Estimating aerosol emissions by assimilating aerosol optical depth in a global aerosol model

N Huneeus, F. Chevallier and O. Boucher

Objective

Estimate the emission of SO_2 and the main aerosol species (DD, SS, BC & OM) through the assimilation of total and fine mode aerosol optical depth (AOD).

Method: Matrix formulation

$$J=(x-x_b)^T \boldsymbol{B}^{-1}(x-x_b)+(y-H[x])^T \boldsymbol{R}^{-1}(y-H[x])$$

$$x_a=x_b-(\mathbf{H}^T\boldsymbol{R}^{-1}\mathbf{H}+\boldsymbol{B}^{-1})^{-1}\mathbf{H}^T\boldsymbol{R}^{-1}(H[x_b]-\mathrm{y})$$

$$x_a=x_b+\mathbf{K}(\mathrm{y}-H[x_b])$$

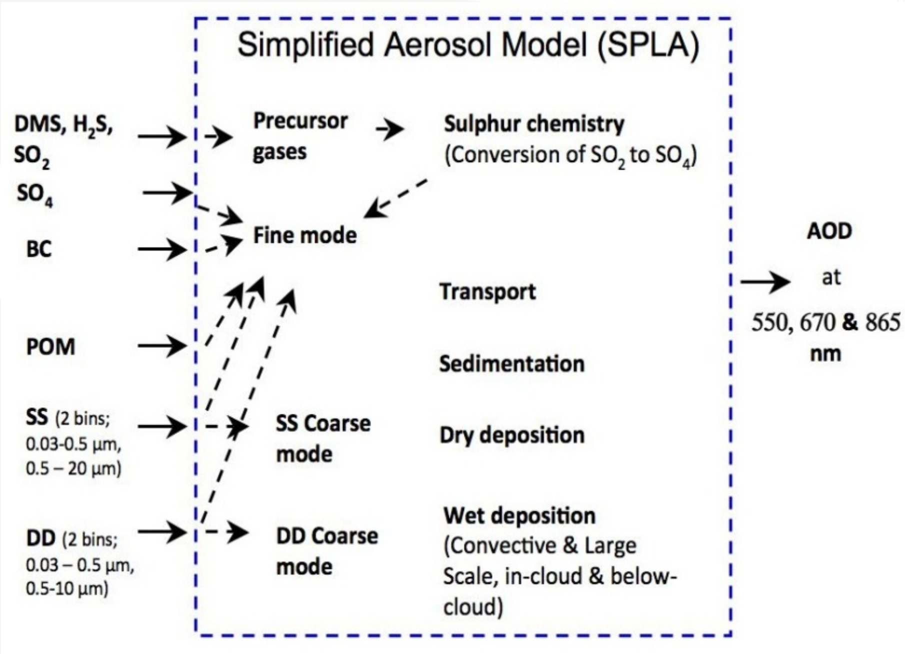
$\mathbf{K}=(\mathbf{H}^T\boldsymbol{R}^{-1}\mathbf{H}+\boldsymbol{B}^{-1})^{-1}\mathbf{H}^T\boldsymbol{R}^{-1}$

H= Linear operator

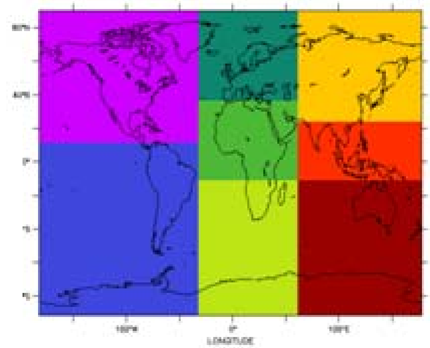
R = observation error covariance matrix

B = background error covariance matrix

Observation operator *(H)*

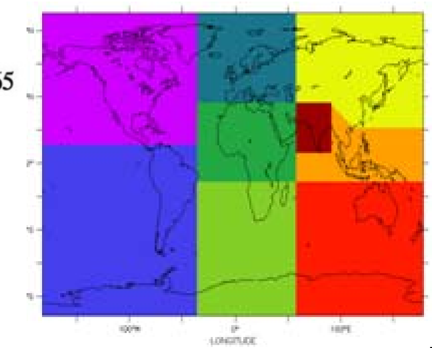


State vector (x)



