Black carbon, diesel and climate change

Diesel Technologies and Climate Change

West Coast Collaborative Partner Meeting

San Francisco, CA

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Black carbon is any combustion particle that strongly absorbs light

Dark smoke indicates high concentration of BC

White smoke indicates low concentration of BC

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Black carbon generates climate impacts in multiple ways

Direct heating of the atmosphere

Indirect cooling via increases in cloud thickness and lifetime; changes in cloud precipitation

Indirect heating via reductions in snow and ice reflectivity (albedo) and mass

Source: Patrick Kelley, US Coast Guard (via Flickr)

icct
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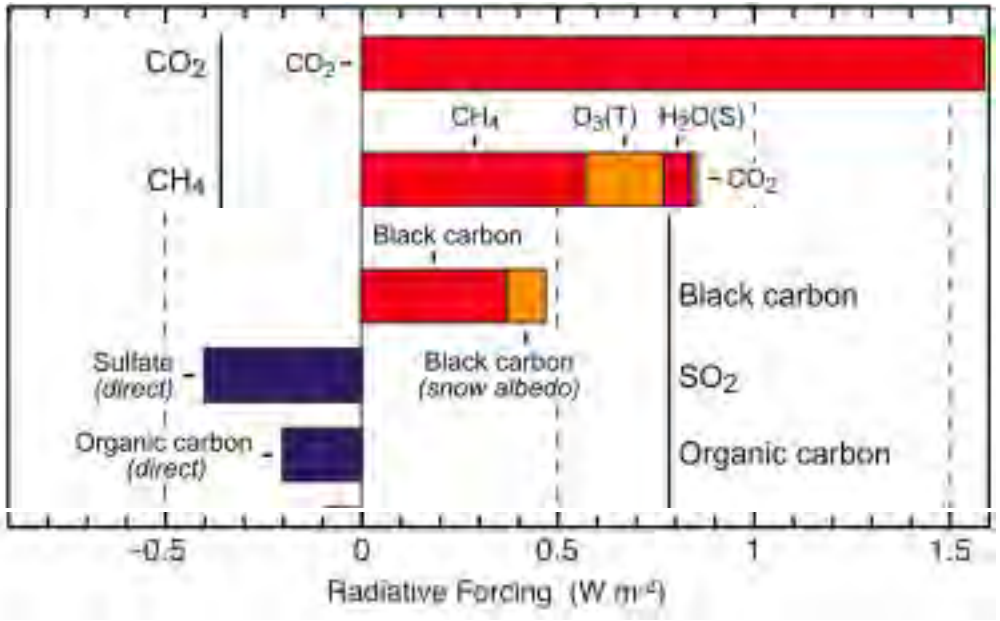
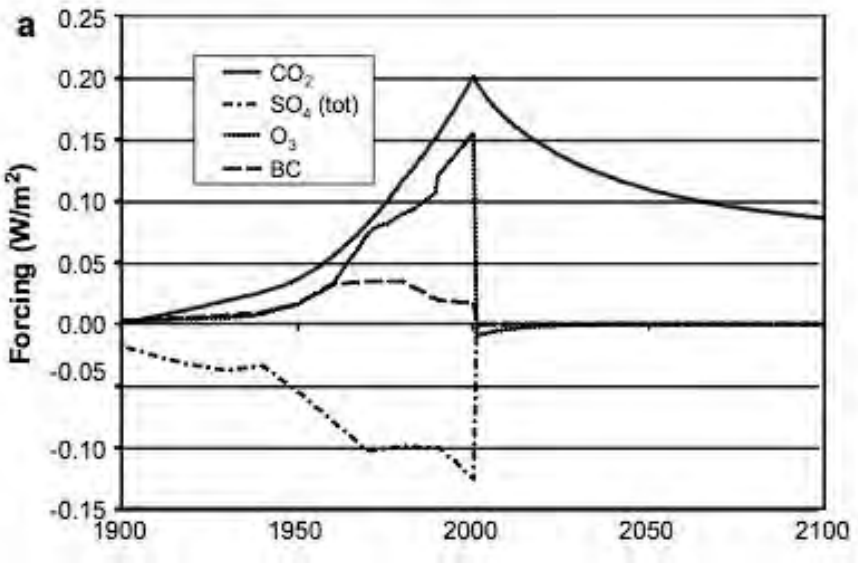
IPCC Estimates of Radiative Forcing

