Variations and Changes in Weather and Climate Extremes

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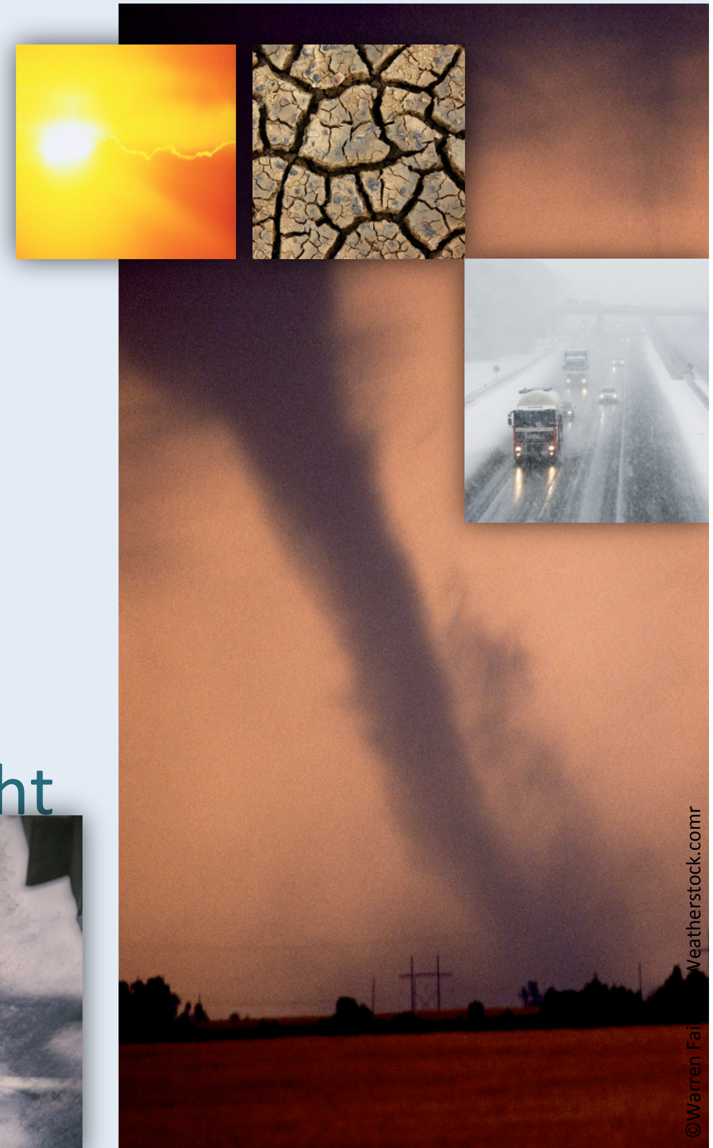
Outline

- **Climate-related activities**
  - **FY13 President's Budget**
- **Motivation**
  - Billion-dollar Disasters
- **State of the Science**
  - Climate Fundamentals
  - Heat and Cold Waves
  - Precipitation/flooding and drought
  - Snowstorms
  - Tornadoes
- **Implications**




NOAA's National Climatic Data Center (NCDC):

Where are we? Who are we? What do we do?

Protecting the Past… Revealing the Future

- 160 Federal Employees
  - Alaska, Colorado, Hawaii, Maryland, Missouri, New York, North Carolina, Texas, Utah, Wisconsin
- 153 NCDC Headquarter Contractors
- 6 Regional Climate Centers
- 2 Cooperative Institutes

Fiscal Year 2013 NOAA Climate-Related President's Budget Request

Activity	$ Millions
Competitive Research Program	146.3
Climate Data and Information	13.0
Marine Ecosystems Climate Regimes and Ecosystem Productivity	1.8
Program Support	3.1
Laboratories and Cooperative Institutes	53.35
- Atlantic Oceanographic & Meteorological Laboratory	
- Air Resources Laboratory	
- Chemical Sciences Division	
- Global Monitoring Division	
- Physical Sciences Division	
- Geophysical Fluid Dynamics Laboratory	
- Pacific Marine Environmental Laboratory	
- Technology Transfer (Office of Research and Technology Applications)	

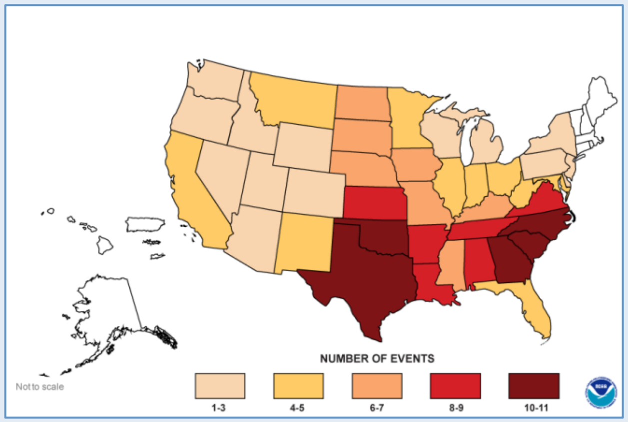
Fiscal Year 2013 NOAA Climate-Related President's Budget Request

