Emission developments for Africa

Cathy Liousse for GEIA African working group

EMISSION INVENTORY : ESSENTIAL TO BIG RESEARCH TOPICS IN ENVIRONMENTAL SCIENCE...A MOTIVATION TO GET IT RIGHT!

Anthropogenic Emissions

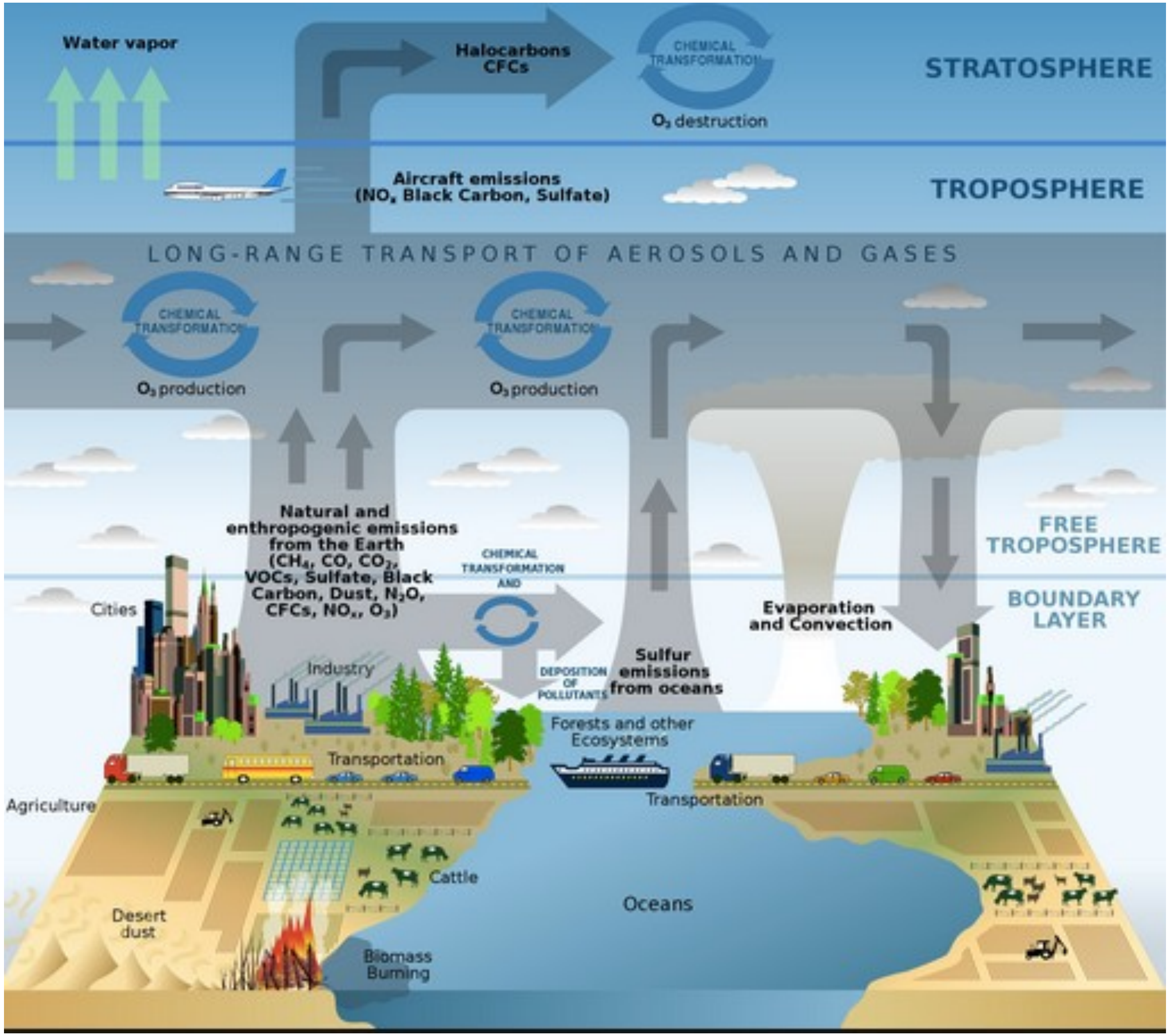
OC, CO, NH_3, …

This presentation ..

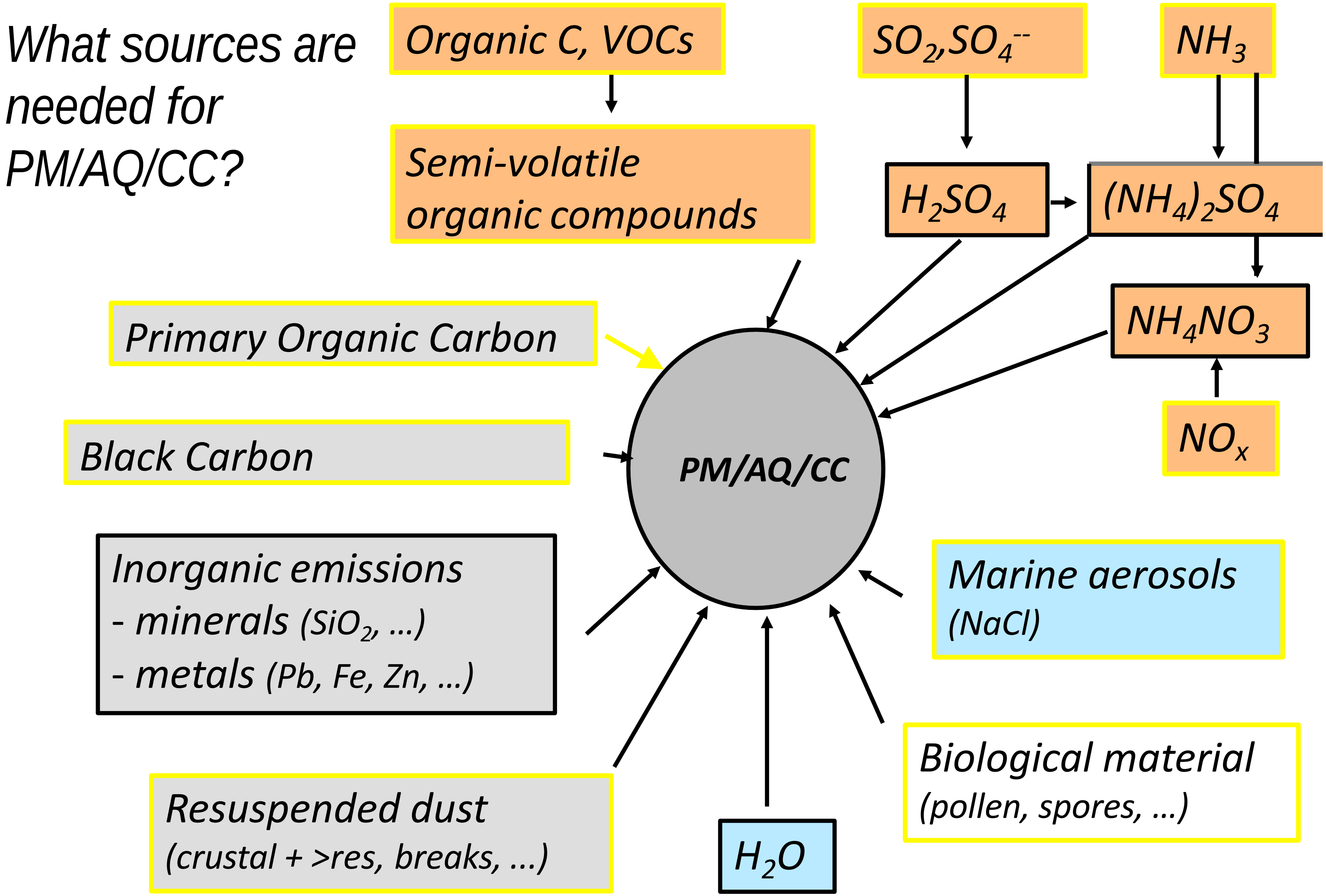
Natural
Anthropogenic
*=> Anthropogenic**

Short lived
Long lived
=> Short

Primary
Secondary
=> primary



* : *Natural emissions are calculated by the model*


What sources are needed for PM/AQ/CC?
Organic C, VOCs
Semi-volatile organic compounds
SO_2,SO_4^{--}
NH_3
H_2SO_4
$(NH_4)_2SO_4$
NH_4NO_3
NO_x
Primary Organic Carbon
Black Carbon
PM/AQ/CC
Inorganic emissions
- minerals (SiO_2, …)
- metals (Pb, Fe, Zn, …)
Marine aerosols
(NaCl)
Resuspended dust
(crustal + >res, breaks, …)
H_2O
Biological material
(pollen, spores, …)

Combustion aerosols

$$CxHyO + O_2 -> CO_2 + H_2O + CO + CH_4 + VOC + HC + particles$$

Different Carbonaceous Aerosols are produced
- with different chemistry
- with different optical properties

Combustion quality Influence (temperature, oxygen supply)
Influence of fuel nature
=> BC/OC variability

Major components :

Scattering/Cooling *Hygroscopic* *Low density …*	*OC* *(Organic Carbon)*	*BC* *EC* *(Black Carbon)*	*Absorbing/Heating* *Hydrophobic* *High density* *Inert : tracer*

BC and OC definition method-dependent

Liousse et al., 2010

Historically

Emissions => a new field of research (including satellite, observations, modeling)
Creation and consolidation of an international community working on emissions (e.g. throughout the GEIA program)

Global scale : Gases inventories and Aerosol inventories (BC, OC, dust, sea salt) for climate studies
Regional scale : Gases and PM10 inventories for AQ studies

Since almost 10 years : Gases and Aerosol inventories (BC, OC, PM25, PM10 ..) with same ancillary data and Regional/Local inventories include PM10 speciation (e.g. TNO 2013)

Now a bridge between : gas/particules inventories with same ancillary data and global/regional/local approaches

- AQ, Health and Climate studies can be performed simultaneously
- Able to propose mitigation solutions to reduce Emission Impact.

Global Emissions InitiAtive

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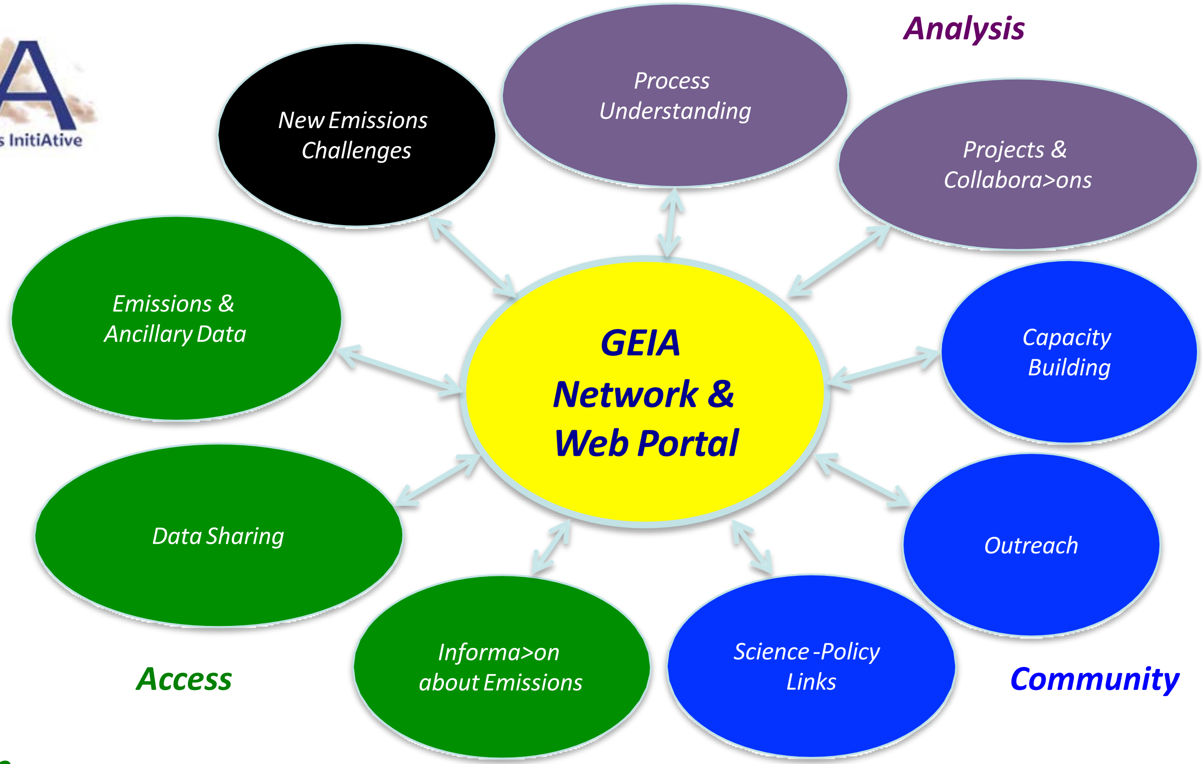
Mission

***GEIA** is a community initiative that builds bridges between environmental science and policy, by bringing together people, data, and tools to create and communicate the highest quality information about **emissions**.*

Goals

***GEIA** aims to be a key forum for emissions knowledge serving stakeholders and decision-makers in a rapidly evolving global society.*



*Building the scientific basis for emissions data by enhancing **analysis** of emissions processes*

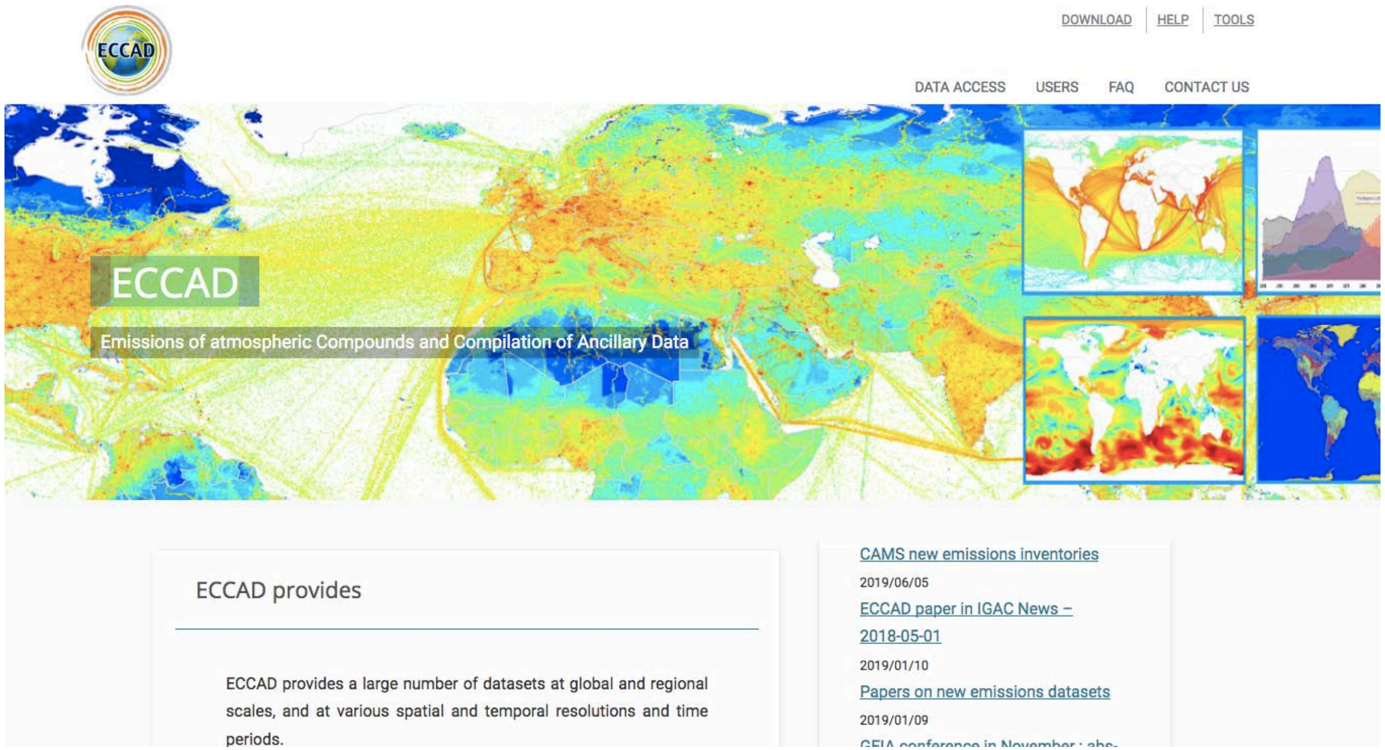
*Promoting broad and consistent **access** to emissions information*

*Strengthening the **community** of emissions stakeholder groups*

ECCAD *Emissions of Atmospheric Compounds and CompilaFon of Ancillary Data*

GEIA Global Emissions InitiAtive

GEIA's emissions database and visualization/ analysis platform with calculation tools



http://eccad.aeris.fr/

Many existing inventories … (from ECCAD database)

Home | Catalogue | On-line Tools | Help

Emissions | Ancillary

Inventories | Species | Sectors | Temporal | Emissions Time Series | Inventory Time Series | Metadata

Title	Categories	Temporal coverage	Time resolution	Grid size	Provider(s)
MACCity Global - 2010	Anthropogenic Biomass burning	1960-2020 1960-2008	Monthly Monthly	0.5°	macc City
ACCMIP Global - 2010	Anthropogenic Biomass burning	1850-2000 1850-2000	Decadal Monthly-Decadal	0.5°	ACCMIP
RCPs Global - 2010	Anthropogenic Biomass burning	2005-2100 2005-2100	Decadal Monthly-Decadal	0.5°	RCPs
HTAPv2 Global - 2010	Anthropogenic	2008-2010	Monthly	0.1°	EDGAR
EDGARv4.2 Global - 2011	Anthropogenic	1970-2008	Yearly	0.1°	EDGAR
ECLIPSE-GAINS-V5a Global - 2014	Anthropogenic	1990-2050	Yearly	0.5°	ECLIPSE
RETRO Global - 2005	Anthropogenic Biomass burning Biogenic Oceanic	1960-2000 1960-2000 1960-2000 1960-2000	Monthly Monthly Monthly Monthly	0.5°	RETRO
Junker-Liousse Global - 2009	Anthropogenic	1860-2003	Daily	1°	LA
Andres-CO2-v2016 Global - 2015	Anthropogenic	1751-2013	Yearly	1°	
POET Global - 2003	Anthropogenic Biomass burning Biogenic Oceanic	1990-2000 1990-2000 1990-2000 1990-2000	Yearly Monthly Monthly Yearly	1°	POET
GEIA Global - 1990	Anthropogenic Biomass burning Biogenic Oceanic Volcanic Lightning	1984-2000 1984-1990 1986-1986 2000-2000 2000-2000 1990-1990	Yearly Yearly Yearly Yearly Yearly Monthly	1°	GEIA
GFASv1.2 Global - 2014	Biomass burning	2003-2015	Monthly	0.1°	macc

+ CAMS ..

