Modeling Aerosol Absorption

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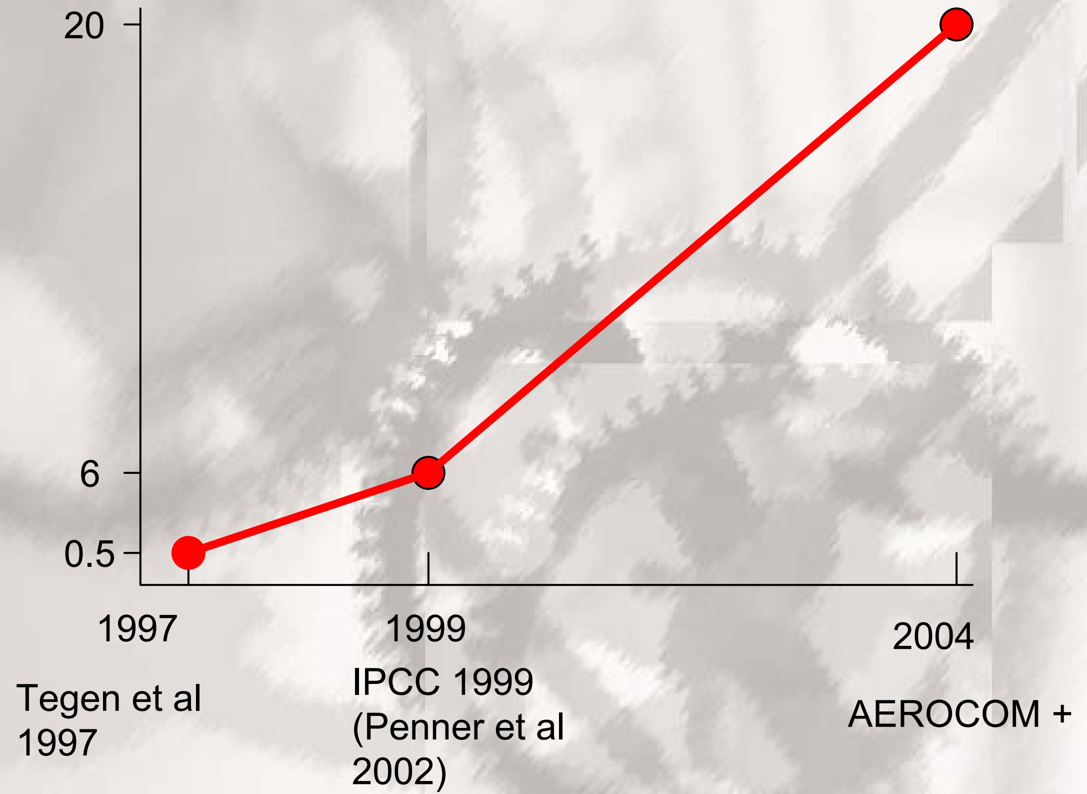
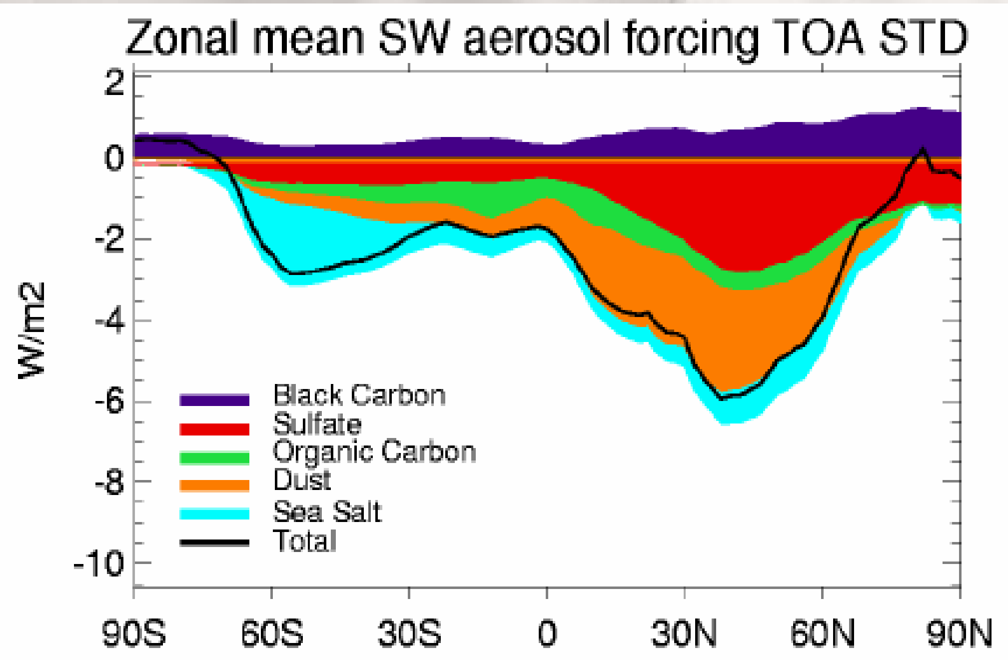
Number of global models that simulates major tropospheric aerosols



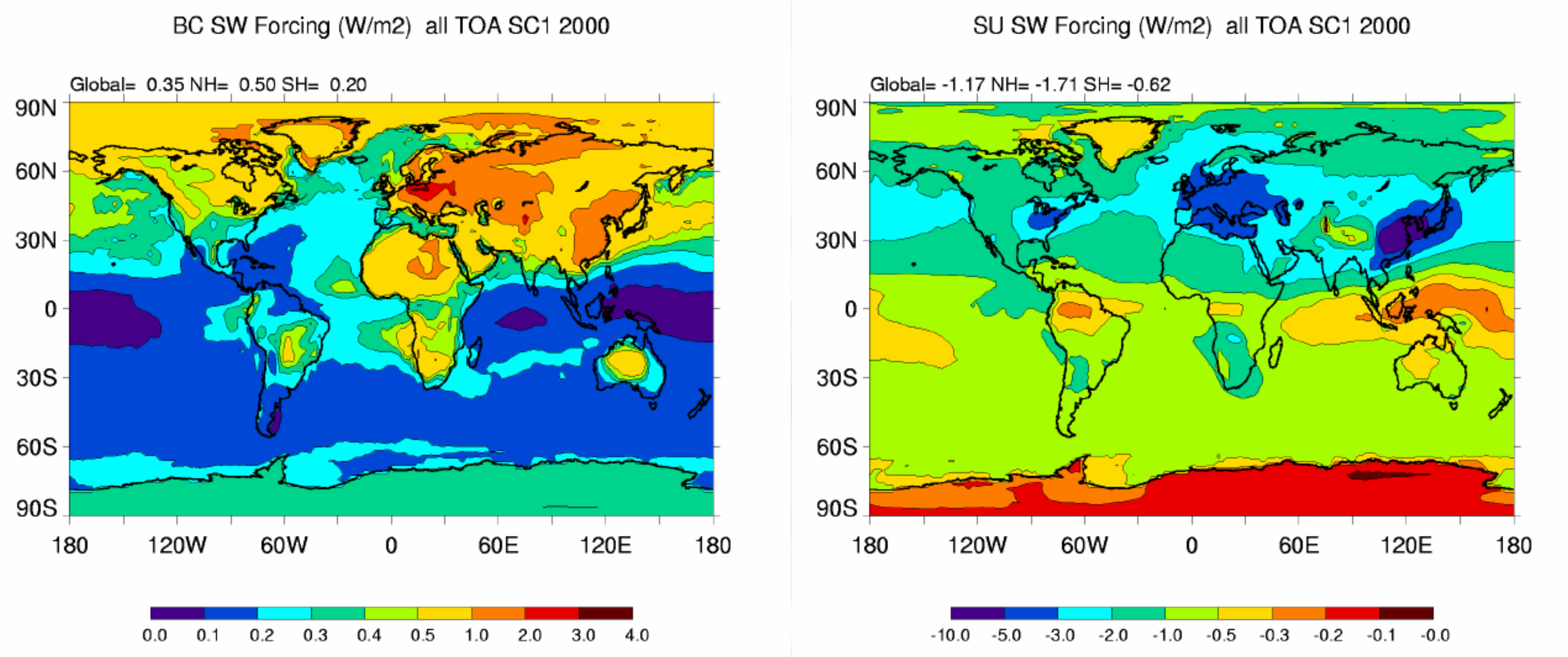
All forcings are equal, but some forcings are more equal than others



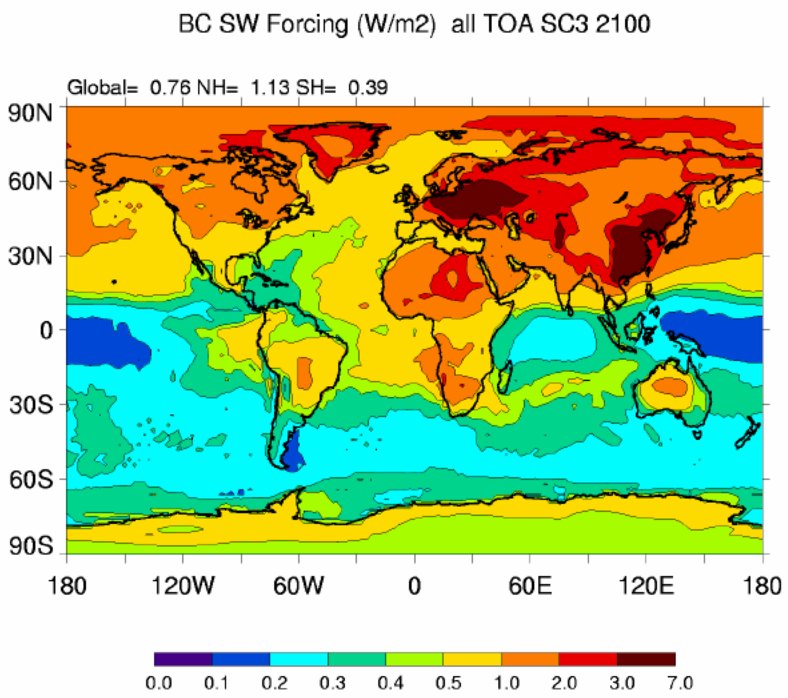
Global Average Aerosol Shortwave Forcing at the Top of the Atmosphere (W/m^2):	
Black Carbon	+0.54
Organic Carbon	-0.50
Sulfate	-1.12
Dust	-1.10
Sea-salt	-0.71
Total	-2.89

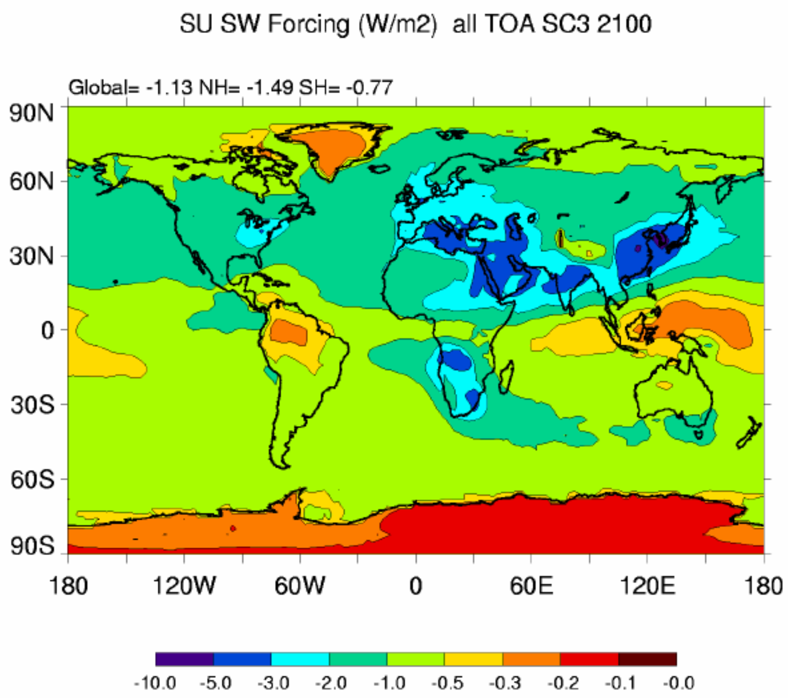
Calculated with the GOCART model

BC and sulfate shortwave direct forcing in 2000 (IPCC emission scenario 1)



