GMI Modeling of Aerosols: Comparisons with Surface and Satellite Observations

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Thanks to GMI core team: Susan Strahan, Bigyani Das, Chris Readinger, Jose Rodriguez

1. Introduction

- *Large uncertainties in current estimations of the aerosol direct & indirect effects on climate (IPCC, 2001) due to*
  - aerosol burdens and lifetimes predicted
  - aerosol size distributions assumed/predicted
  - Hydroscopic, optical properties, mixing states
  - …
- *Aerosol model comparisons (e.g., AEROCOM)*
  - emission-as-is
  - prescribed sources. However, different meteorology, schemes (scavenging, convection, chemistry…)

2. The GMI Aerosol Model

- The global Modeling Initiative (GMI) model, a modular CTM model incorporating different components and inputs, driven by 3 meteo. data: DAO, CCM3, GISS
  - horizontal resolution: 5° x 4°
  - vertical resolution:

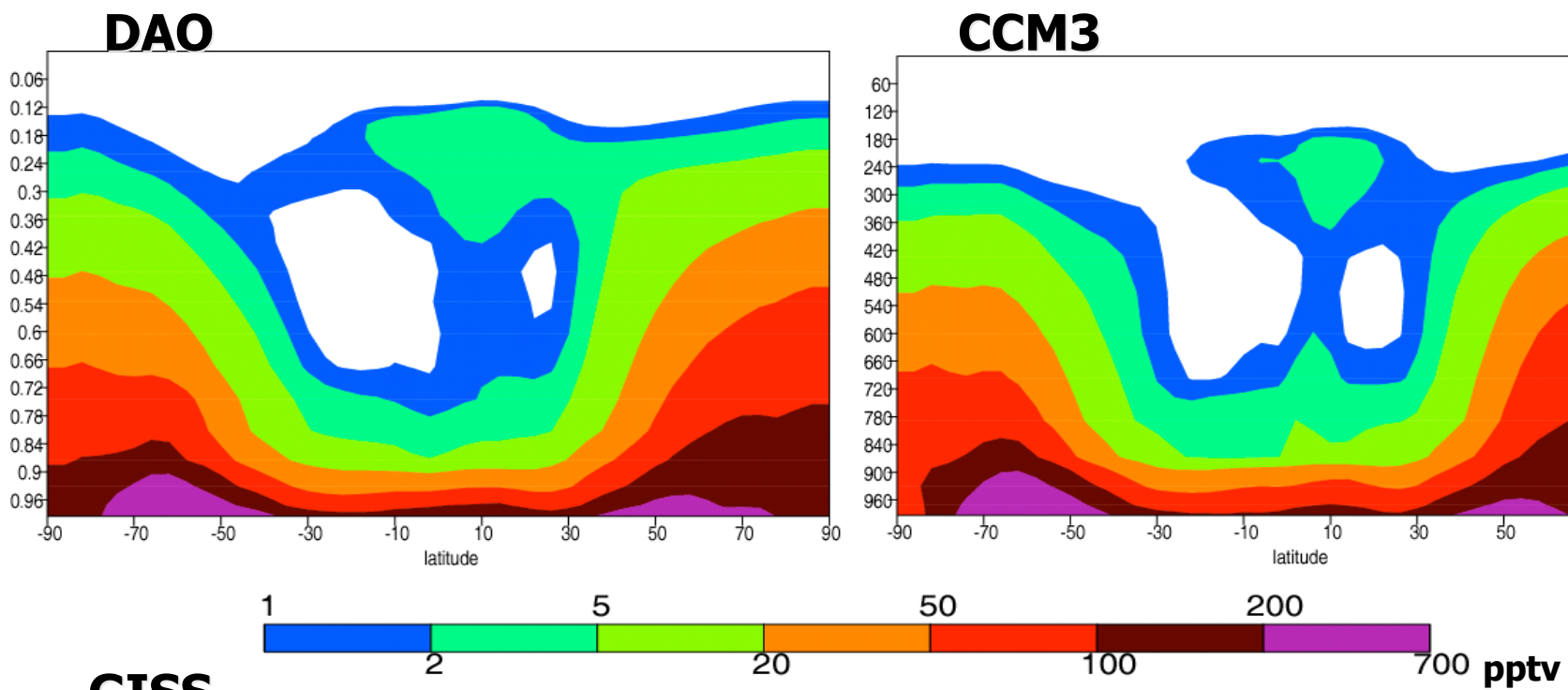
    DAO -- 46 levels, top at 0.1 hPa

    CCM3 -- 52 levels, top at ~0.006 hPa

    GISS -- 23 levels, top at ~0.016 hPa

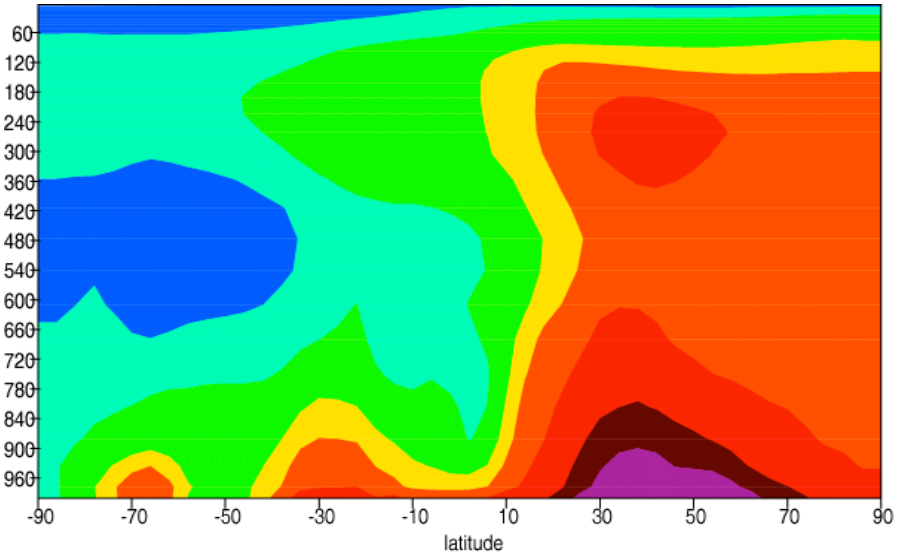
- *Adding aerosol module*
  - prognostic variables: DMS, SO_2, sulfate, H_2O_2, biomass burning OM/BC, fossil fuel OM/BC, natural OM, mineral dust 4 bins & sea salt 4 bins (0.05-0.6, 0.6-1.2, 1.2-2.5, 2.5-10 um radius)
  - gas and aqueous phase sulfate production from SO_2 with OH, H_2O_2, O_3. OH, HO_2, O_3, NO_3 from Michigan.
  - Large-scale stratiform and convective cloud fraction parameterized from Sundqvist et al. (1989) and Xu and Krueger (1991). Cloud water content parameterized from Hack (1998)
  - Dry deposition (Zhang et al., 2001), gravitational settling (Seinfeld and Pandis, 1997).
  - Wet deposition (Giorgi and Chameides, 1986; Balkanski et al., 1993) with in-cloud scavenging efficiency: BC/OM=0.4, SO4=1, dust=1, sea salt=1
  - Hydroscopic growth: Gerber (1991)

- *Emissions*
  - DMS: Kettle et al., (1999), 26.1 Tg S yr^{-1}
  - Fossil fuel SO_2: IPCC-specified 2000 (Nakicenovic et al., 2000), 69 Tg S yr^{-1}
  - Volcanic SO_2: Andres and Kasgnoc (1998), 4.8 Tg S yr^{-1}
  - BC: Fossil fuel and biomass burning (Penner et al., 1993; Liousse et al., 1996)
  - OM: Fossil fuel and biomass burning (Penner et al., 1993; Liousse et al., 1996); Natural OM: 9% of terpene emissions from Guenther et al. (1995)
  - Mineral dust: Ginoux et al. (1997)
  - Sea salt: Gong et al. (1997)

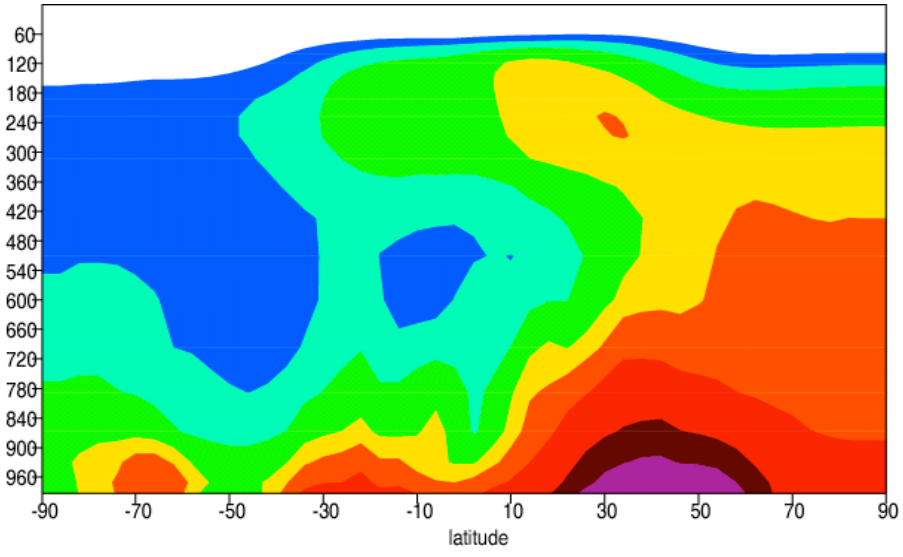


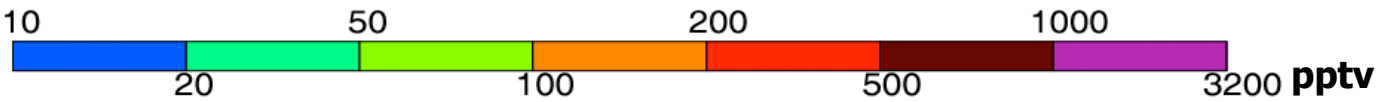
Annual and zonal mean DMS (pptv)

