The Role of Aerosol in a Changing Arctic

Роль аэрозолей на климат в изменении Арктики

Julia Schmale
Paul Scherrer Institute, Switzerland

Российский государственный гидрометеорологический ниверситет

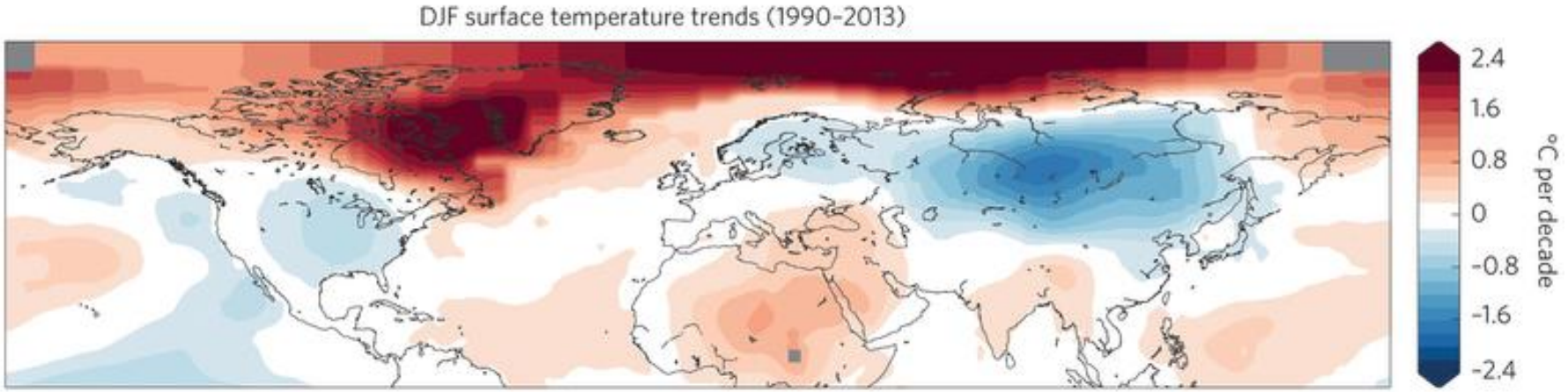
St. Petersburg, 27.05.2016

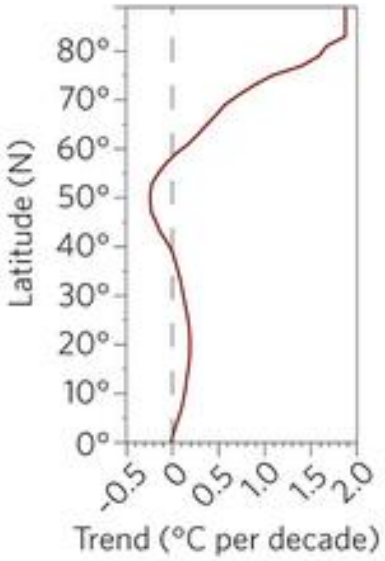
(Stohl et al., 2007)

Outline

- Motivation
- Arctic aerosol
  - Relevant emissions
  - Transport to the Arctic
  - Observations within the Arctic
  - Modeling vs observations
- Arctic climate forcing by aerosol and temperature response
- Summary

Motivation – Arctic Amplification

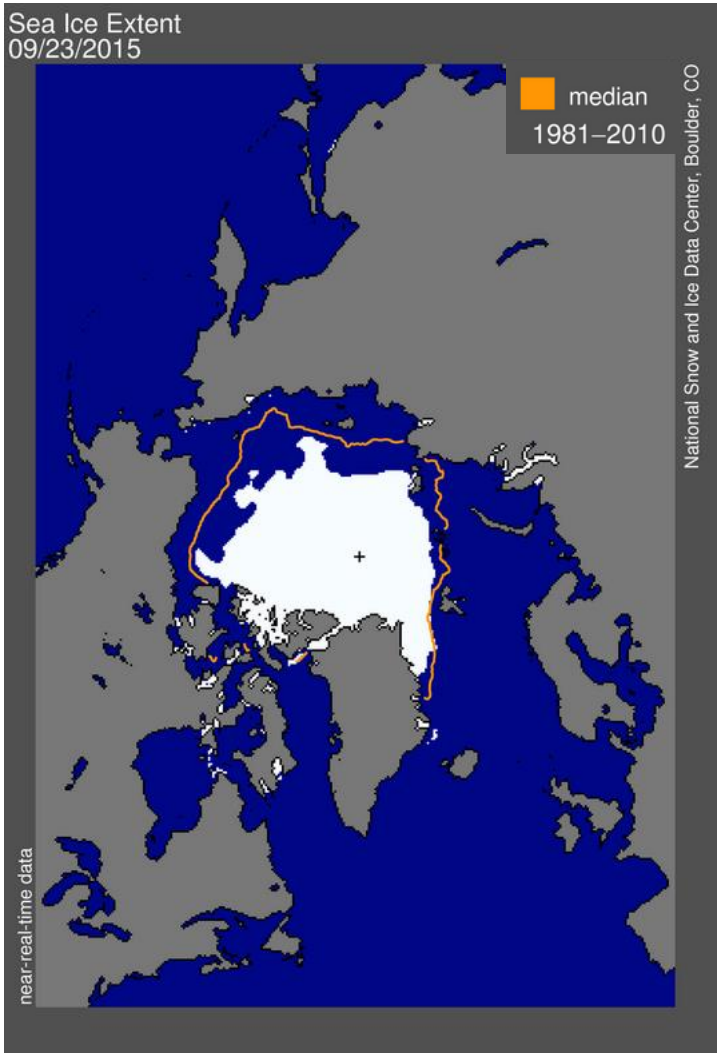




Since the preindustrial period the Arctic has warmed twice as much as the global average.

(Cohen et al., 2014)

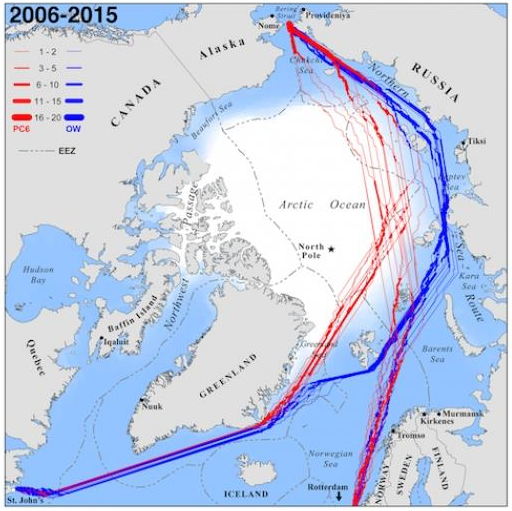
Motivation – From Receptor to Source Region

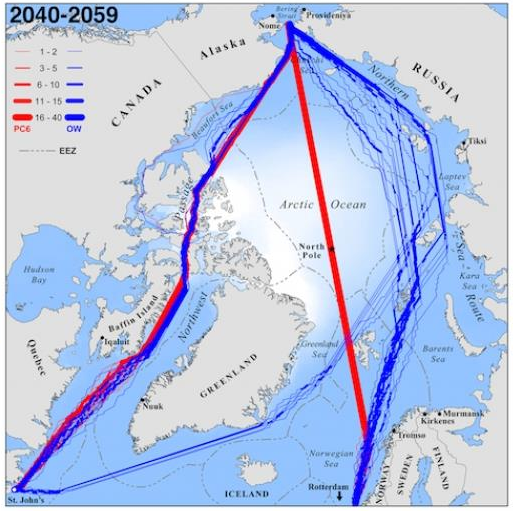


September 2015: 4th lowest sea ice extent since satellite observations

Retreating sea ice and less multi-year ice give prospects to Arctic shipping in the future

- Time and fuel savings
- Enhanced local Arctic emissions
  - Climate forcing
  - Air polltuion

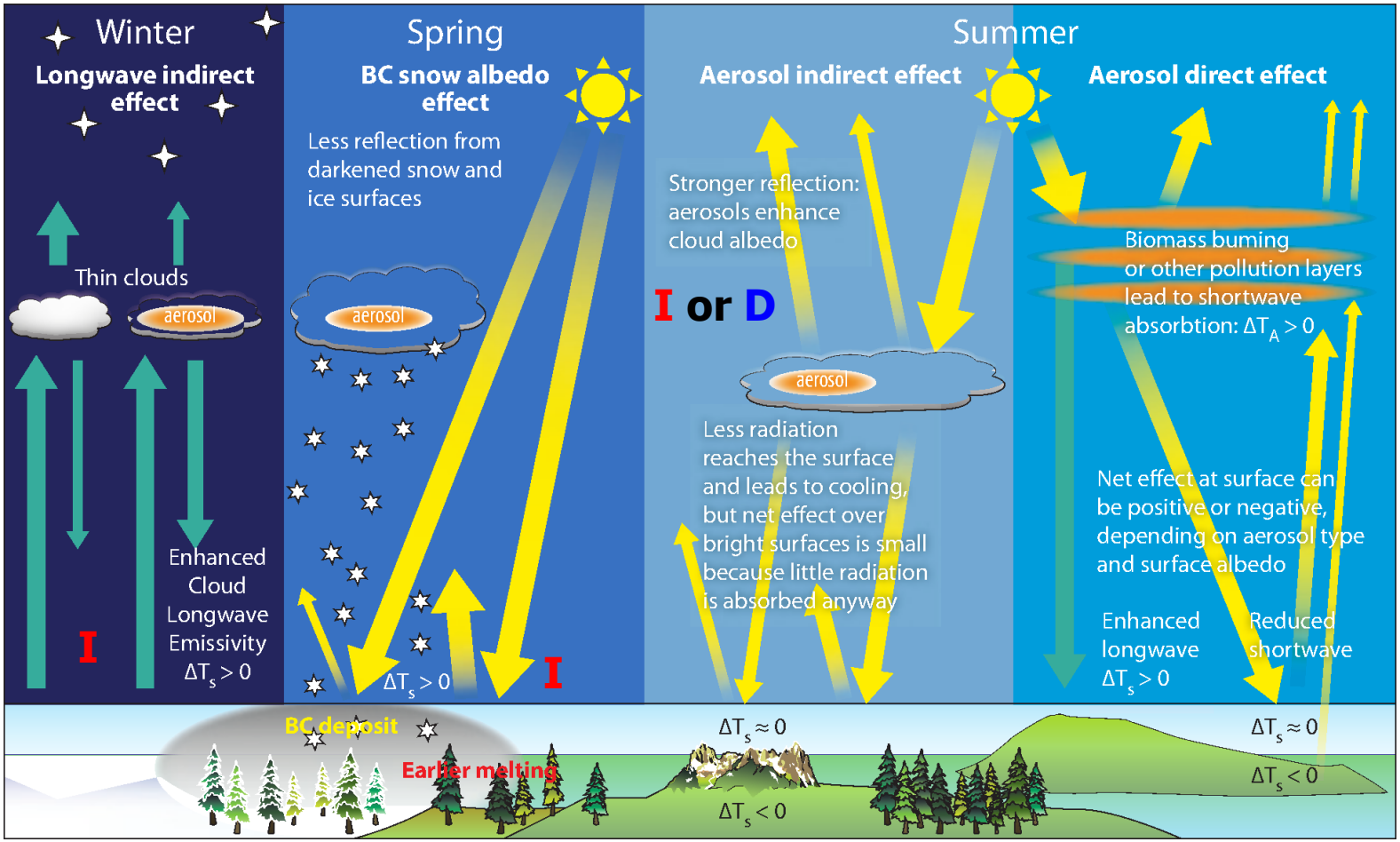




(Smith & Stephenson, 2013)

