Aerosol absorption working group

Dorothy Koch, Tami Bond, Greg Schuster, Philip Stier, and you?!

AeroCom meeting October 26, 2007

Assessment of aerosol absorption in models?

We could do now, compare models with:

1) **BC surface concentrations**
2) **Sun and Bond BC/OC dataset?**
3) **SP2 BC aircraft measurements**
4) **AERONET AAOD**
5) **BC load from AERONET using Schuster et al. method**
6) **OMI AAOD estimates**

More diagnostics needed:

7) **Absorption from e.g. aetholometer measurements**
8) **AAOD at multiple wavelengths (550 and 1000 nm?)**

Experimental:

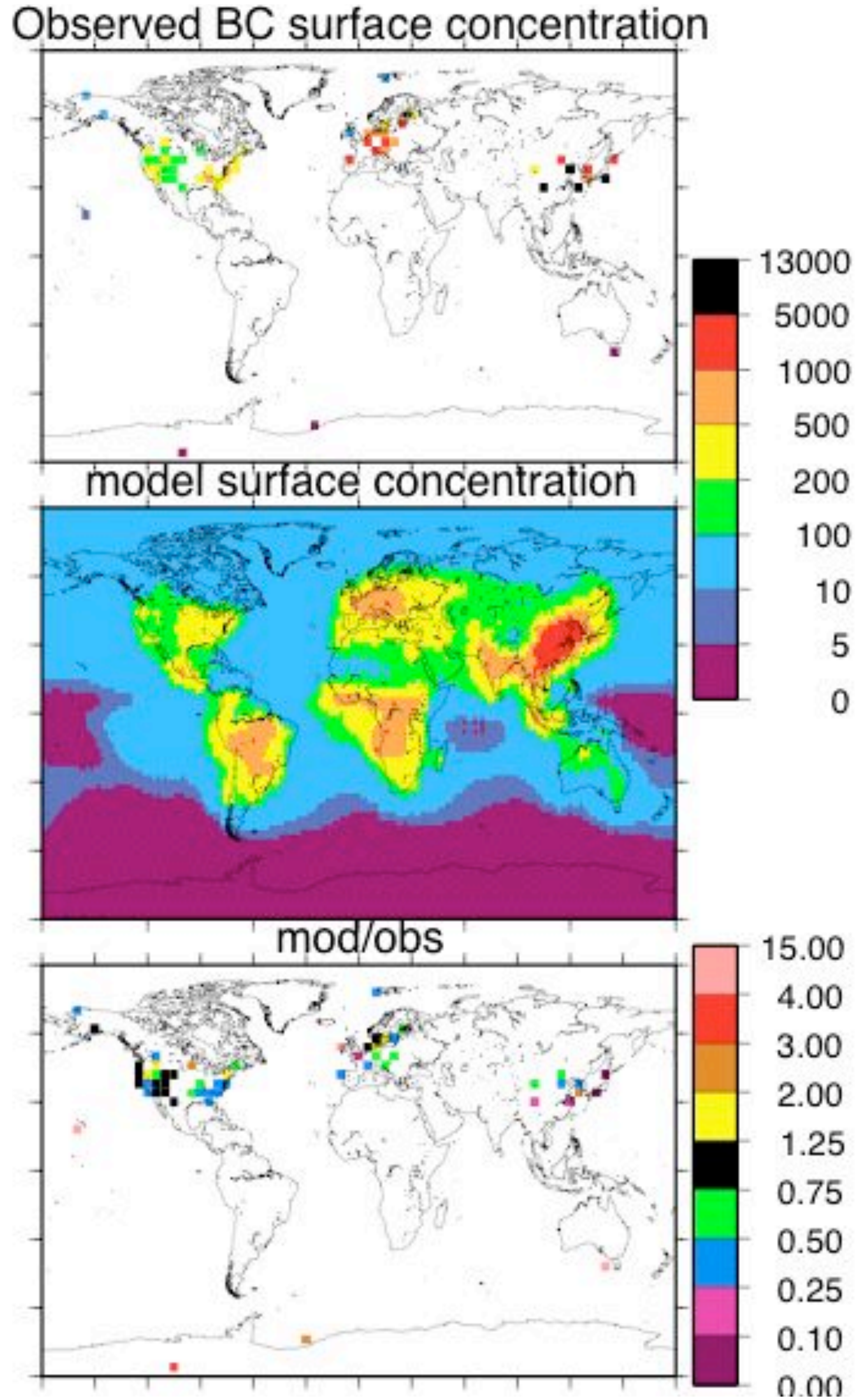
9) **OMI Aerosol Index: higher altitudes**

We need to know:

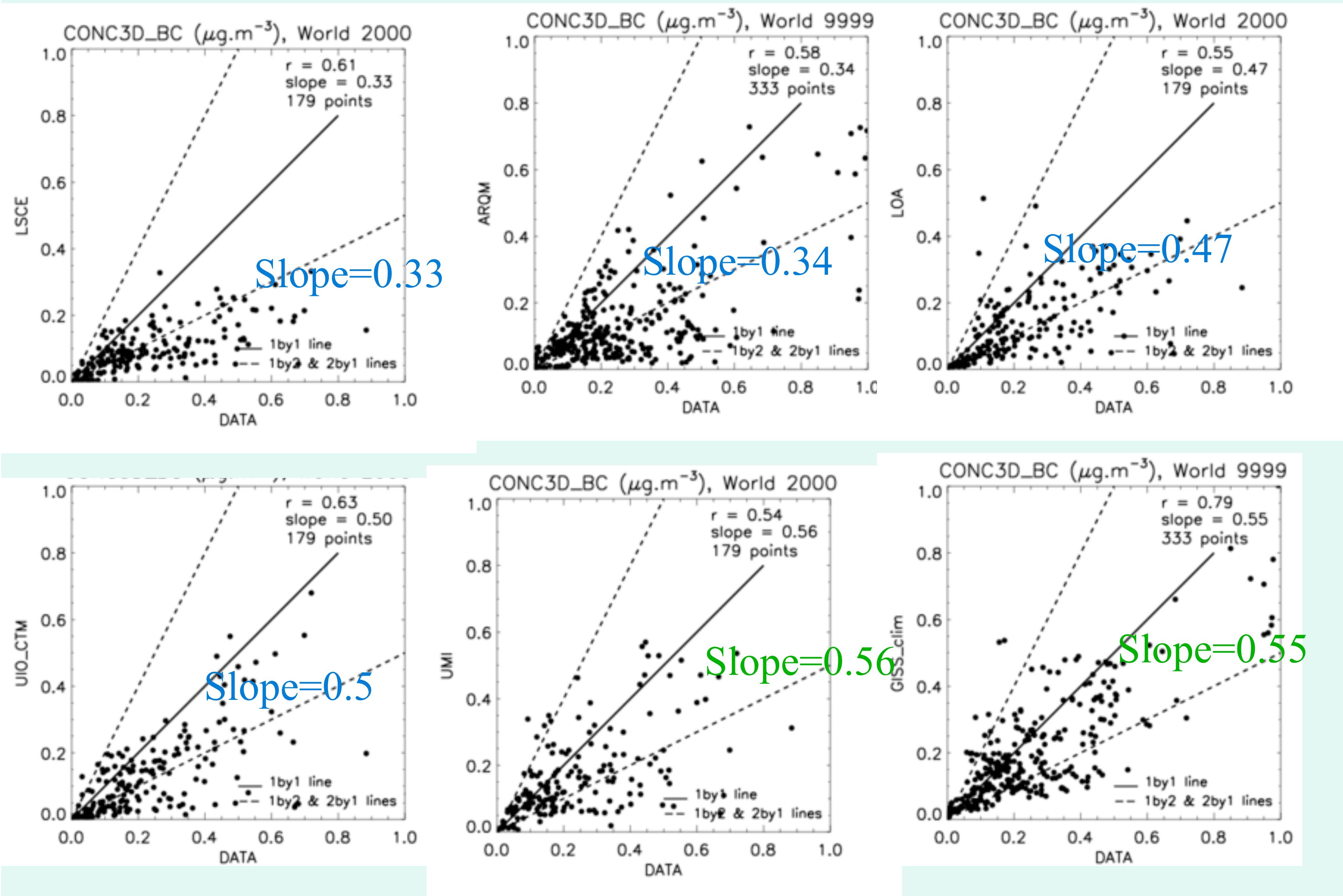
1) Treatment of mixing
2) Removal assumptions ice vs liquid phase clouds
3) mass absorption and scattering cross section
4) backscatter fraction of unmixed and mixed aerosol
5) treatment of absorption for mixed BC and other aerosols
6) BC size distribution and host size distributions for internal mixtures
7) BC refractive index and BC density
8) Hydrophobic-hydrophilic conversion times

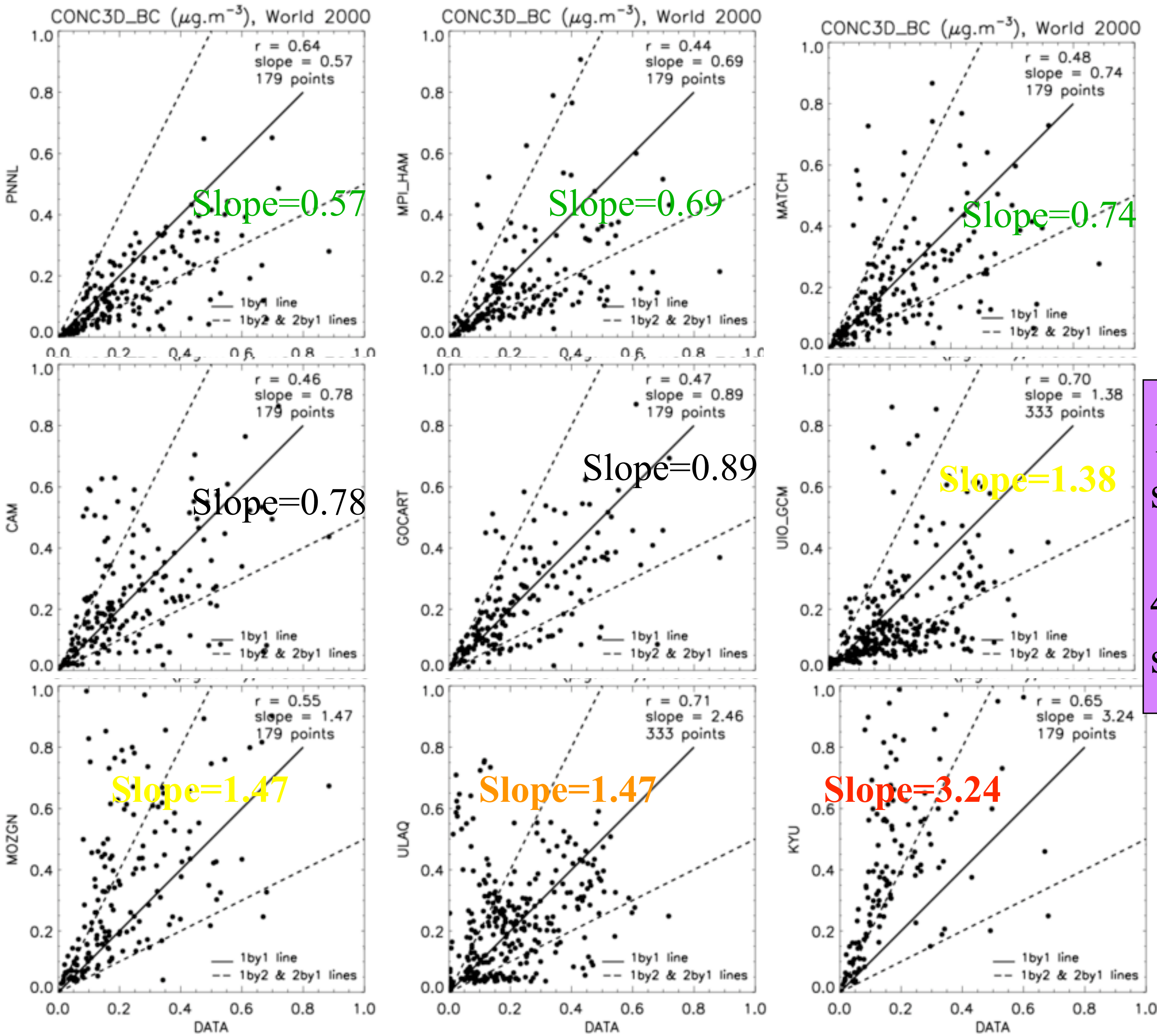
BC Surface Concentrations
(annual average)
and
GISS model

Region	Mod/Obs
NAM	0.78
EUR	0.72
ASIA	0.49
Global	1.0



AeroCom models vs BC surface concentrations in USA: IMPROVE network. From AeroCom website.

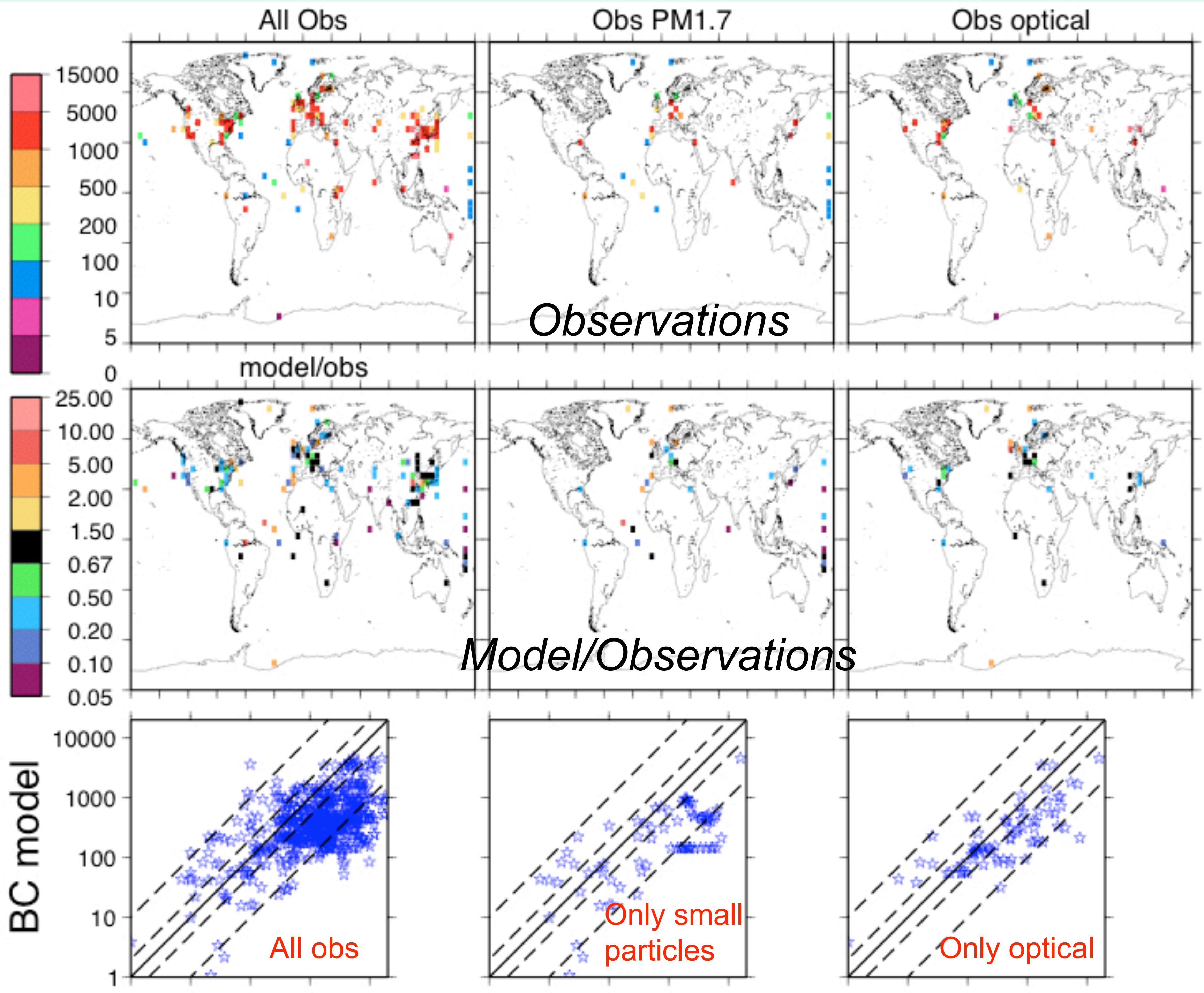




11 models: slope<1

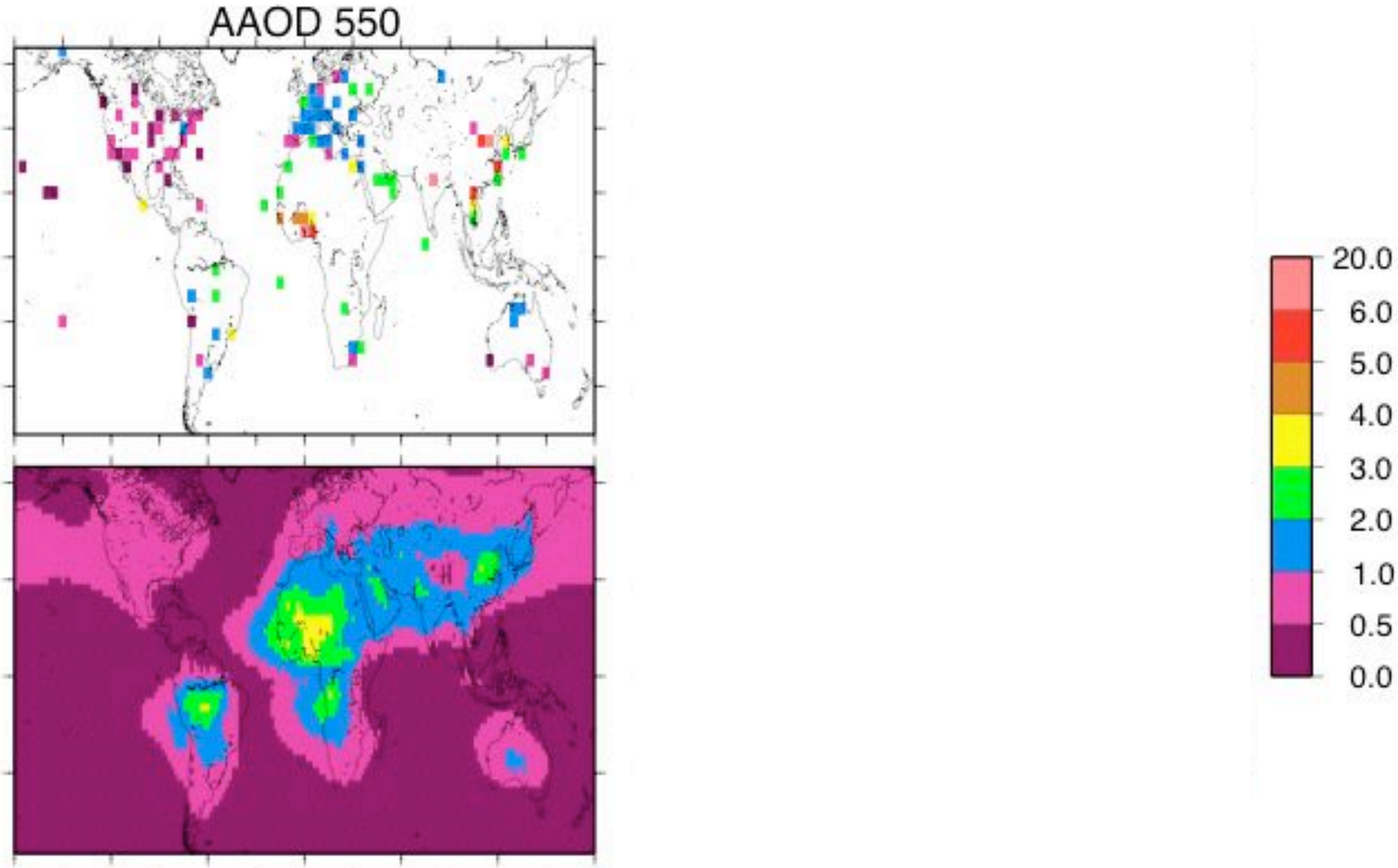
4 models: slope >1

Sun and Bond observation dataset



AERONET
v2
(1996-2006)

GISS model

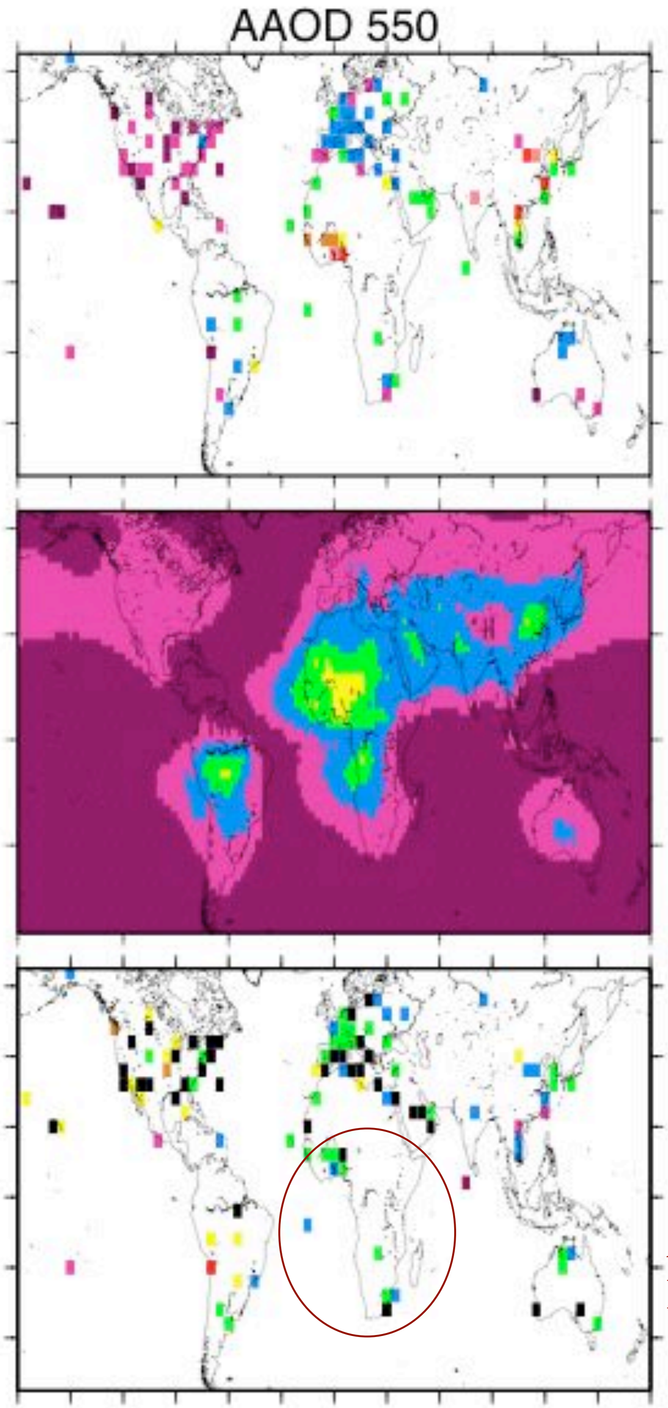


Absorption Aerosol Optical Depth (AAOD) = Extinction OD - Scattering OD

= AOD (1 - SSA)

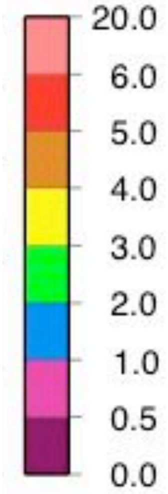
BC-dominated regions (avoiding dust)

