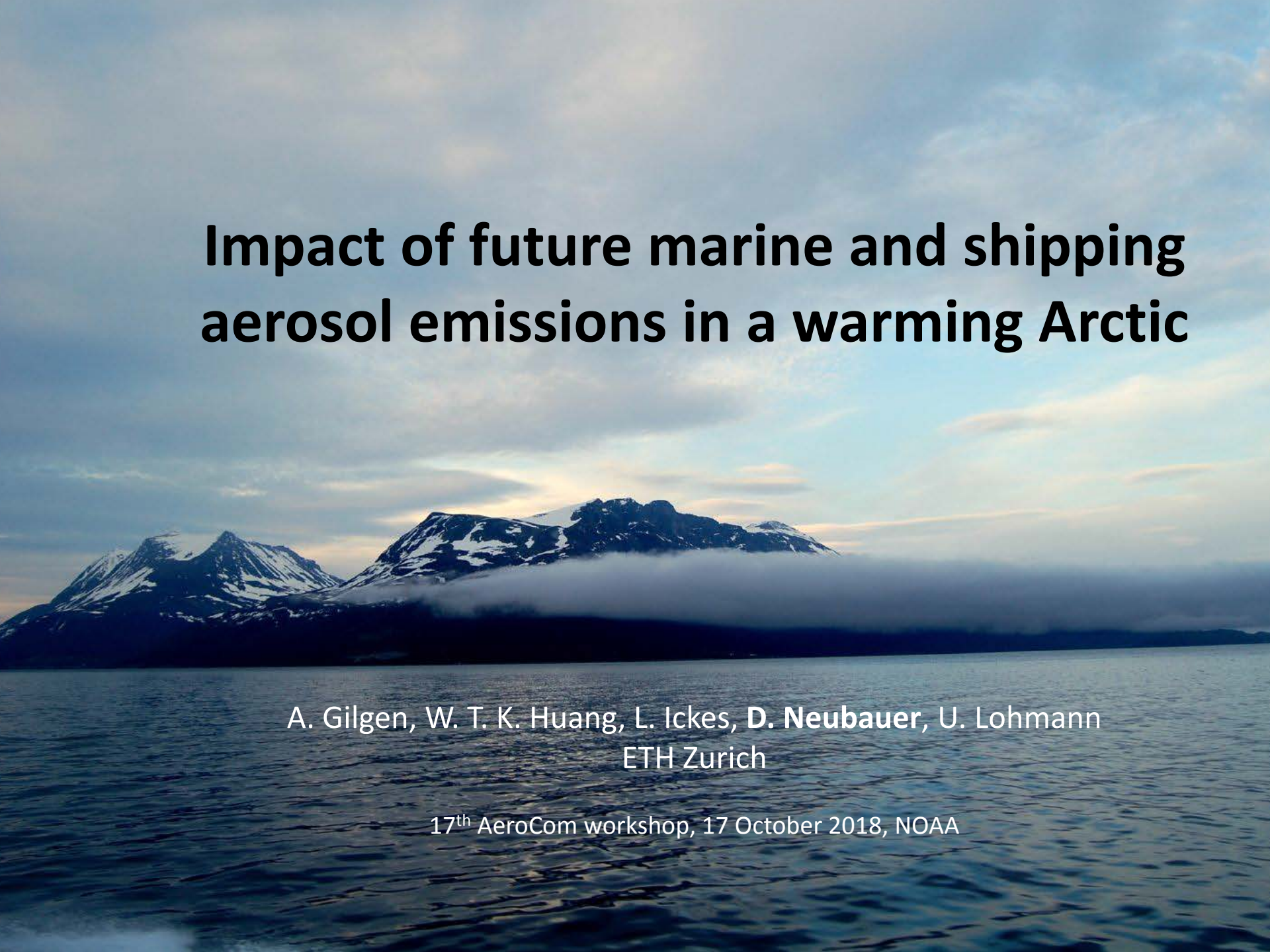

Impact of future marine and shipping aerosol emissions in a warming Arctic

A. Gilgen, W. T. K. Huang, L. Ickes, **D. Neubauer**, U. Lohmann
ETH Zurich

17th AeroCom workshop, 17 October 2018, NOAA

Future ice-free Arctic summer

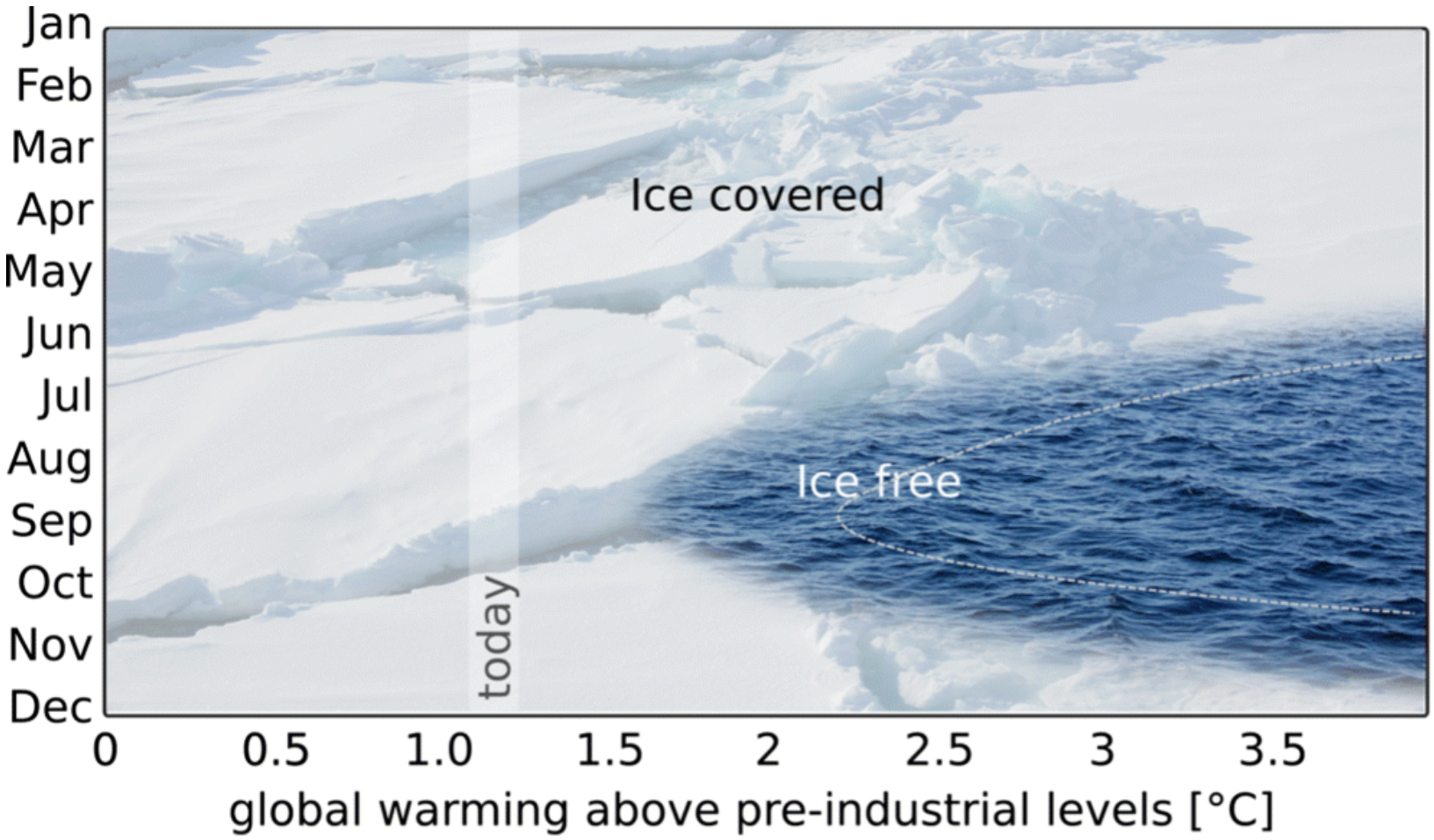

Figure from Notz and Stroeve (2018)

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Changes in natural emissions

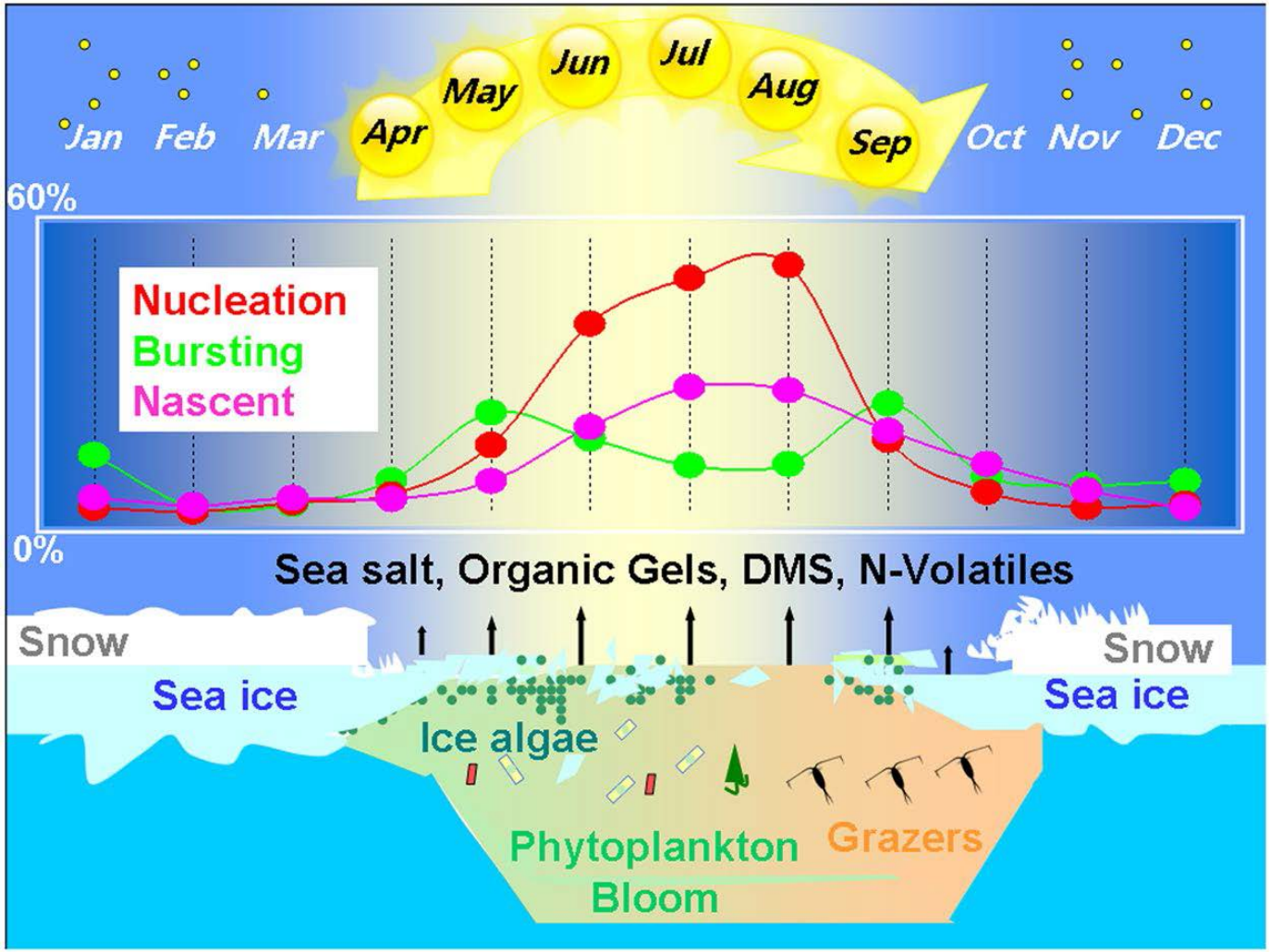

Figure from Dall´Osto et al. (2017)

