Aerosol radiative forcing and effect on tropospheric chemistry: Modeling and uncertainty analysis in the GMI framework

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Project goal, objectives, and approach

Goal and Objectives

- Our goal is to incorporate different meteorological fields into the global aerosol and chemistry model for
  - Estimating the variability in model simulated aerosol distributions and radiative forcing due to the use of different meteorological fields
  - Examining the effects of aerosols and clouds on tropospheric composition via radiative and heterogeneous chemistry processes
  - Evaluating the model assessment credibility with remote sensing and atmospheric measurement data

Approach

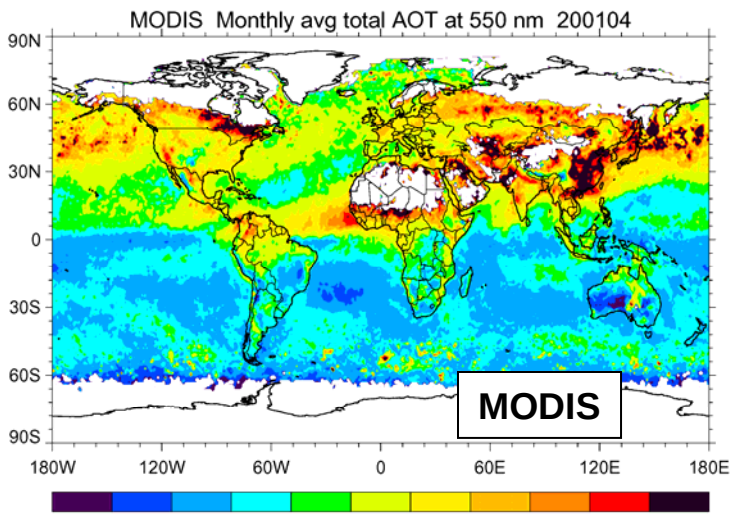
- Incorporating the aerosol processes in the current GOCART model into the flexible and modular GMI framework
- Calculating aerosol concentrations, optical thickness, and direct radiative forcing using the same model but different meteorological fields to quantify the variability of the aerosol fields
- Coupling aerosol and chemistry simulations within the GMI ME
  - Using oxidant fields that are consistent with meteorological conditions
  - Enabling simulation of nitrate aerosols
  - Providing aerosol surface area for heterogeneous chemistry
- Evaluating model results with observations from satellite, ground-based networks, and in-situ measurements
- Quantifying the range of aerosol radiative forcing due to the uncertainties in meteorological fields
- Analyzing the impacts of aerosols and clouds on atmospheric composition

