Black Carbon and Other "Short-Lived Climate Forcers": Climate change science

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Overview

- Short lived climate forcer concept
- Black carbon climate effects
- Estimates of magnitude
- Arctic focus
- Overview of current and projected emissions
- Considering full suite of emissions by sector
- Issues comparing black carbon to GHGs

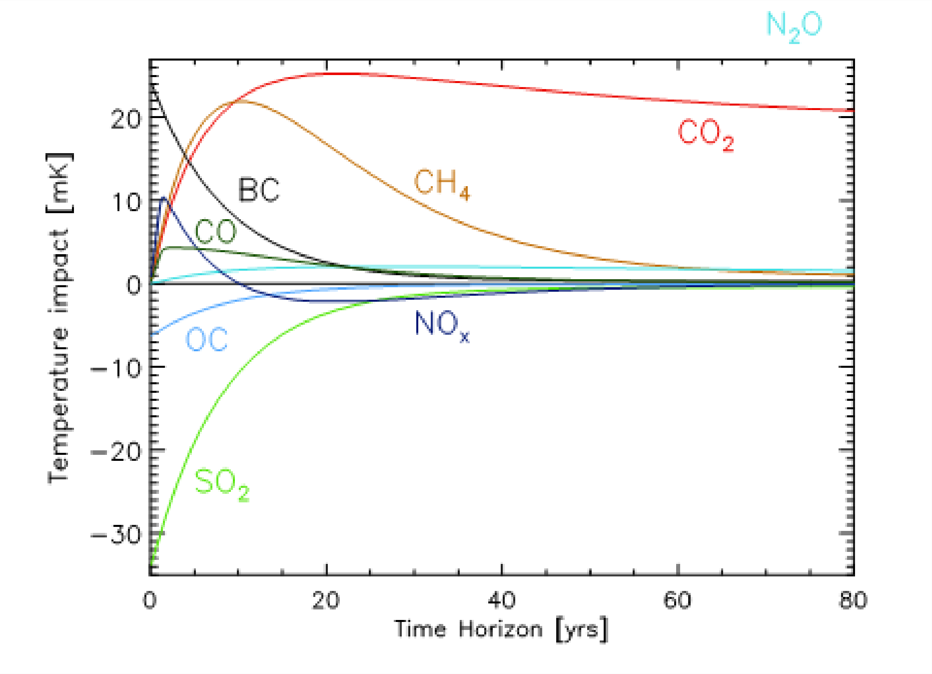
Short Lived Climate Forcer Concept

- Shorter atmospheric lifetime = faster climate response after reducing emissions

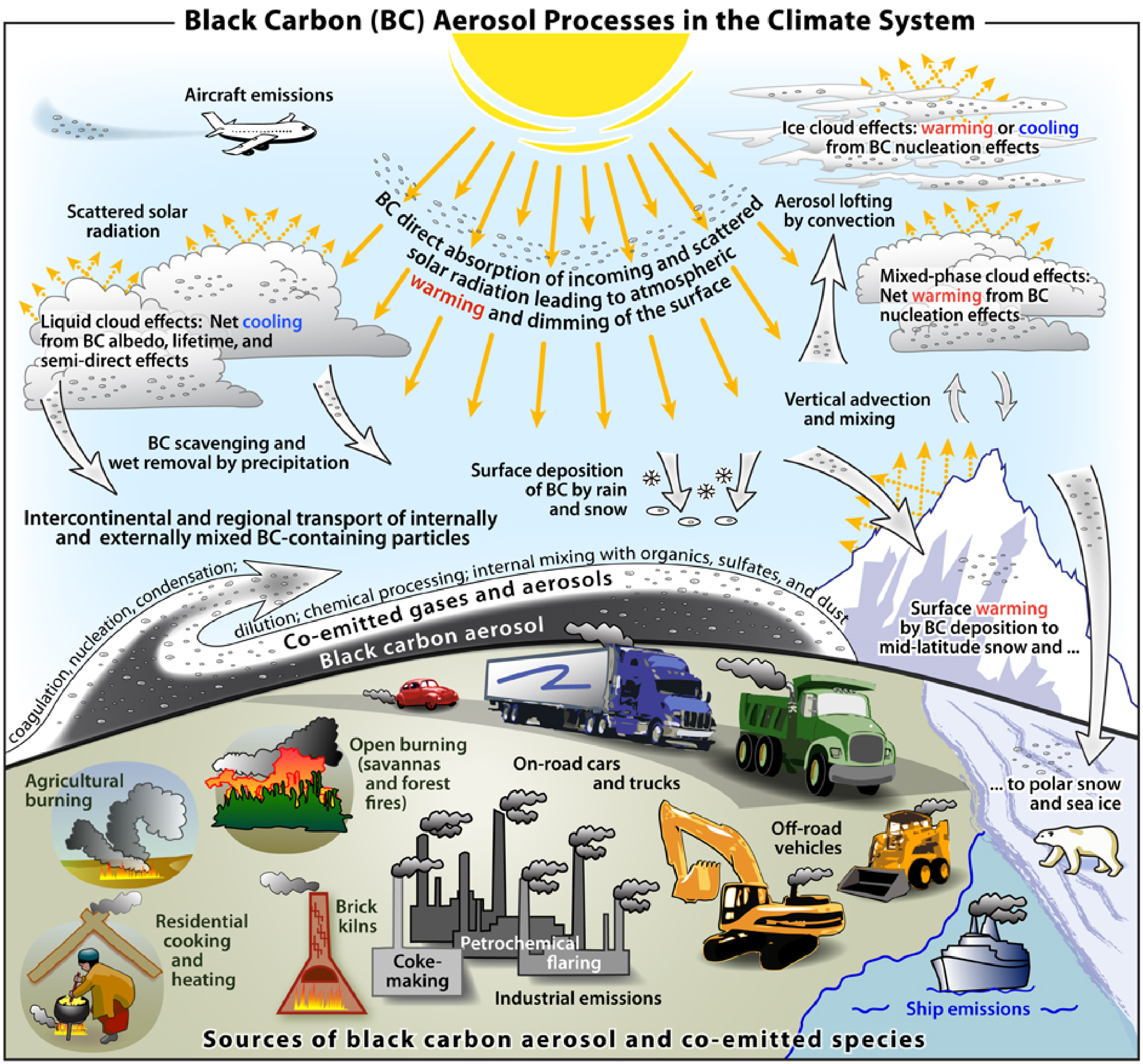
- Many forums/organizations have recently adopted this term
  - Climate and Clean Air Coalition to Reduce Short Lived Climate Forcers (CCAC)
  - Arctic Council

- SLCFs typically include methane (CH_4), black carbon (BC), HFCs, and sometimes tropospheric ozone (O_3)