DAO

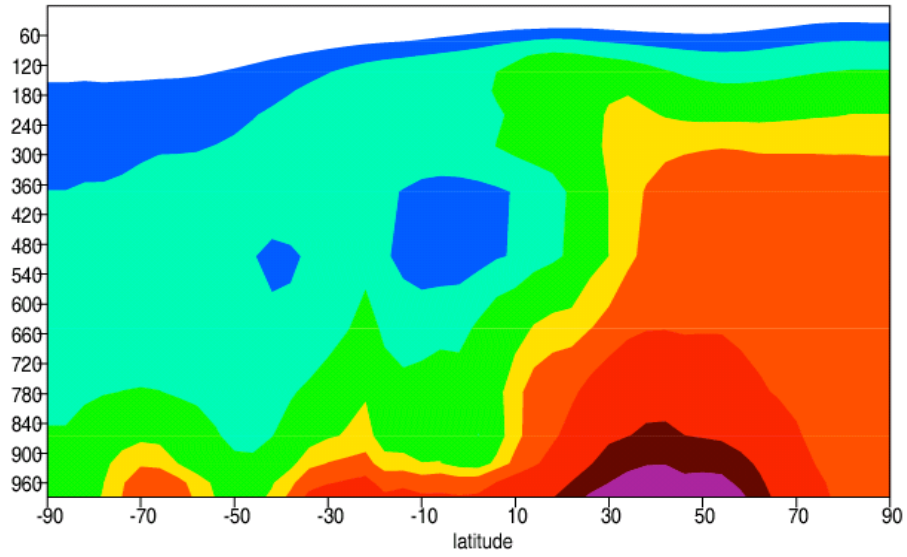


CCM3



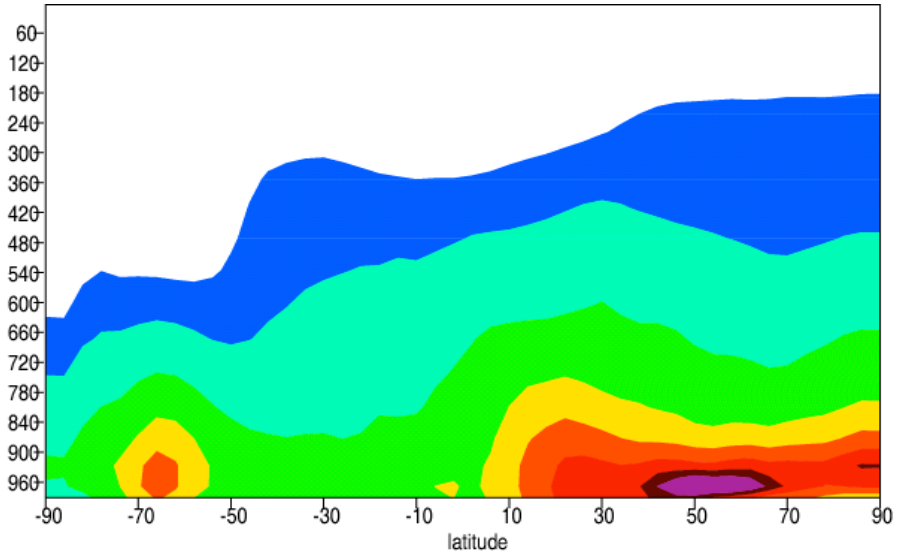


GISS



Annual and zonal mean SO2 (pptv)

DAO



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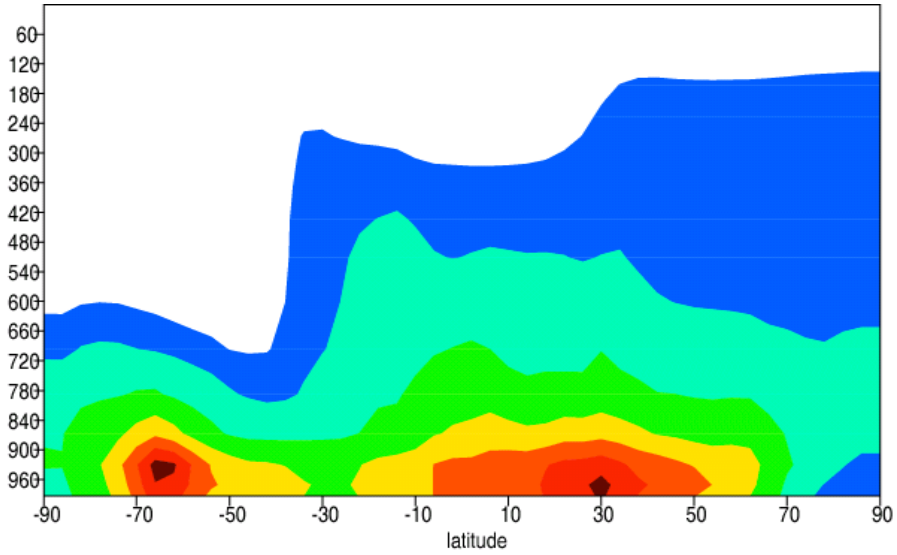
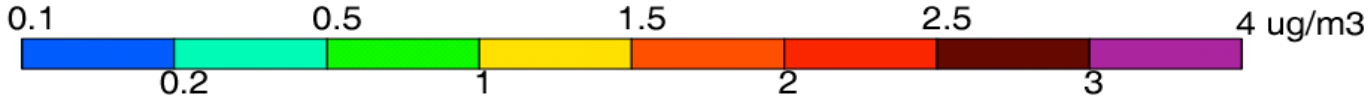
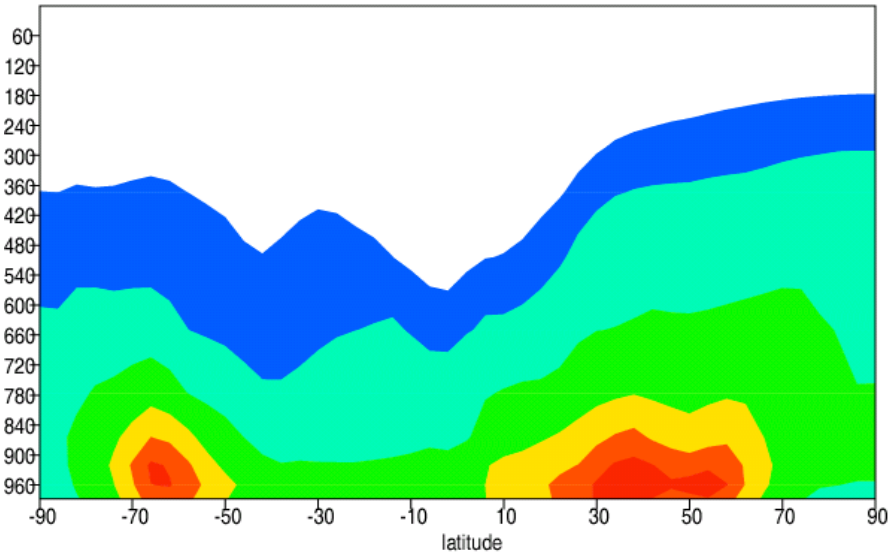


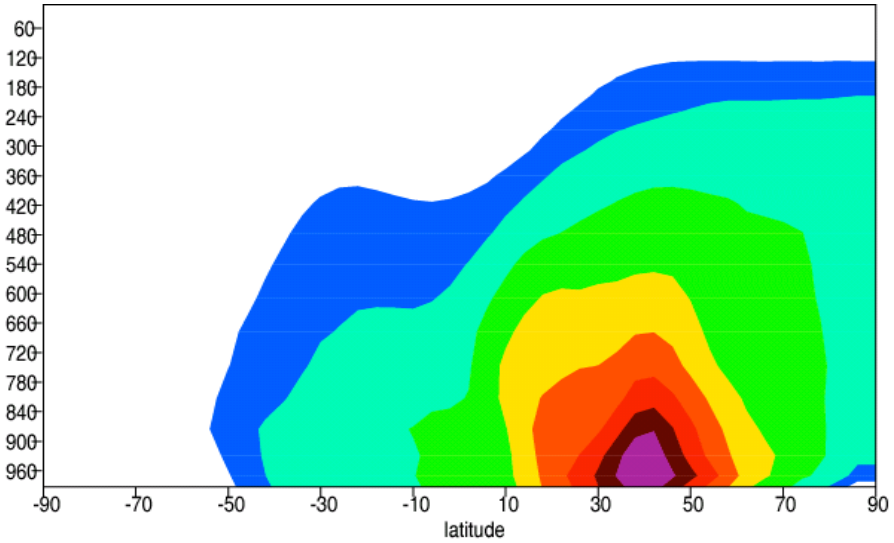


GISS

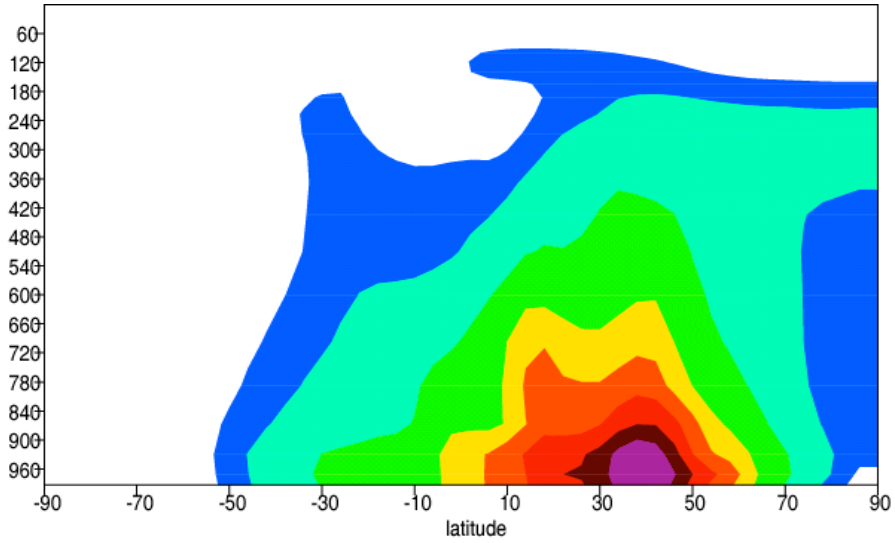


Zonal mean SO4 in Jan. (ug/m3)

