



Inter-annual to multi-decadal Arctic sea ice extent trends in a warming world

GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L15708, [doi:10.1029/2011GL048008](https://doi.org/10.1029/2011GL048008), 2011

Inter-annual to multi-decadal Arctic sea ice extent trends in a warming world

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Received 2 May 2011; revised 1 July 2011; accepted 8 July 2011; published 11 August 2011.

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June 21, 2011 MODIS visible image

Statistically significant Arctic sea ice extent loss is occurring in all months

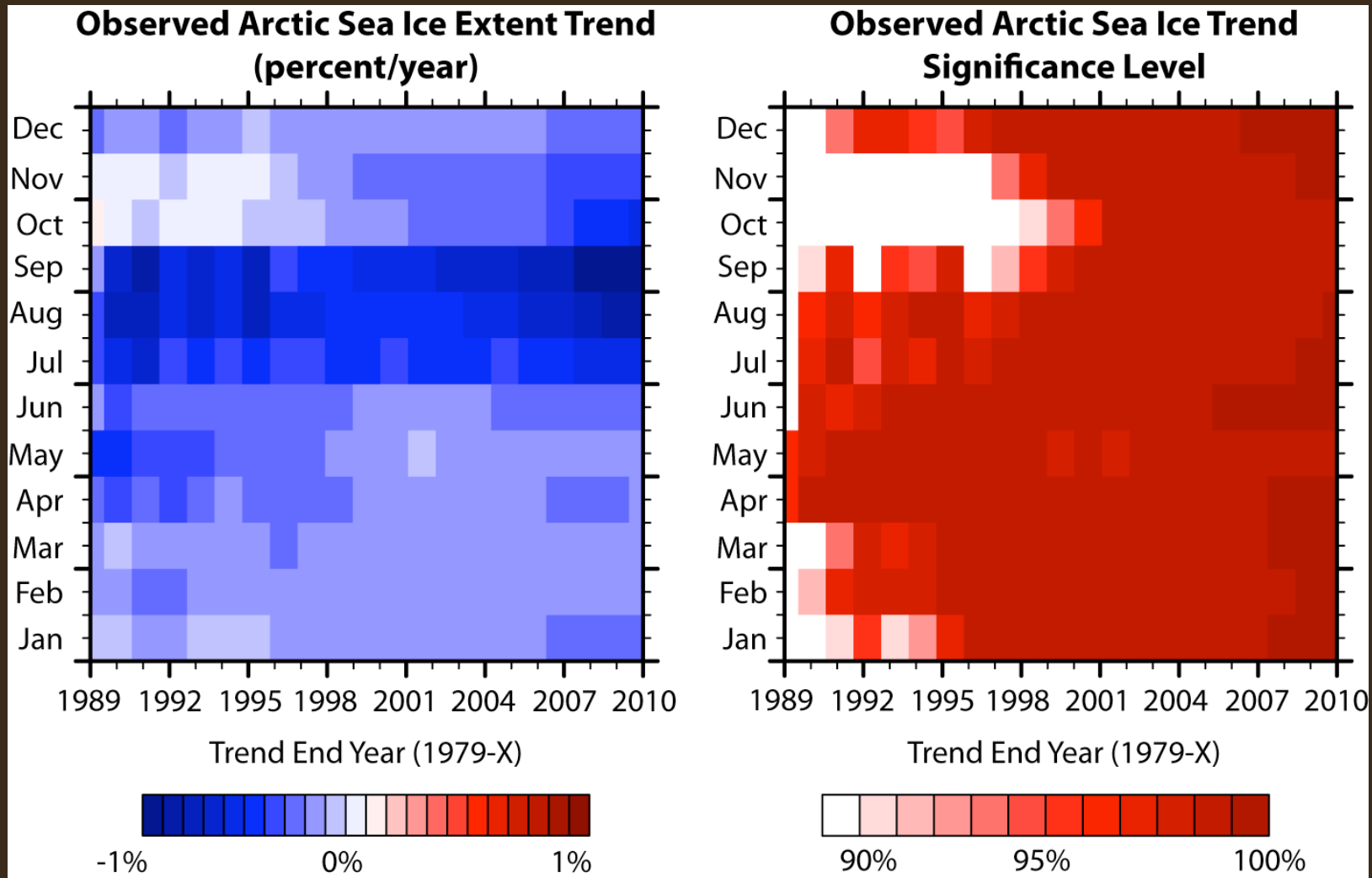


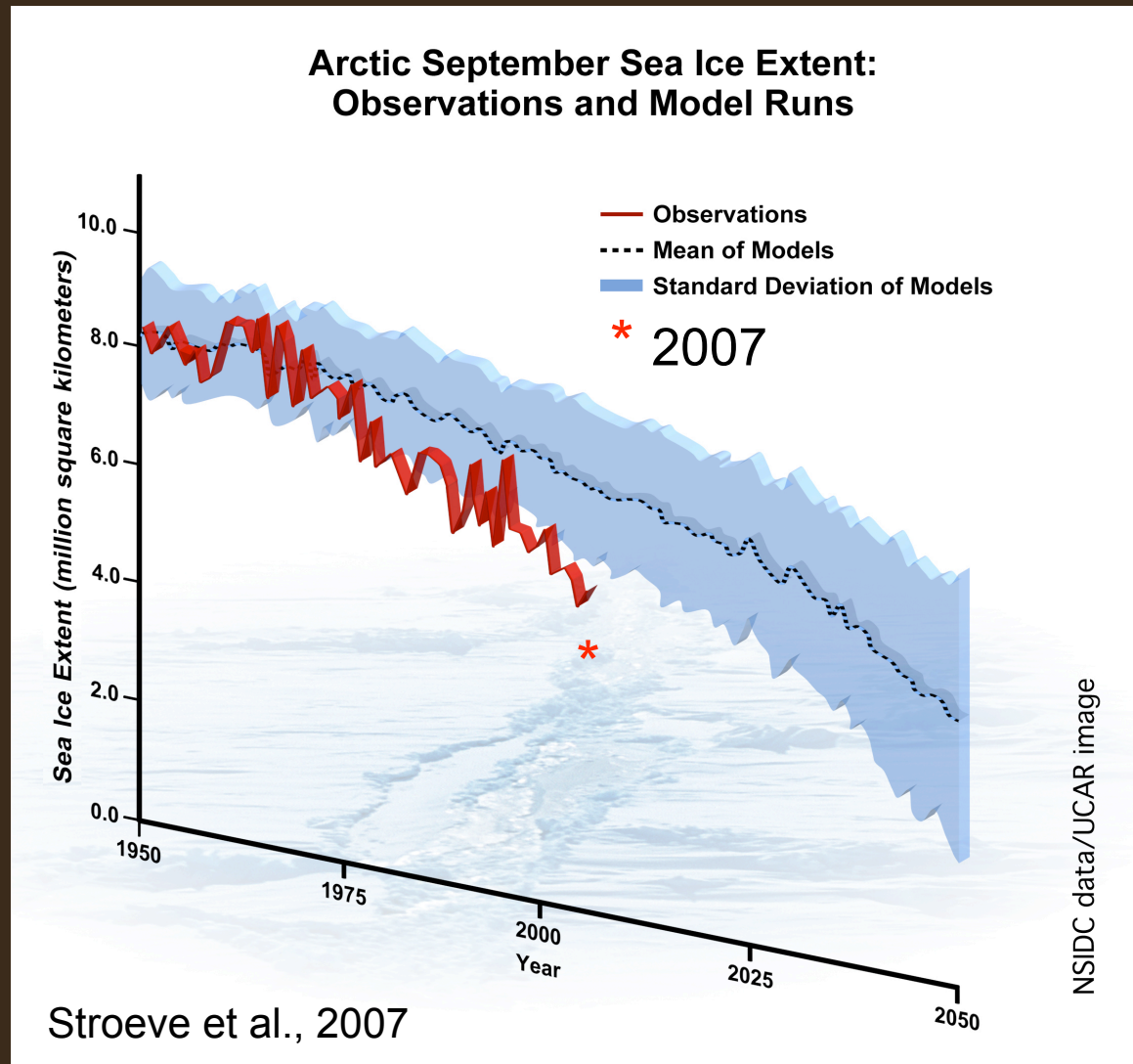
Figure modified from Kay et al. (2011)

**Why has Arctic sea ice extent decreased during the late 20th century?
What do we expect in the future?**

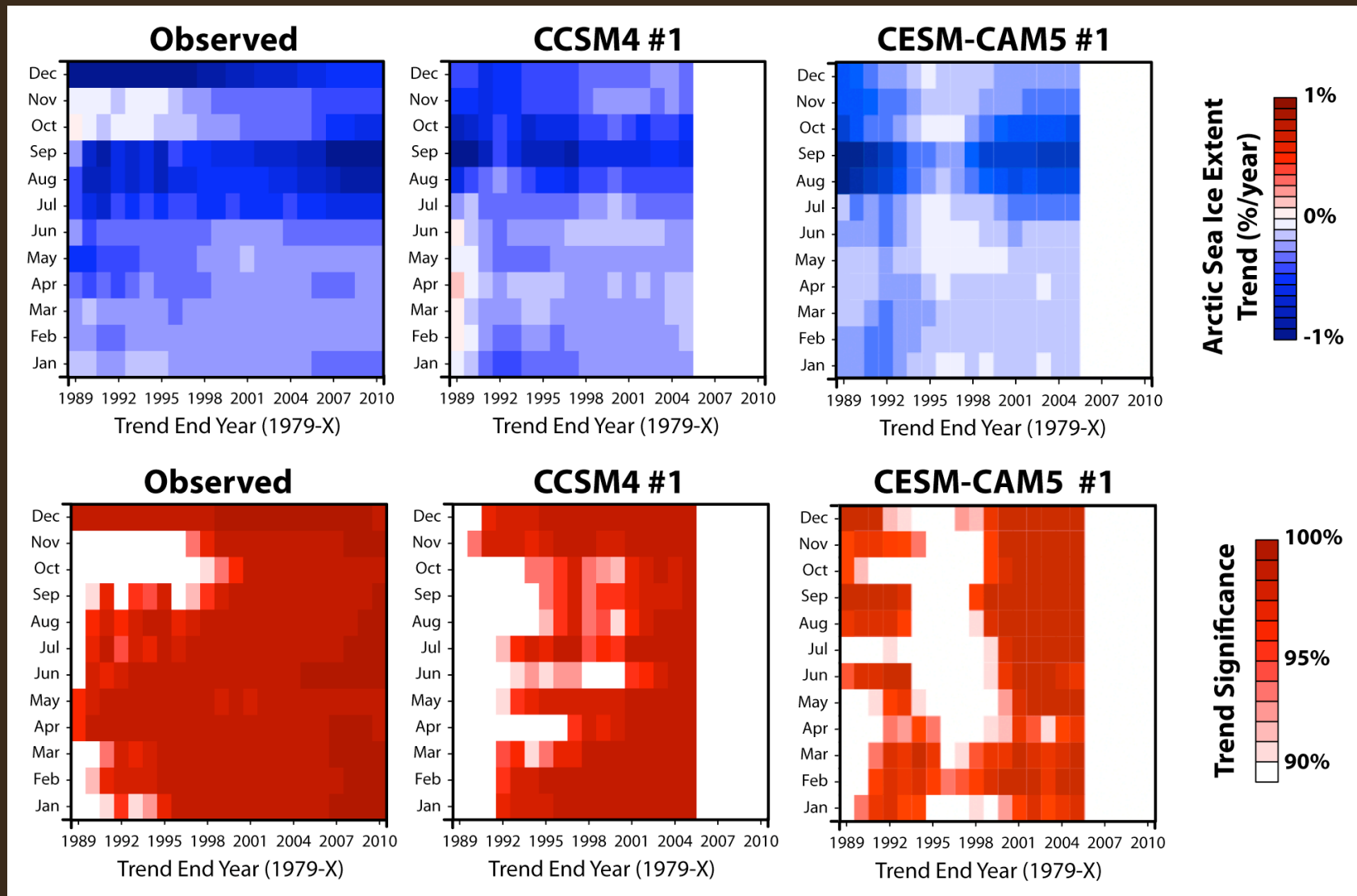


(Let's use climate models, and assume they capture important processes influencing Arctic sea ice trends.)

