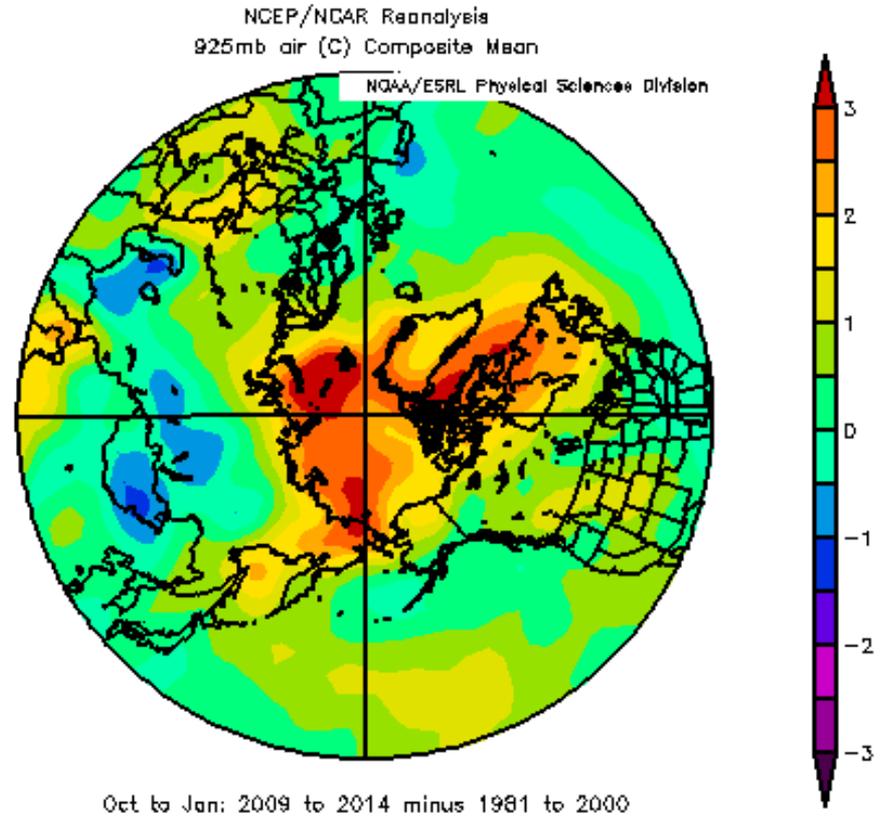
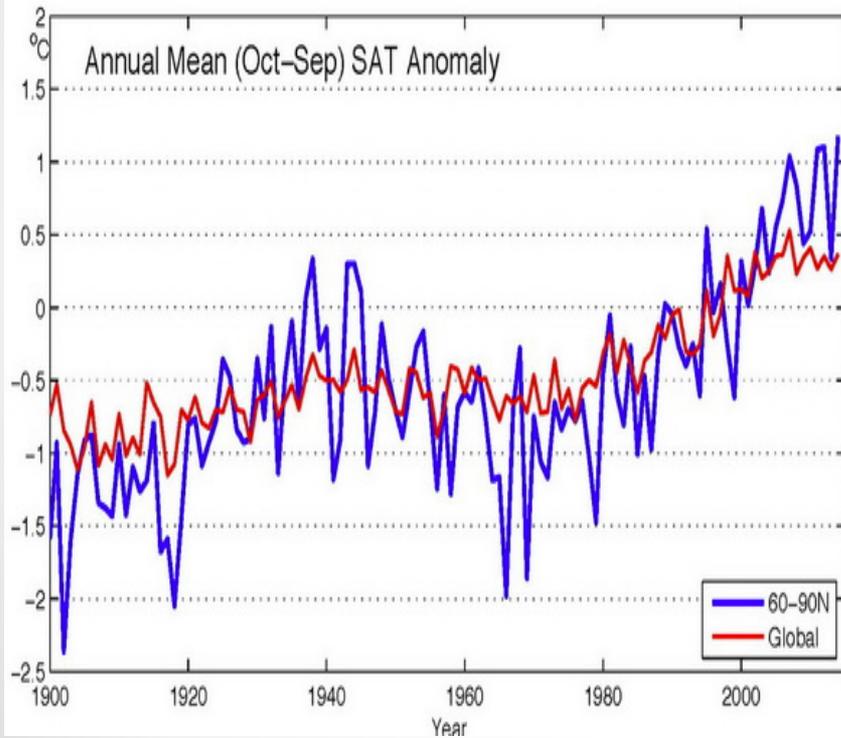




Large Arctic Climate Changes

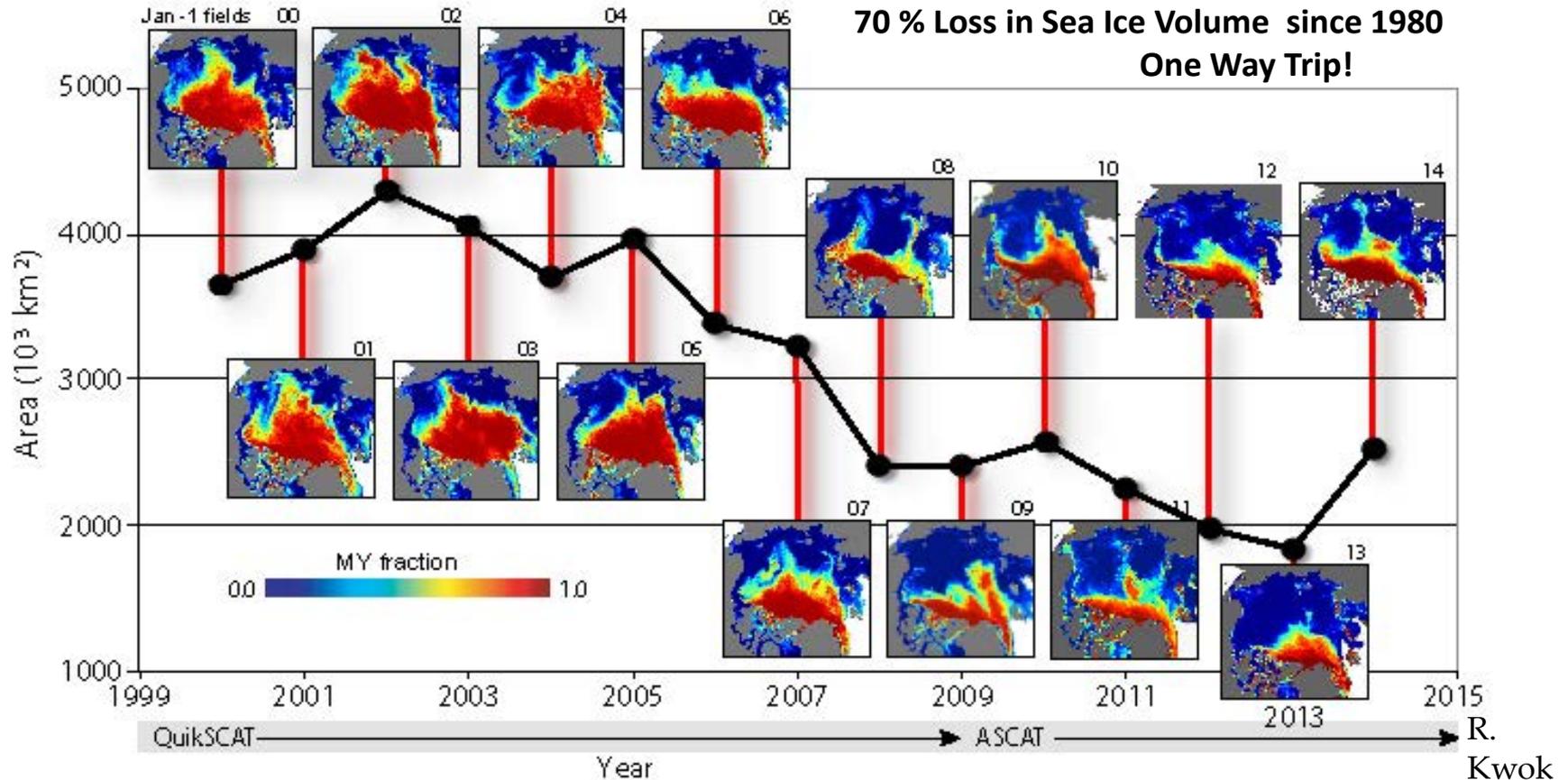
James Overland and Muyin Wang
NOAA/PMEL

Arctic (temperature) Amplification: 2-3 times changes in Mid-latitudes



Decline in Arctic Multiyear Sea Ice Coverage 40 % Since 1980 (Red)

Arctic is Now Mostly First Year Sea Ice(Blue)



October 2014

First year sea ice at 78 N from 300 feet;
New Environment

10/07/2014 20:59

On land, there is additional evidence of the impact of the persistent warming trend.

