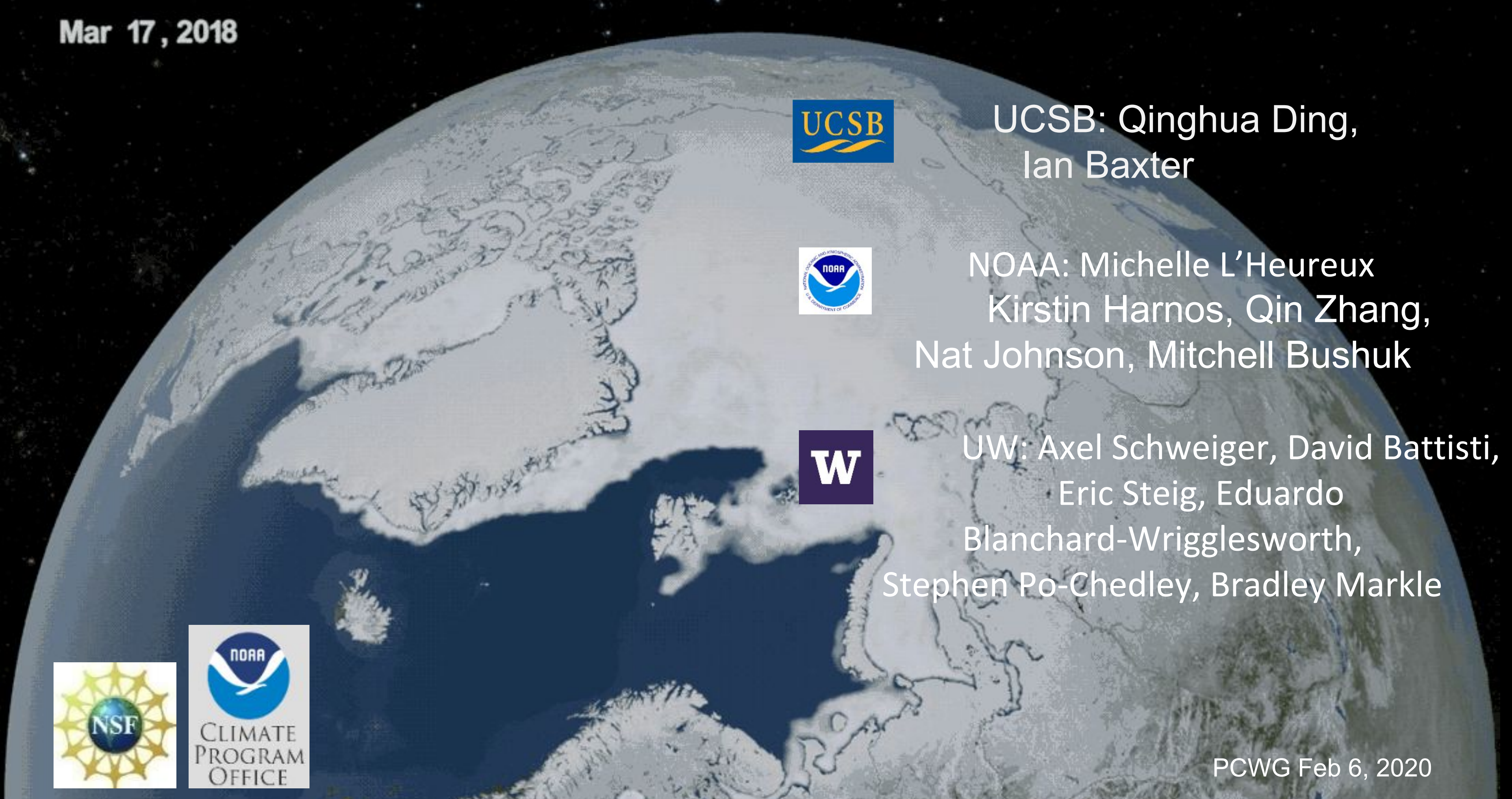
Fingerprints of Internal Drivers of Recent Arctic Warming



UCSB: Qinghua Ding,
Ian Baxter

NOAA: Michelle L'Heureux
Kirstin Harnos, Qin Zhang,
Nat Johnson, Mitchell Bushuk

UW: Axel Schweiger, David Battisti,
Eric Steig, Eduardo
Blanchard-Wrigglesworth,
Stephen Po-Chedley, Bradley Markle

CLIMATE PROGRAM OFFICE

PCWG Feb 6, 2020

(2016).

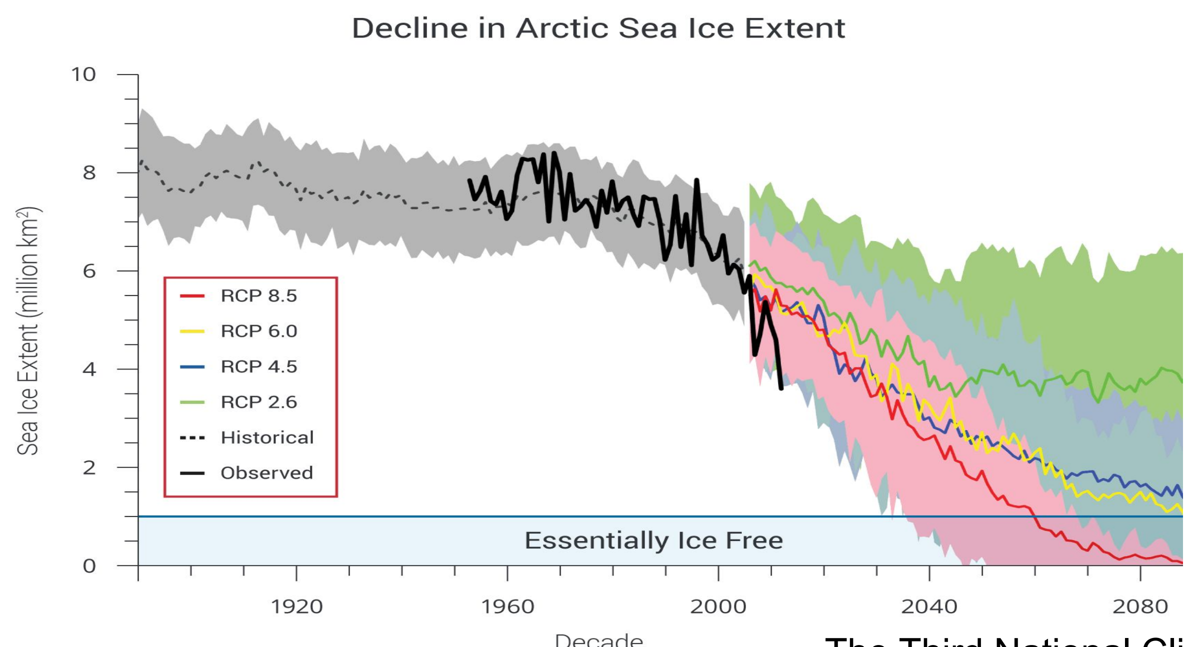
Observed Arctic sea-ice loss directly follows anthropogenic CO_2 emission

