

# **Global Warming: Man or Myth?**

Scott A. Mandia

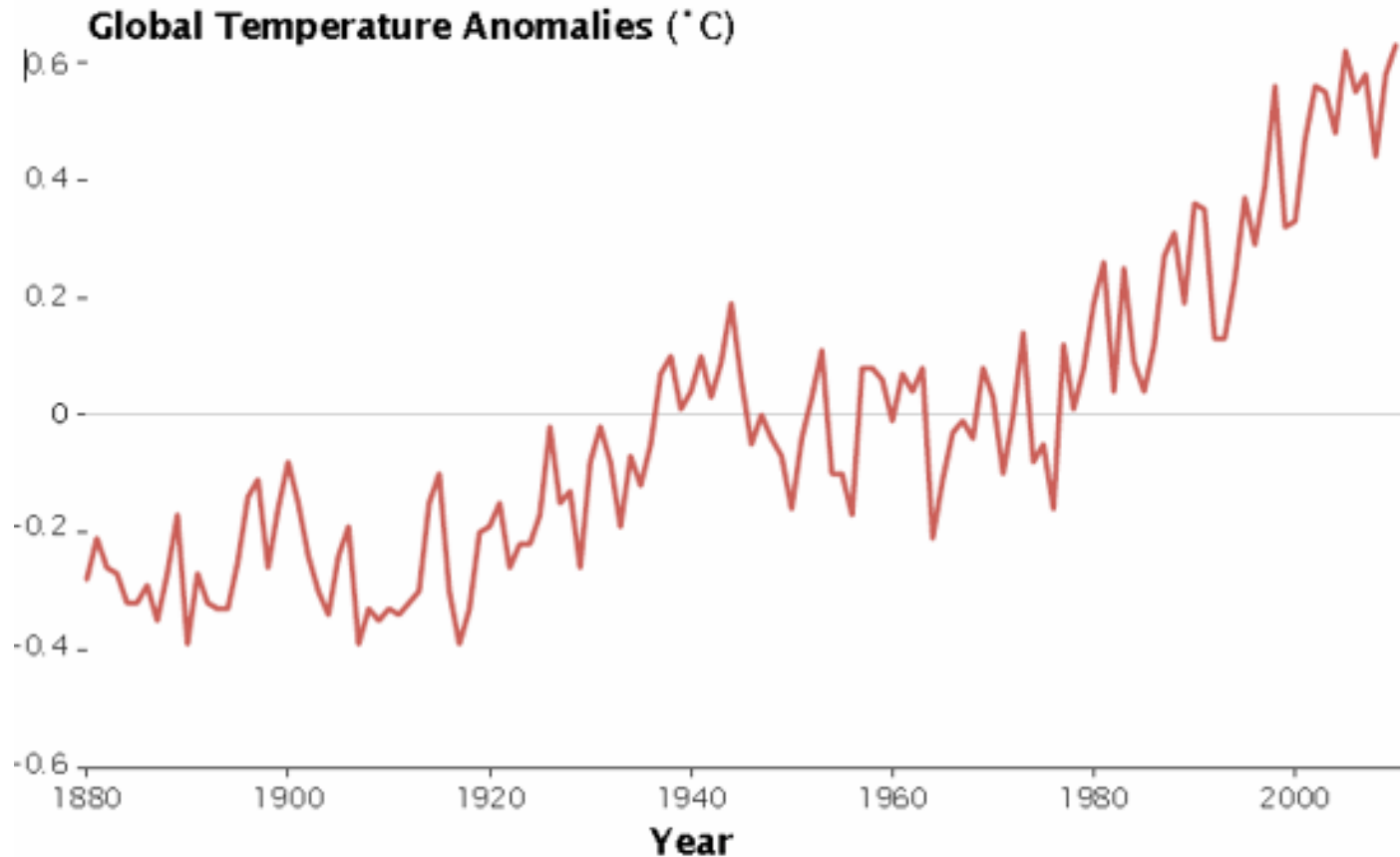
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# Overview

1. The Climate System is Warming
2. Warming is Primarily Caused by Human Activities, esp. Emissions of Heat-Trapping Gases Such as Carbon Dioxide
3. Many of the Skeptics' Arguments are False or Very Misleading

# The Climate System is Warming



Global mean temperature anomalies (compared to 1961-1990) from the years 1850 to 2010 (NASA, 2010)

- Since 1970, global temperatures have warmed  $0.17^{\circ}\text{C} \pm 0.03^{\circ}\text{C}$  per decade

# The Climate System is Warming

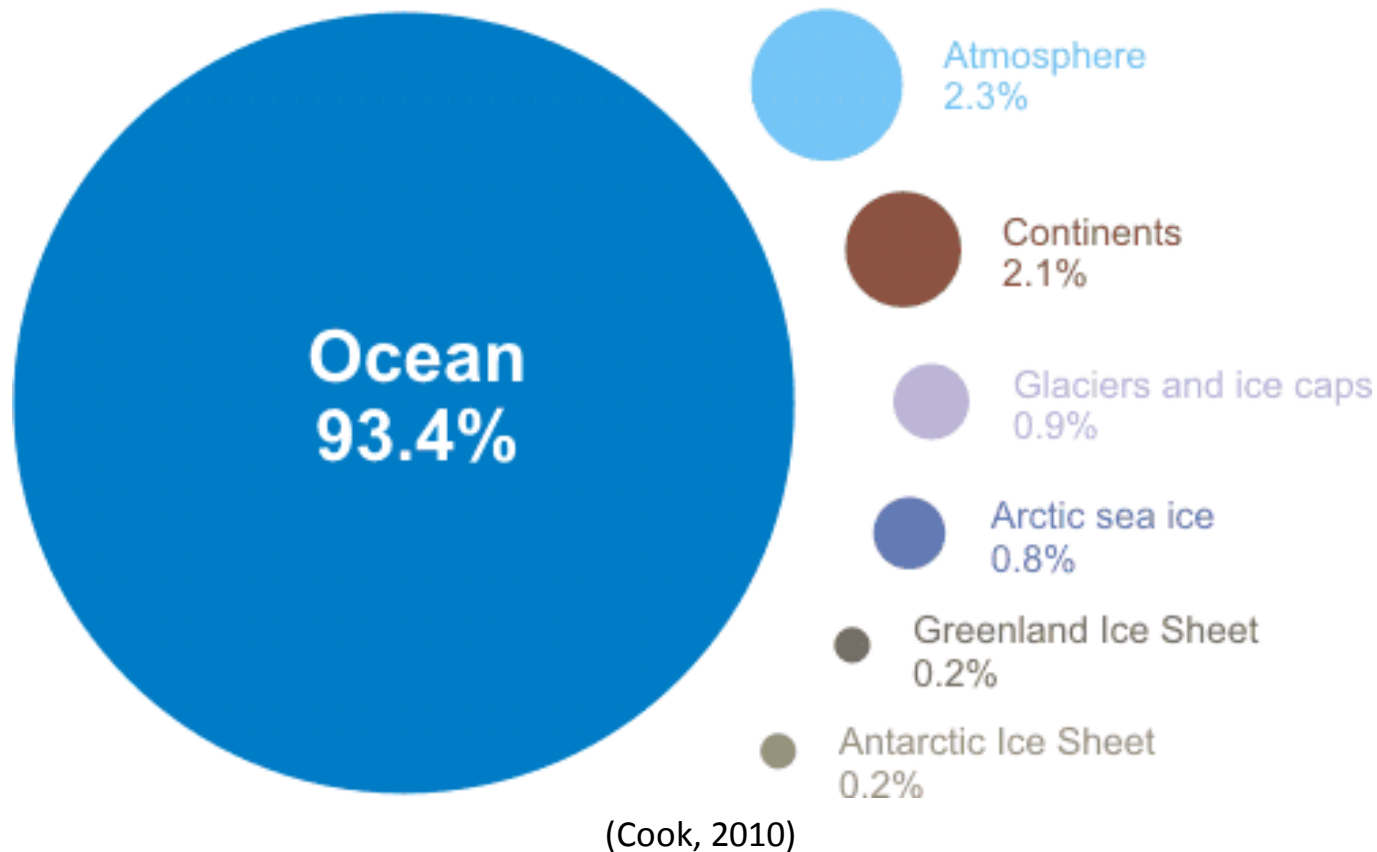
Global Top 10 Warmest Years (Jan-Dec)*	Anomaly °C	Anomaly °F
<b>2010</b>	0.62	1.12
<b>2005</b>	0.62	1.12
<b>1998</b>	0.60	1.08
<b>2003</b>	0.58	1.04
<b>2002</b>	0.58	1.04
<b>2009</b>	0.56	1.01
<b>2006</b>	0.56	1.01
<b>2007</b>	0.55	0.99
<b>2004</b>	0.54	0.97
<b>2001</b>	0.52	0.94

(NOAA, 2010)

- 9 of the top 10 warmest years on record occurred this decade.
- All 12 of the warmest years on record have occurred since 1997
- 20 of the warmest years on record have occurred in the past 25 years
- Each of the past three decades has been warmer than the decade before and each set records at their end

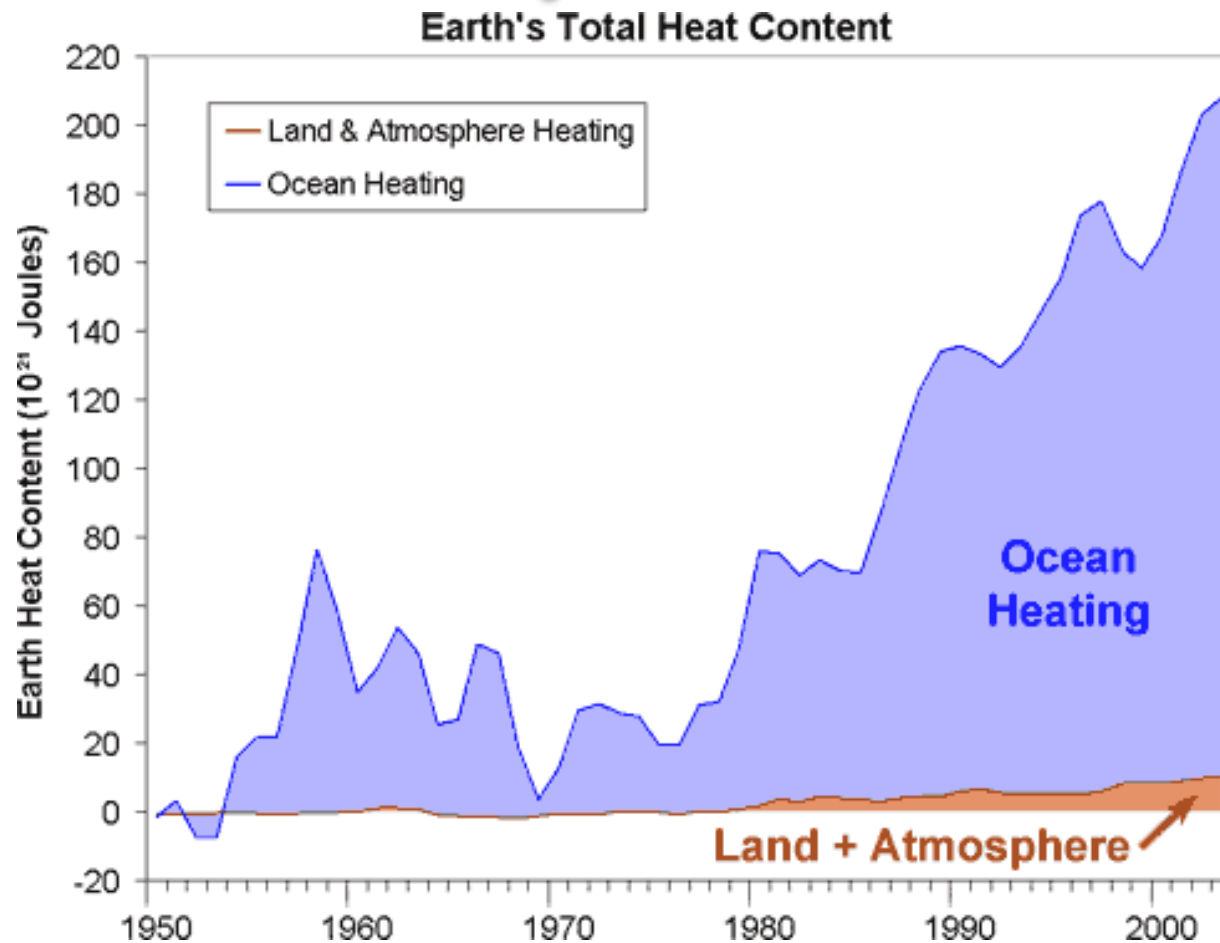
# The Climate System is Warming

Where is global warming going?



- Most of the extra heat is being stored in the oceans due to their tremendous heat capacity. Oceans are the true benchmark of global warming

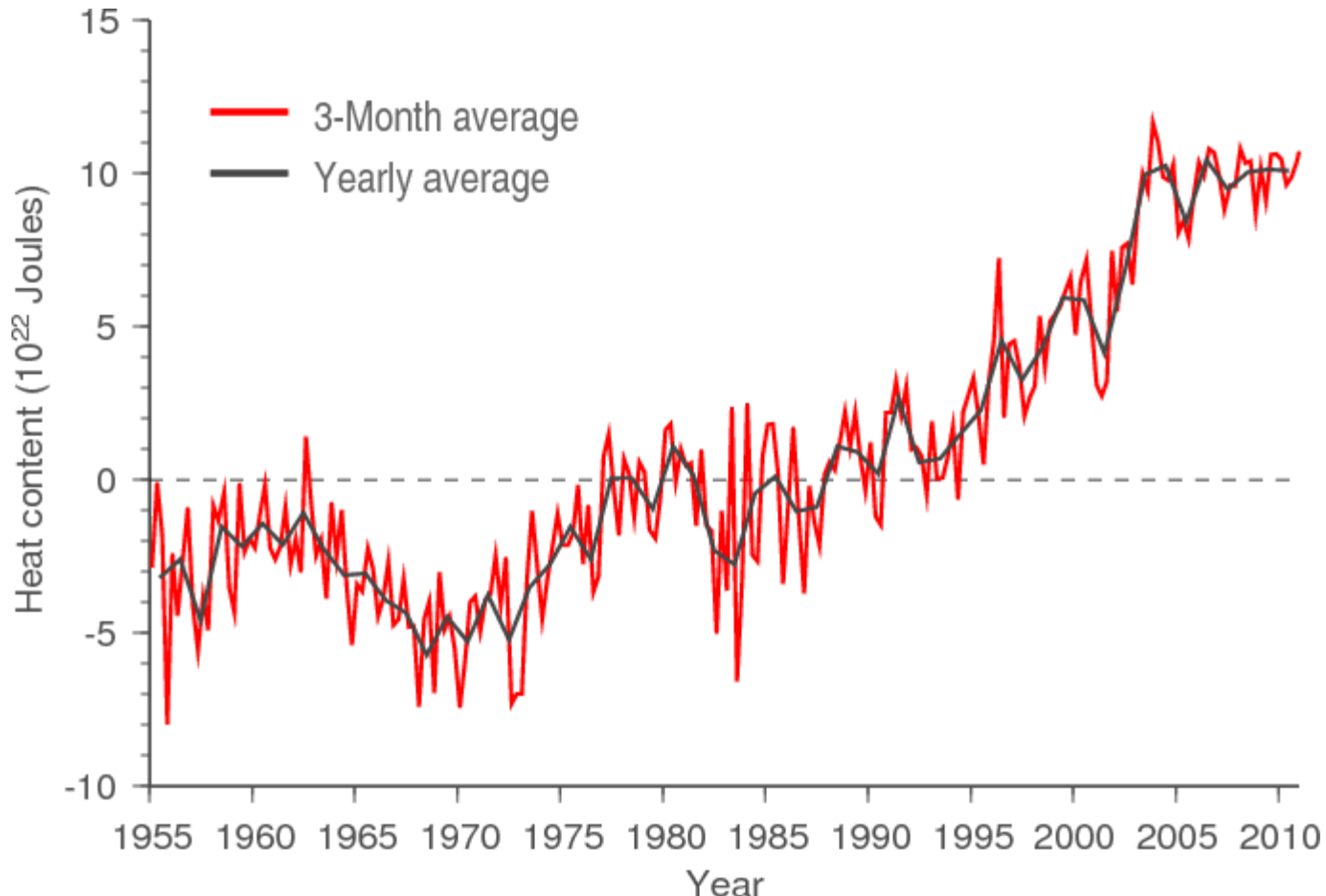
# The Climate System is Warming



(Image: Cook, 2009 Data: Murphy, *et al.*, 2009)

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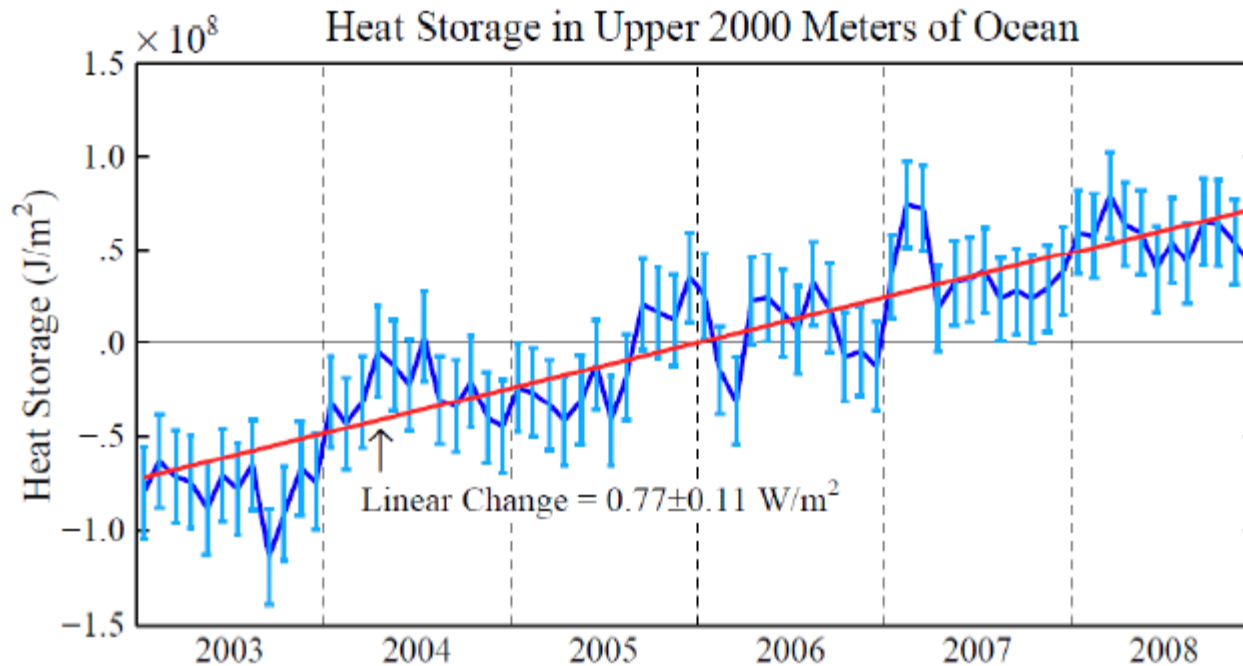
# The Climate System is Warming



(National Oceanographic Data Center, 2011)

- **Most of the extra heat is being stored in the oceans due to their tremendous heat capacity. Oceans are the true benchmark of global warming**

# The Climate System is Warming



Heat storage in upper 2000 meters of ocean during 2003-2008 based on ARGO data.

Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.

Data must be averaged over a decade because of El Nino/La Nina and solar variability.

Energy imbalance is smoking gun for human-made increasing greenhouse effect.

Data source: von Schuckmann *et al.* *J. Geophys. Res.* 114, C09007, 2009, doi:10.1029/2008JC005237.

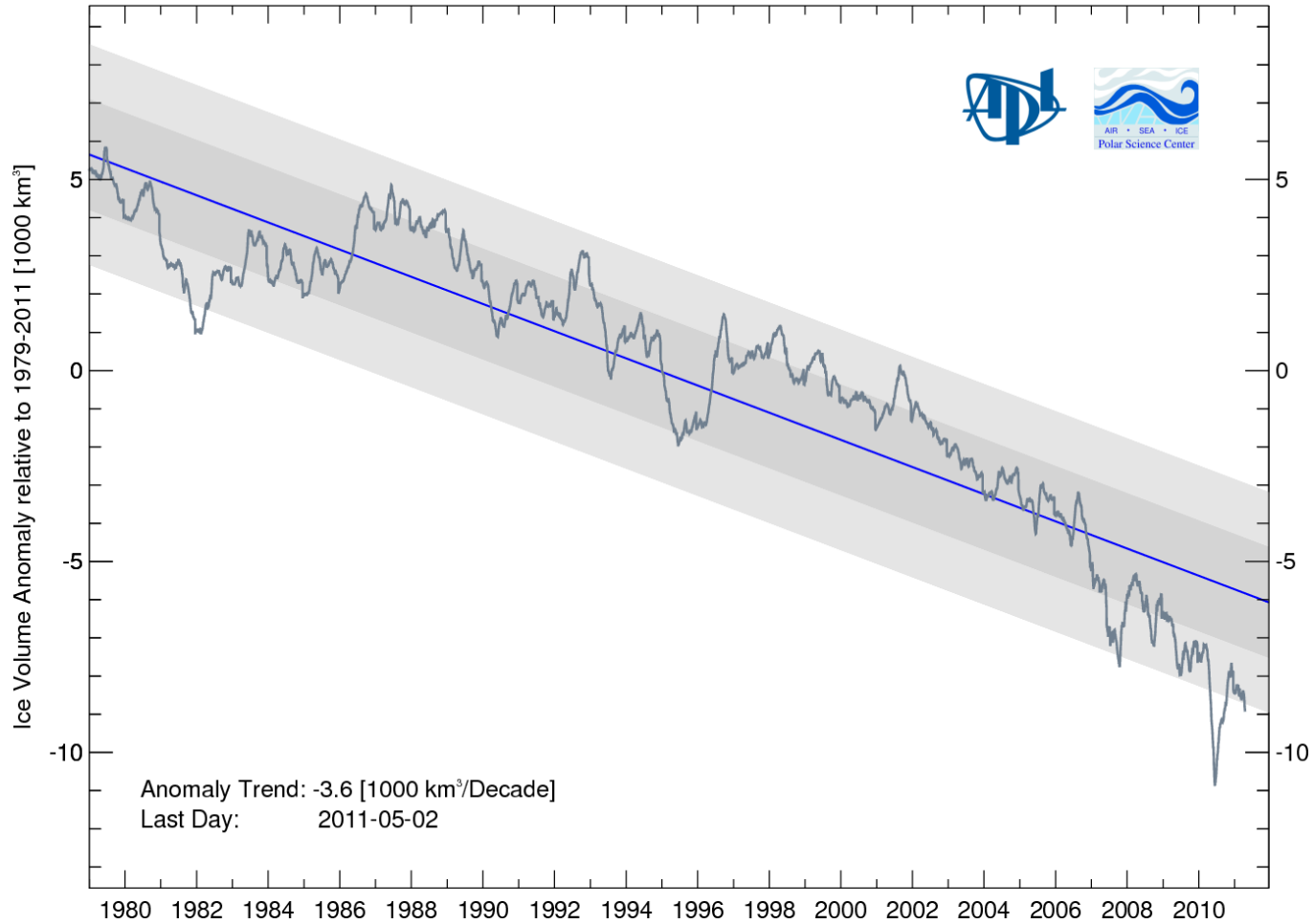
(von Schuckmann *et al.*, 2009)

- Most of the extra heat is being stored in the oceans due to their tremendous heat capacity. Oceans are the true benchmark of global warming



# The Climate System is Warming

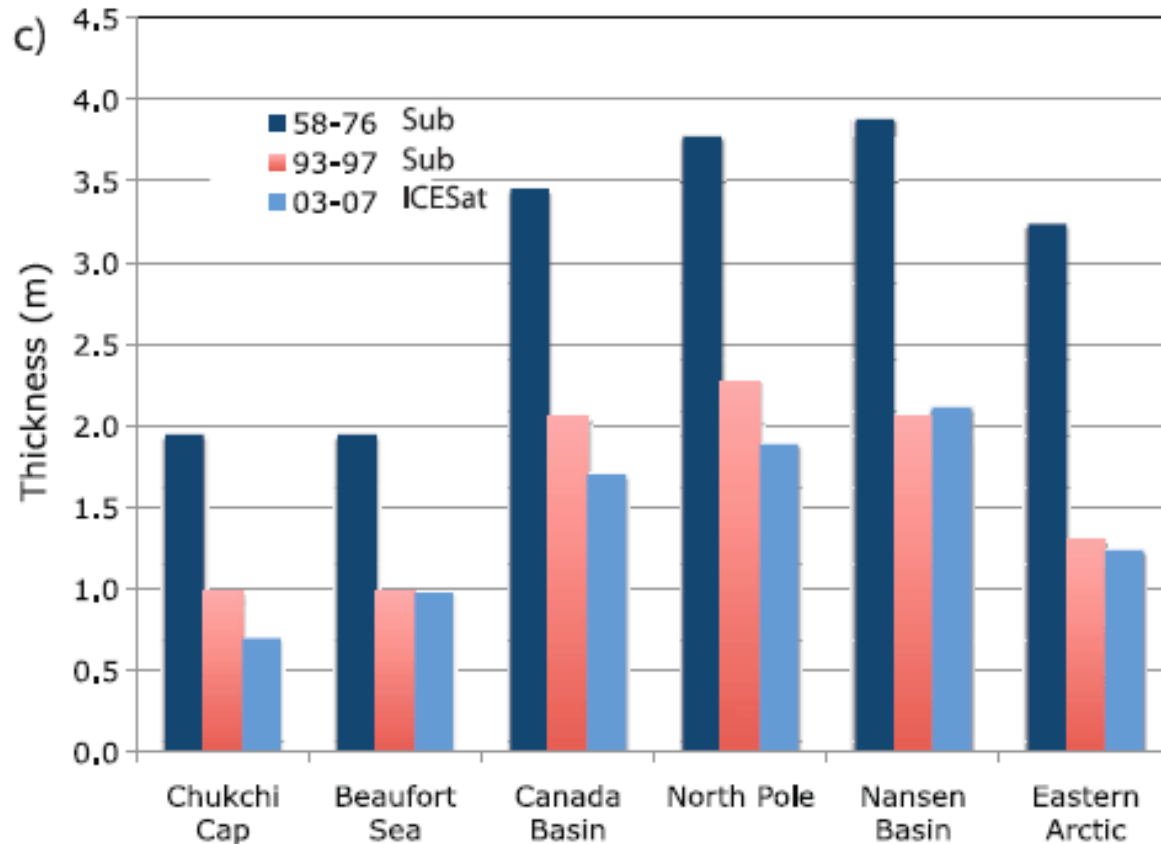
Arctic Sea Ice Volume Anomaly and Trend from PIOMAS



(Polar Science Center., 2010)

- Arctic ice volume is shrinking and is at record low

# The Climate System is Warming

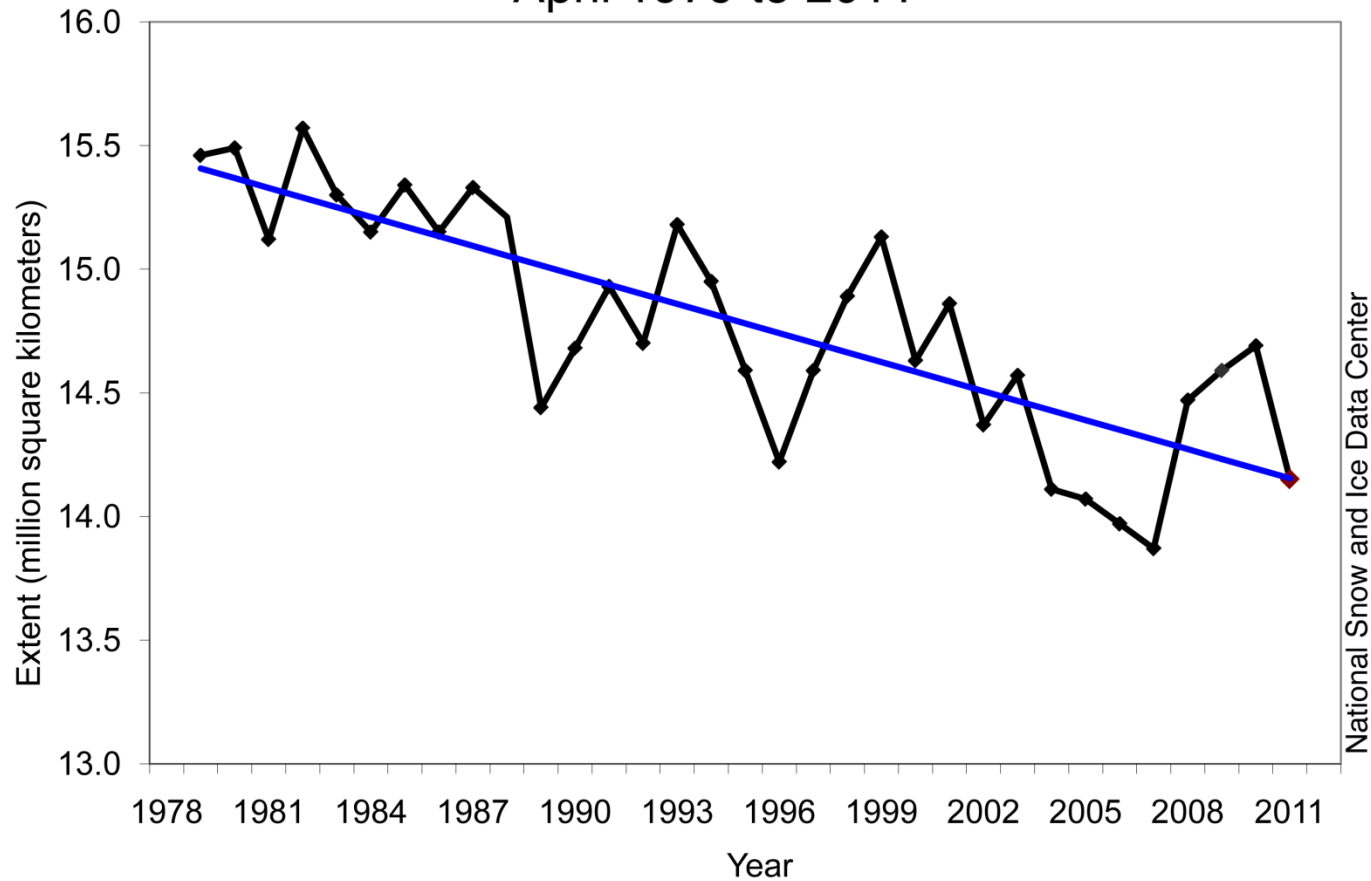


(Kwok & Rothrock, 2009)

- Arctic ice thickness is decreasing and is at record low
- *“This combined analysis shows a long-term trend of sea ice thinning over submarine and ICESat records that span five decades.”*

# The Climate System is Warming

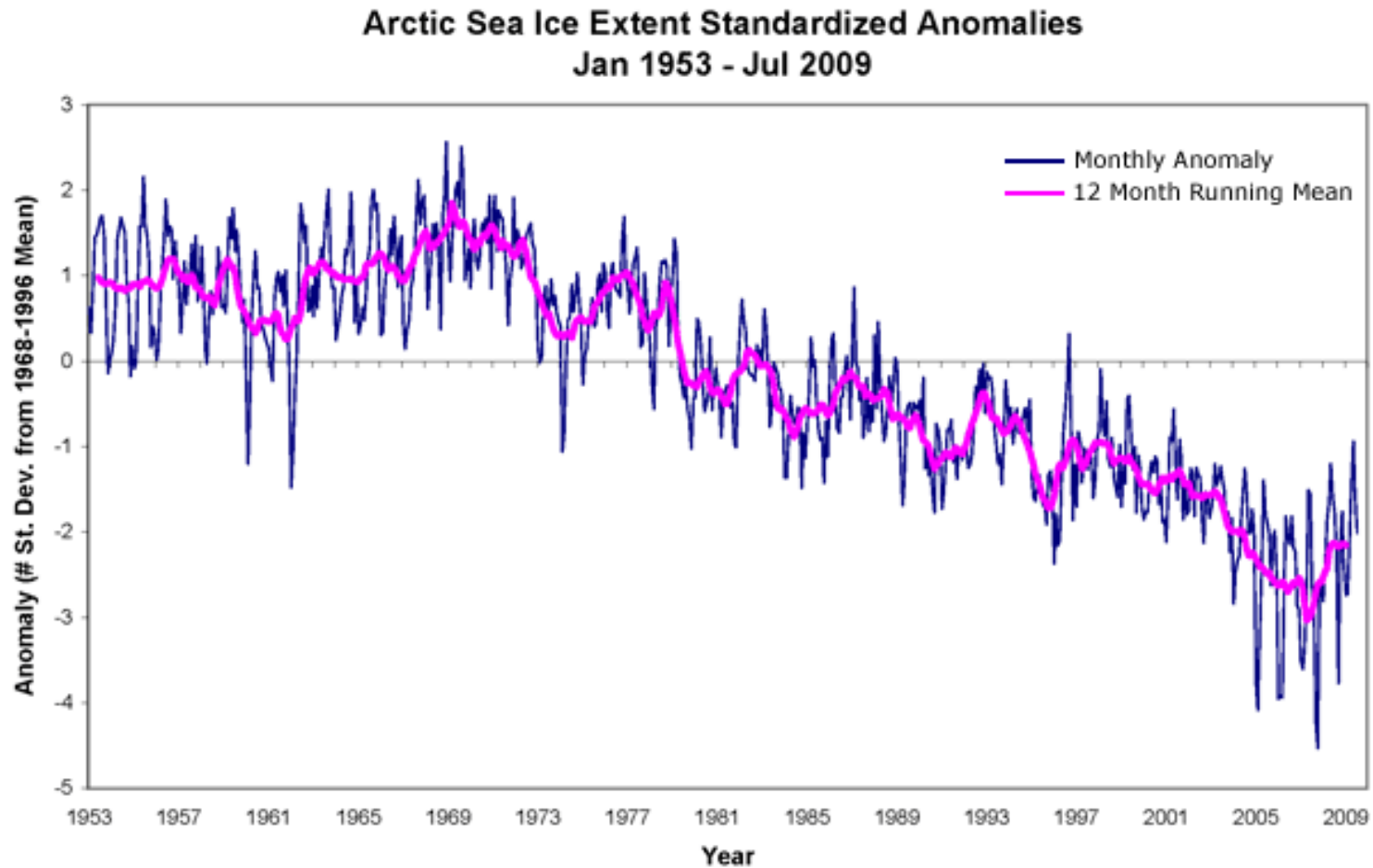
Average monthly Arctic sea ice extent  
April 1979 to 2011



(National Snow & Ice Data Center, 2011)

- Arctic sea ice extent is decreasing

# The Climate System is Warming

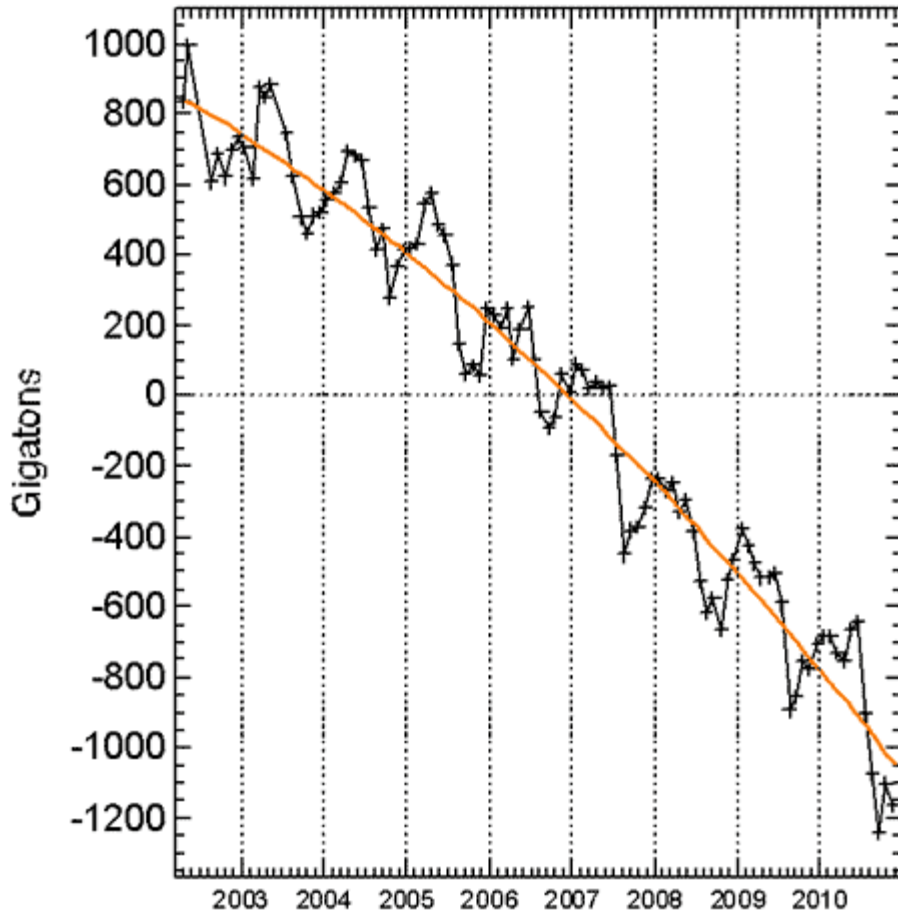


(National Snow & Ice Data Center, 2010)

