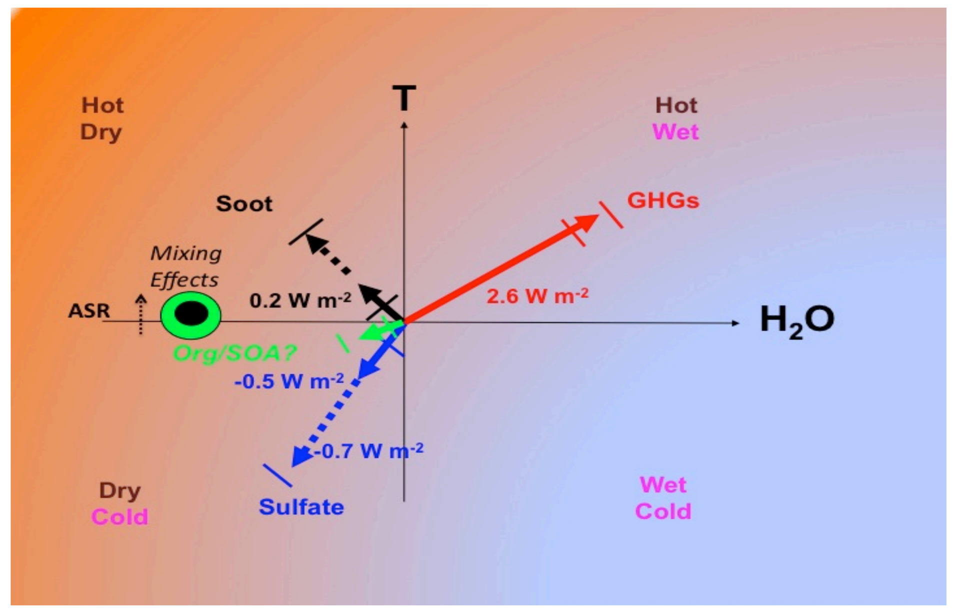
Climate Forcing by Carbonaceous Aerosols: ASR Measurements Enhancing Models

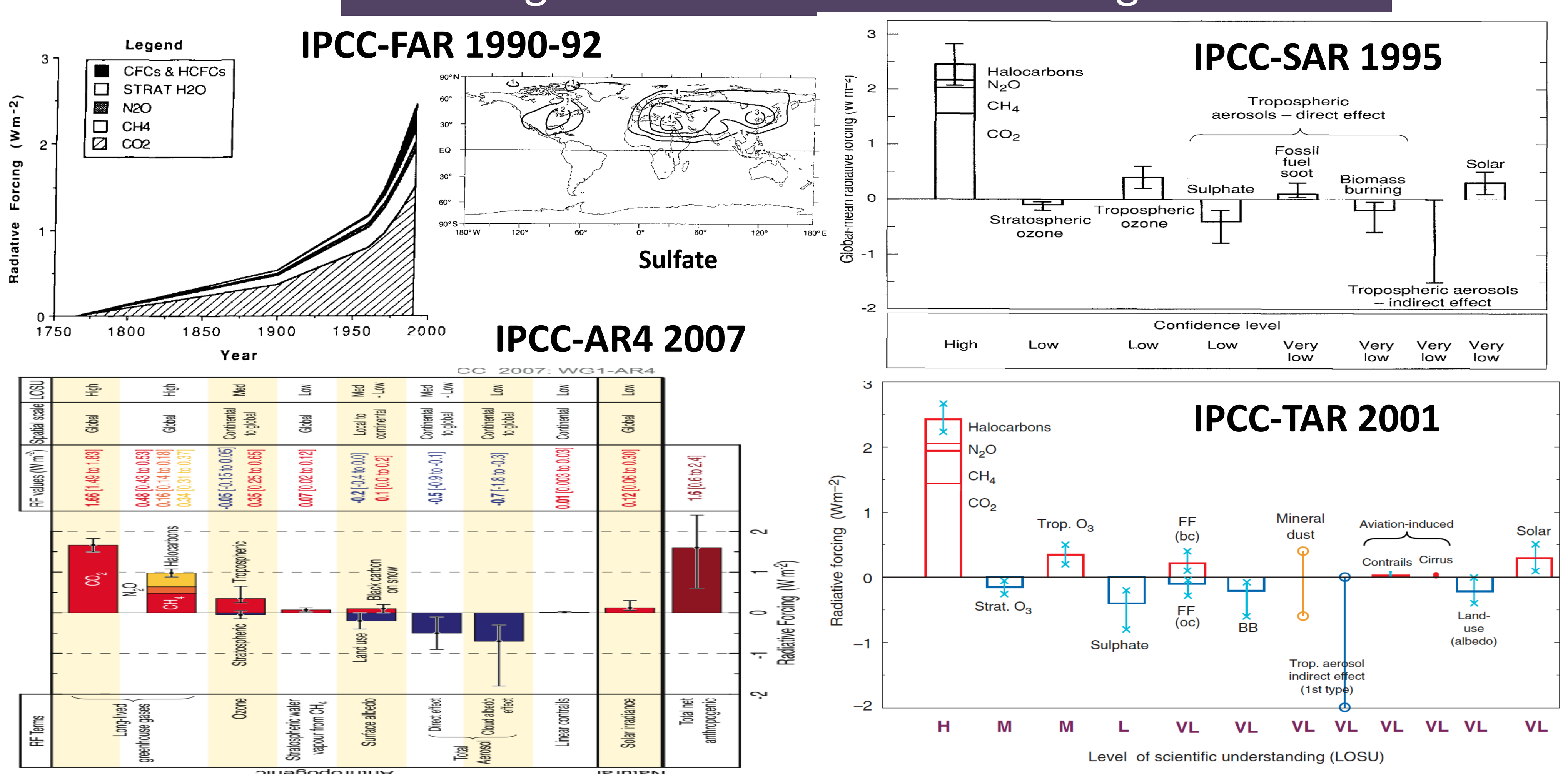
Manvendra Dubey (LANL) and Steve Ghan (PNNL)



