


### 2011: 10 U.S. \$1B weather disasters

- 5 separate tornado outbreaks
- 2 different river floods
  - Upper Midwest, Mississippi
- Southwestern drought
- Northeastern blizzard
  - Jan 25-27 and Jan 31-Feb 2
- Hurricane Irene
  - Aug 27-29



**Is Extreme Weather The New Normal?**  
New England, Nation Experience Destructive Extremes

**Los Angeles Times**  
Weather extremes may be the new norm

**TIME Science**  
what difference does it make?

**Another Blizzard: What Happened to Global Warming?**

### So, the question is...

- ... what is the evidence for climate change?
- ... what do climate scientists think will happen in the future?
- ... are climatic extremes likely to be pervasive in the future?

### Outline of Talk

- Basic glossary for climate change.
- What are extreme events and why should we worry about them.
- Global warming: the current evidence
- Why might climate change in the future
- Projected future climate changes

**CBS EVENING NEWS WITH SCOTT PELLEY**  
Palestinian president speaks to U.N. after applying for statehood

**Weather.com**  
Why twister outbreak? La Niña eyed as key factor

**BBC**  
Wild and deadly weather: Is La Niña to blame?

**WEATHER**  
La Niña causes widespread disruption

### Does the Heat Wave Confirm Climate Change? Yes and No

Jul 7, 2010 - 8:26 PM

(July 7) -- With record-breaking summer temperatures from Beijing to Baghdad to Boston, many people are wondering whether the searing heat is a direct result of global warming.

Most every climatologist will tell you that you can't extrapolate a long-term climate trend from a single weather event or finite period. So, even though the current heat wave gripping much of the world has been rewriting the record books, it may not really tell us all that much about climate change.

Indeed, in attempting to quell climate-change skeptics following a period of heavy snow this past winter, Obama administration scientist Jane Lubchenco stated, "It is important that people recognize that weather is not the same thing as climate."

## Basic Definitions

**Weather:** the day-to-day, hour-to-hour, and even instantaneous state of the atmosphere.

Examples: current temperature, humidity, wind, cloud cover

**Climate:** the long-term average state of the atmosphere; or the average of weather.

Example: the 1980-2010 climate averages of temperature and precipitation

Weather! Climate change not yet postponed.

## Climatic Change

- Any significant systematic change in the statistical distribution of climate (and weather) patterns over periods ranging from decades to millions of years. *It may be a change in climatic averages or in the distribution of extreme events around that average.*
  - Climate change may be limited to a specific region or may occur across the whole Earth.

## Changing Averages

- In an environment of climate change, shifts in long-term averages (of temperature, precipitation, wind) to higher or lower values will increase the number of extreme events.

## Changing Distribution of Events

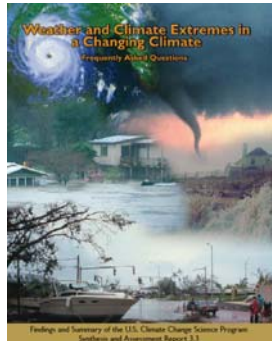
- Another possibility is a "flattening" of the distribution of weather events such that "normal" events occur less frequently but extreme events become more common.

