Black carbon and its effects on the Arctic

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This presentation will

- Describe what is black carbon (BC)
- Present the current understanding on
  - Current anthropogenic emissions and emission projections until 2030
  - Potential for further emission reductions
  - Current and future temperature changes induced by BC
- Focus will be the Arctic but I discuss it in a global context

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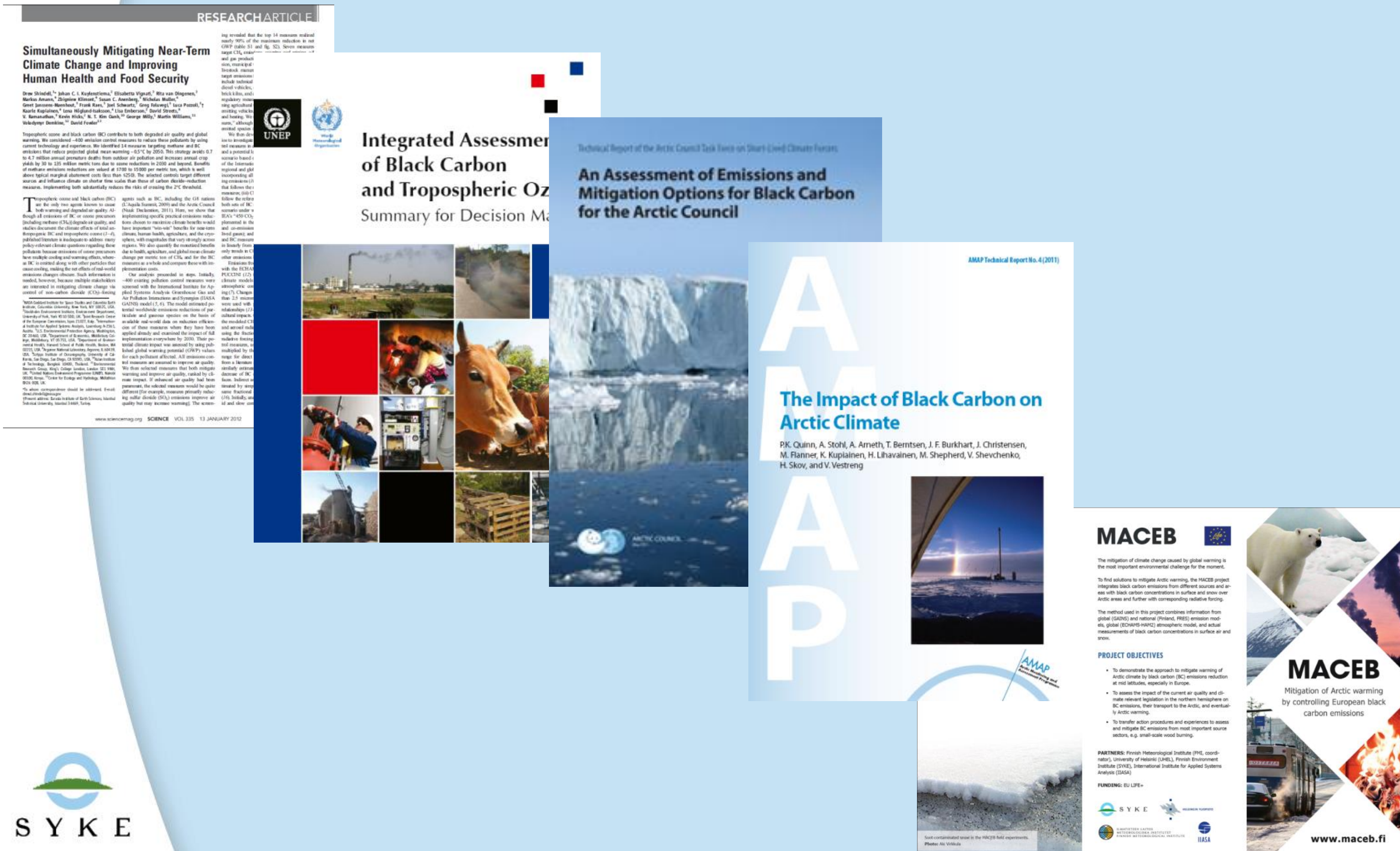
The presentation relies on most recent assessments on effects of BC



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What is black carbon?

- A particle specie formed in incomplete combustion; a component of soot
- Aborbs strongly solar radiation and exerts a warming of the atmosphere
- Light absorption is enhanced on the reflecting snow and ice surfaces
- Deposited BC particles darken the snow and ice
- Has a short life-time in the atmosphere (days to a week) compared with greenhouse gases like CO_2

Photo: Artificial soot deposits on snow during the MACEB project snow albedo campaign (source: www.maceb.fi)

