Short and Long-term Climate Concerns for Agriculture in Indiana and across the Midwest

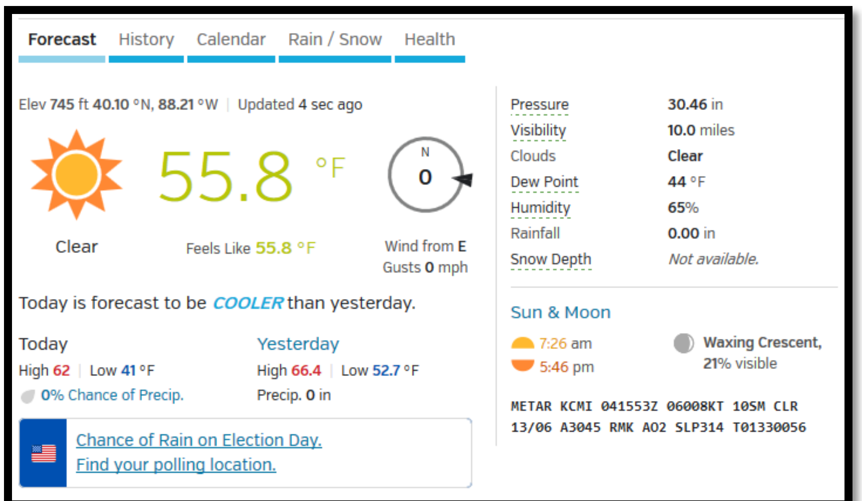
Olivia Kellner, Ph.D.
Climatologist
Illinois State Water Survey

Discussion Points

- Weather and Climate
  - Climate Variability
  - Climate Change
  - Natural and Human-caused climate change
- Understanding Climate Patterns: Analog Years
- Observations and Projections of Weather and Climate in Indiana and the Midwest
  - Understanding the data
  - Understanding climate projections
- Weather and Climate Monitoring Resources
- Conclusions

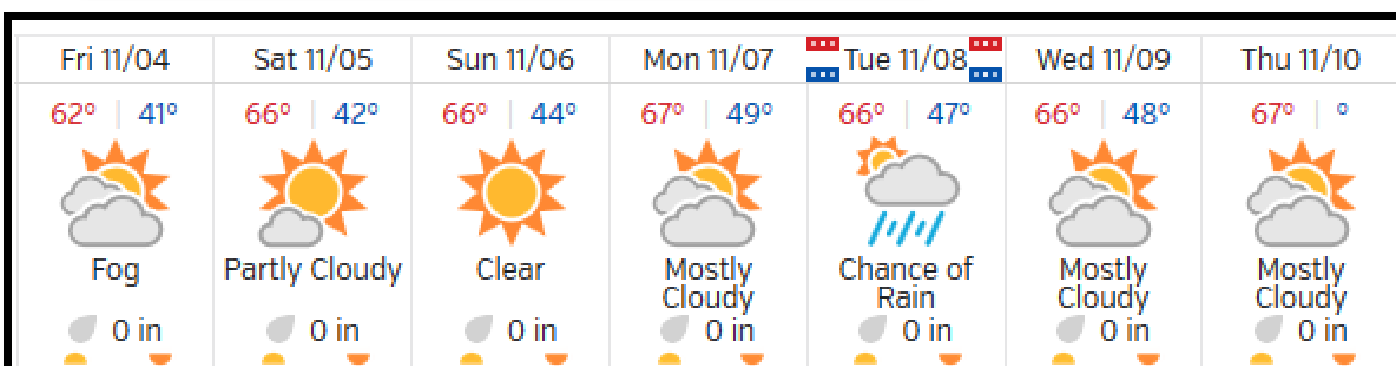
Weather

- What we experience each day
  - It is characteristic to the climate zone we live in



Indiana Climate Zones:

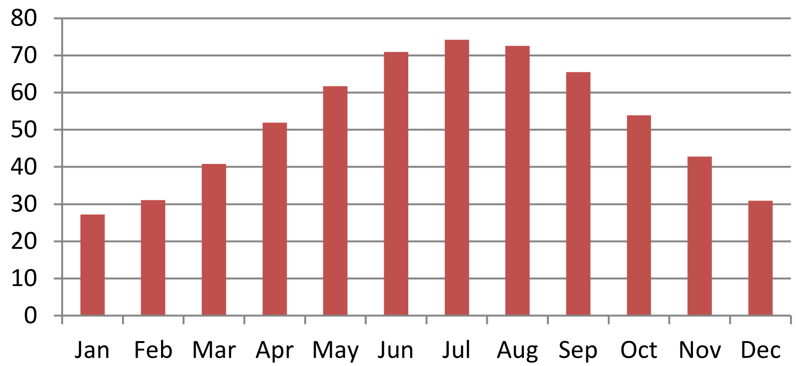
- humid continental (warm summer) (majority of the state)
- humid subtropical (southern counties)



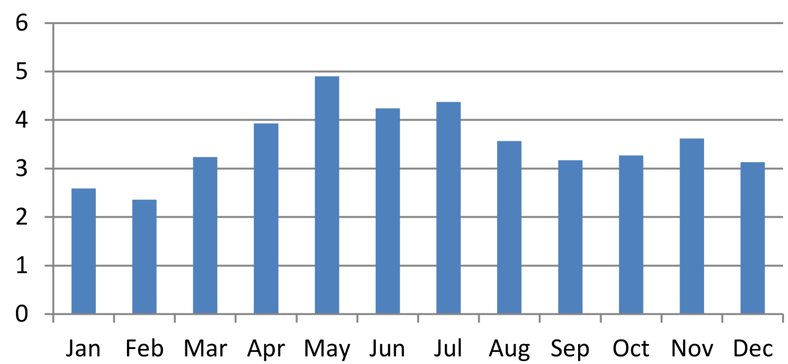
Climate

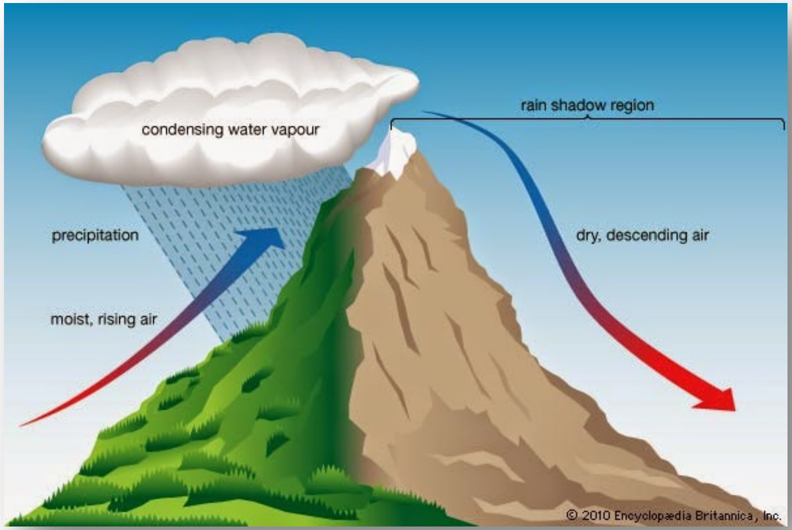
- Climate – the average weather over time for a given place
- Determined by:
  - Proximity to large bodies of water (store heat)
    - Great Lakes
    - Oceans
  - Elevation
  - Proximity to mountains
  - Latitude (distance from poles or equator)

Indiana Average Monthly Temperatures (1981-2010)



Indiana Average Monthly Precipitation (1981-2010)

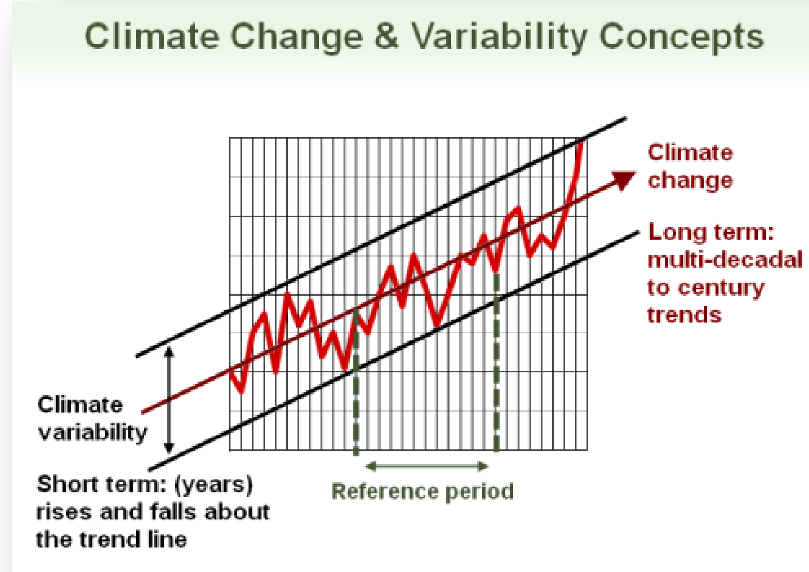




http://cliffmass.blogspot.com/2014_08_01_archive.html

Climate Variability

- Climate Variability: weather over time that is above or below normal, but is still within expectations
  - not considered climate change
- Variability has been documented for centuries and throughout Earth's history
  - proxy data
    - ice cores
    - tree rings
    - pollen samples
    - lake sediments



http://www.pacificclimatefutures.net/en/help/climate-projections/introduction-climate-change-projections/

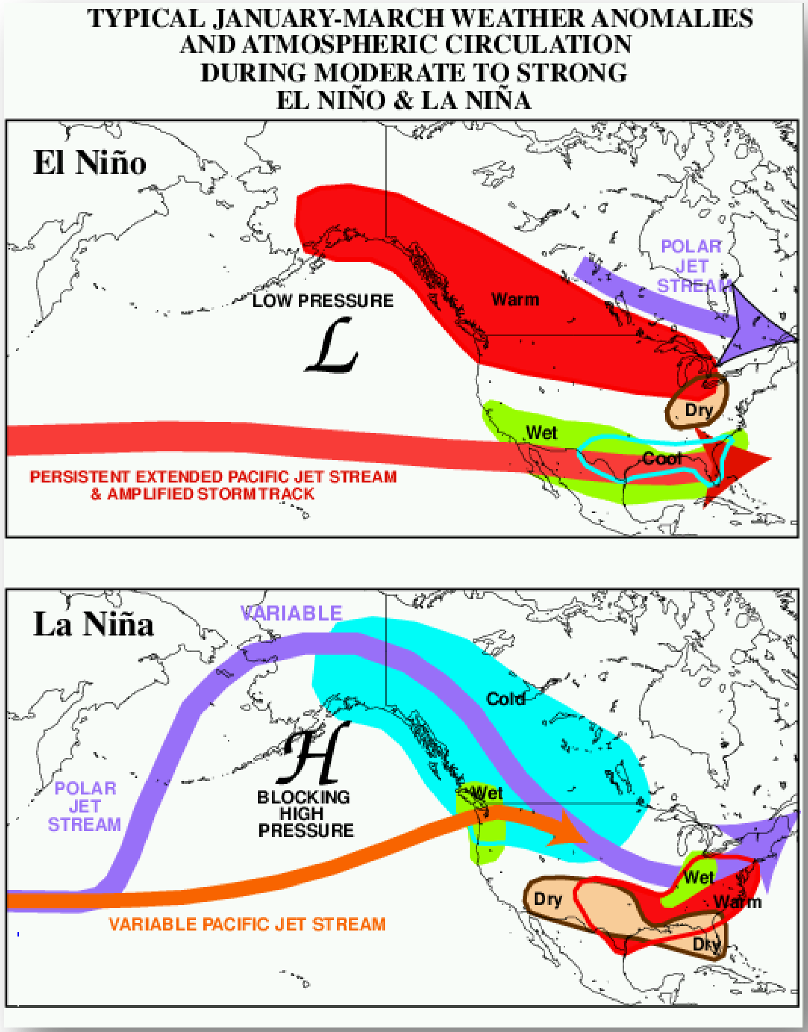
Teleconnections: Causes of Climate Variability

Teleconnections are a linkage of the atmosphere

- Changes in weather at one location impact the weather at another location

Examples:

- El Niño/La Niña
  - Winter 2015-2016
- Arctic Oscillation and the Polar Vortex
  - Winter 2013-2014
- Pacific North American Pattern
- North Atlantic Oscillation
- Pacific Decadal Oscillation