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

Science

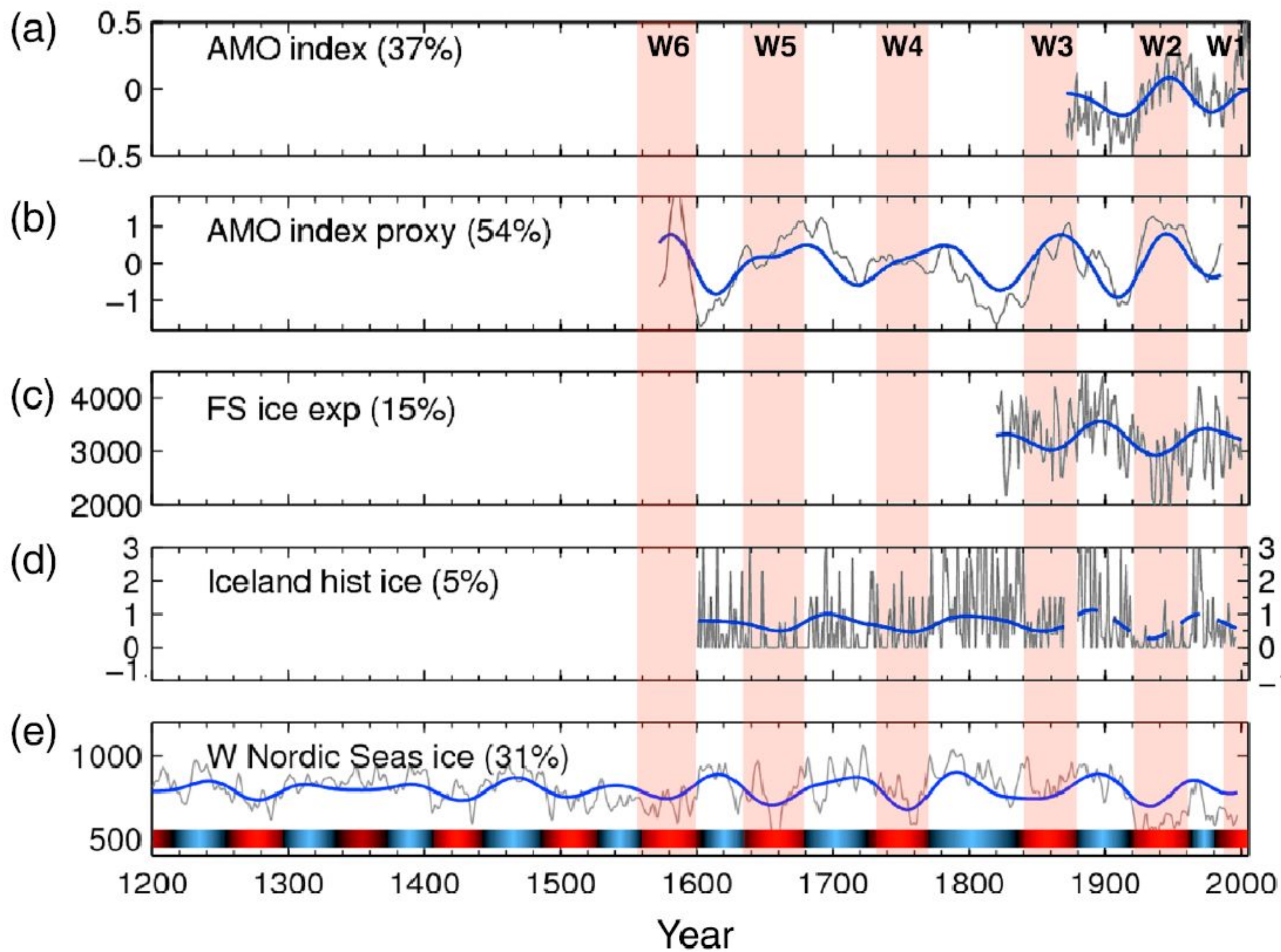
Abstract

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.



The Third National Climate Assessment
Walsh and Wuebbles 2014

Persistent multidecadal (~60–90 years) fluctuations in Arctic sea ice



Miles et al. 2014

Two ideas to explain the discrepancy (lower sensitivity) between the simulations and observations

1. Models are less sensitive (recalibrate)
2. Internal variability (understand internal sources)

Anthropogenic thermal warming

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

Internal atmospheric dynamical warming

Goal: Quantify the relative contributions of internal and anthropogenic forcing in the recent sea ice decline

Approach 1: Use numerical models to search a similarity between the observation and simulated patterns (forced and internal)

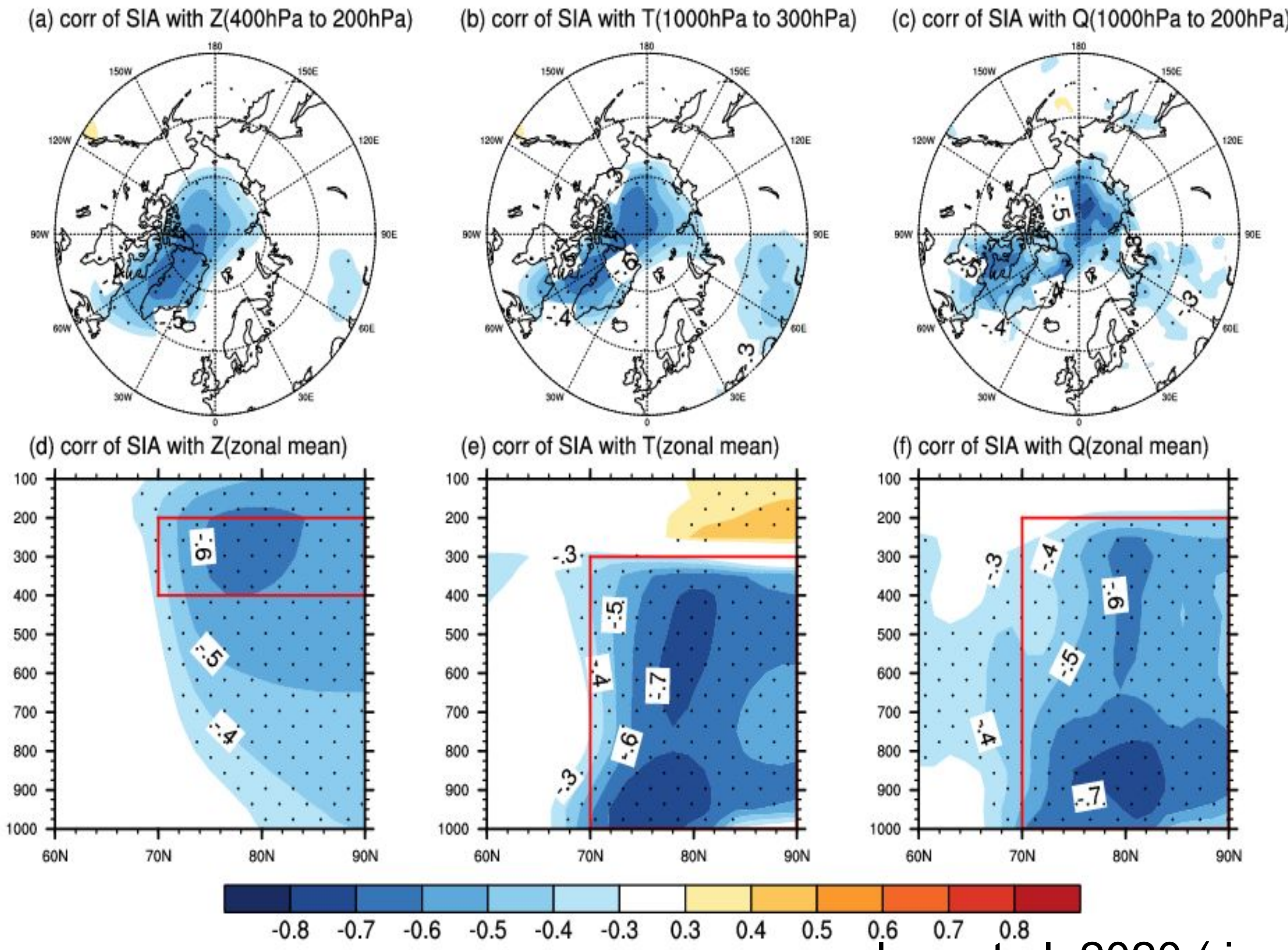
Approach 2: “Replay” observed winds in a model to simulate observed sea ice changes

partially supported by the PCWG
Acknowledge: Ed, Yiyi Huang, Jen Kay, Marika Holland and David Bailey

Focus on a combined effect of models’ internal and forced variability to better understand observations

