Evaluation of Global Biomass Burning Carbon Emission Estimates using Fire Radiative Power and Aerosol products from MODIS

Eric Vermote, UMCP,
Oleg Dubovik, Université des Sciences et Technologies de Lille, France,
Nazmi Saleous, United Arab Emirates University, UAE,
François Petitcolin, ACRI-USA,
Tatyana Lapyonok, Science Systems & Applications (SSAI),
Yoram Kaufman and Mian Chin, Goddard Space Flight Center, and
Louis Giglio, SSAI, and Evan Ellicott, UMCP

Fire has a unique impact on the biosphere

-Aerosol and gas emissions
atmospheric and surface radiative forcing

-Modification of the surface albedo
live biomass to burned area conversion

- Fire is occurring frequently and globally

The estimation of the impact of fire on the biosphere (IGAC, IGBP) is still uncertain

-***Global annual estimate of 8600Tg dry matter burned with an error bar of 50%, (Andreae and Merlet, 2001)***

-***Estimate of gases emissions over South Africa are largely varying.***

Study	*Burned area (10^6 km^2)*	*Biomass burned (Tg)*	*CO_2 (Tg)*	*CO (Tg)*
Hao *et al.* (1990) no specific year	-	1200	1560	99
Hao and Liu (1994) no specific year	-	827	-	68
Hao *et al.* (1996) no specific year	-	1000	-	75
Scholes *et al.* (1996a) (year 1989)	1.68	177	324	14.9
Scholes *et al.* (1996b) no specific year	3.99	1152	-	-
Barbosa *et al.* (1999) (year 1989)	1.54	456	748	31.0
van der Werf *et al.* (2003) (years 1998-2001)	1.16	1147	1848	76.8
van der Werf *et al.* (2004) (years 1997-2001)	-	2040	3286	136.7

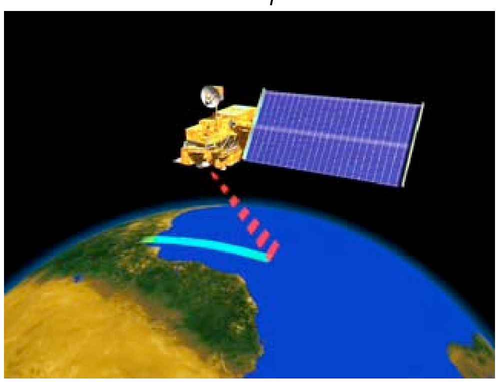
Korontzi S., Phd dissertation, 2004

Why emission estimate are uncertain?

Emissions= burned area _ fuel load _ combustion completeness _ emission factor

Satellite derived estimates of Net Primary Production, empirical relations for fuel types allocation

Fuel loading was derived using a handful of field measurements



MODIS, SPOT VGT

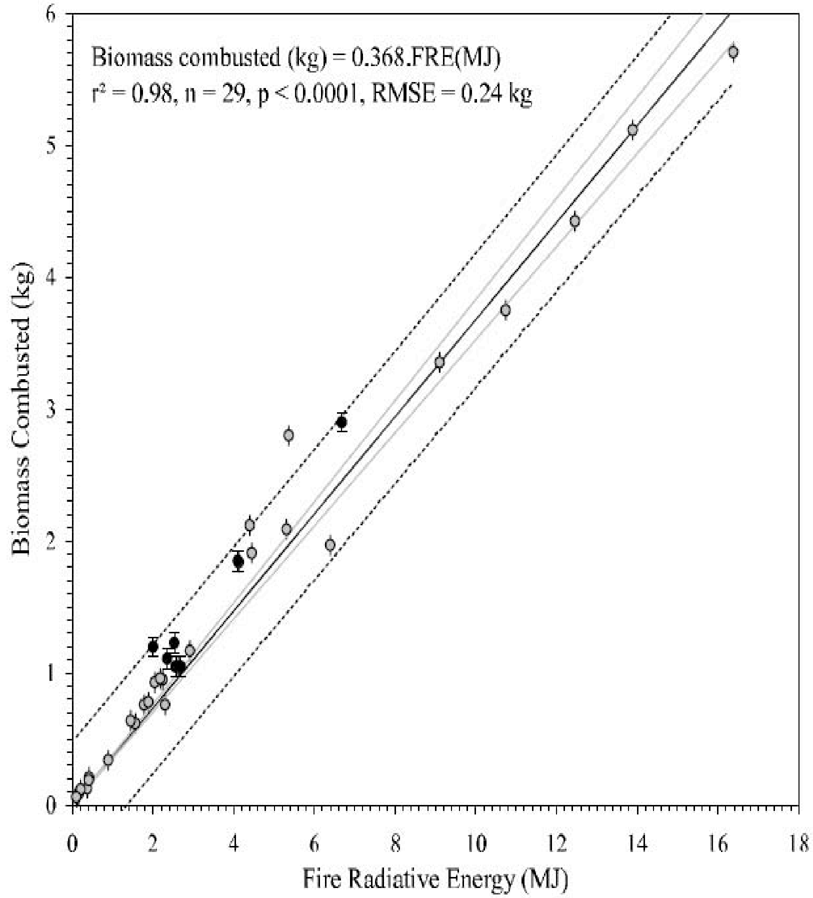
Satellite burned area products are fairly new, active fire was used to estimate burned area

Field based parameterizations based on fuel types and fuel moisture

No seasonal measurements of emission factors (amount of each compound is emitted per kg of fuel burned) or combustion completeness.

