What is the Difference Between Weather and Climate?

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Osher Lifelong Learning Institute (OLLI)
Short Course at George Mason University
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Outline

PART ONE: Weather –vs– Climate

PART TWO: Linking Weather and Climate

PART THREE: Climate Change –vs– Climate Variability

PART FOUR: Long-Term Trends in Weather and Climate Extremes

PART FIVE: Take Away Messages

Acknowledgments

Robert E. Livezey

Thomas R. Karl

Mike Staudenmaier

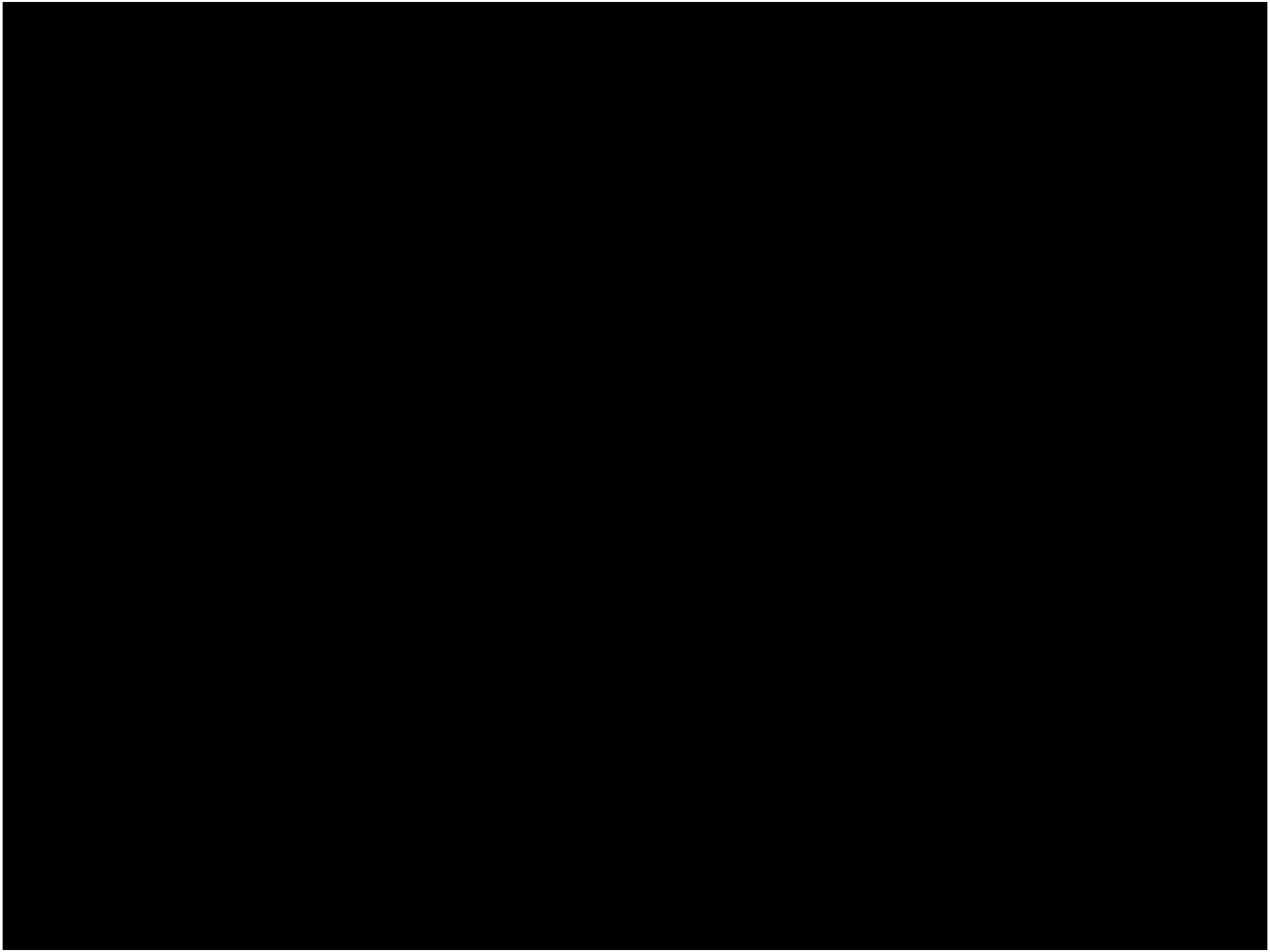
CPC and CSD Staff

NOAA Climate Program Office

Weather – vs – Climate

PART ONE

1971 — Annual 4th of July Picnic — Minneapolis, Minnesota



1972 — 4th of July Picnic — Minneapolis, Minnesota

1980 — 4th of July Picnic — Minneapolis, Minnesota

1990 — Annual 4th of July Picnic — Minneapolis, Minnesota

2000 — Annual 4th of July Picnic — Minneapolis, Minnesota

July 4 Temperatures (°F)

Minneapolis, Minnesota

Year	Min	Max	Year	Min	Max
1971	66	84	1986	68	89
1972	43	71	1987	62	83
1973	59	83	1988	67	95
1974	62	83	1989	67	95
1975	70	86	1990	67	84
1976	60	88	1991	62	78
1977	75	92	1992	53	71
1978	64	79	1993	68	86
1979	61	80	1994	67	86
1980	62	90	1995	68	76
1981	64	85	1996	61	87
1982	64	99	1997	52	73
1983	59	75	1998	60	77
1984	64	84	1999	80	93
1985	63	82	2000	69	80

July 4 Temperatures (°F)

Minneapolis, Minnesota

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1974	62	83	1989	67	95
1975	70	86	1990	67	84
1976	60	88	1991	62	78
1977	75	92	1992	53	71
1978	64	79	1993	68	86
1979	61	80	1994	67	86
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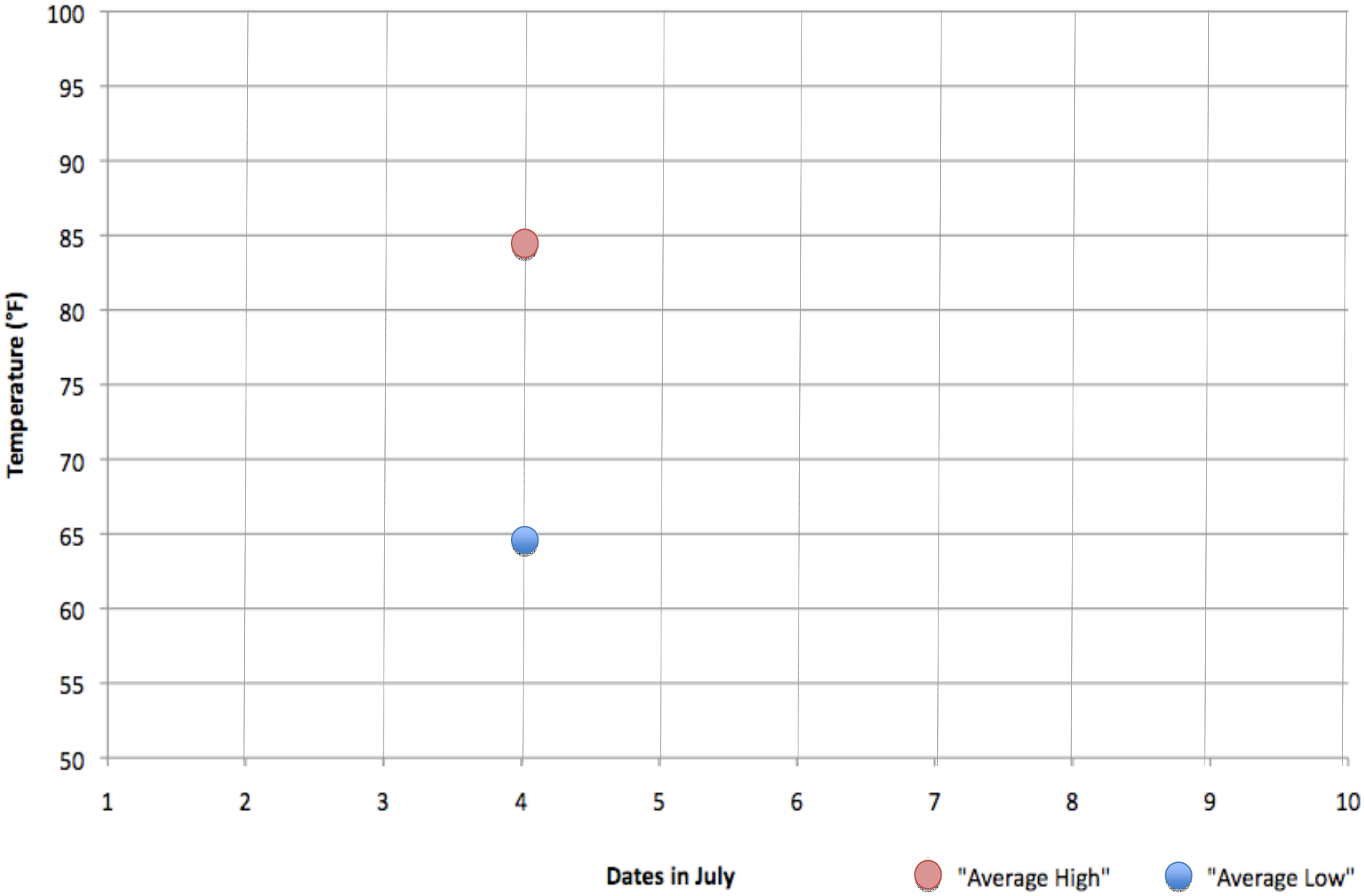
1984	64	84	1999	80	93
1985	63	82	2000	69	80

Average Minimum Temp = 64

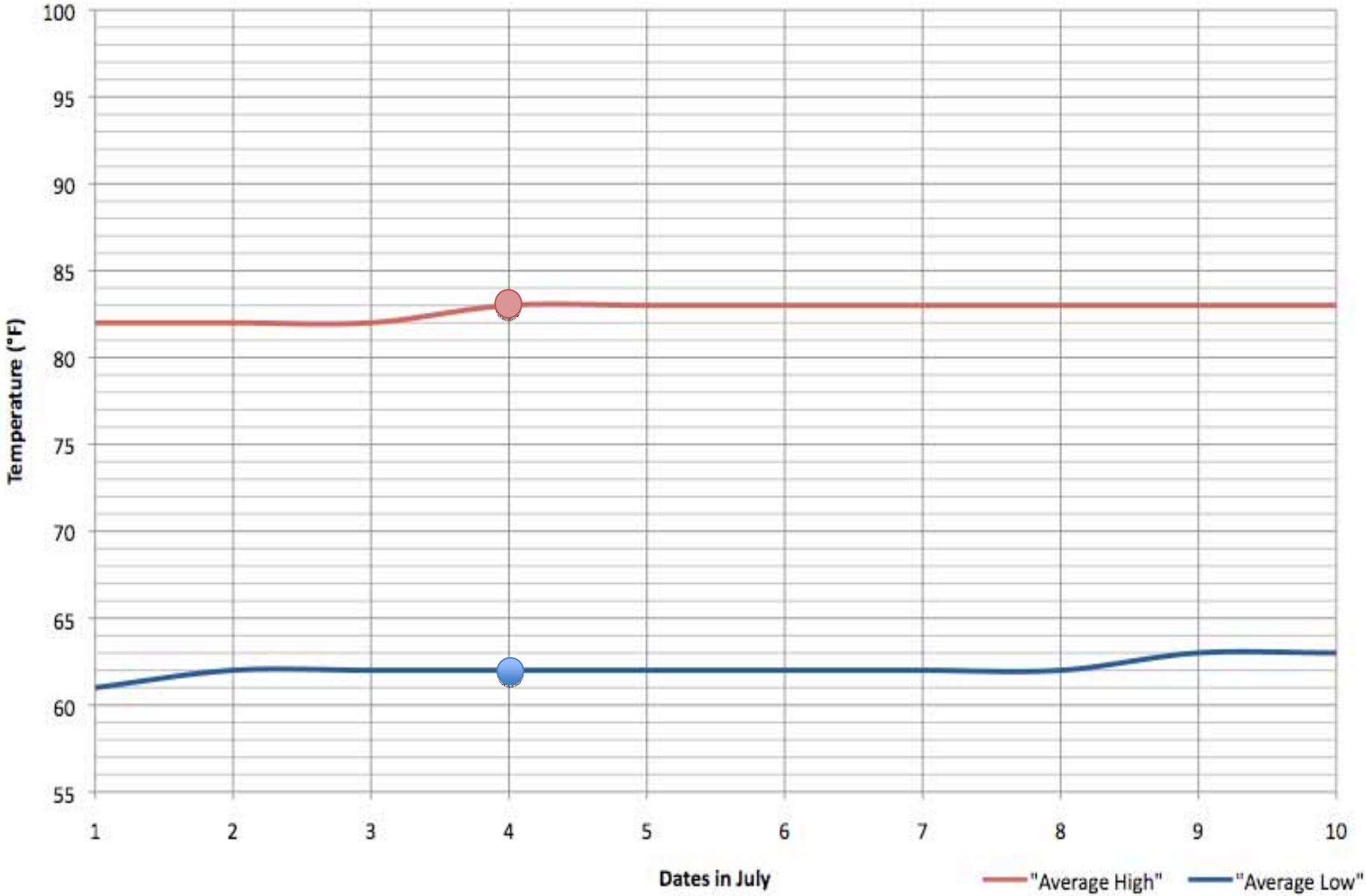
Average Maximum Temp = 84

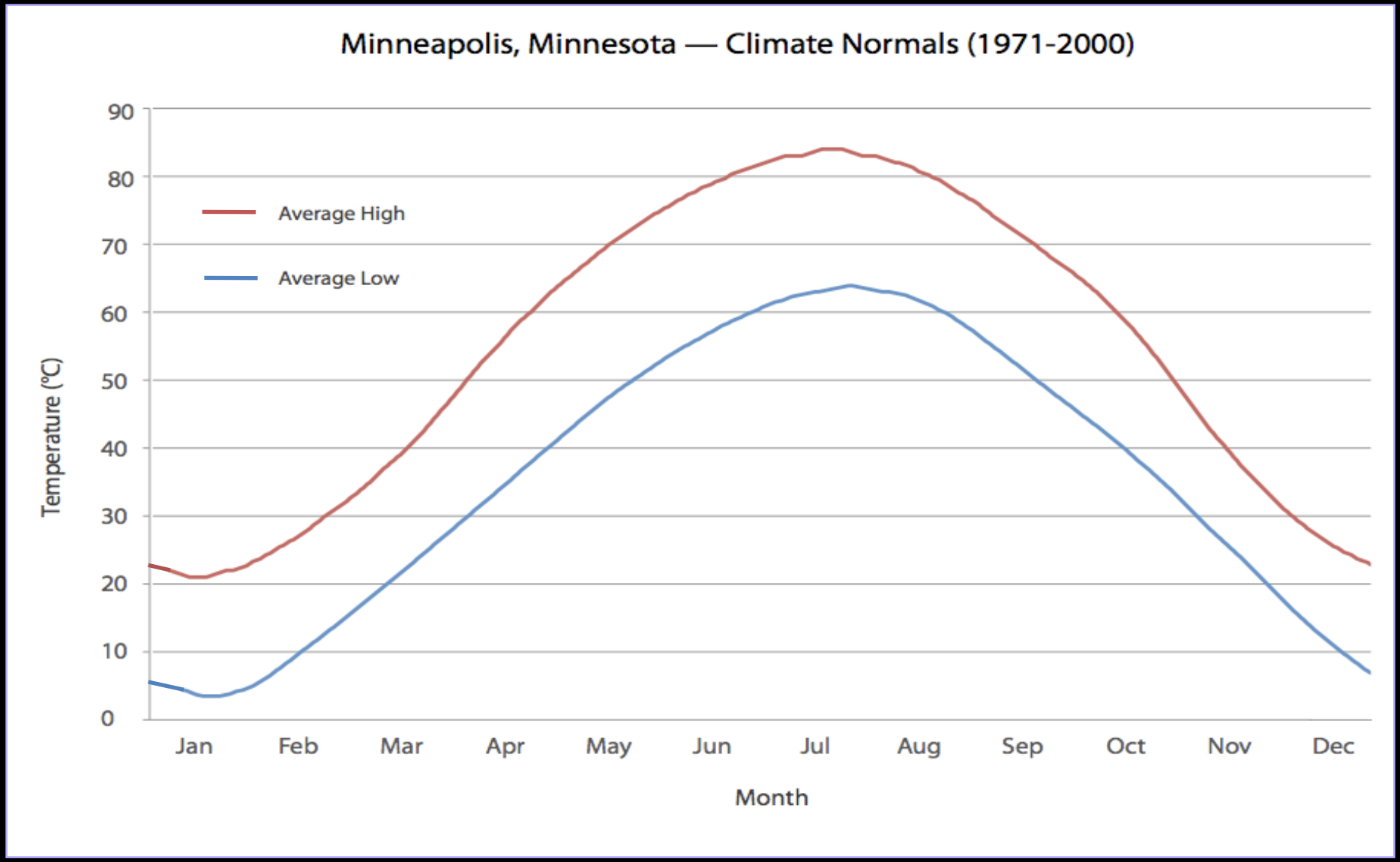
Minneapolis, Minnesota — July 4 Climate Normals