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Changes in anthropogenic emissions

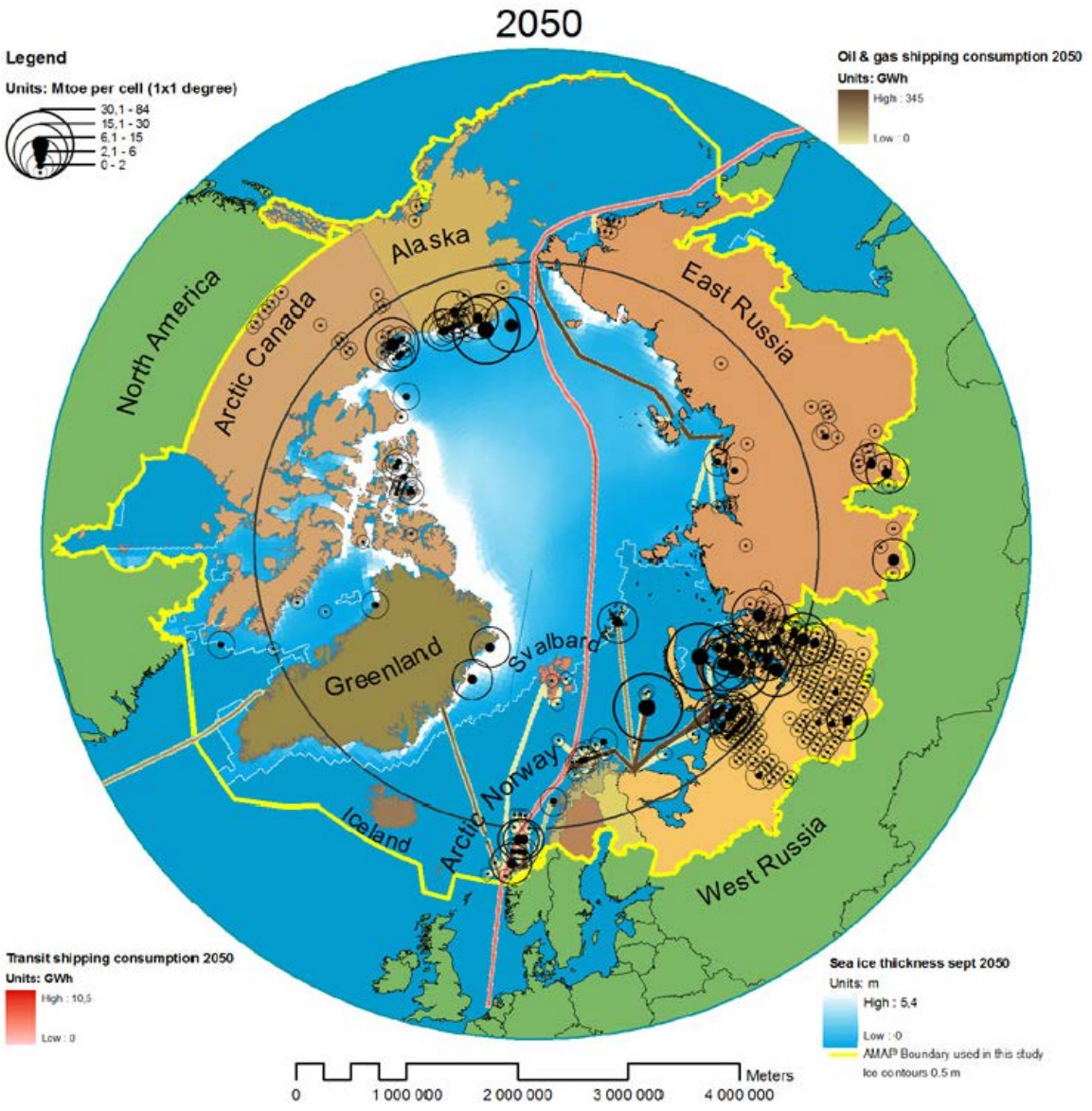

Figure from Peters et al. (2011)

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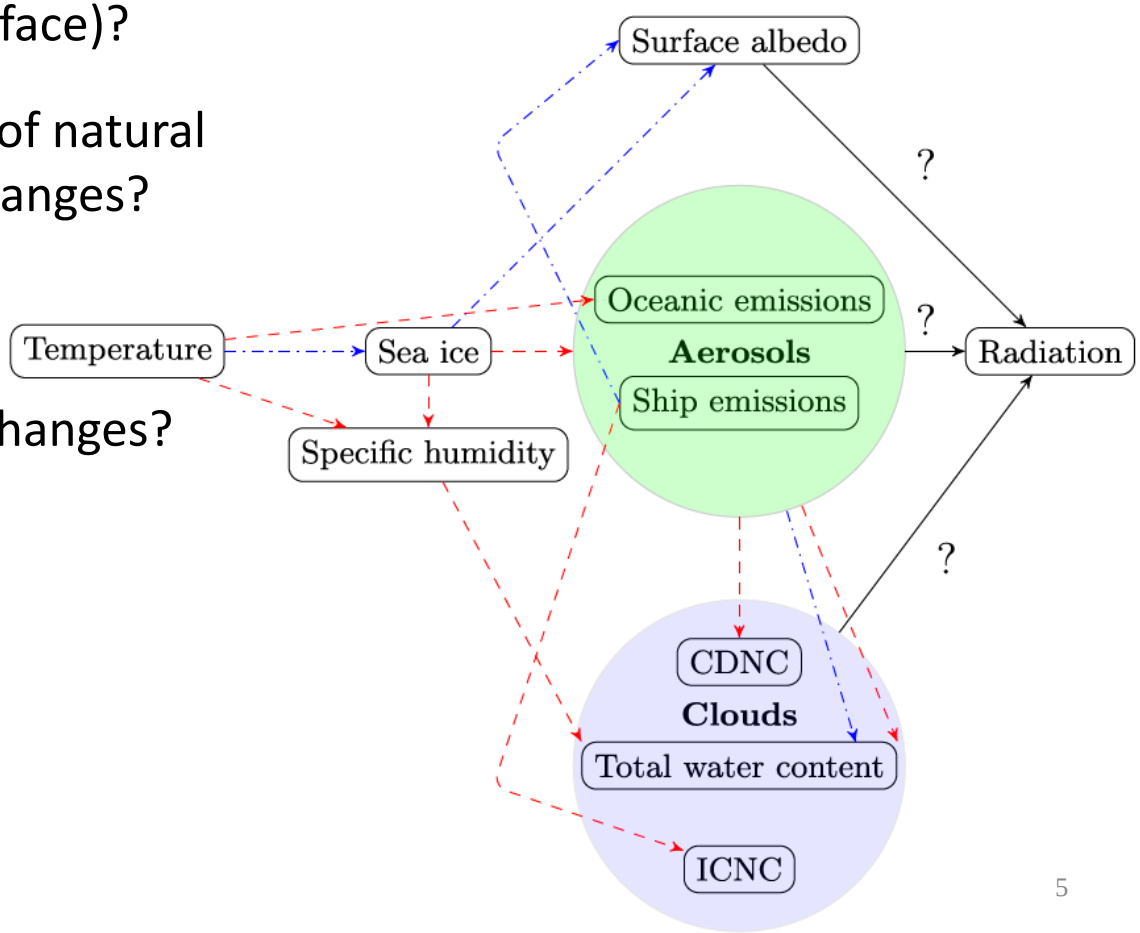
Questions

- How do aerosol and cloud radiative effects change in an ice-free Arctic?
- What is the impact of the sea ice retreat (albedo change/warmer surface)?
- What is the impact of natural aerosol emission changes?
- What is the impact of anthropogenic shipping emission changes?



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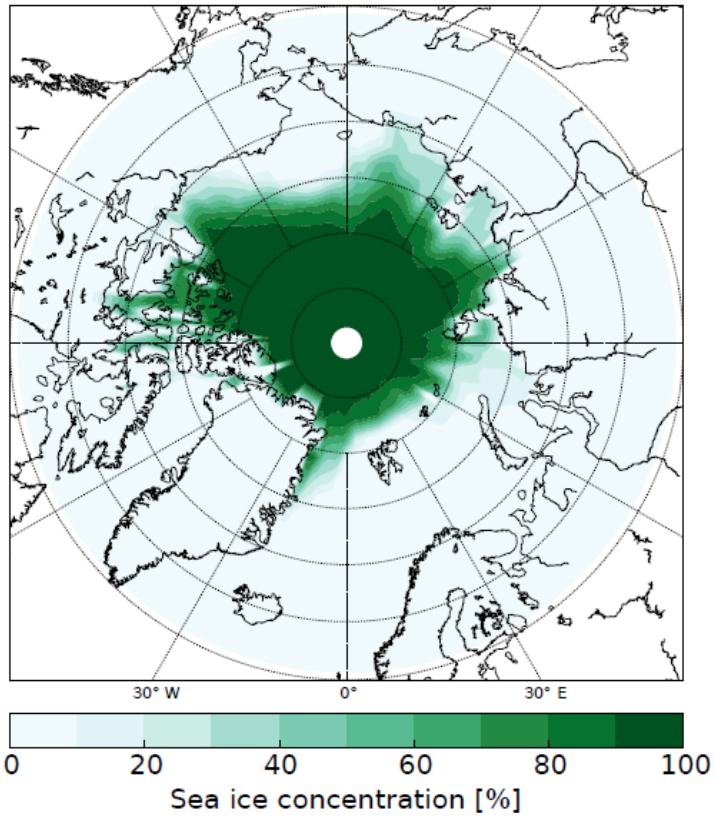
ECHAM6-HAM2 atmospheric experiments

Natural emission changes, two experiments (20 ensemble members each):

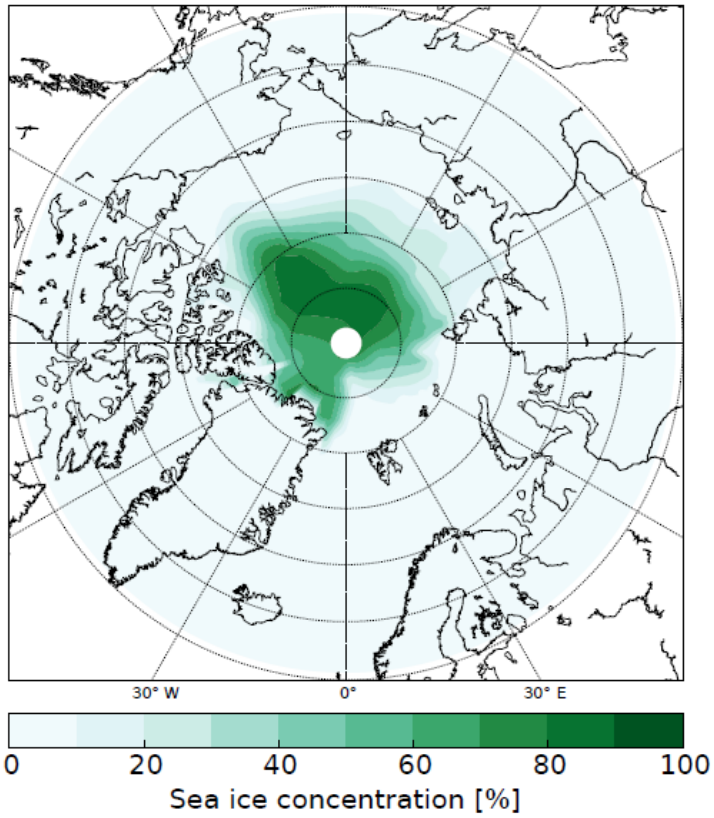
(1) 2004 greenhouse gases and sea surface temperatures/sea ice prescribed
(2) 2050 greenhouse gases and sea surface temperatures/sea ice prescribed

- both: 2004 anthropogenic aerosol emissions prescribed
- both: sea salt, dimethyl sulfide (DMS) and dust emissions calculated online

2004 (Sept./Oct.)



