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A satellite view of global desert dust and primary carbonaceous aerosol emission database, 2006-2011
Part: desert dust

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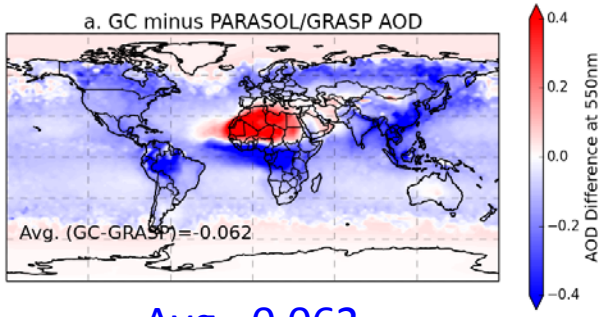
October 10th , 2017

Model simulations *vs.* Satellite observations

- Comparison with PARASOL/GRASP, MODIS and MISR AOD at 550nm

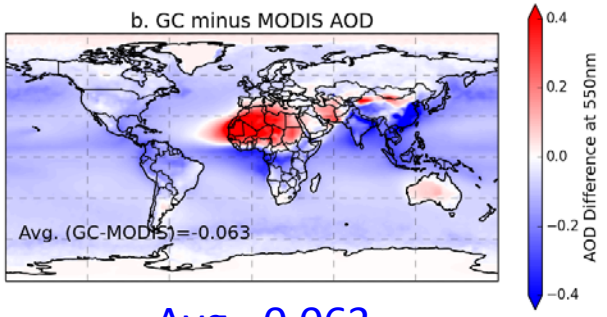
Annual mean (2006-2011)

a. GEOS-Chem minus GRASP AOD



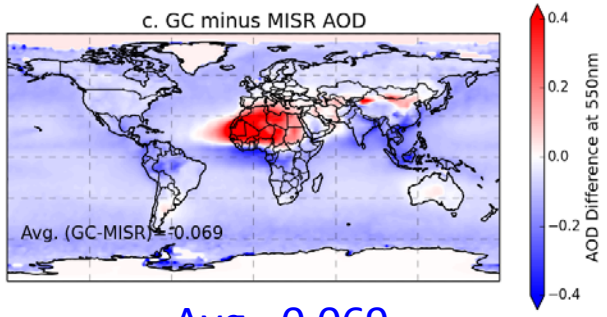
Avg. -0.062

b. GEOS-Chem minus MODIS AOD



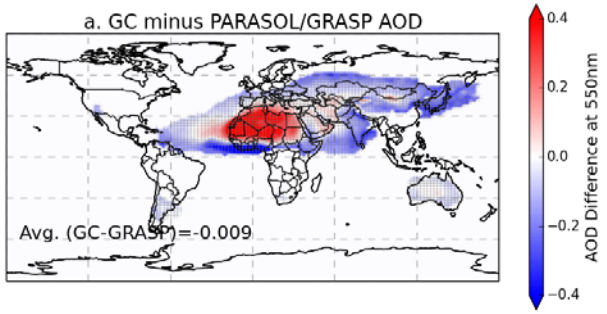
Avg. -0.063

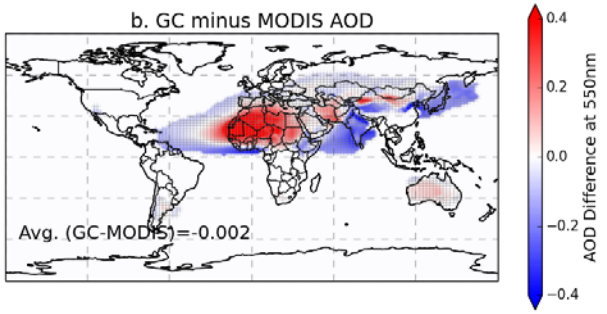
c. GEOS-Chem minus MISR AOD

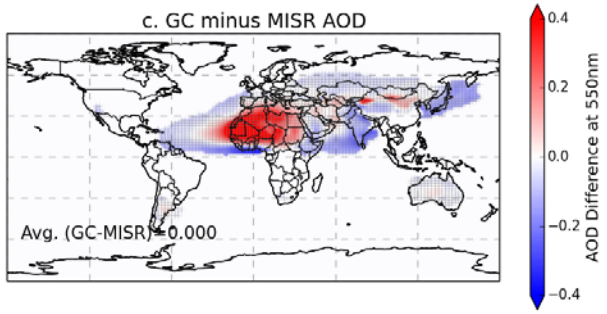


Avg. -0.069

- Select the dust dominant grid boxes ——— *dust is the first contributor to total AOD*







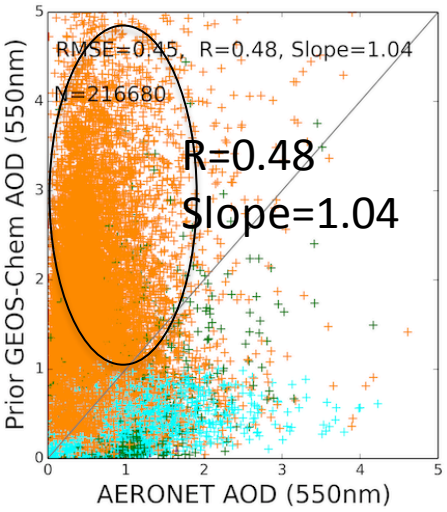
✓ AOD is overrepresented near dust source region. ——— *Emission is too high.*

