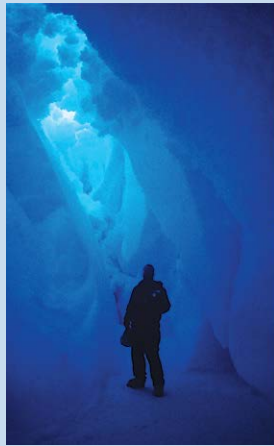


National Snow and Ice Data Center
Supporting Cryospheric Research Since 1976

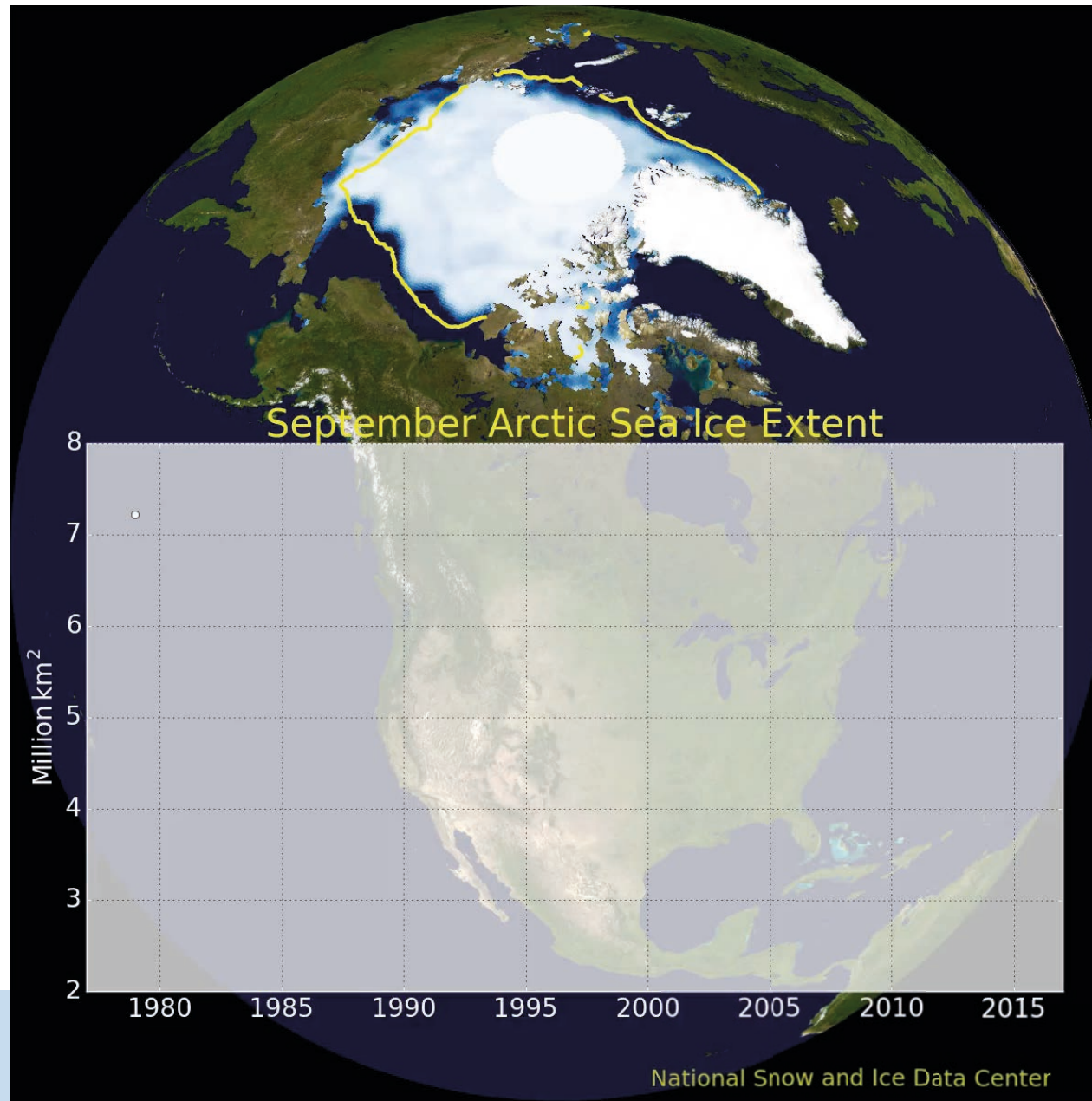


Arctic sea ice loss and the response from CO₂

Julienne Stroeve

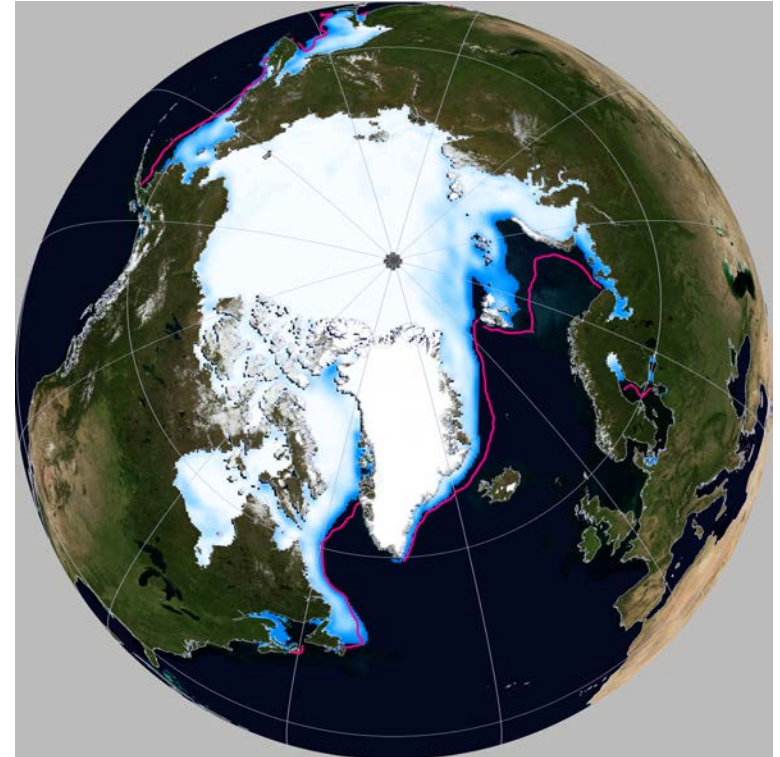
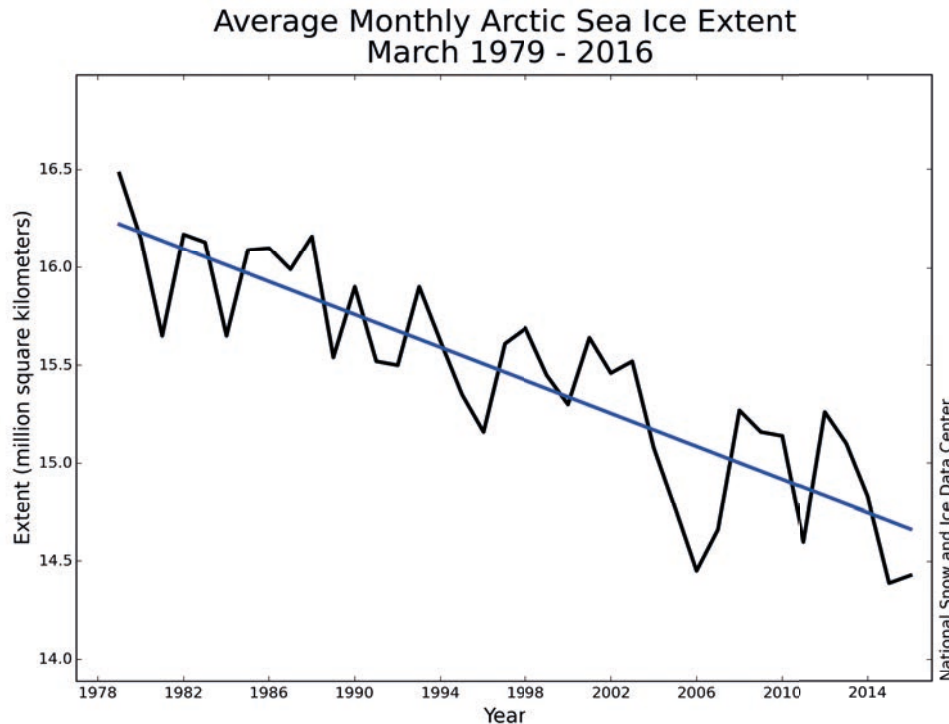


The shrinking summer sea ice cover



