Parameterization and Uncertainty of aerosol processes AeroCom ExpA

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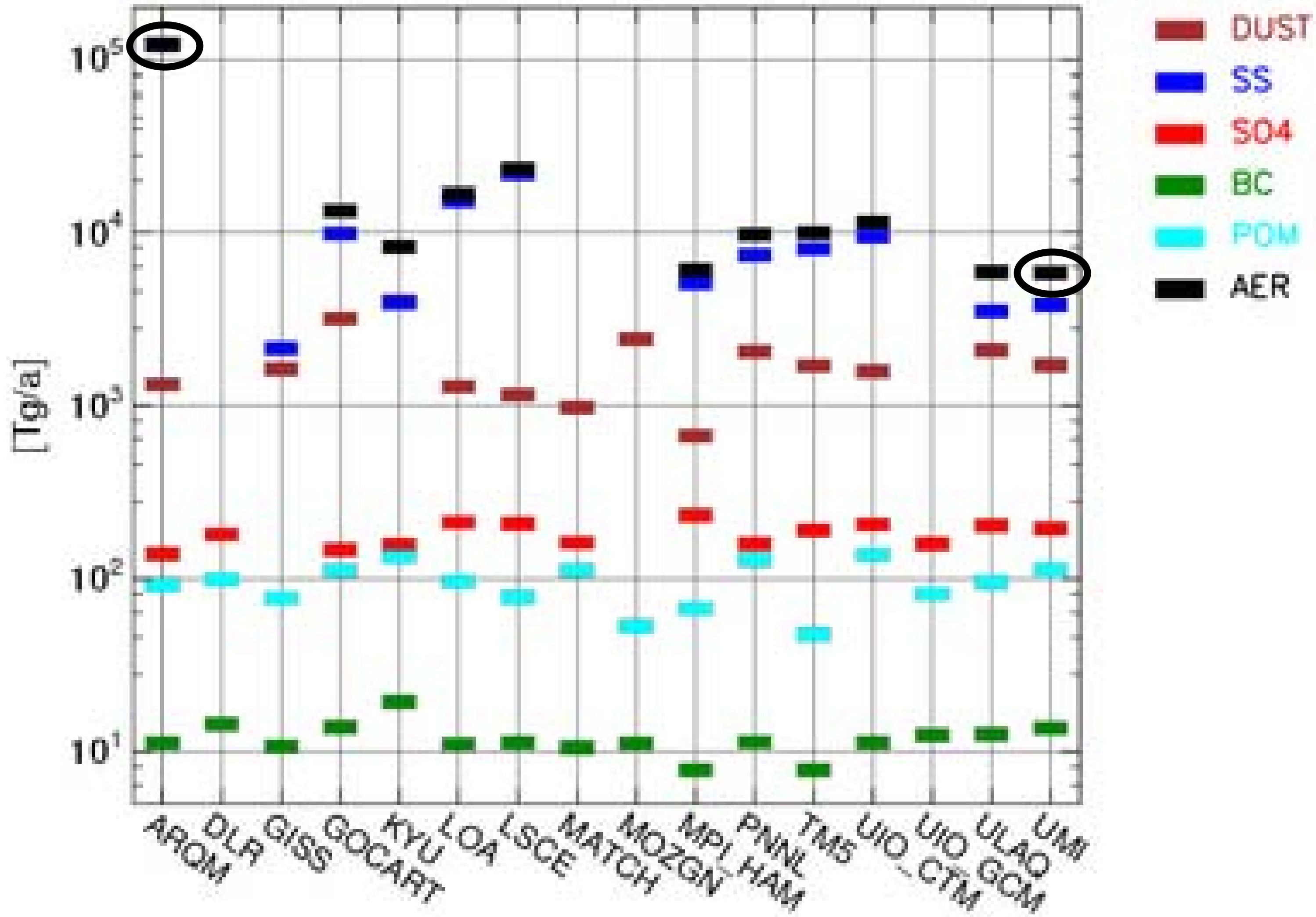
Outline of the talk

- Emissions
- Concept of uncertainty
- Load
- Residence times
- Sink process analysis

Model	Global model	Horizont. Resolution (x y) (lon lat)	Vertical Resolution (# of levels) (type)	Aerosol Module	number of bins or modes	aerosol mixing	Aerosol dynamics
ARQM	**CTM Canadian GCMIII**	128x64 2.81°x2.81°	32 hybrid sigma-p	bin	**17** (12 DU + 5 mixed)	DU + internal	none
DLR	[illegible]	96x48 3.75°x3.75°	19 sigma	modal, sigma fix	**2** nucl+acc	internal	aging of BC and POM SO4 microphysics
GISS	[illegible]	46x72 5°x4°	20 sigma	bin	**10** 2 SS, 4 DU, 1BC, 1 POM, 1 SO4	external	aging of BC and POM
GOCART	G[illegible]	[illegible]91	30 sigma	modal, sigma fix	**17** 8 DU, 4 SS, 2 BC, 2POM, 1 SO4	external	aging of BC and POM
KYU	GC[illegible] CCSR/NIES/FR[illegible] GCM / SPRINTARS [illegible]	[illegible]	20 sigma	modal, sigma fix	**17** 10 DU, 4 SS, 1 BC, 1 BCPOM, 1 SO4	external partly internal for BC/ POM	none
LSCE	GCM LMDzT 3.3	3.[illegible]	[illegible]	modal, sigma fix	**5** acc. sol+insol, coa sol+insol, sup.coa sol	external mixture of internally mixed modes	aging of BC and POM
LOA	GCM LMDzT 3.3	96x72 3.75°x2.5°	[illegible]	bin	**17** 2 DU, 10 SS, 2 BC, 2POM, 1 SO4	external	aging of BC and POM
MATCH	CTM MATCH v 4.2	192x94 1.9°x1.9°	sig[illegible]	[illegible]	**8** 4DU, 1SS,1 BC, 1POM, 1SO4	external	aging of BC and POM
MPI HAM	GCM ECHAM5.2	192x96 1.8°x1.8°	31 hybrid sigma-p	[illegible]	**7**	external mixture of internally mixed modes	Nucl., Coag., Condensation Thermodynamics
MOZGN	CTM MOZART v2.5	192x96 1.9°x1.9°	28 sigma	[illegible]	[illegible]U,	external	aging of BC and POM
PNNL	GCM MIRAGE 2 / derived from NCAR CAM2.0	144x91 2.5°x2.0°	24 hybrid sigma-p	modal, sigma fix	[illegible]	[illegible]nal mixture of [illegible]ixed modes	SO4 microphysics
TM5	CTM TM5	60x45 6°x4°	25 hybrid sigma-p	modal, sigma fix	3 SS, 2 D[illegible] POM, BC, S[illegible]	[illegible]	none
UIO_CTM	CTM OsloCTM2	128x64 2.81°x2.81°	40 sigma	bin	**20** 8 DU, 8 SS, BC, POM, bioburn BCPOM, SO4	ex[illegible]	[illegible]C and POM
UIO_GCM	**GCM CCM3.2**	128x64 2.81°x2.81°	18 hybrid sigma-p	external: modal fix internal: bin	**55** 12 modes 43 bins	8 presc[illegible] 4 transported [illegible] 4 transported inte[illegible]	[illegible]d POM
ULAQ	**CTM ULAQ**	16x19 22.5°x10°	26 log-p	bin	**41**	external	[illegible]C and POM S[illegible]icrophysics
UMI	CTM IMPACT	144x91 2.5°x2°	30 sigma	bin	**13**	external	none

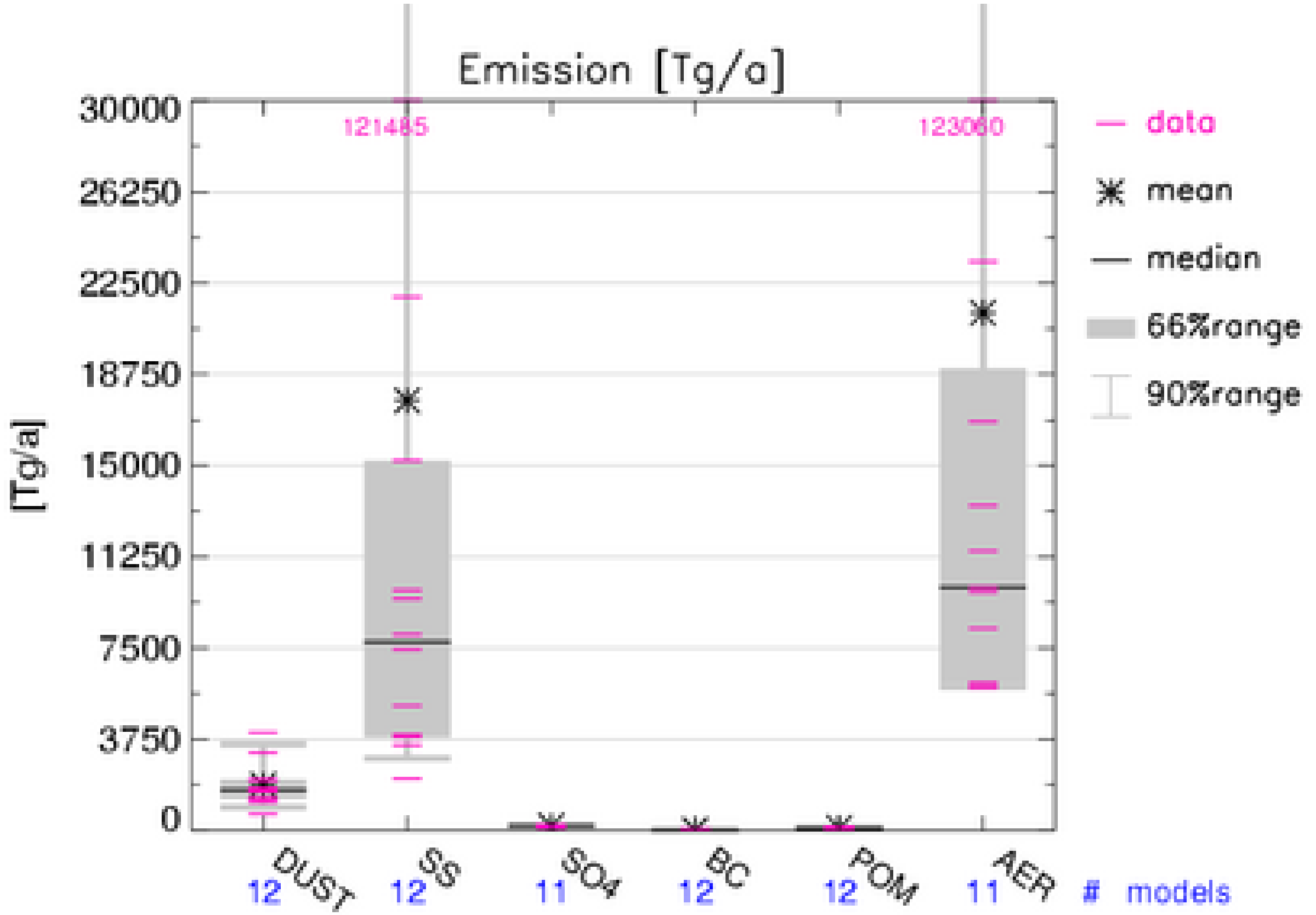
Special thanks to the modellers!

