aerosols and climate : uncertainties and the need for standardization

Frank Raes, Jean-Philippe Putaud, Annette Borowiak

From the letter of invitation:

- Set the stage for Workshop that aims at developing a cross academic, industry, public stakeholder and government outlook on key aerosol metrology issues critical to furthering our understanding of aerosols in the climate *theatre*

OUTLINE

- We are more aware of the importance of a range of aerosol characteristics and processes in the climate system.

- Quantifying the climate impact of changing the concention of individual chemical components of the atmospheric aerosol is still very uncertain.

- Quanitying the climate impact of indivicual human activities , incl. policy measures, is even more uncertain (emissions & their chemical fingerprint are uncertain), but the sign is usually known.

- Deal with uncertainty by adopting a multi-pollutant /multi-effect approach (not just aerosol emissions, not just climate impacts)

OUTLINE

- Standardization doesn't reduce uncertainty of measurements or assessements but improves their comparability.

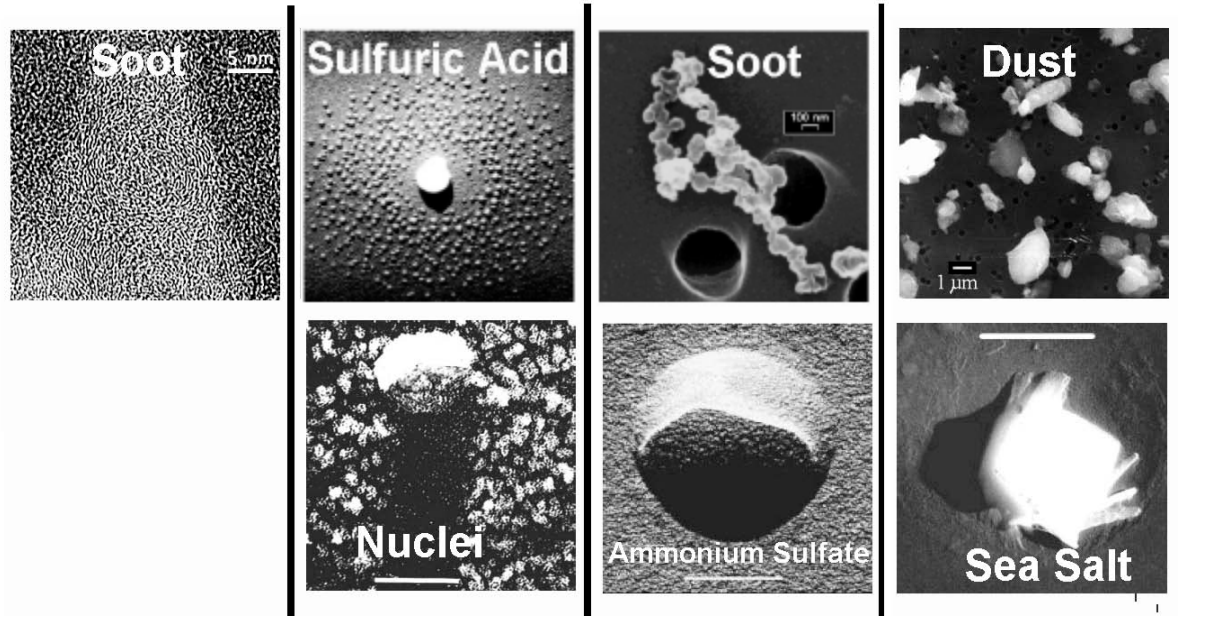
- Policy making and policy implementation *is* about comparing (e.g. comparing climate effects with and without a policy, comparing PM values with target /limit values)

- Polices often affect markets, or are themselves market based: standarization contributes to creating a level playing field. (BC emissions tradeble like CO2 emissions?)

ATMOSPHERIC AEROSOL PARTICLES

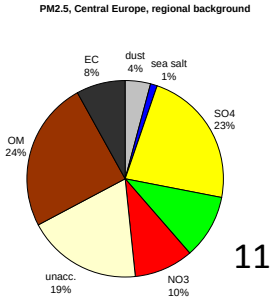
or: Particulate Matter

size, chemical composition, morphology

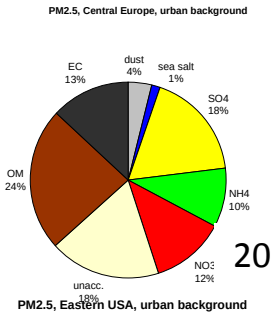


chemical composition of PM2.5, worldwide (2000 – 2010)

Central Europe

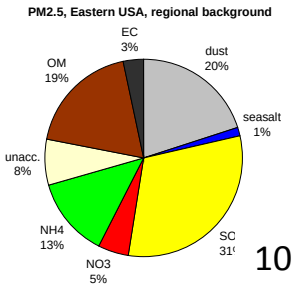


11 µg/m³

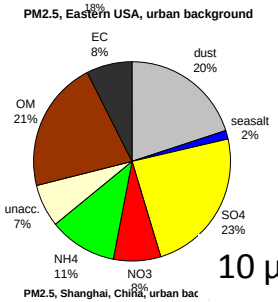


20 µg/m³

Eastern USA

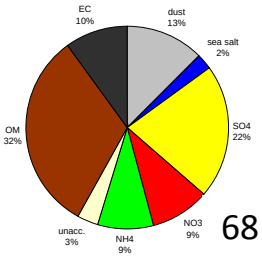


10 µg/m³



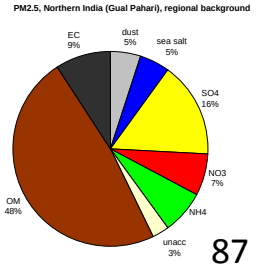
10 µg/m³

China Shanghai

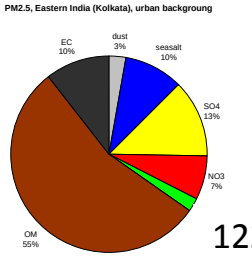


68 µg/m³

Northern India



87 µg/m³



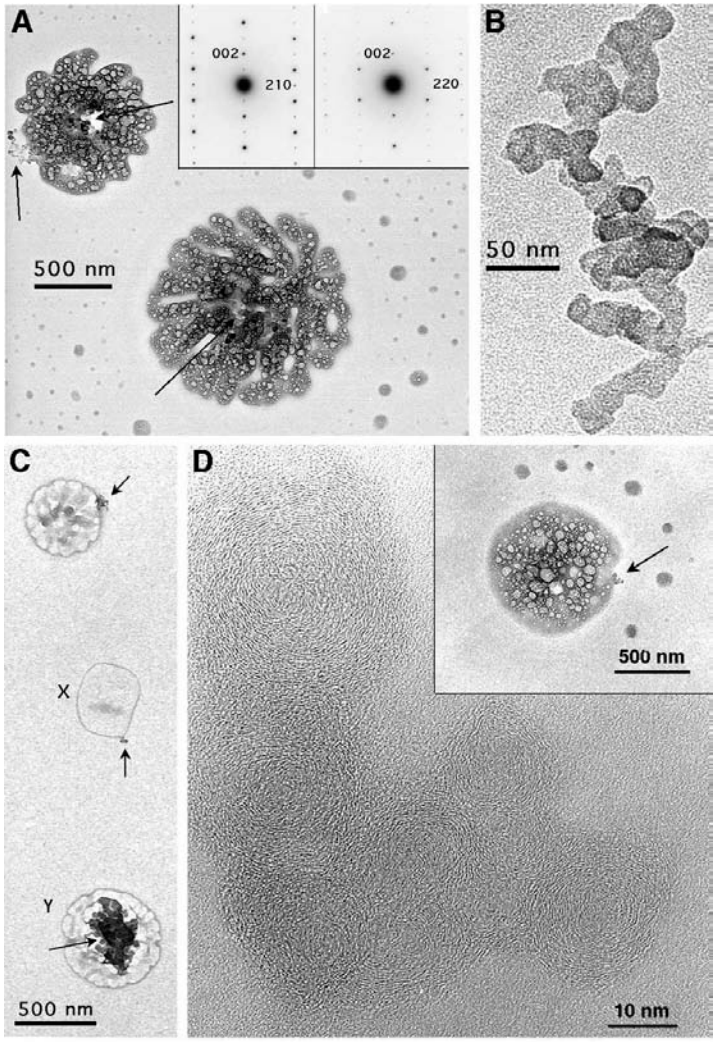
122 µg/m³

regional background

urban background

- Elemental carbon
- *Organic Matter*
- Unaccounted
- Ammonium
- Nitrate
- Sulfate
- Seasalt
- Dust

Source, J.P. Putaud, JRC



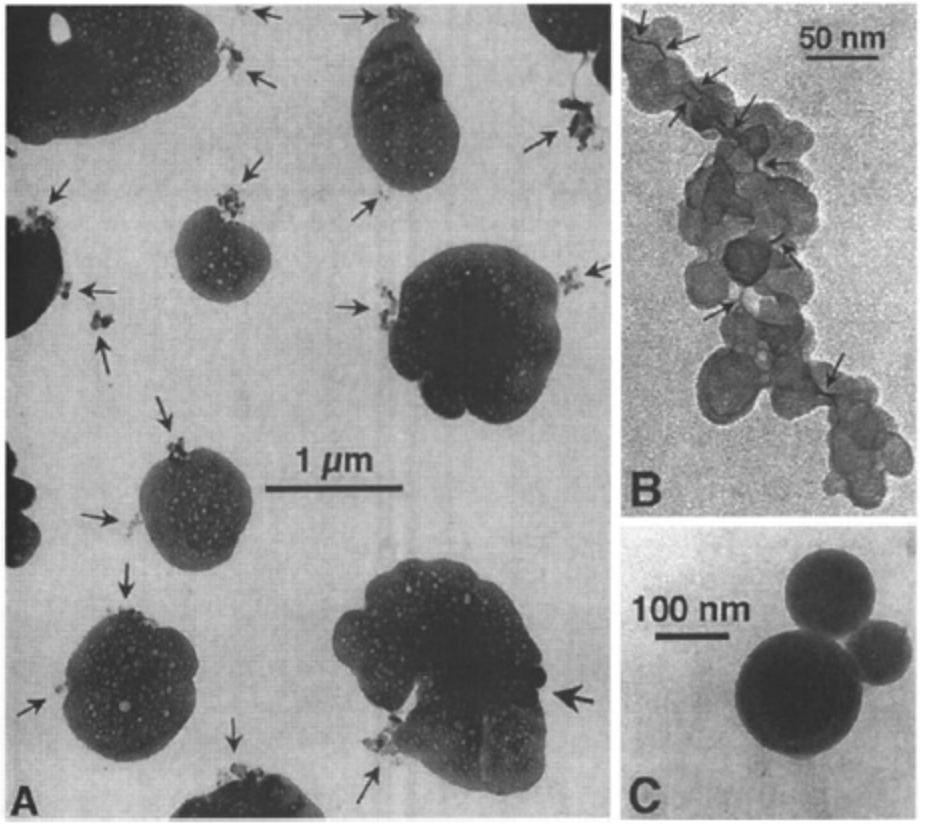
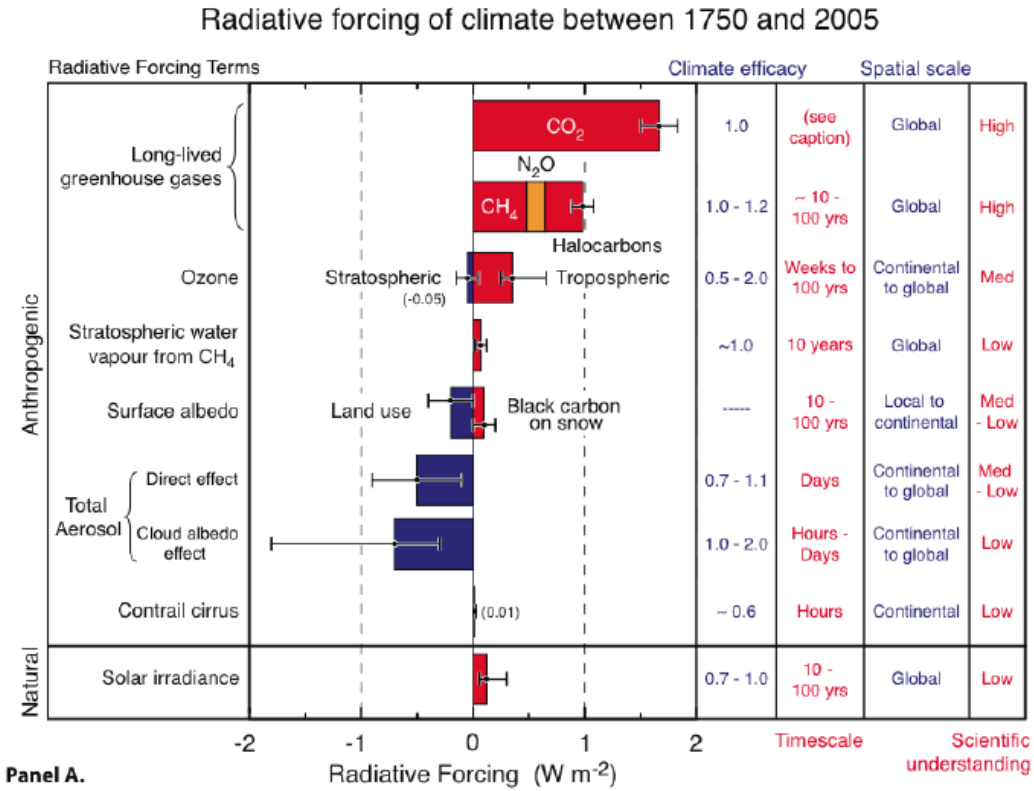


Figure 1. TEM images of aerosol particles collected in the polluted MBL of the North Atlantic Ocean, near the Azores Islands. (a) Ammonium sulfate particles containing soot (marked by the small arrows) and fly-ash spheres (marked by the bold arrow in the lower-right corner). (b) A typical chain-like soot aggregate; the arrows point to a carbon film that connects individual spherules within the aggregate. (c) Fly-ash spheres, consisting of amorphous silica. (d) High-resolution image showing disordered graphitic layers within a soot aggregate. The background of the image is a support film of amorphous carbon onto which the particles were collected. The inset in the upper-left corner is a copy of the boxed area; the graphitic layers are highlighted in the inset.

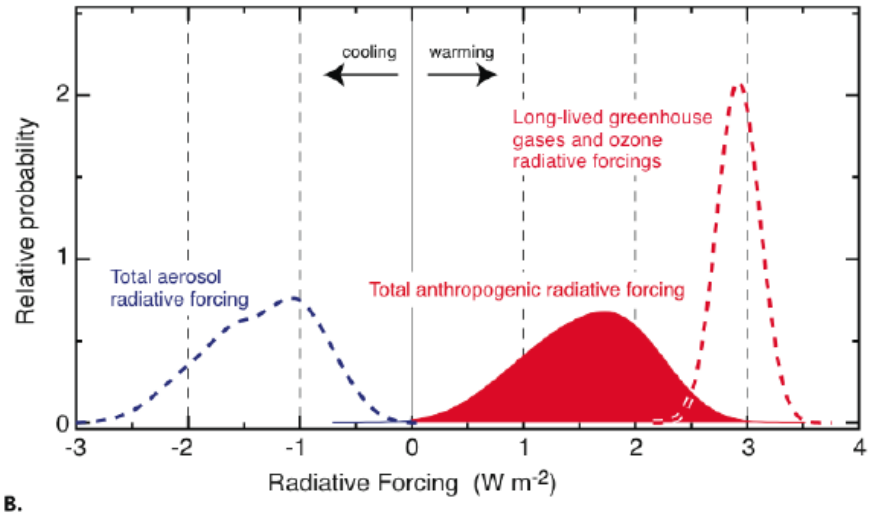
Figure 3. Aerosol particles collected above the Southern Ocean, south of Tasmania. (a) Ammonium sulfate particles with soot inclusions (marked by arrows). The inset displays two different zone-axis SAED patterns that were obtained from a similar particle; spacings are consistent with the structure of ammonium sulfate and are indexed accordingly. (b) A typical, individual soot particle that is not enclosed by sulfate. (c) Residues and soot inclusions (arrowed) that remained after three ammonium sulfate particles were intentionally sublimed with the electron beam. (d) An ammonium sulfate particle with a small soot inclusion (arrowed). Bubbles that resulted from electron-beam damage are visible in the particles in Figures 3a and 3d. The high-resolution image shows the onion-like structure of spherules within the arrowed soot inclusion.

Posfai et al. JGR 1999

TOA Radiative Forcing for components



Panel A.



Panel B.