## What is an Extreme?

### The U.S. Climate Change Science Program (6/19/08)

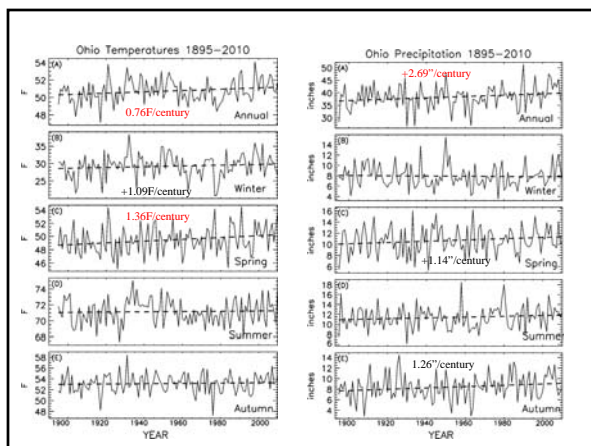
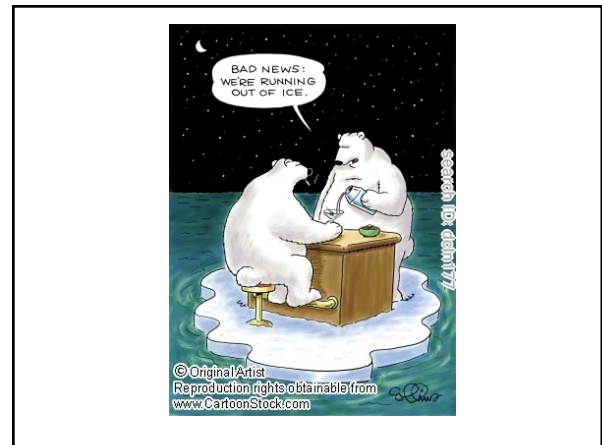
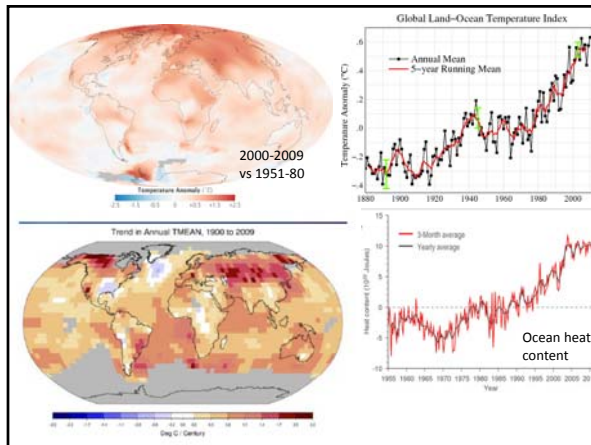
"...biggest impacts of global warming will come in the form of changes in weather and climate extremes."

- More heat waves
- Drought more frequent & severe in some regions
- Precipitation will be less frequent but more intense, high rainfall events more common.



### Global Warming: the current evidence

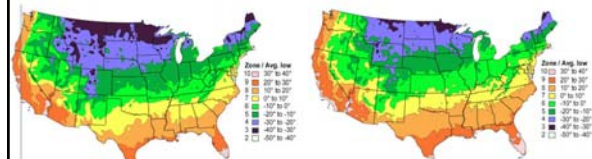
- The gradual increase in the temperature of the earth's atmosphere, believed to be due to the enhanced greenhouse effect, caused by increased levels of carbon dioxide, methane, and other pollutants and exacerbated by activities such as deforestation.
- What evidence exists for recent climate change or global warming?



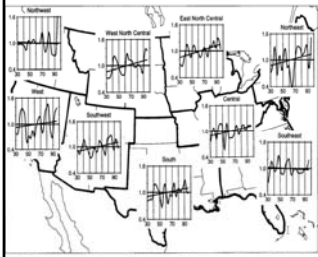
### Plants, Crops, & Climate Change

1990 USDA plant hardiness zones (based on 1974-1986 data)

2006 Nat'l Arbor Day Foundation (based on weather service data 1991-2005)



### Trends in Heavy Precipitation Events, 1931-1996



- Heavy precipitation events have already increased.
- Consistent with increases in atmospheric water vapor associated with human-caused greenhouse gas increases.
- Precipitation has become less frequent but more intense.

(Kunkel, Andsager and Easterling, 1999)

