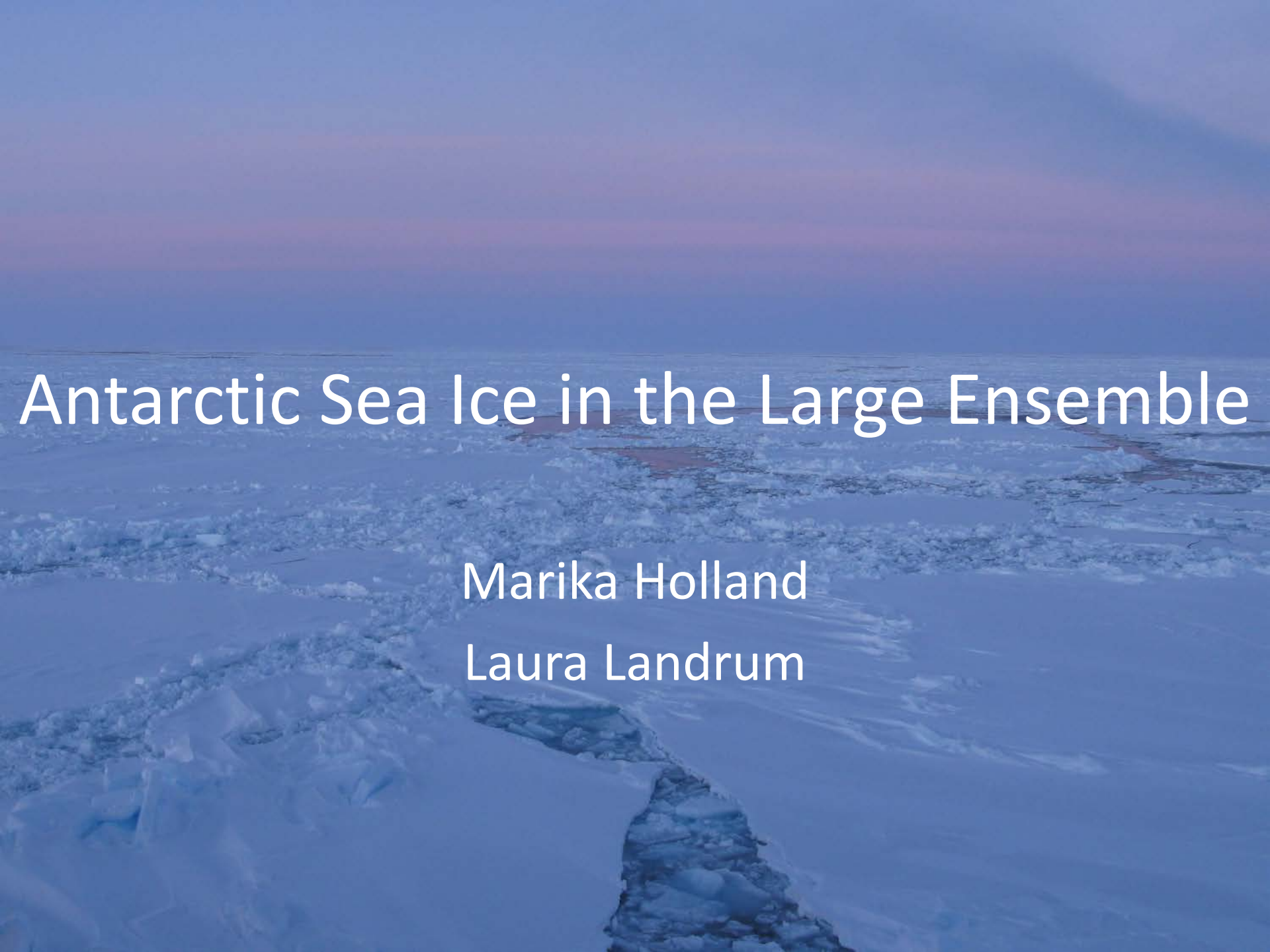
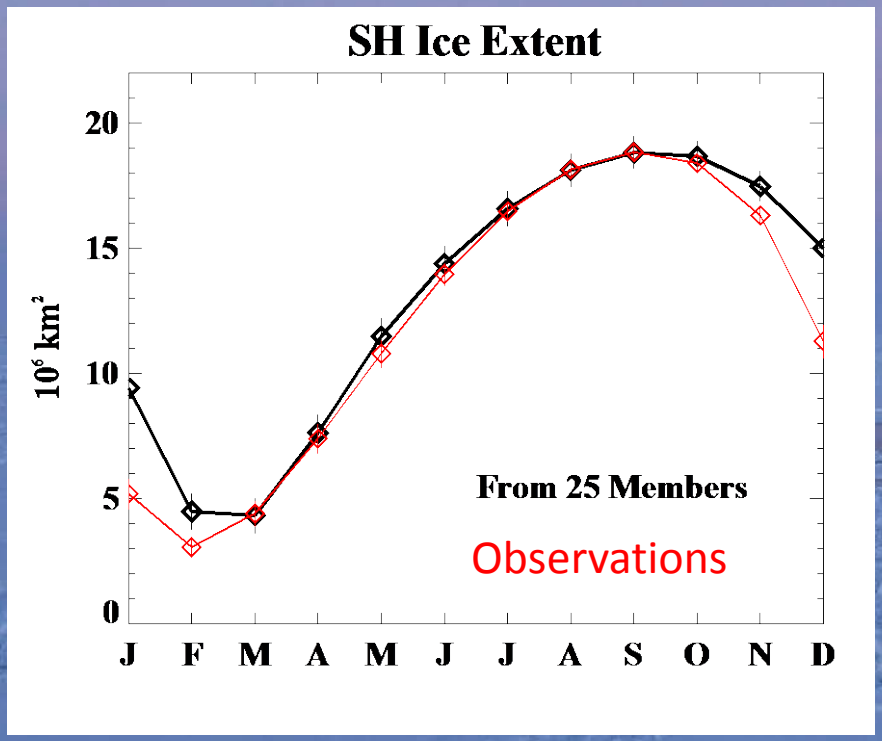