Activity	$ Millions
Operational Climate Programs	135.5
- National Climatic Data Center	
- Climate Data Records	
- Climate Data Modernization Program	
- Regional Climate Service	
- Environmental Data Systems Modernization	
- Earth Observing System (EOS)	
- Cooperative Observer Network – Modernization (HCN-M)	
- Local Warnings and Forecasts – Tropical Atmosphere Ocean (TAO)	
- Climate Prediction Center	
- National Weather Service's Climate Services	
- Comprehensive Large Array Data Stewardship System (CLASS)	
- Jason-3	
- Joint Polar Satellite System (JPSS) Climate Sensors	
- High Performance Computing	

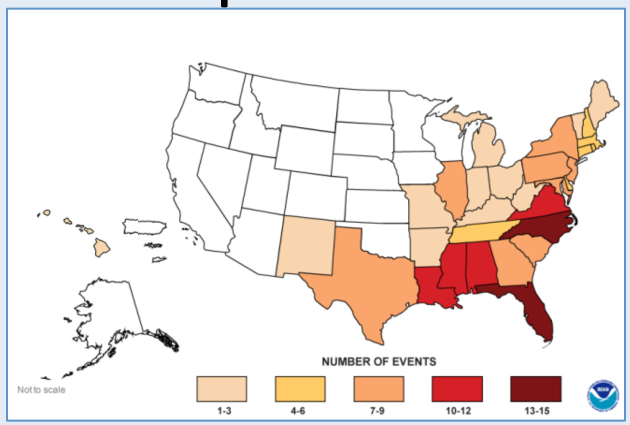
The Nation Is Climate-Conscious… for Good Reason

