

RECENT CHANGES IN THE SEA ICE COVER

Josefino C. Comiso

NASA Goddard Space Flight Center

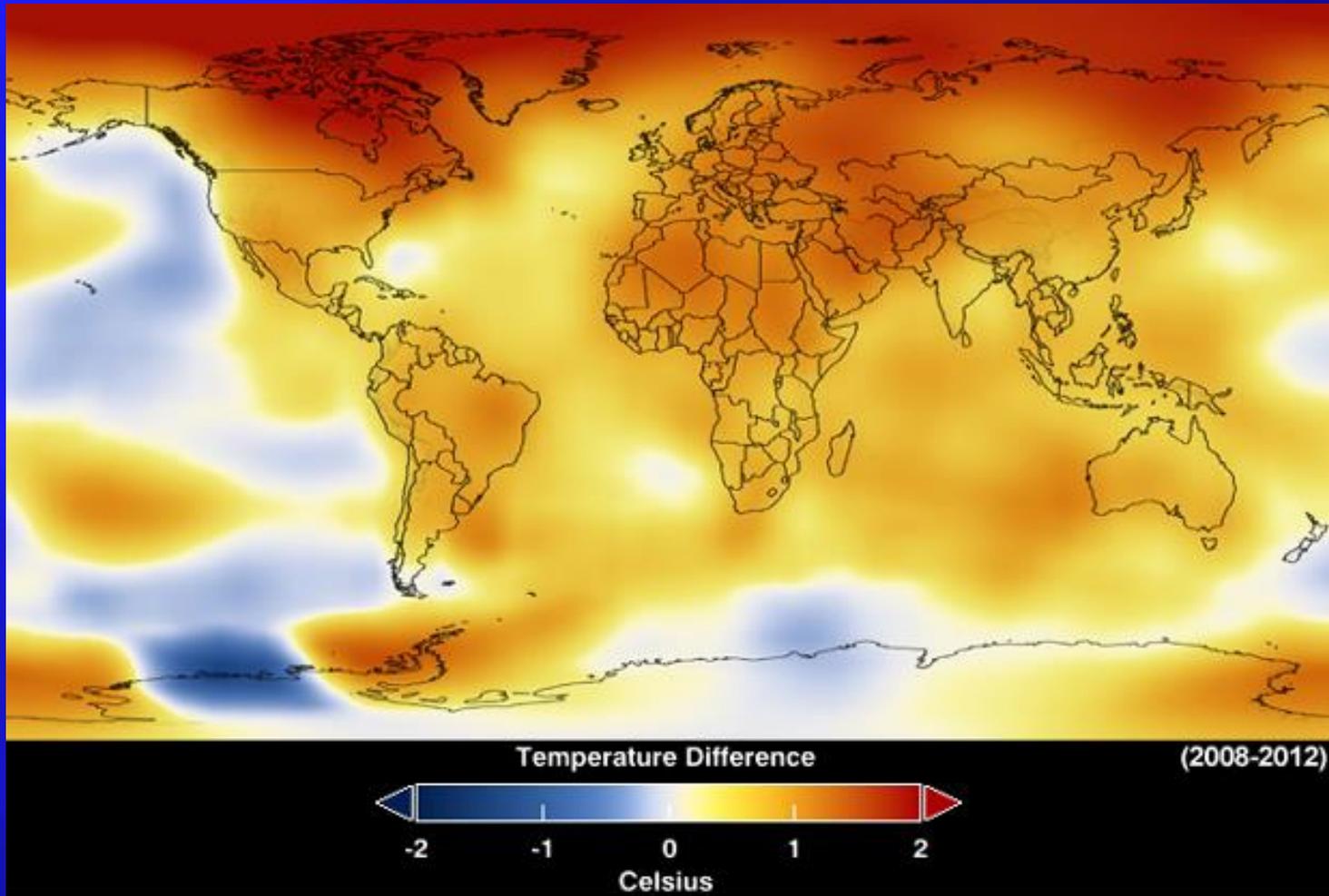
SORCE 11th Anniversary Meeting

Cocoa Beach, FL, 28-31 January 2014

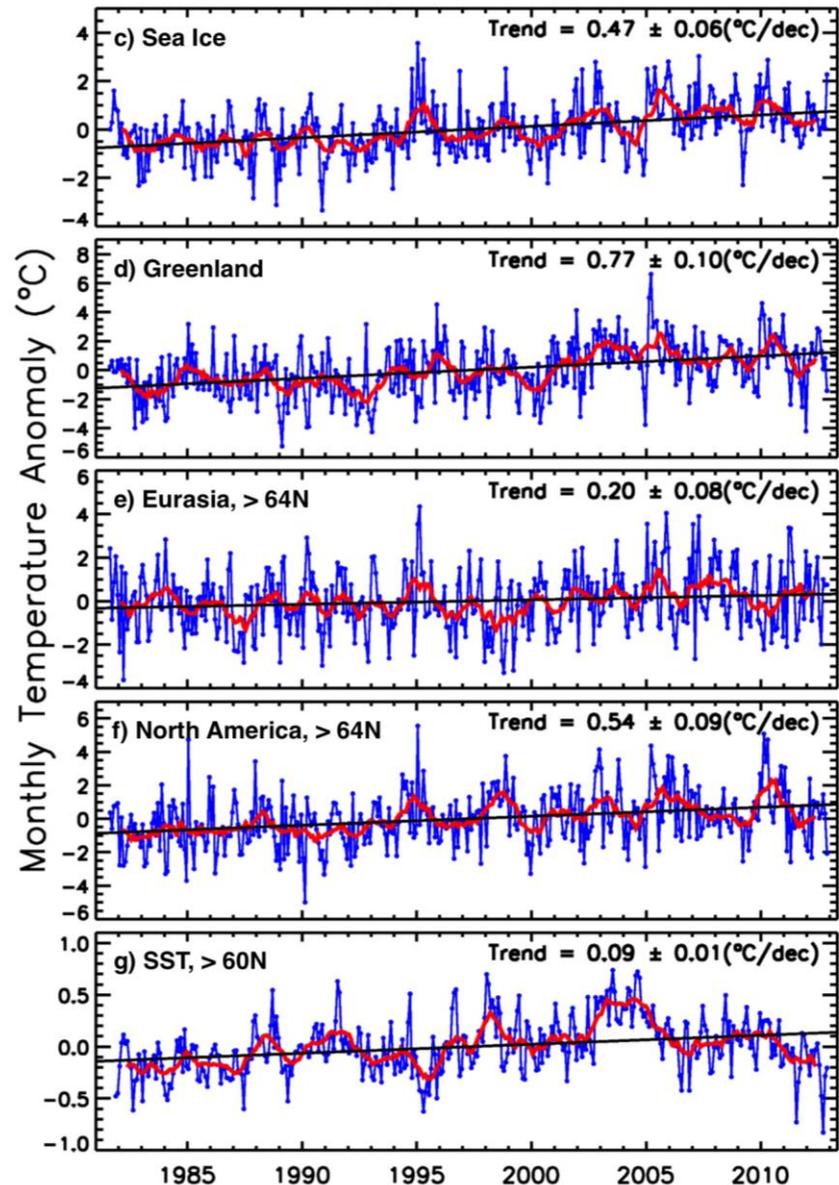
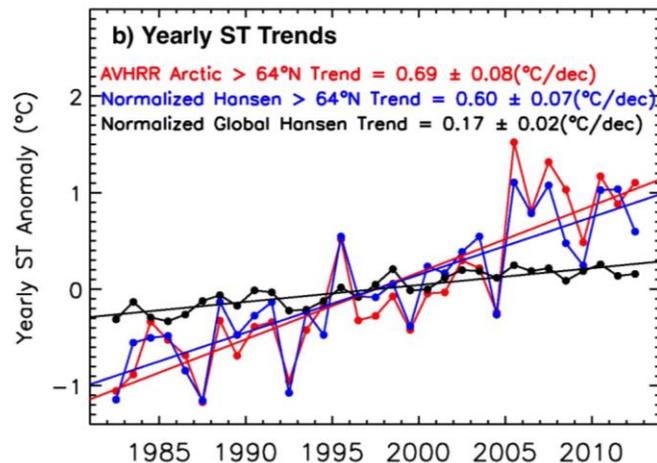
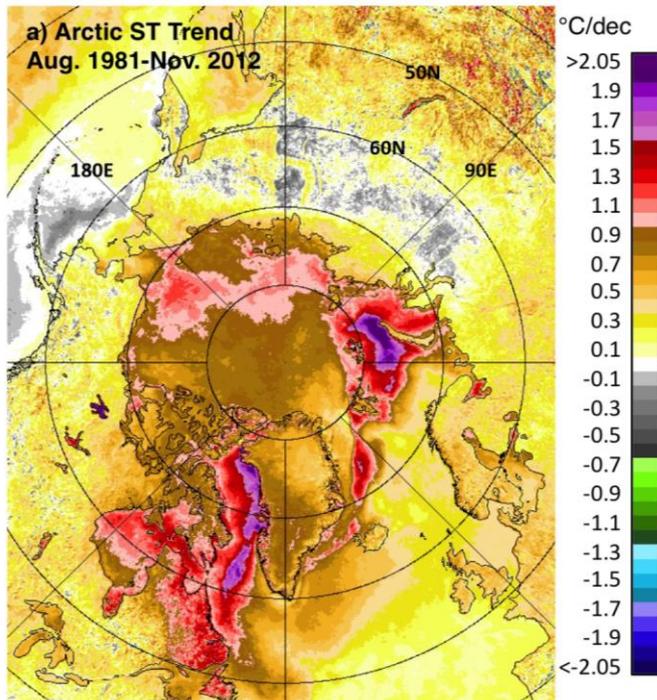
Amplified Warming Signal

Great potential for early signals for a climate change and for discovering new phenomena.

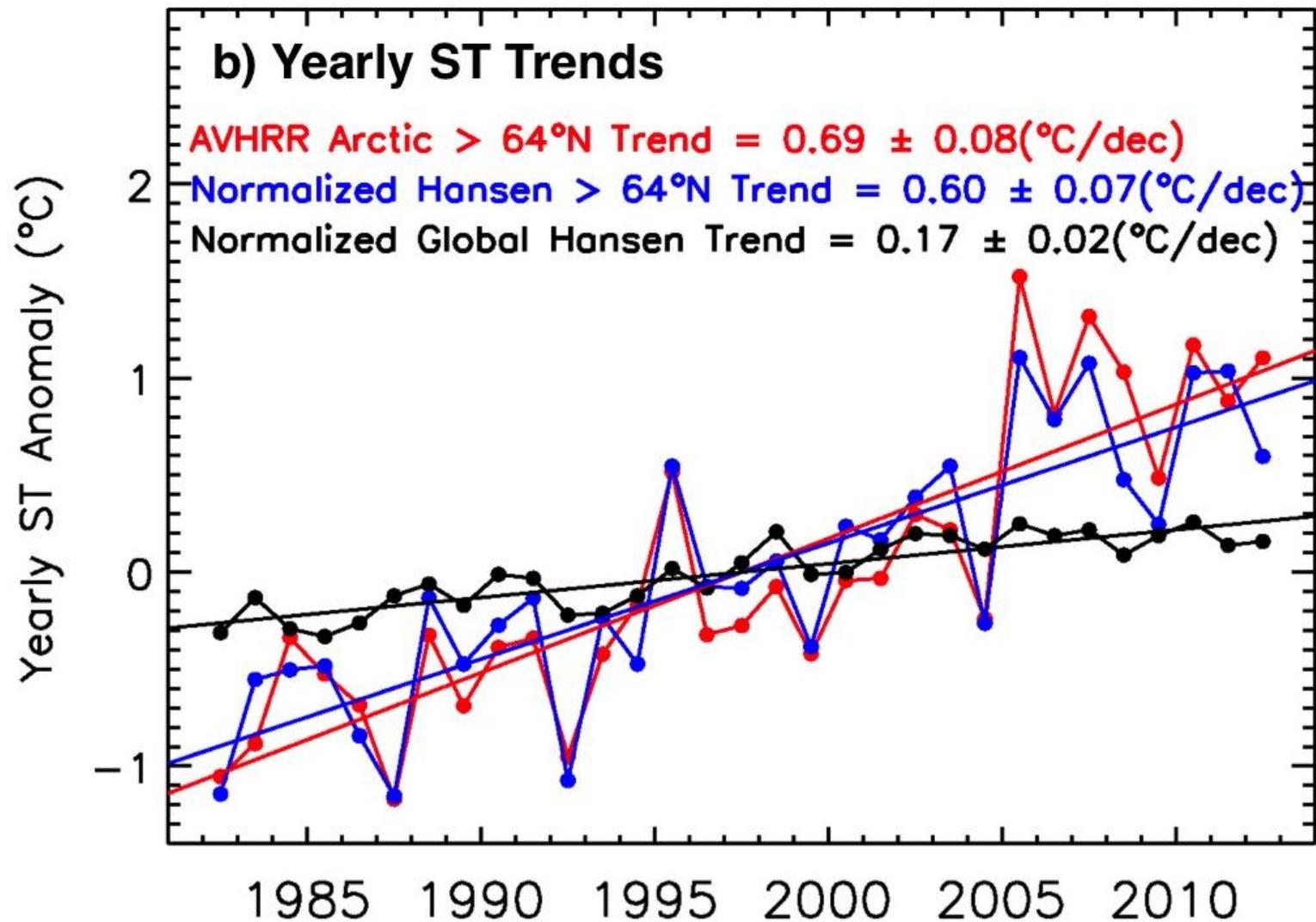
Ref: Hansen et al., 2010



Arctic AVHRR Surface Temperatures



Arctic versus Global Surface Temperatures

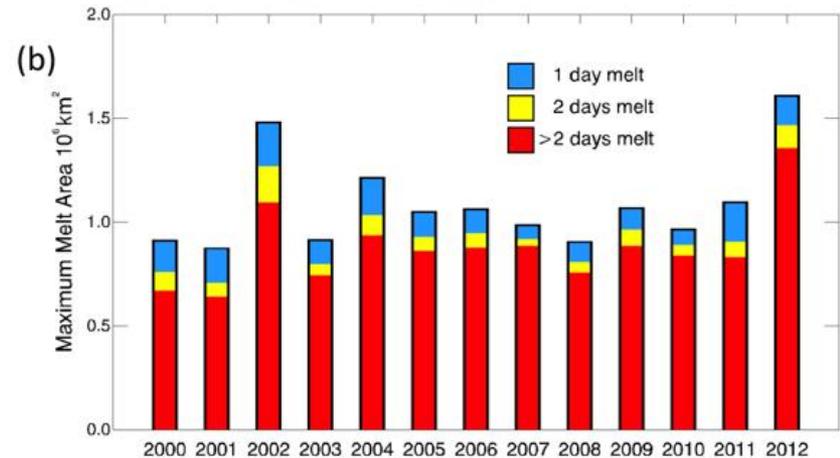
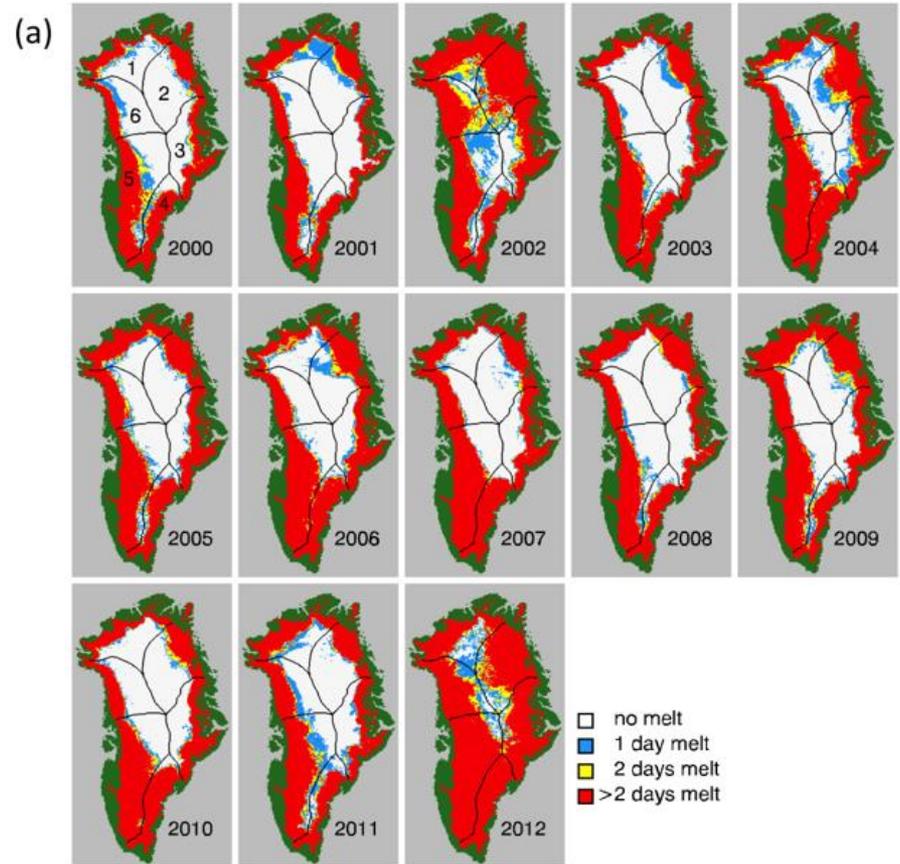


