Aerosol submodel MADE: New developments

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Motivation

(Lauer et al., ACP, 2007; Righi et al., EST, 2011)

Radiative forcing due to ship emissions

- Order of magnitude: several -100 mW/m^2 (?)
- large uncertainty
- dominated by indirect aerosol effect

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New MADE feature

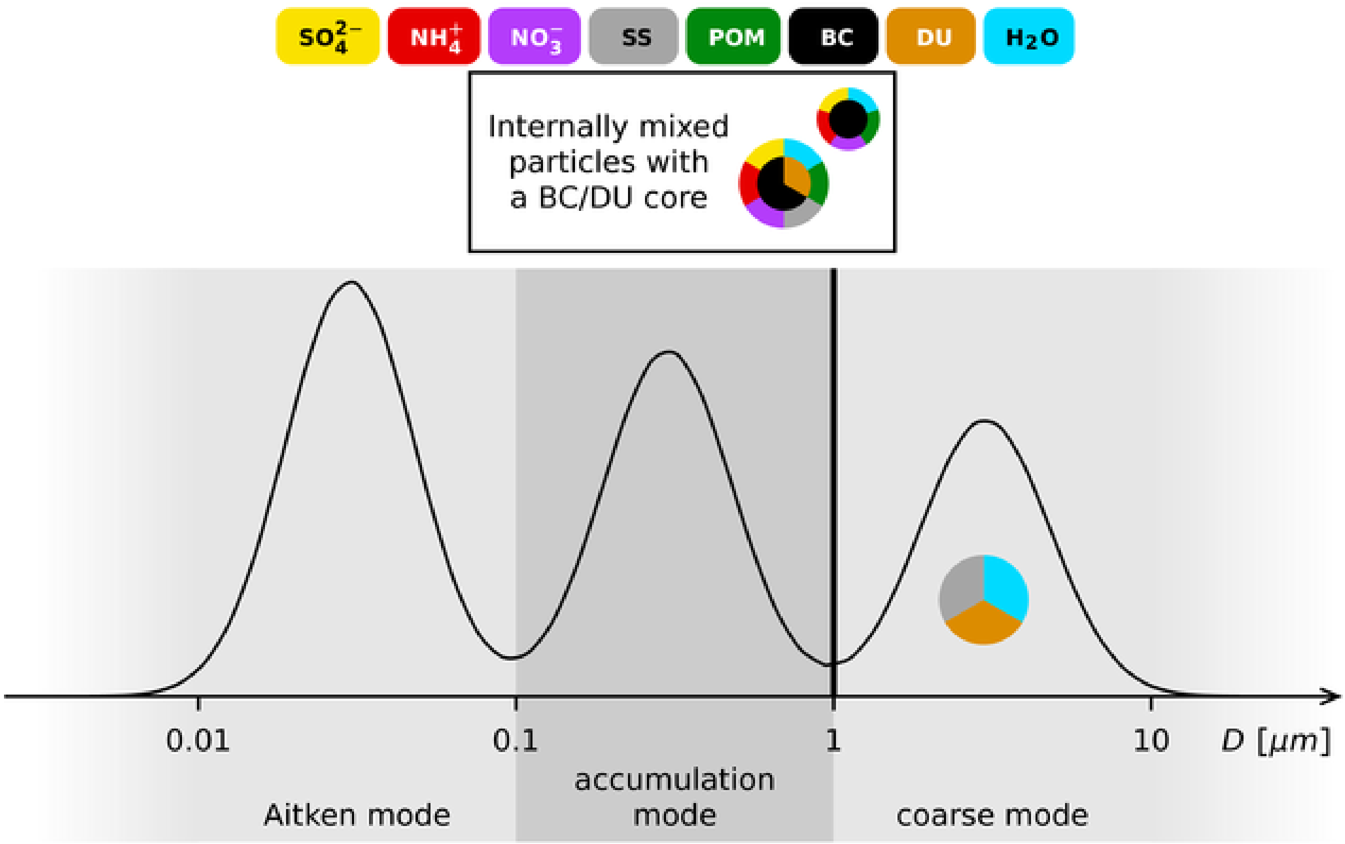
Consideration of coarse particle interactions

→ more realistic description of the atmospheric aerosol

→ influence on cloud condensation nuclei (CCN) concentration?

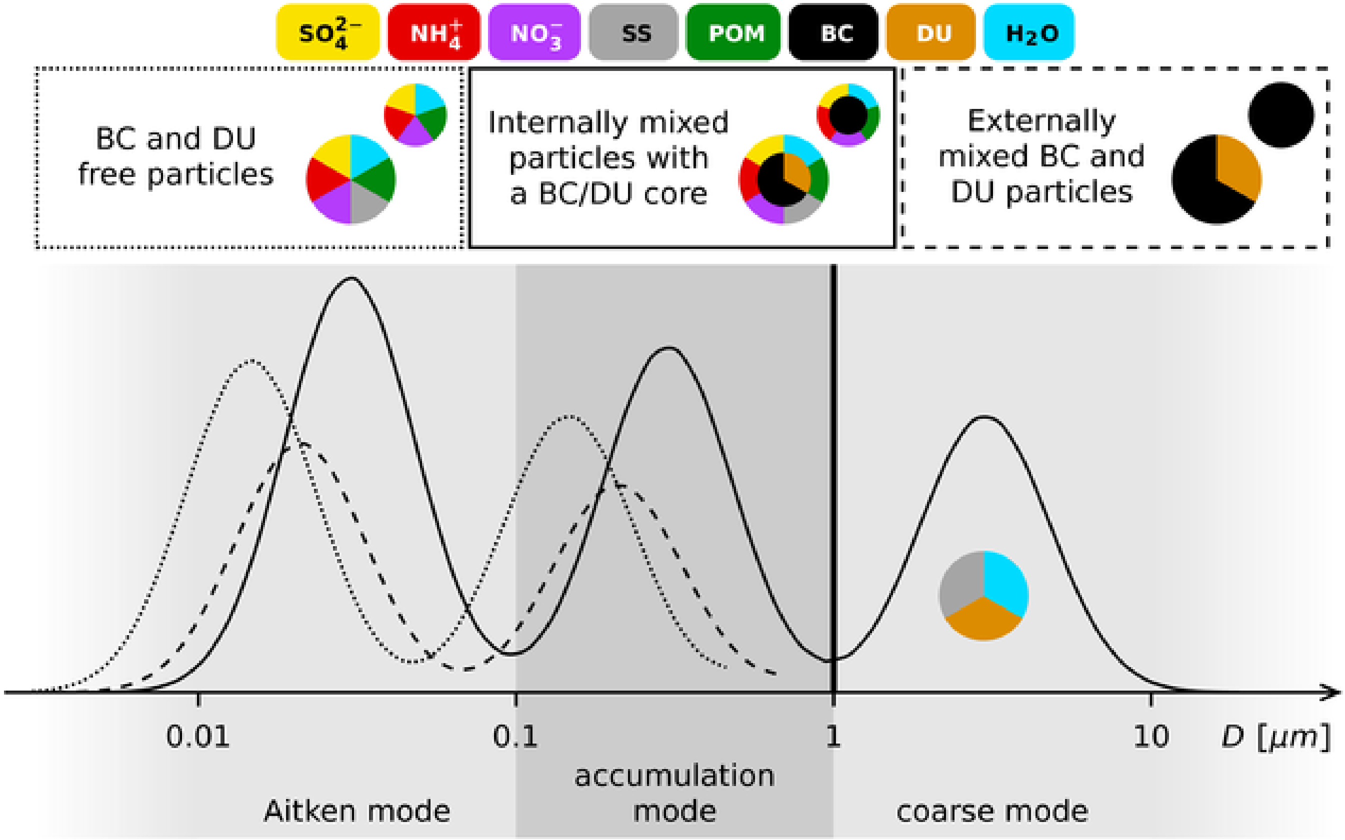
The MESSy aerosol submodel MADE

(Binkowski and Shankar, JGR, 1995; Ackermann et al., AE, 1998; Lauer et al., ACP, 2005)



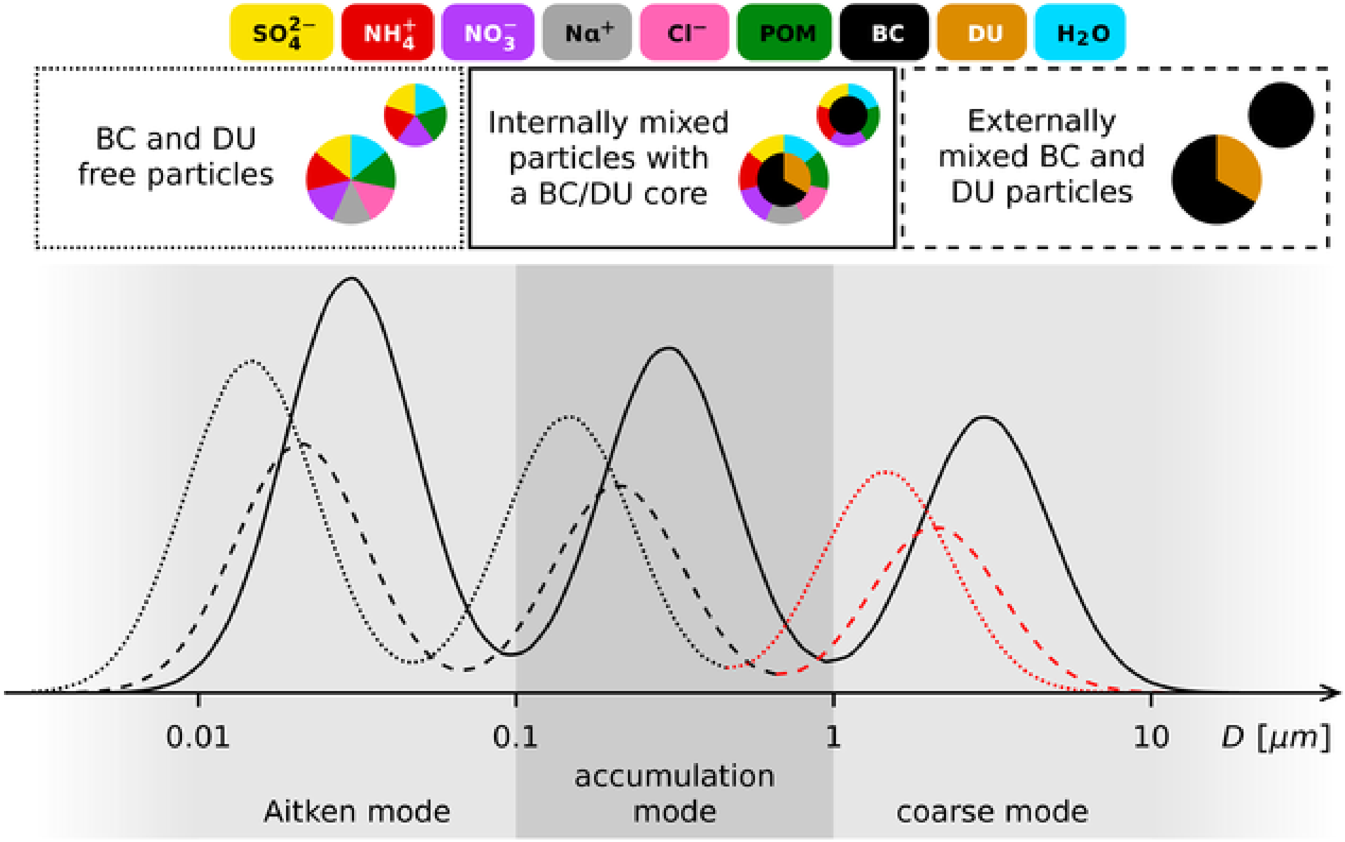
Calculation of number and mass concentrations

The MESSy aerosol submodel MADE-in
(Aquila et al., 2011)



Calculation of number and mass concentrations

The MESSy aerosol submodel MADE3
(Kaiser et al., in preparation, 2013)