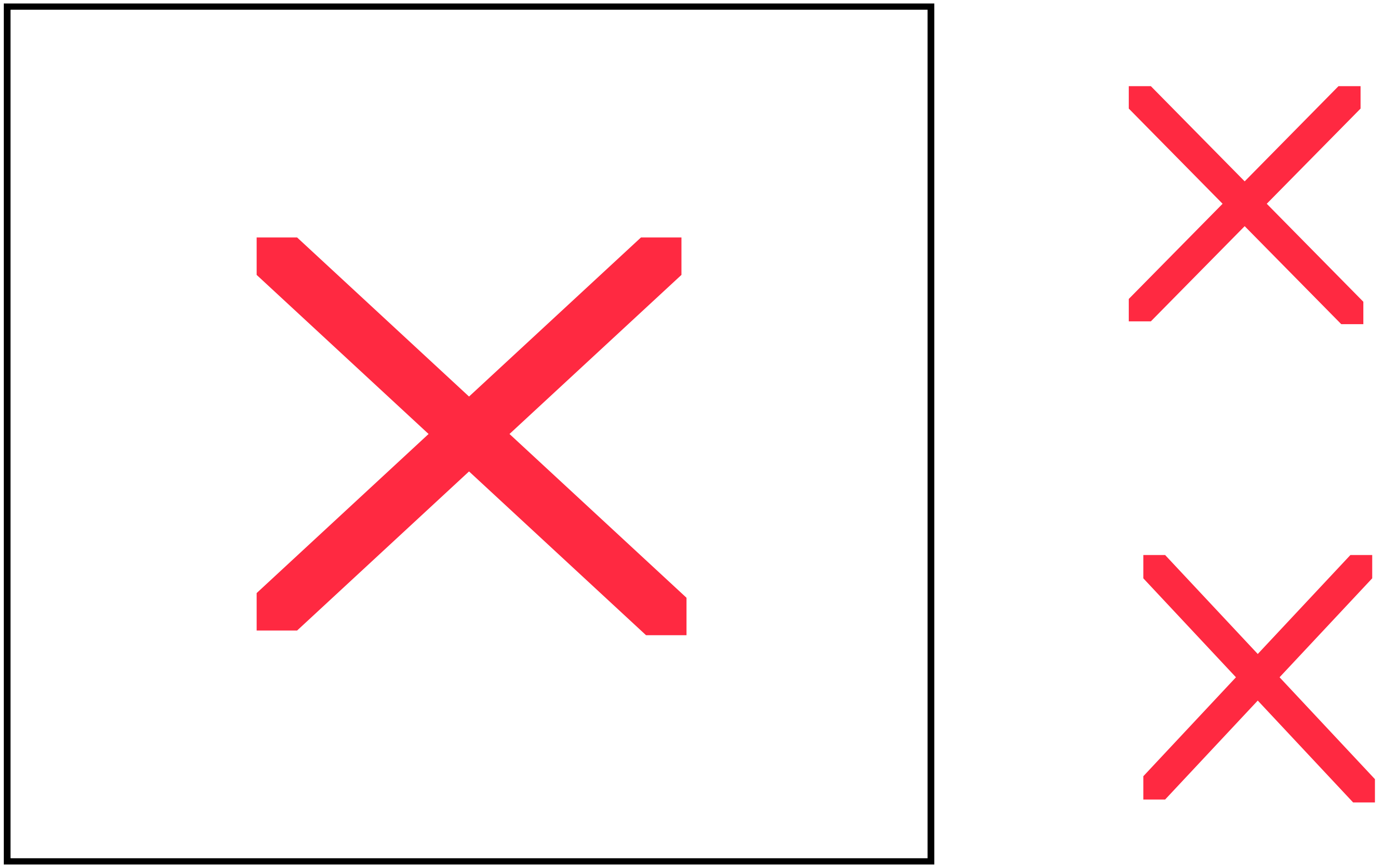
Emission estimates alternate approach

$$\text{Emission} = E_{factor} \times \boxed{}$$



Wooster et al. 2005 ," Retrieval of biomass combustion rates and totals from fire radiative power observations: FRP derivation and calibration relationships between biomass consumption and fire radiative energy release", JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 110, D24311.

Comparison of Aerosol emission estimate with Fire integrated energy over Kazakhstan



Satellite Aerosol inversion to retrieve emissions

(Dubovik et al.)

MODIS:

Global observations of ambient aerosol

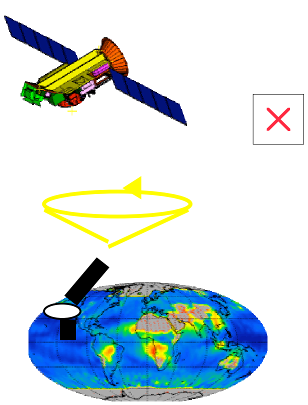
AERONET:

Semi-Global accurate observations of aerosol

GOCART: Global aerosol simulations

- assimilated meteorology
- advection and convection
- removal processes

Main “Uncertainty”: aerosol sources



Synergy of Observation and Modeling:

