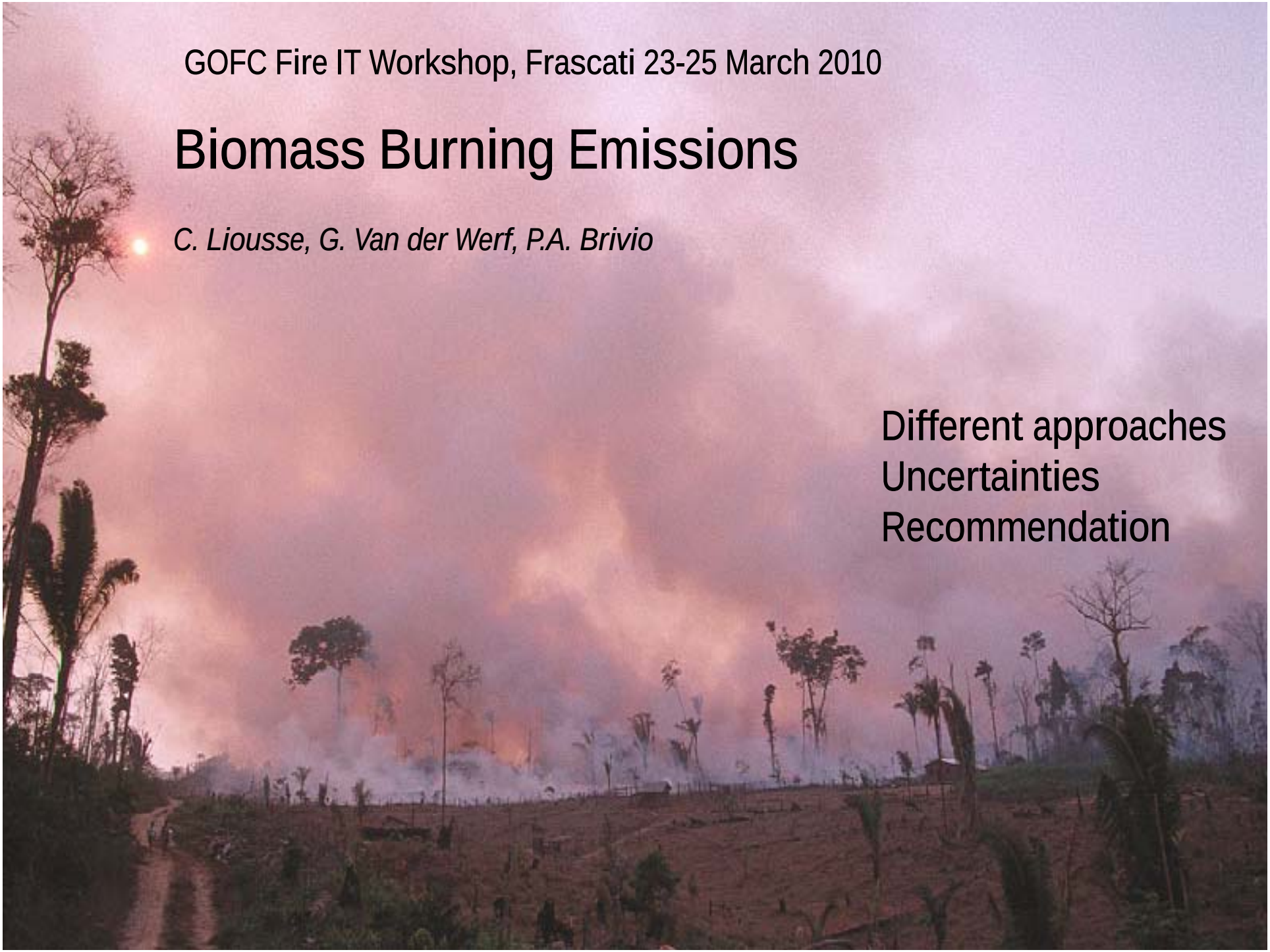


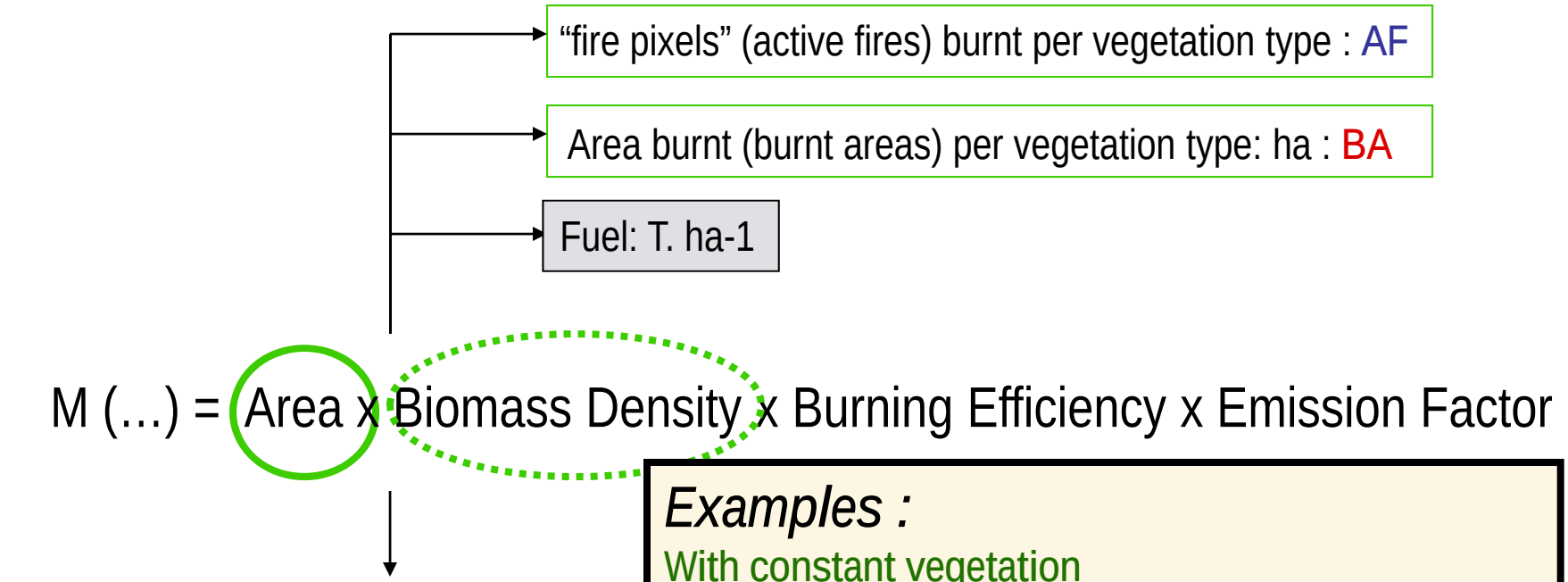
GOFC Fire IT Workshop, Frascati 23-25 March 2010