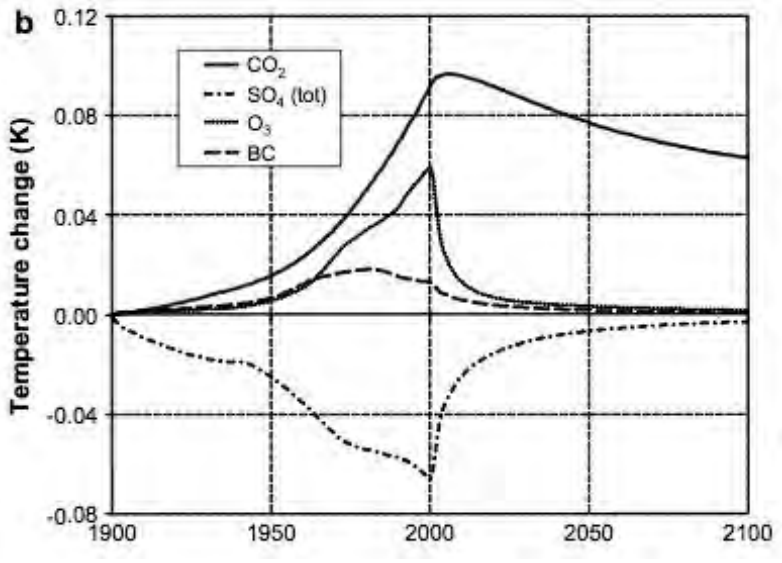


Adapted from Figure 2.21 of the IPCC 4th Assessment Working Group 1 report, Chapter 2: Changes in atmospheric constituents and radiative forcing

Short lifetime may enable more rapid short-term mitigation relative to CO2



Historical radiative forcing (direct and first indirect effects) of emissions from the global transportation fleet assuming zero emissions after the year 2000.



Historical temperature response (from direct and first indirect effects) to emissions from the global transportation fleet assuming zero emissions after the year 2000.

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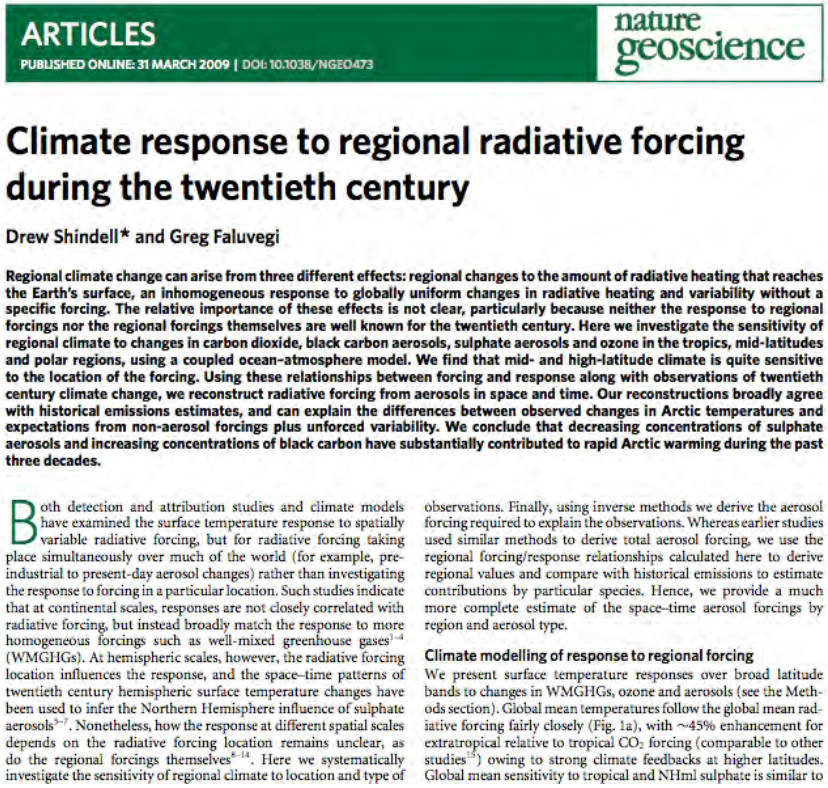
Fuglestvedt et al. Transport impacts on atmosphere and climate: Metrics. Atmospheric Environment (2009) pp. 1-30

