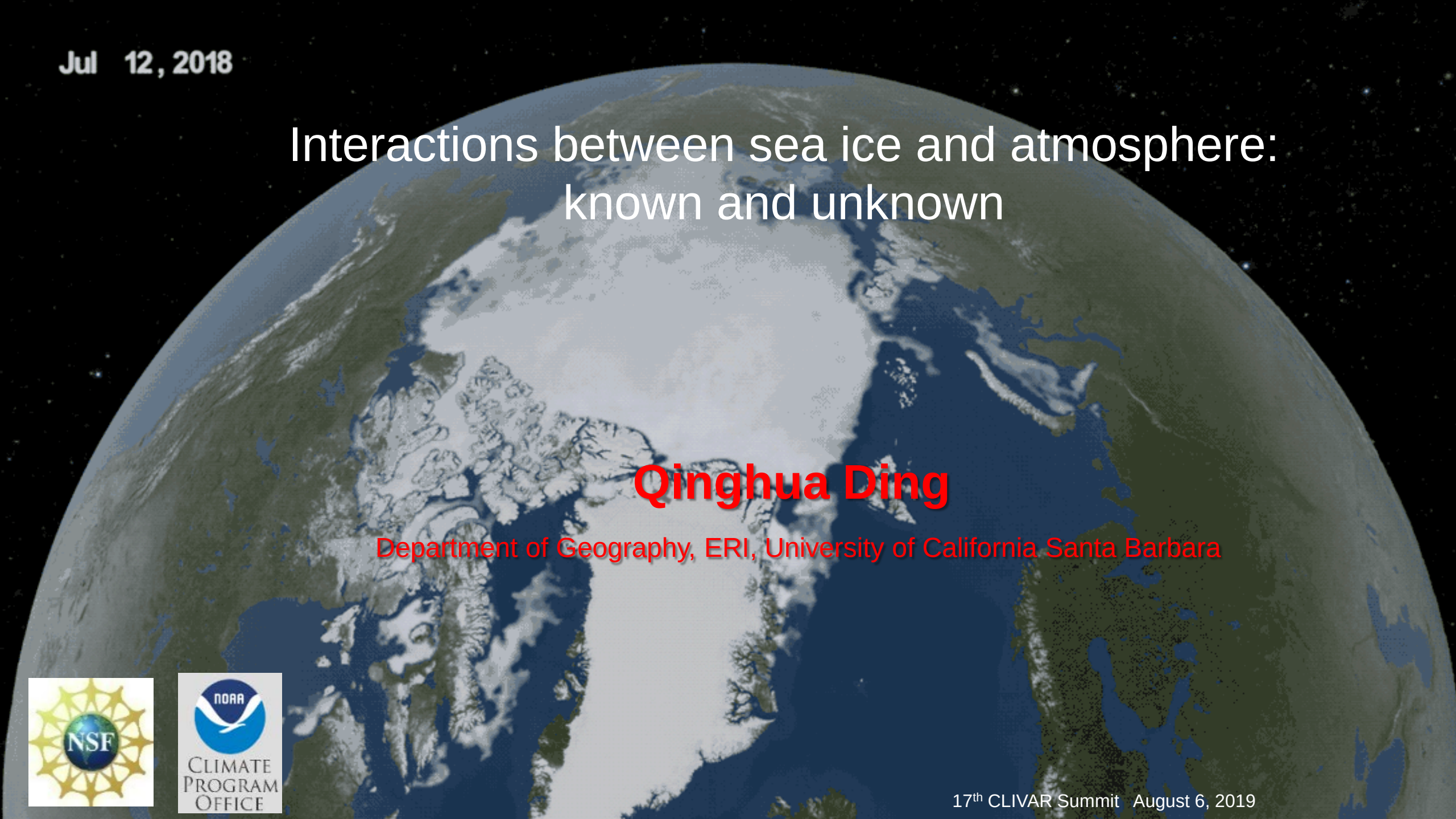


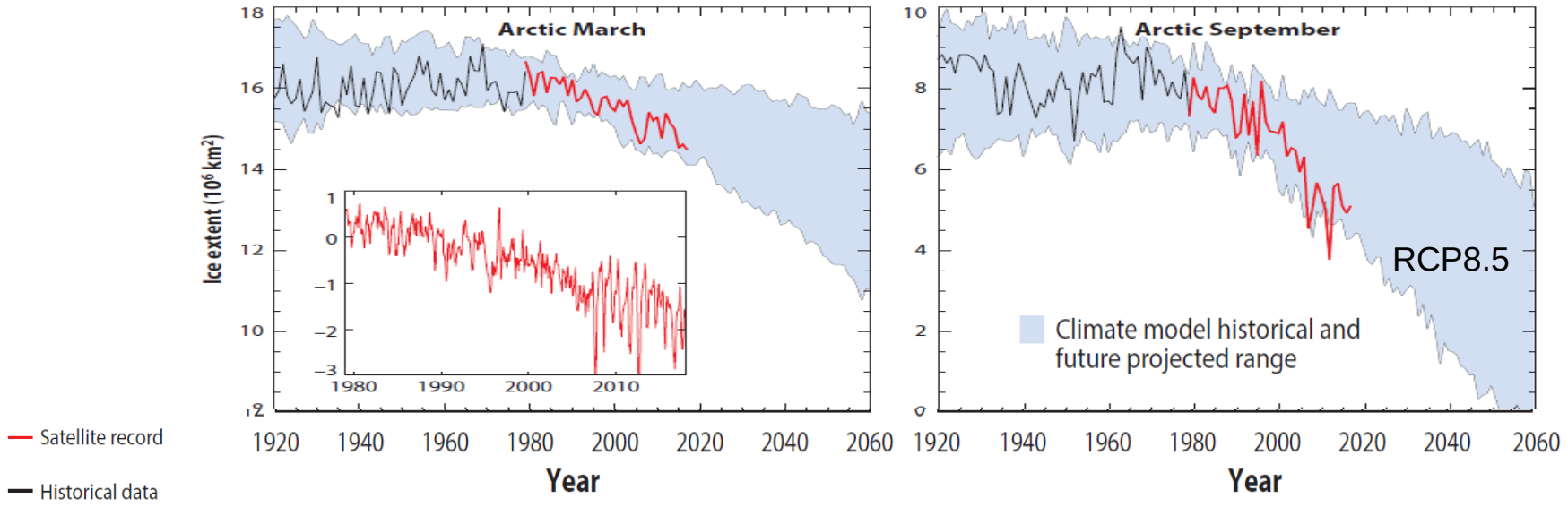
Interactions between sea ice and atmosphere: known and unknown

