

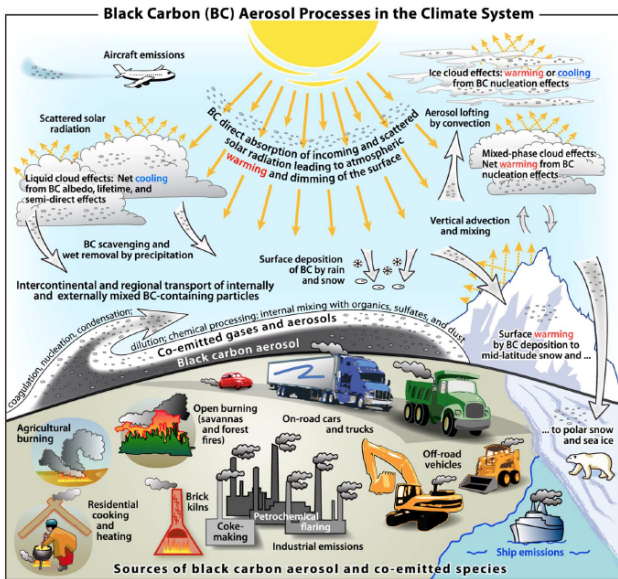
Climate Effects of Black Carbon Aerosols

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Acknowledgements:
Zamin Kanji and André Welts

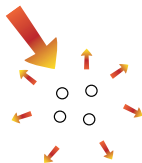




Aerosol-radiation interactions

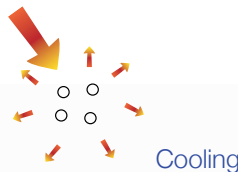
Scattering aerosols

(a)



Aerosols scatter solar radiation. Less solar radiation reaches the surface, which leads to a localised cooling.

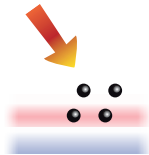
(b)



The atmospheric circulation and mixing processes spread the cooling regionally and in the vertical.

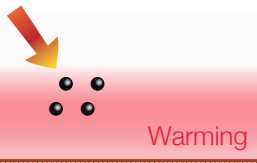
Absorbing aerosols

(c)



Aerosols absorb solar radiation. This heats the aerosol layer but the surface, which receives less solar radiation, can cool locally.

(d)



At the larger scale there is a net warming of the surface and atmosphere because the atmospheric circulation and mixing processes redistribute the thermal energy.

Vertical profiles of BC

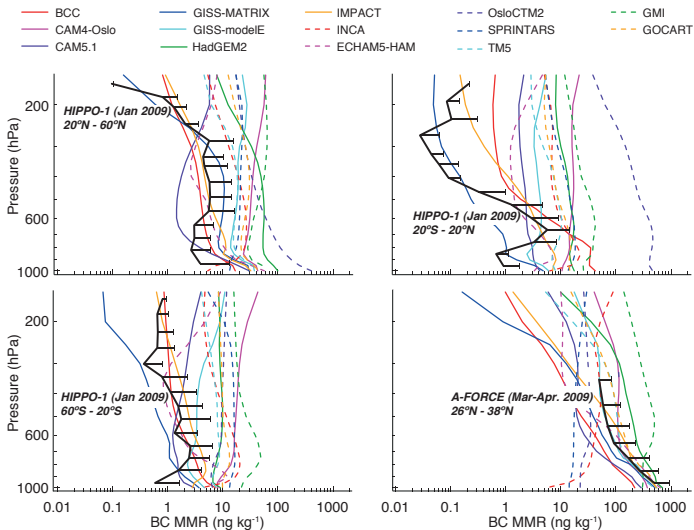
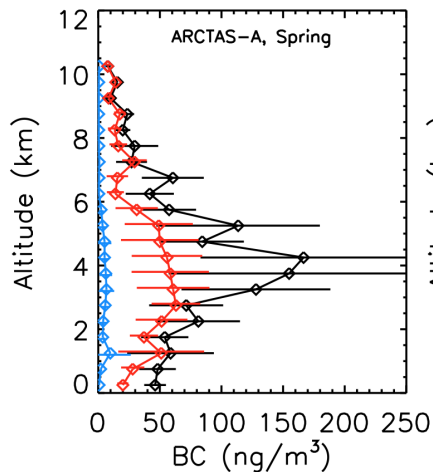
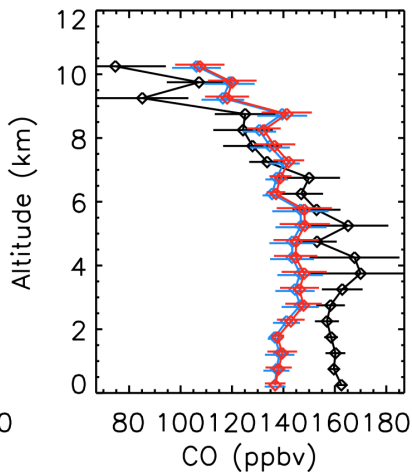


