Vermont in the age of Global Warming

Identifying Weather Patterns that lead to extreme weather events - or not.

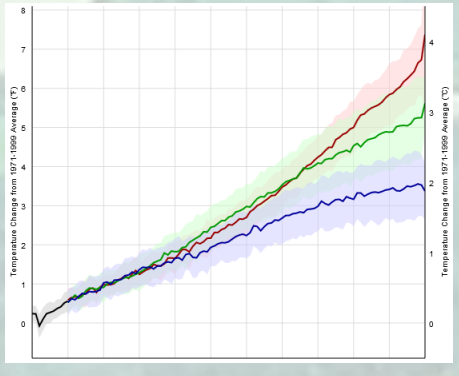
DISCLAIMERS AND ATTRIBUTION

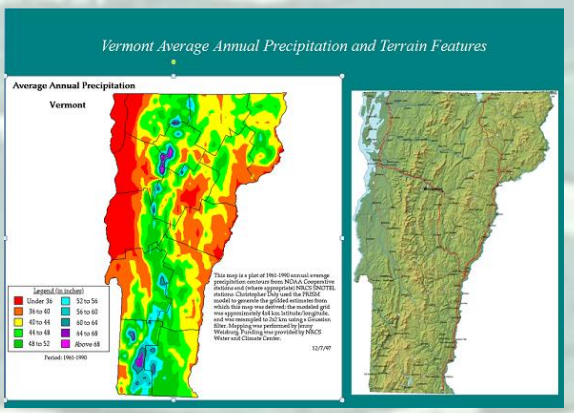
This content and conclusions are drawn by a myself a weather forecaster, not a climate scientist/researcher.

This presentation uses much of the work done by Francis and Vavrus 2012 along with recent updates and observations from experiences in meteorology since the mid 1970s, and some study of various components of the climate system and climatology since the late 1980s.

The presentation will discuss:

- Increasing trends in extreme weather
- Climate Change in a warming world
- Some Vermont Climatology





A New Normal?

- Increased evidence has linked extreme weather to loss of northern hemisphere sea ice

- (Francis-Vavrus 2012) Study says it's happening all over especially the Northern Hemisphere

A flood of floods…

V

na

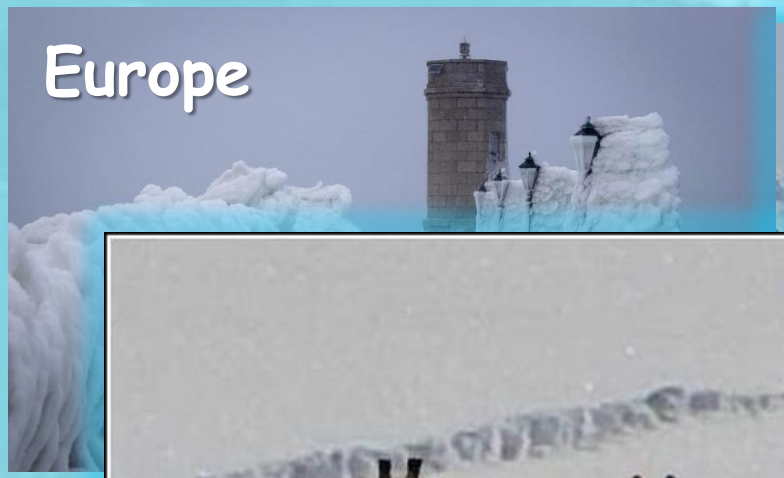
Greenland

Alaska

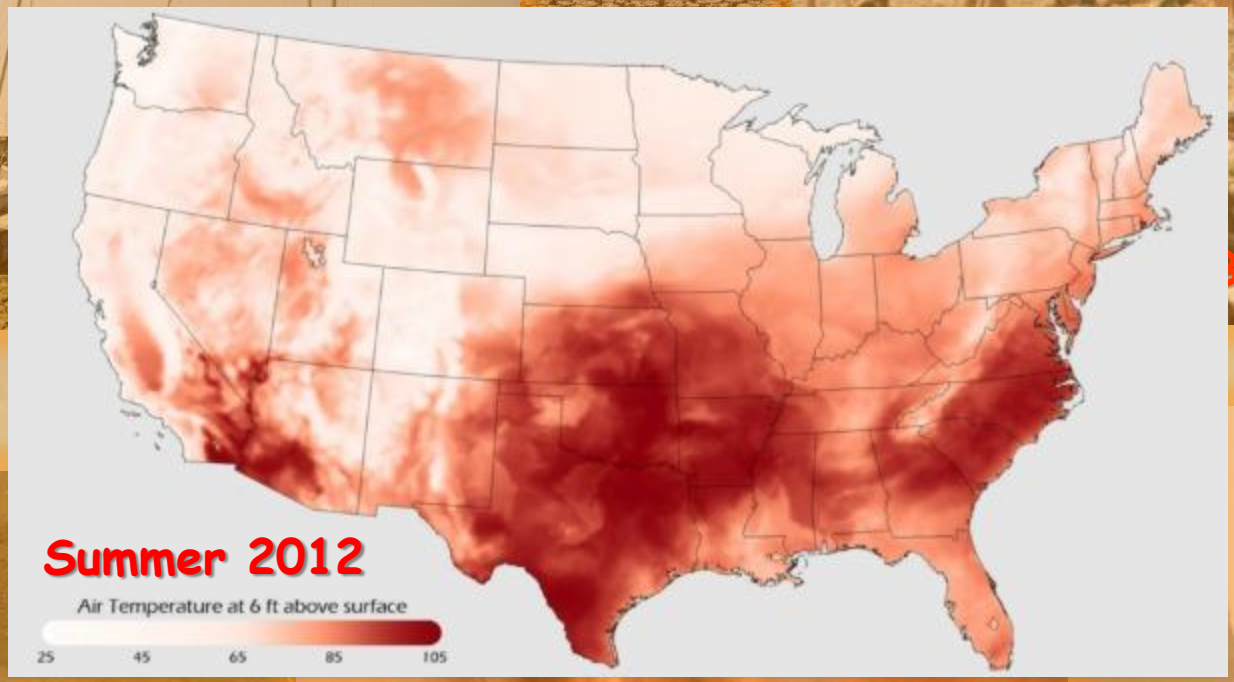
Anchorage Daily News / adn.com

U.K.

A blizzard of cold and snow…



Along with a rash of heat, drought, and fires…



And then there was Sandy…

2013 Chimes In…

Scituate Massachusetts

Feb. 12th 2013
Blizzard

Friday, January 18, 2013

Snow-pocalypse Russia: Snow 'tsunami' swallows streets, cars, buildings

Extreme Japan Snowfall

In the Hakkoda mountains the depth of snow has been measured at 5.61 metres (18.4) – a record for Japan

Extreme Japan Snowfall

Siberian air blows over the Sea of Japan (which never freezes) and the moisture from the sea is orographically lifted by the mountains creating tremendous snowfalls along the northern and western slopes and shoreline.

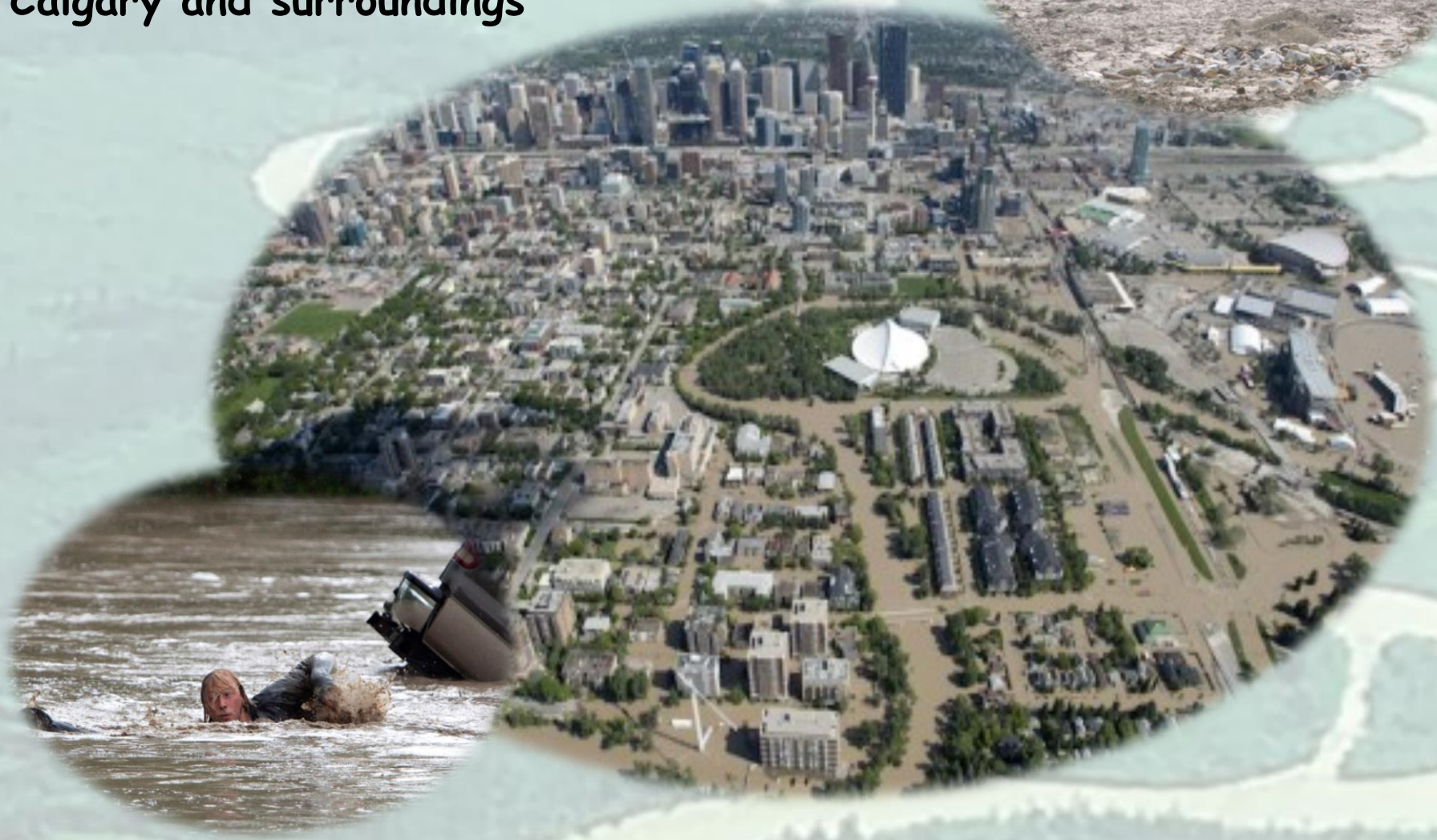
A 'lake effect 'snow pattern, so to speak, but on a sea-like scale.

Central Europe

Record flooding unprecedented since the Middle Ages hit major rivers in Austria, the Czech Republic, Germany, Poland and Slovakia

Calgary Alberta

Heavy rains in southern Alberta force mandatory evacuations in areas of Calgary and surroundings



Boulder Colorado

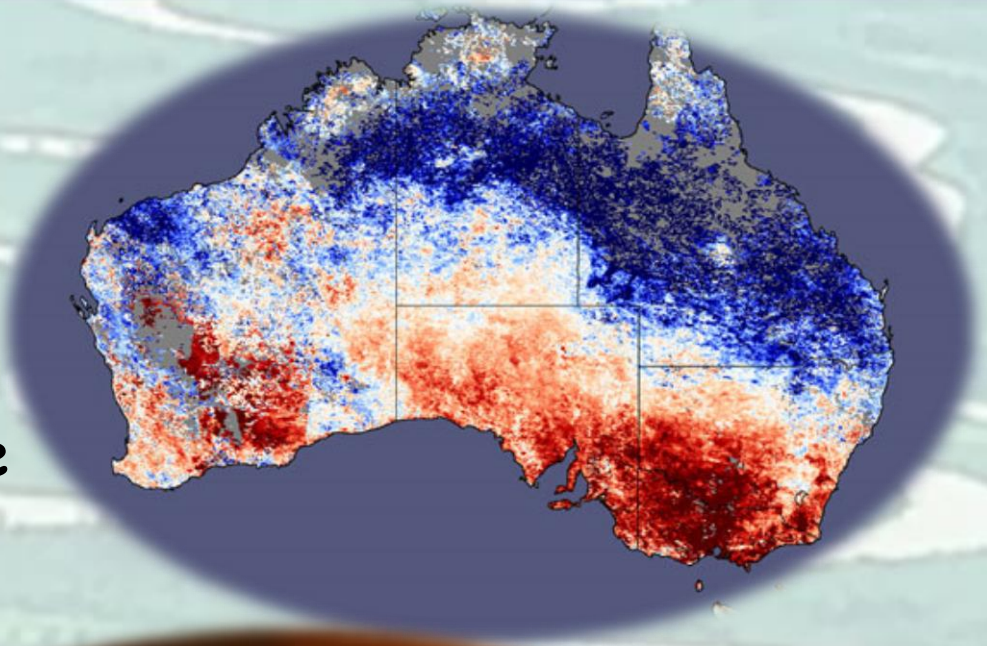
Eight days, 1,000-year rain, 100-year flood
The story of Boulder County's Flood of 2013

Giant Rim Fire near Yosemite

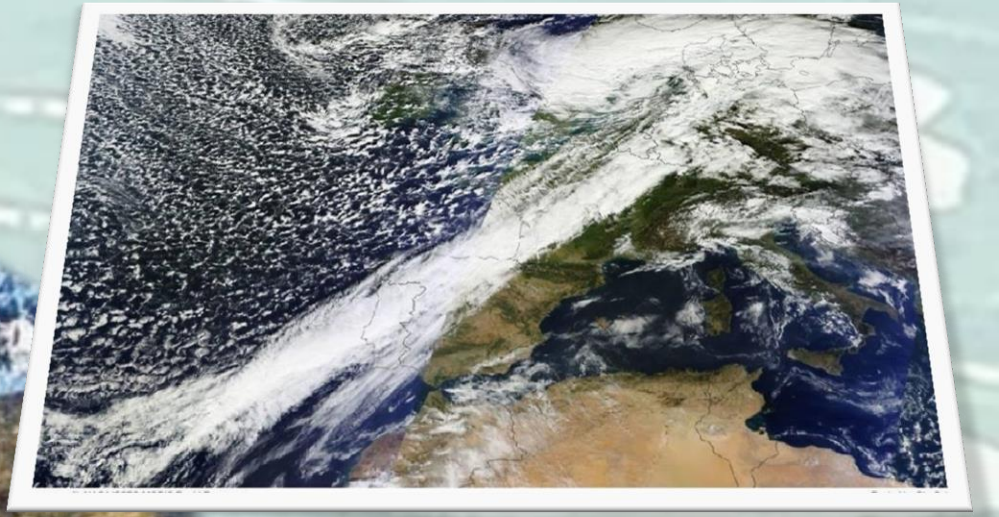
2012-13 Sierra Nevada snowpack, at near record lows, followed by heat of summer, including a major heat wave intensified the record-dry conditions with background of frequent drought years.

