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Comparison of global monthly CO emission maps derived from remotely sensed burned area datasets

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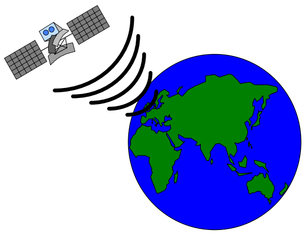
Summary



- **Introduction**
- **Global data sets**
  - bottom up & top-down
- **Spatial & temporal distribution**
  - continental and land cover
- **Conclusion**

Framework

- Since the late 70' **vegetation fires** have been recognized as a significant **anthropogenic source of greenhouse gases**, CO_2 and CH_4 (Crutzen et al., 1979).
- Other carbonaceous compounds are emitted from the **incomplete combustion** of vegetation biomass such as **CO**
- About **40% of the CO annual** budget in the atmosphere is **due to fires** (IPCC 2001). CO, being a precursor of ozone and an important sink for hydroxil radical (OH), plays a **key role in chemistry transport models** of atmospheric pollutants (Jain, 2007)

- Large **uncertainty** still exists in the assessment of gas and particulates emissions from vegetation fires because of their **higher temporal dynamic** with respect to other sources and **high spatial variability** (Liousse et al, 2004, Langmann et al, 2009)
- **Satellite observation** data potentially have all the characteristics for quantifying seasonal and inter-annual information on the emissions from vegetation fires because of their **global and continuous coverage**

Framework

- BBSO (Burnt Biomass and Satellite Observations) workshop within the ACCENT European network and the GEIA/AIMES/IGBP international project in Toulouse, France, December 2005 (www.accent-network.org)

- Intercomparison exercise was organized to analyse emission inventories (CO and particulate matter) derived from Remote Sensing global products: AF (Active Fires) and BA (Burnt Area) under the coordination of the JRC/EC

- The participants agreed on
  i) a common experimental year (2003)
  ii) a common land cover map (GLC2000) and
  iii) a common set of factors to be used in a '*bottom up*' approach

Objectives

- To highlight the agreements /disagreements in terms of spatial and temporal patterns of a set of global CO inventories ('***bottom-up***' approach)
- To compare the results with inventories performed with different approaches (e.g. inverse modeling "***top-down***")
- To investigate the role that the land cover plays in these differences
- To assess the impact of the choice of one product over another (regionally based analysis)

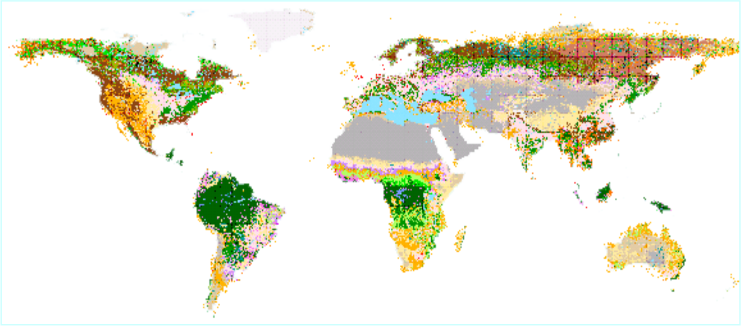
Datasets (July 2009)

***Bottom-up* modeling approach**

Common Static Information

- ❑ Land cover map GLC2000

- ❑ Biomass Density BD_i
- ❑ Burning Efficiency BE_i
- ❑ Emission factors EF_i



Bartholomé E., A. Belward, I.J. Rem Sens., 26 (9) **2005**.

Specific Dynamic Information

❑ Three monthly global CO emission products (0.5°x0.5°) for the year 2003:

- ✓ L3JRC-COR inventory — BA product (source: Liousse, Univ. Toulouse, France)
- ✓ WFA-GBA2000 inventory — AF product (source: Mieville, Univ. P. M. Curie, Paris)
- ✓ MODIS inventory — AF product (source: Mian Chin, NASA Greenbelt, USA)

Global CO emission products

Monthly CO emission maps over the globe for each

0.5° x 0.5° cell and land cover class.

1. **L3JRC COR (VGT)**: based on **burnt areas** from daily SPOT/VGT available for the period 2000 to 2007 (Tansey et al. 2008) with corrections applied to land cover classes GLC3 & GLC12: Deciduous broad-leaved tree, Deciduous shrub (Liousse et al. 2009)

2. **WFA-GBA 2000 (AATSR)**: burnt areas derived from of **night time active fires** derived from AATSR (ESA ENVISAT) between 1997 and 2005 (Mieville et al., 2009) with calibration derived using the GBA2000 dataset for three latitudinal bands (Tansey et al., 2004)

3. **MODIS**: burnt areas based on MODIS (TERRA & AQUA) **8-day active fire counts** at 1-km resolution using a conversion factor (Giglio et al., 2006; Chin et al., 2002)

These inventories are not exhaustive, but they share common static information

Land cover classes are extracted from the GLC2000.

Global CO emission products

Top-down inverse modeling approach

Monthly CO emission maps over the globe

for each 0.5° x 0.5° cell

1. **MOPITT** (TERRA): **CO profiles** from MOPITT (Measurements Of Pollution In The Troposphere) are used together with the **chemistry and transport model MOZART** (Model for Ozone and related chemical Tracers; Horowitz et al. 2003) that simulates the distribution of 63 trace gases in the lower atmosphere.
   For the optimization of the inversion process, a set of a priori sources of emissions (fossil fuel, biogenic fuel, vegetation fires) are used.
   The **a priori biomass burning emissions** have been derived from **MODIS fire counts** (Petron et al. 2004).