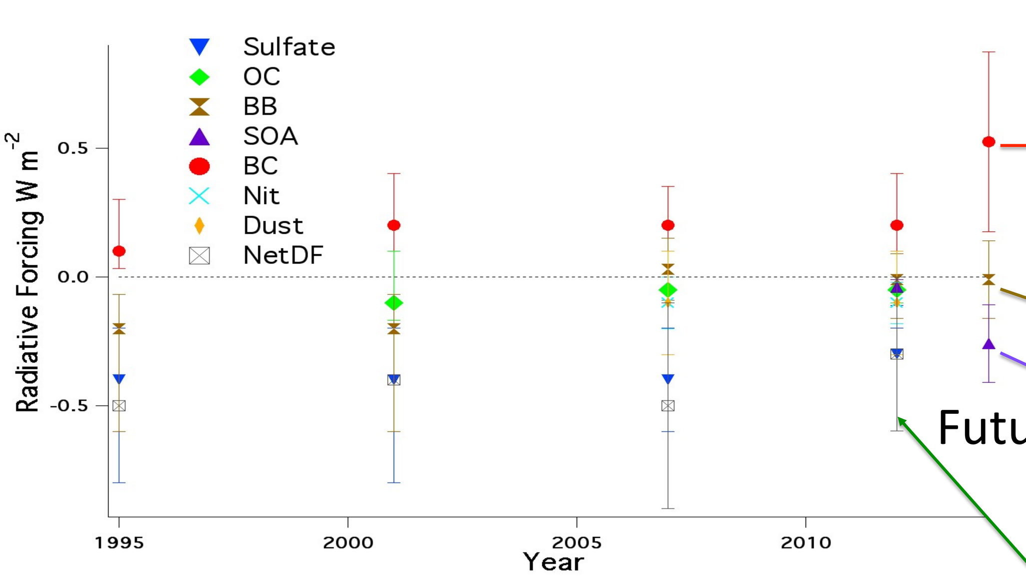
Climate Effects of Manmade Aerosols are More Uncertain and Complex than GHGs

Direct and indirect human aerosol forcing are significant relative to greenhouse gases. Revision in models from a sulfate dominated cooling to a significant role of carbonaceous aerosols that can warm or cool has been driven by observations. Model are being evaluated and refined with data.