IPCC 4AR, 2007

Solar constant

Cloudiness

Single Scattering Albedo

$$\Delta E_{aer,direct} = \frac{1}{2} F_T T^2 (1 - A_c) \left\{ \overline{\omega}\,\overline{\beta} (1 - R_s)^2 - 2(1 - \overline{\omega}) R_s \right\} (\delta - \delta_{pre})$$

Atmosphere transmissivity (w/o aerosols)

Backscatter fraction

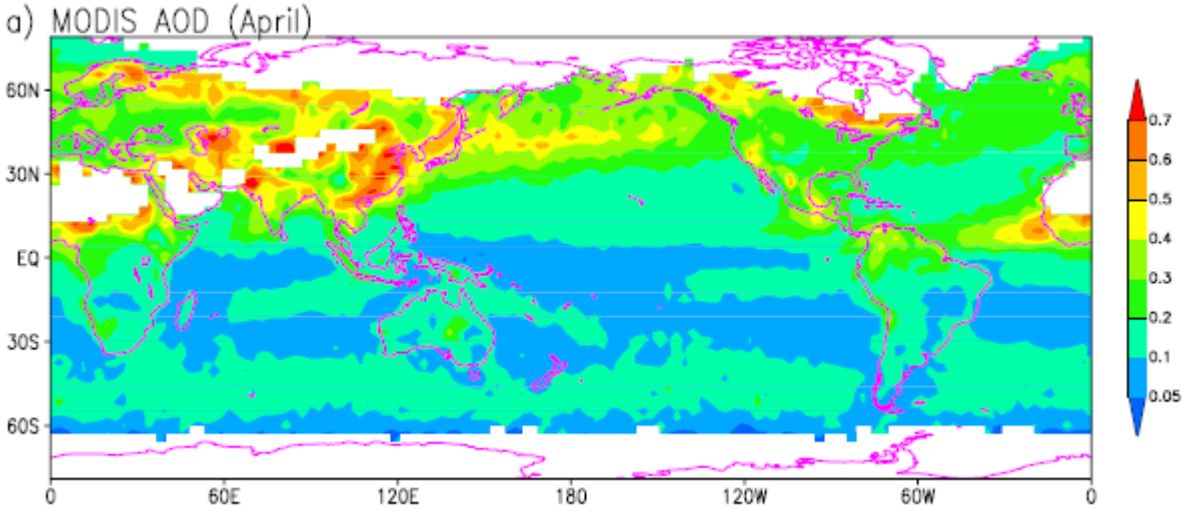
Surface Albedo

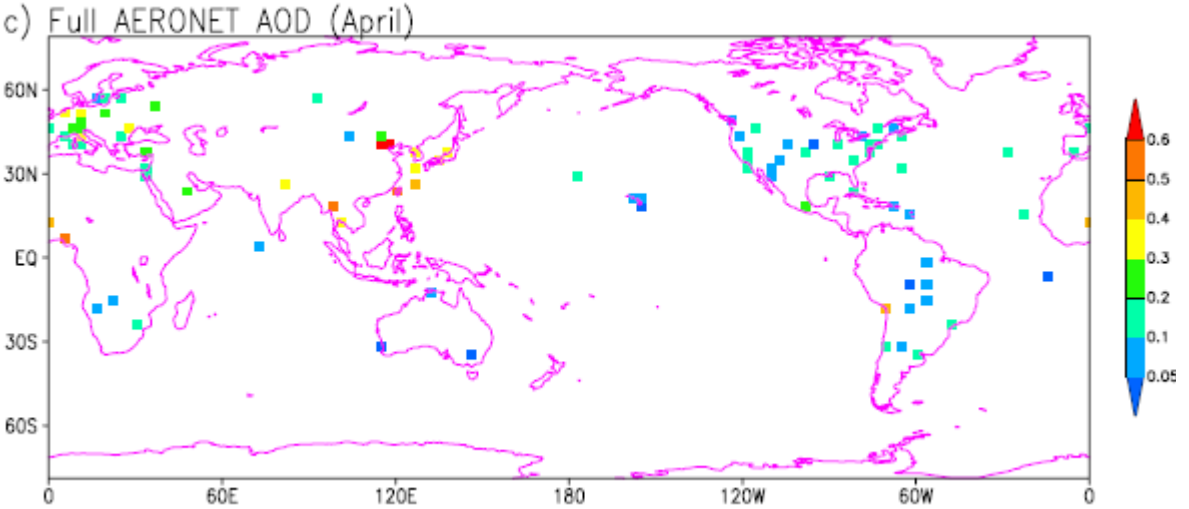
Aerosol Optical Depth

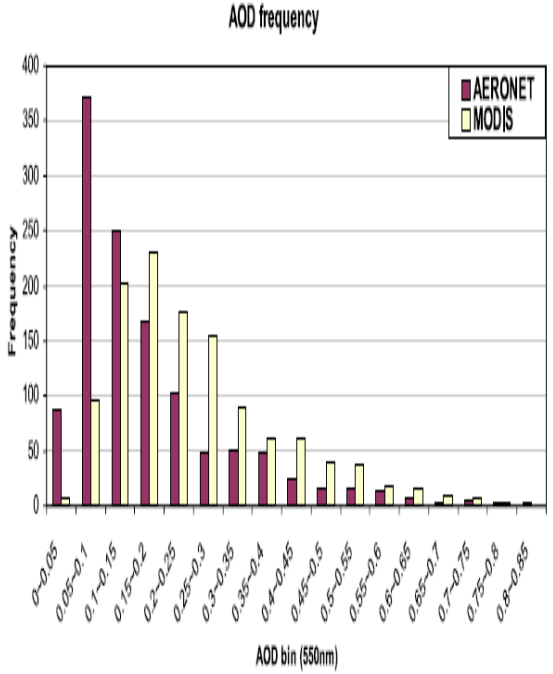
$$\delta_{pre} \approx \delta_{nat}$$

Haywood and Shine,GRL, 1995

Aerosol Optical Depth: MODIS vs. AERONET

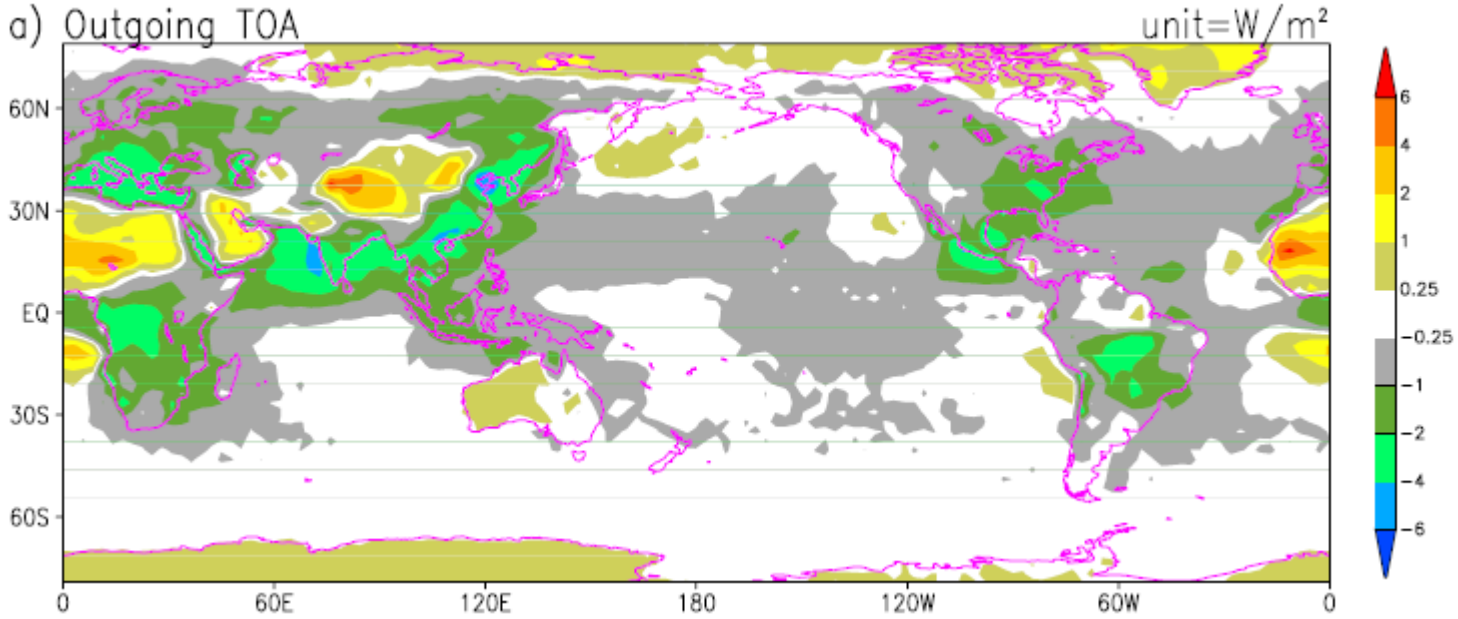






Chung et al., JGR, 2005

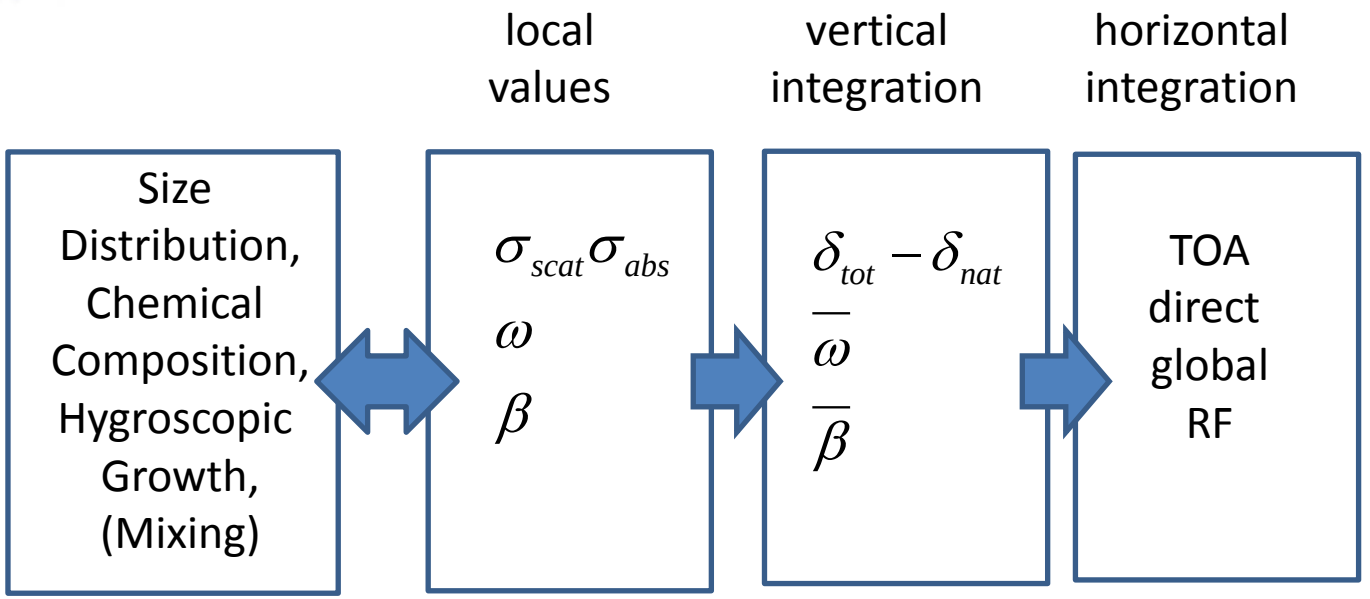
TOA Direct Radiative Forcing by Aerosols



Chung et al., JGR, 2005

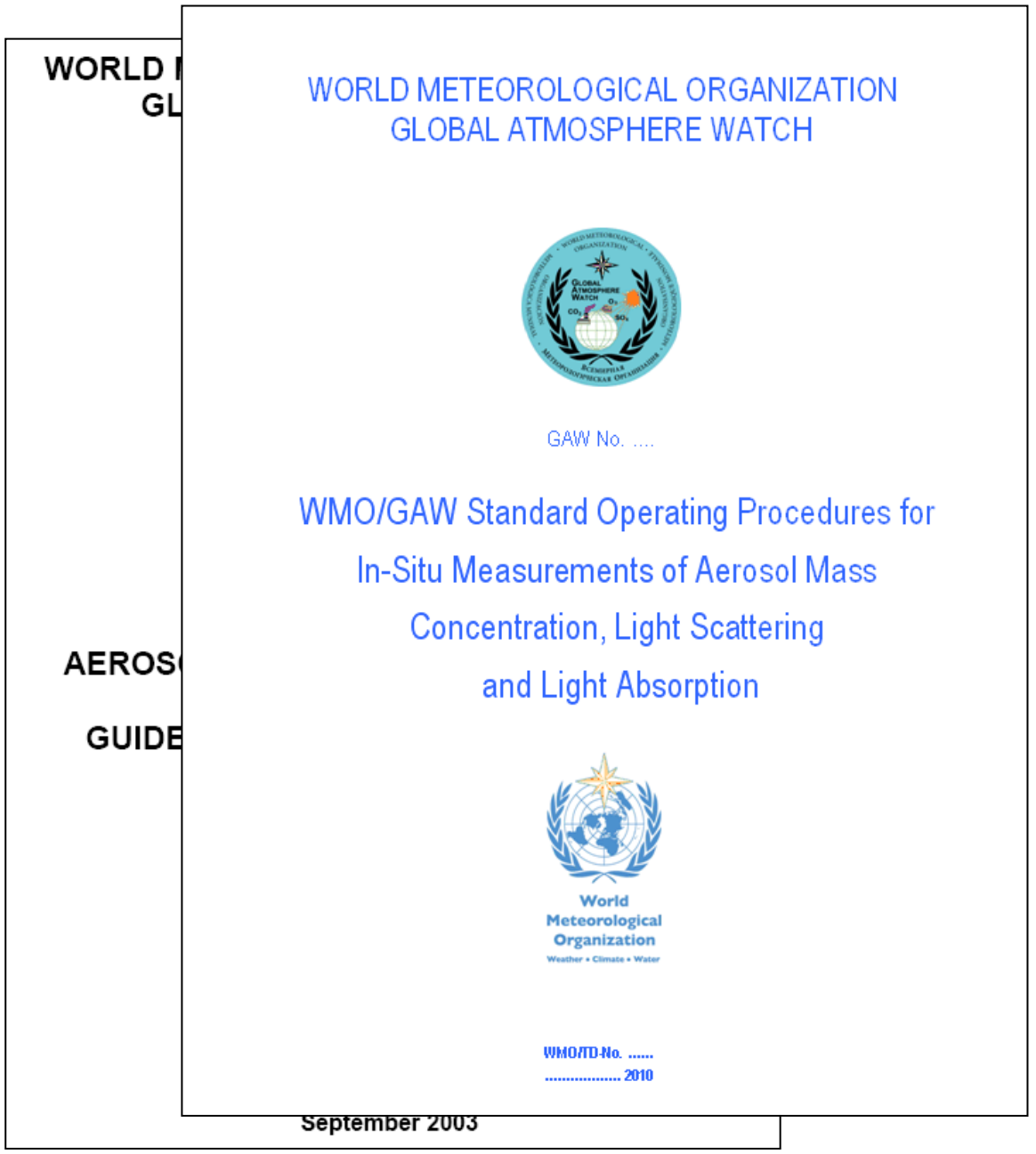
Annual average: - 0,35 Wm-2 (range: - 0,6 to – 0,1 Wm-2)

Uncertainty due to
- absorption properties of the aerosol (single scattering albedo)
- vertical distribution of the aerosol



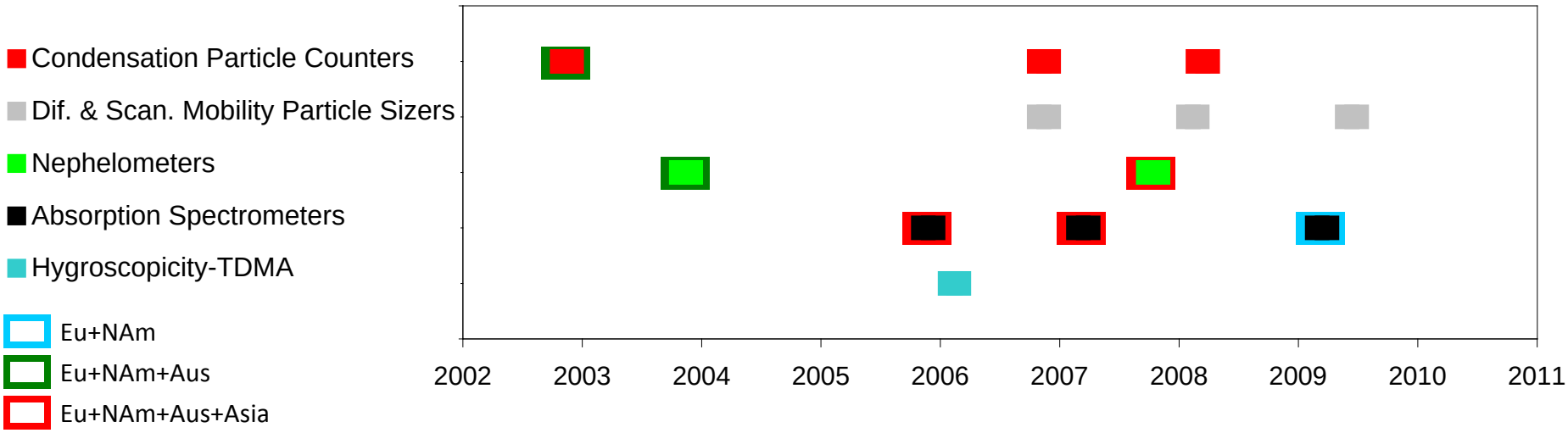
closure experiments

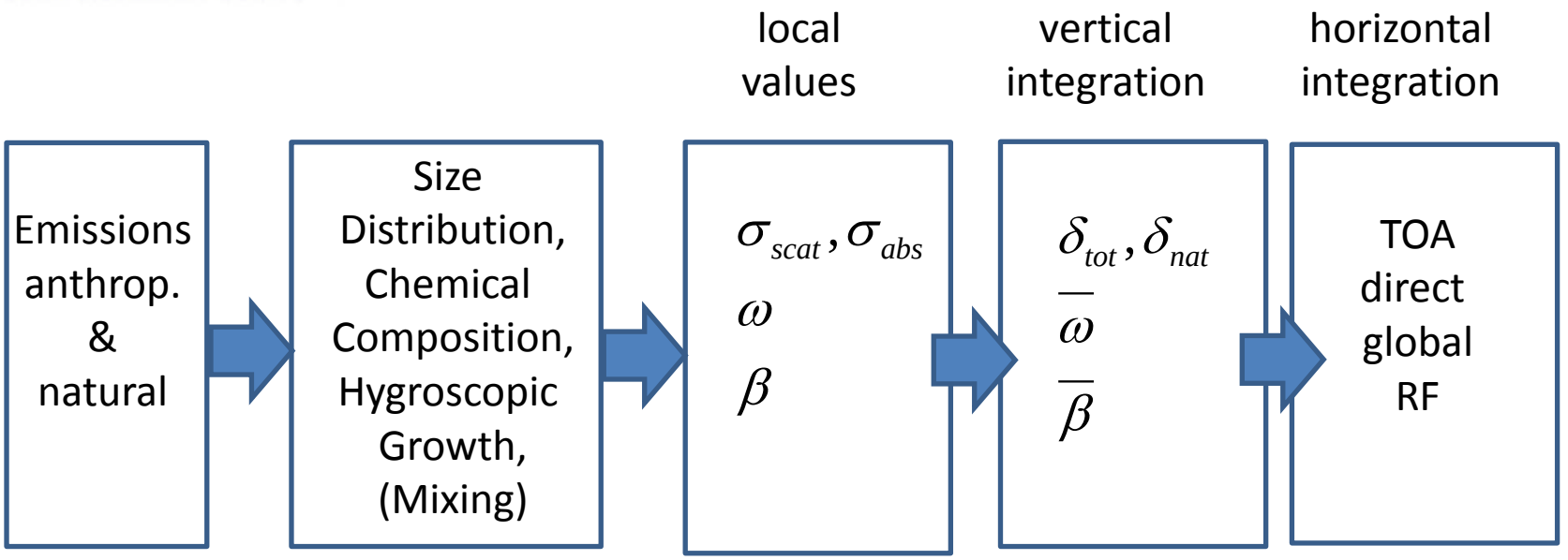
$$\iint Q_{sca}(\lambda, D_p, m)\frac{\pi D_p^2}{4} n(D_p, m) dm dD_p = \sigma_{sp}(\lambda)$$


