SLCF Assessment 2021 – Assessment Scoping

(version December 2019)

I. Assessment Outline (content and coordinating lead authors)

II. Assessment timeline

III. Policy-relevant questions guiding the assessment work

I. Assessment Outline, Content and Coordinating Lead Authors

[Structure of chapters (Google Drive folder for each chapter): Title; Statement of PRSQs; Chapter Material; Conclusions: Clearly state answers to PRSQs; Possible recommendations, if any]

1. Introduction (K. Kupiainen, M. Flanner)

- Setting the stage… what are SLCFs in the context of this report (and SLCFs not considered in this assessment). This report focuses on what's new. Refer back to older reports.
- Processes (atmo, cryo, bio, sea ice, statement of changing natural baseline conditions…)
- Current observations of climate change in the Arctic (Methane future)
- Tradeoff between Climate and AirQuality Impacts

[Textbox] Radiative properties (BC, O C, sulfate, Ozone, methane, Clouds)
[Figure] Radiative balance of the Arctic (atmospheric and ocean heat transport into the Arctic, clouds, ...)
[Figure] on SLCF

2. Emissions of short-lived climate forcers in an Arctic context (K. Kupiainen, , Z. Klimont, L. Höglund-Isaksson, V.-V. Paunu, V. Vestreng, J. Fu, J. Christensen (shipping), M. Crippa, S. Anenberg?)

2.1 Introduction

The section will present the emission data and scenarios used in the modelling studies and compare most recent available emission datasets (for example CLRTAP national emission data, EDGAR, IIASA-GAINS). The plan is also to highlight local emission issues in the Arctic, but these are likely to be discussed in a separate chapter or sub-section.

Policy questions:

- What are the lessons-learnt of earlier and current air pollutant policies in respect to Arctic?
- What is the potential benefit, in terms of reduced Arctic warming, of GHG and SLCF mitigation by Arctic nations (Arctic Council and its Observers countries) and globally in the near-term (i.e. 2050)?
- What is the potential benefit, in terms of reduced Arctic warming, of SLCF mitigation by Arctic nations (Arctic Council and its Observers countries)?
- What are the consequences of the Arctic Council collective black carbon goal for Arctic climate and other impacts?
- What impacts will the other commitments of the countries, i.e. the Paris agreement (CH_4, INDCs/NDCs), have on the Arctic?
- How can GHG and SLCF mitigation best be combined to reduce Arctic warming and achieve other benefits?
- How robust is the knowledge on sector based mitigation potential with regards to Arctic impacts?
- What are the status and trends of short-lived climate forcers such as black carbon and methane in the Arctic atmosphere? Are they in line with what should be

expected, taking into account the Arctic Council and other efforts to reduce emissions?
- What are the impacts of anthropogenic emissions on Arctic climate and public health?
- What are the current and potential future anthropogenic emissions of Arctic and non-Arctic nations?
- How much methane, black carbon, ozone precursors and other relevant pollutants are Arctic nations currently emitting from anthropogenic activities?
- What are the current and future emissions from Arctic shipping?
- How will the magnitude of emissions change in the future and what are the mitigation options?
- How do national emission inventories relate to other available emission datasets?
- How well do we understand where the emissions occur, especially in the Arctic area?
- What percentage of global methane, black carbon, ozone precursors and other relevant pollutant mitigation potential is controlled by Arctic Council nations?
- What are the uncertainties in these estimates of current and future anthropogenic emissions?

2.2 Emission datasets used in AMAP modeling (Eclipse v6a)

Description of developments of the datasets and improvements since 2015 i.e. in the spatial distribution of emissions, emission factors etc.

In this assessment we rely on global SLCF emission mitigation scenarios of multiple air pollutants and greenhouse gases. The work uses the most recent datasets of the GAINS emission/scenario model (http://www.iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv5a.html) to address new information concerning possible scenarios for mitigation of SLCFs from key emission sectors relevant to the Arctic but also incorporates the global GHG reduction scenarios [and include estimation of potential costs of mitigation actions]. We have used the International Energy Agency's (IEA) 2018 World Energy Outlook (WEO) scenarios incorporated into the GAINS model framework.