2050 (Sept./Oct.)



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ECHAM6-HAM2 atmospheric experiments

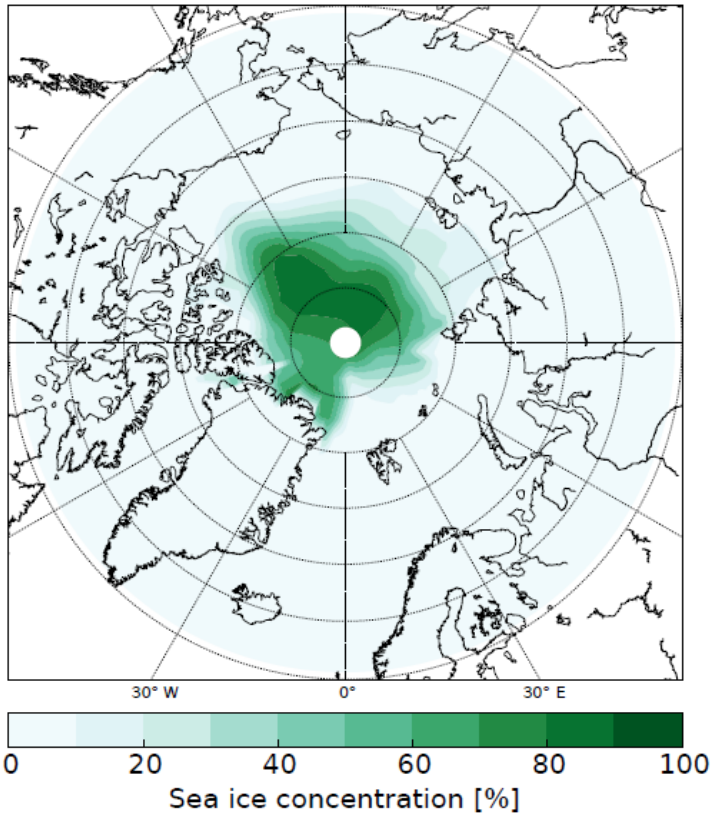
Shipping emission changes, two experiments (20 ensemble members each):

(1) without increased Arctic shipping emissions

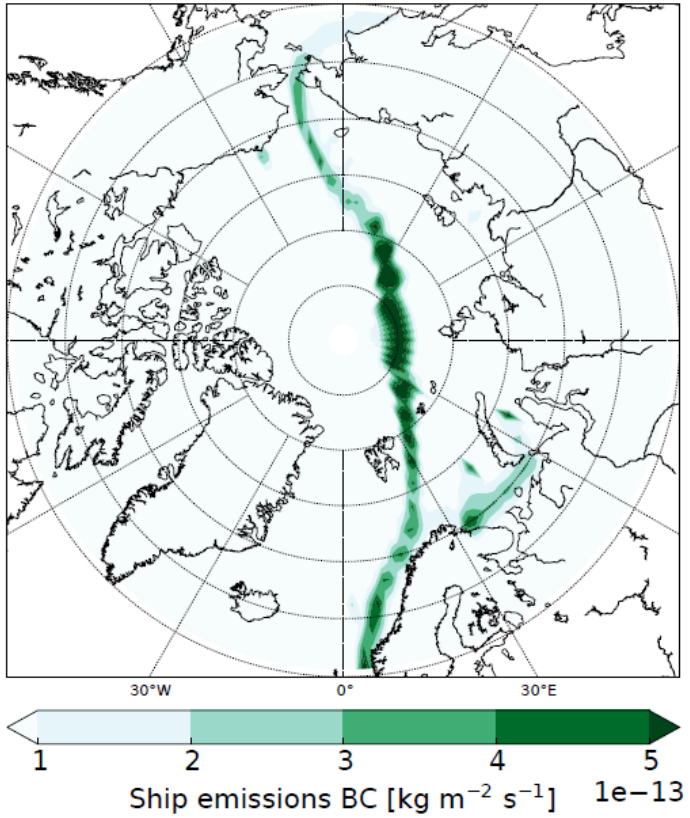
(2) with increased Arctic shipping emissions (10x Peters et al., 2011)

- both: 2050 sea surface temperatures/sea ice prescribed
- both: 2050 (RCP8.5) anthropogenic aerosol emissions prescribed

2050 (Sept./Oct.)



2050 (Sept./Oct.)



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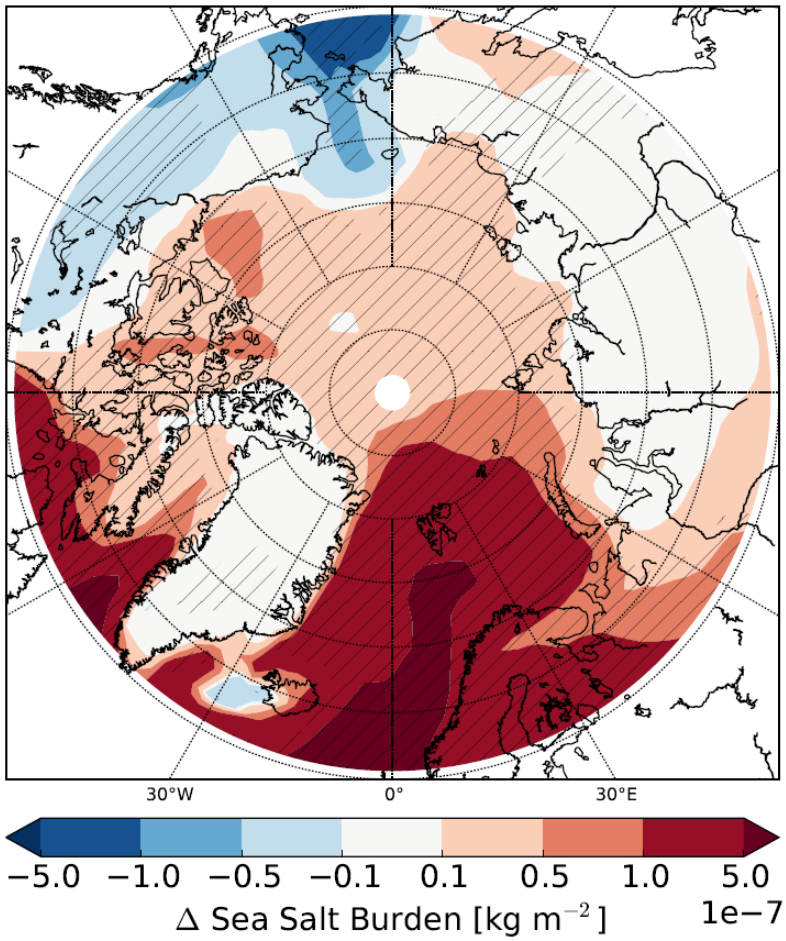
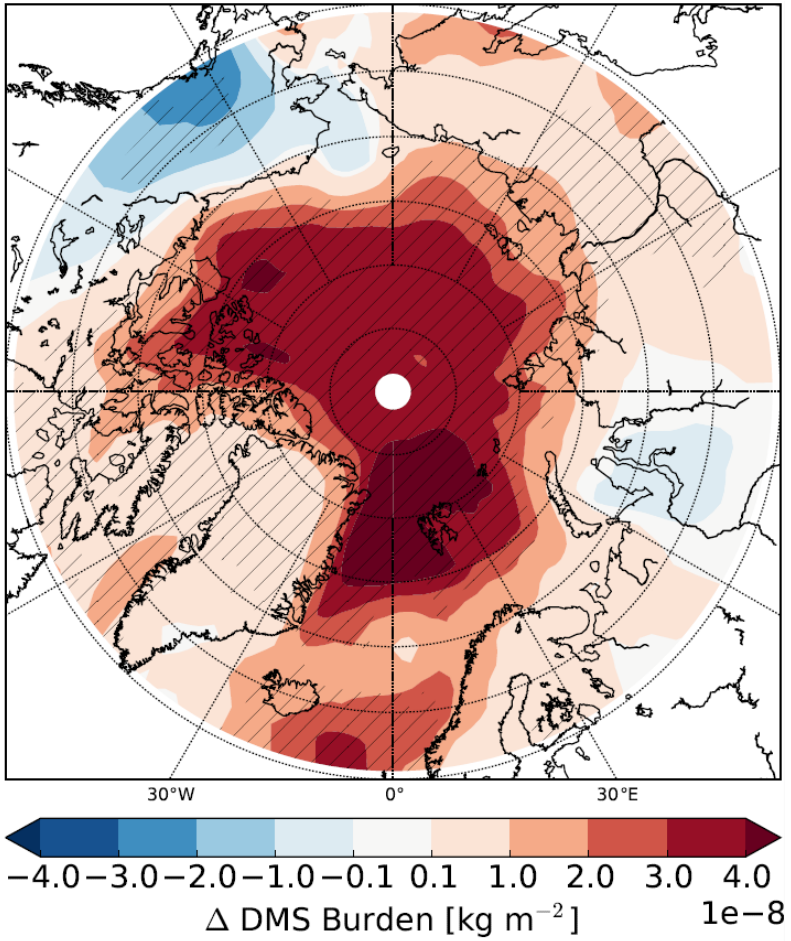
Increases in marine aerosol (2004→2050, Sept./Oct.)



