Black carbon in the atmosphere: Importance, emission estimates, and monitoring

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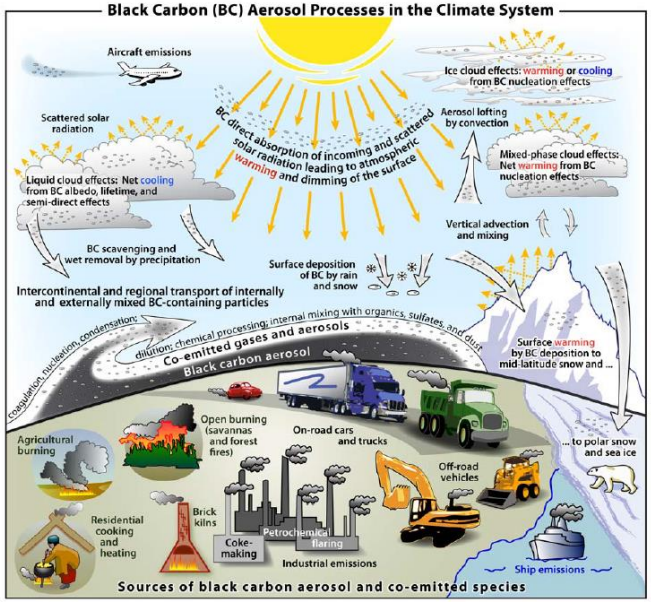
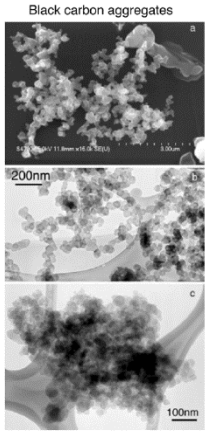
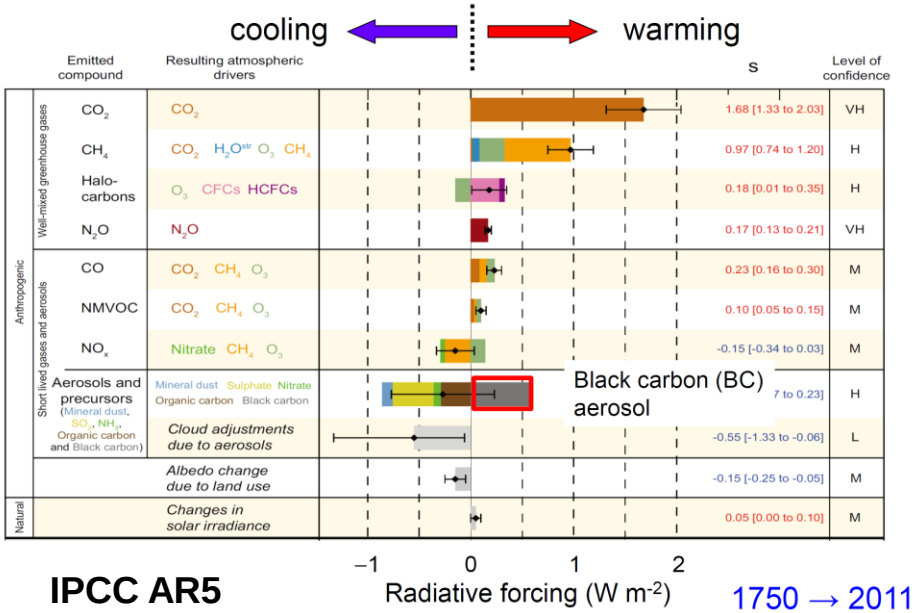
Reference

Kondo, Y. (2015), Effects of black carbon on climate: Advances in measurement and modeling, *Monogr. Environ. Earth Planets*, *3*, 1-85, doi:10.5047/meep.2015.00301.0001.

