Arctic sea ice reduction under global change:

in association with deterioration of Greenland and Antarctic ice sheets

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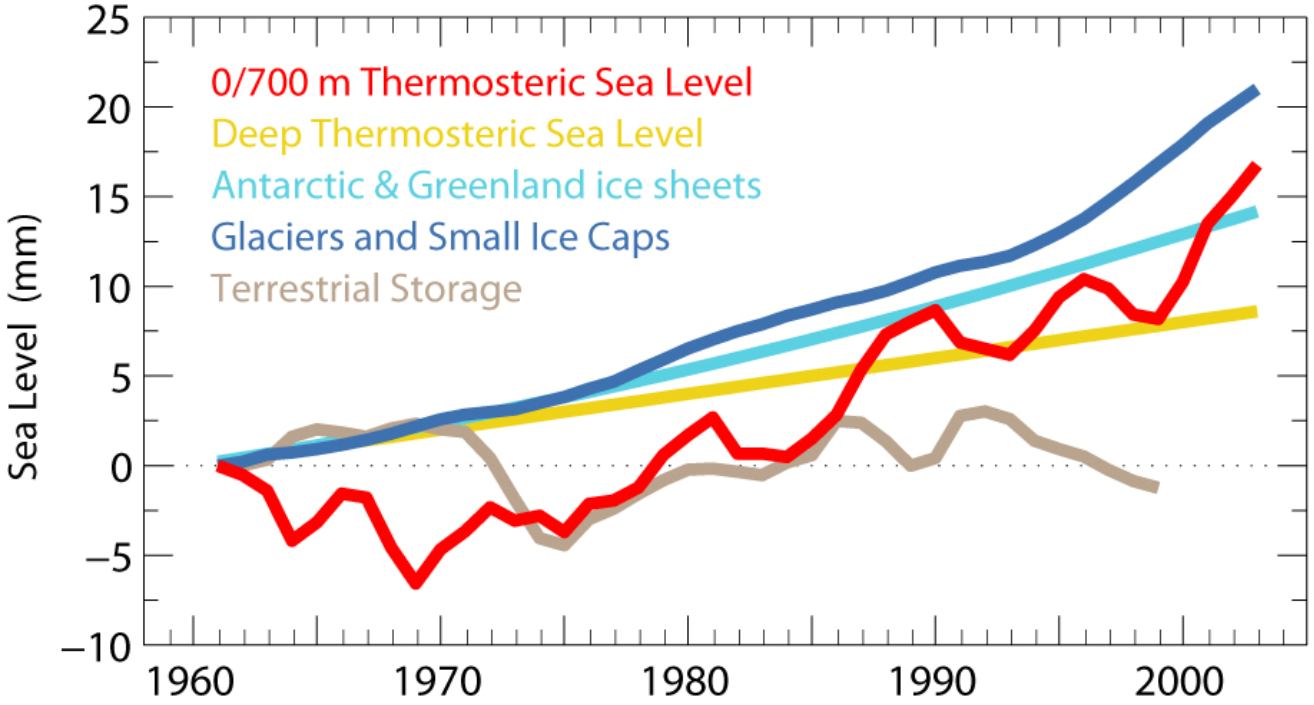
Sea-level rise addition due to ice sheet melting



Thermal expansion is main, while ice sheet melting is also important.

Deep ocean (Antonov et al., GRL, 2005; Kohl et al., JPO, 2007).

