A Global Modeling Study on Carbonaceous Aerosol Microphysical Characteristics and Radiative Forcing

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overview

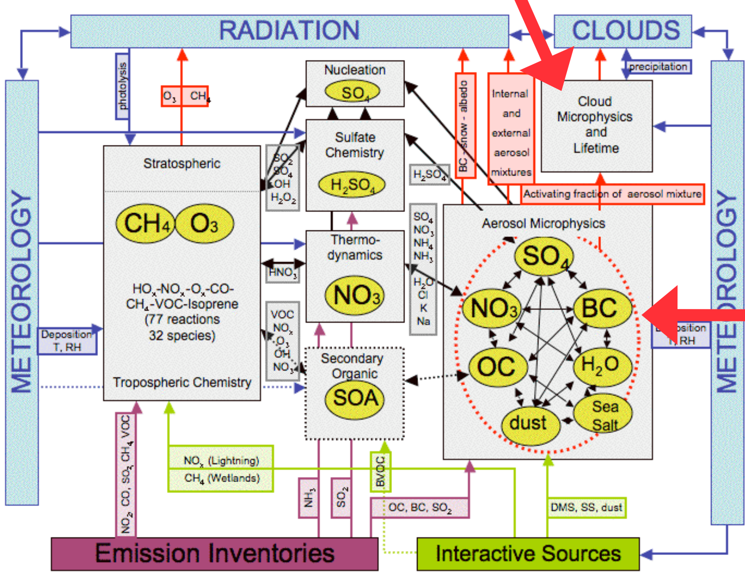
Questions we have to answer:
BC mitigation impacts

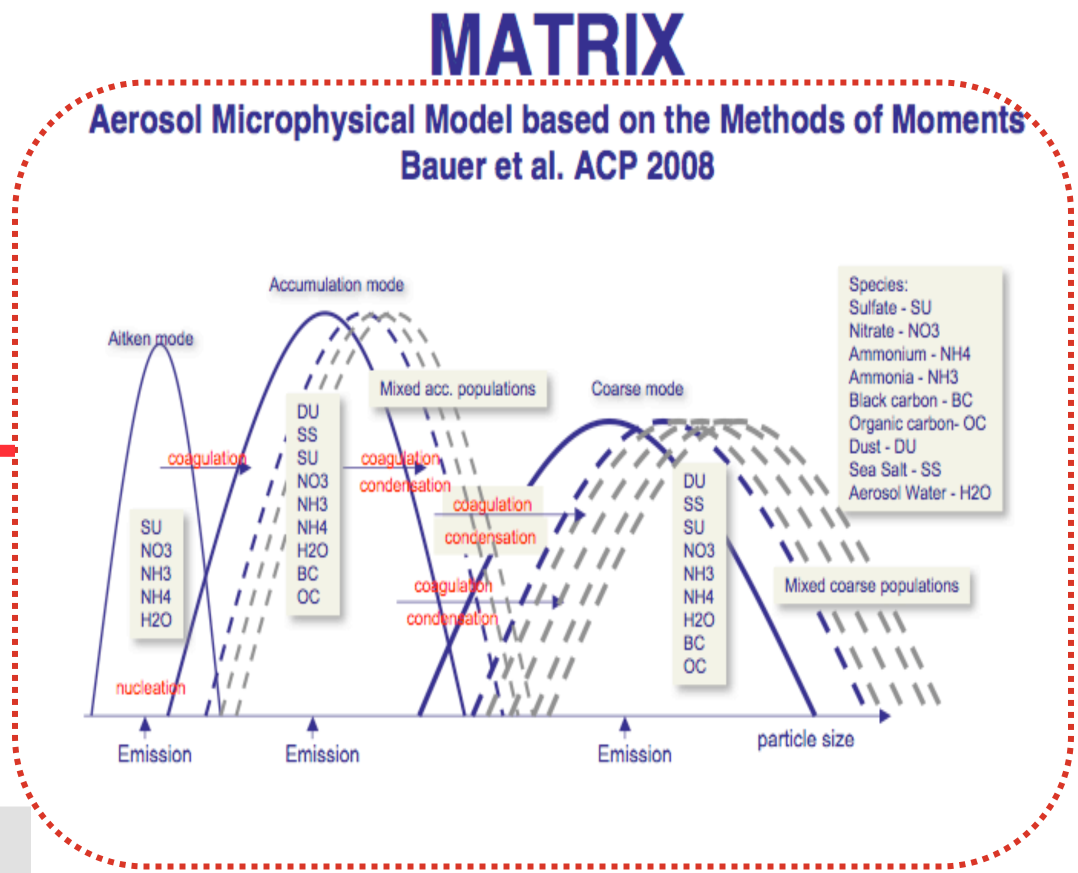
What do we know:
AERONET observations

What do we want to know:
Aerosol and Cloud Microphysical Properties

GISS earth system model: gas and aerosol-phase

Droplet activation:
Adbul Razzak and Ghan (1998, 2000)
Cloud droplet nucleation follows prognostic treatment of Morrison et al. 2005, 2008





Aerosol Microphysics:

- Simulation of aerosol mass, mixing state and size distributions (1). Needed for:
- **Indirect effects**: Microphysical parameter. of aerosol - cloud activation (1,2)
- **Direct effects**: Radiation scheme coupled to aerosol shape and mixing state information (3)

