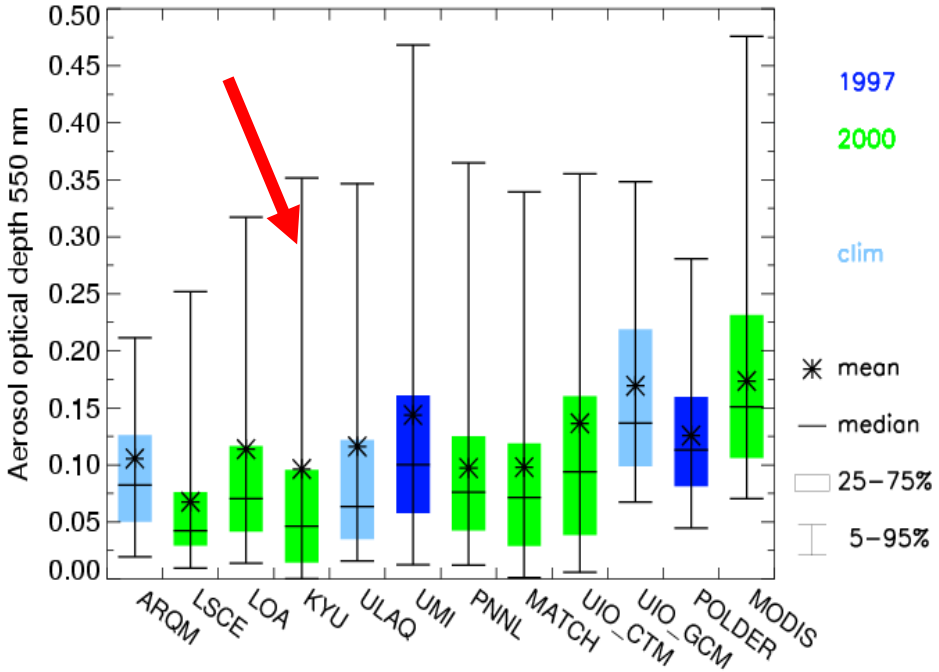
Reducing the Uncertainty of Global Aerosol Simulations

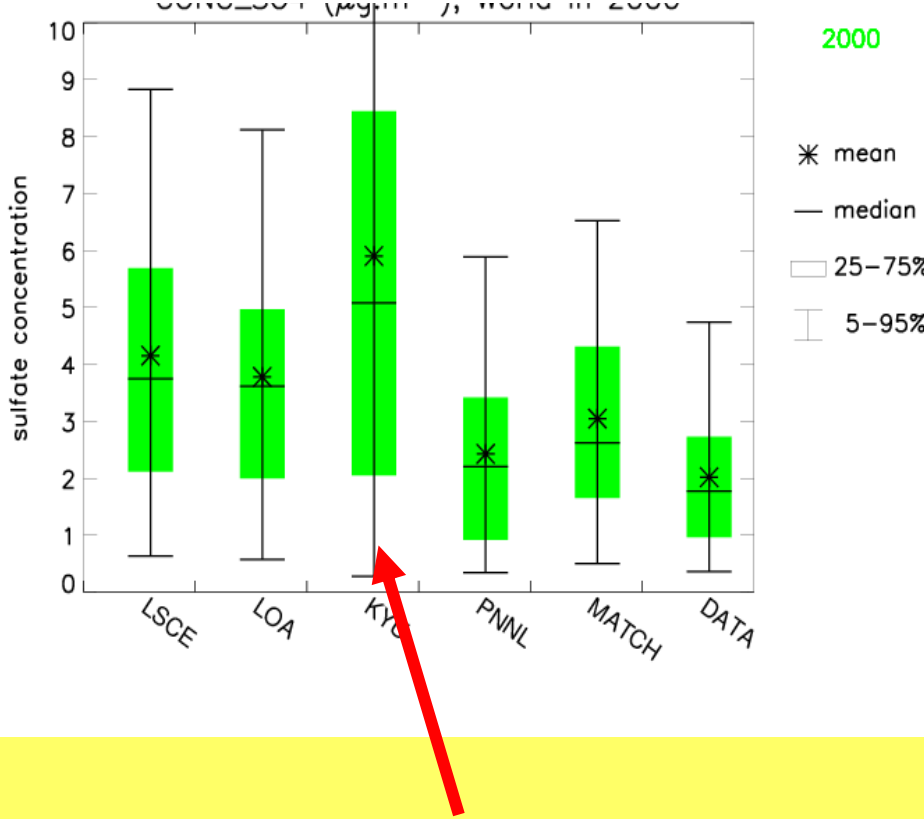
Process analysis

Model versus Data …which model is the best?

optical depth



sulfate concentration at the surface

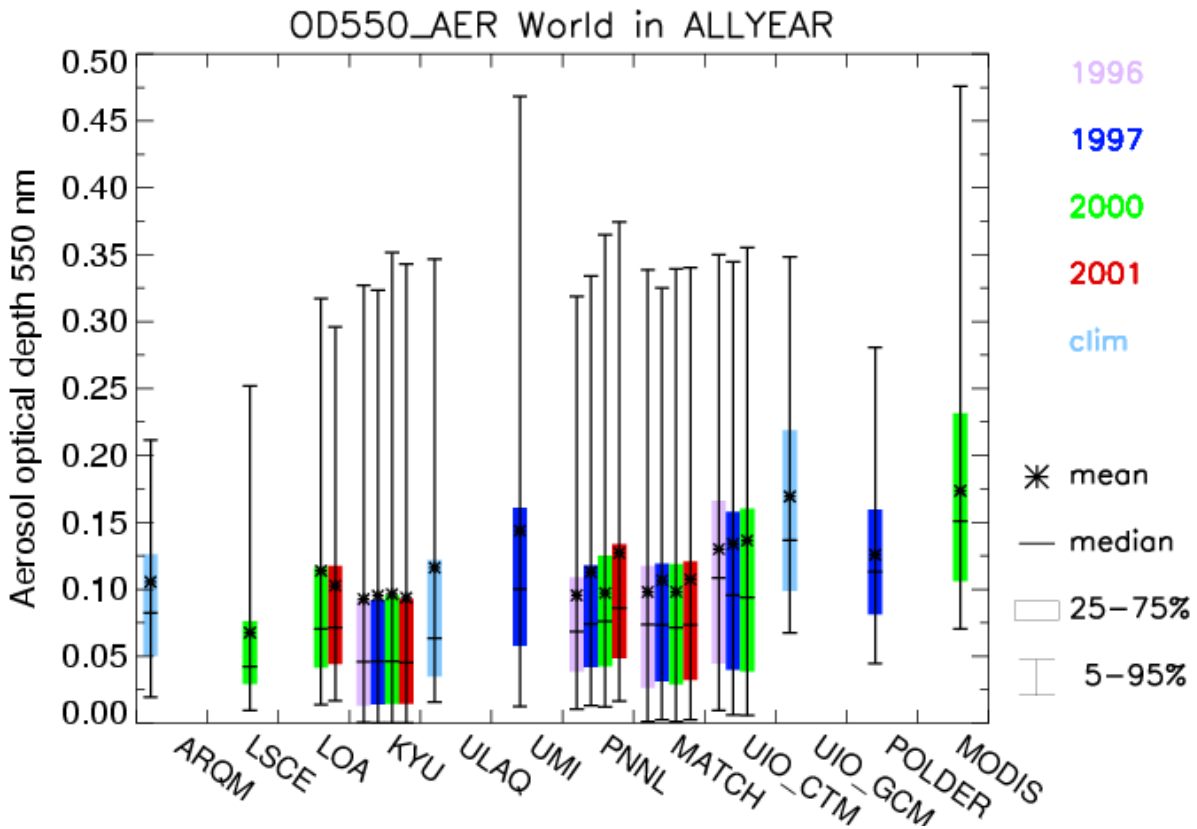


… “BEST“ in which respect?

models can be „right“ for the wrong reasons.

analysis of individual aerosol processes is necessary to better understand the system.

