RECENT CHANGES IN THE SEA ICE COVER

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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

a) Arctic ST Trend

b) Yearly ST Trends
AVHRR Arctic > 64°N Trend = 0.69 ± 0.08°C/dec
Normalized Hansen > 64°N Trend = 0.60 ± 0.07°C/dec
Normalized Global Hansen Trend = 0.17 ± 0.02°C/dec

Sea Ice
Trend = 0.47 ± 0.06°C/dec

Greenland
Trend = 0.77 ± 0.10°C/dec

Eurasia, > 64°N
Trend = 0.20 ± 0.08°C/dec

North America, > 64°N
Trend = 0.54 ± 0.09°C/dec

SST, > 60°N
Trend = 0.09 ± 0.01°C/dec
Arctic versus Global Surface Temperatures

b) Yearly ST Trends

AVHRR Arctic > 64°N Trend = 0.69 ± 0.08(°C/dec)
Normalized Hansen > 64°N Trend = 0.60 ± 0.07(°C/dec)
Normalized Global Hansen Trend = 0.17 ± 0.02(°C/dec)
Area of melt in Greenland. Record high in 2012

Spring melt in Greenland in 2002
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.
From 1980 to 2008, NDVI was increasing and highly correlated with surface warm index and sea ice concentration.

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:
2012 Arctic Storm & Sea Ice Minimum
Historical In Situ and Satellite Data

Annual and Summer Ice Extents

Ice Extent (km$^2$ x 10$^6$)

1880 1900 1920 1940 1960 1980 2000

- Annual W & C, Updated
- Annual SMMR and SSM/I
- Annual AMSR–E
- Summer (JAS) W & C, Updated
- Summer (JAS) SMMR and SSM/I
- Summer (JAS) AMSR–E
Anomalous decline in the Arctic ice thickness from both Submarine and ICESat data

Changes in the atmospheric circulation as revealed by the Arctic Oscillation

(a) Arctic Oscillation (Monthly)

- Run Avg Trend: $-0.0016$ AO Index/yr
- Monthly Trend: $-0.0019$ AO Index/yr

(b) Arctic Oscillation (DJFM Average)

- DJFM Trend: $-0.0046$ AO Index/yr

Time: 1980 to 2010
MY ice periodicity

a) Multiyear Ice Extent

b) Multiyear Ice Area

Multiyear Ice Power Spectra, February

8 years
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, 1981 to 2012
Climate Change Fiction book: Used by some congressmen as a means to justify that there is no climate change
Antarctic decadal extents and seasonal trends of sea ice

(a) Daily Ice Extent

- 1979-1988
- 1989-1998
- 1999-2008
- 2009-2012

(b) Winter (JJA)

(c) Spring (SON)

(d) Summer (DJF)

(e) Autumn (MAM)

Trend (% IC/year)
Validation of Sea Ice Algorithm

Mixing Algorithm:
\[ IC = \frac{(TB - T0)}{(Ti - T0)} \]
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
Reconstructed Data for the Period 1957 to 2006

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
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 ppm
Similarly 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
“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

Model simulation of past

Hansen's 1988 simulations
- Scenario A
- Scenario B
- Scenario C

Observed data
- Weather station data

Model projections of future (in 1988)

Annual mean global temperature change (°C)

Rise in CO$_2$ 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.
Contribution from the Sun
Composite Total Irradiance (Frolich and Lean)
Sea Level Rise Projections to 2100

- Estimates of the past
- Instrumental record
- Projections of the future

Sea level change (mm) vs. Year

Year: 1800, 1850, 1900, 1950, 2000, 2050, 2100

Modeling projections of the future