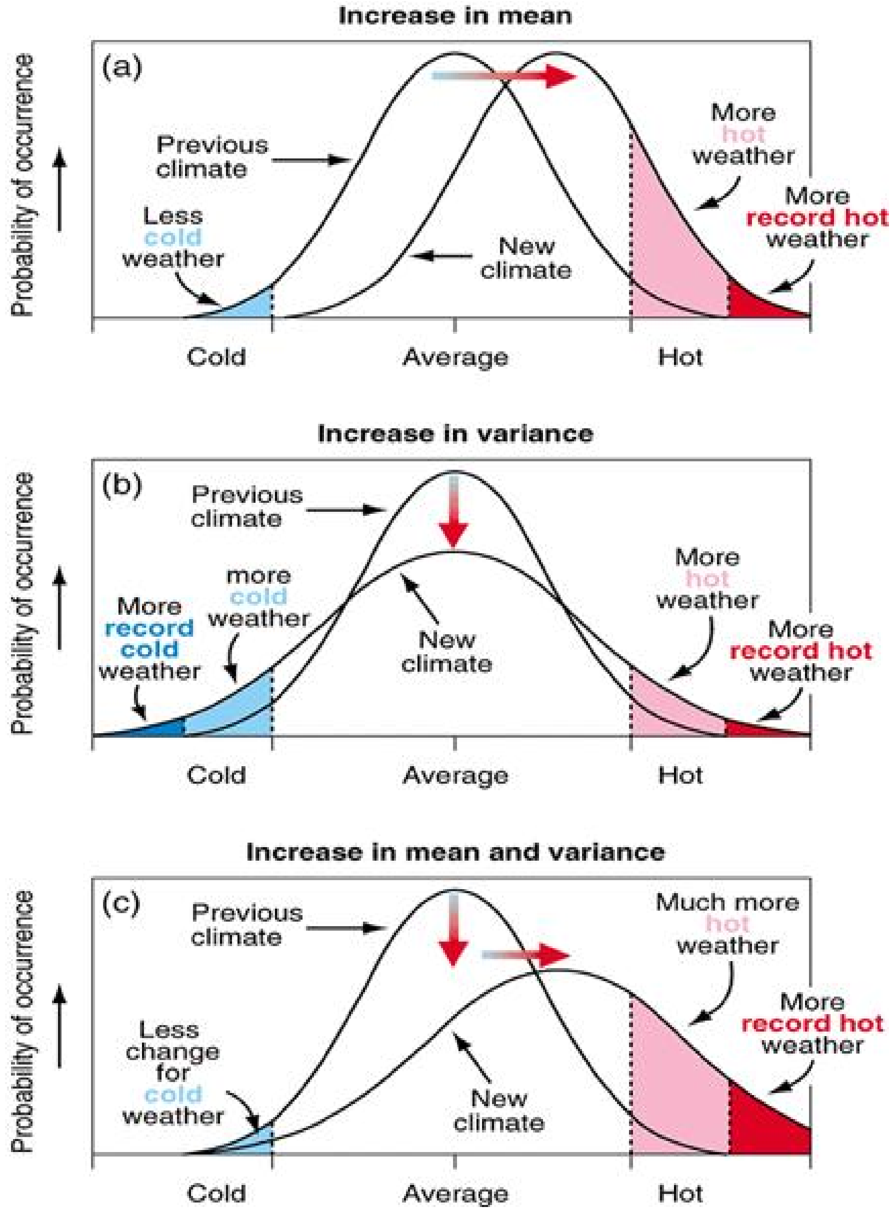


http://www.cpc.noaa.gov/products/analysis_monitoring/ensocycle/nawinter.shtml

Climate Change

- "Any multidecadal or longer alteration or shift in one or more physical, chemical, or biological state variables or fluxes within the climate system"

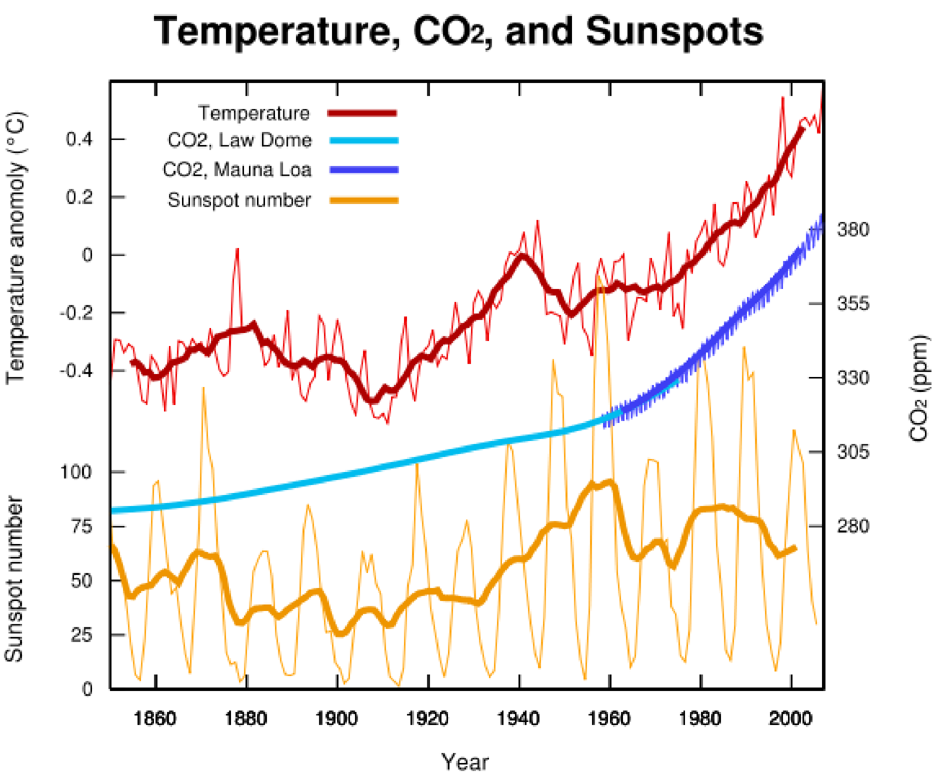
- Physical variables
  - Temperature
  - Precipitation
  - Atmospheric circulation
- Chemical variables
  - Greenhouse gas concentrations
- Biological state variables
  - Ecosystem health and sustainability
    - Animals and vegetation



https://climatesight.org/page/8/

Climate Change

- Natural Causes
  - Solar Cycles
    - Low solar activity = reduction in radiation entering Earth's atmosphere
      - Slightly cooler temperatures
  - Volcanic eruptions
    - Ash prevents solar radiation from reaching Earth's surface
      - Slightly cooler temperatures
  - Milankovitch Cycles
    - Changes in shape of Earth's orbit
    - Changes in tilt of axis
    - Changes in Earth's wobble



http://solar-center.stanford.edu/sun-on-earth/600px-Temp-sunspot-co2.svg.png

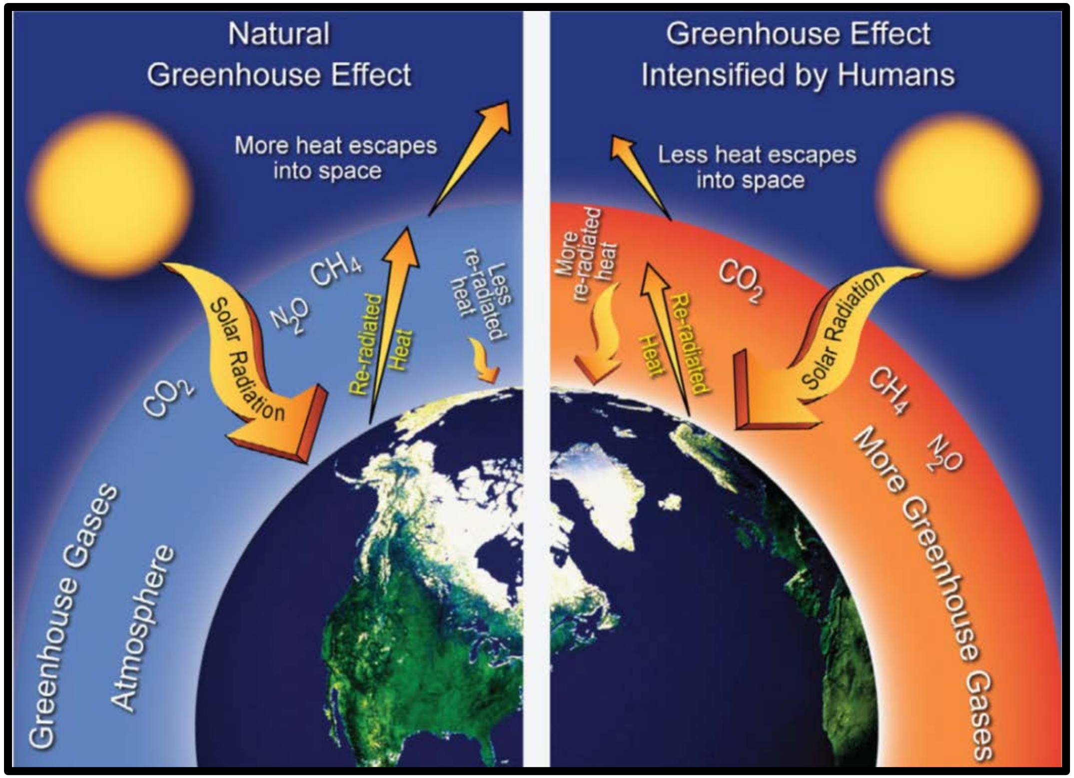
Climate Change

- Human-caused
  - Increased CO_2, methane, pollution/particulates, burning of fossil fuels
    - Stores more heat in the atmosphere!
  - land-use change
    - Changes surface radiation budget and water balance
- Human influence on the climate system first proposed in 1896 by Svante Arrhenius!

http://know.climateofconcern.org/index.php?option=com_content&task=article&id=132

How do We Know Humans Contribute to Climate Change?

- Carbon isotopes
  - number of neutrons in a carbon atom varies
- Natural carbon isotopes: Carbon -12, 13, and 14
  - C-12 most common
  - C-13 ~1% of total
  - C-14 ~one in 1 trillion carbon atoms
- Plants prefer carbon-12
  - Since 1850, the burning of fossil fuels and biomass ("slash and burn") has resulted in a lower carbon 13/12 ratio in the atmosphere due to increased carbon-12 from humans



http://nca2014.globalchange.gov/report/appendices/faqs/graphics/human-influence-greenhouse-effect

This is how we know humans have enhanced the natural Green House Effect!

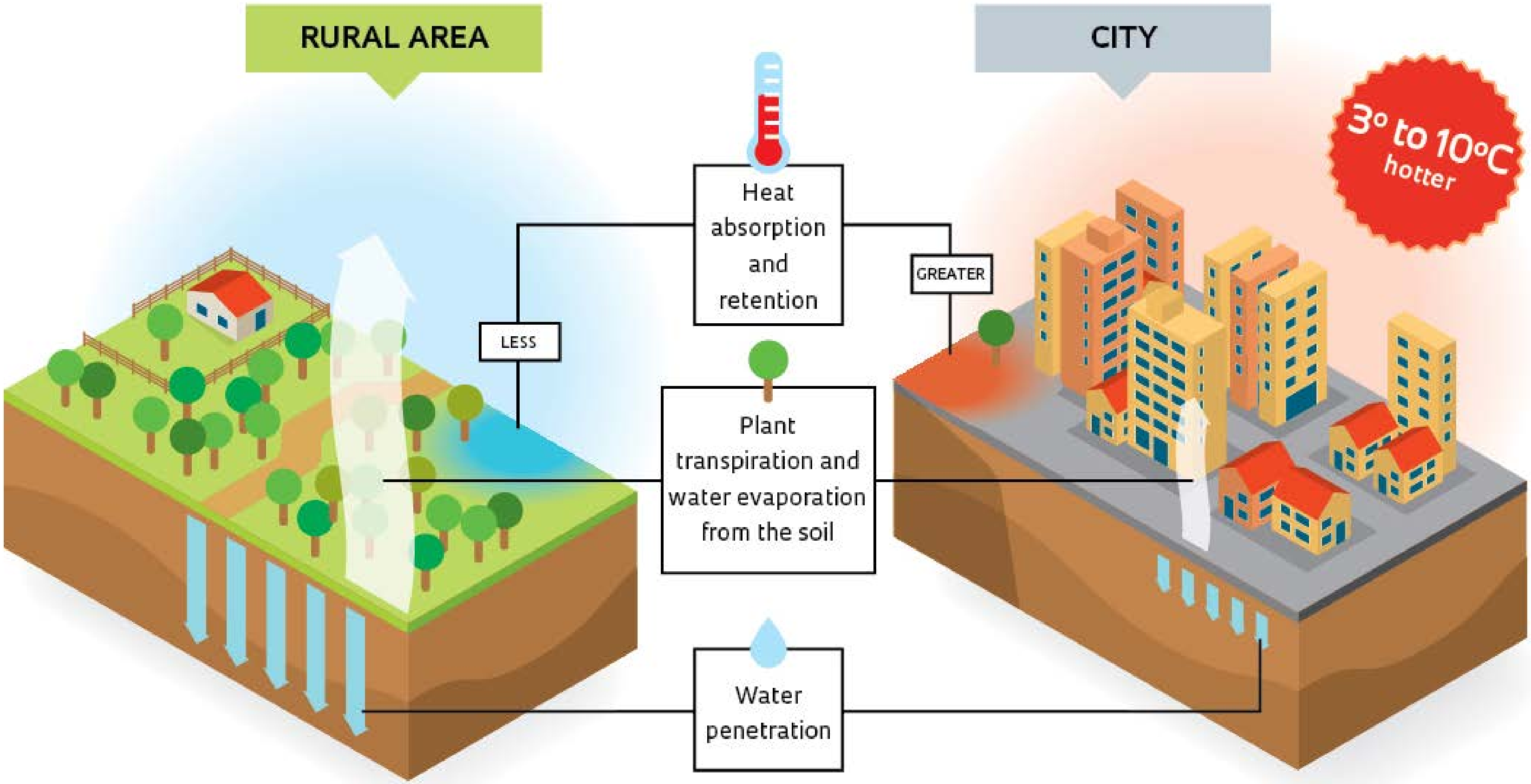
$$\frac{2 \text{ Carbon-13}}{8 \text{ Carbon-12}} = 0.25$$

Add more Carbon-12…

$$\frac{2 \text{ Carbon-13}}{14 \text{ Carbon-12}} = 0.143$$

Smaller ratio!