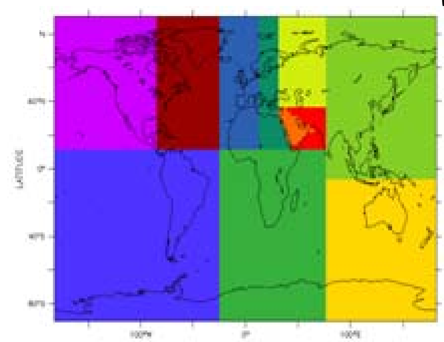
Sulfur Emissions (8)

Combustion of fossil fuels (8)



Biomass Burning (8)

(Huneeus et al., 2009)



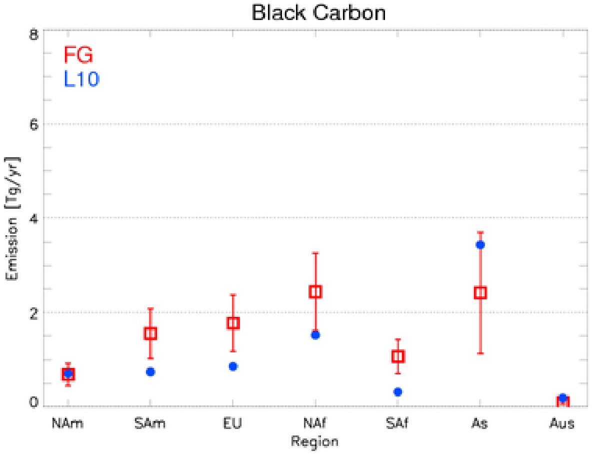
Fine mode desert dust (11)

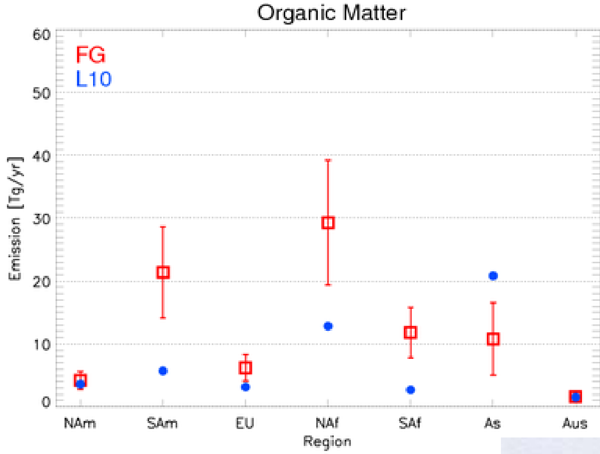
Coarse mode desert dust (11)

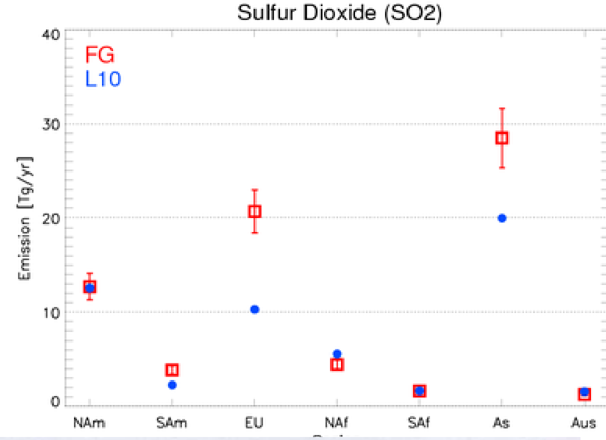
Fine mode sea salt (global)

Coarse mode sea salt (global)

A priori emissions [Tg/yr]







Error characterization (B matrix)

SO2: 31% (Smith et al., 2011)

Black Carbon: 70% (Bond et al., 2004)

Organic Matter: 70% (Bond et al., 2004)

Desert Dust: 203% (Huneeus et al., 2011)

Sea Salt: 18% (Penner et al., 2001).