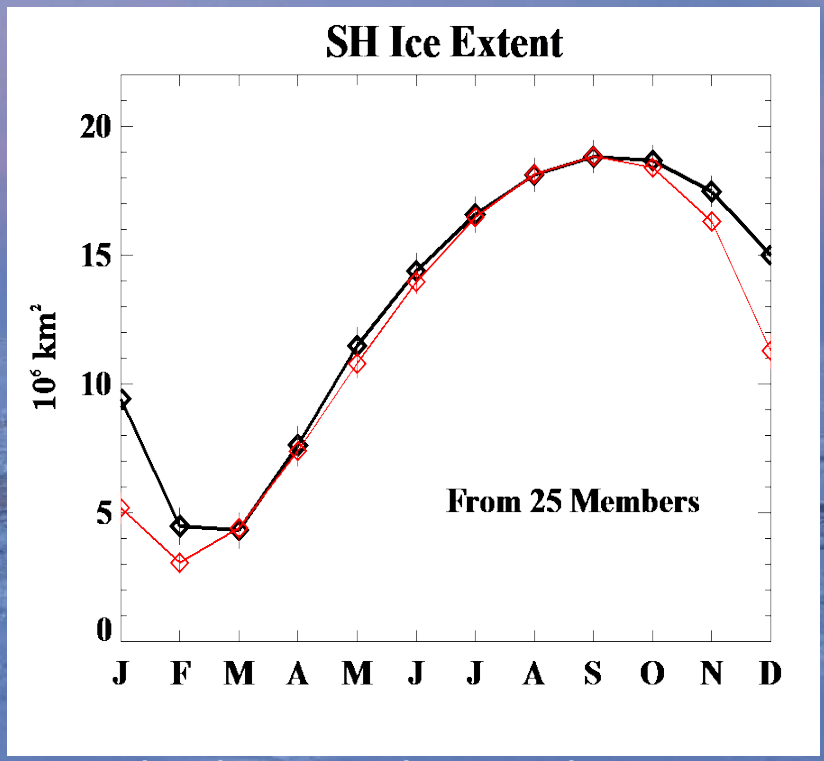
Antarctic Sea Ice in the Large Ensemble

Marika Holland

Laura Landrum

Large Ensemble Sea Ice Climatology





Annual cycle generally well simulated

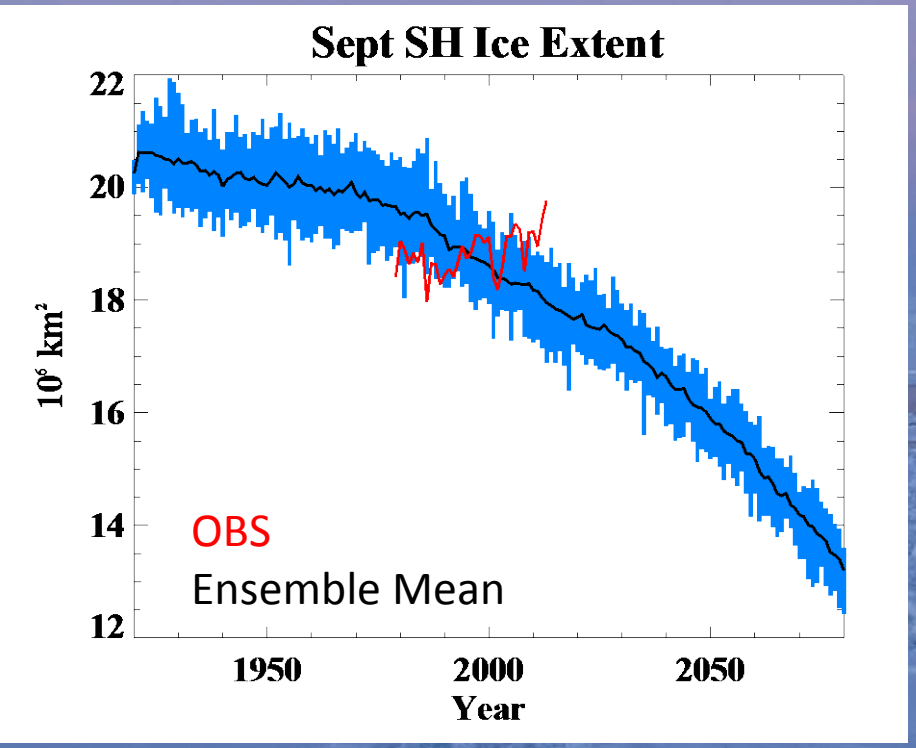
Not enough melt back during summer

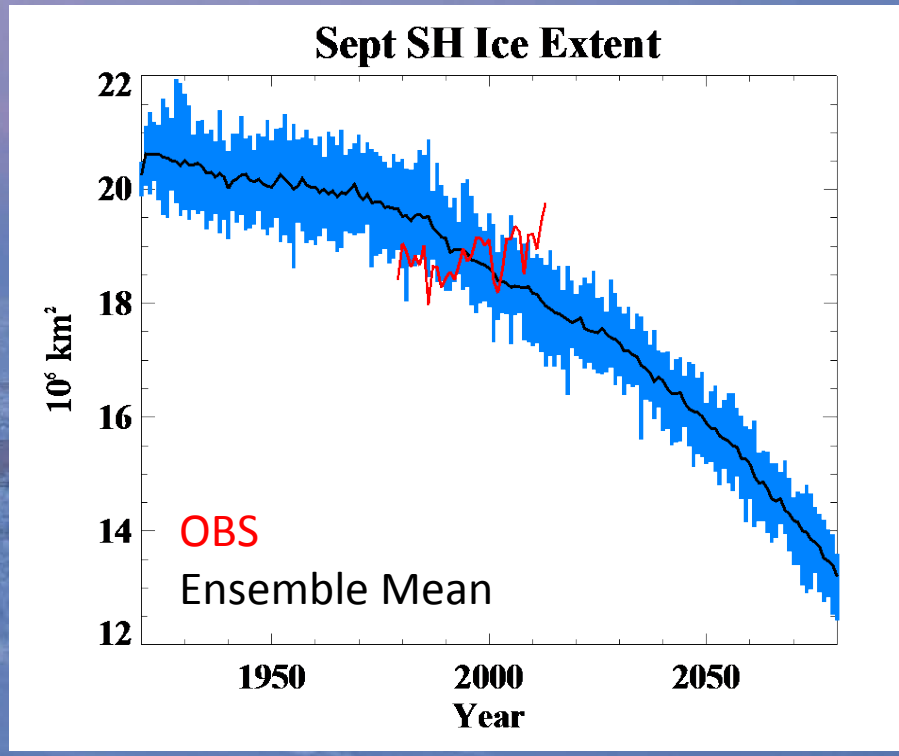
Ice thickness climatology:

Overall thickness is reasonable

Distribution is biased – with thickest ice on wrong side of peninsula

Ice Extent Timeseries

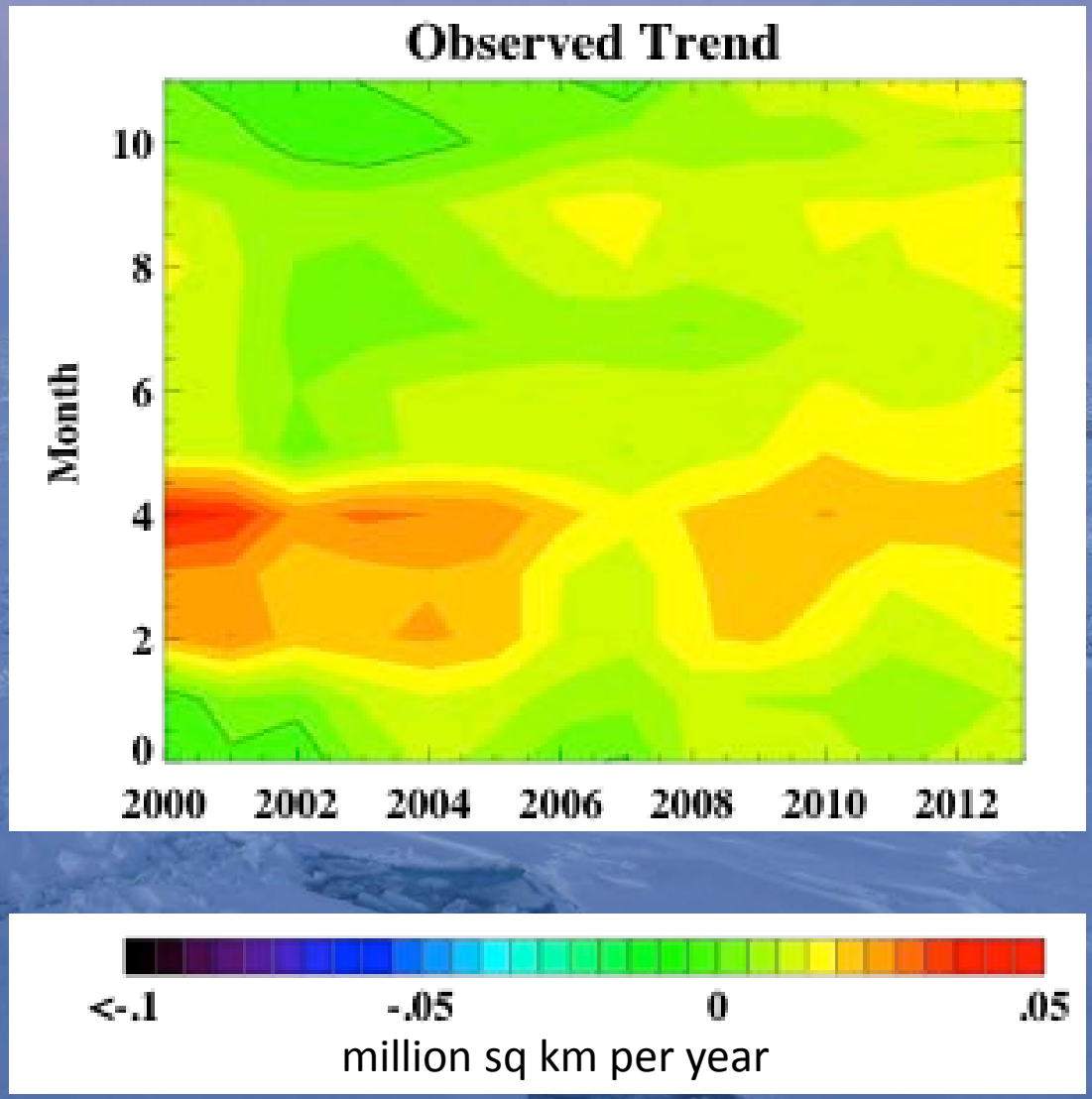


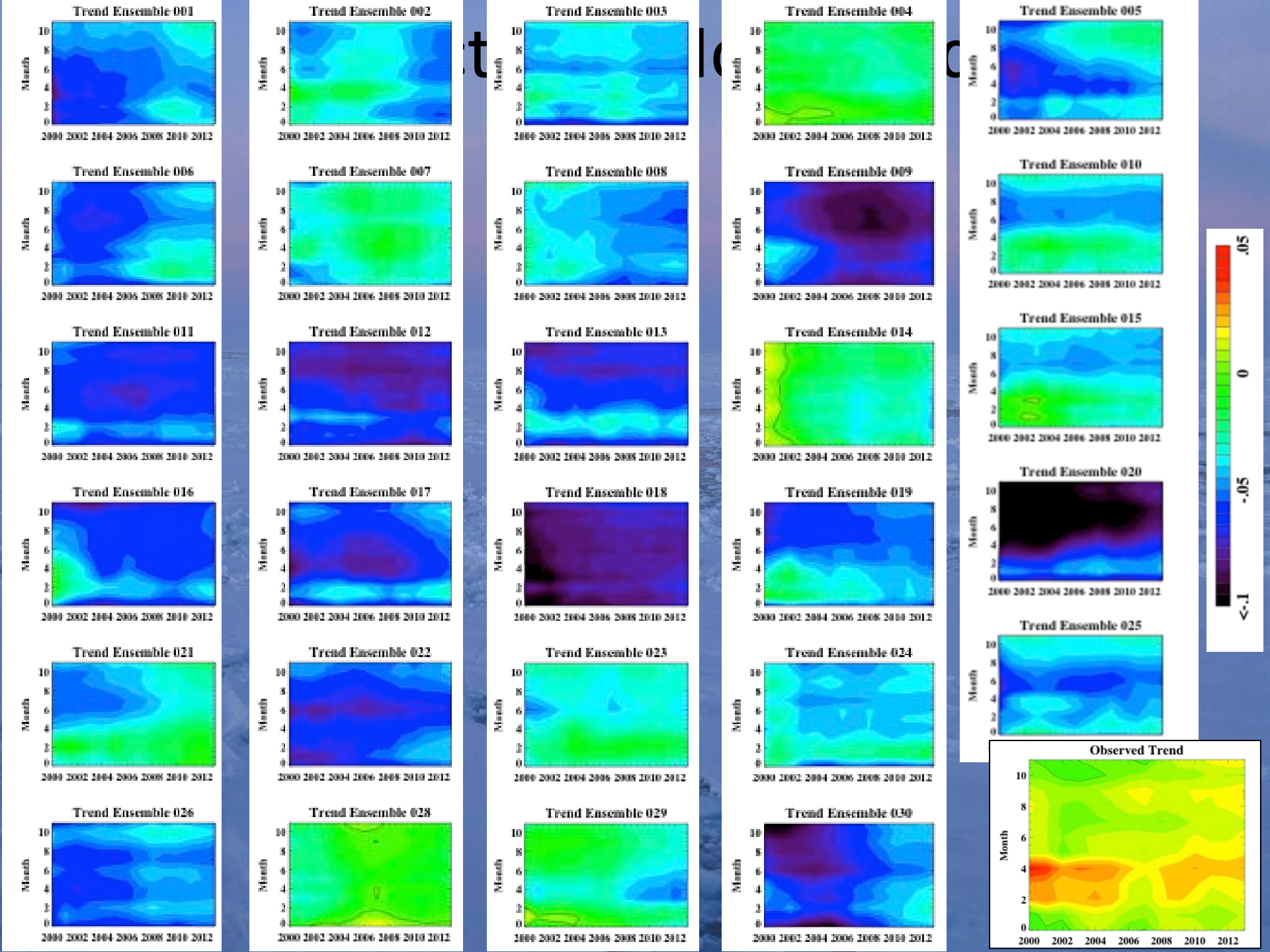


Ensemble mean simulates a decrease in Antarctic sea ice, although members span the range of the observed conditions

