Global dust model intercomparison in AeroCom phase I

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INTRODUCTION

Status of the Article: Manuscript has been accepted to ACPD with minor corrections

Impact on Biogeochemical cycle
- Dust Deposition
- Surface Concentration

Radiative impact (direct effect)
- Aerosol optical depth at 550 nm (total and coarse mode)
- Angström Exponent

AeroCom Models

N	Model	Resolution	Characteristics of size distribution	Reference of emission scheme	Model Reference
3	GISS	5□x4□x20 layers	4 bins 0.1-1-2-4-8 µm	Cakmur et al., 2006)	Schmidt et al., 2006); Bauer and Koch, 2005); Miller et al., 2006)
4	GOCART	2□x2.5□x30 layers	5 bins[1] 0.1-1.0-1.8-3.0-6.0-10.0	Ginoux et al., 2001)	Chin et al., 2000)
5	SPRINTARS	1.125□x1.125□x20 layers	6 bins 0.1-0.22-0.46-1.0-2.15-4.64-10.0	Takemura et al., 2009)	Takemura et al., 2005)
6	LOA	3.75□x2.5□x19 layers	2 bins[2] 0.03-0.5-20 µm	Balkanski et al., 2004)	Reddy et al., 2005a, Reddy et al., 2005b)
7	LSCE	3.75□x2.5□x19 layers	1 mode mmr=1.25 µm σ0=2.0	Balkanski et al., 2004)	Schulz, 2007)
8	MATCH	1.9□x1.9□x28 layers	4 bins 0.1-1.0-2.5-5.0-10	Zender et al., 2003)	Zender et al., 2003)
9	MOZGN	1.9°x1.9°x28 layes	5 bins 0.1-1.0-1.8-3.0-6.0-10.0	Ginoux et al., 2001)	Horowitz et al., 2003); Tie et al., 2005)
10	ECHAM5-HAM	1.8□x1.8□x31 layers	2 modes mmr=0.37,1.75 µm σ0=1.5,2.0	Tegen et al., 2002)	Stier et al., 2005)
11	MIRAGE	2.5□x2.0□x24 layers	4 modes[3] mmr= 0.03,0.16,2.1,2.5 µm σ0=1.6,1.8,1.8,2.0	Ginoux et al., 2001)	Ghan and Easter, 2006)
12	TM5	6□x4□global 1□x1□North America and Europe 25 layers	2 modes mmr=µm σ0=1.59,2.0	Dentener et al., 2006)	Krol et al., 2005); de Meij et al., 2006)
13	UIO_CTM	2.8□x2.8□x40 layers	8 bins 0.03-0.07-0.16-0.37-0.87-2.01-4.65-10.79-25	Grini et al., 2005)	Berglen et al., 2004); Myhre et al., 2007)
14	UMI	2.5□x2□x30 layers	4 bins 0.05-0.63-1.25-2.5-10 um radius	Ginoux et al., 2001)	Liu and Penner, 2002), Liu et al., 2007)

Models **ARQM, DLR, ULAQ, UIO_GCM** were not considered due to a configuration not fit for the comparison.

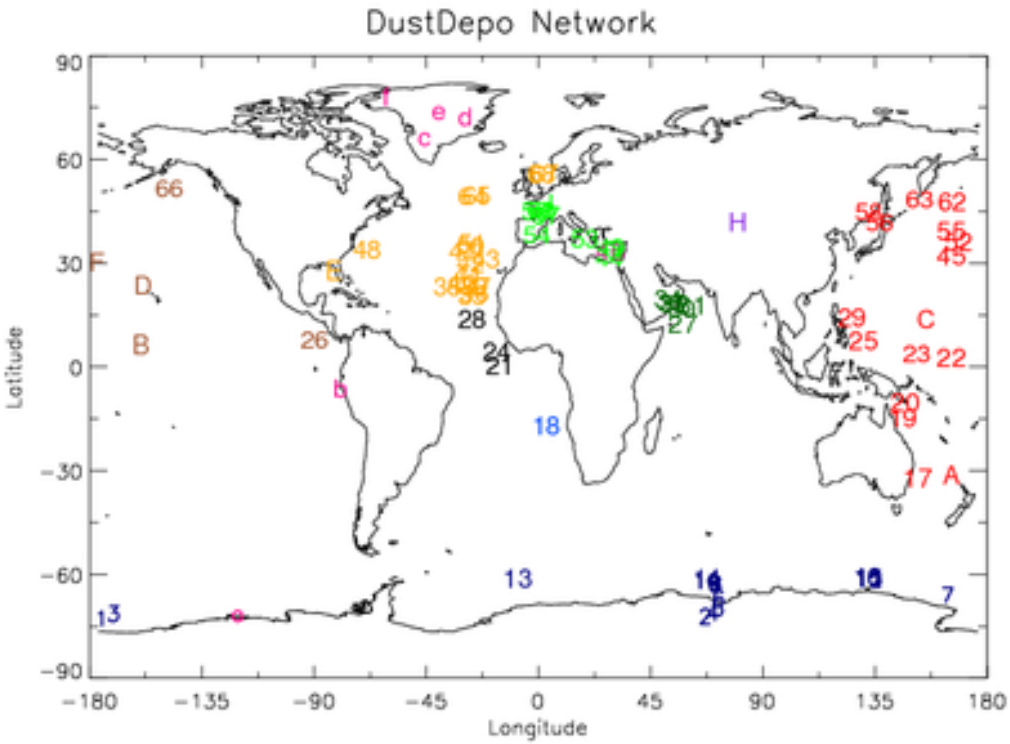
AeroCom Models

AeroCom Median was constructed using the following models for each analyzed variable:

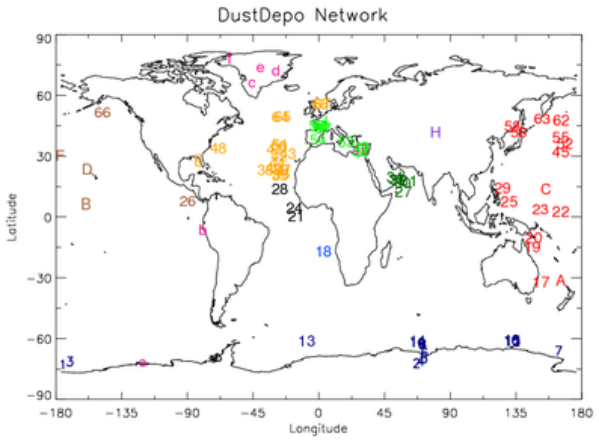
Model	AOD	AE	SCONC	DEPO
CAM				
ECMWF				
GISS	x		x	x
GOCART	x		x	x
SPRINTARS	x	x	x	x
LOA	x	x	x	x
LSCE	x	x	x	x
MATCH	x	x	x	x
MOZGN	x	x	x	x
ECHAM5-HAM	x	x	x	x
MIRAGE	x	x		x
TM5	x	x	x	x
UIO_CTM	x	x	x	x
UMI	x	x	x	x

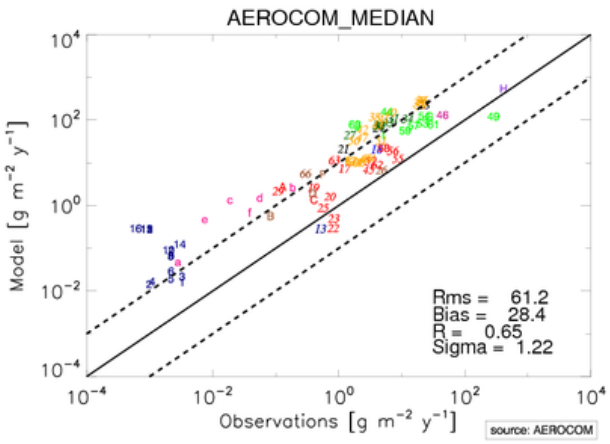
Dust Deposition

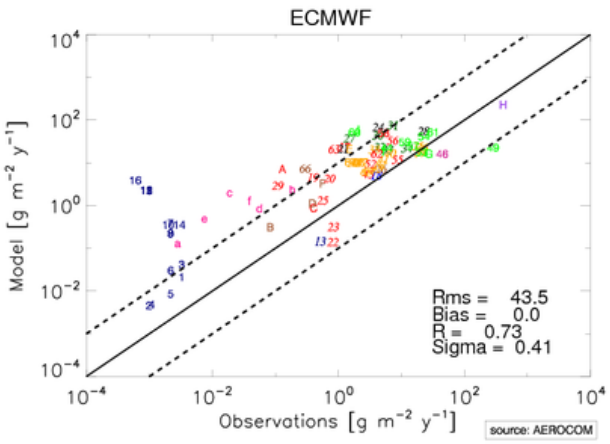
- Total Deposition:
  - -Ginoux et al. (2001) (Capital letters)
  - -Mahowald et al. (2009) (non italic numbers)
  - -DIRTMAP (italic numbers)
  - -Mahowald et al. (1999) (lower case letters)

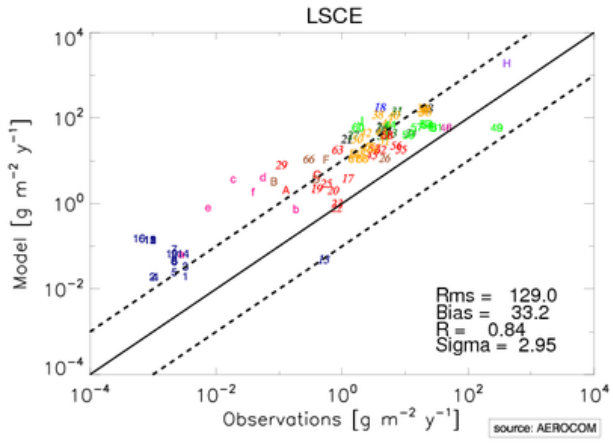


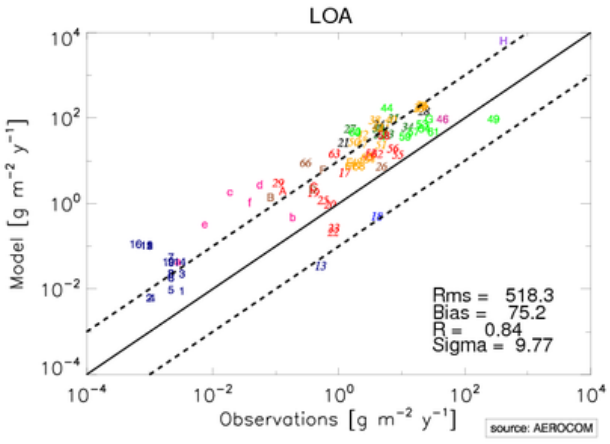
- Total & Wet Deposition
  - -Florida Atmospheric Mercury Study (FAMS) network, April 1994 till end of 1996 (Prospero et al., 2010).