Tundra

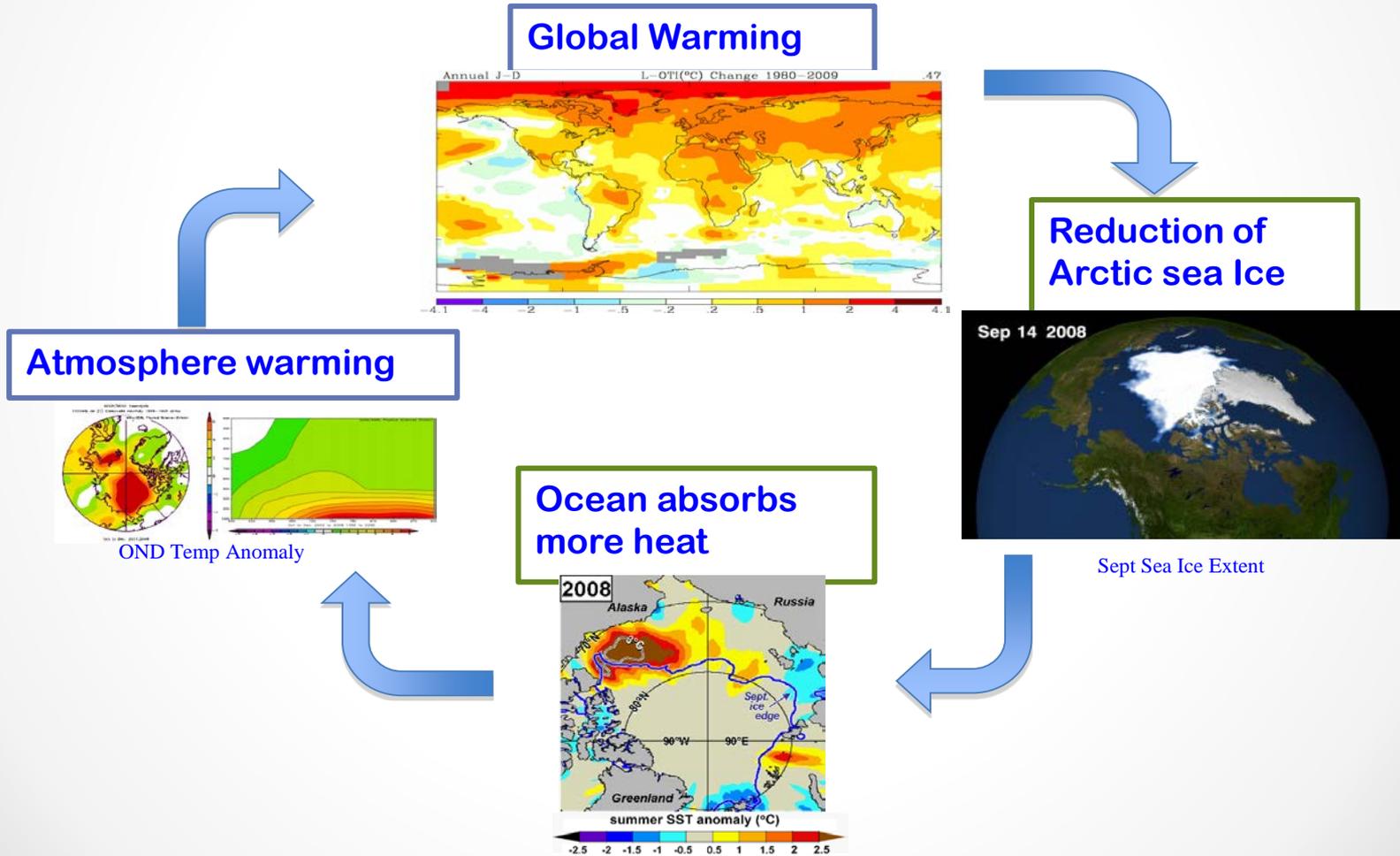


Greenland

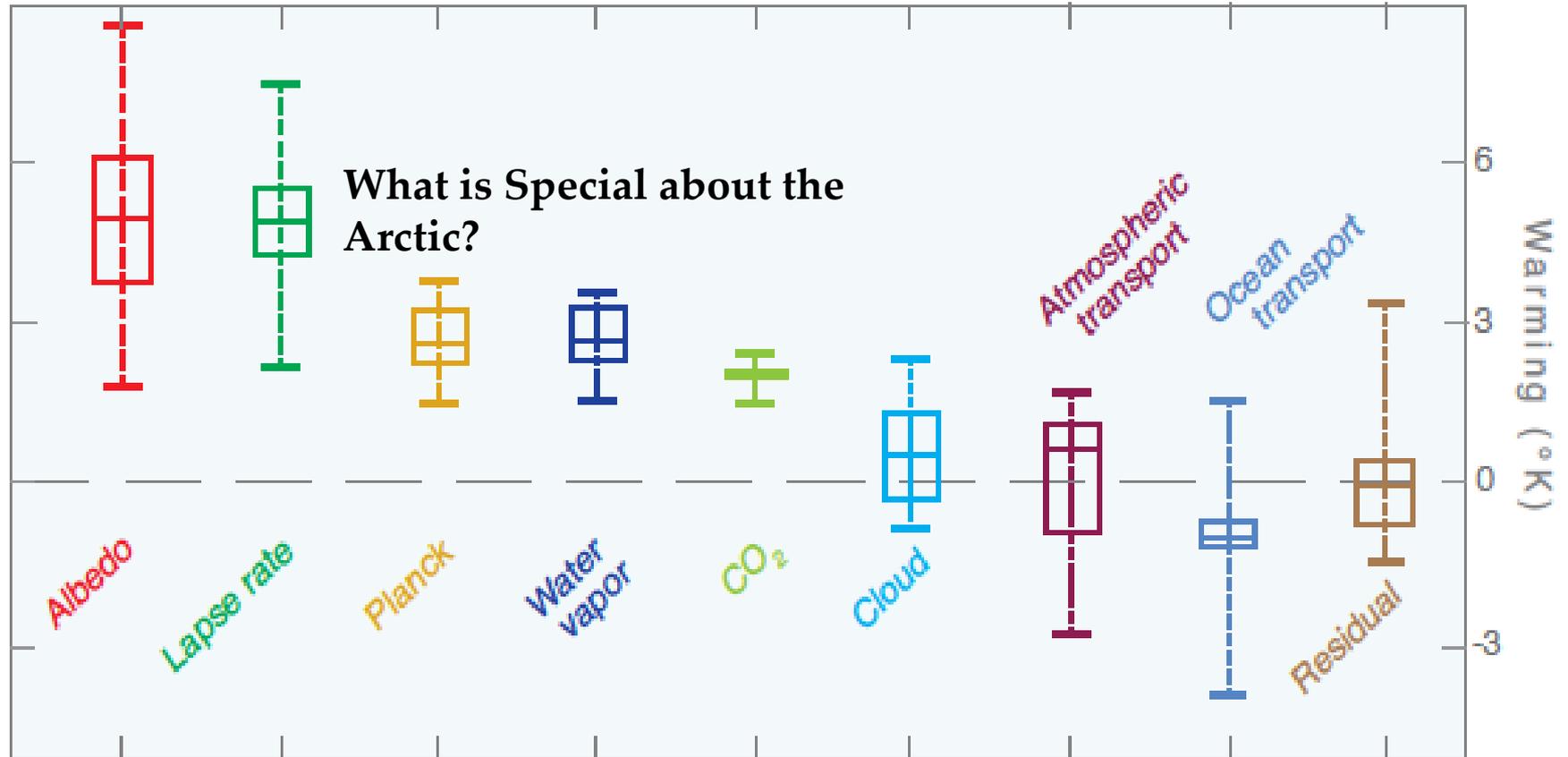


- Between 1982 and 2013, the tundra biomass increased by 20 percent.
- The number of days of melting in June and July 2014 exceeded the 1981–2010 average over most of the ice sheet.