60°N-90°N: +31%



60°N-90°N: +20%

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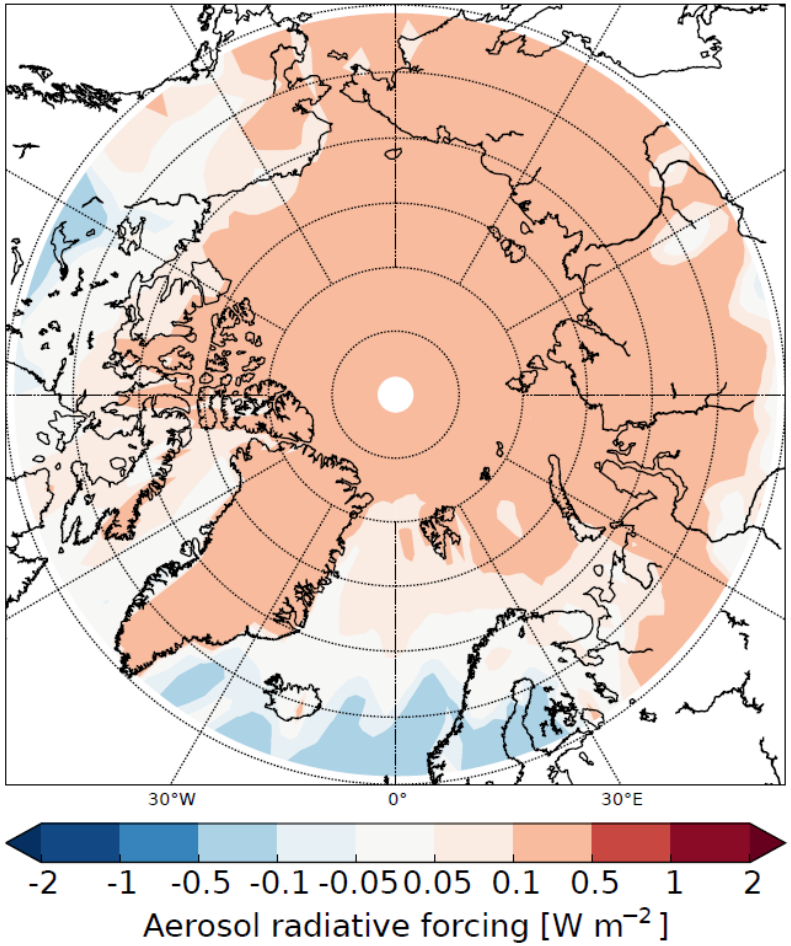
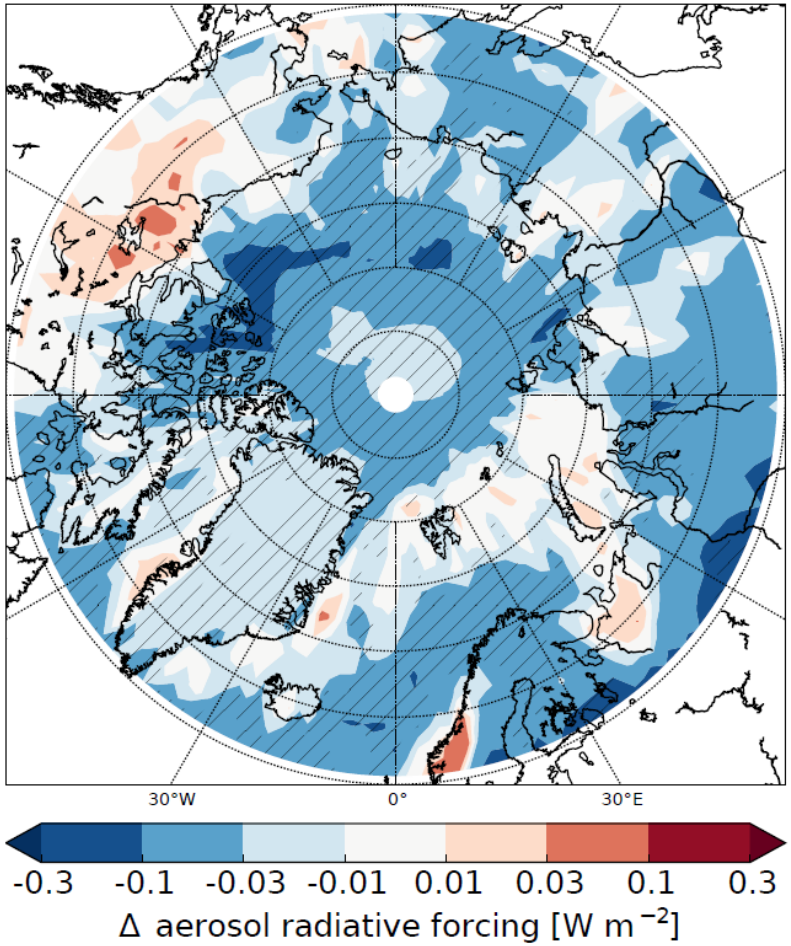
Natural direct aerosol radiative effect changes (2004→2050, Sept./Oct.)



60°N-90°N: 0.019 W m^{-2}



60°N-90°N: -74%

- Small positive aerosol radiative effect becomes weaker

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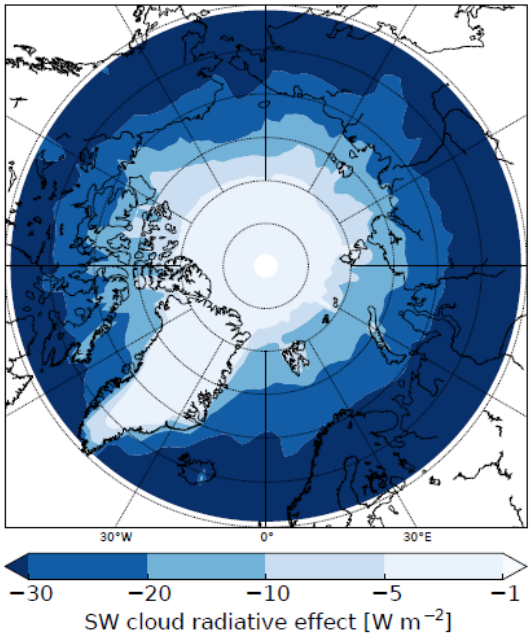
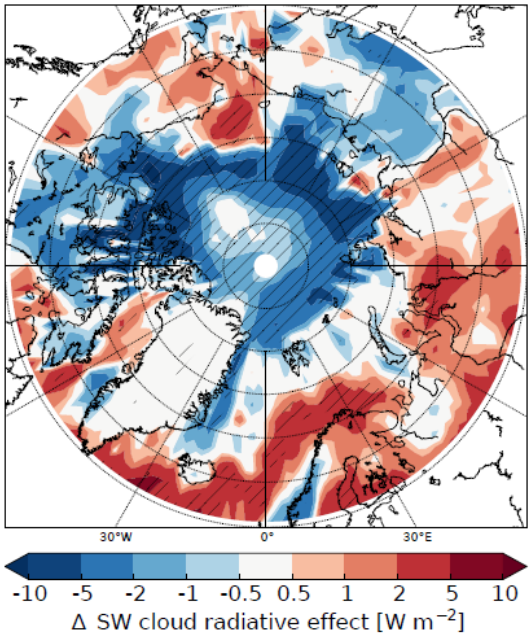
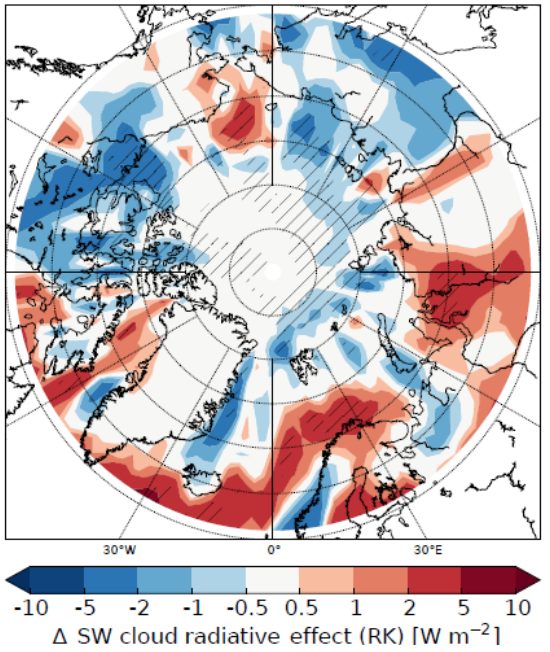
Shortwave (SW) cloud radiative effect (CRE) changes (2004→2050, Sept./Oct.)



75°N-90°N: -7.8 W m^{-2}



75°N-90°N: -2.2 W m^{-2}



75°N-90°N: -0.4 W m^{-2}

- Change in surface albedo is more important than change in cloud properties
- SW CRE (Radiative Kernel, RK): increase in cloud optical thickness (increased cloud condensation nuclei, humidity) and low cloud cover

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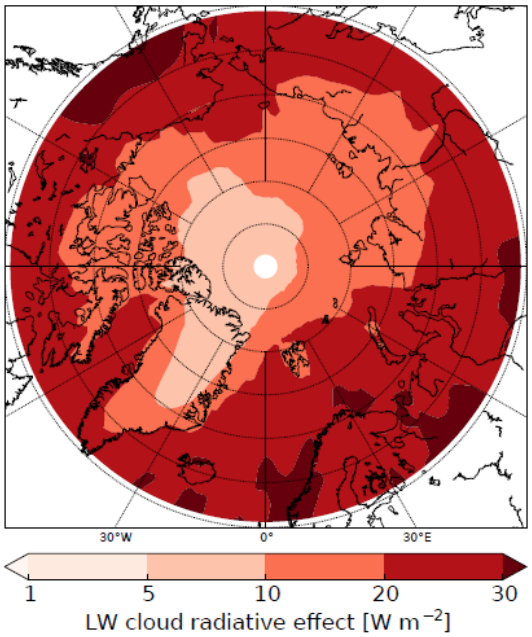
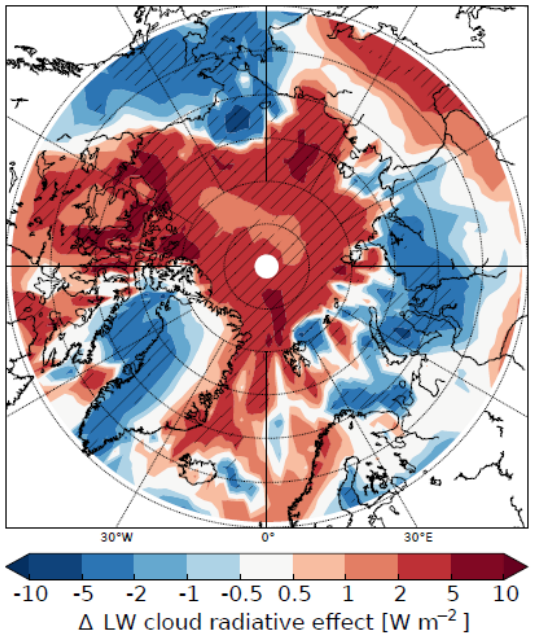
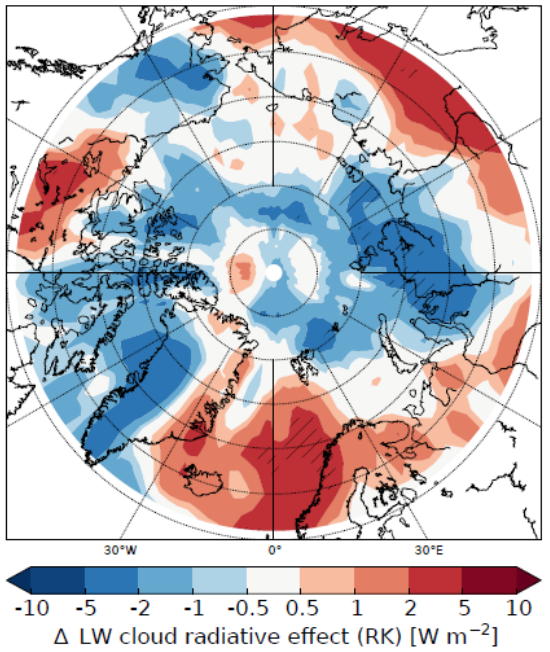
Longwave (LW) cloud radiative effect changes (2004→2050, Sept./Oct.)



75°N-90°N: 13 W m^{-2}



75°N-90°N: 2.0 W m^{-2}



75°N-90°N: -1.0 W m^{-2}

- Change in surface temperature is more important than change in cloud properties

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Summary - Natural aerosol emission changes

- Direct radiative aerosol effect and BC deposition on snow unimportant
- Albedo changes more important than changes in cloud properties
- No large potential for aerosol-mediated feedbacks

What is the impact of additional shipping?