Biomass Burning Emissions

C. Liousse, G. Van der Werf, P.A. Brivio

Different approaches
Uncertainties
Recommendation

Satellite-derived Bottom-up inventories : I



Fuel: T. ha-1 ????
Dry tropical grass savanna: ~ 2 tons/ha
Moist tropical savanna: ~ 10 tons/ha
Boreal forest: ~ 20 tons/ha
Moist tropical forest: ~ 40 tons/ha

BD range: 1 – 36 (1:30)
BE range: 0.3 - 0.9 (1:3)
EF range: 65 – 107 (1:2)

Examples :

With constant vegetation

Ito and Penner 2004 : AF (MODIS, ATSR) x BA (Spot)
Hoelzemann et al. 2005 : AF (ATSR)x BA (Globscar)
Liousse et al. 2004, 2010 : BA (AVHRR, SPOT)
Chin et al., 2005 : AF (MODIS)
Mieville et al., 2009 : AF (ATSR) x BA (Spot)

With a dynamical vegetation model

Van der Werf et al 2006, 2009, Giglio et al. 2006 :
AF(ATSR) x BA (MODIS)

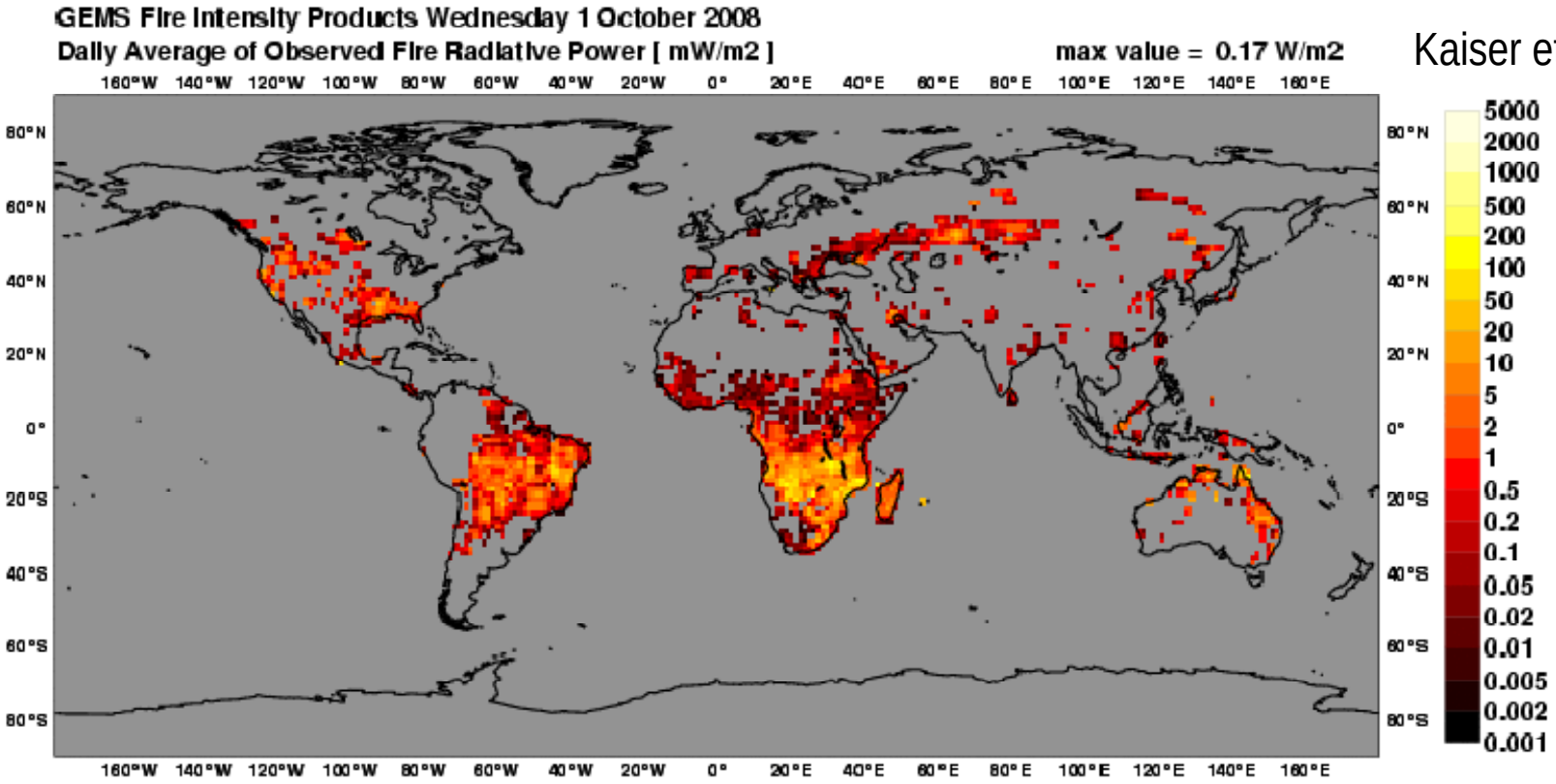
Satellite-derived Bottom-up inventories : II

FRE/FRP-based smoke emissions estimation approach (MODIS & SEVIRI)

- Emissions = Emiss Ratio × BM (from FRE or FRP)

  [Wooster et al. 2005] [Ichoku Kaufman 2005]

  * high range in the emission ratios



Kaiser et al. 09

Satellite-derived Top-Down inventories

Most works used CO (combustion tracer)

e.g. Petron et al. 2004, Bergamaschi et al. 2000, Chevalier et al. 2009

*Recent developments on **black carbon aerosols*** (*Dubovik et al, Vermote et al.2009*)

CO concentrations database well documented at the regional and global level

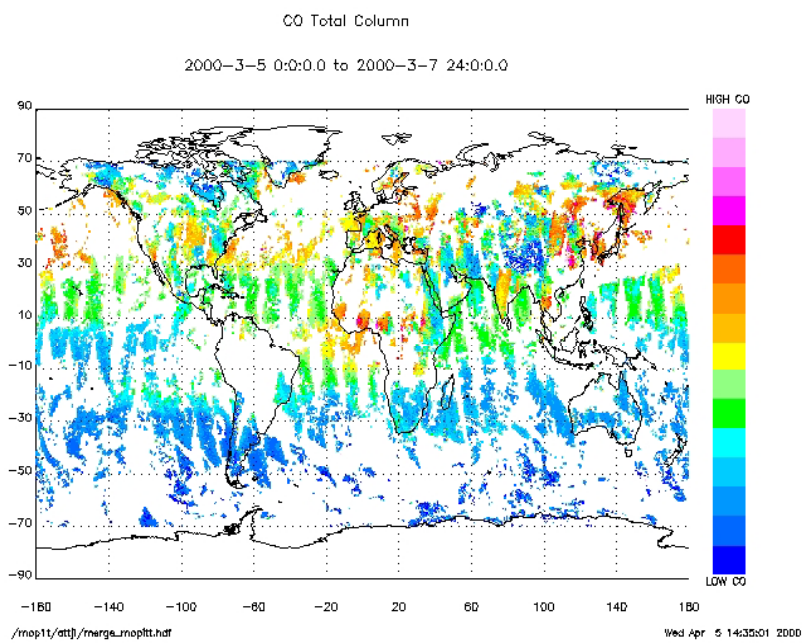
(e.g. MOPITT, AIRS, TES on Terra, Aqua & Aura and SCHIAMACHY on Envisat satellite dataset)