Calculation of number and mass concentrations

The MESSy aerosol submodel MADE3 Processes

1. **Chemical equilibration**

(Metzger et al., JGR, 2002; Metzger et al., ACP, 2006)

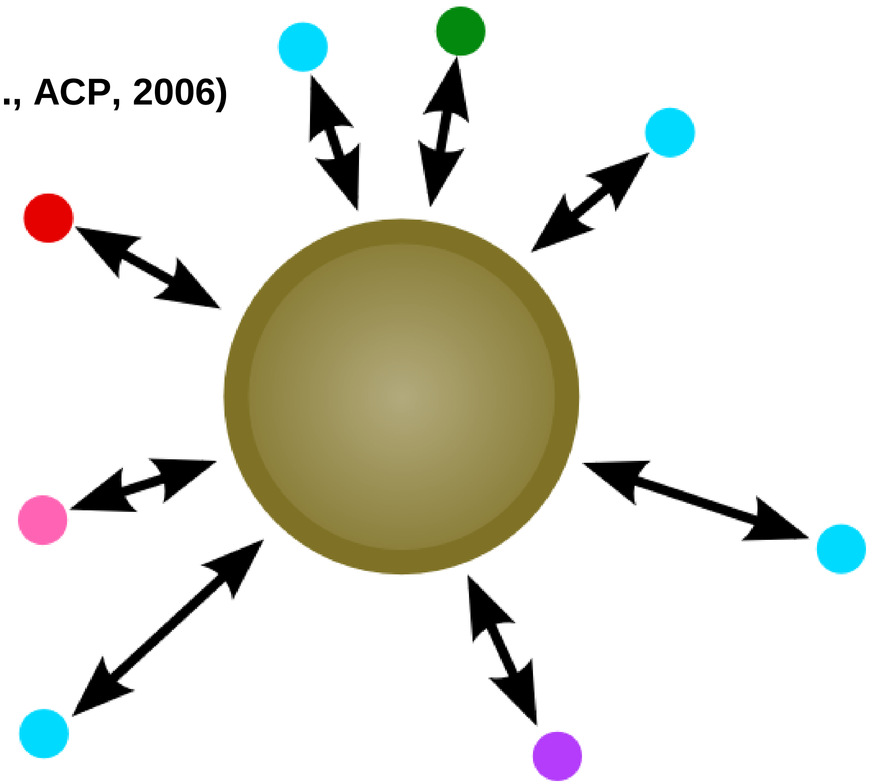
$NH_3 \leftrightarrow NH_4^+$

$HNO_3 \leftrightarrow NO_3^-$

$HCl \leftrightarrow Cl^-$

SOA prec. ↔ POM

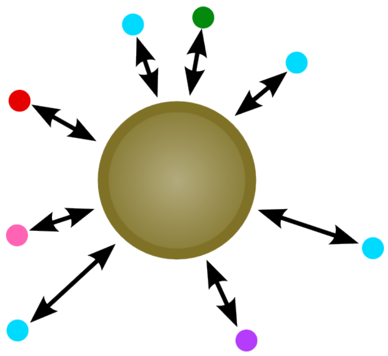
$H_2O(a)$

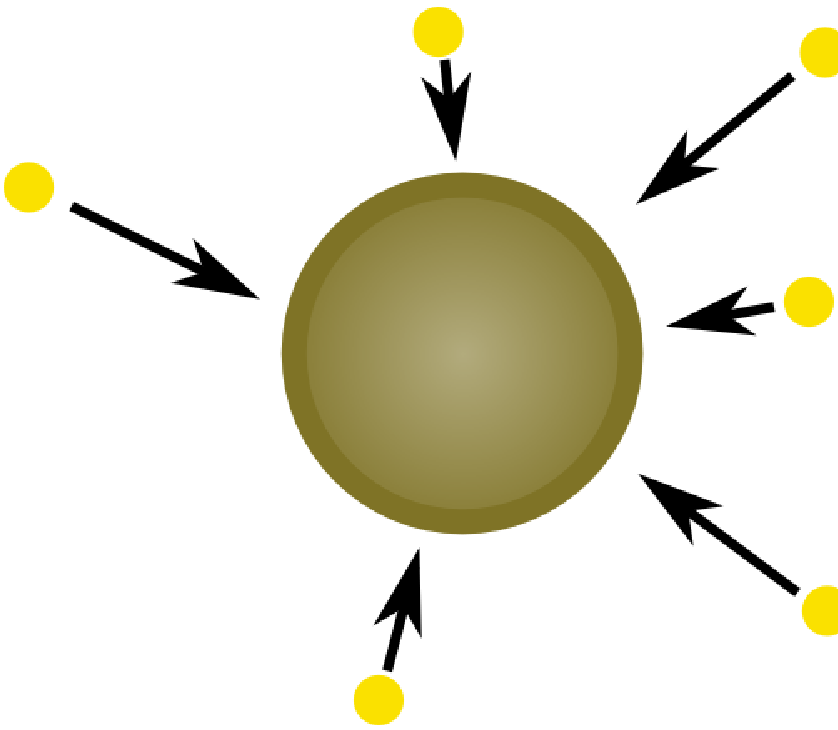


Coarse particles: flux limit
(similar to Pringle et al., GMD, 2010)

The MESSy aerosol submodel MADE3
Processes

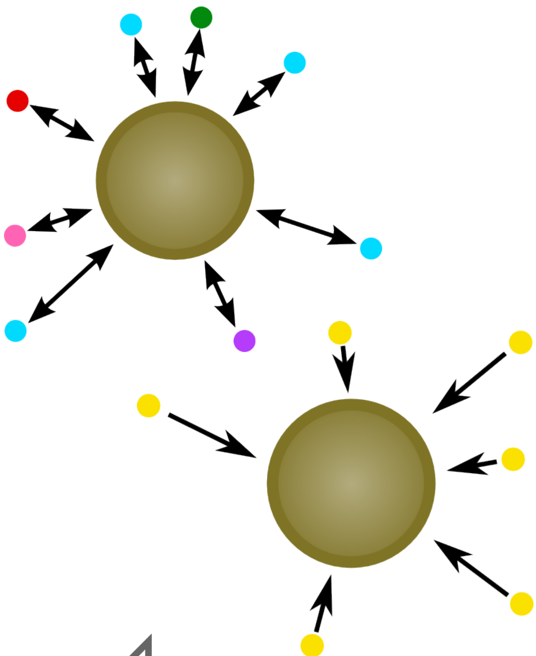
1. Chemical equilibration
2. **Condensation of H_2SO_4**

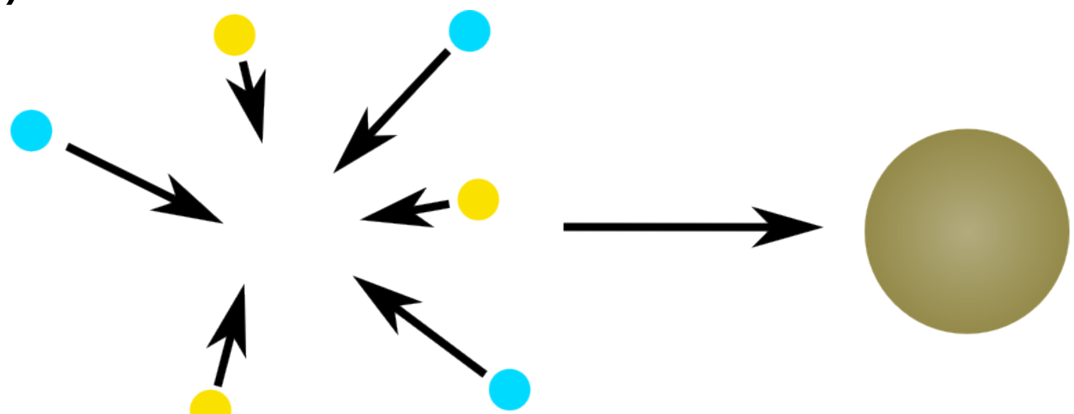




The MESSy aerosol submodel MADE3
Processes

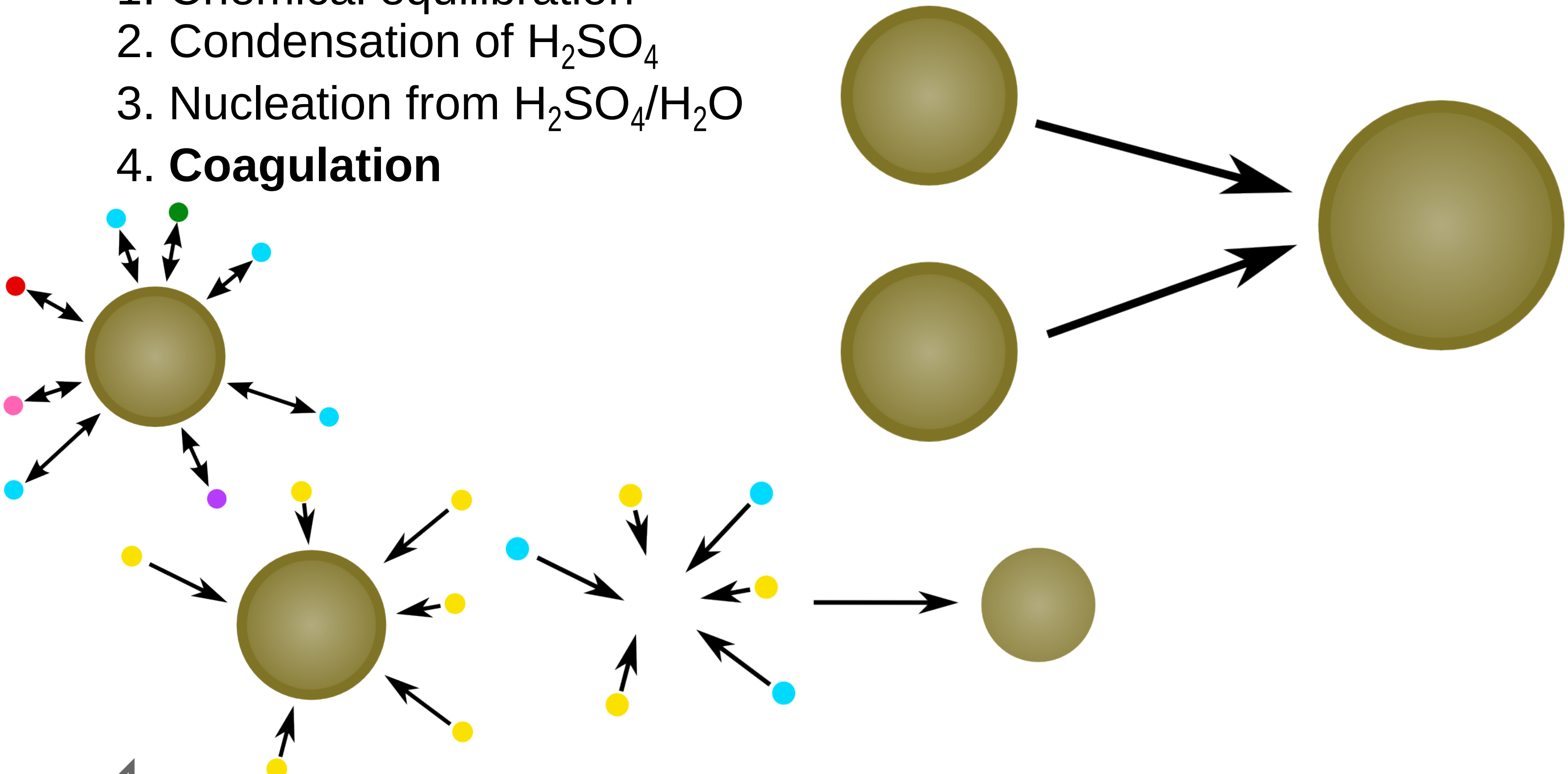
1. Chemical equilibration
2. Condensation of H_2SO_4
3. **Nucleation from H_2SO_4/H_2O**
   (Vehkamäki et al., JGR, 2002)