Importance of black carbon (BC)（Bond et al, 2013）







IPCC AR5

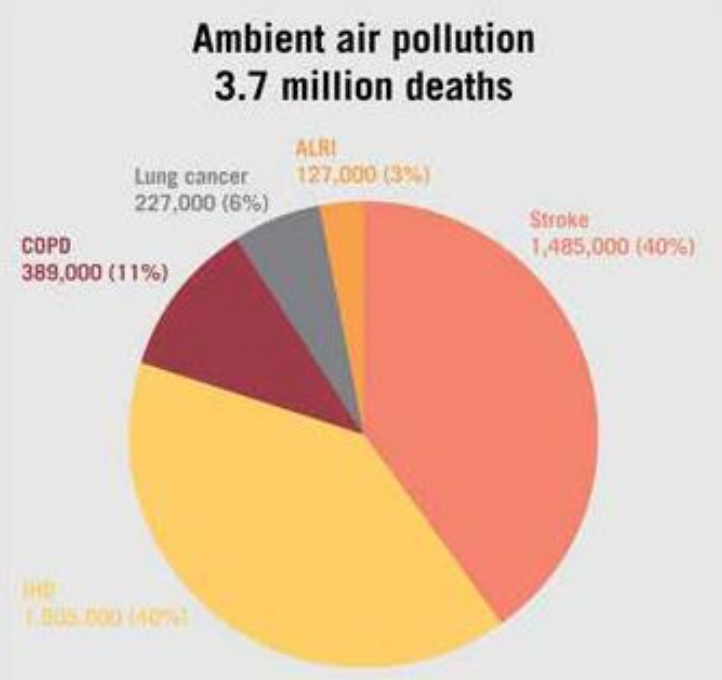
1750 → 2011

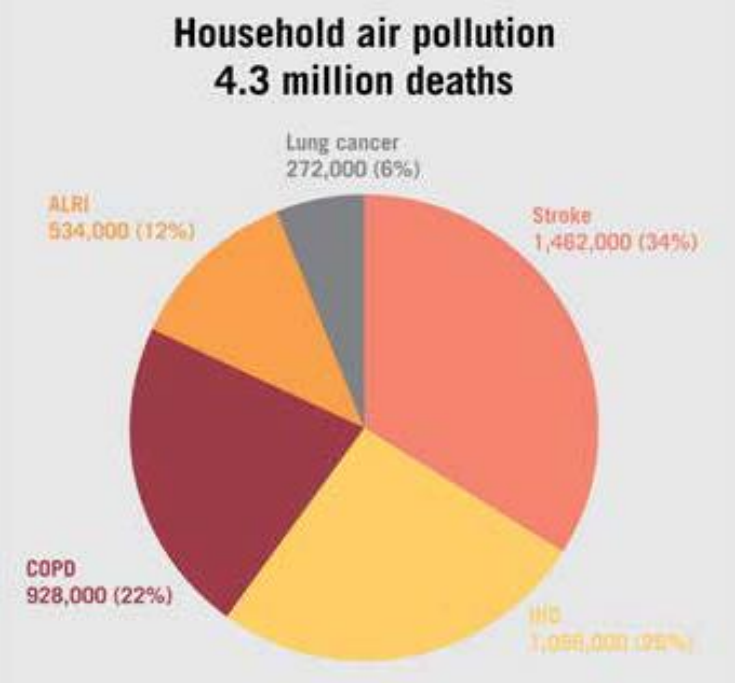
BC is emitted by incolmpete combustion of fossil fuels and biomass
It strongly absorbs solar visible radiation and heats the atmosphere
It deposits on snow and ice and contributes to the warming of the Arctic

BC is the third largest global warming agent, after CO_2 and CH_4
BC and CH_4 are most important short-lived climate forcers (SLCFs)
BC direct radiative forcing (DRF): 0.6 W m^{-2} (about 1/3 of CO_2; IPCC AR5)

However, large uncertainties in the BC DRF
1) BC emissions
2) Processes that control BC distributions

Co-benefit of BC reduction: health effect





Deaths attributable to ambient air pollution, 2012.

