Modelling African Aerosol using regional fossil fuel and biofuel emission inventories for 2005 and 2030

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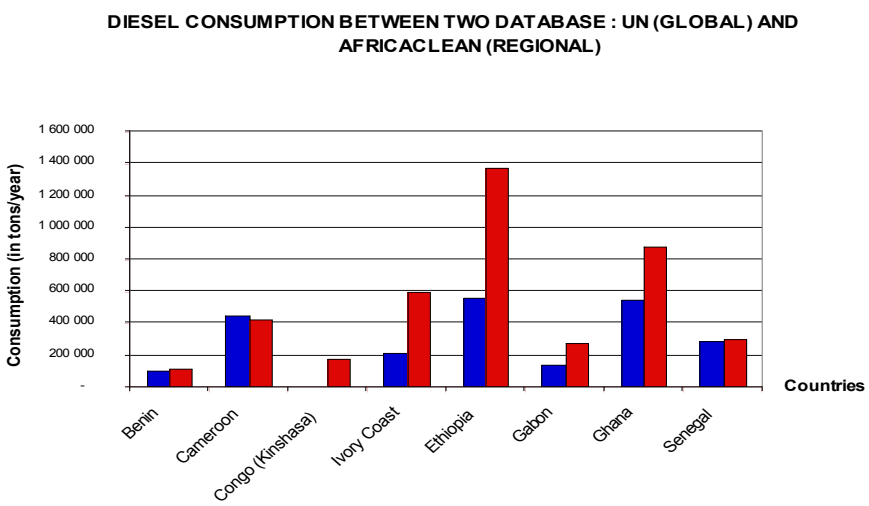
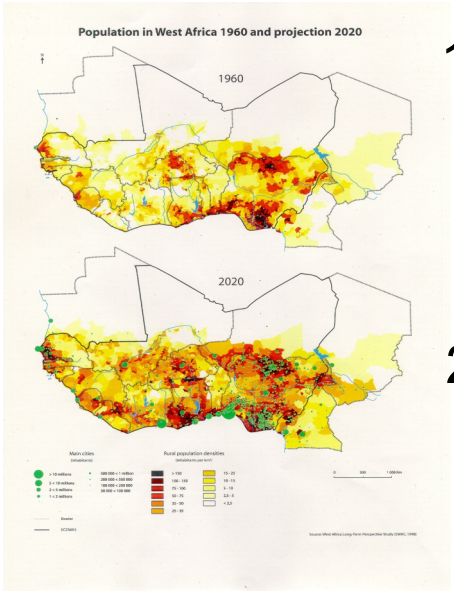
Thanks to different african institutes and persons for all the regional emission data.

Paper in preparation

❖ Preliminary…

- ➢ First AMMA modeling (ORISAM-TM4 & RegCM) have used global fossil fuel and biofuel source inventories to study african aerosol impact with problems to reconstruct AOD along the Guinean Gulf
- ➢ Important discrepancies between global inventory and regional zoom obtained with Africaclean database for the traffic emission inventory
- ➢ Projections in the future; our concern : the expected population increase …..





1960

Population

2020

Methodology to develop african fossil fuel and biofuel inventories for 2005

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

⇒E(kg)/country = C(t)/sector x EF(kg/t)
With activity sectors : traffic/domestic/industry/power plant

⇒Taken into account african specificities (high EF, high CO/CO2 ..)
Assamoi and Liousse 2010, Liousse et al., 2011

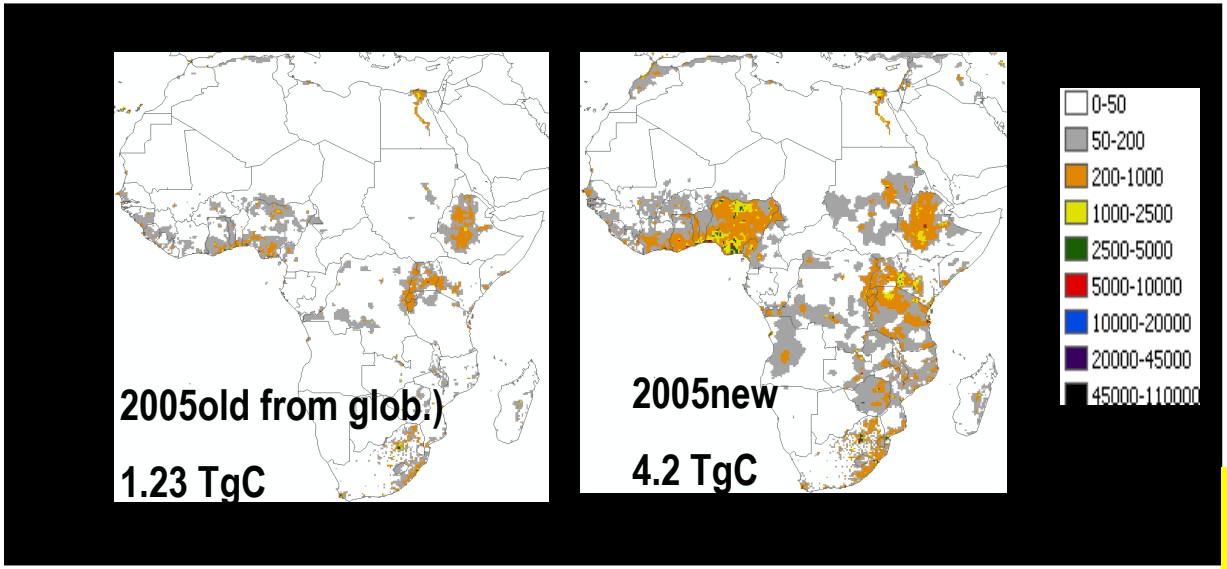
Future BC and OC projections over Africa

New projections by using our present new regional inventory of 2005 and the **POLES** model (Criqui et al.) including both **fossil fuel and biofuel emissions** (fuel/activity**).**

Reference scenario : Reflect the state of the world with what is actually embodied as environmental policy objectives (2000)
CCC scenario : Introduction of carbon penalties as defined by Kyoto for 2010 and a reduction of 37 Gt of CO2 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**

EFs for the Reference scenario : equal to today's
Reduction of EF for the CCC scenario :
Developed countries : based on removal efficiency forecast by the IIASA Rains model
Semi-Developed countries : EFs of developed countries of 1997
Under-Developed countries : EFs of semi-developed countries of 1997