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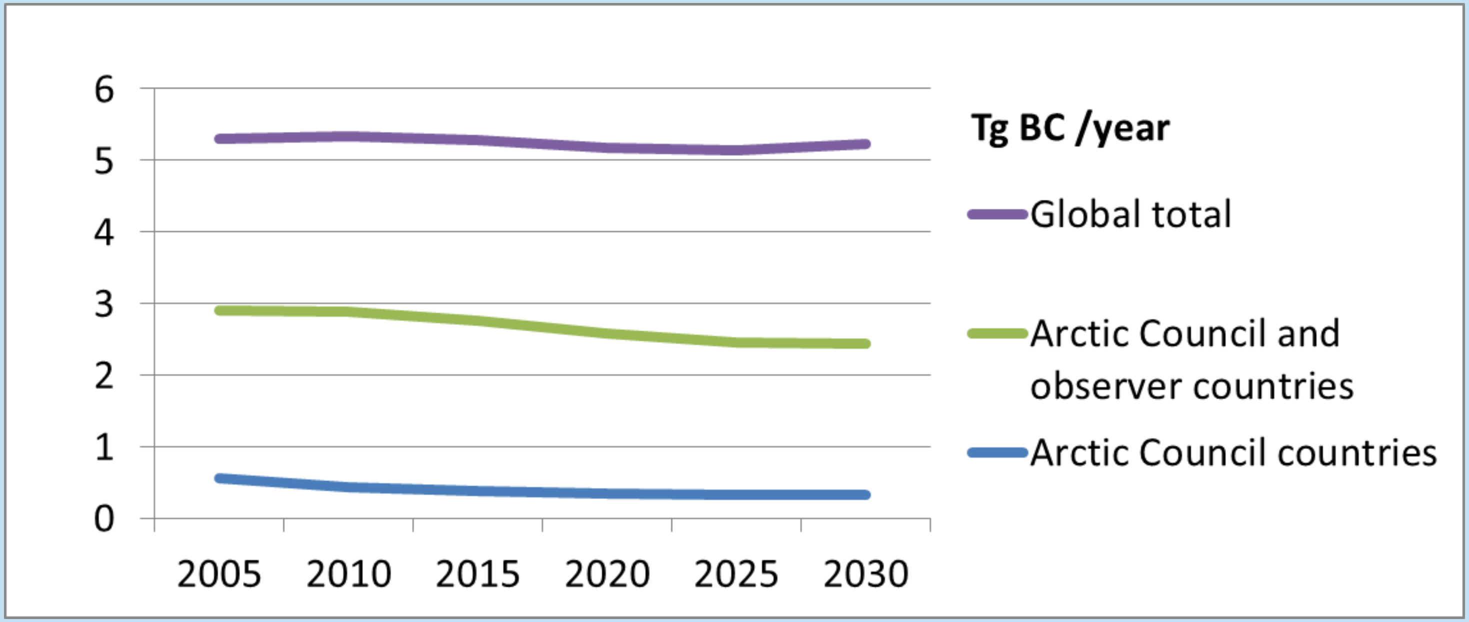
Future emissions – development with currently agreed air pollution legislation



Source: MACEB project (www.maceb.fi), IIASA-GAINS model

- Global main sectors (2010): household cooking and heating (50%), surface transport (23%), industrial combustion (12%)
- With currently agreed policies and legislation global emission are expected to stay on current levels by 2030
- Wildfires add to the figure about 2.5 Tg/year

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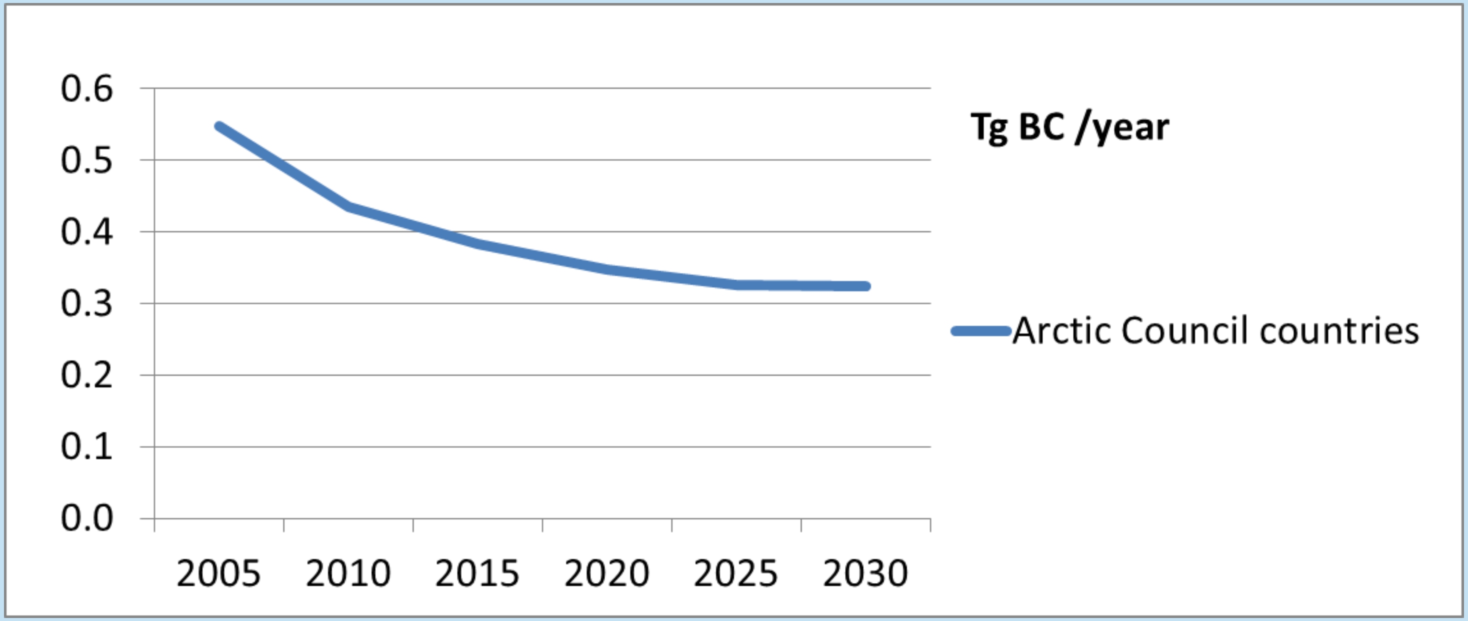
Future emissions –development with currently agreed air pollution legislation



Source: MACEB project (www.maceb.fi), IIASA-GAINS model

- Main sectors 2010: surface transportation (45%), household combustion (20%), flaring (15%), waste burning in agriculture (8%)
- With currently agreed policies and legislation emission reductions in surface transportation account for the decline by 2030