Aerosol Effects – Arctic Climate

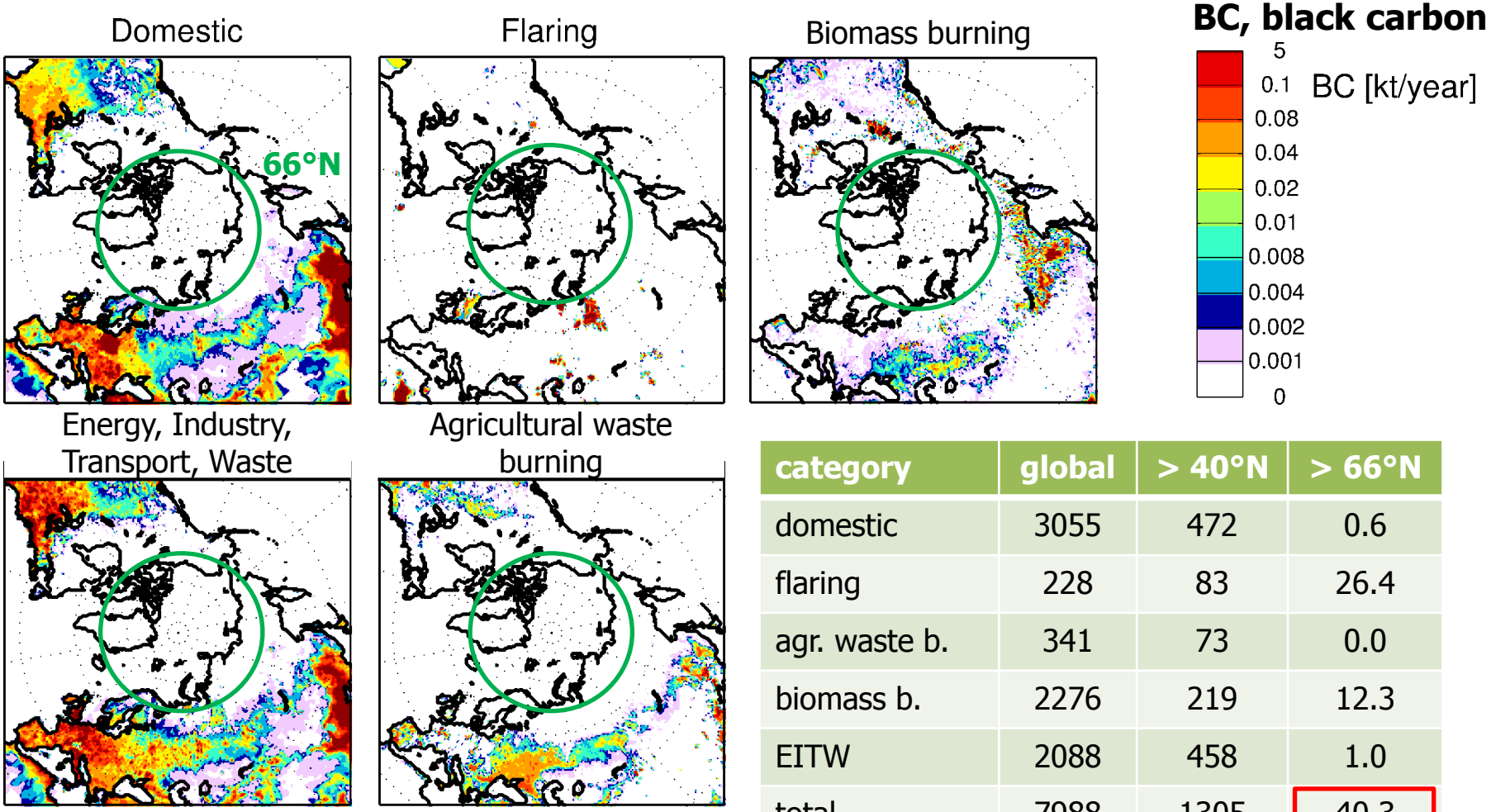
I = temperature increase; D = decrease



(AMAP Technical Report, 2011)

Relevant Emissions & Transport

Emission Regions and Sources



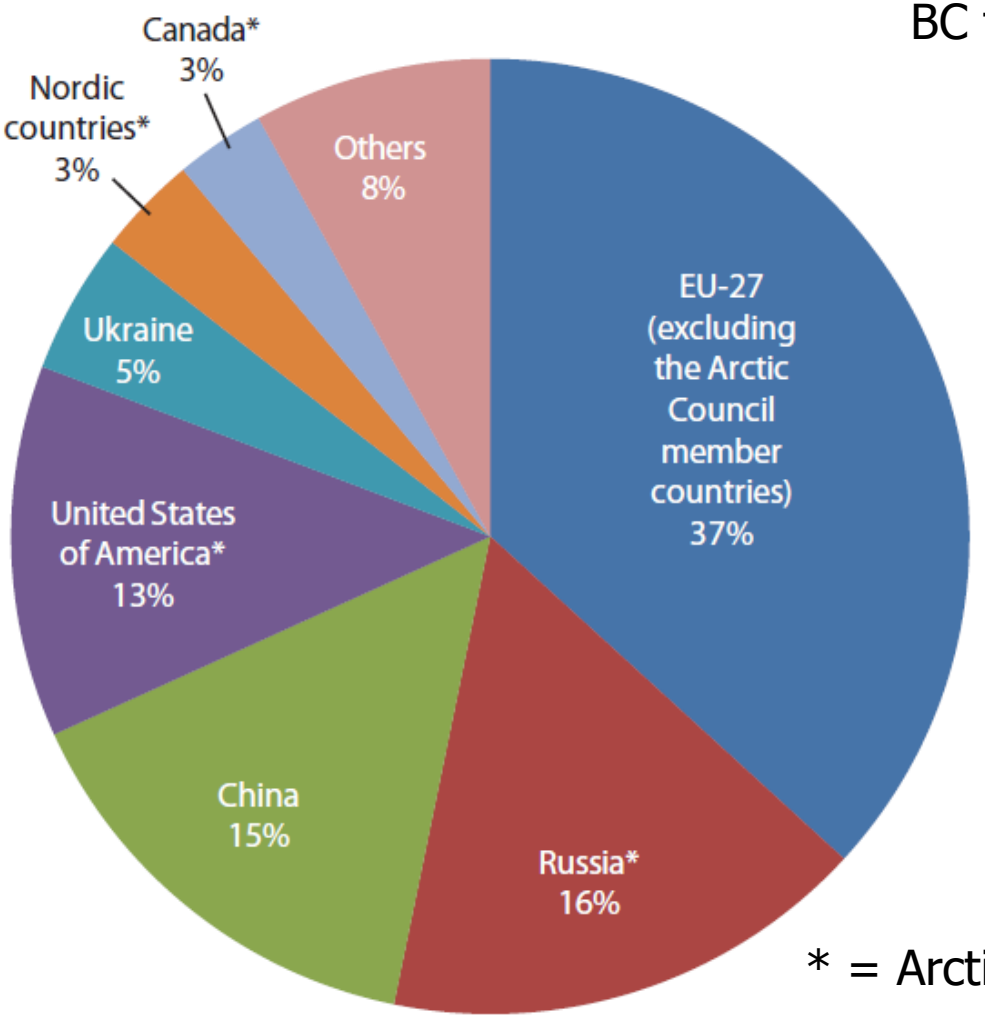
category	global	> 40°N	> 66°N
domestic	3055	472	0.6
flaring	228	83	26.4
agr. waste b.	341	73	0.0
biomass b.	2276	219	12.3
EITW	2088	458	1.0
total	7988	1305	40.3

0.5 % of global, 3.1 % of > 40 °N

(Stohl et al., 2013)

Emission Regions and Sources

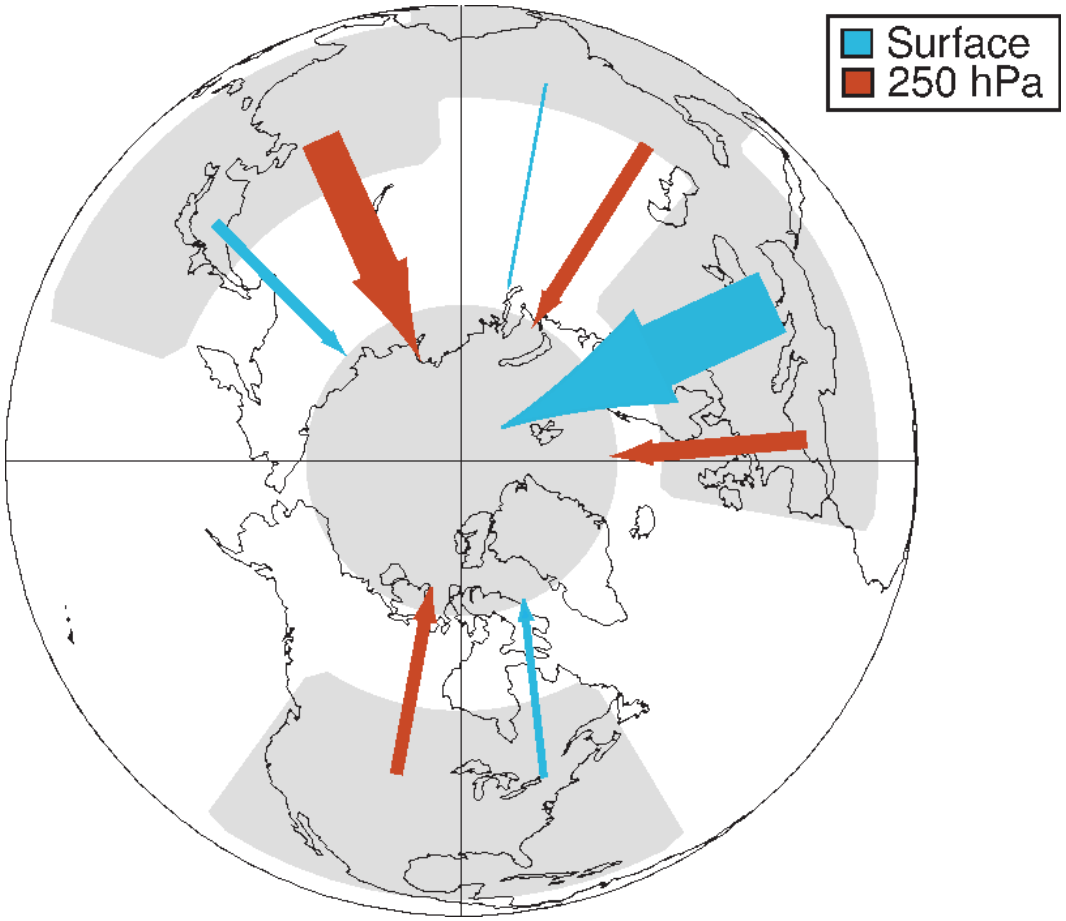
BC fluxes north of 40° N



* = Arctic Council country

(Lamarque et al., 2010; AMAP Technical Report, 2011)

