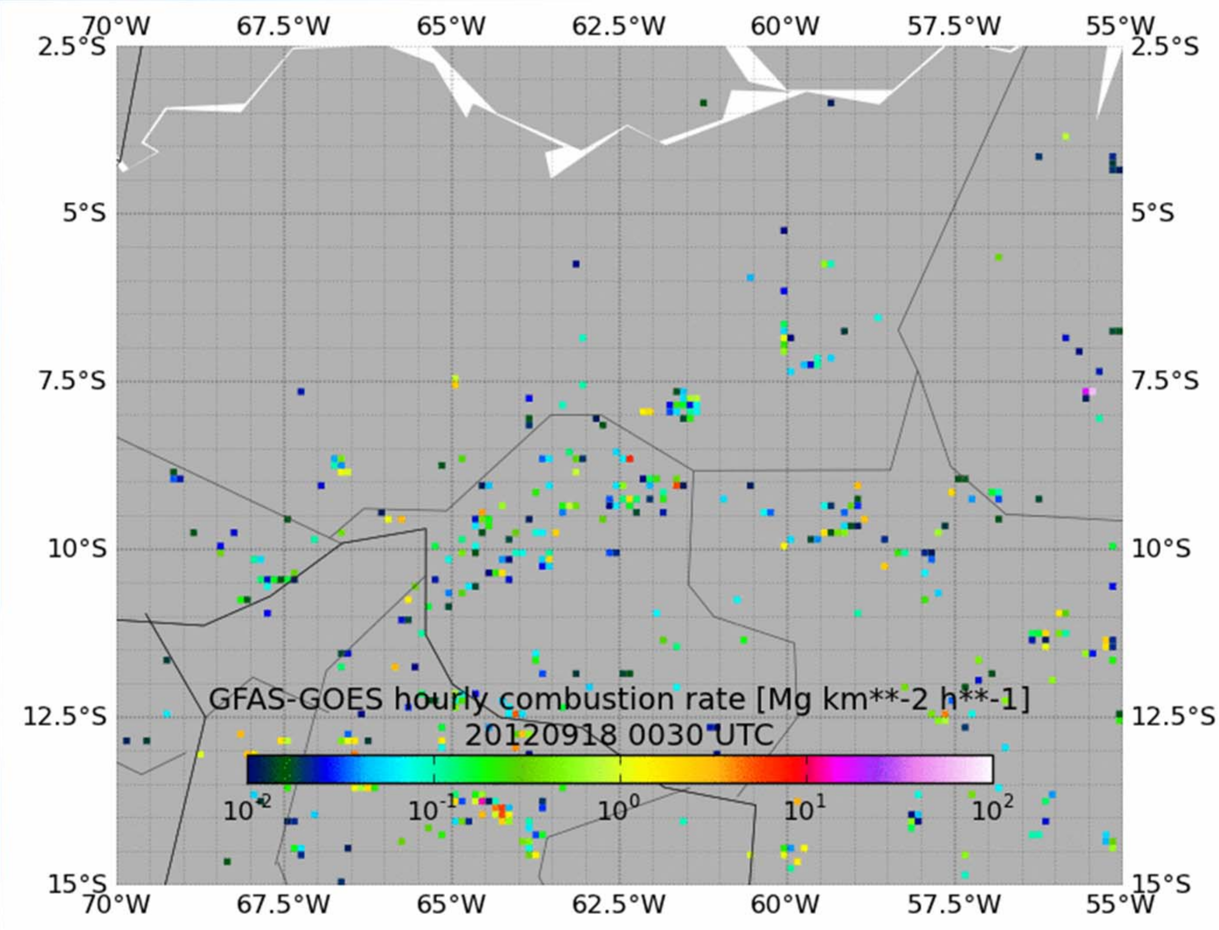
- MISR reference dataset of observed FRP and plume top height created (N America)
- PRM by Freitas et al. 2007 implemented and optimised
    - input data stream from ECMWF operational forecasts
- Sofiev et al. 2012 implemented
- PRMv1 delivered to ECMWF
    - for implementation in GFAS