Global climate response is not sensitive to location of emissions



ARTICLES
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Climate response to regional radiative forcing during the twentieth century

Drew Shindell* and Greg Faluvegi

Regional climate change can arise from three different effects: regional changes to the amount of radiative heating that reaches the Earth's surface, an inhomogeneous response to globally uniform changes in radiative heating and variability without a specific forcing. The relative importance of these effects is not clear, particularly because neither the response to regional forcings nor the regional forcings themselves are well known for the twentieth century. Here we investigate the sensitivity of regional climate to changes in carbon dioxide, black carbon aerosols, sulphate aerosols and ozone in the tropics, mid-latitudes and polar regions, using a coupled ocean–atmosphere model. We find that mid- and high-latitude climate is quite sensitive to the location of the forcing. Using these relationships between forcing and response along with observations of twentieth century climate change, we reconstruct radiative forcing from aerosols in space and time. Our reconstructions broadly agree with historical emissions estimates, and can explain the differences between observed changes in Arctic temperatures and expectations from non-aerosol forcings plus unforced variability. We conclude that decreasing concentrations of sulphate aerosols and increasing concentrations of black carbon have substantially contributed to rapid Arctic warming during the past three decades.

Both detection and attribution studies and climate models have examined the surface temperature response to spatially variable radiative forcing, but for radiative forcing taking place simultaneously over much of the world (for example, pre-industrial to present-day aerosol changes) rather than investigating the response to forcing in a particular location. Such studies indicate that at continental scales, responses are not closely correlated with radiative forcing, but instead broadly match the response to more homogeneous forcings such as well-mixed greenhouse gases[1–4] (WMGHGs). At hemispheric scales, however, the radiative forcing location influences the response, and the space–time patterns of twentieth century hemispheric surface temperature changes have been used to infer the Northern Hemisphere influence of sulphate aerosols[5–7]. Nonetheless, how the response at different spatial scales depends on the radiative forcing location remains unclear, as do the regional forcings themselves[8–14]. Here we systematically investigate the sensitivity of regional climate to location and type of forcing using observations. Finally, using inverse methods we derive the aerosol forcing required to explain the observations. Whereas earlier studies used similar methods to derive total aerosol forcing, we use the regional forcing/response relationships calculated here to derive regional values and compare with historical emissions to estimate contributions by particular species. Hence, we provide a much more complete estimate of the space–time aerosol forcings by region and aerosol type.