Ice loss in winter is less, but remains significant

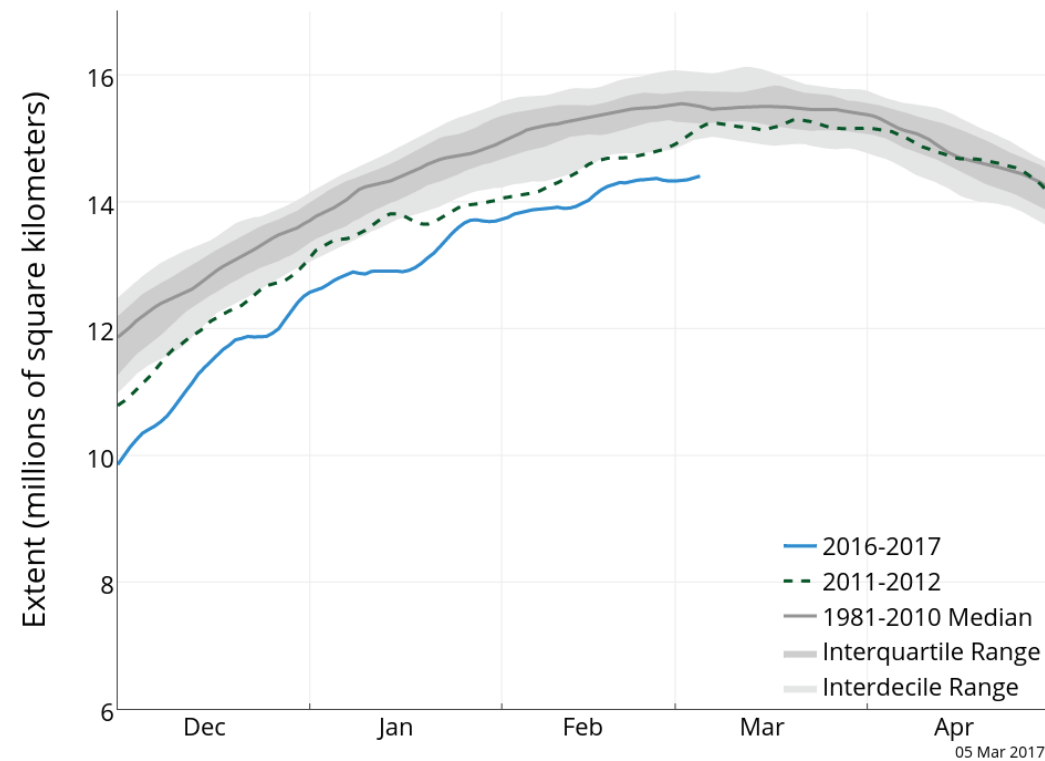
March 2016



- Rate of winter decline is $-43,000 \text{ km}^2/\text{yr}$ or $-2.8\%/decade$ compared to $-87,000 \text{ km}^2/\text{yr}$ in September ($-13.8\%/decade$).
- 2016 is the lowest winter maximum on record, followed previous record lowest maximum in 2015.

