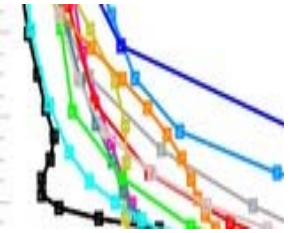


deriving a best guess of aerosol direct radiative forcing

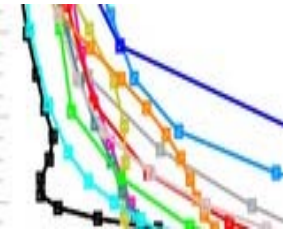
Michael Schulz

Norwegian Meteorological Institute

acknowledgements

Jan Griesfeller, AeroCom modellers, Stefan Kinne, AERONET, Paul Eckhardt and EBAS/EMEP data structure

Motivation
goals / steps / outline



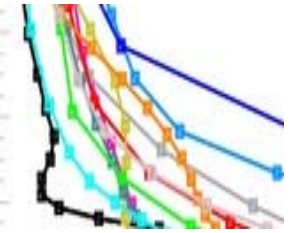
Explore use of observations to reduce model uncertainty in direct radiative forcing

(thus emphasis on models with direct radiative forcing estimate in AeroCom)

Compare multi-model ensemble to multi-parameter observational dataset
Compare phase I and II model submissions
Use year of simulation and climatology of obs data to check robustness of quality
Document quality of models
Find regional AAOD and AOD correction factors
Find regional species-AOD correction factors with multvariate statistics
Adjust regional and species AOD and use forcing efficiency for new forcing estimate
Check if variability in AOD and forcing is reduced
Discuss BC diverse observational constraints specifically
Discuss value of model ensemble AeroCom Median A, B, A2
Discuss anthropogenic fraction uncertainty
Test if weighting models by quality would yield a similar results

Comparison to other forcing estimates
Evaluation against satellite products?

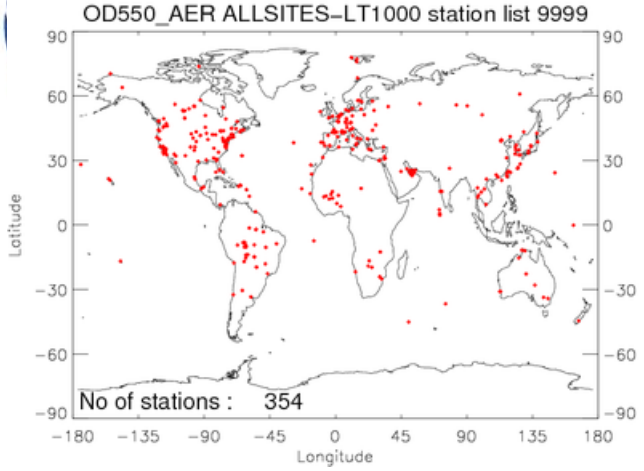
State of Model evaluation analysis
AeroCom B and A2



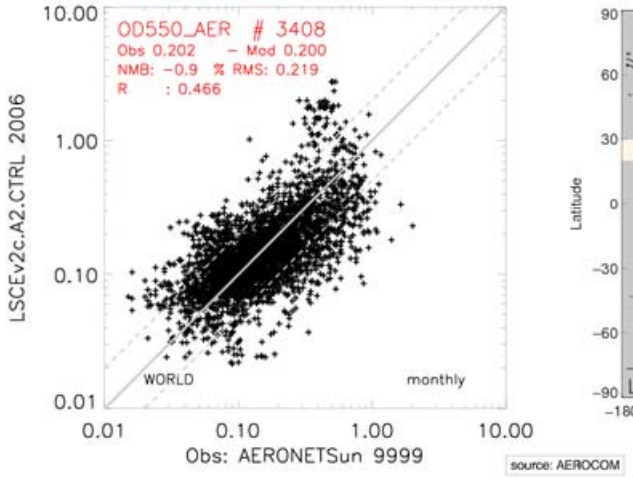
AeroCom B y2000			AeroCom Phase II y2006	
AEROCOM_MEDIAN (expA)				
GISS_B	=>	RF	GISS-modelE.A2.CTRL	RF
			GISS-Matrix	RF
UIO_GCM (clim)	=>	*RF*	CAM4-Oslo-Vcmip5.A2.CTRL (clim)	RF
			CAM5-MAM3-PNNL.A2.CTRL	RF
LOA_B	≠	RF	HadGEM2-ES.A2.CTRL	
			HadGEM2-ES.A2.CTRL-DIRECT	RF
LSCE_B	(=>)	RF	*LSCE.A2.CTRL*	RF?
MATCH_B				
			BCC_AGCM2.0.1_CAM.A2.CTRL	RF
			GMI.A2.CTRL	RF
			GOCART-v4Ed.A2.CTRL	RF?
MOZGN_B	(=>)		*GFDL*	RF?
MPI_HAM	=>	RF	MPIHAM_V2_KZ.A2.CTRL	
			MPIHAM_V2_KZ.A2.CTRL-DIRECT	RF
UIO_CTM_B	=>	RF	OsloCTM2.A2.CTRL	RF
UMI_B		RF	*IMPACT*	
KYU_B	=>	RF	SPRINTARS-v384.A2.CTRL	RF
TM5_B			TM5-V3.A2.CTRL	
ULAQ_B		*RF*		

MODEL NOT ANALYSED YET, missing or error on my side

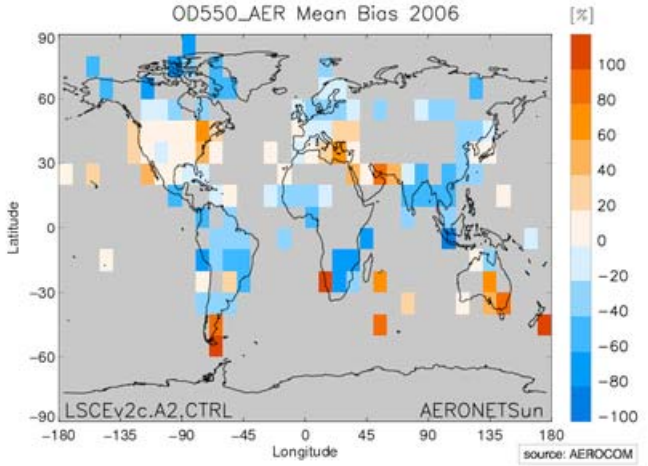
Where compared ?



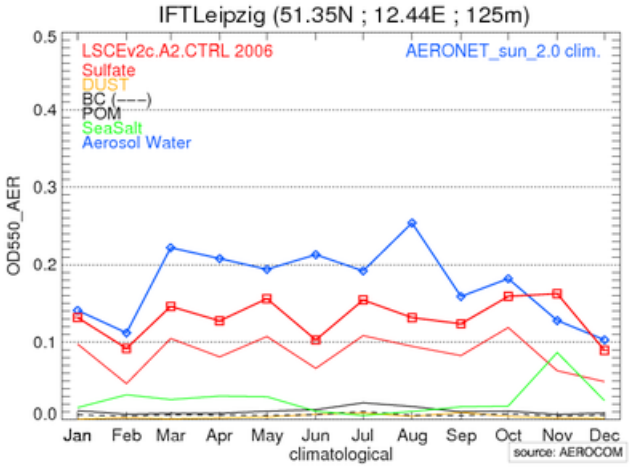
Correlated ?



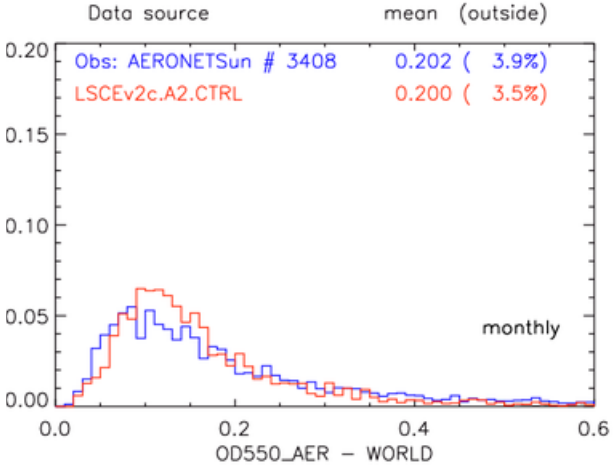
Regional Normalized Bias ?



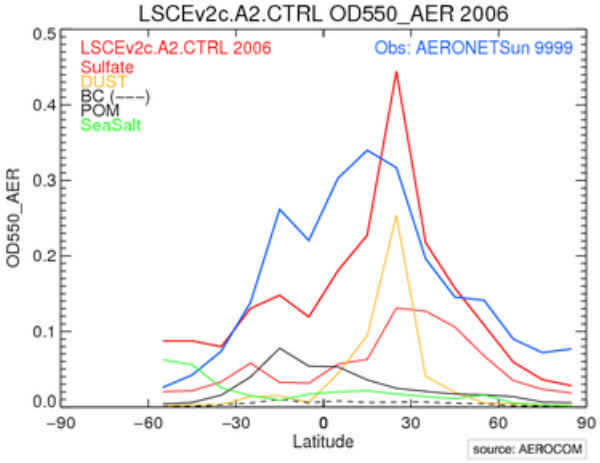
Local month to month variation?



