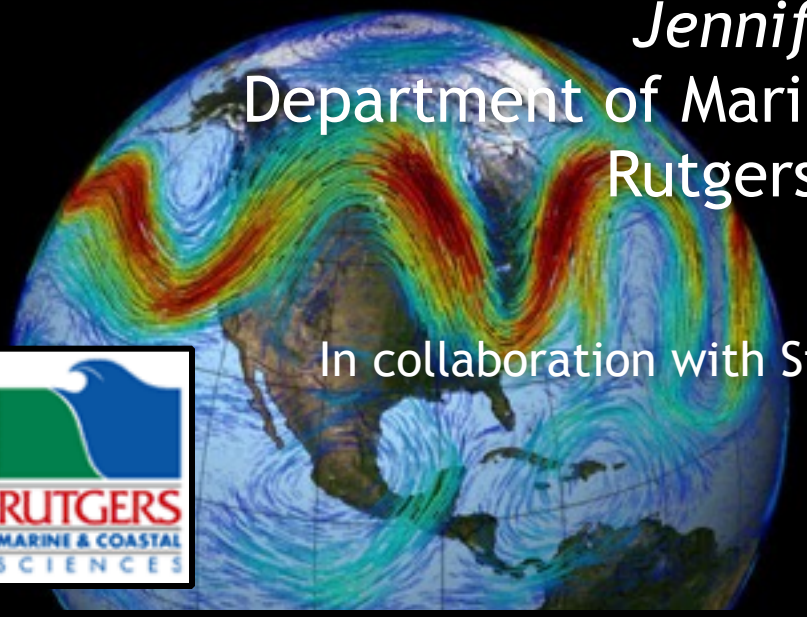
Crazy Weather and Climate Change: Are They Connected?



Jennifer Francis
Department of Marine and Coastal Sciences
Rutgers University

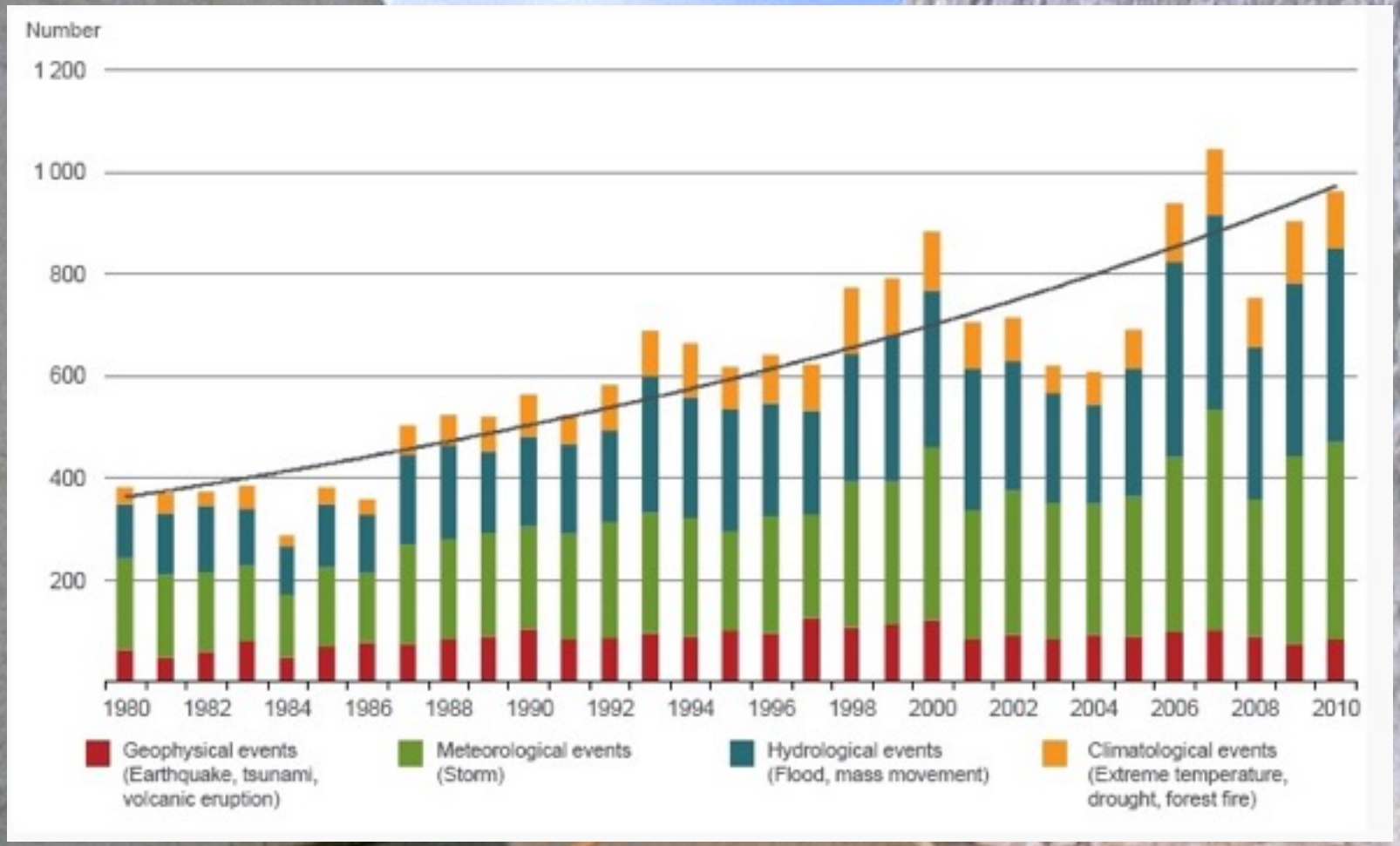
In collaboration with Steve Vavrus, U. of Wisconsin

Boston

One of the many snowstorms during winter 2015


RECORD WARMTH OF MARCH 2012
+5°
+10°
+15°
+15°
+10°
+10°
+10°
+5°
+5°
°F ABOVE NORMAL
15°-20°
10°-15°
5°-10°
©2012 WWW.ACCUWEATHER.COM

Extreme weather events are on the rise…



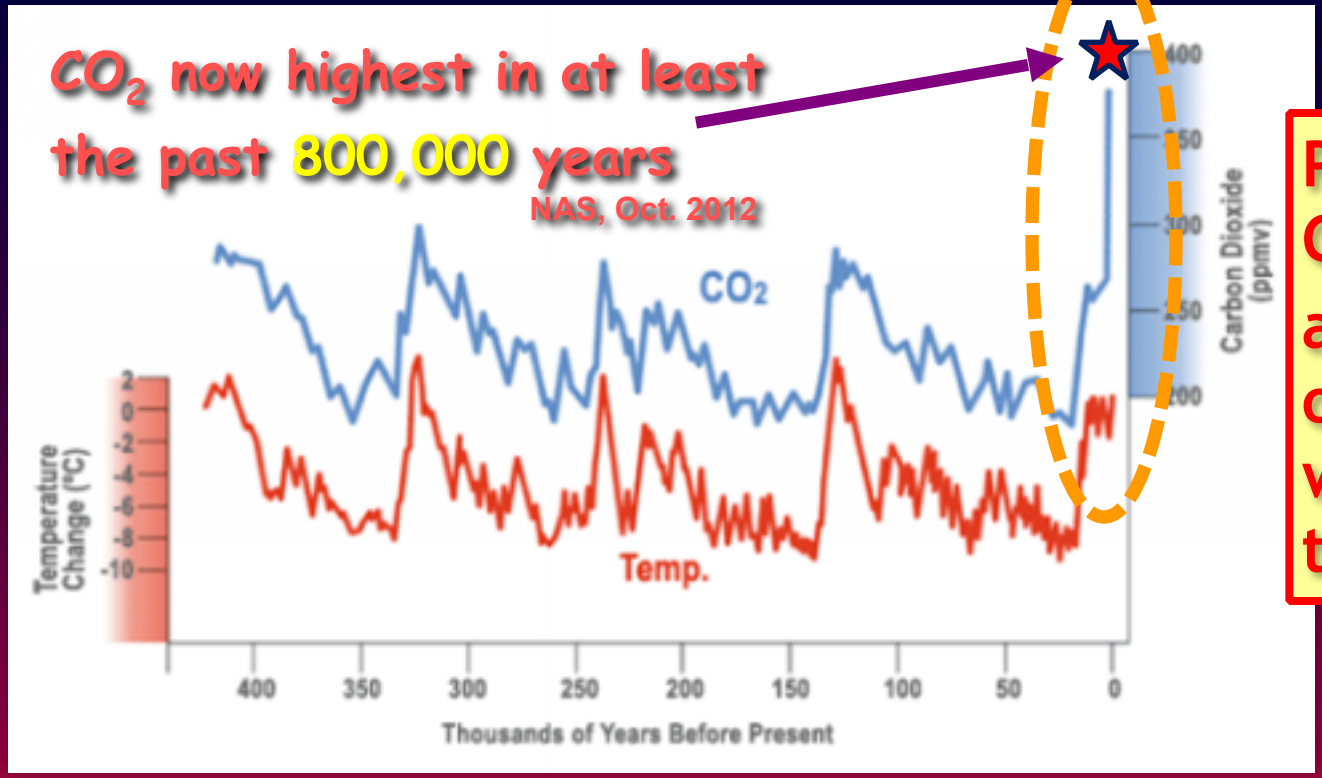
Japan 2012

from Munich RE

So, what the heck is going on??

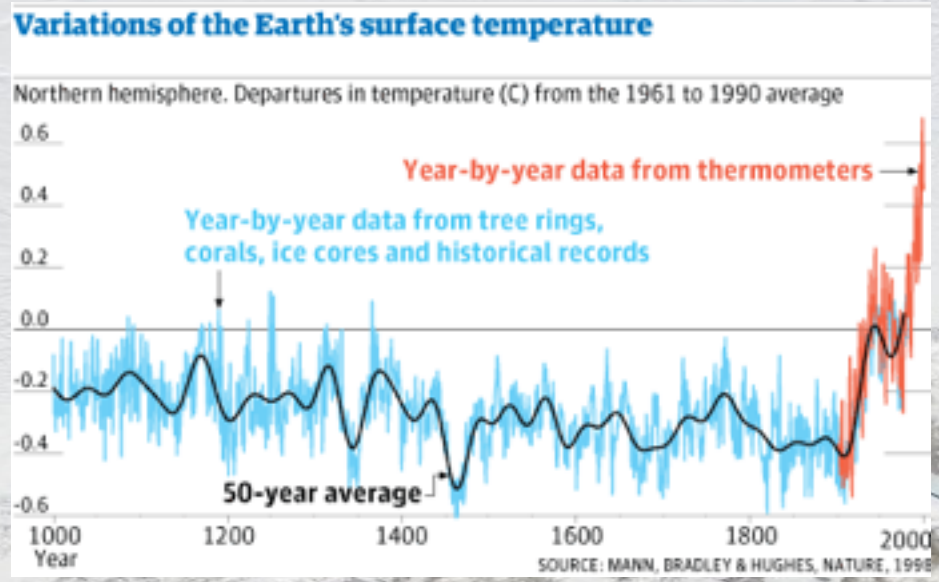
Is human-caused climate change playing a role?

We've put ourselves in a real pickle…



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

The last time CO_2 levels were this high, the globe was several degrees warmer, sea levels were tens of feet higher.

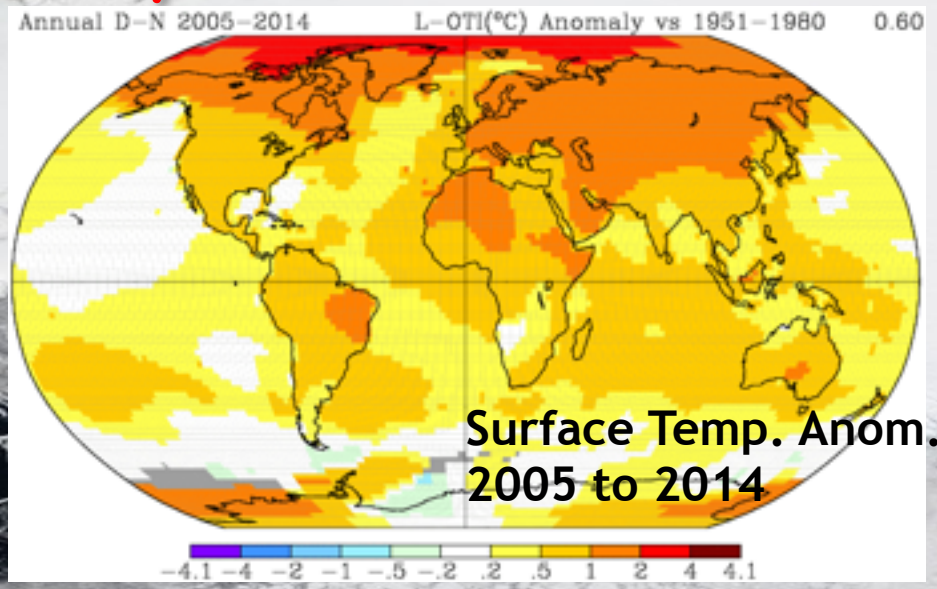


CO_2 levels are highest in at least 800,000 years, and Earth's temperature is responding…

…the warmest 19 years occurred in the past 20 years.

But warming is not even around the globe.

