# The Science of Global Warming
# What do we really know….

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*May, 2015*

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# Intergovernmental Panel Report

The highlights of the recently released IPCC report…

Warming is unequivocal.

Each of the last three decades was warmer than prior decade, it is warmer than its been in 1400 years.

Some extreme weather (heat waves, regional droughts, heavy precipitation and flooding, intense hurricanes) have increased.

Greenland and Antarctica are losing ice.

Decreased snow cover.

Sea levels rising faster than previously thought.

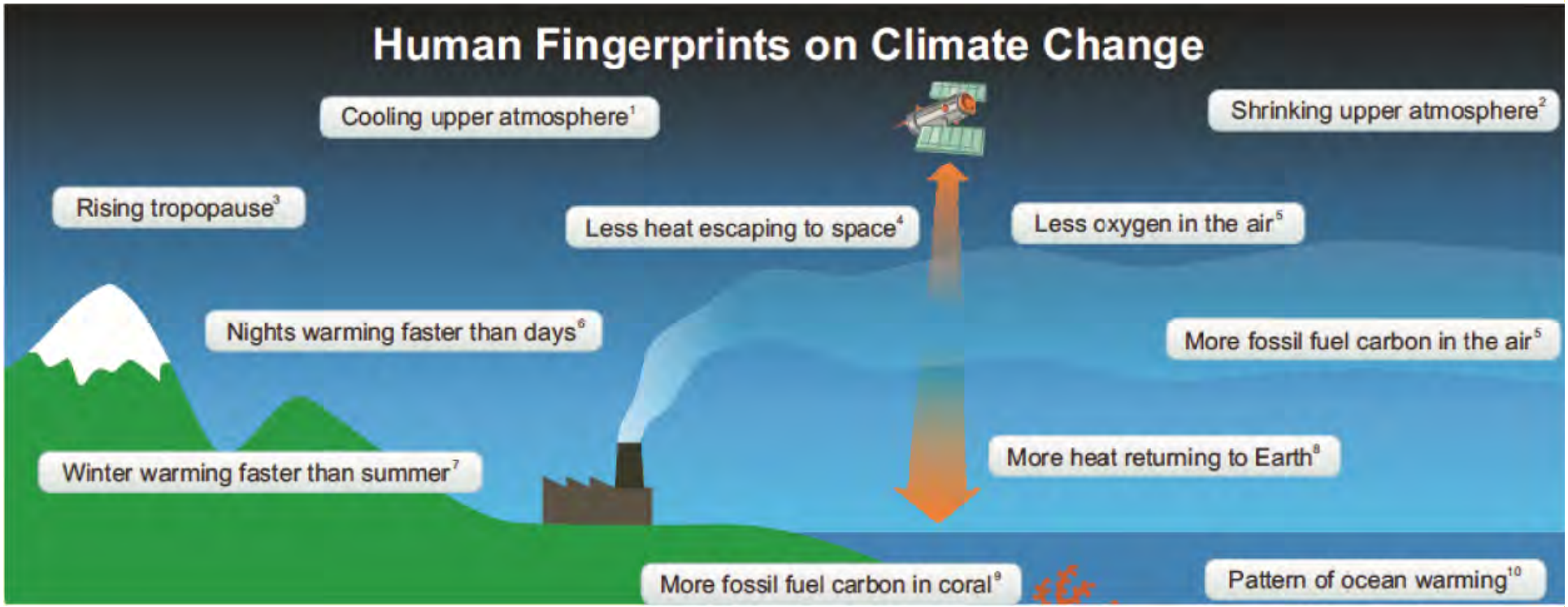
The poles are warming faster than other regions.

Glacier ice loss is widespread.

The ocean is becoming more acidic.

# The Basics….

courtesy of Gary Warden

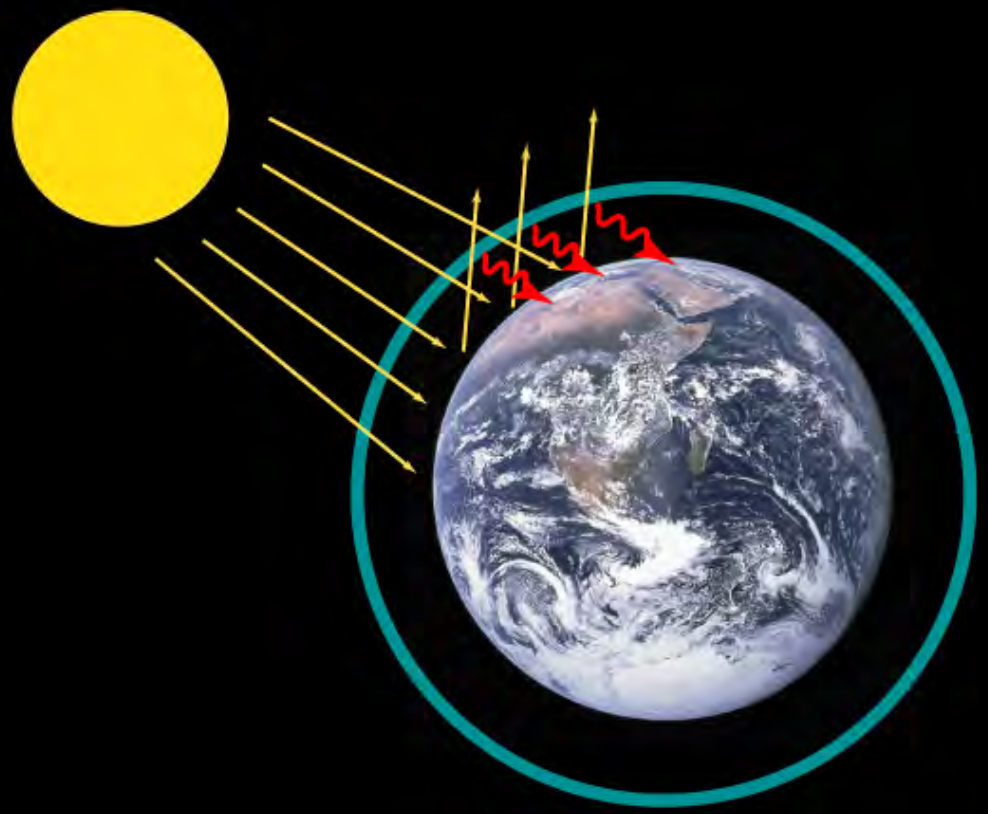

Human Fingerprints on Climate Change
Cooling upper atmosphere[1]
Shrinking upper atmosphere[2]
Rising tropopause[3]
Less heat escaping to space[4]
Less oxygen in the air[5]
Nights warming faster than days[6]
More fossil fuel carbon in the air[5]
Winter warming faster than summer[7]
More heat returning to Earth[8]
More fossil fuel carbon in coral[9]
Pattern of ocean warming[10]

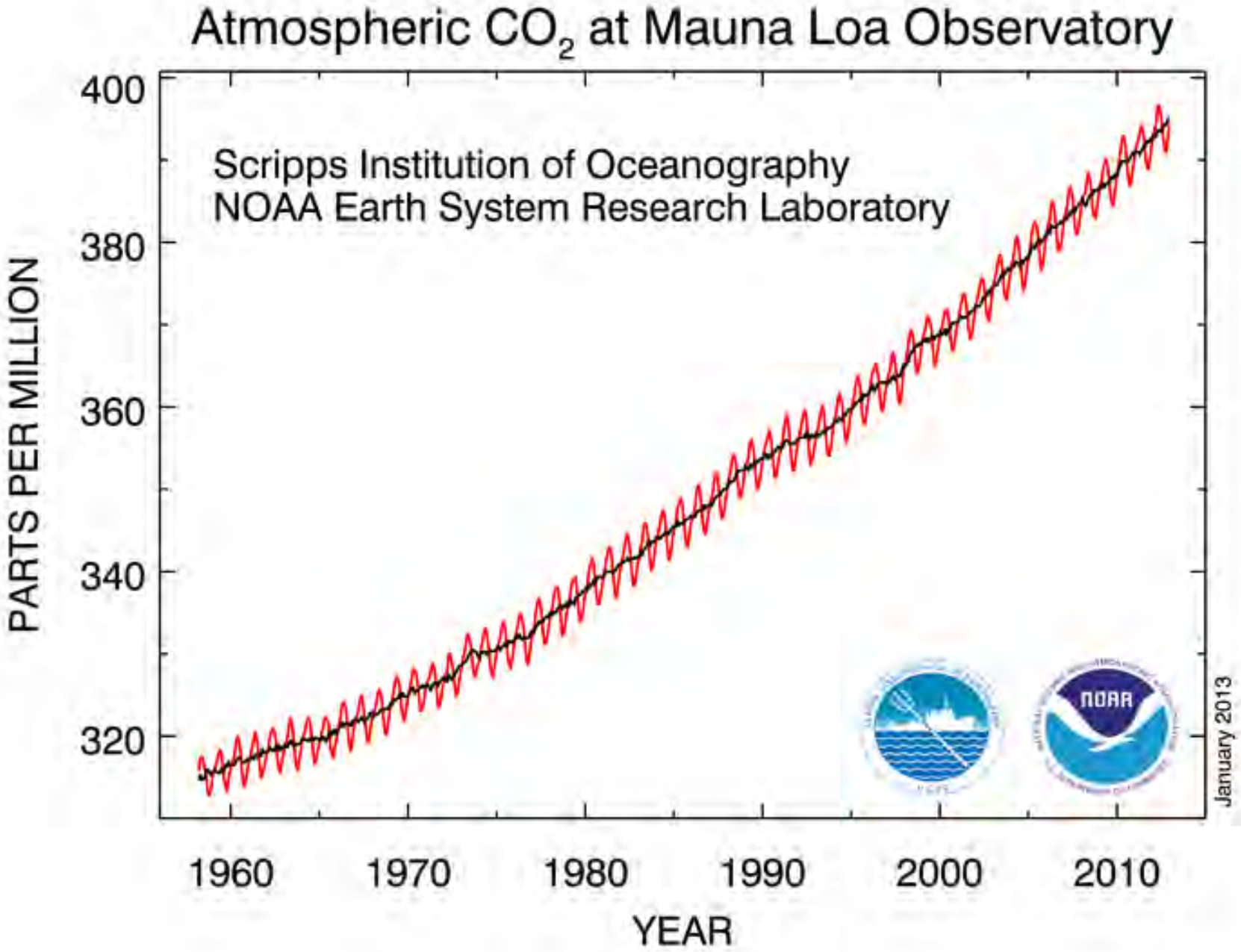
Solar radiation from the sun passes through the earth's atmosphere.

Some light (infrared) is emitted back into space.