Fig. 7.15 (IPCC, 2013)

Transport to the Arctic



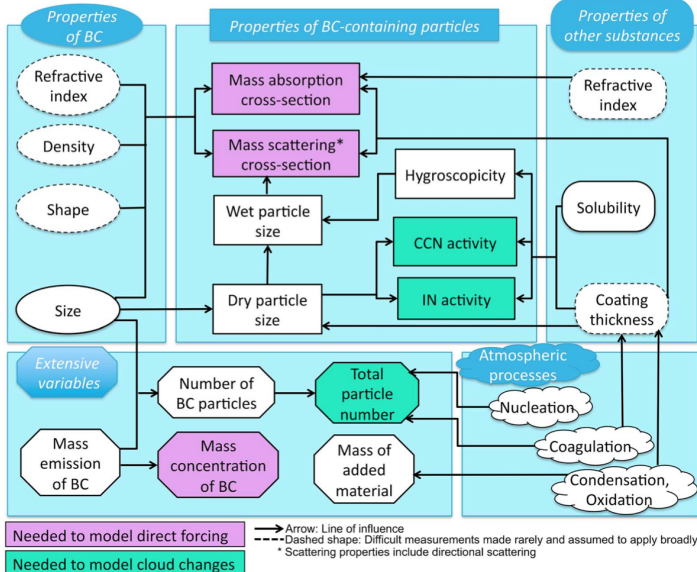
STD - $R^2 = 0.46$ - Mean bias (%) = 95.4
 NEW - $R^2 = 0.69$ - Mean bias (%) = 38.0



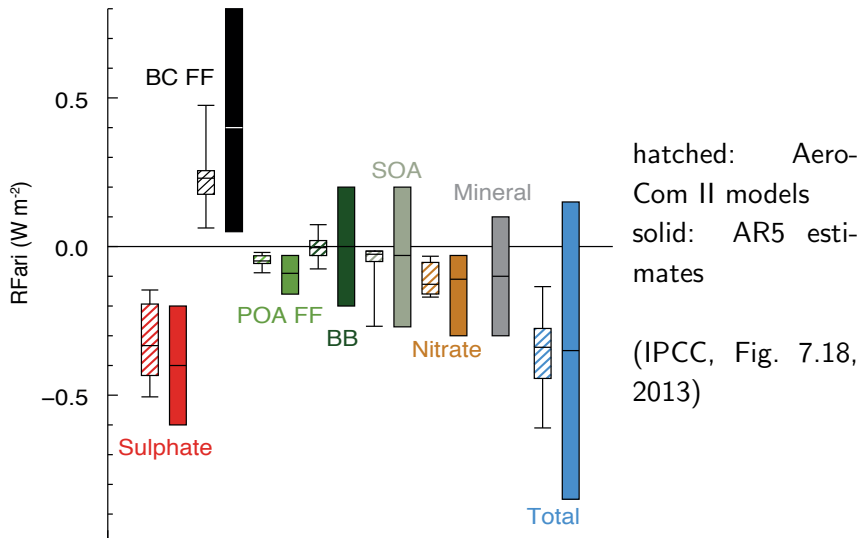
STD - $R^2 = 0.81$ - Mean bias (%) = 12.8
 NEW - $R^2 = 0.79$ - Mean bias (%) = 12.7