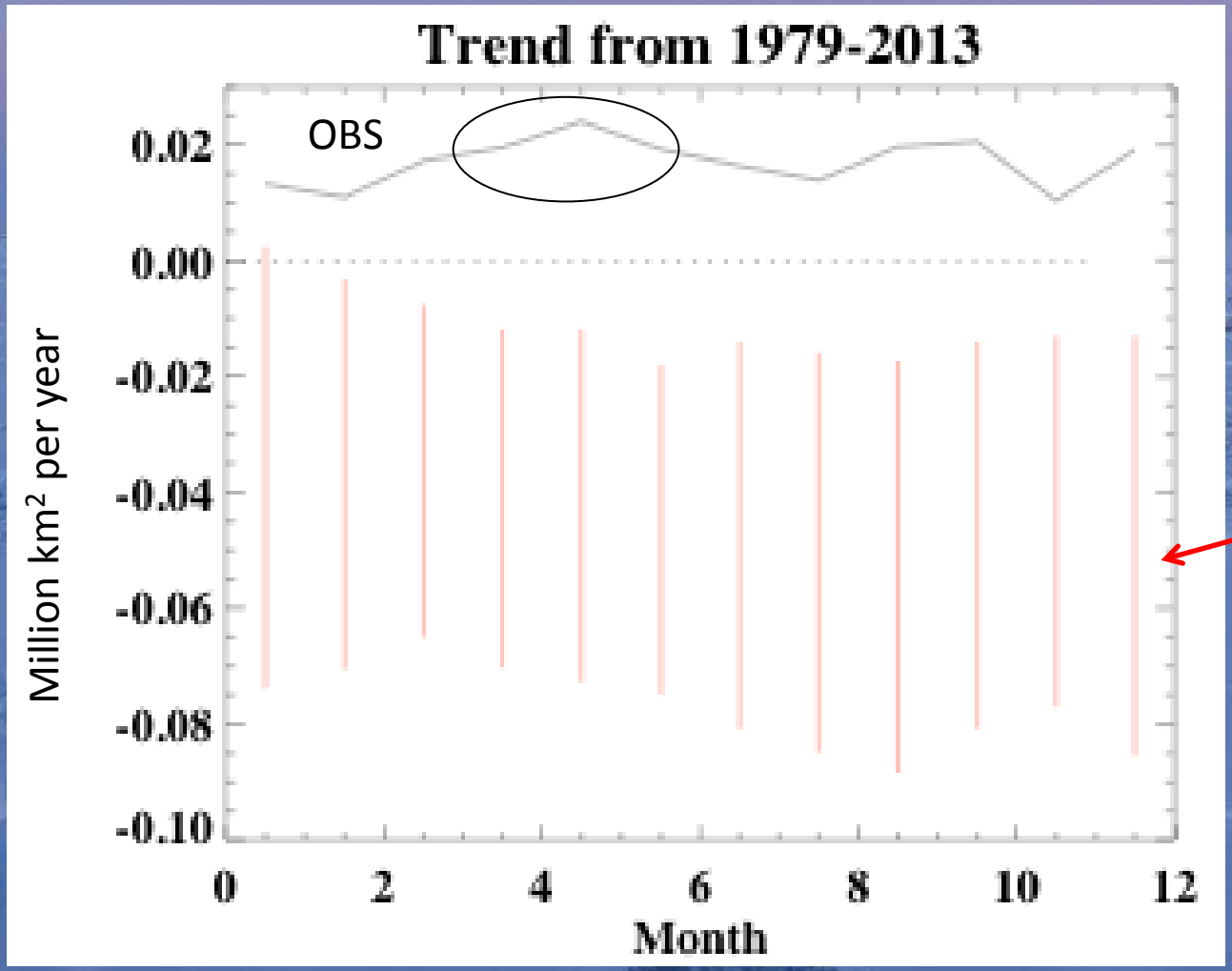
This is in contrast to observations which show an increase in ice cover

Observed Antarctic Sea Ice Trends




Trend Ensemble 001
Trend Ensemble 002
Trend Ensemble 003
Trend Ensemble 004
Trend Ensemble 005
Trend Ensemble 006
Trend Ensemble 007
Trend Ensemble 008
Trend Ensemble 009
Trend Ensemble 010
Trend Ensemble 011
Trend Ensemble 012
Trend Ensemble 013
Trend Ensemble 014
Trend Ensemble 015
Trend Ensemble 016
Trend Ensemble 017
Trend Ensemble 018
Trend Ensemble 019
Trend Ensemble 020
Trend Ensemble 021
Trend Ensemble 022
Trend Ensemble 023
Trend Ensemble 024
Trend Ensemble 025
Trend Ensemble 026
Trend Ensemble 028
Trend Ensemble 029
Trend Ensemble 030
Observed Trend
Month
2000 2002 2004 2006 2008 2010 2012
.05
0
-.05
<-.1

Ice Extent Trends



Range across ensemble members

Possible reasons why LE does not simulate increasing ice in late 20th century

- Regional compensation of trends not well expressed
- Anthropogenic warming signal is too large at the surface
  - For example because of inadequate ocean heat uptake
- Influence of ozone loss not well represented
  - E.g., “slow response” may happen too fast or be too large
- Model has missing processes (e.g. associated with ice sheets)