Human-caused Climate Change

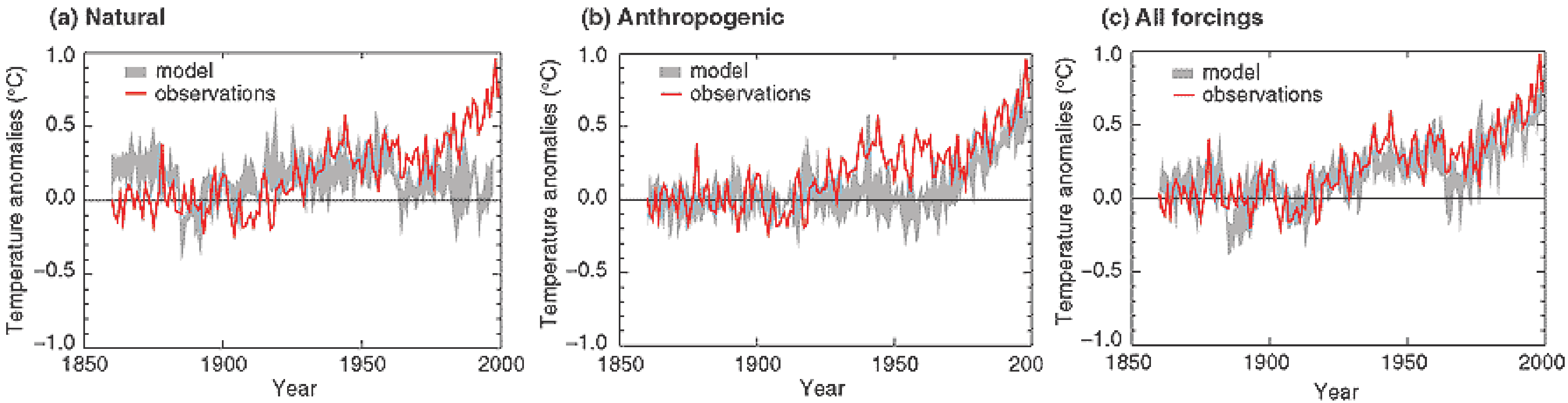


Land-use change is when humans change:

- Forest land to agricultural land
- Forest land to urban areas
- Agricultural land to urban areas

Land-use change…

- Impacts how solar radiation and energy from the sun is absorbed, reflected, and reemitted back into earth's atmosphere
- can increase the heat in the atmosphere
- can change local water cycles



From the Intergovernmental Panel on Climate Change Assessment Reports

Modeling studies show human modification

(a) Natural environment

- Solar and volcanic forcings only
- Fails to predict observed surface temperatures

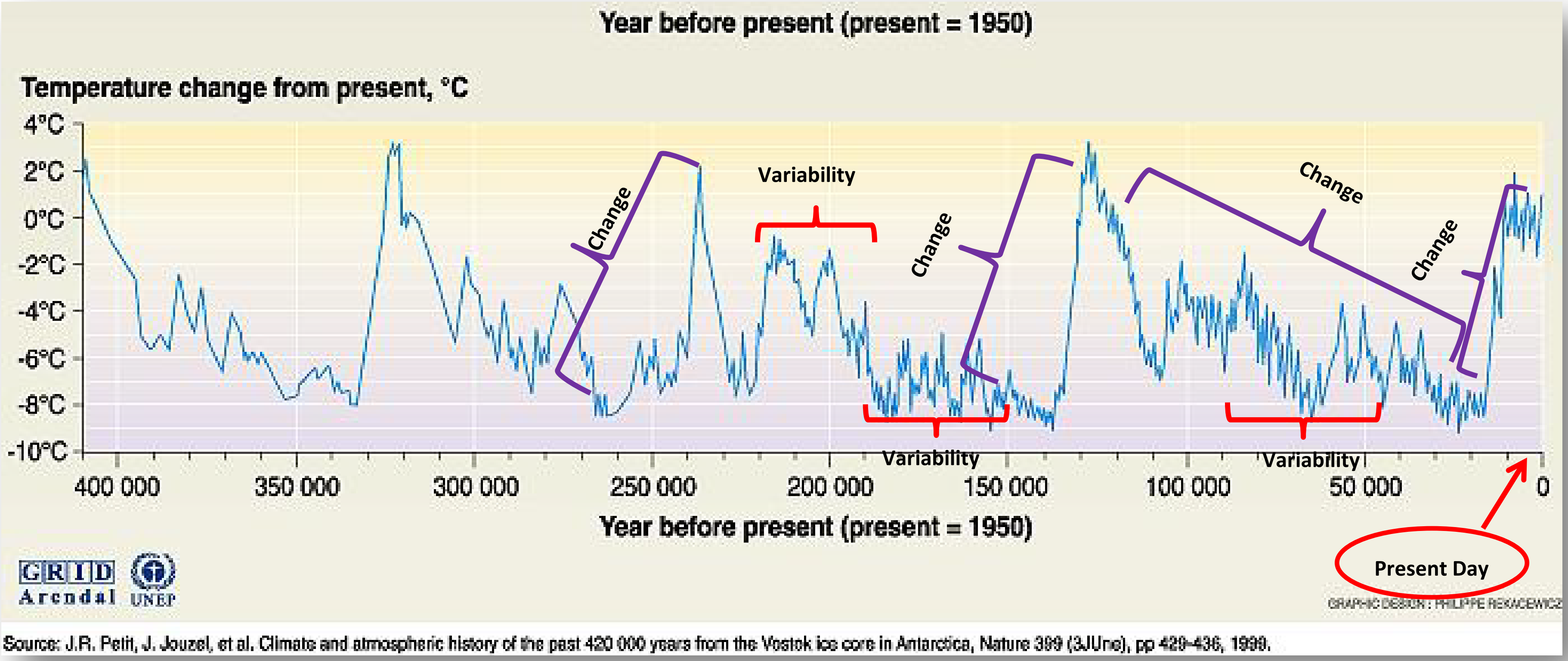
(b) Environment with human impacts

- Greenhouse gases, changes in ozone, sulfate aerosols
- Fails to predict observed surface temperatures

(c) Both natural environment and human impacts

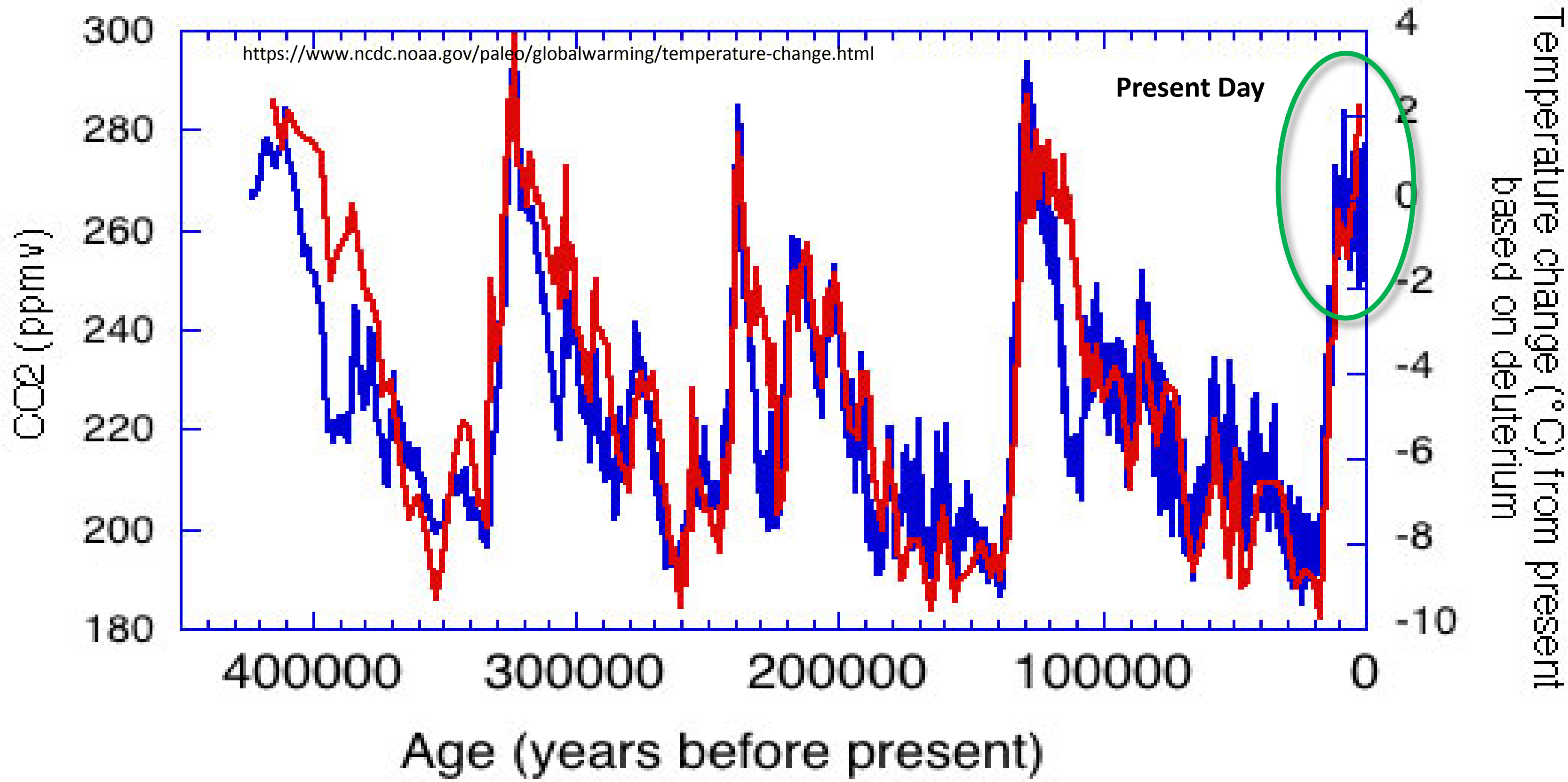
- ***Most accurate forecast generated***

Climate Variability versus Change in the Climate Record



http://joannenova.com.au/2010/02/the-big-picture-65-million-years-of-temperature-swings/

Global CO_2 and Temperature



- Temperature (blue line) and carbon dioxide (red line) are strongly correlated
- Recent surge in CO_2 from burning of fossil fuels has climbed much higher than temperatures in the last several years… this is the evidence supporting anthropogenic climate change

2012 Drought, Noblesville

August 2016 Tornadoes

June 2015 Historic Rainfall

SO… ARE WE CURRENTLY EXPERIENCING CLIMATE CHANGE OR VARIABILITY?

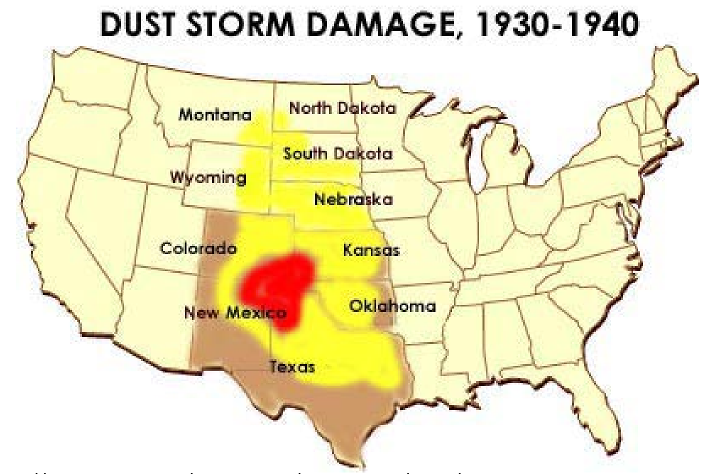
Exploring the past to understand the present and the future

2012 Drought: Climate Change or Variability?

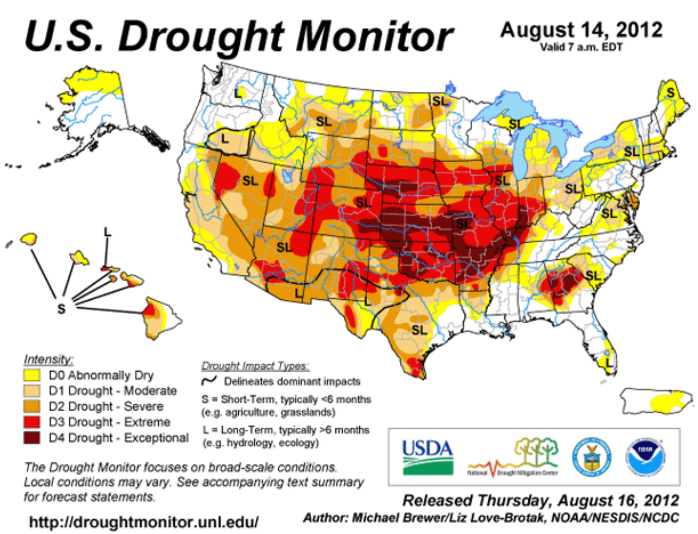
- Look for an analog year(s)
  - Is there a year in climatological history that is very similar to a recent event in the climate pattern?