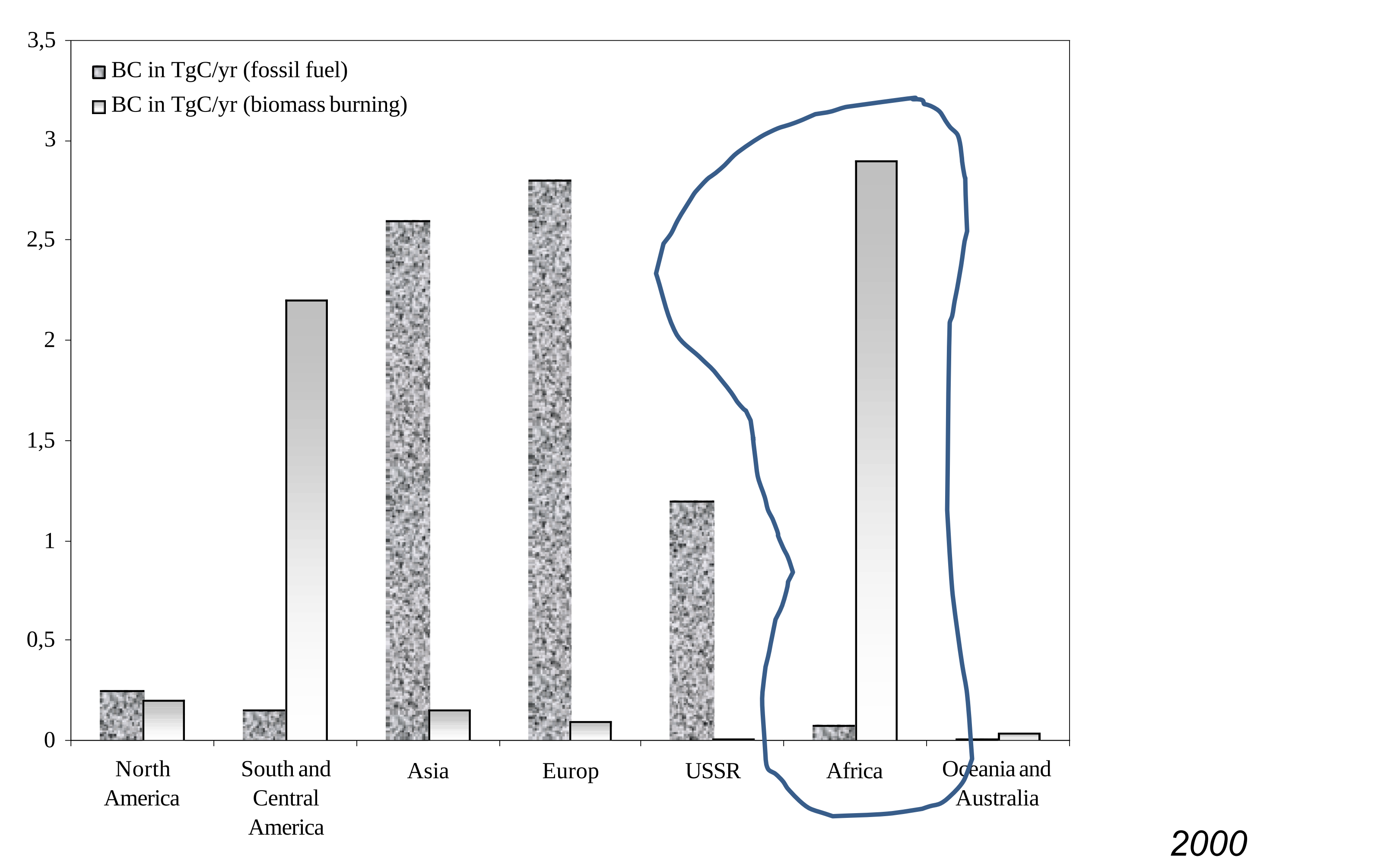
Many existing inventories … (from ECCAD database)

MPI-CNRS South Asia	Anthropogenic	2008-2016	Yearly	0.25°
CR2-MMA Chile	Anthropogenic	2014-2014	Yearly	0.1° 0.01°
CNEA-3iA-GEAA Argentina	Anthropogenic	2016-2016	Yearly	0.1°
REAS2.1 East Asia	Anthropogenic	2000-2008	Monthly	0.25°
IASB-TD-OMI-NCP North China Plain	Anthropogenic	2007-2012	Monthly	0.25°
IASB-TD-OMI Global	Biomass burning Biogenic	2005-2014 2005-2014	Monthly Monthly	0.5°
MarcoPoloKNMI China	Anthropogenic	2007-2013	Yearly	0.25°
SAFAR-India India	Anthropogenic	1991-2011	Monthly	1°
DACCIWA Africa	Anthropogenic	1990-2015	Yearly	0.1°
DACCIWA-flaring Africa	Anthropogenic	1994-2015	Yearly	0.125°
L14-Africa Africa	Anthropogenic	2005-2030	Decadal	0.25°

Etc…

What to choose for AQF studies over Africa ….

Relative importance of biomass burning and fossil fuel in black carbon budget

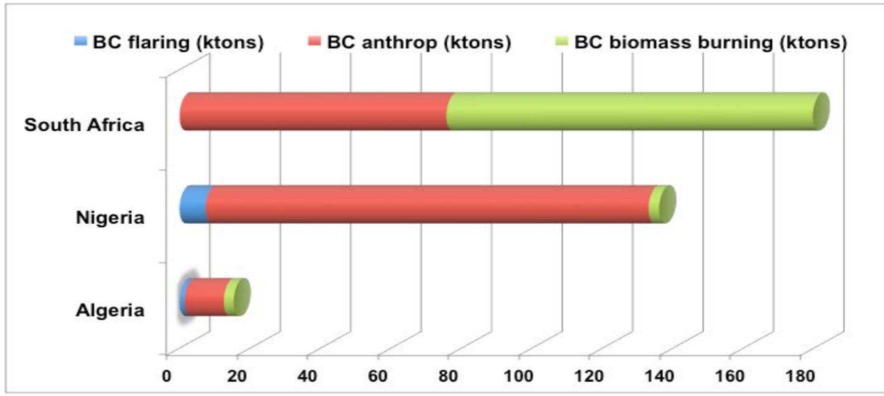


Liousse et al., 2003

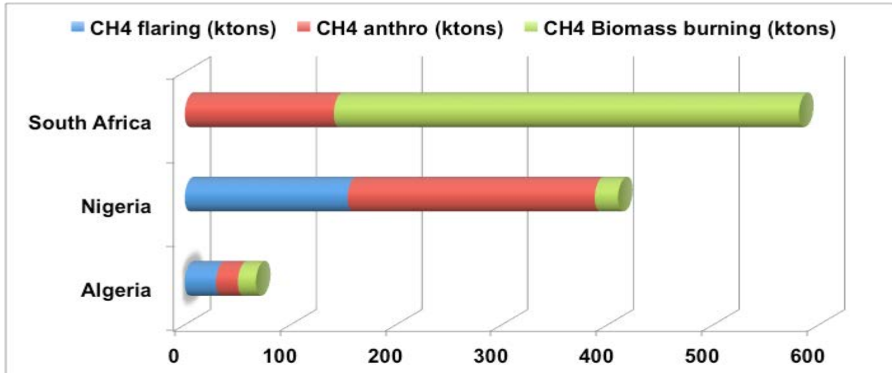
A few years after….

AFRICAN FOSSIL FUEL AND BIOFUEL EMISSION INVENTORIES (Keita et al., 2019)

BC



CH4



Flaring: (Doumbia et al., 2016)
Anthropogenic: (Liousse et al., 2014)
Biomass burning: (Liousse et al., 2010)

The most contributing country is Nigeria.

Relative contribution of each sources : specie and country dependant

Anthropogenic emissions in Africa

Fossil fuel and biofuel Emission inventories : a bottom-up approach

Fuel consumption :

Fuel : (*e.g. charcoal, diesel,…)*

Activity : (*industrial, domestic, traffic, power plant*)

Technology level : (*e.g. pulverized coal, grate firing …)*

Emission Factor (EF)

Main algorithms

Liousse et al.
Keita et al.
Cooke et al. *Junker et Liousse*, *Assamoi et Liousse*

Bond et al. *Schaap et al.*
TNO
IIASA *EPA*
ACCMIP *MACCIty*
EDGAR
ECLIPSE
CAMS
CEDS
RCP…

UN/IEA/Regional data

Lumping: Technology as a function of level of development of each country

EF(BC,OCp, gases) = Direct estimates from measurements

IEA data/Regional/Local data…

- > 50 Technologies
- With/without emission controls

EF(BC,OCp,gases) = BC, OCp : Indirect estimates from EF(PM)

A bottom-up method (Junker and Liousse, ACP 2008) for BC and OC GLOBAL emission inventory (1860-2030)

Example of global inventory

United Nations : Energy database
Fuel consumption data for 185 countries, 33 different fuels and over 50 different usage/technology categories

Emissions are fuel-dependent, fuel usage-dependent and technology-dependent

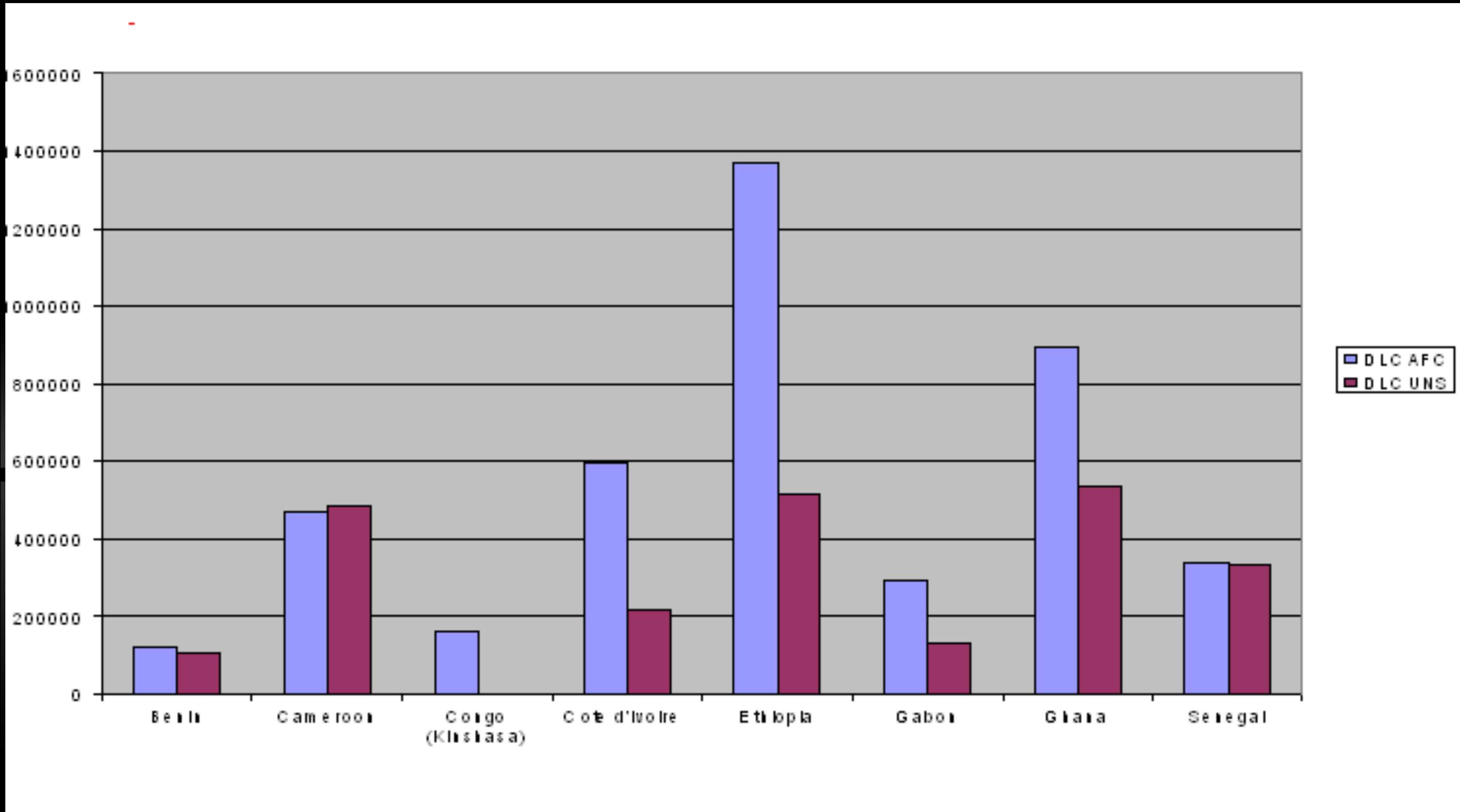
The « lumping » :

Industrial/Domestic/Traffic
Developed/Semi developed/Developing

=> Emission factors for 3 countries classifications, 8 different fuels and 3 usage categories

Population density within each country (population map) and emissions country/country =>
1°X1° spatial distribution of emissions

First tests show importance of regional focus on emissions : Examples for diesel consumptions for some African countries



Important discrepancies between global inventory and regional zoom (by using Africaclean database) for the traffic emission inventory

Asssamoi, phd 2011

African fossil fuel and biofuel inventories : focus on black carbon and organic carbon (phD Assamoi 2011, Liousse et al., 2014)

Present (2005) : A regional bottom up inventory (0.25°x0.25°) :

Data consumption and activities :

United Nations database

International Energy Agency data for power plants

Brocard (1996) for fuelwood and charcoal

Assamoi & Liousse (2010) for two-wheel inventory

Local inquiries (11 answers/26 african countries)

Emission factors :

Junker and Liousse 2008/Bond et al. 2007

Campaigns (AMMA, POLCA)

=> African specificities (2-stroke, truck, charcoal, AW..)

Futur (2030) : based on 2005 inventories and POLES model for 2030 projection

Reference scenario : Reflect the state of the world as environmental policy objectives (2000)

CCC scenario : Introduction of carbon penalties (Kyoto) for 2010 and a reduction of 37 Gt of CO_2 in 2030.

CCC scenario :CCC +*

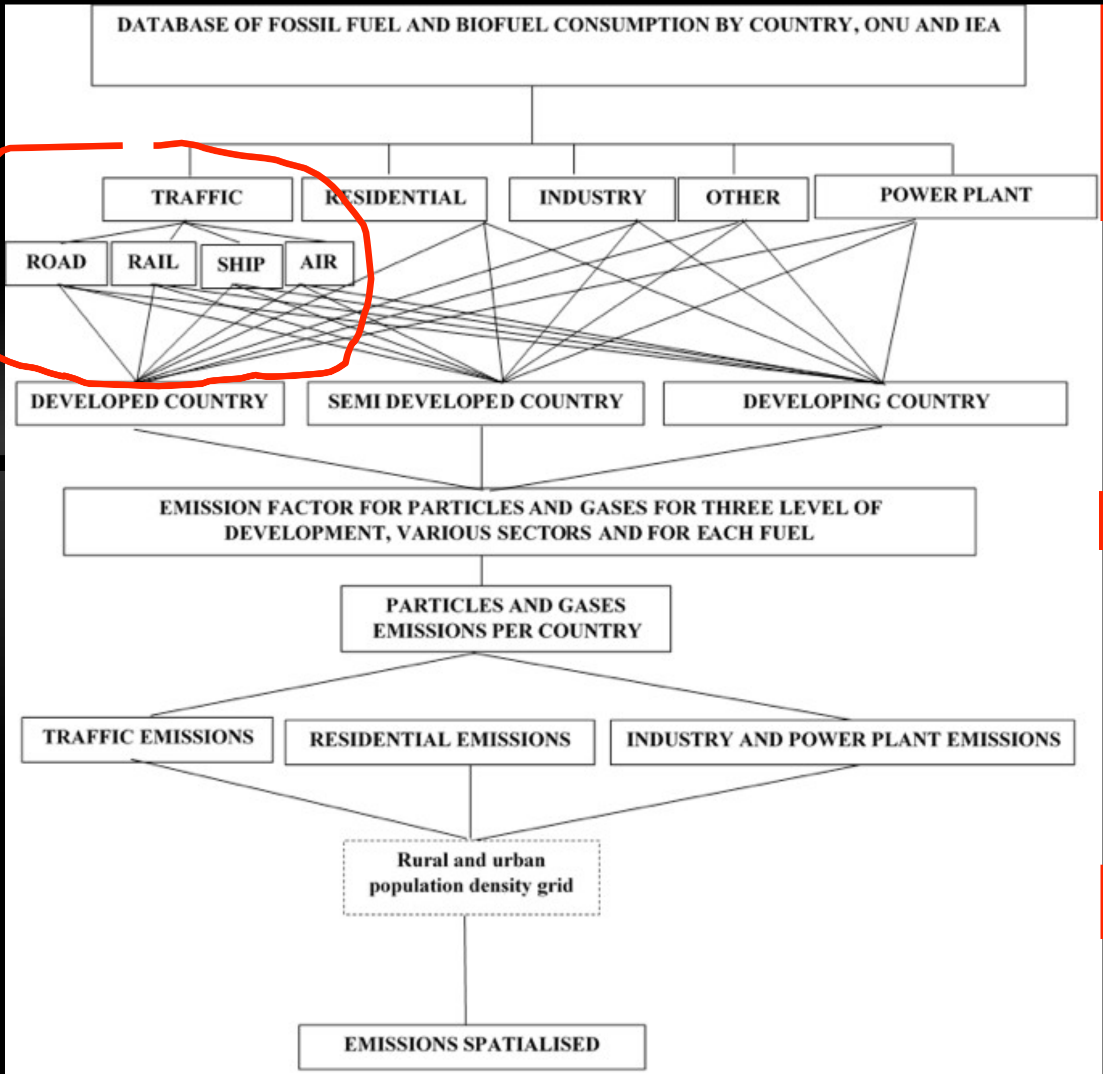
-West Africa : two stroke replaced by four stroke vehicles

-South Africa as a semi developed country for fuel consumption future estimate

-Emission factor of animal waste burning : low part of the range

Example of regional inventory

More recently : the new DACCIWA regional inventory



UN/IEA : 1990-2015
& Local dataset
Extrapolation for 2016 and 2017

Two wheels are included

New measurements of EF

New sources (flaring, waste)

New grids (0.125km)

Keita et al., 2019

Waste burning sources

$$EM_{WB} = P \times MSWp \times Pfrac \times Bfrac \times EF_{species}$$

P : national population, MSWp : mass of annual per capita waste production, Pfrac : fraction of the population assumed to burn some of their waste (nearby the resident or collected dumps) and Bfrac : fraction of waste available to be burned that is actually burned. EF : emission factors

Pfrac, MSWp : Wiedinmyer et al., 2014

e.g. Pfrac : in rural areas in developing countries : no waste collection: 100% burnt nearby the residence; In urban areas: collection country dependant

P : World Bank database

Bfrac = 0.6 (IPCC)

Species : BC, OC, NMVOC, NOx, CO and SO2

EF	BC	OC	NMVOC (C5-C10)	TPM
On field	2.8	6,4	20,4	87,9
Christian et al., 2010	0,7	5,3	22,6	

Keita et al., 2018, & 2019

Flaring sources

✓ $X_{flaring} = Gf_{volume} * X_{EF} * d_f$

$X_{flaring}$ is the emission rate of a pollutant X (kiloton), GF_{volume} is the volume of gas flared in billion of cubic meter (bcm). X_{EF} is the emission factor (EF) in g of X per kg of fuel gas and d_f is the density of the fuel gas.