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

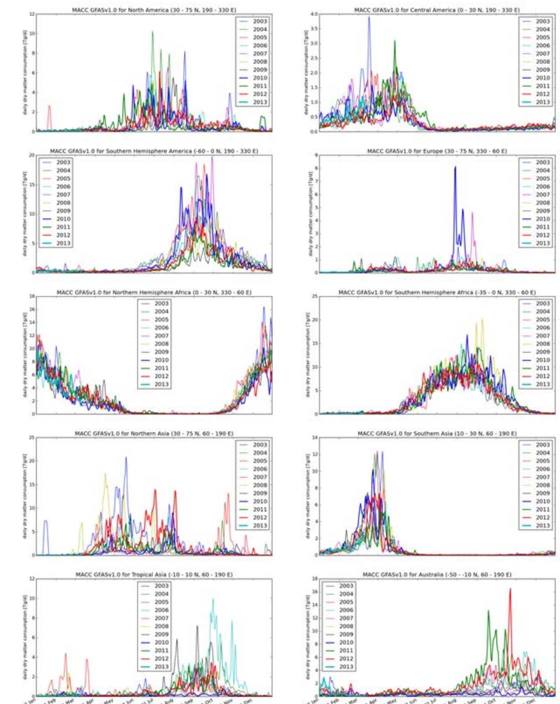


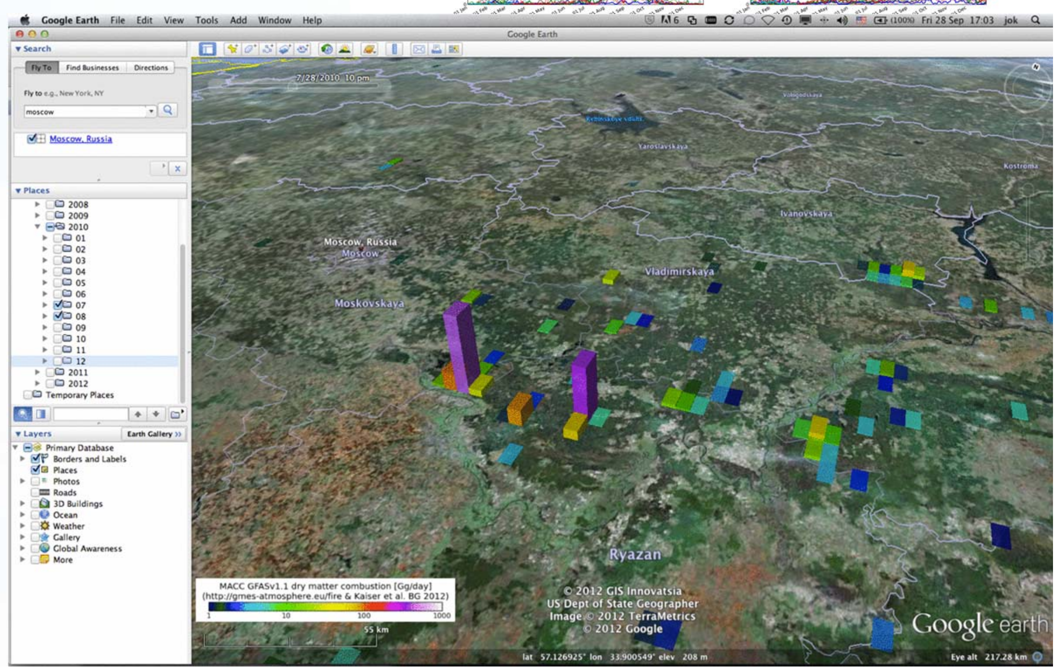
Key Features

satellite-based FRP assimilation :

- global coverage
- NRT availability
- daily resolution (tests: hourly)

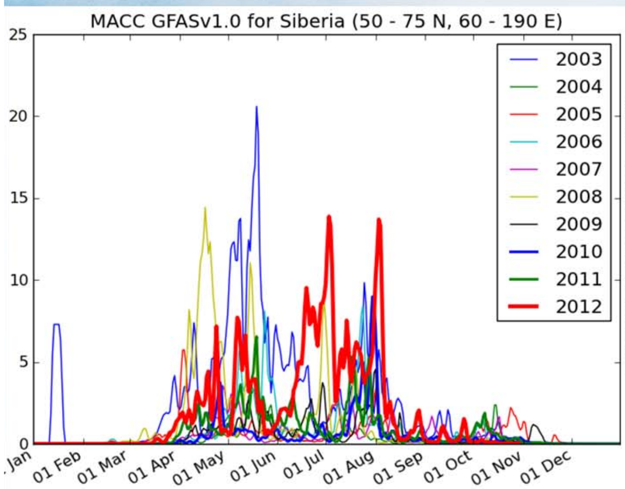
- well documented
- publicly available in several data servers
- various product formats:
  - GRIB
  - NetCDF
  - GIF map
  - PNG spaghetti plot
  - KML