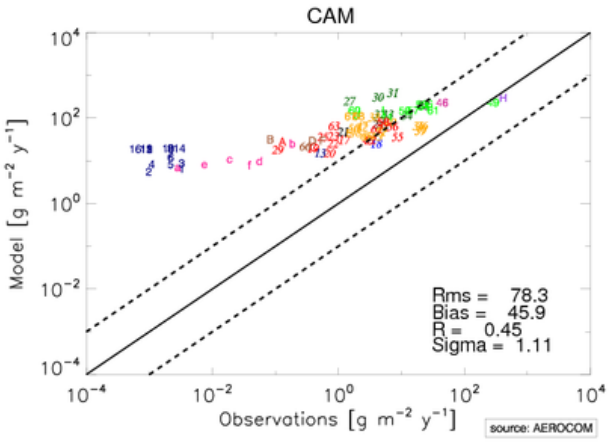

DustDepo Network
Latitude
Longitude

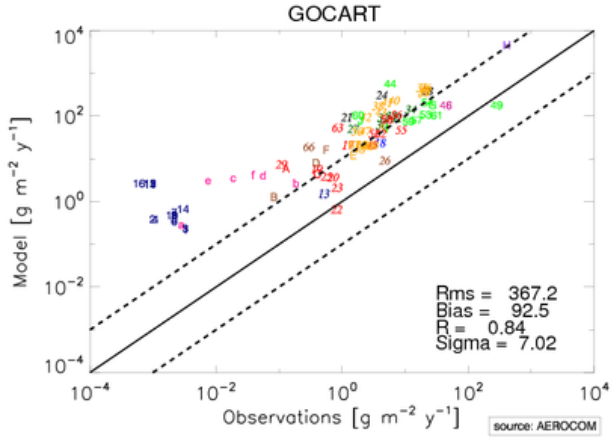

AEROCOM_MEDIAN
Rms = 61.2
Bias = 28.4
R = 0.65
Sigma = 1.22
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM

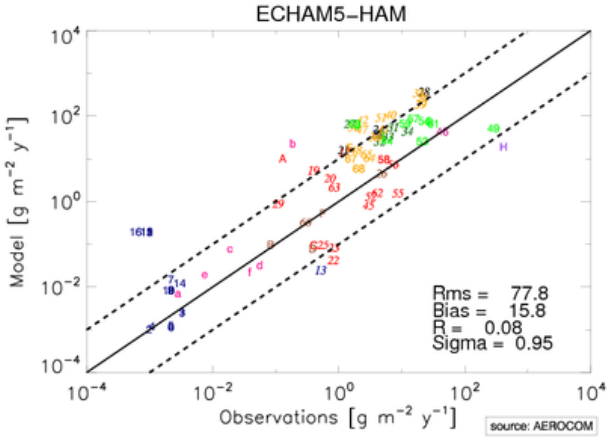

ECMWF
Rms = 43.5
Bias = 0.0
R = 0.73
Sigma = 0.41
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM

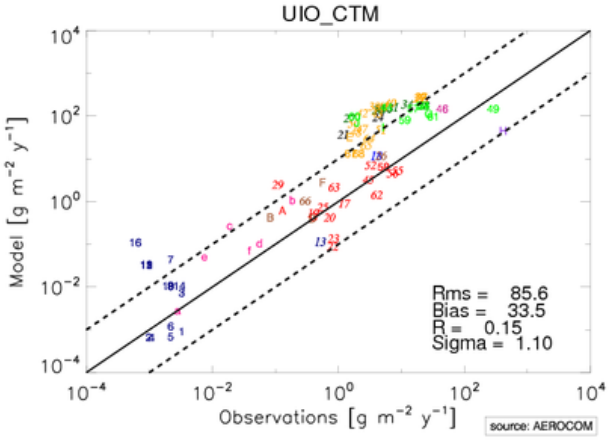

LSCE
Rms = 129.0
Bias = 33.2
R = 0.84
Sigma = 2.95
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM


LOA
Rms = 518.3
Bias = 75.2
R = 0.84
Sigma = 9.77
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM


CAM
Rms = 78.3
Bias = 45.9
R = 0.45
Sigma = 1.11
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM


GOCART
Rms = 367.2
Bias = 92.5
R = 0.84
Sigma = 7.02
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM

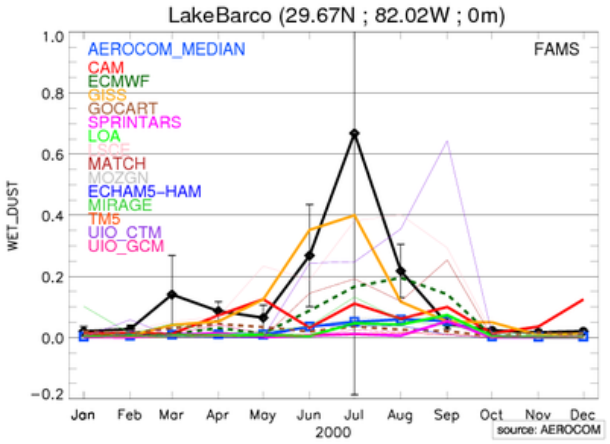

ECHAM5-HAM
Rms = 77.8
Bias = 15.8
R = 0.08
Sigma = 0.95
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM

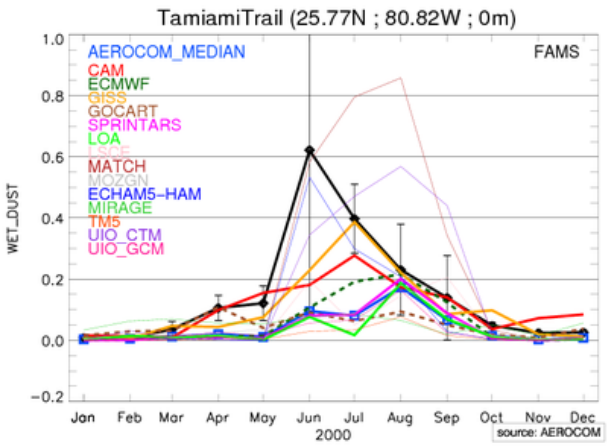

UIO_CTM
Rms = 85.6
Bias = 33.5
R = 0.15
Sigma = 1.10
Model [g m-2 y-1]
Observations [g m-2 y-1]
source: AEROCOM

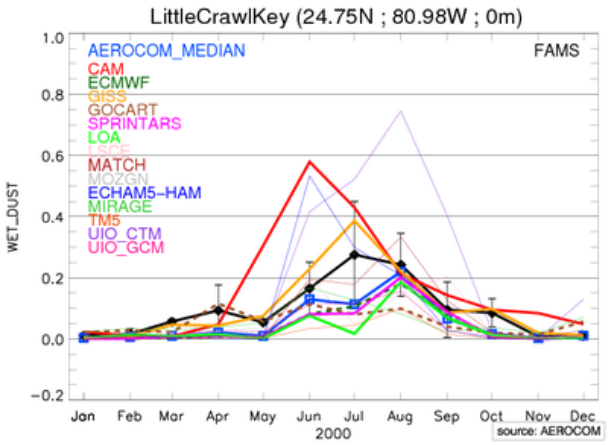
North

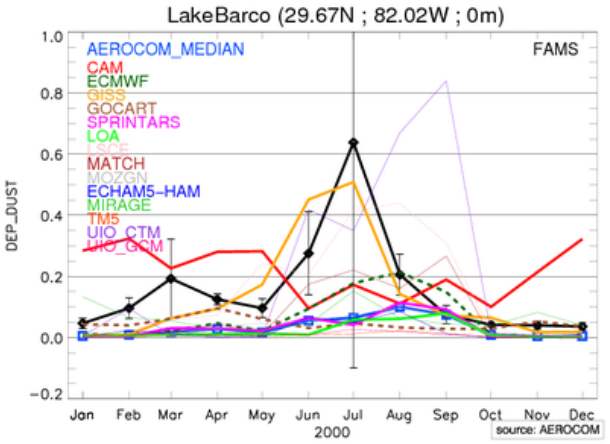
Wet Deposition

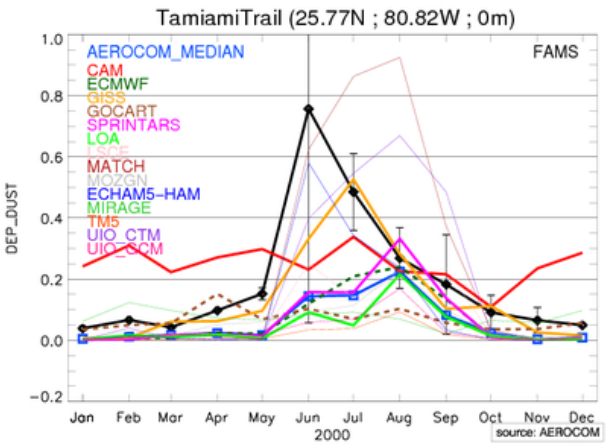
South

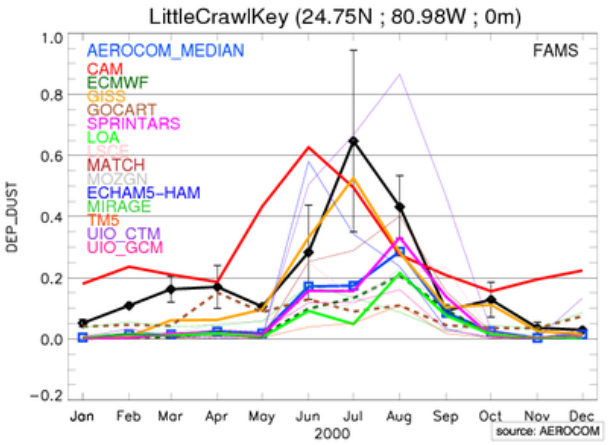












North

Total Deposition

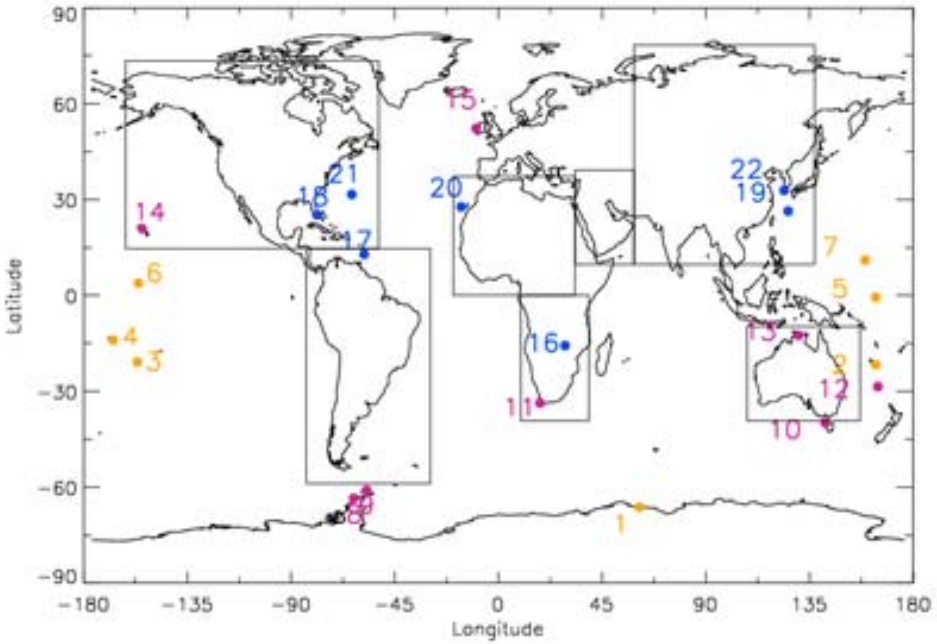
South

Surface Concentration

- Climatology

-SEAREX & AEROCE data + data at Rukomechi (Zimbabwe) and Jabiru (Australia).