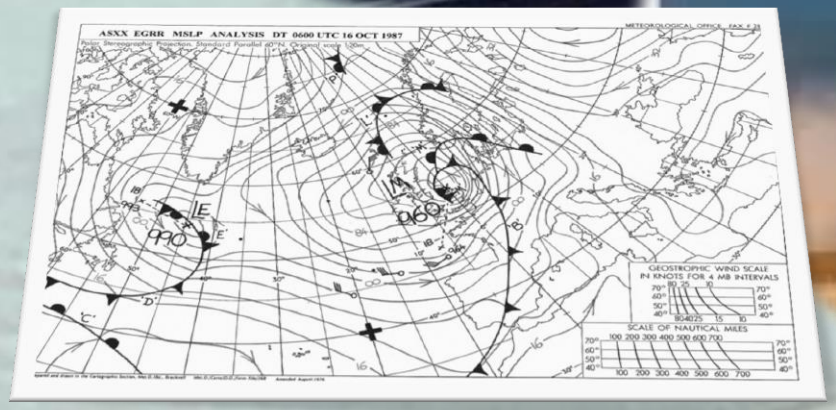
Australian Wild Fires

Australia, U.N. spar over wildfires and climate change

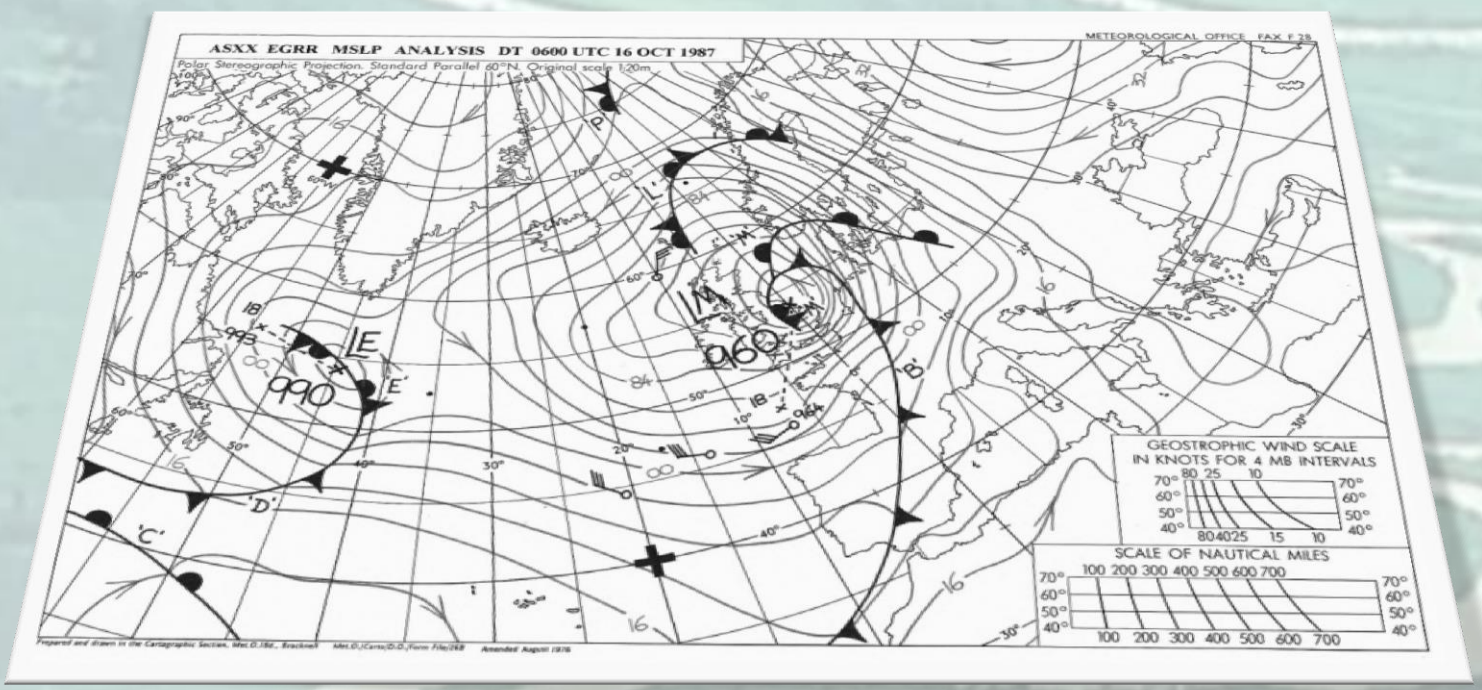


European Windstorm Oct. 28th



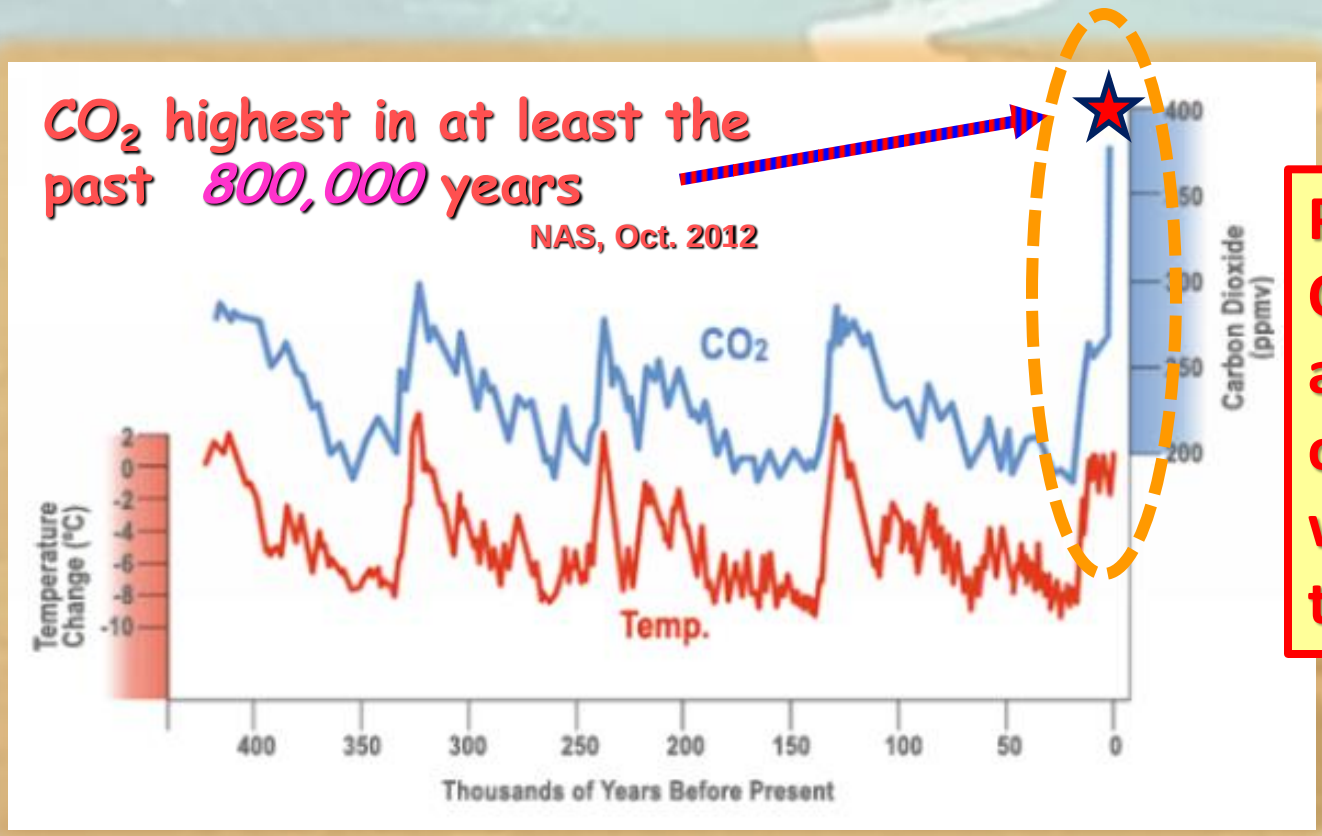


What do these events have in common?



Stuck Weather Patterns

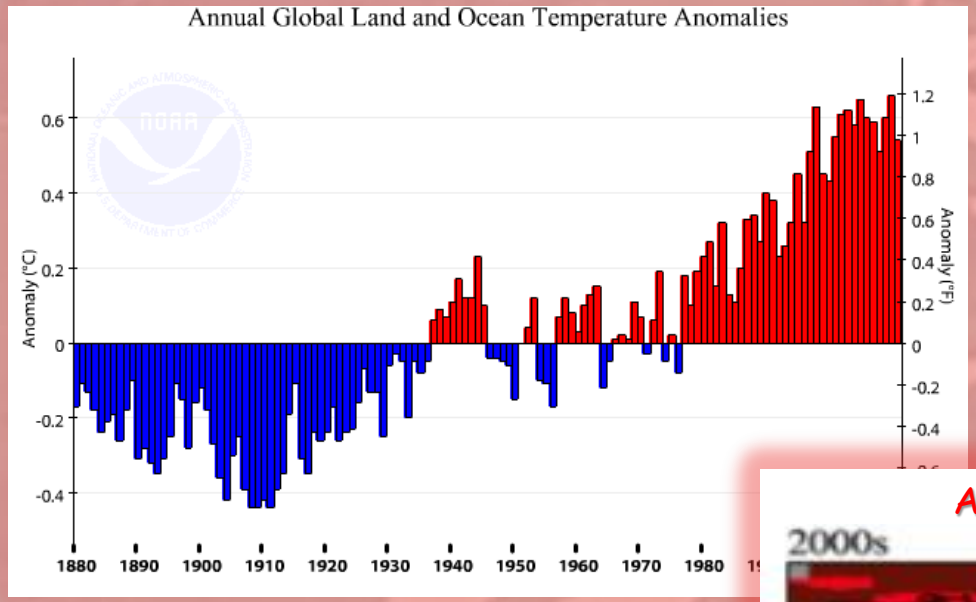
Let's look back a few hundred thousand years…



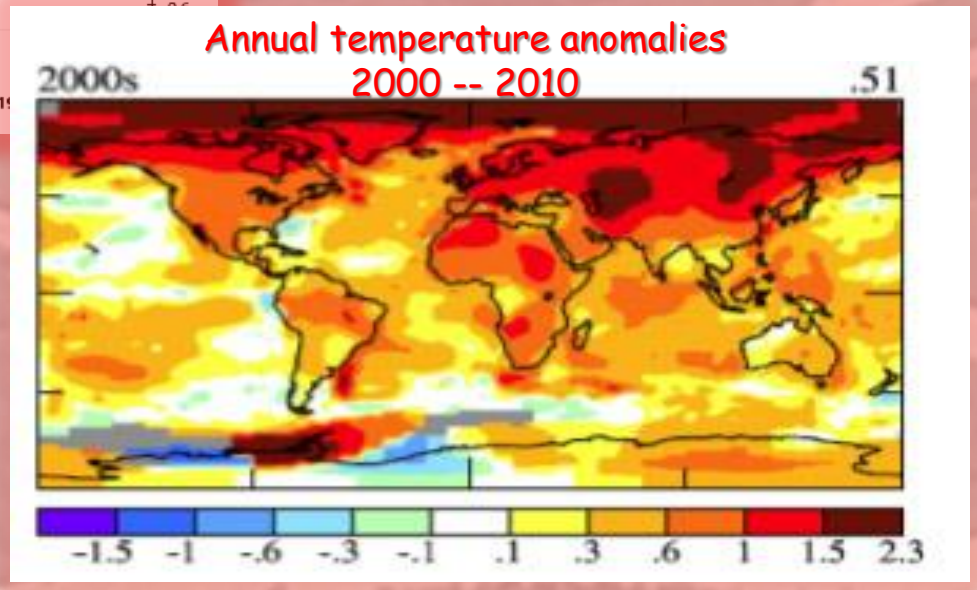
Present CO_2 levels are *WAY* out of whack with temperature

The last time CO2 levels were this high, the globe was several degrees warmer, sea level were tens of feet higher, and humans didn't exist.

The Earth's temperature is starting to catch up

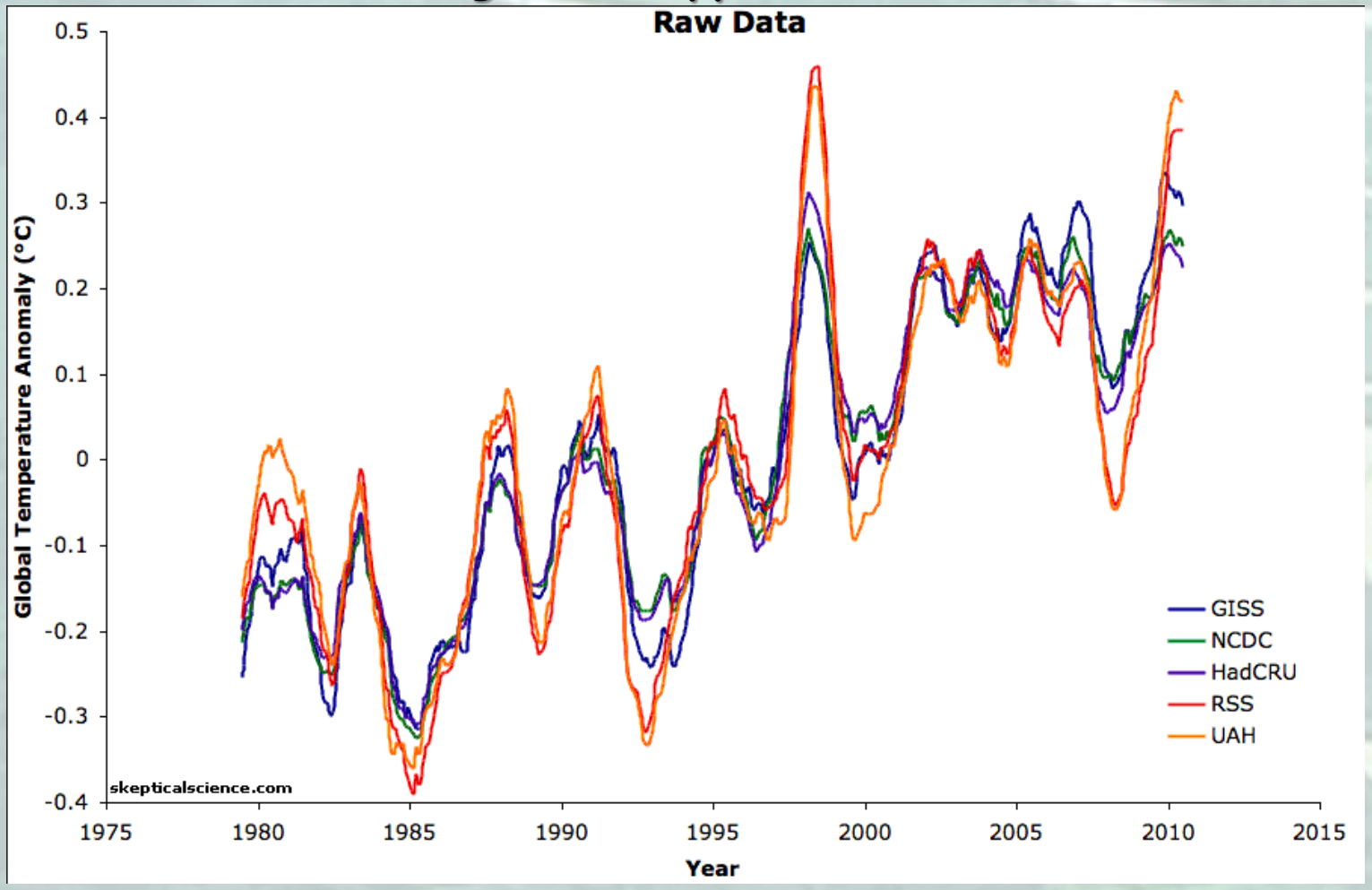


…although not evenly around the globe and in fits and starts



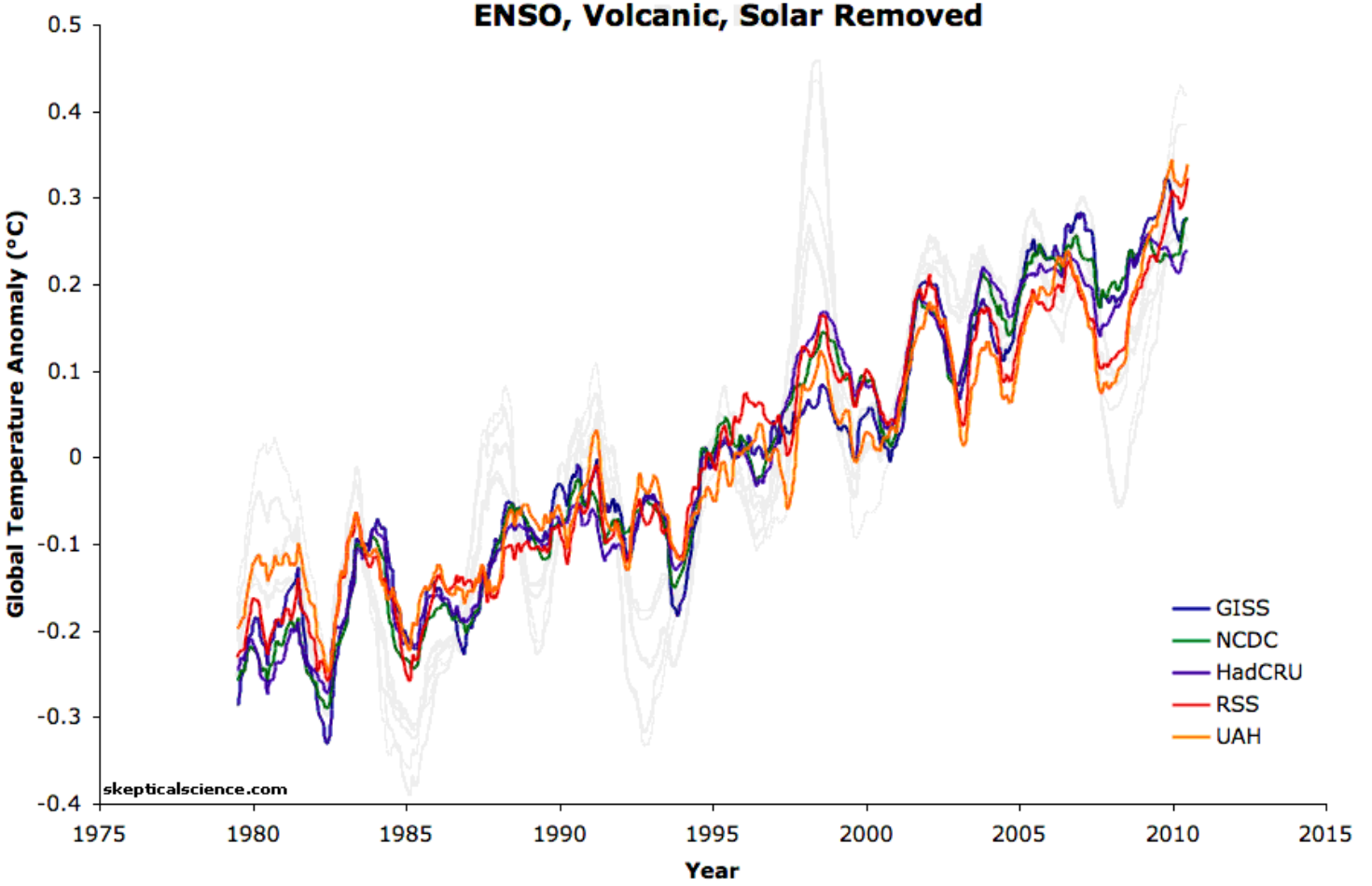
From NASA/GISS

…Troposphere (lower portion of the atmosphere) warming hiatus since the big El Nino year of 1998 is in the news giving the impression that warming has stopped even cooled some?