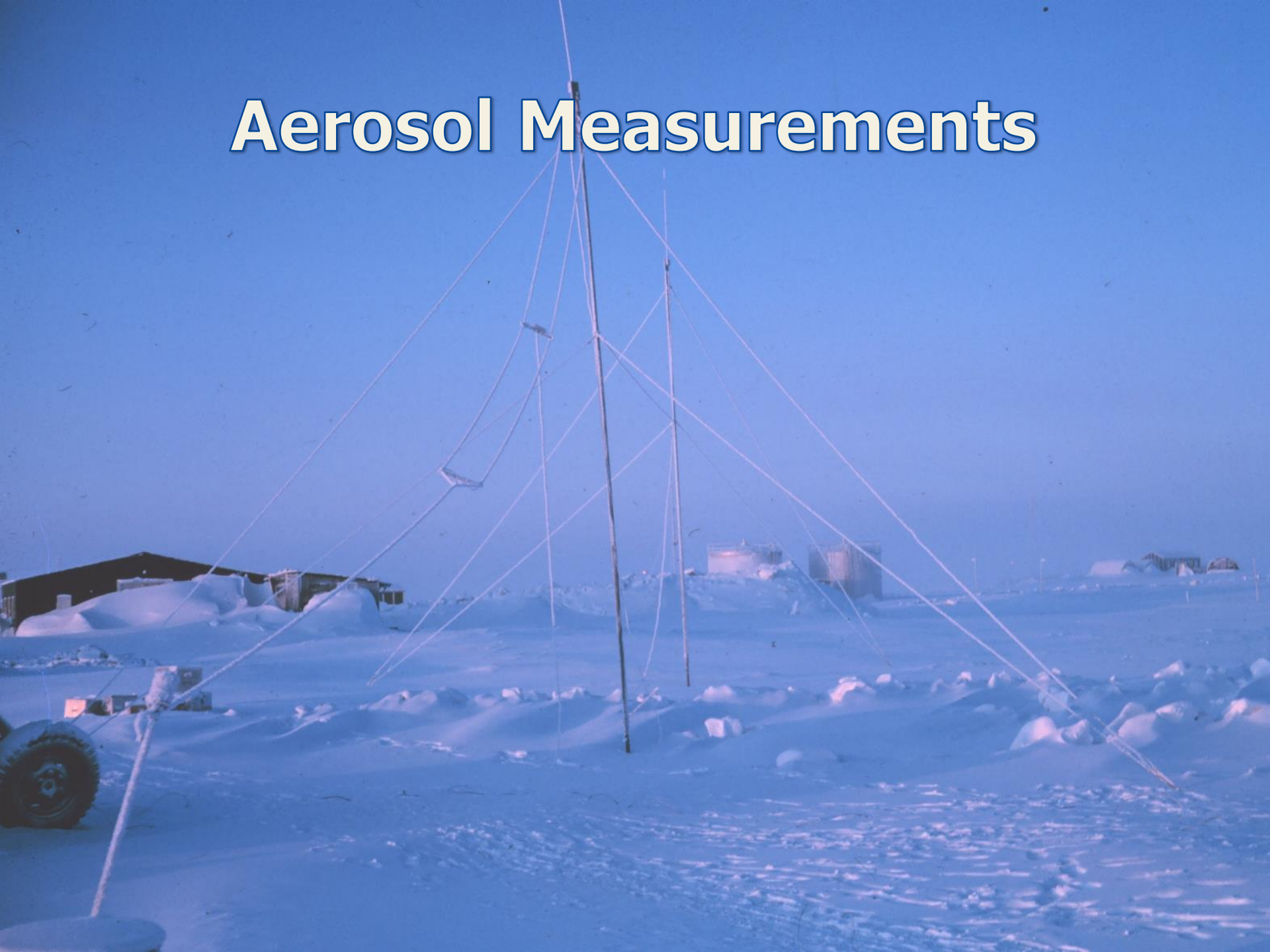
Transport of Aerosol to the Arctic



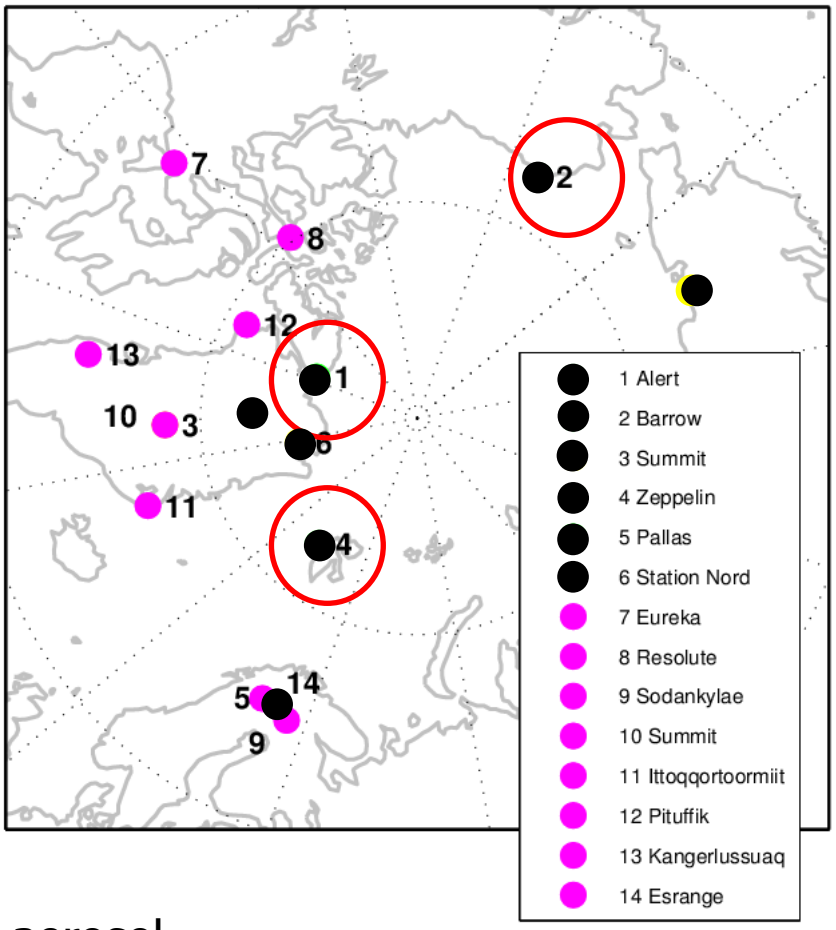
- East Asian emissions dominant in the upper troposphere
- European emissions dominate Arctic surface concentrations
- Deposition of aerosol onto Greenland most sensitive to North American emissions

(Shindell et al., 2008)