Jan. 2015 was 359th consecutive month warmer than 20th century average



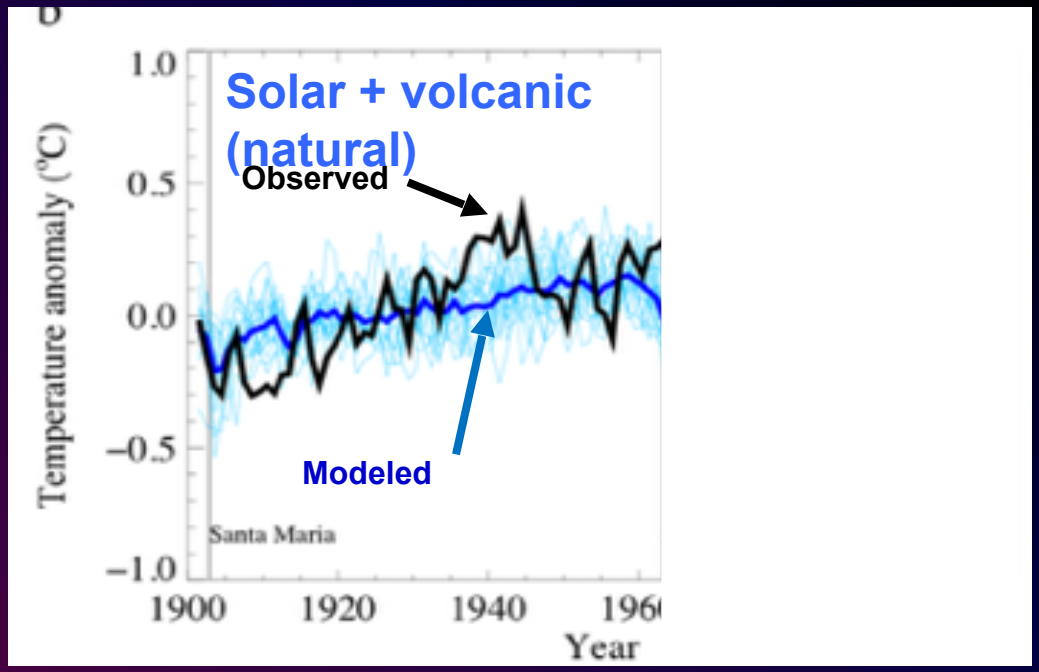
Surface Temp. Anom. 2005 to 2014

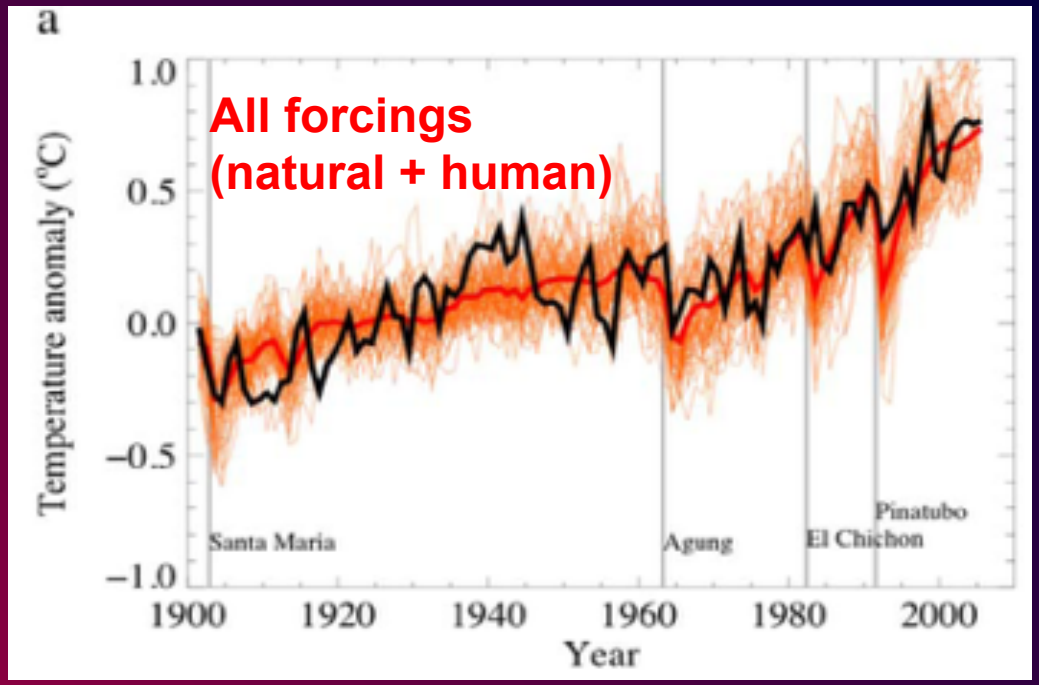
From NASA/GISS


How do we know that humans are responsible?

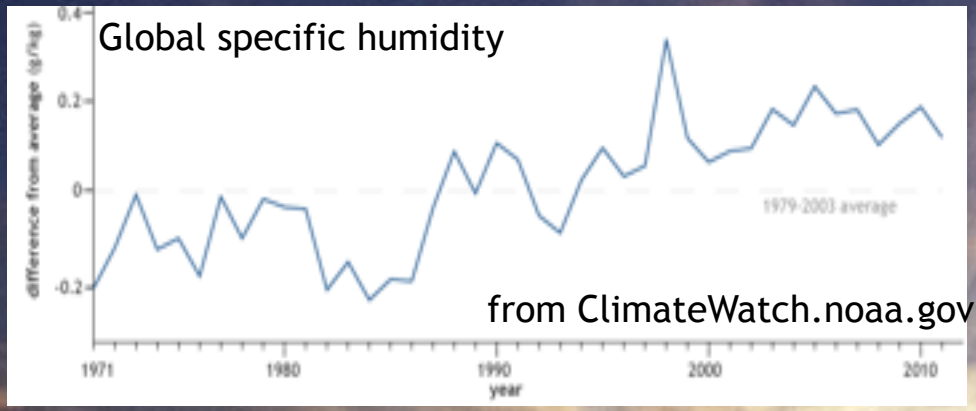
Evidence implicating humans

One of our best tools:
computer programs
- climate models -
that simulate the complex physics of the atmosphere, ocean, snow, ice, and land and all the forces acting on them.

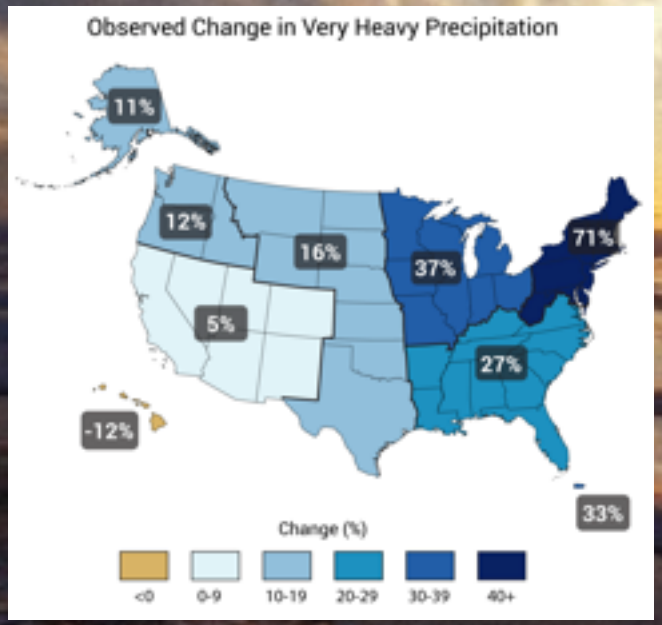




And the atmosphere is gaining moisture…

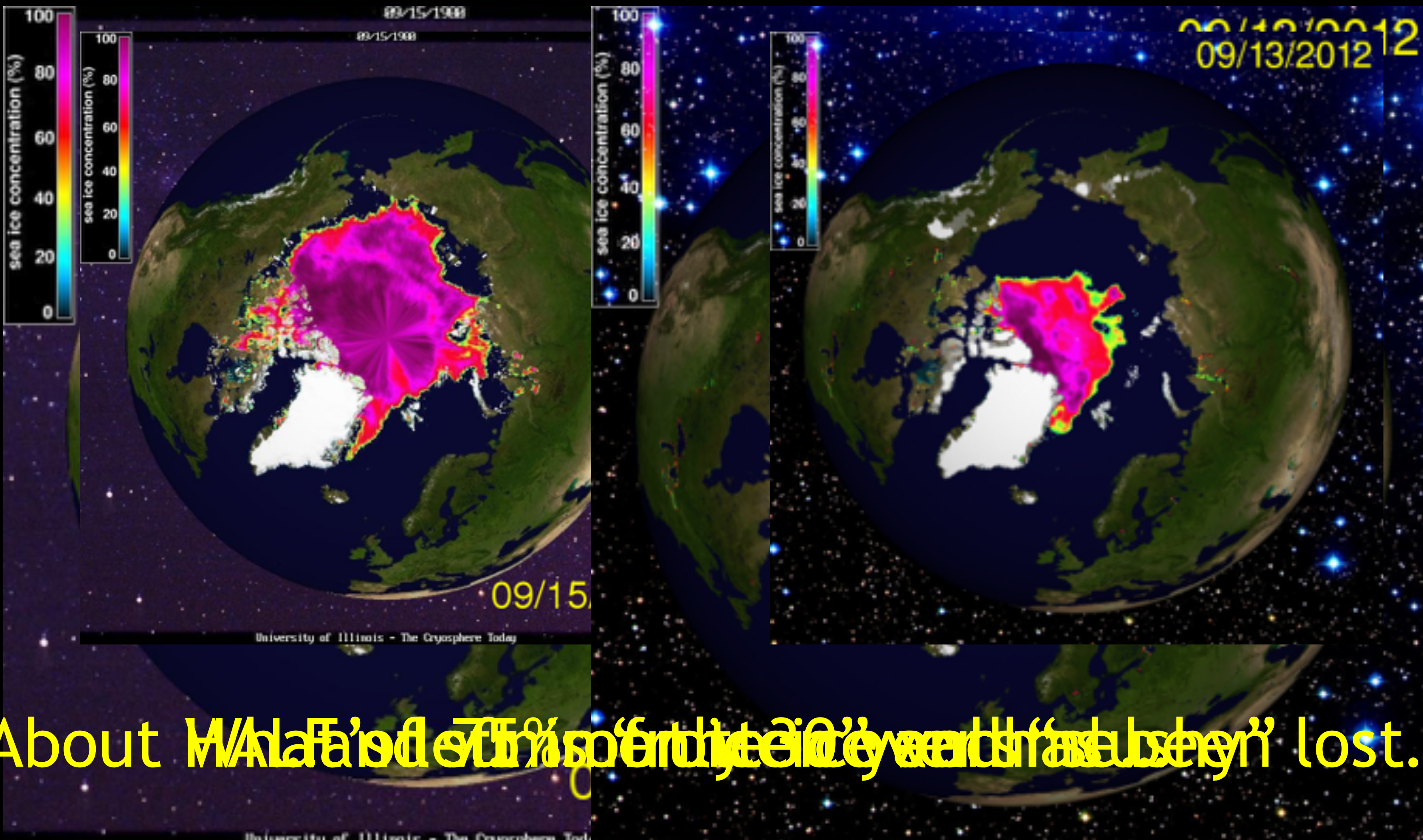


…providing more fuel to energize storms, a stronger greenhouse effect…

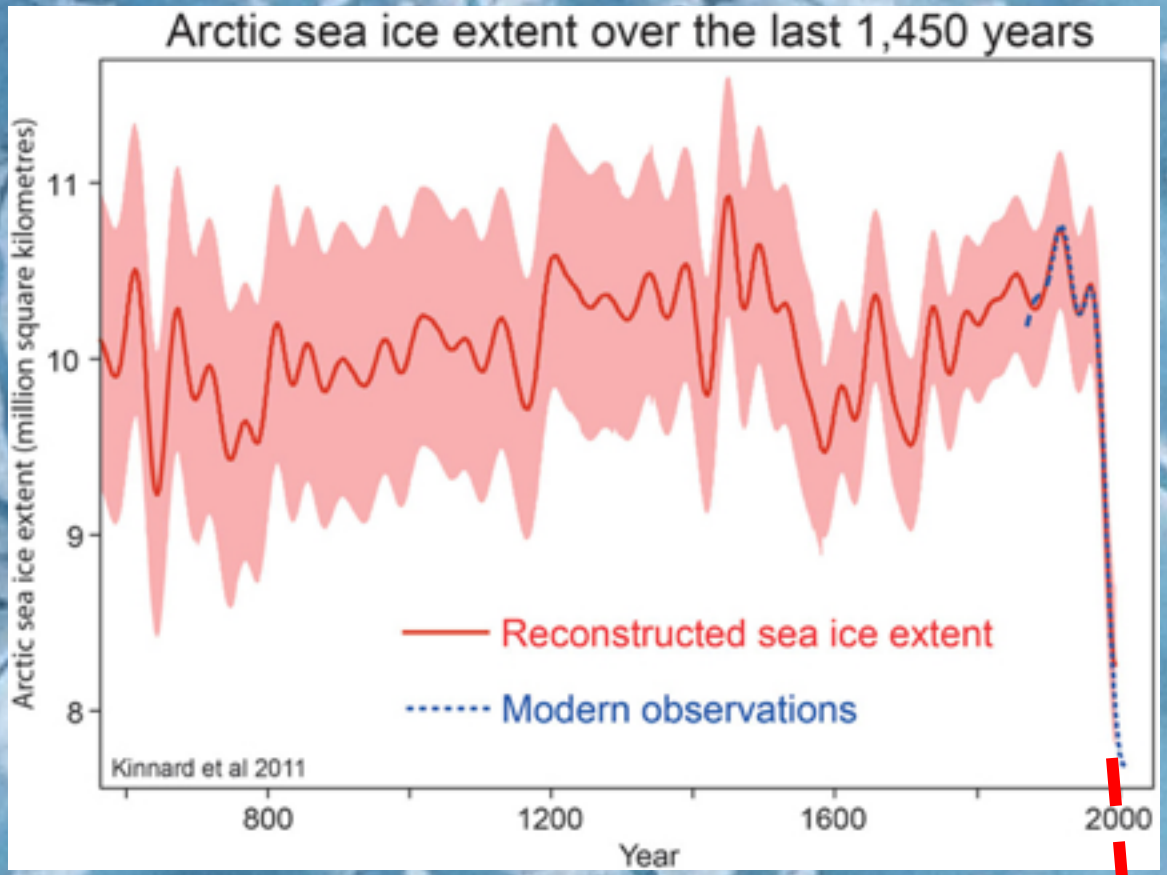


…and an increased frequency of heavy precipitation events.