Bourgeois and Bey, JGR (2011)

Properties of BC and BC-containing particles and their connections to climate models

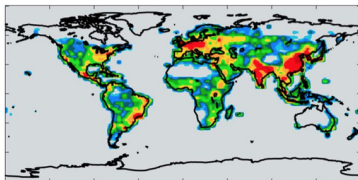


Aerosol radiative forcing 1750-2010

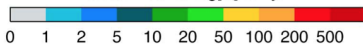


Black carbon diagnostics in the HadGEM1 climate model

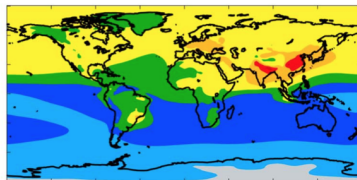
(a) Emissions



Mean = $15.43 \text{ mg[C] m}^{-2} \text{ yr}^{-1}$



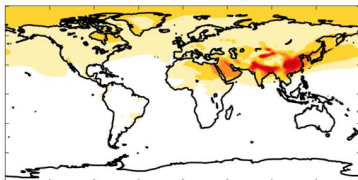
(b) Burden



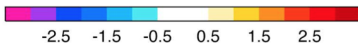
Mean = $0.82 \text{ mg[C] m}^{-2}$



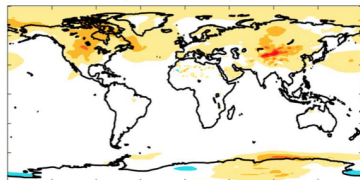
(c) Climate forcing



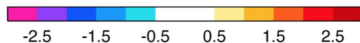
Mean = $+0.45 \text{ W m}^{-2}$



(d) Temperature response



Mean = $+0.28 \text{ K}$

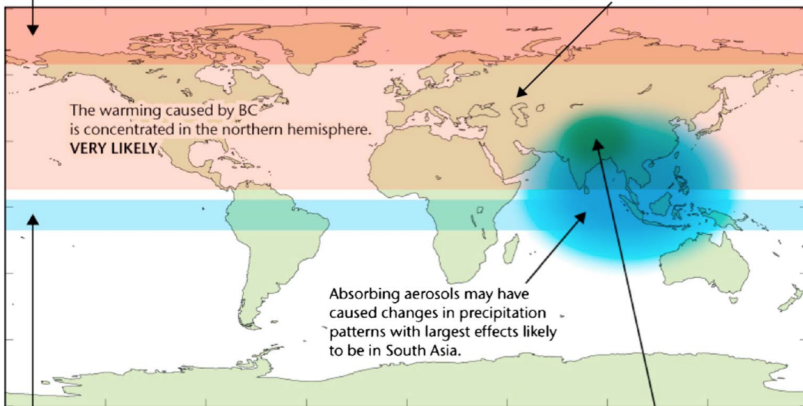


Climate effects of black carbon emissions

The impact of BC on snow and ice causes additional warming in the Arctic region and contributes to snow/ice melting.