Observed Arctic sea ice decline is “faster than forecasted” by CMIP3 models...



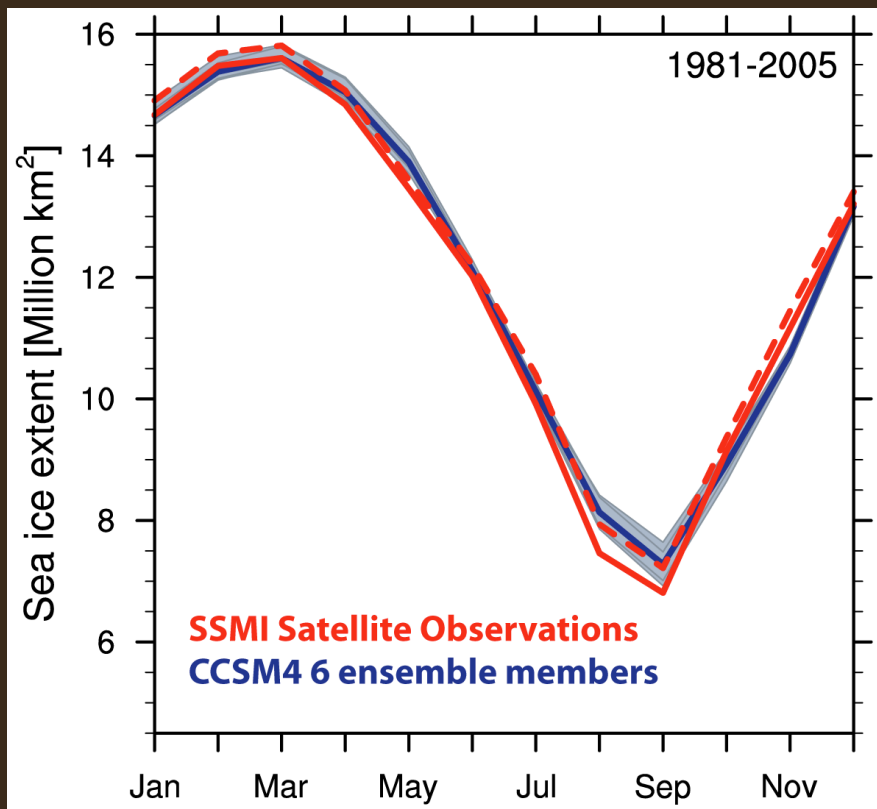
Some climate models can reproduce observed 1979-2005 Arctic sea ice loss...



Many Arctic processes are well represented in CCSM4, but important biases remain.

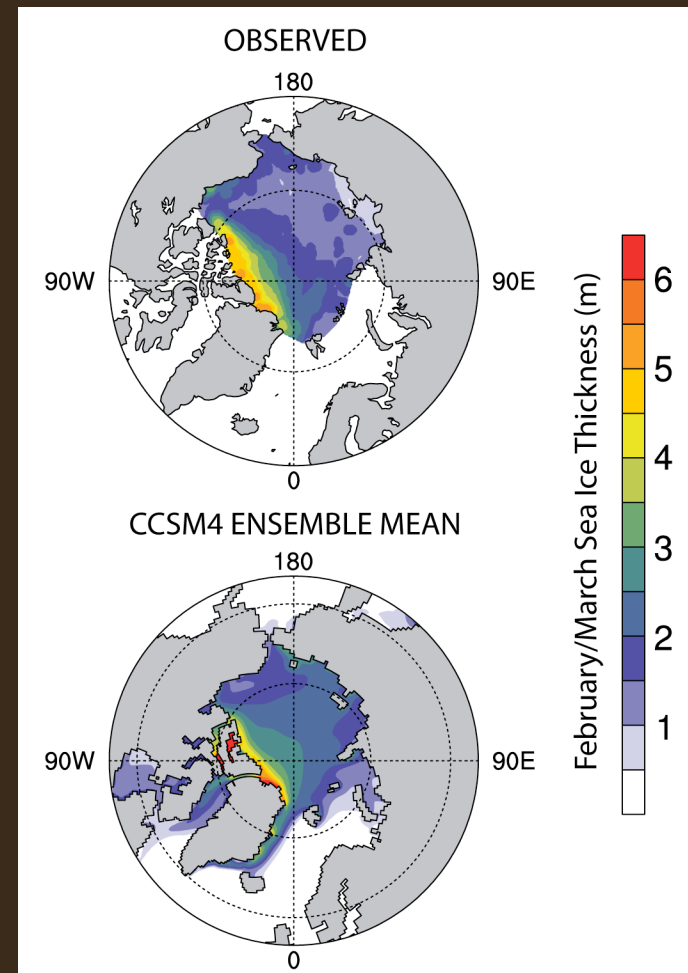
(de Boer et al. accepted, Jahn et al. accepted)