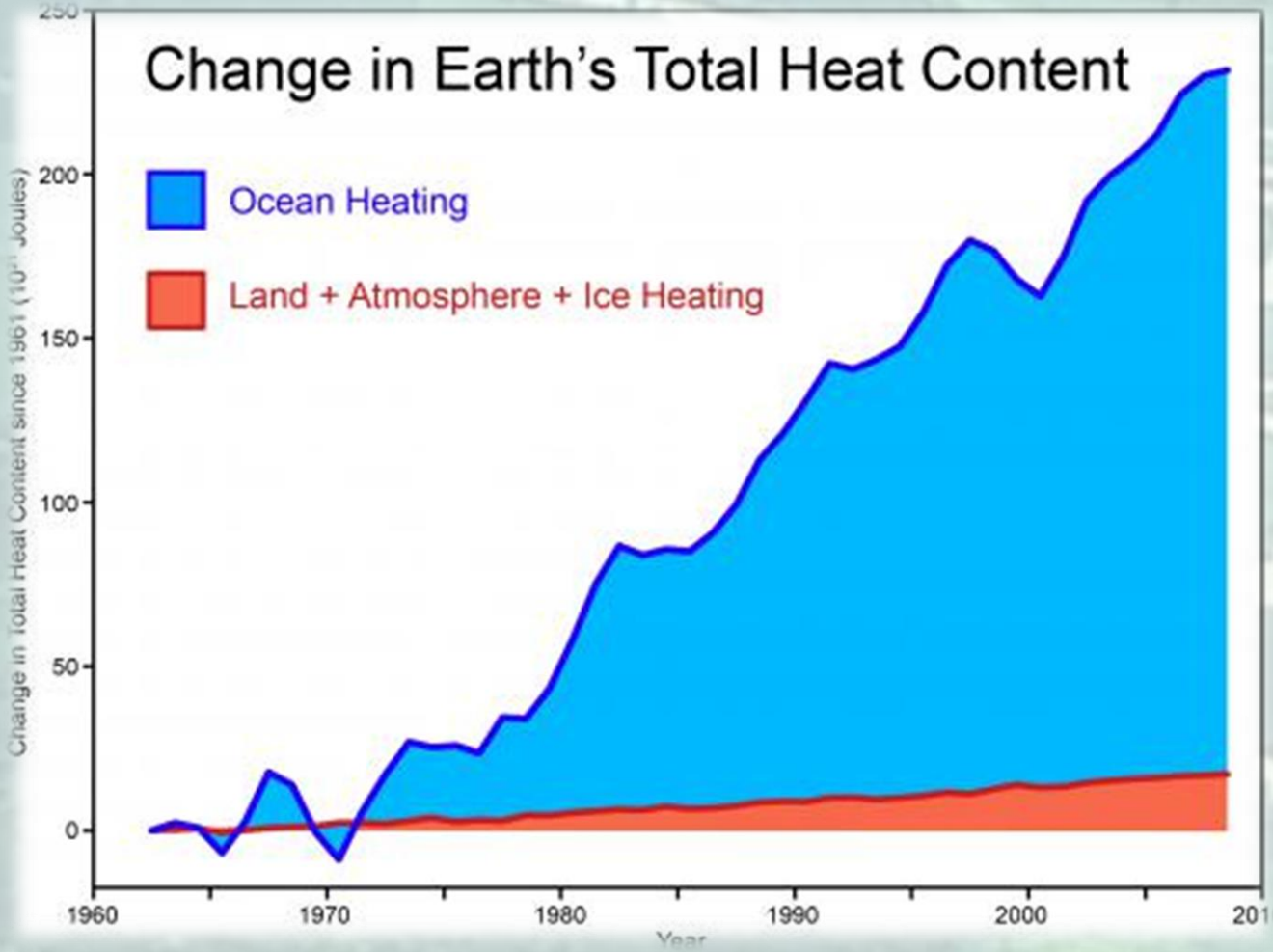


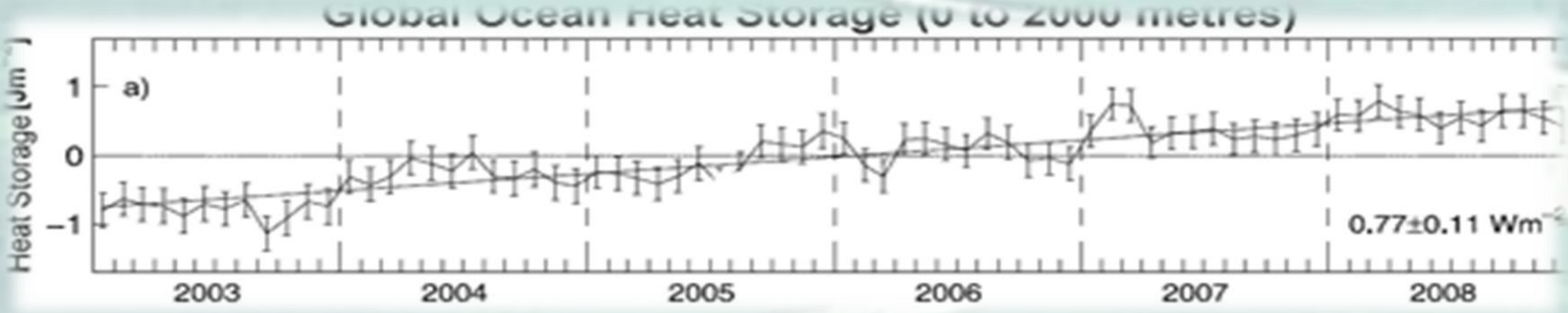
Despite this – Globally 10 of the warmest years on record have occurred since the big El Nino Spike of 1998

If one removes the effects of El Nino, Volcanic Ejection, and Solar cycles -- You unmask fairly steady state of a warming world…



EVEN MORE WORRISOME





USA TODAY
A GANNETT COMPANY

NEWS | SPORTS | LIFE | MONEY | TECH | TRAVEL | OPINION | 44°

This story is part of **CLIMATE CHANGE**

Alaska sinks as climate change thaws permafrost

Wildfire smoke becoming a serious health hazard

U.S. carbon emis... lowest level sin...

Pacific Ocean warming 15 times faster than before

Doyle Rice, USA TODAY *3:55 p.m. EDT October 31, 2013*

Some parts of the Pacific Ocean have warmed 15 times faster in the last 60 years than they did during the previous 10,000 years.

(Photo: Martin Bernetti, AFP/Getty Images)

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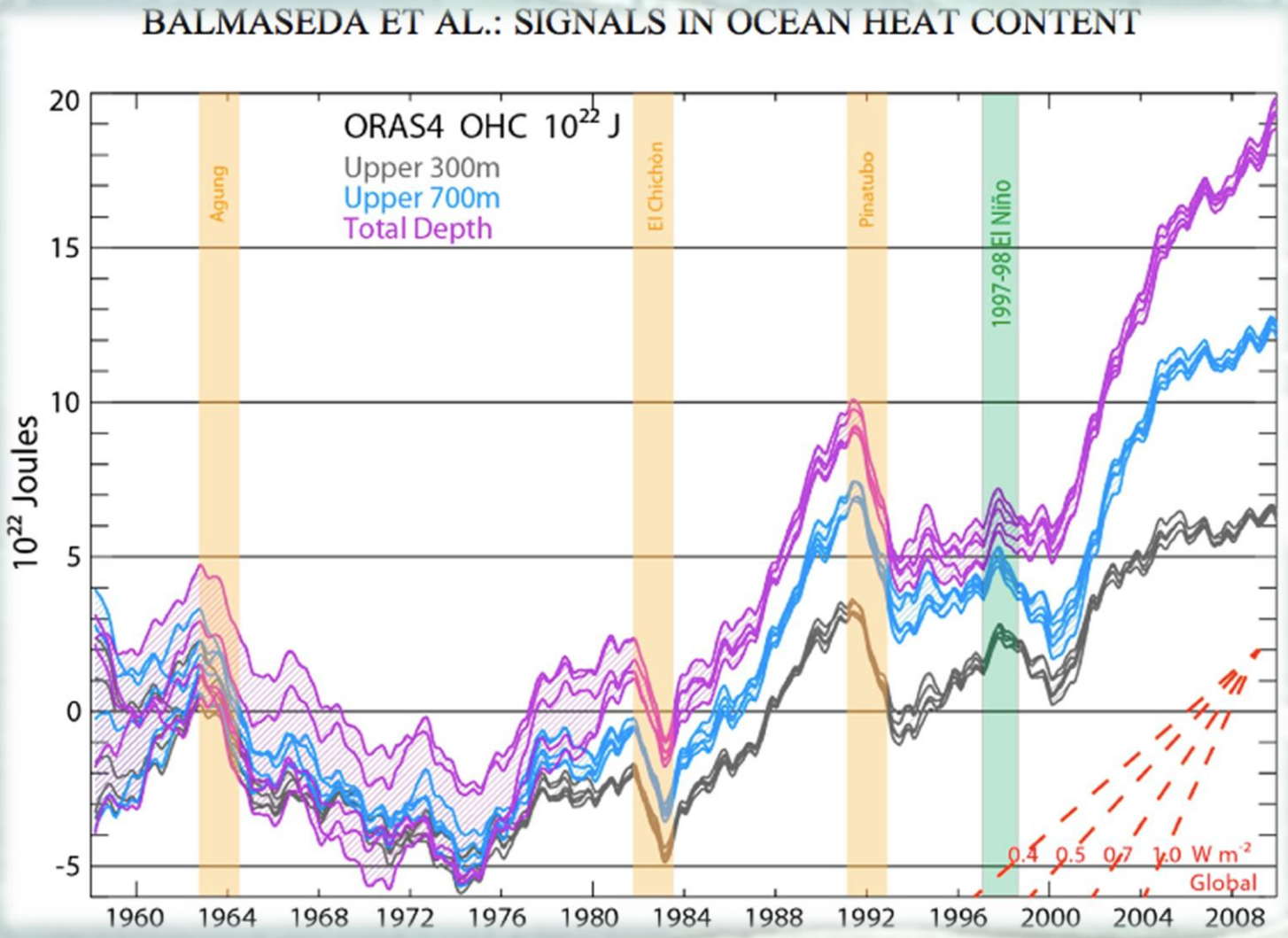
Although the temperature of the Earth's atmosphere may have hit the "pause" button recently — with little global warming measured over the past few years — that hasn't been the case with the oceans.

In a study out today in the journal *Science*, researchers say that the middle depths of a part of the Pacific Ocean have warmed 15 times faster in the past 60 years than they did during the previous

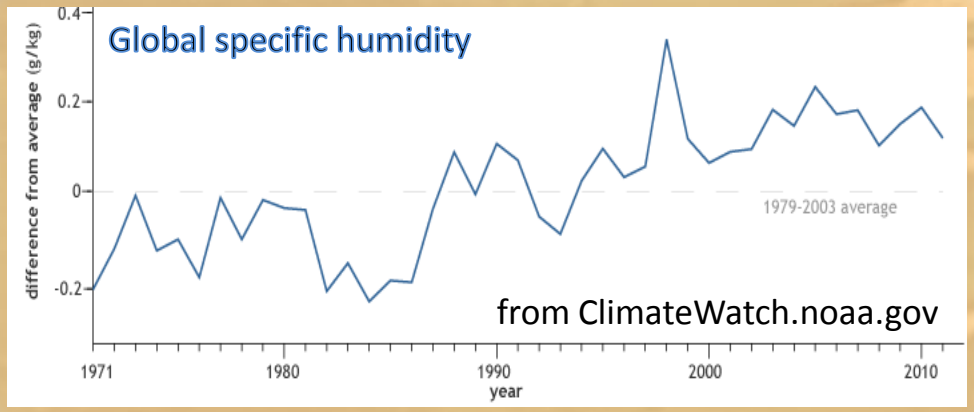
STORY HIGHLIGHTS

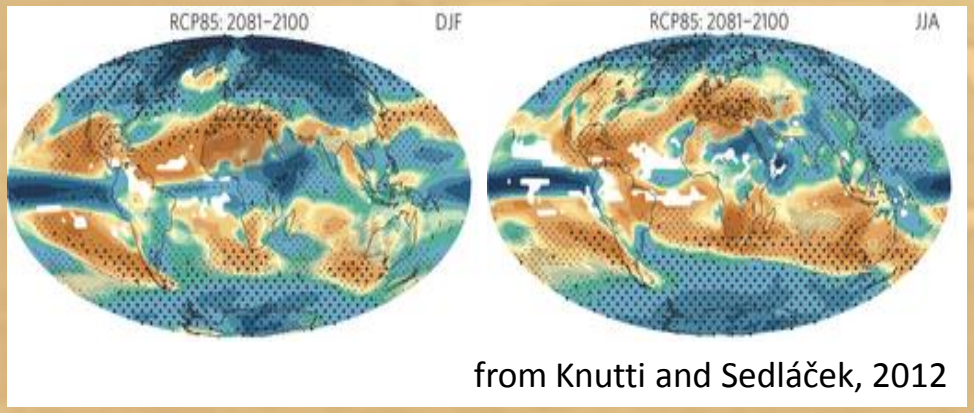
- Scientists may have

Big Ocean Heating !