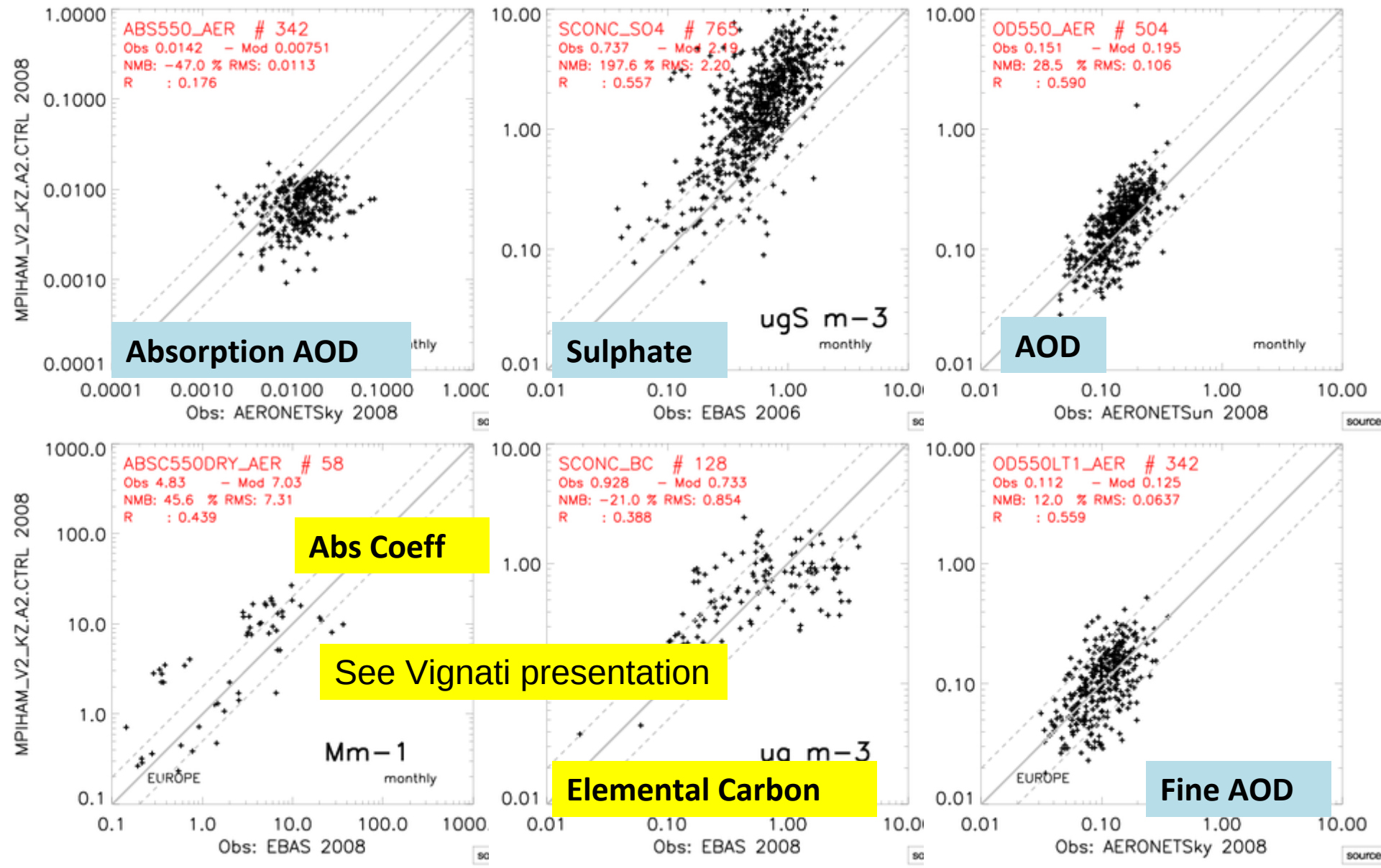
Histogram?



Zonal Absolute Bias ?



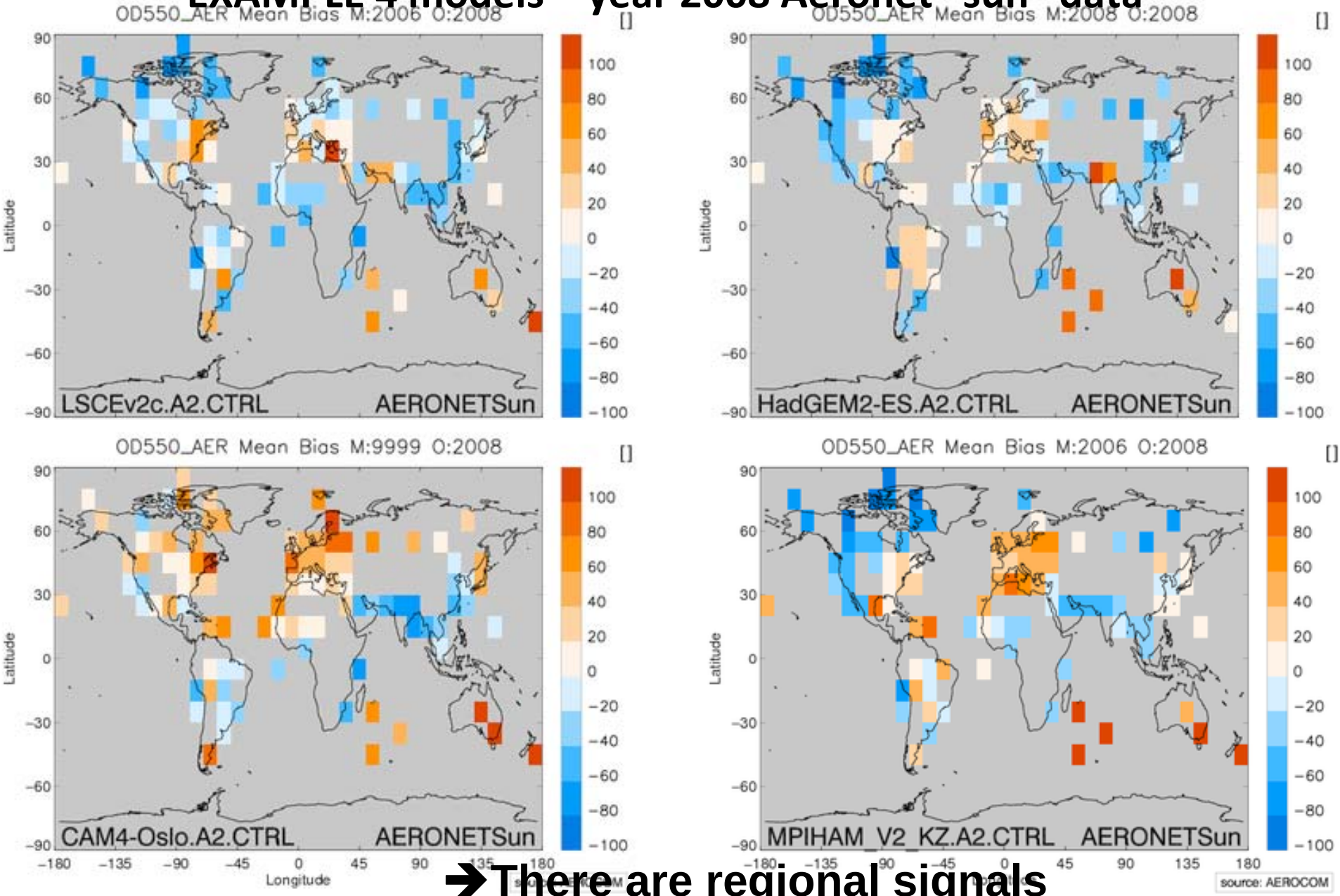
AeroCom phase II standard visualization against observational data
Example LSCE.A2.CTRL / Aeronet Aerosol Optical Depth, year 2006



Evaluation against multiple observational datasets
Example ECHAM5-HAM.A2.CTRL

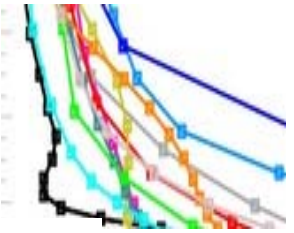
BIAS in Aerosol Optical Depth

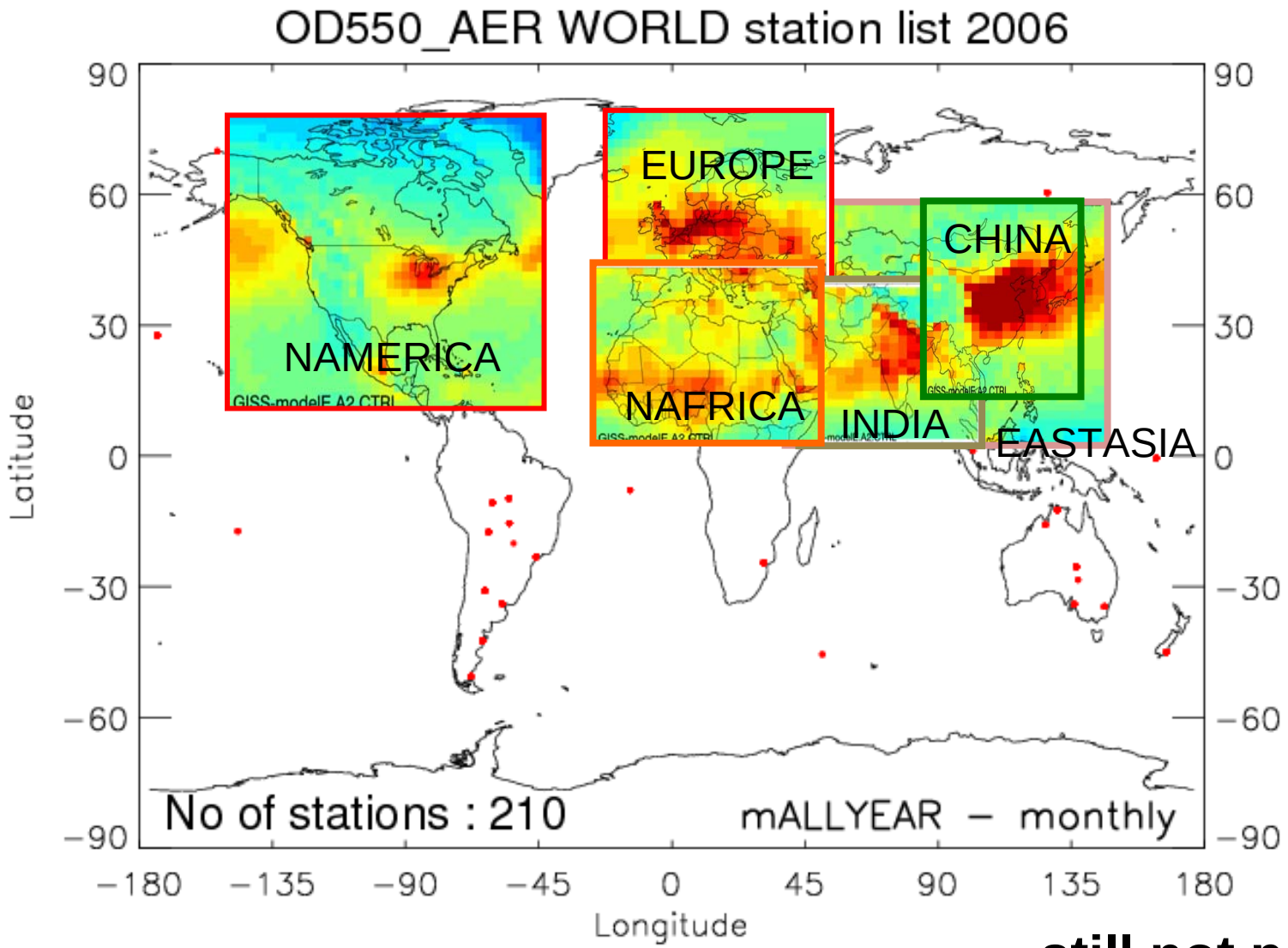
EXAMPLE 4 models – year 2008 Aeronet "sun" data



➔There are regional signals

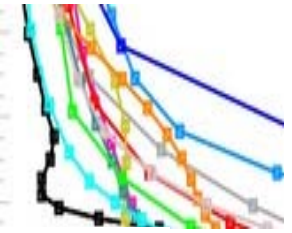
Regional choices so far on AeroCom web interface

