Influence of recent high-latitude atmospheric circulation changes on summertime Arctic sea ice

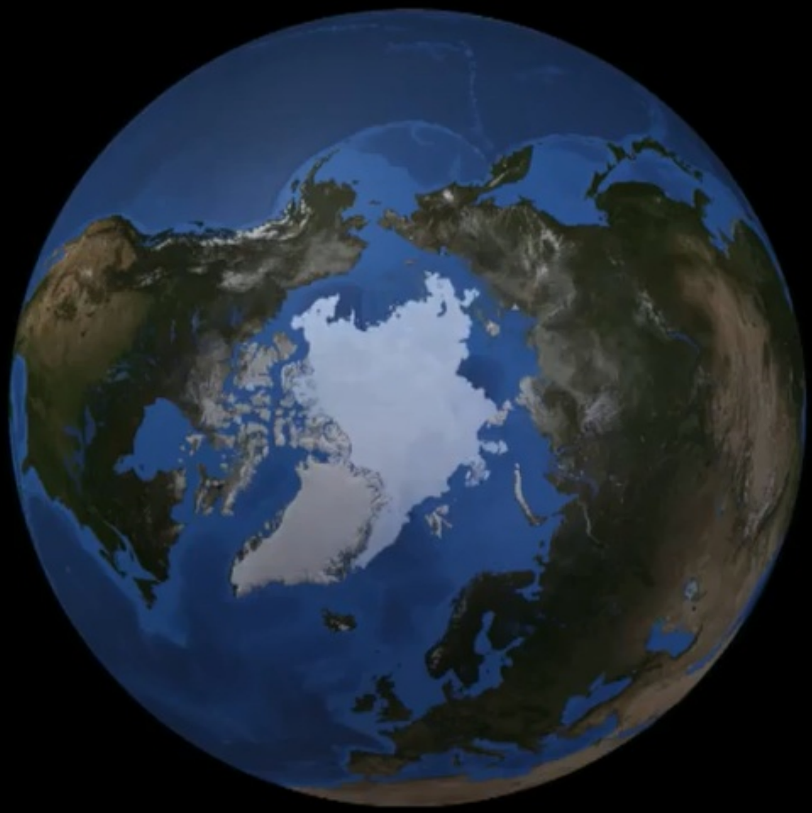


Photo: NASA

UCSB: Qinghua Ding

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

UW: Axel Schweiger, David Battisti,
Eric Steig, Eduardo Blanchard-Wrigglesworth,
Stephen Po-Chedley, Ryan Eastman,
Mike Steele

Acknowledgement:
John Wallace and Cecilia Bitz

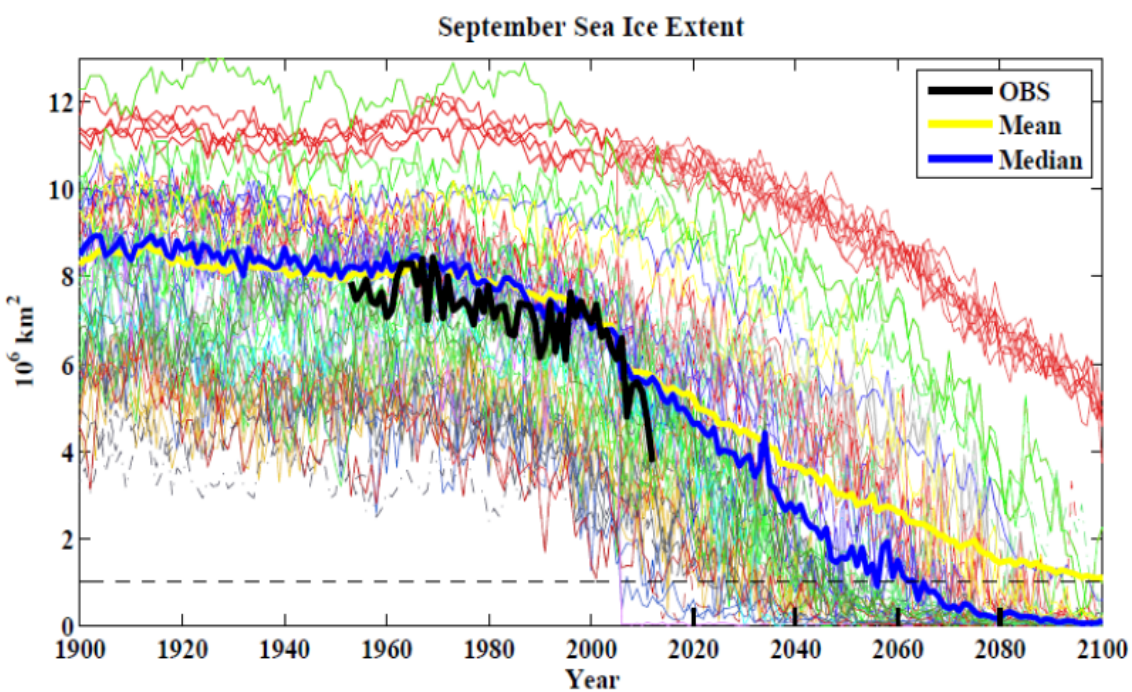
Aspen Workshop on Polar Amplification June12-17, 2017

Science
REPORTS

Observed Arctic sea-ice loss directly follows anthropogenic CO_2 emission

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

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.

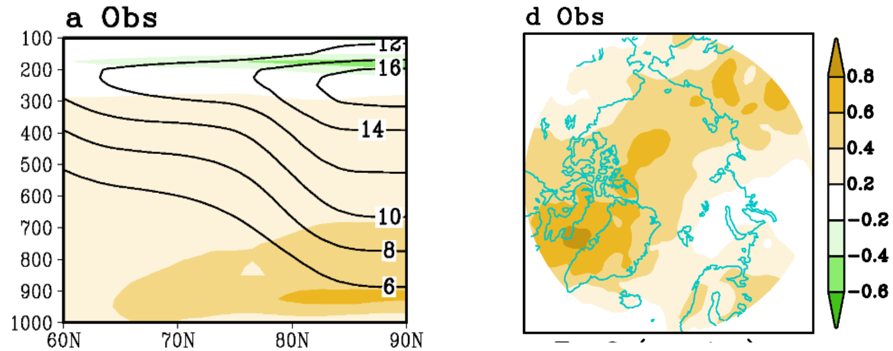


Overland and Wang 2013

Observed JJA Height&Temp linear trends (1979-2014) Meridional-vertical

Zonal mean Temp 1000-750hPa

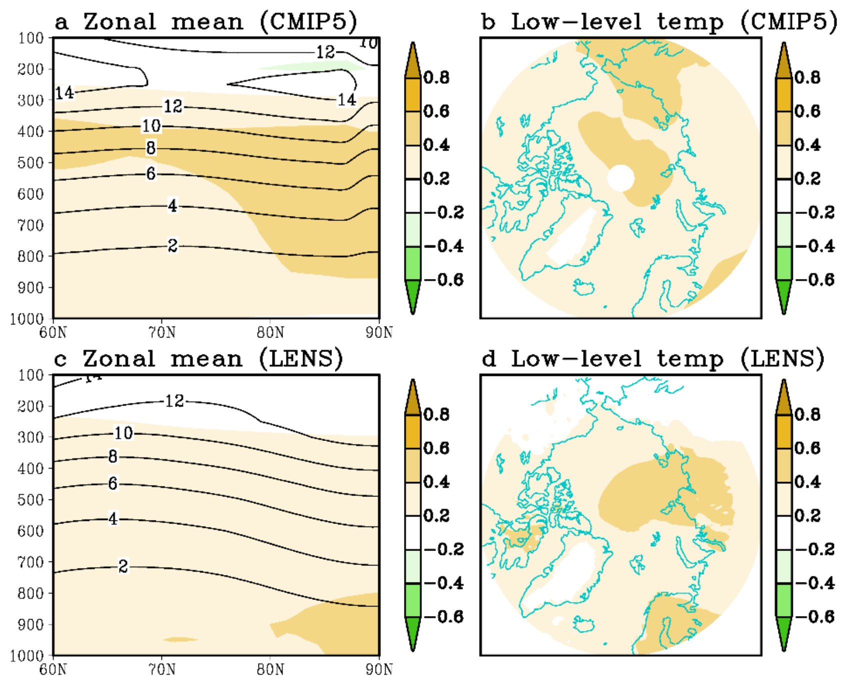
Shading: Temp
Contour: Geopotential height



ERA-I

CMIP5 & CESM Model run (anthropogenic forcing: 1979-2014)