✓ MOPITT inventory CO profile product (source: G. Petron-NOAA and J.Gille/D. Edwards, NCAR, USA)

Bottom-up approach

$$E_i(X) = BA_i \times BD_i \times BE_i \times EF_i(X)$$

Model by Seiler and Crutzen, 1980

E	emissions of the compound X for the land cover i	[Kg]
BA	burnt area in the land cover i	[m^2]
BD	biomass density of the land cover i	[kg m^{-2}]
BE	burning efficiency in the land cover i	[kg kg^{-1}]
EF	emission factor for the compound X in the land cover i	[g kg^{-1}]
i	land cover class	
X	chemical compound	

Land cover classes and factors

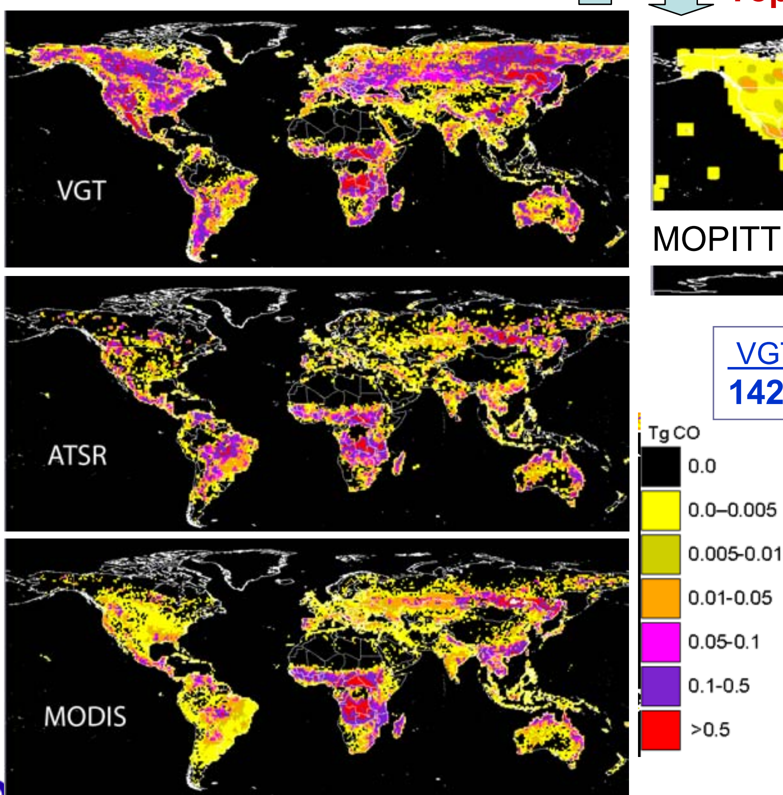
GLC2000 (14 out of 21 global classes)	BD kg/m2	BE	EF gCO/kg
GLC01: Tree Cover, broadleaved, evergreen	23.35	0.25	104
GLC02: Tree Cover, broadleaved, deciduous, closed	20	0.25	107
GLC03: Tree Cover, broadleaved, deciduous, open	36.70	0.25	107
GLC04: Tree Cover, needle-leaved, evergreen	18.90	0.25	107
GLC05: Tree Cover, needle-leaved, deciduous	14.00	0.25	107
GLC06: Tree Cover, mixed leaf type	10.00	0.35	86
GLC09: Mosaic: Tree Cover/Other natural vegetation	1.25	0.90	65
GLC11: Shrub Cover, closed-open, evergreen	3.30	0.40	65
GLC12: Shrub Cover, closed-open, deciduous	1.43	0.90	65
GLC13: Herbaceous Cover, closed-open	0.90	0.60	77.7
GLC14: Sparse herbaceous or sparse shrub cover	0.44	0.60	92
GLC16: Cultivated and managed areas	1.10	0.80	70
GLC17: Mosaic: Cropland/Tree Cover/Other natural	1.00	0.75	73.8
GLC18: Mosaic: Cropland / Shrub and/or grass cover	1.25	0.90	65

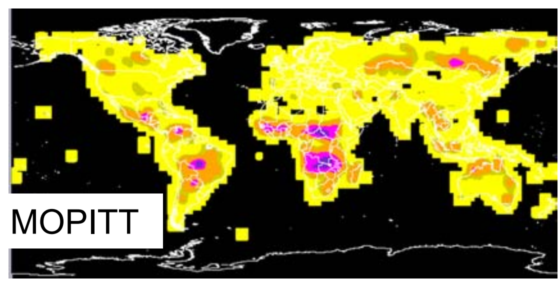
(Liousse et al., 2009; Michel et al., 2005)

BD range: 1 – 36 **BE** range: 0.25 -0.9 **EF** range: 65 - 107

Year 2003: total CO emissions

Bottom-up **Top-down**





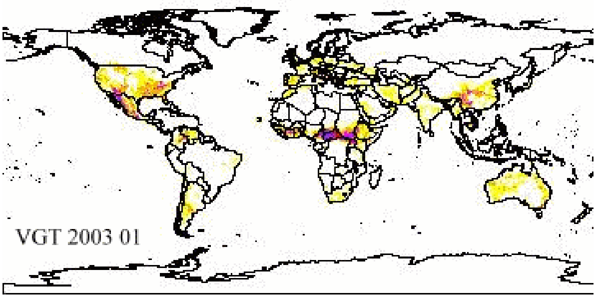
VGT	ATSR	MODIS	MOPITT
1422	**547**	**769**	**594**

Spatial distribution of CO emission [Tg] estimates for 0.5 x 0.5 degree cells over the globe