Sea ice is now a mere shadow of former self…

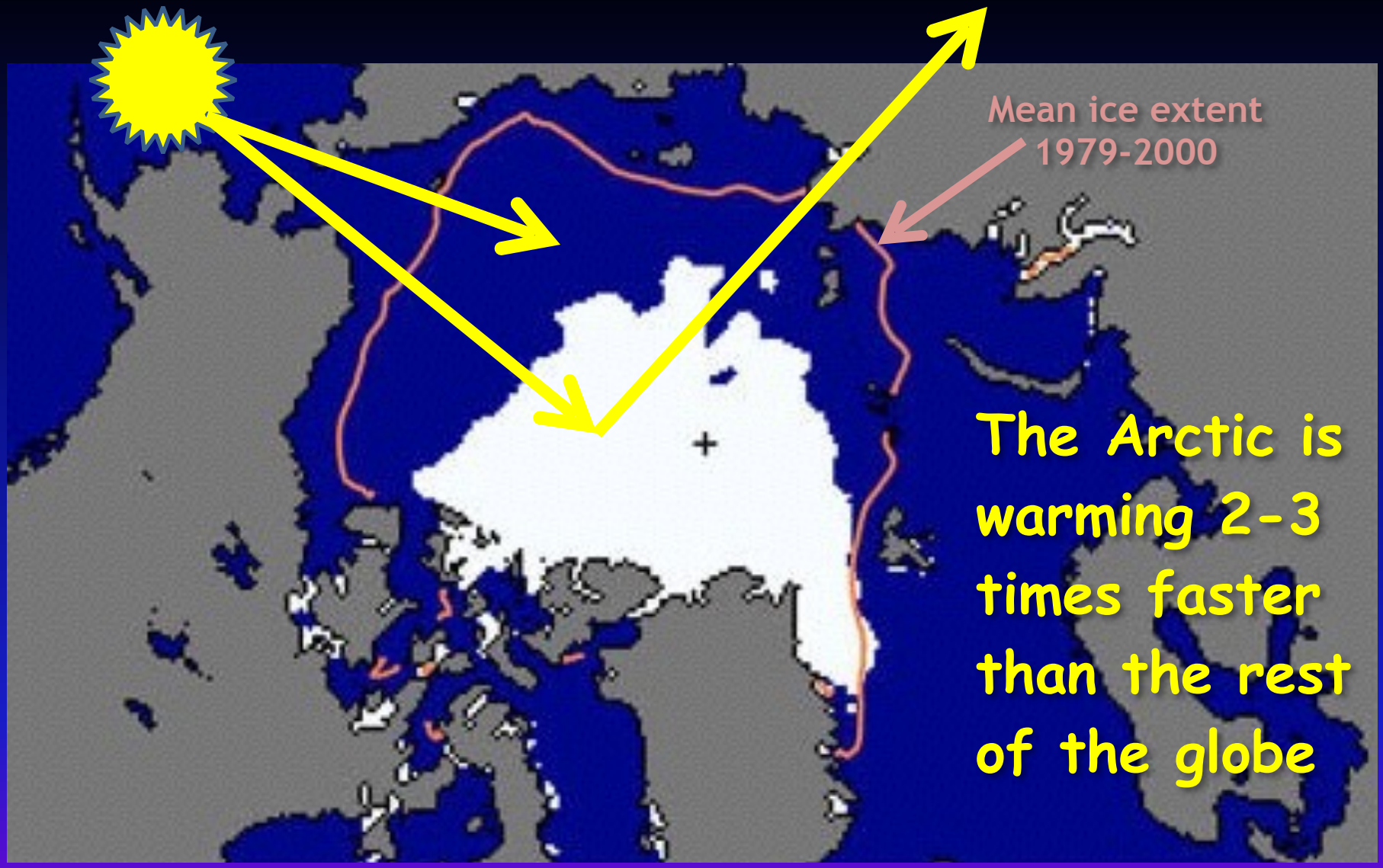


How unusual is the recent loss of Arctic sea ice?



NOAA Ice Age Animation

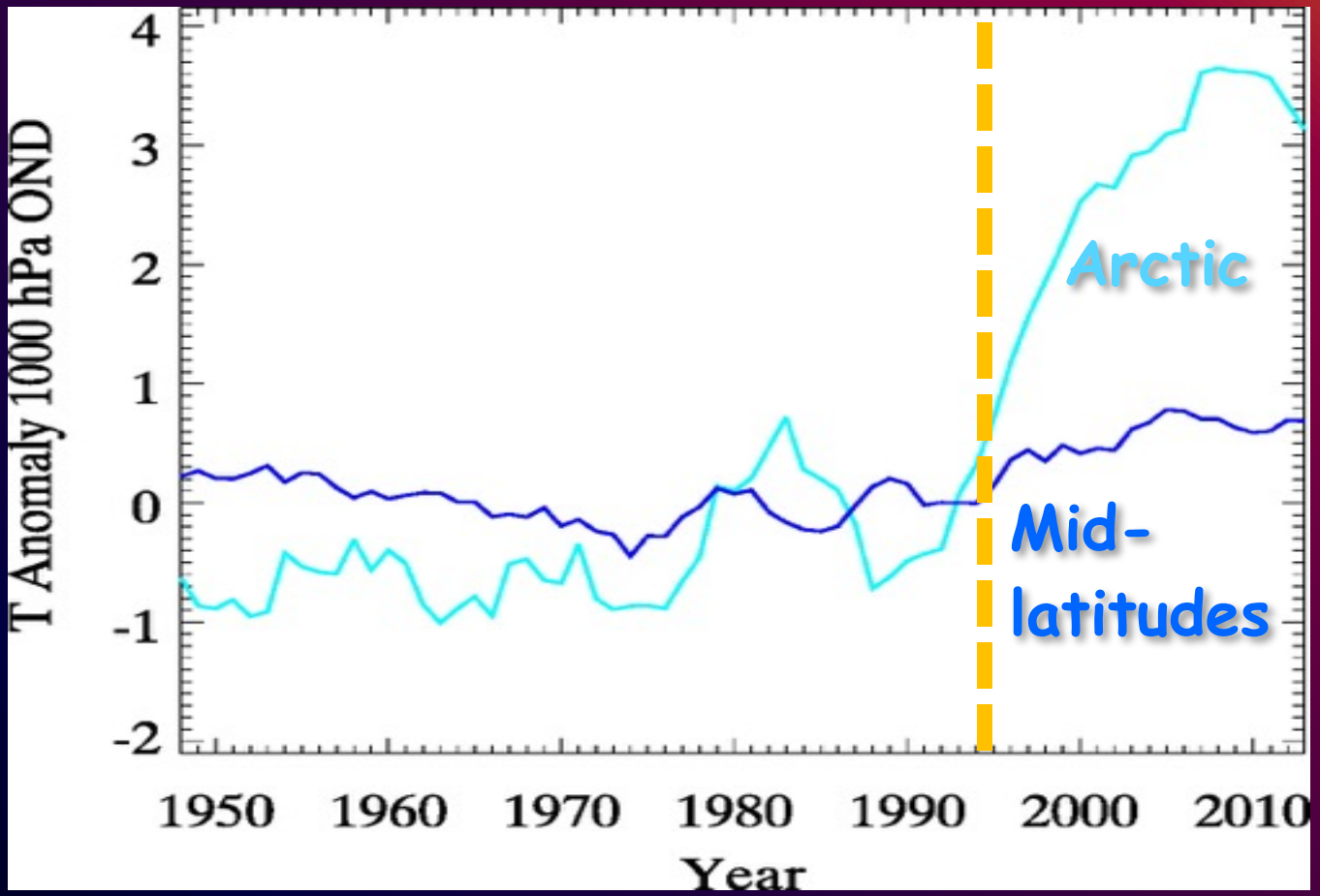
☆2012



Ice extent September 2012

"Arctic Amplification"

Near-surface air temperature (Fall)

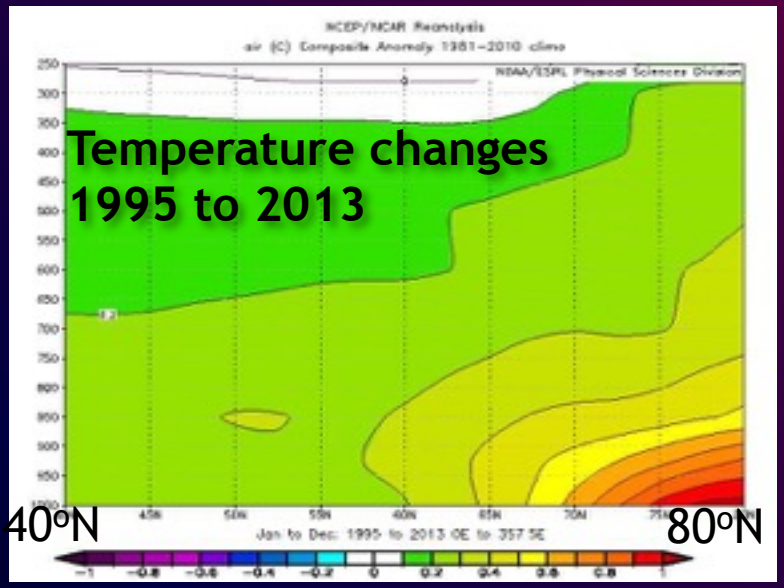


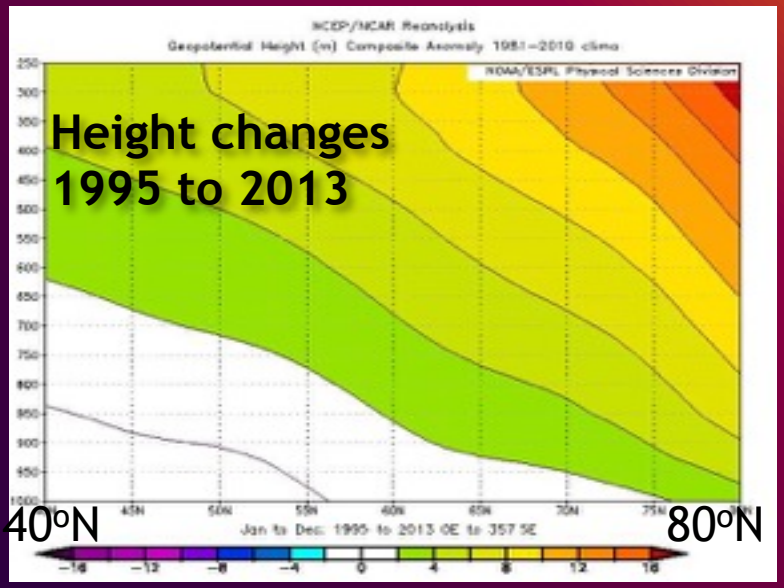
Arctic Amplification

Not confined to surface!