Current ice conditions

Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)

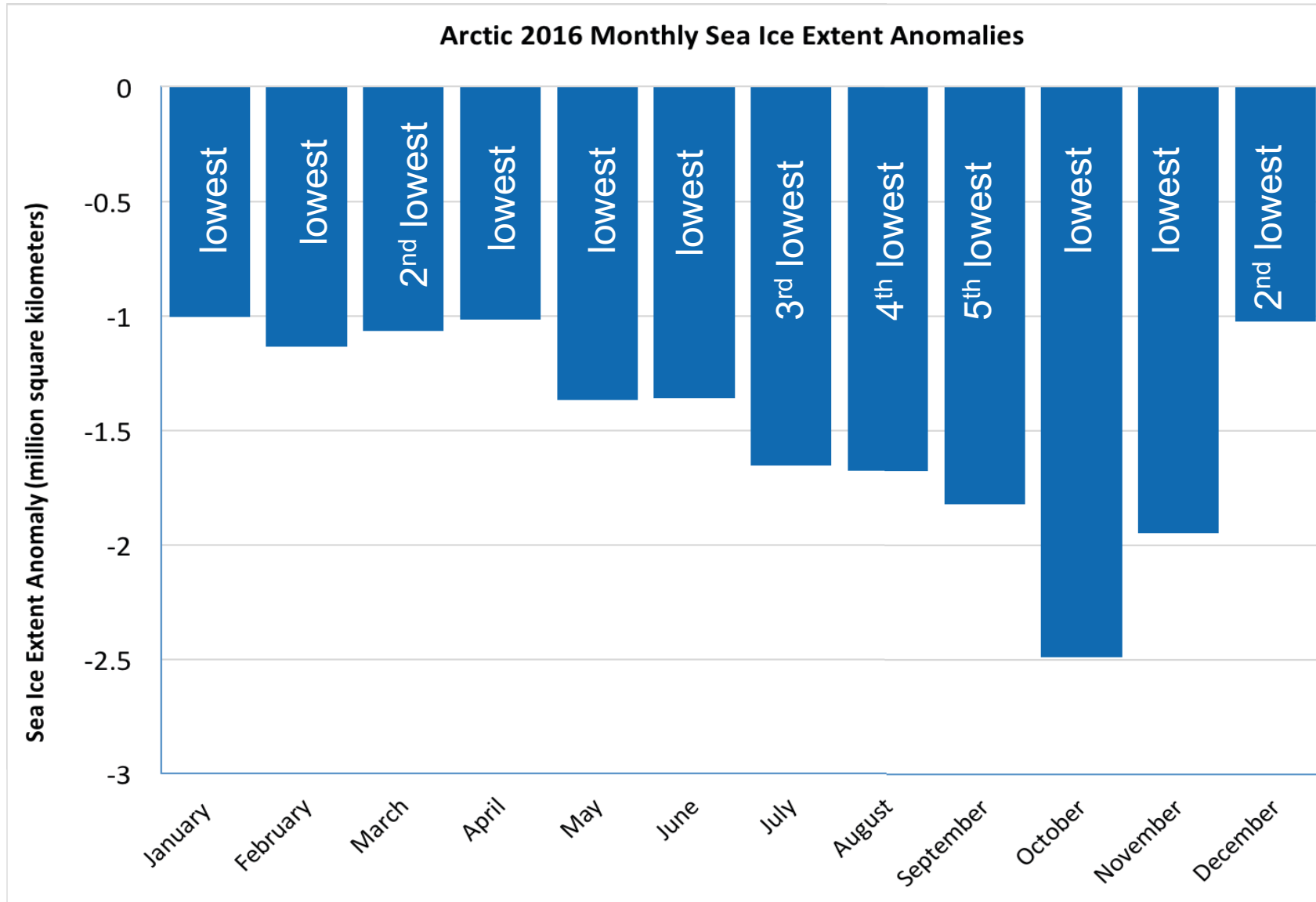


Sea Ice Extent, 06 Mar 2017



National Snow and Ice Data Center, University of Colorado Boulder

How unusual was 2016?