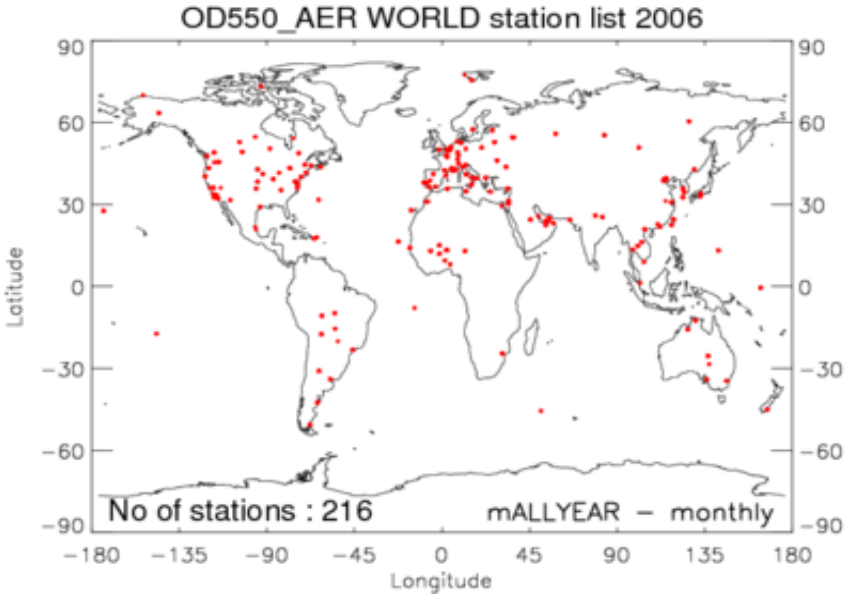


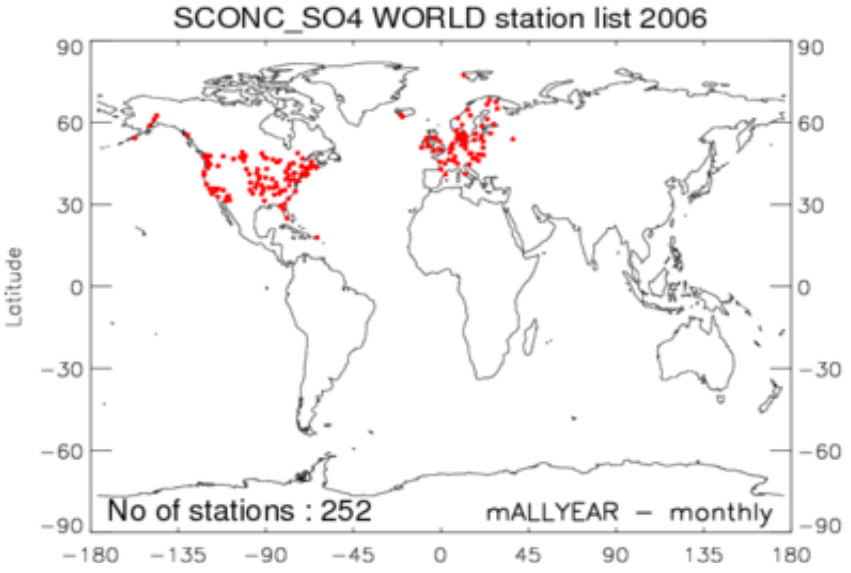


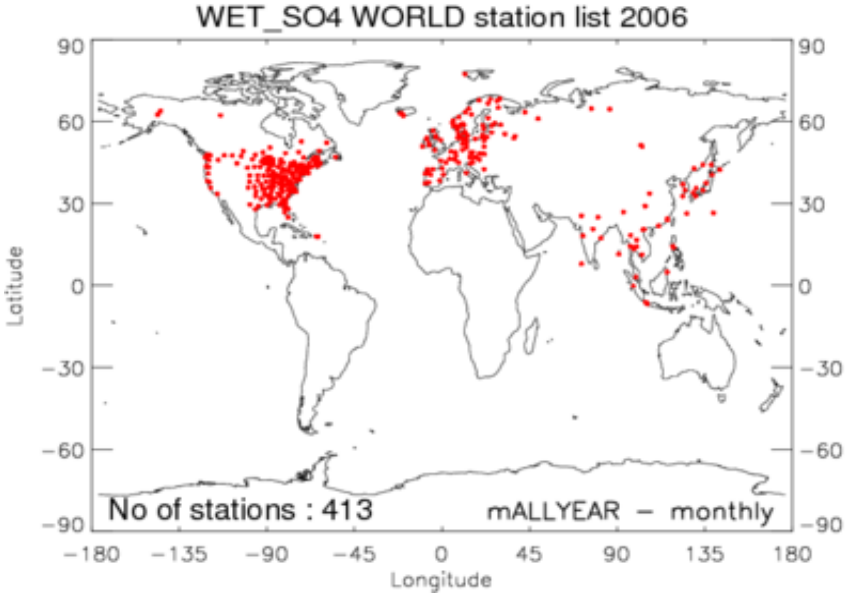
….still not perfect

Where are the stations?



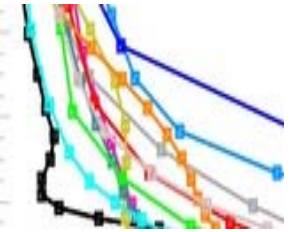


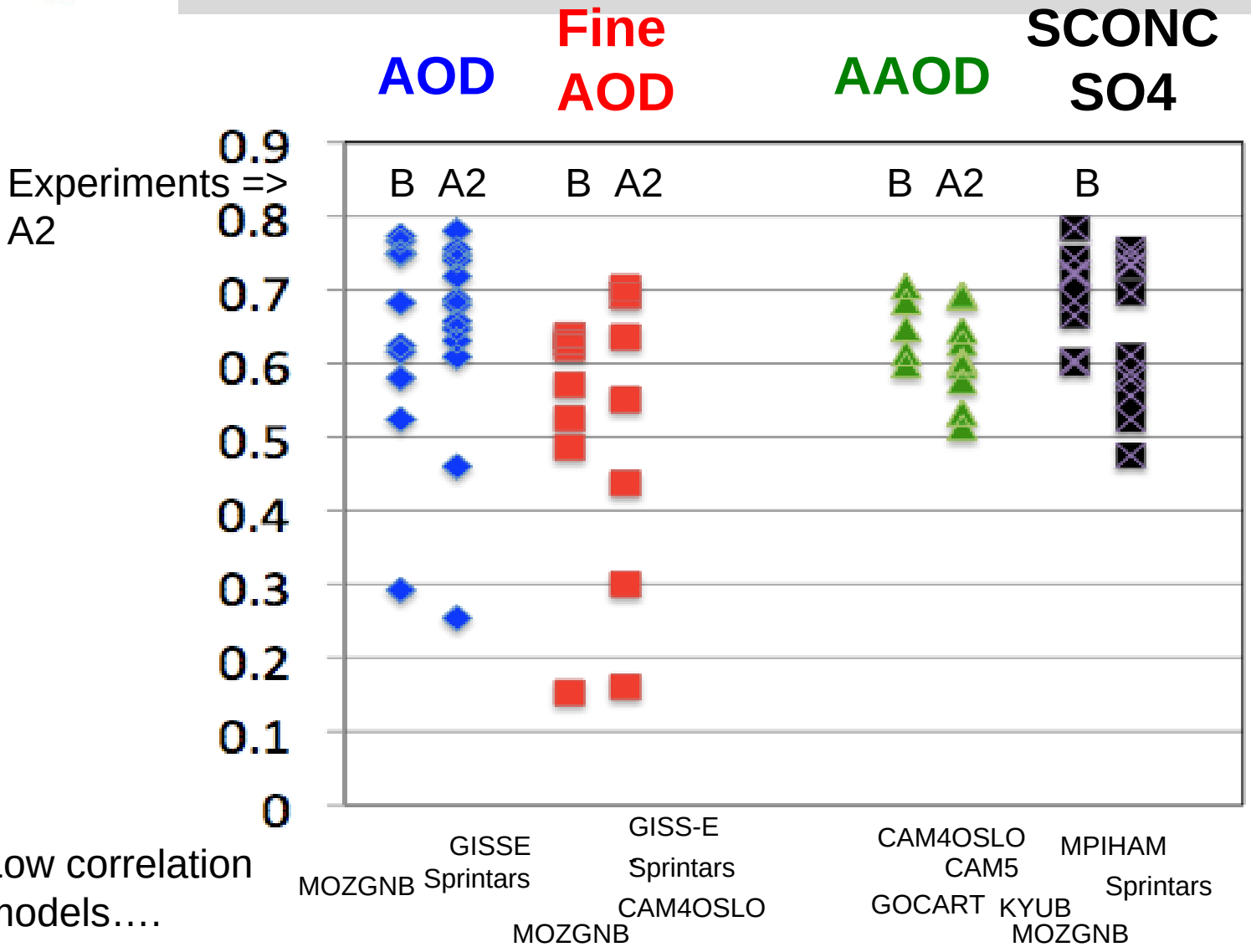




…Aeronet: twice as many sites
in climatology 2000-2009
…not very balanced for sulfate
Surface concentration
…use of SO4 wet deposition prefered
(in progress)