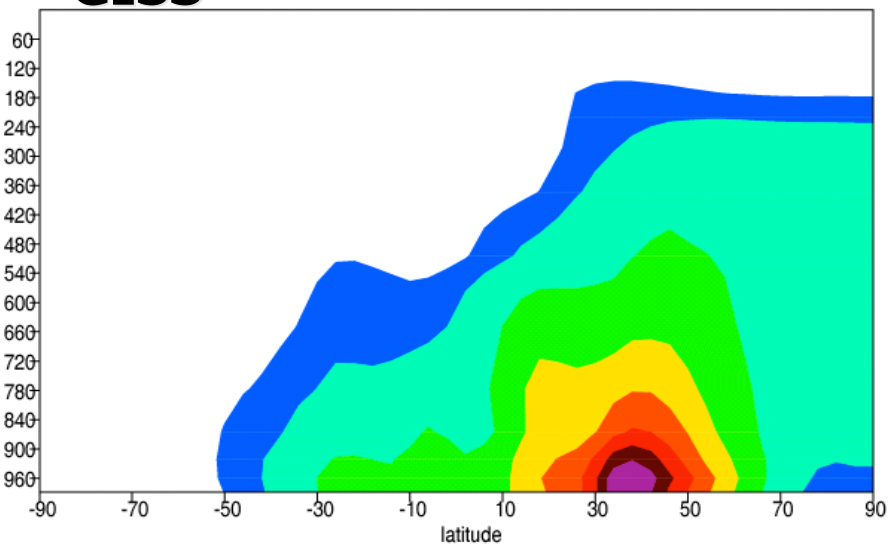
DAO



CCM3

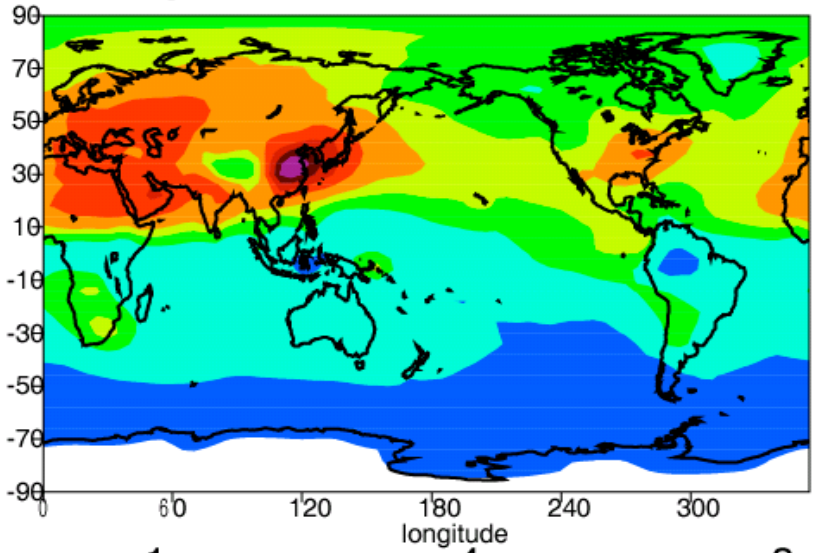


GISS

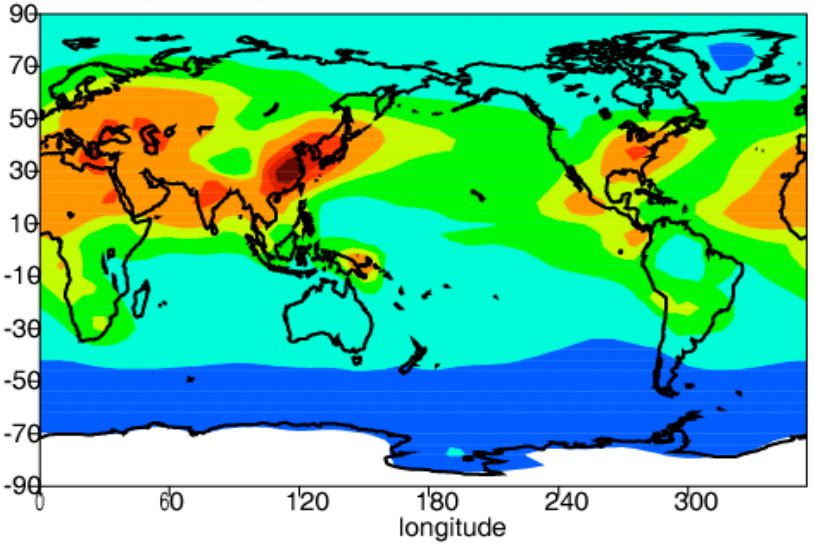


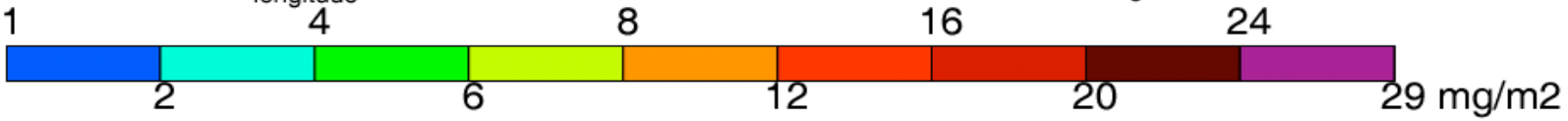
Zonal mean SO4 in July (ug/m3)

DAO

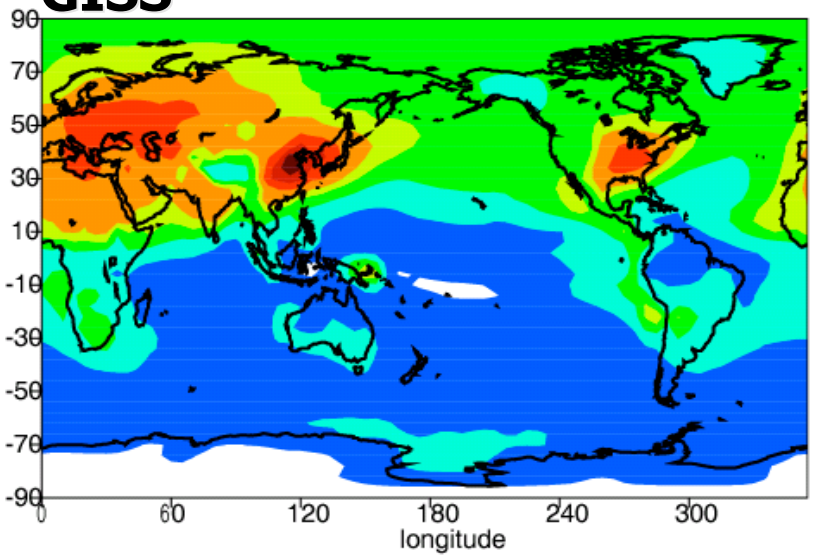


CCM3



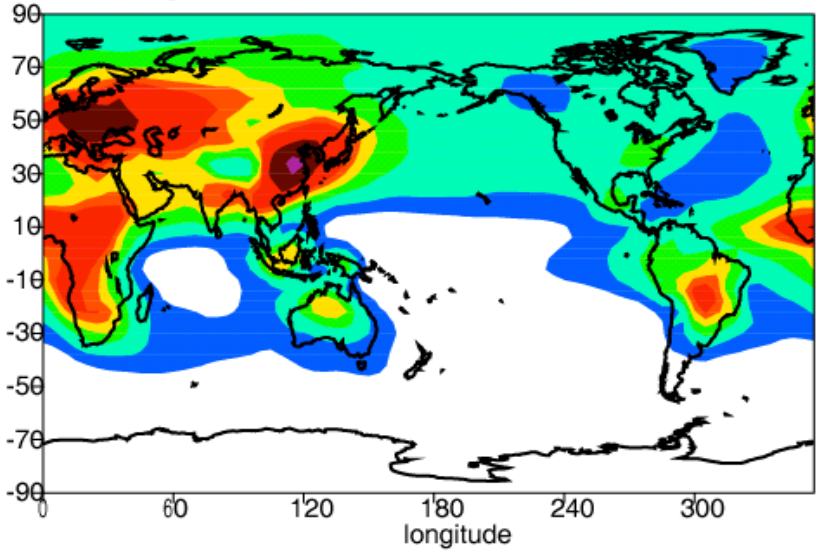


GISS

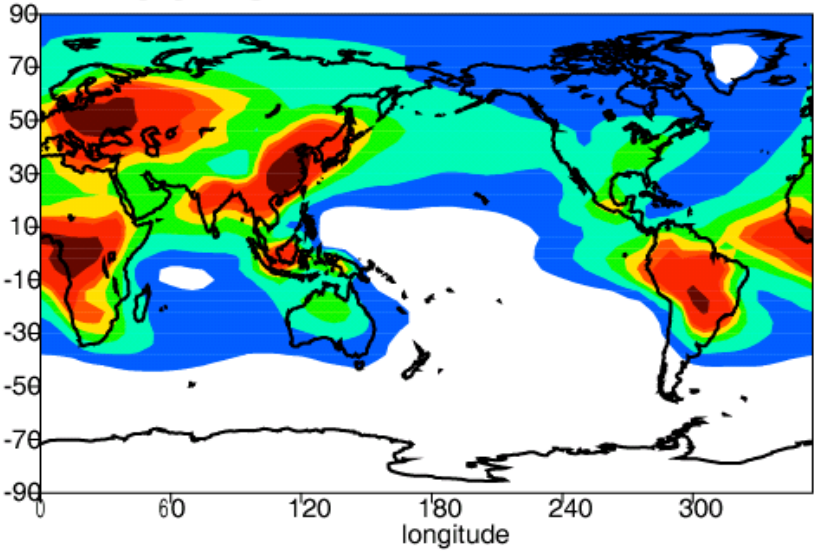


Vertically integrated annual mean SO4 (mg/m2)

DAO



CCM3



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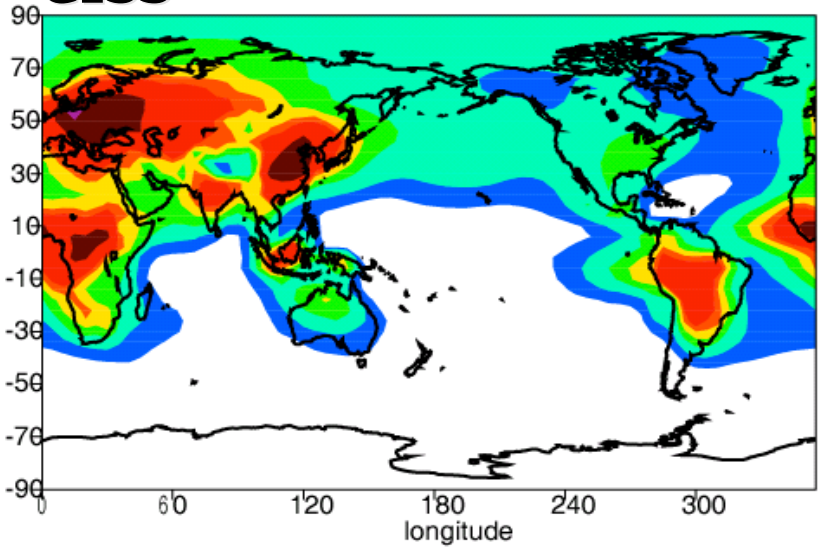
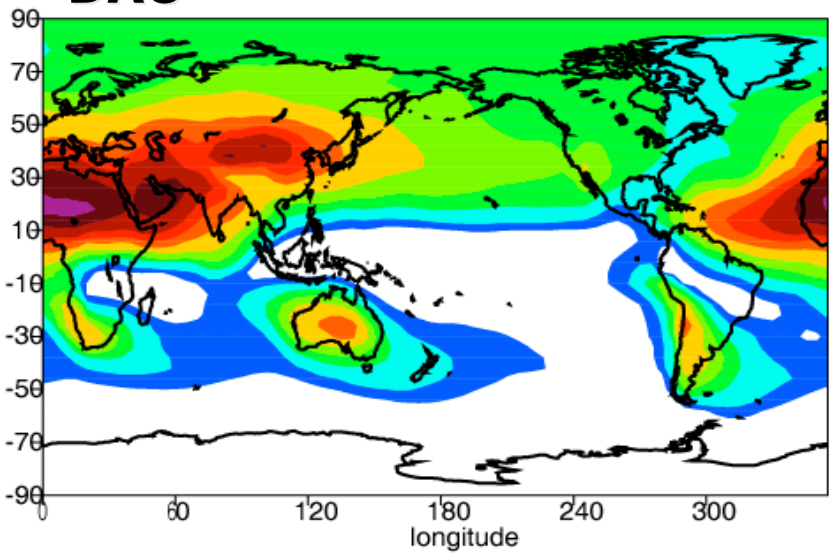
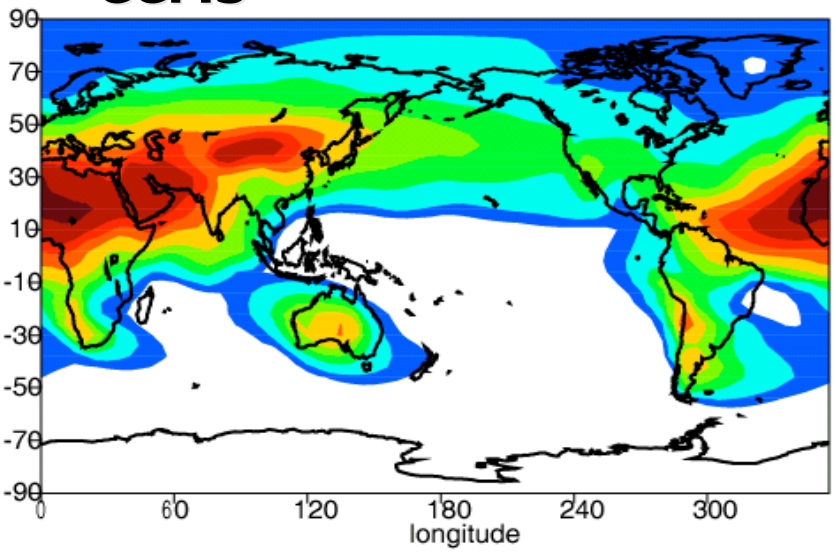