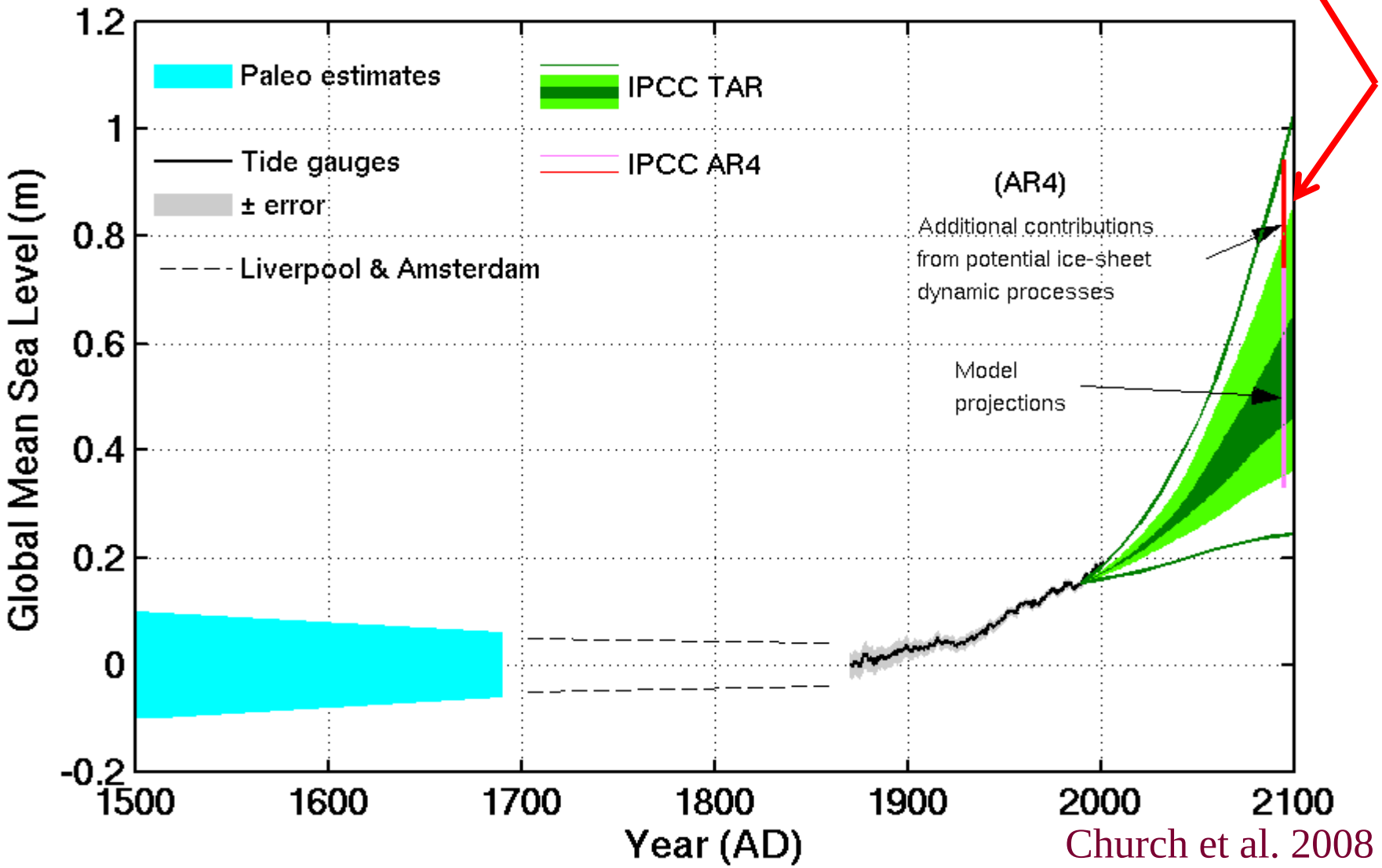
Ice sheets (Lemke et al., IPCC, 2007)

Glacier and small-ice caps (Dyurgerov and Meier, 2004).

Terrestrial storage (Ngo-Duc et al., GRL, 2005).

IPCC projection as the lower limit

Ice sheet melting is additional.



Church et al. 2008

Distinct Indicator
Arctic sea ice

Indigenous people

Polar bear

How soon will the Arctic sea ice change to a seasonal one?

- IPCC Report prediction:

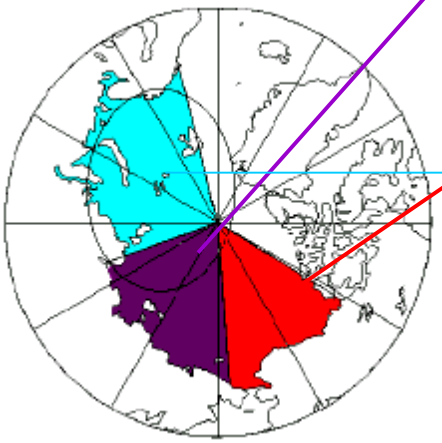
  the ice cover in summer will disappear near the end of the 21st century.
- The anomalously small ice cover in 2007 summer >>some specialists believe disappearance by 2020
- Significant year-to-year variability