Area of melt in Greenland. Record high in 2012

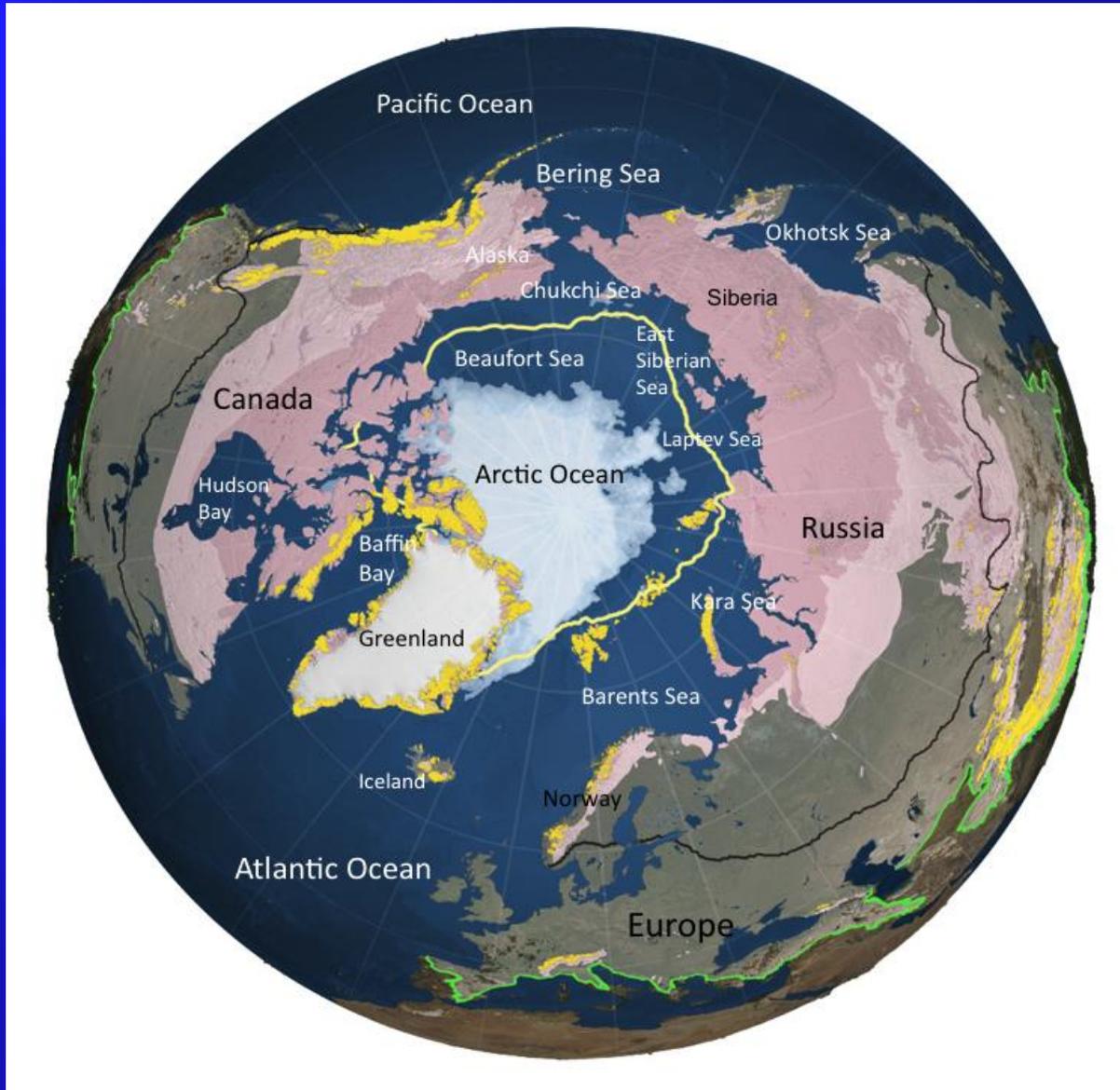
Spring melt in Greenland in 2002



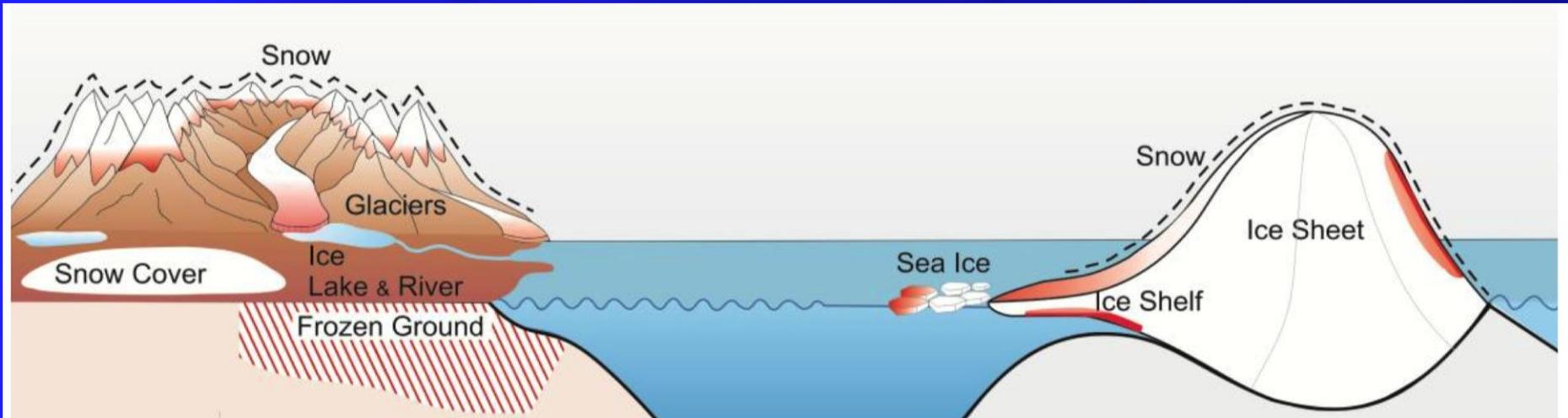
Surface Melt in Greenland



The Changing Cryosphere



Changes in the Cryosphere



- . Glaciers have been losing mass (about 226 Gt/yr since 1971)
- . Ice sheet in Greenland has been losing mass (about 215 Gt/yr since 2002 or 0.6mm/yr of sea level rise)
- . Ice sheet in the Antarctic has been losing 147 Gt/yr since 2002
- . Snow cover has been declining in spring and especially in June
- . Active layer of the permafrost has been warming up while the thickness of seasonally frozen grounds has been decreasing.
- . Sea ice cover in the Arctic has been declining rapidly

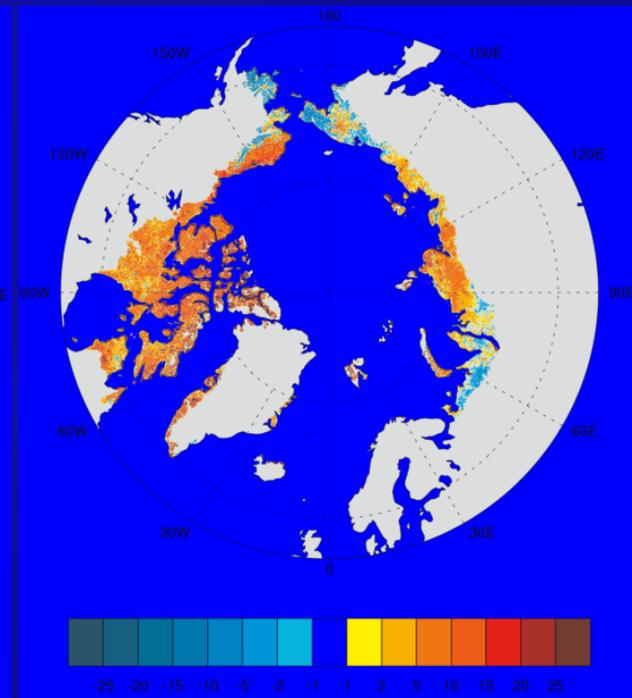
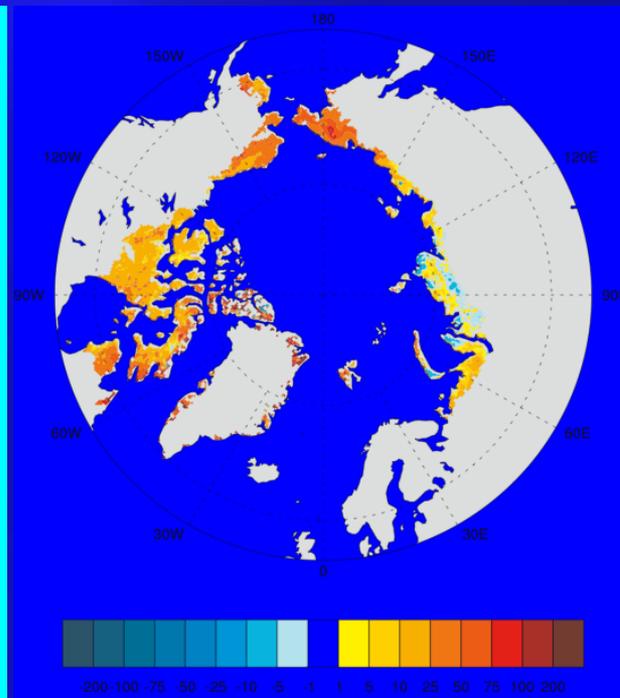
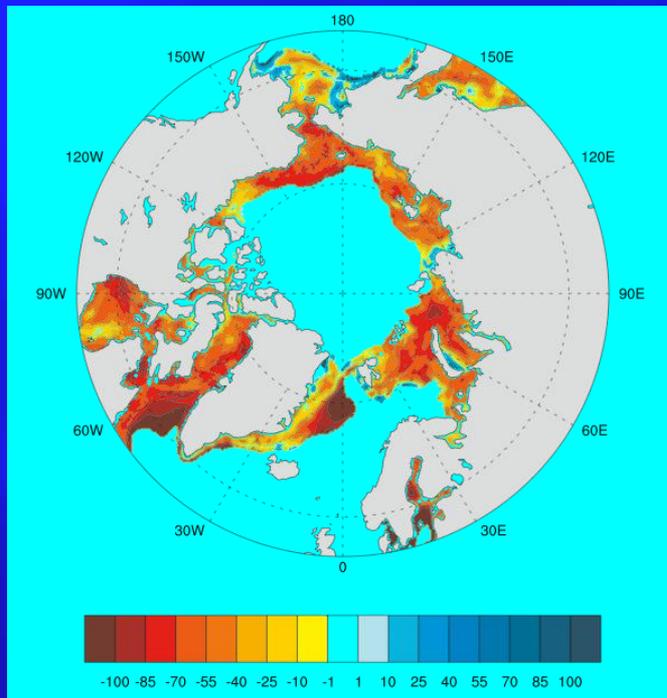
Greening of the Arctic

From 1980 to 2008, NDVI was increasing and highly correlated with surface warm index and sea ice concentration

Sea Ice Concentration

Summer Warmth Index (SWI)

Maximum NDVI



Bhatt, U.S., D. A. Walker, M. Raynolds, J. C. Comiso, ...J.E. Pinzon, C. J. Tucker et al., (2010) Circumpolar Arctic tundra vegetation change is linked to sea-ice decline, *Earth Interactions*, 14, 1-20, doi:10.1175/2010EI315.1.

Relevance of SORCE to Sea Ice Cover Studies

- ▣ Ice-albedo feedback as driven by the sun is a key factor affecting the extent of the sea ice cover
- ▣ Length of ice melt and melt rate is influenced by the sun
- ▣ The role of the sun, clouds and other factors on the rapid decline of the sea ice cover in the Arctic needs to be better understood.