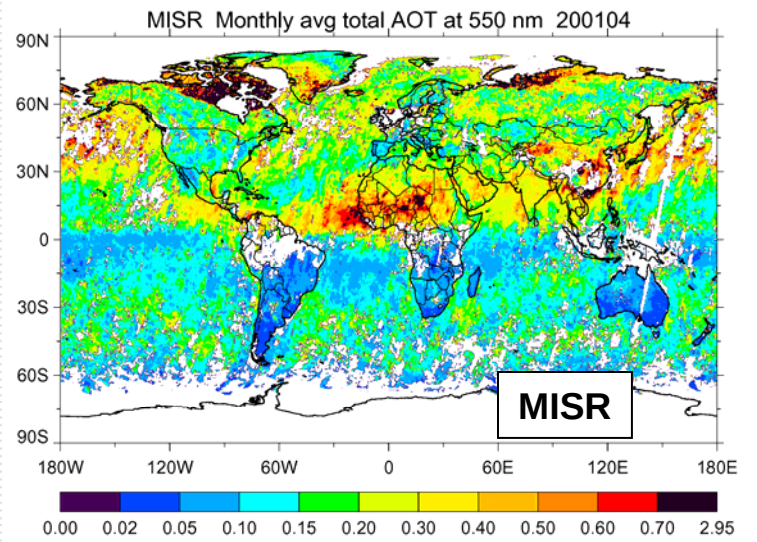
3-year schedule

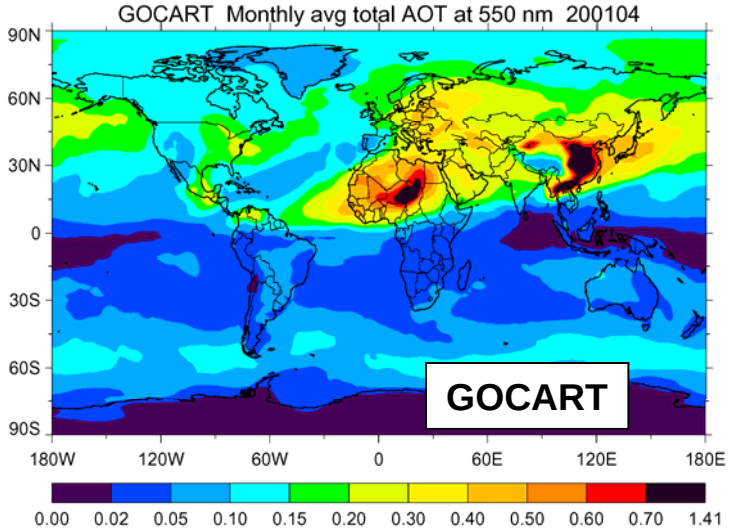
Activity	***Year 1***	***Year 2***	***Year 3***
Implementation of GOCART into GMI	☺		
GMI-GOCART aerosol simulations	☺	☺	☺
Coupled GMI chemistry-aerosol simulations		☺	☺
Model evaluation with observations	☺	☺	☺
Analysis of met data impact on aerosol forcing		☺	☺
Analysis of aerosol & clouds on trop chemistry		☺	☺

Model evaluations

Comparisons of aerosol optical thickness with MODIS and MISR

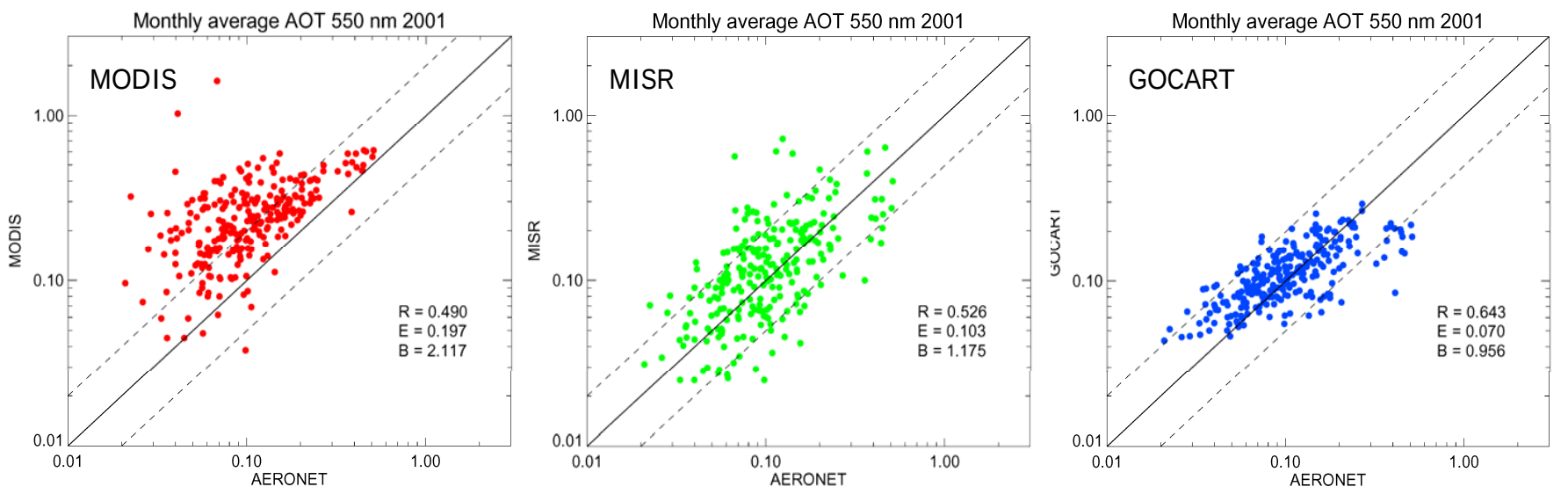






- MODIS AOT is higher over land than both MISR and GOCART
- MODIS and MISR have unrealistically high AOT over snow/ice
- GOCART is lower than MODIS and MISR over ocean

