Research on current and future effects of black carbon particles on climate – follow up

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ABSTRACT
This talk presents an overview on the various steps that are required for this calculation. It is based on the paper by Chung and Seinfeld (2002).

INTRODUCTION
According to IPCC (2001) black carbon (BC) induces a positive radiative forcing (warming) at the top of the atmosphere (TOA), which is however associated with a large uncertainty. Jacobson (2002) came up with the provocative statement that a diesel car meeting the EURO 4 particulate standard (0.025 g/km) will warm climate during the next 100 years more than will a gasoline car. This paper does not attempt to compare radiative forcing by diesel and gasoline emissions. Rather, it outlines the pathway to be followed when calculating radiative forcing.

RESULTS AND CONCLUSIONS
The calculation of the radiative forcing involves several steps. First a global black carbon emission inventory is required. Second, a lifetime has to be attributed to the soot particles. Here, it is estimated that BC becomes coated with hydrophilic material within one day, and is eliminated from the atmosphere by precipitation within 6.4 days (Chung and Seinfeld, 2002). Among other processes, condensation of secondary aerosol (both inorganic and organic) is mainly responsible for this process, which results in an internally mixed aerosol at remote sites such as the Jungfraujoch in the Swiss Alps (3580 m asl) (Weingartner et al., 2002). Based on this lifetime the BC surface concentration is then calculated. Chung and Seinfeld (2002) compared their model results with measurements and found reasonable agreement. In a next step, the radiative forcing of BC is calculated. Here, the morphology and the mixing state of the carbonaceous aerosol have an important influence: An internal mixture results in a significantly higher radiative forcing than an external mixture, while the so-called core model (a core of BC surrounded by scattering material such organics, sulfate and water) lies between the two extremes of internally and externally mixed particles. This is exemplified by a chamber experiment, where diesel soot is coated with the oxidation products of α-pinene, resulting in a significantly higher absorption efficiency of the coated diesel soot (Weingartner et al., 2003). Based on this, the TOA direct radiative forcing is then calculated. According to Chung and Seinfeld (2002), externally and internally mixed BC aerosols yield +0.51 and +0.8 W/m^2, respectively. The latter value is virtually identical with the one given by Jacobson (2000) and indicates that the radiative forcing may be significantly higher than the estimate given

by IPCC (2001). The largest uncertainty in the calculation of this forcing remains in the emission inventory.

Concluding, BC exerts a significant warming on the earth atmosphere, and a rapid deployment of particle filters in diesel cars is therefore advisable not only for health but also for climate issues.

References

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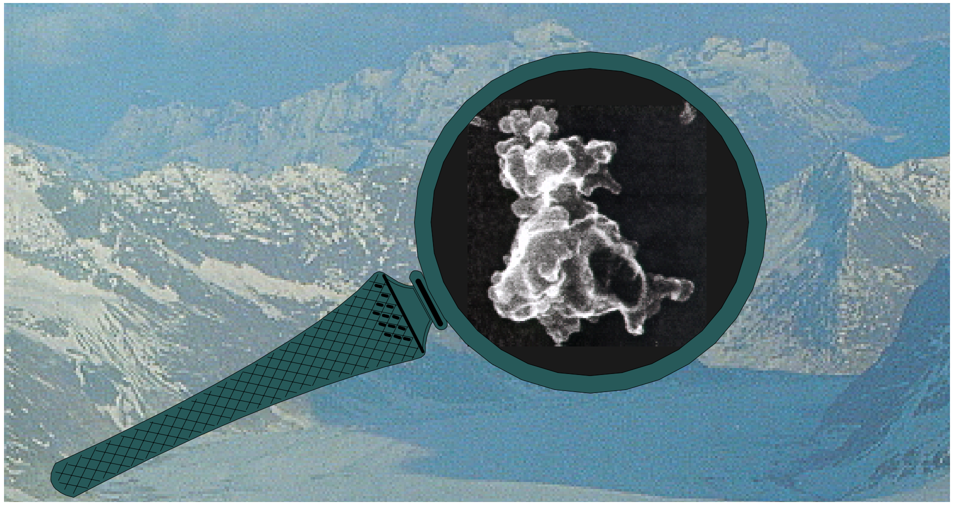