And the atmosphere is gaining moisture…



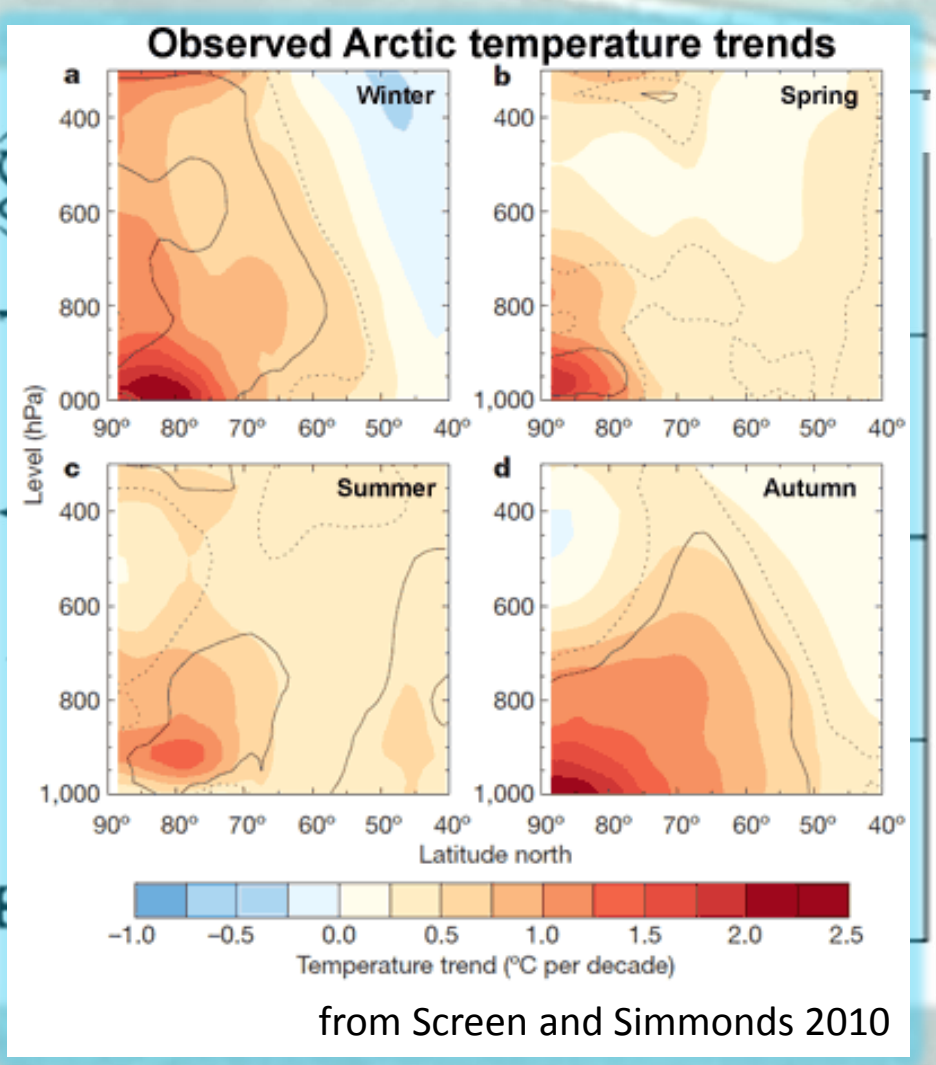


…providing more fuel to energize storms and more water to promote heavier precipitation…

…making wet places wetter, while a warmer world increases evaporation, making dry places drier…

The deck of cards we're playing with has changed…

Zero in on the Arctic…



from Screen and Simmonds 2010

The Arctic is warming at two to three times as fast as the rest of the N. Hemisphere

The last time the Arctic was this warm (~125,000 years ago) *sea level was 6-8 meters higher*

Sea ice is a mere shadow of former self…

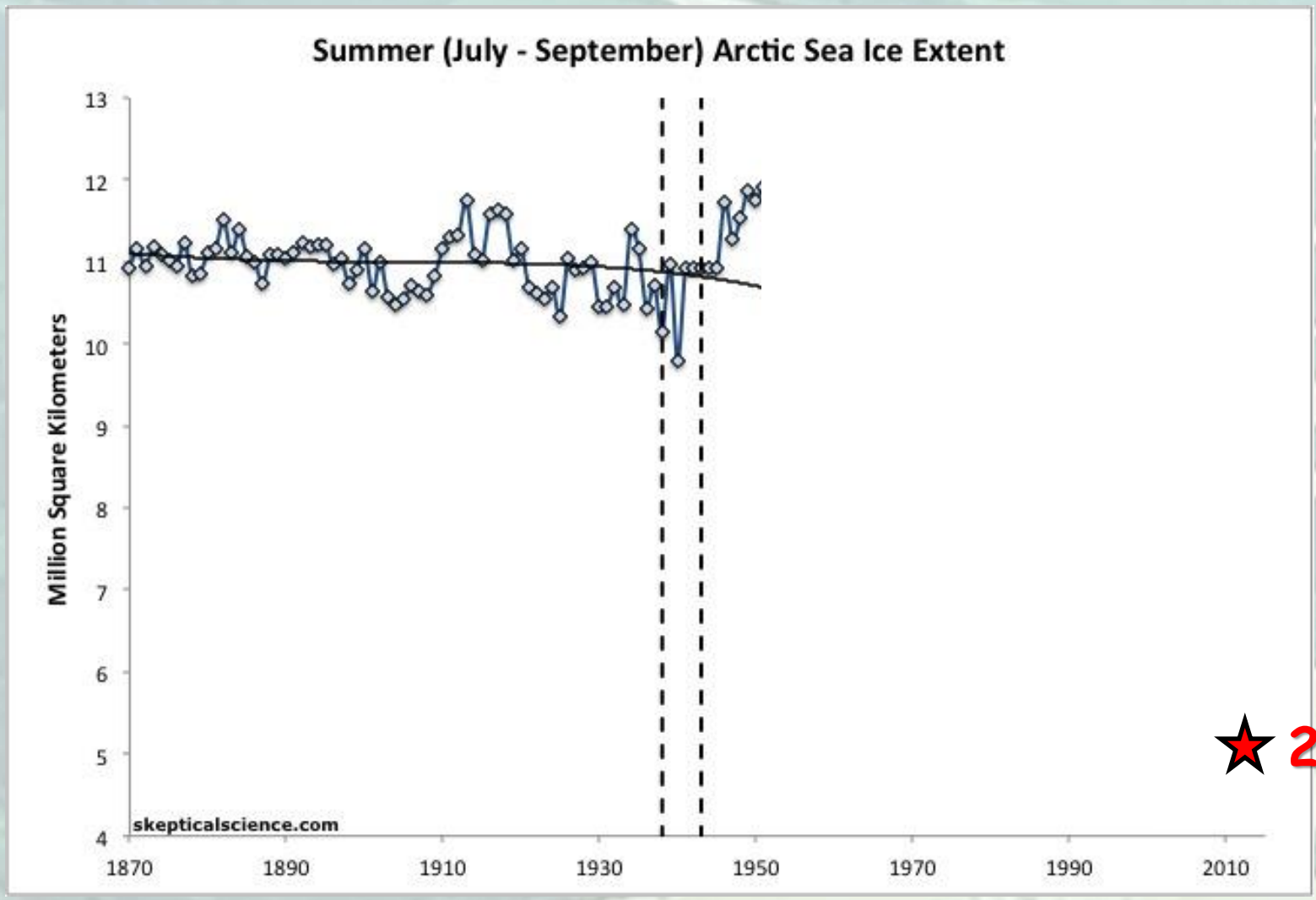
… in only 30 years

What's left is "rotten" and "slushy"

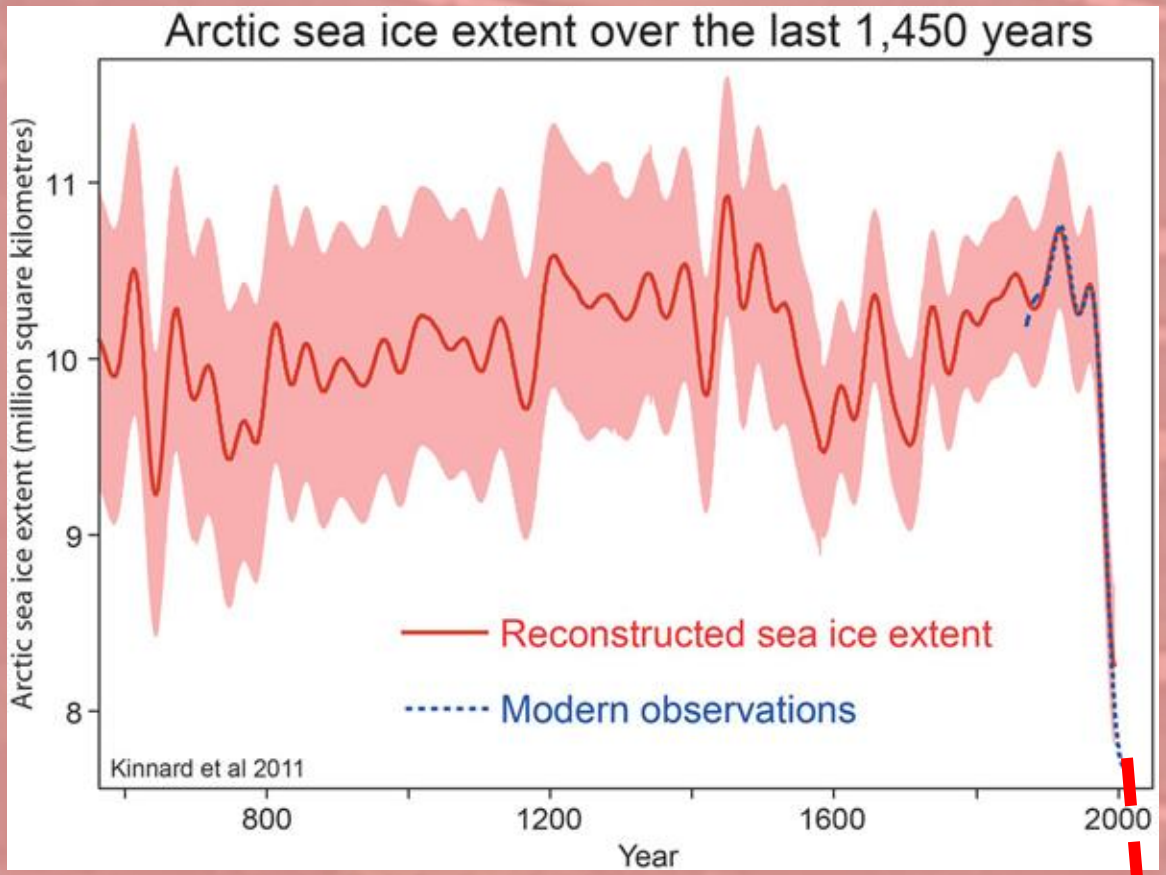
About HALF of summer ice has been lost…

…and 80% of the ice volume…

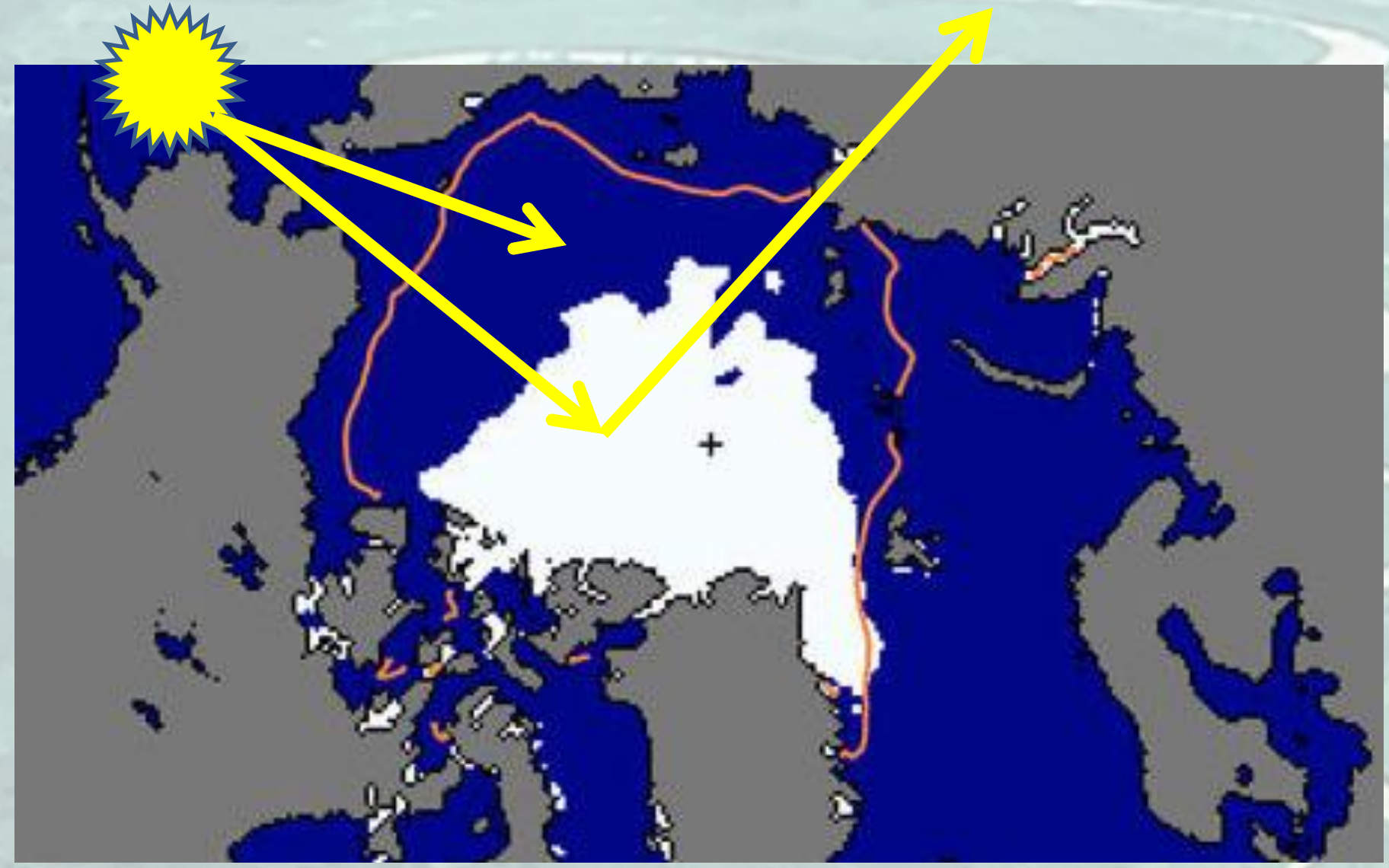
How unusual is this recent loss of Arctic sea ice?