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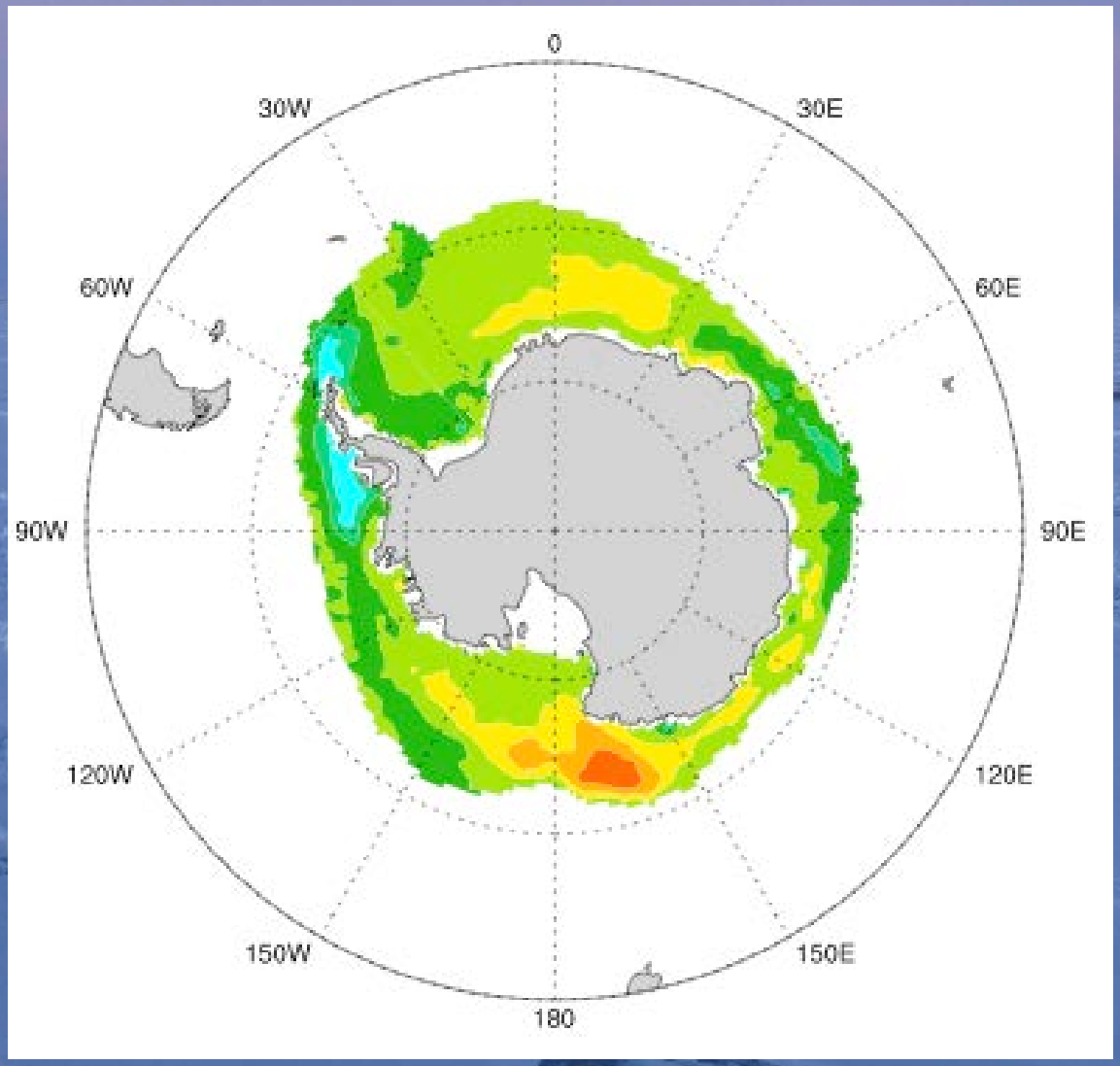
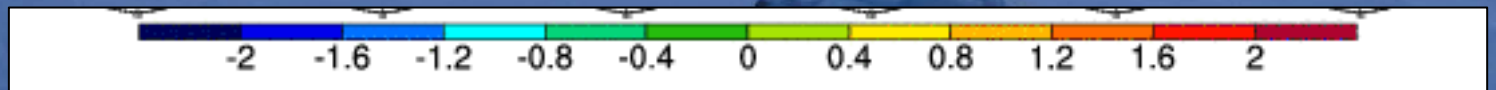
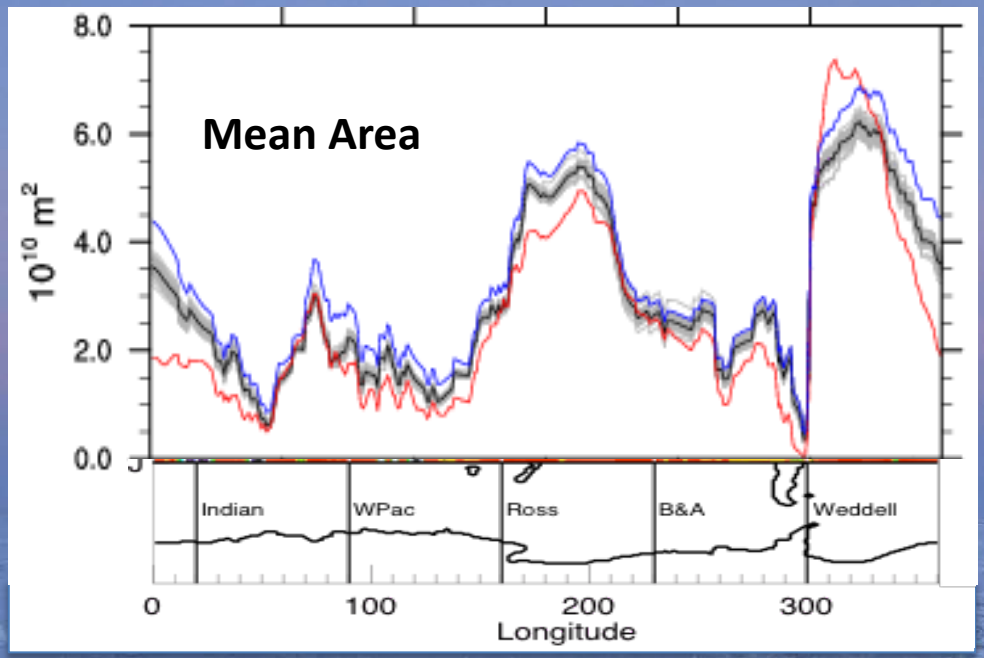
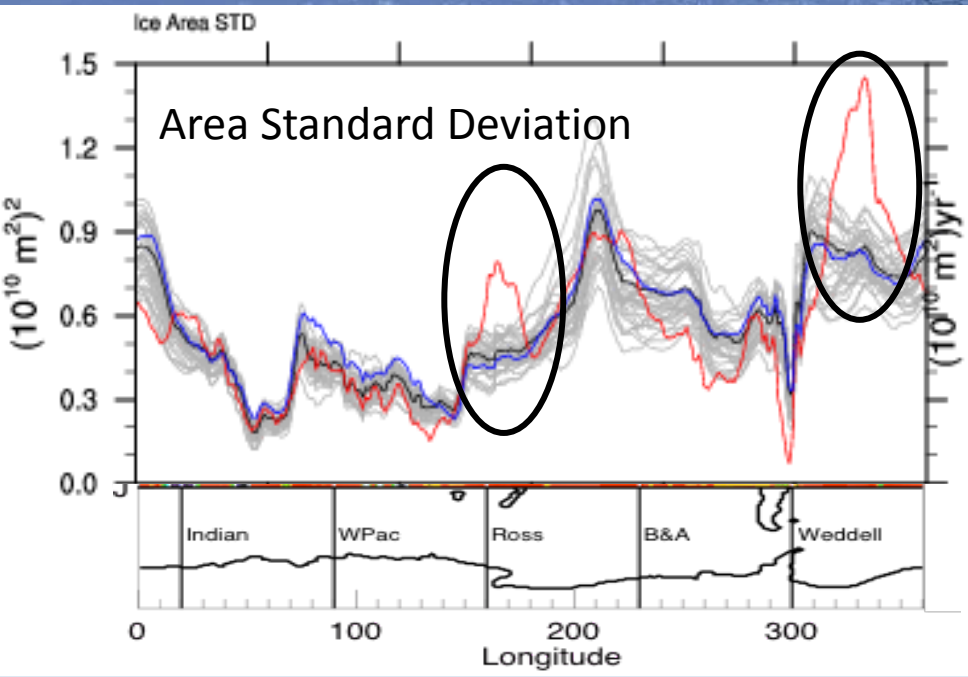
AMJ Observed Trends (1980-2005)