The scenario work will study the expected situation in relation with the Arctic Council collective black carbon goal. The section also reviews the available national emission inventories and projections as reported to the CLRTAP and used in the Arctic Council's EGBCM work.

2.2.1 Impact of existing legislation

2.2.2 Baseline scenarios:

Frozen legislation 2015 (of GHGs and air pollutants)

The New Policies Scenario (NPS) aims to provide directions in which the latest policy ambitions could take the energy sector. It incorporates policies and measures that governments around the world have already put in place, but also takes into account the effects of announced policies, as expressed in official targets and plans. For example the NPS also uses the Nationally Determined Contributions (NDCs) of the UNFCCC Paris Agreement for guidance regarding policy intentions.

The Sustainable Development Scenario (SDS) builds on the Sustainable Development Goals (SDGs) of the United Nations and aims to provide an energy sector pathway of particularly SDG7.1 "to ensure universal access to affordable, reliable and modern energy services by 2030", SDG3.9 "to substantially reduce the air pollution which causes deaths and illness", and SDG13 "to take effective action to combat climate change".

2.2.3 Mitigation scenarios:

The mitigation scenarios are applied as additional to baselines. A mitigation scenario targeting BC and CH4 rich sources will be constructed during 2018. The plan is to target the mitigation measures to regional group (AC8 – Observers – other) and/or sector groups (oil&gas, residential, waste, diesel,…). These will be decided later building on EGBCM Summary & Progress report including the Arctic Council collective black carbon goal, National SLCP action plans, work under the European Commission BC initiative as well as CLRTAP Gothenbourg Protocol (particularly the latest revision).

Maximum Technically Feasible Reductions (MTFR) identifies and applies the technologies with maximum reduction potential (compared with other available technologies) for all pollutants.

These scenarios will also be compared with the SSP scenarios and SSP alternatives with similar characteristics will be identified.

2.3 Global emissions

2.3.1 Trends 1990-2015 and policy actions explaining trends

2.3.2 Emission scenarios

Policies affecting emissions and scope for mitigation since the 2015 assessments; Impact of existing legislation; Anthropogenic Projections and policies including methane; Natural emissions Projections and policies excluding natural releases of methane. Costs of mitigation? -> OECD work.

2.3.3 Comparison of global anthropogenic emission datasets

2.4 Anthropogenic emissions in the Arctic Council region (AC8, AC observers, other?)

Key developments since AMAP 2015

2.4.1 Arctic Council 8 and Arctic Council Observers (trends and scenarios)

2.4.2 Comparison with CLRTAP and other national emission inventories used by AC

2.5 High-Arctic emission sources

2.5.1 Arctic shipping (Jesper, Zig)

2.5.2 Oil and gas activities in the Arctic (Lena, Zig, Joshua, Carbon Limits)

2.5.3 Any information on specific challenges in Arctic communities? (trash burning, diesel generators) (Kaarle)

2.6 Natural releases of methane and selected other species

Main focus on methane, but qualitatively also VOCs and DMS, iodic species (Henrik)

2.7 Uncertainties in emissions estimates

2.8 Summary (include and overview of all sources, including natural releases of methane)

3. Open biomass burning (Jessica, Sabine, Jesper, Zig, Kaarle, HC)

Policy questions:

- What is the impact? What can be managed? Will climate impact fire risk and regimes (fuel conditions, fire weather)?
- What are current black carbon, other aerosol and trace gas emissions from wildfires?
- What are the controlling processes and factors that strongly influence natural emissions?
- What are the interlinkages of natural emissions to human activities?
- How may these emissions from natural sources in the Arctic change in the future?
- What are the uncertainties or limitations in these estimates?
- What role do the natural sources play in emissions, concentrations and impacts? What are the expected trends in natural emissions in the future?