Historical Satellite Ice Extent and Ice Area in the Arctic

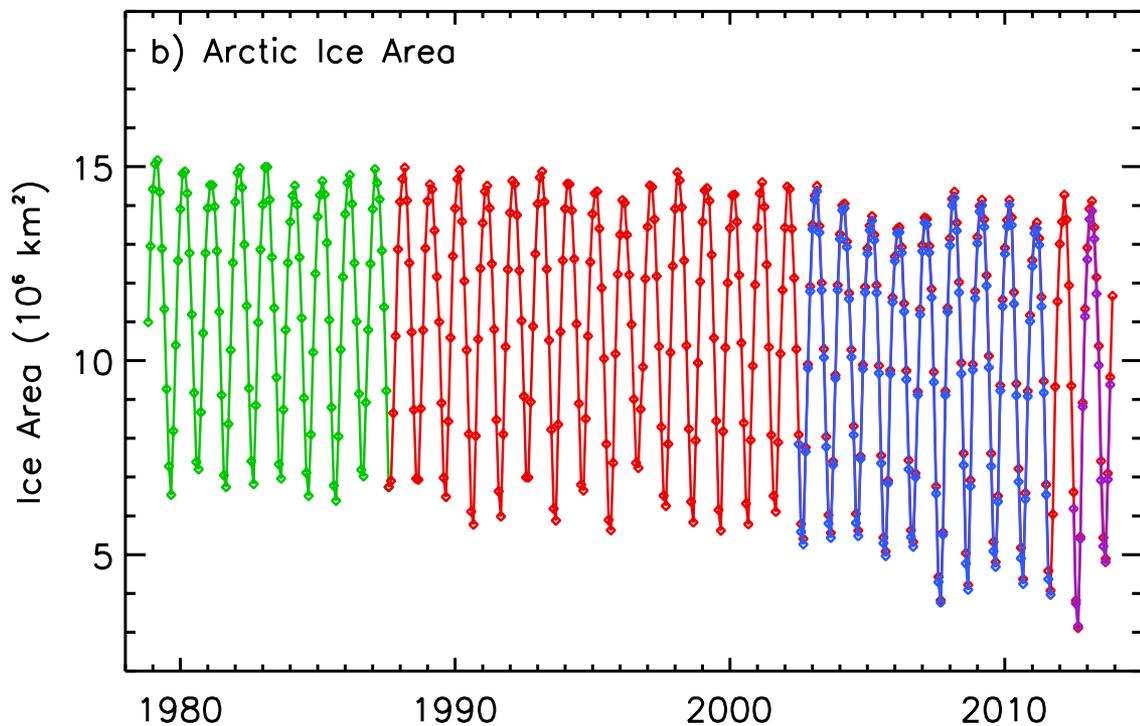
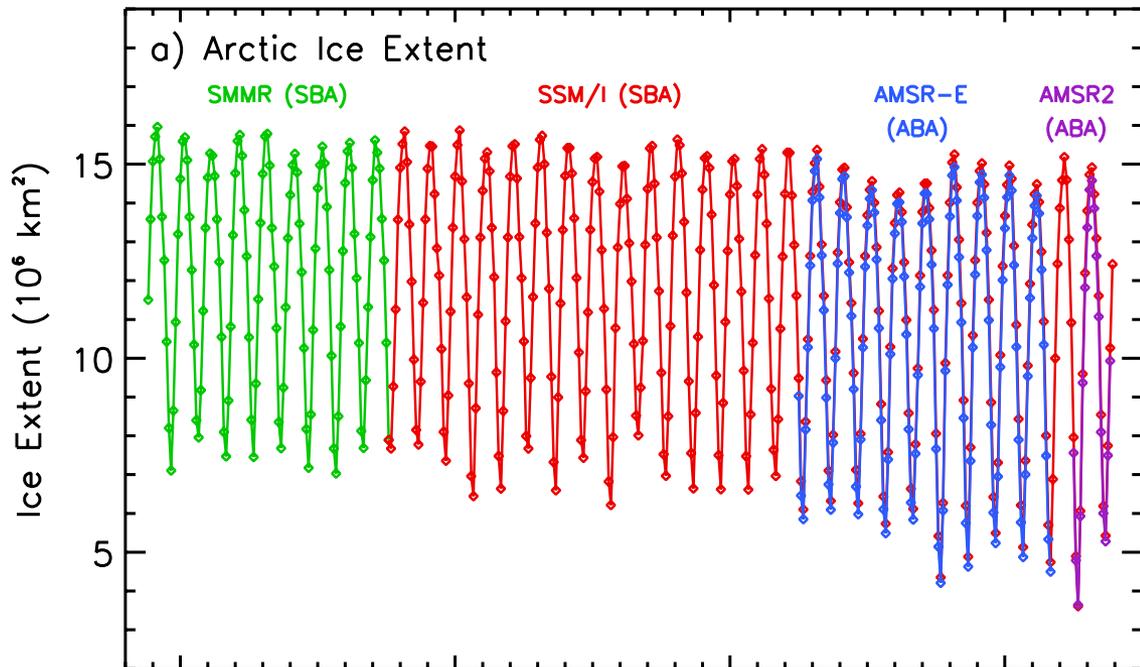
Source:

SMMR (1978 to 1987)

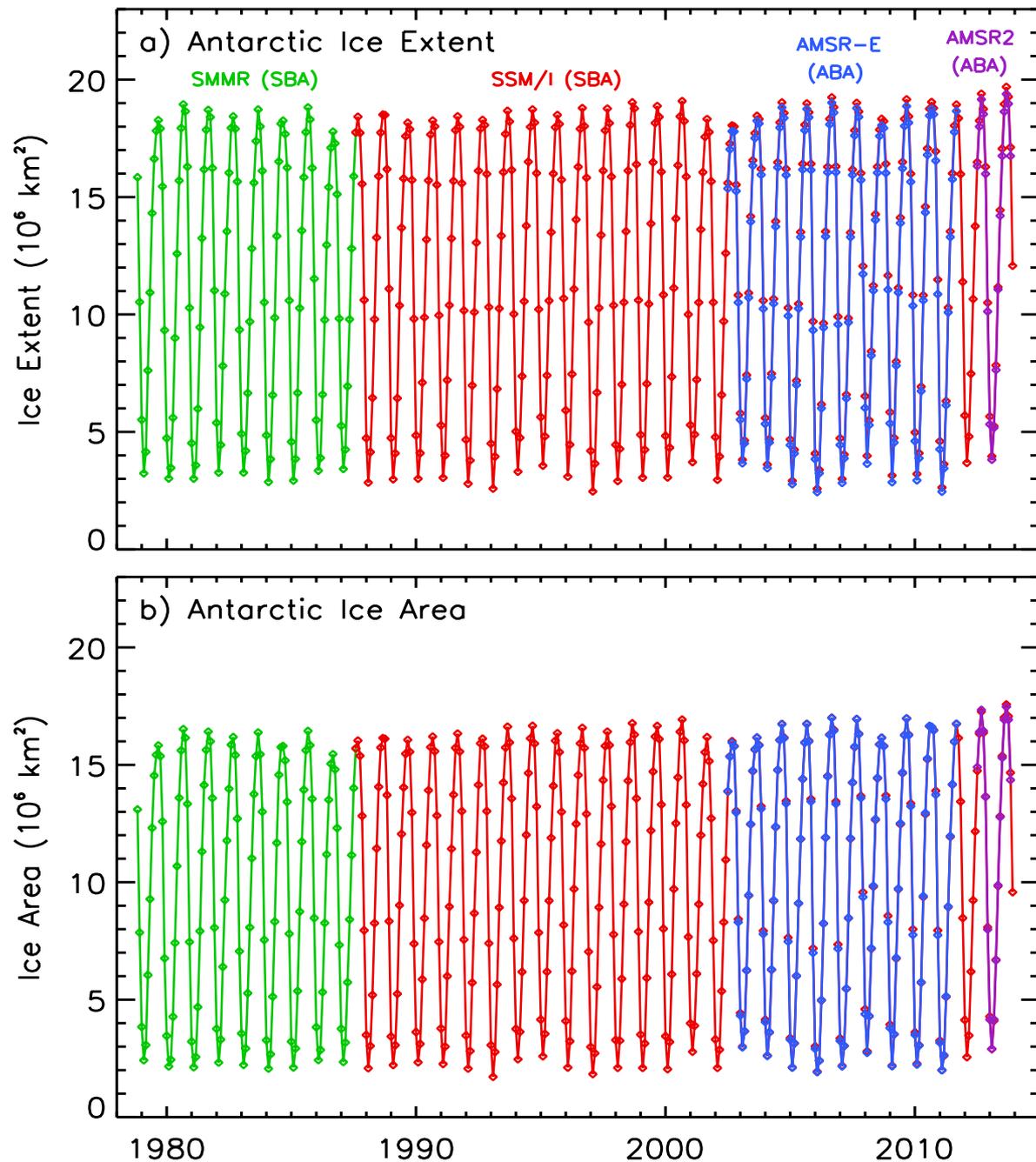
SSM/I (1987 to present)

AMSR-E (2002 to 2011)

AMSR2 (2012 to present)



Historical Satellite Ice Extent and Ice Area in the Antarctic

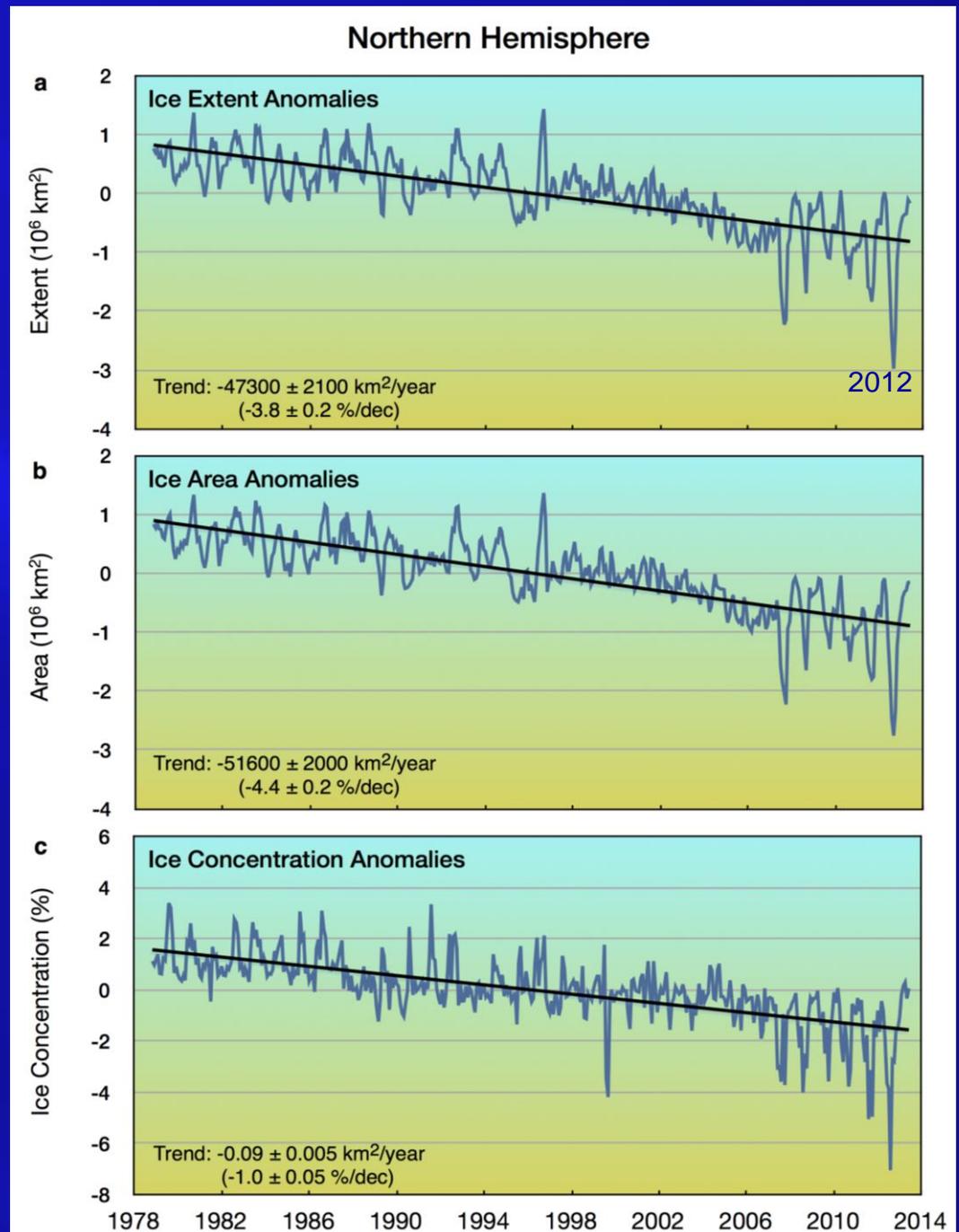


Monthly Anomalies and Trends of Sea Ice Extent and Area in the Arctic

Overall trends from 34-year data set is
-3.8 % per dec, ice extent
-4.4 % per dec, ice area.

Trends since 1996 is
-8.5 % per dec, ice extent
-9.1% per dec, ice area

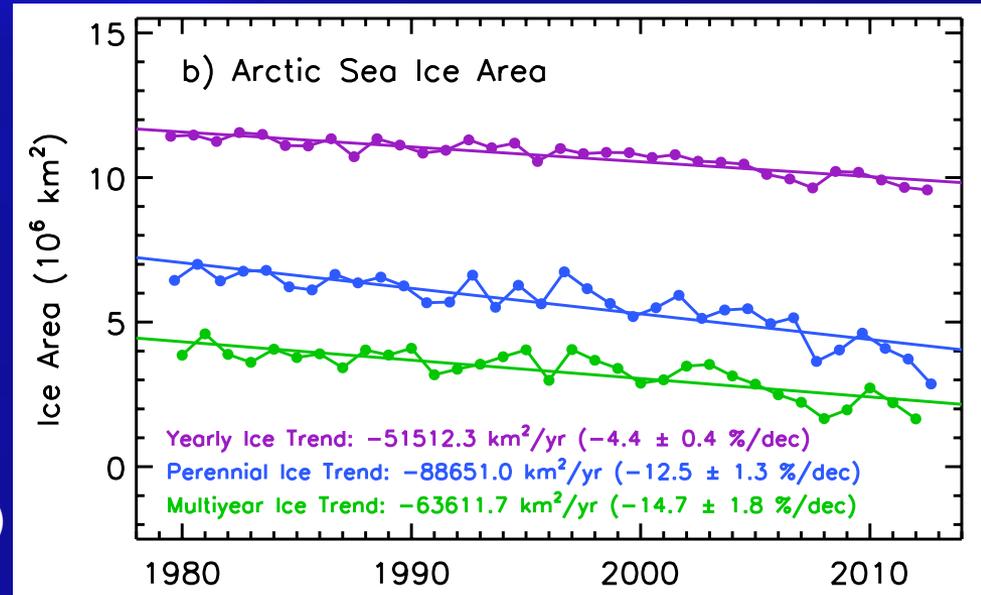
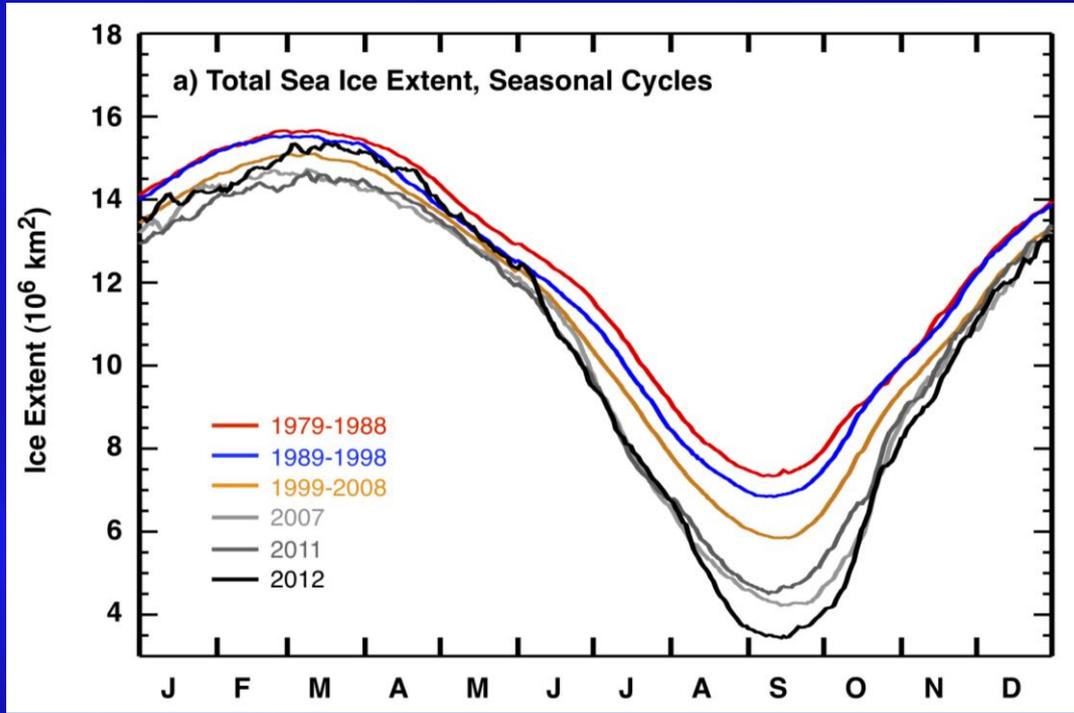
Sea Ice highly variable since 2007



