Atmospheric composition and ocean color feedback to Arctic amplification

C03

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1. Summary

Project C03 aims at improving our understanding of the evolving tropospheric halogen chemistry and surface ocean biogeochemistry during Arctic amplification.

Research questions

Q1 What is the **evolution of the key quantities** (phytoplankton groups (PG), colored dissolved matter (CDOM), ocean radiation, bromine monoxide (BrO)) observed over the last years, which were characterized by rapid Arctic warming?

Q2 How does the changing ocean **surface biogeochemistry (BGC) impact atmospheric radiative forcing** via indirect effects (aerosol precursor emissions and carbon export) combined with its direct feedback to ocean radiation?

Q3 How do changing **tropospheric bromine concentrations impact oxidative capacity** (e.g. OH and O_3 concentrations) and thereby radiative forcing?

Contribution to CCA2, SQ1 & SQ3

Hypothesis

Changes in atmospheric bromine concentrations and optically active ocean components have relevant feedbacks with Arctic amplification through radiative forcing and oxidative capacity.

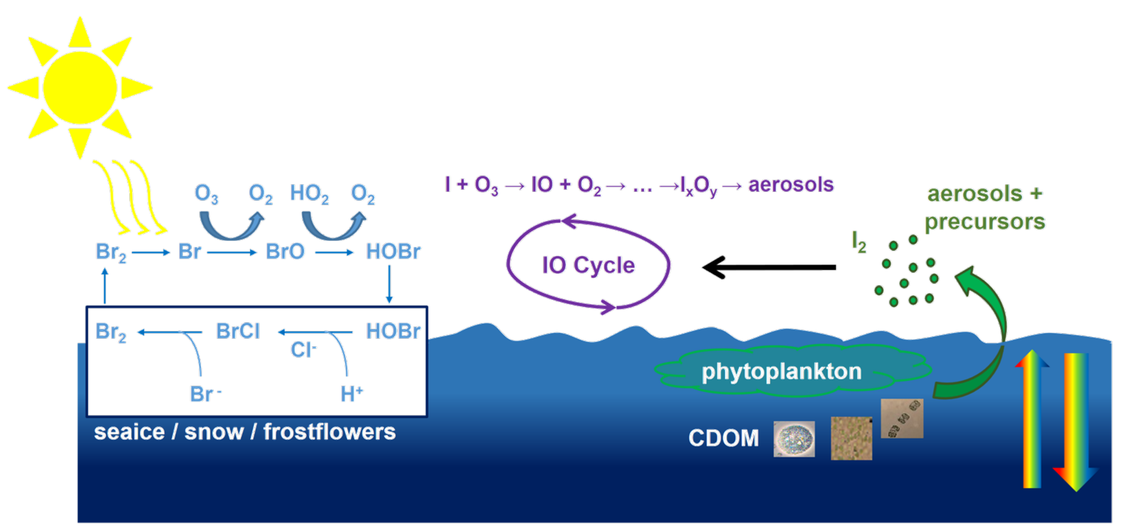


Fig. 1: Concept of interactions of halogen oxides and ocean surface BGC with Arctic amplification through changes in oxidative capacity and radiative forcing.

2. Achievements phase II

Links between meteorology and Ozone Depletion Events (ODEs)

- ODEs often coincide with explosive releases of halogens (mainly Br) from cryosphere:
  1. Identification of ODEs in Ny-Ålesund using two long-term ozone data sets;
  2. Assessment of BrO and meteorological conditions during ODEs

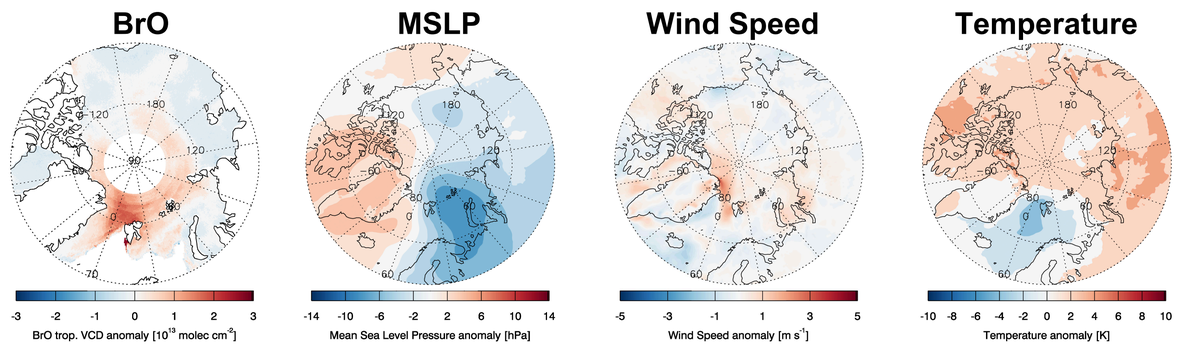


Fig. 2: Tropospheric satellite BrO Vertical Column Densities (VCDs), ERA5 Mean Sea Level Pressure (MSLP), Wind Speed, and Temperature anomalies during ODEs in Ny-Ålesund based on the in-situ ozone data set from Zeppelin mountain, Ny-Ålesund*. From Zilker et al., 2023.*