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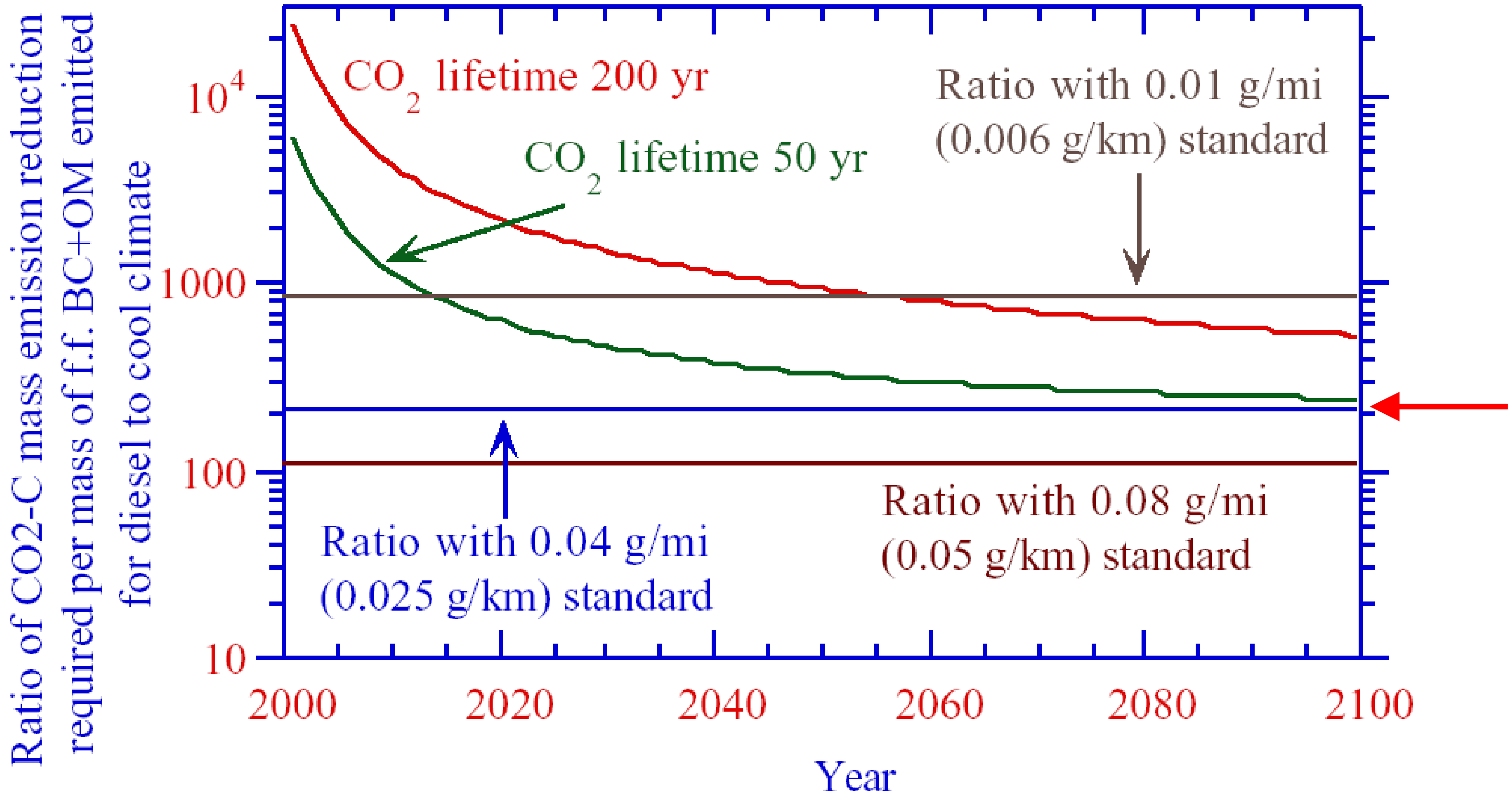
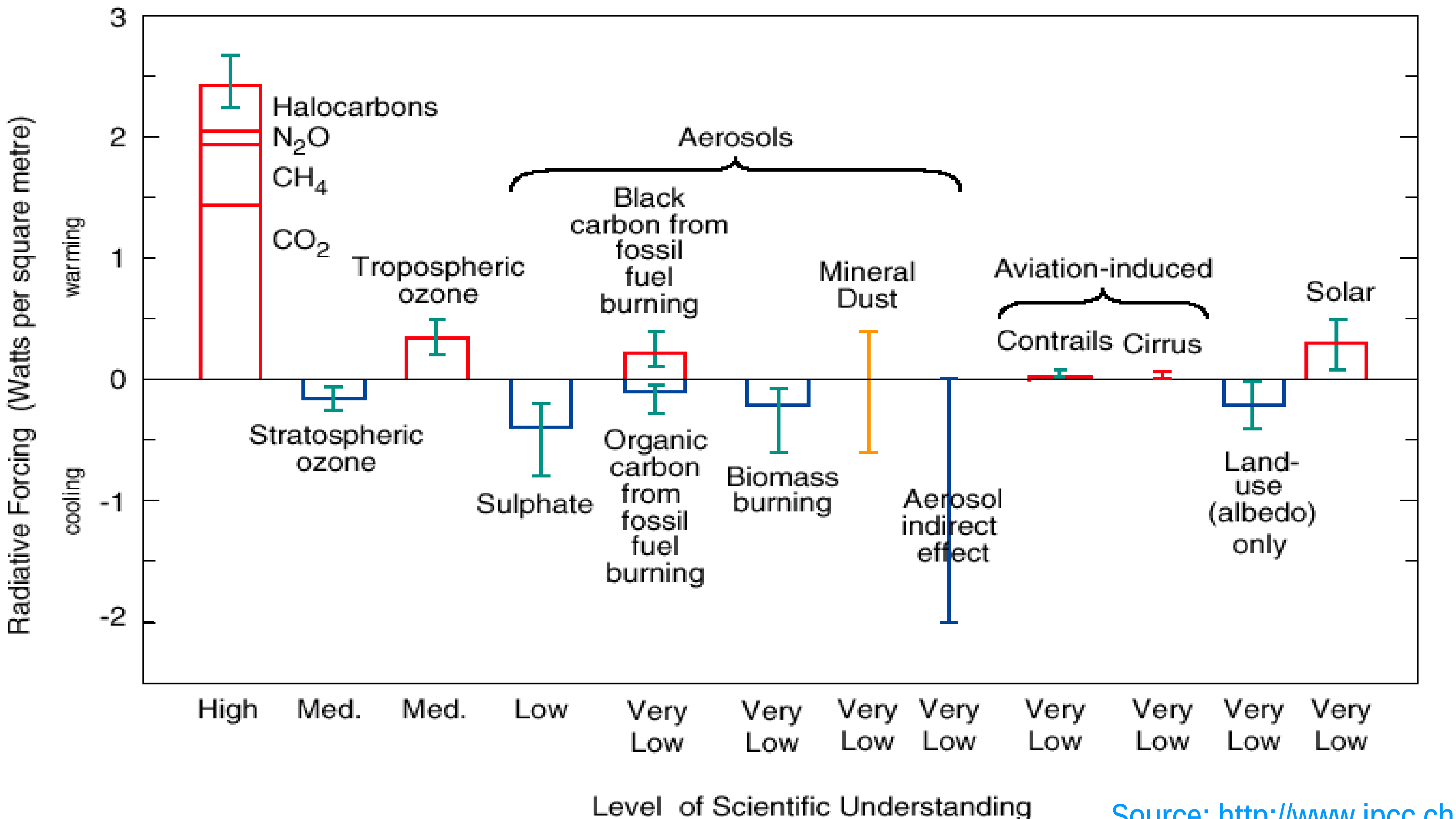
Jacobson‘s JGR paper 2002