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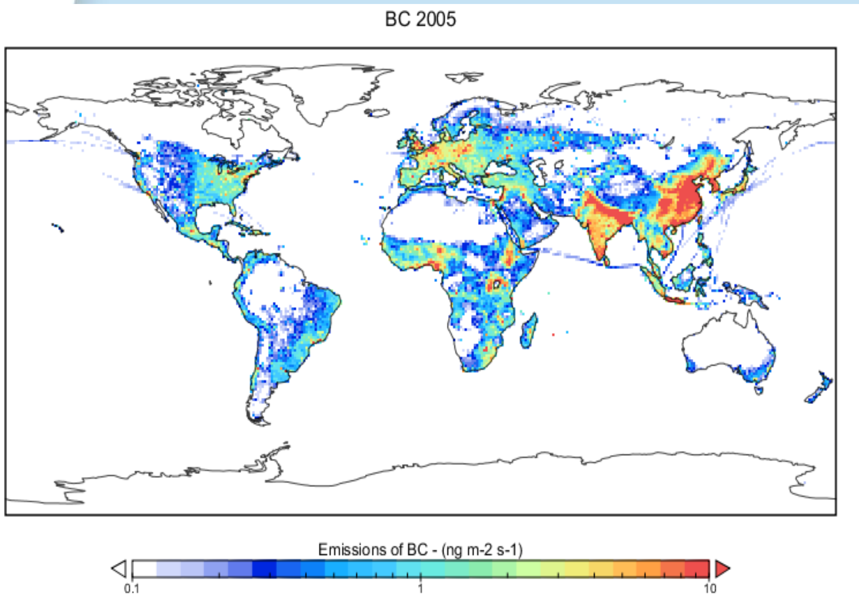
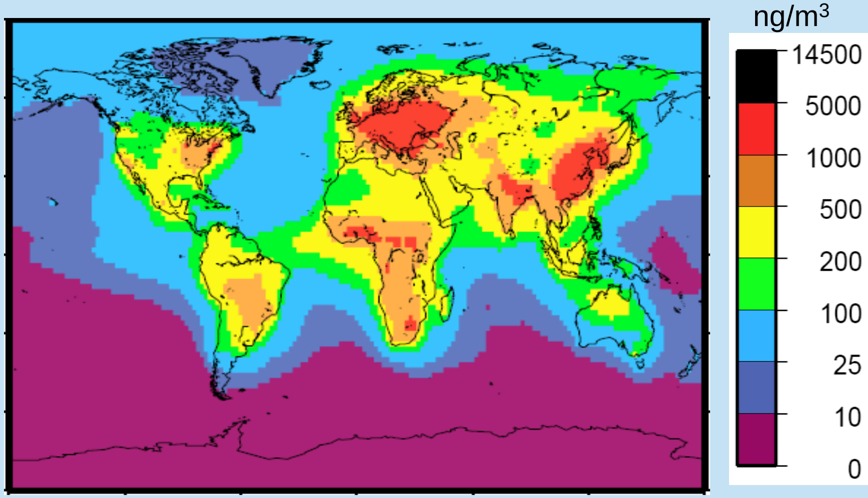
Global BC emission and surface concentrations



Source: UNEP/WMO 2011.



Source: Koch et al. 2009. Atmos.Chem.Phys. 9

- Left figure: global BC emissions in 2005, right figure: modelled BC surface concentrations
- Emission density and short lifetime in the atmosphere affect the concentrations and explain the regional (and potentially temporal) differences
- Concentrations are low in the Arctic compared with lower latitudes and come mostly from outside the area

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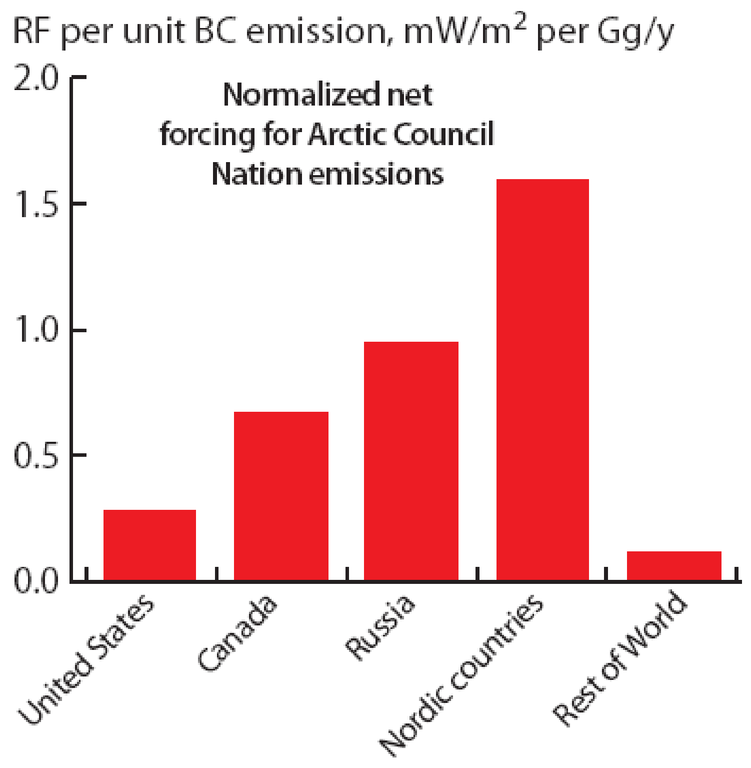
Arctic climate effect per BC unit emission