Inverse modelling chemical transport model (e.g. MOZART, GEOS-chem)

EF and ER(CO) known with low uncertainty factor

↓

A posteriori Emissions



One type of UNCERTAINTIES

In the determination of the spatial and temporal distributions of burnt biomass => distribution of *different products derived from Earth Observations* are used :

- fire pixels (or active fires AF)
- burnt areas (BA)
- or both
- More recently : fire radiative power or energy (FRP, FRE)

And these products lead to *totally different emission results.*

$\Rightarrow$ Intercomparison exercise : BBSO (Burnt Biomass and Satellite Observations) *in the frame of GEIA/ACCENT programs*

BBSO-1 (Toulouse, December 2005)

Two joint initiatives have emerged as a result of the final discussions of the workshop:

- 1) To draft a detailed description of global and regional emission inventories generated by the participants and the methods used for the determination of burnt biomass through BA, AF or FRE. This is presented in **Table 1.**

- 2) To carry out an **intercomparison exercise** for CO emission estimates

  (JRC unit leadership). This will help to understand the origin of the observed differences between the emission estimates in terms of overall budgets and spatial/temporal distribution.

Research group	Vegetation cover map used	Sensor used, day/night?	Using *burnt area* or *active fire*	Species investigated	Transport model used	Comments
C. Granier (SA), J.F. Lamarque (NCAR)	CLM 3,0 (P.J.Lawrence) with 17 PFTs	ATSR (night)	active fires - monthly maps at 0,5 □resolution	CO, NOx, C2H4, C2H6, C3H6, C3H8, butane, butene, CH2O, CH3CHO, CH3OH, C2H5OH, Acetone, Toluene, Mek (ketones)	Mozart	Assume the total amount of CO2 emitted on the 1997-2003 period is equal to the Hao climatology for the 1985-1991 period [Hao and Liu., 1994]. Emission ratios are from Andreae and Merlet [2001]
A. Ito and J.E. Penner	Zhu&Waller [2001] Hansen et al. [2003] Zeng et al. [2000]	MODIS SPOT ATSR	Burnt area	Carbon monoxide	- - - -	Akinori Ito and Joyce E. Penner, Estimates of CO emissions from open biomass burning in southern Africa for the year *J. Geophys. Res., 110*, D19306 2005.
Van der Werf / Randerson/ Kasibhatla	MODIS	both (MODIS / ATSR / VIRS)	active fires, scaled to burnt area [Giglio et al., 2005, ACPD]	Focus on carbon, other species derived using EF's from Andreae and Merlet [2001, GBC]	Geos - chem	Burned area is retrieved using regionally derived active fire to burned area relations. These relations depend on fractional tree cover and active fire cluster size. Also the fire persistence is taken into account to increase the burned area per active fire in deforestation regions. Burned area is used as input for the satellite-driven CASA biogeochemical model to estimate emissions.
UMD, Department of Geography	SAFARI 2000 fuel load data	day	MODIS, GBA-2000, GLOBSCAR	40+ (CO2, CO, OVOC, PM, CH4, etc.)	No transport included	Southern African biomass burning emissions have been modelled. The results have been published by 1) S. Korontzi (2005). Seasonal patterns in biomass burning emissions from southern African vegetation fires, Global Change Biology, 11, 1680-1700 and 2) S. Korontzi, D. P. Roy, C. O. Justice, and D. E. Ward (2004). Modelling and sensitivity analysis of fire emissions in southern Africa during SAFARI 2000, Remote Sensing of Environment, 92(2), 255-275.
ABBI (Asian Biomass Burning Inventory)	UMD	SPOT-VGT	Burnt Area	58 gaseous species and 2 carbonaceous particles	no model used	documentation: Michel et al., 2005 (JGR)
Africa	GLC	SPOT-VGT	Burnt Area	BC, OC	RegCn, TM4	Konare et al. [2006].
Africa	GISS (Matthews)	AVHRR	Burnt Area	BC, OC	MNH	Period 1981-1991. [Liousse et al., 2004]
LSCE/ IPSL	none	night	active fire	POM,BC	LMDz	Global ATSR active fire used for spatial and temporal distribution of fires(not used to retrieve emitted quantities) a) remove active fires detected at a permanent position (gas flares) from the dataset b) apply for a cloud coverage correction Climatological inventories used to have estimates of annual emitted quantities. Here Liousse et al, 1996. Method: 1. Globe divided into large fairly homogeneous regions (see Fig 1 in Generoso et al, 2003) 2. Emission Constant (EC) computed within each region, EC= annual emitted quantities / annual mean number of detected fires (based on detection during 4 years: [Jan97;May97]U[Jun98-Dec01] 3. Apply EC to the monthly distribution of fires Products available: Monthly BC and POM emissions from 1997 to 2003 for the globe
LMCA/ EPFL	none	night	active fire	POM,BC, CO, NOx ...	GEOS-Chem	Same method *but* include updates : 1. Now take into account missing days in ATSR active fire dataset 2. Climatology for BC, POM : Bond et al, 2004 Extended to gas : Climatology for CO, NOx :J.A. Logan, R. Yevich, unpublished data 3. Annual mean number of detected fires (for EC) now calculated based on 6 complete years: 99 to 04 Products available from 1997 to 2004 for the globe
Mian Chin Goddard Space Flight Center, USA)	GISS	MODIS	active fire	BC, OC, CO_2, CO, SO_2	- - - -	Presented at the Burnt Biomass from Satellite Observations BBSO workshop, Toulouse, December 14th and 15th, 2005
C. Ichoku and Y.J. Kaufman	- - - -	MODIS	FRP / FRE	Smoke aerosol	- - - -	Presented at the Burnt Biomass from Satellite Observations BBSO workshop, Toulouse, December 14th and 15th, 2005

Table 1 Species investigated and methods used by the different attending research groups.