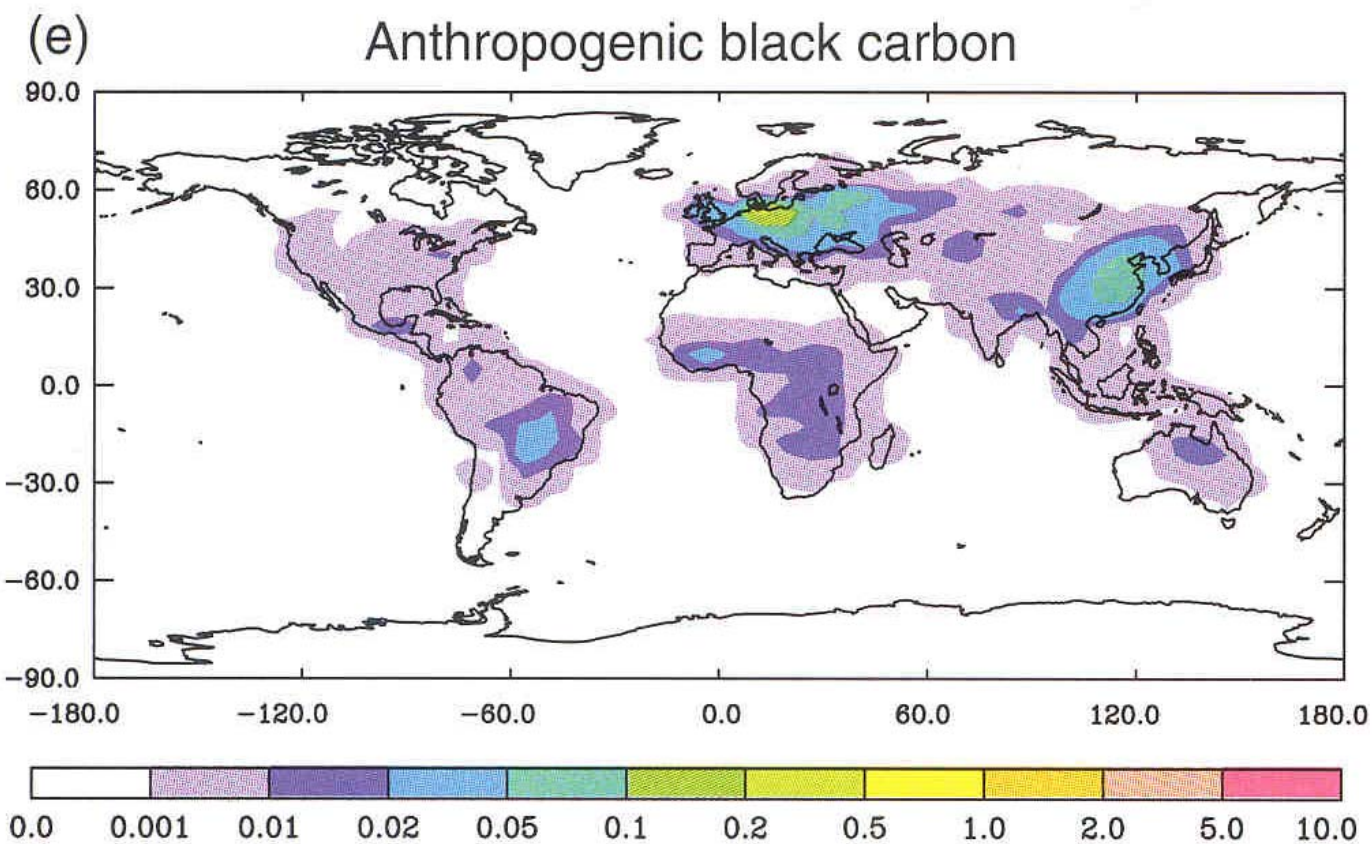
Jacobson‘s provocative statement: a diesel car meeting the EURO 4 particulate standard (0.025 g/km) will warm climate during the next 100 years more than will a gasoline car

The global mean radiative forcing of the climate system for the year 2000, relative to 1750



Source: http://www.ipcc.ch/

First step:
Anthropogenic black carbon emissions (kg km^{-2} hr^{-1})



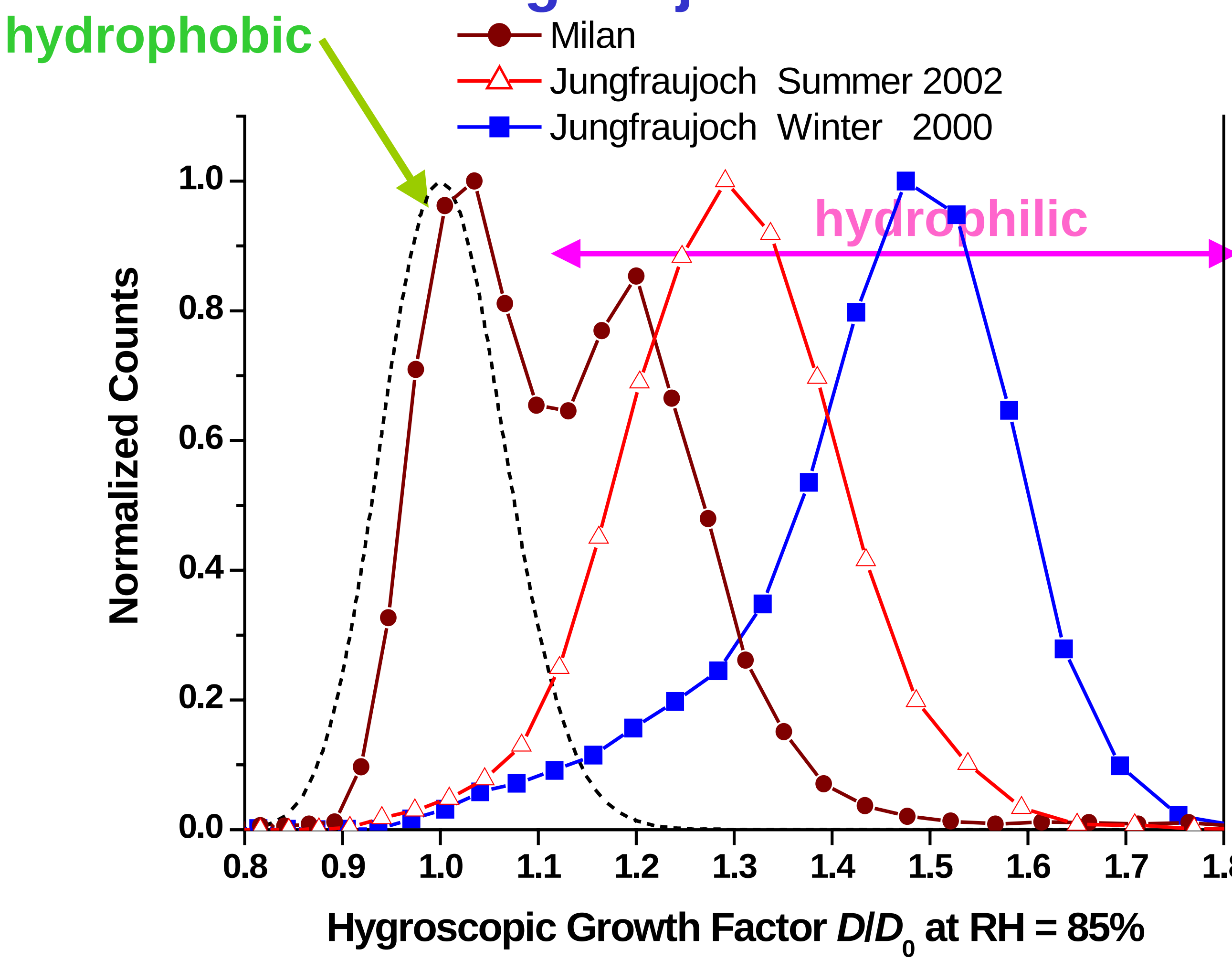
IPCC (2001)