Qinghua Ding

Department of Geography, ERI, University of California Santa Barbara

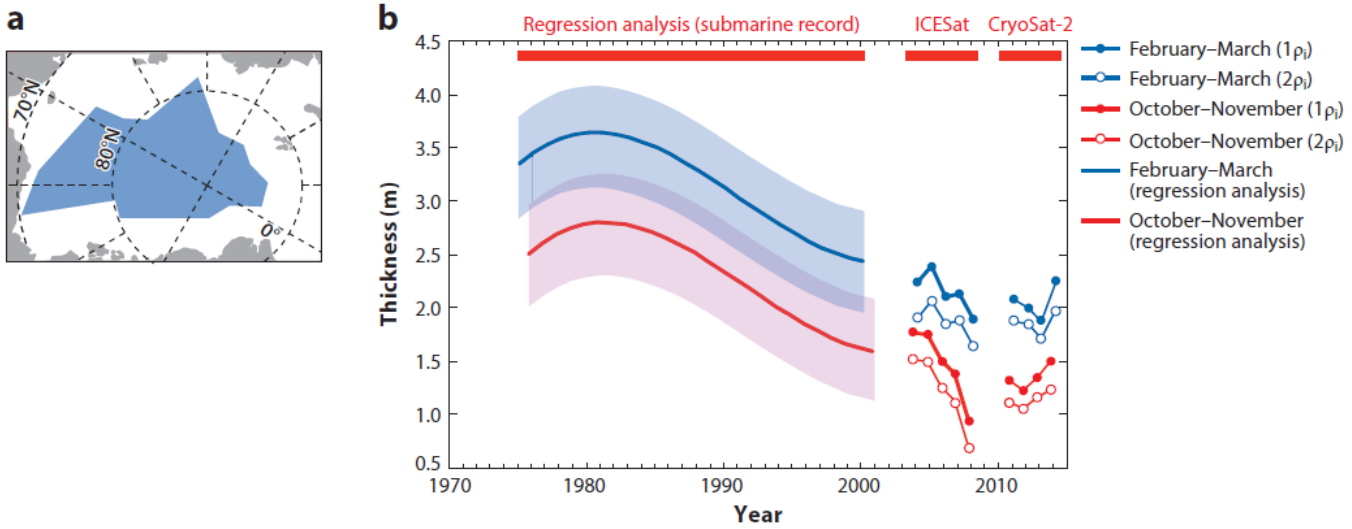
17th CLIVAR Summit August 6, 2019

Arctic ice melting and thinning since the 1980s



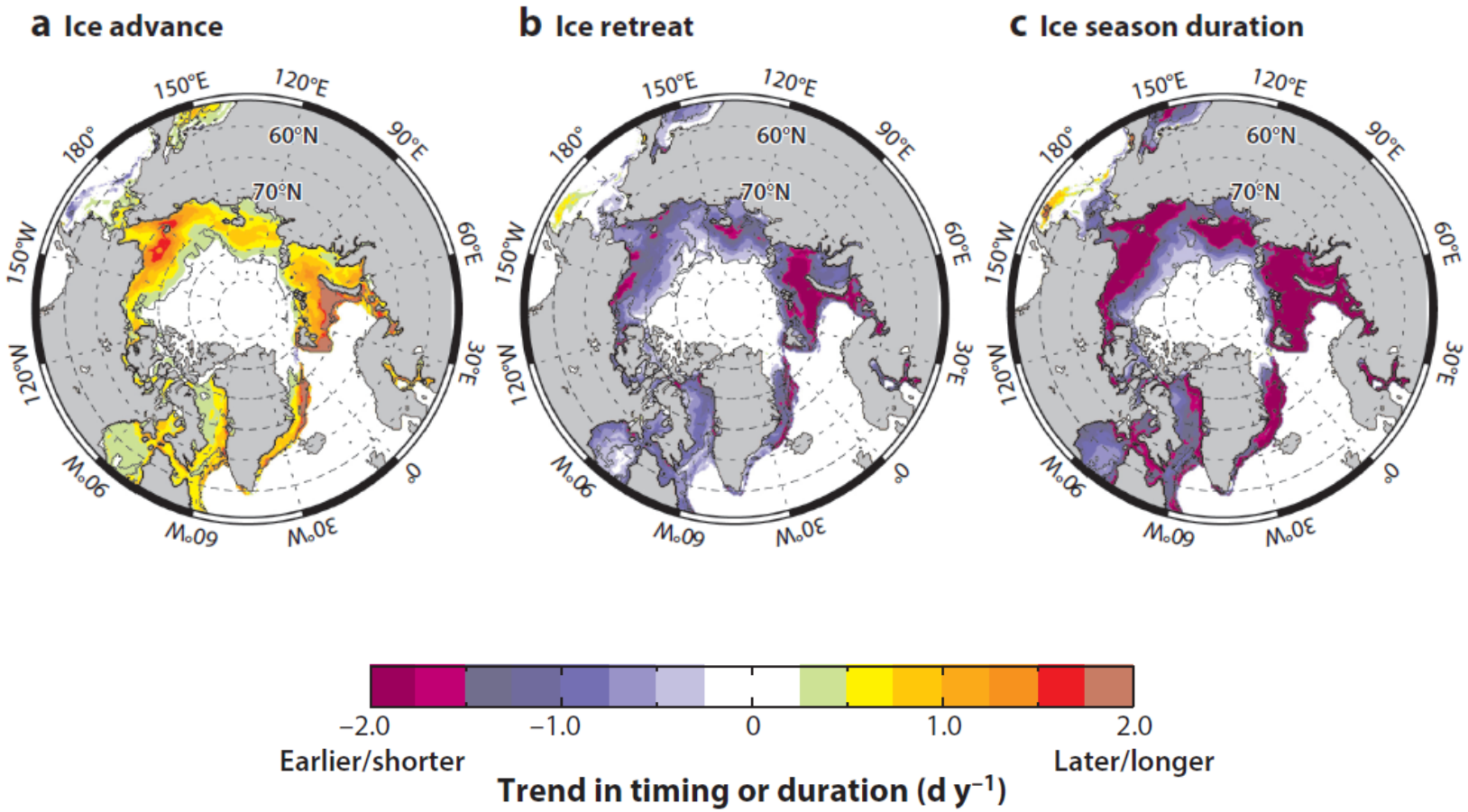
Maksym et al. 2019

Declines in Arctic ice thickness



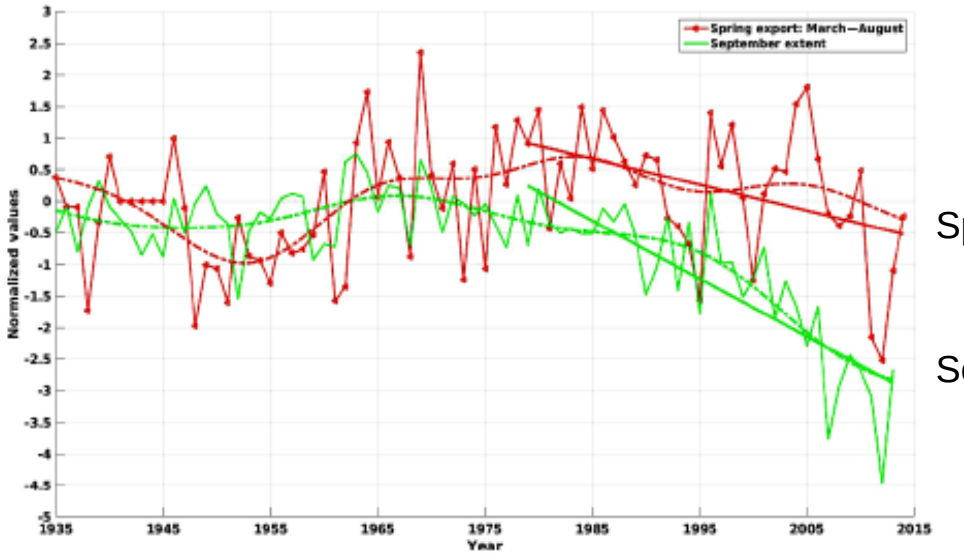
Kwok & Cunningham (2015)

The melting season has been longer



Maksym et al. 2019

Local melting is more important than exporting ice out of the basin



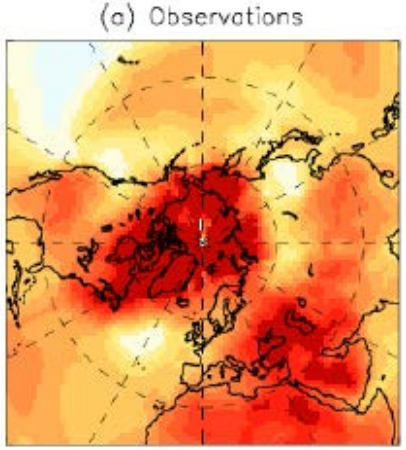
Spring Export (March-Aug)

September extent

Smedsrud et al. 2017

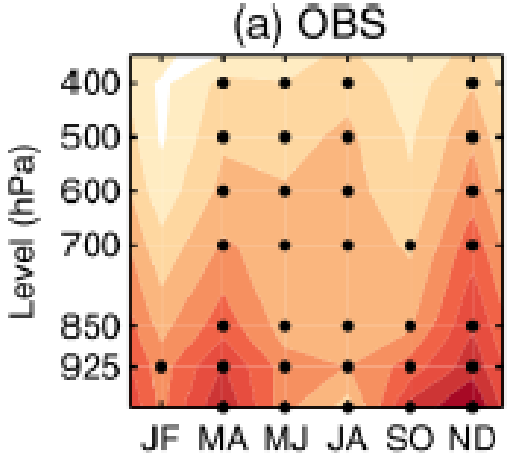