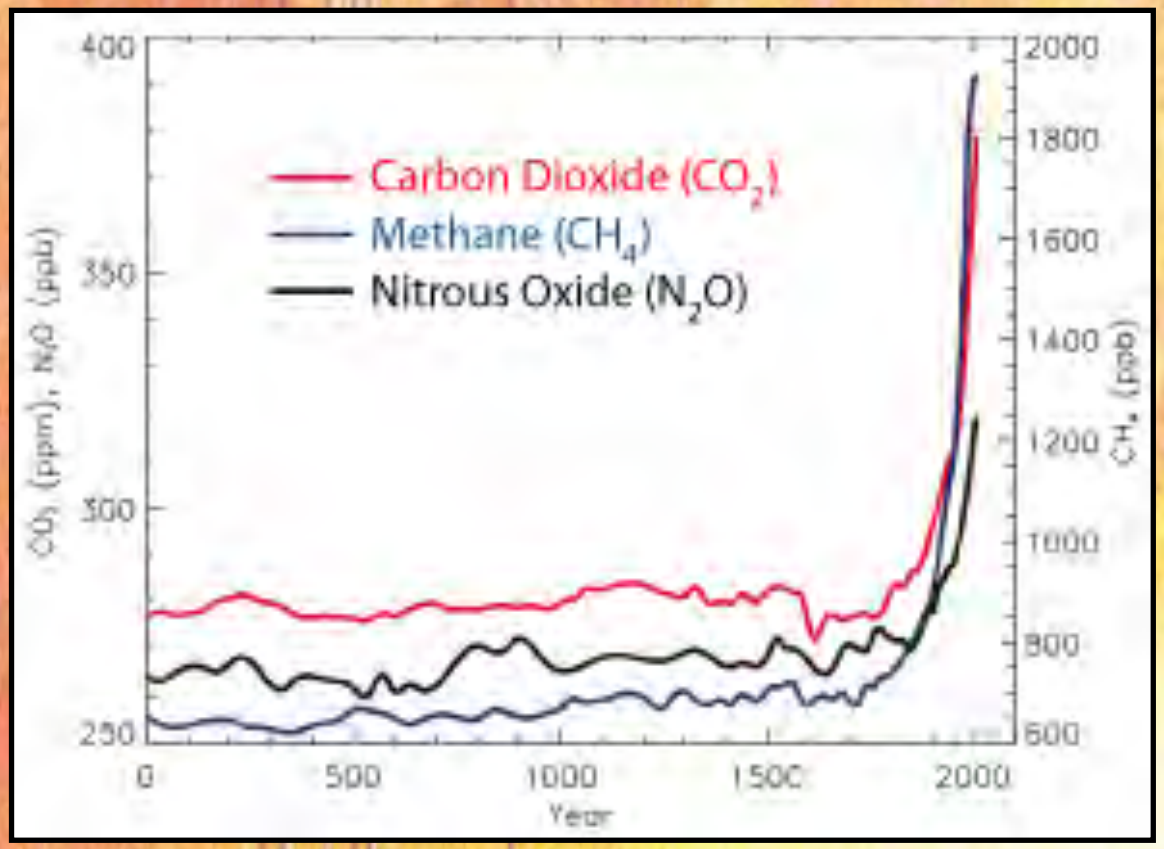
Greenhouse gases are able to trap infrared light.

This trapped light is sent back to earth, causing global warming.




Atmospheric $CO_2$ at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
NOAA
January 2013

# The Basics…. Greenhouse Gases




This increase in $CO_2$ is also accompanied by increases in other greenhouse gases.

- Methane is ~20 times more potent than $CO_2$ over a 100 year period.
- Nitrous Oxide is 300 times more potent than $CO_2$ over a 100 year period.

*(IPCC 2007)*

# The Basics…. What Is My Impact?

Major sources of $CO_2$ emission are from electrical usage and from transportation.

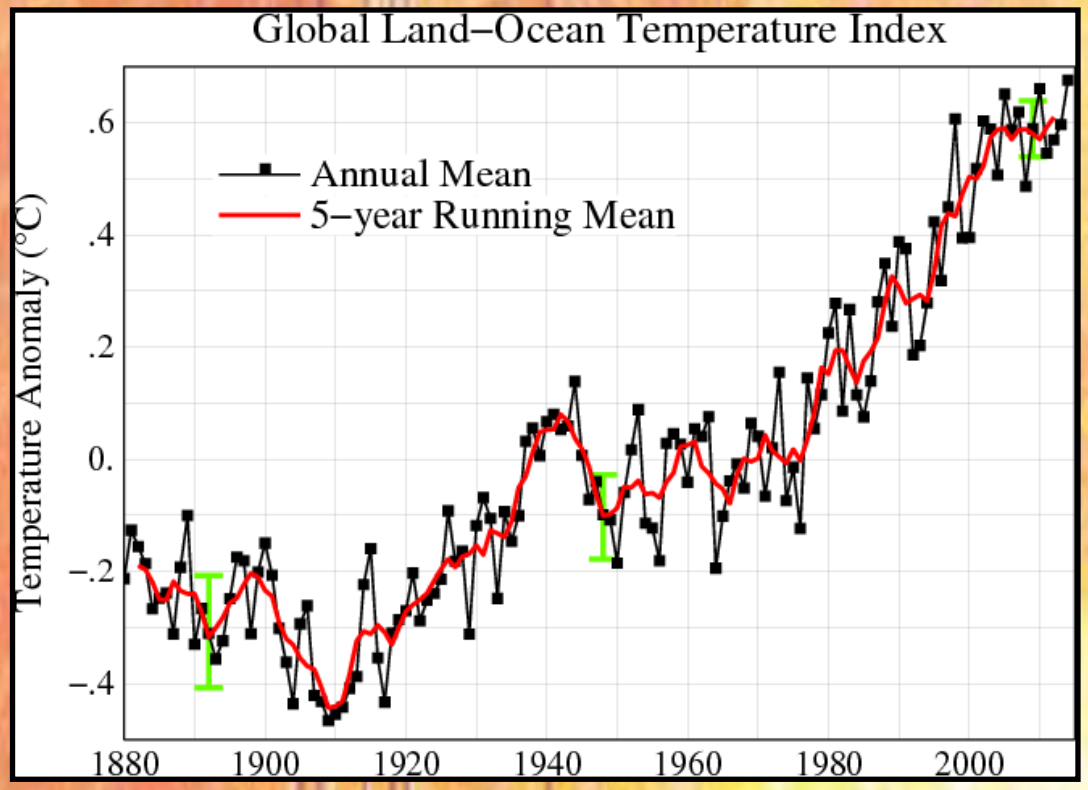
**Electrical Sources:**

- Coal is used to produce approximately 42% of U.S. electricity (33% of $CO_2$ emissions).
- 1 kilowatt-hour of electricity from coal releases 2 pounds of $CO_2$ gas.
- This is equivalent to 18 cubic feet of space.

**Transportation Sources:**

- Burning one gallon of gas releases 20 pounds of $CO_2$ gas.
- This is equivalent to 173 cubic feet of space.

# But is the Earth Really Warming?

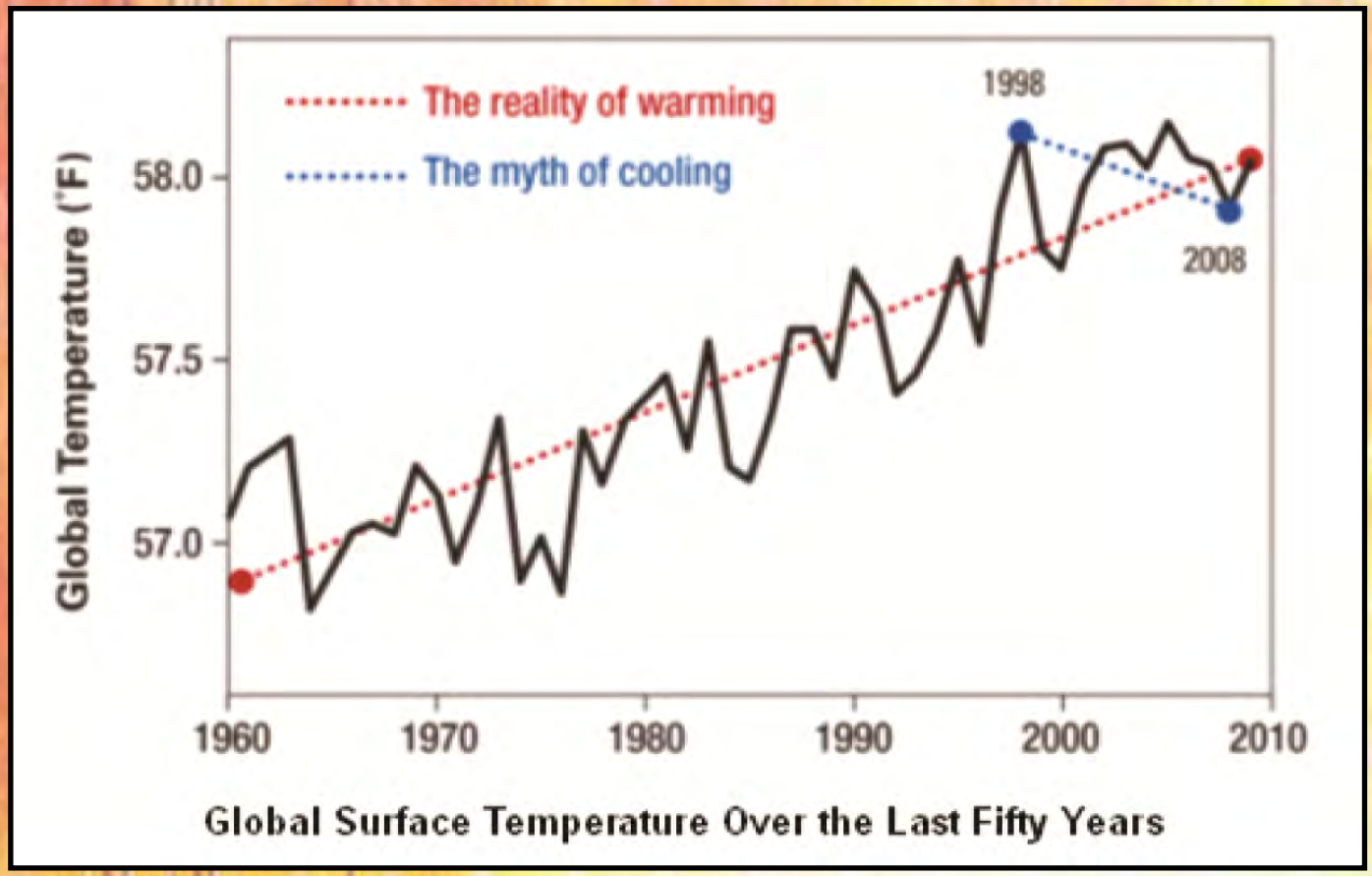



Hottest Years on Record:

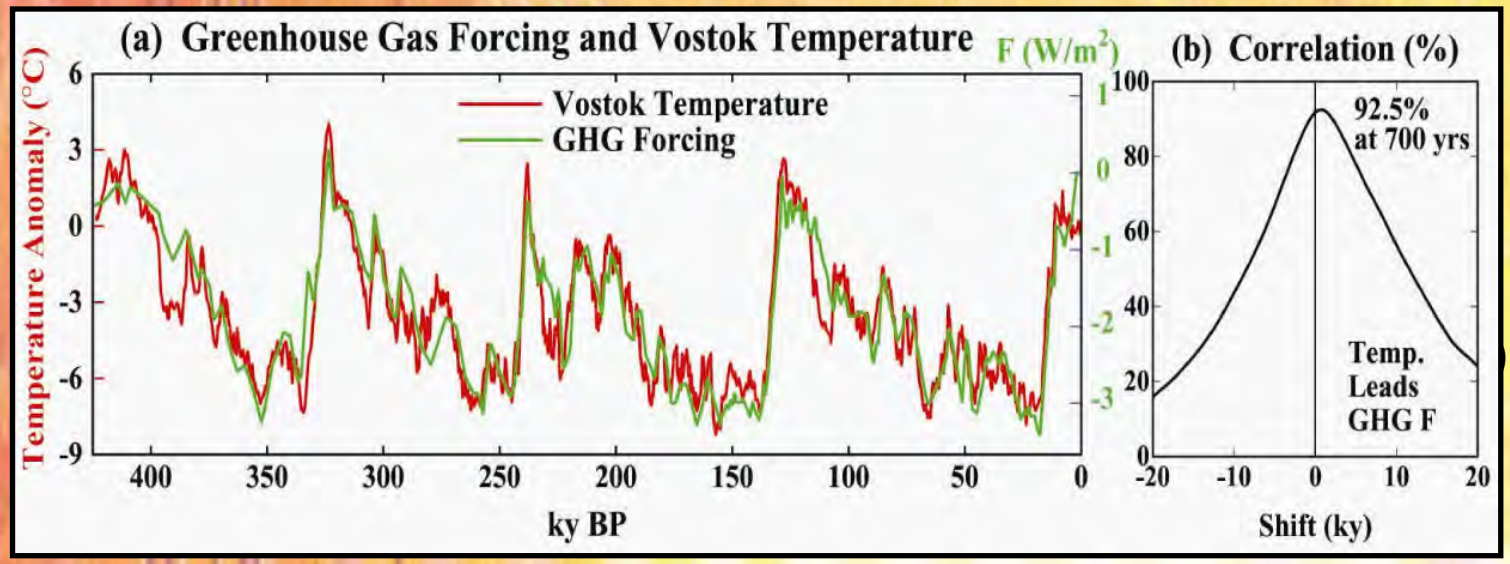
1. **2014**
2. **2010**
3. **2005**
4. **2007**
5. **1998**
6. **2002**
7. **2013**
8. **2003**
9. **2009**
10. **2006**
11. **2012**