WORLD
GL
AEROS
GUIDE
September 2003
WORLD METEOROLOGICAL ORGANIZATION
GLOBAL ATMOSPHERE WATCH
GAW No. ....
WMO/GAW Standard Operating Procedures for
In-Situ Measurements of Aerosol Mass
Concentration, Light Scattering
and Light Absorption
World
Meteorological
Organization
Weather • Climate • Water
WMO/TD-No. .....
..... 2010

- The GAW – World Calibration Centre for Aerosol Physics
  http://gaw.tropos.de/WCCAP/

  - Intercomparisons




local values
vertical integration
horizontal integration
Emissions anthrop. & natural
Size Distribution, Chemical Composition, Hygroscopic Growth, (Mixing)
$\sigma_{scat}, \sigma_{abs}$
ω
β
$\delta_{tot}, \delta_{nat}$
$\overline{\omega}$
$\overline{\beta}$
TOA direct global RF

Emissions of Black Carbon Aerosols

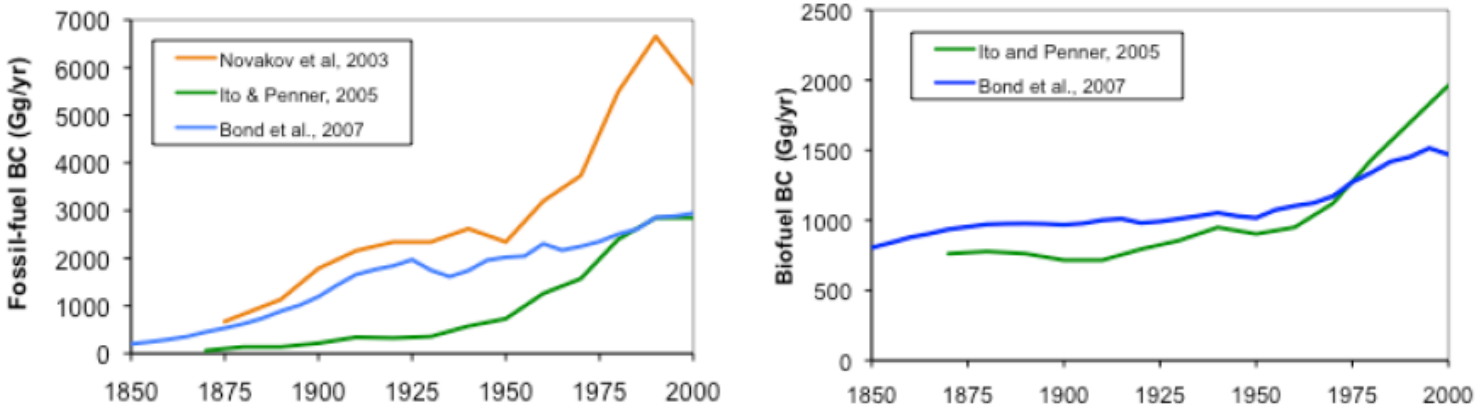
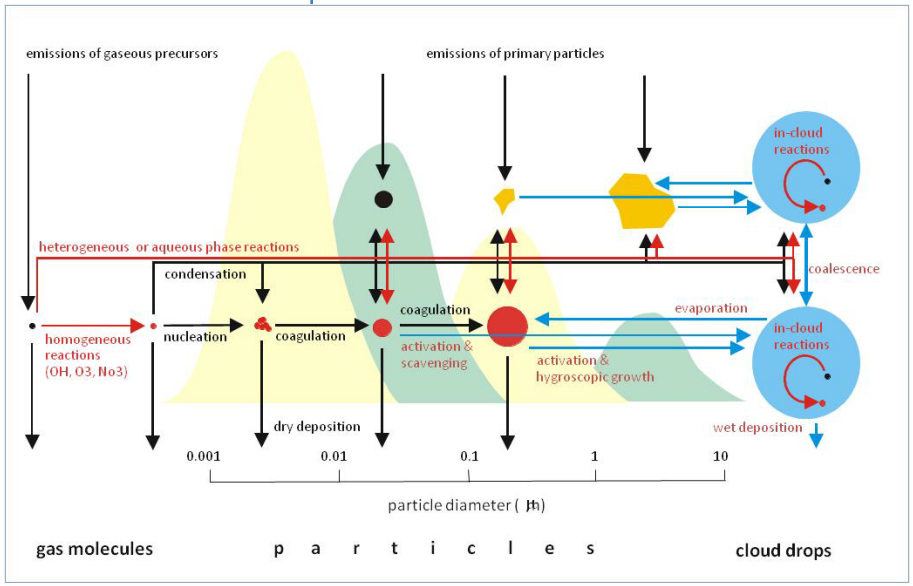


Figure 2.5 Historical BC emission trends from fossil-fuel (left) and biofuel (right) combustion from Novakov et al. (2003), Ito and Penner (2005) and Bond et al. (2007)

BC measured as
- absorbing aerosol
- elemental carbon
- fraction of PM

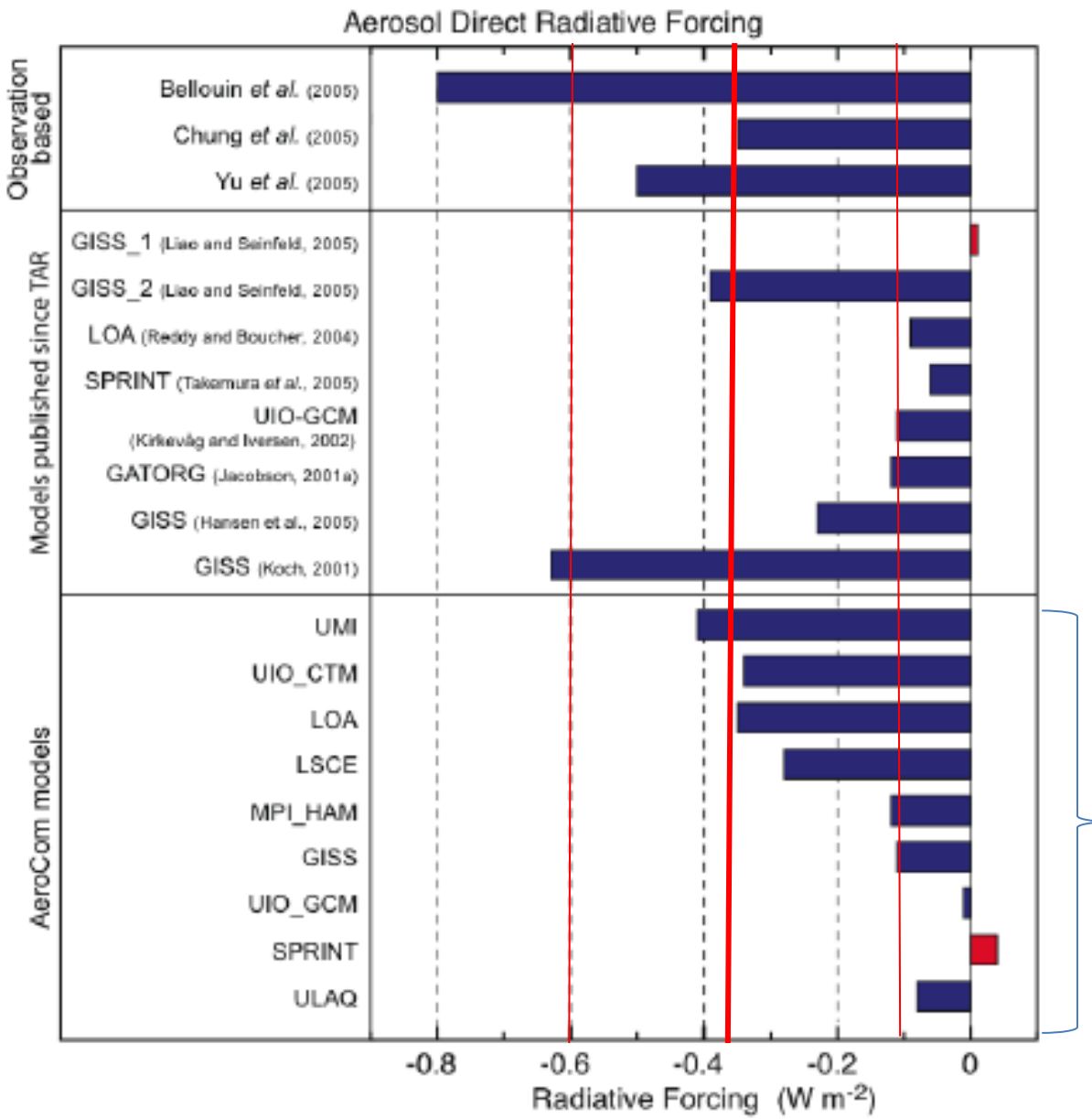
local values | vertical integration | horizontal integration

Emissions anthrop. & natural → Size Distribution, Chemical Composition, Hygroscopic Growth, (Mixing) → $\sigma_{scat}, \sigma_{abs}$ ω β → $\delta_{tot}, \delta_{nat}$ $\overline{\omega}$ $\overline{\beta}$ → TOA direct global RF



Raes et al., Atm. Env., 34, p. 4215, 2000

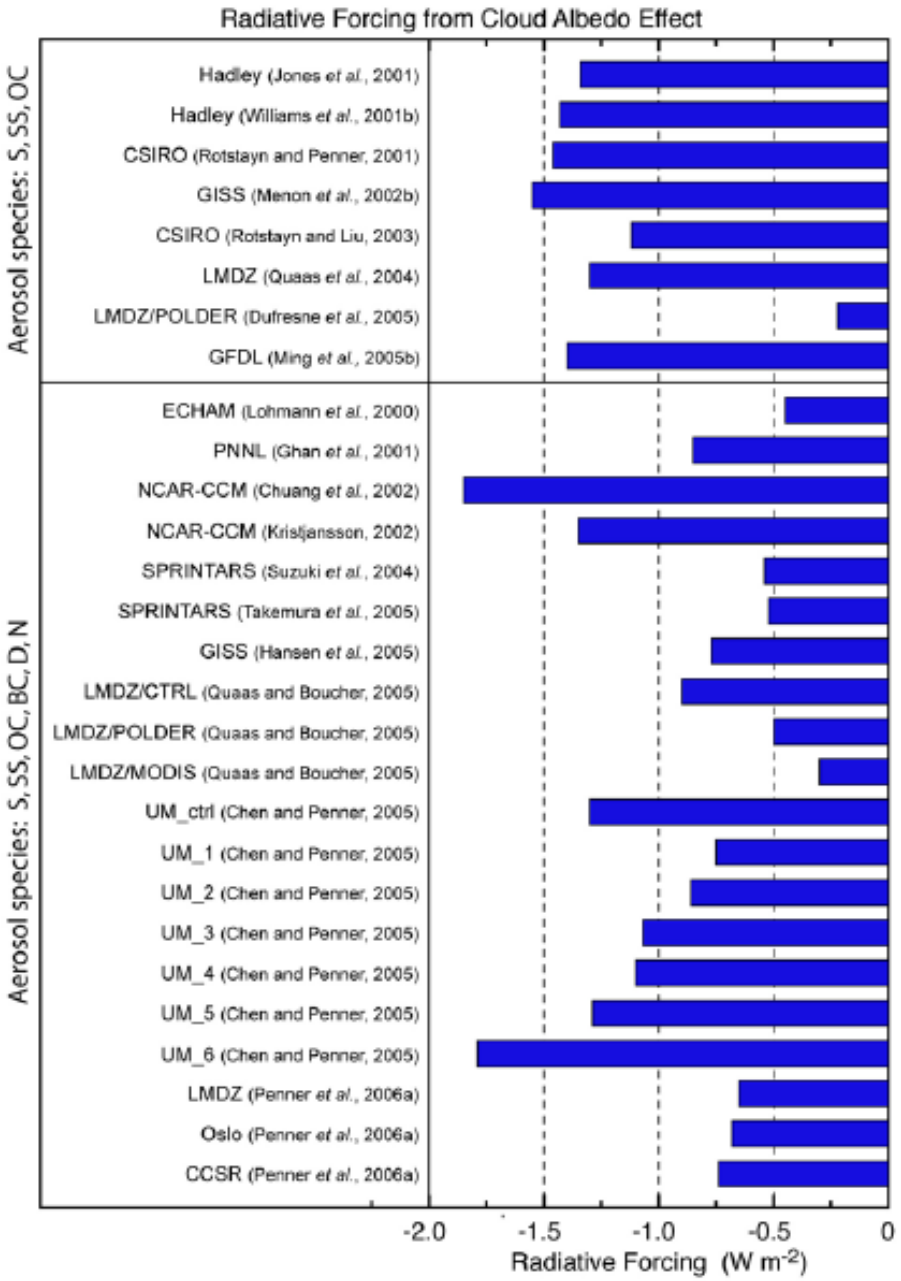
TOA Direct Radiative Forcing by Aerosols