Aerosol Measurements

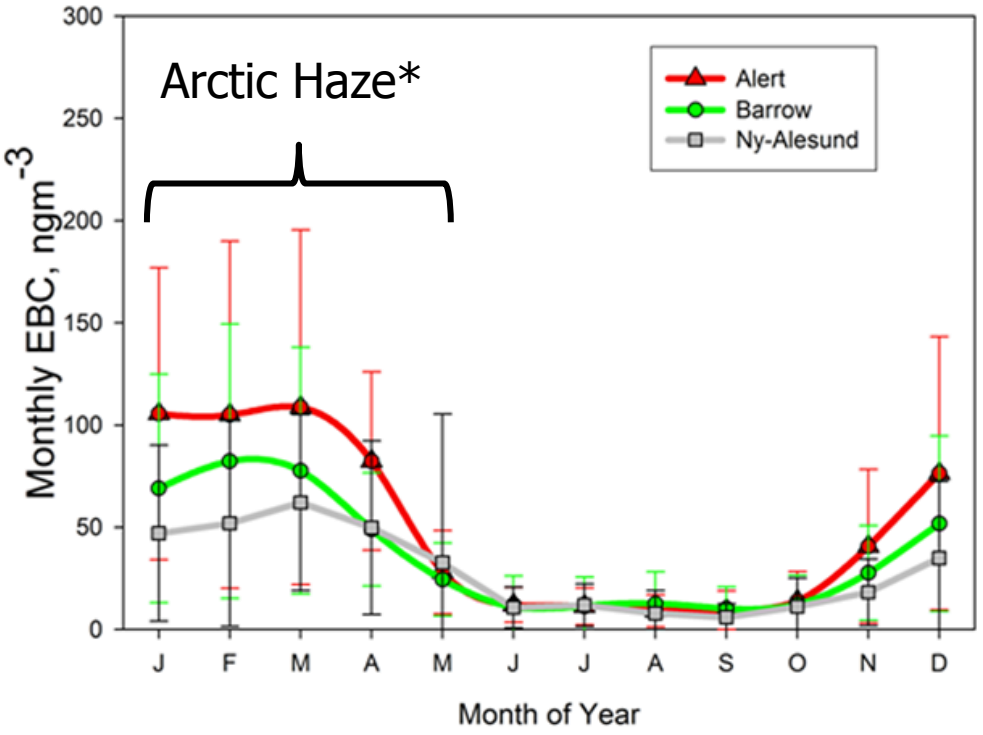


Aerosol Measurements – Long-term ground-based



aerosol

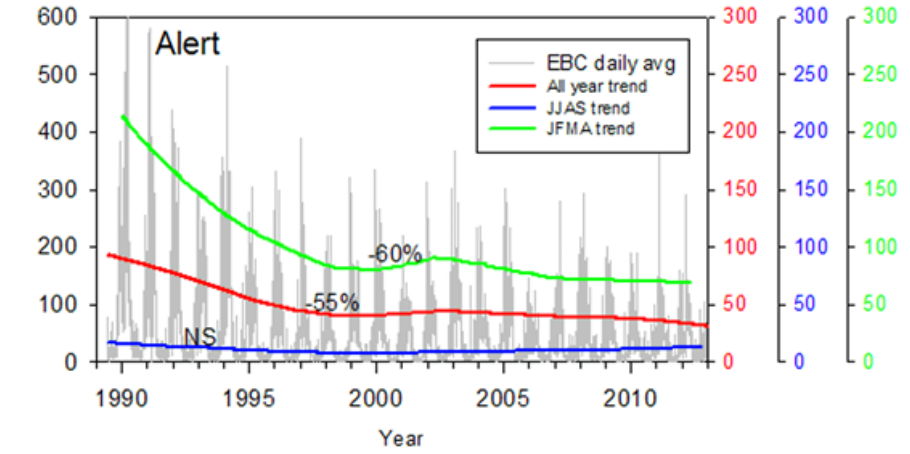
yes ● no ●

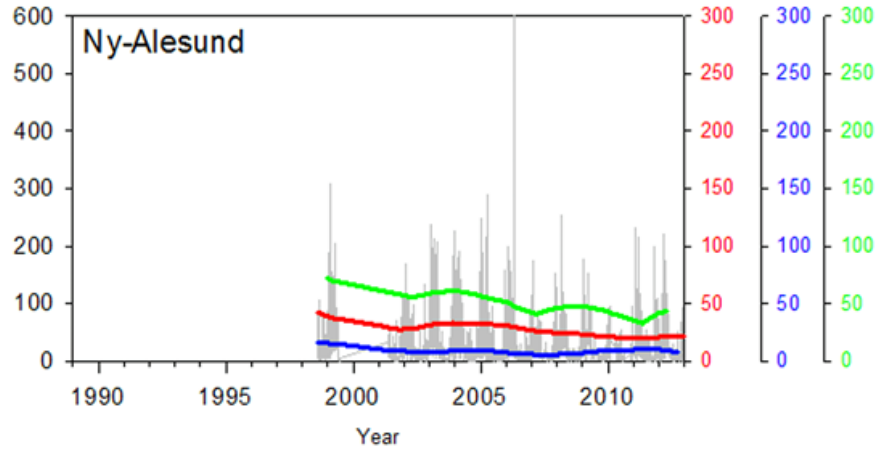


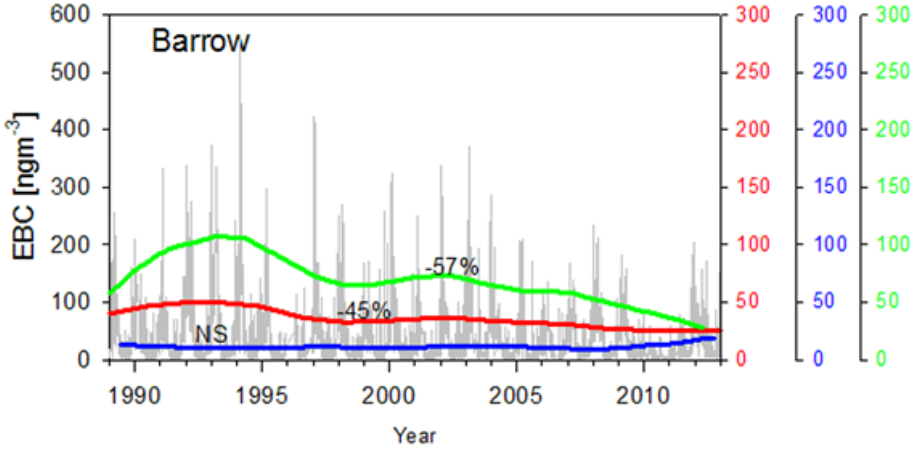
* First time observed by pilots in the 1950s.

(Arctic Report Card, 2013)

Aerosol Measurements – Long-term ground-based







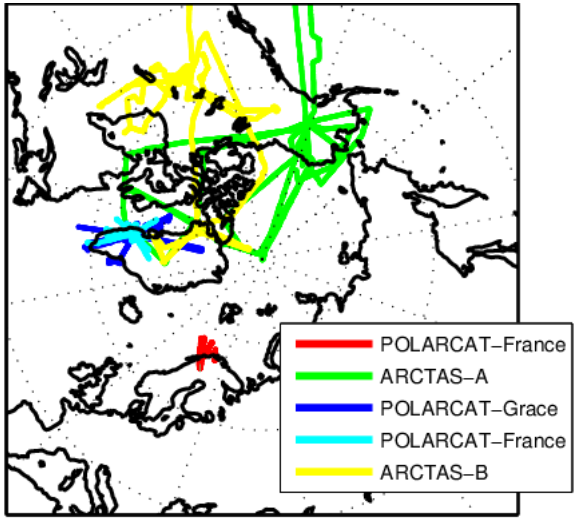
January – April average
Year around average
June – September average

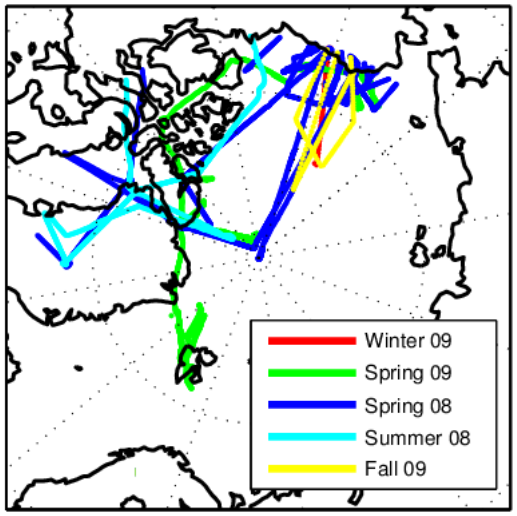
Useful for
- long-term observations
- high precision (long integration times)

But
- no information about vertical structure

(Sharma et al., 2013a, 2013b)