BC and sulfate shortwave direct forcing in 2100 (IPCC emission scenario 3)



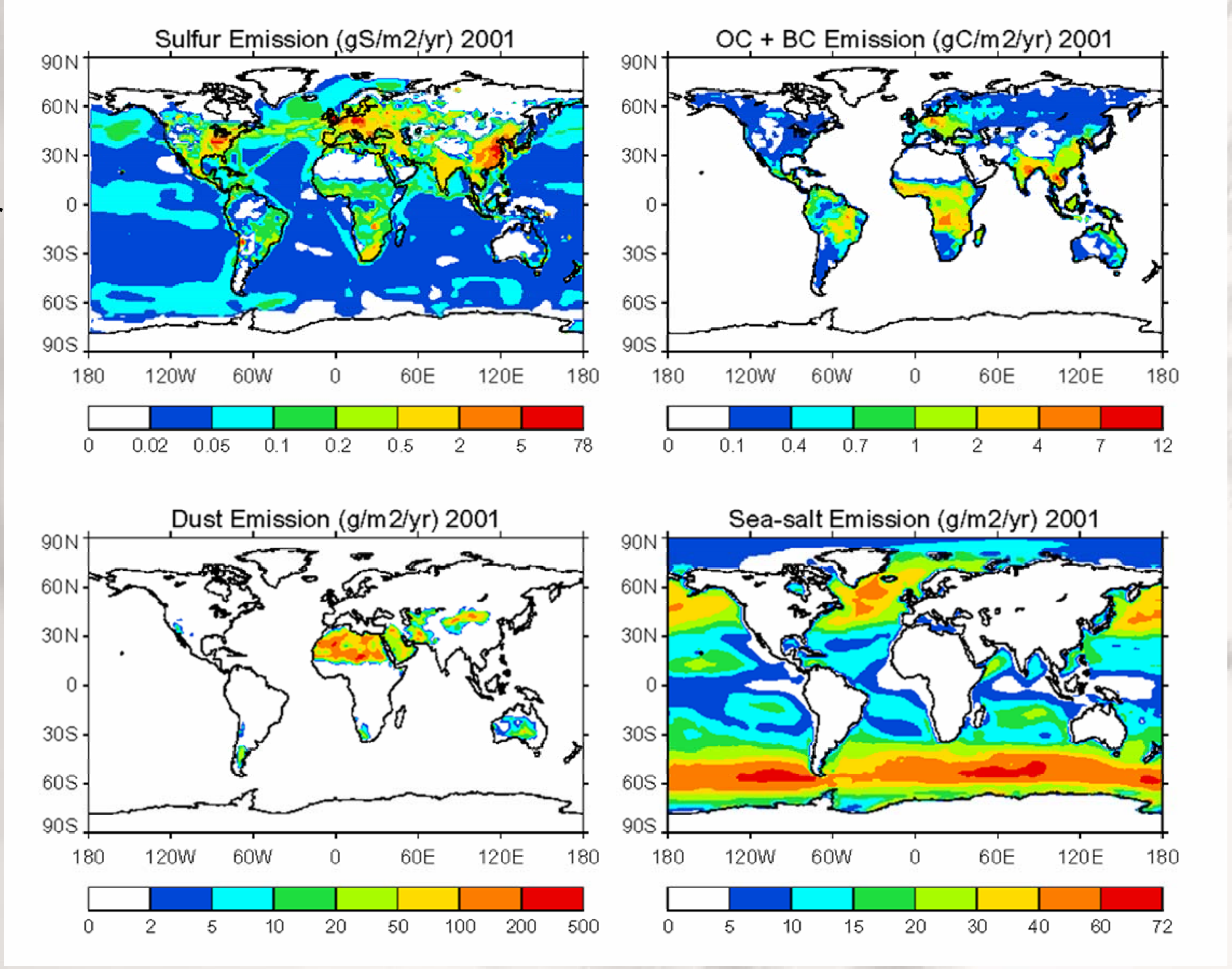


Emissions 2001

94.2 TgS/yr

OC:
98.4 TgC/yr

BC:
16.1 TgC/yr



1590 Tg/yr

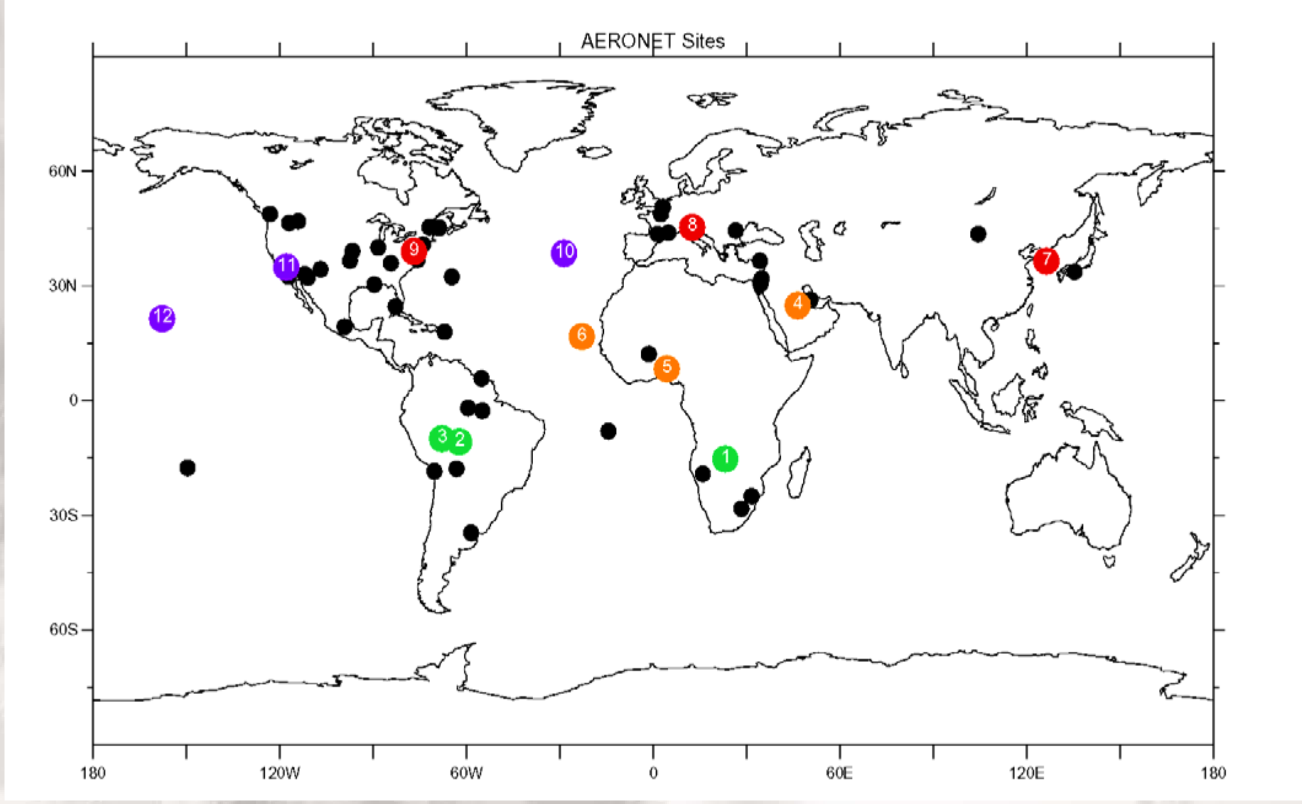
6910 Tg/yr

Microphysical and optical parameters

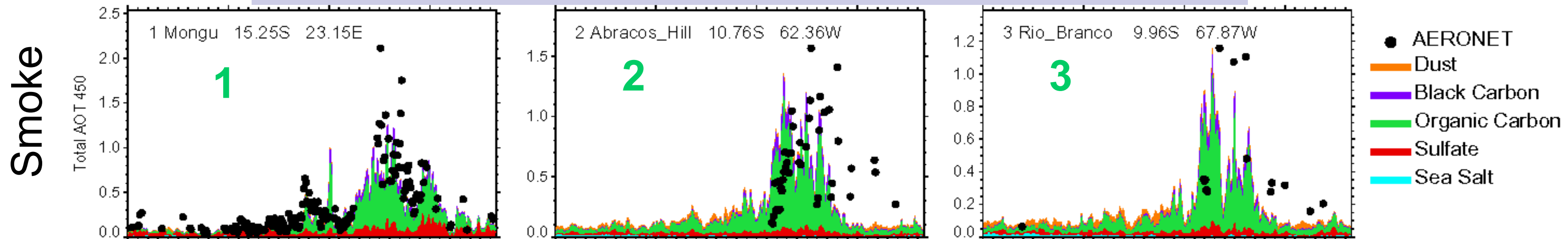
Aerosol Type	*Density ($g\ cm^{-3}$)*	*Dry r_m (μm)*	*Dry r_e (μm)*	*σ_g (μm)*	*Dry β (MEE) at 550 nm ($m^2\ g^{-1}$)*	*Refractive Index at 550 nm*
Sulfate	1.7	0.0695	0.156	2.03	3.143	$1.43 – 10^{-8}\ i$
OC	1.8	0.0212	0.087	2.20	2.668	1.53 – 0.006 *i*
BC	1.0	0.0118	0.039	2.00	9.284	1.75 – 0.44 *i*
Dust	2.6	0.0421	0.14	2.00	2.432	1.53 – 0.0014 *i*
	2.6	0.0722	0.24	2.00	2.578	1.53 – 0.0014 *i*
	2.6	0.1354	0.45	2.00	1.830	1.53 – 0.0014 *i*
	2.6	0.2407	0.80	2.00	1.015	1.53 – 0.0014 *i*
	2.6	0.4212	1.40	2.00	0.497	1.53 – 0.0014 *i*
	2.6	0.7220	2.40	2.00	0.271	1.53 – 0.0014 *i*
	2.6	1.3540	4.50	2.00	0.138	1.53 – 0.0014 *I*
	2.6	2.4070	8.00	2.00	0.075	1.53 – 0.0014 *i*
Sea Salt	2.2	0.228	0.80	2.03	1.152	$1.50 – 10^{-8}\ i$
	2.2	1.64	5.73	2.03	0.128	$1.50 – 10^{-8}\ i$