VERY LIKELY BUT MAGNITUDE UNCERTAIN

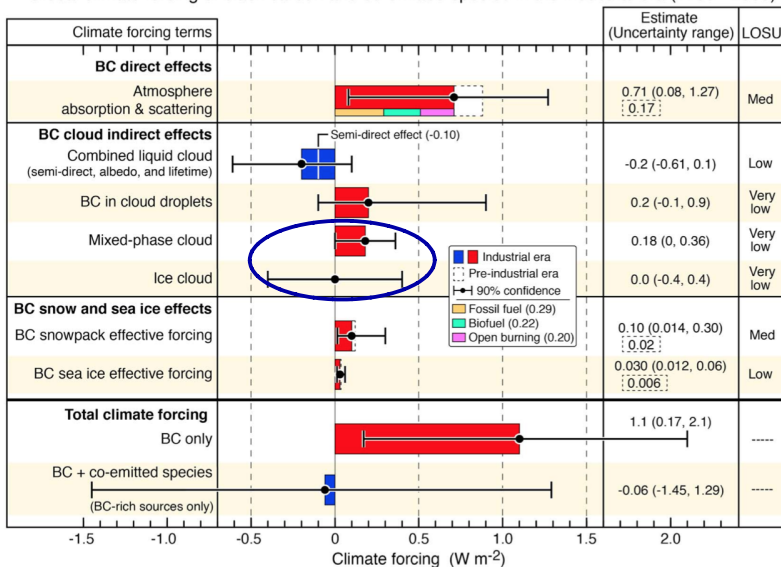
BC in northern hemisphere mid-latitude snow leads to earlier springtime melt and reduces snow cover in some regions. **LIKELY BUT MAGNITUDE UNCERTAIN**



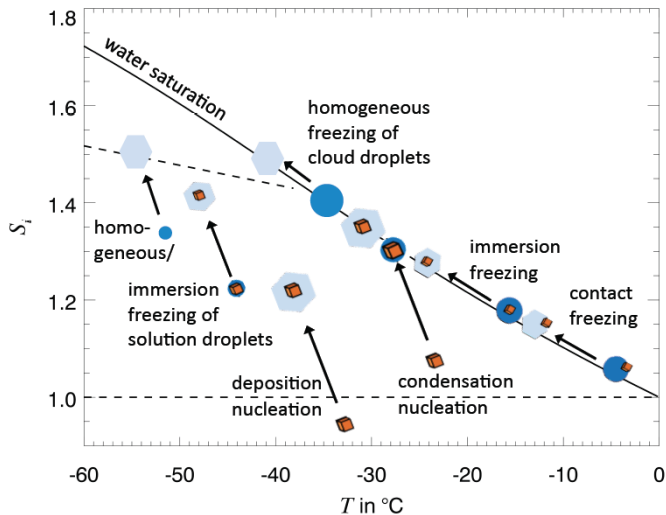
The hemispheric nature of the BC forcing causes a northward shift in the ITCZ. **LIKELY.**

Absorbing aerosols may cause circulation changes over the Tibetan Plateau and darkening of the snow. The importance of this for glacier melting is unknown.

Global climate forcing of black carbon and co-emitted species in the industrial era (1750 - 2005)

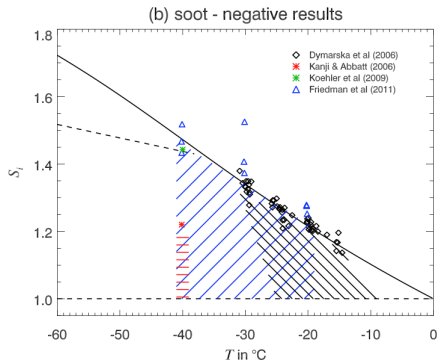
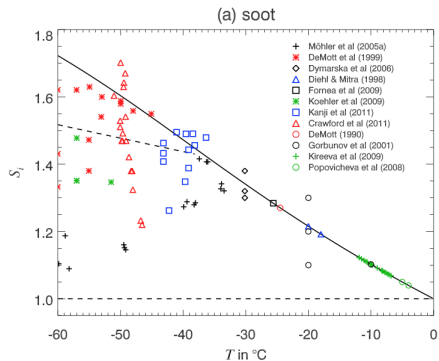