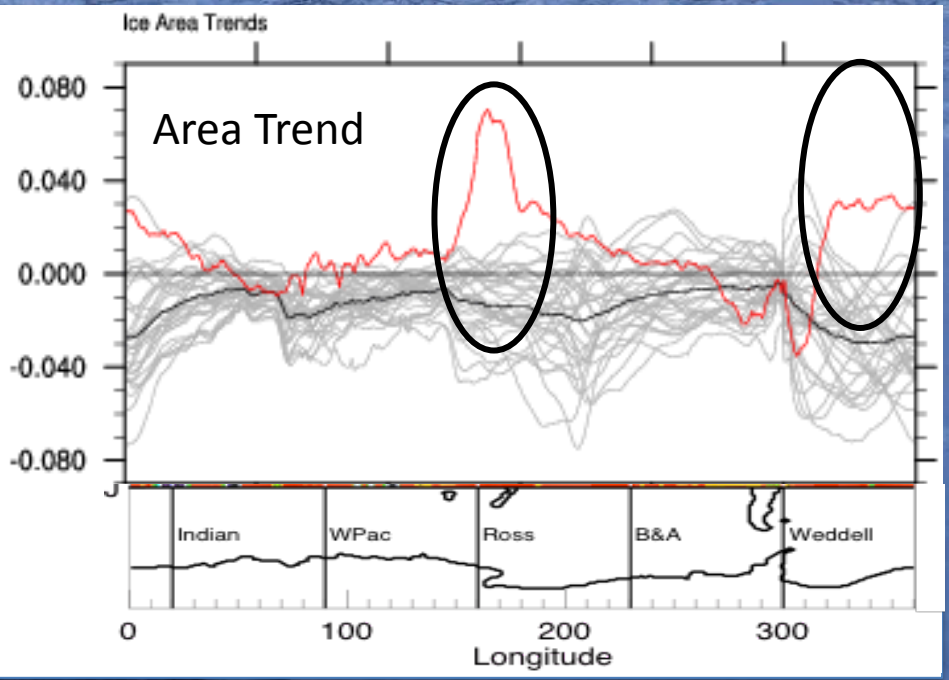




Sea Ice Properties for AMJ

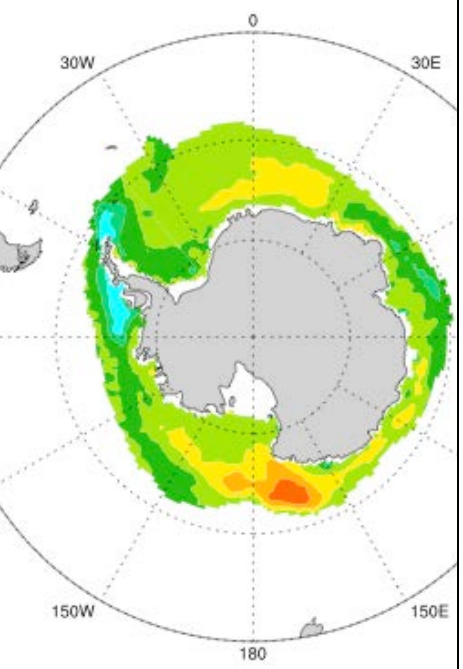




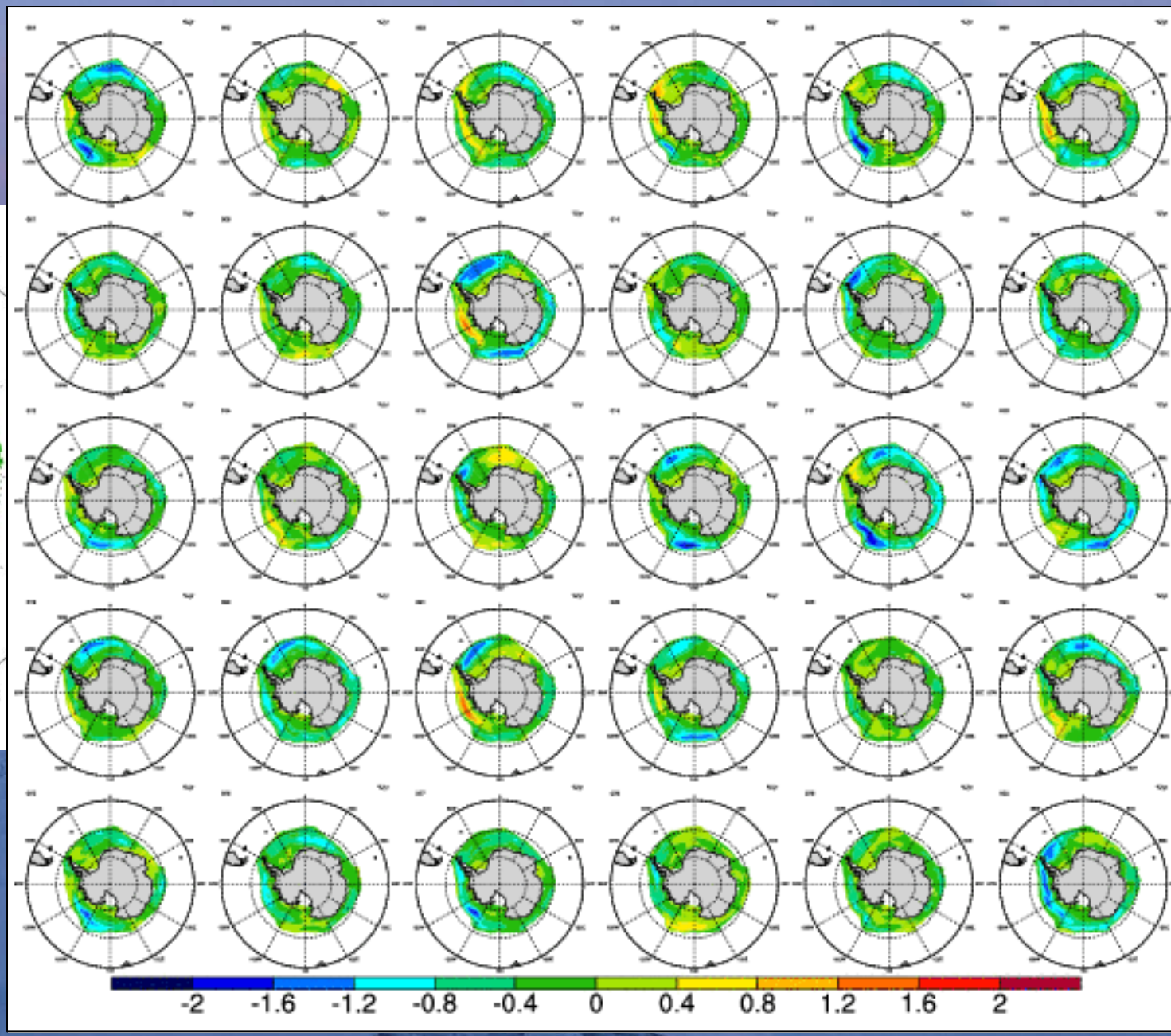


Regional trends

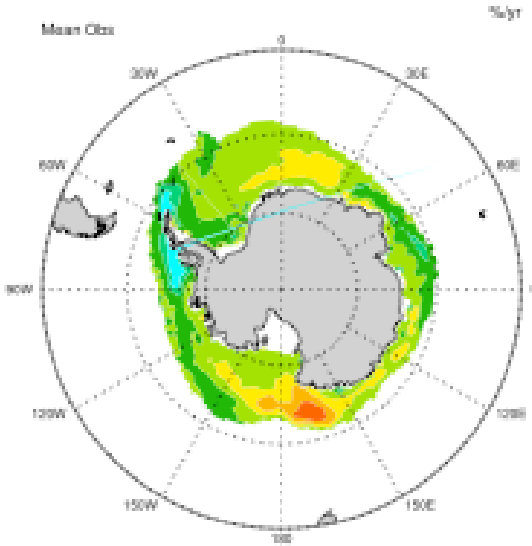
Observed



AMJ Trends, 1980-2005

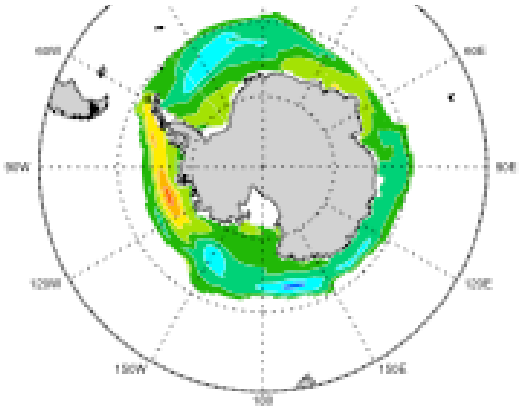


AMJ Trends (1980-2005)

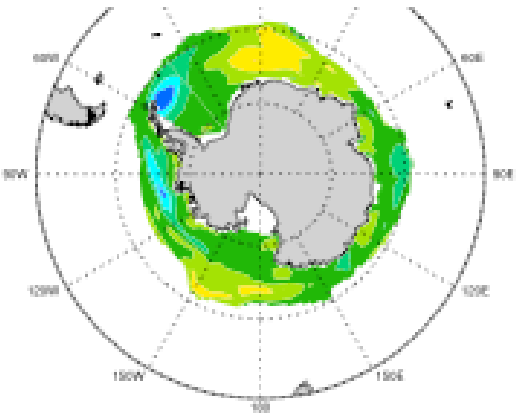


(Observed)