Here : d_f=1

GF volume : DMSP satellite night time lights+NOAA gas flared volumes +GIS

=> Validated for Nigeria

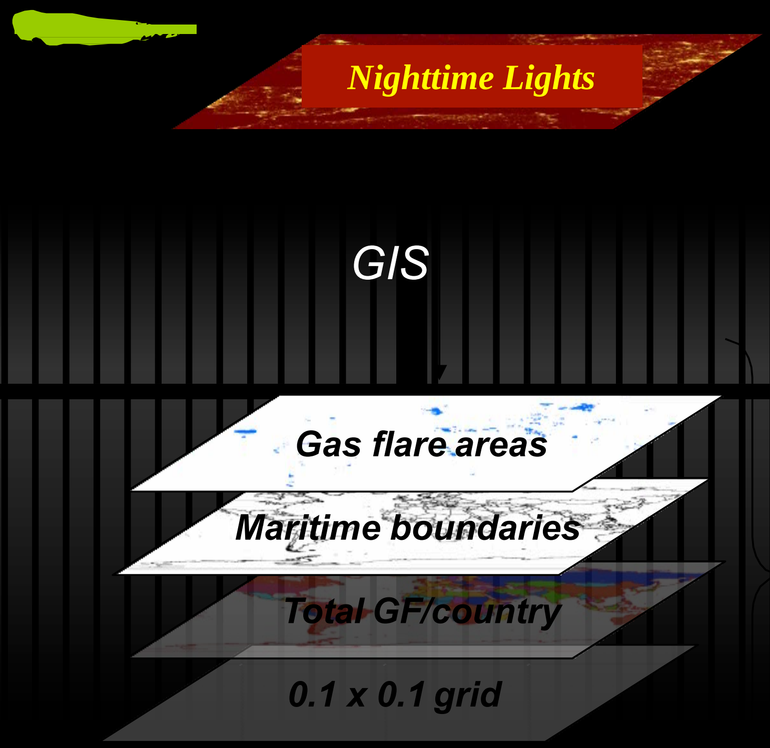
EF (g/kg, this study)	CO_2	CH_4	BC	CO	NOx	SO2	NMVOC	OC
Min	1980	2.5	0.14	5.95	1.05	0.013	3.0	0.15
Max	3366	45	3.2	18	3.7	0.13	12.3	0.15
Mean	2794	19	1.3	8.83	1.77	0.07	7.32	0.15

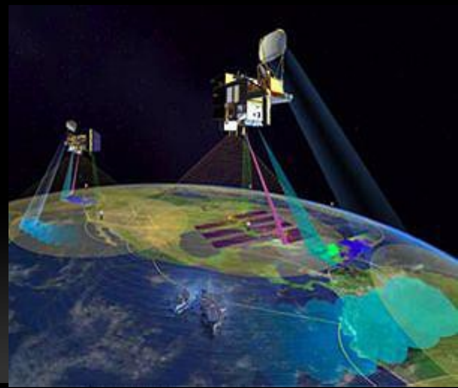
Due to EF uncertainty emission inventories with mean, low and high EF values have been derived

Doumbia et al., 2018

Flaring sources : methodology

DMSP: Defense Meteorological Satellite Program and VIIRS satellite





http://ngdc.noaa.gov/eog/
dmsp/
downloadV4composites.html

Gas Flaring
volumes / country / 0.1x0.1

Doumbia et al., 2018; Deetz et al., 2016

Choice of EF values?

There are no wrong and right EF factors
There are often estimates due to the lack of measurements

How do we check the consistency of these choices?

-by comparing global/regional inventories including technologies details
-by organizing emission experiments where data are lacking

Emission experiments : EF calculation..

An example of methodology to measure EF values

- Real time measurements of CO and CO2
- Aerosol sampling per size (with filters for laboratory analysis : TPM mass, carbonaceous aerosol, ions, trace elements)
- VOC/gas sampling

EF(g/kgC)= Δ(conc. espèces)/Δ(C in the dry plant)

- EF(g/kgC)= Δ(conc. espèces)/Δ(CO+CO2)
- g/kgC into g/kgdm : 45% of carbon in the dry matter

DECAFE 1991

Savanna fires

COTONOU 2005

African truck and zem

Cotonou - May 2005

Bamako 2009

zem

Measurements of emission factors (« zem », trucks…)

fuels

Keita et al., 2018

DACCIWA measurements

Keita et al., 2018

EMISSIONS FACTORS measurements (BC, OC, total PM, VOCs)

Studied Sources :

- DOMESTIC FIRE
- CHARCOAL MAKING
- TRAFFIC
- WASTE BURNING

Old (Liousse et al.) versus new (Keita et al.) EF

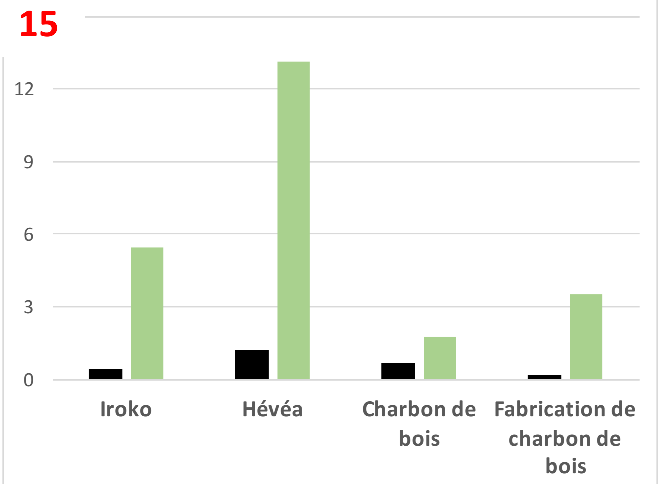
Fuels	EF BC (g/kg)	EF OC (g/kg)	References
Wood	0.9	2.7	Liousse et al., 2014
Wood	0.8 ± 0.4	9.3 ± 3.8	Keita et al., 2018
Charcoal	0.75	2.25	Liousse et al., 2014
Charcoal	0.65 ± 0.3	1.8 ± 2.8	Keita et al., 2018
Waste Burning	0.7	5.3	Christian et al., 2010
Waste Burning	2.8 ± 3.3	6.4 ± 4.6	Keita et al., 2018
TW (road traffic)	2.31	30.56	Liousse et al., 2014
TW (road traffic)	2.13 ± 0.42	28.46 ± 0.4	Keita et al., 2018
Diesel (road trafic)	5	2.5	Liousse et al., 2014
Diesel (road traffic)	3.1 ± 1.9	2.14 ± 1.2	Keita et al., 2018
Gasoline (road trafic)	0.15	0.73	Liousse et al., 2014
Gasoline (road traffic)	0.62 ± 0.49	1.10 ± 0.77	Keita et al., 2018

Keita et al. 2018. Particle and VOC emission factor measurements for anthropogenic sources in West Africa. Atmospheric Chem. Phys. 18, 7691–7708. https://doi.org/10.5194/acp-18-7691-2018

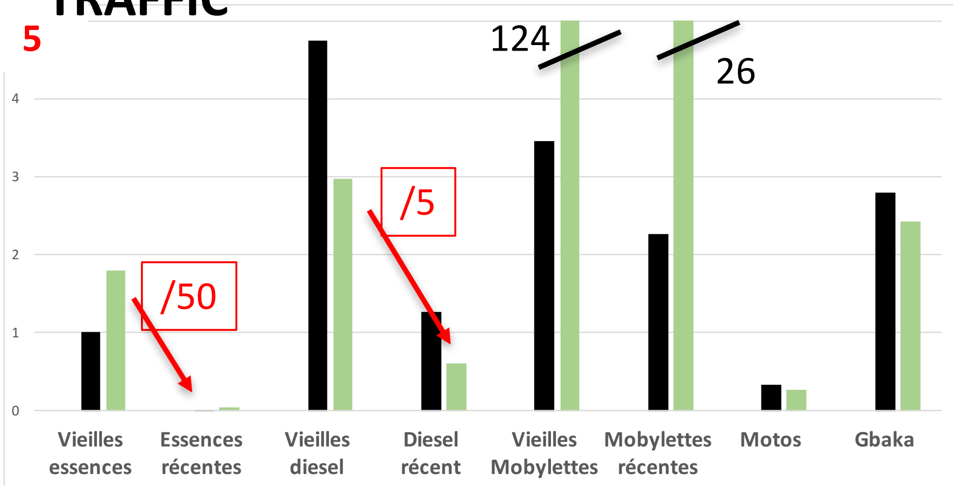
EMISSION FACTORS (g/kg)

Black: BC
Green : OC

DOMESTIC FIRES



TRAFFIC



- ✓ Domestic fire emissions : importance of fuel choice (season also)
- ✓ Traffic emissions : importance of vehicule park

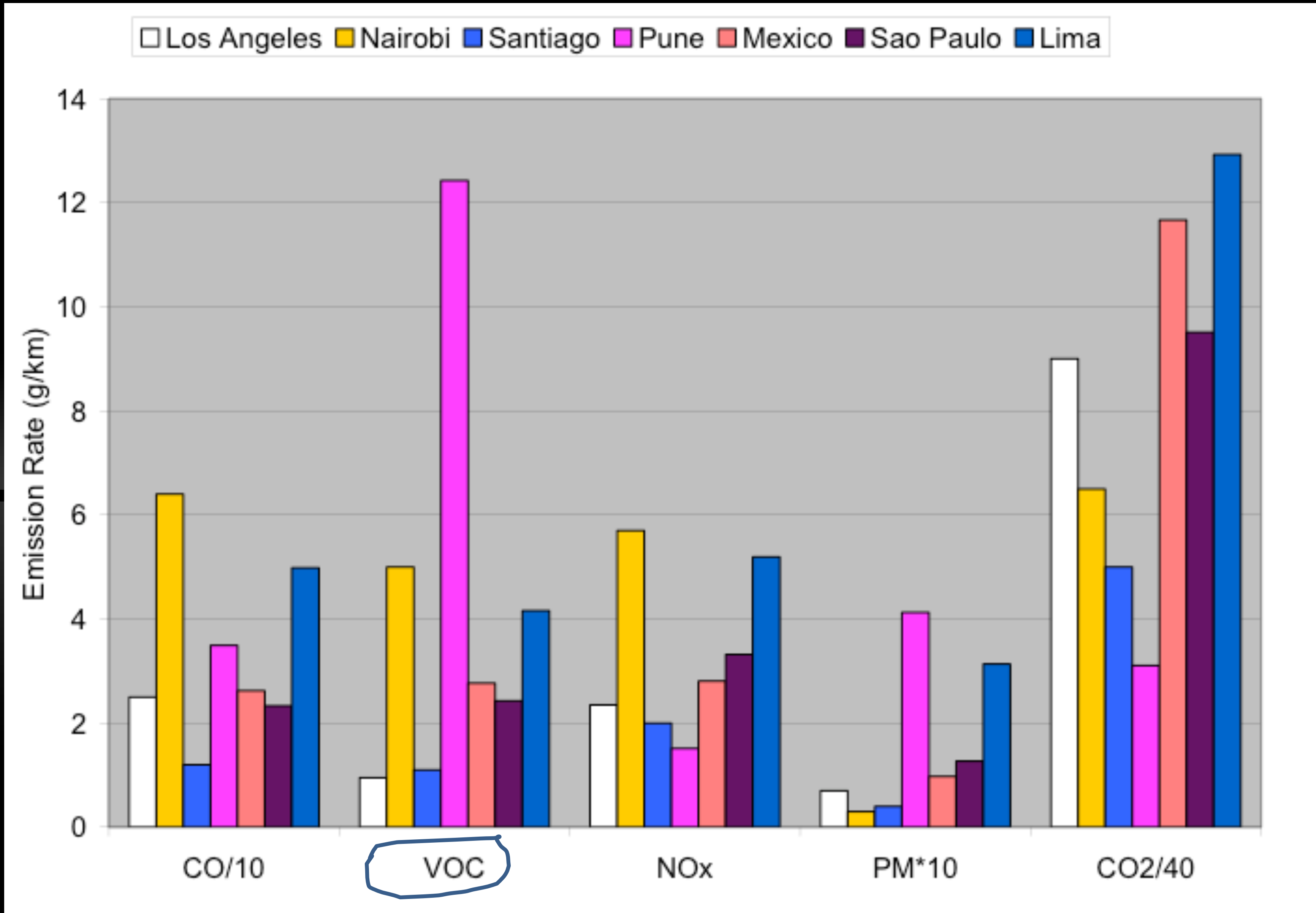
⇒ Old/new cars; 2-stroke/4-stroke; Gbaka

- ✓ Waste burning emissions => EF(BC)= 3, EF(OC)=6.4

DACCIWA measurements (Keita et al., 2018)

Other ways to measure : On-road Emissions

From Behrentz et al., 2007



Osses et al., 2015

VOC speciation : need to be adapted !

MACCITY

methanol
acetone
other alcohols
BC
NH3
butane and higher alcanes
Nox
OC
butene and higher alcenes
other ketones
other aldehydes
CO
propane
ethane
propene
SO2
ethene
formaldehyde
total aromatics

CBMz : chemical model

BC
OC
NH3
NO
CO
CH4
SO2
C2H6
PAR
ACET
HCHO
ETHE
OLT
OLI
ALD2
TOL
XYL
MOH
ISO
RCOOH
BENZ

PAR	2*ethane+3*propane+4*butane and higher alcanes+propene+butene and higher alcenes
ACET	acetone
HCHO	formaldehyde
ETHE	2*ethene
OLT	propene+butene+pentene+methyl pentene+hexene+octene+2*butene and higher alcenes
OLI	trans2butene+cis2butene+cyclopentene+2*butene and higher alcenes

✓ Spatialization

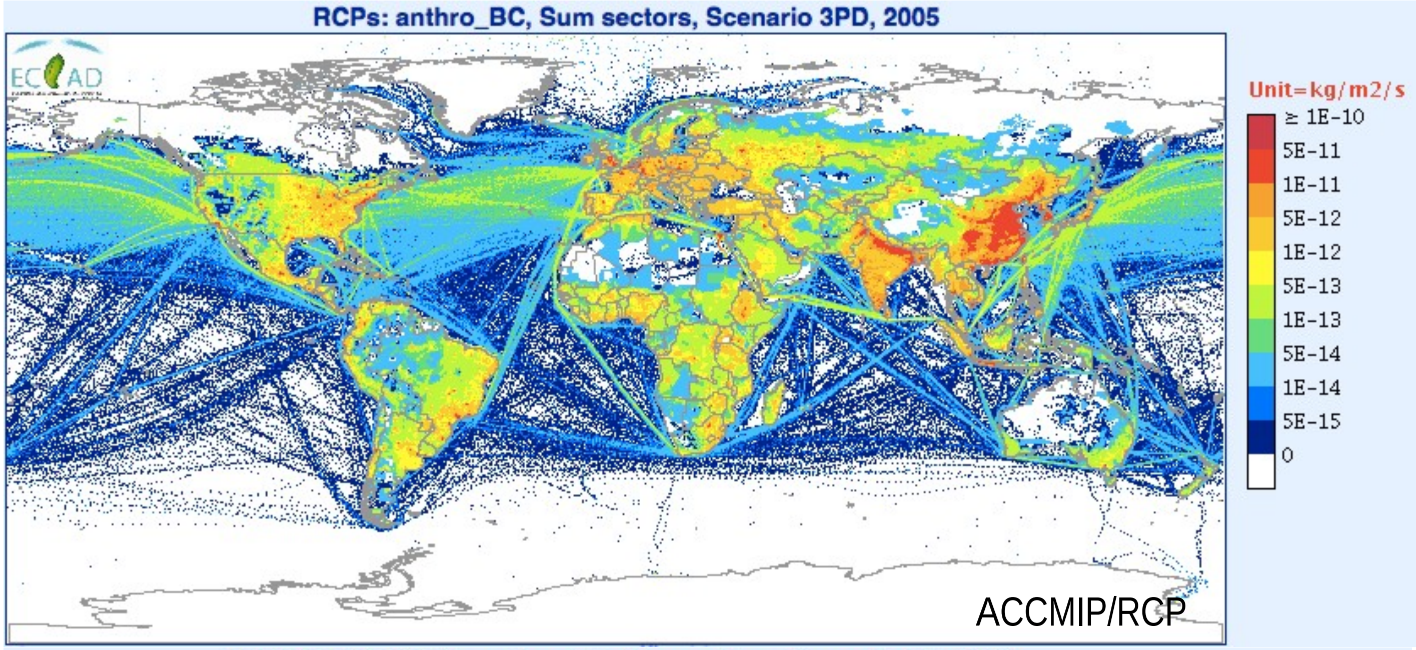
Emissions by countries => African emissions inventories at 0.1°× 0.1° spatial resolution

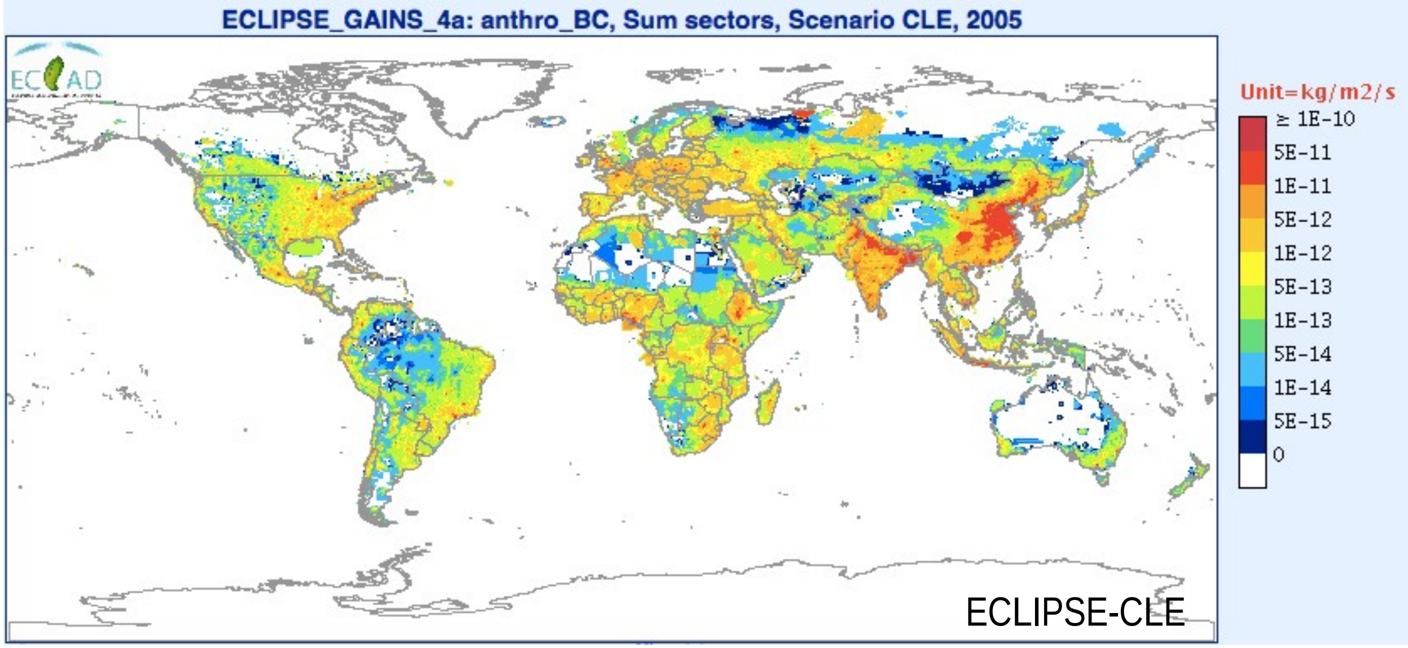
- DOMESTIC FIRES : Population density given by CIESIN (Gridded Population of the World Future Estimate: GPWFE)
- ROAD TRAFIC : African country road networks given by Africa infrastructure (2009)
- INDUSTRIES and POWER PLANTS : African power plant networks given by Africa infrastructure, (2009)
- FLARING : DMSP/VIRRS