inter-annual variability of aot *(AOD at 550nm) …*



12 months of global data

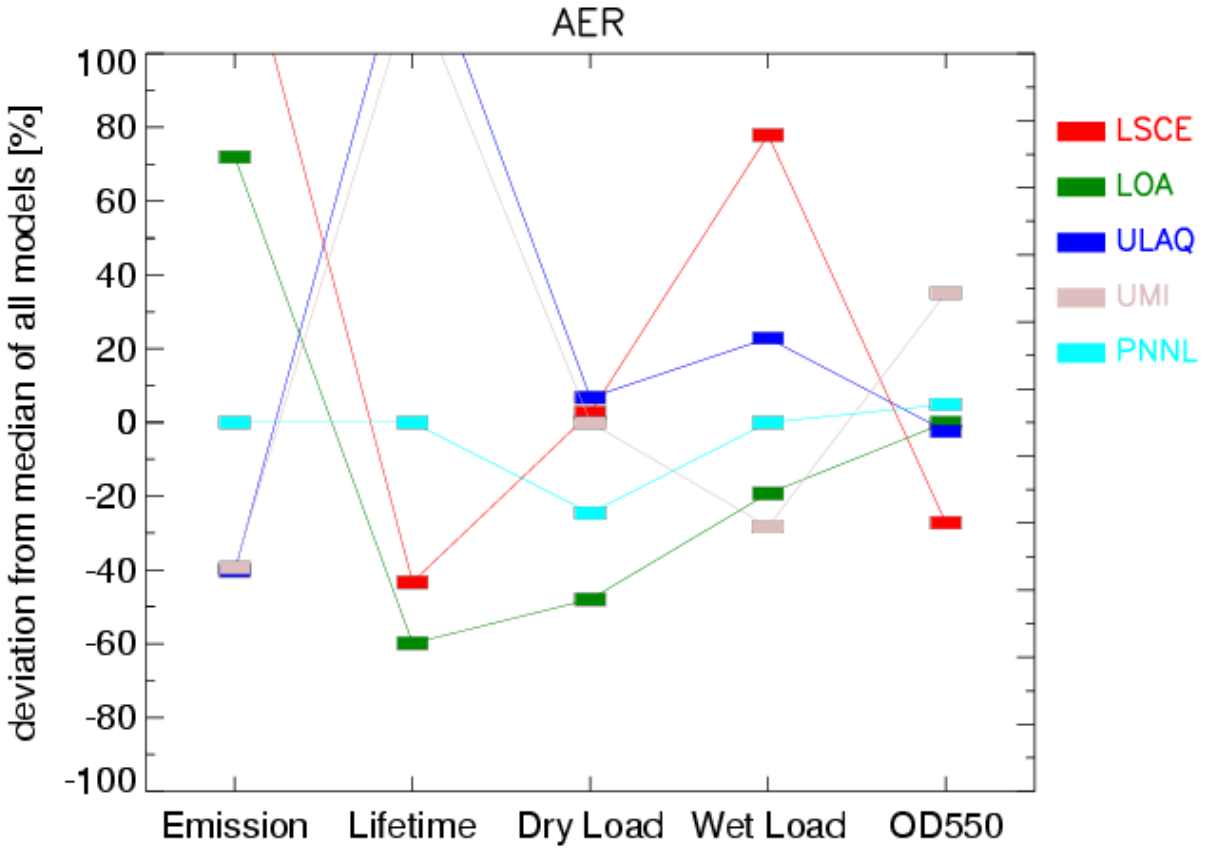
… is small compared to the inter-model variability

The following analysis will focus on

a particular year (2000 data - if available) or

climatological runs (GCM version)

model aot comparison *(total AOD at 550nm)*

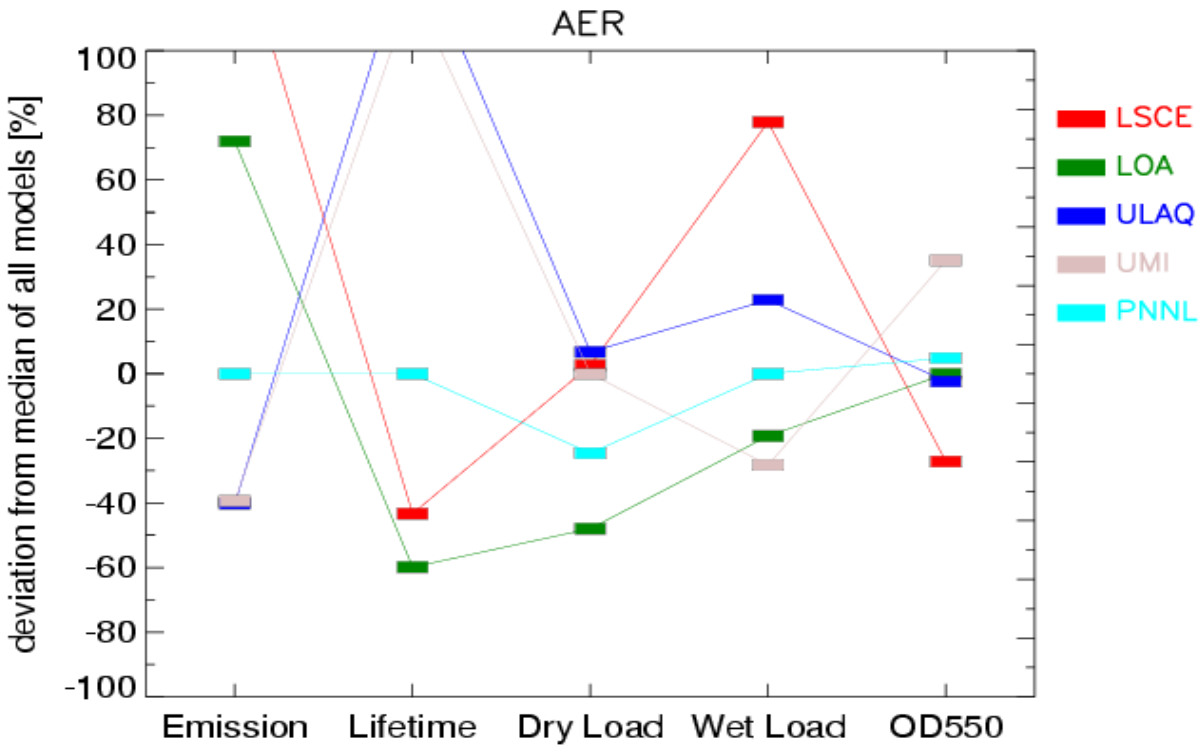


How to compare aerosol processes if no data are available ?

⇨ Take the process/parameter median of all models as reference.

⇨ The relative deviation from this median serves as an indicator for the uncertainty.

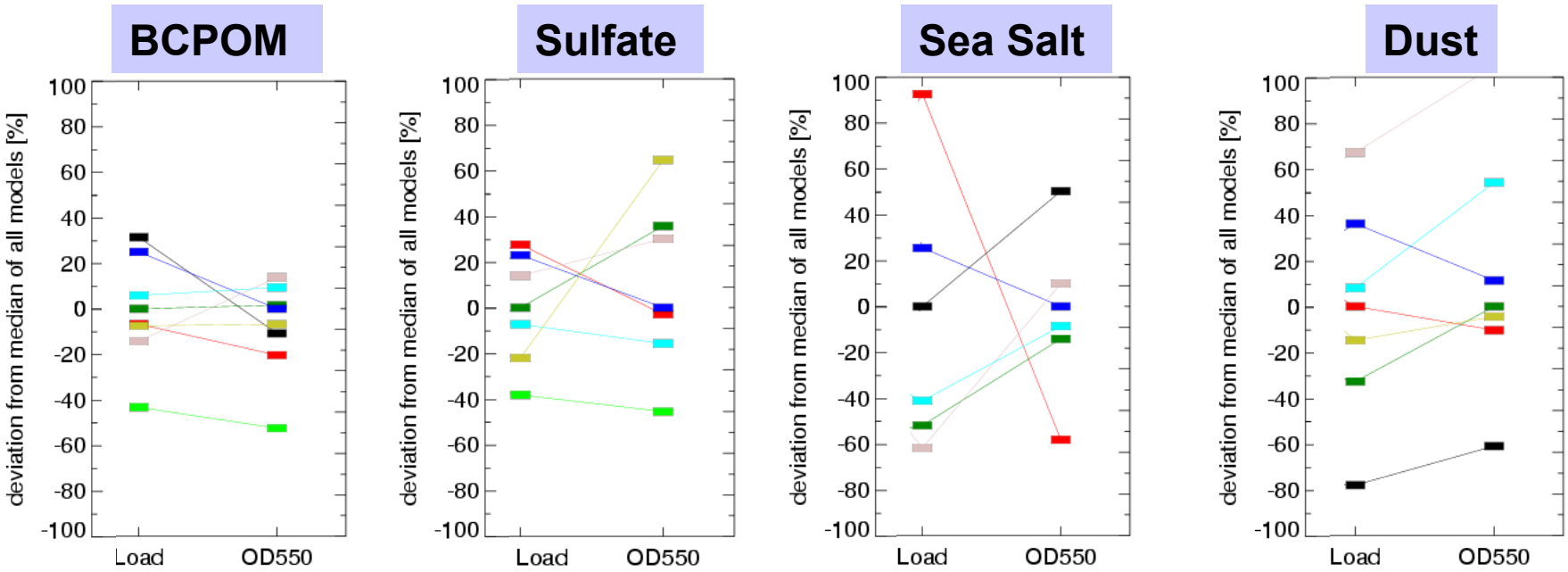
model aot comparison *(total AOD at 550nm)*



uncertainties of predictions for mass (Load) and aot (OD550) are smaller than uncertainties of processes from which they result

there is little agreement on resulting aot (OD550) for a given mass (Wet Load) [– primarily differences in size-assumptions!]