Bauer et al., Atmos. Chem. Phys. 8, 6603-6635, 2008
Menon et al., Atmos. Chem. Phys, to be submitted
Bauer et al., Atmos. Chem. Phys. Dis., 2010

Questions we have to answer:
BC mitigation impacts

Radiative Forcing in 2005 due to emission changes since 1750

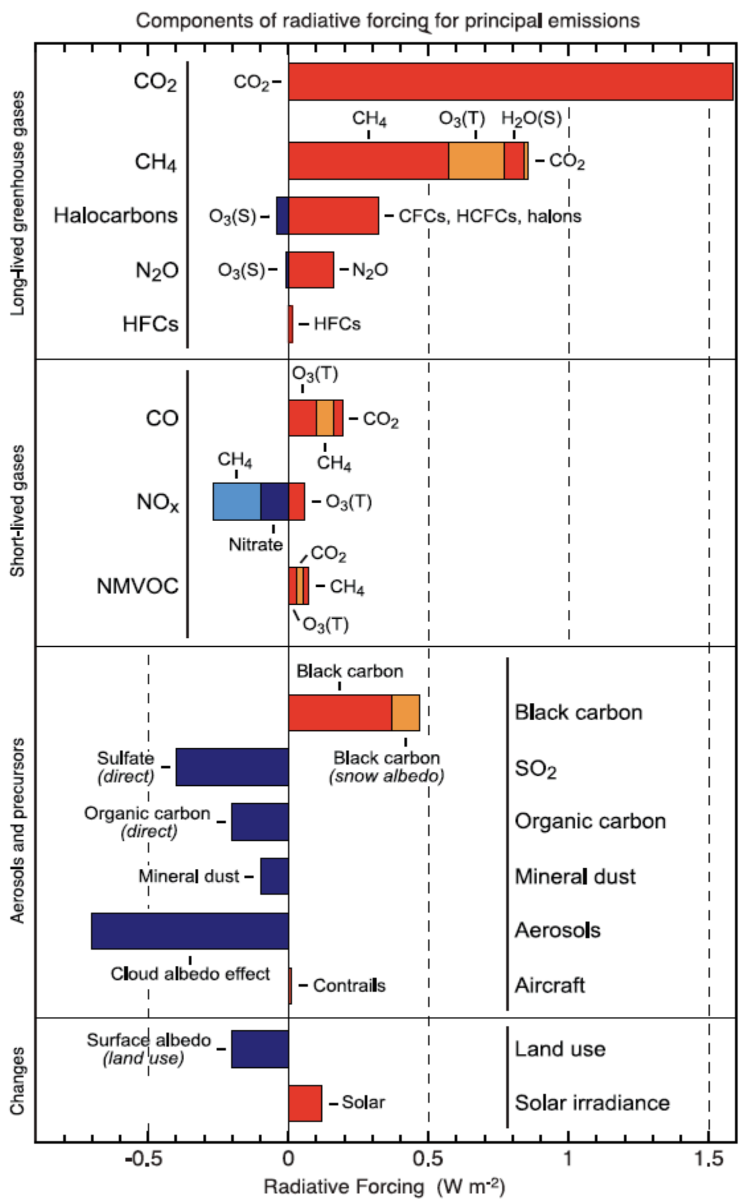


Figure taken from IPCC AR4 report

Global annual BC emissions☆:	8Tg
Open burning	42%
Fossil fuels	38%
Bio fuels	20%

☆ Bond et al 2004 Environ. Res Lett

BC aerosol direct effect

BC mixing sate

Aerosol indirect effect

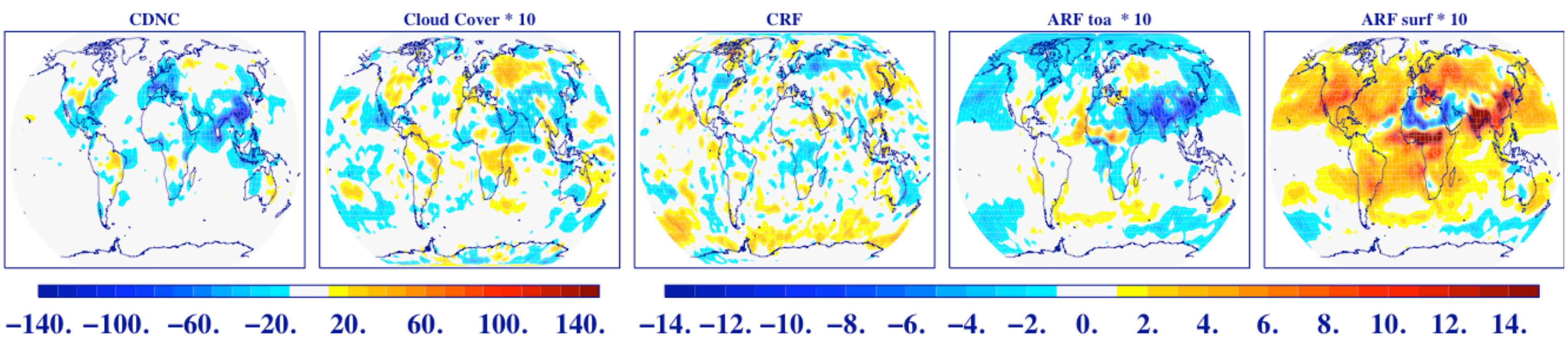
?

bio-fuel mitigation

(Biomass burning emissions: 3.0 Tg BC, 34.2 Tg OC)
Fossil and bio-fuels: 4.6 Tg BC, 30.9 Tg OC

Fossil and -50% bio-fuels: 3.0 Tg BC, 21.9 Tg OC ← 50% bio-fuel burning

Clouds | Aerosols



less CDNC!