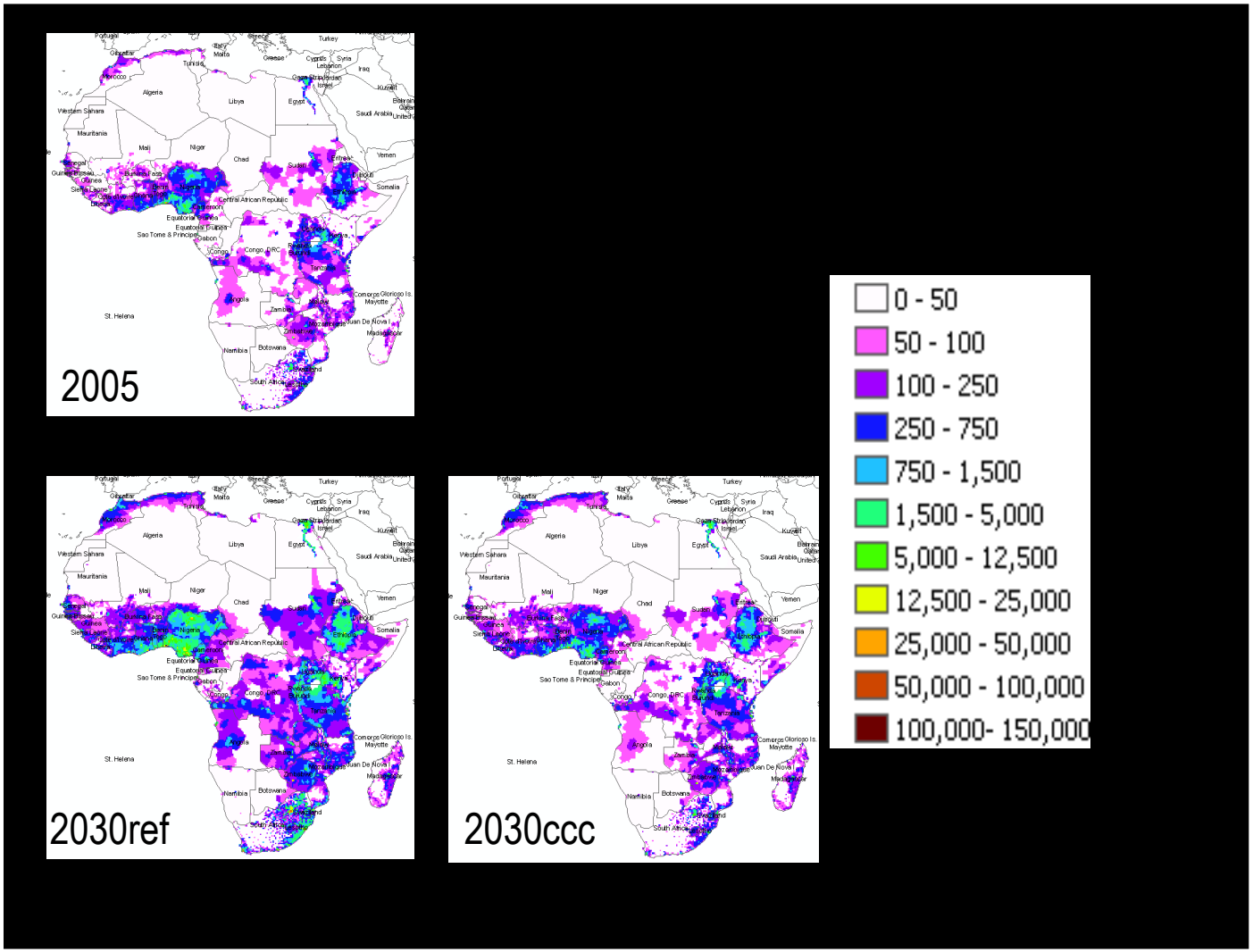
Regional distribution of OC emissions

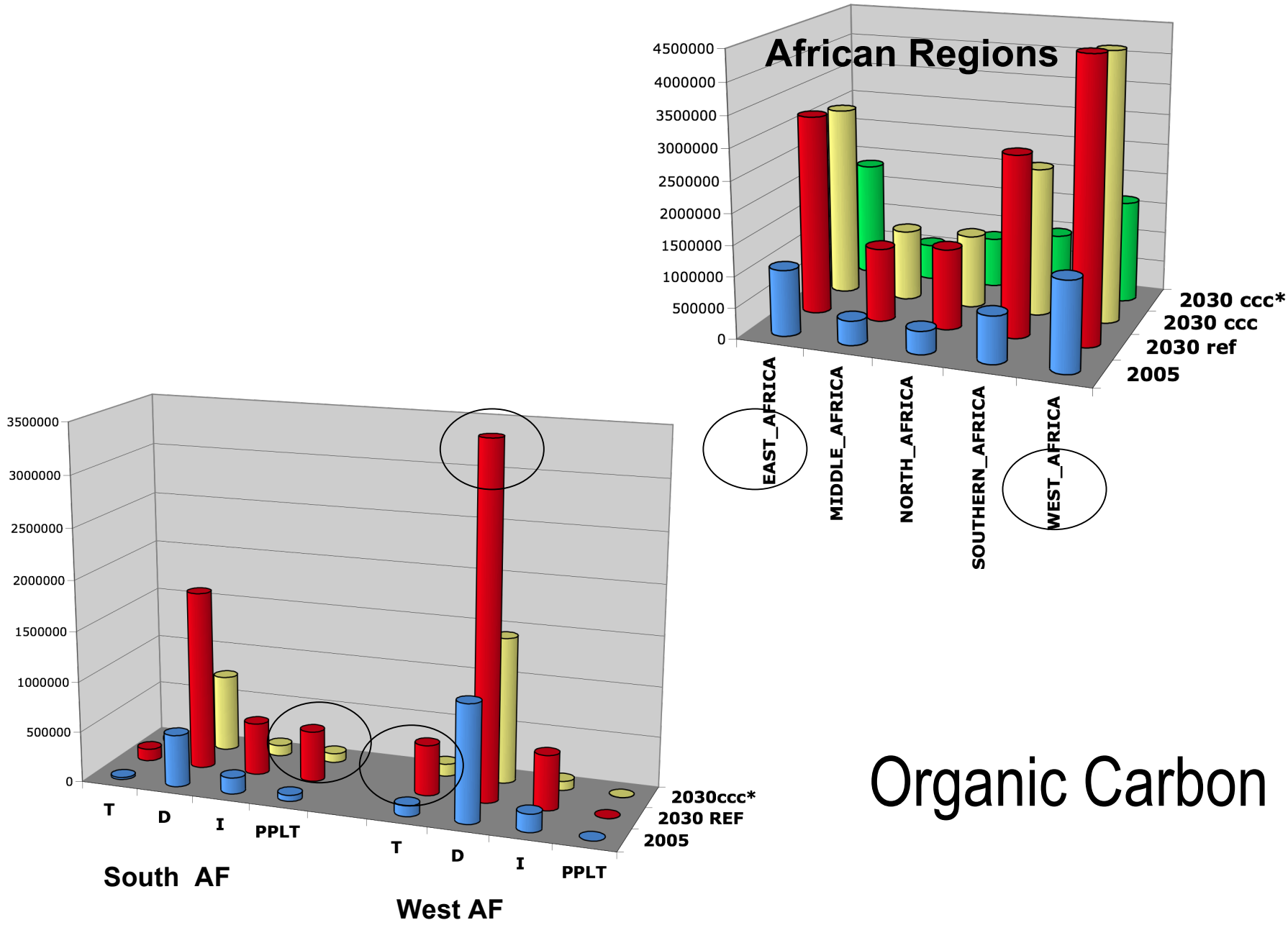


COUNTRIES	OC emissions (tons/year) OLD UN	NEW REG	CHANGE
ALGERIA	5194,53	6418,39	0,24
BENIN	**526,78**	**6305,62**	**10,97**
BURKINA_FASO	**322,83**	**1716,87**	**4,32**
CAMEROON	1202,43	1639,51	0,36
CHAD	95,02	147,83	0,56
EGYPT	29313,70	47613,26	0,62
GHANA	2019,91	2805,84	0,39
GUINEA	226,94	603,21	1,66
GUINEA-BS	56,98	86,76	0,52
IVORYCST.	1025,37	1731,19	0,69
LIBERIA	65,32	109,78	0,68
MALI	**258,45**	**2514,30**	**8,73**
MOROCCO	2742,73	5405,56	0,97
NIGER	426,14	512,48	0,20
NIGERIA	**9140,94**	**37892,97**	**3,15**
SENEGAL	1398,47	1355,32	0,00
SIERRALEO	122,47	239,93	0,96
TOGO	**342,00**	**1603,53**	**3,69**

