Climate Change Through a Meteorological Perspective

Climate Change and Changing Weather

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Arctic Warming Resulting in Mid-Latitude Weather Extremes

1) Warming in the Arctic

2) Relate the Arctic Warmth to Climate and Weather in Mid Latitudes

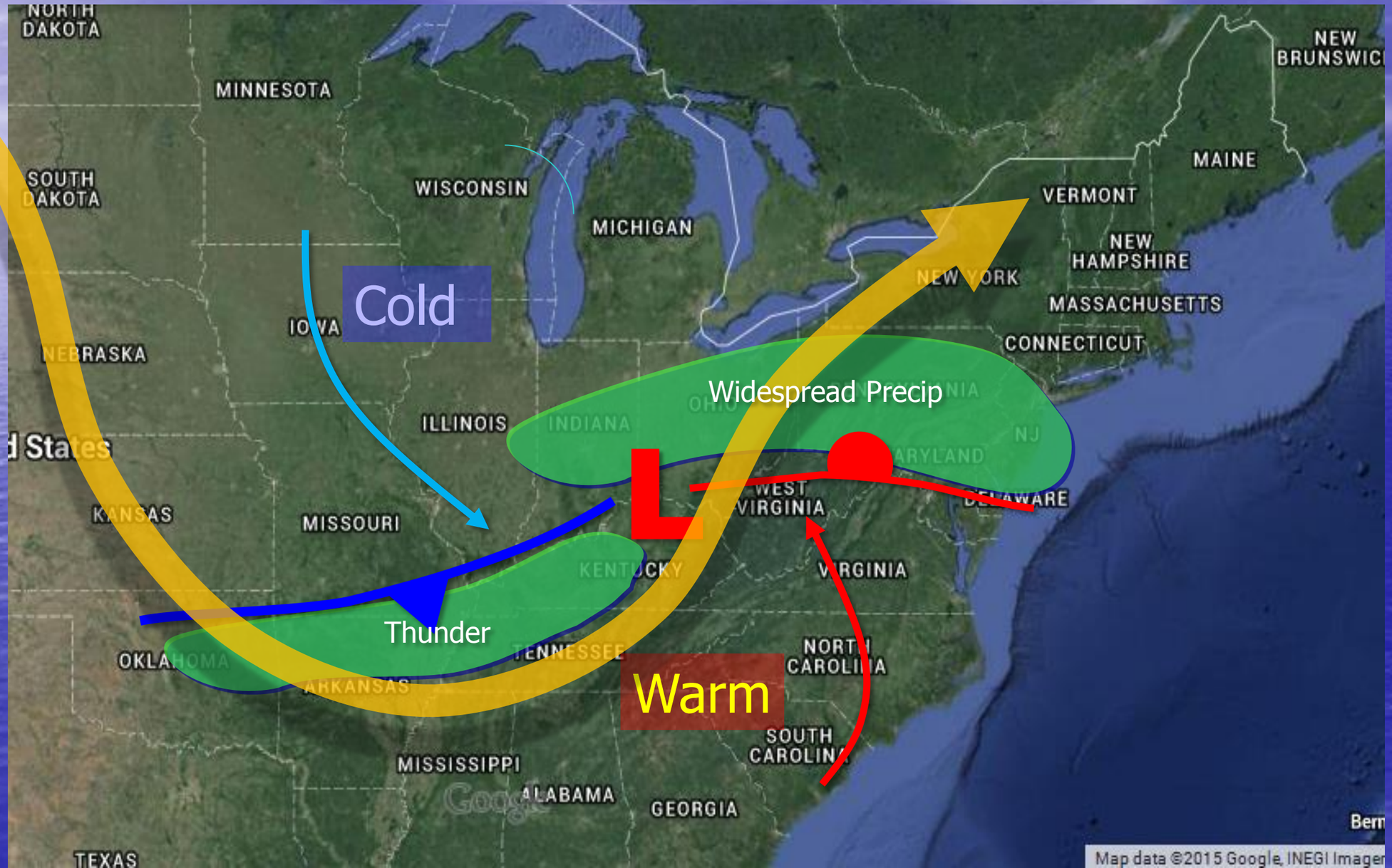
3) Some NE U.S. Regional and Local Impacts and Projections:

Part One

The connection between high altitude winds (The Jet Stream) and mid latitude weather

Jet Stream winds aloft (40,000 feet up) generally flow above weather fronts (zones dividing warm and cold air masses) down at the earth's surface.

The Jet Stream (in yellow) steers storm systems (low pressure systems)



So: Some key points to remember in this talk:

Usually:

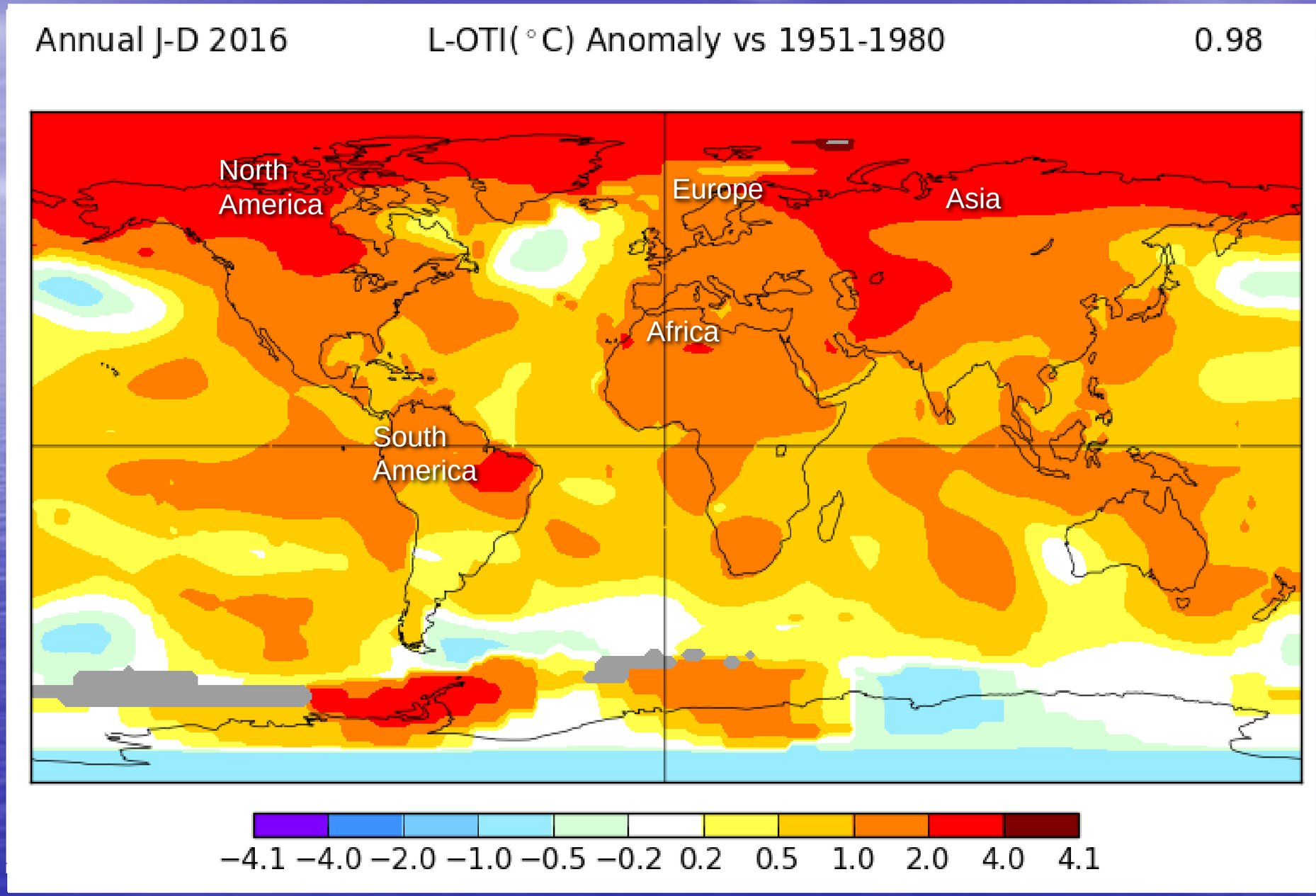
- Stronger winds aloft = Stronger Storm/storm systems
- Stronger winds aloft also = faster moving storms

Part Two: The Arctic

It’s warming fast!

A warmer Arctic, forces changes in the Jet Stream.

Surface Temperature Anomaly



Data: NASA GISS

McCarty Fjords, Kenai Fjords National Park, Alaska.
McCarty Glacier July 30, 1909

National Snow and Ice Data Center/World Data Center for Glaciology, Boulder

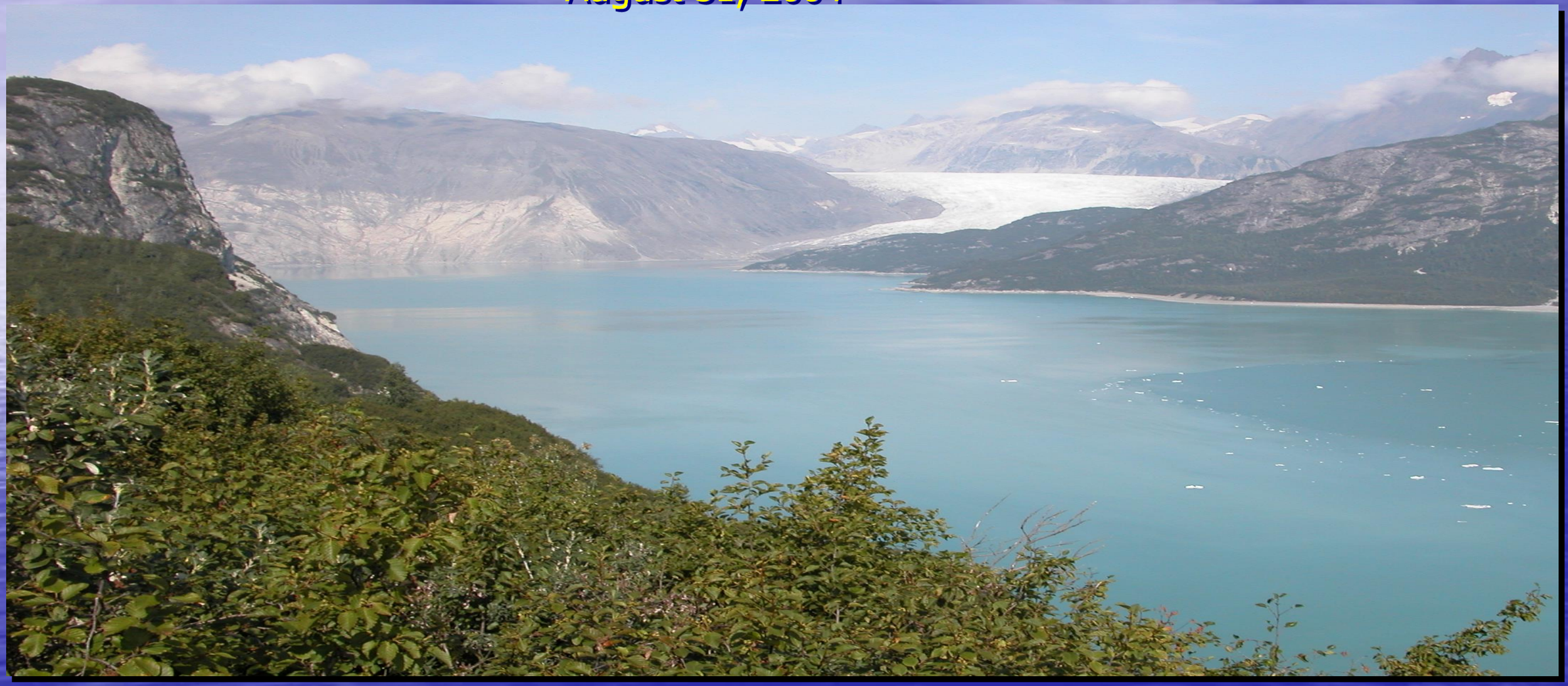
McCarty Fjords, Kenai Fjords National Park, Alaska.
Aug 11, 2004

National Snow and Ice Data Center/World Data Center for Glaciology, Boulder

1941 by W.O. Field on White Thunder Ridge, Muir Inlet,
Glacier Bay National Park and Preserve, Alaska.

National Snow and Ice Data Center/World Data Center for Glaciology, Boulder

Muir Inlet, Glacier Bay National Park and Preserve, Alaska.
August 31, 2004



National Snow and Ice Data Center/World Data Center for Glaciology, Boulder

Turnagain Arm Glacier Southern Alaska Near Anchorage

Turnagain Arm Glacier Southern Alaska Near Anchorage

Turnagain Arm Glacier Southern Alaska Near Anchorage

Dave Eichorn 2017

Reason's for the Arctic Warming:
There are many:

1: Changes in winds from the mid latitudes to the Poles
(Changes in Atmospheric, and Oceanic Circulation)

2: Increased CO_2 and other GHGs

3: Changes in the stratospheric winds

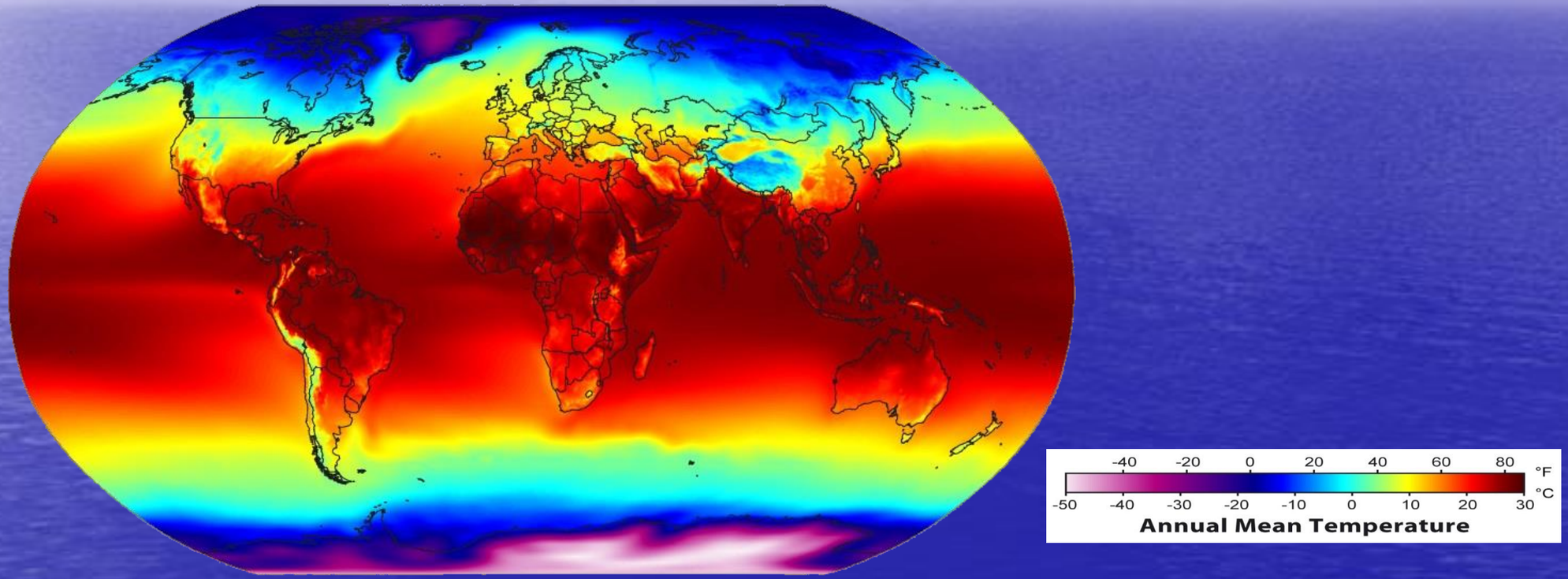
4: Increased air Pollution, Cloud cover, Humidity