Aerosol Emissions in AeroCom Exp A



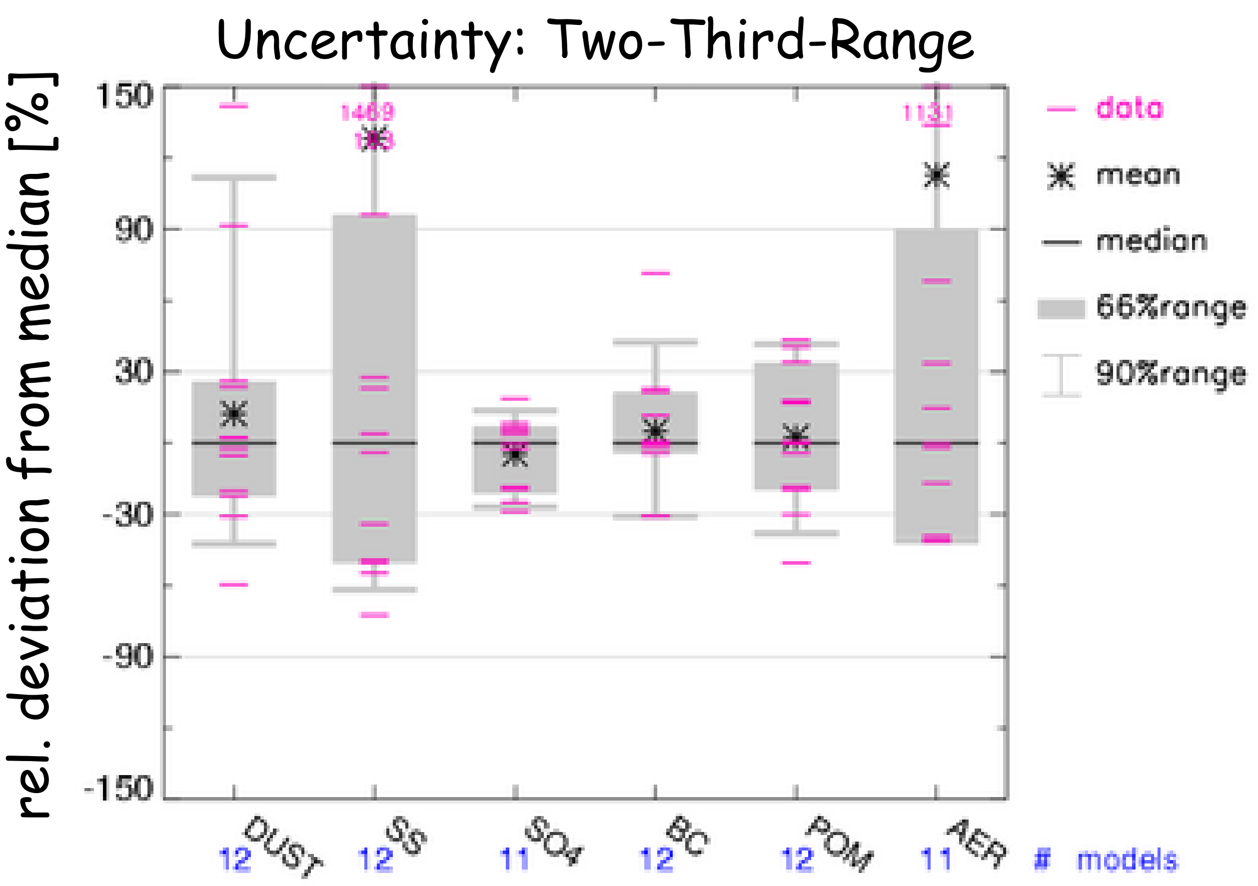
Year 2000 if available

Emissions from all models



„Uncertainty": scatter of model results

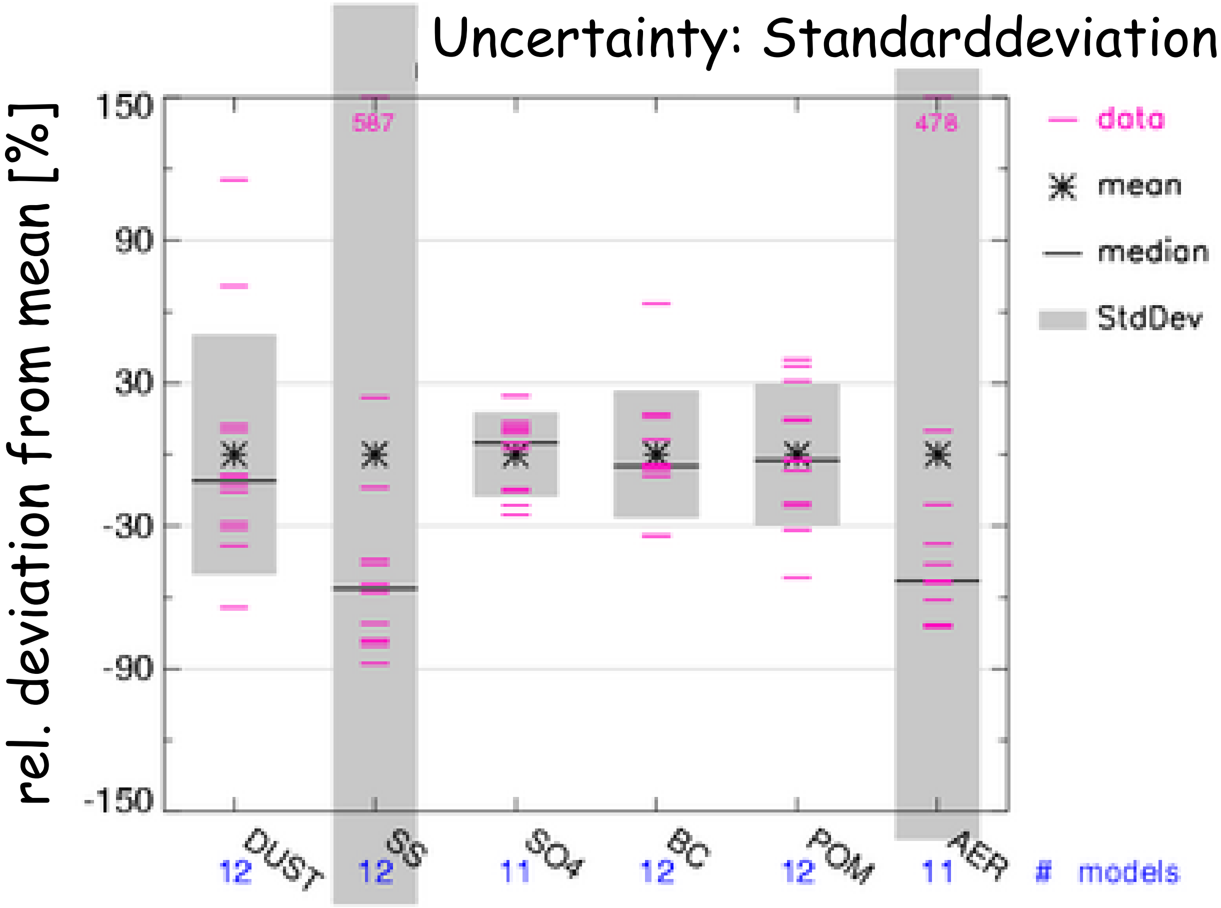
Two-Third-Range around all-models-median



Normalization with all-models-median

$$\text{data} = \frac{\text{model-all models median}}{\text{all models median}} * 100$$

Standarddeviation of normalized deviation from all-models-mean

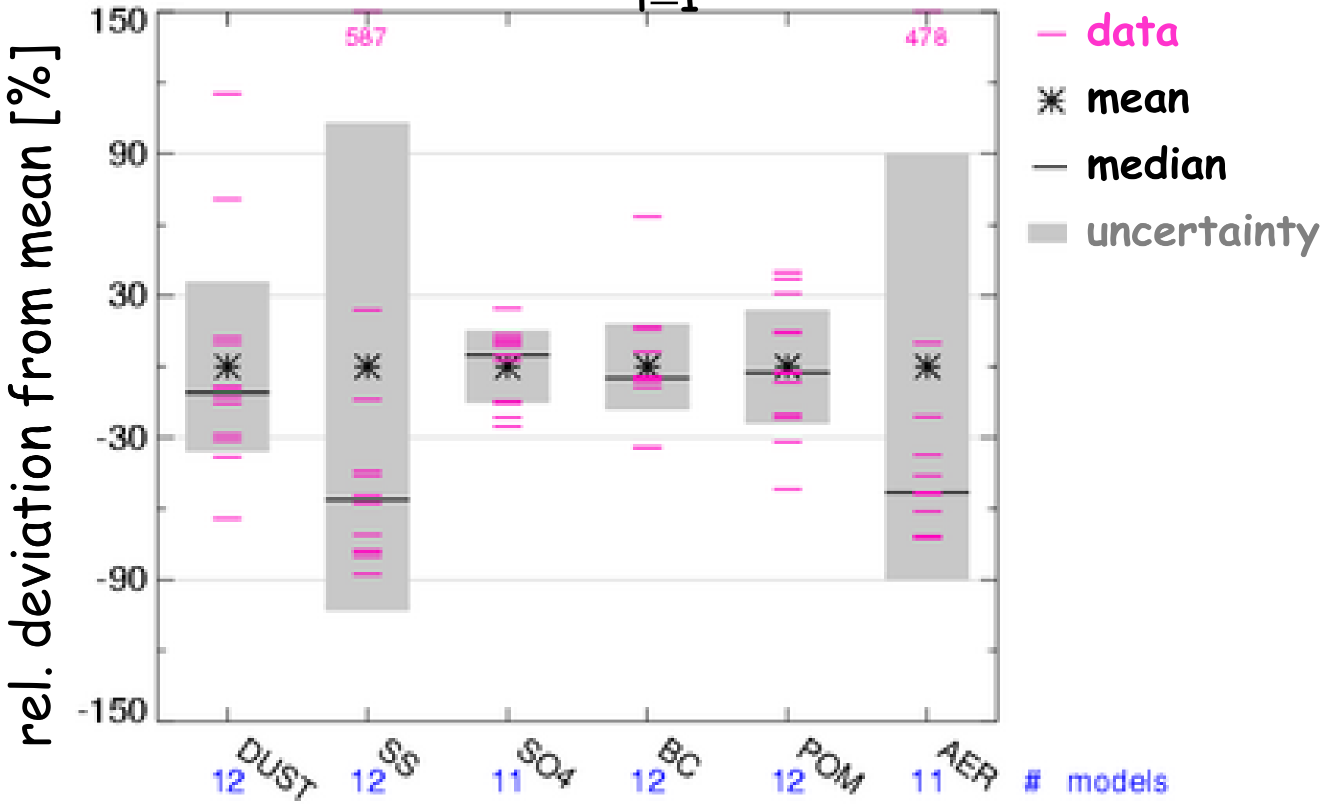


Normalization with all-models-mean

$$\text{data} = \frac{\text{model} - \text{all models mean}}{\text{all models mean}} * 100$$

Average absolute deviation from the all-model-mean of the normalized model results

$$\text{Uncertainty} = \frac{2}{N}\sum_{i=1}^{N}\left|\text{data}\right|$$

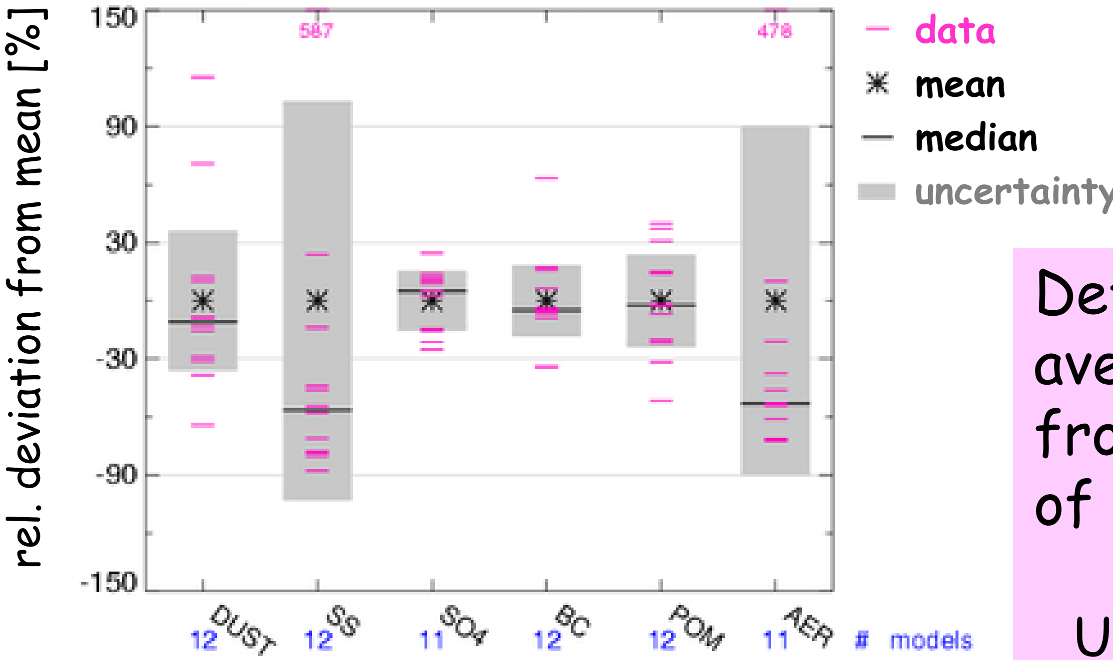


Normalization with all-models-mean

$$\text{data} = \frac{\text{model - all models mean}}{\text{all models mean}} * 100$$

Uncertainty

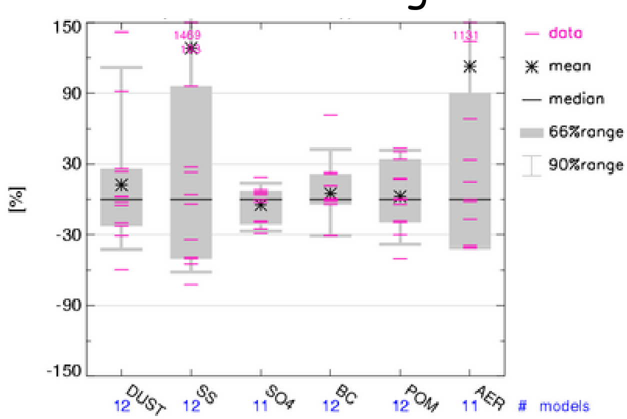
Uncertainty



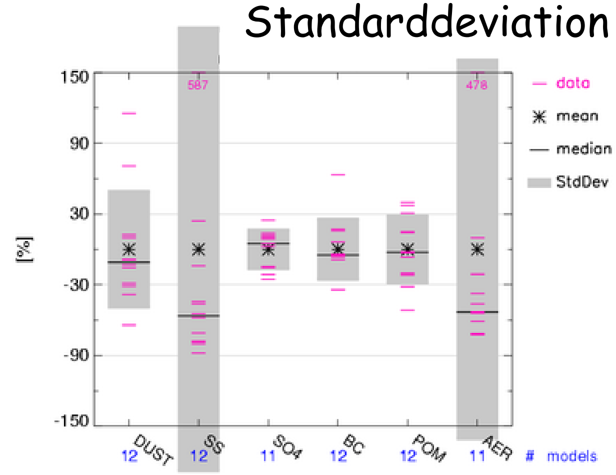
Definition: twice the average absolute deviation from the all-models-mean of the normalized data