- Arctic sea ice extent is decreasing

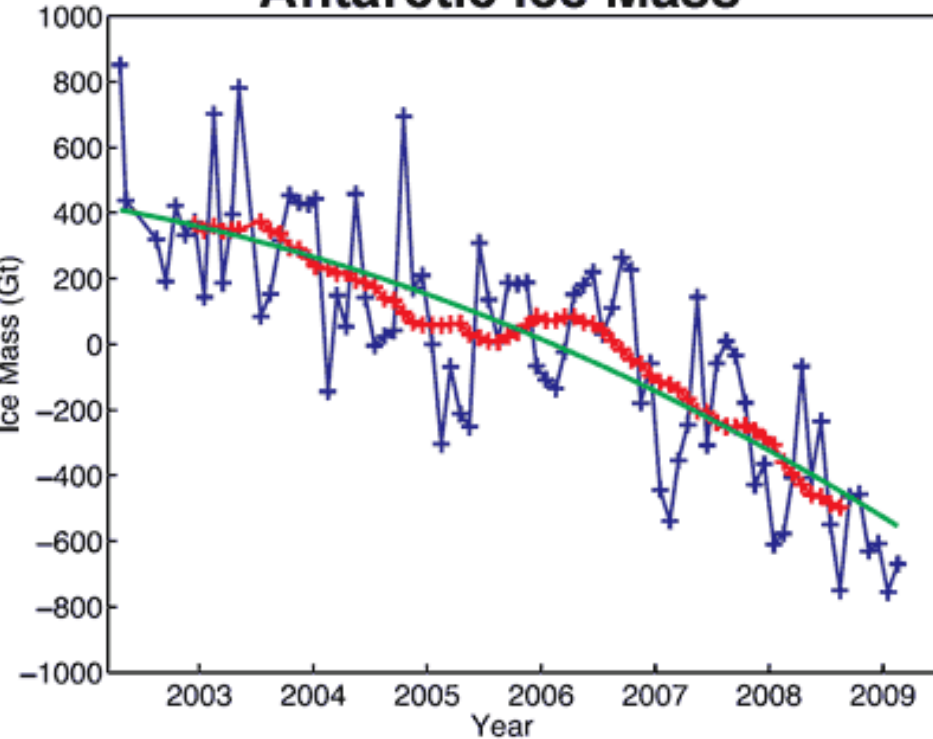
# The Climate System is Warming

Greenland



(Velicogna, 2009 & Wahr, 2010)

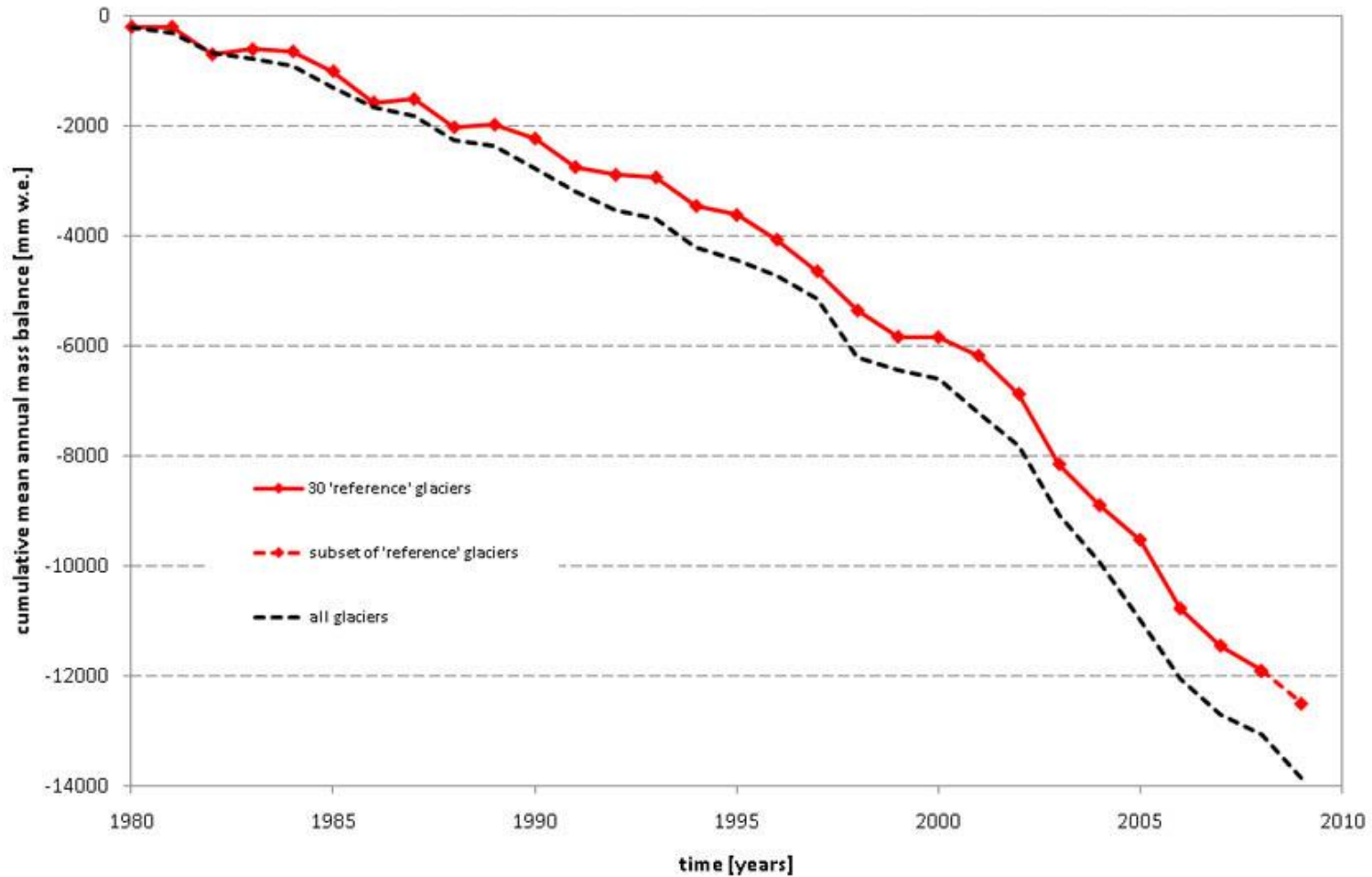
Antarctic Ice Mass



(Velicogna, 2009)

- Greenland and Antarctica are rapidly losing ice mass

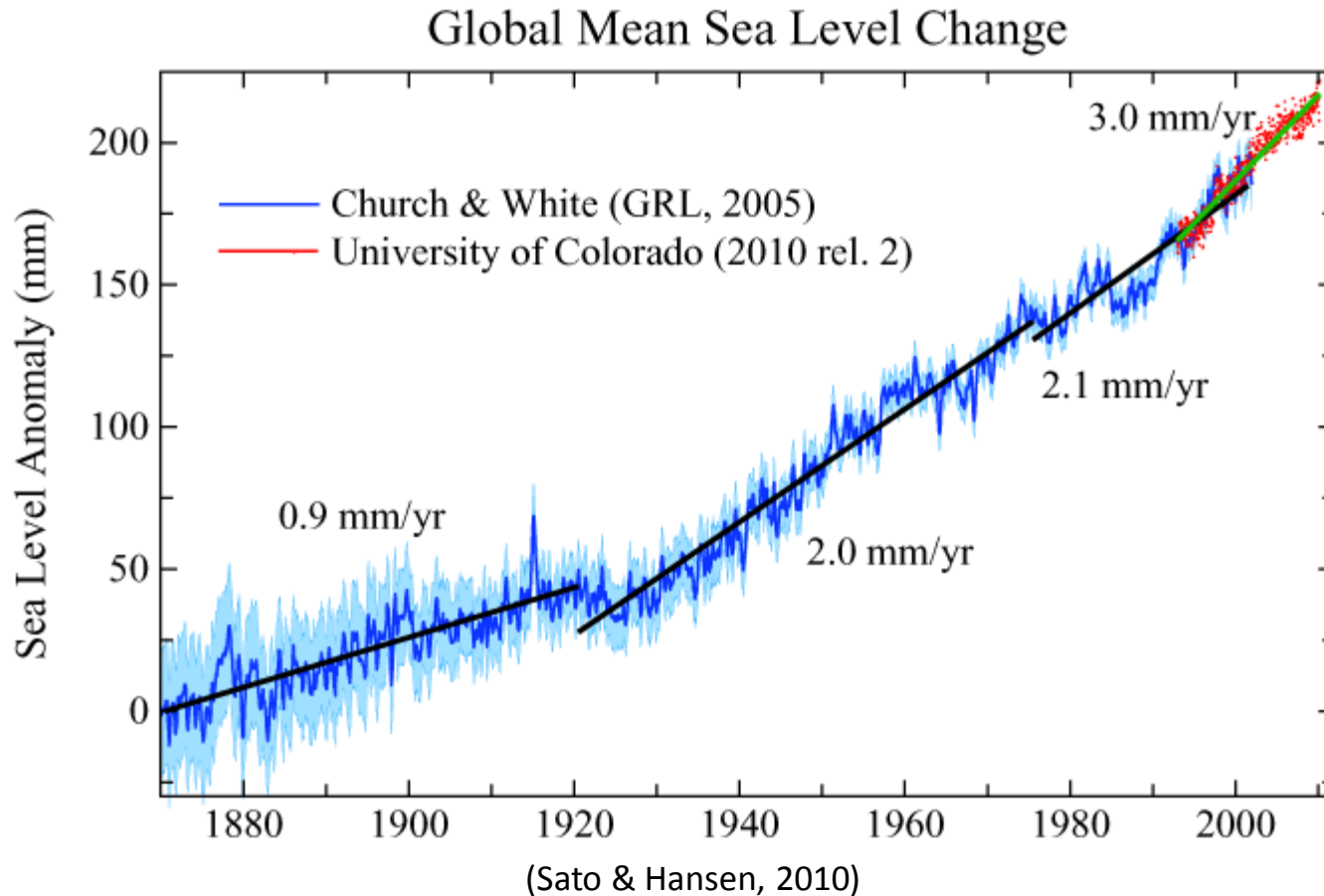
# The Climate System is Warming



(World Glacier Monitoring Service, 2011)

- **World-wide, glaciers are rapidly losing ice**

# The Climate System is Warming

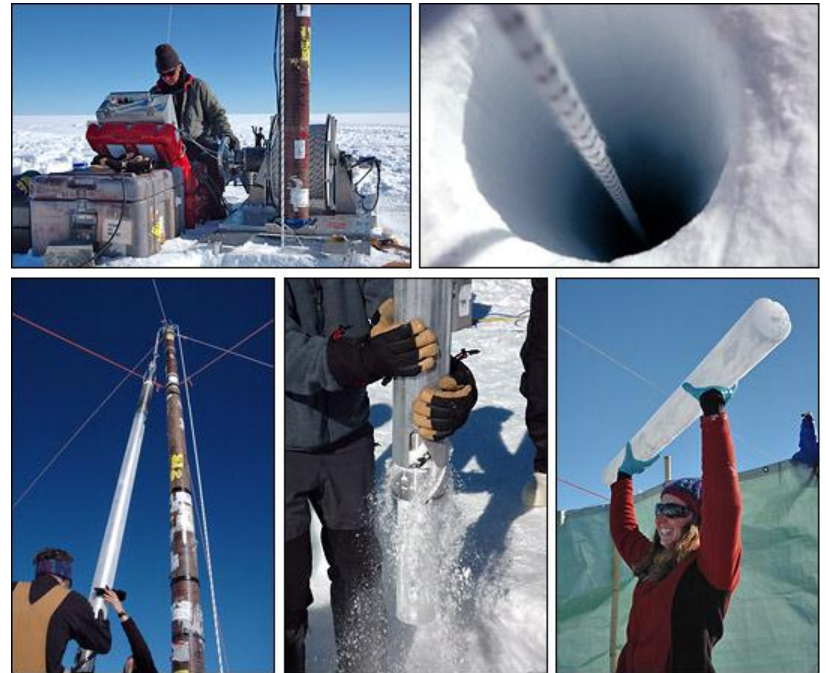


- Sea level is rising due to:
  - Thermal expansion – warmer water takes up more space
  - Land-based melting ice adds water to oceans

# The Climate System is Warming

To determine past climate, scientists use “proxy data” such as:

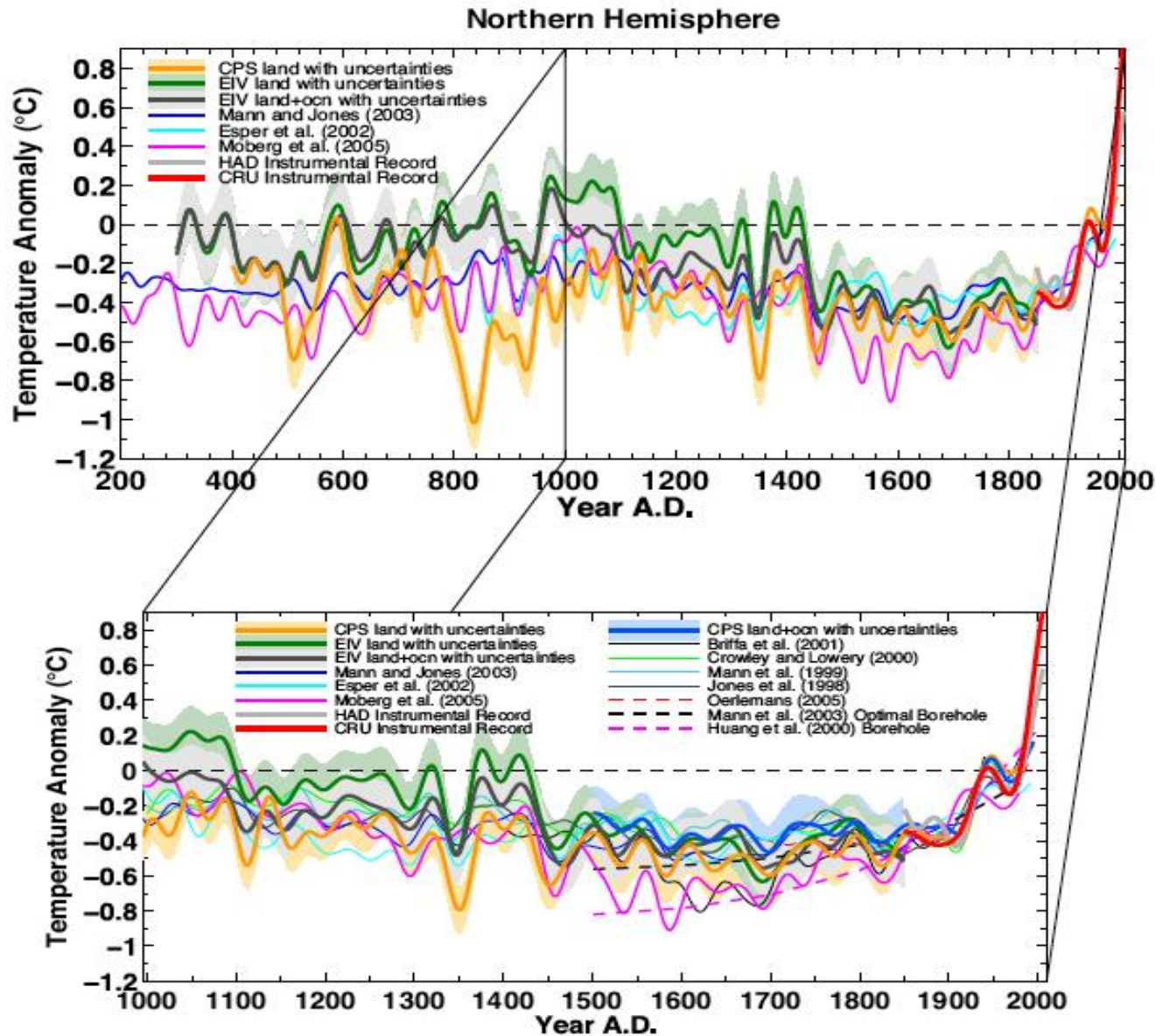
- tree-rings
- marine sediment
- mineral deposits
- lake deposits
- ice cores
- corals
- boreholes
- historical documentary series



Riebeek (2006b)