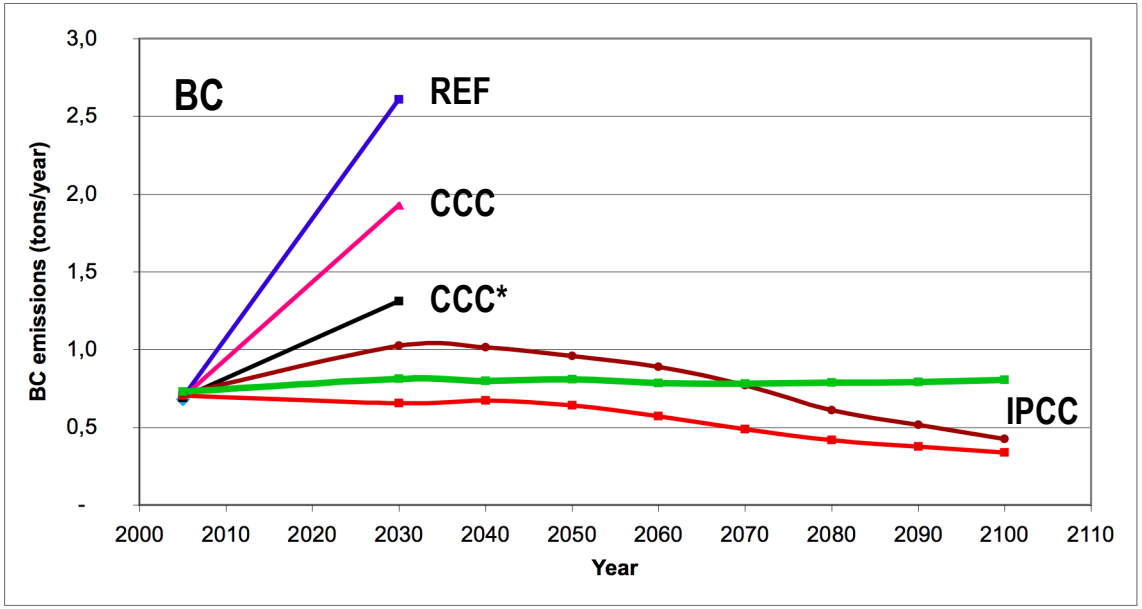
For BC :
BC old : 0.80 TgC
BC new : 0.82 TgC

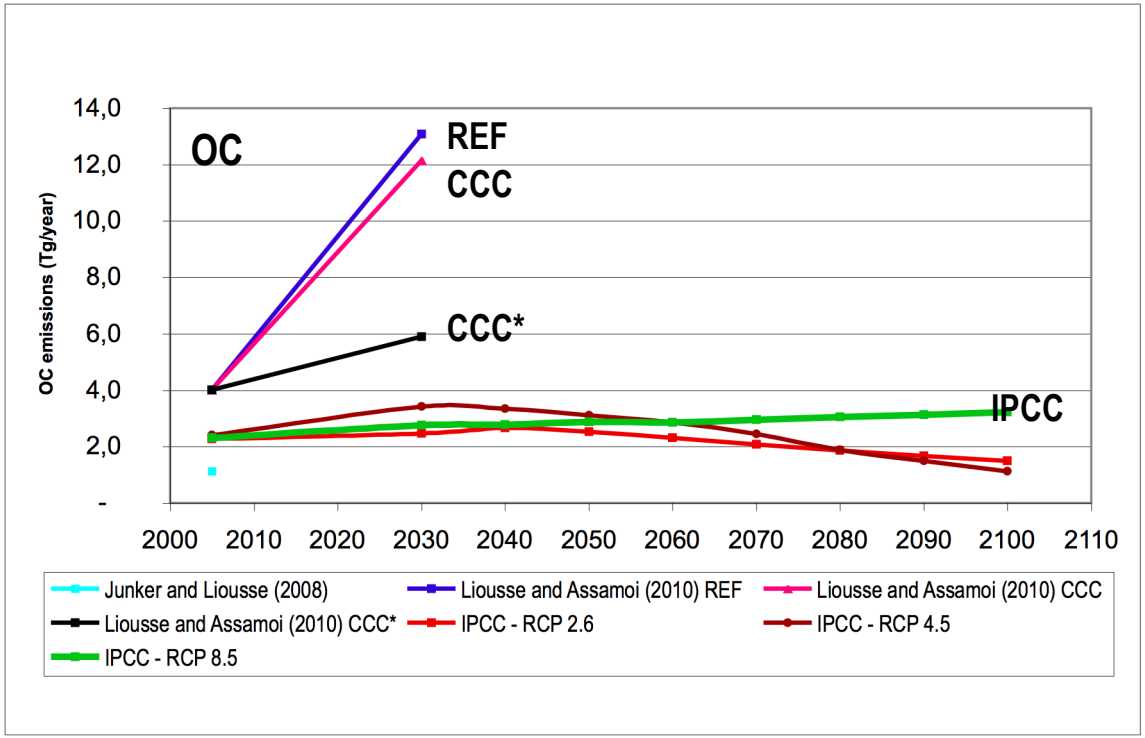
Future Projections of OC emissions





Organic Carbon





Comparison with ACCMIP/RCP

(Lamarque et al., 2011)

ORISAM-TM5 Model description => BC and OC concentration fields

❖ **TM5 standard version**

- 6°x4° global, 3°x2° and 1°x1° over Africa

- 25 vertical levels : 1010 hPa to 0.47 hPa

- Off-line meteorology (ECMWF)

-Wet deposition by stratiform/convective precipitation

❖ **Augmented with ORISAM** (traceur mode : Guillaume et al., 2007)

-6 size bin distribution of aerosol mass concentrations in a sectional aerosol model

-4 aerosol species : BC hydrophilic; BC hydrophobic; OC hydrophilic; OC hydrophobic

❖ **Global and regional BC and OC emissions**

- Biomass burning AMMABB (Liousse et al., 2010)

*- Fossil fuel and biofuel (Assamoi and Liousse, 2010, Liousse et al (2011) for **2005, 2030ref and 2030ccc*,** Junker and Liousse 2008)*

Off-line model *(Wang and Penner, 2009)*=> AOD, Aerosol Direct Effect (ADE)

- Externally mixed of BC and OM emitted from biomass burning over Africa

- Hydrophobic BC with hygroscopicity fact. bbc = 5.e-7

- OM contains 30% hygroscopic materials as ammonium sulfate with bom = 0.14

- ρ_{BC} = 1.8 kg/m^3; ρ_{OM} = 1.0 kg/m^3;

- BC size dist.: Mallet et al., 2003 (r_g=0.028 µm; σ_g=1.94)

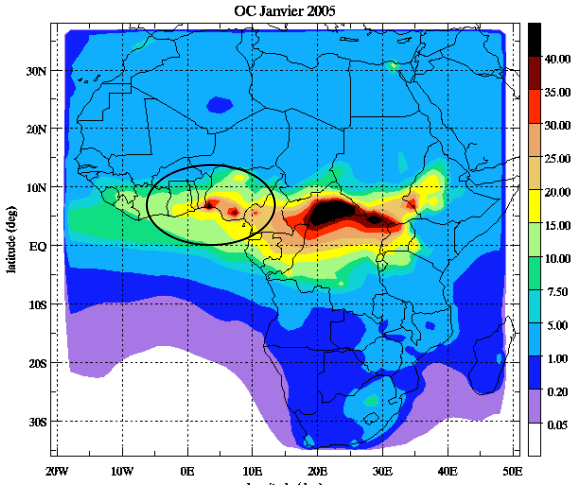
- OM size dist.: Zhang et al., 2005(JGR) (r_g=0.077 µm; σ_g=1.0)

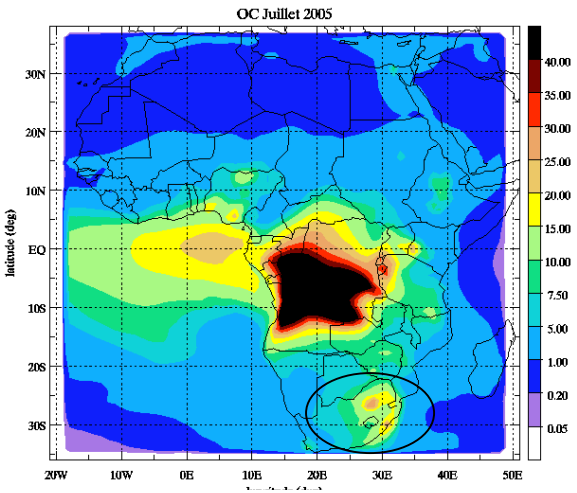
- BC=> 1.76-0.46i (Bond and Bergstrom), 2006; OM=>1.53-0.03i (Kirchstetter et al., 2004)

