

An aerial photograph showing a large cargo ship with a green and white hull navigating through a vast, fragmented field of ice floes in the Arctic. The ice floes are irregular in shape and size, creating a complex, maze-like pattern of white and light blue against the darker water. The ship is positioned in the lower center of the frame, moving towards the upper right.

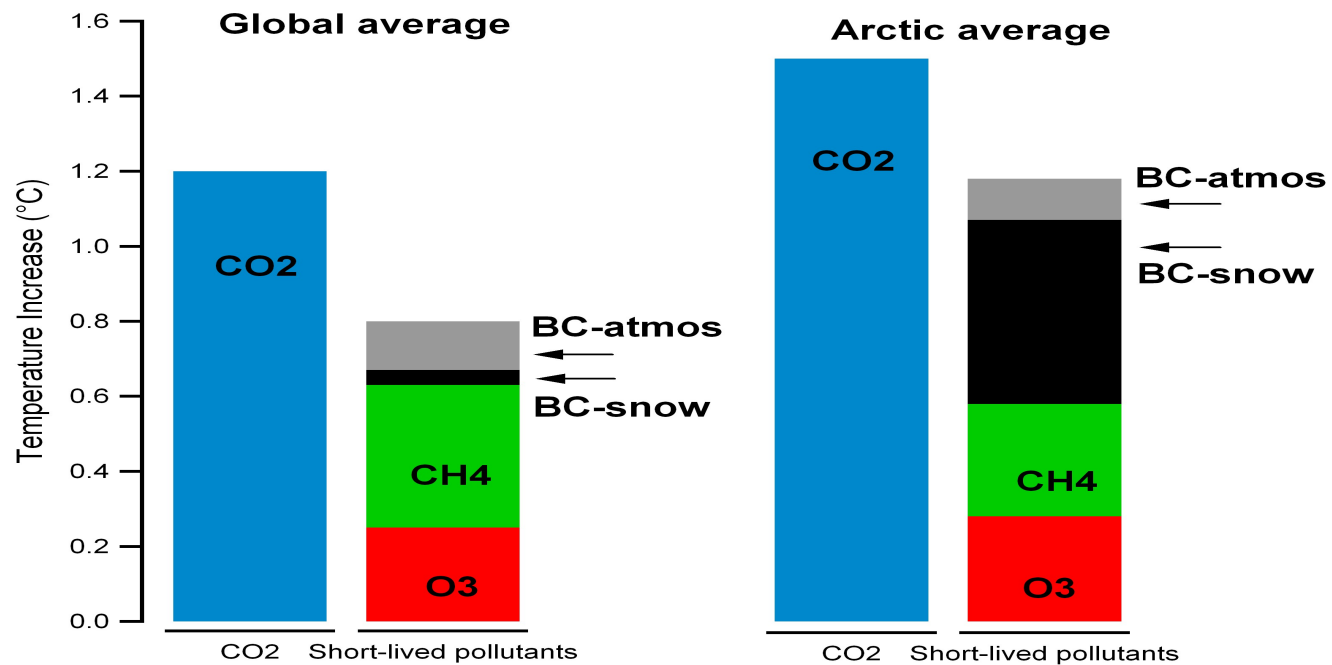
Arctic Shipping and Black Carbon: Cascading Impacts and Global Implications

Pam Pearson, Director
International **Cryosphere**
Climate Initiative

Black Carbon's Climate Impacts

- From incomplete combustion
- Extremely small, dark particles (<PM_{2.5})
- Extremely lightweight, if lofted into high atmosphere (for example, from wildfires) can travel great distances
- More often, deposits (lands) very close to source
- Generally warms when airborne, but more definite warming occurs when over reflective surface such as snow and ice
- ***Most intense warming occurs when deposits on snow and ice***

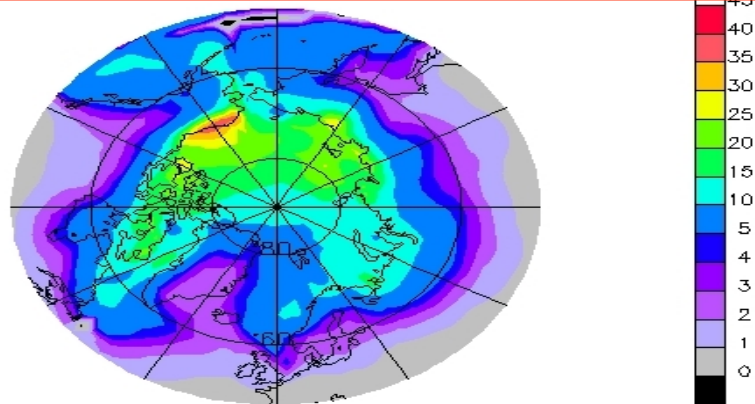
Deposited Black Carbon: Larger Arctic Impact