The aim of BBSO-2 workshop (Toulouse, November 2009) :

- to show results of CO emissions intercomparisons based on different fire products. BBSO
- to present modelling sensitivity tests on the use of different biomass burning emissions

$\Rightarrow$ to propose the best ways to derive burnt biomass distributions and related emissions

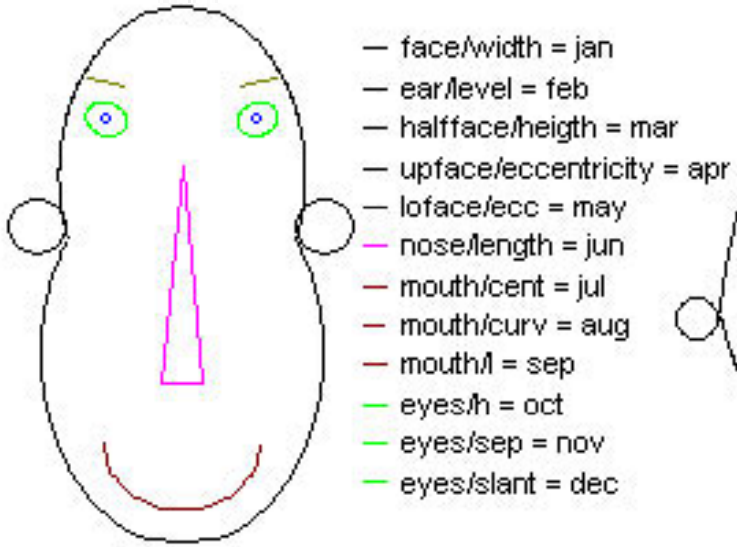
- to discuss on common activities for the coming years

  (next intercomparison studies?, next validations?....)

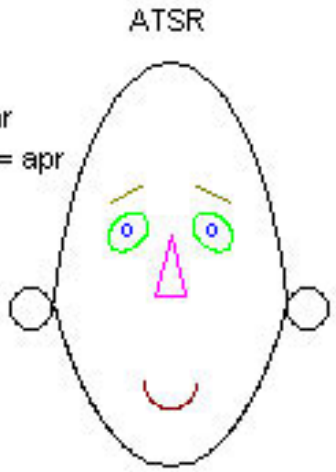
Similarities and discrepancies …

Monthly Global CO emissions maps 2003

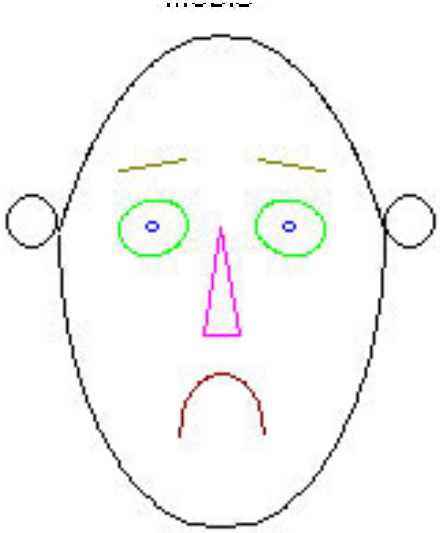
VGT



ATSR



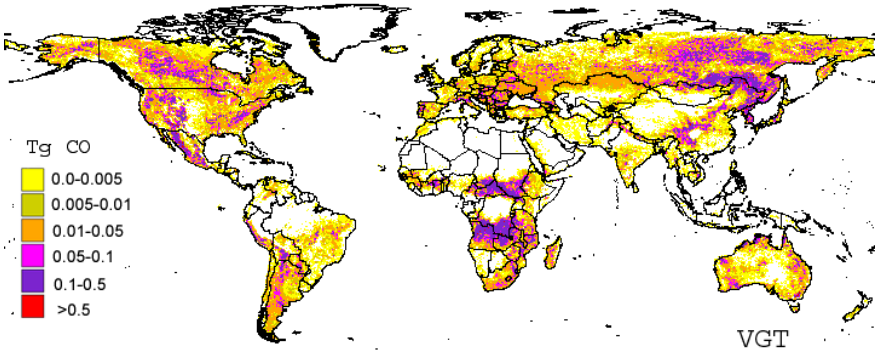
MODIS

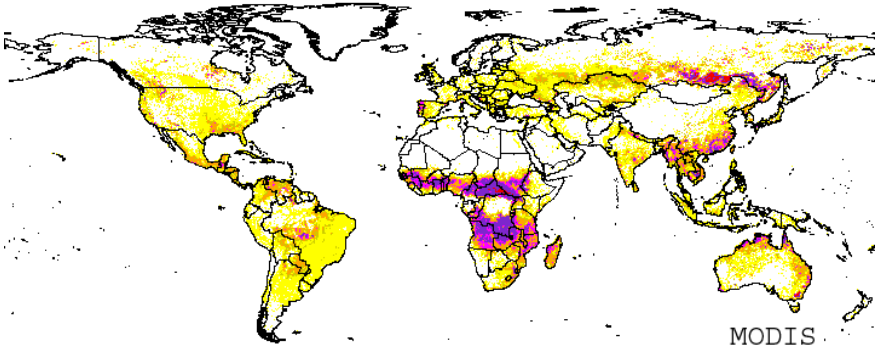


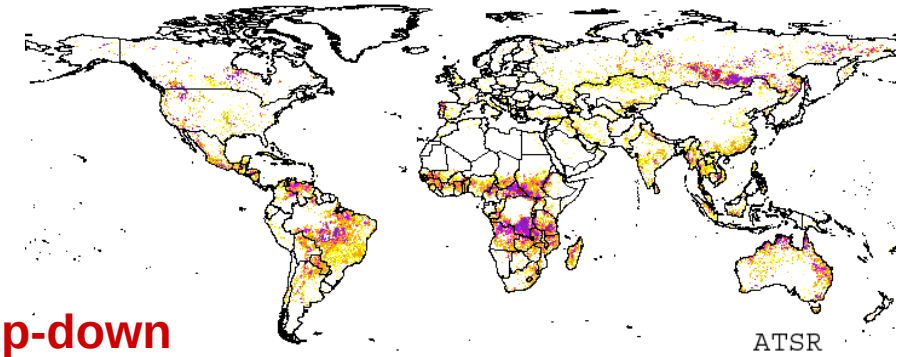
(Brivio, 2009)