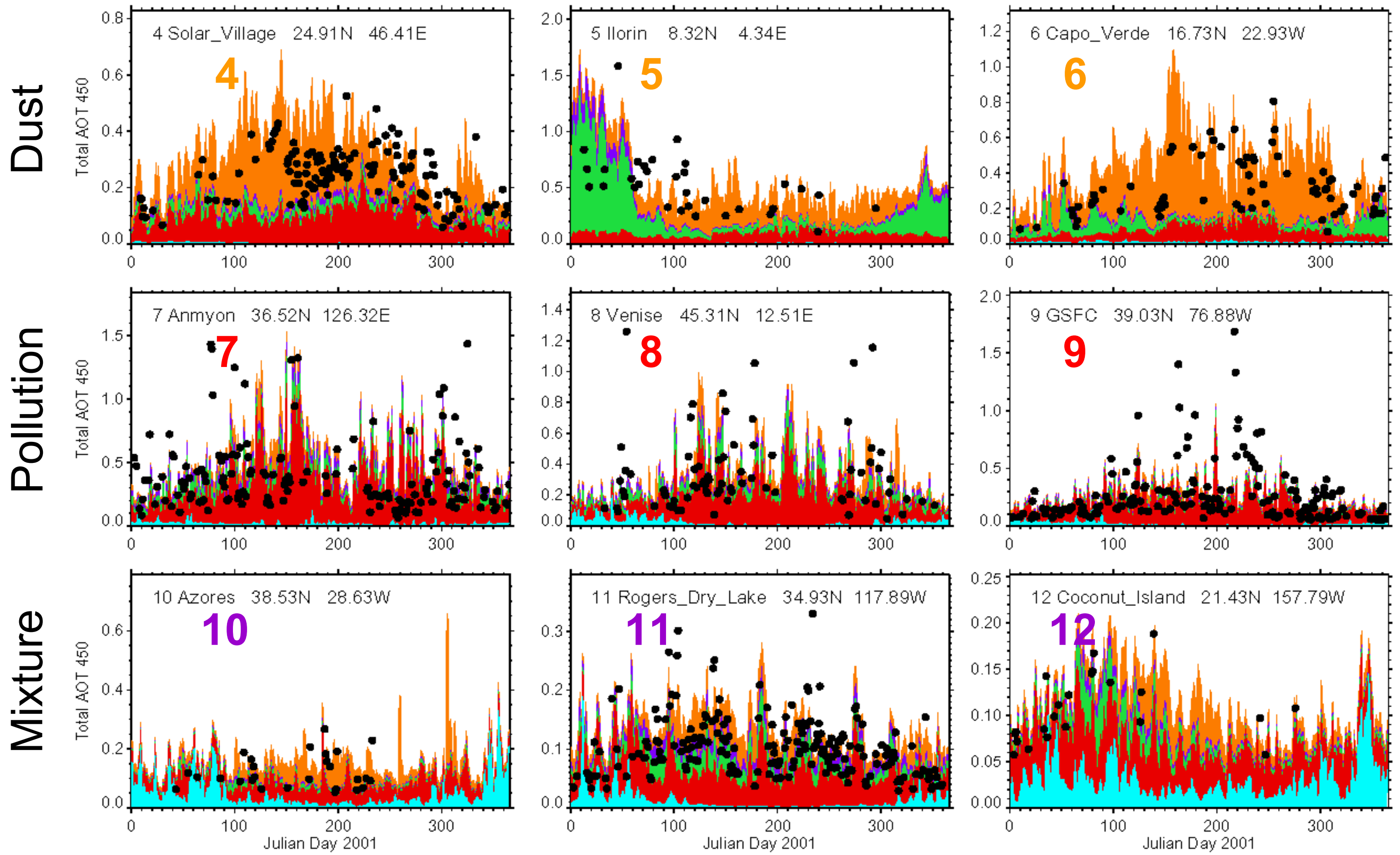
Aerosol absorption

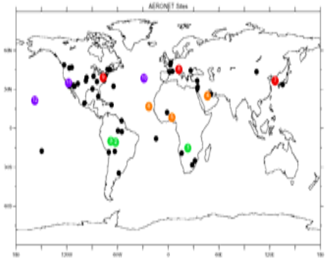
- 57 sites in 2001
- Total aerosol extinction and absorption at 440 and 870 nm (model 450 and 900 nm)
- Absorption Fraction
- Angstrom exponent
- Comparisons with daily data at 12 sites
  - 3 smoke (green)
  - 3 dust (brown)
  - 3 pollution (red)
  - 3 mixture (purple)
- Correlations of monthly averages



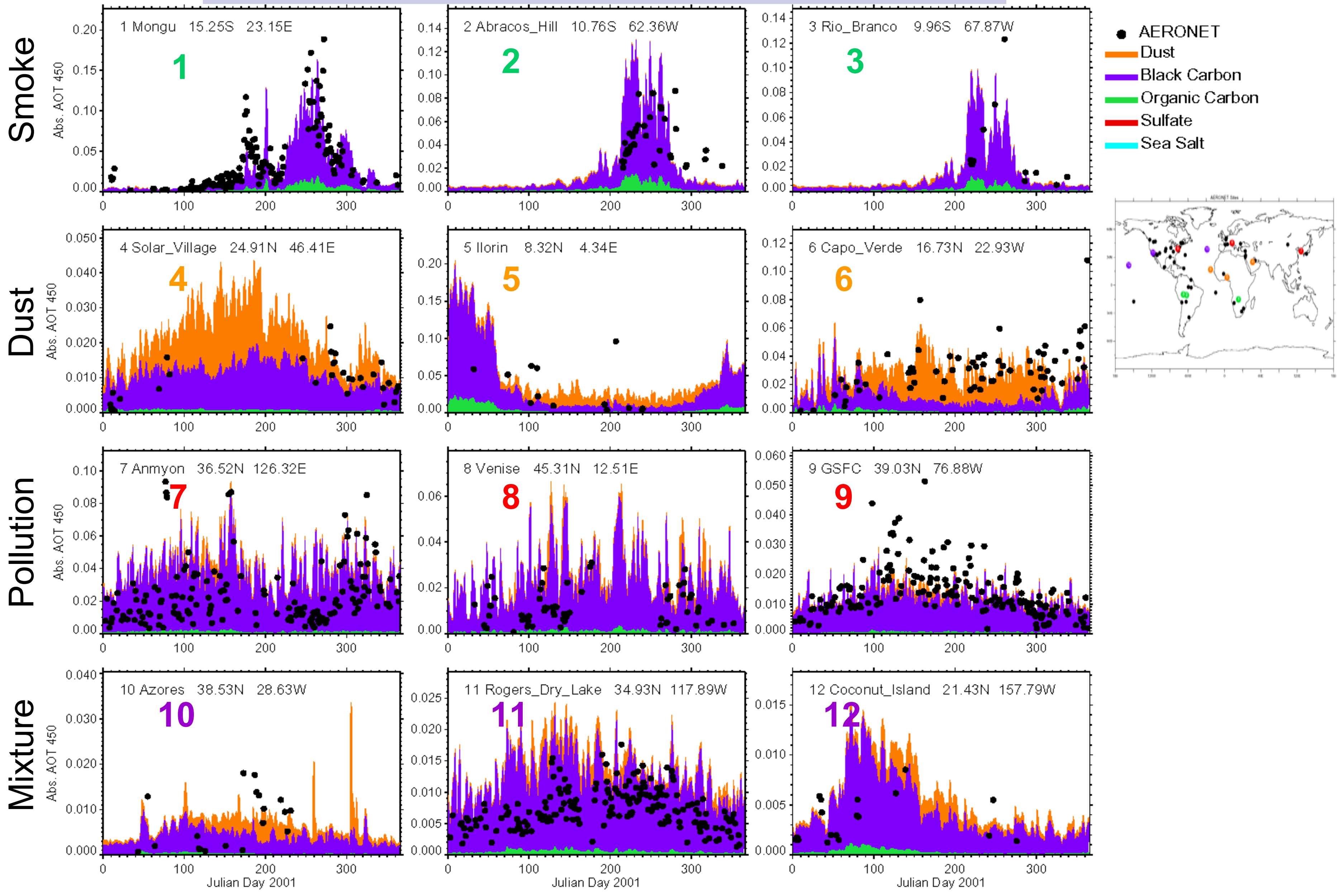
Total Extinction Optical Thickness 440 nm