U.S. Billion-Dollar Weather and Climate Disasters: 1980 – 2011

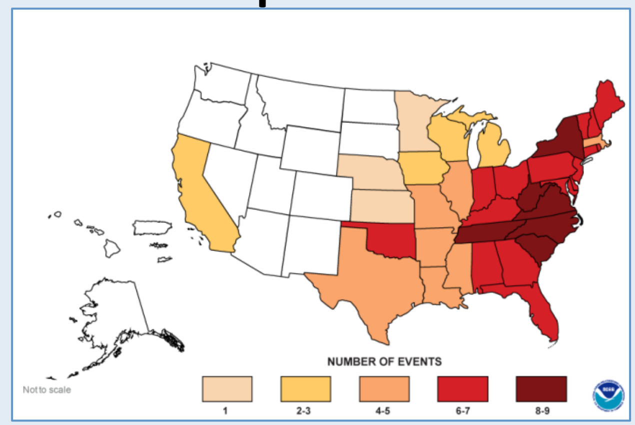
Drought and Heatwaves



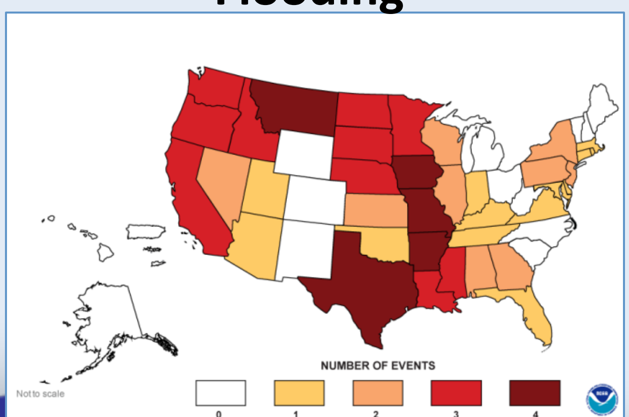
Hurricanes and Tropical Storms



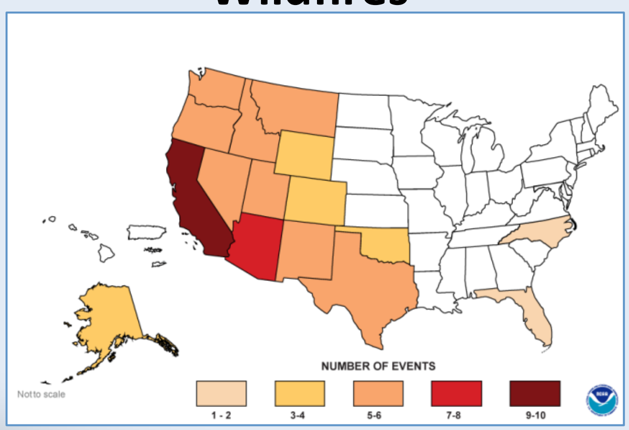
Winter Storms and Crop Freezes



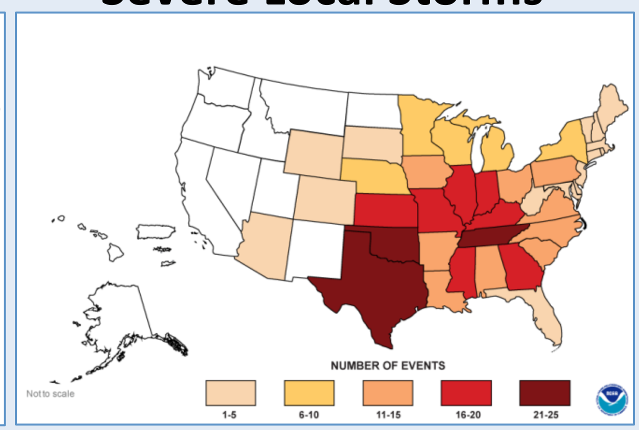
Flooding



Wildfires

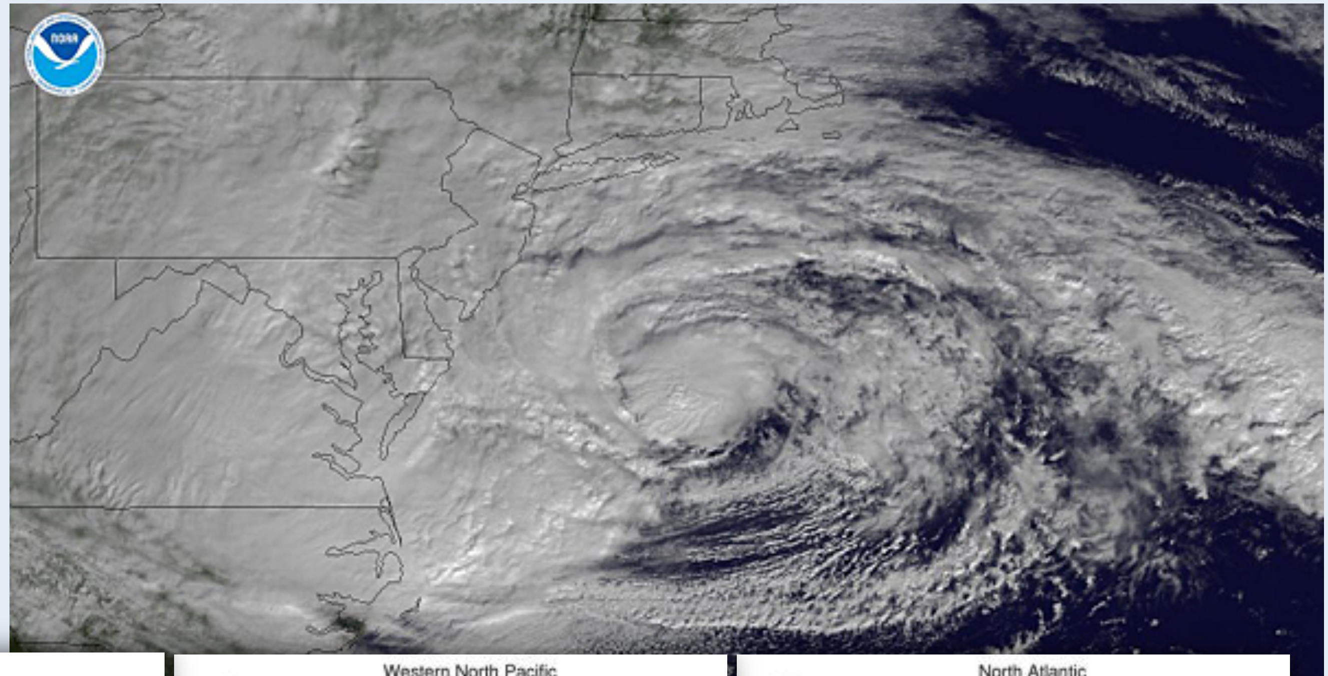