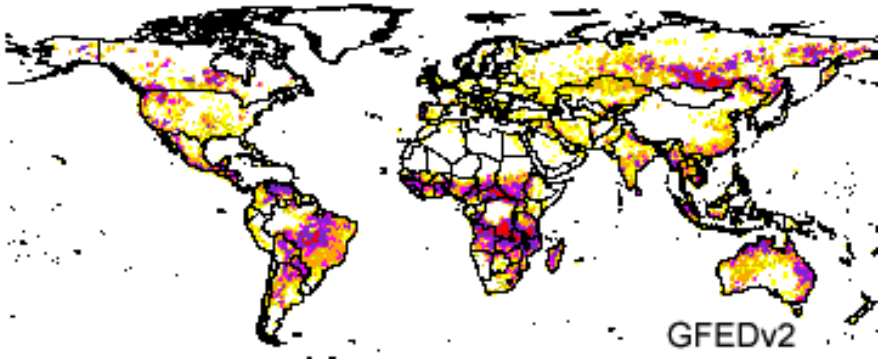
Year 2003: total CO emissions

Bottom-up

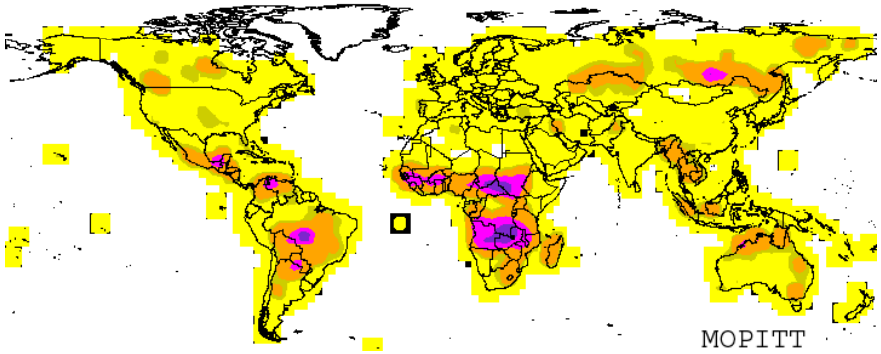






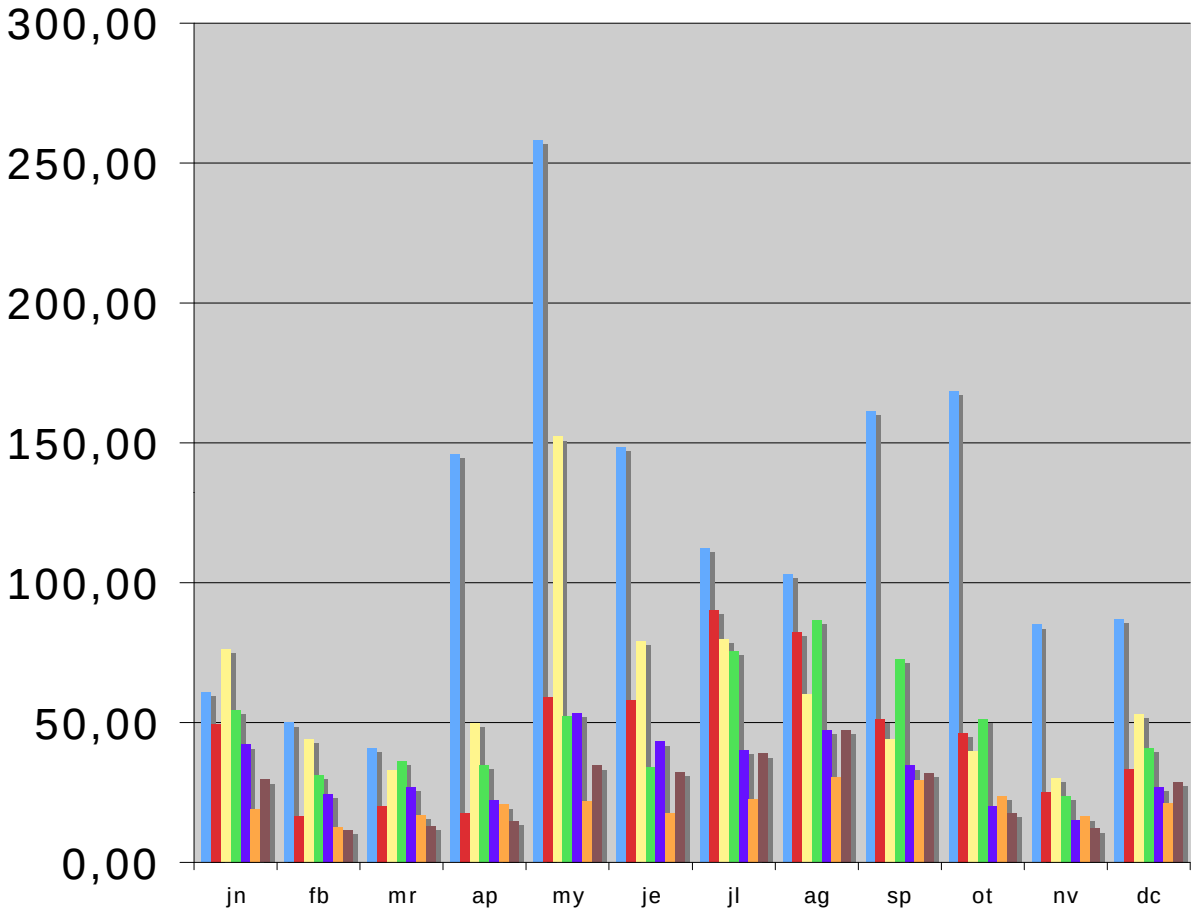


Top-down



VGT	ATSR	MODIS	GFED2	MOPITT
1422	**547**	**769**	**398**	**594**

BBSO



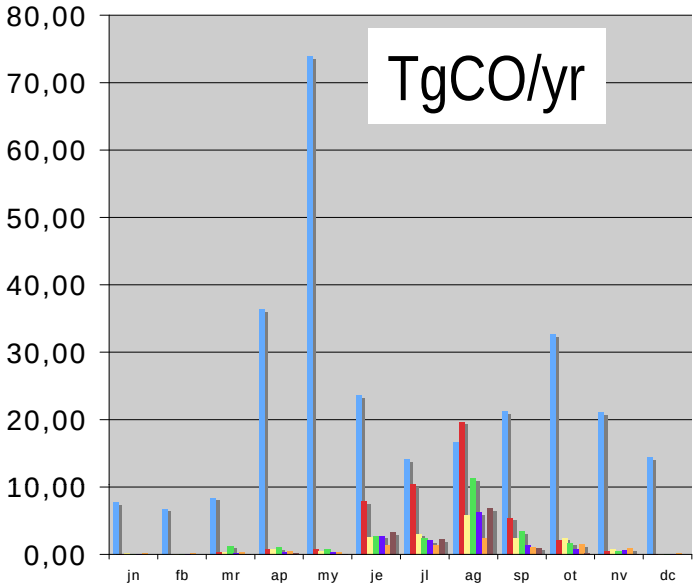
	TgCO/yr
glob VGT	1422
glob ATSR	547
glob MODIS	769
glob MOPITT	594
glob GFED 2	397
glob FRP	253
glob GFED 3	313