3.1 Developments since 2015

Contextual clarification of the concept of what is biomass burning and specific language of fire emission sources

- Landscape-scale determination of fire source in the Arctic (wildland: boreal forest, hemiboreal forest, tundra, grass/shrub/steppe; anthropogenic: croplands, pasture/range, timber/agroforestry)

Scope of open biomass burning for the region via observations

- AOD
- Further observations of emissions from open biomass burning will be discussed in the observations chapters

3.2 Emissions estimates for circa 2017/2018 global and Arctic (60-90 deg N)

- Current and future
- Future fire risk from climate change, do human risks continue?
- Spatiotemporal distribution

3.3 Key drivers

3.4 Emerging needs: injection height, fuels classifications, discussion and collaboration for determining future risk

[Highlight box of wildfire emissions; trends and data/observation needs for the models; examples of Greenland (carbon rich soils), Siberia (forests), Alberta (croplands)]

3.5 Uncertainties

- Inventory comparisons, advances in global fire models GFAS-GFED-FINN, national-level inventories never agree with Earth observation data (lessons learned from EU-BCA)

3.6 Discussion

* Scoping results to match the more precise conceptual framework

* How we add new modeling results, albedo, air quality (lit review and/or model runs; observations are needed to able to drive modeled results on current and future

concentrations and climate impacts/calculations; guidance from what modelers need to be in a better position in the future)

4. Advances in measurement techniques and observational capacity

– Focus on advances and missing observations compared to previous report and that really address the policy questions
– Describe short and clear for non-specialists
– Remove information on properties / this goes into a nice figure for all SLCFs
– Include observational capacity discussion for the different species: networks, satellite data...

Policy Question:

– Are the current monitoring activities (of atmospheric concentrations) sufficient to capture anticipated source changes?
– Why do we need long-term observations? - Strong statement needed here. Is the current network sufficient to be representative….

Introduction to the chapter (Julia et al.)

Why do we need long-term observations? - Strong statement needed here. Is the current network sufficient to be representative… MAX 2000 words in total

4.1 Particulate matter: (Kondo et al.)

4.2.1. Introduction (reference to 2015 report plus updates, short)

4.2.2 Measurement methods in the atmosphere and in snow/ice (Kondo, Decesari, Makoto et al.) – generally info for the appendix, just brief summary here

4.2.3 Recommendations

4.2 Mineral dust: (Outi, Antti et al.)

4.3.1. Introduction (why now explicitly included)

4.3.2. Measurement techniques in atmosphere and snow/ice (Short overview, most should go into appendix)

4.4.3 Recommendations

4.3 Ozone: (Kathy, Henrik, Joakim, Steve et al.)

4.3.1 Introduction

4.3.2 Measurement techniques

4.3.3 Observing networks and satellite observations

– include surface and sondes

4.3.4 Recommendations

4.4 Methane: (Frans-Jan, Lise Lotte et al.)

4.4.1 Introduction

4.4.2 Methane flux measurements (from the 2015 report plus updates)

4.4.3 Methane concentration measurements (from the 2015 report plus updates)

4.4.4 Recommendations

4.5 Clouds: their properties and satellite measurements (Manu, Joakim et al.)

4.5.1 Introduction (why now explicitly included)[FM1]

4.5.2 Available suite of satellite based cloud climate data records

4.6 Recommendations

5. Observations, origins and trends

Focused on existing literature (can include new data) MAX 10’000 Words in total

Policy Question:

- What are the current abundance of short-lived climate forcers such as black carbon and other particulates and ozone in the Arctic atmosphere? Or What is our current understanding of the abundance...
- What role do the natural sources play in emissions and concentrations?
- Are the current monitoring activities (of atmospheric concentrations) sufficient to capture anticipated source changes?