Seasonal variations in sea ice extent

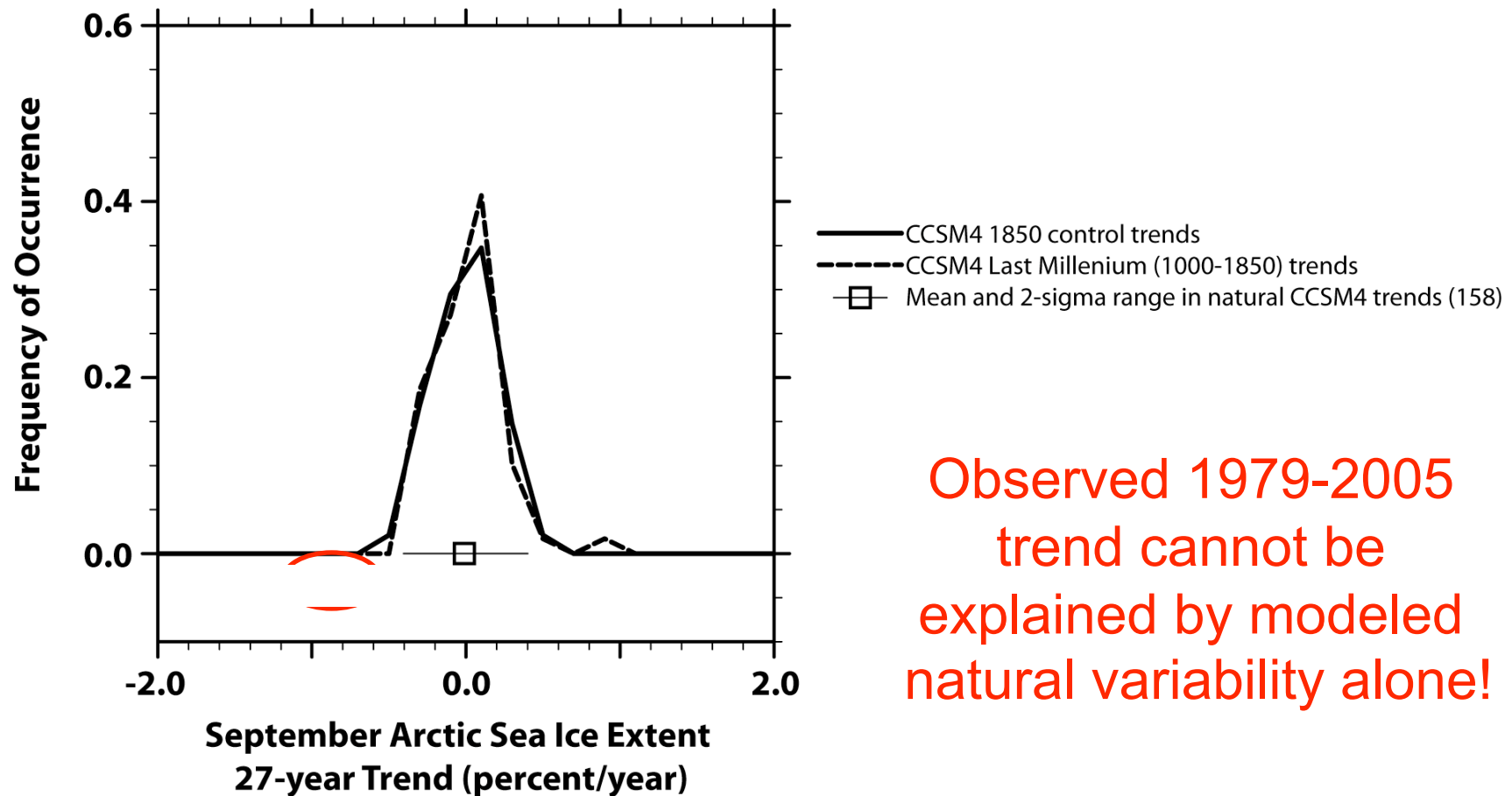


Adapted from Jahn et al. (accepted)

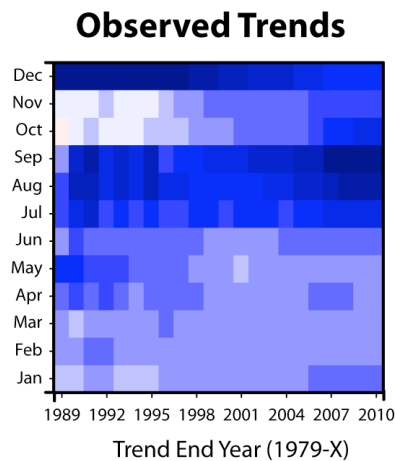
Sea ice thickness distribution



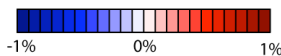
Can natural processes alone explain the observed sea ice extent trends?



CCSM4 has a large spread in 1979-2005 trends. One ensemble member reproduces observed ice loss, another member has no ice loss!



Arctic Sea Ice Extent
Trend (%/year)