ANOMALOUS DECLINE IN THE ARCTIC PERENNIAL AND MULTIYEAR ICE COVER, 1979 TO 2012



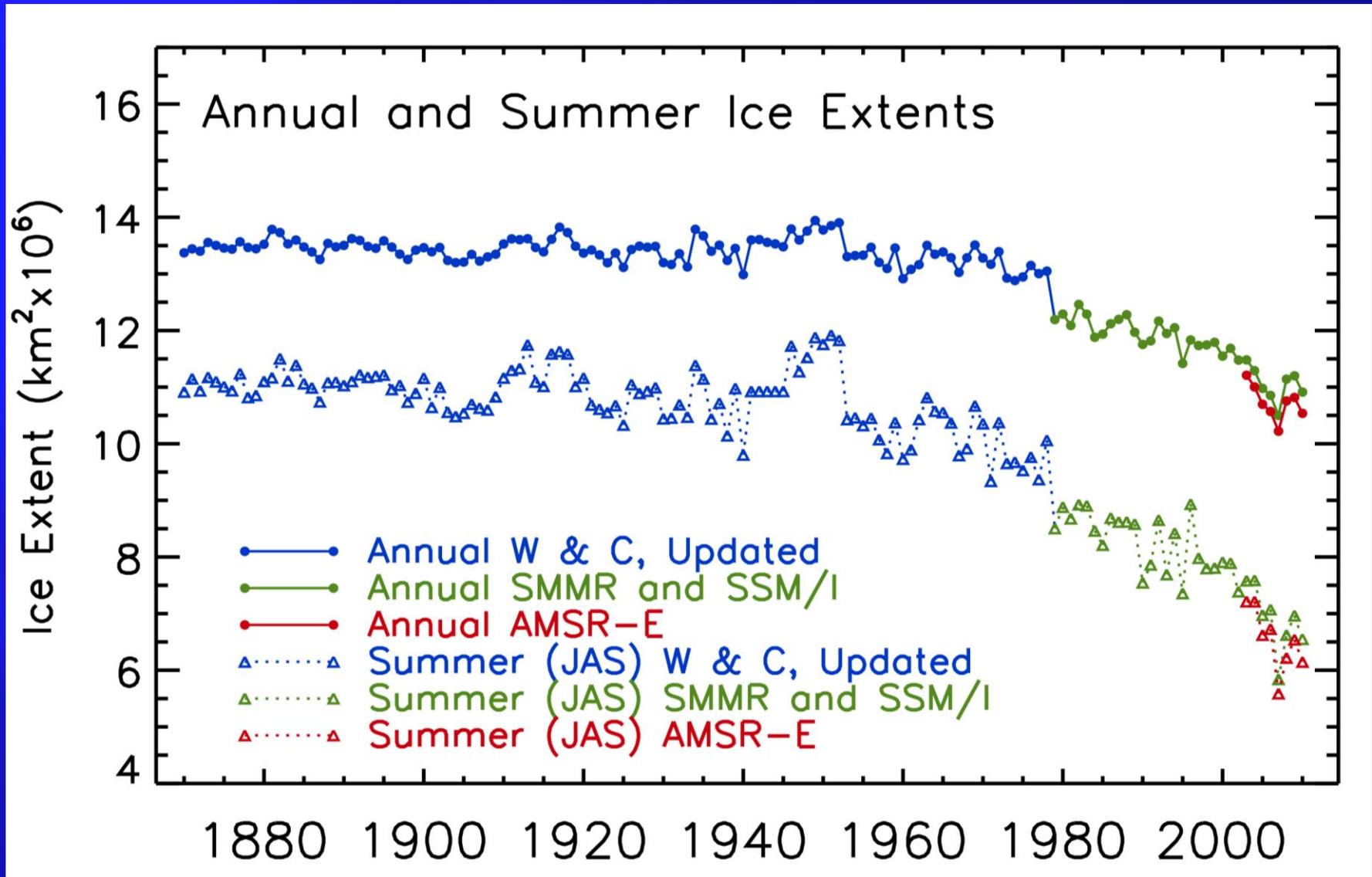
Ice Albedo Feedback:
Comiso, J. C. and C. L. Parkinson, (2004)
Satellite observed changes in the Arctic,
Physics Today, 57(8), 38-44.