✓ AOD is often underestimated in transported area. ——— *Removal is too rapid.*

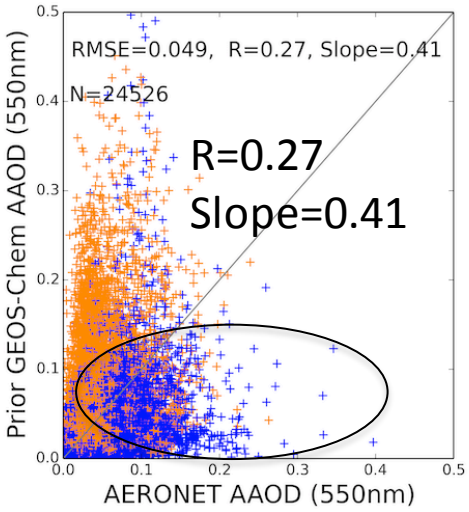
Prior GEOS-Chem evaluation with AERONET and PARASOL/GRASP observations

GC *vs.* AERONET

AOD

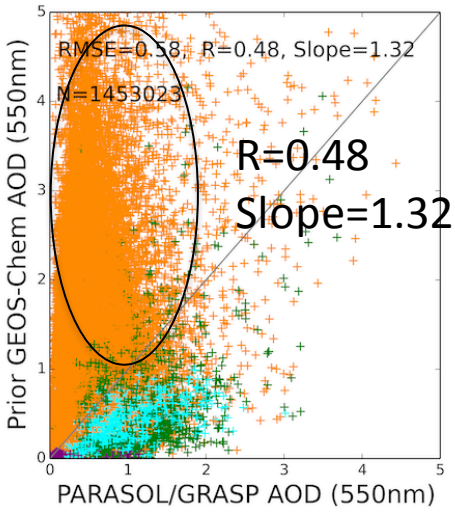


AAOD

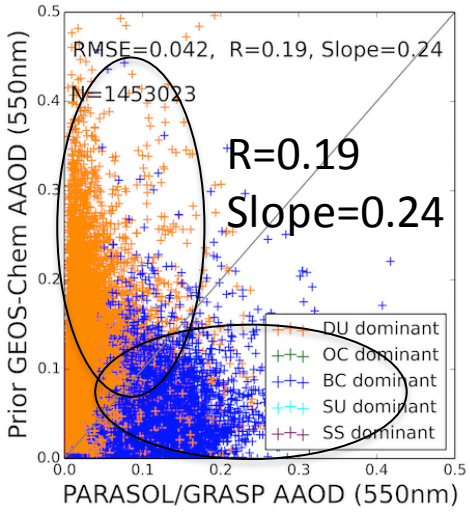


GC *vs.* GRASP

AOD



AAOD



AOD dominant: max{AOD_{BC}/AOD, AOD_{OC}/AOD, AOD_{DU}/AOD, AOD_{SU}/AOD, AOD_{SS}/AOD }

AAOD dominant: max{$AAOD_{BC}$/AAOD, $AAOD_{OC}$/AAOD, $AAOD_{DU}$/AAOD, $AAOD_{SU}$/AAOD, $AAOD_{SS}$/AAOD }

Dust
Organic Carbon
Black Carbon
Sulfate
Sea salt

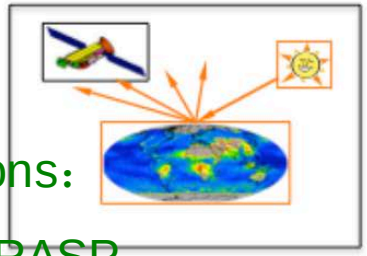
Major findings:

1. Dust AOD and AAOD from the model are broadly overestimated.
2. BC and dust are the two major components dominate the AAOD. However, the BC AAOD is underestimated.
3. The prior model AAOD is significant underestimated, with the linear regression slope ~0.41 with AERONET and ~0.24 with PARASOL/GRASP.

General Concept of Aerosol Emission Inverse Model

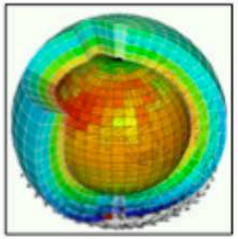
I. Observations:

PARASOL/GRASP



$$m(t,\boldsymbol{x}) = \int_{t_0}^{t} T(t',\boldsymbol{x})(m(t',\boldsymbol{x}) + s(t',\boldsymbol{x}))dt'$$

$$T(t,x) = T_q T_{q-1} \ldots T_3 T_2 T_1$$



II. Model:

GEOS-Chem and its adjoint

Satellite data: observations of ambient aerosol

INVERSION: (e.g. via adjoint model)

Transport Model:
- meteorology
- transport
- chemistry
- removal
- emissions?

III. Inversion

Retrieved Emissions

"Posterior Emissions"

Improved sources (location and strength)
Improved agreement of modeling with observations
Improved aerosol characterization for climate, air quality,etc.