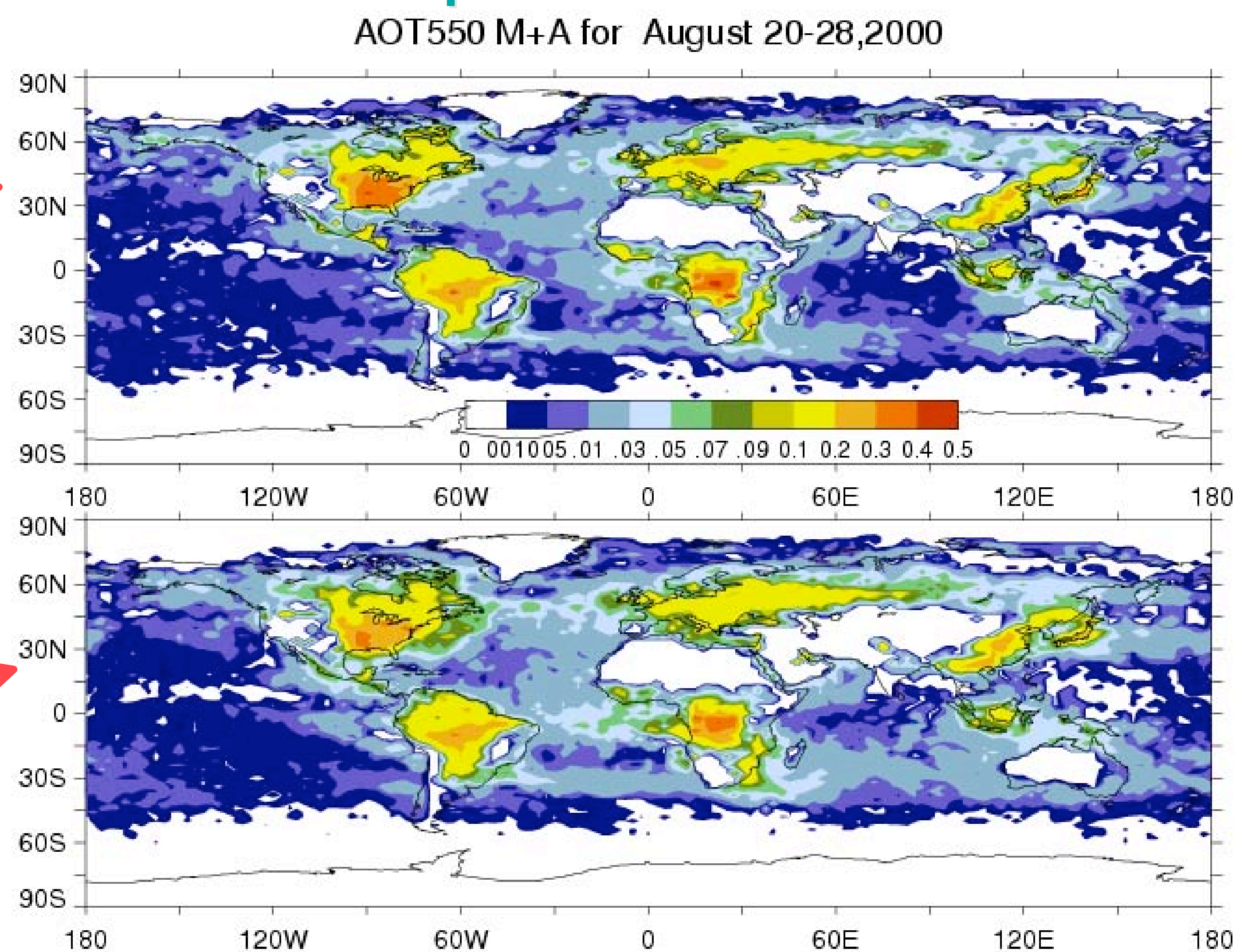
Retrieving sources (location and strength) providing best agreement between observations of MODIS /AERONET and GOCART simulations

Testing of emission inversion
2) How well GOCART reproduces observed aerosol using retrieved emissions

Optical Thickness

MODIS+AERONET Observations

Observations from Retrieved emission



Data

- MODIS FRP Climate Modeling Grid (CMG) 0.5 x 0.5 (2001-2005)

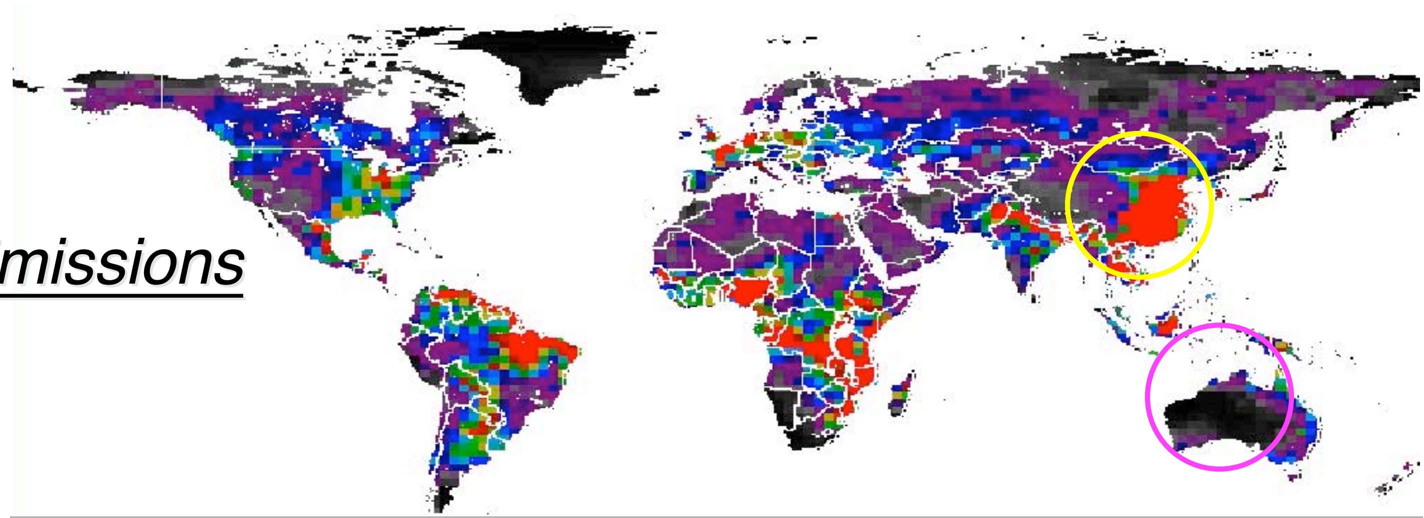
- MODIS based emissions estimates of Organic and Black Carbon (OC-BC) particulate matter (Dubovik et al.) (2001)