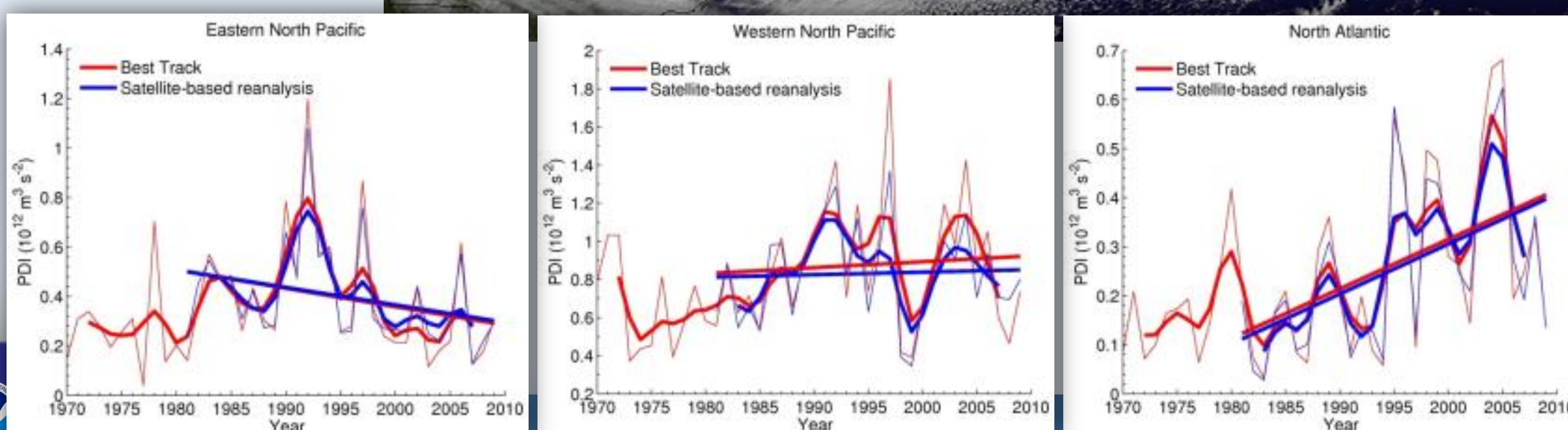
Severe Local Storms



Example: Post-tropical Storm Sandy

- Over 100 lives
- Upwards of $40 billion
- What to expect in future?
- No one storm is "caused" by climate change, but all storms now happen in a changed context

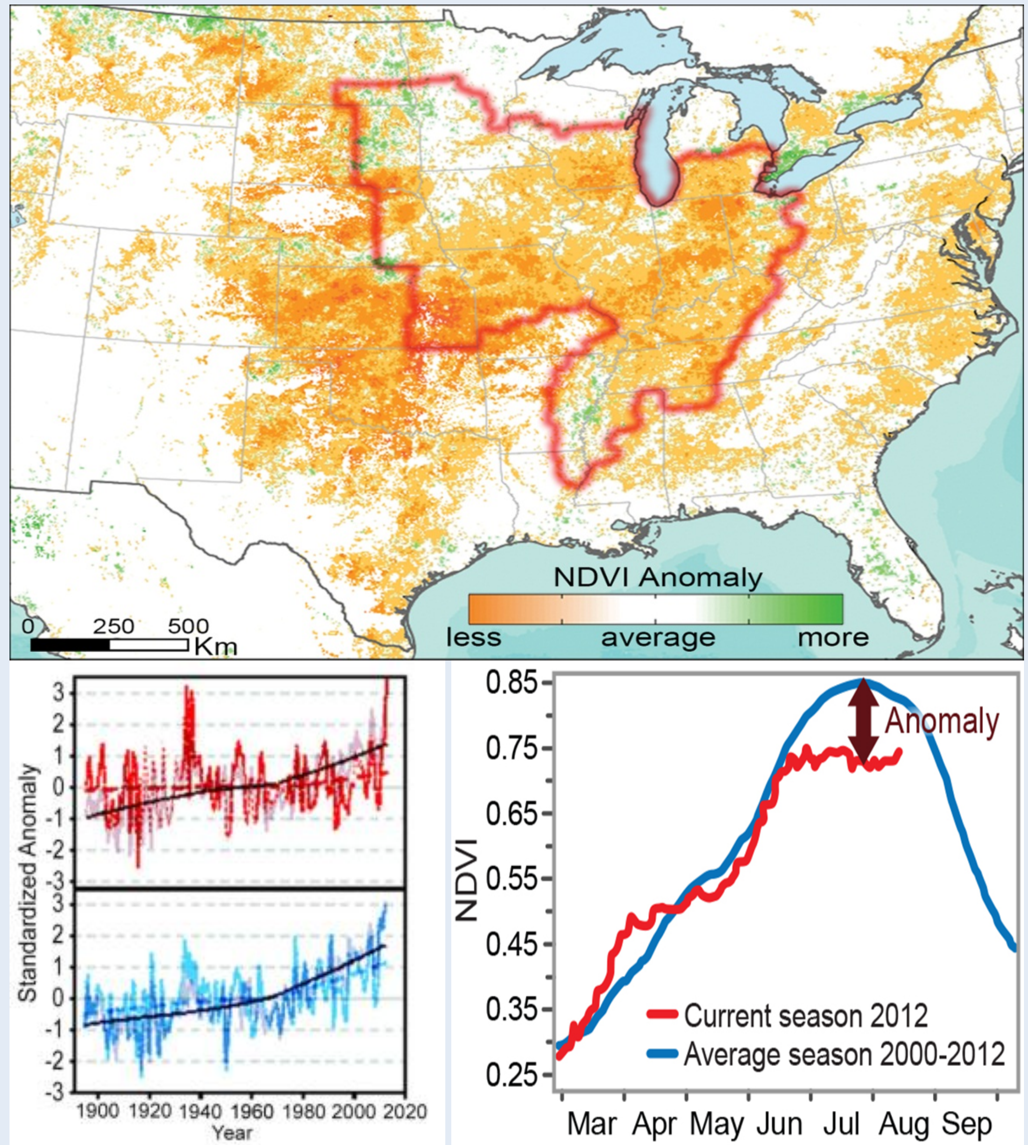




Adapted/updated from Kossin, J. P. (2007), *Geophys. Res. Lett*.