aot calculation from mass *(or load)*

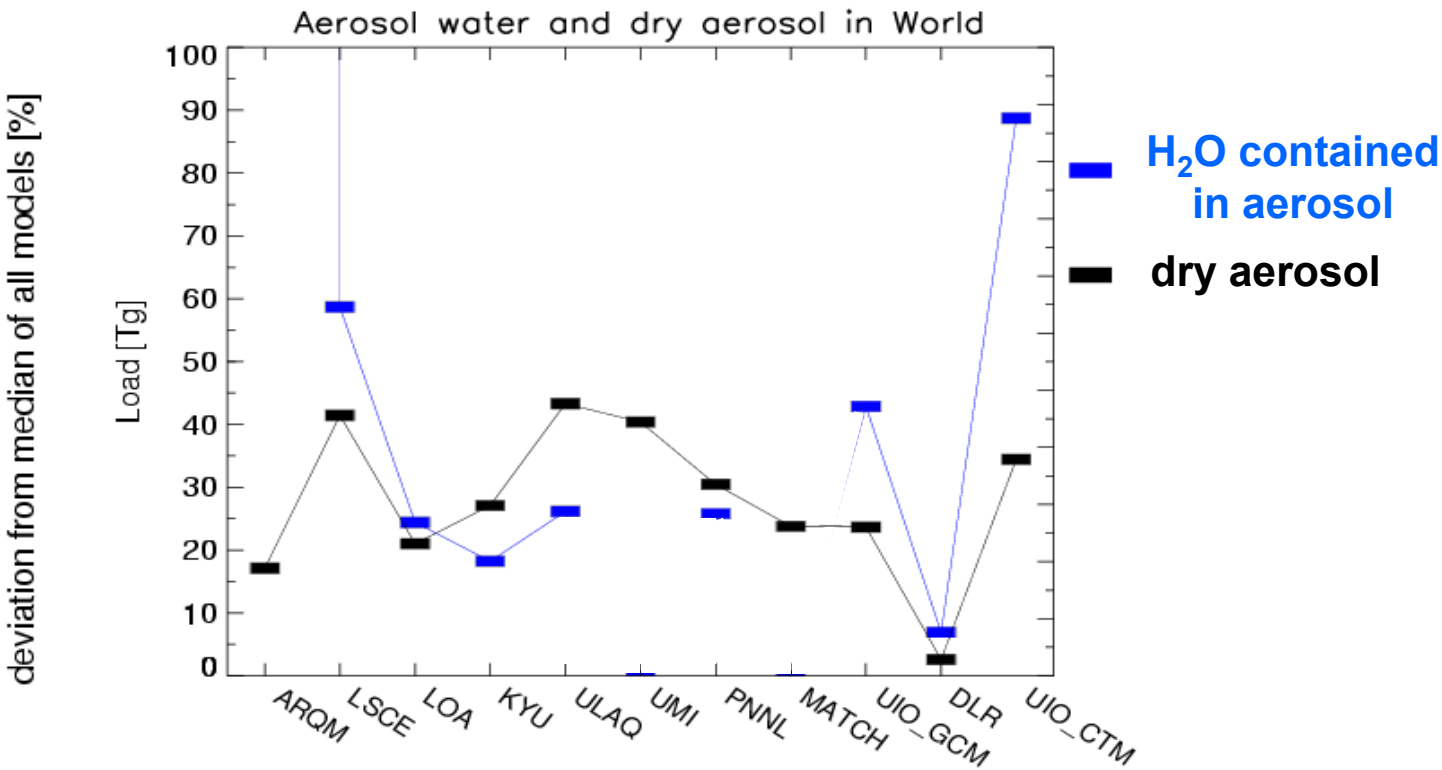


- **no consistency for any species in aot (OD550) calculation from mass (Load)**
- **aot agreement: best for BCPOM, worst for Dust**
- **BCPOM, Sea Salt: uncertainty *decreases* from mass (Load) to aot (OD)**
- **Sulfate, Dust: uncertainty *increases* from mass (Load) to aot (OD)**

➔ **Parameterizations of optical depth should be improved?**

ARQM
LSCE
LOA
KYU
ULAQ
UMI
PNNL
MATCH

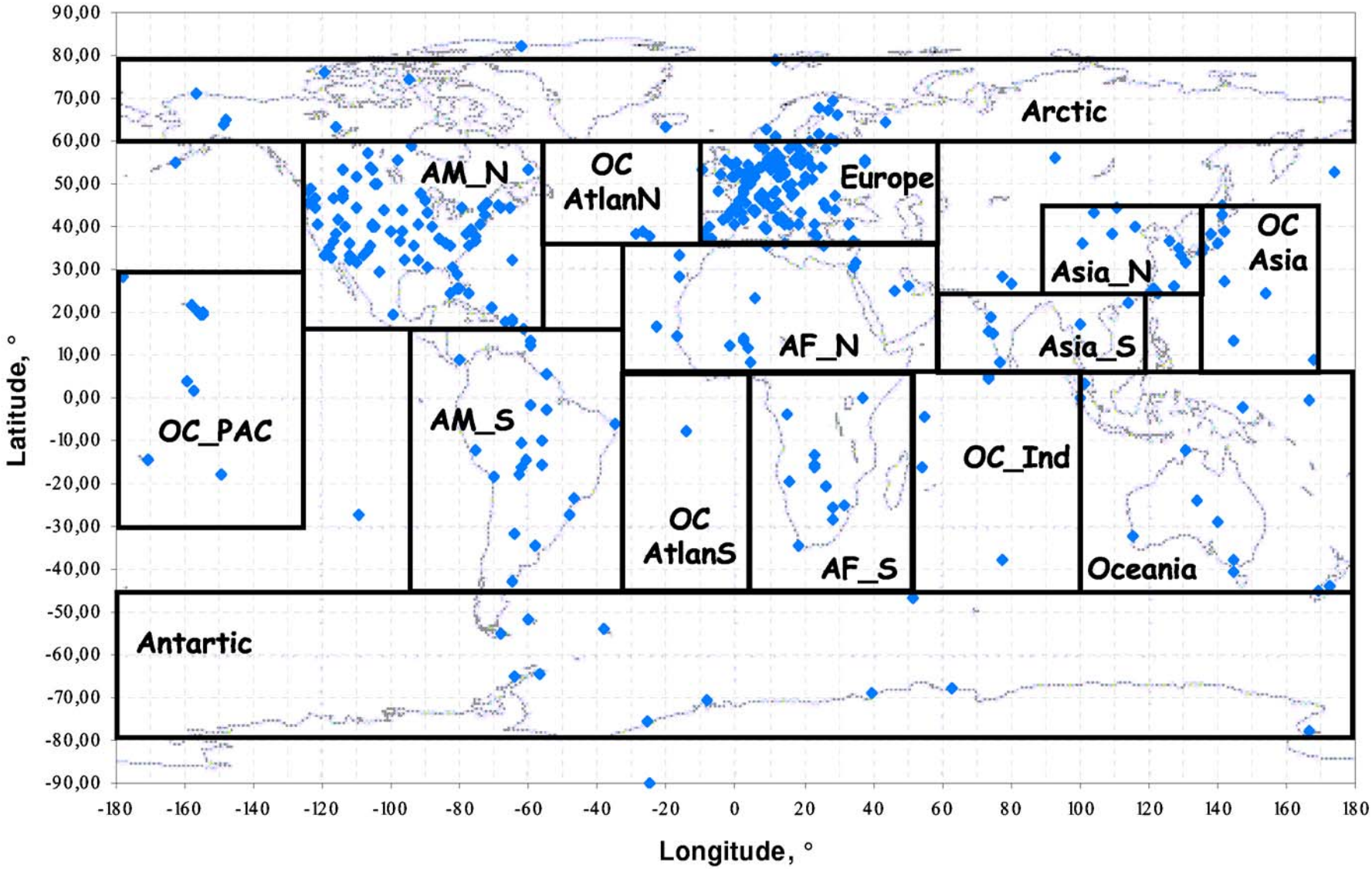
Aerosol water and dry load



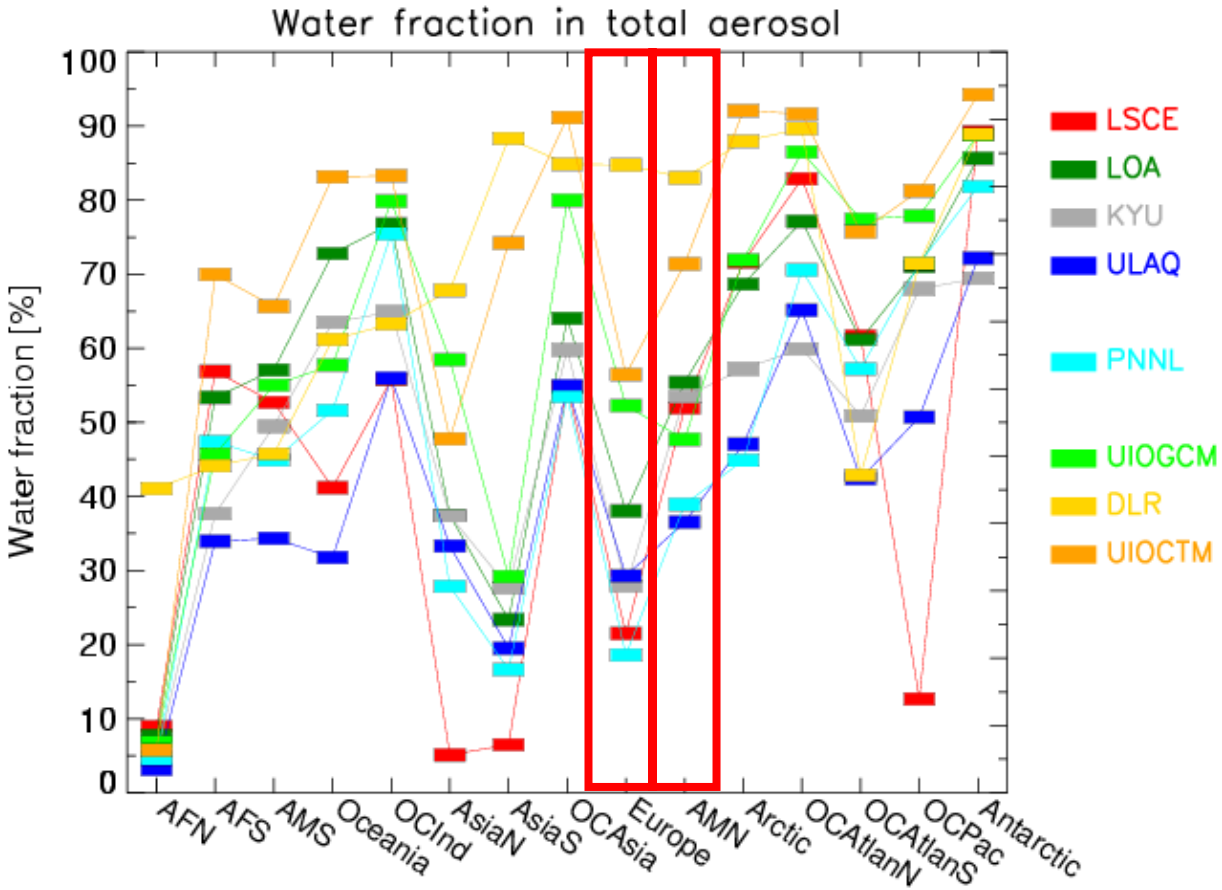
little agreement in terms of hygroscopic particle growth among models