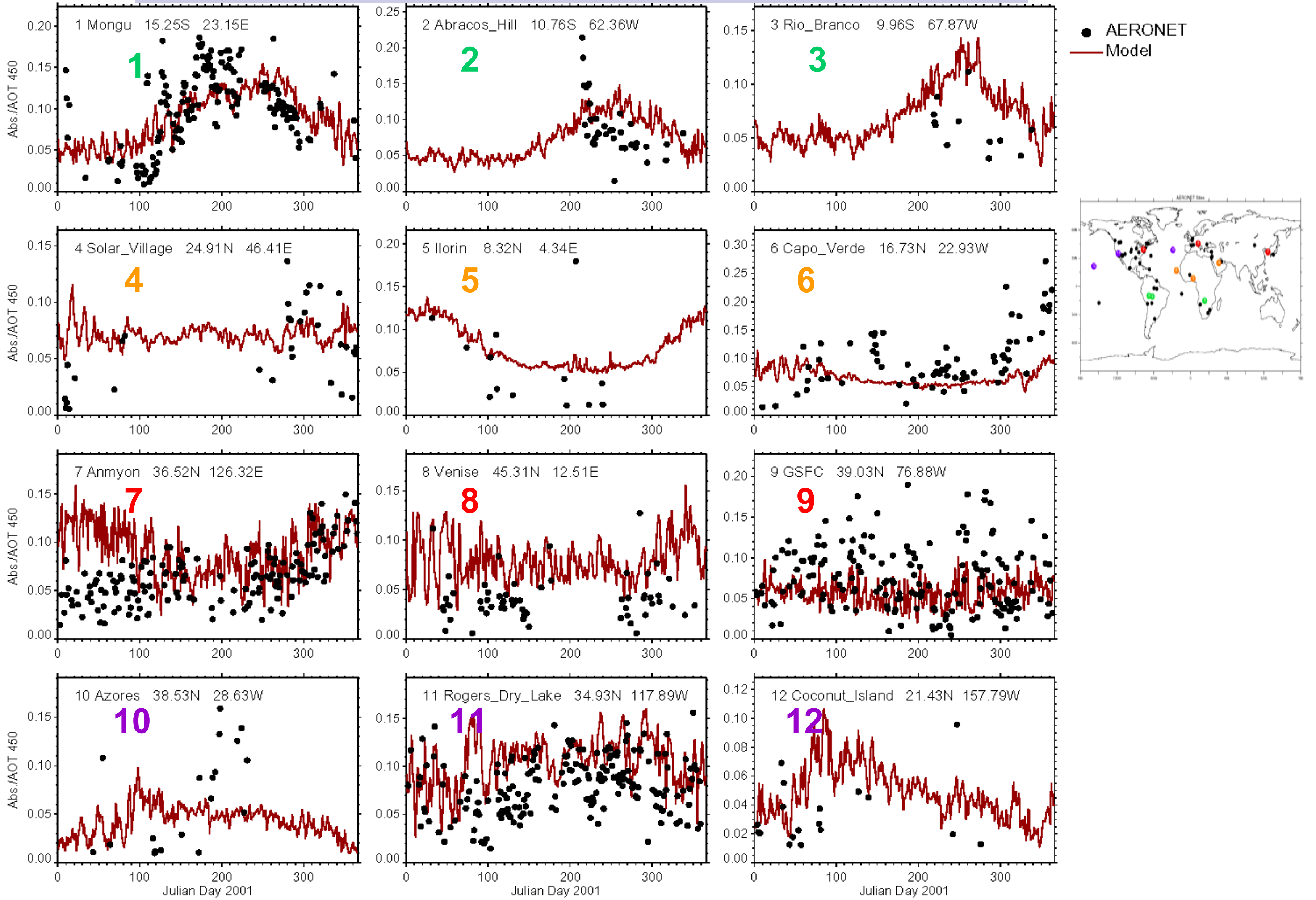




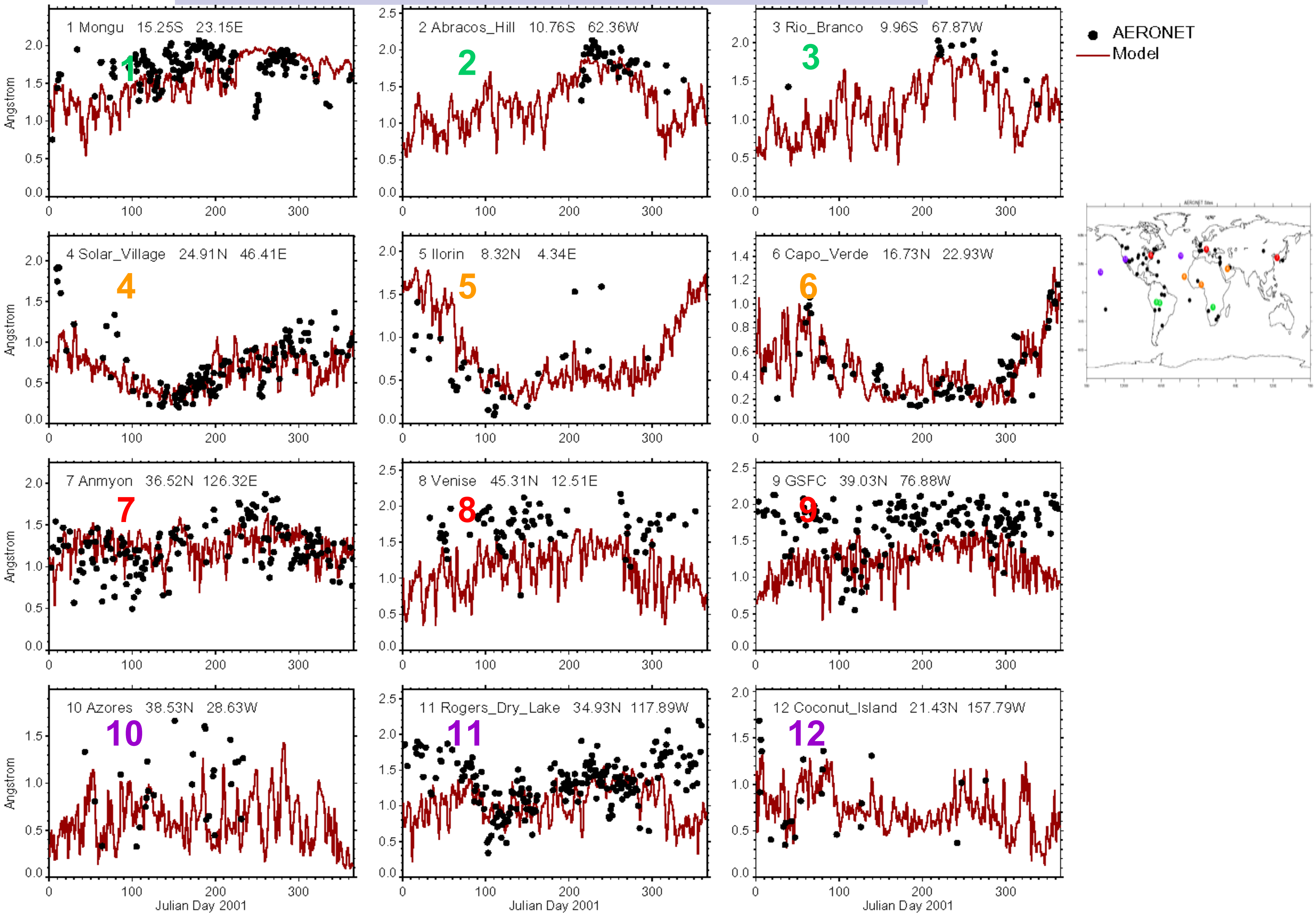
Total Absorption Optical Thickness 440 nm