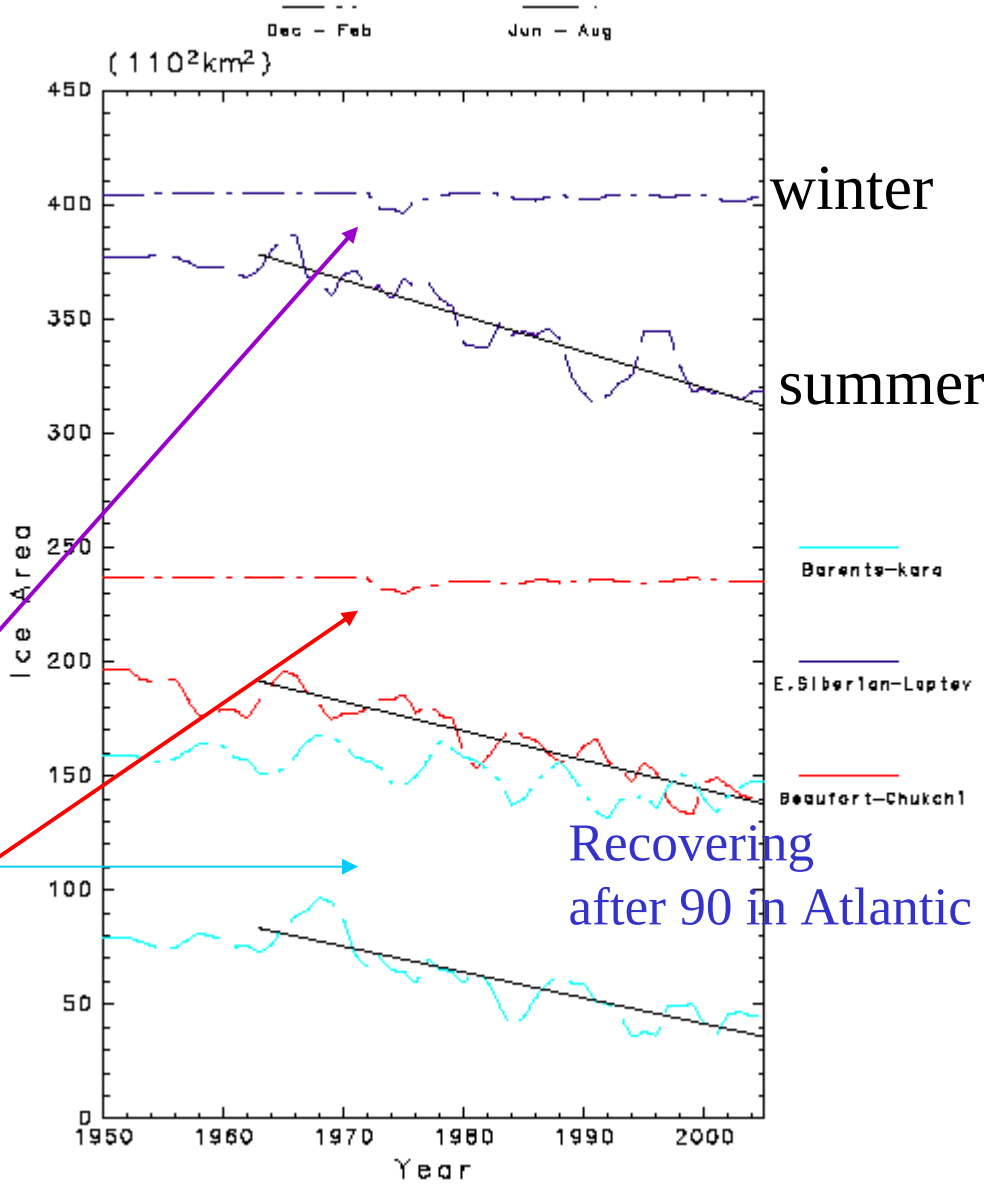
  >>such an early disappearance is exaggeration!?

Ice cover trend and decadal variability

Wang and Ikeda (GRL, 2001)+ α

- Winter (DJF) and summer (JJA)
- Beaufort and Chukchi
- East Siberian and Laptev
- Barents and Kara