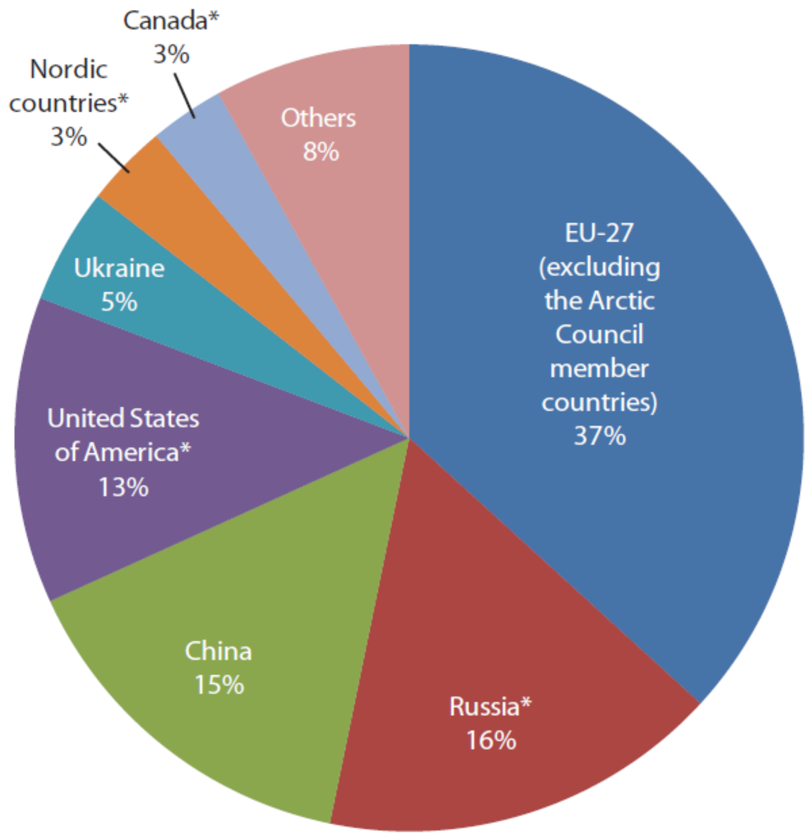


Figure 4.3. Country contributions to anthropogenic BC emission fluxes north of 40° N. Arctic Council nations are marked with an asterisk.

Source: AMAP, 2011.The Impact of Black Carbon on Arctic Climate (2011). By: P.K. Quinn, A. Stohl, et al.

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Within Arctic emissions – shipping and flaring

- Within Arctic emissions can have up to 100 times more impact to the Arctic climate
- Attention should be paid to the within Arctic sources and their future development:
- Current <u>Arctic shipping</u> activities are not a major emission source, but some projections estimate a 4 fold growth by 2030 and a 10 fold growth by 2050
- <u>Flaring in the oil and gas industries</u> is already a significant source of Arctic BC

Pictures: US EPA 2010 report to congress and Carbon Limits 2013 Associated Petroleum Gas Flaring Study…

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What role does BC play in the Arctic climate change?

- High altitude BC warms only little or even cools the surface
- Low altitude and snow deposited BC warms strongly the surface
- The Arctic surface warms more due to BC warming induced outside of the Arctic

- Pathways of climate impact:
  - BC that makes it to the Arctic lower atmosphere and snow/ice
  - BC heated air masses from mid-latitudes

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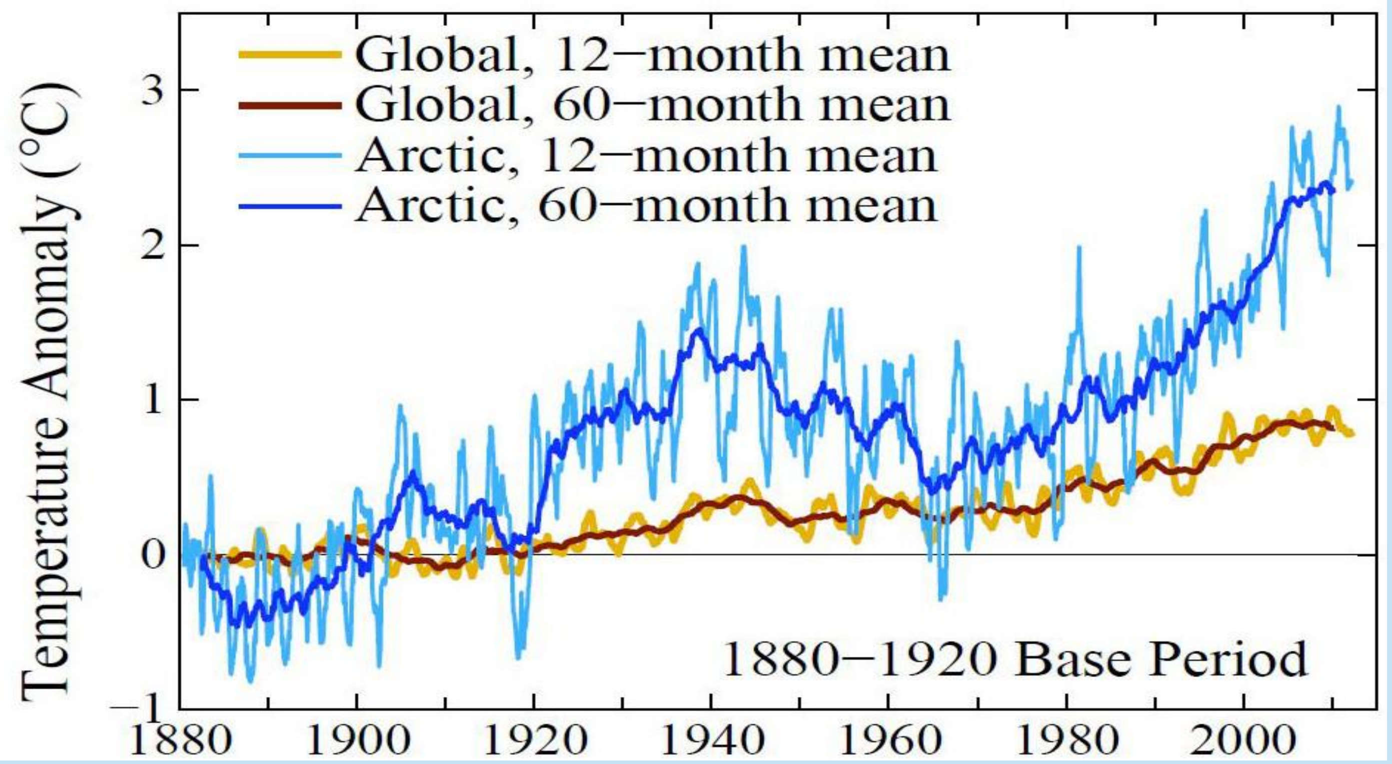
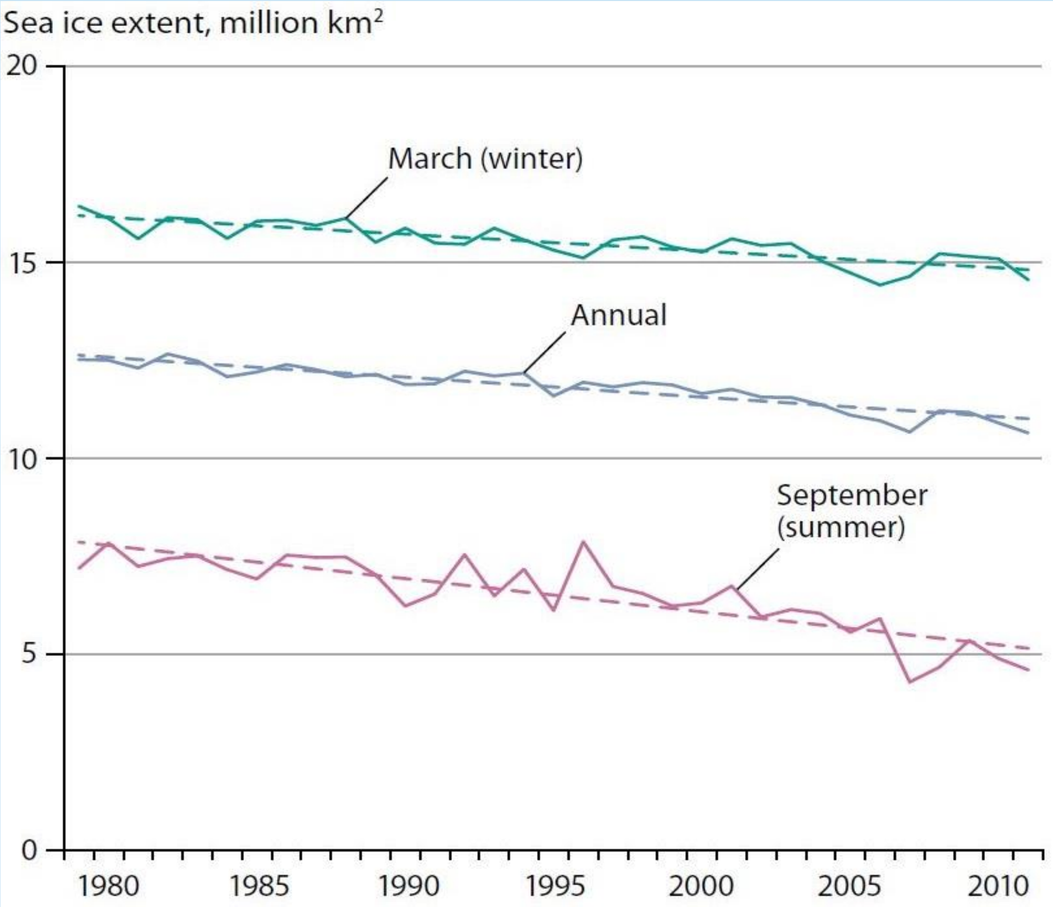
Historical Arctic and global temperatures