… until we have measurement data to support, it is very difficult to judge which model is more correct or wrong.“

Regions of interest



parameterization of hygroscopic particle growth



Dust dominated regions: low water fraction (except 'no-dust DLR model)

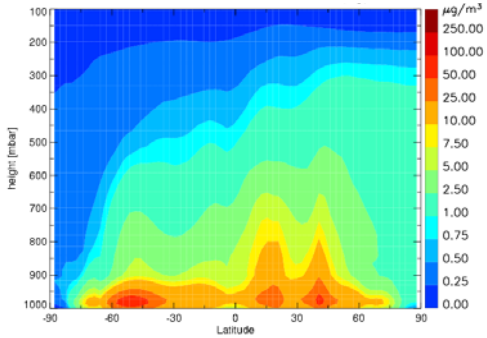
Sea-salt dominated regions: high water fraction **(except 'no-dust DLR)**

poor agreement over continental regions (**BCPOM, SO4** dominated)

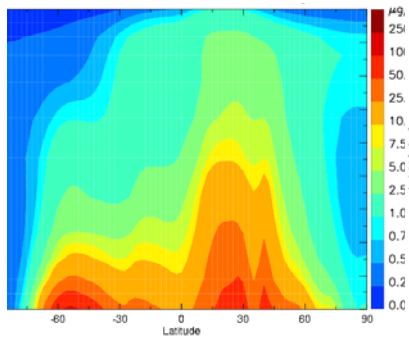
… more detailed analysis required !

Annual mean zonal mean vertical aerosol concentration

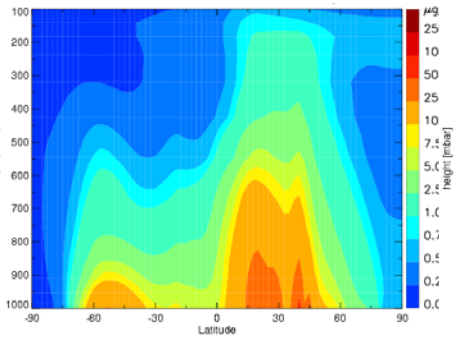
ARQM 1.06



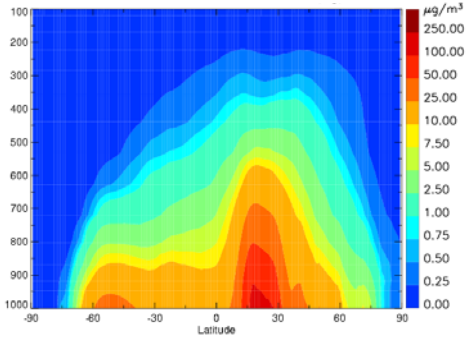
LSCE 1.66



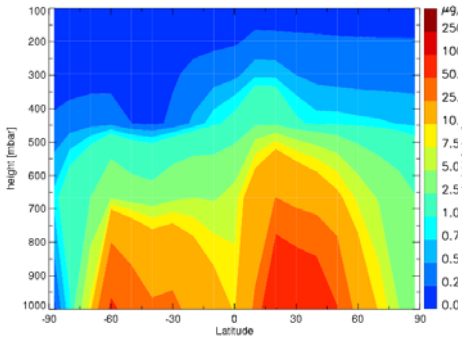
LOA 0.87



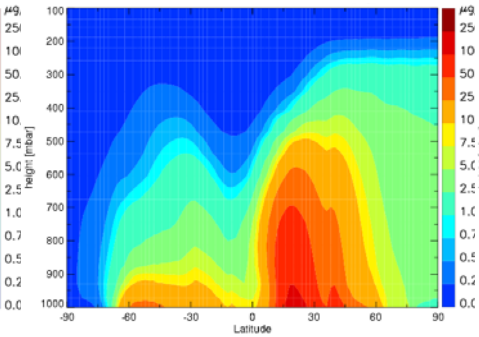
KYU 1.2



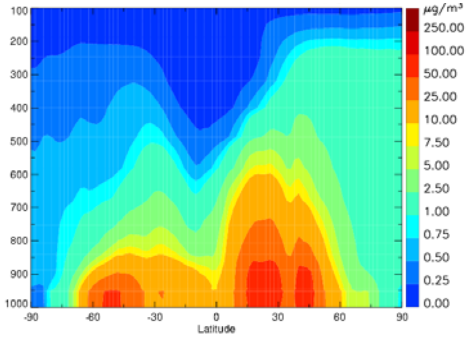
ULAQ 2.69



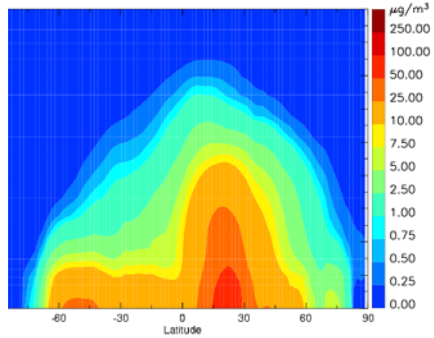
UMI 1.72



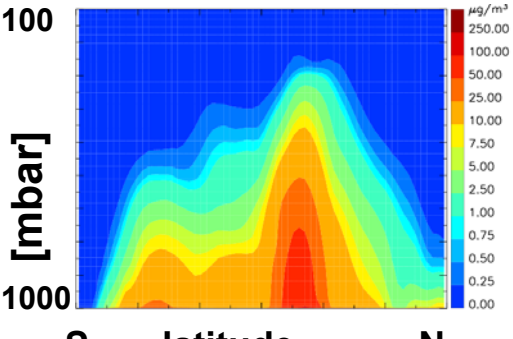
PNNL 3.04



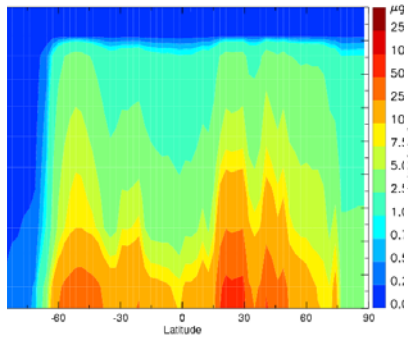
MATCH 0.96



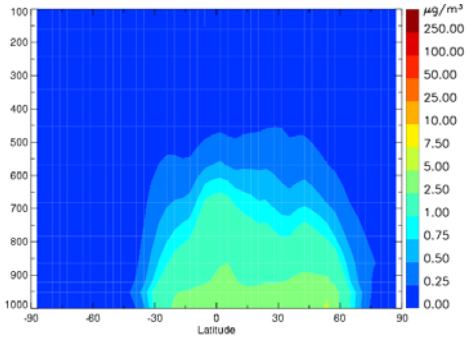
UIO_CTM 1.91



UIO_GCM 1.63



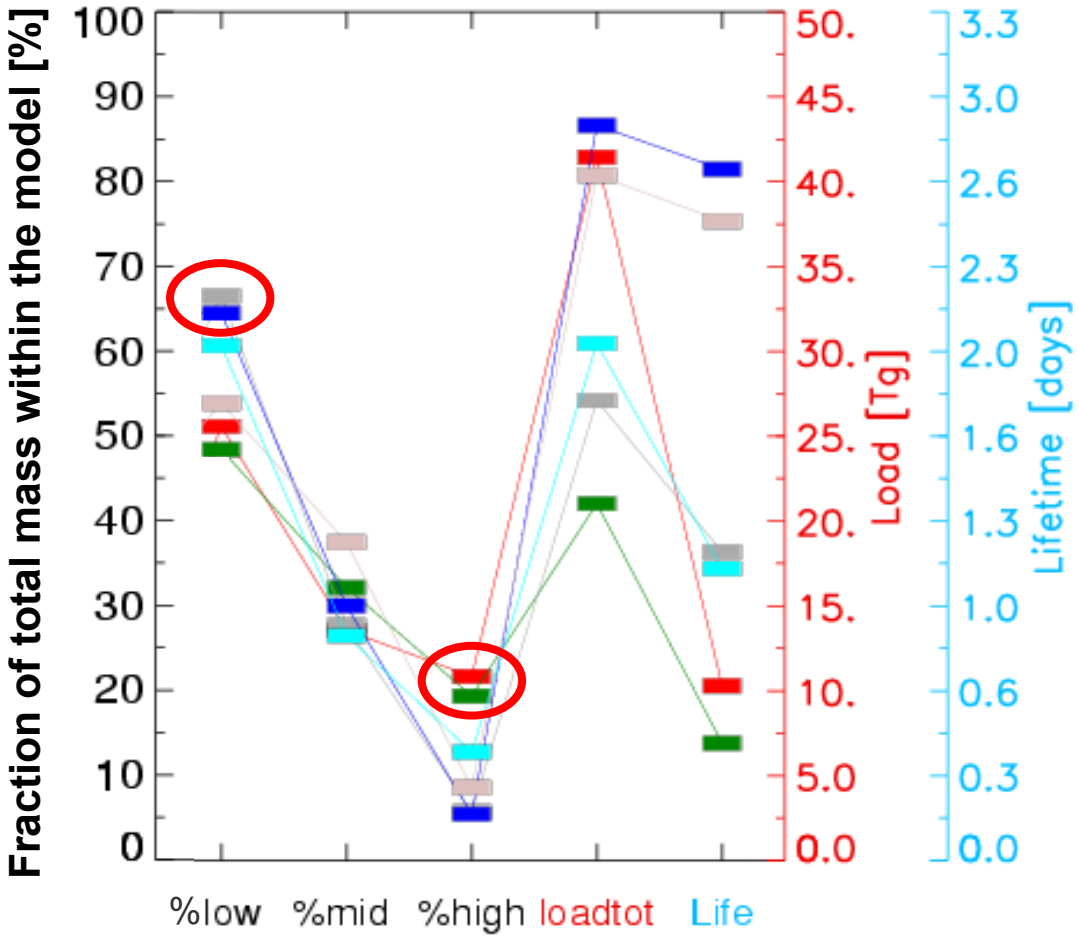
DLR 0.08 (no du ss)