Shading: Temp
Contour: Geopotential height

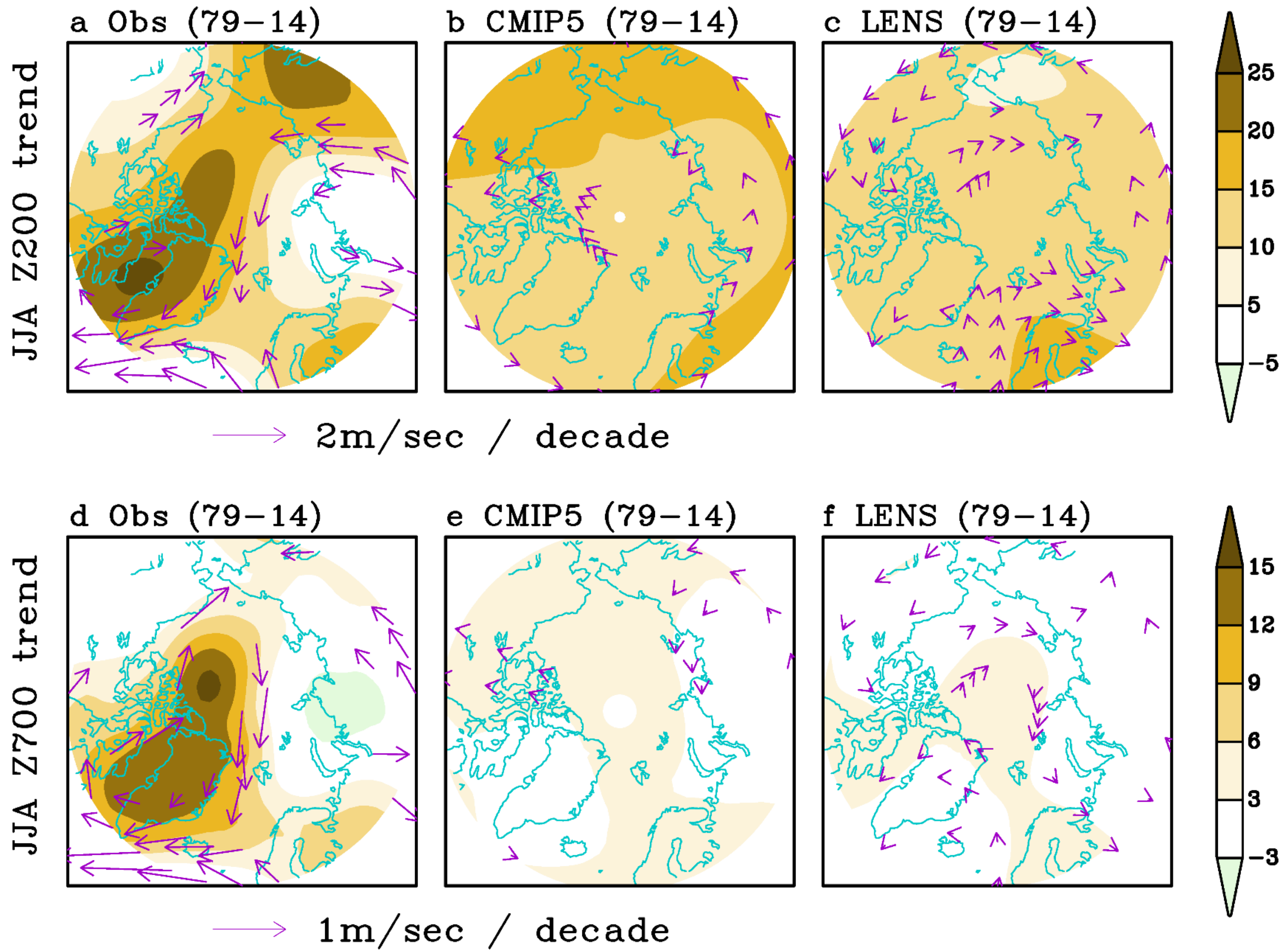


CMIP5

CESM-LENS

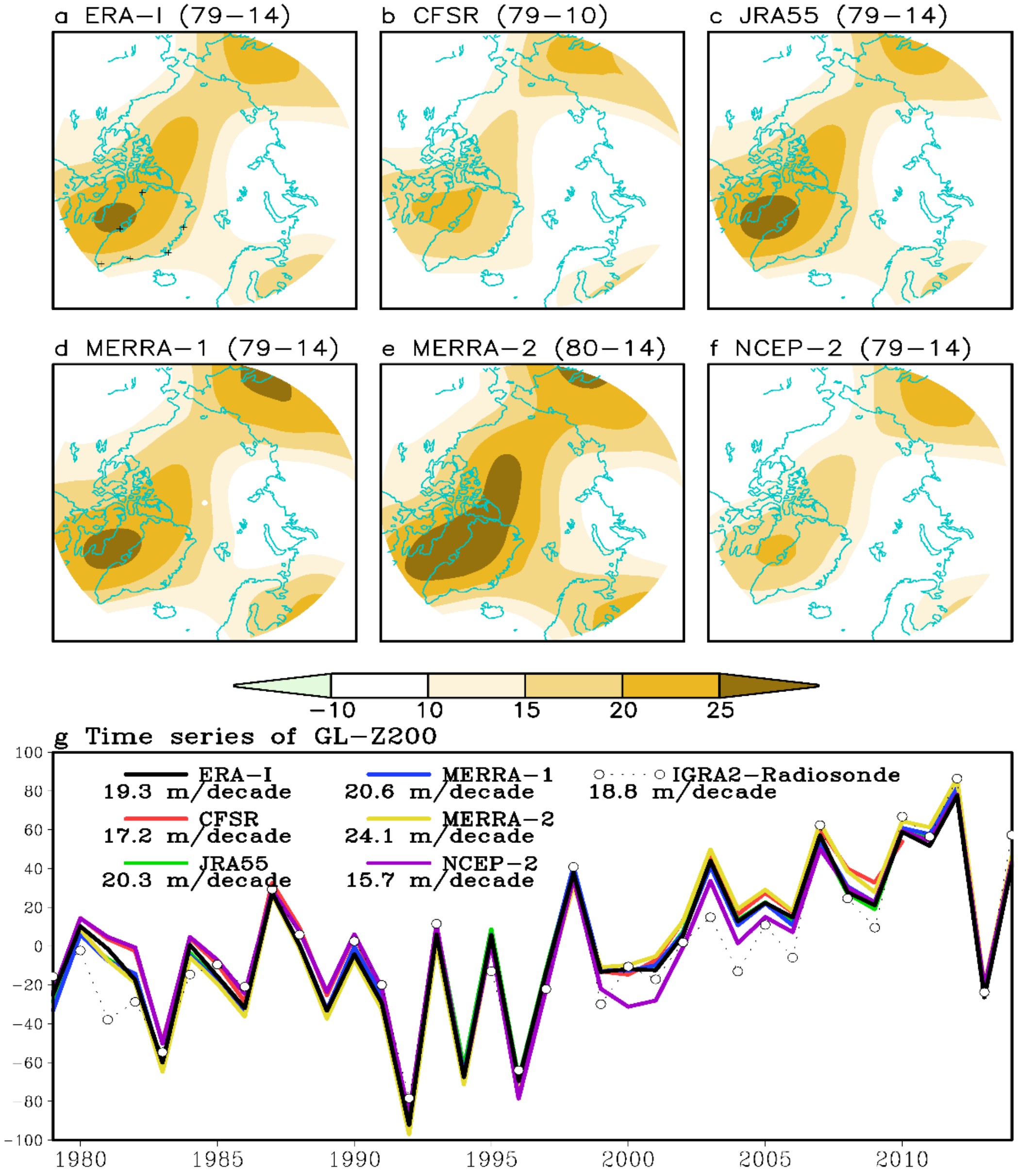
Ding et al 2017

Observed JJA height linear trends (1979-2014)



Ding et al 2017

JJA Z200 trends in the Arctic



Existing theories cannot fully explain observed sea ice trends in the Arctic

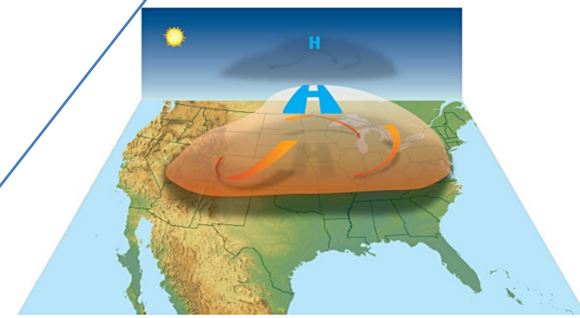
Anthropogenic thermal warming

↓

Arctic amplification

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

Atmospheric dynamical warming



Polar “heat wave”

Data, Models and Methods

DATA

- **Atmospheric reanalysis**
  1979-2014: ERA-interim, NCEPII, MERRA, CFS2
- **SST & sea ice**
  ERSST3, HADISST, Kaplan, COBE, NOAA/NSIDC
- **Surface temperature**
  GISS-TEMP, Delaware, CRU, ERA-interim, MERRA, AVHRR
- **IPCC AR5 historical run** (1979-2014)
- **NCAR CESM Large Ensemble Project**

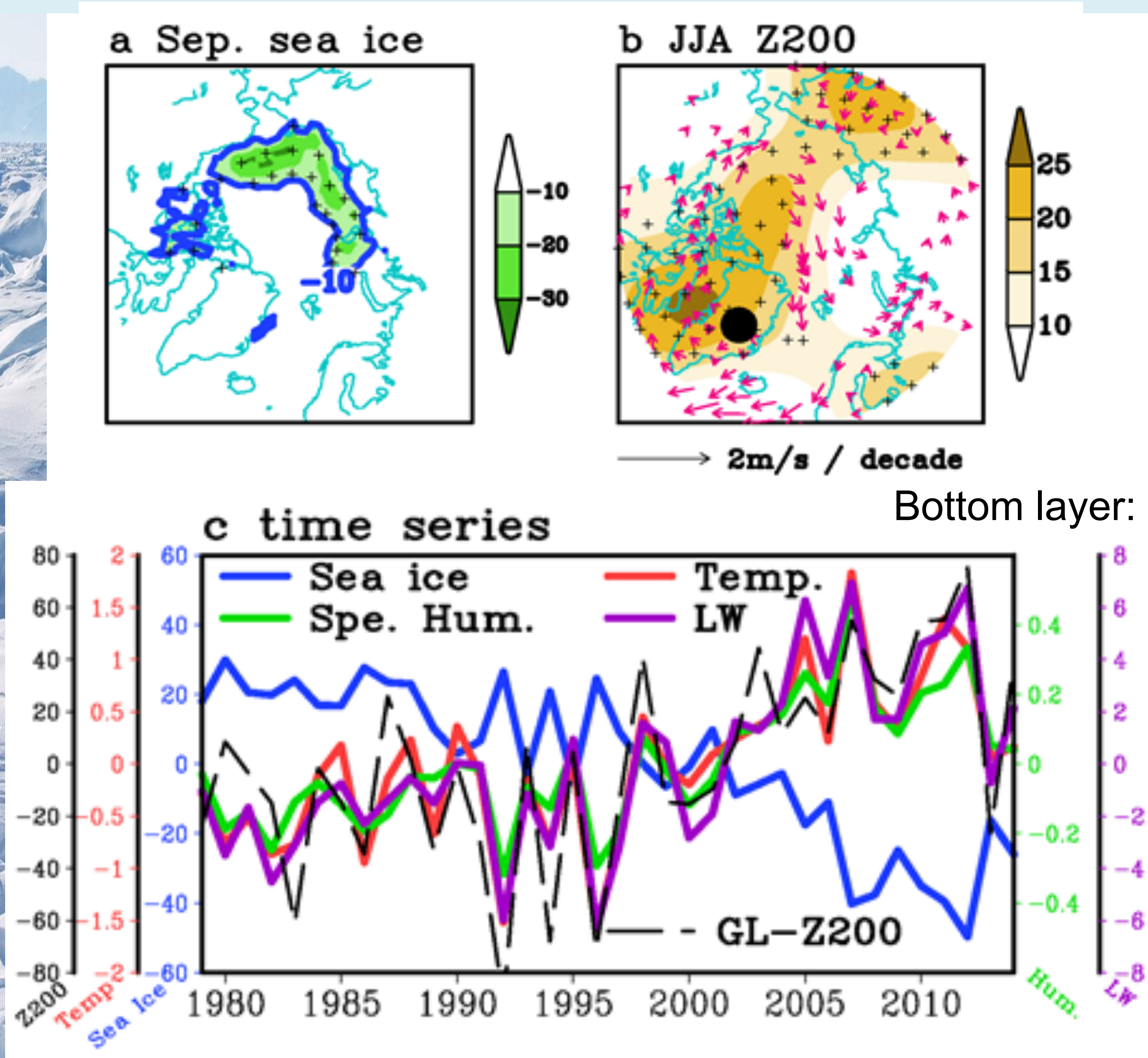
Models

- ECHAM5 model (T42L19)+ slab ocean/sea ice
- CESM1.2 (POP2+CICE2)

Methods

- Trend: epochal difference or linear trend
- Trend significance (signal to noise ratio, Mann-kendall test)
- Upper level circulation

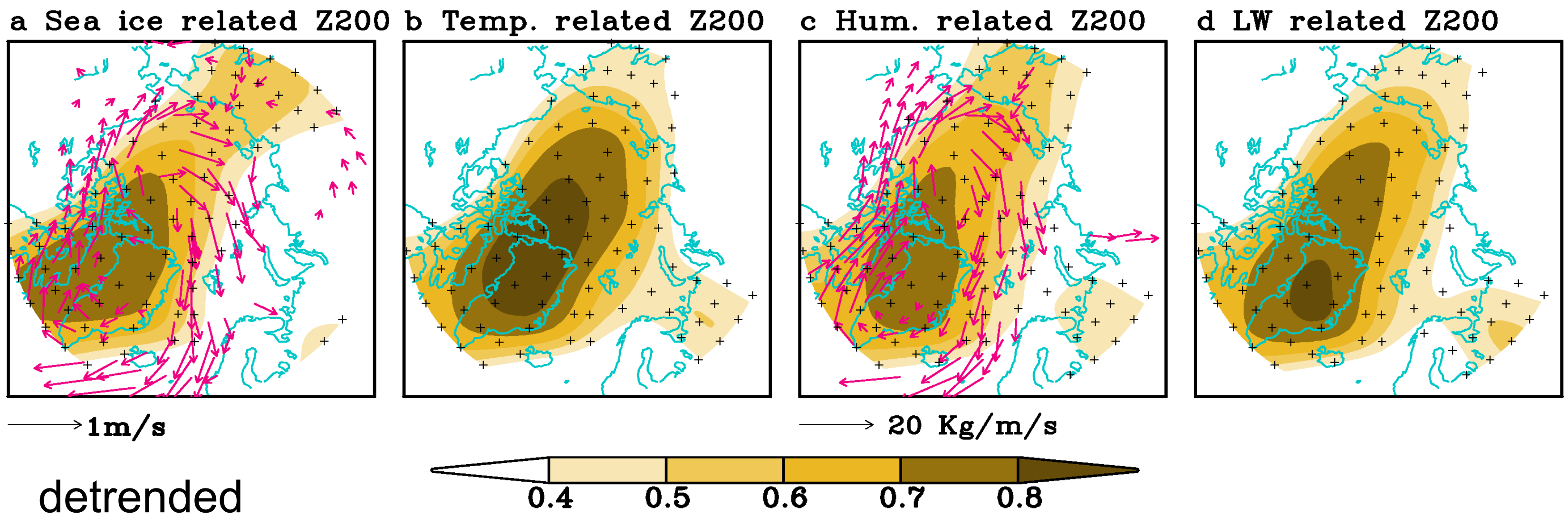
Summertime sea ice – atmospheric circulation coupling in the Arctic (1979-2014)