CCSM4 Trends

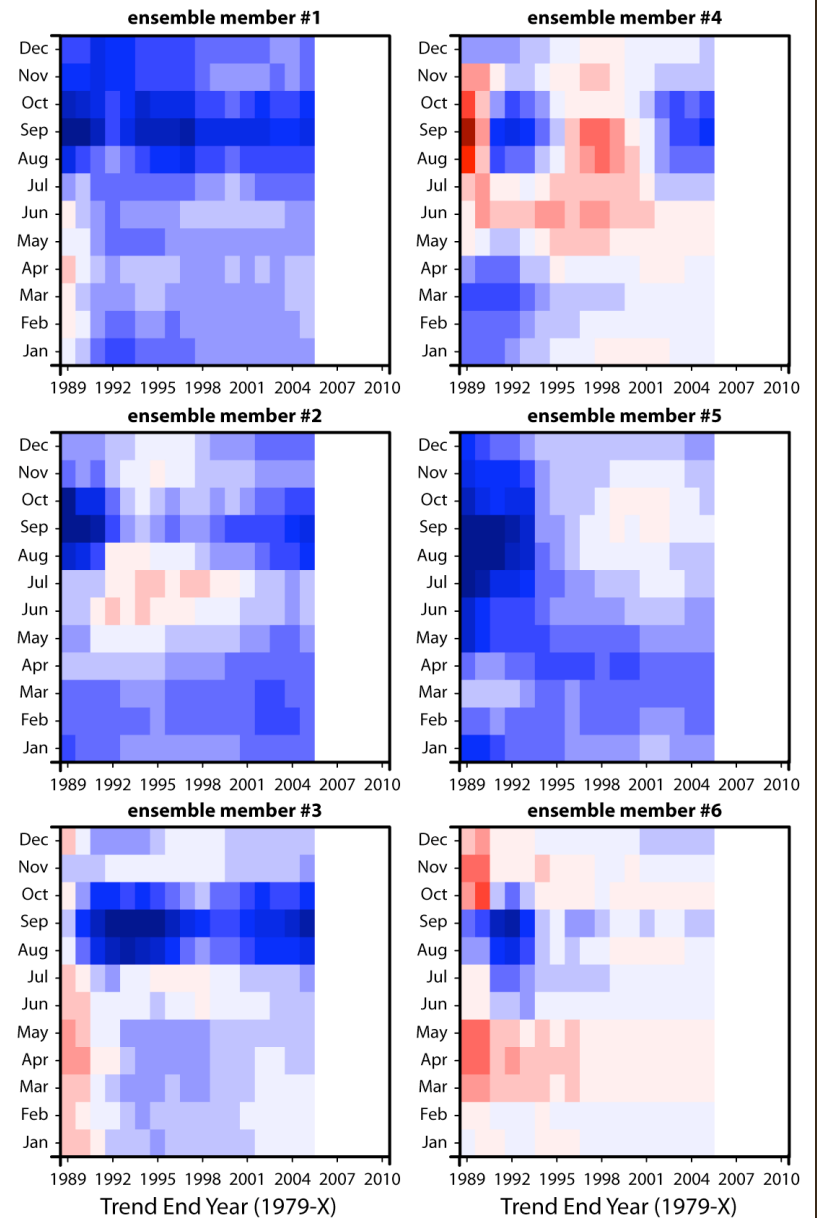
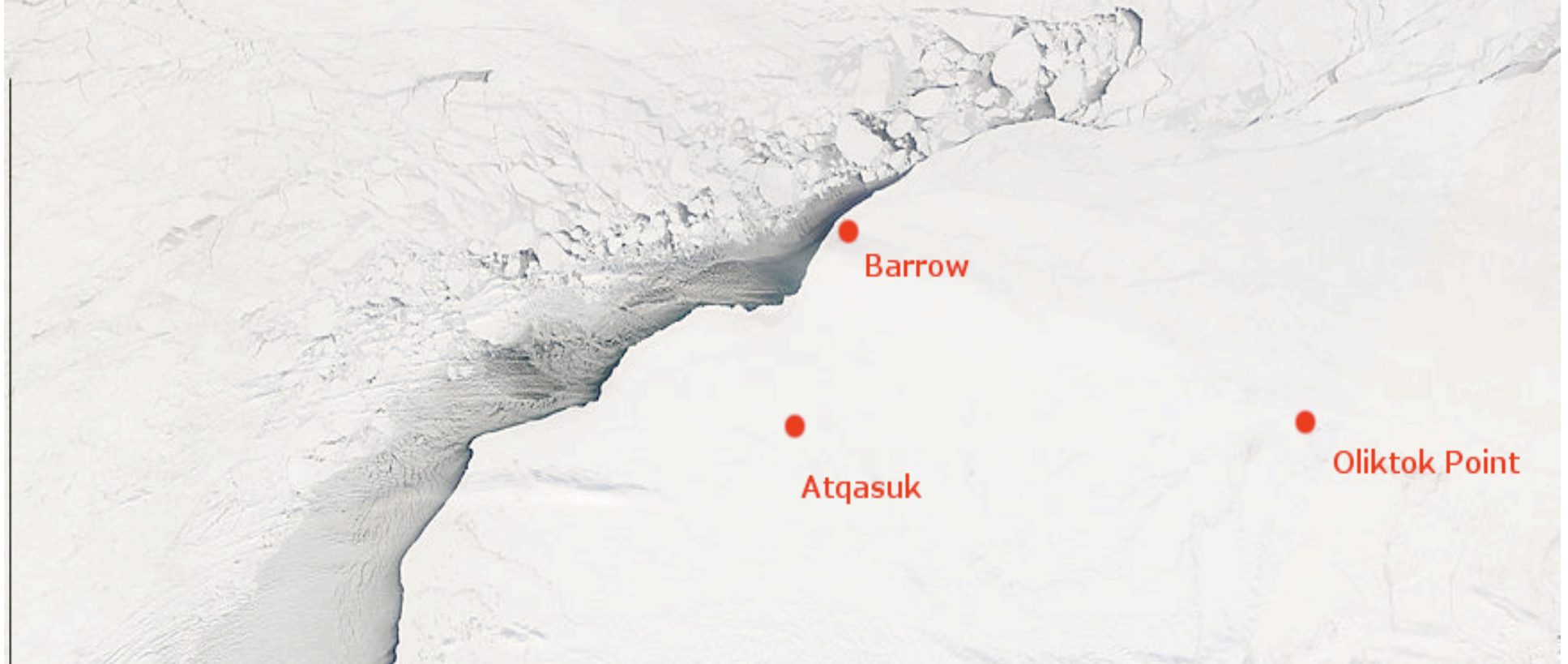


Figure modified from Kay et al. (2011)

Dividing the average CCSM4 trend by the observed trend suggests that internal variability explains approximately half of the observed 1979-2005 September Arctic sea ice extent loss.



Are six CCSM4 ensemble members enough to understand late 20th century Arctic sea ice trends?