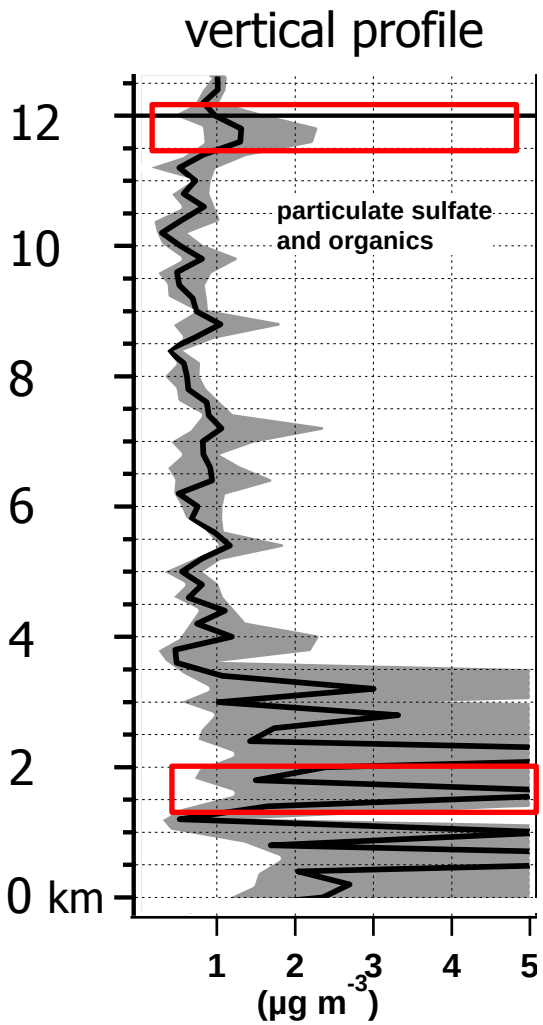
Aerosol Measurements - Airborne

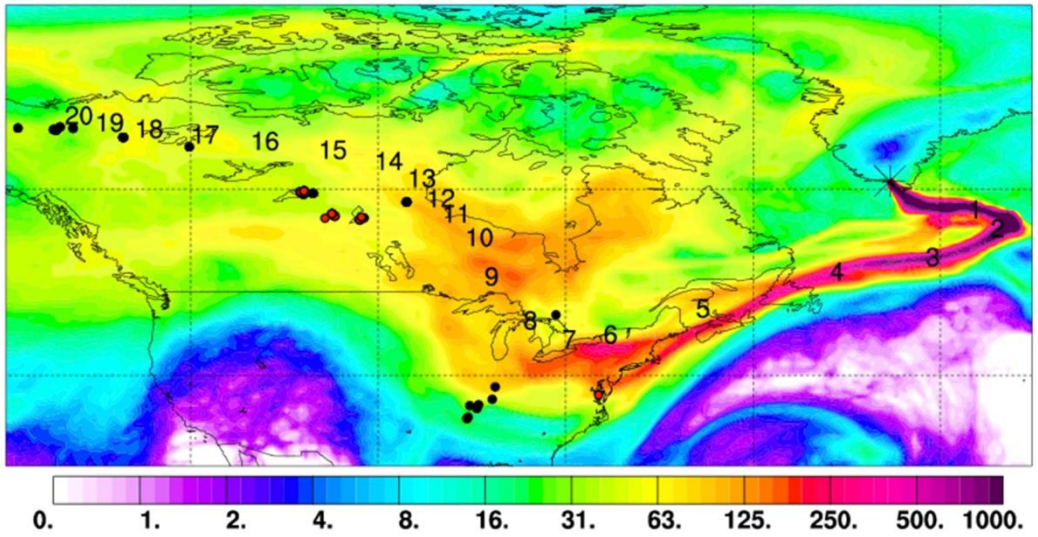


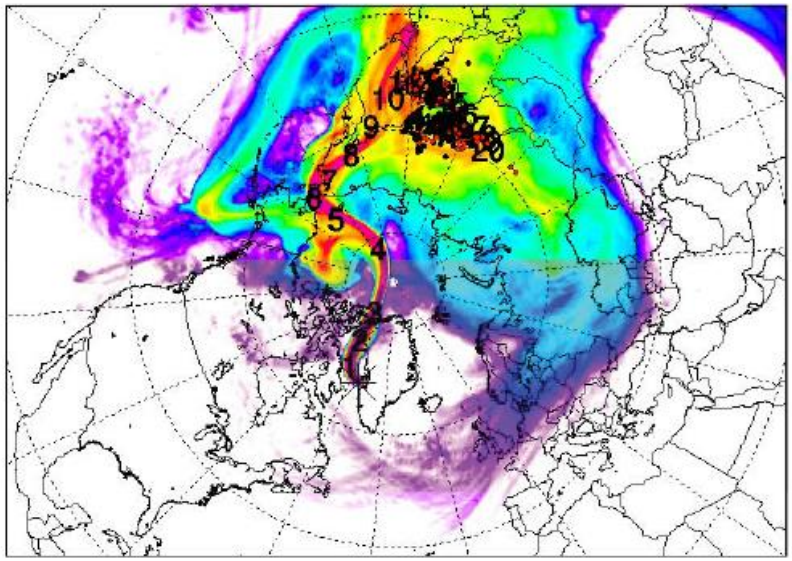


mostly intensive field campaigns during the International Polar Year 2007/2008

Aerosol Measurements - Airborne



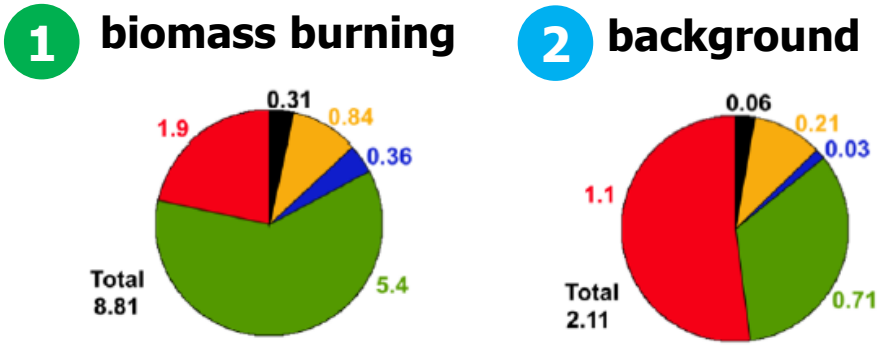


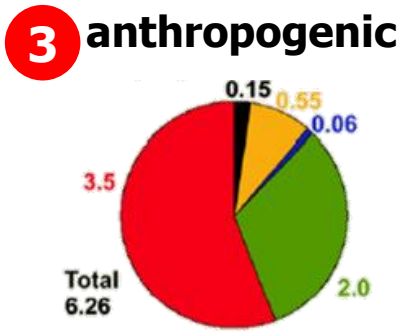


particle dispersion modeling to back track pollution plumes

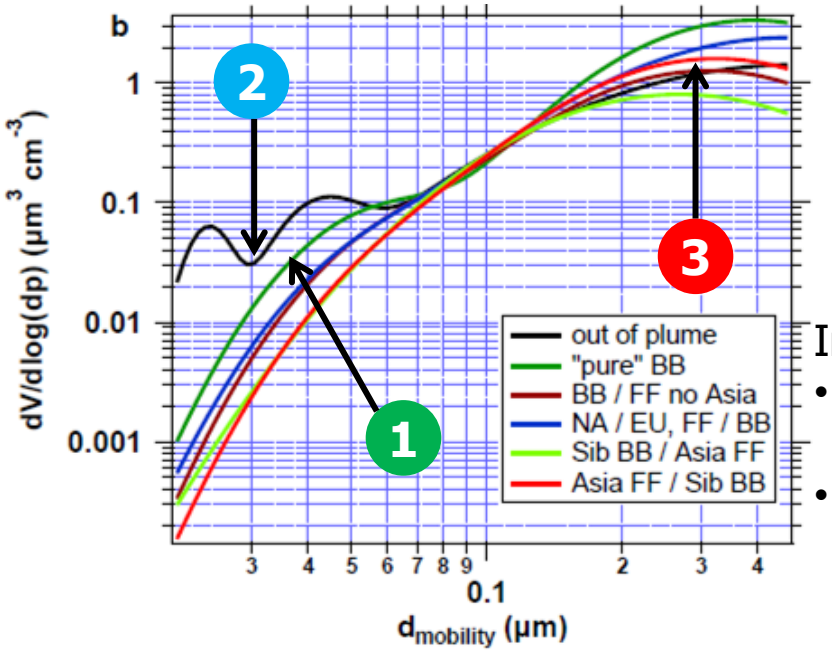
(Schmale et al., 2011; Schmale, 2011)

Aerosol Measurements - Airborne

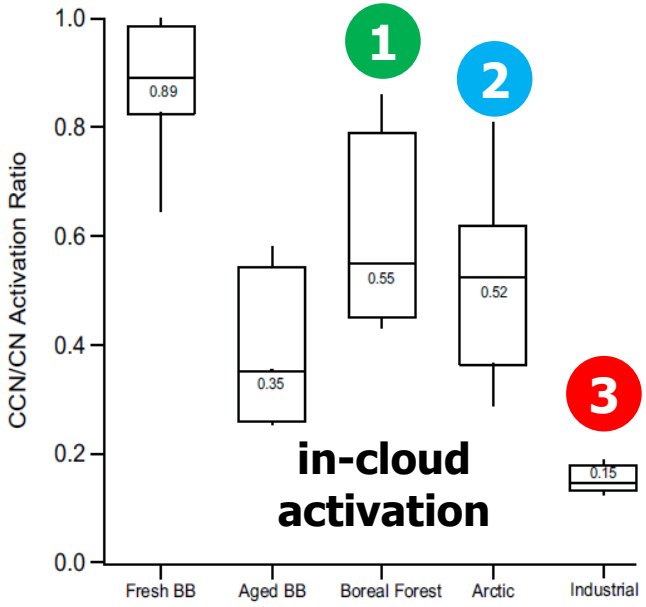




organics
sulfate
ammonium
nitrate
black carbon

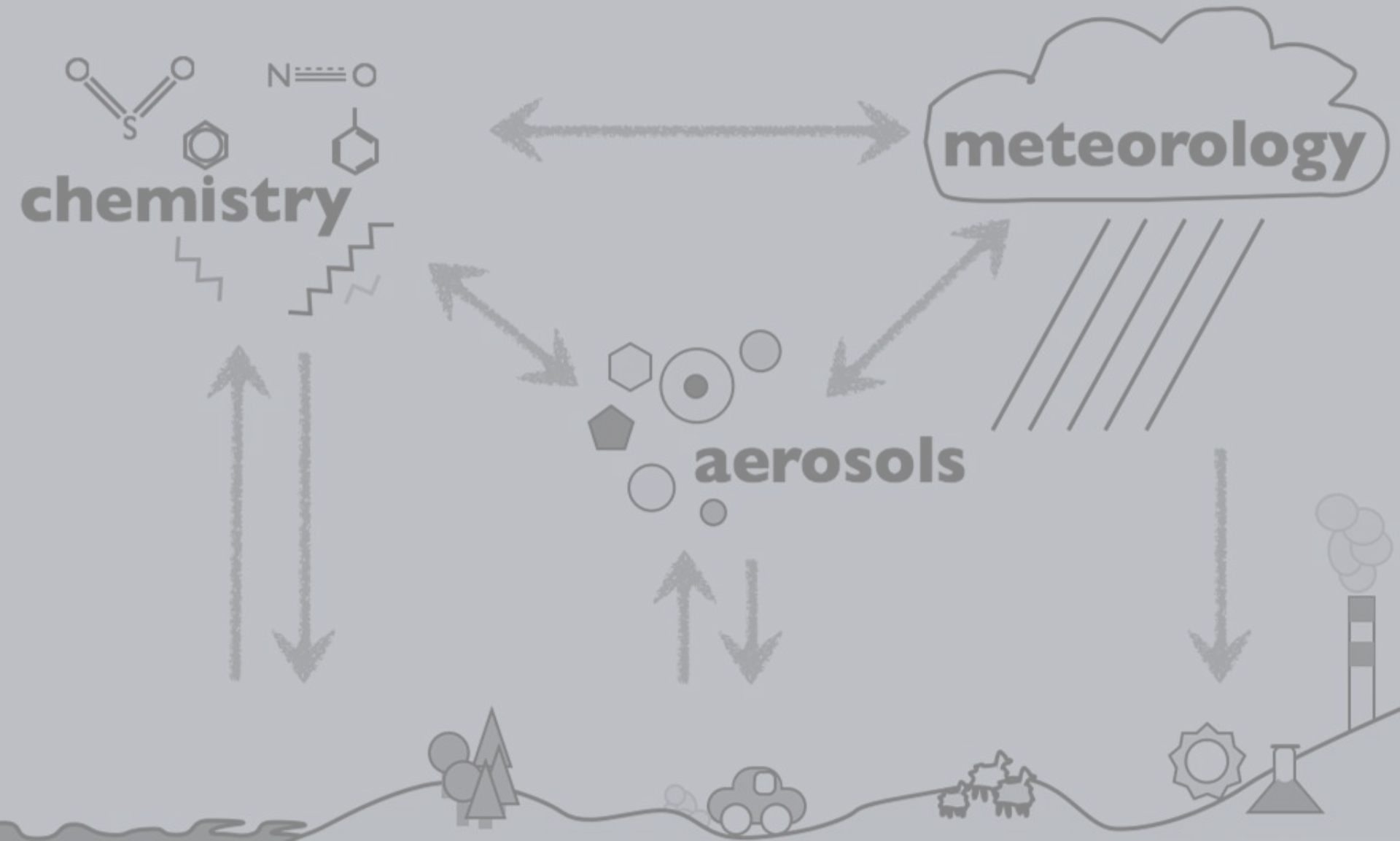


Influences
- optical properties
- activation behavior



(Brock et al., 2010, Lathem et al., 2013, Schmale et al., 2011)

Modeling Arctic Aerosol

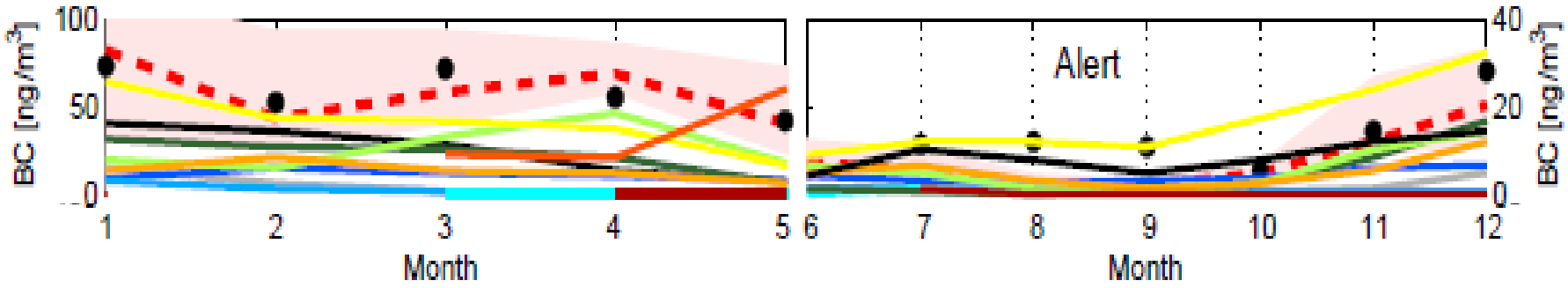


Modeling Arctic Aerosol

- Observations are limited in time and space.