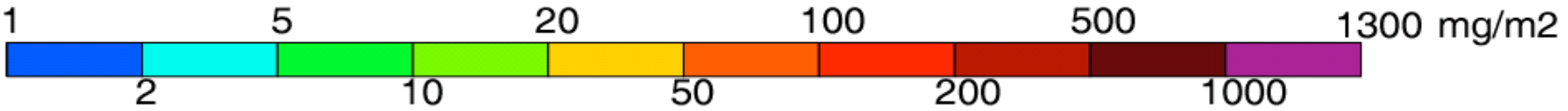
Vertically integrated annual mean BC (mg/m2)

DAO



CCM3





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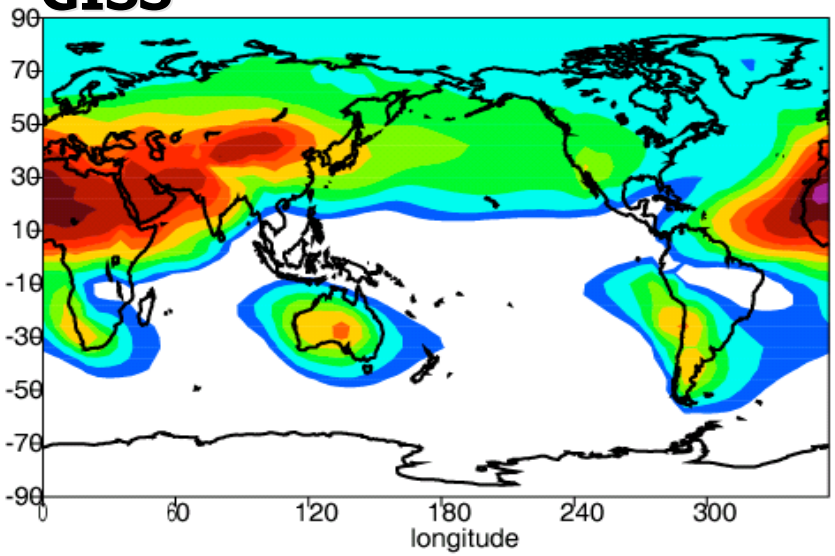
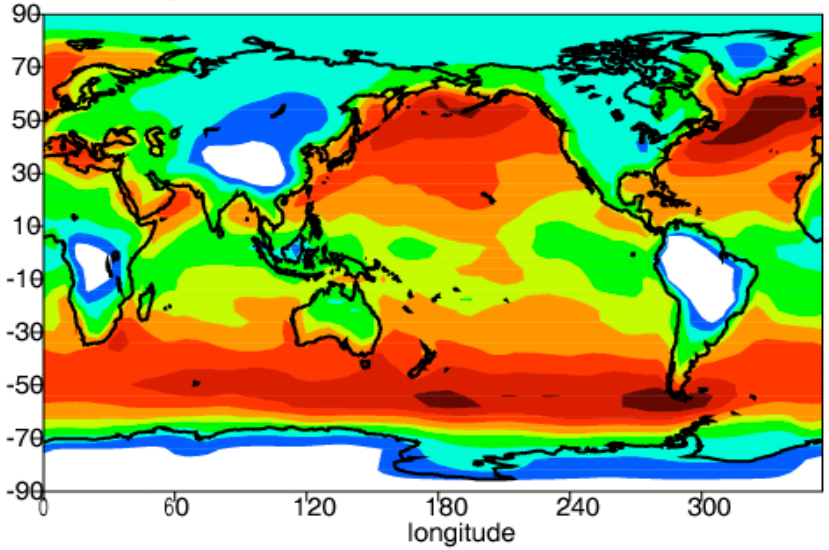
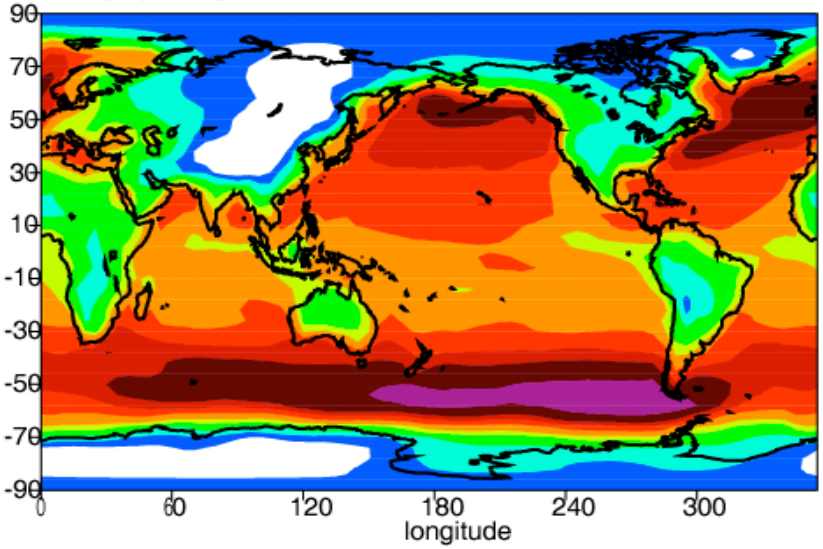


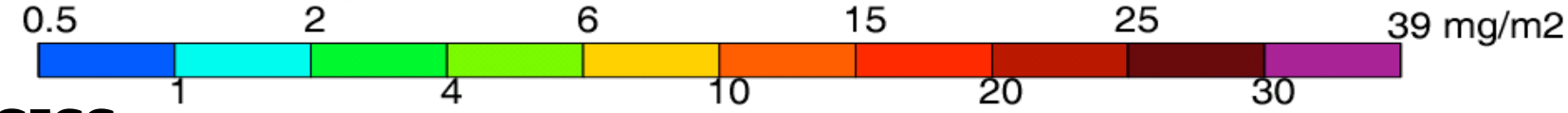
Vertically integrated annual mean dust (mg/m2)

DAO

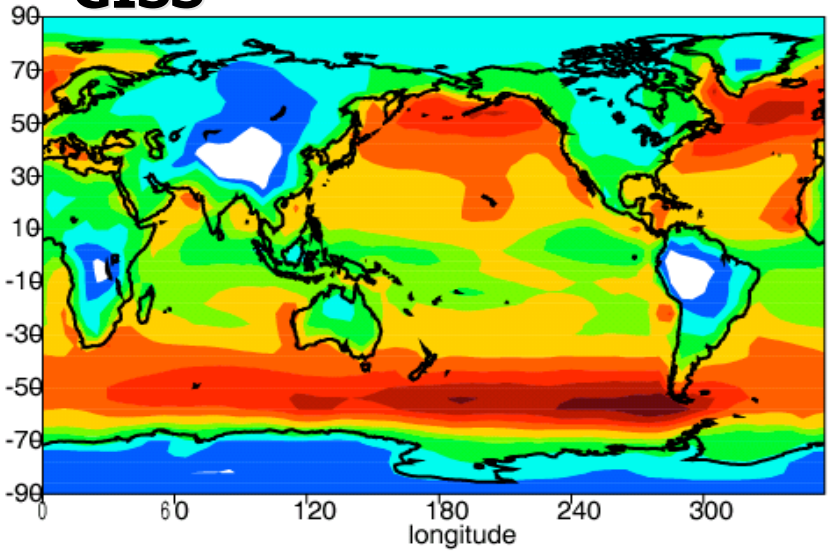


CCM3





GISS



Vertically integrated annual mean sea salt (mg/m2)

Budgets

Sulfate

	DAO	CCM3	GISS	Others
SO_2 oxidation (TgS/yr)	68.6	63.0	65.5	44.7-74.7
by gas phase (%)	30	27	28	
by aqueous phase (%)	70	73	72	
Dry deposition (TgS/yr)	3.4	4.9	3.7	3.9-18.0
Wet deposition (TgS/yr)	65.2	58.0	61.8	34.6-61.0
Burden (TgS)	0.85	0.79	0.65	0.53-1.05
Lifetime (days)	4.5	4.6	3.6	3.9-5.8

Budgets

OM

	DAO	CCM3	GISS	Others
Sources (Tg/yr)	111	111	111	
Dry deposition (Tg/yr)	11.4	17.7	15.7	
Wet deposition (Tg/yr)	99.7	93.4	95.5	
Burden (Tg)	1.43	1.64	1.49	0.95-1.8
Lifetime (days)	4.7	5.4	4.9	3.9-6.4

Budgets

BC

	DAO	CCM3	GISS	Others
Sources (Tg/yr)	13.5	13.5	13.5	
Dry deposition (Tg/yr)	1.6	2.4	2.1	
Wet deposition (Tg/yr)	11.8	11.1	11.4	
Burden (Tg)	0.18	0.19	0.18	0.13-0.29
Lifetime (days)	4.8	5.1	4.9	3.9-8.4

Budgets

Dust

	DAO	CCM3	GISS	Others
Sources (Tg/yr)	1684	1684	1684	
Dry deposition (Tg/yr)	866	986	941	
Wet deposition (Tg/yr)	816	695	741	
Burden (Tg)	23.2	16.8	17.8	8.0-35.9
Lifetime (days)	5.0	3.6	3.9	2.3-7.1

Budgets

Sea Salt

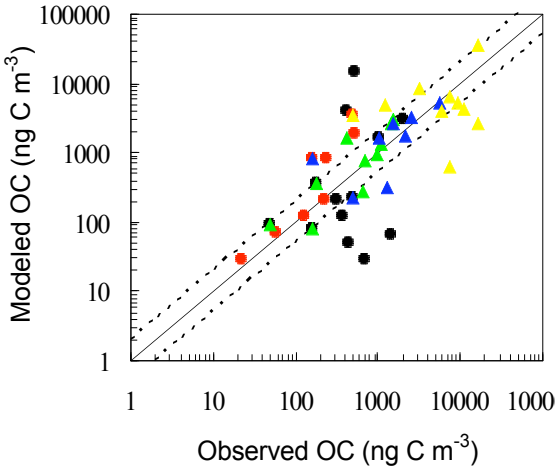
	DAO	CCM3	GISS	Others
Sources (Tg/yr)	3768	3768	3768	
Dry deposition (Tg/yr)	2715	2918	2864	
Wet deposition (Tg/yr)	1048	845	900	
Burden (Tg)	3.4	4.9	3.6	7.3-12
Lifetime (days)	0.33	0.48	0.35	0.6-1.0