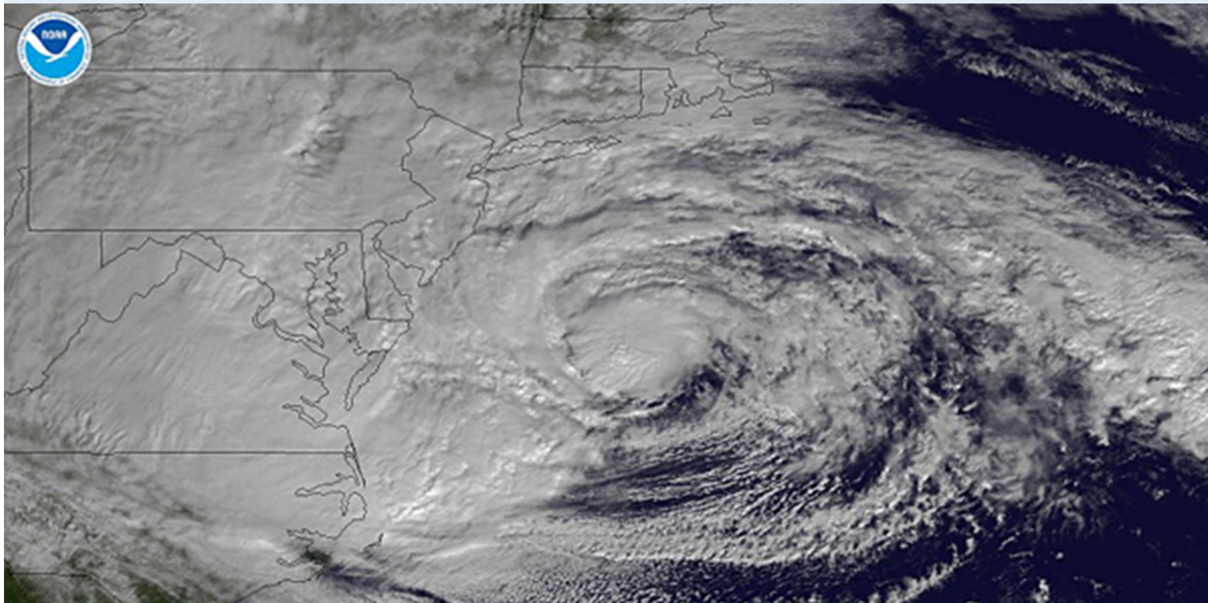
U.S. Drought Spring-Summer 2011-12

- **Spring-summer 2012 Heat & Drought**
  - Early green-up
  - Followed by rapid deterioration of vegetation
  - Impacted primary corn & soybean regions
- **Feedbacks between heat and drought likely to amplify extremes of both in U.S.**



Based on Karl, T.K. et al. (2012). U.S. Temperature and Drought: Anomalies of Spring and Summer 2011-12 and trends. *EOS*