Mod/ AER	550 nm
NAM	1.0
EUR	.70
ASIA	.43
SAM	1.0
AFR	.39

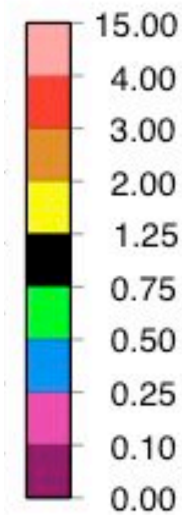


AERONET

GISS model

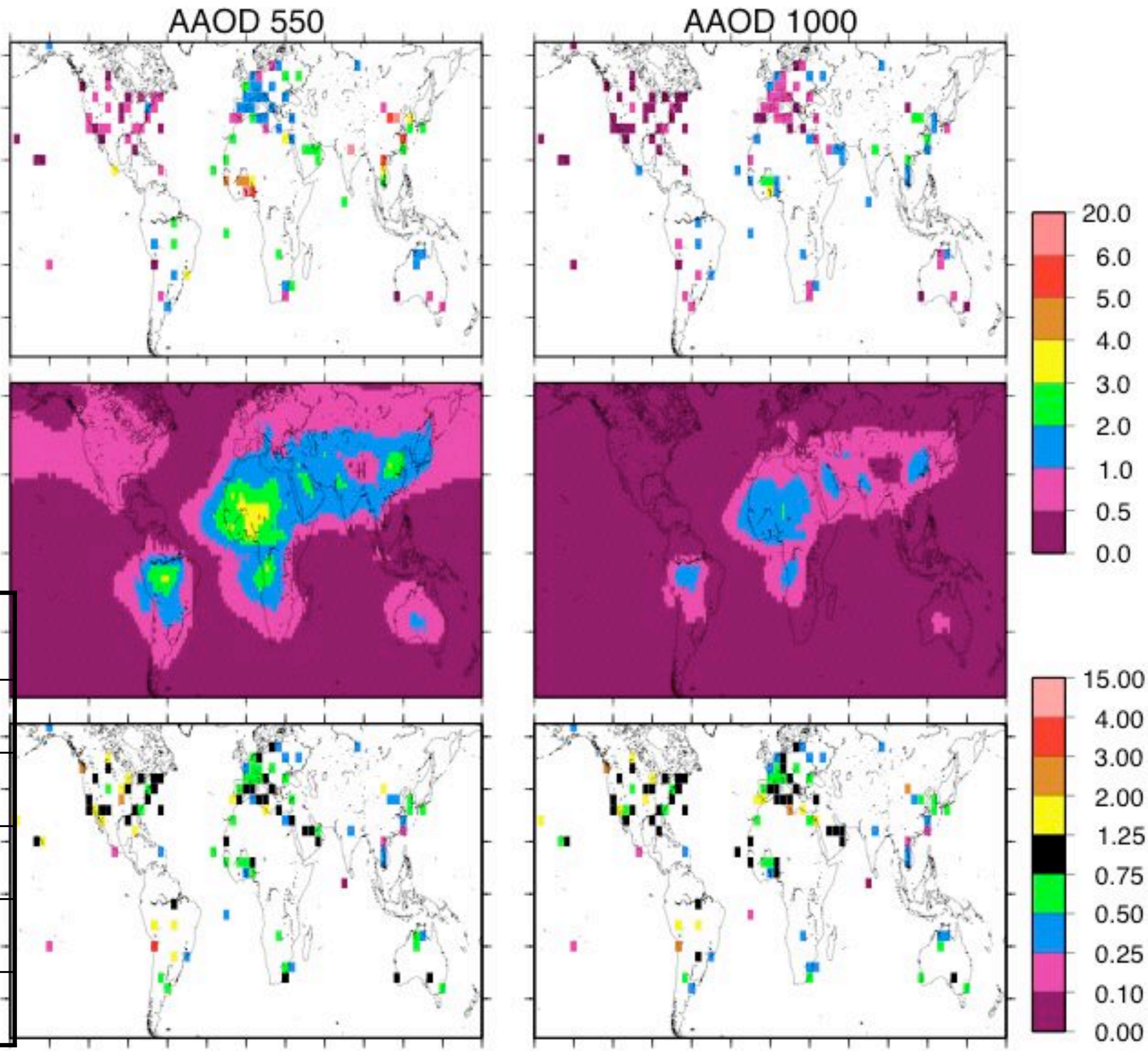


GISS/AERONET



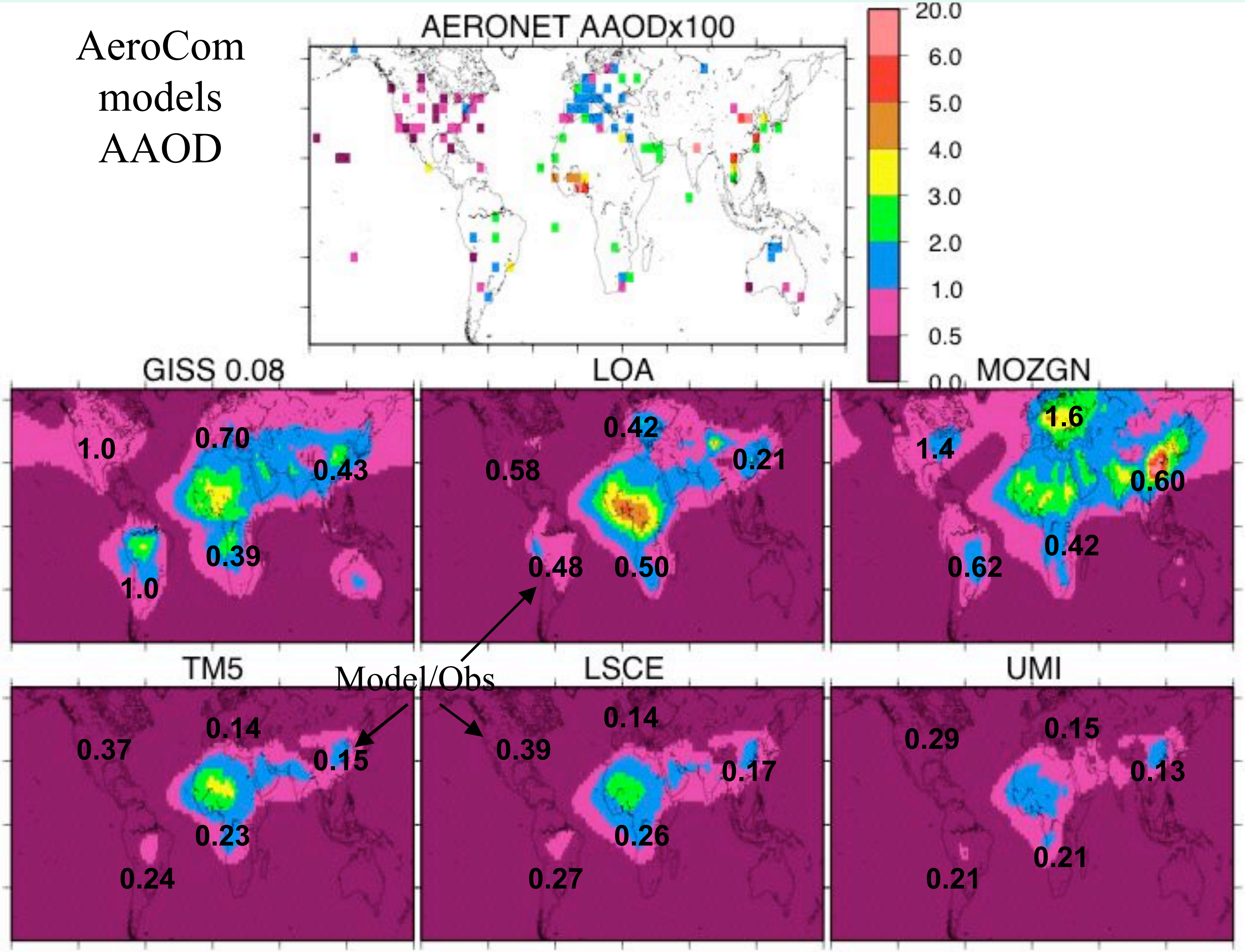
African biomass burning should have larger BC/OC emission factors than South America?

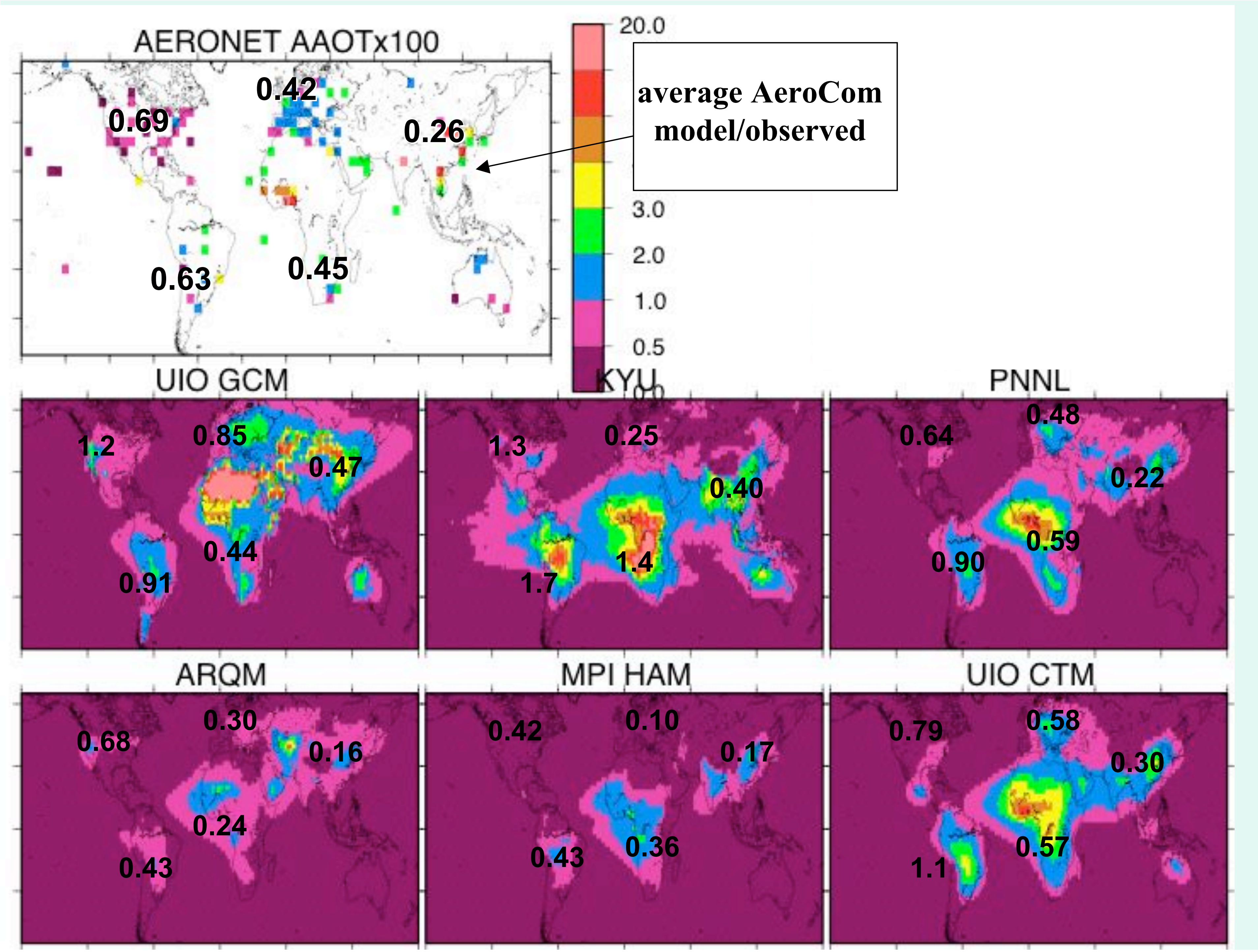
We can use wavelength dependence to test model chemistry

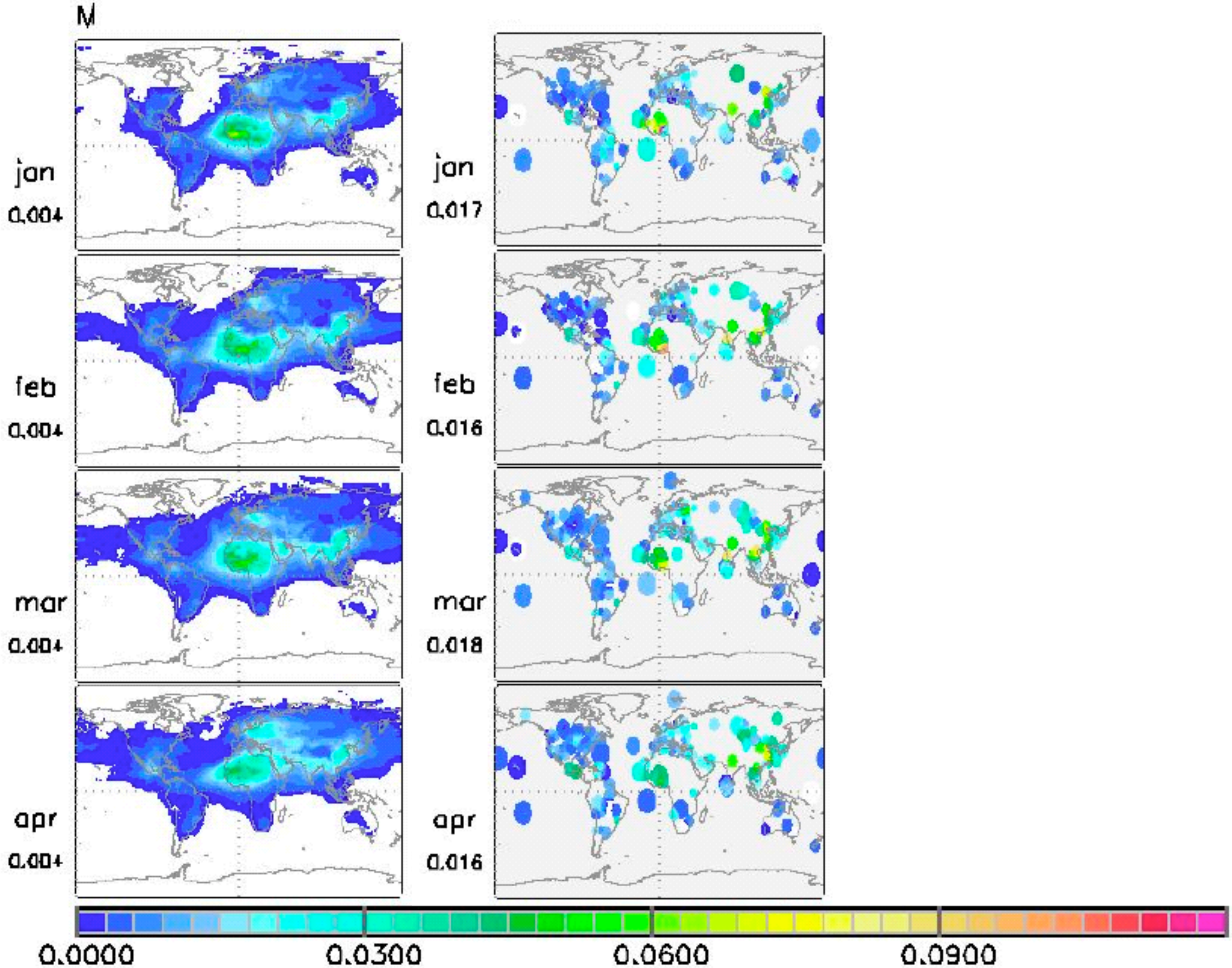


Mod/ AER	550 nm	1000 nm
NAM	1.0	.87
EUR	.70	.72
ASIA	.43	.46
SAM	1.0	.91
AFR	.39	.32

AeroCom models AAOD




AERONET AAOTx100
0.42
0.69
0.26
0.63
0.45
20.0
3.0
2.0
1.0
0.5
0.0
average AeroCom
model/observed
UIO GCM
1.2
0.85
0.47
0.44
0.91
KYU
1.3
0.25
0.40
1.4
1.7
PNNL
0.64
0.48
0.22
0.59
0.90
ARQM
0.68
0.30
0.16
0.24
0.43
MPI HAM
0.42
0.10
0.17
0.36
0.43
UIO CTM
0.79
0.58
0.30
0.57
1.1


M
jan
0.004
jan
0.017
feb
0.004
feb
0.016
mar
0.004
mar
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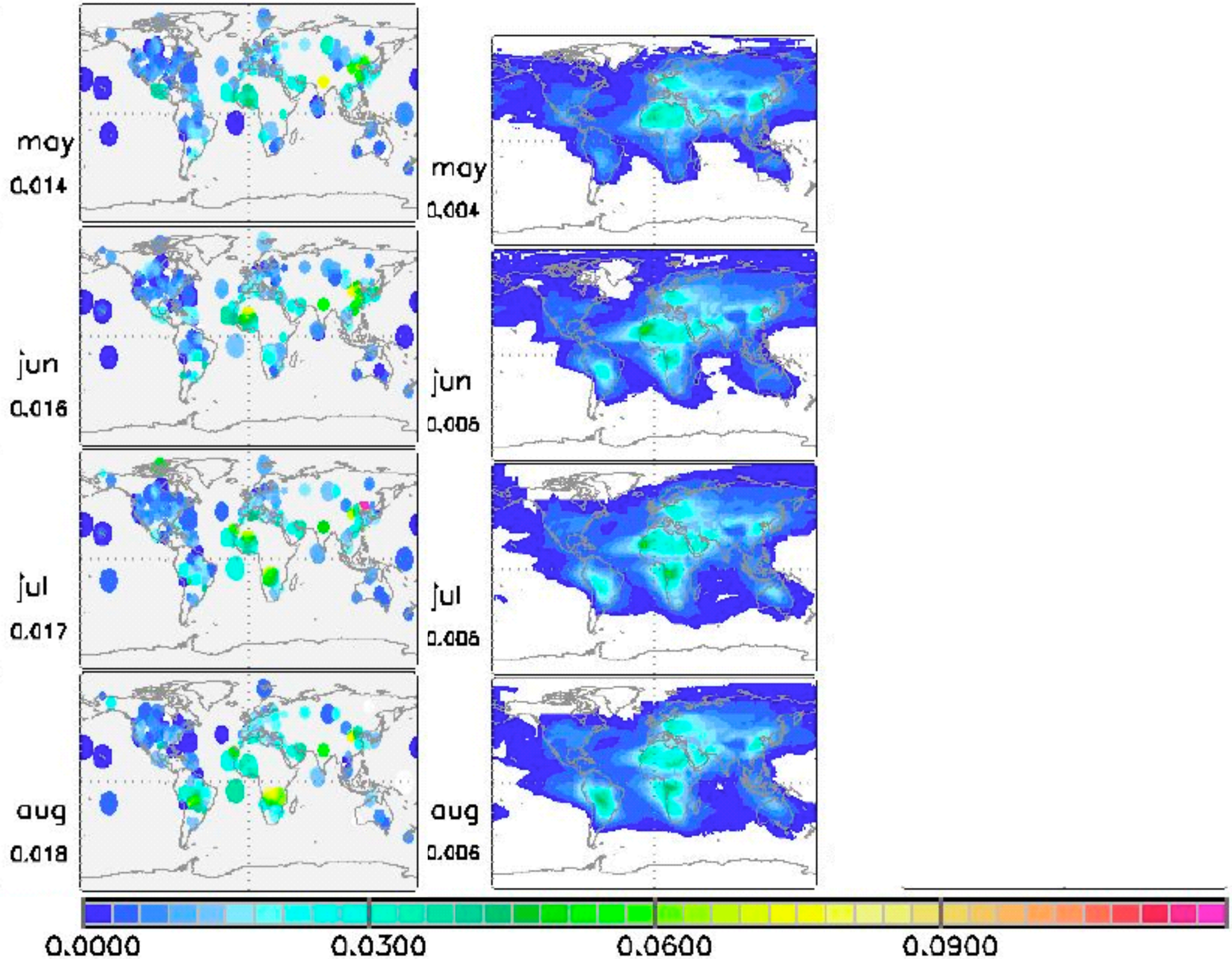
apr
0.004
apr
0.016
0.0000
0.0300
0.0600
0.0900



may
0.014
jun
0.016
jul
0.017
aug
0.018
may
0.004
jun
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aug
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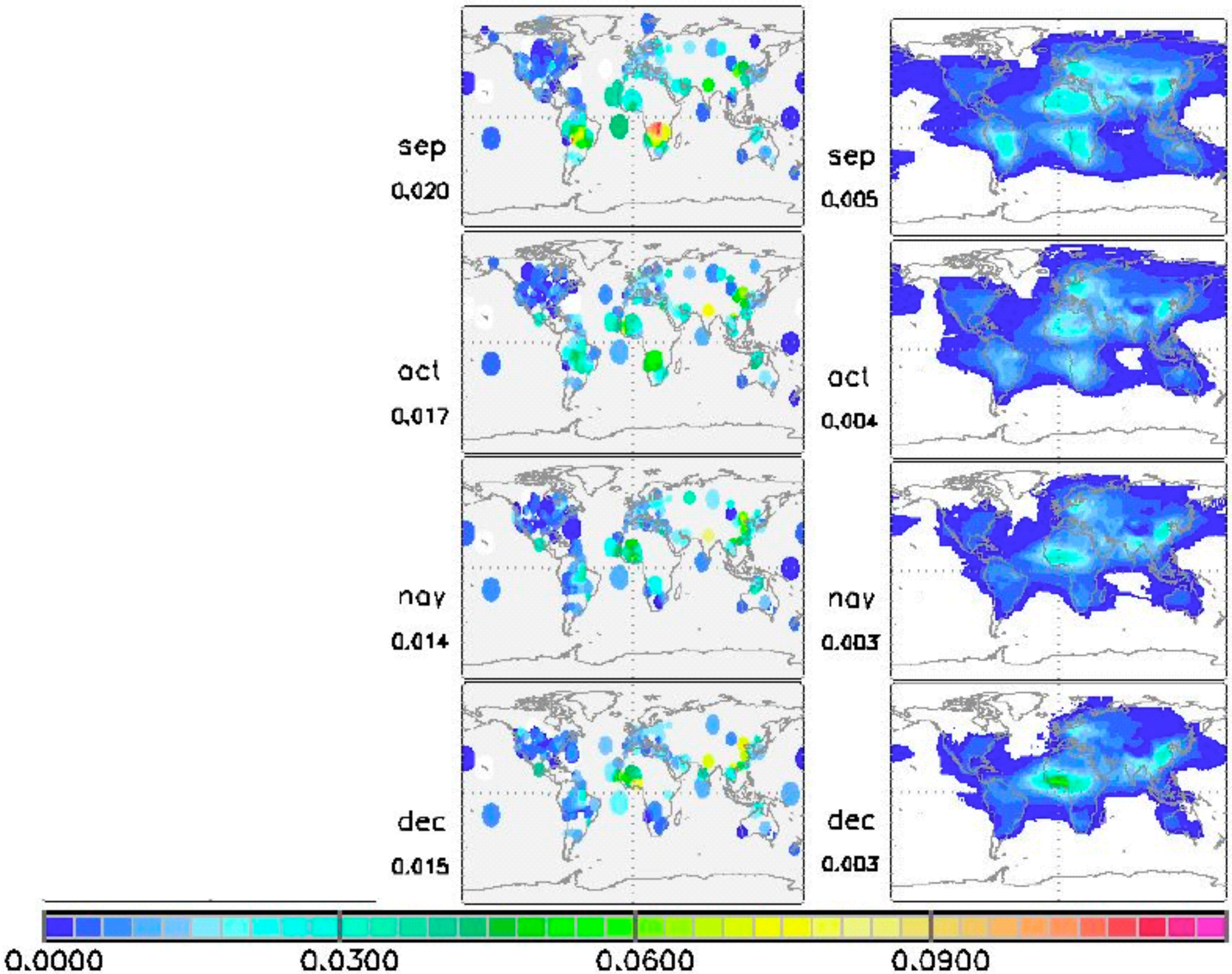
0.0300
0.0600
0.0900



sep
0.020
oct
0.017
nov
0.014
dec
0.015
sep
0.005
oct
0.004
nov
0.003
dec
0.003
0.0000
0.0300
0.0600
0.0900

BC load using Schuster algorhythm

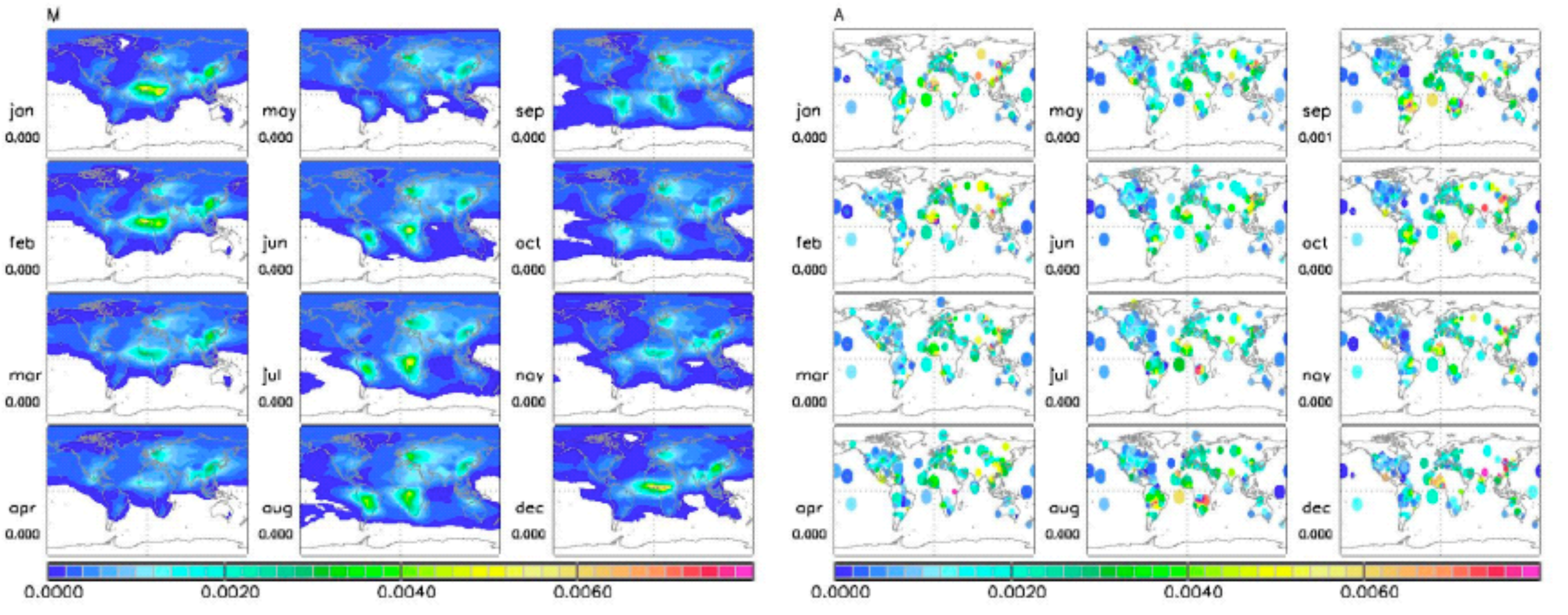


Fig. A3. Monthly soot mass (in g/m2) suggested by modeling (M) and by AERONET (A)

OMI constraints for models?