*(Goddard Institute for Space Science, 2014)*

# But is the Earth Really Warming?



# But is the Earth Really Warming?




*(J Hansen, 2007)*

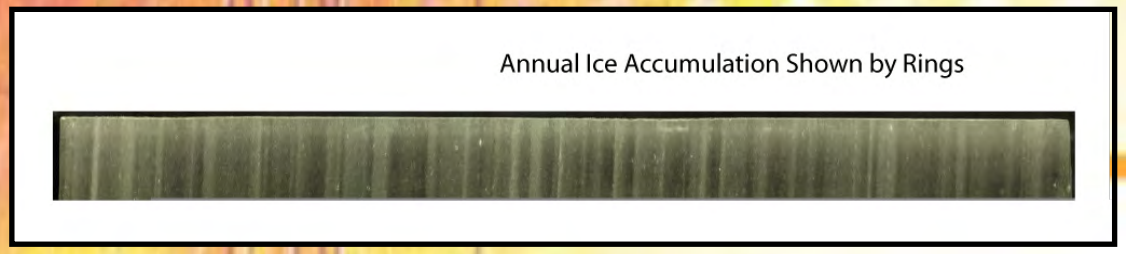
Temperature levels track closely with greenhouse gas levels.

# But is the Earth Really Warming?

How are the temperatures known so far back in time?

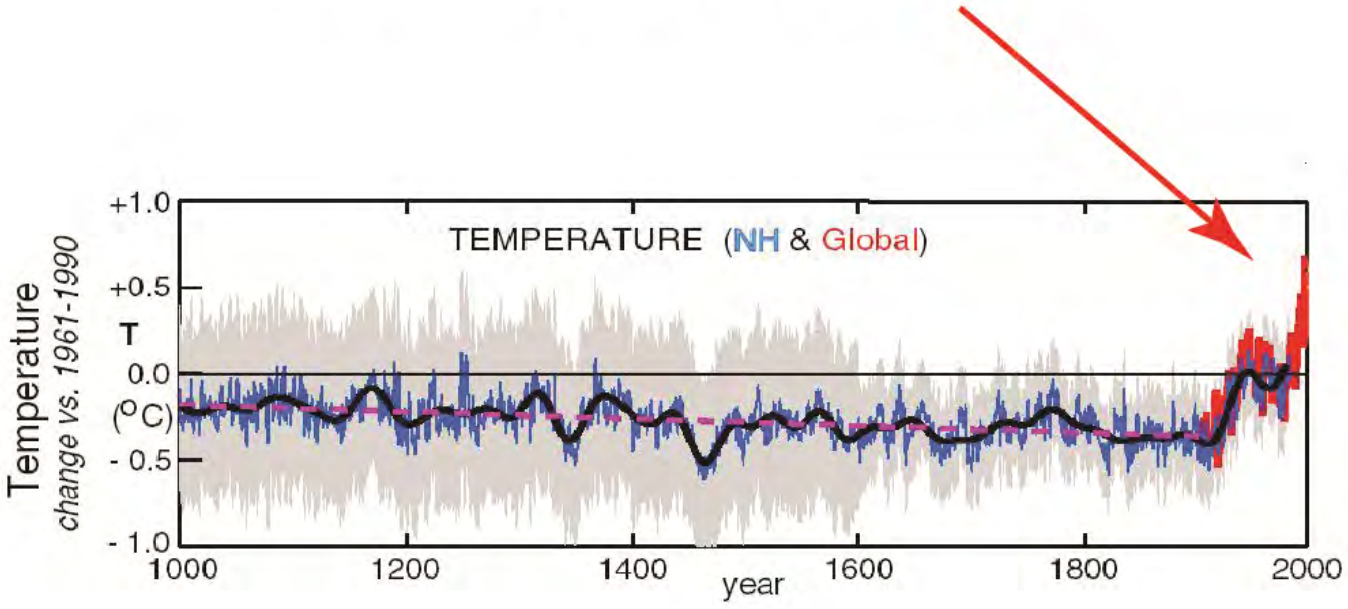
Ice cores are used to measure temperature by "proxy". The type of Oxygen molecules (isotopes) is related to temperatures when the bubble formed. In addition, the trapped air allows scientists to determine the levels of greenhouse gases. Finally, radiometric dating of the gas gives the age. Thus, temperature levels, time, and greenhouse gases are linked.

Photograph courtesy of: Department of Geophysics, Niels Bohr Institute, Univ. Copenhagen



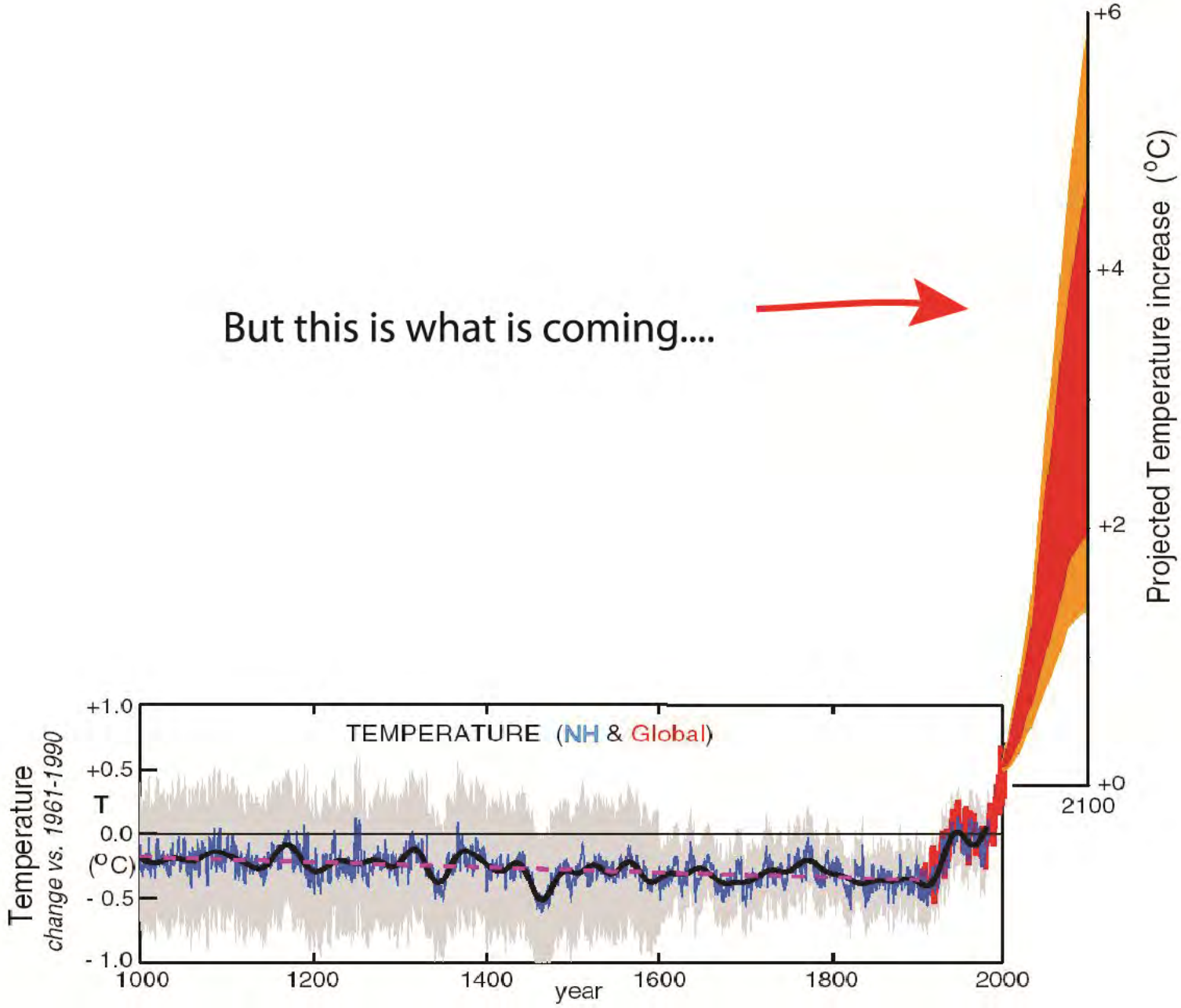

GISP2 Ice Core,
1837-1838 Meters

We are already concerned about this

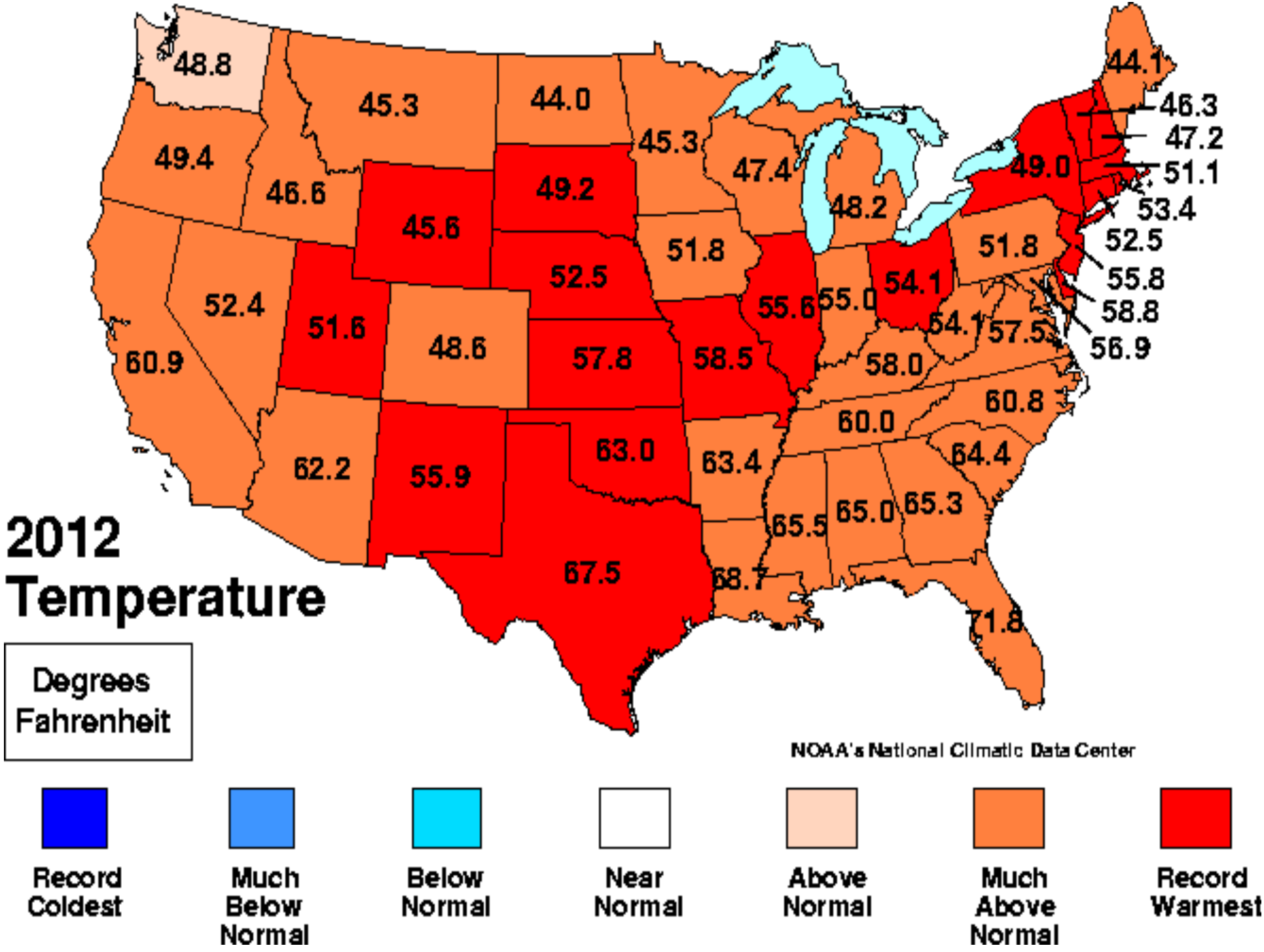



K. Hayhoe

But this is what is coming....