“Arctic Amplification”: Global Warming + Multiple Feedbacks



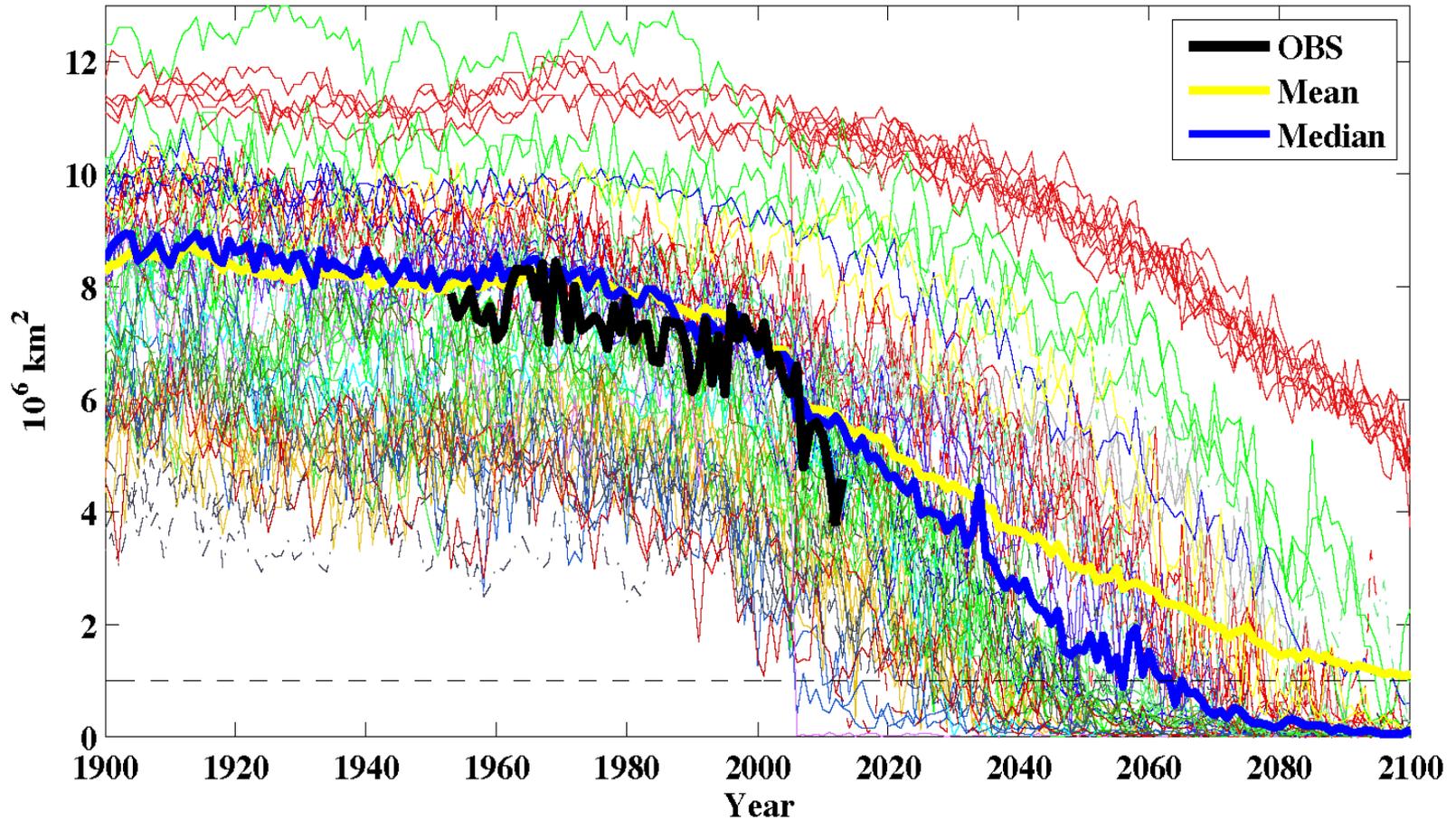
Contributions of various feedbacks to total Arctic warming in climate models



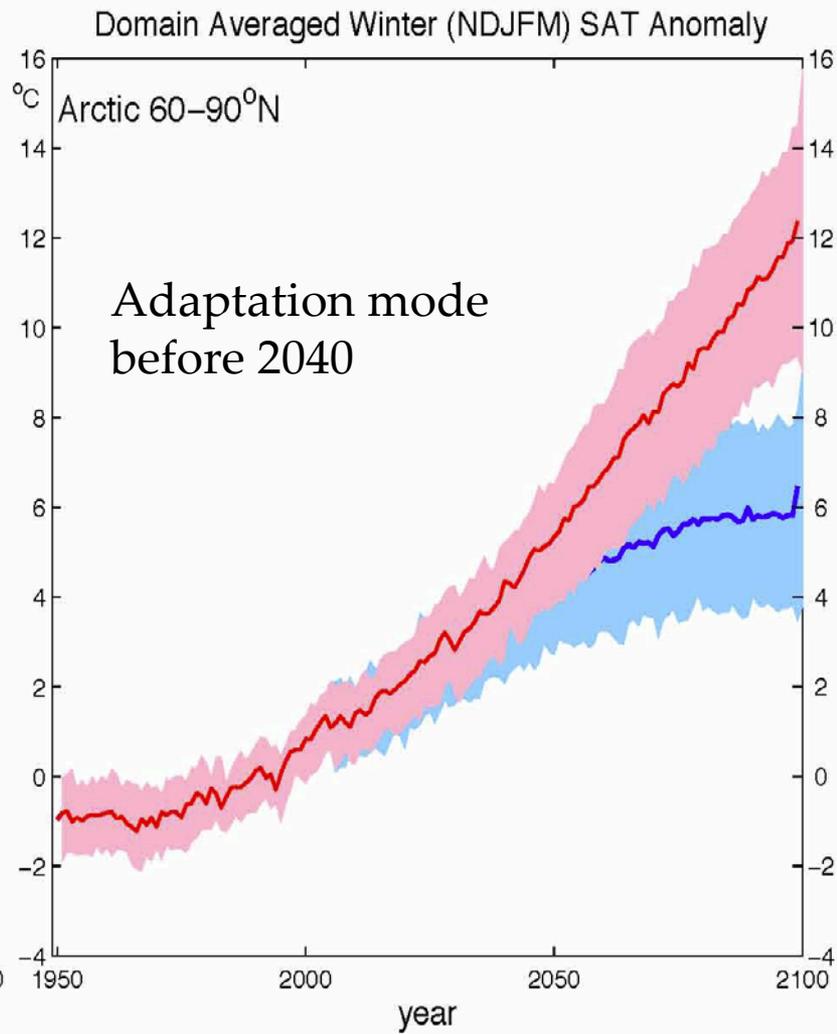
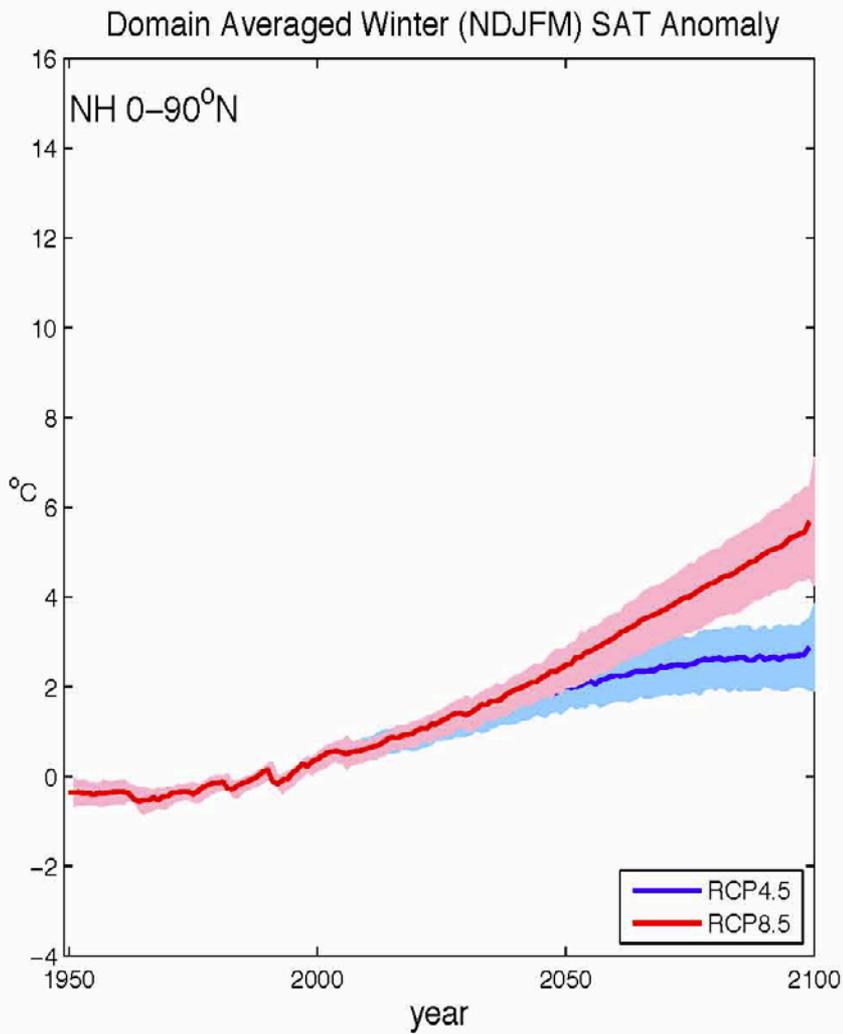
Pithan and Mauritsen, 2014, Nature Geoscience

Future Sea Ice loss Occurring Faster than Projected

Wide Range of September Sea Ice Extent Hindcasts and Predictions from IPCC



89 ensemble members from 36 CMIP5 models under strongest (RCP8.5) emissions scenario Overland and Wang (2013)