winter

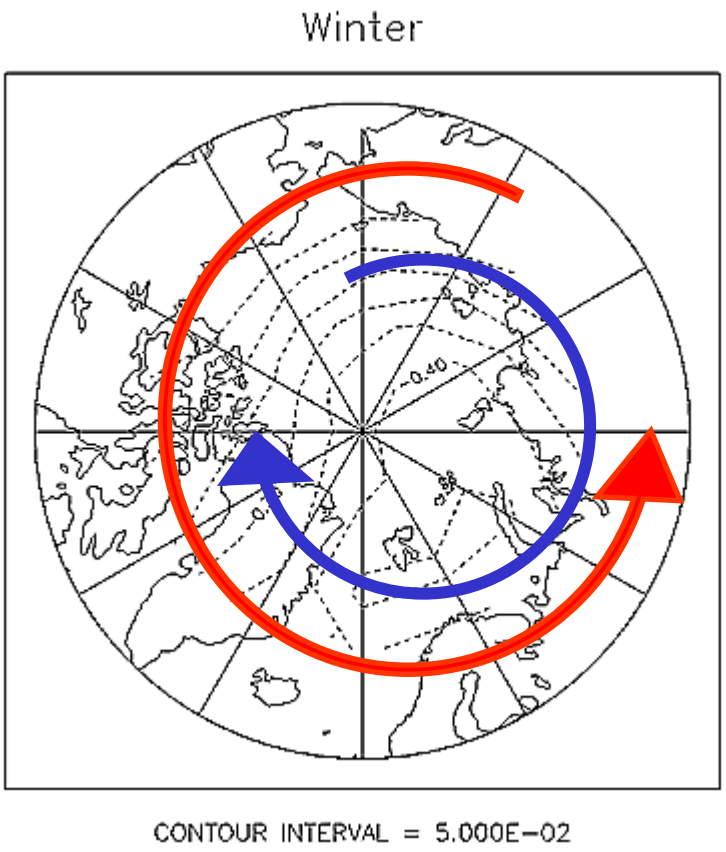
summer

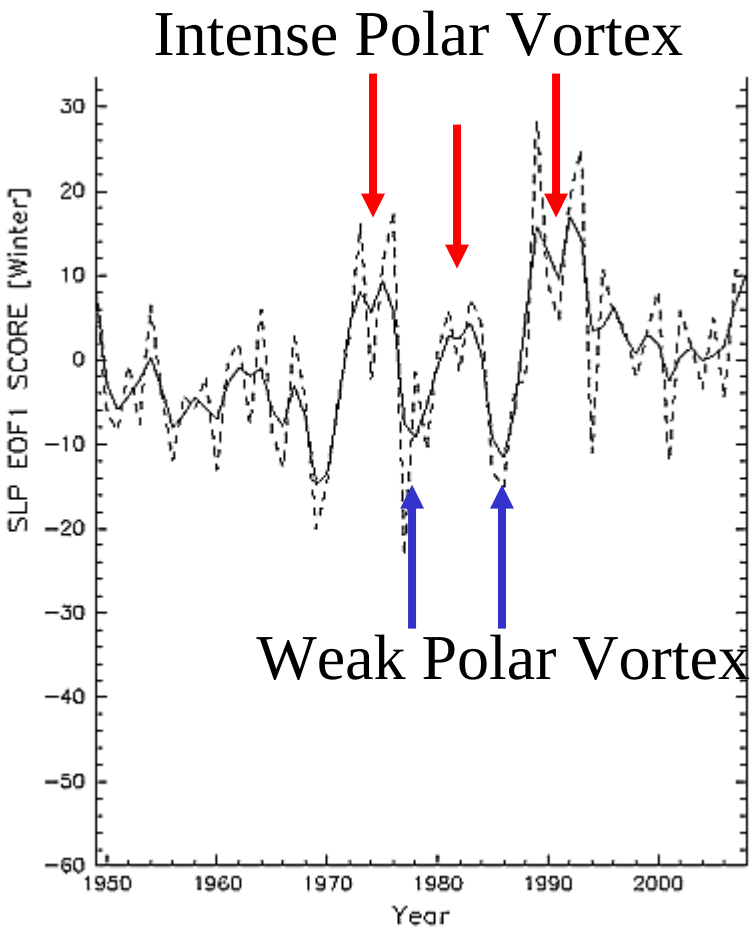
Recovering after 90 in Atlantic

Significant trend and decadal variability

- Sea ice has been reducing in last several decades.
- Decadal variability are clear and related with NAM/AO.
- We should be cautious about change in a few years.

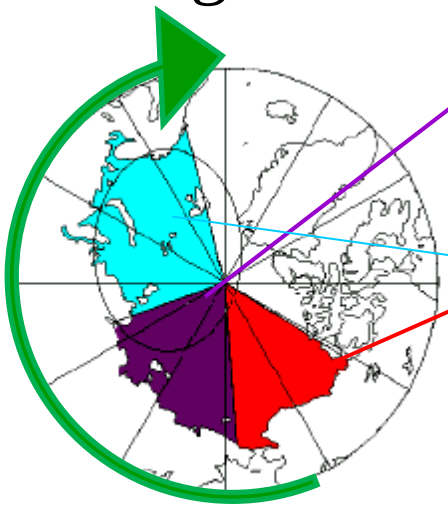
EOF-1 of winter Atmos. Pressure at sea level Northern Annular Mode/Arctic Oscillation