250 hPa

surface

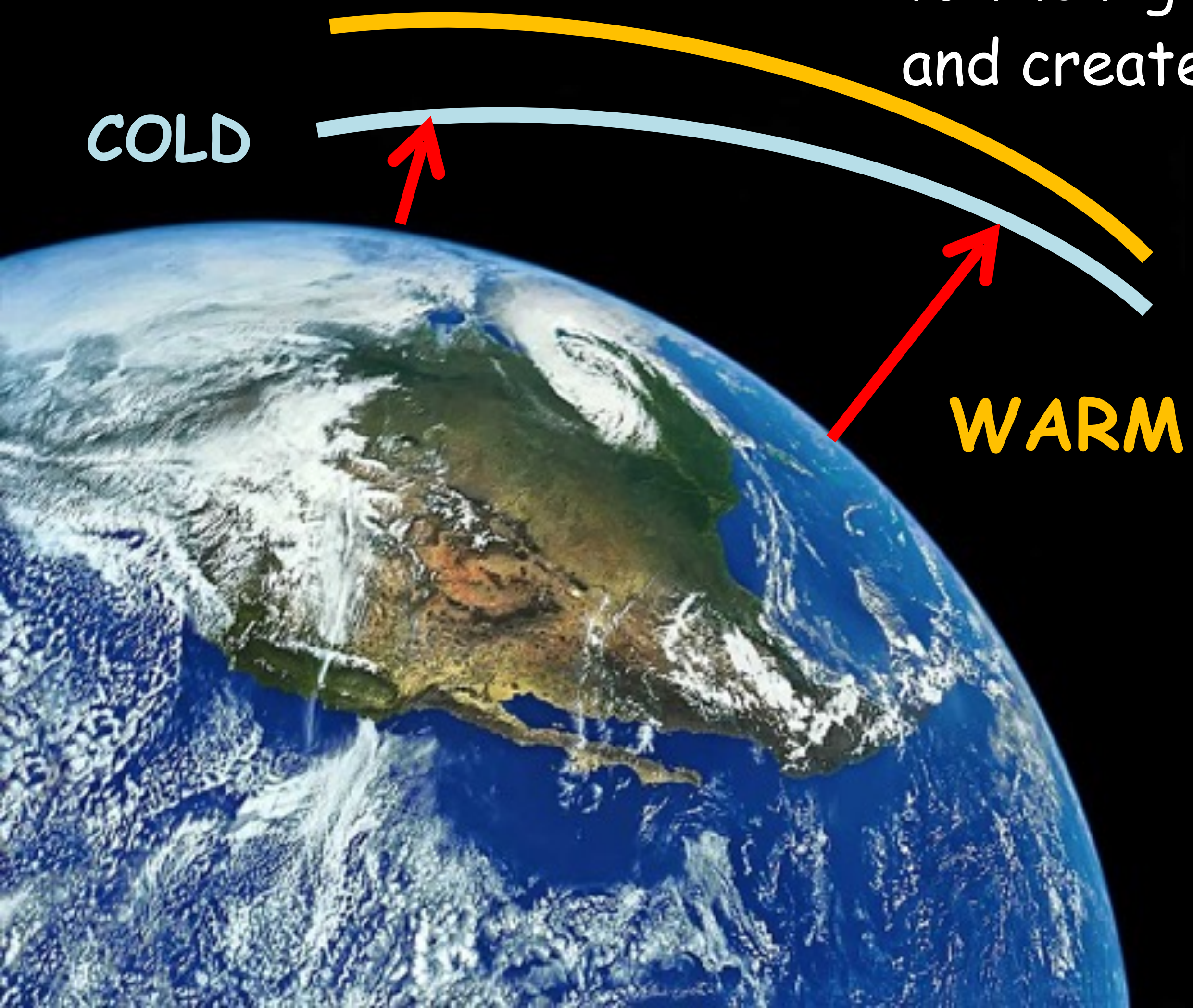




Consider a column of atmosphere stretching from here (warm) to the Arctic (cold)

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

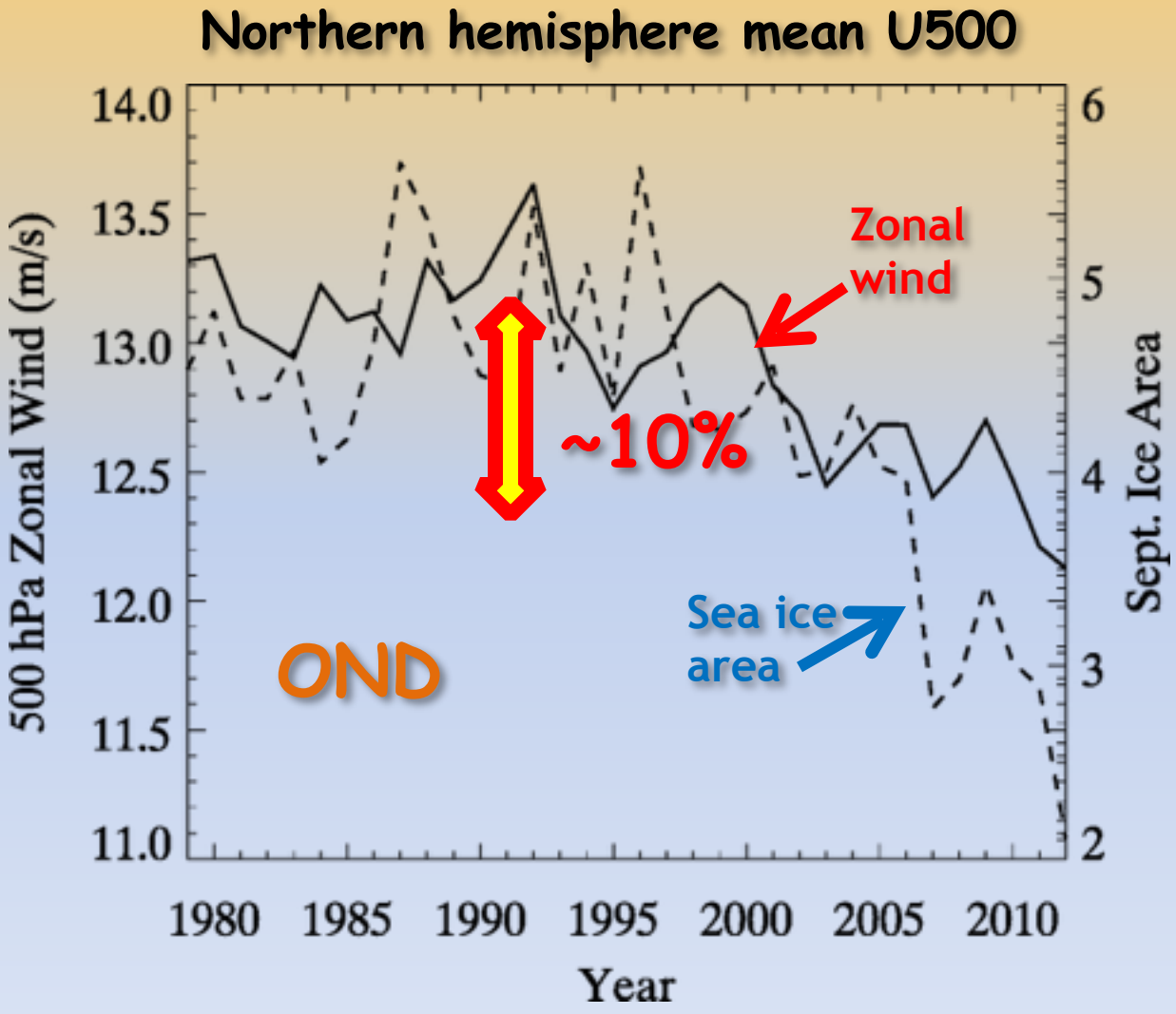
Air flows down this "hill", turns to the right as the Earth spins, and creates the Jet Stream



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

West Winds are Weakening…

"Weaker Westerly Wind is Wavier"

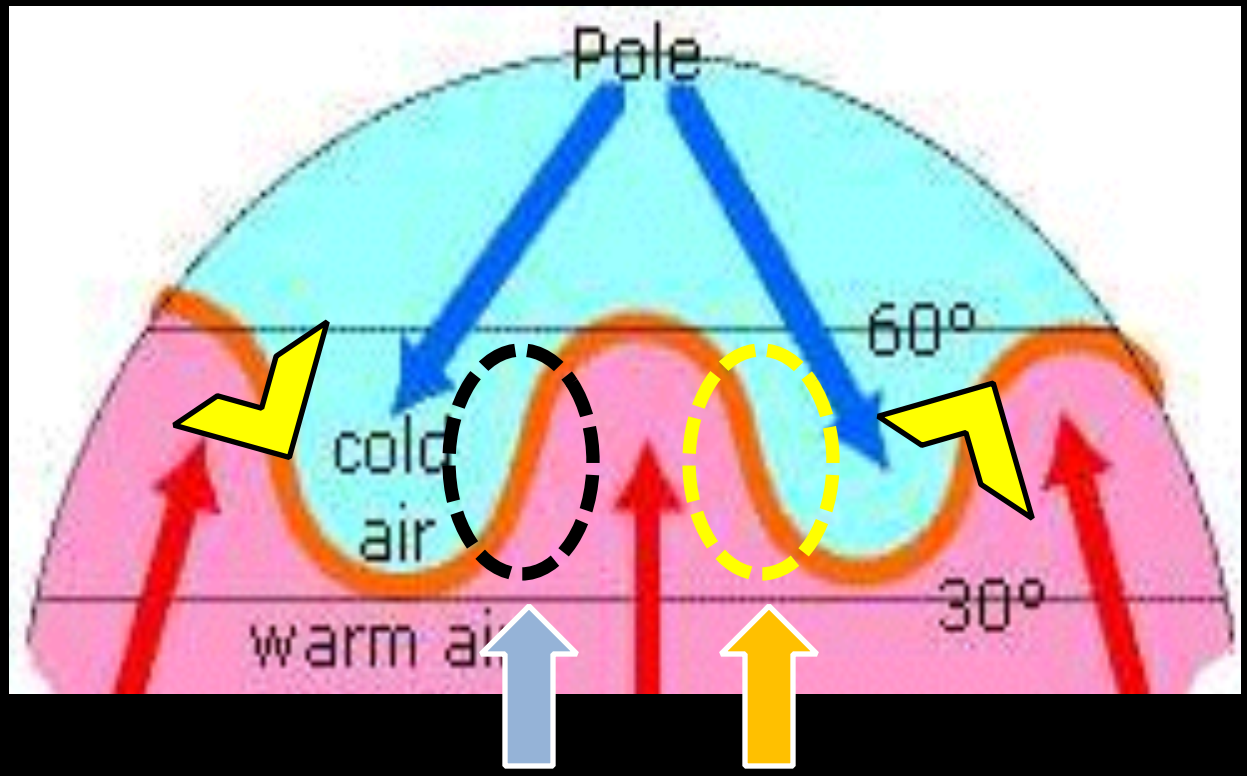


When the waves are small, they move eastward quickly.

When the waves are large, they shift eastward more slowly.