$$\text{Uncertainty} = \frac{2}{N}\sum_{i=1}^{N}\left|\text{data}\right|$$

TwoThird Range

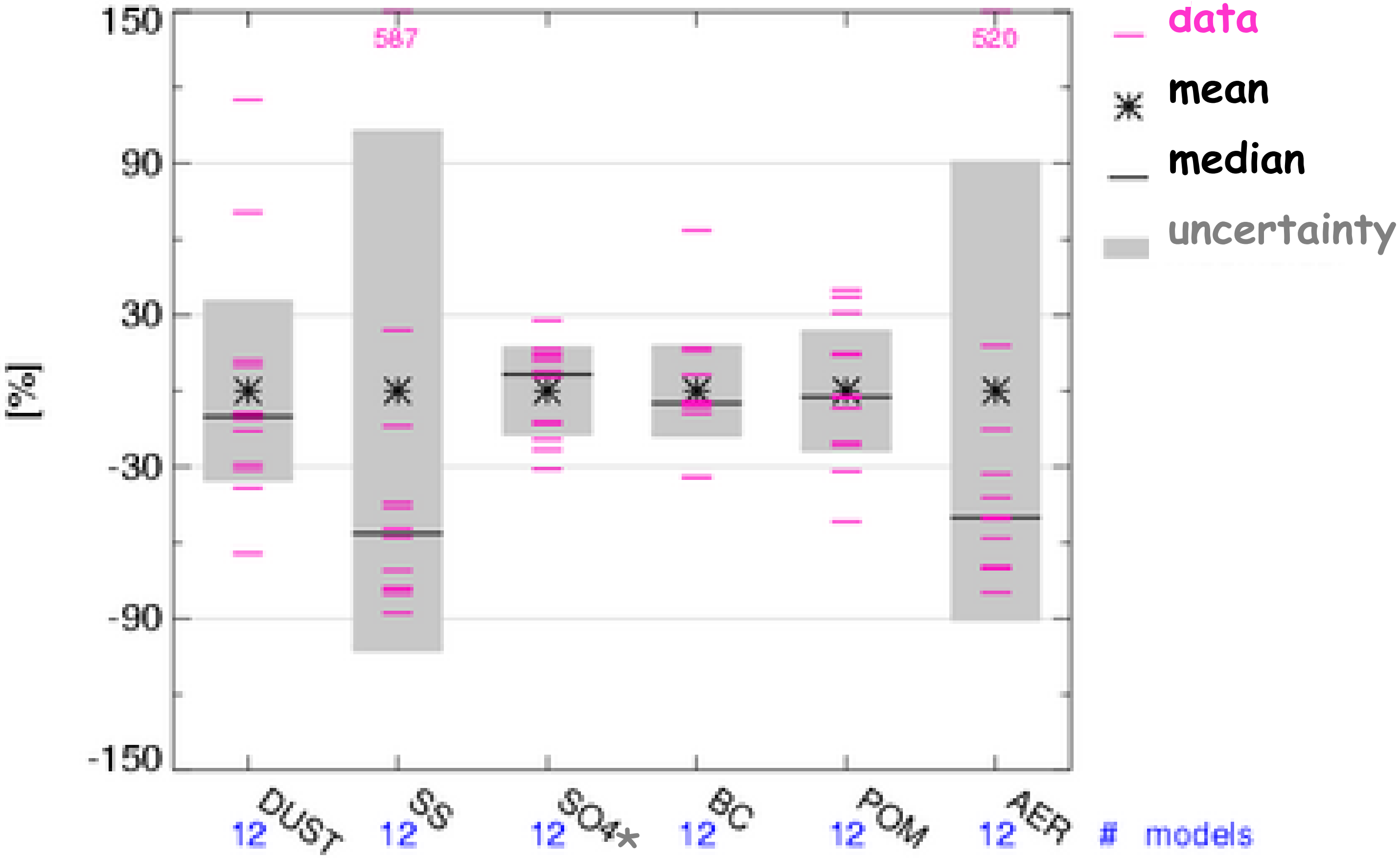


Standarddeviation



Emissions

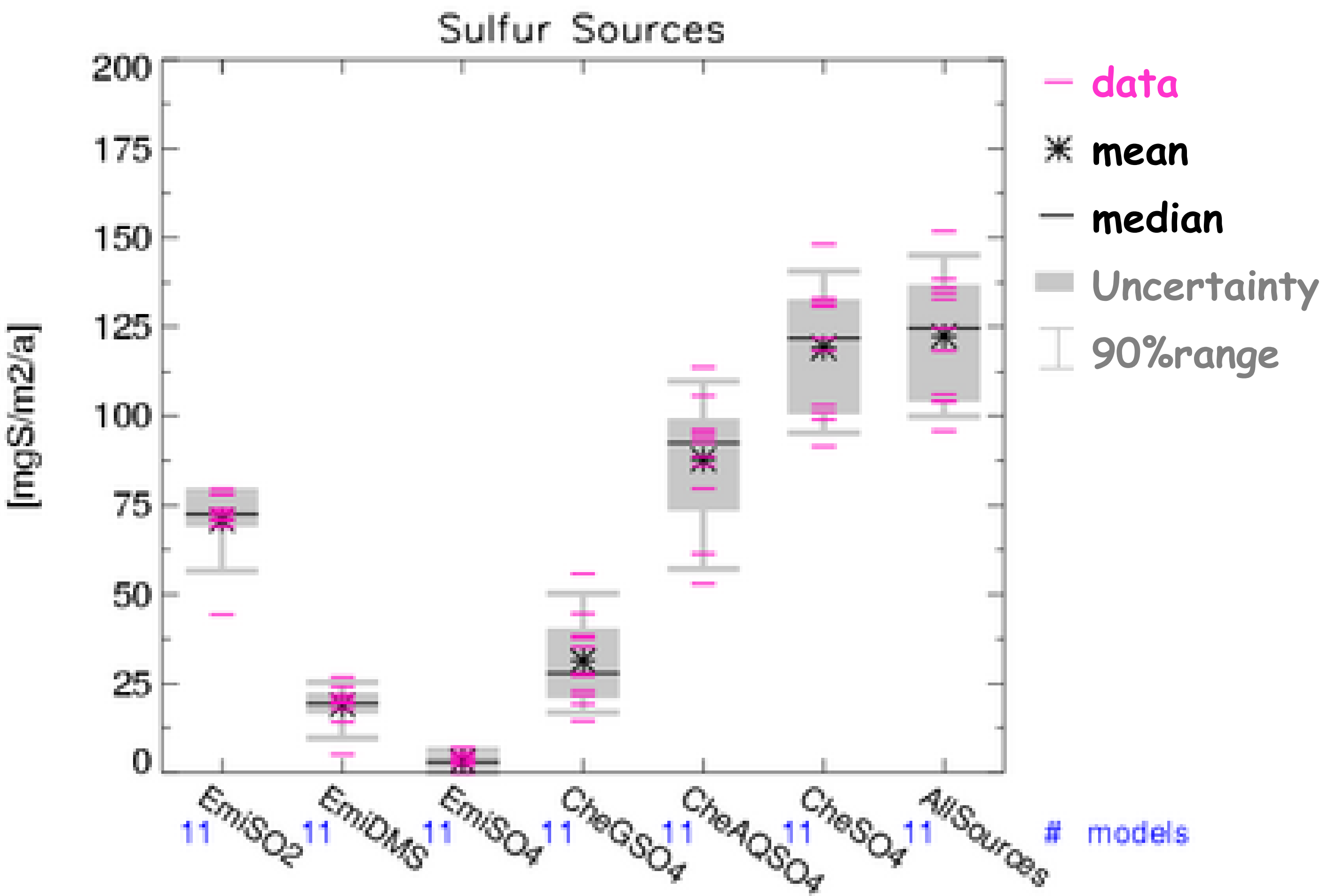
Uncertainty of global annual mean emissions



species	mean [Tg]	median [Tg]	uncertainty [%]
DUST	1873.25	1668.28	69
SS	17670.97	7742.24	204
SO4	186.43	195.59	28
BC	11.86	11.30	34
POM	98.41	96.05	46
AER	21276.93	9996.44	178

* SO4: emi+chep in [TgSO4]

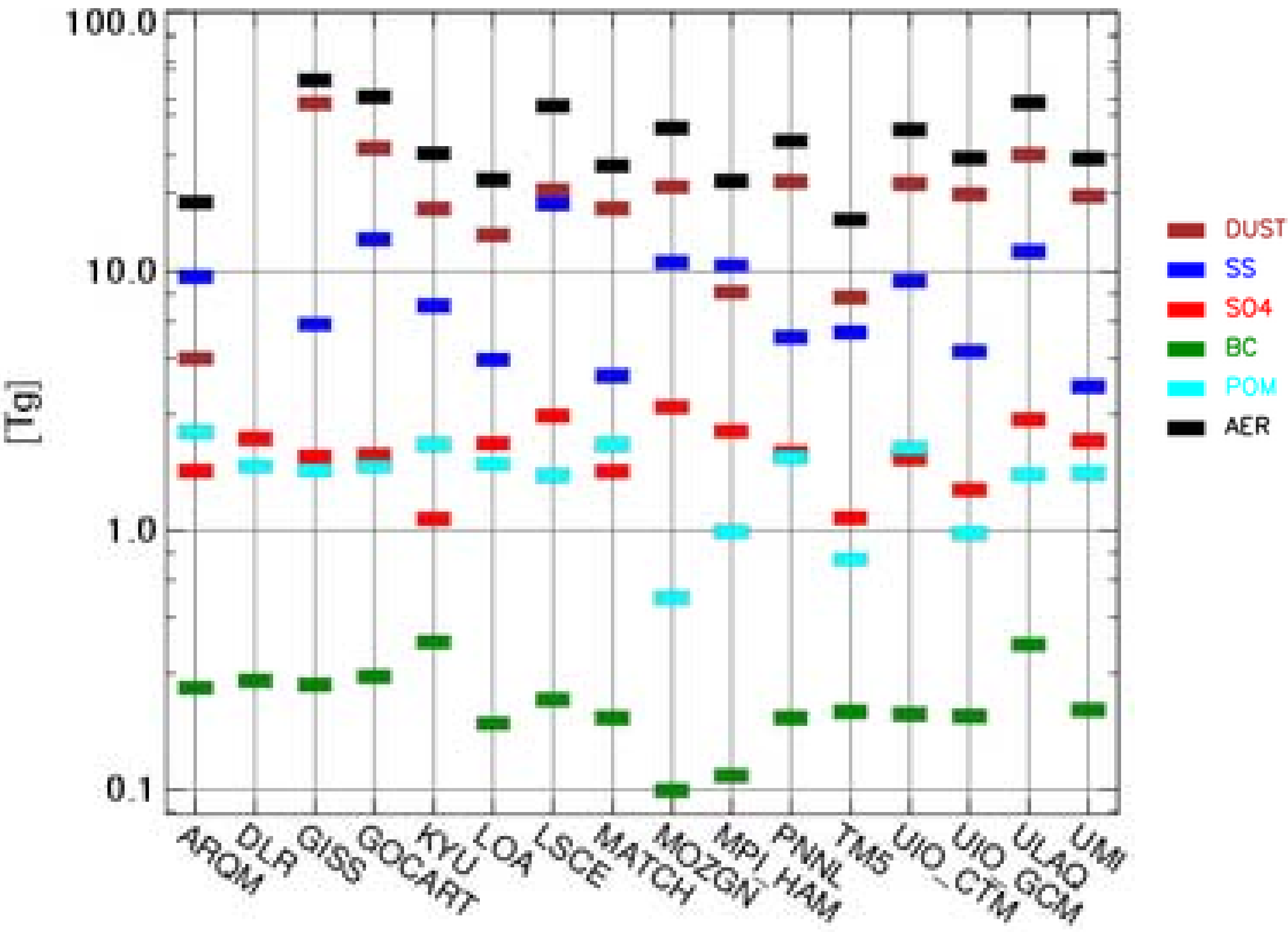
Sulfur sources/Uncertainty



The uncertainty of the sulfur sources is caused by chemistry, not be the emissions.

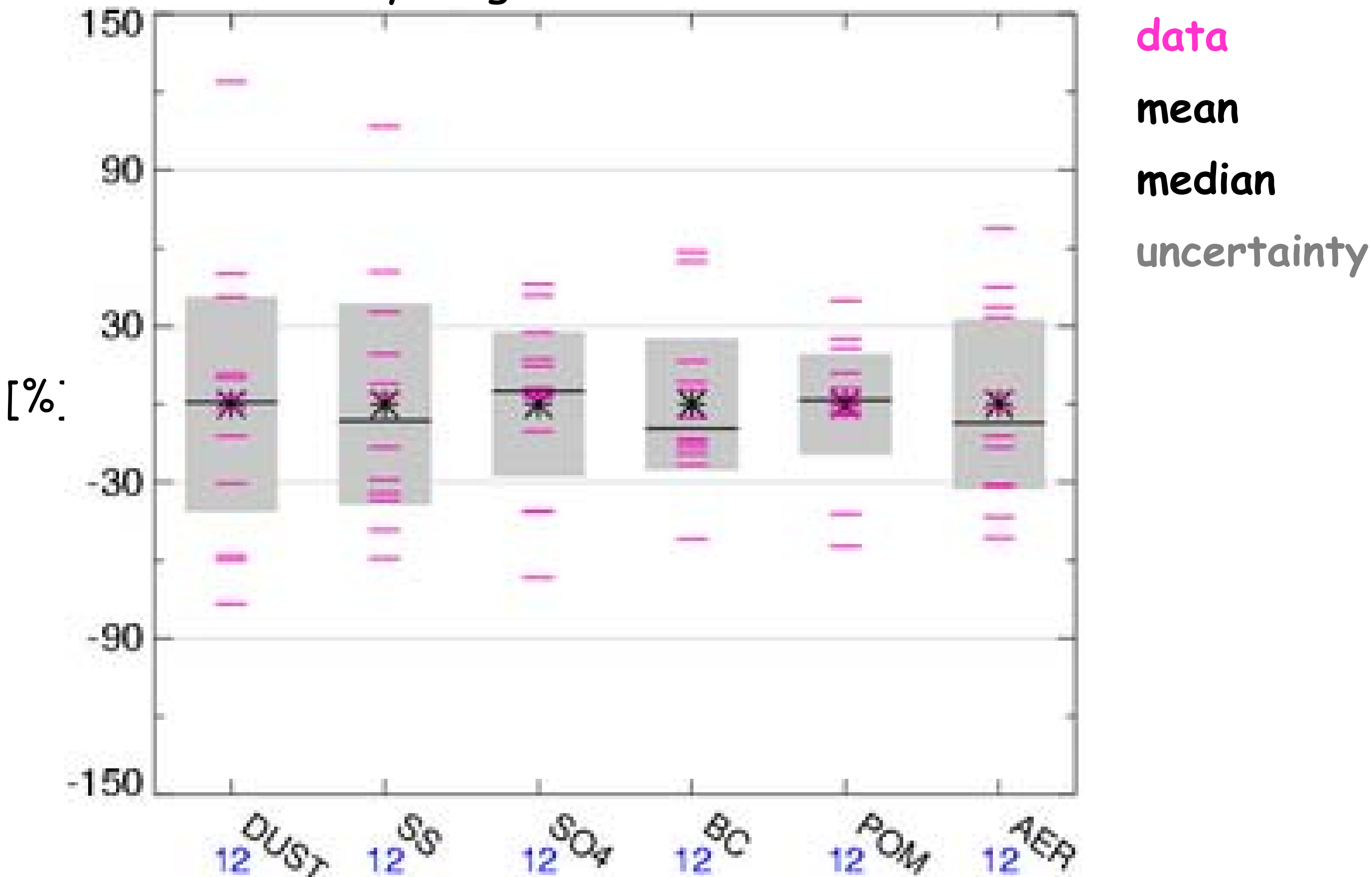
Mass

Global annual mean aerosol mass

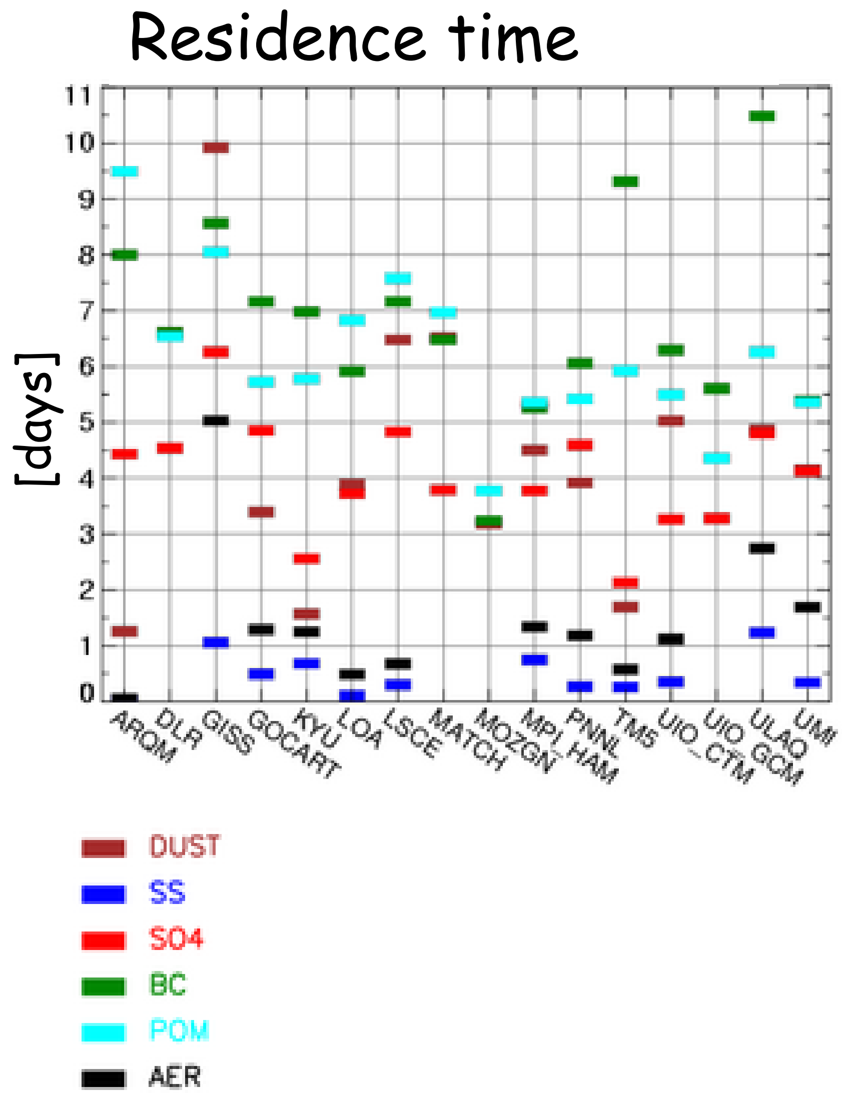


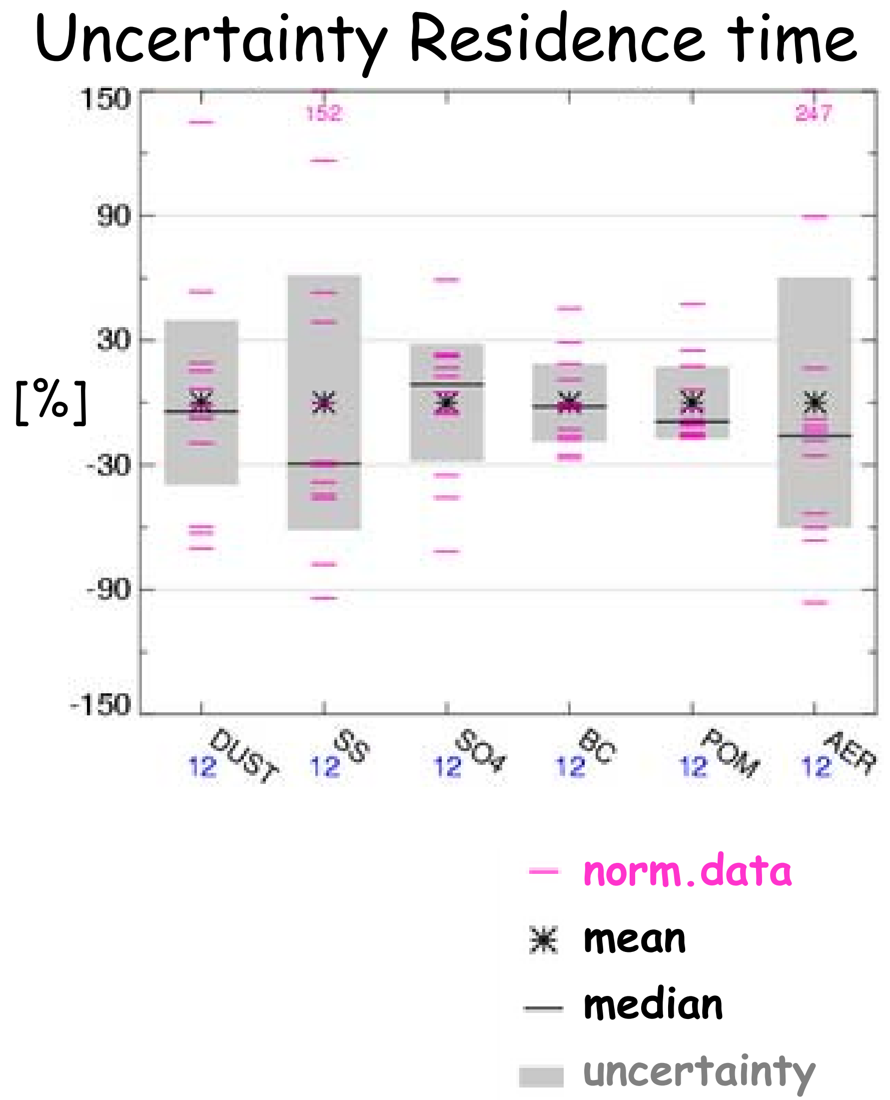
Mass

Uncertainty of global annual mean aerosol mass



species	mean [Tg]	median [Tg]	uncertainty [%]
DUST	19.83	19.97	80
SS	8.80	8.25	75
SO4	1.99	1.98	38
BC	0.23	0.21	48
POM	1.70	1.73	36
AER	32.46	30.12	63