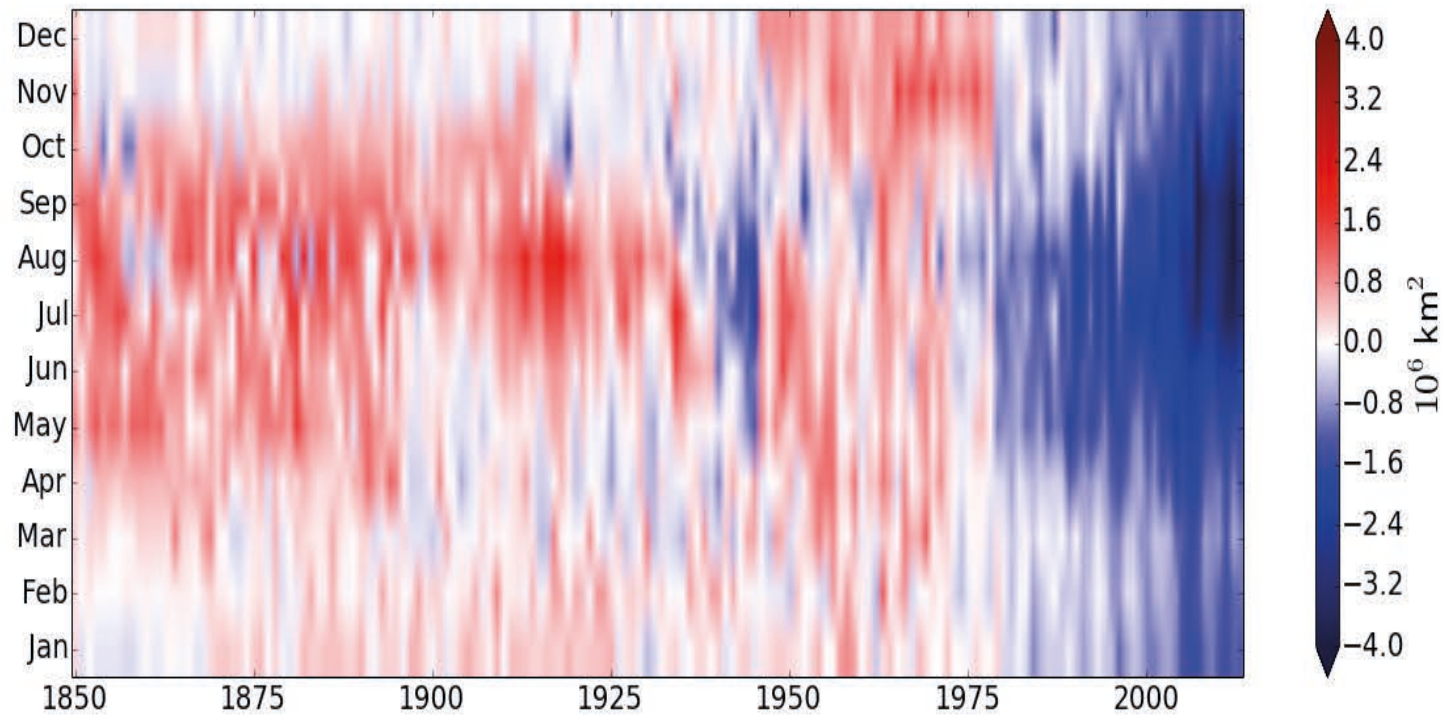


Today's Changes in Longer-term Context

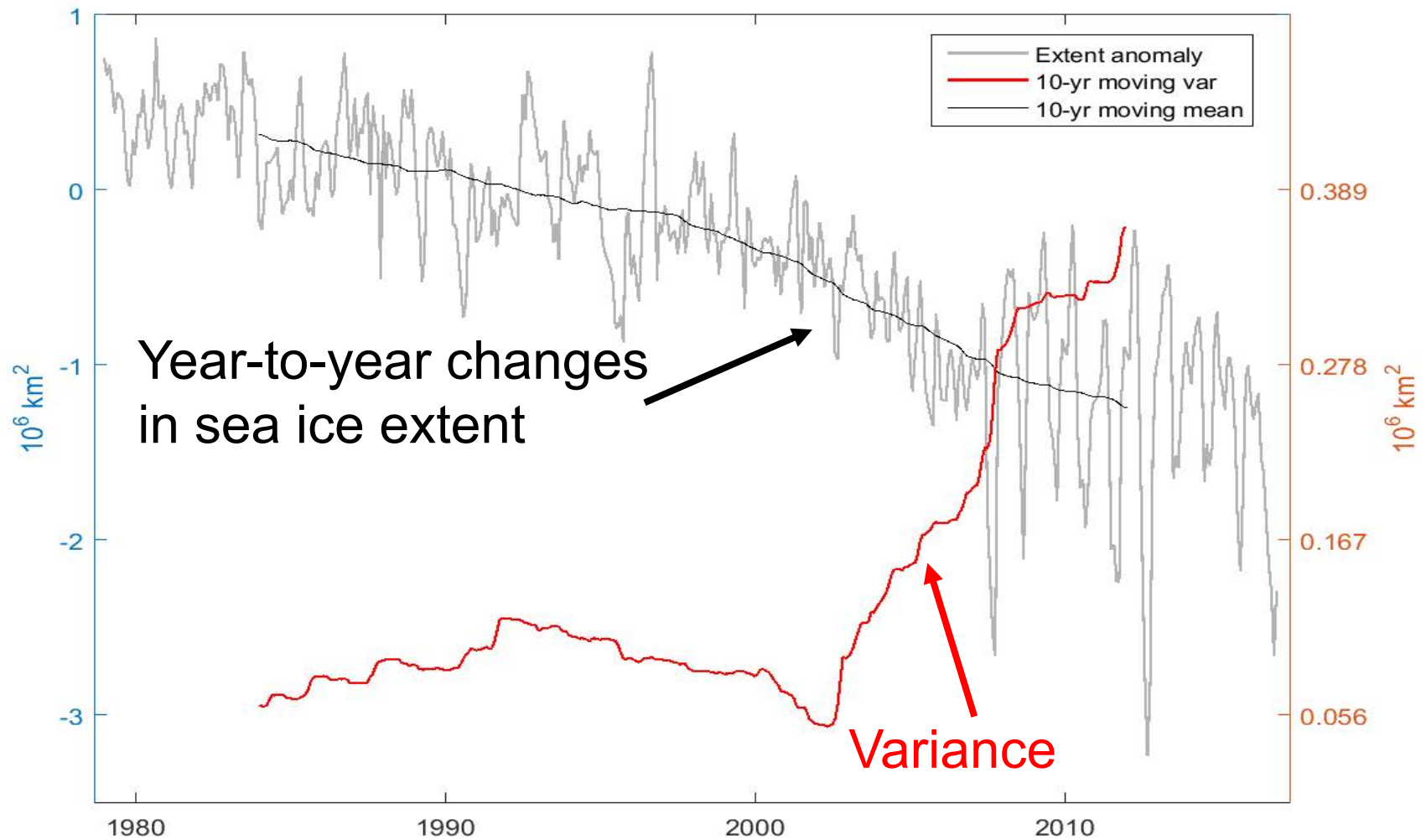


Today's Changes in Longer-term Context

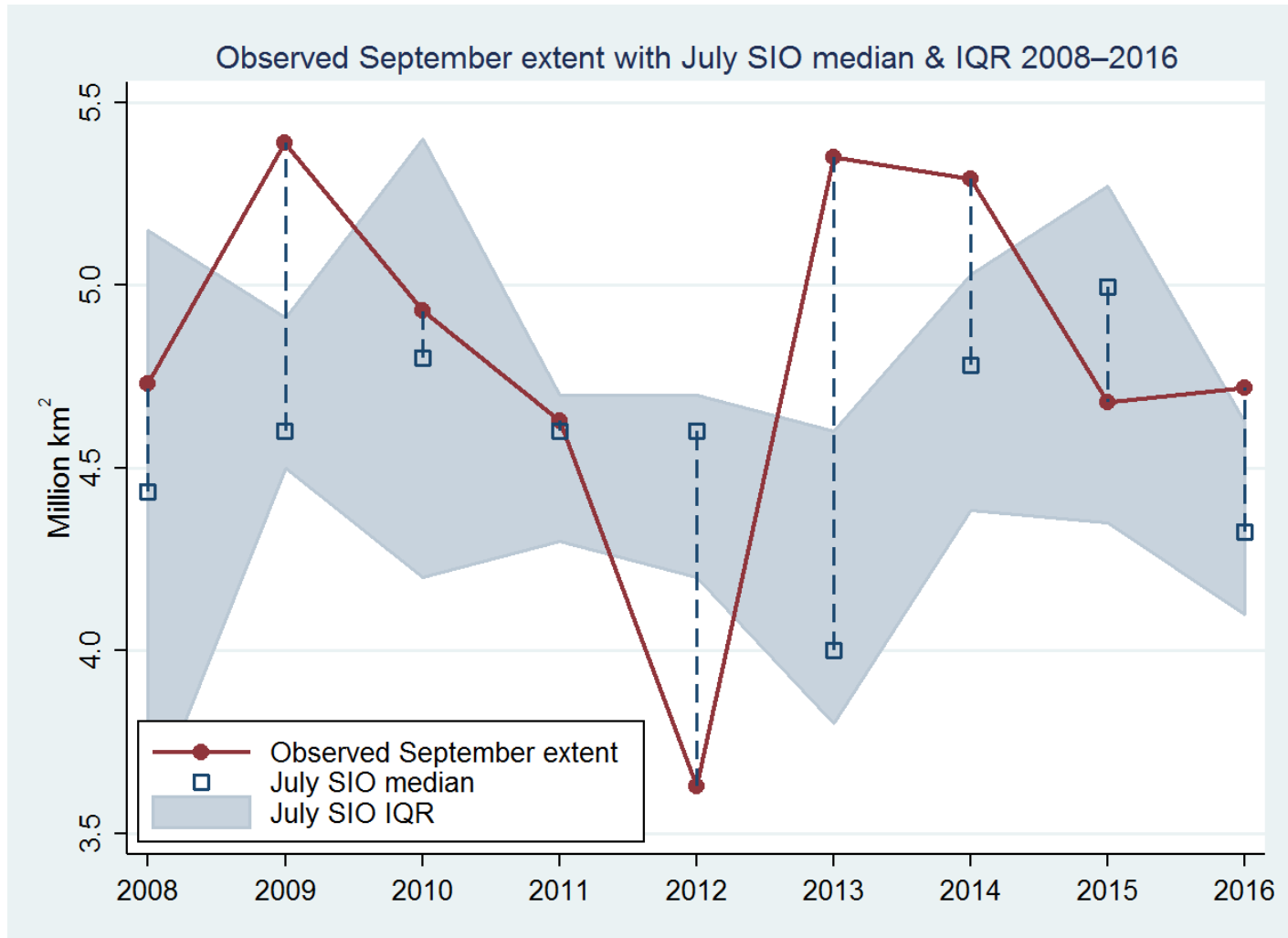