Keita et al., 2019

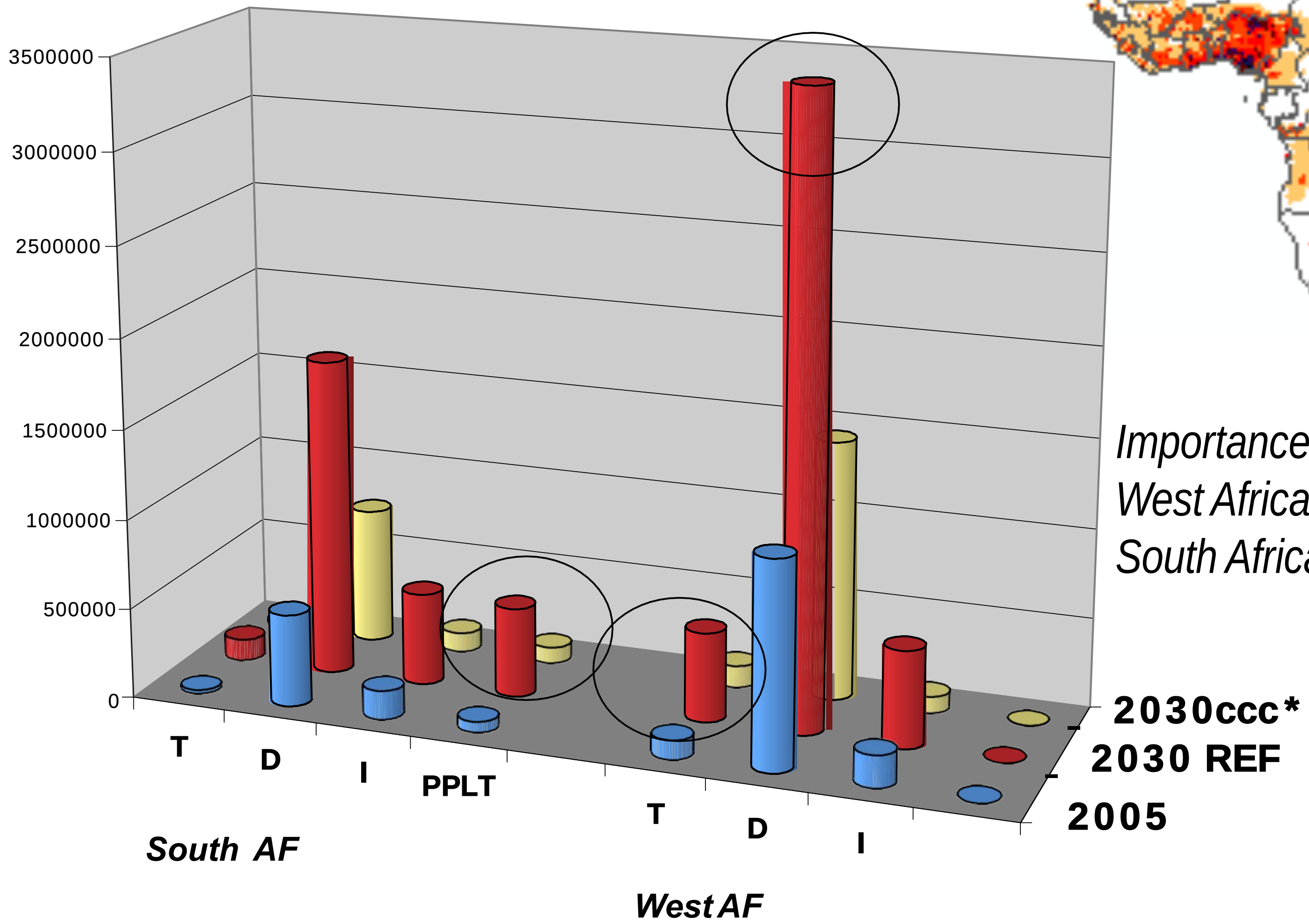
✓Examples of emission inventories

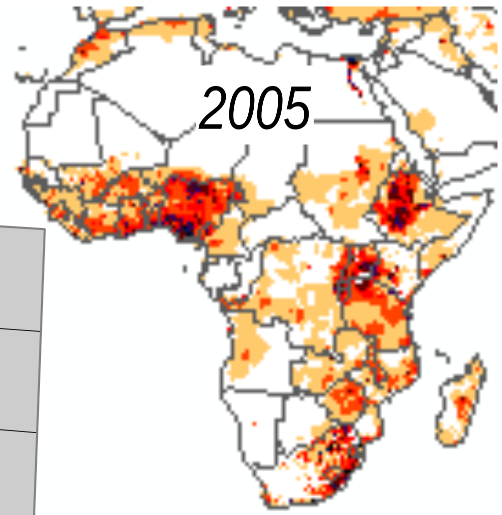
Examples of global emission inventory for 2005 : black carbon





African emission inventories for the Present and the Future: Organic carbon (Liousse et al., 2014)





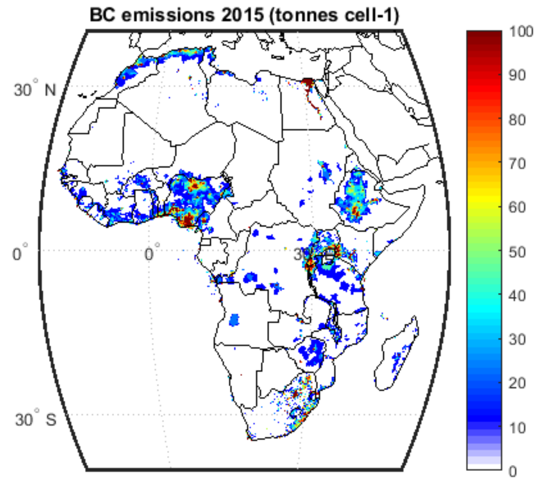
Importance of domestic fires
West Africa : + traffic
South Africa : + industries

NEW DACCIWA Emission inventories (*Keita et al., 2019)*

African region contribution to 2015 emission budget

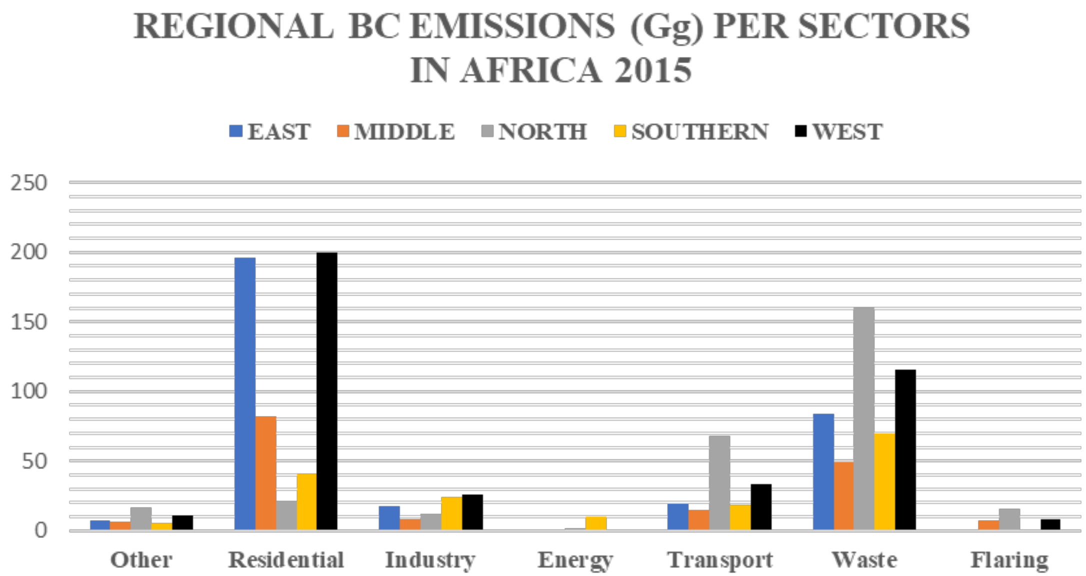
	BC(GgC)	NOx(GgNO2)	OC(GgC)	SO_2(GgSO2)	CO(GgCO)	VOC(GgVOC)
Total Africa	1353.5	7905.7	7428.2	3200.3	94888.4	15866.8
West Africa	386.4	1388.5	2794.4	252.5	33483.7	5759.3
West Africa (%)	29%	17%	38%	8%	35%	36%

- West Africa's contribution is greater than that of the other 4 regions of Africa in terms of BC, OC, CO and VOC
- These pollutants are mainly emitted in the residential and traffic sectors which are the main emitting sectors in WAF

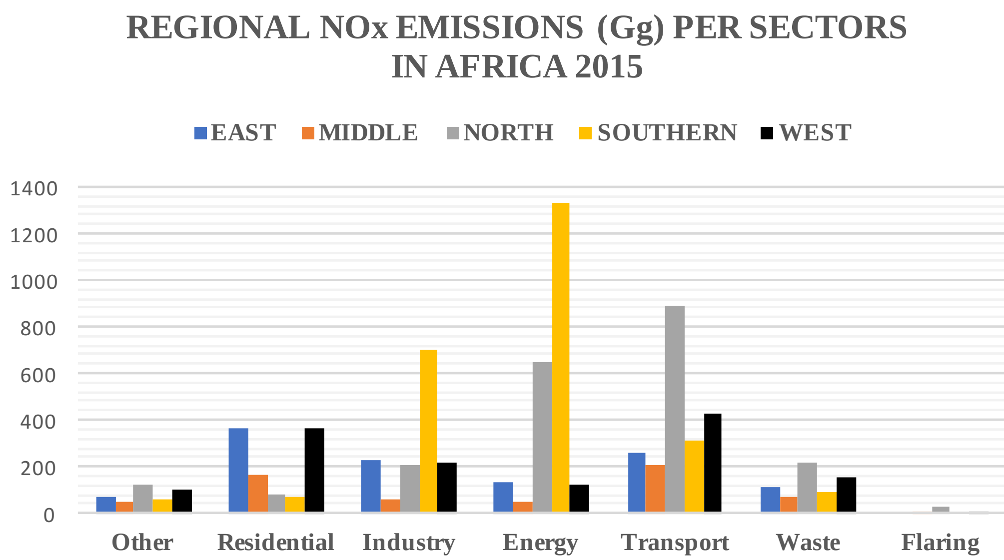


NEW DACCIWA Emission inventories (*Keita et al., 2019)*

BC



NOx



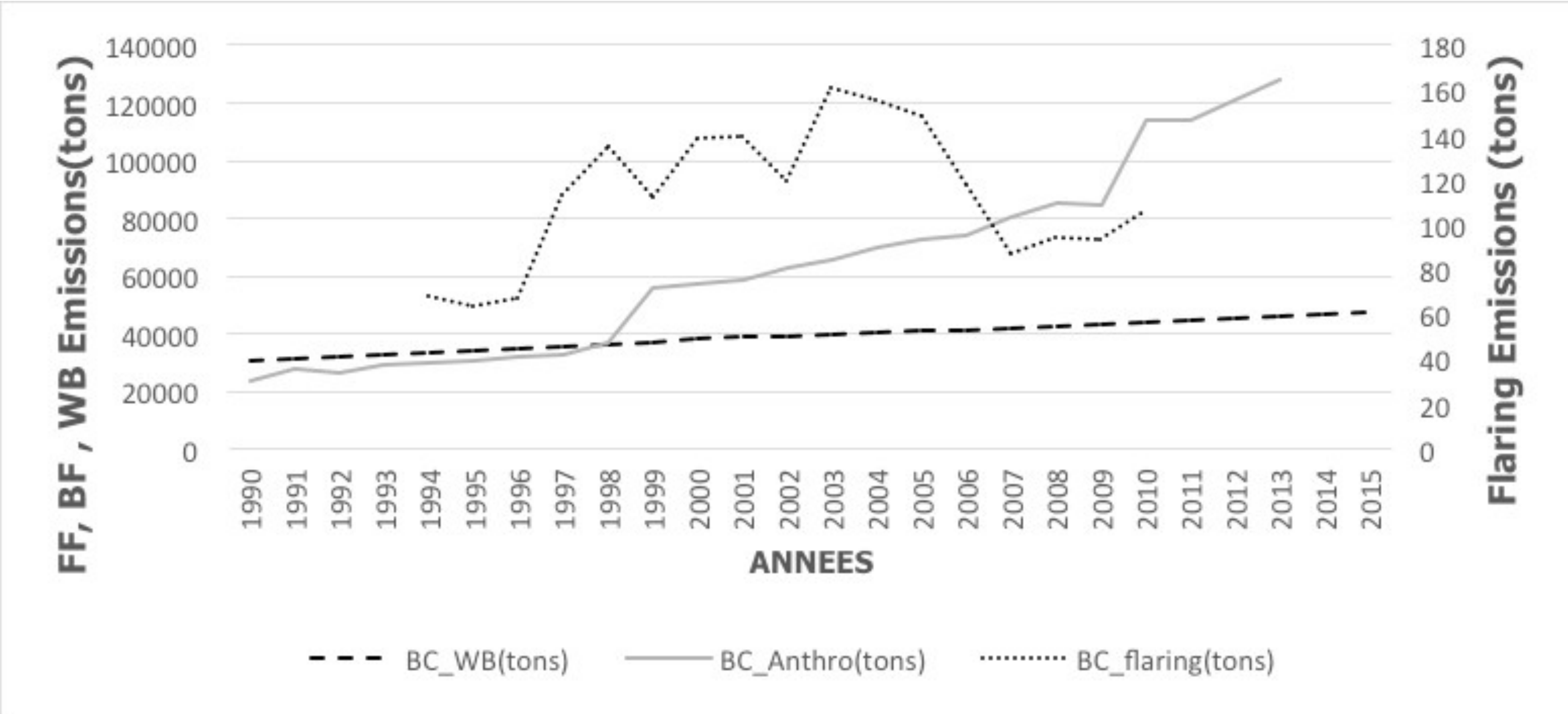
A few features :

- BC, OC, CO, VOCs : importance of domestic fires, waste burning, trafic ..
- NOx, SO2 : importance of energy, industry, transport..
- BC and OC in West and East Africa : domestic fires
- North Africa : Transport and Waste
- NOx in South Africa : energy, industry

Keita et al., 2019

NEW DACCIWA Emission inventories (*Keita et al., 2019)*

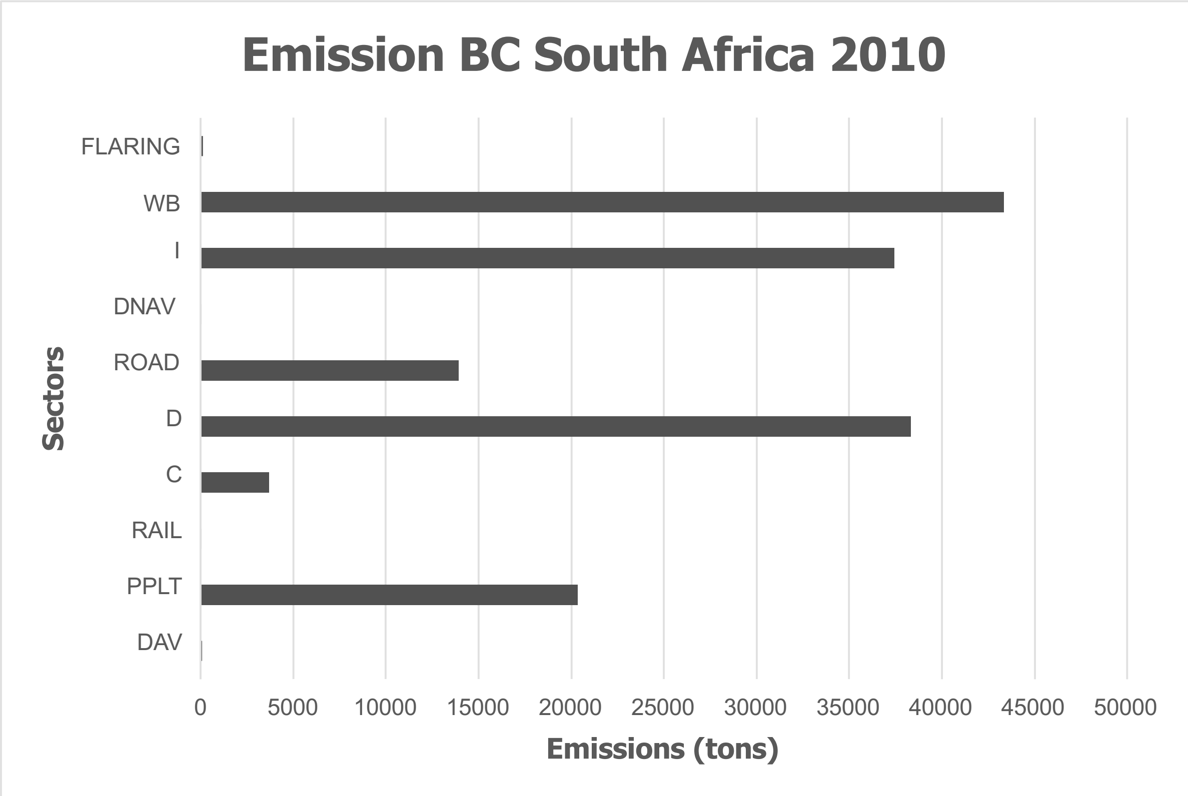
Anthopogenic sources (incl. flaring and waste burning): trends



DACCIWA/GDRI projects (Keita et al., 2019)

NEW DACCIWA Emission inventories (*Keita et al., 2019)*

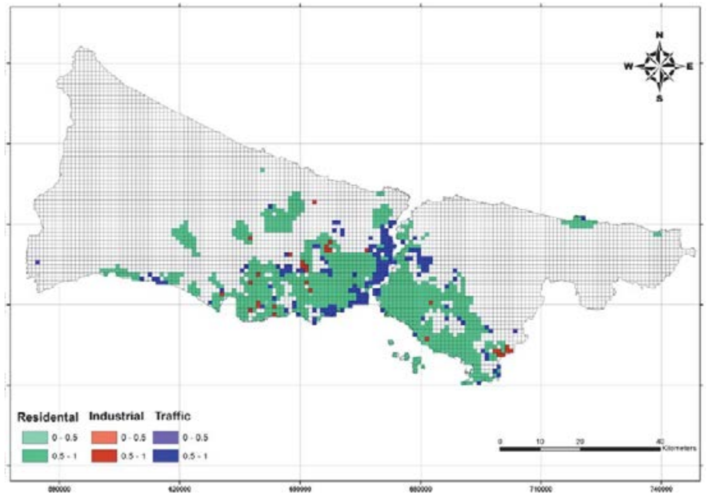
Anthopogenic sources (incl. flaring and waste burning)

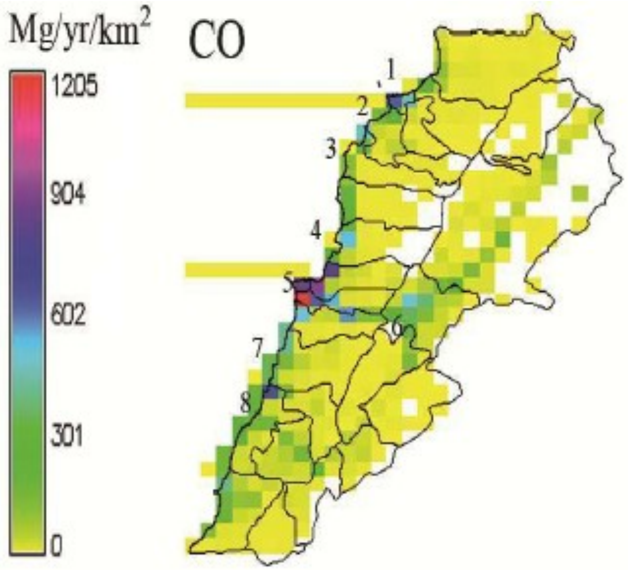


DACCIWA/GDRI projects (Keita et al., 2019)

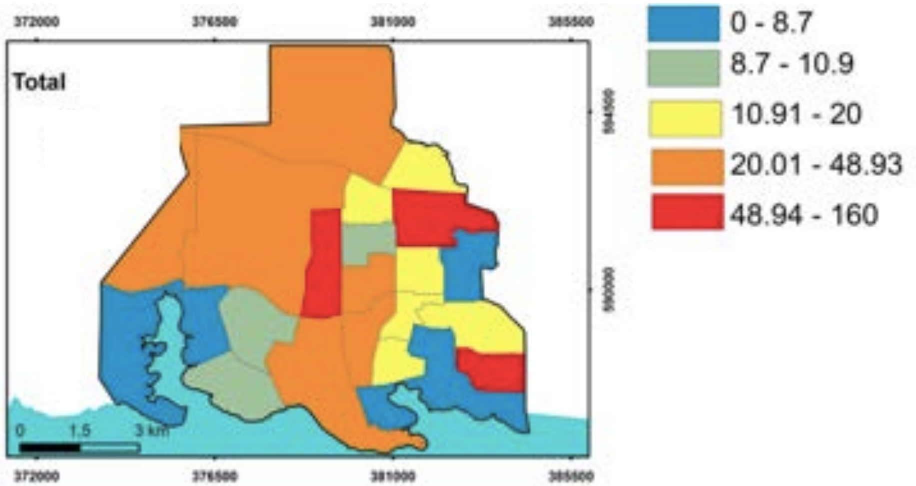
Examples of local/regional inventories

PM10 emissions in Istanbul (Kara et al., 2014)





CO emissions in Lebanon (Waked et al., 2012)



BC domestic emissions in Yopougon (a district of Abidjan, Cote d'Ivoire) (Doumbia M. et al., 2019)

Biomass burning emissions in Africa

Photo M.O. Andreae

How to count?