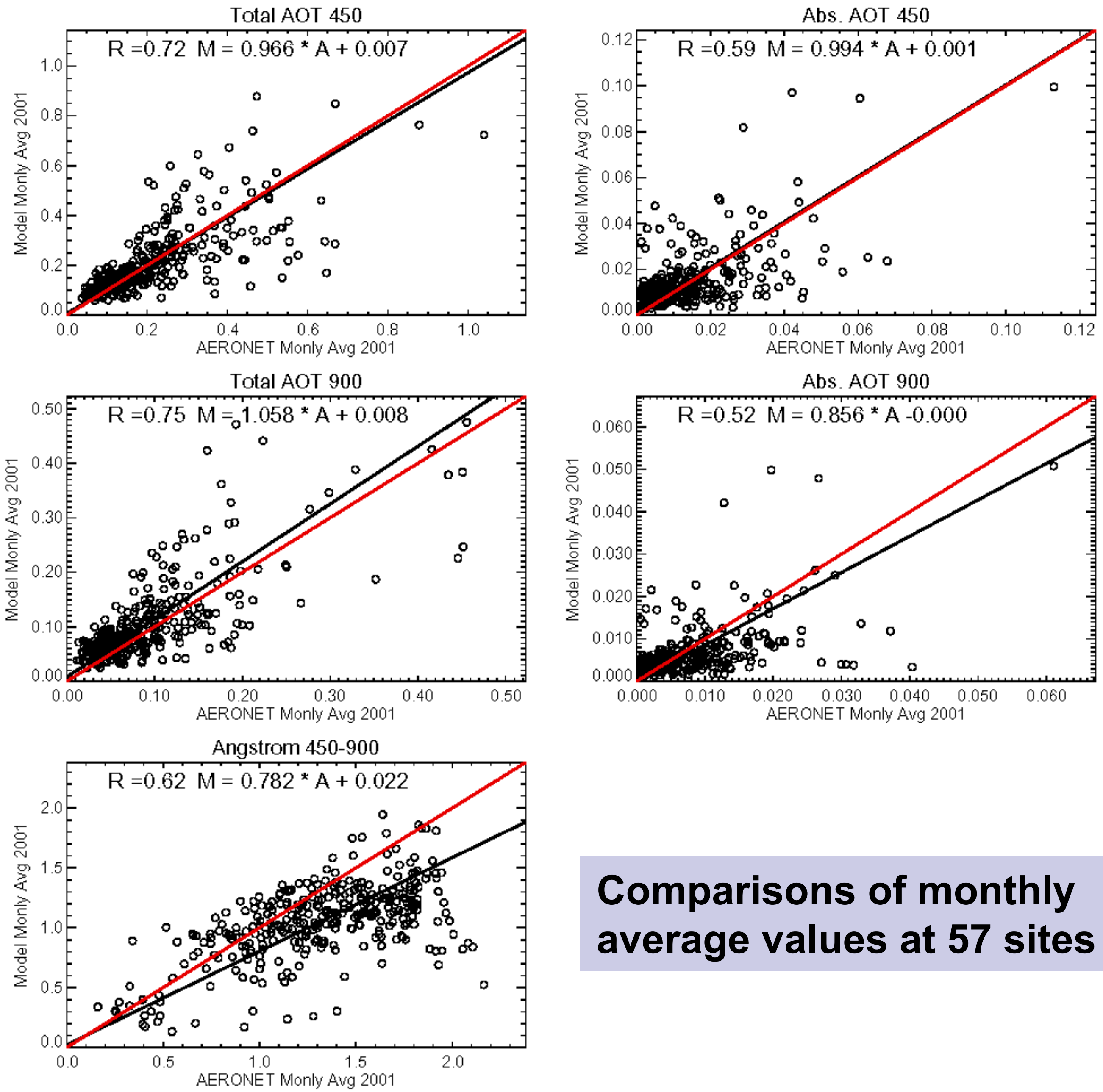


Fraction of Absorption Optical Thickness 440 nm



Angstrom Exponent 440-870 nm

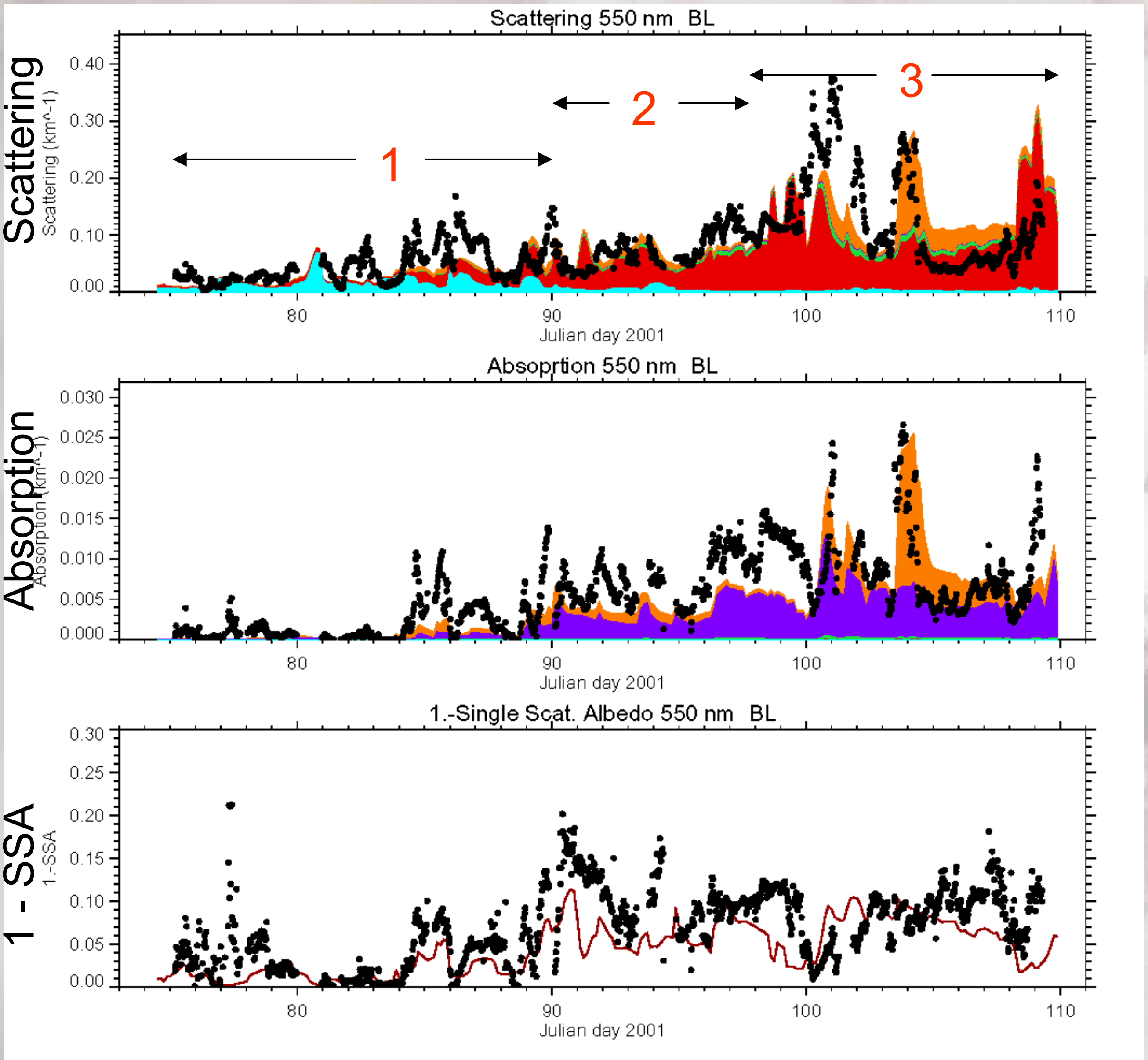


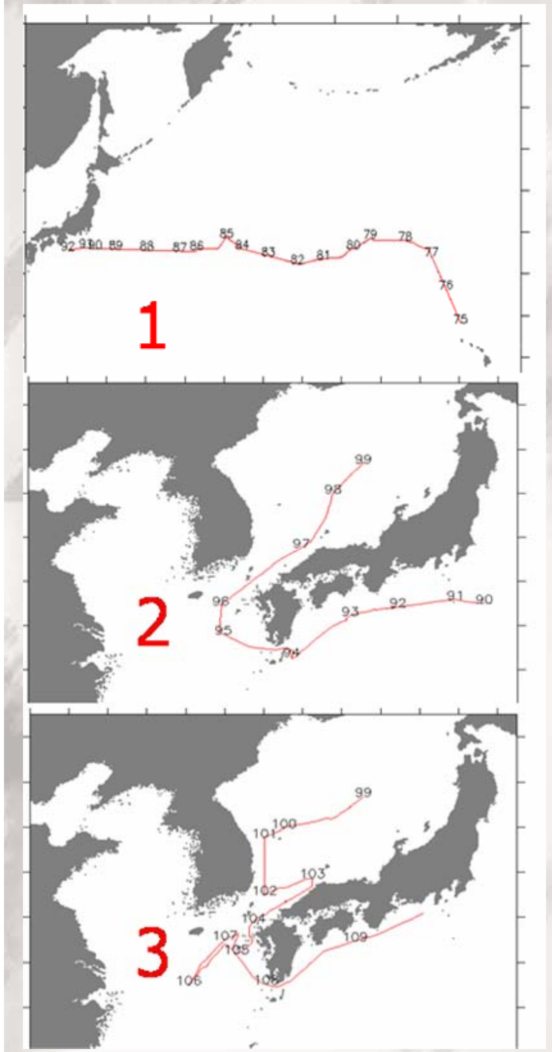


Red line: 1:1 ratio
Black line: Best fit

Comparisons of monthly average values at 57 sites

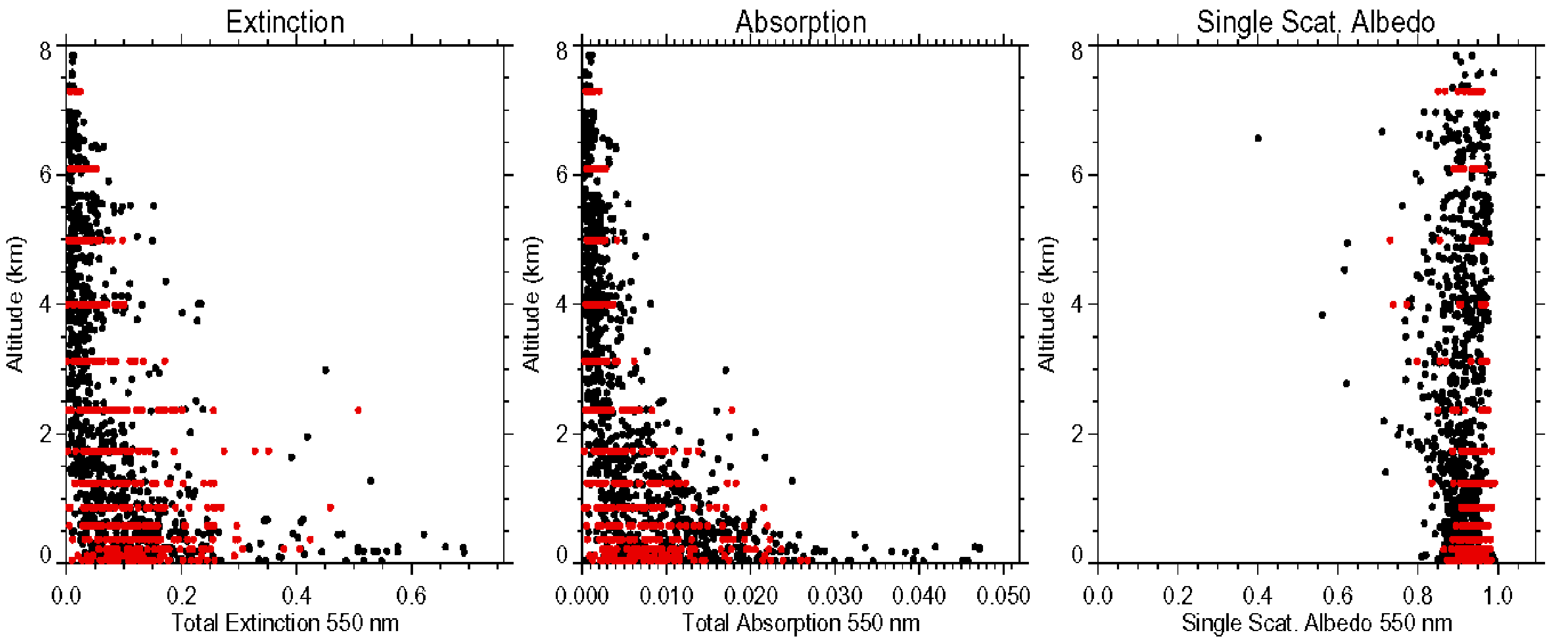
Comparison with ACE-Asia Ron Brown ship measurements
(Data from Patricia Quinn, NOAA/PMEL)



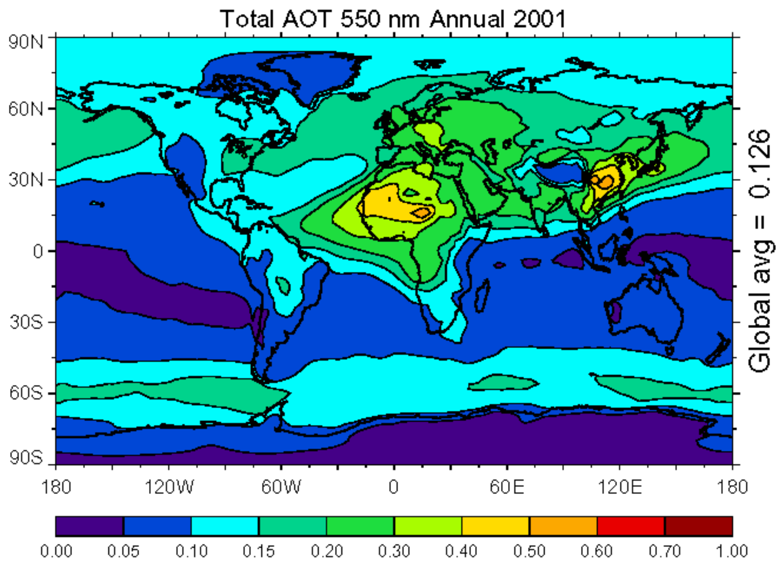


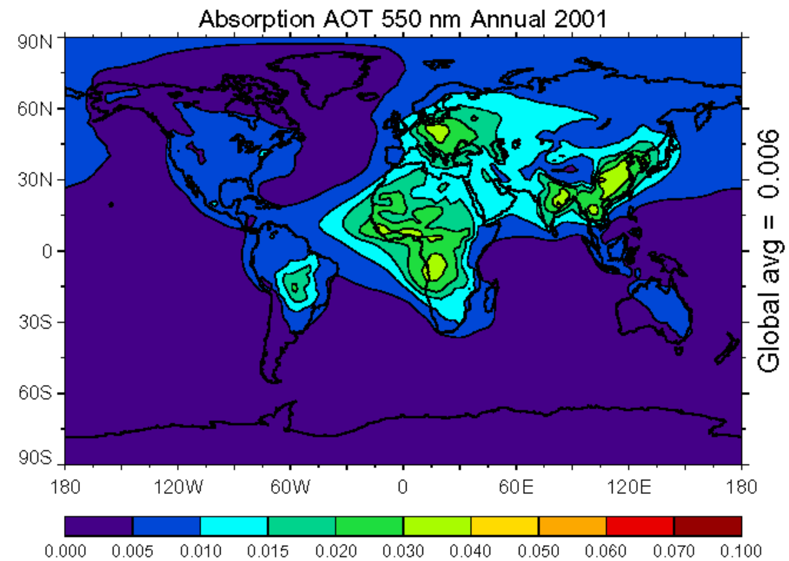
Comparison with ACE-Asia C-130 Measurements

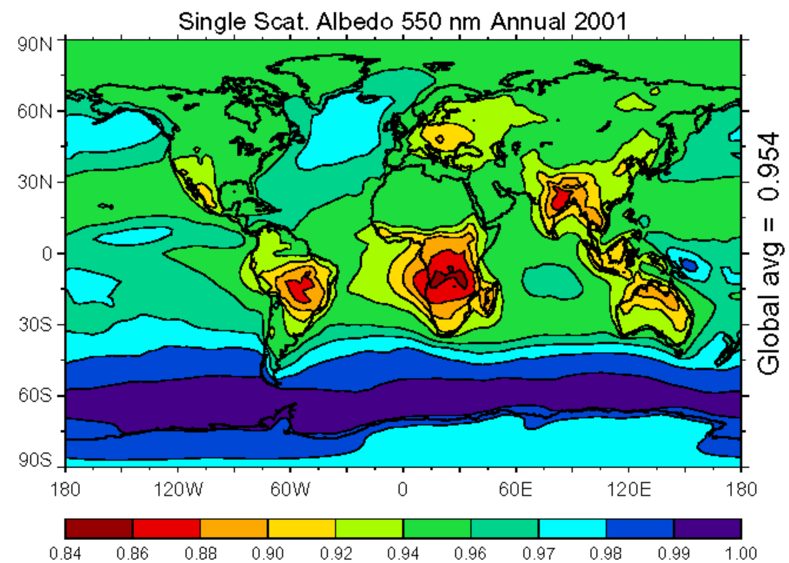
(Data from Tad Anderson & Sarah Masonis, U. Washington)



Global Distributions of Absorbing Aerosol (visible wavelength)







Comments

- Aerosol absorption is very important for climate issues related to global warming, aerosol direct and indirect effects (1st, 2nd, semi, etc.)
- Emissions of BC are still highly uncertain
- Dust absorption property depends on mineral composition which varies from place to place
- Need more lab measurements of dust and BC optical properties
- AERONET data are very helpful
- Future satellite measurements of absorption

Using statistical analysis for model evaluation

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Issues

- Models are the most powerful tools for assessment
- A credible model has to be verified against observations
- “Eyeball” method is very subjective and not quantitative, although it is great to catch the eyes and make good (or bad) impressions
- A few simple statistical methods can be very useful for quantitative and objective model verification