Source: Sato 2014.

Arctic sea ice extent has declined



Source: AMAP, 2011

BC influence on Arctic temperatures and sea-ice extent

- Estimates on historical BC climate impact:
  - Quinn et al. (2008, ACP): ~25% of the temperature increase
  - Koch et al. (2011, J. of Climate): ~20% of the Arctic warming and sea ice loss during the 20th century

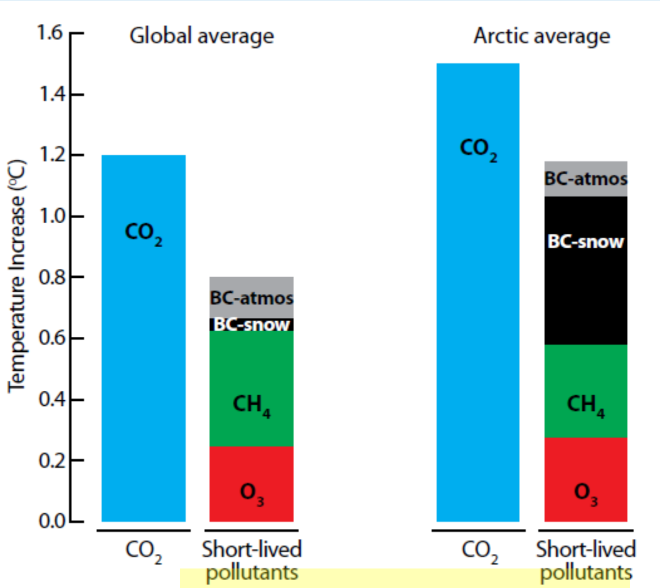


Figure 11. Annually averaged temperature increase for CO_2 and the short-lived warming pollutants relative to pre-industrial. Globally averaged values are shown on the left and Arctic averages on the right. Global values based on IPCC (2007). Arctic values based on Quinn et al. (2008). Note that cooling due to the short-lived pollutants is not included in this depiction. Such cooling may, although not necessarily, offset a portion of the warming (see discussion below).

Quinn et al. 2008. ACP

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Future of Arctic climate and the potential for BC emission mitigation?