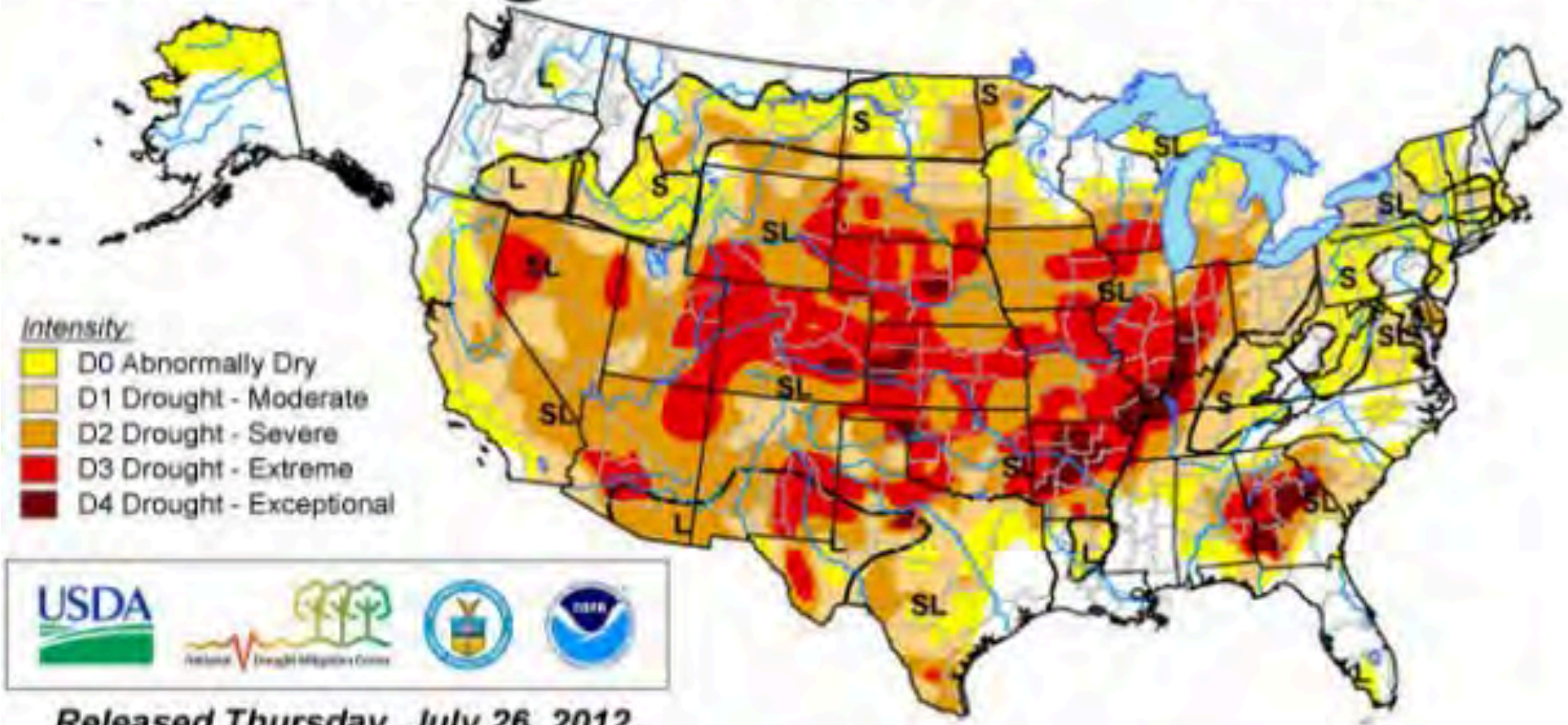



K. Hayhoe


48.8
45.3
44.0
45.3
47.4
48.2
49.0
44.1
46.3
47.2
51.1
53.4
52.5
55.8
58.8
56.9
49.4
46.6
45.6
49.2
51.8
52.5
55.6
55.0
54.1
51.8
54.1
57.5
52.4
51.6
48.6
57.8
58.5
58.0
60.8
60.9
60.0
63.0
63.4
64.4
62.2
55.9
65.5
65.0
65.3
67.5
68.7
71.8
2012
Temperature
Degrees
Fahrenheit
NOAA's National Climatic Data Center
Record
Coldest
Much
Below
Normal
Below
Normal
Near
Normal
Above
Normal
Much
Above
Normal
Record
Warmest

# U.S. Drought Monitor

**July 24, 2012**
Valid 7 a.m. EDT

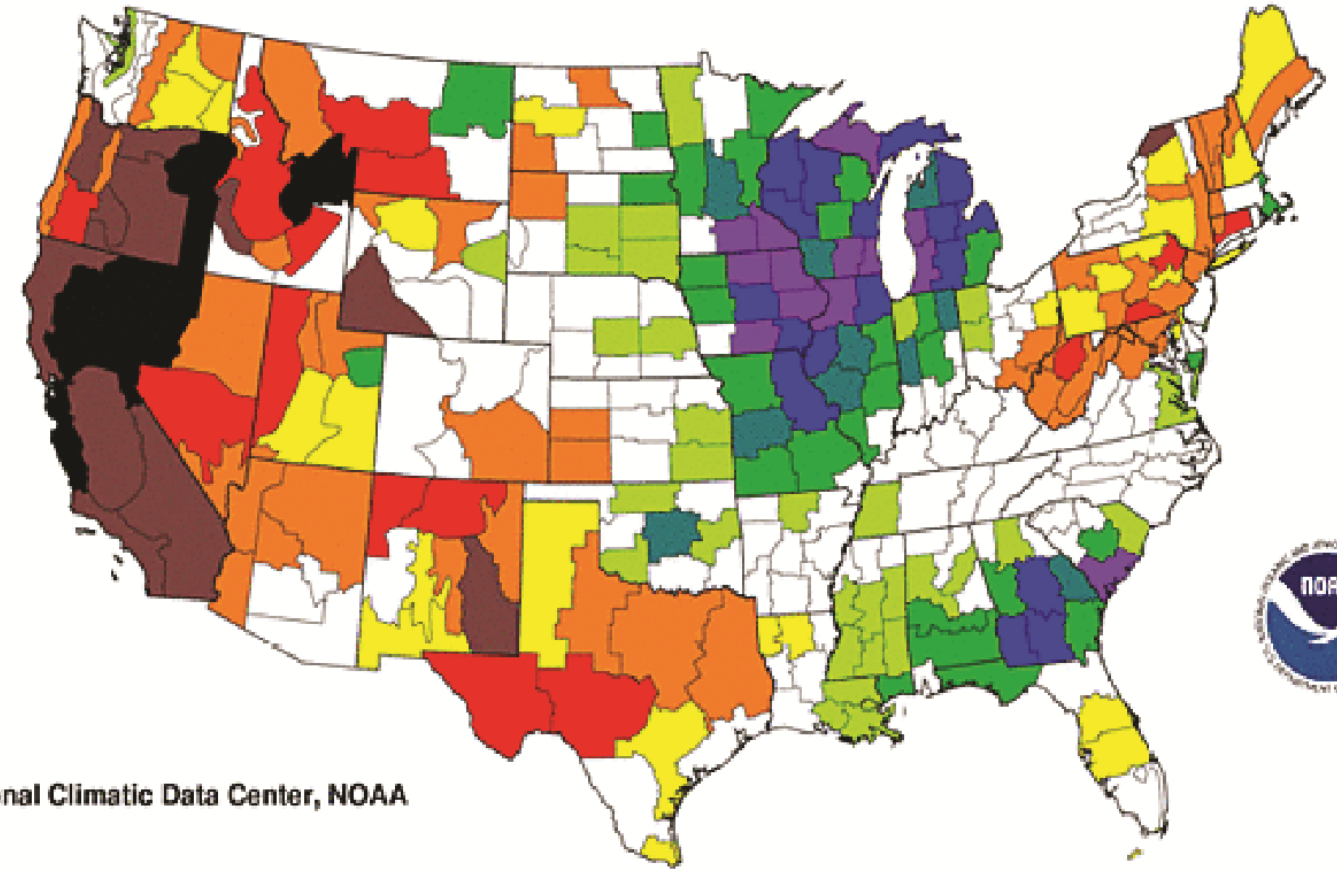



***Released Thursday, July 26, 2012***

***Author: Richard Heim, NOAA/NESDIS/NCDC***

# Standardized Precipitation Index
## Three Months

## February-April 2013



National Climatic Data Center, NOAA

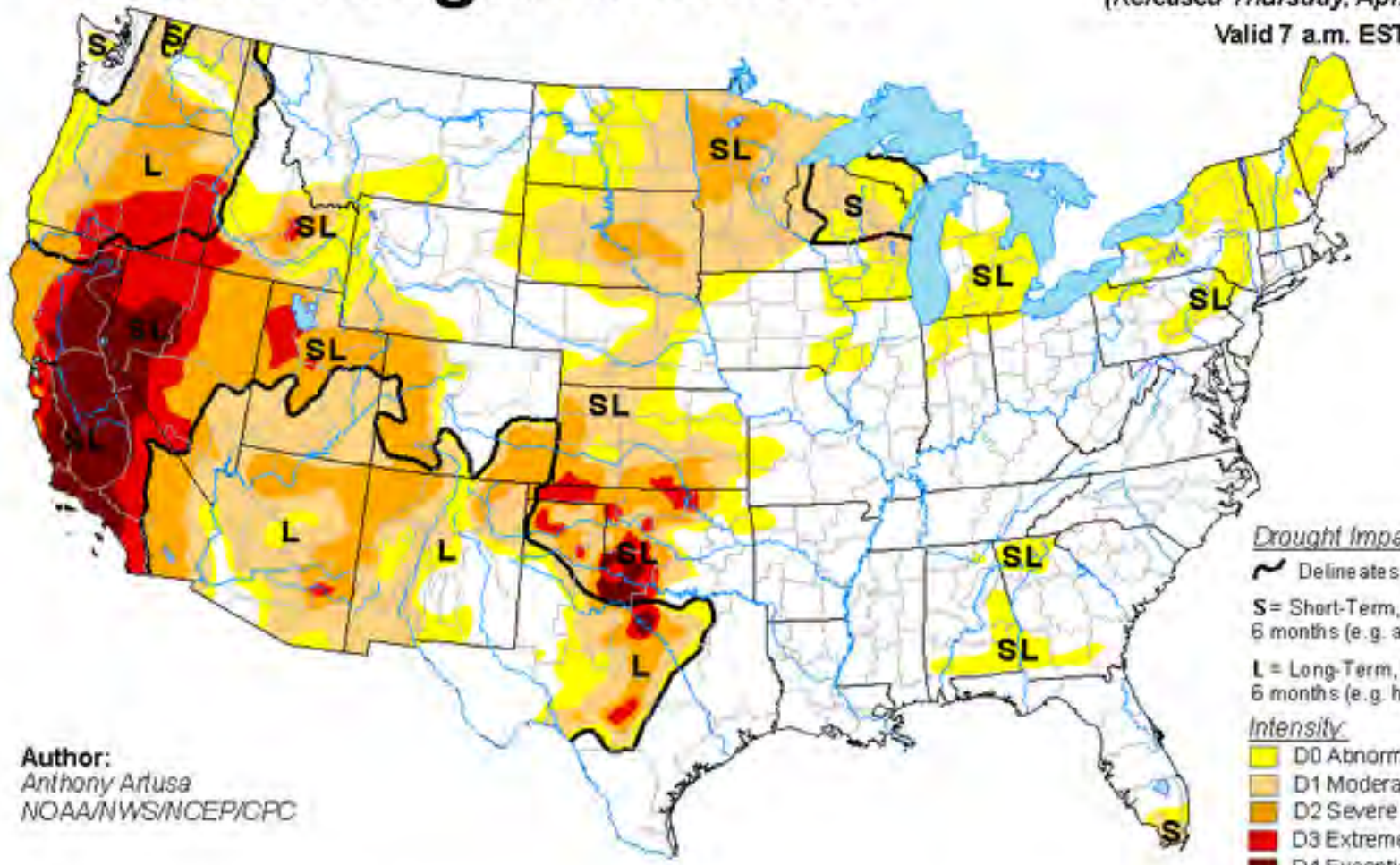
| exceptionally dry | extremely dry | severely dry | moderately dry | abnormally dry | near normal | abnormally moist | moderately moist | very moist | extremely moist | exceptionally moist |
|---|---|---|---|---|---|---|---|---|---|---|
| -2.00 and below | -1.99 to -1.60 | -1.59 to -1.30 | -1.29 to -0.80 | -0.79 to -0.51 | -0.50 to +0.50 | +0.51 to +0.79 | +0.80 to +1.29 | +1.30 to +1.59 | +1.60 to +1.99 | +2.00 and above |