AAOD products when they become available…

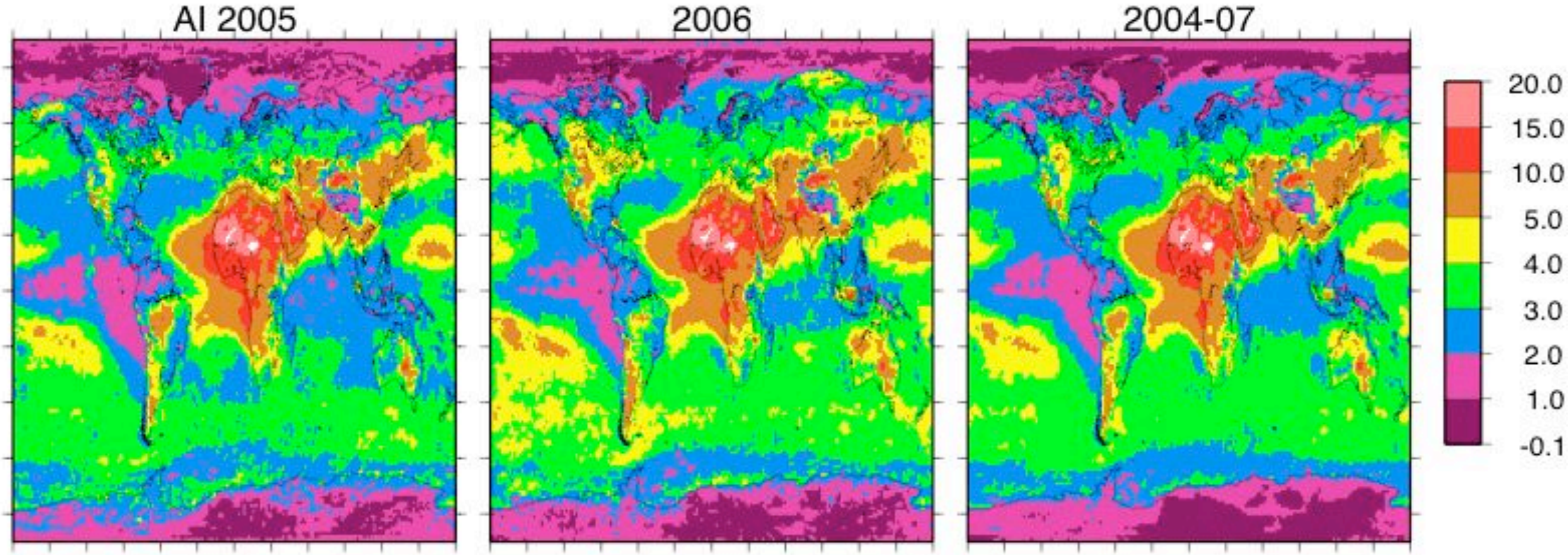
Meanwhile try comparing model with Aerosol Index (AI)?

$$AI = 100 \log_{10} [I_{meas}/I_{calc}] \text{ at } 360nm$$

Data: OMI AI 360nm, Level 3:
ftp://toms.gsfc.nasa.gov/pub/omi/data/aerosol/

From 2004-present

OMI Aerosol Index (x10) annual averages



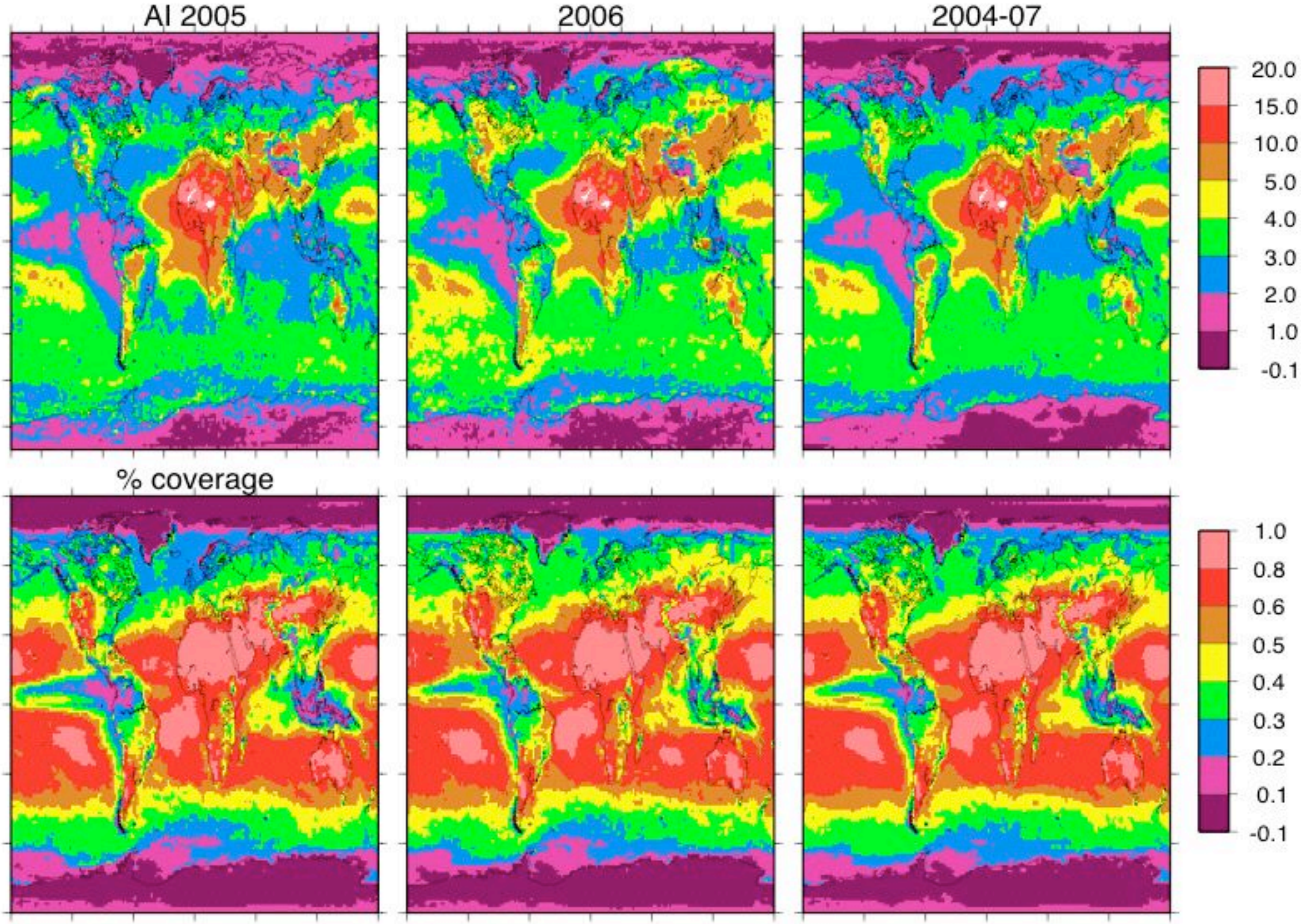
2006: NH activity

Annual features:

- Dust
- Biomass burning
- Asian outflow: dust, burning, pollution?

Data less reliable at high latitudes

OMI Aerosol Index (x10) annual averages



OMI AI in GISS model

1. Extend radiation scheme to the UV (360, 331.2, 340, 380, 312.5 and 308.6)

2. Eventually save radiance ratio

$$AI = 100 \log_{10} [I_{calc}/I_{Rayleigh}] \text{ at } 360\text{nm}$$

But for now use planetary albedo A

$$AI_{model} = 100 \log_{10} [A_{calc}/A_{Rayleigh}] \text{ at } 360\text{nm}$$

Should be qualitatively correct

3. Save AI_{model} diagnostic:

> 1 only

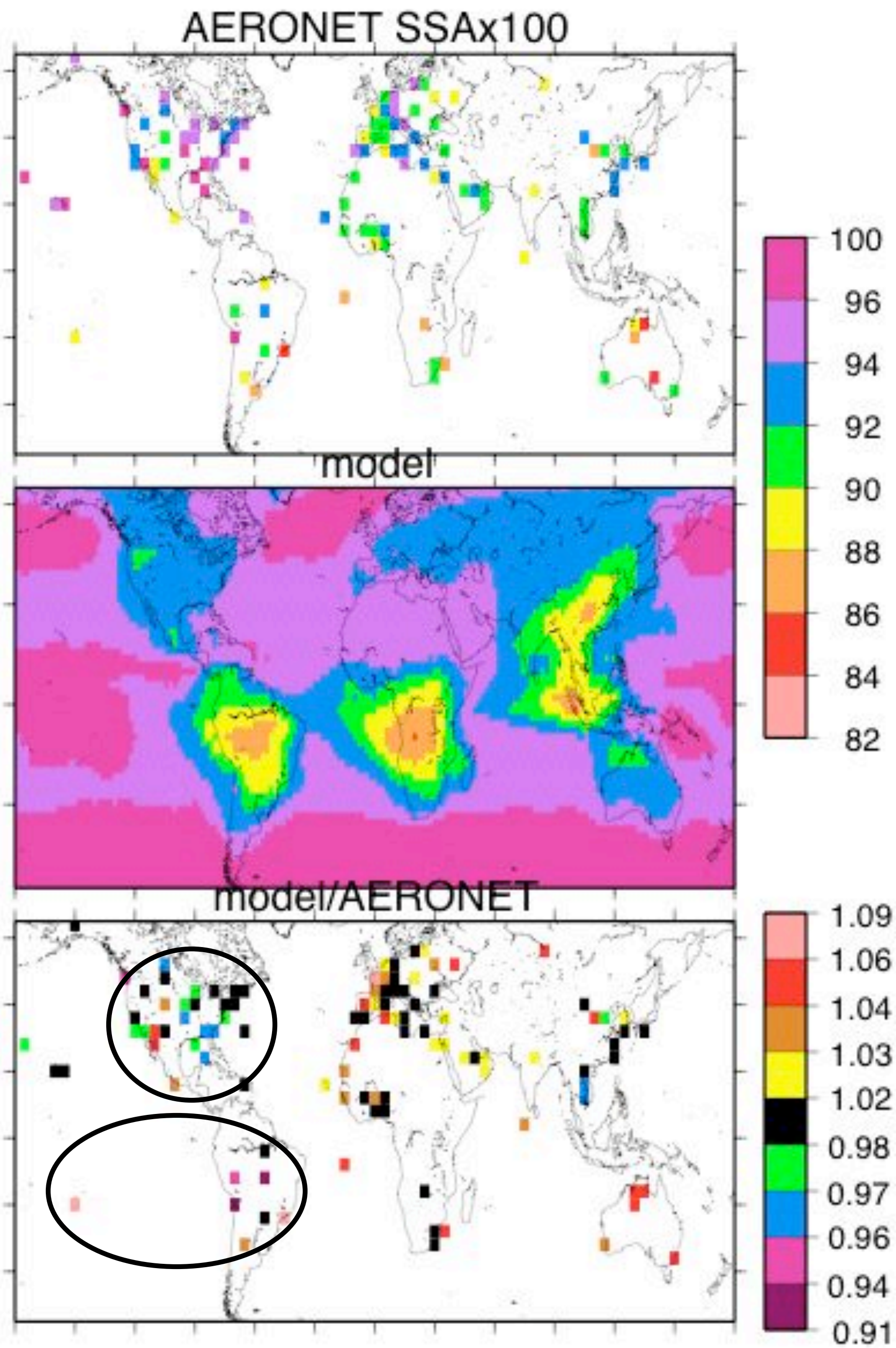
noontime only

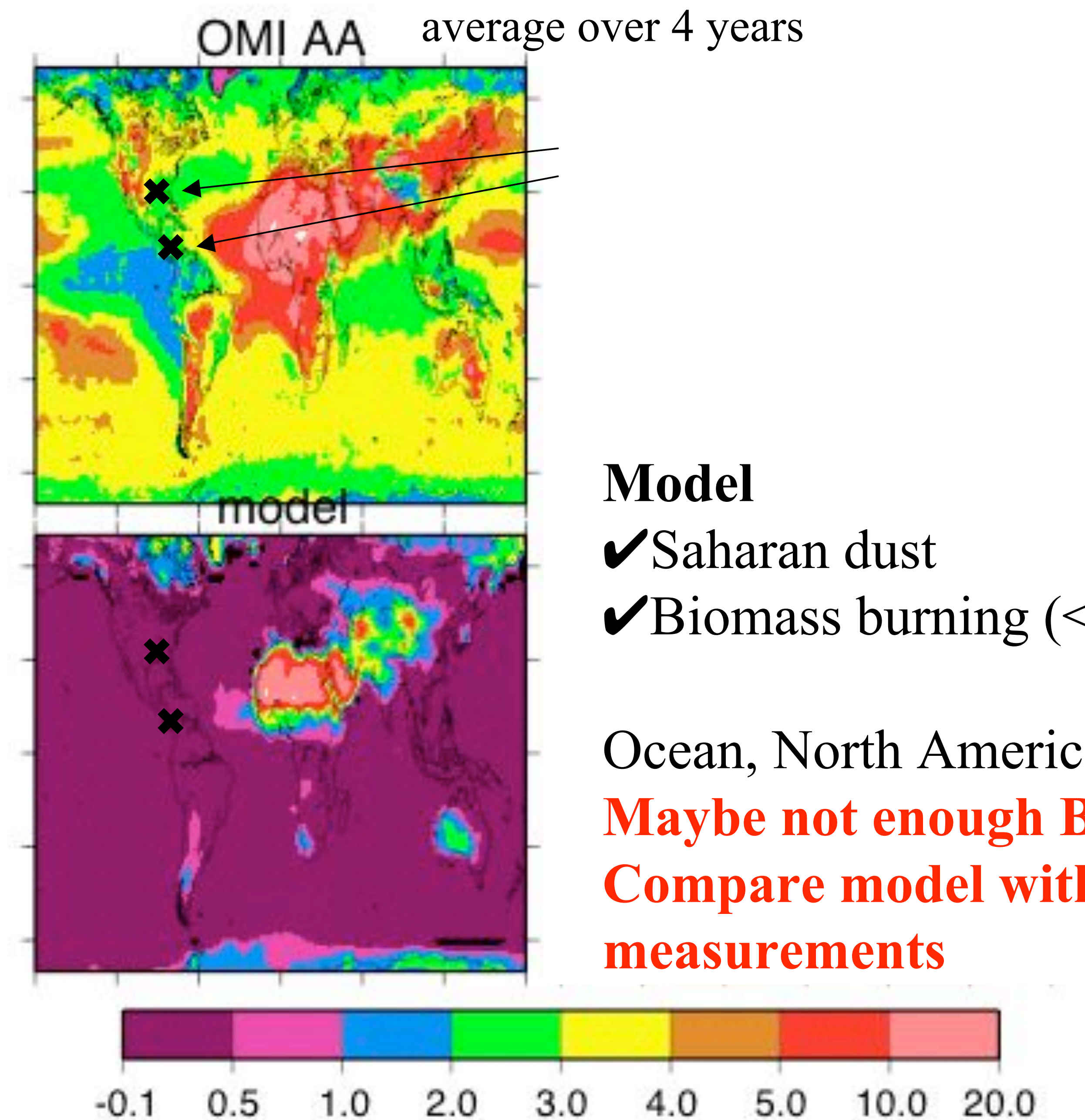
clear sky conditions only

SSA: AERONET vs GISS model

North America, South America SSA is too low, so scattering is NOT overestimated

Region	Mod/Obs
NAM	low
EUR	high
ASIA	?
SAM	Very low
AUST	high





Model

✔Saharan dust

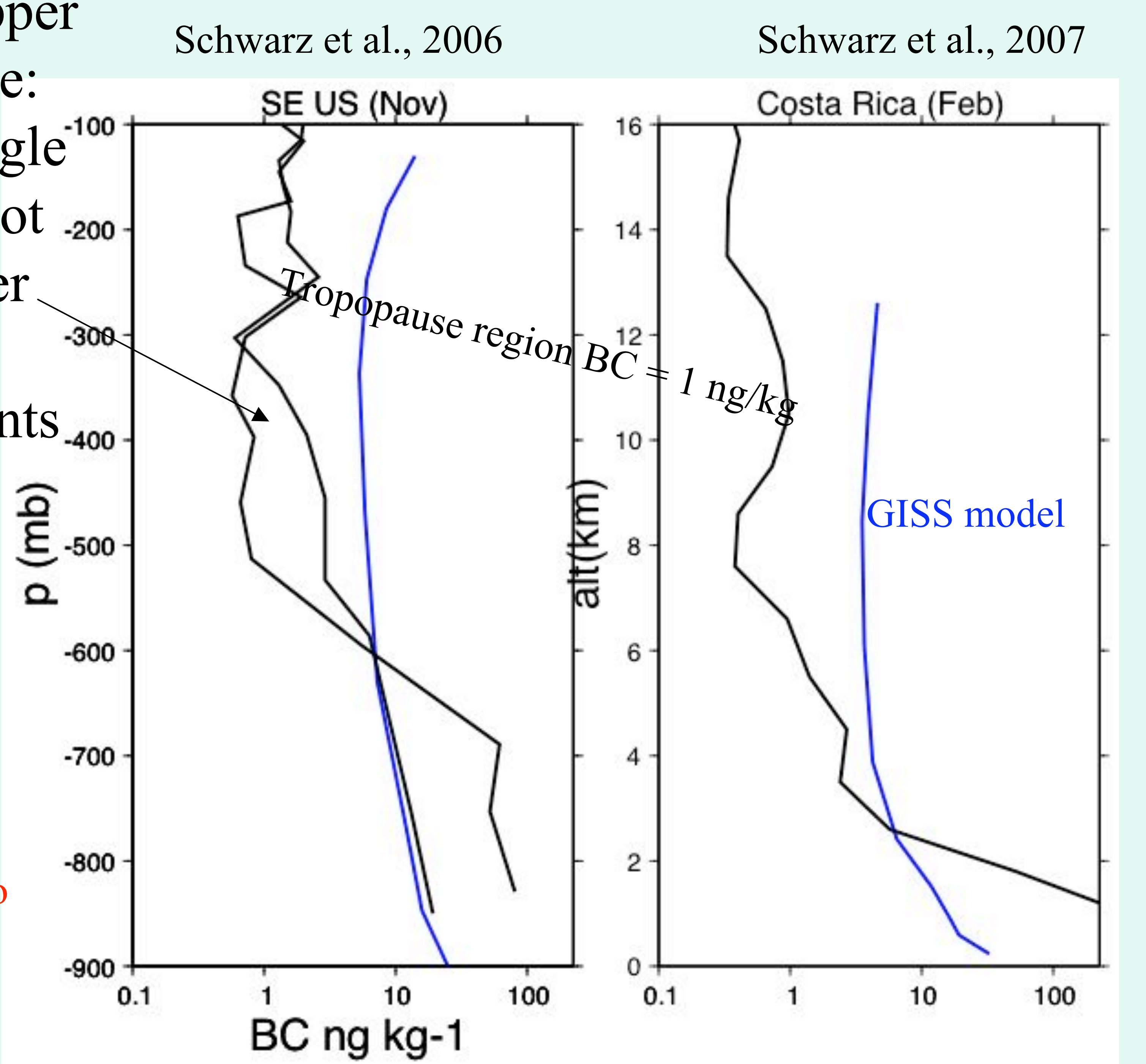
✔Biomass burning (< observed)

Ocean, North America??

Maybe not enough BC at high altitudes?