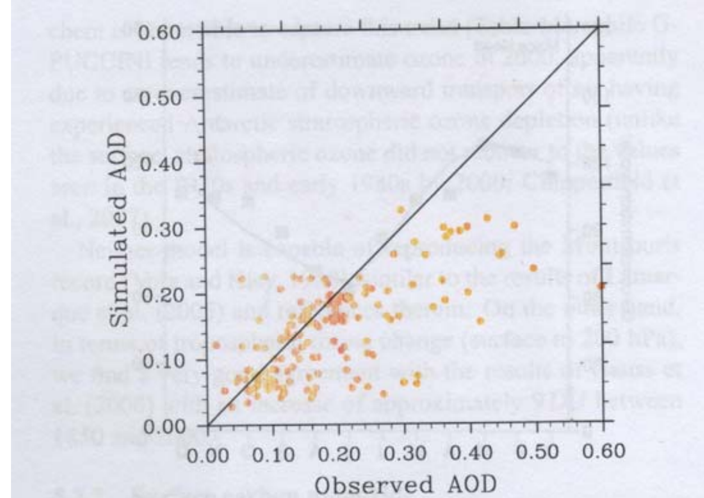


Fig. 11. Comparison between observed and modeled (present-day) annually aerosol optical depth at 500 nm. The observed values are based on annually averaged AERONET optical depths (Holben et al., 1998).

Lamarque et al. (2010)

Observations (y)

•Daily Total and Fine mode AOD from MODIS-Terra Collection 5 (Level 3).

•Total AOD over land and ocean and Fine mode AOD only over ocean

•MODIS data (1°x1°) are thinned to model resolution (2.5°x3.75°)

•Additional data screening over ocean to remove outliers and correct biases.

- Remove pixels with AOD>3
- Remove pixels with cloud fraction larger than 80% (also applied over land)
- No pixel south to 40°S is considered

Error characterization (R matrix)