(1971-2000)

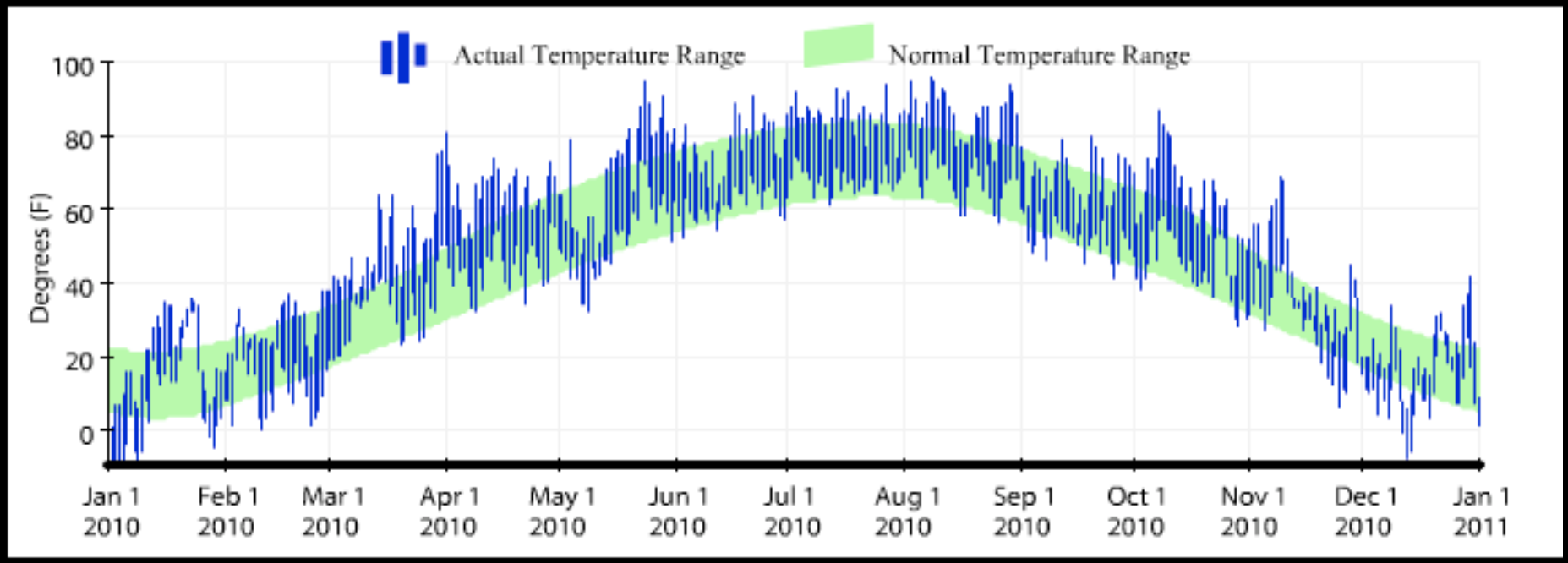


Minneapolis, Minnesota — July 1-10 Climate Normals (1971-2000)

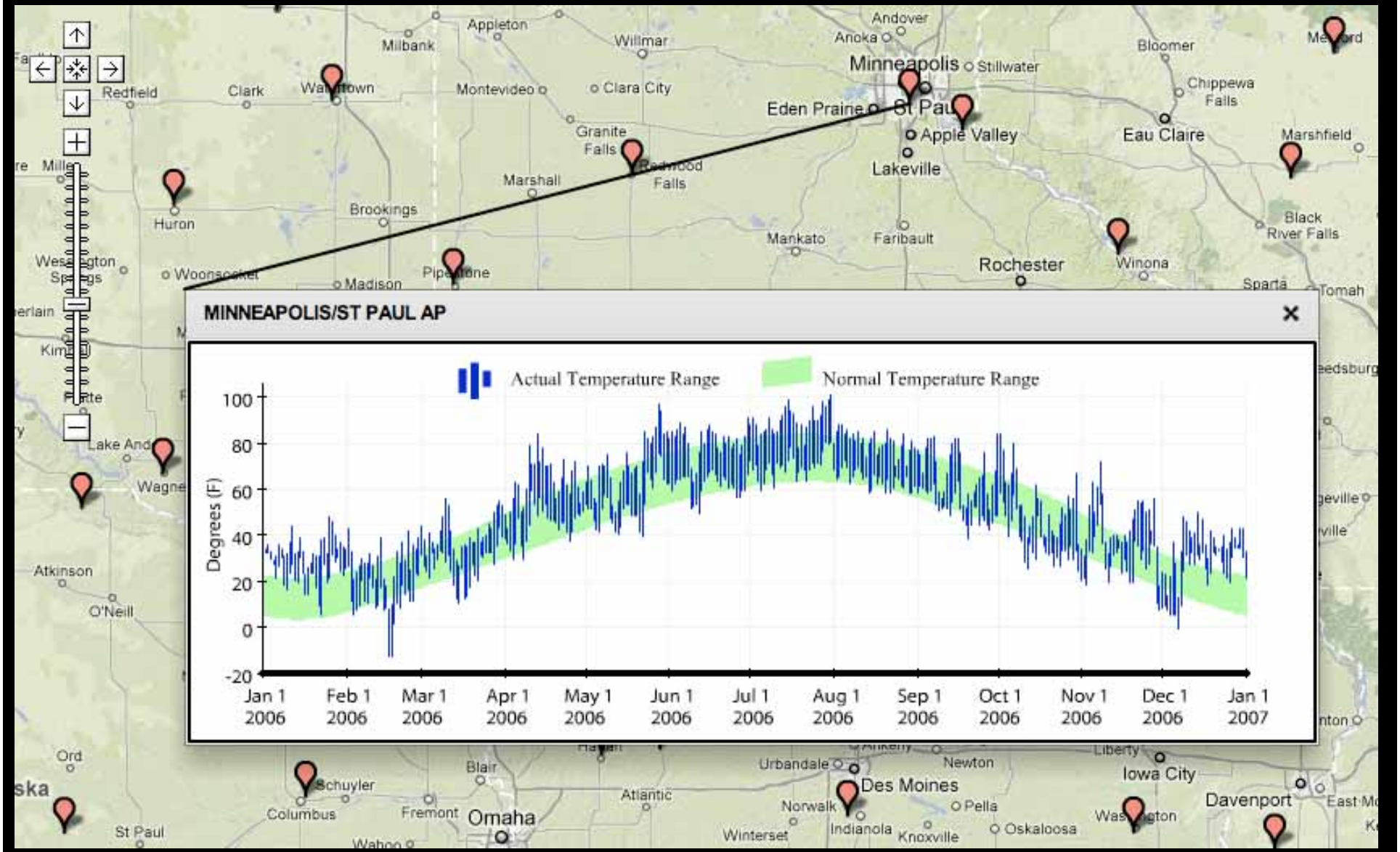



Minneapolis, Minnesota — Climate Normals (1971-2000)
90
80
70
60
50
40
30
20
10
0
Temperature (°C)
Average High
Average Low
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Climate normals for Minneapolis, 1971 - 2000
Compared to 2010 weather



Multigraph Climate Explorer



http://climateexplorer.multigraph.org

Climate? or Weather?

Decide if each of the following phrases describes climate or weather.

Climate? or Weather?

Tells us what kind of clothes to wear

Weather

Tells us what kind of clothes to wear

Climate? or Weather?

Tells us what kind of clothes to buy

Climate

Tells us what kind of clothes to buy

Climate? or Weather?

Can change dramatically from year to year

Weather

Can change dramatically from year to year

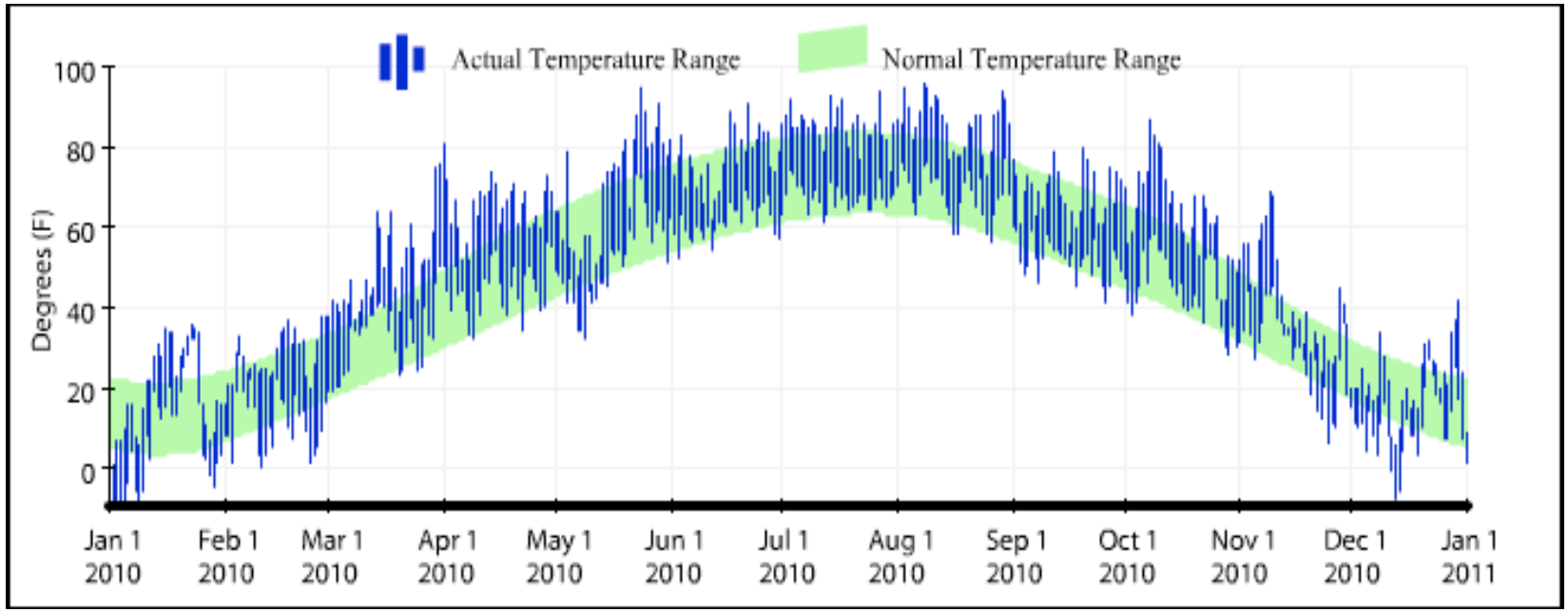
Climate? or Weather?

The picture that comes to your mind when you think of a faraway place

Climate

The picture that comes to your mind when you think of a faraway place

Weather –vs– Climate



Weather: state of the atmosphere at a given time & place, with respect to variables such as temperature, moisture, wind speed & direction, pressure.

Climate: the expected frequency ("normal") of specific states of the atmosphere, ocean, and land with respect to these variables. Climate encompasses weather over longer periods of time .

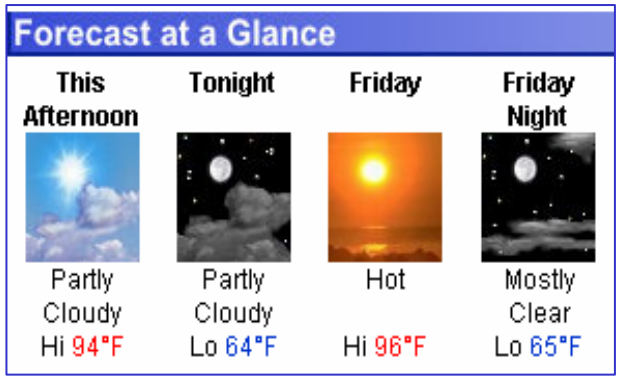
What is the difference between a weather forecast and a climate forecast?

Weather Forecasts:

Event, location and time specific

Deterministic (e.g. how warm, how much rainfall)

Also probabilistic (e.g. 50% chance of rainfall)



Climate Forecasts:

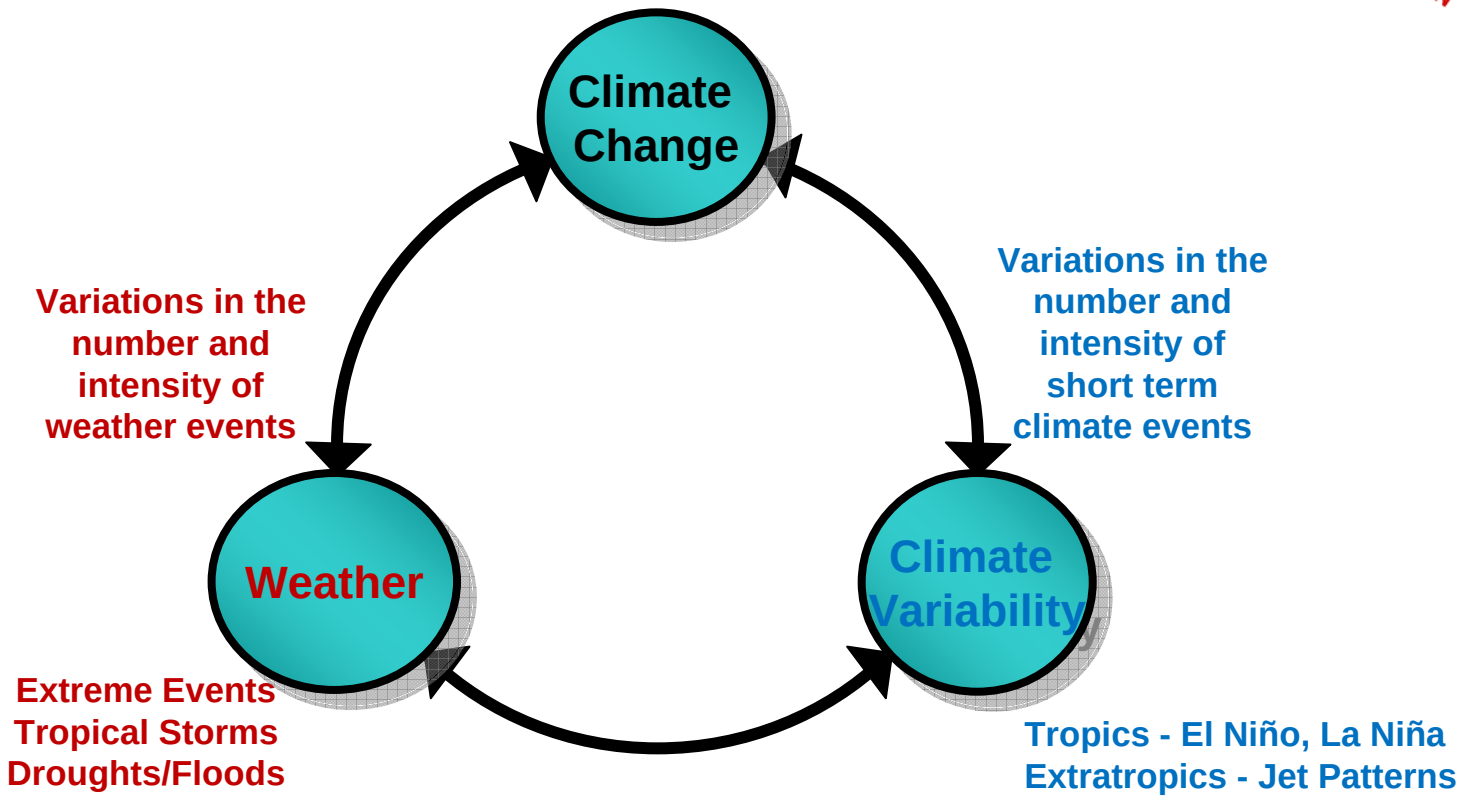
"Average of weather" for a week, month, season, …

Probabilistic (e.g. likelihood of warmer/cooler or wetter/drier than average)

Linking Weather and Climate

PART TWO

Linking Weather and Climate



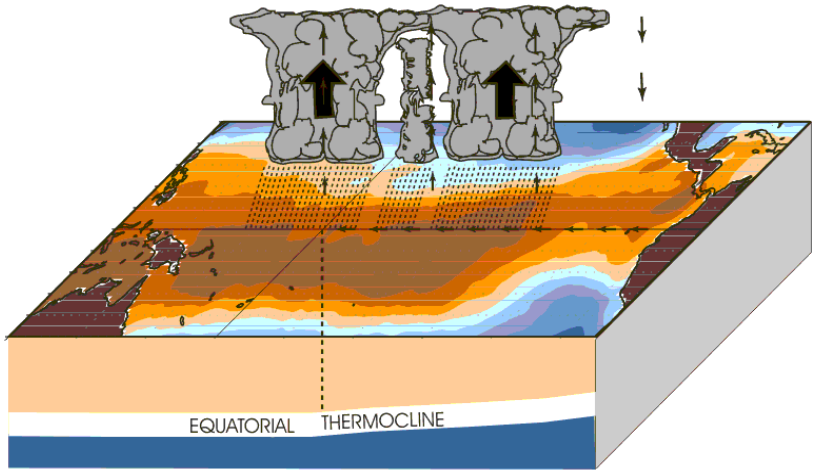
Motivation:

One manifestation of Climate Change is variations in the number and intensity of weather extremes that have significant human impacts, thus posing a serious challenge to society.