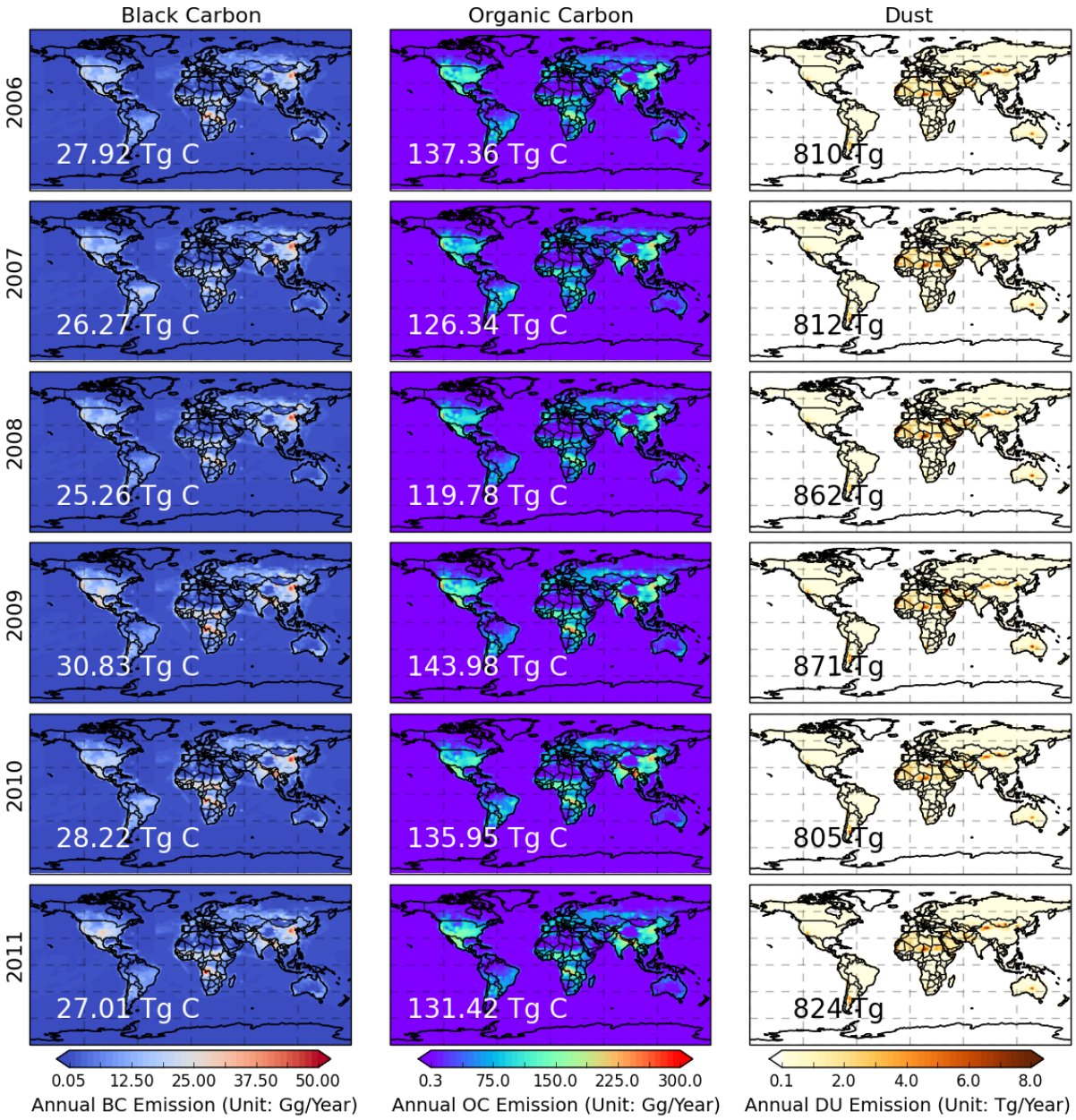
Henze et al., ACP, 2007
Dubovik et al., ACP, 2008

Cost Function: $$\mathrm{J}(\boldsymbol{S}) = \frac{1}{2}\sum_{\tau\in\tau,\tau_a} (\boldsymbol{\tau}(\boldsymbol{S}) - \boldsymbol{\tau}_{obs})^{\mathrm{T}} \mathbf{C}_{obs}^{-1} (\boldsymbol{\tau}(\boldsymbol{S}) - \boldsymbol{\tau}_{obs}) + \frac{1}{2}\gamma_r (\boldsymbol{S} - \boldsymbol{S}_a)^{\mathrm{T}} \mathbf{C}_a^{-1} (\boldsymbol{S}^p - \boldsymbol{S}_a)$$

Source Correction: $$\nabla \mathrm{J}^p(\boldsymbol{S}^p) = \mathbf{T}^{\mathrm{T}} \mathbf{F}^{\mathrm{T}} \mathbf{C}_{obs}^{-1} \Delta\boldsymbol{\tau}^p + \gamma_r \mathbf{C}_a^{-1} (\boldsymbol{S}_a - \boldsymbol{S}^p)$$

Spectral AOD and AAOD help to characterize DU, BC and OC aerosol emissions simultaneously.

GRASP-based aerosol emission database (2006-2011)

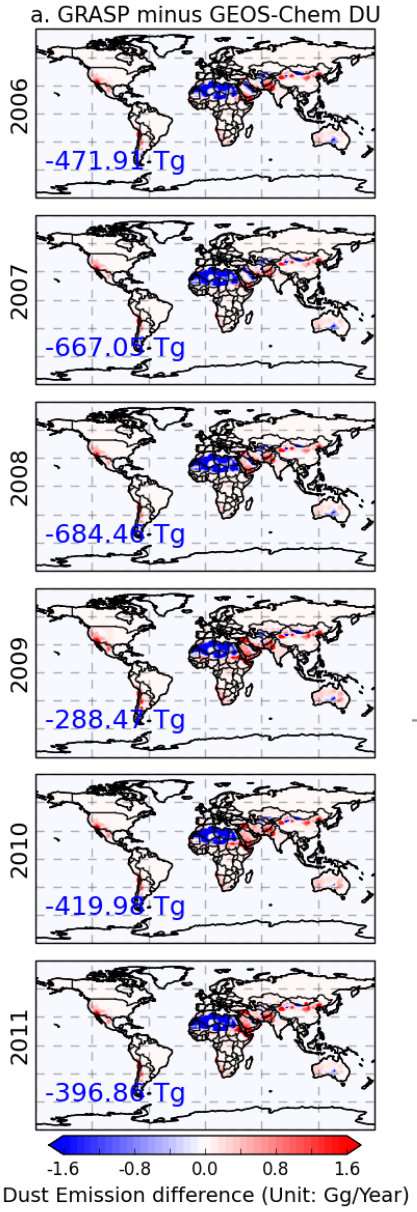


GRASP-based aerosol emission database from 2006-2011.
Spatial resolution: 2° x2.5°
Emission Time resolution:
DU – 24 hours constant
BC – 48 hours constant
OC – 48 hours constant
Dust: 0.1 ~ 6.0 um (exclude super coarse particles)