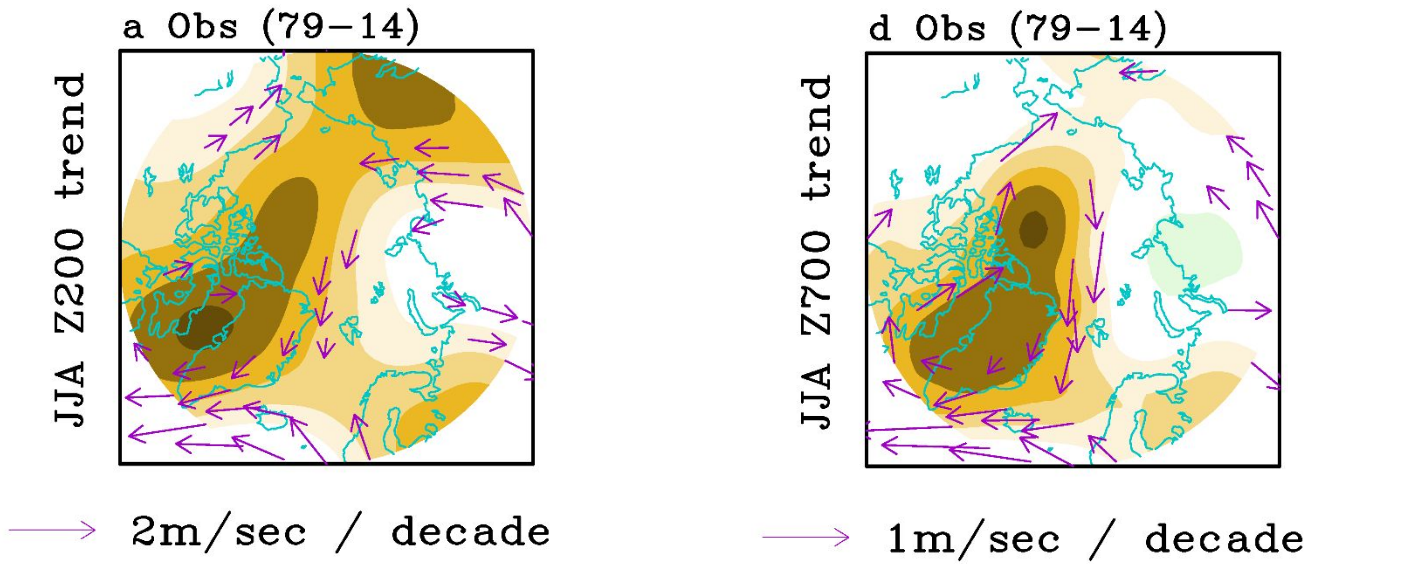
Summertime sea ice – atmospheric circulation coupling in the Arctic (1979-2018)

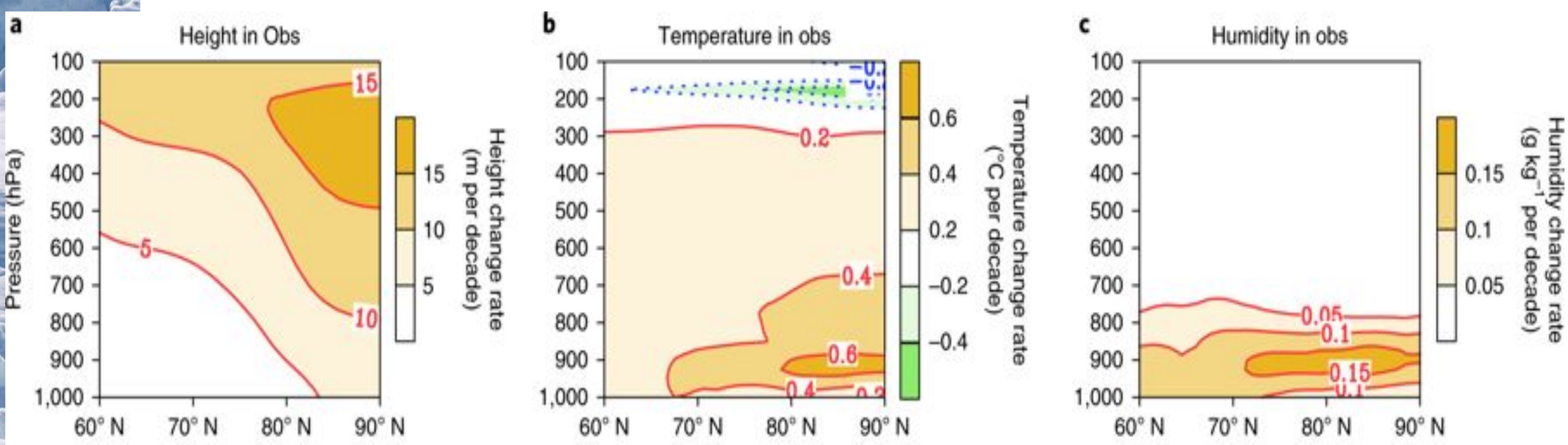
Detrended Sep sea ice correlated with JJA atmospheric variables



Luo et al. 2020 (in preparation)

Observed linear trends of JJA atmospheric variables (1979-2014)





ECHAM5 run (sea ice melting: 1979-2014)

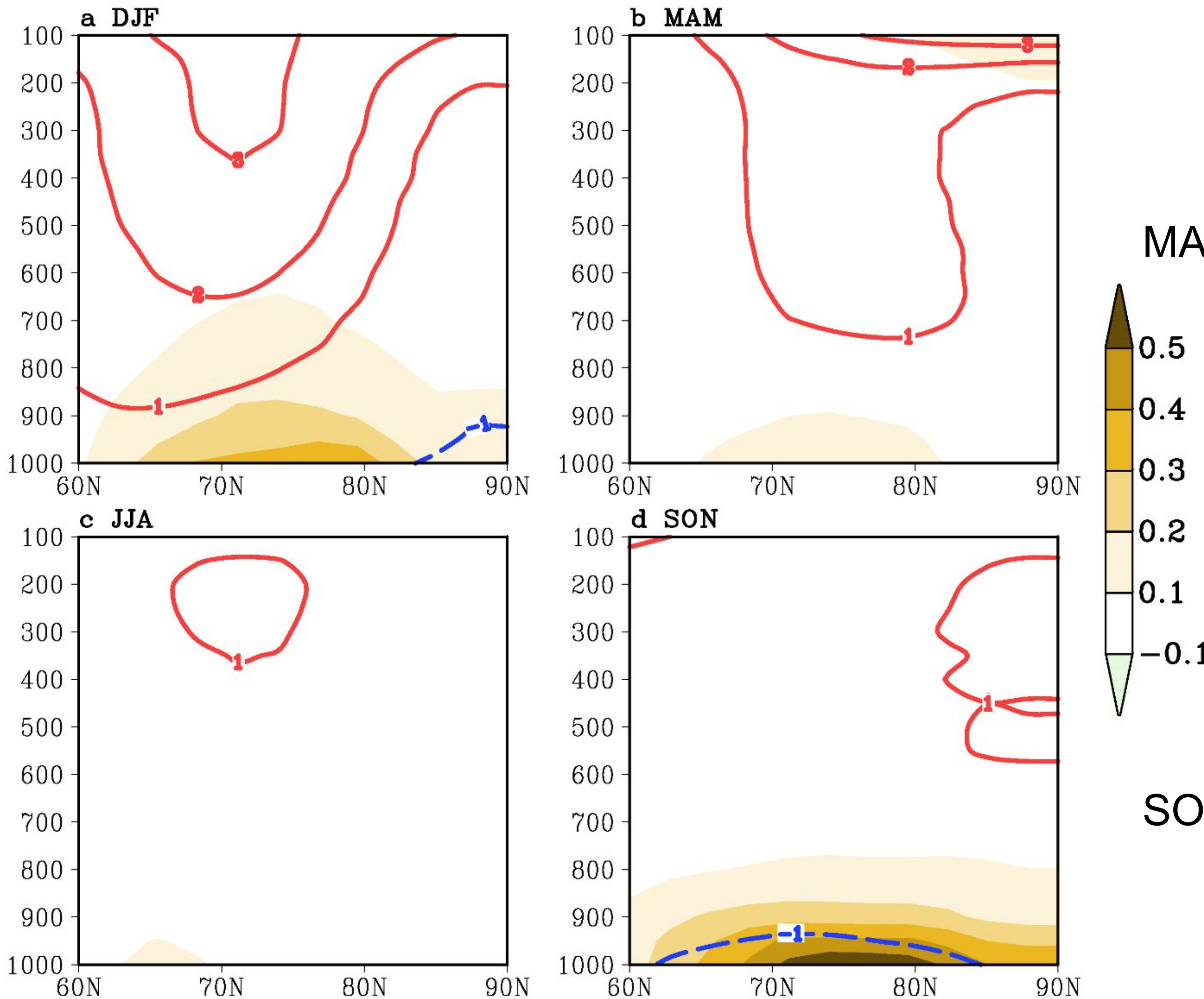
Zonal mean component of linear trends of geopotential height (m/decade contour) and temperature (shading)