- MODIS derived Landcover based on IGBP classification scheme

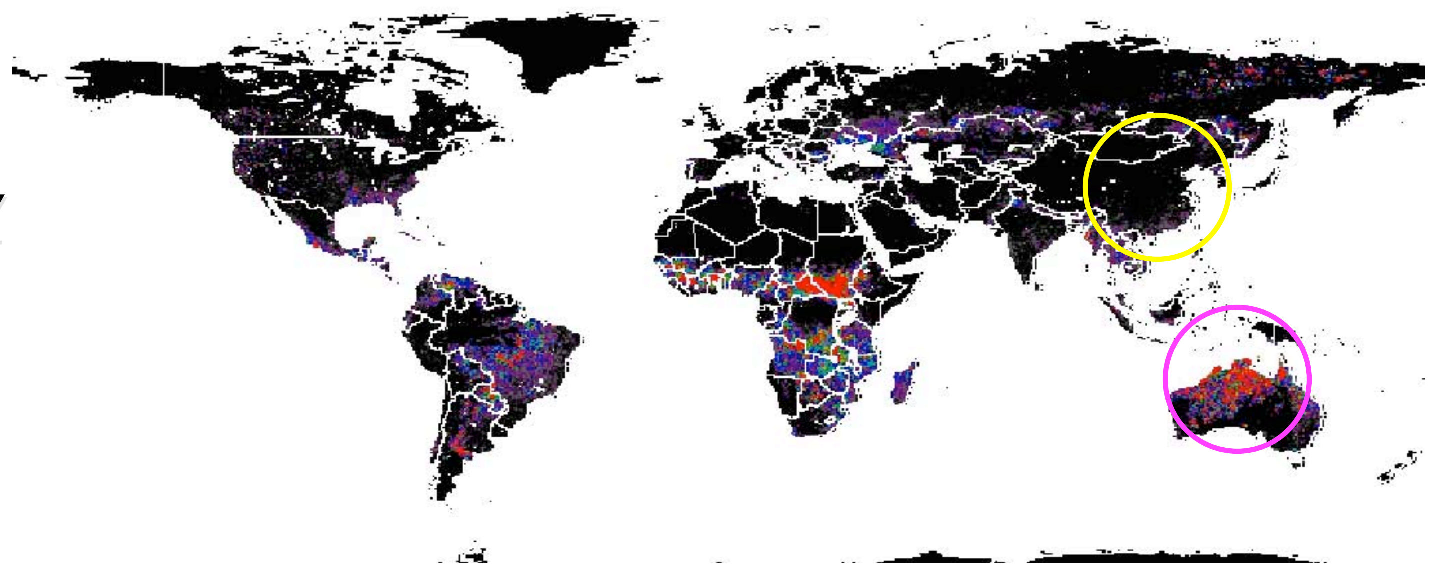
- Stratification of global estimates was based upon regions developed by van der Werf et al. (2006).