ALRI = acute lower respiratory infections; IHD = ischemic heart disease; COPD = chronic obstructive pulmonary disease.
(WHO, 2014)

Emission estimates of BC

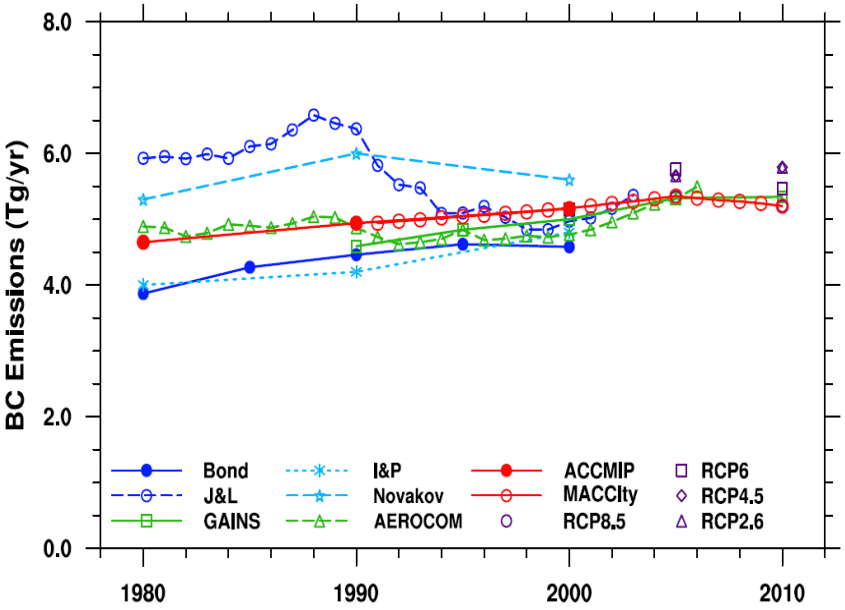
BC emission inventories are currently not required by the UNFCCC.

However, Expert Meeting on Short-Lived Climate Forcers (EM-SLCFs) organized by IPCC Task Force on National Greenhouse Gas Inventories (TFI) will make a recommendation that IPCC TFI will take a lead to make a guideline to compile emission inventories of SLCFs in a consistent manner with those for GHGs (May 2018, tentative information).

SLCFs include BC, organic carbon (OC), PM2.5, NO_x, CO, NMVOCs, SO_2, and NH_3.

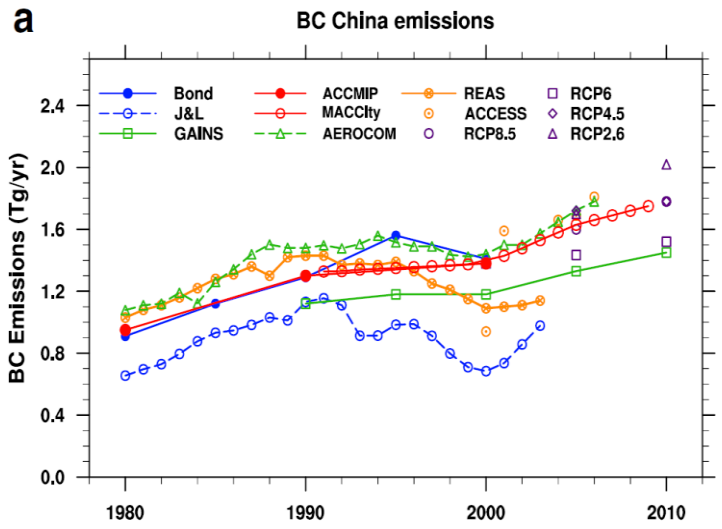
Estimates of BC emission

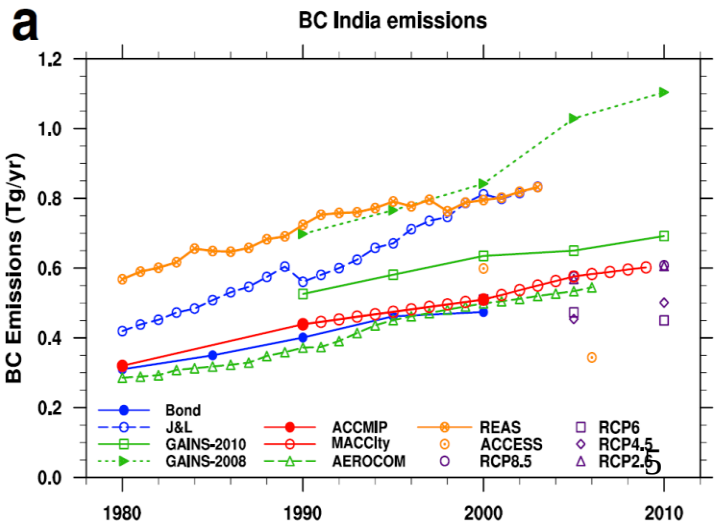
Global emissions
5.0 – 6.0 Tg year^{-1} in 2010