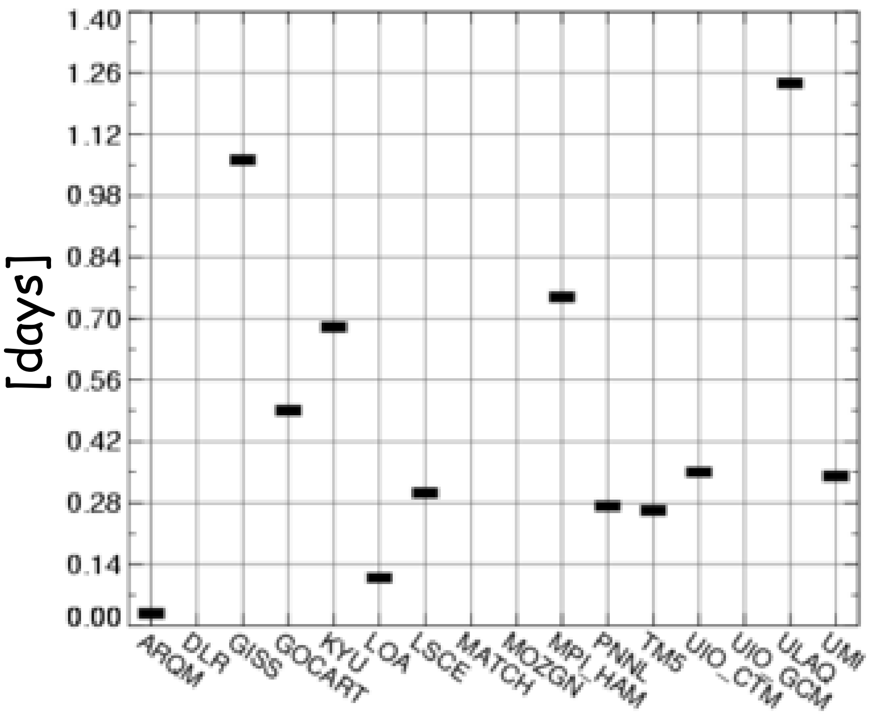

Residence time
[days]
11
10
9
8
7
6
5
4
3
2
1
0
AROM
DLR
GISS
GOCART
KYU
LOA
LSCE
MATCH
MOZGN
MPI_HAM
PNNL
TM5
UIO_CTM
UIO_GCM
ULAQ
UMI
DUST
SS
SO4
BC
POM
AER


Uncertainty Residence time
[%]
150
90
30
-30
-90
-150
152
247
DUST
SS
SO4
BC
POM
AER
12
norm.data
mean
median
uncertainty

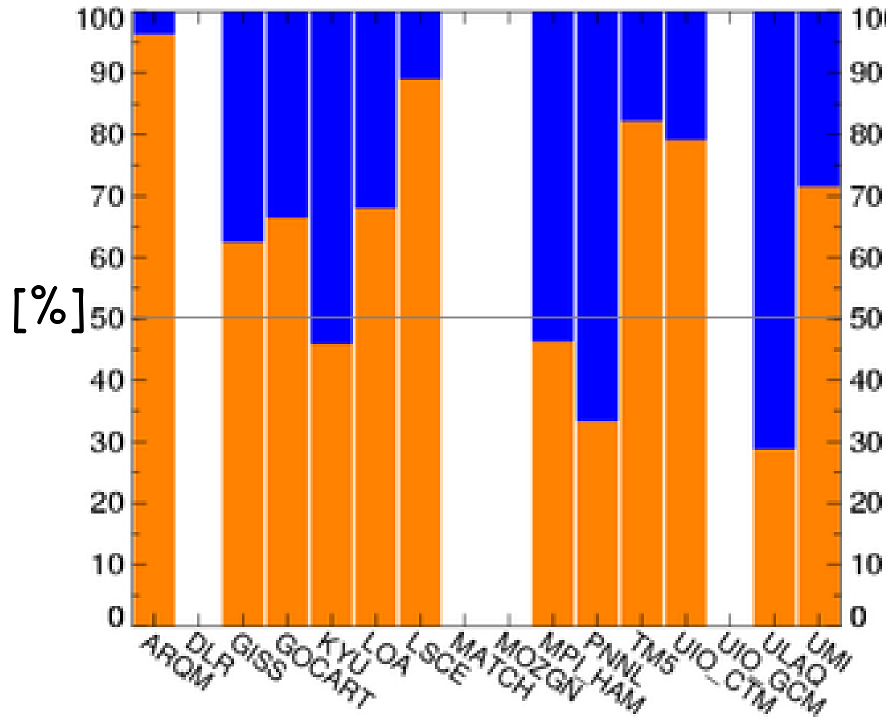
Sink processes: analysis for Sea Salt

dominant sink process:
wet or **dry*** deposition?

Residence time τ SeaSalt



Mass fraction f_i of sinks:
wet/total and **dry**/total



$$\tau = \frac{\text{load}}{\text{sources}} = \frac{\text{load}}{\text{sinks}}$$

$$f_i = \frac{\text{massflux\_sink}_i}{\sum_i (\text{massflux\_sink}_i)}$$

* dry : sedimentation + turbulent dep.

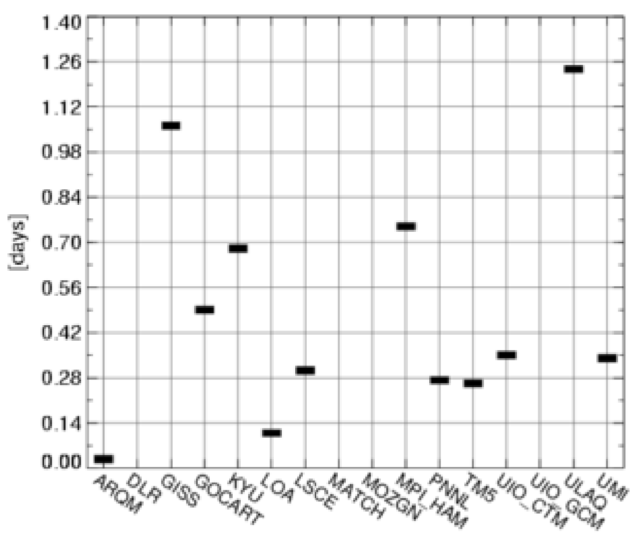
fastest sink process?

Definition of a global mean effective sink rate k,

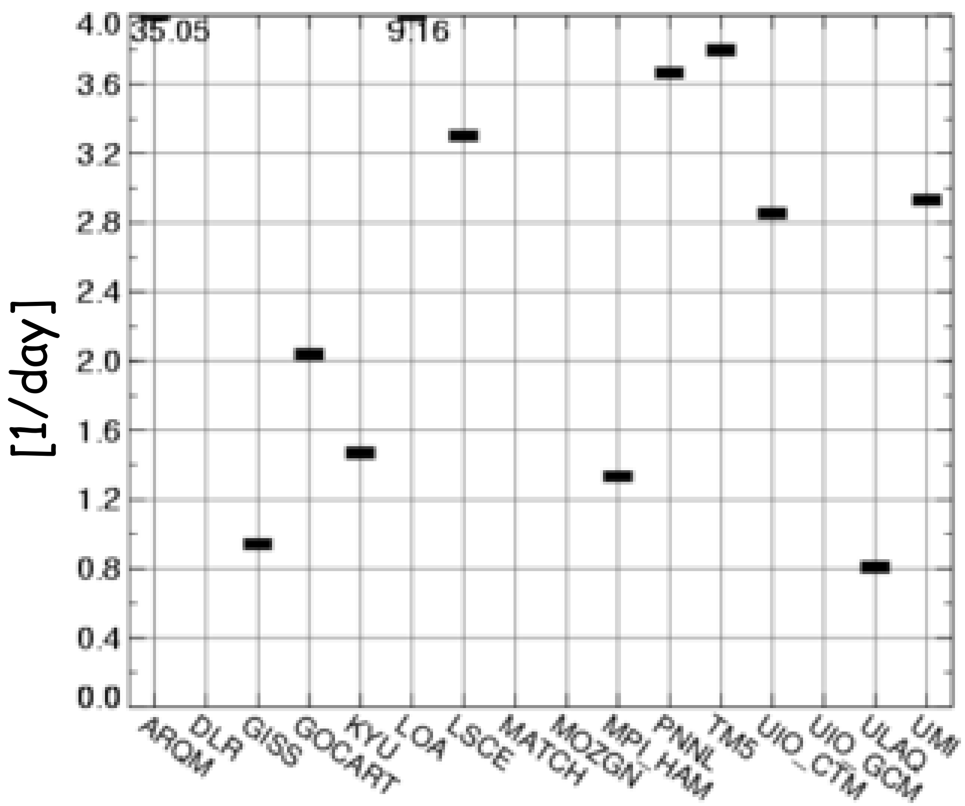
inverse of residence time τ

$$-\frac{dm}{dt} = \tau^{-1} m = k_{total}\, m$$

residence time τ



effective sink rate $\mathbf{k}_{total}$



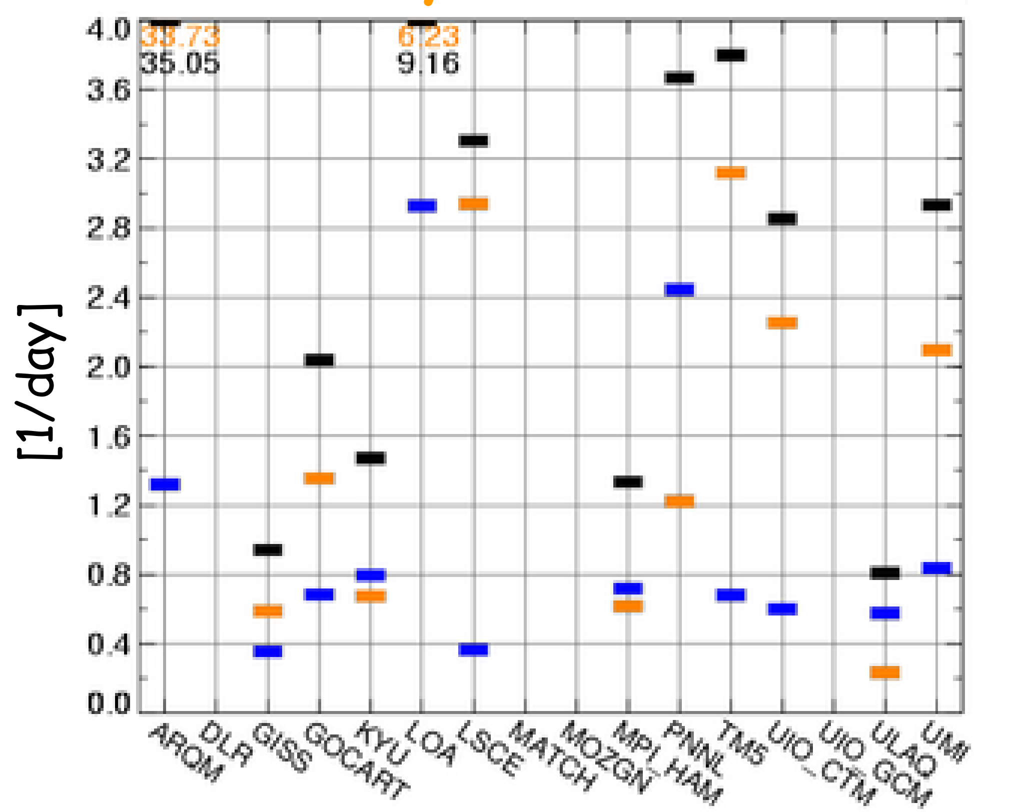
fastest sink process?

The effective rate constants
of the single processes are additive.

$$-\frac{dm}{dt} = k_{wet}\, m + k_{dry}\, m$$

$$k_{total} = k_{wet} + k_{dry}$$

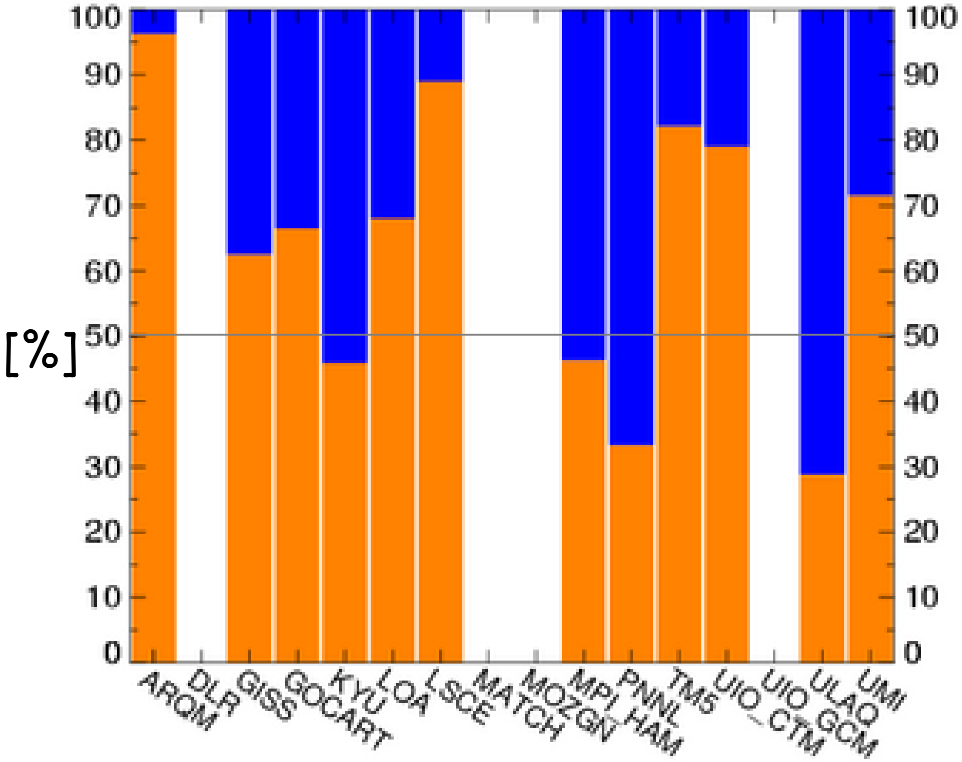
effective sink rates for
wet, dry and **total** sinks