Comparisons with AERONET



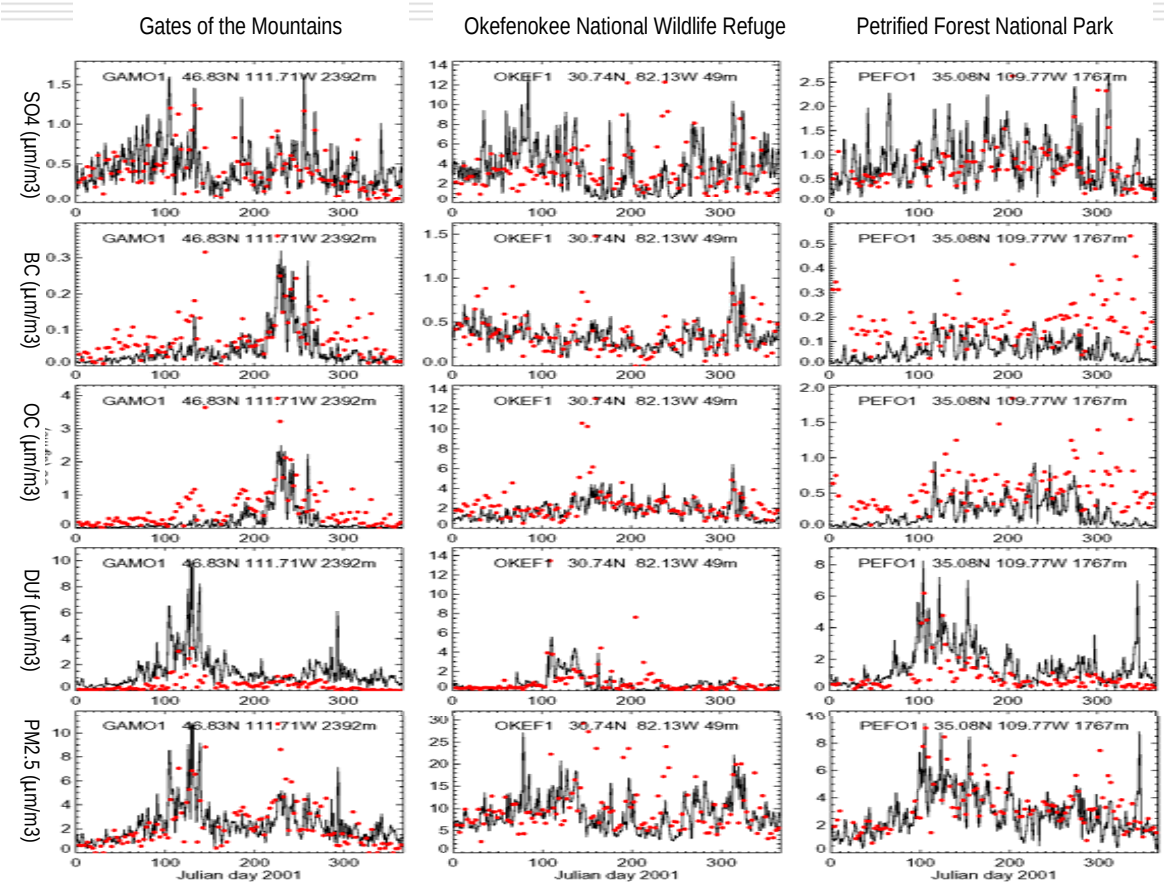
MODIS is biased high by 2x

MISR is pretty good but a bit scattered

GOCART has overall better scores but is “tilted” – too low at high AOT, too high at low AOT

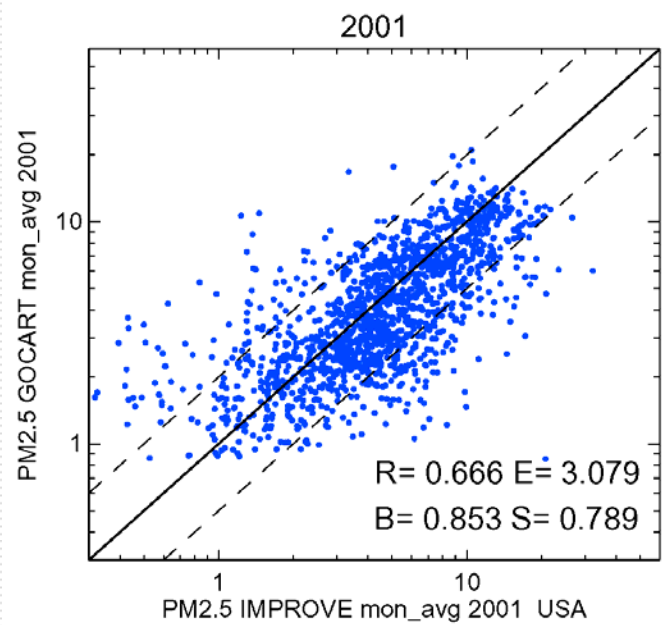
Comparisons of surface PM2.5 with IMPROVE sites over the U.S. (2001)