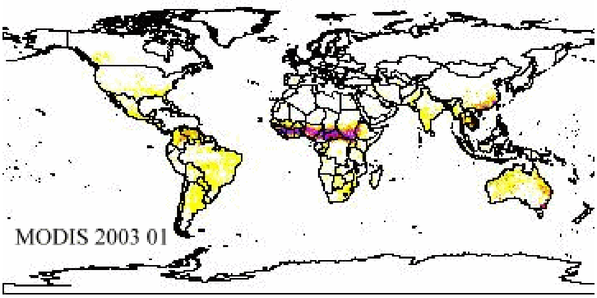
Temporal dynamics of the emissions

Looking at the monthly CO emissions

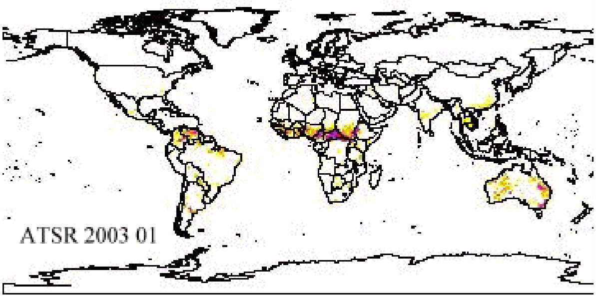
VGT



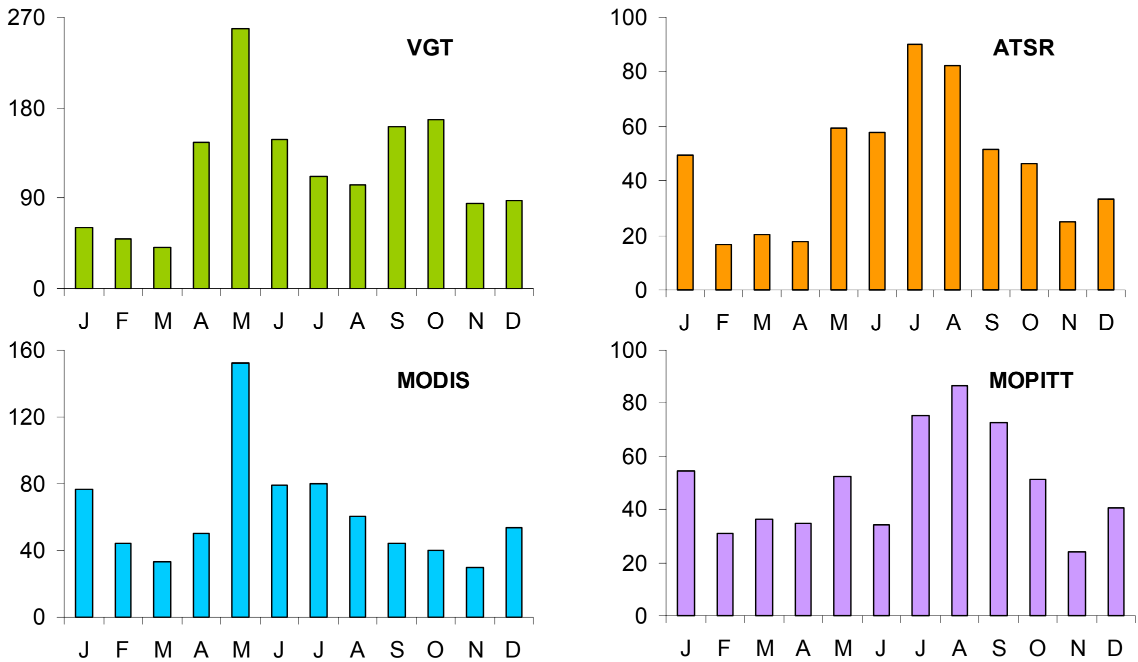
MODIS



ASTR



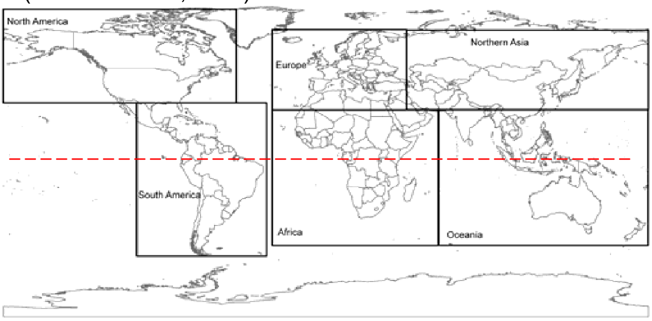
Looking at the monthly CO emissions



	VGT	MODIS	ATSR	MOPITT
Monthly max	258	152	90	87
Year total	1422	769	547	594

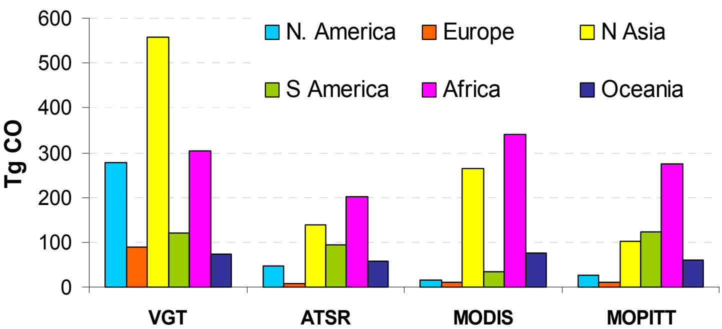
Geographical distribution of emissions

Six continental windows used for the analysis
(Boschetti et al., 2004)