- Most severe drought since at least 1895
  - Exceeded Dust Bowl summers 1934 and 1936 (analog years)

- Causes:
  - reduction in moisture transport from the Gulf
  - lack of weather systems due to large-scale, strong high pressure anchored over Central U.S.

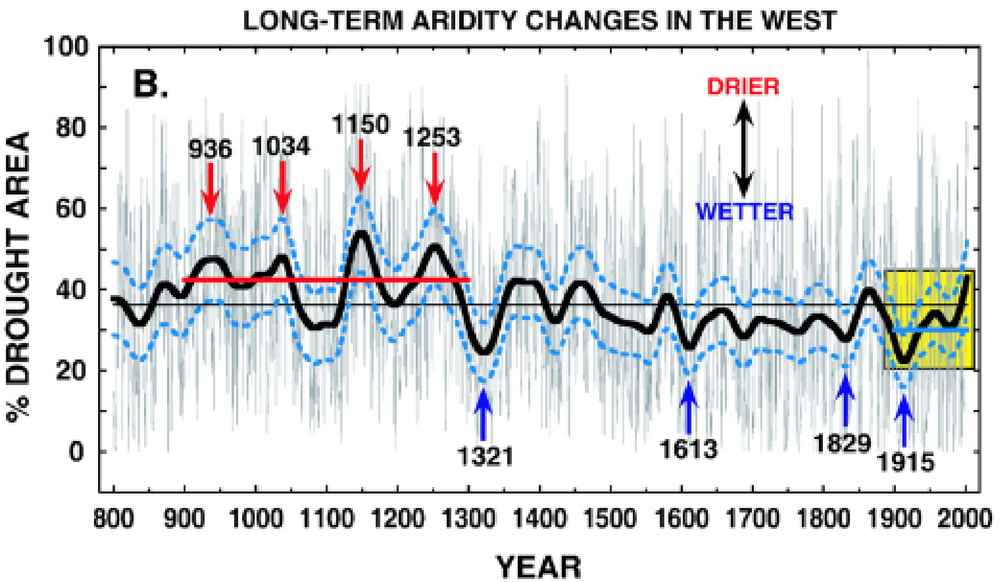


http://www2.ucar.edu/atmosnews/perspective/8349/dust-bowl-v-drought-2012;



2012 Drought: Climate Change or Variability?

- "Indicated hereby is that neither the variations in ocean states nor in greenhouse gases played significant roles in determining the intensity of the rainfall deficits in summer 2012."
  - Hoerling et al., 2014: Causes and Predictability of the 2012 Great Plains Drought.



E.R. Cook et al. / Earth-Science Reviews 81 (2007) 93–134

Proxy data shows that the American West is currently in a wetter climate pattern than the past. However, the yellow square shows the possibility of a return to a drier climate pattern.

Summer 2015: Climate Change or Variability?

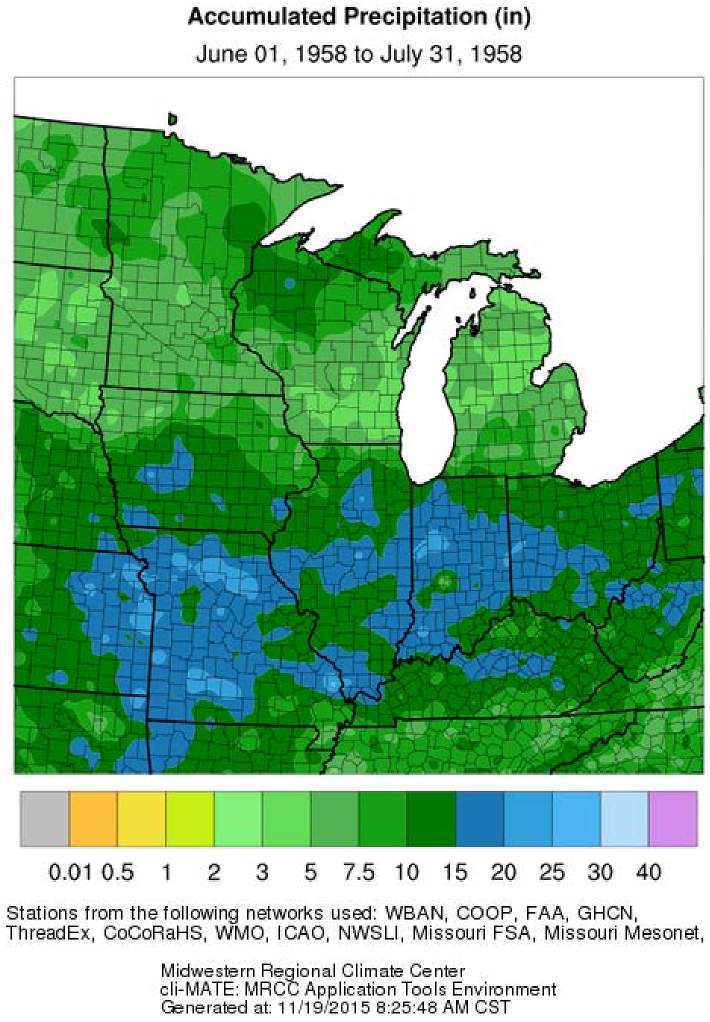
Record rainfall drowns crops across Indiana

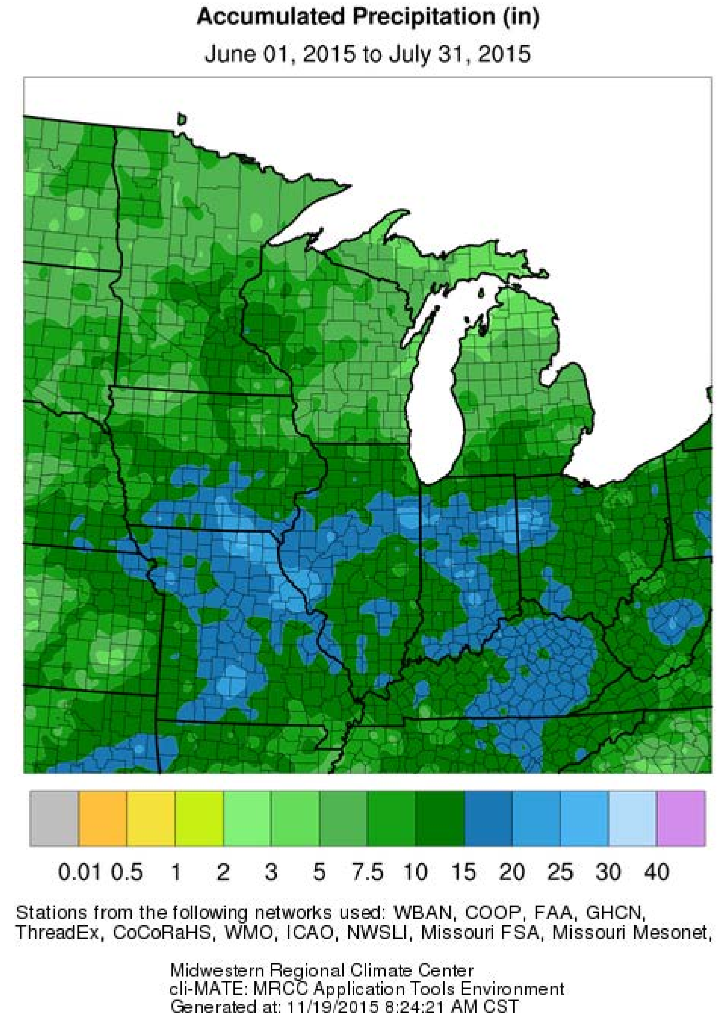
Associated Press
Published: July 7, 2015, 4:41 pm | Updated: July 7, 2015, 4:44 pm

This June 22, 2015 photo shows a flooded soybean field near Terre Haute, Ind. A record 85.1 million acres of soybeans are in the ground in the U.S., though a wet few months have kept farmers from planting in some states, the government said Tuesday, June 30, 2015. The planted soybean acreage is 2 percent more than in 2014, with the largest increases found in Illinois, Indiana, Minnesota and Tennessee. (Austen Leake/Tribune-Star via AP)

- Wettest June on record in Illinois, Indiana, and Ohio
- Wettest July on record in Kentucky
- Five Midwest states with top 3 wettest June-July on record
- Was this a result of climate change?
  - More studies and data are needed before a decision can be concretely made
  - Why?
    - Analogue year: 1958 shows a similar situation has occurred over 50 years ago

June-July 1958 versus June-July 2015





- Indiana 1958 June-July total precip: 16.15 inches (7.54 inches ABOVE normal)
- Indiana 1958 June-July mean temp: 69.7°F (2.9 degrees below normal)

- Indiana 2015 June-July total precip: 15.35 inches (6.74 inches ABOVE normal)
- Indiana 2015 June-July mean temp: 71.9°F (0.7 degrees below normal)

Are the Severity of These Events Attributable to Human Behaviors?

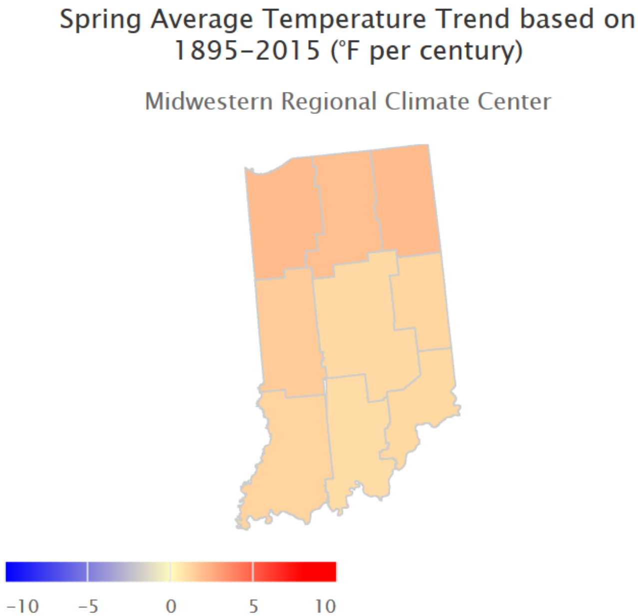
- Based on climatological history
  - No
- Is this to say the extreme nature of these events are definitely not at all linked to human activities?
  - No!
    - The laws of physics tells us human modification of earth's climate system should result in different weather patterns
- Climate science is still an evolving field!
  - Our science will improve and our conclusions may change as more evidence is gathered and analyzed

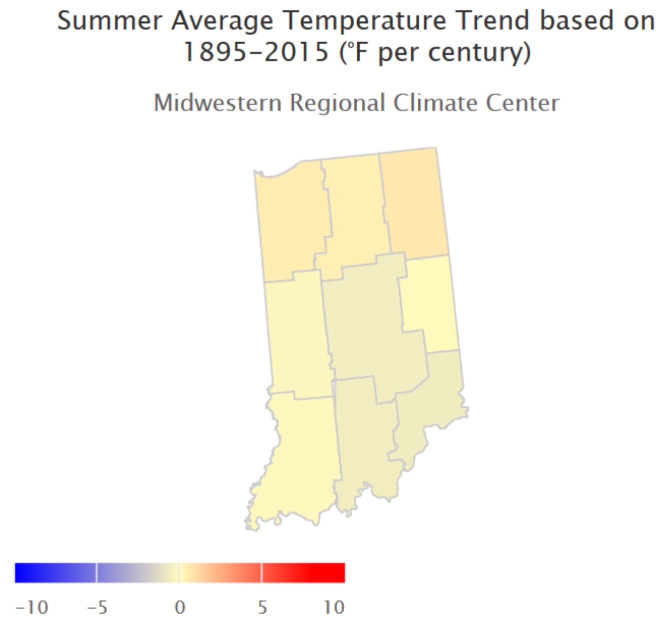
IN A WARMING WORLD, WHAT HAVE WE OBSERVED?