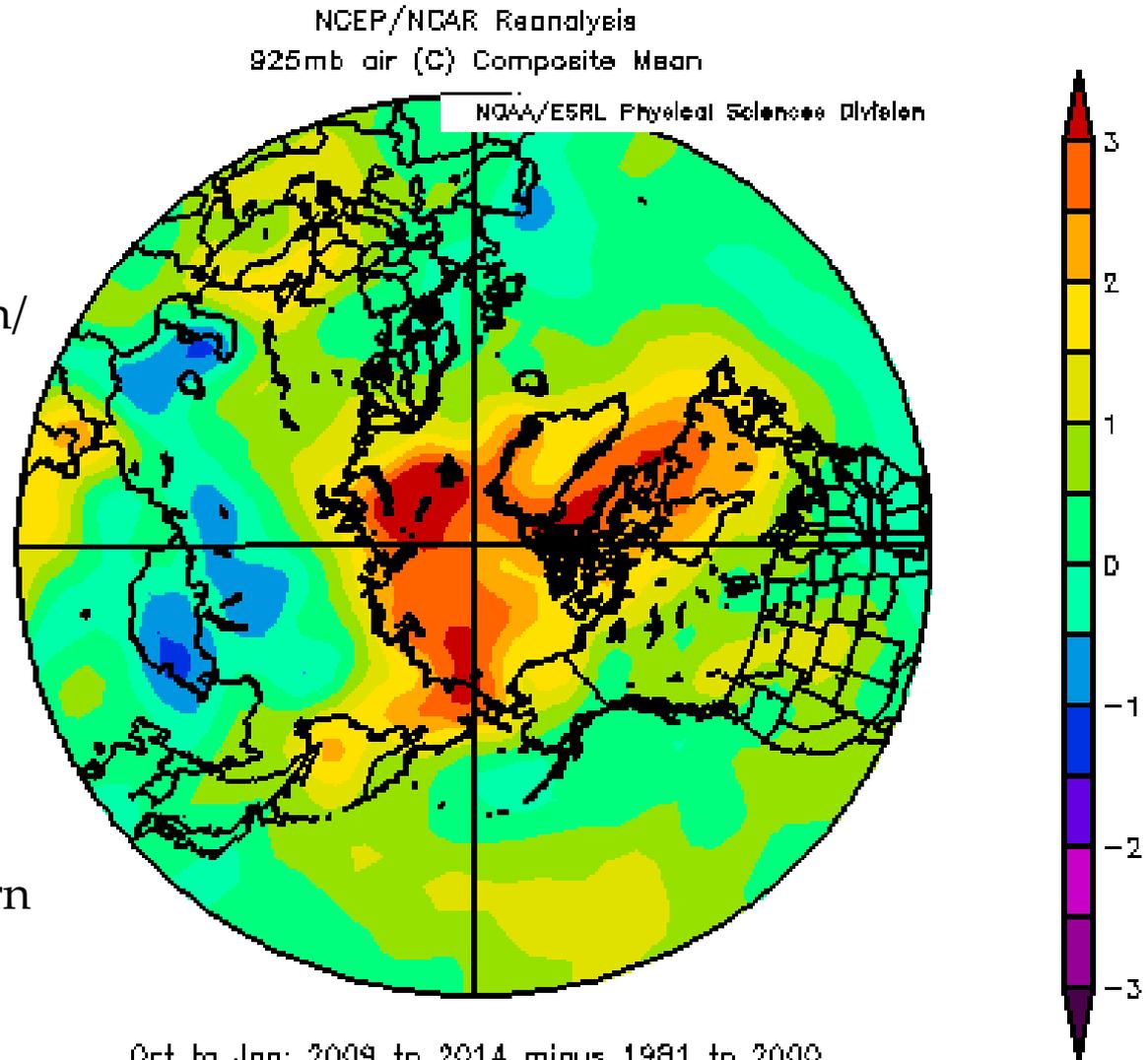


Three Patterns of Arctic/Subarctic Climate Variability

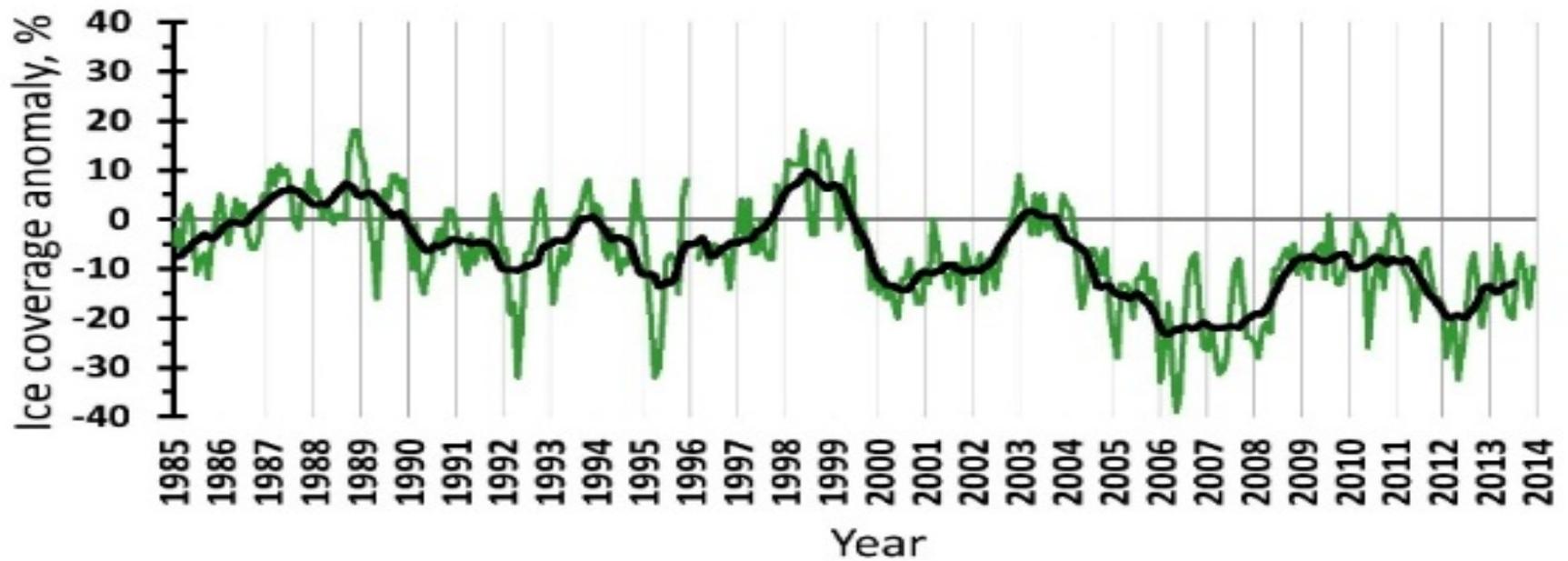
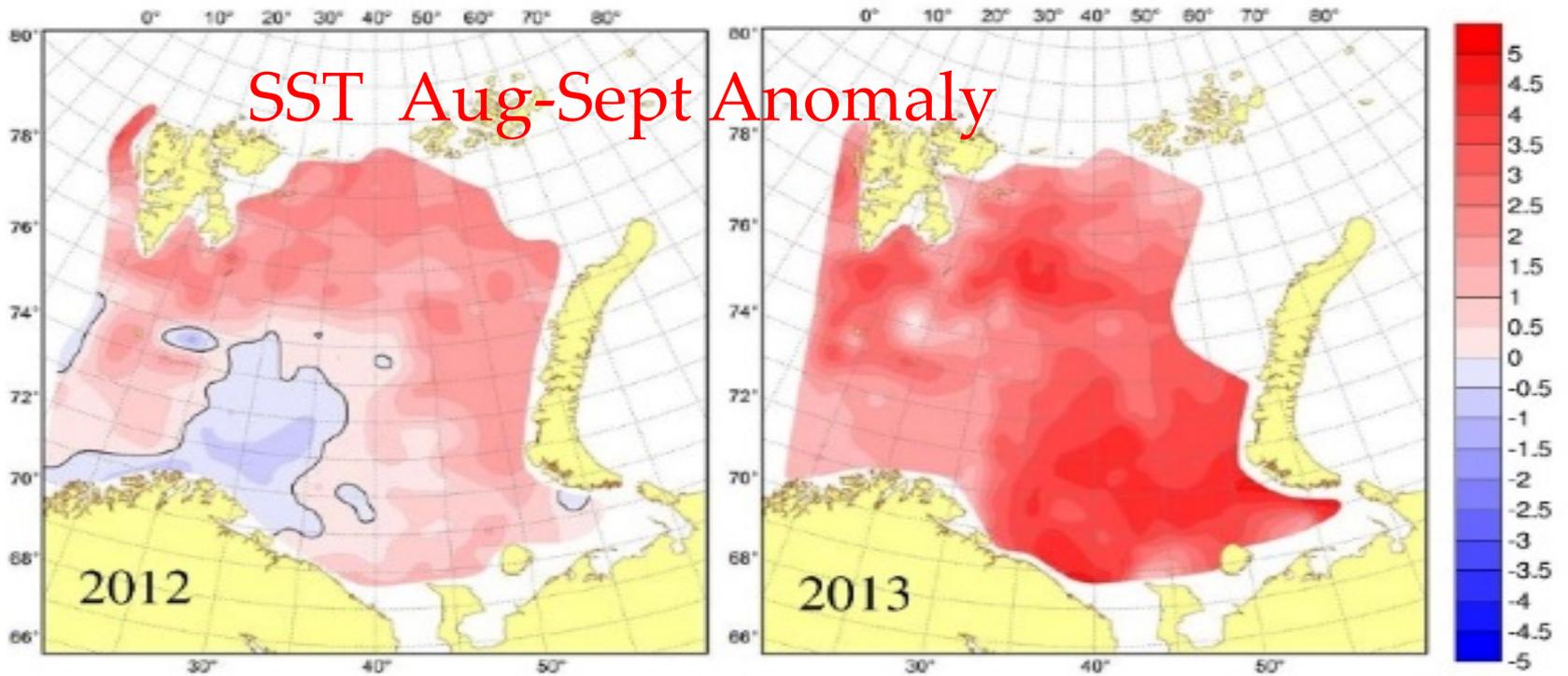
Arctic Warming
Pattern