Jn 2005

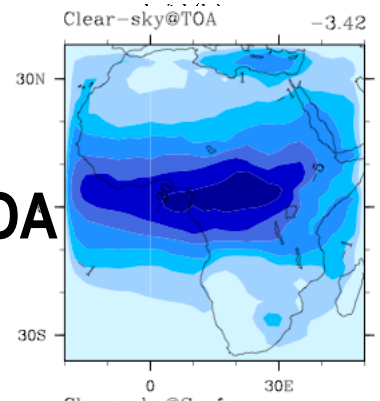
Jl 2005

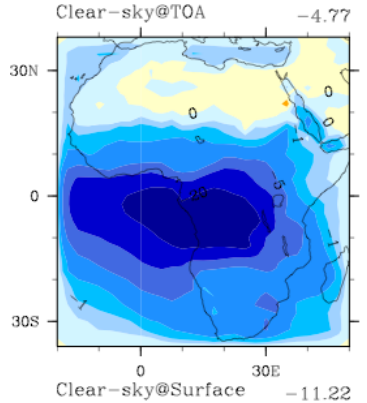
OC (µg/m3)





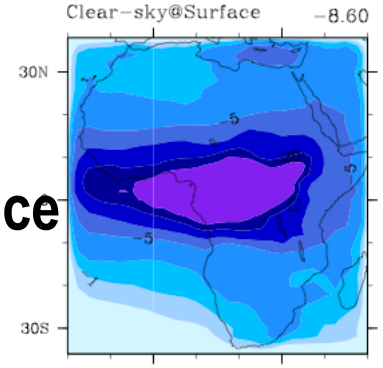
TOA

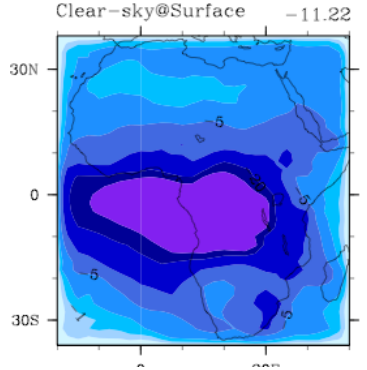


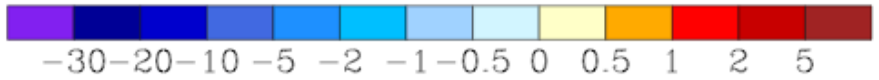


ADE (W/m2)

Surface



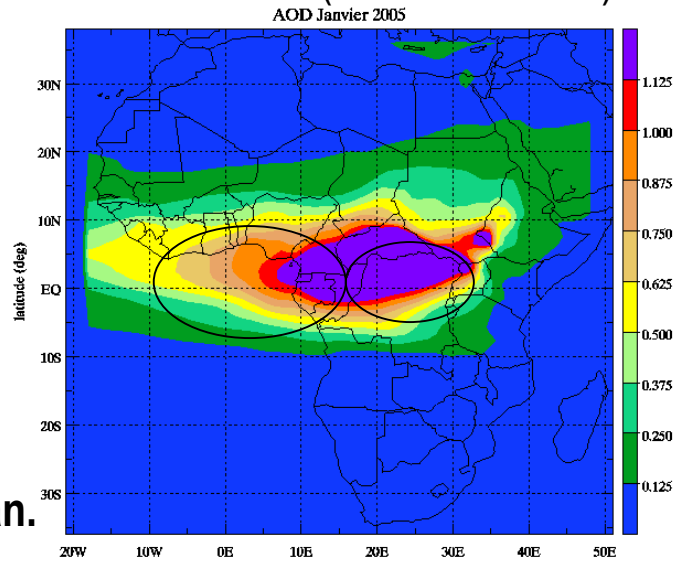




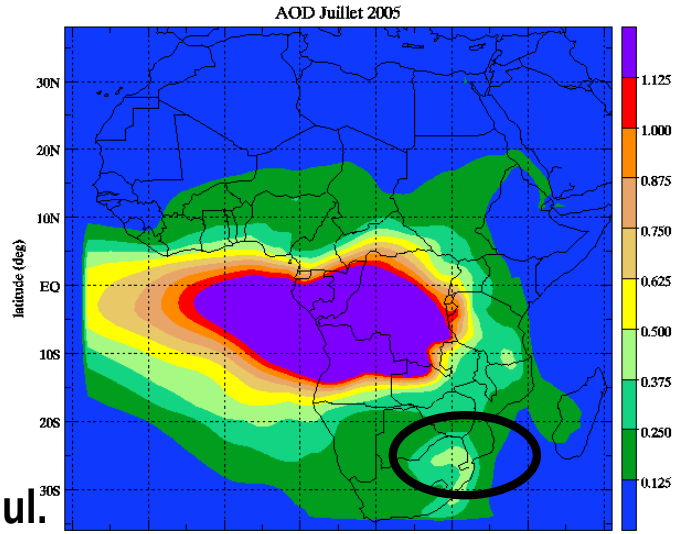
In agreement with RegCM3 studies
on BB (Malavelle et al., Tummon et al.)

Comparison with satellite data (AOD 550 nm) for 2005 …

TM5 Model (no-dust version)



Jan.



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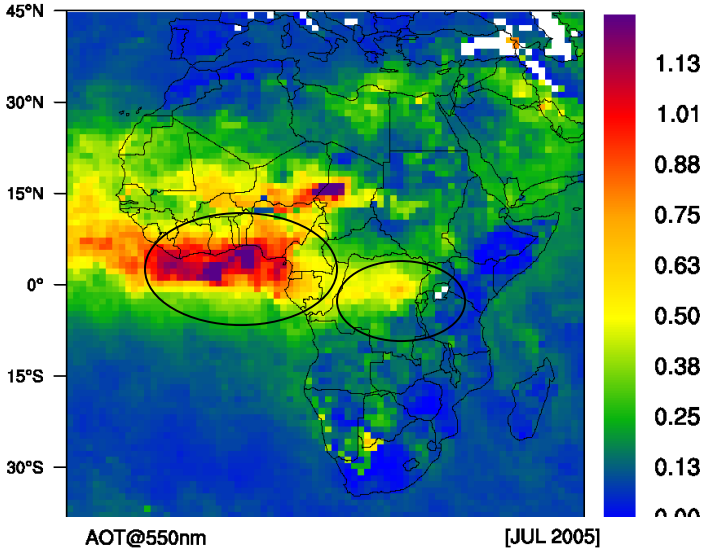
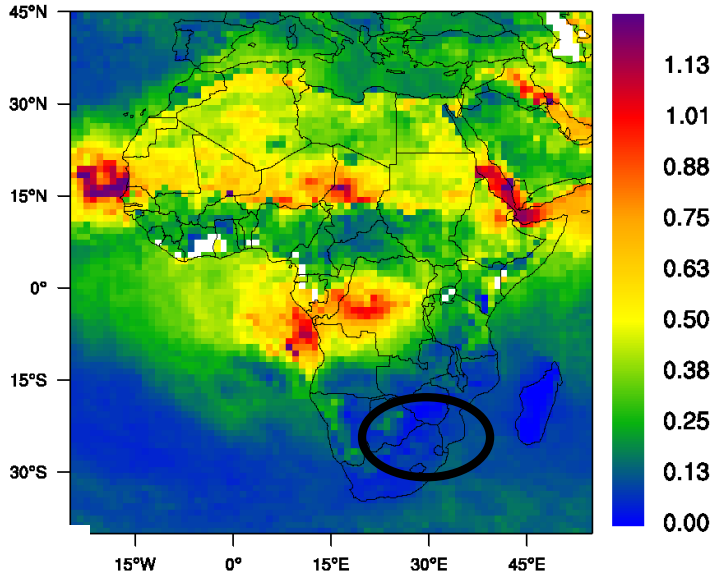
MODIS