Methods: HERBS

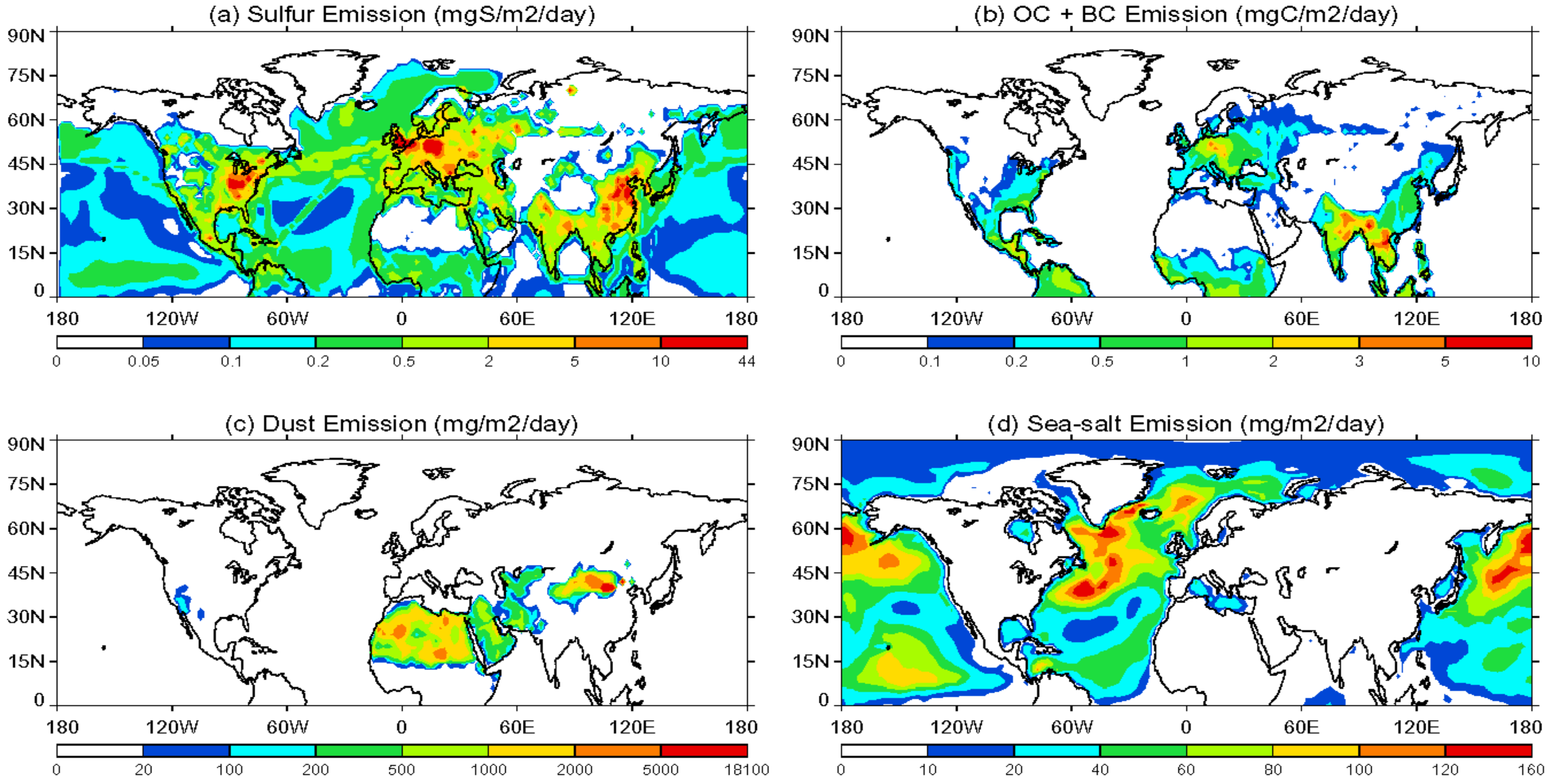
- **How well does the distribution of model results corresponds to the distribution of observed quantities?**
  - Histogram ***H***
- **What is the average error of the model compared to the observations?**
  - Mean error ***E*** $= \sum(M_i – O_i)$
- **How well do the model calculated values correspond to the observed values?**
  - Corr. Coef. ***R***
- **What is the model bias?**
  - Mean bias ***B*** $= \sum M_i / \sum O_i$
- **What is the overall model skill?**
  - Skill score ***S*** $= 4(1+R) / [(\sigma_f + 1/ \sigma_f)^2(1+R_0)]$

    Where R_0=max attandable R, σ_f =std_dev (model)/std_dev (data)

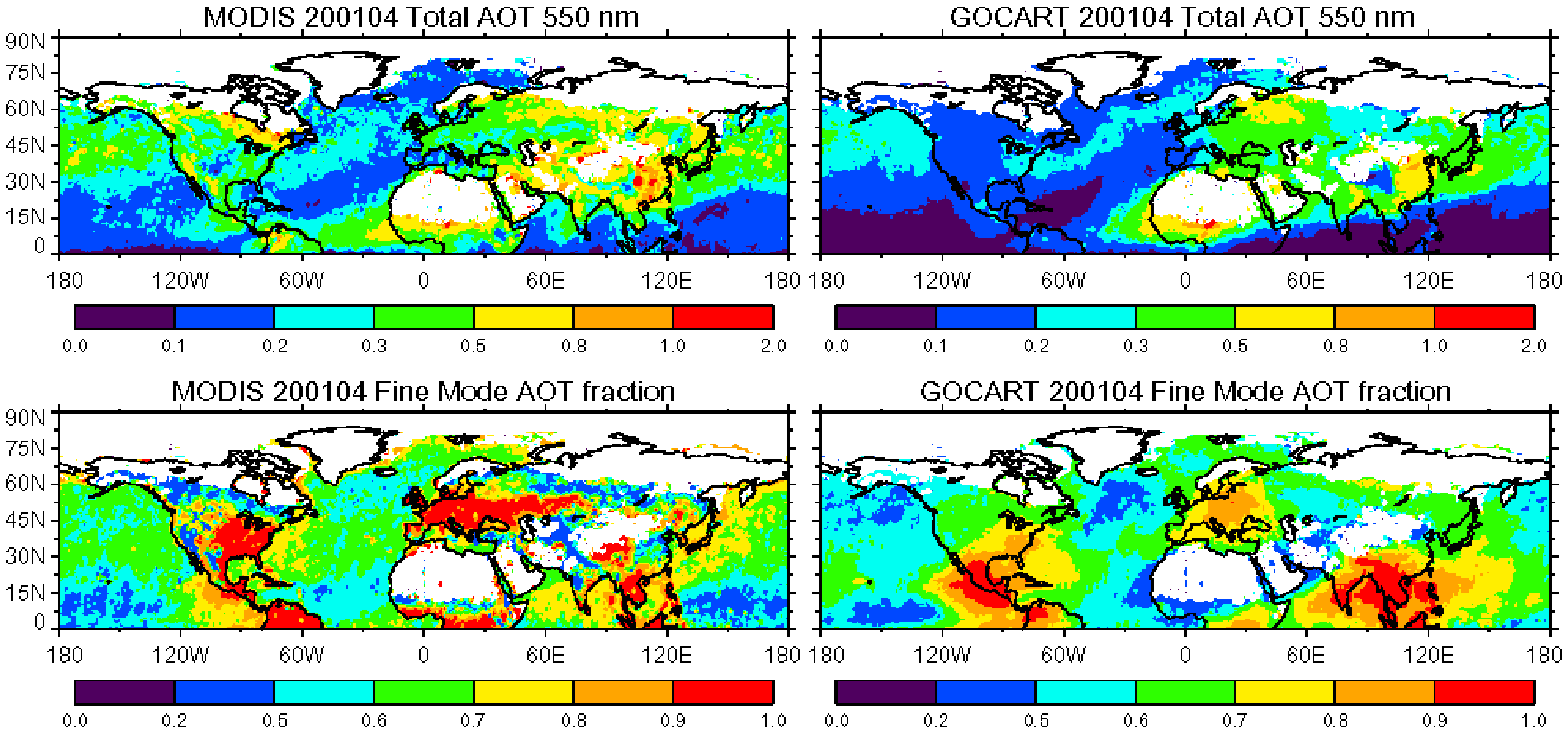
Example:

NH aerosol distributions during ACE-Asia – Comparisons of GOCART model with MODIS and AERONET