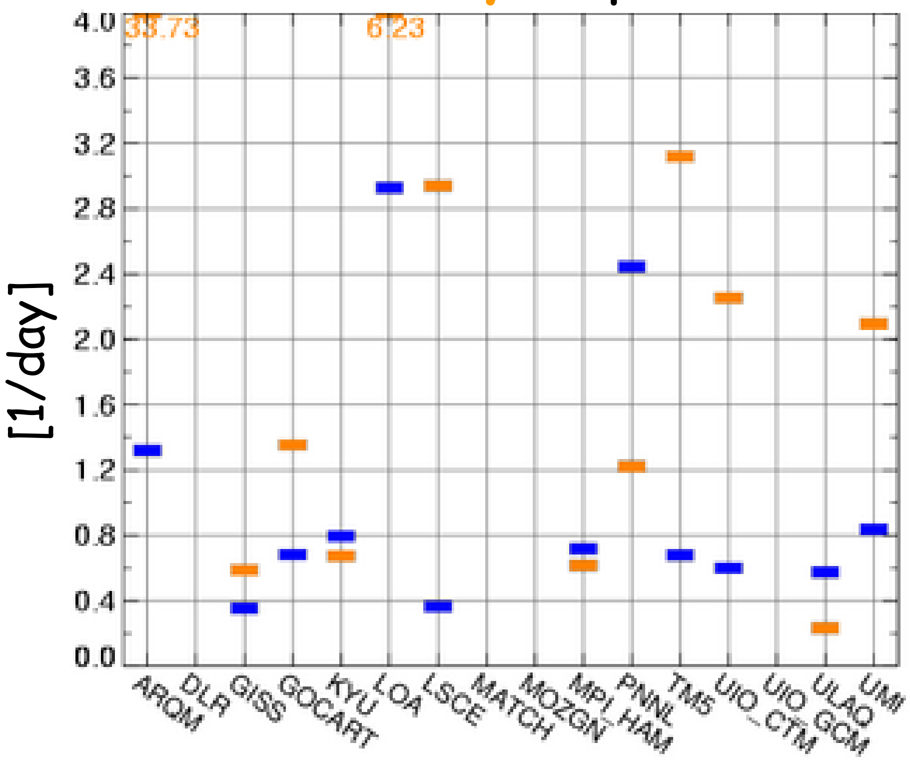
total
wet
dry

Sink processes: analysis for Sea Salt

Mass fraction $\mathbf{f_i}$ of sinks: **wet**/total and **dry**/total



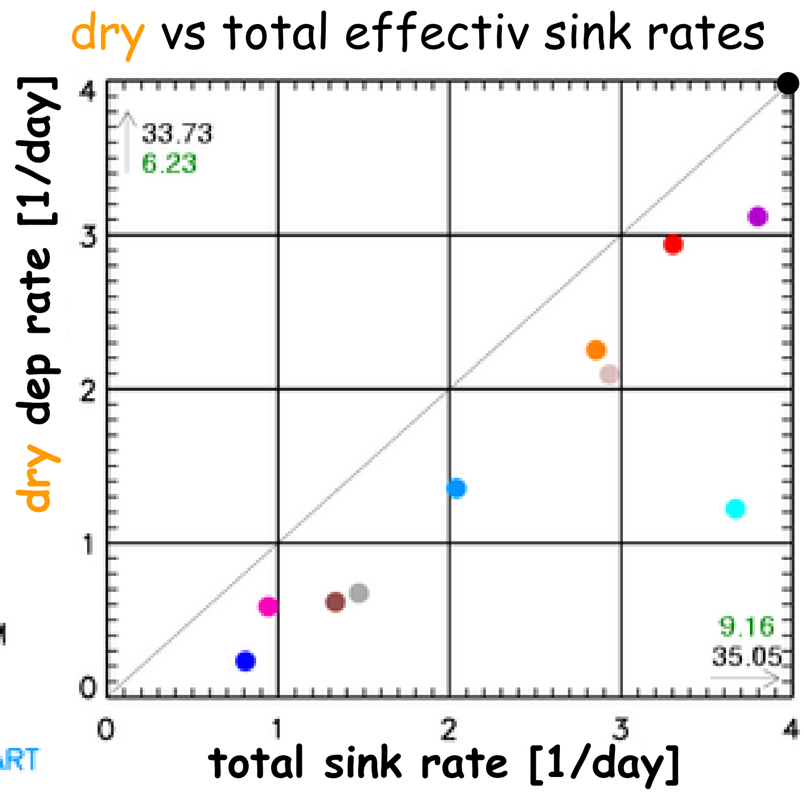
effective sink rates $\mathbf{k_i}$ for **wet** and **dry** deposition

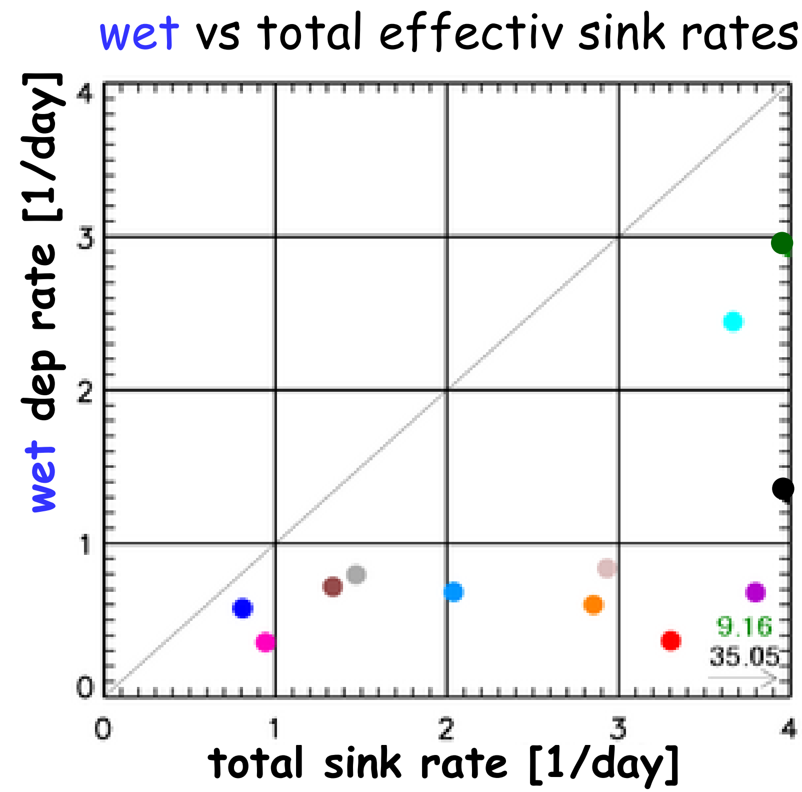


$$f_i = \frac{massflux\_sink_i}{\sum_i (massflux\_sink_i)}$$

$$k_i = f_i * k$$

Sink processes: analysis for Sea Salt



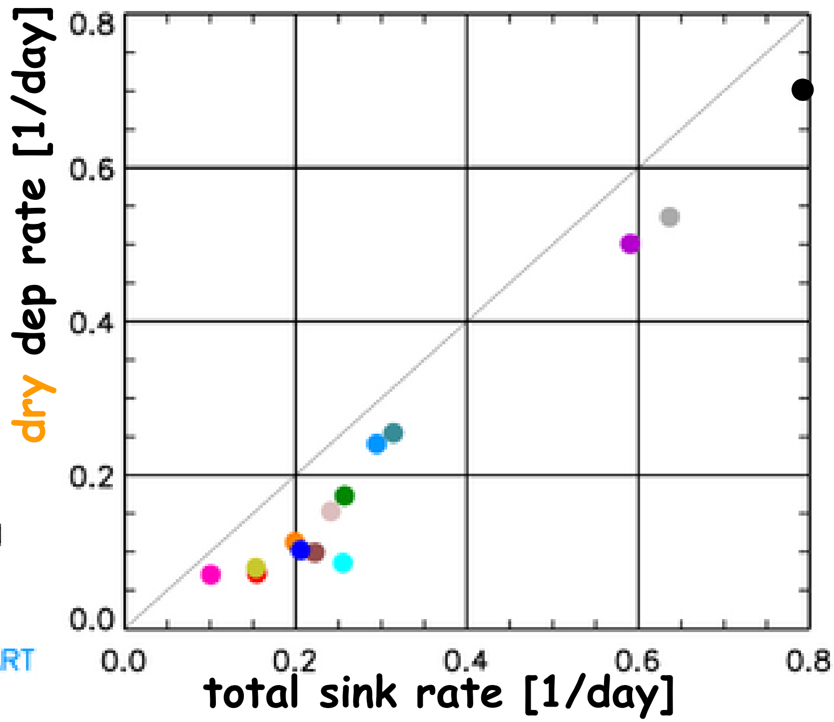


- Differences in the total sink rate are caused by the dry dep. rate.
- Dry dep. is much faster in **ARQM** and **LOA**.

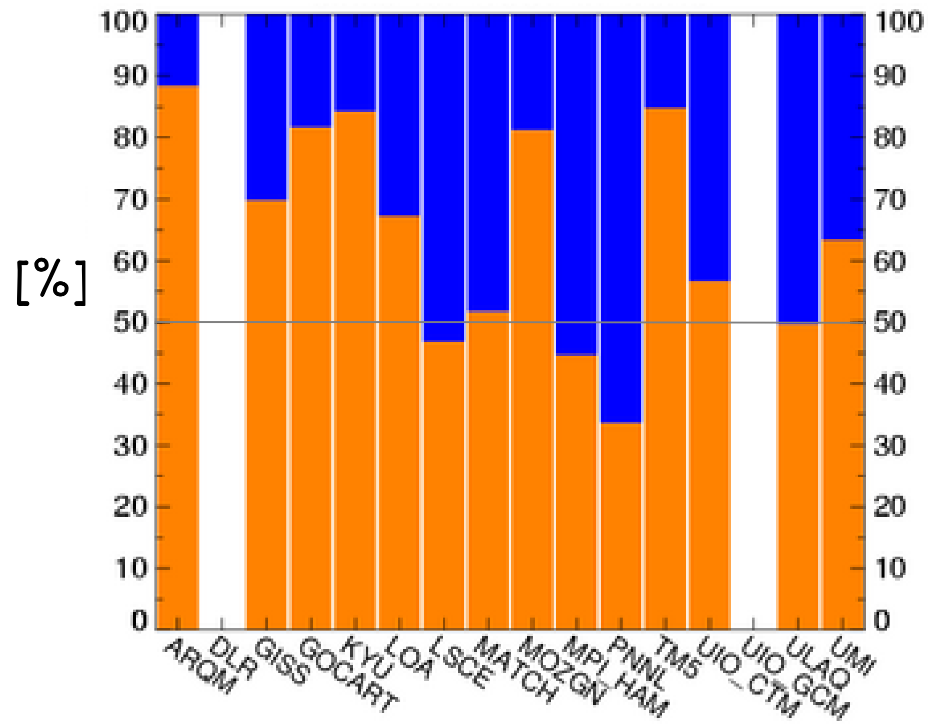
- Wet dep. rate is faster in **LOA**, **PNNL**, and **ARQM**.

Sink processes: analysis for Dust

dry vs total effectiv sink rates

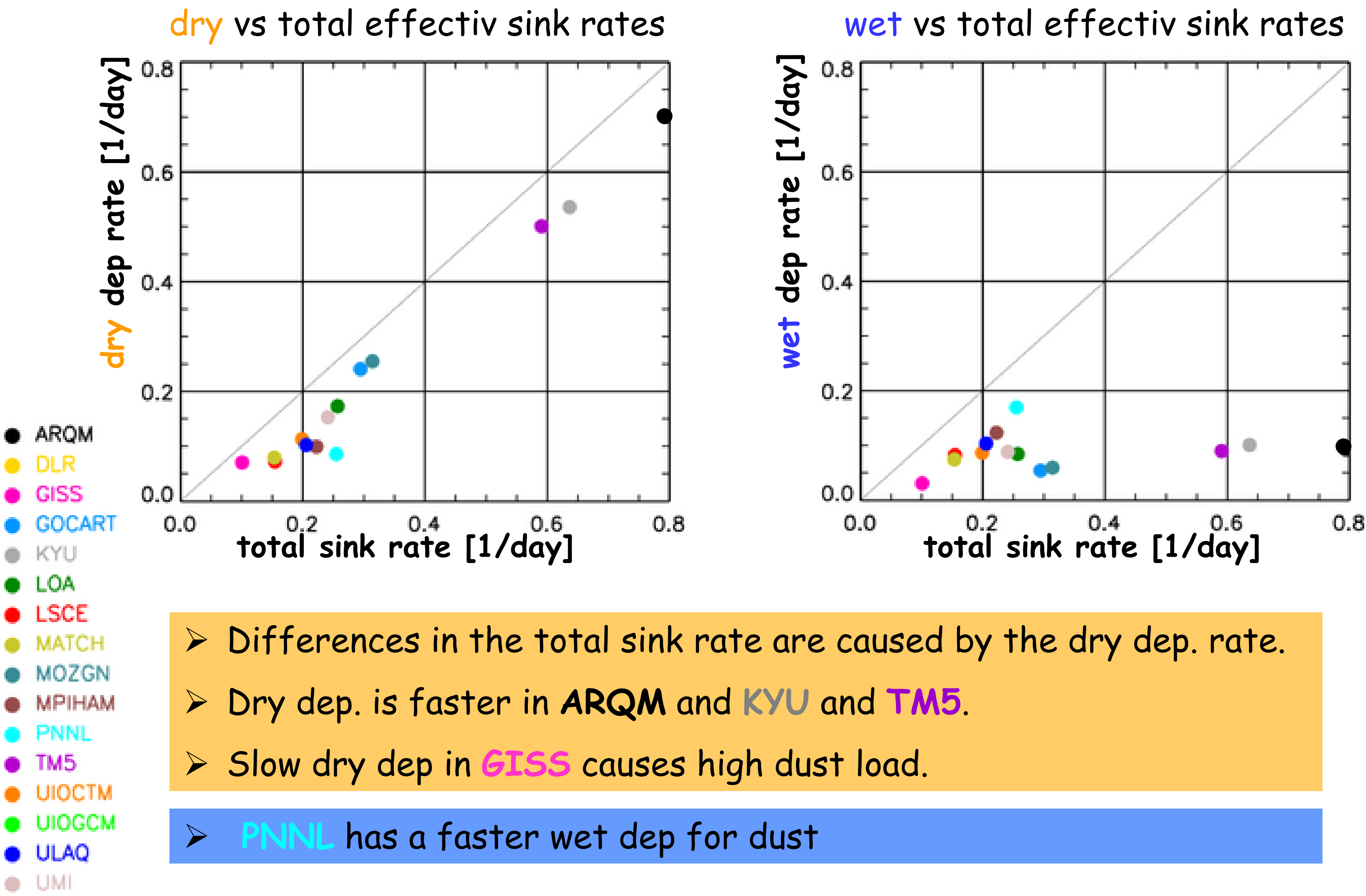


Mass fraction f_i of sinks:
wet/total and dry/total



- Differences in the total sink rate are caused by the dry dep. rate.
- Dry dep. is faster in **ARQM**, KYU and **TM5**.
- Slow dry dep in **GISS** causes high dust load.