Aerosol daily concentrations at 3 IMPROVE sites



Red circles: data Black lines: model

Aerosol monthly average concentrations at all IMPROVE sites



Fire emission based on MODIS fire counts

Emission of aerosols and trace gases from fire

Mass of tracer *i* (M_i) emitted from fire:

$$\boxed{M_i = A \cdot B \cdot C \cdot E_i}$$

Dry mass burned

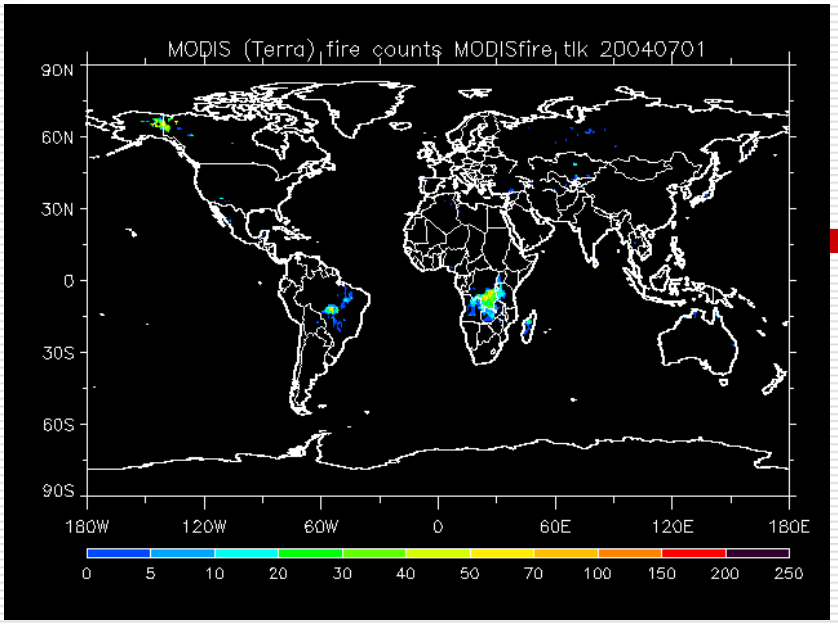
A = Area burned

B = Biomass density (or fuel load)

C = Completeness of burning (or burning efficiency)