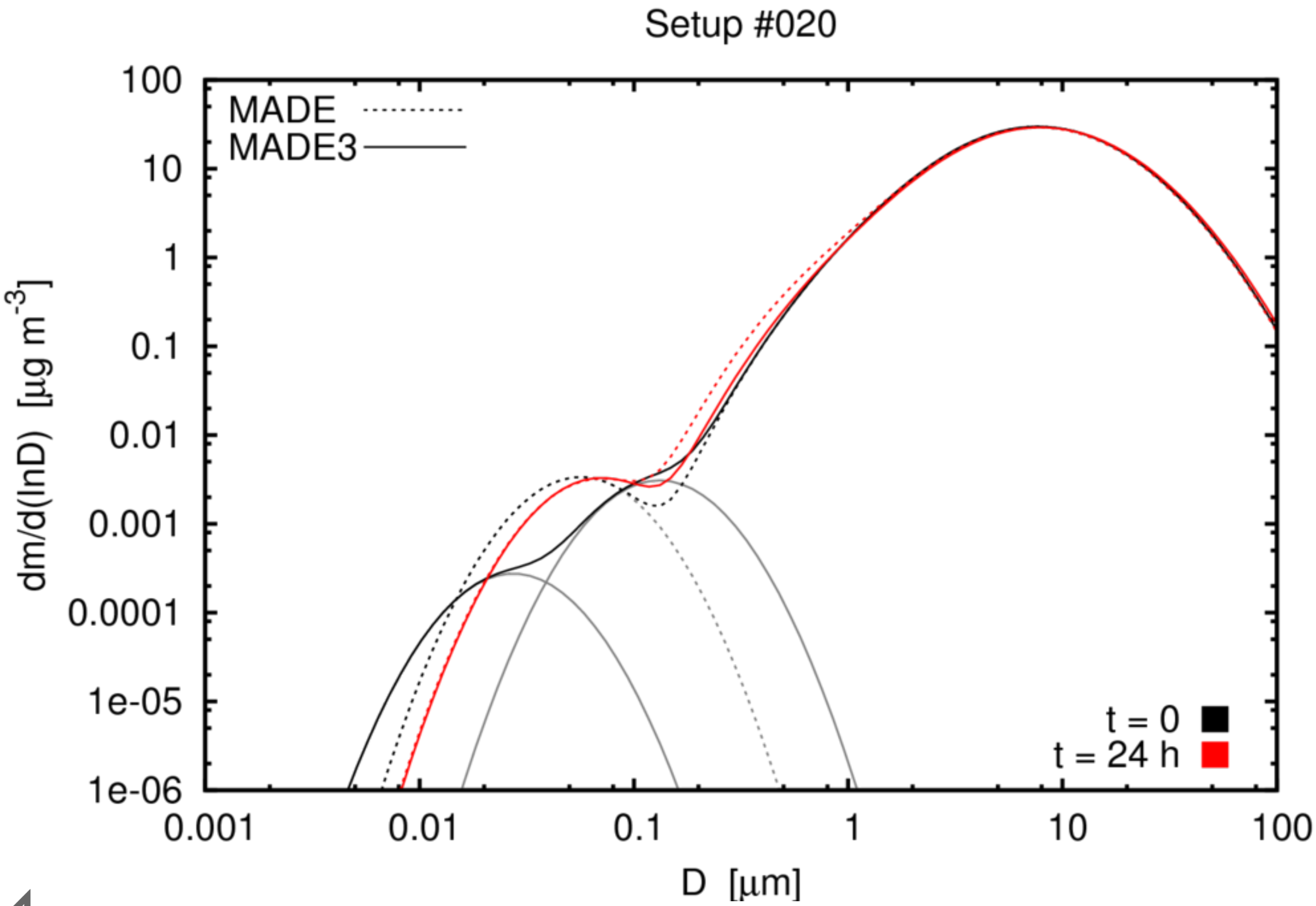


The MESSy aerosol submodel MADE3 Processes

1. Chemical equilibration
2. Condensation of H_2SO_4
3. Nucleation from H_2SO_4/H_2O
4. **Coagulation**



MADE3 vs. MADE
Box model: emissions in marine background



MADE3 vs. PartMC-MOSAIC

(Riemer et al., JGR, 2009; Zaveri et al., JGR, 2008)

	MADE3	PartMC-MOSAIC
Aerosol representation	modal, deterministic	particle-resolved, stochastic
Aerosol chemistry	equilibrium, flux limited	dynamical
Target application	3D, global, long-term	0/1D, local, episodes

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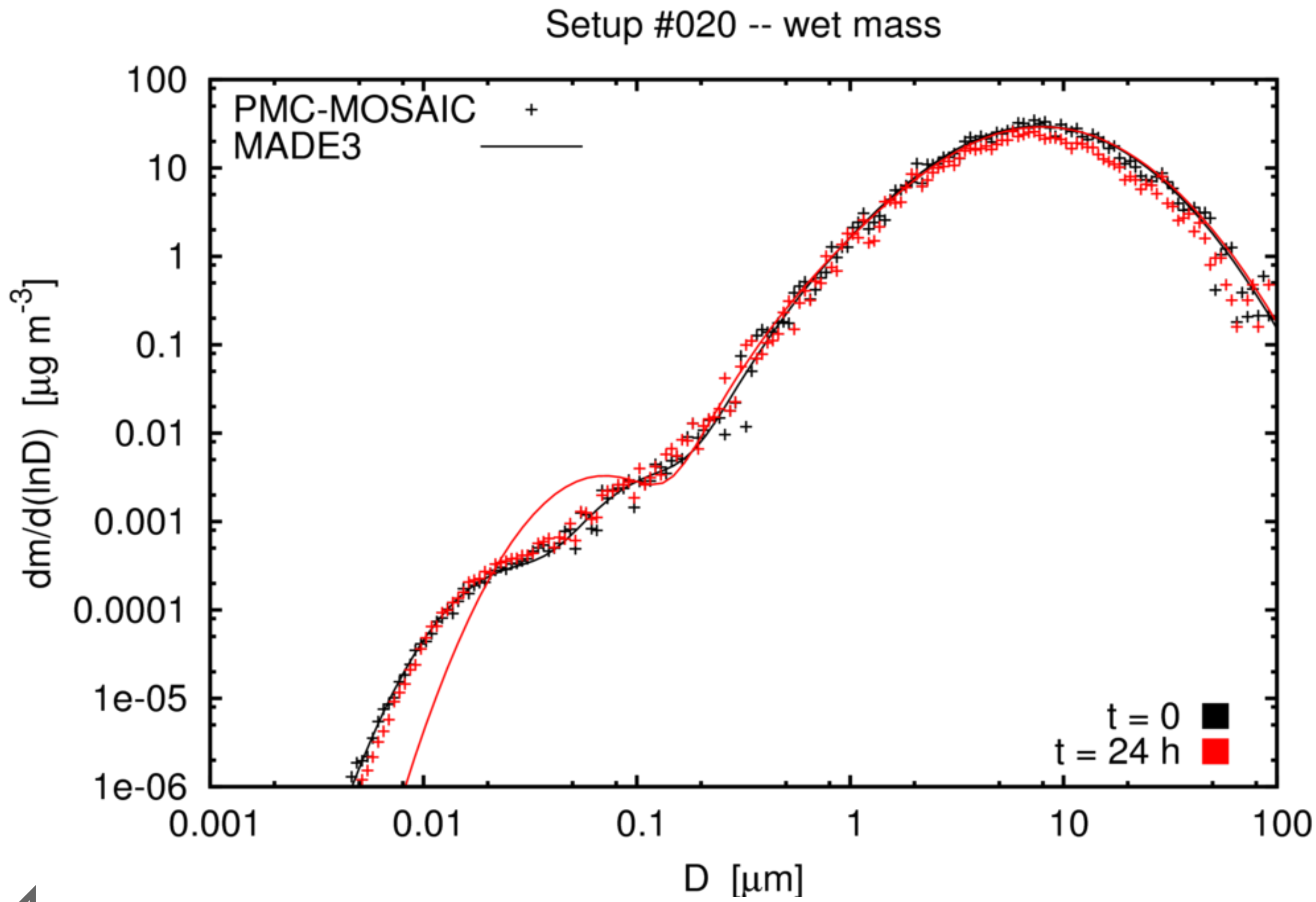

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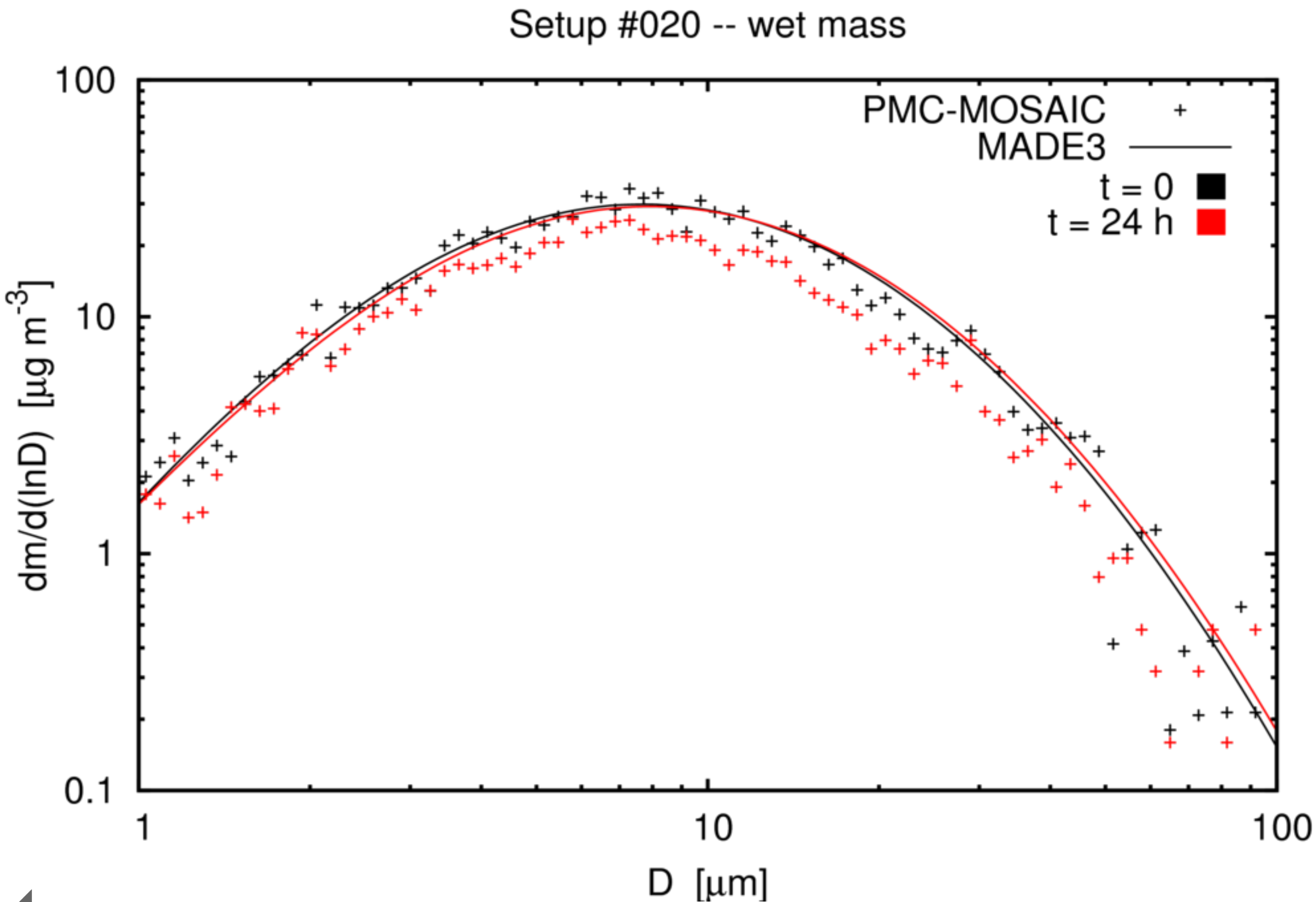