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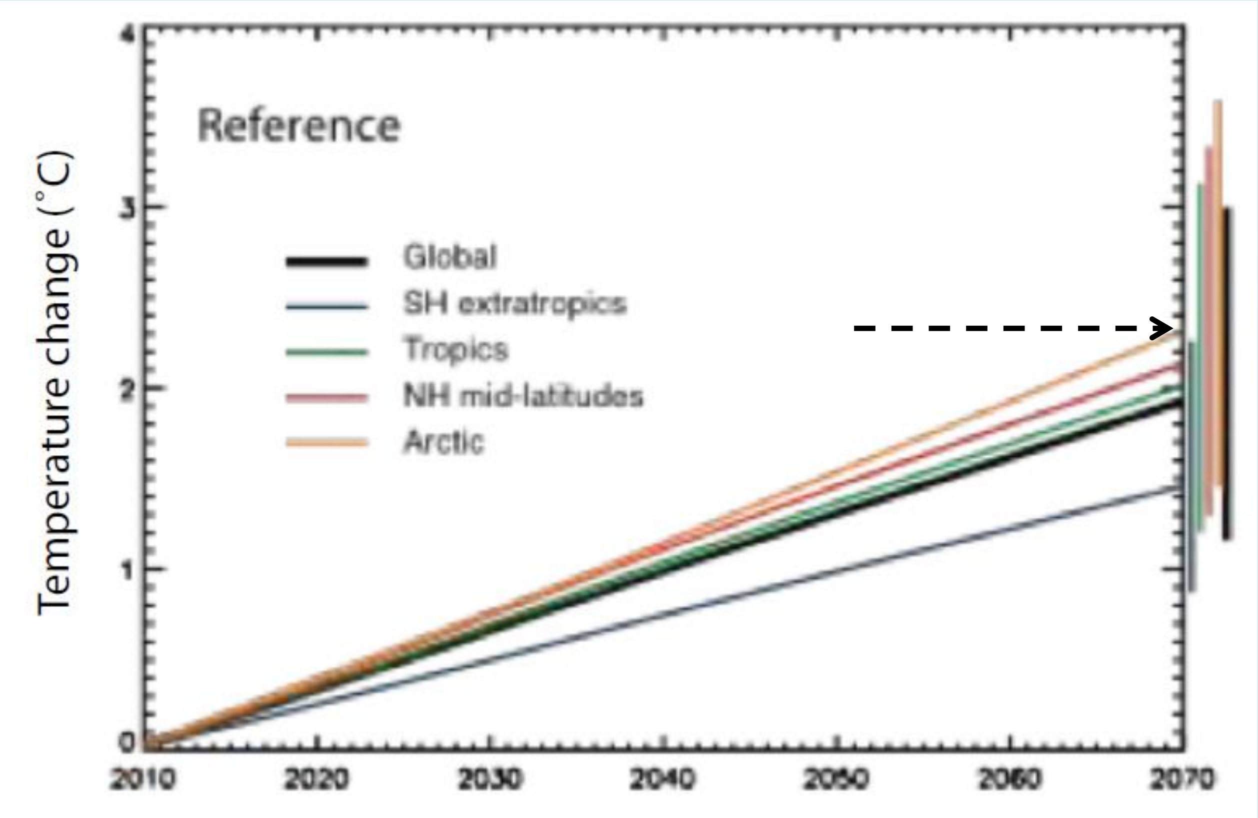
Projected future temperature change



Source: UNEP/WMO 2011: Integrated Assessment of Black Carbon and Troposperic Ozone

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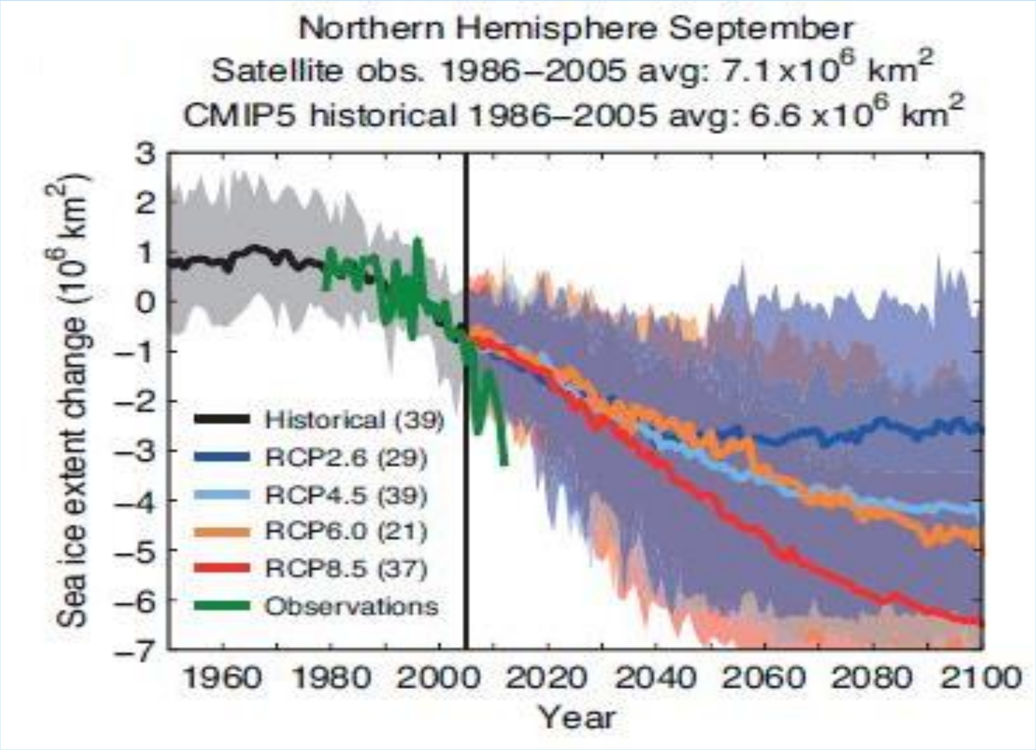
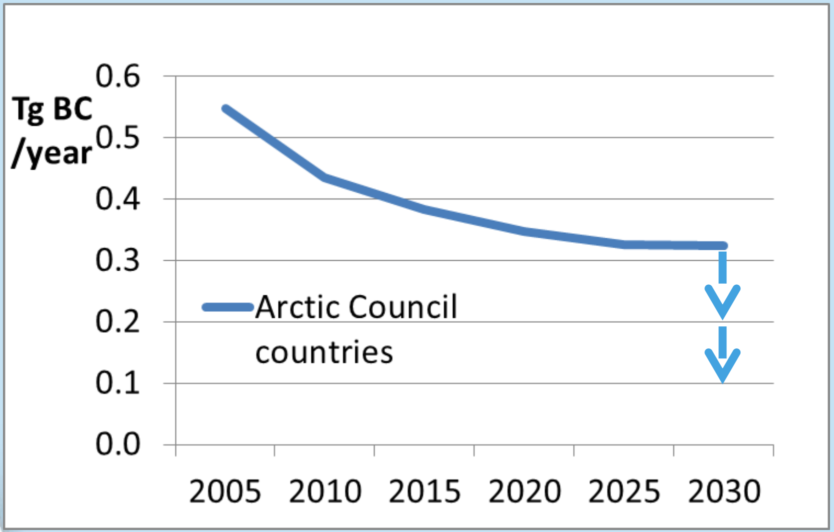
Sea ice extent is expected to decline

