Recent black carbon work in the Arctic Council

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with presenting material from Terje Berntsen, Trish Quinn, Andreas Stohl

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Topics of the presentation

- AMAP assessment 2015 (emphasis on black carbon)
- Way forward with BC in the Arctic Council
- Future information needs in Arctic scientific assessments a potential collaboration area between LRTAP and Arctic work on SLCPs

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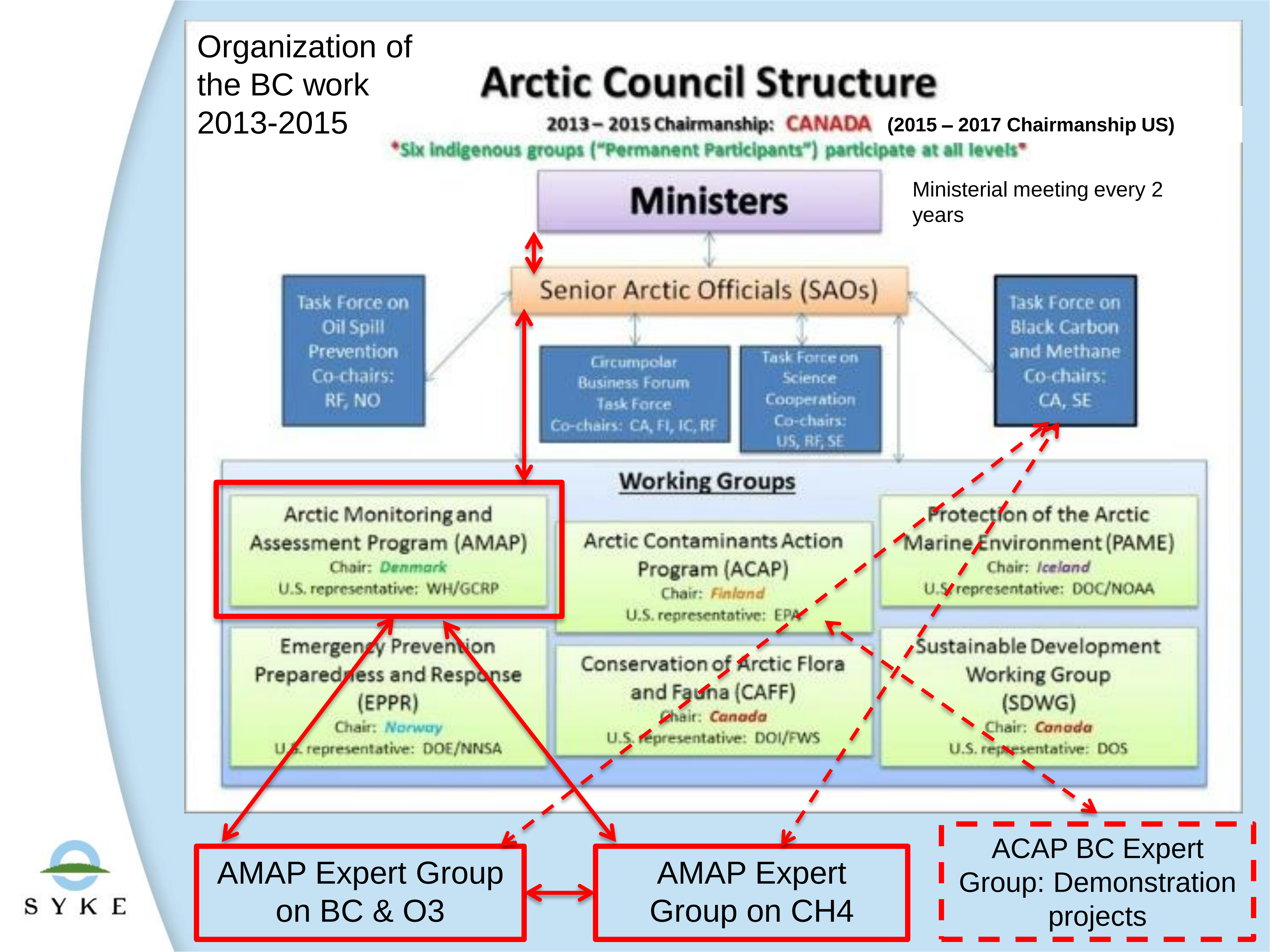
Organization of the BC work 2013-2015
Arctic Council Structure
2013 – 2015 Chairmanship: CANADA (2015 – 2017 Chairmanship US)
Six indigenous groups ("Permanent Participants") participate at all levels
Ministers
Ministerial meeting every 2 years
Senior Arctic Officials (SAOs)
Task Force on Oil Spill Prevention Co-chairs: RF, NO
Circumpolar Business Forum Task Force Co-chairs: CA, FI, IC, RF
Task Force on Science Cooperation Co-chairs: US, RF, SE
Task Force on Black Carbon and Methane Co-chairs: CA, SE
Working Groups
Arctic Monitoring and Assessment Program (AMAP) Chair: Denmark U.S. representative: WH/GCRP
Arctic Contaminants Action Program (ACAP) Chair: Finland U.S. representative: EPA
Protection of the Arctic Marine Environment (PAME) Chair: Iceland U.S. representative: DOC/NOAA
Emergency Prevention Preparedness and Response (EPPR) Chair: Norway U.S. representative: DOE/NNSA
Conservation of Arctic Flora and Fauna (CAFF) Chair: Canada U.S. representative: DOI/FWS
Sustainable Development Working Group (SDWG) Chair: Canada U.S. representative: DOS
AMAP Expert Group on BC & O3
AMAP Expert Group on CH4
ACAP BC Expert Group: Demonstration projects
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AMAP scientific work on BC

2009: AMAP formed an Expert Group in 2009 to write an assessment of the impacts of SLCFs on Arctic climate.

2011: Report: BC and co-emitted OC (emissions, properties, transport, and radiative forcing by BC in the Arctic due to emissions by source region and sector).

2011: AMAP expanded the Expert Group to include tropospheric O3 and species co-emitted with BC. AMAP also formed a second Expert Group on CH4.

2011 – 2015: Each Expert Group worked on assessments to be published in 2015 including literature surveys and model calculations.

2015: A series of reports will be published

- Summary for policy makers. Arctic climate Issues 2015. Short-lived Climate Pollutants.
- Arctic climate Issues 2015. Short-lived Climate Pollutants.
- Technical report of the BC/O3 Expert Group
- Technical report of teh CH4 Expert Group

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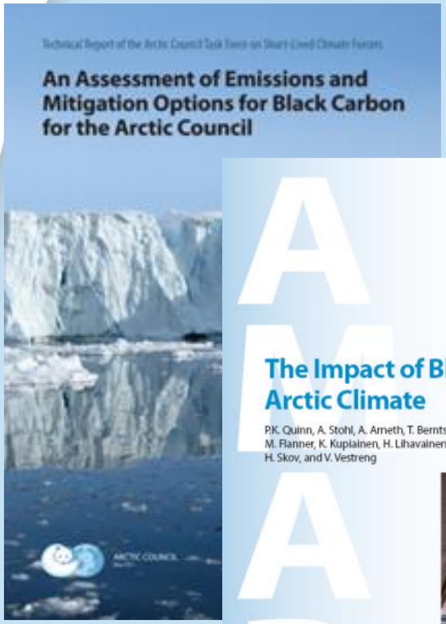
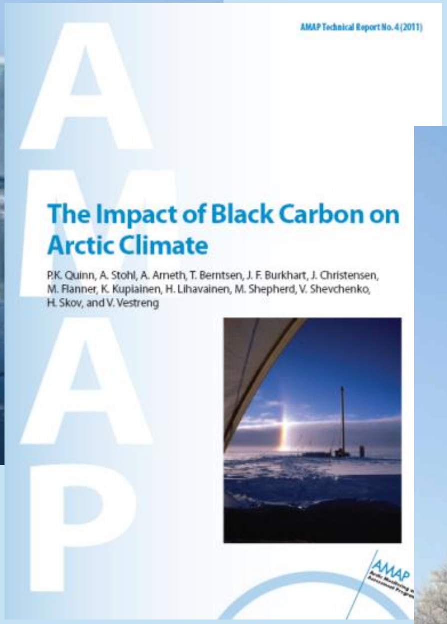
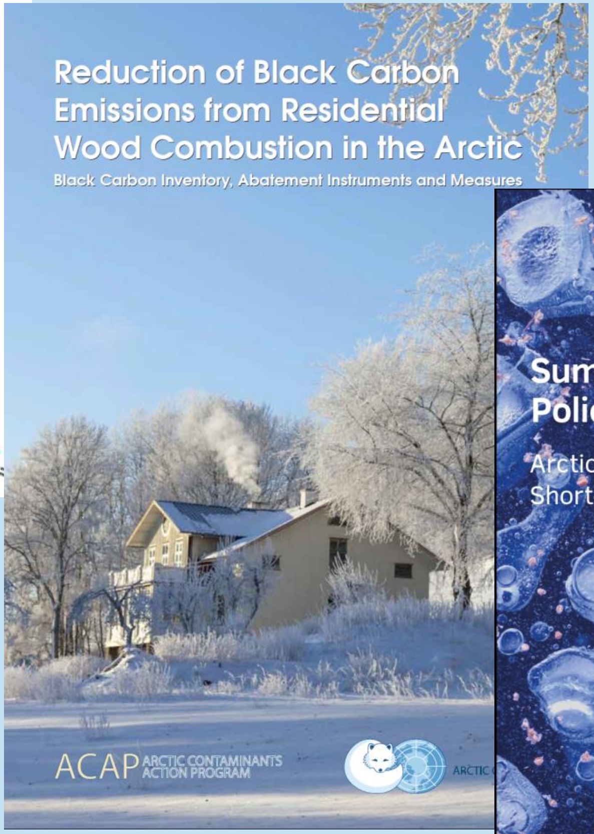
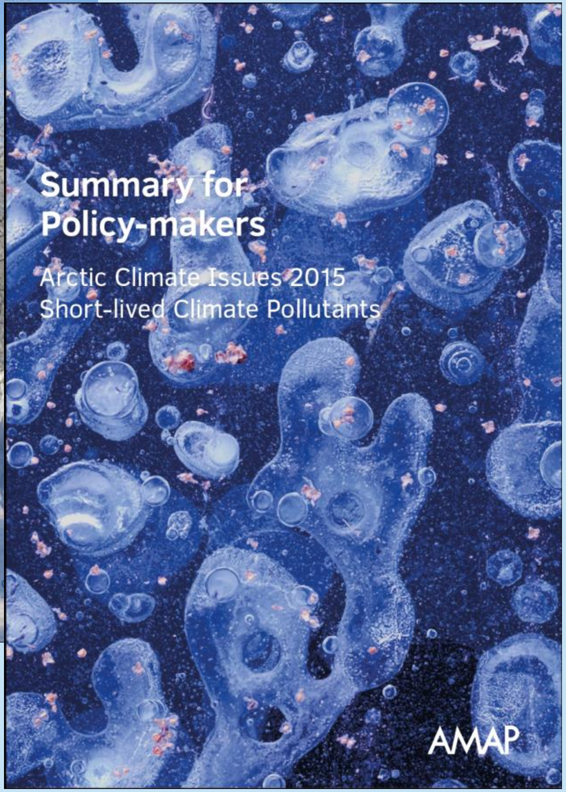
Selected recent (2011-) Arctic Council BC publications