# U.S. Drought Monitor

**April 28, 2015**

*(Released Thursday, Apr. 30, 2015)*

Valid 7 a.m. EST




**Author:**
*Anthony Artusa*
*NOAA/NWS/NCEP/CPC*

*Drought Impact Types:*

Delineates dominant impacts

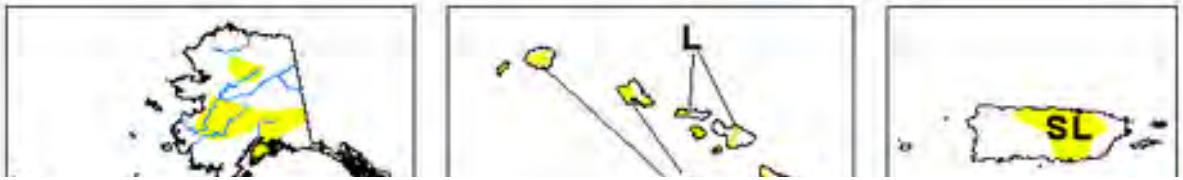
**S** = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

**L** = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

*Intensity*

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

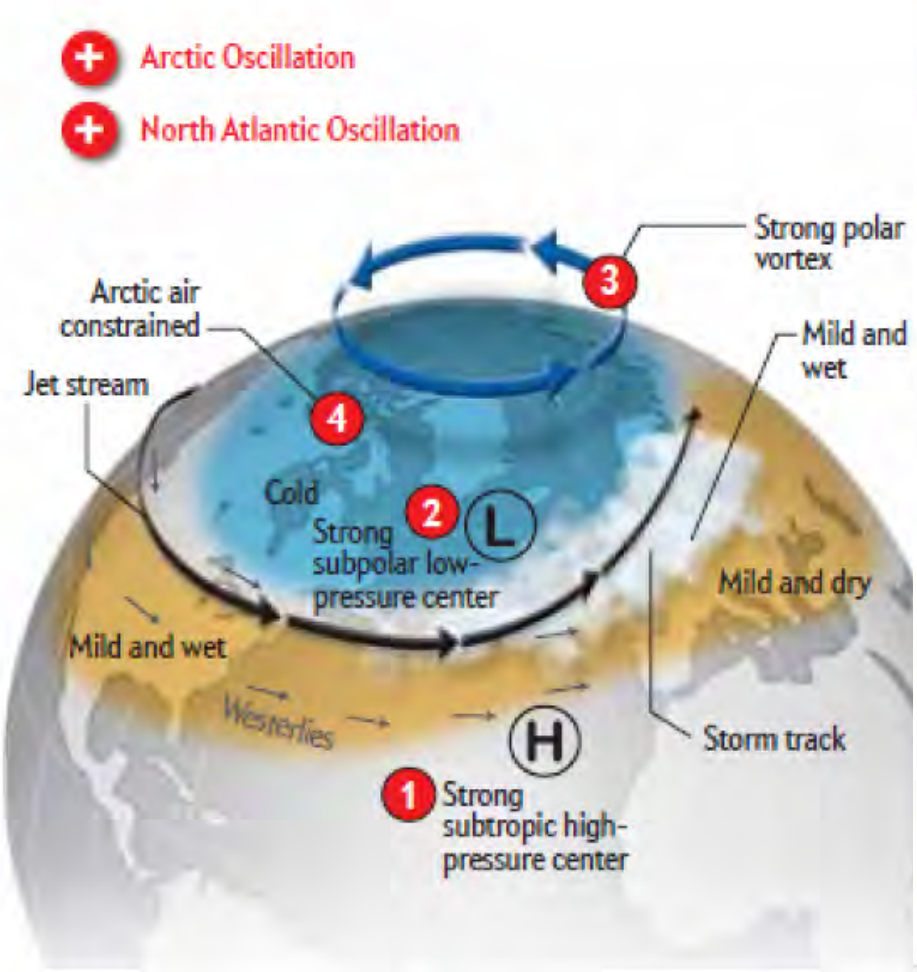
*The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.*

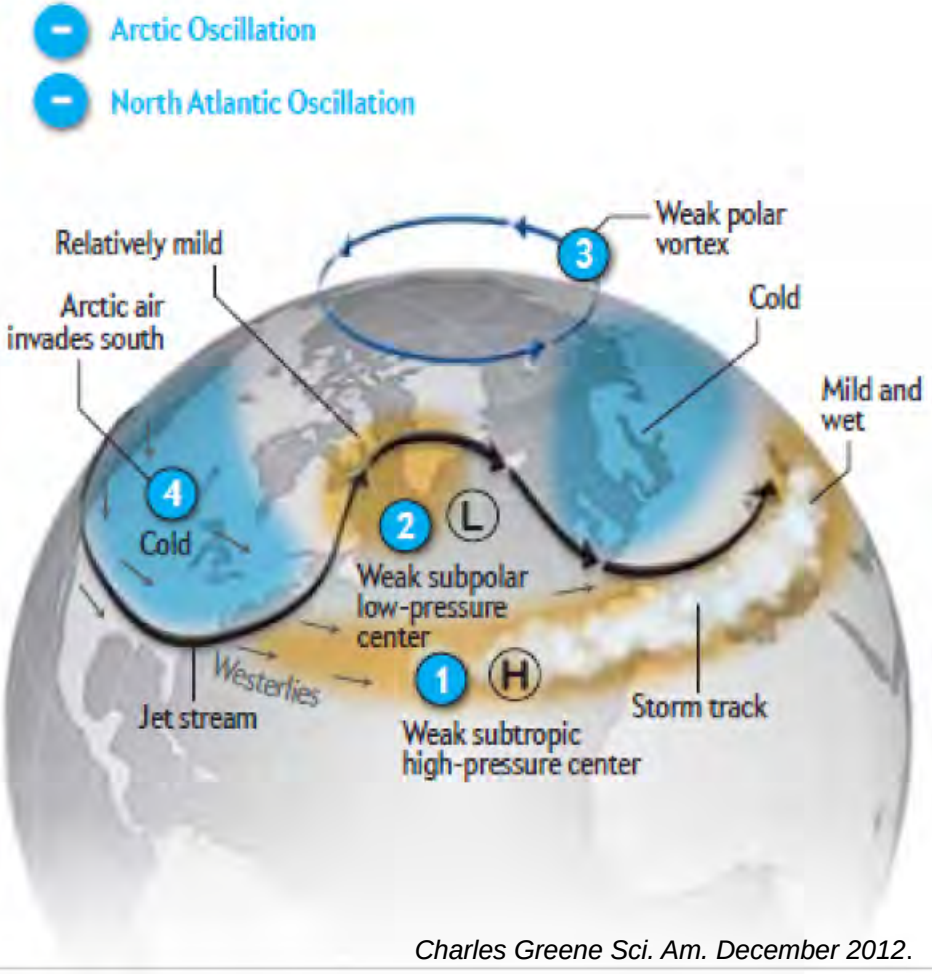



USDA

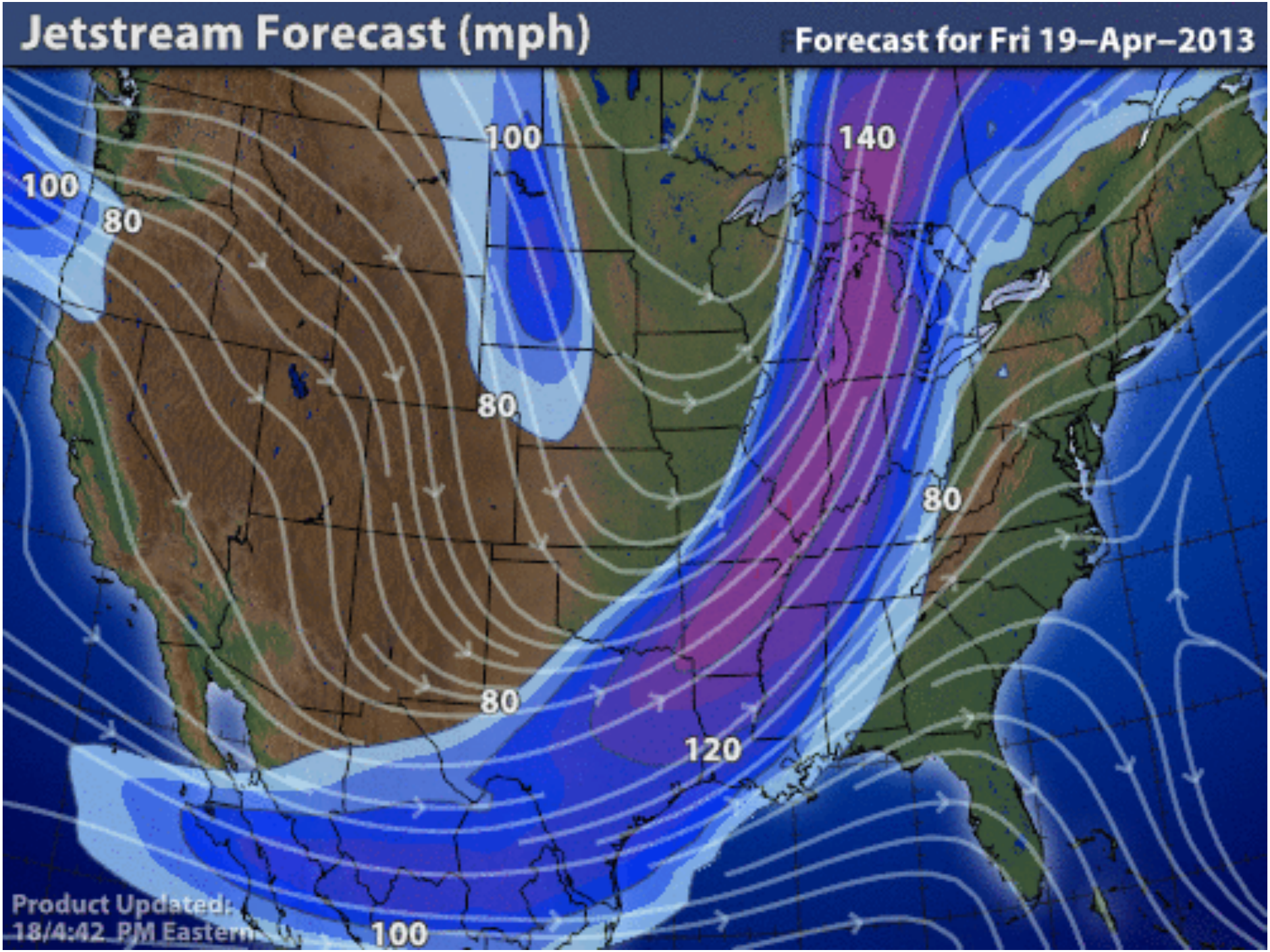
**Positive AO and NAO states** are characterized by a strong atmospheric high-pressure center (H) in the subtropics 1 and a strong low-pressure center (L) in the subarctic 2. The positive AO is also associated with a strong polar vortex 3, which constrains cold Arctic air to the north 4 and allows warm air from southern latitudes to reach far north into the U.S. and Europe. Under these conditions, the jet stream and the typical track of storms follow a northeastward path across the Atlantic, delivering warmth and moisture to northern Europe.