Anomalies in Arctic Sea Ice Extent 1850-2014



Increasing variability from year to year

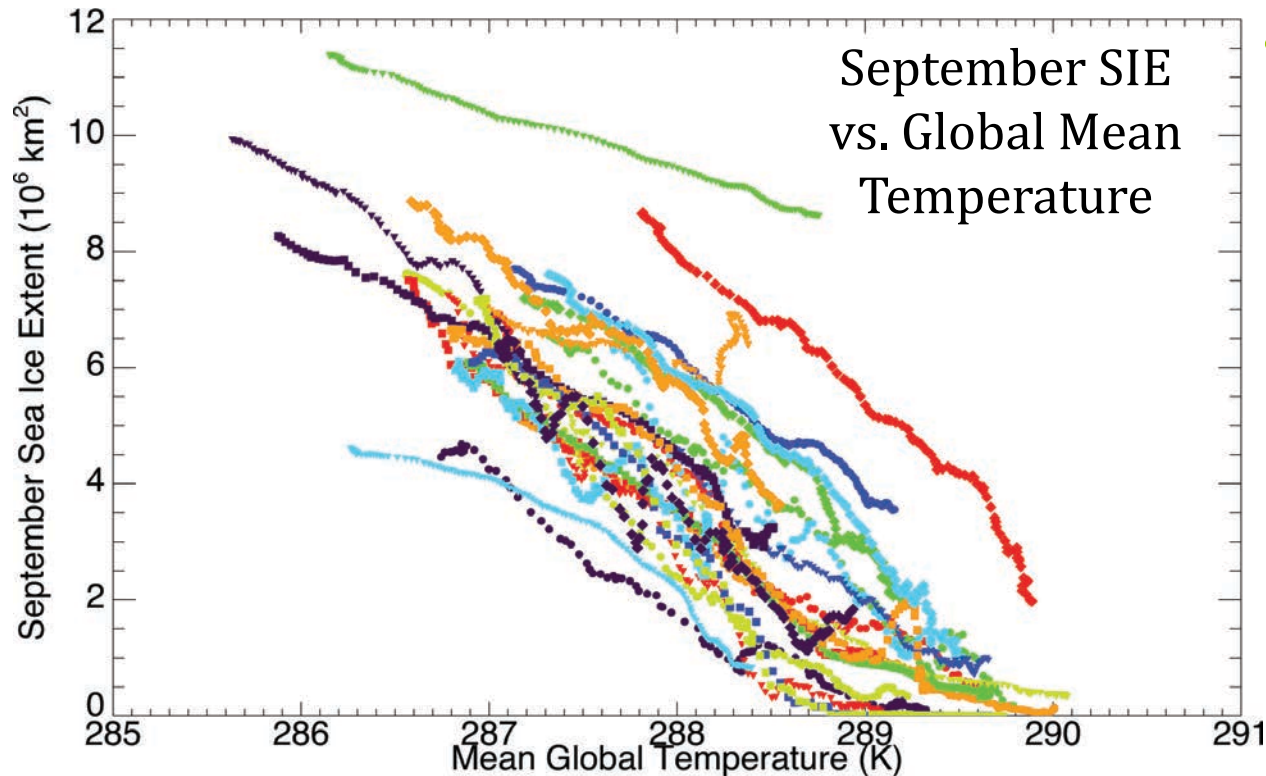


Increasing variability may in part explain difficulties in forecasting September ice extent