Correlation to monthly aggregated data
Several parameters

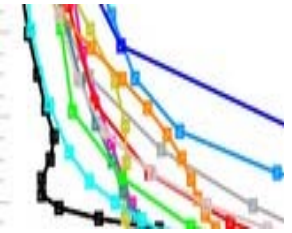


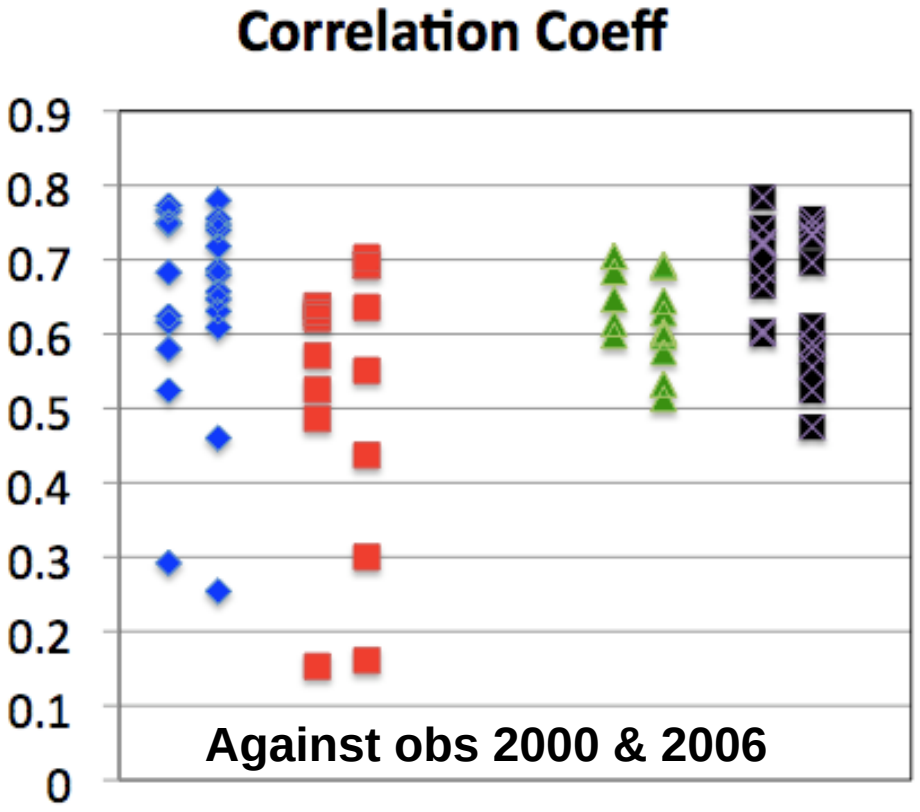


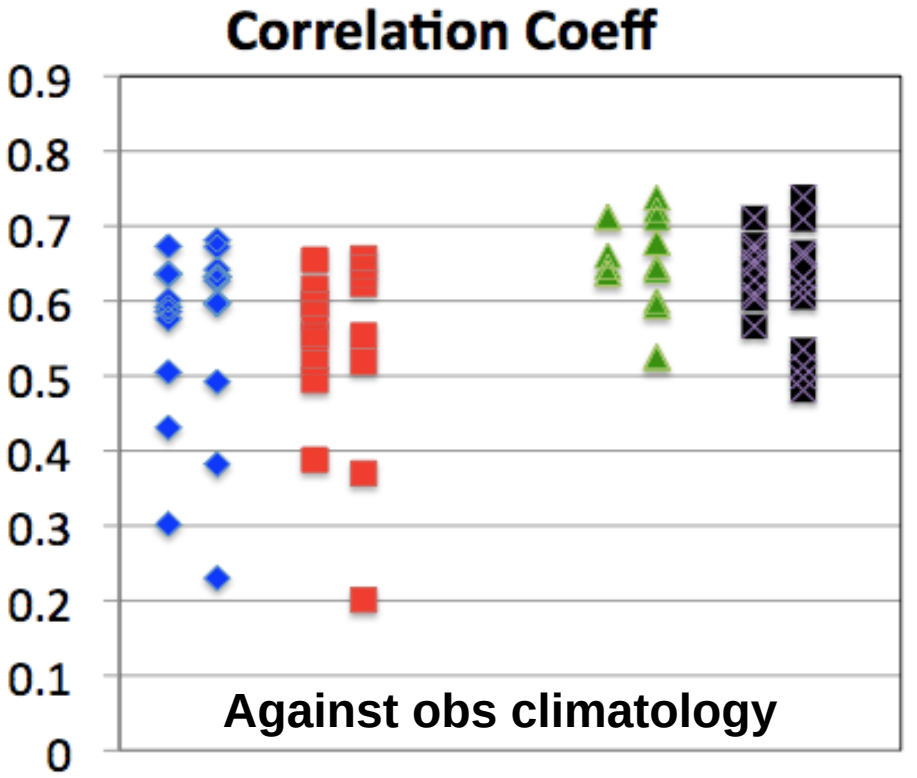
Low correlation models….