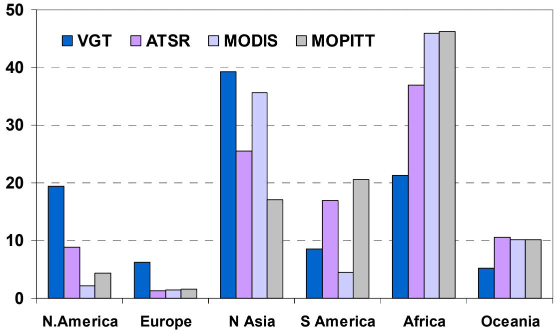


	VGT	ATSR	MODIS	MOPITT
N. America	276.60	48.07	**19.20**	25.48
Europe	87.85	**7.33**	13.16	9.33
N. Asia	559.15	**139.49**	241.64	101.96
S. America	**121.74**	93.08	35.59	121.89
Africa	**302.69**	201.63	367.38	274.83
Oceania	73.96	**57.90**	92.60	60.51
GLOBAL	**1422.0**	**547.50**	**769.56**	**594.00**

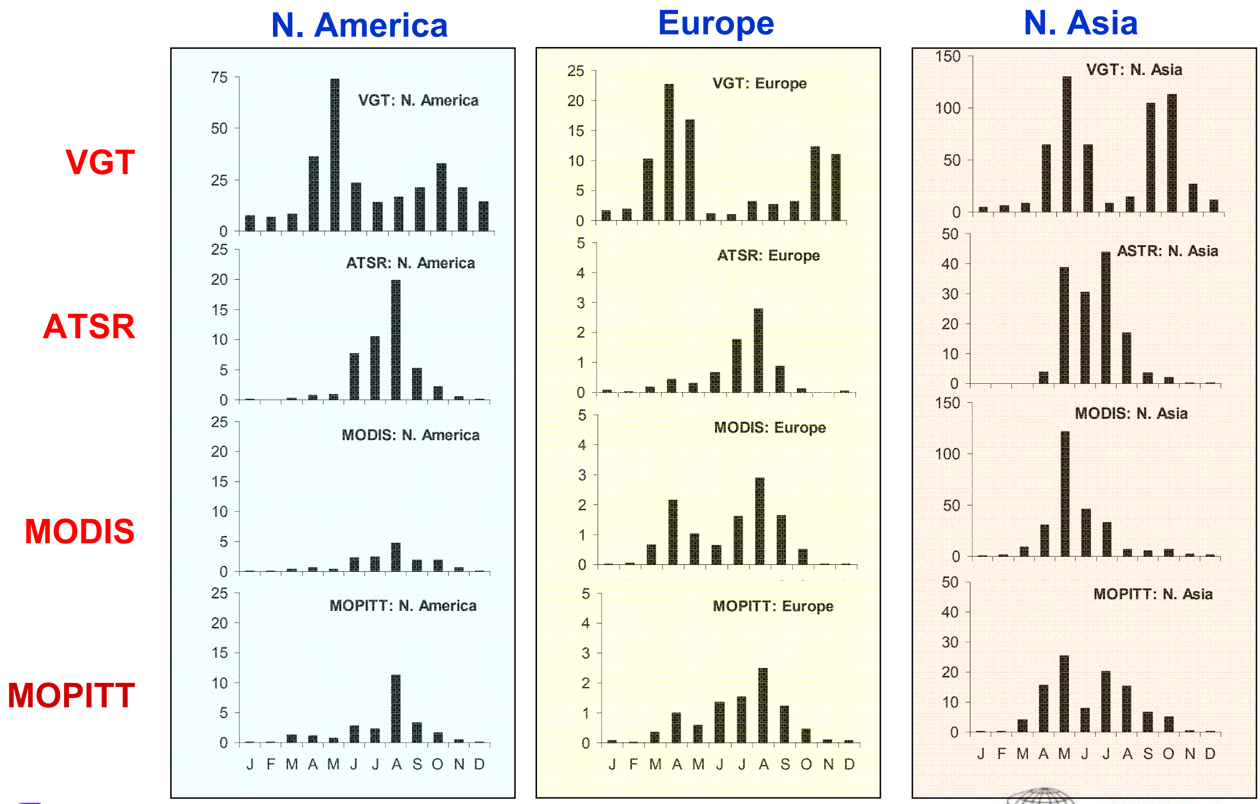
Co emissions