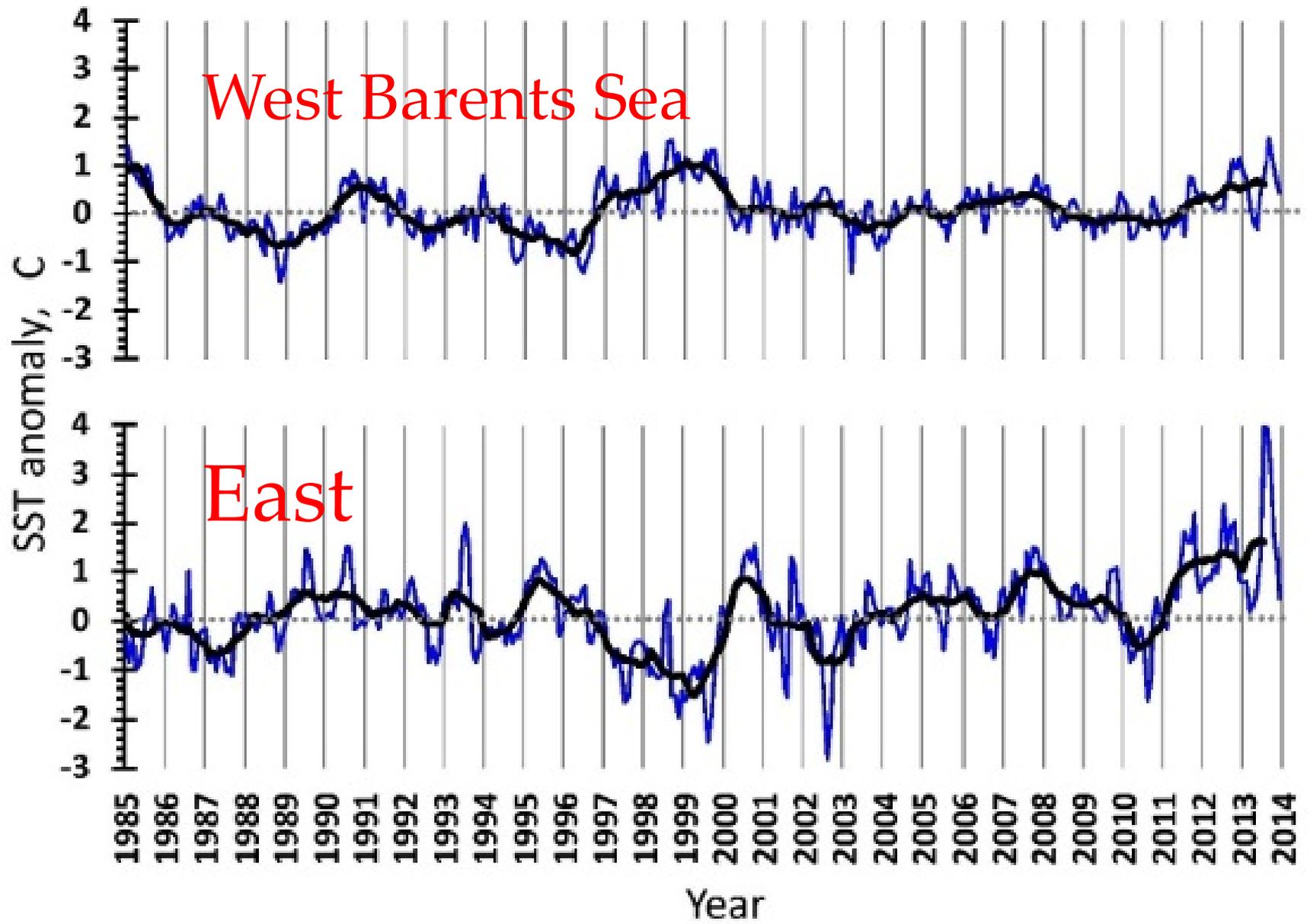
Arctic Oscillation/
North Atlantic
Oscillation
(AO/NAO)

Pacific Decadal
Oscillation/
Pacific North
American Pattern
(PDO/PNA)



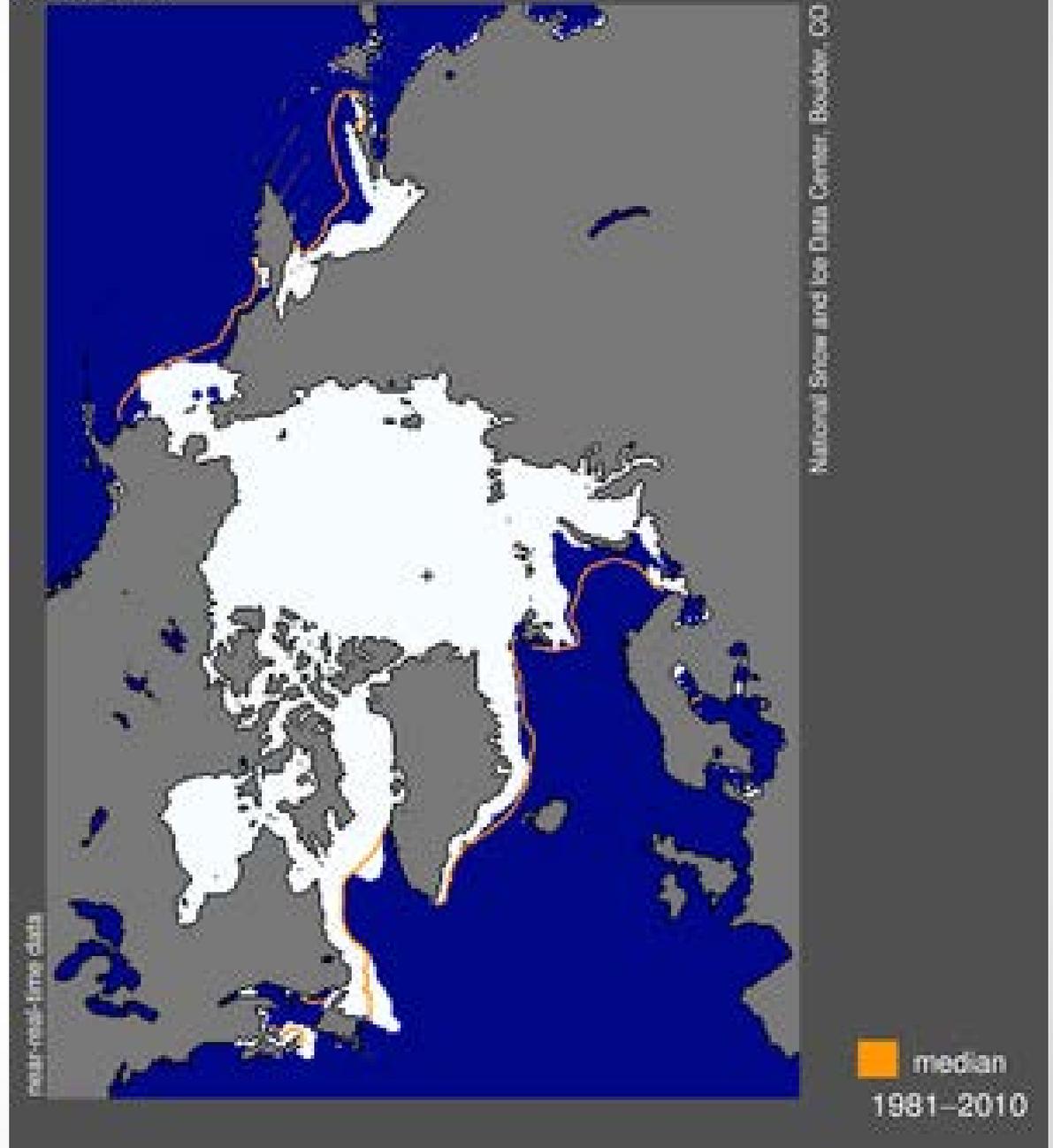
SST Aug-Sept Anomaly





Prediction of sea ice loss and open water duration is difficult for Barents Sea because Atlantic current is too weak in climate models, but Barents is part of Arctic Warming Pattern, so expect major changes by 2030