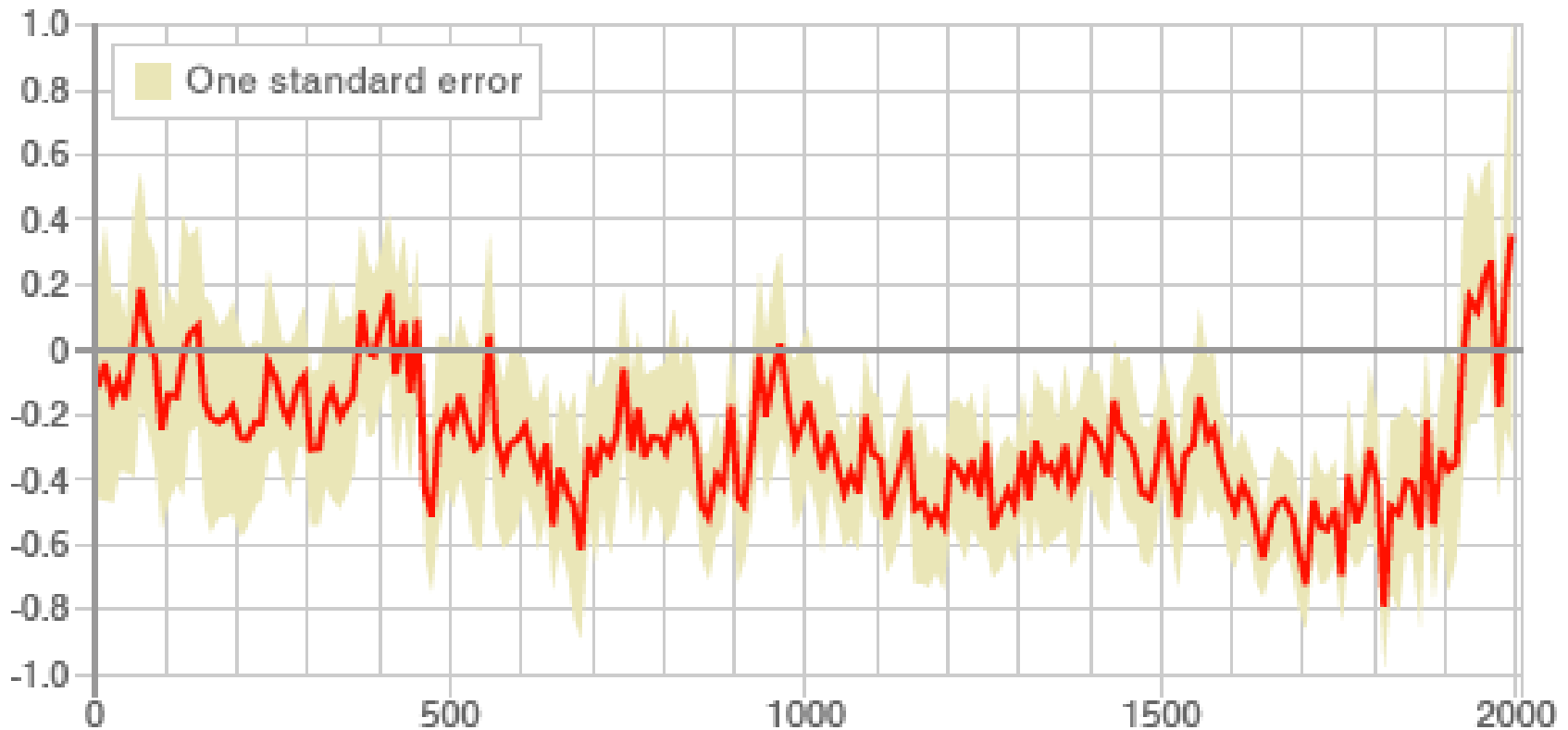
# The Climate System is Warming



# The Climate System is Warming

## Two millenia of Arctic temperatures

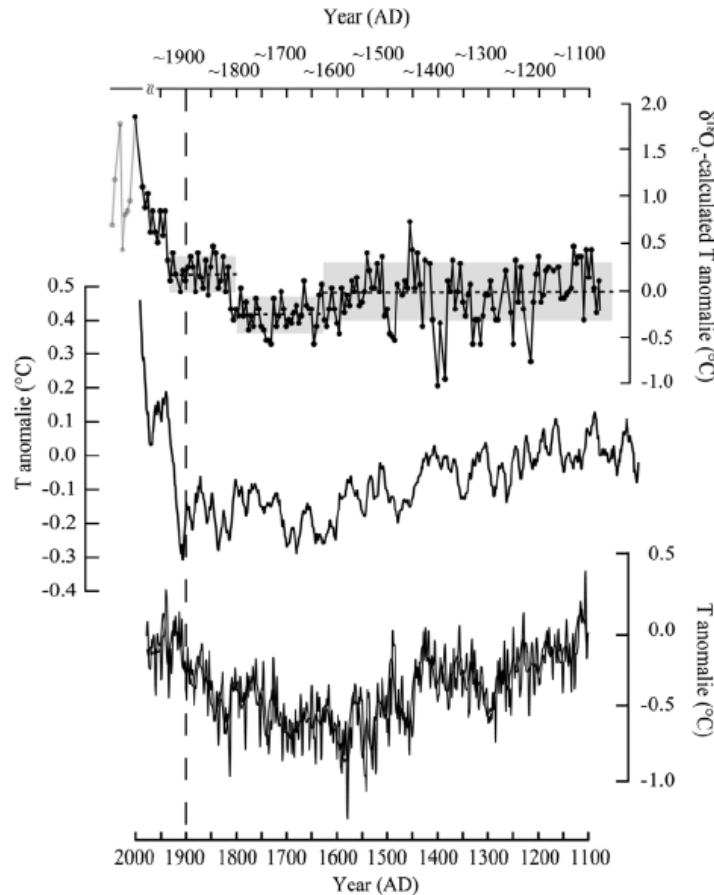
Temperature anomaly °C



SOURCE: Kaufman et al, Science

***“A 2,000 year cooling trend was reversed during the 20th century, with four of the five warmest decades of the 2000-year-long reconstruction occurring between 1950 and 2000.”***

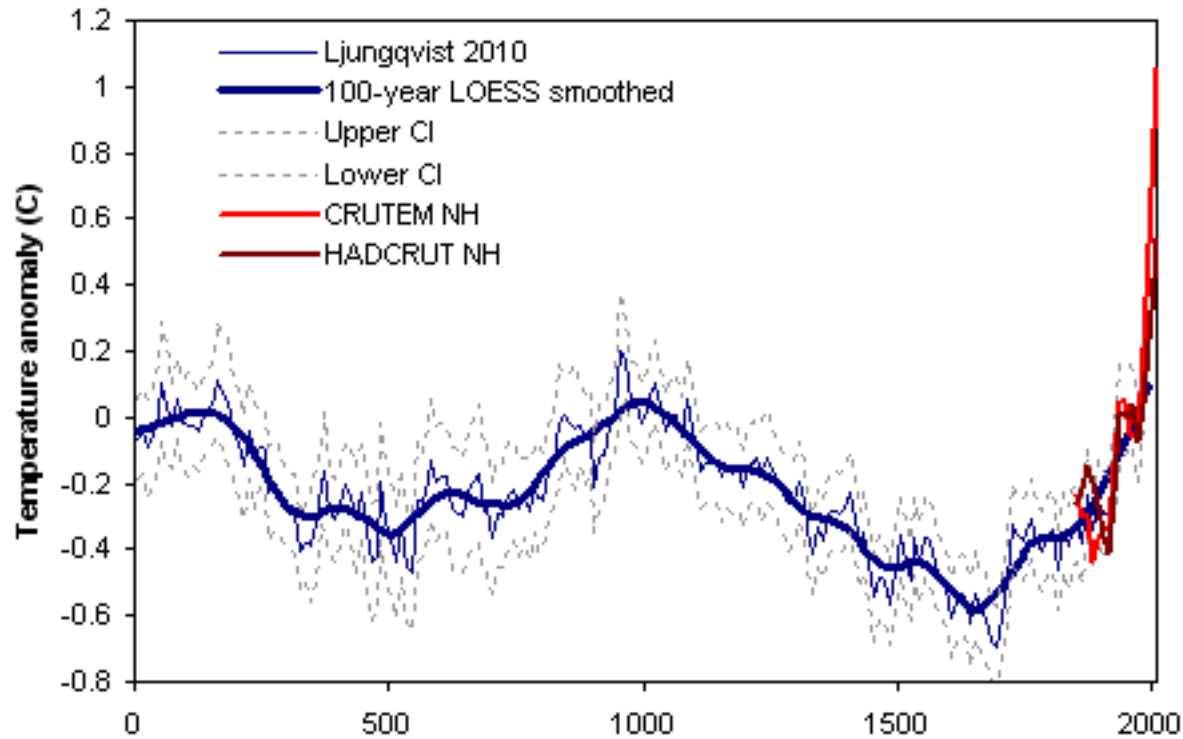
# The Climate System is Warming



(Thibodeau, *et al.*, 2010)

- Isotopic analysis (oxygen isotopes) of shells recovered from sediments of North Atlantic Ocean
- ***“...it is unquestionable that the last century has been marked there by a warming trend having no equivalent over the last millennium.”***

# The Climate System is Warming



(Ljungqvist, 2010)

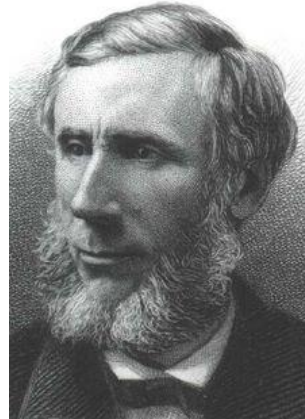
- ***“Our temperature reconstruction agrees well with the reconstructions by Moberg et al. (2005) and Mann et al. (2008) ..., despite significant differences in both data coverage and methodology.”***
- ***“The temperature of the last two decades, however, is possibly higher than during any previous time in the past two millennia...”***

# Humans are Responsible



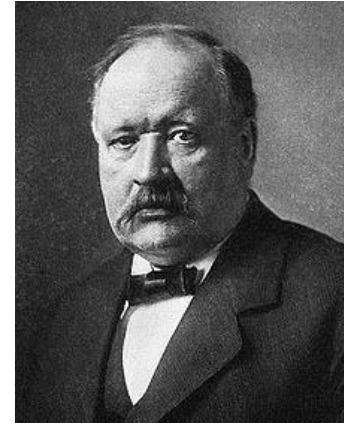
(Wiki, 2006)

**Joseph Fourier**



(Wiki, 2009)

**John Tyndall**

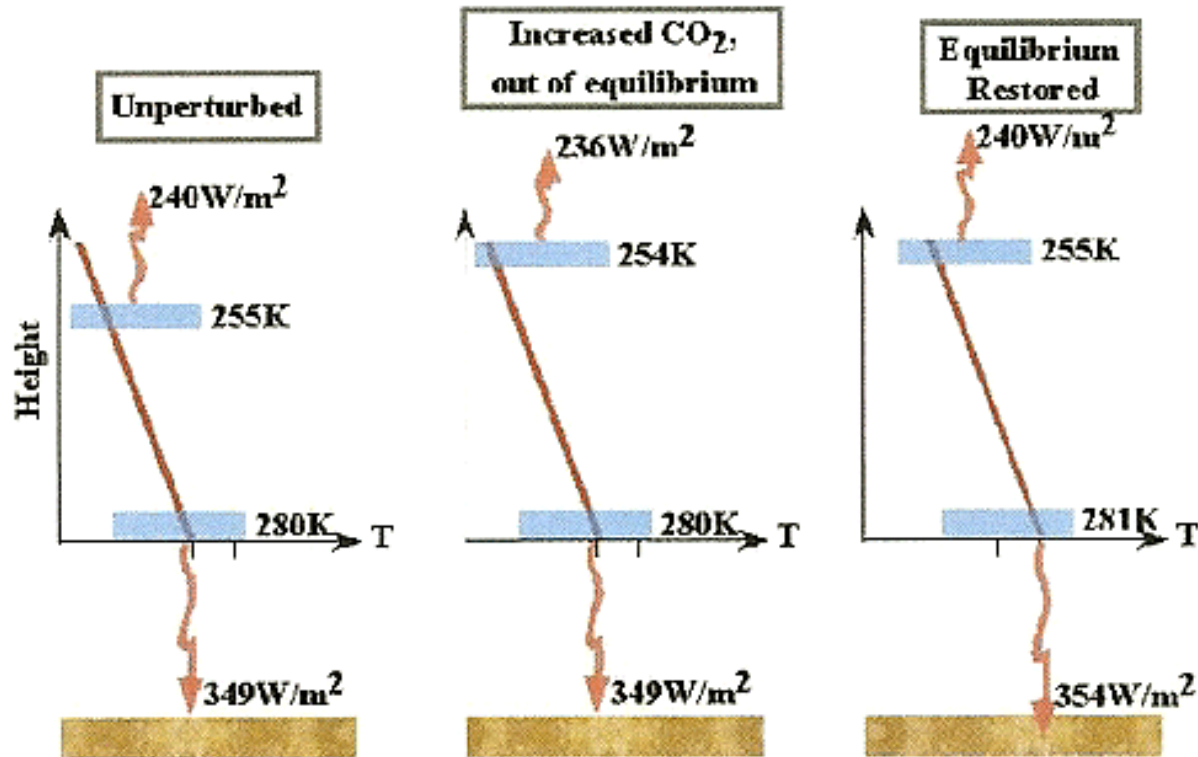


(Wiki, 2004)

**Svante Arrhenius**

- Greenhouse effect (GHE) is not new – **it has been studied for almost 200 years**
- 1820s Fourier publishes papers about the heat-trapping effect of gases
- 1859 Tyndall shows experimentally the greenhouse effect of water vapor and carbon dioxide
- 1896 Svante Arrhenius quantifies GHE.
- He was the first person to predict that emissions of carbon dioxide from the burning of fossil fuels and other combustion processes would cause global warming
- 1906 Arrhenius calculates *climate sensitivity* ( $\Delta T$  caused by a doubling of  $\text{CO}_2$ ) to be **+2.1°C**
- **Modern day estimates of sensitivity are centered on +3°C**

# Humans are Responsible



(Kitchen, 2011)

- In 1967 Syukuro Manabe and Richard Wetherald demonstrated that increasing atmospheric CO<sub>2</sub> concentrations would **increase the altitude at which the earth radiated heat to space**
- Higher altitudes are colder so **less radiation escapes the atmosphere**
- This heat imbalance will warm the planet until the higher altitudes warm enough to radiate energy at the values needed for thermal equilibrium



# Humans are Responsible



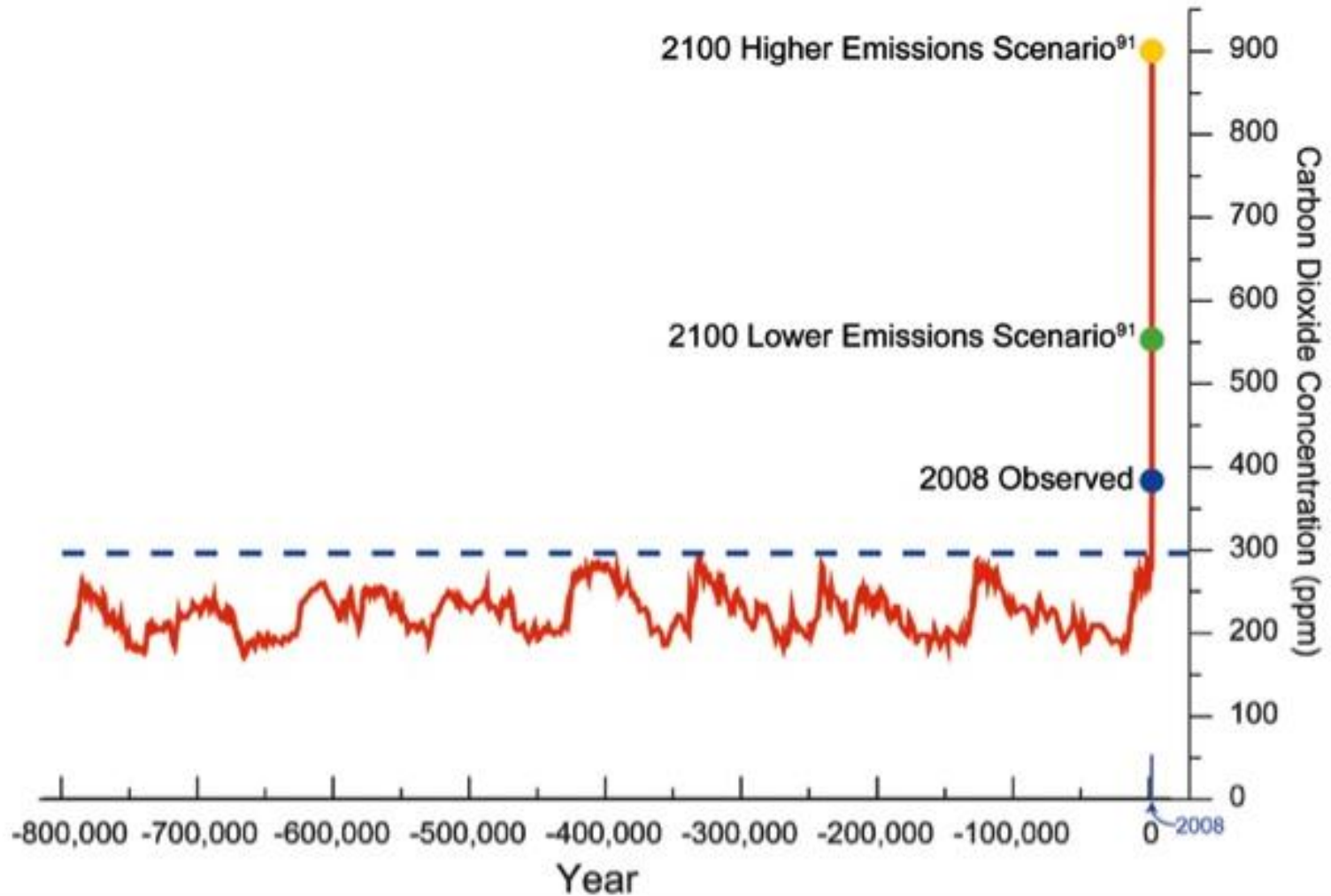
Joshi (2010)



Humans add 2 ppm CO<sub>2</sub> to air every year = 16 billion tons CO<sub>2</sub> per year

Equivalent to **8,000 Gulf Oil Spills per DAY**, every day!

# Humans are Responsible

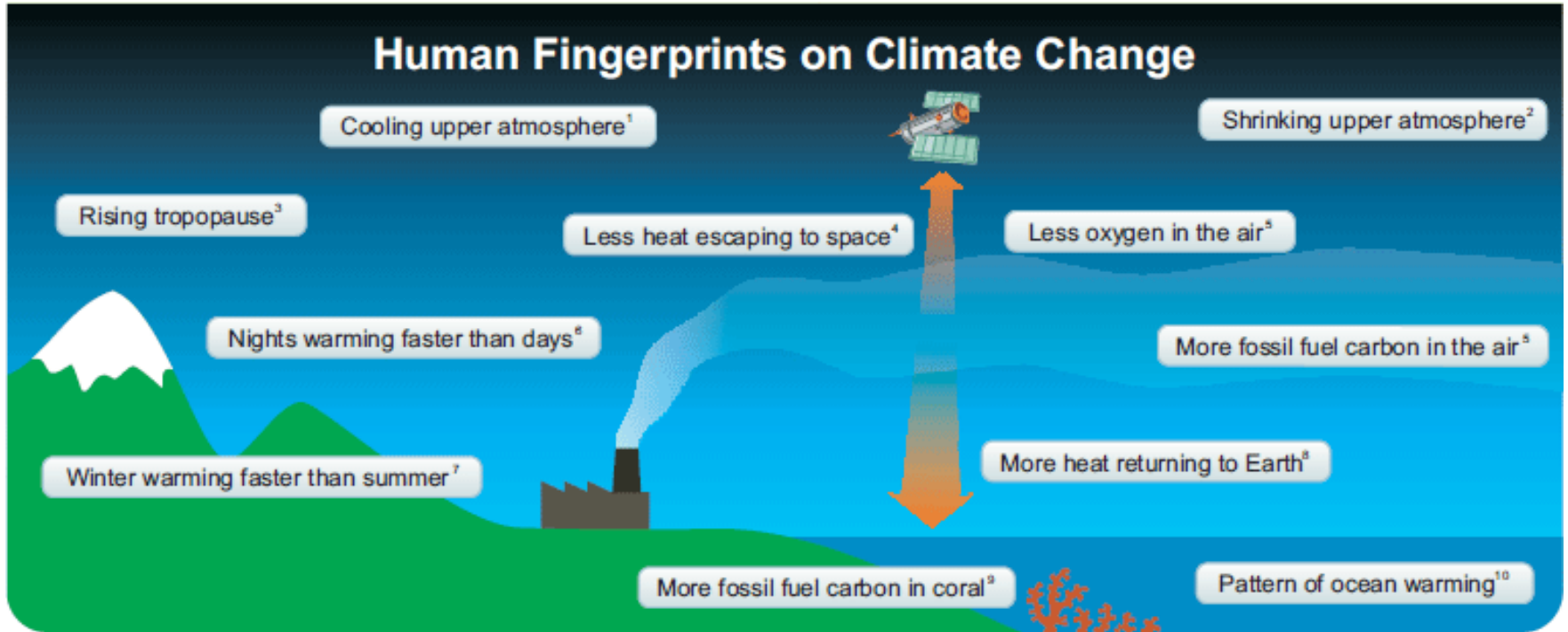


(Hayhoe, 2010)

- Higher values last occurred over 15 million years ago!