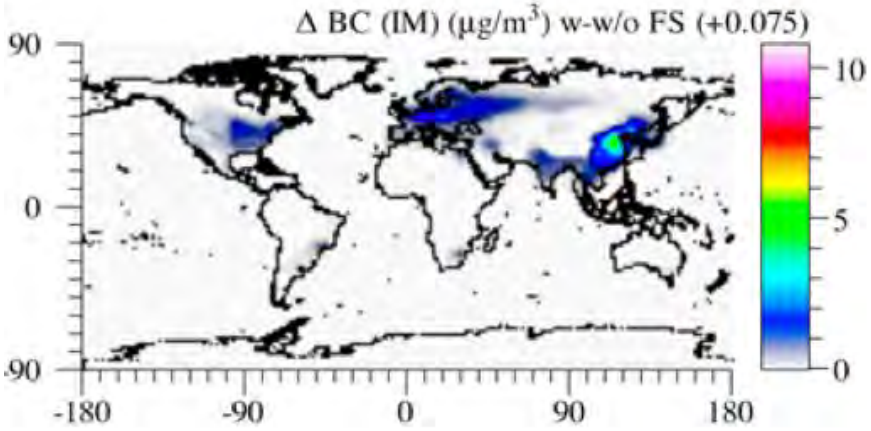
Climate modelling of response to regional forcing

We present surface temperature responses over broad latitude bands to changes in WMGHGs, ozone and aerosols (see the Methods section). Global mean temperatures follow the global mean radiative forcing fairly closely (Fig. 1a), with ~45% enhancement for extratropical relative to tropical CO_2 forcing (comparable to other studies[15]) owing to strong climate feedbacks at higher latitudes. Global mean sensitivity to tropical and NHml sulphate is similar to

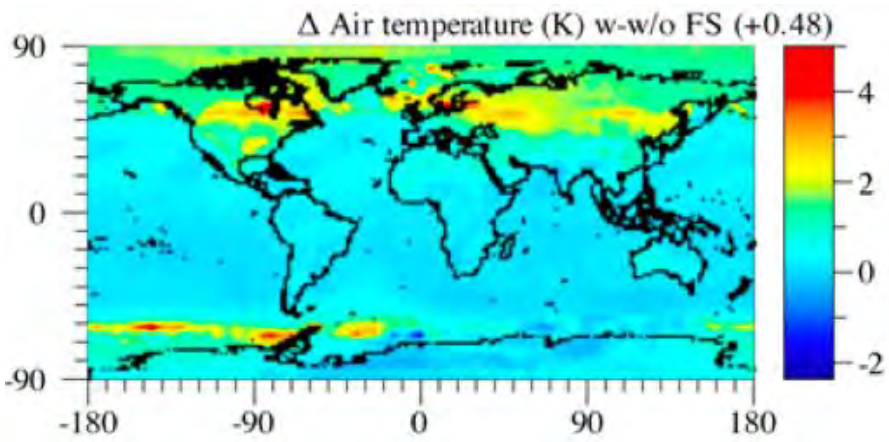
"…global and tropical mean temperature trends during the twentieth century would have been quite similar if short-lived species radiative forcing had been distributed homogenously rather than being concentrated in the extratropics."

- Shindell & Falugevi (2009)

But regional temperature response may be loosely related to location of emissions