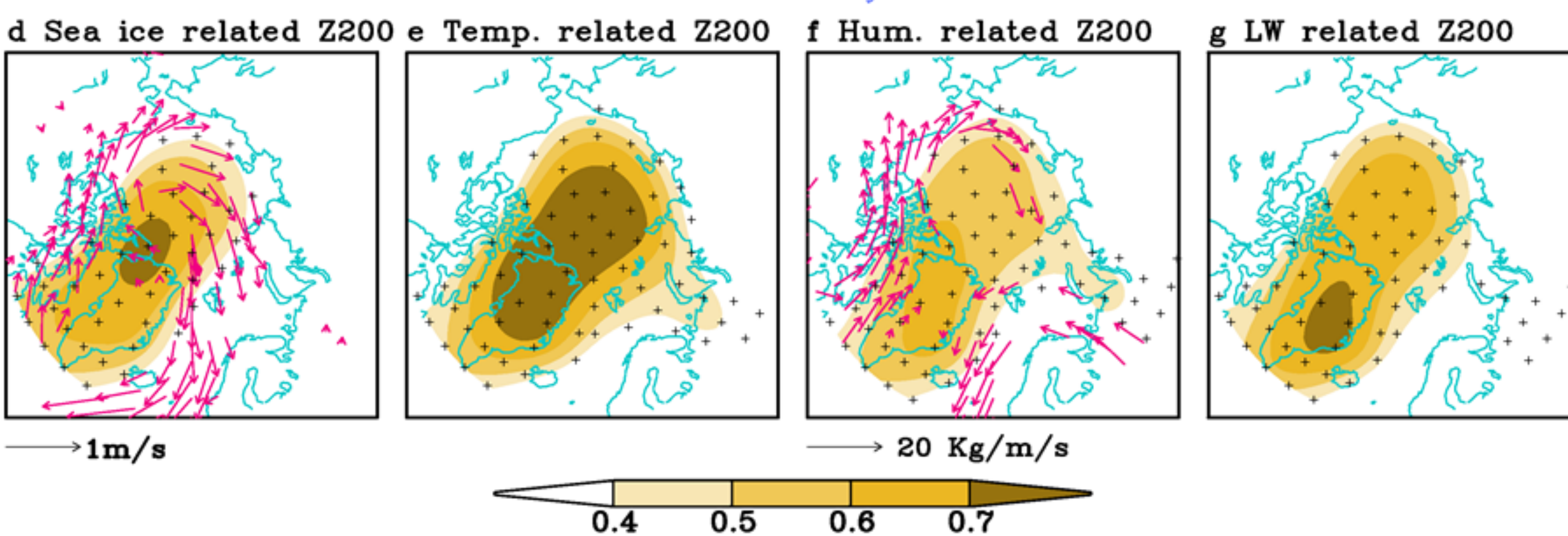


Bottom layer: surface-750hPa

Ding et al. 2017

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

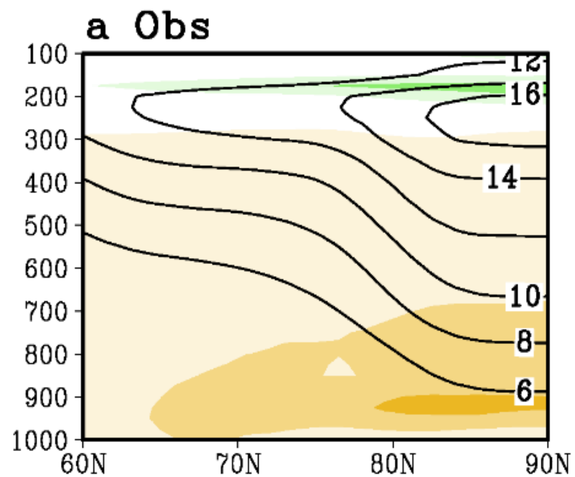




JJA

Linear trends of JJA Temp and Height (1979-2014)