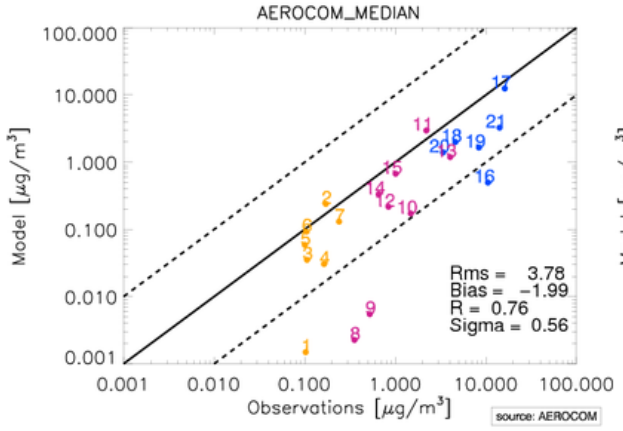
- **Low conc** <1 μg/m^3 (orange)
- **Medium conc**: stations dominated by sources of the SH or remote sites in the NH (violet).
- **High conc**: downwind of main sources in NH (blue).

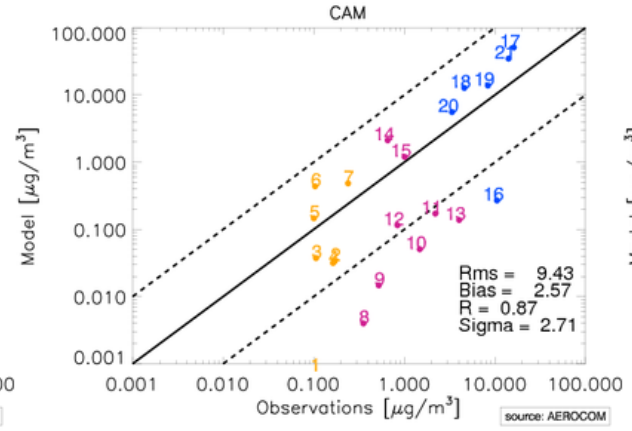


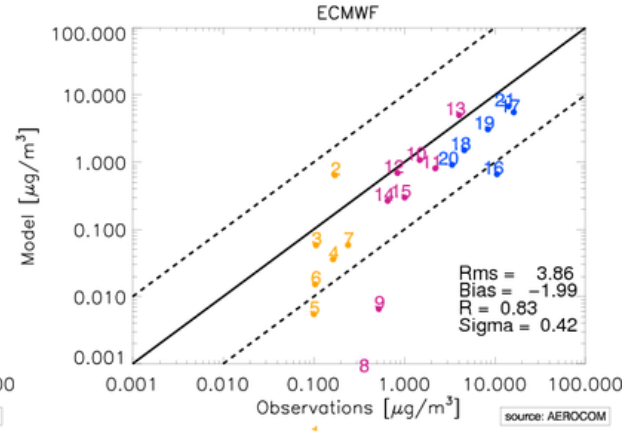
-Mahowald et al. (2009). Cruise data, short term (Not shown)

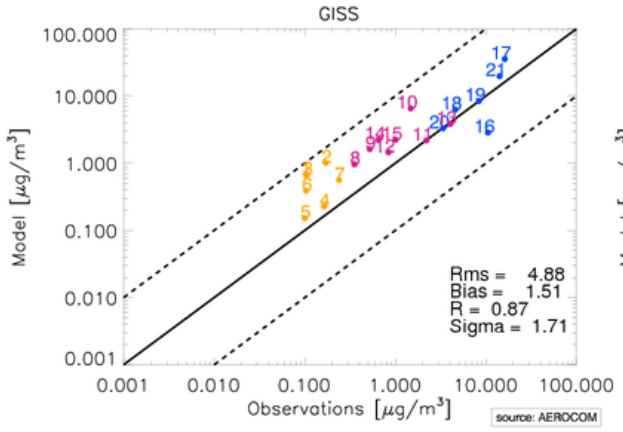
- Present measurements

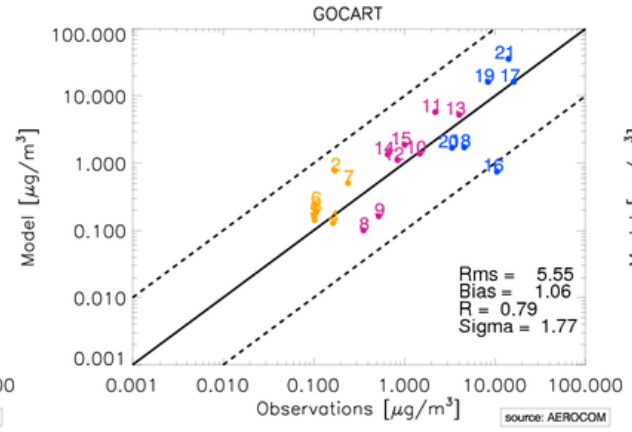
-Surface concentrations at Barbados & Miami for the year 2000

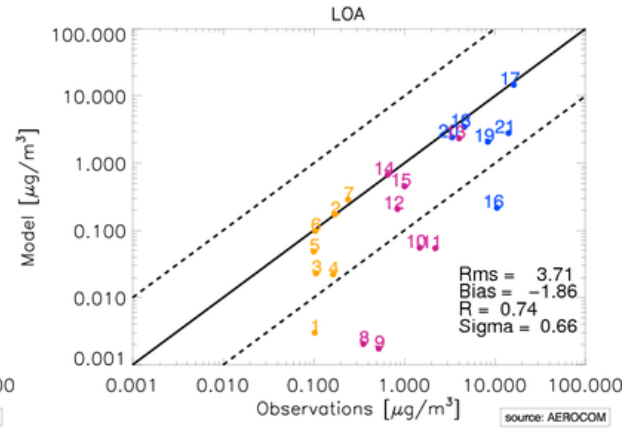

AEROCOM_MEDIAN
Rms = 3.78
Bias = −1.99
R = 0.76
Sigma = 0.56
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM

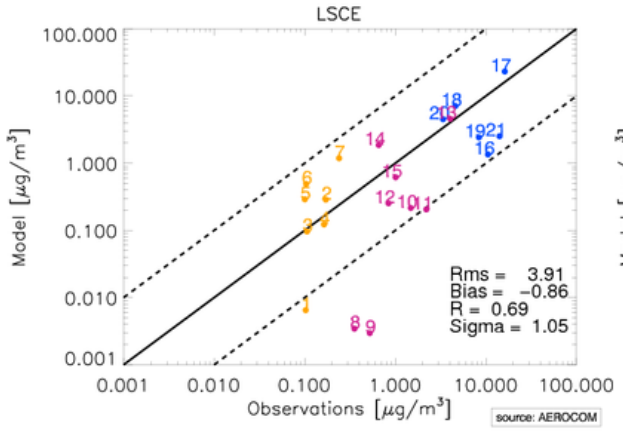

CAM
Rms = 9.43
Bias = 2.57
R = 0.87
Sigma = 2.71
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM

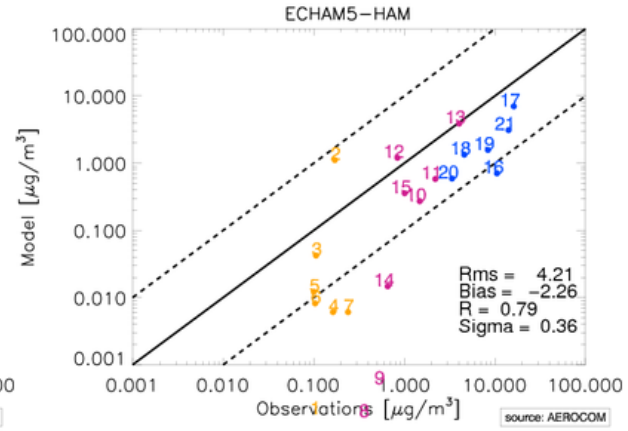

ECMWF
Rms = 3.86
Bias = −1.99
R = 0.83
Sigma = 0.42
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM

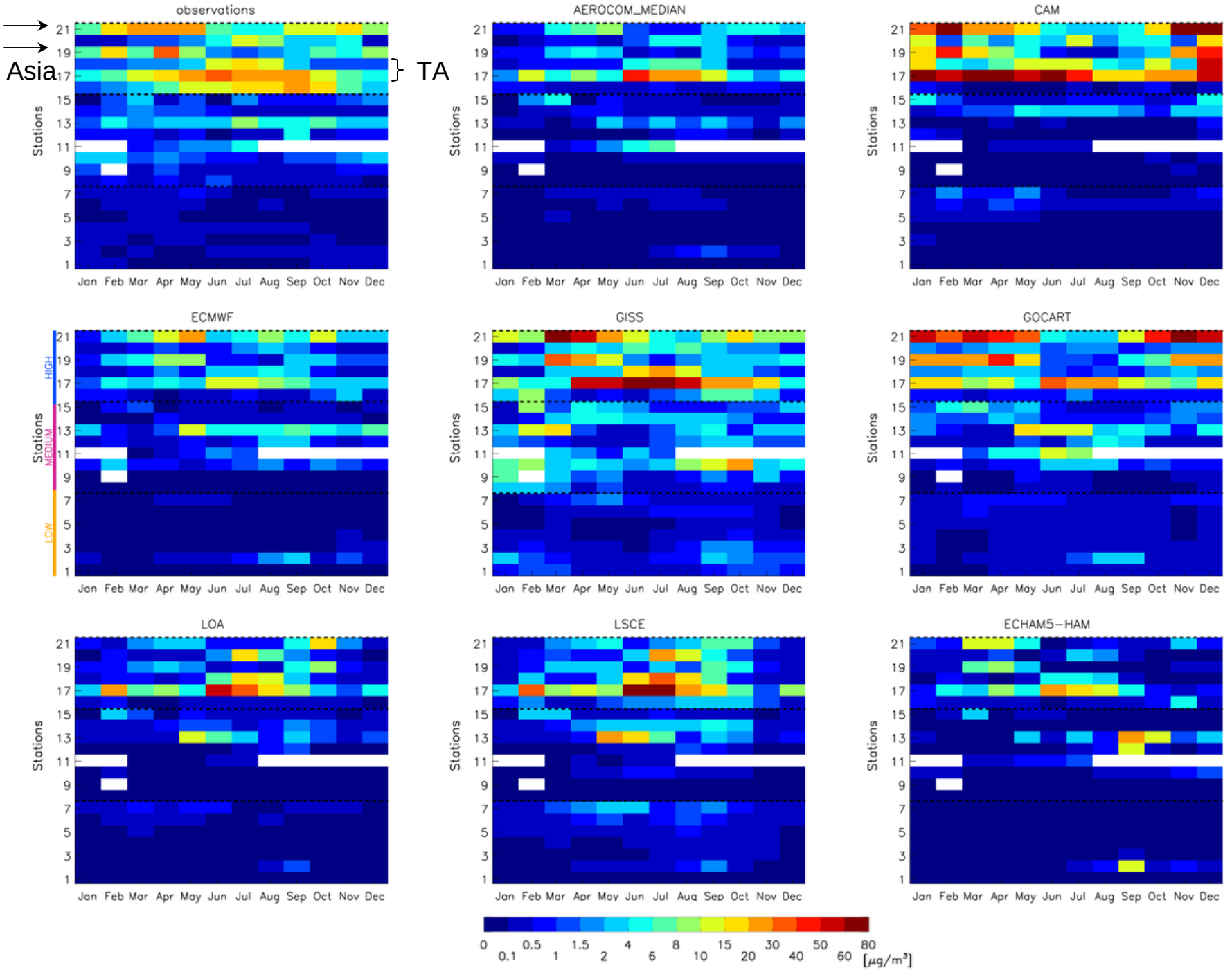

GISS
Rms = 4.88
Bias = 1.51
R = 0.87
Sigma = 1.71
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM


GOCART
Rms = 5.55
Bias = 1.06
R = 0.79
Sigma = 1.77
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM

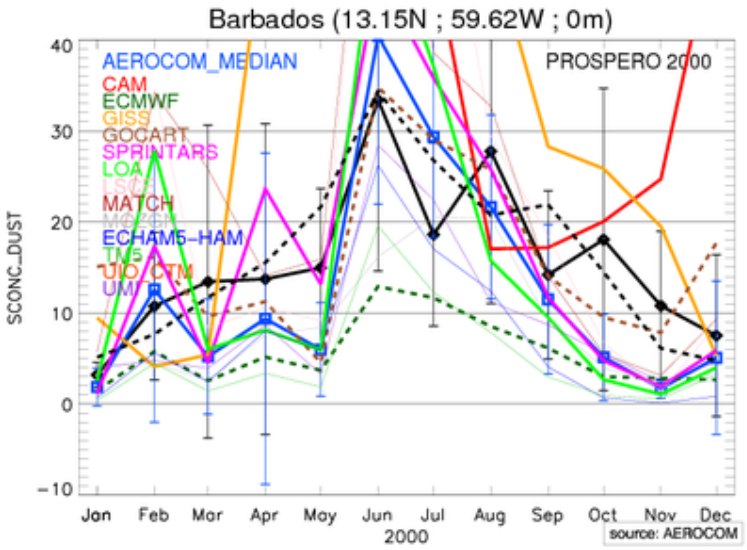

LOA
Rms = 3.71
Bias = −1.86
R = 0.74
Sigma = 0.66
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM

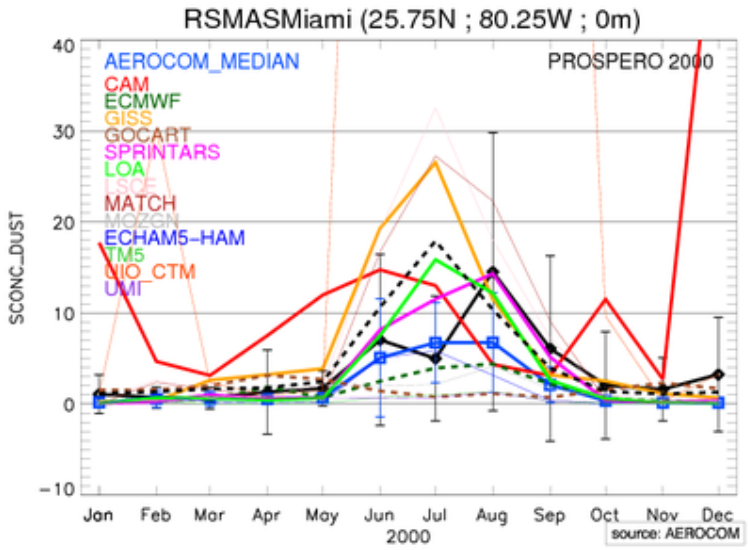

LSCE
Rms = 3.91
Bias = −0.86
R = 0.69
Sigma = 1.05
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM


ECHAM5−HAM
Rms = 4.21
Bias = −2.26
R = 0.79
Sigma = 0.36
Model [μg/m³]
Observations [μg/m³]
source: AEROCOM


observations
AEROCOM_MEDIAN
CAM
ECMWF
GISS
GOCART
LOA
LSCE
ECHAM5−HAM
Asia
TA
Stations
HIGH
MEDIUM
LOW
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
0 0.1 0.5 1 1.5 2 4 6 8 10 15 20 30 40 50 60 80 [μg/m³]

Surface Concentration





AOD & Angström Exponent

- Dusty Stations

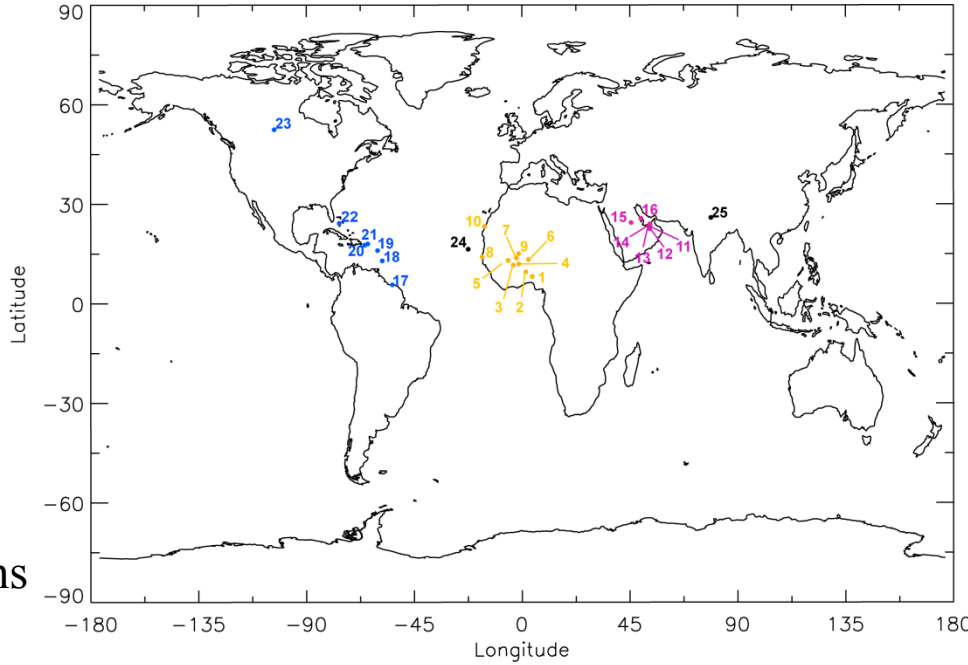
Angström exponent

$\alpha < 0.4$ Natural aerosols

$\tilde{}$ □□ α □ı□Mixture

$\alpha > 1.2$ Anthropogenic Aerosols

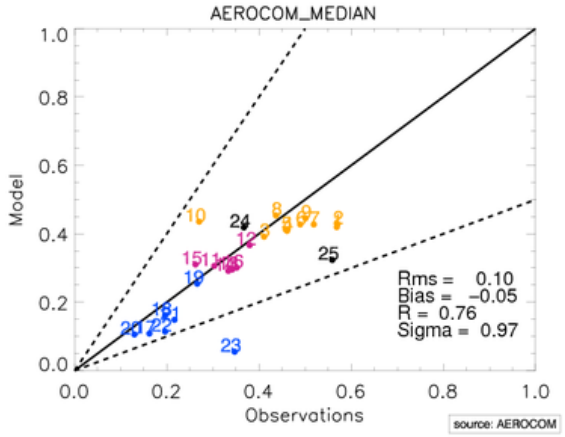
AOD $\tau < 0.2$ Sea salt AERONET stations (Dubovik et al., 2002)

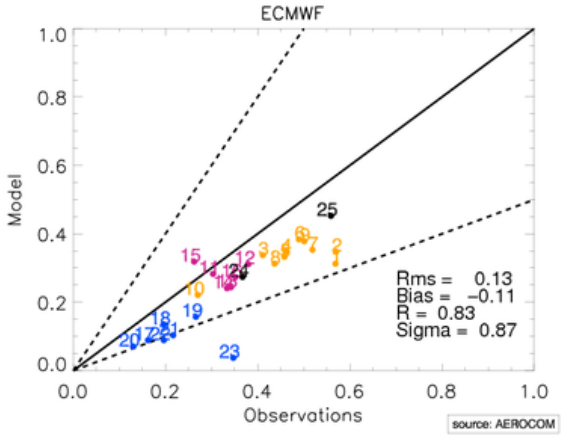


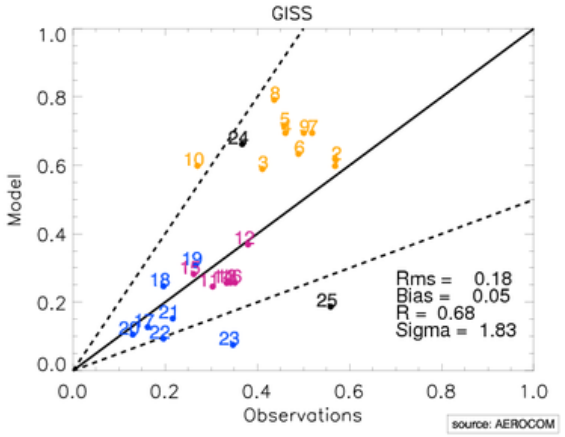
Dusty stations: stations where $\alpha<0.4$ and $\tau>0.2$ for at least two month

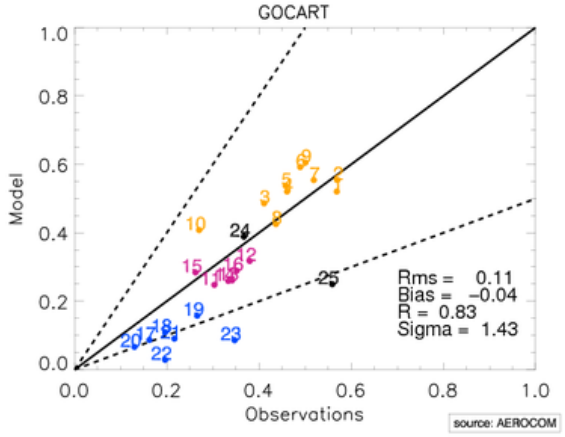
- Climatology (25 Stations)
- Year 2000 (8 Stations) ➡ Only days with obs are considered

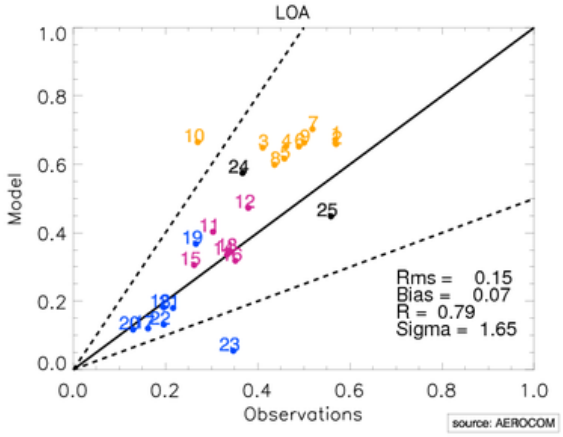
In the analysis month dominated with aerosol mixture (at dusty sites) are also considered