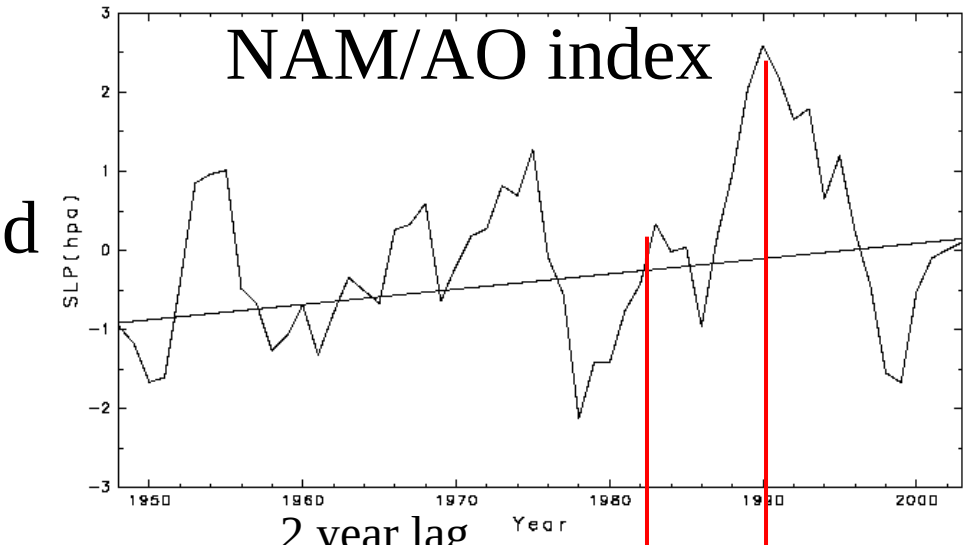


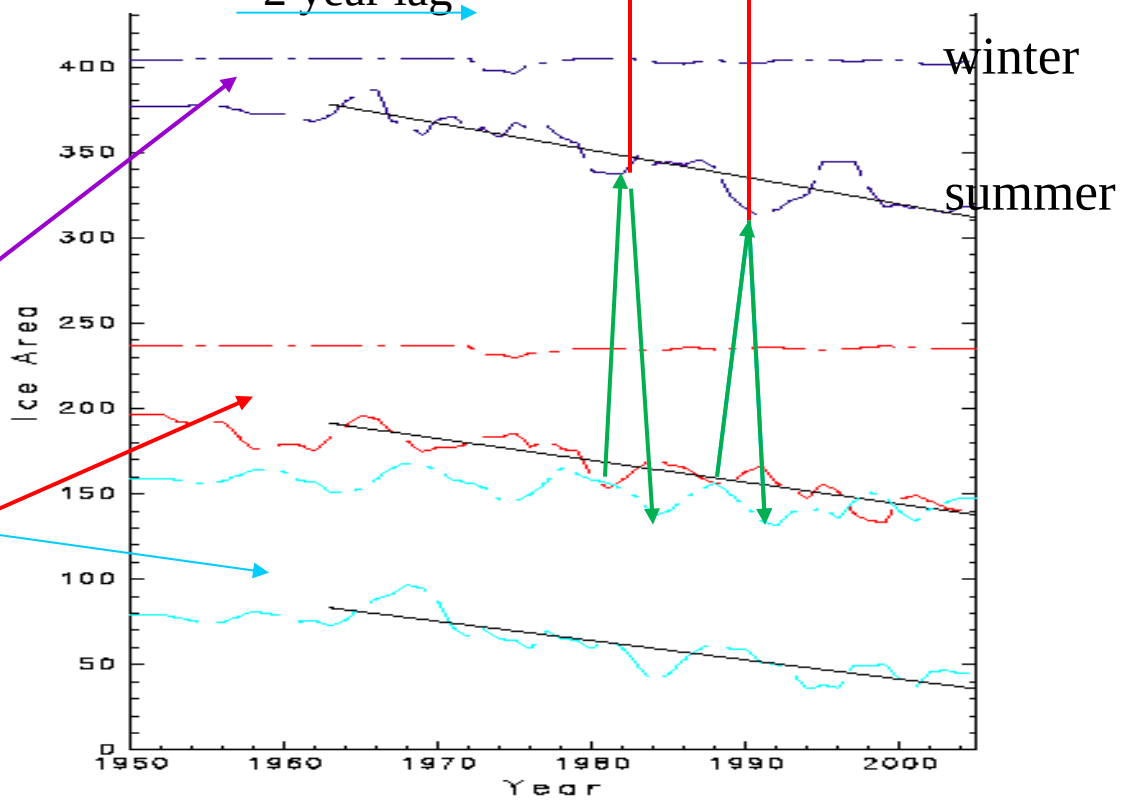


Decadal variability
in sea ice cover produced
by NAM/AO
(Ikeda,1990)