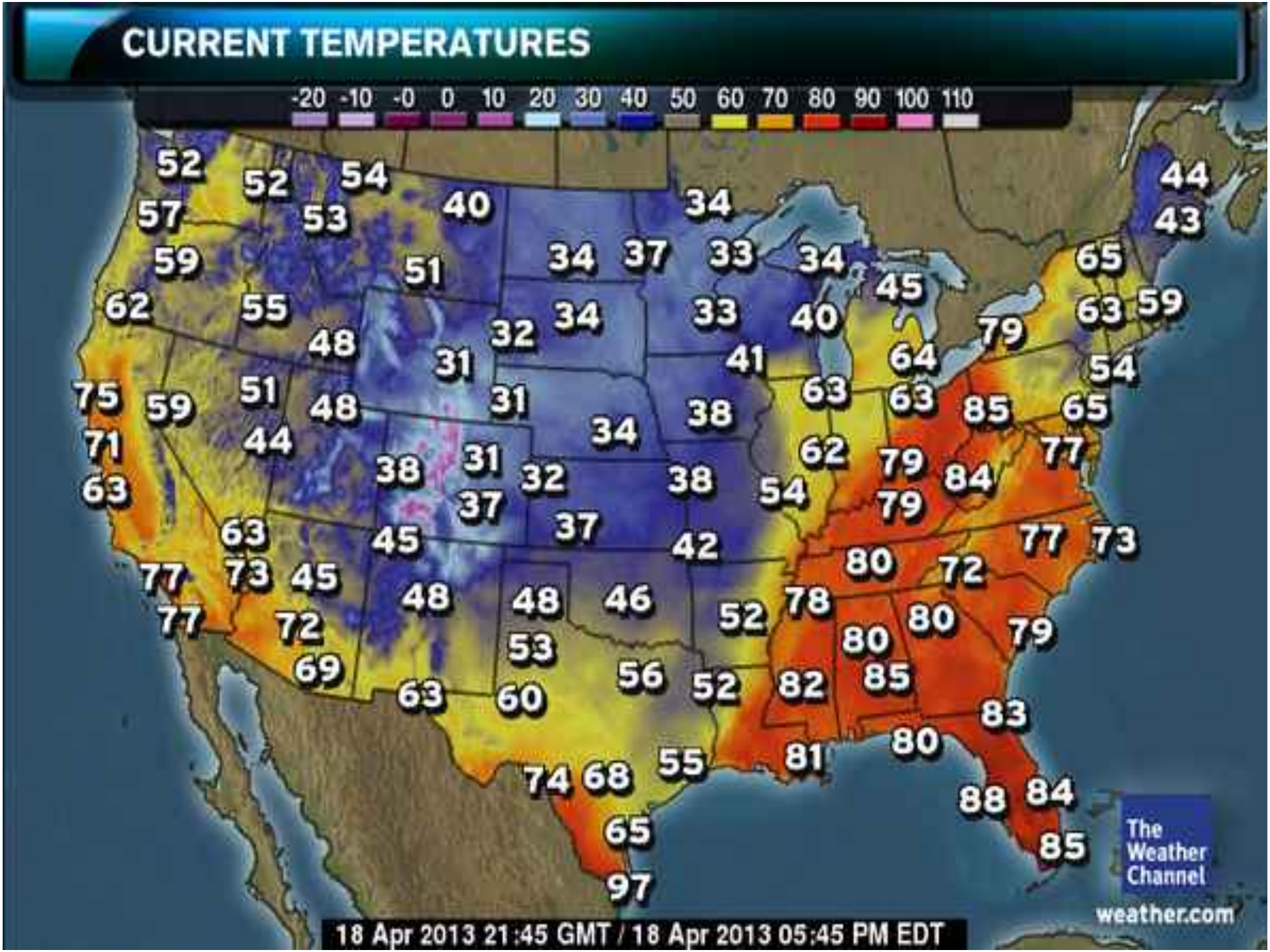
**Negative AO and NAO states** are characterized by weaker atmospheric pressures in the subtropics 1 and the subarctic 2. The negative AO is also associated with a weakened polar vortex 3, which allows cold air to invade south across the U.S. and northern Europe 4. Under these conditions, the jet stream takes a more sinusoidal path, dipping south over the eastern U.S., cresting over the Atlantic Ocean near Greenland, then dipping again toward southern Europe. Storms tend to follow a more direct, eastward path across the Atlantic, bringing moisture to southern Europe.



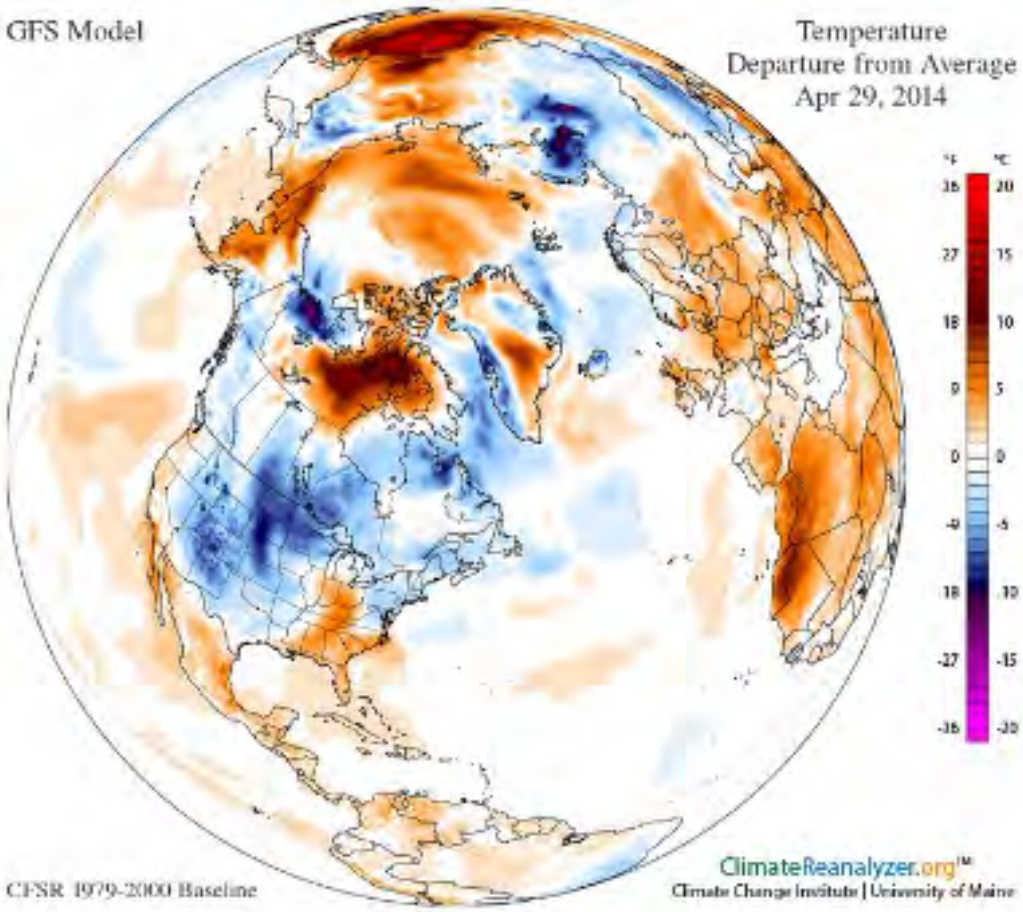




*Charles Greene Sci. Am. December 2012.*

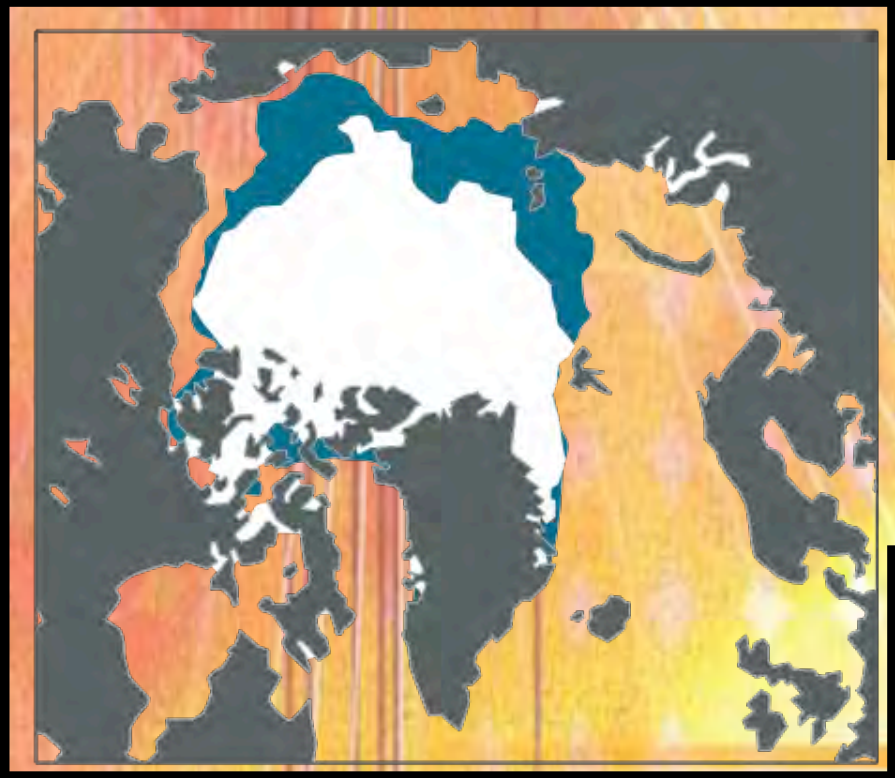

Jetstream Forecast (mph)
Forecast for Fri 19–Apr–2013
100
80
100
140
80
80
80
120
100
Product Updated:
18/4:42 PM Eastern


CURRENT TEMPERATURES
-20 -10 -0 0 10 20 30 40 50 60 70 80 90 100 110
52 52 54 40 34 44
57 53 43
59 51 34 37 33 34 65
62 55 34 45 63 59
48 32 33 40 79
31 41 64 54
75 59 51 48 31 63 63 85 65
71 44 34 38
63 38 31 32 38 62 79 84 77
37 54 79
63 37 77 73
45 42
77 73 45 48 48 46 80 72
77 72 52 78 80
53 80 79
69 56 52 82 85
63 60 83
74 68 55 81 80
88 84
65 85
97
The Weather Channel
weather.com
18 Apr 2013 21:45 GMT / 18 Apr 2013 05:45 PM EDT

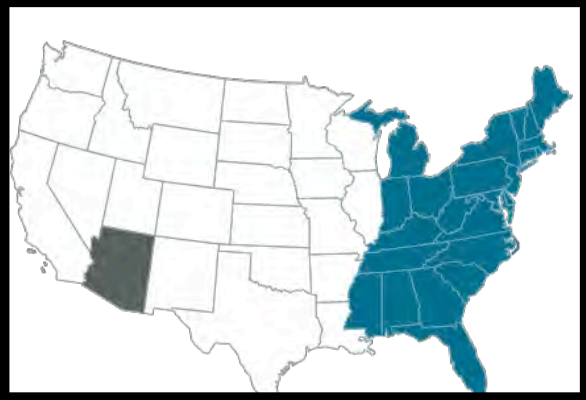

GLOBAL WARMING IS A HOAX
BECAUSE IT IS COLD. TODAY.
WHERE I LIVE.