Second step:
Predicted lifetimes and burden

Aerosol		Burden (Tg)	Lifetime (days)
BC		0.22	6.4
	Hydrophobic	0.03	1.0
	Hydrophilic	0.19	6.4

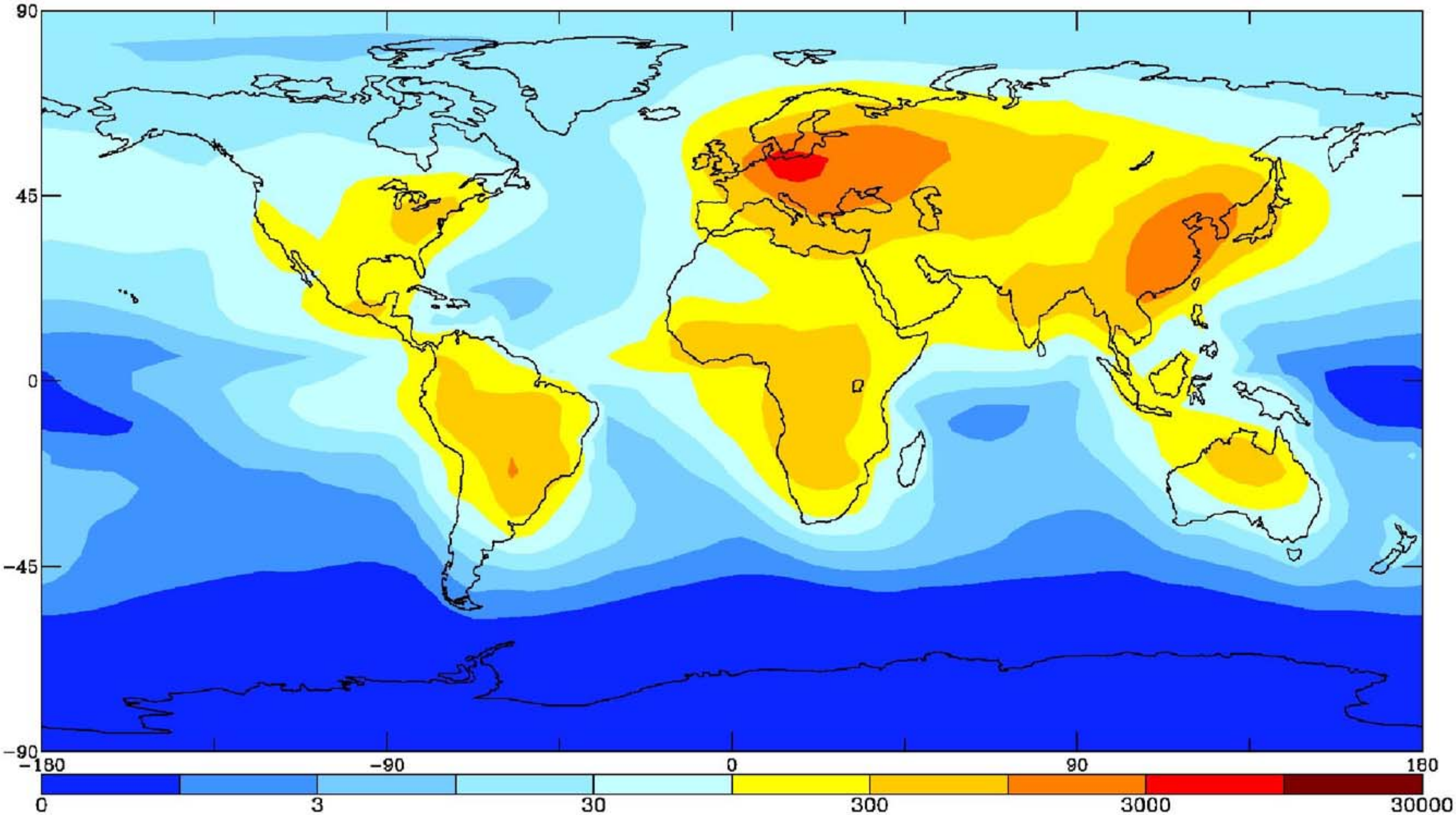
BC becomes coated with hydrophilic material within one day, and is eliminated from the atmosphere by precipitation within 6.4 days