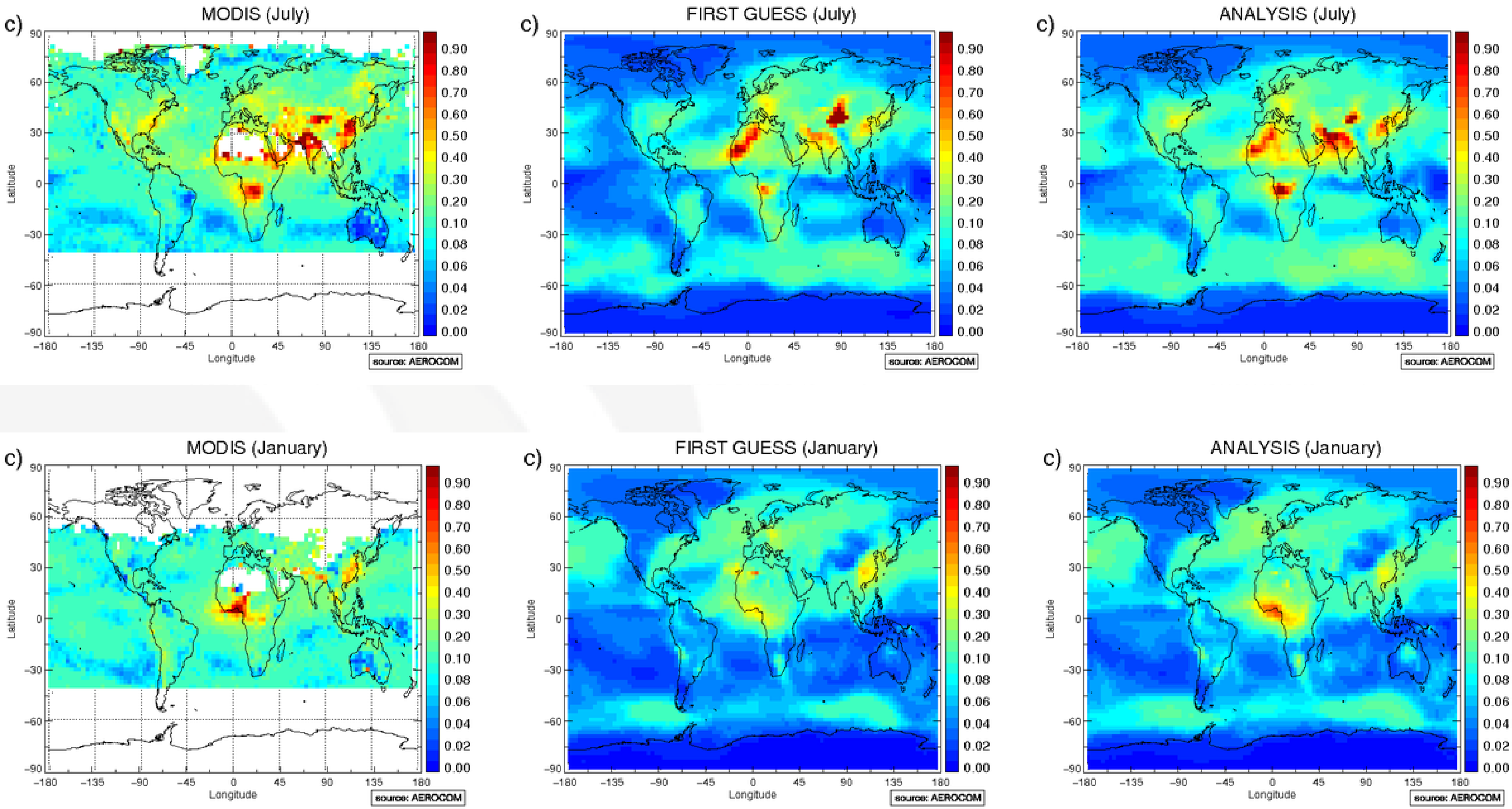
Observation Error

±0.05 ± 0.15*AOD => 0.1 (land)

±0.03 ± 0.05*AOD => 0.05 (ocean)

Model Error 0.02

Comparison with MODIS (total AOD)