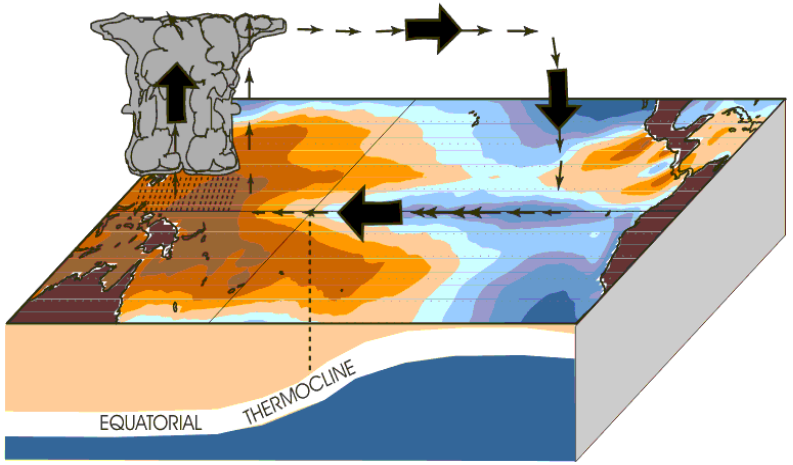
How do climate variations and climate change affect weather events and vice-versa?

El Niño and La Niña

El Niño



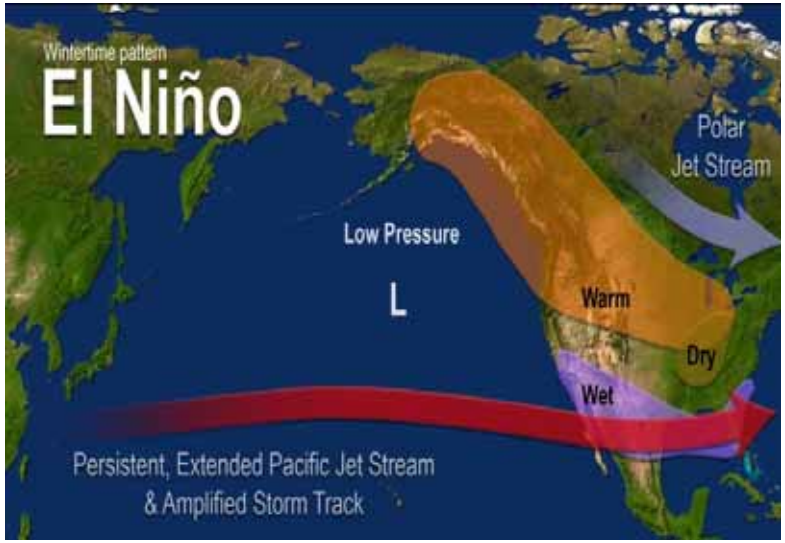
La Niña

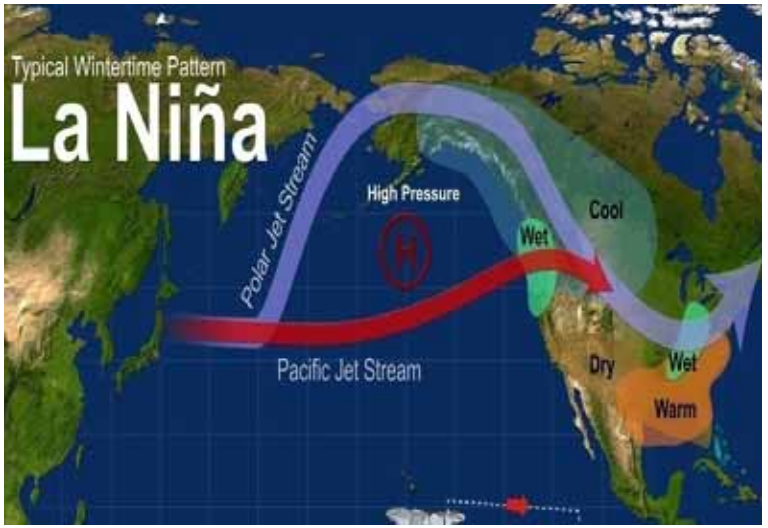


El Niño (La Niña) are characterized by warming (cooling) of the tropical Pacific.

The atmosphere responds to changes in ocean surface temperatures through persistent areas of organized tropical convection (i.e. precipitation).

Changes in Weather and Climate patterns during El Niño and La Niña

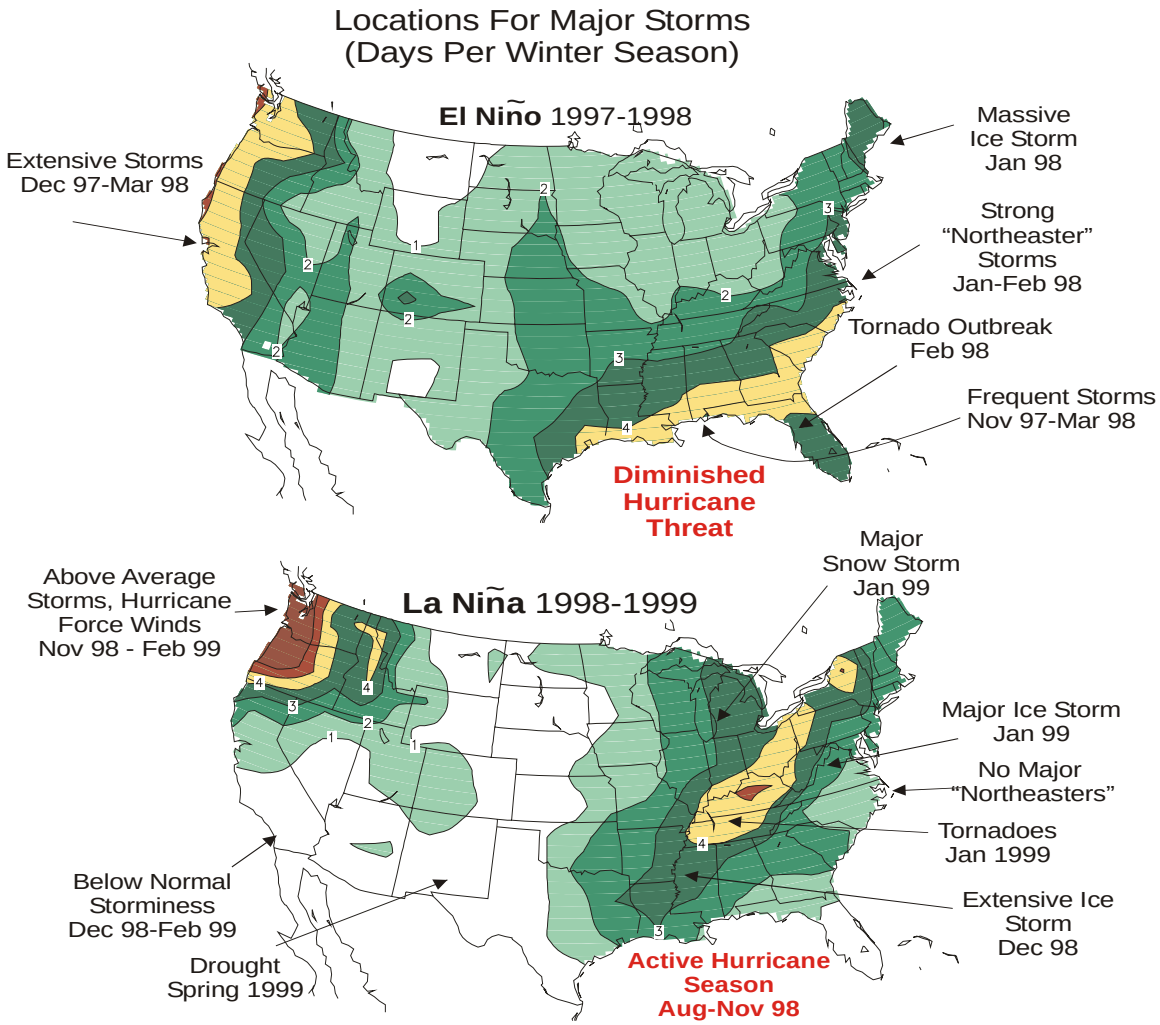




The Pacific jet stream responds by strengthening & extending eastward during El Niño (weakening & retracting westward during La Niña).

Changes in the jet lead to changes in temperature and precipitation patterns, hence changes in the number & intensity of weather events, including extremes.

Changes in Storminess during 1997-98 El Niño and 1998-99 La Niña?



El Nino's Extended Family

There are many patterns of *Natural Climate Variability* that simultaneously influence the weather patterns:

Some originate in the tropics:

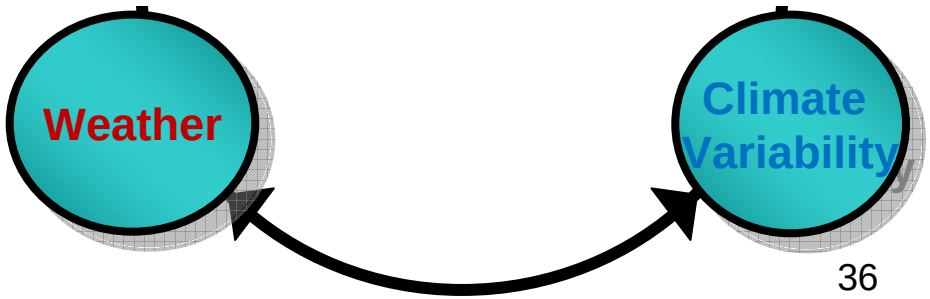
El Niño / La Niña

Madden-Julian Oscillation

Others originate in the extratropics:

North Atlantic Oscillation

Arctic Oscillation

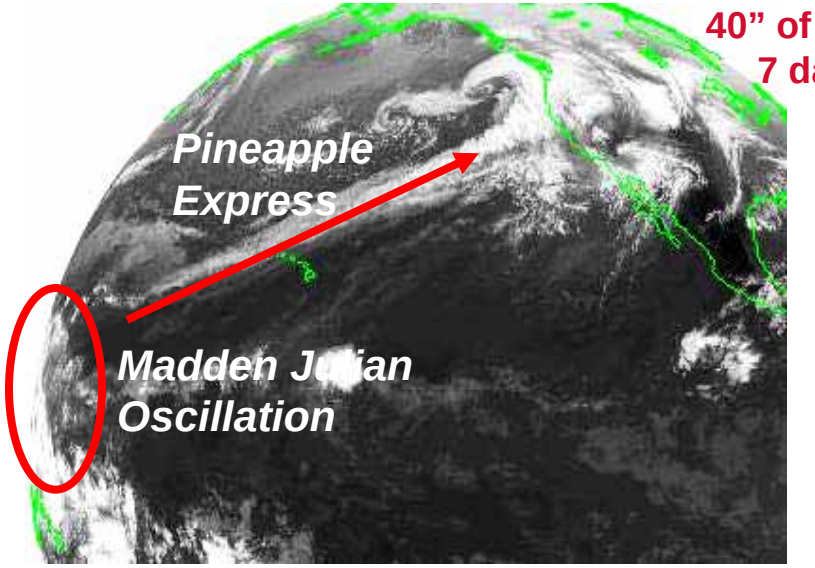


Madden - Julian Oscillation

- **A tropical disturbance that modulates the patterns of tropical precipitation &atmospheric circulation with a period of 30-60 days.**

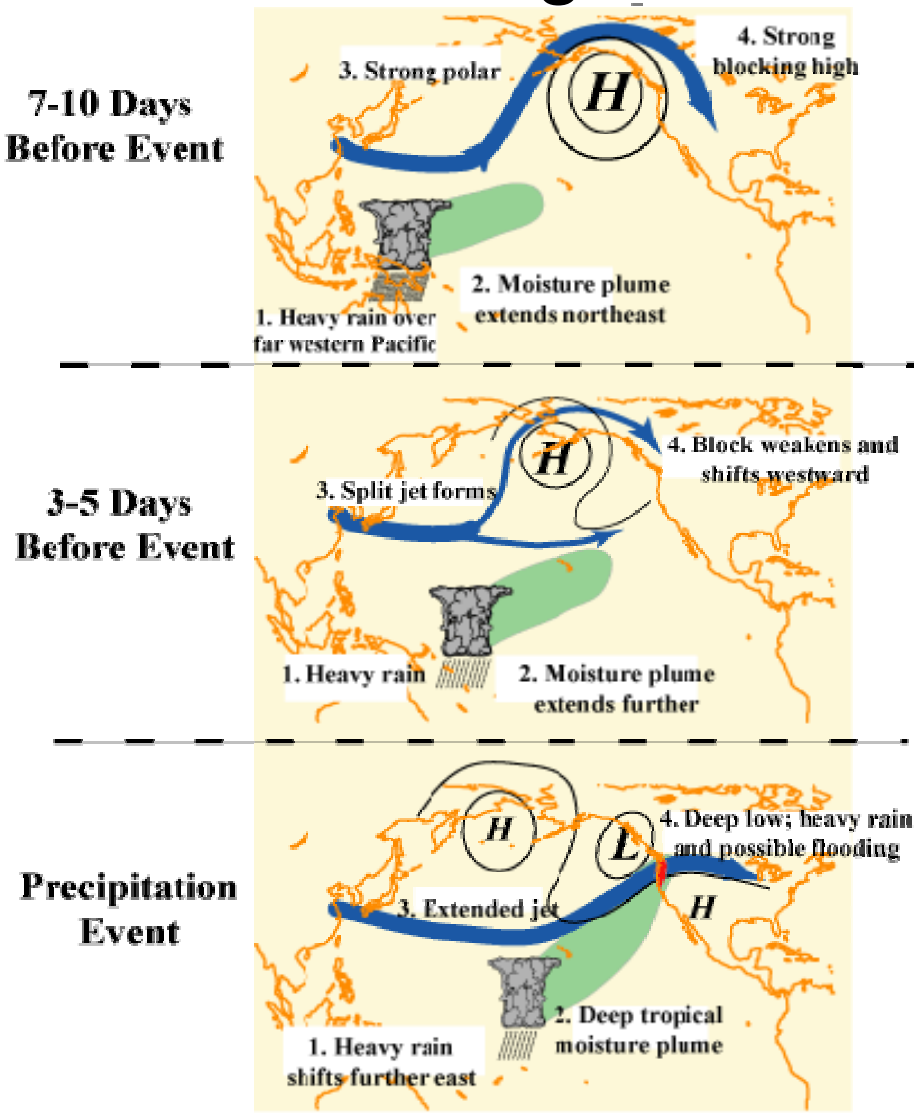
- **It produces effects like El Niño / La Niña, but on 30-60-day time scale.**

- **It modulates the number and intensity of extreme weather events**
  - ✓ **floods in the western US**
  - ✓ **hurricanes**