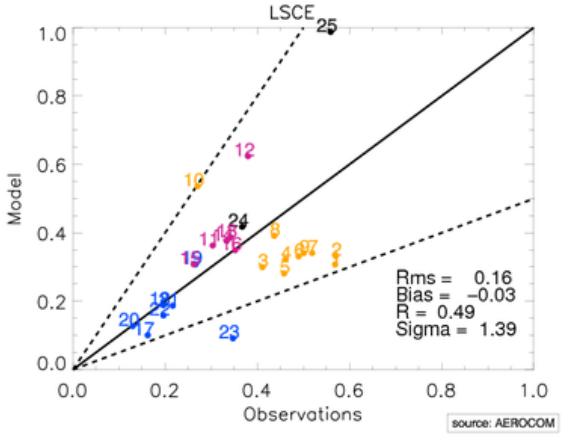

AEROCOM_MEDIAN
Model
Observations
Rms = 0.10
Bias = −0.05
R = 0.76
Sigma = 0.97
source: AEROCOM

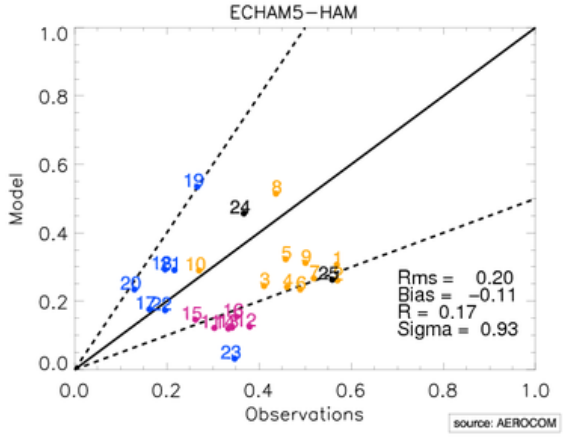

ECMWF
Model
Observations
Rms = 0.13
Bias = −0.11
R = 0.83
Sigma = 0.87
source: AEROCOM

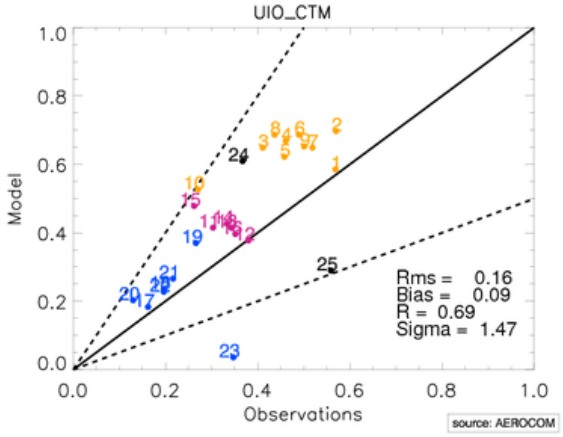

GISS
Model
Observations
Rms = 0.18
Bias = 0.05
R = 0.68
Sigma = 1.83
source: AEROCOM


GOCART
Model
Observations
Rms = 0.11
Bias = −0.04
R = 0.83
Sigma = 1.43
source: AEROCOM

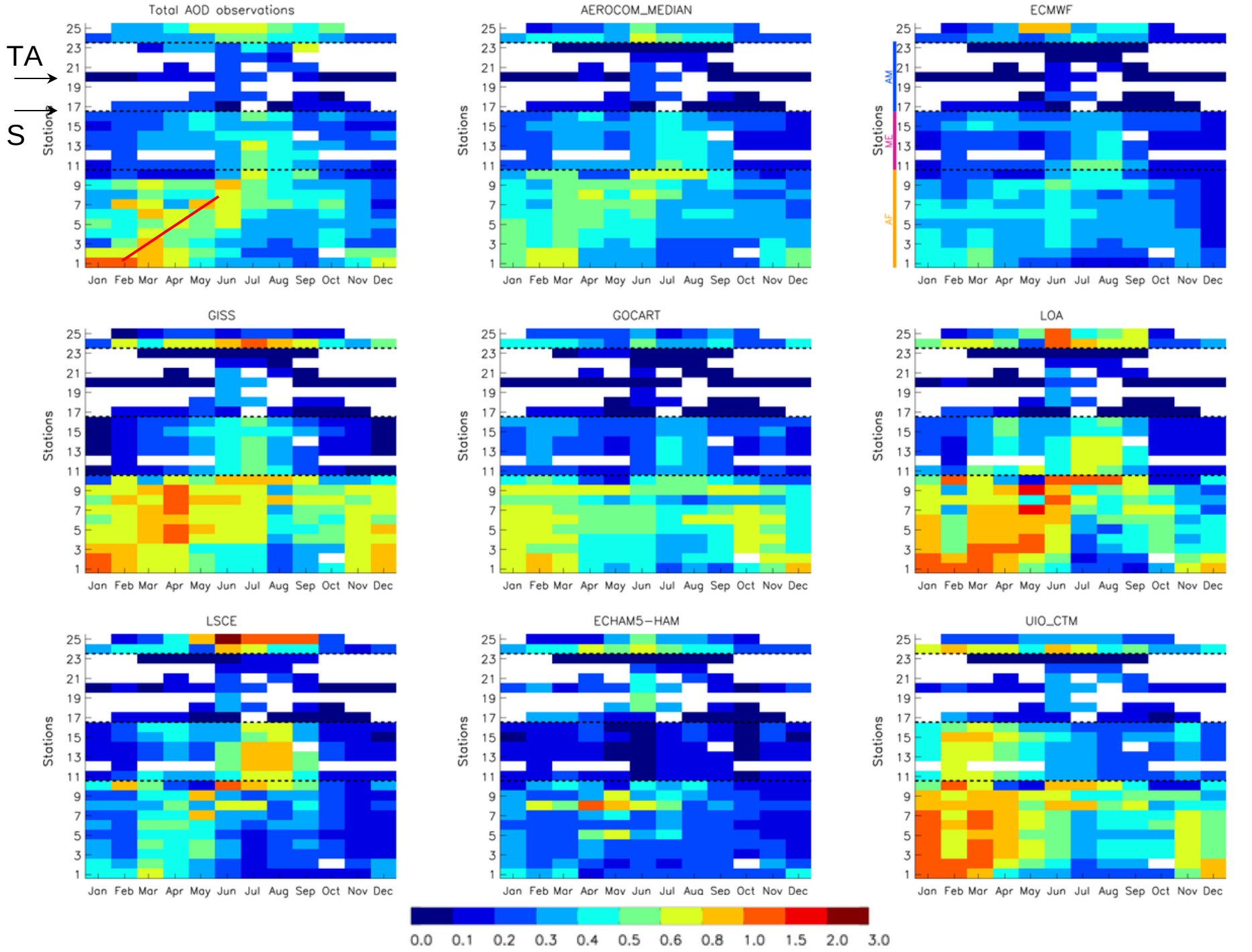

LOA
Model
Observations
Rms = 0.15
Bias = 0.07
R = 0.79
Sigma = 1.65
source: AEROCOM

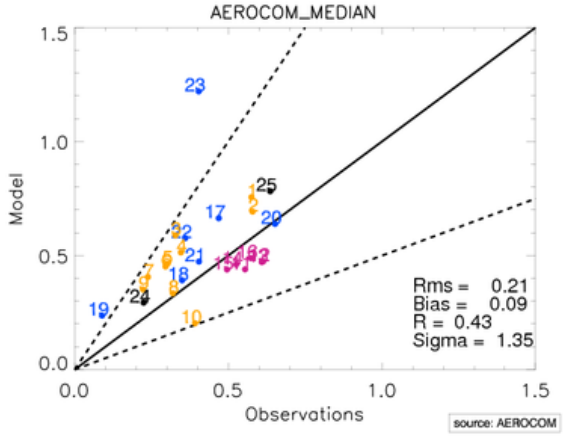

LSCE
Model
Observations
Rms = 0.16
Bias = −0.03
R = 0.49
Sigma = 1.39
source: AEROCOM

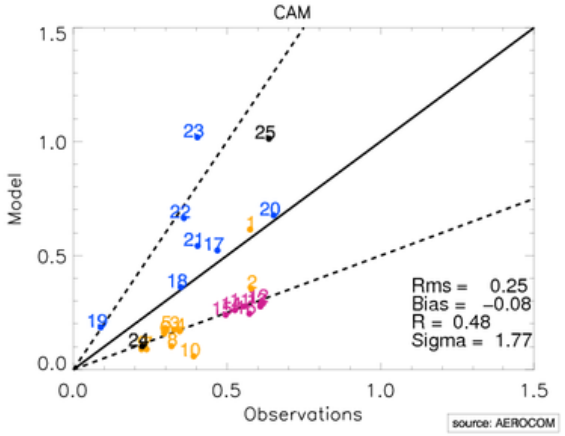

ECHAM5−HAM
Model
Observations
Rms = 0.20
Bias = −0.11
R = 0.17
Sigma = 0.93
source: AEROCOM

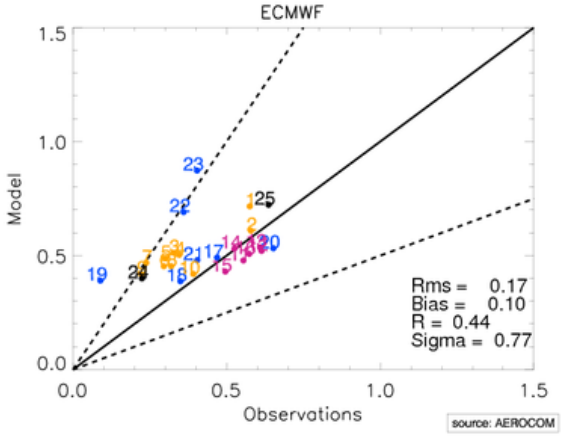

UIO_CTM
Model
Observations
Rms = 0.16
Bias = 0.09
R = 0.69
Sigma = 1.47
source: AEROCOM

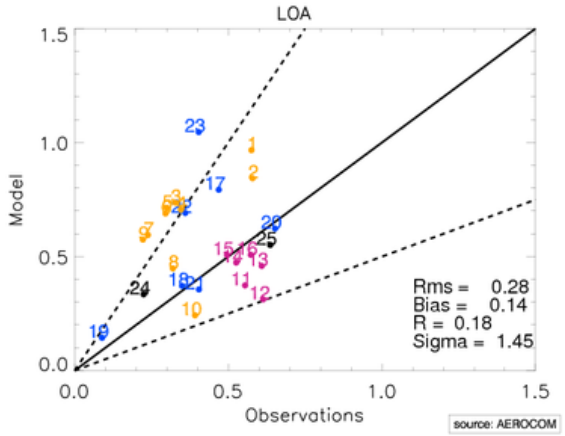
AOD

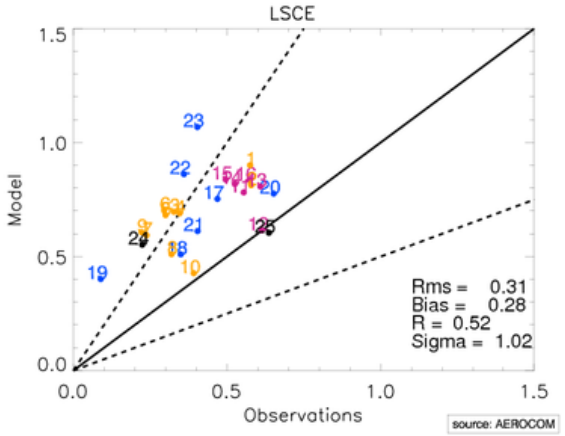

Total AOD observations
AEROCOM_MEDIAN
ECMWF
GISS
GOCART
LOA
LSCE
ECHAM5−HAM
UIO_CTM
TA
S
Stations
AM
ME
AF
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.8 1.0 1.5 2.0 3.0