Looking even farther back in time…

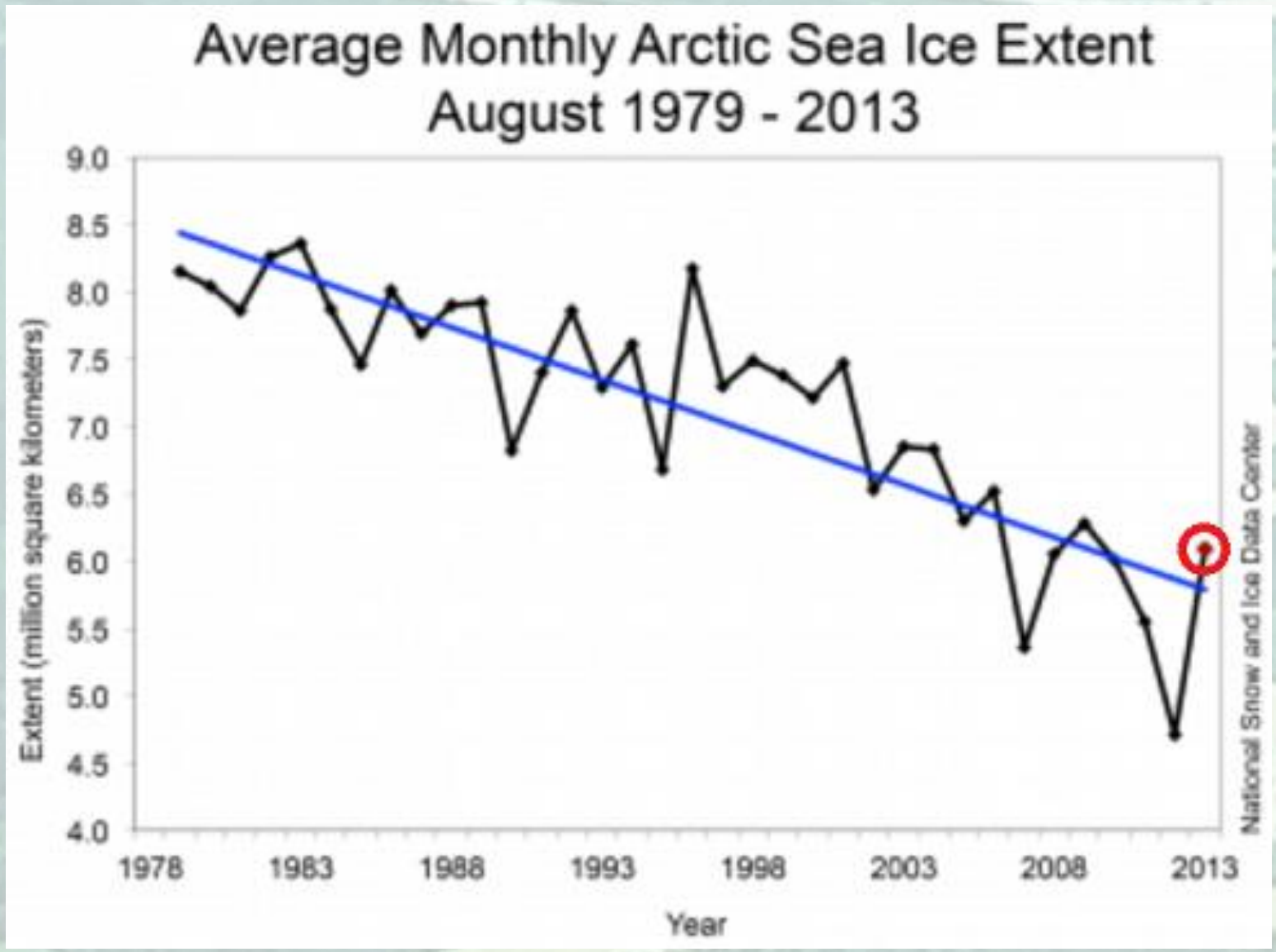


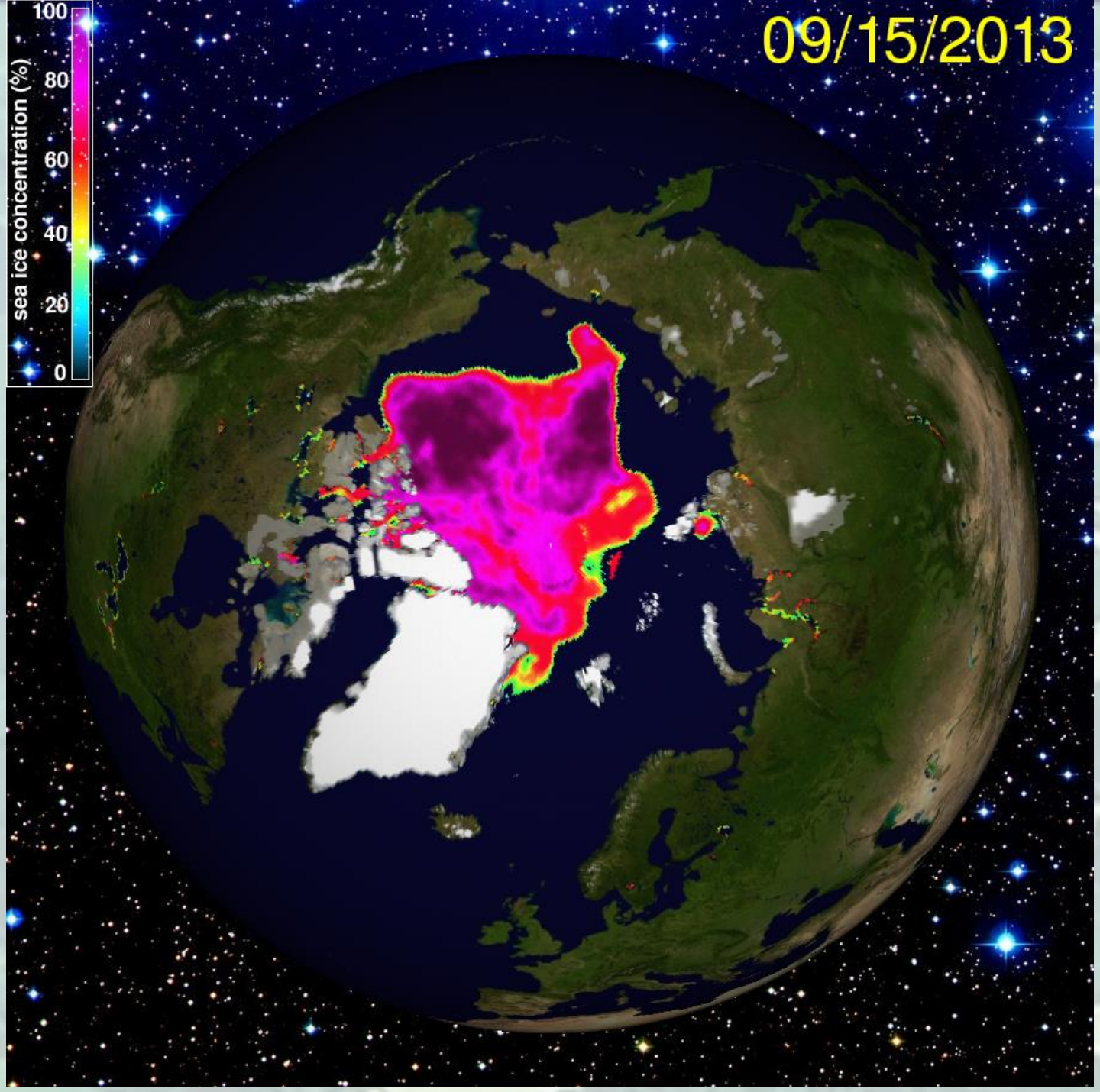
2012



Extreme minimum Ice extent September 2012

Sea Ice Extent Last Summer

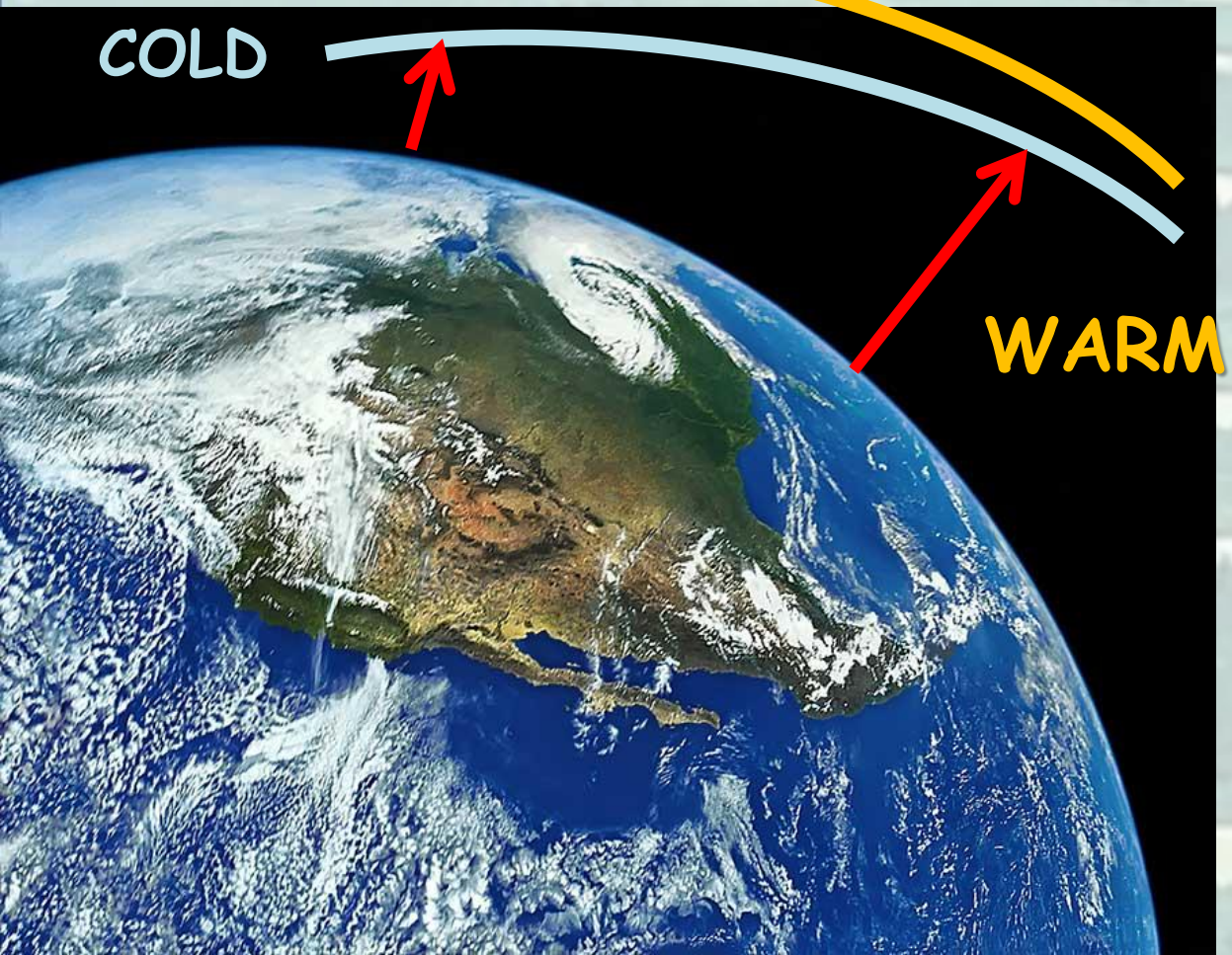



09/15/2013
sea ice concentration (%)
100
80
60
40
20
0

Because warm air expands, the layer will be thicker here than it is in the Arctic.

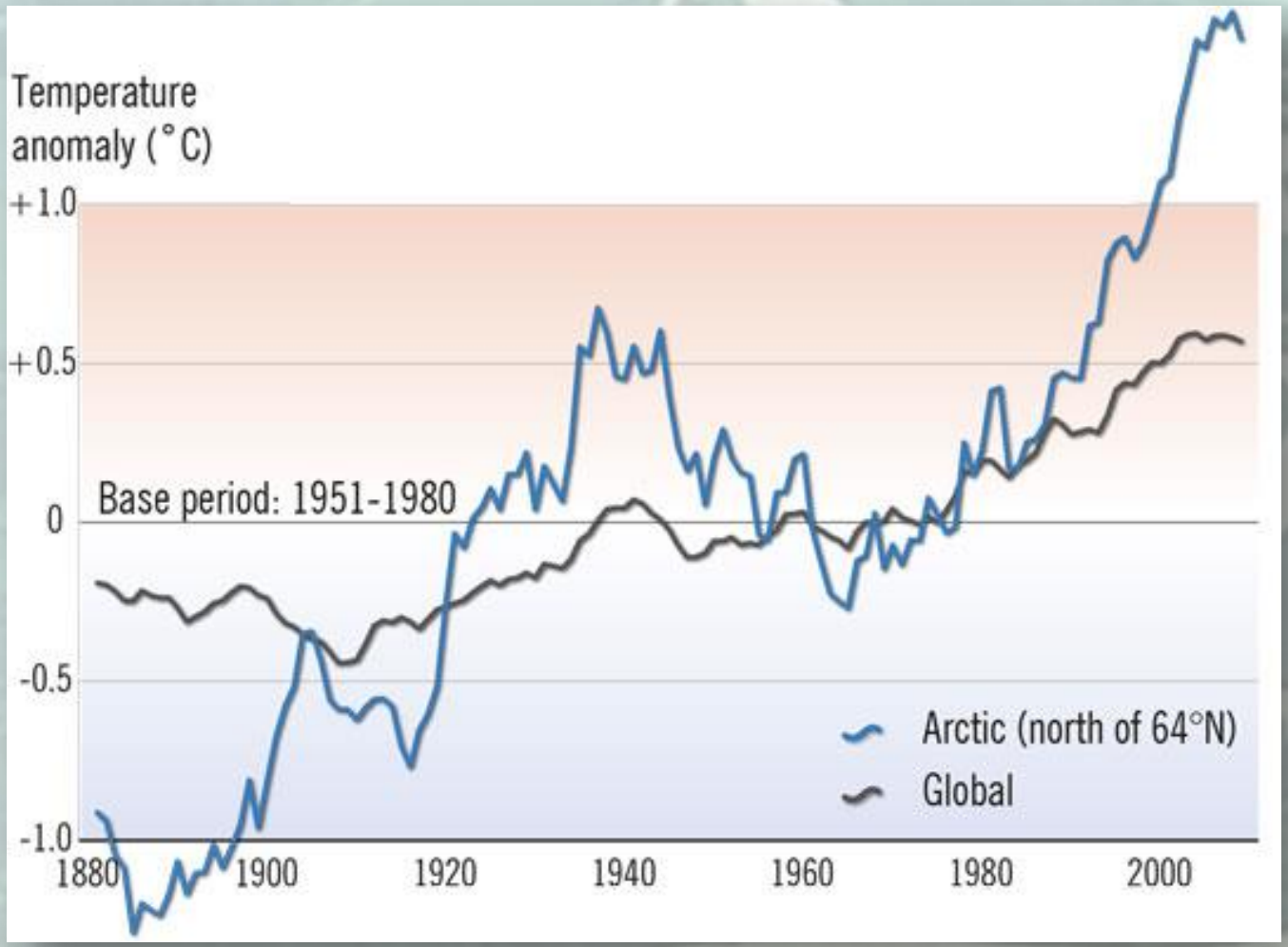
Consider a layer of atmosphere stretching from here (warm) to the Arctic (cold)

Air flows down this "hill", turns to the right as the Earth spins, and creates the Jet Stream



As the Arctic warms faster, the hill flattens, and the zonal component of the jet stream weakens