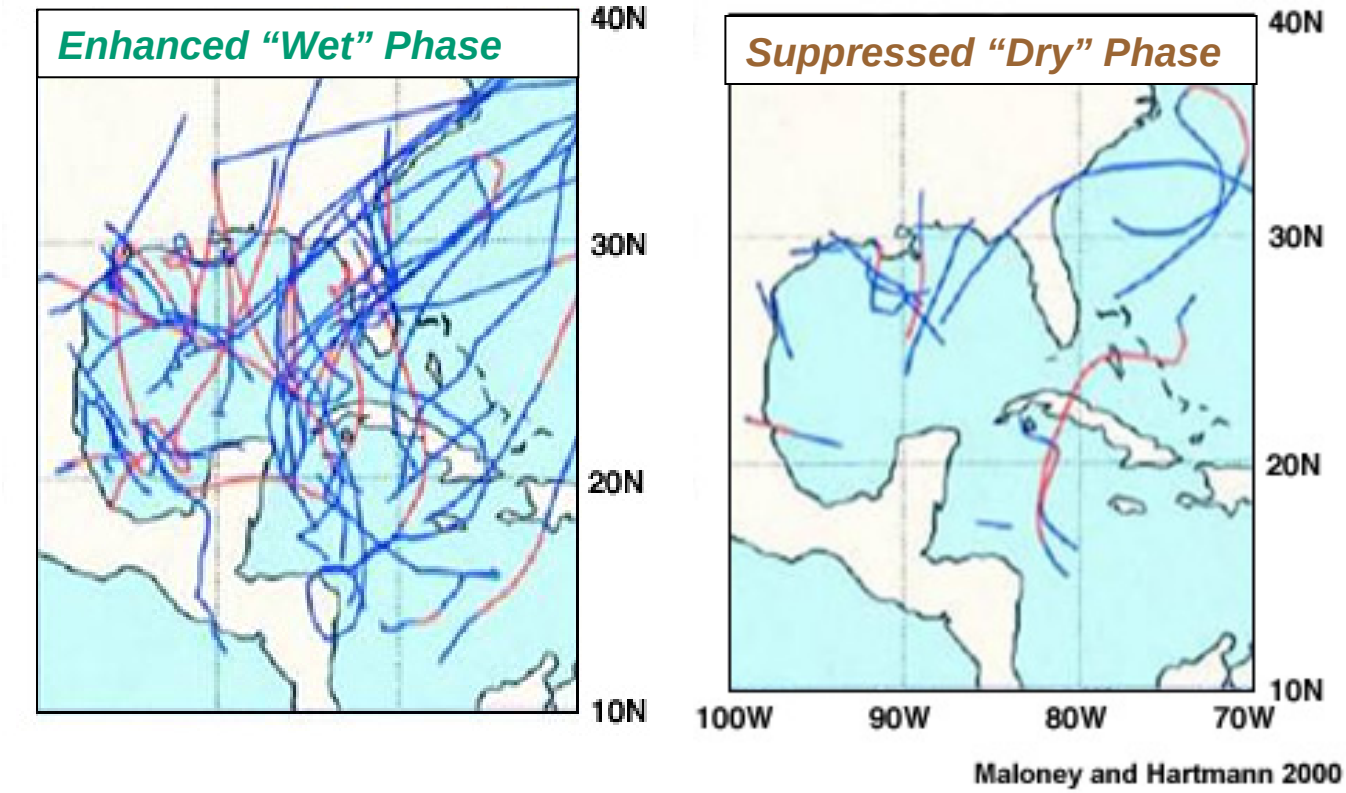


The Madden-Julian Oscillation and West Coast Flooding

Conditions associated with the Madden-Julian Oscillation lead to extreme precipitation events during winter



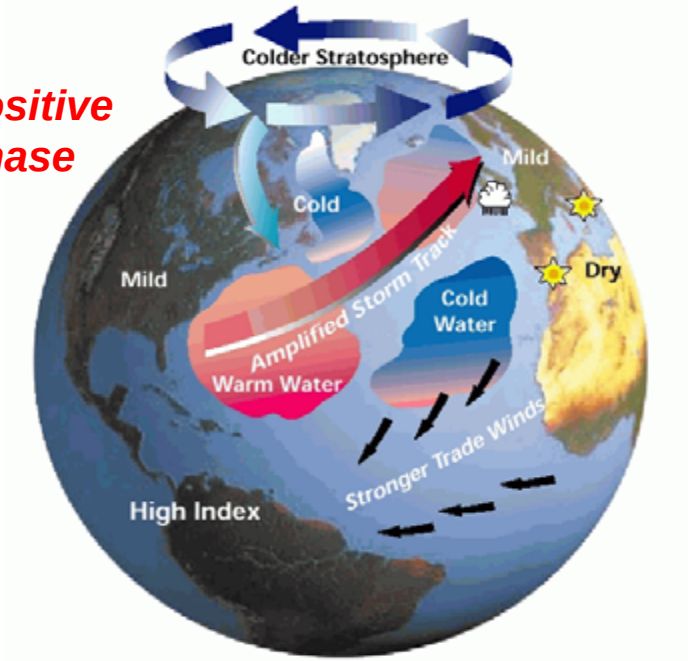
The Madden-Julian Oscillation and Tropical Cyclones



The Madden-Julian Oscillation often leads to "bursts" and "lulls" in tropical cyclone activity depending on the phase of the oscillation.

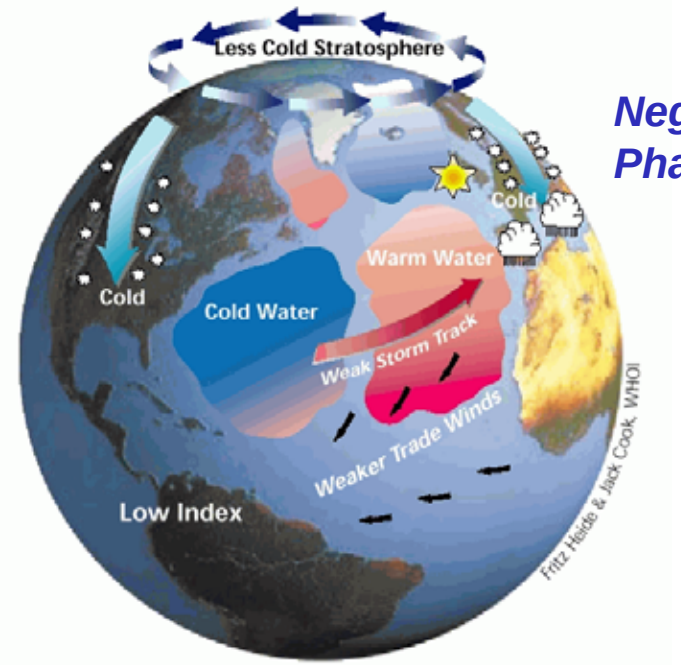
Arctic Oscillation / North Atlantic Oscillation and Changes in Winter Weather Patterns

Positive Phase



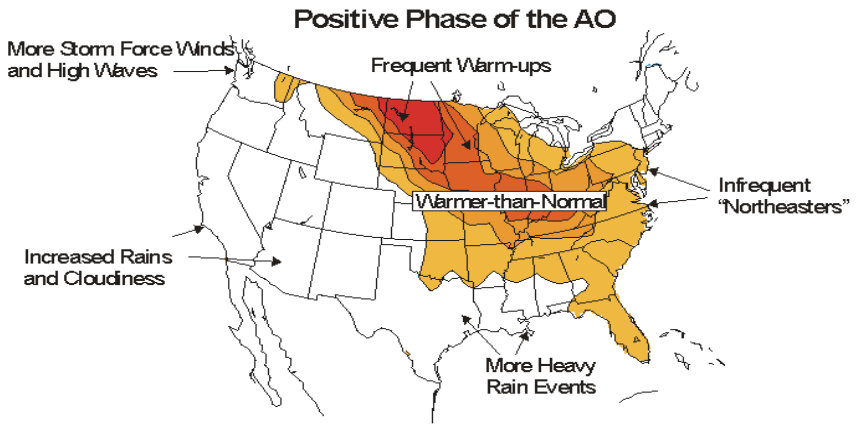
- Strong polar vortex
- Cold pole
- Warm mid-latitudes
- More extreme warm days
- Fewer snowstorms

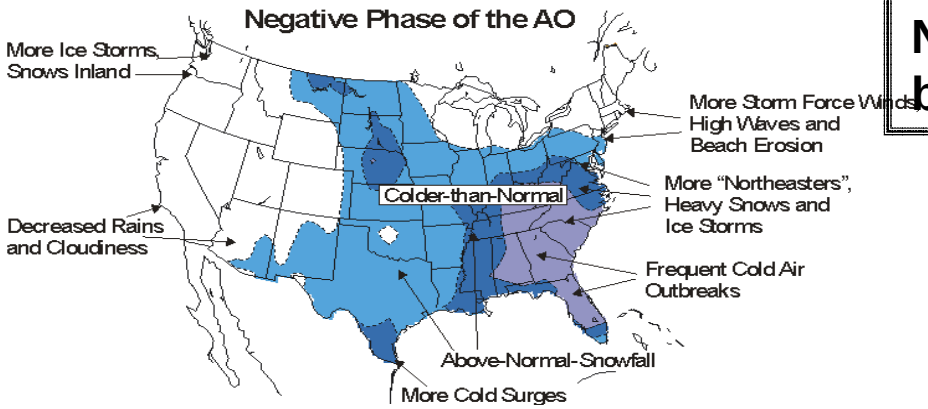
Negative Phase



- Weak polar vortex
- Warm pole
- Cold mid-latitudes
- More extreme cold days
- More snowstorms

The Arctic Oscillation and Winter Impacts over the U.S.





Influences the number and intensity of weather events (including extremes)

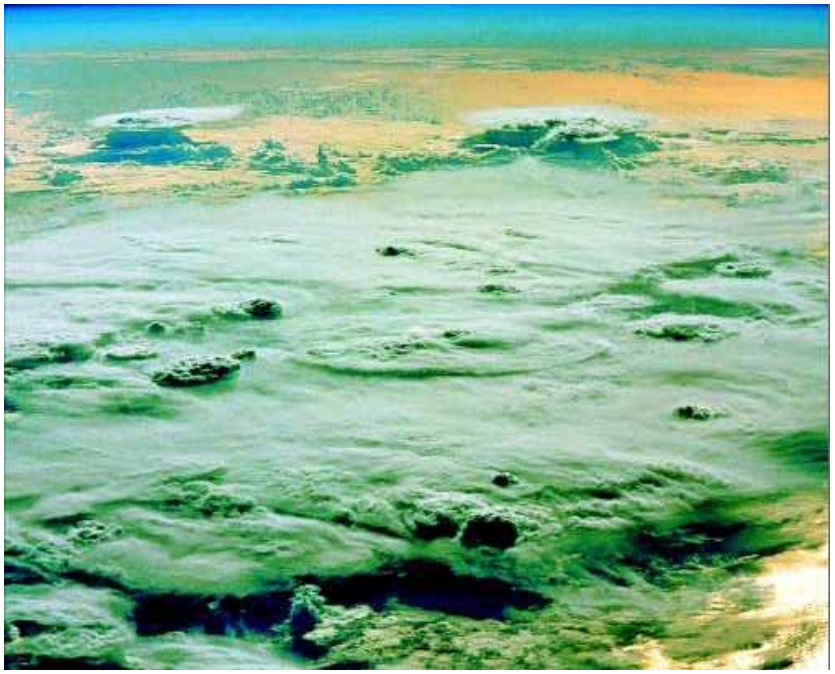
A Winter "Wildcard":

No capability to forecast beyond a week or two.

Climate Change –vs– Climate Variability

PART THREE

Climate Change: What is it?



- **Climate change is the departure from the expected average weather or climate normals for a given place and time of year.**

- **In contrast with extreme events, such as snowfall in Florida, climate change is the long-term shift in the average weather.**

Why Worry About Climate Change?

Source: NOAA

- **Temperature increases will have significant impacts on human health, economic activities and national security among others.**
- **To be prepared for the effects of these potential impacts we need to know how much the Earth is warming, for how long it has been warming, and the causes.**
- **Answers will provide a better basis for decision making (preparedness and planning) across many sectors of the economy.**

Abrupt Climate Change

- **Abrupt Climate Change (ACC) is a shift that occurs quickly (a few decades or less) and persists for decades to millennia.**
- **Three types of ACC that pose a major challenge to society:**
  - **Rapid change in glaciers, ice sheets, and sea level**
  - **Changes to the hydrologic cycle, including droughts**
  - **Rapid release to the atmosphere of methane**

Abrupt Climate Change

- **Glaciers are melting**

1913

2005

Shepard Glacier, Glacier National Park, USA

By 2030, Glacier National Park could be glacier-free

Abrupt Climate Change

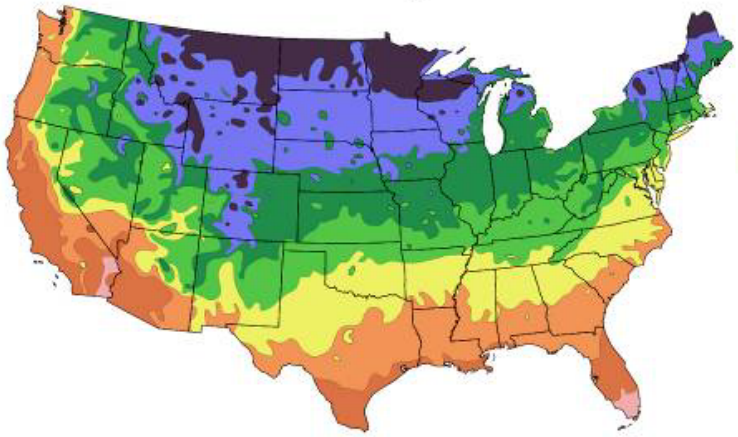
- **Lima's water supply is disappearing**

1 billion depend on glacier melt for water supply

Abrupt Climate Change

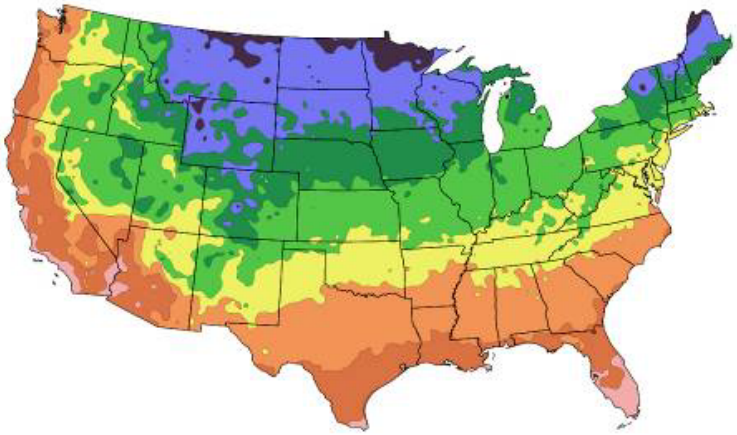
- **Plant hardiness zones are moving north**

1990 Map



After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990

2006 Map



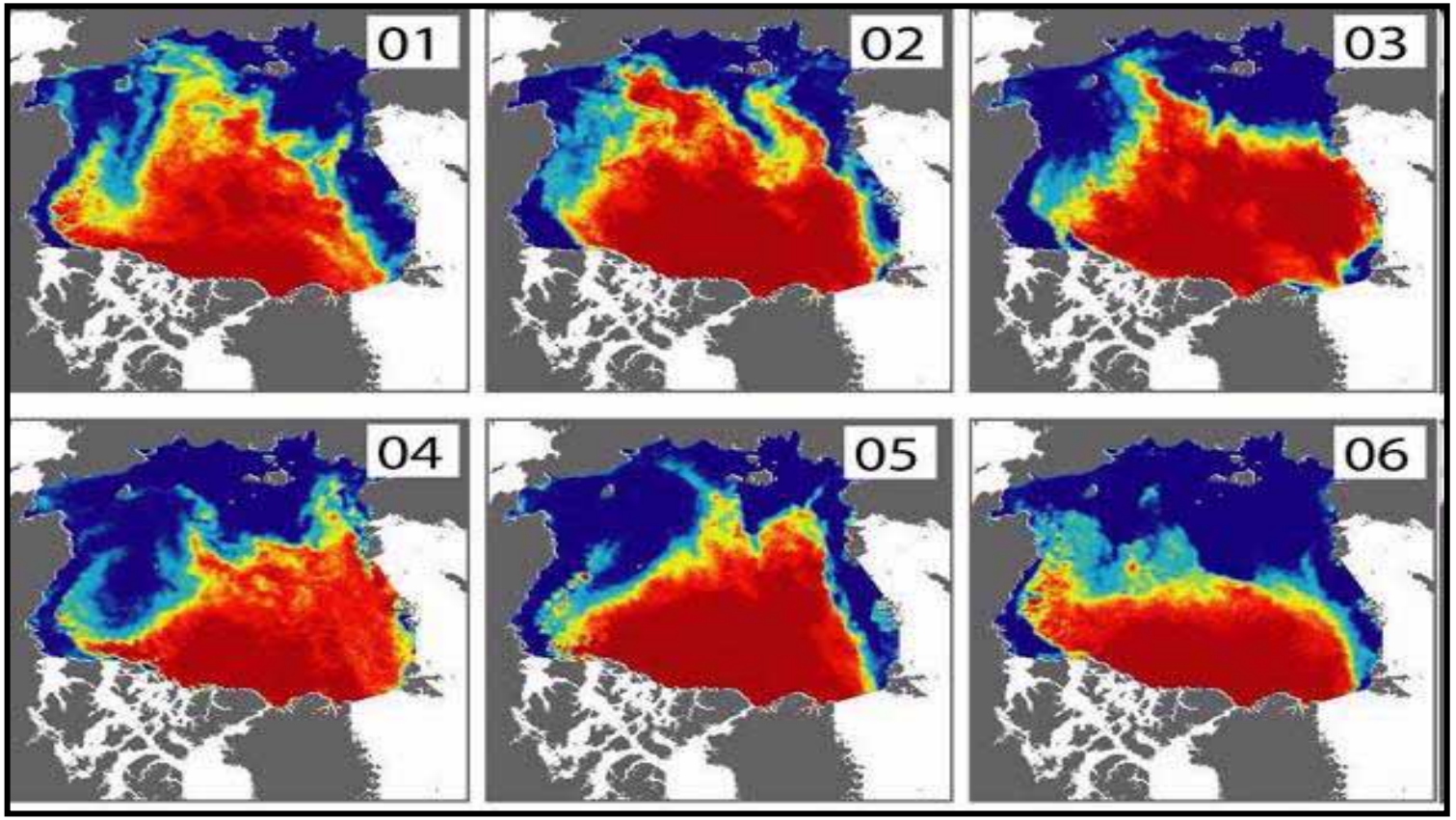
National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.