| World | Northern Hemisphere | Arctic |
|---|---|---|
| + 0.41 °C | + 0.78 °C | + 1.03 °C |
| **Tropics** | **Southern Hemisphere** | **Antarctic** |
| + 0.62 °C | + 0.04 °C | + 0.59 °C |



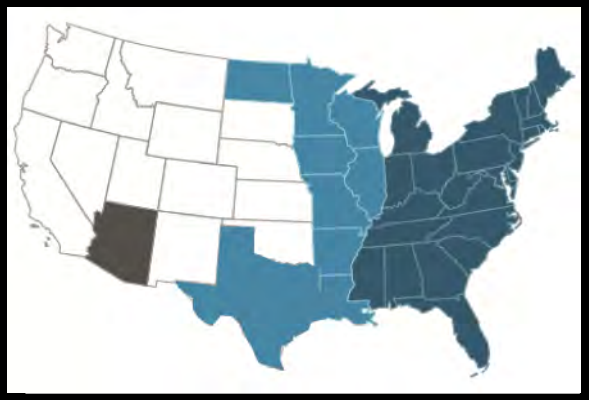
2005 Arctic Ice



Equivalent Region

*Gore, 2007*

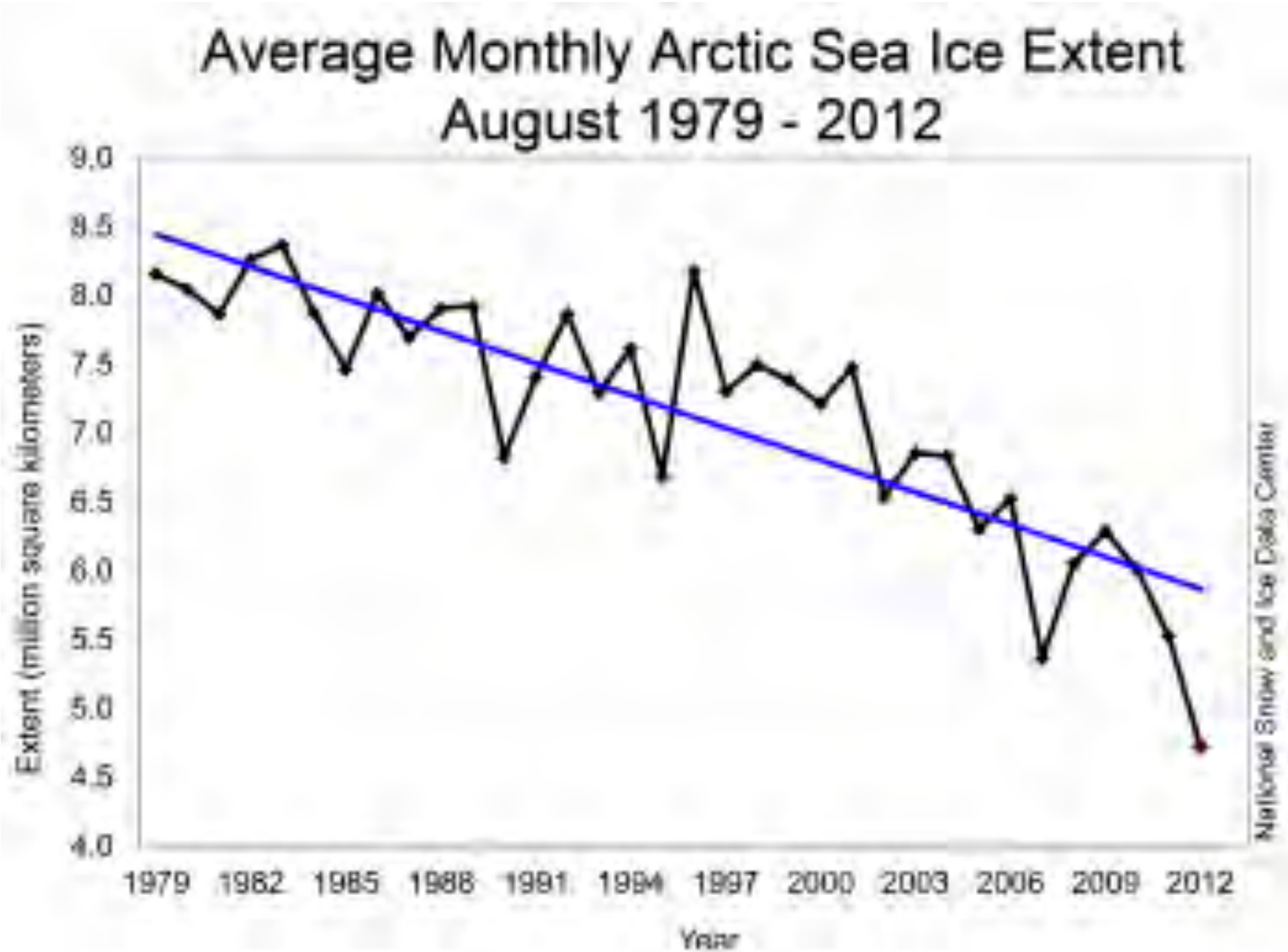
2007 Arctic Ice



Equivalent Region

Since then, we lost ice equal to Texas

*Gore, 2007*

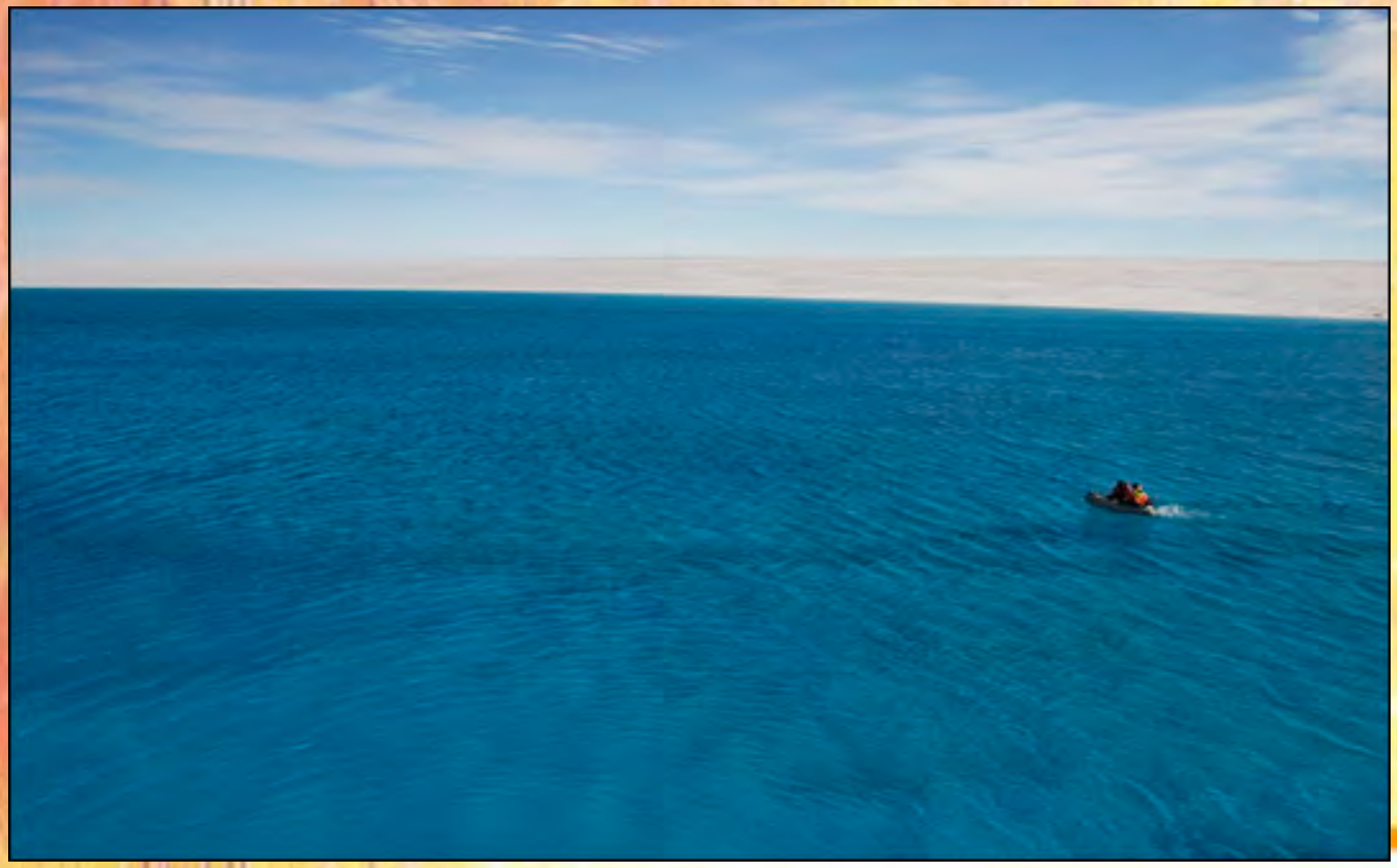

Average Monthly Arctic Sea Ice Extent
August 1979 - 2012
Extent (million square kilometers)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Year
National Snow and Ice Data Center

# How Bad Will it Get?

There is a potential of dramatic ice loss. Moulins can drastically accelerate melting.