….And More: http://www.arctic.noaa.gov/reportcard/

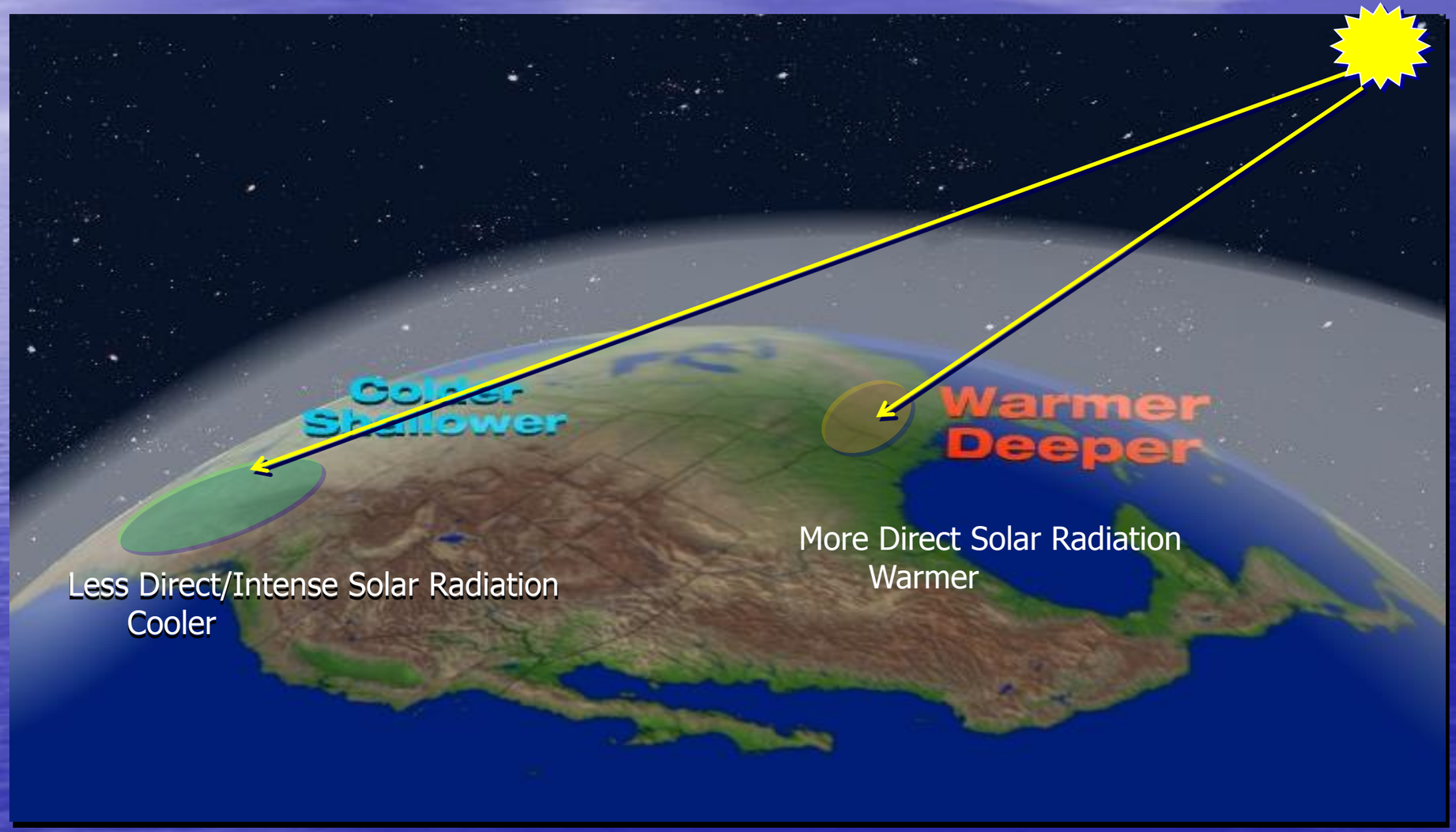
Here is how a warmer Arctic changes everything for us:

Let’s go back to the jet stream and high altitude winds over the mid-latitudes

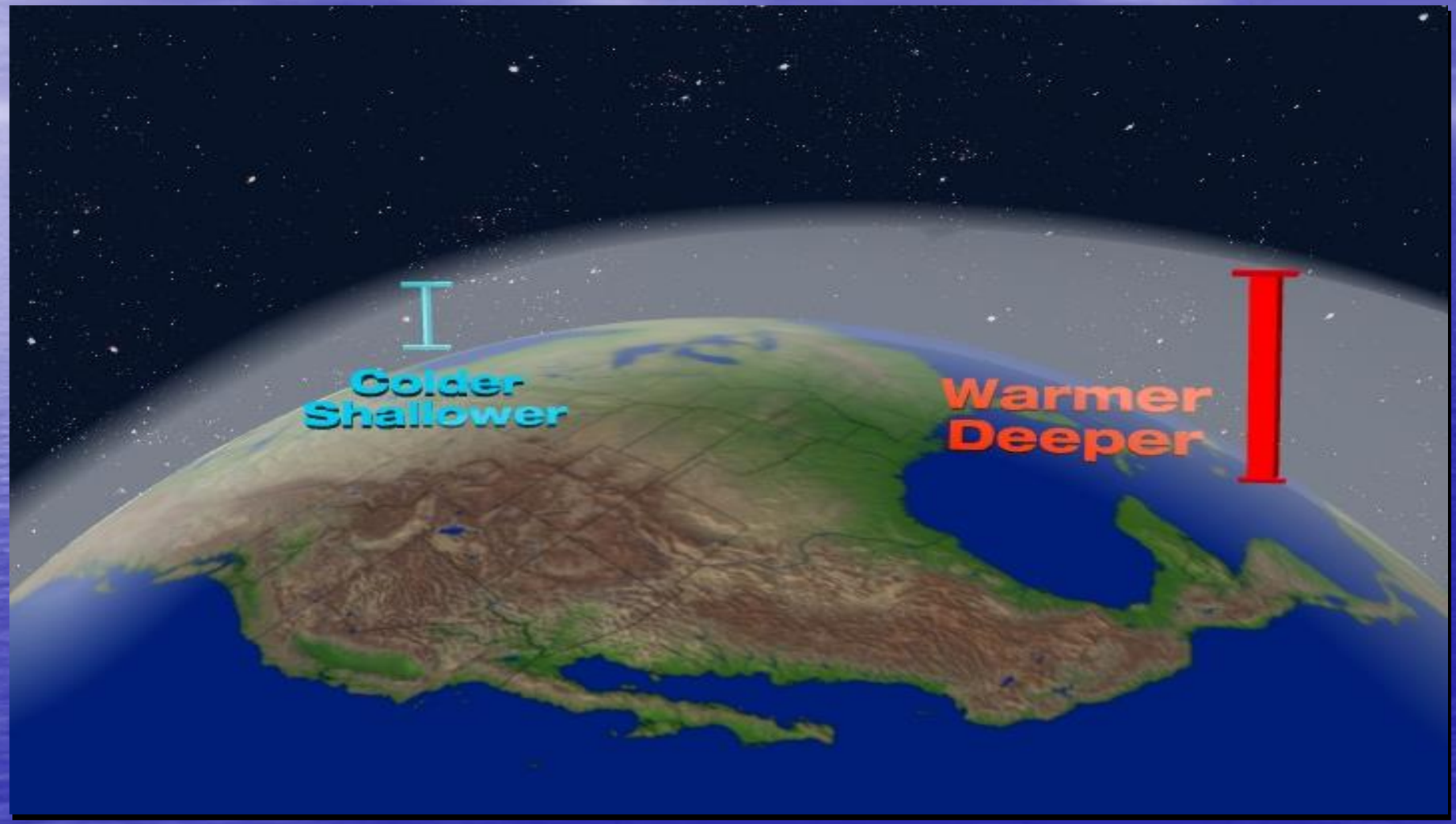
Differences in temperature across latitude are what drive high altitude winds



Angle of Incoming Solar Radiation



Tropospheric Depth Changes With Latitude



Air Pressure Decrease With Height

500 Millibars

700 Millibars

850 Millibars

925 Millibars

Climate Change and Atmospheric Heating

Climate Change and Atmospheric Heating

400 Millibars?

500 Millibars

5200 Meters up in Altitude

700 Millibars

Cold Air
North Pole

850 Millibars

950 Millibars

1000 Millibars

500 Millibars

5800 Meters up in Altitude

700 Millibars

Warm Air
Equator

850 Millibars

950 Millibars

1000 Millibars

At 5800 Meters Up: Higher Pressure Over Warmer Air

400 Millibars

Lower Pressure

500 Millibars

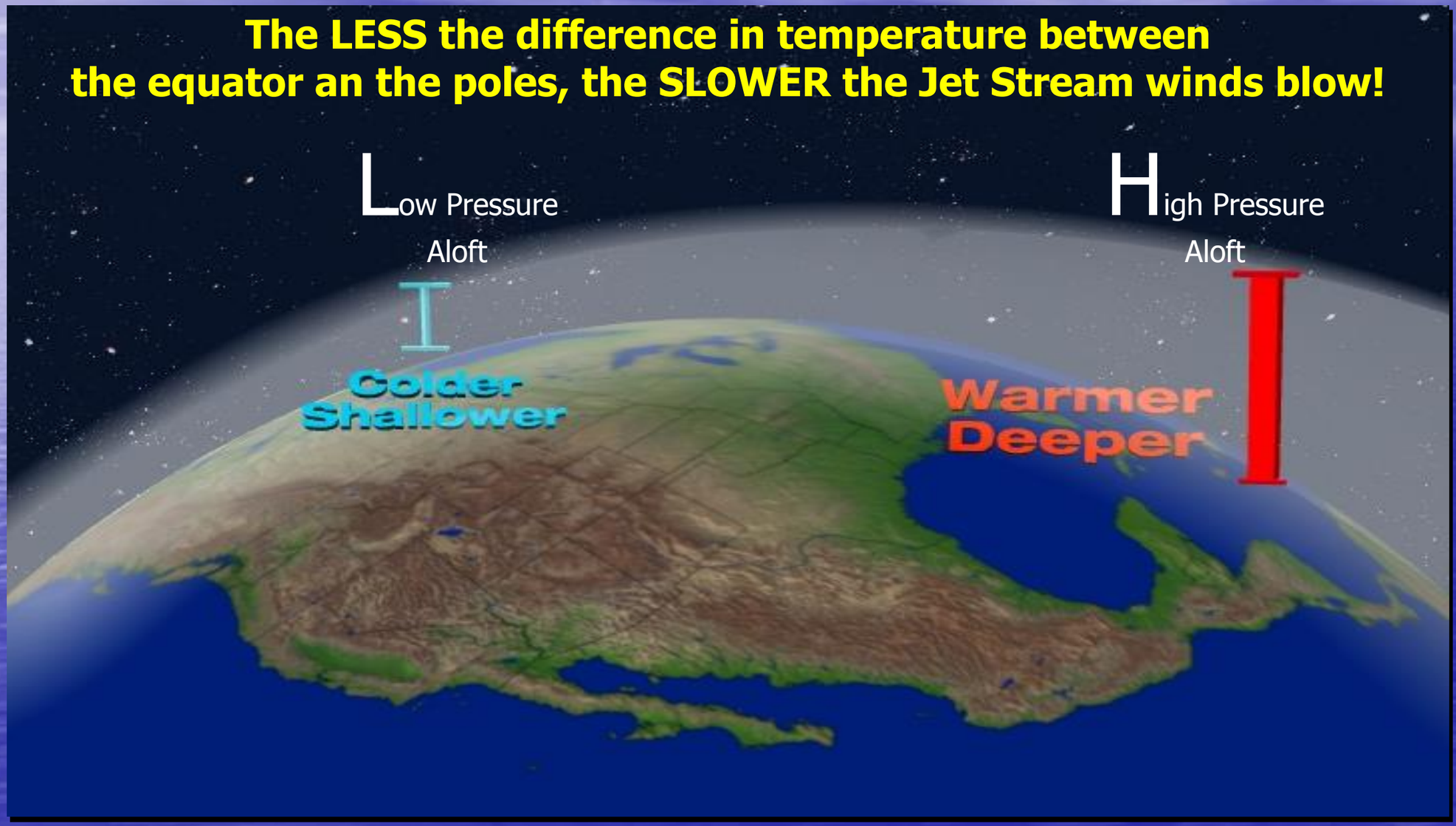
Higher Pressure

Cold Air

North Pole

Warm Air

Equator


The LESS the difference in temperature between
the equator an the poles, the SLOWER the Jet Stream winds blow!
Low Pressure
Aloft
High Pressure
Aloft
Colder
Shallower
Warmer
Deeper