DJF

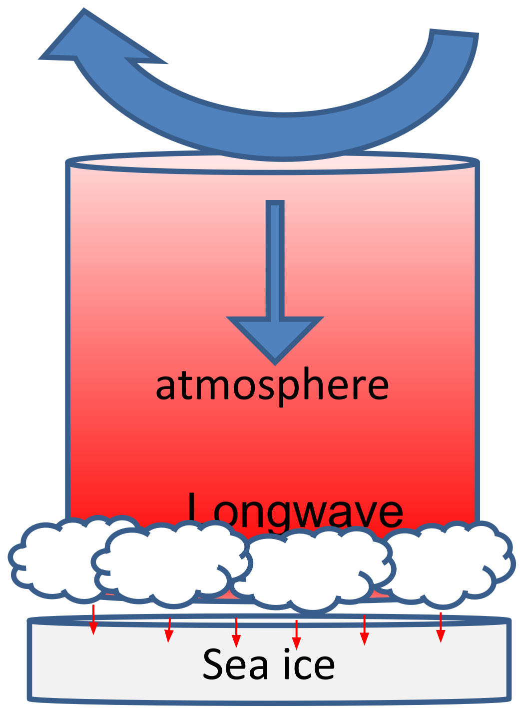
MAM

JJA

SON



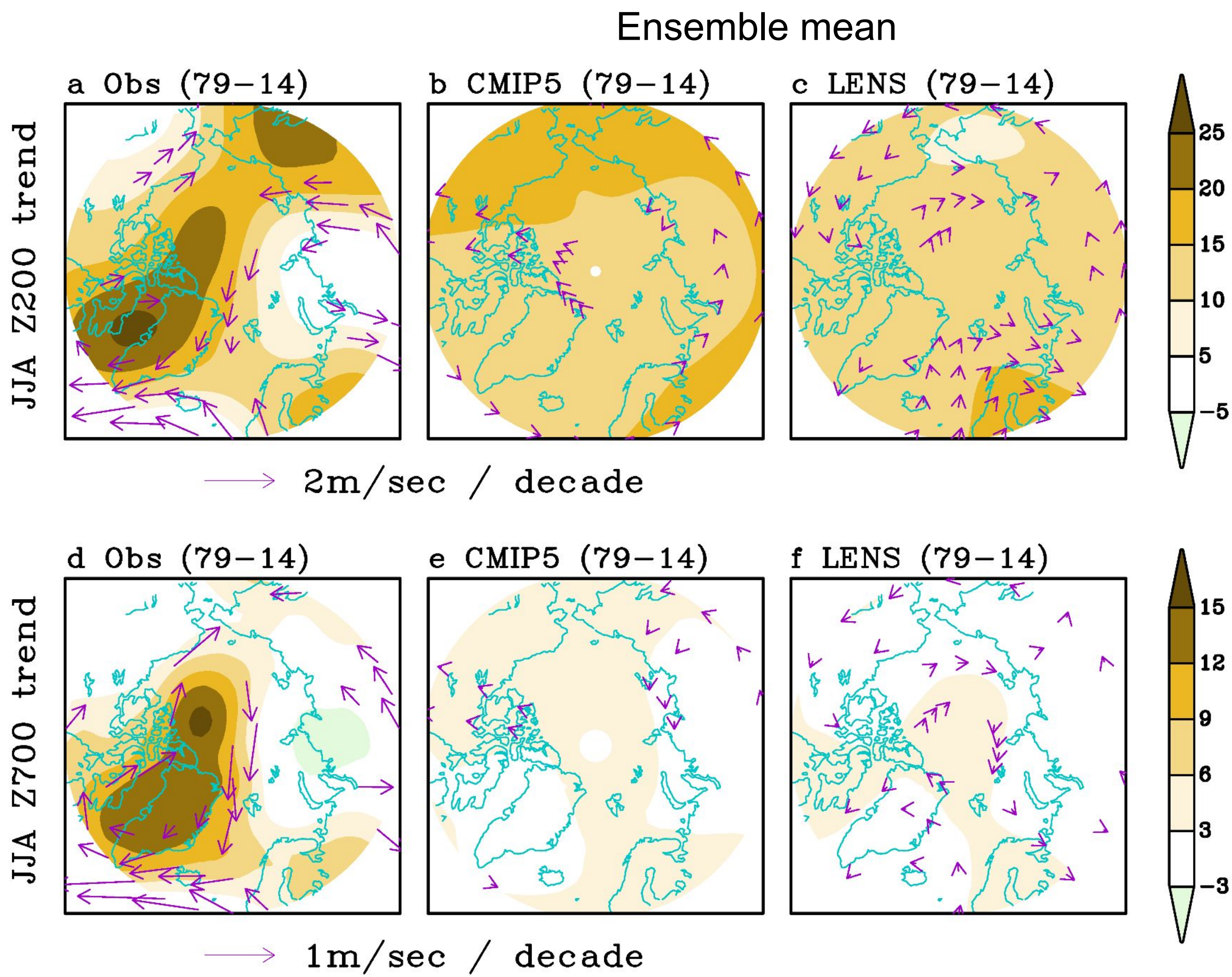
Warming effects of “Polar heat wave”



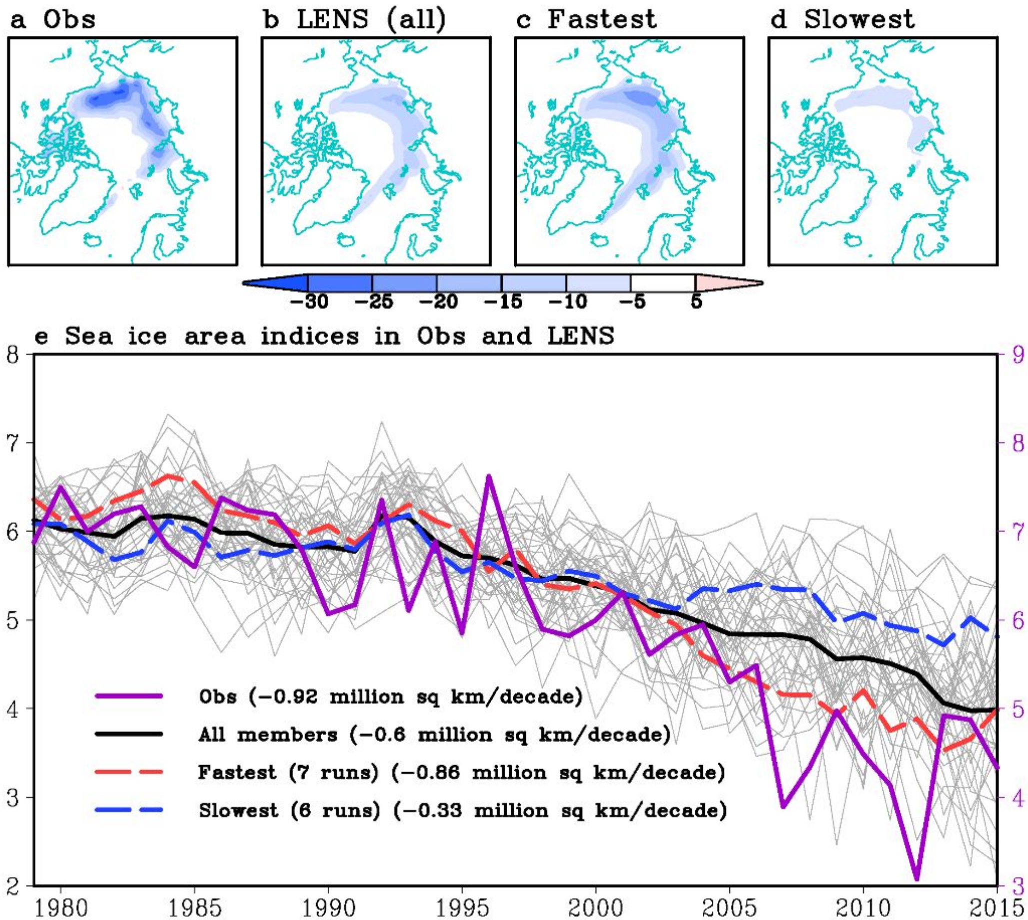
Clouds may change to strength this dynamical warming

Hypothesis: an anticyclonic circulation pattern with strong subsidence favors warmer, wetter, cloudier (low level) atmosphere above sea ice
This mechanism works on a broad range of time scales