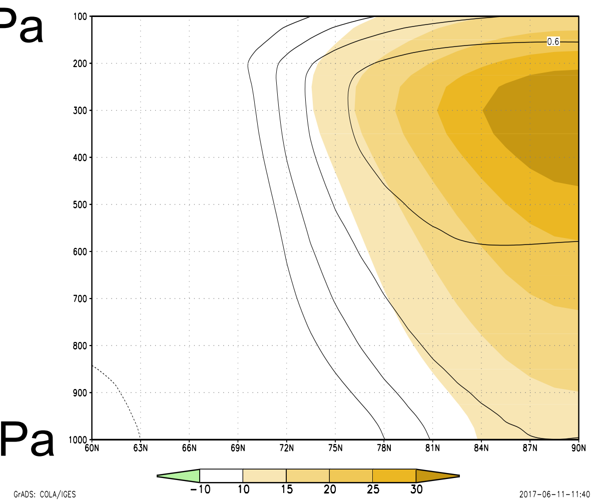
ERA-I



Corr between detrended Sep sea ice with

Detrended JJA height

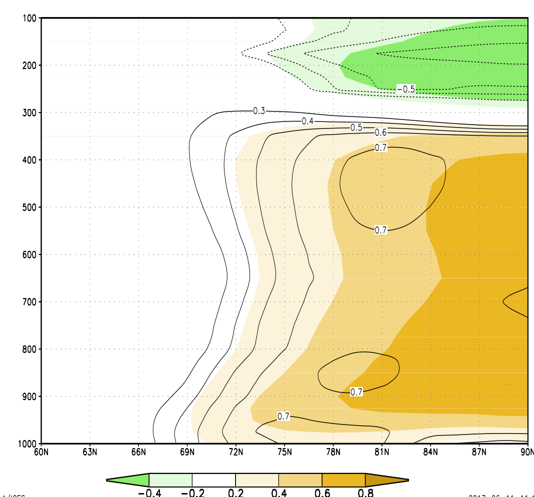
100hPa



1000hPa

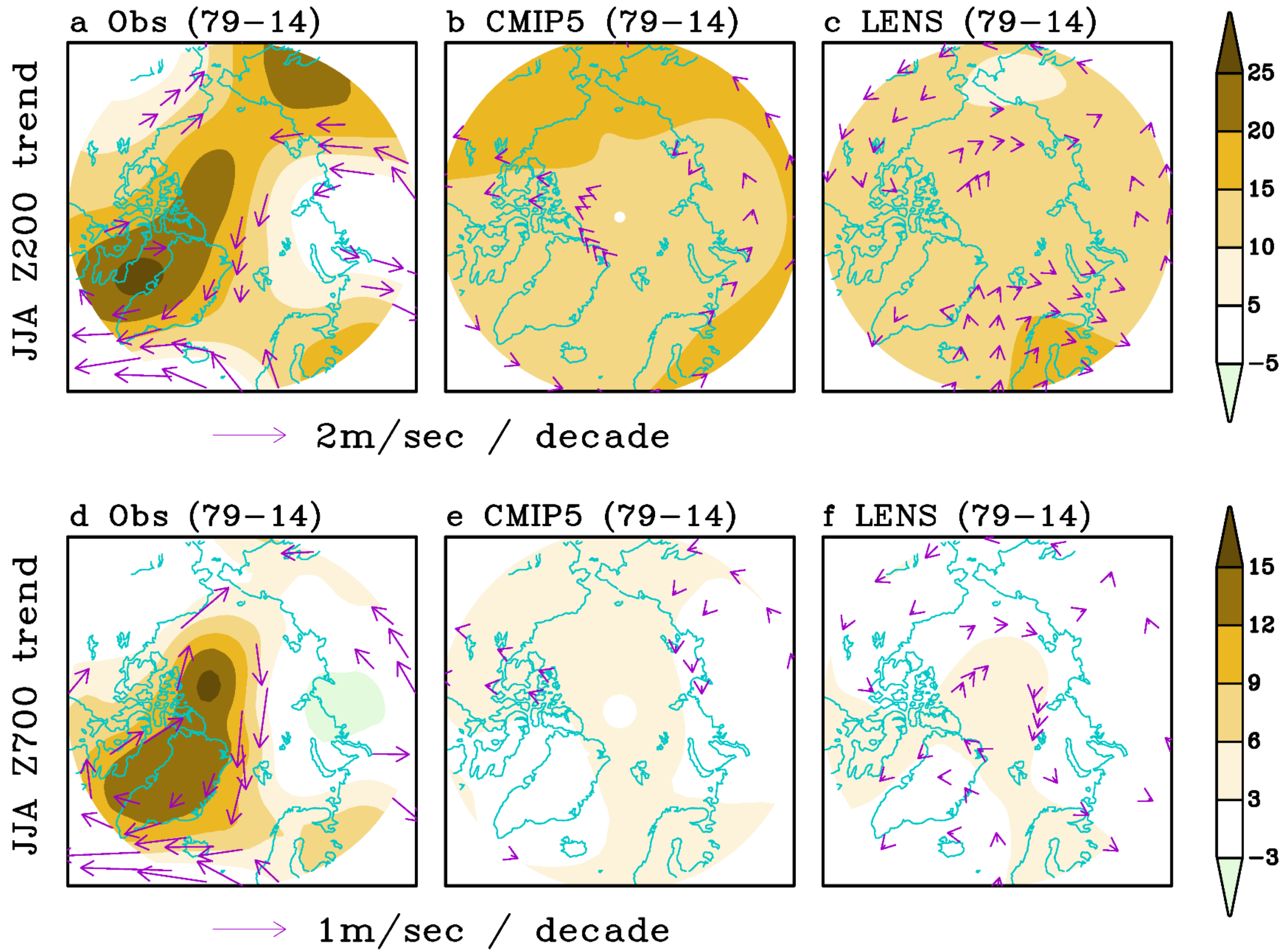
60N 90N

Detrended JJA Temp



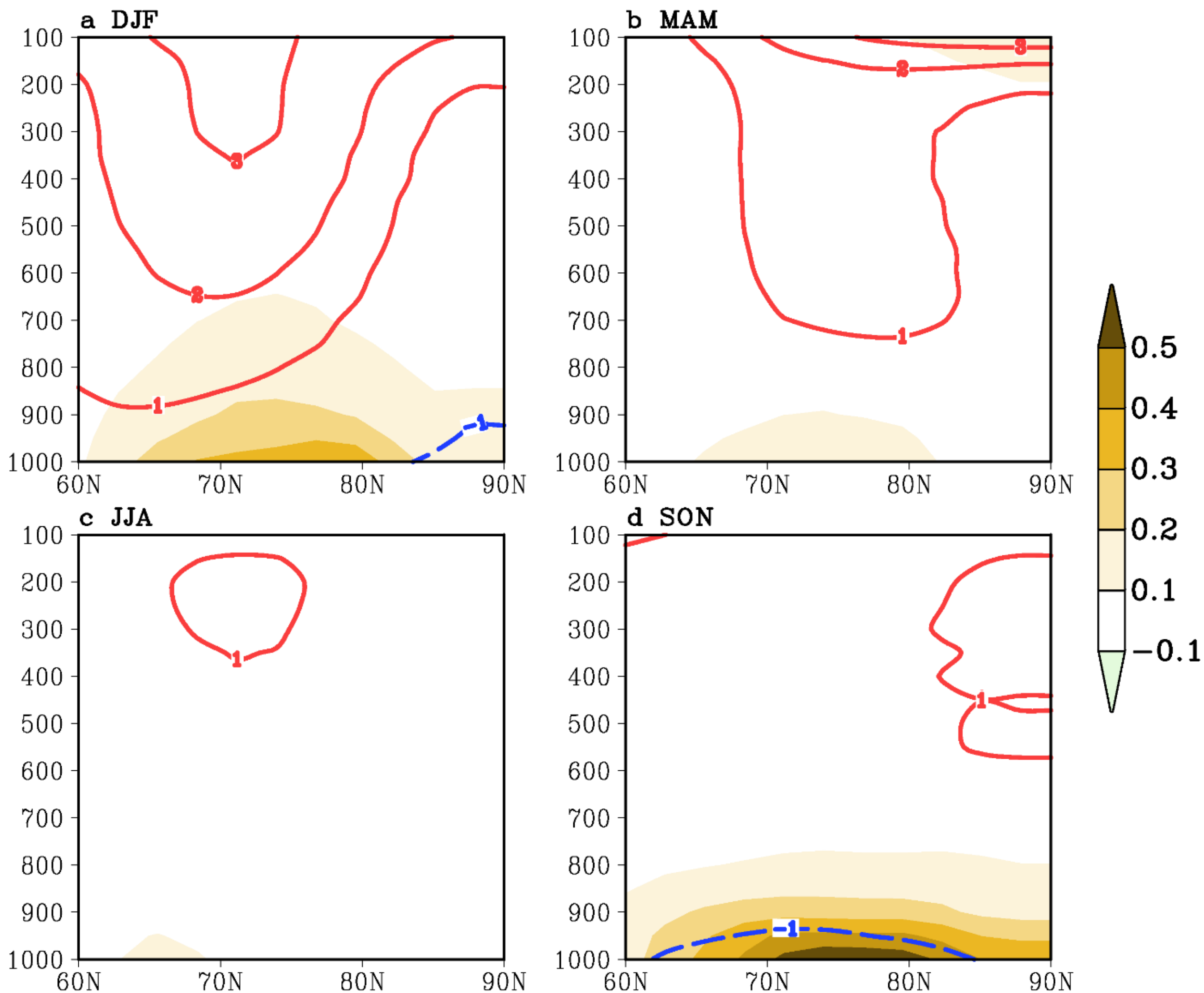
60N 90N

The models could similate the right sign of the obs due to a wrong reason



ECHAM5 run (sea ice melting: 1979-2014)

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

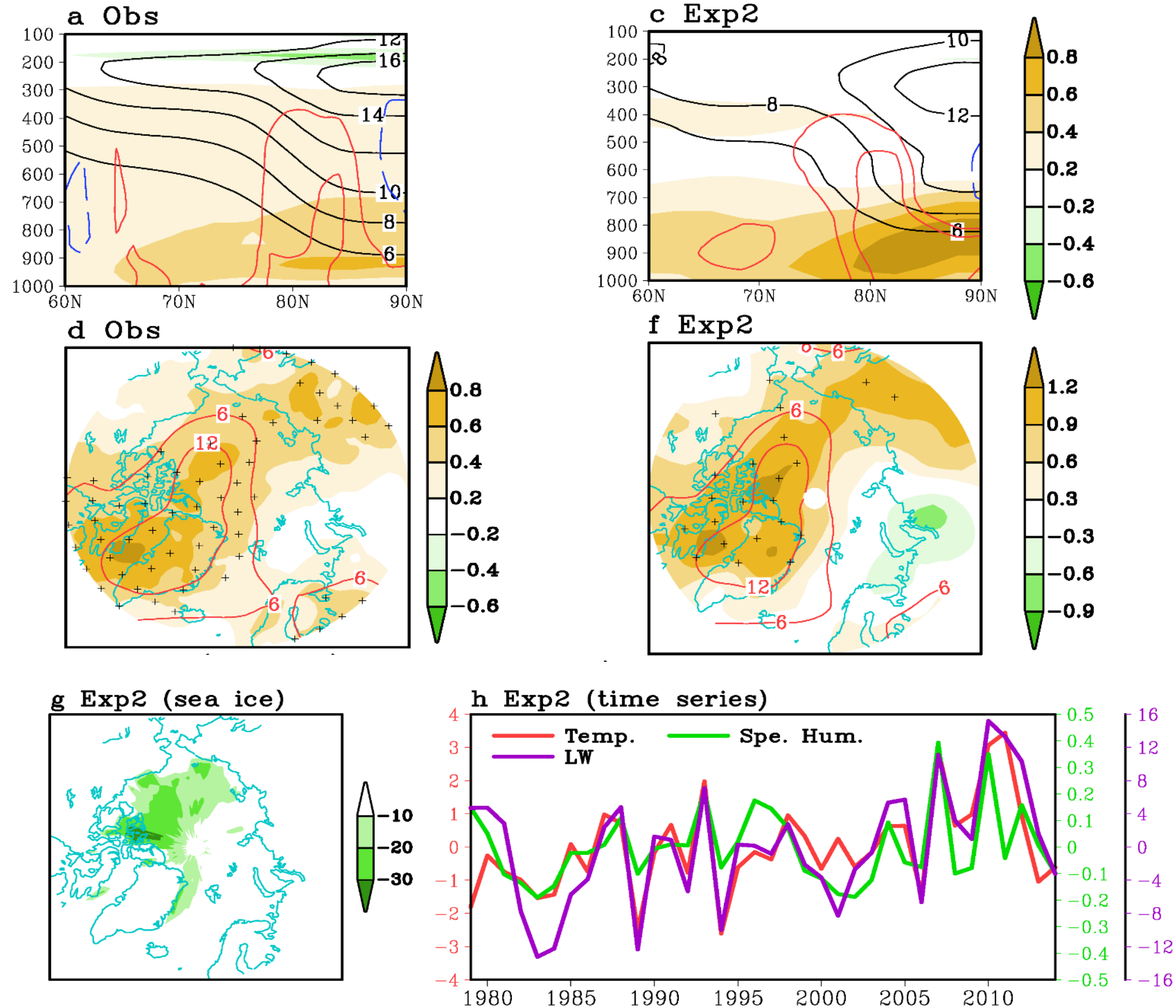


ECHAM5 with 3-D winds nudged to observation (1979-2014)

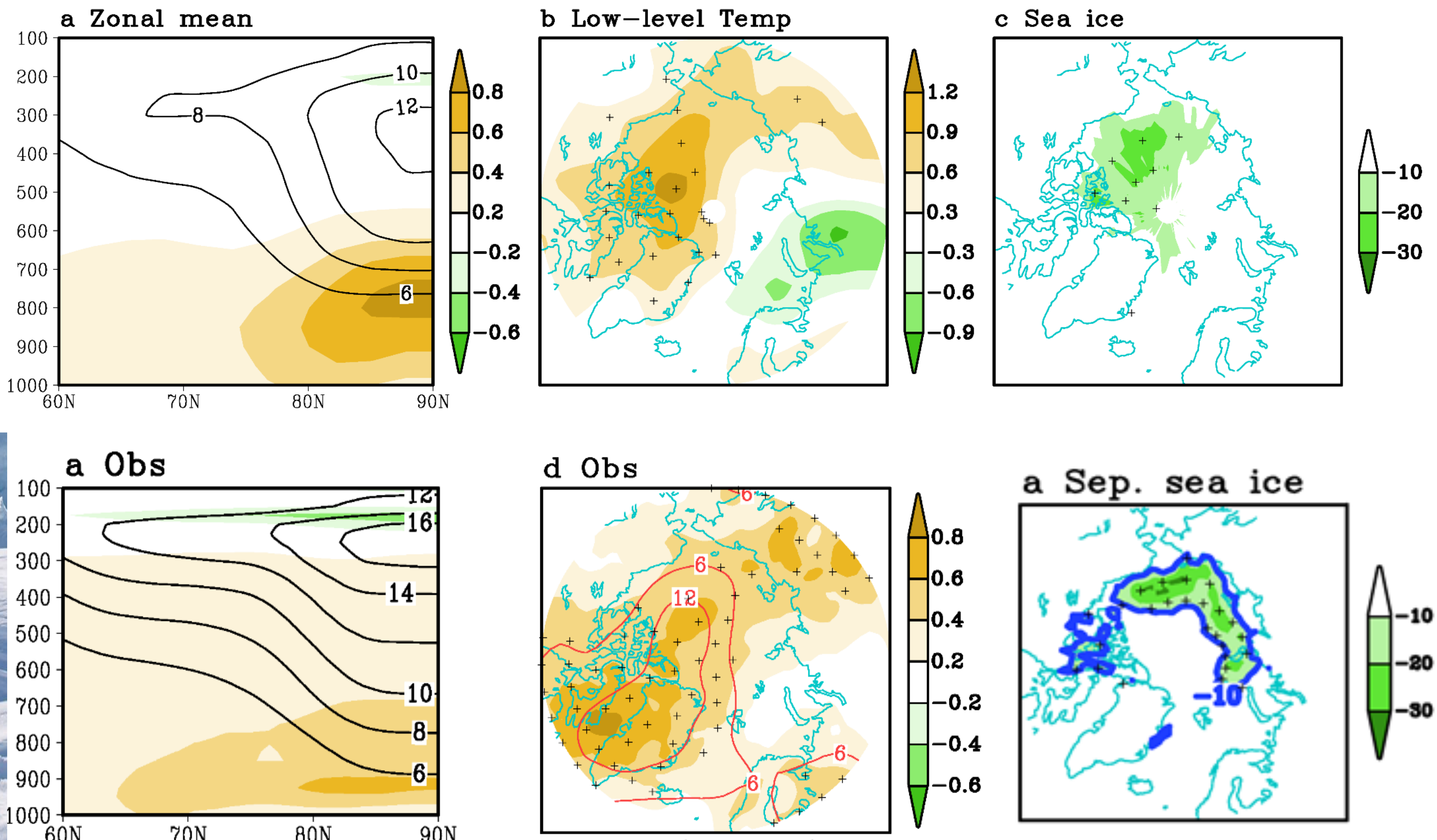
Shading: trend of JJA temperature since 1979
Contour: trend of JJA geopotential height since 1979