# Humans are Responsible



(Cook, 2010)

- Only increases in heat-trapping gases such as CO<sub>2</sub> can lead to these collective observations
- **There are no known natural explanations**

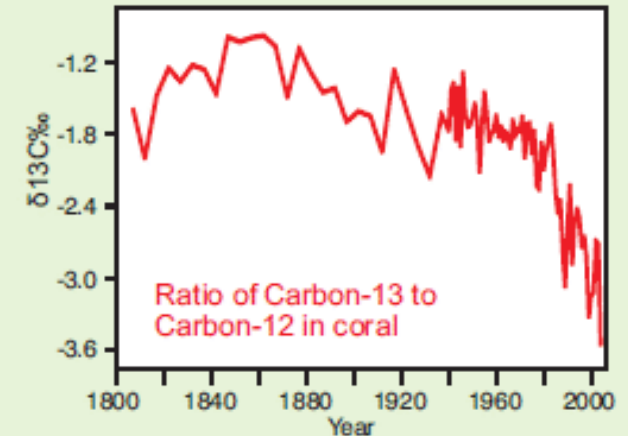
# Humans are Responsible

## Human Fingerprint #1 Fossil fuel signature in the air & coral

There are different types of carbon in the air known as carbon isotopes. The most common type is Carbon-12. A heavier type of carbon is Carbon-13. Plants prefer the lighter Carbon-12.

Fossil fuels like coal or oil come from ancient plants. So when we burn fossil fuels, we're sending more of the lighter Carbon-12 into the air. So we expect to see the ratio of Carbon-13 to Carbon-12 fall.

This is just what we observe, in measurements of the atmosphere<sup>5</sup>, in corals<sup>9</sup> and sea sponges.<sup>15</sup> So we have strong evidence that the increase in carbon dioxide in the air is directly linked to human emissions.



Measurements of  $\delta^{13}\text{C}$  (ratio of Carbon-13 to Carbon-12) from corals in the Great Barrier Reef.<sup>9</sup>

(Graphic: Cook, 2010) (Data: Wei, *et al.*, 2009)

- **Increases in CO<sub>2</sub> have isotopic signature of fossil fuel combustion**

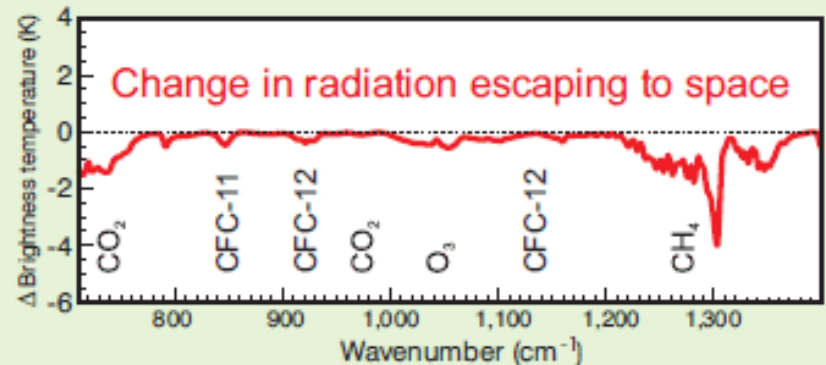
# Humans are Responsible

## Human Fingerprint #2

Less heat is escaping out to space

Satellites measure infrared radiation as it escapes out to space, clearly observing the greenhouse effect. A comparison between satellite data from 1970 to 1996 found that even less energy is escaping to space at the wavelengths that greenhouse gases absorb energy. Researchers described this result as “*direct experimental evidence for a significant increase in the Earth’s greenhouse effect*”.<sup>4</sup>

This has since been confirmed by subsequent measurements from several different satellites.<sup>19,20</sup>



Change in outgoing radiation spectrum from 1970 to 1996 due to increasing greenhouse gases. Negative values mean less outgoing heat.<sup>4</sup>

(Graphic: Cook, 2010) (Data: Harries, *et al.*, 2001)

- Measured decreases in escaping heat in the CO<sub>2</sub> band
- **“*direct experimental evidence for a significant increase in Earth’s greenhouse effect.*”**

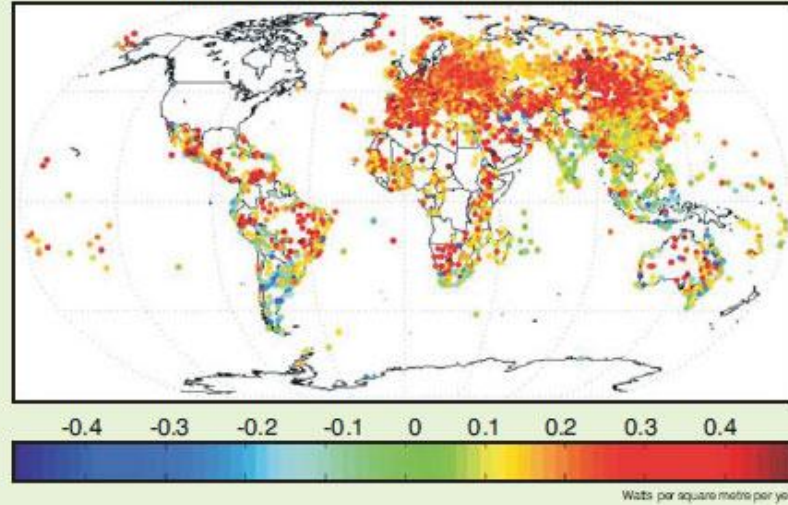
# Humans are Responsible

## Human Fingerprint #5 More heat is returning to Earth

An increased greenhouse effect means we should see more infrared radiation returning down to Earth from the atmosphere. This has been directly observed. When we take a close look at the spectrum of the downward radiation, we can work out how much each greenhouse gas is contributing to the warming effect. From these results, it was concluded:

*"This experimental data should effectively end the argument by skeptics that no experimental evidence exists for the connection between greenhouse gas increases in the atmosphere and global warming."*<sup>43</sup>

Trend in downward infrared radiation



Trend in downward infrared radiation over 1973 to 2008. North America is blank because data in those regions don't cover the entire 1973 to 2008 period.<sup>43</sup>

(Graphic: Cook, 2010) (Data: Wang, K. & Liang, S., 2009)

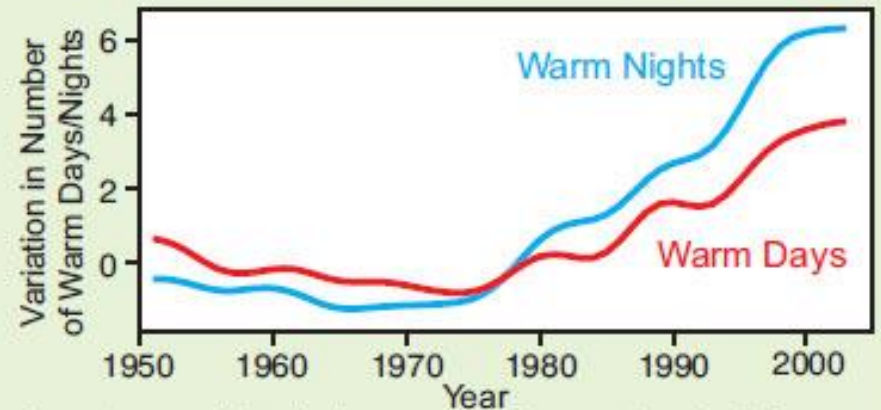
- Measured increases in downward IR radiation
- ***"This experimental data should effectively end the argument by skeptics that no experimental evidence exists for the connection between greenhouse gas increases in the atmosphere and global warming."***



# Humans are Responsible

## Human Fingerprint #4 Nights warming faster than days

An increased greenhouse effect means nights should warm faster than days. During the day, the sun warms the Earth's surface. At nighttime, the surface cools by radiating its heat out to space. Greenhouse gases slow down this cooling process. If global warming was caused by the sun, we would expect the warming trend to be greatest in daytime. Instead, what we see is the number of warm nights increasing faster than the number of warm days.<sup>6</sup>



Long-term variation in the number of warm days (red) & warm nights (blue) per year. Warm is defined as the top 10%.<sup>6</sup>

(Graphic: Cook, 2010) (Data: Alexander, *et al.*, 2006)

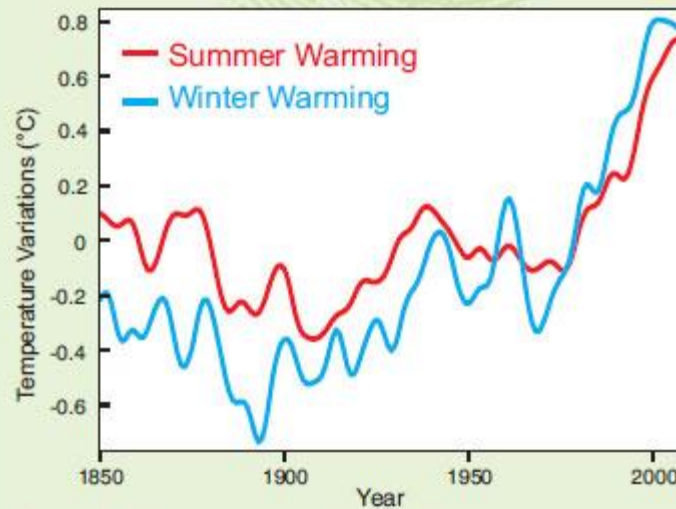
- **Nights are warming faster than days**

# Humans are Responsible

## Human Fingerprint #6

### Winter warming faster

As greenhouse warming increases, winters are expected to warm faster than summers. This is because the greenhouse effect has a greater influence over winter. This is what is observed in the instrumental record.<sup>7,98</sup>



*Smoothed temperature variations for winter and summer, averaged over land only, from 1850 to 2009.<sup>21</sup>*

(Graphic: Cook, 2010) (Data: Met Office)

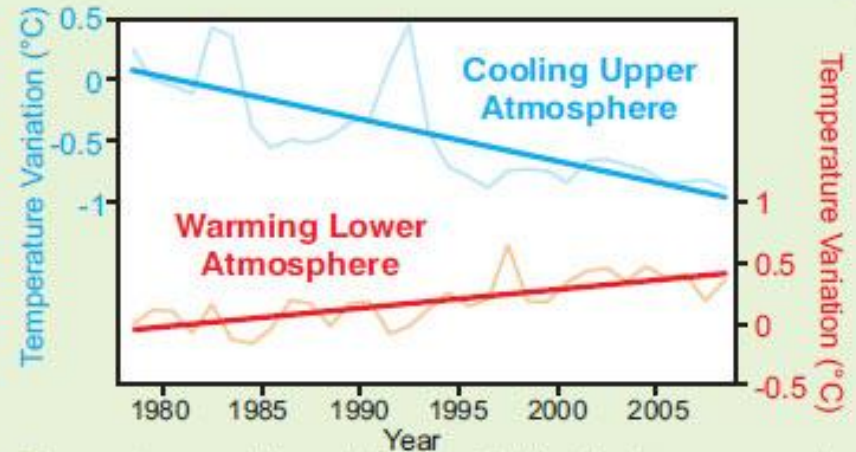
- **Winters are warming faster than summers**

# Humans are Responsible

## Human Fingerprint #7

### Cooling upper atmosphere

As greenhouse gases trap more heat in the lower atmosphere, less heat reaches the upper atmosphere (the stratosphere and higher layers). So we expect to see a warming lower atmosphere and cooling upper atmosphere. This has been observed by satellites and weather balloons.<sup>1</sup>

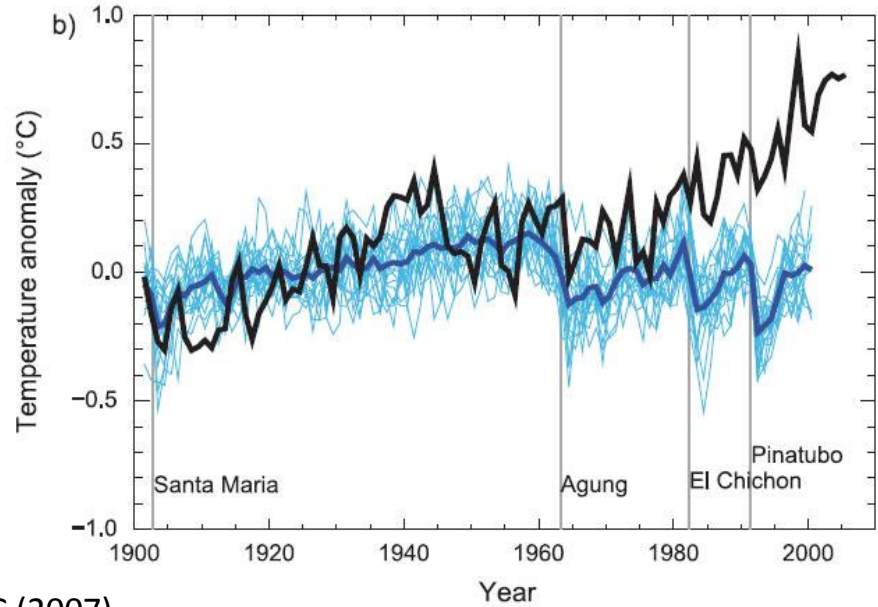
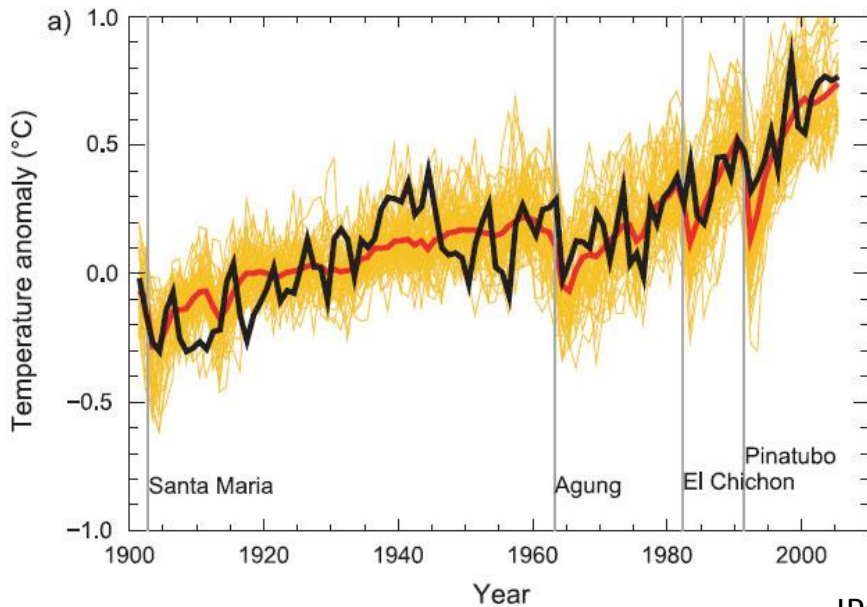


Temperature variations (degrees Celsius) in the upper and lower atmosphere, measured by satellites (RSS).<sup>64</sup>

(Graphic: Cook, 2010) (Data: Jones, *et al.*, 2003, and Mears, C. & Wentz, F., 2009)

- **Lower atmosphere is warming while upper atmosphere is cooling**

# Humans are Responsible



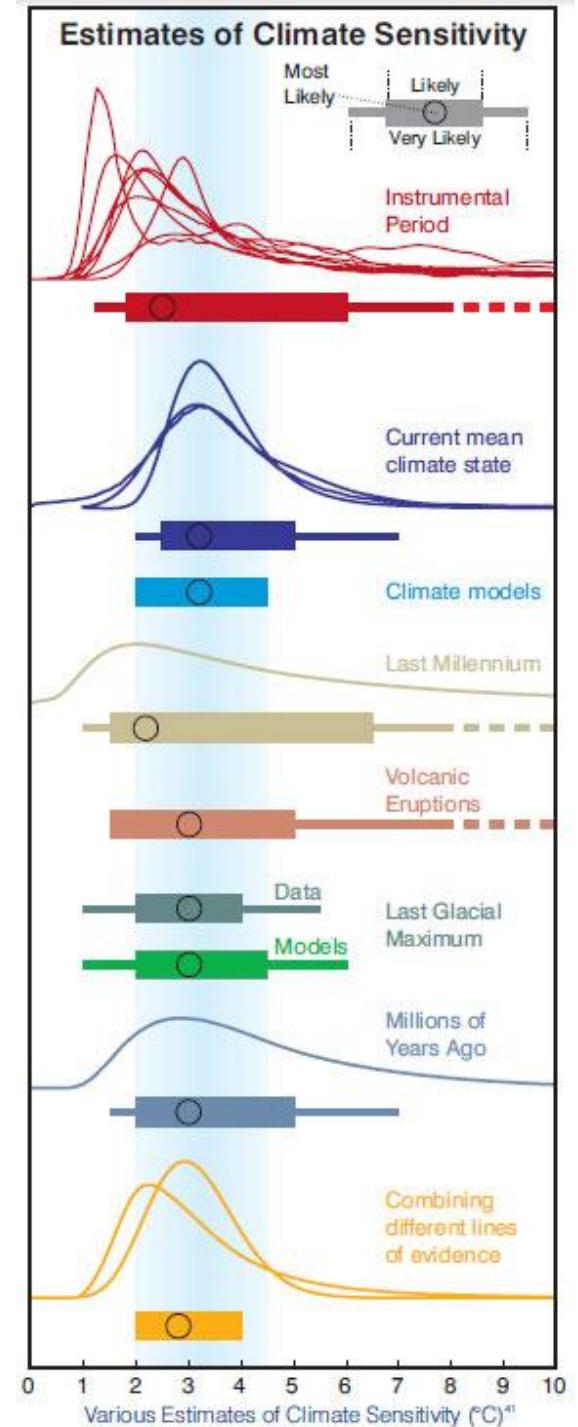
IPCC (2007)

- Observed global T (**black** line)
- Models using all known forcings - natural and GHGs (**red** line)
- Models using only natural forcings (**blue** line)
- **Only when including CO<sub>2</sub> and other GHGs can observed global T be duplicated**