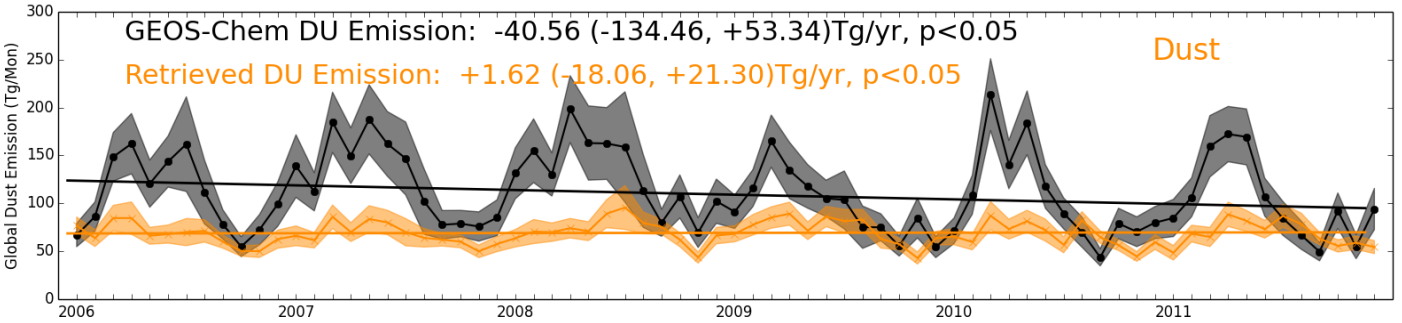
Annual Mean (2006-2011)	
BC: 27.6 Tg/yr	+294%
OC: 132.5 Tg/yr	+245%
DU: 831 Tg/yr	-38%

Dust Emissions (2006-2011)

Retrieval *minus* GEOS-Chem DU Emission



Monthly variation: Retrieval vs. GEOS-Chem dust emissions



GEOS-Chem Dust module:

DEAD dust model combined with GOCART dust source function

Ginoux et al., (2001)

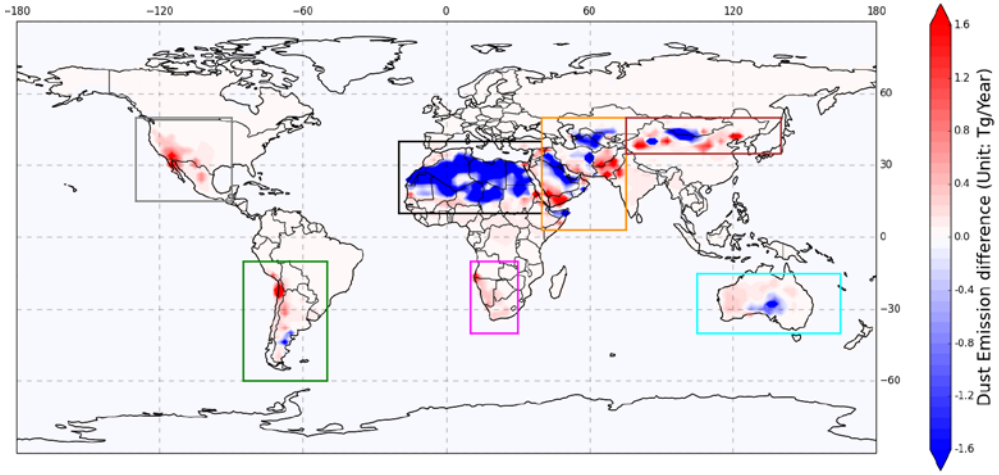
Zender et al., (2003)

Fairlie et al., (2007)