Global annual mean aerosol concentration

[ug/m^3]

Vertical distribution: global aerosol



low: < 800mbar 47-67%

mid: 800-500 mbar 25-37 %

high: > 500 mbar 5-25%

of total mass

model-range of (total global yearly) mass is about 20 % at each altitude level

KYU and ULAQ: most mass in the PBL.

LOA and LSCE: most mass in the free troposphere (most above clouds)

Aerosol processes

of 12 global aerosol models (1)

GCM / CTM

- climatological (GCM)-, nudged (GCM)-, or assimilated (CTM) models
- horizontal resolution: 1.25^o x 1.25^o (320x160) to 22.5^o x 9.5^o (16x19)
- vertical resolution: 12 to 32 layers, different vertical levels
- different representations (parameterizaions) for
  - advective transport
  - diffusive transport
  - convective transport
  - clouds /precipitation
  - ...

Aerosol processes

of 12 global aerosol models (2)

Aerosol Modules (1)

- **Size distribution**
  sectional or modal schemes
- **Composition**:
  external or internal mixtures,
  may be different for water uptake and optical properties.
- **Emissions**:
  various parameterizations for dust and sea salt
  emission inventories for sulfate and BCPOM
- **Sedimentation**:
  dependent on particle sizes

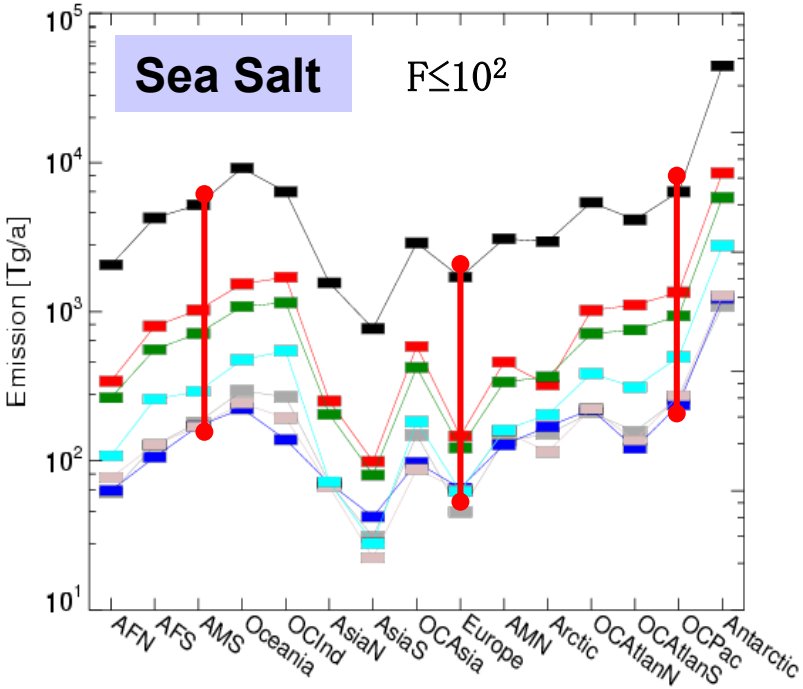
Aerosol processes

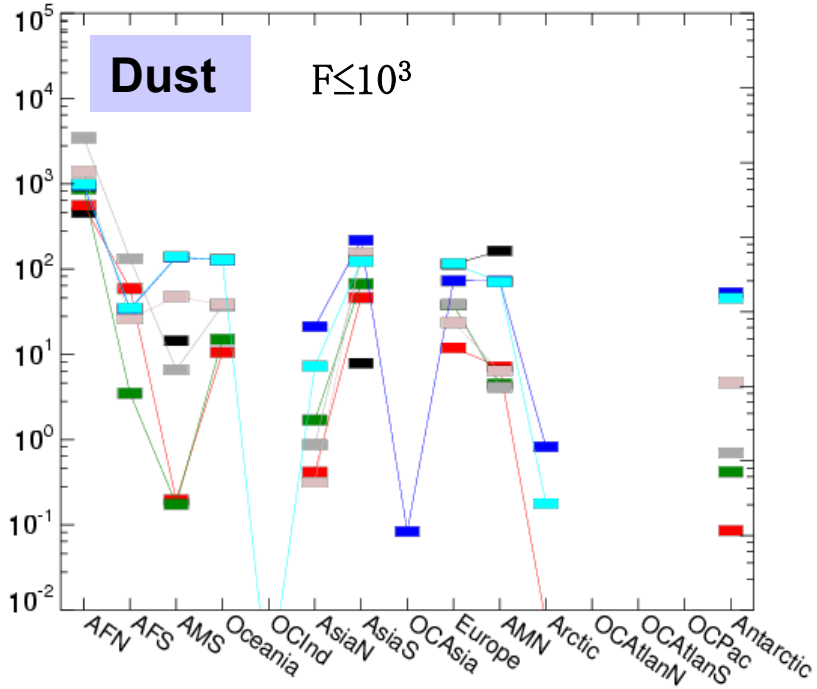
of 12 global aerosol models (3)

Aerosol Modules (2)

- **Dry deposition**:
  resistance techniques
  or constant deposition velocities
- **Wet deposition**:
  convective and stratiform precipitation
  LWC from the model or prescribed
- **Aerosol microphysics**:
  nucleation, aggregation, aging of insoluble particles, water uptake
- **Optical properties**
  various parameterizations