Sensitivity of sea ice to global warming

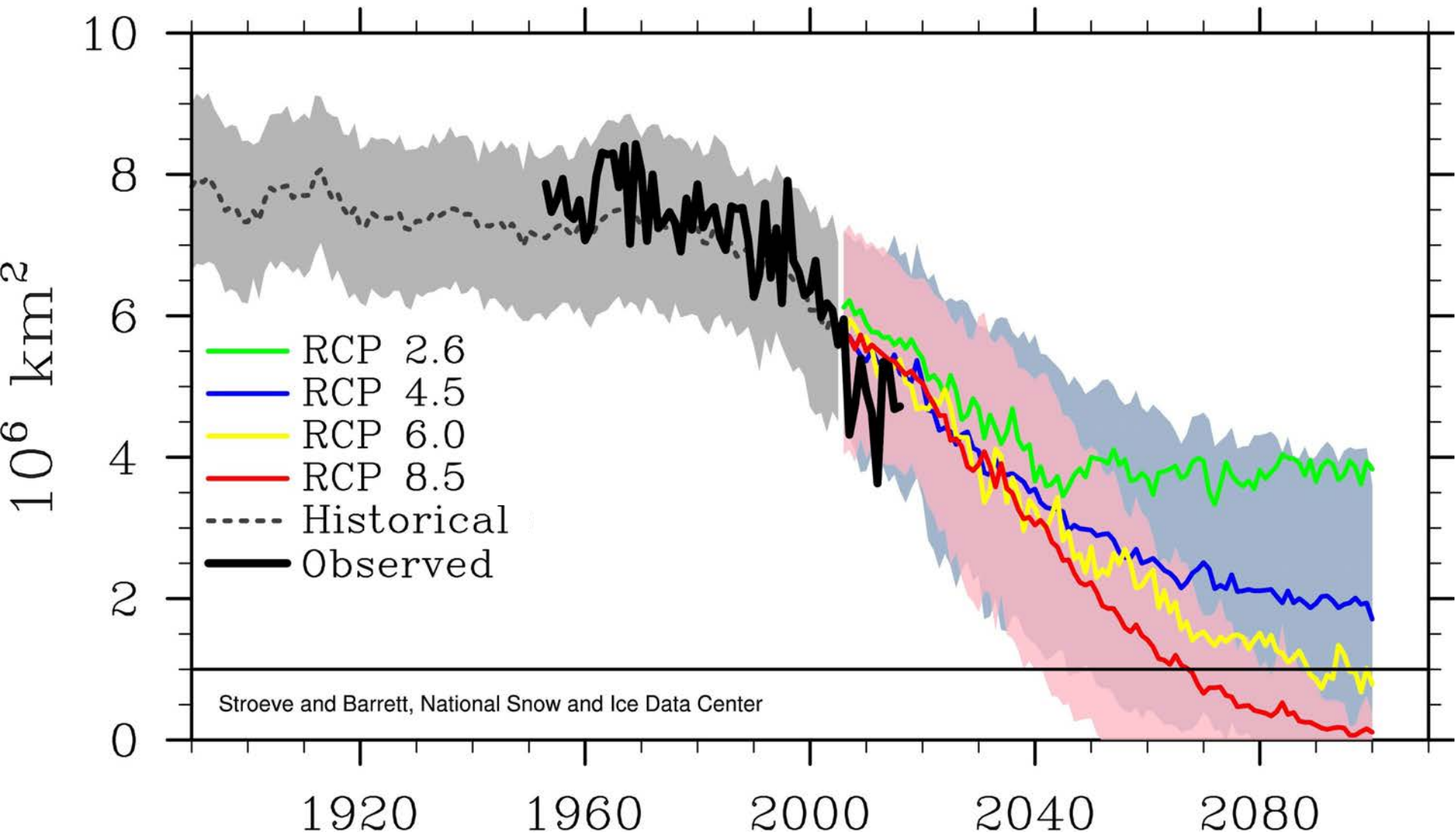
- Climate models show that Arctic sea ice declines as global warming increases



- However, the models generally underestimate the observed sensitivity of $4.2 \pm 0.4 \text{ } 10^6 \text{ km}^2$ per degree of global warming (MME = $2.3 \pm 0.6 \text{ } 10^6 \text{ km}^2$)

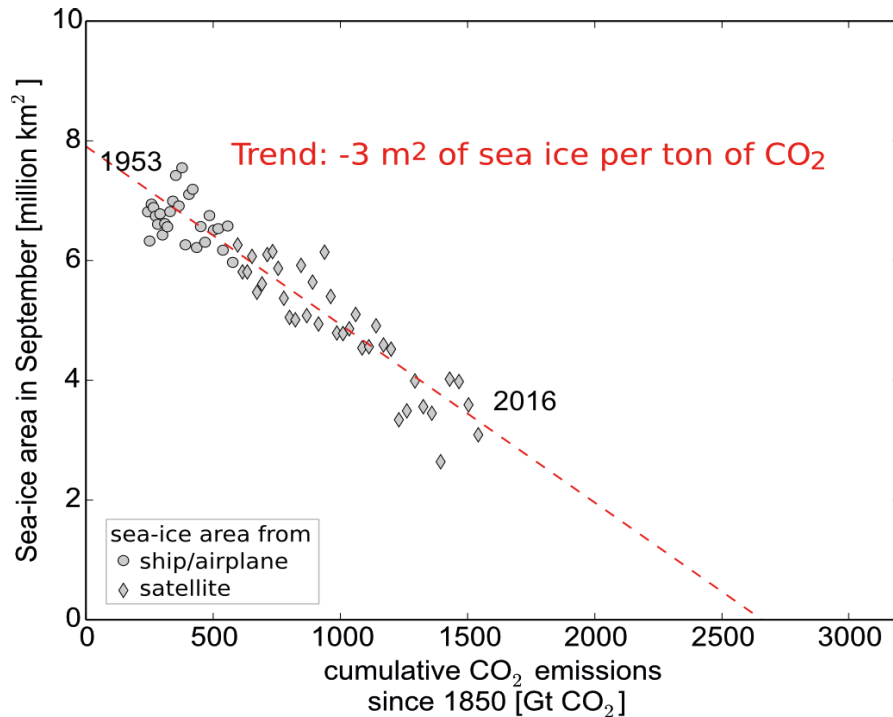
Figure from Stroeve and Notz, 2015, Global and Planetary Change