Comparison of raw emission estimates

<u>*OC-BC Particulate Emissions (Dubovik)*</u>

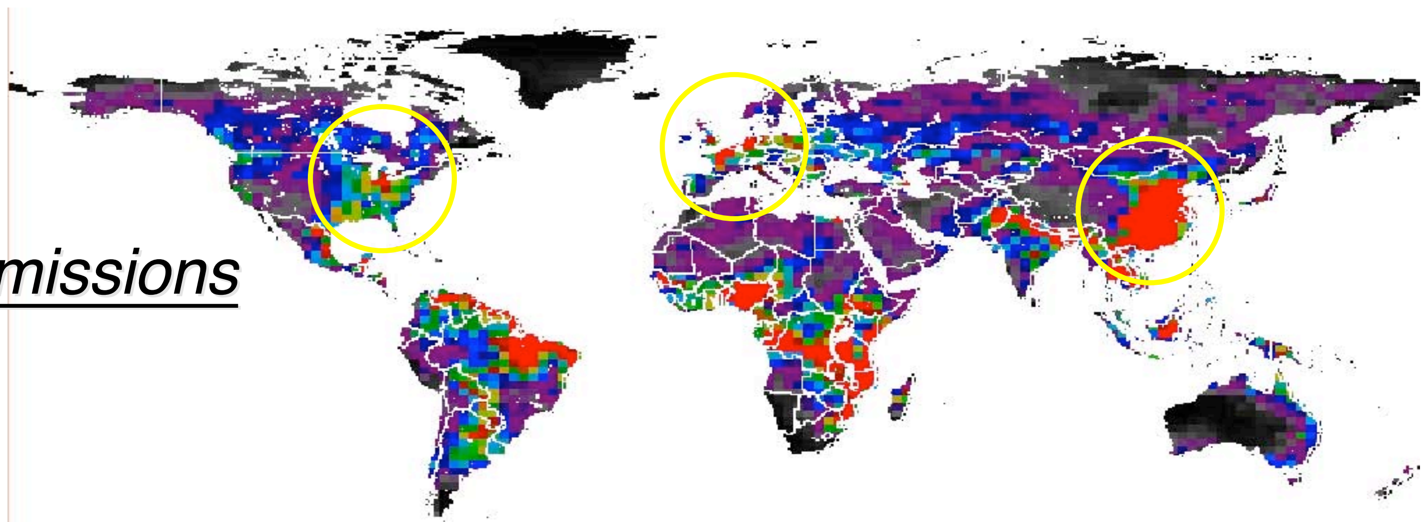


<u>*Terra energy estimate*</u>



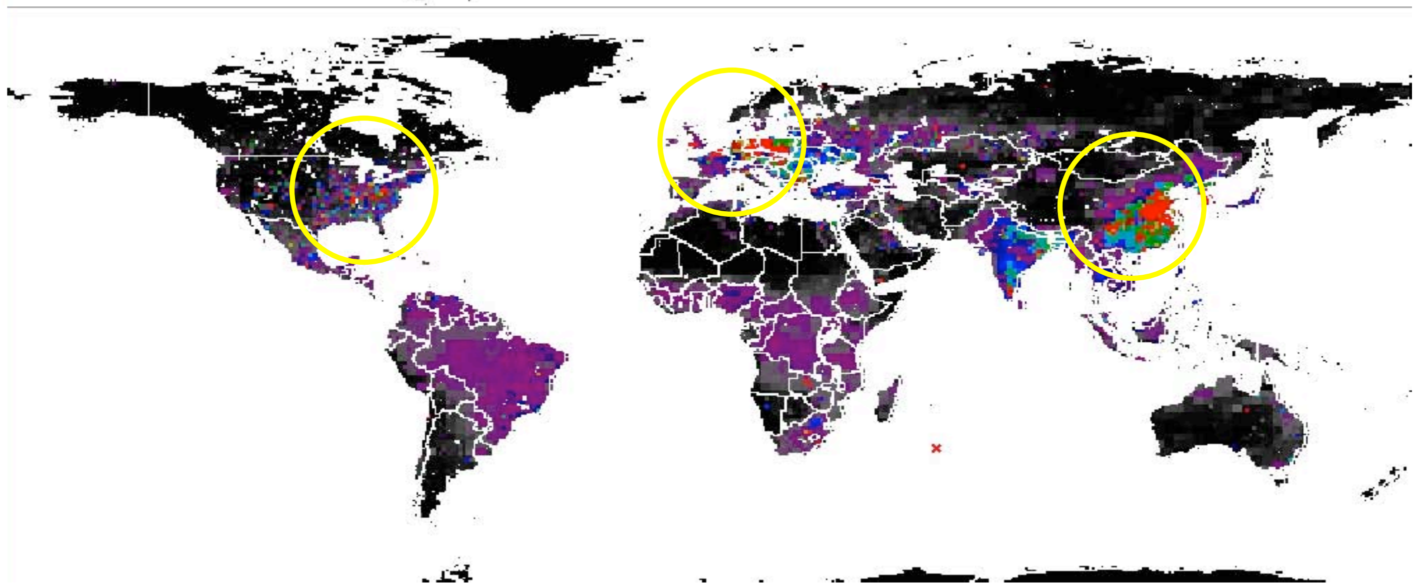
Correction for various non fire emissions

OC-BC
Particulate Emissions



Fossil Fuel
Emissions

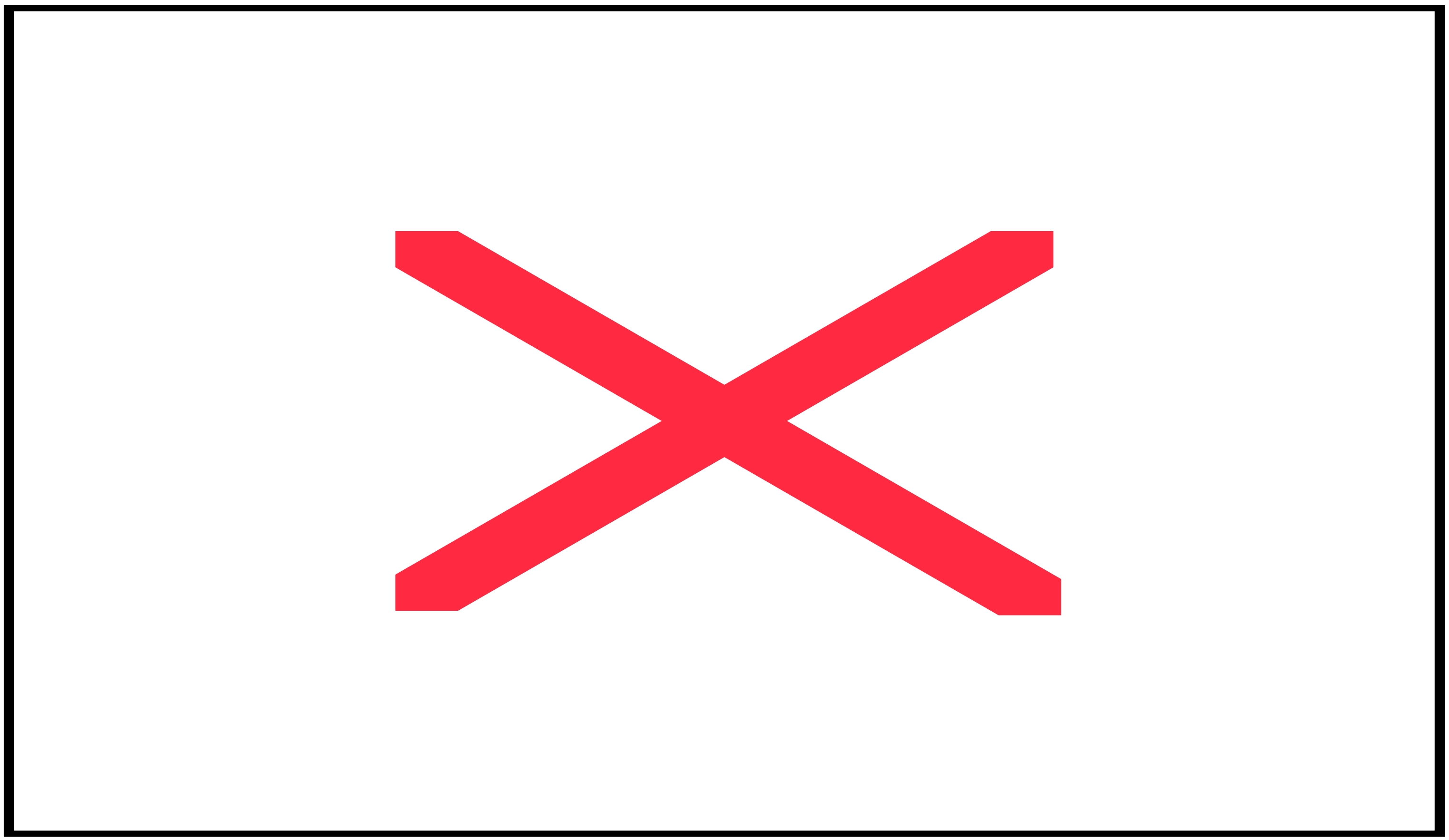
- Chin et al. 2002
- Cooke et al., 19
- EDGAR, 2001