Local melting is mainly due to the warming atmosphere since the 1980s

Trend of annual mean surf_Temp



Smith et al. 2019

Trend of tropospheric Temp



Screen et al. 2012

Drivers of observed sea ice loss

Anthropogenic forcing

Internal forcing

Three pathways

Atmospheric pathways

Oceanic pathways

Freshwater discharge

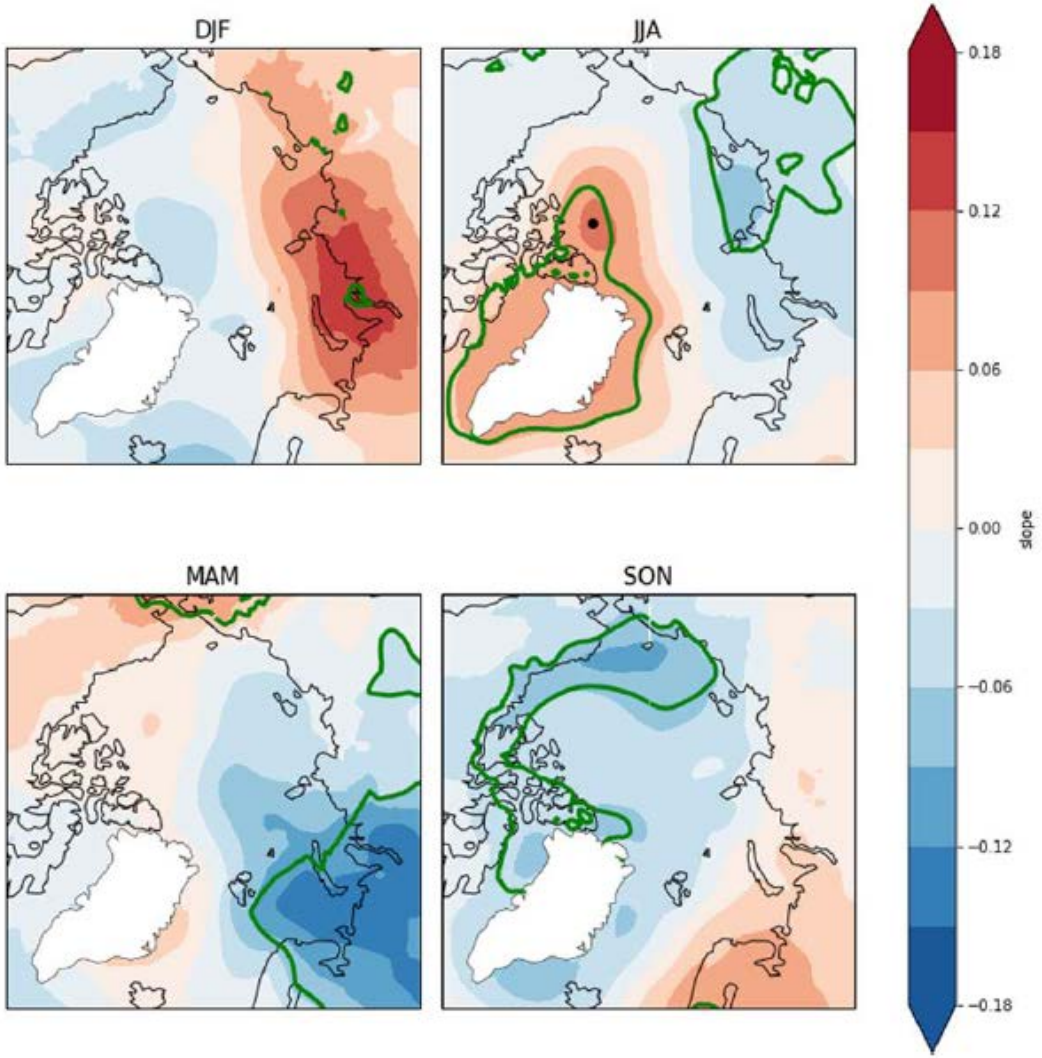
Arctic Amplification

- Sea ice loss
- Albedo feedback
- Cloud cover and water vapor
- Black carbon aerosol
- Local thermal inversion/Lapse rate feedback
- Vegetation feedback
- Poleward heat and moisture transport by atmosphere and ocean
- Many others