So:
A warmer Arctic weakens the jet stream

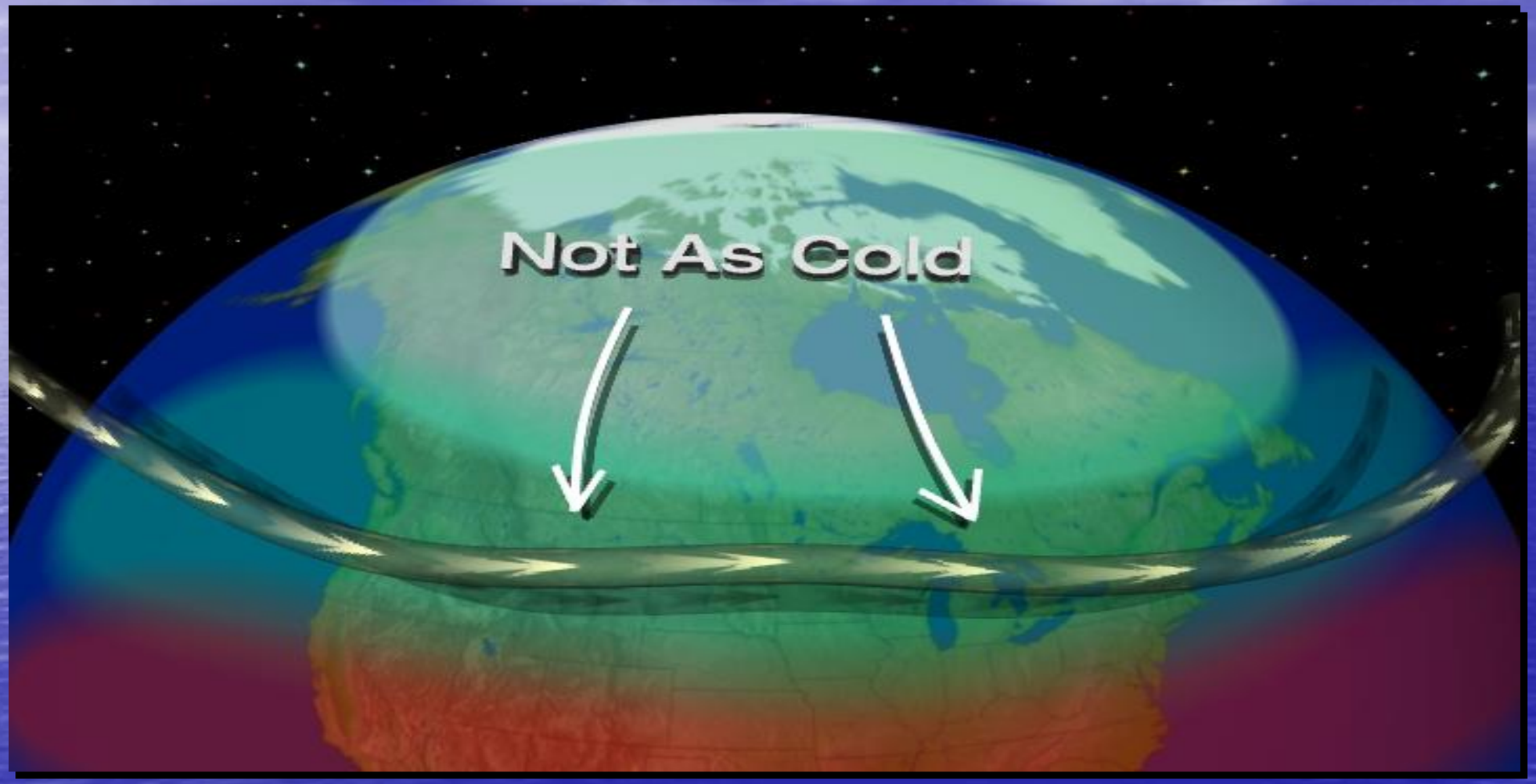
Also

A warmer Arctic often displaces the jet stream. It has to find a “new home.”

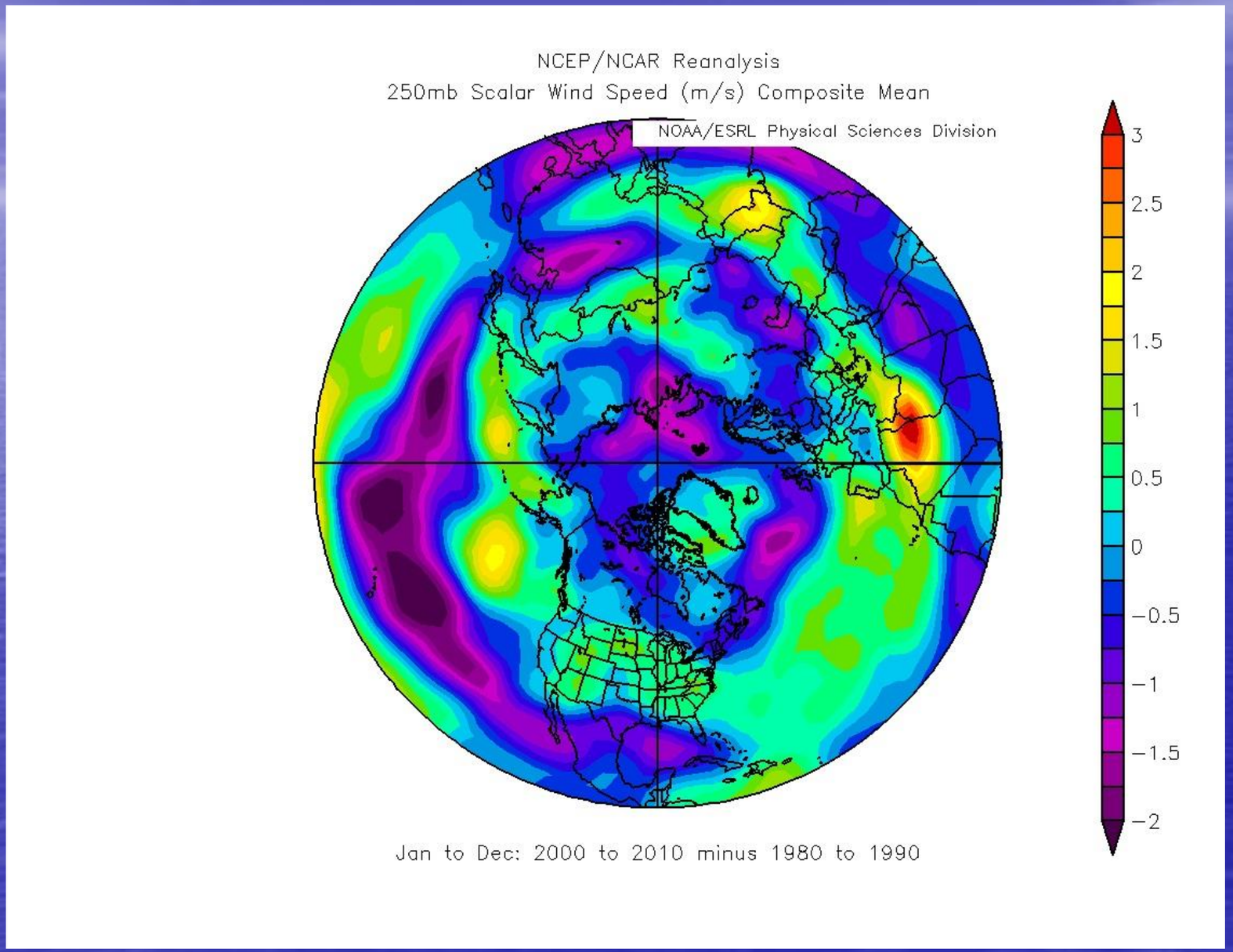
Guess where the Jetstream is now spending more time.

“Normal” Jet Stream Pattern.

For one thing, the stronger westerlies shift south (They are fitting to better temperature contrast)



Annual Average Jet Stream Wind Changes from the last 20 years



The consequences of a slower, and displaced jet stream are complex

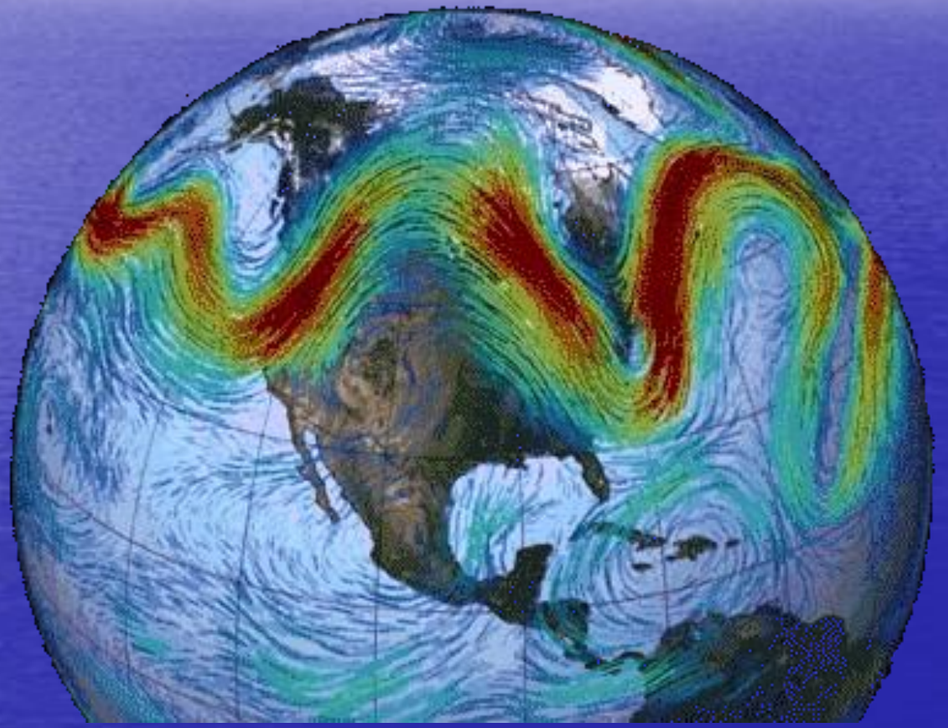
For example….

Mid latitude thunderstorms depend on strong winds aloft.

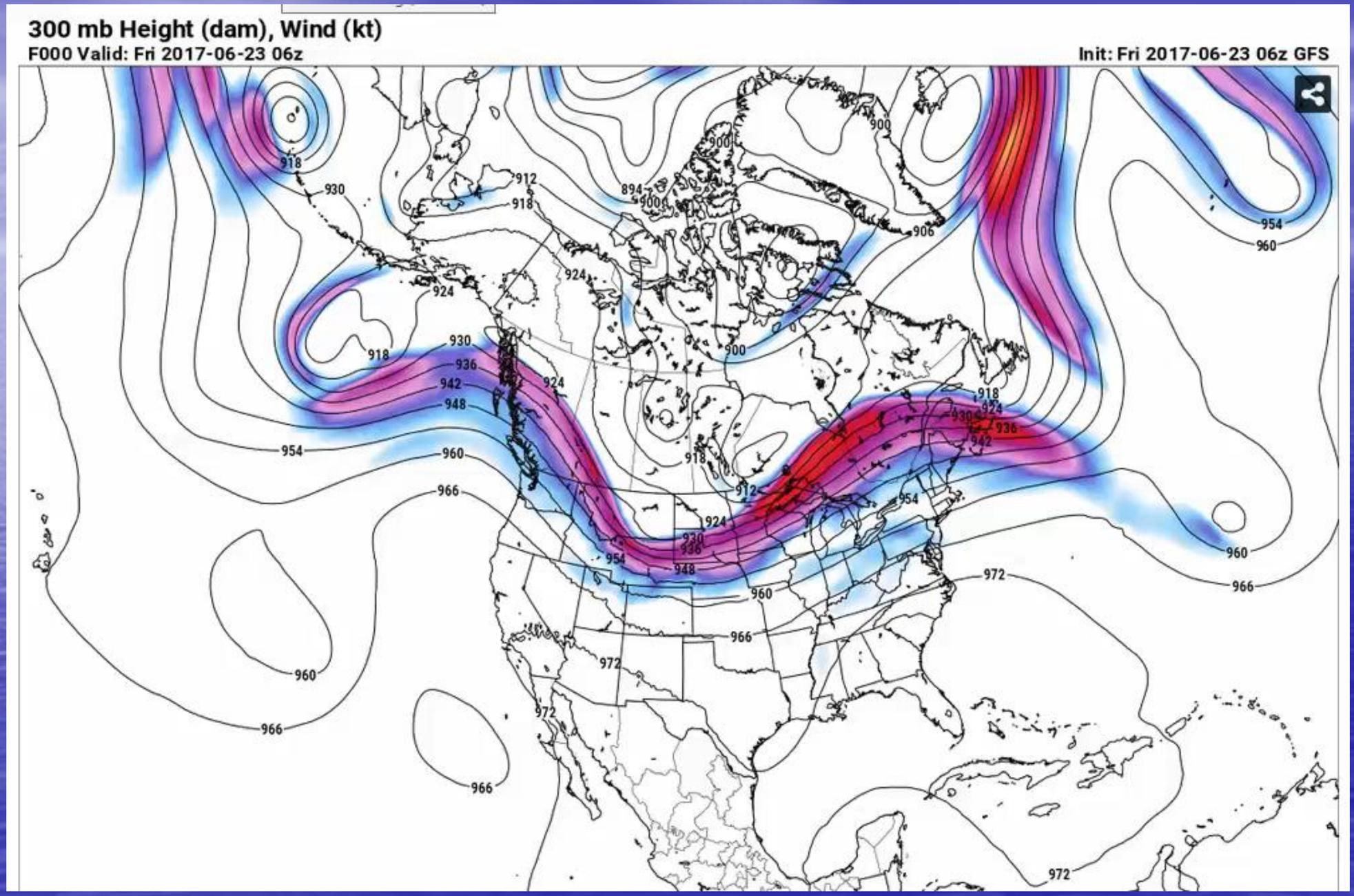
Thunderstorm with it’s classic flat anvil top (Taken from Nasa Space Shuttle)


Strong winds aloft help to “ventilate” storms below.
Removal of air aloft promotes updrafts, and tilts the storms
…which helps sustains the storms.