Zonal mean

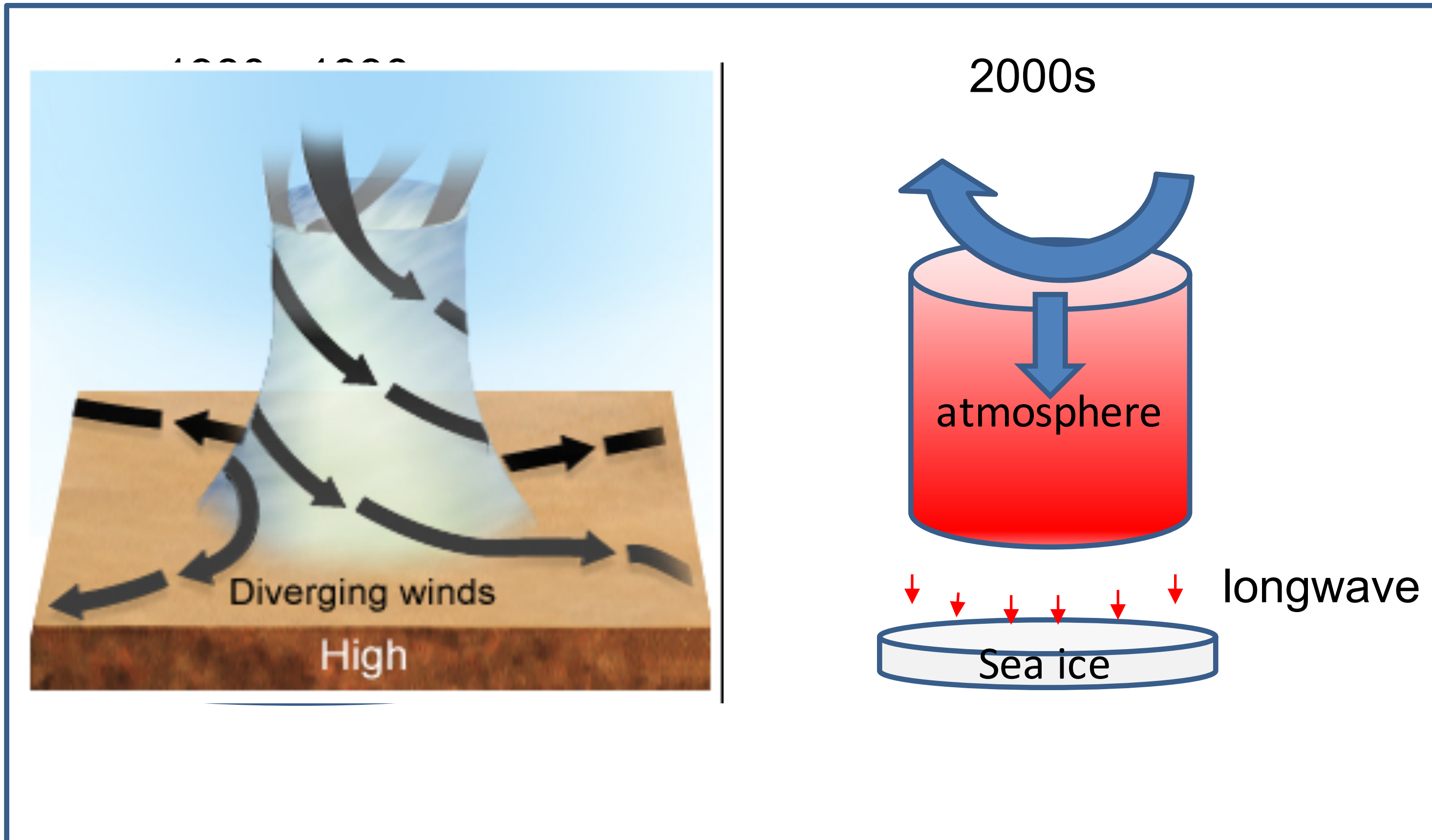
Temperature 1000-750hPa



ECHAM5 with 3-D winds nudged to observation (1979-2014) above 700hPa



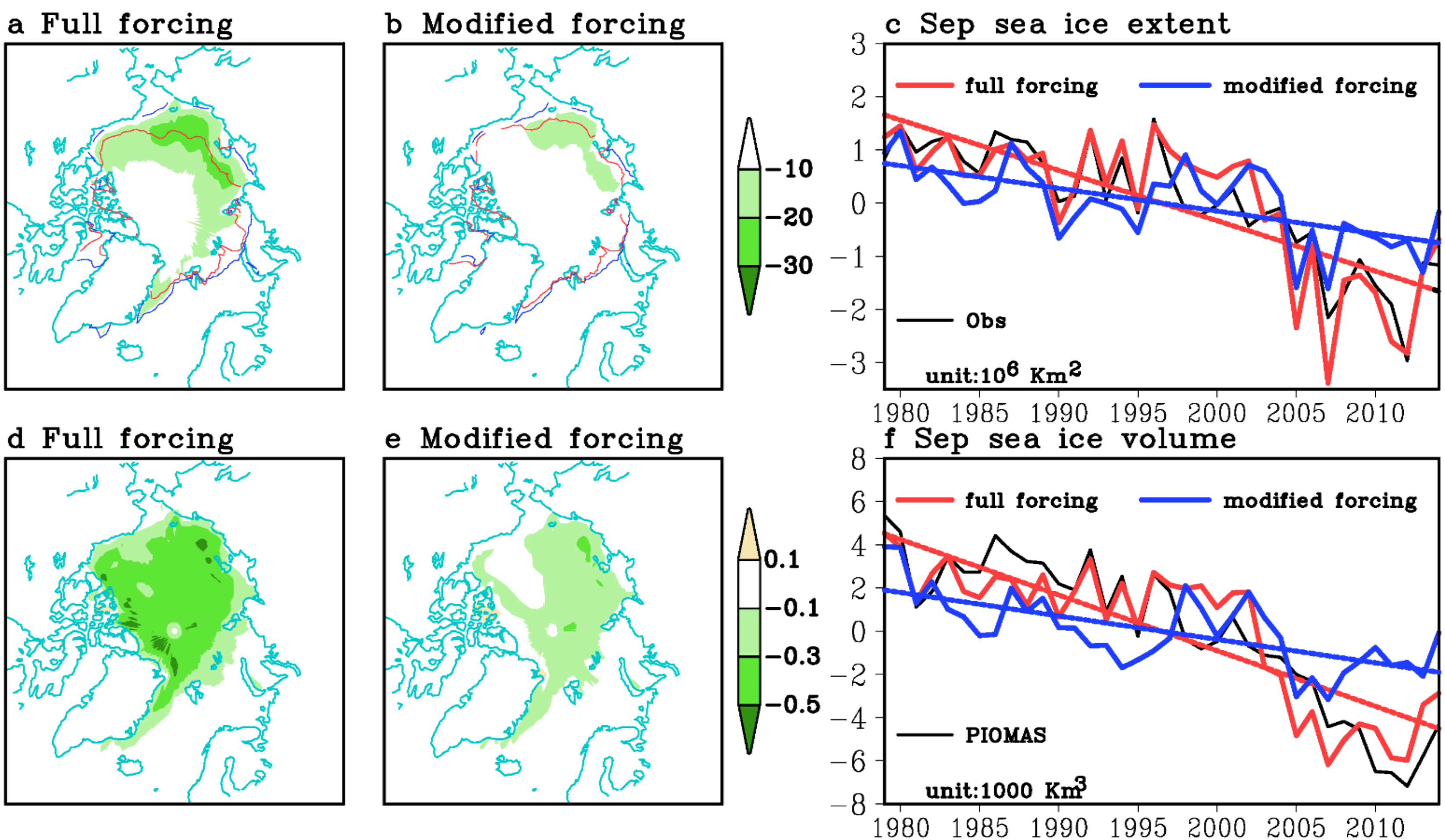
“Polar heat wave”



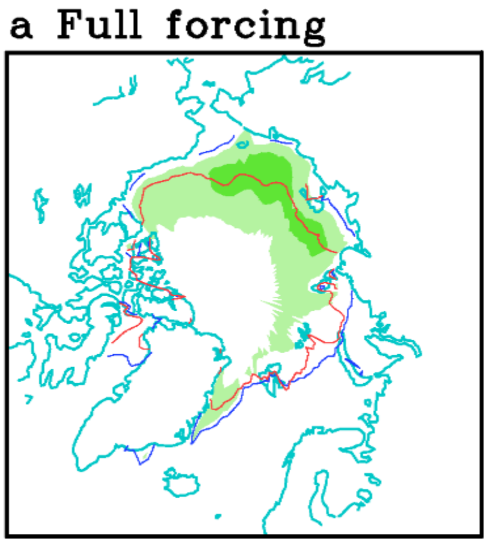
POP2+CICE4 forced by ERA-I forcing (1979-2014)

JJA circulation trend over Greenland could explain 60% of Sep sea ice melting

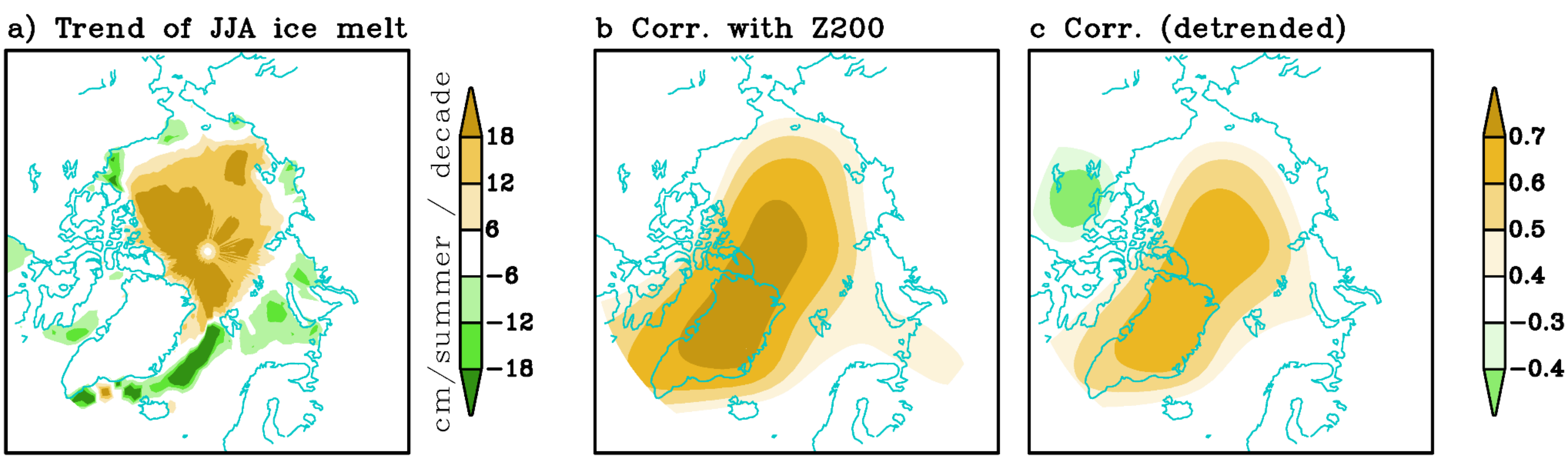
Linear trend of Sep sea ice extent/thickness



Linear trend of Sep sea ice extent



Trend of JJA total melting (1979-2014)



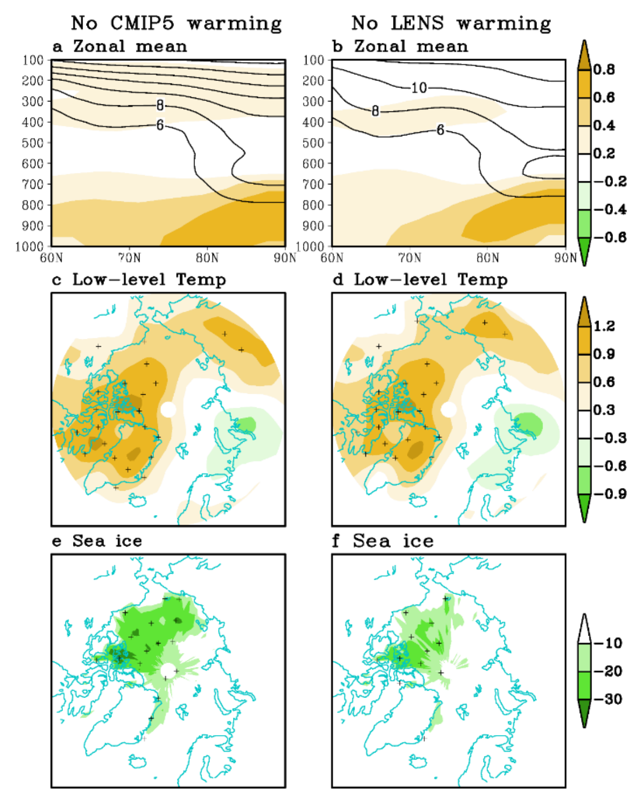
Contribution of anthropogenic forcing in generating the Z200 trend over Greenland (20m/decade) 1979-2014