Data from INTERMEDE BBSO-2

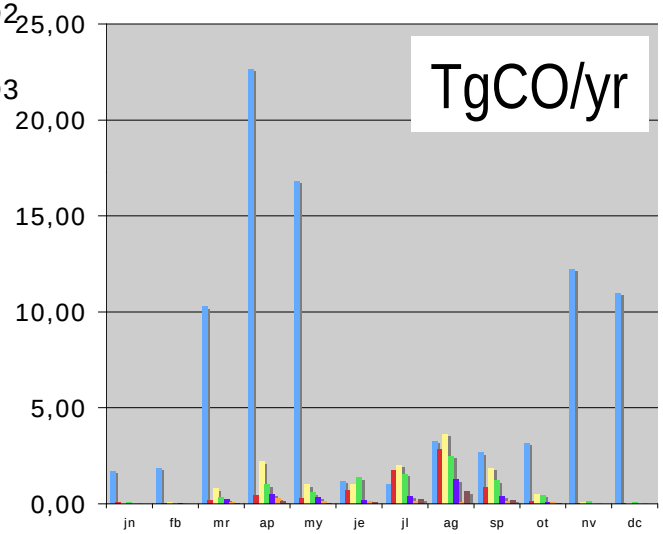
Global CO emissions comparisons for 2003

BBSO

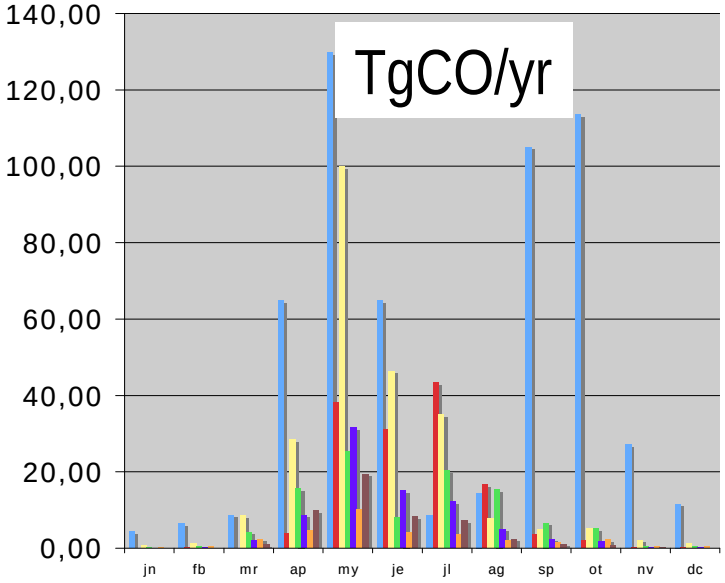
	VGT	ATSR	MODIS	MOPITT	GFED2	FRP	GFED3
N.Ame	276,60	48,07	19,20	25,48	14,75	10,29	14,00
Europe	87,85	7,33	13,16	9,33	3,51	1,09	1,40
N.Asia	559,15	139,49	241,64	101,96	78,99	31,89	49,92



North Am VGT
North Am ATSR
North Am MODIS
North Am MOPITT
North AmGFED2
North AmFRP
North AmGFED3



Europe VGT
Europe ATSR
Europe MODIS
Europe MOPITT
Europe GFED2
Europe FRP
Europe GFED3

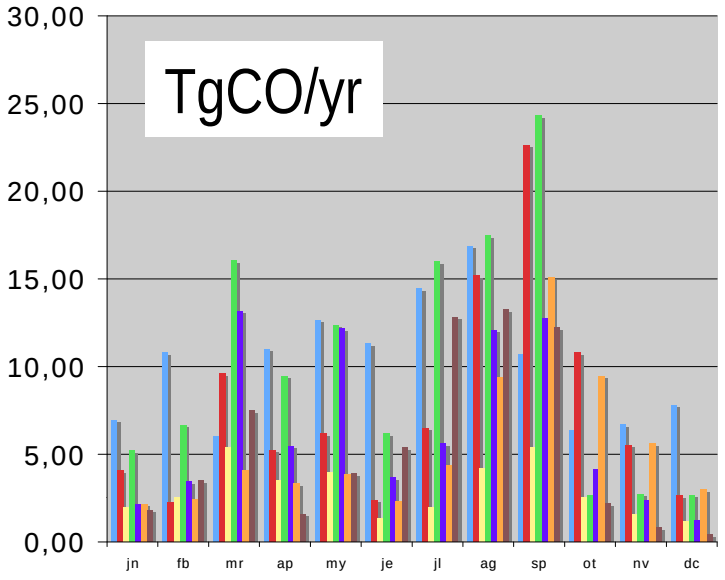


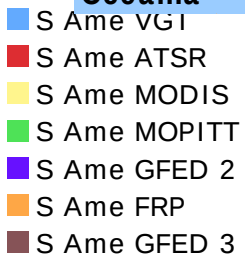
N. Asia VGT
N. Asia ATSR
N. Asia MODIS
N. Asia MOPITT
N,Asia GFED2
N,AsiaFRP
N,Asia GFED3

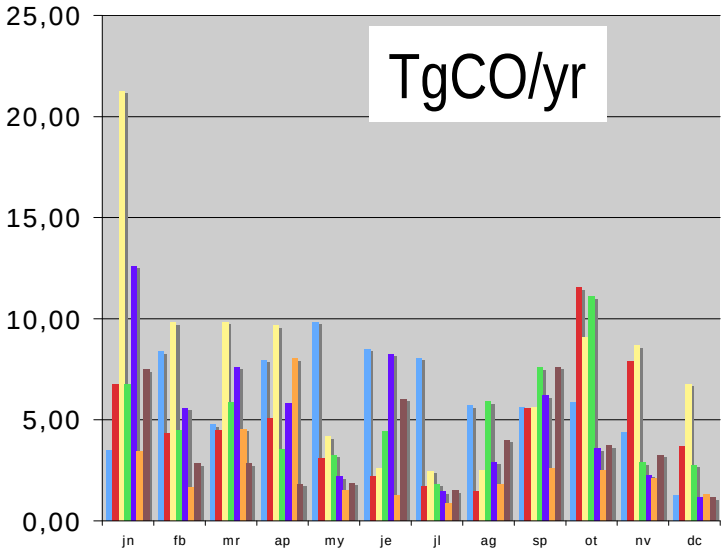
Data from INTERMEDE BBSO-2
CO comparisons for 2003