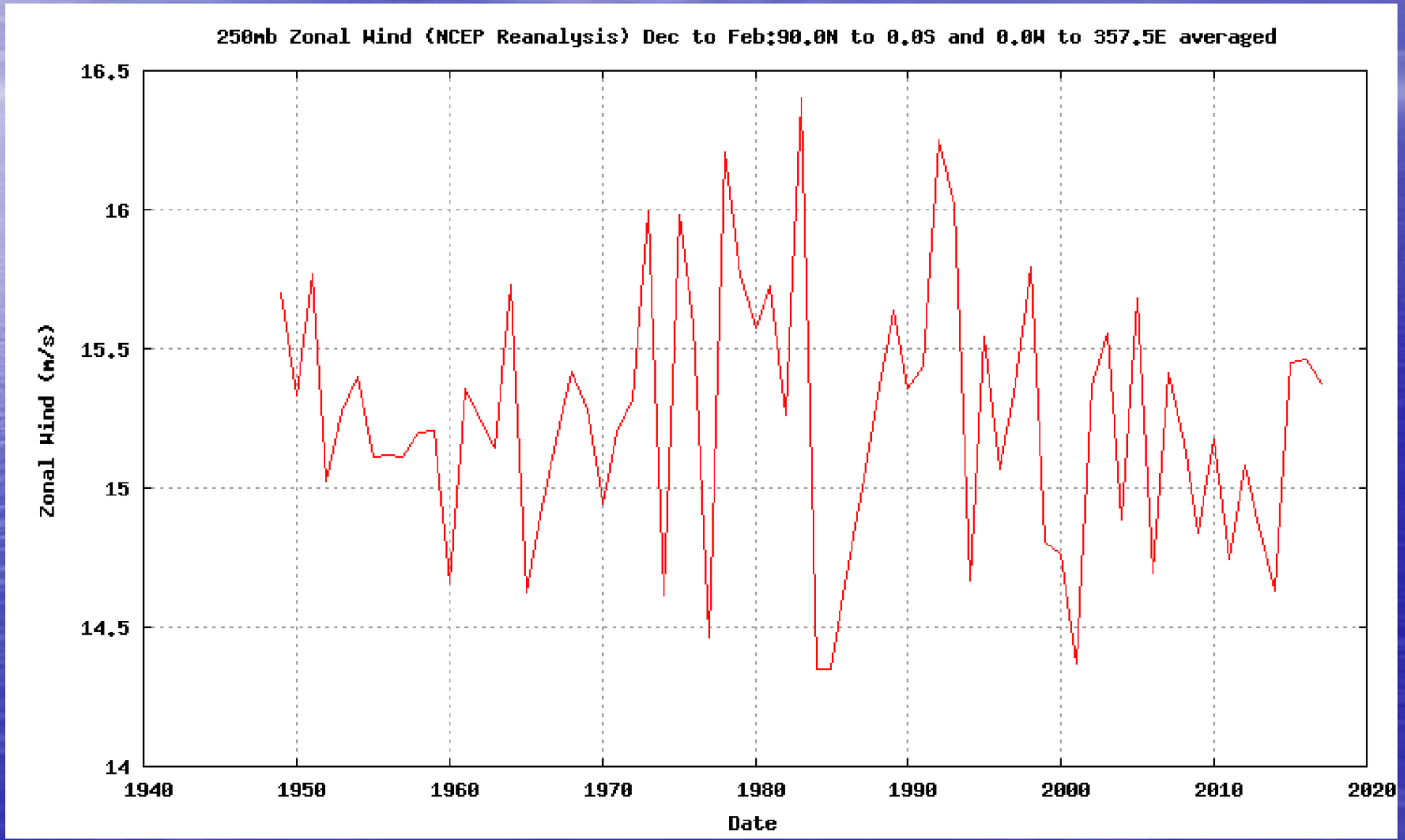
Winds aloft oscillate north and south in waves called ridges and troughs.



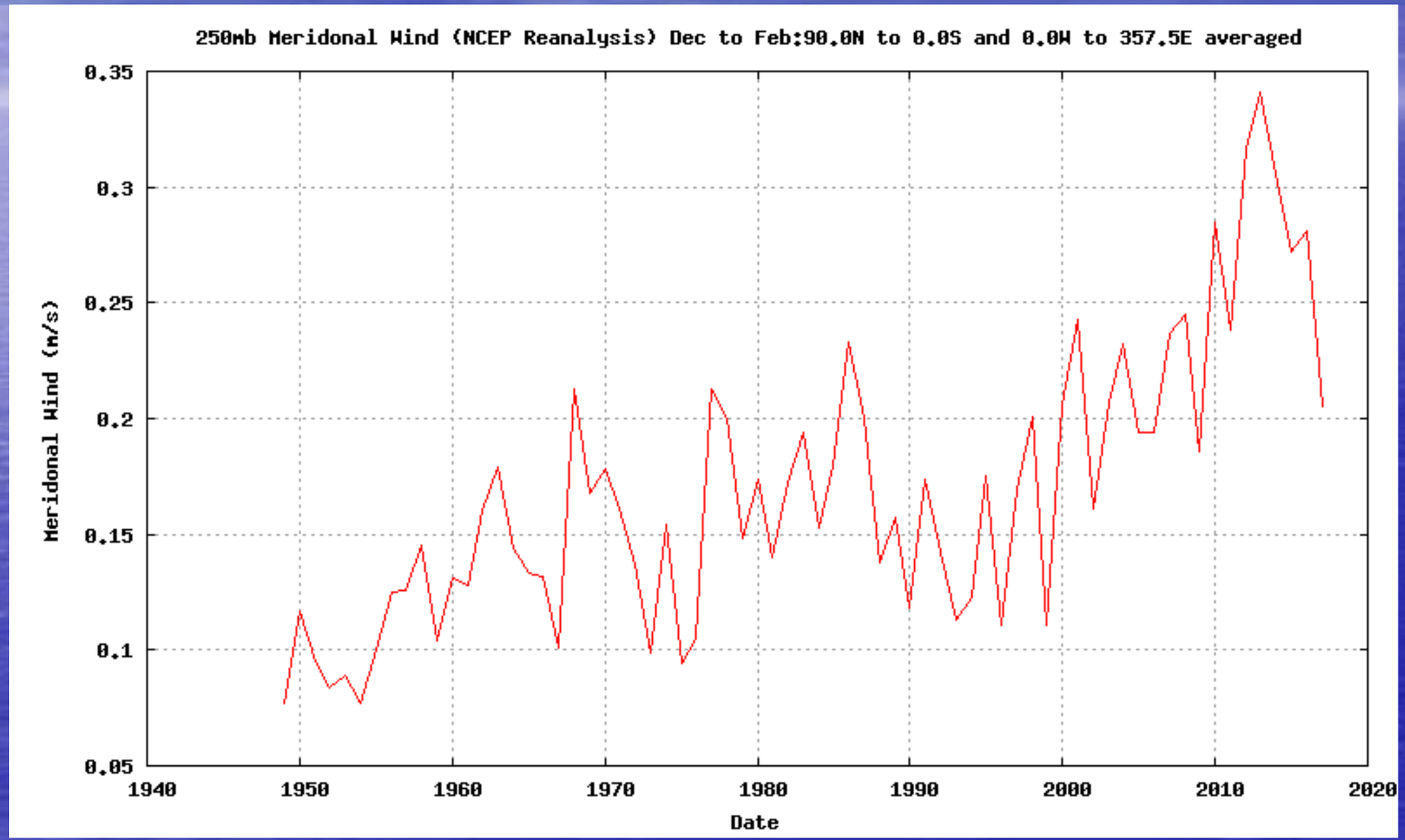
These ridges and troughs propagate along like waves in the ocean.


300 mb Height (dam), Wind (kt)
F000 Valid: Fri 2017-06-23 06z
Init: Fri 2017-06-23 06z GFS

The West to East Component of High Altitude Winds (U) (Northern Hemisphere Winter) Decreasing



The Northward and Southward Component of High Altitude Winds (V) (Northern Hemisphere Winter)

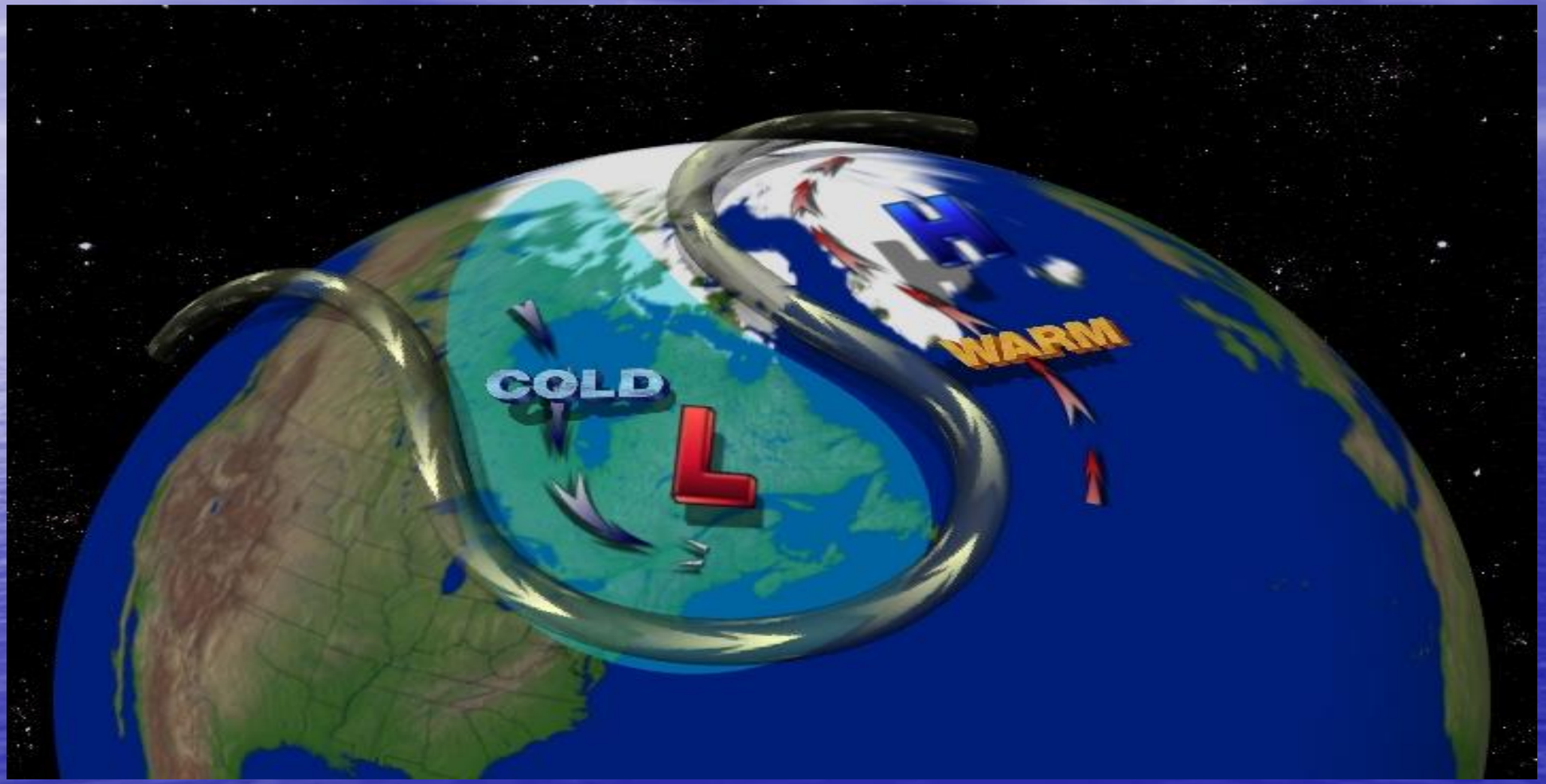


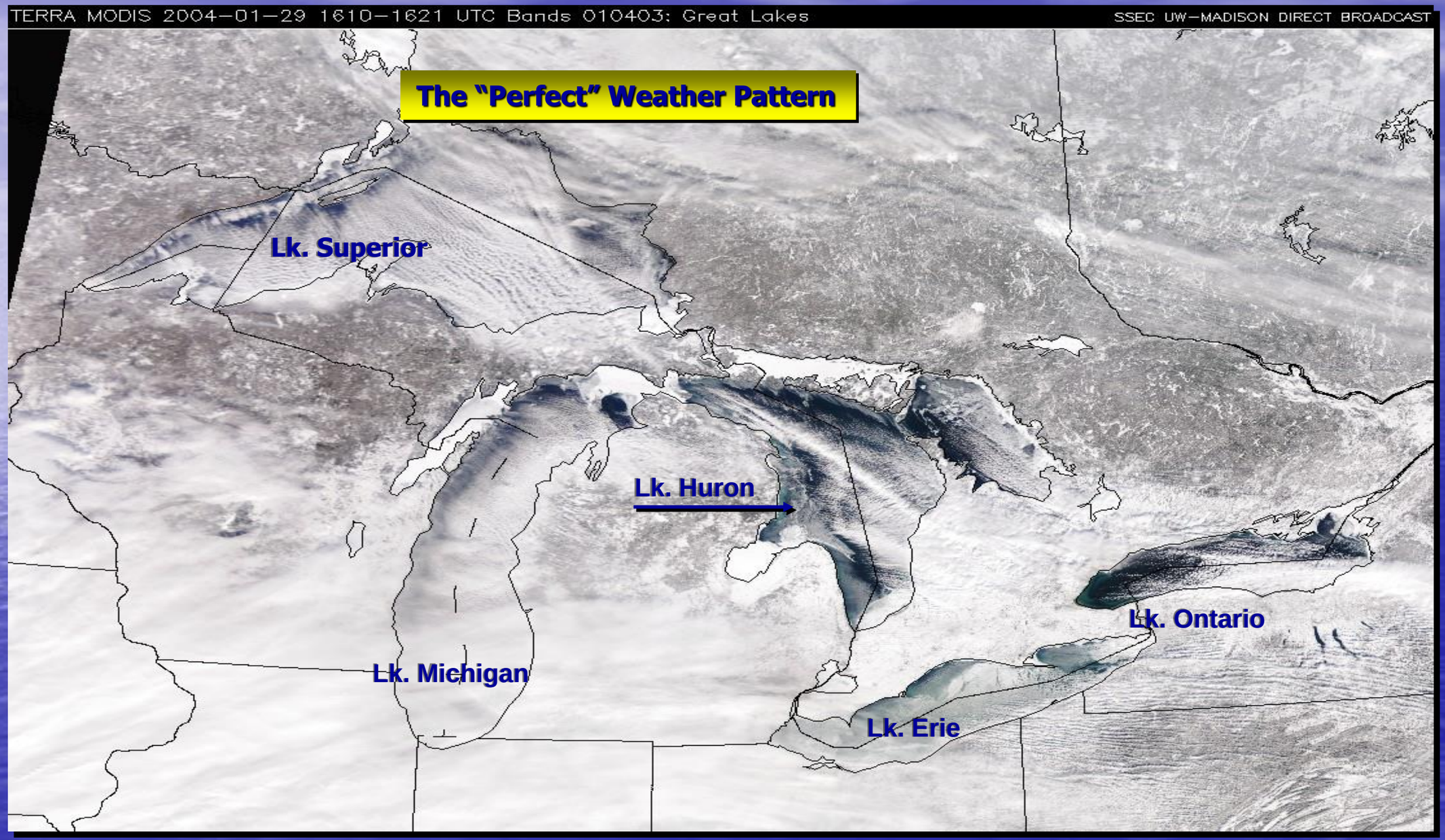
U.S. Department of Commerce | National Oceanic and Atmospheric Administration
Earth System Research Laboratory https://www.esrl.noaa.gov/

Some extreme examples

Greenland Block
January 2004

A Good Example: More Blocking Highs (Lately over Greenland and Alaska)




TERRA MODIS 2004-01-29 1610-1621 UTC Bands 010403: Great Lakes
SSEC UW-MADISON DIRECT BROADCAST
The "Perfect" Weather Pattern
Lk. Superior
Lk. Huron
Lk. Ontario
Lk. Michigan
Lk. Erie

The results of the Greenland Block:

Release Date: April 14, 2004

ALBANY, N.Y. – The Federal Emergency Management Agency announced that the first $1 million in federal disaster aid…..