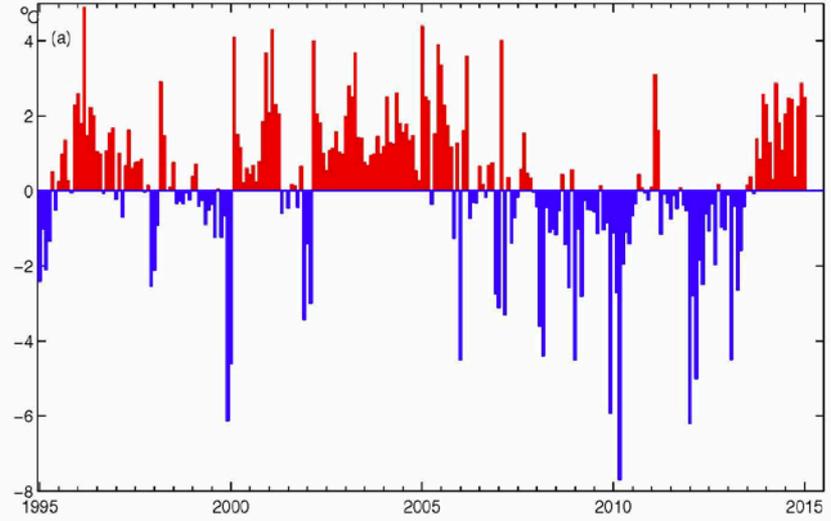
Sea Ice Extent
04/08/2015



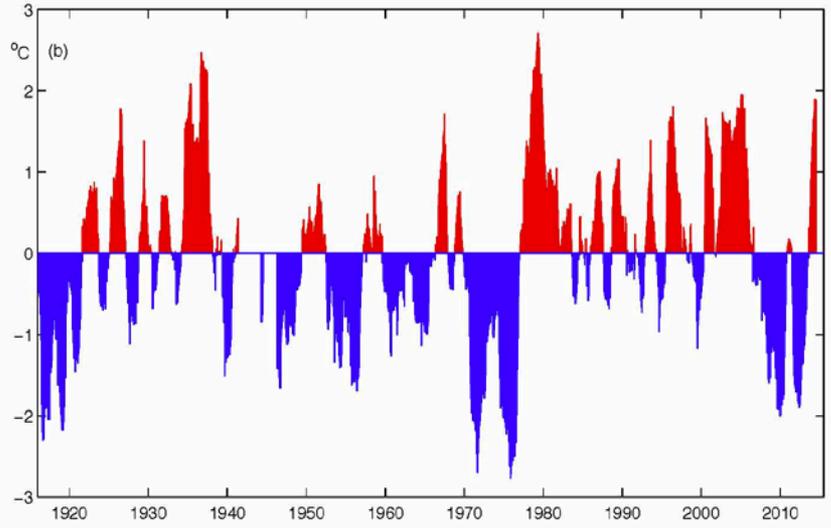
Southeastern Bering Sea

Variability much larger than Global Warming contribution

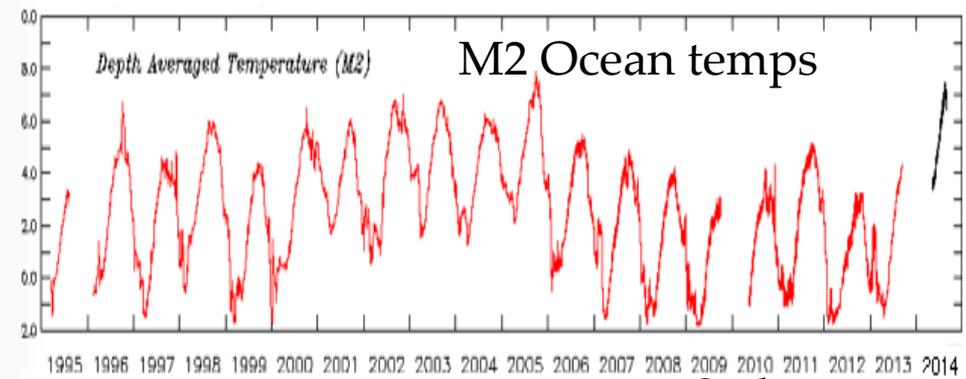
Monthly St Paul Island Temp Anomaly



2000 2015
St Paul air temperatures

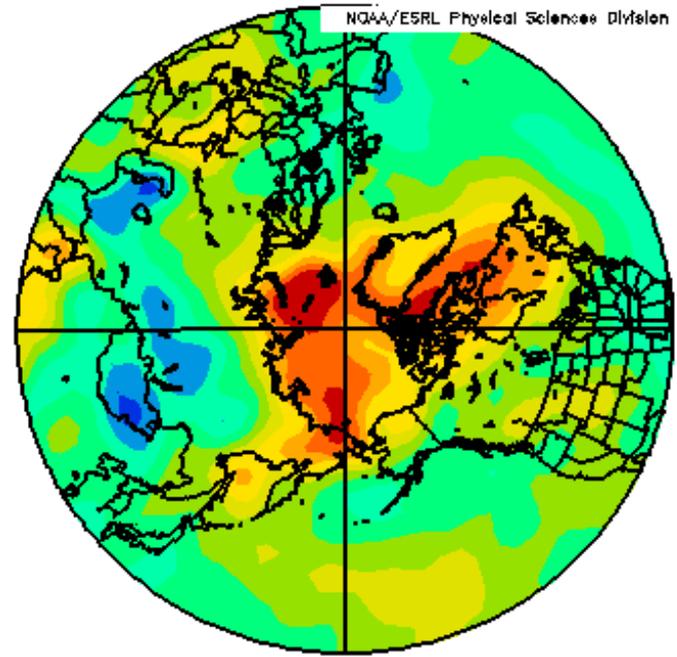


1970 2000



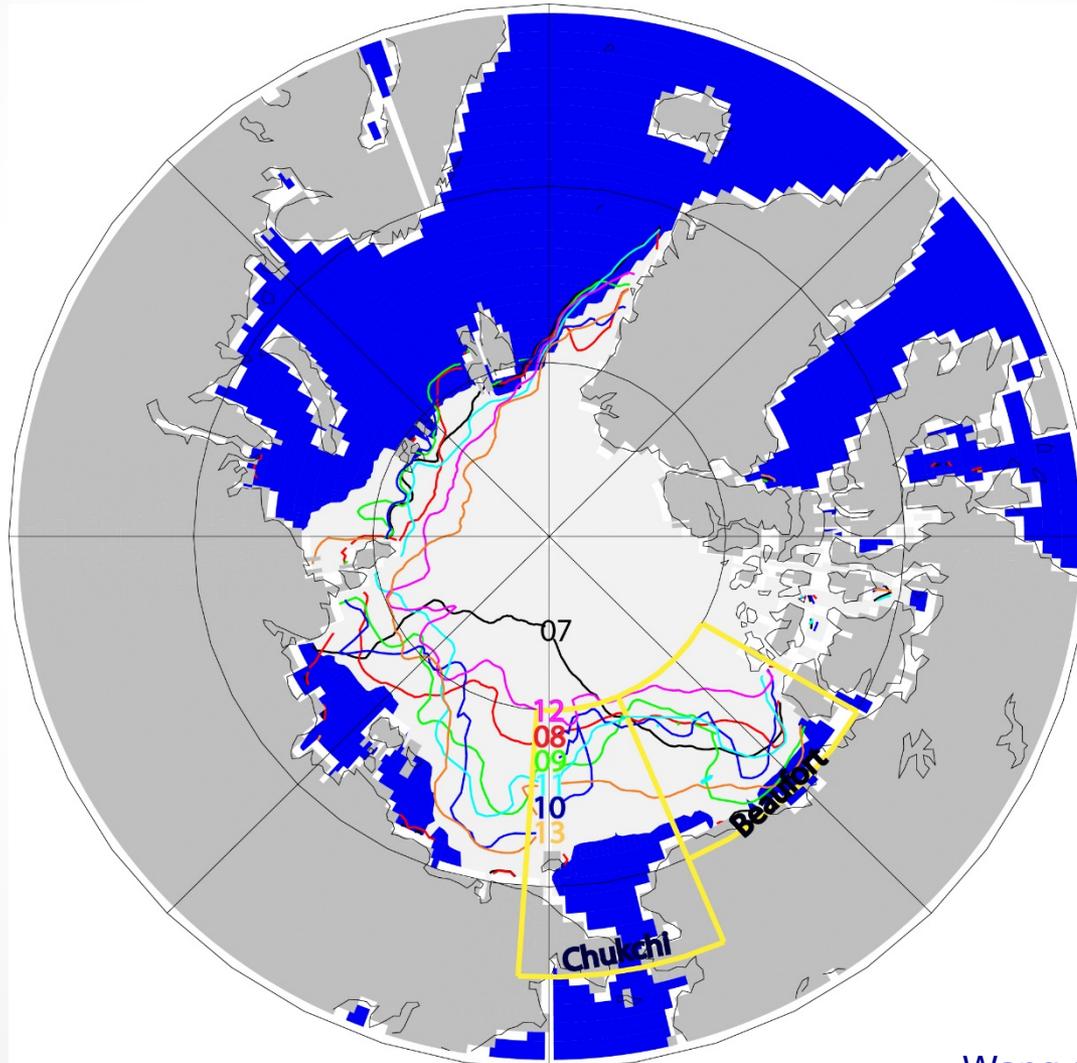
Stabeno

NCEP/NCAR Reanalysis
925mb air (C) Composite Mean
NOAA/ESRL Physical Sciences Division