5.1 Particulate matter: black carbon, sulfate and organic aerosols (Julia et al.)

5.1.1 New observations since the last report, include satellite data (Andi Massling, HC, et al.)

5.1.2 Concentrations and seasonal cycles from surface observations (Stefano, Andi M. et al.)

5.1.3 Vertical distribution (Marco et al.)

5.1.4 Historical and present day trends (Julia, Sangeeta et al.)

5.1.5 Summary

5.2 Mineral dust: (Outi, Antti et al.)

5.2.1 Significance for the Arctic

5.2.2 Processes that govern dust emissions and long range transport

5.2.3 Concentrations (air, snow, ice/temporal, seasonal and spatial variability)

5.2.4 Historical trends (ice cores, glaciers, Greenland)

5.2.5 Summary

5.3 Ozone and precursors (Kathy, Henrik, Steve, Joakim et al.)

5.3.1 Observed concentrations of ozone and precursors

5.3.2 Ozone sources and sinks

5.3.3 Observed trends in ozone

5.3.4 Open questions

5.3.5 Summary

5.4 Methane (Frans-Jan, Lise Lotte et al.)

5.4.1 New observations since last report

5.4.2 Natural methane sources: estimates from observations and process models (Frans-Jan, Torben, Brett, Lise Lotte …)

– Terrestrial, freshwater, marine, modeled, total natural

5.4.3 Trends in concentrations of methane

5.4.4 Summary

5.5 Clouds (Manu et al.)

5.5.1 Climatological overview of cloud amount

5.5.2 Assessment of trends based on satellite climate data records

5.5.3 Seasonal aspects

5.5.4 Summary

5.6 Conclusions and Recommendations

6. Evaluation of modelled distributions and trends of SLCFs and cloud properties

Re-phrase questions in context of models, don't repeat the questions from previous chapters

More methane/wetland modelling and evaluation?

Policy Question:

- What are the current abundance and trends of short-lived climate forcers such as black carbon and methane in the Arctic atmosphere? Are they in line with what should be expected, taking into account the Arctic Council and other efforts to reduce emissions?
- What are the trends and variability in Arctic methane, black carbon, ozone and other relevant pollutant concentrations in the atmosphere, in snow and ice, lake sediments etc. and what are the primary drivers of this variability?
- How useful is satellite data in monitoring Arctic concentrations of methane, black carbon , ozone or other relevant pollutants? What are the limitations?

- How do the modelled concentrations in the atmosphere, in snow and ice, lake sediments etc. relate to observations?

6.1 Introduction

Add literature review of existing model capabilities (e.g., models not used in this report)

6.2 Models for simulations of short-lived climate forcers and radiative forcings

6.2.1 Chemistry-Climate and Chemistry Transport Models

6.2.2 Earth System Models

6.3 Evaluation of 2008-2015 short-lived climate forcers, air pollutants and cloud properties (Cyndi, Julia, Knut, Dave, Kathy, Steve, Sangeeta, Lin, Rashed, Tahya, Barbara, Andreas, Mark, Joakim, Michael, Yiran, Jean-Christoph, Ulas, Jesper, Joshua, Sabine)

6.3.1 Aerosols and trace gases in the Arctic

6.3.1.1 Mean concentrations and seasonal variability at surface sites

6.3.1.2 Black carbon in snow and ice

6.3.1.3 Comparisons with remote sensing observations

6.3.2 Continental sources of short-lived climate forcers and long-range transport

6.3.2.1 Mean concentrations and seasonal variability at surface sites

6.3.2.2 Comparisons with remote sensing observations

6.3.2.3 Comparisons of vertical profiles based on aircraft /satellite observations (refer to previous report, any better now?)

6.3.3 Historical trends

6.3.4 Clouds and radiation in models and observations (Manu, Joakim, HC,...)

6.4. Trend evaluation (1990-2015): observations, simulations, emissions

Models (those that provided 1990-2015) will be evaluated at Arctic (>60oN) ground stations that have long (at least early 2000s) time series. Model and measurement time series will be plotted together, and trends discussed.

7. Simulated impacts on climate and air quality (or similar)

- What are the climate penalties of emission reductions of cooling species (i.e. sulfur, NOx) vs the climate benefits of emission reductions of warming species (black carbon, methane, greenhouse gases)? What sources and sectors should be prioritized to maximize the climate benefits?
- What is the Arctic climate response to SLCF emissions and emission reductions, from Arctic regions / nations and from global sources?