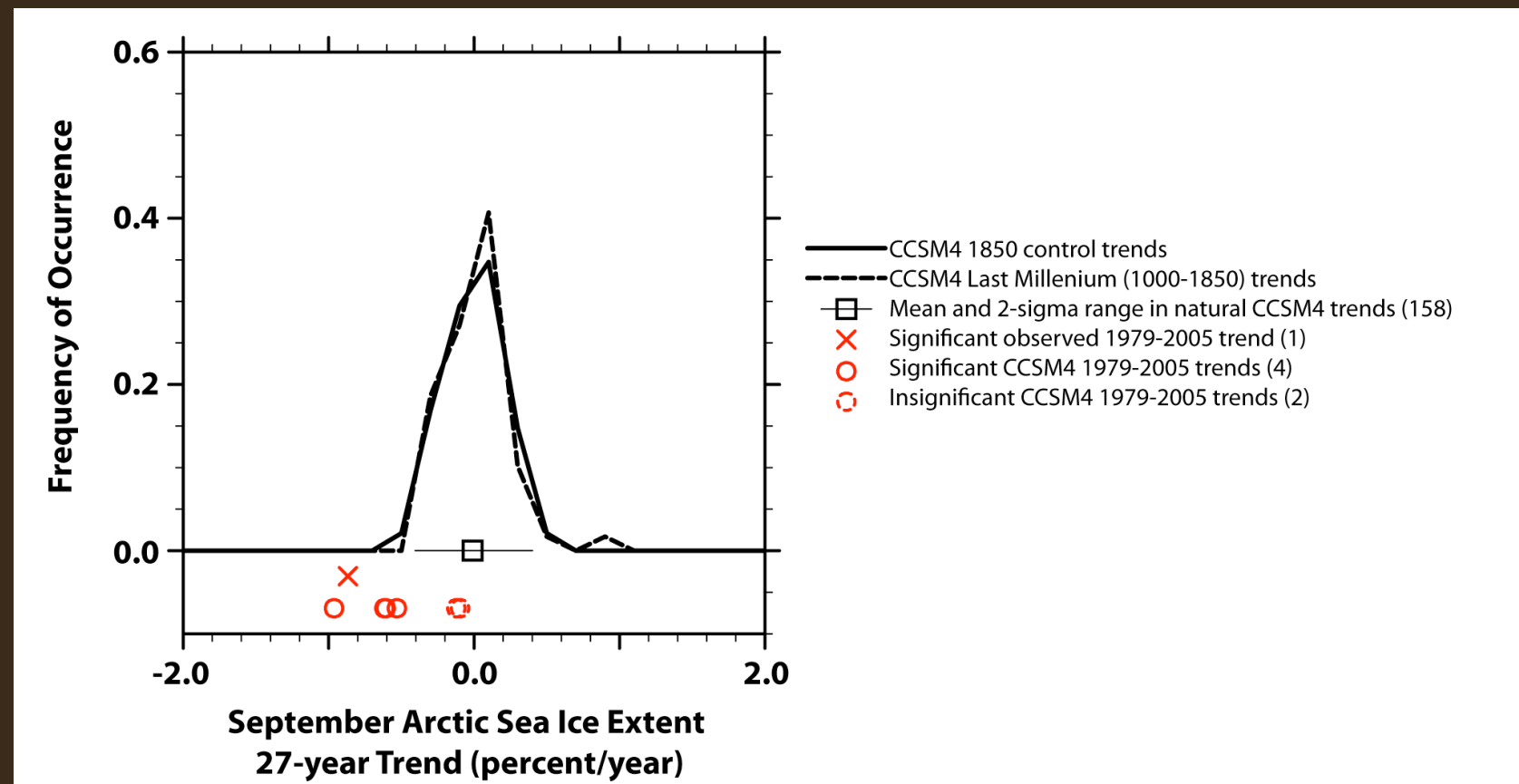


Figure modified from Kay et al. (2011)

Can Arctic sea ice extent temporarily increase in a warming world?

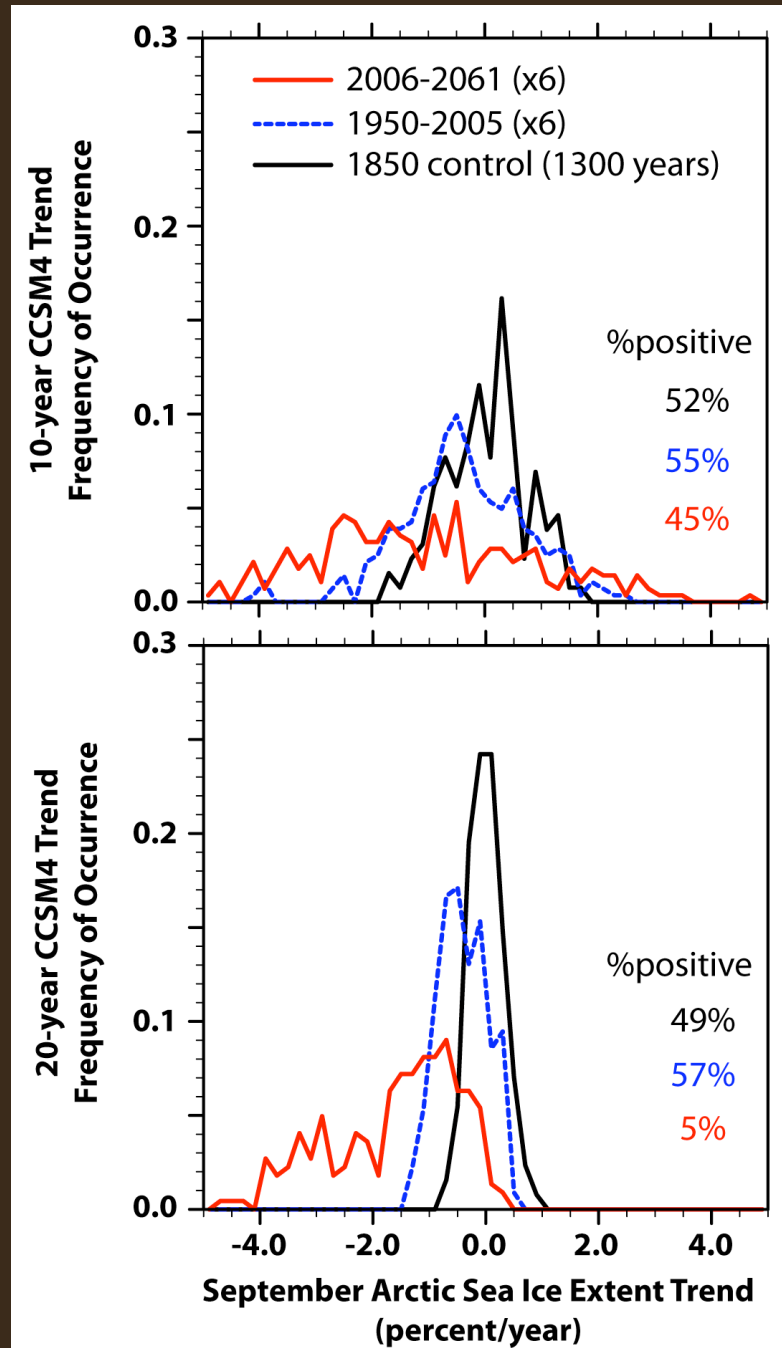


Figure modified from Kay et al. (2011)

A satellite image of Earth showing the Arctic region. The image displays a complex pattern of white sea ice and dark blue ocean water. The text 'Summary' is overlaid in a large, bold, black font in the upper center. Below it, a list of three bullet points is presented in a black font on a semi-transparent white background. In the bottom right corner, the text 'September 9, 2011 MODIS image' is written in a smaller, italicized black font.