DU: -38%

GEOS-Chem: 1345 Tg/yr

Retrieval: 831 Tg/yr



Relative Change

North Africa: -564 Tg/yr

Middle East: -3 Tg/yr

South Africa: +63 Tg/yr

Australia: -6 Tg/yr

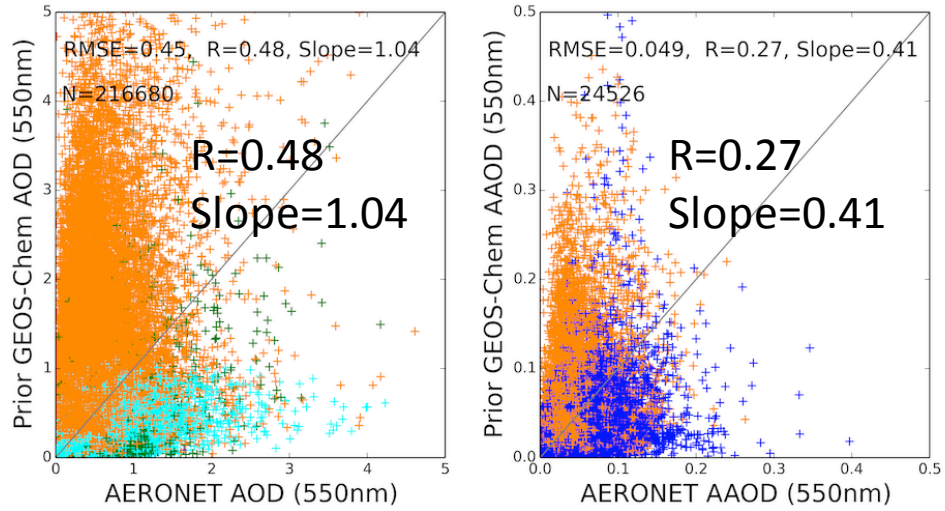
East Asia: -18 Tg/yr

South America: +14 Tg/yr

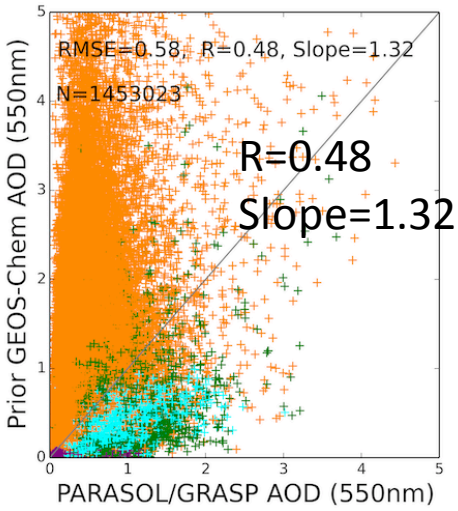
North America: +23 Tg/yr

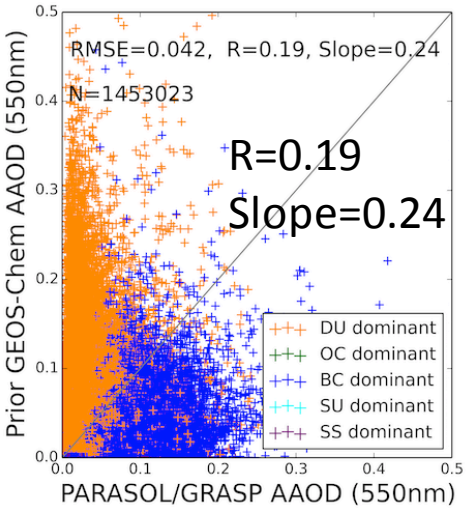
Posterior *vs.* Prior GEOS-Chem simulation

Prior GC *vs.* AERONET



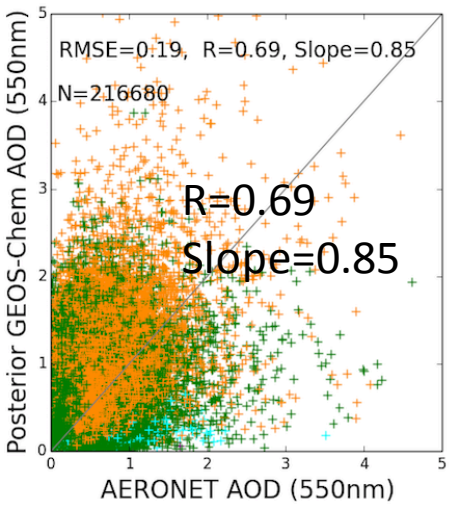
Prior GC *vs.* GRASP



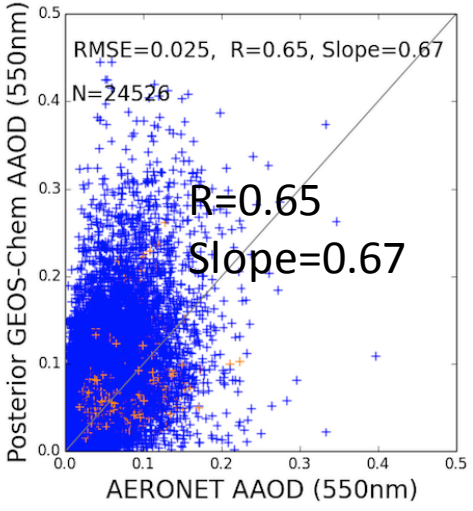


Post GC *vs.* AERONET

AOD

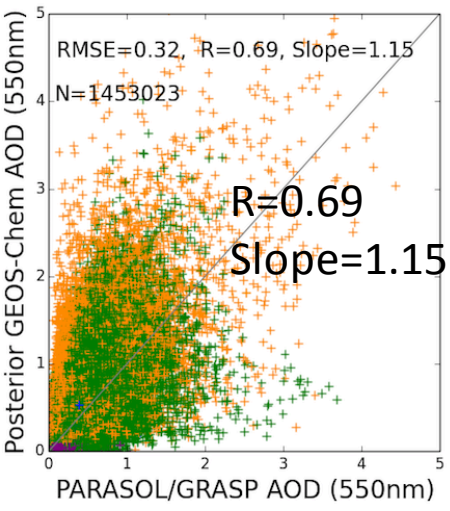


AAOD

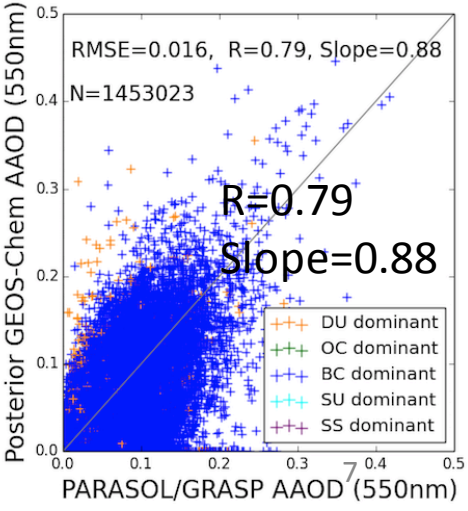


Post GC *vs.* GRASP

AOD



AAOD



Posterior GEOS-Chem Simulation *vs.* Observation

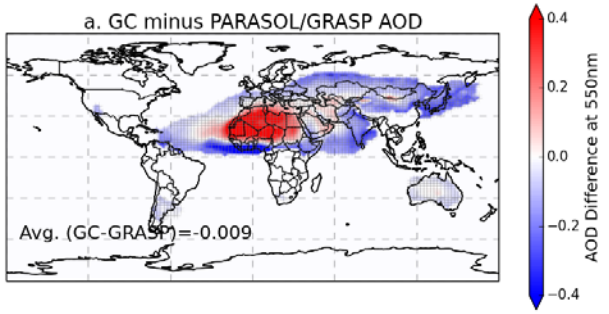
Annual mean (2006-2011)

only dusty grid boxes

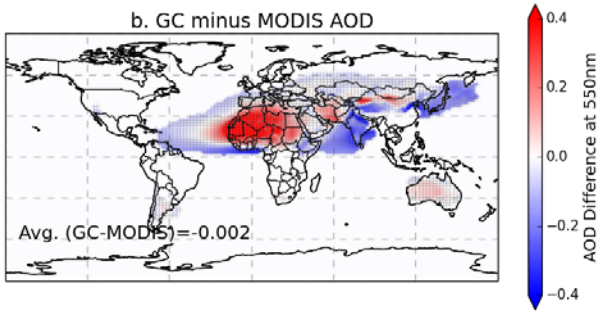
Posterior Simulation:
GRASP-based DU, BC and OC emissions
+ Prior GEOS-Chem SU and SS