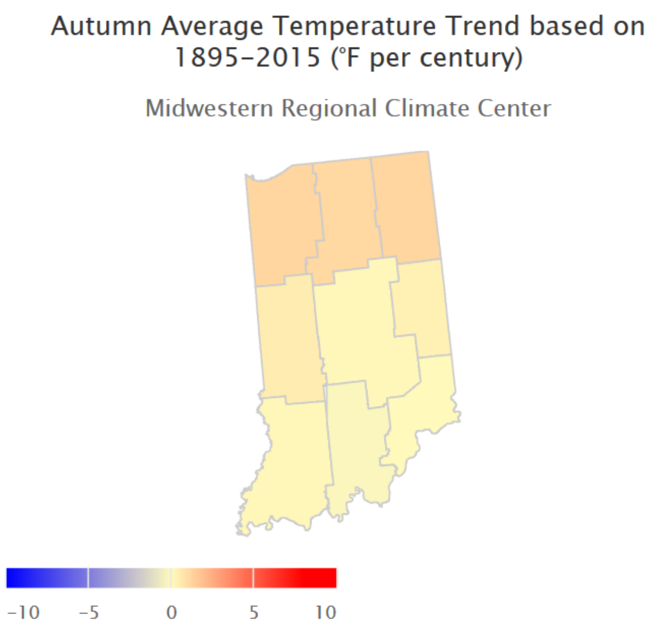
http://www.jpl.nasa.gov/news/news.php?feature=1273

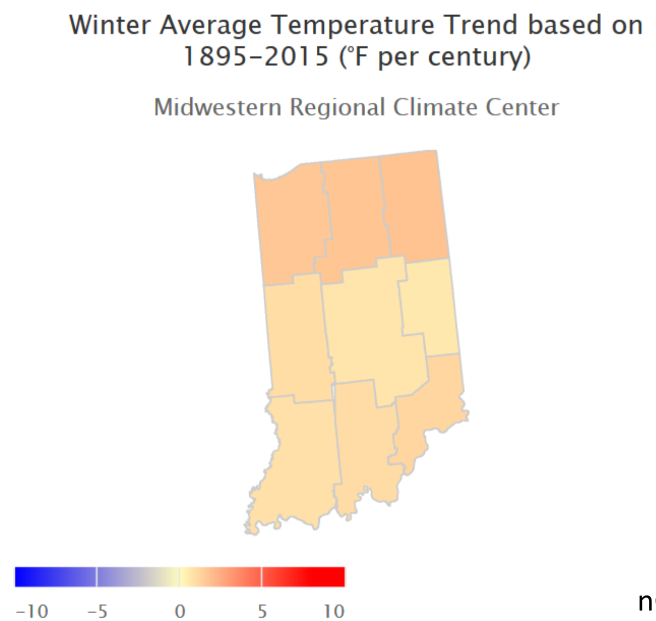
http://www.noaanews.noaa.gov/stories2006/s2707.htm

Observed Ave. Temperatures in Indiana (1895-2015)



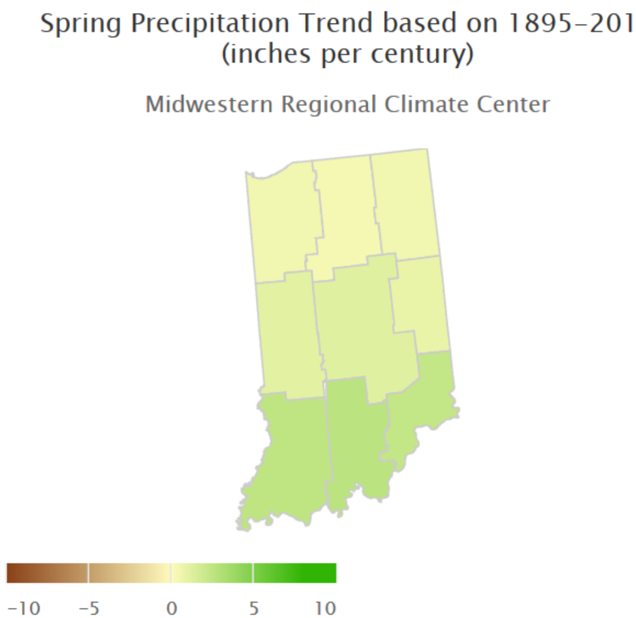


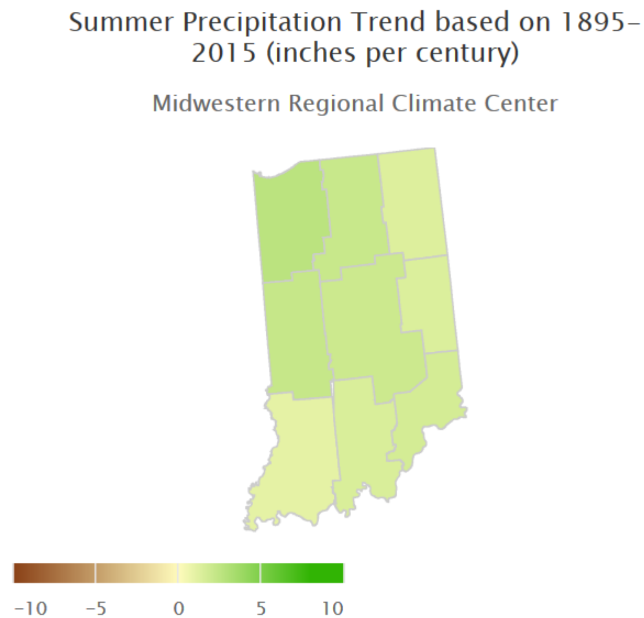


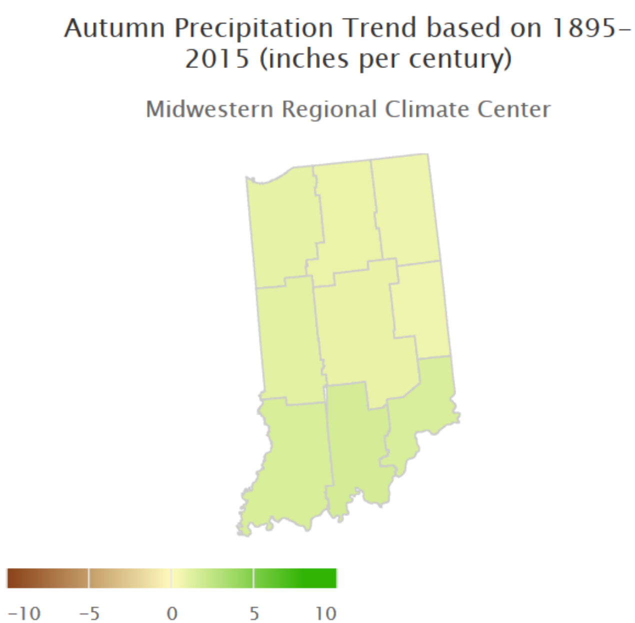


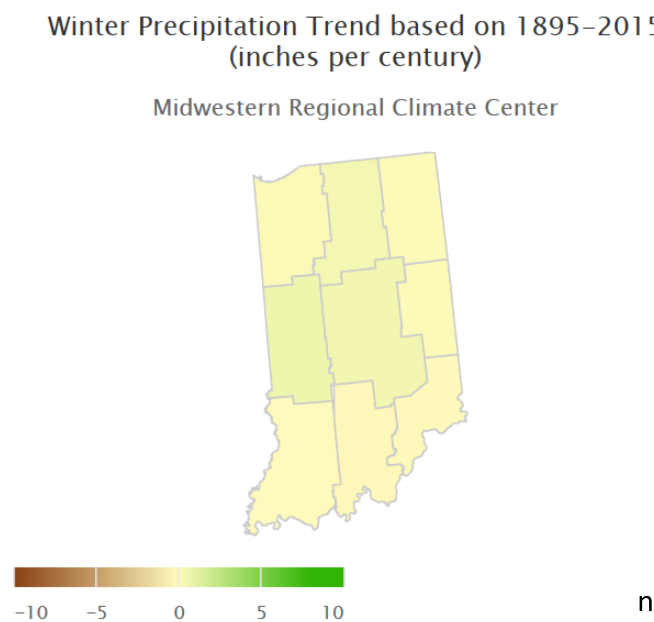
nClimDiv Dataset, NCEI

Observed Precipitation in Indiana (1895-2015)







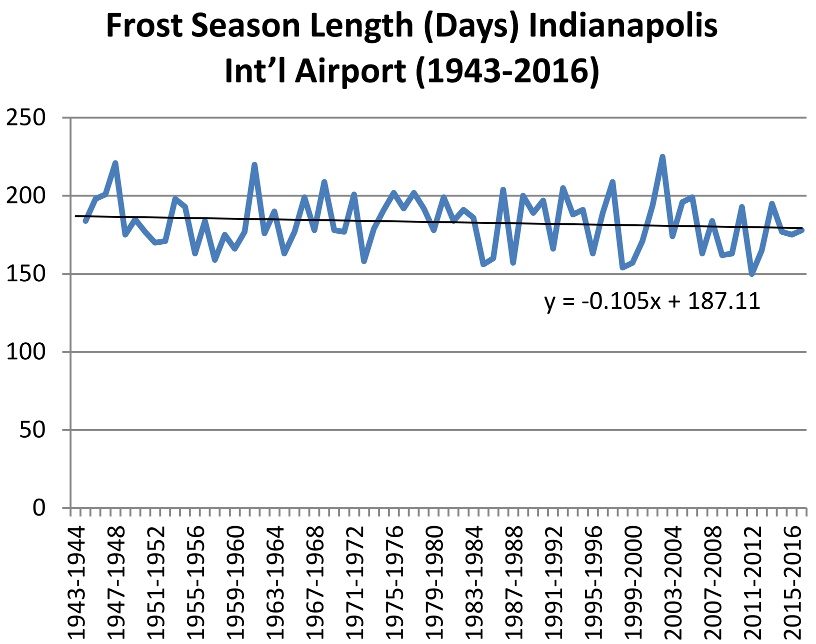


nClimDiv Dataset, NCEI

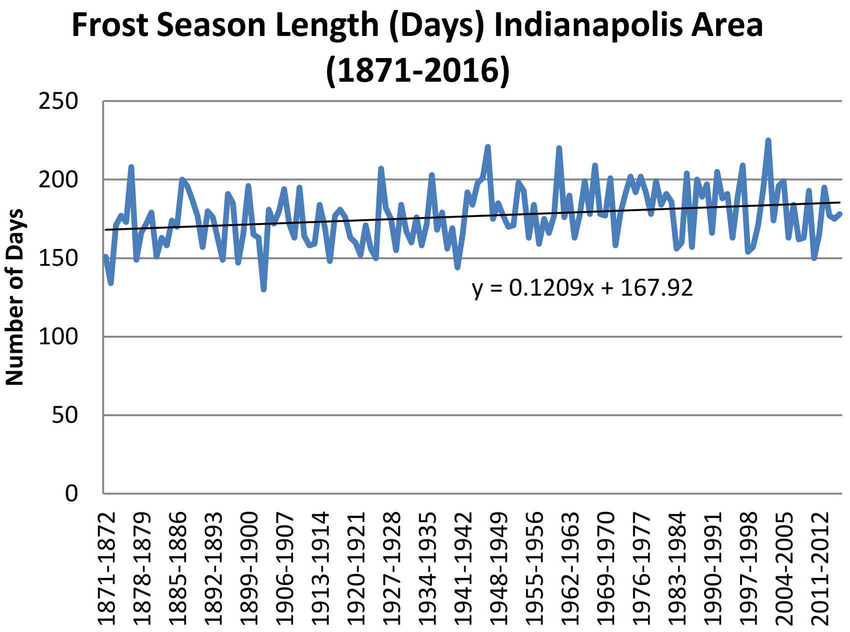
Understanding Data to Make Your Own Conclusions

Maps we just saw showed trends of warming and increased rainfall. However, climate data can be complex!

- 73 years of data
- Slight reduction in the number of frost days



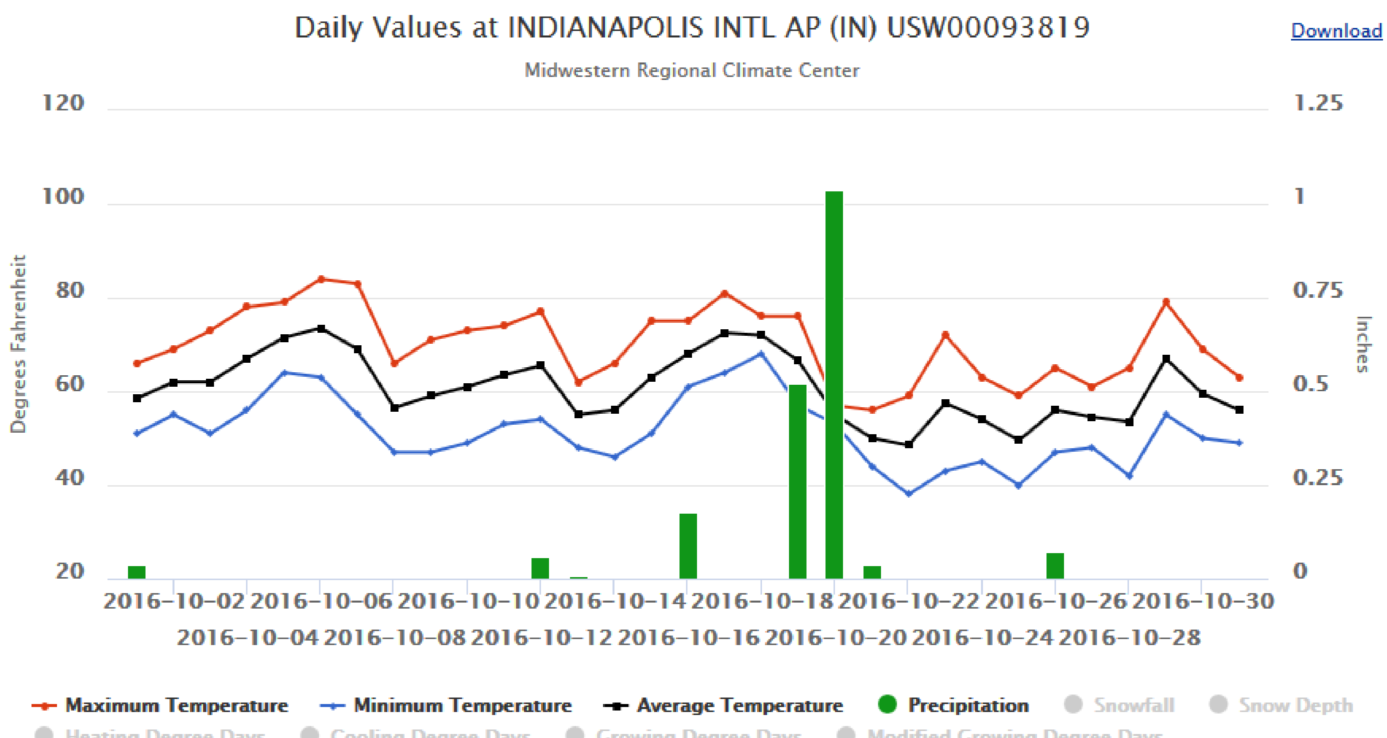
- 144 years of data
- Slight increase in the number of frost days