Graphics by John Garrett for SkepticalScience.com

Why do we care about these waves? The Jet Stream makes our weather

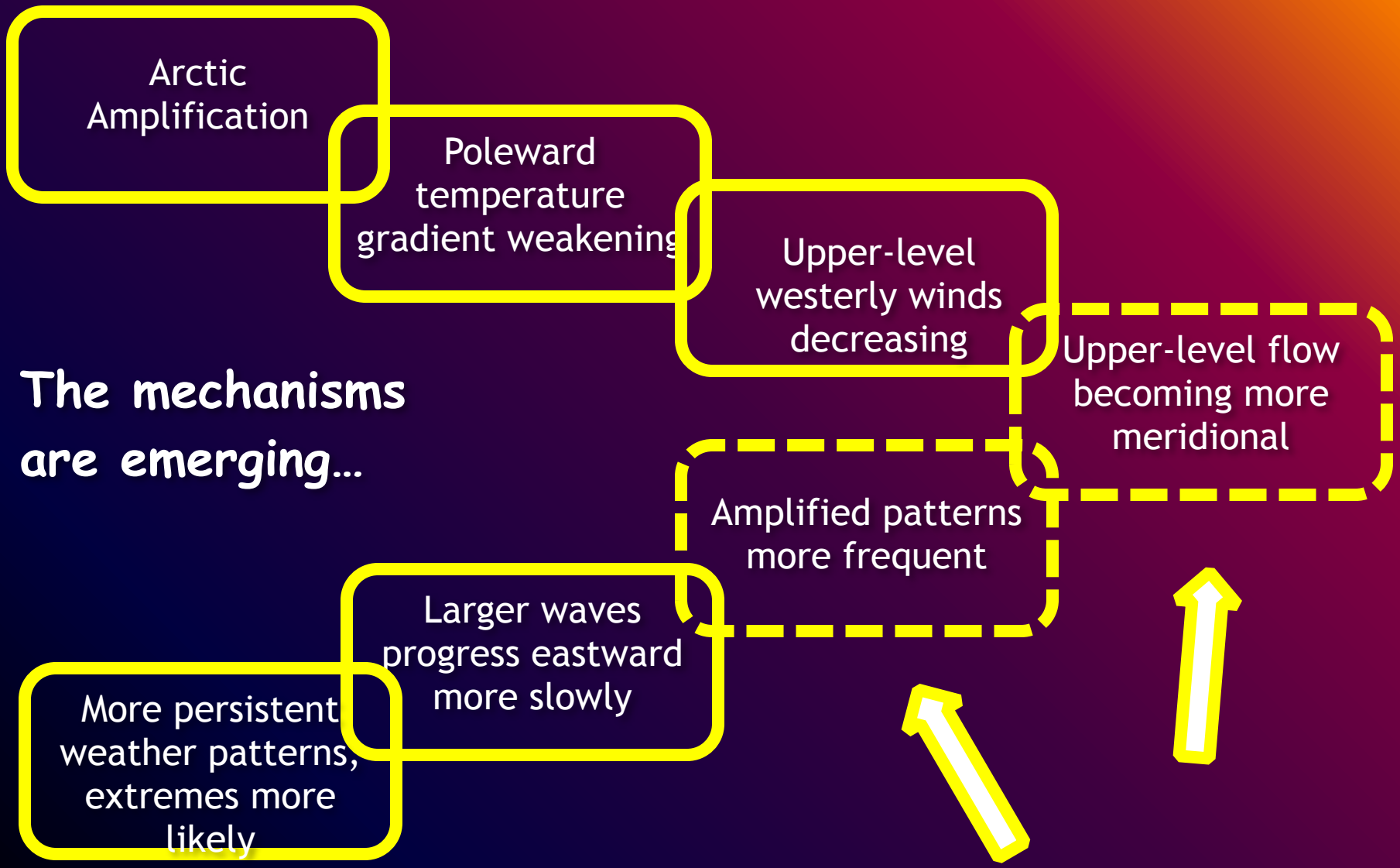


NASA Jet Stream

Wet and stormy

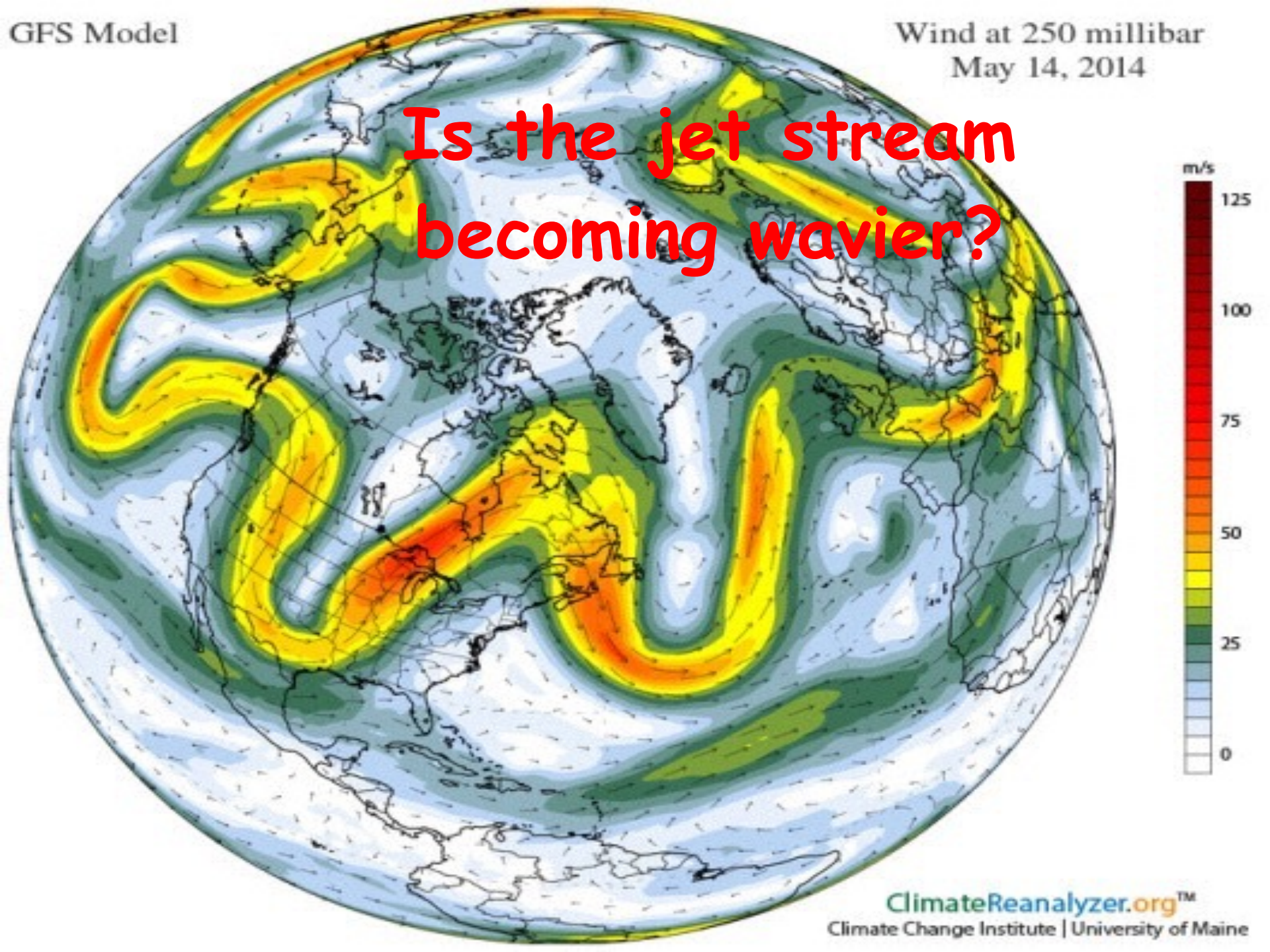
Dry and settled

Chain of Events Linking Arctic Amplification (AA) with Increased Extreme Weather in Mid-Latitudes: a hypothesis

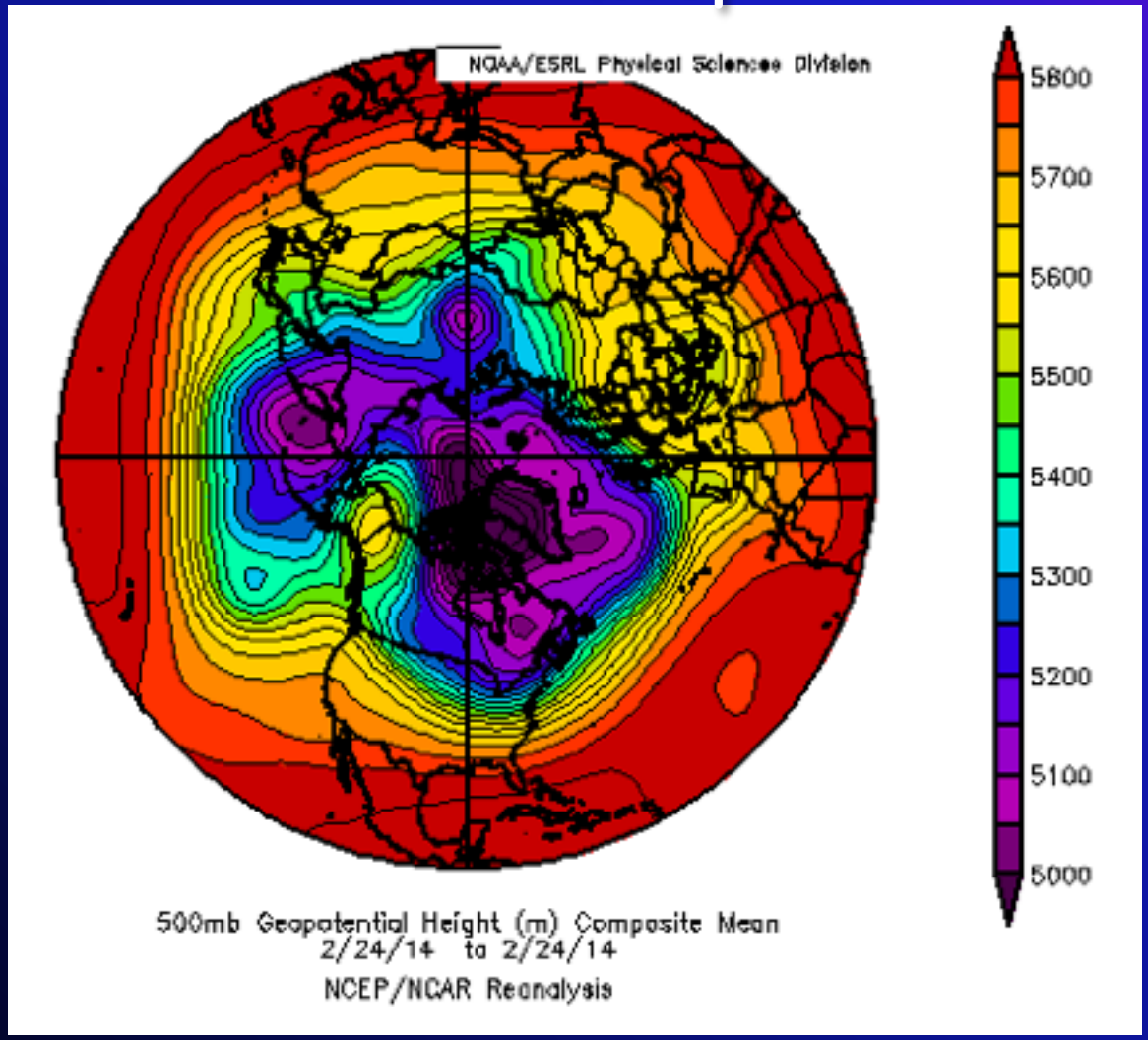


The mechanisms are emerging…

Francis and Vavrus, 2012


GFS Model
Wind at 250 millibar
May 14, 2014
Is the jet stream becoming wavier?
m/s
125
100
75
50
25
0
ClimateReanalyzer.org™
Climate Change Institute | University of Maine