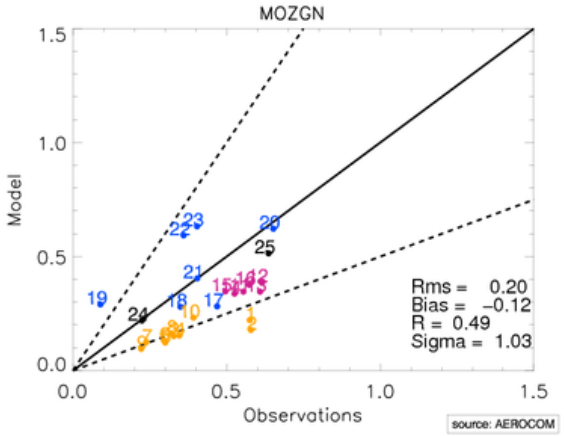


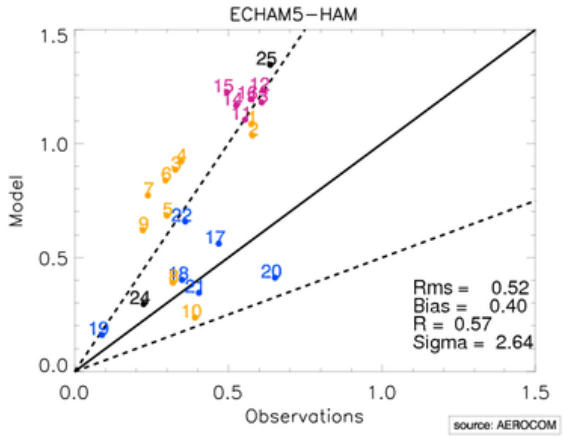


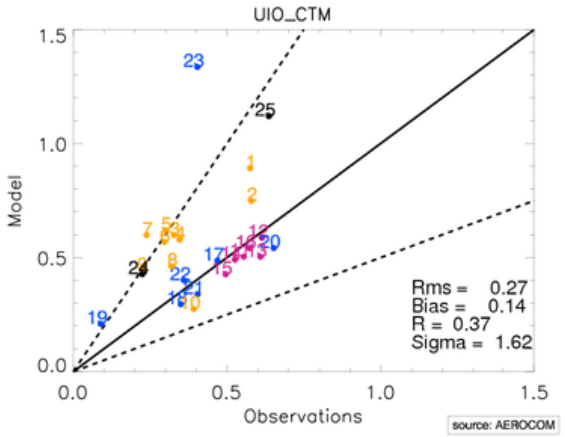




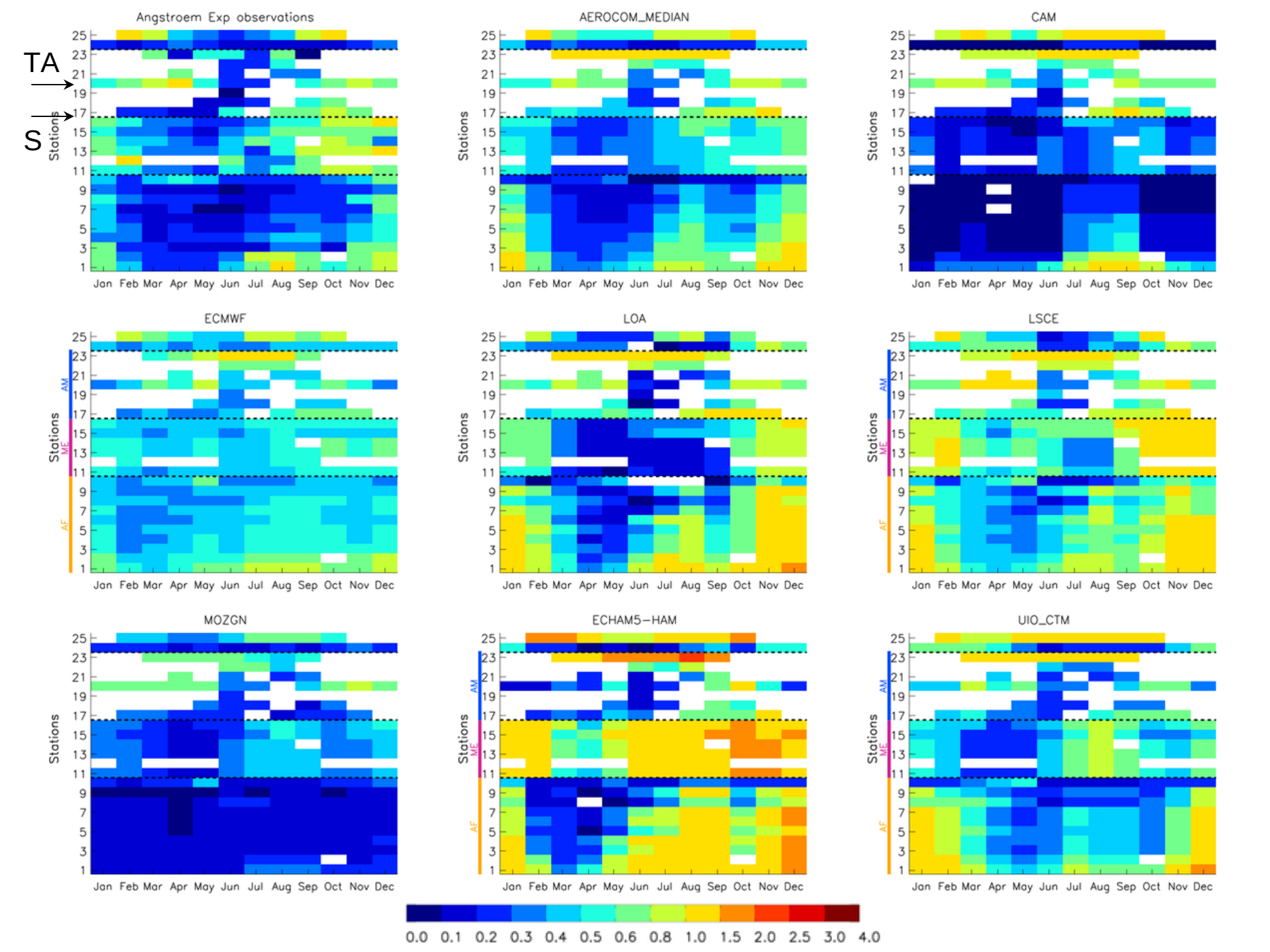




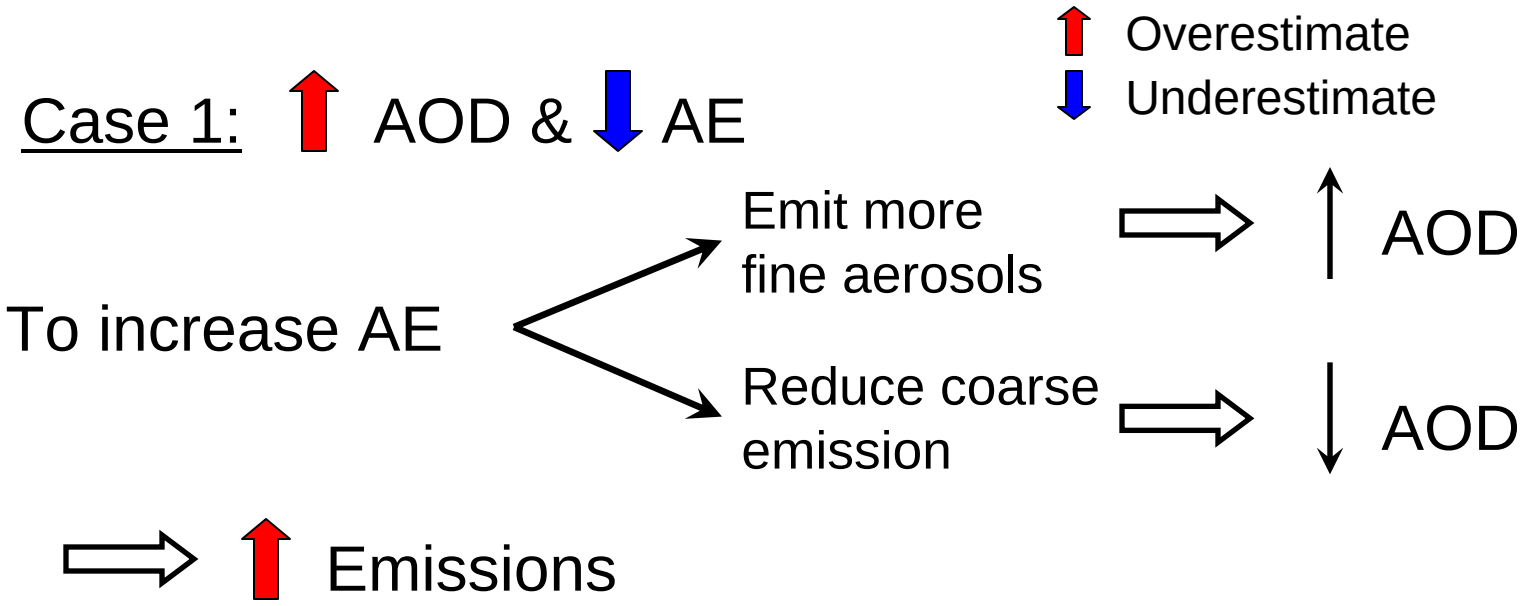




Angström Exponent (AE)

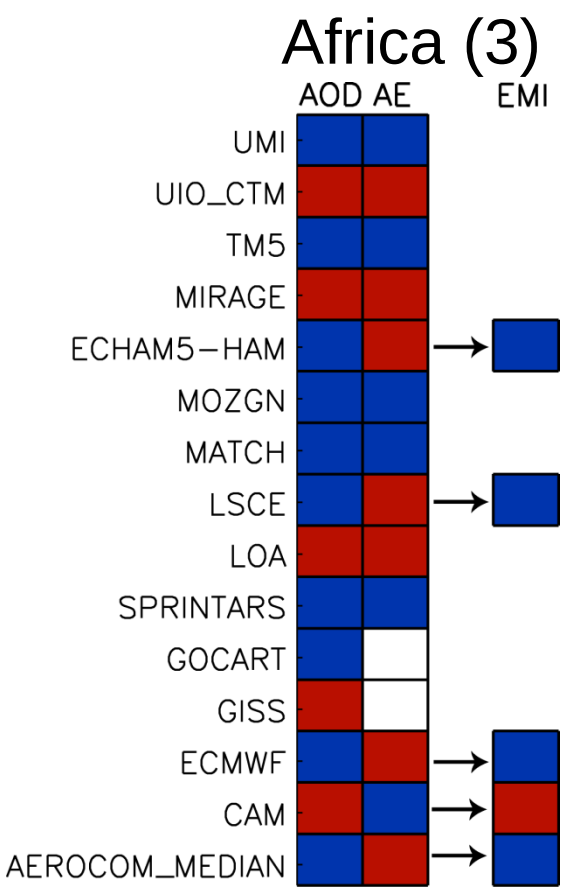

Angstroem Exp observations
AEROCOM_MEDIAN
CAM
ECMWF
LOA
LSCE
MOZGN
ECHAM5−HAM
UIO_CTM
TA
S
Stations
AM
ME
AF
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.8 1.0 1.5 2.0 2.5 3.0 4.0