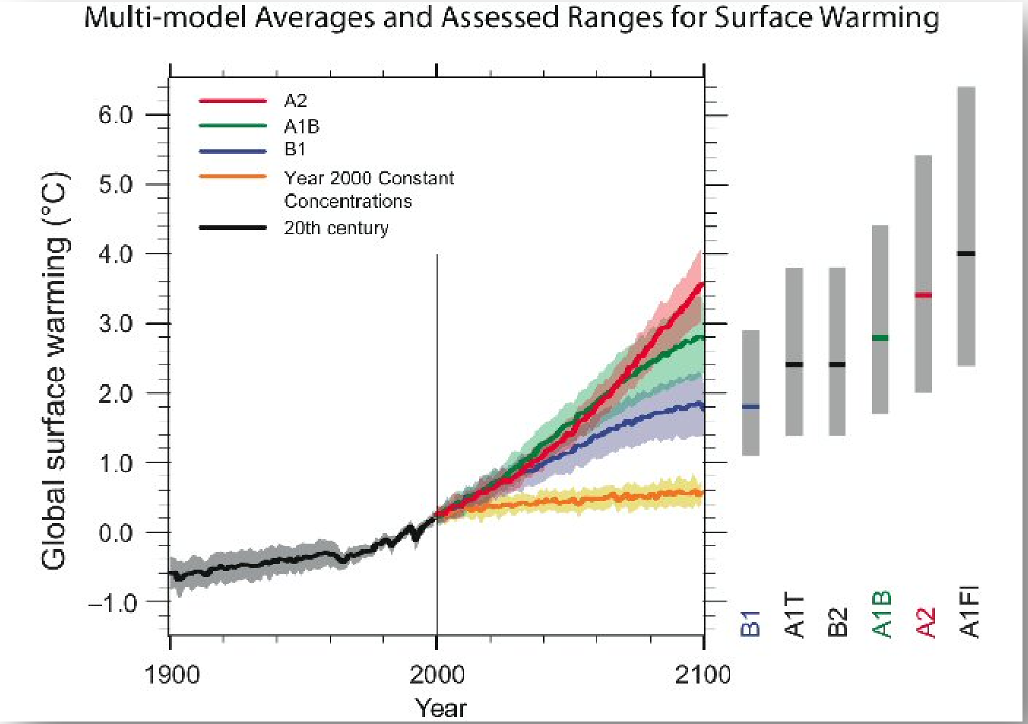
The number of observations determines the trend you see! Always have a much data as possible to reach a conclusion.

Obtaining Data to Explore Yourself

- All official data housed by the National Centers of Environmental Information (NCEI)
  - Data disseminated for free by regional climate centers
    - Midwestern Regional Climate Center (MRCC)
    - Data from mid 1800s – present for some locations
    - Hourly, daily, monthly, seasonal, and annual data by station, county, climate division, and region for thousands of locations across the United States

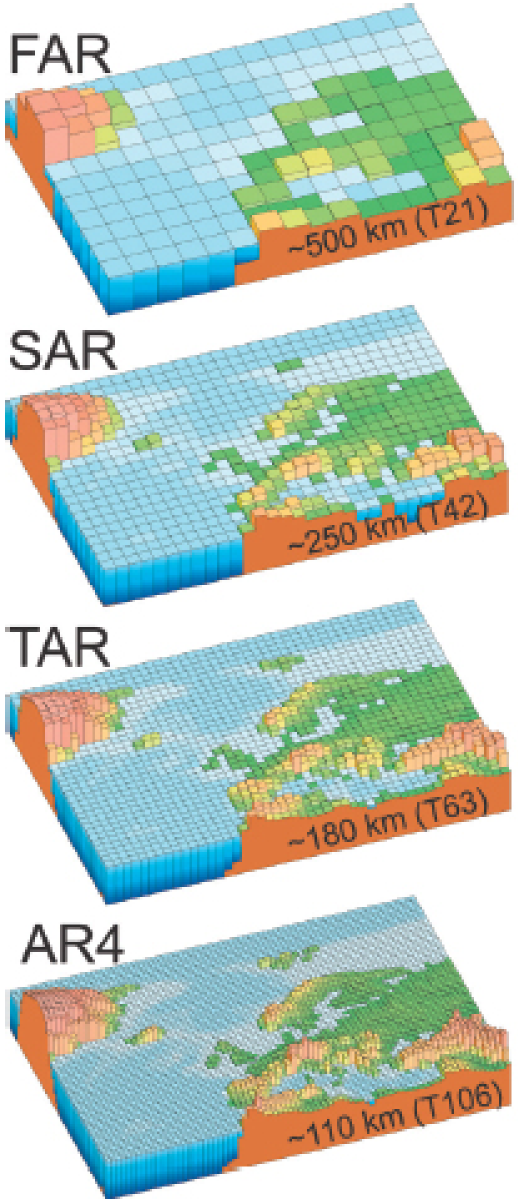


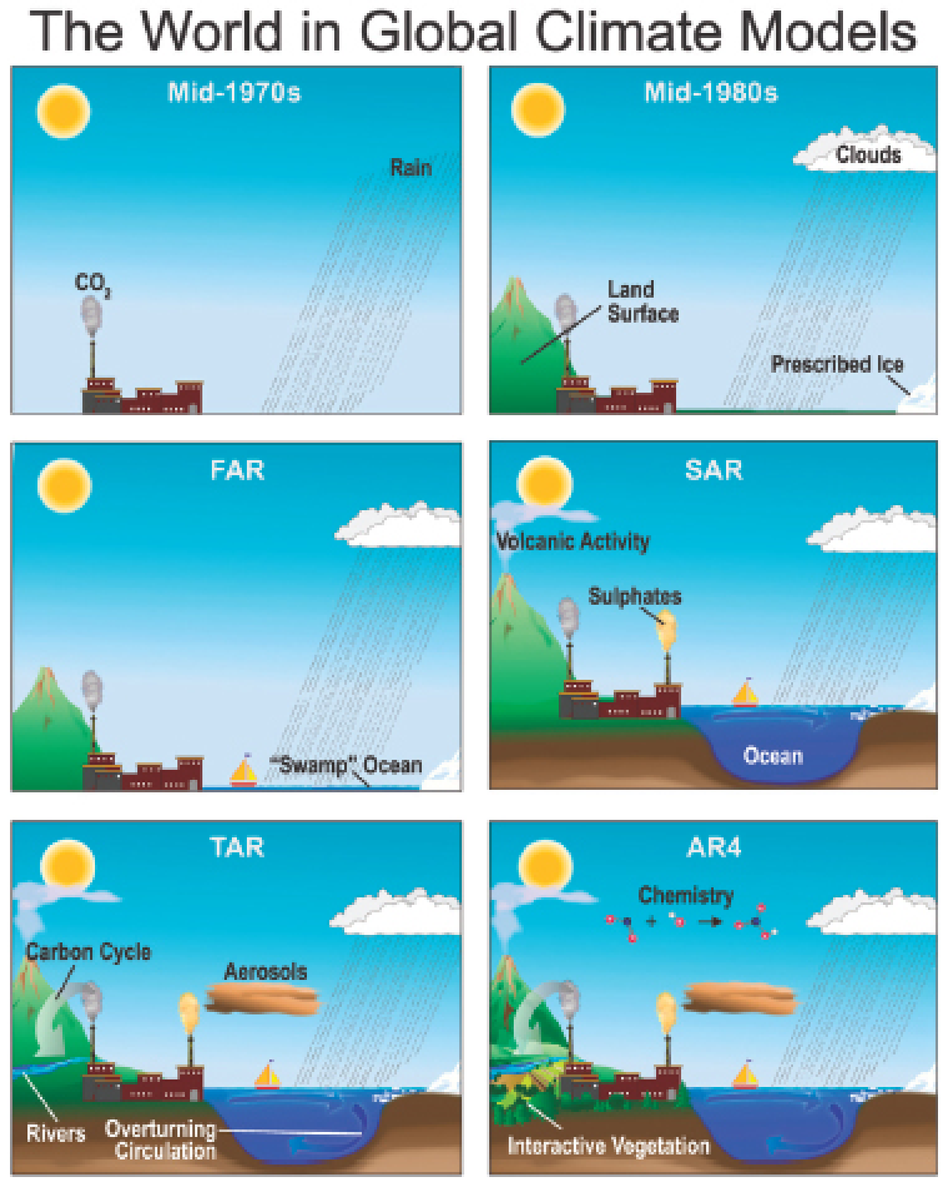
CLIMATE PROJECTIONS



What is expected in Indiana and across the Midwest?

The National Climate Assessment, Regional, and Global Climate Models

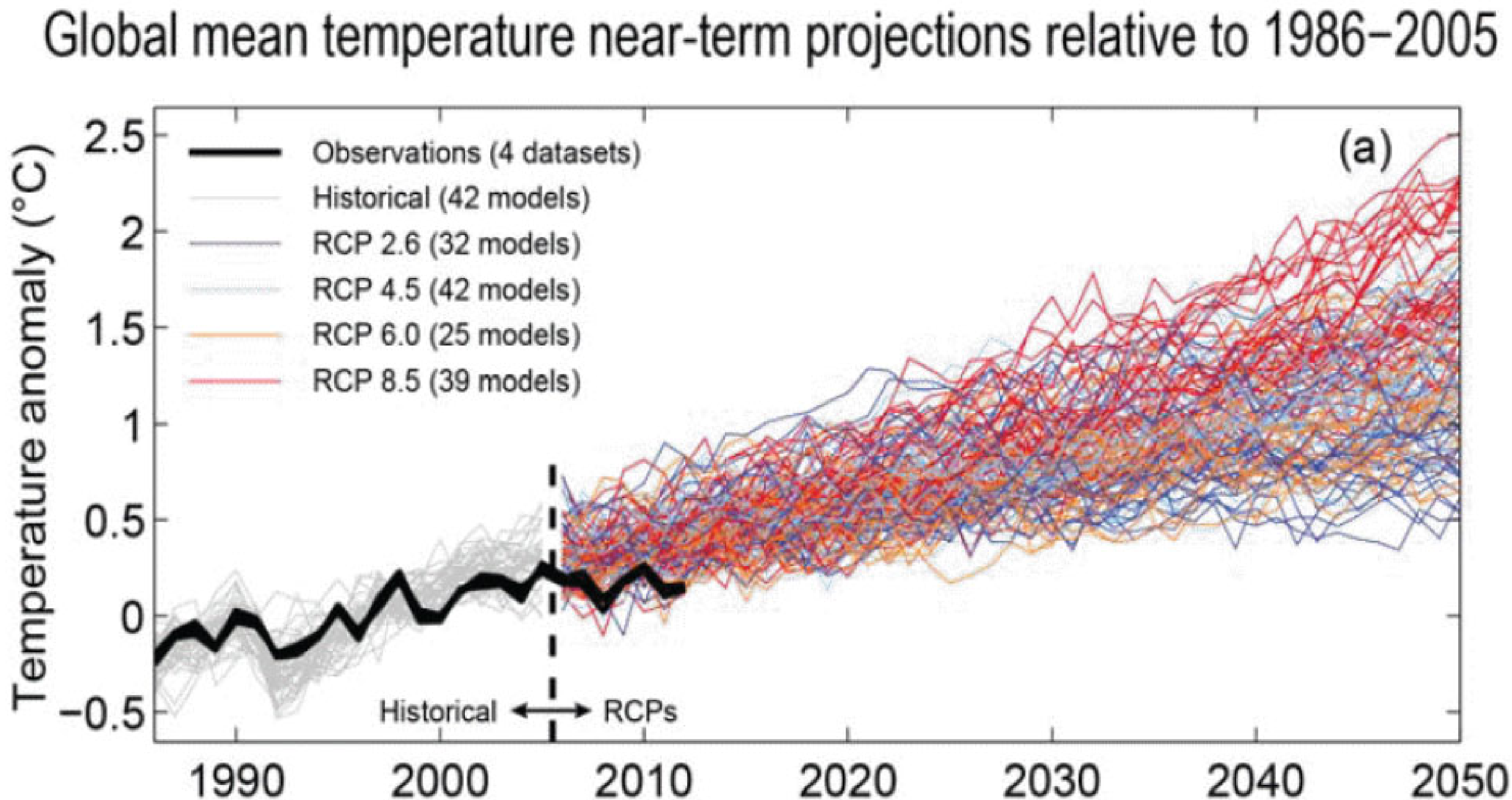




~500 km = ~310 miles
~250 km = ~155 miles
~180 km = ~111 miles
~110 km = ~68 miles

https://www.nap.edu/read/13430/chapter/7

Figure from: IPCC's report "Climate Change 2013: The Physical Science Basis"



1) The Intergovernmental Panel on Climate Change (IPCC) and the scientists of the National Climate Assessment (NCA) run numerous different models with different starting temperatures that are then combined to create an "ensemble" (or average) forecast of all forecasts.
2) This final forecast is the basis for conclusions regarding future climate evolution

How do We Know Models Can Forecast Well?