A "topographic map" of a layer in the atmosphere

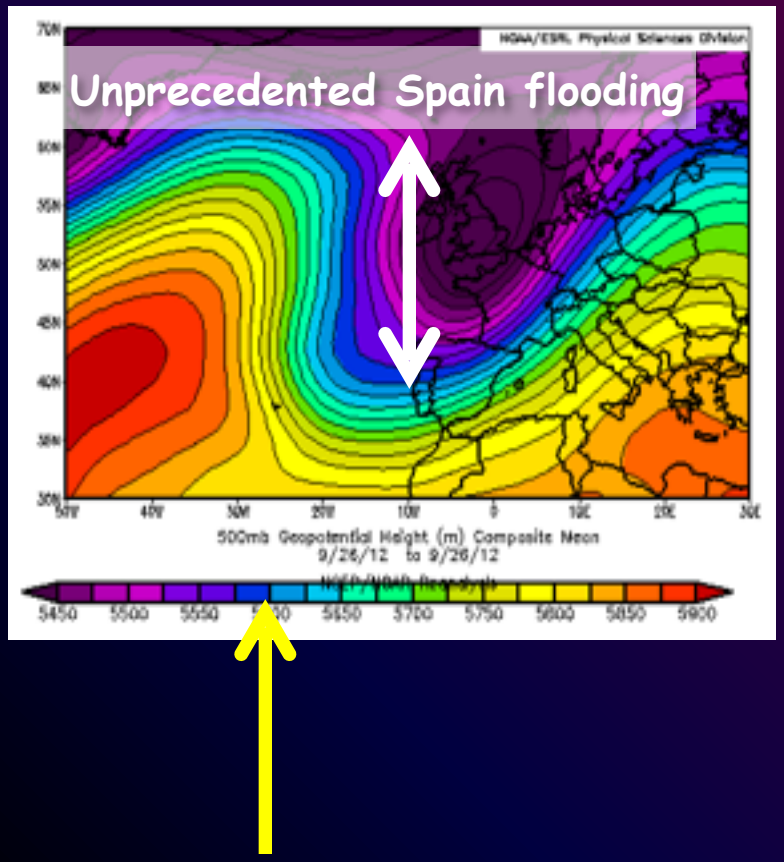


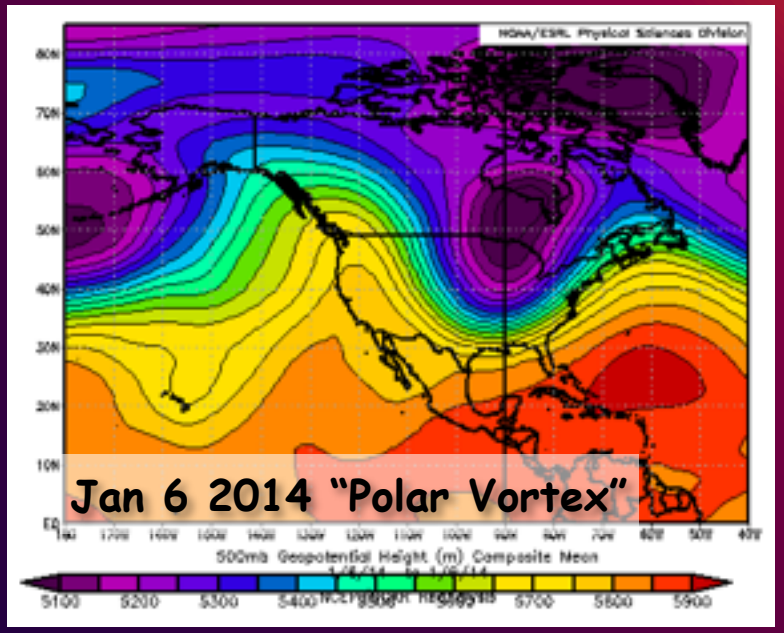
5

Amplified patterns more frequent

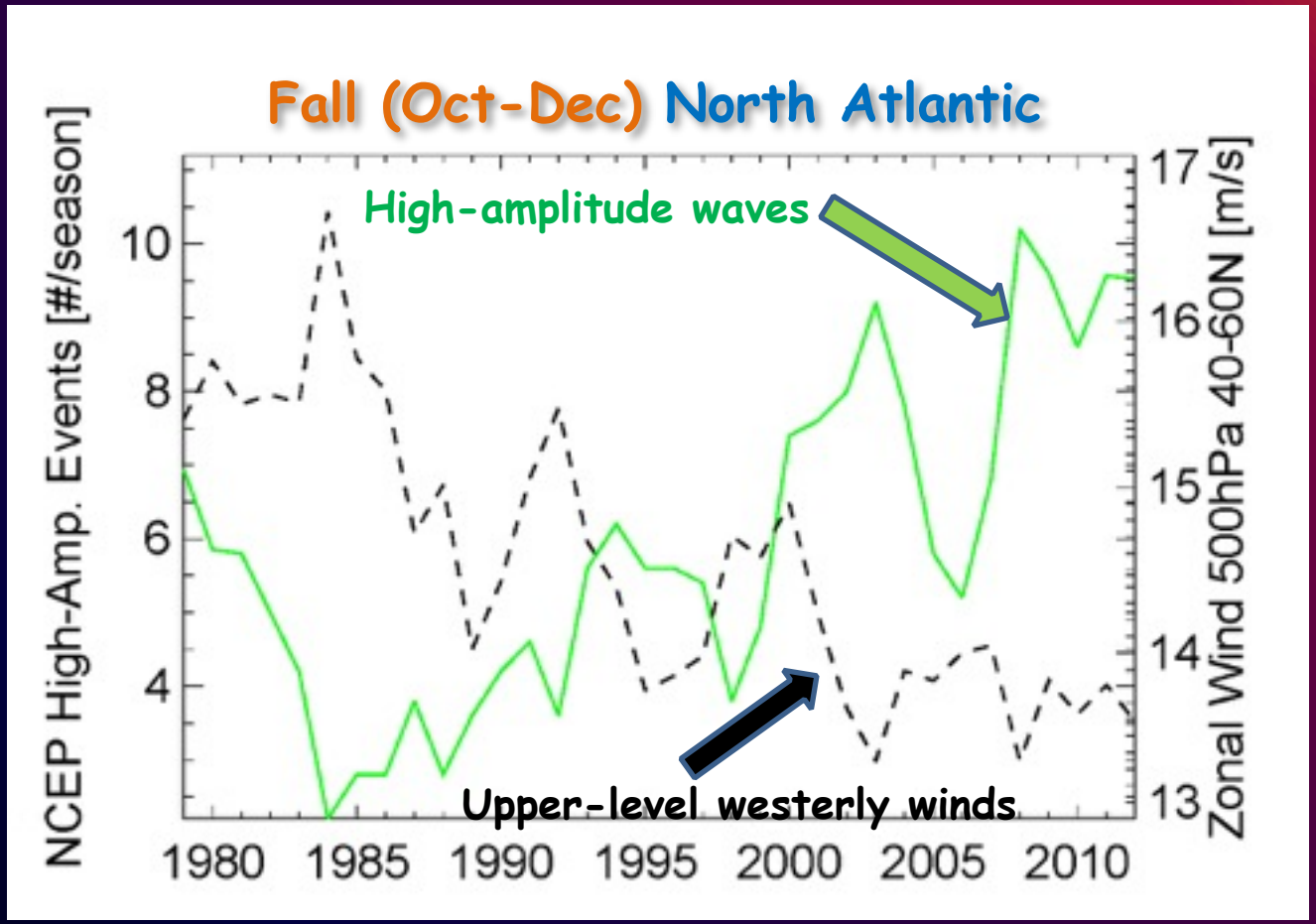
High-Amplitude Patterns (HAPs)

500 hPa contour range > 35° latitude





Are very wavy jet-stream patterns really happening more often?



Change (%) in frequency of high-amplitude patterns 1995-2013 versus 1979-1994

Region	JFM	AMJ	JAS	OND
Atlantic 285 - 60E	19*	5	57**	47**
North America 220 - 290E	18*	12	59**	23
Europe -15 - 45E	1	3	6	17
Asia 30 - 150E	4	1	-15*	65**
Pacific 150 - 240E	-18	12*	-3	25*
Northern Hemisphere	-6	1	-5	16

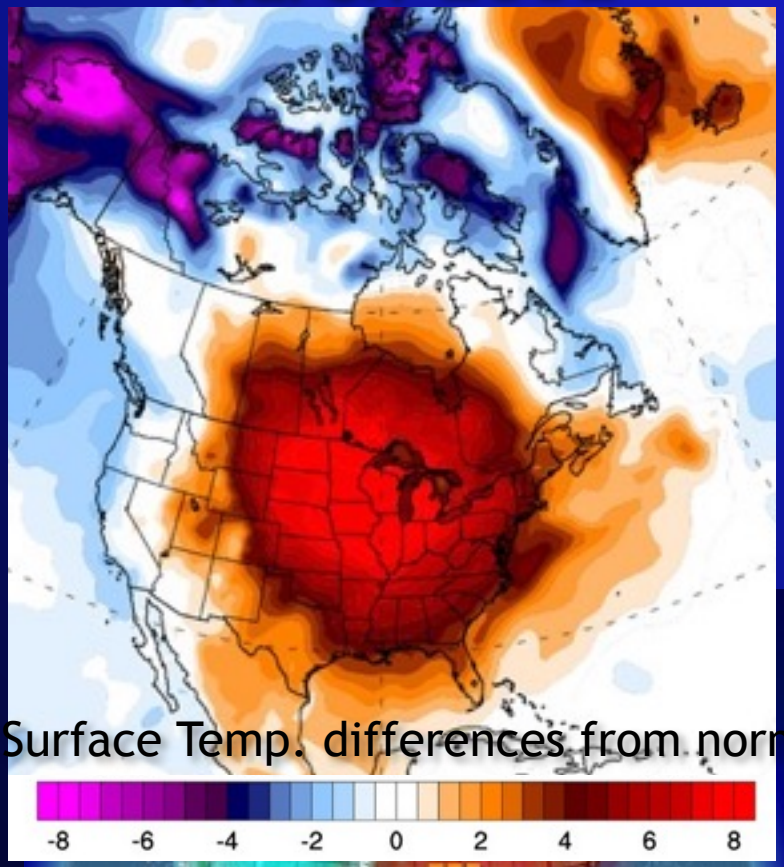
< -40%	-39 to 30%	-29 to 20%	-19 to 10%	-9 to 0%
0 to 9%	10 to 19%	20 to 29%	30 to 39%	> 40%

Francis and Vavrus, 2015

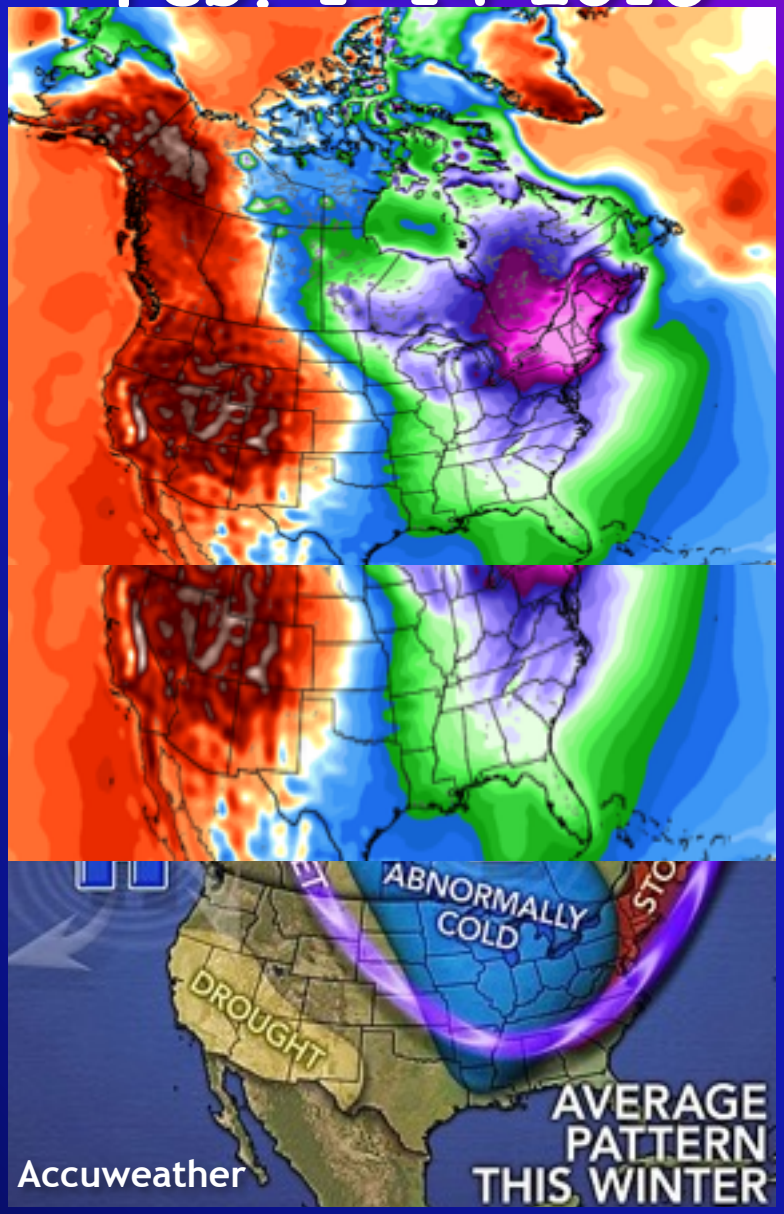
* > 1 SD, ** > 2 SD


Do recent extreme weather events
patterns fit this story?
Boston – early February 2015