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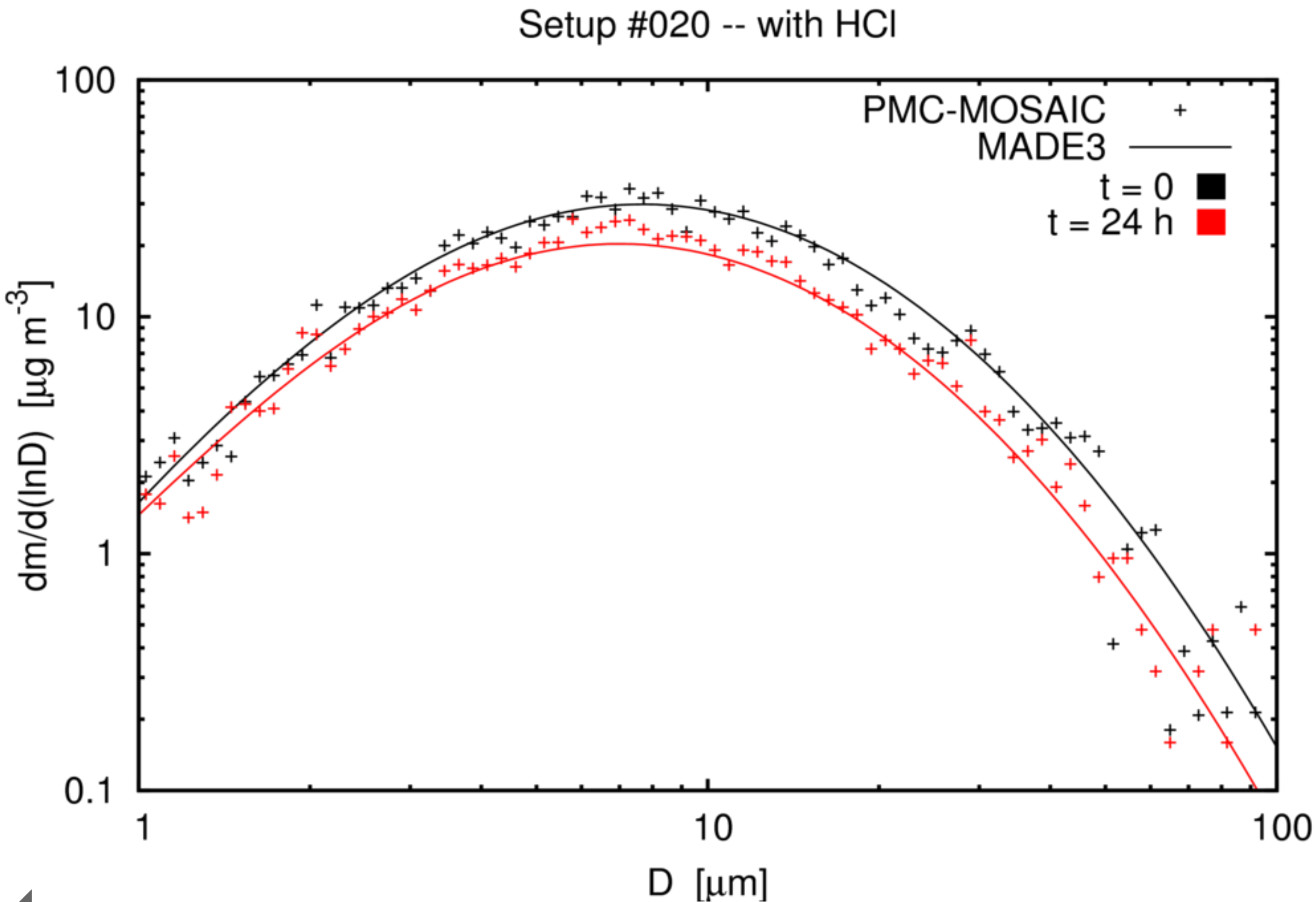
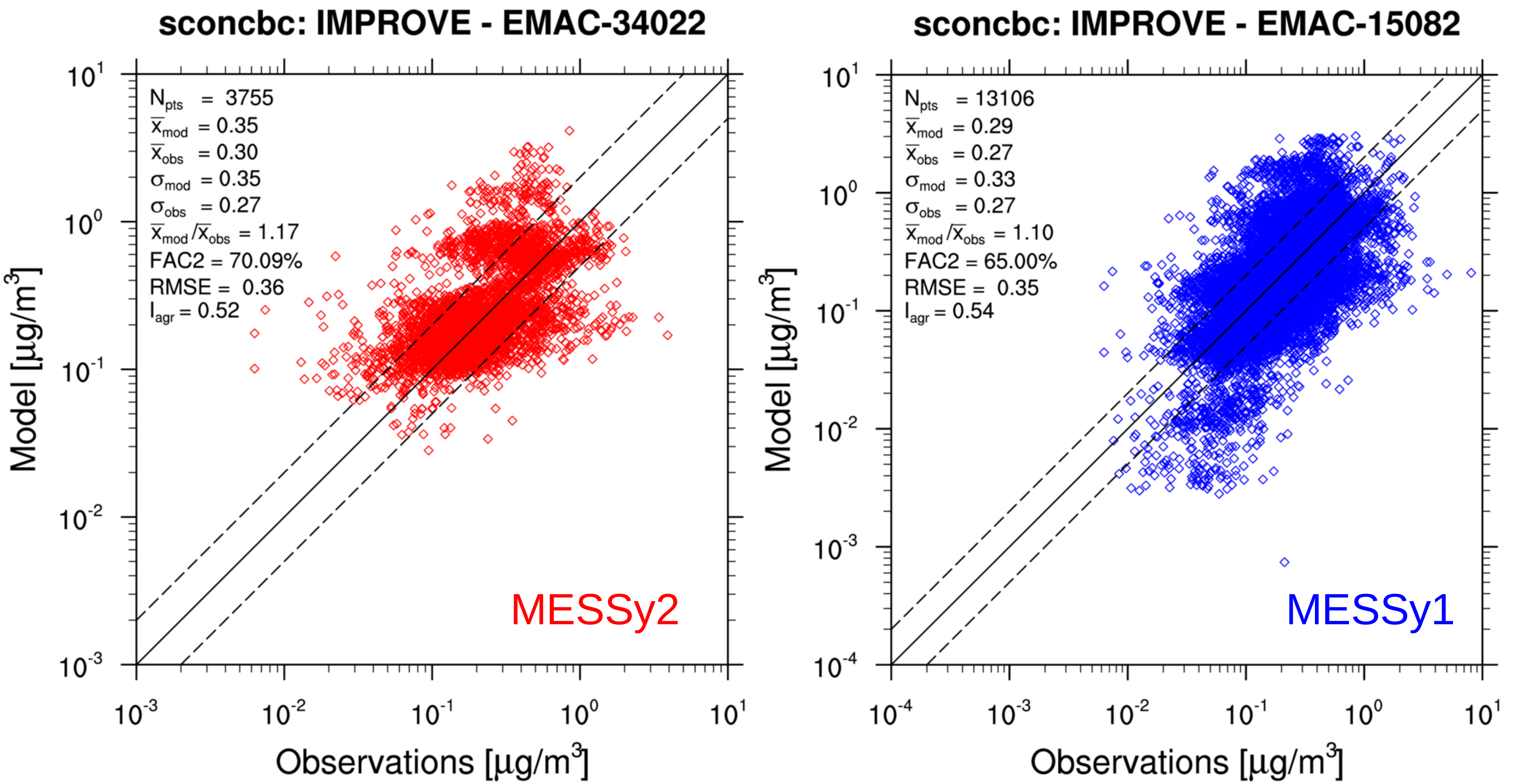


MADE in MESSy2
3D: reference run



MADE in MESSy2
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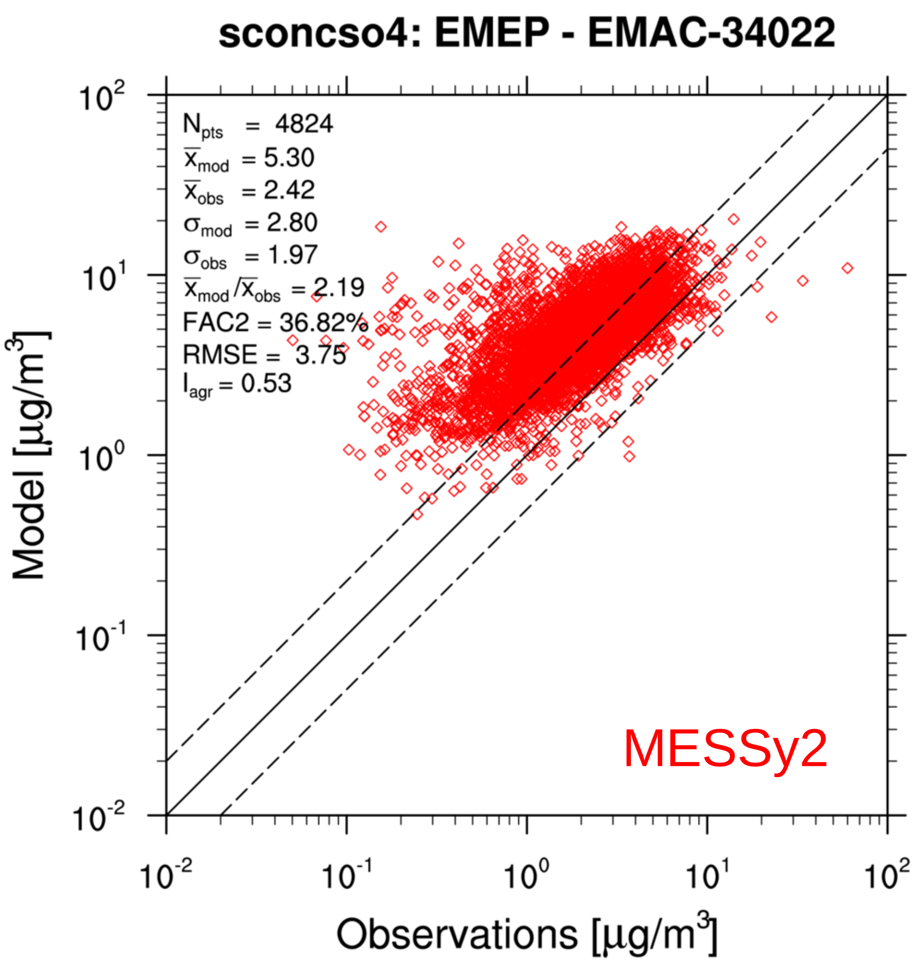

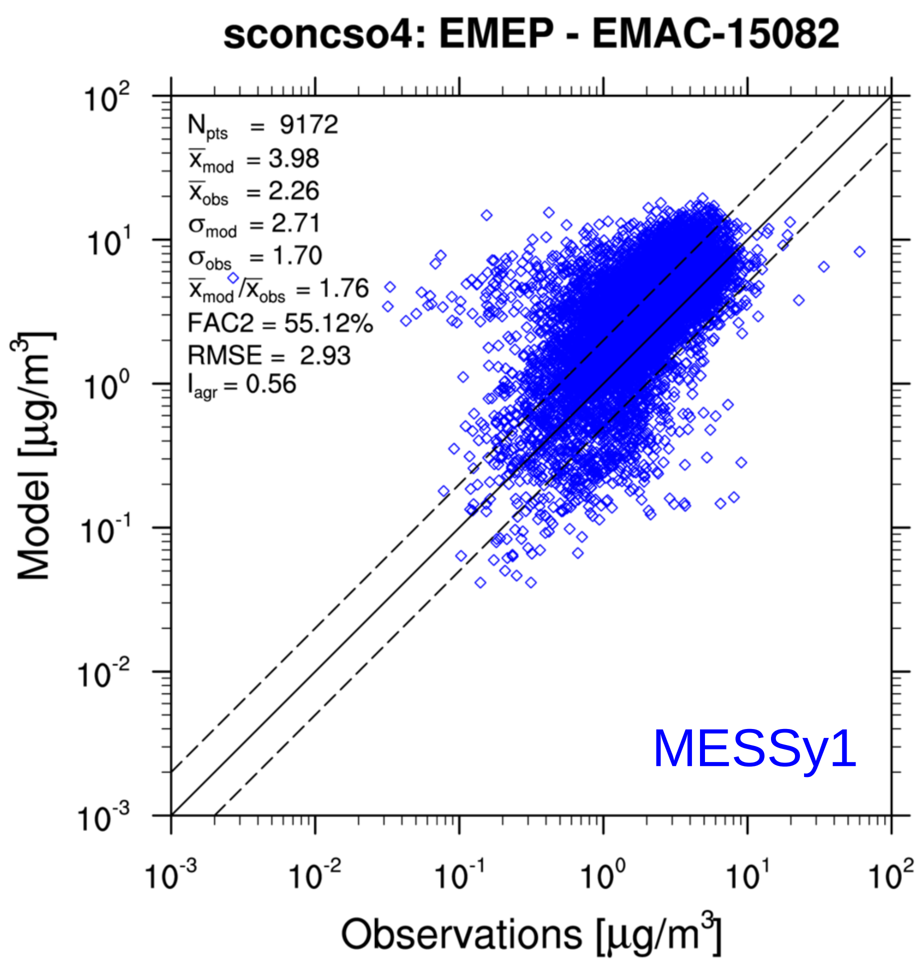

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To Do

- Understand/Reduce MADE-observation discrepancies in MESSy2
- Implement MADE3 in MESSy2
  (emissions partitioning, inclusion of HCl in simplified chemistry)
- Gather observational data for evaluation
  (focus: marine boundary layer, coarse particles)
- Test/Implement interactive aerosol couplings
  (radiation, clouds)

Comments welcome!