- Climate scientists complete a “hind-cast”

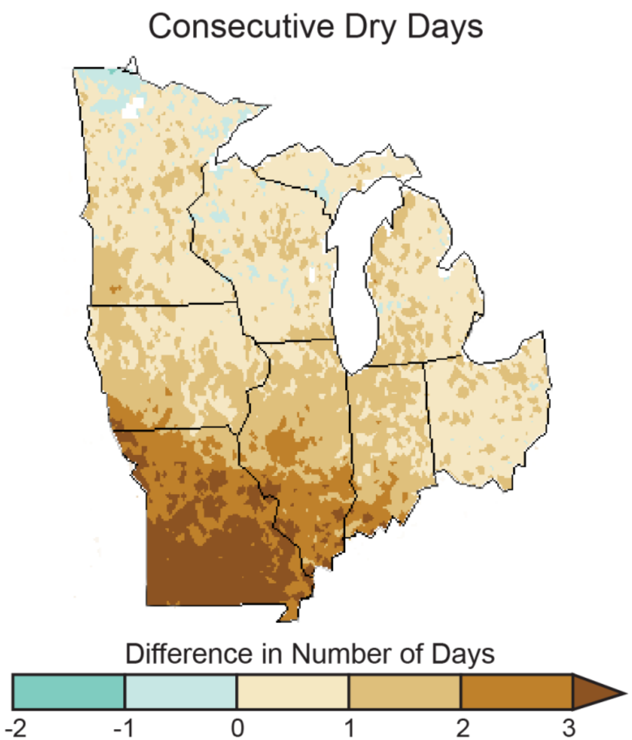
    1) Provide a climate model with observed data from a date 50 years ago (e.g. 1966)

    2) Have the model create a forecast from that initial day through today

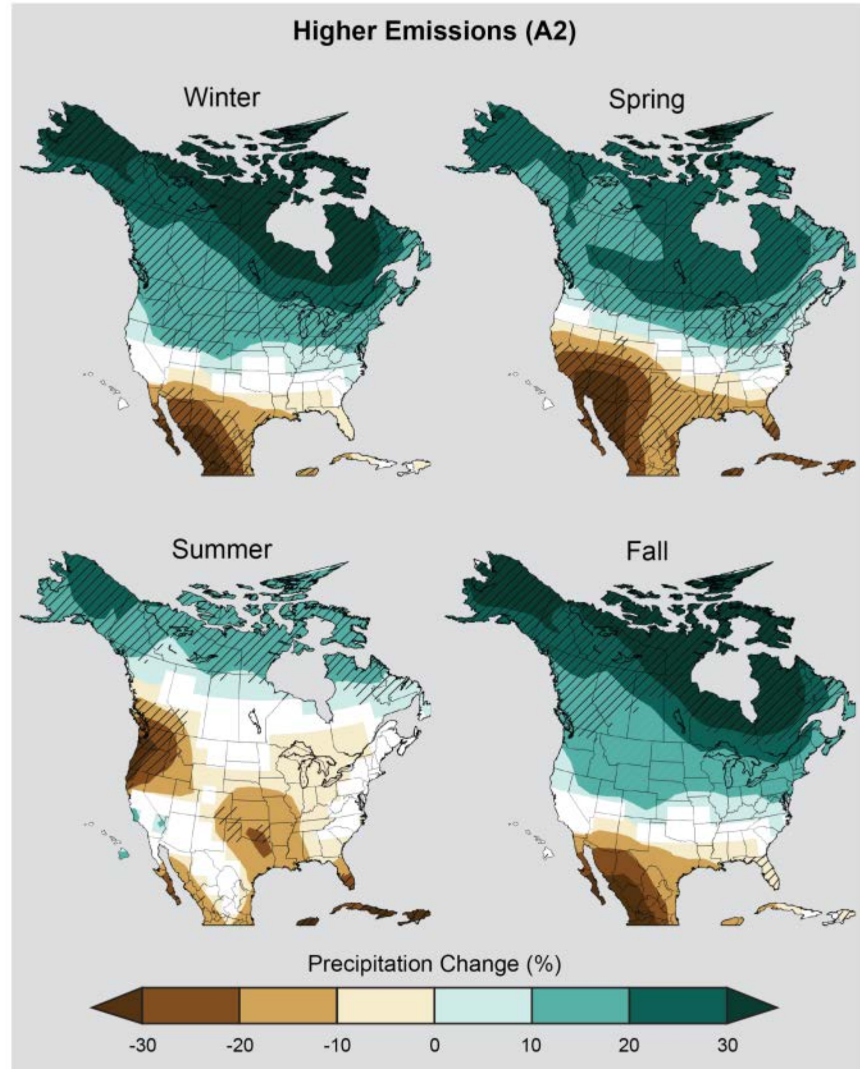
    3) Compare the forecast to all observations up till today to test the model’s “skill”

    4) Models with good “skill” are used to develop climate forecasts/projections

Expectations for the Midwest under Projected Warming Scenarios

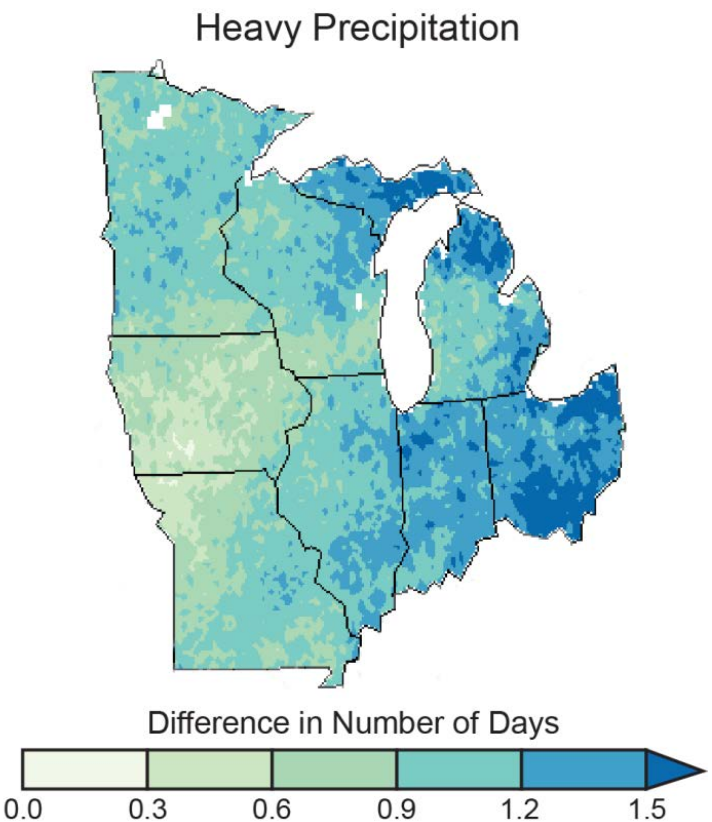


Change in average maximum number of consecutive days each year with no precipitation in 2071-2099 (compared to 1971-2000) (*NCA 2014)*

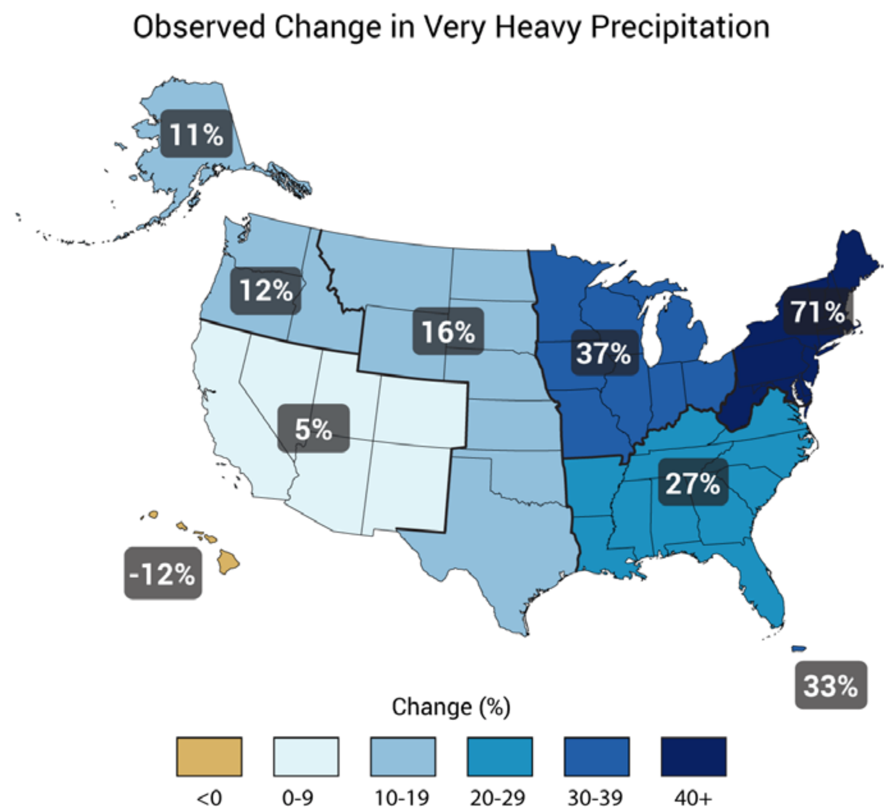


Projected percent change by season for 2071-2099 (compared to 1971-1999) (*NCA 2014)*

Expectations for the Midwest under Projected Warming Scenarios

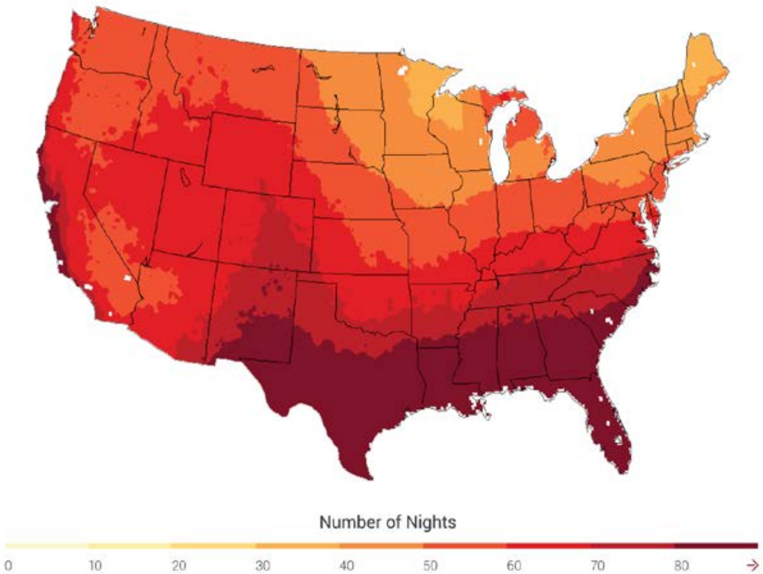


Increase in number of days with very heavy precipitation (top 2% of rainfalls) in 2071-2099 (compared to 1971-2000) (*NCA 2014)*



The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. (Figure source: updated from Karl et al. 2009) – NCA 2014

Expectations for the Midwest under the Projected Warming Scenarios



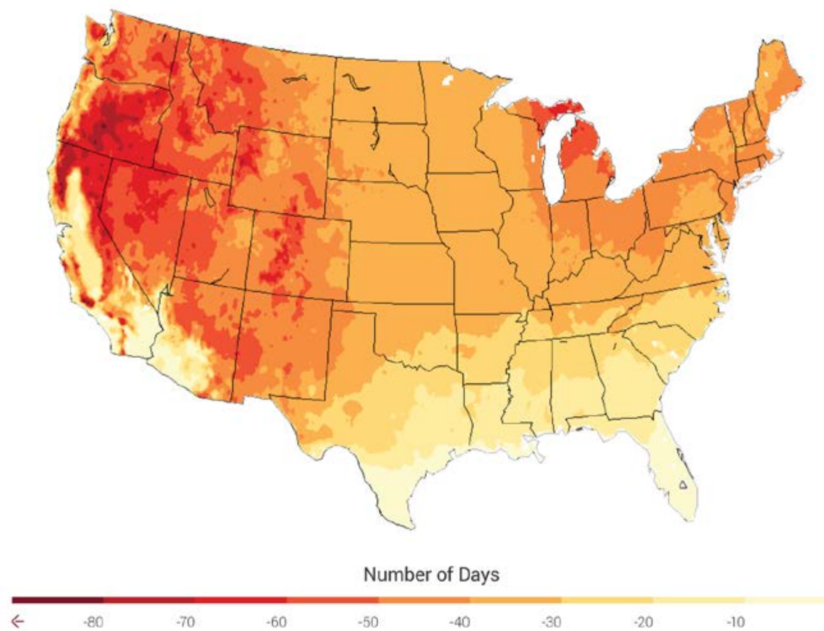
Change in number of hot nights
at the end of the century (2070-2099)
compared to 1971-2000 (NCA 2014)