### One Inch Rain Days per Year: Ohio

#### 1900-1910

Dayton: 6 days  
Columbus: 4.5 days  
Cleveland: under 4 days

#### 2000's

Dayton: Over 9 days  
Columbus: ~ 8 days  
Cleveland: ~ 7 days

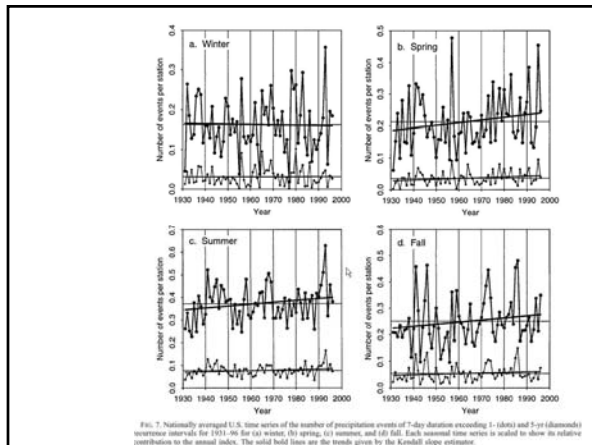
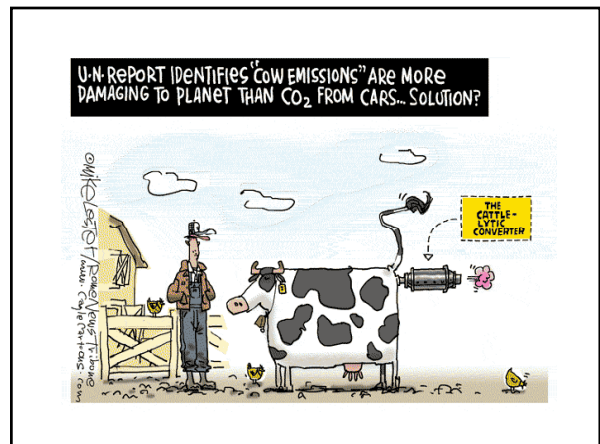
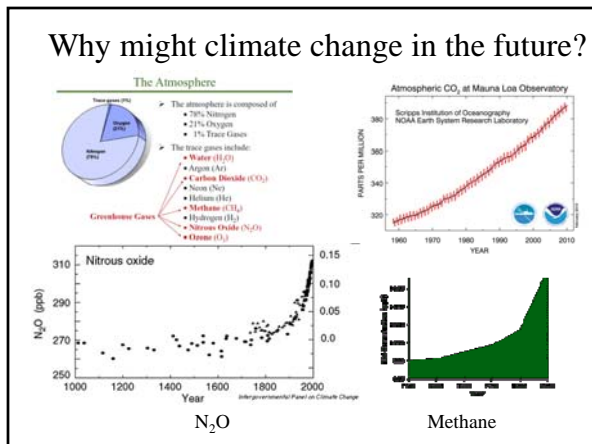
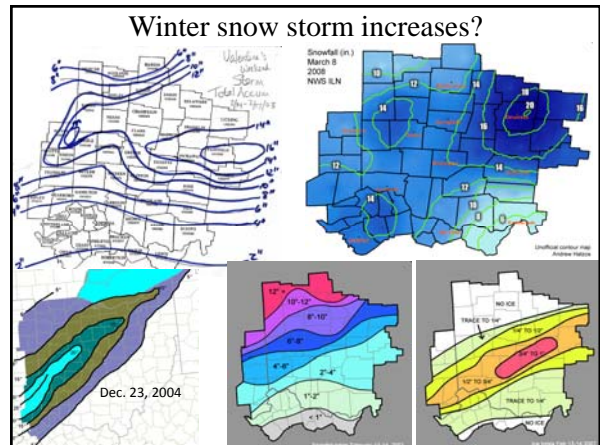


FIG. 7. Nationally averaged U.S. time series of the number of precipitation events of 7-day duration exceeding 1- (left) and 5+ (right) inches for (a) winter, (b) spring, (c) summer, and (d) fall. Each seasonal time series is scaled to show its relative contribution to the annual index. The solid bold lines are the trends given for the 4-month steps estimates.



## What are Greenhouse Gases?

- Greenhouse gases
  - (i) absorb outward bound infrared radiation from the earth's surface.
  - (ii) Delay the return of infrared radiation to space
  - (iii) warm the atmosphere.
- The "greenhouse effect" modulates radiation in the earth-atmosphere system.

## Greenhouse Gases (GHGs)

(ranked by importance)

Gas	Source	Residency in air
Water Vapor	Evaporation from surface, future impact poorly understood	About 10 days
Carbon Dioxide	Fossil fuel consumption, deforestation	100-500 years
Methane	Ag byproduct; fossil fuel extraction	12 years
Ozone	Car combustion; it is part of photochemical smog	Hours/days
Nitrous Oxide	Decay of fertilizers; car exhaust	114 years
CFC's	Aerosol sprays pre-1990s	Up to 3,000 yr

## Earth with Greenhouse Gases

With Greenhouse gases (CO<sub>2</sub> and H<sub>2</sub>O vapor) the planet's average temperature fluctuates around +59°F.