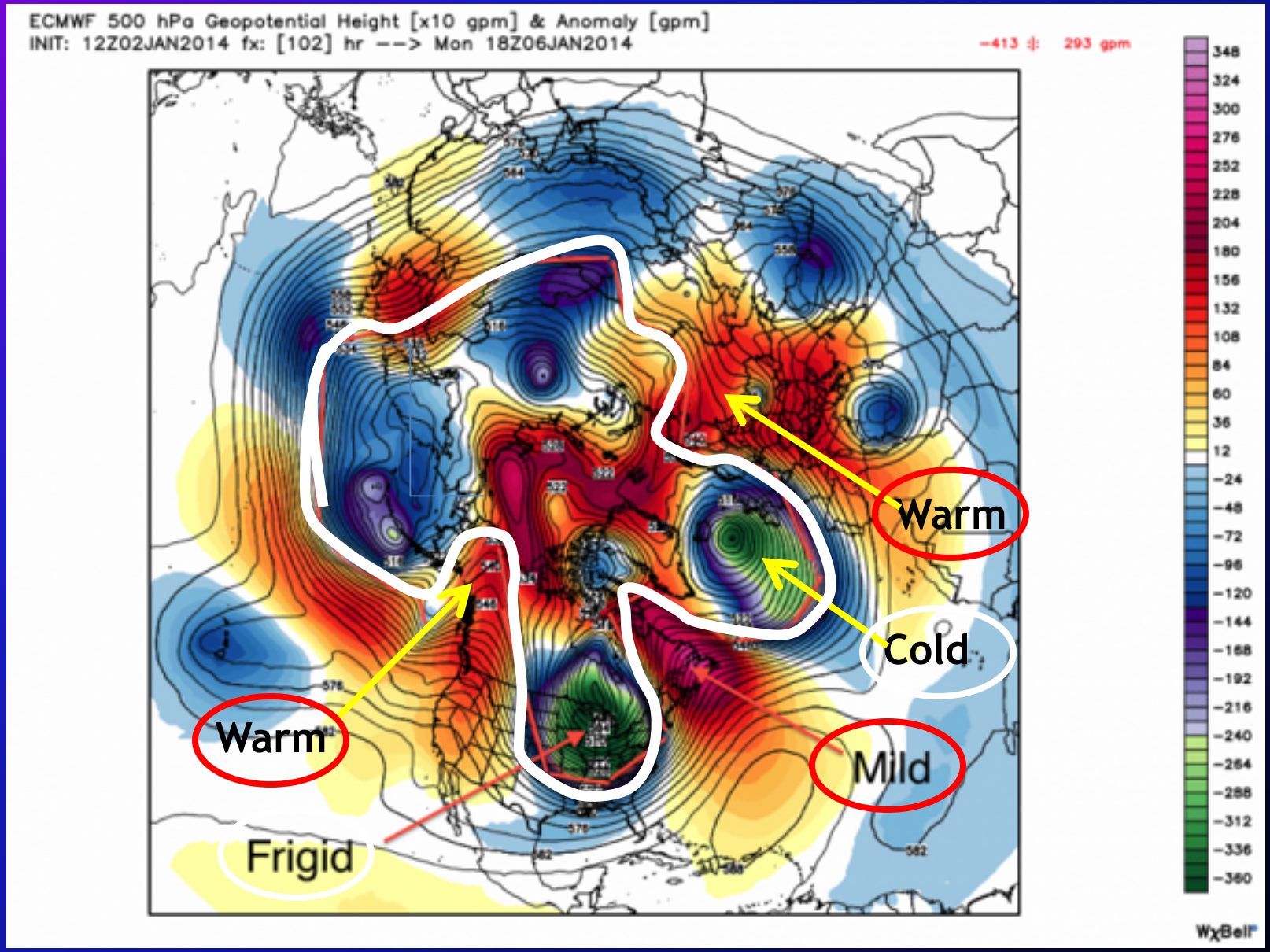
March 2012



Feb. 1-14 2015



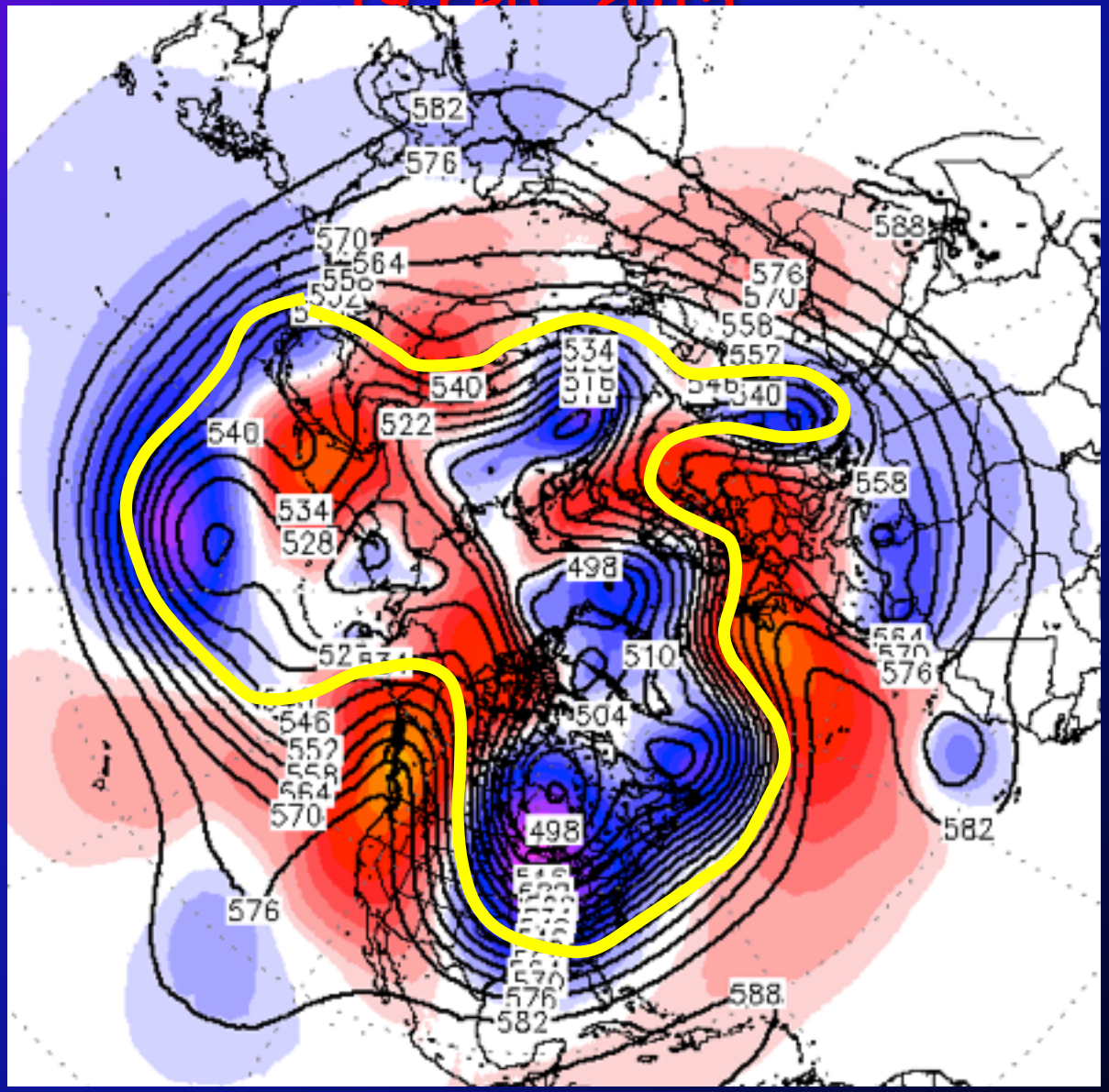
"Ridiculously Resistent Ridge/Trough:" Dec.'13-Feb.'14



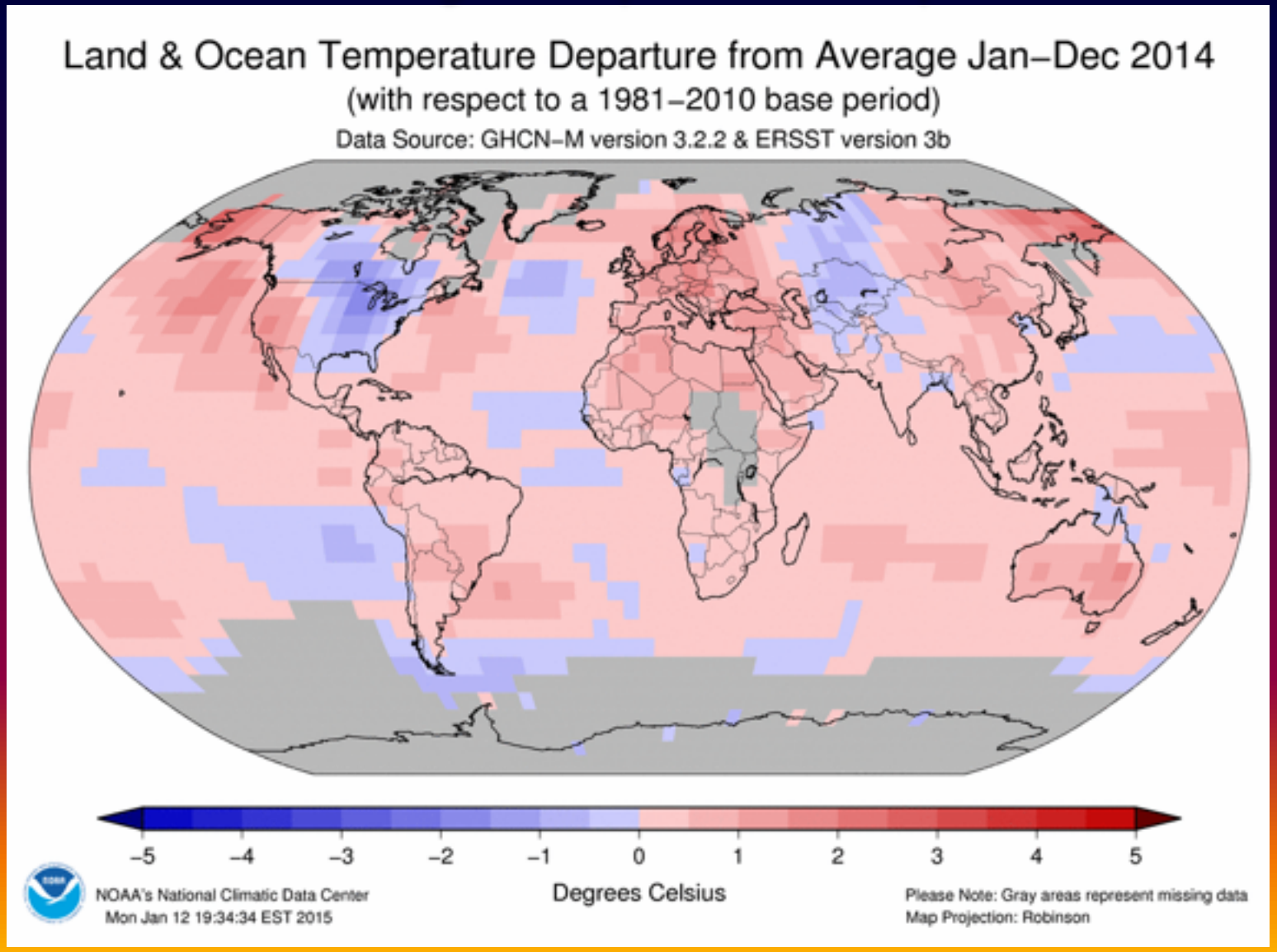
"Ridiculously Resistant Ridge/Trough"

19 Feb 2015

Déjà vu?



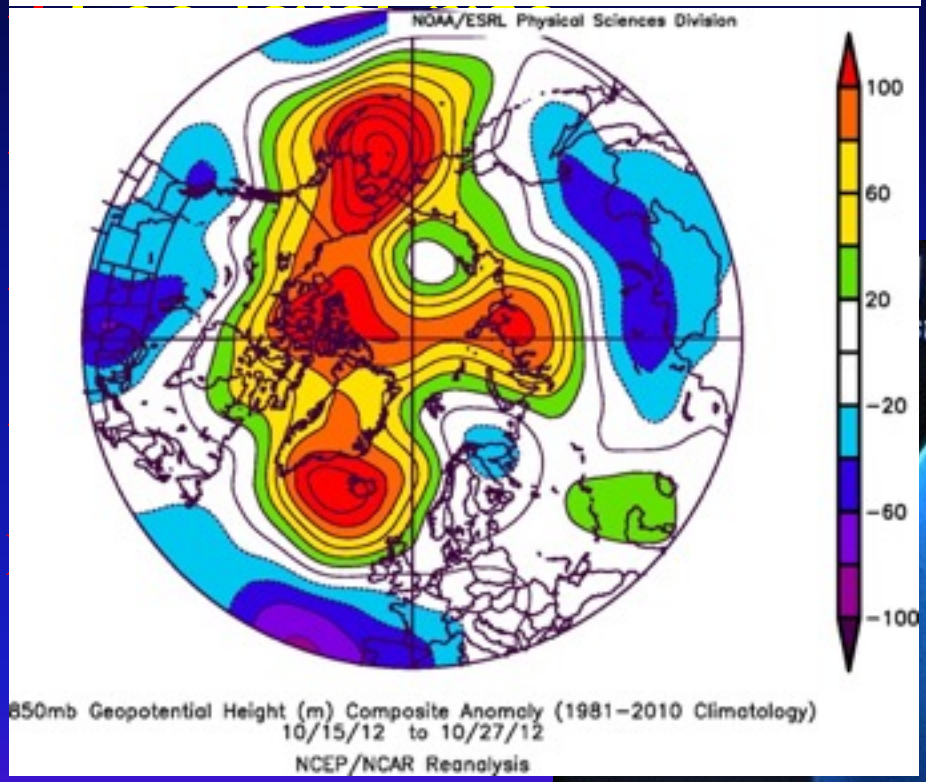
Ridiculously Resilient Ridge/Trough Pattern Evident in 2014 Average Temperature Departures



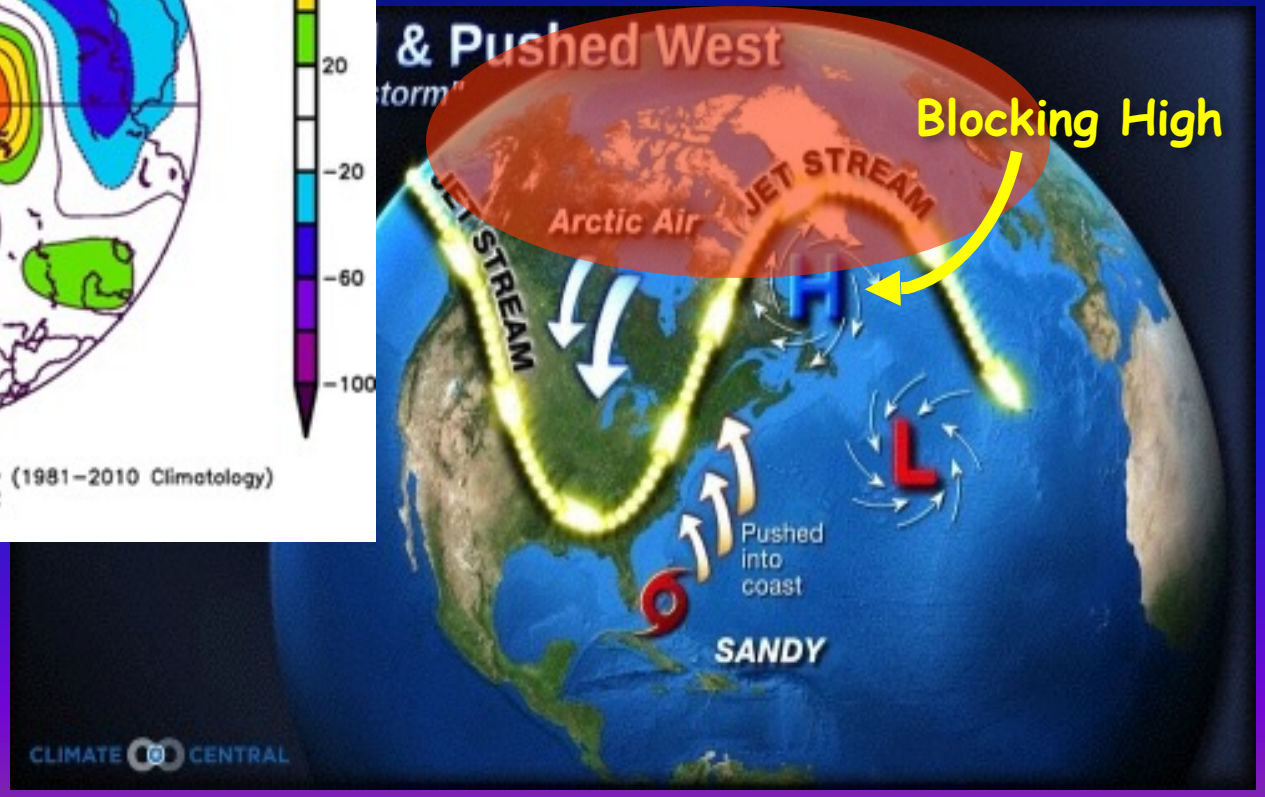
Did Climate Change Contribute to Sandy?