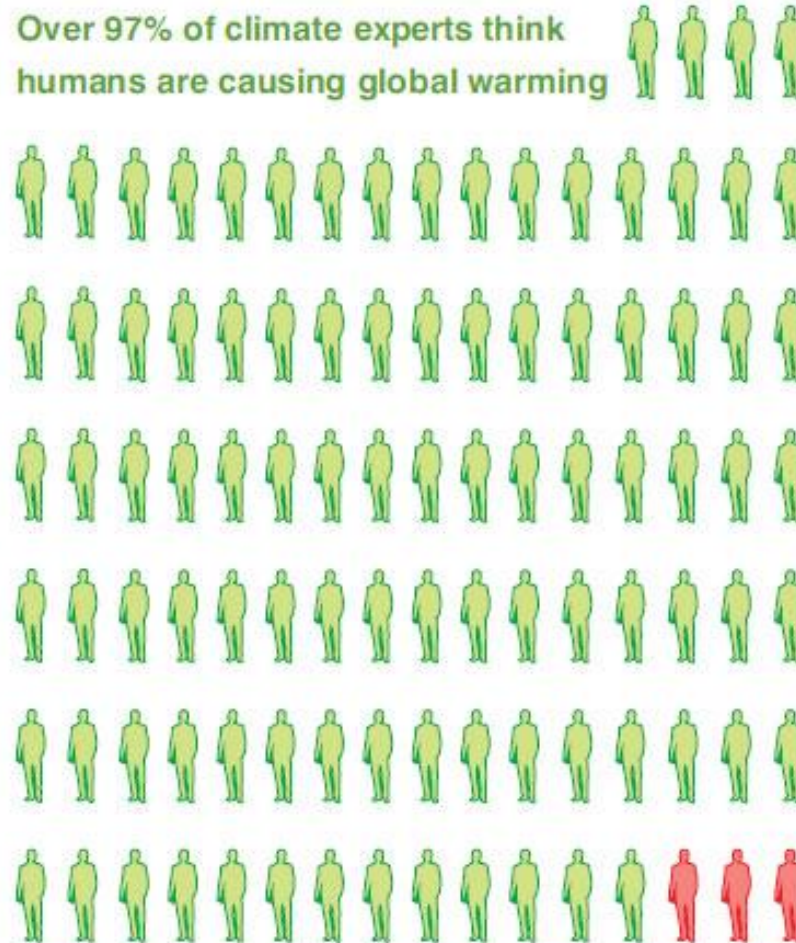
# Humans are Responsible

- Climate sensitivity values are estimated to be between 2 – 4.5°C with multiple lines of evidence converging on 3°C
- Sensitivity estimates are based on:
  - **Physics**
  - **Historical evidence**
  - **Model projections**



(Graphic: Cook, 2010) (Data:Knutti, R., Hegerl, G. C., 2008)

# Humans are Responsible



(Cook, 2010)

- Published research shows that 97-98% of publishing climate scientists know that humans are driving most of the global warming (Anderegg, *et al.*, 2010 and Doran and Zimmerman, 2009)

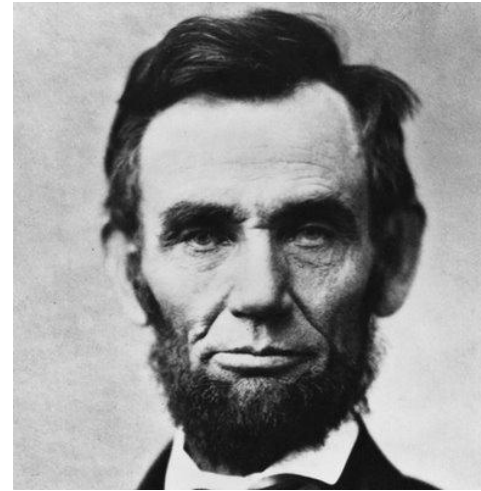
# Humans are Responsible



Travelvivi.com (2010)

- 98 airline mechanics tell you that they are *certain* the plane will never make it
- 2 airline mechanics tell you that they are not sure about the success of the flight
- 1 **auto** mechanic tells you that he is certain the plane will make it and all the other airline mechanics are wrong

# Humans are Responsible



United States National Academy of Sciences (2010)

*“A strong, credible body of scientific evidence shows that climate change is occurring, is caused largely by human activities, and poses significant risks for a broad range of human and natural systems.... Some scientific conclusions or theories have been so thoroughly examined and tested, and supported by so many independent observations and results, that their likelihood of subsequently being found to be wrong is vanishingly small. Such conclusions and theories are then regarded as **settled facts**. This is the case for the conclusions that the Earth system is warming and that much of this warming is very likely due to human activities.”*

# Humans are Responsible

American Association for the Advancement of Science  
American Astronomical Society  
American Chemical Society  
American Geophysical Union  
American Institute of Physics  
American Meteorological Society  
American Physical Society  
Australian Coral Reef Society  
Australian Meteorological and Oceanographic Society  
Australian Bureau of Meteorology and the CSIRO  
British Antarctic Survey  
Canadian Foundation for Climate and Atmospheric Sciences  
Canadian Meteorological and Oceanographic Society  
Environmental Protection Agency  
European Federation of Geologists  
European Geosciences Union  
European Physical Society  
Federation of American Scientists  
Federation of Australian Scientific and Technological Societies  
Geological Society of America  
Geological Society of Australia  
International Union for Quaternary Research (INQUA)  
International Union of Geodesy and Geophysics  
National Center for Atmospheric Research  
National Oceanic and Atmospheric Administration  
Royal Meteorological Society  
Royal Society of the UK

The Academies of Science from 19 different countries all endorse the consensus. 11 countries have signed a joint statement endorsing the consensus position:

Academia Brasileira de Ciencias (Brazil)  
Royal Society of Canada  
Chinese Academy of Sciences  
Academie des Sciences (France)  
Deutsche Akademie der Naturforscher Leopoldina (Germany)  
Indian National Science Academy

Accademia dei Lincei (Italy)  
Science Council of Japan  
Russian Academy of Sciences  
Royal Society (United Kingdom)

A letter from 18 scientific organizations to US Congress states:

*"Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver. These conclusions are based on multiple independent lines of evidence, and contrary assertions are inconsistent with an objective assessment of the vast body of peer-reviewed science."*

The consensus is also endorsed by a Joint statement by the Network of African Science Academies (NASAC), including the following bodies:

African Academy of Sciences  
Cameroon Academy of Sciences  
Ghana Academy of Arts and Sciences  
Kenya National Academy of Sciences  
Madagascar's National Academy of Arts, Letters and Sciences  
Nigerian Academy of Sciences  
l'Académie des Sciences et Techniques du Sénégal  
Uganda National Academy of Sciences  
Academy of Science of South Africa  
Tanzania Academy of Sciences  
Zimbabwe Academy of Sciences  
Zambia Academy of Sciences  
Sudan Academy of Sciences

Two other Academies of Sciences that endorse the consensus:

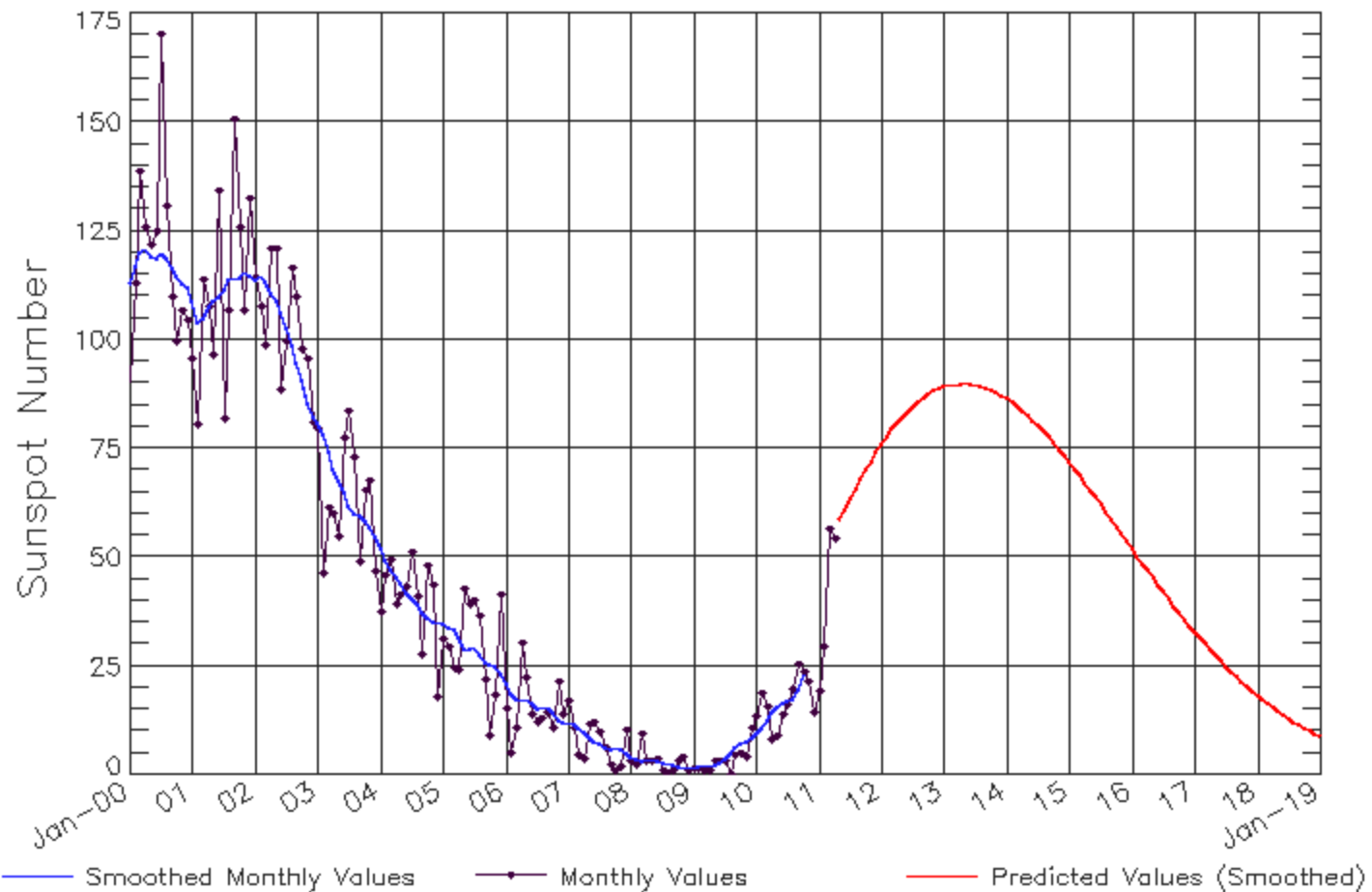
Royal Society of New Zealand  
Polish Academy of Sciences

(Cook, 2010)

# Misinformation

## Is it the sun?

ISES Solar Cycle Sunspot Number Progression  
Observed data through Apr 2011



Updated 2011 May 3

NOAA/SWPC Boulder, CO USA

- **Most of the past decade featured a deep solar minima yet we still set records!**



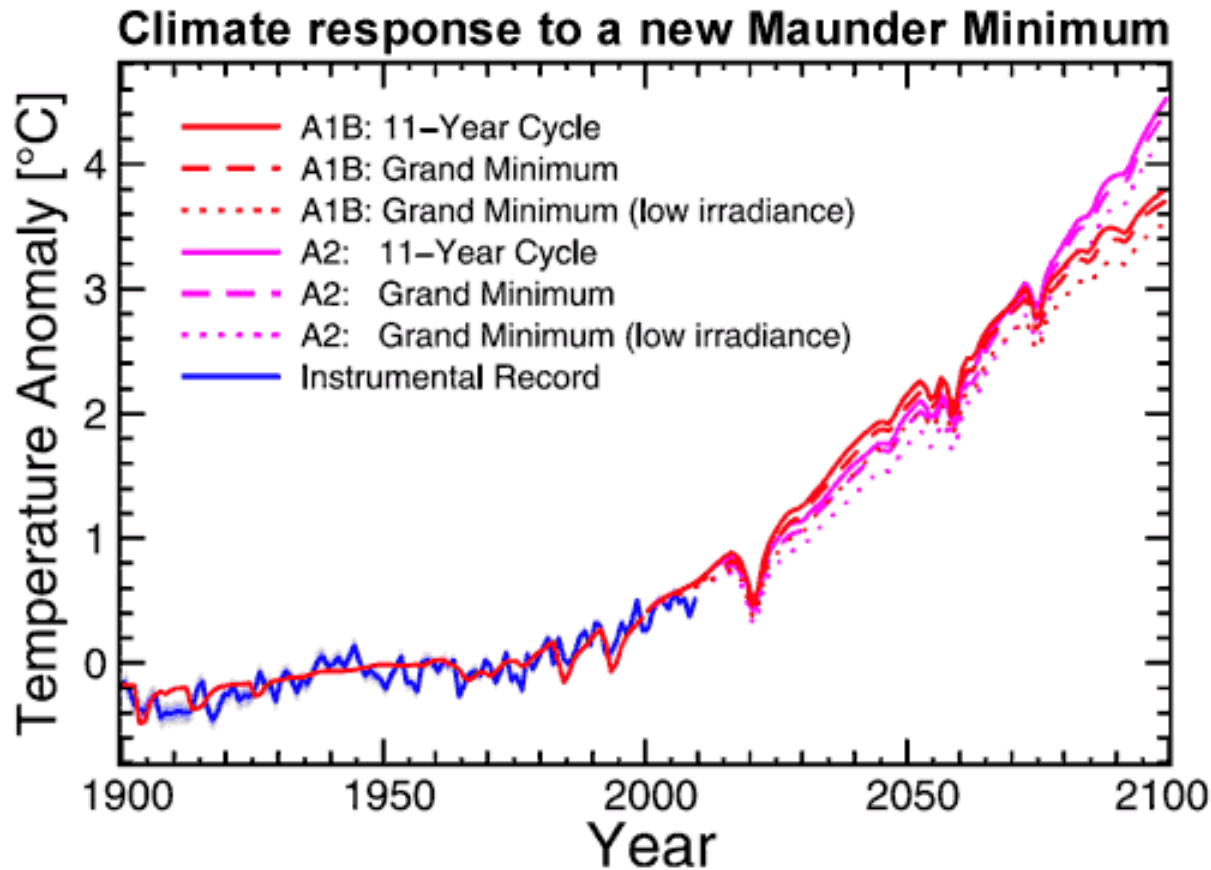
# Misinformation

## Is it the sun?

- Most of the past decade featured a deep solar minima yet we still set records
- Sun cannot be warming the lower atmosphere but cooling the upper atmosphere
- Sun cannot make nights warmer
- According to the IPCC (2007) current estimates suggest that only 0.1 °C of the 0.8 °C of warming since the late 1800s is due to solar irradiance. More importantly, **since direct satellite measurements (1980 – present) solar contribution to the observed rapid warming is negligible.**
- *...that Earth was substantially out of energy balance, 0.59 +or- 0.15 W/m<sup>2</sup>, during the recent deep solar minimum (2005-2010), more energy coming in than going out. This confirms that human-made greenhouse gases are the overwhelming drive for climate change... (Hansen, 2011)*

# Misinformation

## Is it the sun?

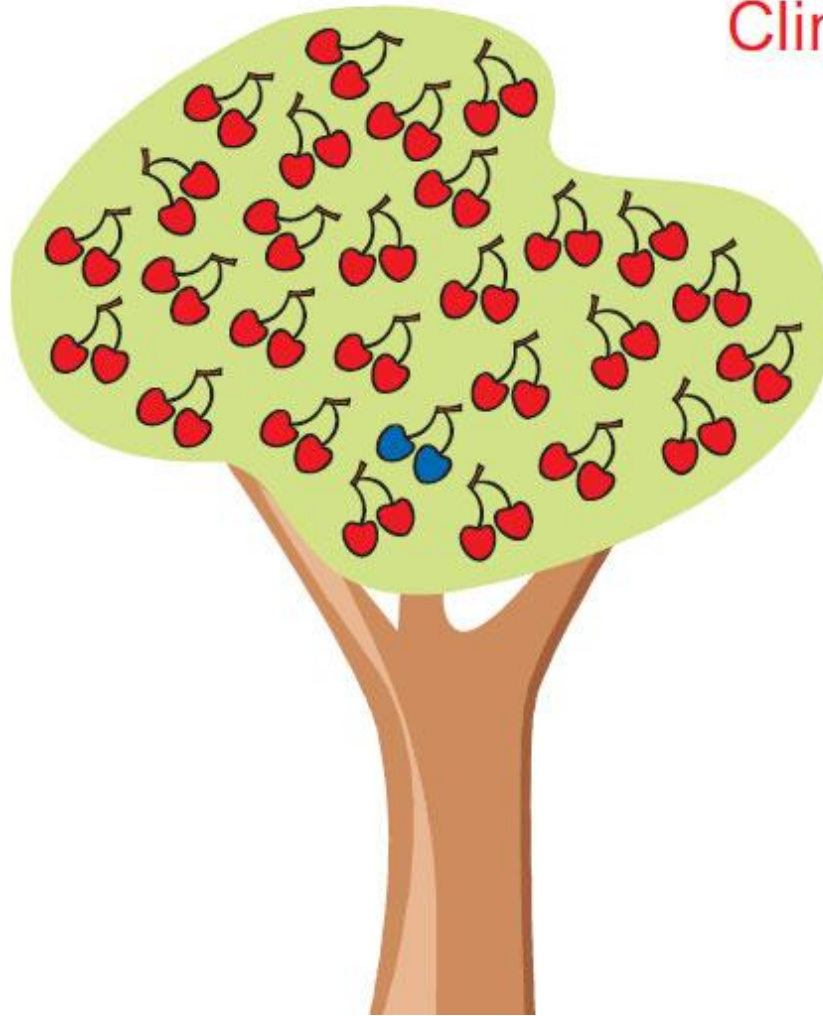


Feulner and Rahmstorf (2010)

*“For both the A1B and A2 emission scenario, **the effect of a Maunder Minimum on global temperature is minimal.** The TSI reconstruction with lesser variation shows a decrease in global temperature of around 0.09°C while the stronger variation in solar forcing shows a difference of around 0.3°C. Compare this to global warming between 3.7°C (A1B scenario) to 4.5°C (A2 scenario). Considering the less variable solar reconstruction shows such strong agreement with past temperature, **the authors conclude the most likely impact of a Maunder Minimum by 2100 would be a decrease in global temperature of 0.1°C.** With all uncertainties taken into account, **the estimated maximum decrease in global temperature is 0.3°C.**”*



# Misinformation



## Climate cherry picking

Selective cherry picking could have you thinking this is a blue cherry tree.

But what does the full body of evidence tell you?