- How large are the SLCF climate responses in the context of carbon dioxide and other greenhouse gas reduction policies?
- What impact will future atmospheric concentrations of methane, black carbon, ozone and other relevant pollutants have on climate?
- Will Arctic nations have the ability to influence that impact through mitigation of anthropogenic emissions?

7.1 Introduction (everybody)

Literature review, radiative forcings, modelling of Arctic processes and impacts (incl. IPCC models), methane

7.2 Future changes in global and Arctic climate systems (Maria, Annica, Srinath, Ulas, Thomas...)

7.2.1 Summary of Type 3 simulations

7.2.2 CO2 impacts (either via ARTP or Type3 analysis)

7.2.3 PM2.5, ozone, and methane trends

7.3 Impacts of regional emissions on Arctic temperature, SLCFs, and air quality (Knut, Mark, Naga, Terje, Stephen, Kathy, Joakim, Maria, Dirk, Shilpa, Marcus, Ulas, Joshua...) NOTE: Results from type-1 and 2 runs, bar and time series plots...

7.3.1 Radiative forcings and absolute Arctic temperature change potentials

7.3.2 Comparison with Earth System Model projections and historic changes

7.3.3 Changes in burdens and concentrations of short-lived climate forcers in the Arctic

7.3.3.1 Methane

7.3.3.2 Black carbon

7.3.3.3 Ozone

7.3.3.4 Sulphate and OC

7.3.3.5 PM2.5,

7.3.3.6 Exceedance of AQ standards

7.3.4 Changes in radiative forcings within the Arctic

7.3.4.1 Methane

7.3.4.2 Black carbon

7.3.4.3 Ozone precursors

7.3.4.4 Sulphate and OC

7.3.4.5 CO_2

7.3.5 Equilibrium temperature changes

7.3.6 Historic changes in Arctic temperature and air quality

7.3.7 Mitigation scenario impacts on Arctic temperature and air quality

Tentative: using model output to evaluate suitability of observational network to observe future changes (link to Freud paper)

7.4 Conclusions (everybody)

7.4.1 Summary of uncertainty

7.4.2 Answers to policy-relevant science questions

8. Health, and Ecosystem Impacts (S. Anenberg, S. Rao, S. Tsyro, R. Van Dingenen, Julia Schmale, Kathy Law, Steve Arnold, Joakim Langner, Marcus Sarofim, Raimo Salonen, Joshua Fu, Heli Lehtomaki CTM PM2.5 and ozone modelers, potentially an ecosystem expert (TBN), a representative from indigenous community (TBN))

– What are the potential present-day impacts of pollutant emissions on human health, crop yields and ecosystems and what benefits can be achieved via emission mitigation in the future?

Objective of chapter (what we can provide):

8.1. Introduction and Background

PM & Ozone contribute to health & ecosystem impacts. BC & Methane policies will influence PM & Ozone, and therefore these impacts. These additional benefits are important factors to consider when designing policies.

Climate vs health impacts?

Relevant PM & Ozone will come from both local sources & long-range transport

8.2 Review of evidence on air quality related health and ecosystem Impacts

8.2.1 Health effects

– Health effects of PM2.5
– Health effects of ozone
– Combined effects of PM/BC and ozone
– Combined effects of air pollution and heat
– Wildfires
– Causality support from toxicology studies
– What influences net health impacts: population distribution & vulnerability, exposure, etc.
– Description of ecosystem impacts, including N deposition and ozone damage

8.2.2 Arctic Specific Issues

- Different Indoor/outdoor behavior, emission sources, boundary layer stability & height
- Observations of urban & rural air quality in the Arctic (Fairbanks, etc.)
- Note that monitoring is often placed away from populations for high latitude monitoring
- NAAQS & other air quality framework exceedances
- Health studies: Existing studies on Alaska & Finland epi, NordicWelfAIR; Arctic burden of disease: ICCI/World Bank 2013 report On Thin Ice
- Ecosystem studies in the Arctic