Sea ice cover
anomaly propagates
in three regions





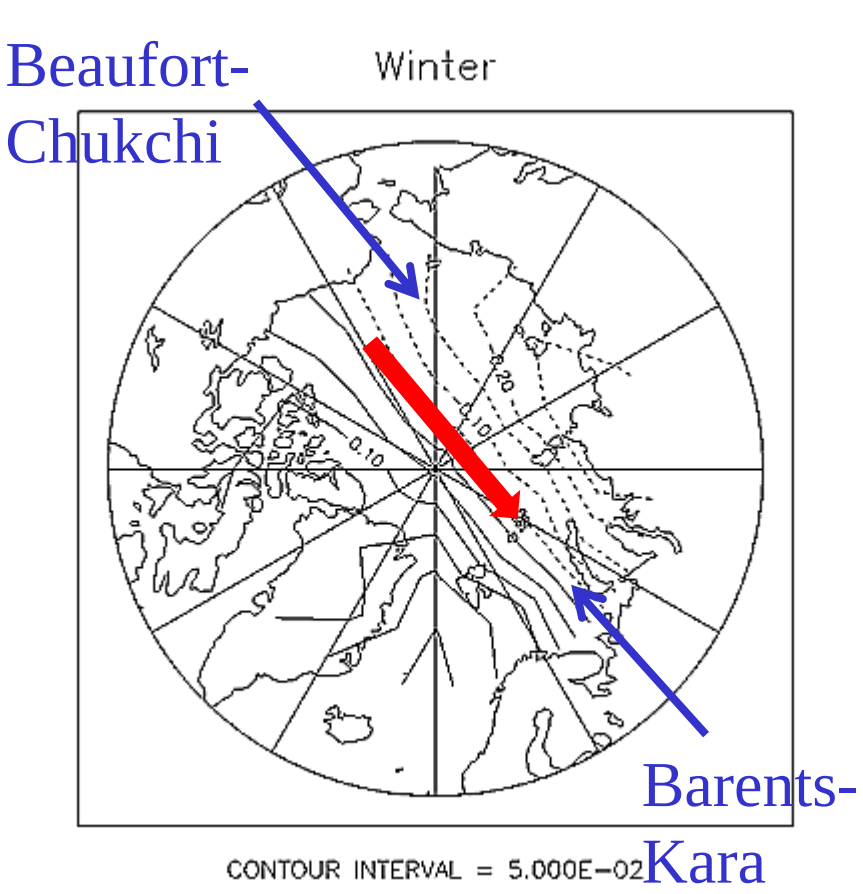


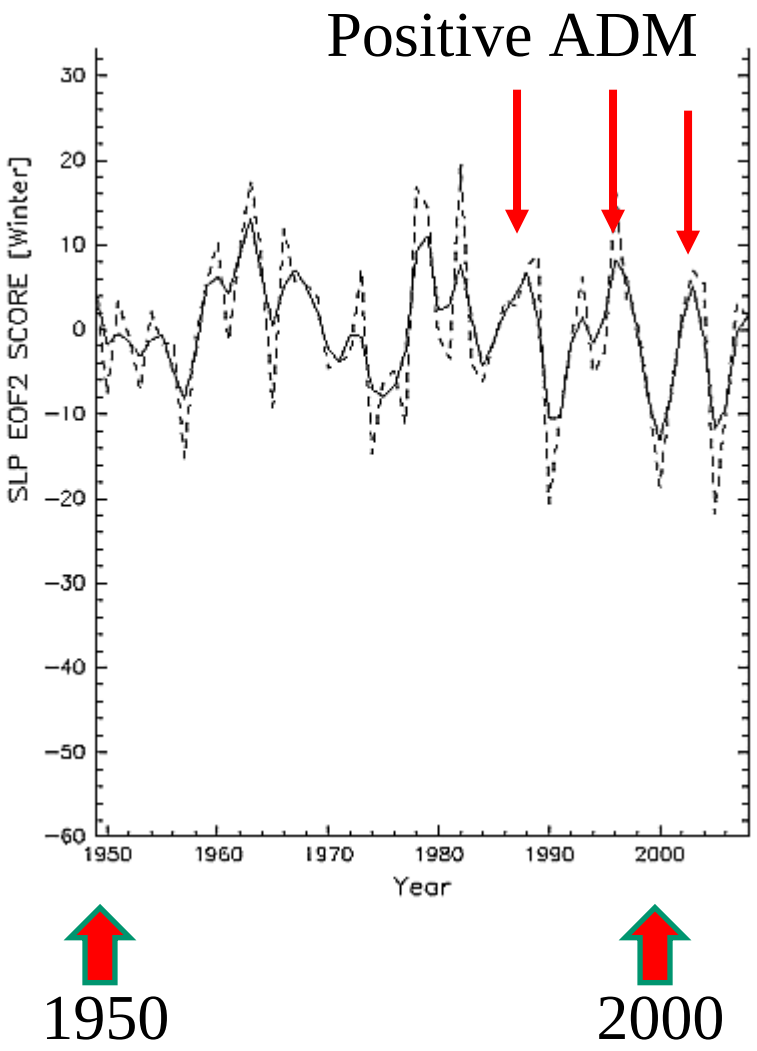
Arctic Dipole Mode (ADM)

- Sea ice has been reducing more rapidly in the Pacific sector after 1990.
- NAM/AO is not so significant after 1990.
- EOF-2 has been proposed to be important

  by Wu et al. (2006), Wang et al. (2009), etc.