…. has been approved for local governments and non-profit organizations in Cayuga, Oneida, Oswego and Lewis counties.

We did it again! February, 2007

FEMA: February 2007 Lake Effect Snowstorm

“February 23, 2007, (The President) declared a federal emergency…to help recover from the February 2-12, 2007… lake-effect snowstorms.

Counties eligible for assistance include Lewis, Oneida and Oswego.”

Winter in a week, 2007

February 2007 : 9 Days of extreme Lake Effect

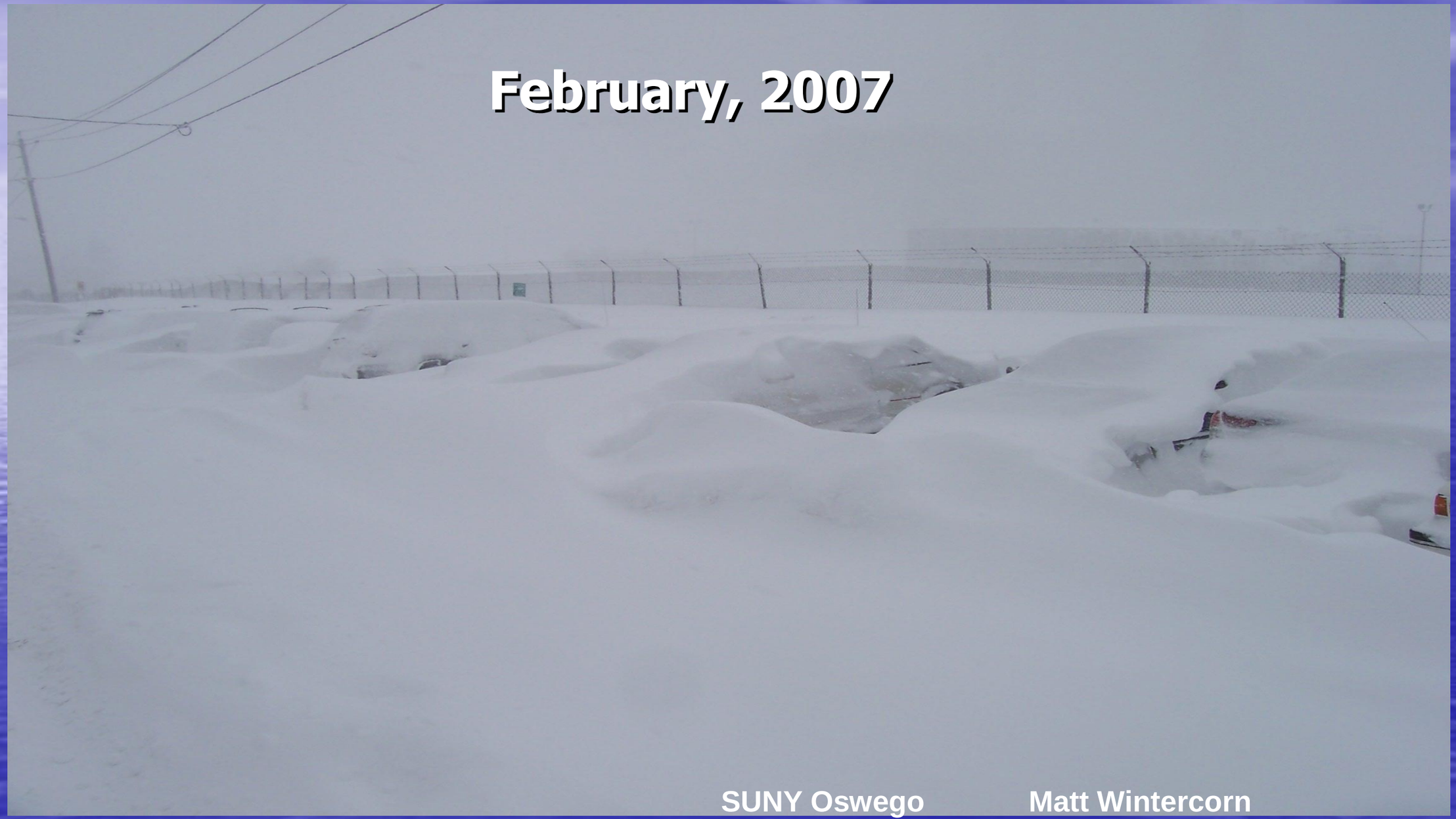
North Redfield, NY 144 inches of snow

Photo: Carol Yerdon

Parish, New York

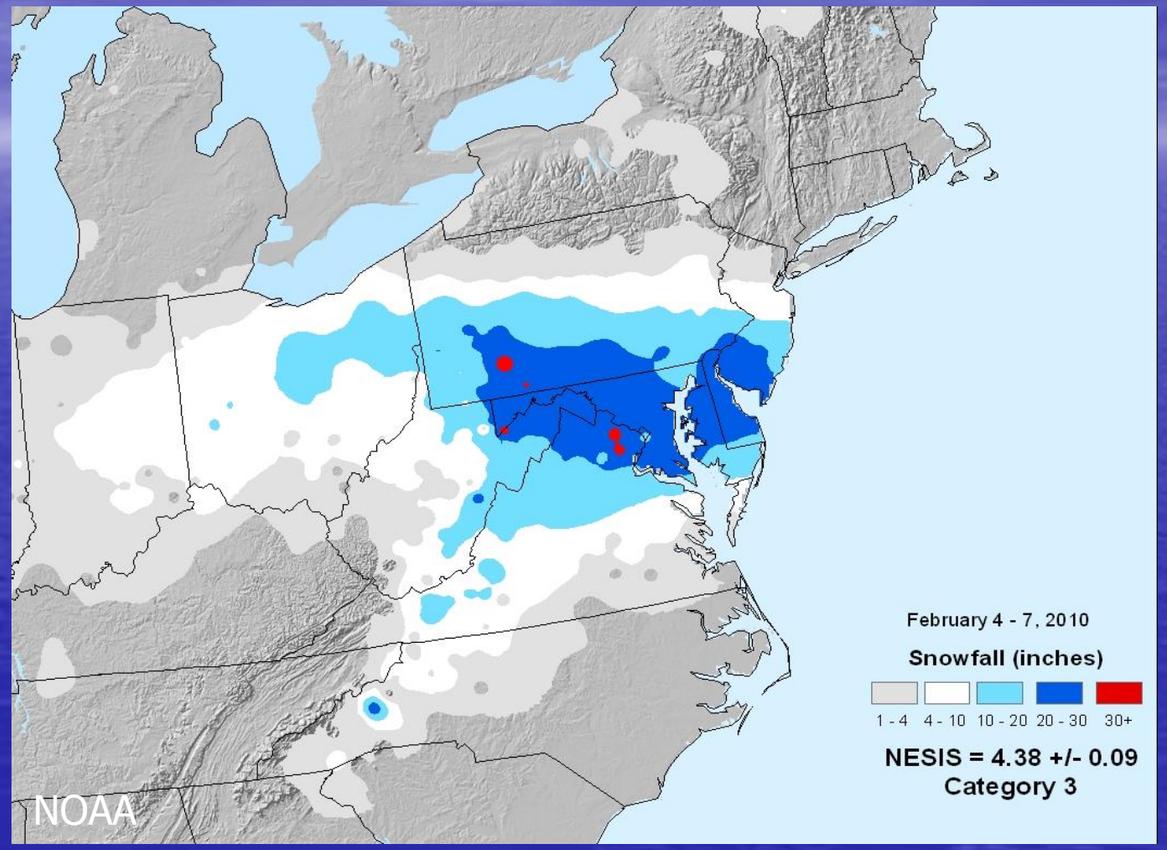
Photo: Mike Osborn

February, 2007



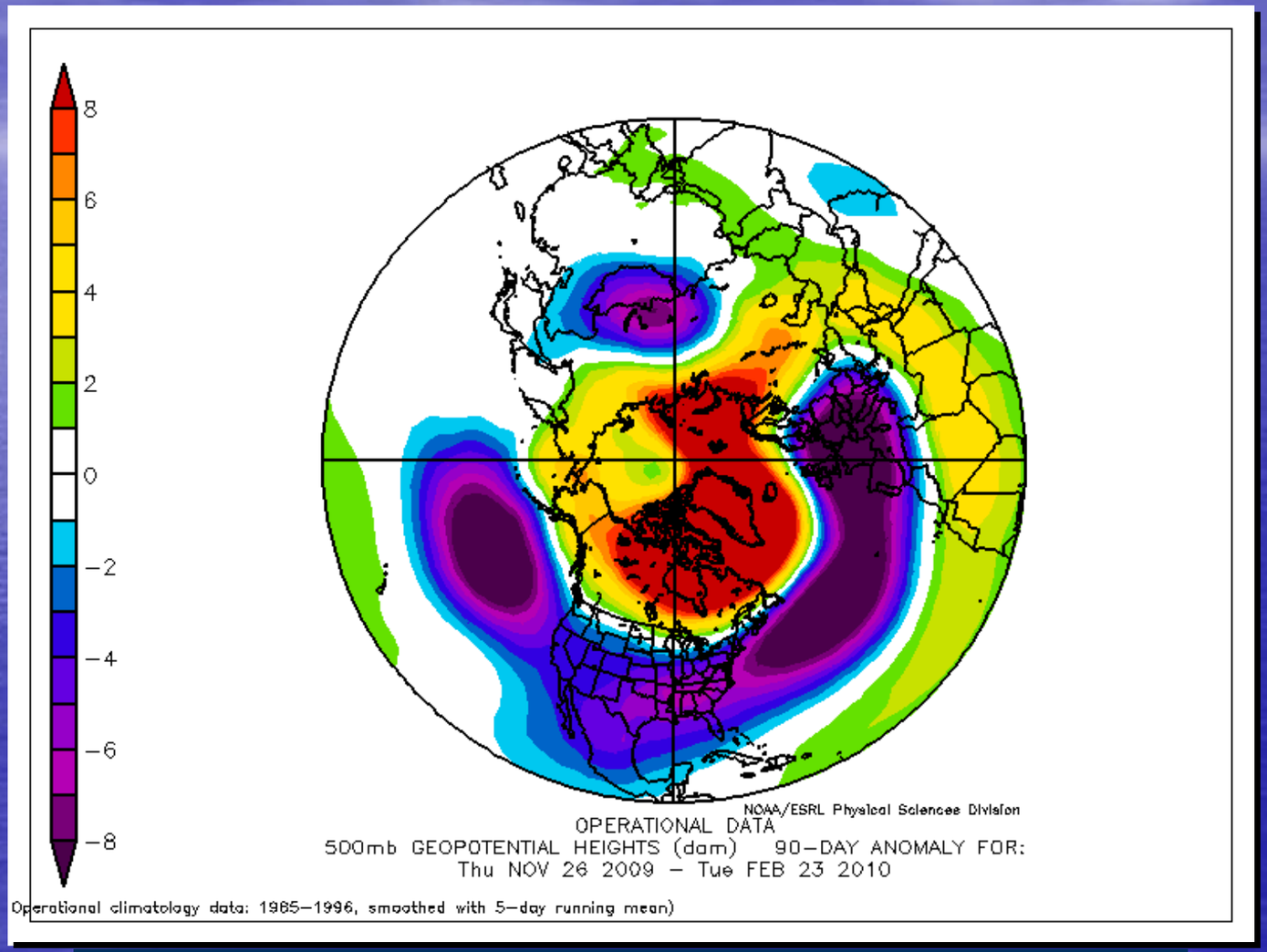
SUNY Oswego Matt Wintercorn

Washington and Philadelphia



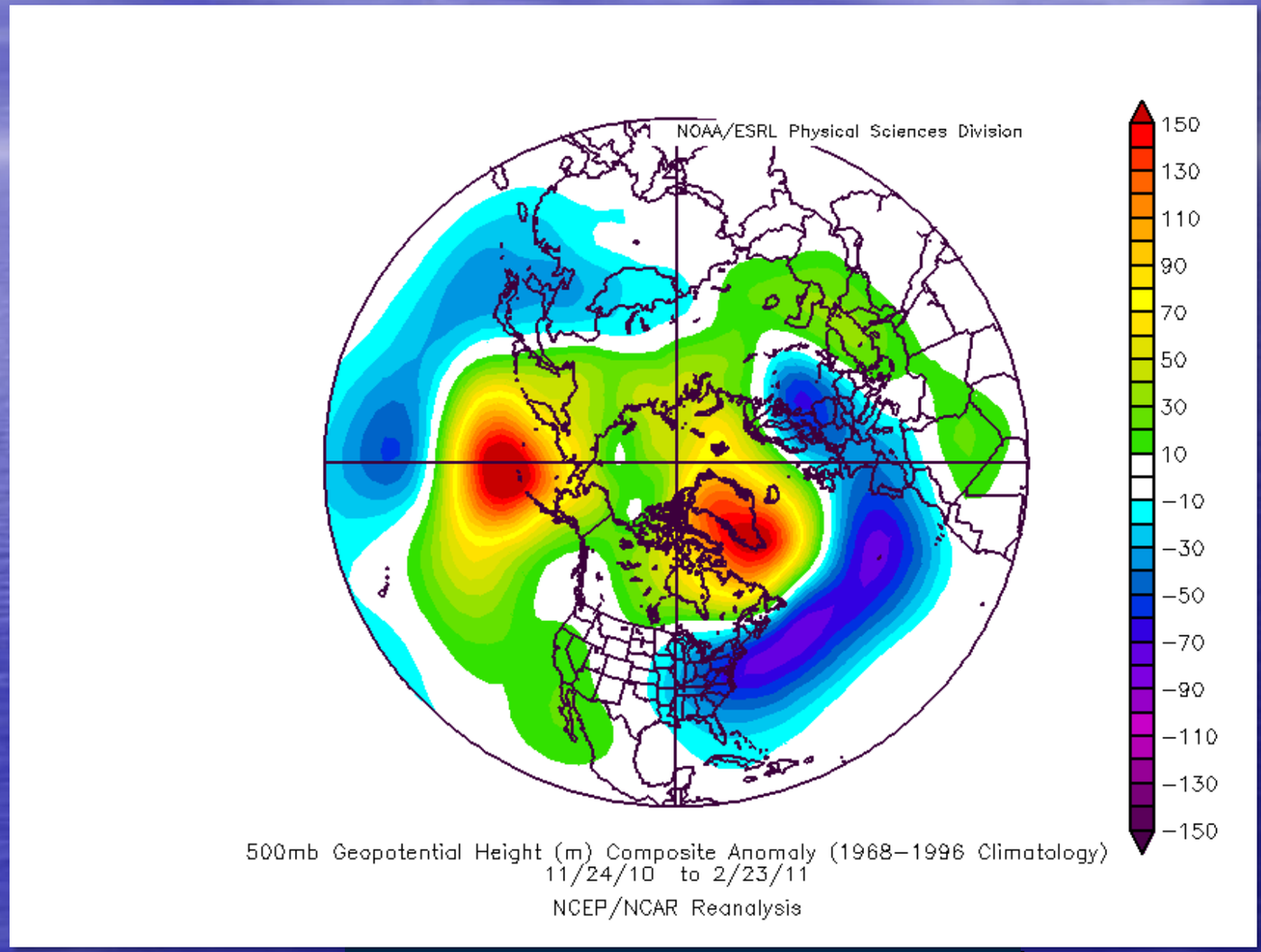
2010

Washington and Philadelphia



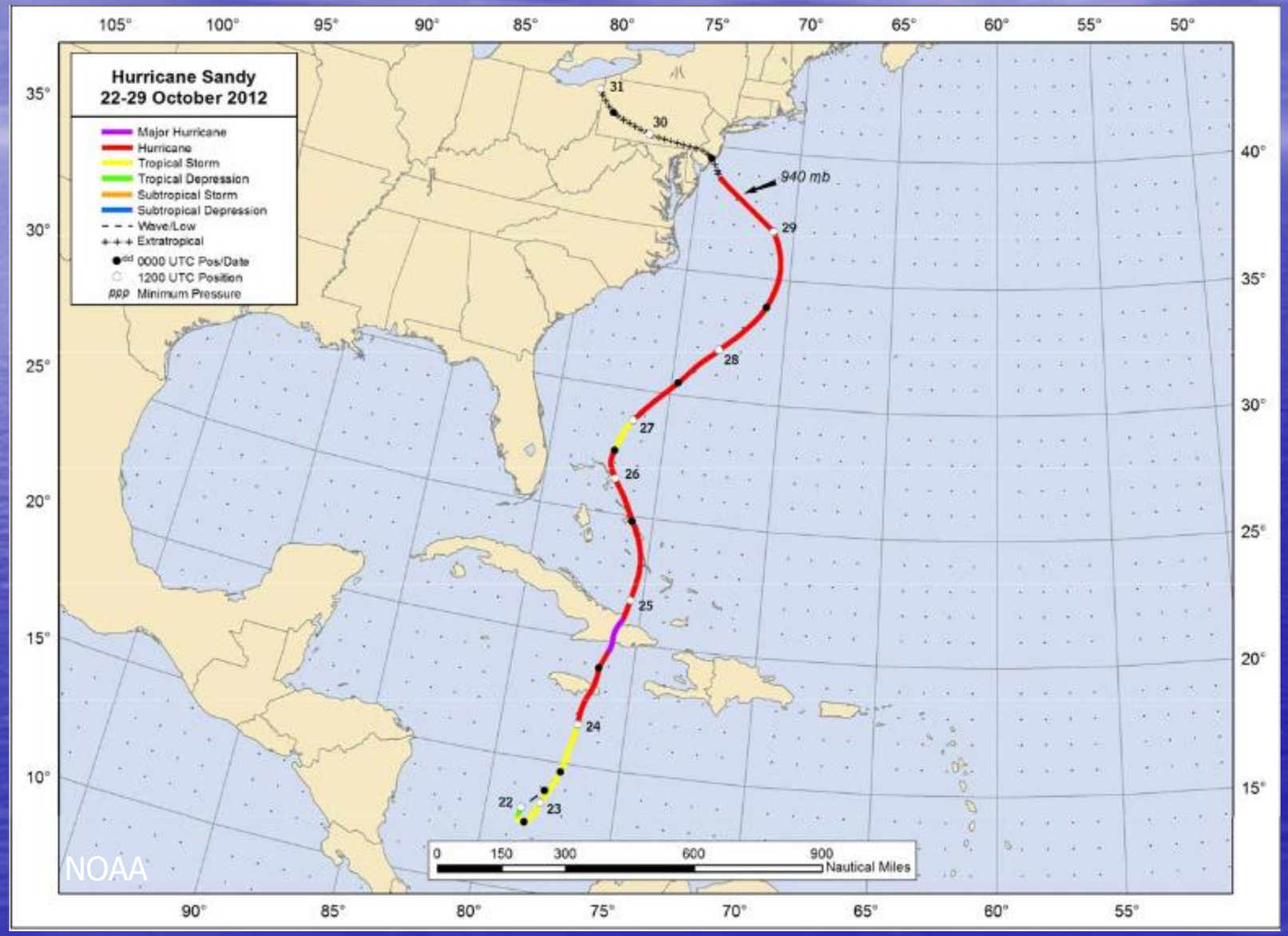
December – January 2009/2010

Another Extreme event in 2010-2011

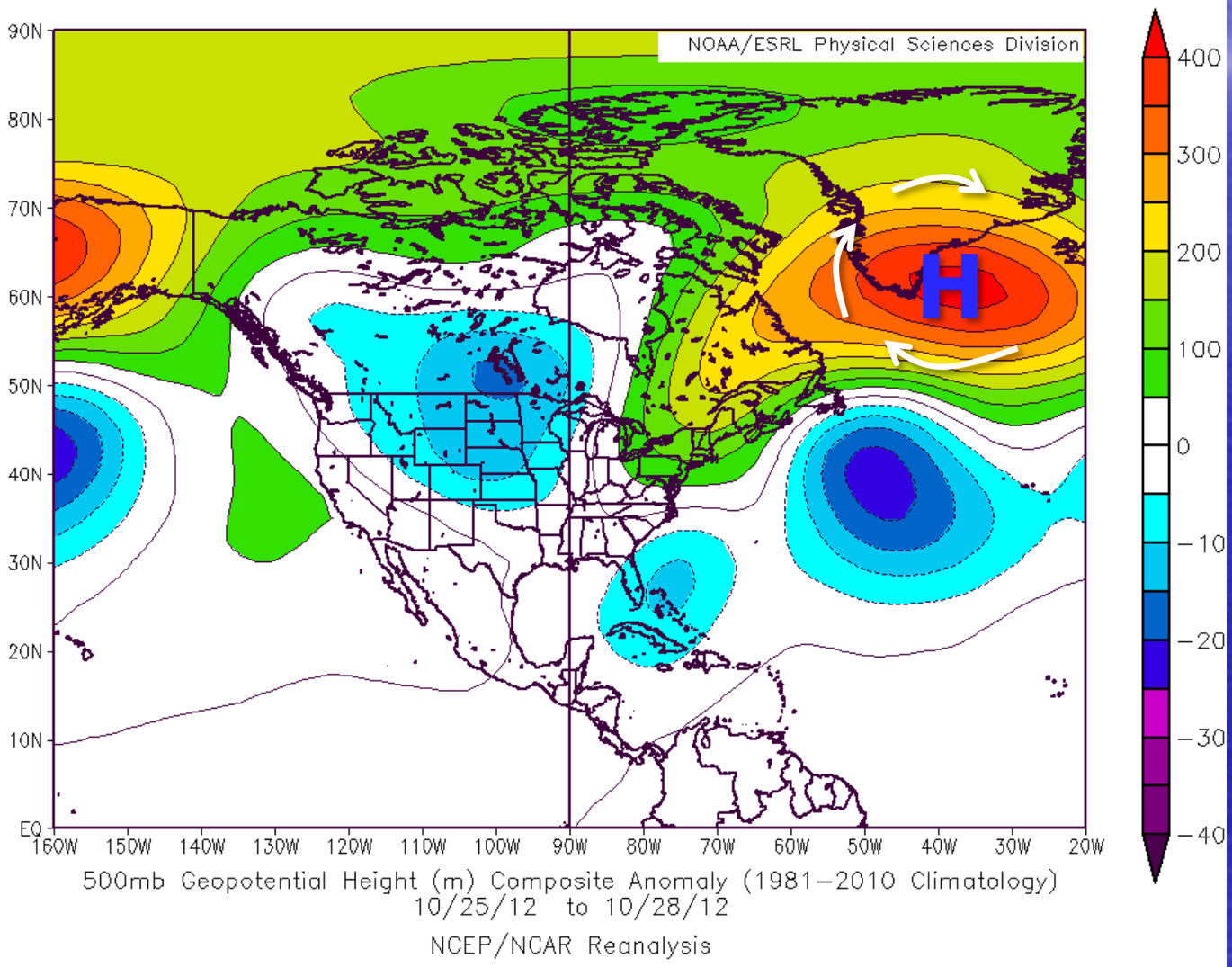


Nov 2010 – Feb 2011

Hurricane/Extratropical Storm Sandy



Hurricane/Extratropical Storm Sandy



As the Arctic Warms, The mid latitudes are greatly affected