Future projections in September sea ice extent

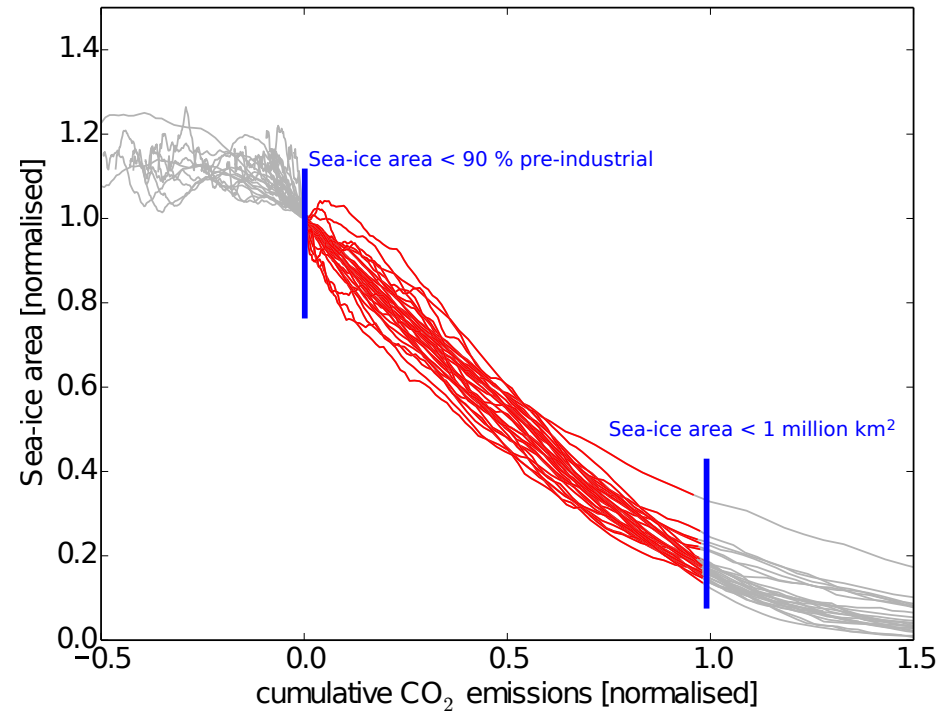


Sea ice loss directly linked to CO₂

Observed sensitivity of sea ice to CO₂



Modeled sensitivity of sea ice to CO₂

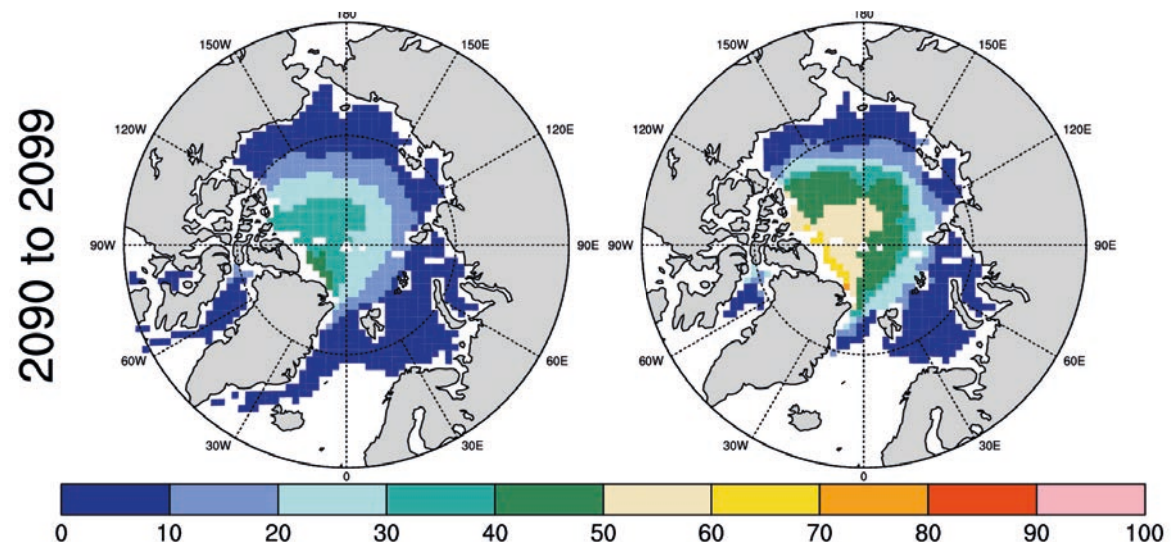


Figures modified from Notz and Stroeve, 2016

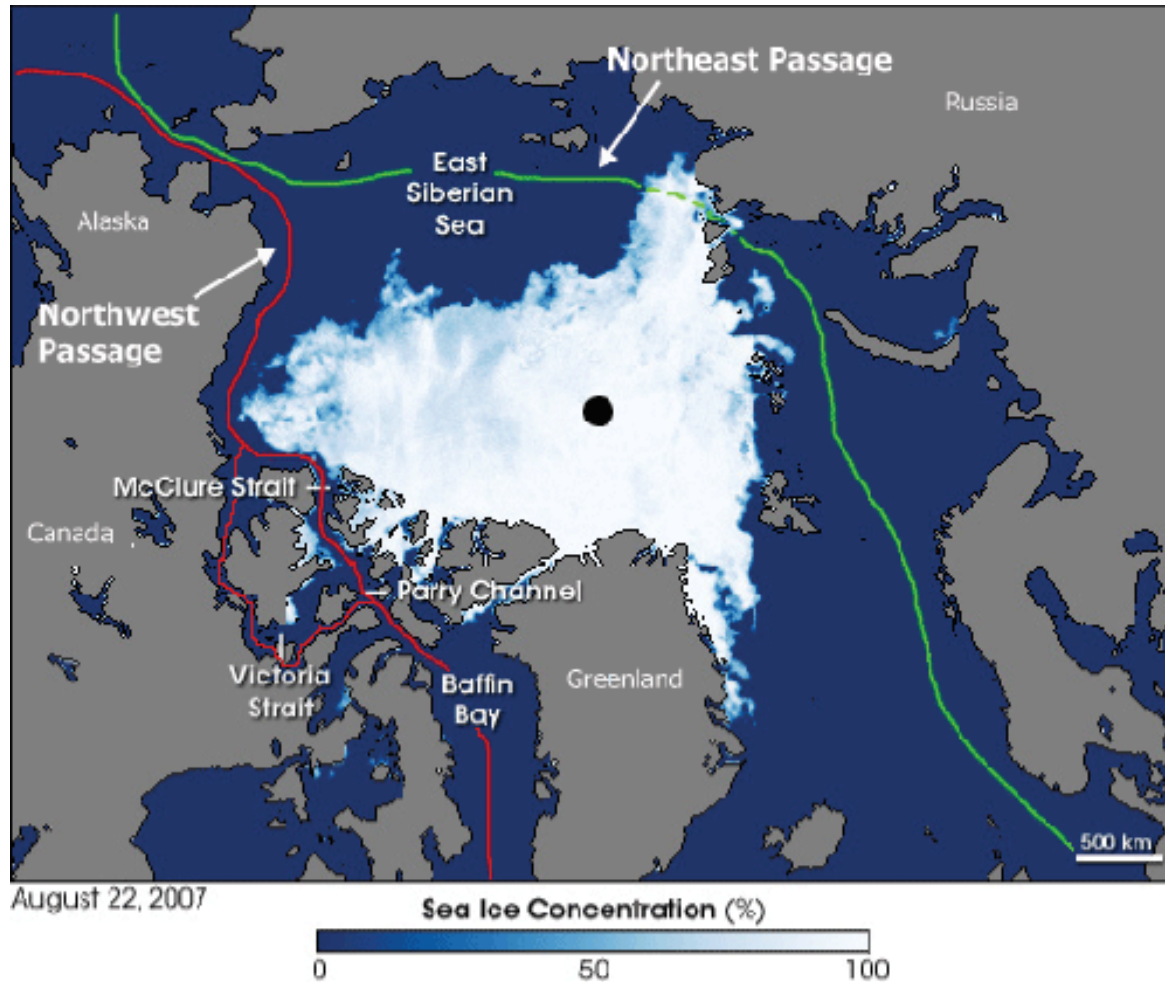
Inferences from observed sensitivity to CO₂