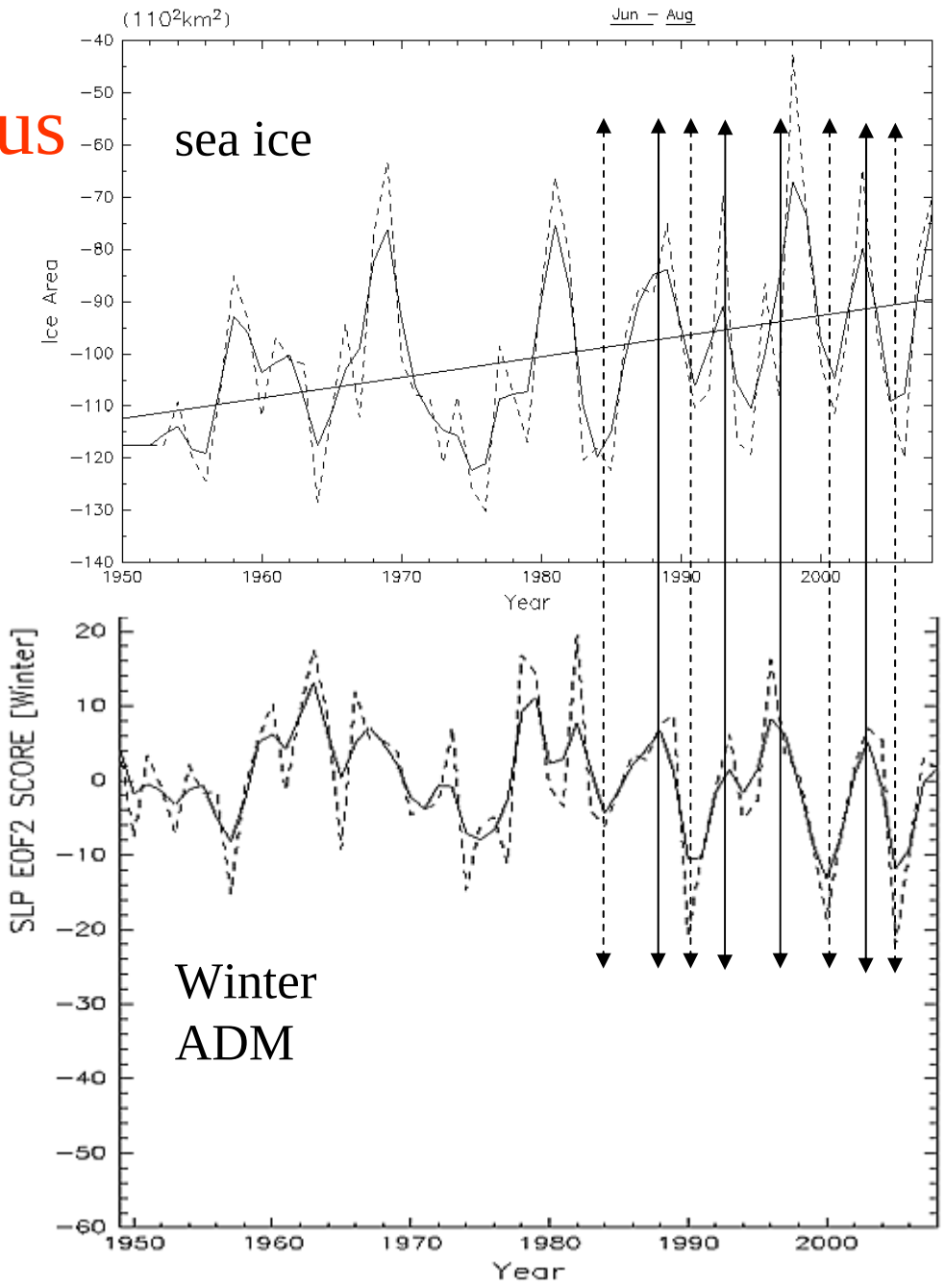
2nd EOF of sea level pressure in winter Arctic Dipole Mode (ADM)