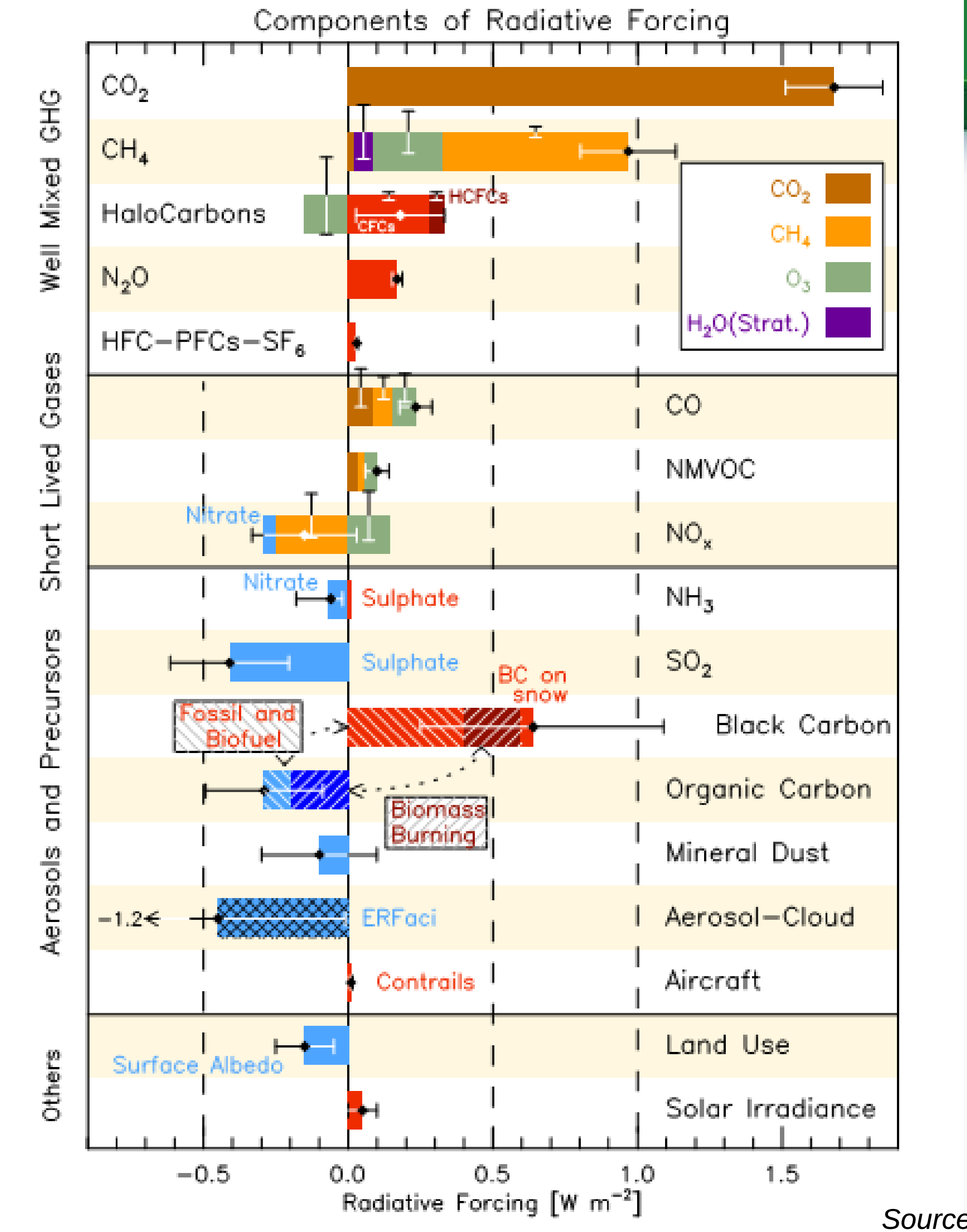
- Terminology can be confusing!
  - CH_4 and HFCs are part of 'basket of GHGs' that are long-lived, well-mixed in atmosphere



Source: IPCC AR5 WG1, Chapter 8, 2013



Source: Bond et al. (2013)



Updated globally averaged radiative forcing estimates from IPCC (2013)

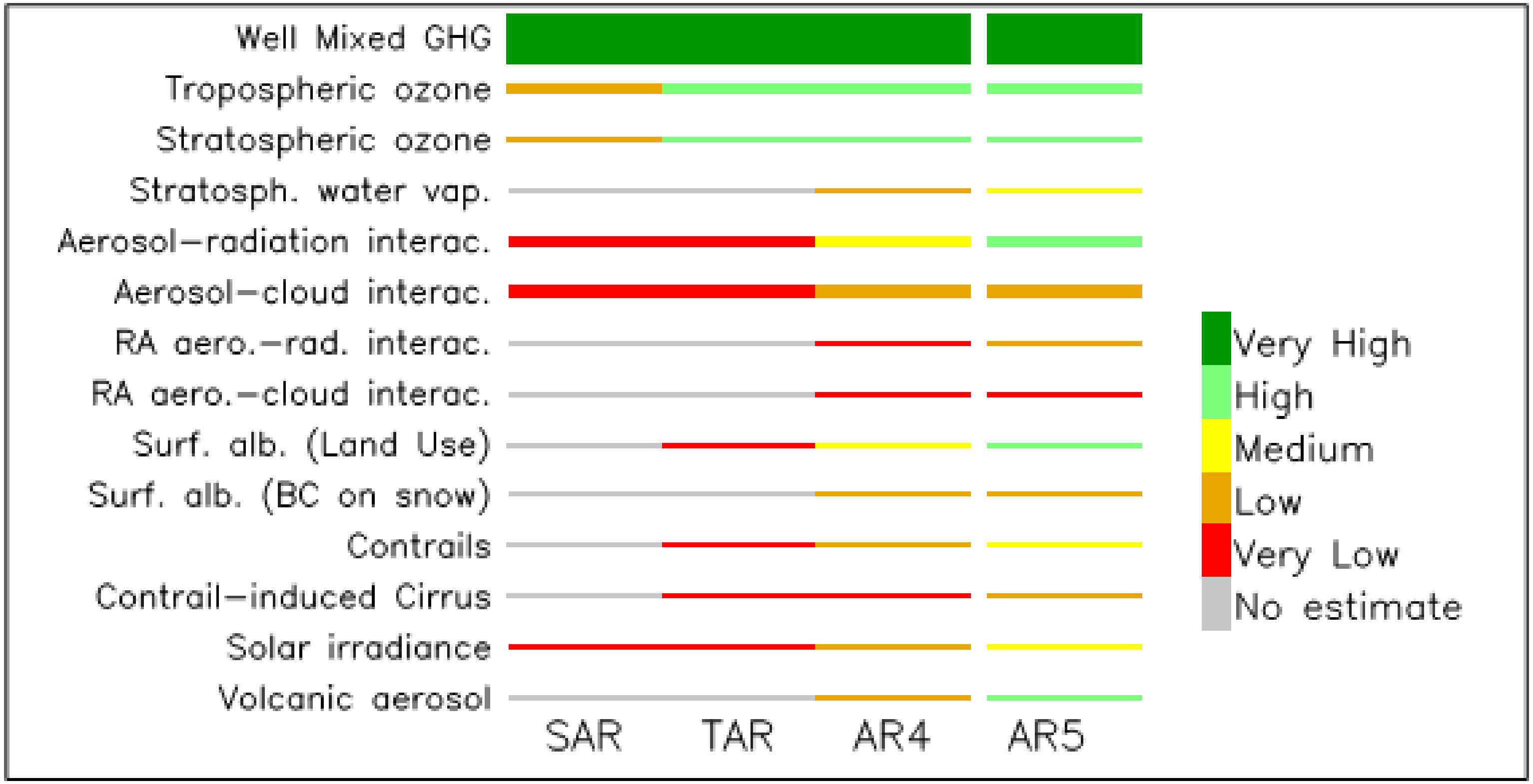
- CO_2, CH_4 and BC are largest warming agents
- BC warming effect less certain than well-mixed GHGs