Comparison with MODIS

Total AOD

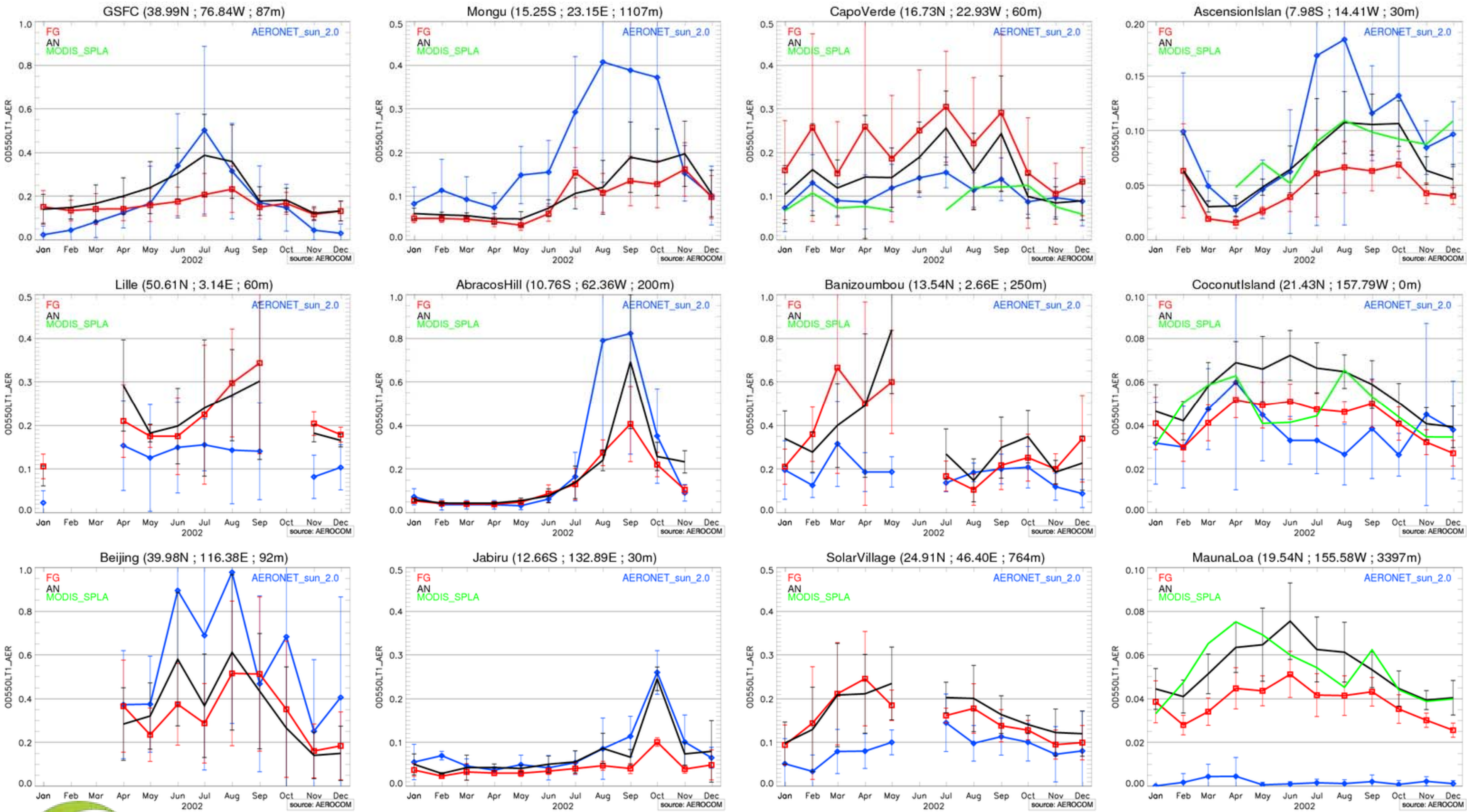
	RMS	**Bias**	**Correlation**
First Guess	0.177	-0.068	0.442
Analysis	0.106	-0.052	0.652

Fine Mode AOD

	RMS	**Bias**	**Correlation**
First Guess	0.051	-0,016	0.548
Analysis	0,044	-0.0008	0.634