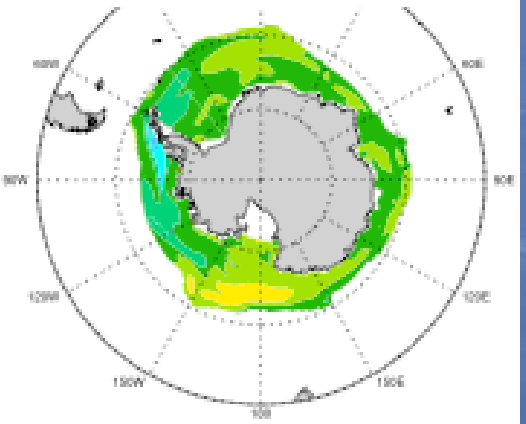
Pattern correlation ~-0.4
Trend ~-0.05

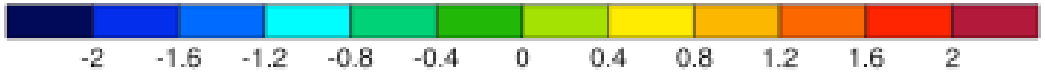


Pattern correlation ~0.45
Trend ~-0.012

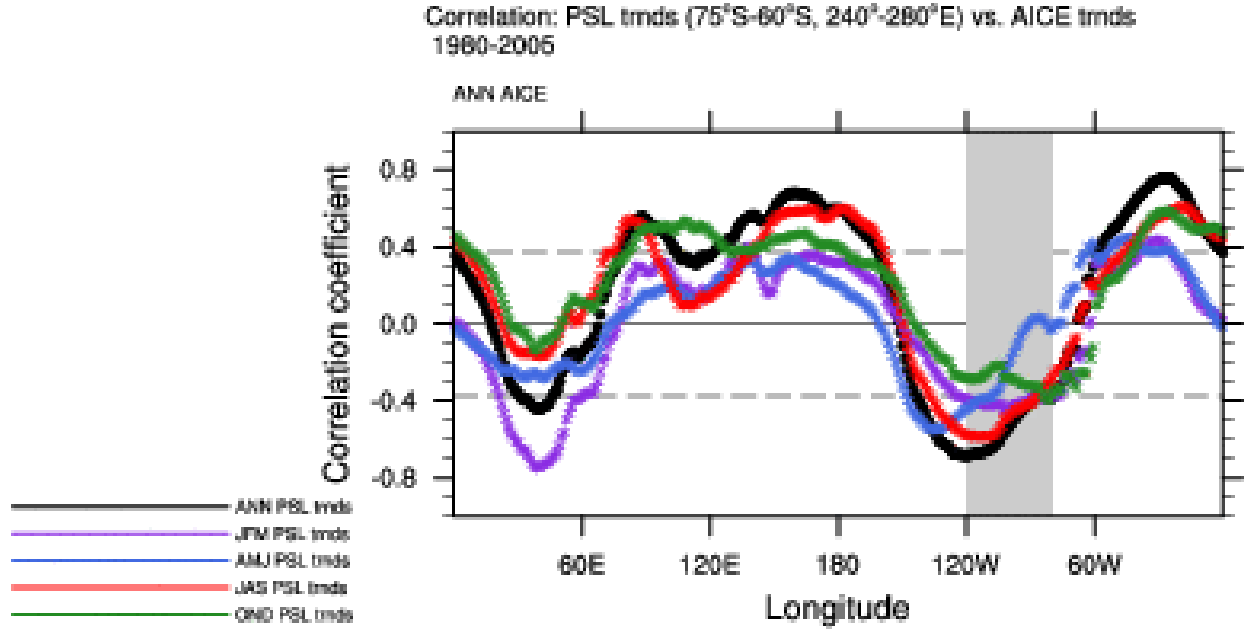


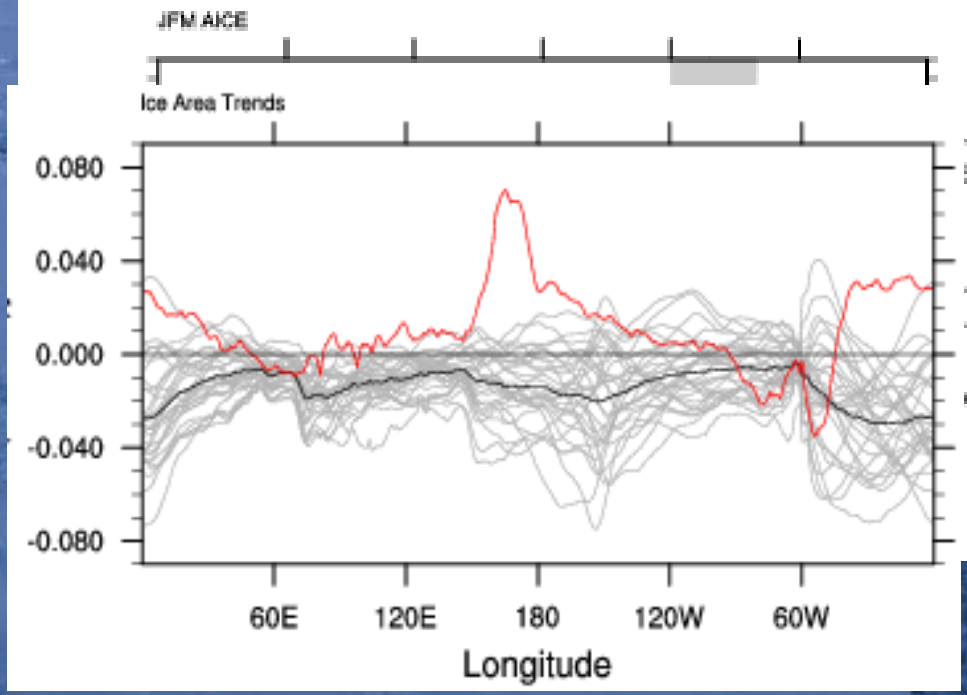
Pattern correlation ~0.5
Trend ~-0.015

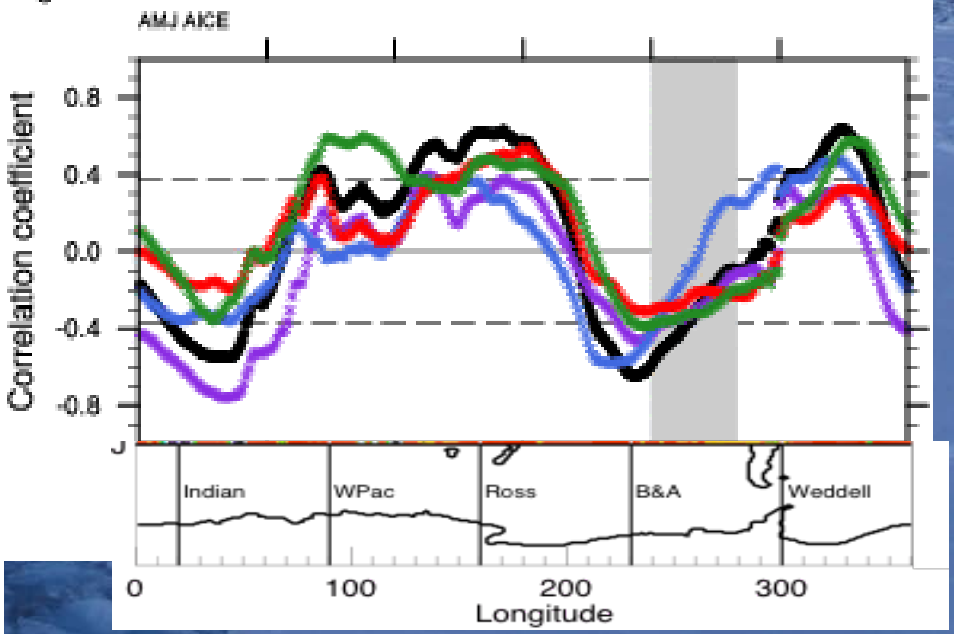




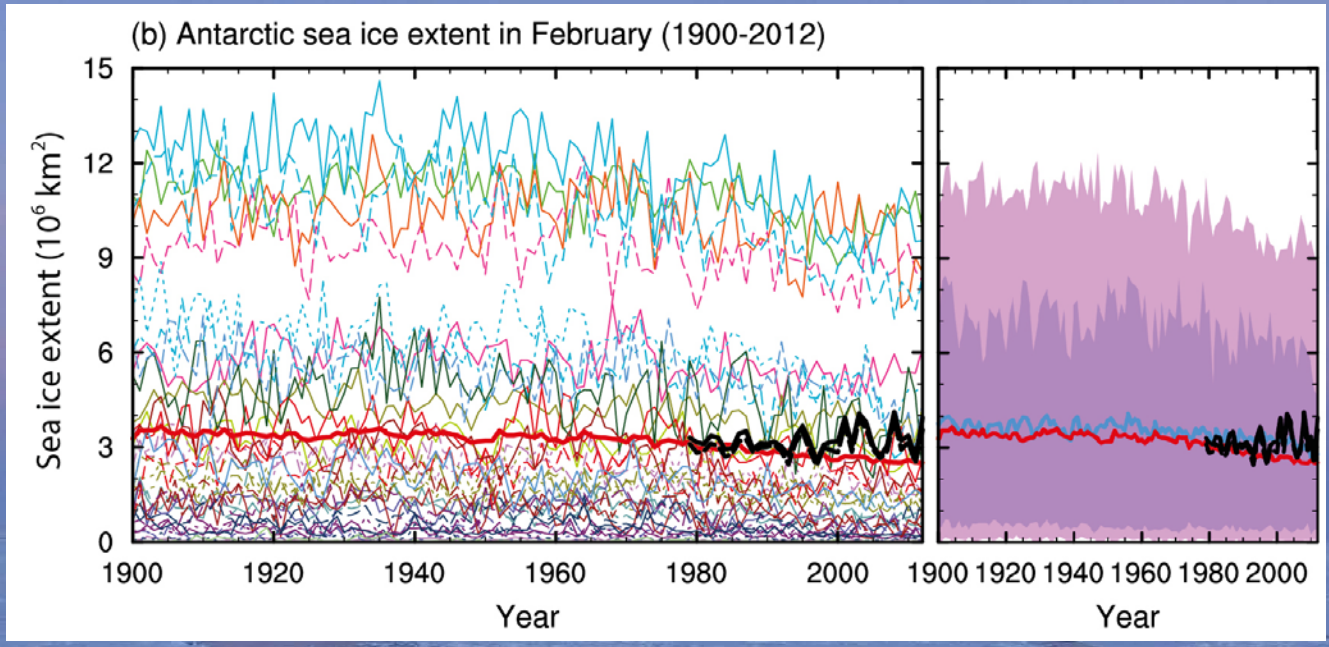
The simulations with high pattern correlation generally have less ice loss

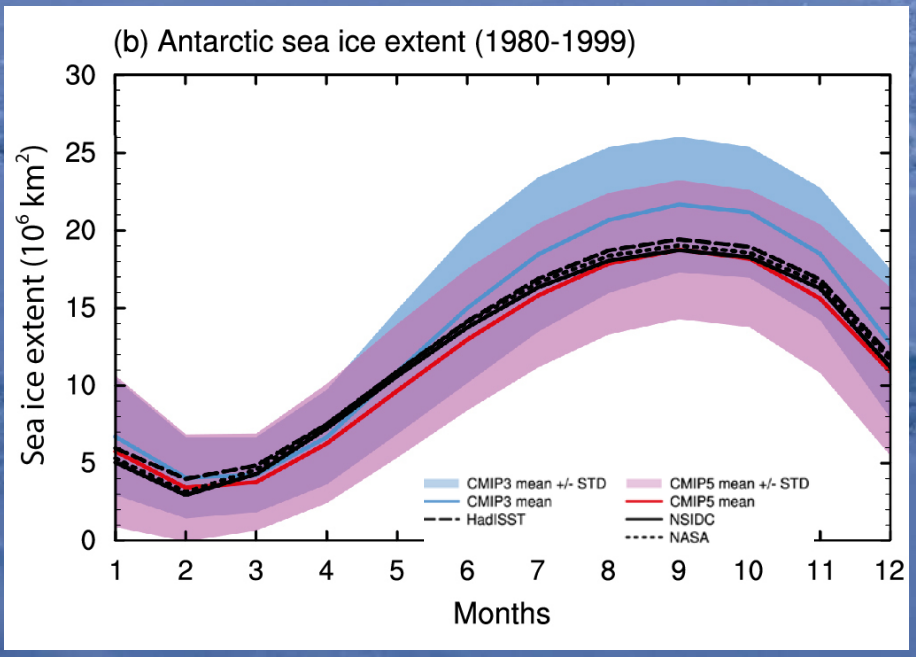

Correlation: PSL trnds (75°S-60°S, 240°-280°E) vs. AICE trnds
1980-2005
ANN AICE
Correlation coefficient
0.8
0.4
0.0
-0.4
-0.8
60E
120E
180
120W
60W
Longitude
ANN PSL trnds
JFM PSL trnds
AMJ PSL trnds
JAS PSL trnds
OND PSL trnds


JFM AICE
Ice Area Trends
0.080
0.040
0.000
-0.040
-0.080
60E
120E
180
120W
60W
Longitude