Hot night = night with a minimum temperature higher than 98% of the minimum temperatures between 1971-2000

- Indiana will see an increase of approximately 50 hot nights

Change in number of frost days
at the end of the century (2070-2099)
compared to 1971-2000 (NCA 2014)

- Indiana is expected to see a decrease of 30 to 40 frost days
- Longer growing seasons



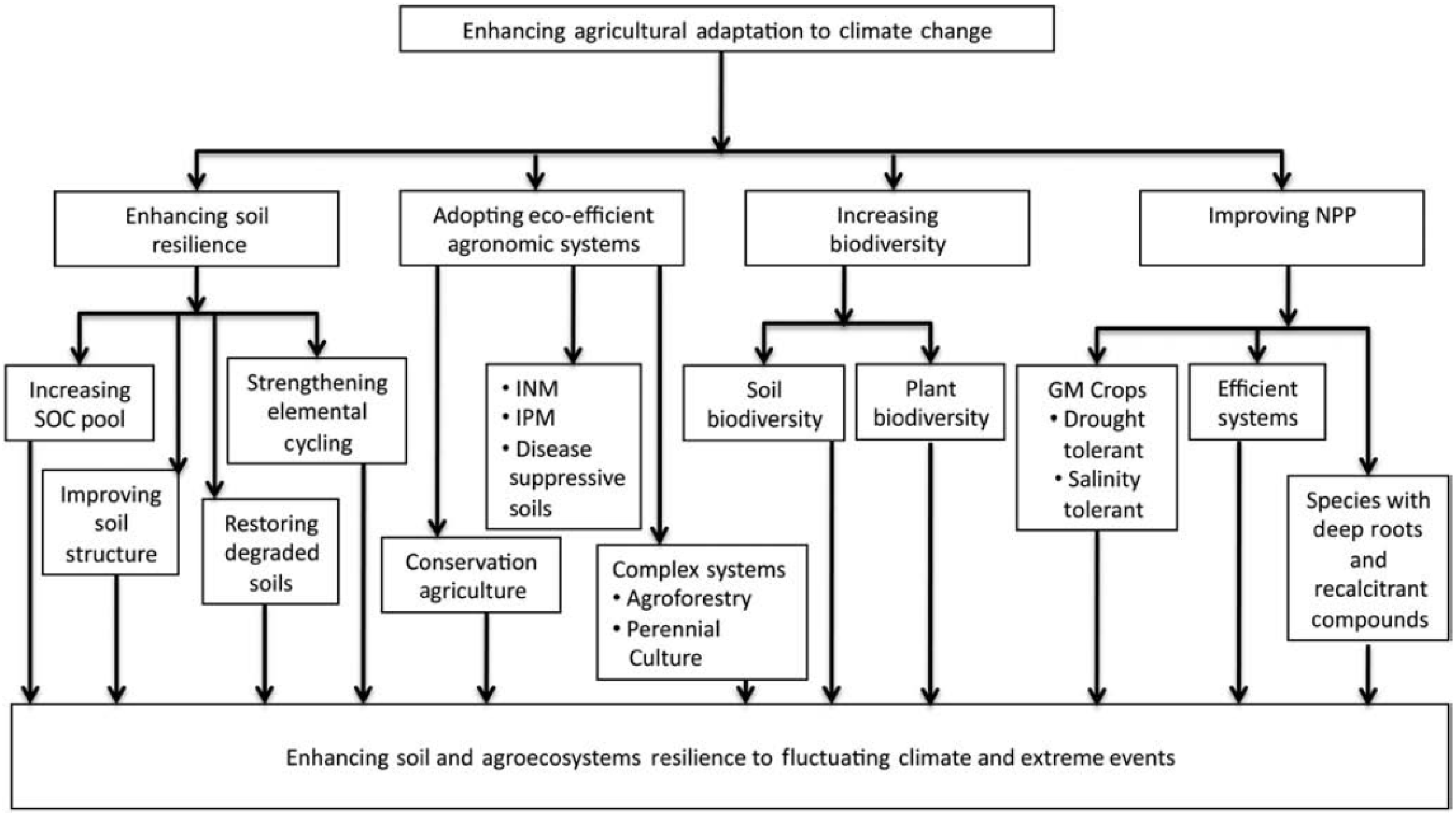
Expected Climate Change Impacts to Crop Production

- Longer growing seasons
  - Possible bumper crops
- Longer dry spells
  - Increased moisture stress
    - Increase in irrigation
      - Water resources management
- Heavy rainfall events
  - Heavy rainfall on dry soils = runoff
    - Nitrogen and nutrient loss
    - Decrease in ground water infiltration
  - Heavy rainfall on saturated soils lead to surface ponding
- Warmer temperatures
  - Increased heat stress on crops
- Increase in invasive species from the south
  - Fight with crops for water, soil nutrients
- Increased disease
  - Increased aflatoxin such as seen in 2012 with warm, wet spring then dry summer

http://agcrops.osu.edu/newsletters/2012/19

http://nca2014.globalchange.gov/report/sectors/agriculture

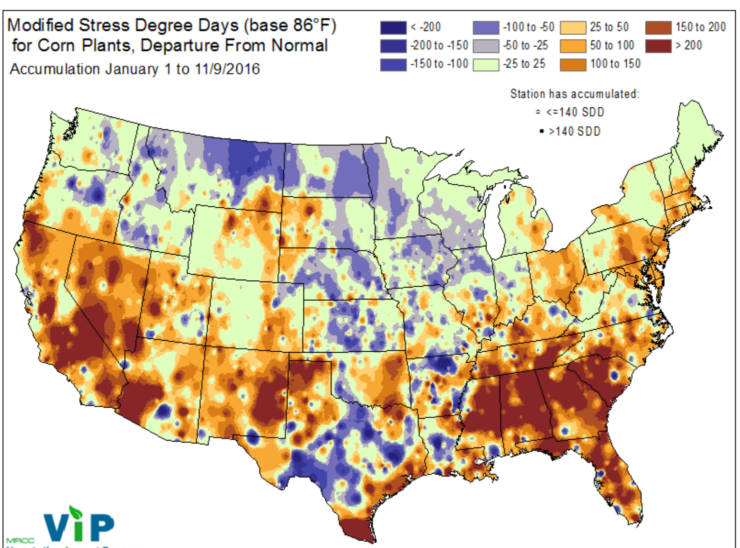
HOW CAN YOU REDUCE YOUR RISK TO EXPECTED CHANGES IN WEATHER PATTERNS?



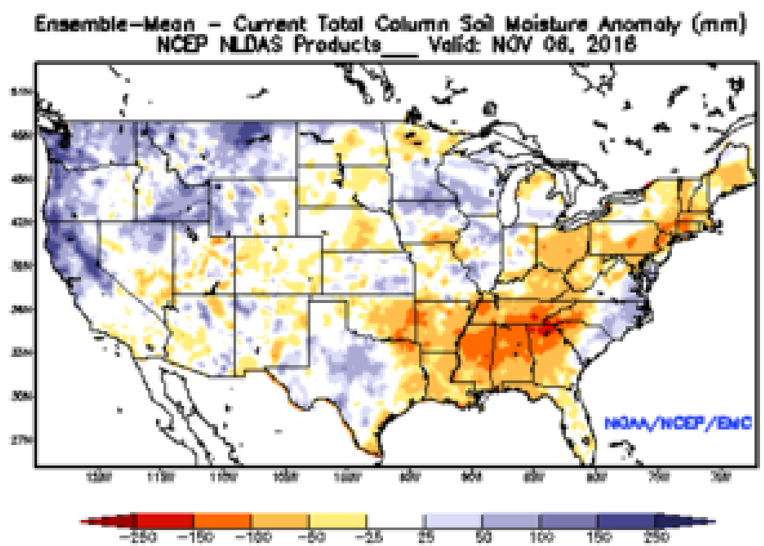
Lal, R., 2010: Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security. *BioScience.* Vol. 60. No. 9, 708-721.

- **Educate yourself**
  - Review the National Climate Assessment
    - It was written for the public!
  - Visit the USDA Climate Hubs: https://www.climatehubs.oce.usda.gov/midwest
  - Read USDA publications:
    - Climate Change and Agriculture in the United States: Effects and Adaptation
    - Quantifying Greenhouse gas Fluxes in Agriculture and Forestry
    - Adaptation Resources for Agriculture: Responding to Climate Variability and Change in the Midwest and Northeast
- Utilize resources developed to help you monitor weather and climate

Corn Stress Degree Days - MRCC



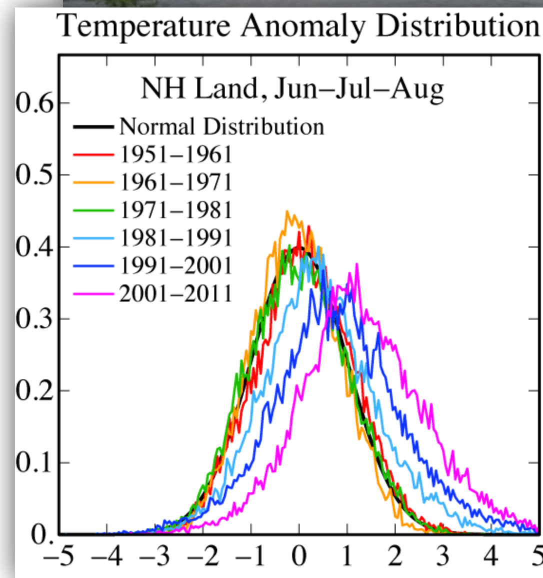
NLDAS Soil Moisture Maps



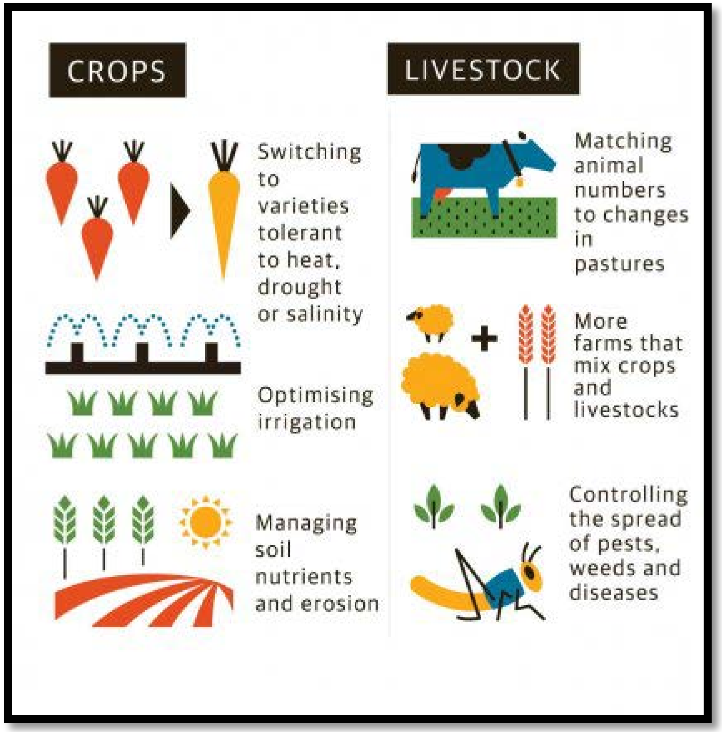

final
thoughts

Key Points

- Climate variability is expected to manifest as extreme weather
  - heavy rainfall events
  - Longer dry spells
    - "flash droughts"
  - sudden temperature swings (hot and cold)
    - Crop loss due to sudden freeze events
- Climate change occurs over a more prolonged period of time compared to climate variability
  - A shift towards:
    - consistently warmer temperatures,
    - longer dry spells between rainfall,
    - heavier rainfall events during the growing season,
    - longer growing season



- Best way to mitigate affects:
  - Make environmentally conservative changes to agronomic practices:
    - Cover crops
    - Tile drainage
    - Fertilizer application during optimal weather conditions
    - Drought-tolerant hybrids
    - Drip irrigation vs. center pivot or lateral move
    - Conservation tillage
    - Plant more resilient forage
    - Wind or solar energy for power
    - Cisterns
- Remain informed
- Remain aware



http://ccafs.cgiar.org/blog/climate-change-and-farming-what-you-need-know-about-ipcc-report#.VK1tgntWIc9

THANK YOU!

I WILL TAKE ANY QUESTIONS AT THIS TIME

Contact Information: kellnero@illinois.edu

Other resources for information : Indiana State Climate Office, Midwestern Regional Climate Center, USDA Midwest Climate Hub