Emissions of natural species

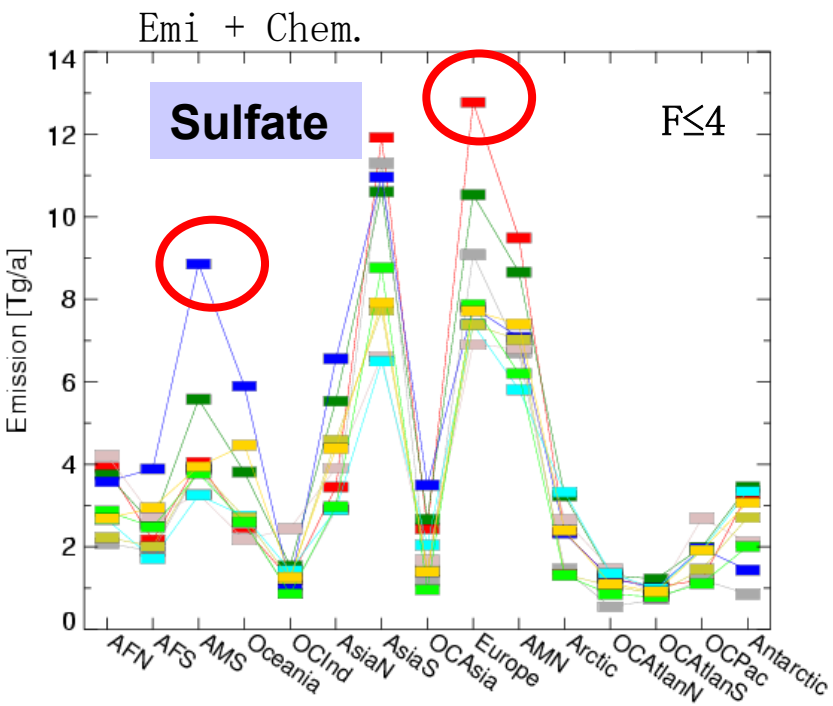


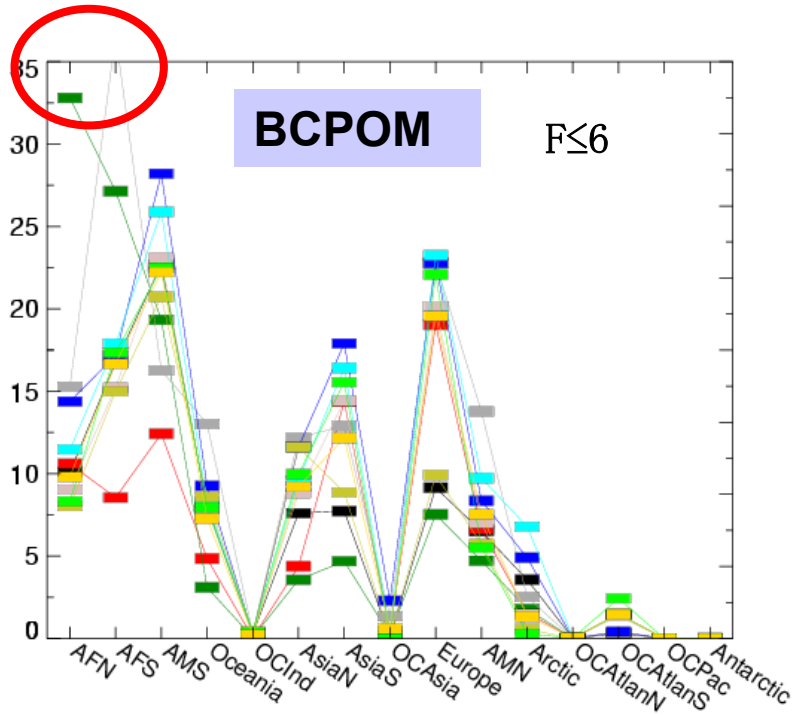


- **high uncertainty … because of coupling to model meteorology (wind speed, soil moisture).**
- **SeaSalt: constant bias caused by constant dependence on wind velocity.**
- **Dust: Uncertainty reflects also regional different in soil properties.**
- **differences in particle sizes an associated differences in life-time compensate the scatter in emissions.**

ARQM
LSCE
LOA
KYU
ULAQ
UMI
PNNL

Emissions of anthropogenic species

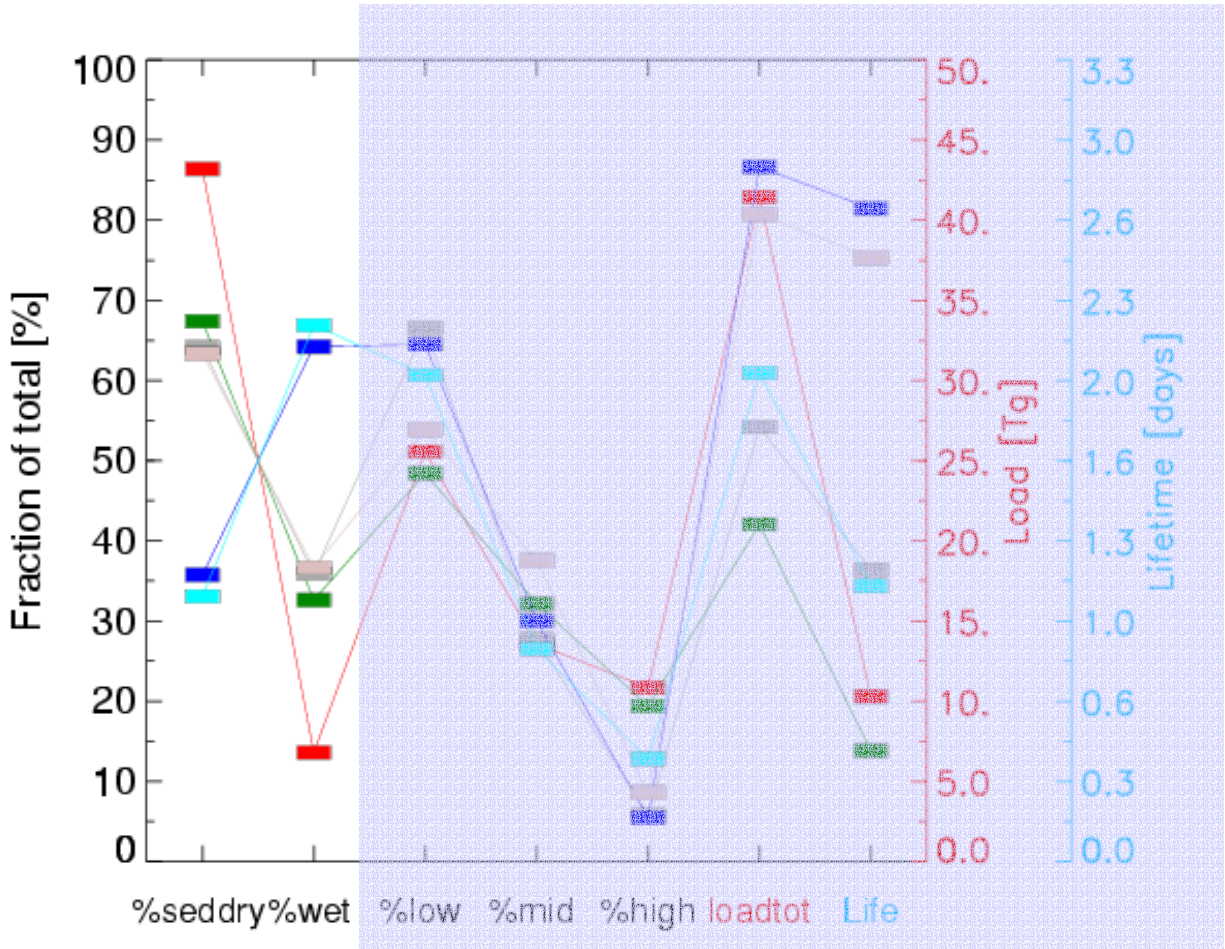


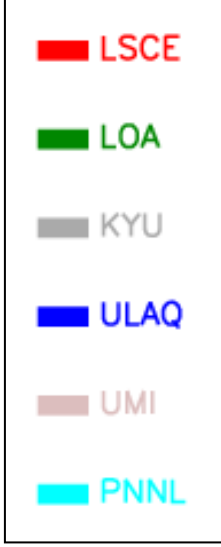


- **lower uncertainty because emissions are prescribed …**
  … based on inventories.
- **uncertainty varies with region**
- **some outliers are difficult to explain (more investigations needed)**

ARQM
LSCE
LOA
KYU
ULAQ
UMI
PNNL
MATCH
UIOGCM
DLR

Sinks and vertical distribution: global aerosol



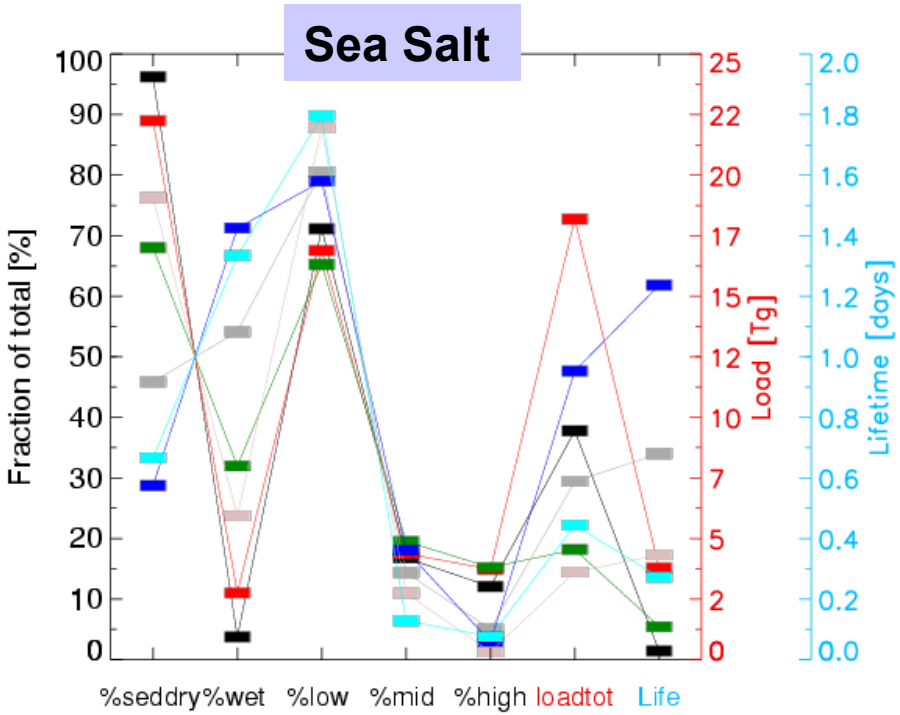


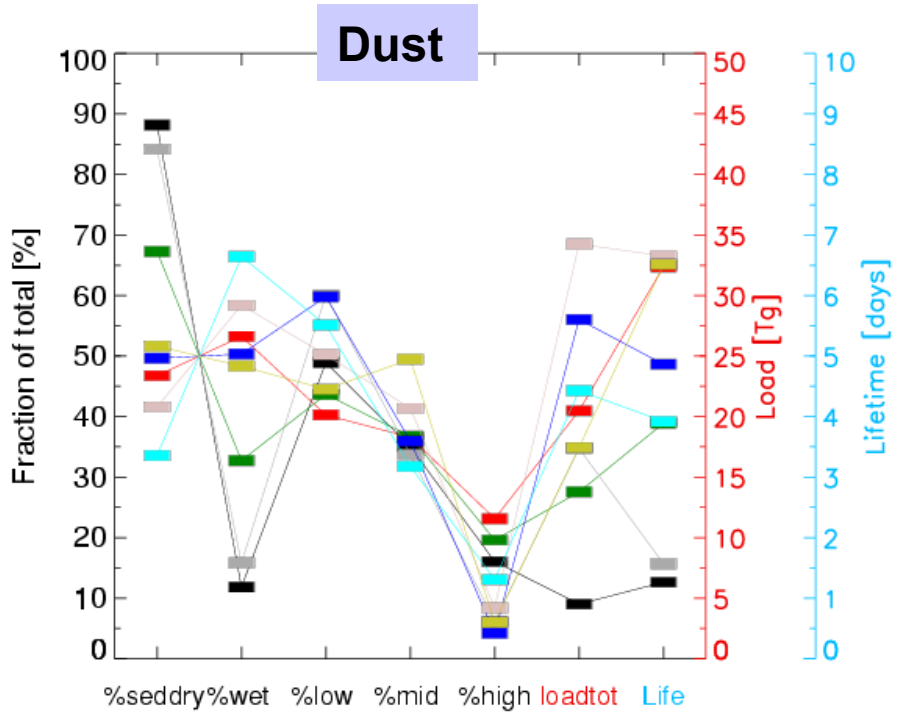
little agreement on dominant sink process

high contribution of sedimentation ... if particles are large.

total aerosol mass is dominated by dust and sea salt.