Aerosol and precursor emissions in northern hemisphere, April 2001

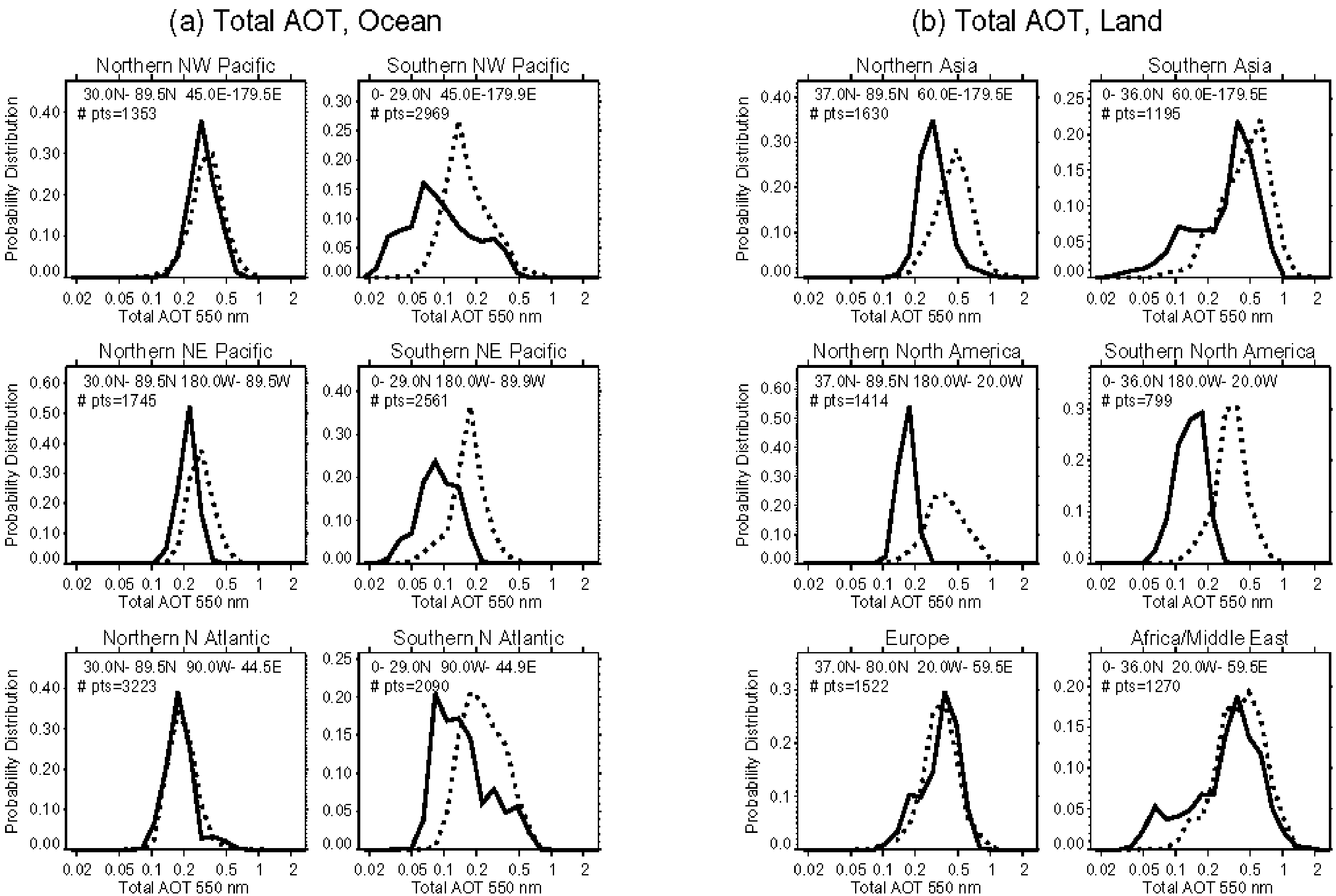


Distributions of aerosol optical thickness and fine mode fraction



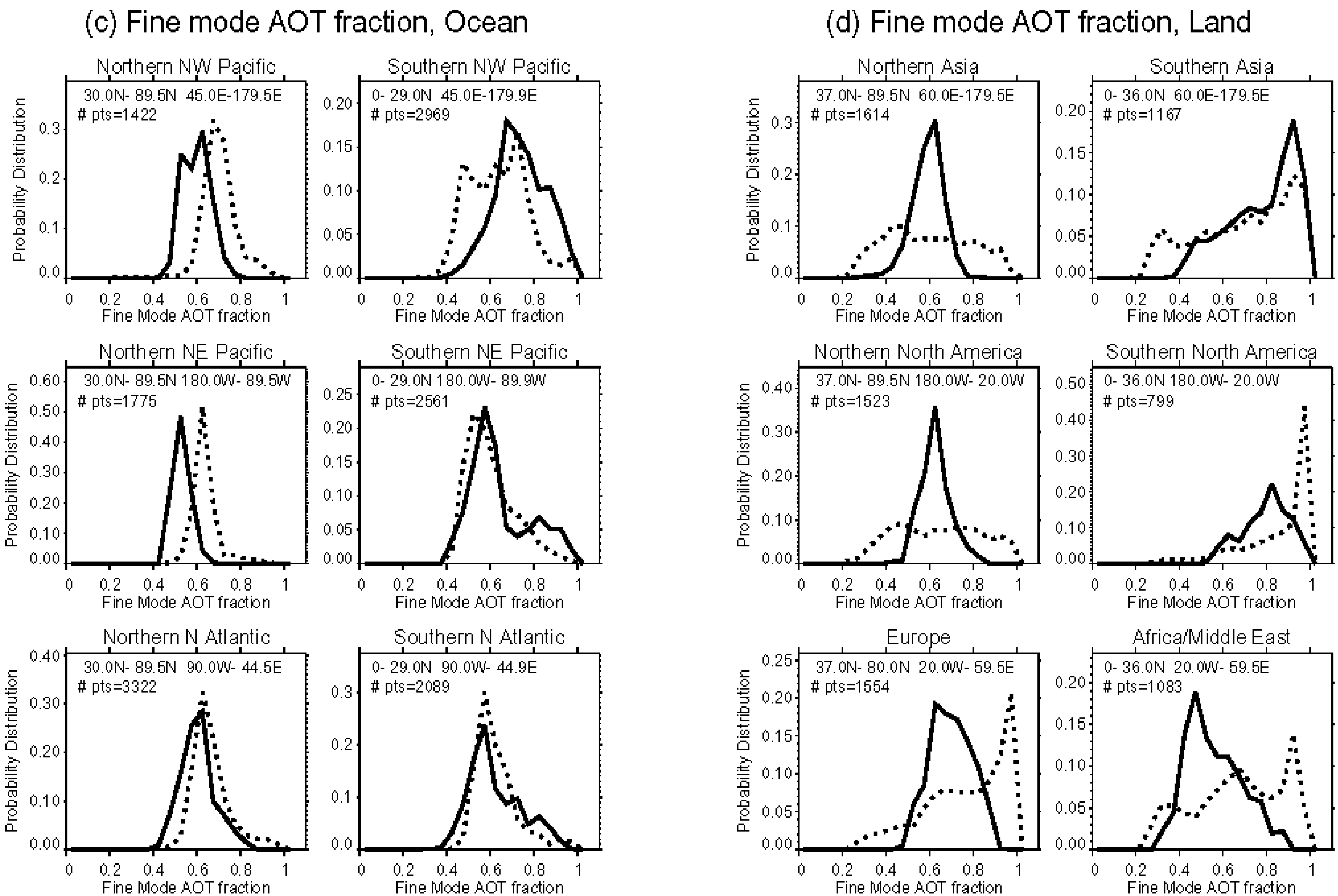
Probability distributions - AOT

Solid lines: GOCART   Dotted lines: MODIS

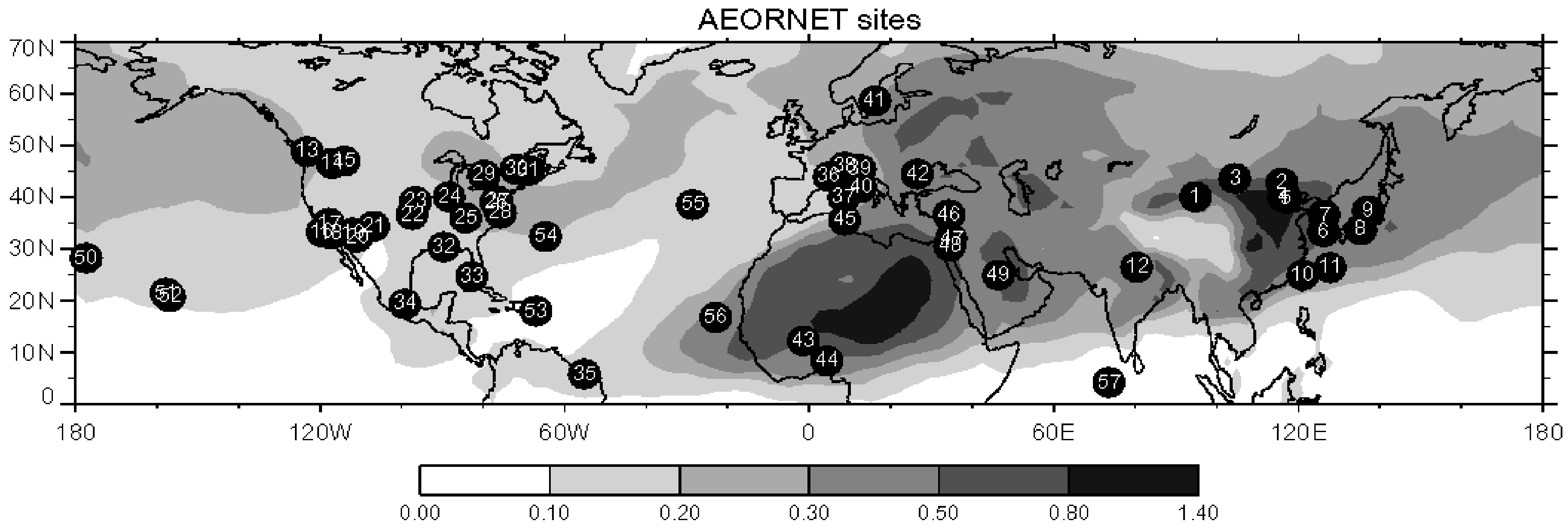


Probability distributions - f_{fine}

Solid lines: GOCART   Dotted lines: MODIS



Comparisons with AERONET



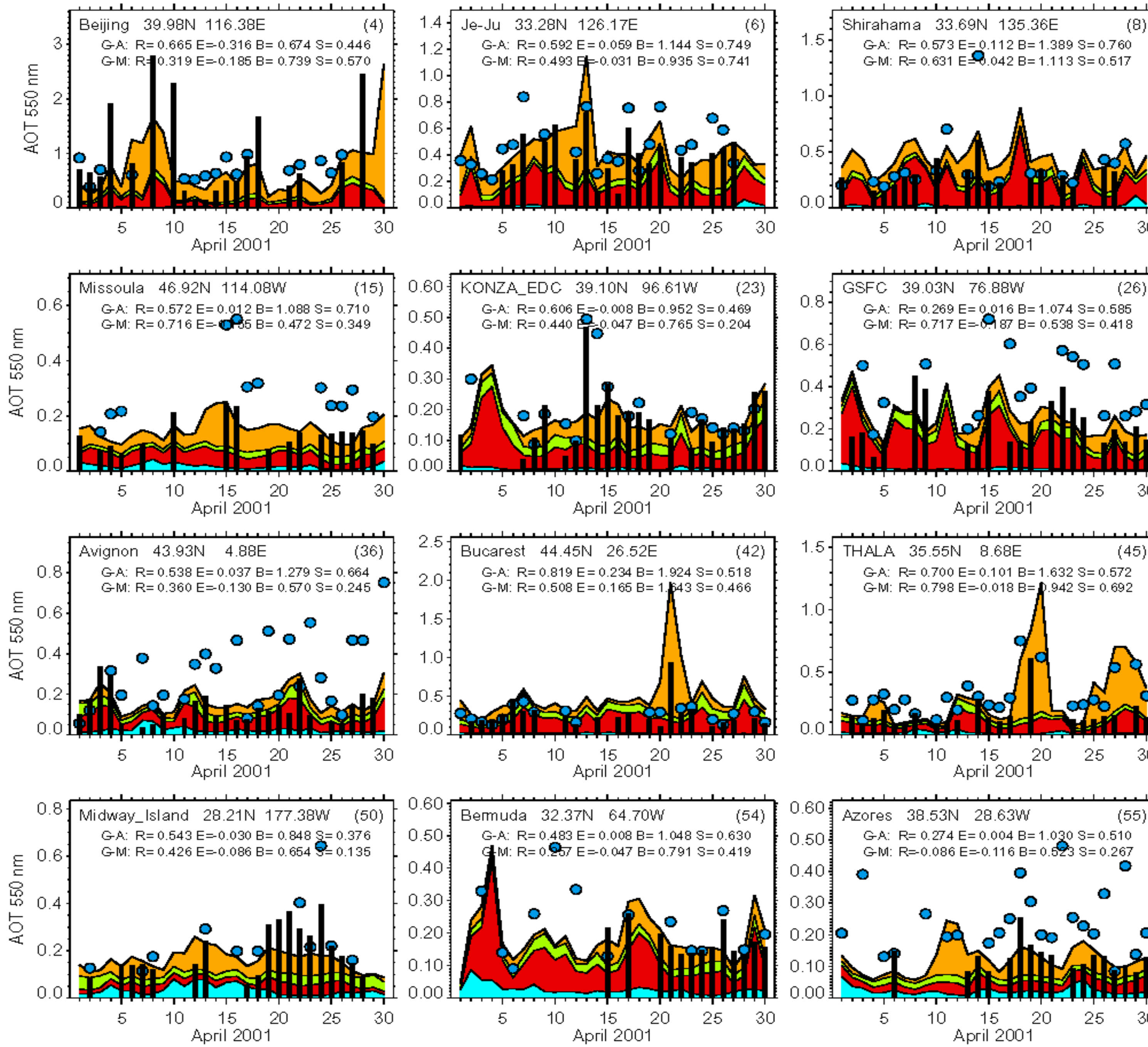
- Sites 1-12: Asia
- Sites 13-36: North America and Surinam (South America)
- Sites 37-49: Europe, Africa, Middle East
- Sites 50-57: Oceans