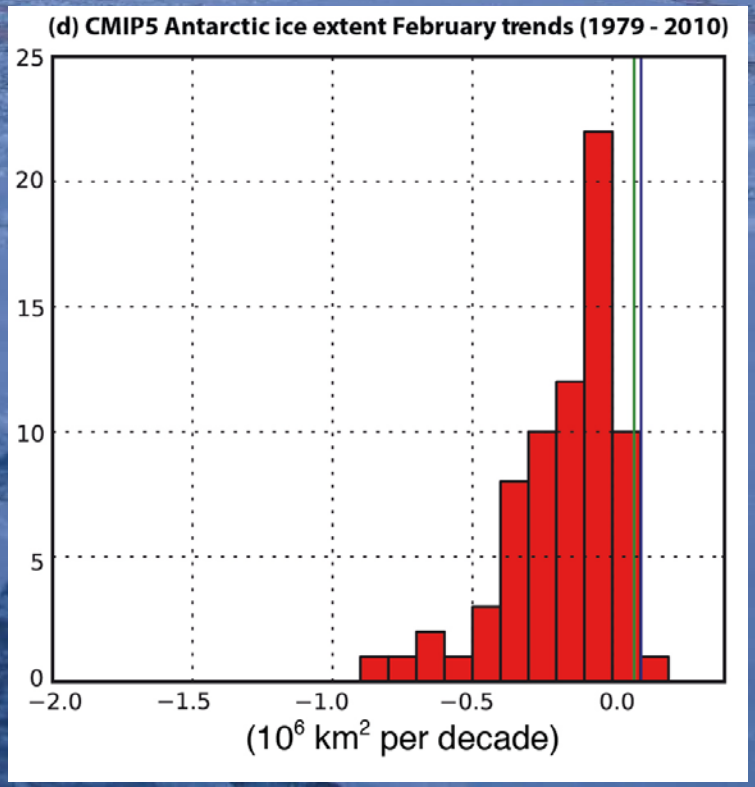

AMJ AICE
Correlation coefficient
0.8
0.4
0.0
-0.4
-0.8
Indian
WPac
Ross
B&A
Weddell
0
100
200
300
Longitude

CMIP5 simulations





IPCC WG1 AR5 Figure 9.22

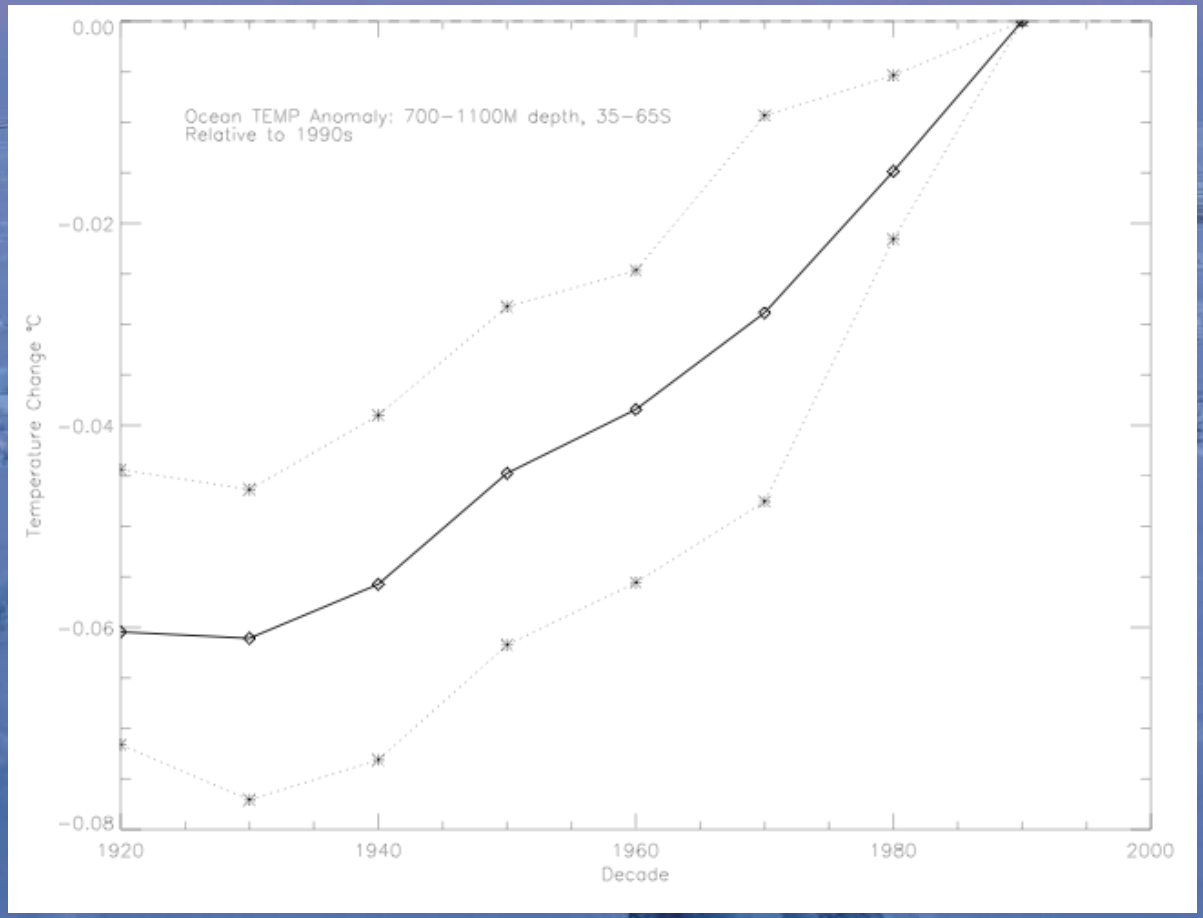


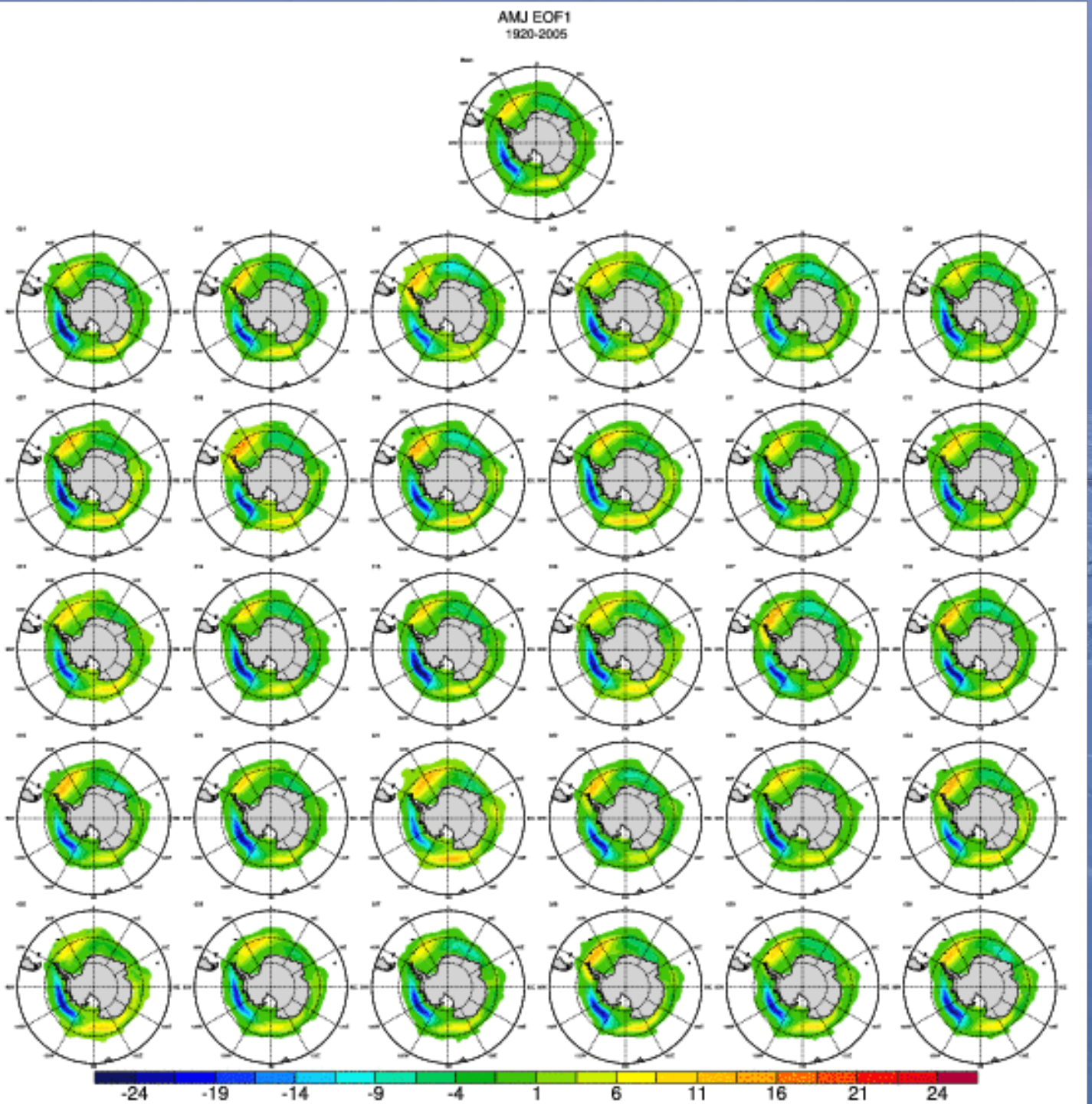
IPCC AR5 Figure 9.24

Conclusions

- CESM Large Ensemble simulations show reductions in Antarctic sea ice in contrast to observations
- Some members do simulate regional ice trend patterns similar to observations
  - these typically have less ice loss
- CESM-LE has smaller standard deviation in areas of increasing ice trends
  - ongoing work is diagnosing the drivers of this variability
- Other factors that may affect overall Antarctic sea ice loss are also being investigated