Sinks and vertical distribution: natural species





little agreement on the dominant sink process

stronger stratification for Sea-Salt

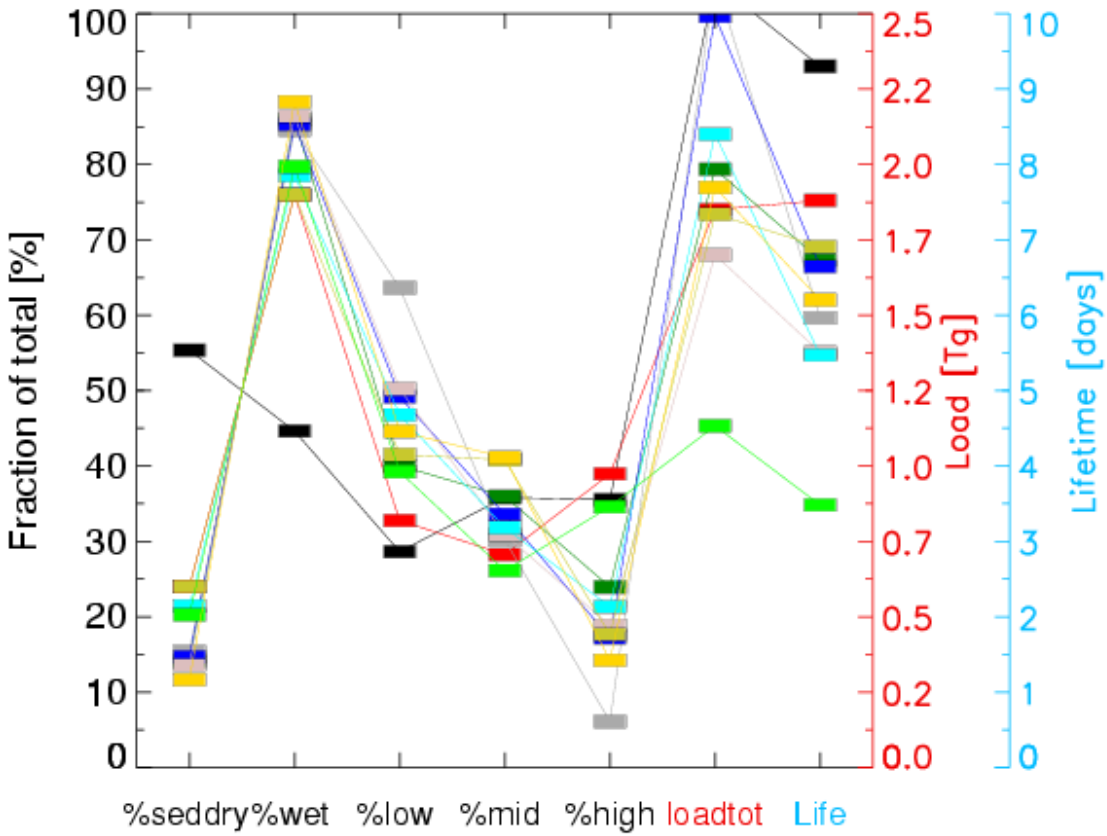
Dust is present in greater heights then Sea-Salt.

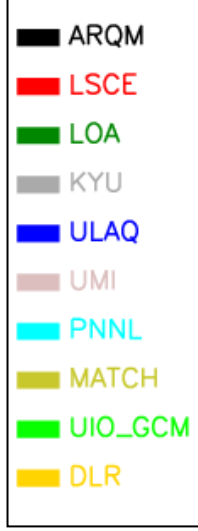
large scatter in mass and life-time.

low:	**< 800mbar**
mid:	**800-500 mbar**
high:	**> 500 mbar**

ARQM
LSCE
LOA
KYU
ULAQ
UMI
PNNL
MATCH
UIOGCM
DLR

Sinks and vertical distribution: BCPOM





low: **< 800mbar**

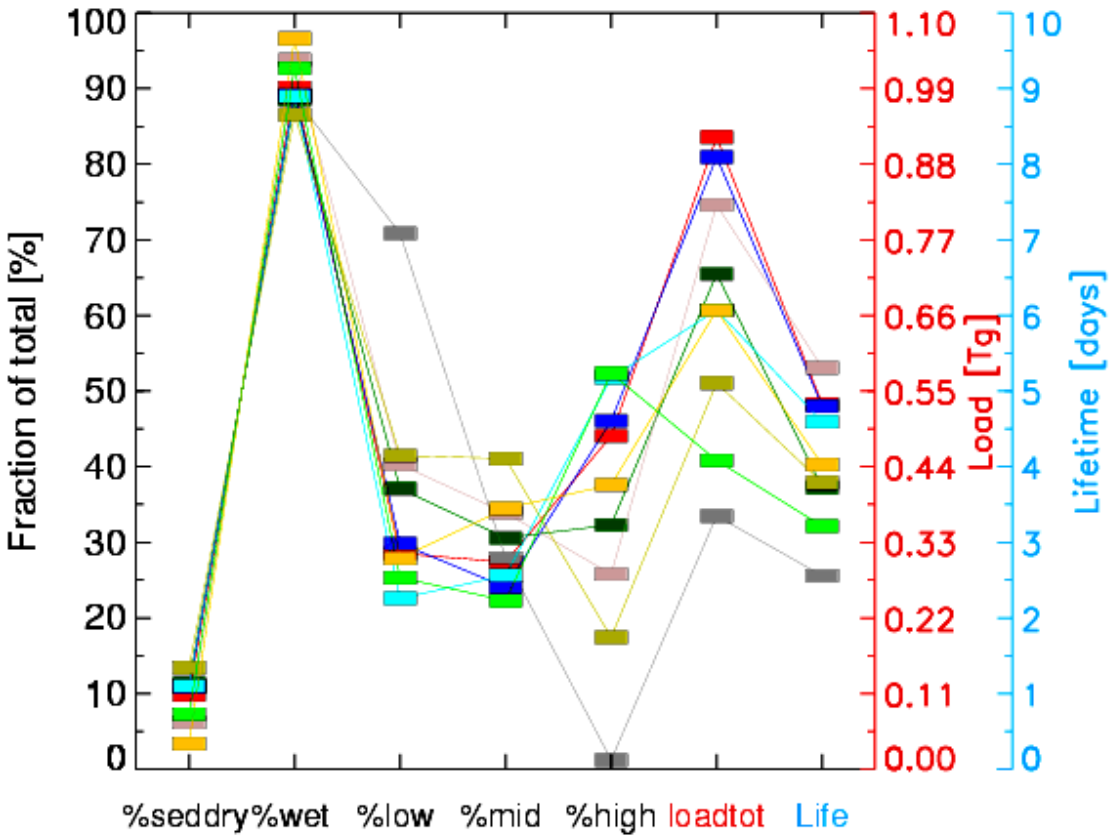
mid: **800-500 mbar**

high: **> 500 mbar**

dominance of wet deposition in all models (except ARQM)

maximum in the lowest level for all models (except ARQM)

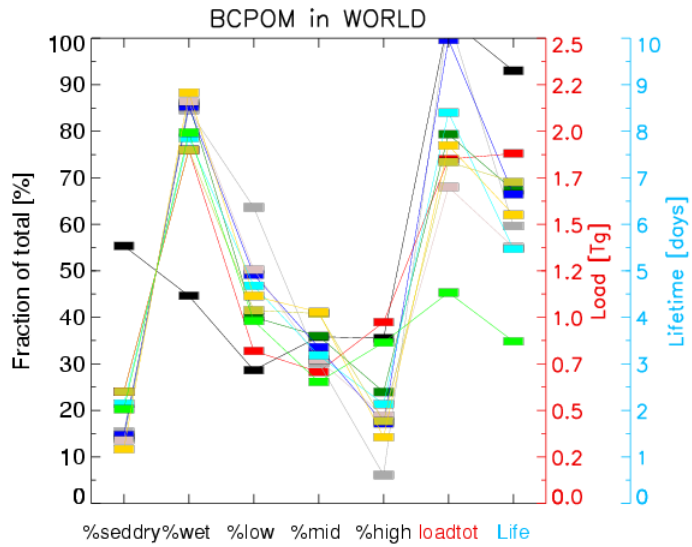
Sinks and vertical distribution: Sulfate