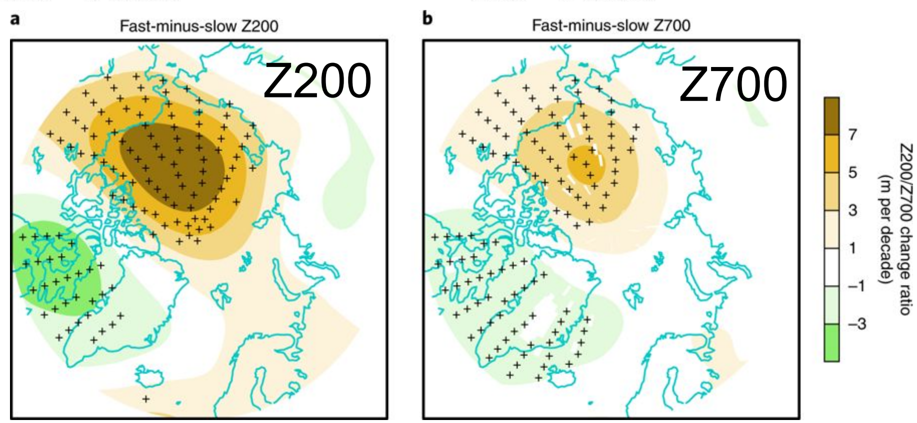
Observed and simulated JJA height linear trends (1979-2014)



Ding et al 2017



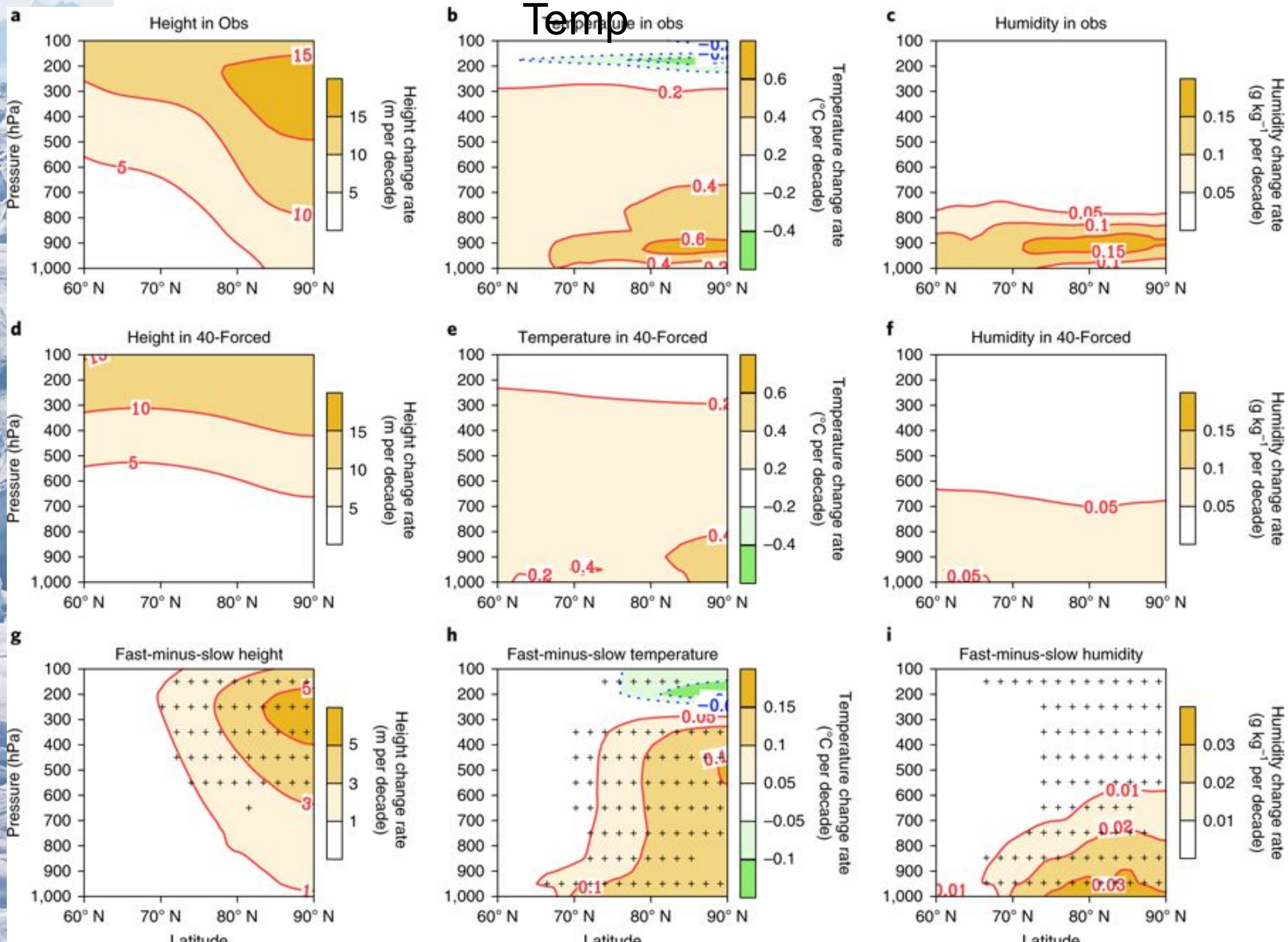
Let’s focus on Internal variability



Fastest minus slowest

Linear trends of JJA height and temperature (1979 to 2015) in CESM LENS

JJA Height | JJA Temp | JJA Humidity



Obs

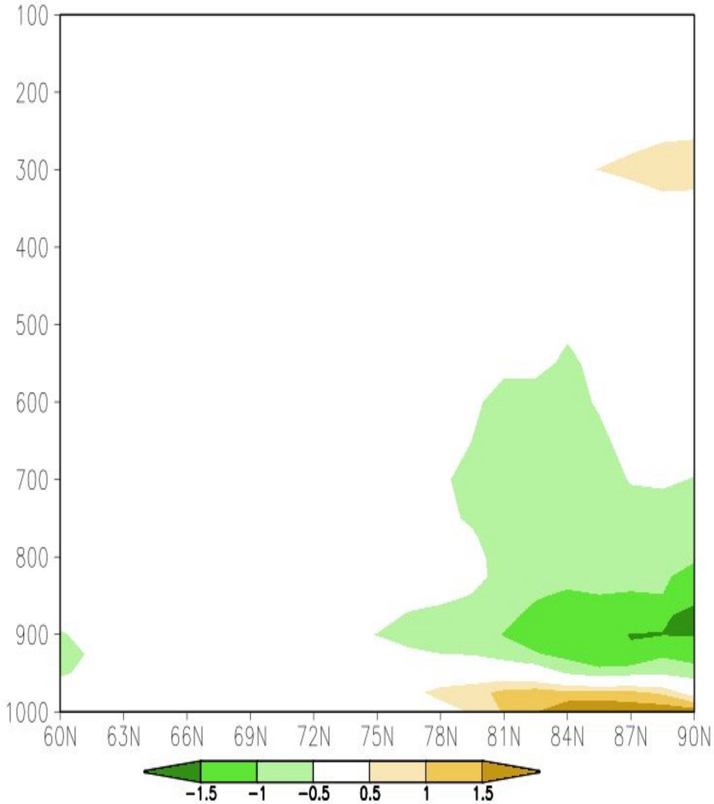
Forced response

Fastest minus slowest

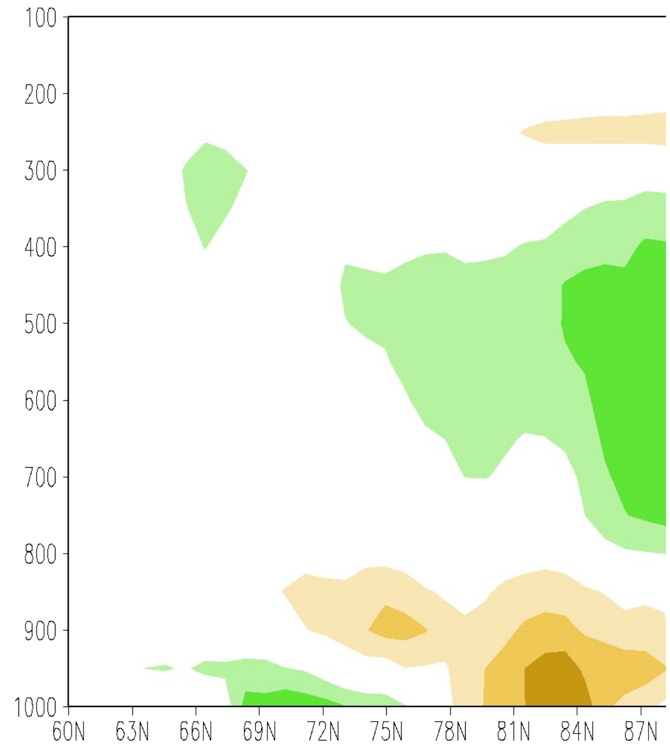
Internal variability

Trend of zonal mean JJA cloud fraction (79-15)