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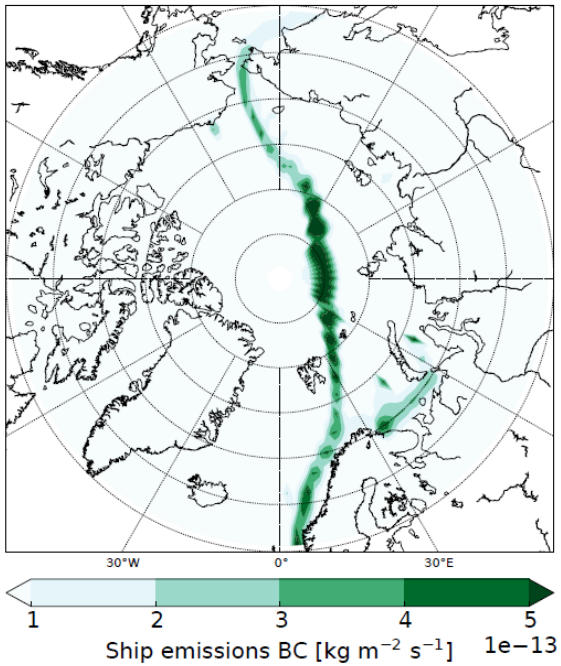
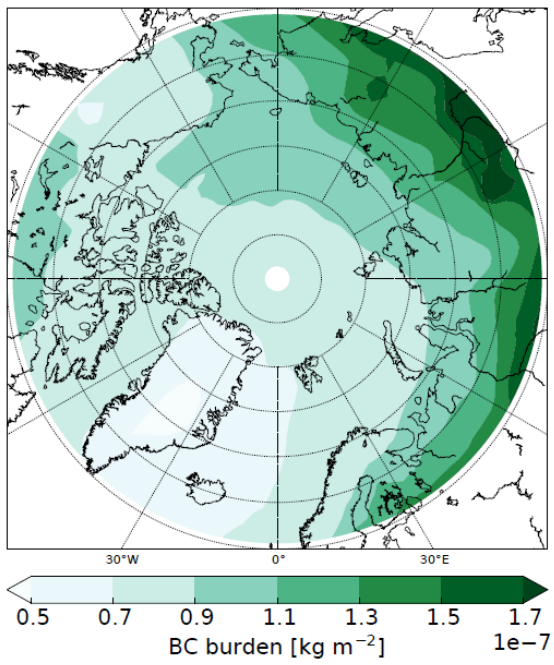
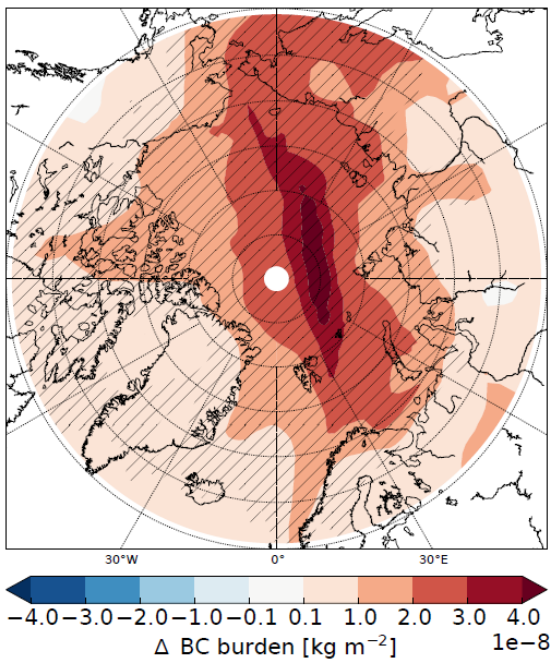
Increased Arctic ship emissions (2050, Sept./Oct.)





60°N-90°N: $0.95 \cdot 10^{-7}$ kg m^{-2}



60°N-90°N: +13%

- Considerable increase in black carbon (BC) (weaker increase of sulfate/organic carbon) near the surface and higher up

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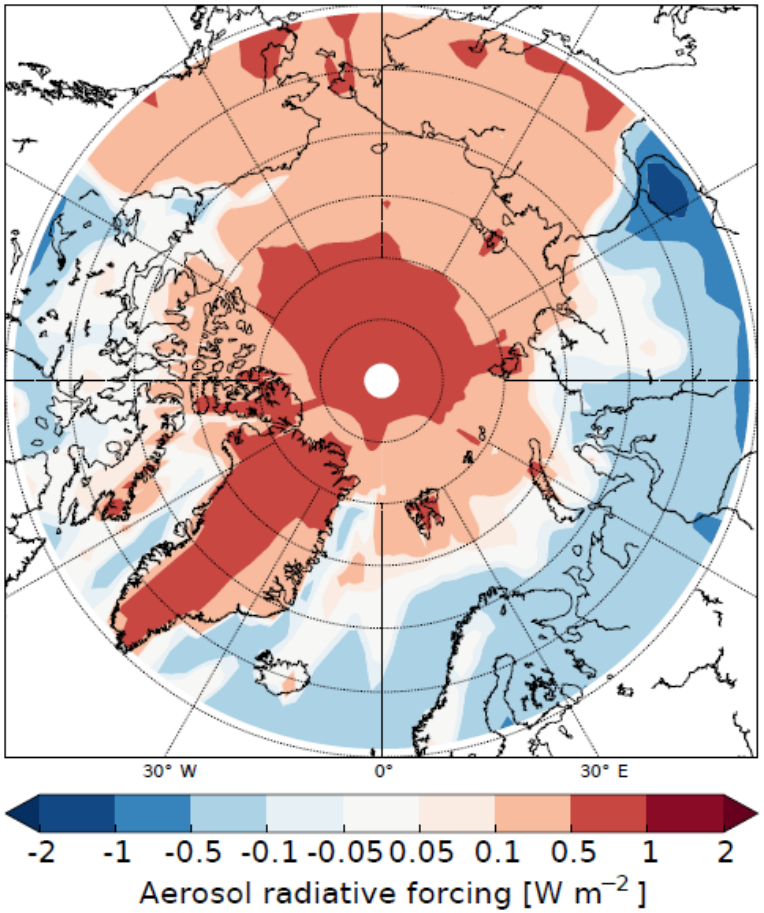
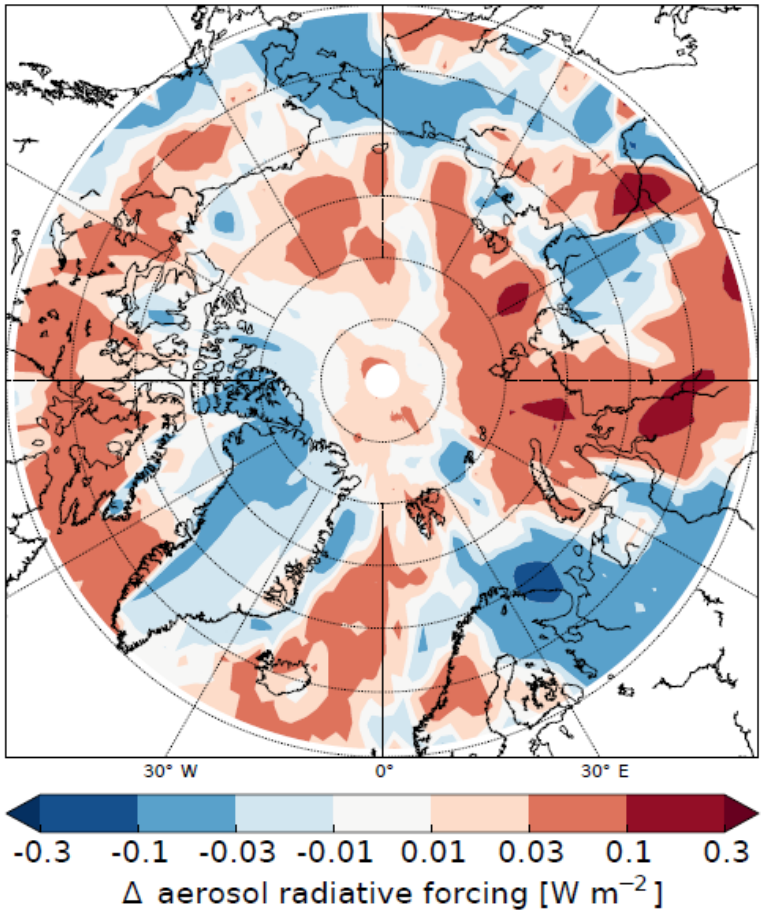
Natural direct aerosol radiative effect changes (2050, July/Aug.)





60°N-90°N: 0.011 W m^{-2}

60°N-90°N: -7.1%

- No significant change in small positive aerosol radiative effect

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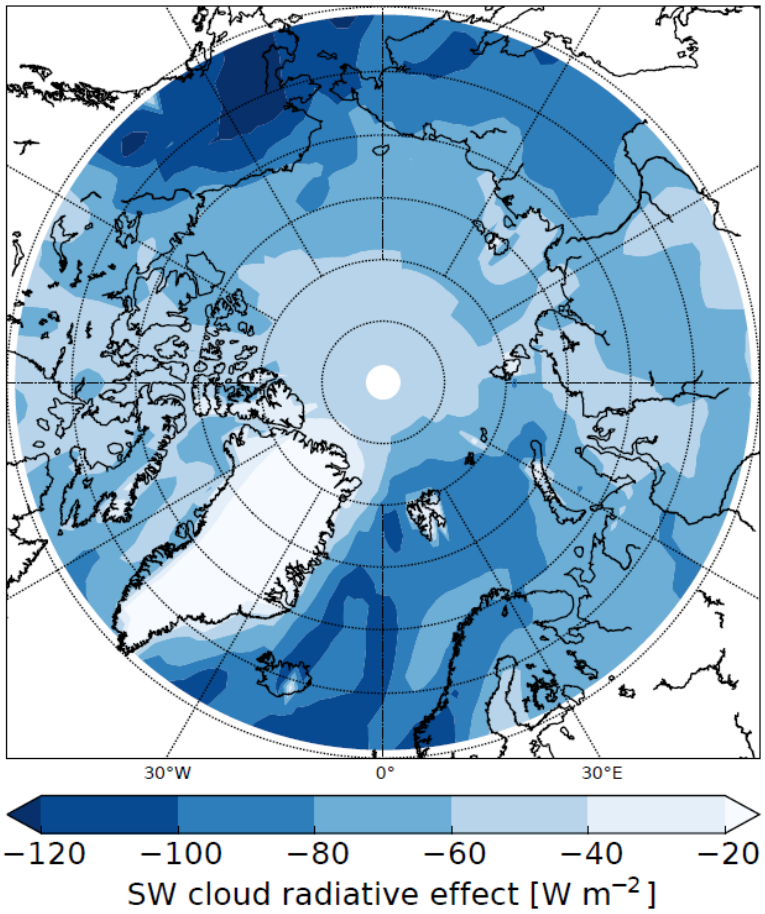
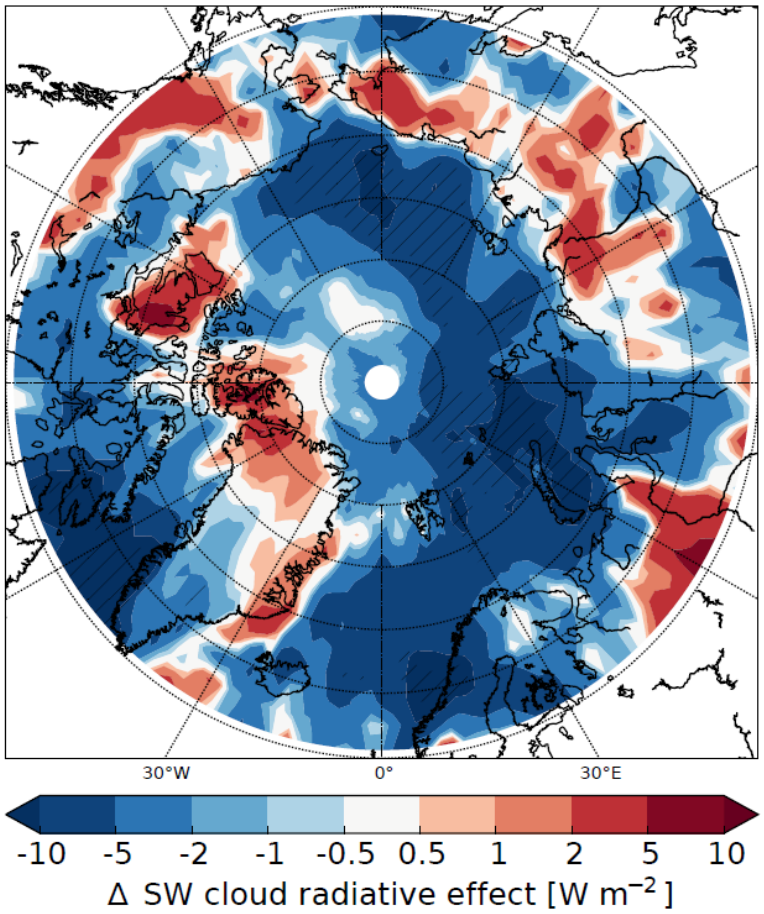
SW cloud radiative forcing (2050, July/Aug.)