Asia

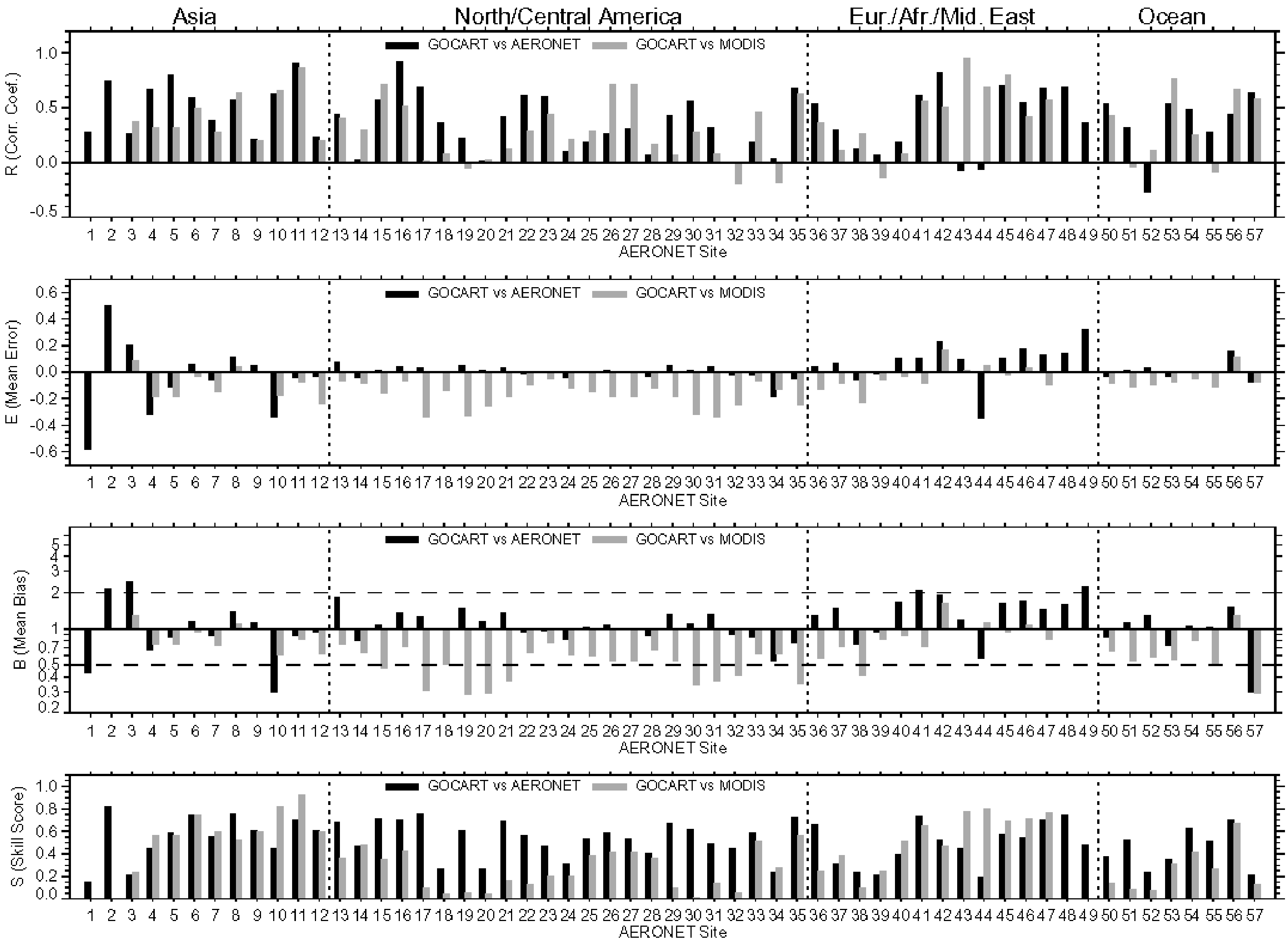
North America

Europe/ Africa

Oceans

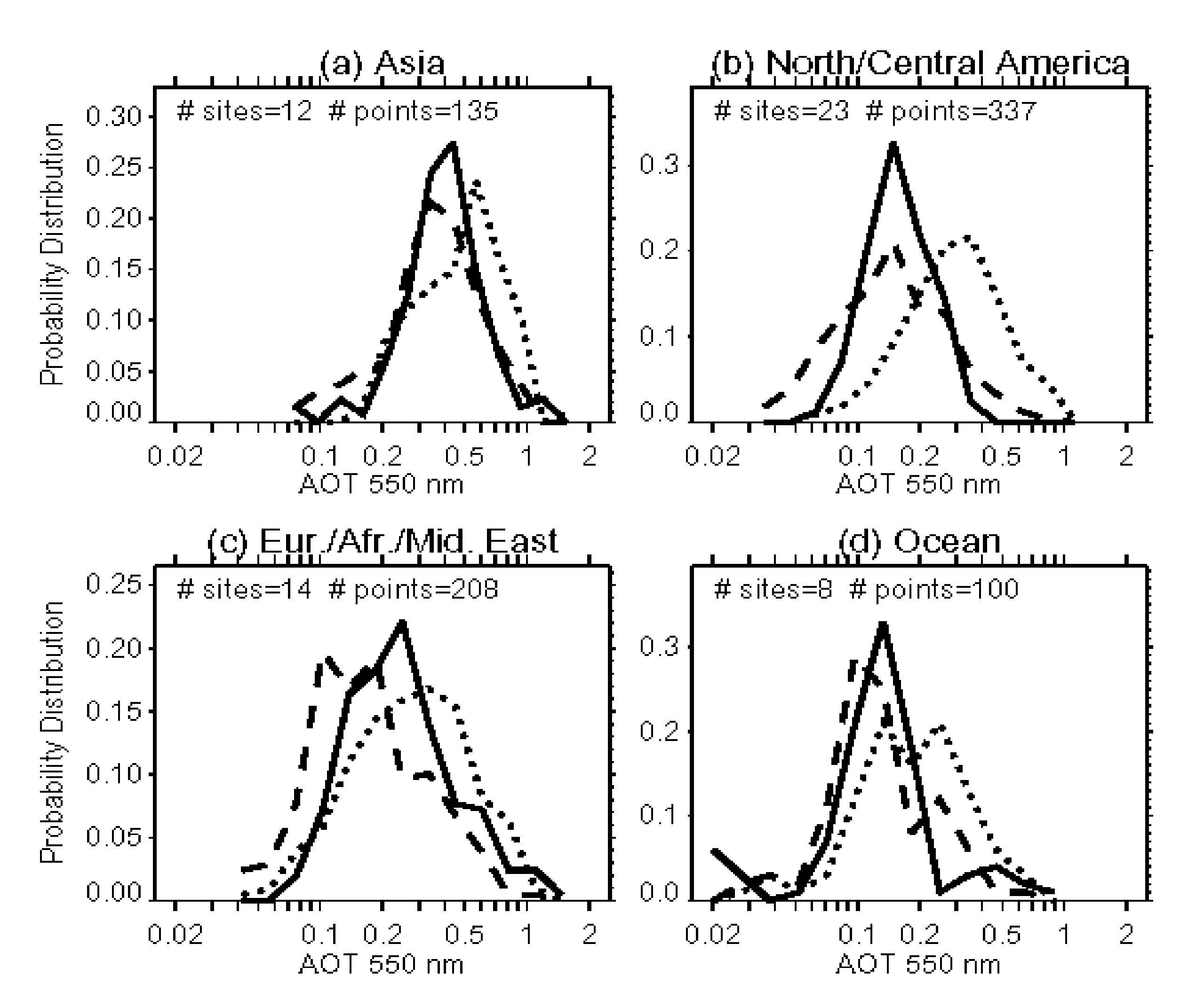


Statistical parameters of GOCART vs AERONET and GOCART vs MODIS

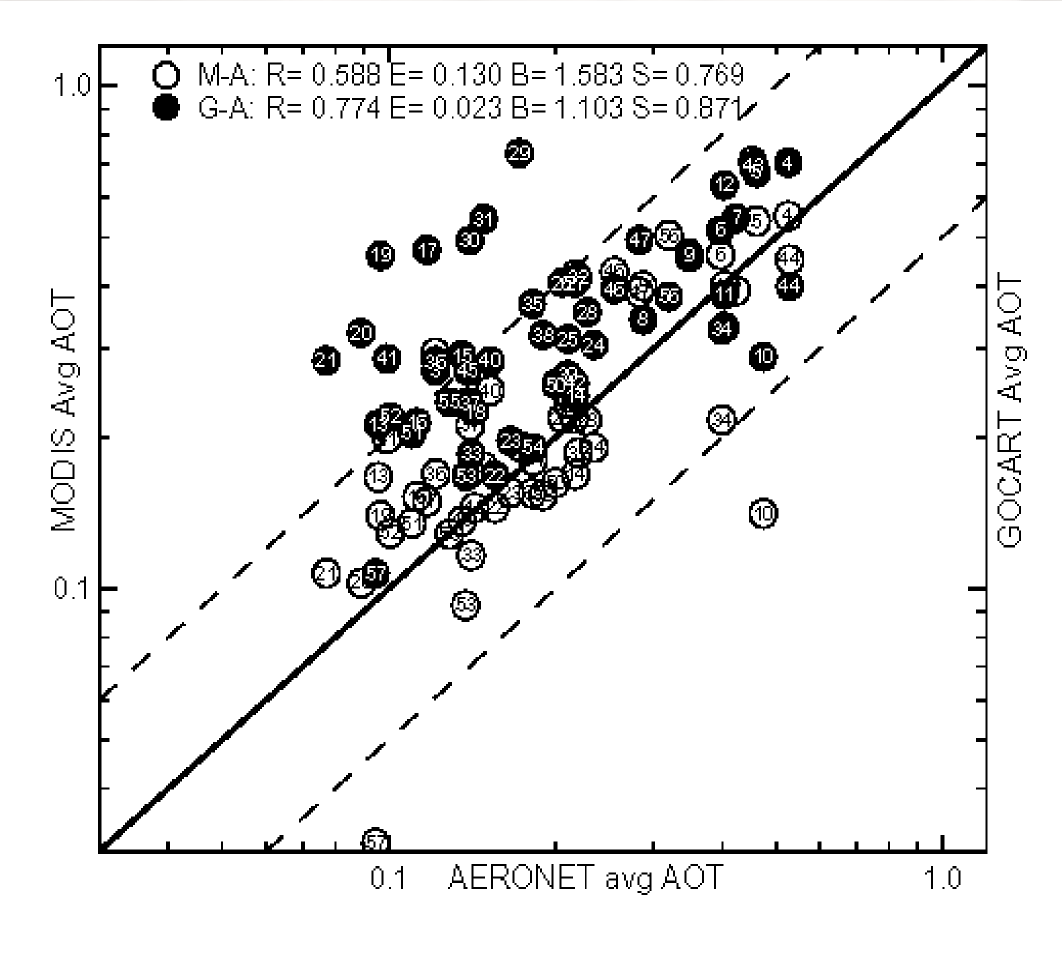


Probability distributions

Solid lines: GOCART   Dotted lines: MODIS Dashed lines: AERONET



Scatter plot



Comments

- The largest discrepancies between the MODIS and GOCART AOT in April 2001 are in North America and the tropical oceans
- It seems that MODIS is biased high in North America mostly in the SW and NE regions due to the surface reflectance
- Model is likely having problems in the tropical oceans, but more direct measurements are needed to verify
- AERONET – currently is still the best judge because it is the direct measurement

Recommendations

- Histogram (or probability distribution) is the probably the most appropriate tool to compare datasets especially when the intrinsic differences (e.g., spatial resolution, sampling time) exist between different datasets
- Error, bias, and correlation coefficient are also necessary for model evaluations with a reference dataset
- Time series (e.g. daily or seasonally variations) and vertical profiles are important because they offer information about model processes
- Assign skill scores to all the models to see “who is the best” (anonymously, no feeling hurting)
- (Minor ☺): Using log scale for scatter plots of aerosol optical depth since aerosols are log-normally distributed