- IPCC AR5 estimate of BC warming effect is twice as large as AR4
- AR5 estimate is within the range presented by EPA RTC
- AR5 estimate is somewhat smaller than Bond et al.
  (major multi-author paper including EPA authors published in January 2013)

Source: IPCC AR5 WG1, Chapter 8, 2013

Evolution of level of understanding of different climate agents (1995 to 2013)

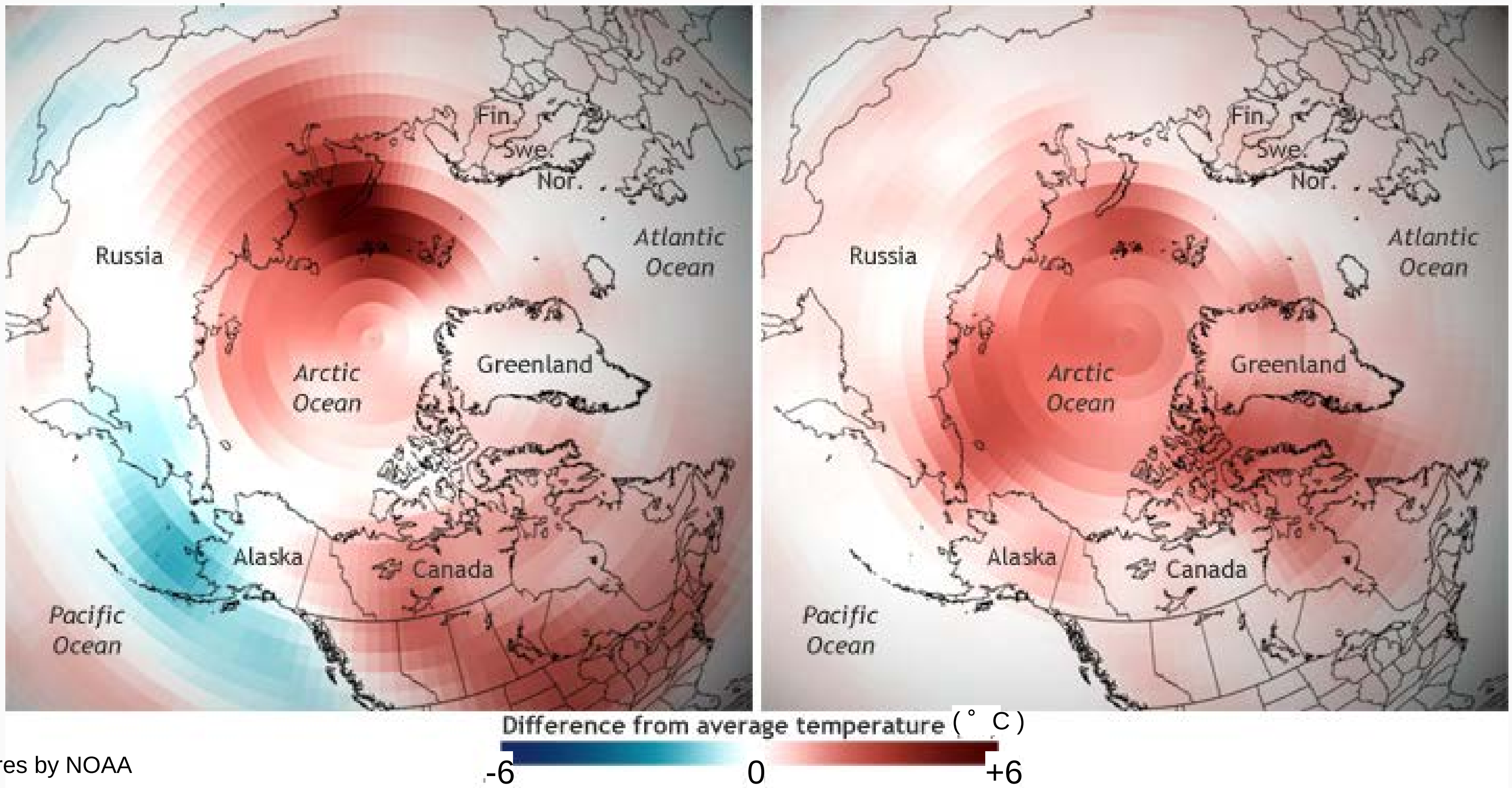
Well-mixed GHGs have always been, remain best understood; understanding for black carbon/aerosols improving, but interactions with clouds remain largest uncertainty



Source: IPCC AR5 WG1, Chapter 8, 2013

Arctic Amplification of Global Warming

Surface temperatures in the Arctic are increasing at about twice the rate of those in the rest of the World



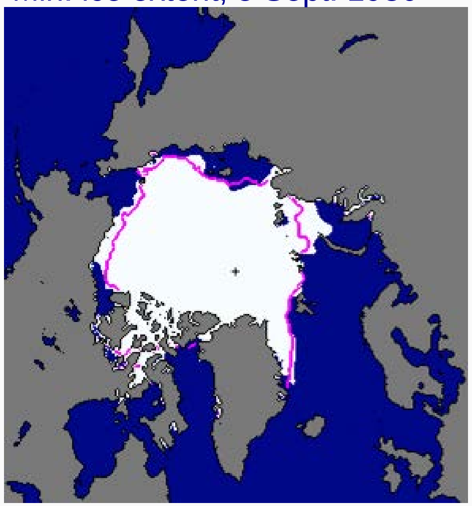
Figures by NOAA

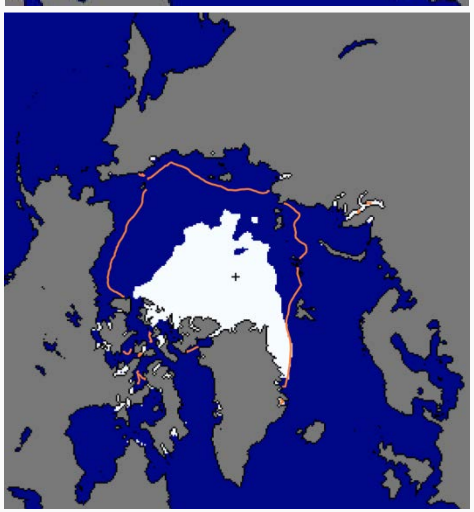
Temperature anomaly (° C) for October 2011 - September 2012 relative to the 1981-2010 average.