Cook (2010)

# Misinformation

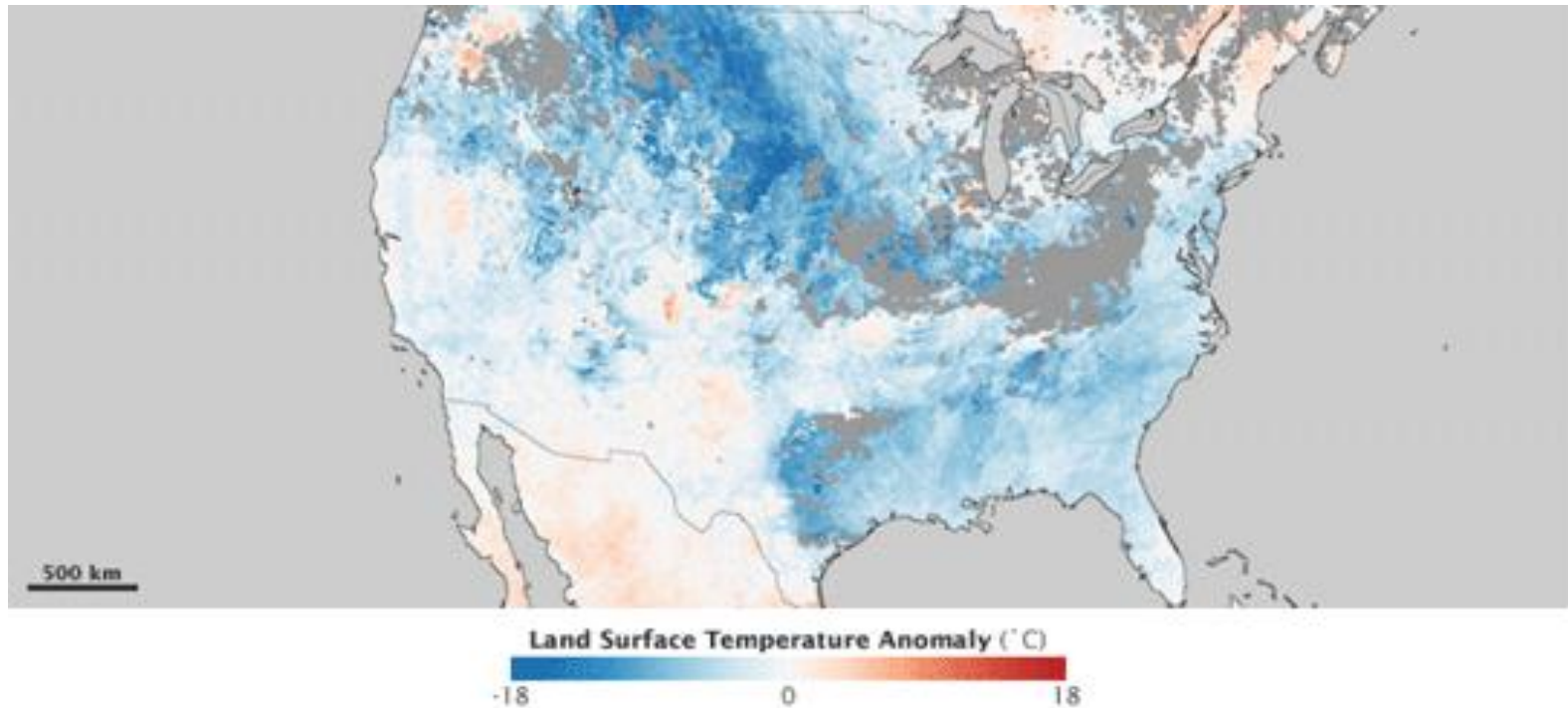
**Global Warming at It's Best!**



(Great Britain, 2009.....NASA satellite photo)

- Dr. Arvid Pasto used this image in a recent presentation to suggest that snow in Europe casts doubt about global warming

# Misinformation



- A cherry-picker might show how cold it was this winter in the U.S.

# Misinformation



Earth Observatory

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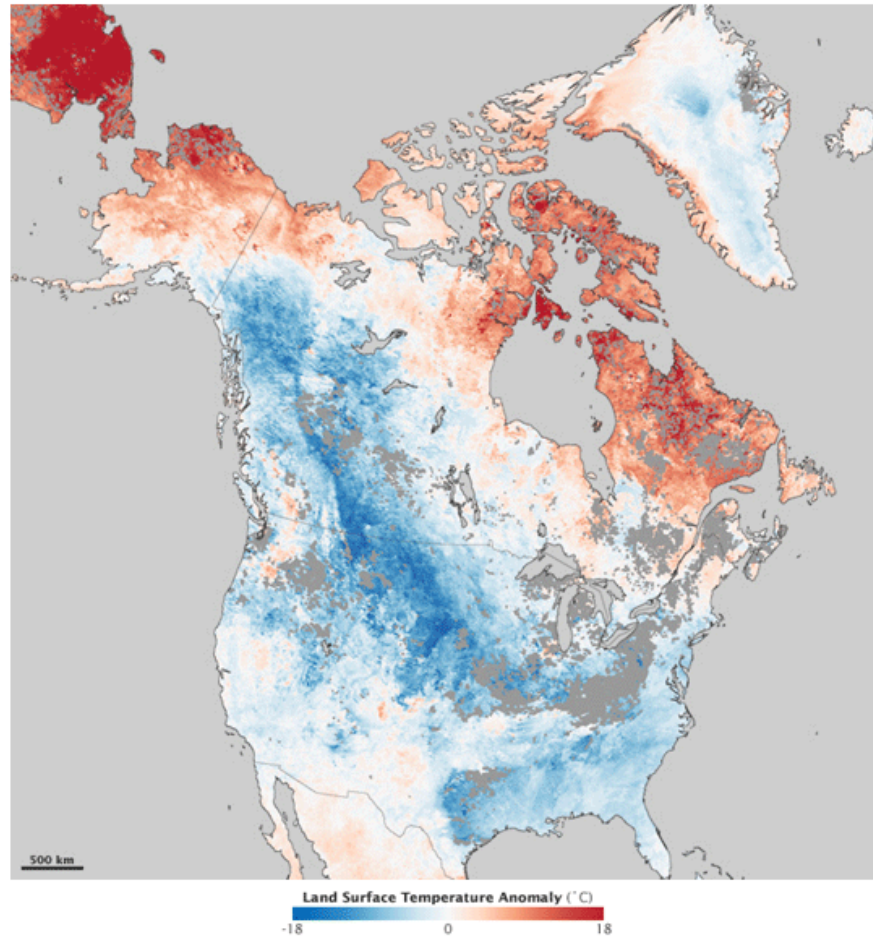
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## Arctic Oscillation Chills North America, Warms Arctic

Posted January 26, 2011

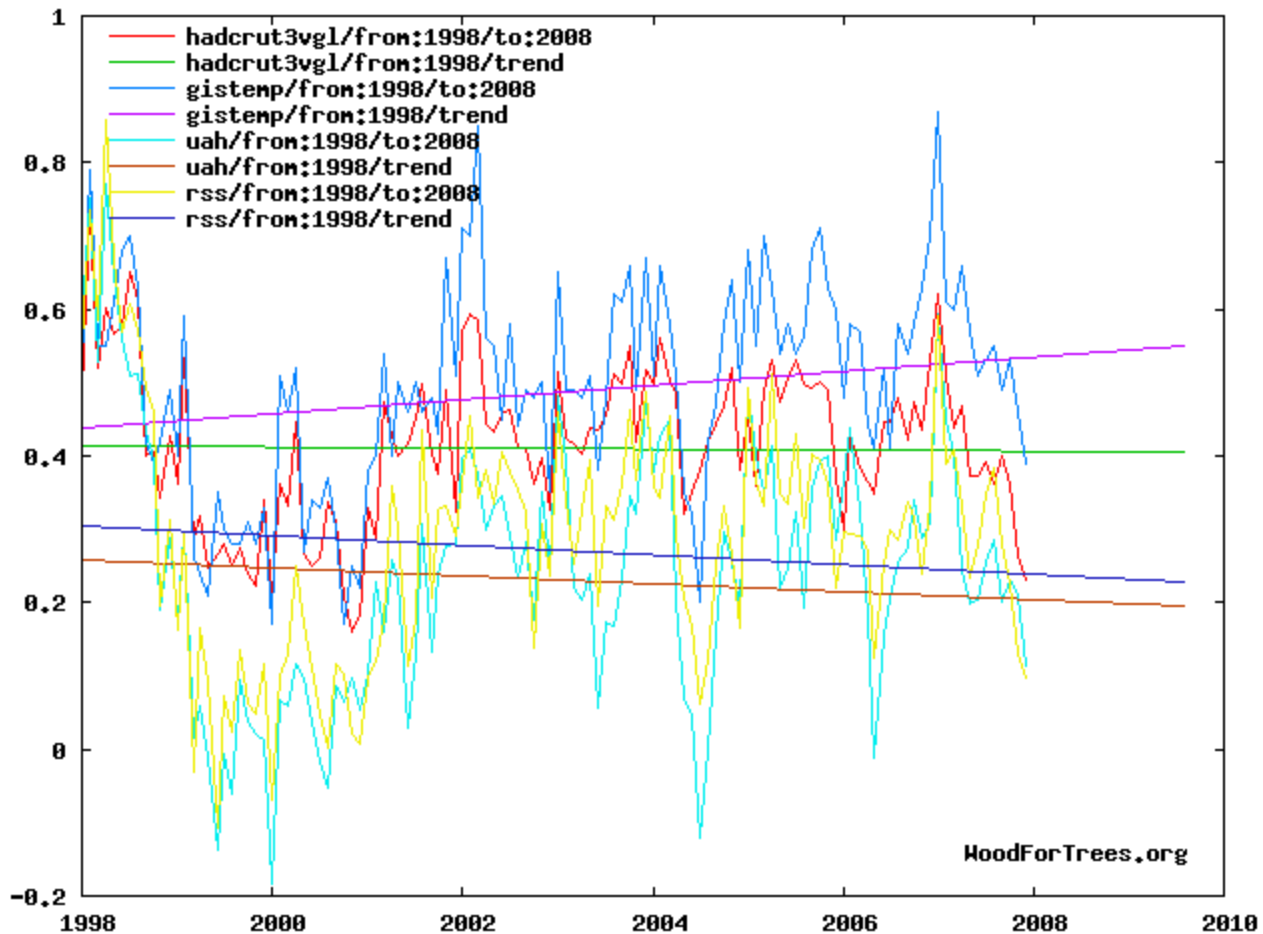
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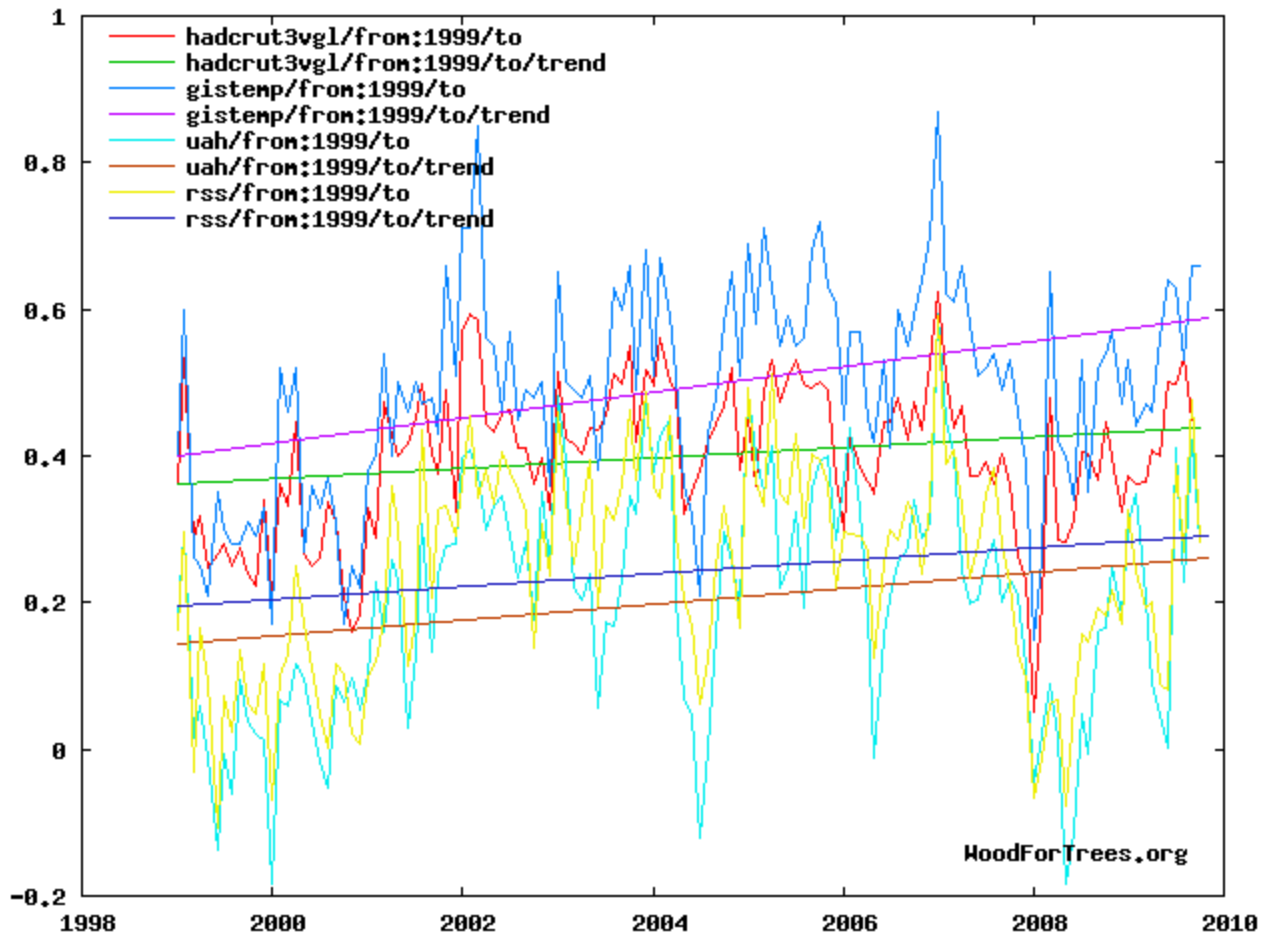
- Tell that to Northern Canadians who had one of the warmest winters ever!

# Misinformation



- Choosing 1998 (record El Nino) and ending with 2008 (weak sun, La Nina)

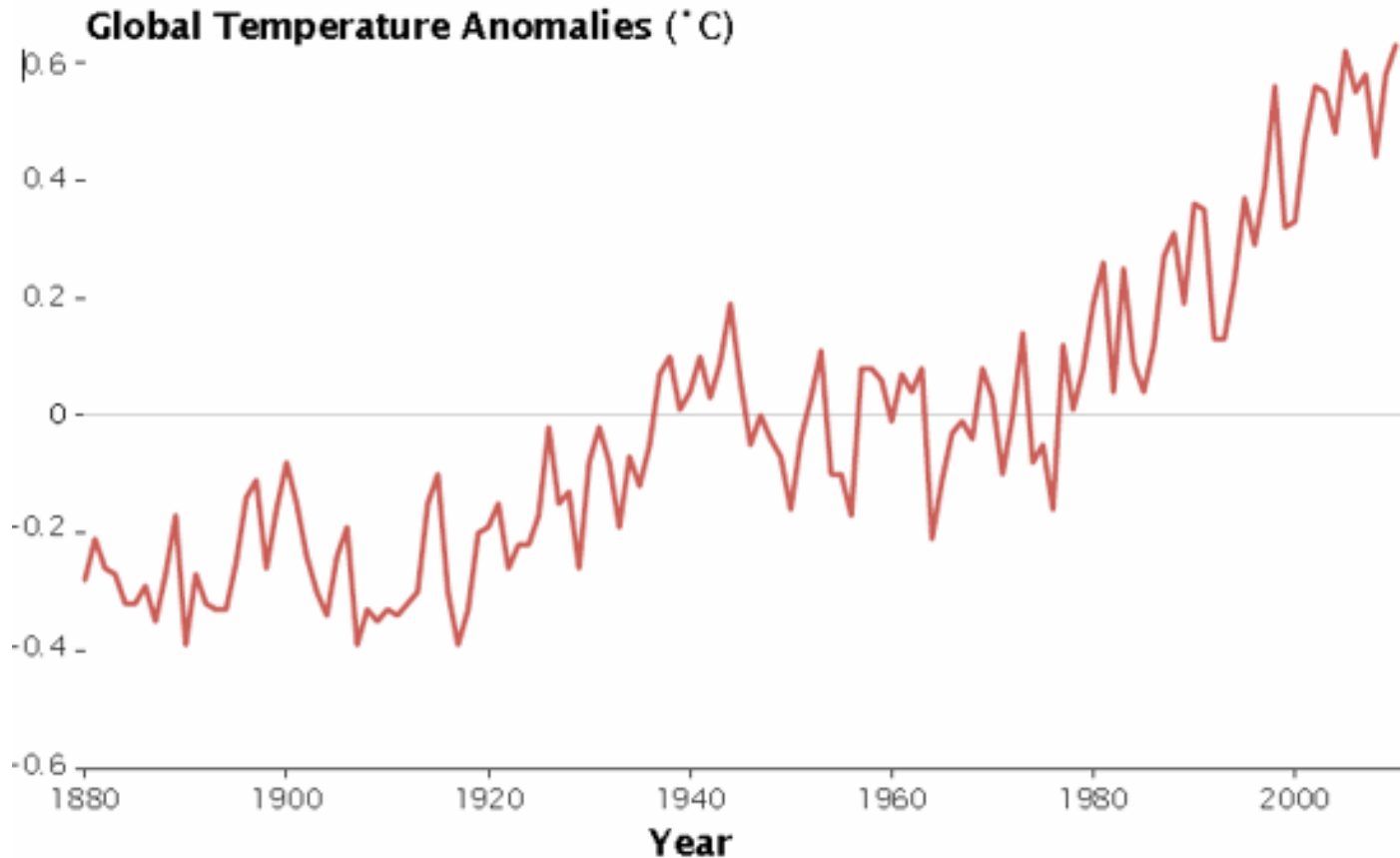
# Misinformation



- Moving just one year ahead



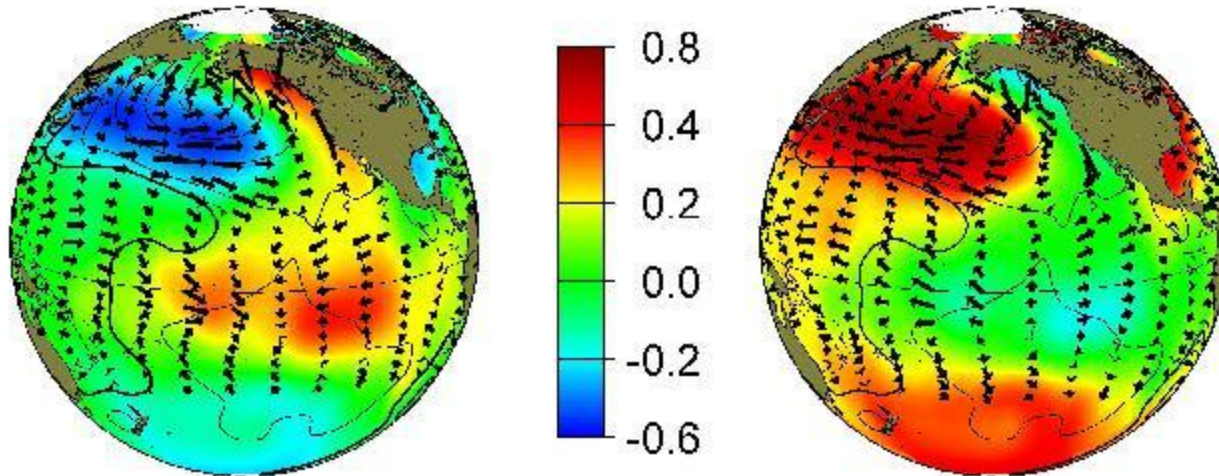
# Misinformation



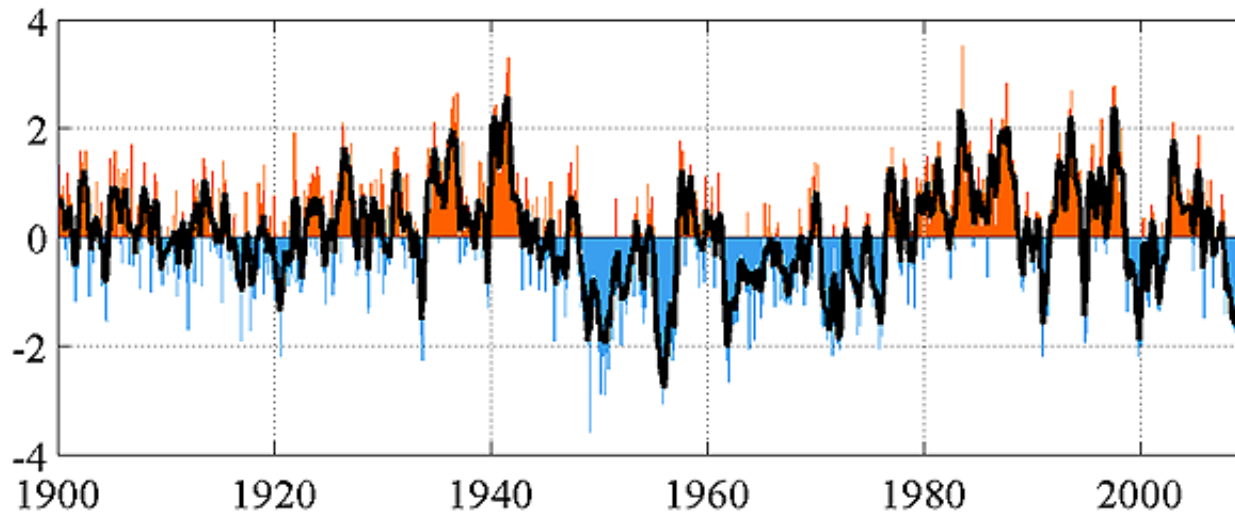
Global mean temperature anomalies (compared to 1961-1990) from the years 1850 to 2010 (NASA, 2010)