Compare model with BC SP2 aircraft measurements

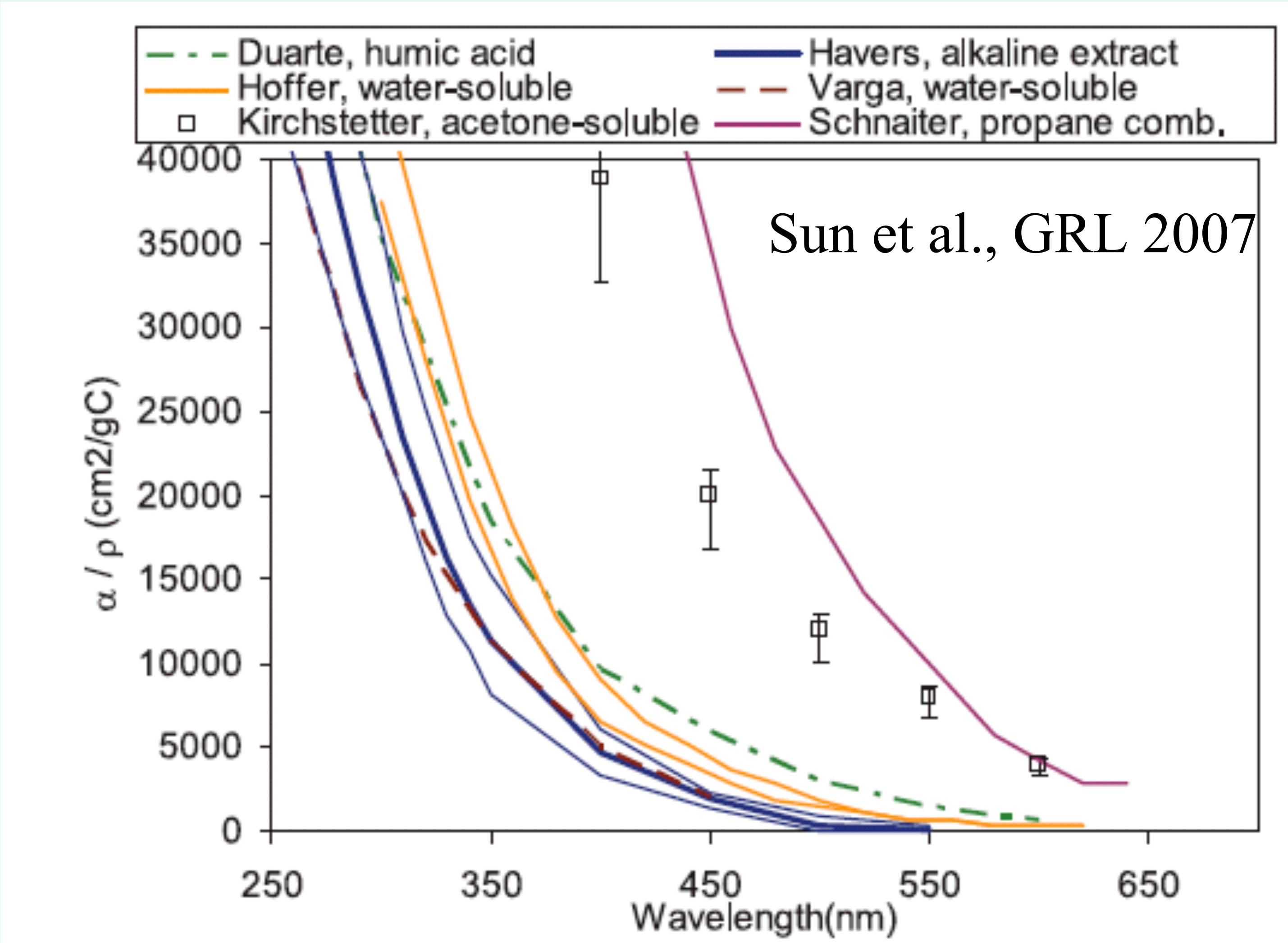
BC in the upper troposphere: Aircraft Single Particle Soot Photometer (SP2) measurements



GISS model actually has excessive BC in UT/LS region.

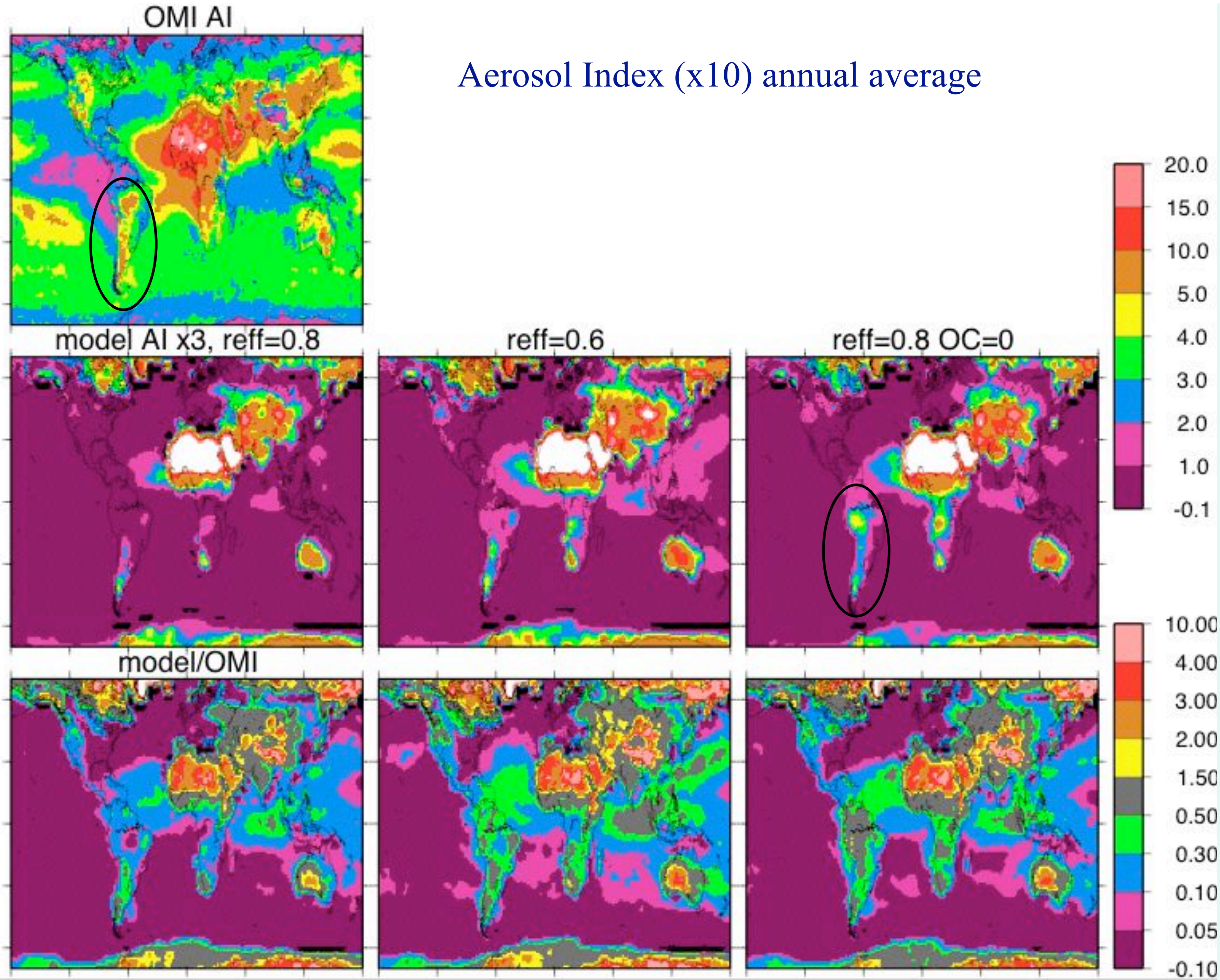
What about ratio of BC to other aerosols?

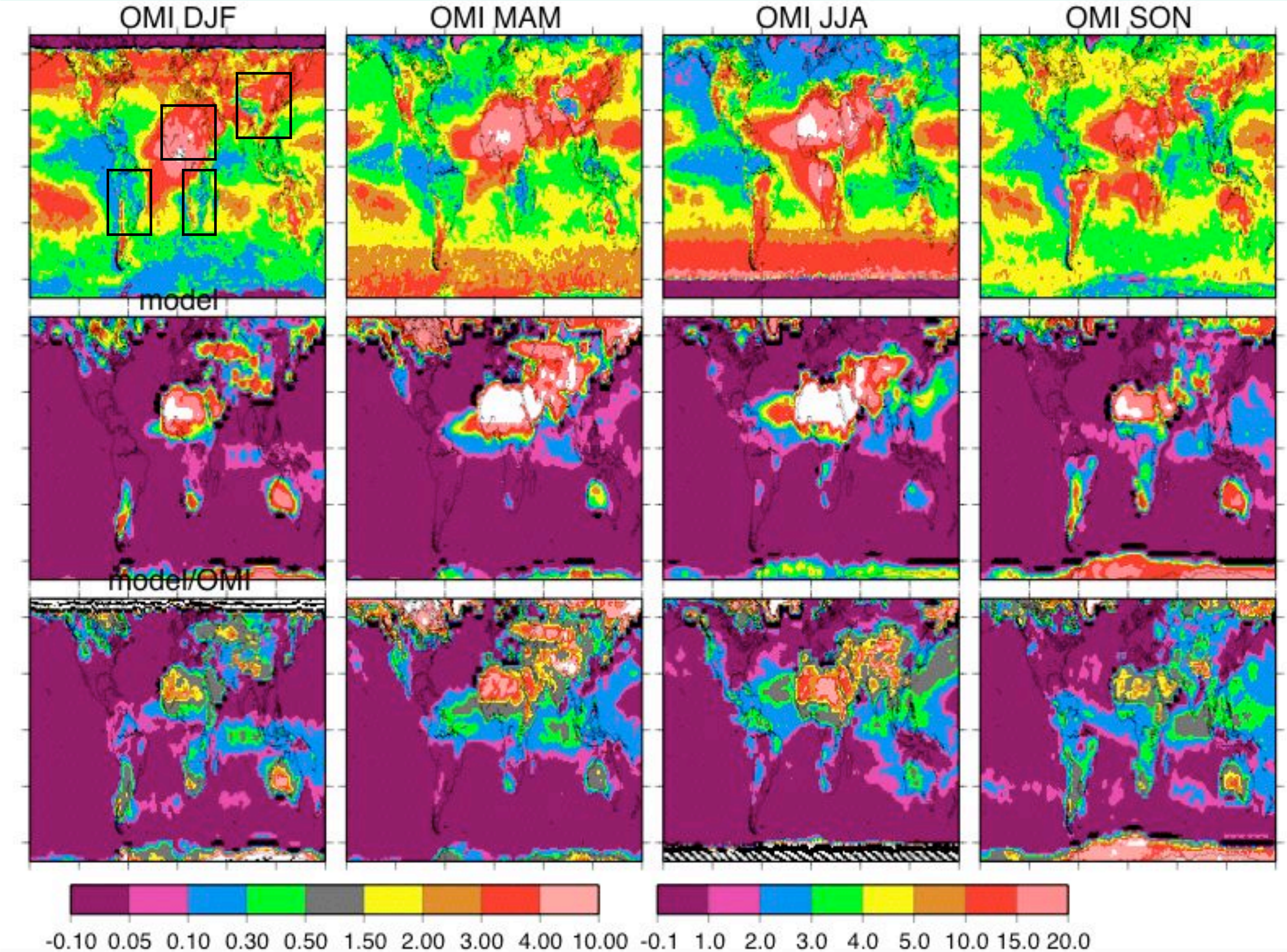
Some organic aerosols are absorbing in UV



Organics are very mildly absorbing in GISS model. Try OC=0…

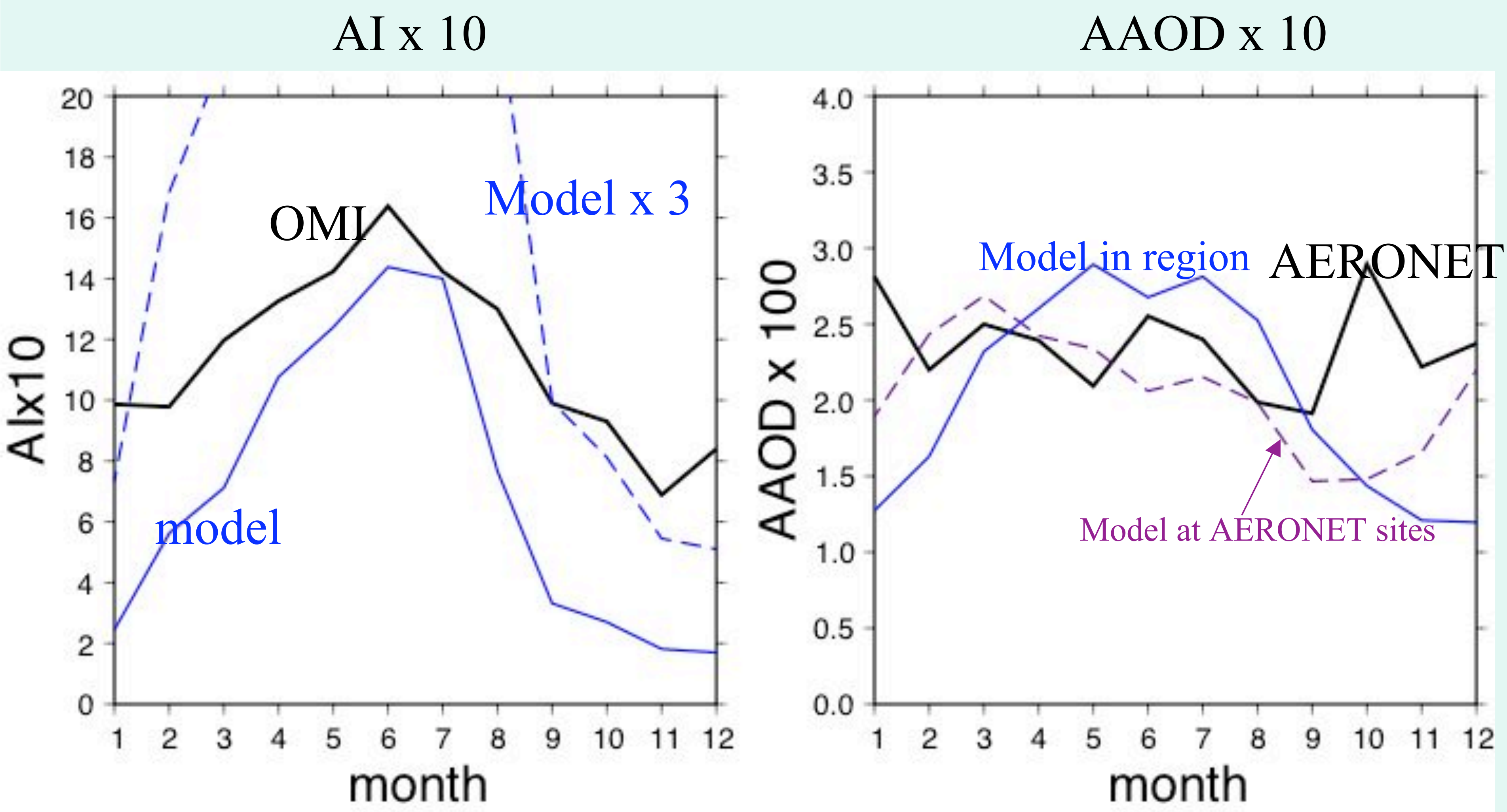
Aerosol Index (x10) annual average



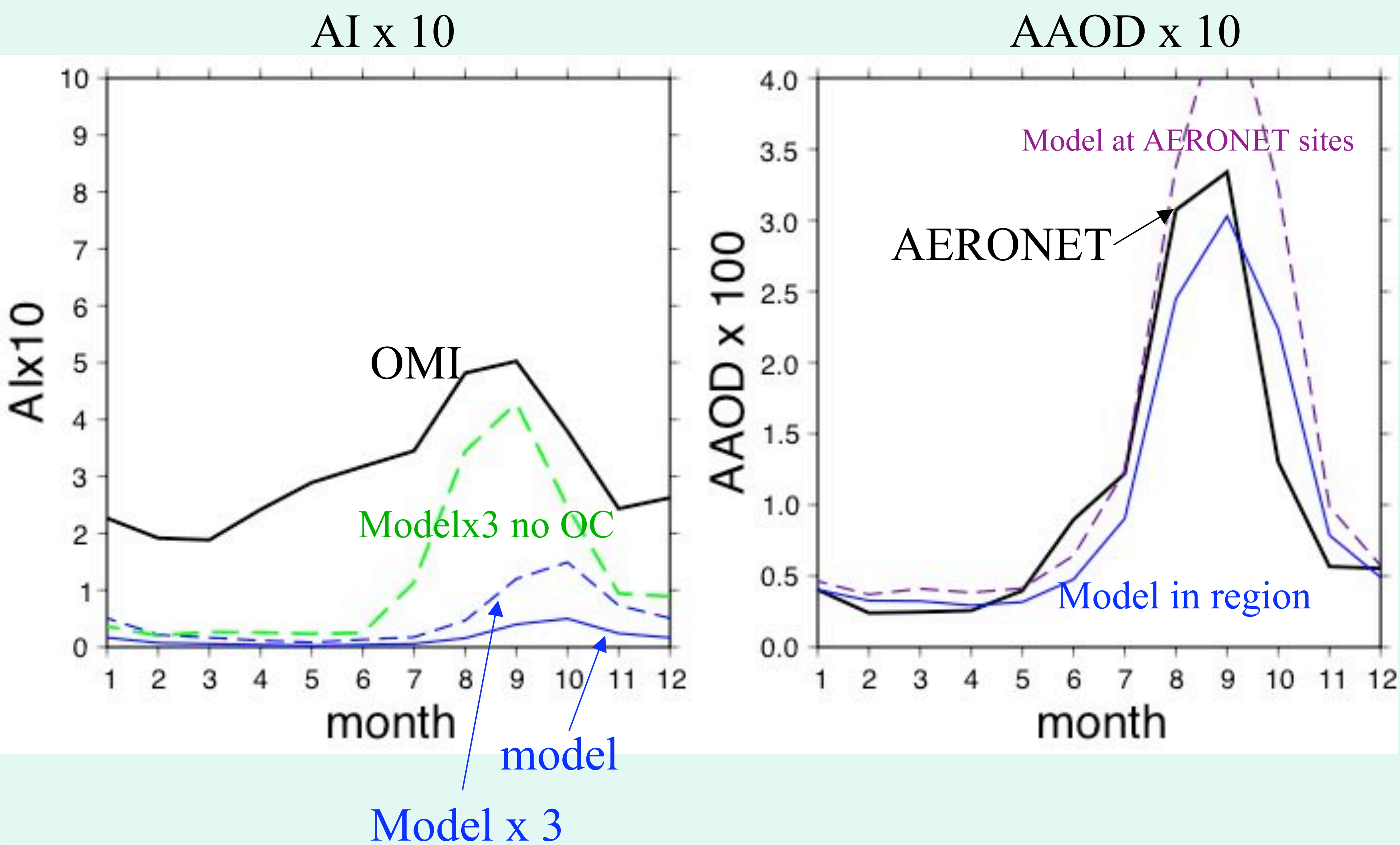


OMI DJF
OMI MAM
OMI JJA
OMI SON
model
model/OMI
-0.10 0.05 0.10 0.30 0.50 1.50 2.00 3.00 4.00 10.00
-0.1 1.0 2.0 3.0 4.0 5.0 10.0 15.0 20.0

Seasonality in Saharan dust region

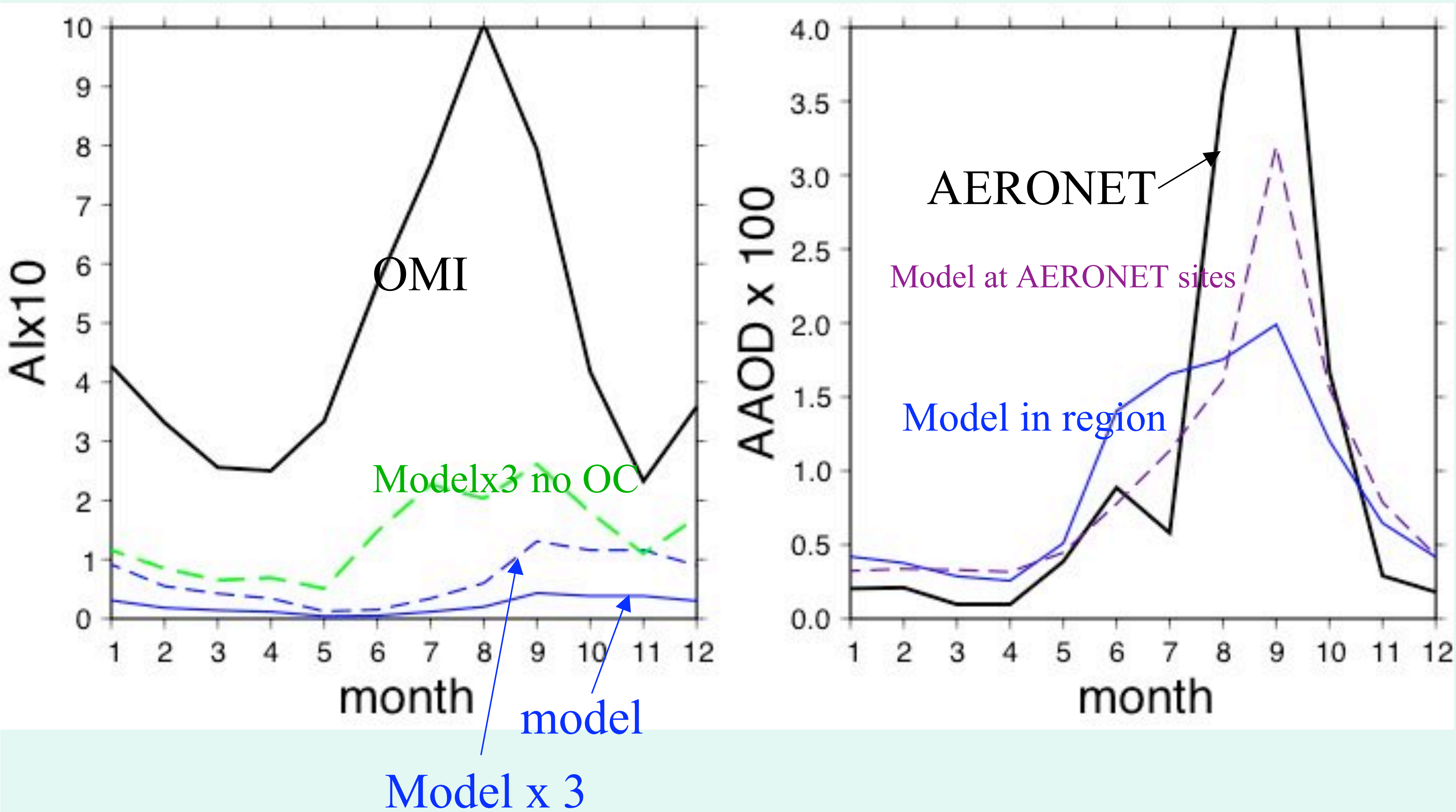


Seasonality in South American biomass burn region

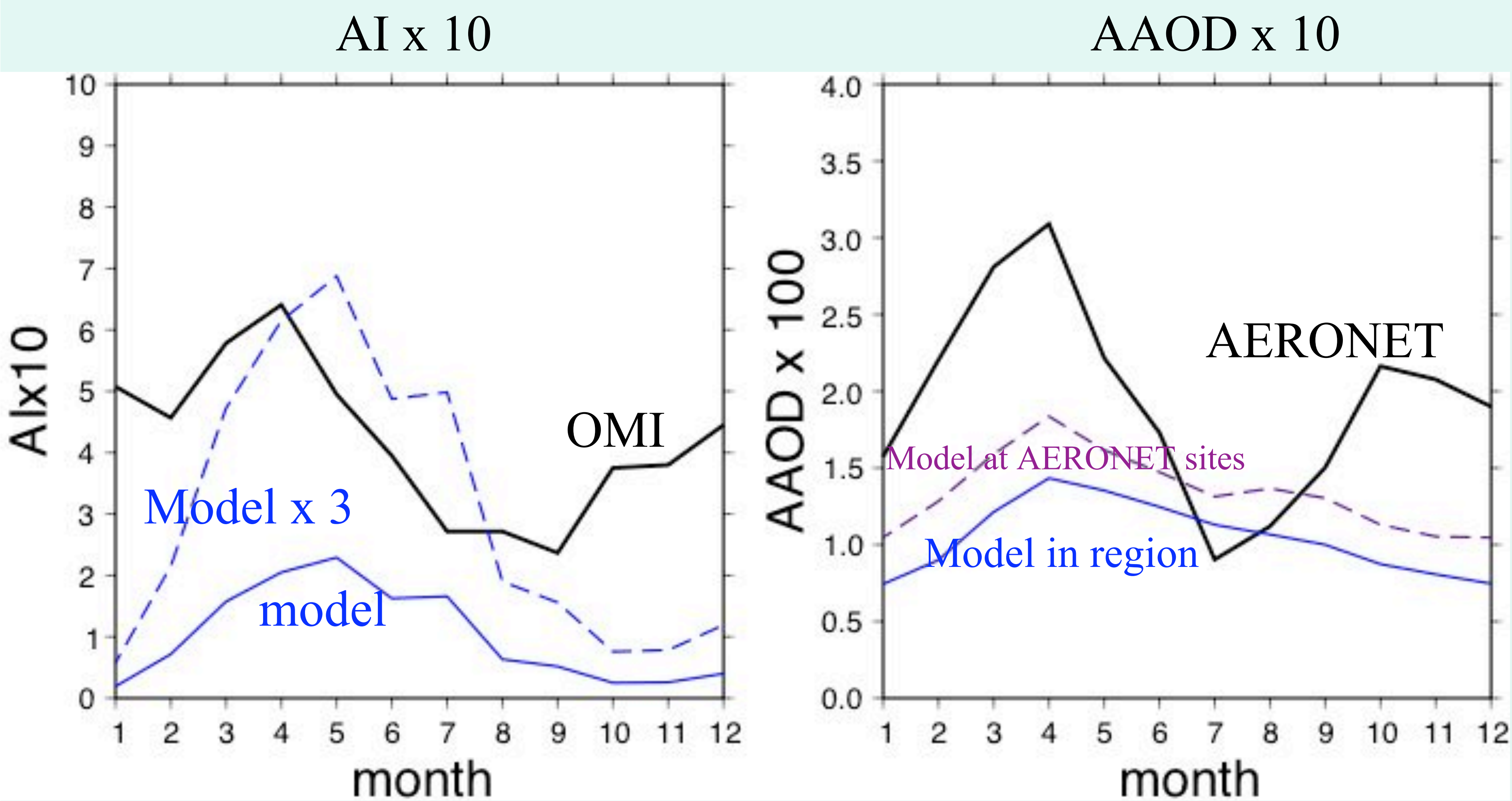


Seasonality in African biomass burn region

AI x 10 AAOD x 10



Seasonality in Southeast Asia region



Conclusions

AERONET AAOD and BC surface concentrations: GISS model underestimates BC and aerosol absorption especially in Asia, African biomass

AERONET AAOD vs AeroCom: most models underestimate aerosol absorption especially in Asia, Europe and African biomass

Model AI diagnostic

First attempt: planetary albedo at 360nm instead of radiance

Successful in clear/dusty region

Models should perhaps have larger BC/OC emission factor for African savannah compared to tropical biomass burning??? Reid et al. (2005): very uncertain

Conclusions

AI probably sensitive to absorbing OC. We plan to add OC absorption from Sun et al. (2007).