….check models individually

Correlation to monthly aggregated data
Several parameters two time frames





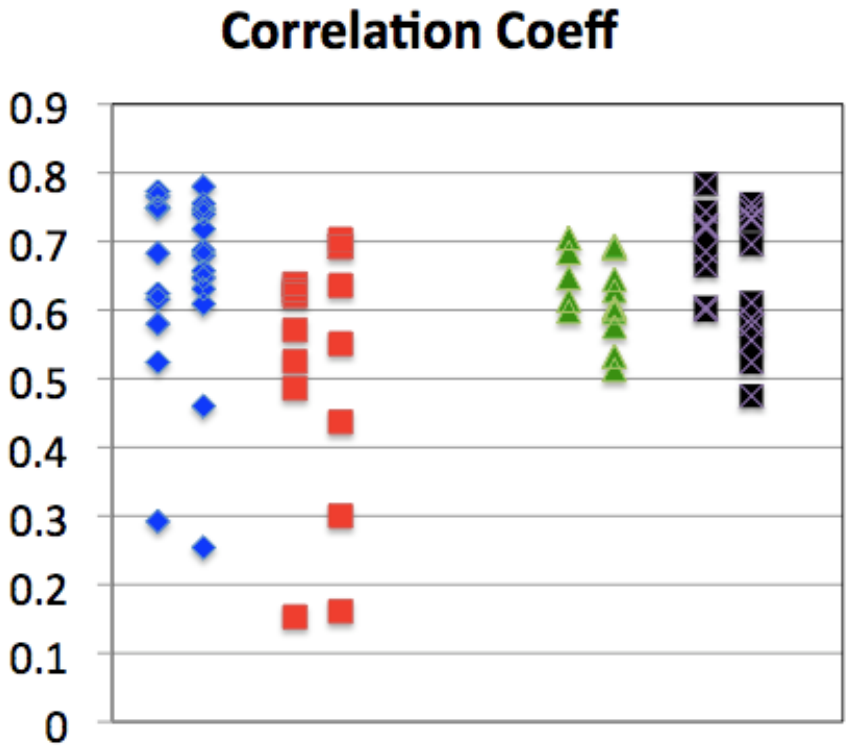


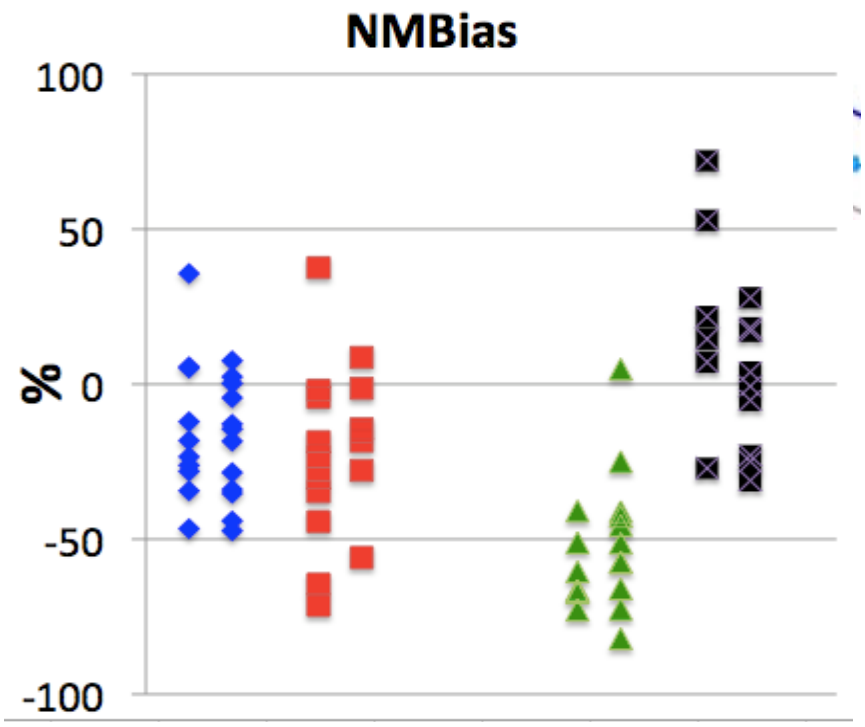
AOD

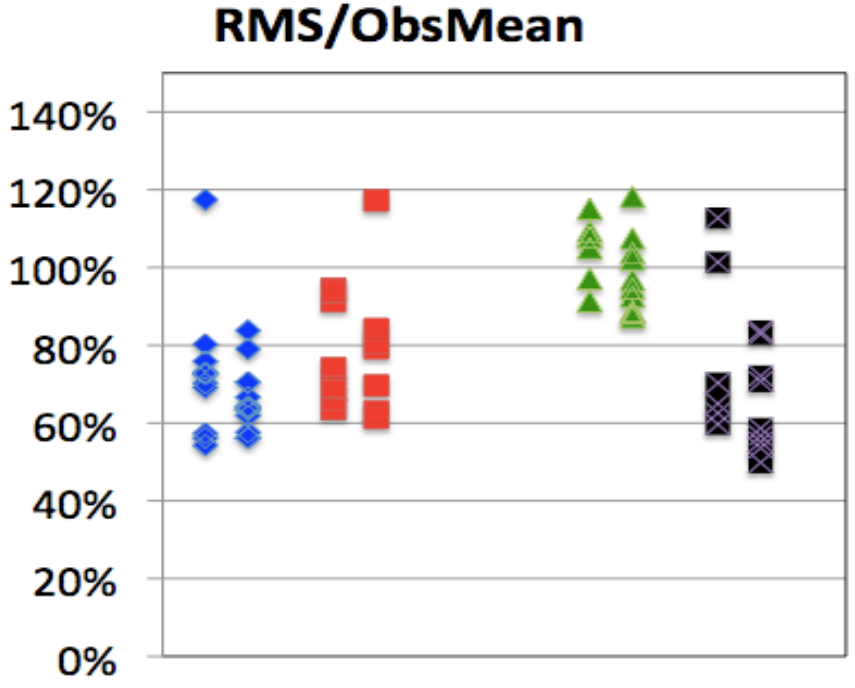
Fine AOD

AAOD

SCONC SO4

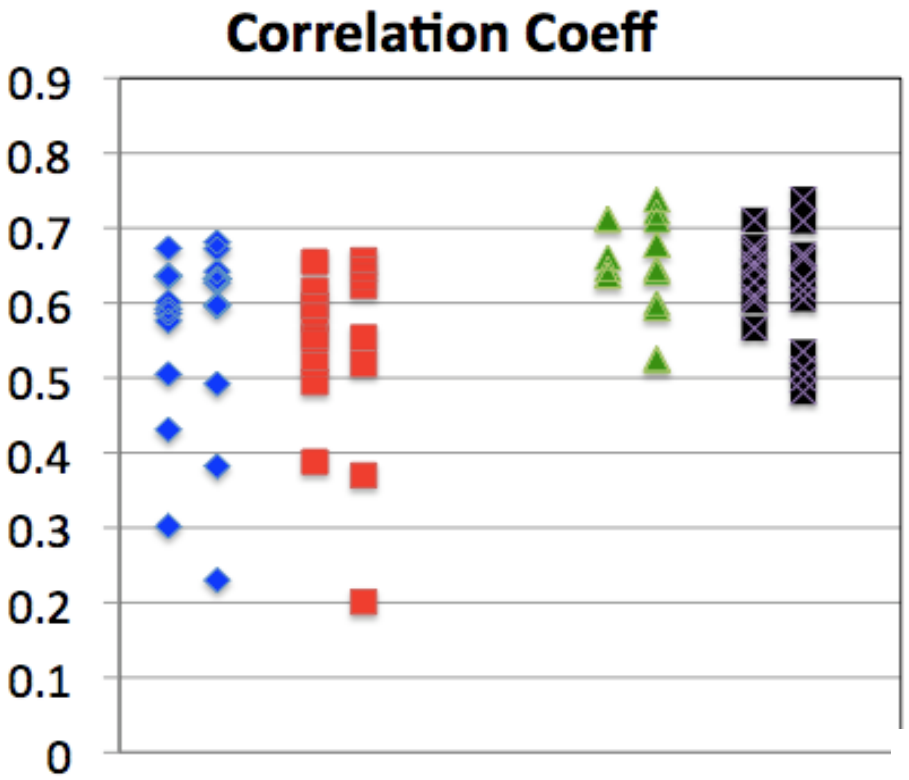


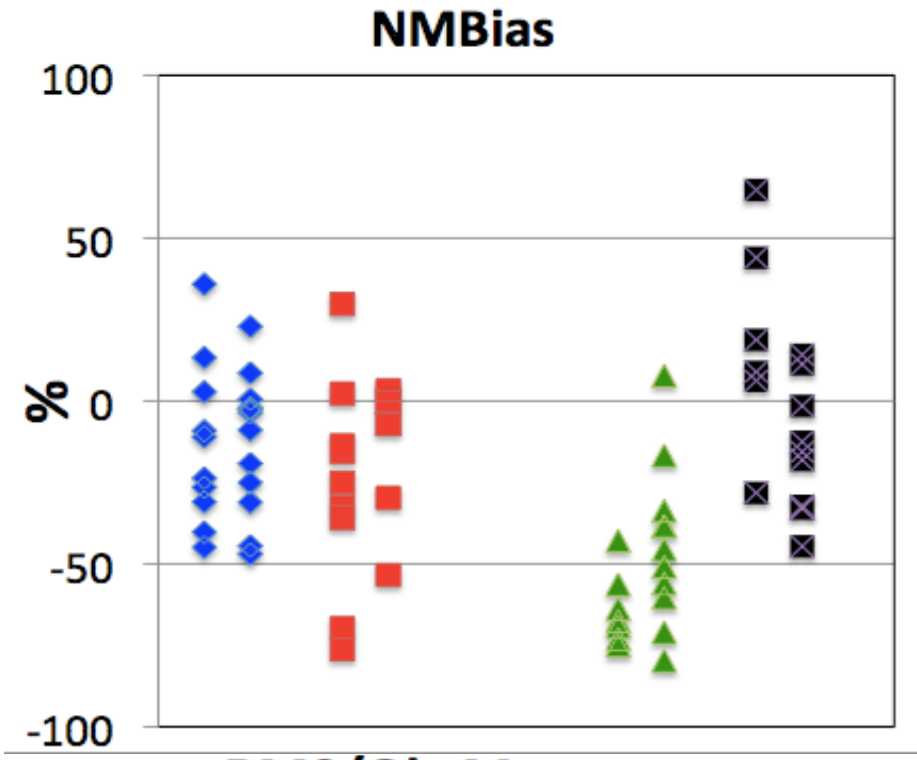


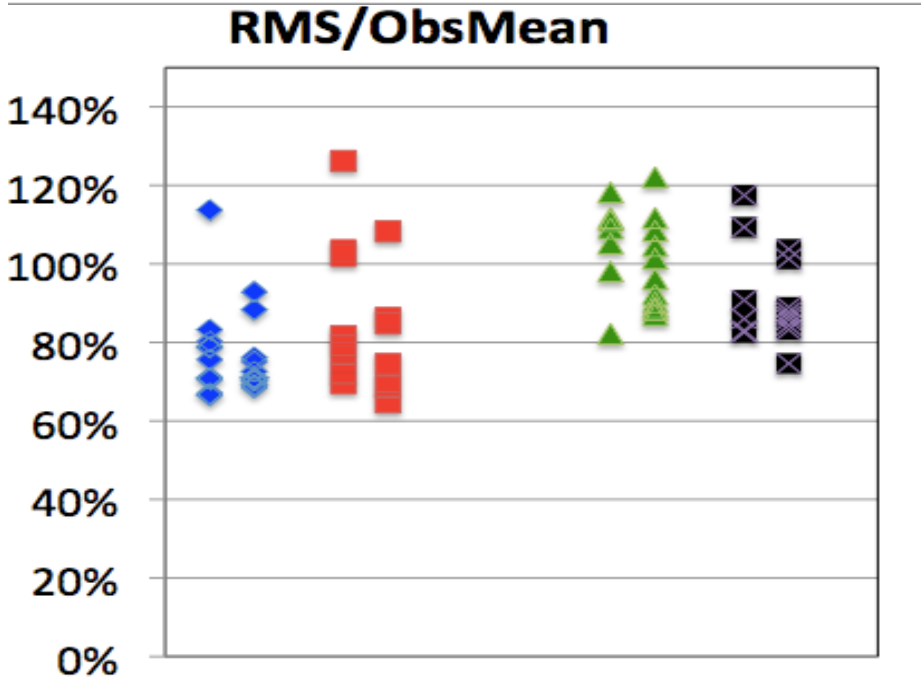


Against obs 2000 & 2006

AOD **Fine AOD** **AAOD** **SCONC SO4**



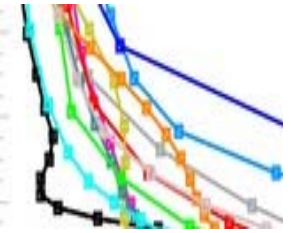




Against obs climatology

AOD **Fine AOD** **AAOD** **SCONC SO4**

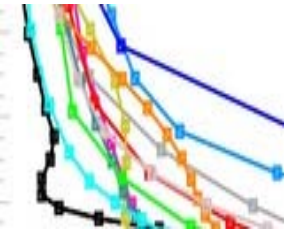
Summary
Correlation, bias and rms analysis



…. Check outliers and include missing models pending

Model generations A/B and A2 are quite different
Only AOD seemed to have improved
Using 2000 vs 2006 influences A/B vs A2 comparison for r+rms
R and RMS worse against climatology
Bias 2000/06 similar to climatology 2000-2009
Fine mode AOD and AAOD are consistently more problematic
Underestimate of AOD < fine AOD < AAOD (50%)
Sulfate surface concentration seems to be overestimated
(more in 2000 than in 2006… emissions in model&reality?)

Multiple regression of AOD species versus total AOD



Assuming

Sum of diagnosed AOD species contribution is total AOD
Average regional and species linear correction factors *a* apply

$$AOD_{j\ observed} = c + \Sigma\ a_{ij} * AOD_{ij\ modelled}$$

j= regions i=aerosol species c=constant

Solving with linear multiple regression analysis
Against Aeronet monthly AOD

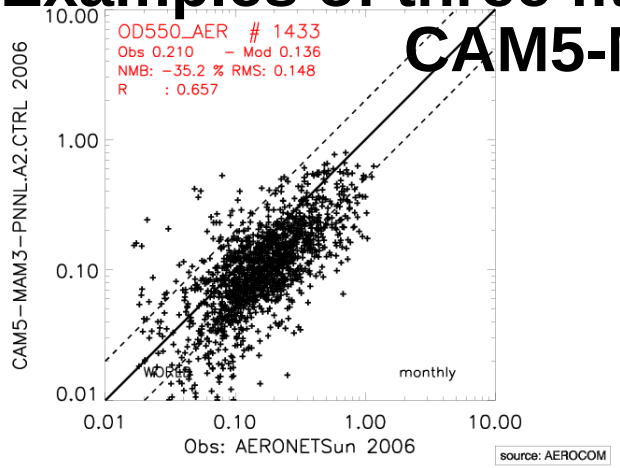
Assuming error 10% in observed AOD
Neglecting model data lt/gt factor 3 (2-10% outliers)