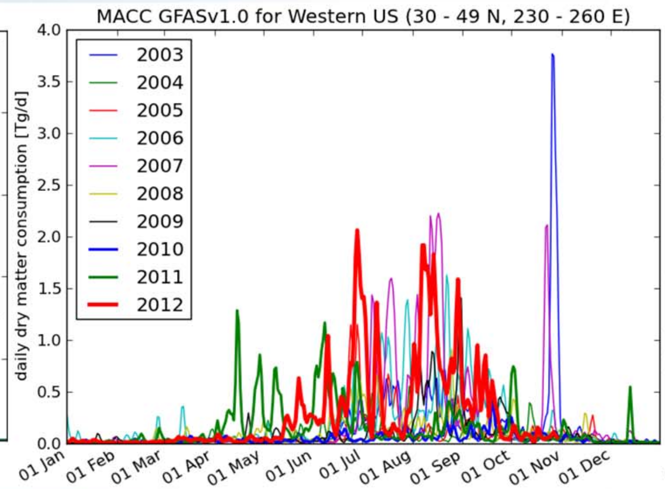


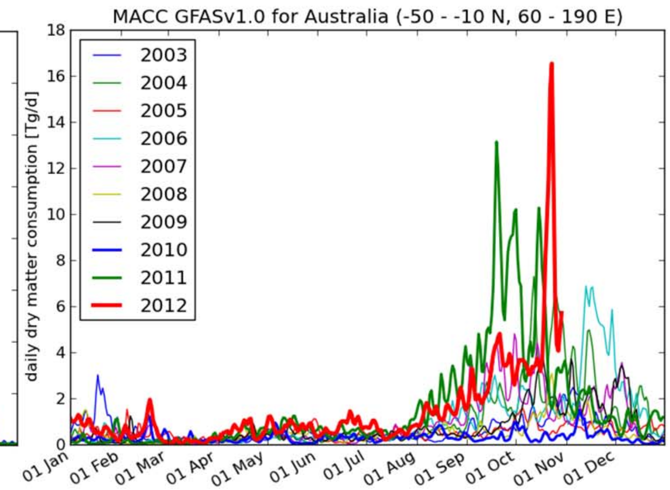


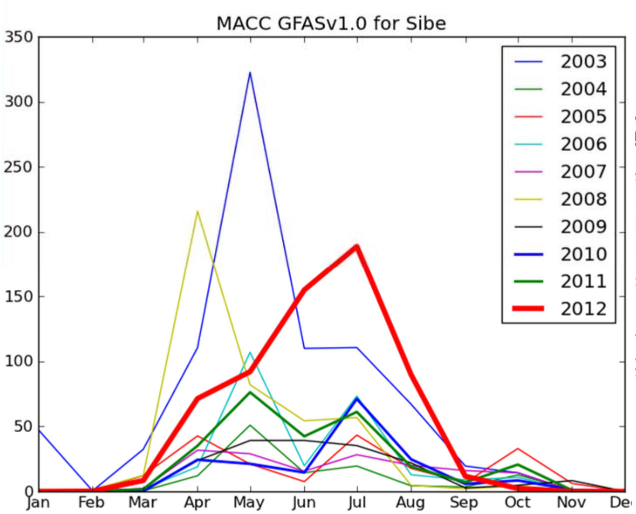
http://gmes-atmosphere.eu/fire

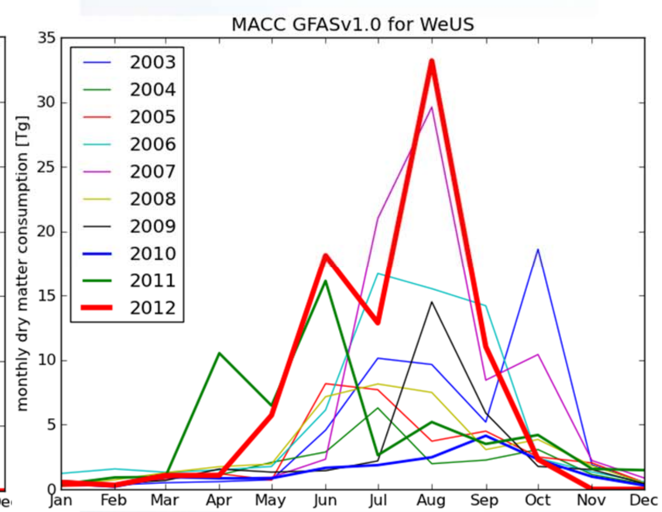
2012 is most interesting: Siberia, Western US & Australia!

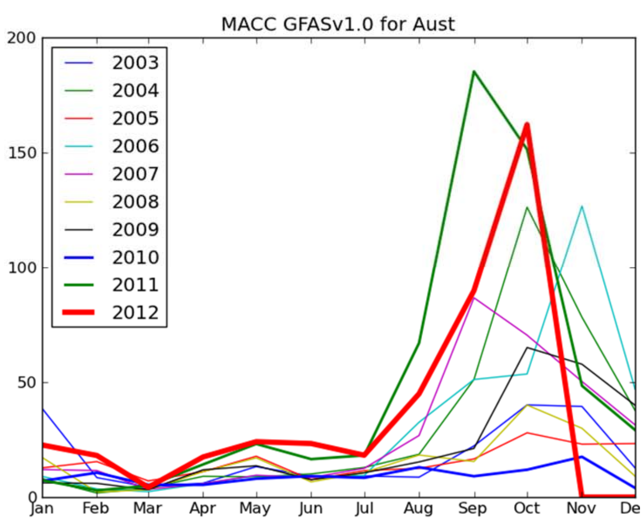












User statistics: GEIA ECCAD

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