E_i = Emission factor of tracer *i*

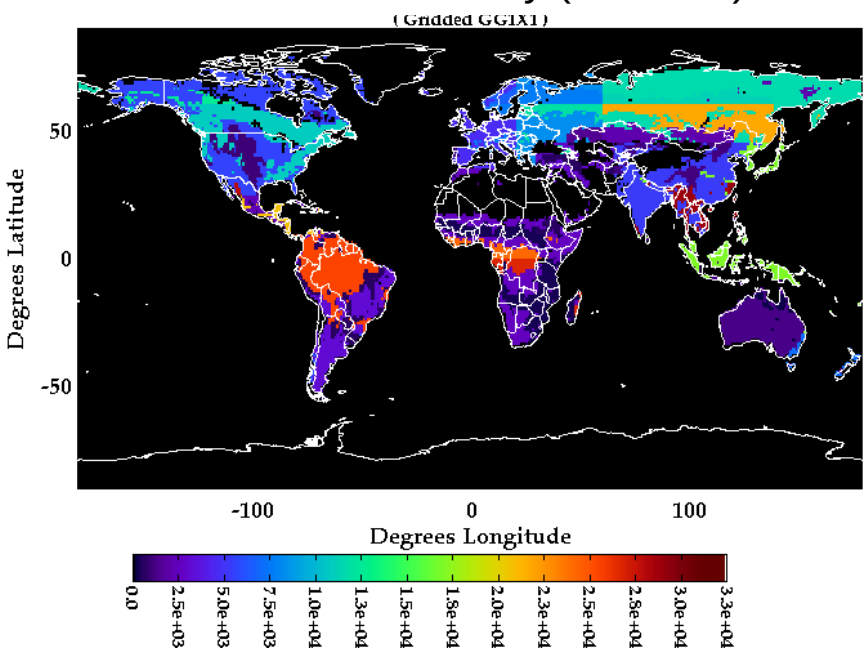
A = Terra-MODIS fire counts 20040701



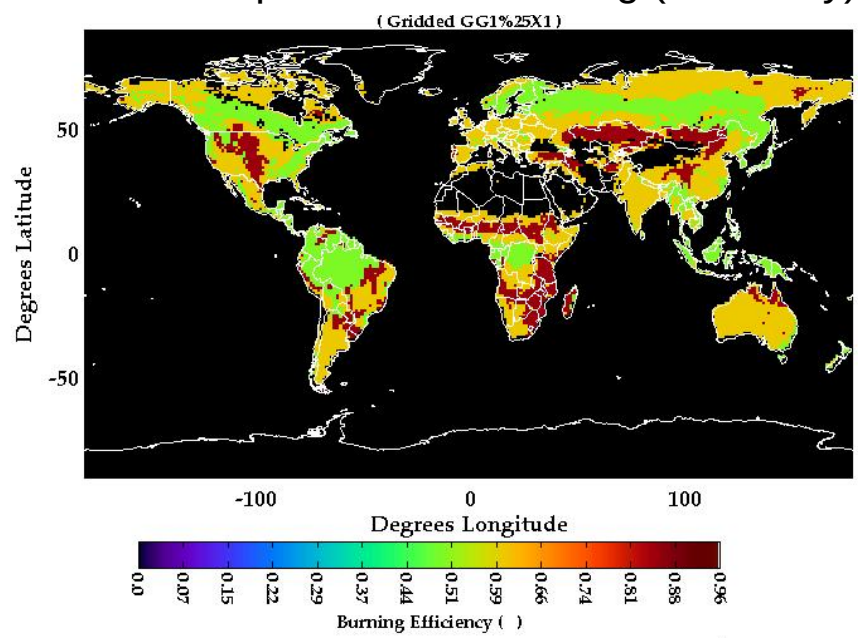
E = Emission factors

	Savana/ Grassland	Tropical Forest	Extratropfo rest	Biofuel	Agriculture Residual
BC	0.48±0.18	0.66±0.31	0.56±0.19	0.59±0.37	0.69±0.13
OC	3.4±1.4	5.2±1.5	8.6 – 9.7	4.0±1.2	3.3
SO_2	0.35±0.16	0.57±0.23	1.0	0.27±0.3	0.4
CO	65±20	104±20	107±37	78±31	92±84
CO_2	1613±95	1580±90	1569±131	1550±95	1515±177

B = Biomass density (fuel load)



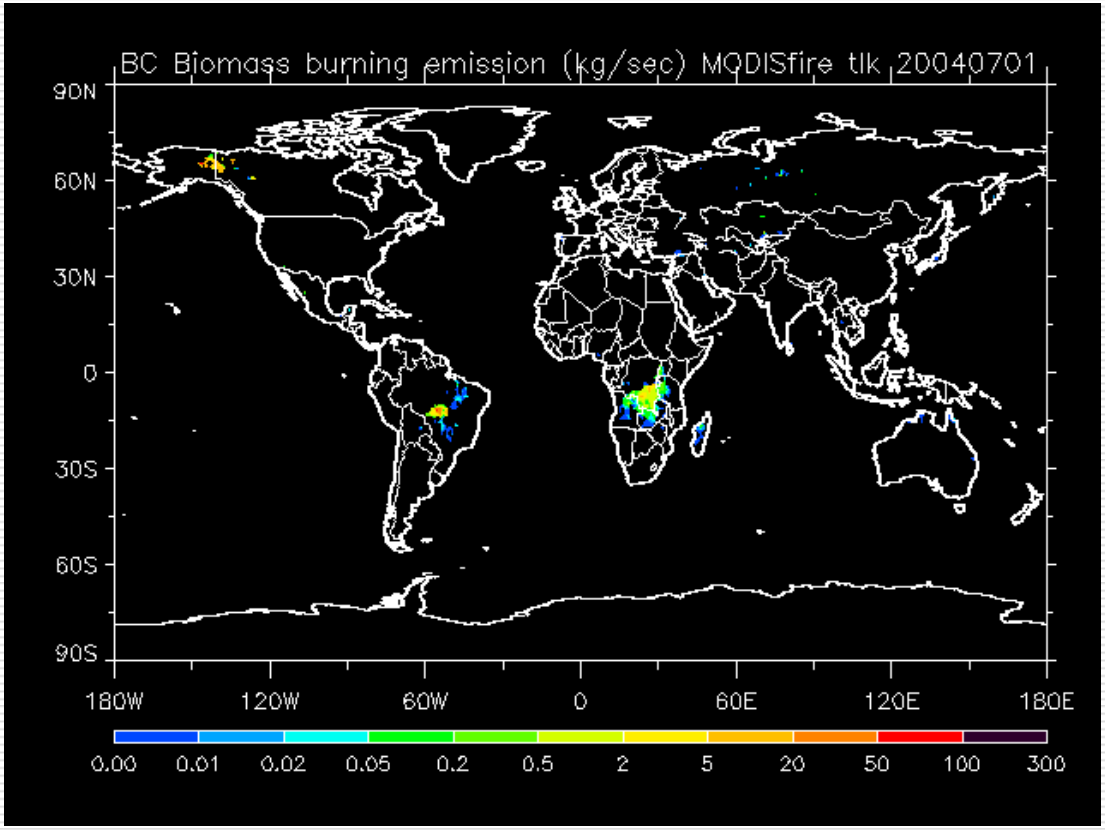
C = Completeness of burning (efficiency)