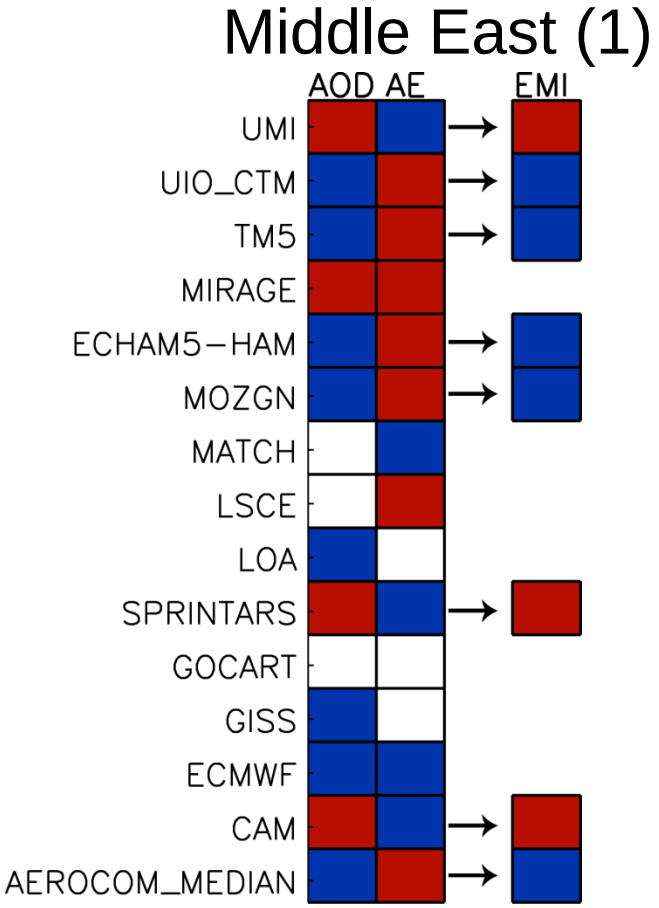
Emission


Overestimate
Underestimate
Case 1: AOD & AE
To increase AE
Emit more fine aerosols
AOD
Reduce coarse emission
AOD
Emissions
Case 2: AOD & AE
Emissions
Case 3: AOD & AE
Case 4: AOD & AE
Not Conclusive

Emission

- Only data of year 2000 are considered



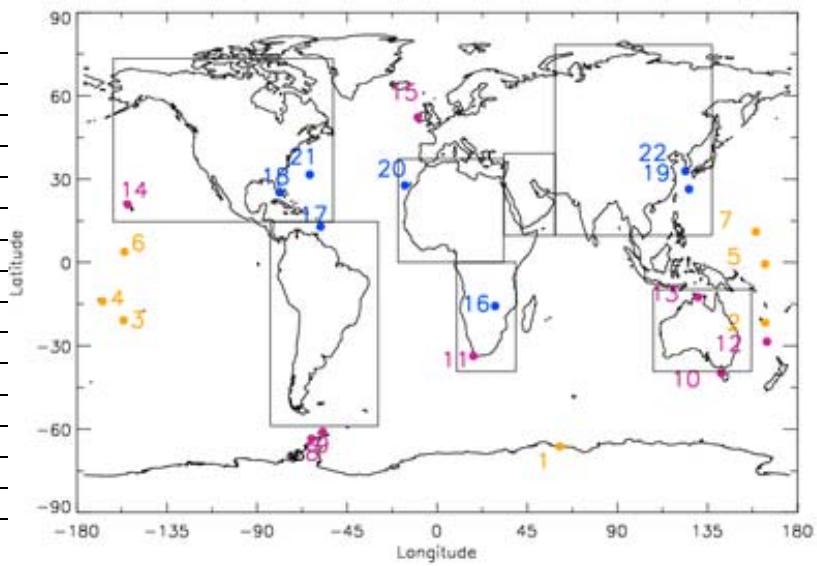


Overestimation

Underestimation

Emission

	North Africa	Middle East	Asia	South America	South Africa	Australia	North America
AEROCOM MEDIAN	**792**	**128**	137	9,8	11,8	30,7	2,0
CAM	**2271**	**526**	727	13,7	2,9	12,2	286
ECMWF	**204**	68	125	1,0	16,3	57,0	15,3
GISS	1031	125	180	39,9	31,7	87,8	7,3
GOCART	1736	348	873	66,5	25,0	111	13,0
SPRINTARS	2888	**531**	363	6,9	113	36,8	4,1
LOA	772	114	411	0,5	3,5	14,9	4,5
LSCE	**529**	39,2	509	0,2	57,2	10,6	7,2
MATCH	539	241	100	19,3	24,5	40,9	2,4
MOZGN	1410	**376**	294	92,8	55,4	89,5	12,7
ECHAM5-HAM	**401**	**25,6**	54	3,7	40,2	58,4	1,7
MIRAGE	703	292	608	186	25,0	129	70,8
TM5	1091	**212**	253	30,4	15,3	59,4	8,1
UIO_CTM	1213	**206**	27	5,0	11,6	9,0	1,8
UMI	933	**329**	340	47,1	20,6	35,4	6,1



⇨ North Africa { < 2271 Tg/yr (1803 Tg/yr) Cakmur et al. (2006); > 792 Tg/yr (964Tg/yr) }

Middle East { < 526 Tg/yr (132 Tg/yr); > 376 Tg/yr (23Tg/yr) }

Estimation for ME is based only on 1 station and 1 year whereas Cakmur et al. (2006) uses different datasets and 5 years of simulation

⇨ Range of emissions 514 - 4313 Tg/yr → 1162 - 4326 Tg/yr

Conclusion

•Models agree in largely overestimating the dust deposition over most of the globe. Differences in model performance exists in remote regions.

•Models reproduce better climatology of vertically integrated variables than surface variables. Data quality might explain some of the difference but not all of it.

•Dust transport across the Atlantic is simulated but difficulties arise in reproducing its north & southward displacement though the year

•Asian dust was not explored due to definition of dust sources, but surface concentration data suggest that models simulate better transatlantic dust transport than asian dust over the Pacific Ocean.

•Emission in the Sahara < 2271 TG/yr and > 792 Tg/yr. In the Middle East emissions < 526 Tg/yr and > 376 Tg/yr.

•New range of dust emissions is 1162 - 4326 Tg/yr (instead of 514-4313 Tg/yr)

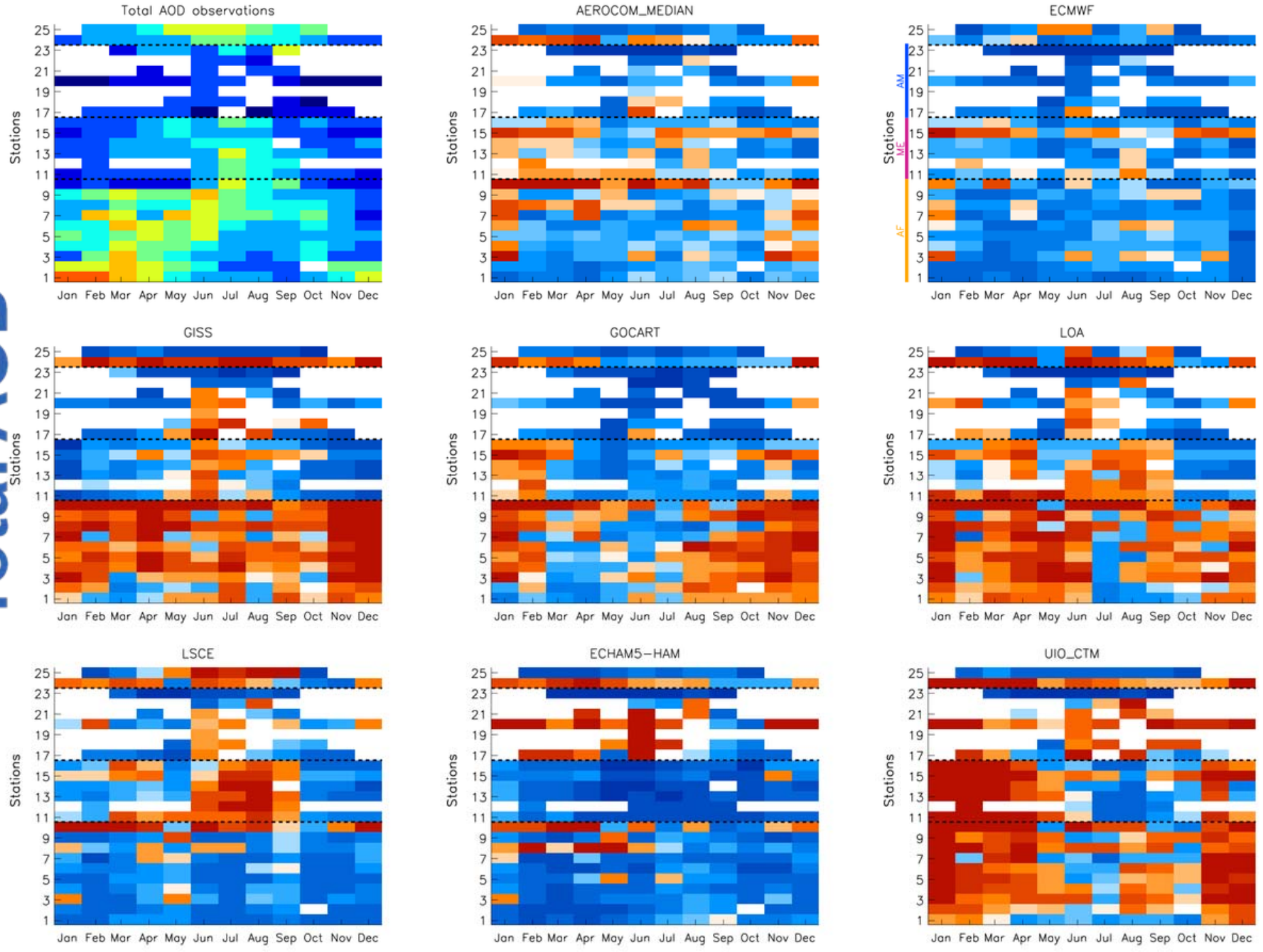
•Datasets are available in AeroCom database waiting to be used.

•AeroCom Phase II will allow conducting additional comparisons (e.g. size distribution) to asses the model performance to simulate the dust cycle.