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The Role of Short-Lived Climate Forcers (Ozone, Black Carbon and Co-Emitted Species) for Climate Change in the Arctic

Lead authors: Patricia K. Quinn (NOAA PMEL) and Andreas Stohl (NILU)

Authors: Steve Arnold, Alexander Baklanov, Terje Berntsen, Jesper Christensen, Sabine Eckhardt, Mark Flanner, Andreas Herber, Ulrik Korsholm, Kaarle Kupiainen, Joakim Langer, Kathy Law, Sarah Monks, Boris Quennehen, Knut von Salzen, Maria Sand, Julia Schmale, Vigdis Vestreng, Christine Wiedinmyer

Contributing authors: Chaoyi Jiao, Sangeeta Sharma, Maryam Namazi, Ribu Cherian, Nikos Daskalakis, Chris Heyes, Øivind Hodnebrog, Maria Kanakidou, Zbigniew Klimont, Marianne Lund, Gunnar Myhre, Stelios Myriokefalitakis, Dirk Olivie, Johannes Quaas, Jean-Christophe Raut, Bjørn Samset, Michael Schulz, Ragnhild Skeie, David Parrish, Markus Amann

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AMAP 2015 assessment (2011-2015)

- Tasked by AMAP to
  - To provide policymakers with estimates of contribution to Arctic temperature change by emissions of SLCFs
  - To quantify the potential for reducing the Arctic warming by mitigation of SLCFs

- Extension of 2011 report on BC to also include
  - Tropospheric O_3 impact
  - Inclusion of co-emitted species (multi-pollutant)
  - Temperature response

- Mix between literature review and own studies.

- A second expert group worked on methane.

Acknowledgements: EU for funding the ECLIPSE project.

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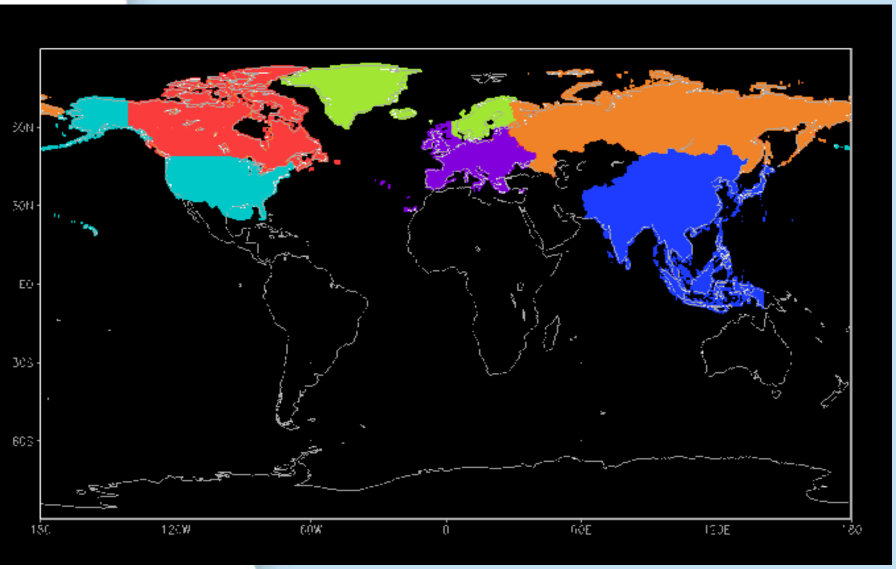
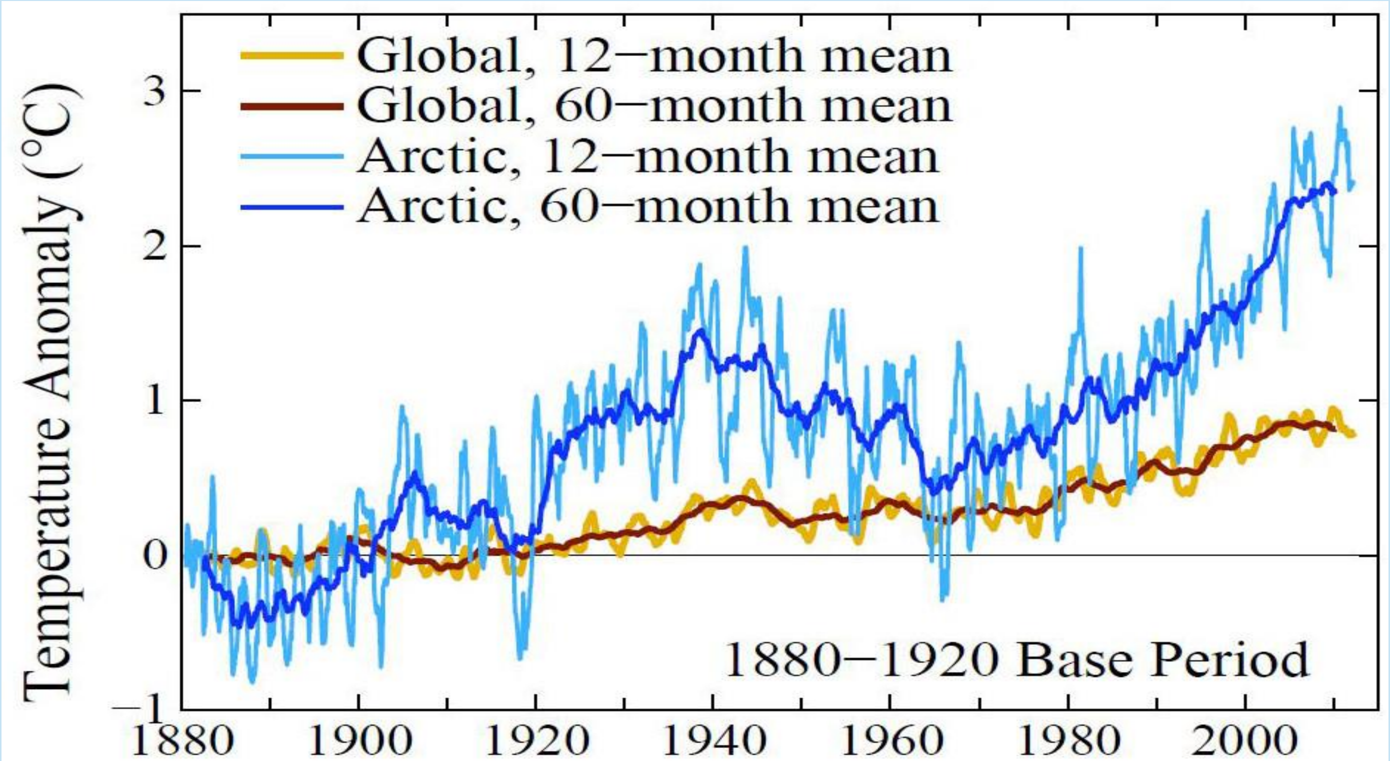
Modeling approach of the AMAP assessment

- 7 Regions: United States, Canada, Russia, Nordic countries, Other European countries, South and East Asia, Rest Of the World (ROW)
- 5 Emission category/sector: Energy+Industry+waste, Domestic combustion, Transport, Gas Flaring, and wildfires
- Emitted SLCFs: Black Carbon (BC), Organic Carbon (OC), SO_2, NOx, CO and VOCs **AND** methane
- Emission data: IIASA-GAINS (anthropogenic), GFED3 (natural sources), RCPs (GHGs). Emission data compared with other datsets
- Atmospheric impact used a suite of models: 3 Chemistry Climate Models, 5 Chemistry Transport models