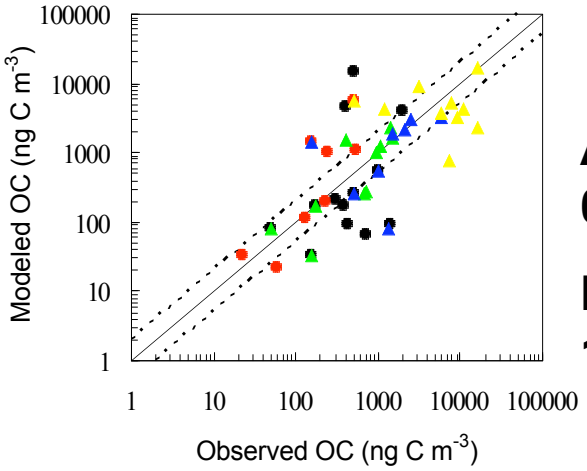
Comparison of modeled OC with observations at surface

DAO

Average bias: 0.53 ug/m3

Relative bias: 157 %





CCM3

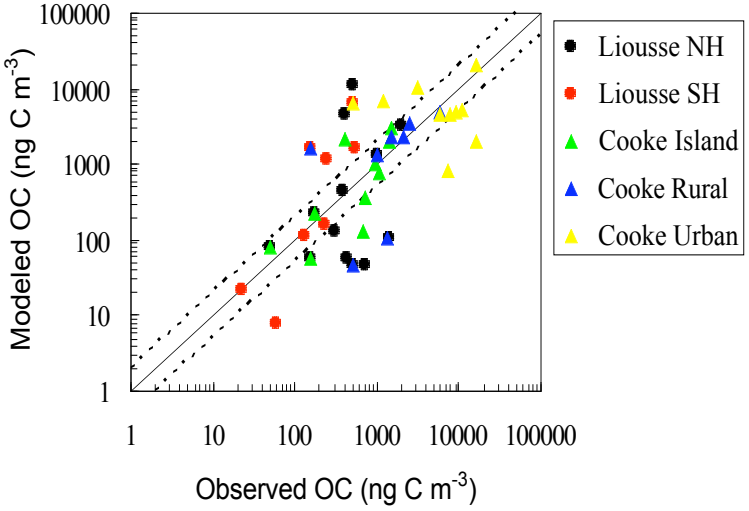
Average bias: 0.38 ug/m3

Relative bias: 180 %

GISS

Average bias: 0.79 ug/m3

Relative bias: 221 %

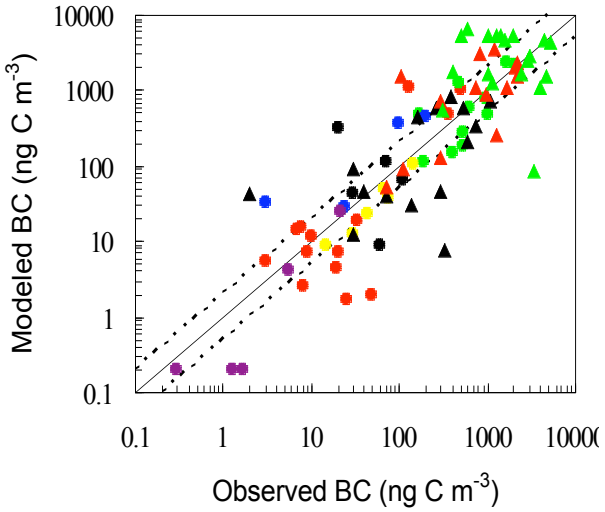


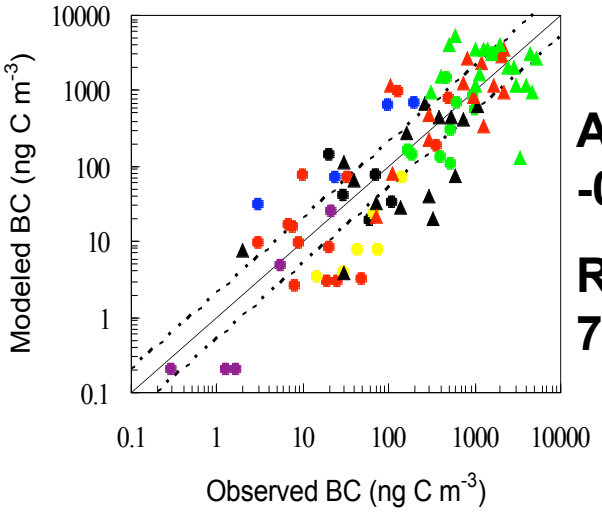
Comparison of modeled BC with observations at surface