Oct to Jan: 2009 to 2014 minus 1981 to 2000

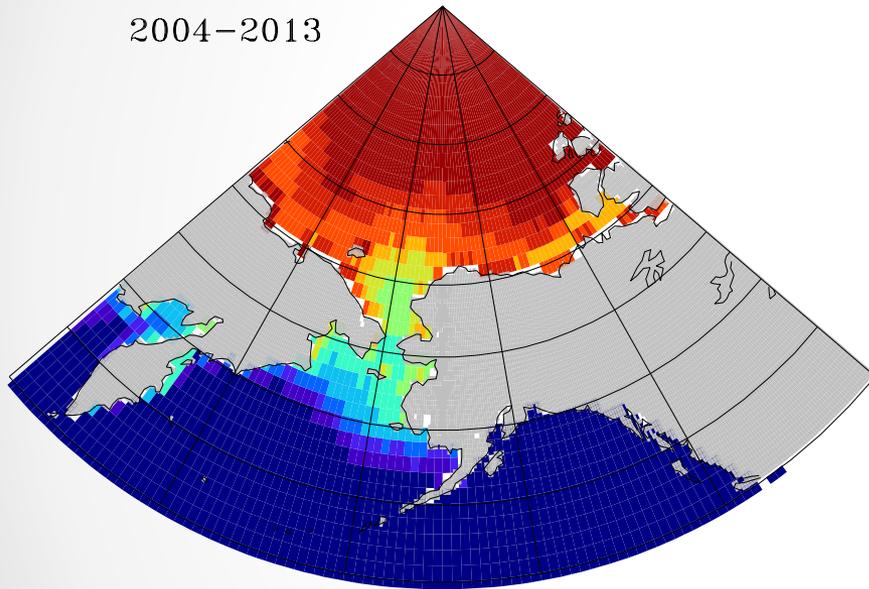
September Sea Ice Minimums



Future Sea Ice Duration in Alaska Arctic

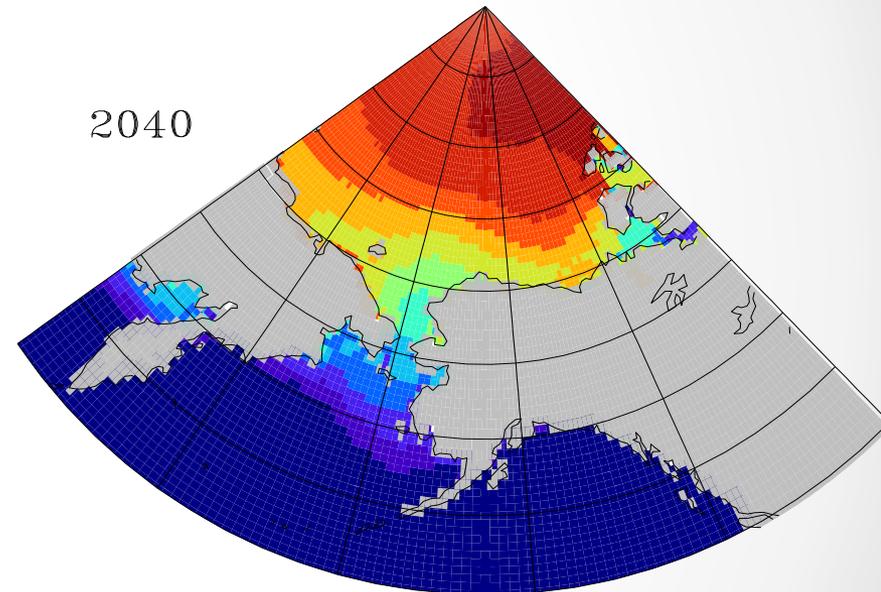
Still have a winter wall of freezing temperatures

2004–2013

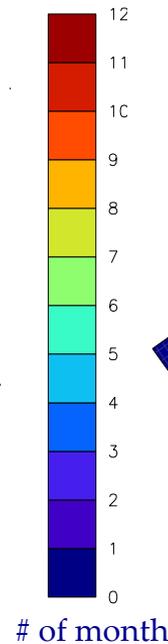


Observations (72 N)
3 months Open Water Now

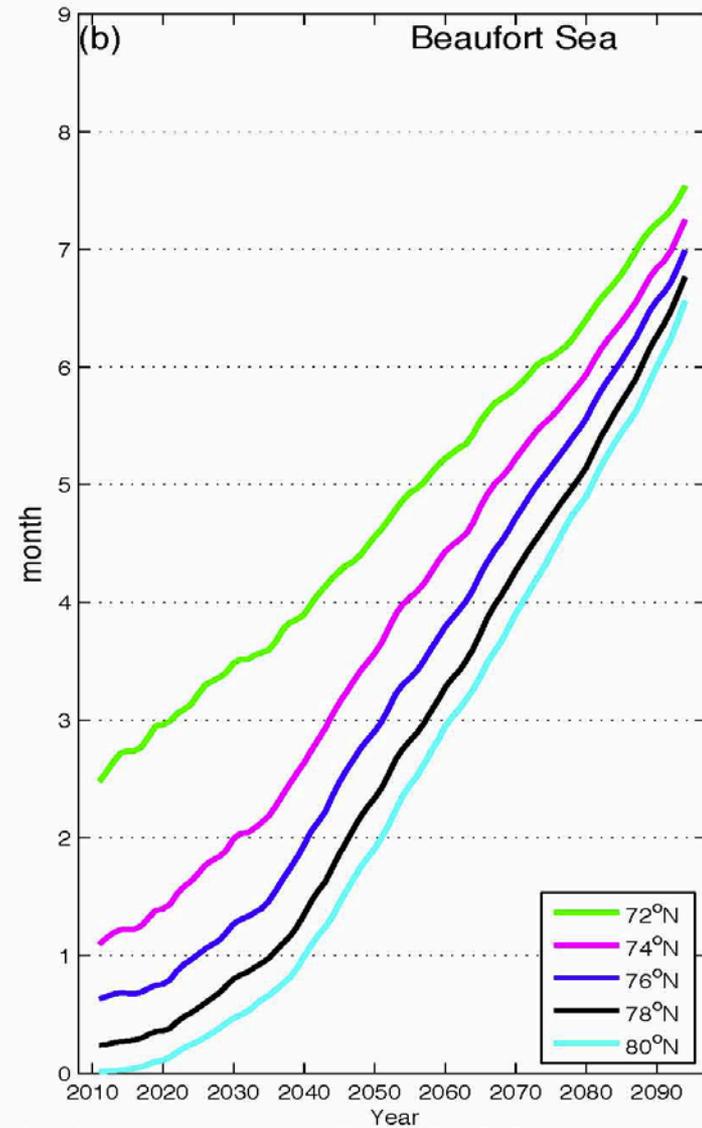
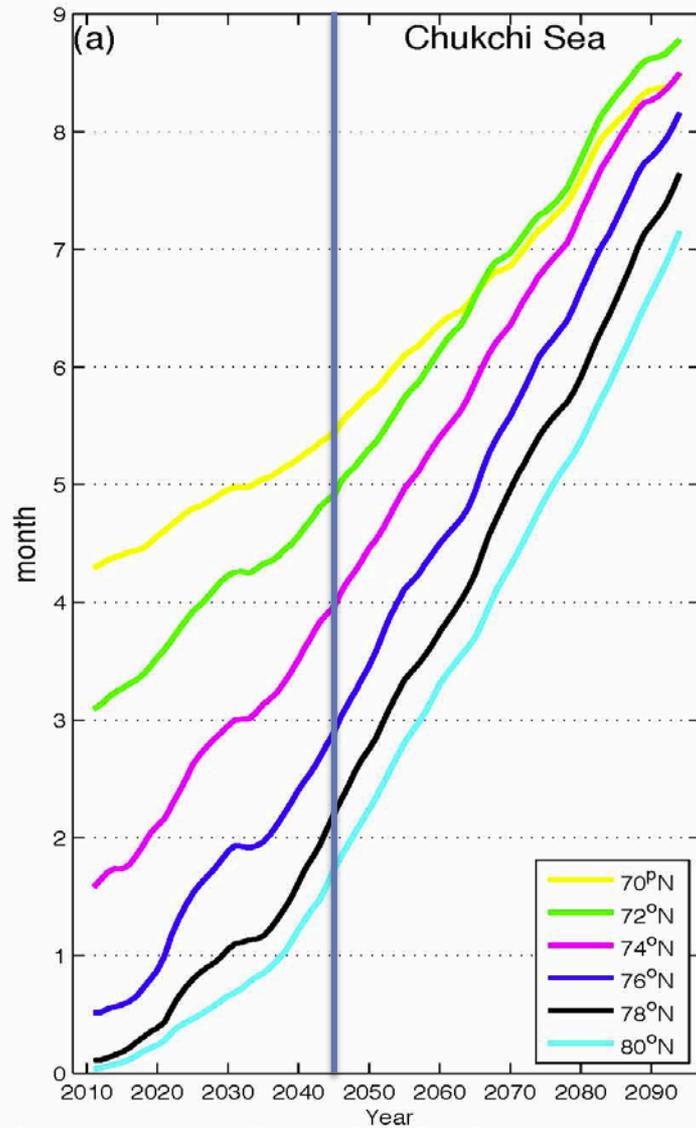
2040