"Climate change also alters dynamical characteristics of the atmosphere that in turn affect weather patterns and storms.

In the mid-latitudes, where most of the continental U.S. is located, there is an upward trend in extreme precipitation in the vicinity of fronts associated with mid-latitude storms."

Balling, Jr., R. C., and G. B. Goodrich, 2011: Spatial analysis of variations in precipitation intensity in the USA. *Theoretical and Applied Climatology*, **104**, 415-421, doi:10.1007/s00704-010-0353-0.

Regional Consequences
The Northeast

As internal forcing (GHG),
and external forcing “duke it out”,
more variability in our weather?

Regional Change: Max Temps NE U.S.

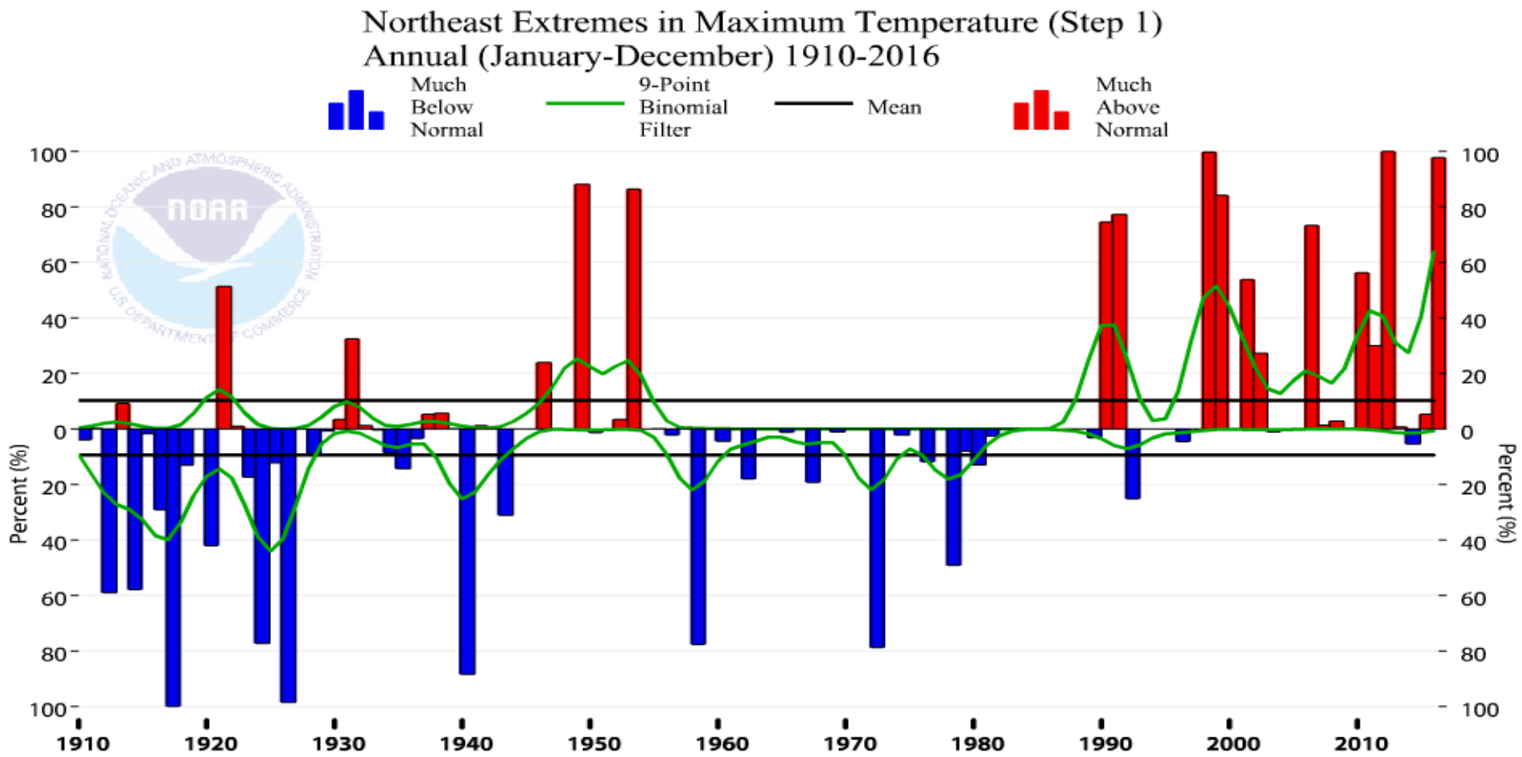
Region: Northeast

Period: Annual (January-December)

Indicator: Extremes in Maximum Temperature (Step 1)

Plot

Move mouse towards an axis until highlighted. Left-click mouse to **pan**. *Shift key + left-click to* **zoom**.



http://www.ncdc.noaa.gov/extremes/cei/graph/ne/4/12-02

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

Regional Change: Min Temps NE U.S.