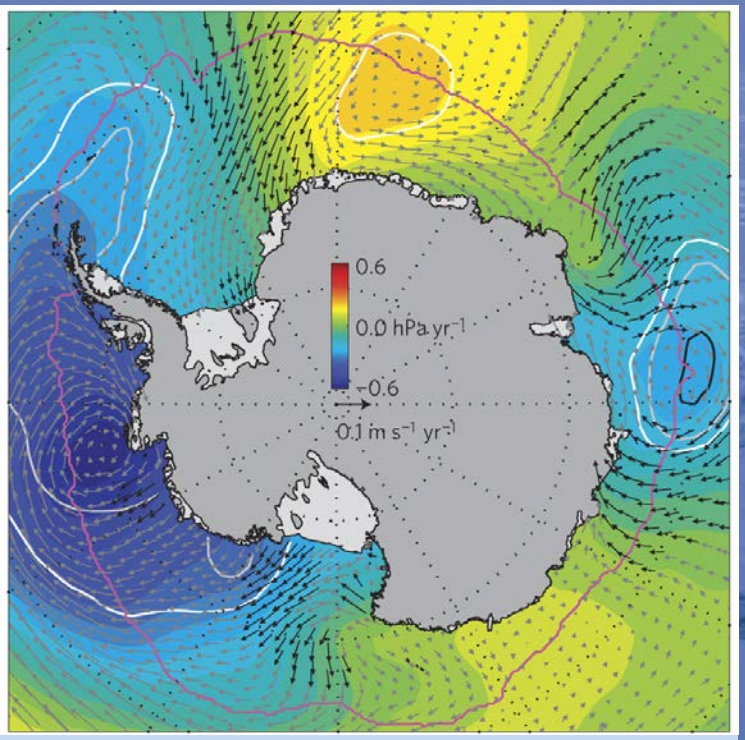
Ocean Temperature Change



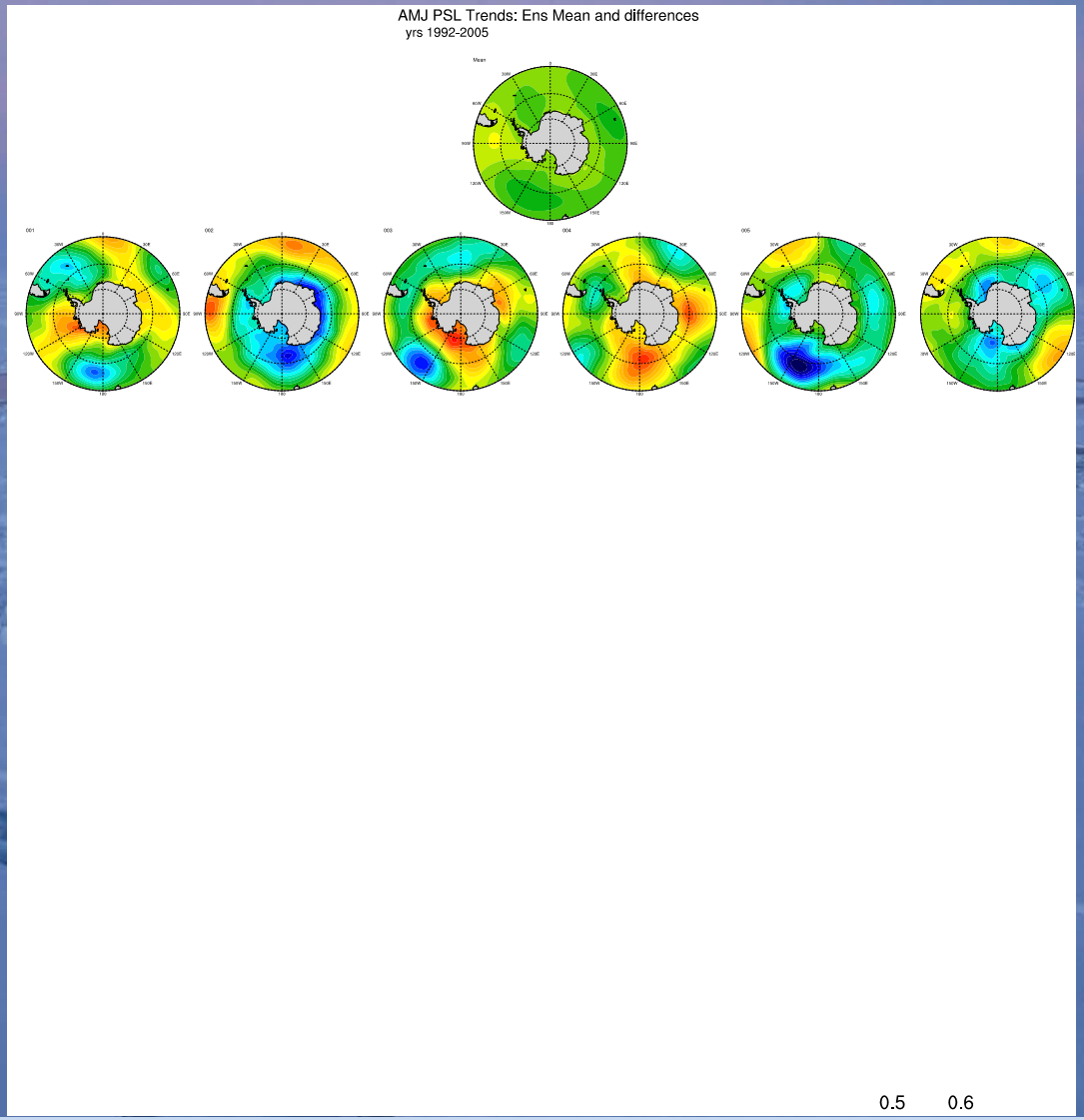


1st EOF of AMJ sea ice concentration

Model correctly simulates processes but not correct regional and/or seasonal magnitudes or ratios



Autumn (AMJ) 1992-2010 trends in winds (vectors) and sea level pressure (contours).
Fig. 3 from Holland and Kwok, 2012, Nature Geoscience, 5, 872-875.



CESM LE: AMJ Sea Level Pressure trends, 1992-2005, ens. Mean and individual runs

Project overview

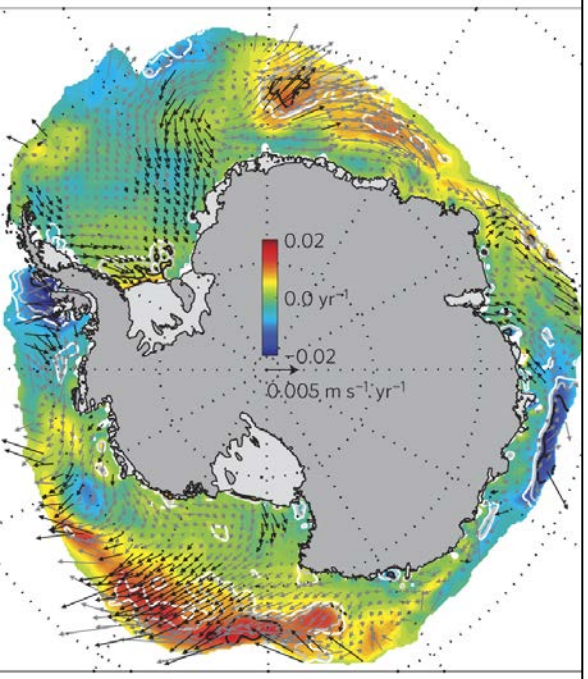
- Majority of CMIP5 models show decreasing trends (over the satellite era) in SH (summer) sea ice in contrast to observations
- Most CMIP5 models also overestimate SH (winter) sea ice variability (trends vs. natural variability?)
- Ozone changes impact atmospheric circulation in SH – how does this effect sea ice (and can we rely on model projections?
  - E.g. Sigmond and Fyfe, 2010, Has the ozone hole contributed to increased Antarctic sea ice extent? GRL, **37** and Smith, Polvani and Marsh, 2012, Mitigation of 21st century Antarctic sea ice loss by stratospheric ozone recovery, GRL, **39**.
- Why?
  - Use the CESM Large Ensemble (30 20th-21st Century simulations) to try to tease apart some answers to a complicated question
  - Ocn, atm, ice responses to greenhouse gas and ozone changes

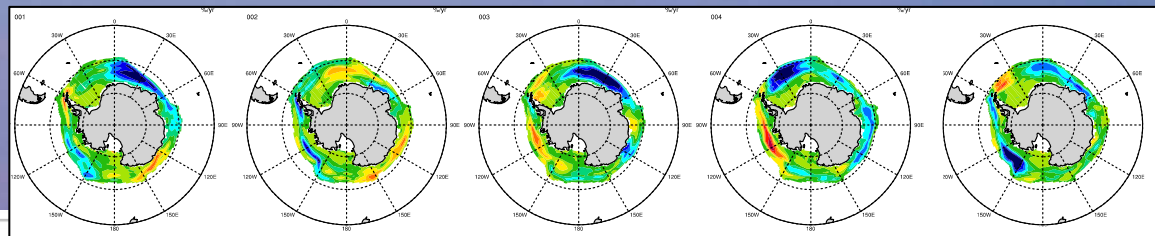
Preliminary figures and first steps

- Use LE simulations individually to look at regional and seasonal processes (regional similarities vs. mean hemisphere differences; seasonality)

Regional trends

AMJ 1992-2010 Trends
Holland and Kwok, 2012





CESM LE: AMJ Ice concentration trends, 1992-2005, ens. Mean and individual runs