Hygroscopic growth factors at the Jungfraujoch and in Milan



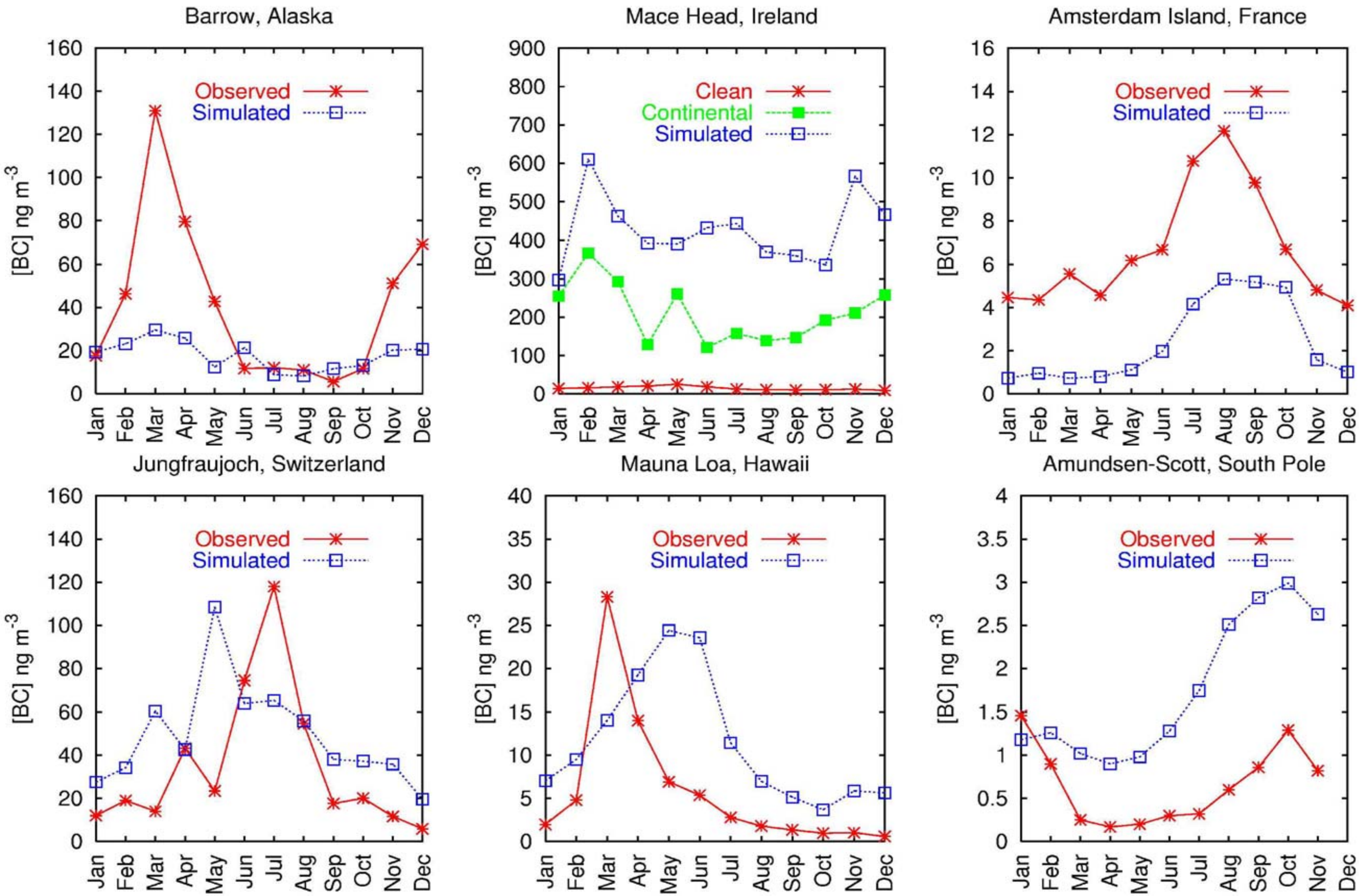
Baltensperger et al., JGR 2002, Weingartner et al., EST, 2002

Third step:
BC Surface Concentrations (ng m^{-3})