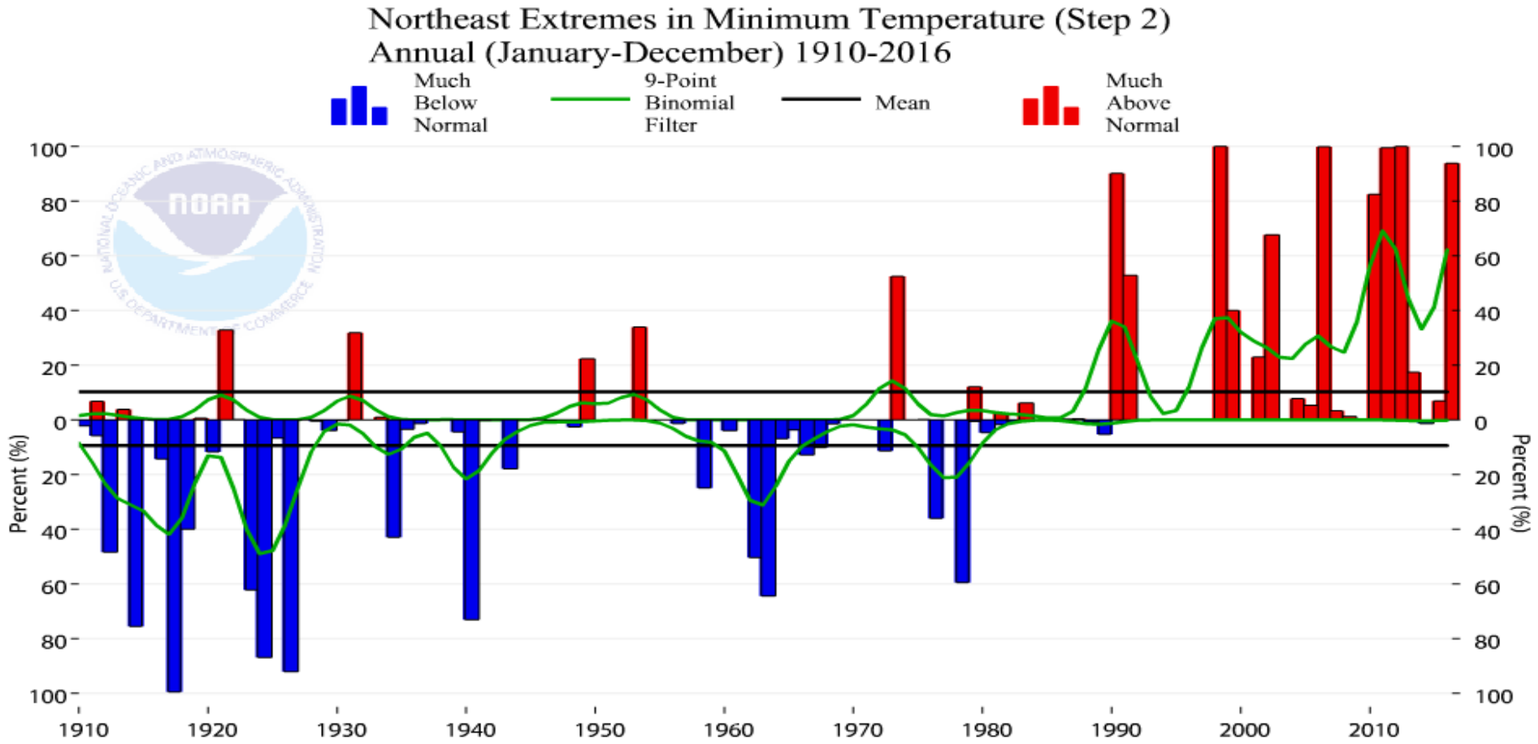
Region: Northeast

Period: Annual (January-December)

Indicator: Extremes in Minimum Temperature (Step 2)

Plot

Move mouse towards an axis until highlighted. Left-click mouse to **pan**. *Shift key + left-click to* **zoom**.



http://www.ncdc.noaa.gov/extremes/cei/graph/ne/4/12-02

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

Regional Change: Precip NE U.S.

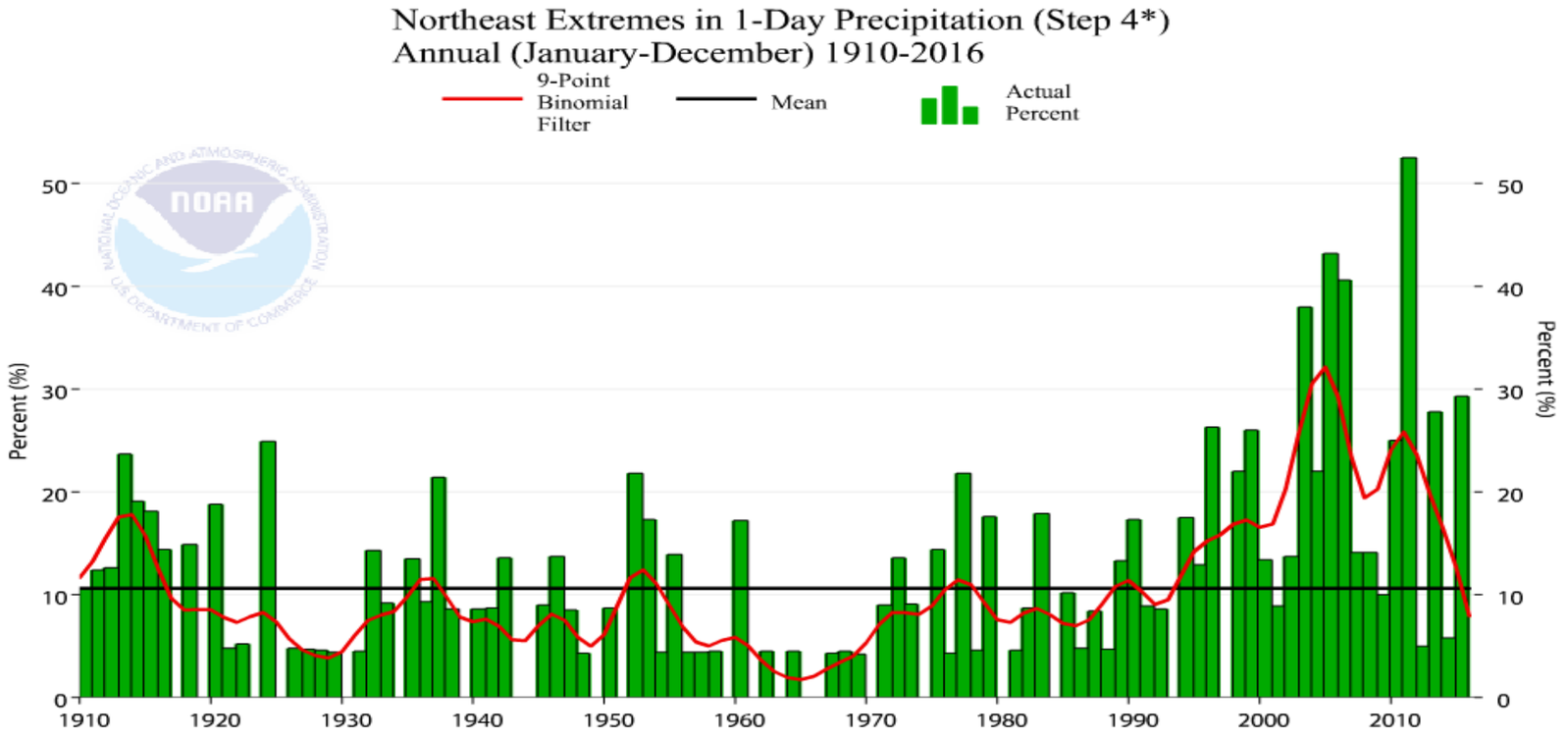
Region: Northeast

Period: Annual (January-December)

Indicator: Extremes in 1-Day Precipitation (Step 4*)

Plot

Move mouse towards an axis until highlighted. Left-click mouse to **pan**. *Shift key + left-click to* **zoom**.



http://www.ncdc.noaa.gov/extremes/cei/graph/ne/4/12-02

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

Regional Change: Summer Drought NE U.S.

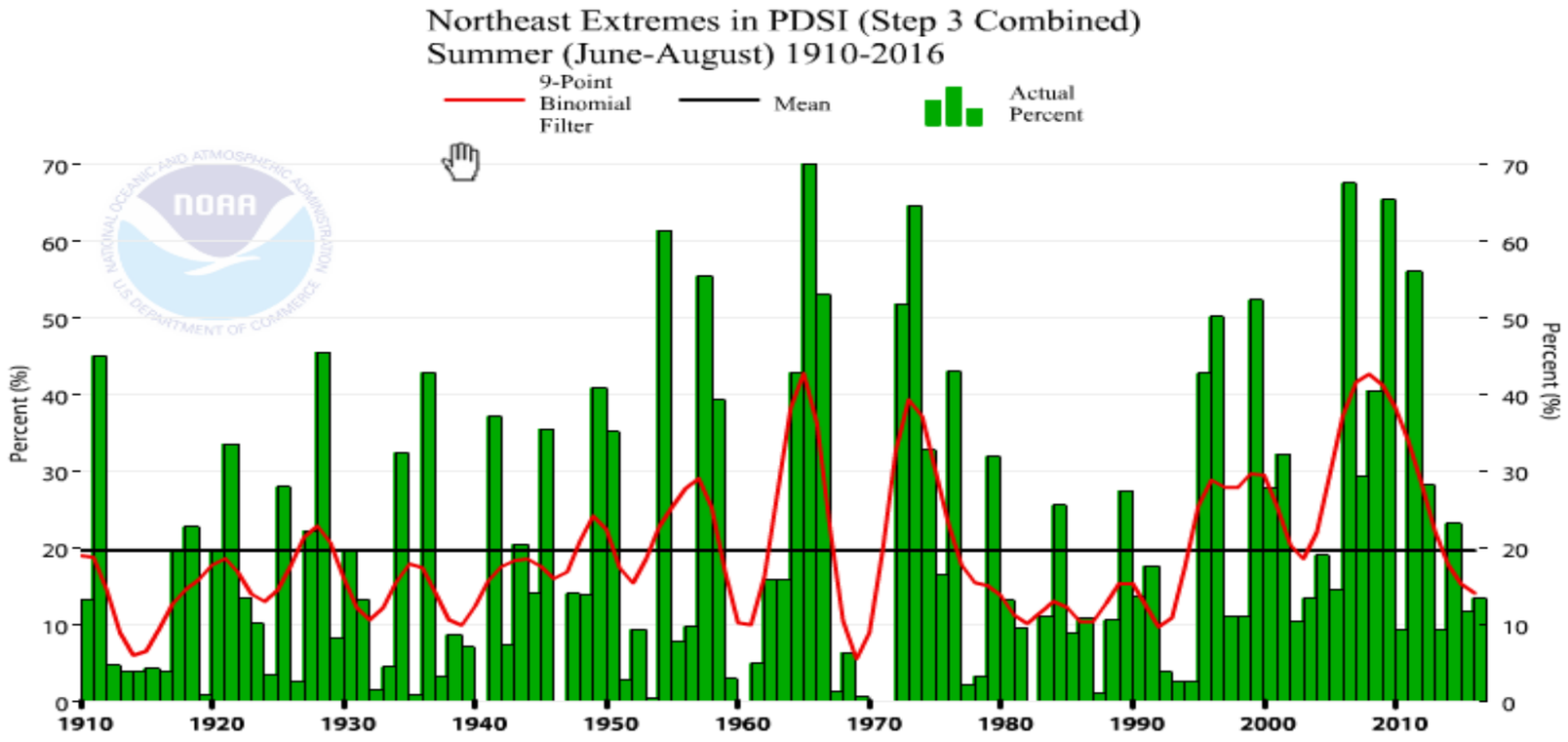
Region: Northeast

Period: Summer (June-August)

Indicator: Extremes in PDSI (Step 3 Combined)

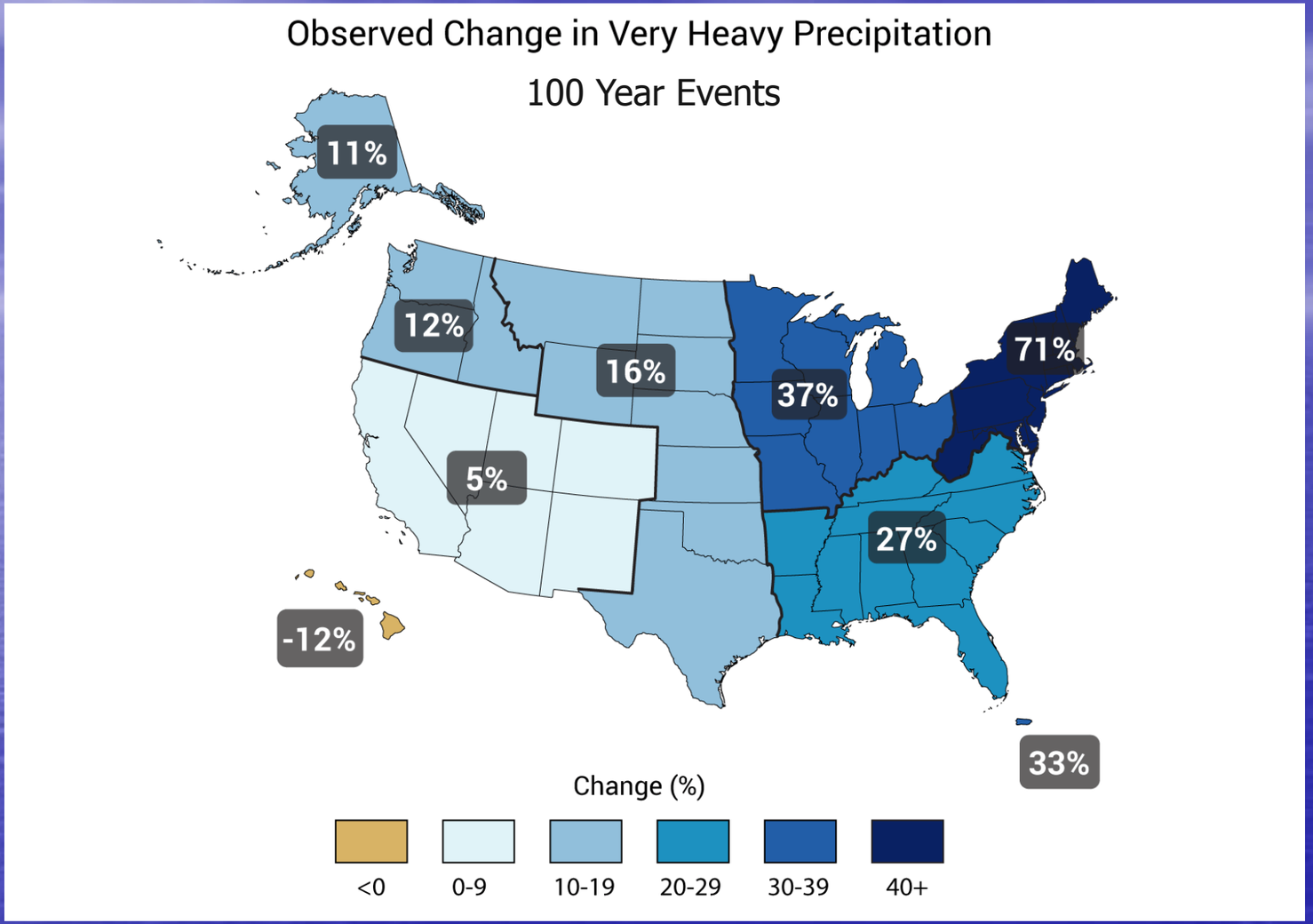
Plot

Move mouse towards an axis until highlighted. Left-click mouse to **pan**. *Shift key + left-click to* **zoom**.