instability of the ice cover

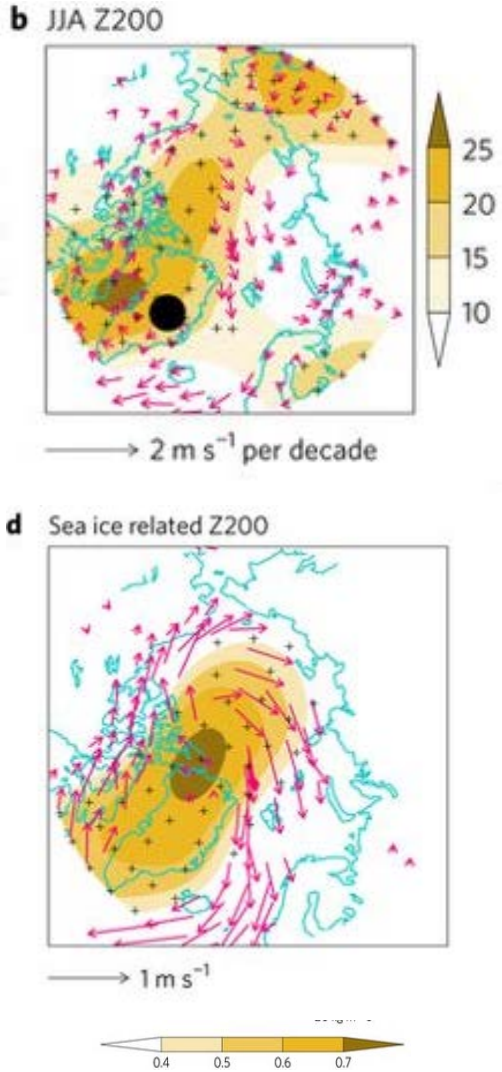
Atmospheric circulation changes and atmosphere–sea ice couplings are most significant in JJA

Observed SLP trends from 1979 to 2017



Stroeve and Notz 2018

Observed coupling in JJA

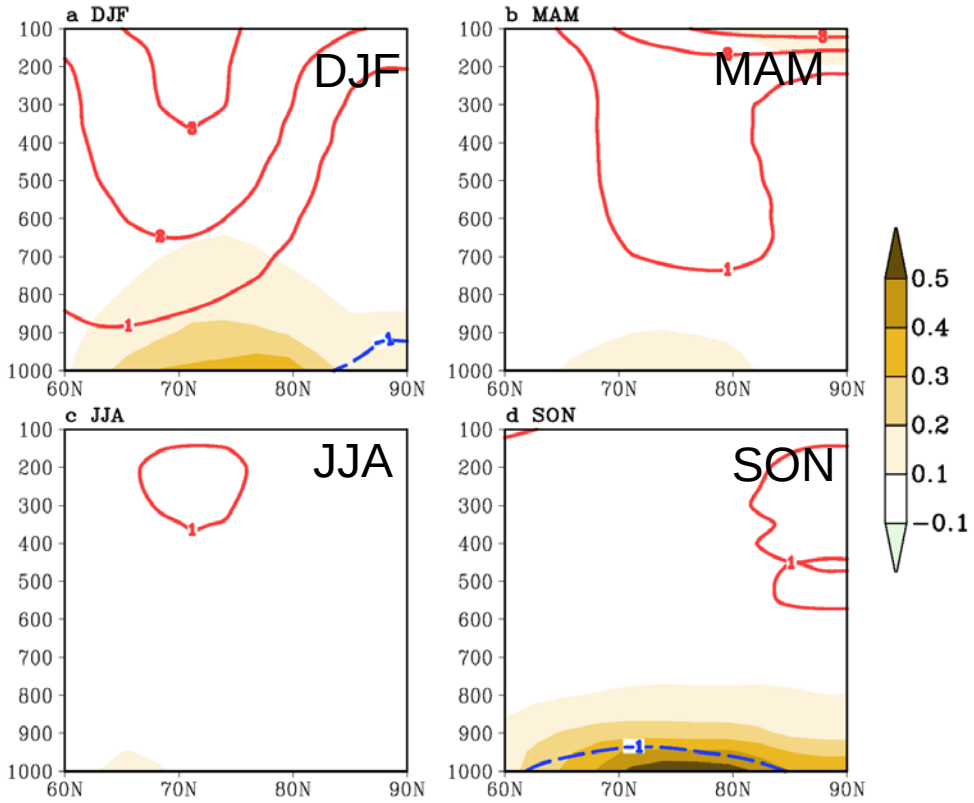


Ding et al .2017

Open issue 1: how to understand the observed local relationship?

ECHAM5 response to observed sea ice melting(1979-2014)

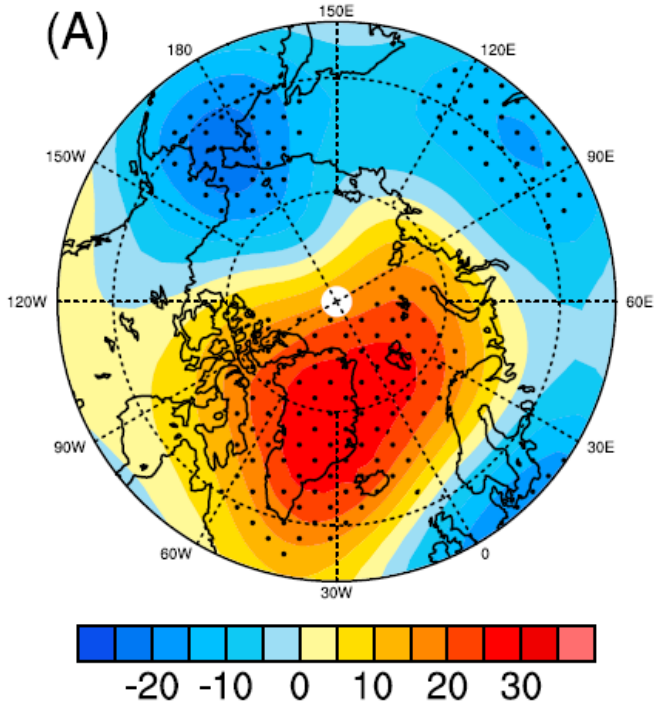
Zonal mean component of linear trends of geopotential height (m/decade contour) and temperature (shading)