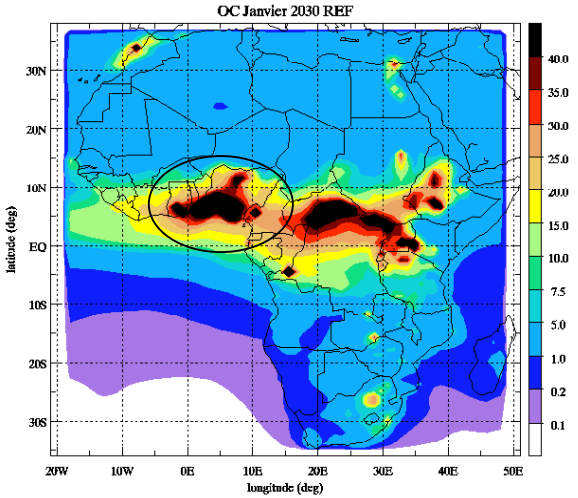


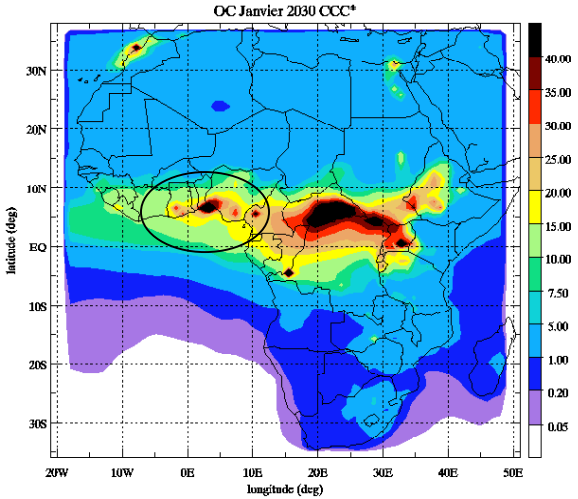
In agreement with RegCM3 studies
on BB (Malavelle et al., Tummon et al.)

2030ref 2030ccc*

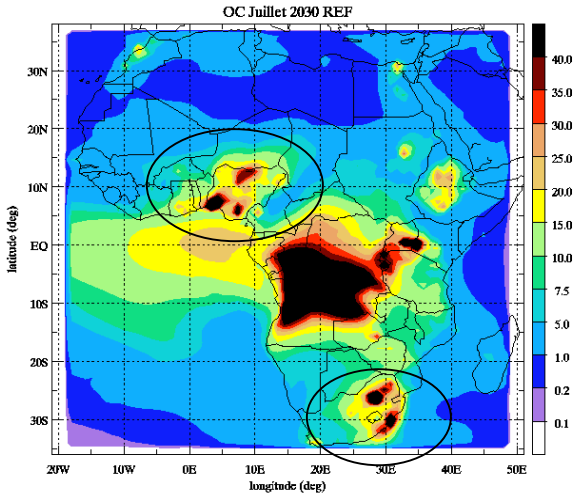
OC (µg/m3)