Sink processes: analysis for Dust

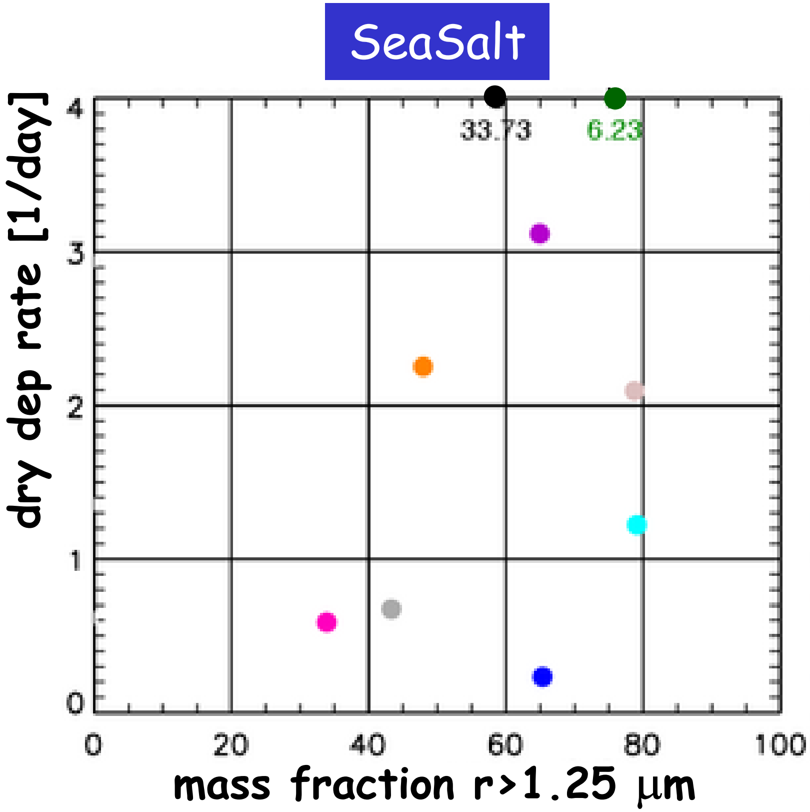


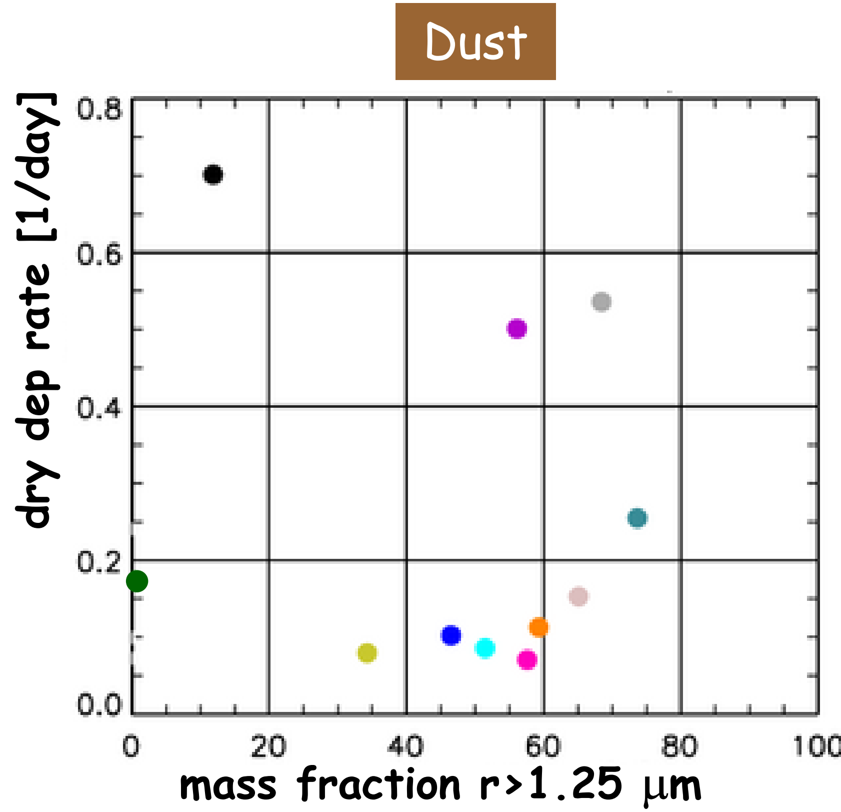
- Differences in the total sink rate are caused by the dry dep. rate.
- Dry dep. is faster in **ARQM** and KYU and **TM5**.
- Slow dry dep in **GISS** causes high dust load.

- PNNL has a faster wet dep for dust

Sink processes: analysis for large particles

Dry dep rate vs. Supercoarse mass fraction

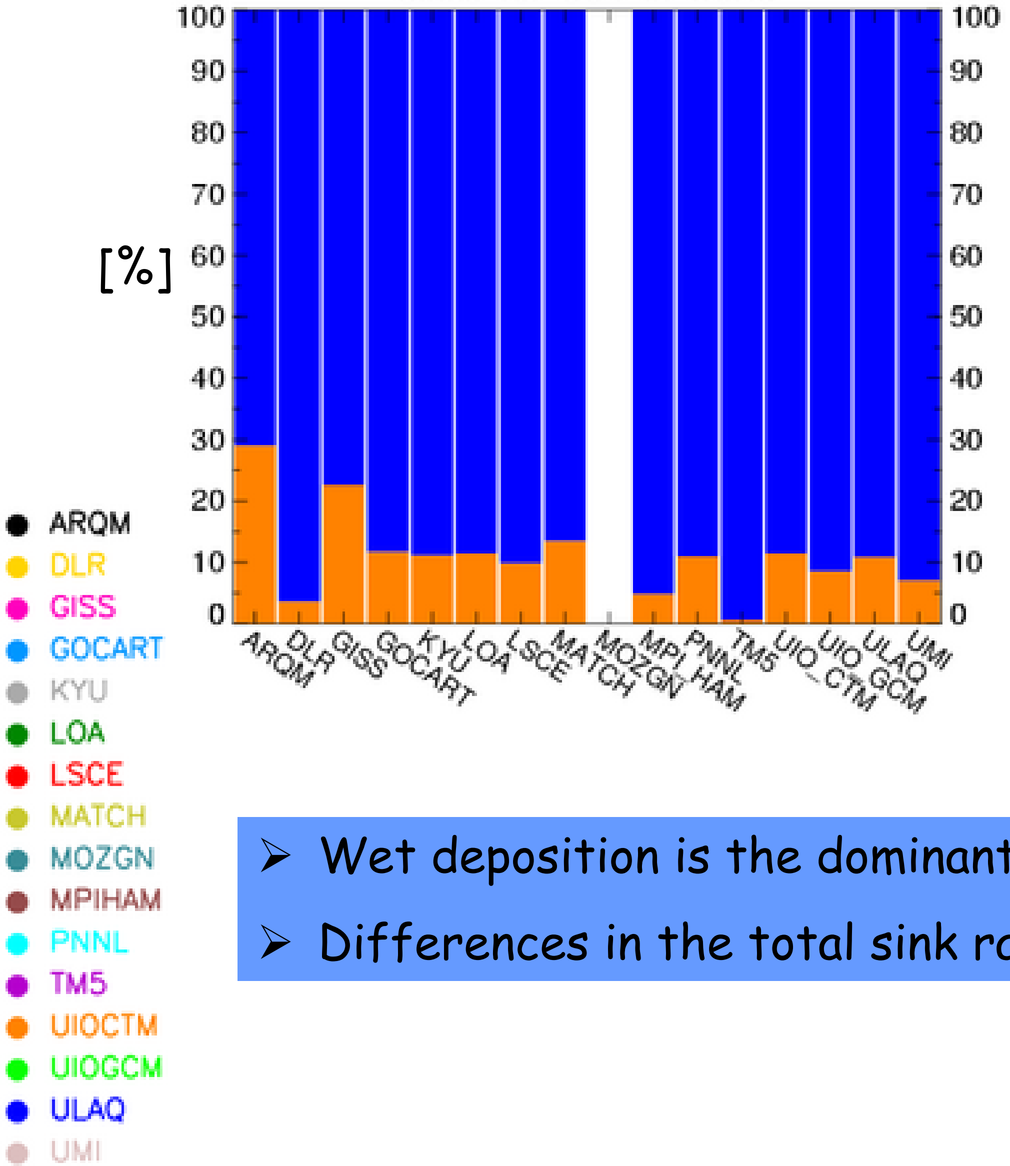




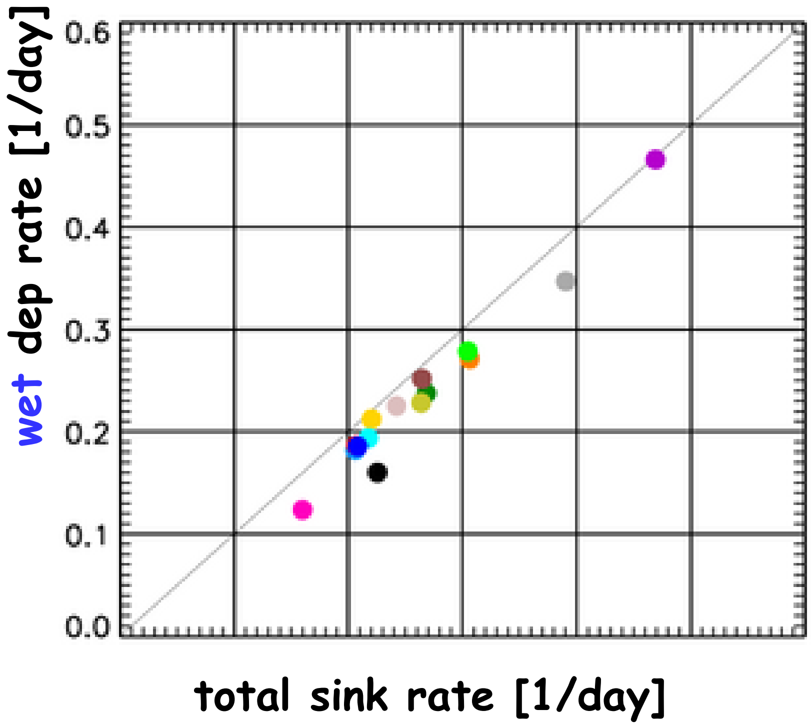
Dry dep rate of large particles is - in general - faster.

Sink processes: analysis for Sulfate

Mass fraction f_i of sinks:
wet/total and **dry**/total

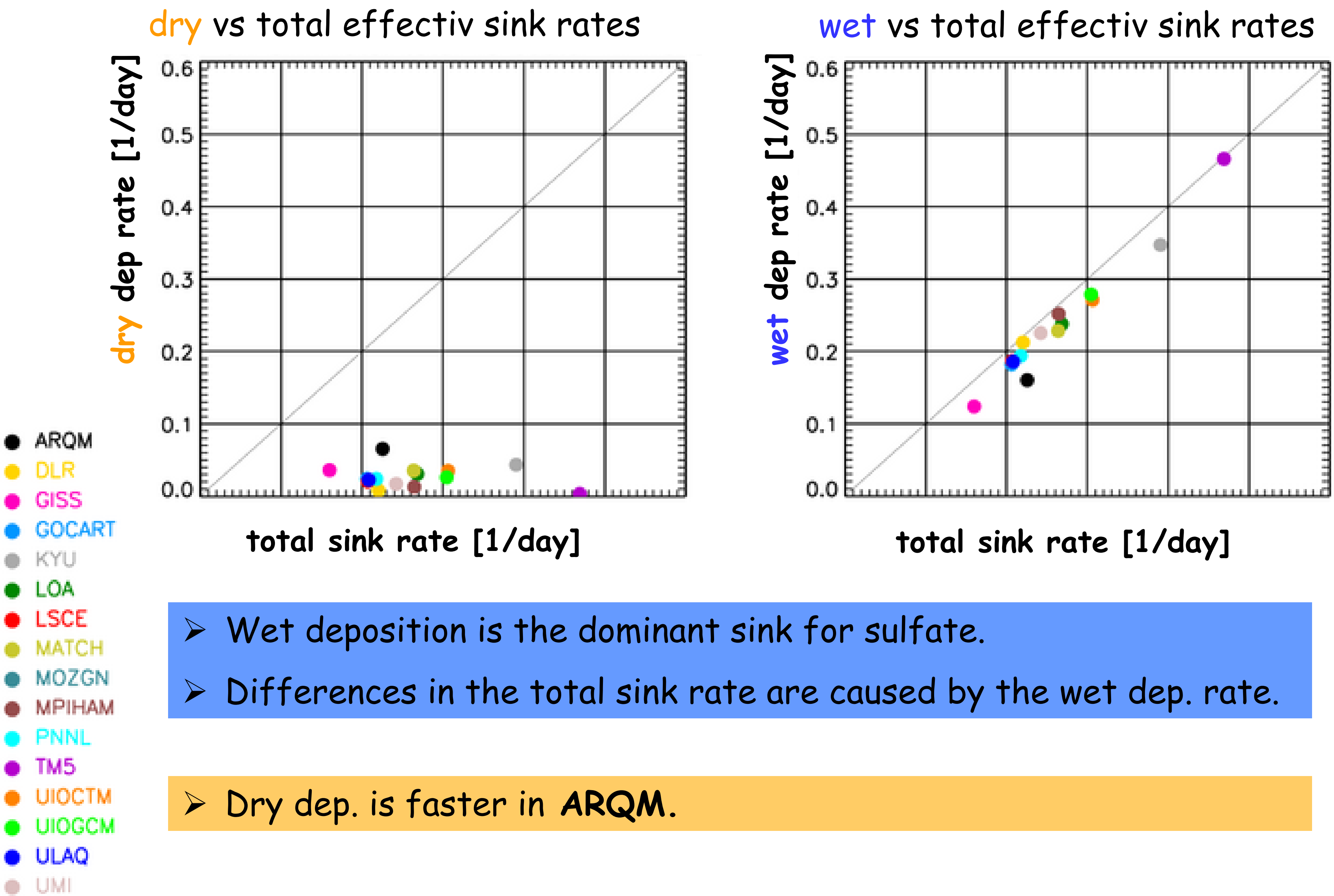


wet vs total effectiv sink rates



- Wet deposition is the dominant sink for sulfate.
- Differences in the total sink rate are caused by the wet dep. rate.

Sink processes: analysis for Sulfate

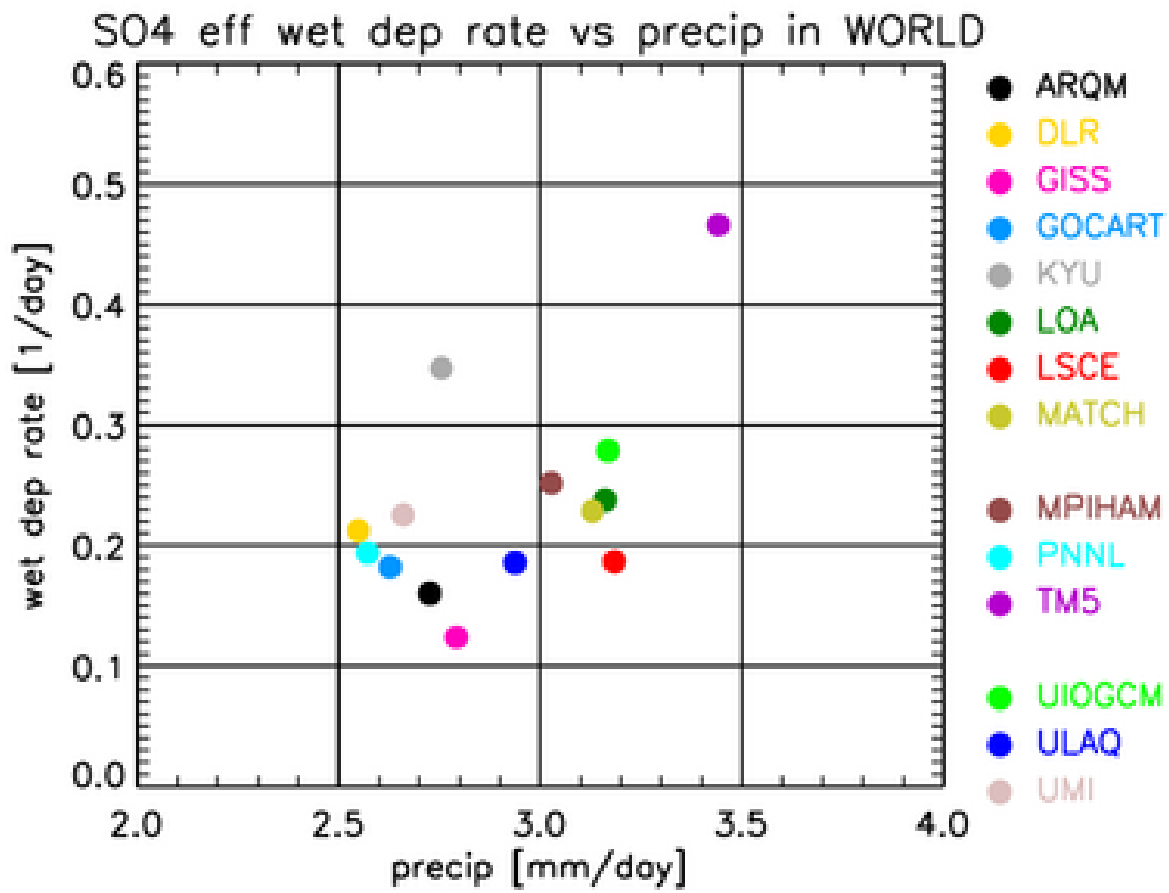


- Wet deposition is the dominant sink for sulfate.
- Differences in the total sink rate are caused by the wet dep. rate.