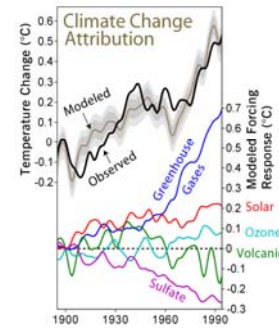
This is 60°F warmer than with no greenhouse gases  
40°F is contributed by H<sub>2</sub>O vapor,  
20°F by CO<sub>2</sub>

Our societal debate is whether the observed increases in GHGs will increase the air temperature beyond 59°F, to 60°F, 61°F, etc.

Carina Van Vliet

## Attribution of Climate Change to Human Activities

- Modeled climate change (shaded gray) is close to observed variability (black line).
- The climate change is the sum of the "forcings" shown at bottom, producing a net warming.
- Natural forcings neutral.
- Modeled climate: DOE parallel climate model



Meehl et al (2004; J. Climate)

## Aerosols & Sulfate

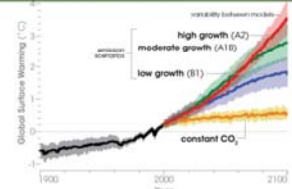
- Aerosols: Tiny particles & liquid droplets from burning of fossil fuels that also have radiative effects in our atmosphere.

- Sulfates are aerosols from coal & oil burning; they backscatter solar radiation & cool the climate. "Global dimming".

## Projected Future Climate Change

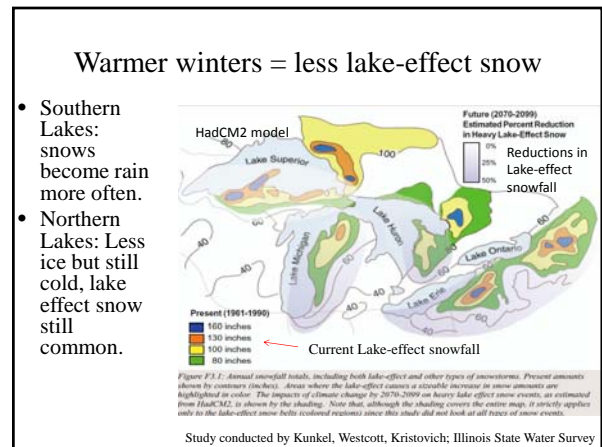
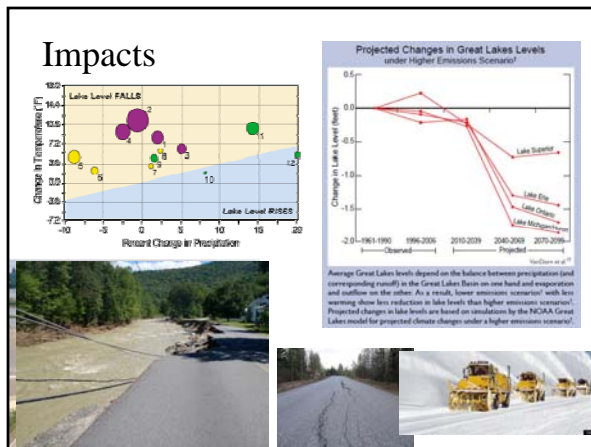
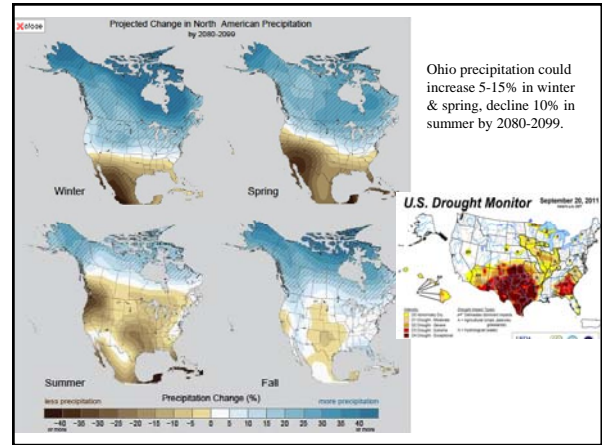
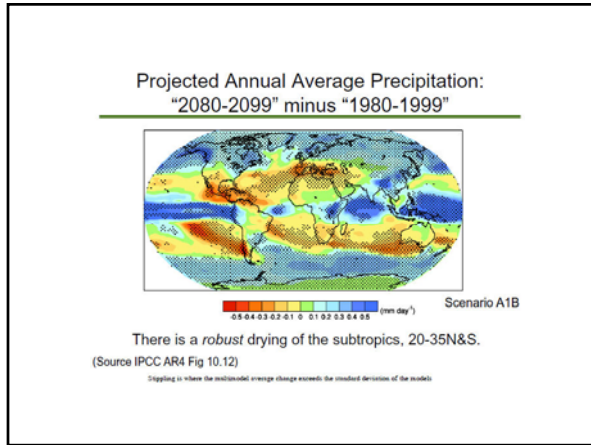
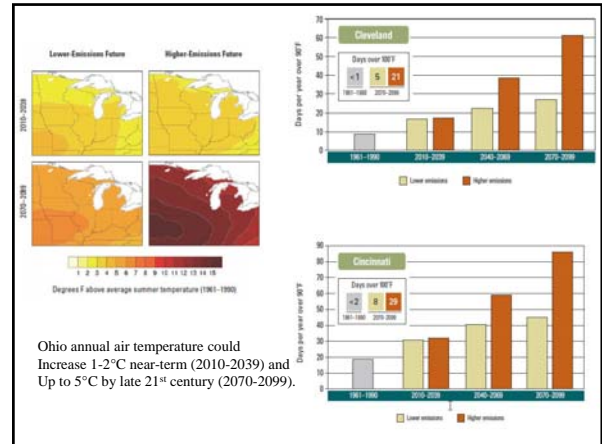
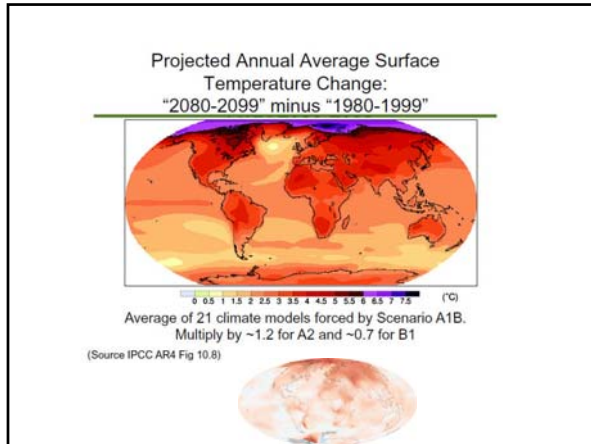
- Atmosphere-ocean coupled models are the only way to predict the future with any certainty