Bottom-up Method for deriving Biomass burning emissions

In global and regional existing inventories, *(Cooke and Wilson, 1996, Liousse et al., 1996, Reddy et al. 2001, Galbally et al. 2001,…)* gaz and aerosol source emissions (Q(X)) is calculated as following :

Q = M x EF(X) where

EF(X) is the emission factor (gX/kgdm)

M is the burnt biomass ; it may be obtained from :

M= A x B x α x β where

A is the burned area

B the biomass density

α, the fraction of aboveground biomass

and β the burning efficiency.

Thanks to many experiments (under the IGAC flag : DECAFE, EXPRESSO, SAFARI, SCAR-B, LBA, FIRESCAN…)

- Uncertainty on EF has been improved *(Andreae and Merlet, 2001, Scholes and Andreae, 2001, Akagi et al., 2011)*

Investigations are still needed for agricultural fires, humid forest fires, boreal and mediterranean ecosystems, for some compounds (WSOC emissions)..

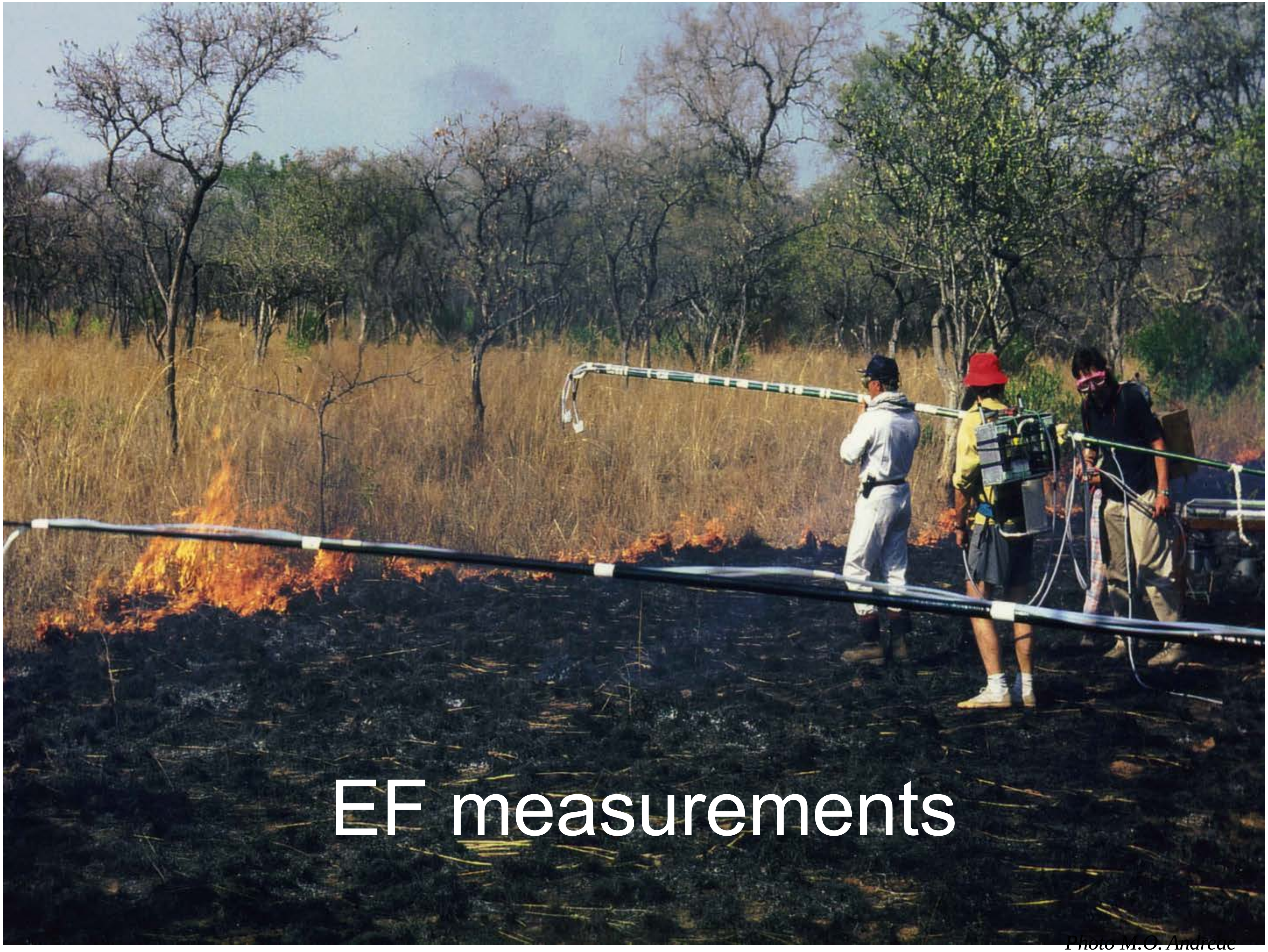
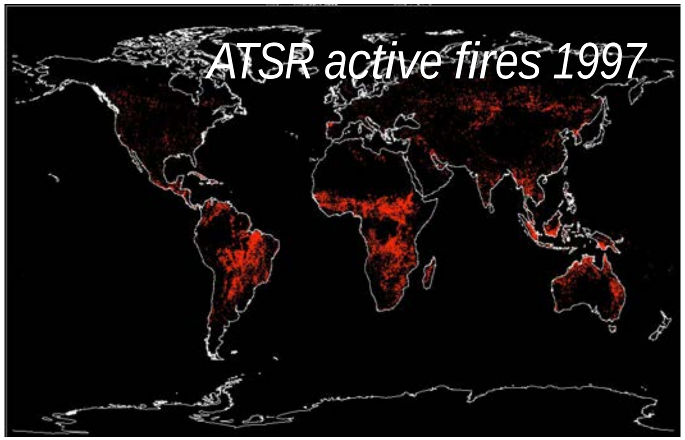


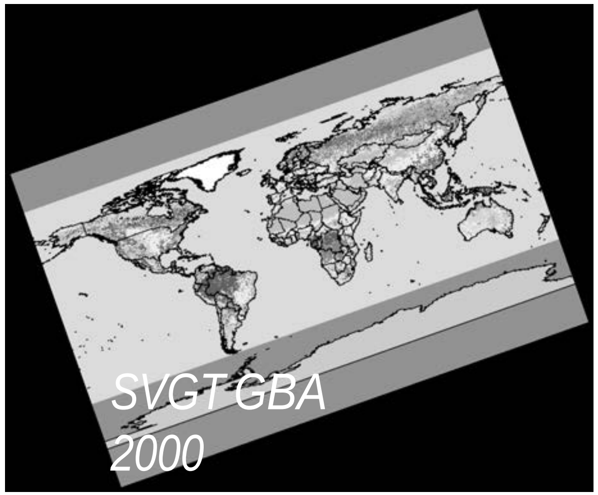
Photo M.O. Andreae

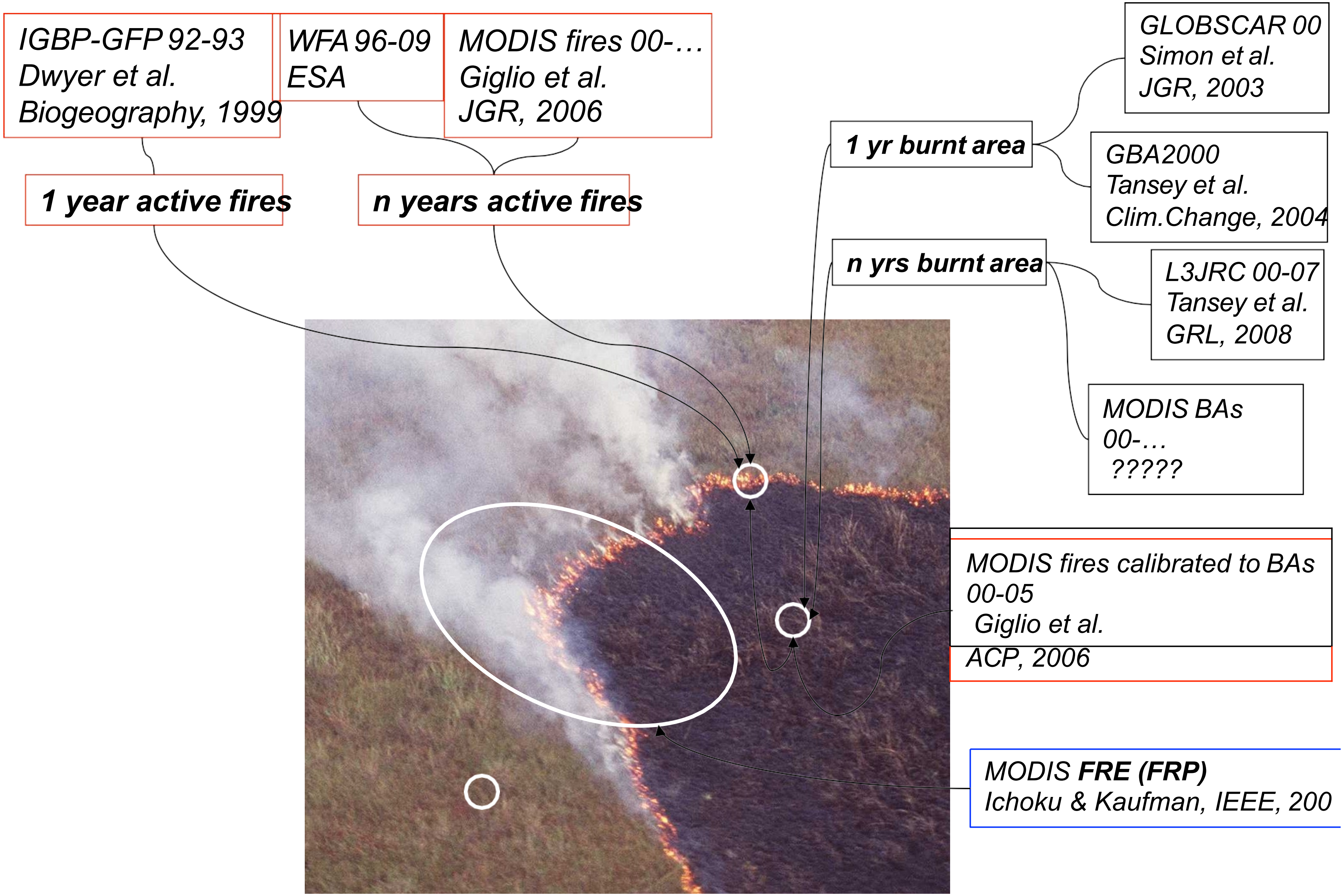
M : the burnt biomass : AxBxCE

Uncertainty on A (the burnt areas distribution) parametrization
Up to 1998, determined from statistical data (Hao et al., 1991) = a factor of 2 to 3 of uncertainty

Improvement of A (burnt areas) by using satellite data.
•Qualitative improvement from global distribution of active fires given by ATSR, NOAA AVHRR, MODIS sensors
• Quantitative improvement from global distribution of burnt areas given by NOAA AVHRR, Spot vegetation, ATSR, MODIS…







Thanks to J.M. Grégoire

Uncertainty linked to A determination from satellite

- *Which fraction of pixel area is actually burning (50%) ?*
- *Fires with a low injection height are not captured by satellite data (ex. with small agricultural fires or fires under dense humid forests)*

=> Risk of double counting with agricultural fires and flaring.

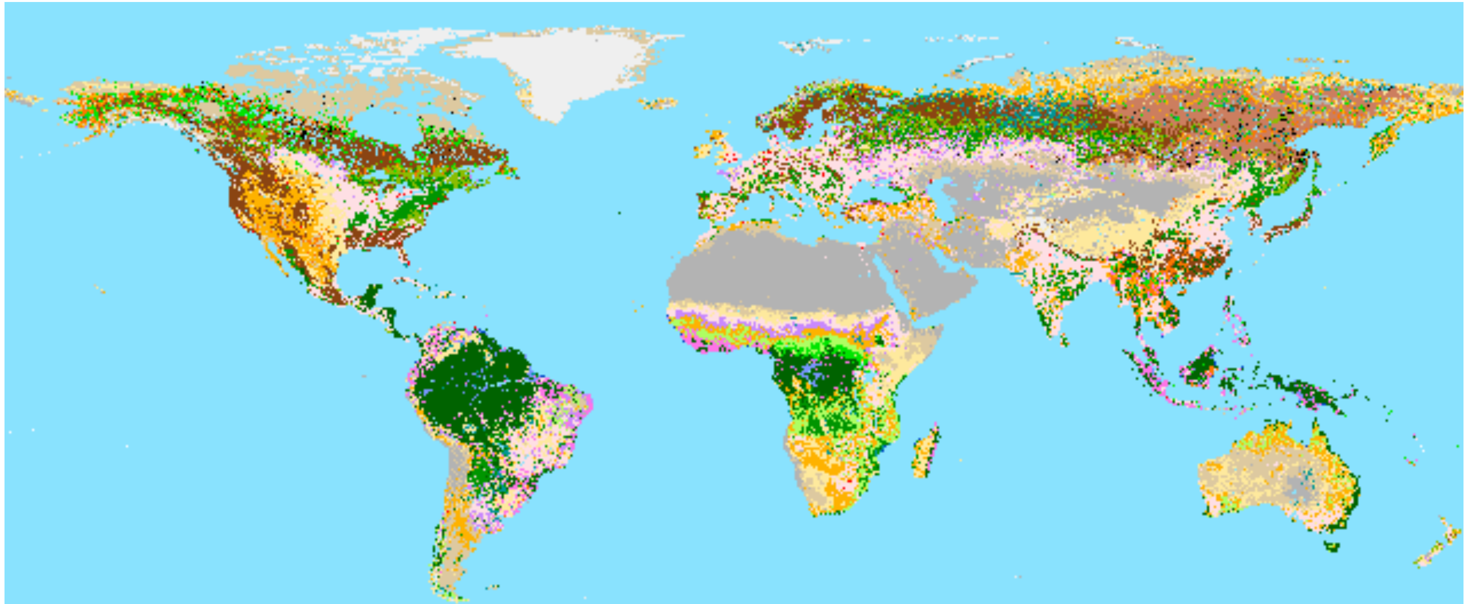
Biomass density, aboveground biomass and combustion efficiency

1) need a vegetation map (Matthiews GISS, UMD Maryland, GLC JRC-Ispra, MODIS, CLM …) with vegetation classes. In more recent developments, a vegetation model.

2) need to find corresponding biomass density, burning efficiency and EF values for each vegetation classes*

** Burning efficiency also depends on vegetation dryness state*

Example with GLC map (Ispra) (0.5°x0.5°)



Assumptions by Liousse et al., 2010

GLC map	Density biomass (kg/m2)	Combustion efficiency	EFCO (g/kg)
Broadleaf evergreen GLC1	23,35	0,25	104
Closed broadleaf deciduous GLC2	20	0,25	107
Open Broadleaf deciduous GLC3	3,3	0,4	65
Evergreen needleleaf forest GLC4	36,7	0,25	107
Deciduous needleleaf GLC5	18,9	0,25	107
Mixed leaf type GLC6	14	0,25	106,9571
Tree Cover, regularly flooded, fresh (-brackish) GLC7	27	0,25	104,003
Tree Cover, regularly flooded, saline, (daily variation) GLC8	14	0,6	82,7543
Mosaic : tree cover/other natural vegetation GLC9	10	0,35	86
Shrub, closed-open, evergreen GLC11	1,25	0,9	65
Shrub, closed-open, deciduous GLC12	3,3	0,4	65
Herbaceous cover, closed open GLC13	1,425	0,9	65
Sparse herbaceous or sparse shrub cover GLC14	0,9	0,6	77,69
Cultivated and managed areas GLC16	0,44	0,6	92
Mosaic : cropland/tree cover/other natural vegetation GLC17	1,1	0,8	70
Mosaic : cropland/shrub or grass GLC18	1	0,75	73,812

Liousse et al., 2010

Biomass density, aboveground biomass and combustion efficiency

- *Biggest uncertainty is now on the relationship with the surface (biomass density, burning efficiency)*

- *Expected improvement by using micro-satellite and by coupling dynamic fire model (see GFED product with CASA model, (Van de Werf et al. and Venevski et al. works)*

- *Importance of intraannual and interannual variability; some ecosystems poorly documented*

Exemple of african biomass burning emissions (savanna, forest and agricultural fires)

The most adapted method to derive African BB emission => a bottom up method based on satellite burnt area map (*Liousse et al., 2004*)

Method for AMMA and SACCLAP (2000-2007, now extended until 2015) :

Pollutants : BC, OCp, OCtot, CO, CO_2, NOx, NMVOC, SO_2

and all the species listed in Andreae and Merlet, 2004

Emissions = SB x GLCv x BEv x BDv x EFv

SB : area burned => GBA 2000 product (0.5°x0.5°, monthly) and L3JRC/MODIS products (1kmx1km/day) GLCv : quantity of vegetation v present in cell (%) => GLC 2000 map