- Dry dep. is faster in **ARQM**.

Sink processes: analysis for Sulfate

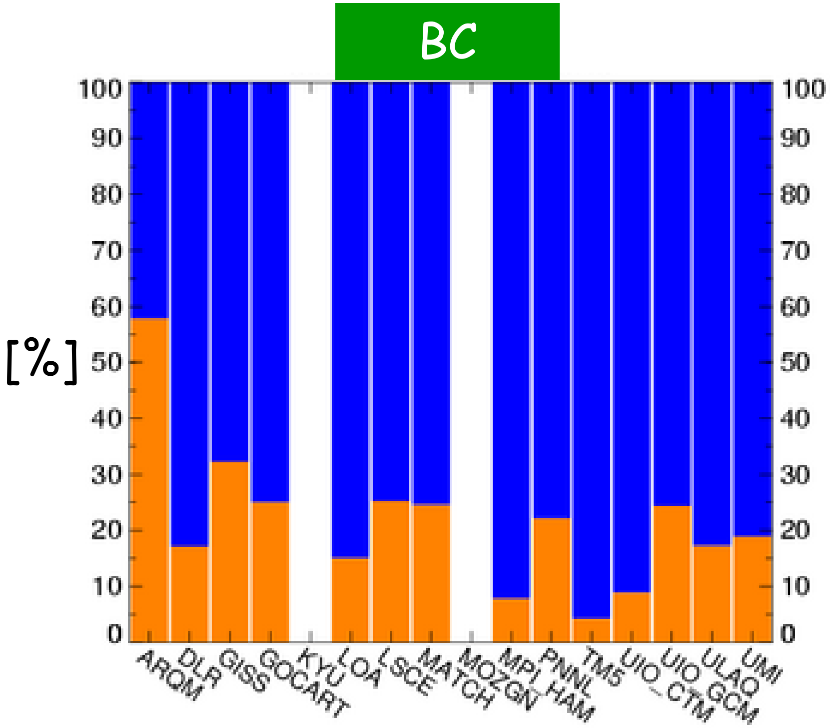
Wet dep rate vs. Precipitation rate

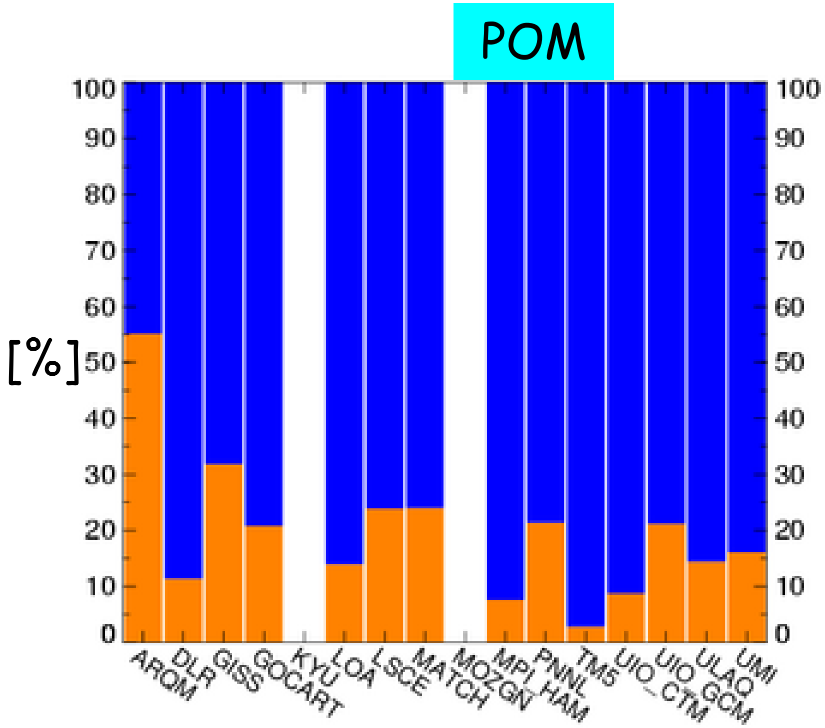


Wet dep rate increases with increasing global annual precip rate.

Sink processes: analysis for BC and POM

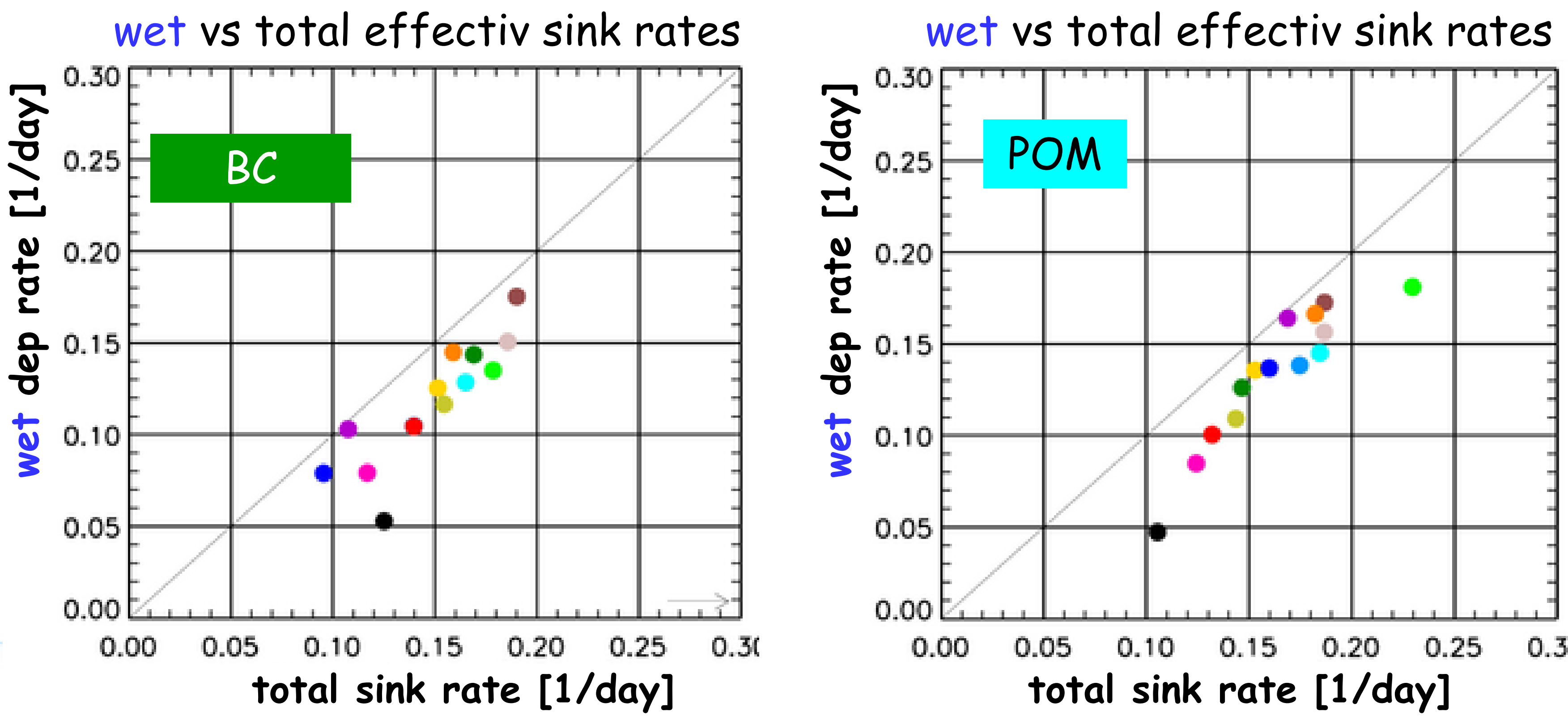
Mass fraction f_i of sinks: wet/total and dry/total





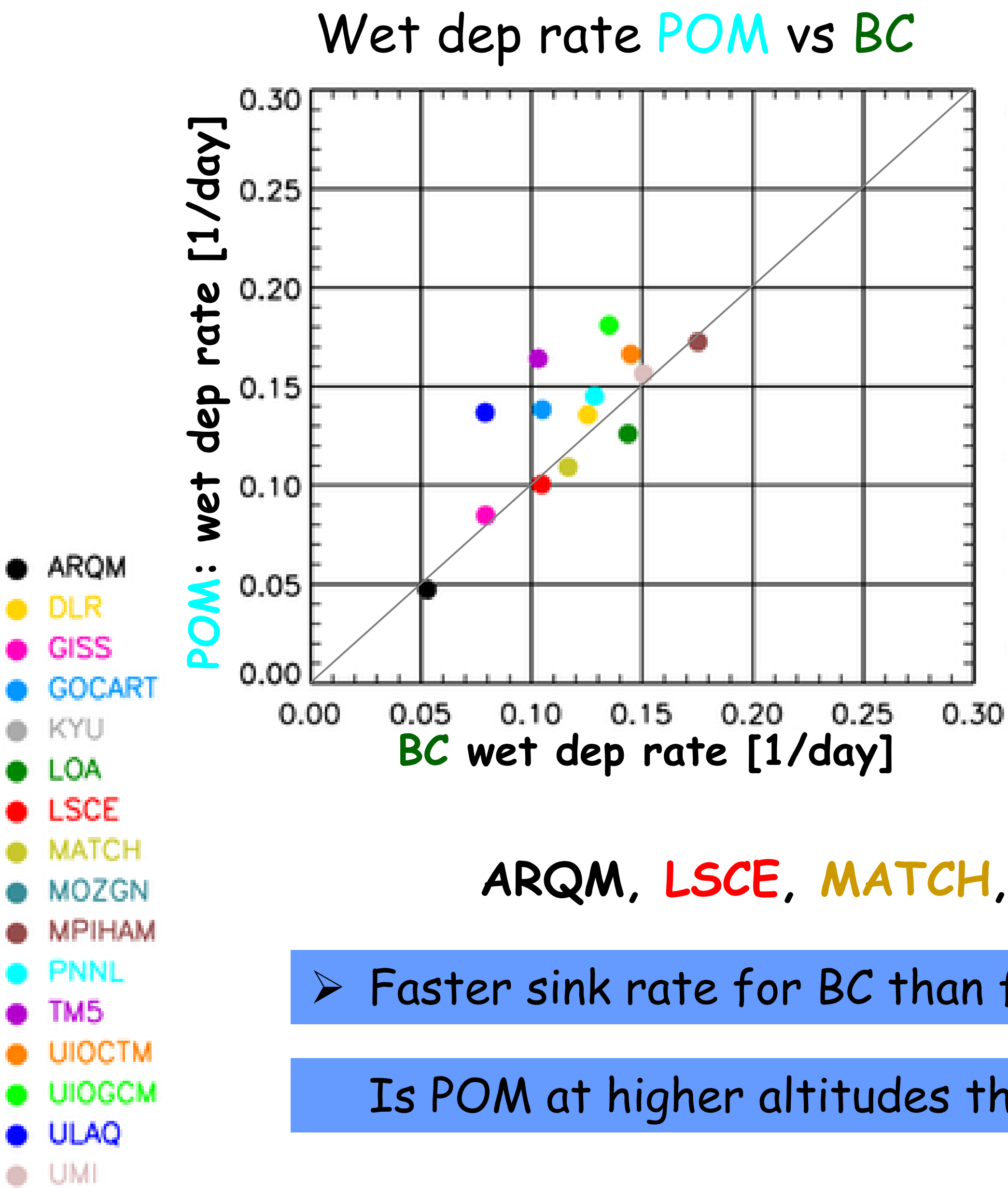
Wet dep is dominant in all models except for **ARQM**.

Sink processes: analysis for BC and POM



- Differences in the total sink rate are caused by the wet dep. Rate, except for **ARQM** (BC, POM).

Sink processes: Wet dep



ARQM, LSCE, MATCH, LOA.

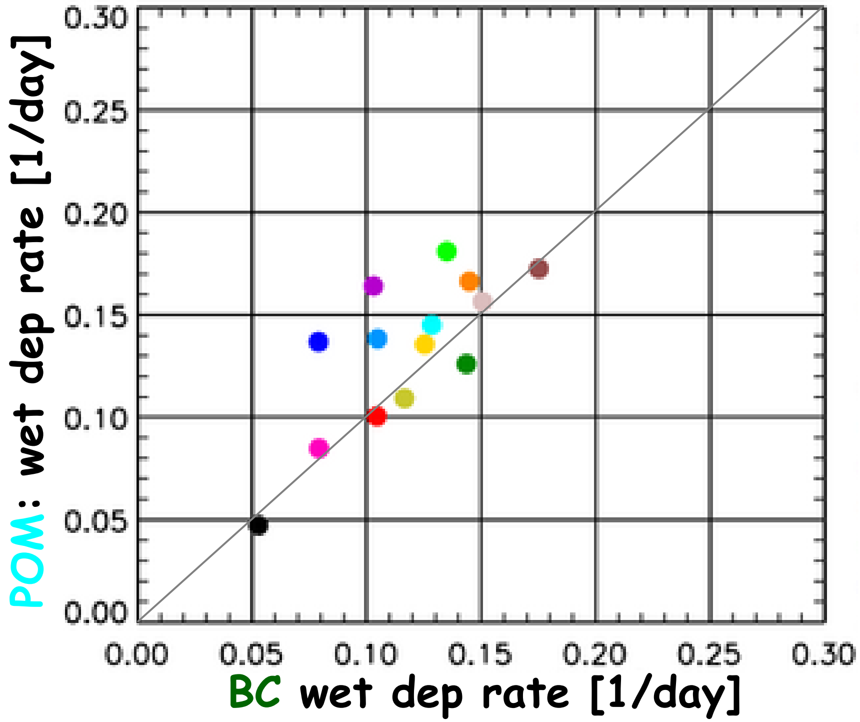
- Faster sink rate for BC than for POM

Is POM at higher altitudes than BC?

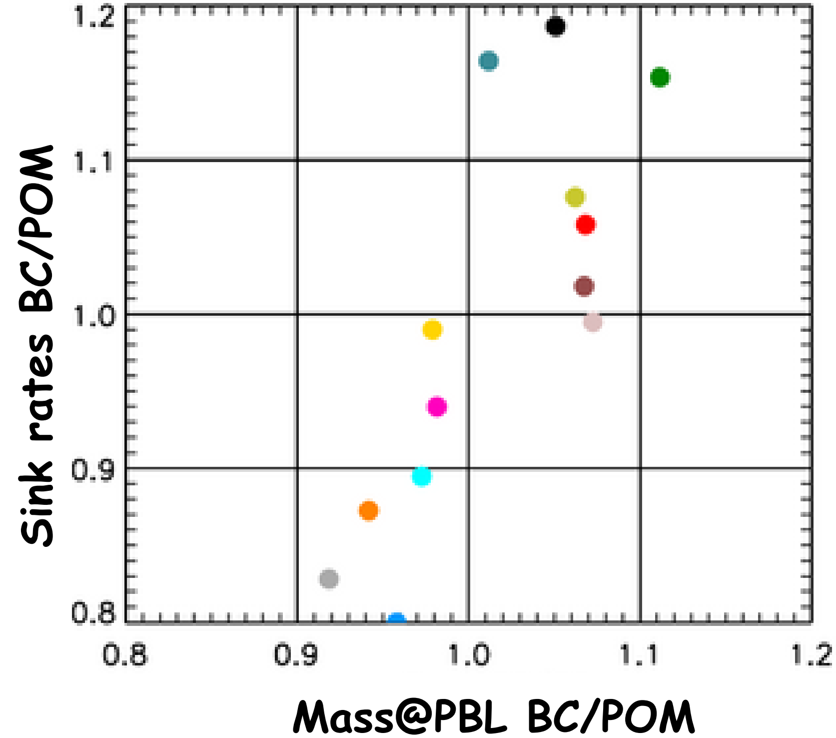
?