IPCC based Past and Projected Global Annual Average Surface Temperature (primarily as a response to GHG emissions)



Referenced to the 1980-1999 Average Temperature

Solid lines: average of all models used. Number of models used varies; shaded area is the standard deviation of the models (Source IPCC AR4 Fig 10.4)



IPCC projections/summary of changes observed and anticipated to occur with “high degree of confidence”

- Warmer, and fewer cold days and nights
- Warmer and more frequent hot days and nights
- Warm spells/heat waves frequency increase
- Heavy precipitation more frequent
- Drought areas increase
- Some possibility of increase in storms
- *Generally: more extreme weather is predicted*

## Perils of putting off action and what's there to lose?



## When Planning for change in Ohio

(things to think about)

- Most studies, assessments, and (increasingly) observations, and projections support climate is changing (how, how much, and why continues to be debated).
- Knowing that changes are underway can help plan.
- Planning for climate variations and change can help develop resilience for climate change.
- Temperature changes will be regional and have impacts depending on what the application is (e.g., frost, heat stress) and may be mitigated by technological changes.
- Heavier rain/snow events are highly likely in the future.
- Expect climate & weather extremes: expect to be at the edge of the envelope.

## Thank You

Ohio Climate Office

Jeffrey C. Rogers

E-mail: [rogers.21@osu.edu](mailto:rogers.21@osu.edu)

Web: <http://www.geography.ohio-state.edu/faculty/rogers/statclim.html>

Changing Climate Ohio: <http://changingclimate.osu.edu/>