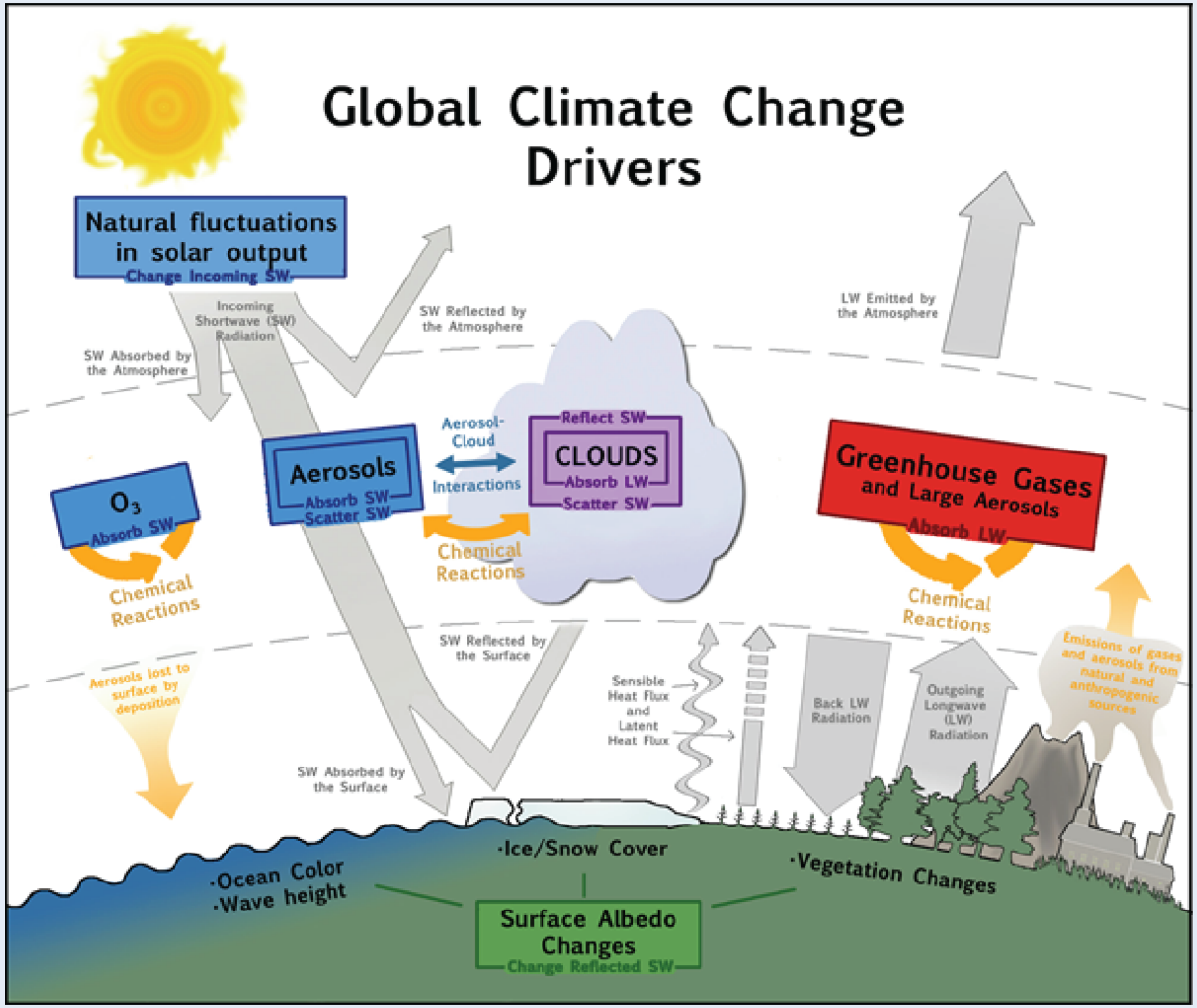
Are Recent Extreme Events Related to Climate Change?



> $1B DISASTERS in 2011

What causes the climate to vary and change?

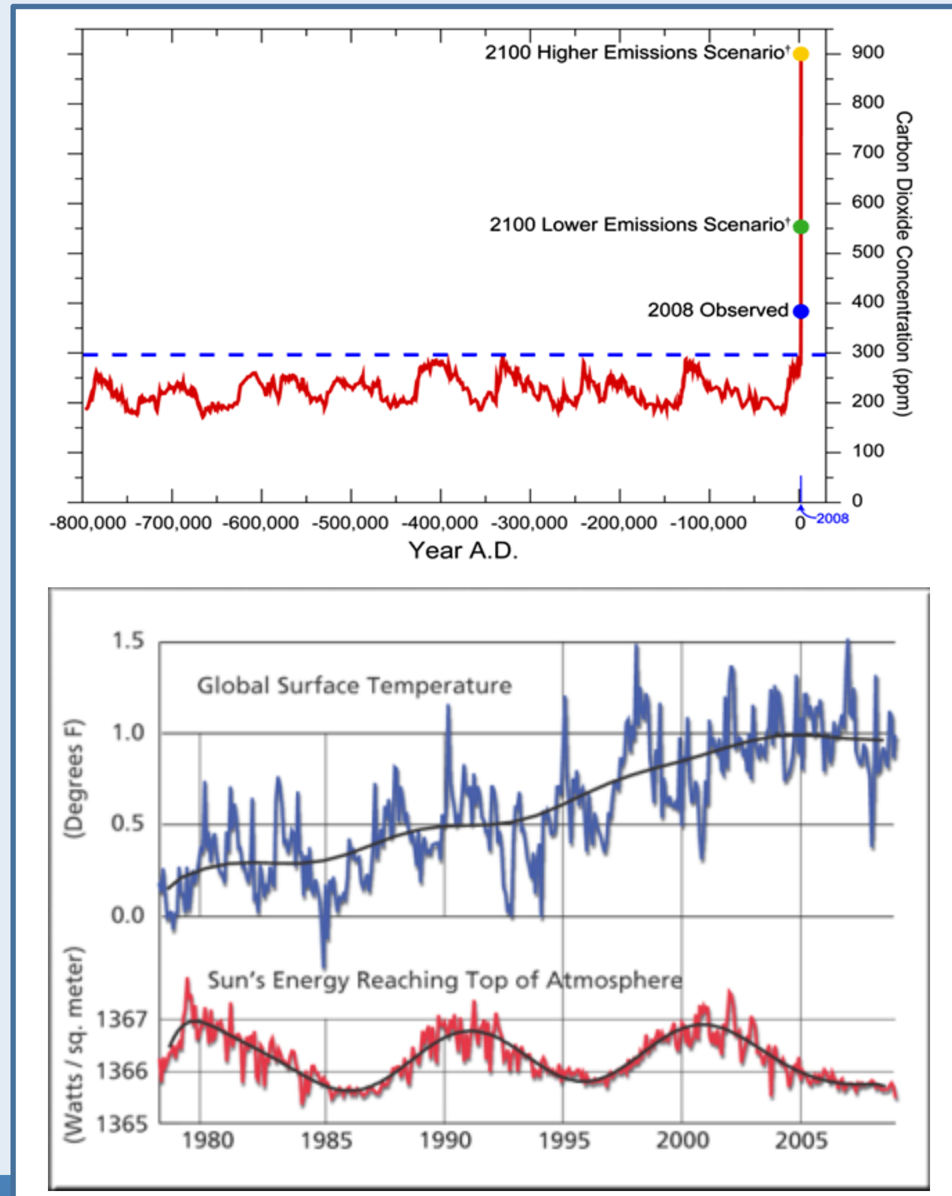
- Natural fluctuations in solar output
  - Output from the sun
  - Orbital mechanics
- Changes in atmospheric composition
  - Heat-trapping gasses
  - Heat-absorbing and reflecting particles
- Changes in Earth's reflectivity (albedo)
  - Clouds, land (ice, snow, land use), sea ice
- Important gaps in knowledge
  - Clouds-particulate interaction, complex feedbacks