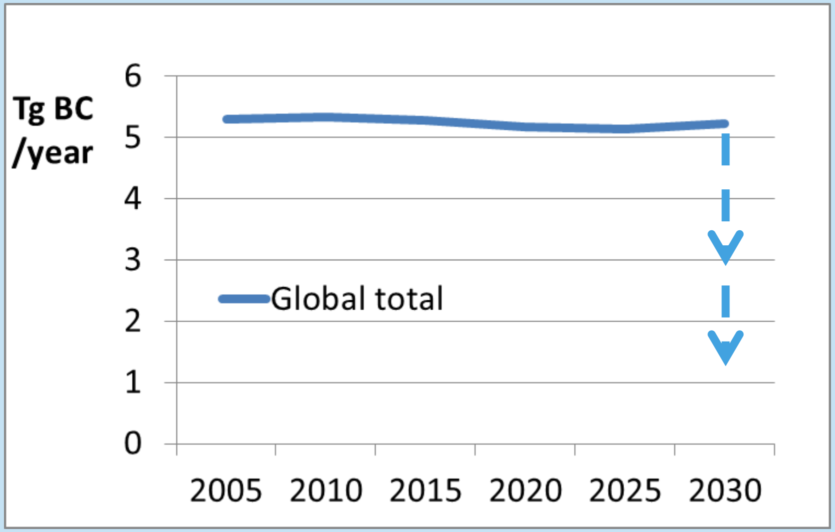


Source: IPCC, 2013

Potential for further BC emission reductions

- Prioritizing BC rich sectors it is technically possible to reduce BC emissions further significantly
- Global potential for emission reductions 40 to 70%
- Arctic Council potential emission reductions 30 to 70%
- Impact assessments need to estimate the net-effect of all relevant co-emitted species





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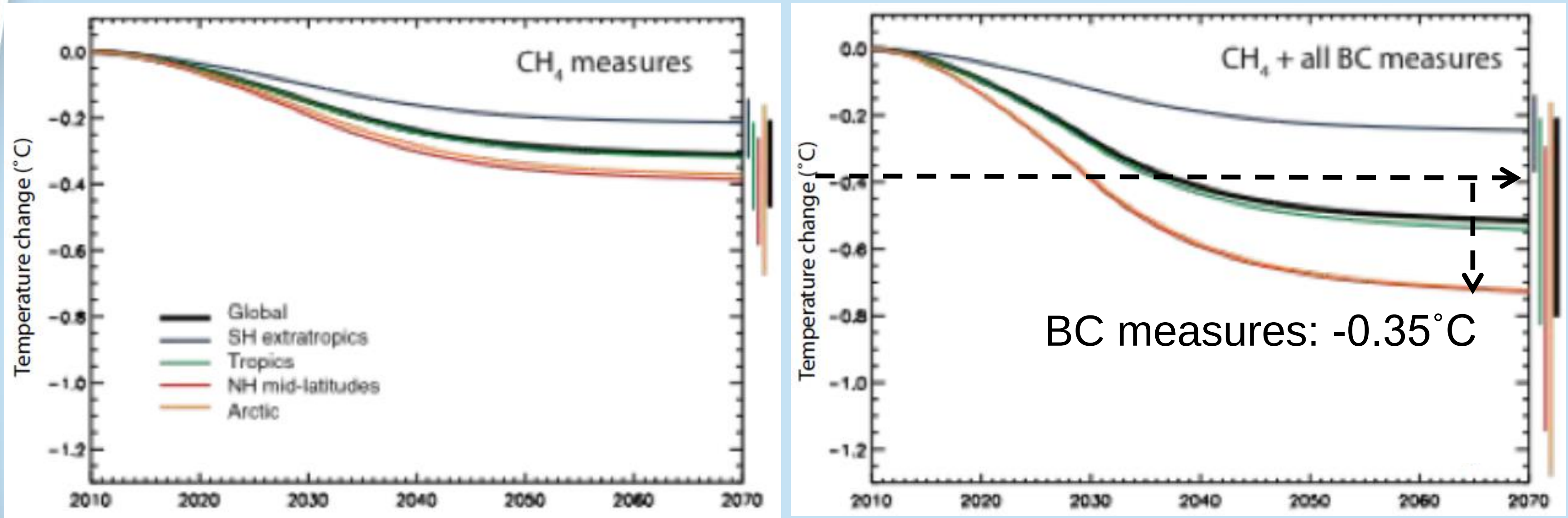
Relative temperature change with significant global BC emission reductions

Source: UNEP/WMO 2011: Integrated Assessment of Black Carbon and Tropospheric Ozone



- Targeted emission mitigation of BC rich sources could cut the projected global and Arctic temperature rise significantly (net effect of all short-lived species)
- The emission reductions could
  - offset up to about a fourth of the projected total warming in the Arctic by 2050’s.
  - Slow down the decline in sea ice extent

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Relative temperature change with significant global BC emission reductions

Source: UNEP/WMO 2011: Integrated Assessment of Black Carbon and Troposperic Ozone

- A sustainable global climate policy should be based on emission reductions of carbon dioxide, but
- Supplementing it with reductions of BC and other short-lived species could bring additional benefits for both global and Arctic climate
- Implementing the full emission reduction potential by 2030