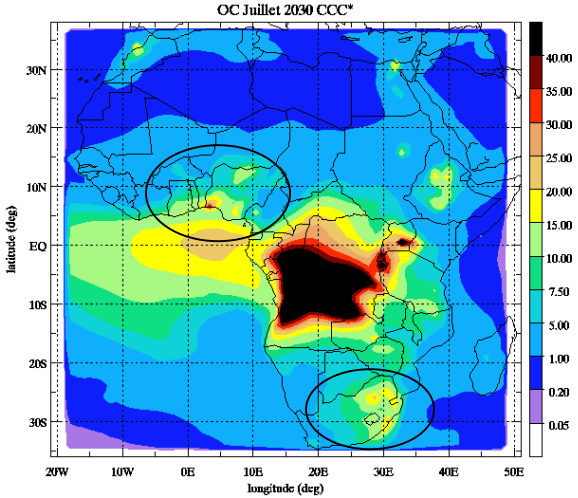
Jn



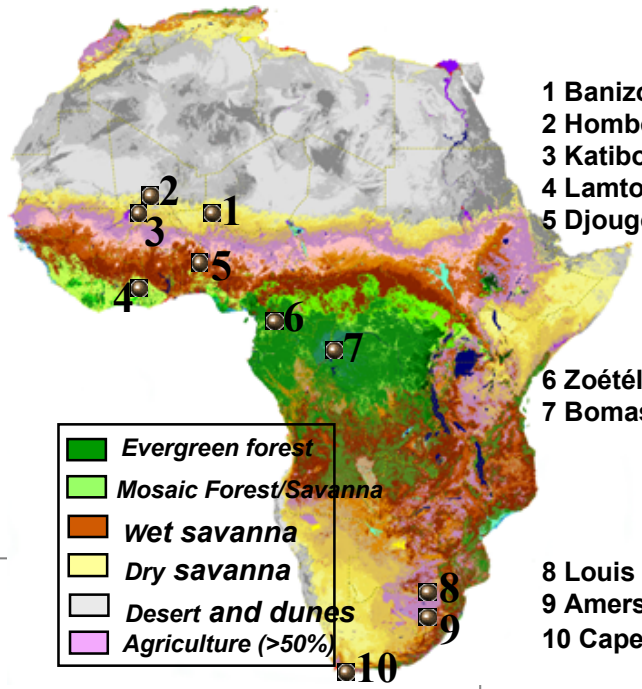


Jl





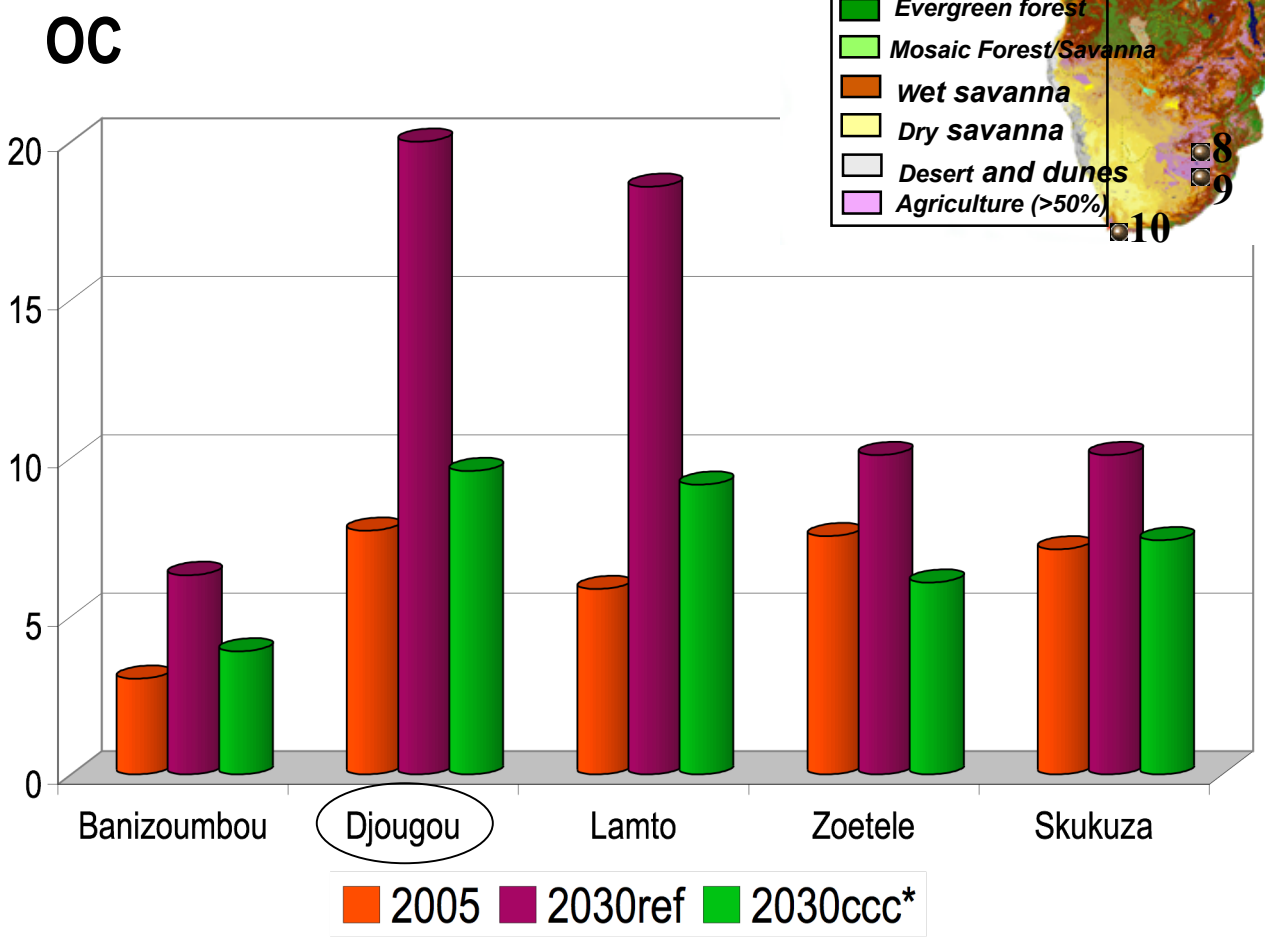
IDAF rural sites : are they affected?



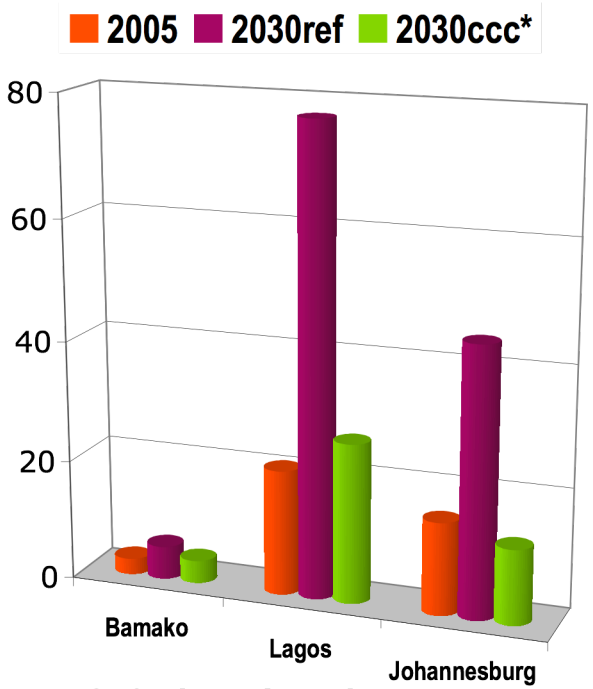
1 Banizoumbou (Niger)
2 Hombori (Mali)
3 Katibougou (Mali)
4 Lamto (Côte 'dIvoire)
5 Djougou (Benin)

6 Zoétélé (Cameroon)
7 Bomassa (Congo)

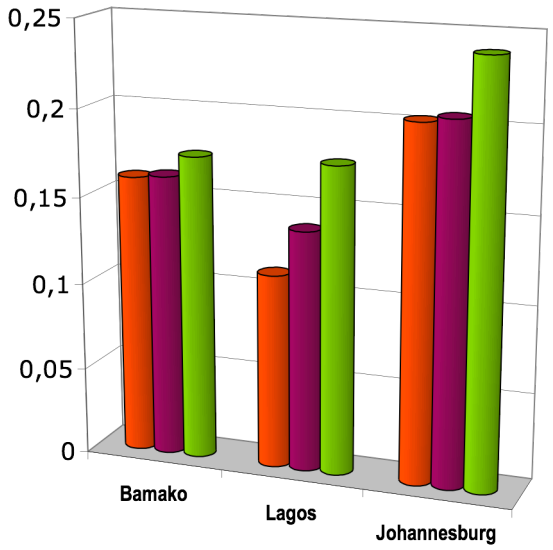
8 Louis Trichardt (SA)
9 Amersfoort (SA)
10 Cape point (SA)



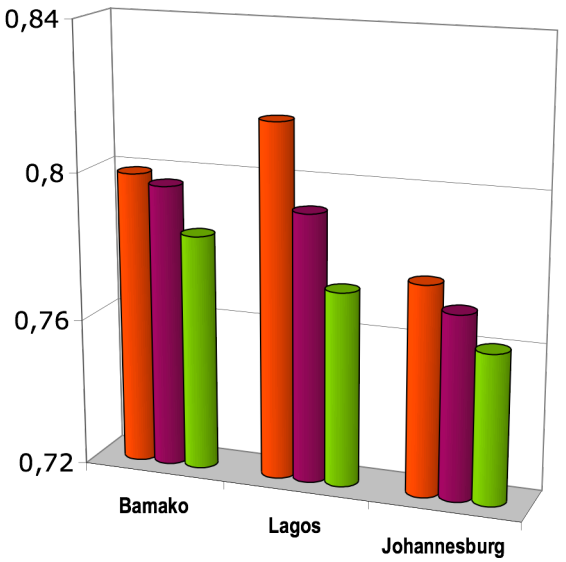
Urban sites : how are they affected? …



OC (µg/m3)