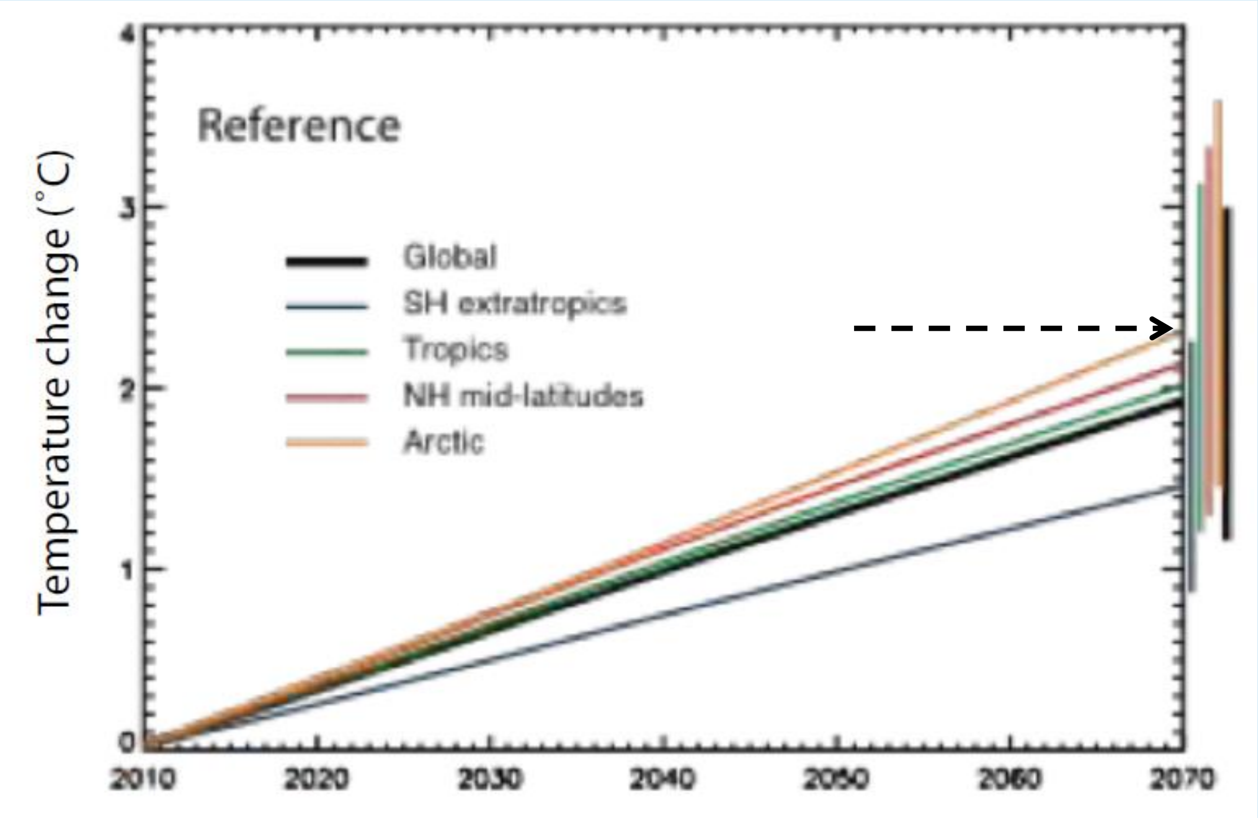


Historical Arctic and global temperatures



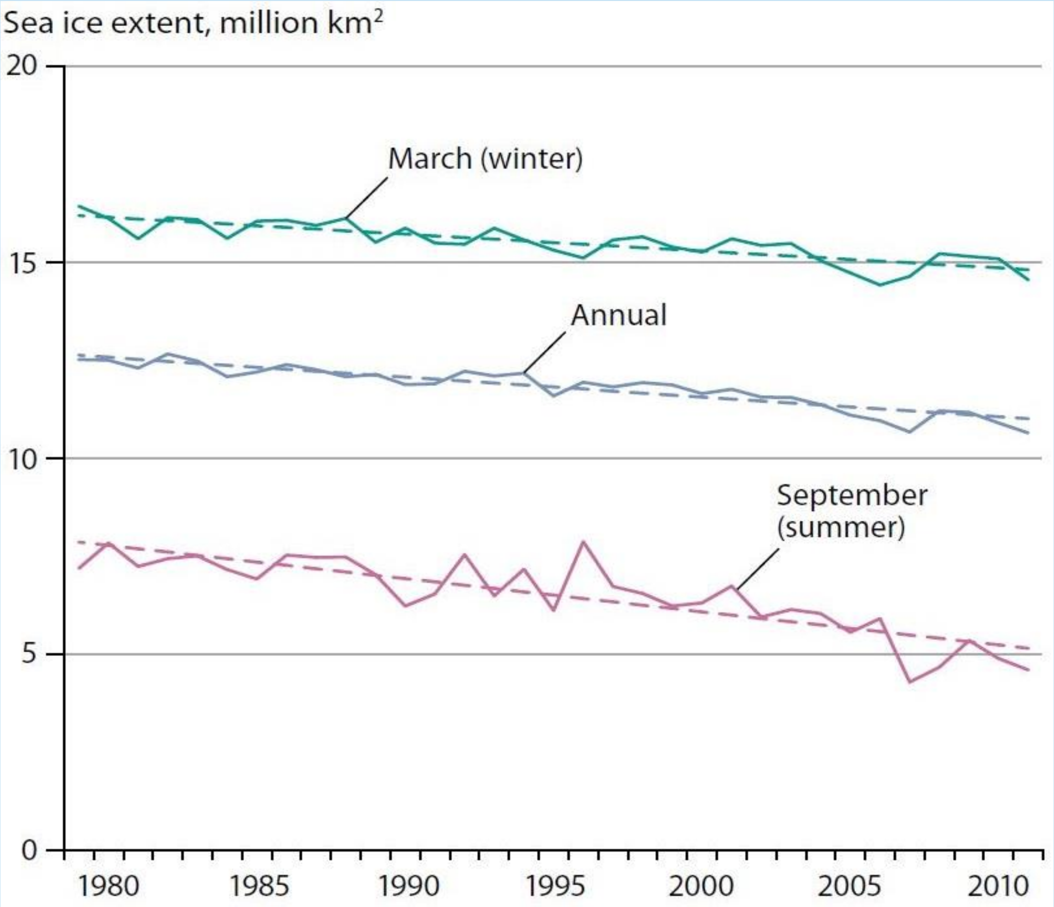
Source: Sato 2014.

Projected future temperature change



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

Arctic sea ice extent has declined



Source: AMAP, 2011

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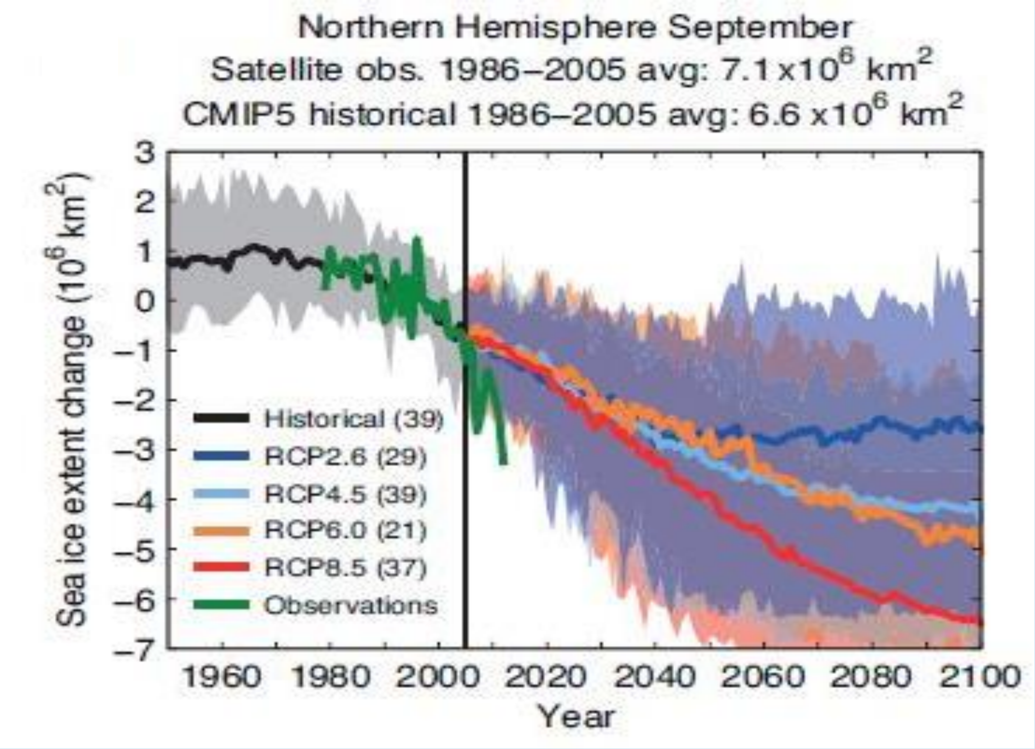
Sea ice extent is expected to decline



Source: IPCC, 2013

What role do SLCPs and BC play in the Arctic climate and is there potential to reduce the impacts by targeting SLCP emissions?

Results from the AMAP 2015 assessment

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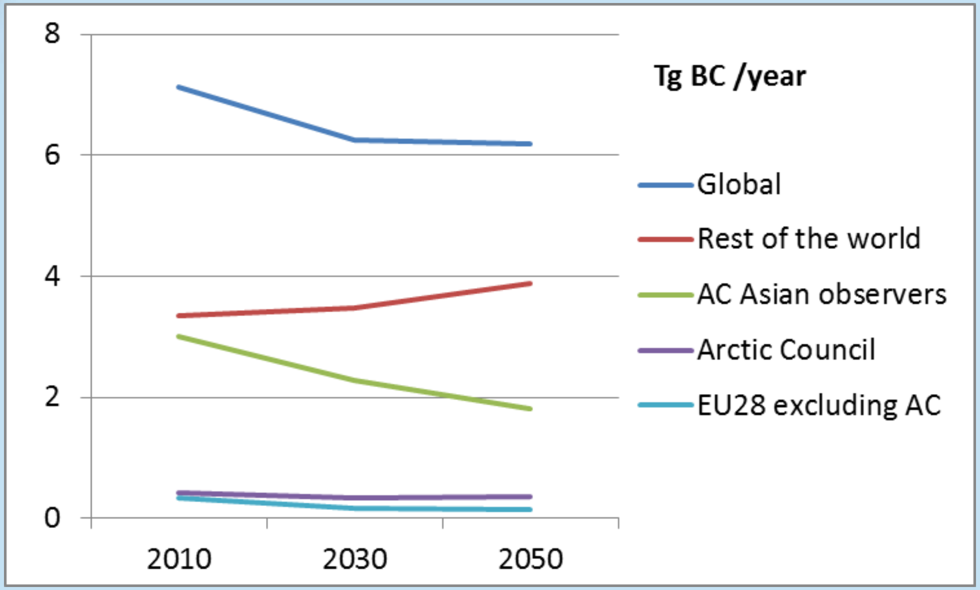
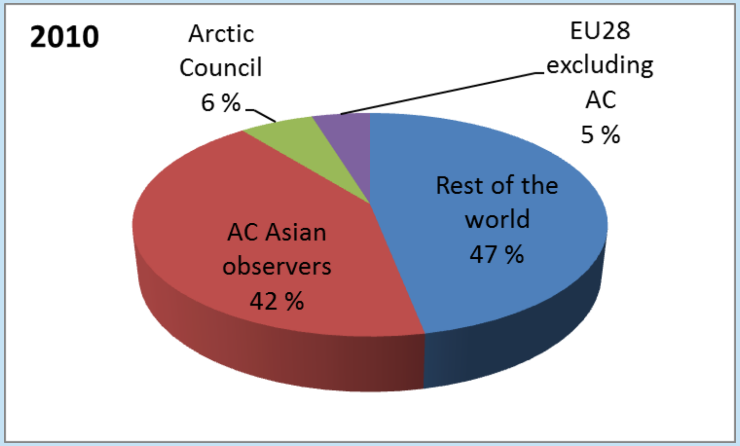
Future emissions – development with currently agreed air pollution legislation