8.3 Modeled results of air quality, health and ecosystem impacts of baseline & mitigation scenarios on Arctic Council nations & observers

- Contributions to Arctic burden of disease from region/sector emissions
- Air quality and health and ecosystem benefits of mitigation scenarios
- Sensitivity analyses
- Case studies to look at local reductions in pollution sources and health
- Deposition results and mention potential effects without going into details in 1-2 paragraph
- Crop loss effects

8.4. Conclusion

8.4.1 Summary of uncertainty

8.4.2 Policy relevant statements

9. Conclusions and scientific next steps

- What is the potential benefit, in terms of reduced Arctic warming, of SLCF mitigation by Arctic nations (Arctic Council and its Observers countries)?
- What are the consequences of the Arctic Council collective black carbon goal for Arctic climate and other impacts?
- What impacts will the other commitments of the countries, i.e. the Paris agreement (CH4, INDCs/NDCs), have on the Arctic?
- How can GHG and SLCF mitigation best be combined to reduce Arctic warming and achieve other benefits?
- Are the current monitoring activities (of atmospheric concentrations) sufficient to capture anticipated source changes? In terms of geographical location and vertical distribution

Research, observations, and modeling needs

Important aspects we cannot cover, Closing remarks

II. Assessment Timeline

The provisional timeline for the work is as follows:

- Mid-January 2019: Emissions reference scenario (provided to the modelling groups)
- Early 2019: Mitigation scenarios (provided to the modelling groups)
- Summer/fall 2019: atmospheric and climate modellings (with teleconferences)
- 5-7 November 2019: EG meeting (to discuss the results in place and launch the writing)
- 15 December 2019: Type 0 model simulaitons completed/archived
- 31 January 2020: Preliminary answers to policy-relevant science questions (PRSQs)
- 30 April 2020: Type 1-2-3 model simulaitons completed/archived
- 1 – 15 May 2020 (or sooner): Preliminary drafts available for internal reviews, including answers to PRSQs
- 1/15 May - 31 May 2020: Internal review; engage science-writer
- 1/15 May - 7 June 2020: National data check (in parallel with internal review)
- 7 – 15 June 2020: Working Meeting (including remote participation) in Oslo or Stockholm (TBD)
- 30 June 2020: Technical report submitted to the AMAP secretariat for external peer review
- July/August 2020: External peer review; 1st draft of the Executive Summary and the SPM (for internal comments from the EG)
- September/October 2020: Revisions of the technical report to respond to external peer review comments; 2nd draft of the Executive Summary and the SPM
- 15 September – 15 October 2020: Possible second meeting to discuss SPM
- 31 October 2020: Final draft of technical report submitted to the AMAP secretariat for layout
- End of 2020 / early 2021: final products published
- Spring 2021: Arctic council ministerial meeting

Possible delivery events:

- Arctic Circle (October 2020, Reykjavik)
- EGU (3-8 May 2020, Vienna)
- AGU (December 2020, USA)
- Arctic Frontiers (January 2021, Tromsø)
- Arctic Science Summit Week (March 2021, Lisbon)