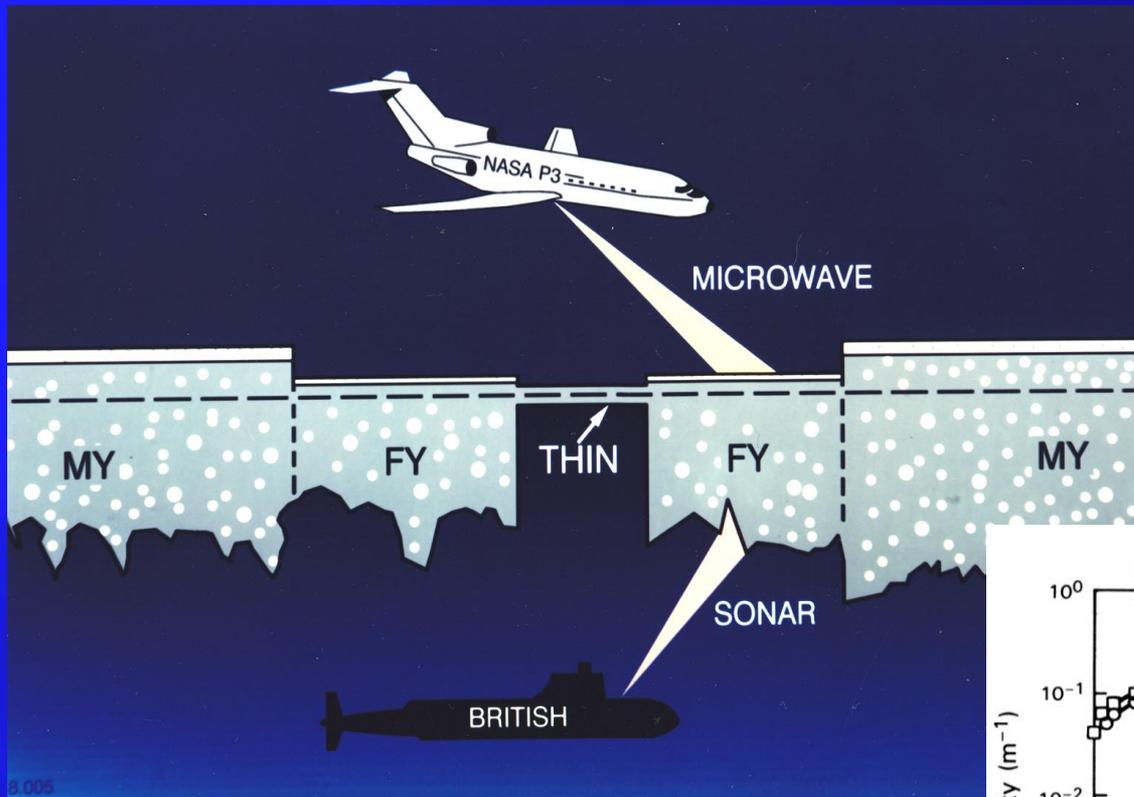
2012 Arctic Storm & Sea Ice Minimum



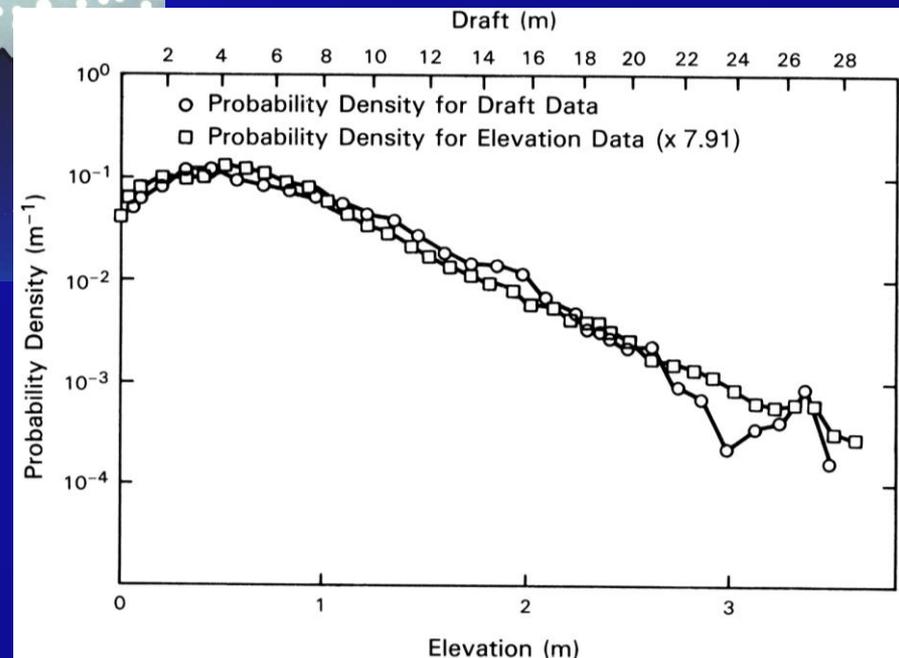
Historical In Situ and Satellite Data



NASA P3 Overflight over a British Nuclear Submarine

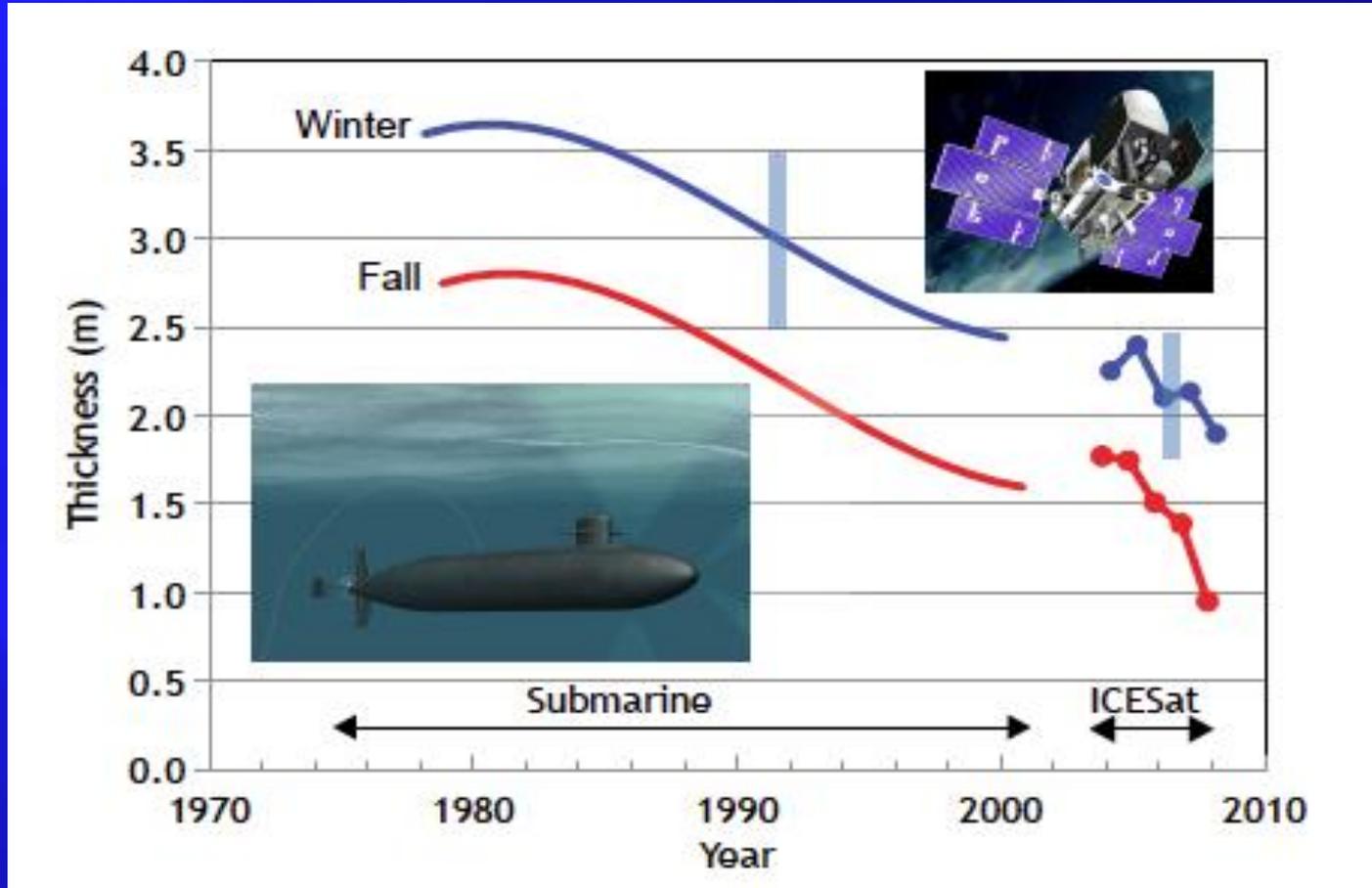


Sonar Draft vs ATM freeboard



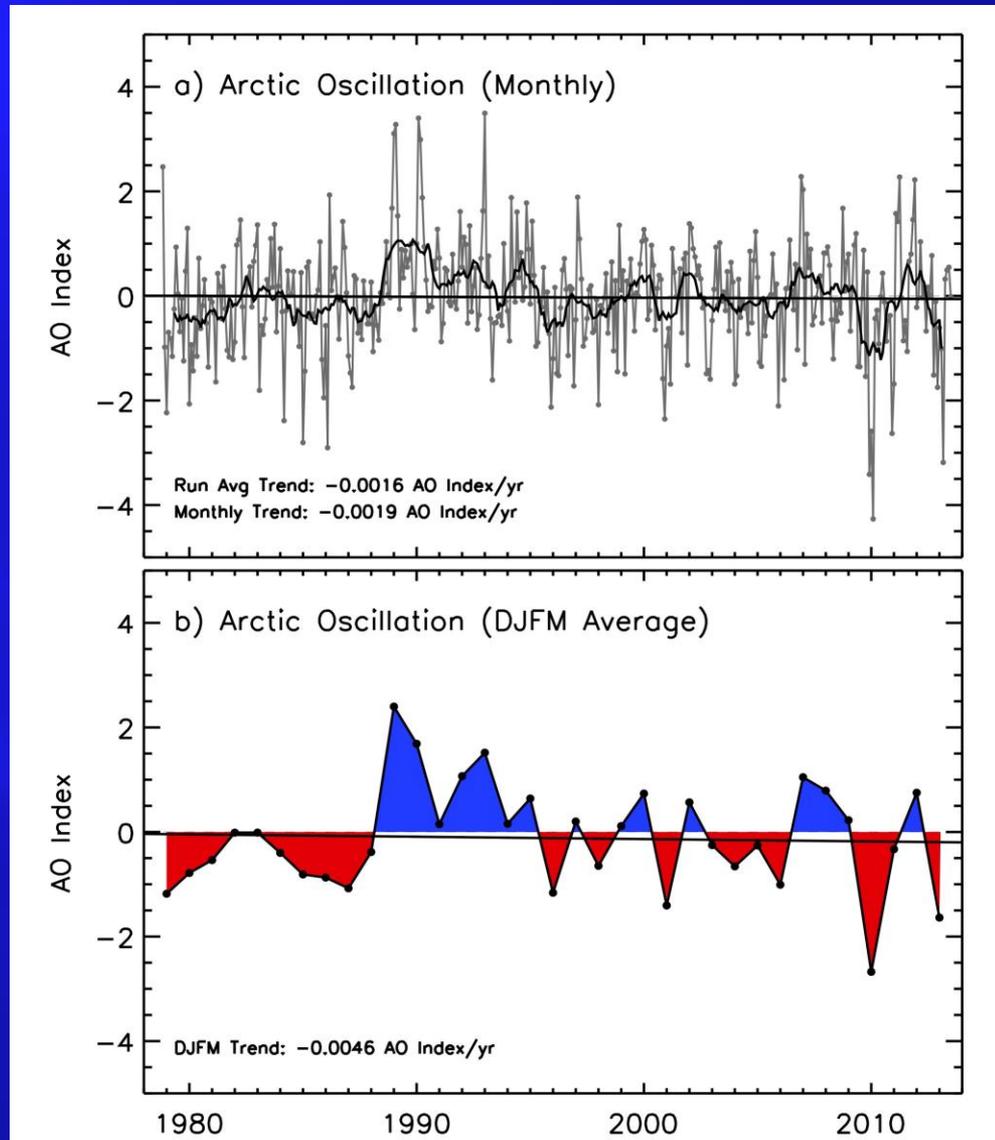
Comiso, J.C., P. Wadhams, W. Krabill, R. Swift, J. Crawford, and W. Tucker, Top/Bottom multisensor remote sensing of Arctic sea ice, *J. Geophys. Res.*, 96(C2), 2693-2711, 1991.

Anomalous decline in the Arctic ice thickness from both Submarine and ICESat data

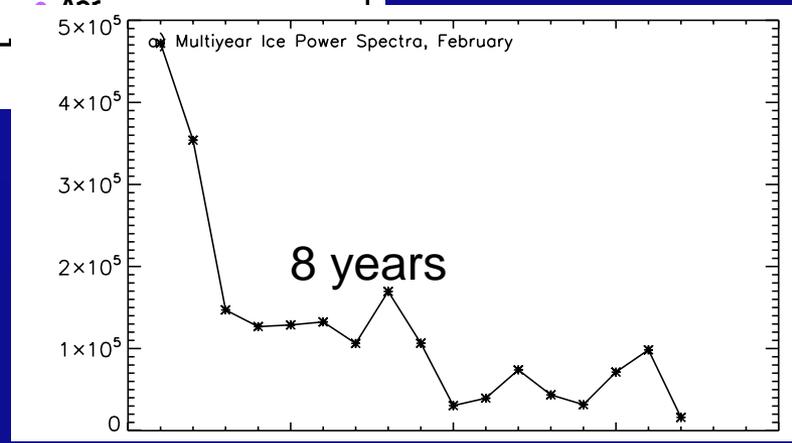
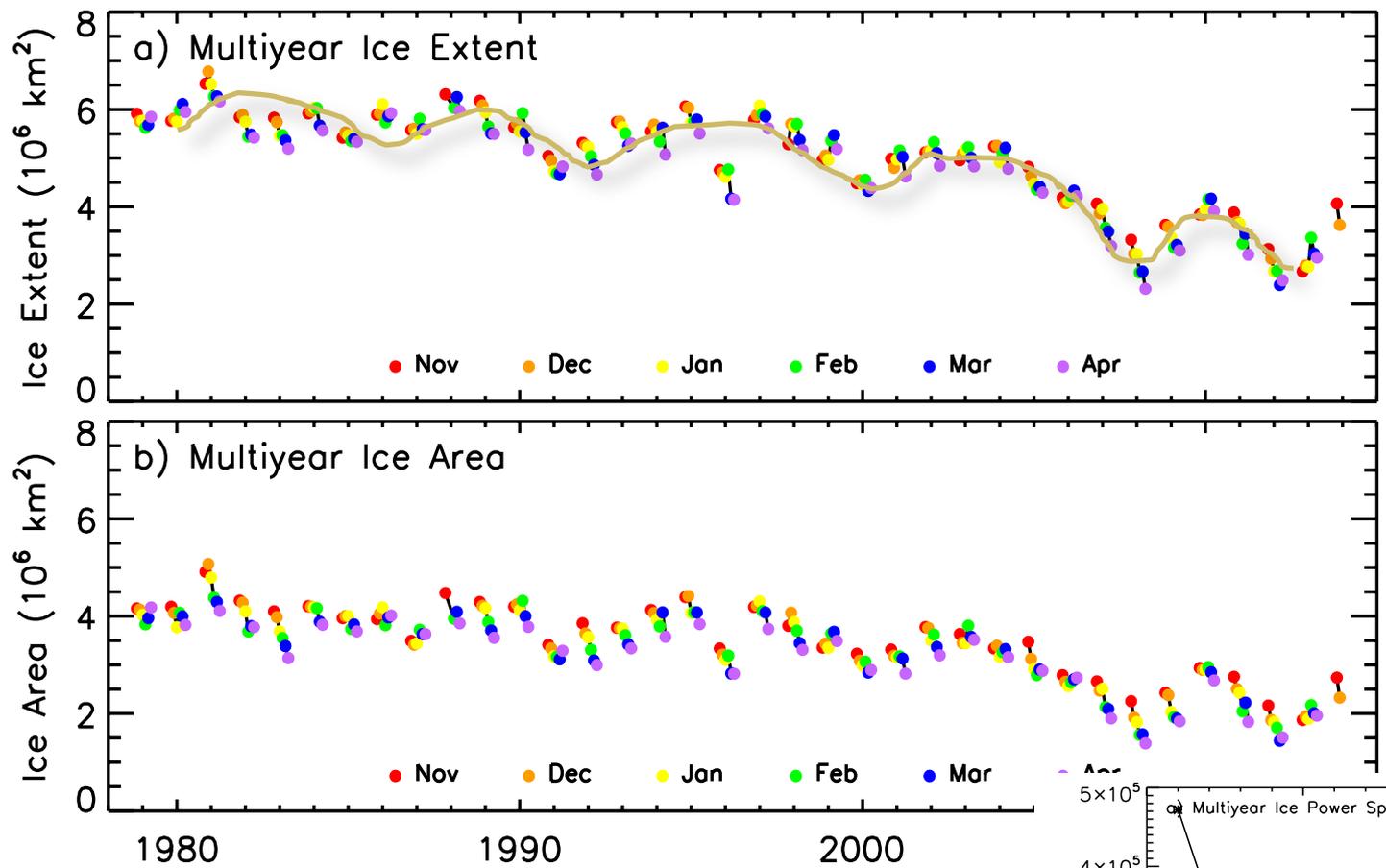


Kwok, R. and N. Untersteiner, 2011, The Thinning of Arctic Sea Ice, Physics Today, 64(4), 36-43.

Changes in the atmospheric circulation as revealed by the Arctic Oscillation



MY ice periodicity



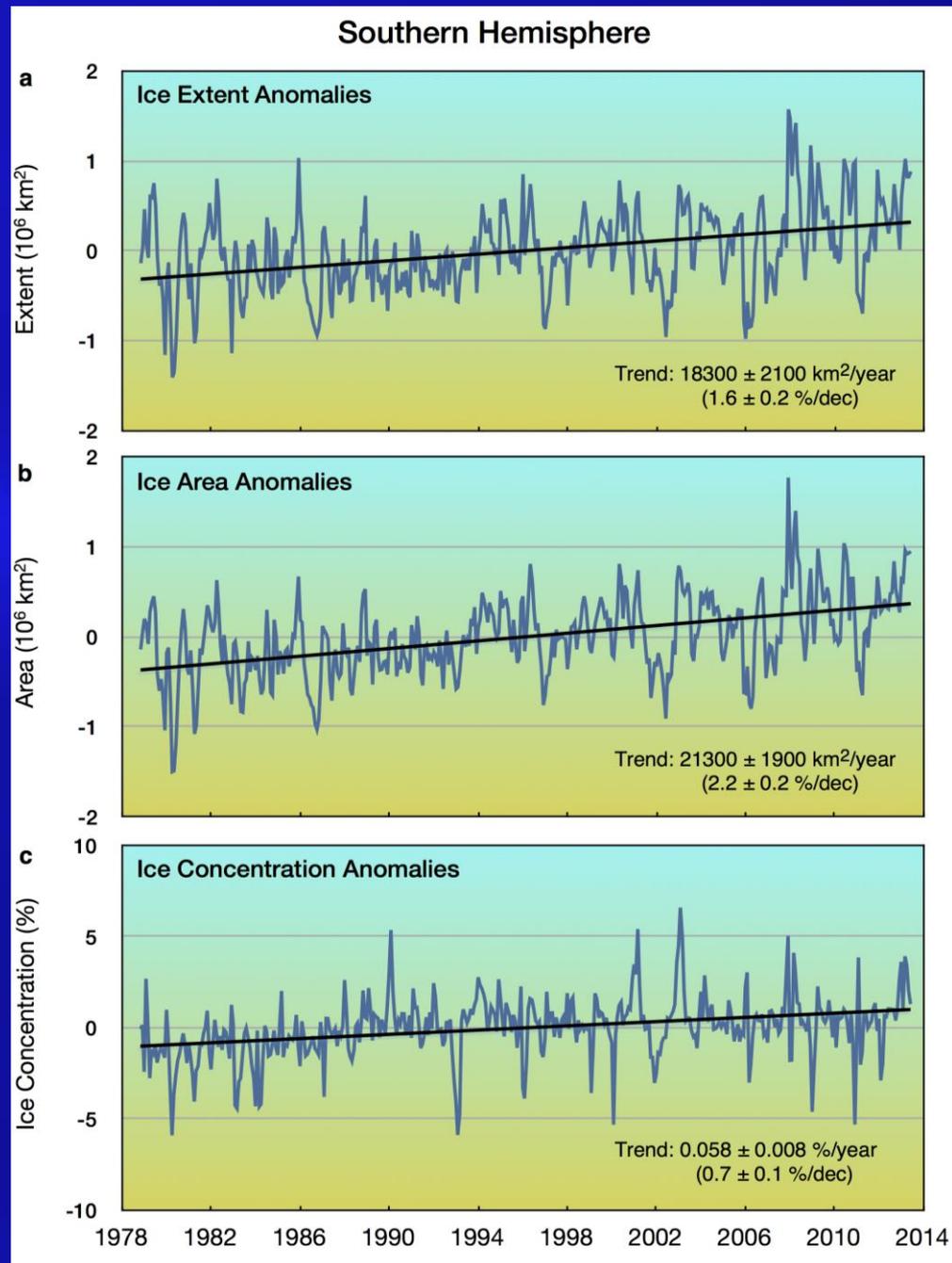
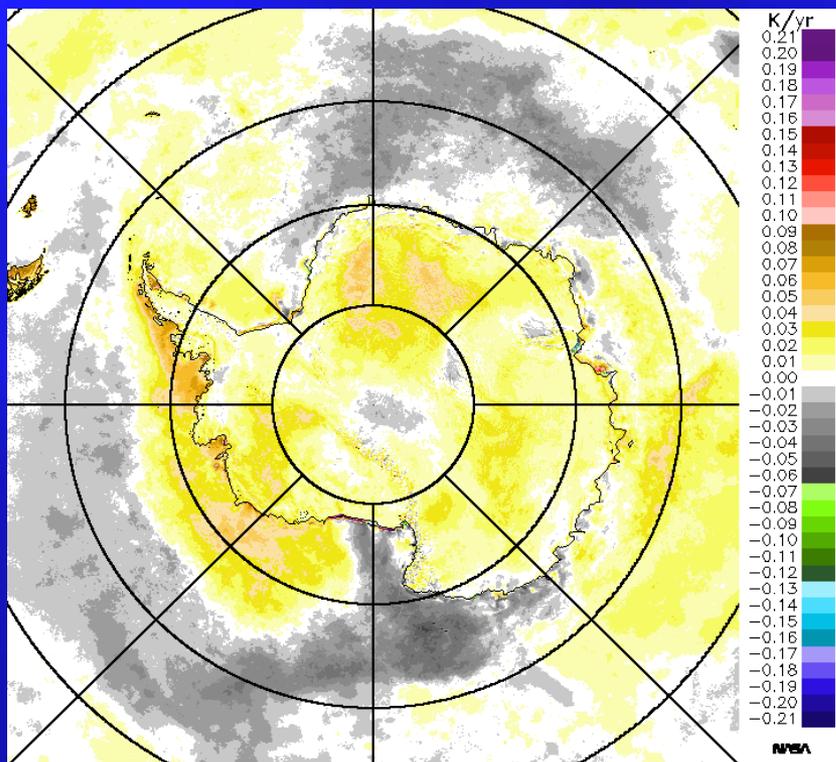
Unexpected Trends

- ▣ Cooling in parts of Antarctica
- ▣ Positive trend in the Antarctic sea ice cover