DAO

Average bias: 0.057 ug/m3

Relative bias: 113 %





CCM3

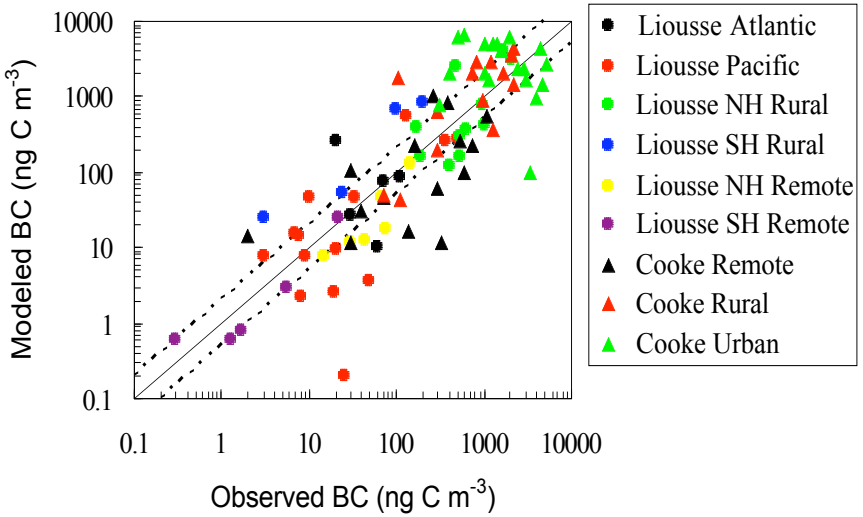
Average bias: -0.13 ug/m3

Relative bias: 74 %

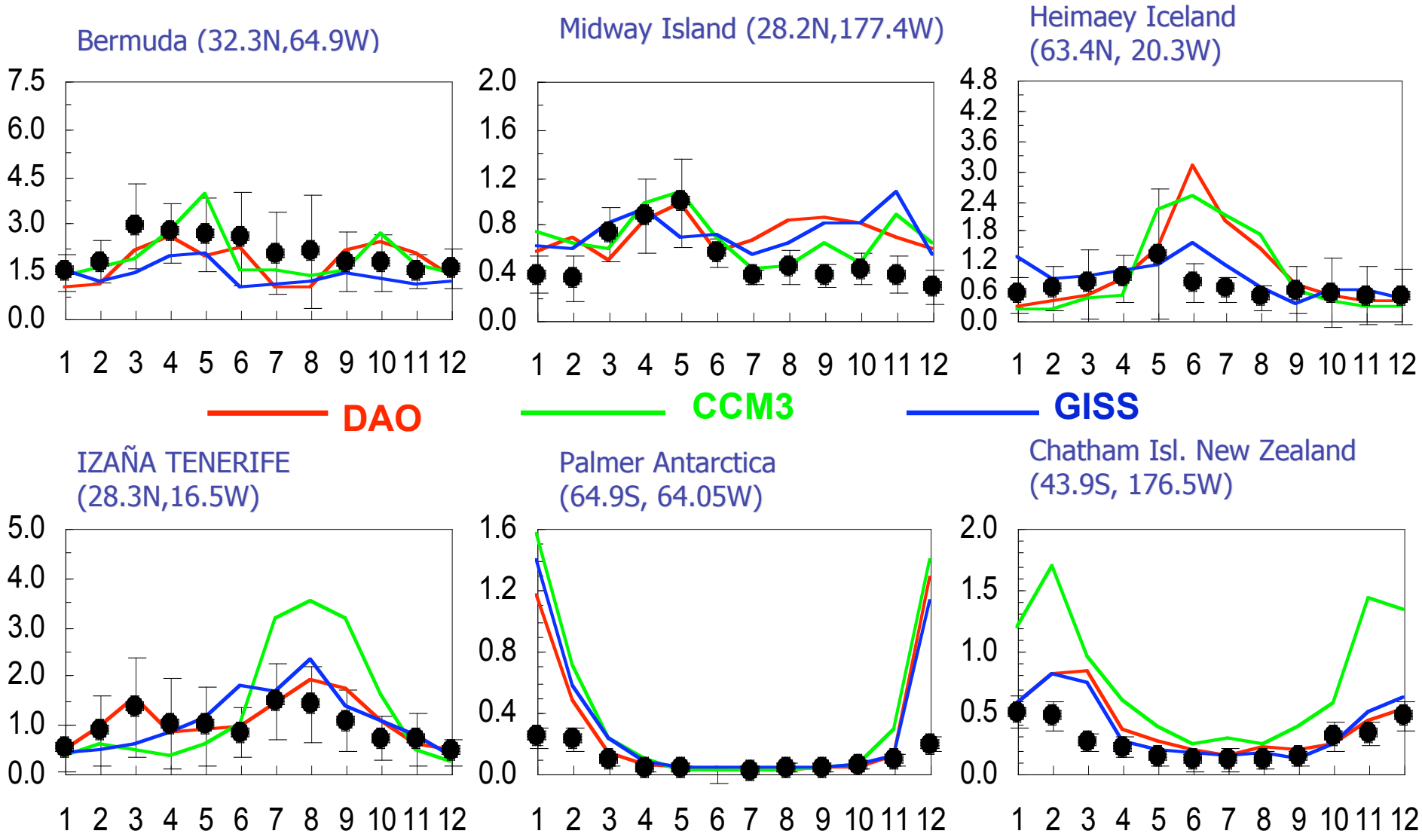
GISS

Average bias: 0.099 ug/m3

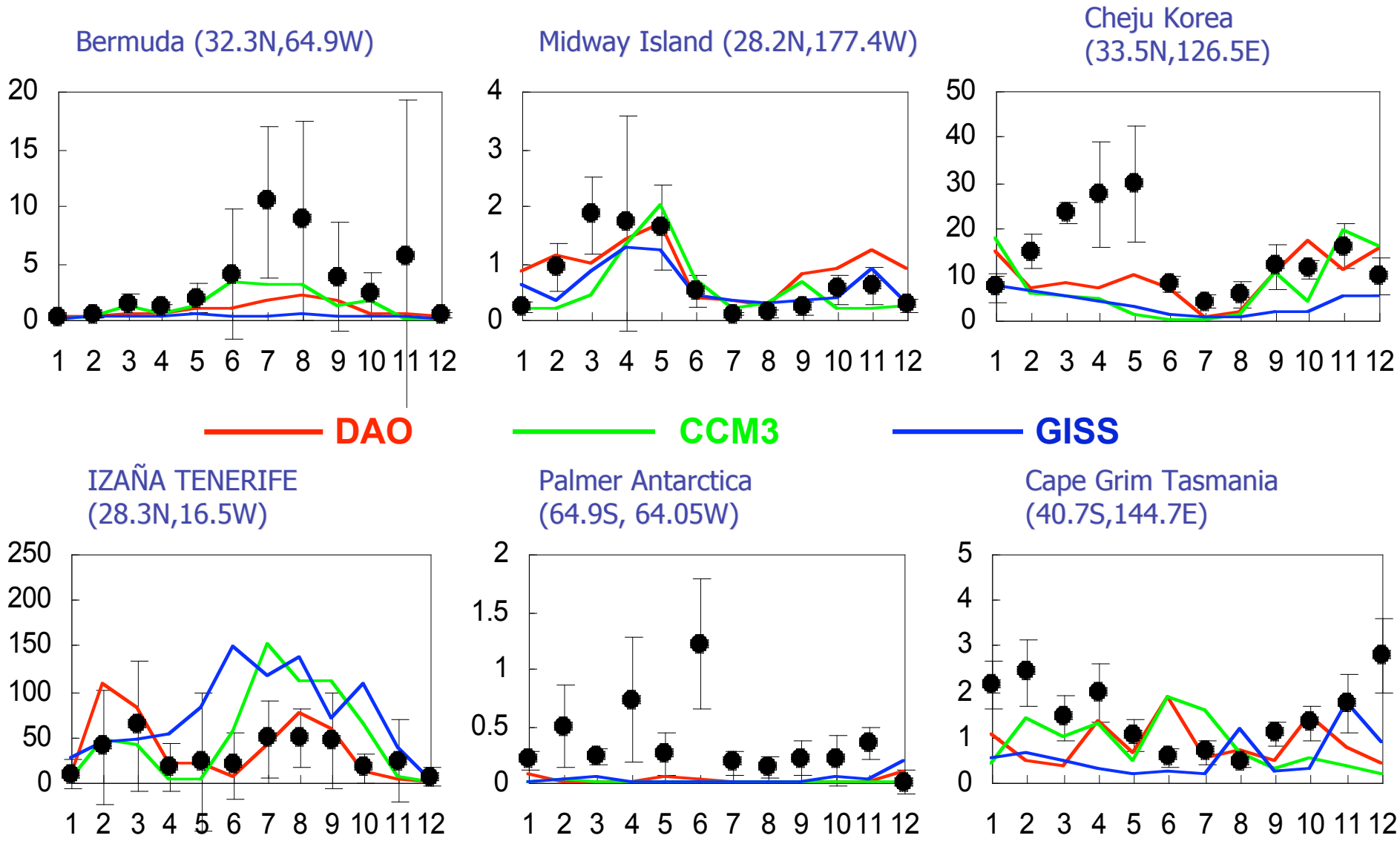
Relative bias: 106 %



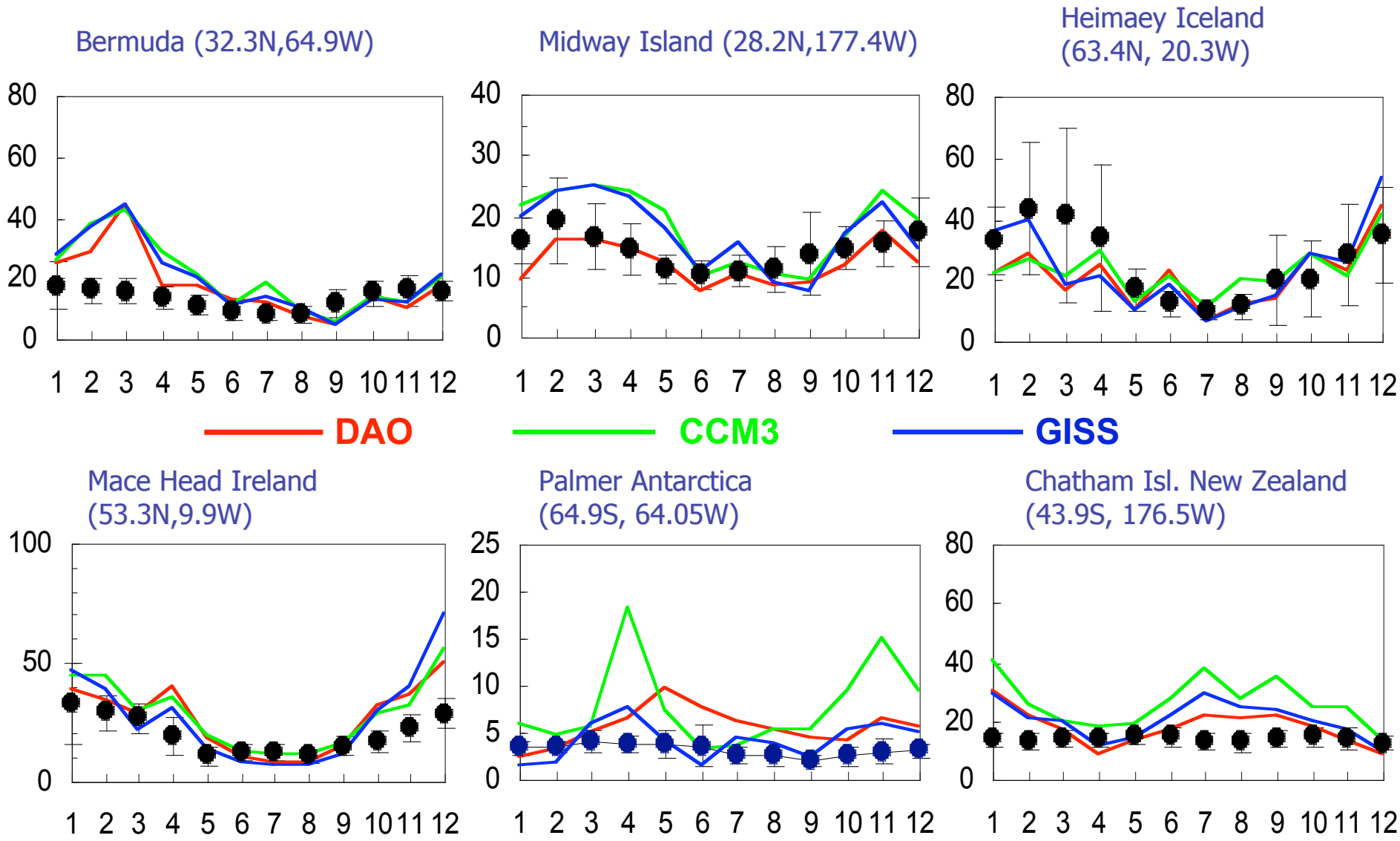
Comparison of modeled SO_4 with observations at surface



Comparison of modeled dust with observations at surface



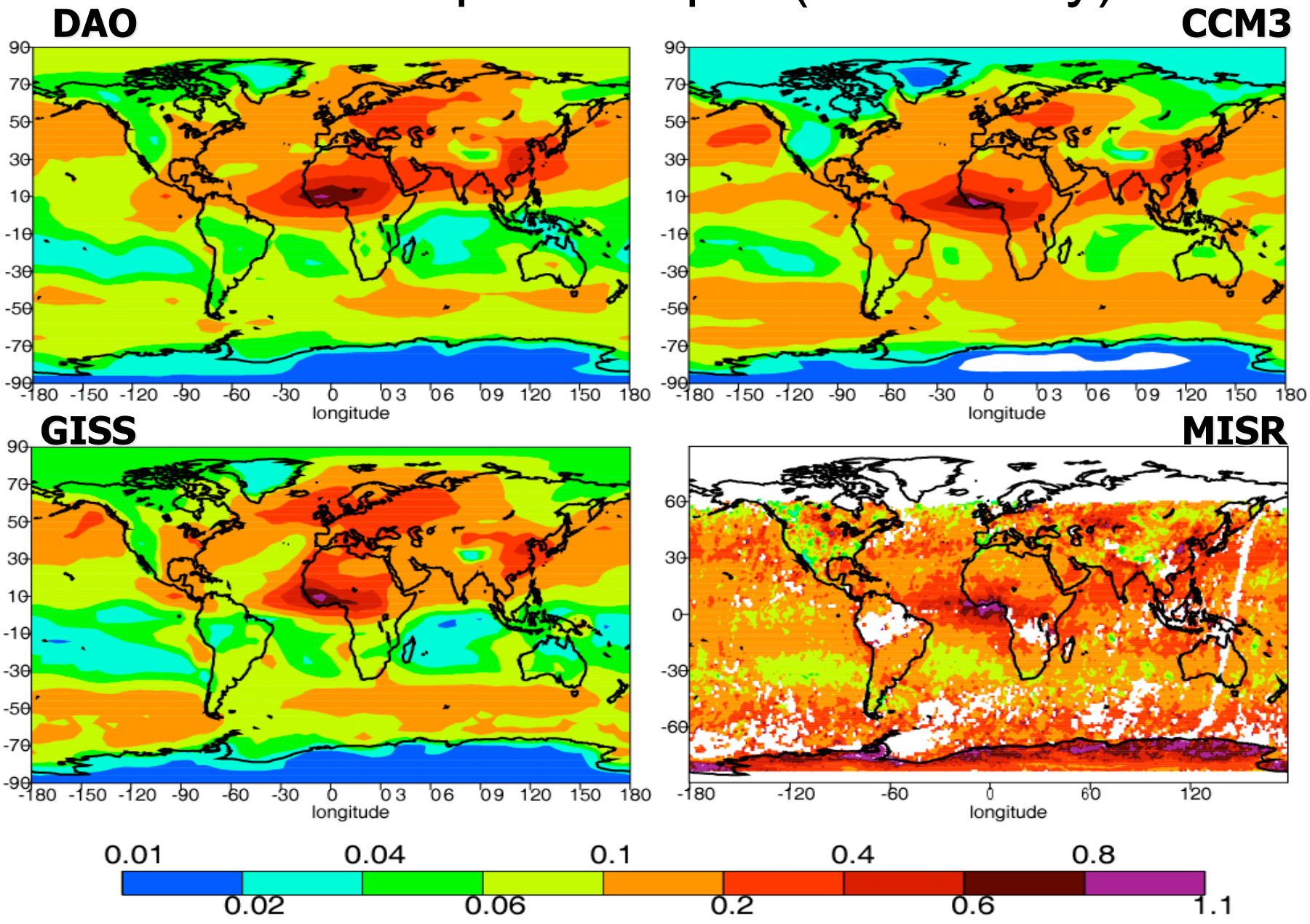
Comparison of modeled sea salt with observations at surface