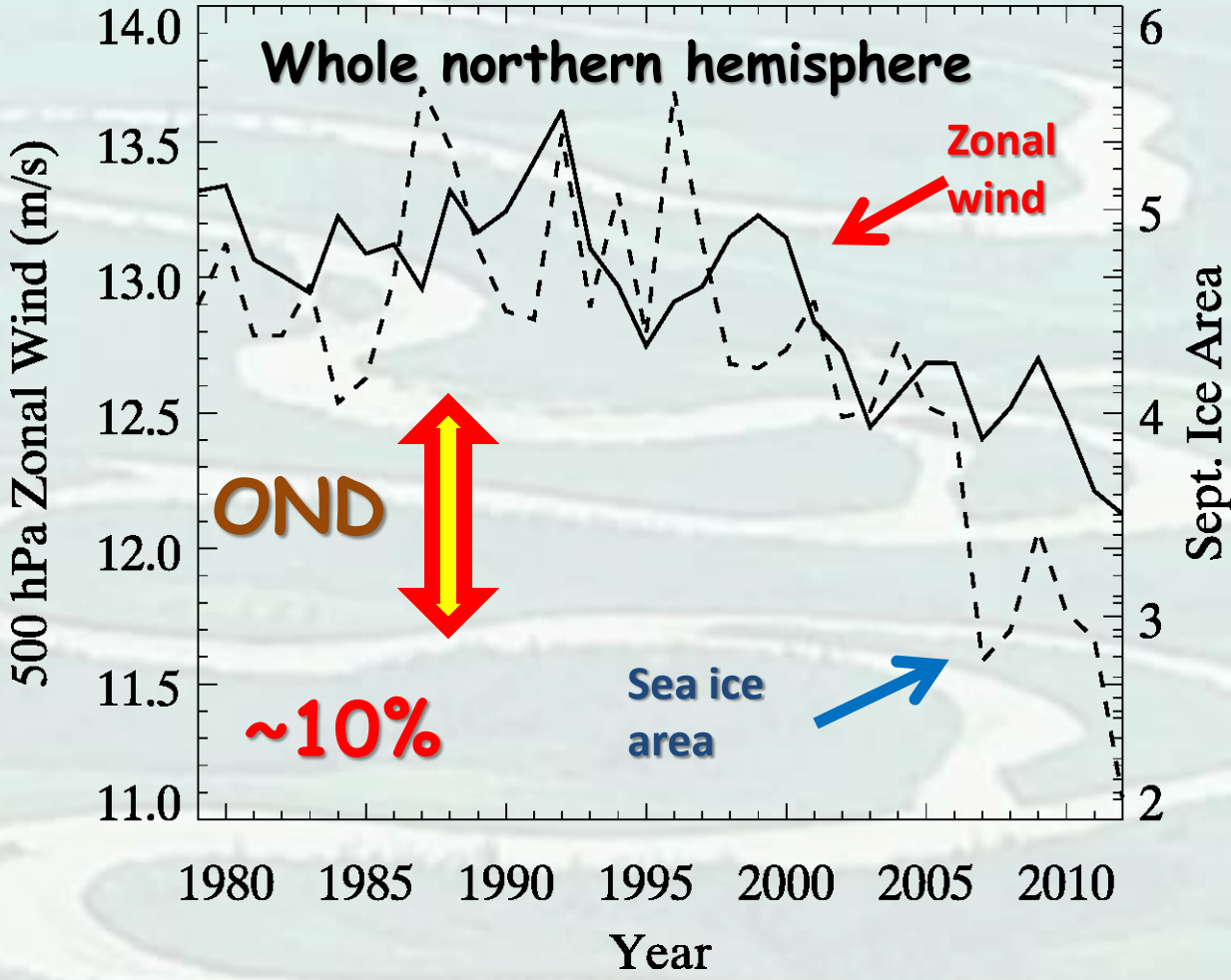
Arctic Amplification Process



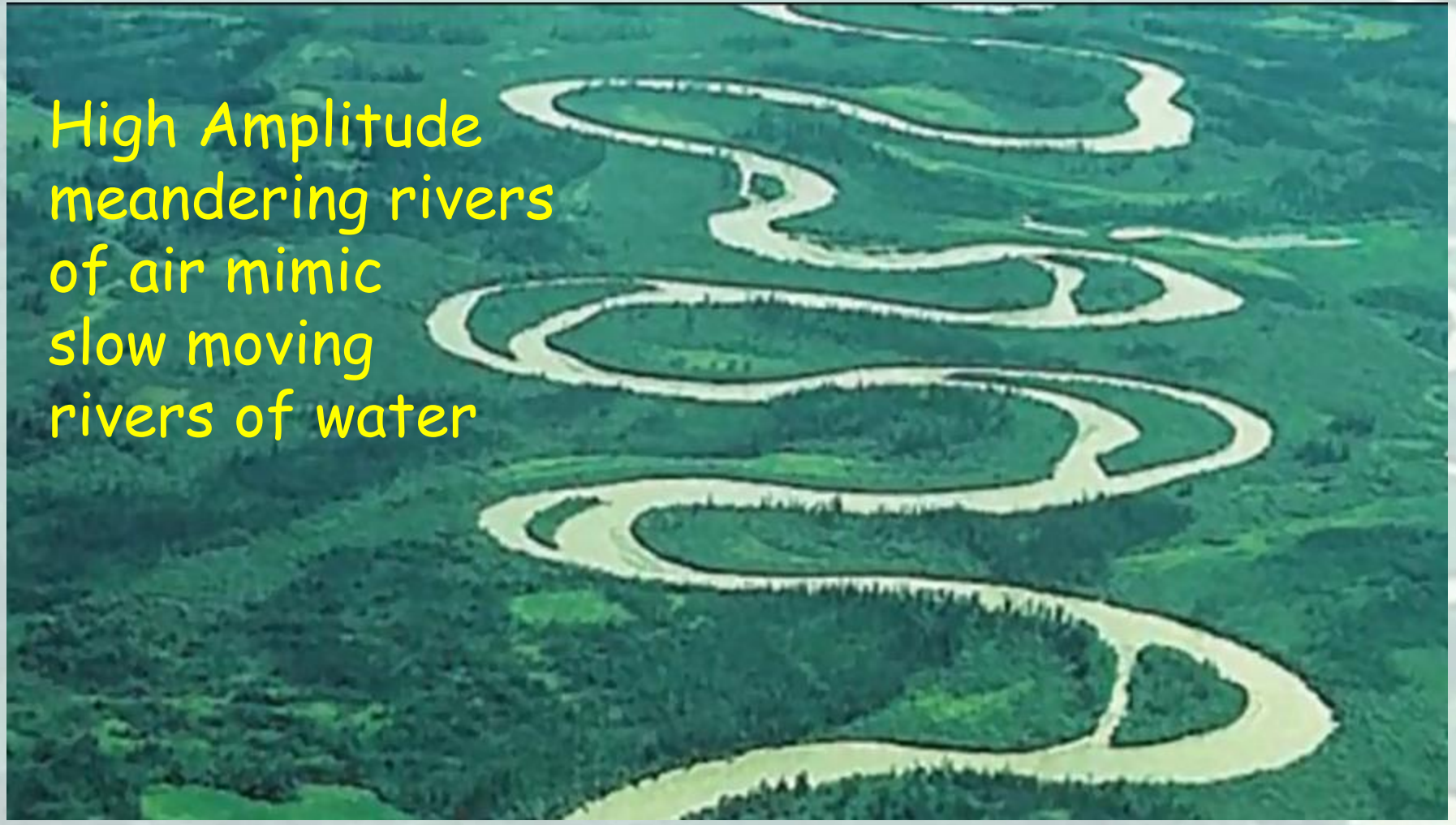
As the
HIGH
LATITUDES

warm faster
than the

MIDDLE
LATITUDES



Rossby theory - weaker westerly flow favors more meandering pattern, slower eastward wave propagation.

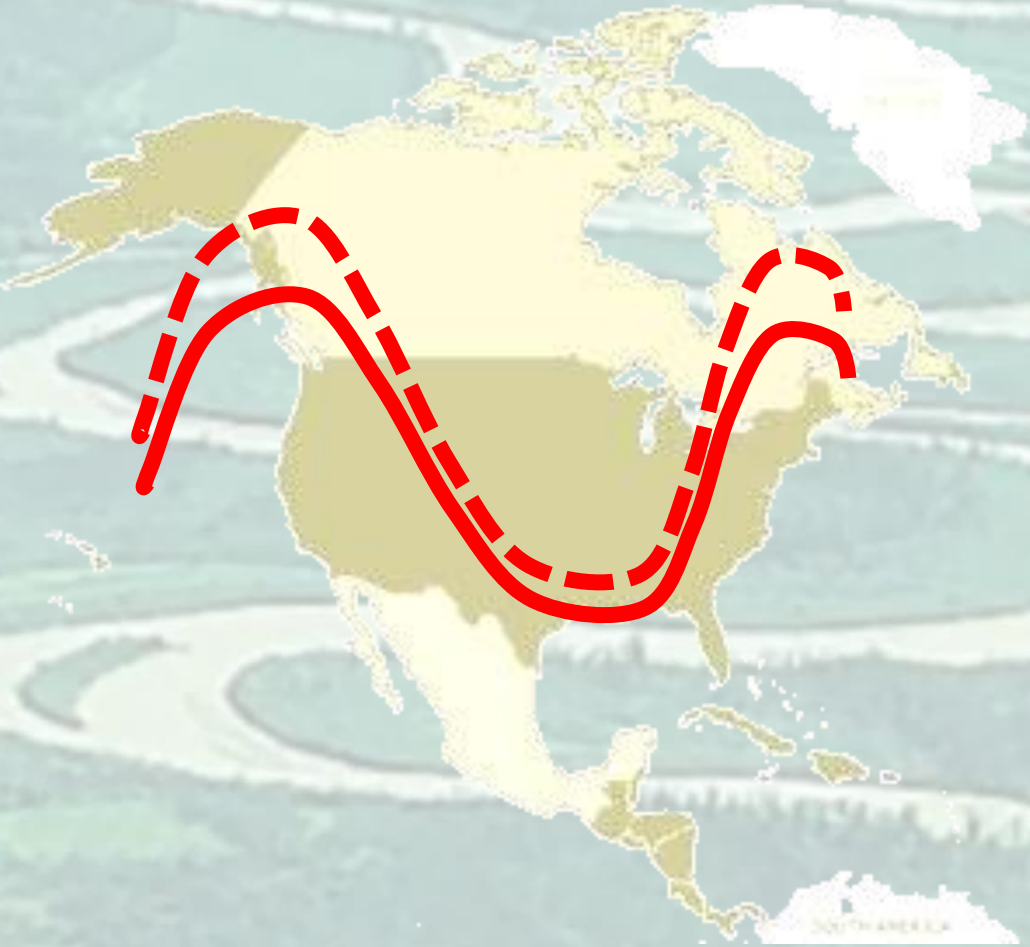


Note the interesting island deposits of sediments

As the
HIGH
LATITUDES

warm faster
than the

MIDDLE
LATITUDES



from Francis and Vavrus, GRL 2012

Arctic Amplification is alive and well:

High latitudes are warming much faster than mid-latitudes, especially in fall and winter

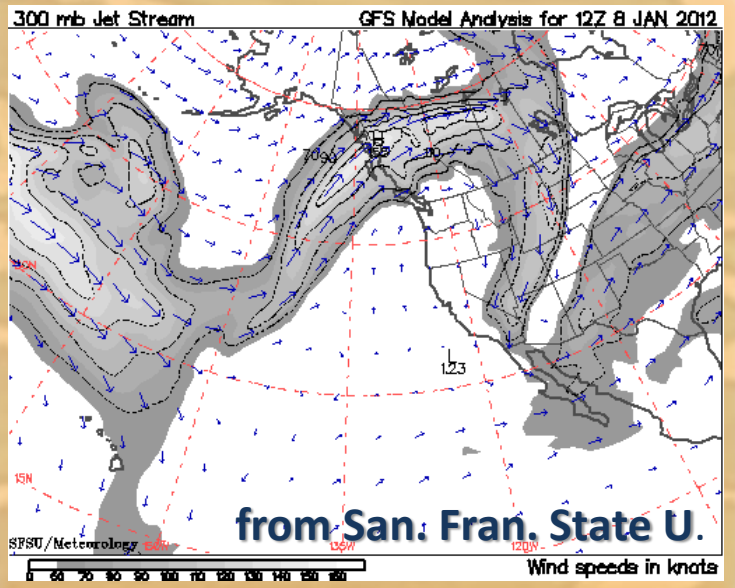
- Poleward thickness gradient is weakening

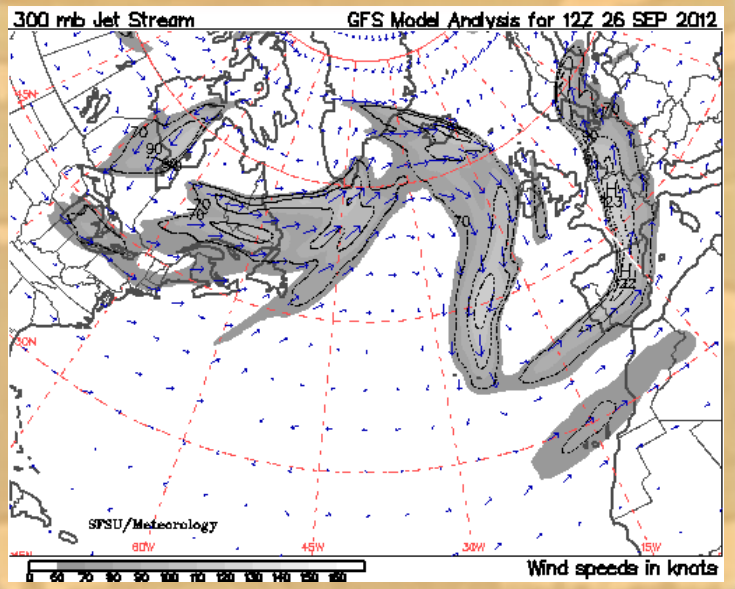
Zonal-mean flow @500mb is weakening, flow meanders more

Peaks of ridges are elongating northward, wave amplitude is increasing

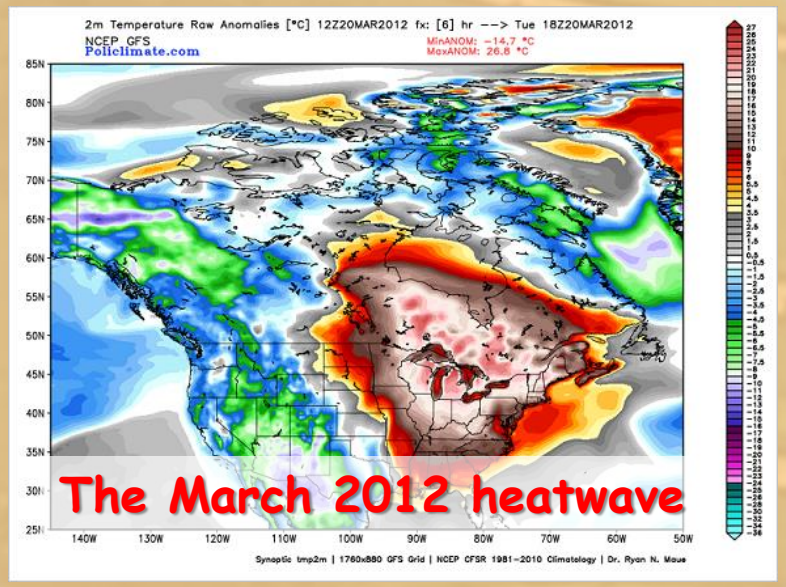
- More amplified Rossby waves *should* progress eastward more slowly and increase likelihood of blocking
- Weather conditions more persistent
- *Increased probability of extremes: cold spells, heat waves, flooding, prolonged snowfall, and drought*

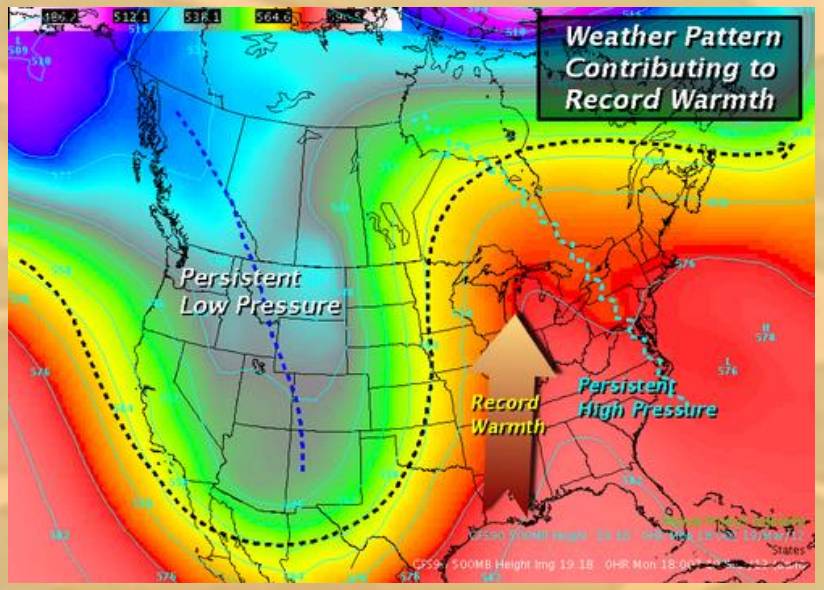
The signature of persistent patterns that can lead to extremes…

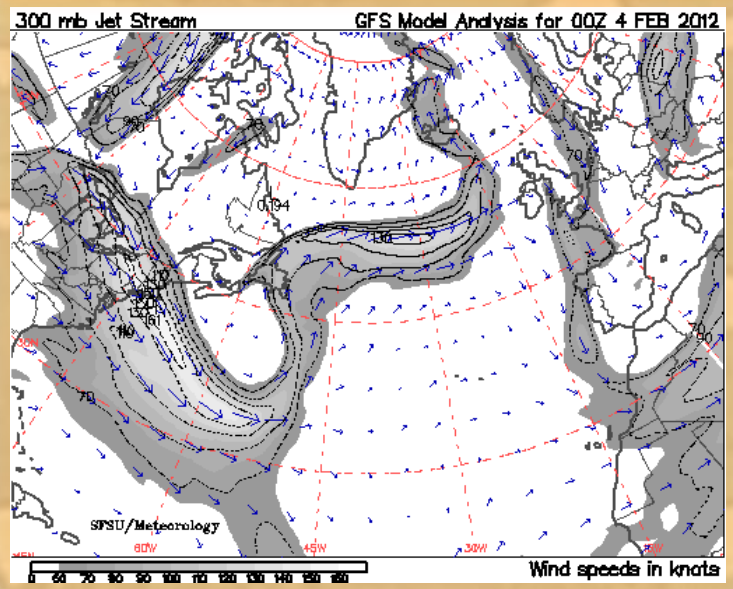




The signature of persistent patterns that can lead to extremes…

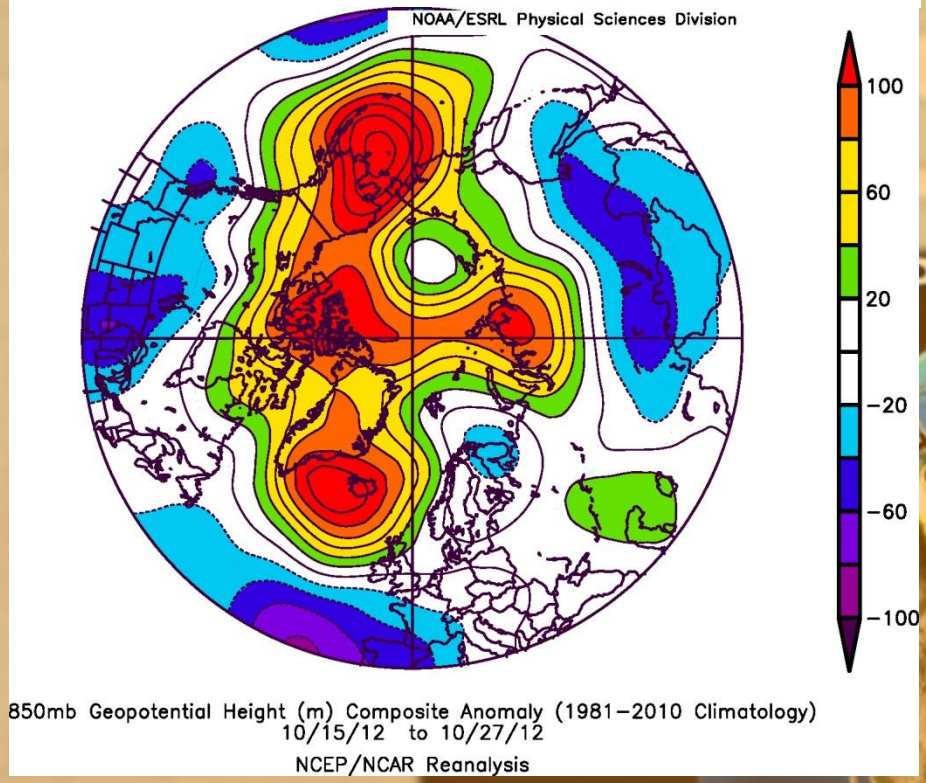






The $64B question: Was the path of Sandy affected by the record sea-ice loss in 2012?