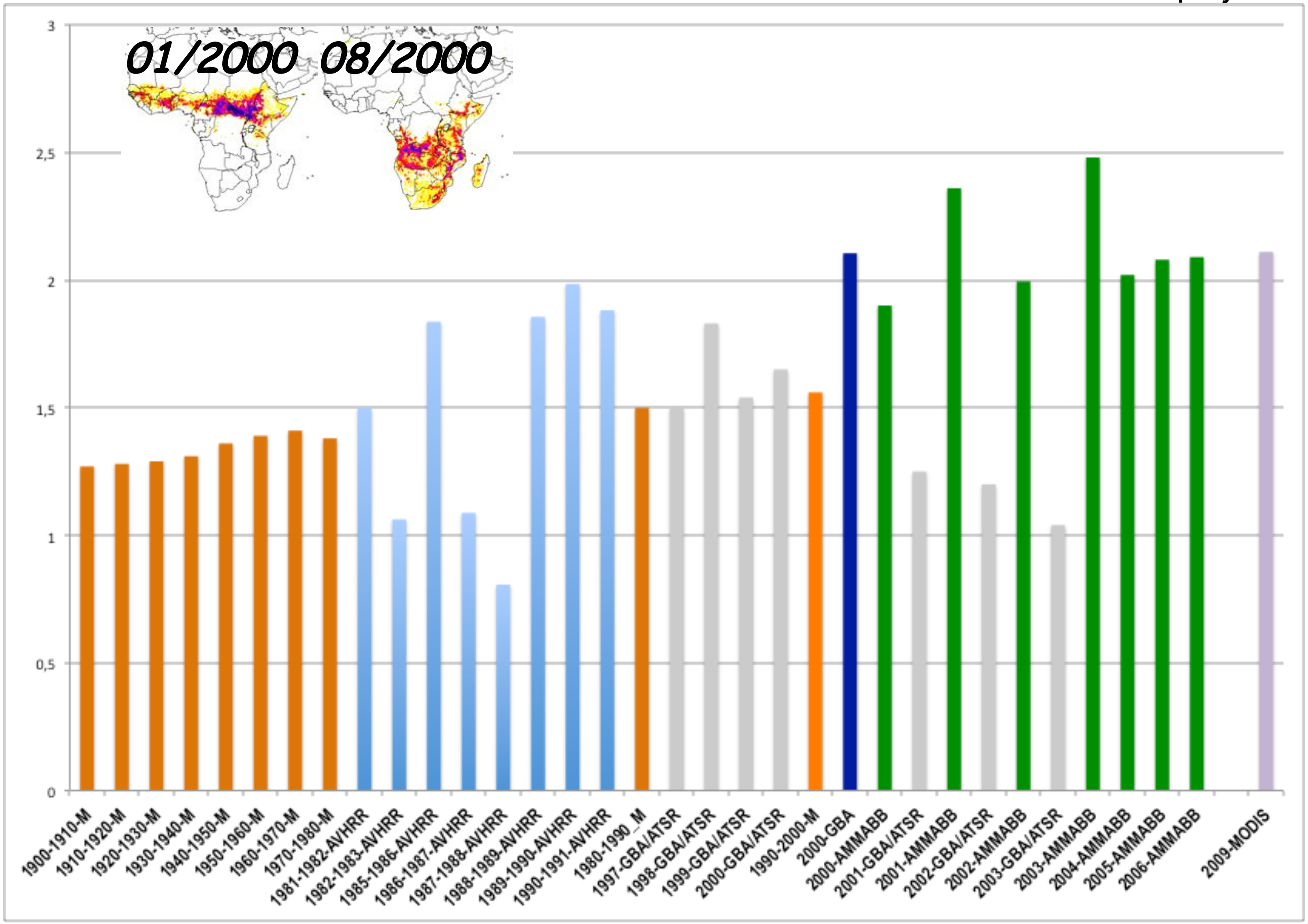
BEv,BDv : biomass density and burning efficiency by vegetation type

EFv : emission factor by vegetation type

Liousse et al., 2010, Ndatchoh Touré et al., 2019

African Biomass burning BC emissions

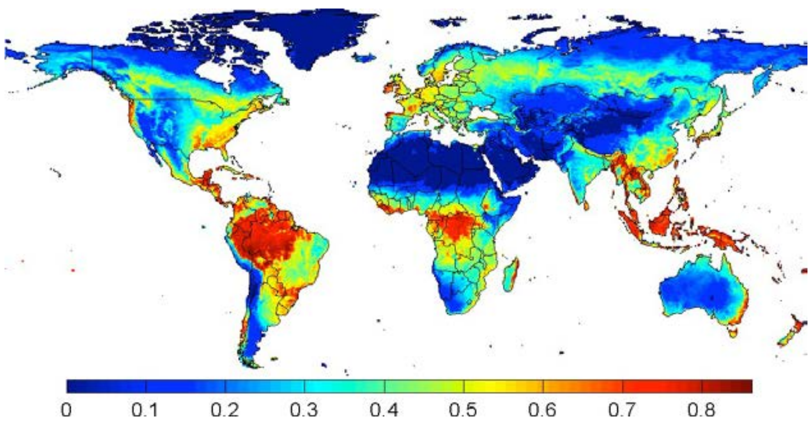
AMMA/GDRI projects



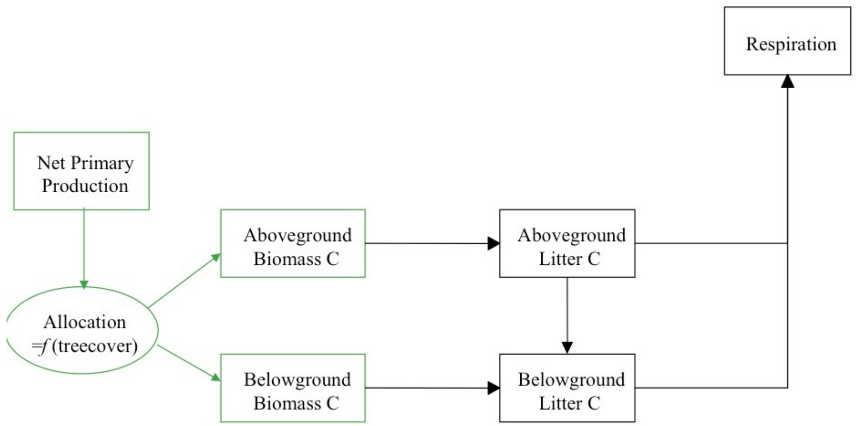
Liousse et al., 2010

Example of global BB : GFED Approach

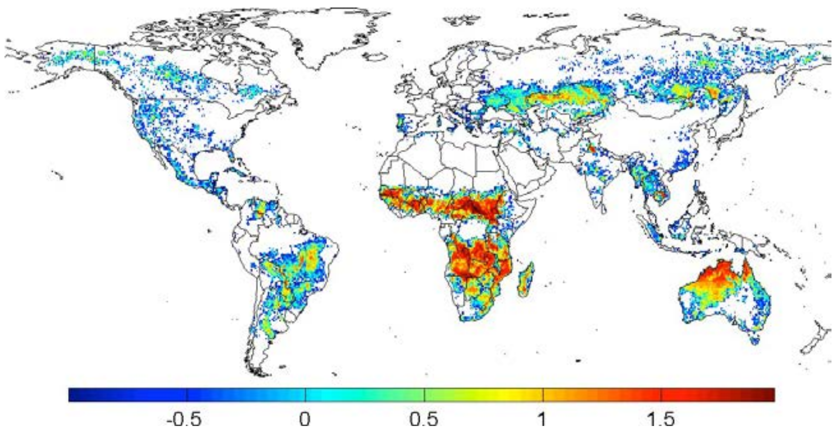
Monthly FPAR (vegetation productivity)



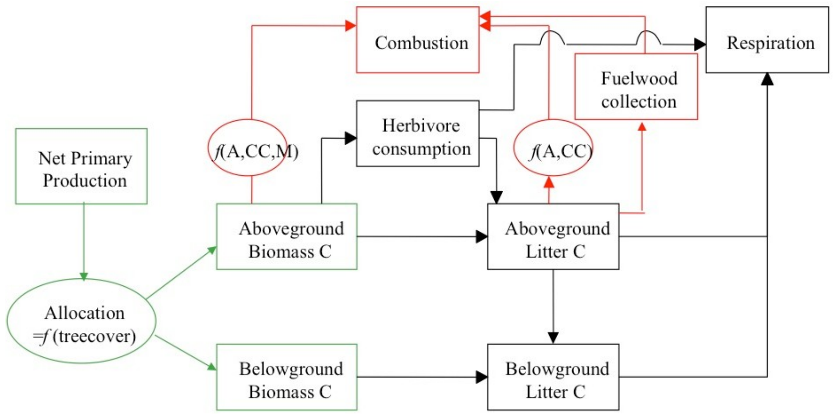
CASA model: biomass production and decay



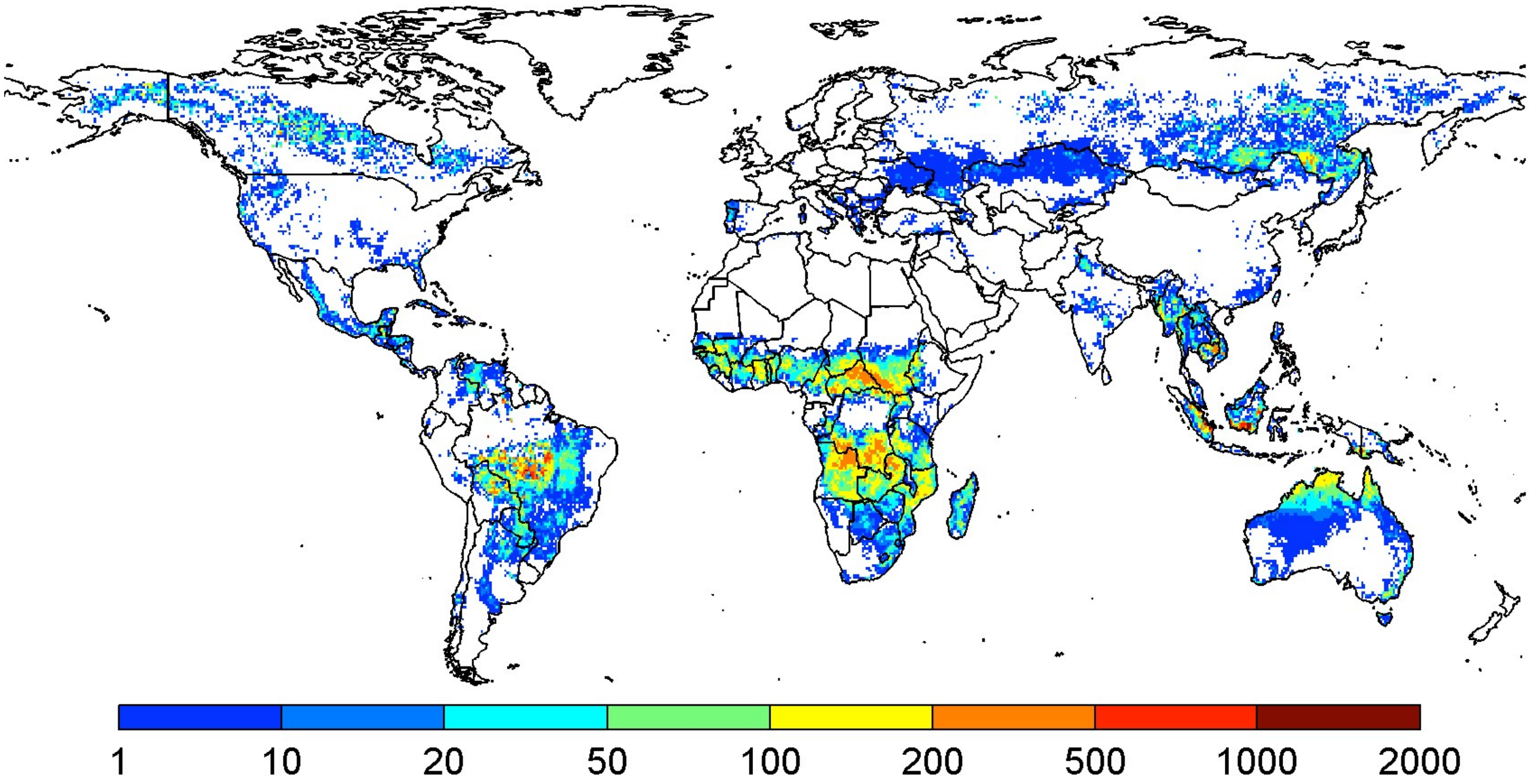
Burned area



Fire module in CASA model



GFED Emission pattern (1997 – 2008)



GFED3, g C / m² / year

A new method with FRE (e.g. GFAS inventory)

„Active Fire remote sensing" approach

Emission = C_a * FRP

C_a = emission coefficient **FRP = Fire radiative power**

Relates energy of the fire with the rate of biomass consumption.

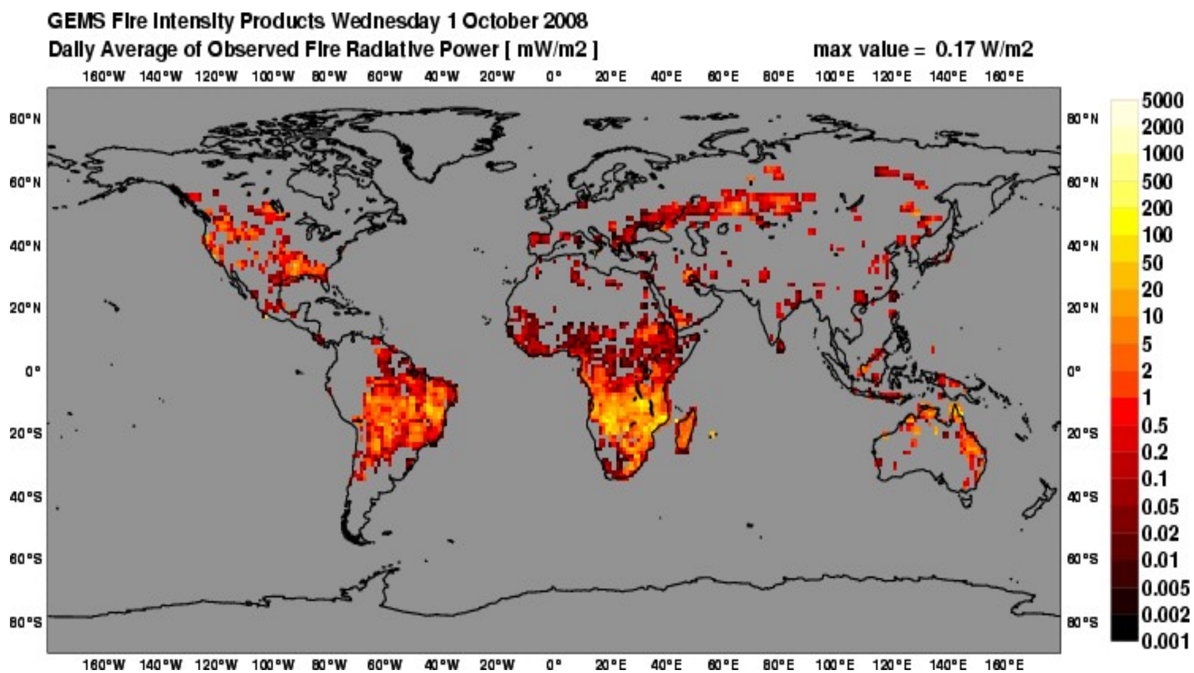
Challenges:

- Dependence of emissions on quality and completeness of observations

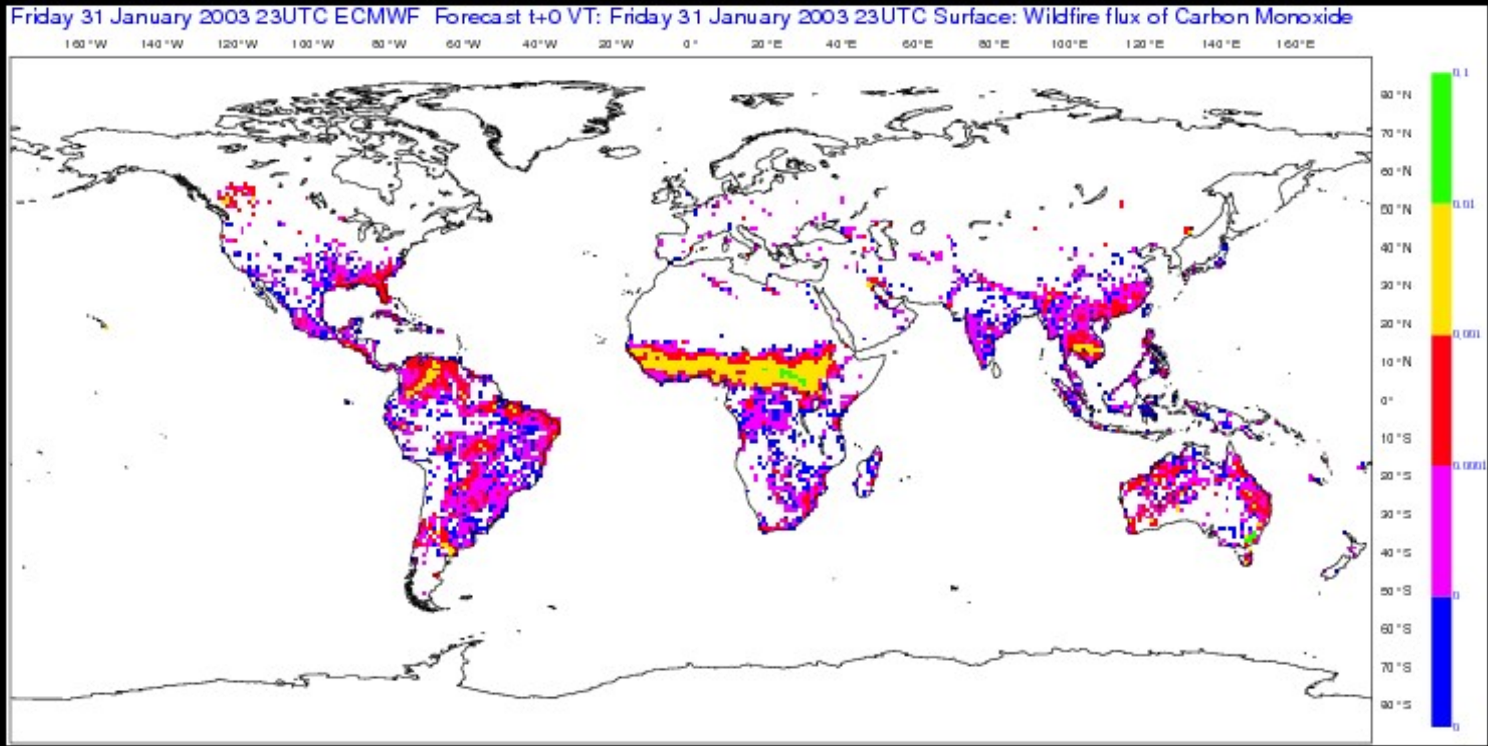
Datasets: GFAS, QFED *(Kaufman et al., 1998; Ichoku&Kaufman, 2005)*

FRP from MODIS & SEVIRI

- FRP-based, real time, global
- 10 km spatial res.
- 1 hour temporal res.
- MODIS correction for small fires with SEVIRI detection



GFAS : CO in 2003 (kg/m2): Monthly



Kaiser et al.

MACC

- MACC is merging FRP observational data from SEVIRI and MODIS to monitor global fire emissions in real time:
  - organic matter, black carbon, CO, CO_2, CH_4, SO_2, C, VOCs …
  - The emissions are increasingly being used by the MACC forecasting systems.
  - The products are publicly available and several users are interested

- Product in MACC:
  - dynamic correction for fires below detection threshold
  - assimilation for filling of observation gaps
  - improved temporal and spatial resolution: 1h, 10km
  - emission factor optimisation (fire types, blacklist oil production & volcanoes)
    - by comparison to "traditional" emission inventories
  - conversion factor (FRP → combustion rate)
    - determined by scaling global emission budget to GFEDv2 over 8 months
    - needs to be calculated by inversion of observed plumes

Top-down approaches :

Most works used CO (combustion tracer) but recent developments by Dubovik et al on black carbon aerosols.