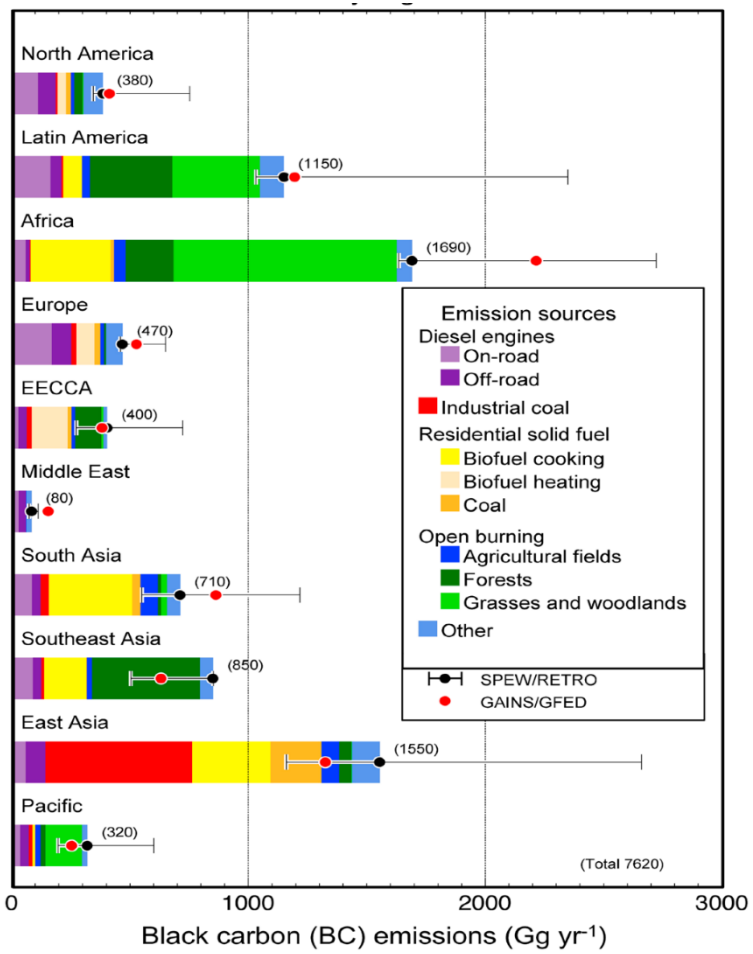
Granier et al., 2011
adopted in AMAP report, 2015

These estimates need to be re-evaluated





Emission of BC by region (2000)