III. Policy-relevant science questions guiding the work of the AMAP SLCF expert group

What are the lessons-learnt of earlier and current air pollutant policies in respect to Arctic? **What is the potential benefit, in terms of reduced Arctic warming, of GHG and SLCF mitigation by Arctic nations (Arctic Council and its Observers countries) and globally in the near-term (i.e. 2050)?** - What is the potential benefit, in terms of reduced Arctic warming, of SLCF mitigation by Arctic nations (Arctic Council and its Observers countries)? - What are the consequence of the Arctic Council collective black carbon goal to the Arctic climate and other impacts? - What consequences do the other commitments of the countries, i.e. the Paris agreement (CH_4, INDCs/NDCs), have on the Arctic? - How can GHG and SLCF mitigation best be combined to reduce Arctic warming and achieve other benefits? **How robust is the knowledge on sector based mitigation potential with regards to Arctic impacts?** **Set of questions inspired by the *2015 Arctic Council Framework for Action on Black Carbon and Methane* document:** - What is the status and trends of short-lived climate pollutants such as black carbon and methane in the Arctic atmosphere? Are they in line with what should be expected taking into account the Arctic Council and other efforts to reduce emissions? - What are the impacts of anthropogenic emissions on Arctic climate and public health? - What are the associated costs of emission mitigation? - What role do the natural sources play in emissions, concentrations and impacts? What are the expected trends in natural emissions in the future?				
Topic 1 Natural emissions	**Topic 2 Anthropogenic emissions**	**Topic 3 Monitoring and trends**	**Topic 4 Impacts**	**Various chapters**
What are current and potential future natural emissions from the Arctic region?	What are the current and potential future anthropogenic emissions of Arctic and non-Arctic nations?	What are the trends and variability in Arctic methane, black carbon, ozone and other relevant pollutant concentrations in the atmosphere, in snow and ice,	What is the Arctic climate response to SLCF emissions and emission reductions, from Arctic regions / nations and from global sources? How do the SLCF climate responses look like in the context of carbon dioxide and other greenhouse gas	What are the uncertainties in understanding the Arctic climate response to SLCFs?

		lake sediments etc. and what are the primary drivers of this variability?	reduction policies? What are the potential present-day impacts of pollutant emissions on human health, crop yields and ecosystems and what benefits can be achieved via emission mitigation in the future?	
What are current methane emissions from terrestrial and marine sources? What are current black carbon, other aerosol and trace gas emissions from wildfires? What are current and potential future dust emissions in the Arctic area? What are the controlling processes and factors that strongly influence natural emissions? What are the interlinkages of	How much methane, black carbon, ozone precursors and other relevant pollutants are Arctic nations currently emitting from anthropogenic activities? What are the current and future emissions from Arctic shipping? How will the magnitude of emissions change in the future and what are the mitigation options? How do national emission inventories relate to other available emission datasets? How well do we understand	Is there evidence of increasing Arctic methane, black carbon, ozone or other relevant pollutant emissions in the atmospheric observations and what could explain such trends? Are emission trends consistent with the trends observed in concentrations in the atmosphere, in snow and ice, lake sediments etc.? How do the modelled concentrations in the atmosphere, in snow and ice, lake sediments etc. relate to observations?	What is the contribution of historical changes in global atmospheric methane, black carbon, ozone and other relevant pollutants to Arctic climate warming? What impact will future atmospheric concentrations of methane, black carbon, ozone and other relevant pollutants have on climate and will Arctic nations have the ability to influence that impact through mitigation of anthropogenic emissions? To what extent might possible changes in natural emissions (i.e. increases in methane) offset mitigation of anthropogenic emissions?	…in relation to anthropogenic emissions characterization and quantification as well as projections? …in relation to natural emissions characterization and quantification as well as projections from terrestrial and marine sources? …in relation to climate response?

natural emissions to human activities? How may these emissions from natural sources in the Arctic change in the future? What are the uncertainties or limitations in these estimates?	where the emissions occur, especially in the Arctic area? What percentage of global methane, black carbon, ozone precursors and other relevant pollutant mitigation potential is controlled by Arctic Council nations? What are the uncertainties in these estimates of current and future anthropogenic emissions?	How small a trend in atmospheric methane concentrations can we detect with the current monitoring network and satellites? How useful is satellite data in monitoring Arctic concentrations of methane, black carbon, ozone or other relevant pollutants? Are the current monitoring activities (of atmospheric concentrations) sufficient to capture anticipated source changes?	Does the location of methane emissions matter for the Arctic climate impacts? What are the climate penalties of emission reductions of cooling species (i.e. sulfur, NOx) vs the climate benefits of emission reductions of warming species (black carbon, methane, greenhouse gases)? What sources and sectors should be prioritized to maximize the climate benefits?	…in relation to measuring changes in concentrations in the atmosphere, in snow and ice, lake sediments etc.?