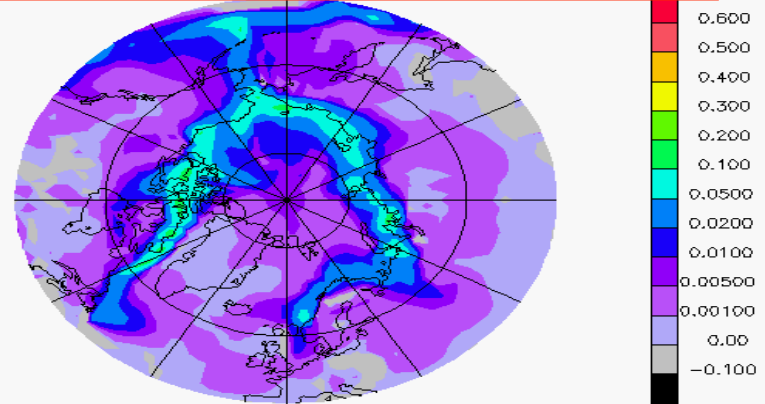
Quinn, Impact of Short-Lived Pollutants on Arctic Climate, presented at AMAP, Oslo, September 15 2008

Increased Shipping Brings More Warming from BC/Ozone to Arctic = Greater Ice Loss

Potential surface ozone increase, by 2050
from shipping



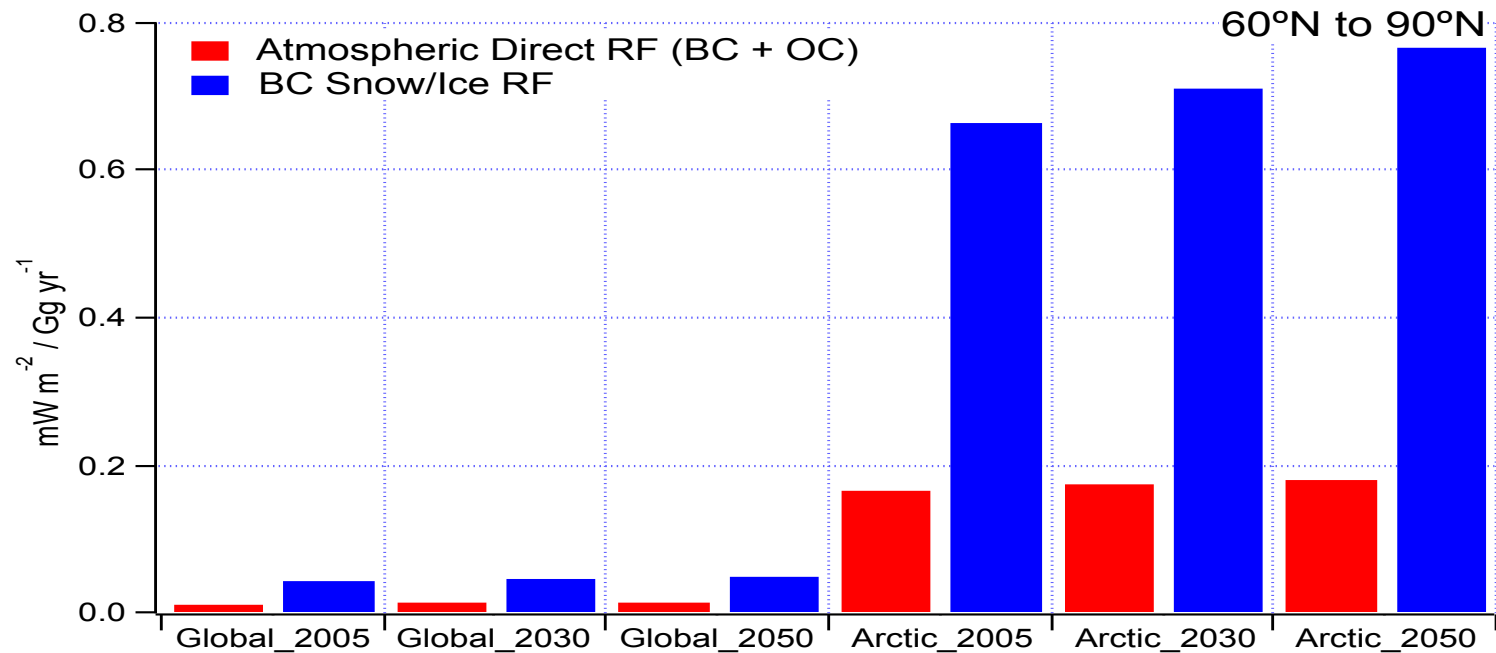
Potential black carbon increase, by
2050 from shipping



Granier CATF/GISS Arctic
workshop, January 7, 2007,
NYC

In-Arctic Shipping Likely the Single Most Effective “Delivery System” for Black Carbon Impacts on Arctic Sea Ice, Arctic Climate and Globally

Normalized Atmospheric Direct RF (BC + OC) and BC-Snow/Ice RF due to Projected Increases in Global and Within-Arctic Shipping Emissions (Model:NCAR CCSM)