Ding et al. 2017

CAM4 response to observed sea ice melting

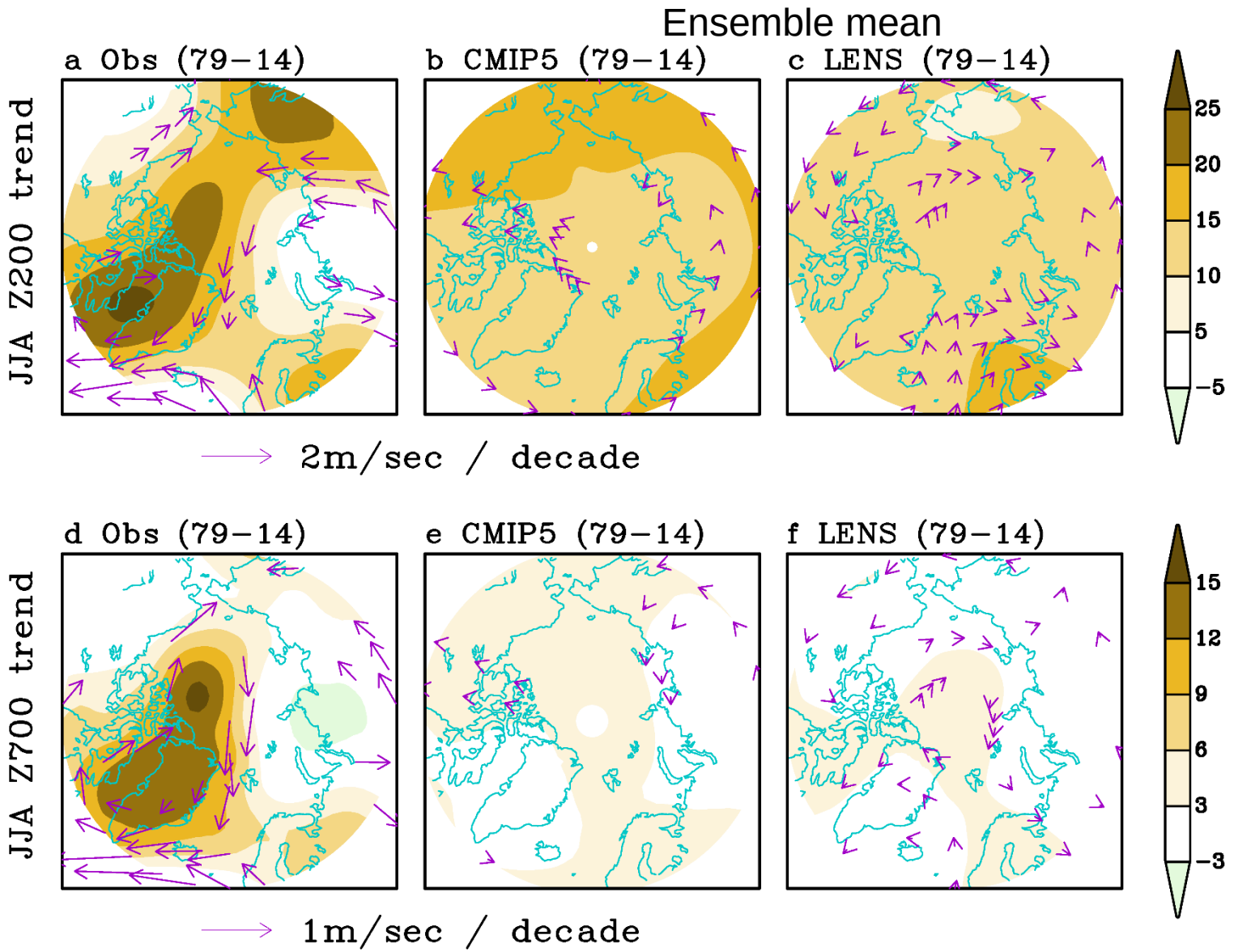
Z500 response in JJA



Liu et al. 2015

Open issue 1: is the local coupling due to anthropogenic forcing?

Observed and simulated JJA height linear trends (1979-2014)