Concentrations of black carbon(μg/m^3) attributable to fossil-fuel sources



Change in air temperature (K) caused by fossil-fuel soot

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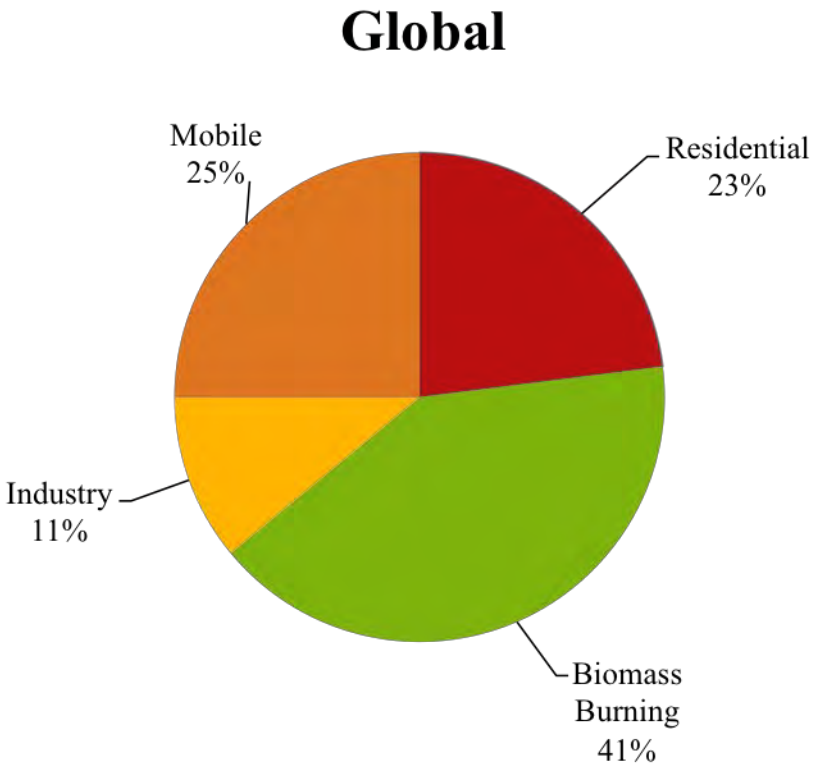
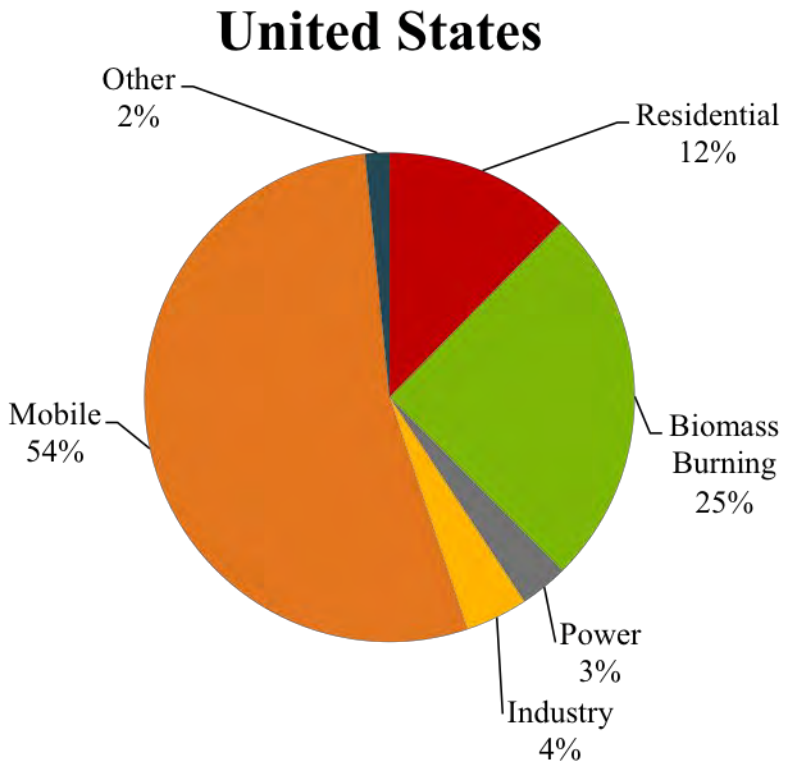
Jacobson, M. Short-term effects of controlling fossil-fuel soot, biofuel soot and gases, and methane on climate, Arctic ice, and air pollution health. Journal of Geophysical Research (2010) vol. 115 (D14209) pp. 1-24