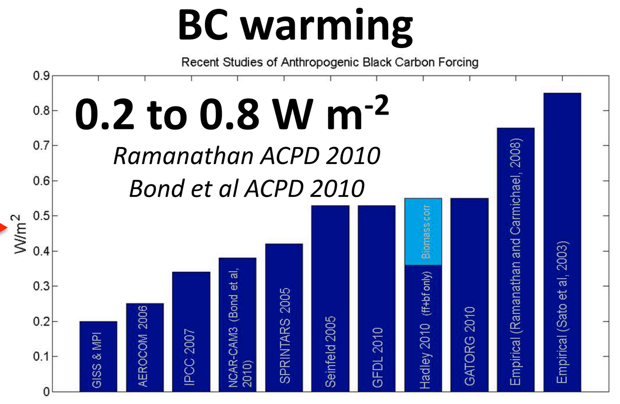
Evolving Estimates of Climate Forcing from IPCC



Aerosol Forcings versus Time (IPCC)



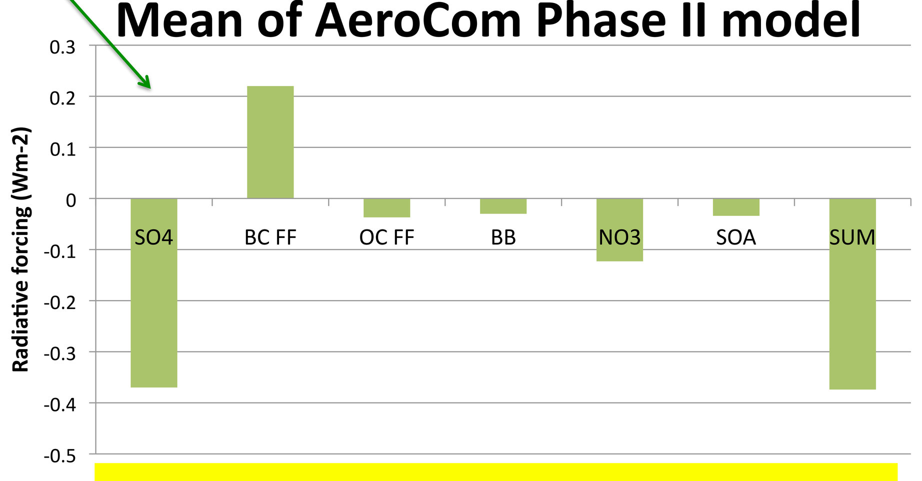
BC warming



Relative OC/BC from BB-fires?

SOA cooling -0.3 W m^{-2}
(Spracklen et al ACP 2011)

Mean of AeroCom Phase II model



Std Dev/mean

	RF	Burden	NRF
SO4	38%	23%	26%
BC	46%	53%	40%
OC	55%	66%	27%

For sulphate burden & radiative properties contribute about similar to the range in RF. For carbonaceous aerosols burden dominates.

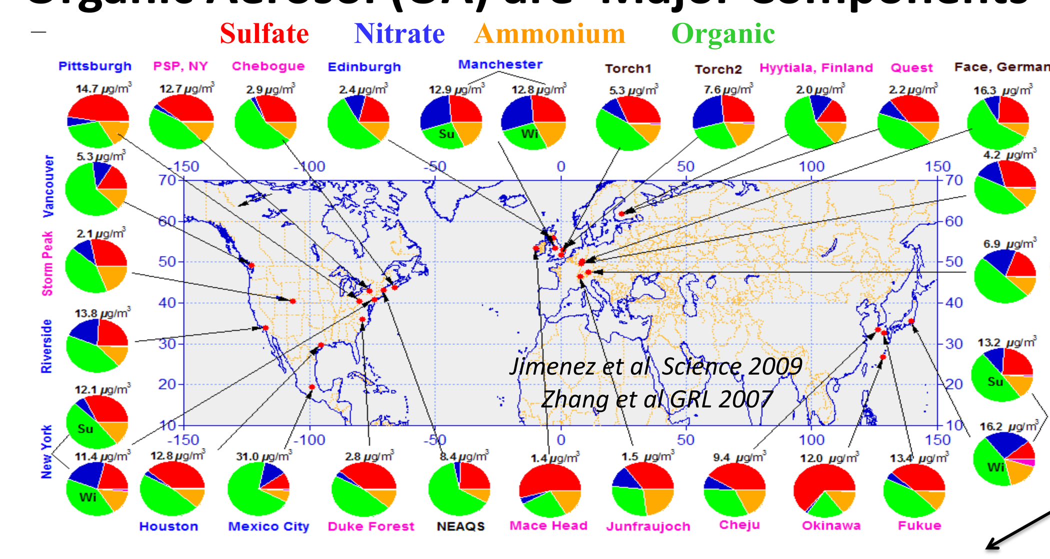
Summary

In situ ASR studies continue to guide aerosol treatments in climate models. Carbonaceous aerosols are being treated in models. However, variability amongst their estimated radiative forcing persists. IPCC models treat all aerosol components and the consensus direct forcing has increased to -0.3 W m^{-2} from -0.5 W m^{-2}. This is driven by lower sulfate cooling and the inclusion of carbonaceous aerosols. There are significant gaps (SOA, BC-mixing with OA and Brown Carbon) between data and models, that suggest a low-medium level of confidence.