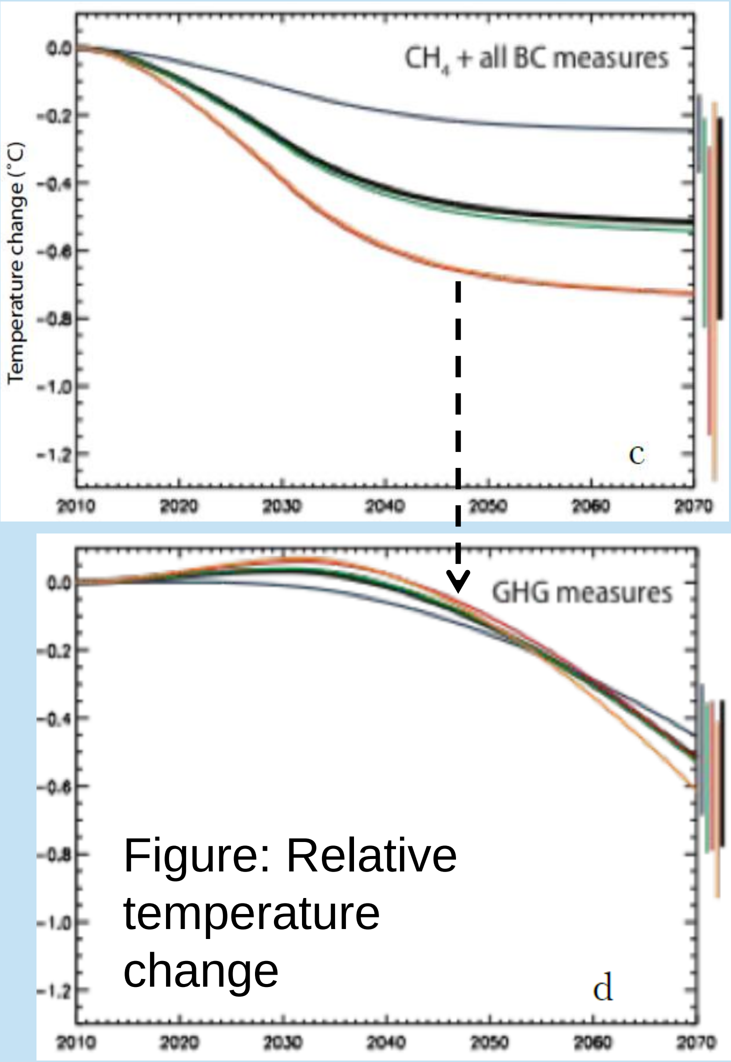

Figure: Relative temperature change

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Global effects of SLCF mitigation

Source: UNEP/WMO 2011: Integrated Assessment of Black Carbon and Troposperic Ozone

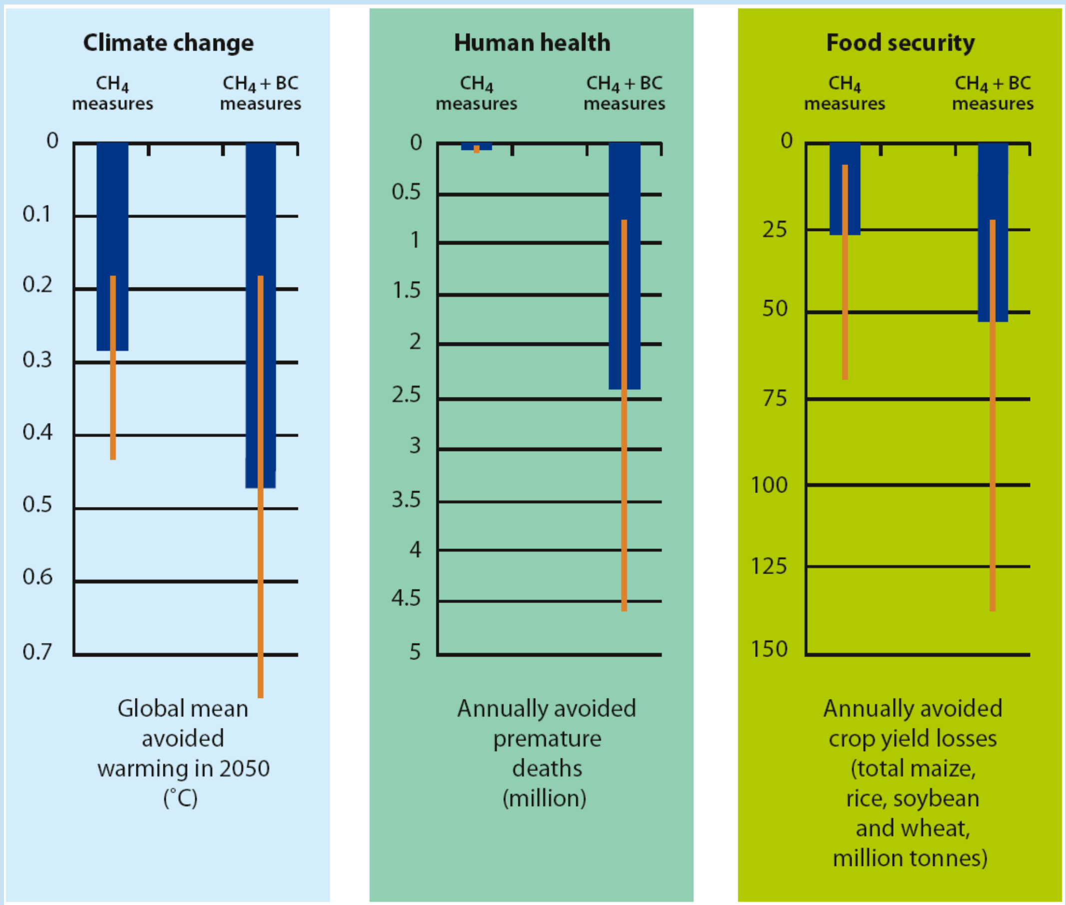

Figure 1. Global benefits from full implementation of the identified measures in 2030 compared to the reference scenario. The climate change benefit is estimated for a given year (2050) and human health and crop benefits are for 2030 and beyond.

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Conclusions

- Reductions in the emissions of CO_2 are key in mitigating climate change, but
- It is technically possible to supplement it with reductions of BC and other short-lived species and bring additional benefits for both global and Arctic climate
- Arctic climate is strongly coupled to the whole northern hemisphere climate.
- The mitigation efforts should have a hemispheric or global approach

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Thank you for your attention!