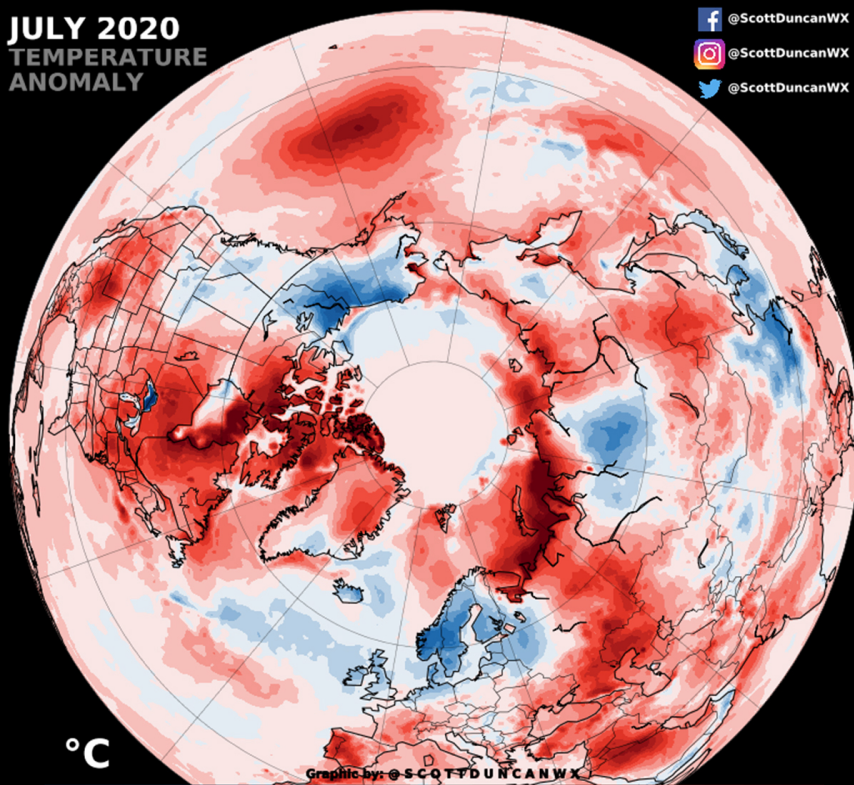
Source: Arctic Council/AMAP SLF
Task Force Final Report, 2011

RF=Radiative Forcing
(climate warming impact)

Temperature records in the Arctic

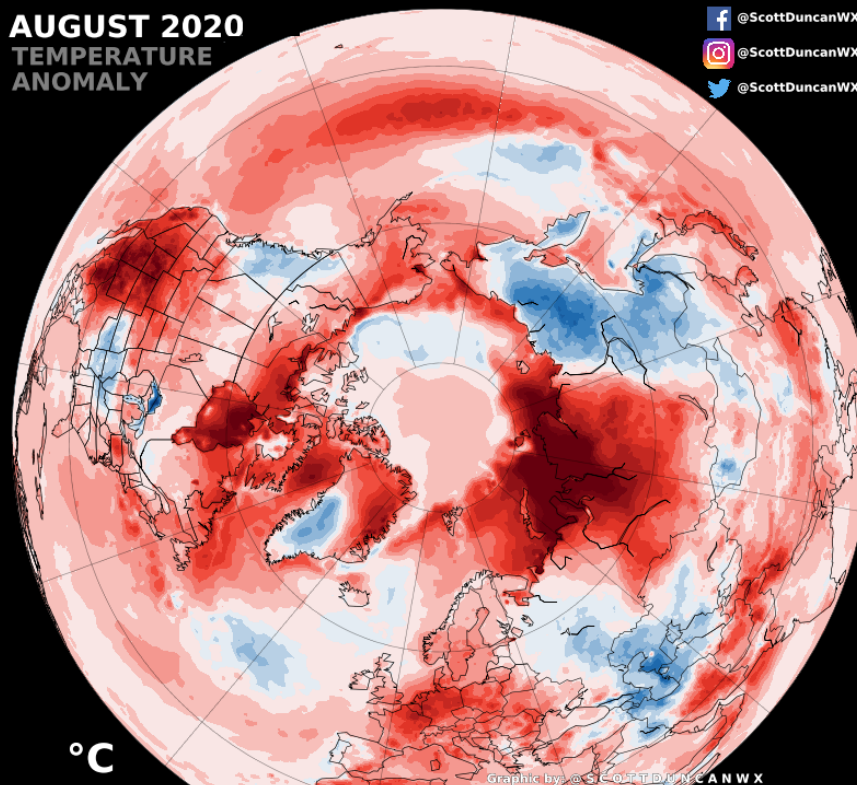
JULY 2020
TEMPERATURE
ANOMALY

Facebook: @ScottDuncanWX
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Twitter: @ScottDuncanWX