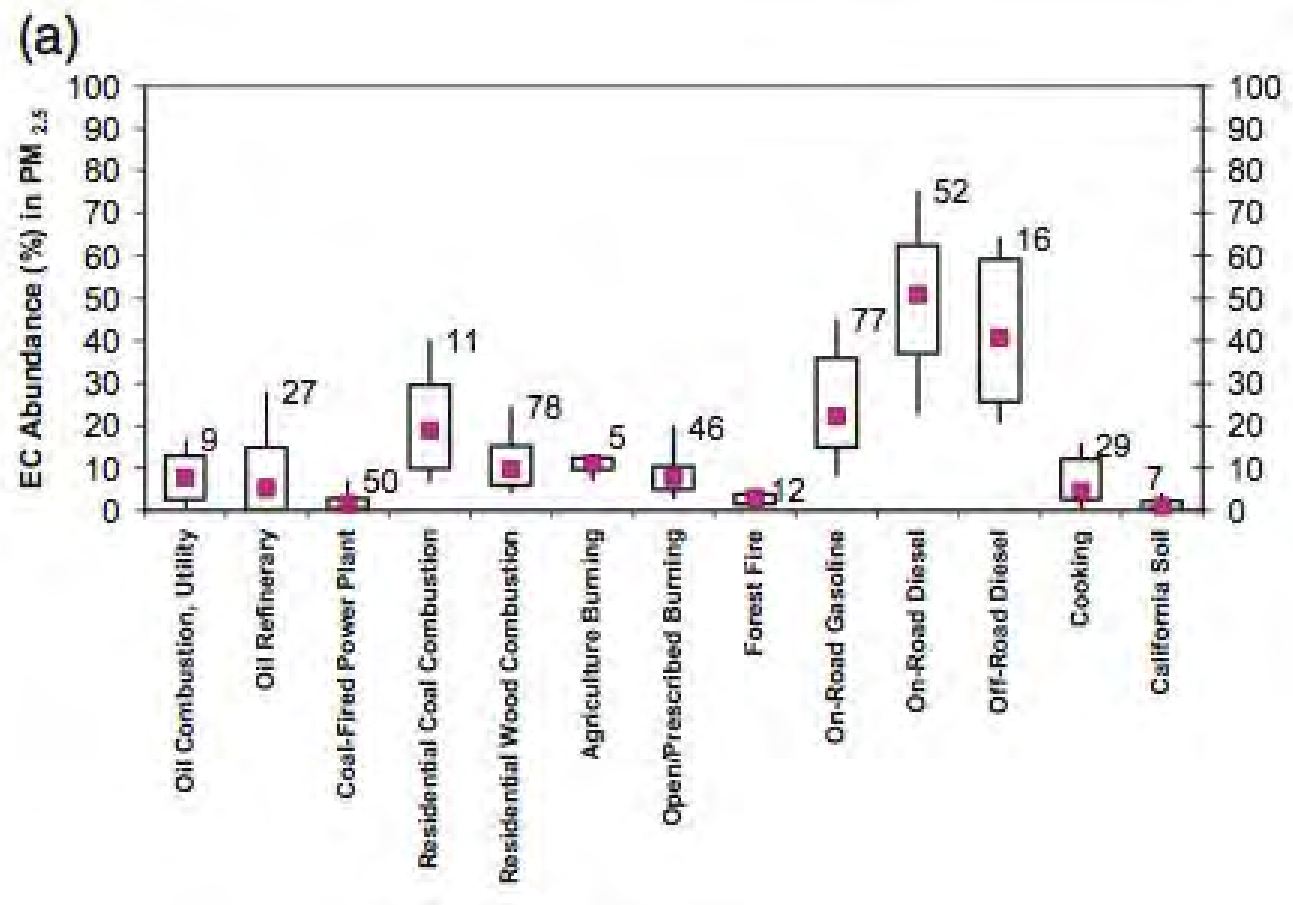
Black Carbon Sources, 2000





Global: (Bond et al., GBC 2007 + van der Werf, 2006 + updates for IPCC AR5)
US: Bahner et al. Use of black carbon and organic carbon inventories for projections and mitigation analysis

Diesel PM contains a relatively high fraction of BC



Chow et al. Black and organic carbon emission inventories: Review and application to California. J Air & Waste Manage Assoc (2010) vol. 60 pp. 497-507

Thank You

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