60°N-90°N: -69 W m^{-2}

60°N-90°N: -2.9 W m^{-2}

- SW CRE is significantly more negative with additional ship emissions

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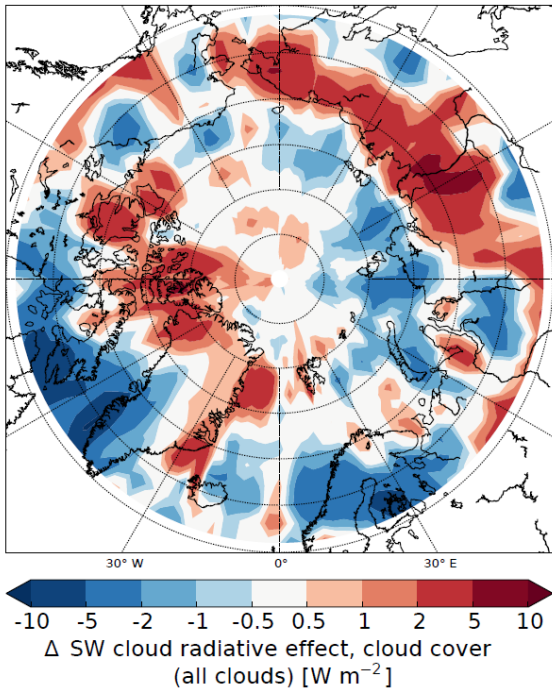
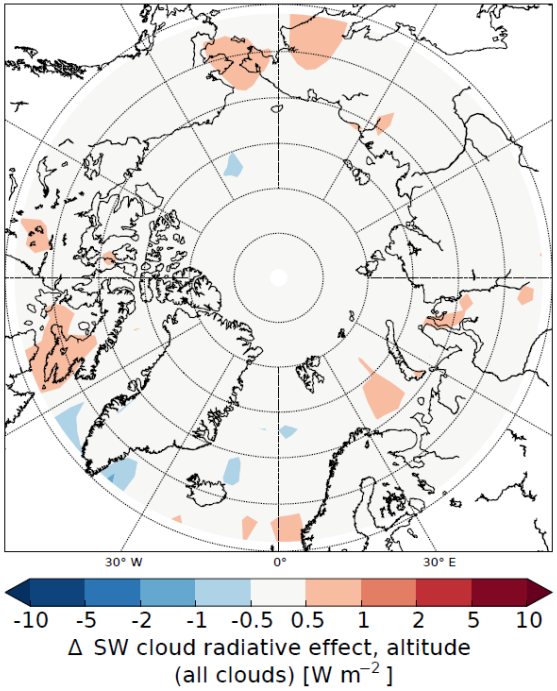
Components of SW cloud radiative forcing (2050, July/Aug.)

Cloud cover



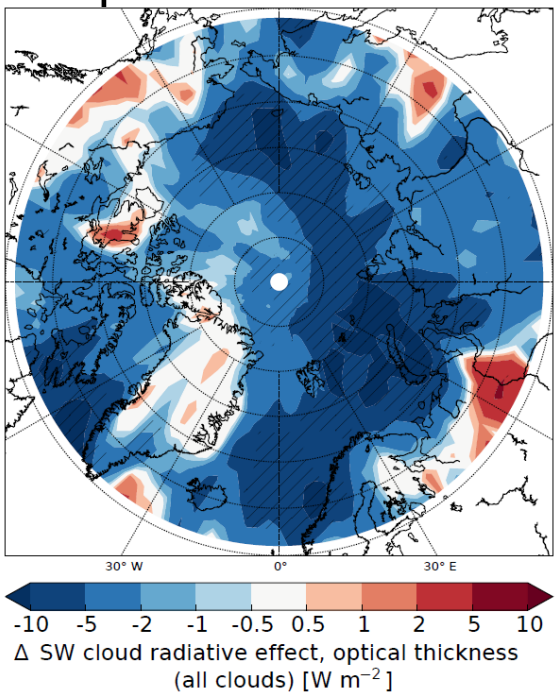
60°N-90°N: -0.1 W m^{-2}

Altitude



60°N-90°N: 0.1 W m^{-2}

Optical thickness



60°N-90°N: -3.6 W m^{-2}

- Change in cloud optical thickness most pronounced (mostly in low clouds)

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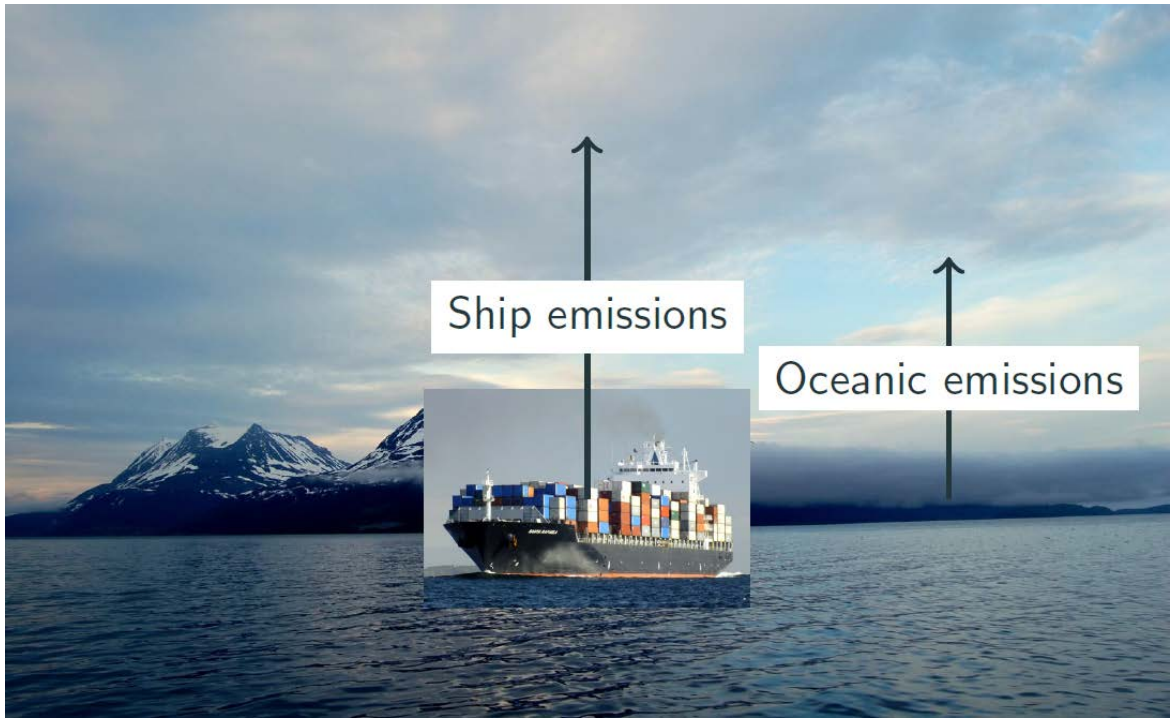
Summary and Outlook

- **No large potential for aerosol-mediated feedbacks in the Arctic Summer/Fall (Albedo/Planck feedbacks dominate)**
- **Additional Arctic ship emissions could lead to a cooling effect but only for upper emission estimate**
- Earth system model simulations to test feedbacks of additional Arctic ship emissions
- Extension to all seasons

Gilgen et al., 2018, ACP



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References

- Image of Arctic Ocean: http://blogs.agu.org/geospace/2015/07/22/warmer-air-less-sea-iceleads-to-mercury-decline-in-arctic-ocean/
- Image of ship in Arctic Ocean: https://www.tc.gc.ca/eng/marinesafety/tp-tp13670-menu-2315.htm
- Image of cargo ship: http://maritime-connector.com/ship/santa-rafaela-9227297/