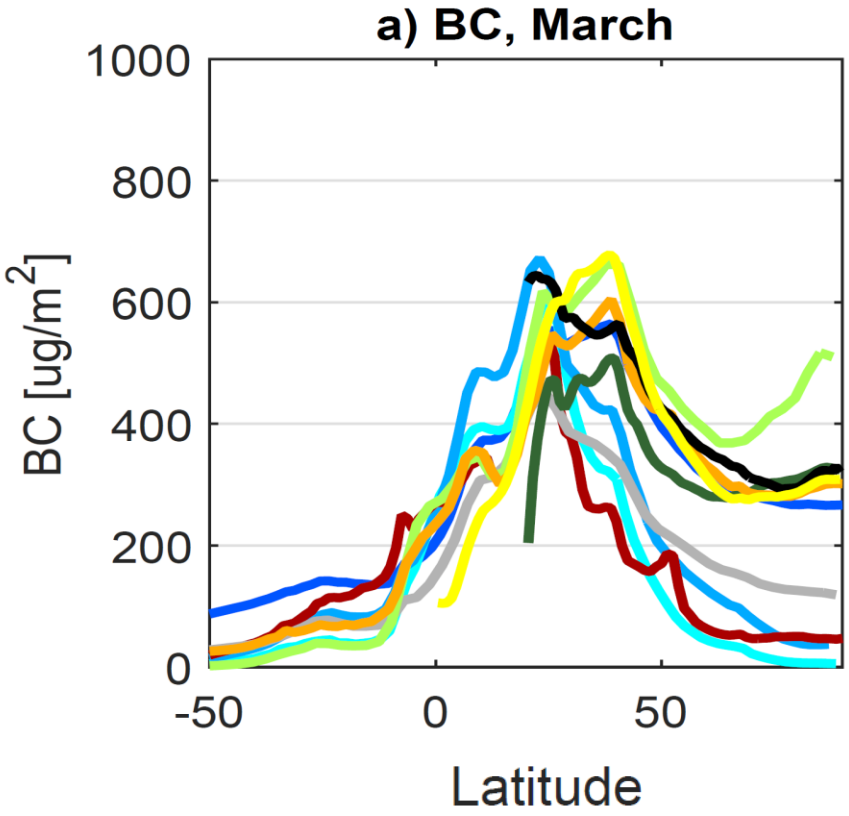
Bond et al. (2013)