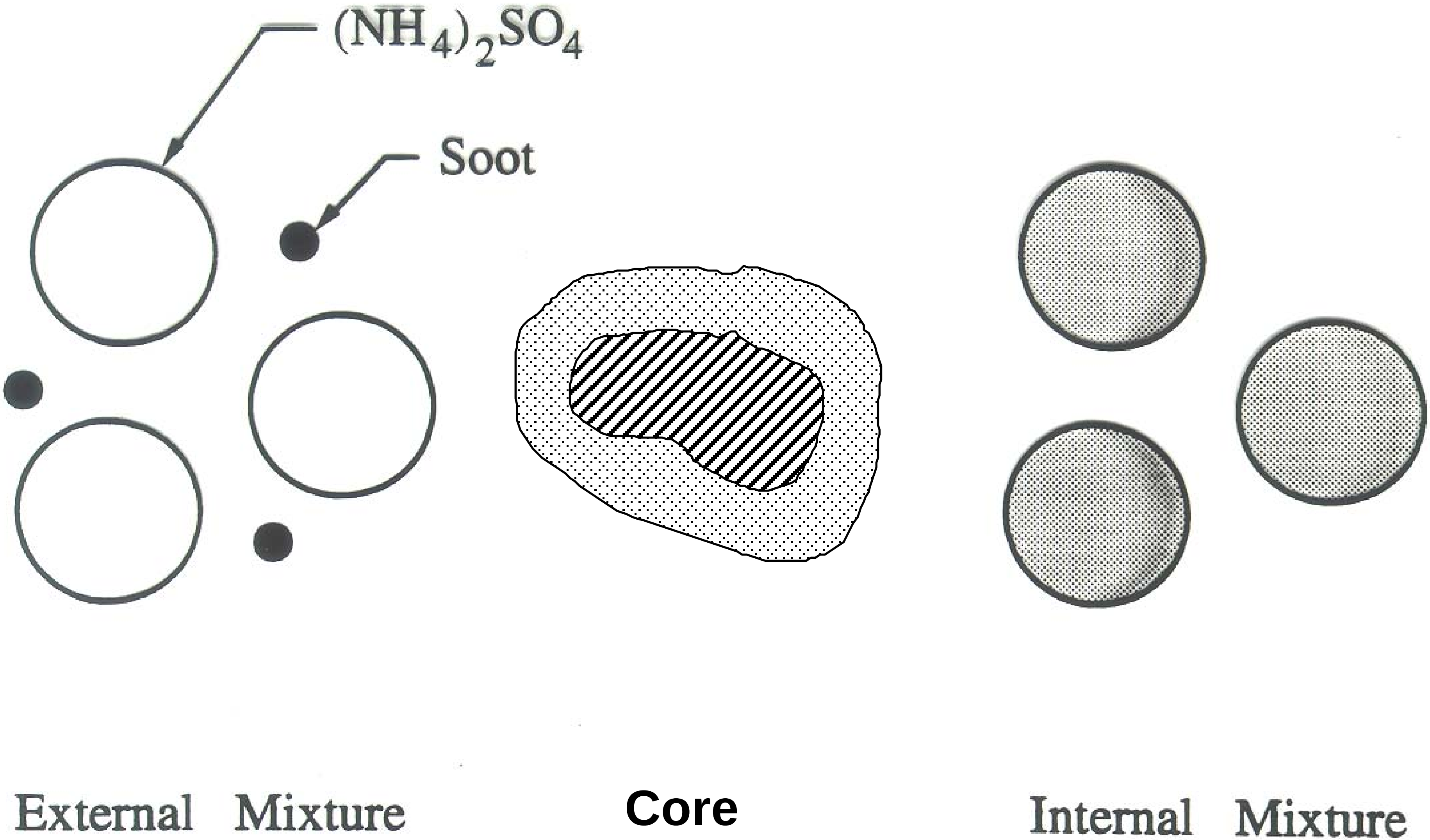
Chung and Seinfeld, JGR 2002

Comparison with Observations

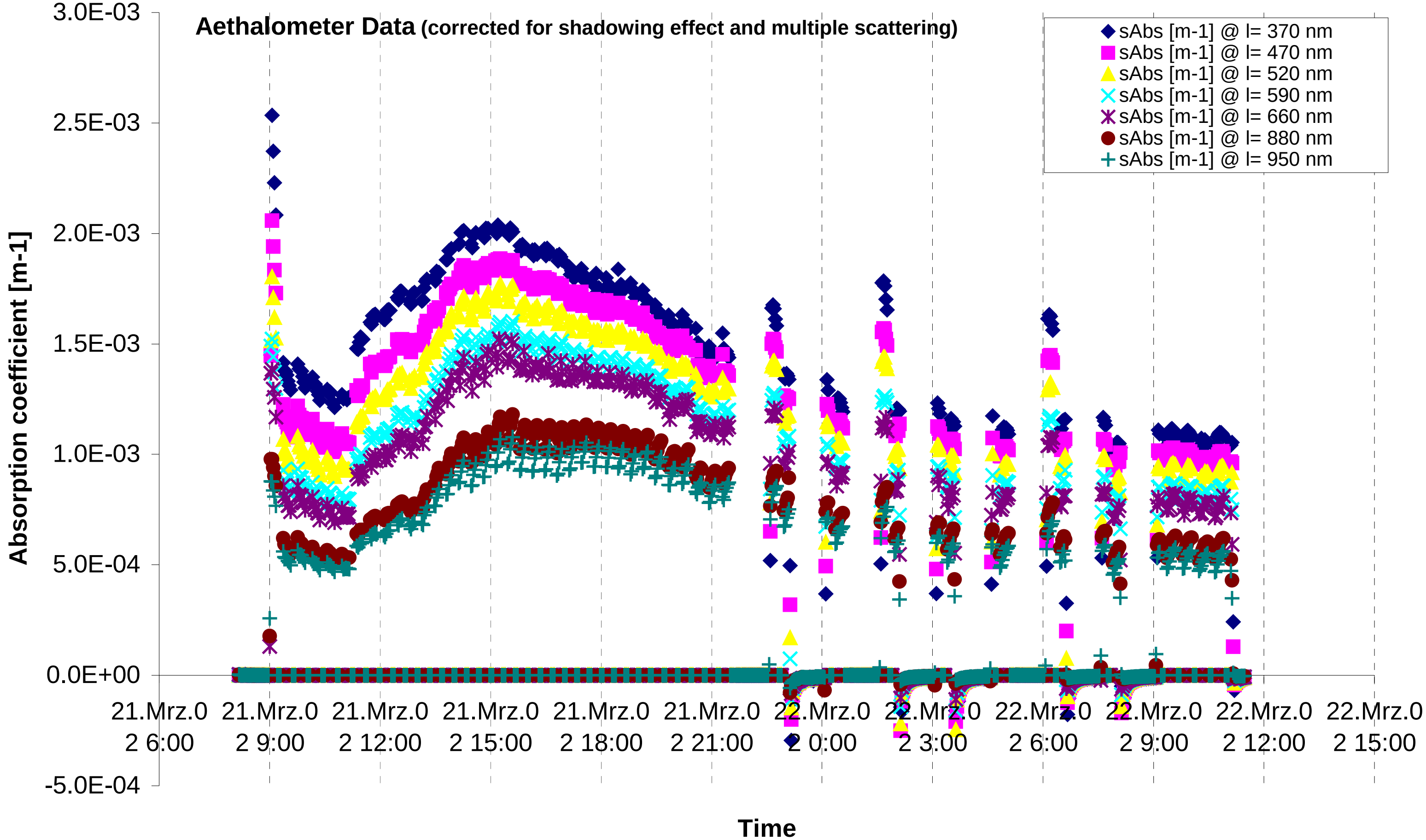


Chung and Seinfeld, JGR 2002