GISS (Li and Lacis): implement radiance diagnostic for AI

Consider sensitivity to height of aerosol layers

Improve treatment of cloudy conditions to look more like OMI AI retrieval?

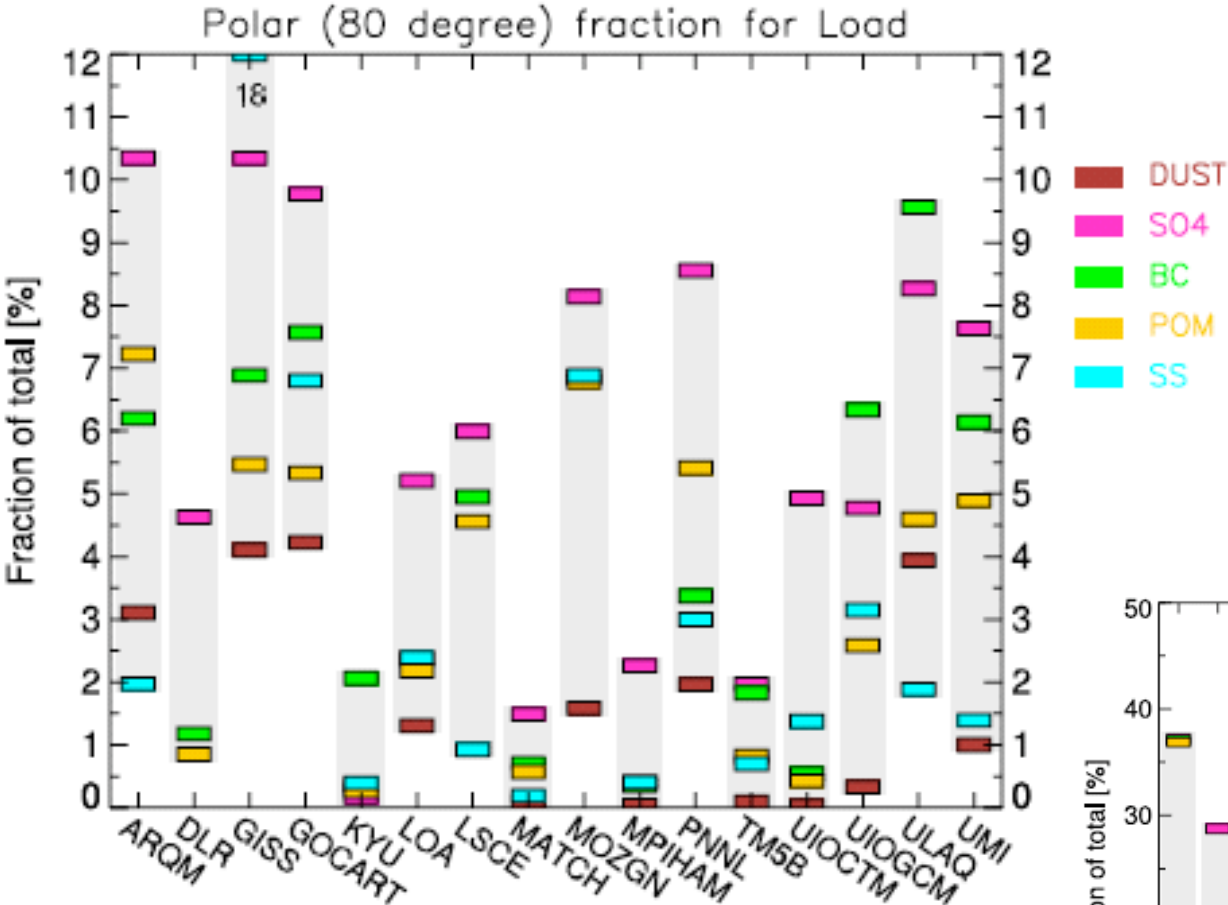
Is there a simpler "AI" diagnostic that models might use to test aerosol absorption?

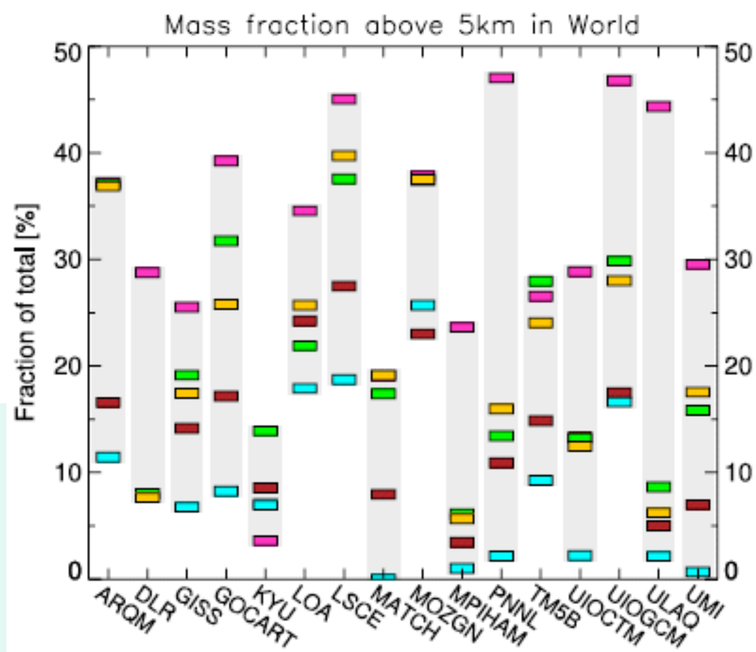
BC in the Arctic

Do models transport BC to the Arctic correctly?

Do models remove BC in the Arctic correctly: Deposition has implications for BC-snow albedo effects. Are model Arctic clouds liquid or ice phase? How much BC is removed by liquid/frozen precipitation?

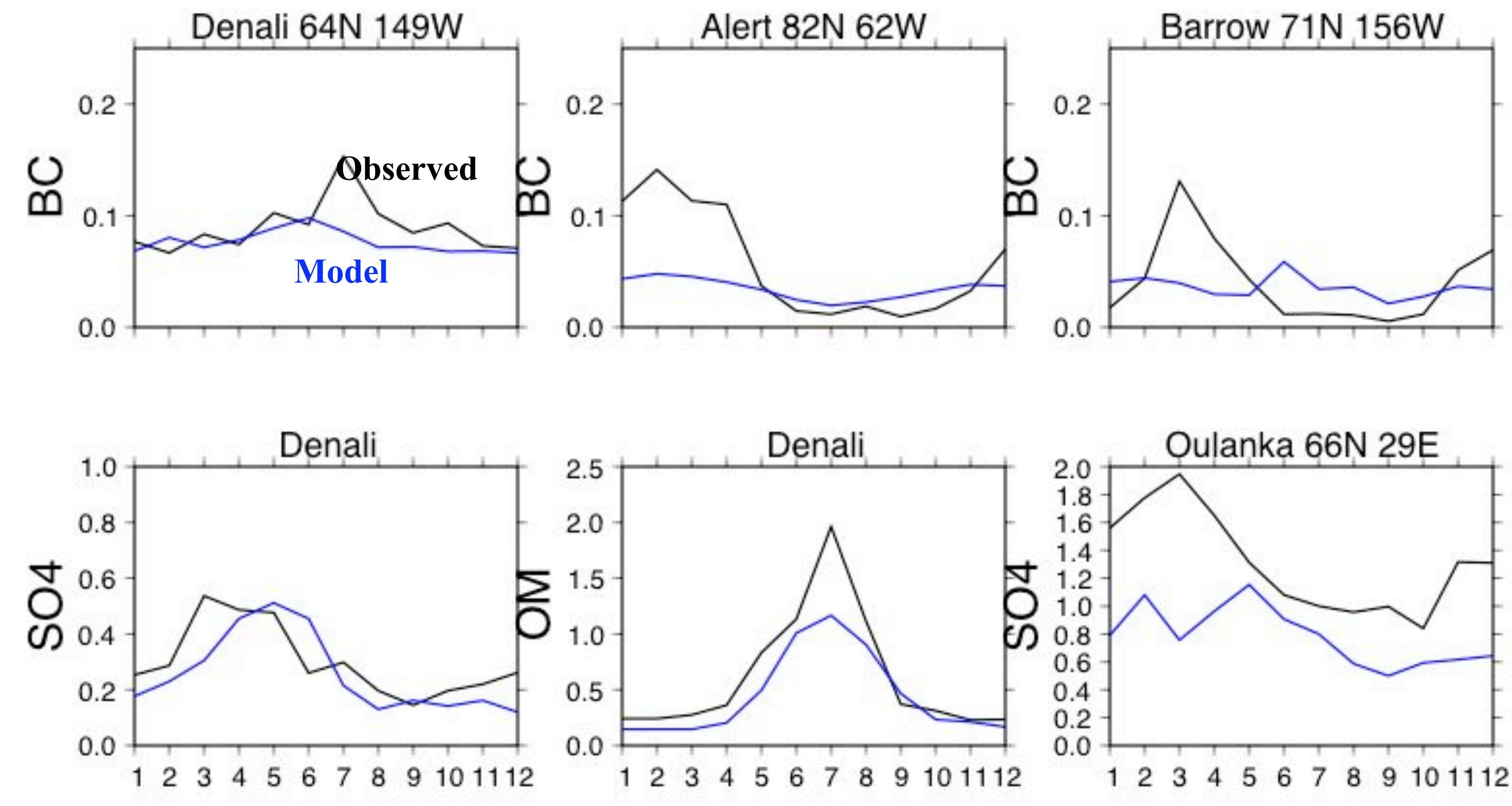
Where do (AeroCom) models distribute their loads?



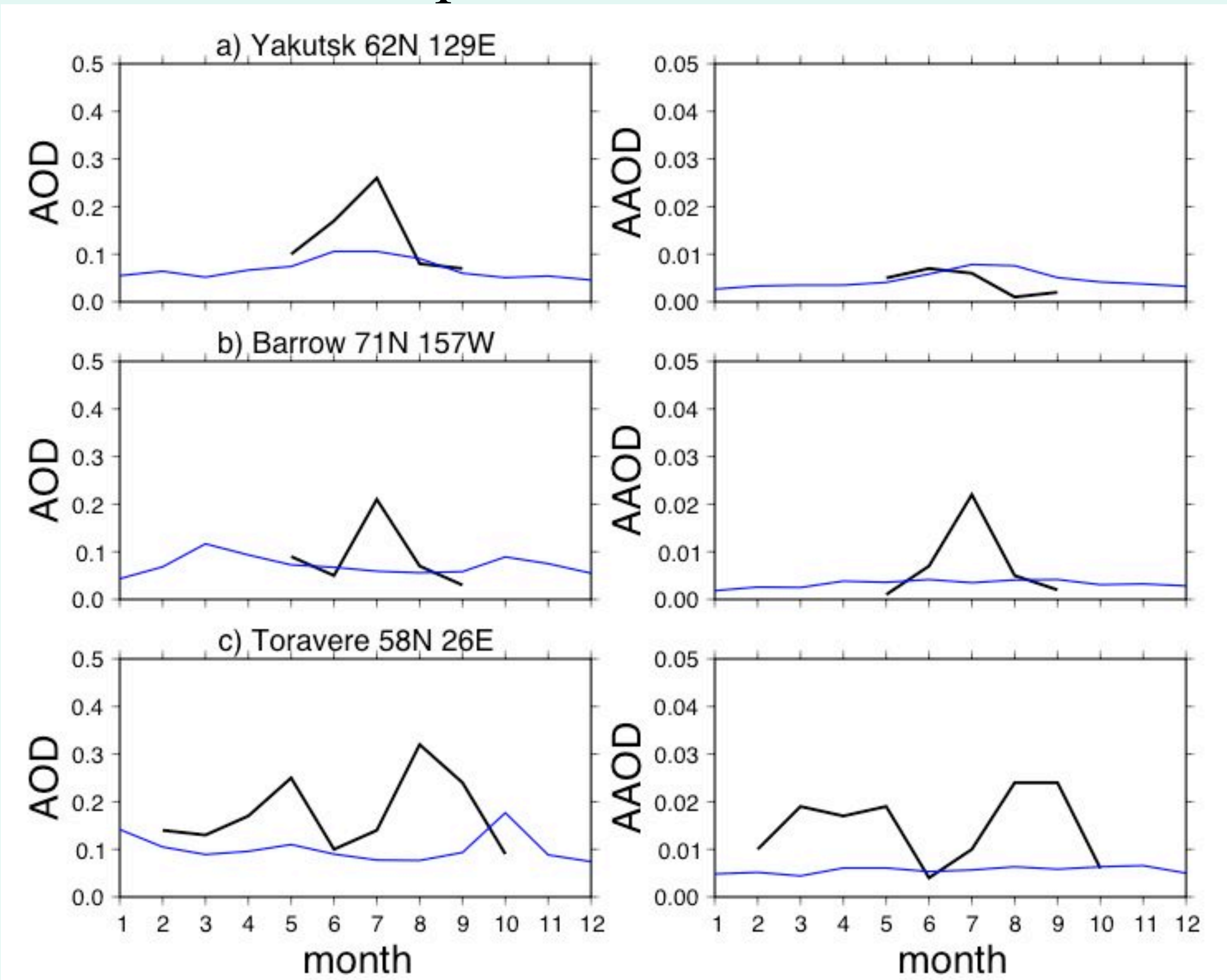


Textor *et al.*, *ACP*, 2006

Model compared to Arctic aerosol surface concentrations



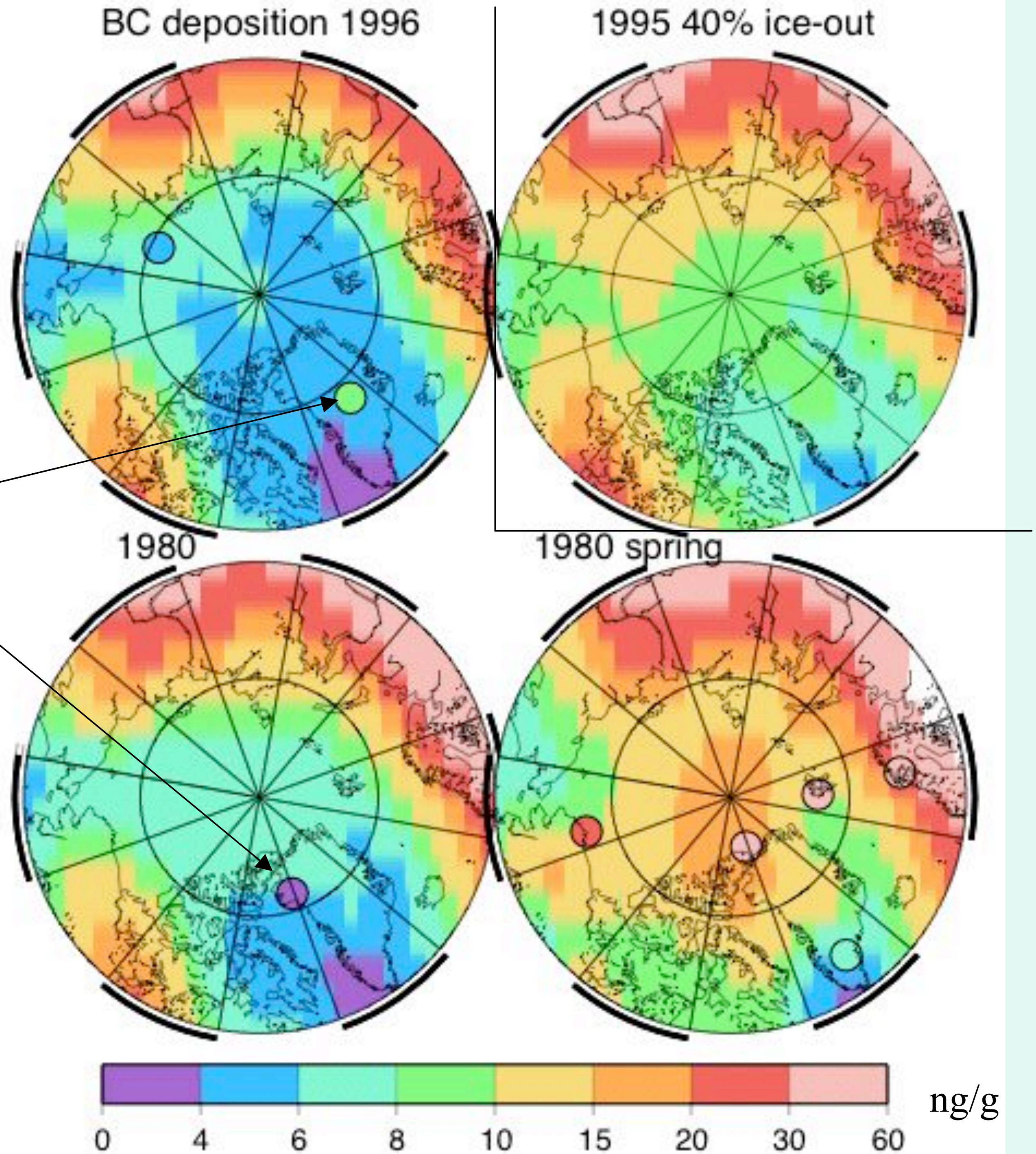
Model compared to Arctic AERONET



BC snow concentration

Observations compiled by Flanner et al. (2007)

GISS model with 5% ice phase cloud removal (compared to liquid), Arctic BC is generally smaller than observed

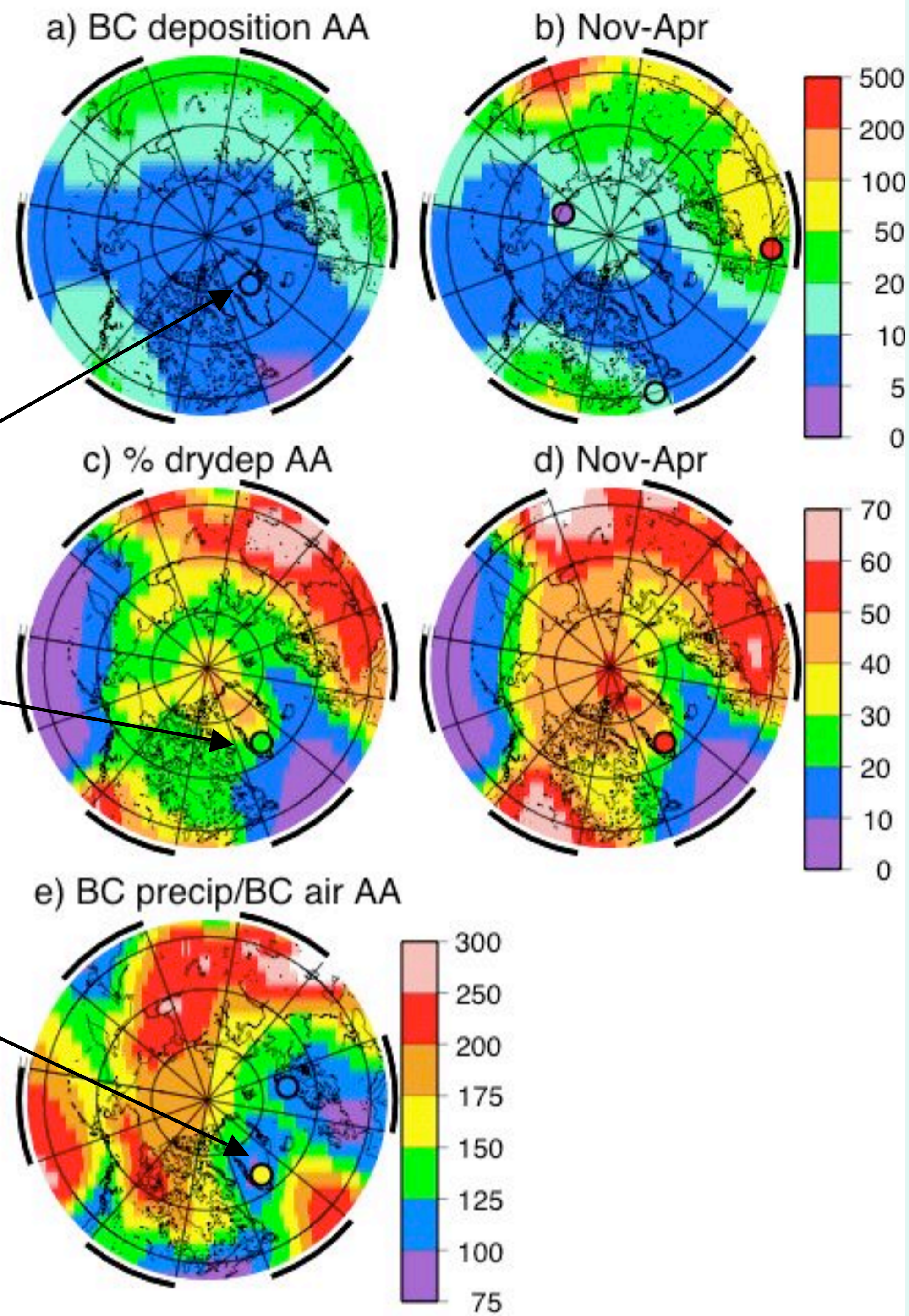


These are sensitive to removal assumptions. Here we assume 12% removal by ice phase (compared to liquid phase)

BC deposition compiled in Flanner et al. (2007)

Percent dry deposition from Davidson et al (1985)

Scavenging ratio from Davidson et al (1985) and Noone and Clarke (1988)