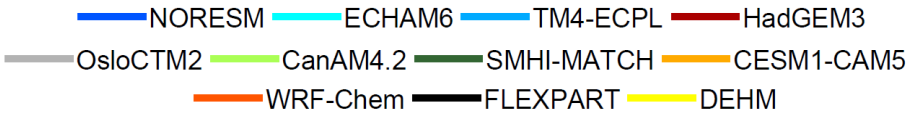
Data sources: SPEW, GAINS, and RETRO

7.5 Tg year^{-1} in 2000

The types of BC vary greatly, depending on the regions

Uncertainties in model calculations of BC



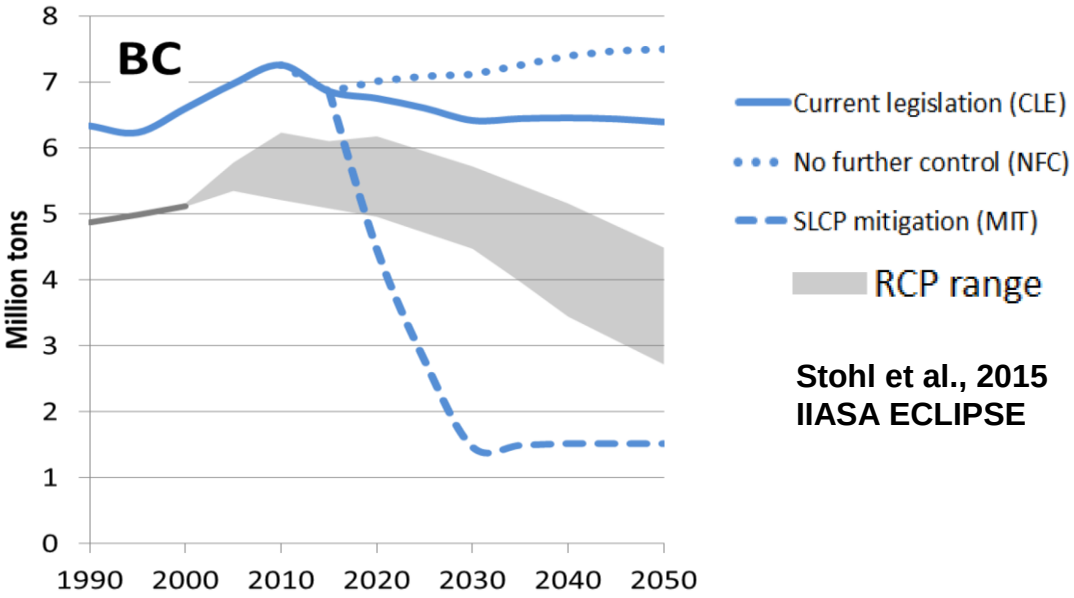


Eckhardt et al., 2015

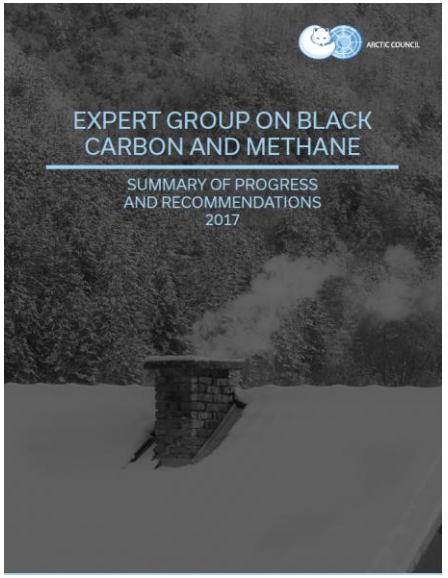
Large variabilities in the BC column amounts calculated by models. Uncertainties in 1) emissions and 2) removal during transport are major sources of errors

Improved estimates in BC emissions are highly needed

Scenarios of BC emission and Arctic warming



Stohl et al., 2015
IIASA ECLIPSE



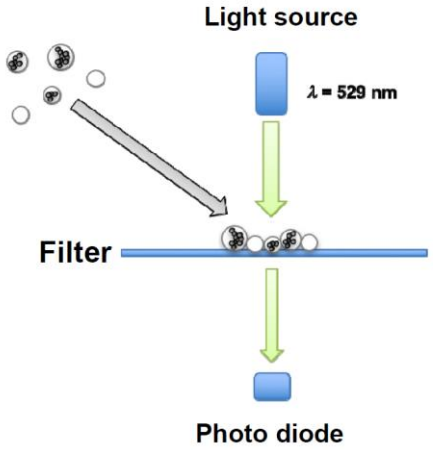
Ambitious reductions of BC emission are recommended, for example, by the Expert Group on Black Carbon and Methane (EGBCM) of the Arctic Council (AC) to partially mitigate global warming caused by the increase in long-lived GHGs

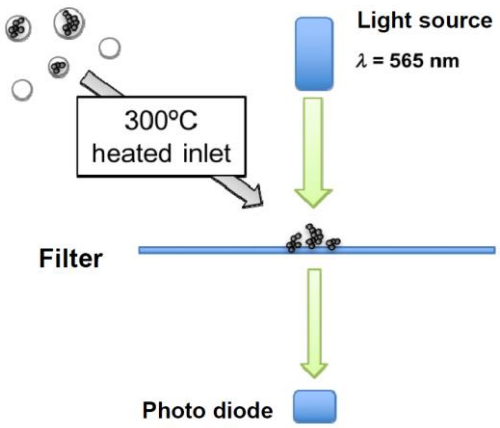
EGBCM is taking an initiative to compile BC emission inventories for AC countries and observer countries

National reports from these countries were submitted in 2017

COSMOS (Continuous soot monitoring system) for BC measurements

Extinction coefficient (b_0) is derived by the change in the transmittance through the filter loaded with aerosols





PSAP and Aethalometer

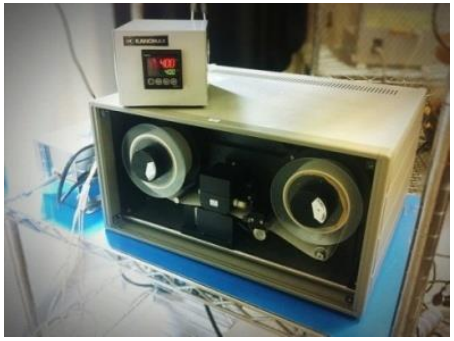
b_{abs} **(PSAP) =** $f_{fil}b_0 - f_{sca}b_{sc}$

Correction of non-BC aerosols ($f_{sca}b_{sc}$) is a source of large errors

Remove non-BC particles by heating (300ºC)