➡ **Specific large-scale meteorological patterns and enhanced BrO values are observed during ODEs in Ny-Ålesund.**

Feedbacks of surface ocean biogeochemistry

- Satellite time series 2003-today on phytoplankton groups and spectral attenuation of underwater light Impact of phytoplankton and CDOM on SST, SIC, and heat flux

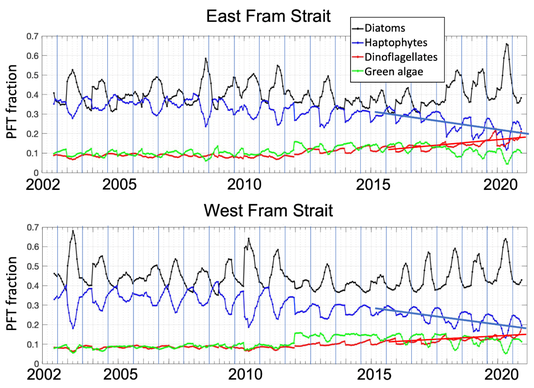


Fig. 3: Satellite-derived fractions of phytoplankton groups for the East and West Fram Strait.

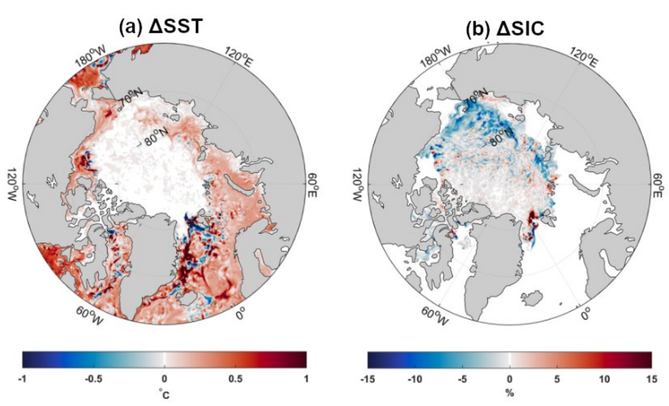
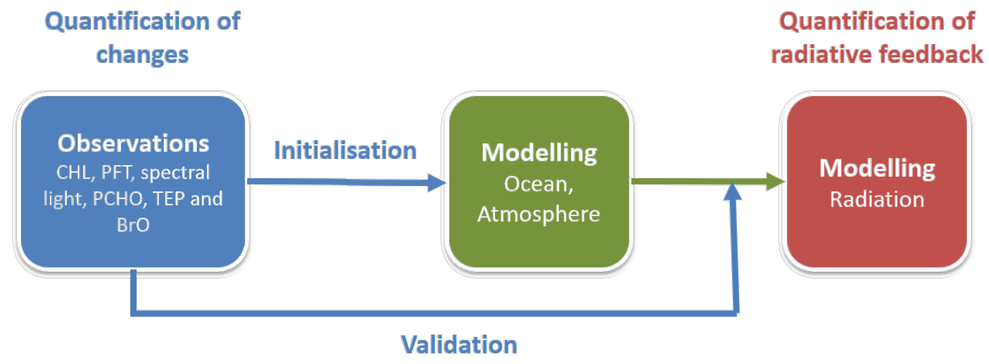


Fig. 4: Differences of sea surface temperature (a) and sea ice concentration (b) in Darwin-MITgcm for August 2012 when incorporating the radiative feedback of BGC to underwater light attenuation.

➡ **Radiative feedback from surface water BGC to ocean physics in coupled model significantly changes sea surface temperature and sea ice concentration.**

3. Research plan phase III



1) Observations

Extend observations of key BGC quantities, ocean radiation, and BrO

- Include recent years, characterized by rapid Arctic change
- Ocean color: Eastern Greenland Sea and Fram Strait, link to in-situ observations
- BrO: TROPOMI data, link to validation measurements in Ny-Ålesund
- Revisit previous observation based trend studies

2) Modeling

Simulation of key biological, chemical and physical processes leading to changes in Arctic ocean color and tropospheric O_3

- Introduce RTM model from phase II and add biogenic aerosol tracers into FESOM2.1-REcoM3
- Setup WRF-Chem or GEOS-Chem for atmospheric halogen and O_3 modelling
- Initialize, validate and optimize with satellite and other observations

3) Radiative Impact

Evaluate impact of ocean and atmosphere parameters on radiation

- Quantify feedback from changes in constituents
- Assess indirect feedbacks via marine aerosol formation
- Investigate feedback between sea ice changes, atmospheric BrO and O_3 changes and radiation

4. Legacy & Major expected results

Project Legacy

- 30 year 4 km model output on aerosol precursors and short wave radiation in the upper Arctic Ocean (results from phase II and comprehensive assessment in phase 3)
- Long-term satellite time series of surface ocean BGC and BrO covering 30 years results from phase II and phase 3 updates)

Major expected results within phase III

- Homogenized data sets of satellite-derived ocean surface BGC, underwater light field, trace gas BrO
- Simulated long-term time-series of ocean BGC, spectral underwater light field, aerosol precursors, atmospheric halogen and ozone chemistry
- Quantification of radiative feedbacks of these constituents

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