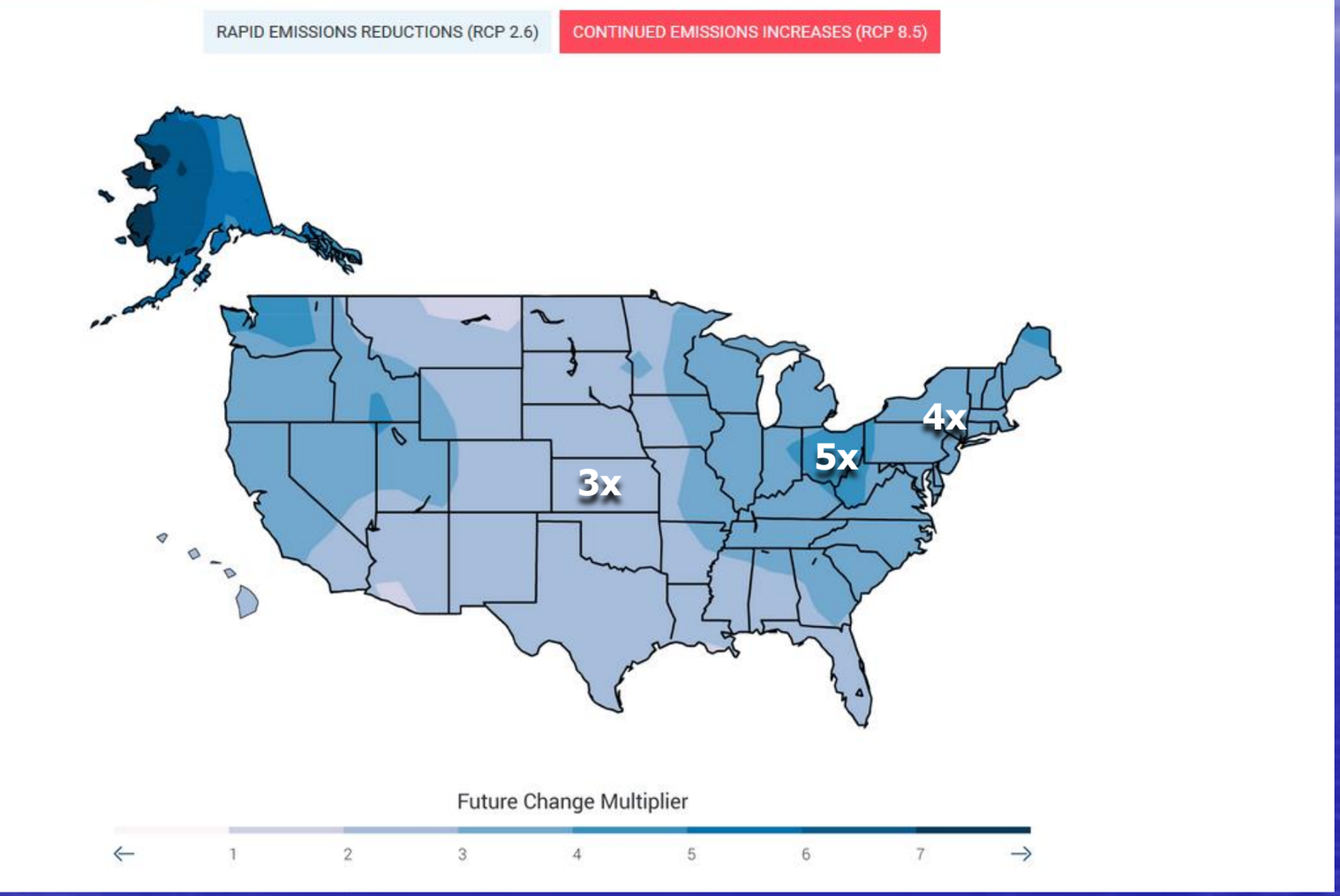
http://www.ncdc.noaa.gov/extremes/cei/graph/ne/4/12-02

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)



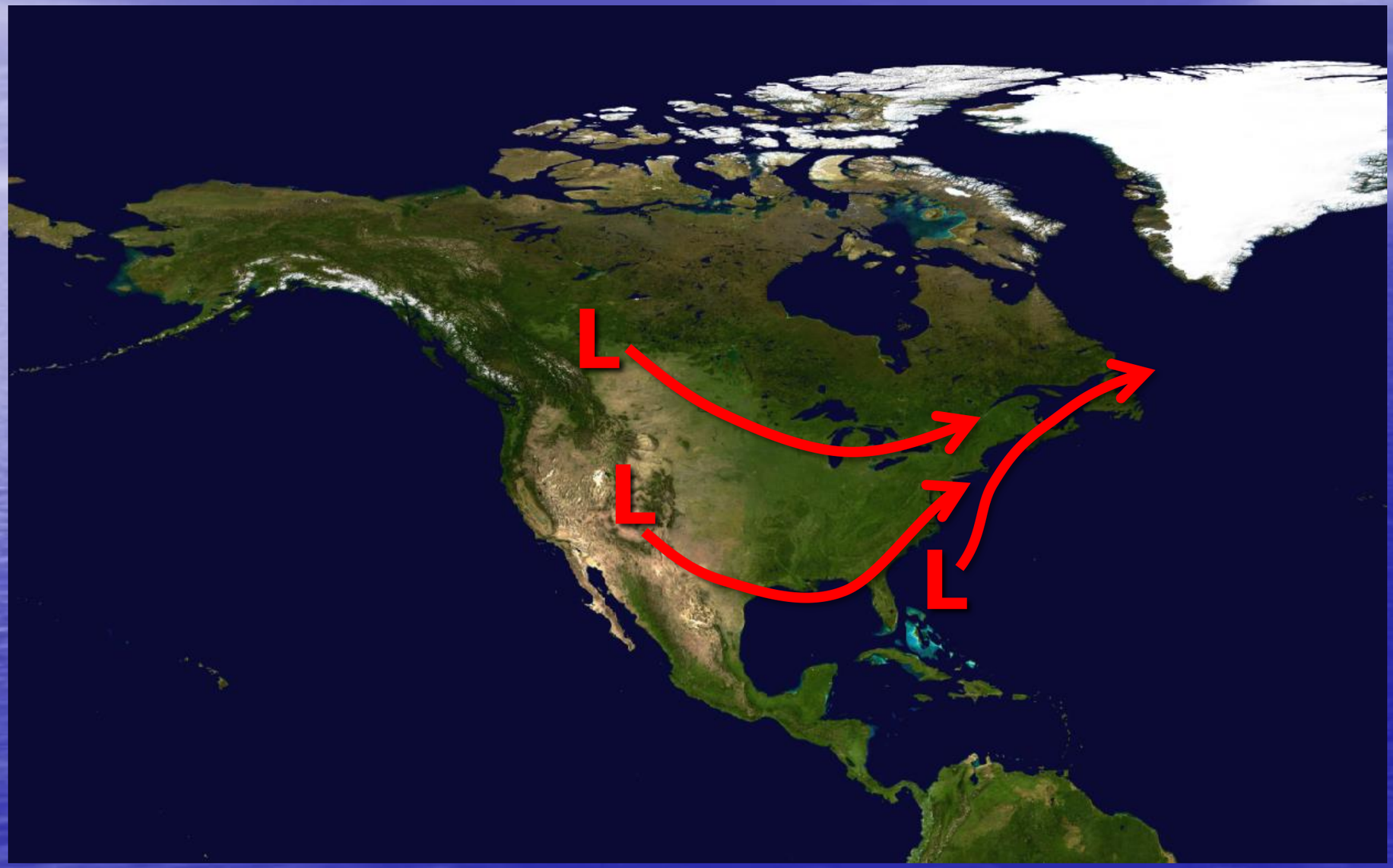
The Northeast has experienced a greater recent increase in extreme precipitation than any other region in the United States;
between 1958 and 2010, the Northeast saw more than a 70% increase
in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events)
(Figure source: updated from Karl et al. 2009).

The Future (With Current rate of GHG Increases)



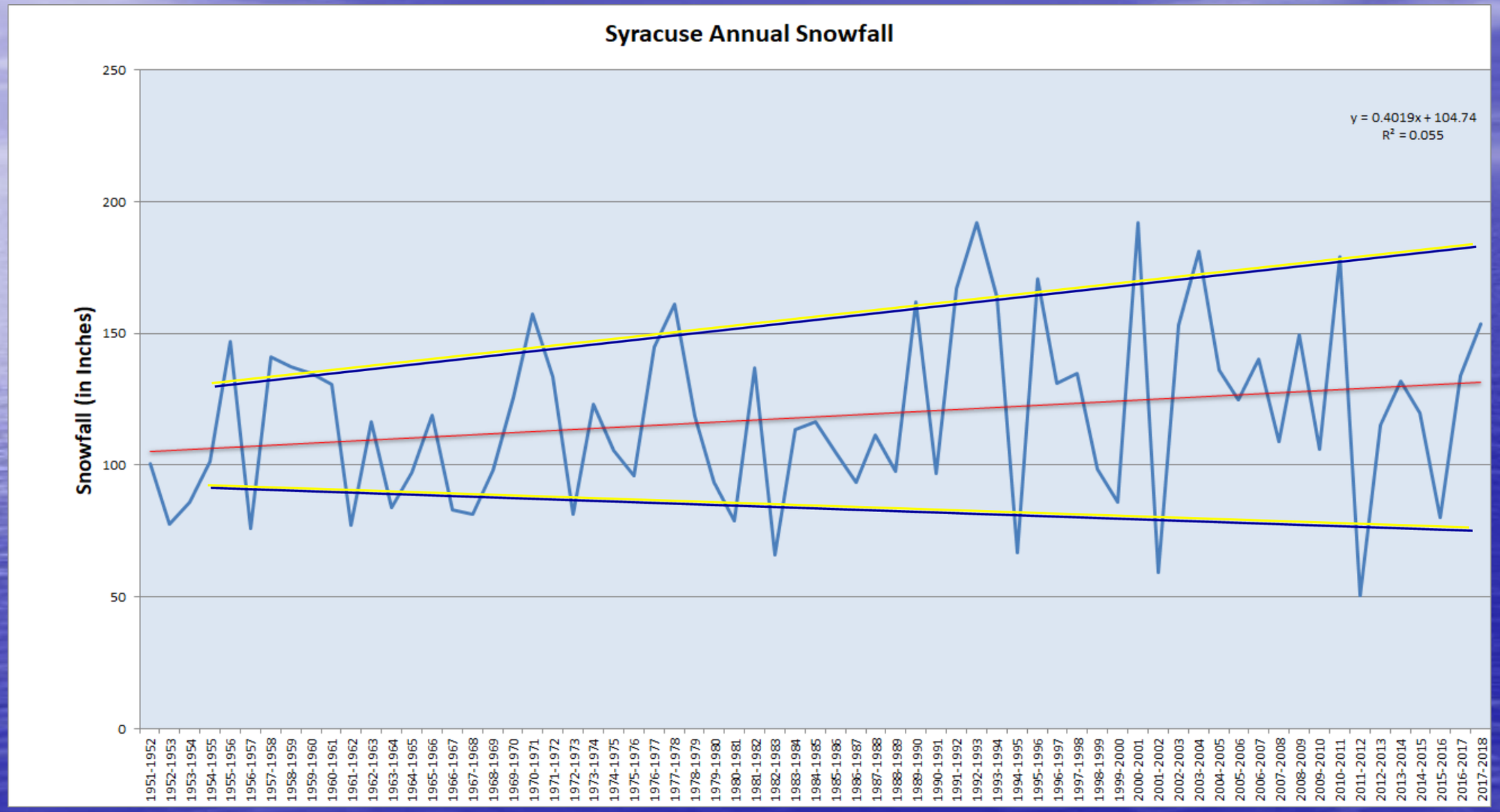
Projected 2081-2100 Precipitation Extremes relative to 1981-2000
(Figure source: NOAA NCDC / CICS-NC
From: Climate Change Impacts in the United States

Why the Northeastern U.S.?



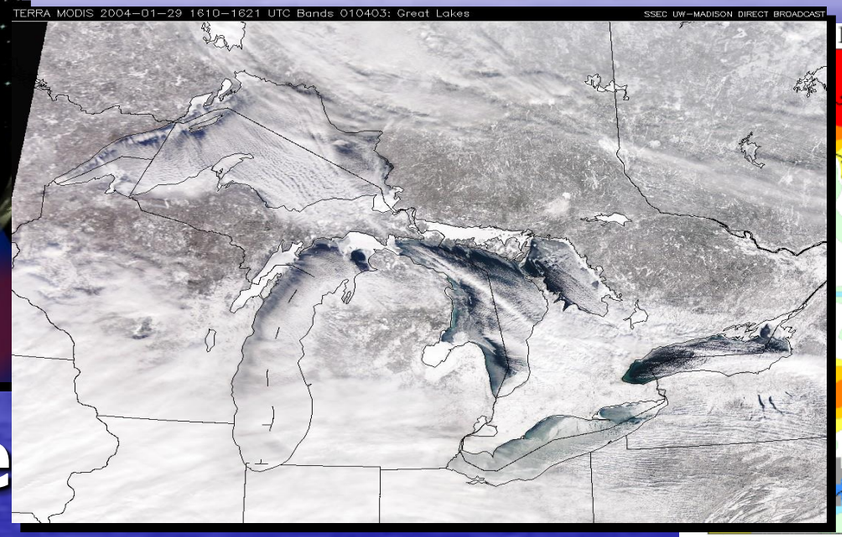
Storms generally track through the NE U.S.

Local Change: Syracuse Annual Snowfall



Data: NOAA, National Weather Service

Summary:



3) Weather patterns here will likely Change...
They may have already begun to.

References

NOAA's Arctic Report Card

http://www.arctic.noaa.gov/report-card

NOAA's Arctic Climate Extremes Index

https://www.ncdc.noaa.gov/extremes/cei/

Arctic Warming and Greenland Blocking.

http://onlinelibrary.wiley.com/doi/10.1002/joc.4673/full

Arctic Warming and Greenland Blocking.

http://iopscience.iop.org/article/10.1088/1748-9326/10/1/014005#citations

Research In Planetary Wave amplification and Motion:

https://ore.exeter.ac.uk/repository/bitstream/handle/10871/10401/Screen_Simmonds_2013_GRL.pdf?sequence=2

Reference to sea Ice Loss:

https://www.esrl.noaa.gov/psd/people/lantao.sun/publications/2016_SPH_GRL.pdf

https://nsidc.org/arcticseaicenews/