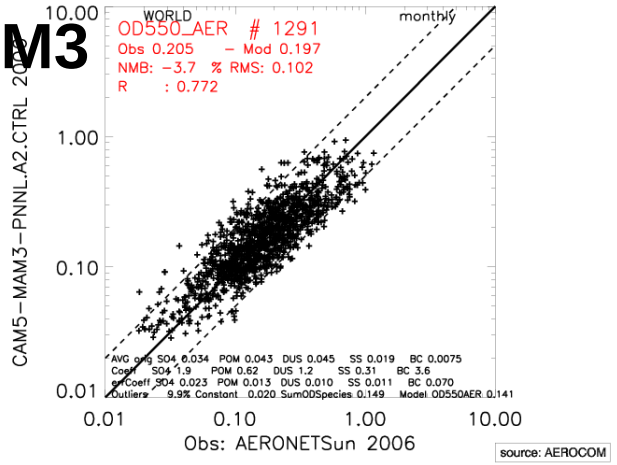
Examples of three fits

Original model data

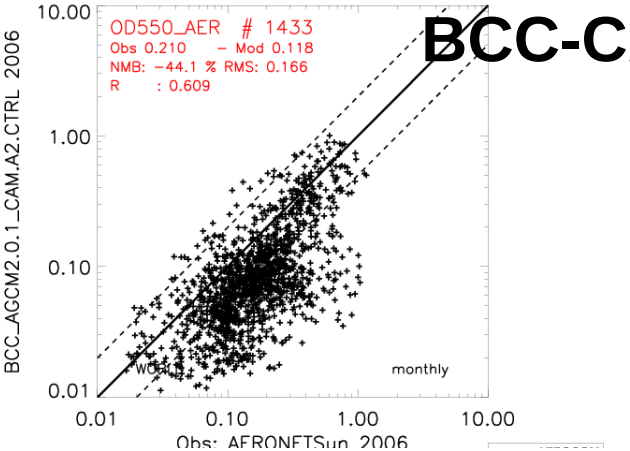
Fitted model composition

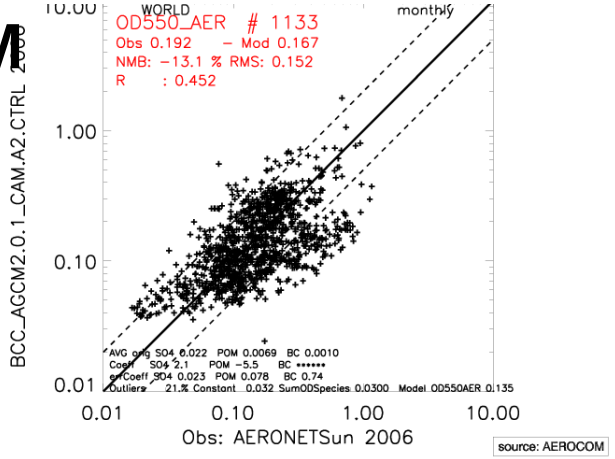
CAM5-MAM3



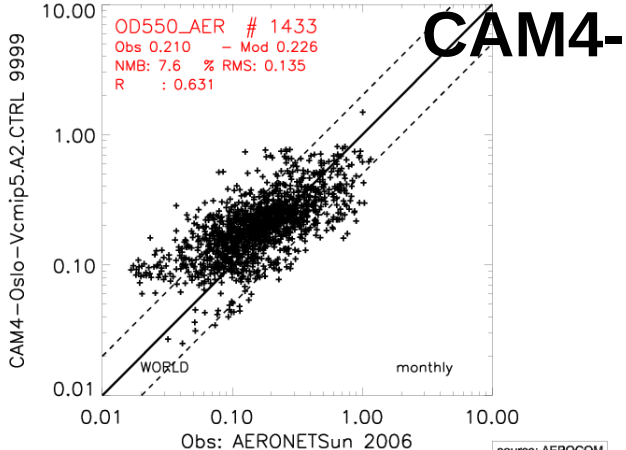


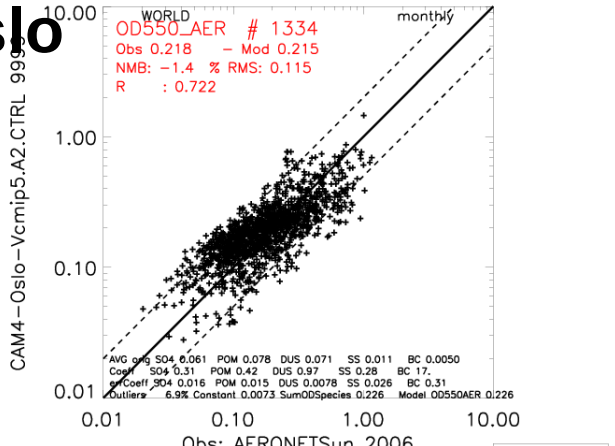
BCC-CAM





CAM4-Oslo

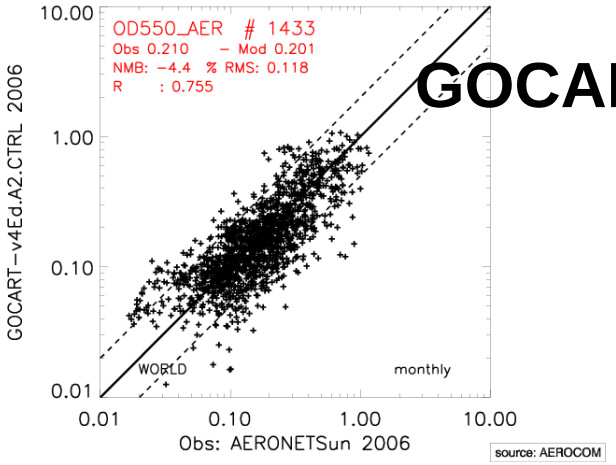


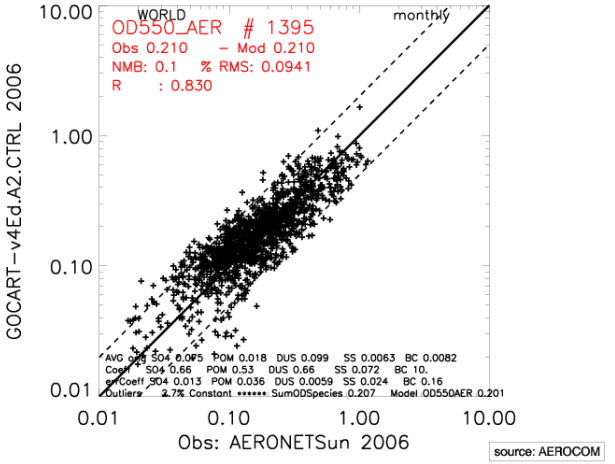


Original model data

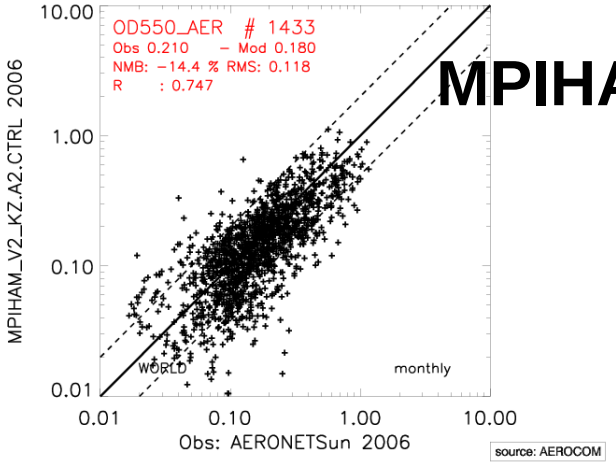
Fitted model composition

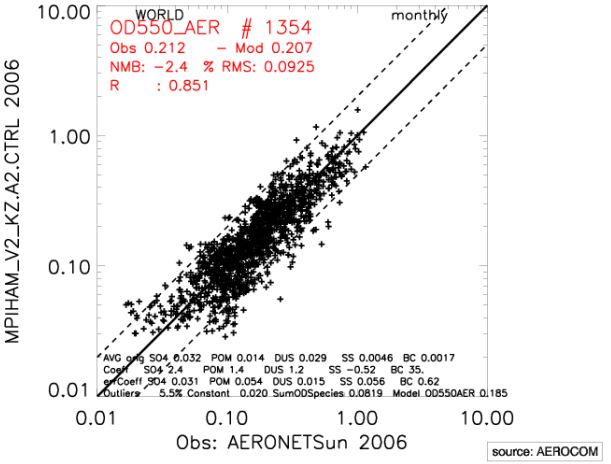
GOCART



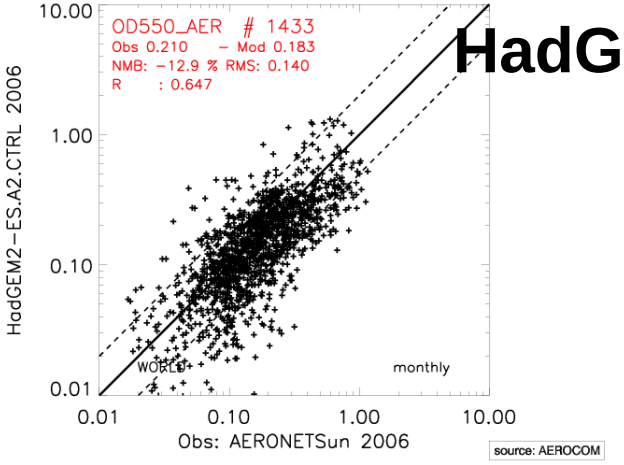


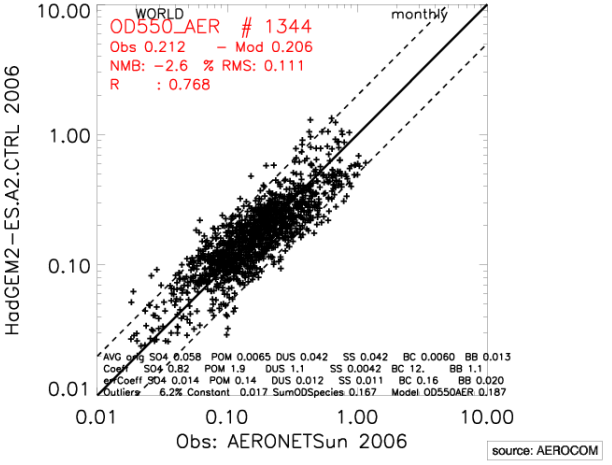
MPIHAM



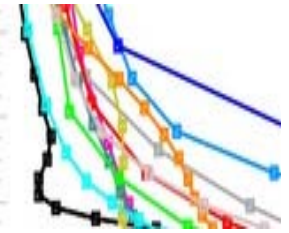


HadGEM





Fit implications on AOD composition



So …..

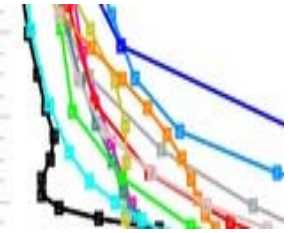
what change in aerosol composition is needed to
Better fit the variability in observed total AOD?

Assuming that the models have just a linear factor wrong

Factor =
any combination of extinction coefficient, life time, emission

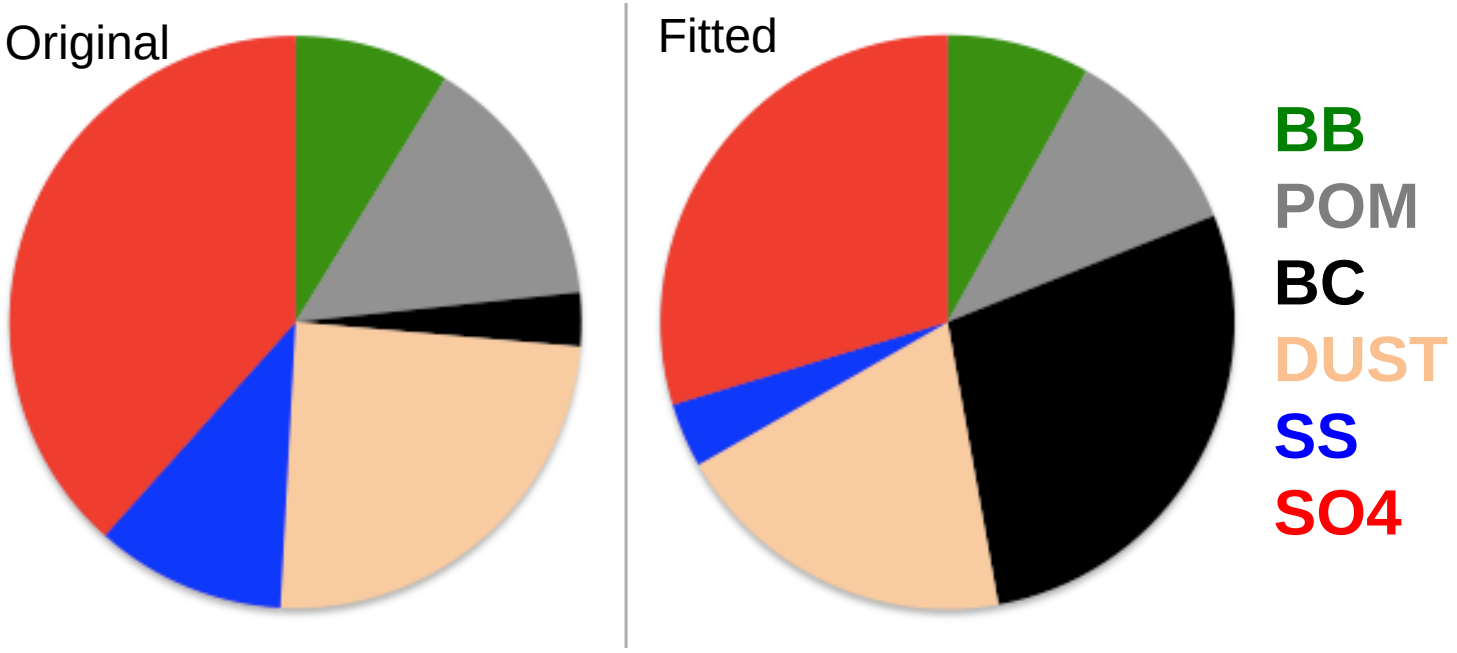
After preliminary inspection, omitting "strange" models:
MOZGNB, MPIHAM B&A2,
SPRINTARS A2, BCC-AGCM, TM5.A2 for now….