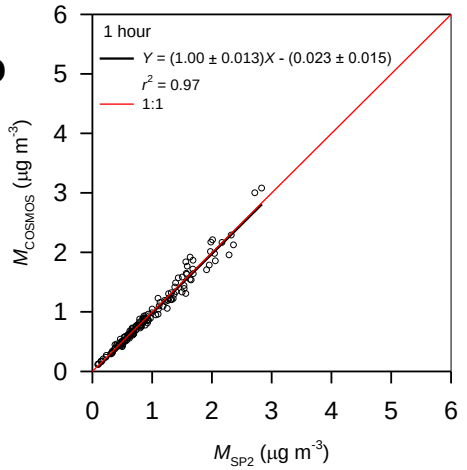
b_{abs} **(COSMOS) =** $f_{fil}b_0$

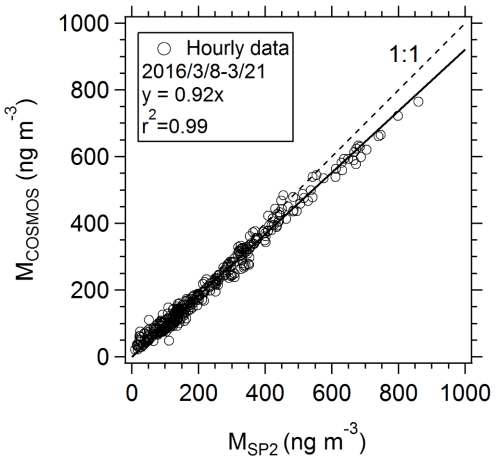
No interference by non-BC aerosols



BC mass concentration (M_{BC}) inter-comparison

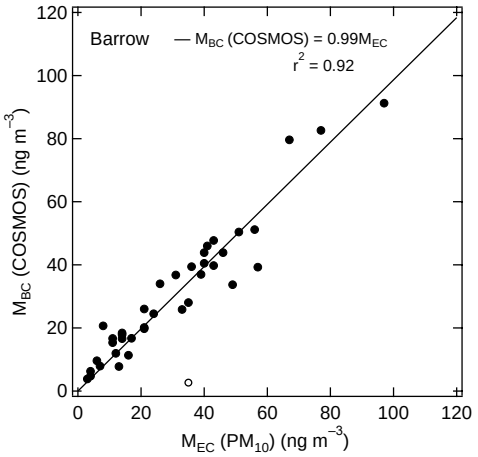
Tokyo

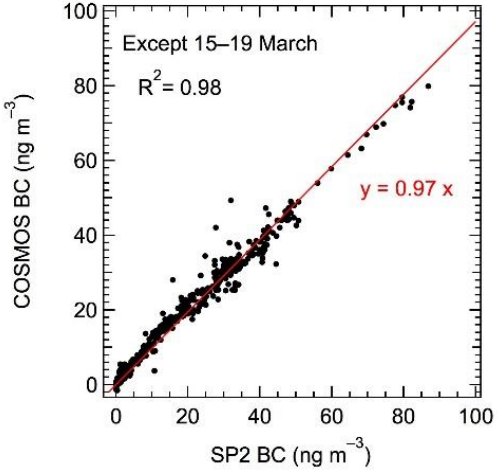




Hedo in Okinawa (downstream of China)