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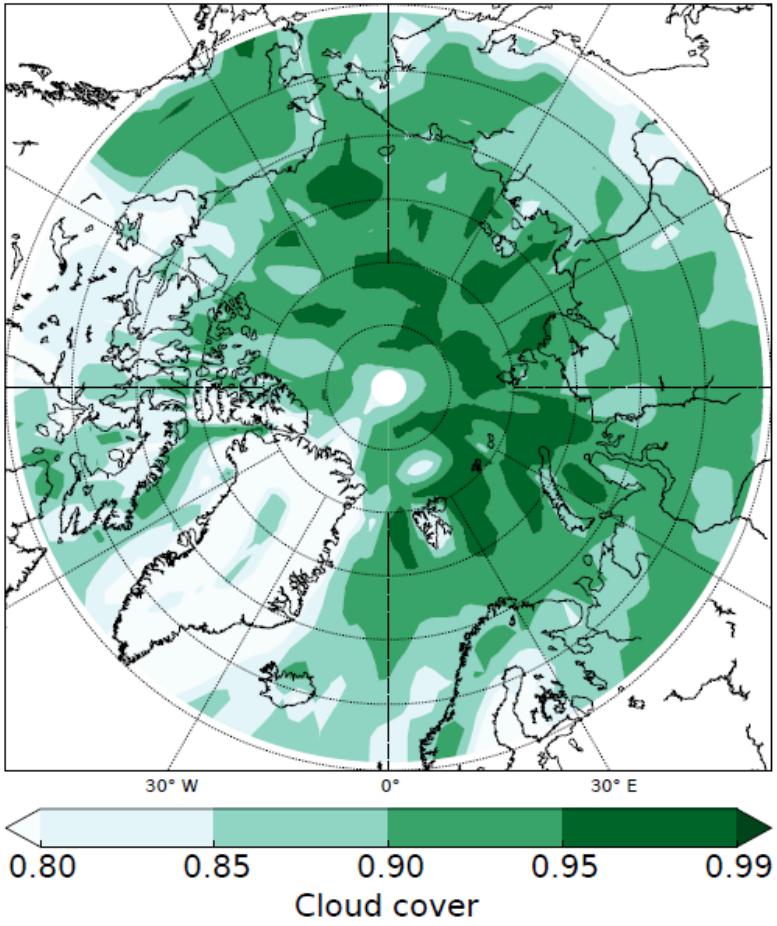
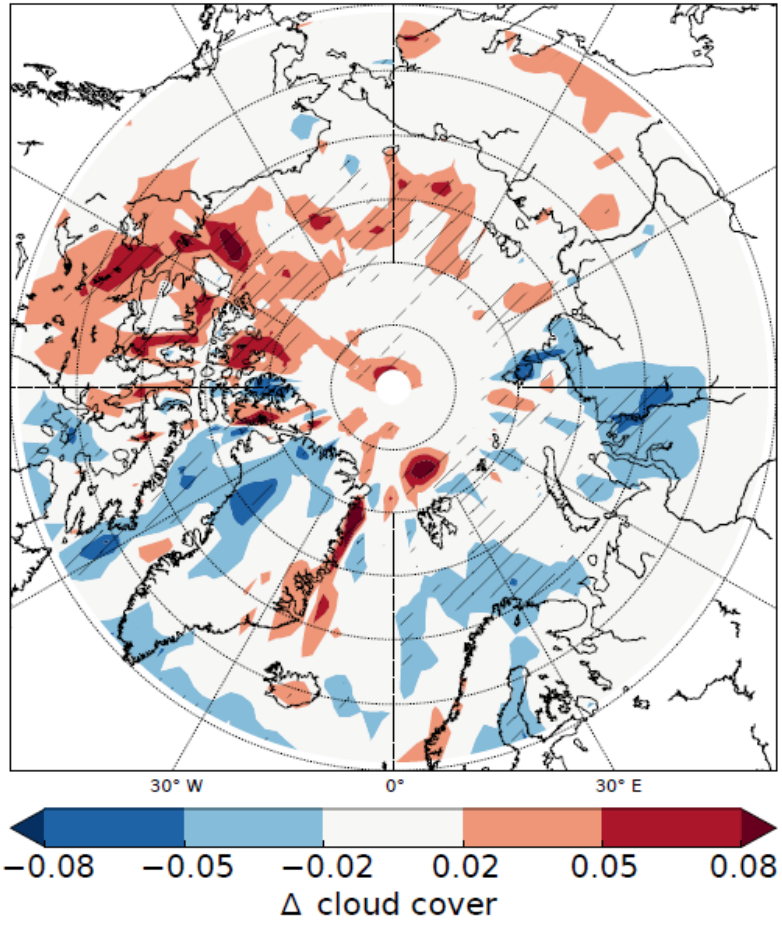
Cloud cover
(2004→2050, Sept./Oct.)





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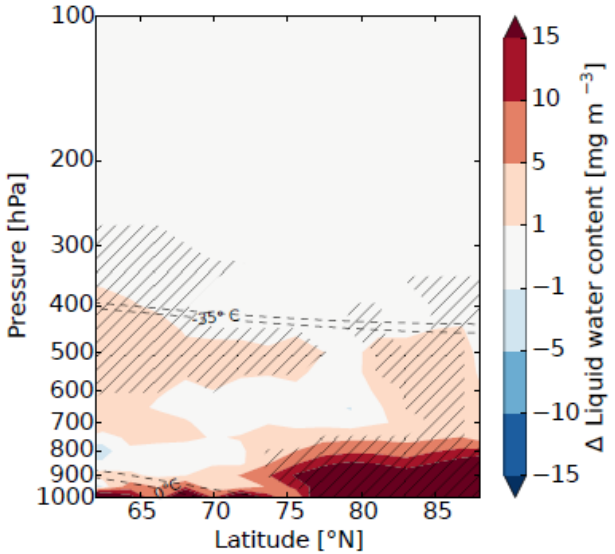
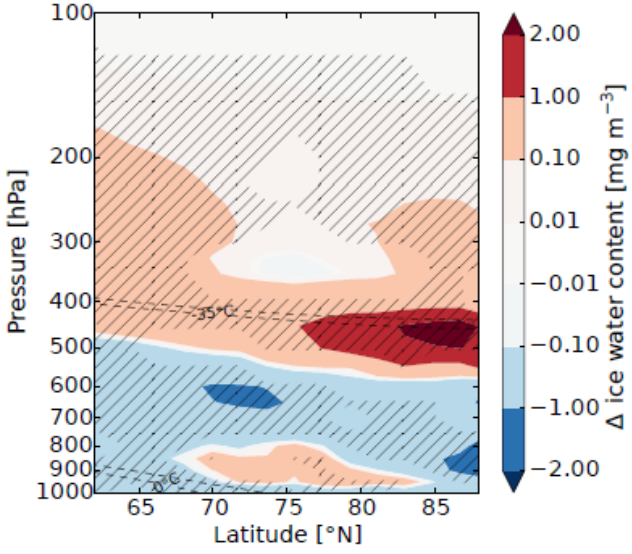
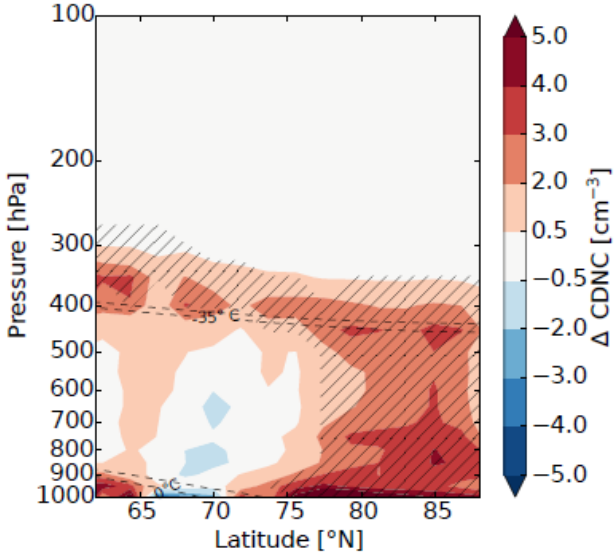
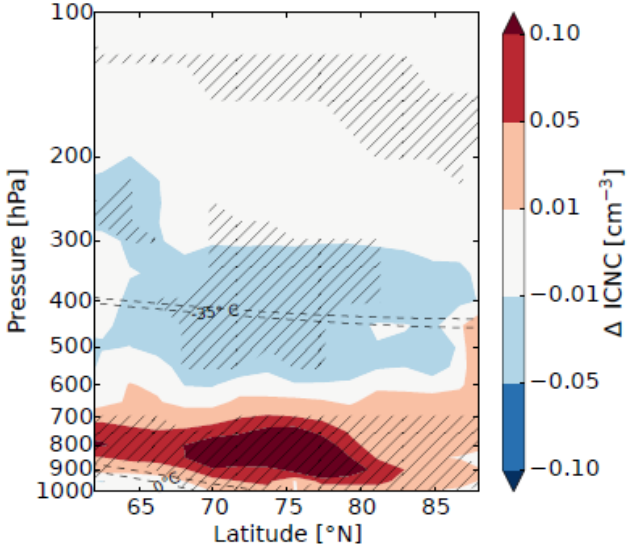
2004→2050, Sept./Oct.

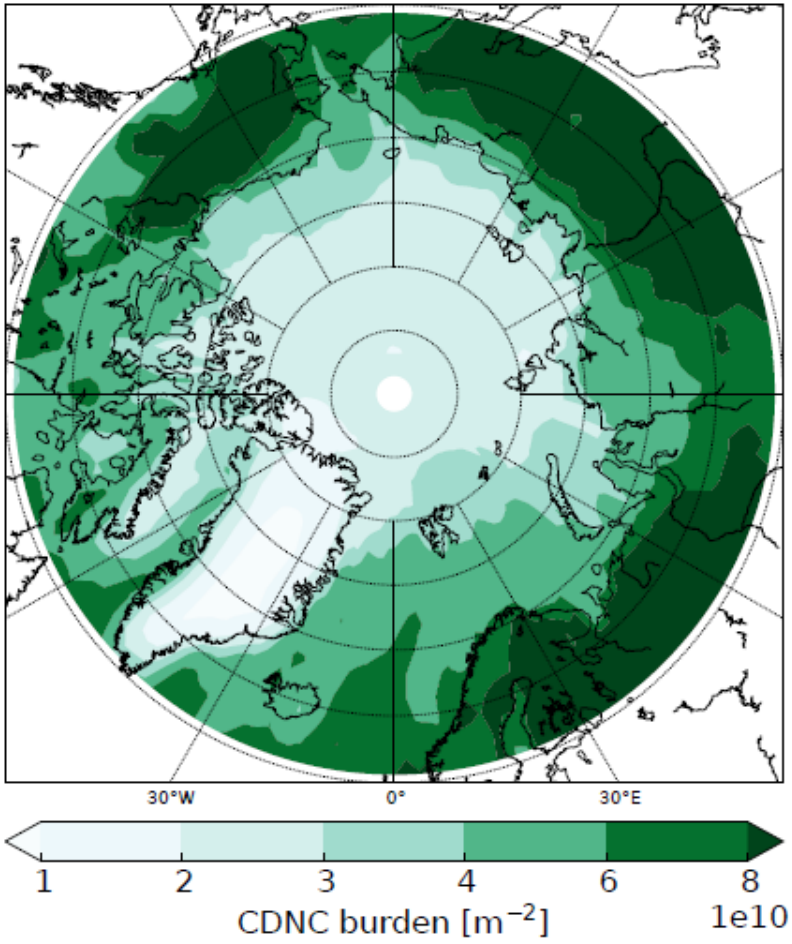


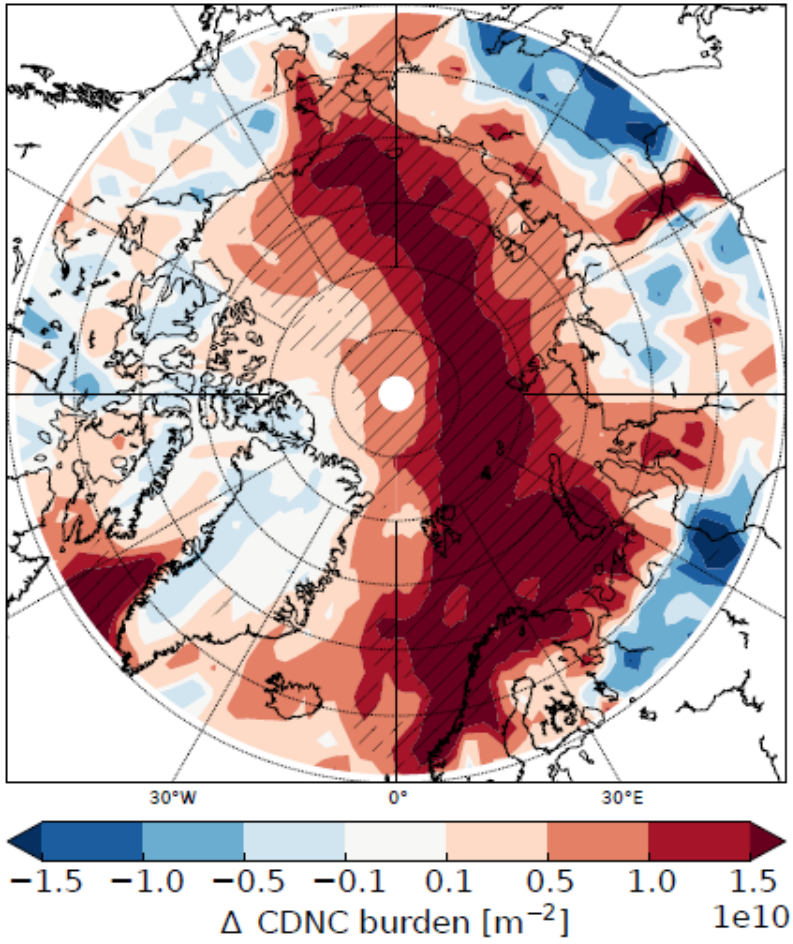






Cloud droplet number concentration (CDNC) (2050, July/Aug.)