Example: BC biomass burning emission

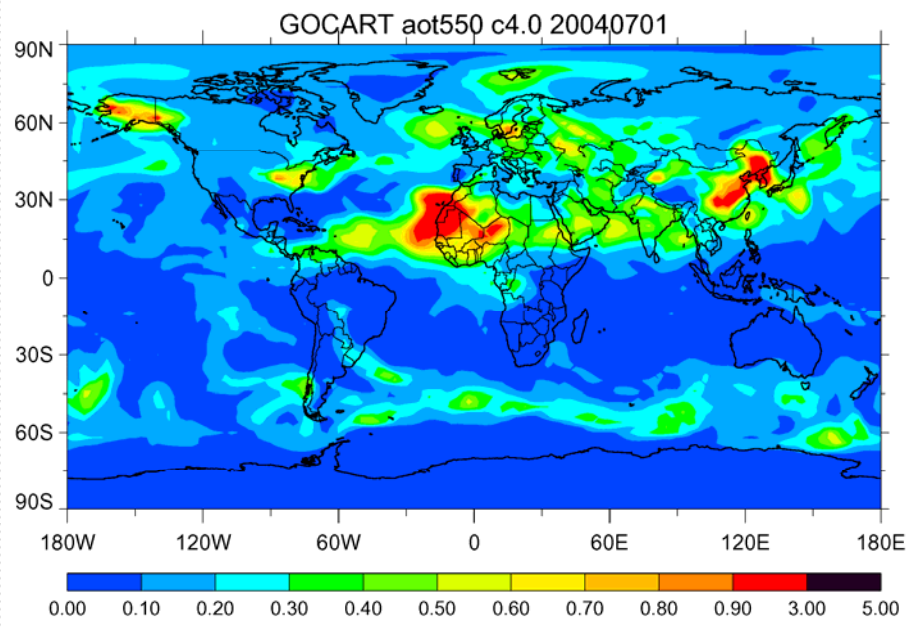
($M_{BC} = A \cdot B \cdot C \cdot E_{BC}$)