AUGUST 2020
TEMPERATURE
ANOMALY

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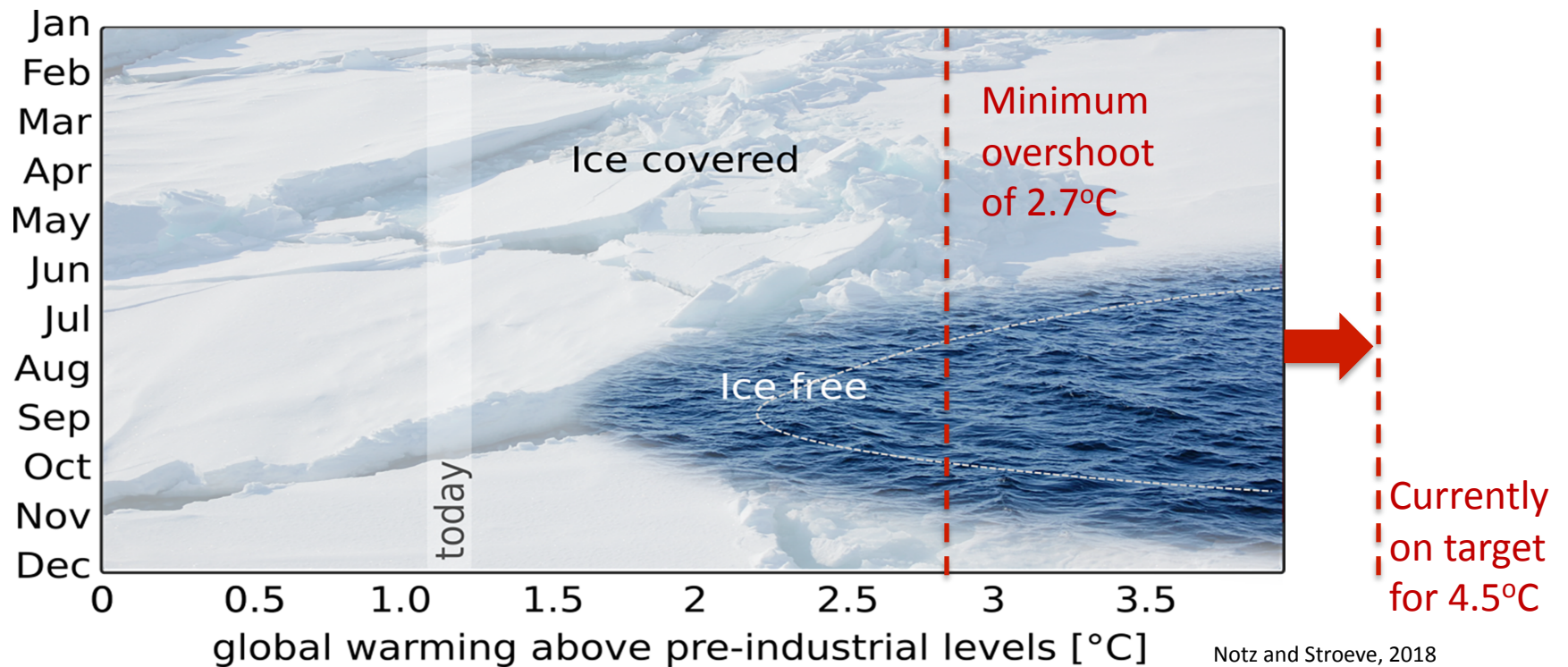


°C
-5 -4 -3 -2 -1 0 1 2 3 4 5

°C
-5 -4 -3 -2 -1 0 1 2 3 4 5

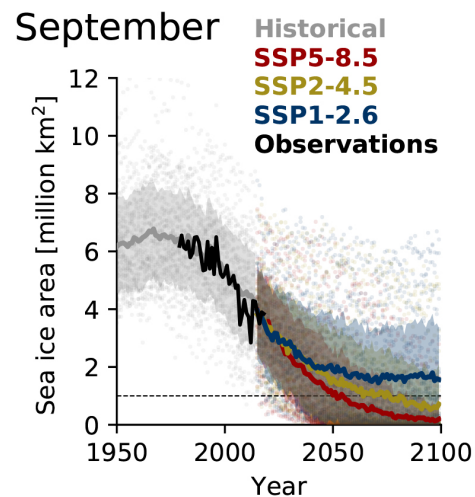
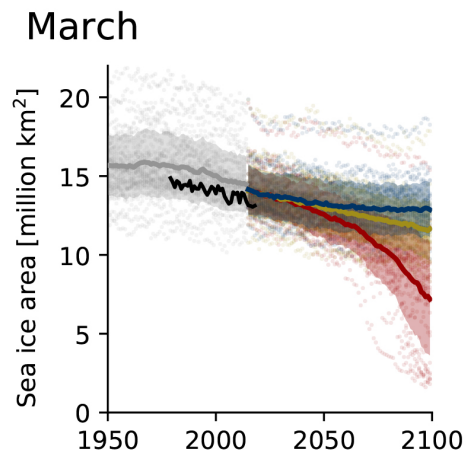
Arctic Sea Ice:

Summer ice-free periods starting $\sim 1.7^{\circ}\text{C}$

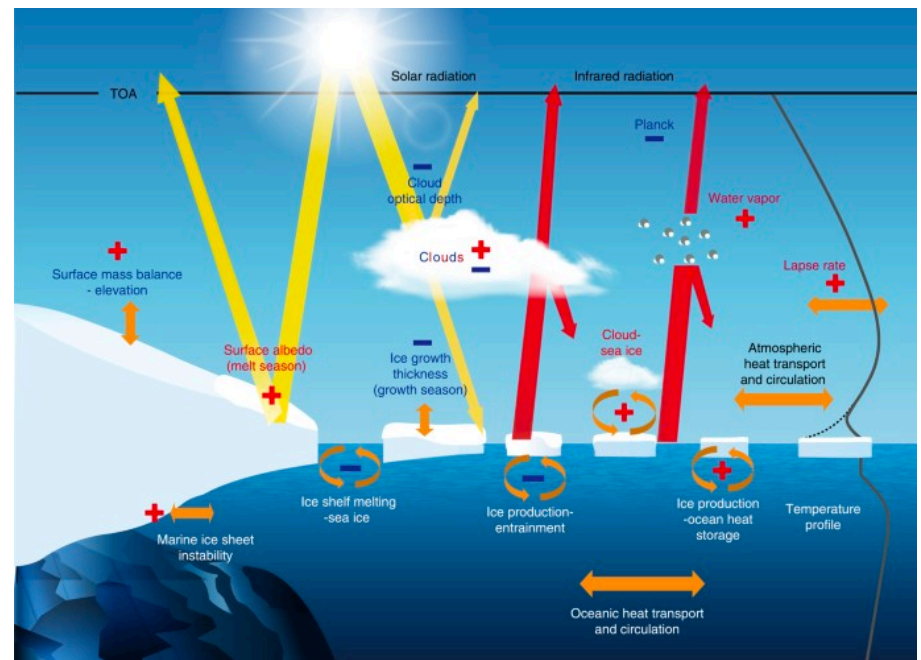


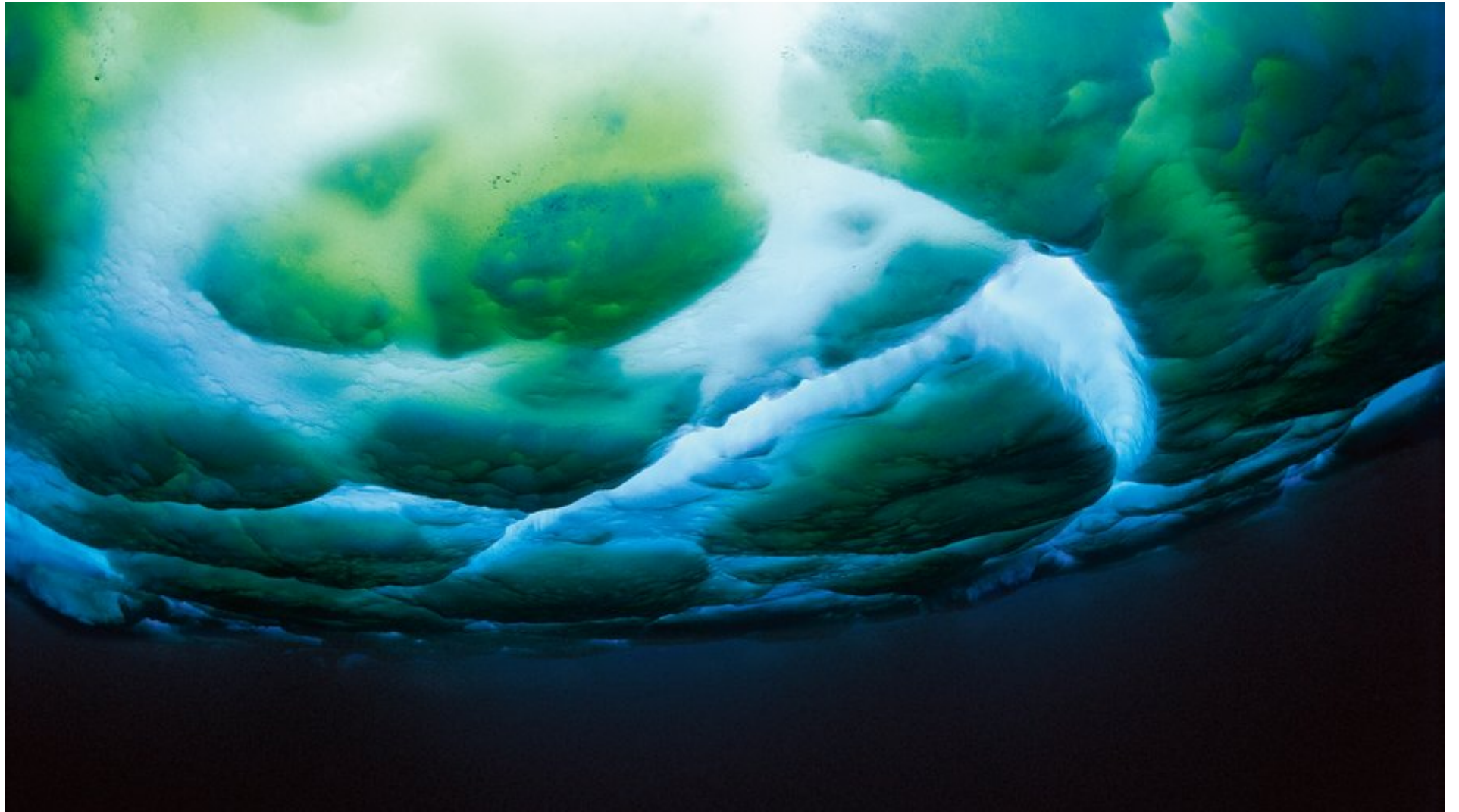
Sea Ice: Climate Model Projections

Why should we care?