low: < 800mbar

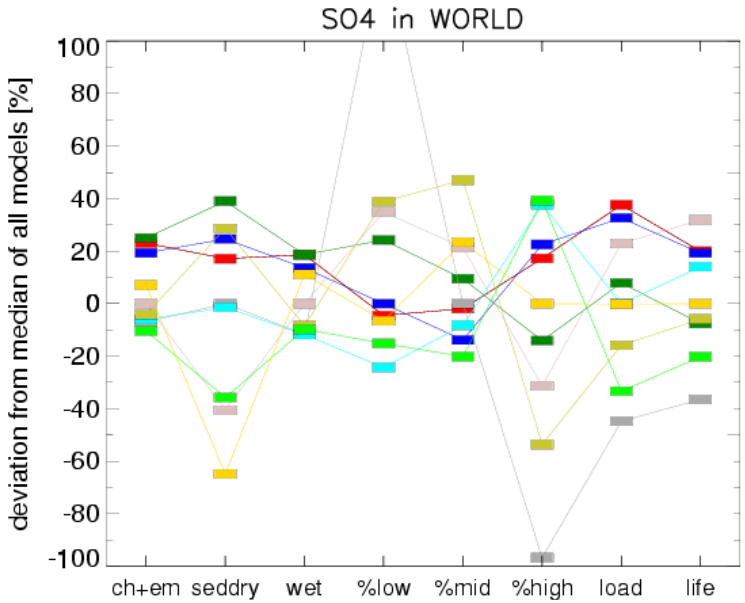
mid: 800-500 mbar

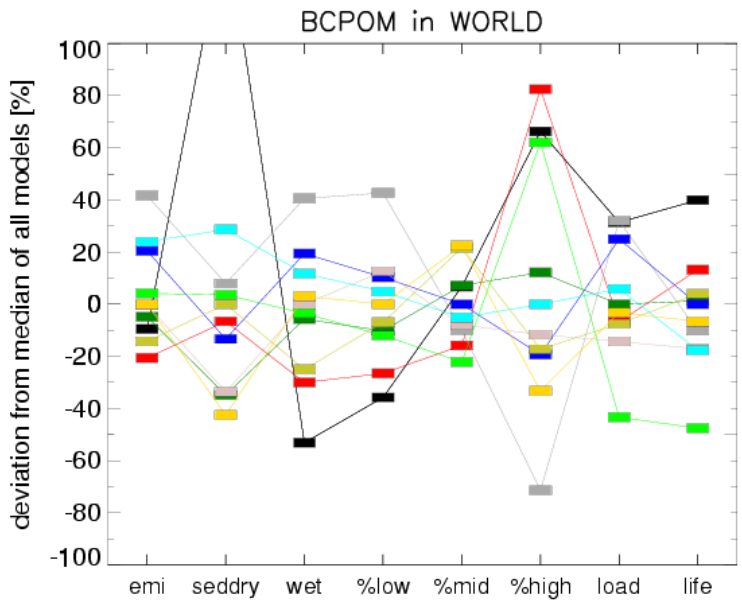
high: > 500 mbar

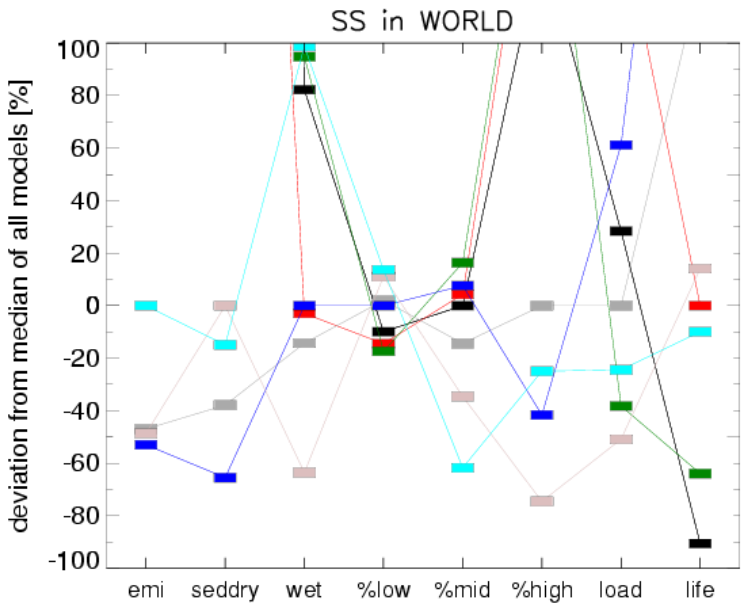


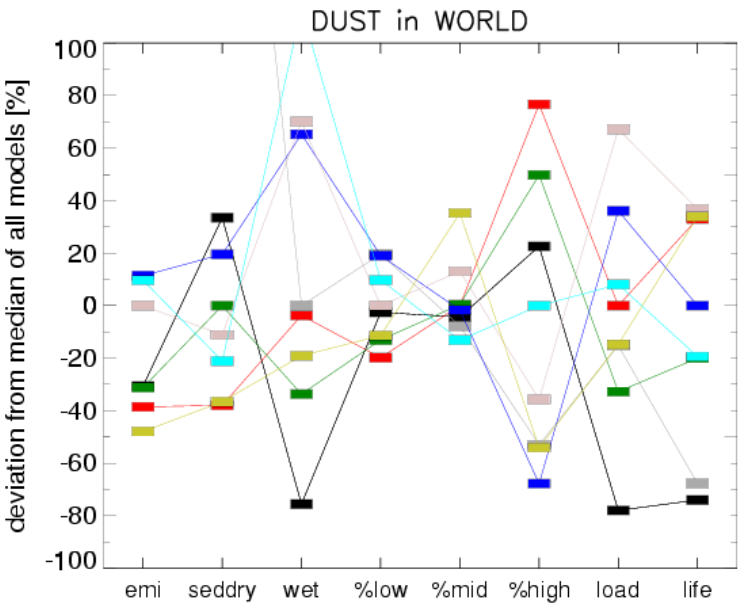
- strong dominance of wet deposition in all models
- no agreement on height of sulfate
- the higher the aerosol …the greater the mass and …the longer the life-time

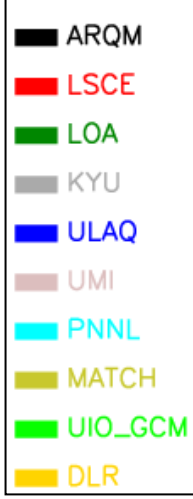
Uncertainty for individual aerosol species











Uncertainty for individual aerosol species

	Emissions	Lifetime	Load	AOD
BCPOM	-20 to +30 Δ=50	-50 to +40 Δ=90	-40 to +30 Δ=70	-50 to +15 Δ=65
Sulfate	-10 to +25 Δ=35	-30 to +15 Δ=45	-40 to +30 Δ=70	-50 to +65 Δ=115
Sea salt	-30 to +1000 Δ≈1000	-70 to +40 Δ=110	-70 to +70 Δ=140	-60 to +110 Δ=170
Dust	-80 to + 10000 Δ≈10000	-90 to +1000 Δ≈1000	-60 to +90 Δ=150	-60 to +50 Δ=110

BCPOM and sulfate:	improve internal processes
Sea salt and dust:	improve emissions and size distributions
all components:	improve parameterization for optical depth

Representation of aerosol species in the models

	ARQM	LSCE	LOA	KYU	ULAQ	UMI	PNNL	MATCH	UIO GCM	DLR
SO4		M E	E	M Lo Hi T O		T	Lo	Hi Mi W O		W
BCPOM	M Lo W T	Hi T		Lo Hi					Mi E T O	Mi
SS	E D T O	Hi E D O	Hi E	T	E D T		Lo Mi D			
Dust	M D T O	Hi		E D T	Lo Hi E	T O	E W O	Mi T		

M	**total mass**
Hi	**mass fraction above clouds**
Lo	**mass fraction in the PBL**
Mi	**mass fraction at middle level**
E	**emission**
W	**wet deposition/tot. dep**
D	**(dry dep+sed)/tot. dep**
T	**life time**
O	**optical depth**

red	high
blue	low

this table is not complete…

Summary

Emissions

- moderate uncertainty for BC, POM, and SO_2/SO_4 (based on inventories)
  (different treatment in models lead to increased uncertainty in mass and aot)
- high uncertainty for Sea-Salt and Dust
  (various parameterizations, different particle sizes)

Aerosol water content: high scatter!

Vertical distribution: range of fractions per height level

- Sea salt and dust +/- 20%
- BCPOM +/- 40%
- Sulfate +/- 60%

Sinks: sedimentation (dry and wet)

- High uncertainty for sea salt and dust due to uncertain particle size.
- Wet deposition dominant for BCPOM and sulfate.

Optical depth: Low agreement on calculation from a given aerosol load.

Outlook

„Which model is the best?“

descriptive analysis

→ detailed understanding of processes

- **comparison to data, use of daily model output, etc….**
- **AeroCom experiment B with harmonized emissions**
- **More information on parameterizations necessary!**

your input wanted!

Resolutions of models

ARQM	LSCE	LOA	KYU	ULAQ	UMI	PNNL	MATCH	UIO GCM	UIO CTM	DLR
129x64 2.79 x2.81	96x73 3.75 x2.5	96x73 3.75 x2.5	320x160 1.25 x1.25	16x19 22.5 x9.47	144x91 2.5 x1.98	144x91 2.5 x1.98	192x94 1.875 x1.875	128x64 2.81 x2.81	192x96 1.875 x1.875	96x48 3.75 x3.75
32 hyb	19 pres	19 pres	20 sig	12 hei	26 sig	24 hyb	28 hyb	19 hyb	19 hyb	19 hyb