BC/OC

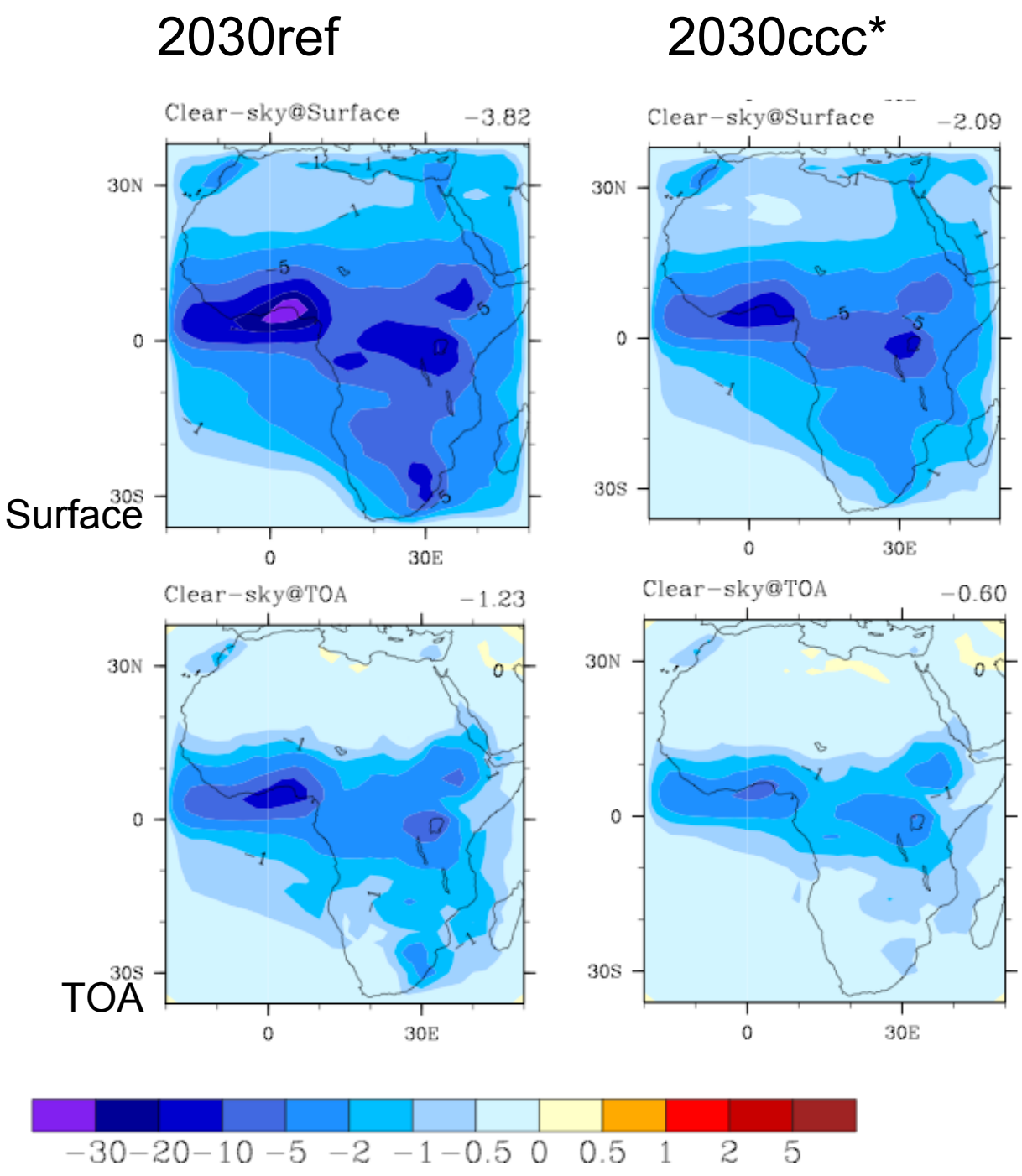


SSA

Less OC => Air quality improvement
our first results on
aerosol toxicological effect :
OC more biologically active than BC

More BC/OC, Less SSA => More Absorption

SW forcing FF only



More heating in 2030ccc*!

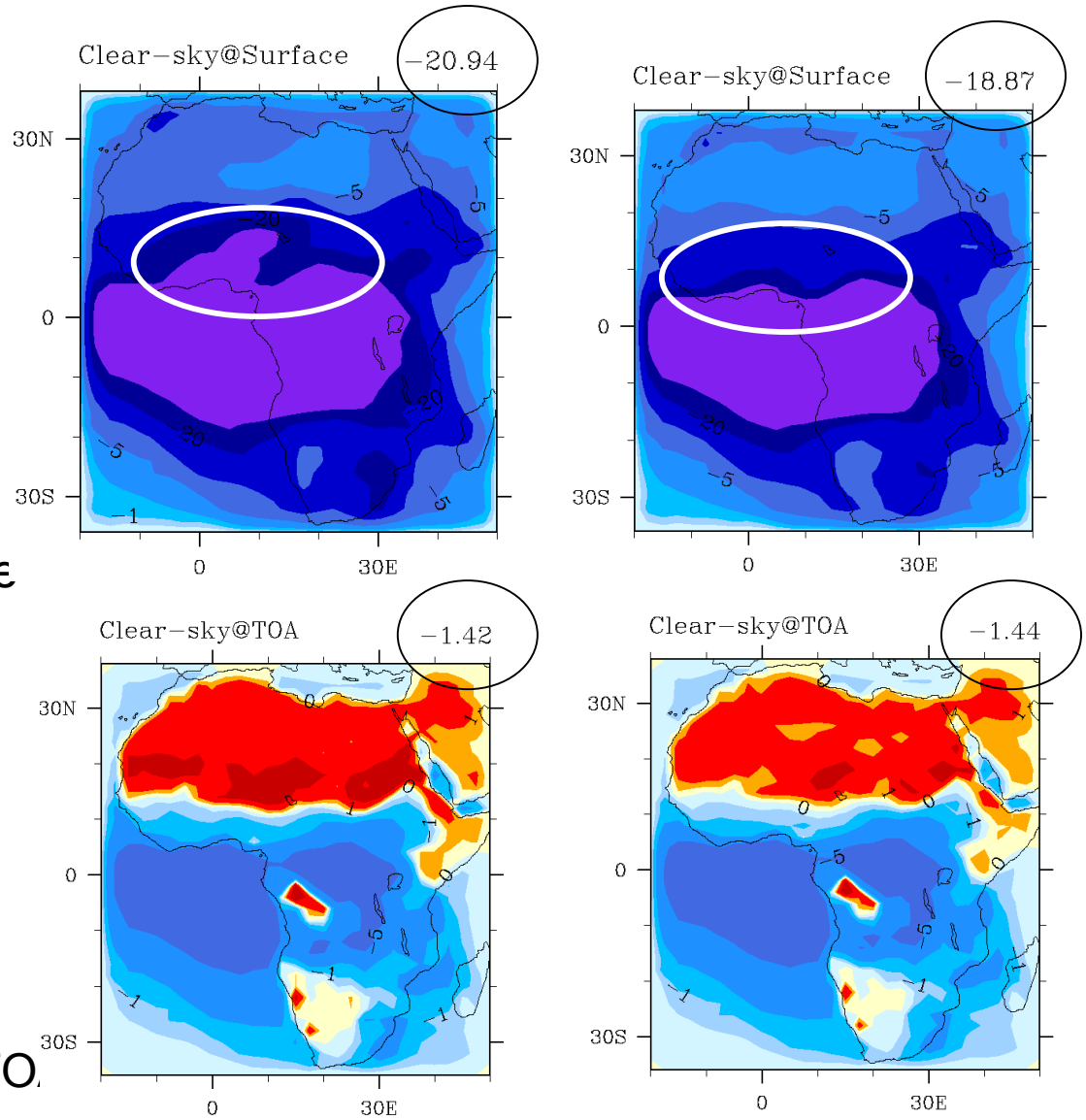
SW forcing FF + BB

July 2030ref

July 2030ccc*

Surface

TOA



More surface heating in 2030ccc*!

TOA of the same order in 2030ccc*!

CONCLUSION and PERSPECTIVES

- **How to use?** : regional inventories very different than ACCMIP and RCP
- **On going:**

Sensitivity tests on optical properties *(OC absorption : Alexander et al., 2008 =1.67-0.27i for brown carbon, different properties for BB and FF ..)*

Emission inventory improvement :

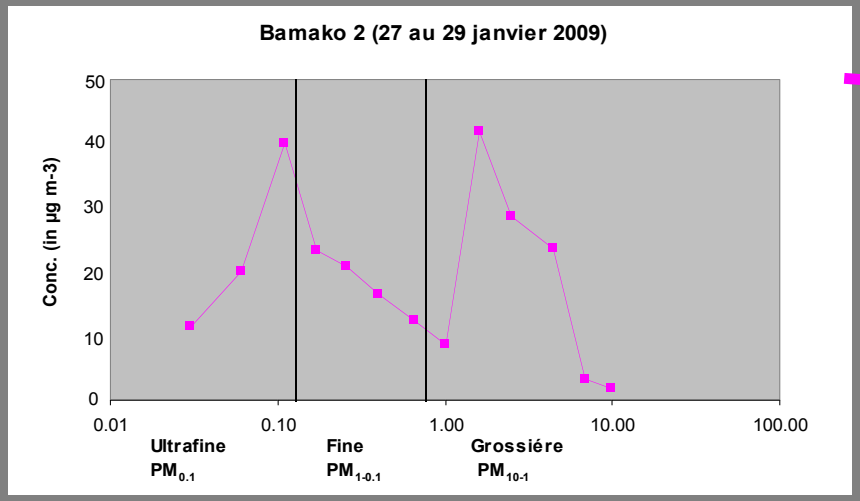
South Africa : emission factor measurements for domestic fire (townships) and power plant emission (collab. K. Pienaar NWU, S. Picket CSIR)
Northern Africa: a zoom within Charmex program
West Africa: to develop an inventory for « flaring » emissions (AOD in Guinean golf?)