Correlating global monthly Terra energy with OC+BC emission (1/3)

<u>*Regions*</u>

Correlating global monthly Terra energy with OC+BC emission (2/3)



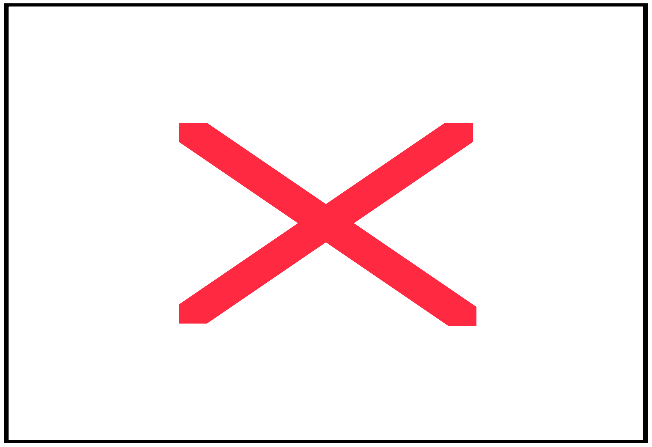
Correlating global monthly Terra energy with OC+BC emission (3/3)

Results

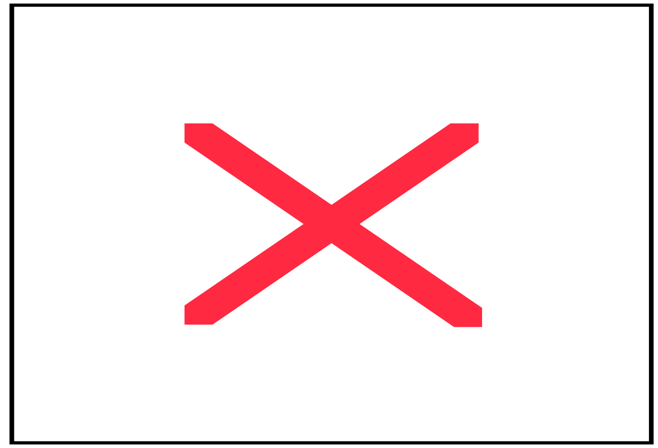
- Southern Hemisphere Africa (SHAF) demonstrated the strongest correlation
- Europe (EURO), North American (TENA, and Australia (AUST) had the weakest

Region	**emission coefficient**	**R**
AUST	0.0018	0.2760
BONA	0.3445	0.4754
EURO	0.0307	0.1253
MIDE	0.3161	0.5759
TENA	0.0330	0.2035
CEAM	0.0366	0.8237
NHSA	0.0698	0.7363
SHSA	0.0247	0.8263
NHAF	0.0112	0.7055
SHAF	0.0254	0.9399
SEAS	0.0821	0.7999
EQAS	0.0908	0.7132
CEAS	0.0512	0.4387
BOAS	0.0742	0.8338

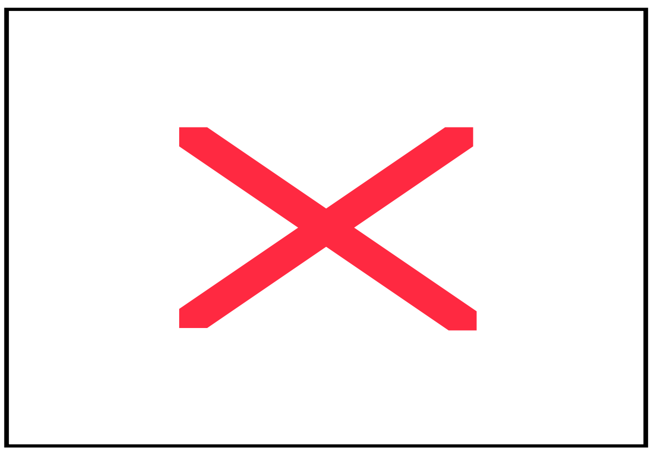
Analyzing variation in emission coefficients