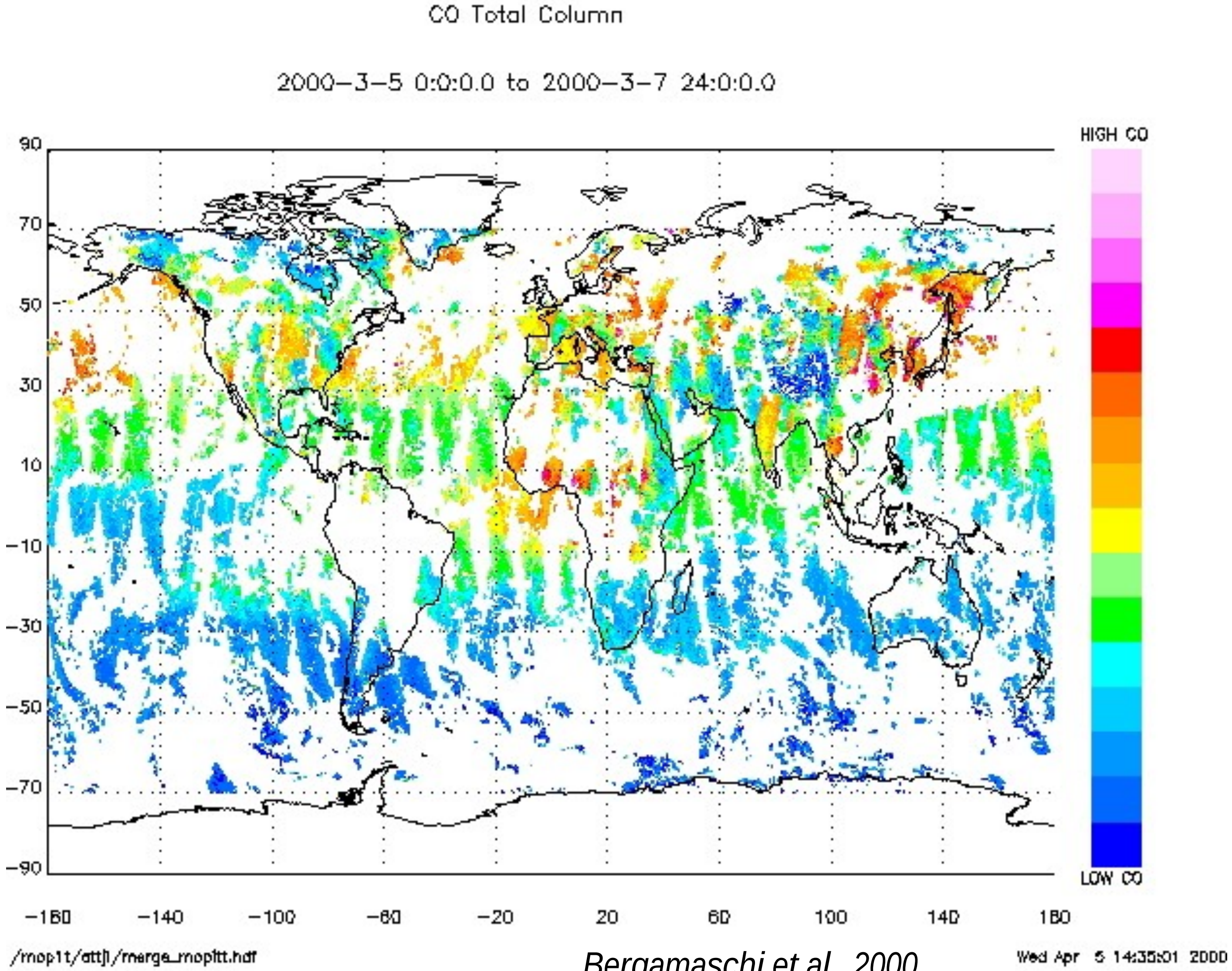
CO concentrations database well documented at the regional and global level.

EF and ER(CO) known with low uncertainty factor

CO deposition well parametrized in the model.

e.g. : Monthly CO emission maps over the globe for each 0.5° x 0.5° cell from MOPITT (NASA-TERRA) satellite and MOZART model (Petron et al., 2004)

Global CO from MOPITT



Bergamaschi et al., 2000

Fire emission models

Comparison of fire emission models

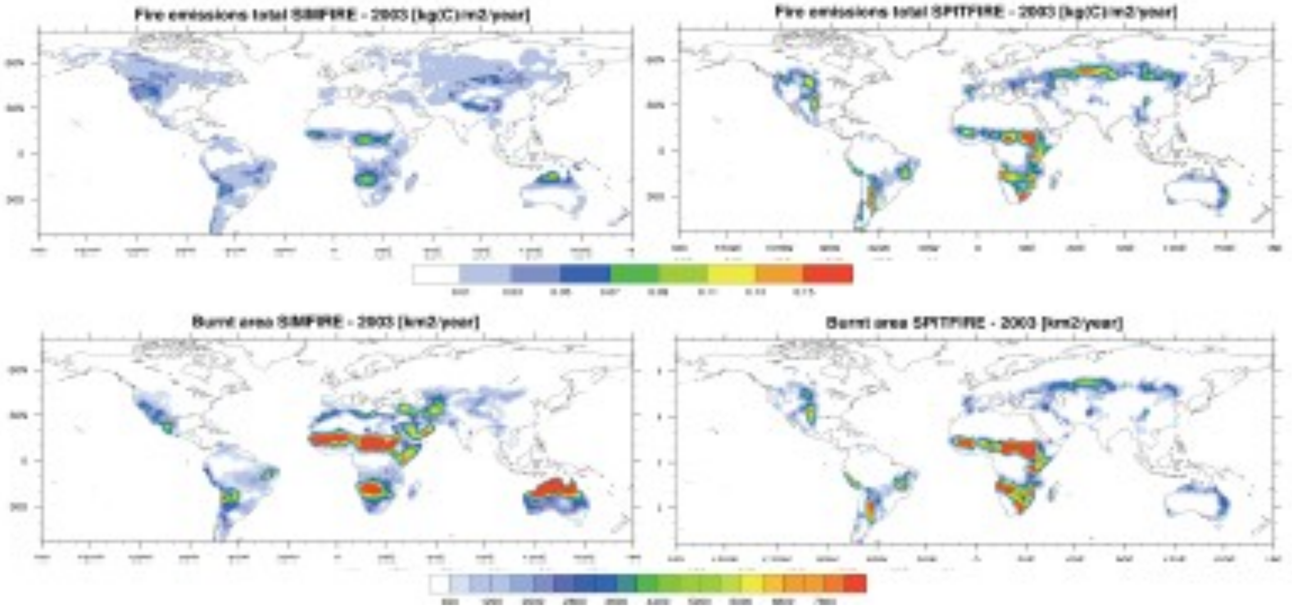
Due to lack of satellite observations prior to 1980s, the historical emission dataset will need to rely on results from fire emission models. In our analysis we included models SPITFIRE and SIMFIRE. Since the two models vary by 20% globally and up to factor of 2 regionally, we here compare the input model parameters to better understand the discrepancies. The differences can be explained by a combination of vegetation extent, area burnt and fuel load (green and woody litter) simulated by each model.

SIMFIRE model (Knorr et al., 2014)

- Lund University, Lund, Sweden
- satellite-based burnt area combined with dynamical vegetation model LPJ-GUESS
- CRU NCEP meteorology

SPITFIRE model (Lasslop et al., 2014)

- Max Planck Institute for Meteorology, Hamburg, Germany
- mechanistic model embeded to MPI Earth System model
- CRU NCEP meteorology



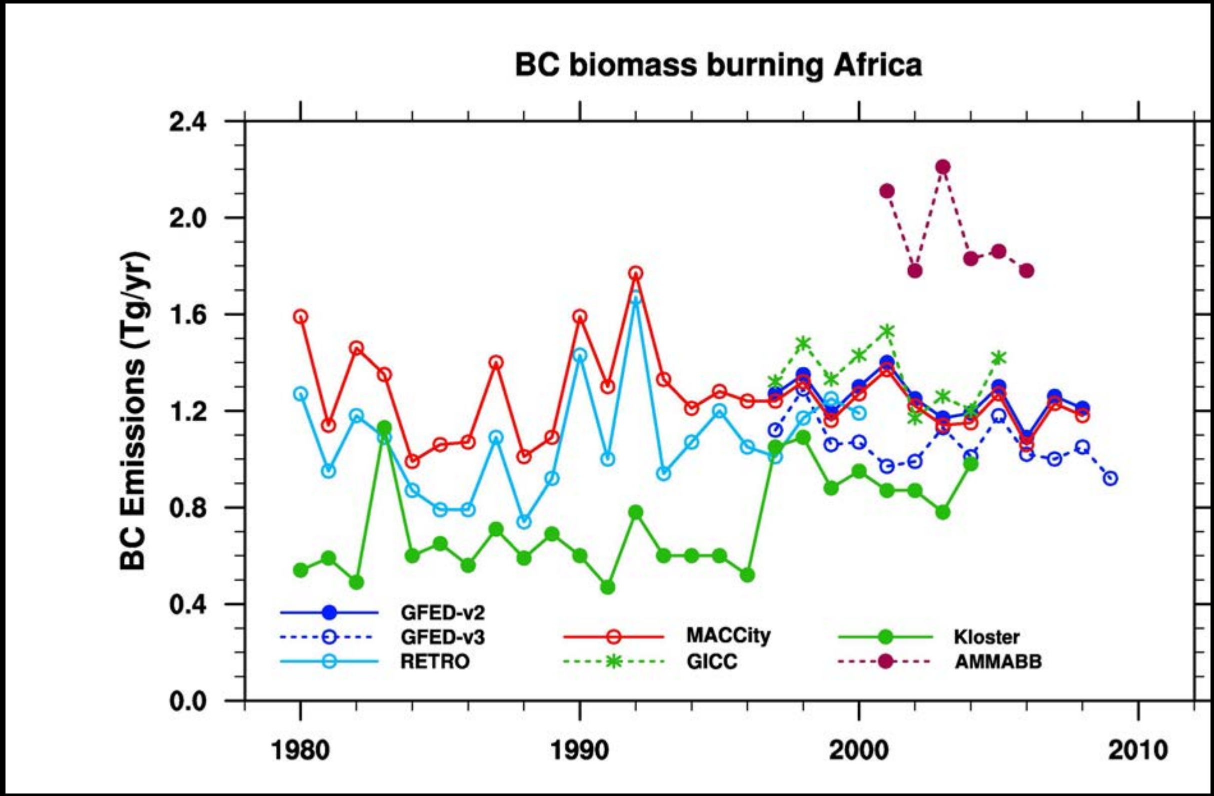
Sindelarova et al., 2015

How to limit emission inventory uncertainties?

How to limit uncertainties on Emissions inventories

- Emission inventories for gases and particles (same ancillary data)
- Local/Regional/Global inventories Emission inventory intercomparisons
- Emission experiments (Lack of EF for some species and some sources/ properties..)
- Organic budget : VOC/SVOC/POC
- Temporal variations (diurnal/seasonal/interannual/projections)
- Spatialization keys
- by including these inventories in multi scale models and comparing modeled and measured pollutant concentrations and/or optical properties

Biomass burning in Africa: BC emissions

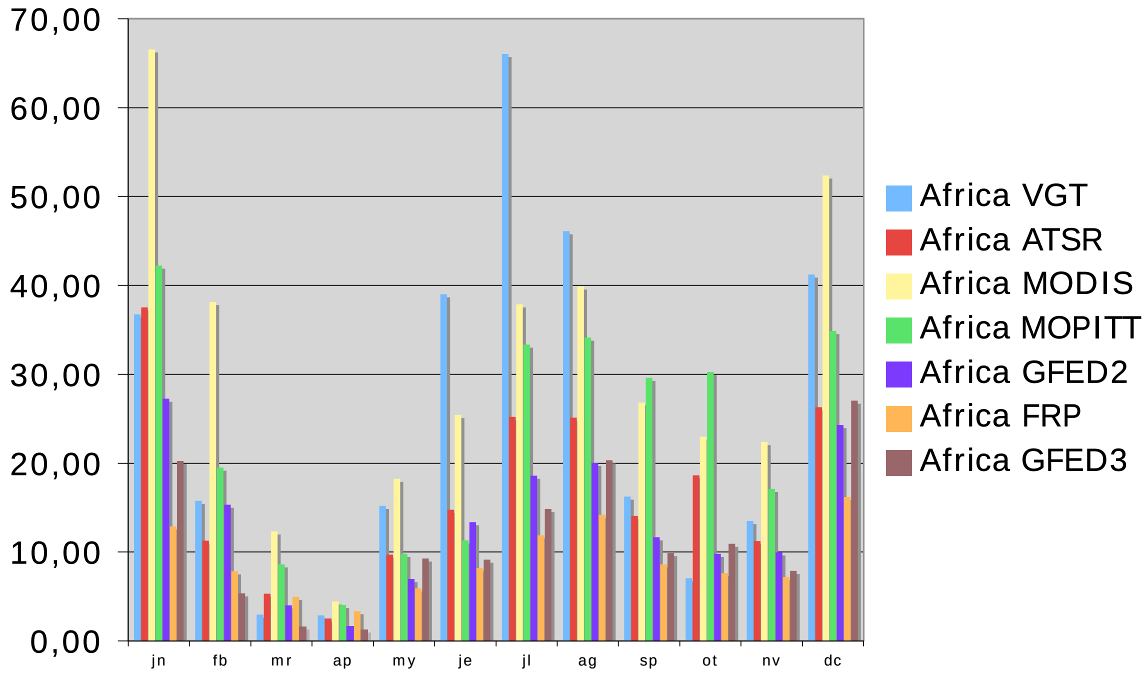


AMMABB values:
→Very different from other datasets

Maybe the most consistent with:
-Observations
-Inverse modeling studies

(Liousse et al. 2010 Granier et al., 2011)

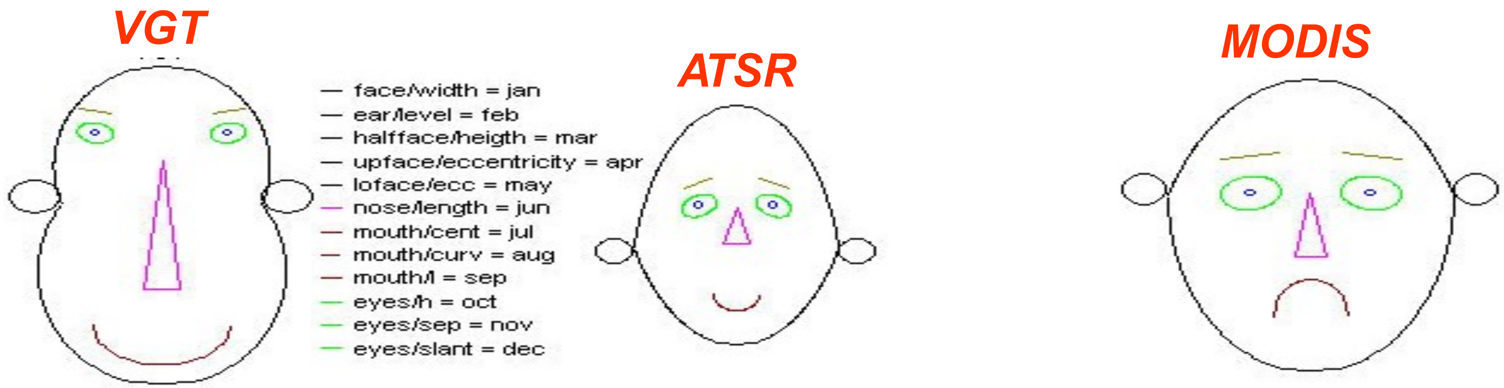
African Biomass Burning CO EMISSIONS in TgCO/yr in 2003



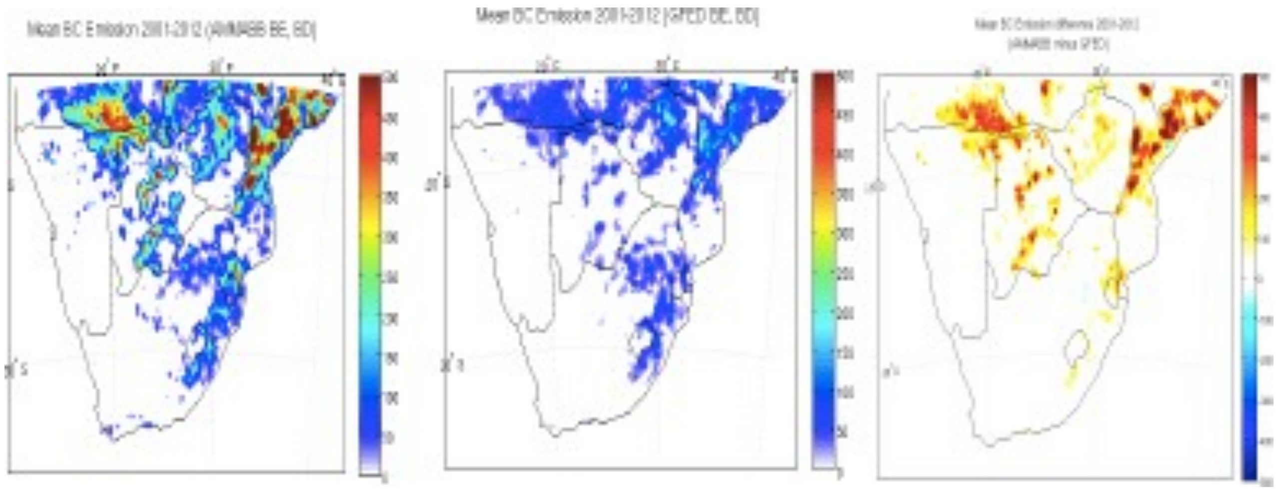
AMMABB values:
→Very different from other datasets

BUT is the most consistent with:
- Observations
- Inverse modeling studies

INTERMEDE BBSO exercise : Sentivity tests on burnt areas (satellite data) => Same vegetation, Same EF (Stroppiana et a., 2011)



Biomass burning emissions : a test of sensitivity on vegetation : same burnt areas (MODIS), same EF

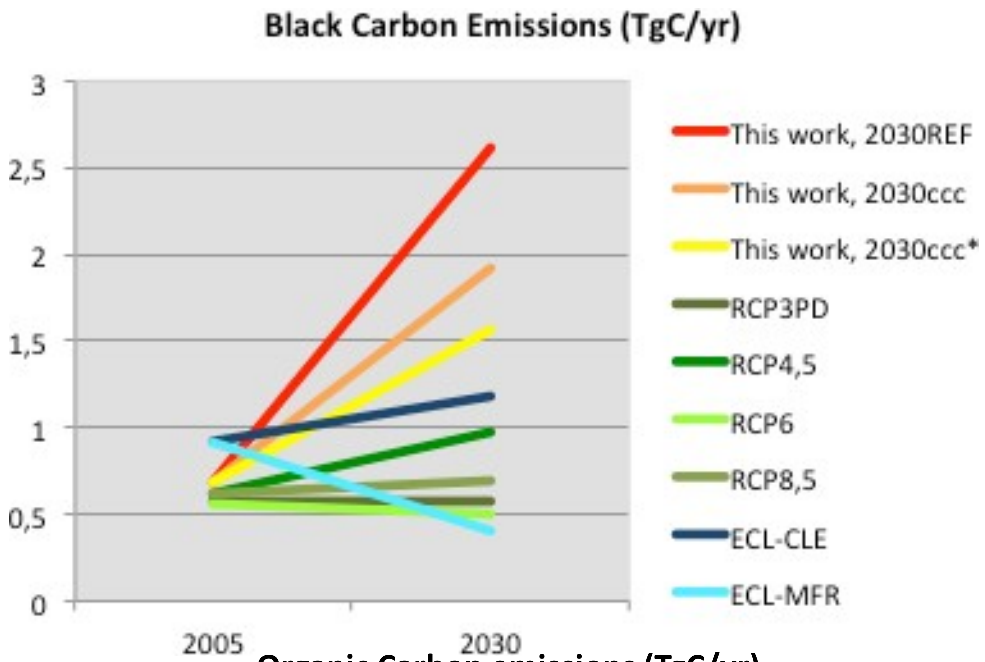


AMMABB *GFED-GFAS* *AMMABB - GFED*

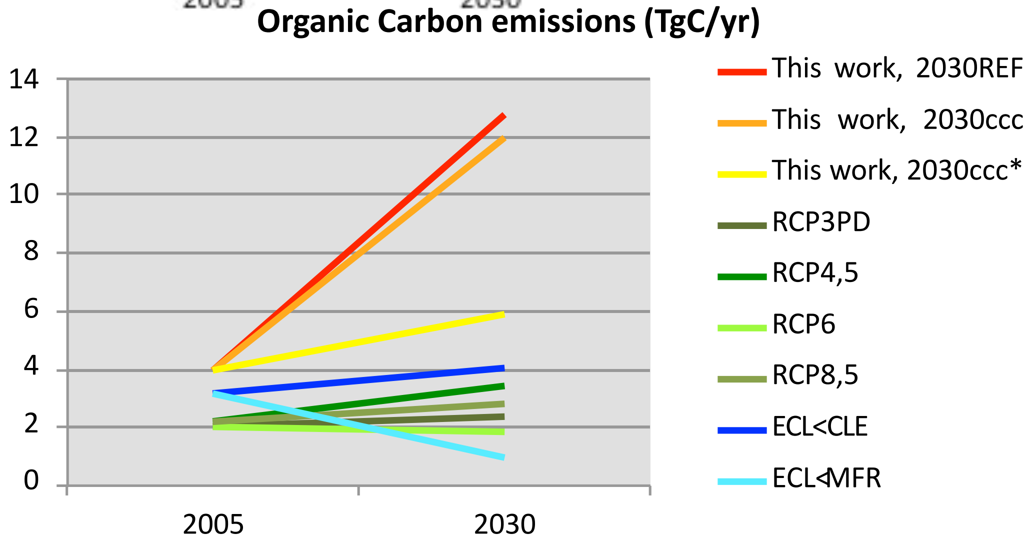
The most uncertain parameter is the vegetation : urgent need of measurements over Africa