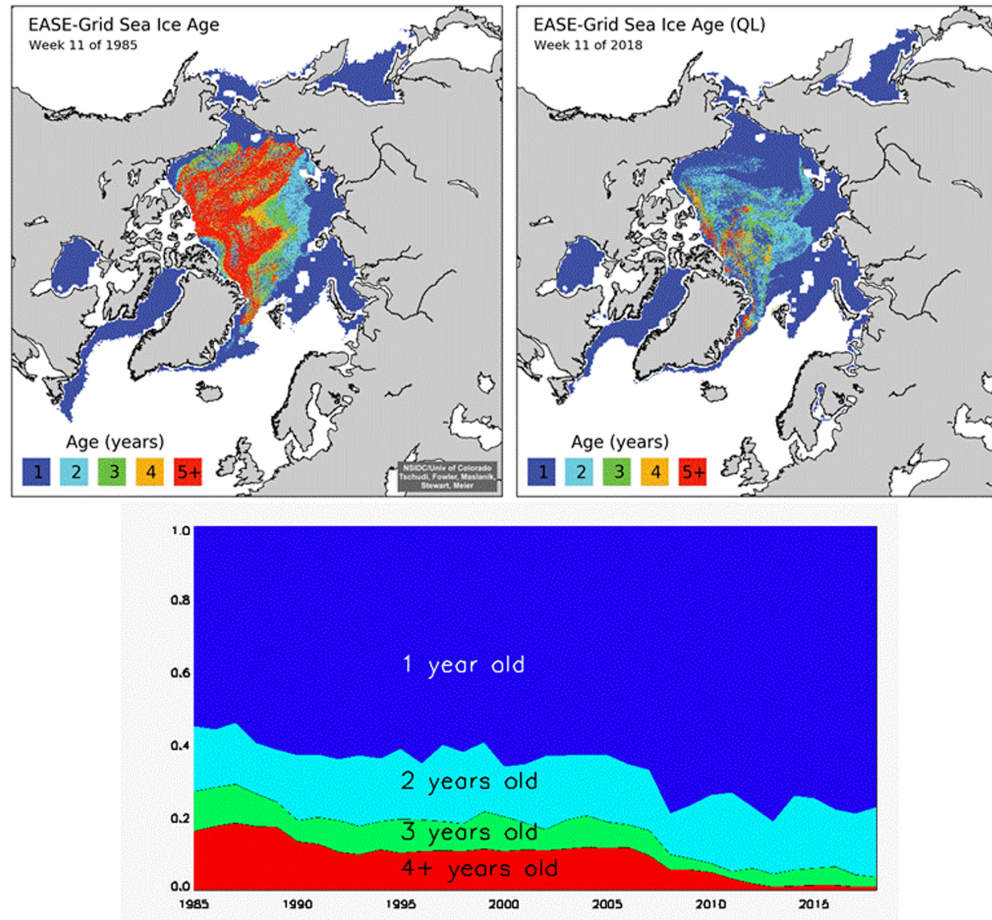


SIMIP, 2020



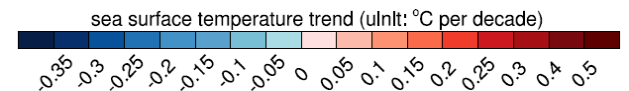
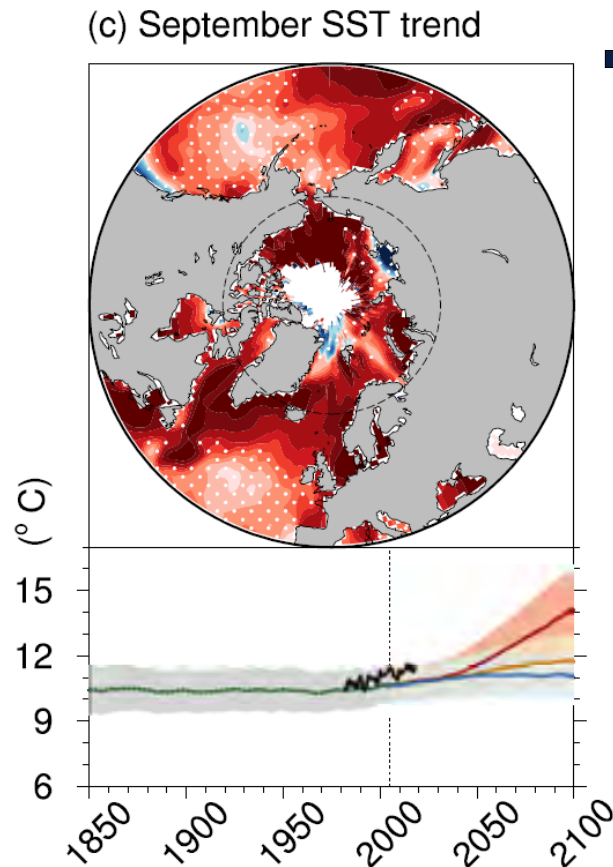
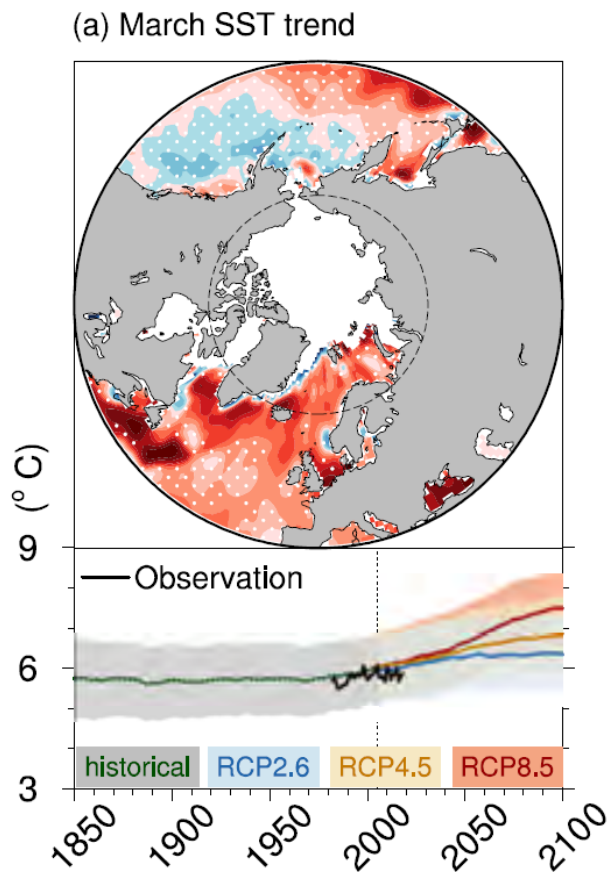