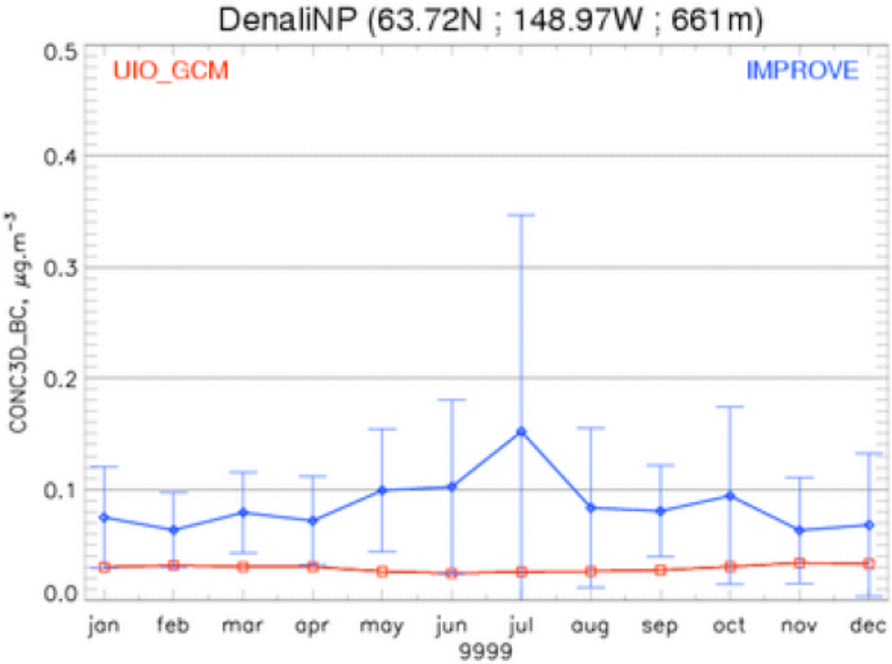


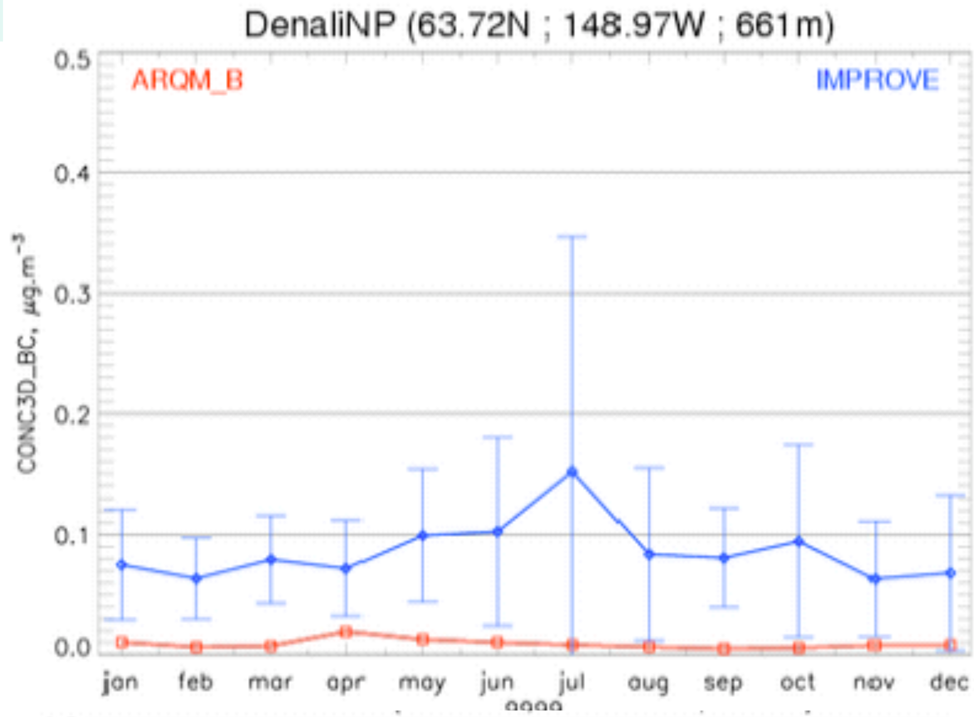
AeroCom BC models in Denali and Barrow Alaska