Ndatchoh Touré et al., 2016

Anthropogenic emissions in Africa : Liousse et al., 2014/Global inventories

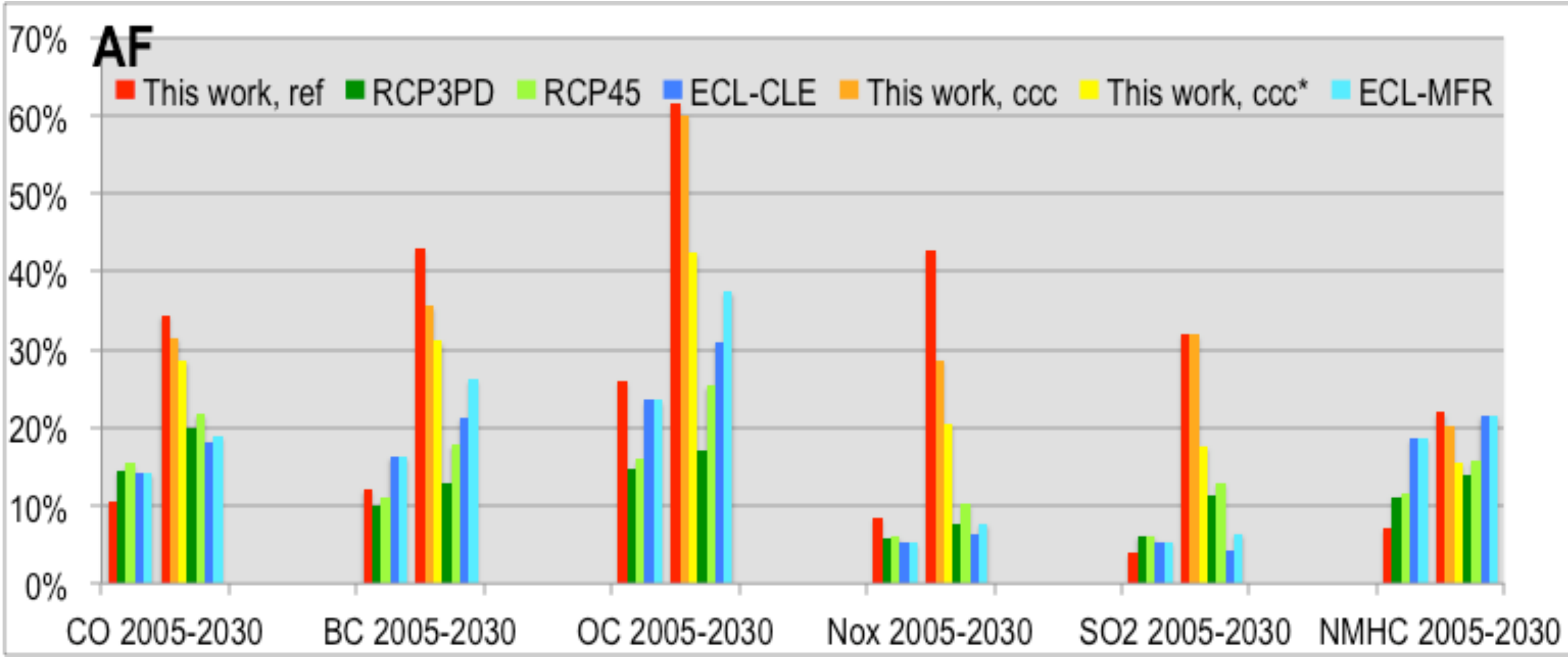


Present BC : similar except ECL
Large range in BC projections



Present OC : a factor of 2 of difference
Large range in OC projections
L14 ref and ccc highly different than other projections
Other projections closer than L14 best « perfect » ccc scenario*

Anthropogenic emissions in Africa : Liousse et al., 2014/Global inventories



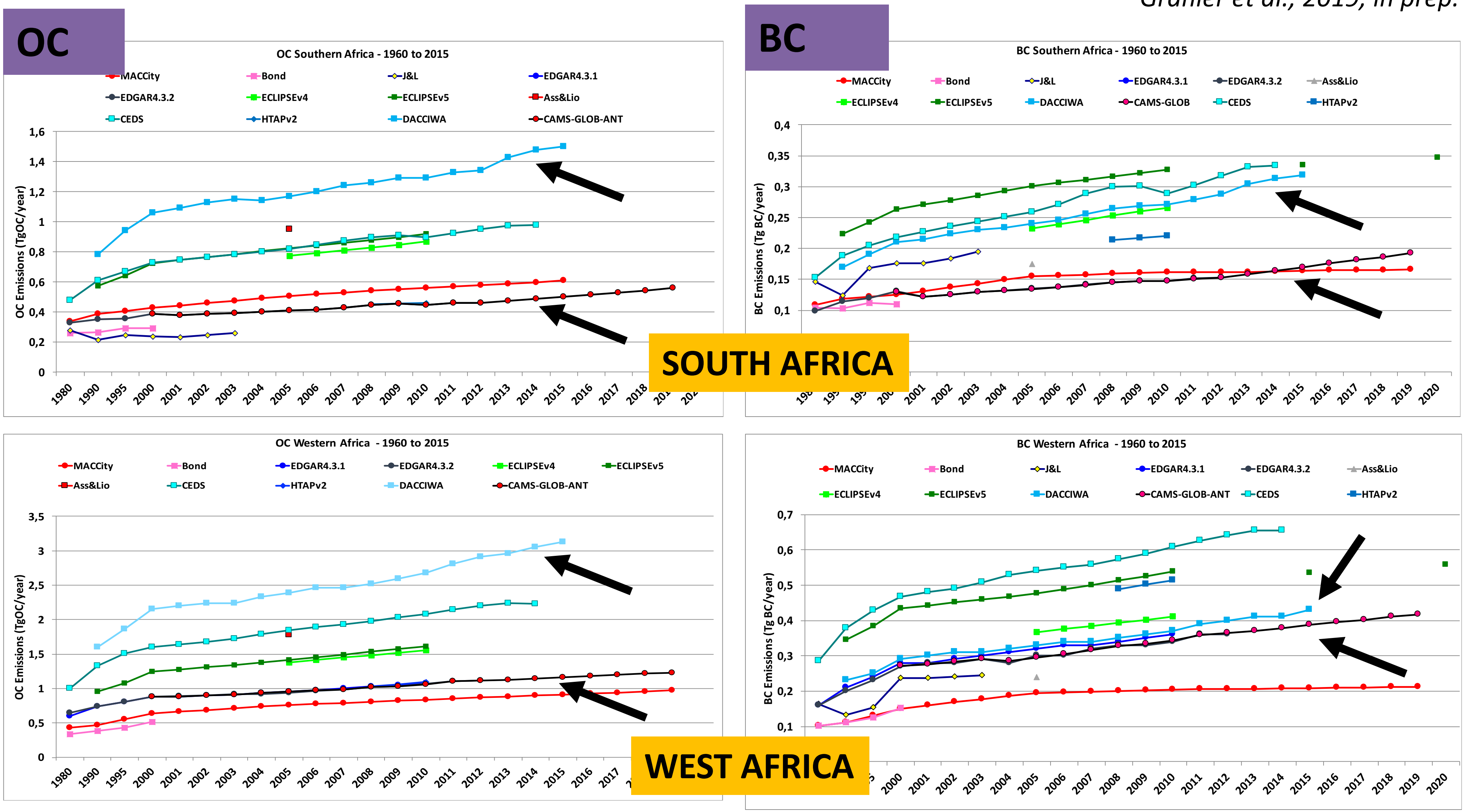
African relative contribution to the global total anthropogenic combustion emissions (biomass burning excluded)

For OC : 25% in 2005 => 60% in 2030 !

=> In that case, relative importance of Africa would be higher than inAsia

Anthropogenic emissions in Africa : DACCIWA / Other inventories

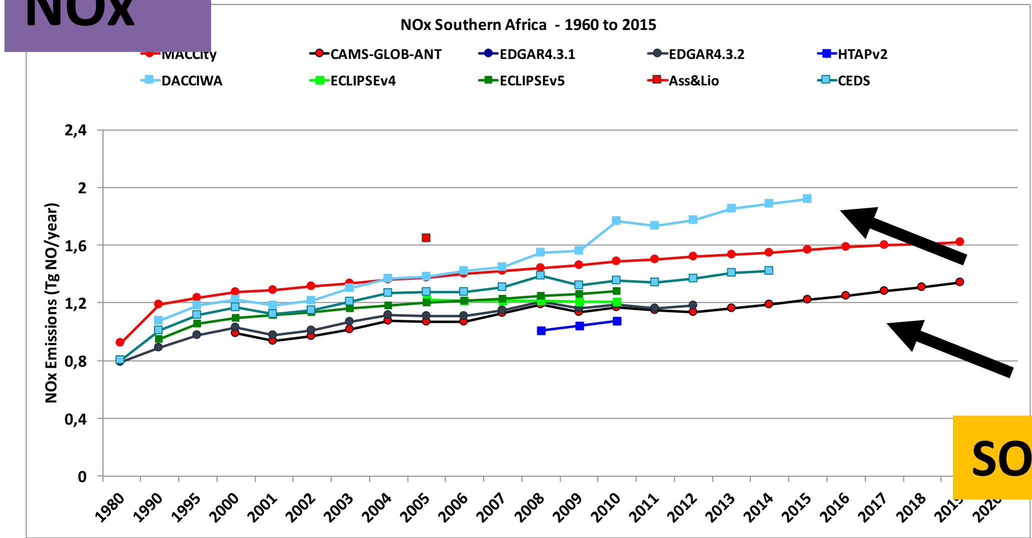
Granier et al., 2019, in prep.



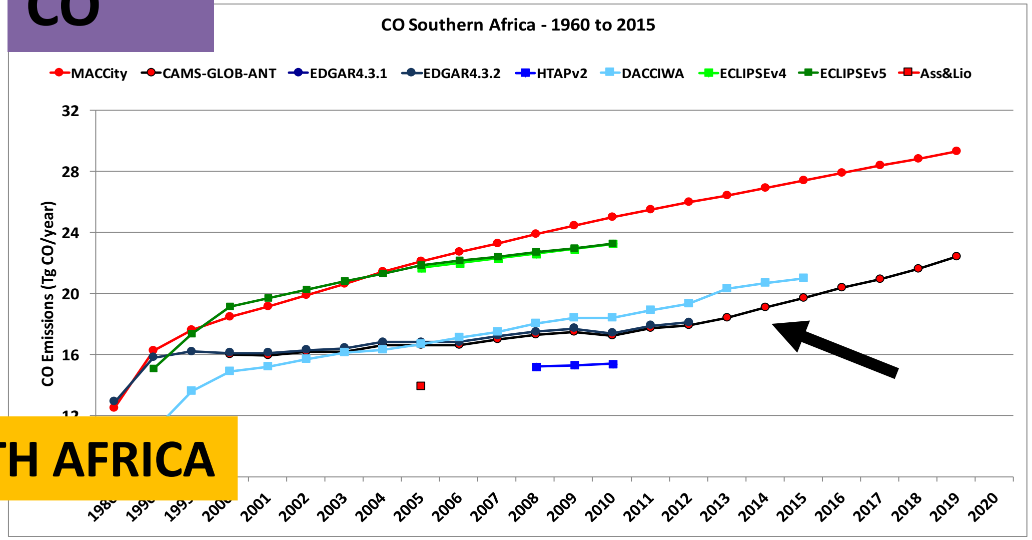
Anthropogenic emissions in Africa : DACCIWA / Other inventories

Granier et al., 2019, in prep.

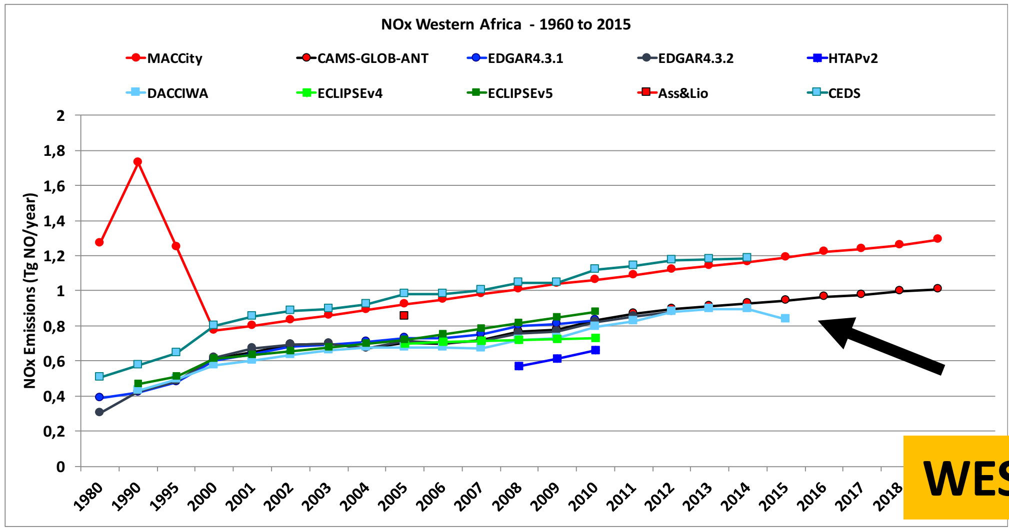
NOx

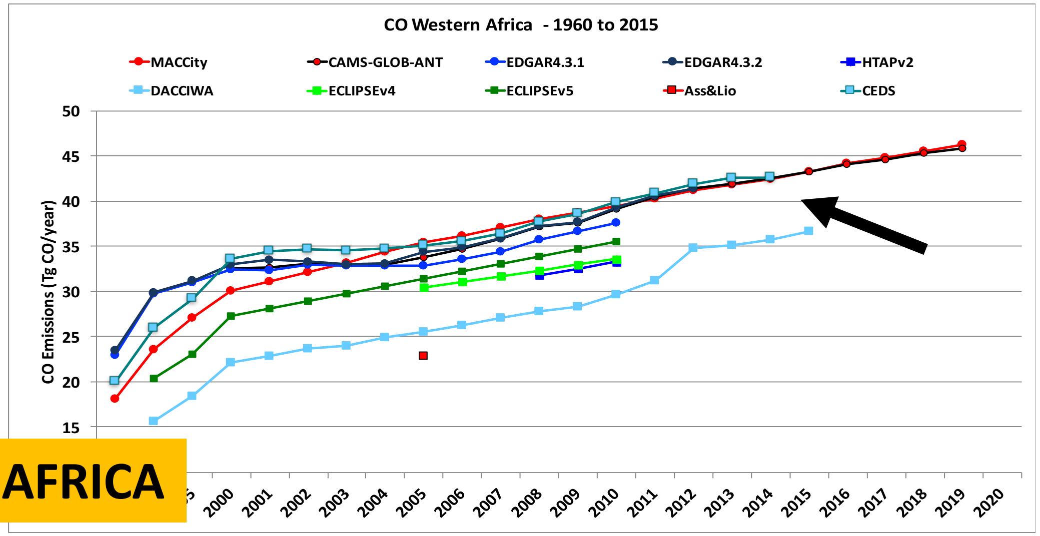


CO



SOUTH AFRICA





WEST AFRICA

How to limit uncertainties on Emissions inventories

- Emission inventories for gases and particles (same ancillary data)
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- Emission experiments (Lack of EF for some species and some sources/ properties..)
- Organic budget : VOC/SVOC/POC
- Temporal variations (diurnal/seasonal/interannual/projections)
- Spatialization keys
- by including these inventories in multi scale models and comparing modeled and measured pollutant concentrations and/or optical properties

Emission experiments


- Valus of EF given for EPA can not be worldwide used (age of the car, fuels..)

- Need to document both gases and particles with size chemical speciation

- Different methodologies to measure EF : need to be harmonized

- ✓ g of species/kgCburnt (C is refered to CO+CO2)
- ✓ on-line gas chromatographs with tracer (e.g. n-propane)
- ✓ Flux measurements (tower+receptor model)
- ✓ Traffic : Motor test bench, field measurements (behind vehicles), tunnel experiment…
- ✓ Which solutions for sources with high stacks (industries, power plant ..)?
- ✓ Laboratory/Field measurements

- Not wellknown sources : flaring, ships ...

How to limit uncertainties on Emissions inventories

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Next generation of POA emissions

- OC from POA and (ASOA and BSOA) formation from VOC (GEOS-chem, MACC (regional/global), …) => need POA and VOC emission inventories

- If more details in the chemistry scheme (e.g. part of POA after emissions is revolatilized into SVOC species, see Robinson, Donahue, Pandis, Couvidat .. Works), need to develop new emission inventories either for POA, SVOC and VOC

VOC speciation

- in the different existing emission inventories, this speciation is often based on a UK NAEI studies. Ugent need of experiments!

How to limit uncertainties on Emissions inventories

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- Local/Regional/Global inventories Emission inventory intercomparisons
- Emission experiments (Lack of EF for some species and some sources/properties..)
- Organic budget : VOC/SVOC/POC/WSOC
- Temporal variations (diurnal/seasonal/interannual/projections*)
- Spatialization keys
- Missing sources (road dust resuspension, electonical waste burning..) and new species of interest (PAH, WSOC, SVOC ..)
- by including these inventories in multi scale models and comparing modeled and measured pollutant concentrations and/or optical properties

**: with regional specific scenarios with socioeconomists*

NEW WORKING GROUP

Cathy Liousse, Mogesh Naidoo, Sekou Keita

Next meeting : November 6 at 12:00 in GEIA Conference at Santiago (Chile)

GEIA Africa Emissions Working group

GEIA's AFE WG is promoting community efforts in emission development for Africa. The working group consists of a list of members, which is in construction, to create a network on emissions with strong connections between experts (African and non-African) on African emissions, representatives of international groups and projects such as IGAC, IGAC-Africa ANGA, WMO, ILEAPS, AMIGO, MAP-AQ, IBBI, DEBITS, PASMU, LIA-ARSAIO etc .. and regional decision makers. The WG is currently planning :

- To evaluate African-specific emission inventories.
- To consider specific emissions in Africa, for each sector from regional to city spatial resolution.
- To create a regional database including local informations on fuel activity and consumption, emission factors and emission inventories. This database will deal with sources for present, historical and future emissions including mitigation scenario.
- To develop a continental wide African emission inventory, with the most recent DACCIWA inventory as a baseline and local informations (e.g. Doumbia for Cote d'Ivoire, South Africa new inventory …)
- To organize training sessions on emissions in Africa.