Comparison with AERONET

Anthropogenic	Biomass Burning	Desert Dust	Sea Salt



Comparison with AERONET

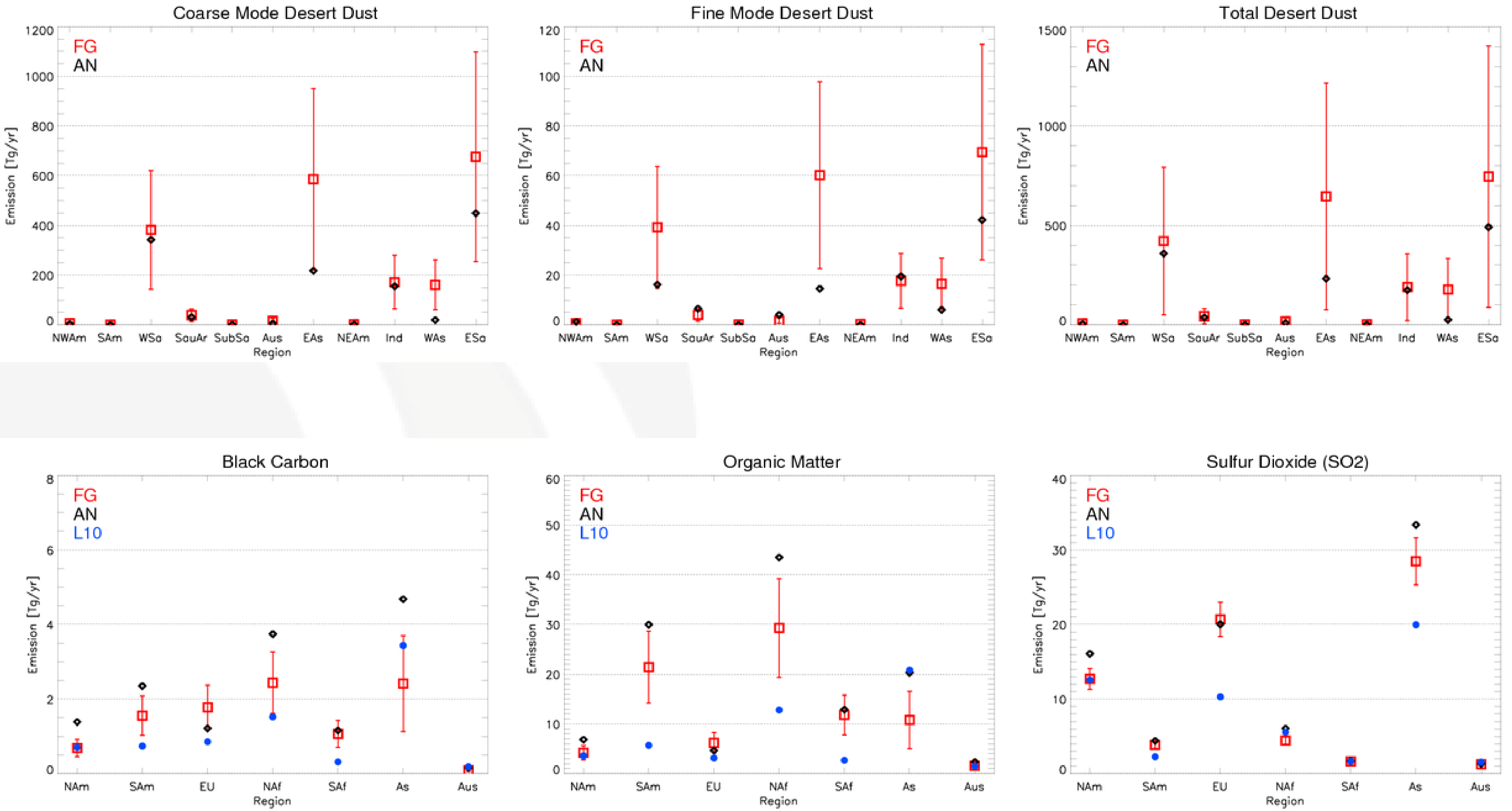
Total AOD

	RMS	Bias	Correlation
First Guess	0.136	-0.065	0.702
Analysis	0.119	-0.047	0.756

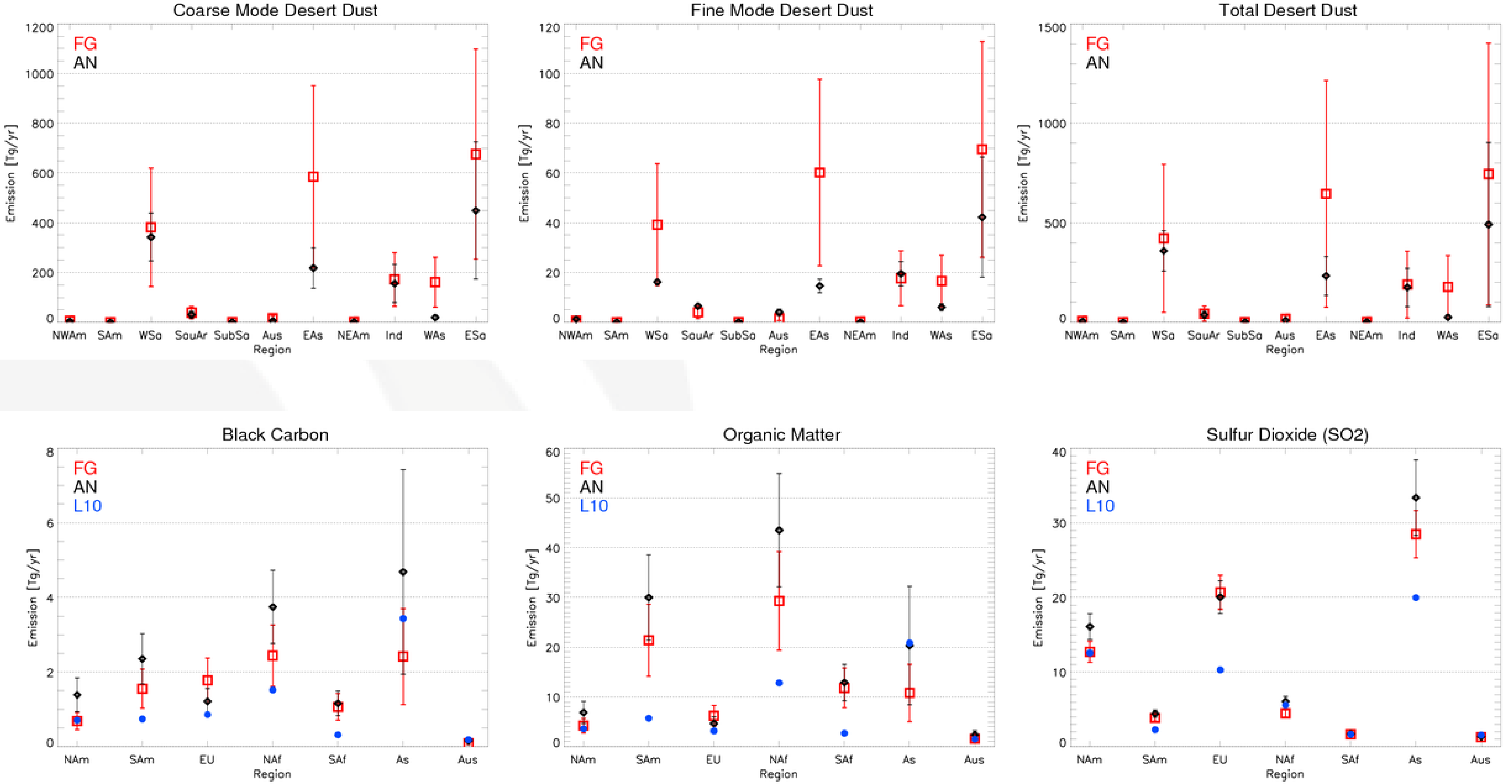
Fine Mode AOD

	RMS	Bias	Correlation
First Guess	0.118	-0.0082	0.60
Analysis	0.108	-0.0075	0.68

Estimated emissions [Tg/yr]



Uncertainty analysis [%]



Conclusion & Perspective

- The assimilation reduces the large overestimation of AOD associated to desert dust and increases the AOD associated to biomass burning and fossil fuel combustion

- The assimilation improves total and fine mode AOD with respect to MODIS.

- Improvement is reduced when comparing the output to independent data as AERONET (representativity, difference with assimilated observation).