Temperature anomaly (° C) for 2001-2011 relative to 1971-2000.

Declining Sea Ice Extent…role of/for SLCFs?

Min. ice extent, 5 Sept. 1980

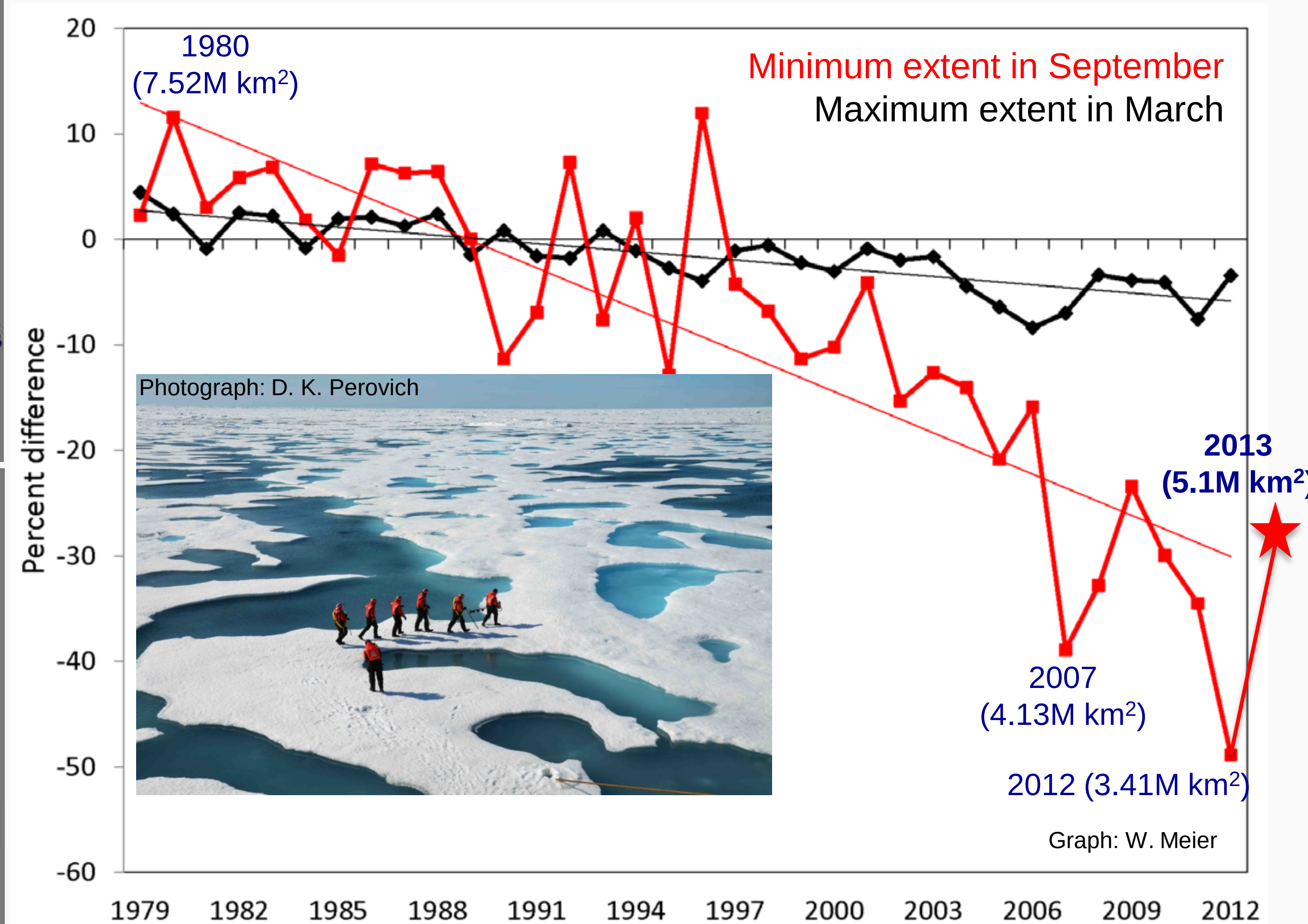




Min. ice extent, 16 Sept. 2012

Source: NSIDC

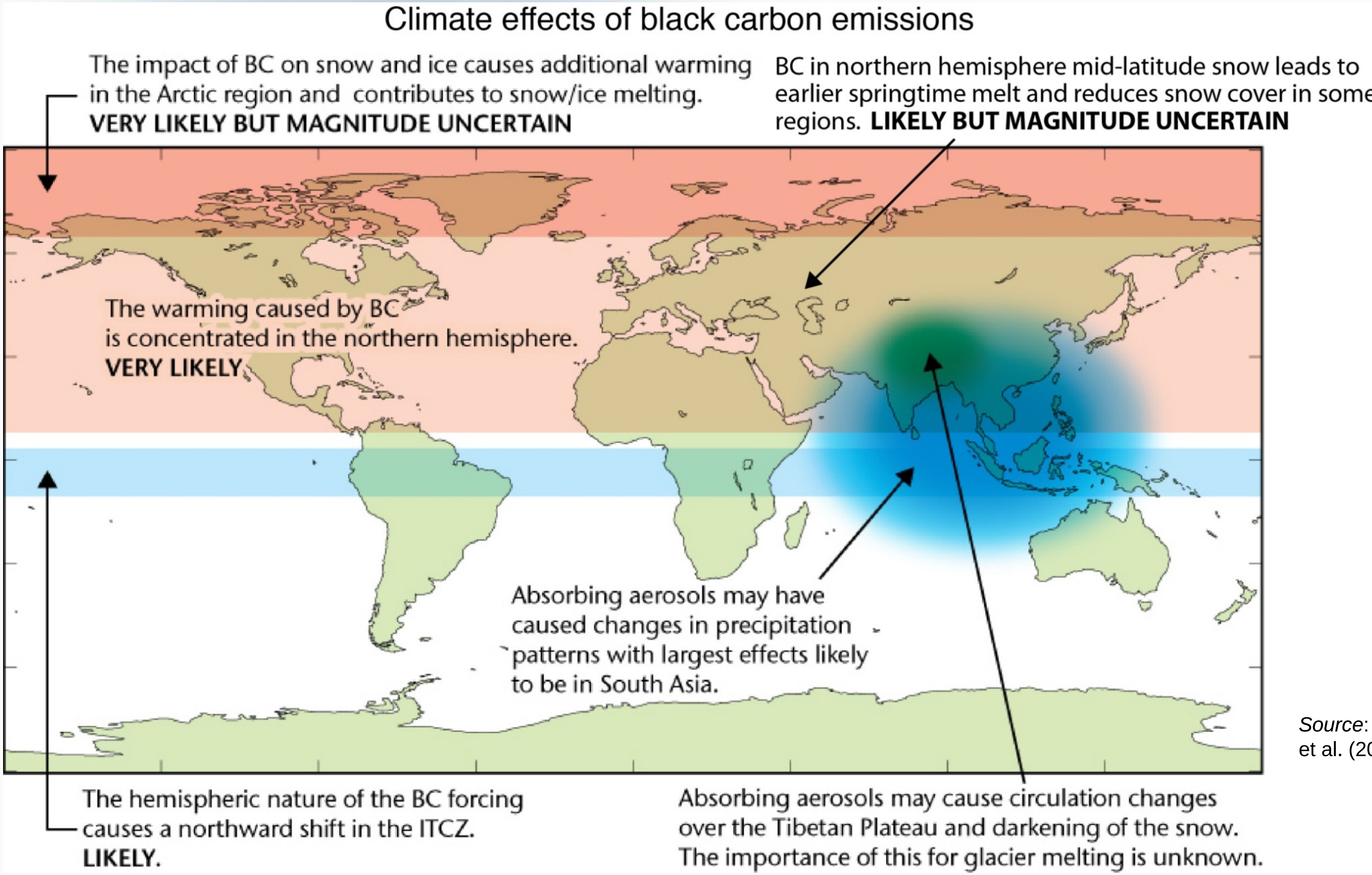
Anomaly relative to the 1979-2000 average