Overall mean (15 model versions B&A2) result of AOD compositon fit

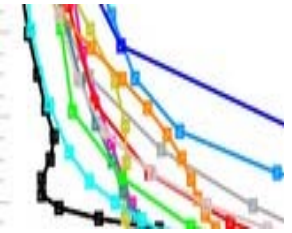


	Observation	Model	Fitted Model
Mean AOD	0.195	0.186	0.188
Correlation		0.64	0.78
RMS		0.147	0.097

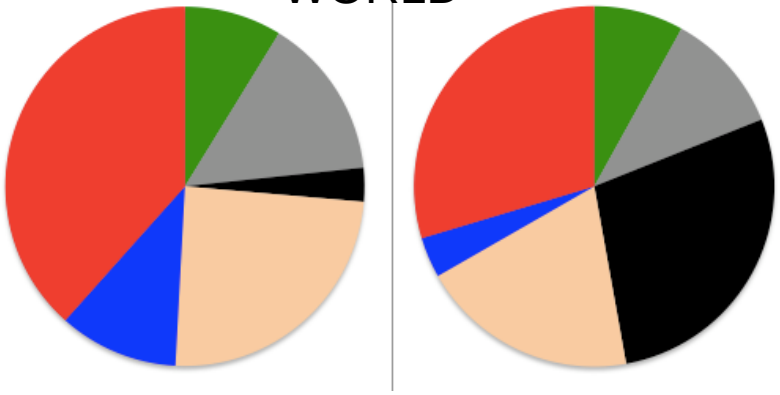
World Aerosol Composition At Aeronet Sites



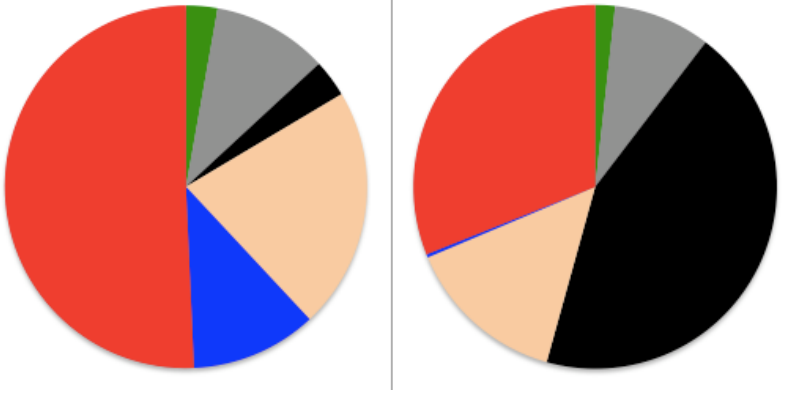
AOD Composition before/after fit
World and three regions



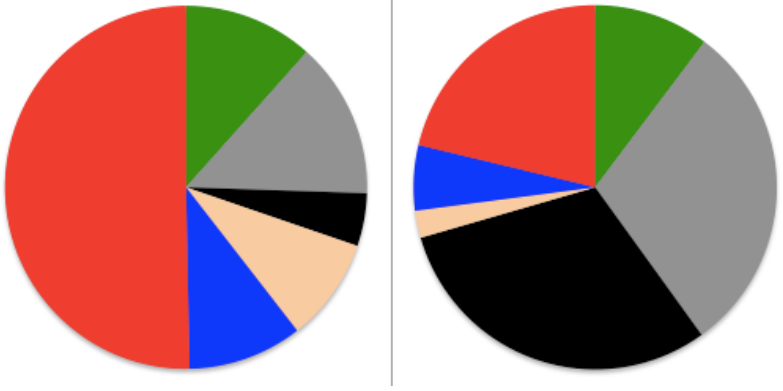
Original WORLD Fitted



Original EUROPE Fitted

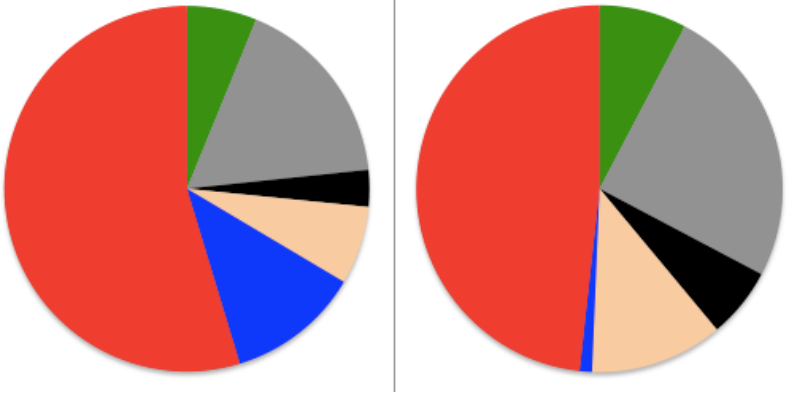


Original EASTASIA Fitted

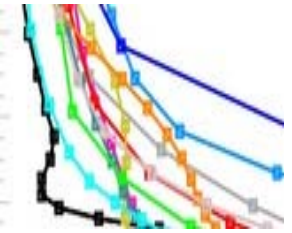


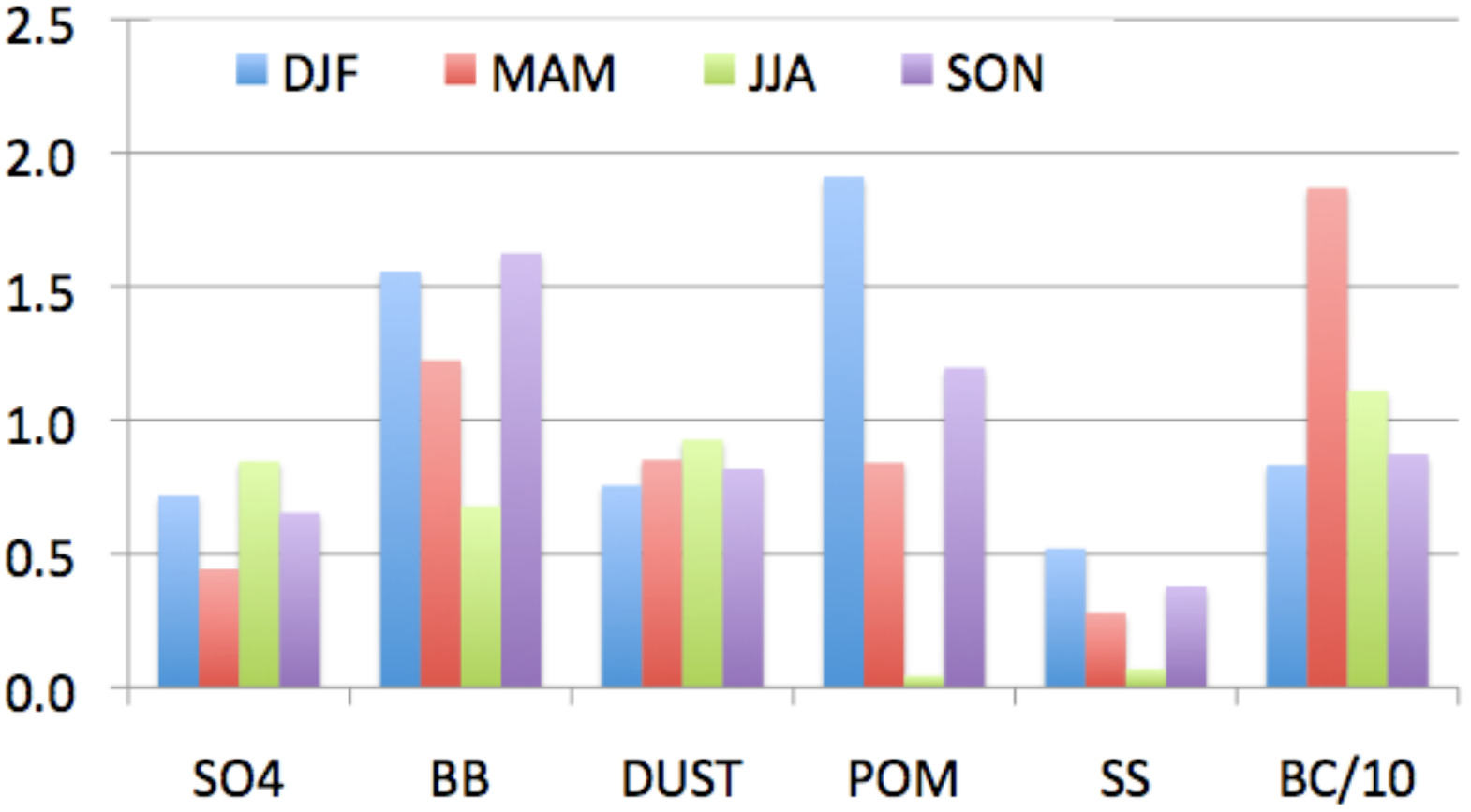
BB
POM
BC
DUST
SS
SO4

Original NAMERICA Fitted

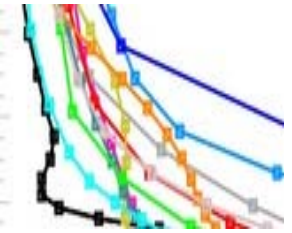


Regression coefficients in World
Calculated for each season





Summary
Interpretation of regression coefficients composition fit to total AOD



SO4: Reduction suggested in Europe/Asia + all seasons

BC: 10fold increase suggested ???

- Covariance with other primary aerosols?
- Underestimate consistent with AAOD evaluation
- Asia and Europe BC underestimates most significant

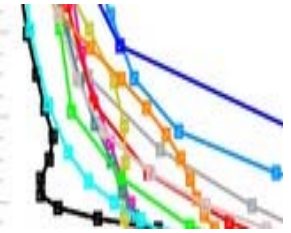
POM: increased suggested in Asia and Namerica

BB: remarkably steady, but seasonal cycle of correction

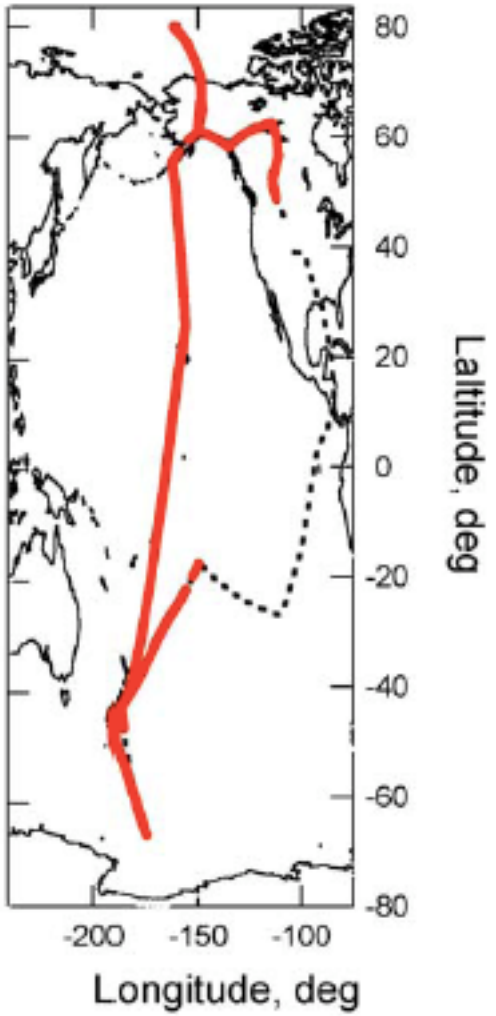
Seasalt: transport into continents overestimated?