Source: IIASA-GAINS model, ECLIPSE dataset

- Global main sectors (2010): household cooking and heating (58%), surface transport (22%)
- Wildfires add to the figure about 2.5 Tg/year

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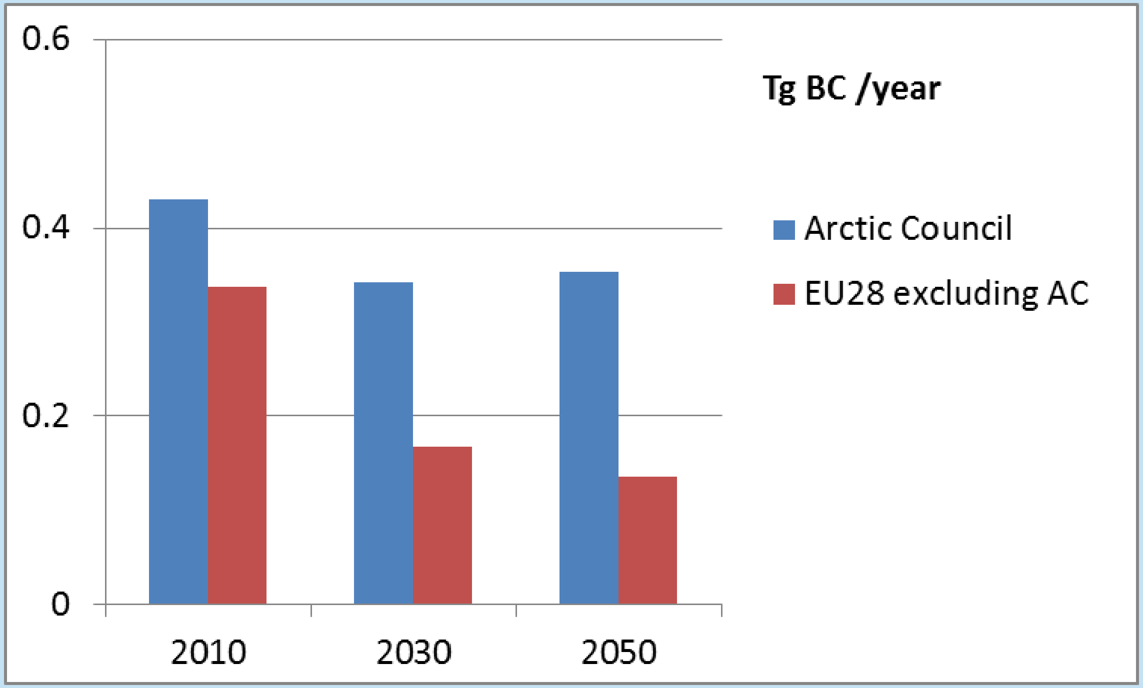
Future emissions –development with currently agreed air pollution legislation



Source: IIASA-GAINS model, ECLIPSE dataset

- Main sectors in the Arctic Council in 2010: surface transportation (46%), household combustion (19%), flaring (16%), waste burning in agriculture (9%)
- With currently agreed policies and legislation emission reductions in surface transportation account for the decline by 2030