Difference PD: BASE - BCmitigation:

Indirect effect:	0.17	W/m^2
Direct effect:	-0.05	W/m^2
Net Rad. change:	0.12	W/m^2

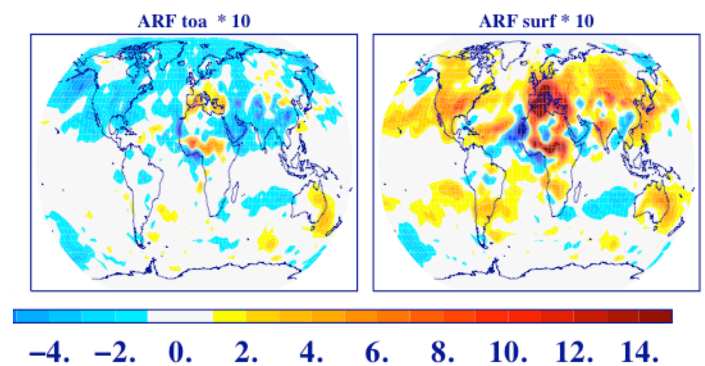
diesel mitigation

(Biomass burning emissions: 3.0 Tg BC, 34.2 Tg OC)

Fossil and bio-fuels: 4.6 Tg BC, 30.9 Tg OC

Fossil and bio-fuel w/o diesel: 3.3 Tg BC, 30.3 Tg OC ← no diesel

Aerosols



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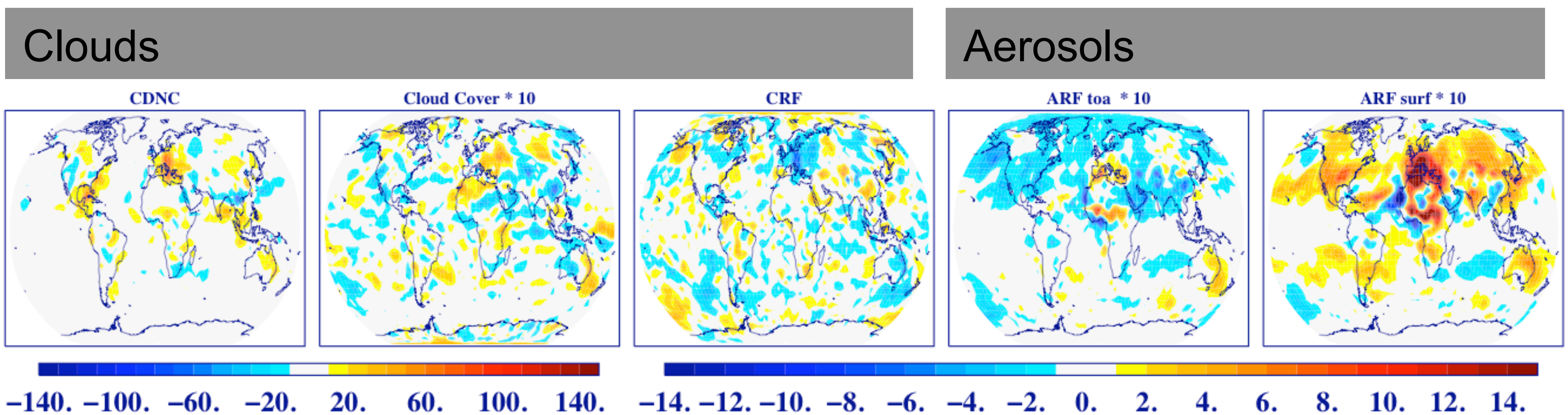

more CDNC!

Difference PD: BASE - BCmitigation:

Indirect effect: -0.05 W/m²
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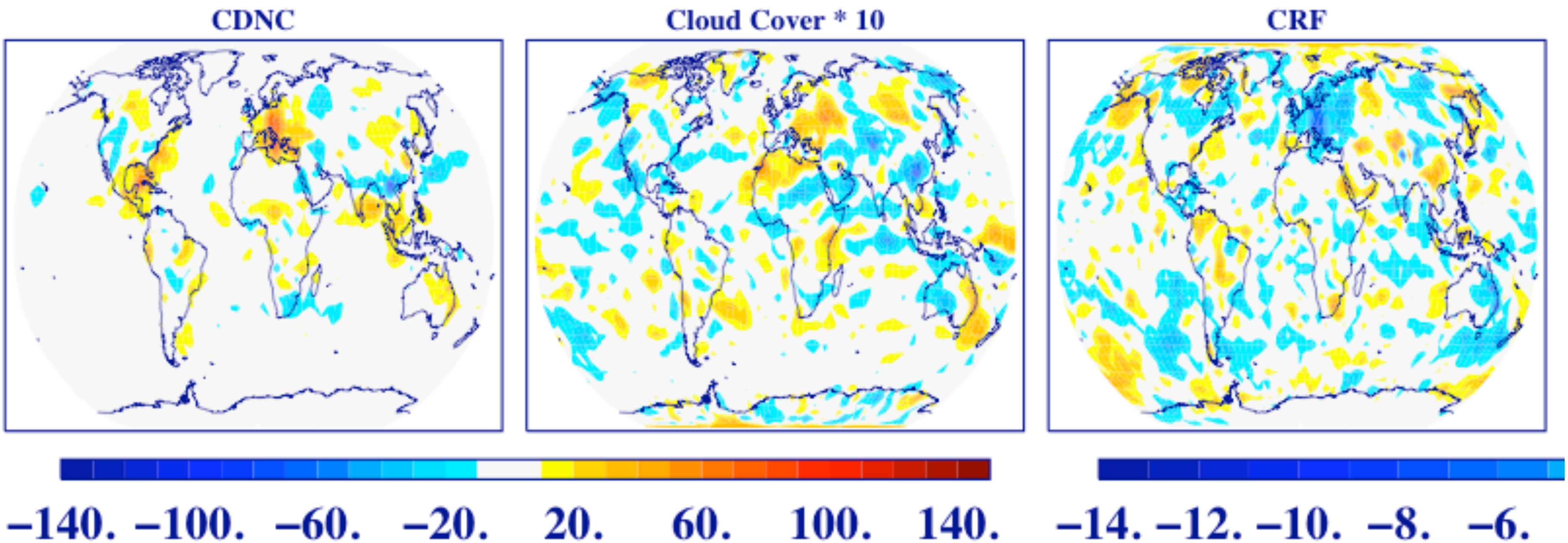
diesel mitigation