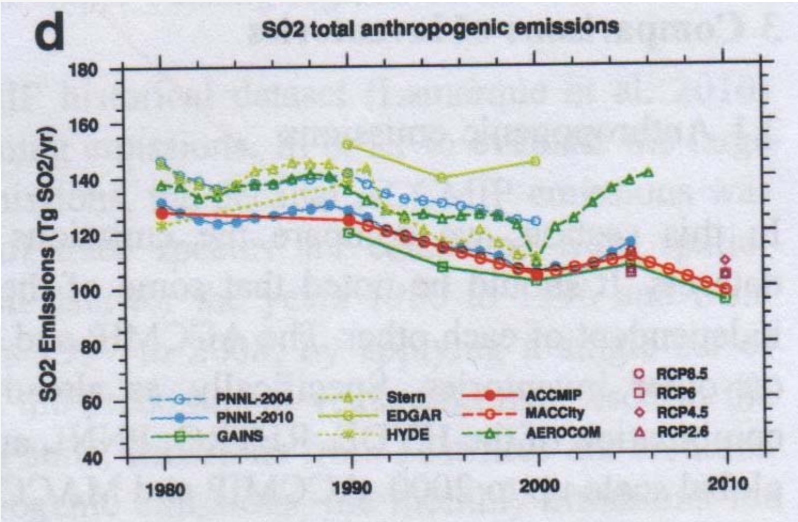
- Assimilation system allows to estimate the emission errors.

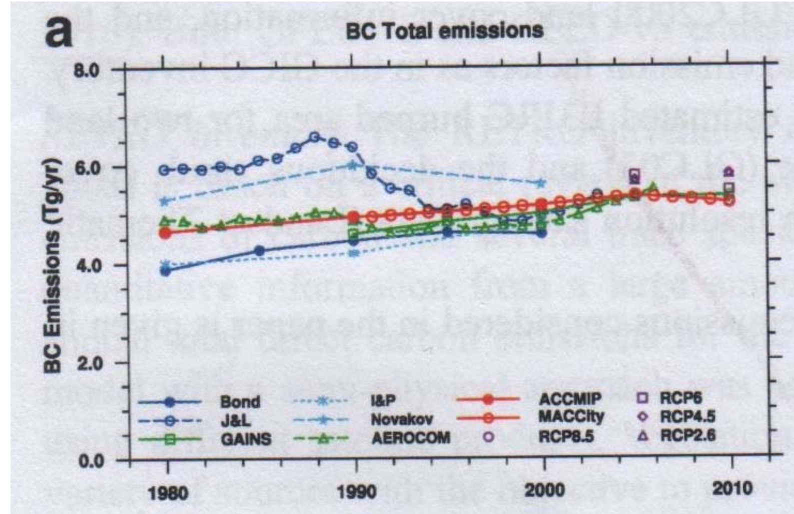
- The assimilation of total and fine mode AOD improves slightly the Angström Exponent.

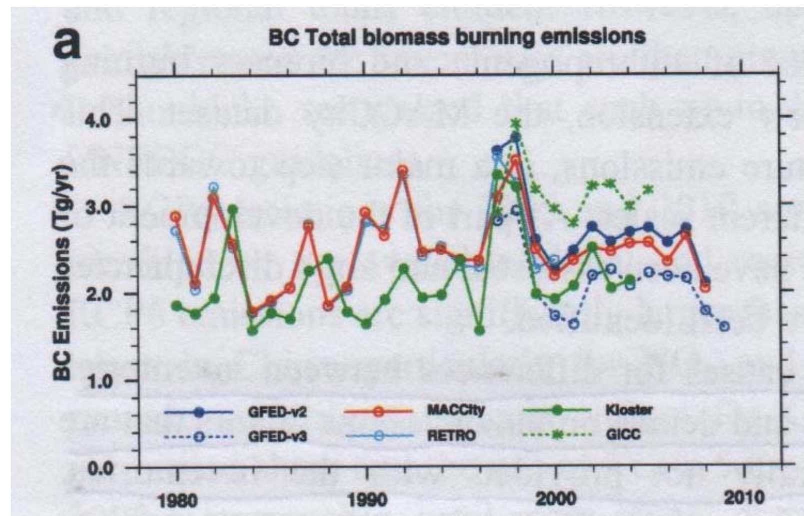
- Remains to be seen if the new emissions improve the performance in a model with increased complexity.

Thank you for your attention

Introduction







Comparison of emission inventories

Granier et al. (2011)