Trend of minimum ice extent: -13.0% per decade

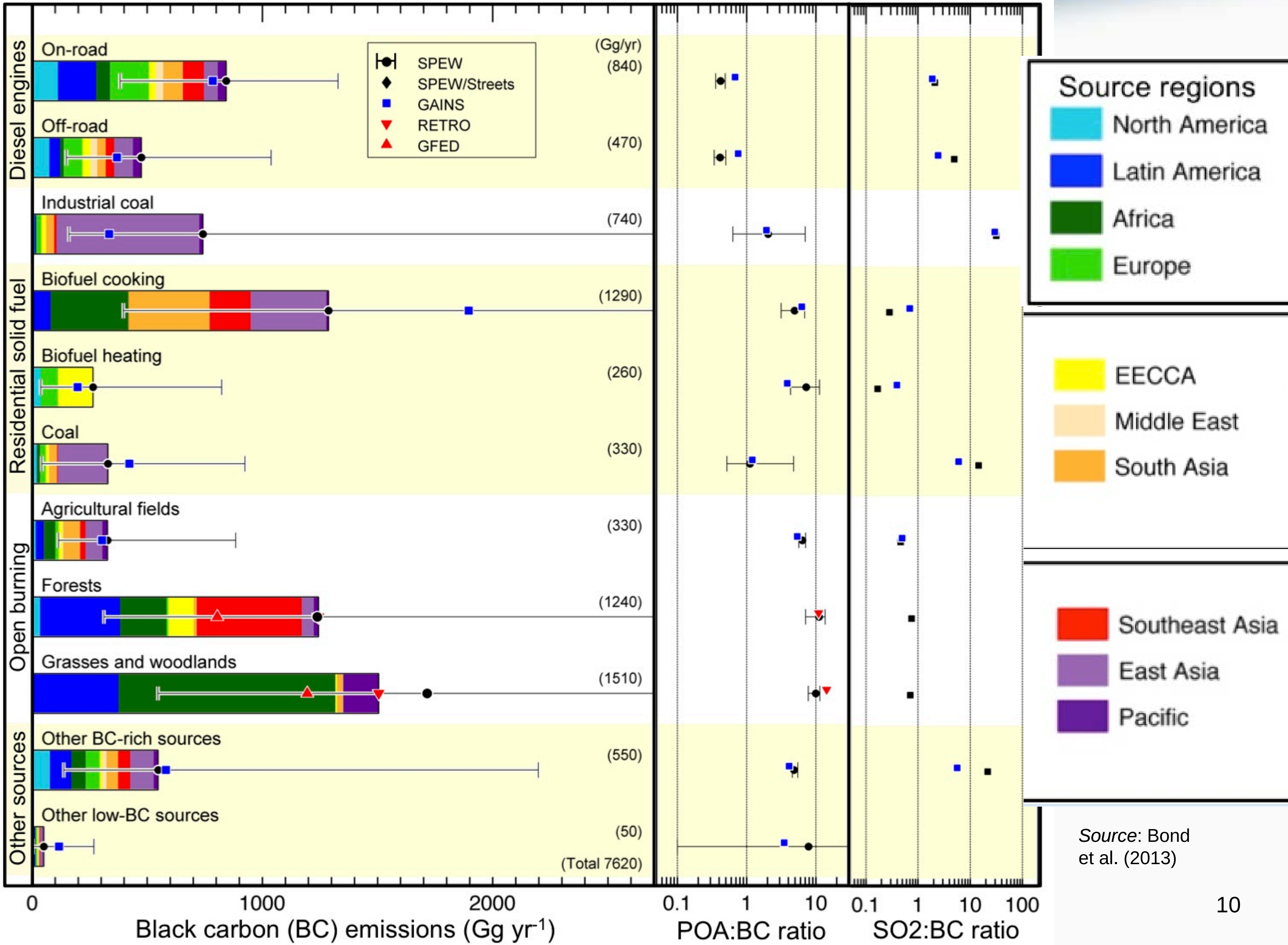
Trend of maximum ice extent: -2.6% per decade