Dust: more in America , less in Asia , no seasonal cycle

Discussion
constraints for BC



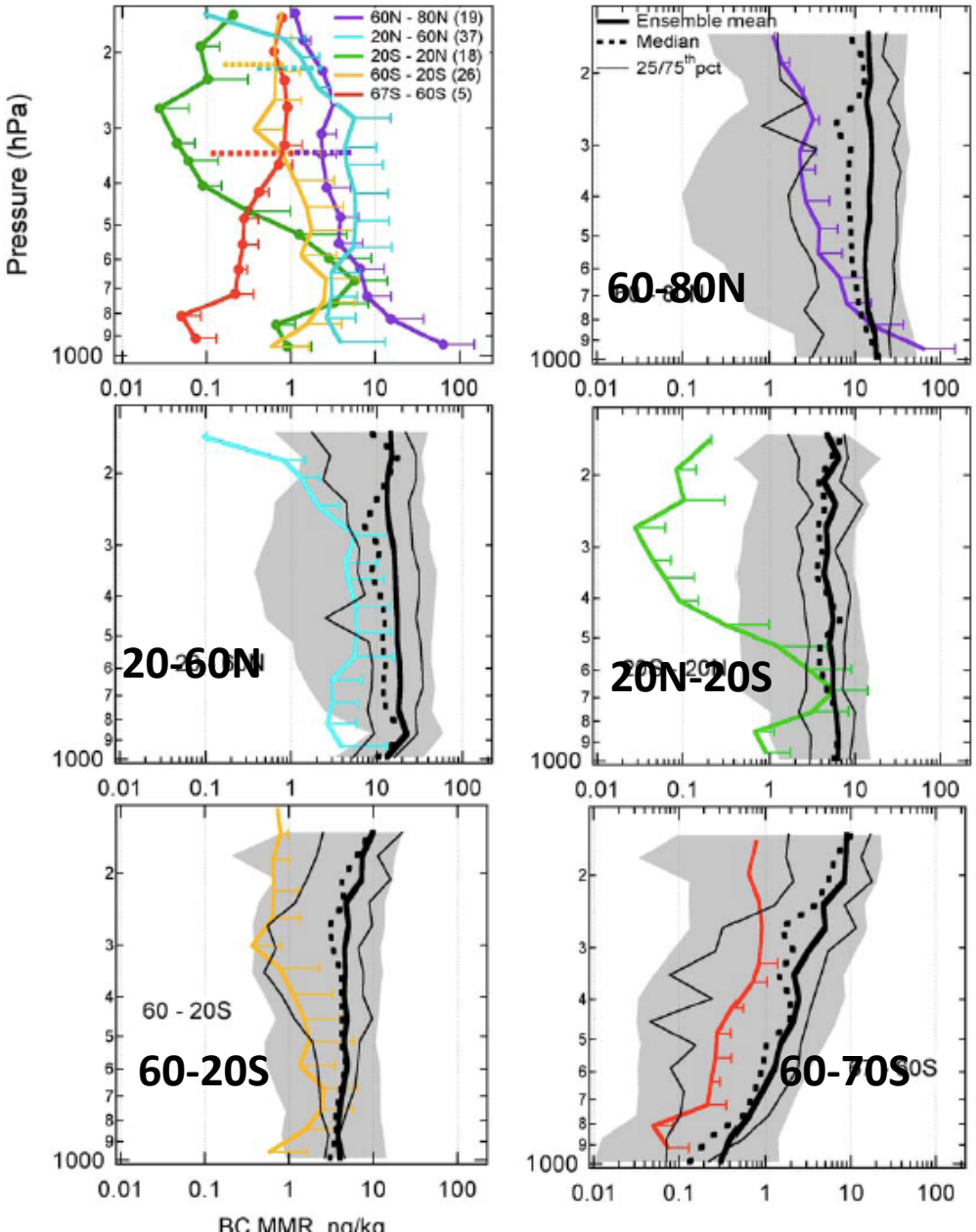
HIPPO flight campaign vs Aerocom models refractory Black Carbon



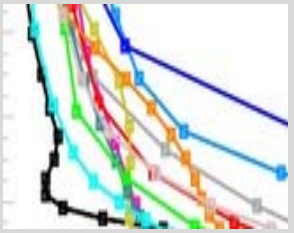
Schwarz et al. GRL 2010

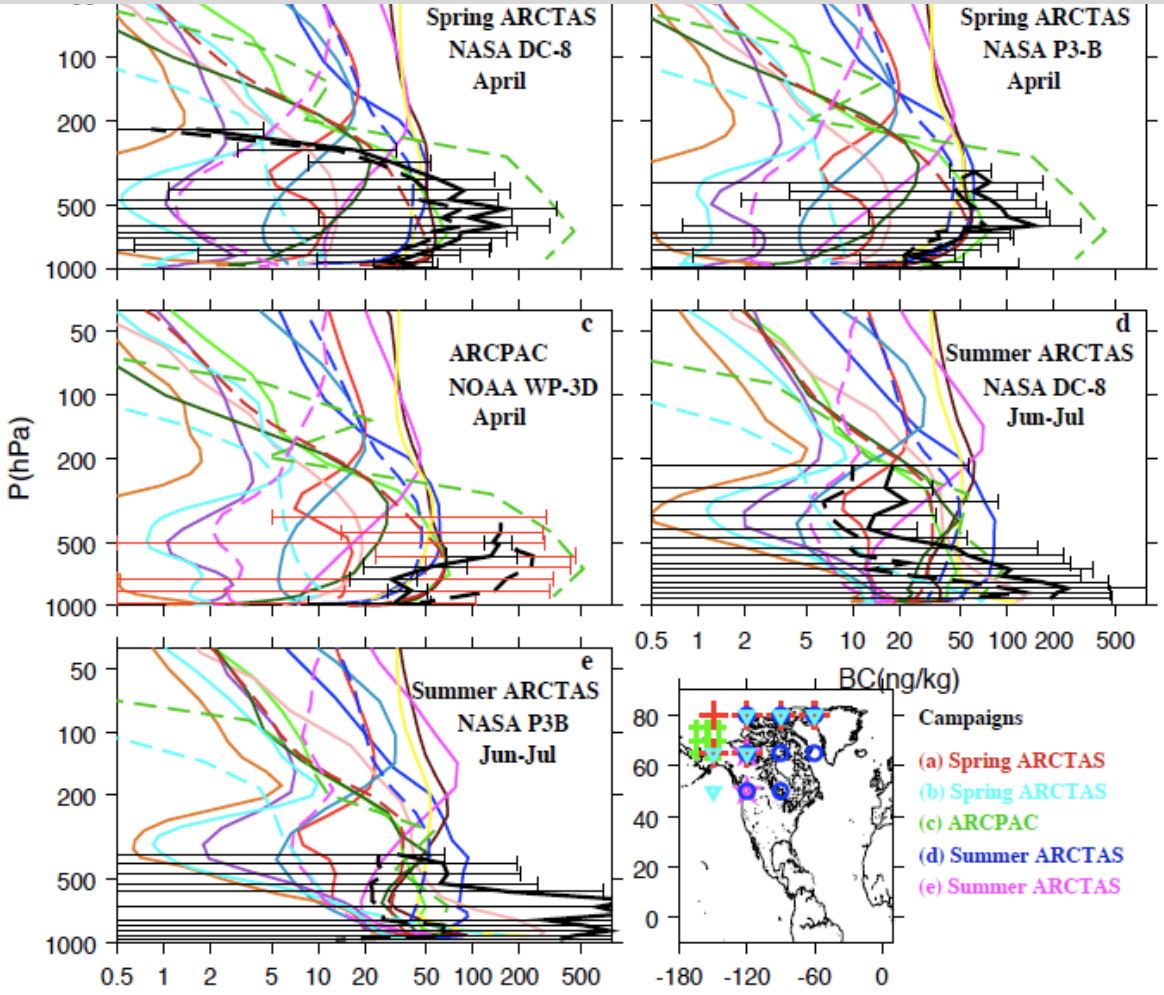
Observed == **measured** BC vertical profiles

Model Median and Range of model results



Vertical distribution of BC in Arctic
SP2 aircraft measurements



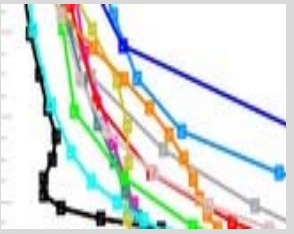


Aircraft campaign Averages

vs MODELS

Koch et al. ACP, 2009

Looking at the Black Carbon Distribution from different angles



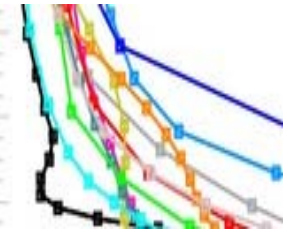
Black Carbon evaluation, AeroCom models against different datasets

Average model biases	N Am	Eur	Asia	S Am	Afr	Rest
	Model/Measurement ratio					
Surface concentration	1.6	2.6	0.50	NA	NA	1.4
BC burden	0.42	0.58	0.64	0.42	0.64	0.40
AERONET AAOD	0.86	0.81	0.67	0.68	0.53	0.55
OMI AAOD	0.52	1.6	0.71	0.35	0.47	0.26

Aircraft rBC , Pacific upper Troposphere Pacific, Overestimate
Aircarft rBC, Arctic mid Troposphere, Underestimate

Koch et al. ACP, 2009

outline for a paper ?



explore use of observations to reduce model uncertainty in direct radiative forcing
(thus emphasis on models with direct radiative forcing estimate in AeroCom)

- ✓ Compare multi-model ensemble to multi-parameter observational dataset
- ✓ Compare phase I and II model submissions
- ✓ Use year of simulation and climatology of obs data to check robustness of quality
- ✓ Document quality of models
- ✓? Find regional AAOD and AOD correction factors (to match observations)
- ? Find regional species-AOD correction factors with multivariate statistics
- ? Adjust regional and species AOD with forcing efficiency for better forcing estimate
- ? Check, if variability in AOD and forcing is reduced
- ? Discuss BC diverse observational constraints specifically
- ? Discuss value of model ensemble AeroCom Median A, B, A2
- ? Discuss anthropogenic fraction uncertainty
- ? Test if weighting models by quality would yield a similar results
- ? Comparison to other forcing estimates
- ? Evaluation against satellite products?