Zone

Zones have shifted up to 200 miles in 20 years

Abrupt Climate Change

- **Arctic Sea Ice is diminishing**

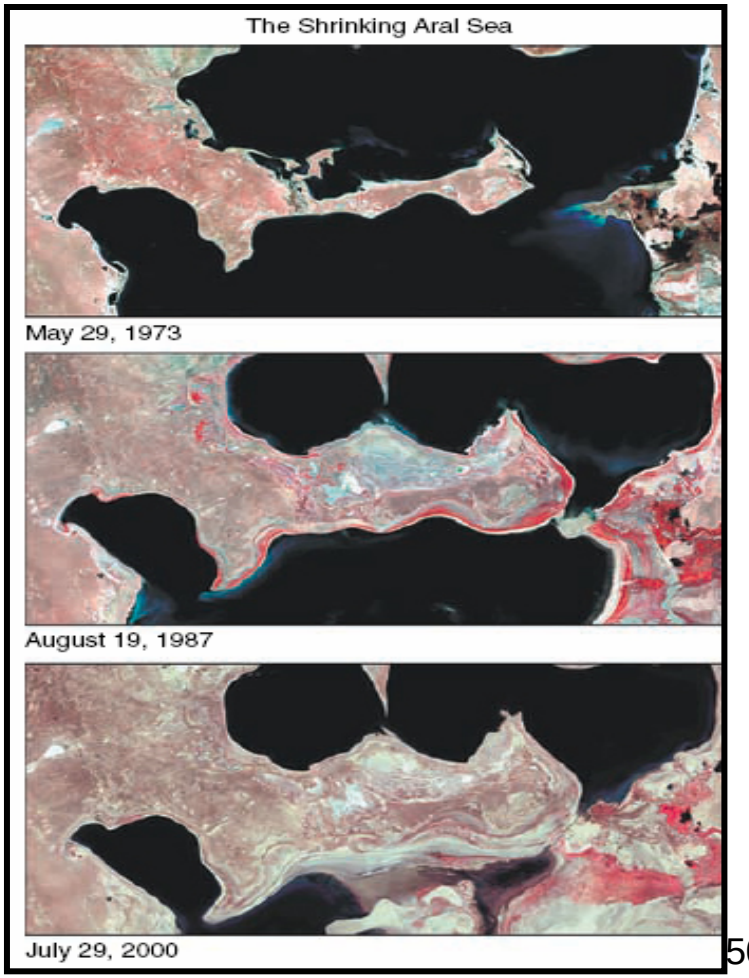


Satellite studies indicate Arctic sea ice declining annually

Abrupt Climate Change

- **Desertification is happening**

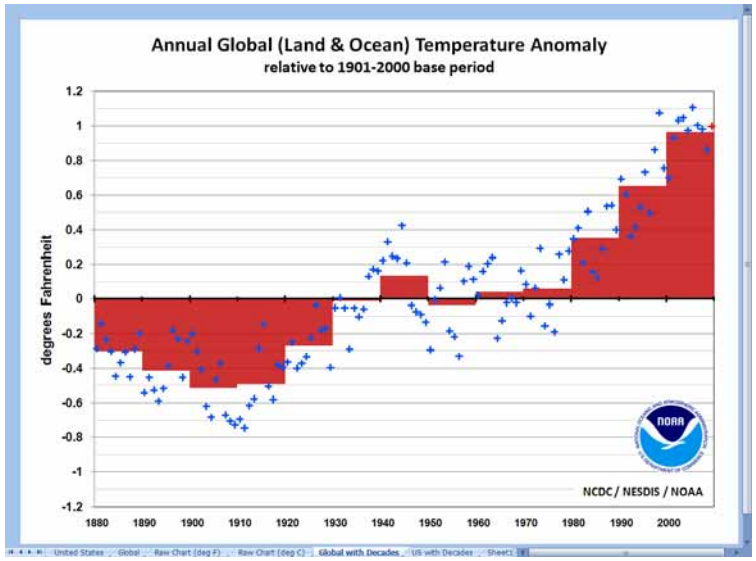
The disappearance of the Aral Sea, as seen by Landsat satellite during the period 1973 to 2000. Over this period, more than 60% of the lake vanished, replaced with a dry, dusty plain.

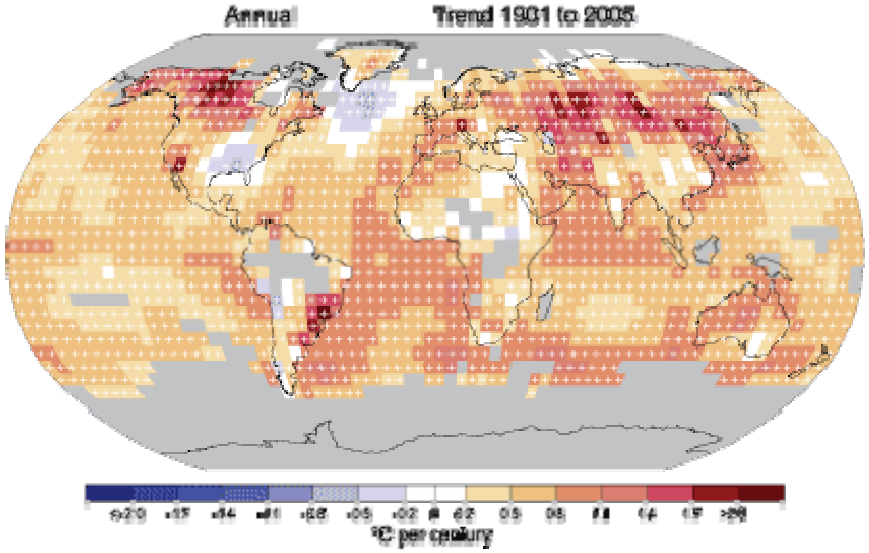


Global Warming: What is it?

- The term Global Warming refers to the observation that the atmosphere near the Earth's surface is warming, without any implications for the cause or magnitude.
- This warming is one of many kinds of climate change that the Earth has experienced in the past and will continue to experience in the future.
- It implies an overall average warming across the entire globe.

Is there global warming?

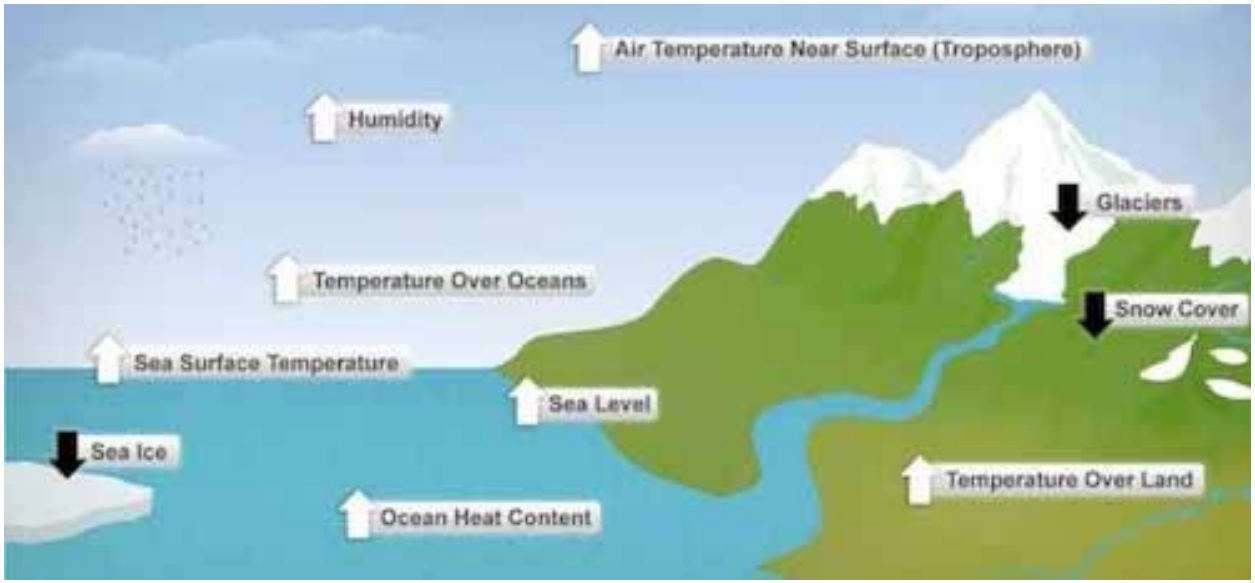




- Global surface temperatures have increased about 0.75°C since the late-19th century.
- The trend is +0.13°C per decade for the past 50 years.
- The warming has not been uniform. Some areas have cooled slightly.
- The recent warmth has been greatest over North America and Eurasia.

Source: National Climatic Data Center

How do we know the Earth's climate is warming?



- **Land and ocean temperature observations (from weather stations, ships, buoys and satellites) are combined into time series of global average temperature change.**

- **The warming trend is confirmed by other observations, such as the melting of mountain glaciers, reductions in snow cover and sea ice, and rising sea levels.**

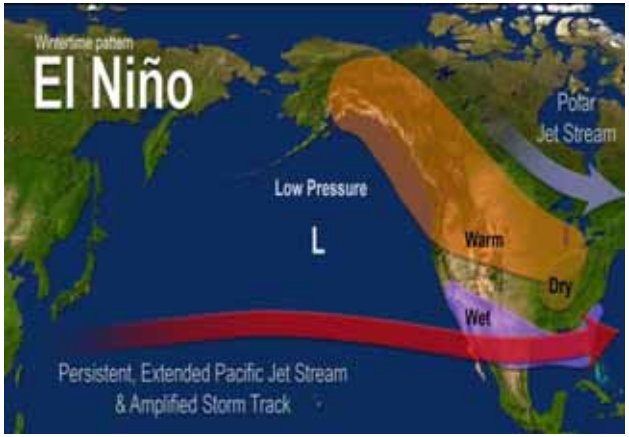
Source: National Climatic Data Center

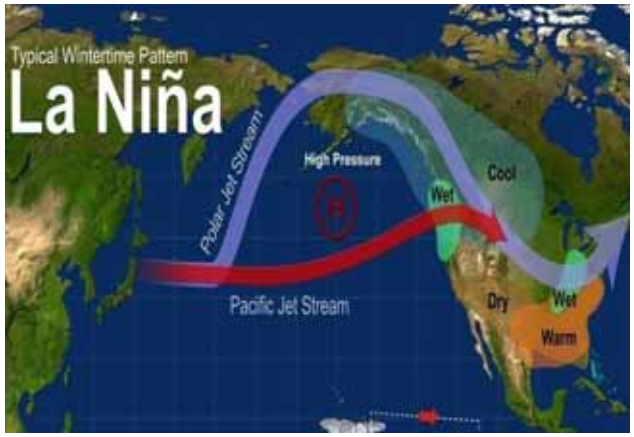
Are El Niños related to global warming?

•El Niños are not caused by global warming. El Niños have been present for millions of years.

• It is well known that warmer global sea surface temperatures enhance El Niño, and it is also true that El Niños have been more frequent and intense in recent decades.

• The relationship between climate change & El Niño is a major research question.



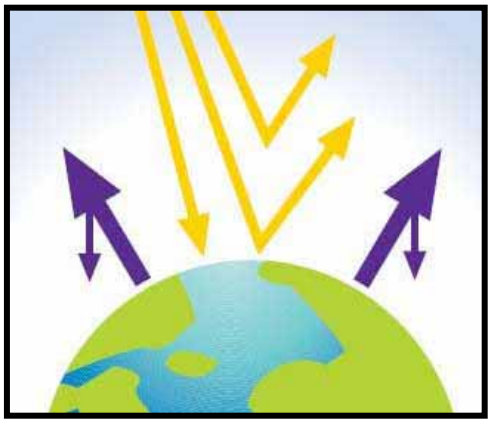


What is the Greenhouse Effect?

How is it related to Climate Change?

THE NATURAL GREENHOUSE EFFECT

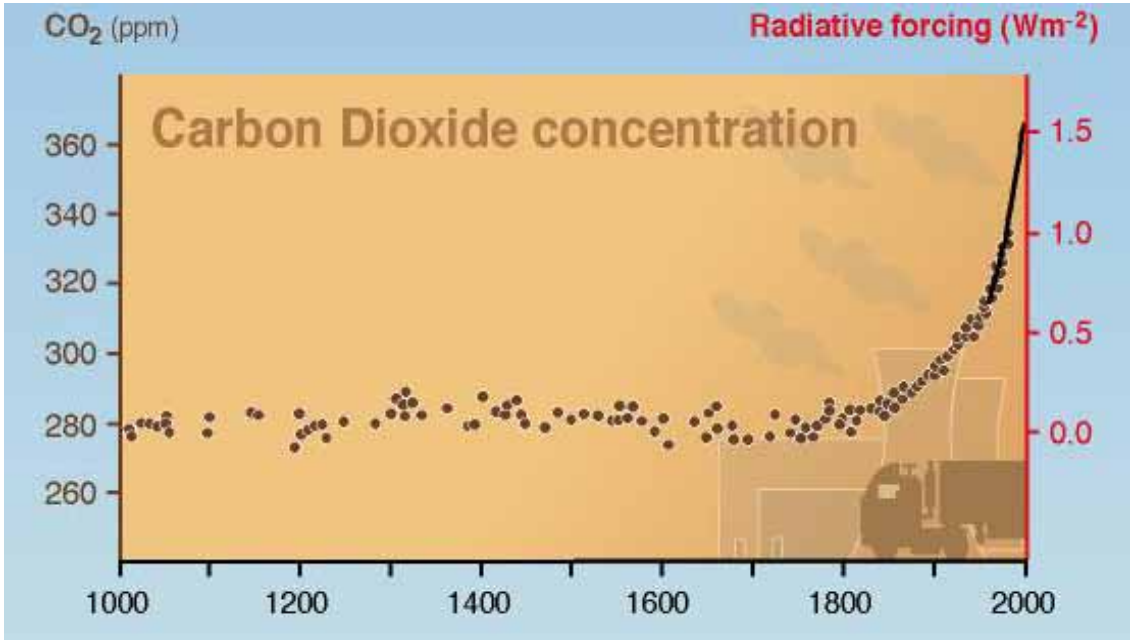
Heat absorption by carbon dioxide, water vapor and other trace gases in the atmosphere warms the earth by 70°F (like a greenhouse)



THE ENHANCED GREENHOUSE EFFECT

Human activities have increased greenhouse gases, hence have artificially increased Earth's temperature by another 1.4°F

Are Greenhouse Gases Increasing?