- To cover a wider geographical area and to make projections for the future atmospheric chemistry models are applied.

Modeling Arctic Aerosol - Surface

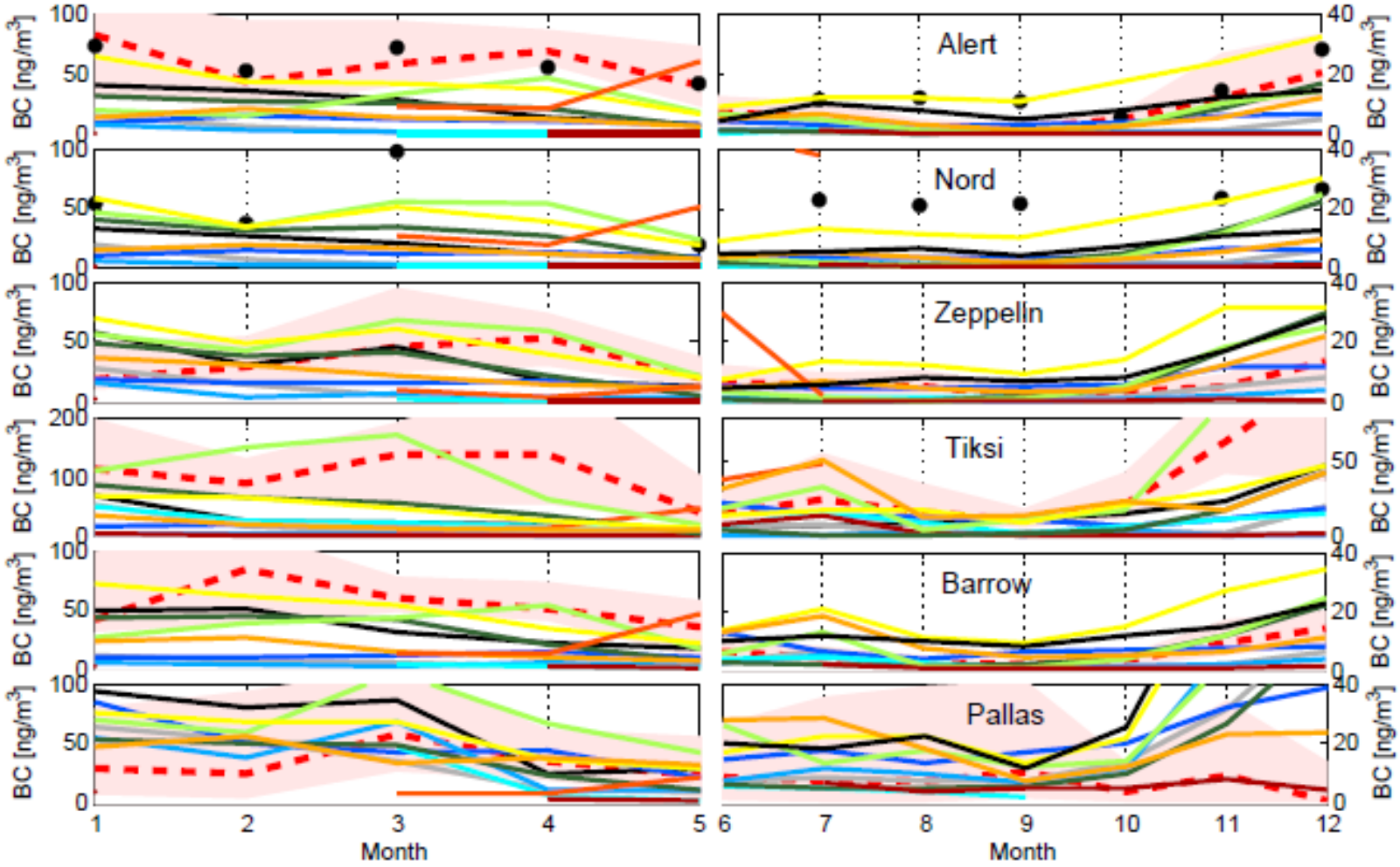


observations

colored lines: model results

(Eckhardt et al., 2015)

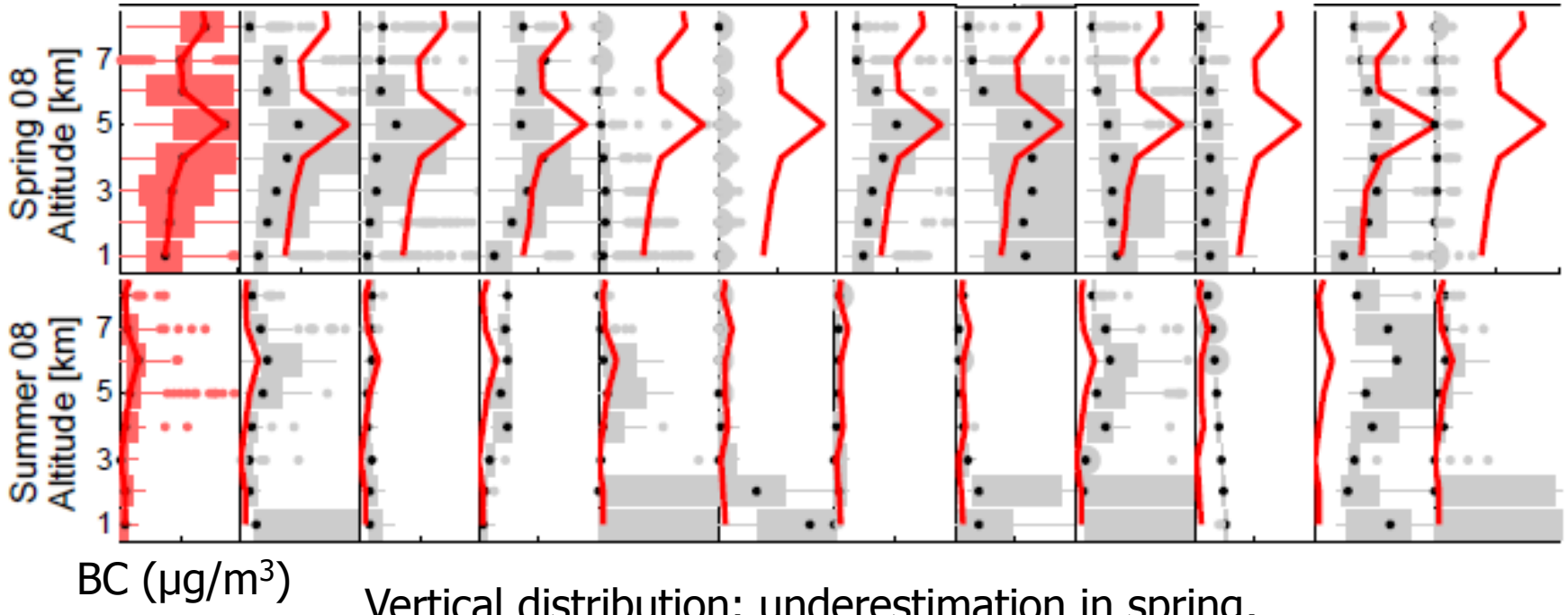
Modeling Arctic Aerosol - Surface



Models tend to underestimate surface concentrations

(Eckhardt et al., 2015)

Modeling Arctic Aerosol – Vertical profile



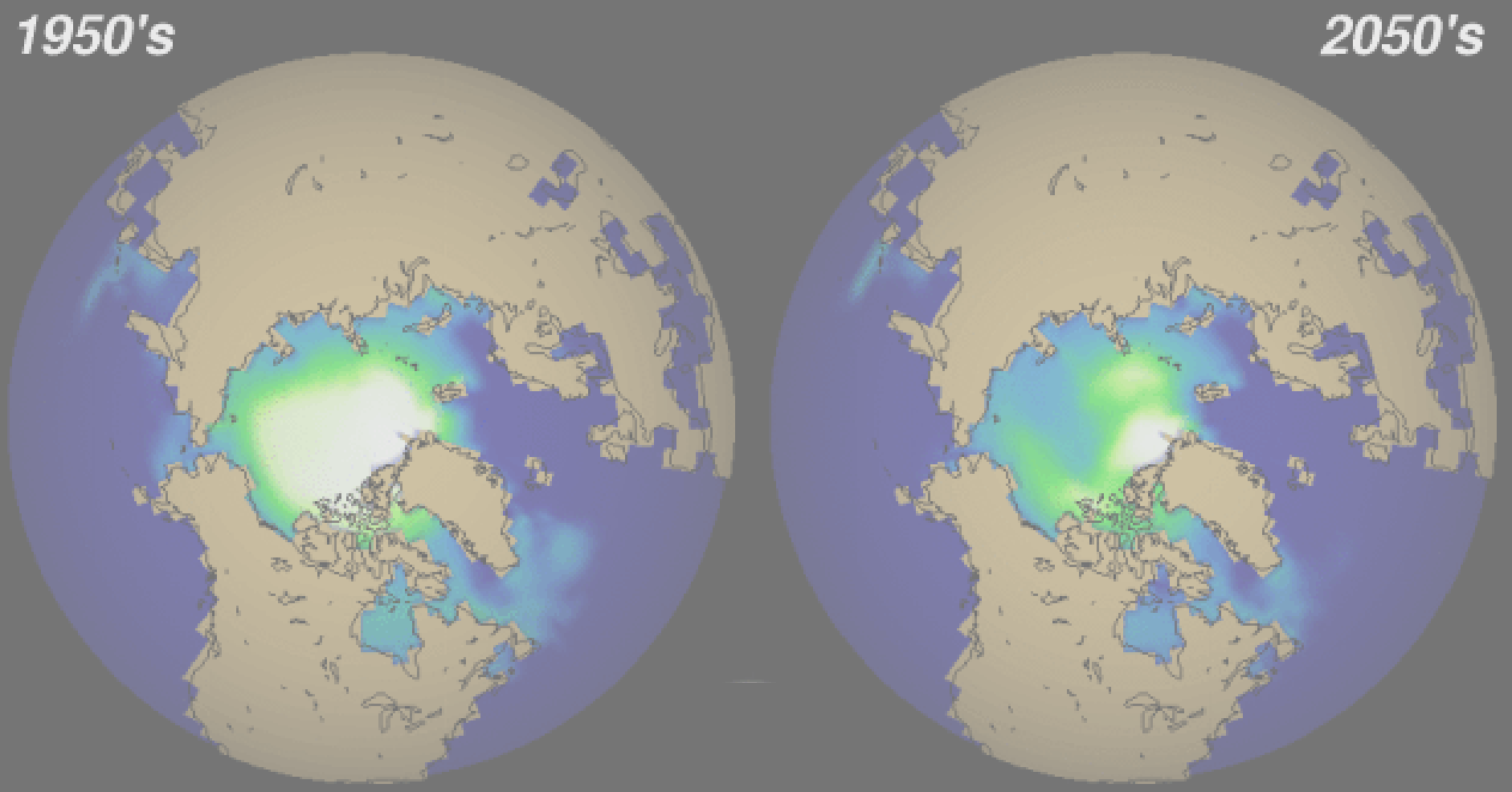
Vertical distribution: underestimation in spring, overestimation in summer