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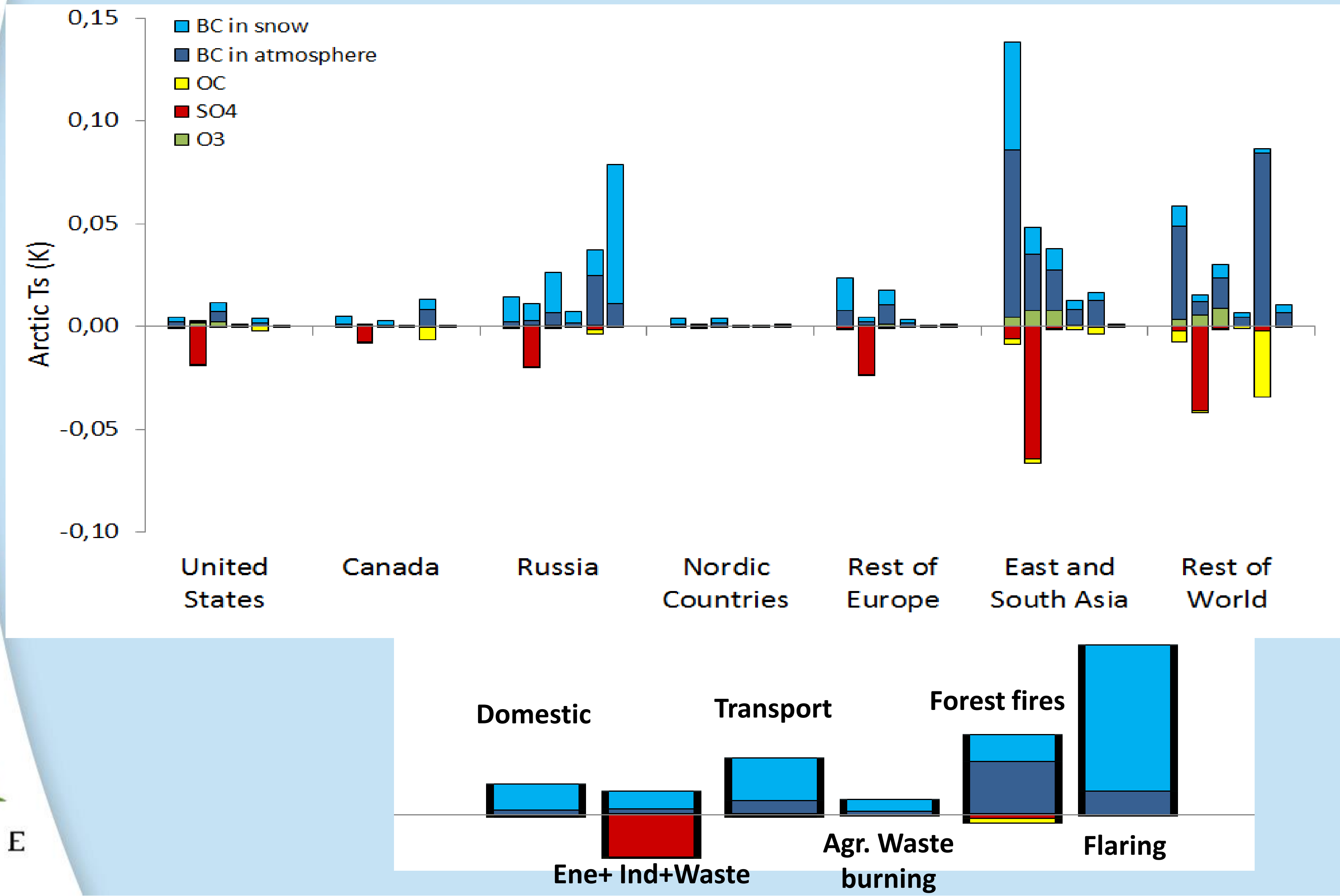
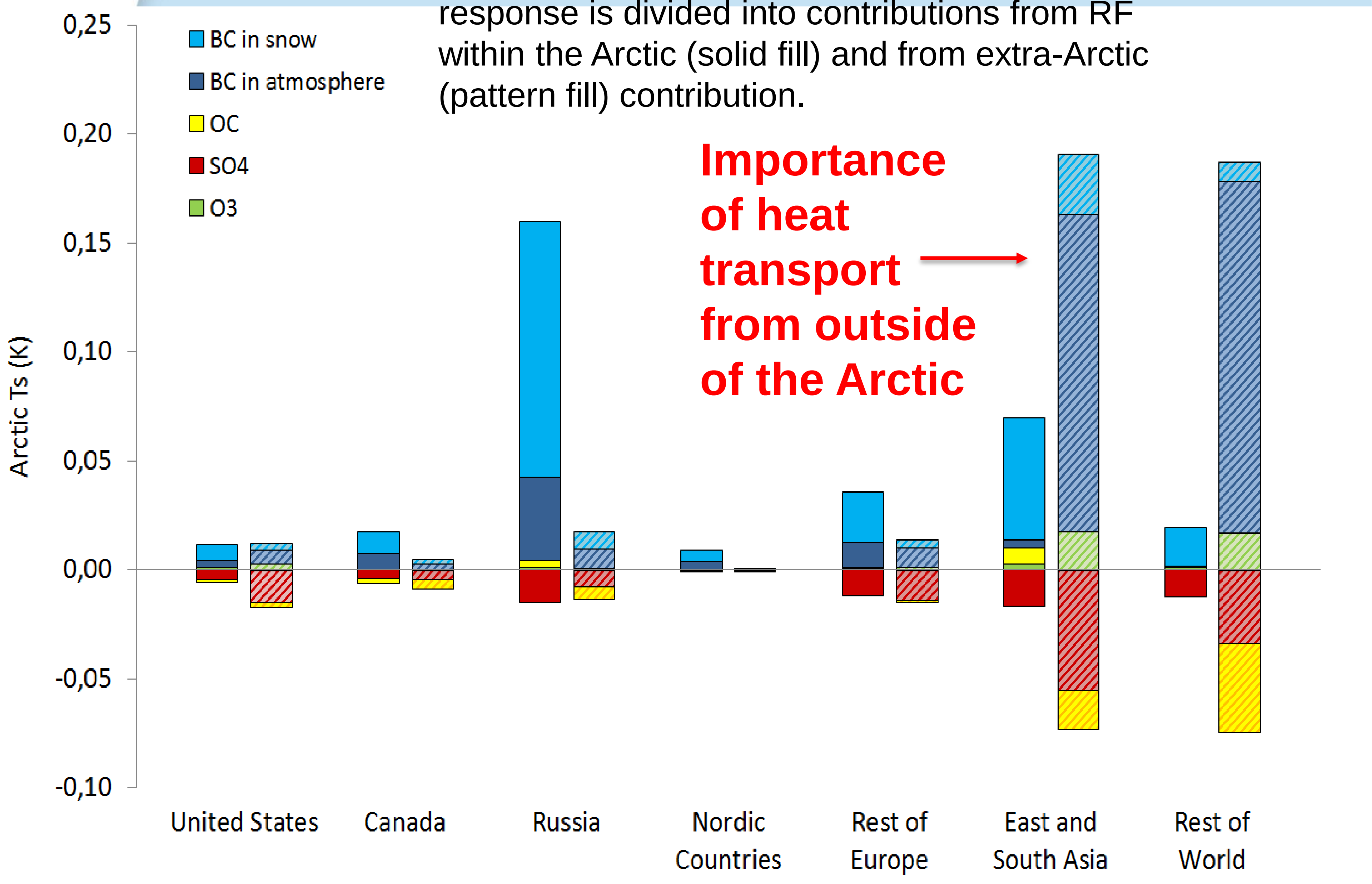
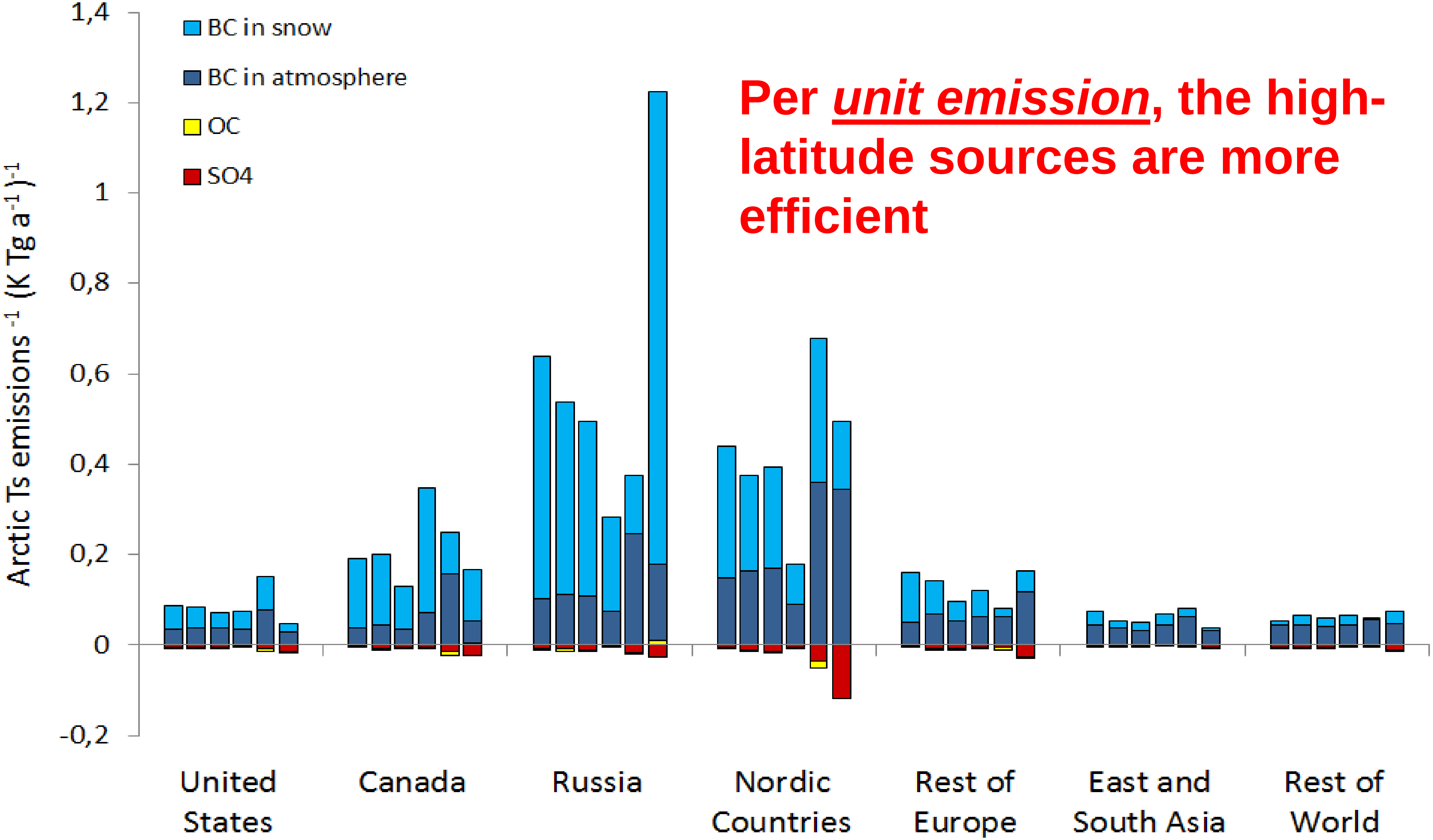
Contribution to Arctic warming by sector, region and aerosol component. Average of four models



Arctic equilibrium surface temperature response due to direct forcing by BC, OC, SO_4 and O_3 averaged over four models. The Arctic response is divided into contributions from RF within the Arctic (solid fill) and from extra-Arctic (pattern fill) contribution.



Arctic warming per unit emissions
Unit: °C/Tg(yr)$^{-1}$



Per *unit emission*, the high-latitude sources are more efficient

Within Arctic emissions – shipping and flaring

- Attention should be paid to the within Arctic sources and their future development:
- Current Arctic shipping activities are not a major emission source, but some projections estimate a 4 fold growth by 2030 and a 10 fold growth by 2050
- Flaring in the oil and gas industries is already a significant source of Arctic BC (Stohl et al. 2013)

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 significantly 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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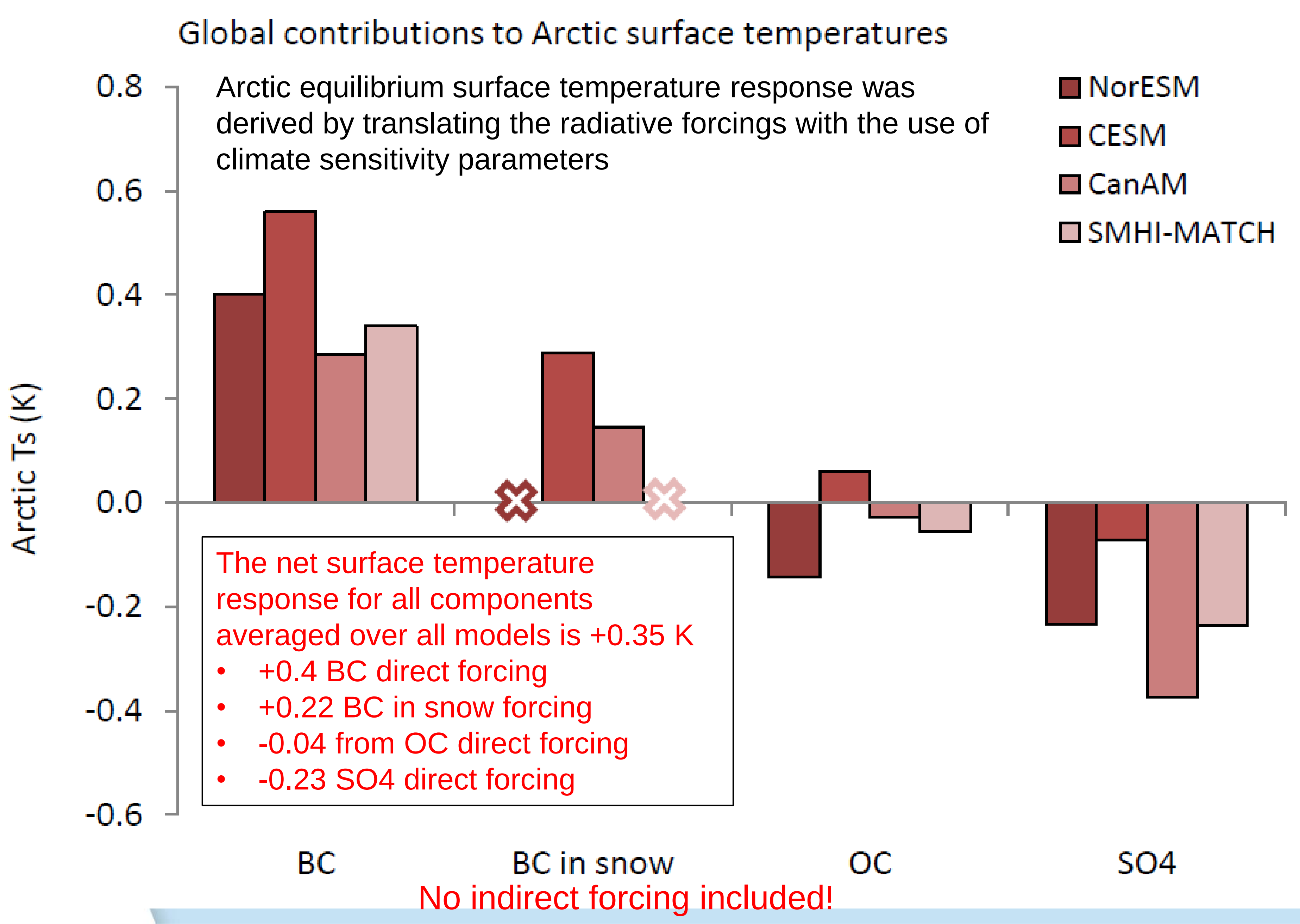

Global contributions to Arctic surface temperatures
Arctic equilibrium surface temperature response was derived by translating the radiative forcings with the use of climate sensitivity parameters
NorESM
CESM
CanAM
SMHI-MATCH
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Arctic Ts (K)
The net surface temperature response for all components averaged over all models is +0.35 K
• +0.4 BC direct forcing
• +0.22 BC in snow forcing
• -0.04 from OC direct forcing
• -0.23 SO4 direct forcing
BC
BC in snow
OC
SO4
No indirect forcing included!