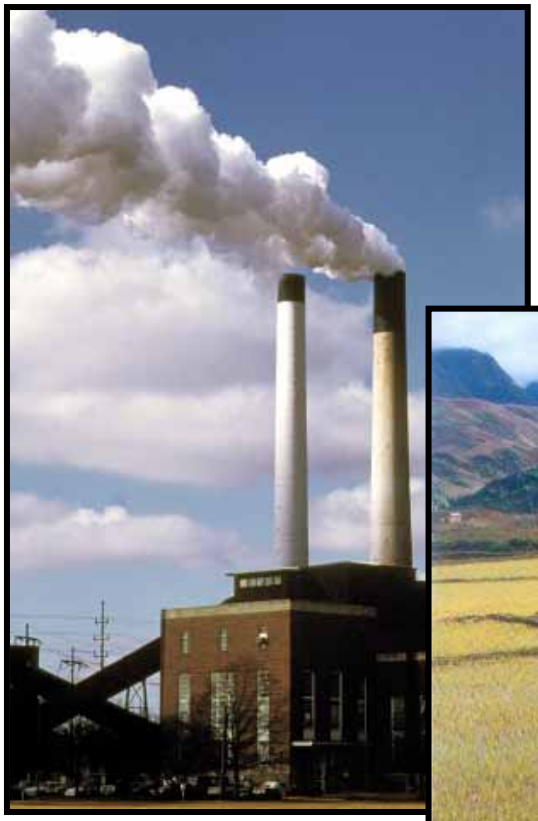


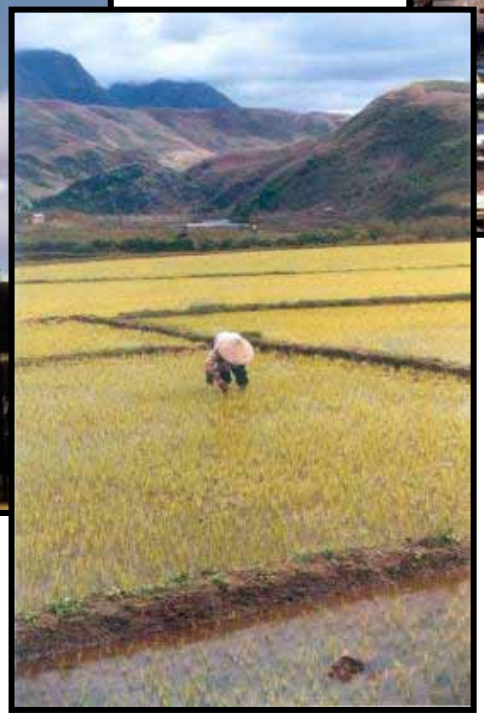
•Human activity has increased the concentration of greenhouse gases in the atmosphere (mostly Carbon Dioxide) from combustion of coal, oil, and gas

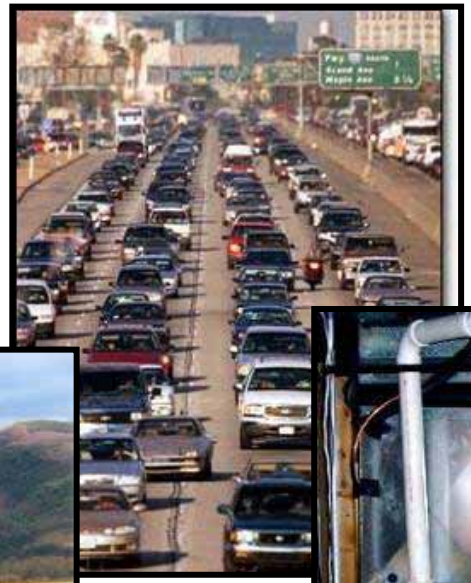
Pre-industrial levels: ~280 ppm
Current levels: ~380 ppm
Current rate of increase: ~1.9 ppm yr^{-1}.

• CO_2 concentration today exceeds the natural range over the last 650,000 yr .

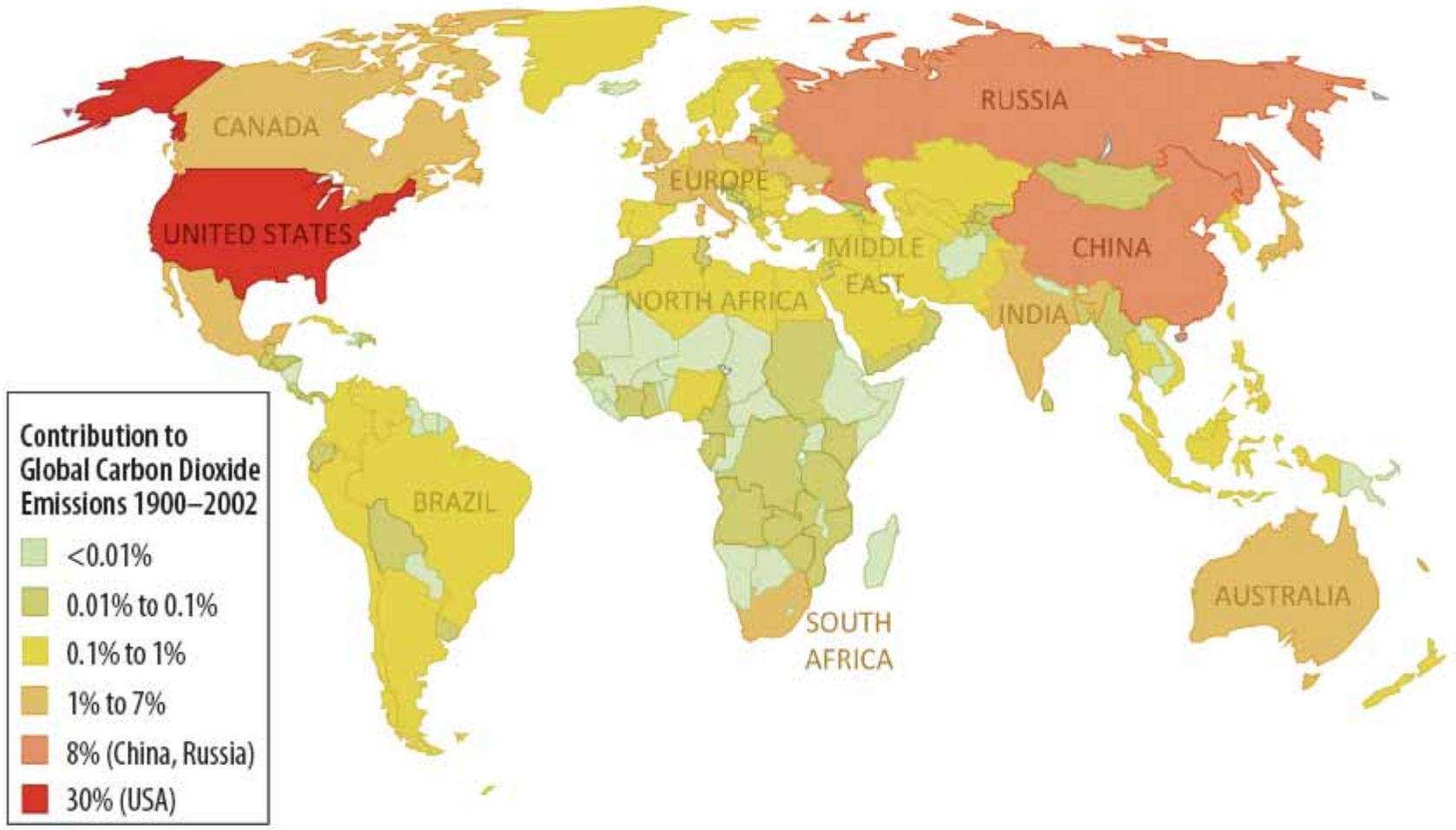
Where do these gases come from?







Who is responsible?

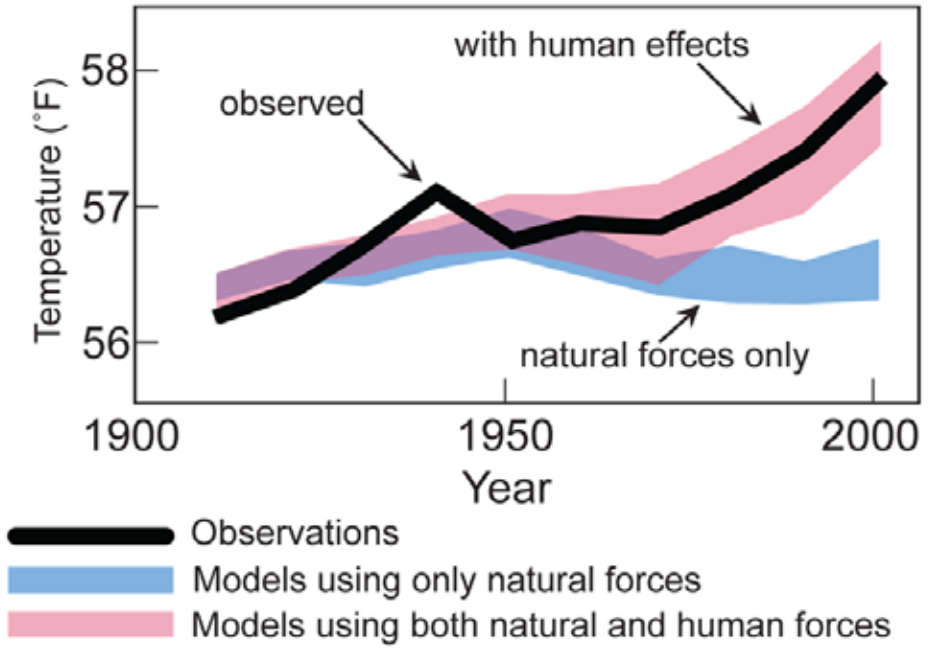


How do we know humans are the primary cause of the warming?

- **Both natural and human factors can lead to climate change.**

- **Even if people burn no fossil fuels, we would still see changes in Earth's climate due to natural forces (e.g. solar cycles, volcanos).**

- **Model evidence helps confirm that the observed warming over the last half-century is primarily due to human factors.**



IPCC 2007

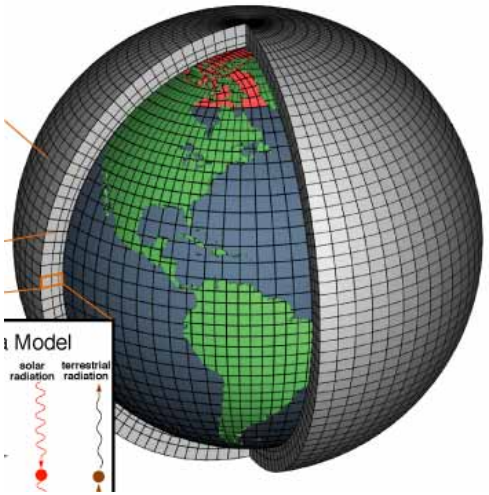
What can we expect in the Future?

- Future scenarios use Climate Models to project future climates by changing certain parameters, such as the concentration of greenhouse gases, to understand how the climate would change in response.
- To credibly project a parameter (such as temperature) into the future, a Climate Model must credibly treat it in the past.
- Extrapolation of extremes requires Climate Models with credible weather statistics (i.e. frequency, intensity, seasonality and variance).

What are Climate Models?

- **Just like the virtual realities of video games, math and physics are used to build "virtual Earths" called Climate Models.**

- **After decades of experimentation, today's "virtual Earths" behave a lot like the real Earth and are used to predict what Earth will be like in the future.**



Climate Model Capabilities

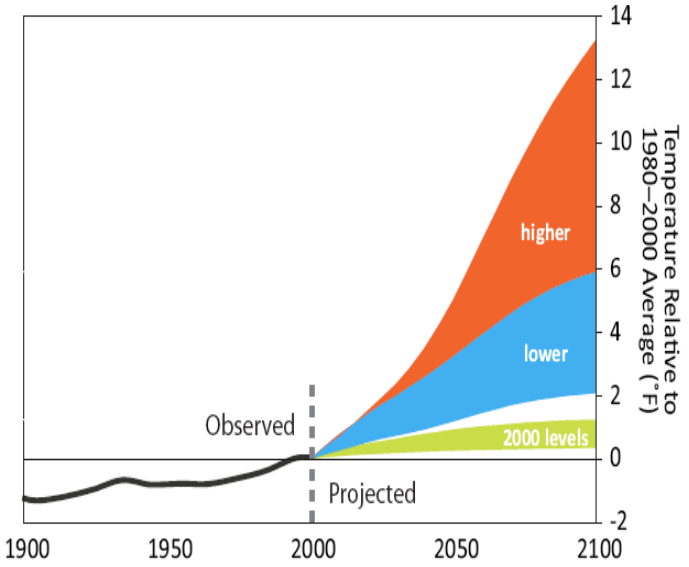
Parameter	*Level of Interest for decision makers*	*Ability of climate models to reproduce the last 50 years*
Mean annual global surface temperature	**No Interest**	**Exceptional Ability**
Regional and seasonal mean temperature and precipitation	**Considerable Interest**	**Fair ability (surface temperature)** **Poor Ability (precipitation)**
Regional and seasonal risks of weather extremes & high-impact events	**Intense Interest**	**Poor Ability**

If we can't predict the weather a week out, then why believe 100 yr climate model projections?

Weather models predict day-to-day features; eventually, small-scale chaotic features grow to dominate, making it impossible to predict beyond about 8 to 10 days.

Climate models predict average conditions for the next month, season, or even century by using information about long-term processes (e.g. the ocean circulation, land surface conditions, and variations in the patterns of incoming sunlight) .

Projected 100 year warming depending on emission levels



Long Term Trends in Weather and Climate Extremes

PART FOUR

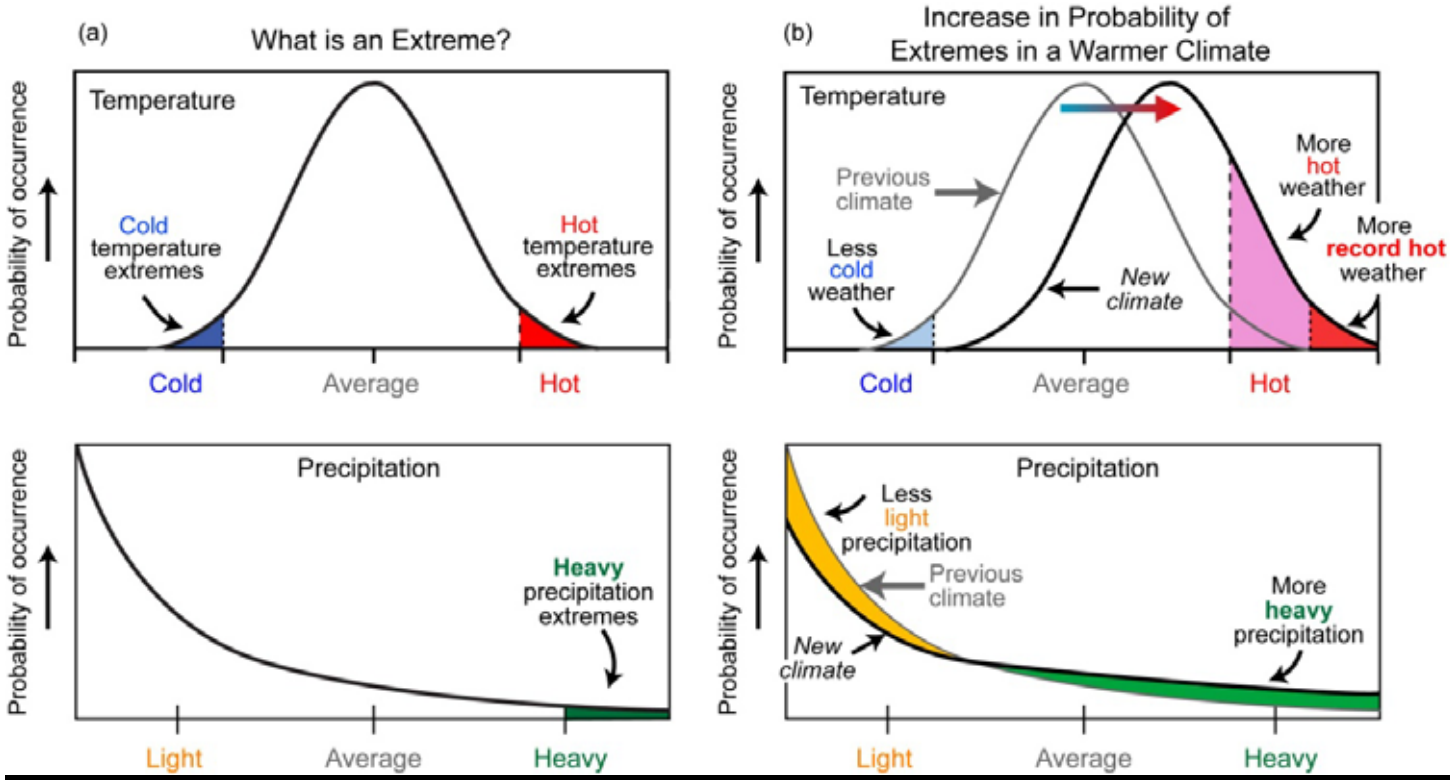
Long - Term Trends in Weather and Climate Extremes

Motivation

Changes in weather and climate extremes have significant human impacts and are among the most serious challenges to society in coping with a changing climate.