IPCC 4AR ,2007

same emissions

TOA 1st Indirect Radiative Forcing by Aerosols



IPCC 4AR ,2007

constrained by observations

sensitivity analysis with the same model

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

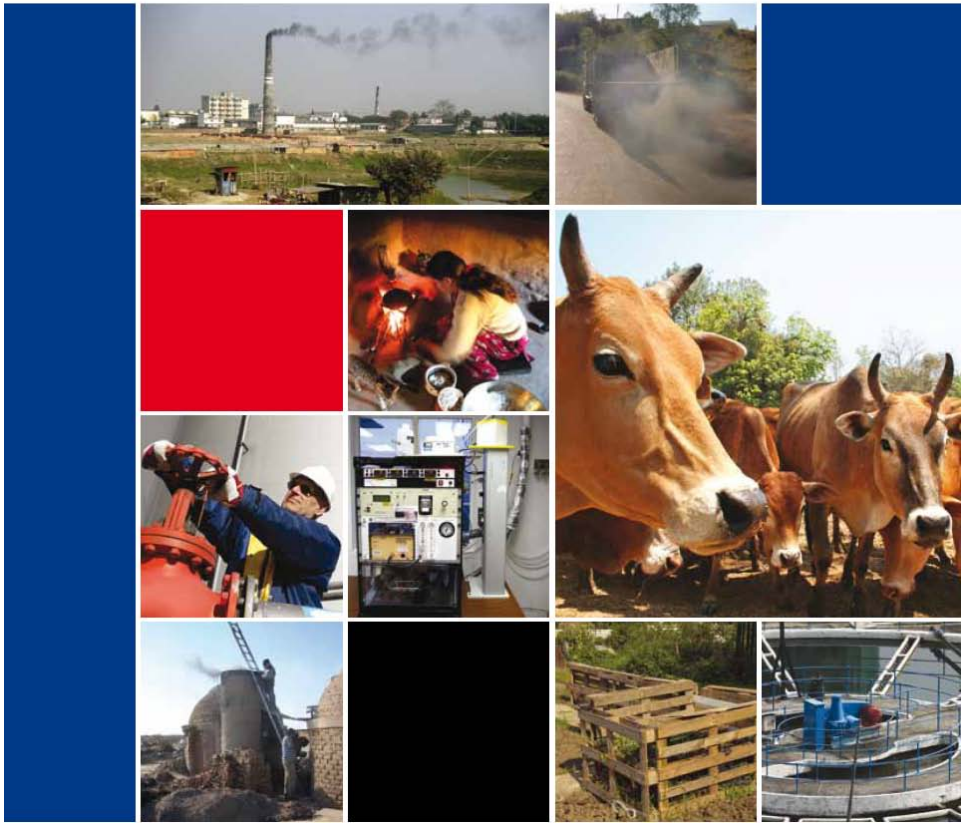
Joint Research Centre

UNEP

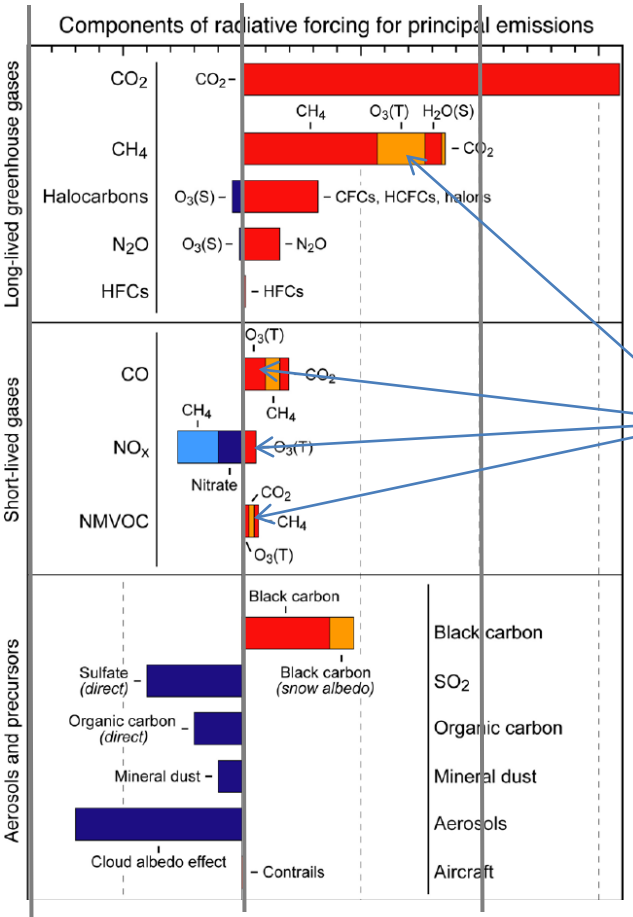
World Meteorological Organization

Integrated Assessment of Black Carbon and Tropospheric Ozone

Summary for Decision Makers

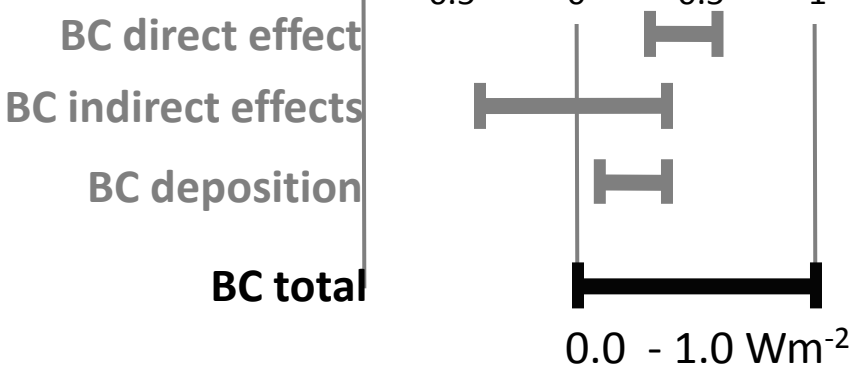


TOA Radiative Forcing for emissions



O_3,troposphere
0.25 - 0.45 Wm^{-2}

IPCC 4AR, 2007

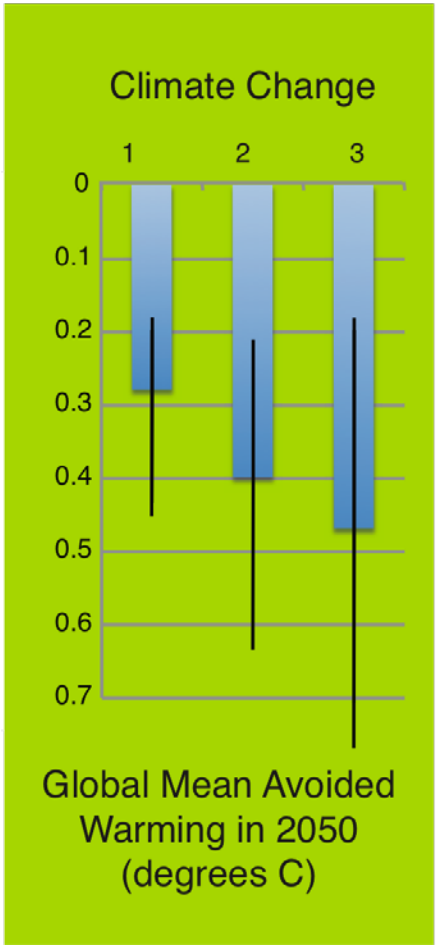


UNEP, 2011

Joint Research Centre

Global Impacts of Additional Emissions Controls on Methane and Products of Incomplete Combustion

1: CH_4 measures, 2: CH_4+BC Group 1 measures, 3: CH_4+ all BC measures



Climate given at 2050, air quality benefits for 2030 and beyond

UNEP 2011

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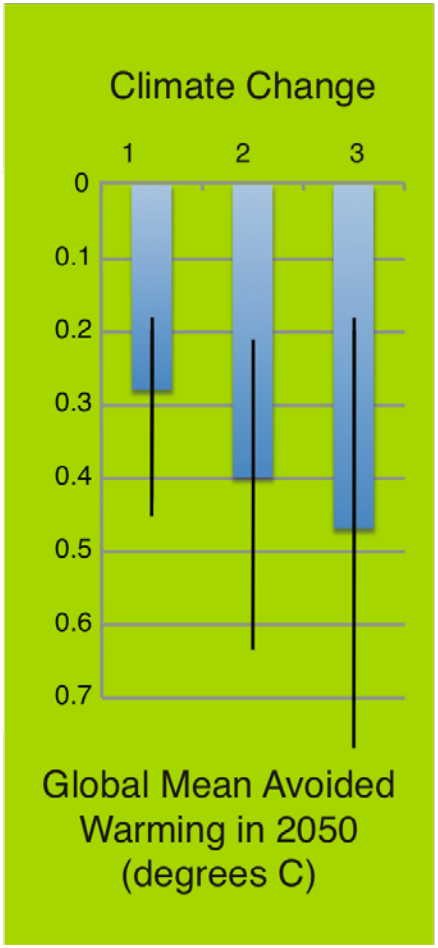

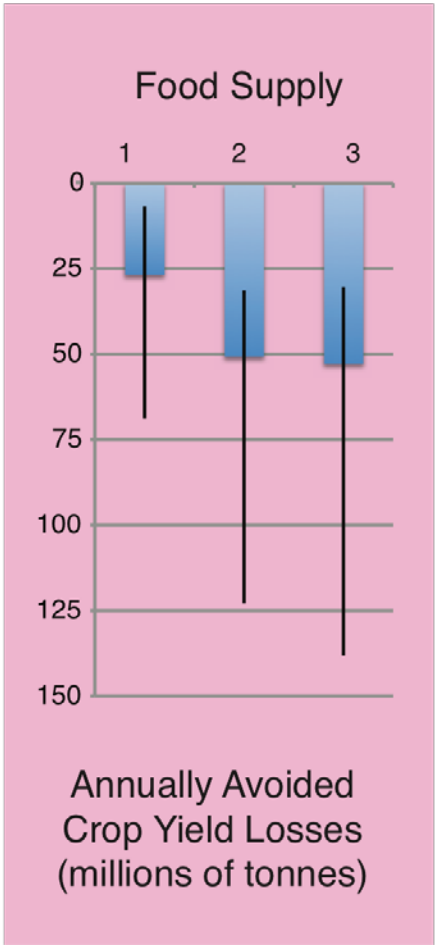

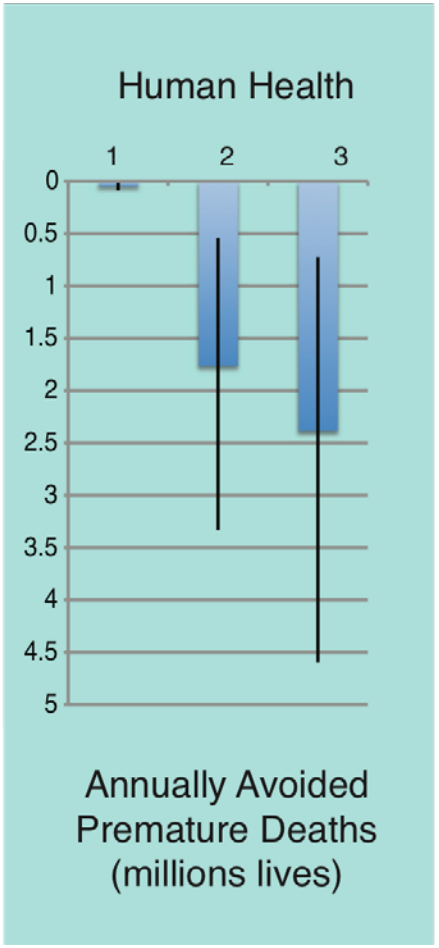

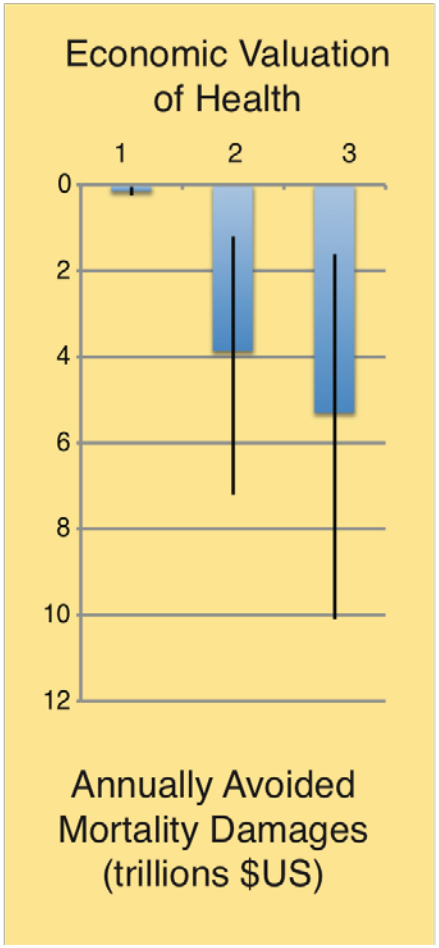

Climate given at 2050, air quality benefits for 2030 and beyond

UNEP 2011

Standardization activities in EU by CEN

Published standards

EN 12341: PM10 filter sampling & weighing (required by2008 directive

EN 14907: PM2.5 filter sampling & weighing (required by2008 directive

EN 14902: Cd, As Ni, Pb in PM

EN 15549: BaP in PM

prEN 15980: PAHs in PM

CEN TC 264 – currently active WGs

WG 15: PM2.5 and PM10 (filter sampling & weighing)

WG 21: measurement of PAHs

WG 32: Particle number concentration

WG 35: EC/OC in PM

TC amount measured in NIST RM 8785 by 13 labs in Europe

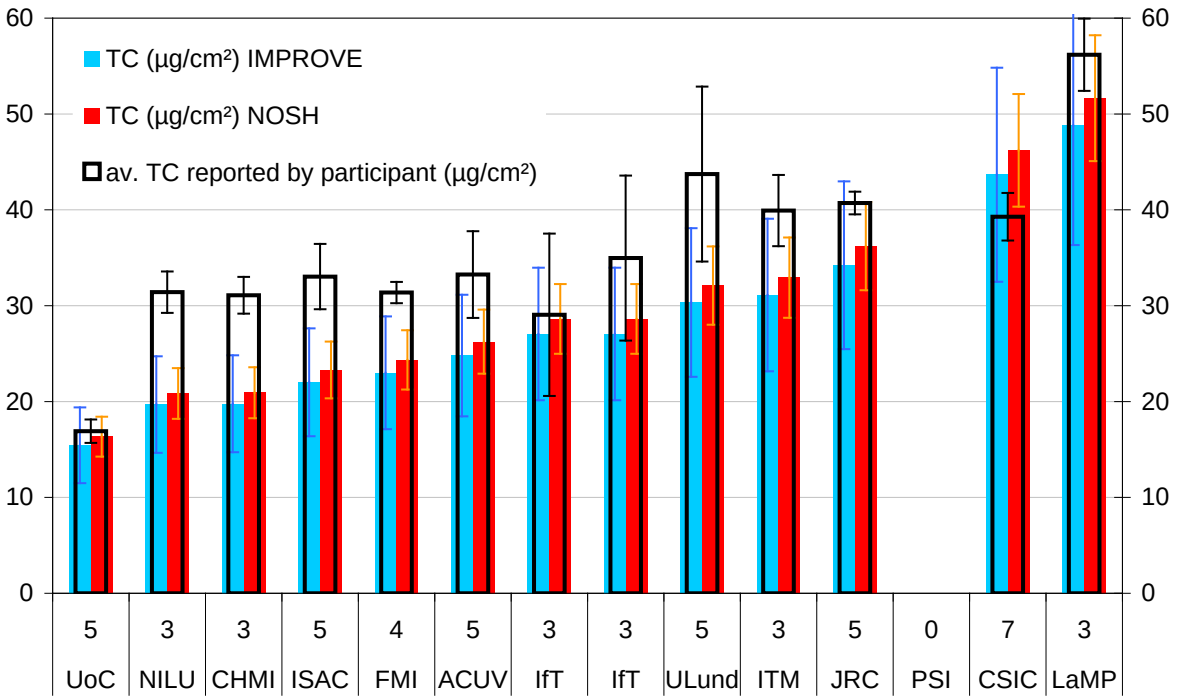

*Fig. 1: TC amounts determined **by the EUSAAR partners** and reference values. Also shown are the uncertainties of these values.*

- Deviations to reference cannot be explained by measurement inaccuracy (based on previous inter-comparisons)
- Large filter inhomogeneity
- No certified values for OC and EC (thermal protocol dependent)

CONCLUSIONS

- We are more aware of the importance of a range of aerosol characteristics and processes in the climate system.
-Quantifyingthe climate impactof changing the concentraion of individual chemical components of the atmospheric aerosol is still very uncertain.
-Quanitying the climate impact of indivicual human activities , incl. policy measures, is even more uncertain (emissions & their
chemical fingerprint are uncertain) but the sign is usually known.
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- Polices often affect markets, or are themselves market based: standarization contributes to creating a level playing field. (BC emissions tradeble like CO2 emissions?)