Sink processes: Wet dep

Wet dep rate POM vs BC



Ratios BC/POM:
sink rates vs mass in PBL



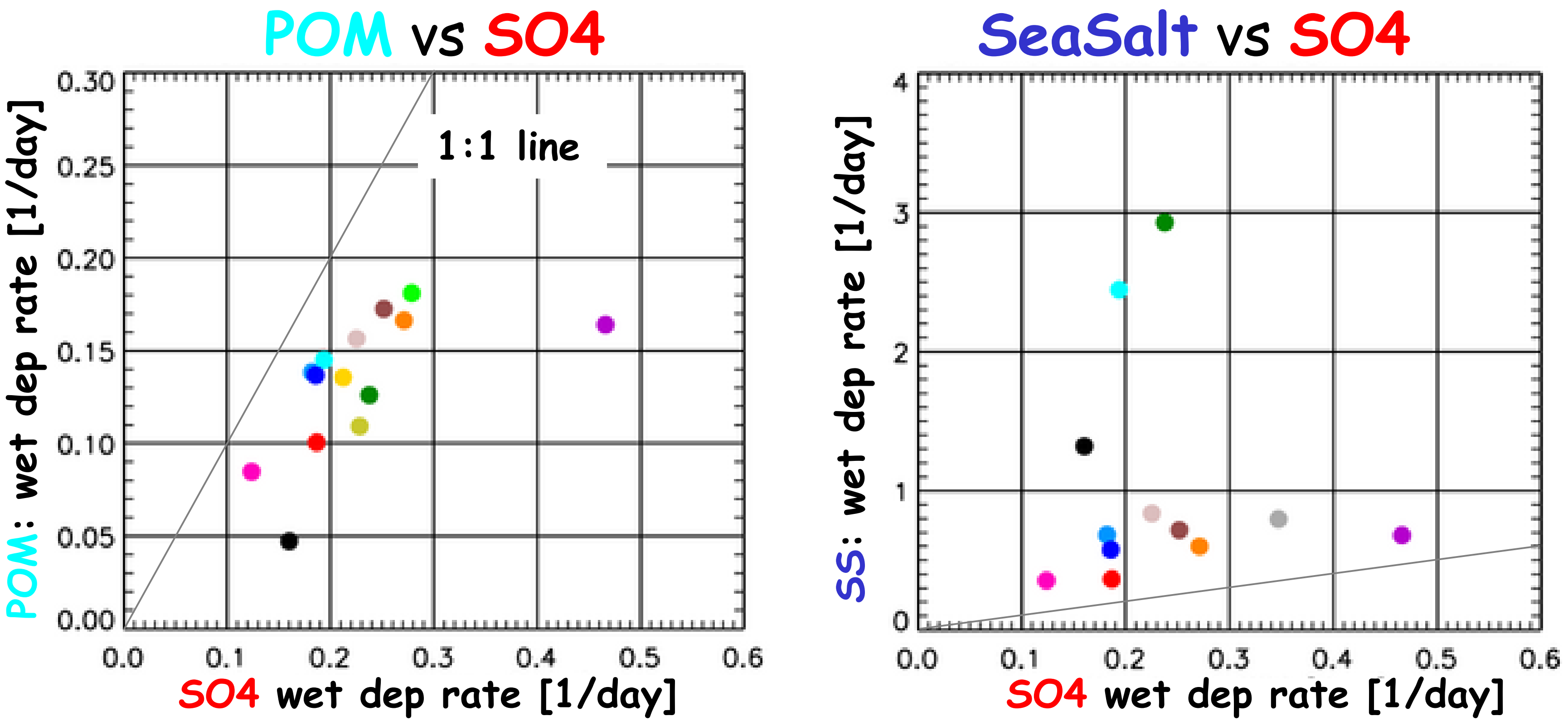
ARQM, LSCE, MATCH, LOA :

- Faster sink rate for BC than for POM

More mass in the PBL ↔ Faster sink rates

?

Sink processes: Wet dep

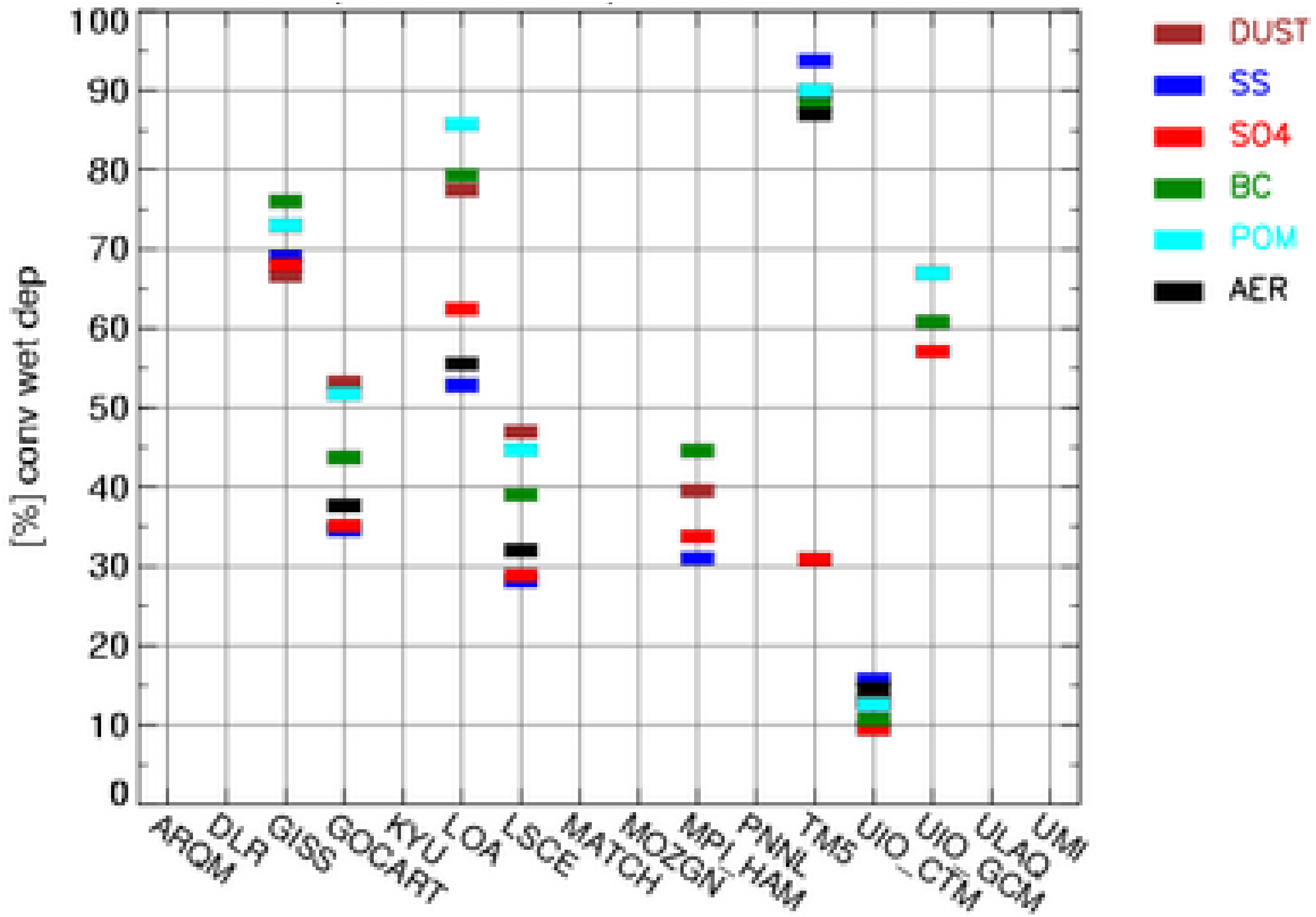


POM ≈ 2/3 SO4 wet in most models

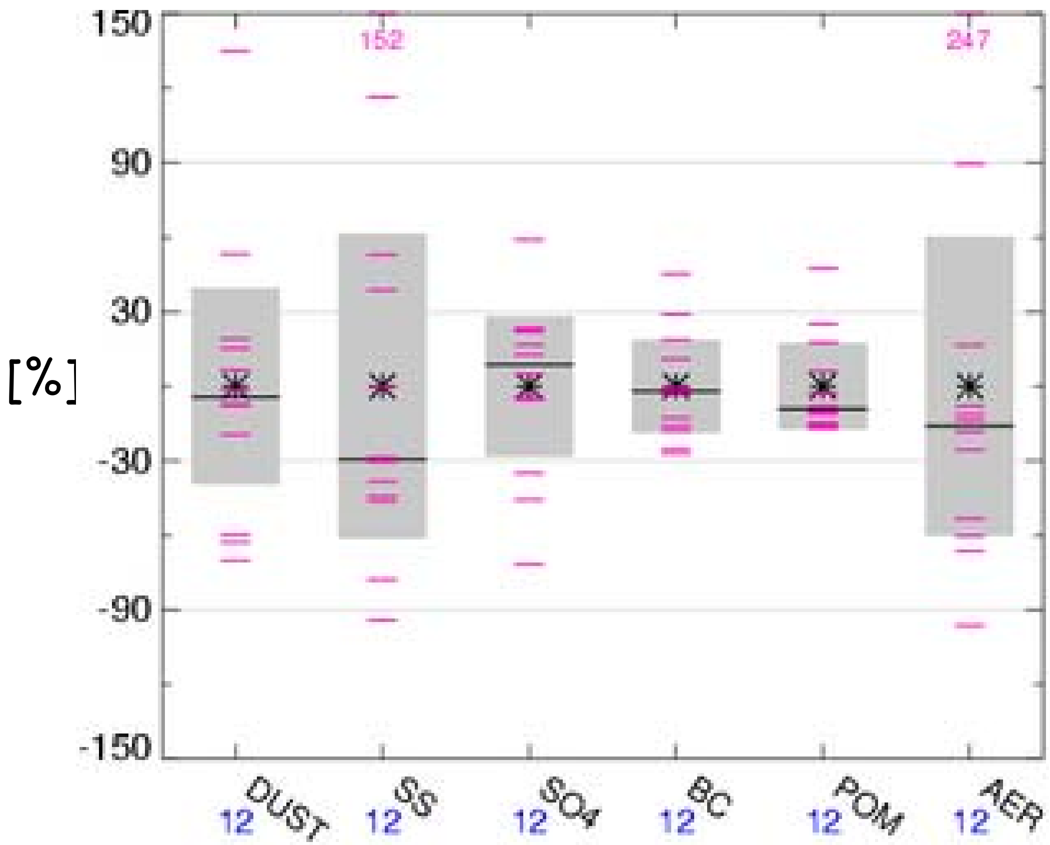
Sea Salt > SO_4

Sink processes: Wet dep

Fraction of convective wet dep over total wet dep



Uncertainty: Residence time τ



norm.data
mean
median
uncertainty

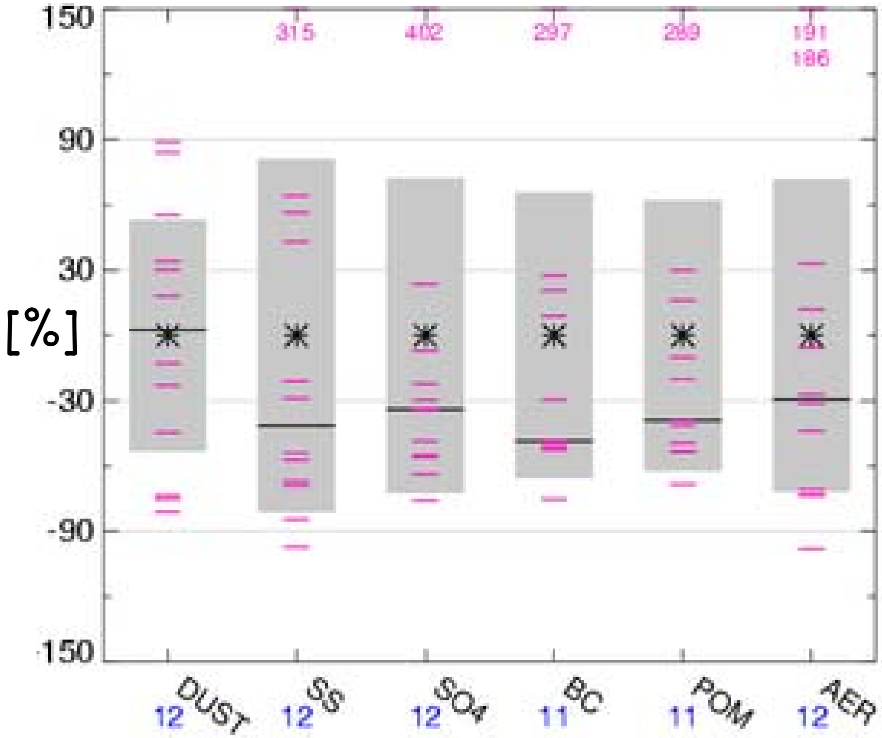
— Normalized data
⁕ Mean
— Median
Uncertainty

$$\tau^{-1}_{\text{total}} = \tau^{-1}_{\text{wet}} + \tau^{-1}_{\text{dry}}$$

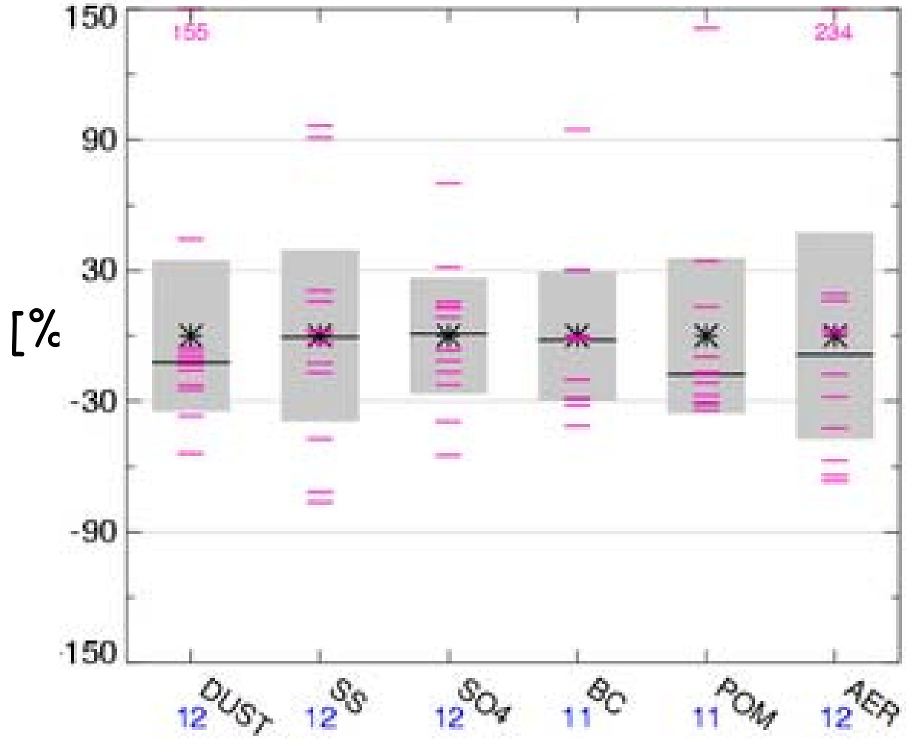
$$k_{\text{total}} = k_{\text{wet}} + k_{\text{dry}}$$

Uncertainty: Residence time due to individual sink processes

Residence time dry dep



Residence time wet dep



— normalized data

✳ mean

— median

uncertainty

Conclusions

Sink process analysis - mutually dependent effets of:

- spatial distribution of emissions
- vertical and horizontal transport
- precipitation rate
- particle sizes
- parameterization of processes

Uncertainties:

- are in general greater for sea salt and dust:
  - sources interactively calculated
  - meteorology
  - particle sizes
  - spatial distribution
  - two sink processes
- Sulfate: atmospheric chemistry