Fourth step: radiative forcing



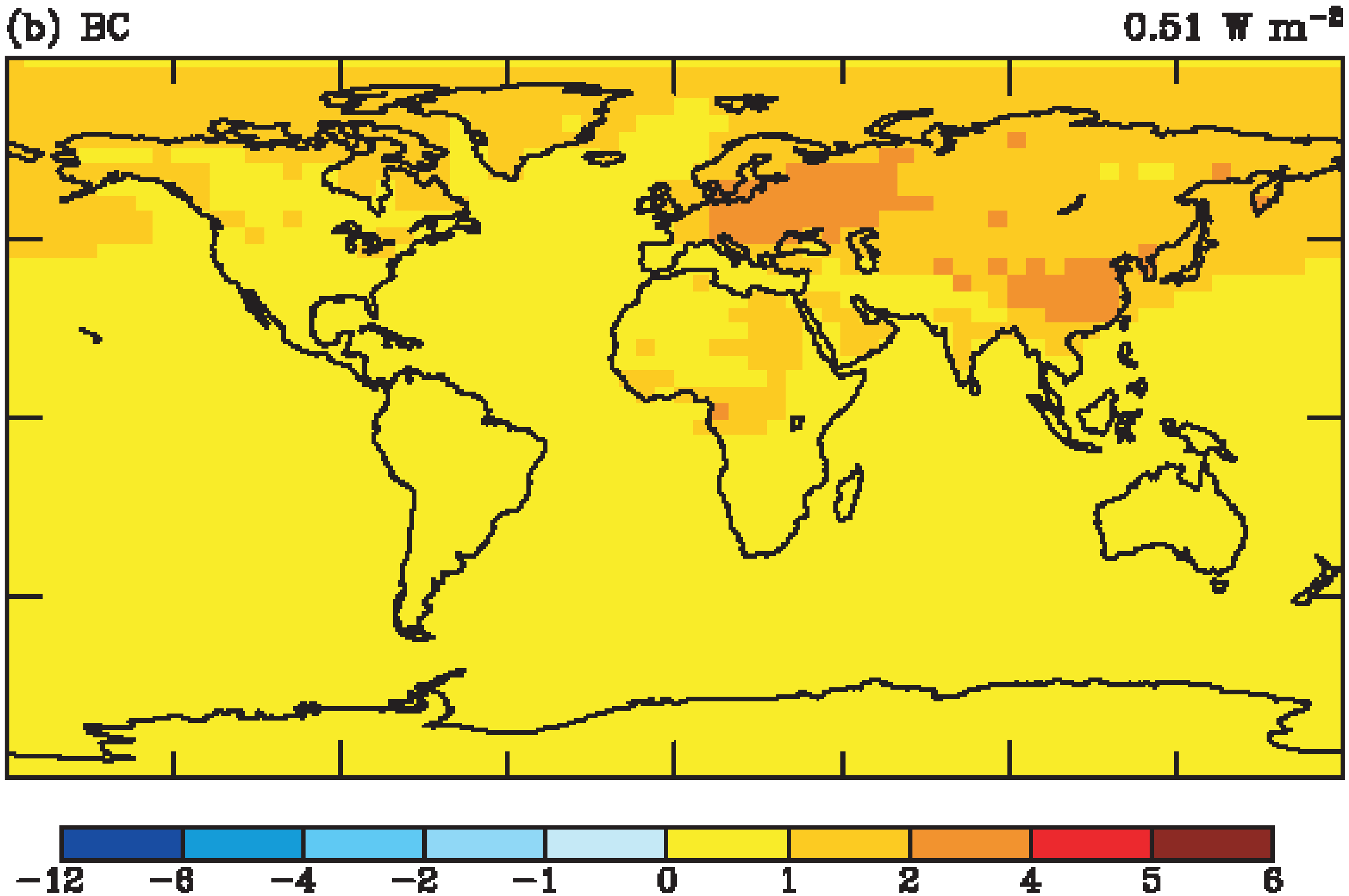
Enhancement of the absorption coefficient by coating Diesel soot particles with scattering material*