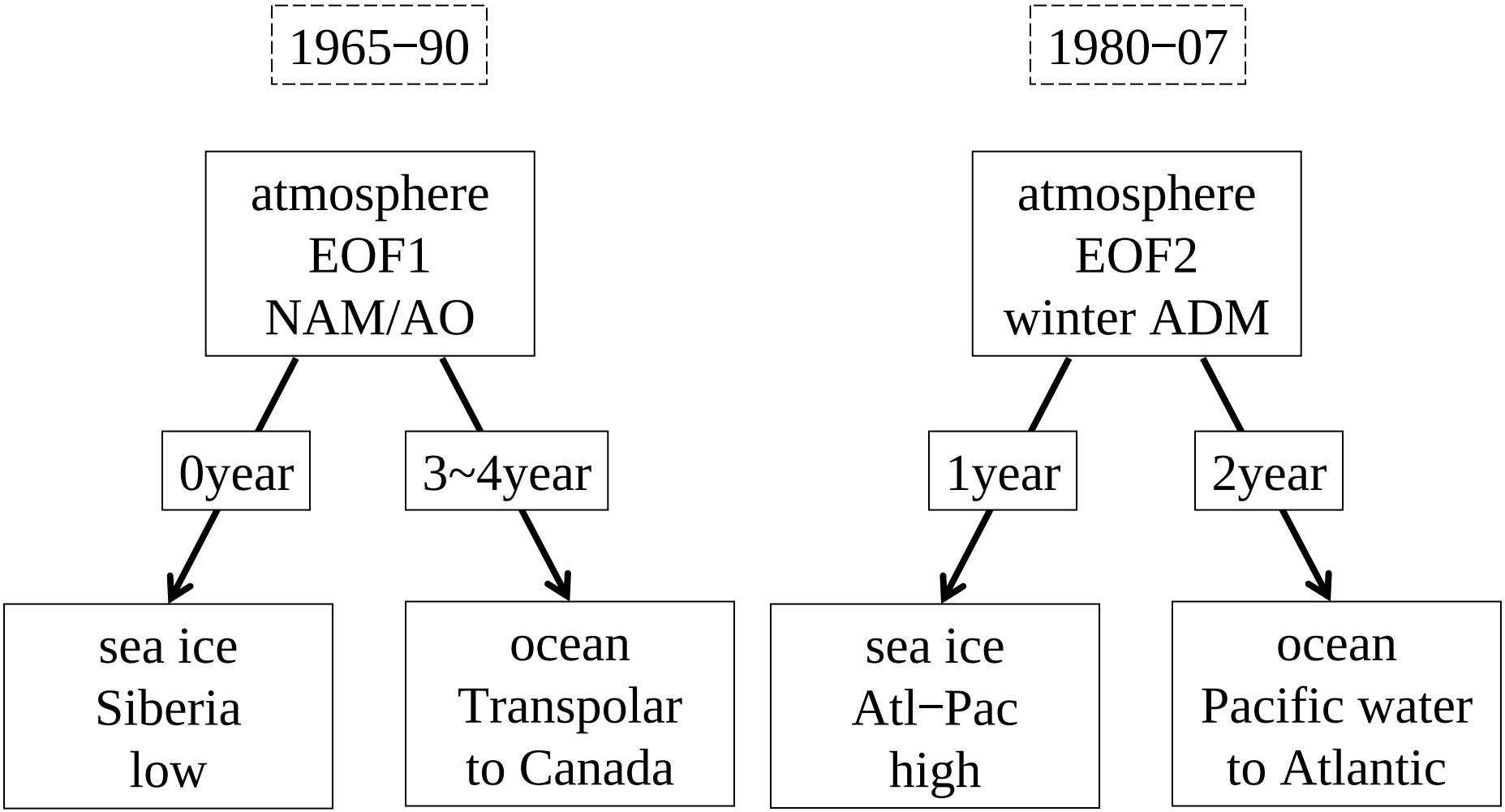


Sea ice anomalies in
(Barents & Kara) minus
(Beaufort & Chukchi)
(1 year lagged)
vs.
Winter ADM

Correlation is 0.5
after trend removal.
This mode has become
significant after 1980.



Summary of shift from NAM/AO to ADM



Remark and open questions?

- We should separate interannual fluctuations from the trend! Our projection should not be disturbed.
- Precipitation increase under global warming?
- More intense snow and rain also?
- Hydrology cycle important for ice cover?

Global citizens should

- watch the transportation sector to reduce total energy consumption by using the Arctic routes (higher efficiency often leads to more business activities rather than saving energy)
- more importantly, prevent the petroleum industry from developing offshore oil on the Arctic Shelves (our descendants would criticize the present human as we take advantage of the consequence of global warming/ice-free Arctic for acceleration of global warming/more CO2 emission)