Anomalous Sea Ice Trend in the Antarctic

1.6% /dec ice extent
2.2%/dec ice area

Surface temperature trend, 181 to 2012

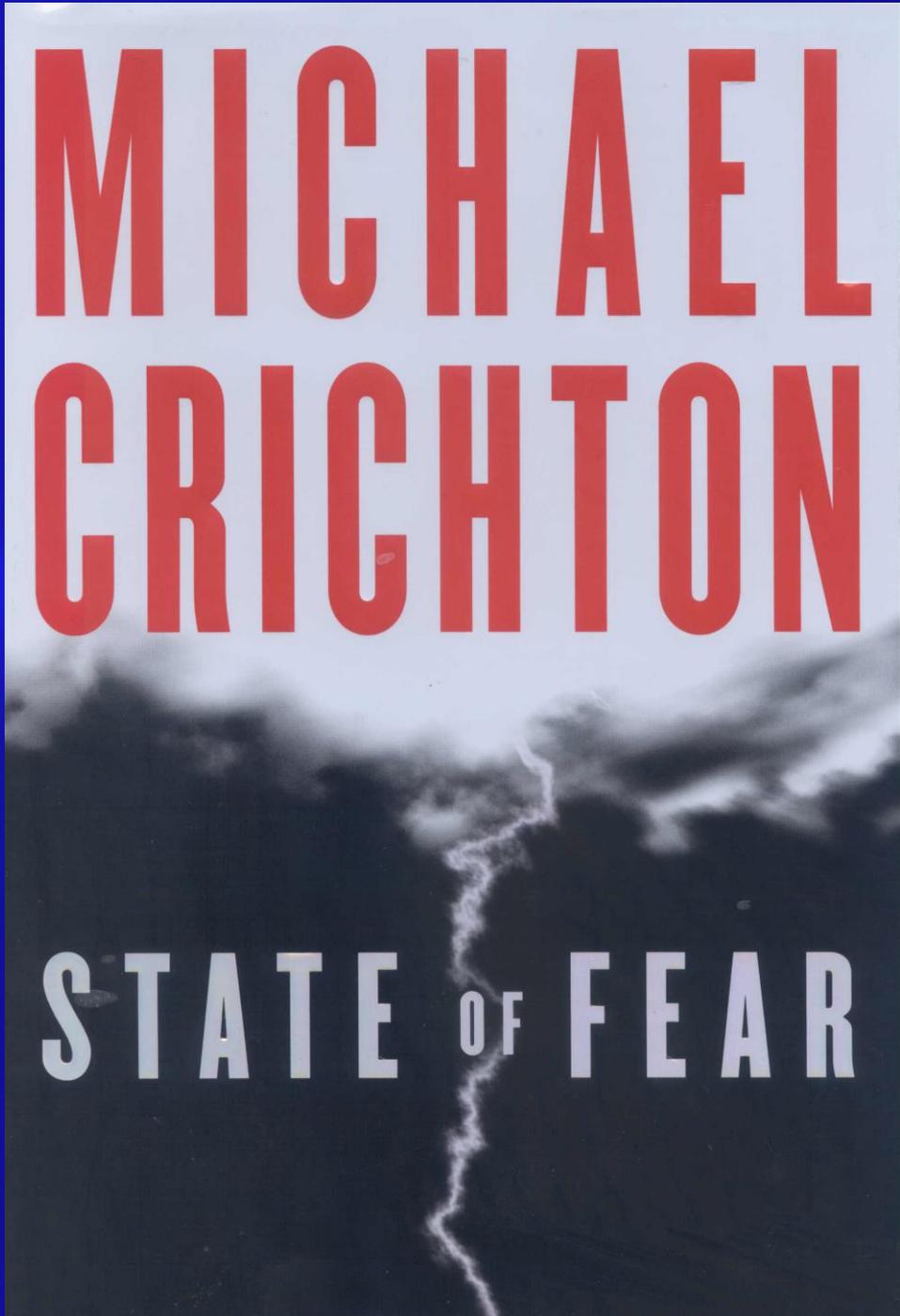


**Climate
Change
Fiction book:**

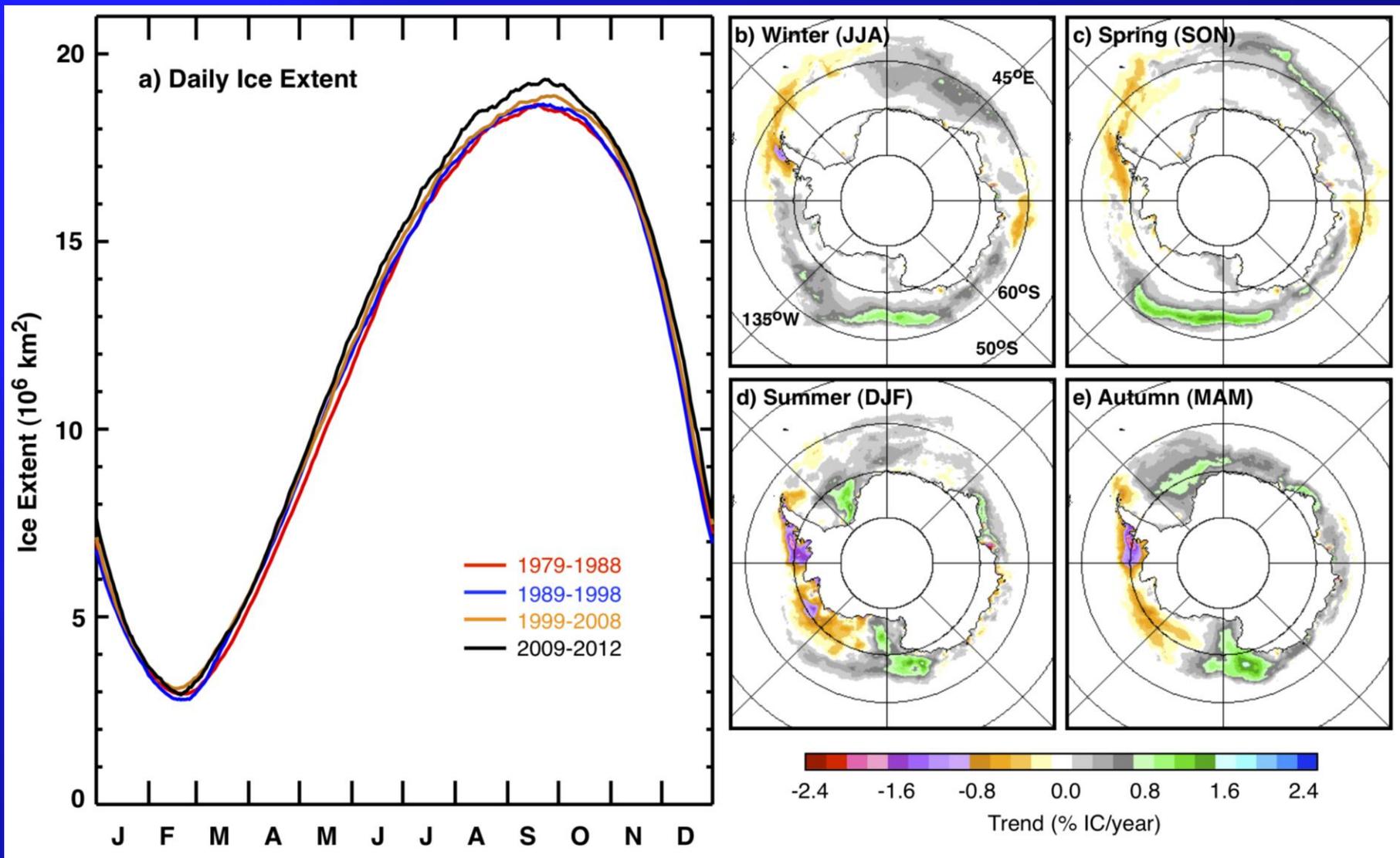
Used by some
congressmen as a
means to justify
that there is no
climate change

**MICHAEL
CRICHTON**

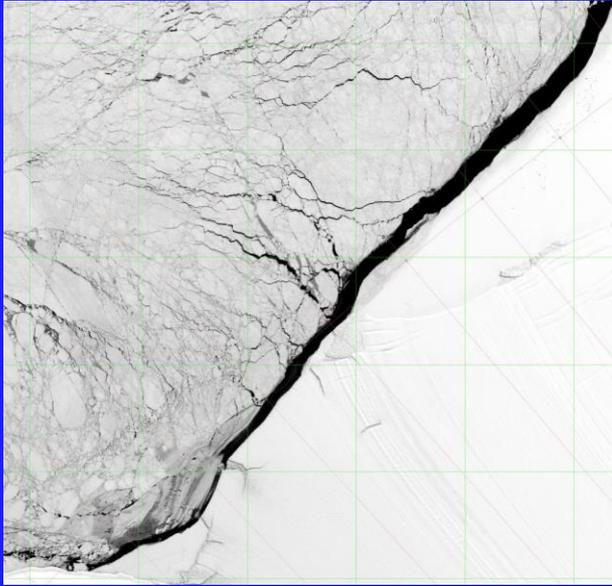
STATE OF FEAR



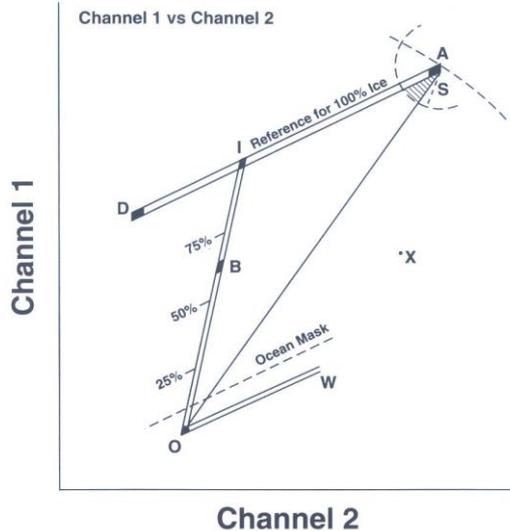
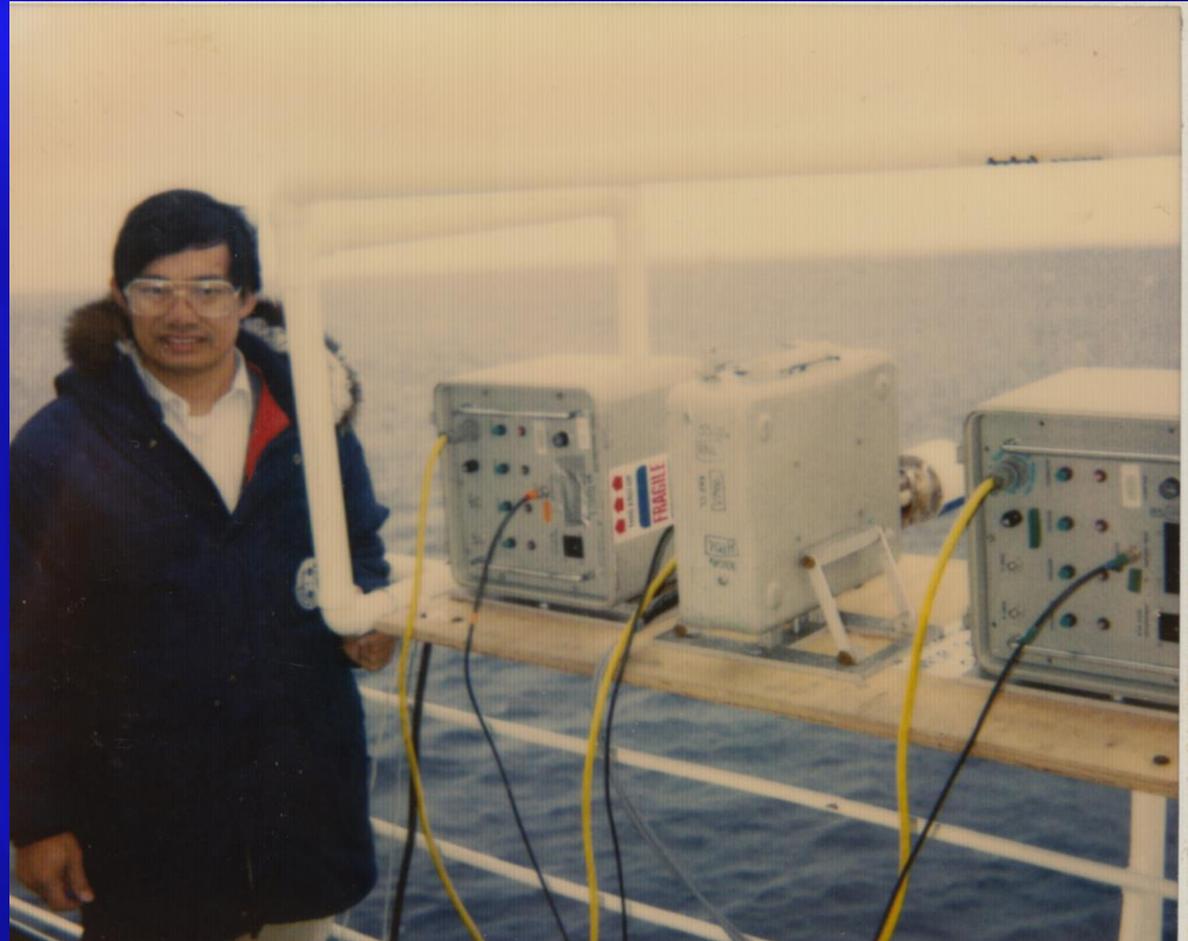
Antarctic decadal extents and seasonal trends of sea ice



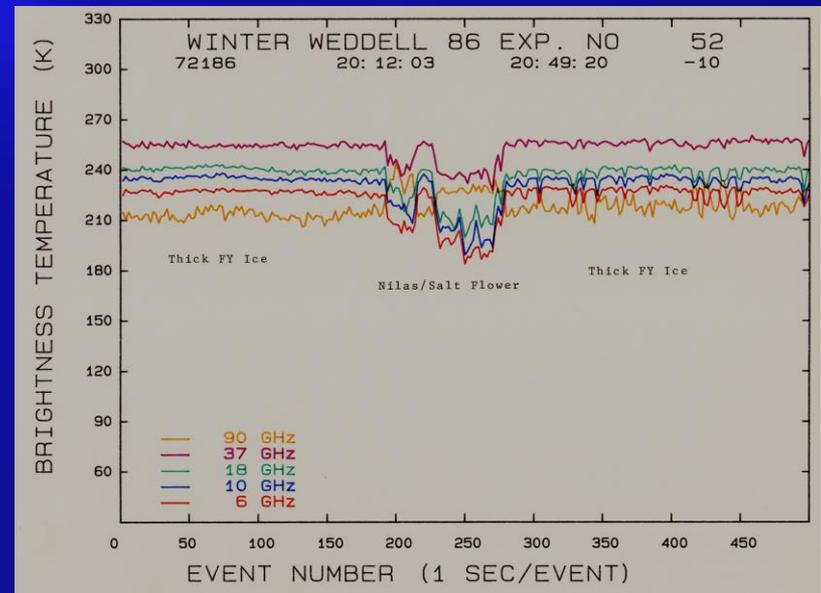
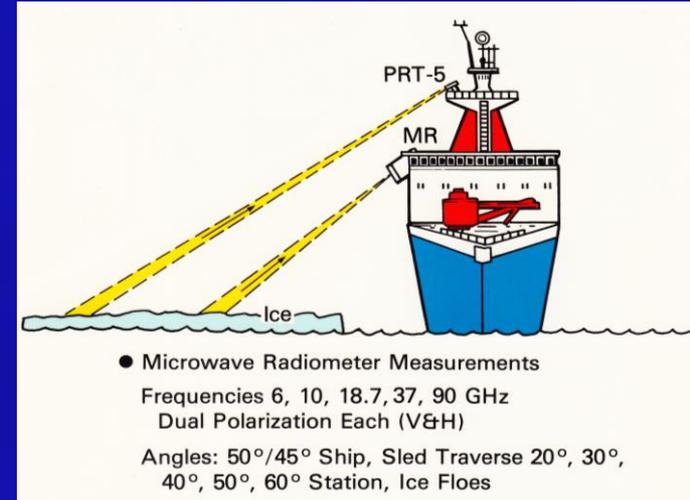
Validation of Sea Ice Algorithm