BC in snow: overestimation in Greenland, underestimation in the Arctic Ocean, roughly agreement elsewhere

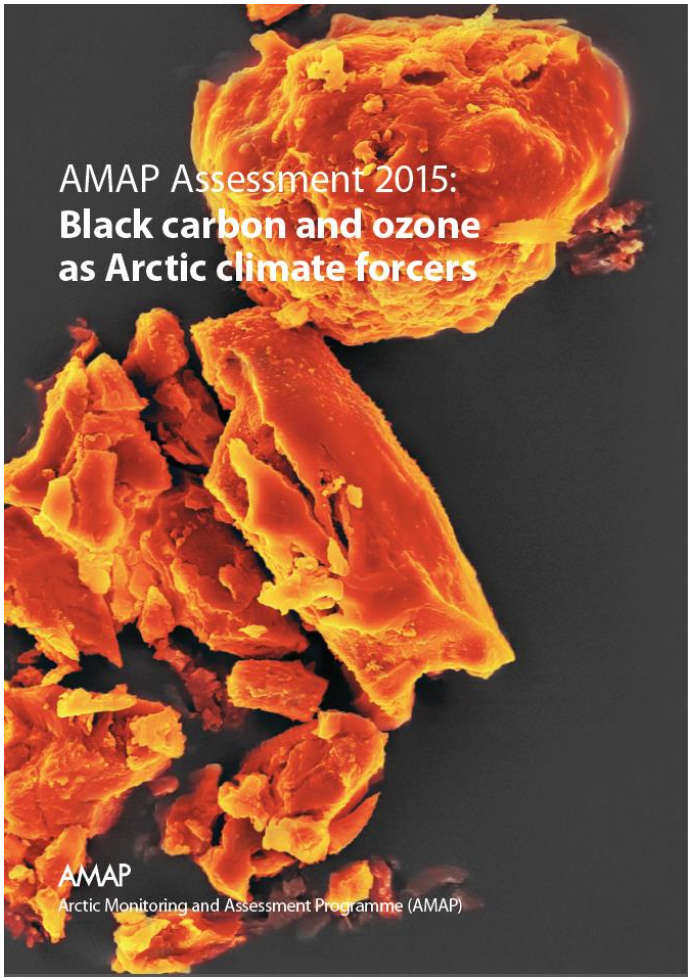
We need model calculations to estimate the Arctic climate response.

(Eckhardt et al., 2015)

Arctic Climate Forcing and Temperature Response



Results from the latest Assessment



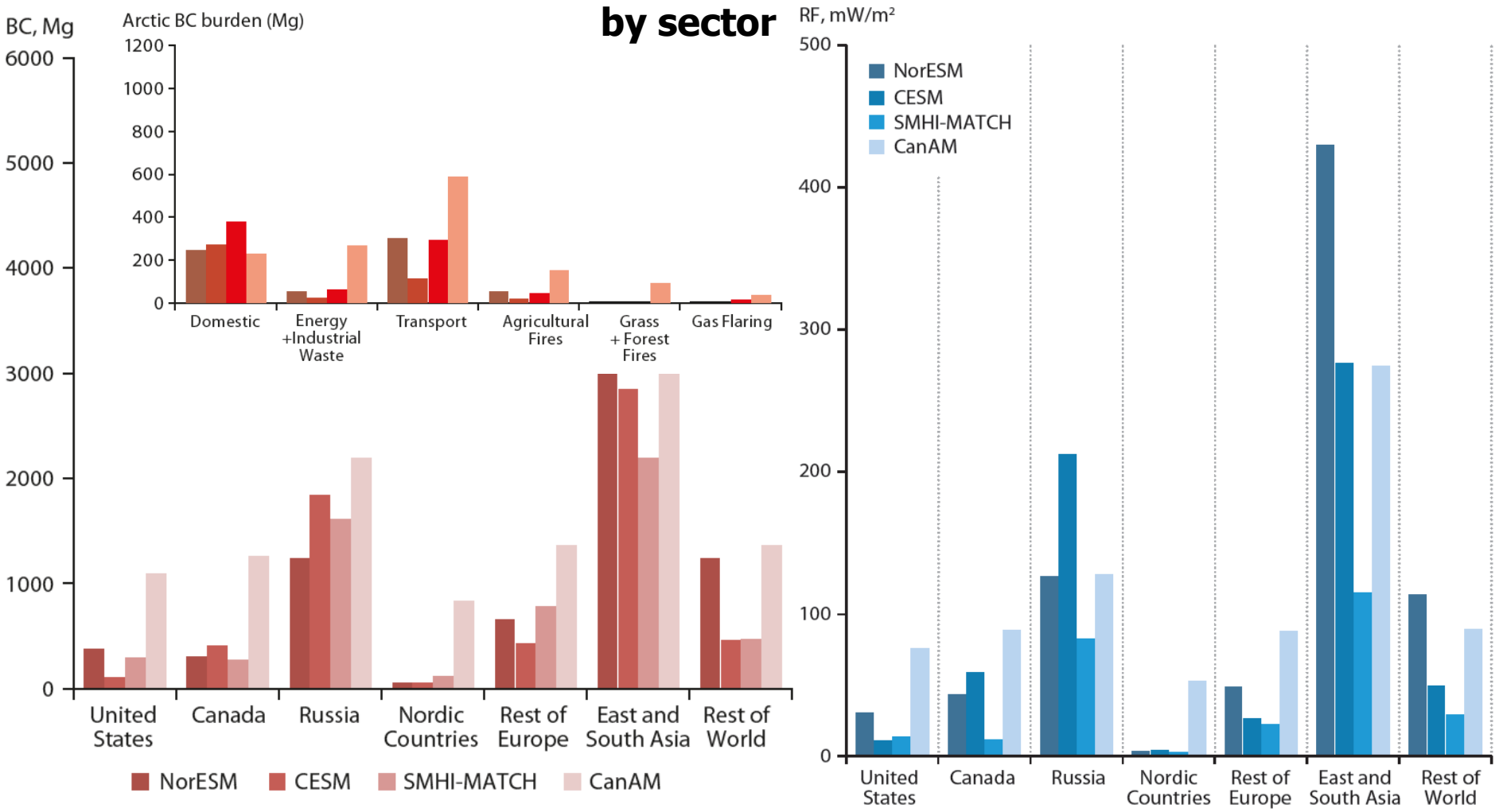
Arctic Monitoring and Assessment Programme

Produces reports roughly every 4 years

Methodology:

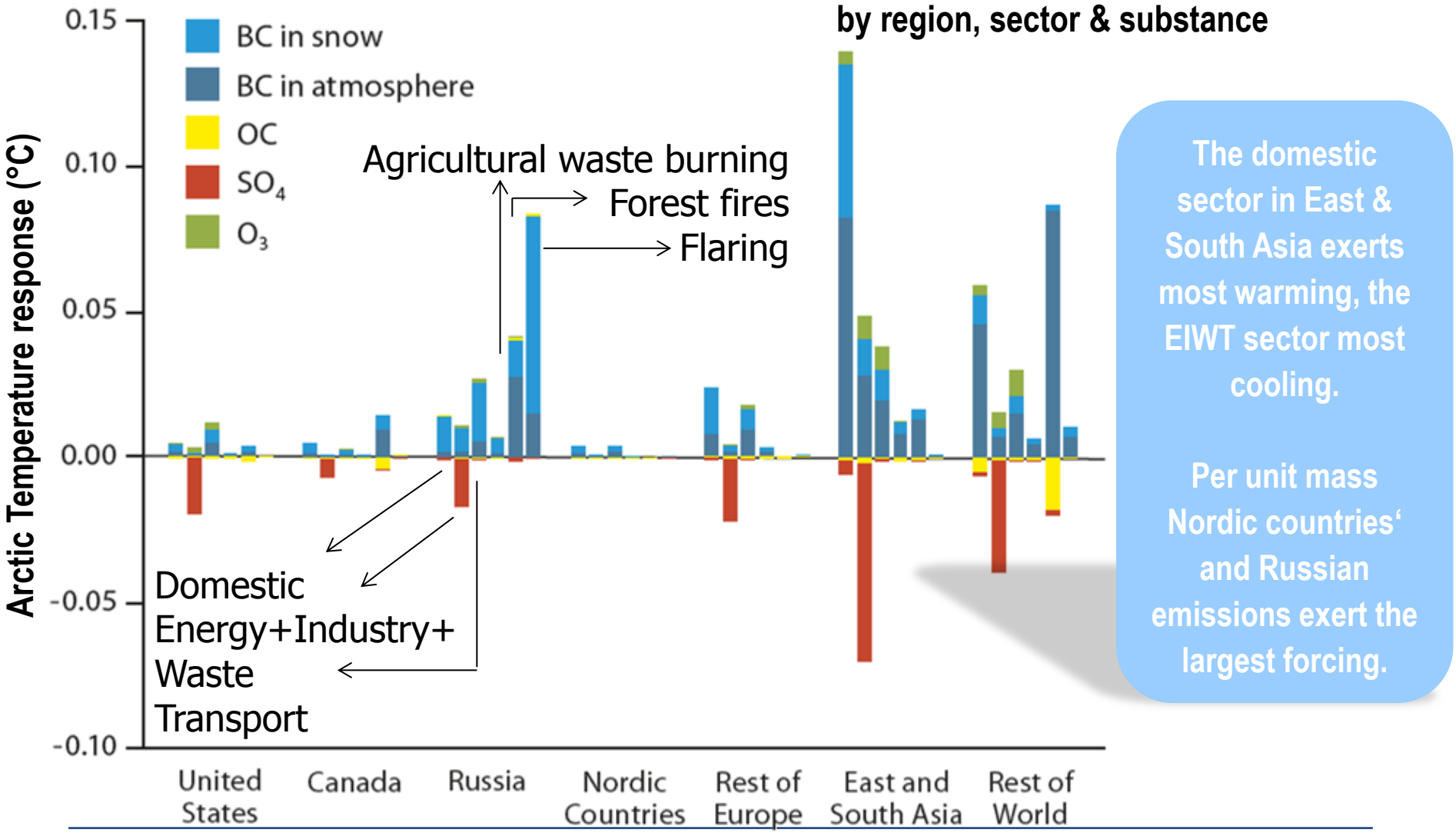
- Validate model ensemble with observational data
- Estimate radiative forcing and temperature response with the validated models