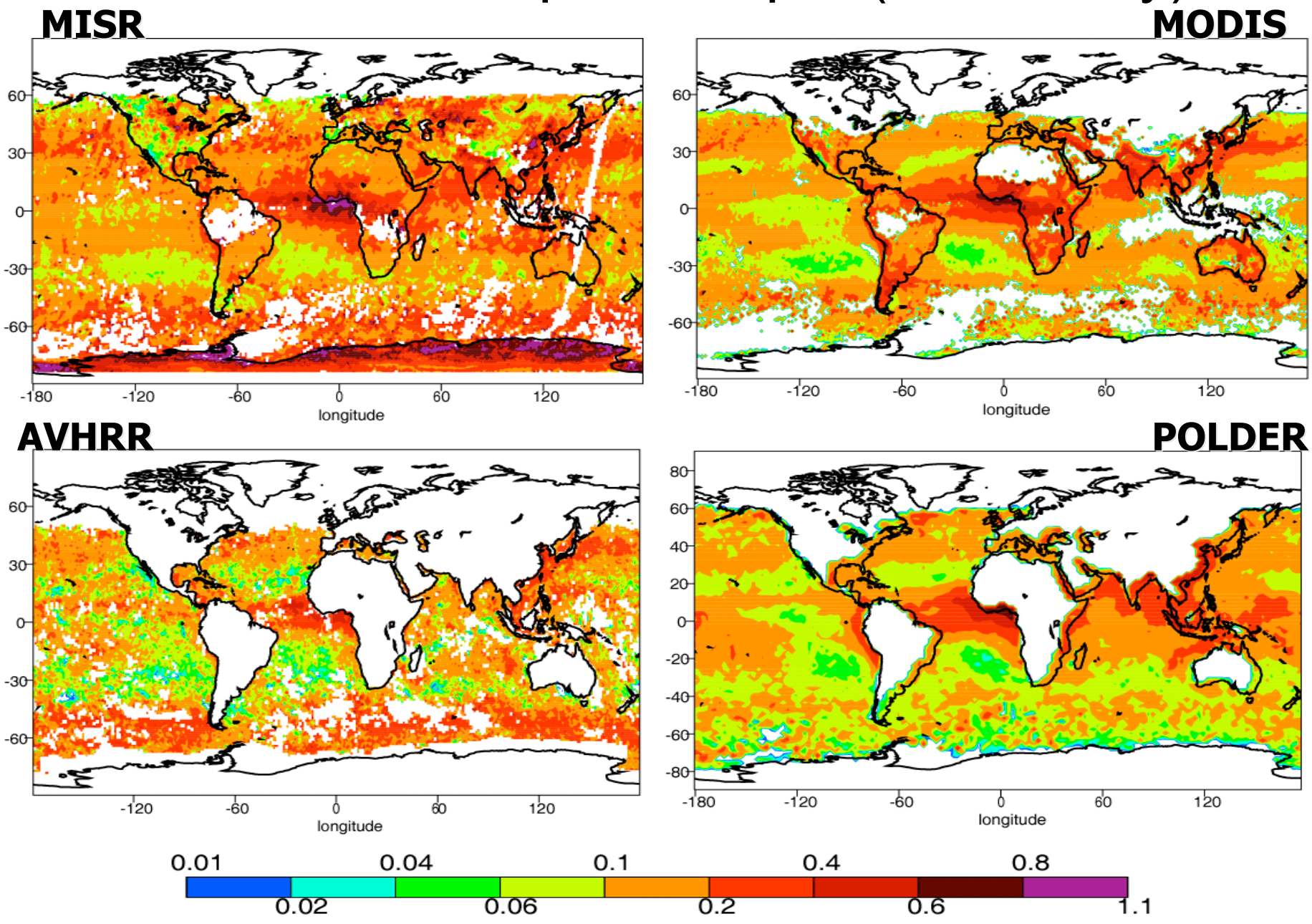
Compare modeled aerosol optical depth with satellite observations (MISR, MODIS, AVHRR, POLDER)

- Calculate modeled aerosol optical depth from monthly aerosol concentrations predicted
- meteorological data at every 6-hr (T, P, qv)
- Aerosol scattering coefficients (Ke) calculated from Mie theory. RH-dependent Ke for SO_4 and sea salt.

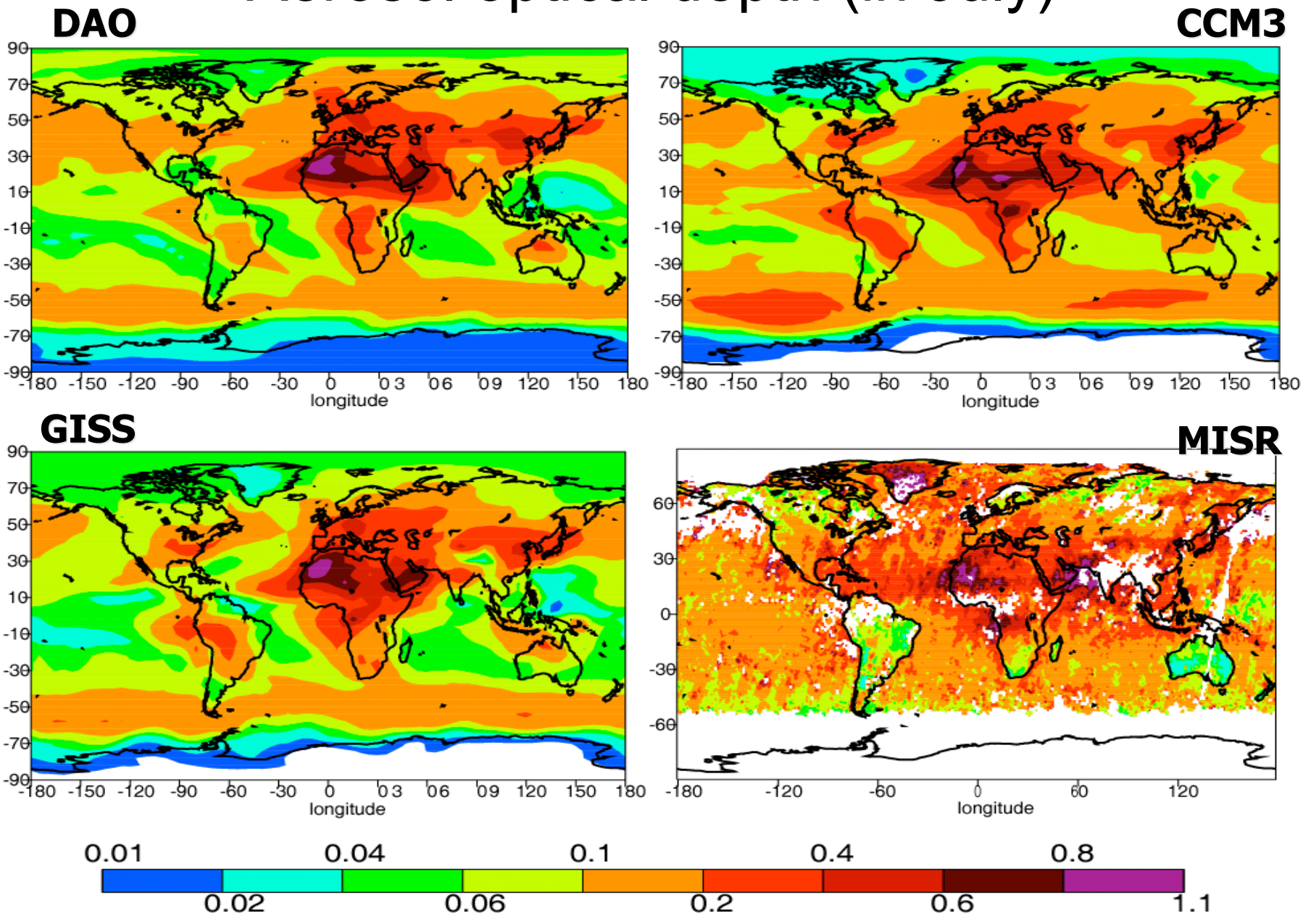
Aerosol optical depth (in January)



Aerosol optical depth (in January)

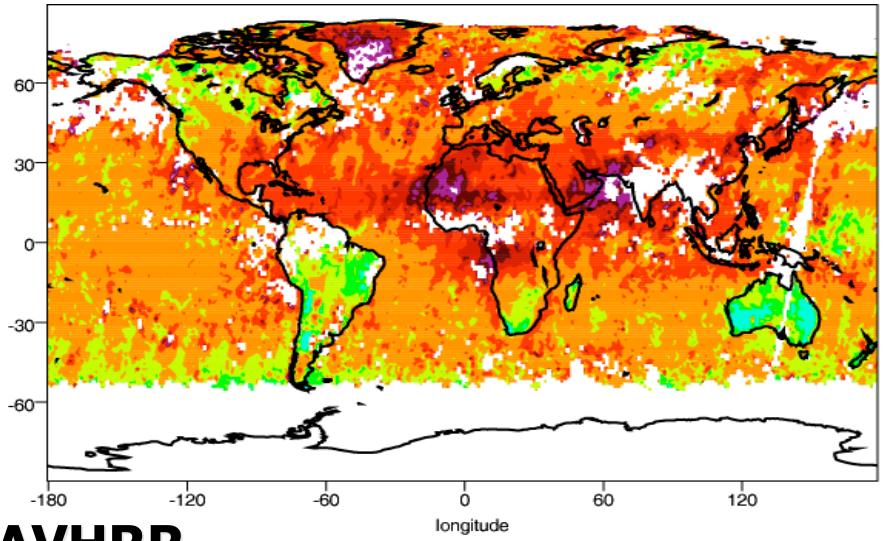


Aerosol optical depth (in July)

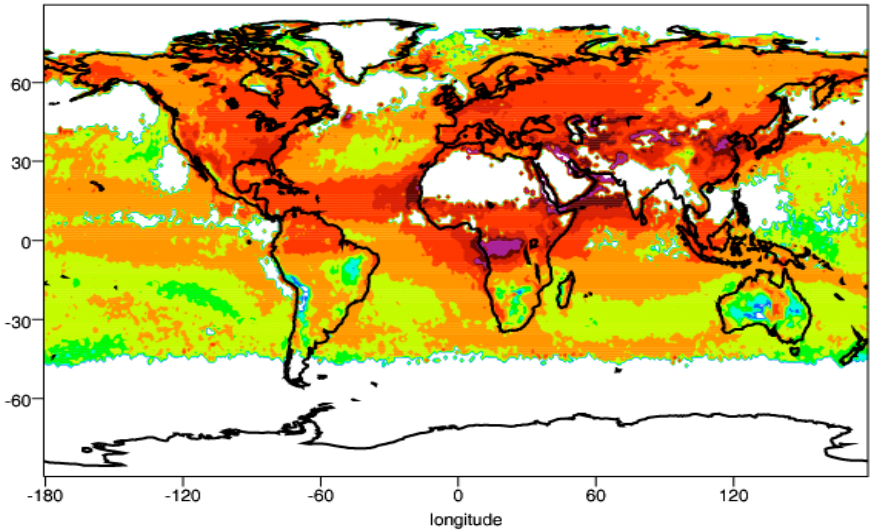


Aerosol optical depth (in July)