BC biomass burning emission July 1 2004

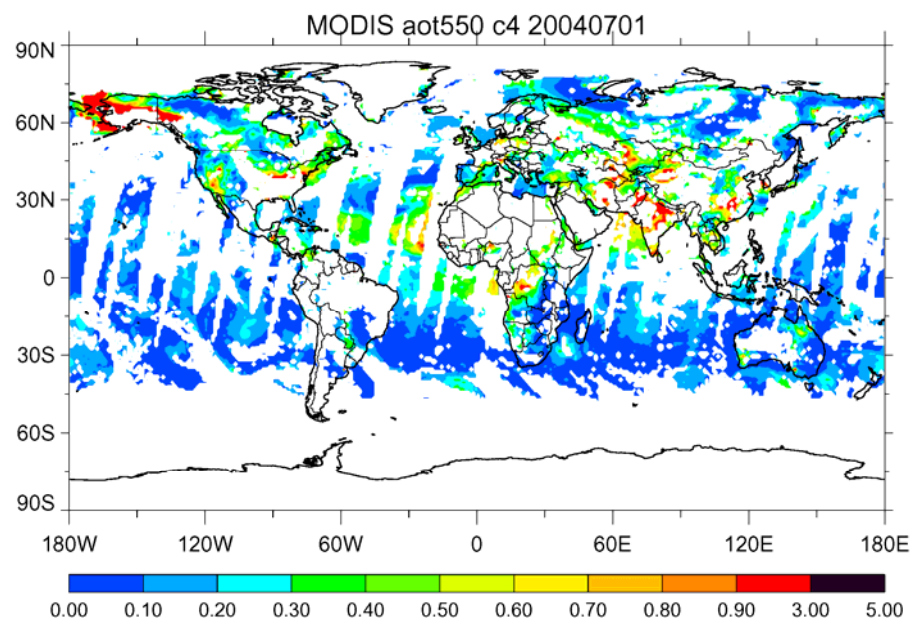


Total aerosol optical thickness at 550 nm, July 1, 2004 (including all emissions)