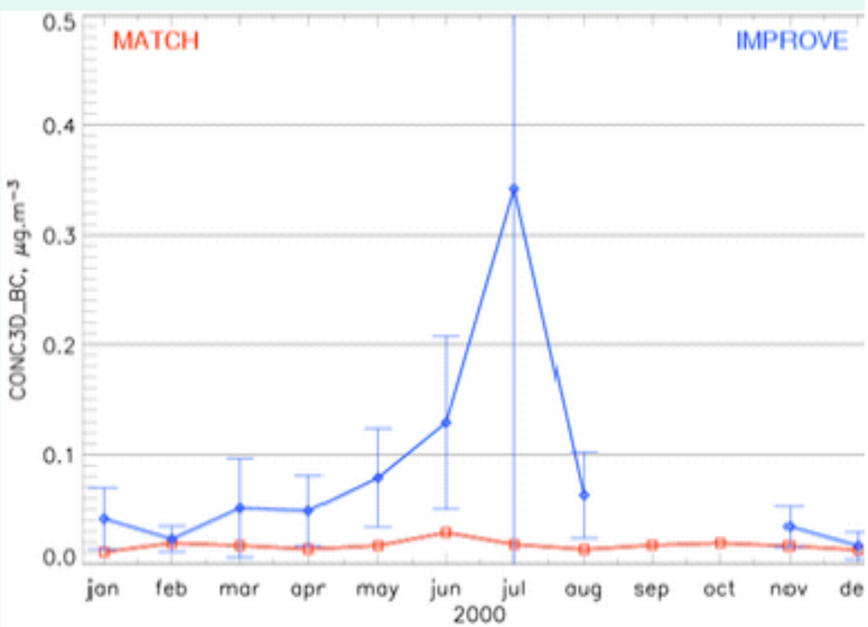
Denali

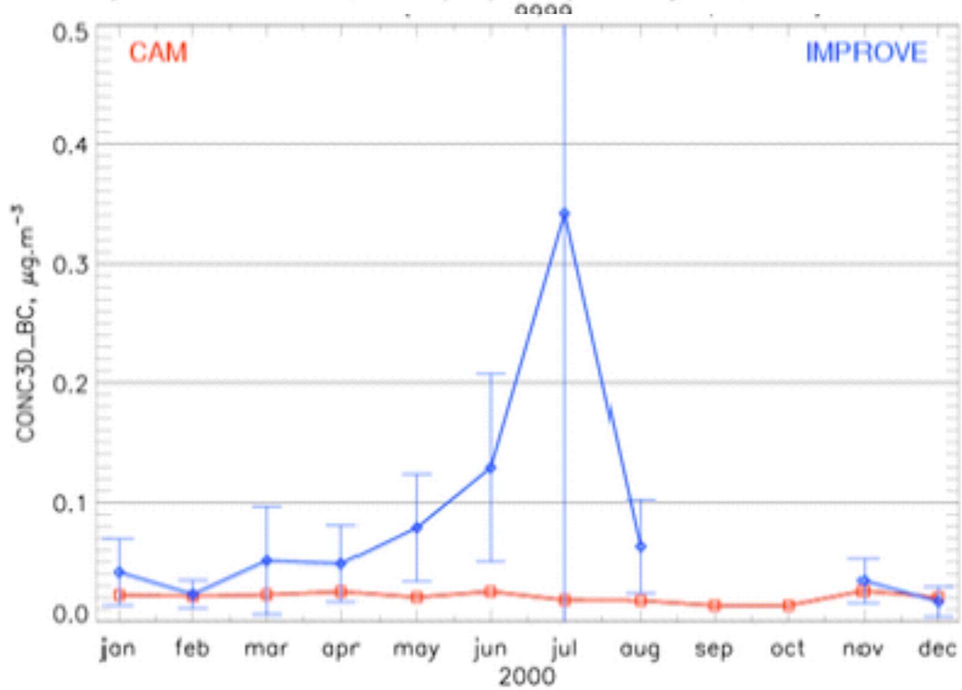
Barrow

BC Models in Denali, Alaska

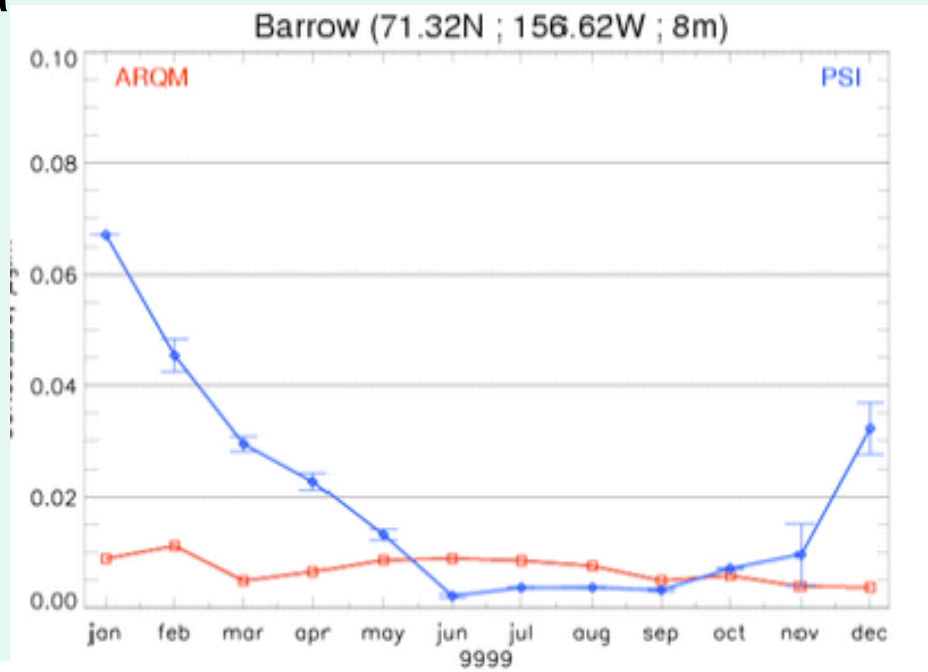


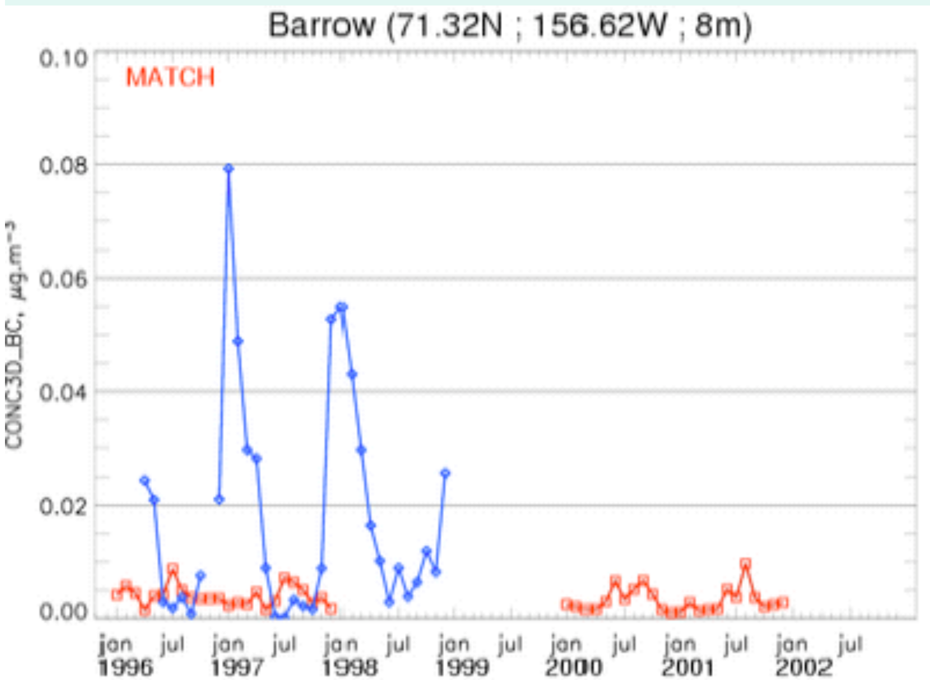


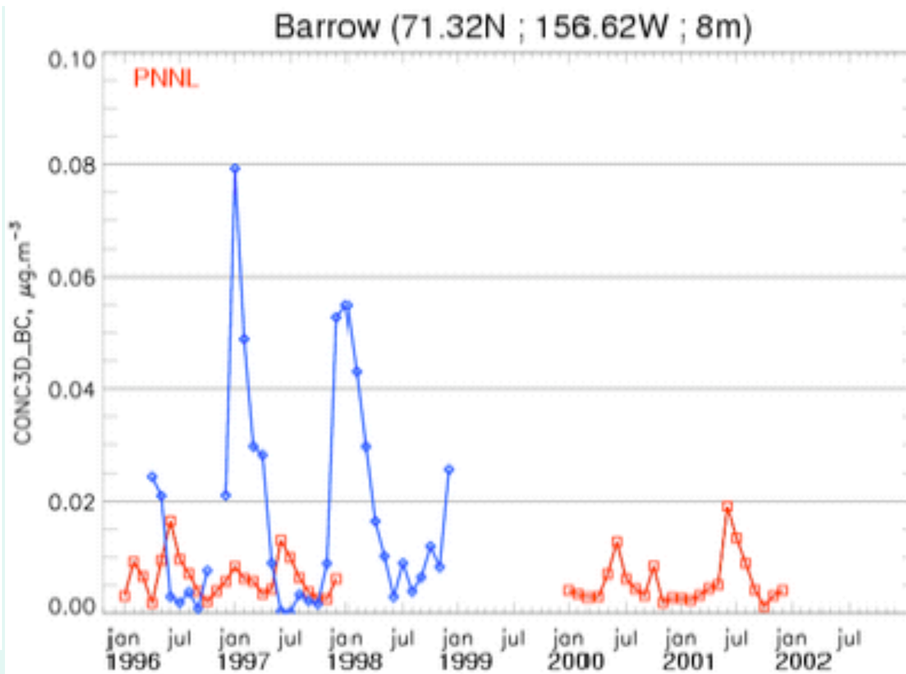




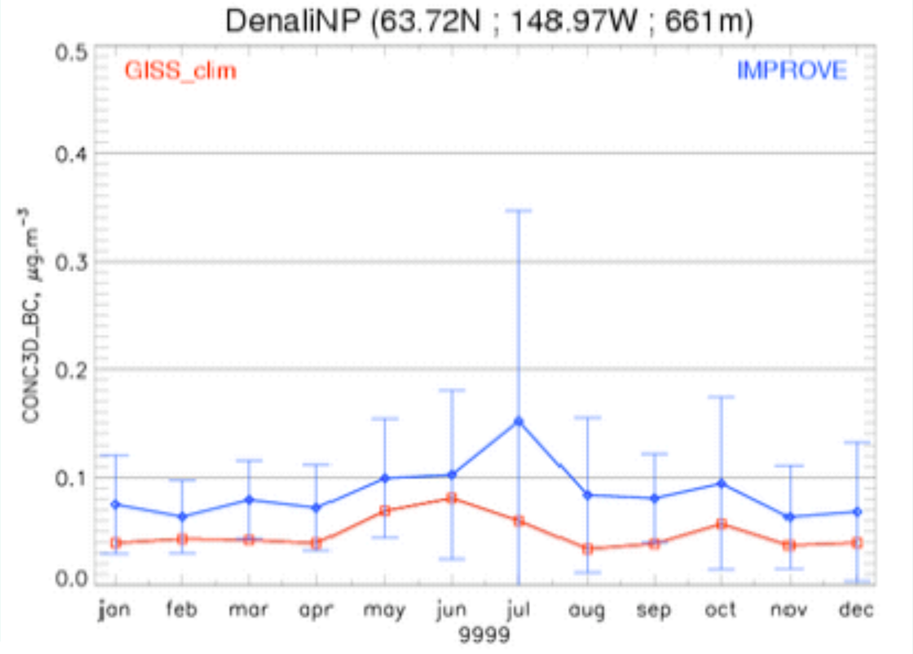
BC Models in Barrow, Alaska

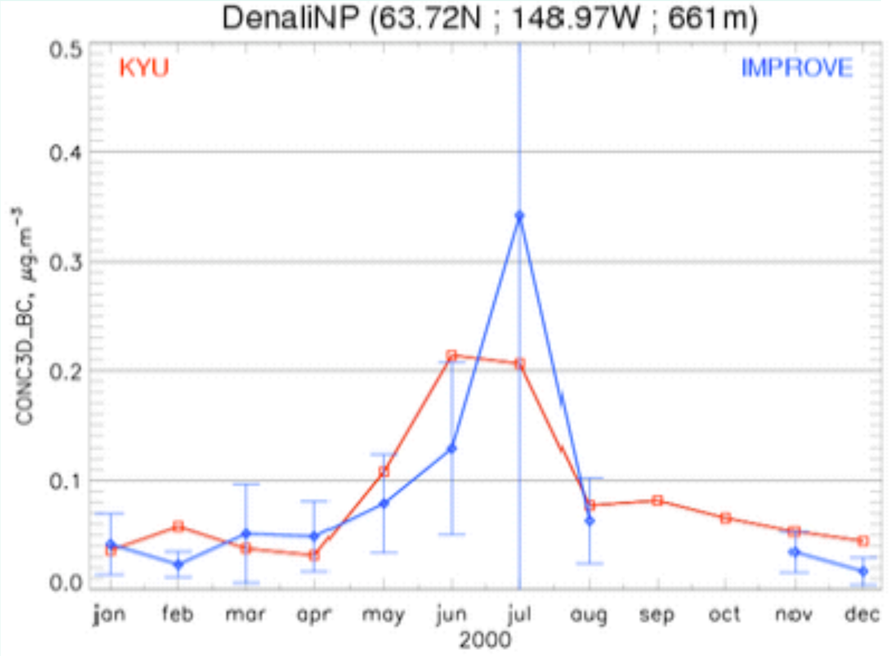


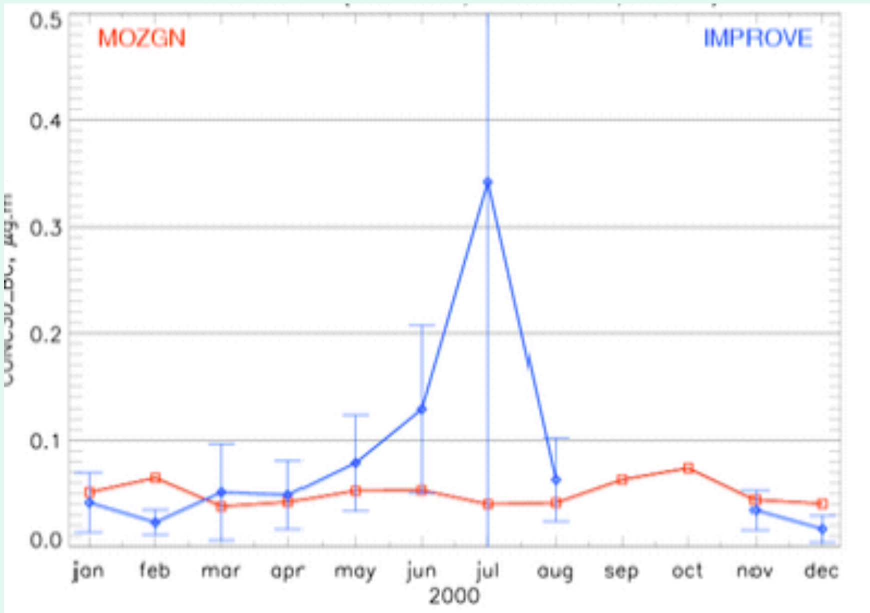




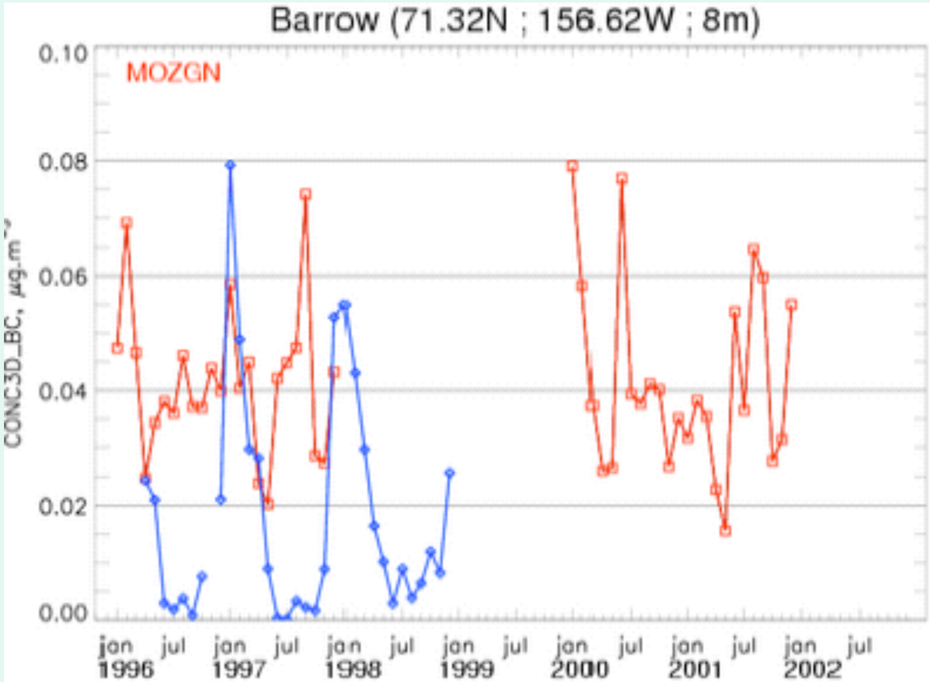
BC Models in Denali, Alaska

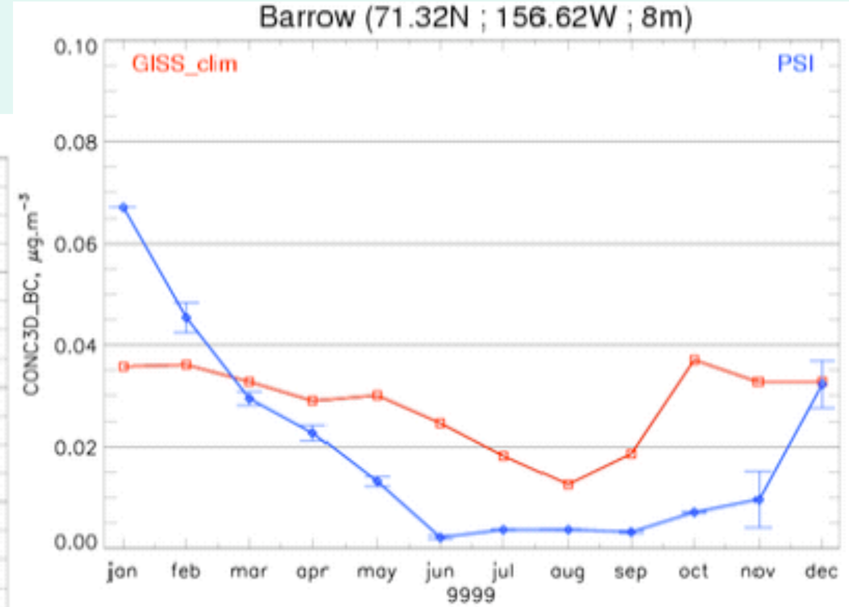


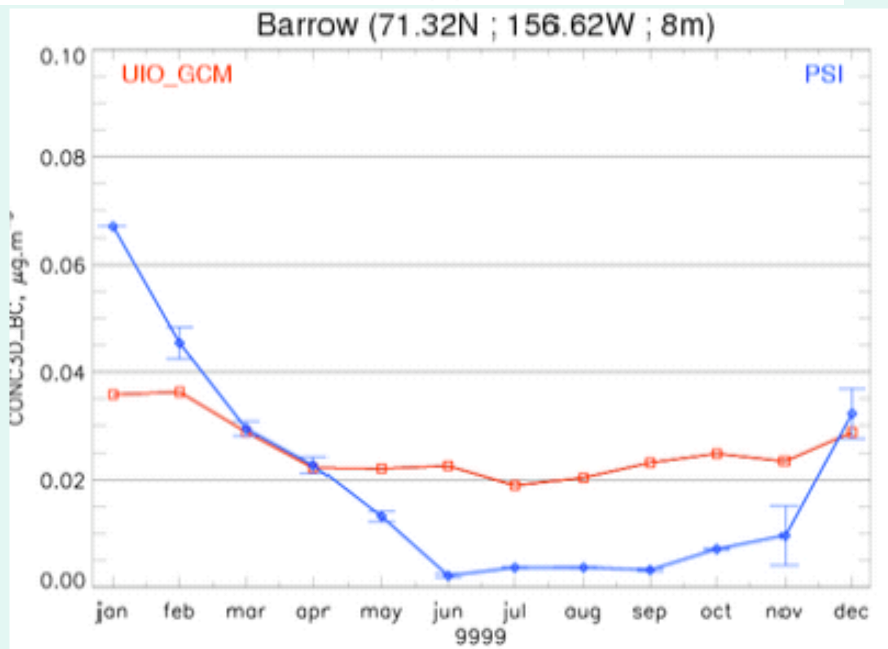


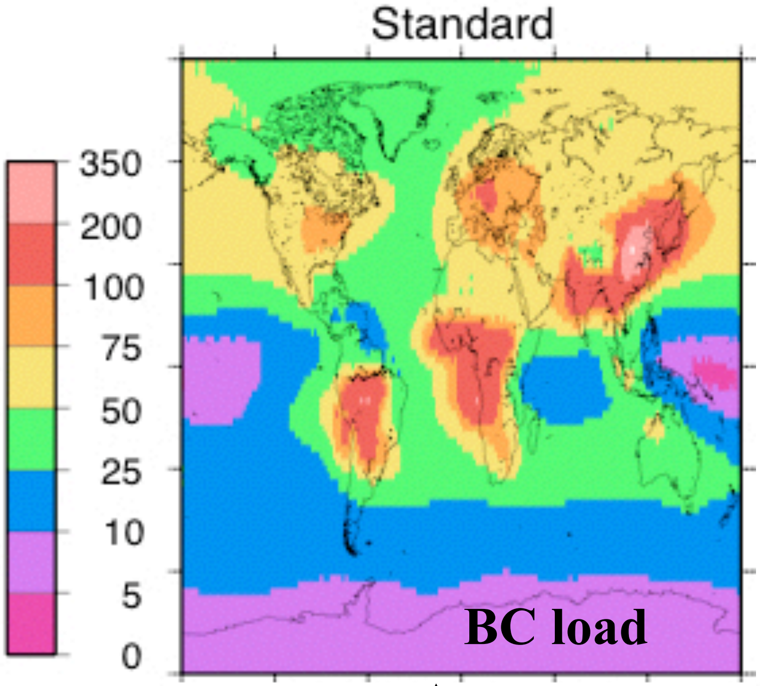


BC Models in Barrow, Alaska



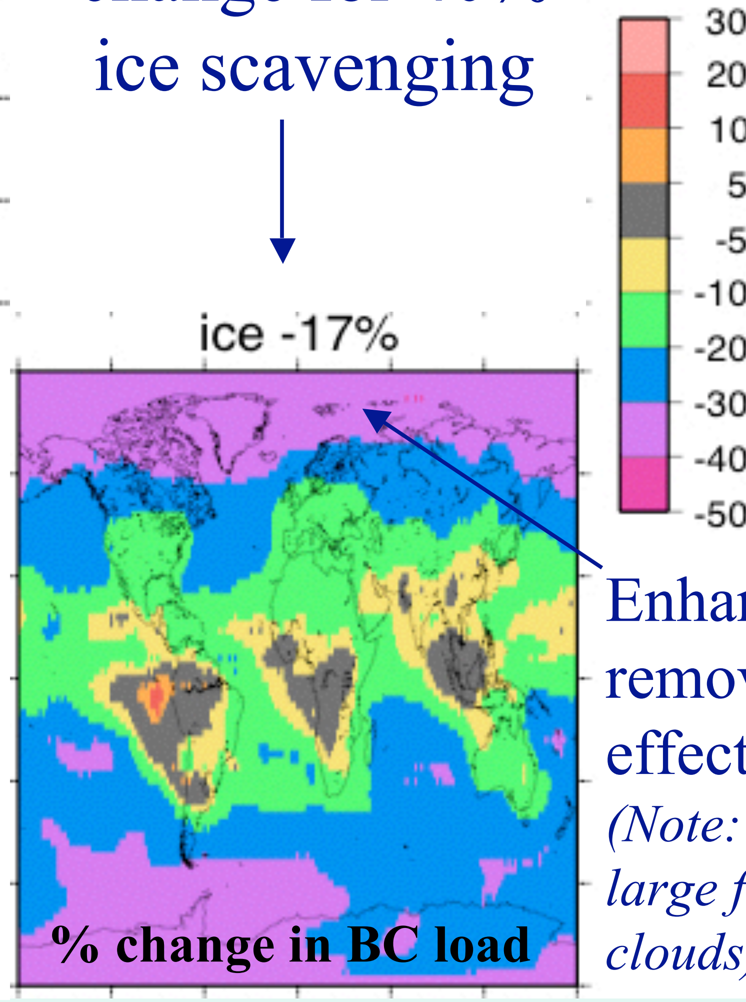






Standard BC load assuming 5% ice scavenging (relative to rain)

% BC load change for 40% ice scavenging

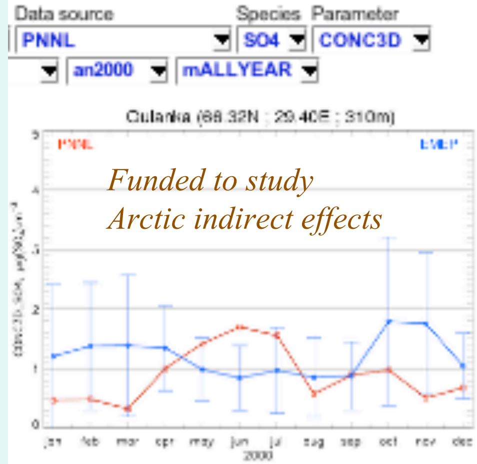


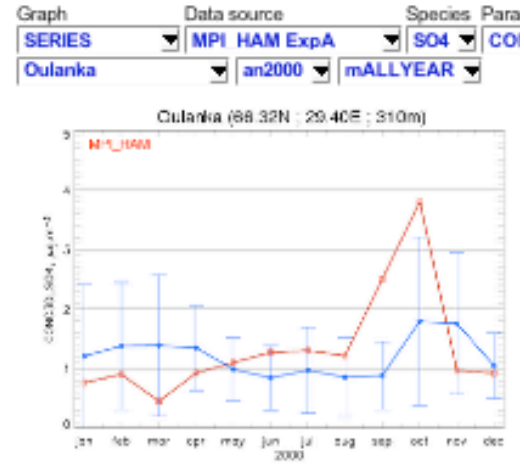
%

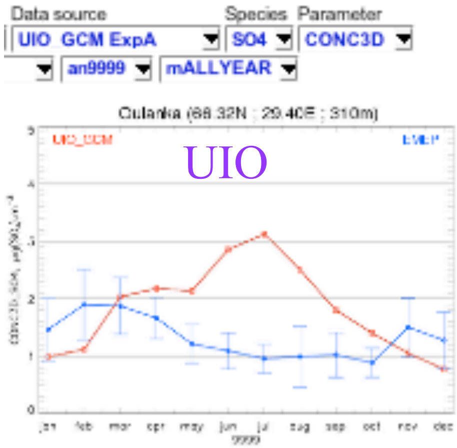
Enhancing ice removal has big effect at the poles.

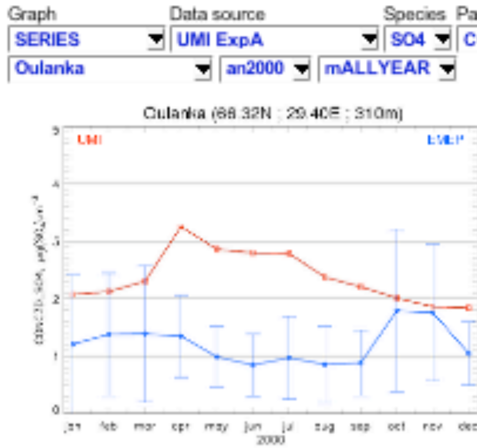
(Note: GISS model has large fraction of ice-clouds)

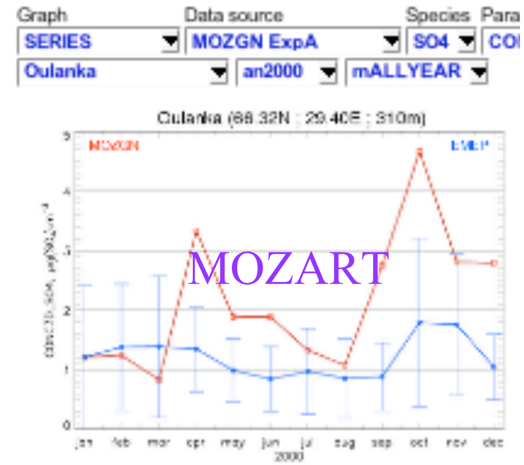
AEROCOM models in Oulanka, Norway sulfate

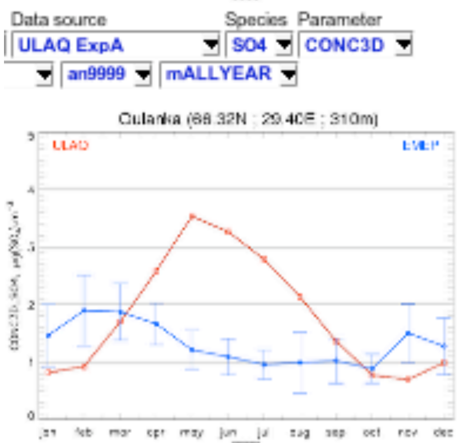


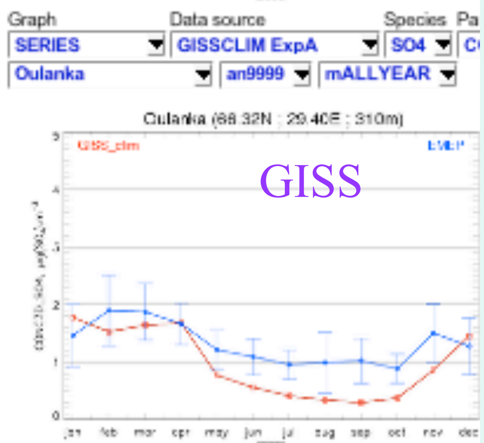




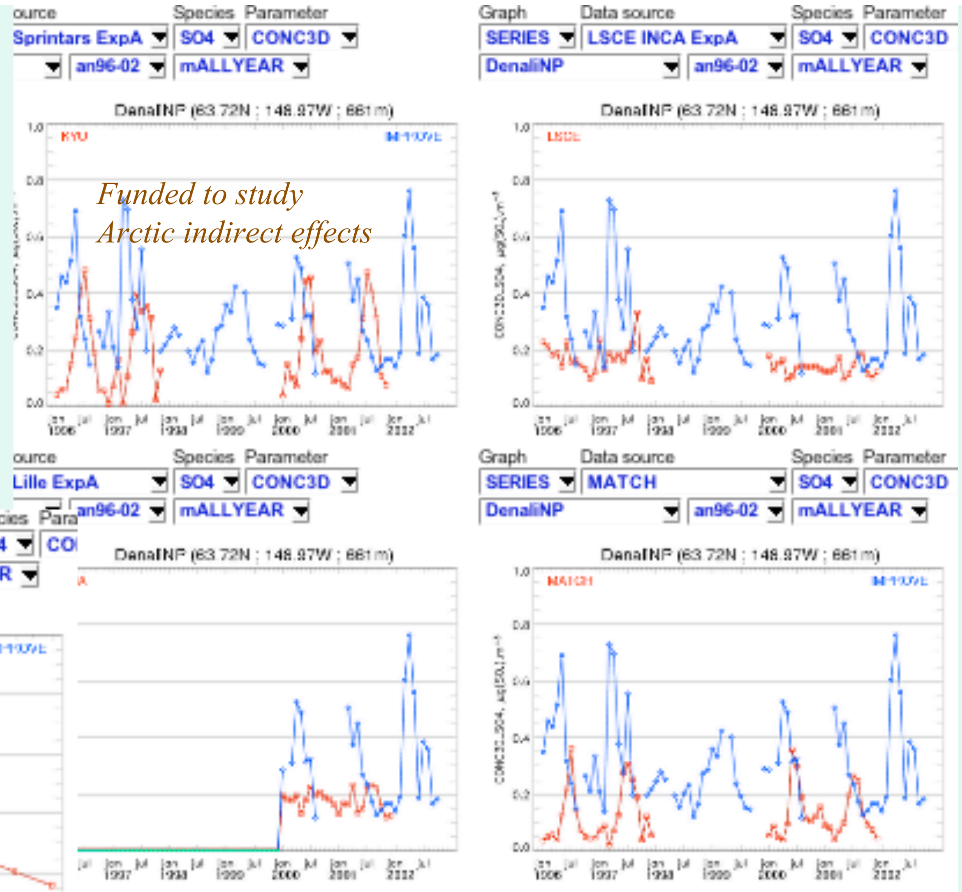


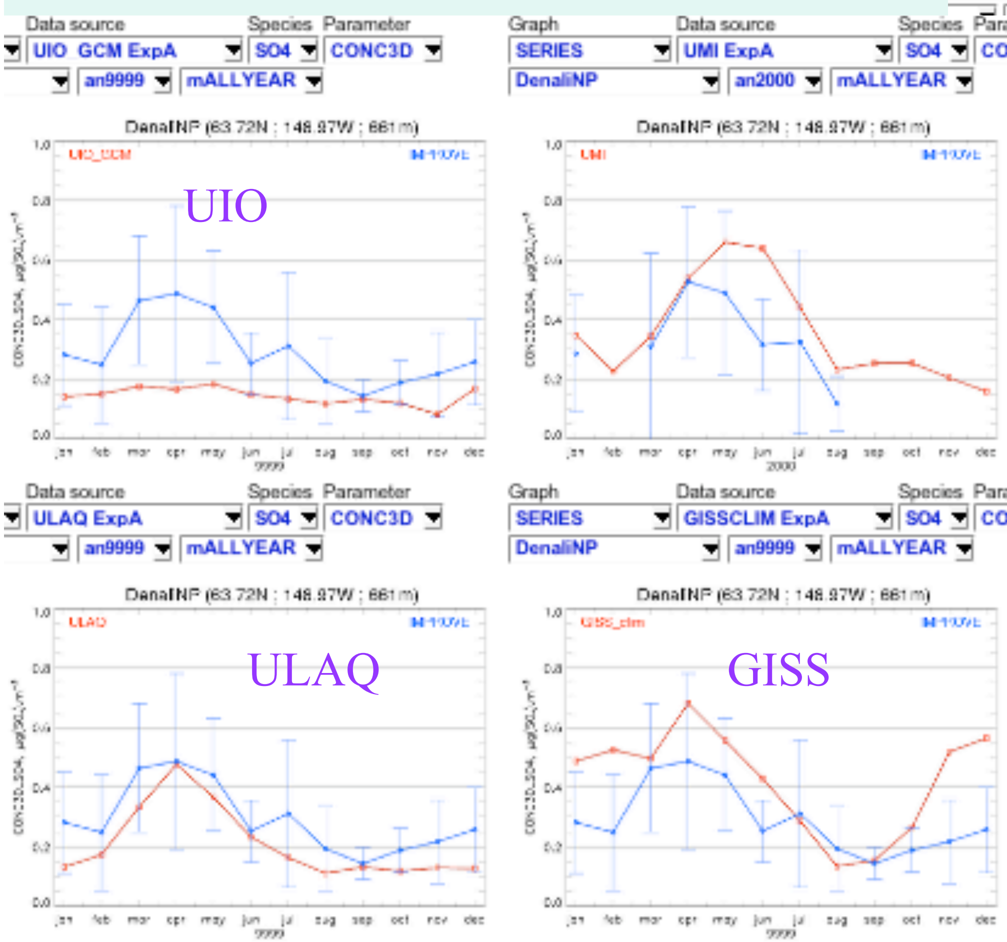


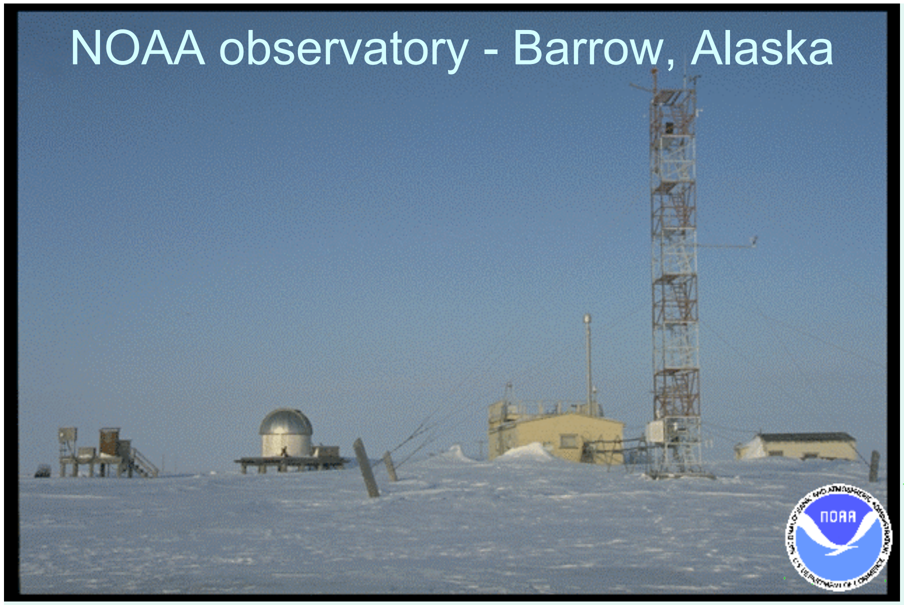




AEROCOM models in Denali, Alaska sulfate

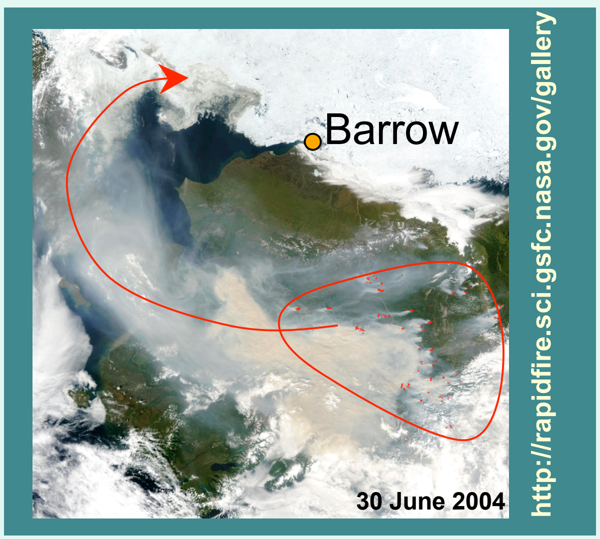




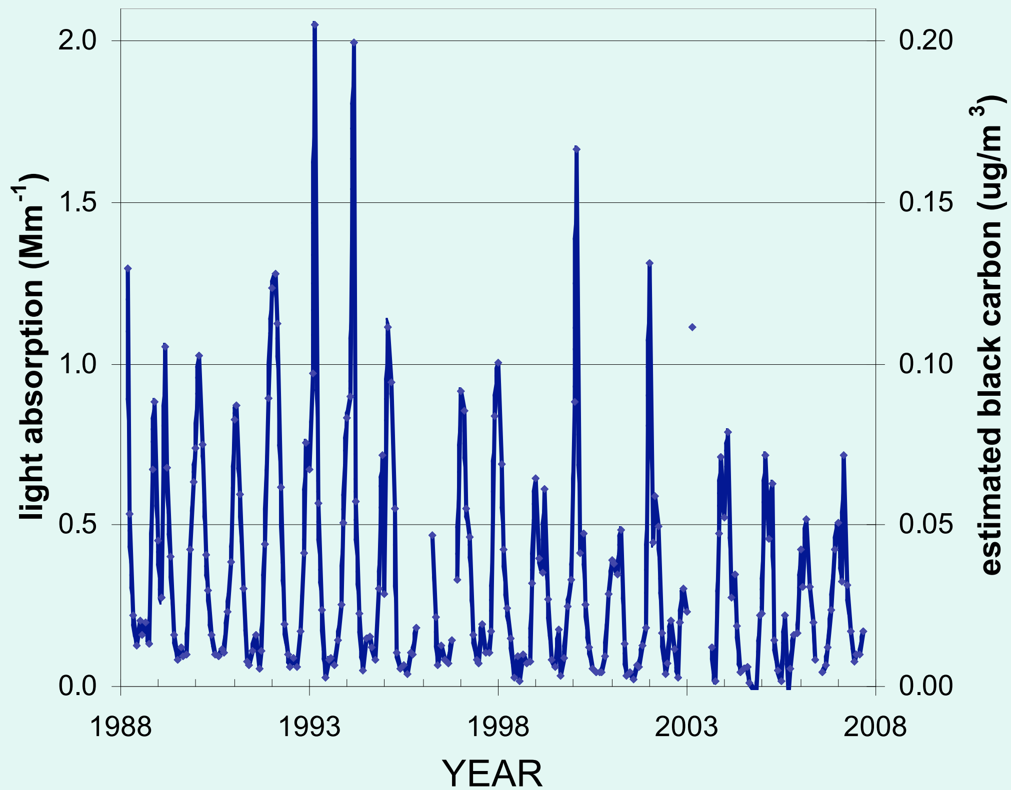


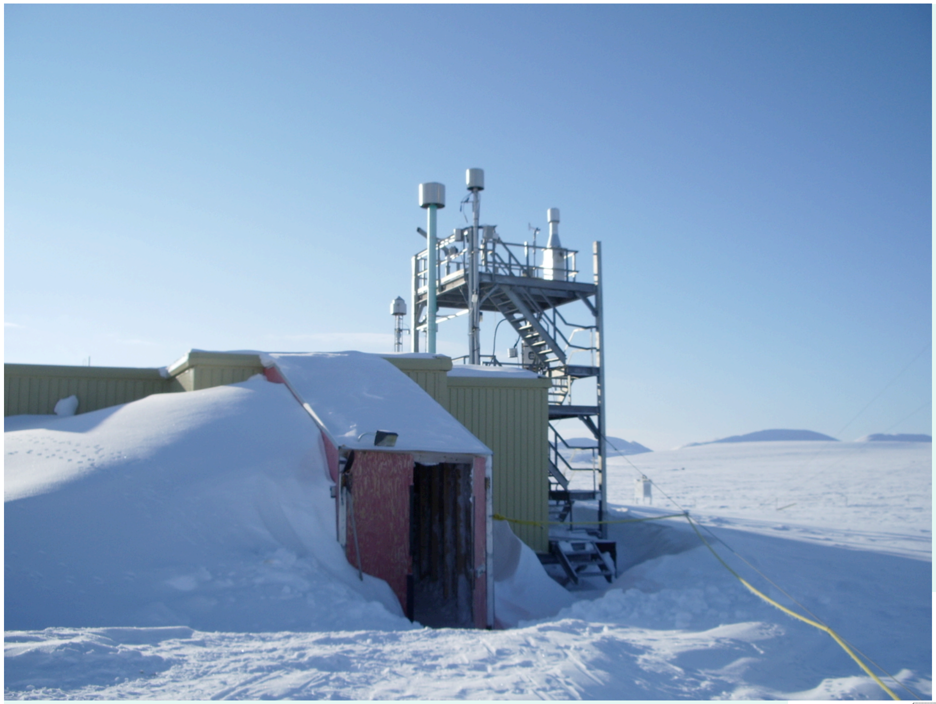
Aerosol light absorption at Barrow

- Proportional to black carbon
- Measured by NOAA since 1988
- Seasonal - peak in winter from “Arctic haze”
- Forest fires (one source of Arctic BC) may be increasing (Soja et al., 2006)



Smoke transport to Barrow from 2004 Alaska forest fires





Black Carbon (BC) Measurements at Alert.

-Measurements conducted by Environment Canada since 1989.