ERA5



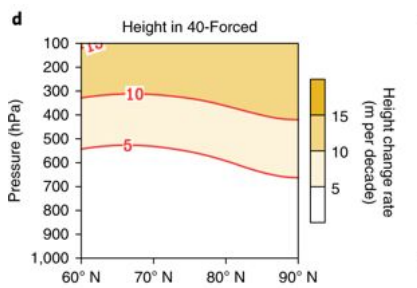
Fast minus slow in
CESM LEN



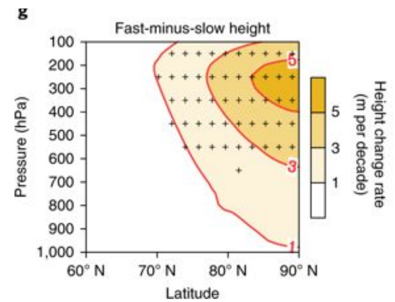
Circulation is important to couple temperature, humidity and cloud fields together to melt sea ice

A fingerprint match using CESM LENS runs

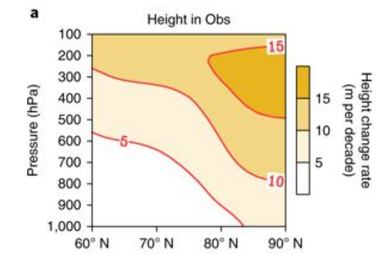
Internal variability explains 50% of Sep sea ice melting



+

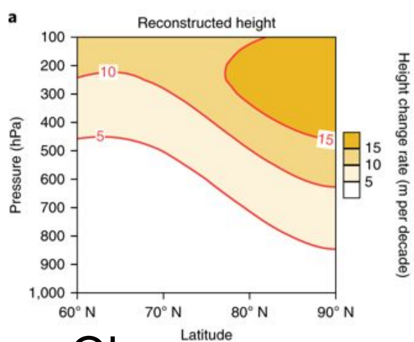


=

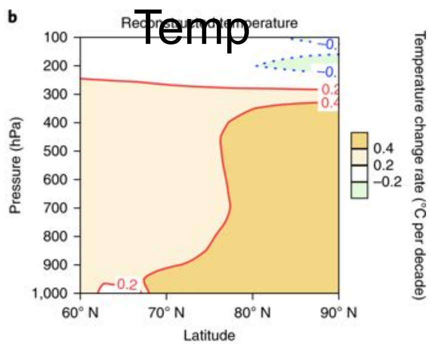


Forced +internal using CESM LENS

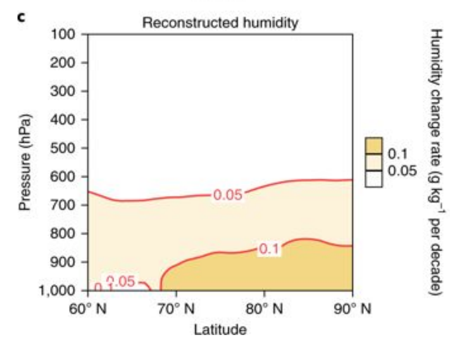
JJA Height



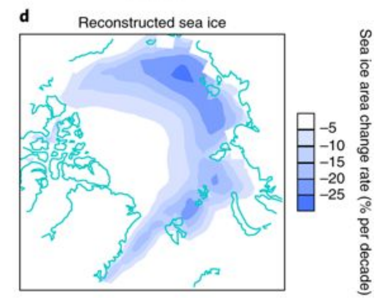
JJA Temp



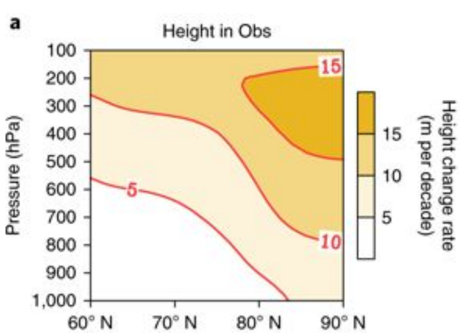
JJA Humidity

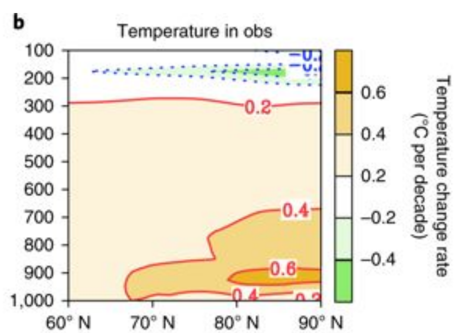


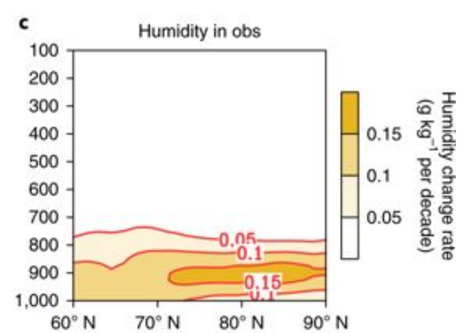
Sep Sea ice



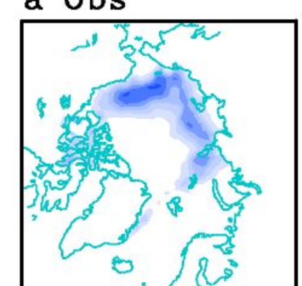
Obs







a Obs



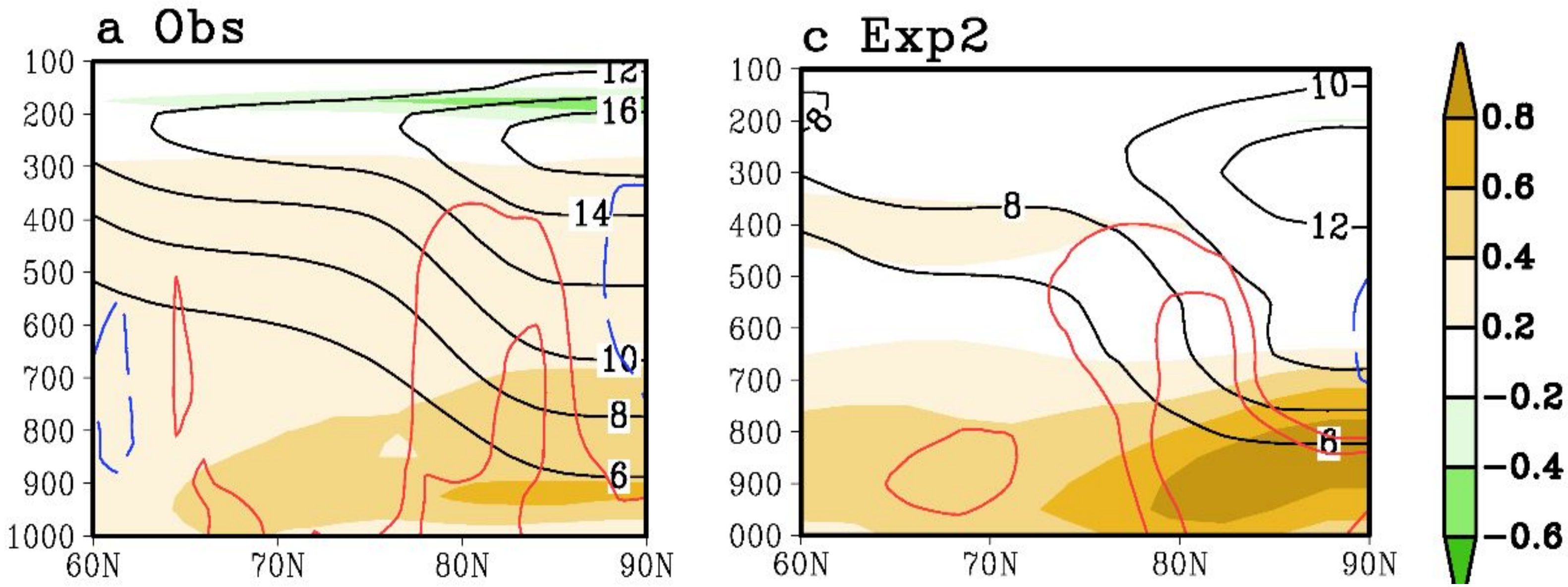
Approach II

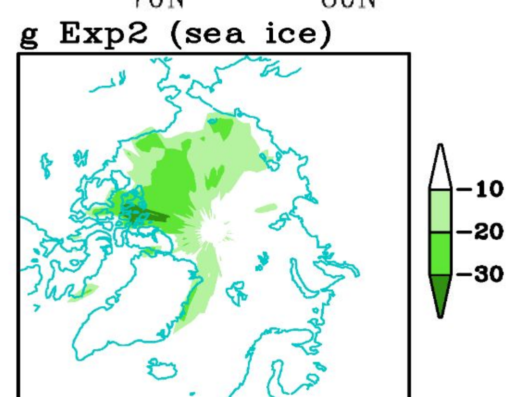
ECHAM5 with 3-D winds nudged to observations (1979-2014)