- For an additional 1000Gt of CO₂ emissions, Arctic sea ice will disappear in September (i.e. 2°C target).
- If we keep the additional accumulation to 500 Gt of CO₂, the Arctic will have about 2 million km²
- At current emission rates of 35-40 Gt/year, the ice will be gone in September by ~2040.

CMIP5 multi-model mean sea ice concentration (left) and % of models with ice (right).



Opening of shipping routes



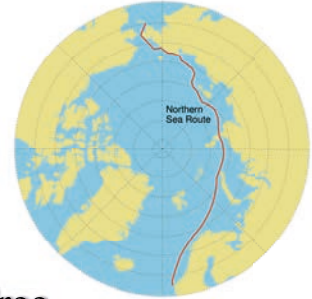
<http://www.wunderground.com/climate/NorthernPassages.asp>



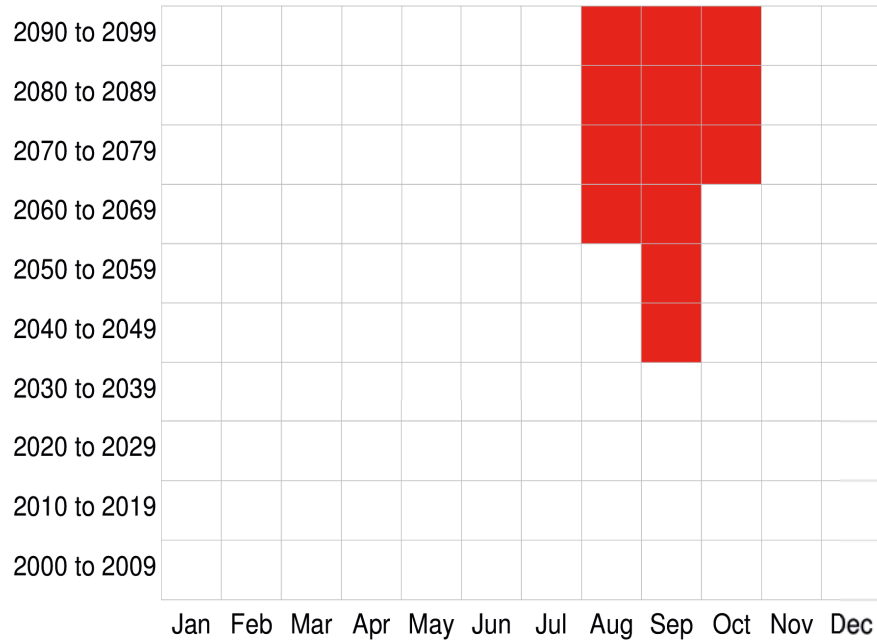
<http://thegreatimmensity.org/2011/>

Opening of shipping routes

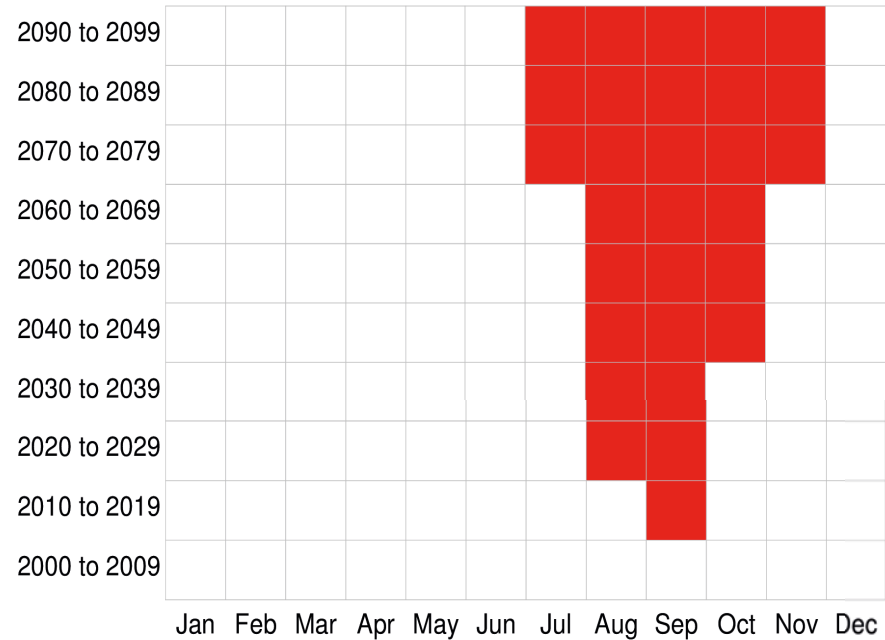
Number of months the NSR may be ice free under RCP8.5



80% Ice-Free



50% Ice-Free



Each country's contribution to Arctic sea ice loss