1. Short obs (since 1979): JJA global mean Z200 trend (6m/decade) (30%)
2. Long term obs (from 1950s to 2010s): Z200 trend over Greenland (5m/decade) (25%)
3. CMIP5 (50% to 20%)
4. ECHAM5 simulation (30%- 10%)

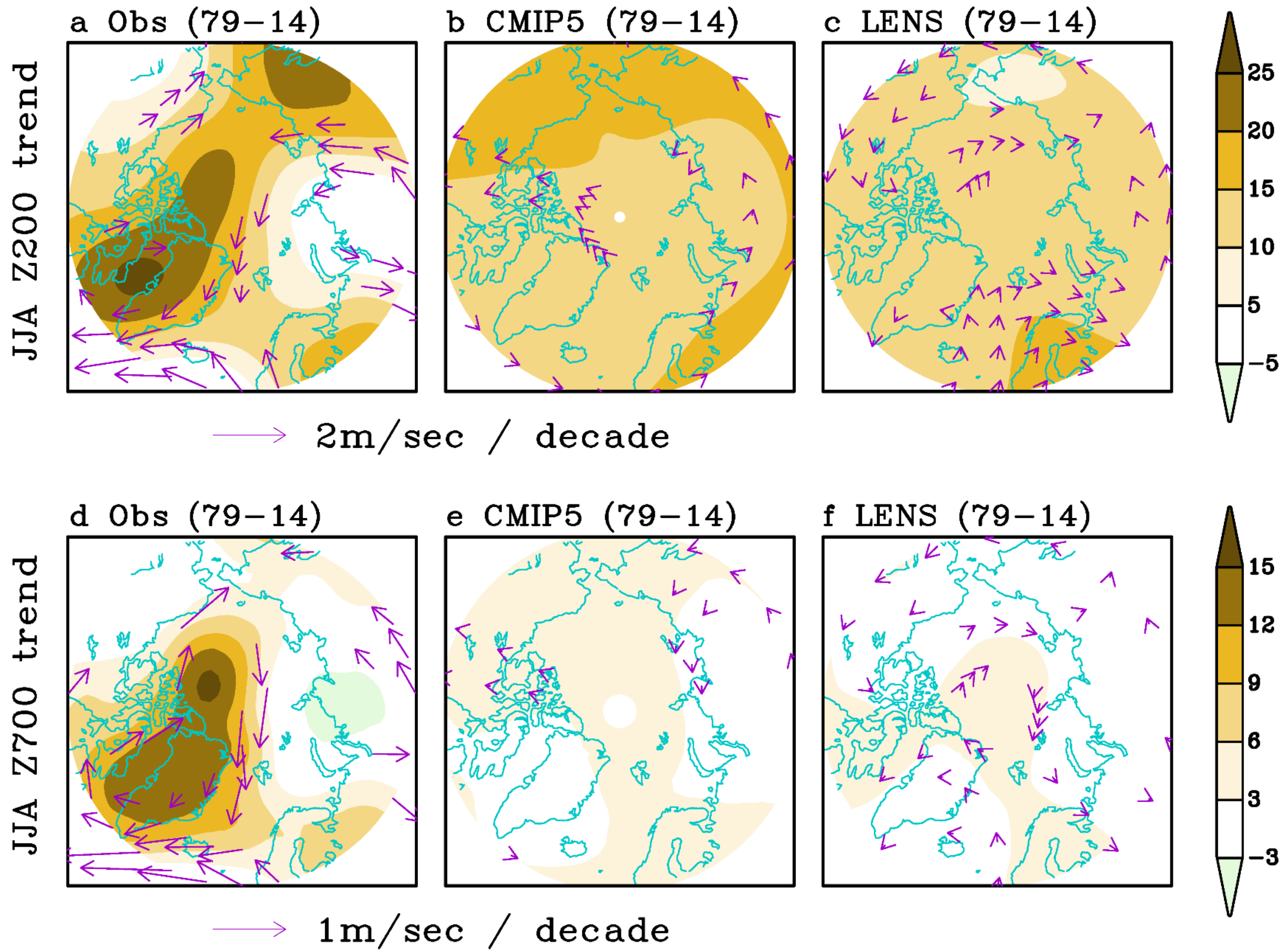
~30%

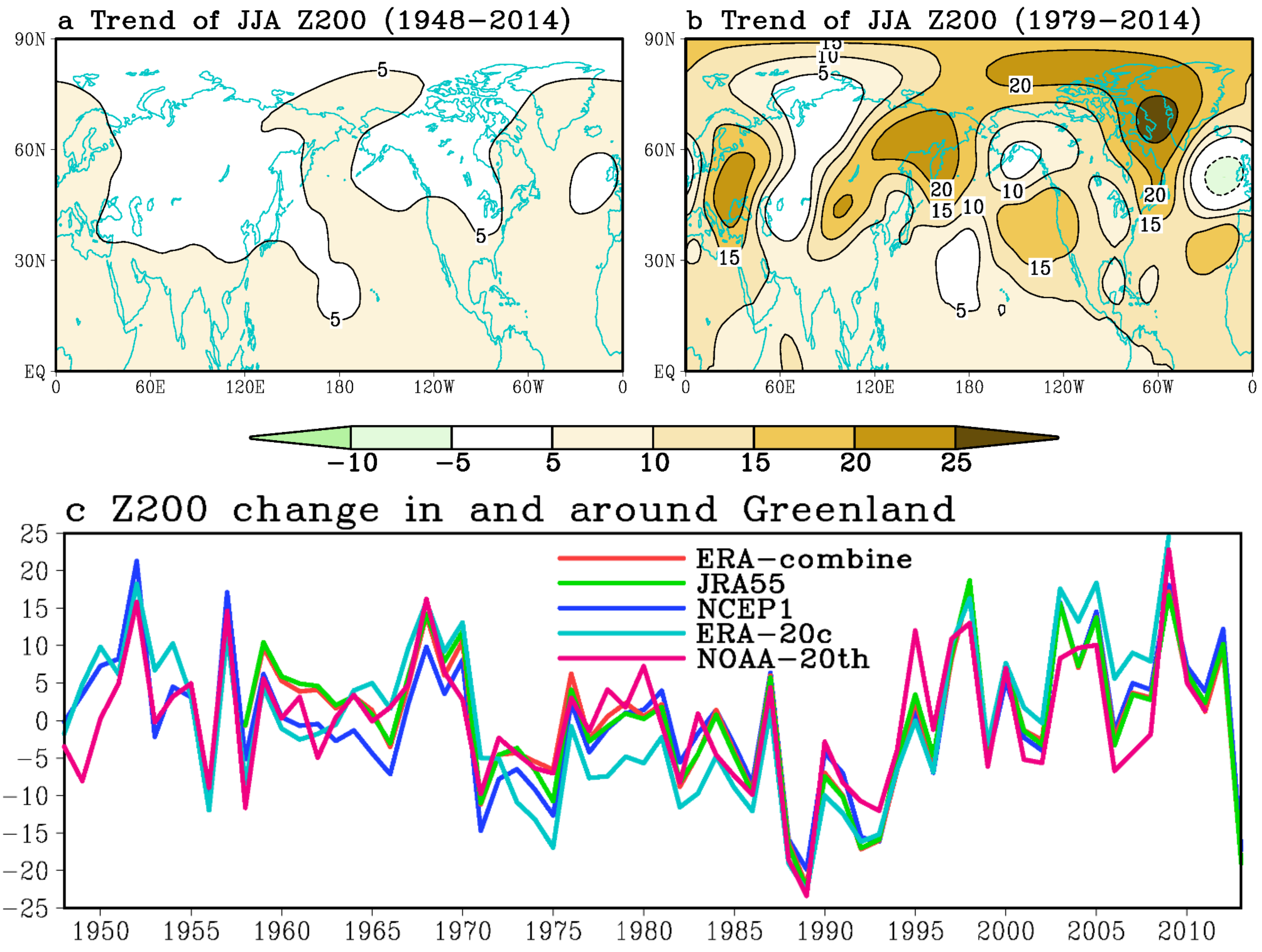
60% × (1-30%) = 40%

Internal circulation changes contributes 40% of sea ice melting



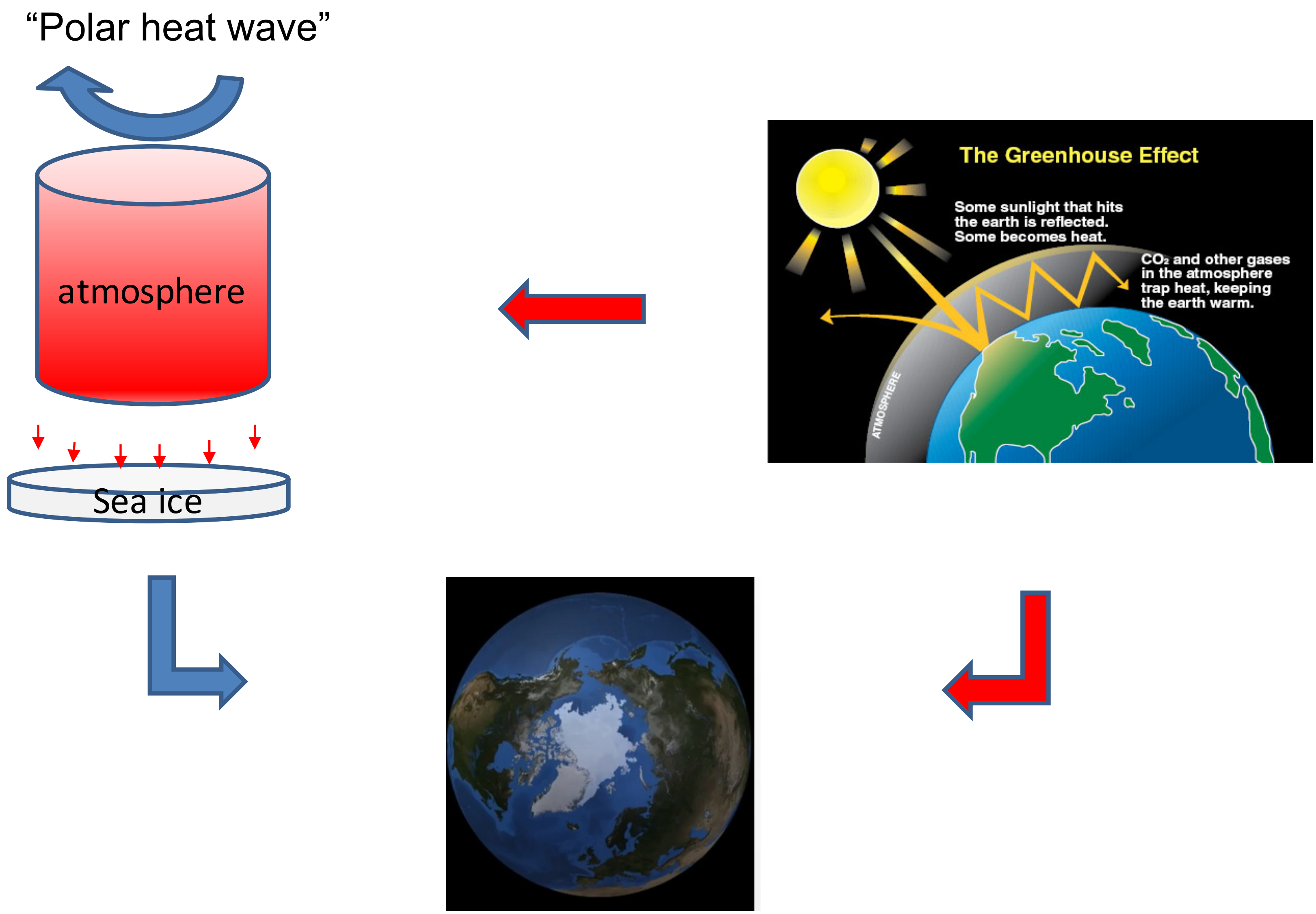
Different vertical structure between the obs and model results





a Trend of JJA Z200 (1948–2014)
b Trend of JJA Z200 (1979–2014)
90N
60N
30N
EQ
0
60E
120E
180
120W
60W
0
−10
−5
5
10
15
20
25
c Z200 change in and around Greenland
ERA−combine
JRA55
NCEP1
ERA−20c
NOAA−20th
25
20
15
10
5
0
−5
−10
−15
−20
−25
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Take-home message