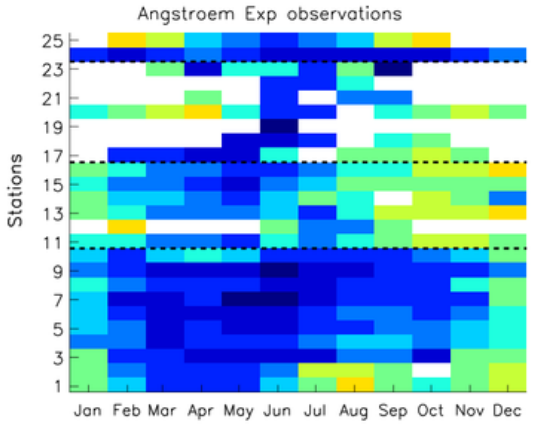
•I invite you to participate in the interactive discussion in ACPD.

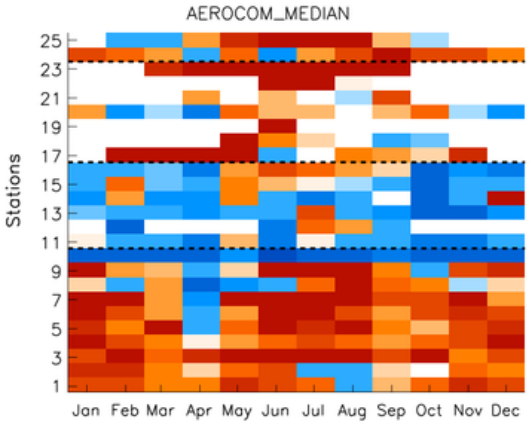
Thank you for your attention!

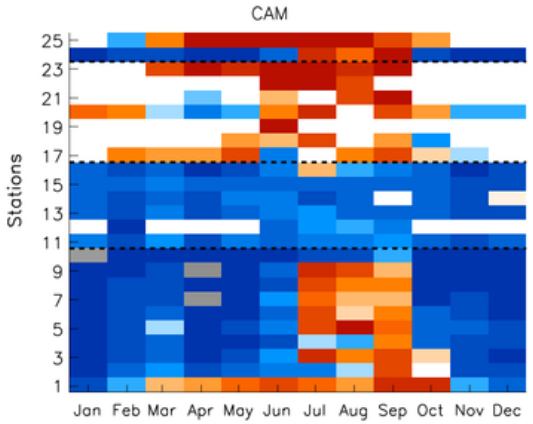
Total AOD

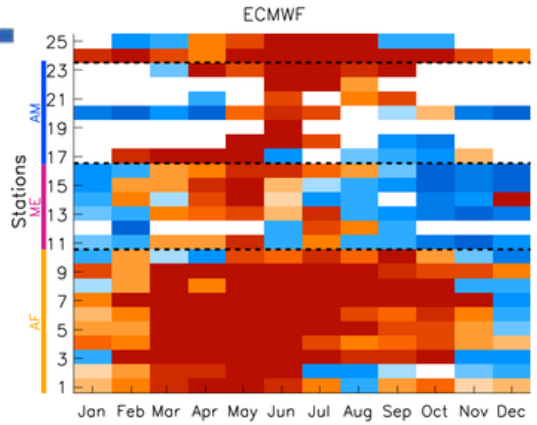

Total AOD observations
AEROCOM_MEDIAN
ECMWF
GISS
GOCART
LOA
LSCE
ECHAM5−HAM
UIO_CTM
Stations
AM
MF
AF
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

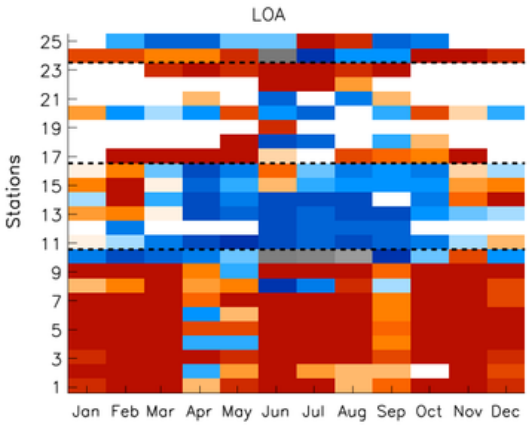
Angström Exponent

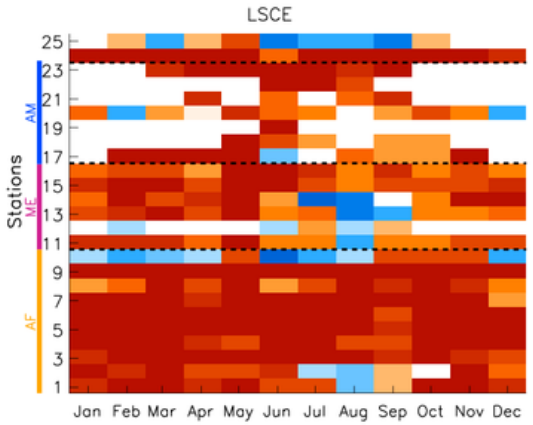


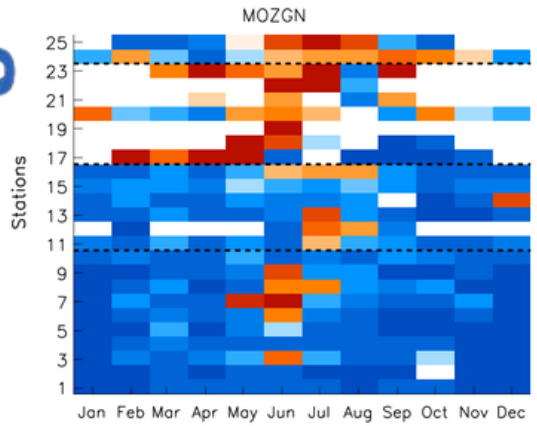


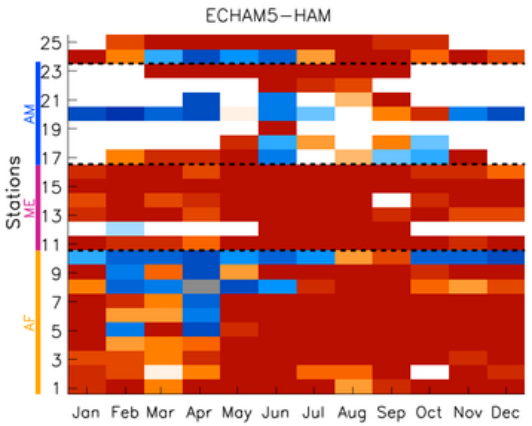


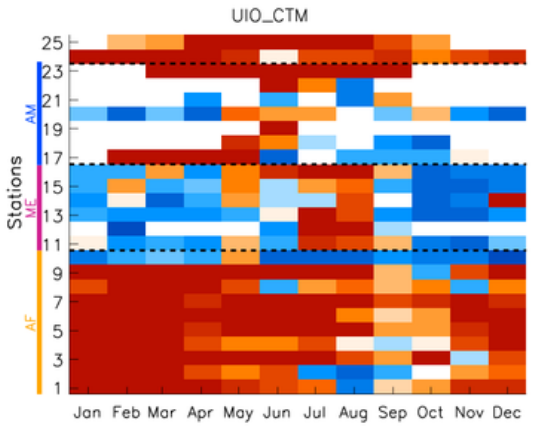




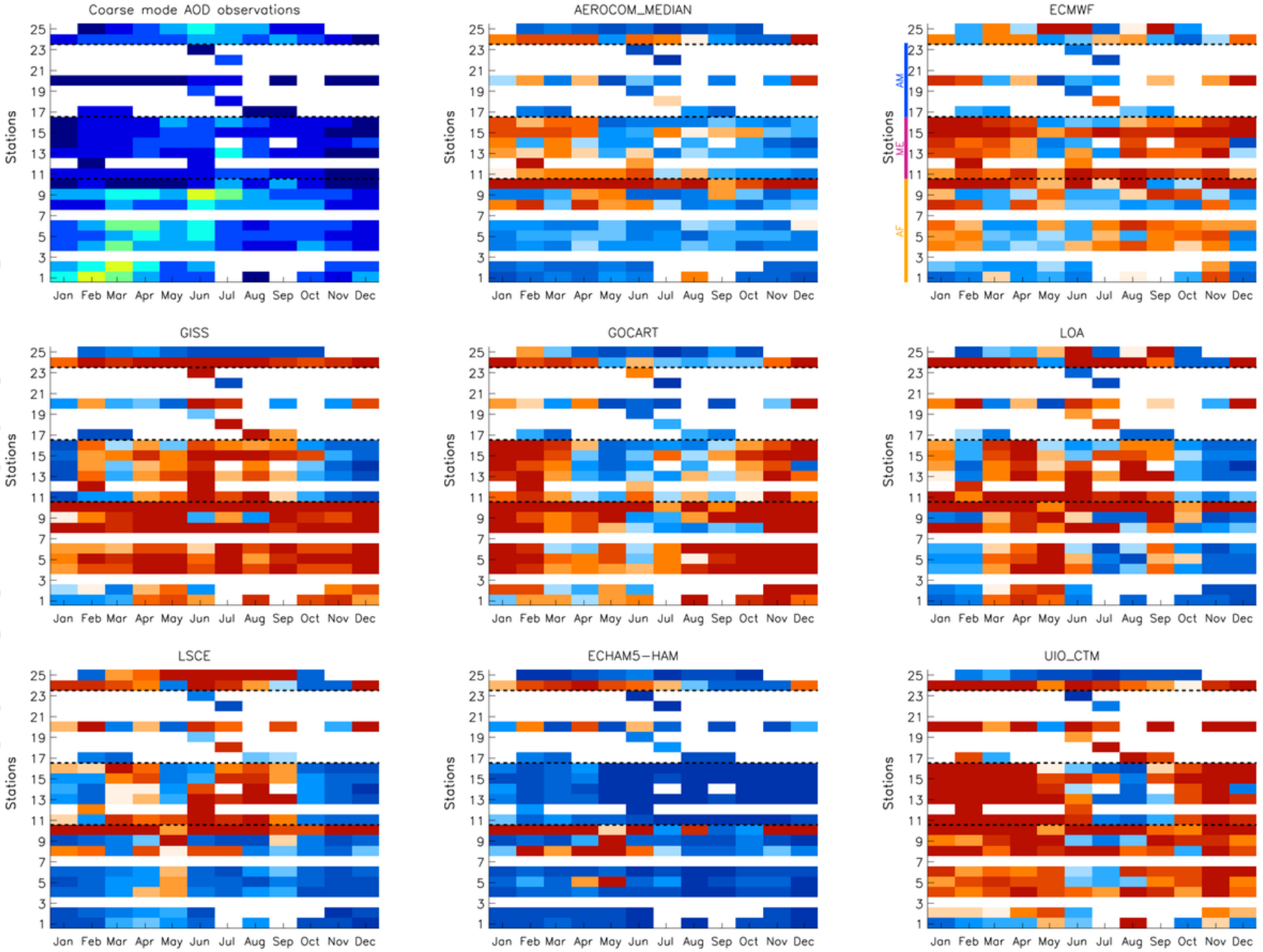








Coarse mode AOD



Coarse mode AOD