The Arctic was MUCH warmer than normal

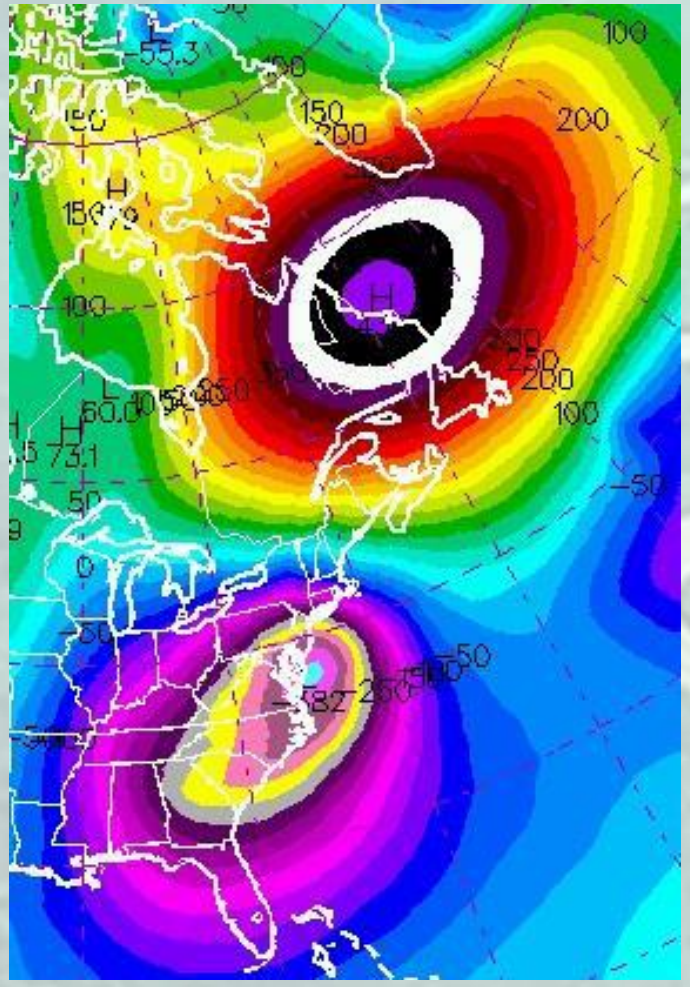


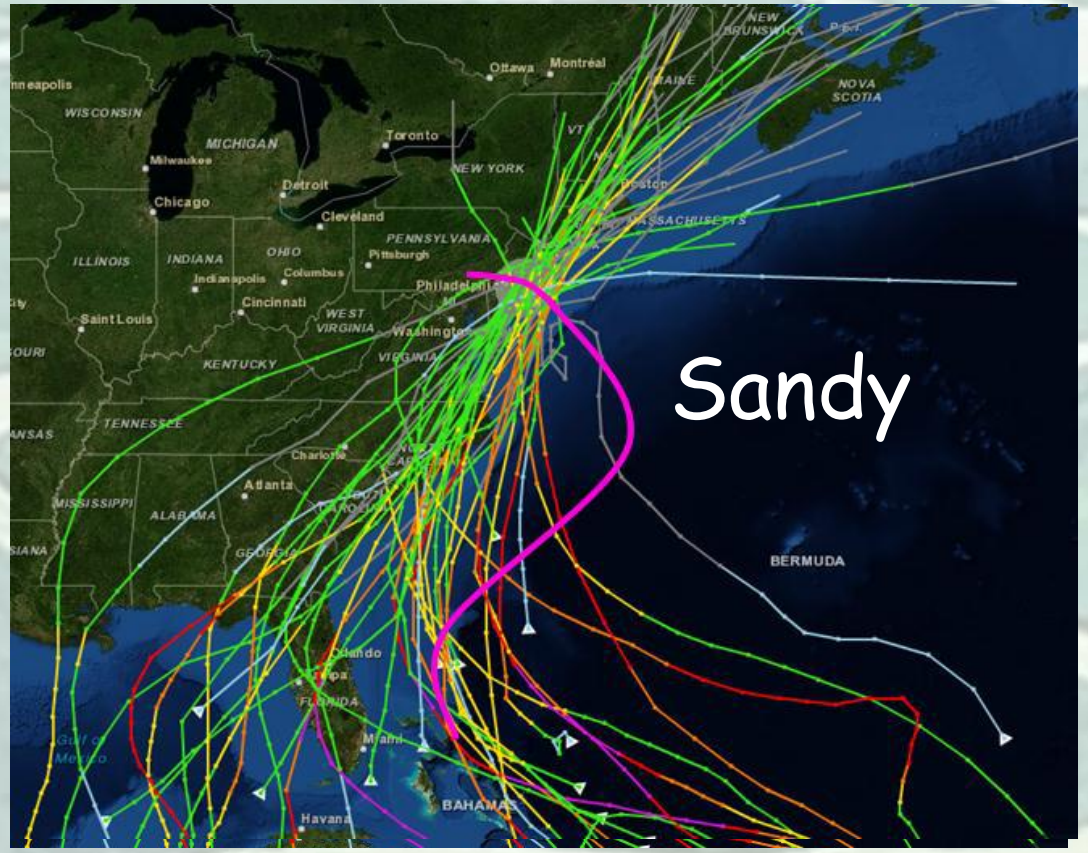
Was block strengthened, extended northward, or prolonged by AA?

Maybe.

As oceans warm, hurricane seasons may lengthen, storms can survive farther north, and perhaps interact more frequently with jet-stream troughs

Sandy




Sandy
Ottawa
Montréal
Toronto
Milwaukee
Detroit
Chicago
Cleveland
Pittsburgh
Columbus
Indianapolis
Cincinnati
Saint Louis
Philadelphia
Washington
Charlotte
Atlanta
Orlando
Miami
Havana
WISCONSIN
MICHIGAN
NEW YORK
PENNSYLVANIA
OHIO
INDIANA
ILLINOIS
WEST VIRGINIA
VIRGINIA
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
MAINE
NOVA SCOTIA
BERMUDA
BAHAMAS

To Recap

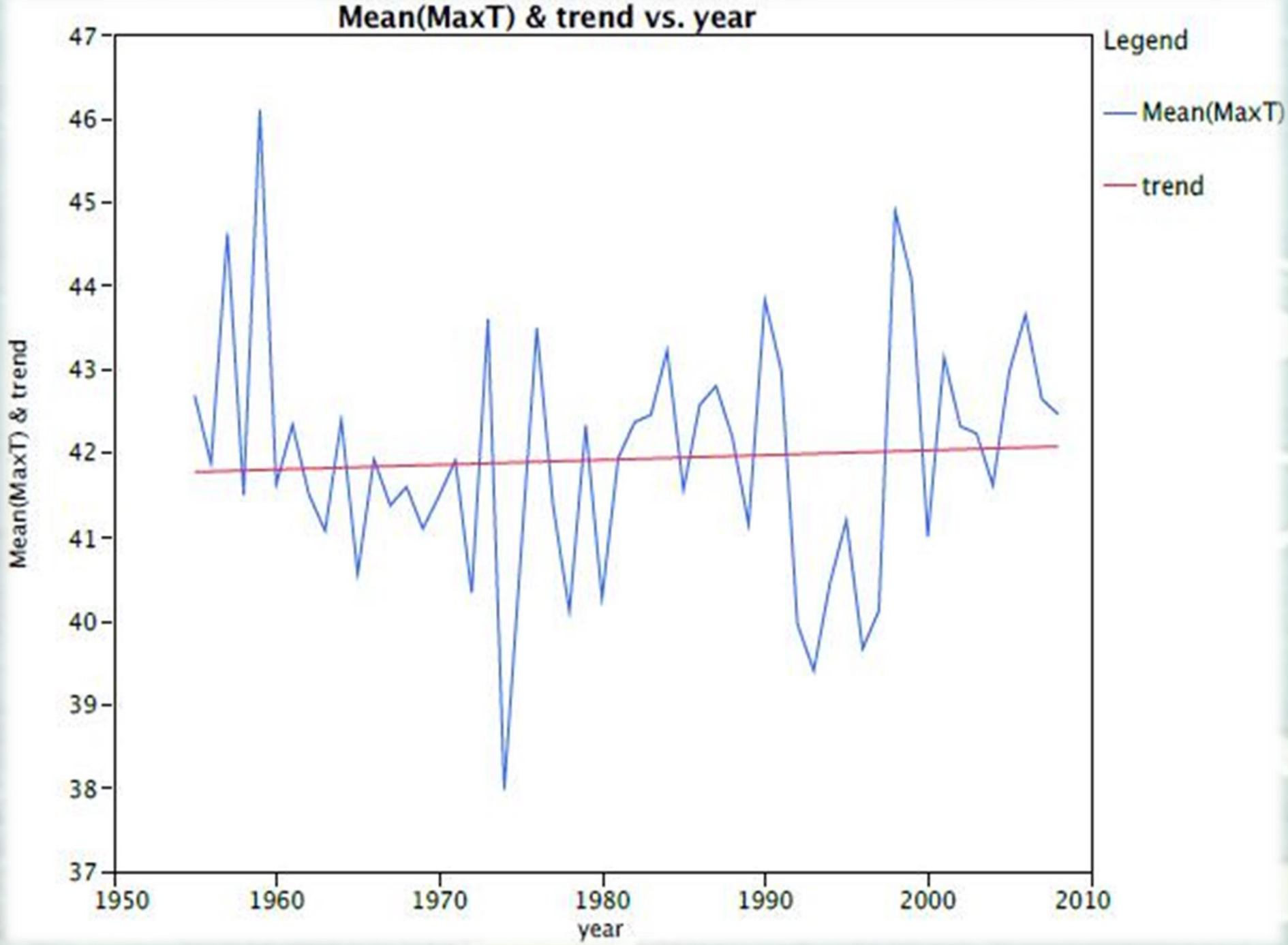
- Meandering slowing sometimes stuck jet stream can make for persistent storms and from what I can tell, it can happen here in Vermont.

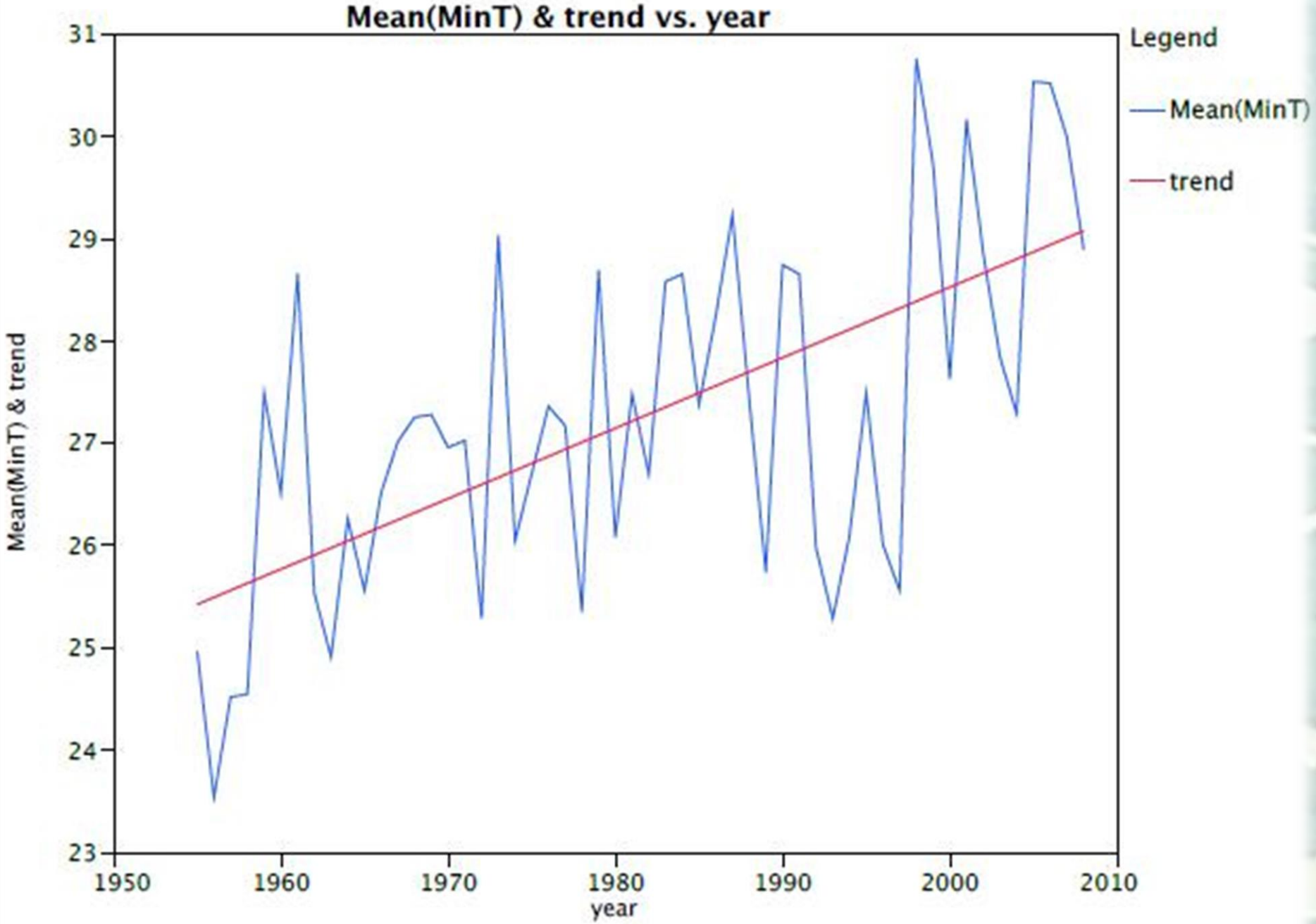
- Thus slow moving weather systems can mean extra trouble…persistent weather systems can bring too much of one thing. During certain times of any season keep a lookout for this on daily weather maps

MOUNT MANSFIELD STUDY -

Rising Temperature and Precipitation Trends on Mount Mansfield Summit Wesley Alan Wright, Academic Computing Services, University of Vermont waw@uvm.edu
Vermont Monitoring Cooperative 2009 Annual Meeting

Results suggest that over a 58 year period the minimum daily temperature, precipitation, and snow depth have risen, while the maximum daily temperature has remained steady.