Thanks to:

Valentina Aquila

Patrick Jöckel

Axel Lauer

Swen Metzger

Nicole Riemer

Robert Sausen

Holger Tost

Rahul Zaveri

… and more colleagues at DLR

Additional material

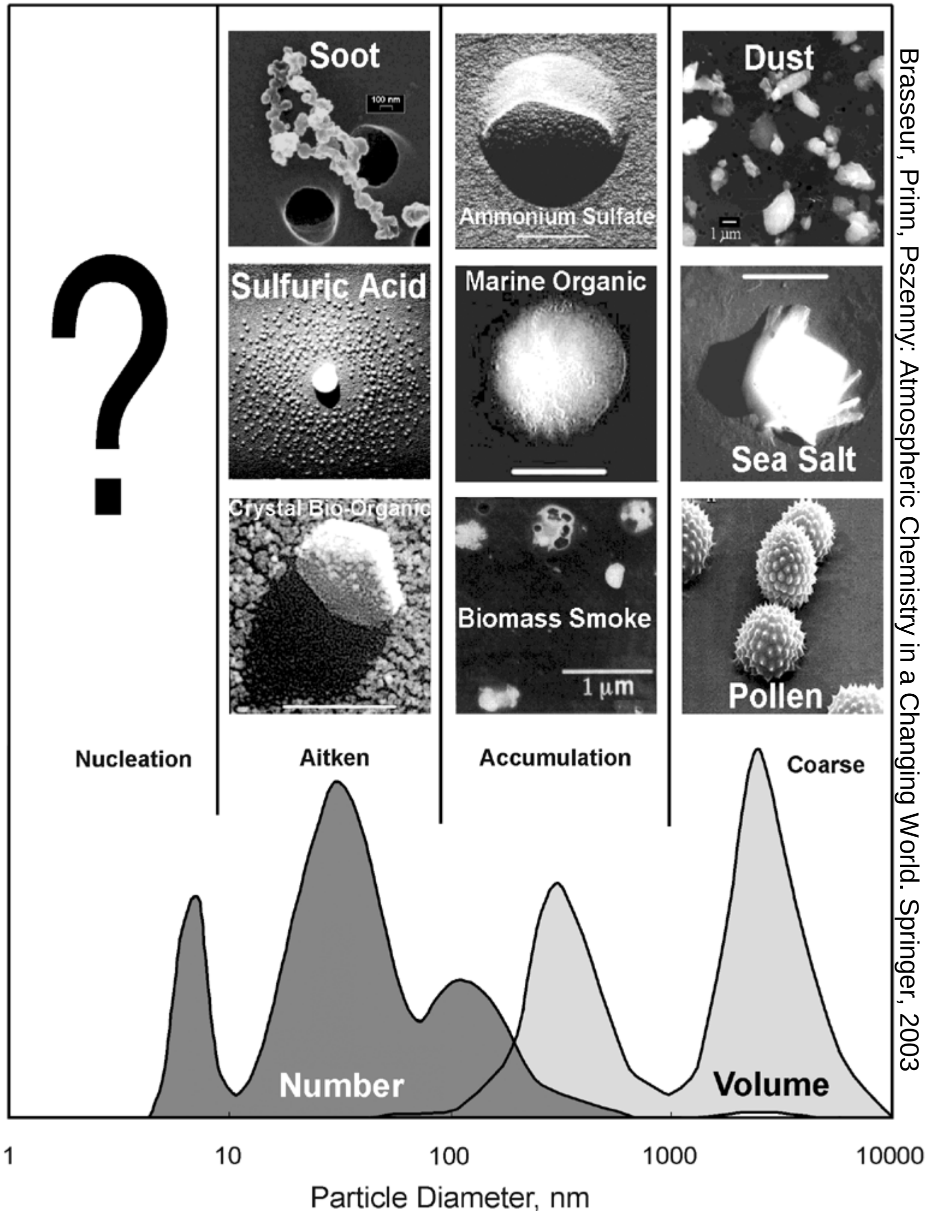
Aerosole

Definition:

Schwebteilchen in einem Gas(gemisch)

Wichtige Prozesse:

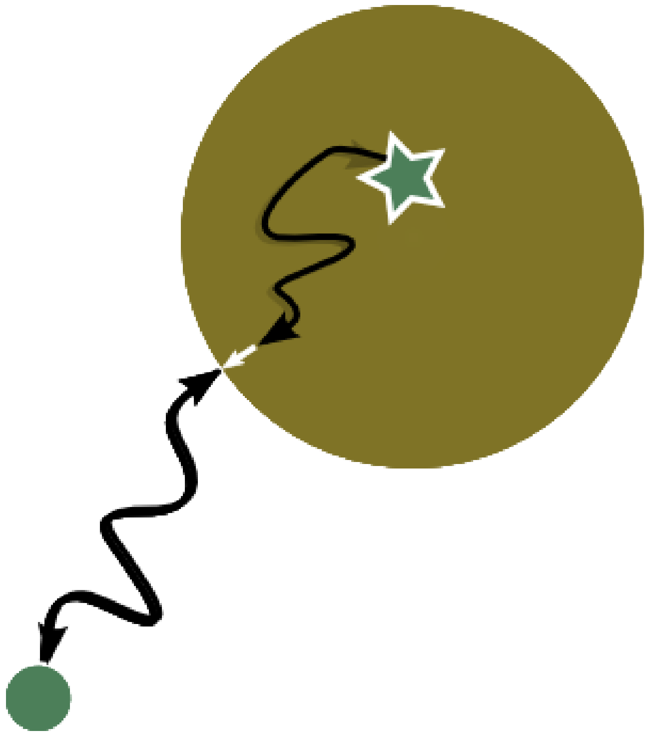
- Emission
- Nukleation
- Koagulation
- Kondensation/ Verdampfung
- Sedimentation
- Auswaschen



Brasseur, Prinn, Pszenny: Atmospheric Chemistry in a Changing World. Springer, 2003

Aerosol chemistry: Kinetics

1. Gas diffusion to the particle
2. Transport through the interface
3. (Solvation in the liquid phase)
4. Diffusion within the particle
5. Reaction within the particle



Aerosolrepräsentation in Klimamodellen: Der modale Ansatz

Annahmen:

- Lognormalverteilung für die Teilchenzahldichte in jeder Mode

$$\frac{dN}{d\ln D} = \frac{N_t}{\sqrt{2\pi}\ln\sigma}\exp\left(\frac{\left(\ln D - \ln D_g\right)^2}{2\left(\ln\sigma\right)^2}\right)$$

D_g: Median-Durchmesser (geometrischer Mittelwert)

N_t: Teilchenzahldichte

σ : Geometrische Standardabweichung

- Gleiche Zusammensetzung für alle Teilchen einer Mode
- Konstante Standardabweichung

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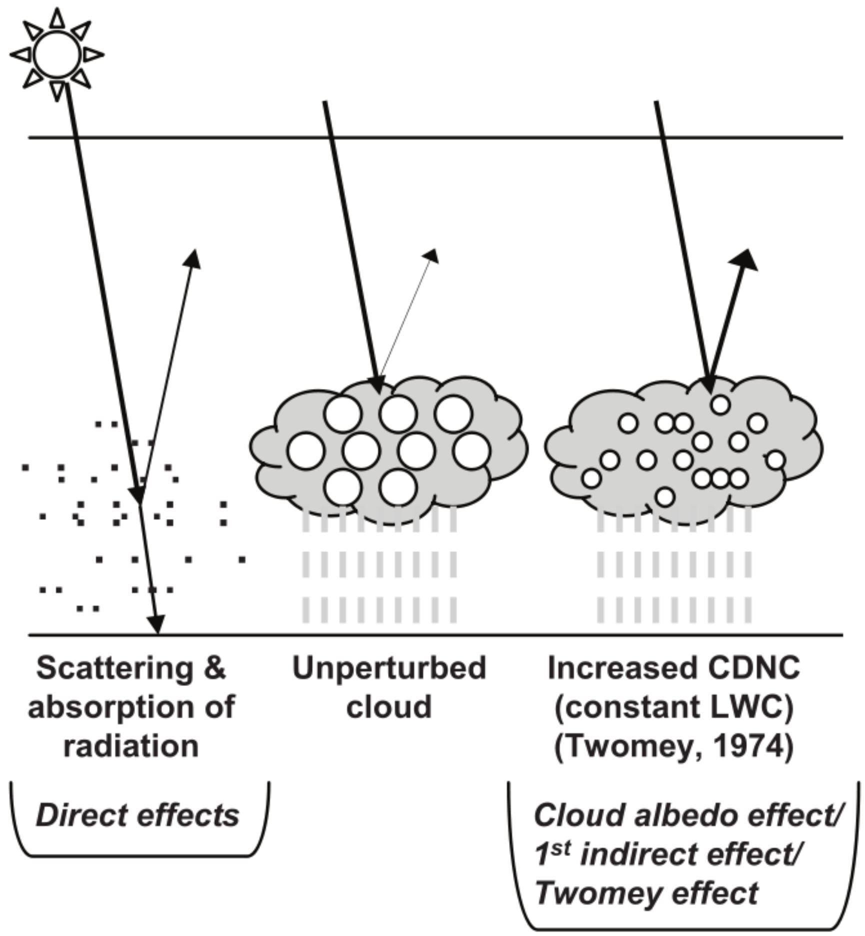
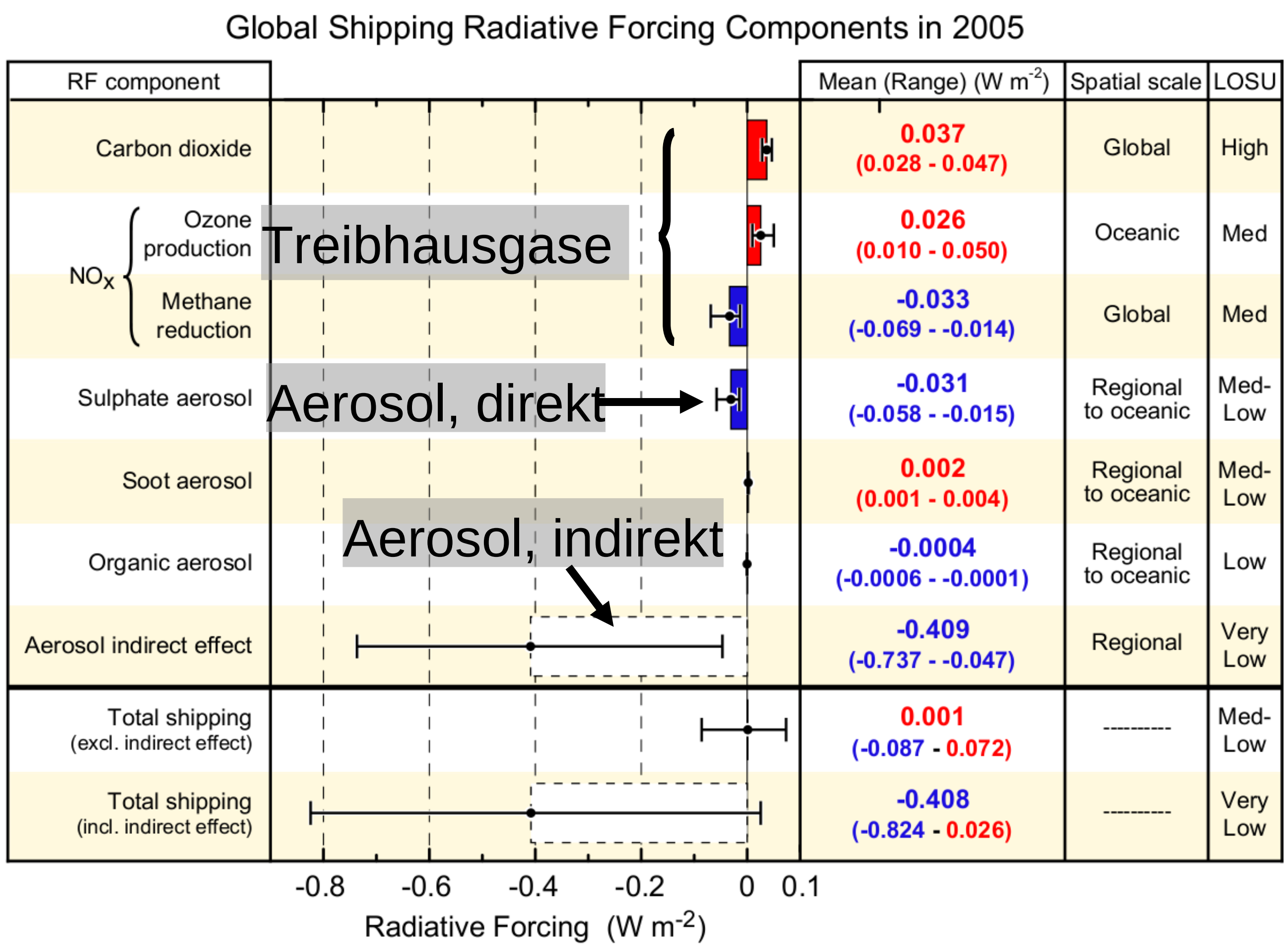
Klimawirkung des globalen Schiffsverkehrs: Aerosol-Effekte