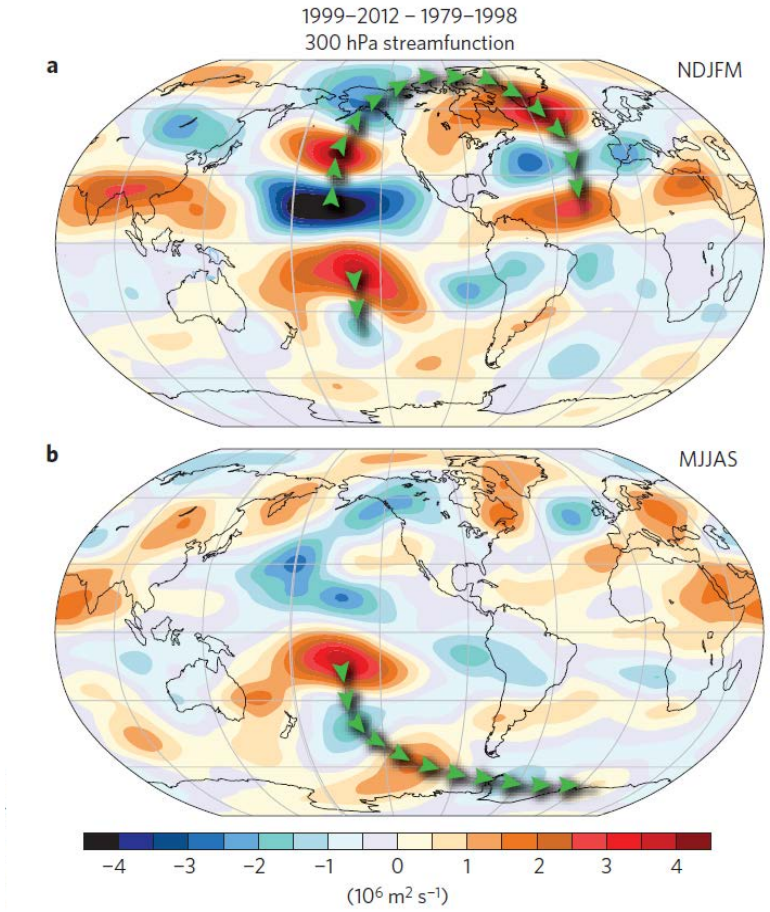


Ding et al 2017

Open issue 2: Remote drivers of atmospheric circulation in the Arctic

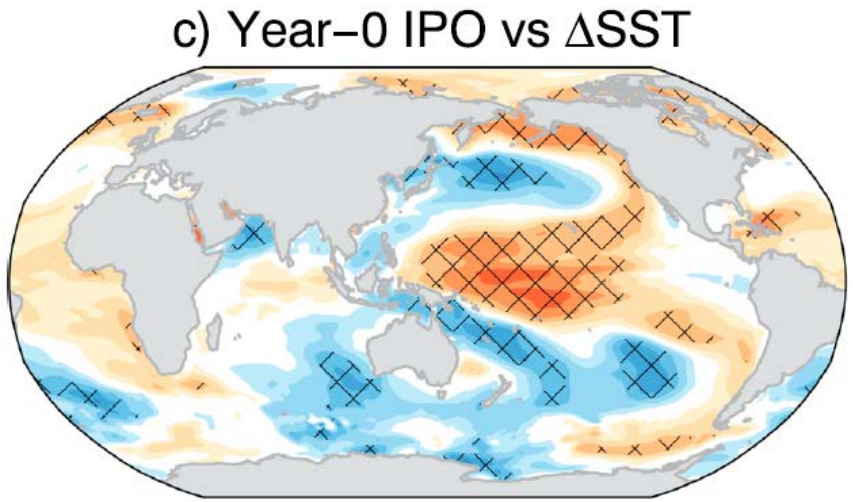
Tropical drivers (the ENSO, IPO, Asian summer monsoons, Atlantic SST, MJO, QBO etc.)
Extratropical drivers (the AMO, PDO)

Some models seem to favor an opposite phase or show no skill



Trenberth et al. 2014

CESM LEN



Screen and Deser 2019

Open issue 3:why do models show a lower sensitivity?

(2016).

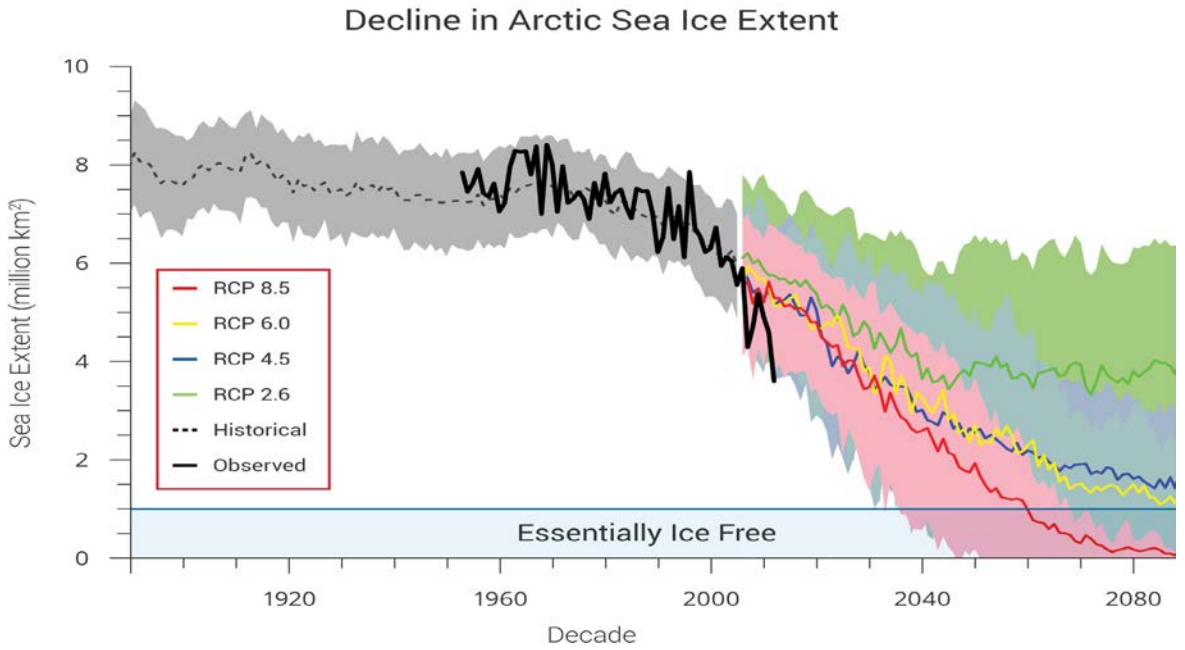
Observed Arctic sea-ice loss directly follows anthropogenic CO_2 emission

Science

Dirk Notz[1]* and Julienne Stroeve[2,3]

Abstract **Most models show a lower sensitivity, which is possibly linked to an underestimation of the modeled increase in incoming longwave radiation and of the modeled Transient Climate Response.**

- models are less sensitive
  Solution: recalibration
- Internal variability is important
  Solution: understand the internal source



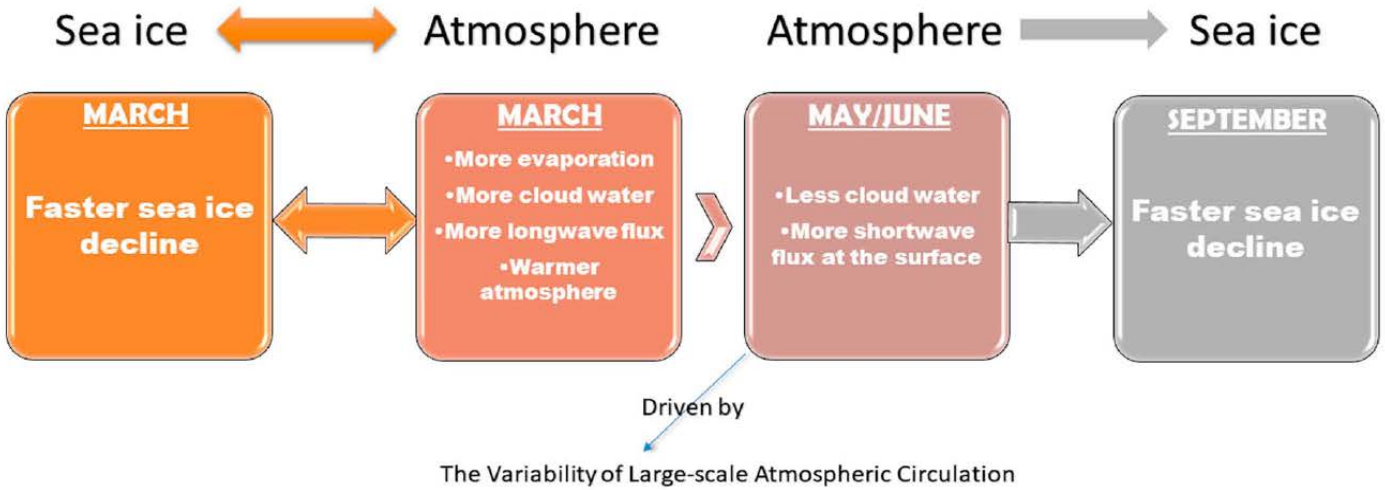
The Third National Climate Assessment
Walsh and Wuebbles 2014