Arctic BC Burden and resulting radiative forcing



(AMAP, 2015)

Arctic Temperature Response

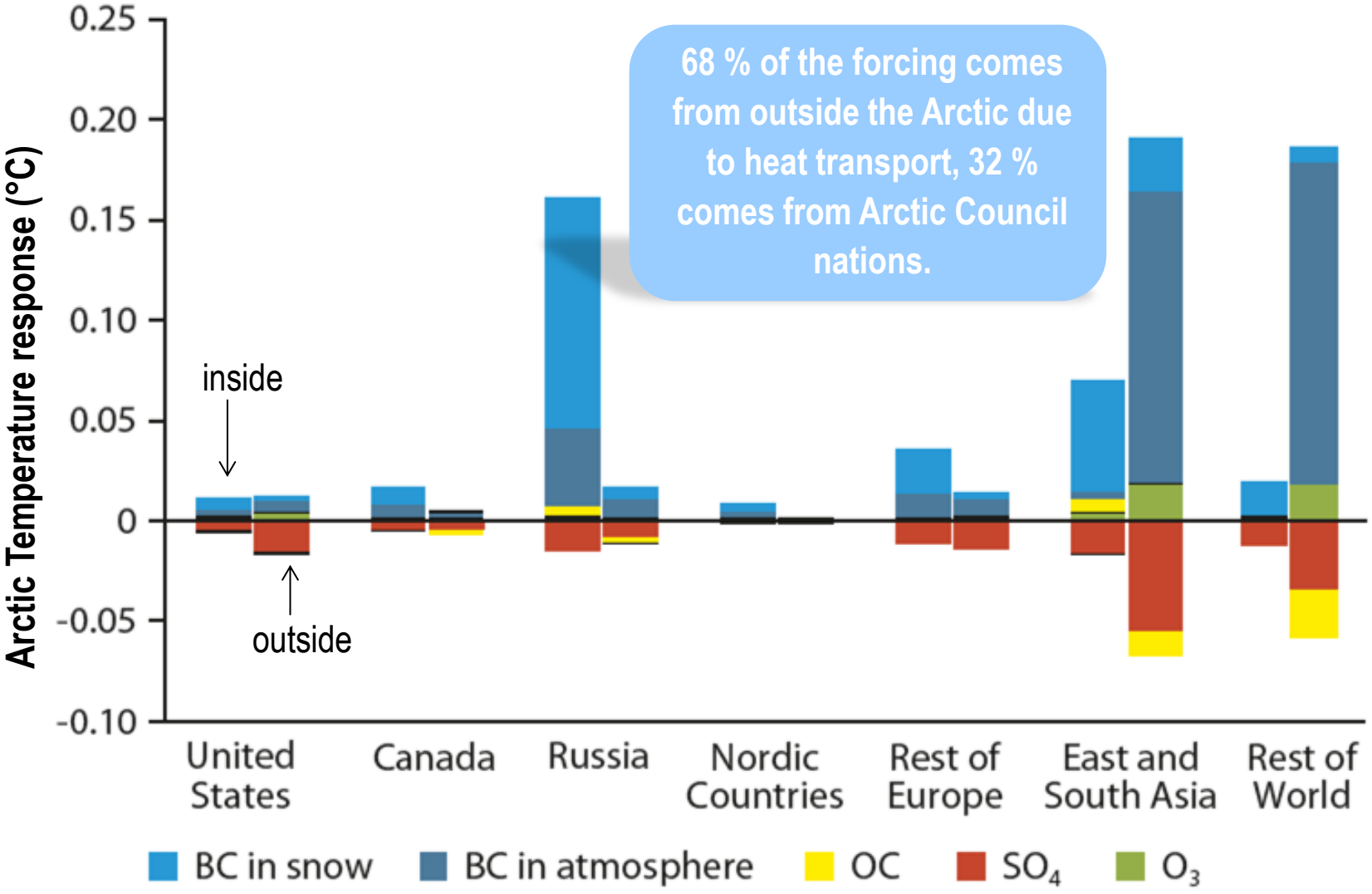


The domestic sector in East & South Asia exerts most warming, the EIWT sector most cooling.

Per unit mass Nordic countries' and Russian emissions exert the largest forcing.

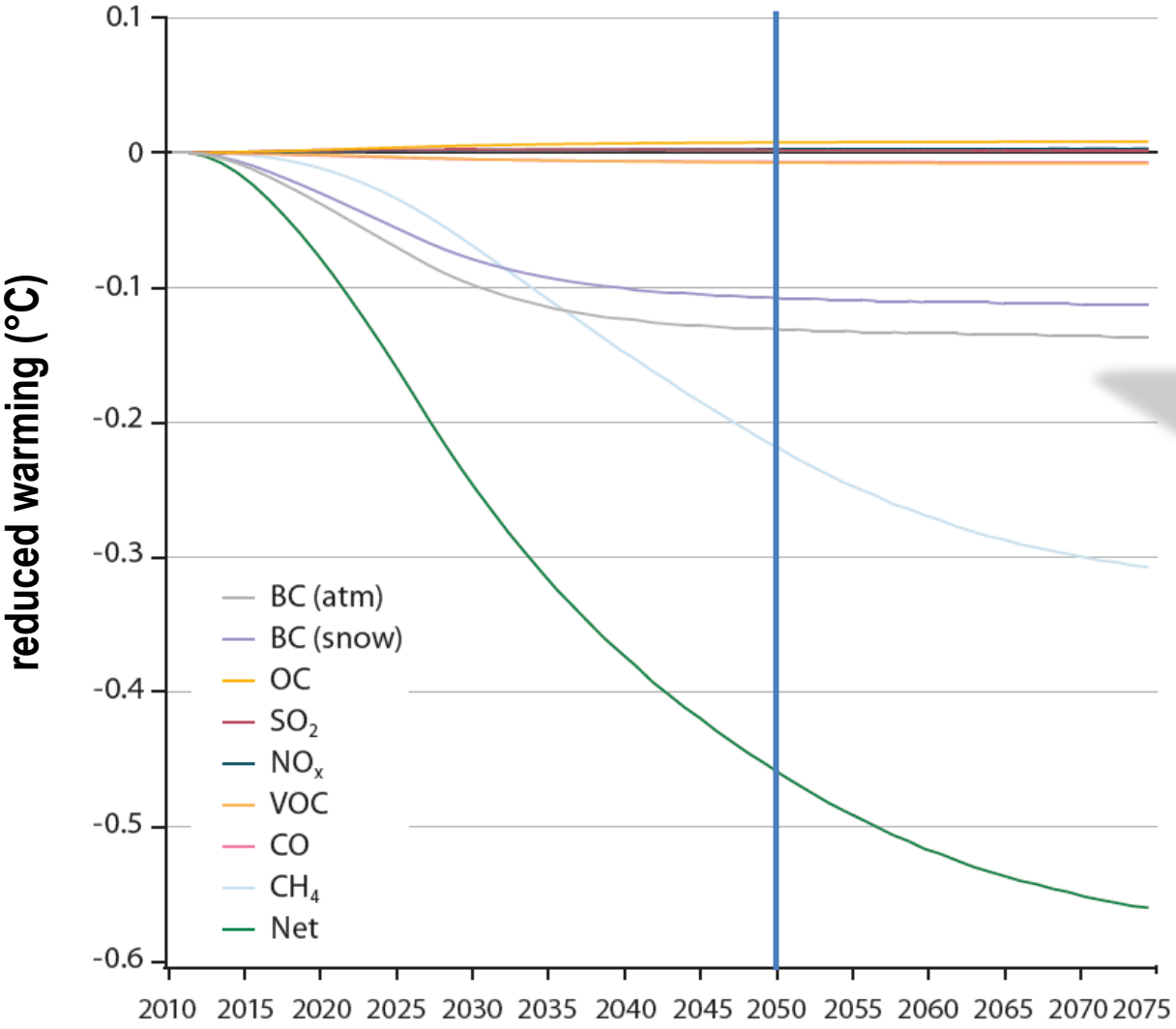
(AMAP, 2015)

Inside vs Outside Arctic Forcing



(AMAP, 2015)

Mitigation Scenario for Reduced Arctic Warming



Aggressive mitigation:
-0.3 to -0.6 K by 2050
BC and CH_4 have equal shares
7 % less loss in sea ice

BC and CH_4 vs CO_2 emission reductions

Reductions in the emission of carbon dioxide (CO_2) are the backbone of any meaningful effort to mitigate climate change in the Arctic.

CO_2 mitigation yields long-term climate benefits
but exerts also strong effects in the short-term.

20 year time horizon:
sustained BC reduction of 1 Tg/yr (13 % of global emissions)
= sustained 10 % CO_2 reduction each year (or less)

Summary

- The Arctic is/has been on of the largest intact ecosystems on Earth.
- However, the Arctic is warming twice as fast as the global average

- The emission of aerosol within the Arctic and their transport from mid-latitudes change the radiative balance through
  - absorption and scattering of sunlight,
  - changes in cloud properties, and
  - changes in surface albedo.

- Considerable efforts to understand the chemical and physical processes have been conducted during the International Polar Year 2007-2008. Yet, large uncertainties remain, and modeling and predictive skills are still poor.

- Newest estimates suggest Arctic equilibrium temperature to be +0.35 K (multi-model range +0.03 to +0.84 K) from global comubstion derived BC, OC and sulfur emissions

Challenges and how to address them