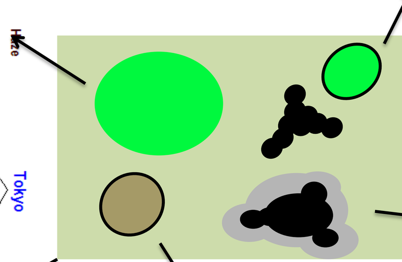
ASR Observations Have Identified Gaps in Models and Helped Develop Process Level Treatments of Carbonaceous Aerosols in Global Climate Models

ASR has deployed state-of-the art size resolved aerosol chemical and optical in the laboratory and field (ground and air) to evaluate parameterizations of aerosol composition and optical properties that determine aerosol radiative forcing.

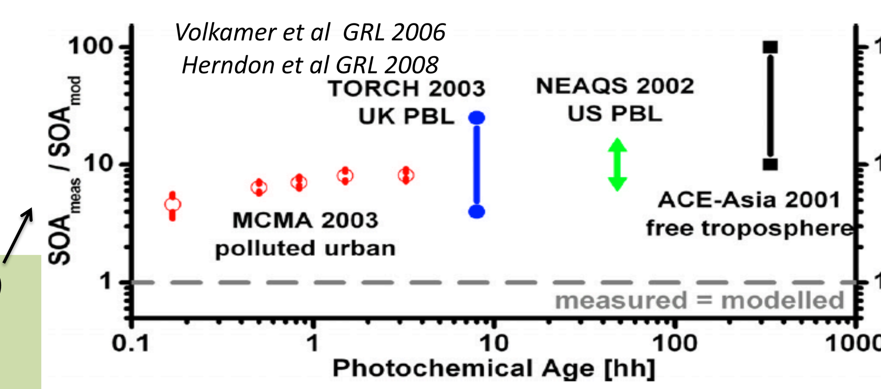
Organic Aerosol (OA) are Major Components

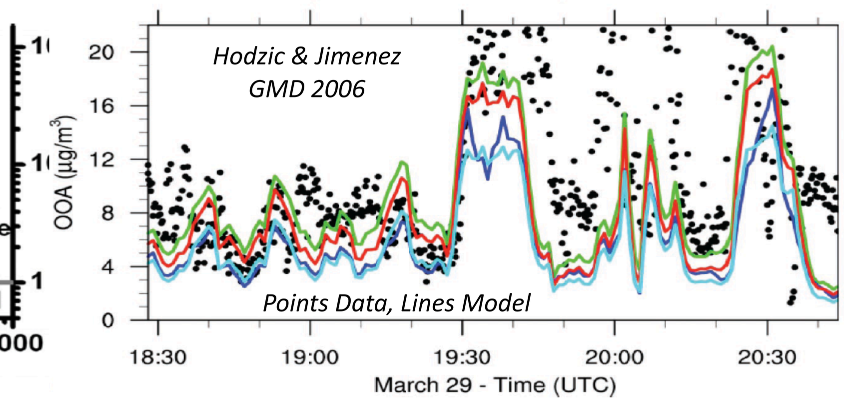


Carbonaceous Aerosols



Enhanced Secondary Organic Aerosol (SOA)