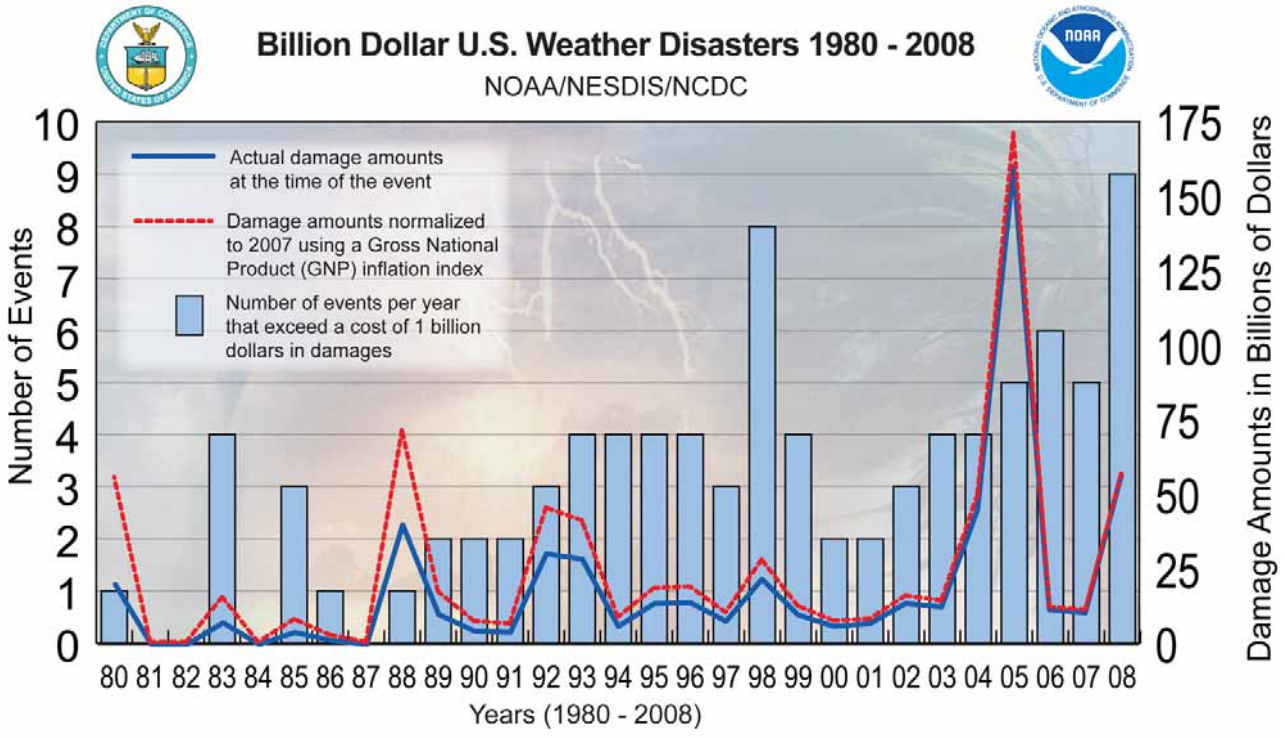
What are Extremes and Why do they Matter?

Small changes in averages for many variables result in larger changes in extremes.



What are Extremes and Why do they Matter?

The majority of events outside the historical range have primarily negative impacts.



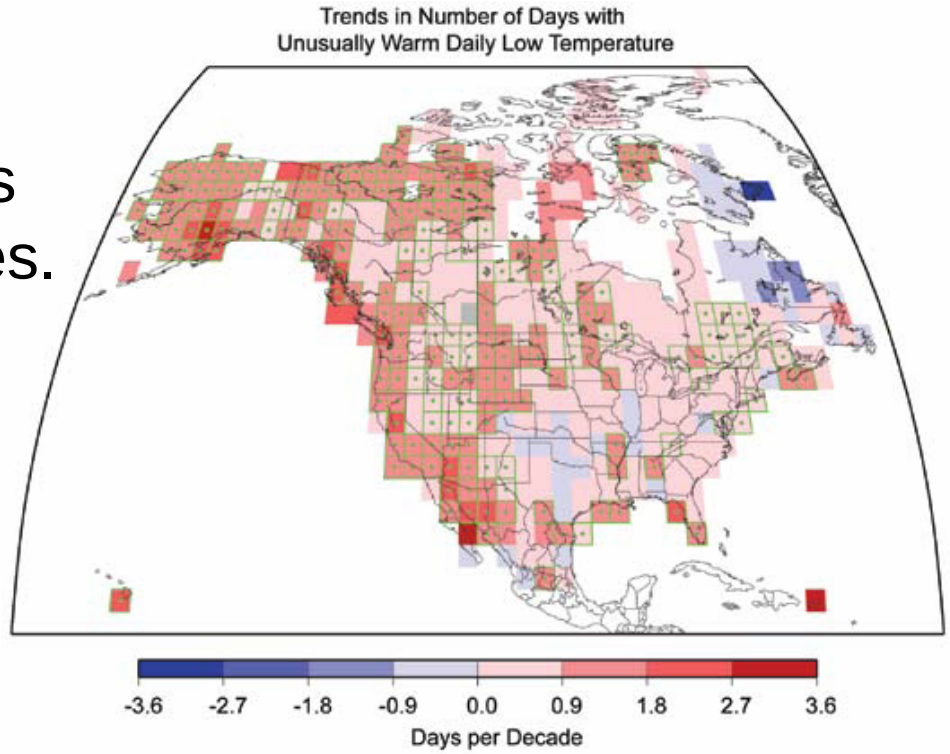
** This graphic does not include losses that are non-monetary, e.g., loss of life, biodiversity etc.*

Temperature Extremes

Observed Changes ----

- More unusually warm days and nights in recent decades.

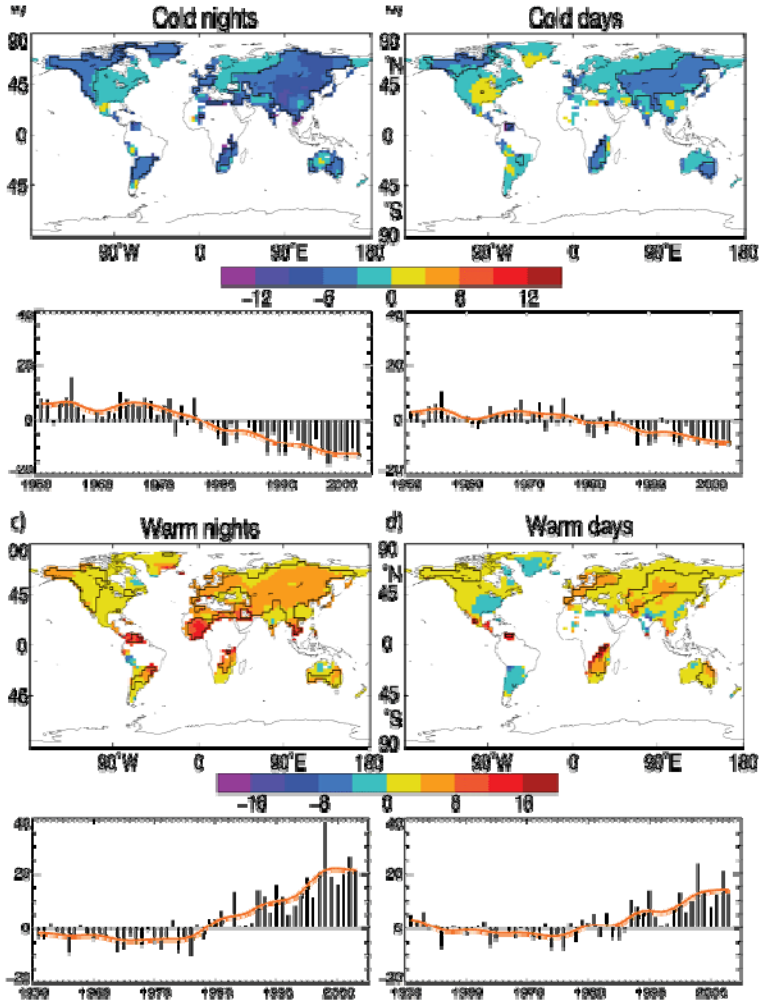
- Increasing number of heat waves, but 1930s still most severe



Temperature Extremes

Observed Changes ----

- Fewer unusually cold days and nights
- More unusually warm days and nights.
- Increasing number of heat waves, but 1930s still most severe



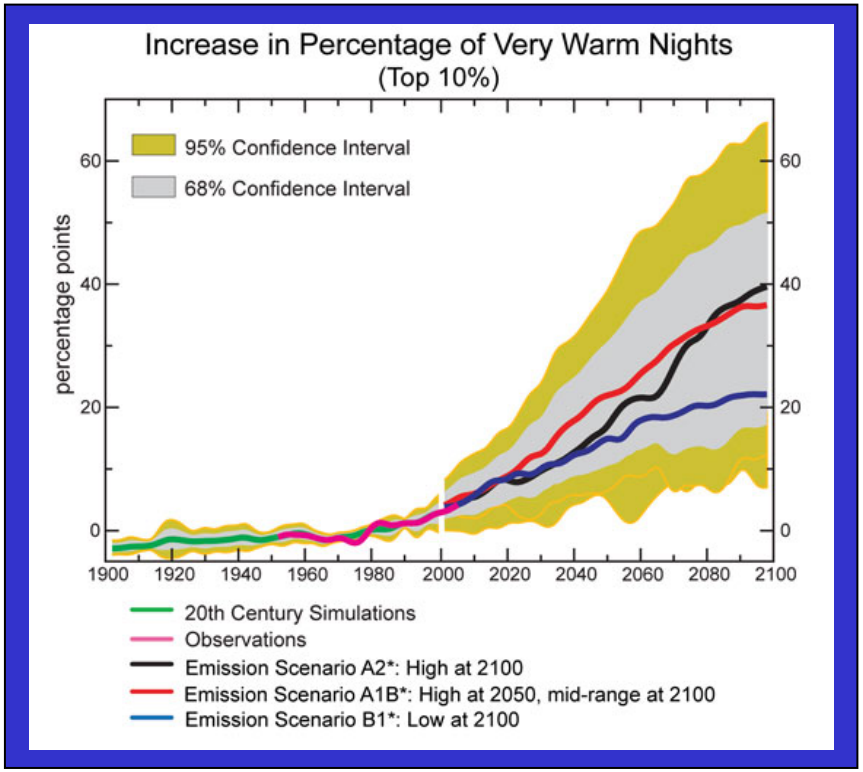
Temperature Extremes

Projection of Changes ----

- Warm days and nights, and heat waves - very likely more frequent.

- Cold days and cold nights – very likely much less frequent.

- Days with frost – very likely to decrease.

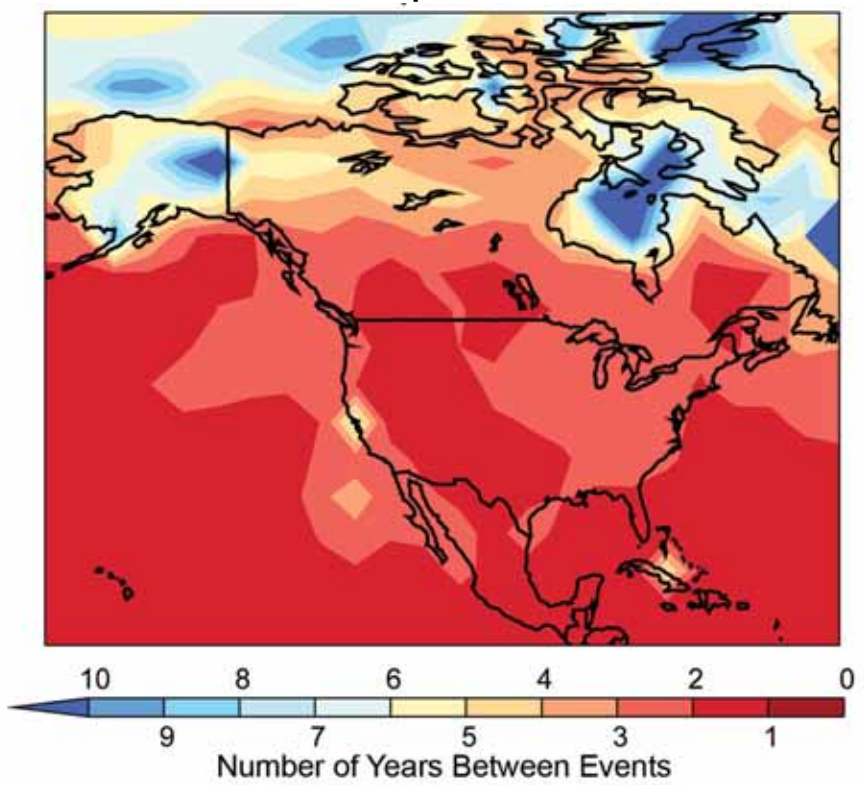


Temperature Extremes

Projection of Changes ----

• Hot days currently experienced once every 20 years would occur every other year or more by the end of the century.

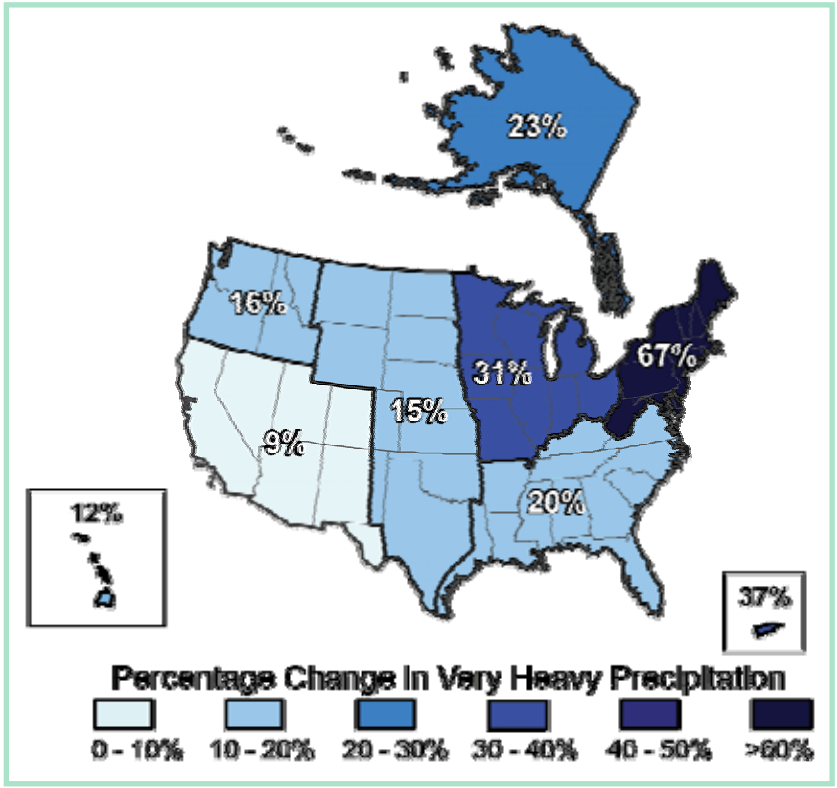
Temperature



Precipitation Extremes

Observed Changes ----

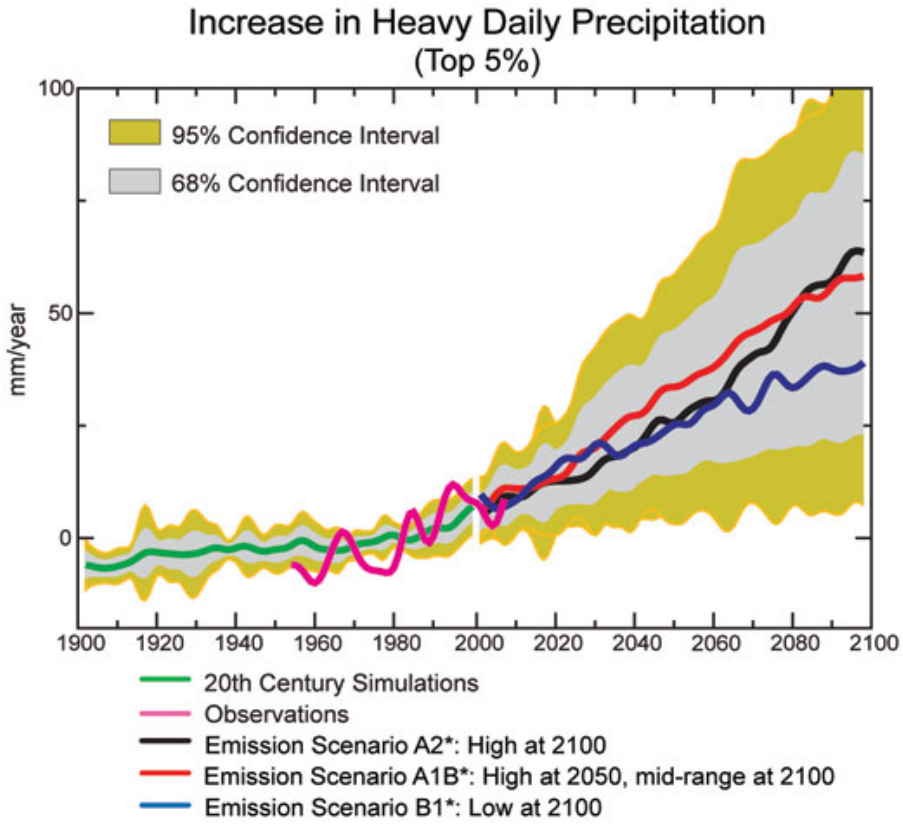
• Intense precipitation events (the heaviest 1%) in the continental U.S. increased by 20% over the past century while total precipitation increased by 7%.