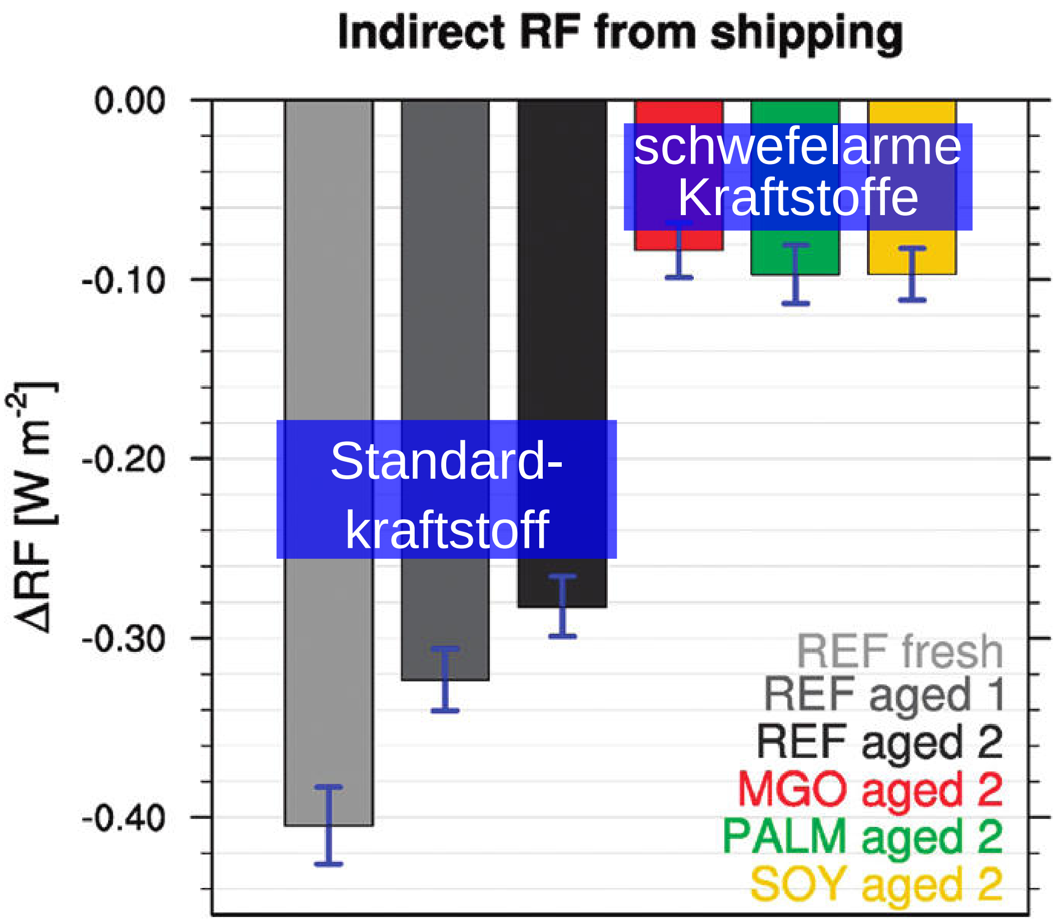
Forster et al., IPCC AR4 (WG1), 2007

Stand der Forschung: Klimawirkung des globalen Schiffsverkehrs



Eyring et al., Atmos. Environ., 2010

Stand der Forschung:
Klimawirkung des globalen Schiffsverkehrs



Righi et al., Environ. Sci. Tech., 2011

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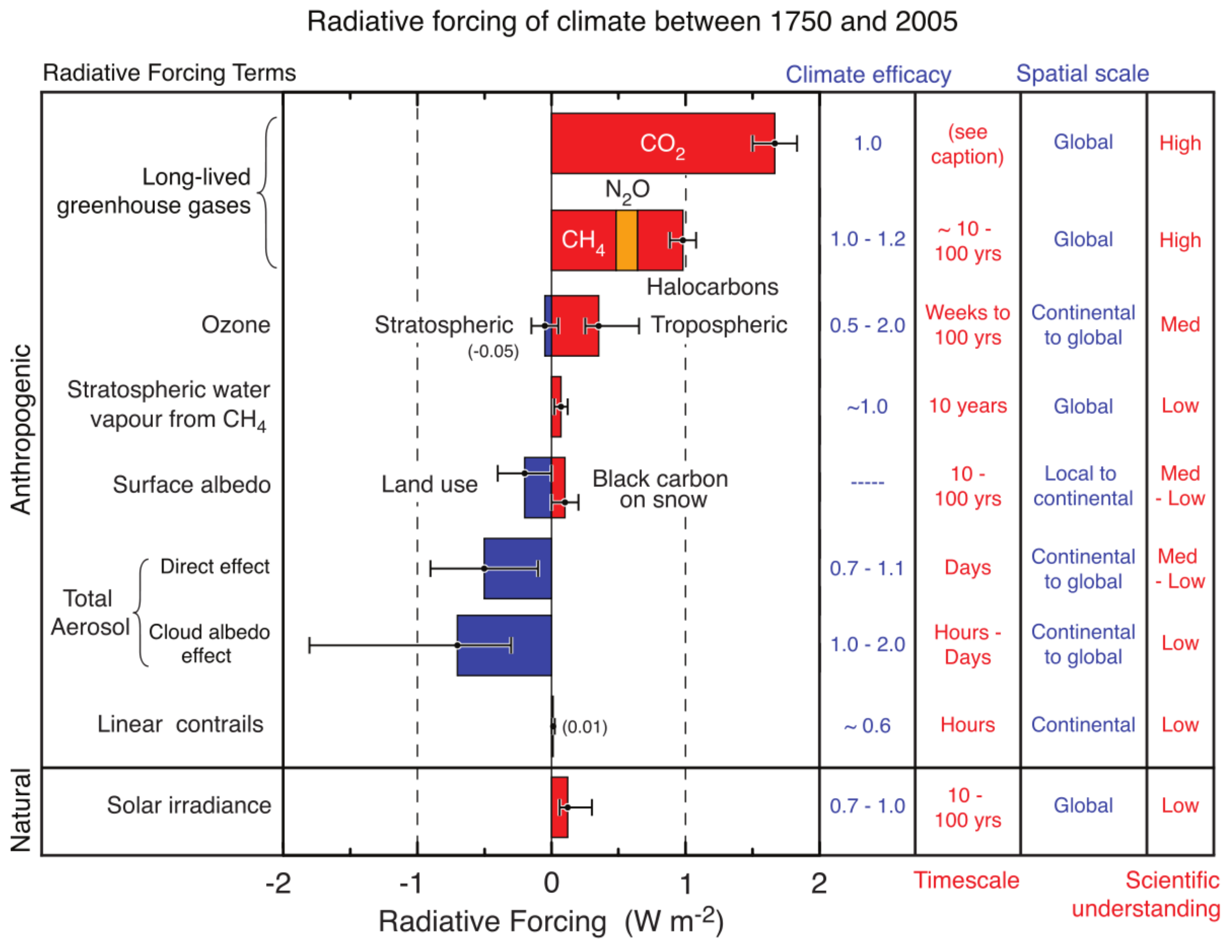
Strahlungsantrieb gesamt