GOCART



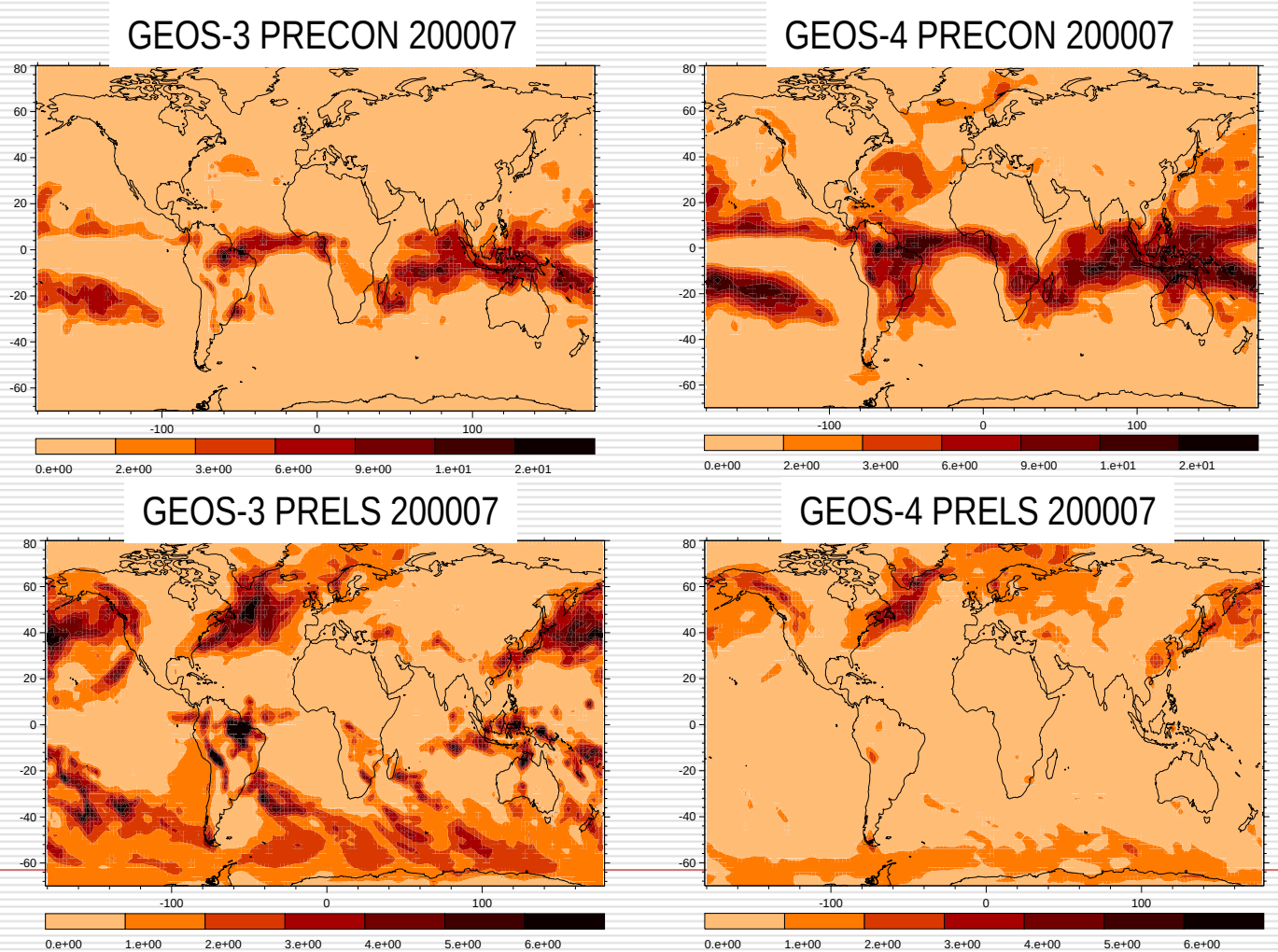
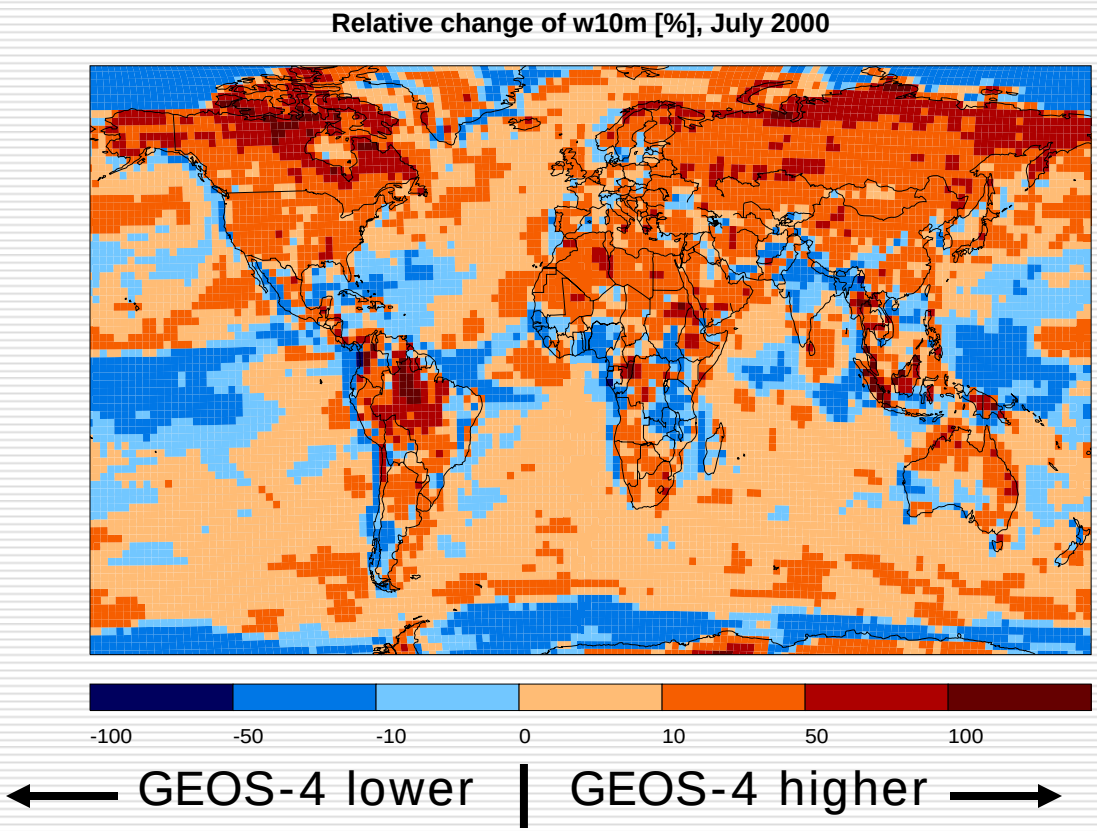
MODIS



One-year GMI-GOCART simulations with GEOS-3 DAS, GEOS-4 DAS, GEOS-4 forecast (e.g. 2001)

- GEOS-3 DAS precip are closer to GEOS-4 Forecast than to GEOS-4 DAS
- GEOS-3 DAS is less windy than both GEOS-4 forecast and GEOS-4 DAS

Large difference between GEOS-3 and GEOS-4 DAS:



Large differences in 10-m wind speed between GEOS-3 and GEOS-4