Clouds



more CDNC!

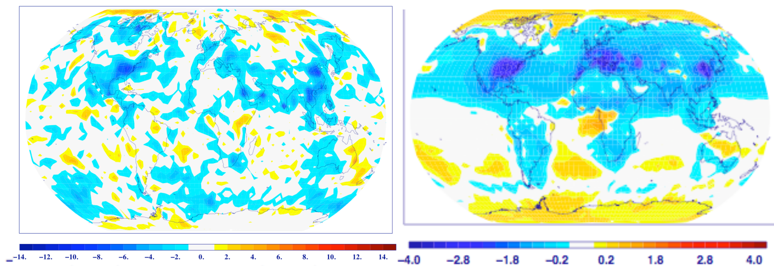
Difference PD: BASE - BCmitigation:

Indirect effect:	-0.05 W/m^2
Direct effect:	-0.05 W/m^2
Net Rad. change:	-0.10 W/m^2

Black Carbon Mitigation Studies

Radiative Forcing changes 1750 to 2000

Cloud Forcing | Aerosol Forcing [W/m^2]



Indirect effect: -0.40 W/m^2
Direct effect: -0.17 W/m^2
Net Rad. change: -0.57 W/m^2

Black Carbon Mitigation Scenarios:

(Forcing numbers show differences in respect to the Pre-industrial to Present day changes)

diesel BC reductions

Indirect effect: -0.05 W/m^2
Direct effect: -0.05 W/m^2
Net Rad. change: -0.10 W/m^2

bio-fuel BC and OC reductions

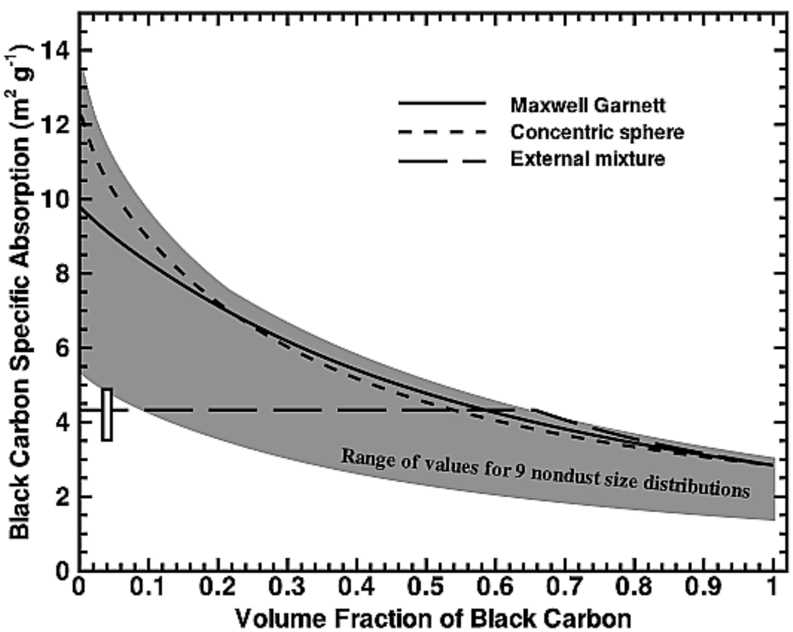
Indirect effect: 0.17 W/m^2
Direct effect: -0.05 W/m^2
Net Rad. change: 0.12 W/m^2

Results depend on microphysical properties!
Mixing state determines BC absorption strength and CDNC distributions.