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

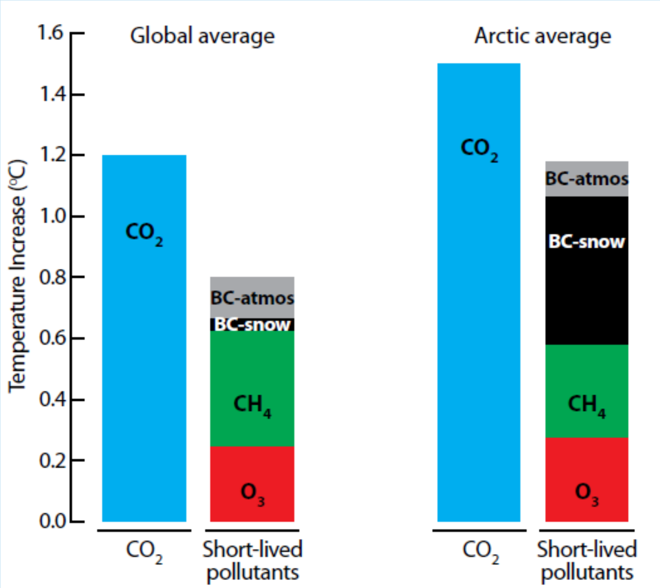

Figure 11. Annually averaged temperature increase for CO_2 and the short-lived warming pollutants relative to pre-industrial. Globally averaged values are shown on the left and Arctic averages on the right. Global values based on IPCC (2007). Arctic values based on Quinn et al. (2008). Note that cooling 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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Potential for further BC emission reductions (AMAP)

IIASA-GAINS ECLIPSE (Z. Klimont will talk in more detail):

- Prioritizing measures that target SLCPs it is technically possible to reduce BC emissions significantly from CLE levels
- Global potential for emission reductions 70 to 80%
- Arctic Council potential emission reductions 75%

- Impact on Arctic climate:
  - Additional emission reductions in of non-methane SLCPs reduce warming by 0.25 °C in the Arctic region
  - This corresponds to about 10 - 15% of the Arctic-region warming that is expected over the 2006-2050 period in globally-averaged surface air temperature, due to all climate forcers in a high emission scenario (RCP8.5).
  - Emission reductions slow down the decline in Arctic sea ice

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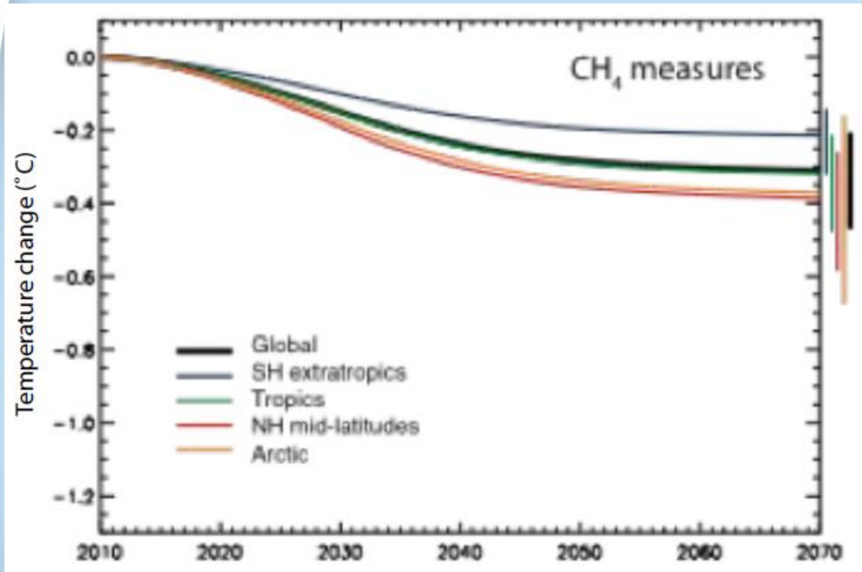
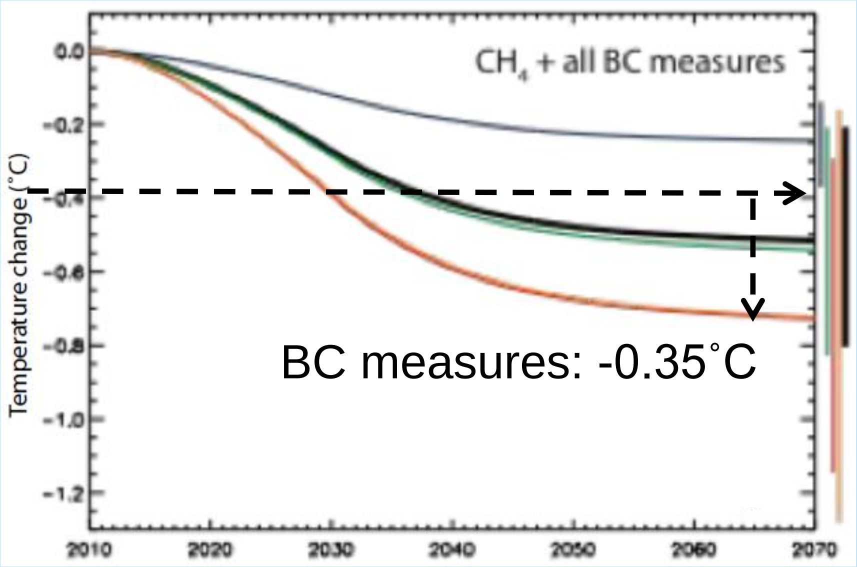
For comparison: results from UNEP/WMO 2011 Integrated Assessment of Black Carbon and Troposperic Ozone





- 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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Some AMAP 2015 findings on model results vs observations

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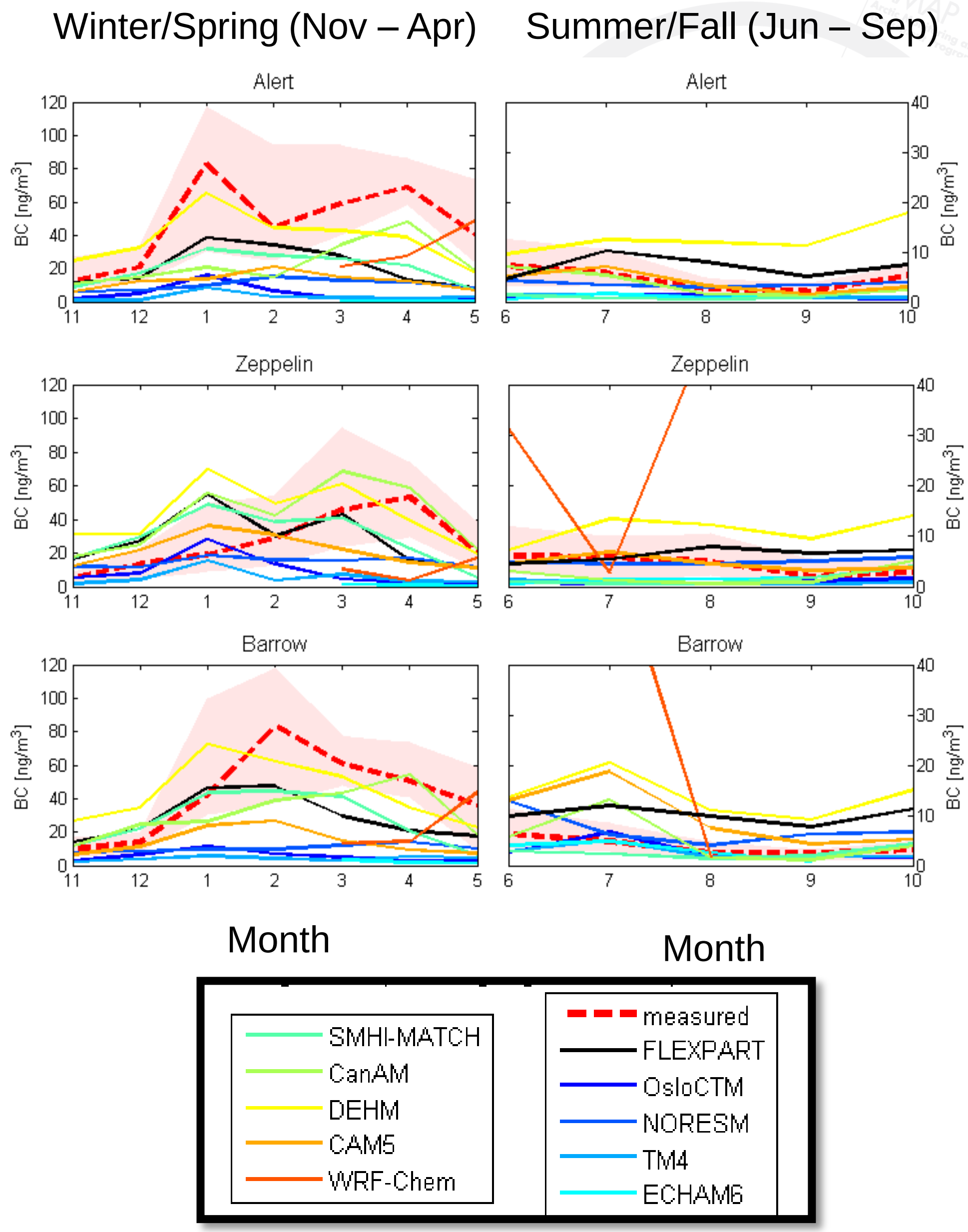
Model performance for atmospheric BC

- Performance of aerosol models (CTMs, CCMs, etc.) has been improved considerably over last few years (better treatments of BC aging and scavenging processes, seasonally varying emissions, flaring emissions).