- Aerosol & Climate science has become relevant!


thanks

TOA Direct Radiative Forcing by Aerosols

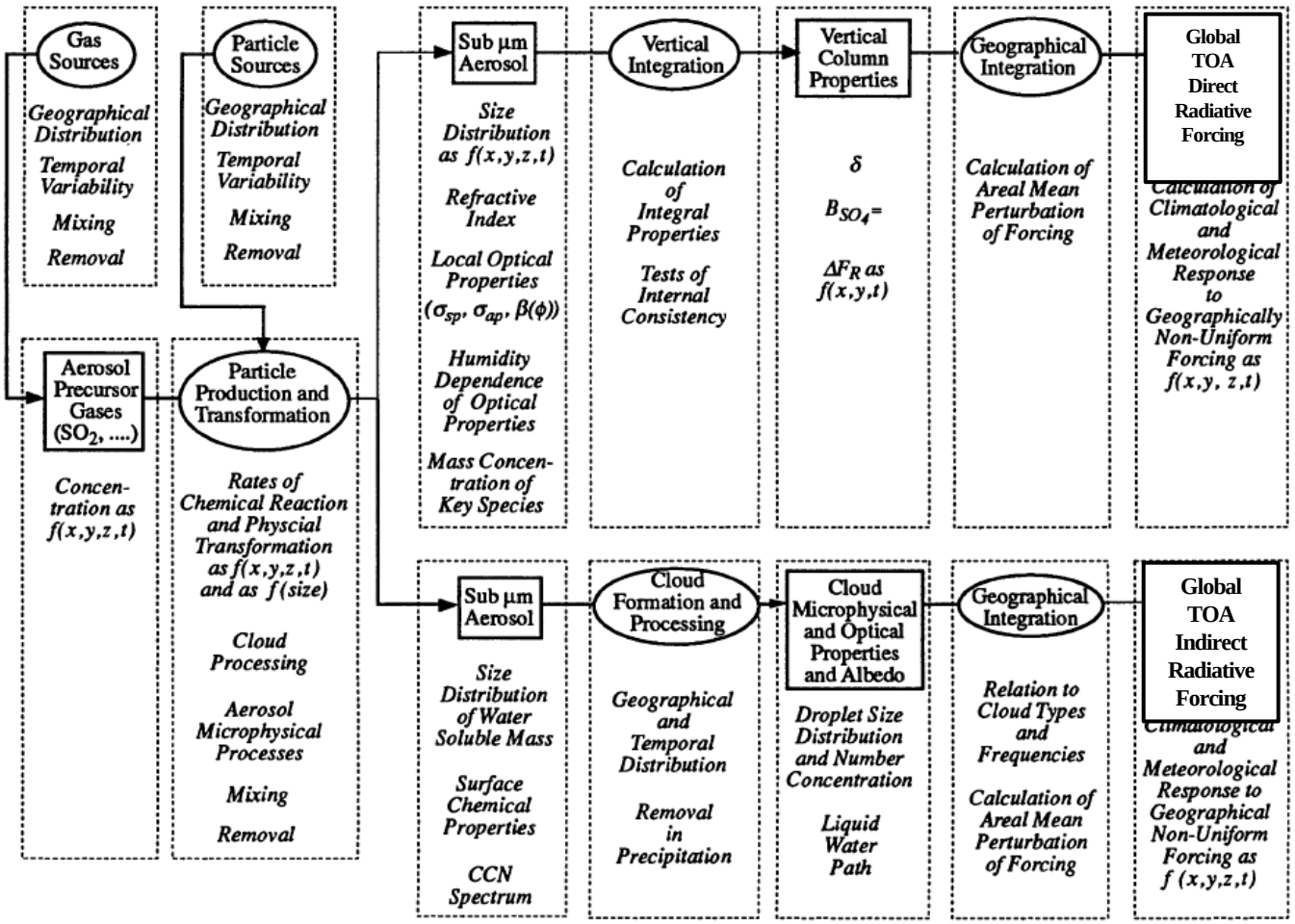
AeroCom (Schultz et al., 2006)
compared instantaneous direct radiative forcing due to anthropogenic aerosols produced by 9 different global models (from Europe, Japan and the USA) with detailed aerosol modules,USING THE SAME EMISSIONS

Differences in computed direct aerosol forcing (range +0.04 to $-0.41 Wm^{-2}$) are due to:

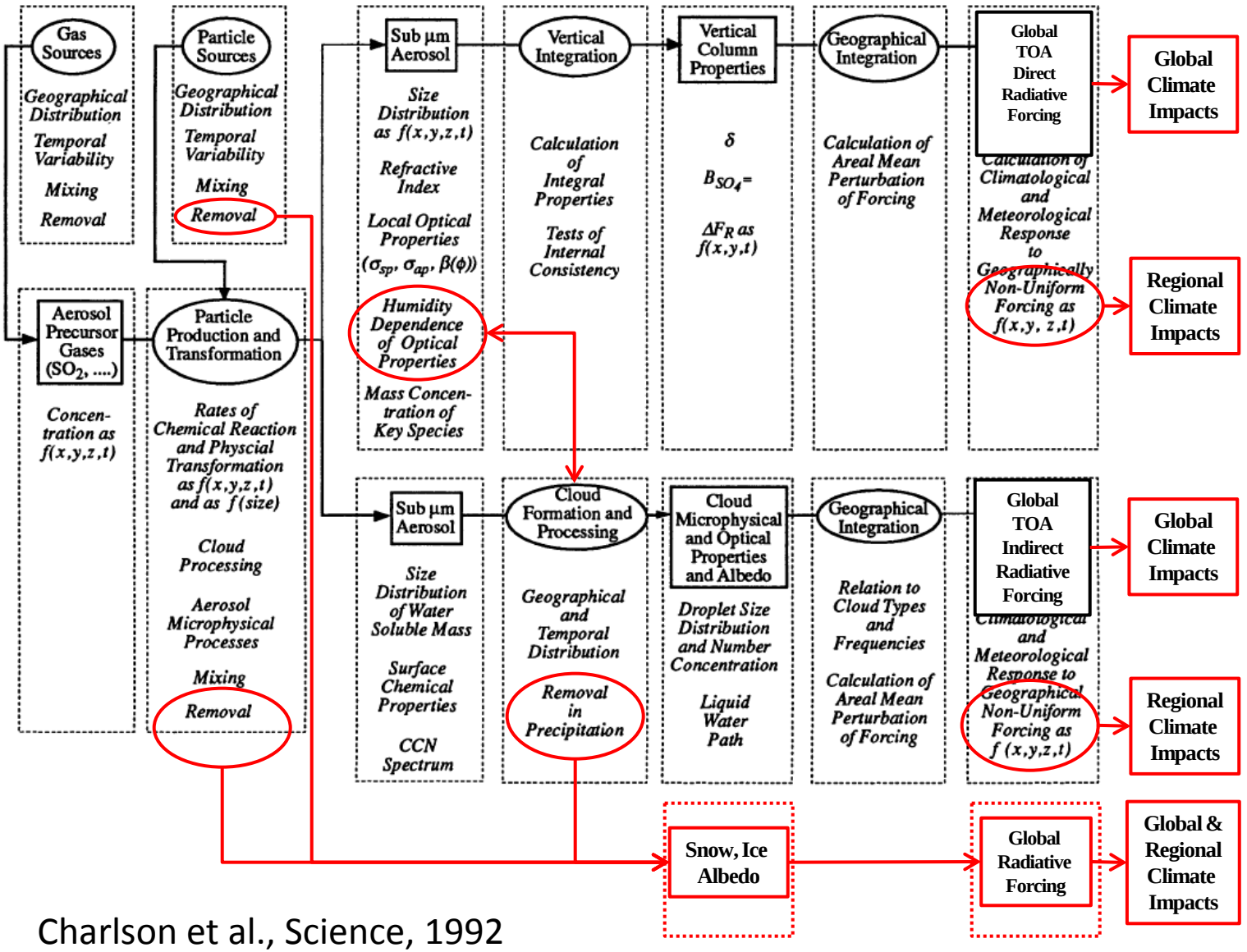
- diversity in simulated aerosol residence times
- mass extinction coefficients
- **forcing efficiencies** (forcing per unit optical depth)

+

- in clear-sky conditions: aerosol absorption, size, and surface albedo
- in cloud-sky conditions: cloud fields and relative altitudes of absorbing aerosol and clouds



Charlson et al., Science, 1992



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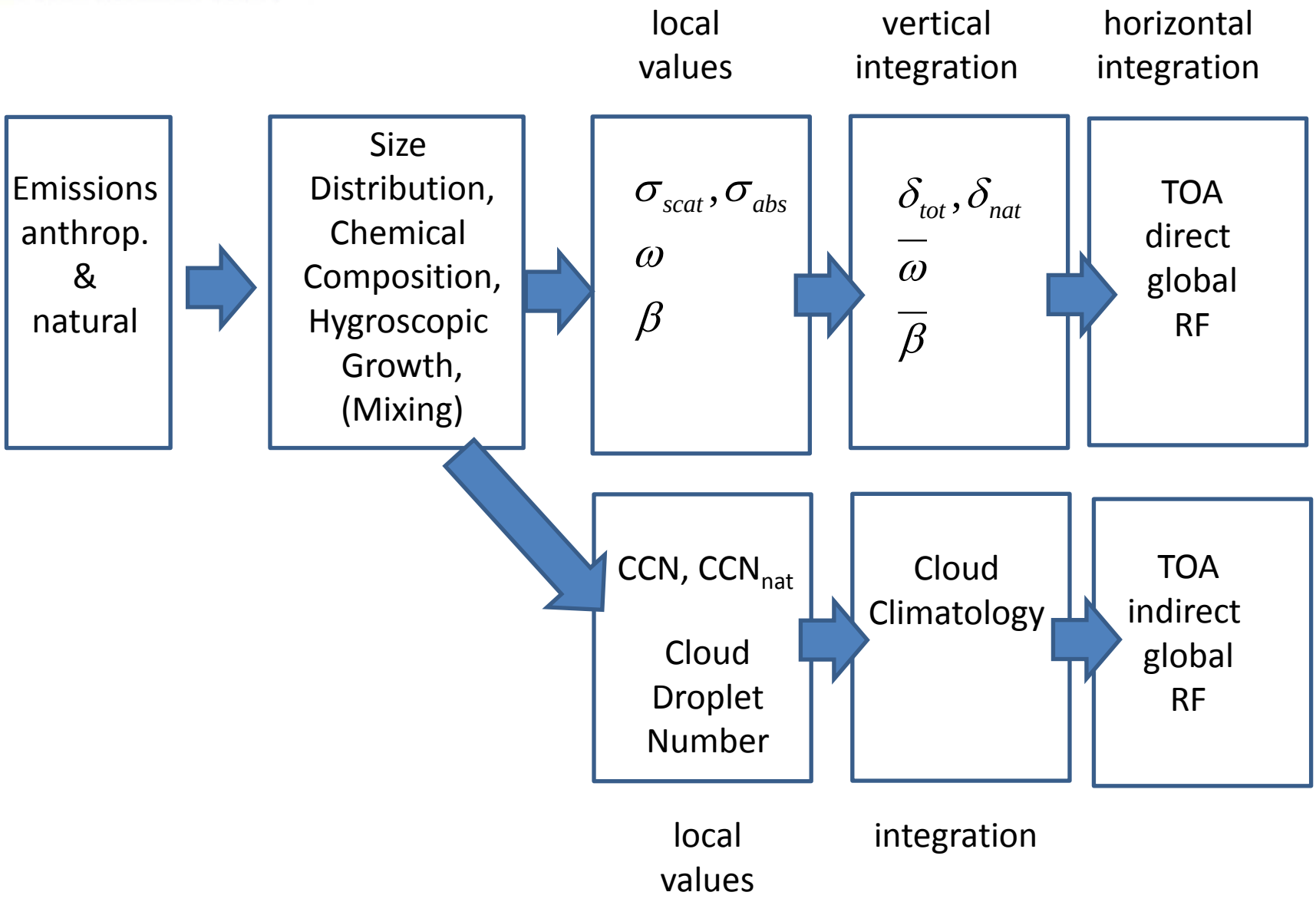
local values
vertical integration
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Emissions anthrop. & natural
Size Distribution, Chemical Composition, Hygroscopic Growth, (Mixing)
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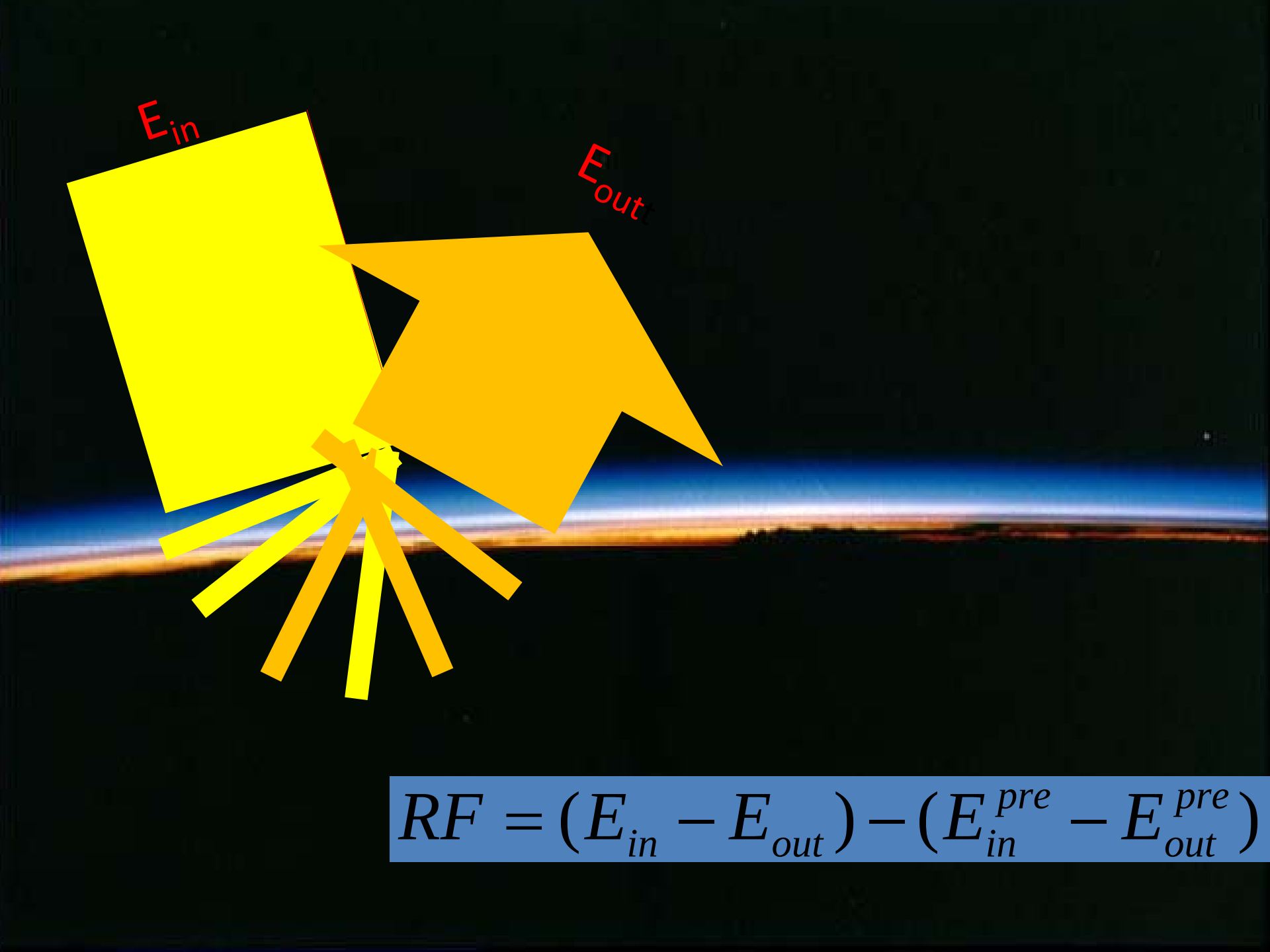
$\overline{\omega}$
$\overline{\beta}$
TOA direct global RF
CCN, CCN_{nat}
Cloud Droplet Number
Cloud Climatology
TOA indirect global RF
local values
integration



$$RF = (E_{in} - E_{out}) - (E_{in}^{pre} - E_{out}^{pre})$$

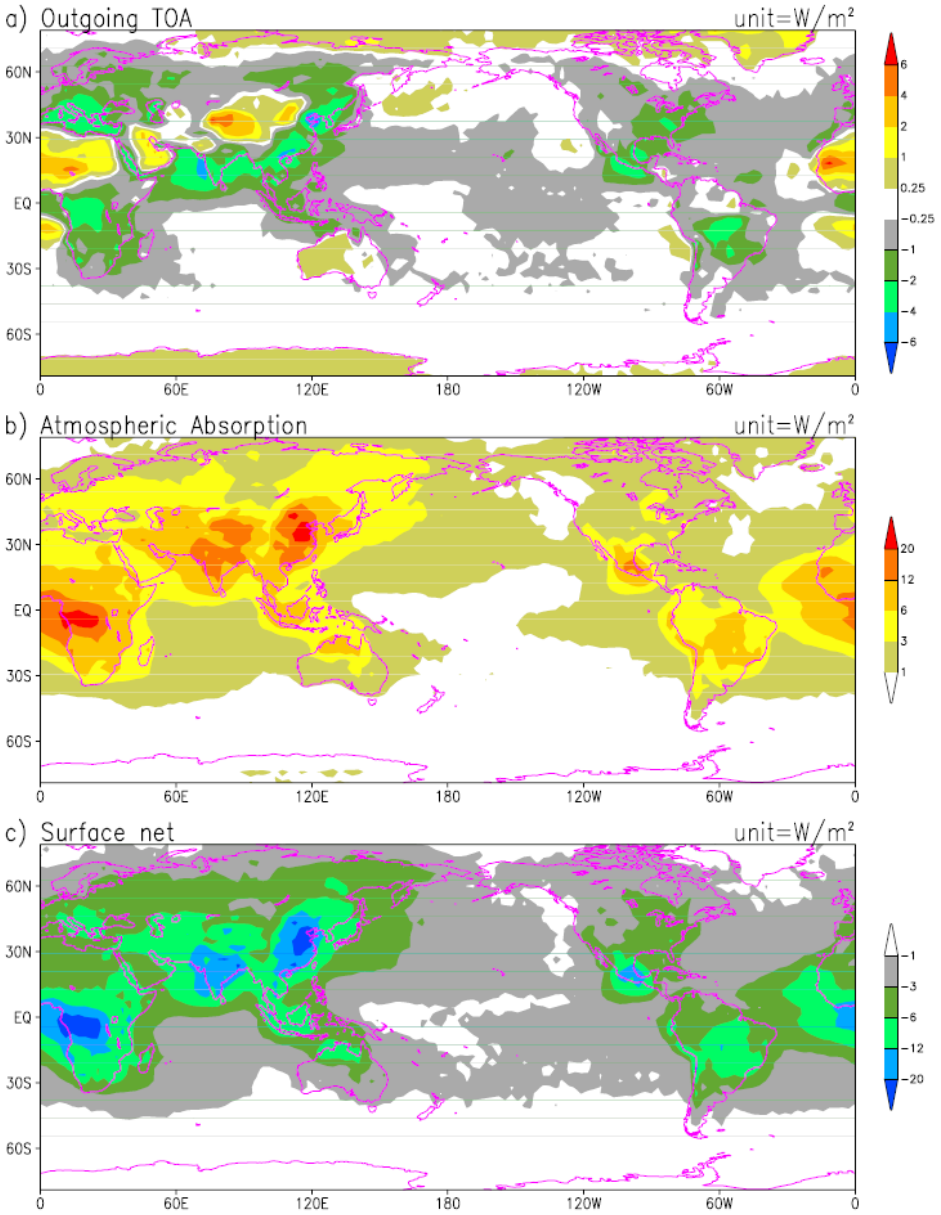
Radiative Forcing: bottom-up

$$RF = (E_{in} - E_{out}) - (E_{in}^{pre} - E_{out}^{pre})$$

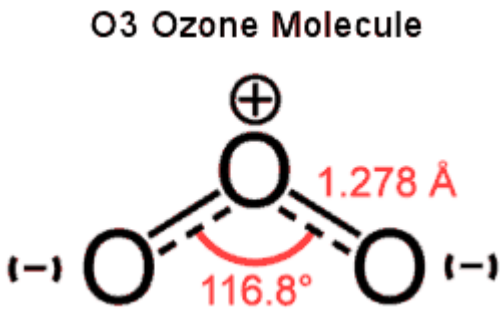
$$RF = (E_{in} - E_{in}^{pre}) - (E_{out} - E_{out}^{pre})$$

$$RF = \Delta E_{in} - \Delta E_{out}$$

$$RF = \Delta E_{in,solar} - \Delta E_{out,GHG} - \Delta E_{out,aerosols} - \Delta E_{out,surface\_albedo}$$


a) Outgoing TOA
unit=W/m²
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
6
4
2
1
0.25
-0.25
-1
-2
-4
-6
b) Atmospheric Absorption
unit=W/m²
20
12
6
3
1
c) Surface net
unit=W/m²
-1
-3
-6
-12
-20