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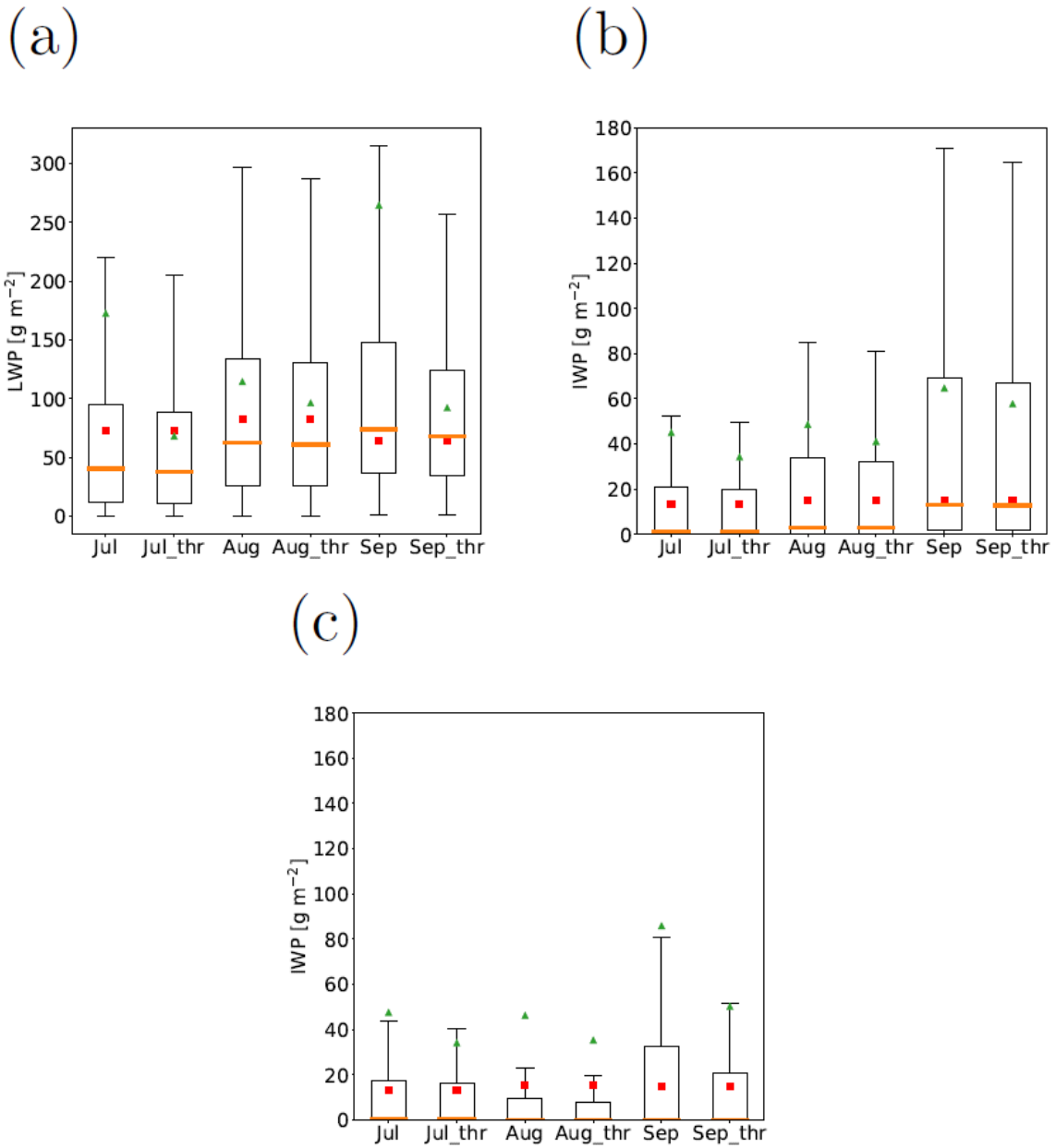
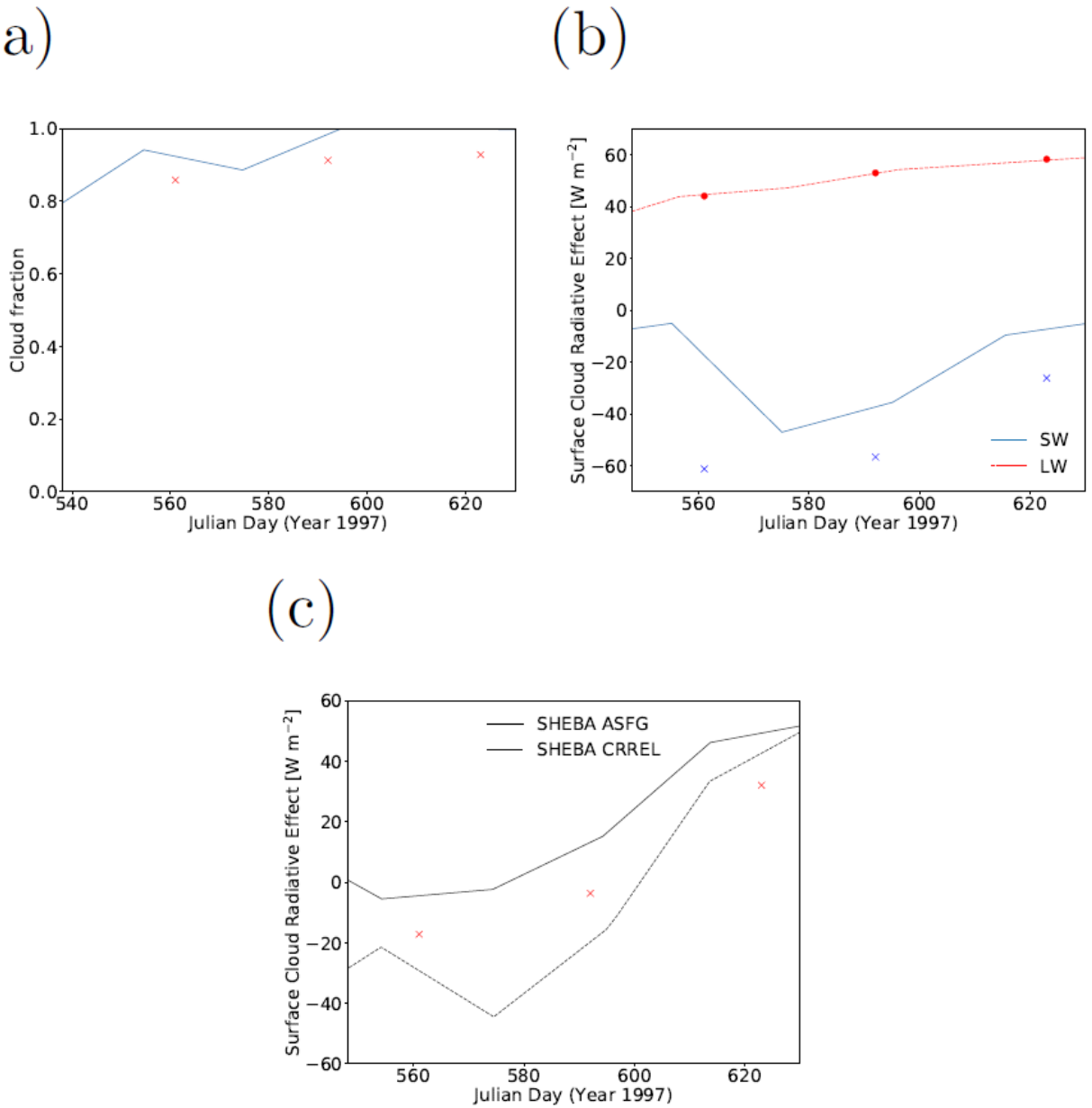
SHEBA campaign LWP/IWP



SHEBA campaign CRE



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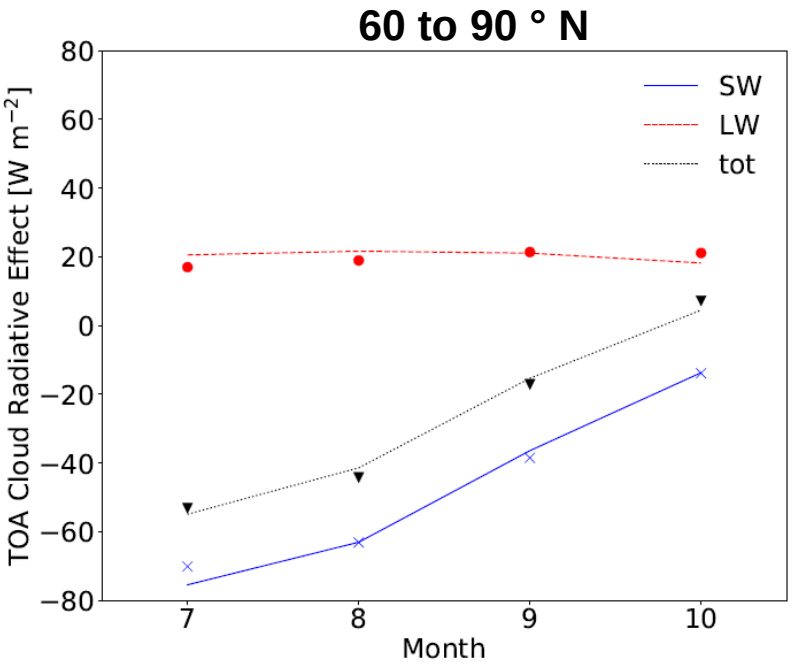
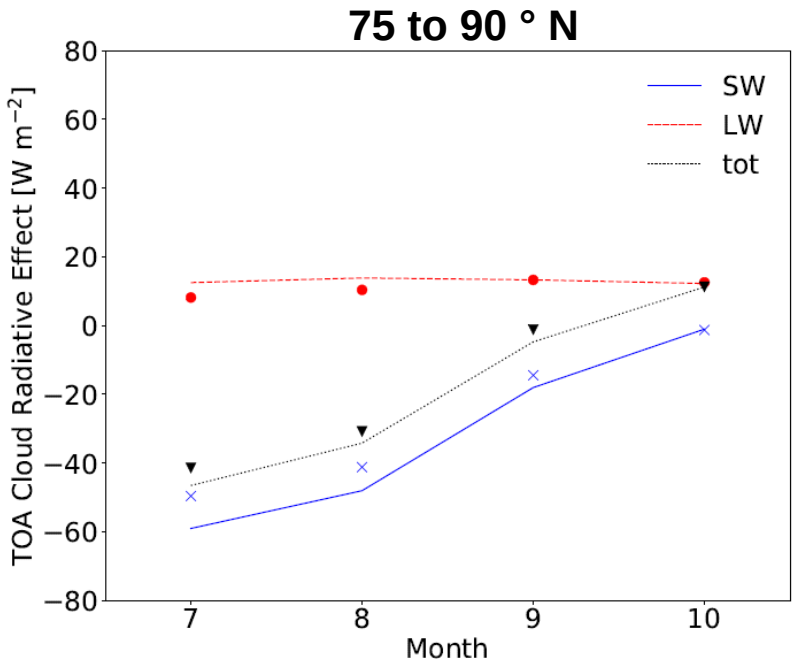
CERES-EBAF CRE





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