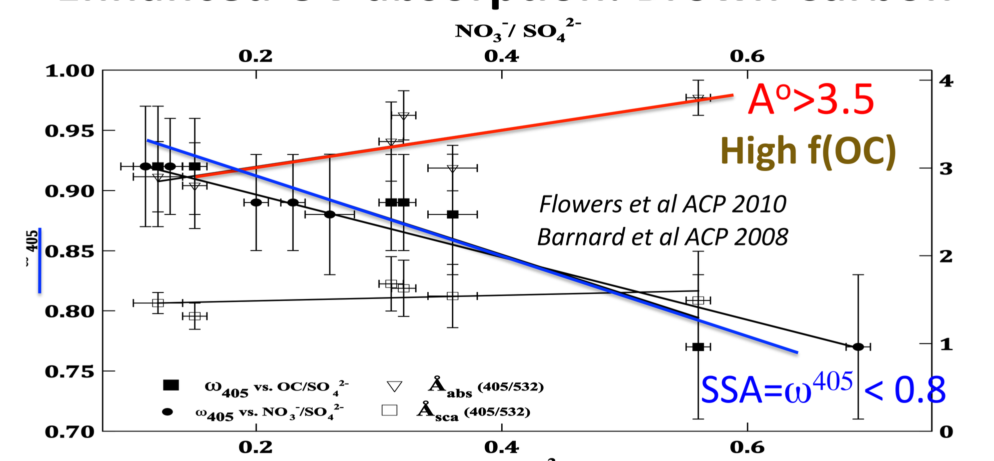
Direct SOA cooling -0.3 W m^{-2} (Spracklen et al ACP 2011)

Black Carbon (BC) Model (AEROCOM)/Obs.

Average model biases	N Am	Eur	Asia	S Am	Afr	Rest
			Koch et al ACP 2009			
Surface concentration	1.6	2.6	0.50	NA	NA	1.4
BC burden	0.42	0.58	0.64	0.42	0.64	0.40
AERONET AAOD	0.86	0.81	0.67	0.68	0.53	0.55
OMI AAOD	0.52	1.6	0.71	0.35	0.47	0.26

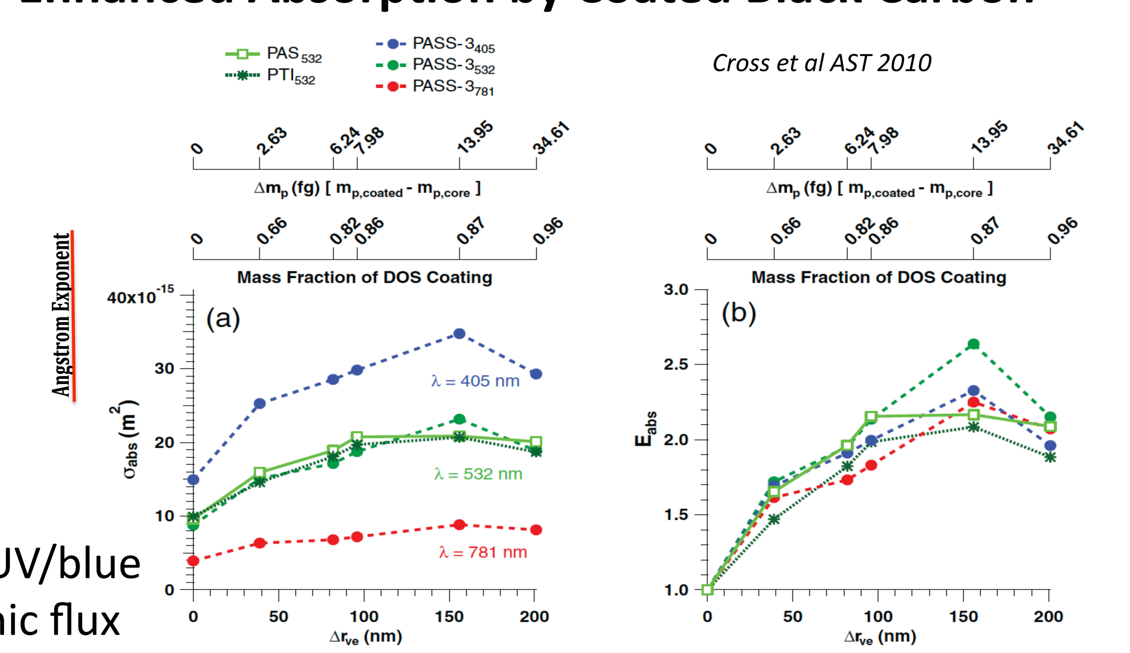
High BC Forcing of 0.5 W m^{-2}: Models lower than AERONET/Asia and low refractive index (<0.7i) and no coating effects. But AERONET can be high from dust and *in situ* filter BC data may be high.