Mixing Algorithm:
 $IC = (TB - T_0)/(T_i - T_0)$



Winter Weddell 1986 Cruise



The 89 GHz channel provides the best resolution but also the highest variability

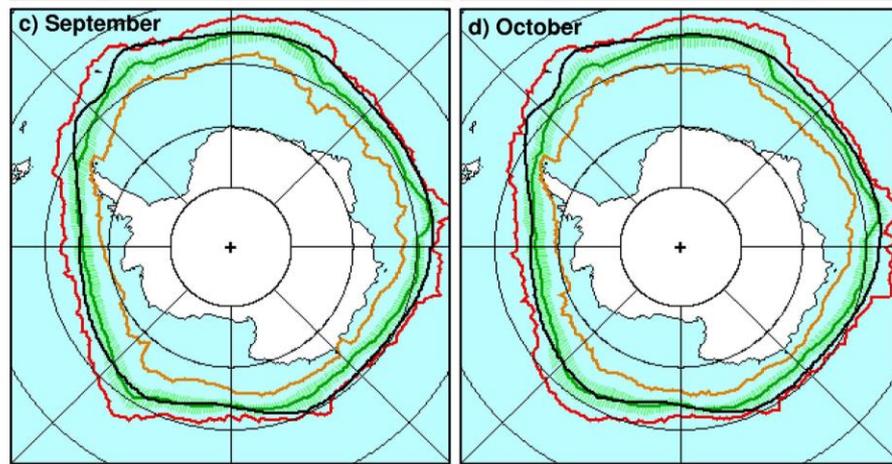
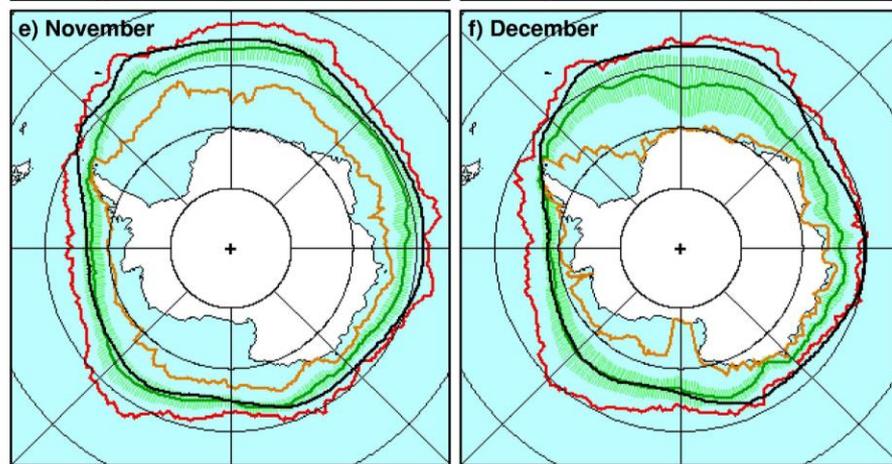
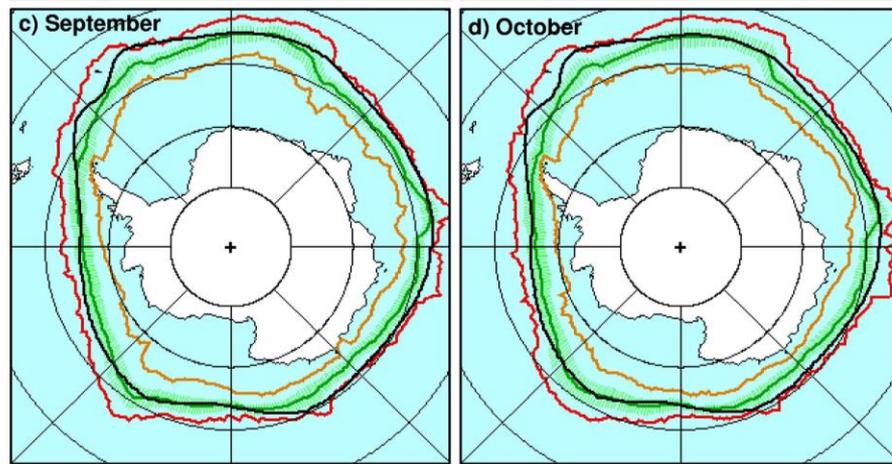
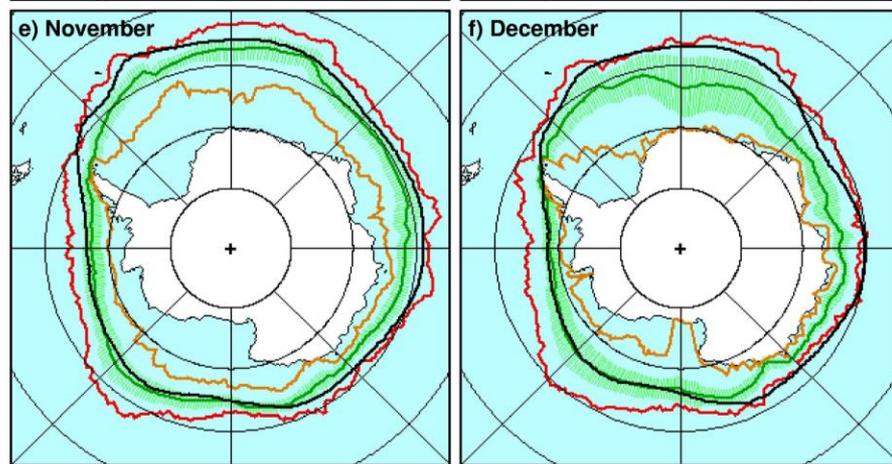
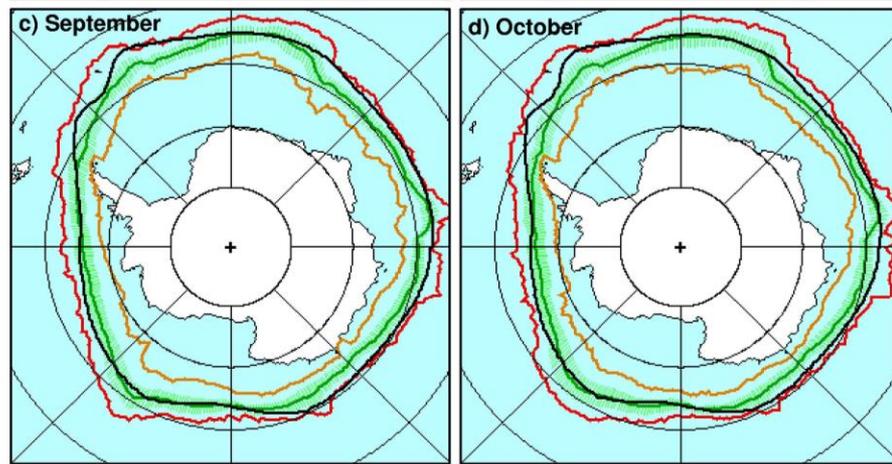
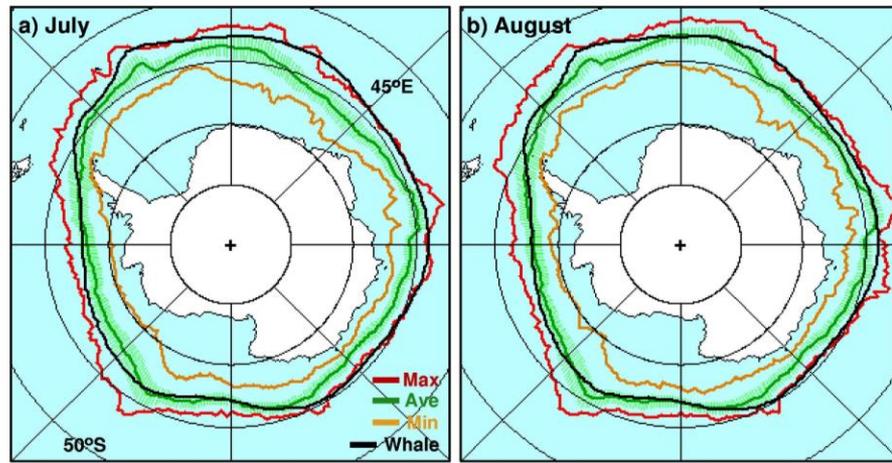
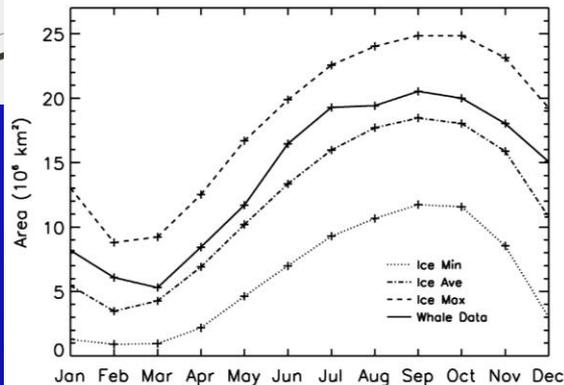
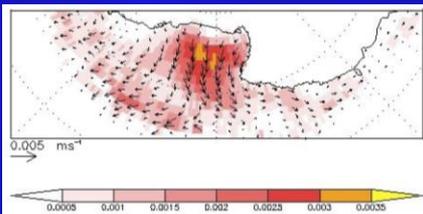
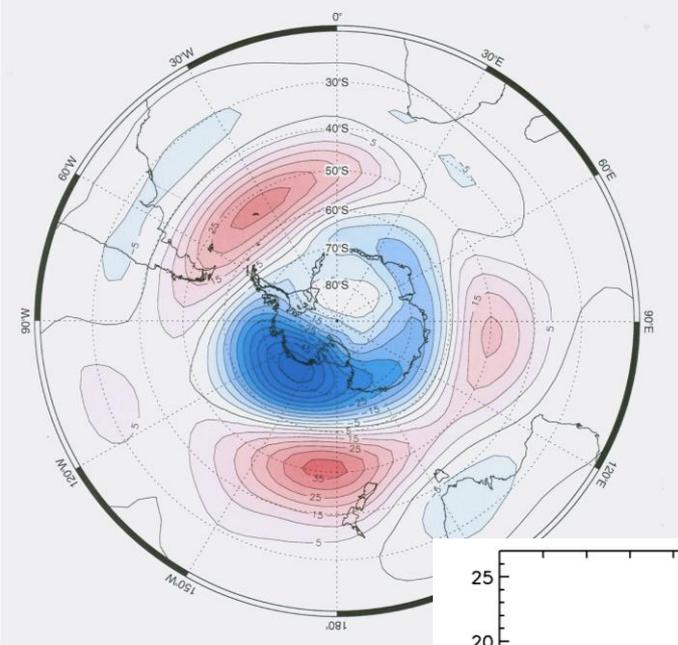
P3 over Antarctic Sea Ice with Bob Cahalan and research team



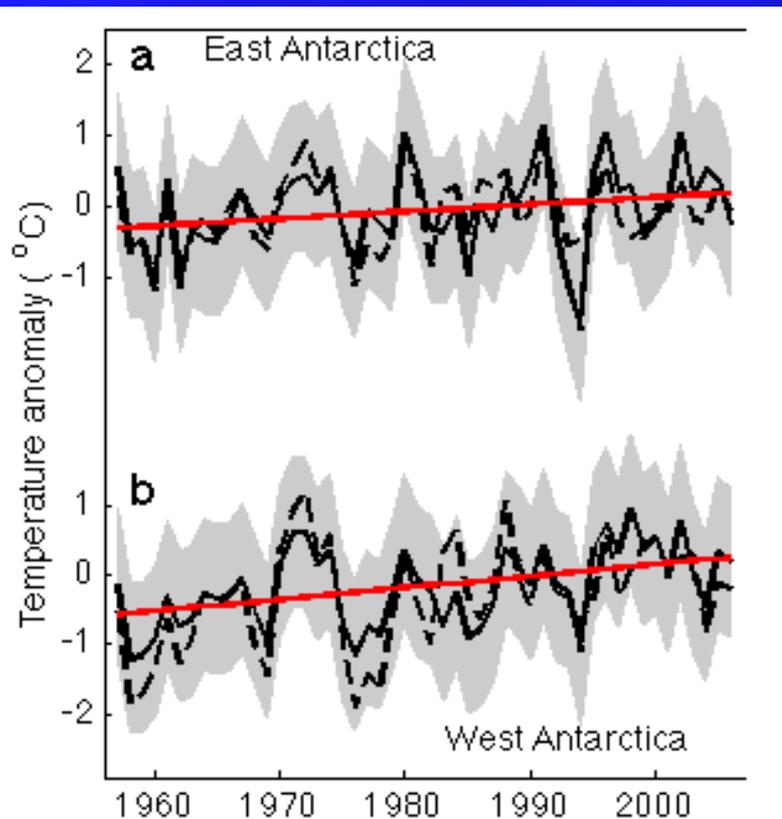
Ozone Hole Effect and McKintosh Whaling Ice Edge Data (1940s to 1950s) versus Satellite Data (1979 to 2008)

Ref: Turner et al, 2009;
de la Mare, Science, 1999

Decadal autumn 500 gphT trends, 1979-2001 (m)



Reconstructed Data for the Period 1957 to 2006



NATURE INSIGHT RNA SILENCING

22 January 2009 | www.nature.com/nature | £10 THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

nature

ANTARCTIC WARMING

Climate reconstruction gets to the heart of the continent

WHO DO YOU THINK YOU ARE?
Personal genomics changes the rules

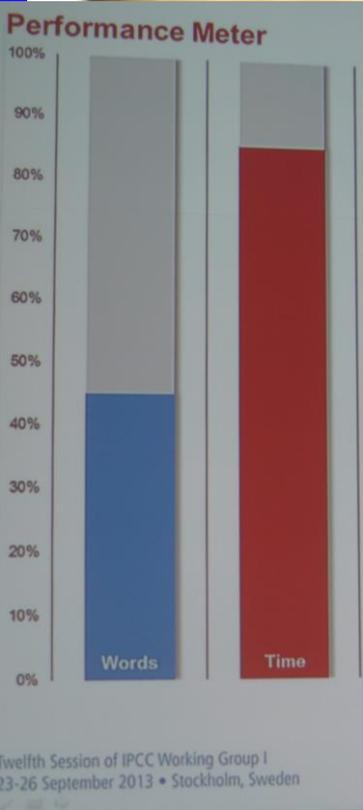
SOLAR SYSTEM EXPLORATION
The Titan-versus-Europa dilemma