Forster et al., IPCC AR4 (WG1), 2007

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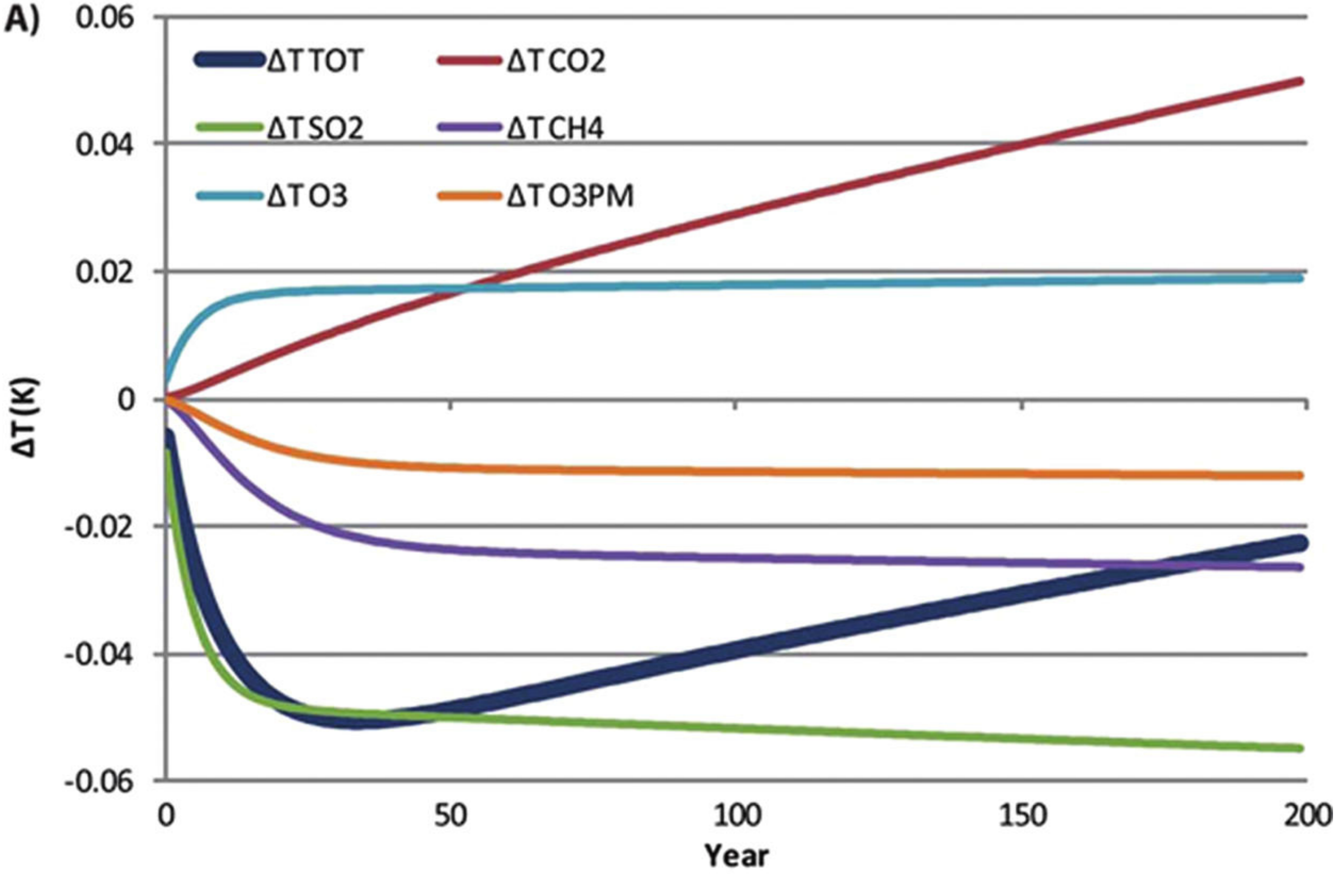
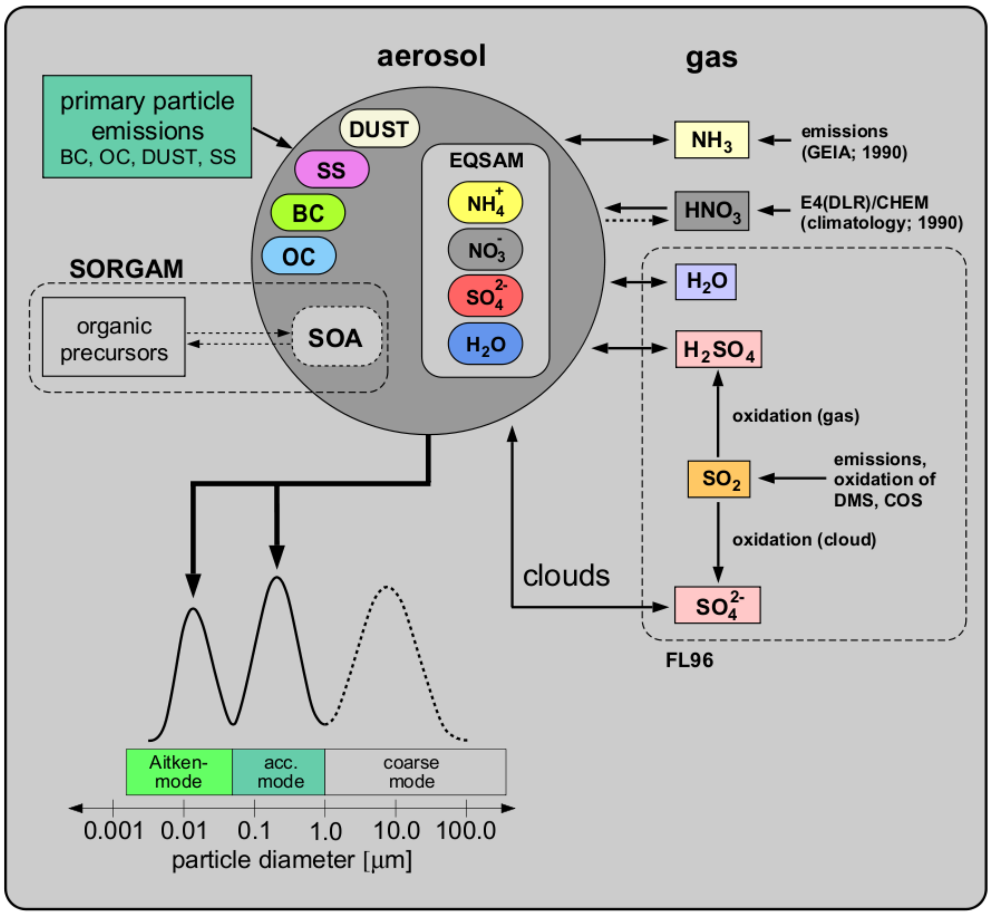


Fuglestvedt et al., EST, 2009

Aerosolrepräsentation in EMAC (am DLR): Prozesse in MADE(-IN)



Prozesse

removal
size dependent
wet & dry deposition,
sedimentation

tracer transport
advection,
convection,
diffusion

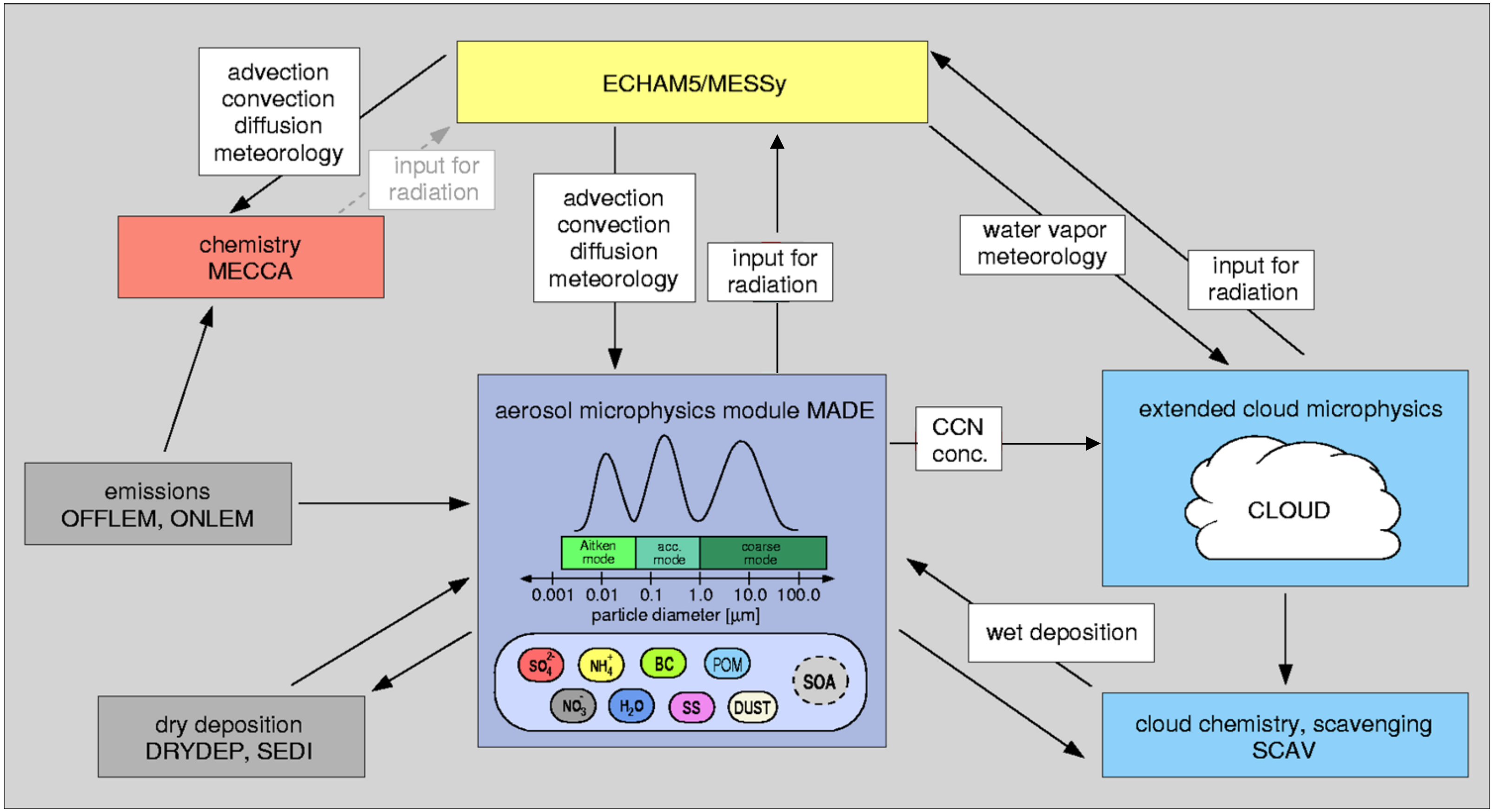
aerosol dynamics
condensation, nucleation,
coagulation,
cloud-aerosol-interactions

chemistry
multiphase sulfur chemistry,
gas-/particle equilibrium

emissions
emissions of particles
and precursors

Lauer et al., ACP, 2005

Aerosolrepräsentation in EMAC (am DLR): Integration von MADE(-IN)