Enhanced UV absorption: Brown Carbon



Brown OC from fires absorbs significantly in UV/blue (<405nm) and can amount to 14-86% of actinic flux absorbed by BC (Kirsshtetter & Thatcher ACPD 2012)

Enhanced Absorption by Coated Black Carbon

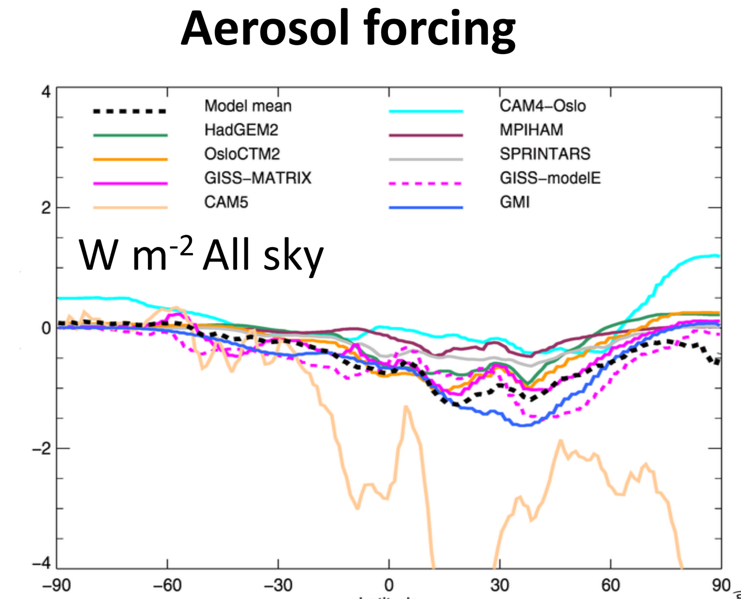


Increassd model BC forcing by 0.3 W m^{-2}
(Jacobsen 2001, Ma et al ACPD 2012)

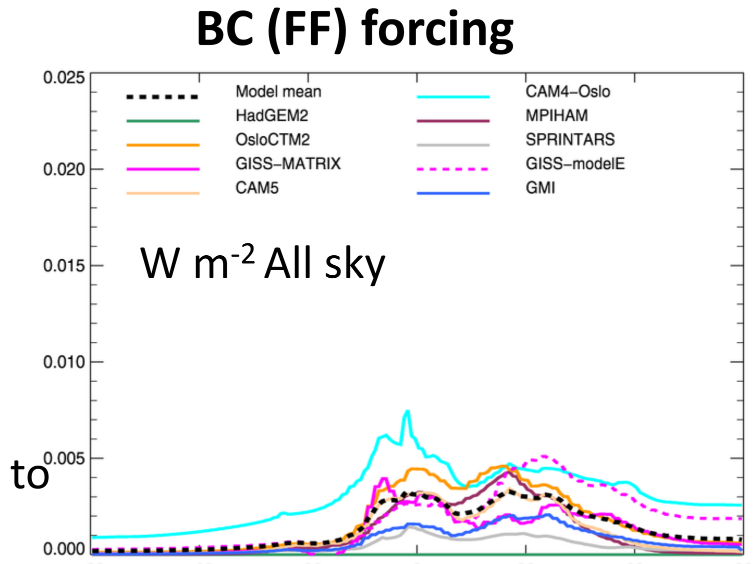
Global Model Evaluation: AEROCOM Phase II http://aerocom.met.no

The AEROCOM-project is an open international initiative to advance understanding of the global aerosol and climate. Extensive observations (satellite, AERONET and in situ) and results from 14 global models have been assembled to evaluate state of the art modeling of the global aerosol. A common protocol has been established and models are asked to make use of the AEROCOM emission inventories for the year 2000 and preindustrial times