What do we know:
AERONET observations

Direct forcing: BC absorption strength

impact of mixing state on optical properties



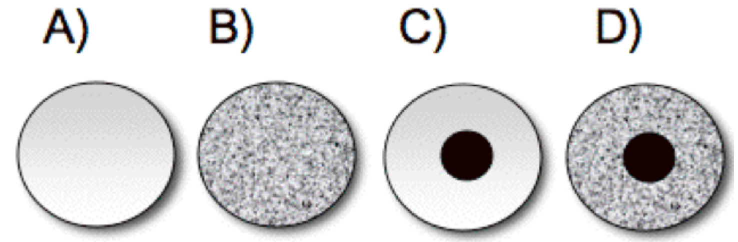
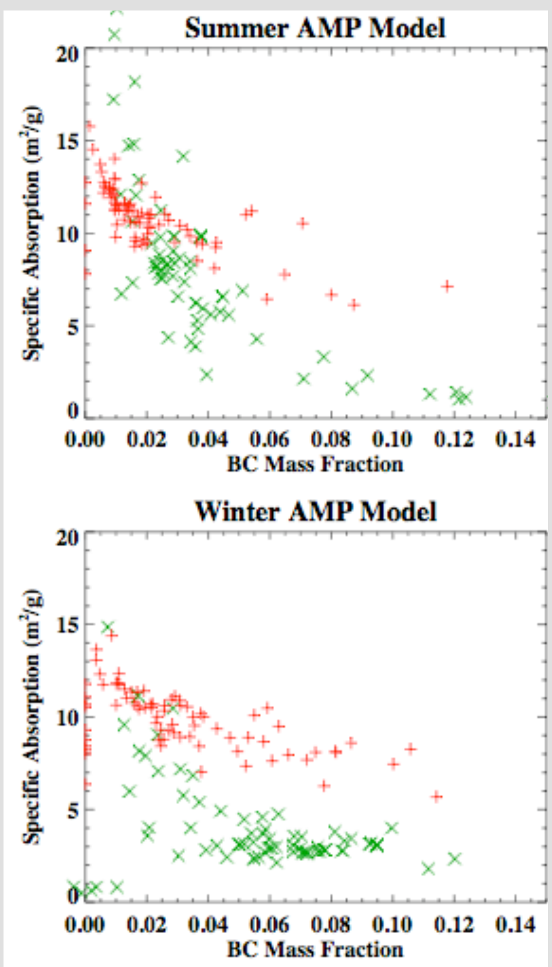


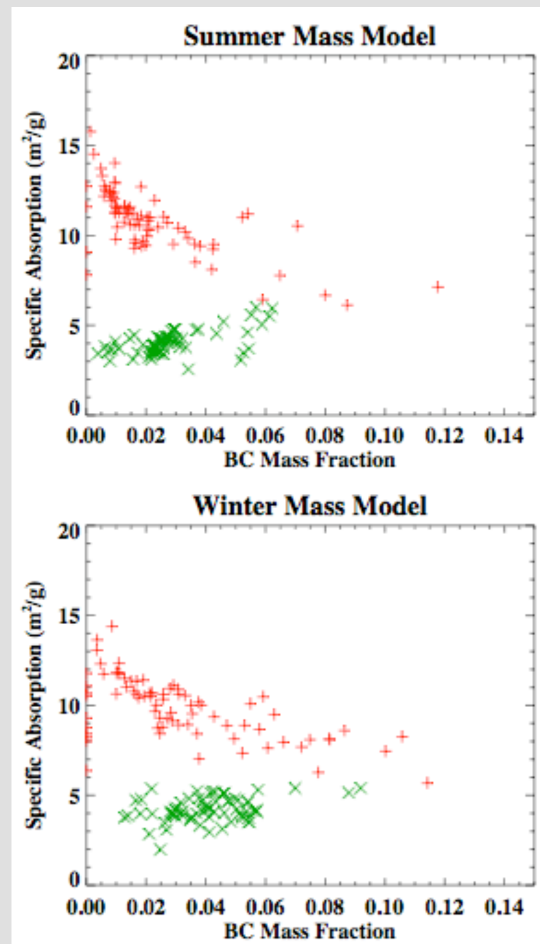
Figure 6. from *Schuster et al (2005)* Black carbon specific absorption (l = 0.55 mm) inferred from size distribution climatologies in the work of Dubovik et al. [2002] and black carbon mixed with ammonium sulfate. The shaded area indicates the range of results for internal mixture on nine non-dust size distributions.

AERONET and model: specific absorption / BC mass fraction

Microphysics



No Microphysics



aerosol direct effect: absorption

AeroCom model mean: pred. externally mixed aerosols (D.Koch et al ACP, 2009)

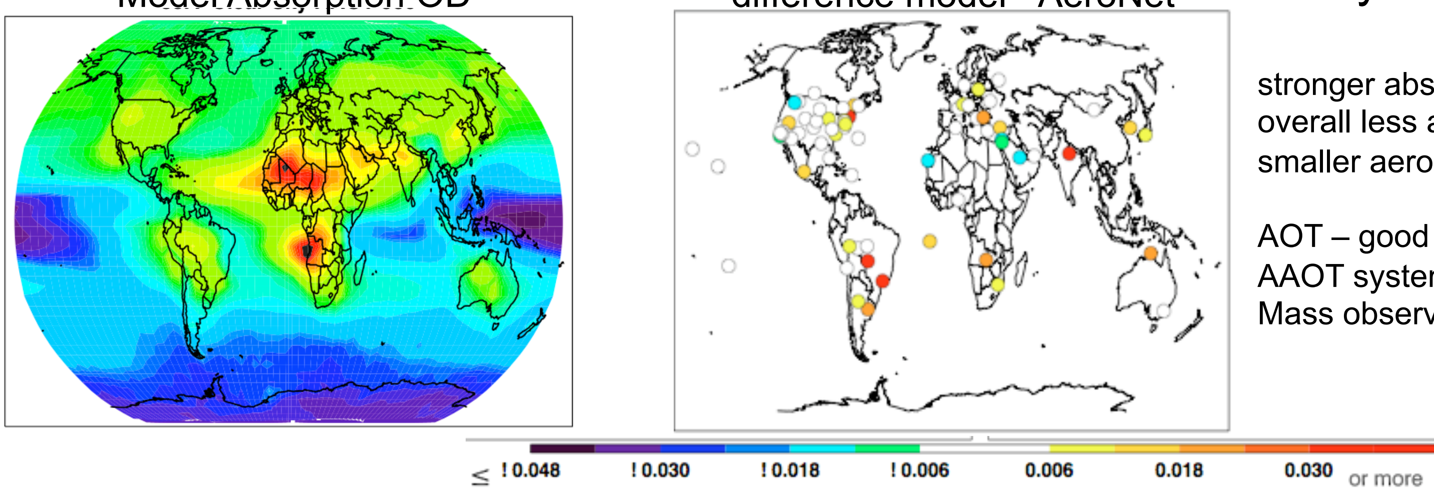
	N.Am.	Eur.	Asia	S.Am.	Afr.	Rest
model biases AAOD:						
AERONET	0.86	0.81	0.67	0.68	0.53	0.55
OMI	0.52	1.6	0.71	0.35	0.47	0.26