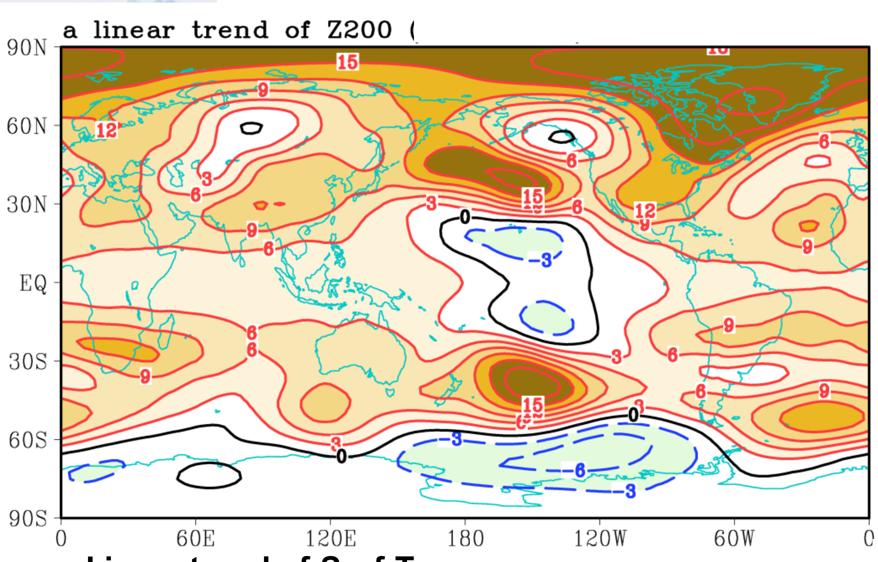


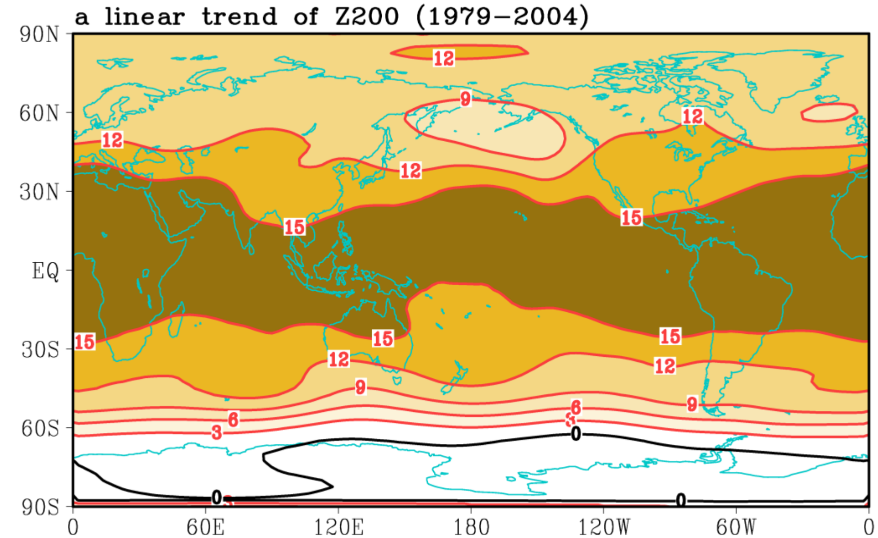
Internal variability vs forced response

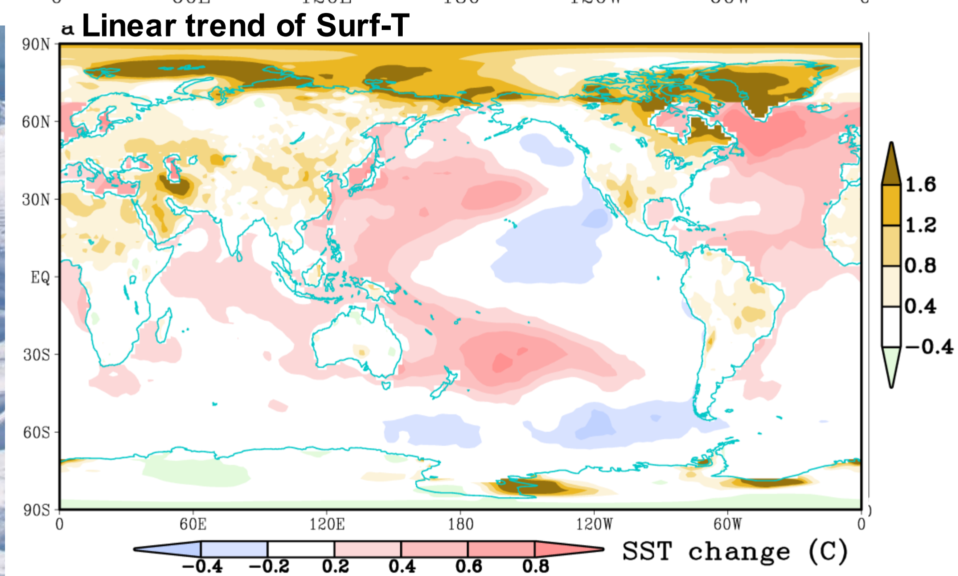
Annual mean
m/decade

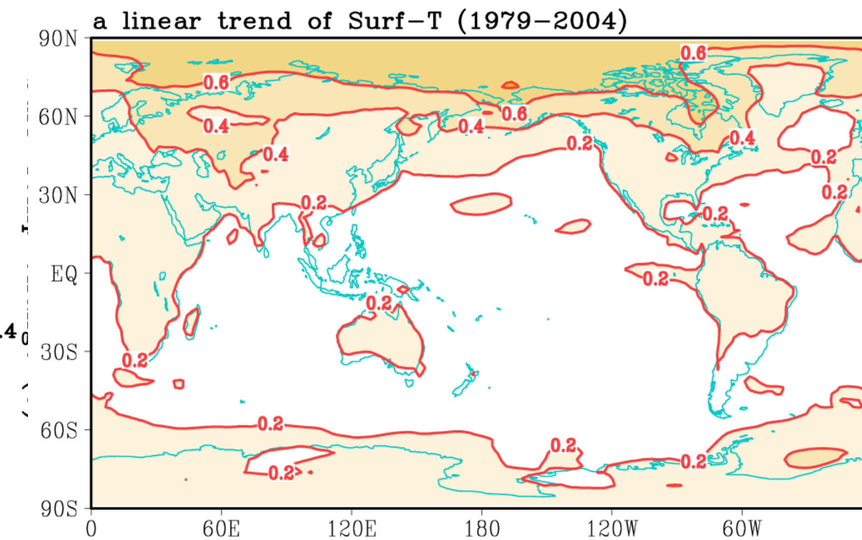
Observation (1979-2013)

IPCC AR5 historical run
(ensemble mean of 40 model)





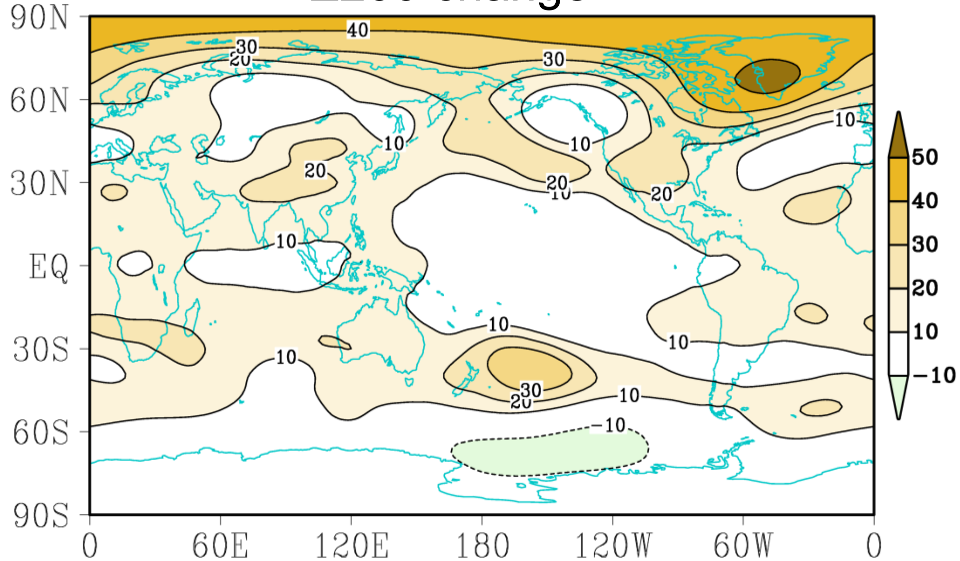




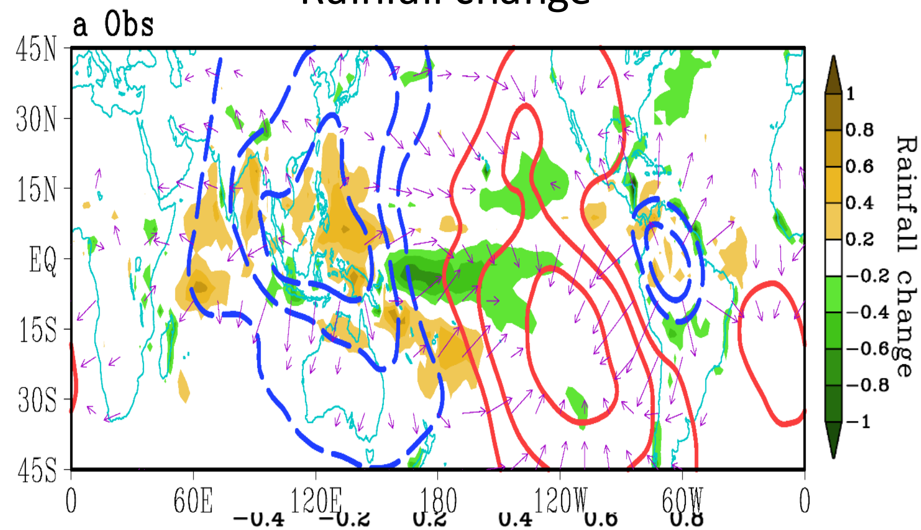
Ding et al. 2014

Annual mean Z200 and SST change (1996-2013 minus 1979-1995)