Prior GEOS-Chem AOD *minus* Observations

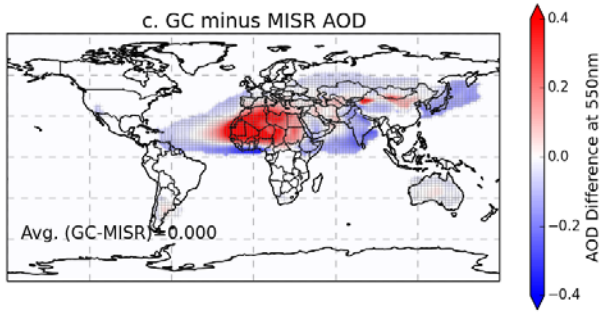
GEOS-Chem minus GRASP AOD



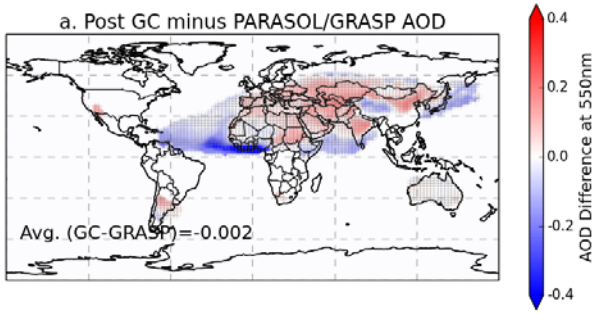
GEOS-Chem minus MODIS AOD

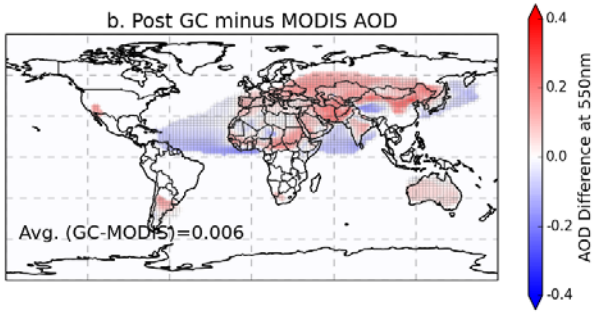


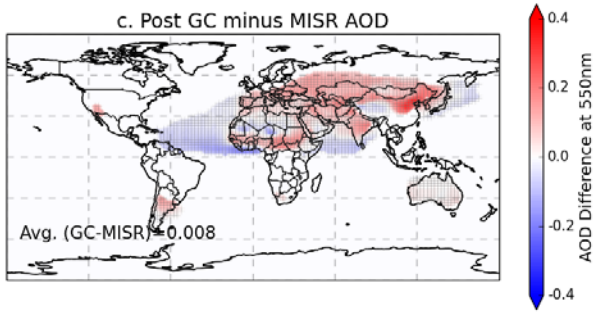
GEOS-Chem minus MISR AOD



Posterior GEOS-Chem AOD *minus* Observations





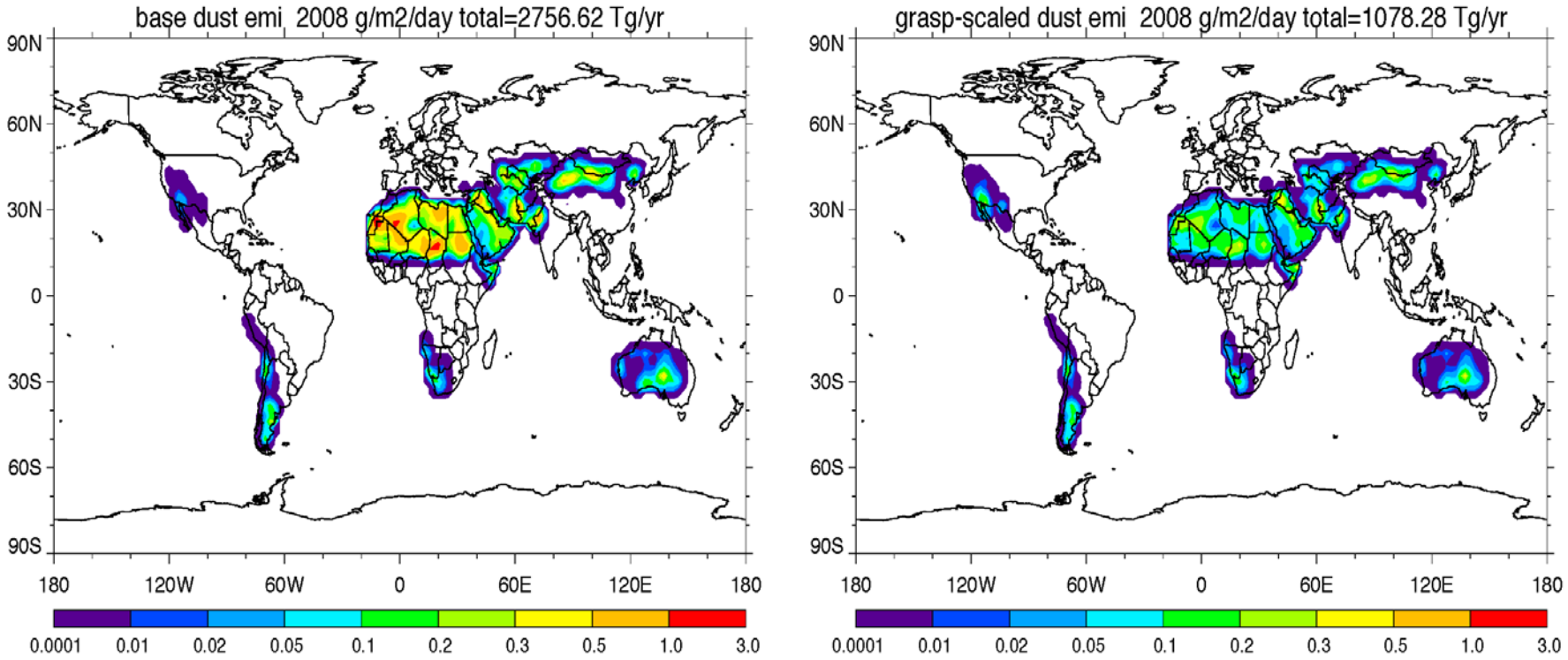


- ✓ Near dust source region: AOD too high (prior) -> fitted or slight high (posterior)
- ✓ Transported region: AOD slight low (prior) -> fitted over ocean & slight high over land (posterior)

Implement GRASP aerosol emissions on GEOS-5/GOCART