Summary

- Statistically significant late 20th century September Arctic sea ice extent loss cannot be explained by natural processes alone.
- A 6-member CCSM4 ensemble suggests that internal variability explains approximately half of the observed 1979-2005 September Arctic sea ice extent loss.
- Because both internal variability and greenhouse forcing are important, large ensembles from credible climate models are needed to understand Arctic sea ice trends in a warming world.

September 9, 2011 MODIS image

EXTRA SLIDES

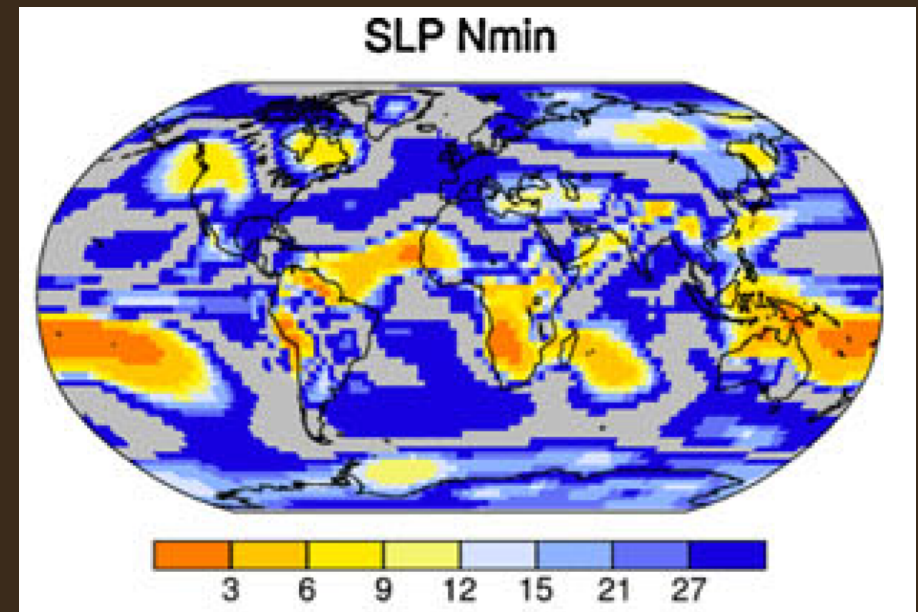
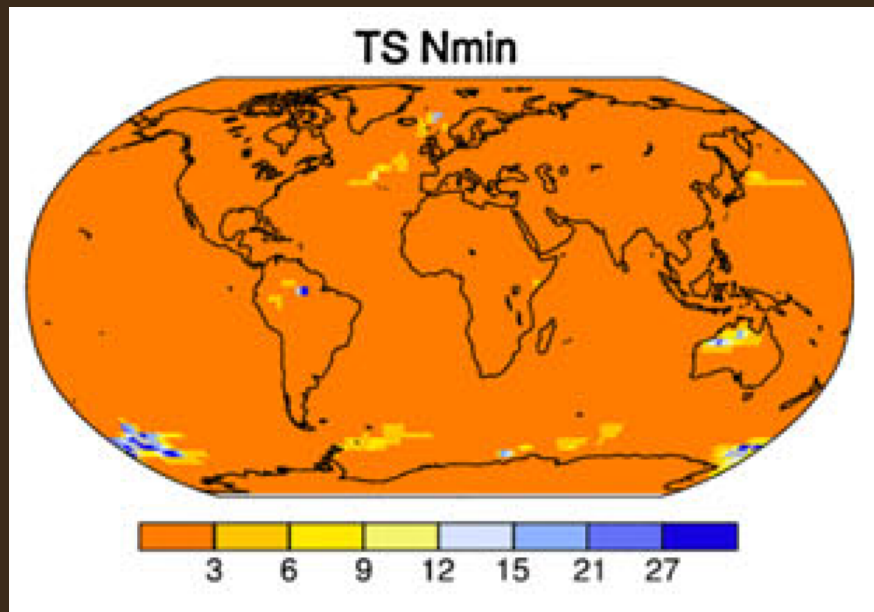
New data + Ice loss = New discoveries

*No cloud response
to summer sea ice
loss, but cloud
increases over
newly open water
during early fall.*