Mean(MaxT) & trend vs. year
Legend
Mean(MaxT)
trend
Mean(MaxT) & trend
year
47
46
45
44
43
42
41
40
39
38
37
1950
1960
1970
1980
1990
2000
2010


Mean(MinT) & trend vs. year
Legend
Mean(MinT)
trend
Mean(MinT) & trend
year
31
30
29
28
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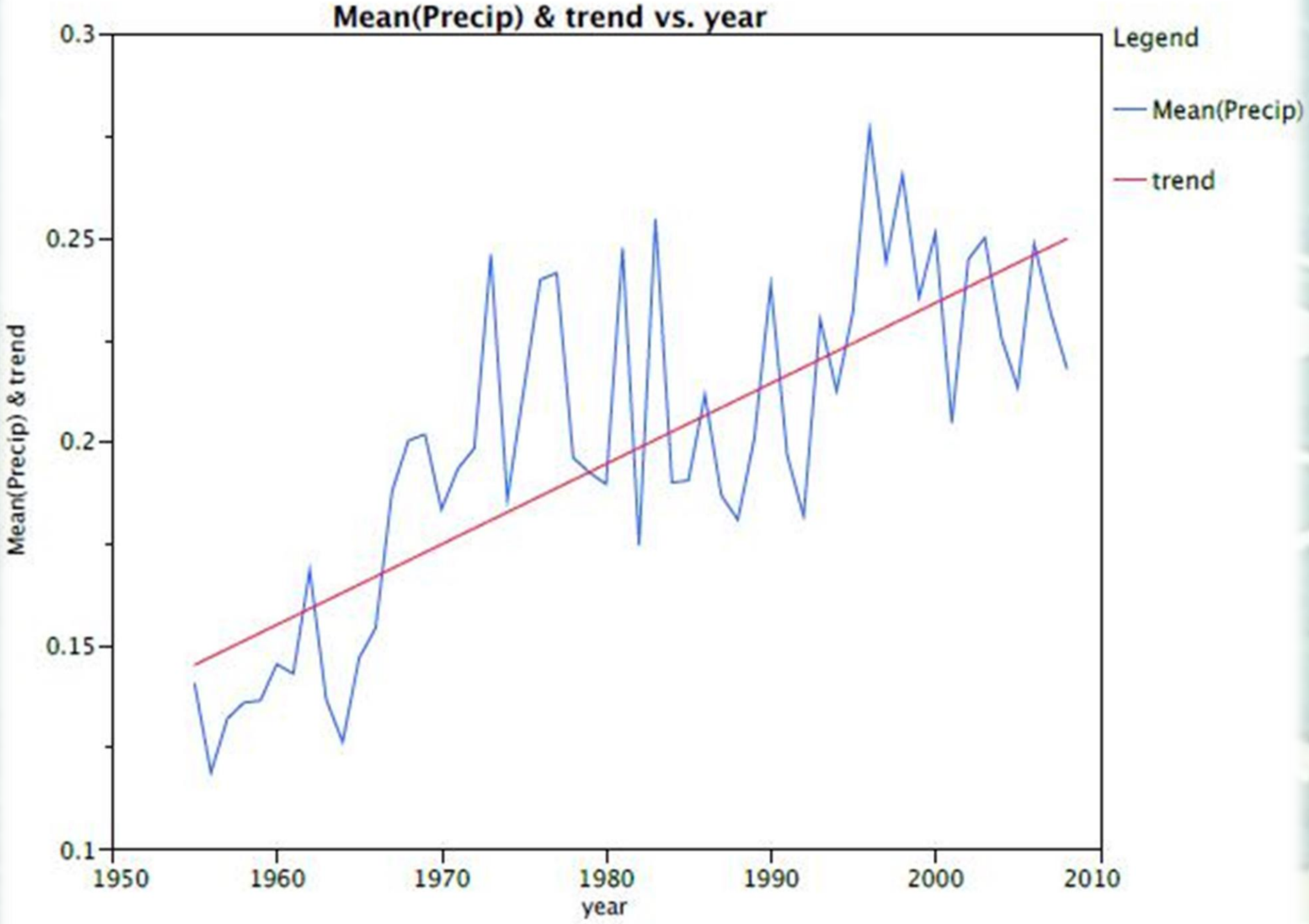
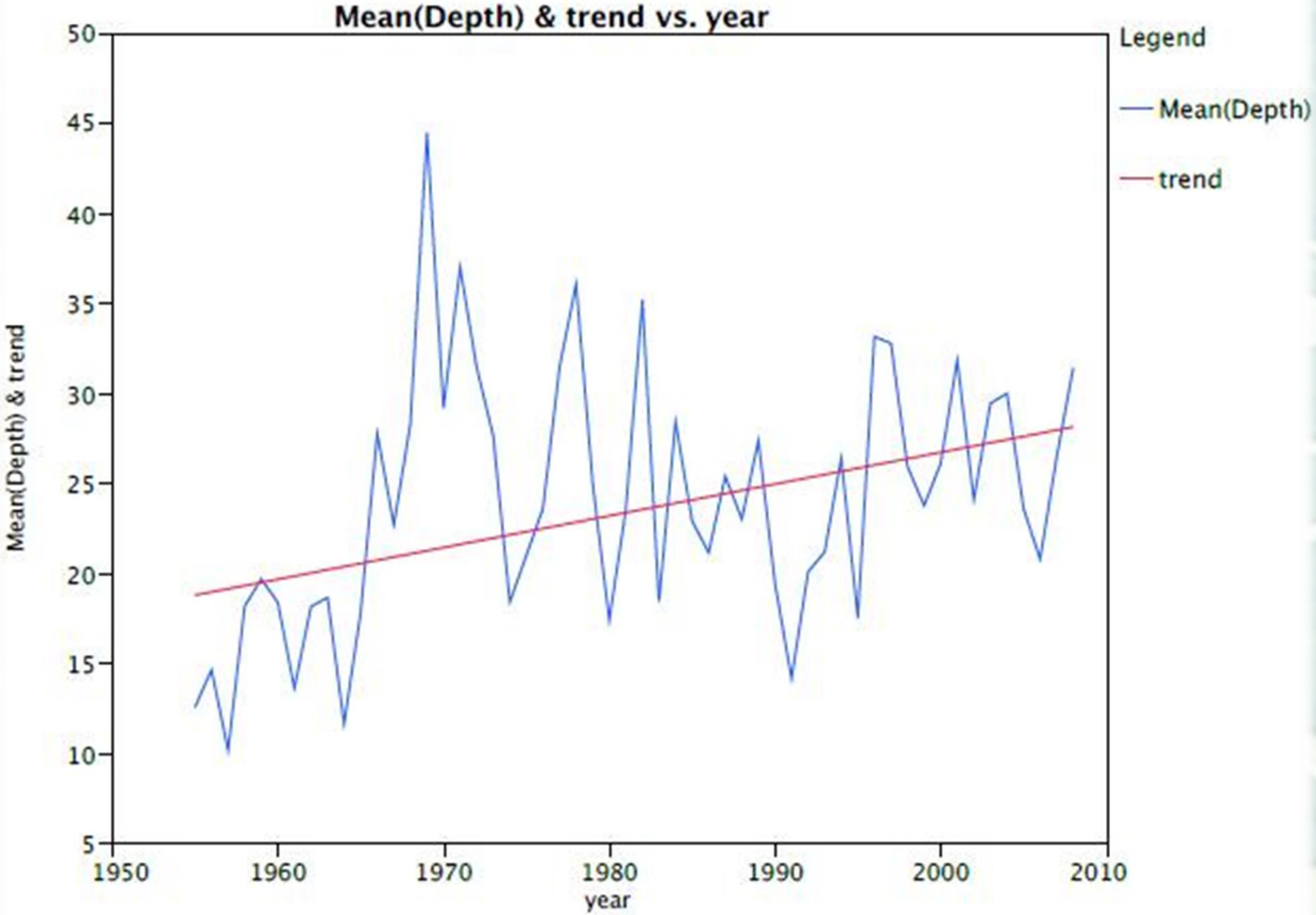
1950
1960
1970
1980
1990
2000
2010

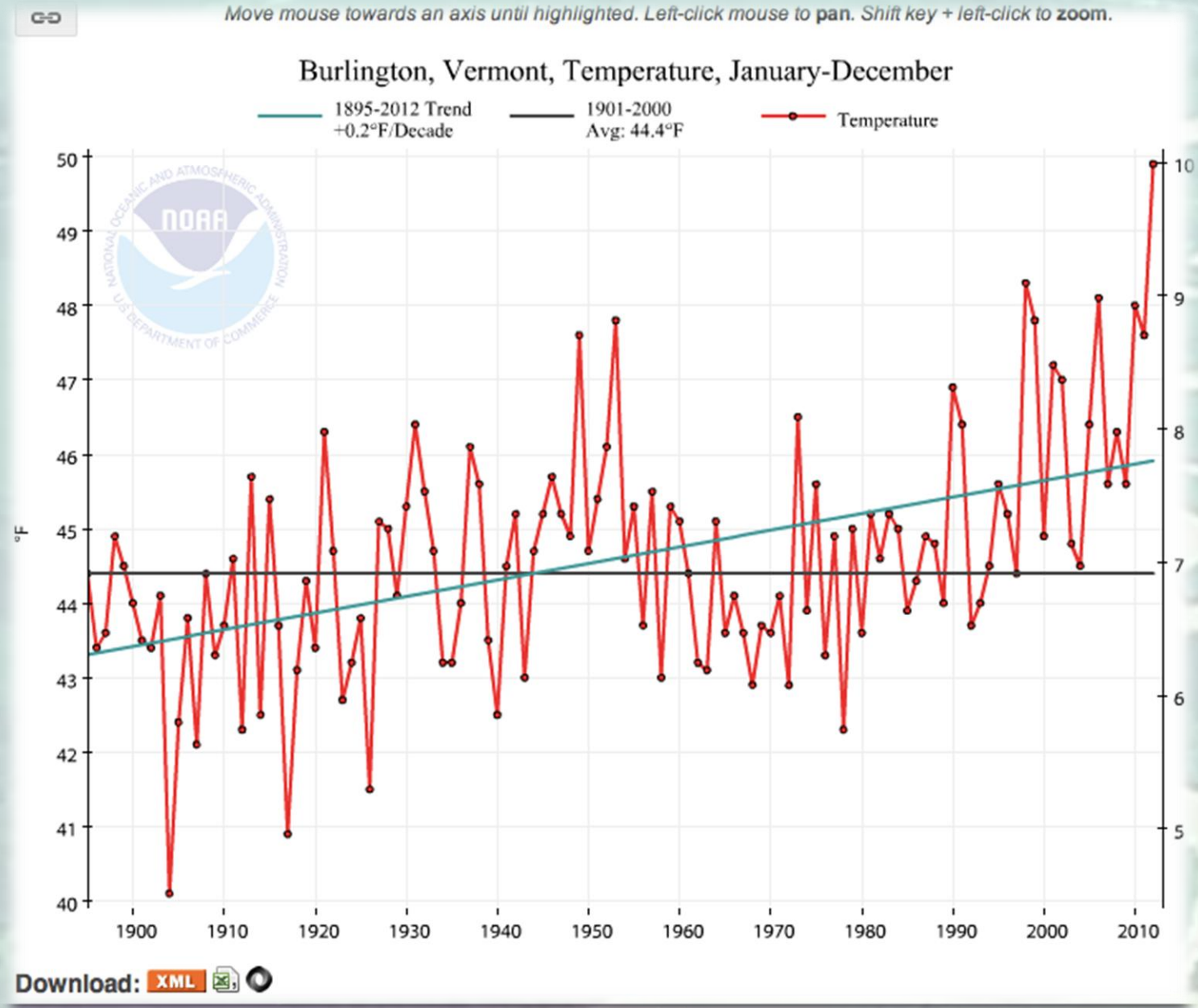

Mean(Precip) & trend vs. year
Legend
Mean(Precip)
trend
0.3
0.25
0.2
0.15
0.1
Mean(Precip) & trend
1950
1960
1970
1980
1990
2000
2010
year


Mean(Depth) & trend vs. year
Legend
Mean(Depth)
trend
Mean(Depth) & trend
year
50
45
40
35
30
25
20
15
10
5
1950
1960
1970
1980
1990
2000
2010

Conclusions:

The results present strong evidence that while daytime temperatures on Mount Mansfield have remained consistent over the last half century, night time temperatures, precipitation, and summit snow depth are all on the rise. However, snow depth is not increasing as quickly as precipitation.

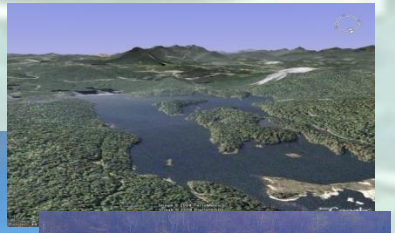
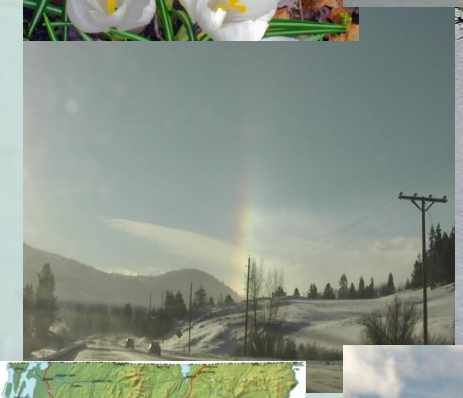
This may suggest that the rising temperatures will spell more rain rather than snow events in coming years.

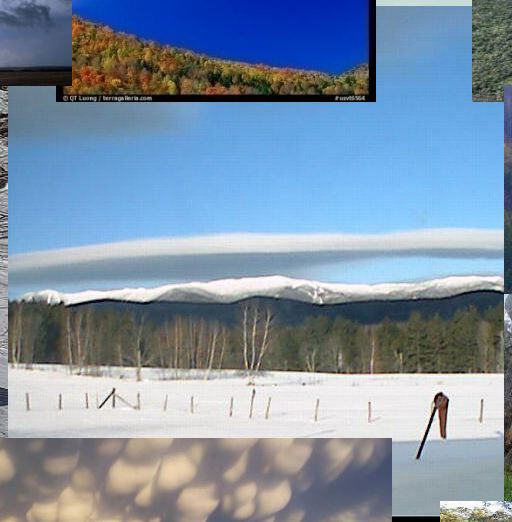

Move mouse towards an axis until highlighted. Left-click mouse to pan. Shift key + left-click to zoom.
Burlington, Vermont, Temperature, January-December
1895-2012 Trend
+0.2°F/Decade
1901-2000
Avg: 44.4°F
Temperature
°F
50
49
48
47
46
45
44
43
42
41
40
10
9
8
7
6
5
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Download: XML

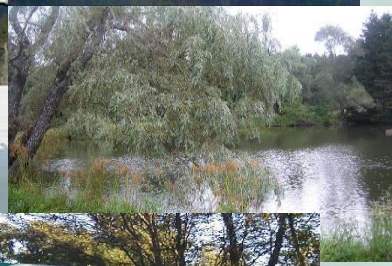
QUESTIONS

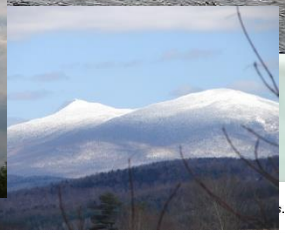




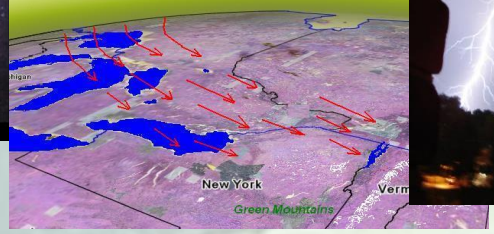



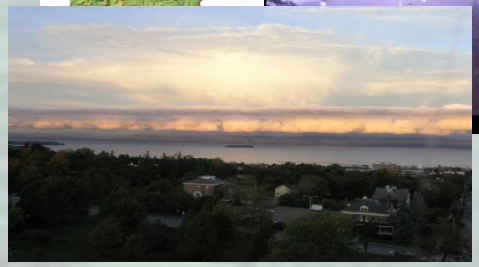











WELCOME TO VERMONT
GREEN MOUNTAIN STATE
WELCOME CENTER
2004/05/14
Alberta Clipper systems that travel through the prairies of Canada
up copious amonts of Great Lakes moisture and slam it into the Gree
This northwesterly flow will be around through the Christmas holida
New York
Green Mountains
Glaciation or cirro-form fuzzy tops...
Low Topped Convection
Looks north from the Burlington International Airport,
one of two waves of thunderstorms/showers moving
toward the station late in the day
Dark Bases of the clouds
Cool Regime Thunderstorms crossed out of Canada July 2nd
and brought gusty winds and sparse lightning.