Axel Lauer

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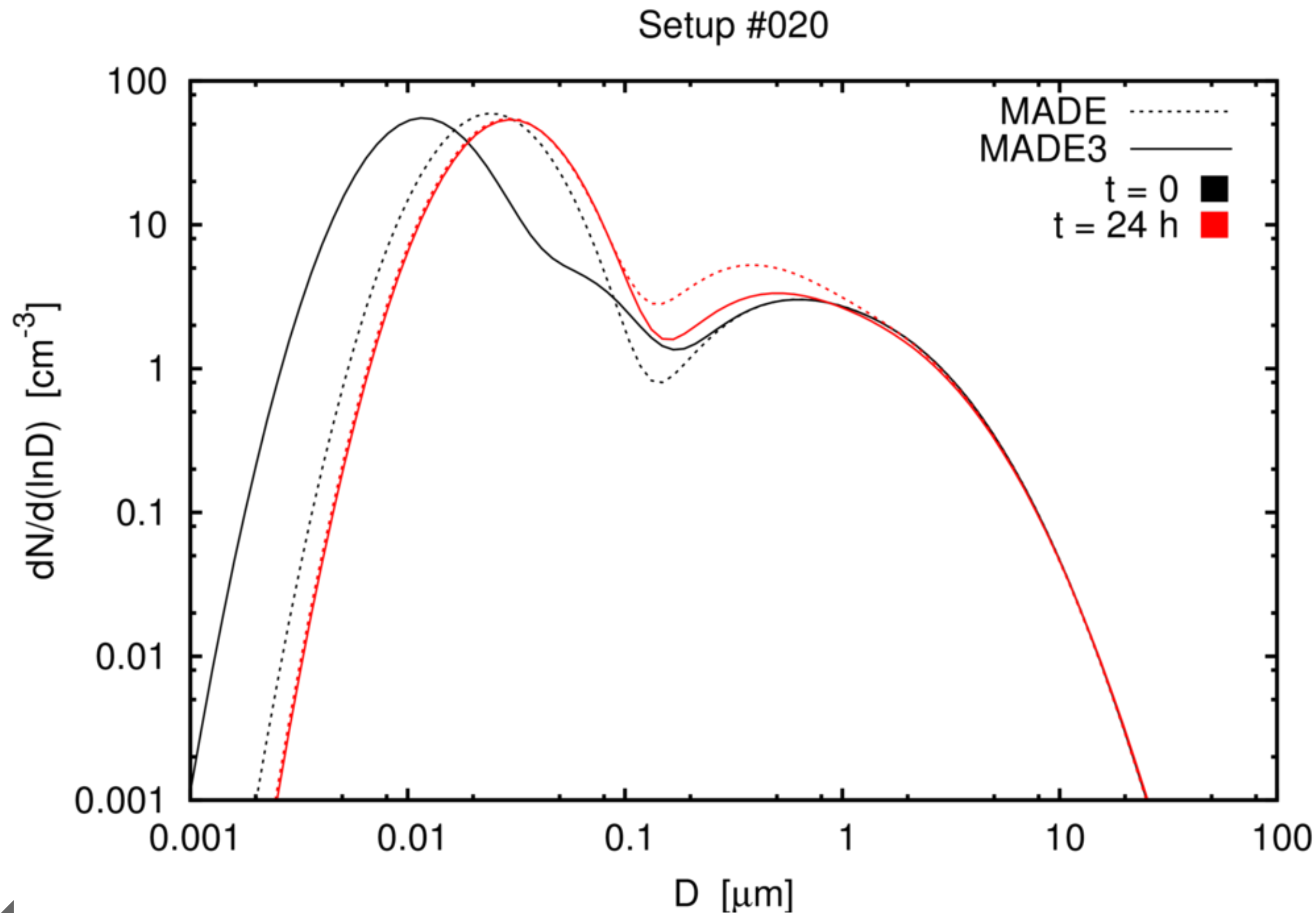
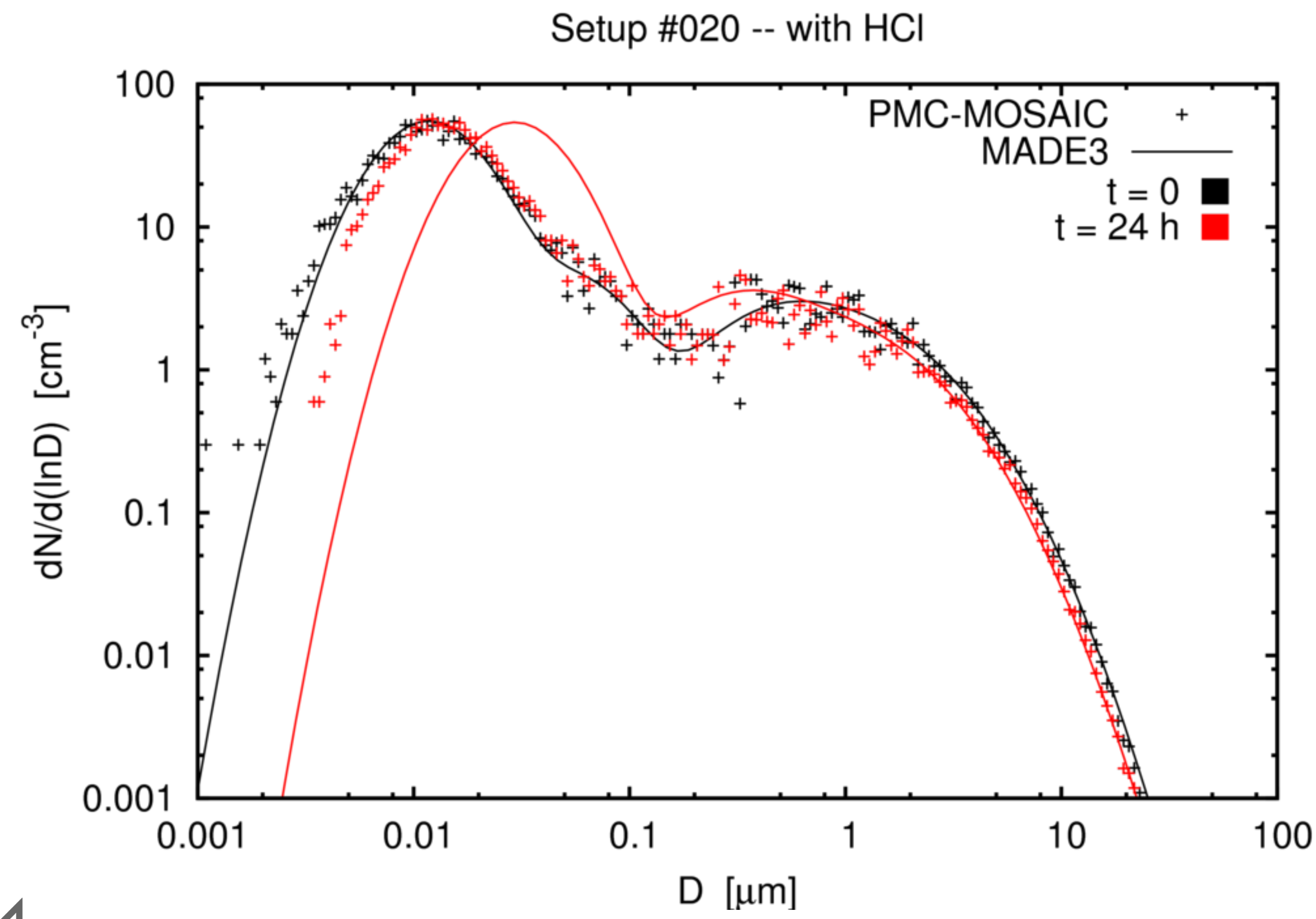


MADE3 vs. PartMC-MOSAIC
Box model: emissions in marine background



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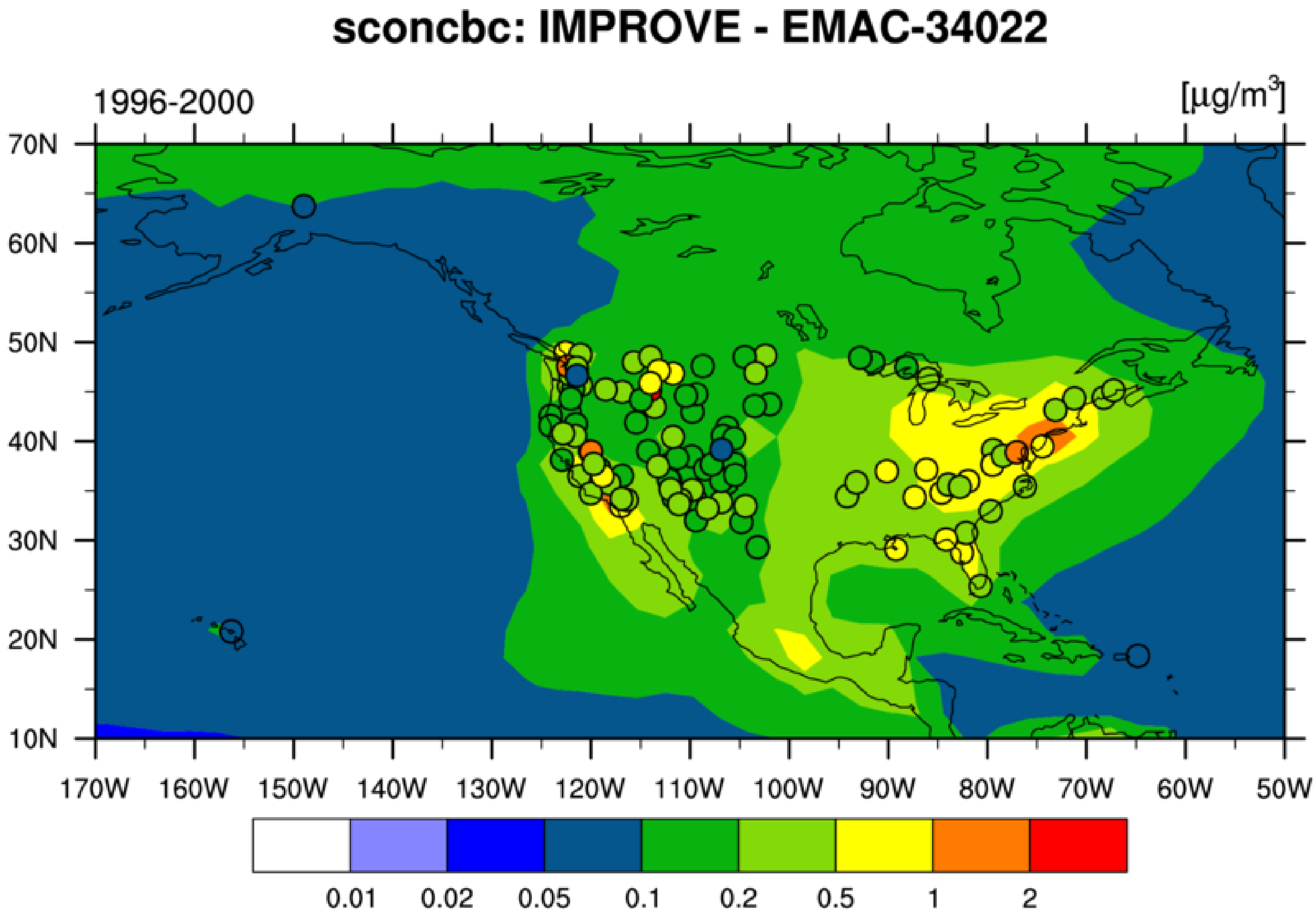
3D: reference run



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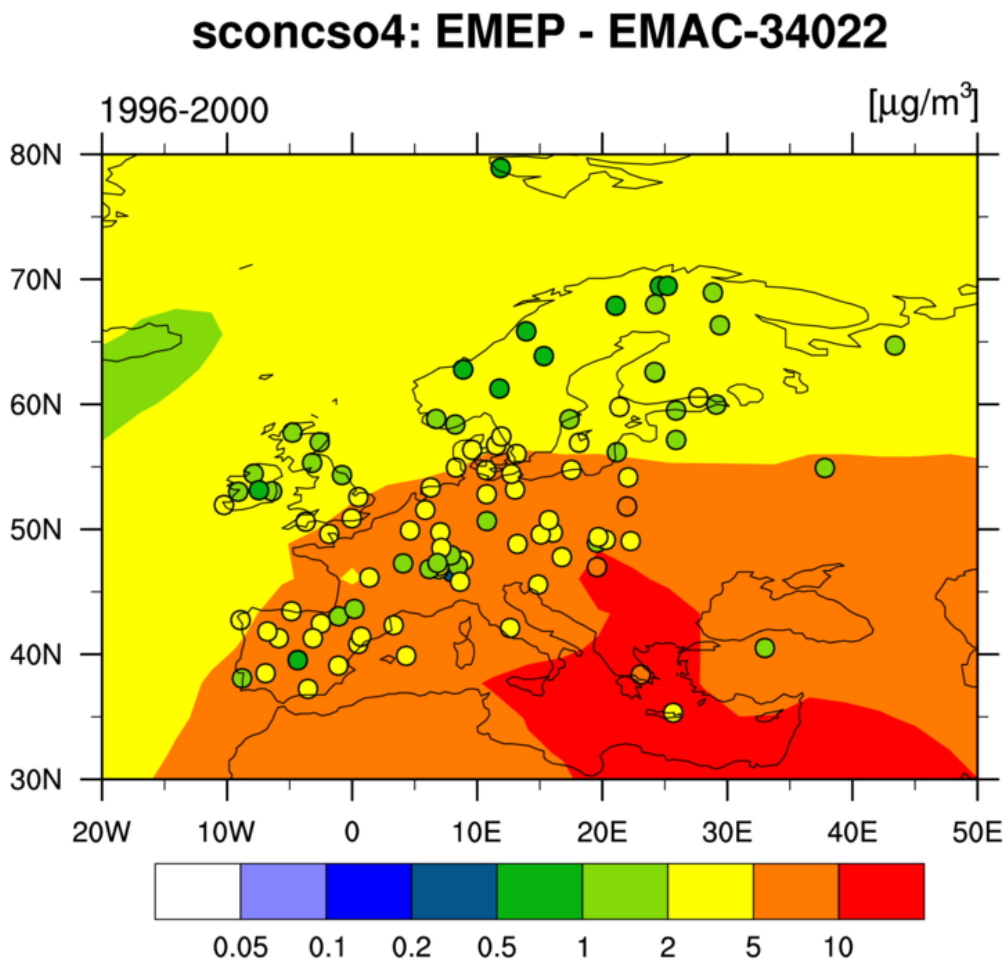
3D: reference run



Erste Ergebnisse: Boxmodelltests von MADE-IN

4 Testkonfigurationen:
- urban
- Hintergrund kontinental
- **marine Grenzschicht**
- freie Troposphäre