Big picture black carbon climate effects

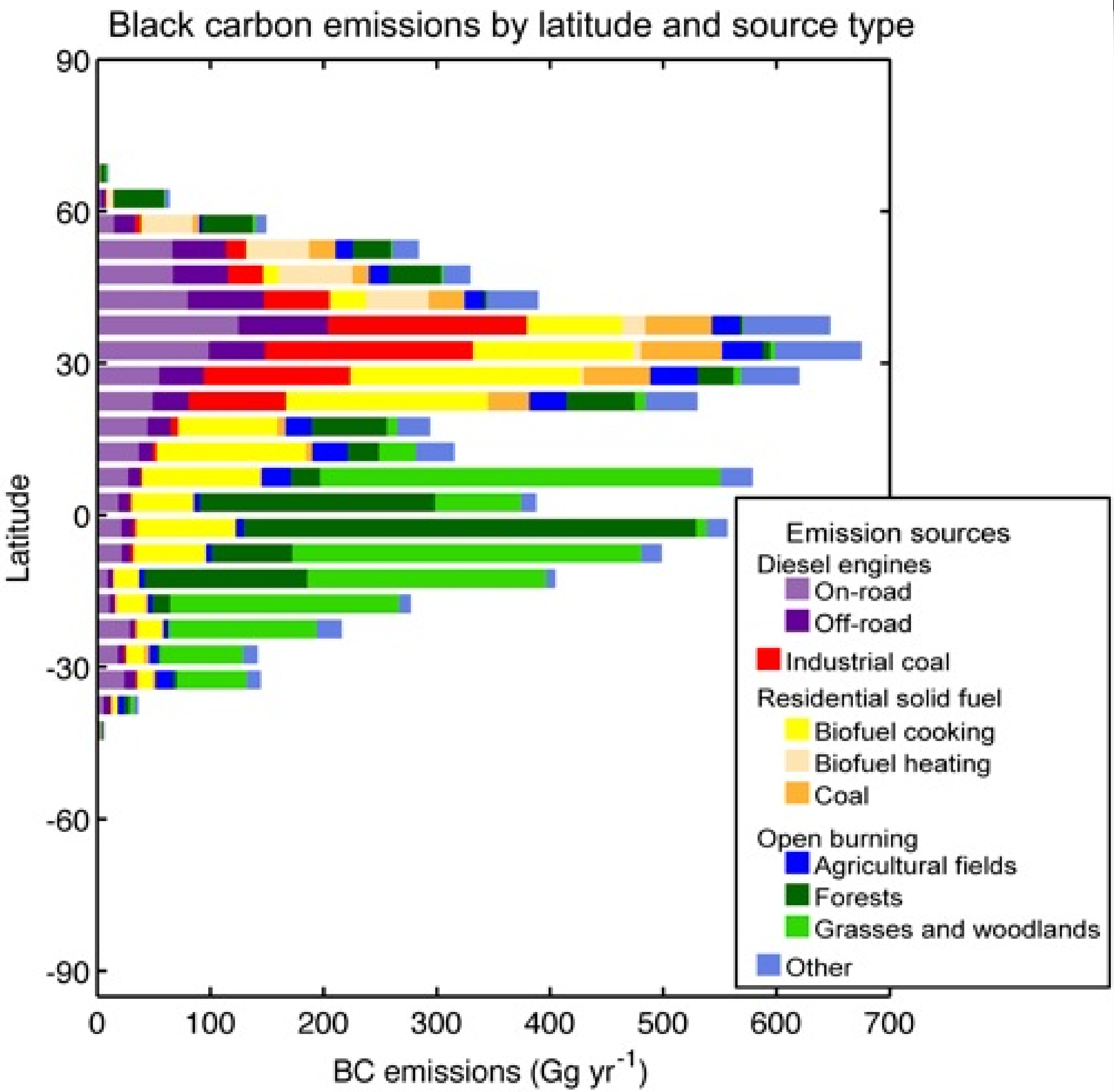


Source: Bond et al. (2013)

Black carbon and co-emitted species by region and source in 2000



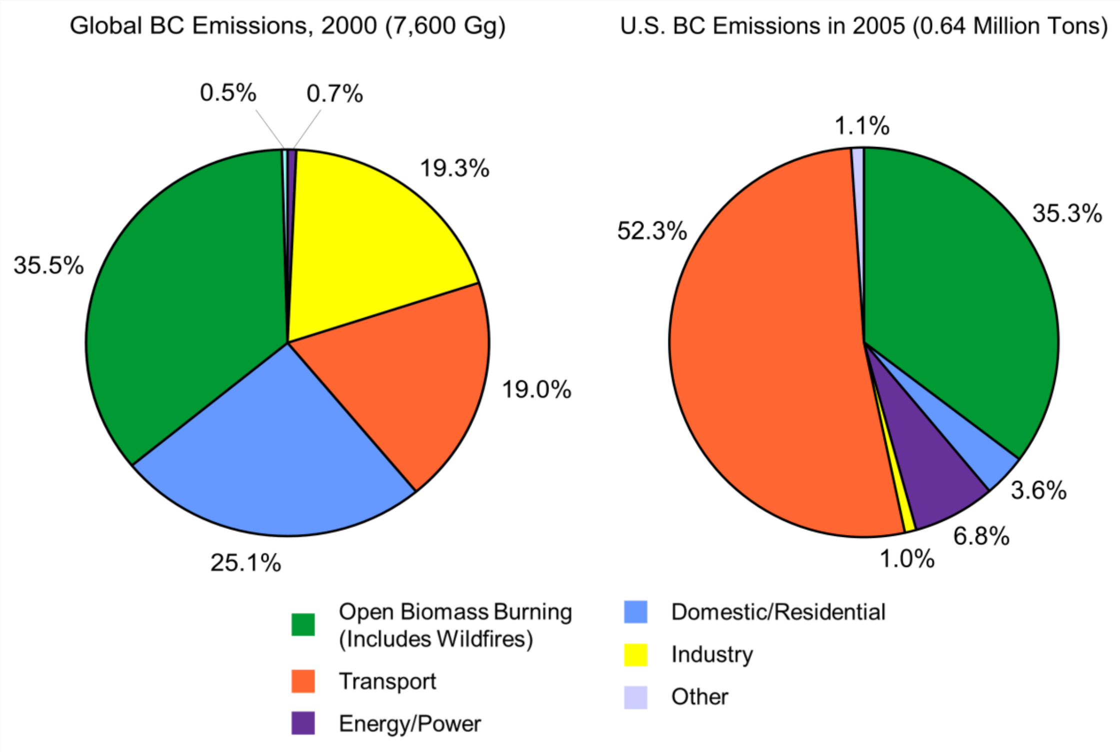
Source: Bond et al. (2013)



Source: Bond et al. (2013)

Global vs. U.S. black carbon emissions

- The United States currently accounts for approximately 8% of the global total, and this fraction is declining.



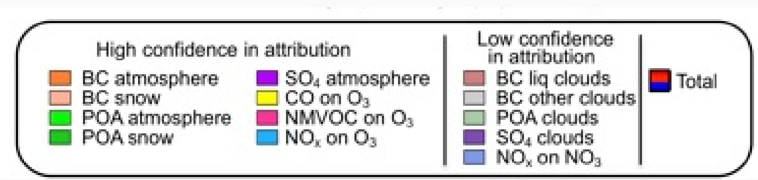
- U.S. 2005 BC emissions = 640,000 tons, or approximately 12% of all direct $PM_{2.5}$ emissions nationwide.
- Mobile sources are the largest U.S. BC emissions category.
  - Diesel engines and vehicles account for 93% of mobile source BC emissions.