Open issue 4: Roles of clouds in Arctic warming processes

Three important discoveries about roles of clouds

1. Importance of Liquid-Containing Clouds for Arctic Climate
2. Increased Absorbed Shortwave Radiation Associated with Sea Ice Loss During Summer
3. Fall Clouds Respond to Arctic Sea Ice Loss

Kay et al. 2016



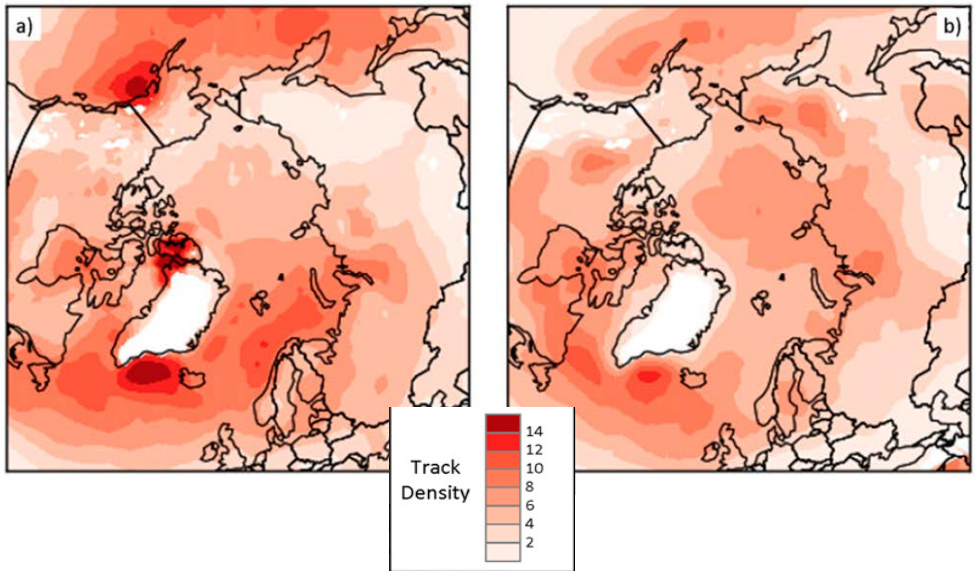
Huang et al. 2019

Open issue 5:
Different effects of Arctic cyclones (dynamic processes) and anticyclones (thermodynamic processes) on seasonal sea ice loss

Frequency of cyclone tracks (1979-2014)