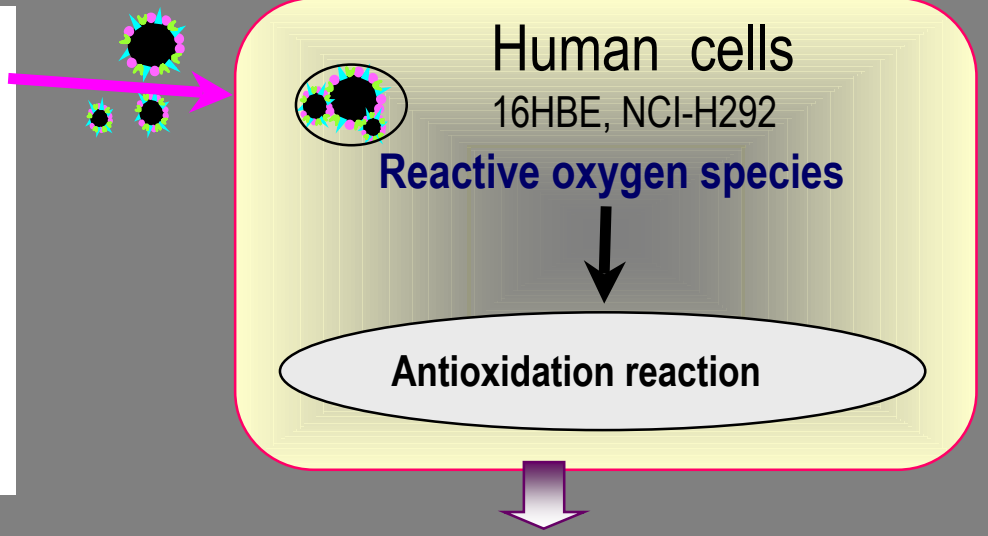
Regional climatic impact of present and future African BC and OC aerosols (RegCM3)

URBAN long term measurements (by type of sources) in Africa (GDRI, IDAF, IRD)

⇒ IMPACTS : how to mitigate?
First results : « best scenario (2030ccc*) » => BC/OC increase
++ for air quality : OC has been shown to be more «biologically reactive» particle than BC
- - for climate change : relative increase of heating !!

Thank you for your attention!!

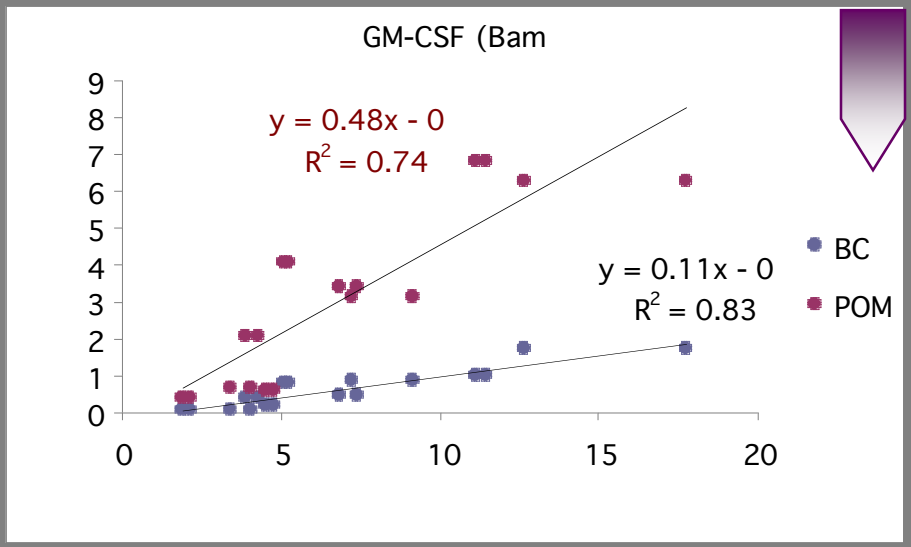




pro-inflammatory response with Cytokines secretion (GM-CSF, IL-8…)

Biomarkers

Bamako



Physicochemical works : phD T. Doumbia EDI; In vitro experiment : Baeza A., S. Val and I. George

Focus on Western African fossil fuel emissions

Following a questionary sent to all african countries here are the fuel consumptions we collected =>

(11 answers/26 african countries)

PAYS	SOURCE CONSO		
	C	D	I
ALGERIA	REG	REG	REG
ANGOLA	UN	UN	UN
BENIN	REG	REG	UN
BOTSWANA	UN	UN	UN
BURKINA_FASO	REG	REG	REG
BURUNDI	UN	UN	UN
CAFRREP	UN	UN	UN
CAMEROON	REG	UN	UN
CAPEVERDE	UN	UN	UN
CHAD	REG	UN	UN
COMOROS	UN	UN	UN
CONGO	UN	UN	UN
DJIBOUTI	UN	UN	UN
EGYPT	REG	UN	UN
EQGUINEA	UN	UN	UN
ETHIOPIA	UN	UN	UN
GABON	UN	UN	UN
GAMBIA	UN	UN	UN
GHANA	REG	UN	UN
GUINEA	REG	UN	UN
GUINEA-BS	REG	UN	UN
IVORYCST.	REG	REG	REG
KENYA	UN	UN	UN
LIBERIA	REG	UN	UN
LIBYA	UN	UN	UN
MADAGASCR	UN	UN	UN
MALAWI	UN	UN	UN
MALI	REG	UN	UN
MAURITANI	UN	UN	UN
MAURITIUS	UN	UN	UN
MOROCCO	REG	REG	REG
MOZAMBIQU	UN	UN	UN
NAMIBIA	UN	UN	UN
NIGER	REG	UN	UN
NIGERIA	REG	REG	REG
REUNION	UN	UN	UN
RWANDA	UN	UN	UN
SAFRICA	UN	UN	UN
SAOTOME&	UN	UN	UN
SENEGAL	REG	UN	UN
SEYCHELLS	UN	UN	UN
SIERRALEO	REG	UN	UN
SOMALIA	UN	UN	UN
STHELENA	UN	UN	UN
SUDAN	UN	UN	UN
SWAZILAN	UN	UN	UN
TANZANIA	UN	UN	UN
TOGO	REG	UN	UN
TUNISIA	UN	UN	UN
UGANDA	UN	UN	UN
W.SAHARA	UN	UN	UN
ZAIRE	UN	UN	UN
ZAMBIA	UN	UN	UN
ZIMBABWE	UN	UN	UN

Methodology to develop african fossil fuel and biofuel inventories for 2005

⇒A bottom up inventory : **E(kg)/country = C(t)/sector x EF(kg/t)**
With activity sectors : traffic/domestic/industry/power plant

Data consumption :
- Local inquiries including Africaclean results (see diesel data)

Where no available :
- United Nations database for fossil fuel (industry and domestic)
- International Energy Agency data (power plants)
- updated Brocard (1996) for biofuel (fuelwood and charcoal)

Assamoi & Liousse (2010) for two-wheel inventory with the maximum scenario (with measured EF)

Emission factors depending on fuel/activity sectors/technology

A proxy method for technology and norms by using GDP : semi developed/developing countries

Data from : AMMA 2005 campaign in Cotonou (Guinot et al. 2011)
POLCA campaigns in Dakar and Bamako
Junker and Liousse 2008
Bond et al. 2004

« Regional » *resolution* grid for mapping emission (country=>regional distribution) :

- 0.25°x0.25°(SEDAC : http://sedac.ciesin.columbia.edu/)