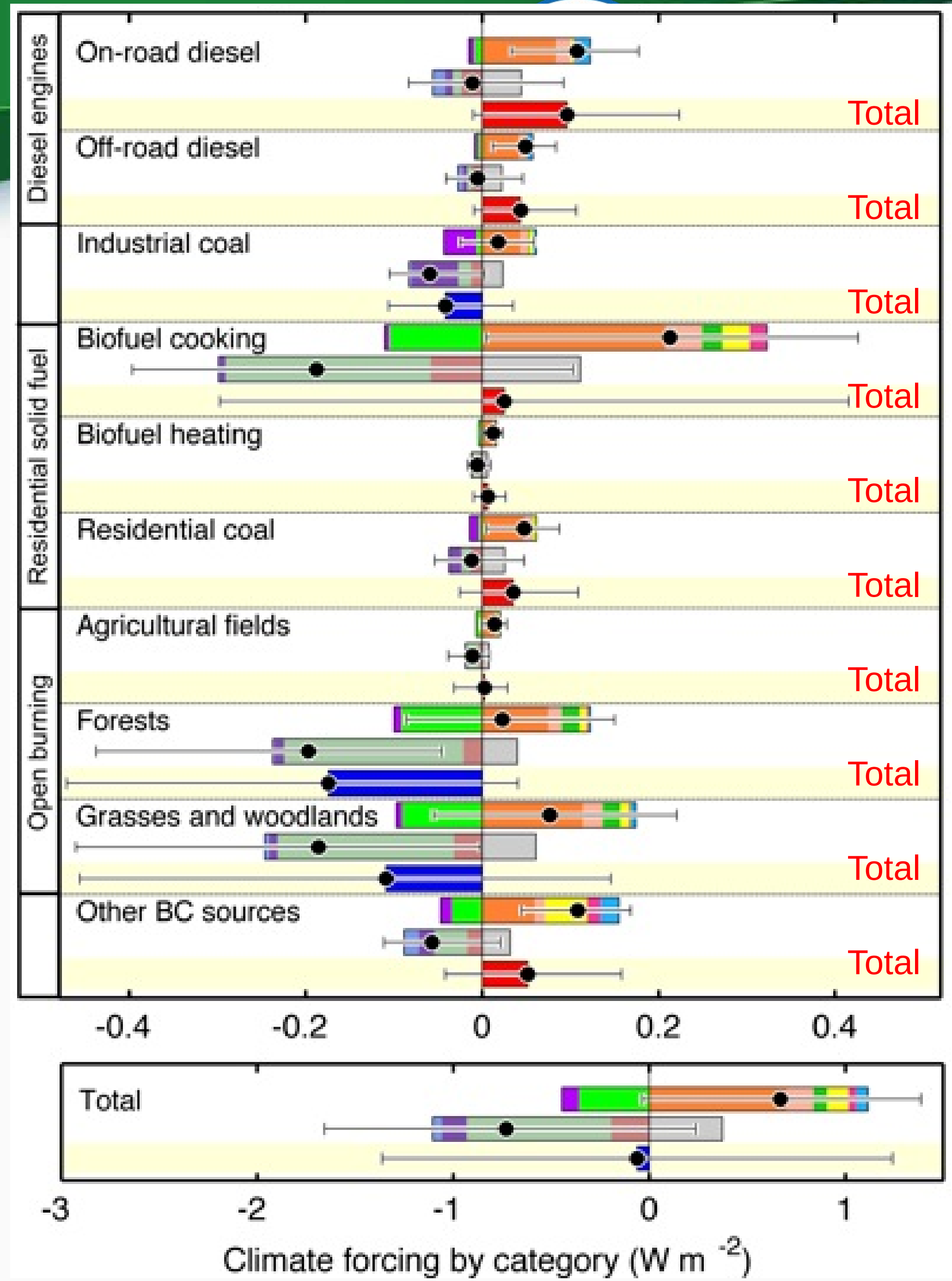
Source: EPA (2012) Report to Congress on Black Carbon

What about net warming/cooling effects by sector?

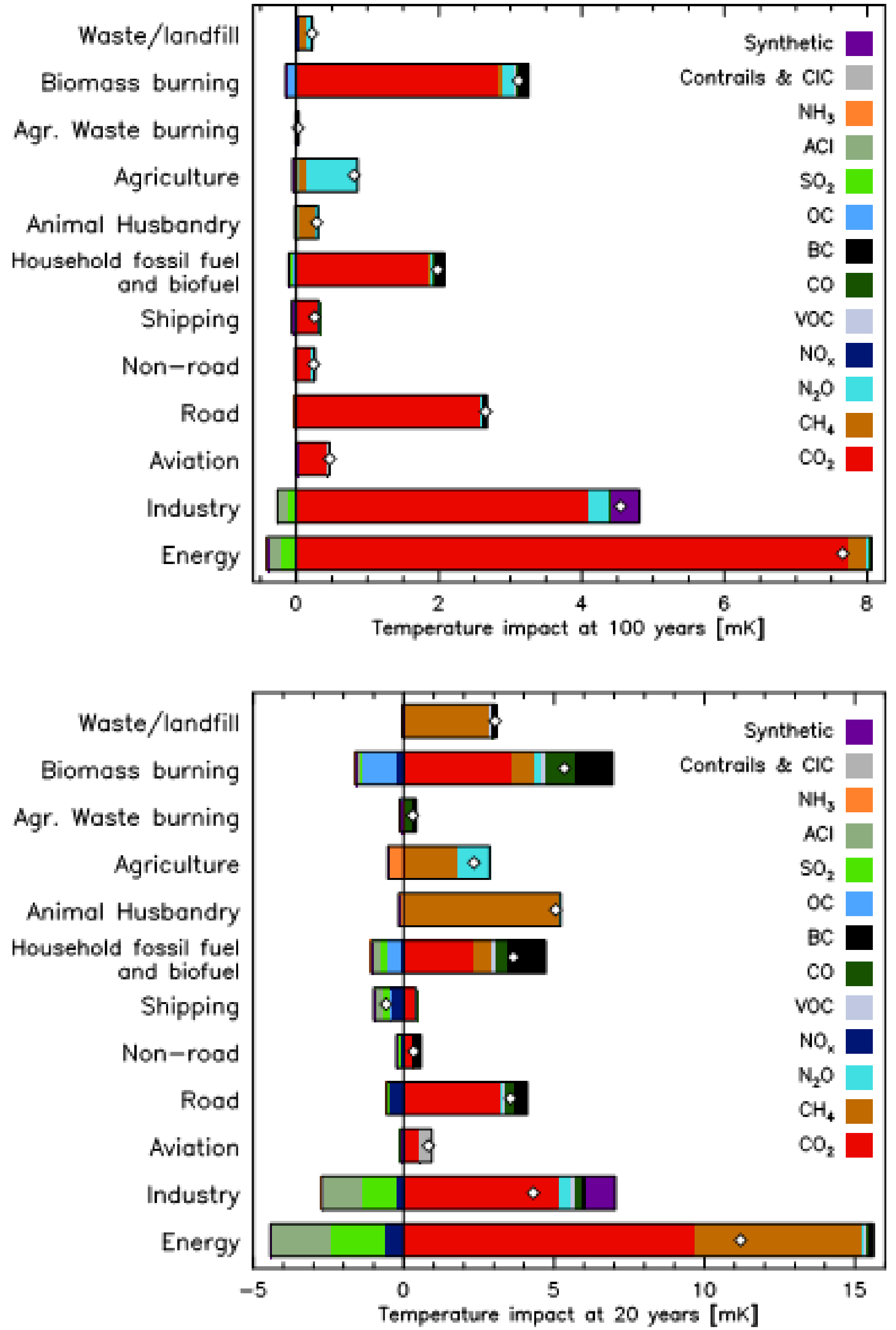
Short-lived species only

- Some categories are net positive (red)
- Some are net negative (blue)
- Some are uncertain– sign unknown