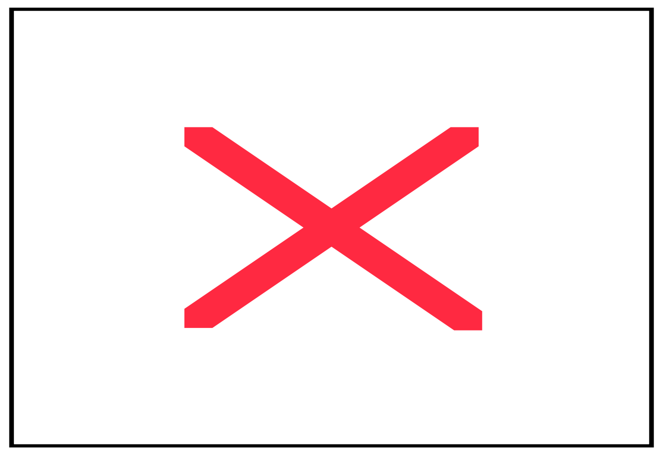
NHAF: *EF = 0.0112*



NHSA: *EF = 0.0698*



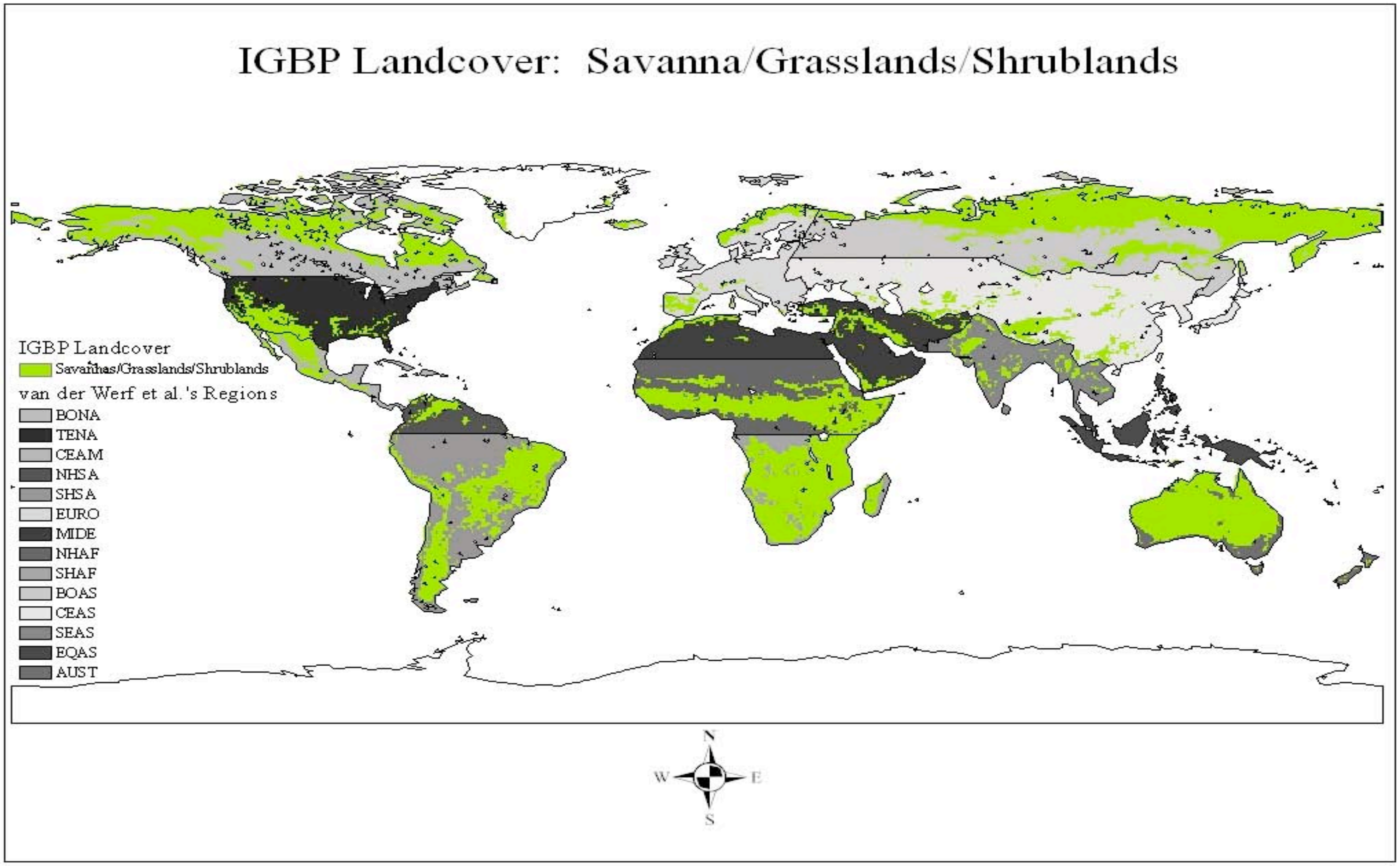
SHAF: *EF = 0.0254*



SHSA: *EF = 0.0247*

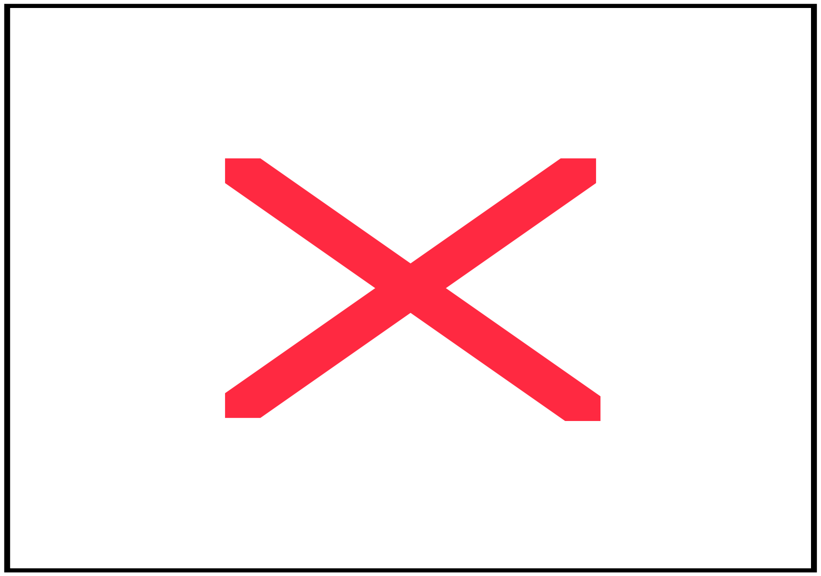
Possible cause for different emissions coefficients

- Land Cover (Andreae, 2001)
  - Savannah and Grassland (3.7 g/Kg)
  - Tropical forest (6.6 g/Kg)
  - Extra tropical forest (6.6-10.4g/Kg)
  - Agricultural residues (4.0g/Kg)
- Fire Regime
  - Difference between Terra energy and integrated energy