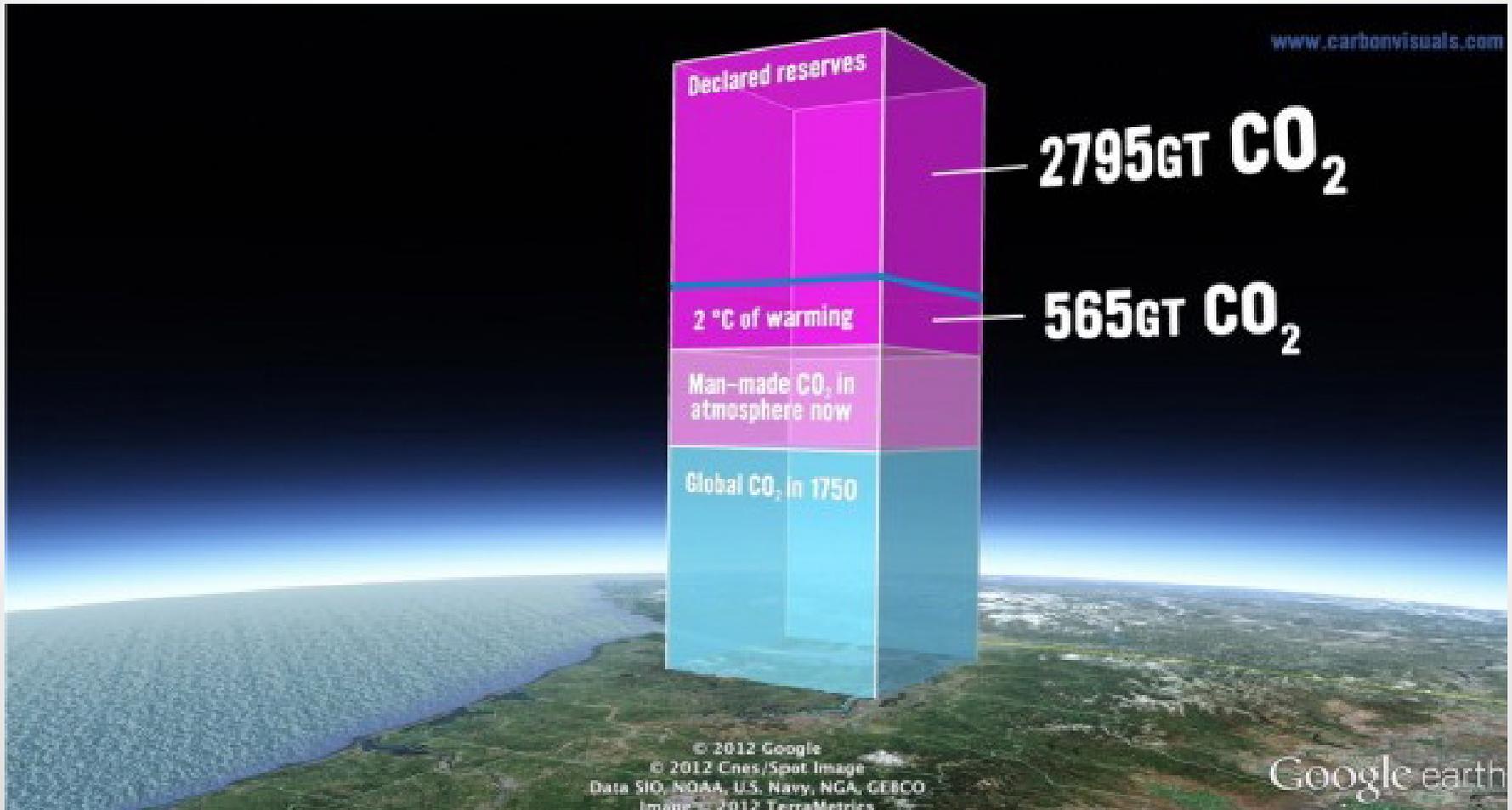
Ensemble mean of 12 CMIP5 models
5 months Open Water by 2040

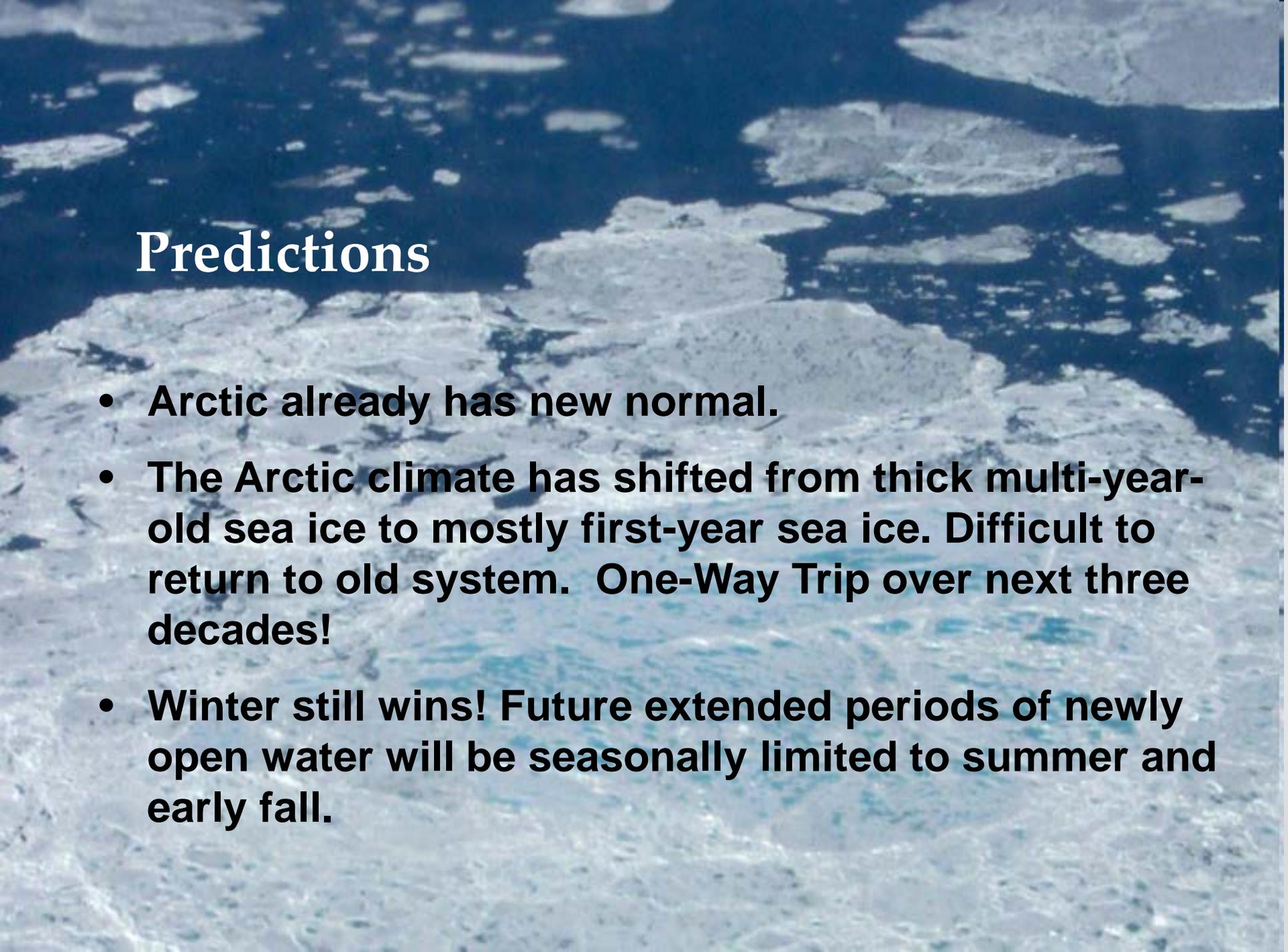


Zonal Mean Distribution of Ice Free Months



Modest Global Warming + Large Arctic Amplification = Adaptation in next 20 Years



An aerial photograph showing a vast expanse of fragmented sea ice. The ice consists of numerous irregular, light-colored floes of varying sizes, scattered across a dark blue, open ocean. The floes are densely packed in some areas and more sparse in others, creating a complex, textured appearance. The overall scene conveys a sense of a dynamic and changing polar environment.

Predictions

- **Arctic already has new normal.**
- **The Arctic climate has shifted from thick multi-year-old sea ice to mostly first-year sea ice. Difficult to return to old system. One-Way Trip over next three decades!**
- **Winter still wins! Future extended periods of newly open water will be seasonally limited to summer and early fall.**