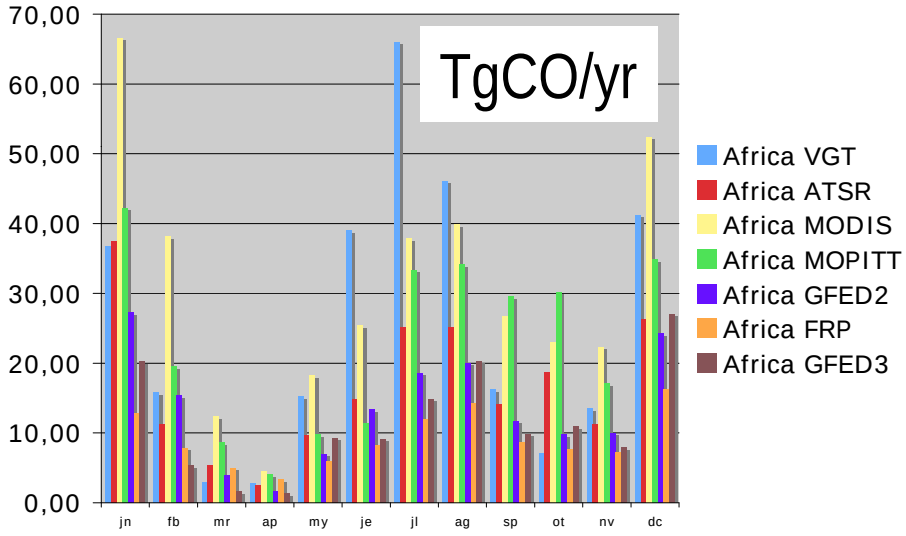
BBSO

	VGT	ATSR	MODIS	MOPITT	GFED2	FRP	GFED3
S. Ame	**121,74**	**93,08**	**35,59**	**121,89**	**78,32**	**65,09**	**65,47**
Africa	**302,69**	**201,63**	**367,38**	**274,83**	**162,84**	**108,83**	**137,86**
Oceania	**73,96**	**57,90**	**92,60**	**60,51**	**59,74**	**31,69**	**44,26**









Data from INTERMEDE BBSO
CO comparisons for 2003

From this workshop activity – 1/3 :

From the talk of Jean-Marie Grégoire on BBSO comparisons results :

- Africa : no big differences between the 3 products (VGT/MODIS/ATSR)
  Reason for that : African evergreen broad forest ecosystems don't burn while burning occurs in South America and Asian forest

- Outside Africa : we can not use the same satellite fire products in the forest and non forest ecosystem

Recommendation : From the year 2000, the best solution is to use MODIS suite of products : BA for herbaceous/shrub/boreal forest, BA/FRP for evergreen forest and AF for temporal distribution at the seasonal scale.

Specific for Africa : Can use SEVIRI / Geostationary fire in addition to derive diurnal cycle of fire activities (aerosol)

From this workshop activity – 2/3 : BBSO

1) to have a focus on the new window « mediterranean area »

2) Adding in our comparison :
- CO emissions from new MODIS BA with the same constant vegetation for 2003
- CO emissions obtained from MODIS FRP for 2003

3) A new global exercise for 2003 : CO emissions from BA/AF MODIS (GFED-3) with different vegetation (CASA, ISAM, GLC ..)
=> Our concern : Africa/GFED-3 : underestimates have been noticed from modeling studies

=> Important for choice done in IPCC emissions based on GFED-2 /but nobody knows uncertainties

4) A modeling exercise with comparison to experimental data over Africa with GFED/VGT/Seviri : year (within 2003-2006 including 2004 for Seviri), species (aerosols, CO?), models (RegCM, Chimere, others?) need to be defined…

From this workshop activity – 3/3 :

BBSO

- to recommend experiments per land cover type to better experimentally characterize emissions from FRP (need comparisons with BA and AF emissions).
Example : need in Southern Europe, Africa, boreal areas, South America
.... and experiments in combustion chamber

- to coordinate GEIA review on biomass burning emissions (next may)

- GEIA : IGAC/ILEAPS : to develop a BB page dedicated to all experiments around the world (past and planned) => BIBEx

- to be closely linked to joint our effort to other BB programs (ESF..)

A few recommendations

Co-ordinations are needed on these questions within :

GOFC and GEIA, IGAC, ILEAPS and ACCENT…

=> To gather satellite providers and users, modellers, vegetation community ...

(*Such as collaborations within IGBP-DIS and BIBEx during 1990s*)

Another type of uncertainties to be treated :

- FRP-based emission inventories : high range in the emission ratios (Wooster/Ichoku) => need experiments to validate this method
- Vegetation : what is the uncertainty on the vegetation choice?

  (constant, dynamical…) => need an intercomparison exercise with same satellite products and different vegetation schemes.
- Emission factors for some ecosystems.
- Historical trends : need for informations of satellite product compatibility to reconstruct emission trends.

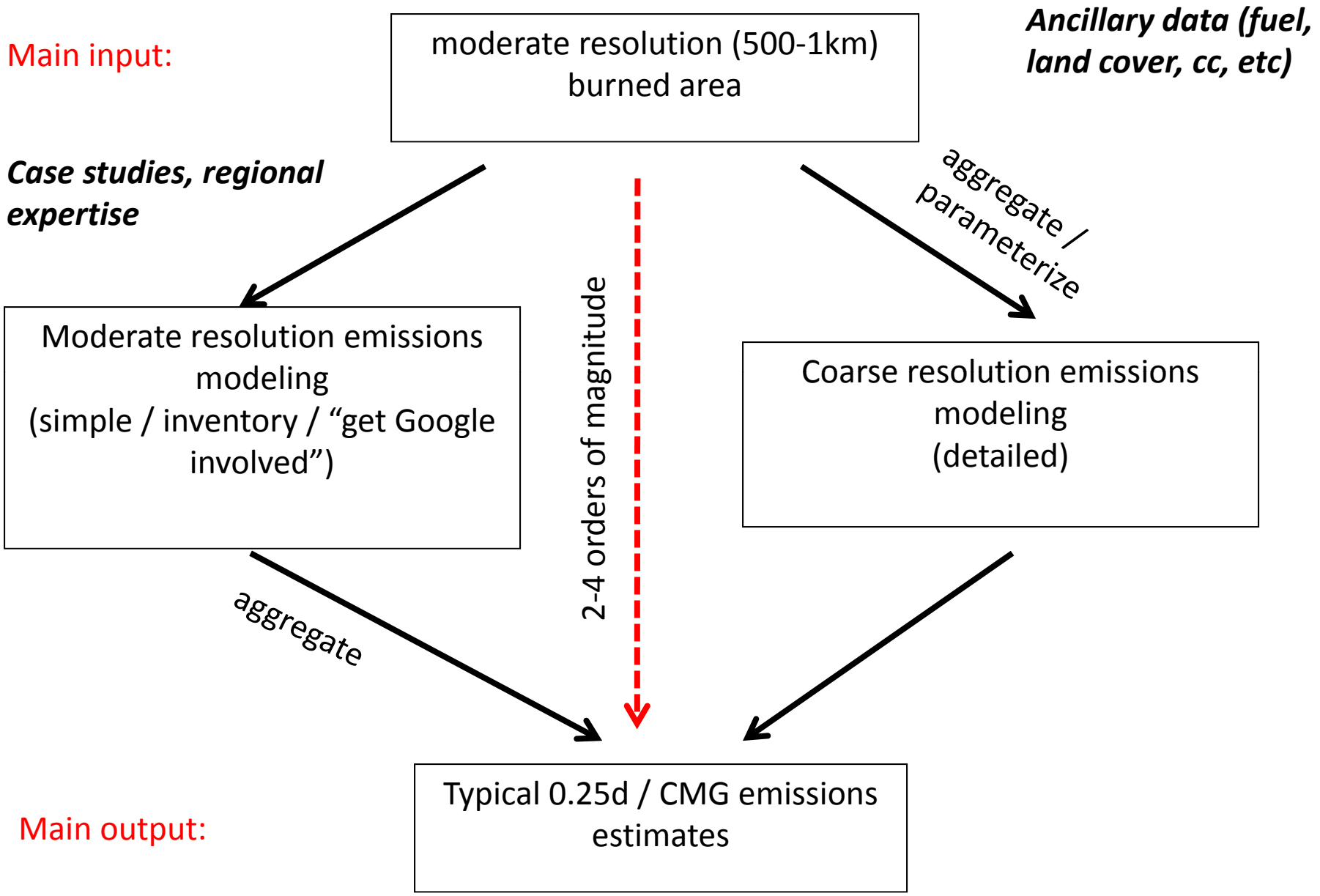
=> *We (BBSO group) have been asked to write a GEIA review on biomass burning emissions (may)*