Zonal mean

Shading: trend of JJA temperature since 1979
Contour: trend of JJA geopotential height since 1979

Nudging experiment





Internal variability explains 30-50% of Sep sea ice melting

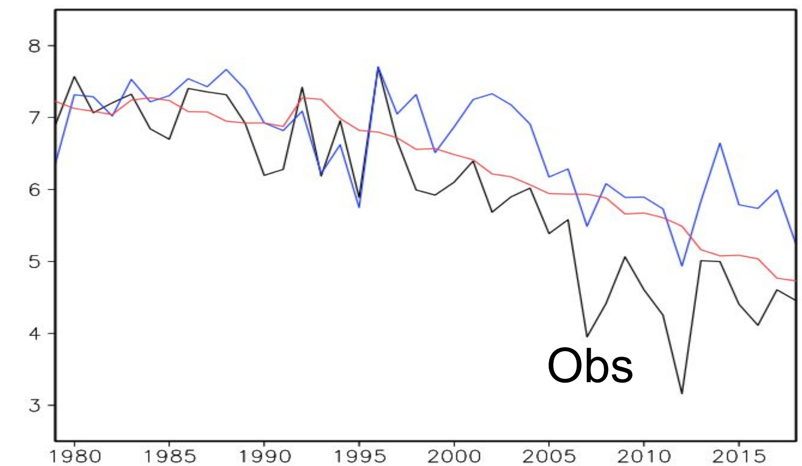
CESM1 with 3-D winds nudged to observations (1979-2018)

Nudging domain: the Arctic (60N-90N), above 800hPa, partial nudging=0.5
CO_2: 367ppm

Sep sea ice area

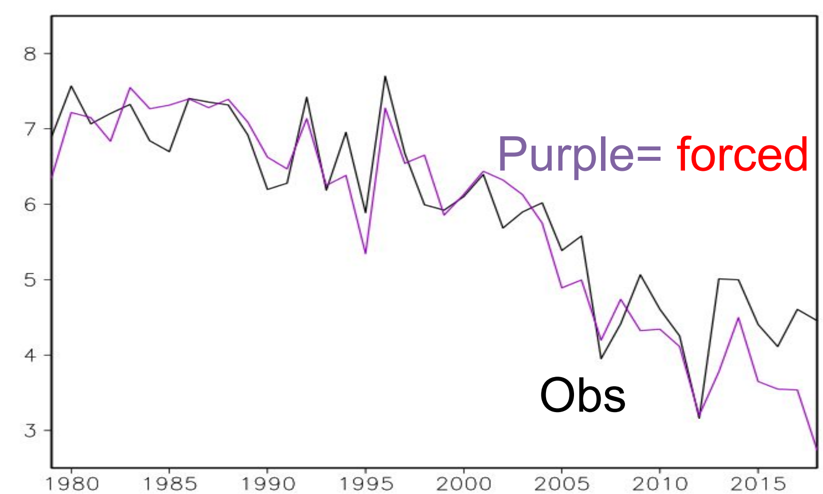
Blue: nudging

Red: forced (CESM LEN 40members)