U.S. National Climate Assessment unpublished work

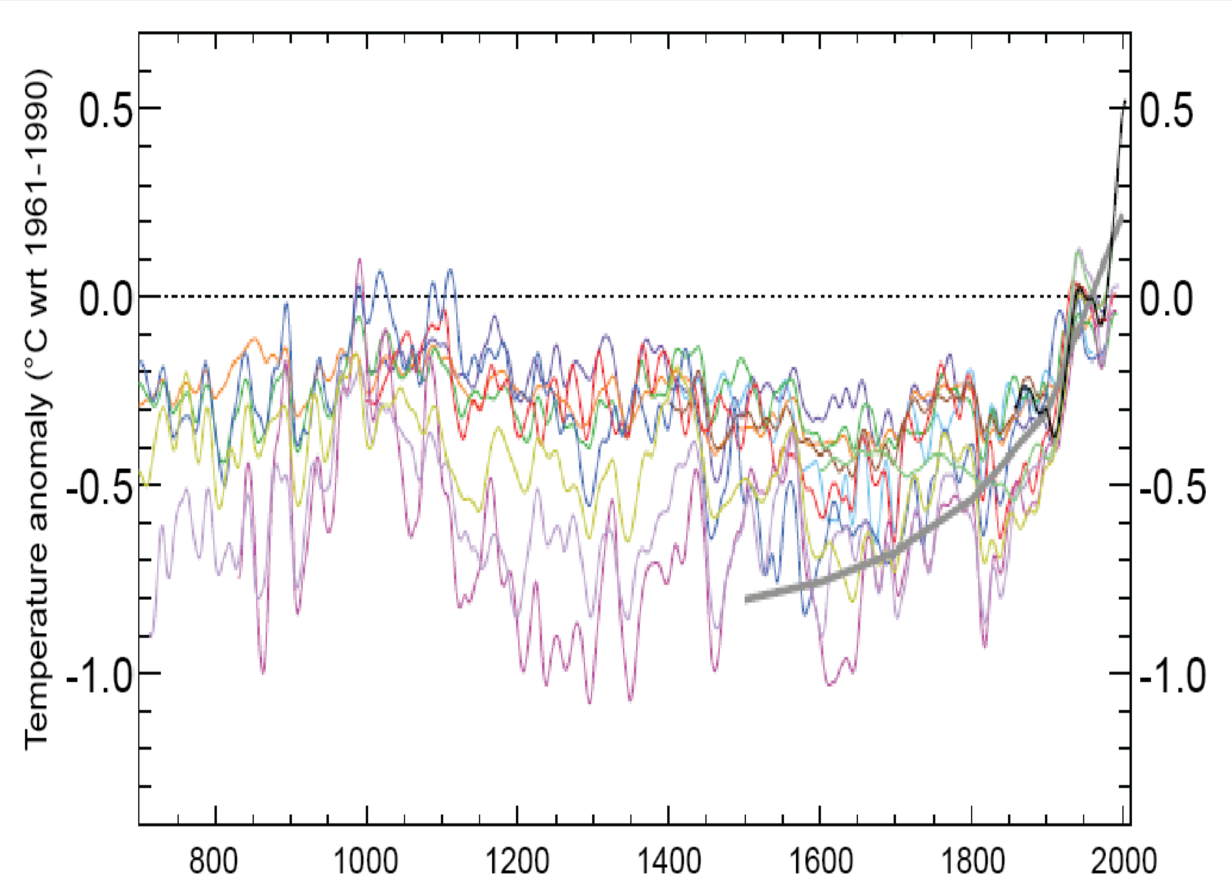
Is climate changing and how do we know?