Percentage Co emissions



Seasonality of Northern Regions



Seasonality of Southern Regions

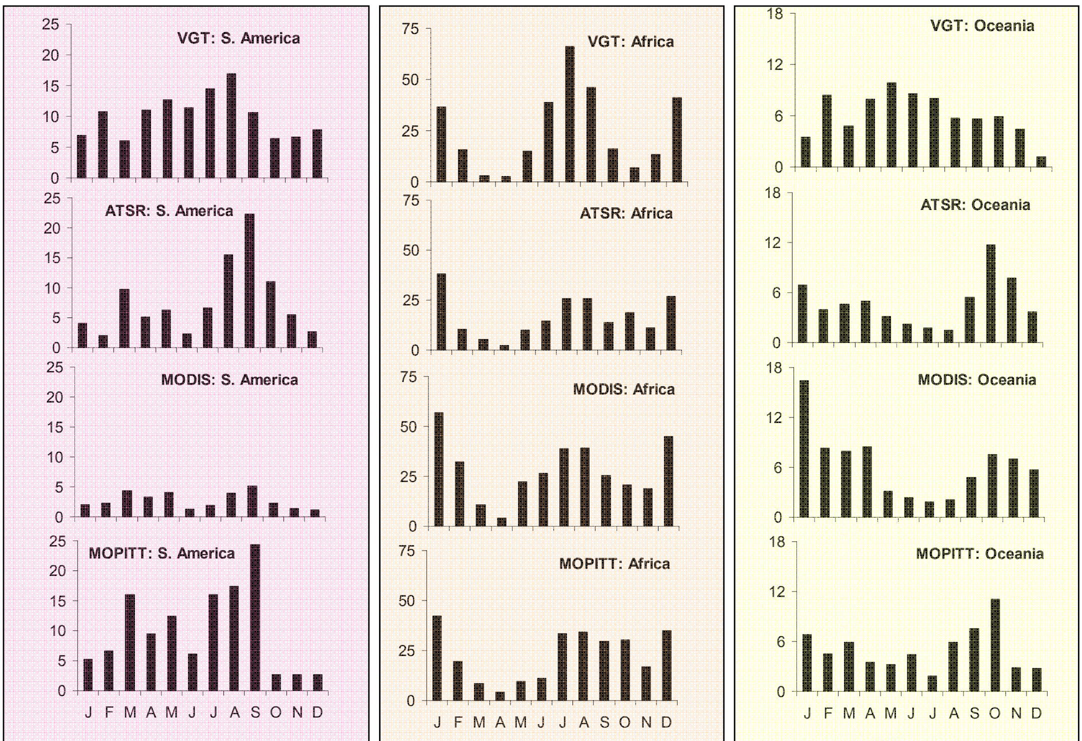
S. America | Africa | Oceania

VGT

ATSR

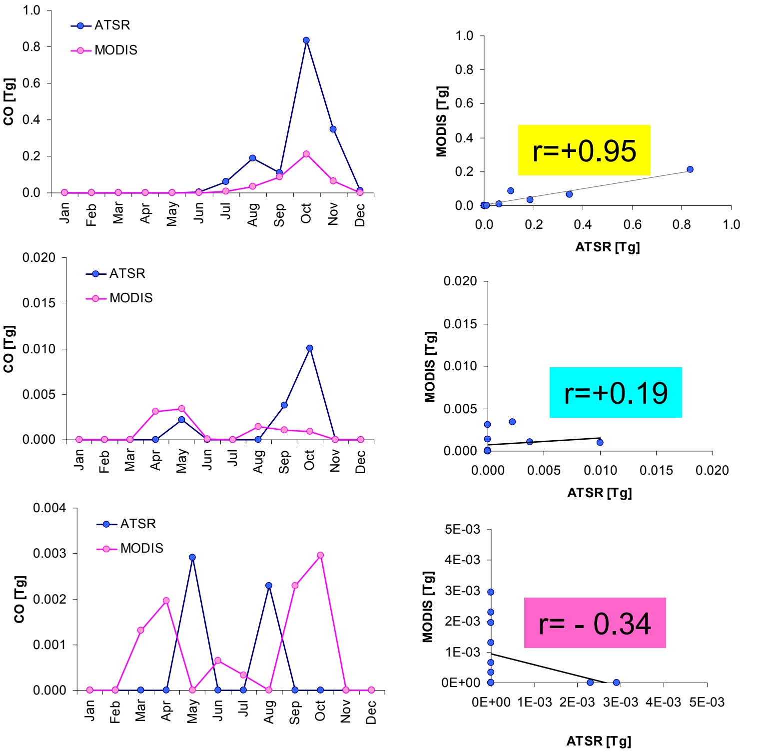
MODIS

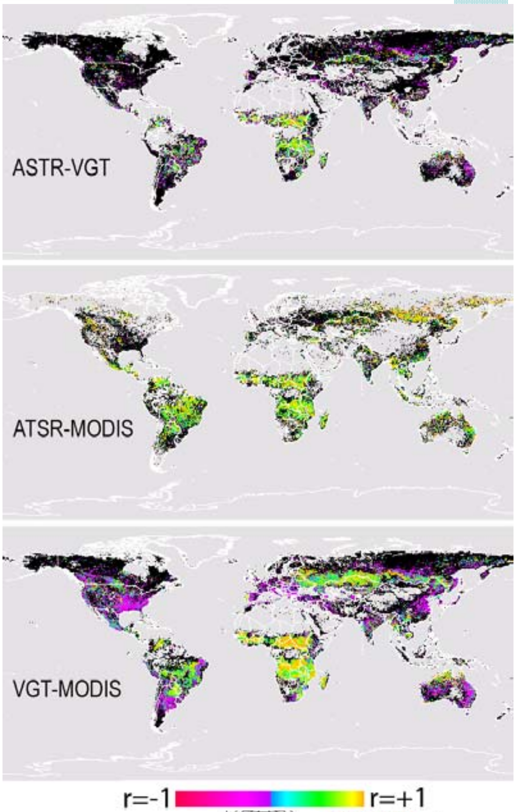
MOPITT



Seasonality agreement

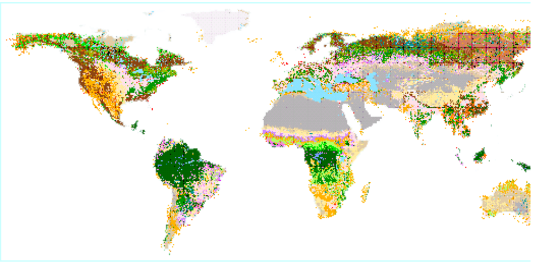
- **Cell by cell** seasonal correlation of CO emissions