Obs: -0.95
Nudging: -0.45
Forced: -0.66

million km^2 /decade

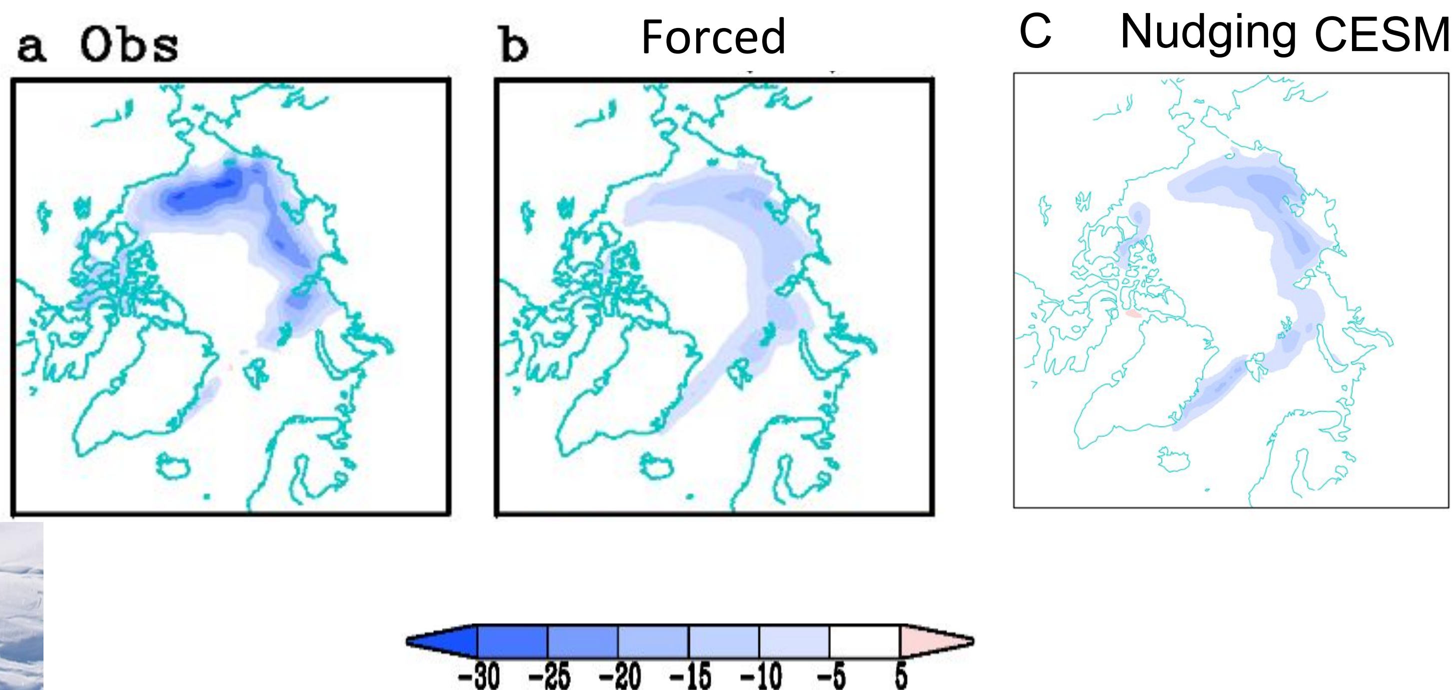


Purple= forced +nudging

Internal variability explains 40% of Sep sea ice melting in the past 40 yers

Trend of Sep sea ice

CESM LEN 40 members

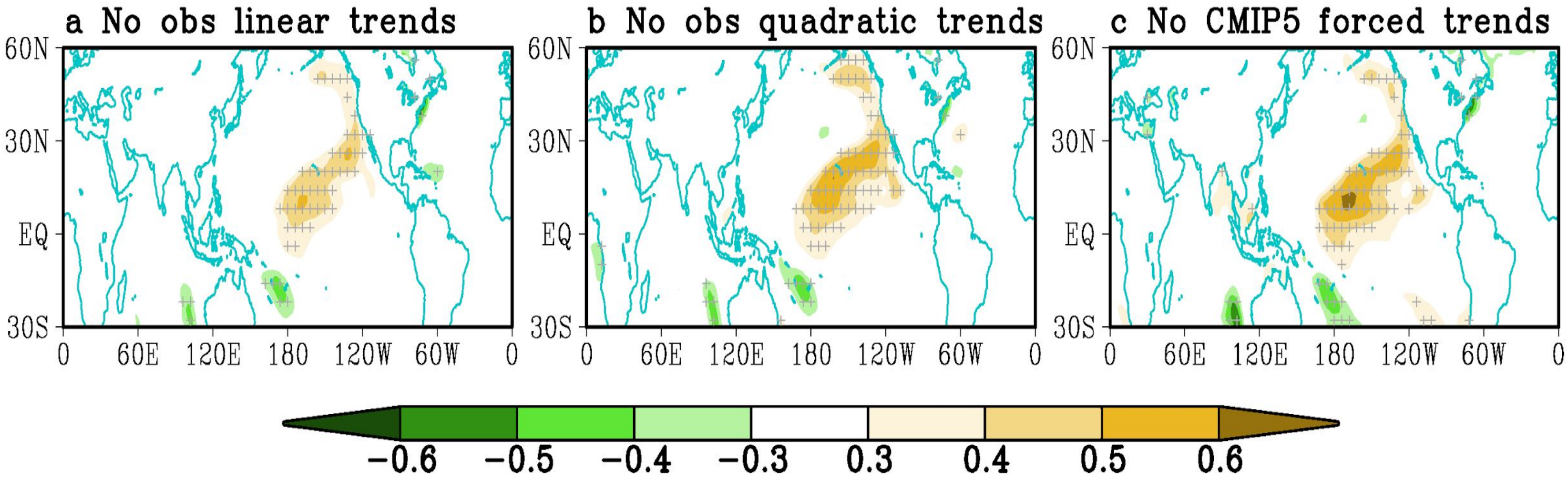


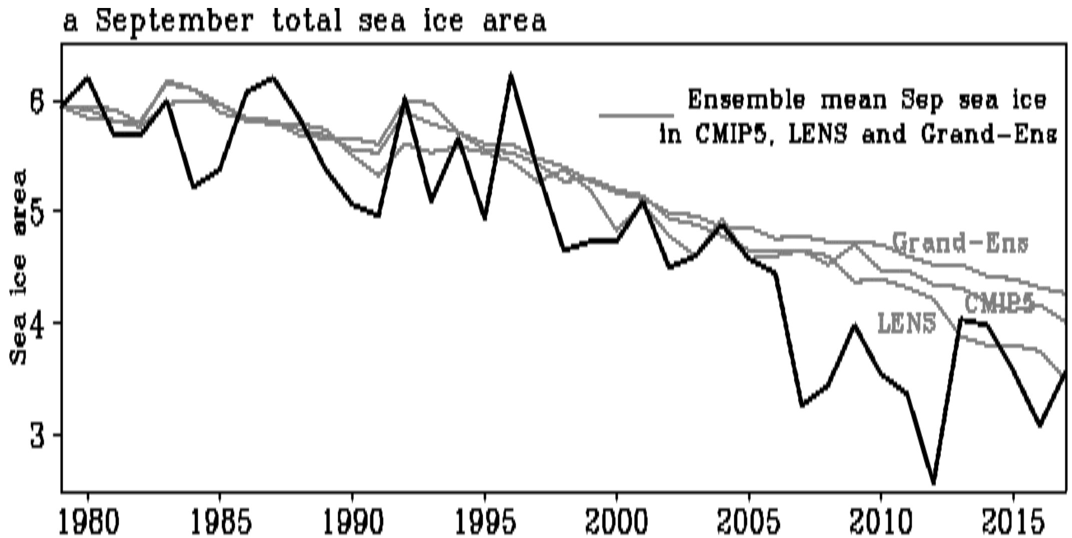
Two ideas to explain the discrepancy (lower sensitivity) between the simulations and observations

1. Models are less sensitive (recalibrate)
2. Internal variability (understand internal sources)

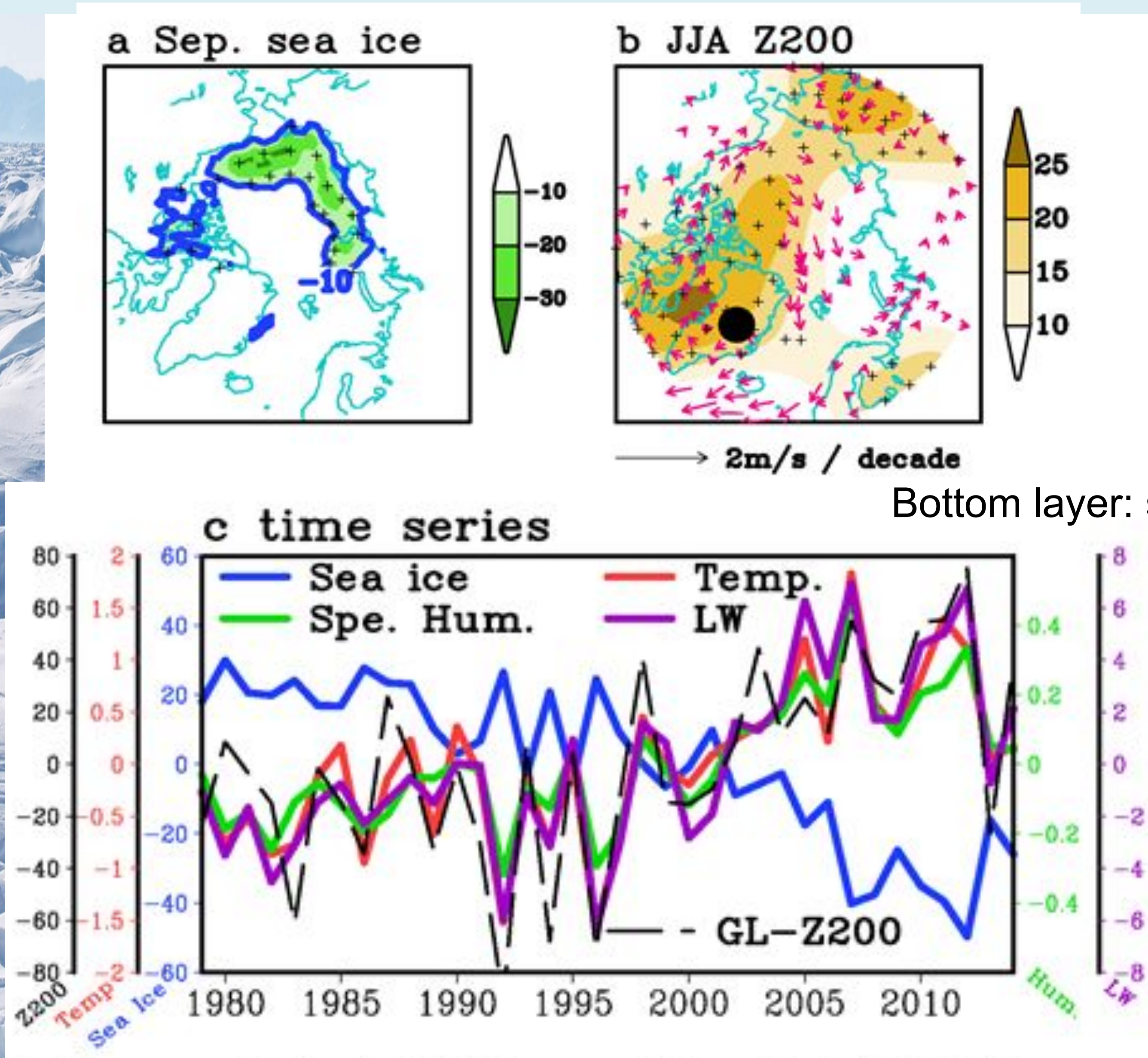
What is the internal source driving circulation change in the Arctic?

Correlation between Sep sea ice with JJA SST (1979-2017)




a September total sea ice area
Ensemble mean Sep sea ice
in CMIP5, LENS and Grand-Ens
Grand-Ens
CMIP5
LENS
Sea ice area
6
5
4
3
1980
1985
1990
1995
2000
2005
2010
2015

Summertime sea ice – atmospheric circulation coupling in the Arctic (1979-2014)



Bottom layer: surface-750hPa

(70N-90N)

Ding et al. 2017

Summertime sea ice – atmospheric circulation coupling in the Arctic (1979-2014)