Heterogeneous freezing



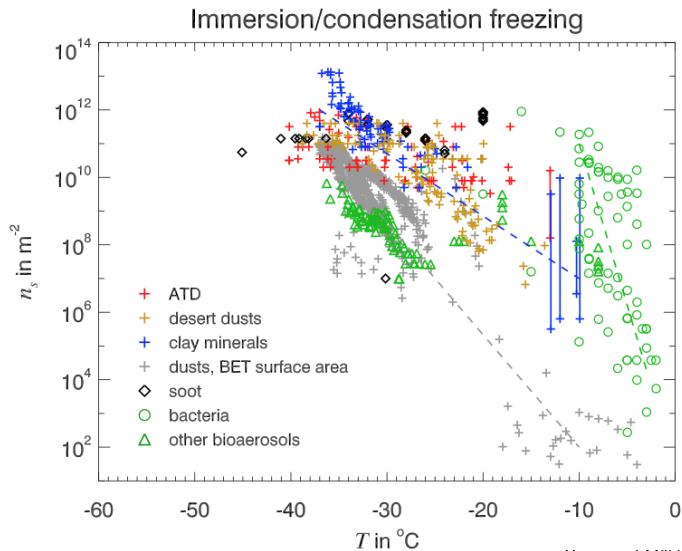
Hoose and Möhler, ACP (2012)

Compilation of freezing data on soot



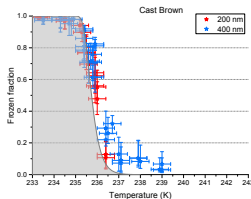
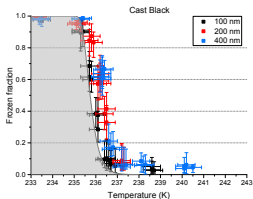
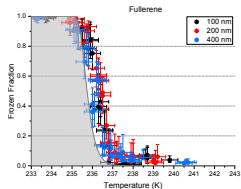
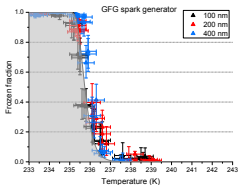
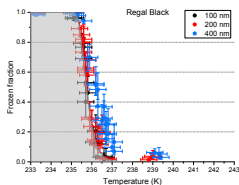
Hoose and Möhler, ACP (2012)

Ice nucleation active surface site (INAS) density



Hoose and Möhler, ACP (2012)

Frozen fraction of droplets containing BC



Courtesy André Welti and Zamin Kanji (ETHZ)

Conclusions

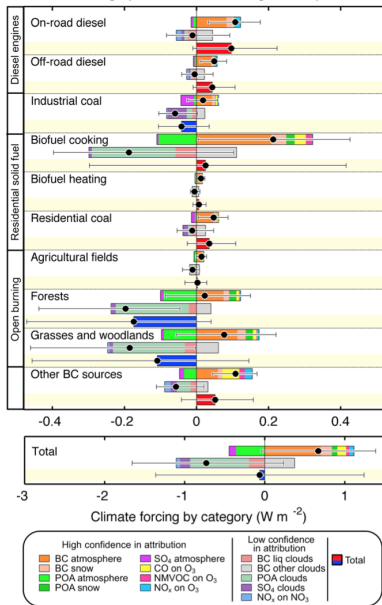
BC as ice nuclei:

- ▶ BC nucleates ice only at rather cold temperatures
- ▶ The studies testing BC as an ice nuclei obtain conflicting results

Climate effects of BC:

- ▶ The total climate forcing of BC is positive, but could be close to zero if co-emitted species are considered as well
- ▶ The effect of BC on clouds seems to counteract its direct radiative effect, but they are much more uncertain

Climate forcing by BC-rich source categories in year 2005



BC-rich sources comprise 99% of all BC emissions

- ▶ Top bar: direct forcing by aerosol and most gases and aerosol cryosphere forcing
- ▶ Middle bar: cloud effects and nitrate
- ▶ Bottom bar: net climate forcing by each emission source

Bond et al., JGR (2013)