ATMOSPHERIC OZONE



Computing future aerosol radiative forcing:

scenarios → emissions → concentration fields → climate forcing

- Model validation (against measured aerosol constituents' concentrations too)

- Model inter-comparisons

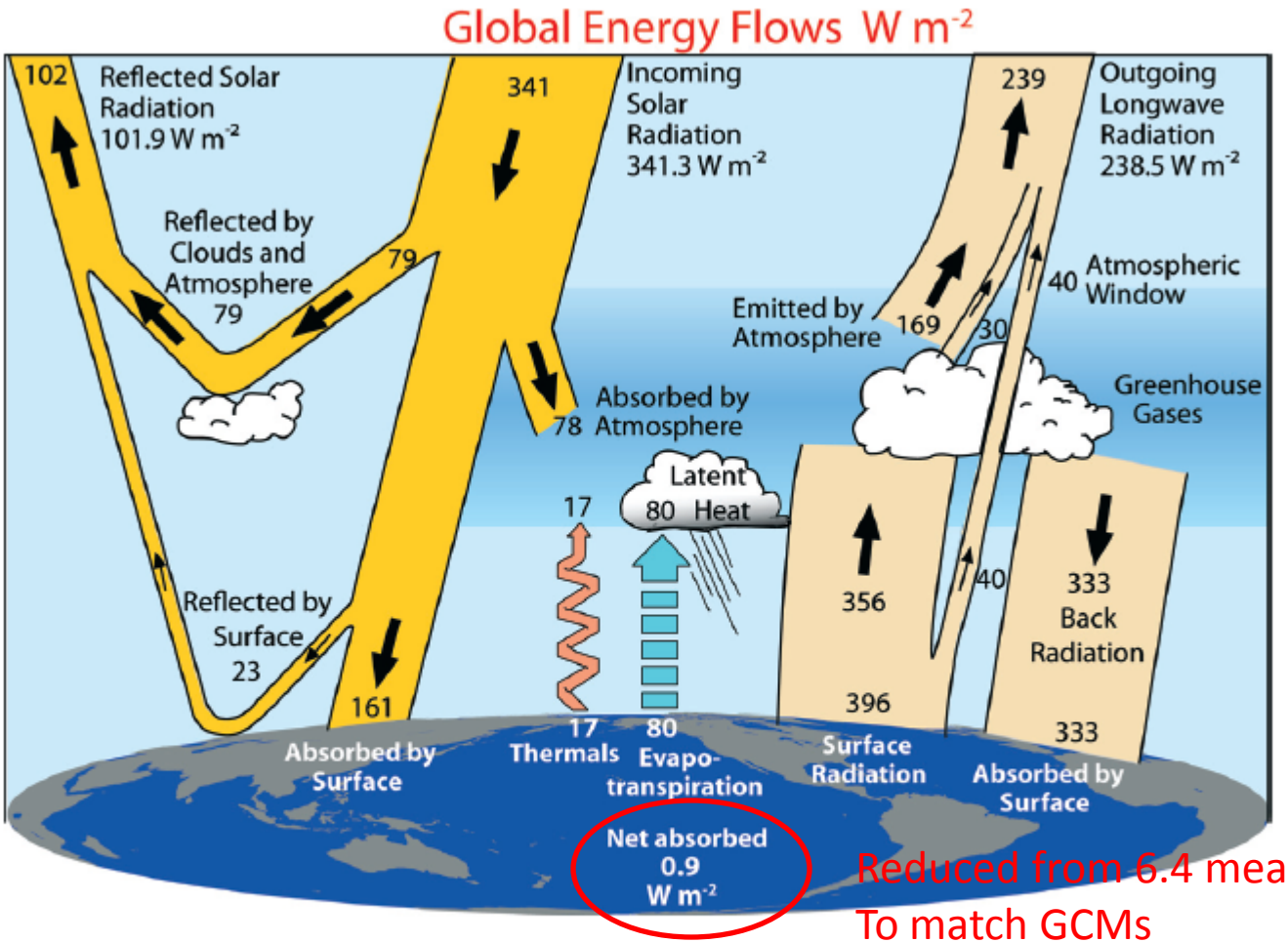
AeroCom (Schultz et al., 2006) compared instantaneous direct radiative forcing due to anthropogenic aerosols produced by 9 different global models (from Europe, Japan and the USA) with detailed aerosol modules.

Differences in computed direct aerosol forcing (range +0.04 to $-0.41 Wm^{-2}$) are due to:

- diversity in simulated aerosol residence times
- mass extinction coefficients
- **forcing efficiencies** (forcing per unit optical depth)

+

- in clear-sky conditions: aerosol absorption, size, and surface albedo
- in cloud-sky conditions: cloud fields and relative altitudes of absorbing aerosol and clouds

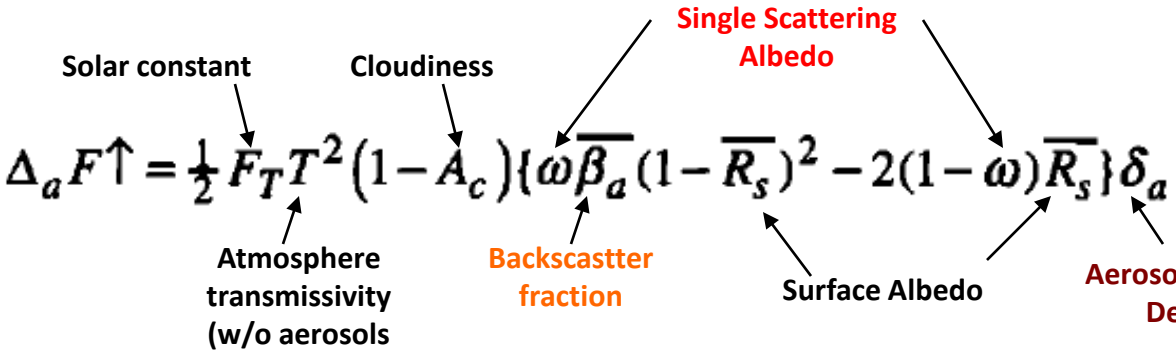


Reduced from 6.4 measured to 0,9
To match GCMs

FIG. 1. The global annual mean Earth's energy budget for the Mar 2000 to May 2004 period (W m^{-2}). The broad arrows indicate the schematic flow of energy in proportion to their importance.

Computing current aerosol **direct** radiative forcing:

- E.g. Haywood and Shine's approximation (1995) for a given WL:



Is total present forcing, not

Bar = average over solar an

In Charlsons work, optical depth is that of anthro
If you use measurements you have natural + ant

- Radiative transfer modules (e.g. Modtran) need:
  - extinction vertical profile
  - extinction, absorption, and asymmetry factor WL dependence

Computing current aerosol **indirect** radiative forcing:

- mainly (?) remote sensing
- CCN number ↔ CN number size distribution, hygroscopicity

Measurements of aerosol characteristics relevant to climate forcing

are currently performed for research (rather than regulation) purposes

⇒ they are done with conscience and awareness

Different flow rates in Nephelometer give same scattering measurements
Different ΔT in CPCs give same number of particles with Dp>50nm

go back to a basic physical principle

⇒ they aim at getting true (and not only "comparable") values
No need for standardisation if several methods can measure the same truth

E.g. - aerosol absorption from **photoacoustic spectrometer** =
- **extinction cell (**extinction – scattering)

In contrast with PM mass concentration (gravimetric methods) which give wrong data because of sampling artifacts and analytical artifacts (aerosol water uptake at 45-50% RH), and then errors have to be the same everywhere.

⇒ continuous closure checks used as strigent data quality check

Still a lot has been done regarding standardisation in the field of aerosol metrology for climate over the past decade (GAW SAG, GAW-WCCAP, …,EMEP) Very often payed by European Commission

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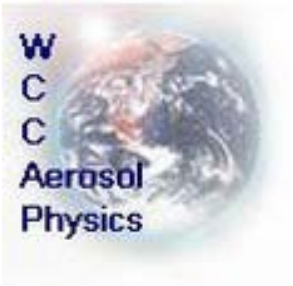
2003 WMO-GAW Guidelines (72 p.)

2011 WMO-GAW SOPs (76 p.)

- The GAW – World Calibration Centre for Aerosol Physics
  http://gaw.tropos.de/WCCAP/



- Intercomparisons

- Audits (on-site check of sampling configuration, instruments, etc…)

Tamanrasset/Assekrem	Algeria	2003
Hohenpeissenberg Germany		2003
Anmyeon	South-Korea	2004
Pallas	Finland	2004
Danum Valley	Malaysia	2004
Mace Head	Ireland	2004
Waliguan-Beijing	China	2005
Danum Valley	Malaysia	2005
Danum Valley	Malaysia	2006
Cape Point	South Africa	2006
Ny-Alesund	Norway	2006
Beo-Moussala	Bulgaria	2006
Izana	Tenerife, Spain	2006
Point Barrow	Alaska, USA	2007
Monte Cimone	Italy	2007
Harwell	UK	2007
Mauna Loa	Hawaii, USA	2007
Finokalia	Crete, Greece	2007
Cabauw	The Netherlands	2008
Bukit Koto Tabang Indonesia		2008
Vavihill	Sweden	2008
Cape Grim	Australia	2008
Shangdianzi	China	2009
Danum Valley	Malaysia	2009
Hyytiälä	Finland	2009
Birkenes	Norway	2009
Finokalia	Crete, Greece	2009
Preila	Lithuania	2009
Aspvreten	Sweden	2009
Melpitz	Germany	2009
Ispra	Italy	2010
JFJ, PdD, Kosetice, K-Puszta		2010 ?

I can make a GANTT-like diagram with this too, highlighting stations from the 5 continents

Computing future aerosol radiative forcing:

scenarios → emissions → concentration fields → climate forcing

- Model validation (against measured aerosol constituents' concentrations too)

  - inorganics: nitrate, sulfate, (ammonium), etc…

    - ∃ reference materials (NIST **S**RM 2694, IRMM xxx, …)

    - ∃ yearly or twice yearly regular inter-comparisons
      GAW - QA/SAC-Americas: 78 labs worldwide
      (http://qasac-americas.org/)
      EMEP- CCC: 51 labs worldwide
      (http://tarantula.nilu.no/projects/ccc/)

  - carbonaceous aerosol

    - reference material (NIST RM 8785) ?

    - yearly inter-comparison with EUSSAR project (18 Eu labs)

    - punctual inter-continental inter-comparison
      EnvCan, IMPROVE, EUSAAR

TC amount measured in NIST RM 8785 by 13 labs in Europe

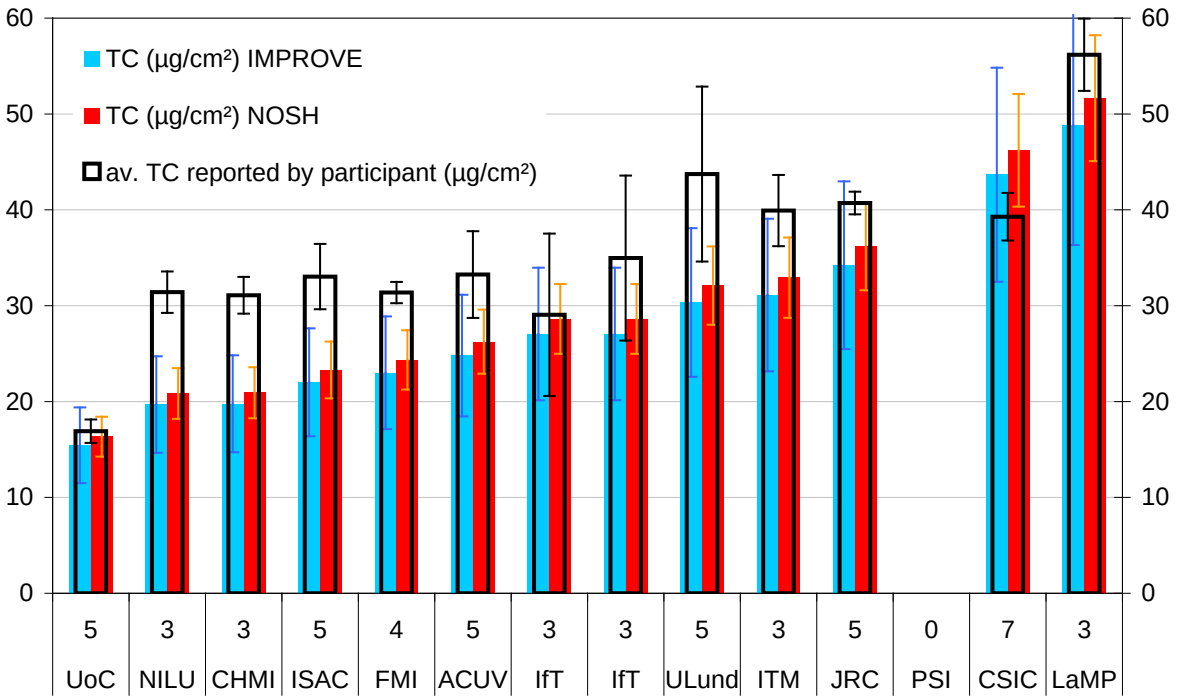
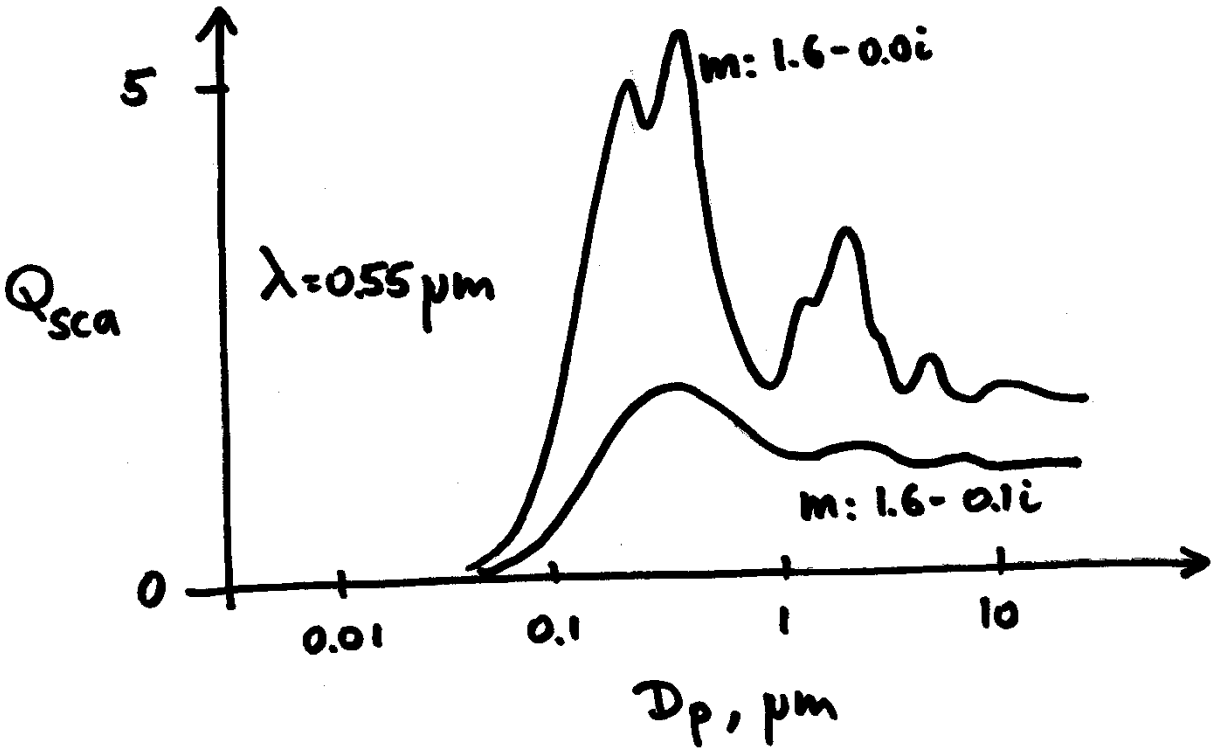


*Fig. 1: TC amounts determined **by the EUSAAR partners** and reference values. Also shown are the uncertainties of these values.*

- Deviations to reference cannot be explained by measurement inaccuracy (based on previous inter-comparisons)
- Large filter inhomogeneity
- No certified values for OC and EC (thermal protocol dependent)