*** photooxidation products of α-pinene**

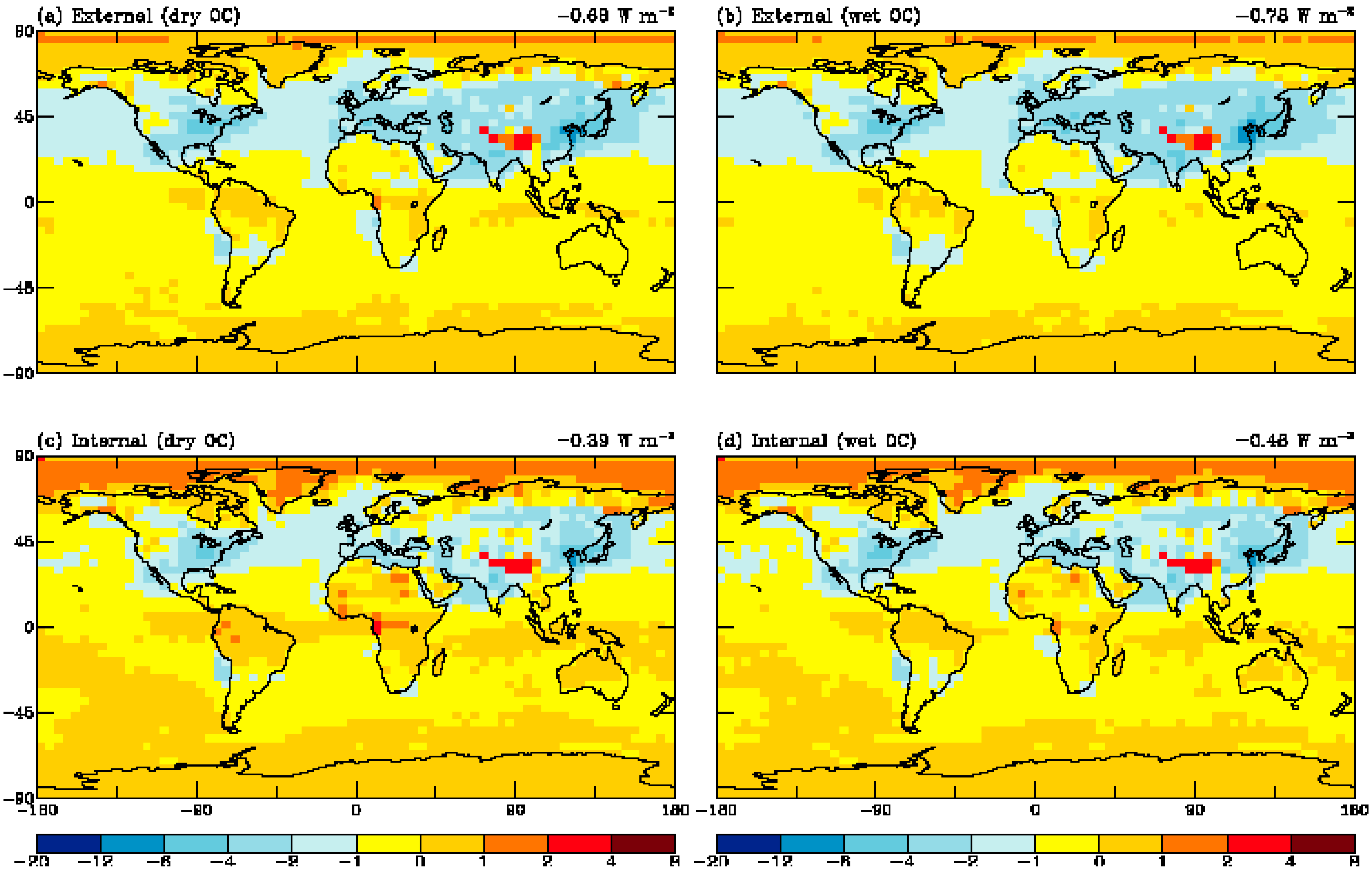
Weingartner et al., JAS 2003

Predicted anthropogenic TOA direct radiative forcing by black carbon, external mixture (W m^{-2})



Chung and Seinfeld, JGR 2002

Combined TOA direct radiative forcing for BC, OC and ammonium sulfate



Chung and Seinfeld, JGR 2002

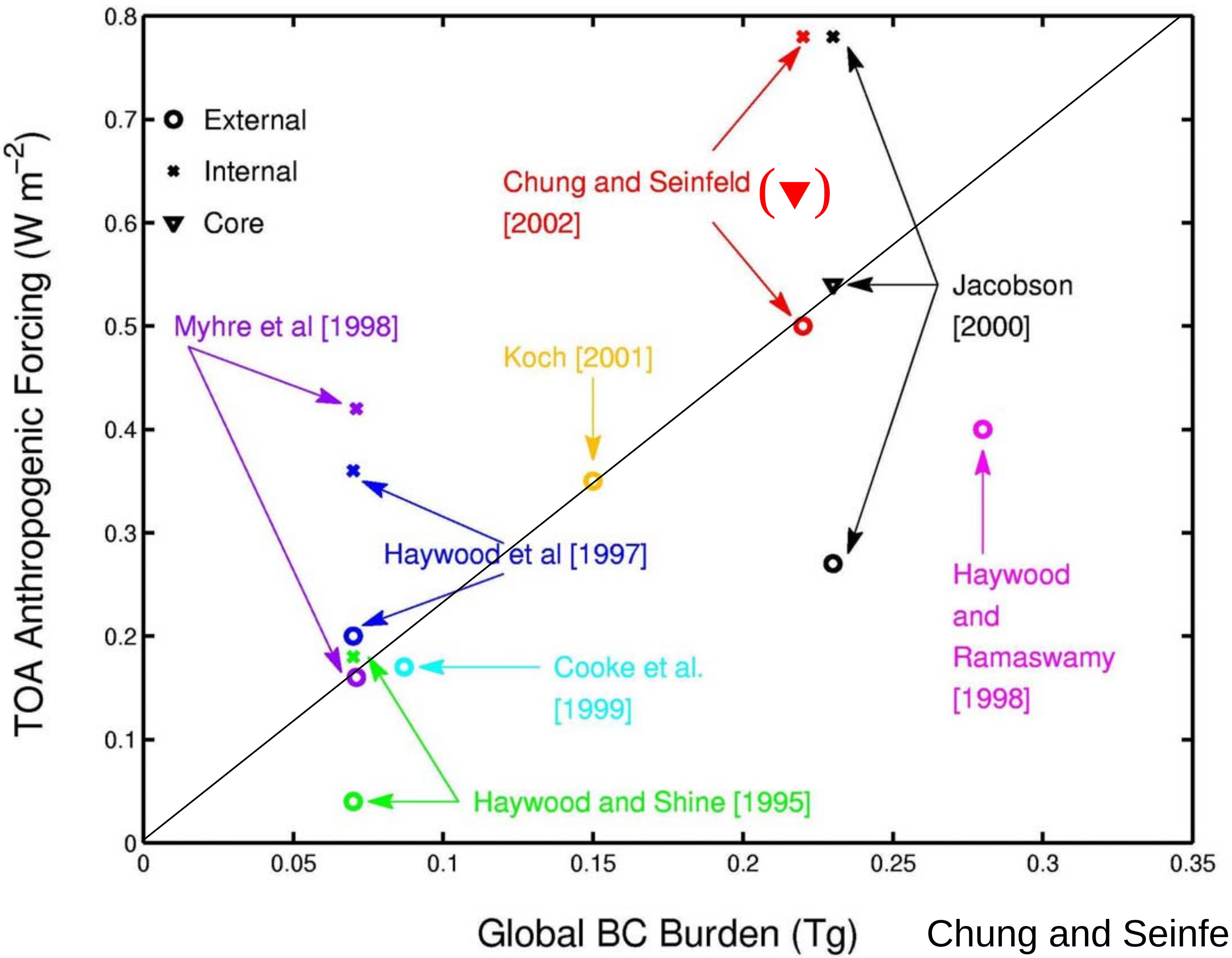
TOA direct radiative forcings (W m^{-2})

Aerosol Type	Modern Day	Anthropogenic
$(NH_4)_2SO_4$	-1.63	-1.10
BC	+0.57	+0.51
OC (dry)	-0.09	-0.09
OC (wet)	-0.21	-0.18
External Mixture (dry OC)	-1.15	-0.68
External Mixture (wet OC)	-1.26	-0.78
Internal Mixture (dry OC)	-0.86	-0.39
Internal Mixture (wet OC)	-0.97	-0.48

$\Sigma = 0.8$

$\Delta = 0.3$

Uncertainties in radiative forcing of black carbon



Chung and Seinfeld, JGR 2002

Conclusions

- Chung and Seinfeld (2002) did not attempt to compare radiative forcing by diesel and gasoline emissions
- Their study confirms the high radiative forcing for black carbon (0.51 to 0.8 W m^{-2}; similar to Jacobson)
- The most probable morphology for black carbon is described by the core model, which yields a forcing between internal and external mixture
- The largest uncertainty in the estimation of the radiative forcing remains the emission inventory
- Eliminating diesel soot does eliminate a significant source of positive radiative forcing