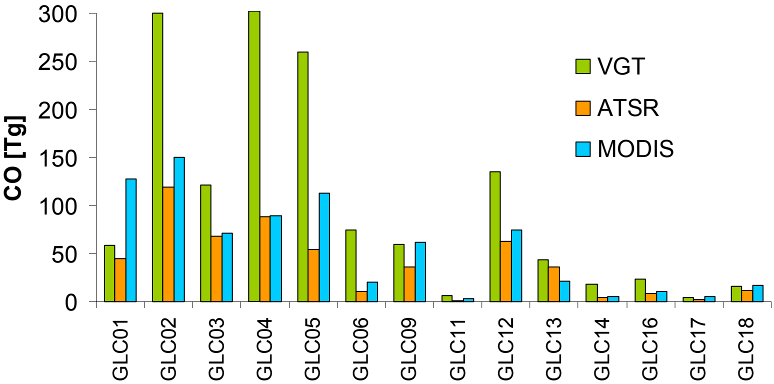




Role of the land cover

GLC2000





		Total CO [Tg]		
Broad LC class	**GLC codes**	**VGT**	**ATSR**	**MODIS**
Broadleaved forest	1, 2	**359**	**163**	**278**
Needleleaved forest	4, 5, 6	**636**	**153**	**223**
Mixed tree cover	3, 9	**181**	**104**	**132.2**
Savanna & grassland	11, 12, 13, 14	**203**	**104**	**104**
Agriculture	16, 17, 18	**43**	**22**	**32**

Forest and tree (GLC 1 to 9) land cover classes are major responsible as percentage

	GLC 1 to 9	GLC 11 to 14
VGT	83%	14%
ATSR	77%	19%
MODIS	82%	13%

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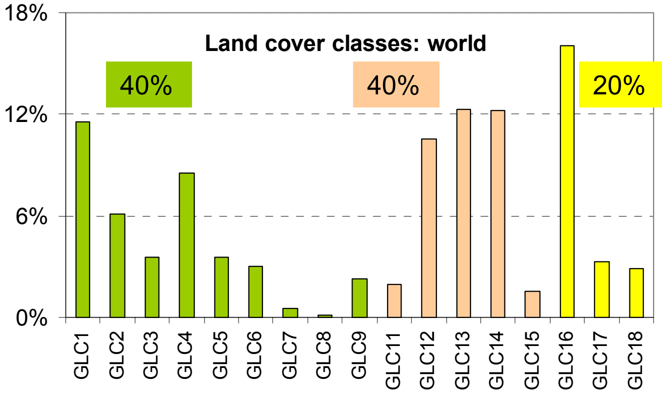
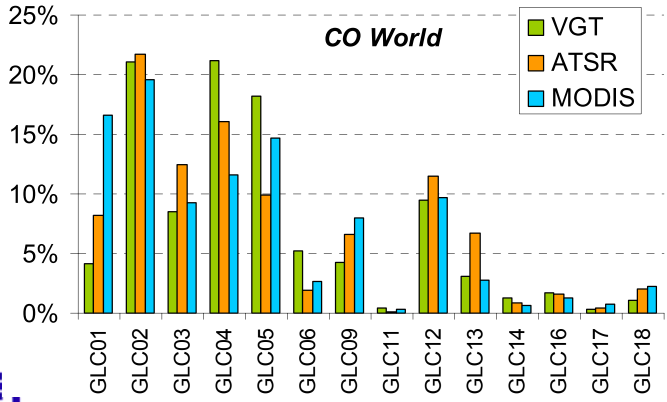
Land cover and CO emissions



Percentage of spatial occupation by the GLC2000 land cover classes

GLC 1 to 9	40 %
GLC 11 to 14	40 %
GLC 16 to 18	20 %



Percentage of CO emissions by the broad land cover classes

	VGT	ASTR	MODIS
GLC 1 to 9	83 %	77 %	82 %
GLC 11 to 14	14 %	19 %	13 %
GLC 16 to 18	3 %	4 %	4 %

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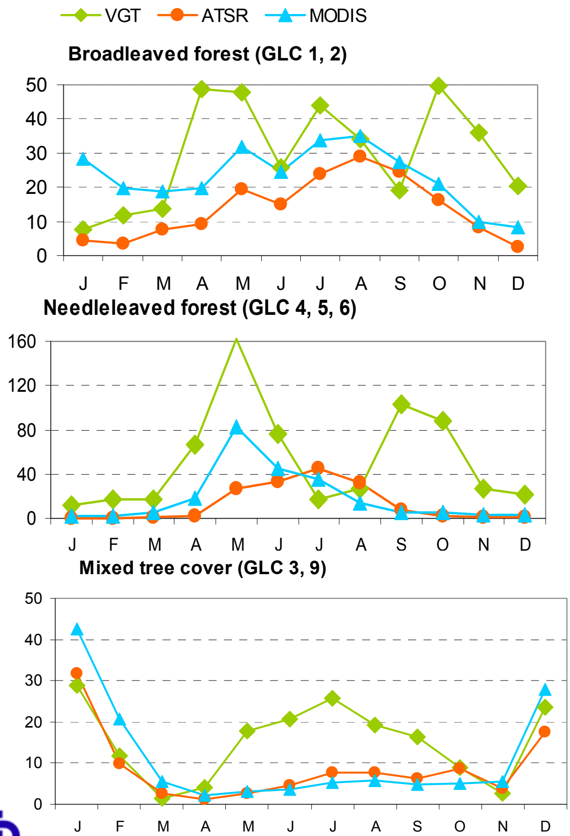
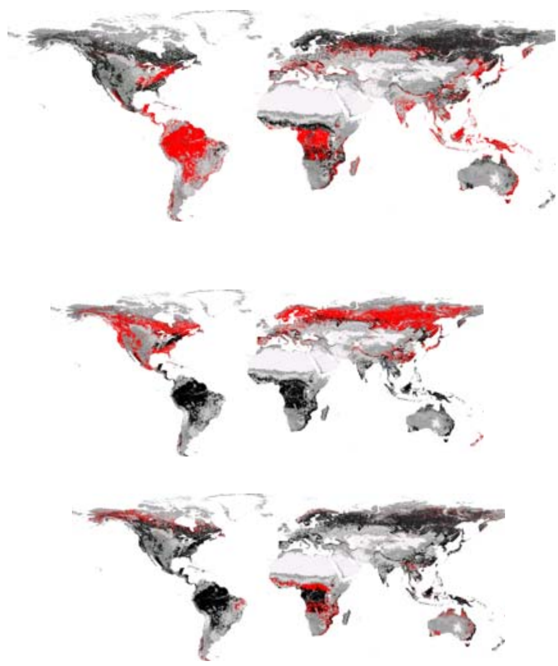
Milano