Barrow in Alaska



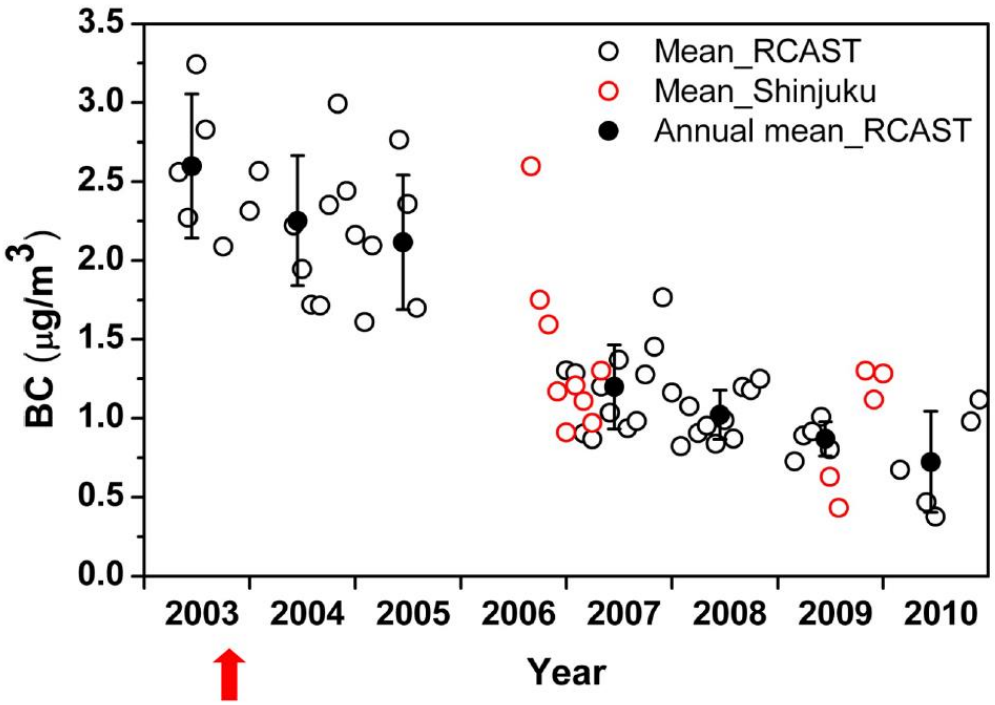


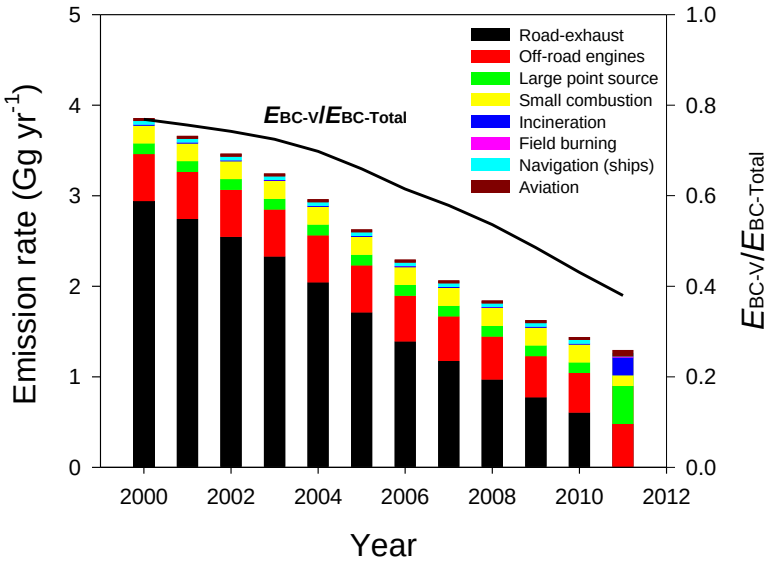
Ny-Alesund in Spitzbergen

SP2 and EC are not interfered by non-BC aerosols. However, they cannot be used for automated long-term observations.

M_{BC} (COSMOS) agreed with M_{BC} (SP2) or M_{BC} (EC) in Asia and the Arctic to within about 10%.

Reduction of BC in Tokyo in 2003-2010 (Kondo et al., 2012)





BC decreased to 1/3 in Tokyo over 7 years
This is due to stringent regulations of emissions of particles from vehicles implemented by MOEJ.

It is important to validate the effects of regulations of BC (PM2.5) by reliable measurements

Summary

1. **Black Carbon aerosol (BC) is one of the important SLCFs. However, there are large uncertainties in BC radiative forcing estimates (IPCC AR5), due partly to the uncertainties in the estimates of BC emissions.**

2. **Reductions of BC emissions are needed also for human health in Asia. It is important to improve estimates of emissions BC and other SLCFs**

3. **We have shown that BC can be measured by COSMOS with an accuracy of 10 % in Asia and the Arctic. Monitoring of BC by COSMOS is useful to validate the effects of regulations being implemented**

Acknowledgments

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