Source: Bond et al. (2013)

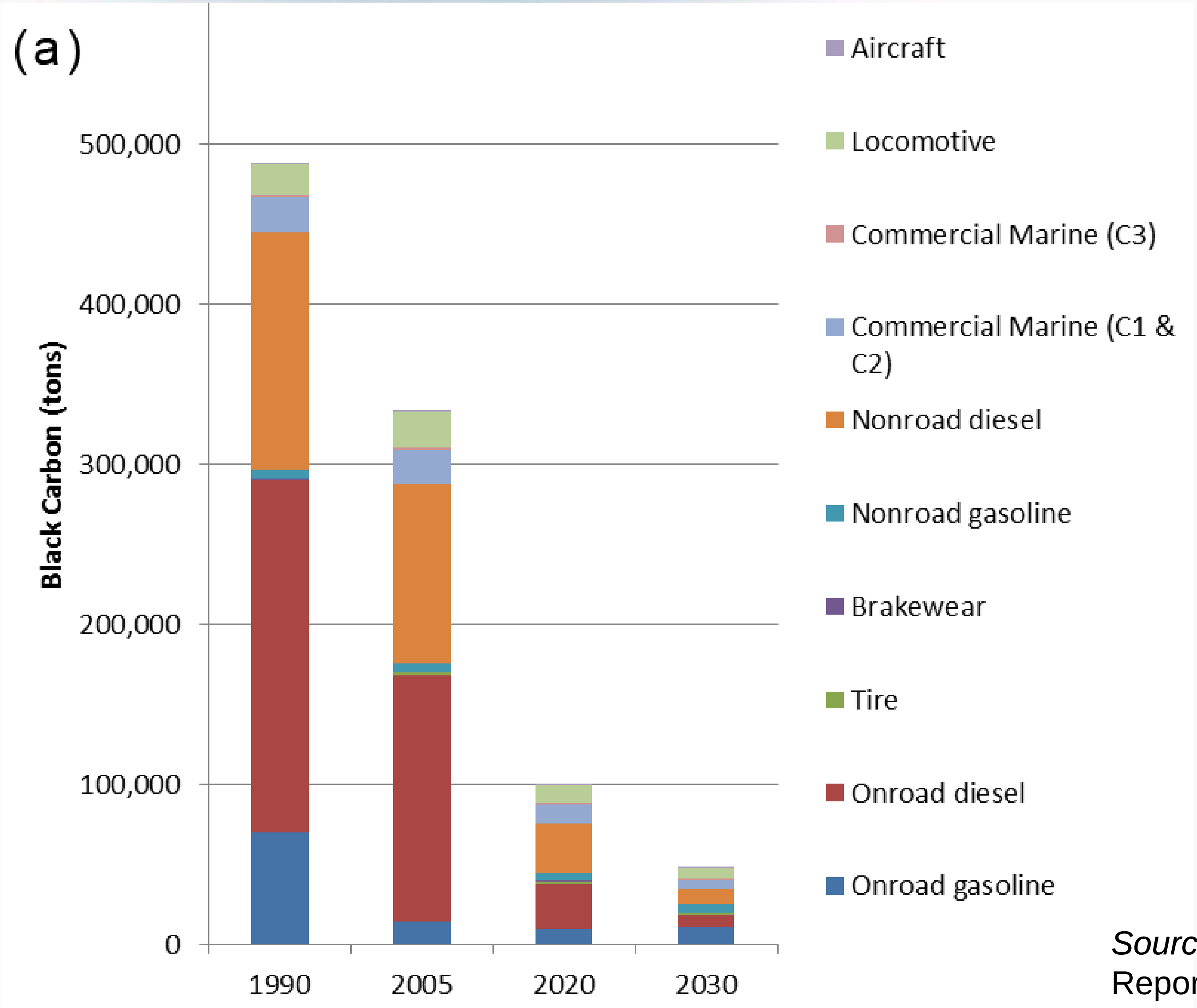


Consideration of net climate effects by sector, with both short- and long-lived agents

- Over 20-year timeframe, black carbon (and organic carbon) and methane have large impact
- Over 100-year timeframe, CO_2 is even more dominant

Source: IPCC AR5 WG1, Chapter 8, 2013

Projected U.S. Mobile Source Black Carbon Emissions



Total U.S. mobile source BC emissions are projected to decline by 86% between 2005 and 2030 (by 90% from 1990 levels) due to regulations already promulgated.

Source: EPA (2012) Report to Congress on Black Carbon

Comparing BC to GHGs

- IPCC (2013) has synthesized available metrics in literature
- Our RTC discusses metrics at length (chapter 2)
- Bond et al. (2013):

  "Black carbon and CO_2 emission amounts with equivalent 100-GWPs have different impacts on climate, temperature, rainfall, and the timing of these impacts. These and other differences raise questions about the appropriateness of using a single metric to compare black carbon and greenhouse gases."

Table 8.A.6: GWP and GTP from the literature for BC and OC for time horizons of 20 and 100 years. For the reference gas CO_2, RE and IRF from AR4 are used in the calculations. The GWP100 and GTP100 values can be scaled by 0.94 and 0.92, respectively, to account for updated values for the reference gas CO_2. For 20 years the changes are negligible.

	GWP		GTP	
	H = 20	**H = 100**	**H = 20**	**H = 100**
BC total, global[c]	3200 (270–6200)	900 (100–1700)	920 (95–2400)	130 (5–340)
BC (4 regions)[d]	1200 ± 720	345 ± 207	420 ± 190	56 ± 25
BC global[a]	1,600	460	470	64
BC aerosol-radiation interaction +albedo, global[b]	2,900 ± 1,500	830 ± 440		
OC global[a]	–240	–69	–71	–10
OC global[b]	–160 (–60, –320)	–46 (–18, –92)		
OC (4 regions)	–160 ± 168	–46 ± 20	–55 ± 16	–7.3±2.1

Notes:
(a) Fuglestvedt et al. (2010)
(b) Bond et al. (2011). Uncertainties for OC are asymmetric and are presented as ranges.
(c) Bond et al. (2013). Metric values are given for total effect.

Source: IPCC AR5 WG1, Chapter 8, 2013

Summary thoughts

- Increased attention on role of BC in climate change
- Generally estimated magnitude of climate effect has increased with latest findings
- Uncertainties remain high relative to understanding for GHGs
- Important role of geographic location and (cooling) co-emissions mean climate effects are variable by source and therefore by mitigation option
- U.S. transportation sources, especially diesel sources, have a high BC:OC ratio and are thus a net warming source, but are on downward trajectory (not necessarily so for other world regions in near term)
- Metrics are available to compare with GHG climate effects, but no commonly accepted approach, so use with caution