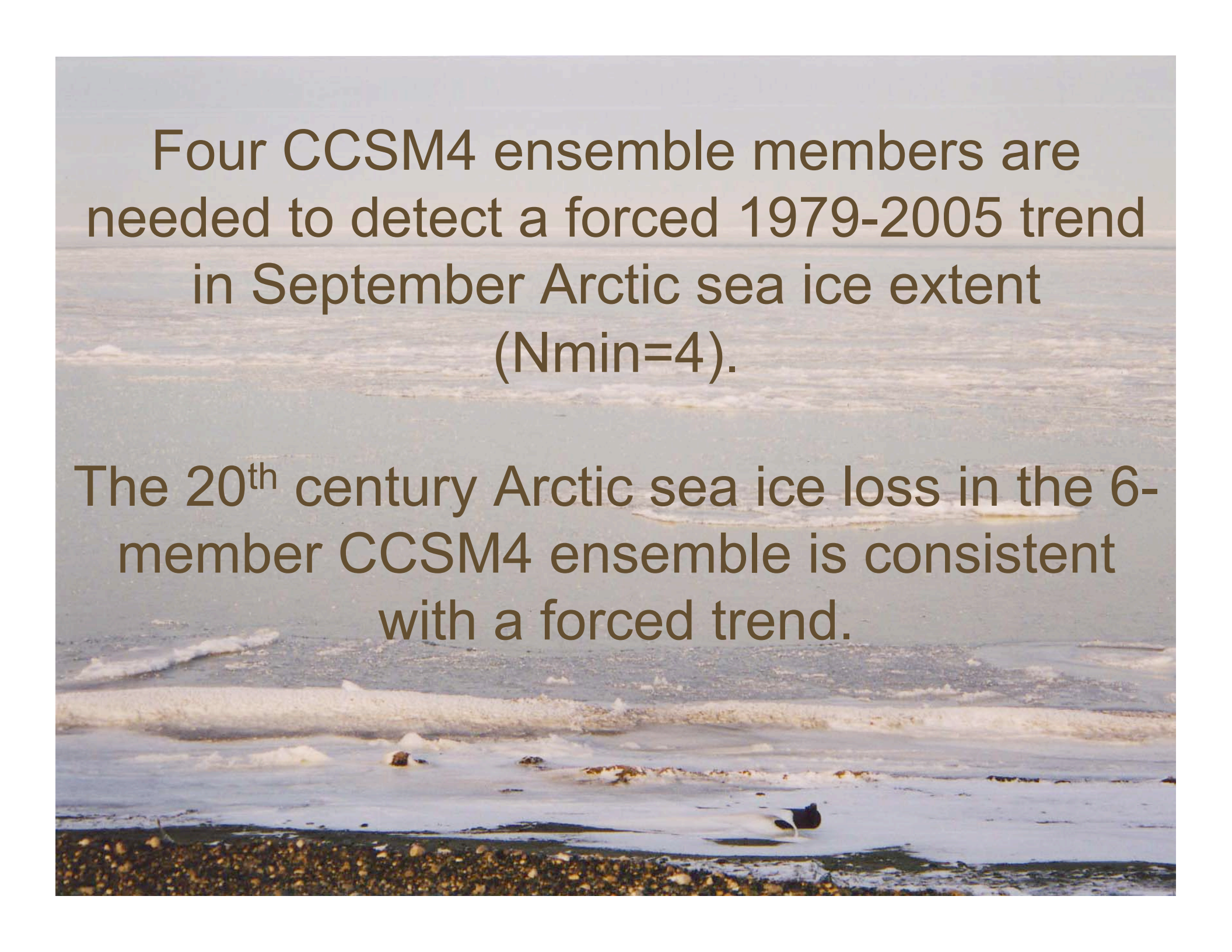
*Kay and Gettelman
(2009)*



How many ensemble members are required to detect a forced trend (Nmin)?



*Nmin for detecting JJA differences
between 2060-2051 and 2005-2014
from Deser et al. (2010)*

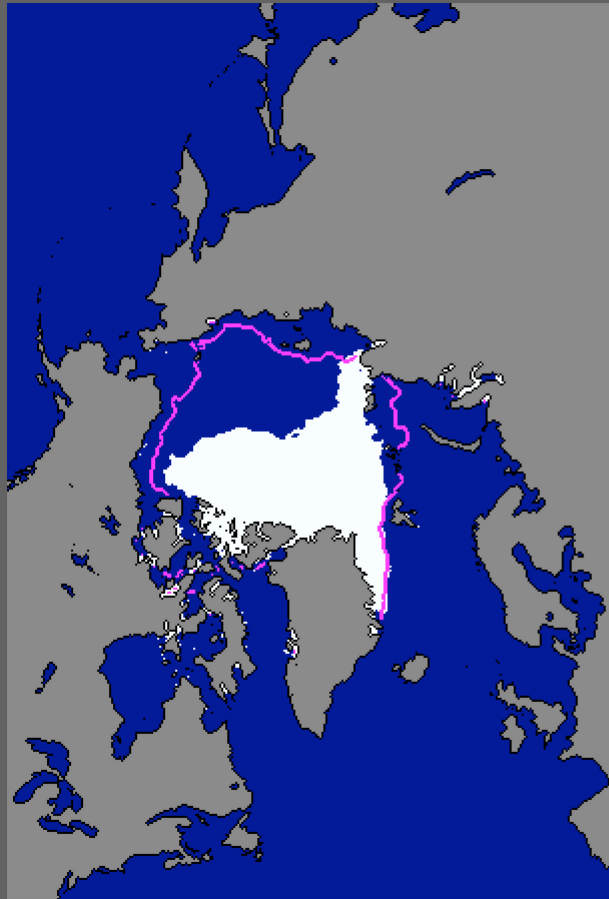


Four CCSM4 ensemble members are needed to detect a forced 1979-2005 trend in September Arctic sea ice extent ($N_{\min}=4$).

The 20th century Arctic sea ice loss in the 6-member CCSM4 ensemble is consistent with a forced trend.

A new Arctic environment

Current Ice Extent
09/16/2007

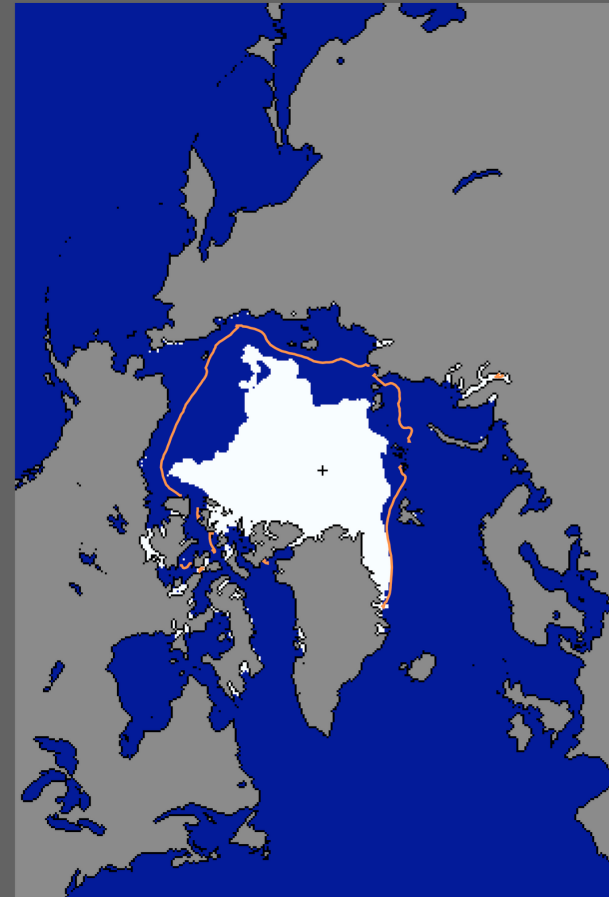


National Snow and Ice Data Center, Boulder, CO

median
ice edge

Total extent = 4.1 million sq km

Sea Ice Extent
09/09/2011



National Snow and Ice Data Center, Boulder, CO

median
1979-2000

Maps from NSIDC

Declining sea ice creates new challenges and opportunities.