*(Roger Braithwaite, University of Manchester)*

# How Bad Will it Get?

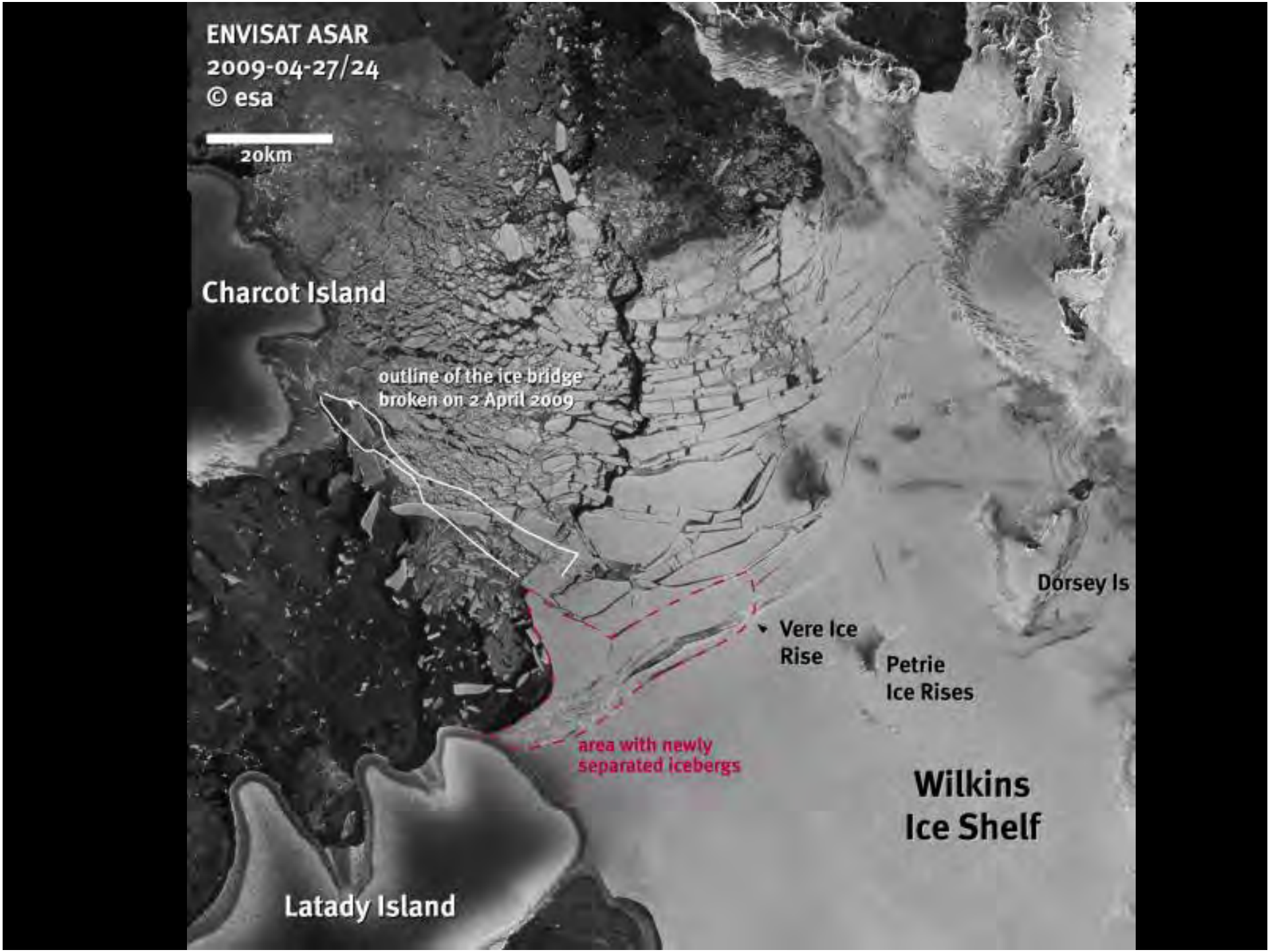


*Moulin on an ice sheet (Courtesy of NASA)*



University of St. Thomas
Minnesota


Robert Rohde


ENVISAT ASAR
2009-04-27/24
© esa
20km
Charcot Island
outline of the ice bridge
broken on 2 April 2009
Dorsey Is
Vere Ice
Rise
Petrie
Ice Rises
area with newly
separated icebergs
Wilkins
Ice Shelf
Latady Island

# McCarty Glacier - Alaska

Robert Rohde

# Muir and Riggs Glaciers


Robert Rohde

# How Bad Will it Get?

Land-based ice losses…

*(Alpine Glacier, 1990 court. Munich Society for Environmental Research)*

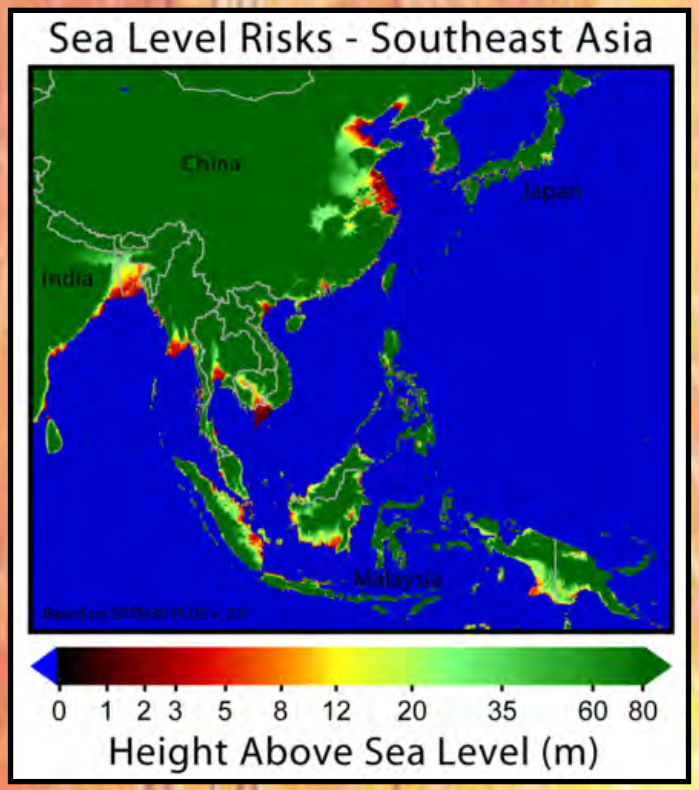
# How Bad Will it Get?

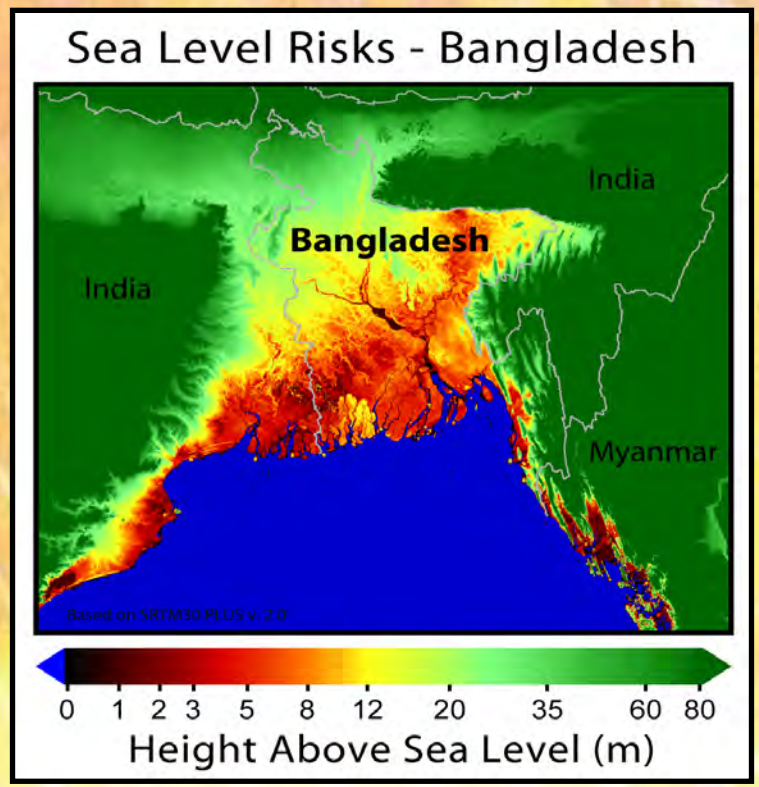
Land-based ice losses…



*(Portage Glacier, 1914 and 2004)*

# How Bad Will it Get?



# How Bad Will it Get?

# How Bad Will it Get?

How much will ocean levels rise if:

Greenland melts….. 7 meters (23 feet)

West Antarctica melts….. 5 meters (17 feet)

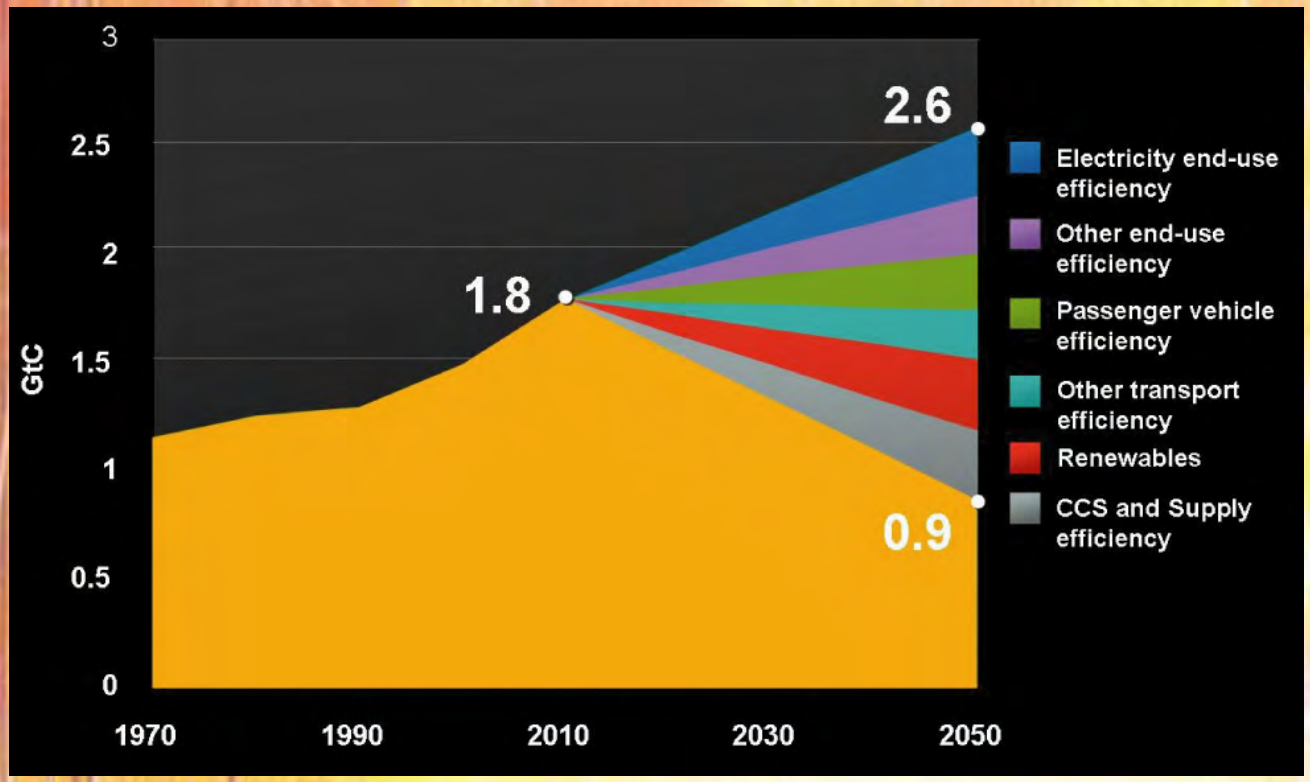
All of Antarctica melts….. 83 meters (270 feet)

# How Bad Will it Get?

Climate change will also lead to…..

- Lower crop yields, particularly in regions populated by subsistence farmers.
- Ocean acidification
- Redistribution of water (less in some areas, more in others).
- Increase of “extreme” weather events. (100-years floods occuring frequently).
- Potential increase of hurricanes (jury still out…) but increase in Atlantic
- Increase of invasive species.
- Migration of flora.
- Widespread extinctions.

# What Do We Do Now?




*(Pacala and Socolow, 2004)*

The way forward is multi-pathed.

# What Do We Do Now?

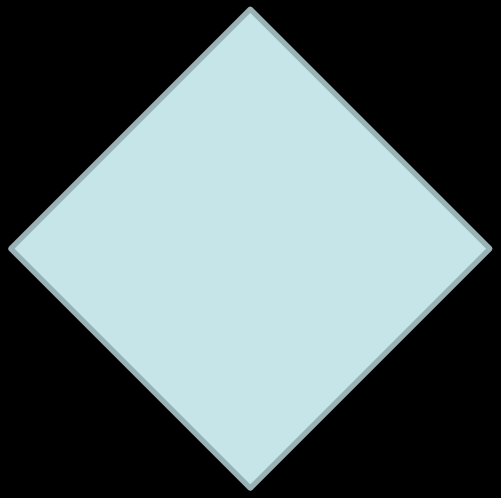
1. Talk to your representatives.
   - Ask for increased car-fuel standards
   - Ask for limits to carbon dioxide emissions
   - Make sure they know this is important
2. Talk to your friends
   - Most people are confused by multiple media sources
3. Reduce home electrical usage, purchase renewable if possible
4. Reduce transportation  emissions
5. Contact me if you have any questions about the science.

# Change is possible

K. Hayhoe

Scientists know that we are changing the climate, we've known for more than 150 years…

There is a cost to delayed action…



We can solve this problem today, with today's technology…

We can help the environment, create jobs, generate energy, and improve national security…

# Other Voices

*"I hope that all members of the international community can agree on a responsible, credible and supportive response to this worrisome and complex phenomenon, keeping in mind the needs of the poorest populations and of future generations." – Pope Benedict XVI*

*"I recall a popular saying: 'God always forgives, we sometimes forgive, but when nature – creation – is mistreated, she never forgives!'. We have also witnessed the devastating effects of several recent natural disasters." – Pope Francis*

*"At its core, global climate change is not about economic theory or political platforms, nor about partisan advantage or interest group pressures. It is about the future of God's creation and the one human family." – US Bishops*