Dust emission 2008: BASE vs. GRASP

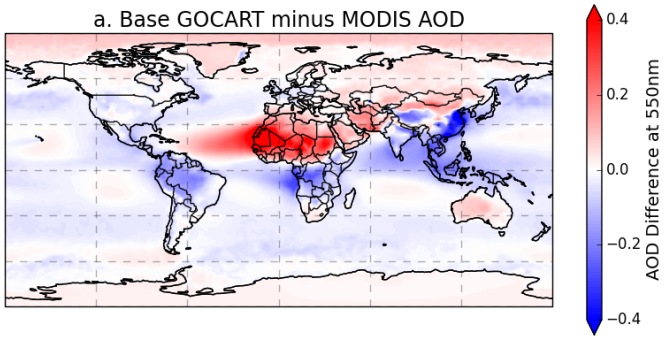
GRASP/BASE = 0.39



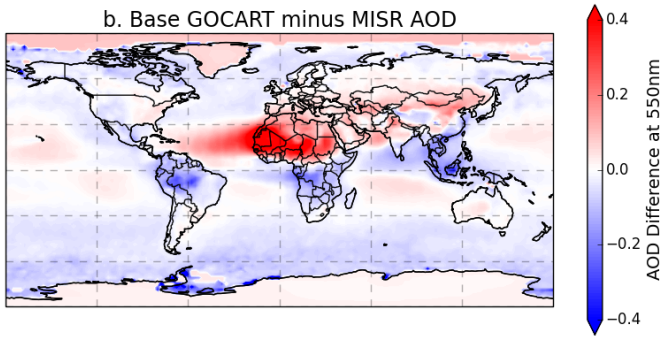
- Daily total gridded BC and OA emissions directly used as input to the model

Implement GRASP emission into GEOS-5/GOCART model

a. Base GOCART - MODIS



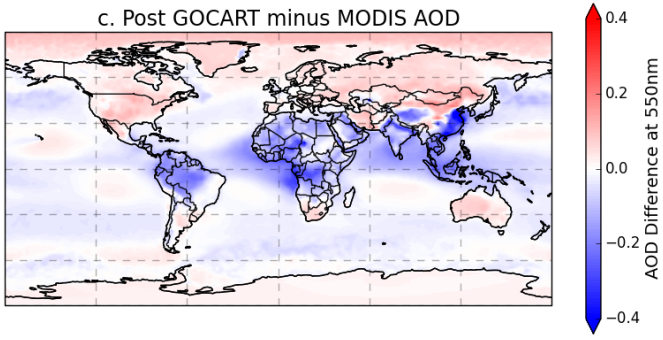
b. Base GOCART - MISR



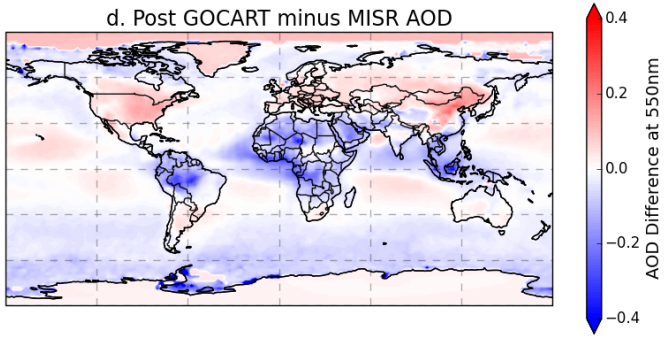
Base Simulation:

- ✓ Ginoux DU model
- ✓ HTAP v2 + FEER CC
- ✓ Online SS
- ✓ GOCART SU
- ✓ …

c. Posterior GOCART - MODIS

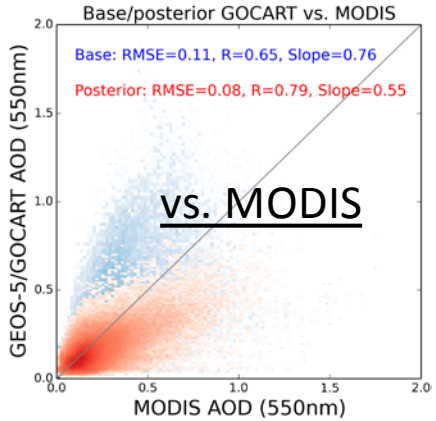


d. Posterior GOCART - MISR



Posterior Simulation:

- ✓ GRASP DU -60%
- ✓ GRASP CC + 150%
- ✓ Online SS
- ✓ GOCART SU
- ✓ …



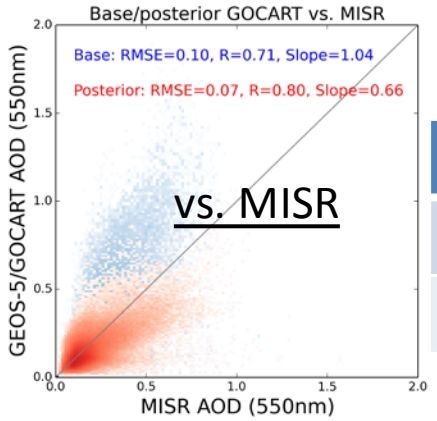
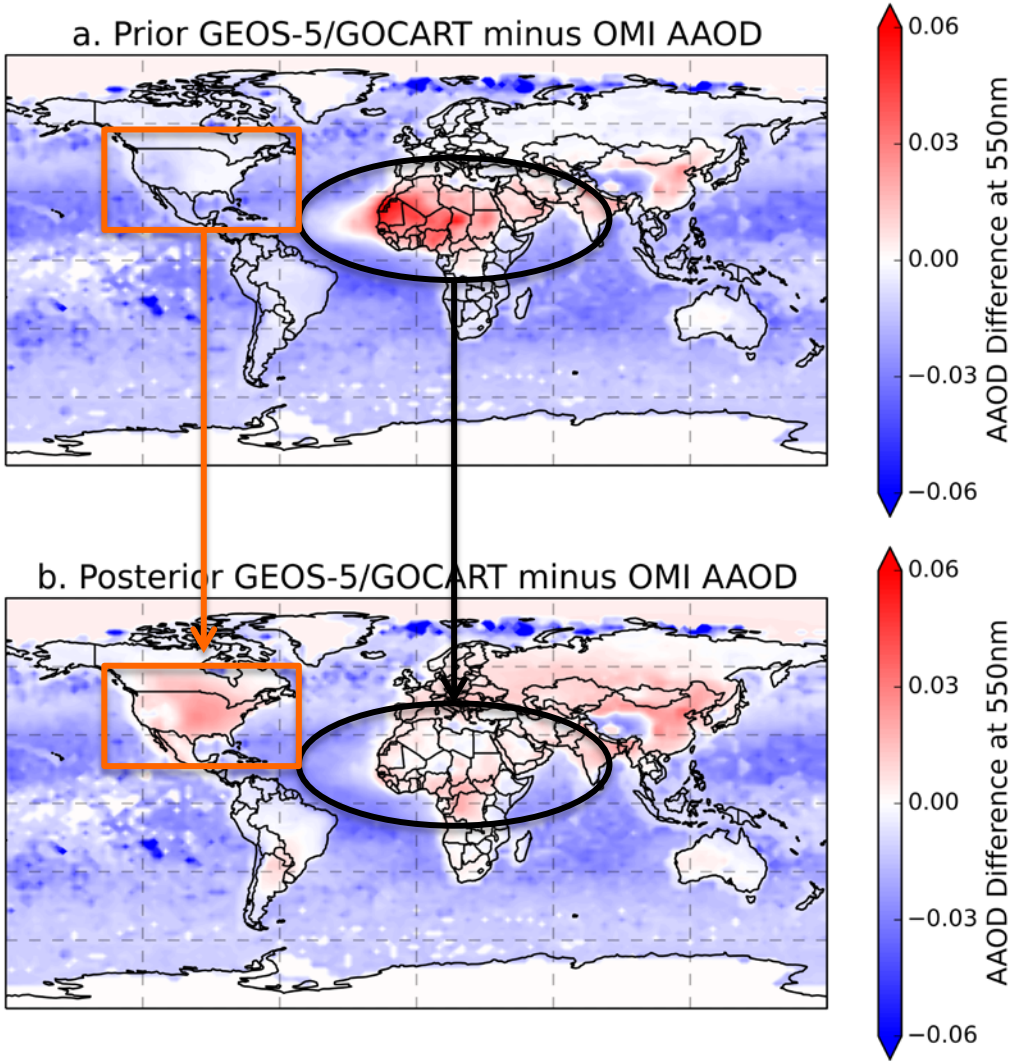


Table. Comparison of base/posterior GEOS-5/GOCART AOD with MODIS and MISR

	vs. MODIS	*vs.* MISR
Base	R=0.65; RMSE=0.11; Slope=0.76	R=0.71; RMSE=0.10; Slope=1.04
Posterior	R=0.79; RMSE=0.08; Slope=0.55	R=0.80; RMSE=0.07; Slope=0.66

Base/posterior GEOS-5/GOCART AAOD



OMI AAOD
(OMAERUV version 1.7.4)

Base GOCART – OMI AAOD

Posterior GOCART – OMI AAOD

- ✓ Adjust model AAOD overestimation over North Africa
- ✓ Our database produce more CC over North America

Conclusions and Perspectives

- Highlights:
  - Emission retrieved from PARASOL/GRASP observations with weak constrain of a prior knowledge of emission distribution and strength.
  - Model posterior simulated aerosol properties (AOD, AAOD, SSA and AExp) with our emission database can fit well with independent measurements (AERONET, MODIS, MISR, OMI). (see poster)
- Limitations:
  - We neglect the differences could be attributed to poorly modeled removal processes and model defined aerosol microphysical properties instead of emissions.
  - From optical view of satellite, our database can't distinguish between natural and anthropogenic sources.
- Now:

Look for AEROCOM modellers who are willing to test GRASP-based aerosol emission database to further validate in your CTM systems.

Please contact me: cheng1.chen@ed.univ-lille1.fr

Thanks for your attention !

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Acknowledge:

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AERONET team
GOCART team
…