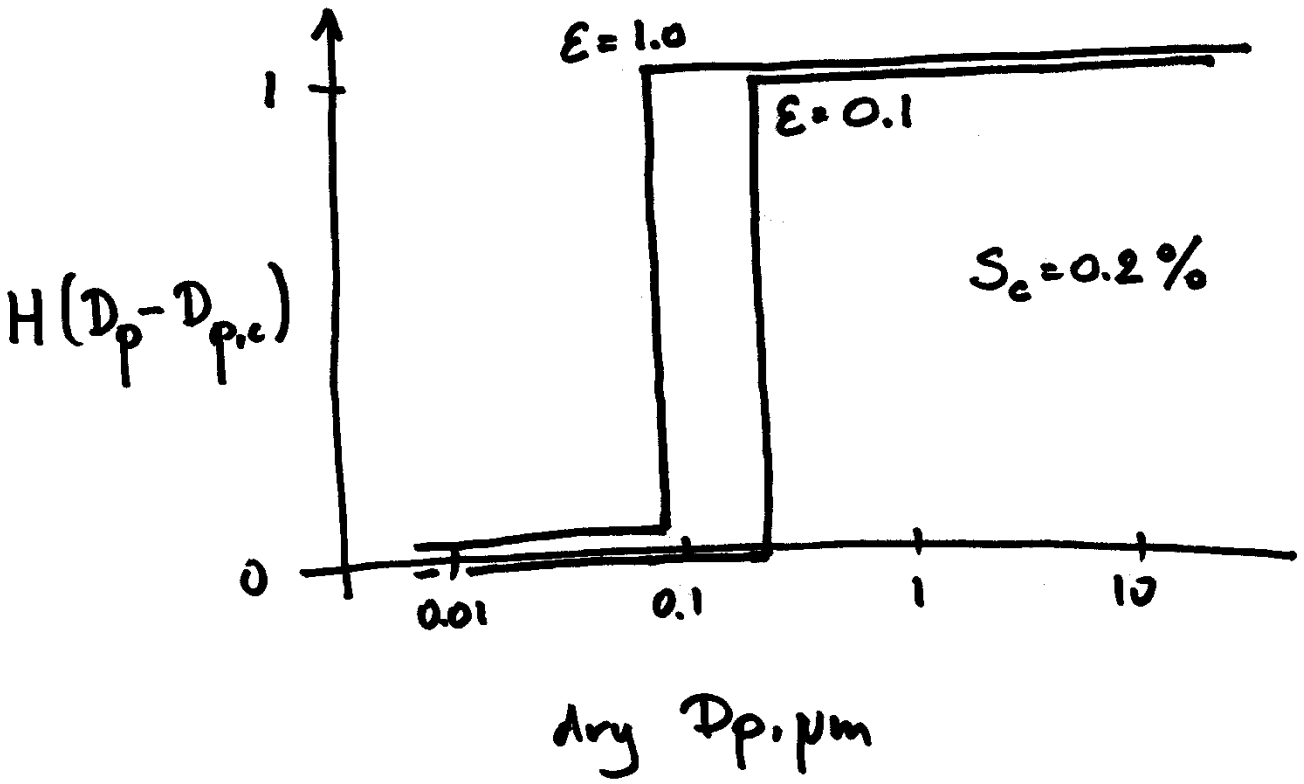
effects on radiation balance: scattering and absorption

$$\sigma_{sca}(\lambda,\bar{r},t)=\iint Q_{sca}(\lambda,D_p,m)\frac{\pi D_p^2}{4}N(D_p,m,\bar{r},t)dmdD_p$$



effects on clouds: cloud condensation nuclei

$$CCN(S_c, \bar{r}, t) = \iint H[D_p - D_{p,c}(S_c, \varepsilon)] N(D_p, \varepsilon, \bar{r}, t) d\varepsilon dD_p$$



The GAW – World Calibration Centre for Aerosol Physics
http://gaw.tropos.de/WCCAP/

- Intercomparisons

- Audits

- Travelling reference instruments (for especially remote stations)

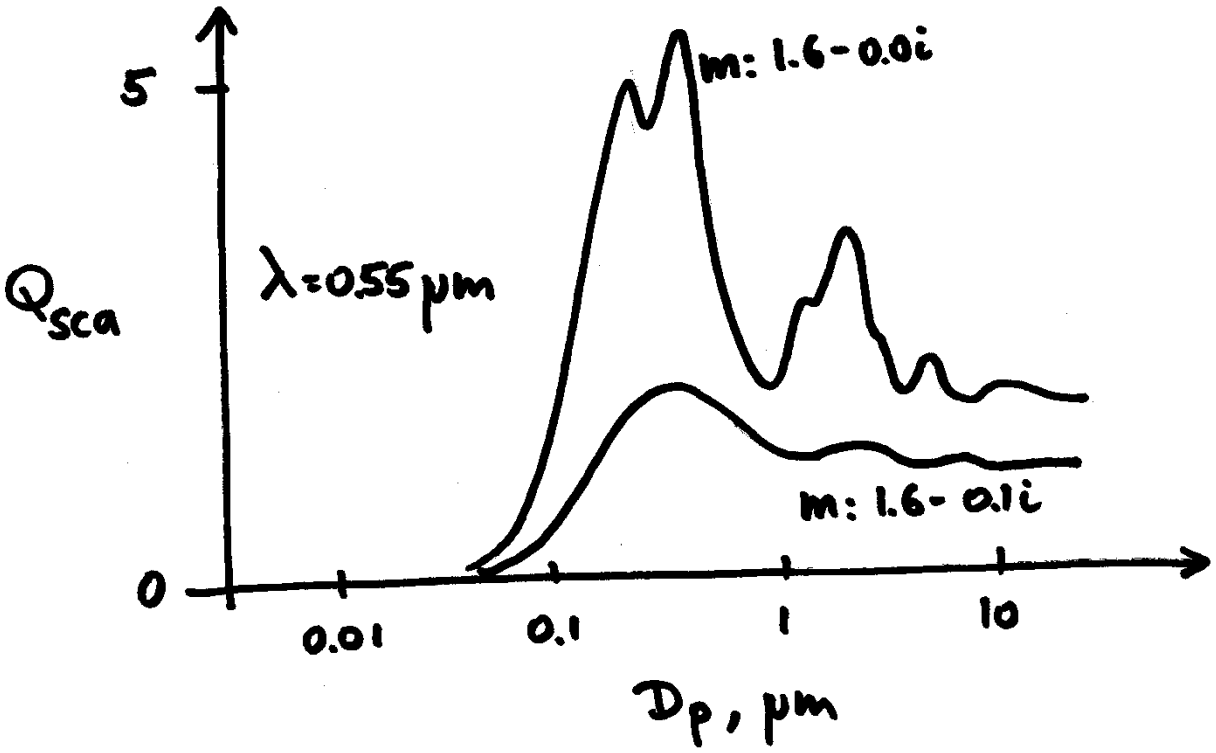
Definitions

What is a Standard?

- A standard is an established norm or requirement
- It is usually a formal document that establishes uniform technical criteria, methods, processes and practices
- It may be developed privately or unilaterally, for example by a corporation, regulatory body, military
- Simply <u>They define how things should be done</u>

effects on radiation balance: scattering and absorption

$$\sigma_{sca}(\lambda,\bar{r},t)=\iint Q_{sca}(\lambda,D_p,m)\frac{\pi D_p^2}{4}N(D_p,m,\bar{r},t)dmdD_p$$



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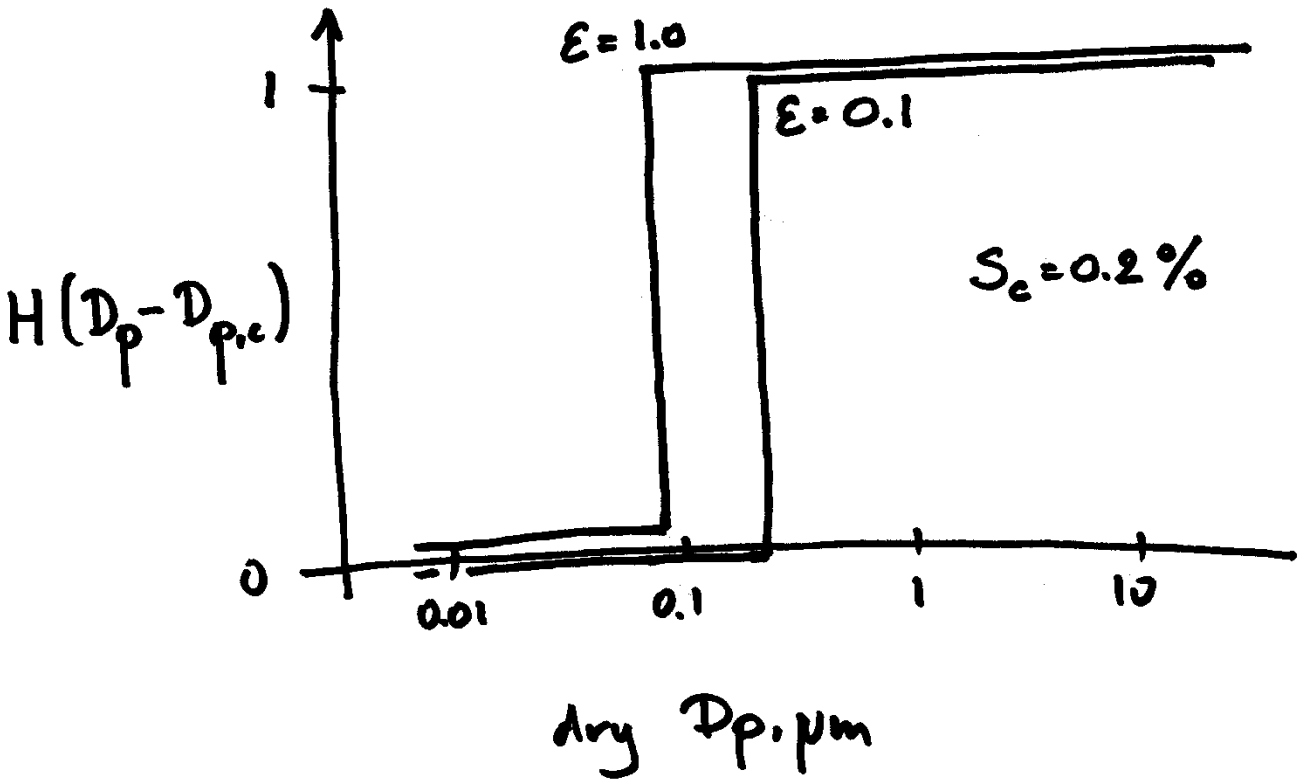

BLACK CARBON PARTICLES

"Black Carbon" or "Elemental Carbon" is:

- carbon-containing particulate matter, resulting from incomplete combustion
  - it withstands high temperatures
  - it is black, hence absorbs light
- emitted together with CO_2, CO, NMHC, organic particlate matter)

Anthropogenic forcing??

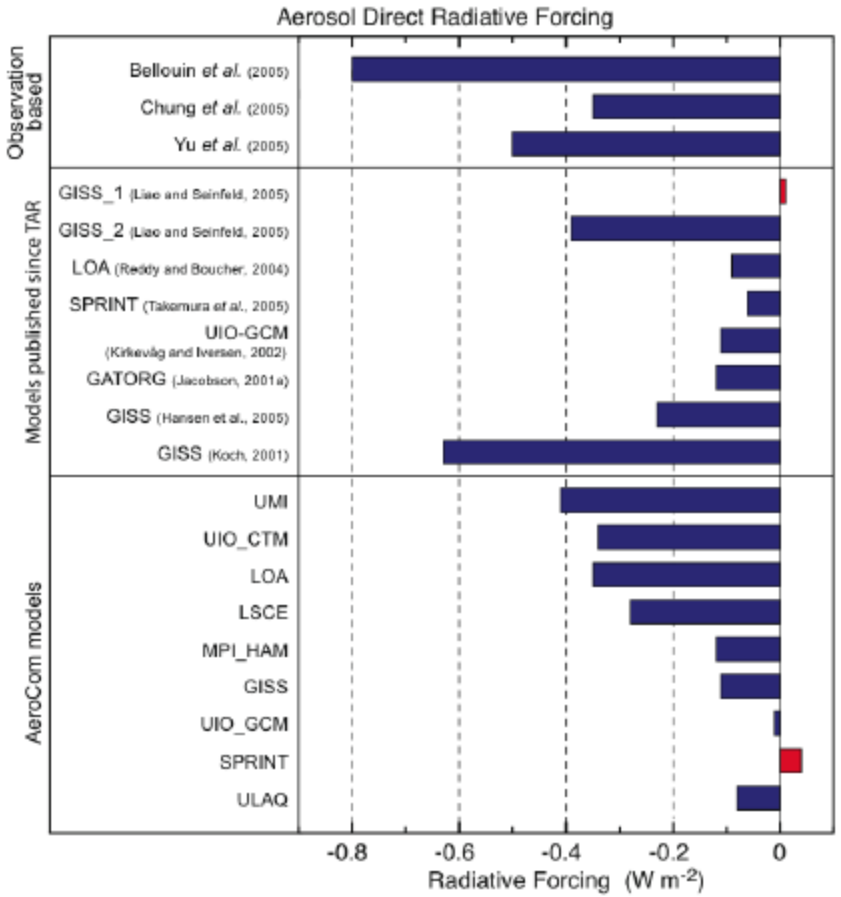

Figure 2.13. Estimates of the direct aerosol RF since the TAR from observational based studies, independent modelling studies, and AEROCOM results with identical aerosol and aerosol precursor emissions. GISS_1 refers to a study employing an internal mixture of aerosol, and GISS_2 to a study employing an external mixture.

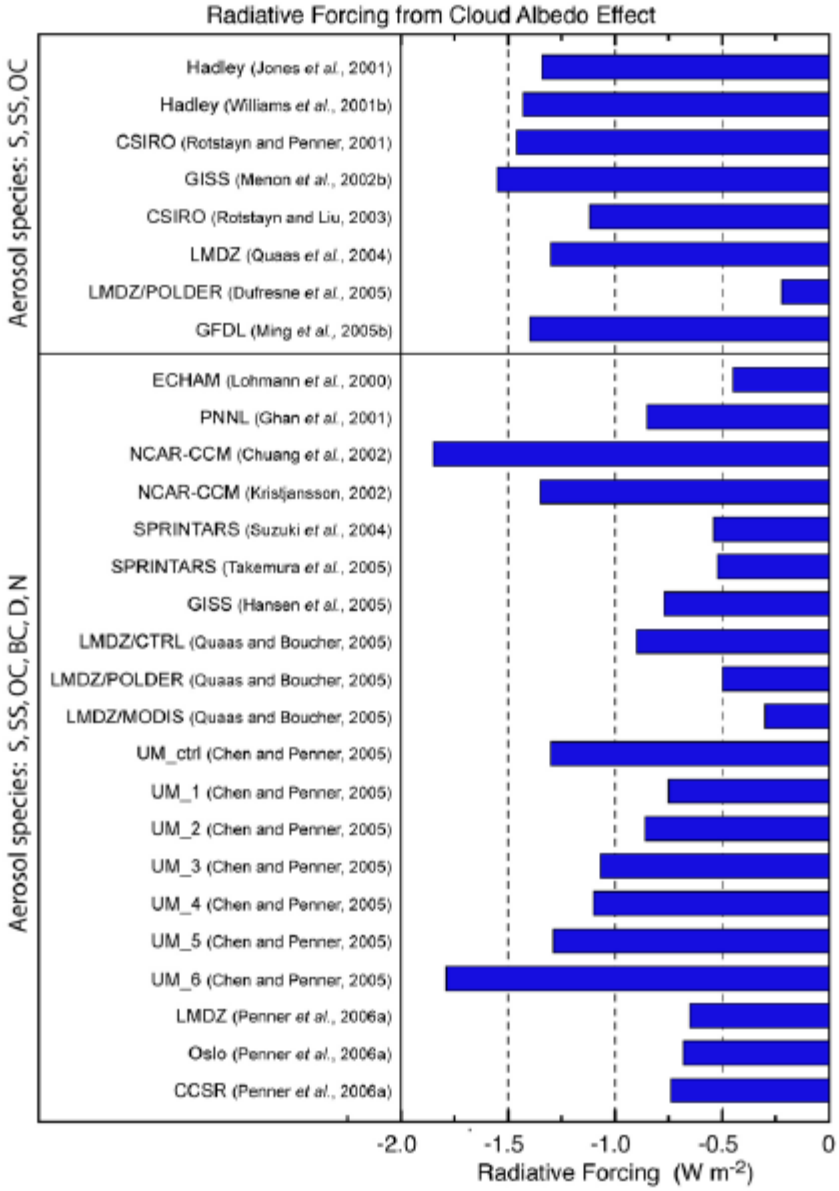

Figure 2.14. Radiative forcing due to the cloud albedo effect, in the context of liquid water clouds, from the global climate models that appear in Table 2.7. The labels next to the bars correspond to the published study; the notes of Table 2.7 explains the species abbreviations listed on the left hand side. Top panel: results correspond to models that consider a limited number of species, primarily anthropogenic sulphate (S). Bottom panel: results correspond to studies that include a variety of aerosol compositions and mixtures; the estimates here cover a larger range than those in the top panel. Chen and Penner (2005) present a sensitivity