AAOD:
systematic underestimation

MATRIX: internally mixed aerosols

Model Absorption OD

difference model - AeroNet



AAOD:
No systematic bias

stronger absorption
overall less aerosol cooling
smaller aerosol direct effect

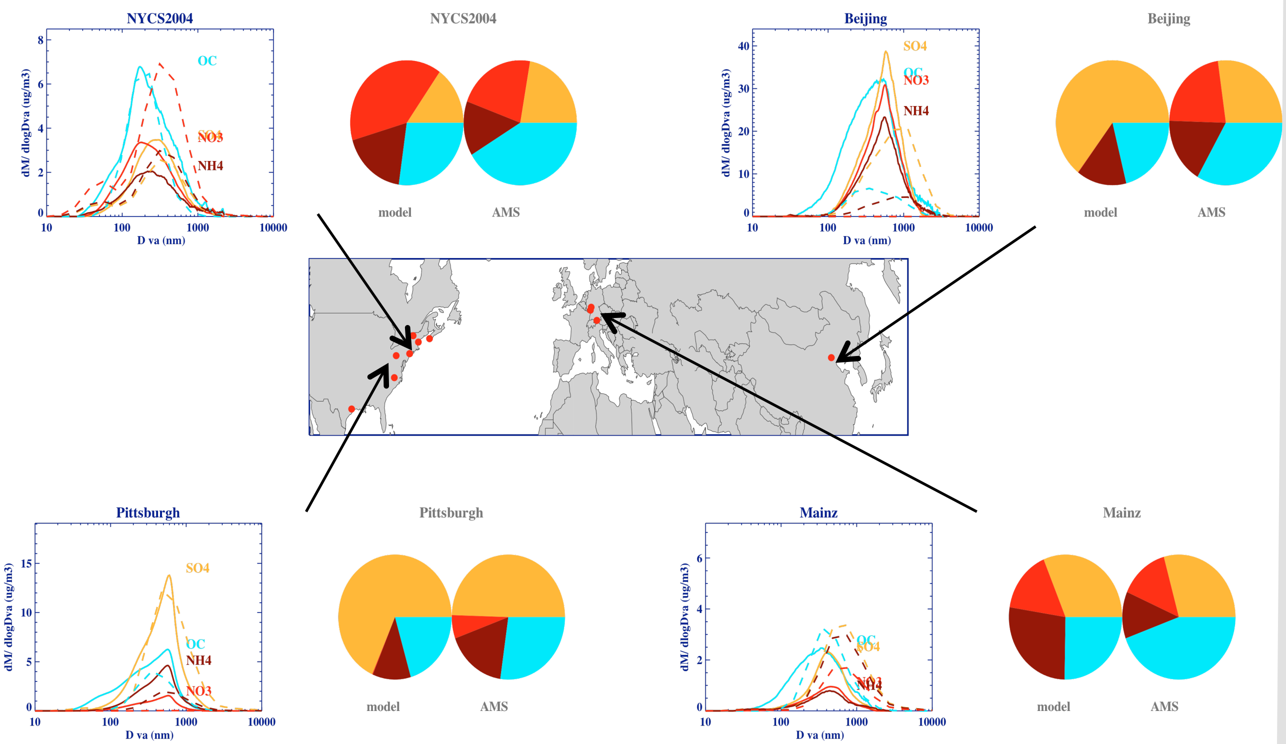
AOT – good – was always good
AAOT systematically to low – now good
Mass observations – as good as before

What do we want to know:

Aerosol and Cloud Microphysical Properties

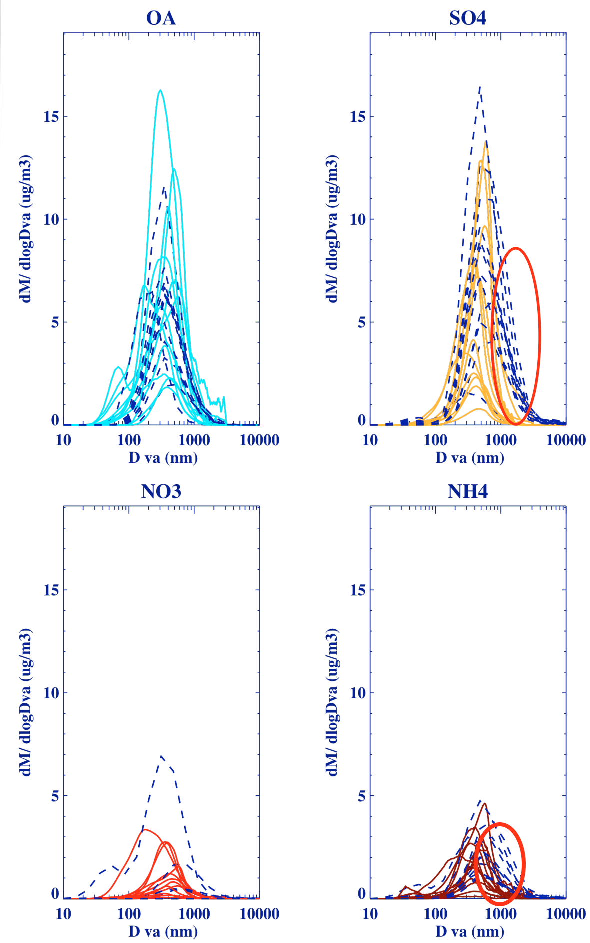
First steps….

AMS aerosol mass spectroscopy



NO_3 SO_4 OA NH_4

Size distributions at
all 12 stations (excl. Beijing):

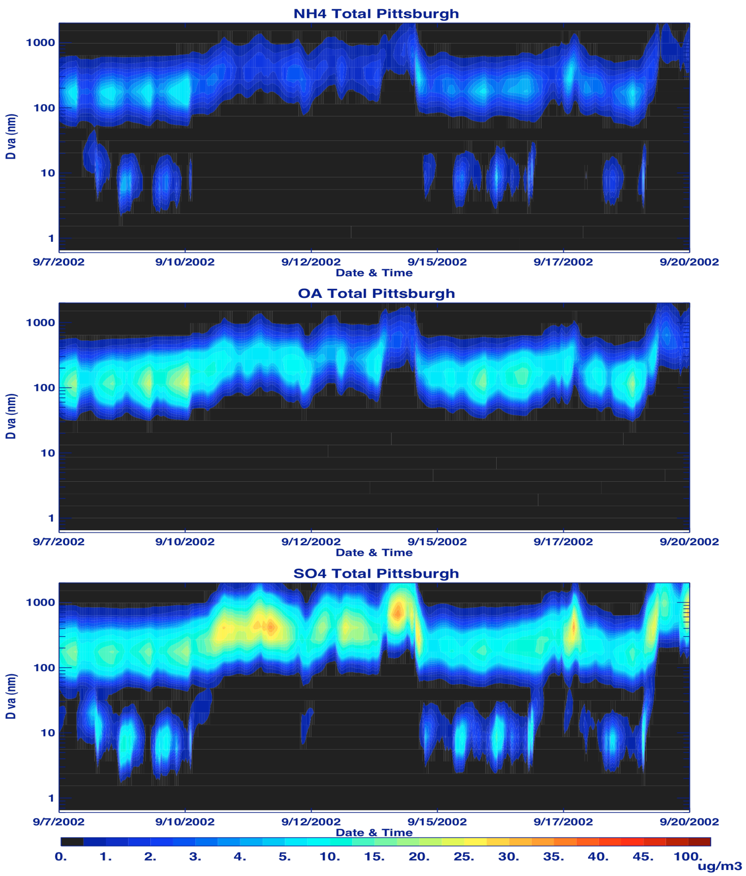


Qi Zhang's Poster: Size Resolved Chemical Composition of Aerosol Particles in Multiple Urban, Rural and Remote Atmospheric Environments: An Integrated View Via Aerosol Mass Spectrometry Analysis of global AMS datasets was supported by a DOE ASP grant DEFG02-08ER64627

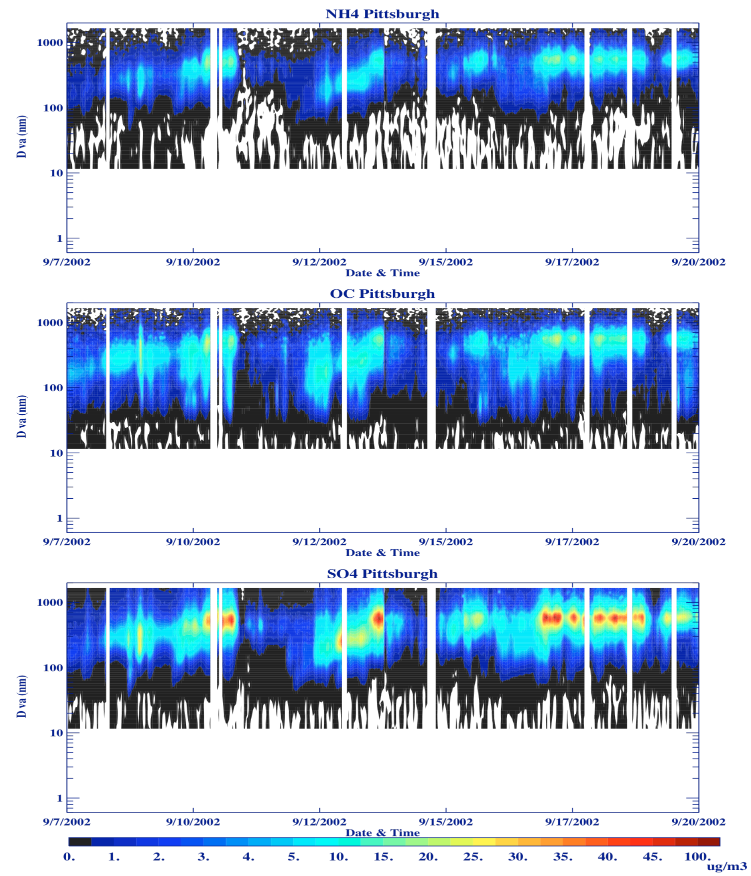
OA size is well simulated
SO4 and HN4 have large bias
NO3 concentrations are low