SEXUAL REPRODUCTION
A long wait for *Aspergillus*

NATUREJOBS
Biotech & pharmaceuticals



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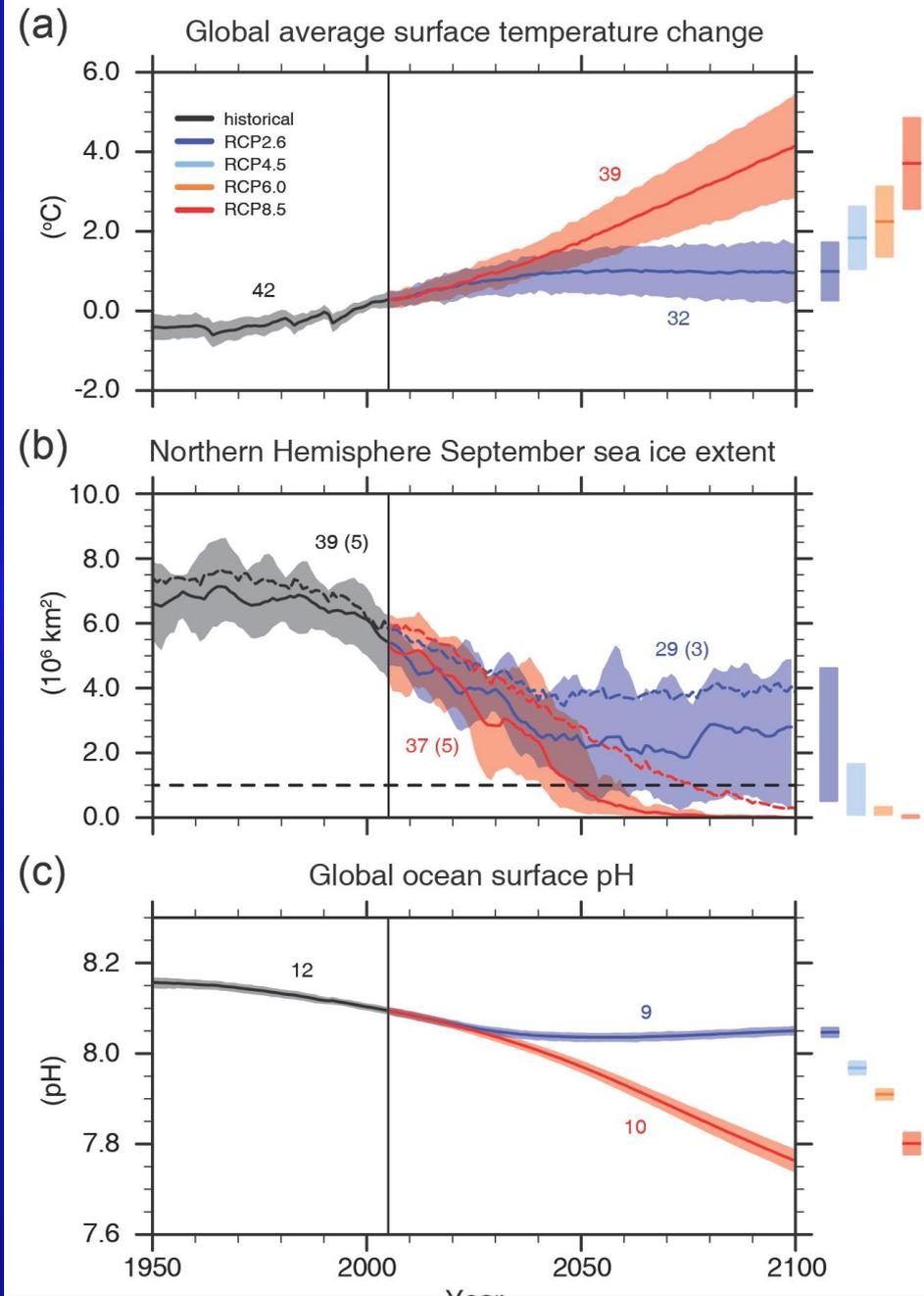
09/27/2013 03:02



09/26/

Some Key Modeling Results (CMIP5)

- Warming in the Climate System is Unequivocal
- Human Influence on the climate is evident in most regions of the globe.
- Representative Concentration Pathways (RCP)
 - RCP2.6 – 421 ppm CO₂
 - RCP4.5 – 538 ppm
 - RCP6.0 – 670 ppm
 - RCP8.5 – 936 ppmSimilarly for other greenhouse gases.



Summary and Conclusions

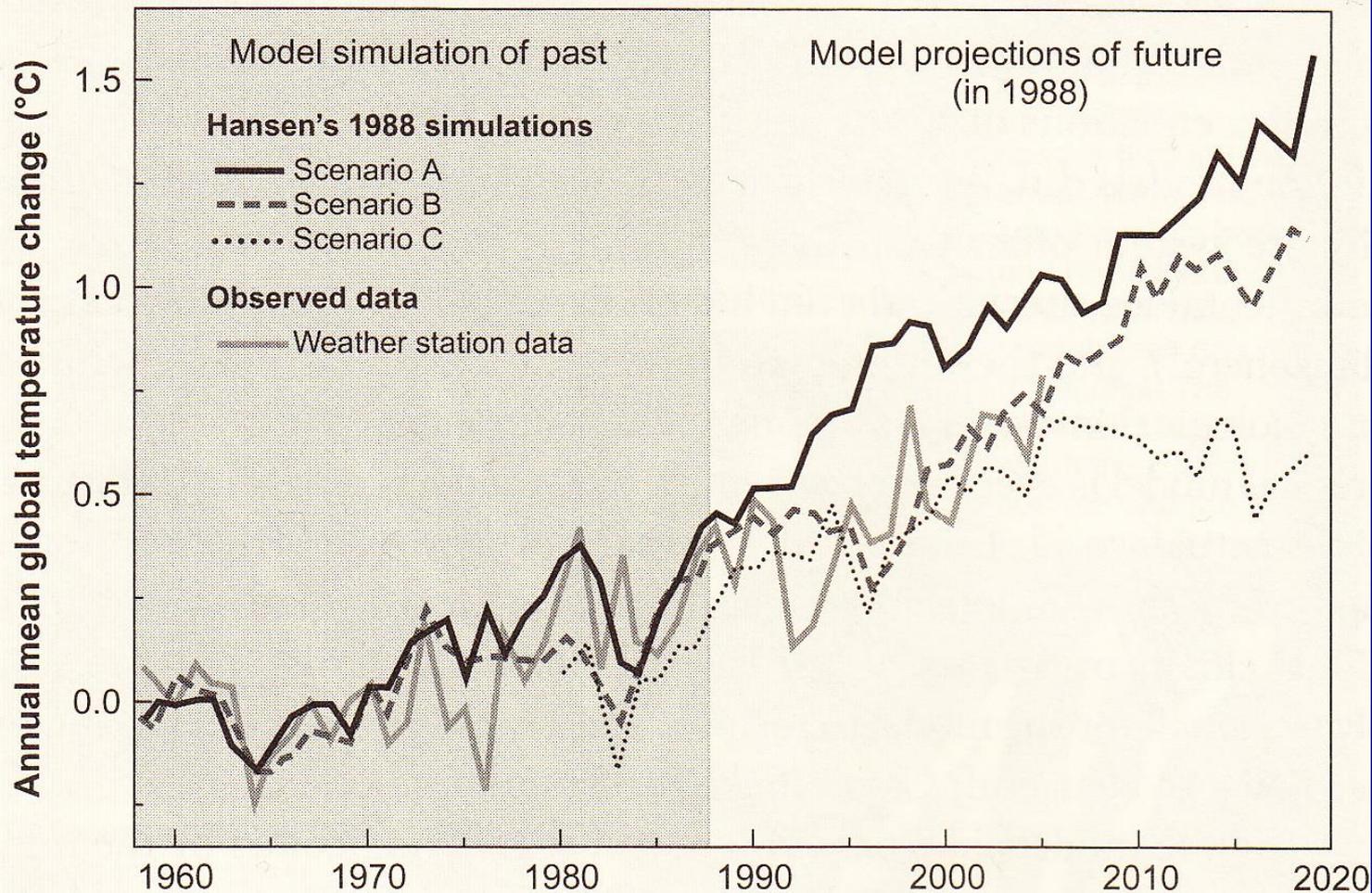
- ❑ Warming is amplified in the Arctic
- ❑ Multiple observational data in the cryosphere provides strong global warming signals
- ❑ The changes in the Arctic sea ice are dramatic and may have profound influence on the climate, the circulation of the World's oceans and the ecology and environment of the region.
- ❑ Changes in the Antarctic sea ice are surprisingly in the opposite direction but other factors contribute and further research is needed to understand its connection to climate change
- ❑ SORCE data is expected to provide insights into the cause of observed changes

End of Presentation

APS statement of climate change

“The evidence is incontrovertible: Global warming is occurring. If no mitigating actions are taken, significant disruptions in the Earth’s physical and ecological systems, social systems, security and human health are likely to occur. We must reduce emissions of greenhouse gases beginning now.”

Hansen's three projected global warming scenarios



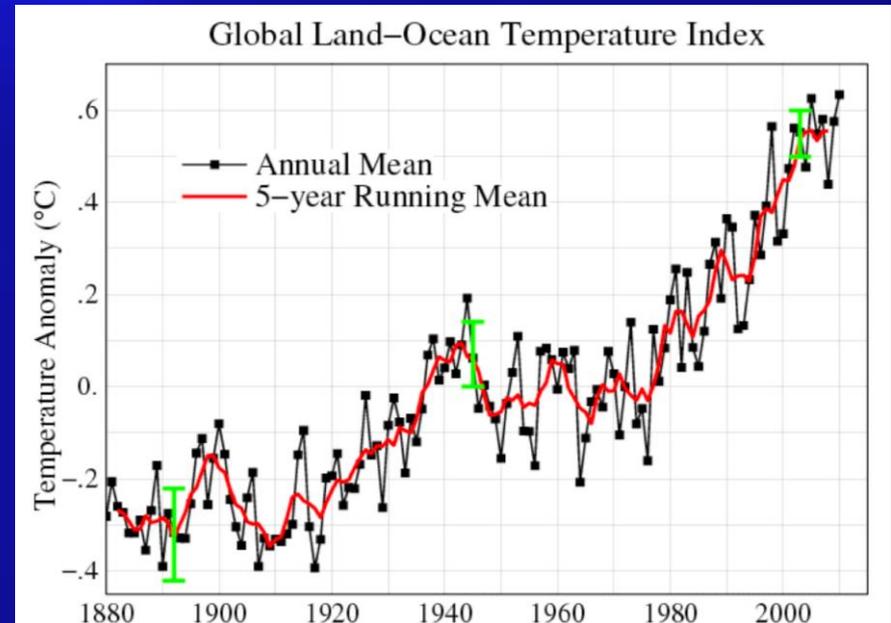
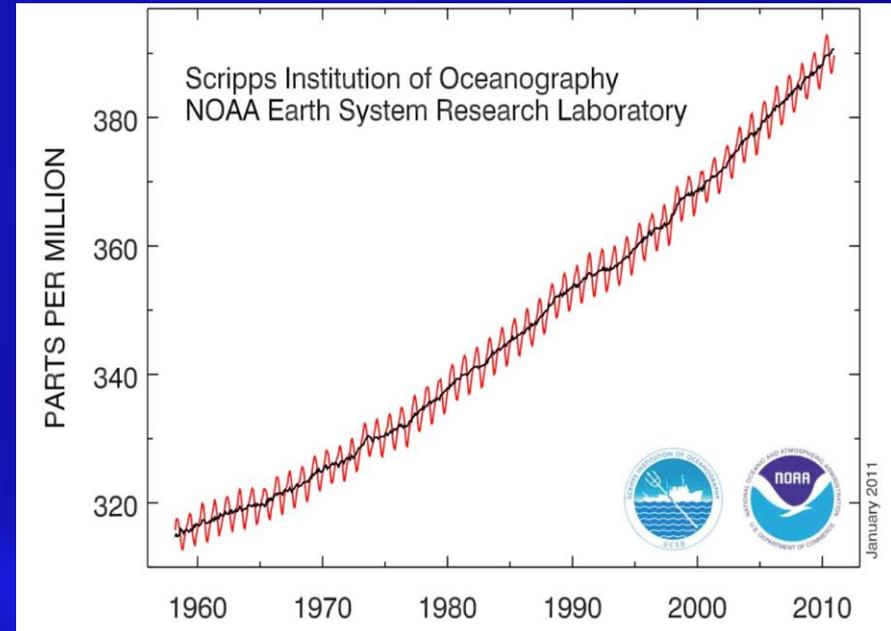
NASA Mission to Planet Earth

Rise in CO₂ concentration was more rapid than expected. Vante Arrhenius estimated that it would take 3000 yrs for a doubling to occur.

Concerns about global warming led to NASA's mission to planet Earth and the Earth Observation System.

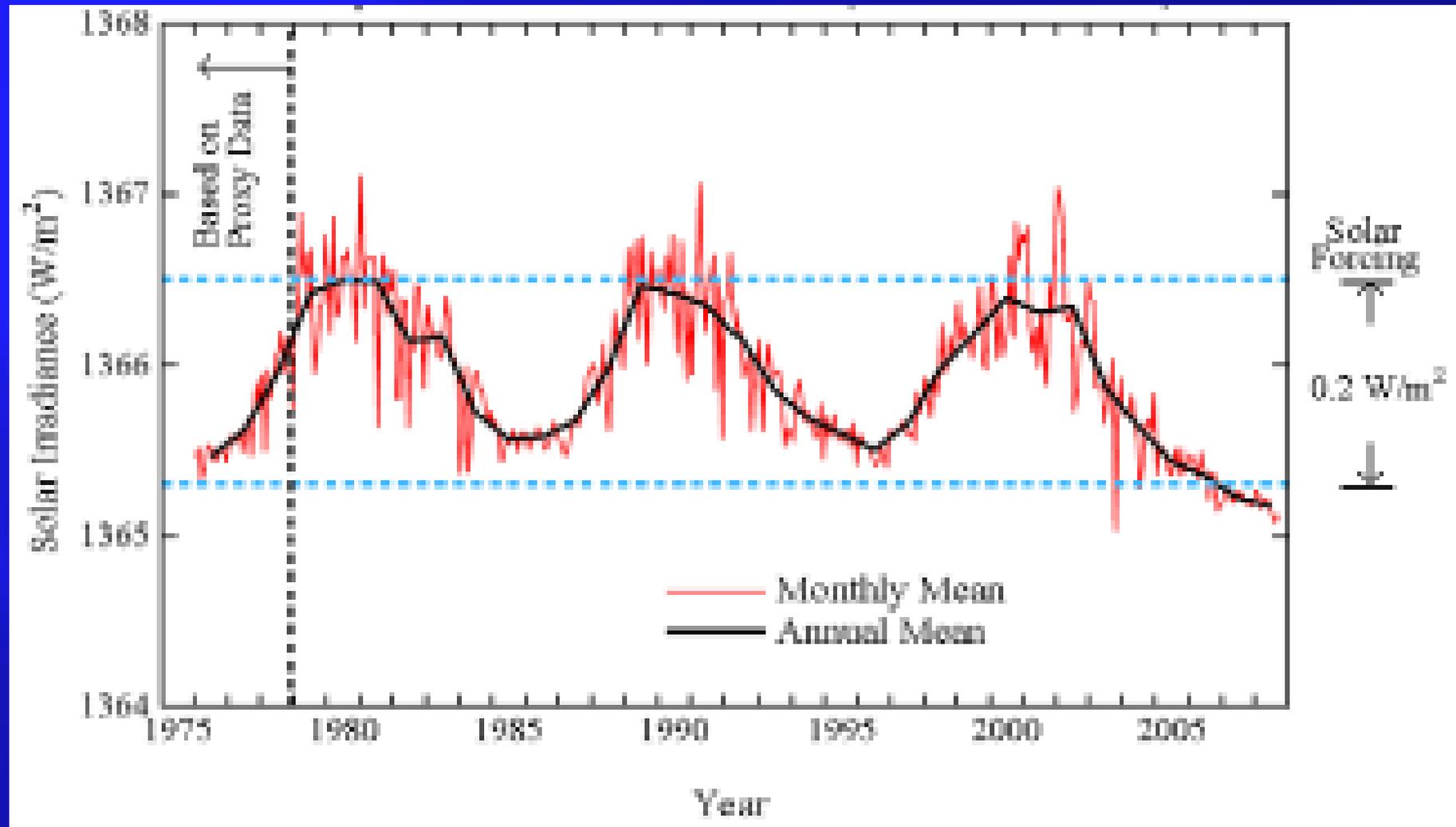
Analysis of NASA data resulted to many insights into our changing climate including that of the sea ice cover.

Keeling atmospheric CO₂ (in ppm)



Contribution from the Sun

Composite Total Irradiance (Frolich and Lean)



Modeling projections of the future

Sea Level Rise Projections to 2100