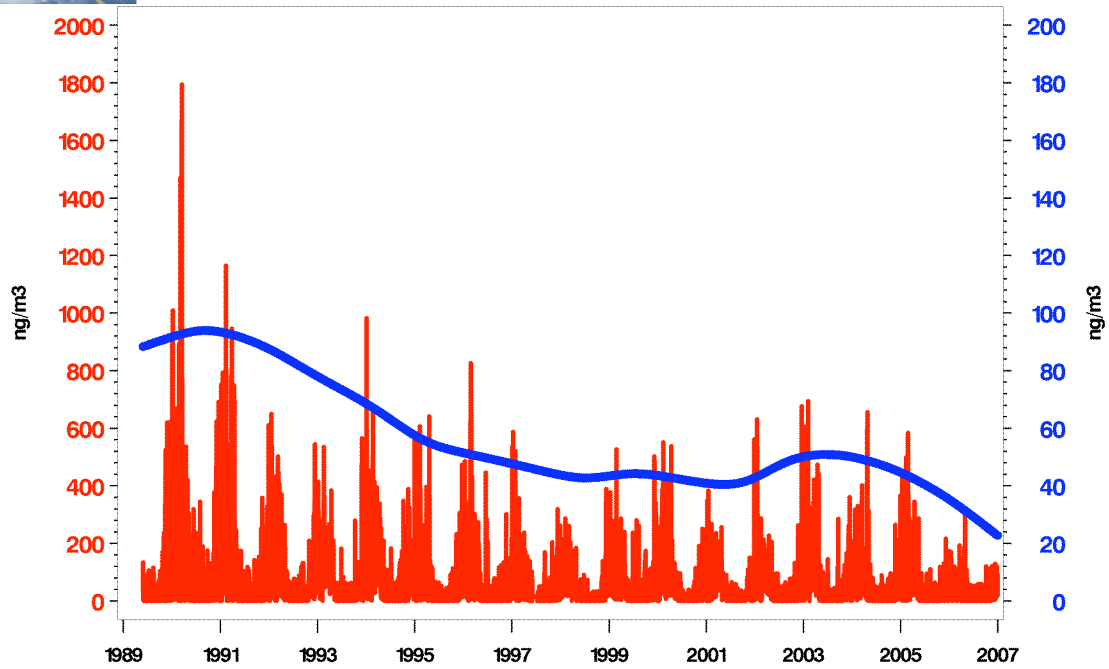
-Higher BC in winter due to "Arctic Haze".

-Decline in trends of BC measurements since 1989 by 55% (Sharma et al., 2004).

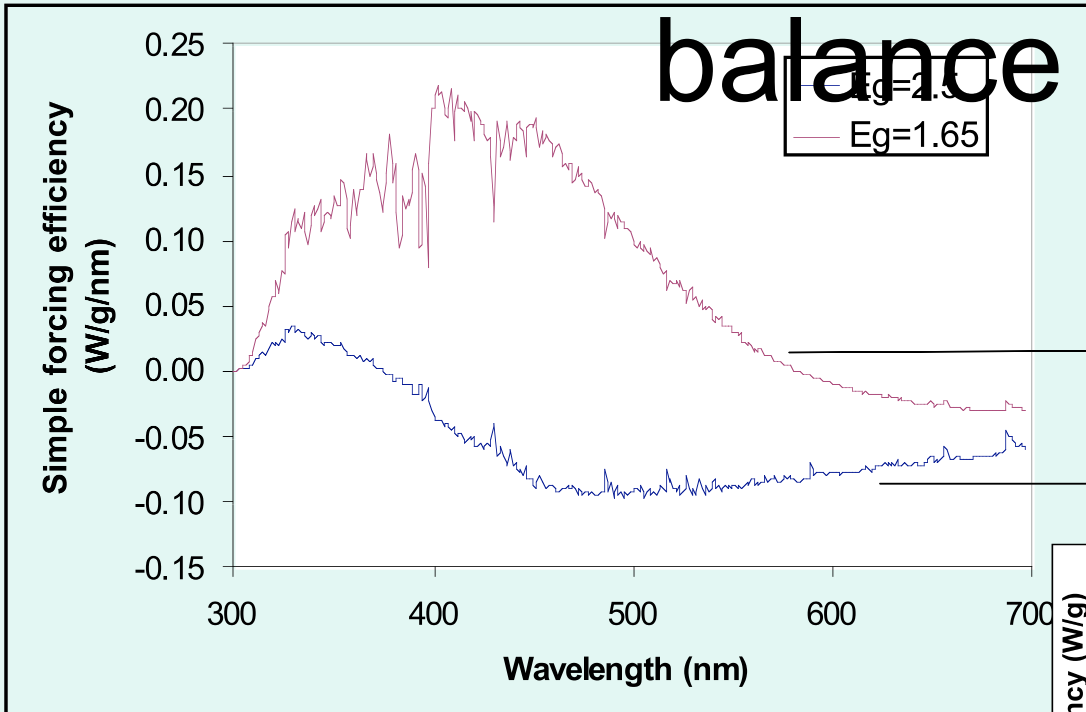
Environment Canada Environnement Canada

-Change in BC measurements are proportional to changes in emissions and Atmospheric transport to the Arctic.

Long—term Trend for Black Carbon



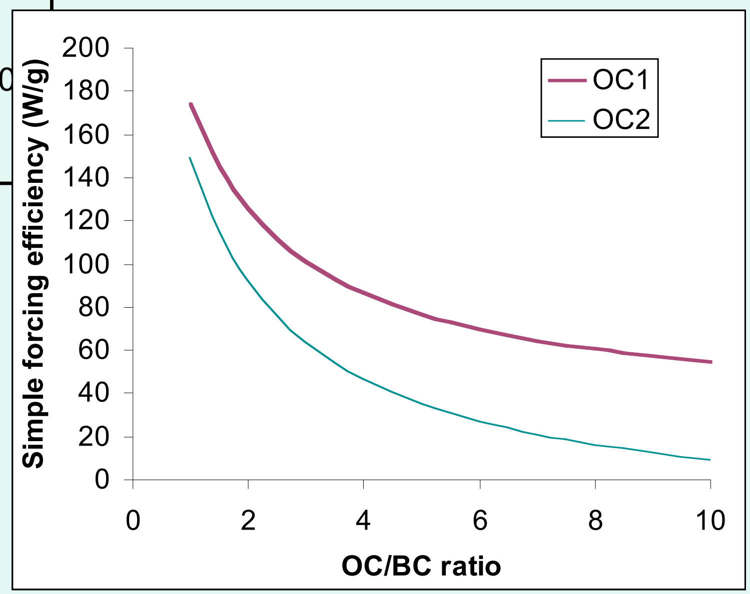
Implications for Earth's energy balance



compare black carbon ~320 W/g

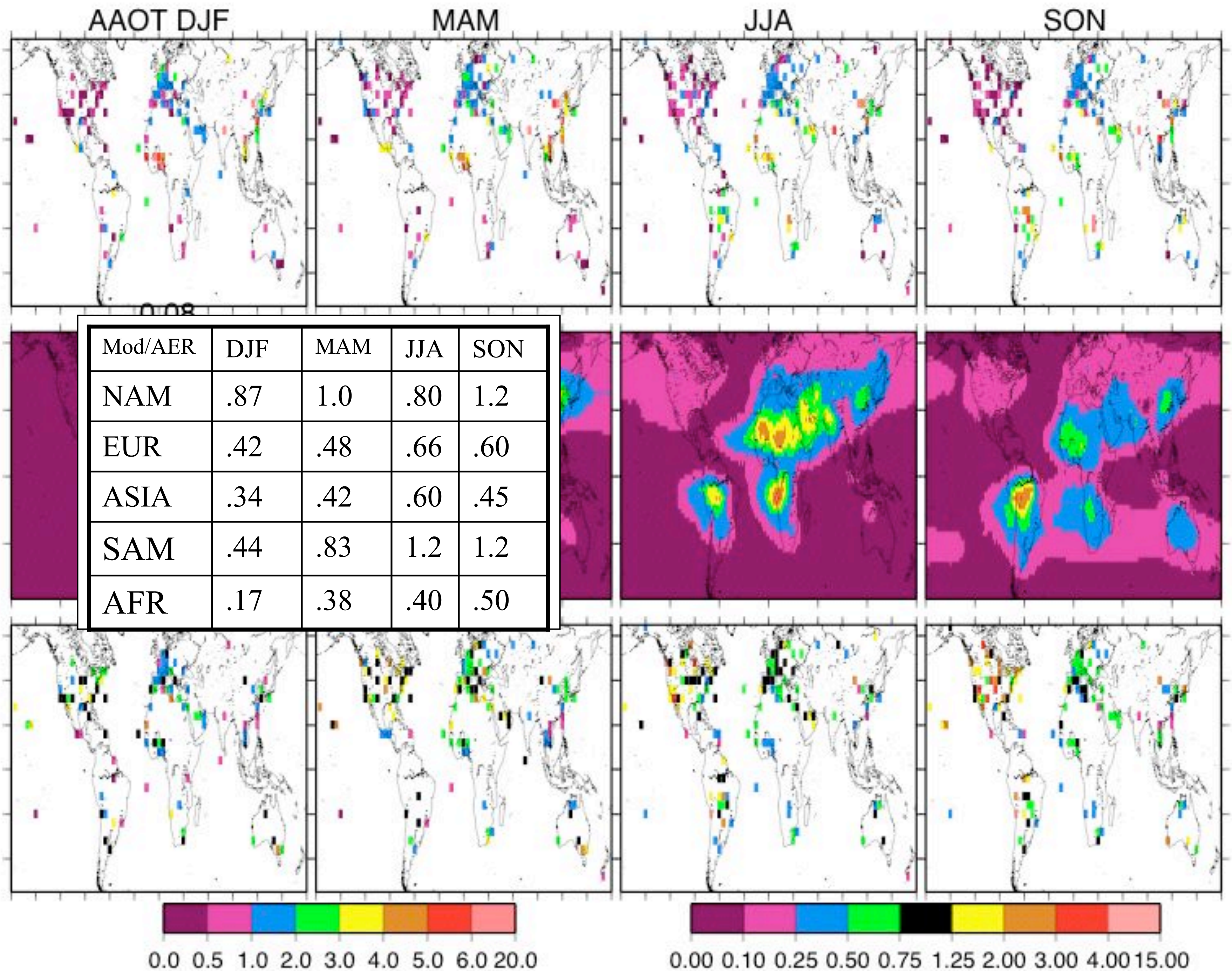
+28 W/g

-22 W/g



assumptions: count mean diameter 150 nm, geometric std dev 1.5, real refractive index 1.55 Mie calculation plus simple forcing efficiency

3b. implications



Mod/AER	DJF	MAM	JJA	SON
NAM	.87	1.0	.80	1.2
EUR	.42	.48	.66	.60
ASIA	.34	.42	.60	.45
SAM	.44	.83	1.2	1.2
AFR	.17	.38	.40	.50

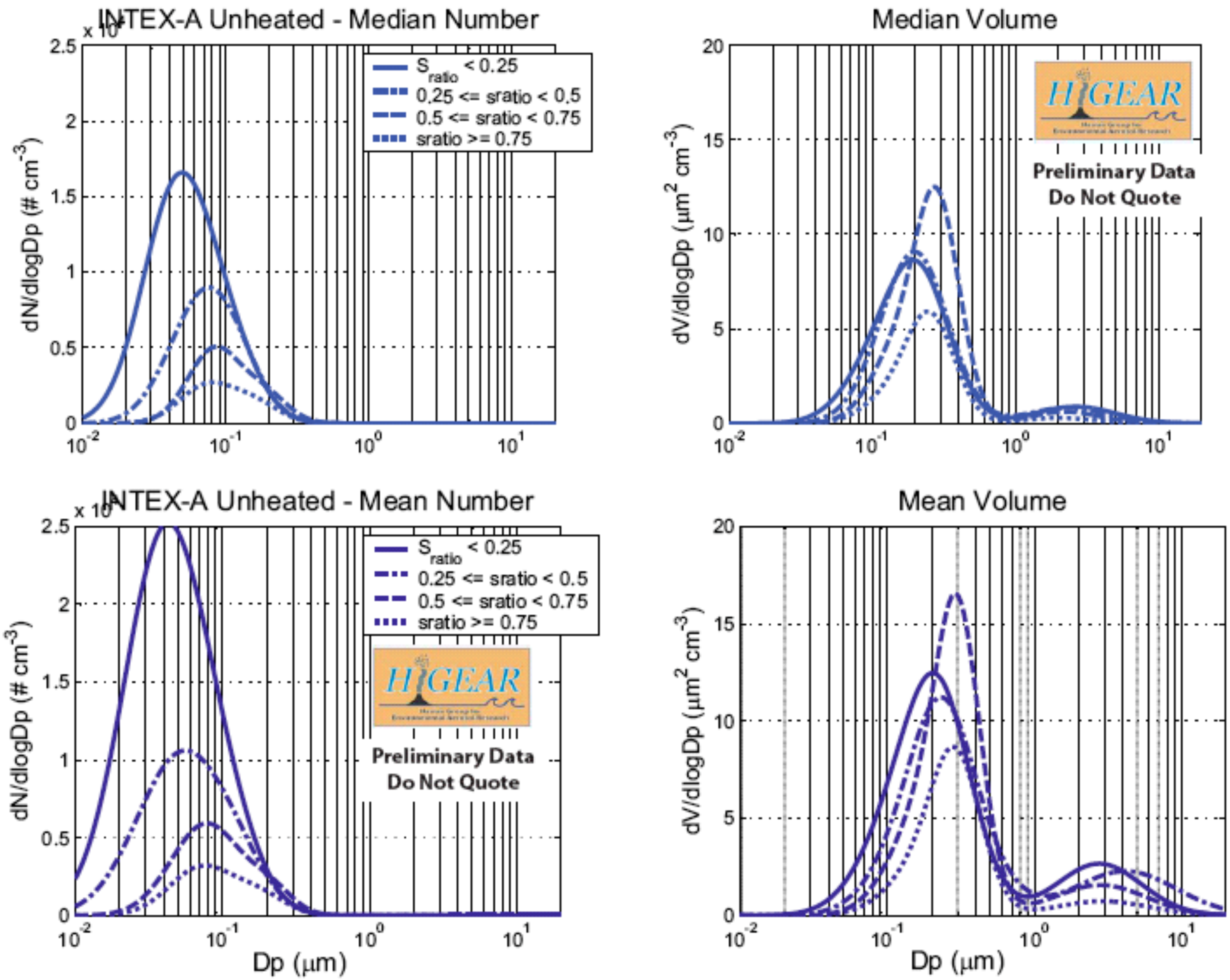


Figure 1 - Median (top) and mean (bottom) aerosol number (left) and volume (right) size distributions measured in the continental boundary layer (CBL) over Eastern North America during NASA's INTEX-A (Summer 2004) airborne field campaign. Stratifying the distributions according to $SO4/(SO2 + SO4)$ is an indicator of the age of the aerosol population. Geometric mean diameter of the submicrometer distributions increase while the standard deviation of the distribution decrases through condensation and coagulation. The supermicrometer (urban dust) geometric mean diameter decreases while the standard deviation tends to increase. This behaviour is consistent with gravitational settling during transport in the CBL.

Table 1 - Summary of dry (RH < 40%) single scatter albedo (SSA) at three wavelengths for total and submicrometer aerosol measured over Eastern North America during NASA's INTEX-A field campaign (Summer, 2004)

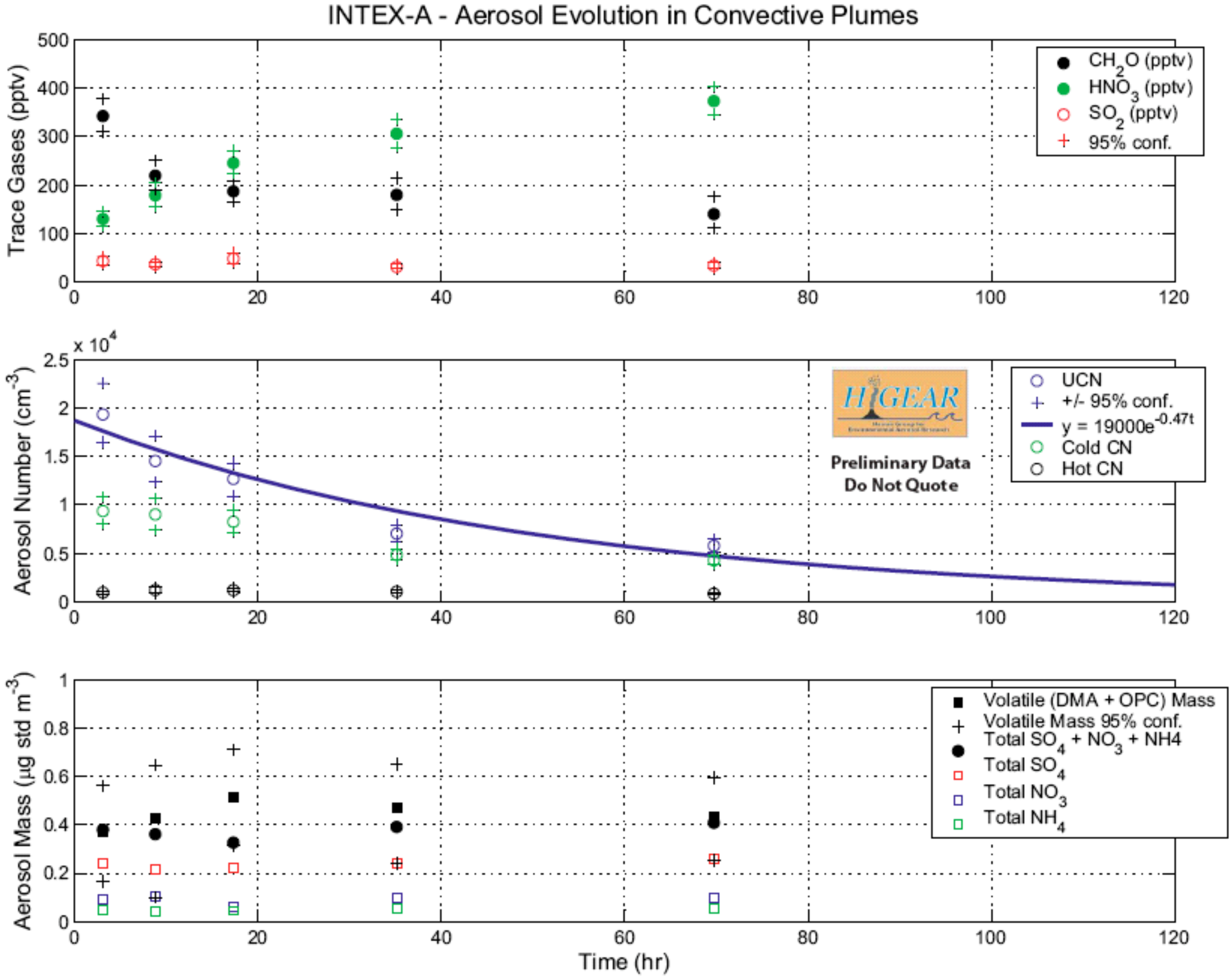
Eastern N. America		N	Total			Submicron			Notes
			450/470	550/530	700/660	450/470	550/530	700/660	
LT	BB mc	110	0.950 (0.037)	0.950 (0.044)	0.946 (0.040)		0.942 (0.048)		BB SSA < Anthro SSA at 450 and 550 nm
	Anthro mc	48	0.964 (0.033)	0.965 (0.034)	0.955 (0.033)		0.958 (0.036)		BB SSA = Anthro SSA at 700 nm
BL	Age 1	58	0.962 (0.022)	0.960 (0.024)	0.948 (0.027)		0.945 (0.022)		For Total and Sub: Age 1 SSA < Age 3 SSA
	Age 2	179	0.970 (0.020)	0.964 (0.024)	0.952 (0.028)		0.949 (0.026)		
	Age 3	165	0.979 (0.015)	0.975 (0.018)	0.963 (0.021)		0.961 (0.022)		

HiGEAR

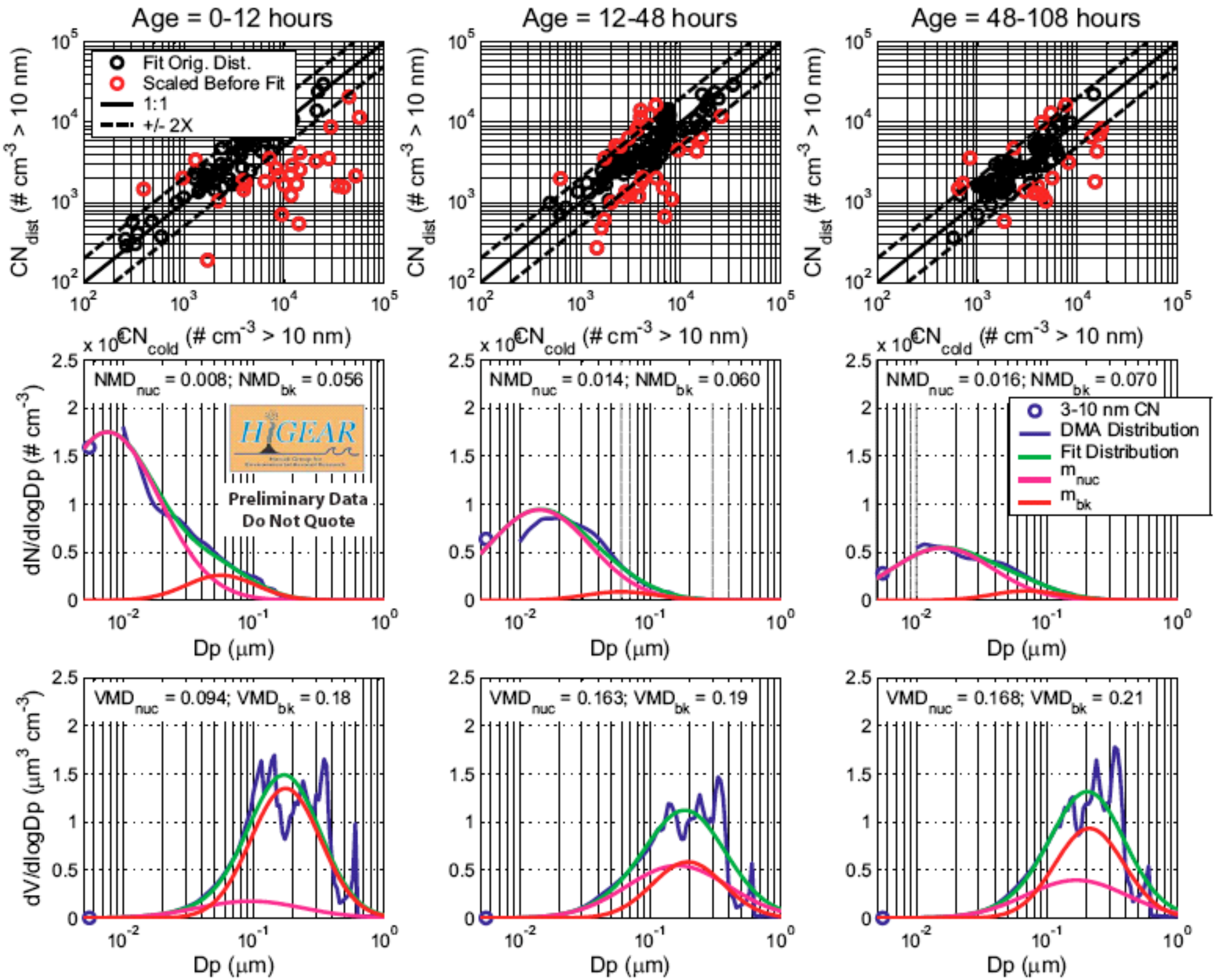
Preliminary Data
Do Not Quote

Table 2 - Summary of the increase in aerosol light scattering as a function of relative humidity measured over Eastern North America during NASA's INTEX-A field campaign (Summer, 2004).

Eastern N. America		Submicrometer				Total Aerosol				Notes
		N	gamma	f(80:40)	f(98:40)	N	gamma	f(80:40)	f(98:40)	
UT										
LT	BB mc					132	0.21 (0.05)	1.3	2.0	BB gamma < Anthro gamma
	Anthro mc					64	0.50 (0.09)	2.0	5.4	
BL	Age 1	10	0.50 (0.08)	2.0	5.6	63	0.44 (0.08)	1.8	4.5	Sub Age 1 gamma > Age 3 gamma (Age 1 NMD < Age 3 NMD)
	Age 2	66	0.43 (0.10)	1.8	4.3	151	0.47 (0.08)	1.9	4.9	Total Age 1 gamma < Age 3 gamma
	Age 3	48	0.40 (0.10)	1.7	3.8	147	0.50 (0.08)	2.0	5.4	(Age 1 [urban Dust] > Age 3 [urban Dust])



IA_UTbertram_aging_3panel.fig, IA_UT_Bertram_convection_rev1.m, Cam, 2007-10-23



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