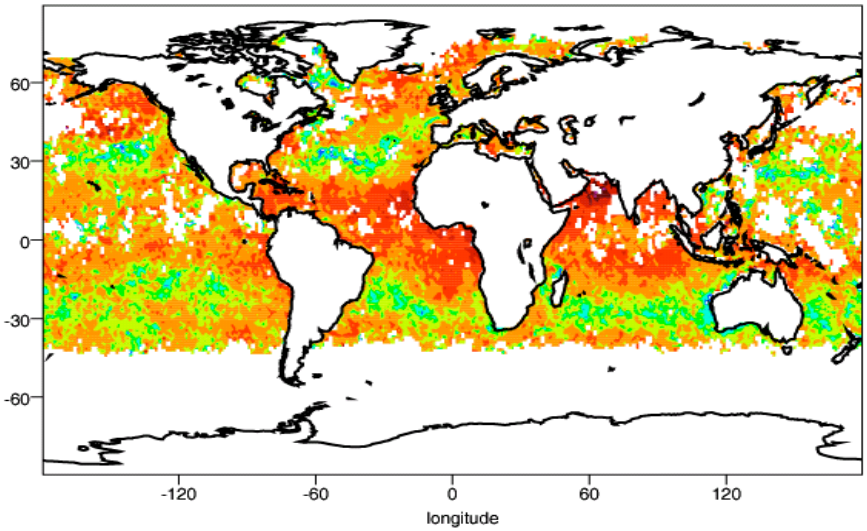
MISR



MODIS



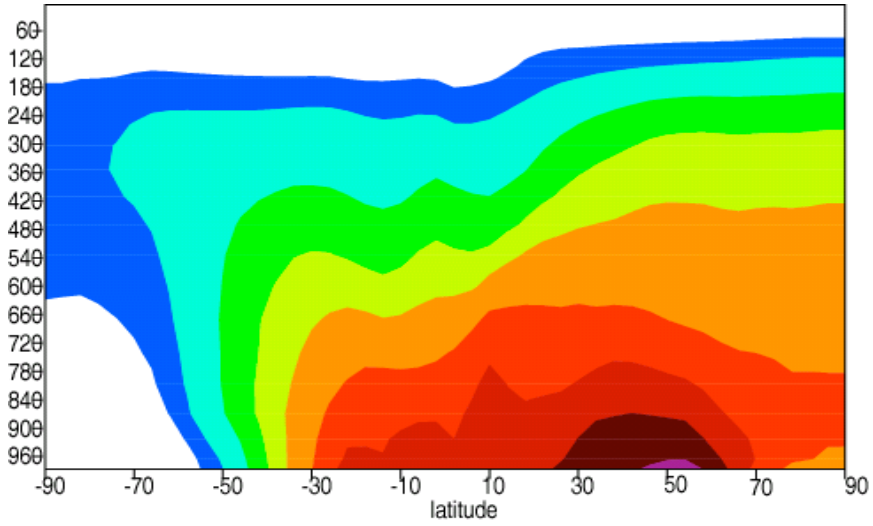
AVHRR



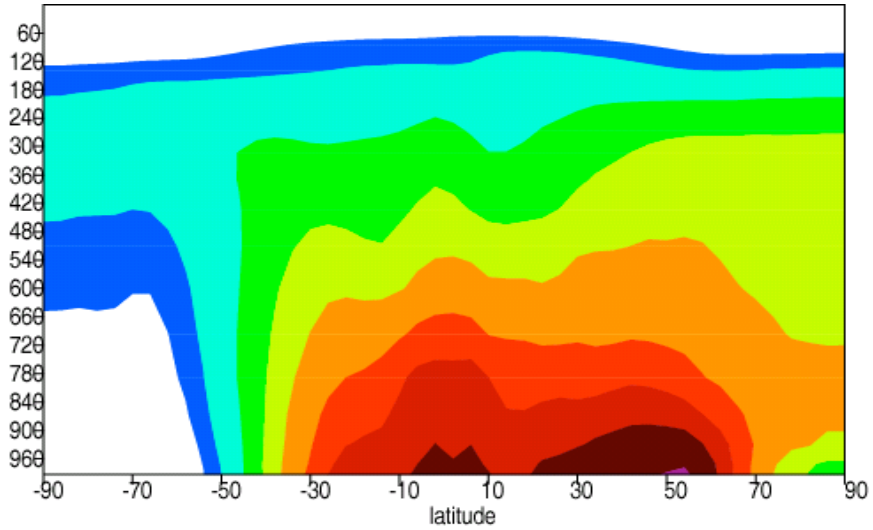
Conclusions

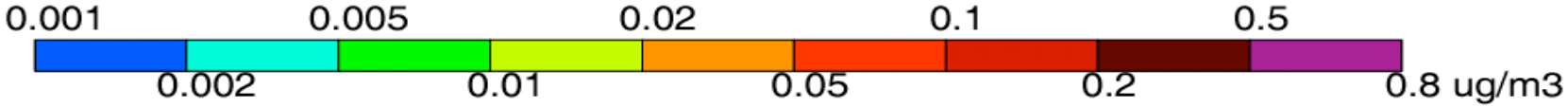
- Different distribution patterns of aerosols associated with 3 met fields
- Aerosol burdens are within 40% for 3 met fields
- Aerosol simulations generally reflect changes of observations, however, improvements are needed for emissions, scavenging…

DAO

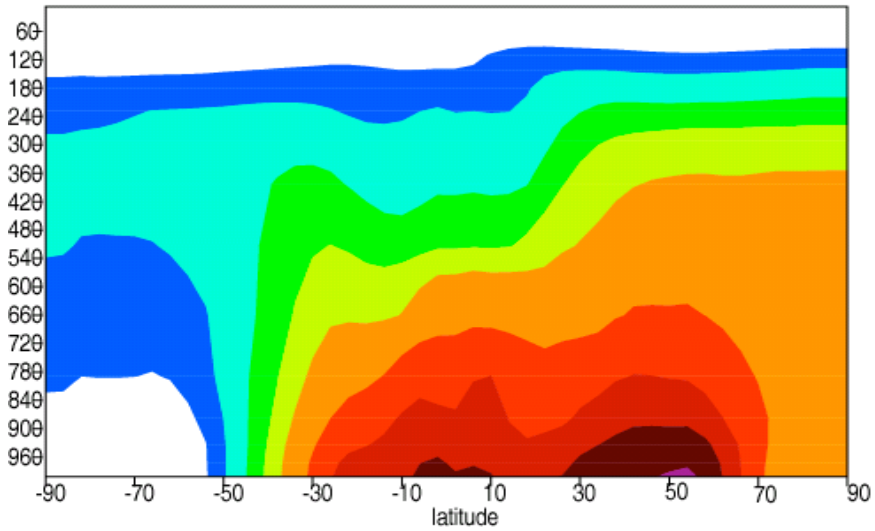


CCM3



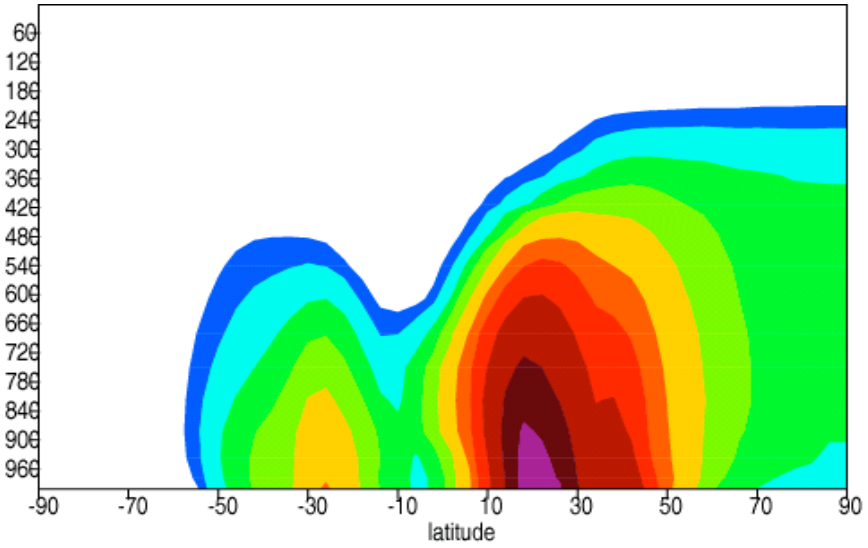


GISS

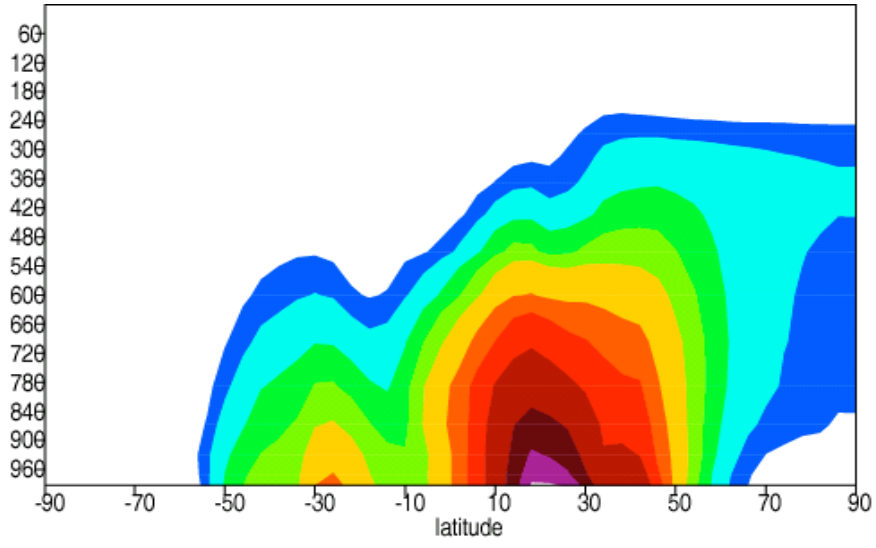


Annual and zonal mean BC (ug/m3)

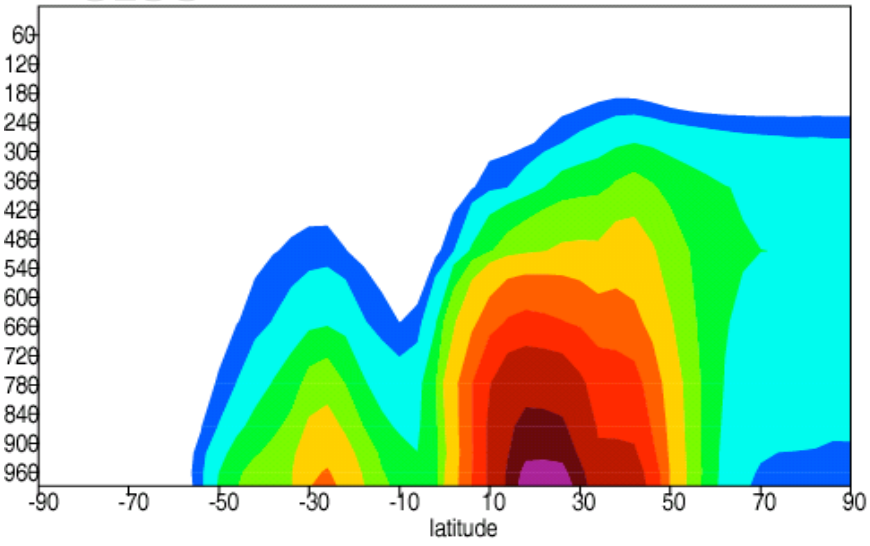
DAO



CCM3



GISS



Annual and zonal mean dust (ug/m3)