- However, the magnitude of the seasonal cycle of BC concentrations in the Arctic is still underestimated.

- The peak concentrations in spring are underestimated, more so at highest latitudes. Concentrations in summer and fall are overestimated.

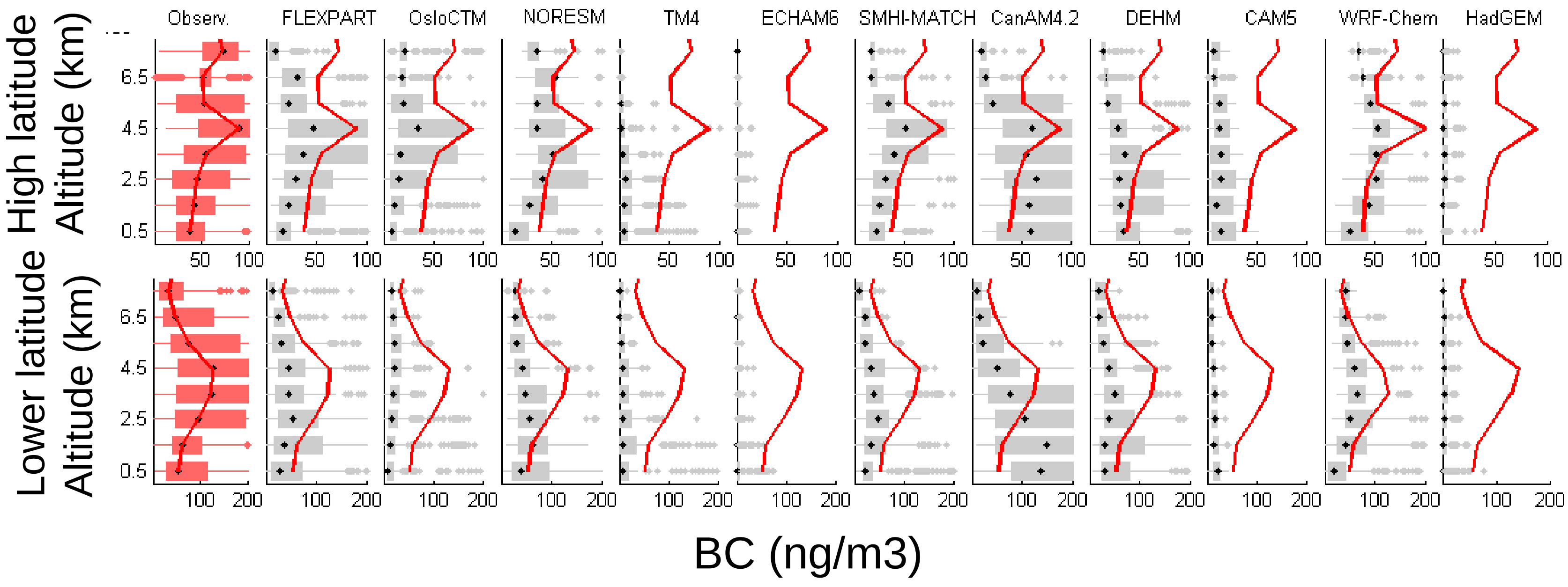
- Monthly median concentrations of BC still deviate by an order of magnitude or more between models.



Red: Observations
Other colors: AMAP & ECLIPSE models

Eckhardt et al., in prep, 2015

Comparison of modeled atmospheric BC with observations of rBC from the ARCTAS-spring and ARCPAC campaigns in Spring 2008

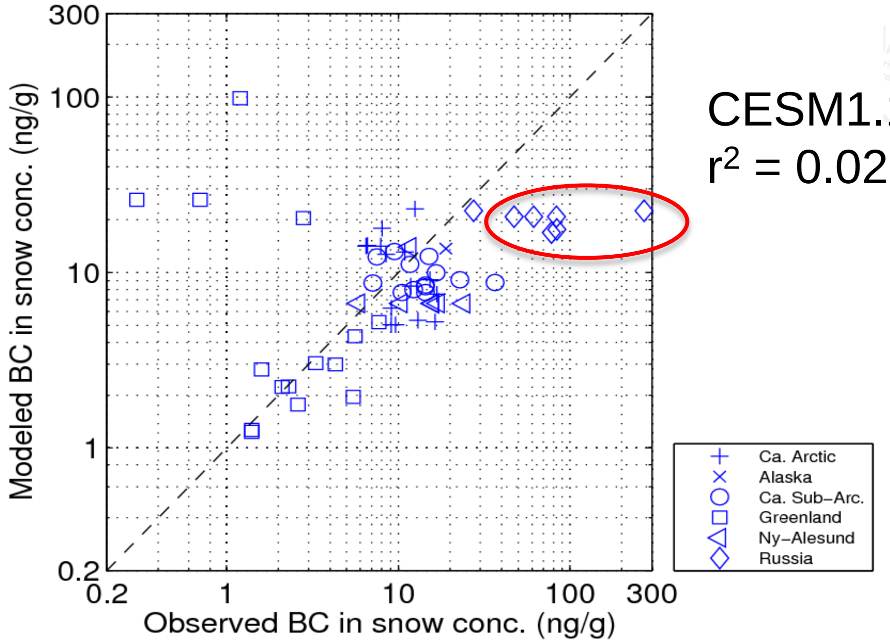


- All models except CanAM4.2 underestimate measured values throughout the depth of the troposphere.
- Strong influence from biomass burning in Spring 2008 → Emissions may have been underestimated or emission altitudes may have been wrong.
- But… models also underestimate SO4 at all altitudes and not much SO4 is produced in biomass burning plumes.

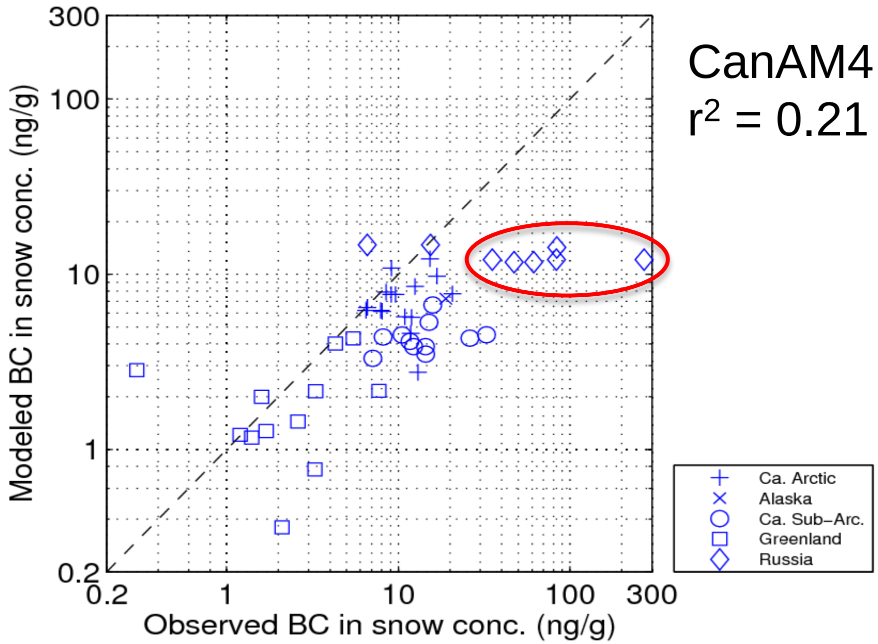
Eckhardt et al., in prep, 2015

Model performance for BC in snow

- Concentrations of BC in snow from two models (CESM1.1.1 and CanAM4.2) compared with measurements from Doherty et al. (2010).
- High concentrations in Russia not captured by either model.
- CESM simulates too little BC in the near-surface Arctic atmosphere but reasonable snow concentrations.
- CanAM simulates better near-surface atmospheric concentrations but too little BC in snow.
- Further research on Arctic aerosol deposition processes, melt-induced impurity accumulation, sublimation, and distribution through snow layers is required.