Precipitation Extremes

Projection of Changes ----

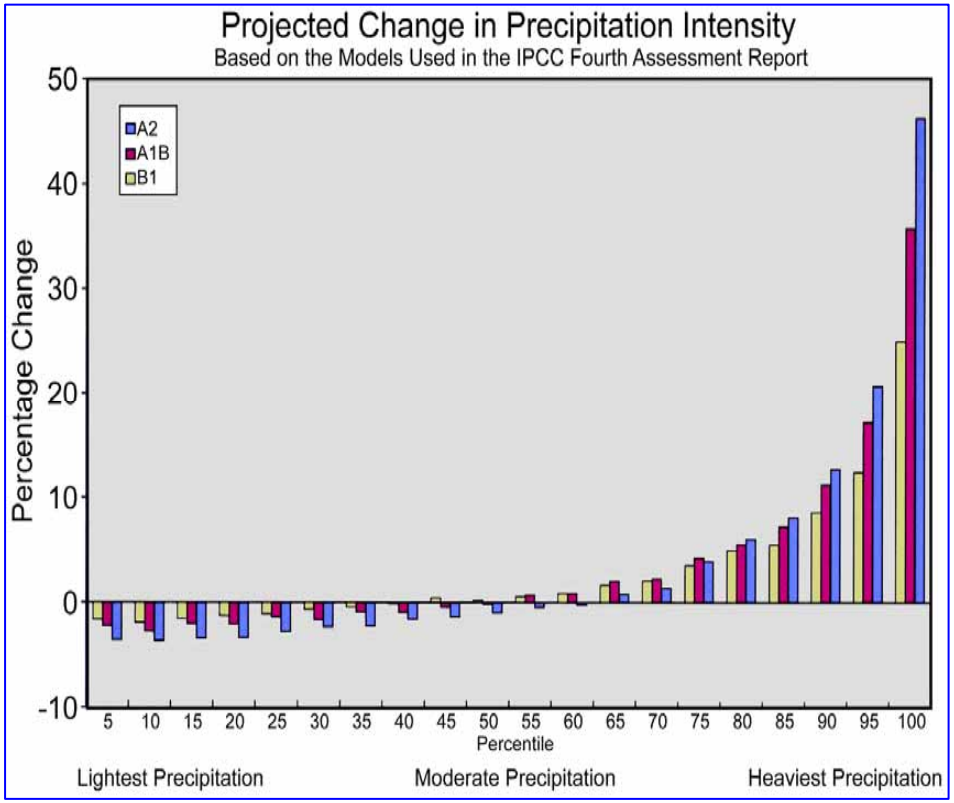
- An increase in precipitation intensity is expected, consistent with the observed increases in atmospheric water vapor (linked to human-induced increases in greenhouse gases).



Precipitation Extremes

Projection of Changes ----

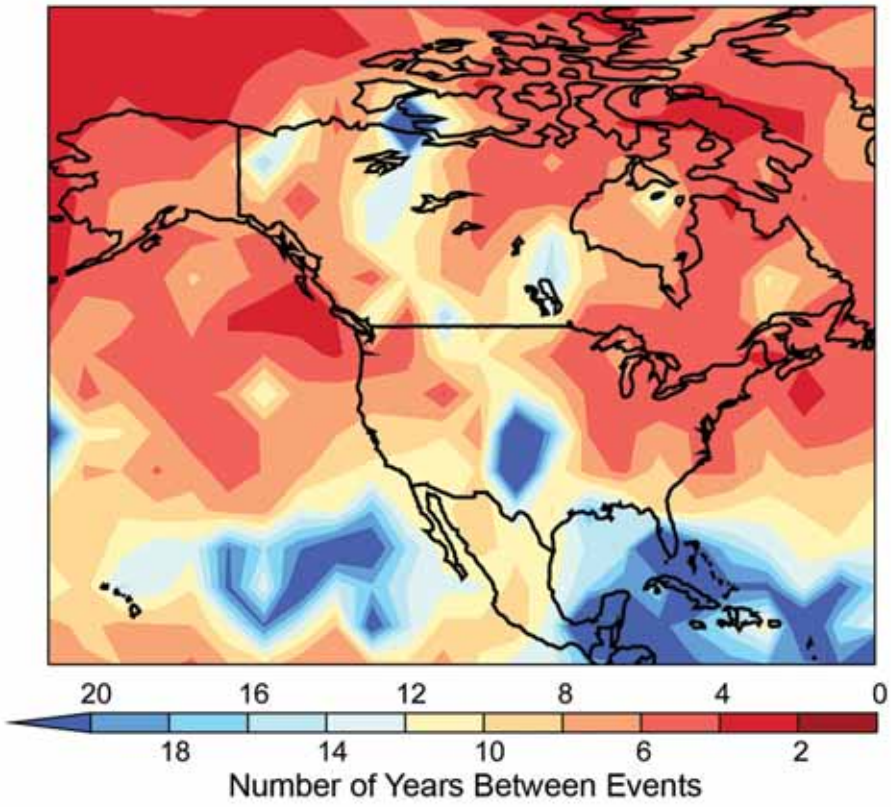
- Lightest precipitation is projected to decrease.
- Heaviest precipitation is projected to increase strongly.
- Higher greenhouse gas emission scenarios produce larger changes in extreme precipitation.



Precipitation Extremes

Projection of Changes ----

• Daily total precipitation events currently experienced every 20 years would occur once every 4-6 years for NE North America by the end of the century.

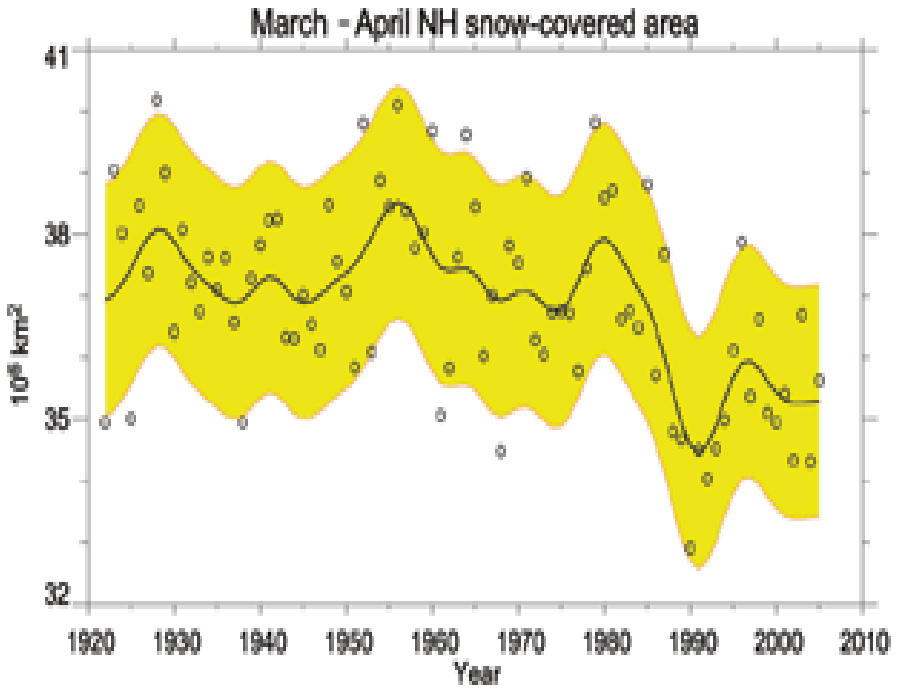


Snow Cover
(Northern Hemisphere Spring)

Observed Changes ----

- Has decreased by about 10% since 1966.

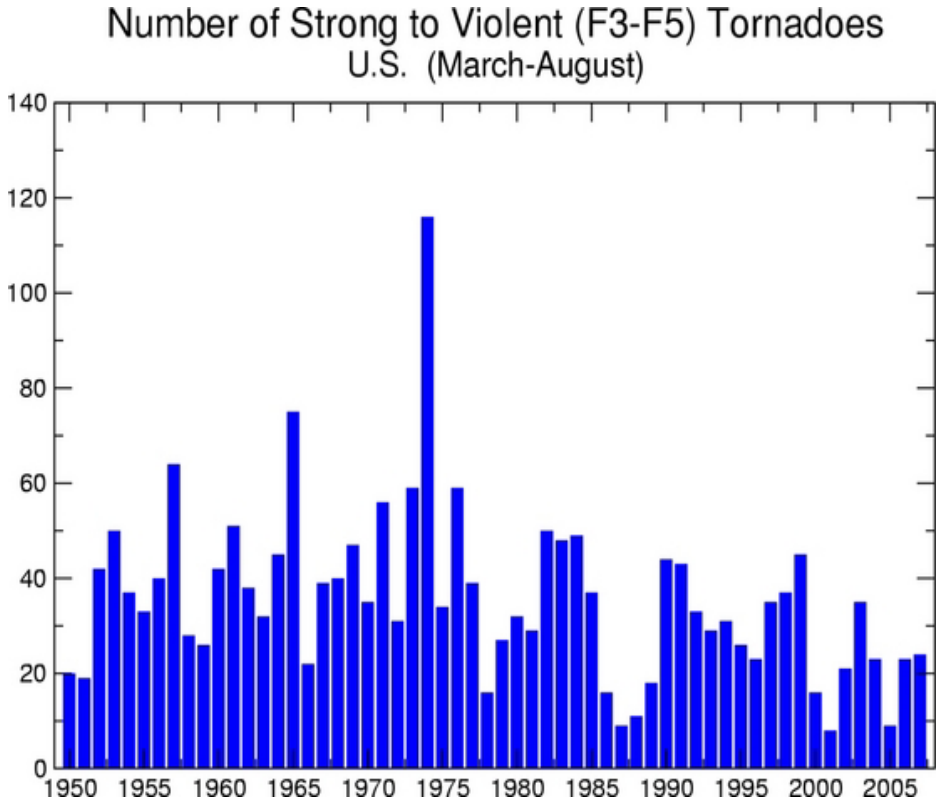
- Winter and autumn show no significant trend for the over the same period.



Is there a Long-term Trend in Tornadoes?

Observed Changes ----

- **No trend that can't be explained by trends in observing & reporting.**



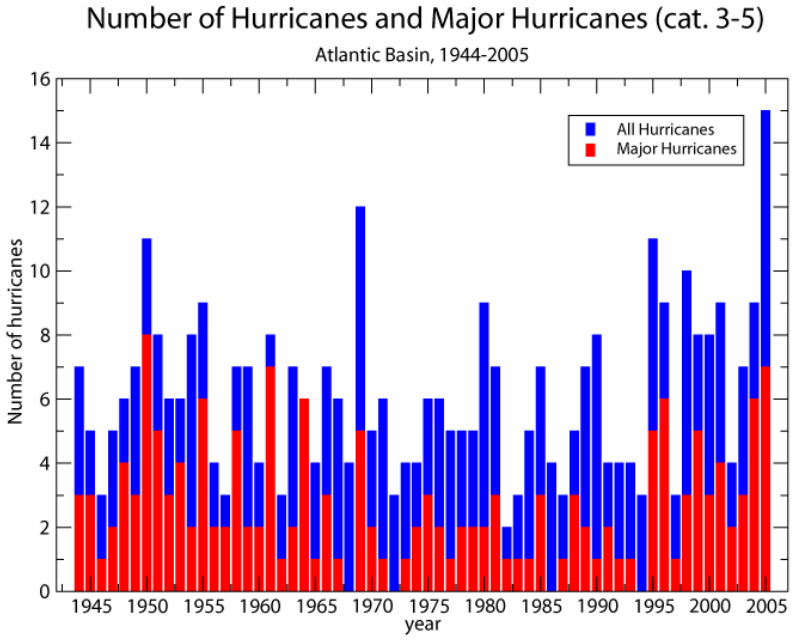
Are hail storms becoming more frequent in the US?

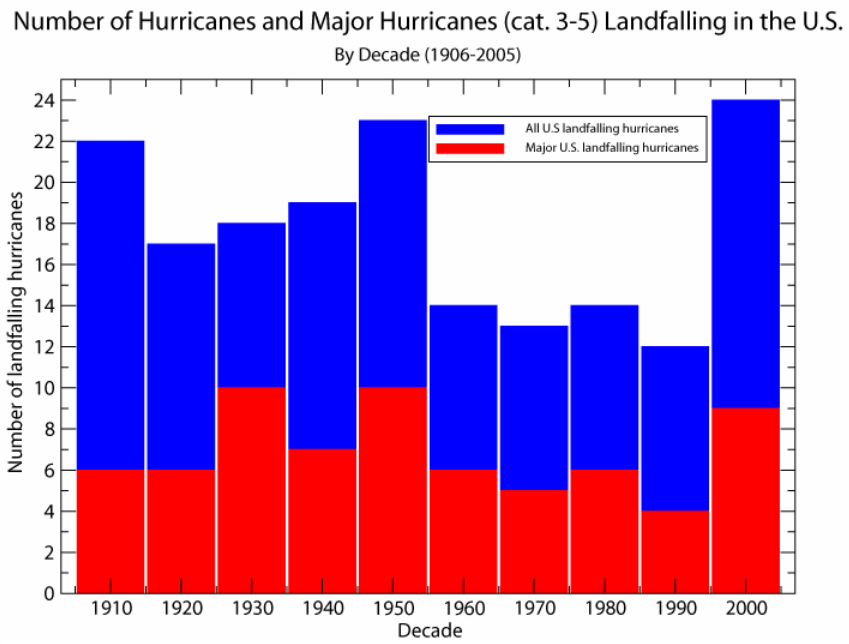
Observed Changes ----

- **No trend that can't be explained by changes in observing & reporting.**

- **Increases in hail losses are due to increasing population in storm prone areas.**

Are hurricanes increasing in the Atlantic Basin?





<u>The Argument</u>:

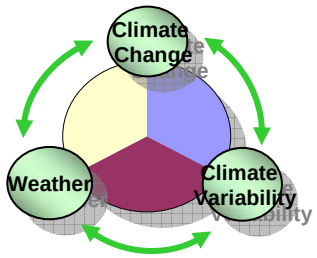
- Human activity--particularly through greenhouse warming--has had a discernible impact on Atlantic hurricane activity through increasing SST's.

<u>The Evidence</u>:

- The increase in hurricane activity since 1995 has precedence. Detection of trends is made more difficult by changes in hurricane observation methods over time.

Linking Weather and Climate: The Big Unknowns

- Projecting what and where impacts of weather and climate extremes will occur
- Reducing uncertainties in forecasts at specific locations
- Recognizing that the climate system can respond in non-linear ways and produce surprises



Take Away Messages

PART FIVE

Take Away Messages

- **Climate Change is manifested as variations in the number and intensity of weather extremes that have significant human impacts**
- **There are important long-term trends in the mean temperature and precipitation climates of North America and the globe.**
- **Links between trends in green-house gas concentration and trends in some weather extremes have not been fully established.**
- **Credible extrapolation of trends (other than for gross features of the climate) depends on future model improvements.**
- **Recent progress in our ability to predict phenomena at the interface between weather and climate has been impressive and is serving as a vital component of Earth system science.**

Additional Resources

- **NOAA Climate Service Portal:** http://www.climate.gov
- **Climate Prediction Center:** http://www.cpc.ncep.noaa.gov
- **IPCC Website:** http://www.ipcc.ch/
- **USGCRP Website:** http://www.globalchange.gov/
- **National Climatic Data Center site on Global Warming:** http://www.ncdc.noaa.gov/oa/climate/globalwarming.html
- **Global Change Master Directory:** http://gcmd.gsfc.nasa.gov/Resources/pointers/glob_warm.html