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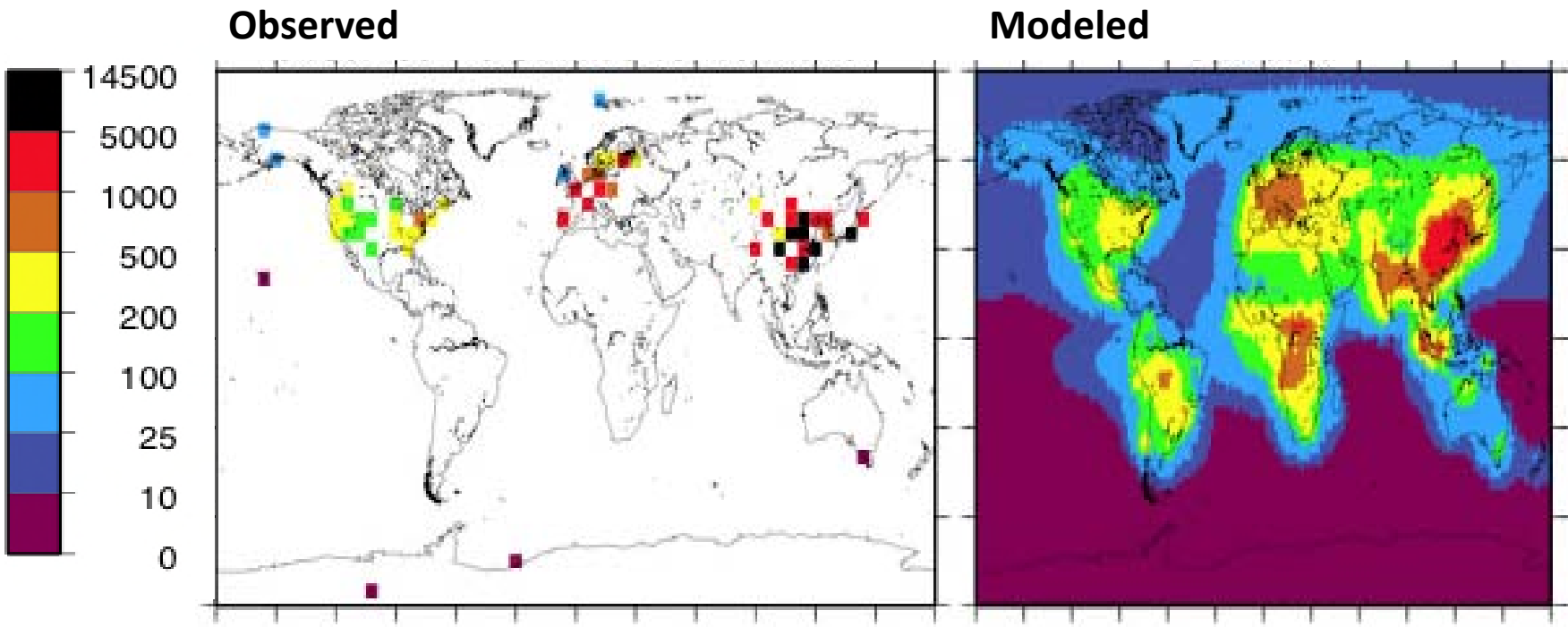
Measuring and modeling BC surface concentrations



Koch et al., 2009

impacts of BC and tropospheric ozone

On air quality

Black carbon and ozone in the lower atmosphere are harmful air pollutants affecting health of humans and ecosystems

Black carbon, a component of particulate matter, and ozone both lead to premature deaths worldwide. (PM2.5: ~2 million per year , WHO)

Ozone is also the most important air pollutant, responsible for reducing crop yields, and thus affects food security.

On global and regional climate ?

present impacts of BC and tropospheric ozone

On global and regional climate

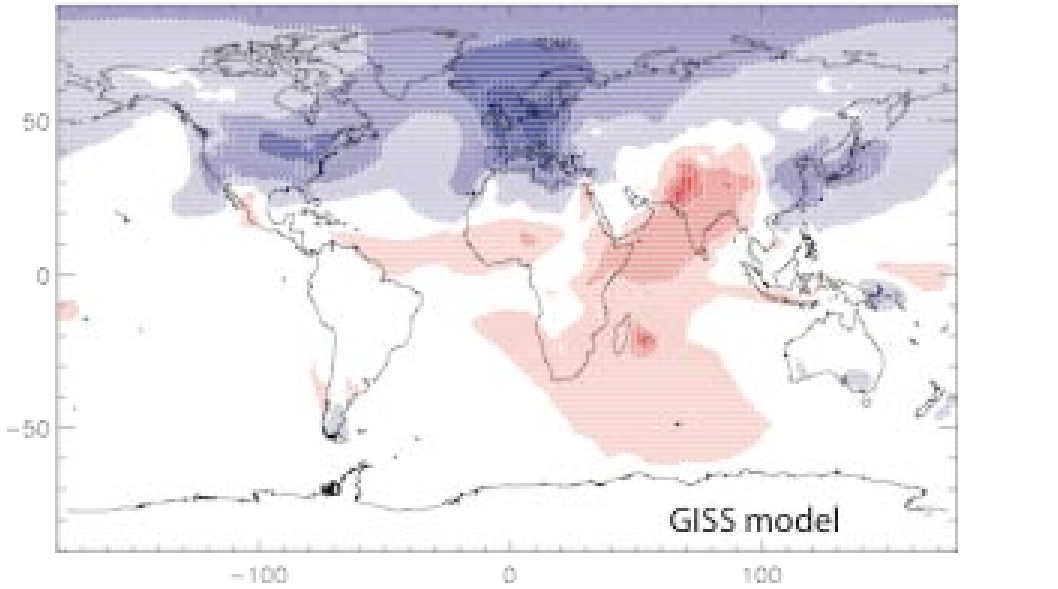
Changes in their burdens over the 20th Century result in an expected equilibrium global warming of 0.0-0.8 C due to BC and 0.1-0.4 C due to O_3. (The equilibrium warming expected from CO2 is about 1.3 C.)

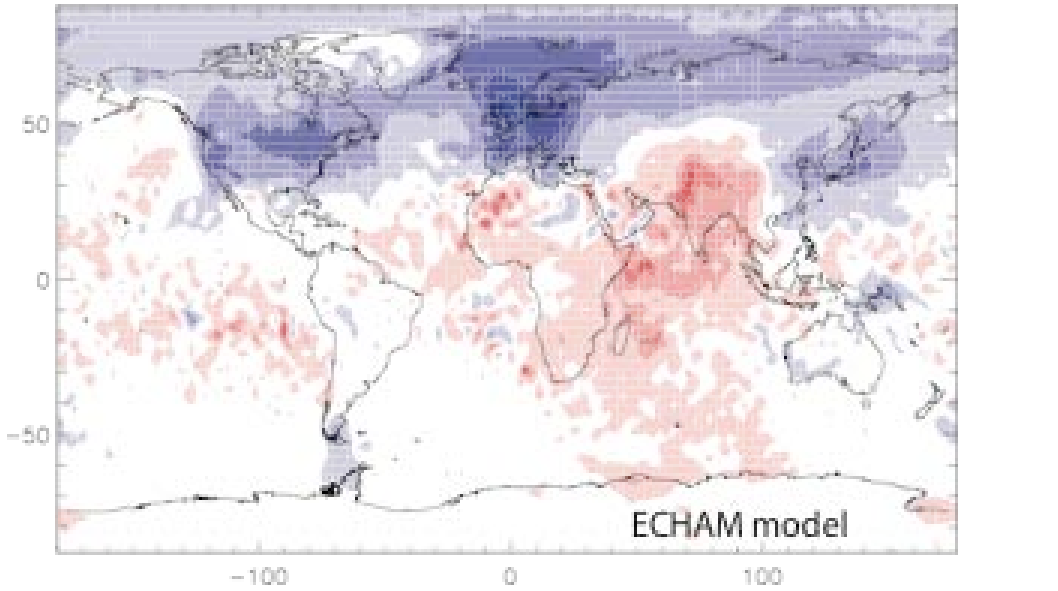
Atmospheric heating by BC disturbs tropical rainfall and regional circulation patterns such as the Asian monsoon.

Black carbon's darkening of snow and ice surfaces increases their absorption of sunlight, which, along with atmospheric heating, exacerbates melting of snow and ice around the world, including in the Arctic, the Himalayas.

change in BC deposition: 2005 to 2030

reference scenario





UNEP, 2011

expected impacts of BC and tropospheric ozone

ireference scenario: 2005 to 2030

Avoidance of 0.2-1.8 million premature deaths per year , in North America, East Asia, SE Asia & Pacific, While in increase by 0.1-2.0 million in South, West & Central Asia and Africa..

Decreasing production of wheat, rice corn and soy by 7 to 120 million tonnes across Asia with an associated economic loss of US$ 1 – 20 billion. Increasing crop yields in US and Europe.

The compensating warming and cooling impacts of changes in BC, ozone and other aerosols lead to a small net warming of less than 0.1 C globally

Black carbon's darkening of snow and ice and atmospheric heating, keeps exacerbating melting of snow and ice in the Himalayas

Conclusions so far:

based on our knowledge of the behaviour of BC and ozone in the atmosphere, and of their impacts on air quality, And on lobal and regional climate in teh near term

it makes a lot of sense to look for measures that specifically target the emissions of BC and ozone precursors in order to solve a range of important problems at once.


thanks

calculation effects of aerosols

Closure experiments

scattering, absorpttion $$\sigma_{sp}(\lambda) = \iint Q_{sca}(\lambda, D_p, m) \frac{\pi D_p^2}{4} n(D_p, m) dm dD_p$$

cloud activation: $$CCN(S_c) = \iint H[D_p - D_{p,c}(S_c, \varepsilon)] n(D_p, \varepsilon) d\varepsilon dD_p$$

particulate matter $$PM_x = \int_0^x \int \rho(D_p) \frac{\pi D_p^3}{6} n(D_p, \rho) d\rho dD_p$$

assuming internal mixing of chemical species into an average one

$$n(D_p, \varepsilon) = n(D_p)\delta(\varepsilon - \overline{\varepsilon})$$

with δ the Kronecker delta function

assuming external mixing of i chemical species

$$n(D_p, \varepsilon) = \sum_1^k n_i(D_p)\delta(\varepsilon - \varepsilon_i)$$

conclusions

- We are more aware of the importance of a range of aerosol processes in the climate system.
-Quantifyingthe climate impactof changing the concentraion of individual chemical components of the atmospheric aerosol is still very uncertain.
-Quanitying the climate impact of indivicual human activities , incl. policy measures, is even more uncertain (emissions & their
chemical fingerprint are uncertain) but the sign is usually known.
-Deal with uncertainty by adopting a multi-pollutant /multi-effect
approach (not just aerosol emissions, not just climate impacts)

conclusions

- Standardization doesn't reduce uncertainty of measurements or assessemnts but improves their comparability.

- Policy making and policy implementation about camparing (e.g. climate effect with and without a policy, comparing PM values with target /limit values)

- Polices often affect markets, or are themselves market based: standarization contributes to creating a level playing field. (BC emissions tradeble like CO2 emissions?)

- Aerosol & Climate science has become relevant!

$$RF = (E_{in} - E_{out}) - (E_{in}^{ref} - E_{out}^{ref})$$

reference = pre-industrial era

hence $(E_{in}^{ref} - E_{out}^{ref}) \approx 0$

and $$RF = (E_{in} - E_{out})$$

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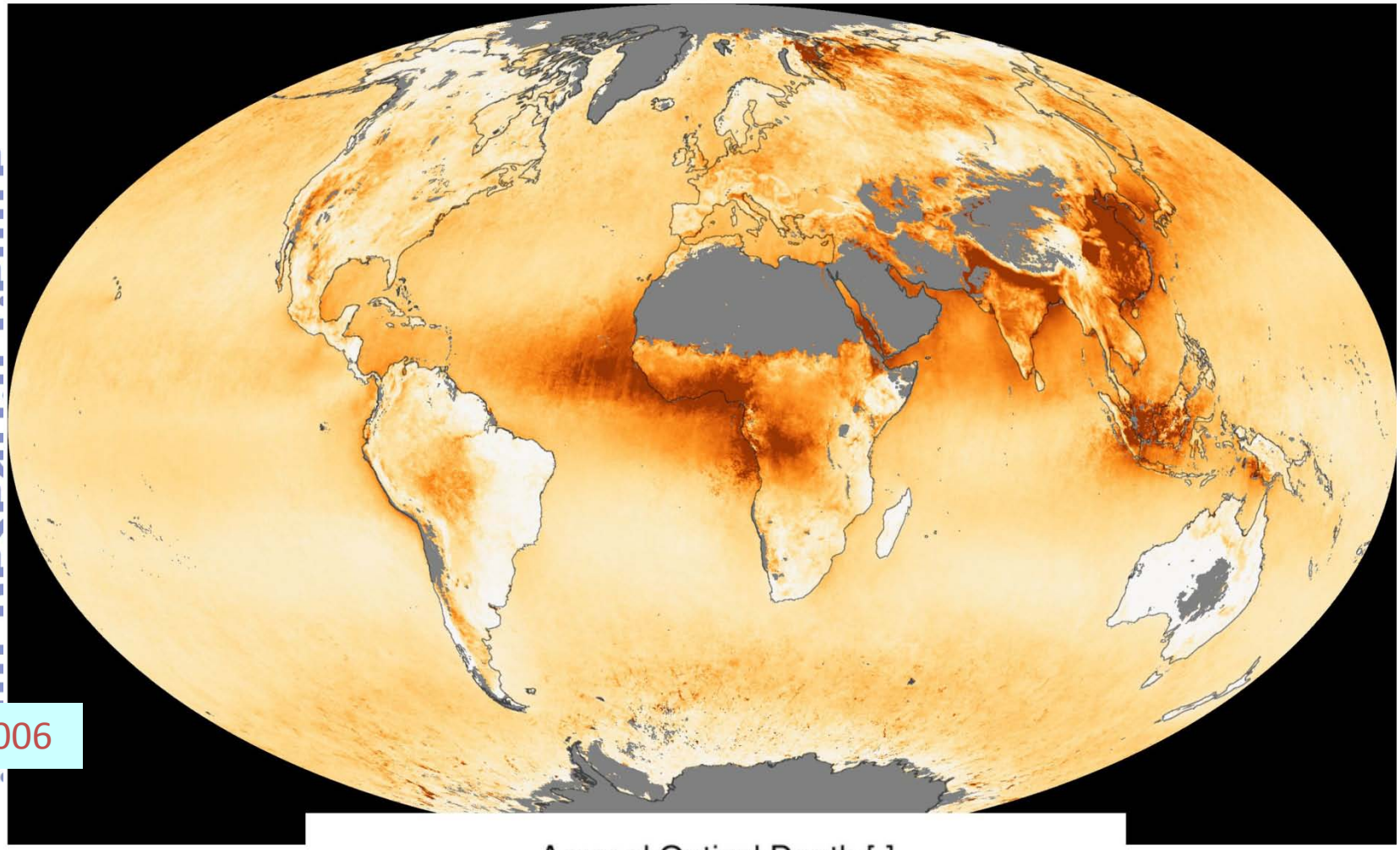
ATMOSPHERIC AEROSOL: macroscopic view



2006

MISR

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Differences in computed direct aerosol forcing (range +0.04 to −0.41Wm^{-2}) are due to:

- diversity in simulated aerosol residence times
- mass extinction coefficients
- **forcing efficiencies** (forcing per unit optical depth)

+

- in clear-sky conditions: aerosol absorption, size, and surface albedo
- in cloud-sky conditions: cloud fields and relative altitudes of absorbing aerosol and clouds

- For any statement that I going to make there is an expert in the room that can go much mre n depth, or even challenge it
- Steve: father if not grand-father: without a beard mor like a father
- When interest of standardization organizations > relevance!
- PM/healt already relevant: legislation > lavel playing field money (even though this community knows much less aerosol,but there is epidemiological evidence!) (do we havedirect evidence of impacts of aerosols on climate:, and that it is important?)
- **How can we go from microscopic compexity to values regional or glonal impacts on radiation balece and climate?**
- **Do we need to consider all that complexity, to come to usefull values?**
- Not yet legislation for aerosols and climate, scientific need (but e.g. BC in CDM is discussed ?) anyway relevance
- Ozone vs PM, PM external internal mixing: onc you ave O3, RF easy to calculate.once you have PM dot easy to calculate
- TOA forcing, RF = delta(present) – delta (pre-industrial) > role of knowing pre-industrial values
  - Overall Earth radiation balance
  - Delta aerosols, delta GHG.delat alsbedl
- - IPCC usual graph (not policy relevant), immediately show other IPCC (more relevant) > Shindell
- At this point usefull to make a distinction between – assessement of present day effects of PM on climate (relevant to monitor compliamce with legilation: standardization) – predicting future impacts of PM on climate (policy development)
- Paper Charlson et al. / Haywood & Shine
  - based on secondary parameters: problem of pre-industrial
  - Based on primar parameters related to emisioins
- What did we learn? Include TOA > TOA+ surface+atmospheric forcing >regional impacts
- We know a lot about aerosols, compared to what health people know or want to consider about PM. Still the latter made it to policy and hence standardization: research becomes different ...
- Ibe exampels of standardization work in air quality work
- Two communities are any way mergibg: e.g. UNEP assessement.
  - RF of BC emissions (IGAC, telephone conference India, US, Nairobi, Europe)
  - Effect on Climate, Health Crops. Integrated > **uncertainties are less problematic**.
- Conclusion?