Loss Today of Thick, Older Sea Ice



**Essential change in
Arctic ecosystem
structure**

Arctic Ocean: Growing Warmer, Fresher, and More Acidic

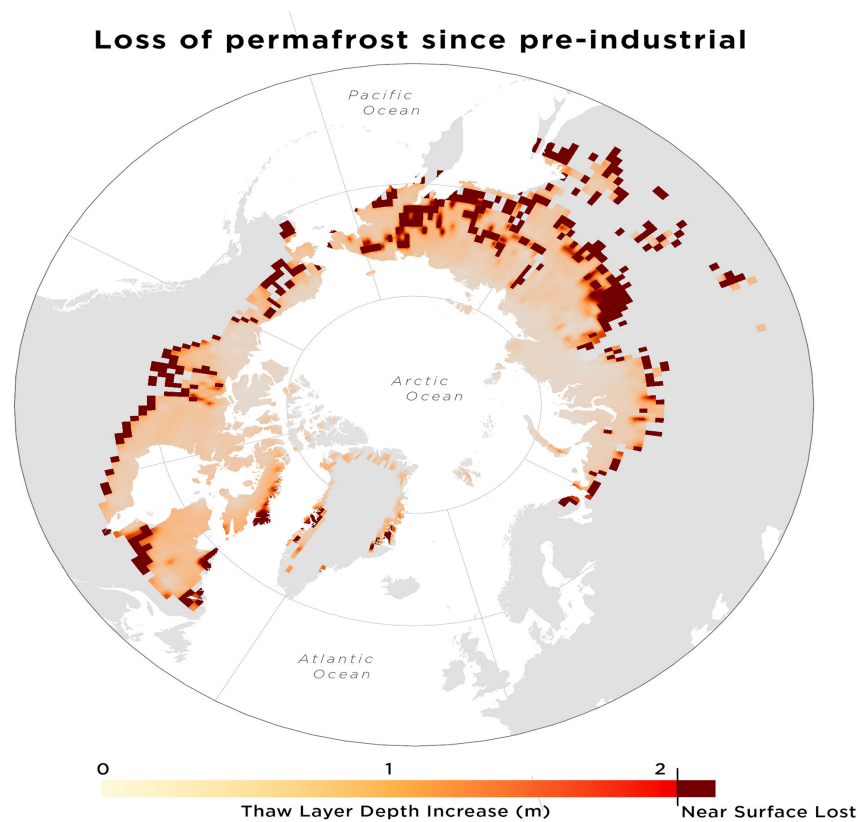


Top figures: Arctic and near-Arctic waters **already** warmed by 0.5°C per decade 1982–2017

Bottom graphs:
Arctic Ocean warms much less in a 1.5°C “Paris” World (RCP2.6) but important fisheries (cod, lobster) under threat