- **Long-term trend (climate) is obviously warming despite short-term “weather” blips**

# Misinformation



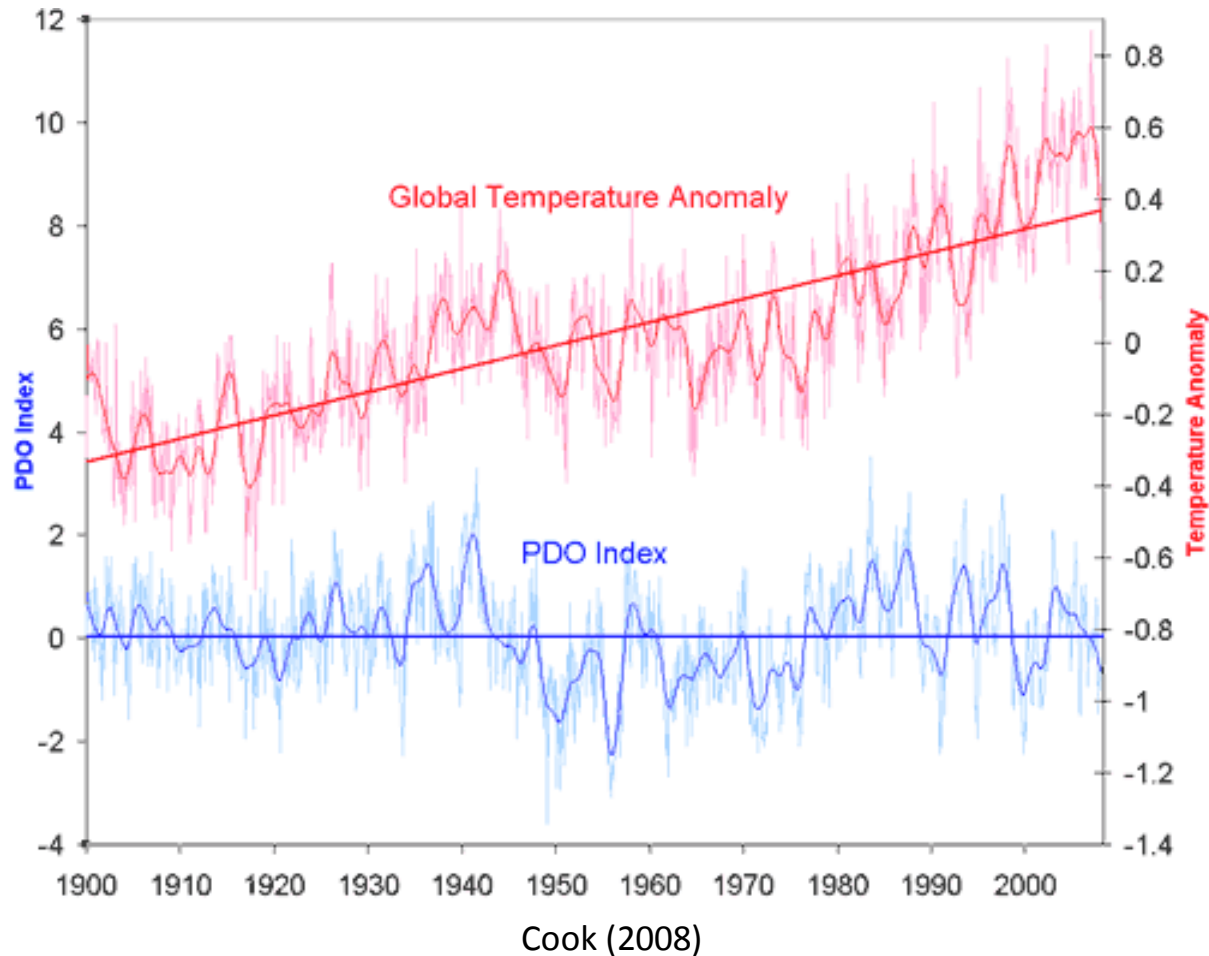
monthly values for the PDO index: 1900-September 2009



Mantua (2000)

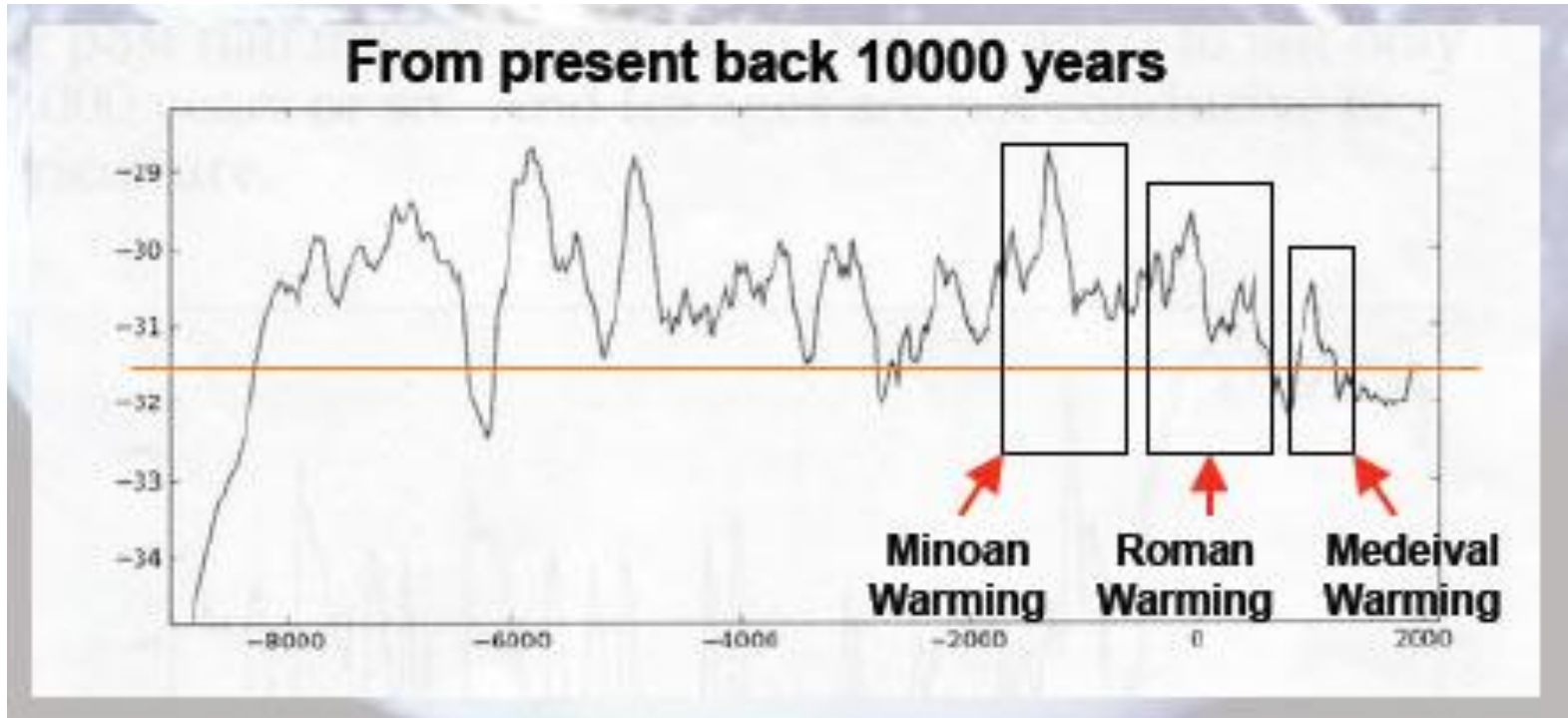
- Can oceans be causing the warming? Pacific Decadal Oscillation (PDO)

# Misinformation



- **PDO does not correlate with global T**
- **If oceans were heating the air, the oceans would be cooling and they are not!**

# Misinformation



Pasto (2011)

- 1<sup>st</sup> problem: Central Greenland T is not a proxy for global T
- 2<sup>nd</sup> problem: Does Greenland ice core show most of the past 10,000 years warmer than present?
- Notice the “present” line on the plot?
- See where the data ends?

# Misinformation

DATA:

1. Temperature in central Greenland

Column 1: Age (thousand years before present)

Column 2: Temperature in central Greenland (degrees C)

Age	Temperature (C)
0.0951409	-31.5913
0.10713	-31.622
0.113149	-31.6026
0.119205	-31.6002

- Actual line-by-line data from Alley, R.B. 2000 and Cuffey, K.M., and G.D. Clow. 1997
- Dr. Richard Alley has confirmed that the GISP2 “present” is 1950 and that the **most recent temperature in the GISP2 series is therefore 1855!**

# Misinformation

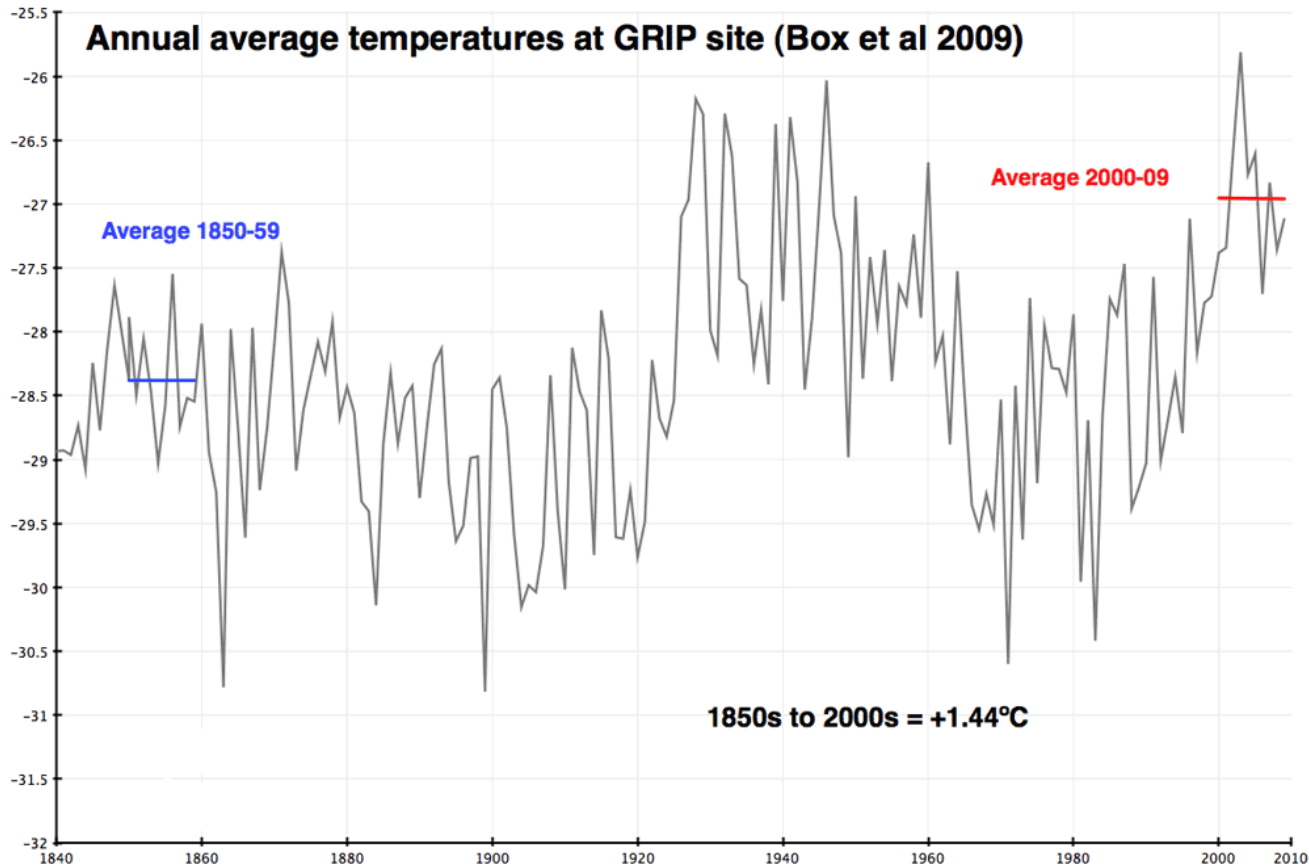


Image: Modified from Renowden (2011)

- This data shows measured central Greenland temperatures since 1855
- Since 1850, central Greenland T has increased by 1.44°C
- Note: GRIP data is 0.9 °C warmer than GISP2 data



# Misinformation

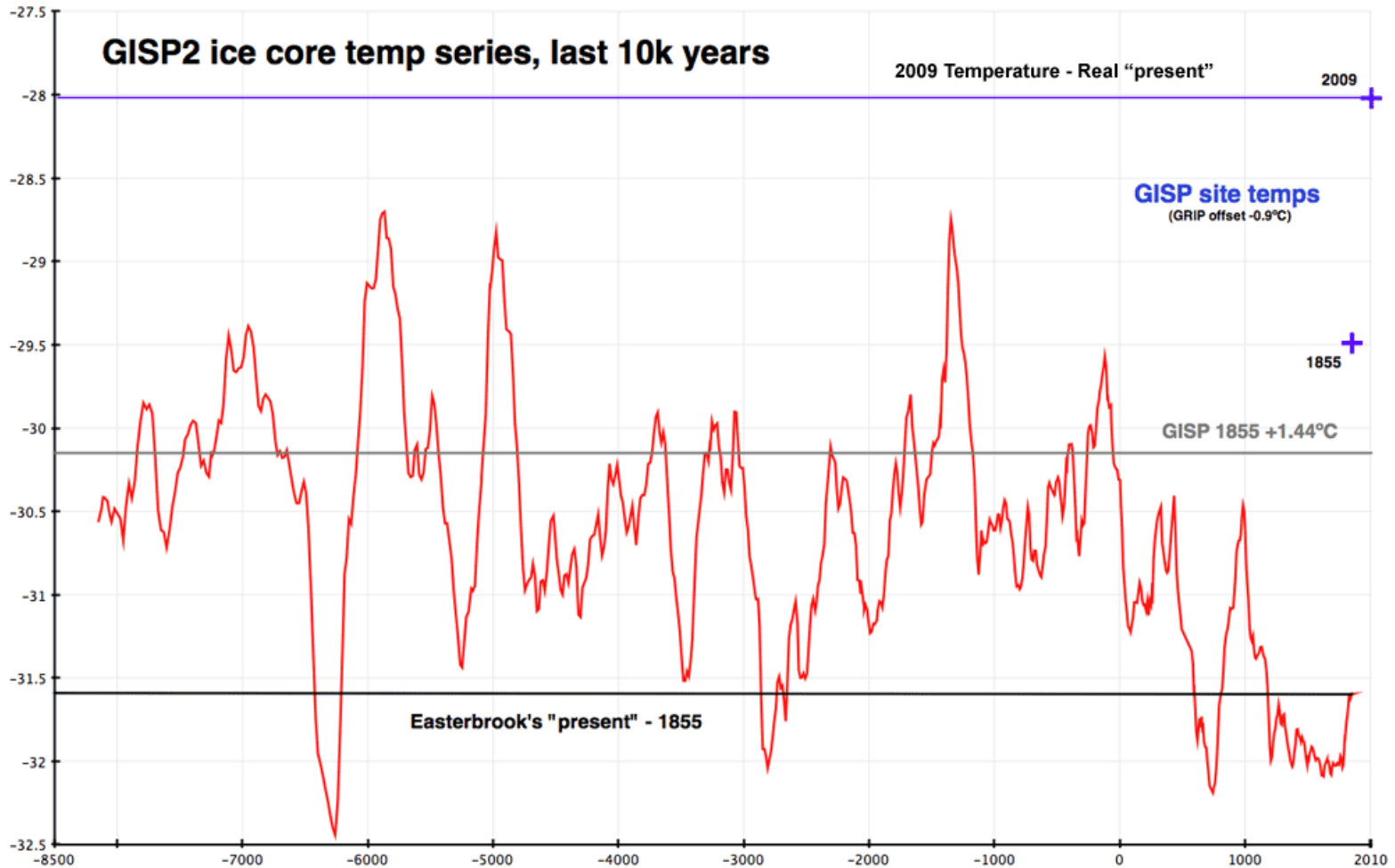


Image: Modified from Renowden (2011)

- This data shows central Greenland temperatures with a REAL present T
- **Current T higher than at any time in the past 10,000 years!**

# Conclusion



If it looks like a duck, walks like duck, ...

If increases in CO<sub>2</sub> are not causing modern day global warming then two things must be true:

1. Something ***unknown*** is suppressing the well-understood greenhouse effect (and doing so during massive increases in GHGs).
2. Something ***unknown*** is causing the warming that mirrors the GHE.

So we can accept what **we know to be true (AGW)** or we accept two unknowns.

(Powell, 2010)