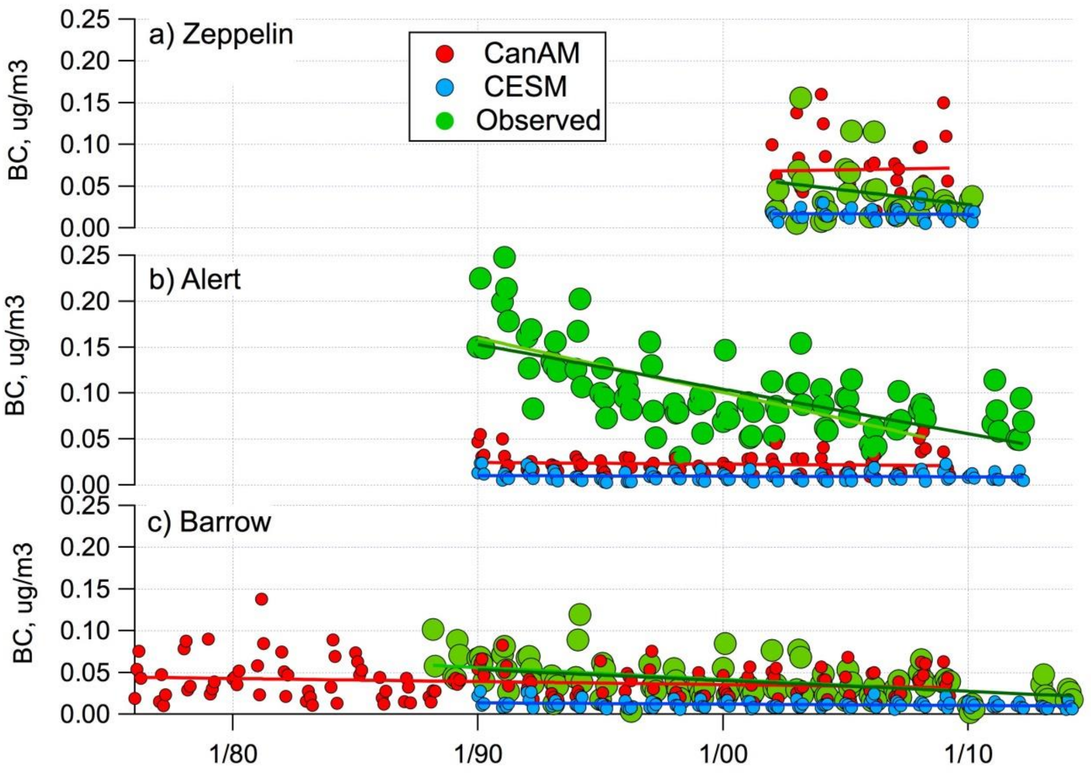


CESM1.1.1
$r^2 = 0.02$



CanAM4.2
$r^2 = 0.21$

Long term trends in eBC for the Arctic Haze season (Jan – April): Model – measurement comparison



% Change per year		
Obs	Modeled	
	CanAM	CESM
-3.2	-0.27	-2.25
-3.6	-1.3	-0.41
-1.9	-0.52	-0.85

Red values indicate a ≥ 90% significance of a trend.

- Observations of eBC indicate a stronger decrease in concentration over the measurement period than is simulated by the models.
- Sensitivity tests to evaluate how emissions from different regions and source sectors affect concentration trends in the Arctic are needed.

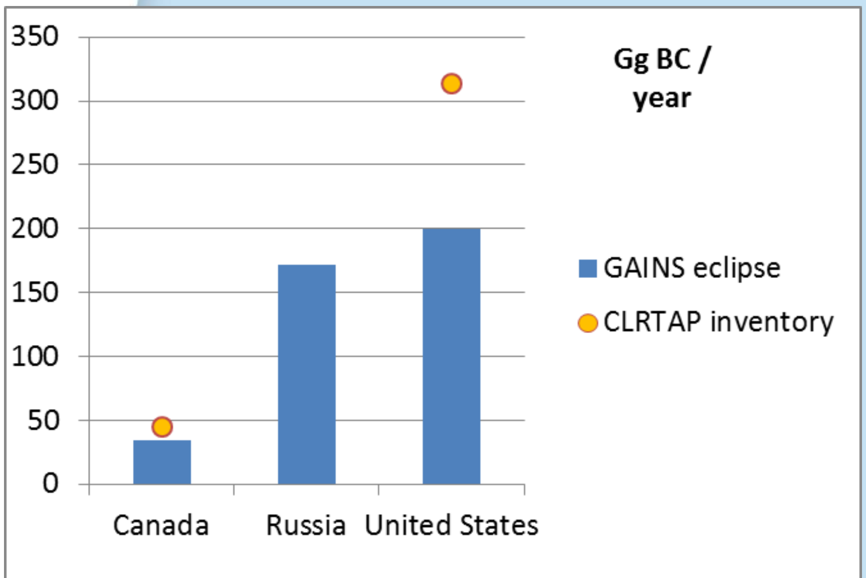
Emissions:
Spatial representation of emissions in high latitudes

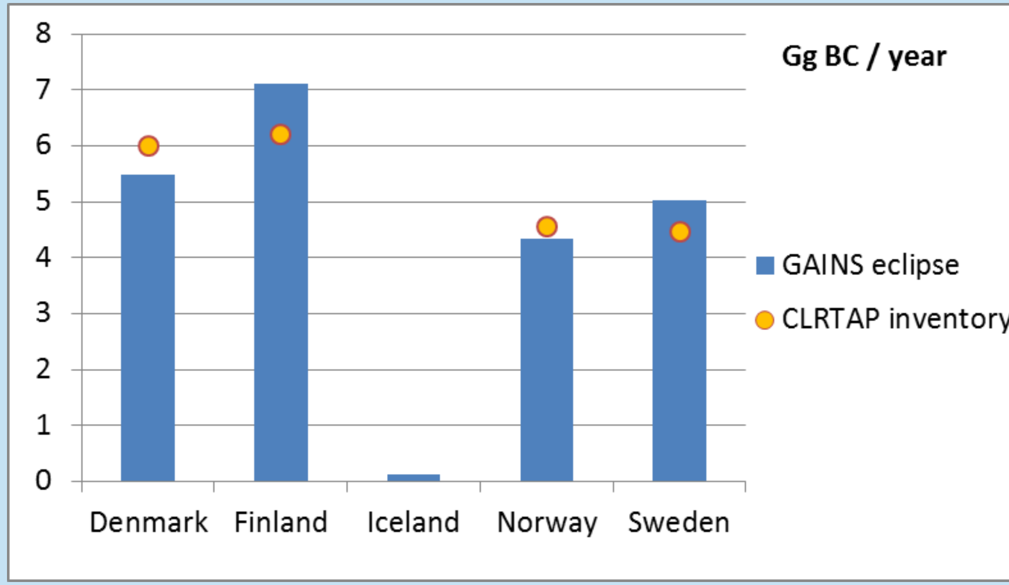
Comparison of different global emission inventories: Values give ratios between maximum and minimum emissions for different latitude bands (Paunu & Kupiainen 2015, under preparation)

		Global	40˚N	60˚N	70˚N
Black carbon (BC)	2000	1.30	1.15	1.53	3.01
	2005	1.08	1.17	3.91	4.49
	2010	1.20	1.40	3.09	3.52
Organic carbon (OC)	2000	2.43	1.94	2.09	1.97
	2005	1.09	1.61	1.93	4.83
	2010	1.21	1.61	2.32	5.67
Sulfur dioxide (SO2)	2000	1.20	1.09	2.39	1.51
	2005	1.13	1.13	1.23	1.25
	2010	1.22	1.32	1.58	2.82
Nitrogen oxides (NOX)	2000	1.28	1.26	3.51	7.19
	2005	1.12	1.14	1.42	2.37
	2010	1.17	1.23	1.46	2.46
Carbon monoxide (CO)	2000	1.60	1.70	2.91	13.31
	2005	1.19	1.32	1.25	1.55
	2010	1.38	1.48	2.30	10.47

- Inclusion of relevant source sectors (e.g. flaring) and spatial distributions of the emission data, including the hotspots.
- Emissions at high latitudes are more sensitive to uncertainties in regionally important source sectors.
- Variations in the sector emission estimates arise from uncertainties in key parameters, i.e. activities and emission factors.

CLRTAP national BC submissions 2015 (US 2014) and GAINS eclipse





Note: US data without natural fires and prescribed burning of forests

Further work on improving BC emission inventories is also a priority in the Arctic Council (i.e. ACAPWOOD, Task Force on Black Carbon and Methane)

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Way forward with BC in the Arctic Council

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Iqaluit, Canada, April 24, 2015

IQALUIT DECLARATION 2015

On the occasion of the Ninth Ministerial Meeting of the Arctic Council

PROTECTING THE UNIQUE ARCTIC ENVIRONMENT

22. **Acknowledge** that reducing greenhouse gas emissions continues to be the most important contribution to addressing global and Arctic climate change and to the long-term conservation and sustainability of the unique Arctic environment, **recognize** that short-lived climate pollutants emitted within and beyond the borders of the Arctic States have substantial impact on the Arctic, and **further recognize** that efforts undertaken by the Arctic states to reduce these emissions, which complement initiatives such as the Climate and Clean Air Coalition, lead to climate, as well as health and economic benefits, in the Arctic,

23. **Welcome** the assessments and conclusions on black carbon, tropospheric ozone and methane which provide a clear and compelling basis for further action on short-lived climate forcers in the Arctic and beyond, as well as the successful work related to reducing black carbon emissions from diesel and residential wood combustion,

24. **Decide** to implement the Framework for Action on Enhanced Black Carbon and Methane Emissions reductions, **establish** an expert group reporting to Senior Arctic Officials to report on our collective progress, and **call upon** observer states to join us in these actions given the global nature of the challenge,

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Arctic Council Framework for Action on Enhanced Black Carbon and Methane Emission Reductions

- Arctic Council countries commit to…
  - provide BC inventories starting in 2015
  - Adopt an ambitious, aspirational and quantitative collective goal on black carbon by 2017
- Enhace actions at national level
  - Develop and improve emission inventories
  - Submit a national report to AC secretariat every 2 years.
    - Summary of national emissions (BC will rely on CLRTAP submissions)
    - Summary of national actions and mitigation strategies
    - Highlight best practices, projects and other available information
  - The AC secretariat will compile a high level summary from the national reports.

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Arctic Council Framework for Action on Enhanced Black Carbon and Methane Emission Reductions

- Enhance collective action
  - Establish an Expert Group to drive the process and follow up collective progress
    - ”Summary of Progress and Recommendations” report to the biannual ministerial meeting
  - Support a 4-year periodic science work (monitoring; climate and health impacts; cost of mitigation)
  - Increase awareness
  - Project and sector specific activities
- Promote action by others
  - AC looks forward for the observers to join in implementing the framework
  - Actively work with other stakeholders and international and regional forums and agreements

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Potential future information needs in Arctic scientific assessments

- Emission scenarios and associated costs of emission mitigation
- Climate impacts
- Health impacts
- Optimization of emission reductions from an Arctic perspective?

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Thank you for your attention!

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