YES! – In At Least 5 Ways

The Arctic was MUCH warmer than normal

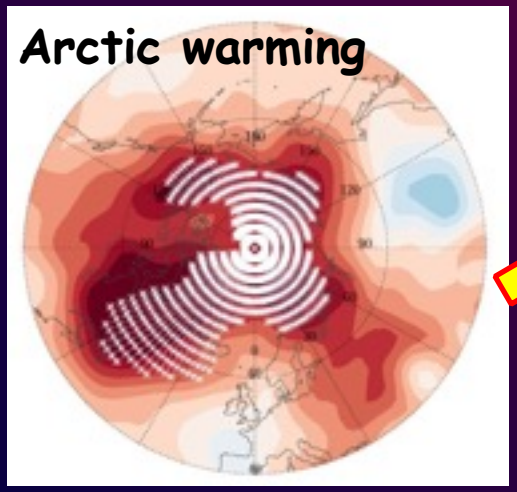


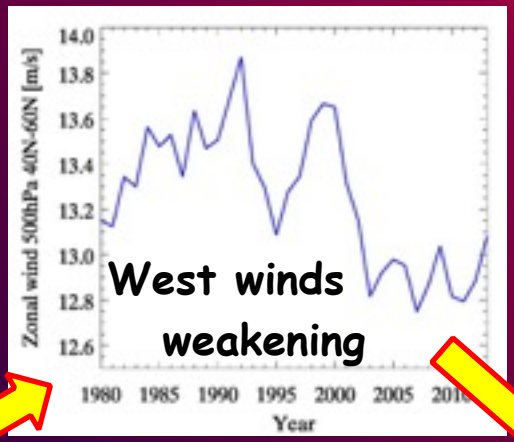
Was block strengthened, extended northward, or prolonged by warm Arctic?
We think so.

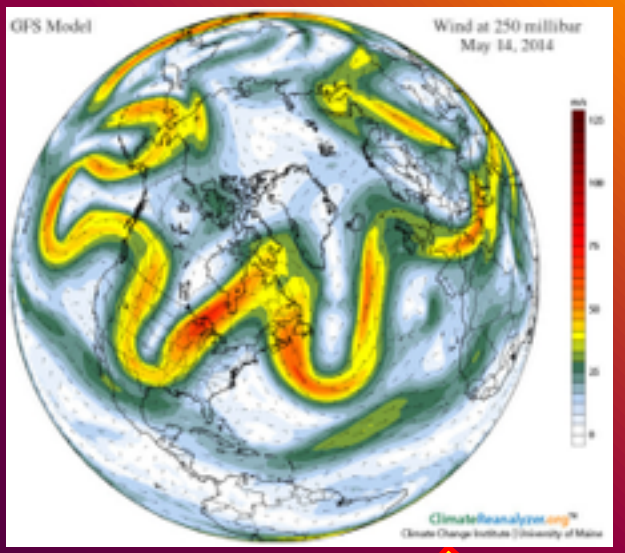


J.A. Francis

Summary

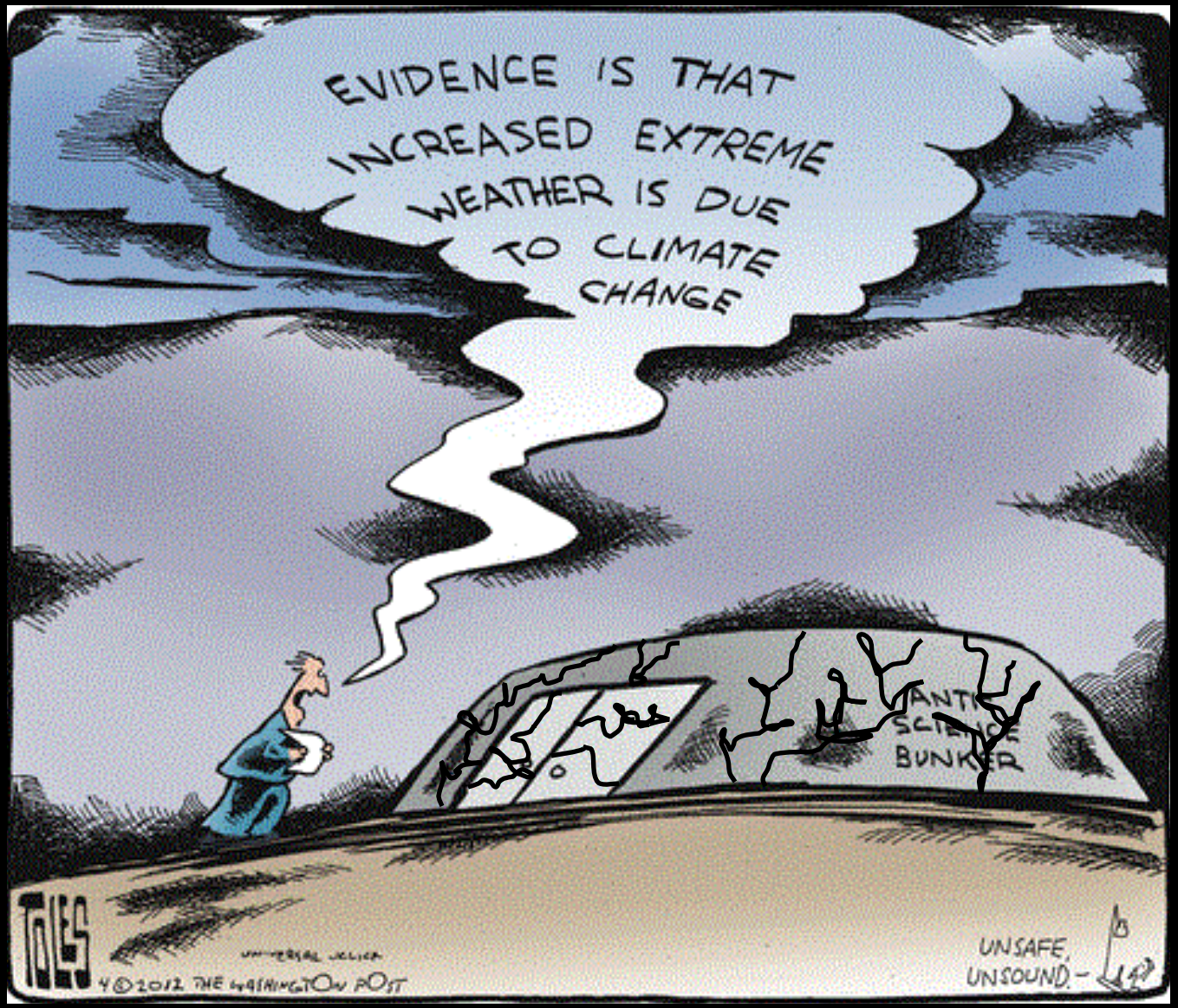

Arctic warming


Zonal wind 500hPa 40N-60N [m/s]
14.0
13.8
13.6
13.4
13.2
13.0
12.8
12.6
1980 1985 1990 1995 2000 2005
Year
West winds
weakening


GFS Model
Wind at 250 millibar
May 14, 2014

?

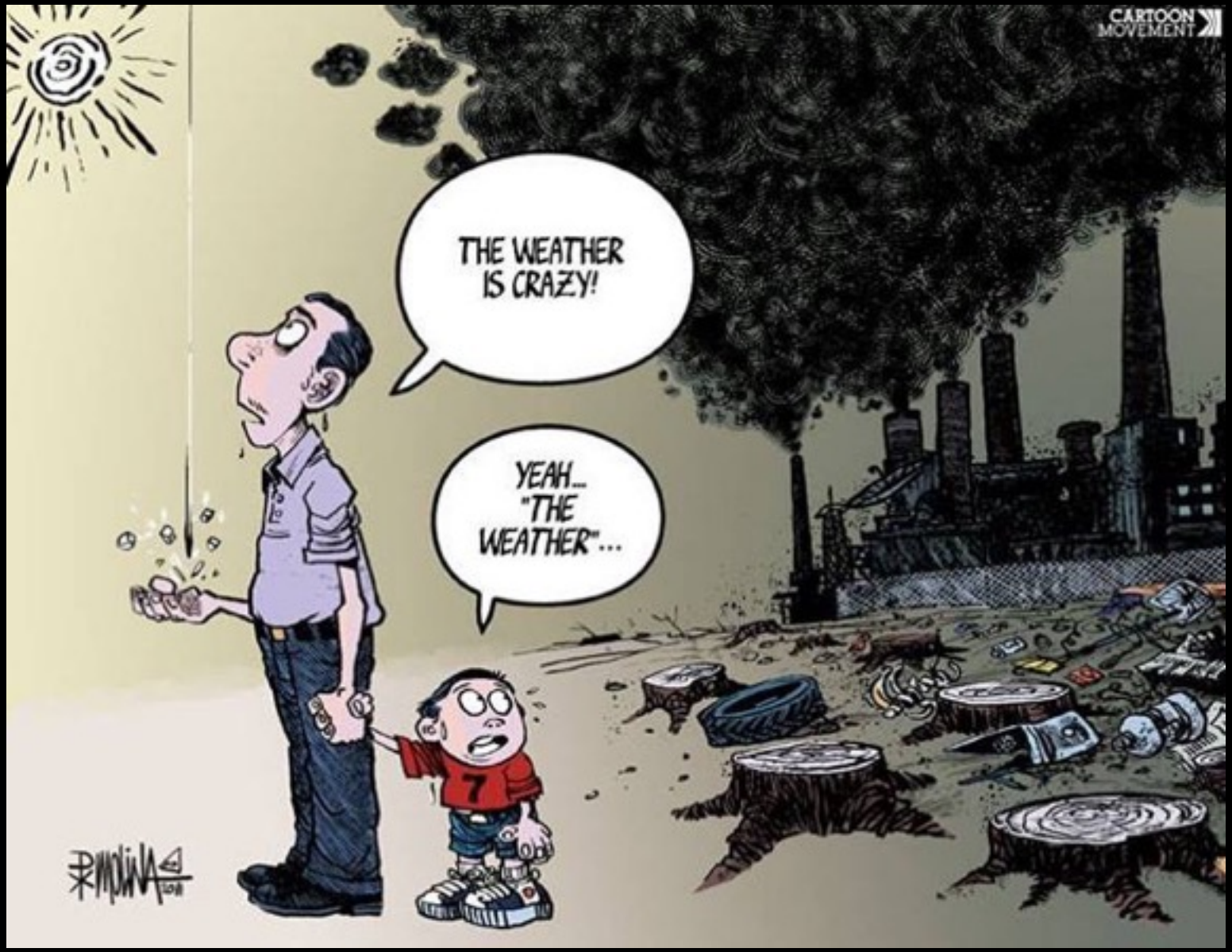

EUROPE THIS MARCH
COLD & WET
H
L
STORMY
WARM



THANK-YOU !!

francis@imcs.rutgers.edu

Extras



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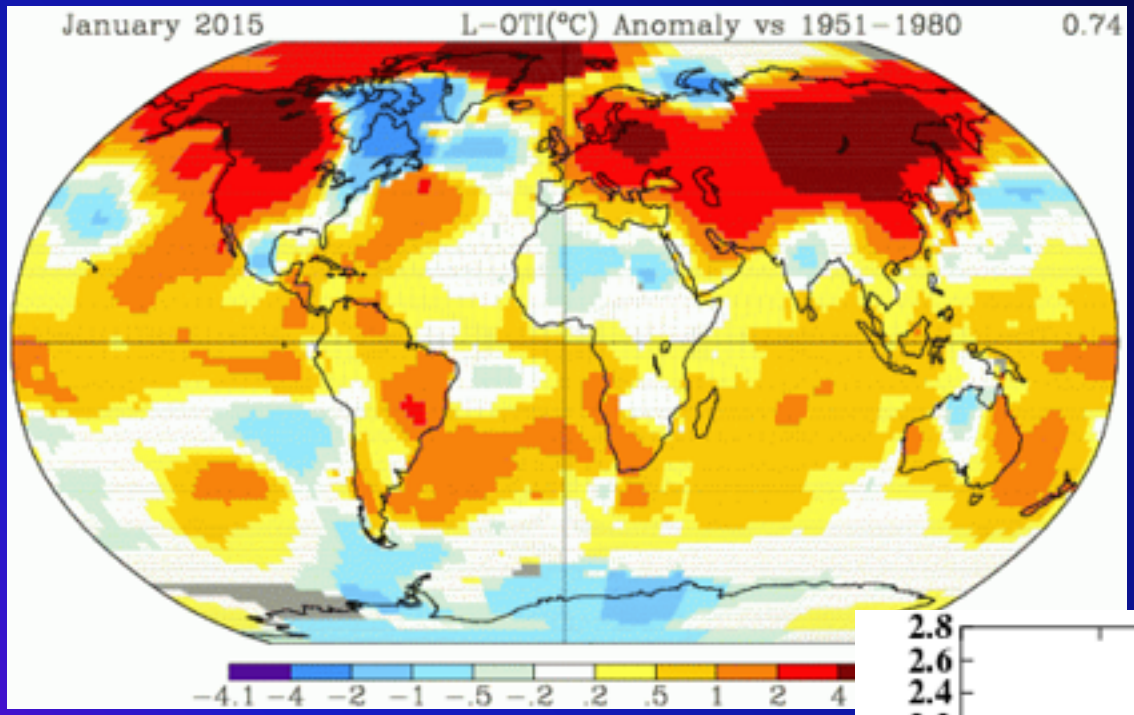

January 2015 is warmest January on record.

Jan. 2015 zonal temperature anomalies