Forest & tree land cover seasonality



Broad classes GLC2000 spatial distribution



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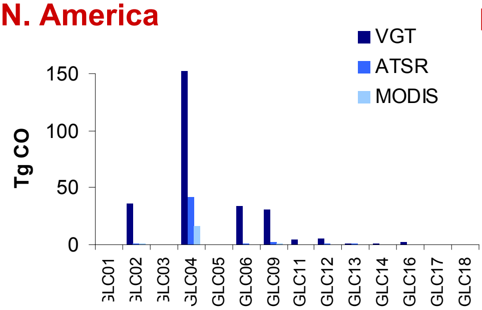
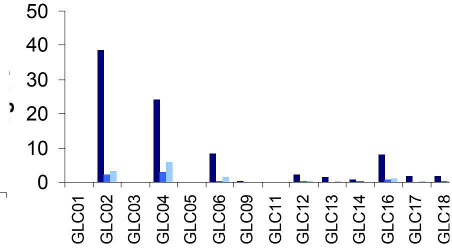
Milano

Regional land cover

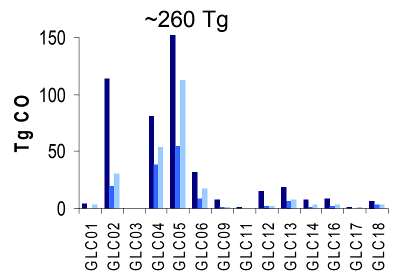
N. America



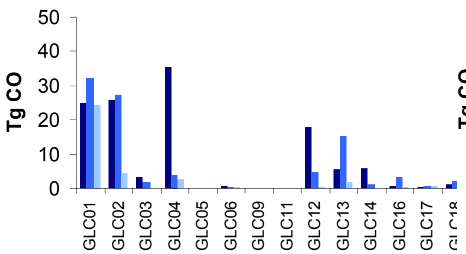
Europe



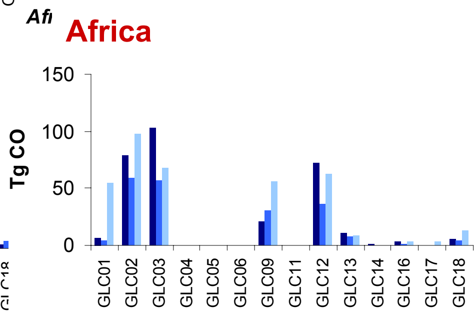
N. Asia



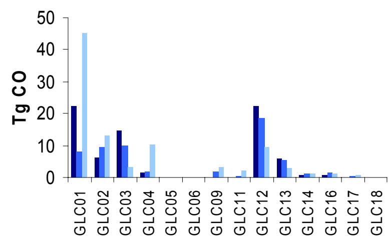
S. America



Africa



Oceania

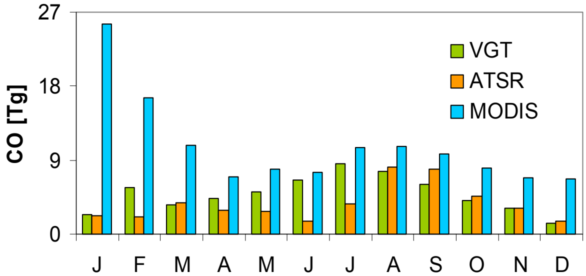


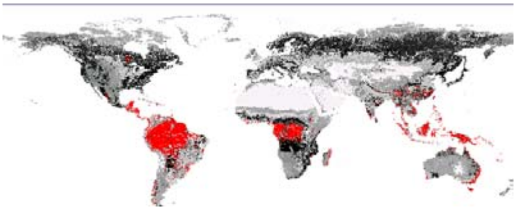
- Exceptionally high emissions by VGT in forest classes GLC02, GLC04 and GLC05
- Among the non forest classes, deciduous shrubs (GLC12) strongly contribute
- Contribution of forest classes at the northernmost latitudes
- Africa: good agreement in forest and non forest; source of emissions from deciduous shrubs