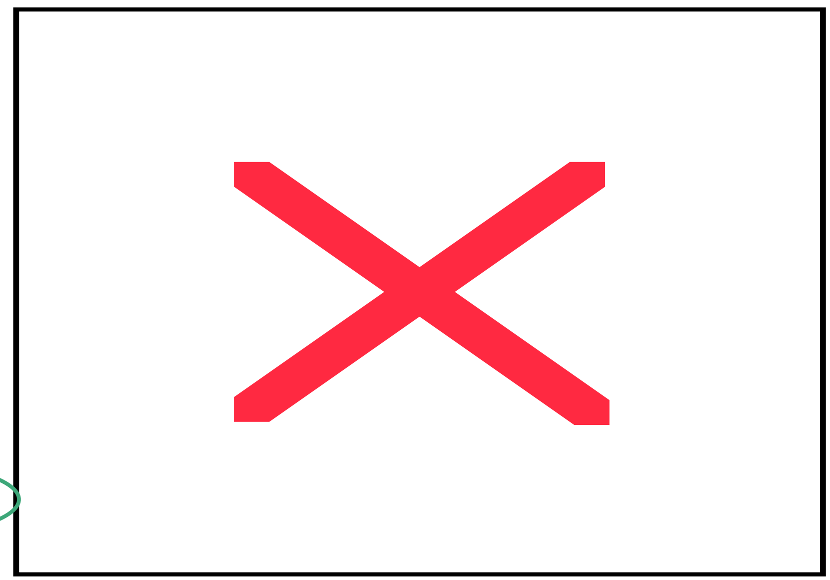
- 750 million ha/year (Hao et al.,1990)
- 1/3 of global burning (Dwyer et al., 2000)
- 50%+ detected in Africa (Dwyer et al., 2000)

Analyzing variation in emission coefficients for the Savanna/Grassland biome with the Aqua/Terra Energy ratio (1/2)

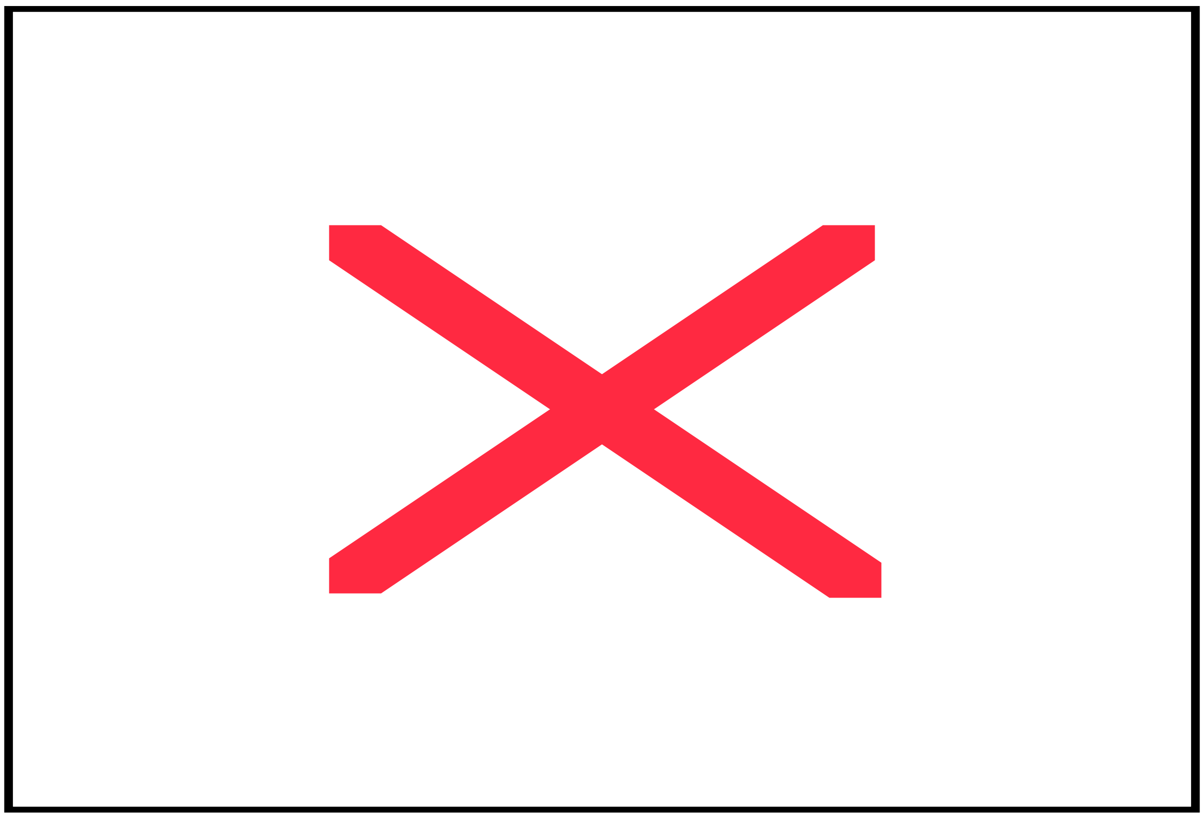


BOAS Open Shrubland
Ef = 0.042
****
2003-2005
Aqua/Terra = 1.12

SHAF Savannas
Ef = 0.019
****
2003-2005
Aqua/Terra = 3.383



Analyzing variation in emission coefficients for the Savanna/Grassland biome with the Aqua/Terra Energy ratio (2/2)



Proposed Global alternative approach for Fire emission estimate

$$\text{Emission} = Ef * \int \text{Fire Energy}\, .\, dt$$

Theory

$$\text{Emission} = Ef^{t} * \text{Terra Energy}$$

Demonstrated empirically

$$\text{Emission} = Ef\,(\text{biome}) * f(\text{Aqua/Terra}) * \text{Terra Energy}$$

Tested for Grassland/savanna

Future Directions

- Expand Aqua/Terra Ratio analysis to other land cover types
- Validate Model
  - Analyze relationship between Aqua/Terra ratio and FRE (Roberts et al. (2005) – SEVIRI)
  - Relate emission coefficient to previously published values (e.g Andreae & Merlet (2001))
  - Compare with other estimates (e.g. van der Werf, 2006)
  - Extend to CO emissions