AMS aerosol mass spectroscopy

MATRIX



AMS



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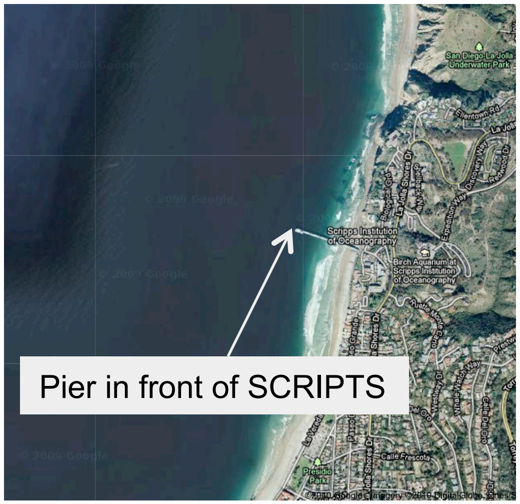
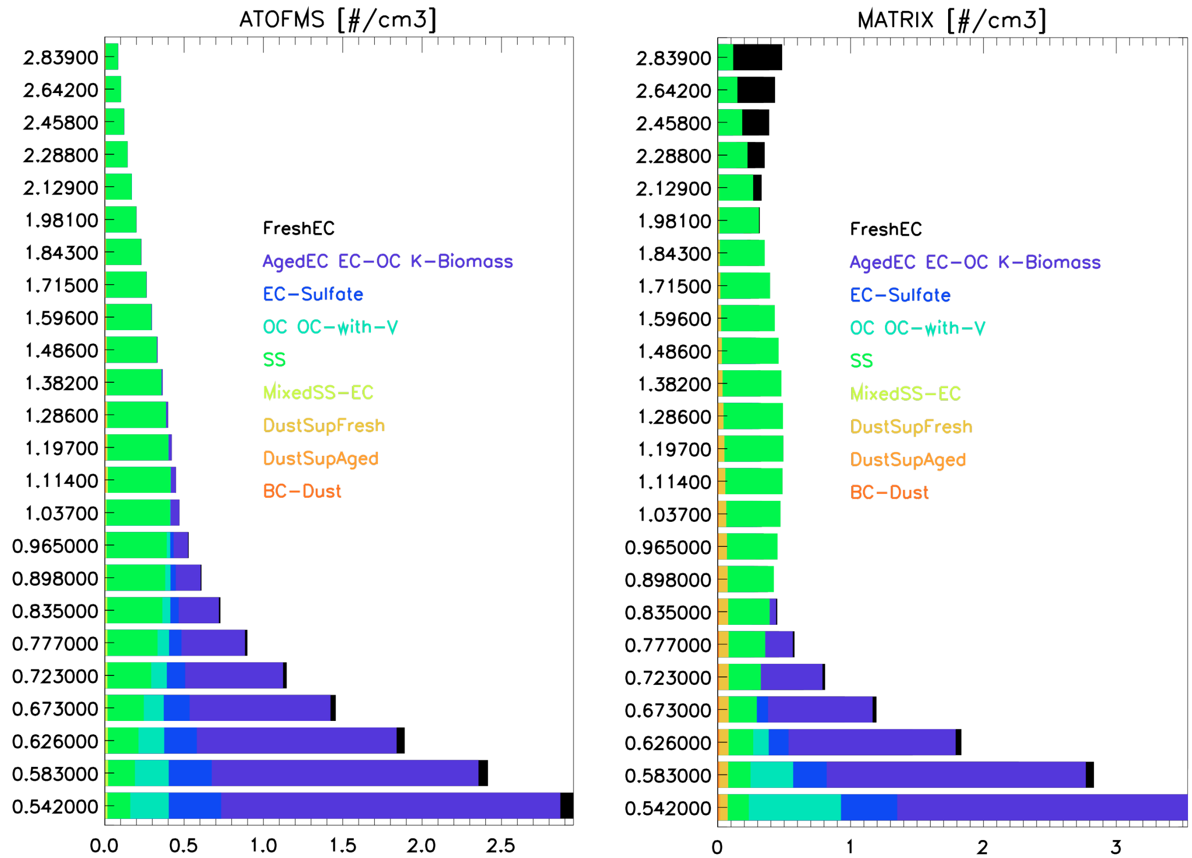
single particle AMS





Aerosol Time of Flight Mass Spectrometer (ATOFMS)
UC San Diego Kim Prather
Size resolved observation of aerosol mixing state.
Observations by Kim Prather et al.: Monthly mean mixing state September 2006, La Jolla Pier.

What do we want to know:

Aerosol and Cloud Microphysical Properties

Aerosol Indirect Effect

FASTER Project (PI Yangang Liu)

Our team: Surabi Menon, Gijs de Boer, Susanne Bauer

Evaluate the link between aerosol microphysics and cloud activation with long -term ARM observations, IOP studies and field campaign data.

Testing new parameterization developed within the framework of FASTER

Climate implications