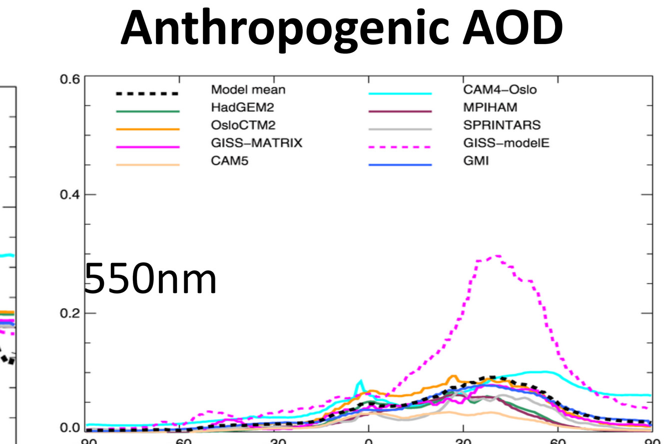
Aerosol forcing

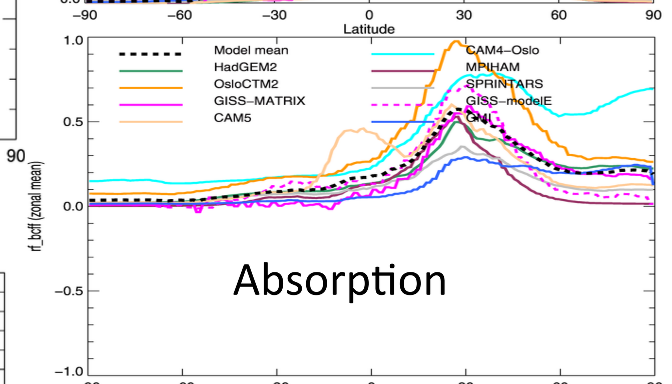


BC (FF) forcing

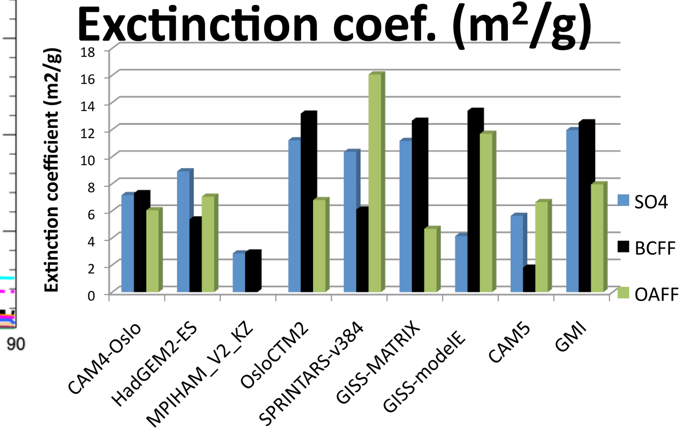


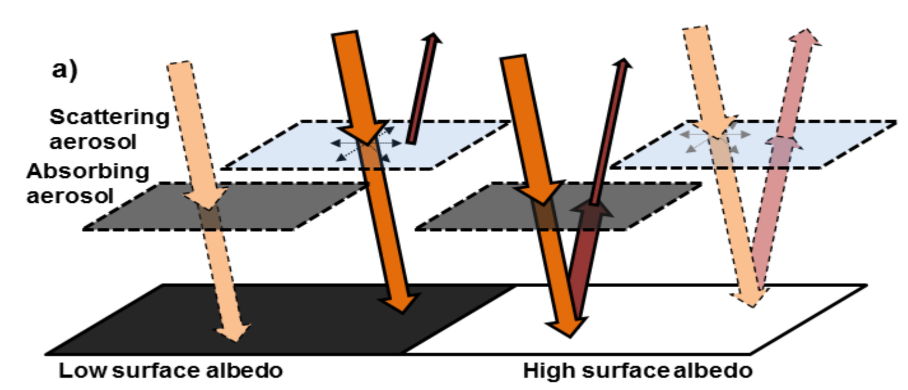
Anthropogenic AOD





Exctinction coef. (m^2/g)





S = Solar constant
T = Transmission
N = Cloudiness
g = Asymm Param
w = Single scatt. Albedo
a = Surface albedo
τ = Aerosol optical depth

$$\Delta F = -\frac{S}{4} T^2 (1-N)\,\tau\,[(1-a)^2(1-g)\omega - 4a(1-\omega)]$$

TOA aerosol radiative forcing (ΔF) is a strong function of the surface albedo that varies with latitude and cloud and aerosol distributions. Aerosol optical properties are derived from first principles from emissions inventory, atmospheric transport and transformations. Size resolved speciated treatments of aerosol processes and radiative transfer calculations based on mixing state are used to calculate aerosol optical properties.

Most models simulate a maximum negative radiative forcing around 20–50°N, in the region with highest aerosol concentrations. Most models show a positive forcing in the north due to the high albedo from ice and snow there.

The models have simplified or no treatments of SOA, a diversity of BC and OC treatments, that all need to catch up with observational findings discussed above.

Zonal Mean Albedo