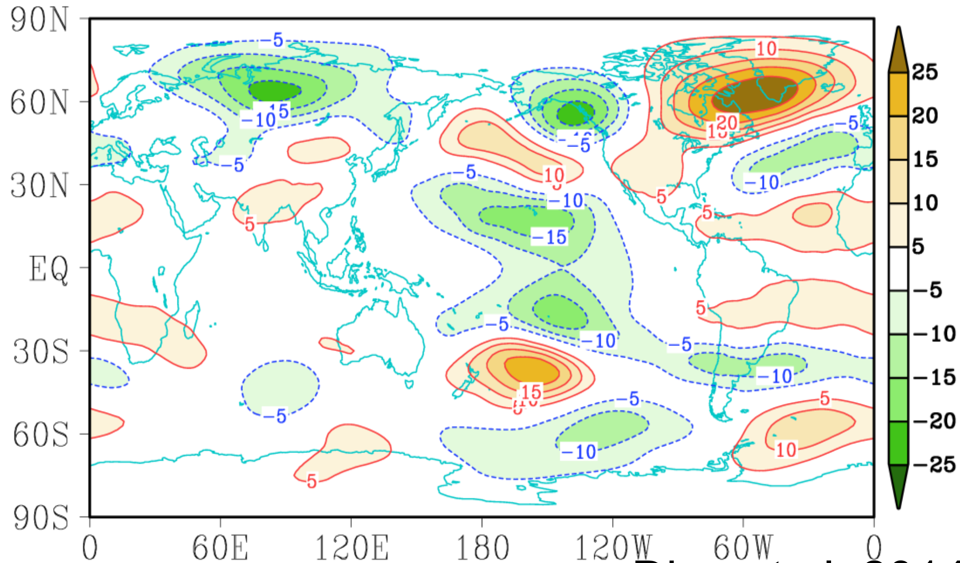
Z200 change

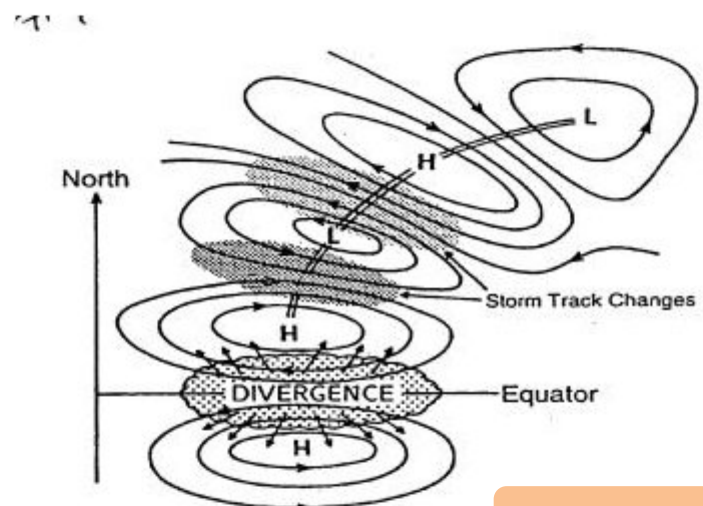


Rainfall change



Non-zonal

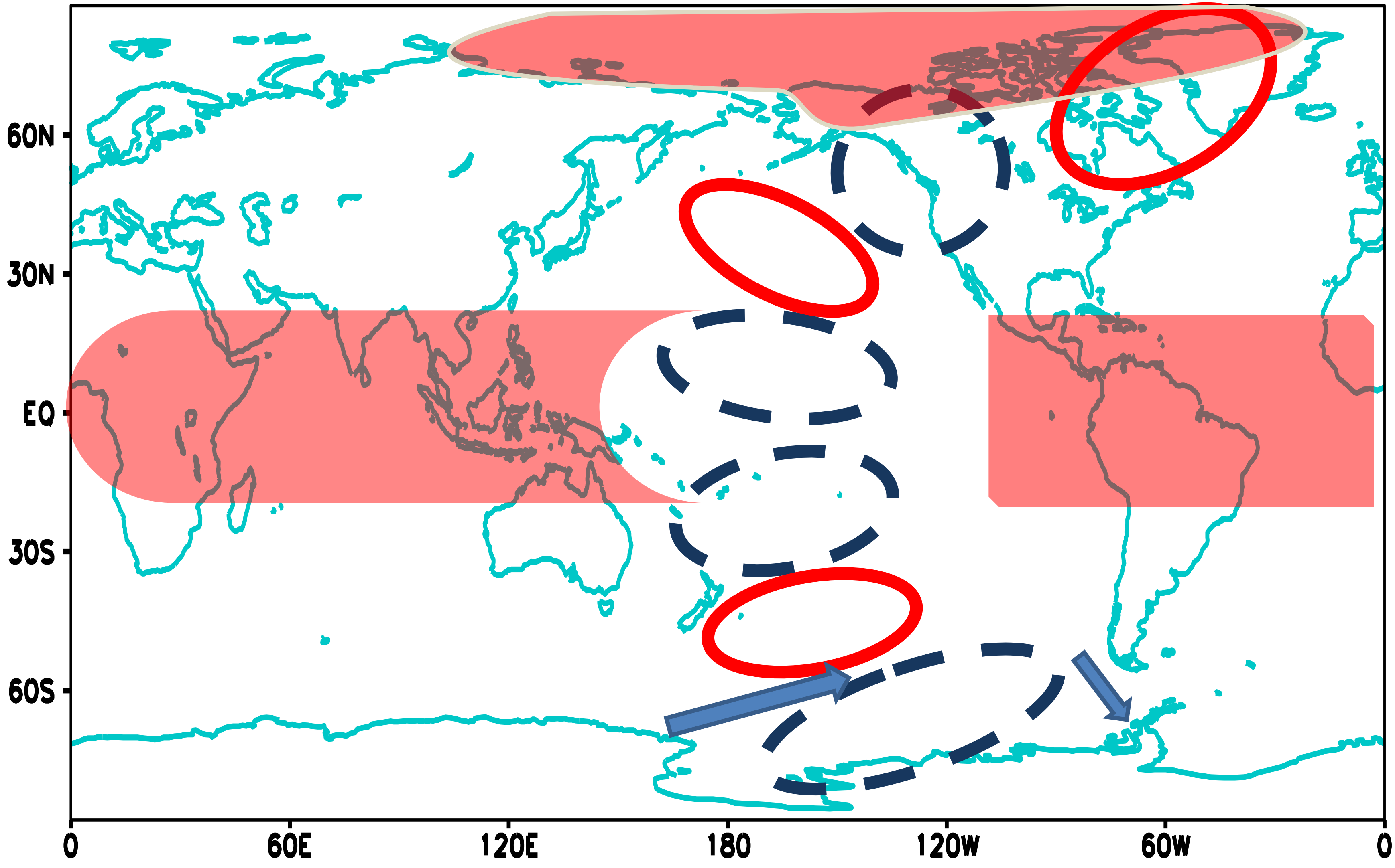




Ding et al. 2014

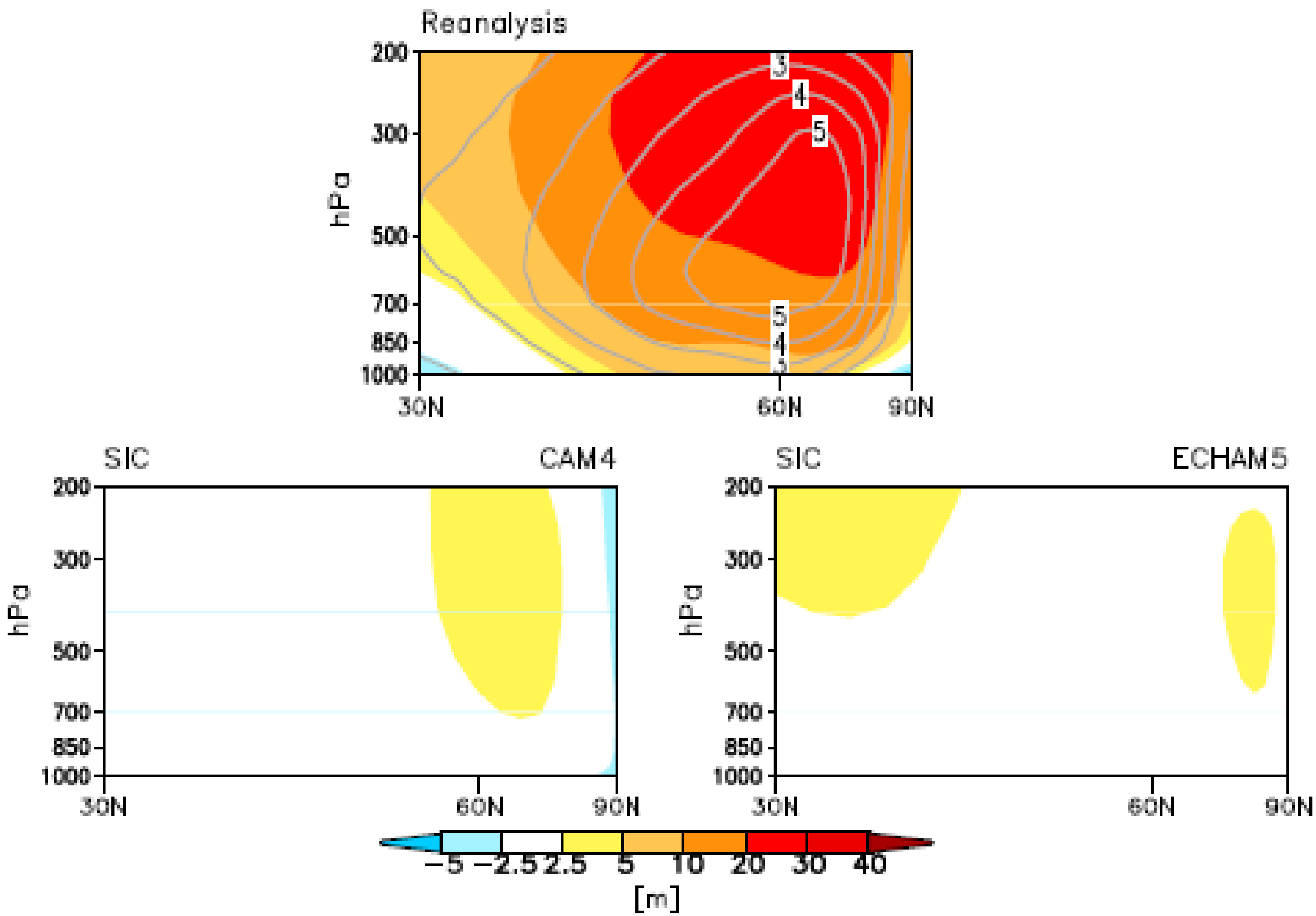
Trenberth 1995

Tropical forcing is partly causing the recent sea ice change in the Arctic



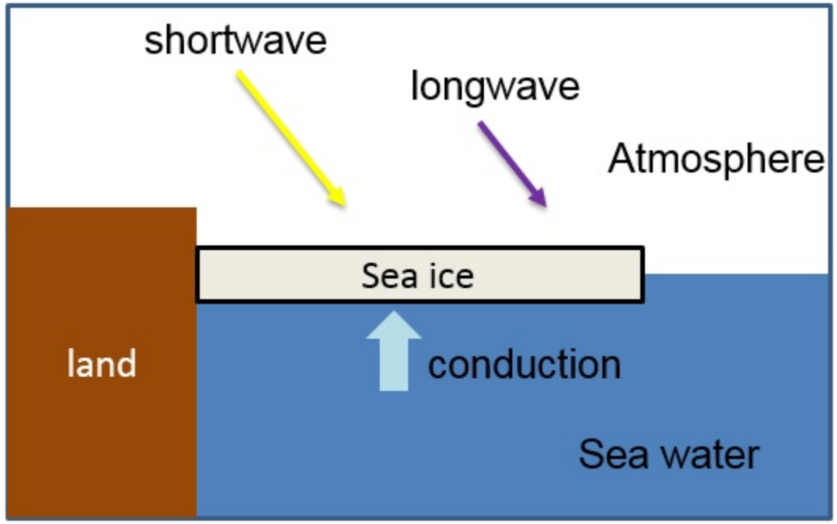
Atmospheric circulation change in the Arctic is not due to sea ice melting

Shading: trend of zonal mean geopotential height since 1979



Perlwitz et al. 2015

Sea ice melting process



JJA downward SW and LW (at surface) in the Arctic (70ºN-90ºN)

W/m2