DJF

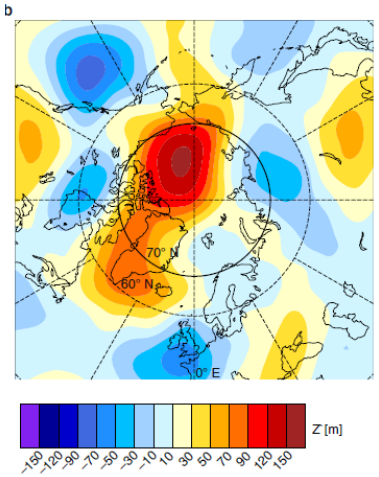
JJA



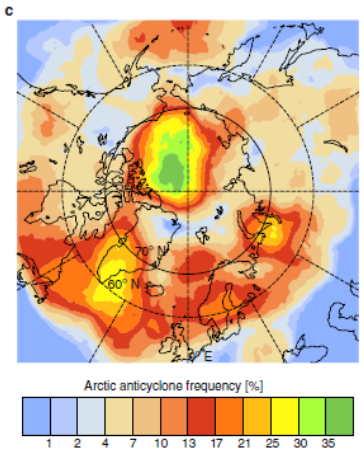
Crawford and Serreze 2016

JJA of 2007

Anomalous Z300



Frequency of Arctic anticyclones

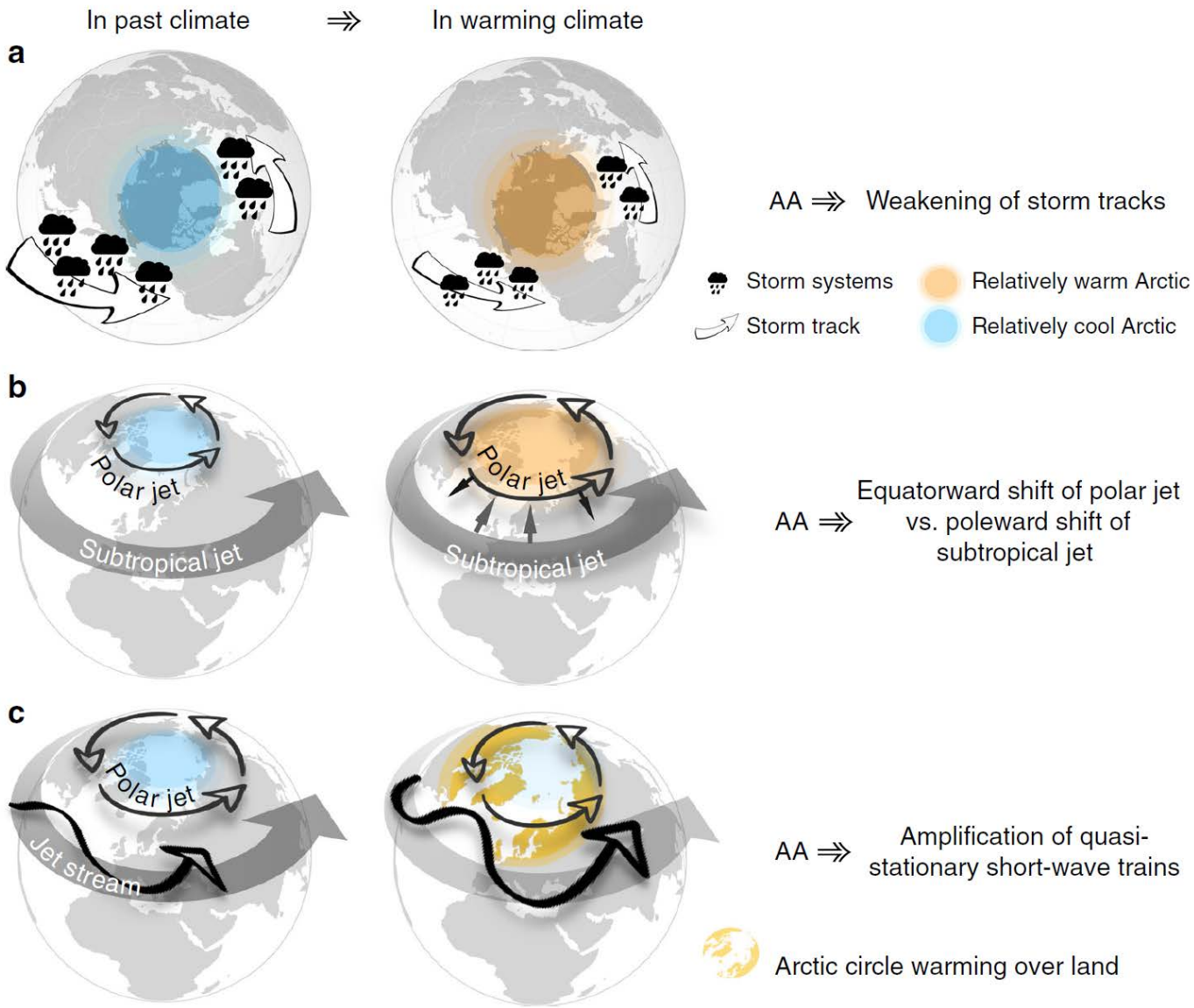


Wernli and Papritz 2017

melting sea ice via wave fracture, ocean mixing, moisture and heat transport, sea ice export

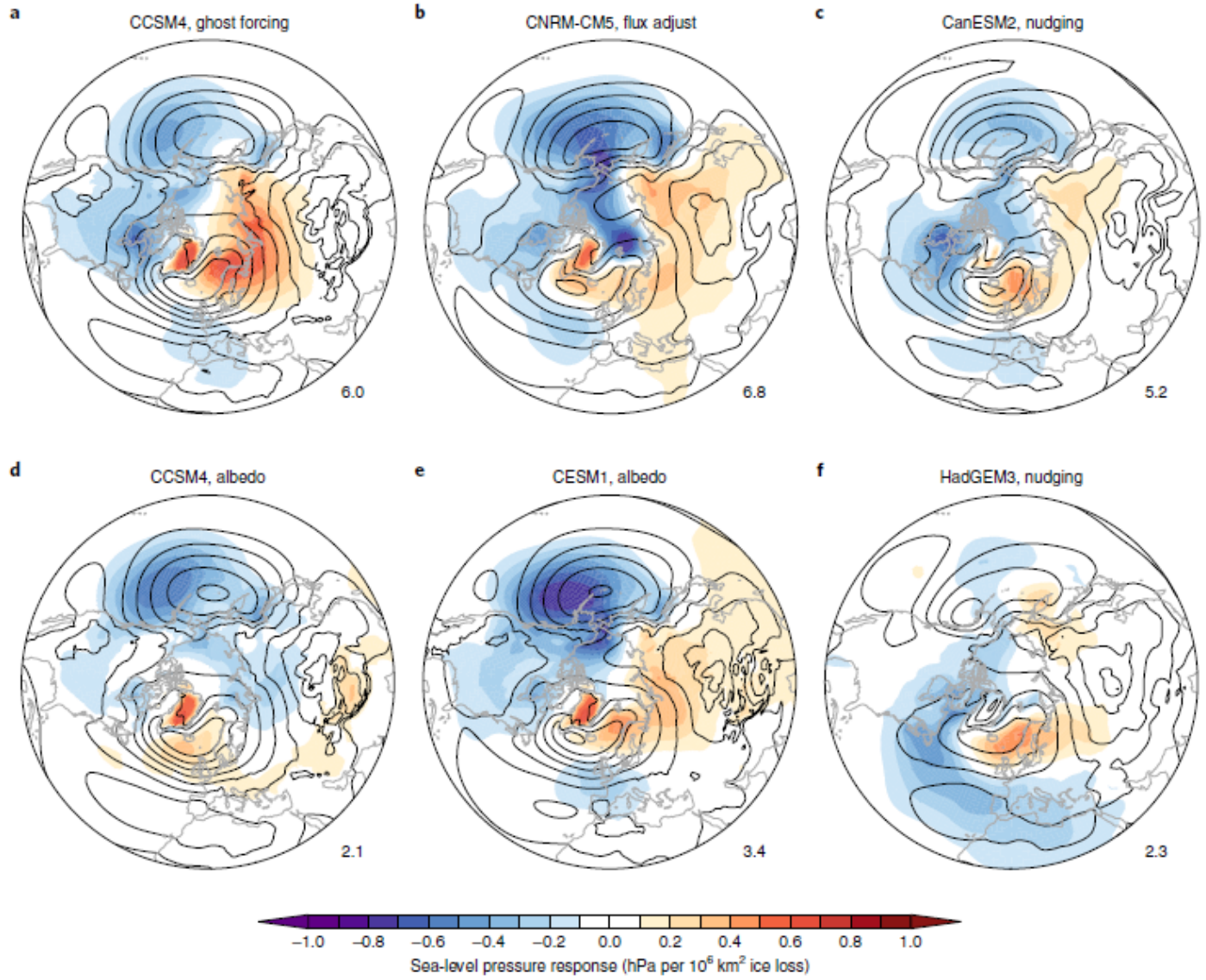
melting sea ice through changing radiation fluxes

The influence of Arctic amplification on mid-latitude summer circulation



Coumou et al. (2018)

The influence of Arctic amplification on lower-latitude winter circulation



Screen et al. 2018

Scientific issues

- local atmosphere-sea ice relationship in JJA: How to understand its causality? How well do models replicate this relationship?
- Teleconnections between Arctic circulation with remote drivers: why observations disagree on this and models seem to be inconsistent in reproducing observed patterns
- The relative contributions of internal and anthropogenic forcing in recent sea ice loss: do models own a reasonable sensitivity to climate forcing (internal and anthropogenic) in the Arctic?
- Roles of clouds ad their interactions with other systems (atmosphere, sea ice, sea state, boundary layer, precipitation, energy fluxes etc.)
- Feedbacks of Arctic warming to the lower latitudes in summer and winter: how to tease apart factors and outcomes?
- Short time scale drivers: which is more important to melt sea ice, Arctic cyclones or anticyclones? Their governing dynamics?
- Across-time scale interactions: Are Arctic cyclones and anticyclones sensitive to large scale circulation, SST and radiative forcing?