Specific land cover: forest

GLC-01 evergreen broadleaved forest

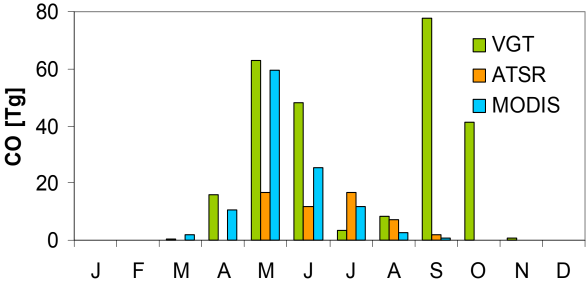
VGT 59
ATSR 45
MODIS 128

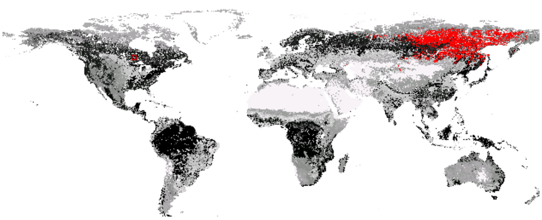




GLC-05 deciduous needle leaved forest

VGT 259
ATSR 54
MODIS 113

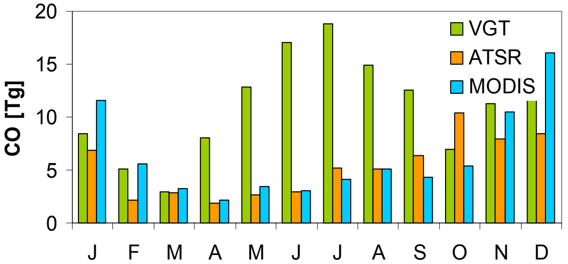


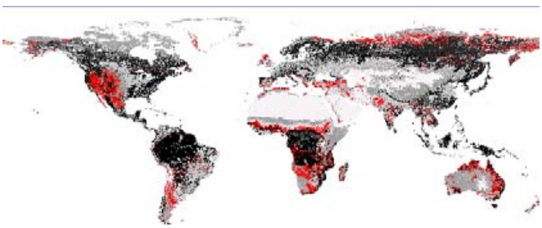


Specific land cover: savanna

GLC-12 closed / open deciduous shrubs

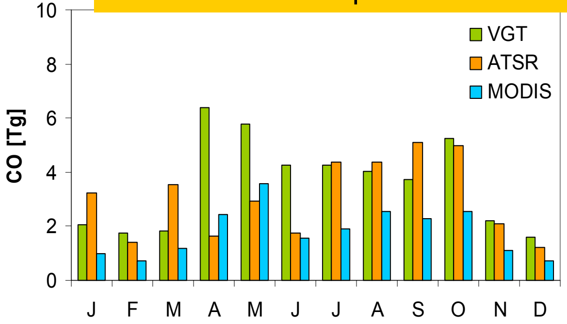
VGT 135
ATSR 63
MODIS 75

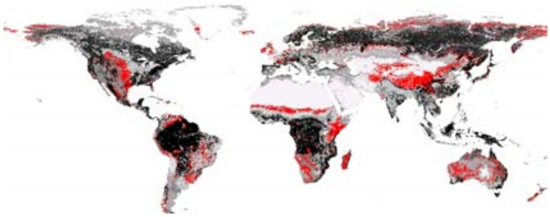




GLC-13 closed / open herbaceous cover

VGT 43
ATSR 37
MODIS 22





Conclusions

- At global level: 2003 CO emissions as estimated with VGT are 1.8 times higher than MODIS and 2.5 times higher than ATSR and MOPITT estimates
- Emission peak for VGT and MODIS occurs in May, while for ATSR and MOPITT is between July and August
- At regional level: large discrepancies in northern regions (Asia and America) compared with the southern ones
- In South America for VGT and MOPITT CO emissions coincide (121 Tg)
- Good agreement also for Africa (VGT: 302, ATSR: 202, MODIS: 367 and MOPITT: 275 Tg)
- The best seasonal agreement is in Africa between ATSR and MODIS and MOPITT
- At the Land cover level: Forest classes (GLC01 to GLC05) require particular attention due to the high biomass involved in burning.

Conclusions

- High VGT emissions (in disagreement with ATSR and MODIS) are observed in the deciduous needle-leaf forest (GLC05) in September/October 2003
- The choice of one inventory over the other appears particularly critical in the northern regions
- The intercomparison exercise should include emissions based on Fire Radiative Power (FRP/FRE) and other top-down approaches

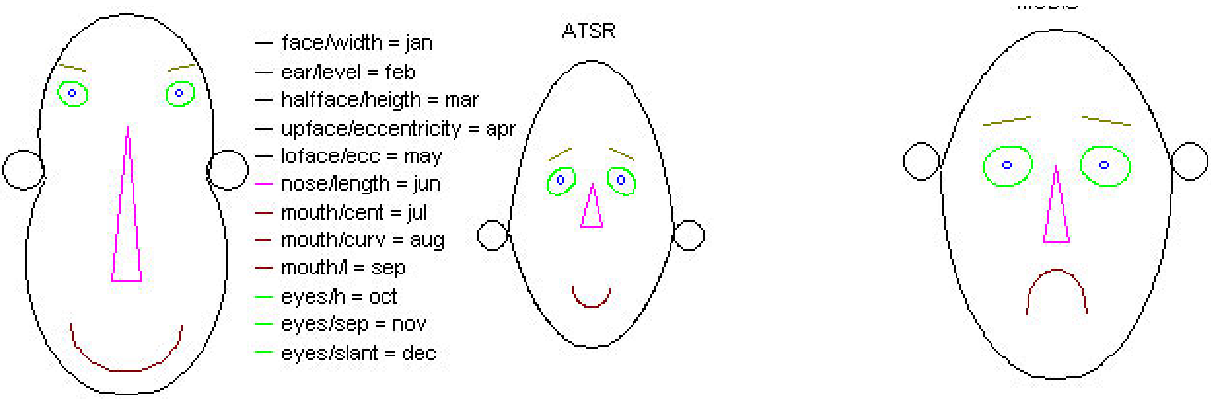
BBSO-2 Burnt Biomass and Satellite Observations workshop
is planned for **18-19 November 2009** in Toulouse (France)
bringing together specialists of fire products and atmospheric chemistry to understand how to correctly reproduce the global distribution of biomass burning and related emissions.

Should the future emission inventories be based on the **integration** (at regional or land cover level) of **multiple BA / AF / FRE** biomass burnt products?

Similarities and discrepancies …

Monthly Global CO emissions maps 2003

VGT **ATSR** **MODIS**



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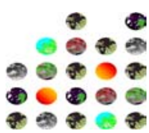

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