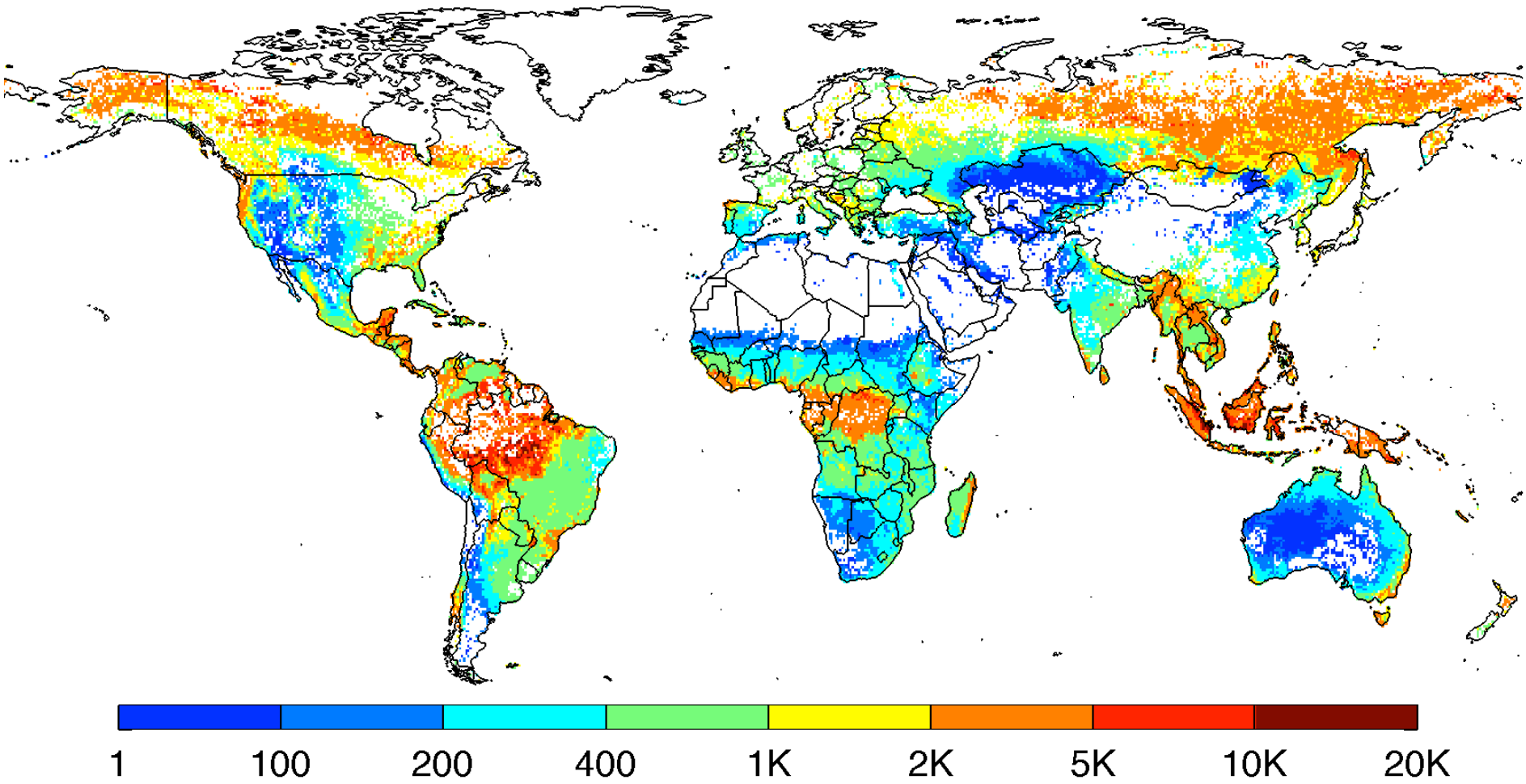
⇒*In GEIA : IGAC/ILEAPS (can be also within GOFC) = to develop a BB webpage dedicated to all experiments around the world* (*past and planned*).

FRE/FRP

1980	1996	2003	2004	2009/2010
Seiler & Crutzen Average fire frequency Average biomass Per-capita clearing rates	*Hao et al.* Seasonality based on precipitation rates	*Duncan et al.* ATSR fire hot spots + Inventory = Spatial and temporal variability	*Ito & Penner* *Hoelzemann et al.* Burned area (2000) + fuel model = Emissions GFED1	*Multi-year burned area* GFED3

- Emissions estimates follow improvements in fire remote sensing (except FRP approach?)
  - *Always one step behind*
- Modelers need data and will use what is (most readily) available and what works best. A product that is right for the wrong reasons is preferred above a product that is wrong for the right reasons (…).
- No real dedicated fire emissions modeling community; estimates usually developed to further some scientific field. Community small and poorly organized. BBSO first intercomparison. No QA
- Atmospheric community has powerful tool though: compare estimated emissions with what is seen in the atmosphere: feedback on regional / continental scales
  - *Emission factor/ratios uncertainty has to be dealt with*
- Current uncertainties too high but ~25% (?) over large scales might be tolerable / unavoidable
  - *Other uncertainties larger, e.g., OH levels, atmospheric transport*
  - *Except possibly for country-level emissions reporting*
  - *~25% uncertainty challenging for deforestation regions, and areas with organic soil burning (3th dimension not captured by satellite)*


Main input:
moderate resolution (500-1km) burned area
Ancillary data (fuel, land cover, cc, etc)
Case studies, regional expertise
aggregate / parameterize
Moderate resolution emissions modeling (simple / inventory / "get Google involved")
2-4 orders of magnitude
Coarse resolution emissions modeling (detailed)
aggregate
Typical 0.25d / CMG emissions estimates
Main output:



GFED3 fuel consumption (g C / m^2)