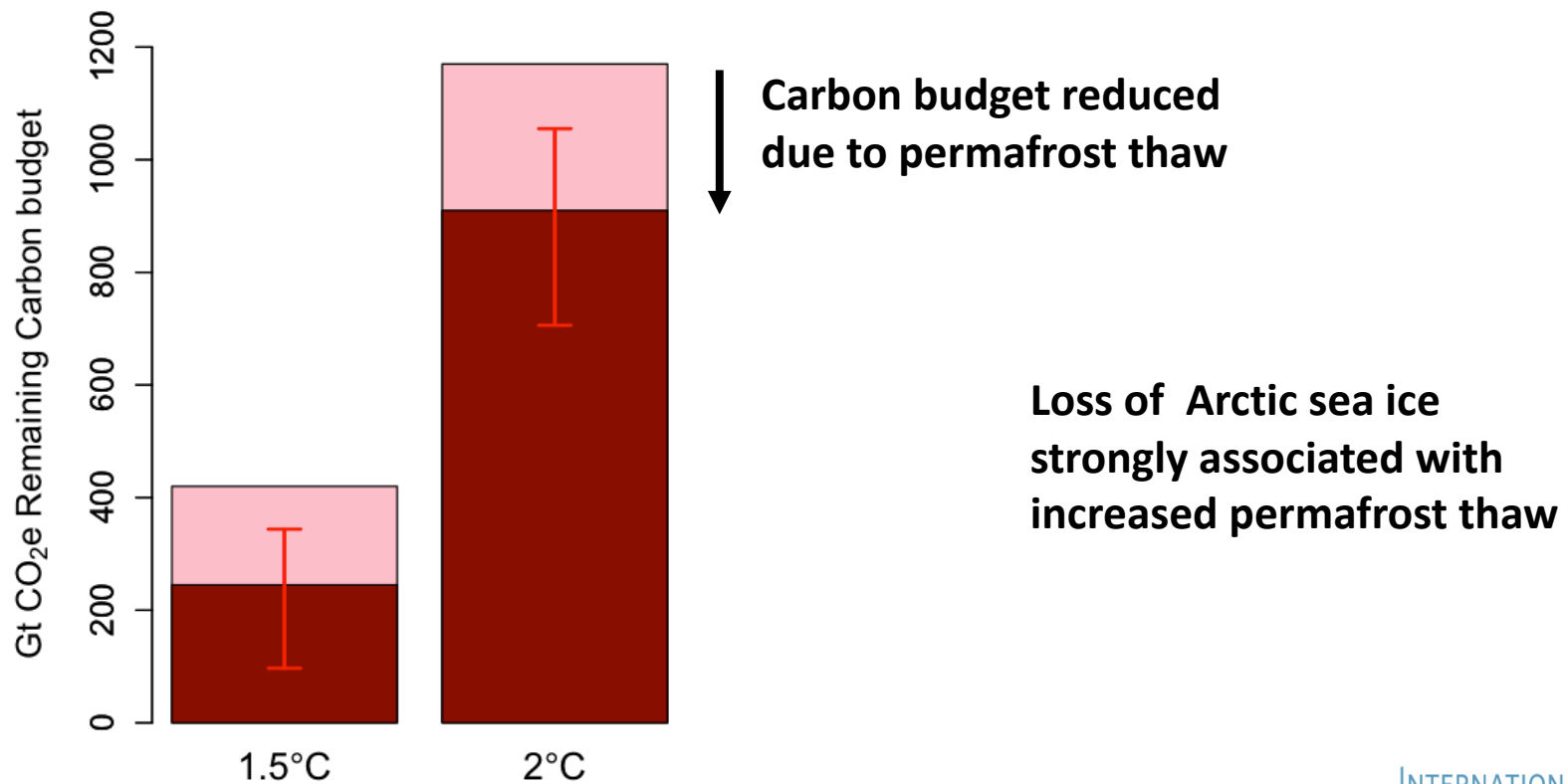
IPCC SROCC 2019

Permafrost Thaw and Losses Today (at 1.1°C)



Permafrost thaw data from coupled CLM5 runs for CMIP6. Analysis by Sarah Chadburn and Eleanor Burke. Graphic design by Greg Fiske.

Permafrost Thaw Decreases Our Carbon Budget

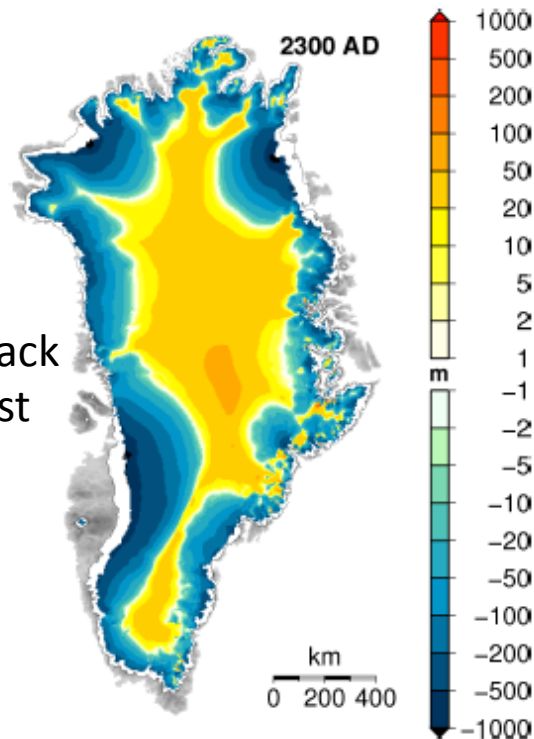


Data sources: IPCC SR15, Gasser et al (2018), Turetsky et al (2020)

INTERNATIONAL CRYOSPHERE
CLIMATE INITIATIVE

Sea-level Rise from Greenland

Direct impact of BC
Plus sea ice loss feedback
Plus thawed permafrost
carbon feedback



Greenland Ice Sheet Thinning
Above 2 Degrees:
Rapid lowering of altitude,
Leads to irreversible loss of
most of ice sheet, ~6 m SLR

Fürst et al., 2015

Arctic Feedbacks:

**Loss of Reflective Ice/Snow Increases Arctic and GMT,
Associated with:**

- Arctic Ocean/northern Seas acidification/freshening/eutrophication = fisheries collapse
- Permafrost Thaw and Emissions (>200 years duration)
- SLR from Greenland Ice Sheet and Arctic Glaciers (2-7+m)
- Slowing of AMOC
- Disturbance of mid-latitude weather patterns

**IPCC SROCC (2019): *All of above observed/in progress already
at today's 1.1°C***

Working on Arctic Black Carbon:

- Arctic Council
 - ✓ Two Expert Groups: Policy (Iceland chair), Science (U.S.+Finland Co-chairs)
 - ✓ **2017 Ministerial Commitment to 25-33% Reduction by 2025**
- LRTAP Convention/UNECE/Göteborg Protocol
 - ✓ 2012: Black carbon included as constituent of PM_{2.5}
- Climate and Clean Air Coalition/UNEP

Bottom Line: Halting BC Emissions from Arctic shipping will not solve the problem of loss of ice and Arctic warming feedbacks – but with Arctic ice already on the edge, ***every effort*** needed to decrease pressure and associated risks