- We have observed changes in the drivers of global climate
  - Solar radiation
  - Carbon dioxide and other greenhouse gases
  - Human-generated micron-size particulates: “aerosols”



Is climate changing and how do we know?

- How are changes in the drivers affecting the climate?
  - Paleoclimate records give a geological context



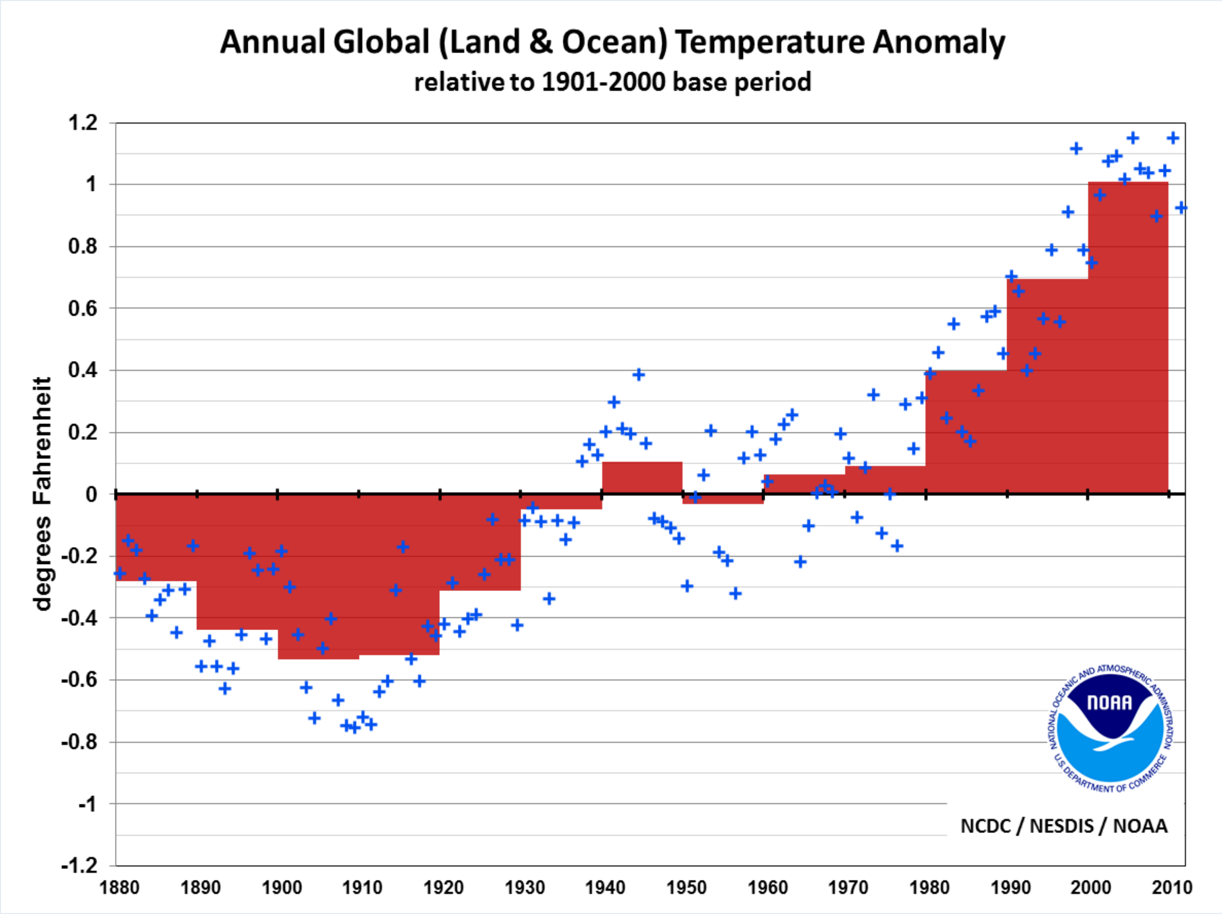
Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

Has global warming stopped?

Records Set This Decade

In 132-year period of record:

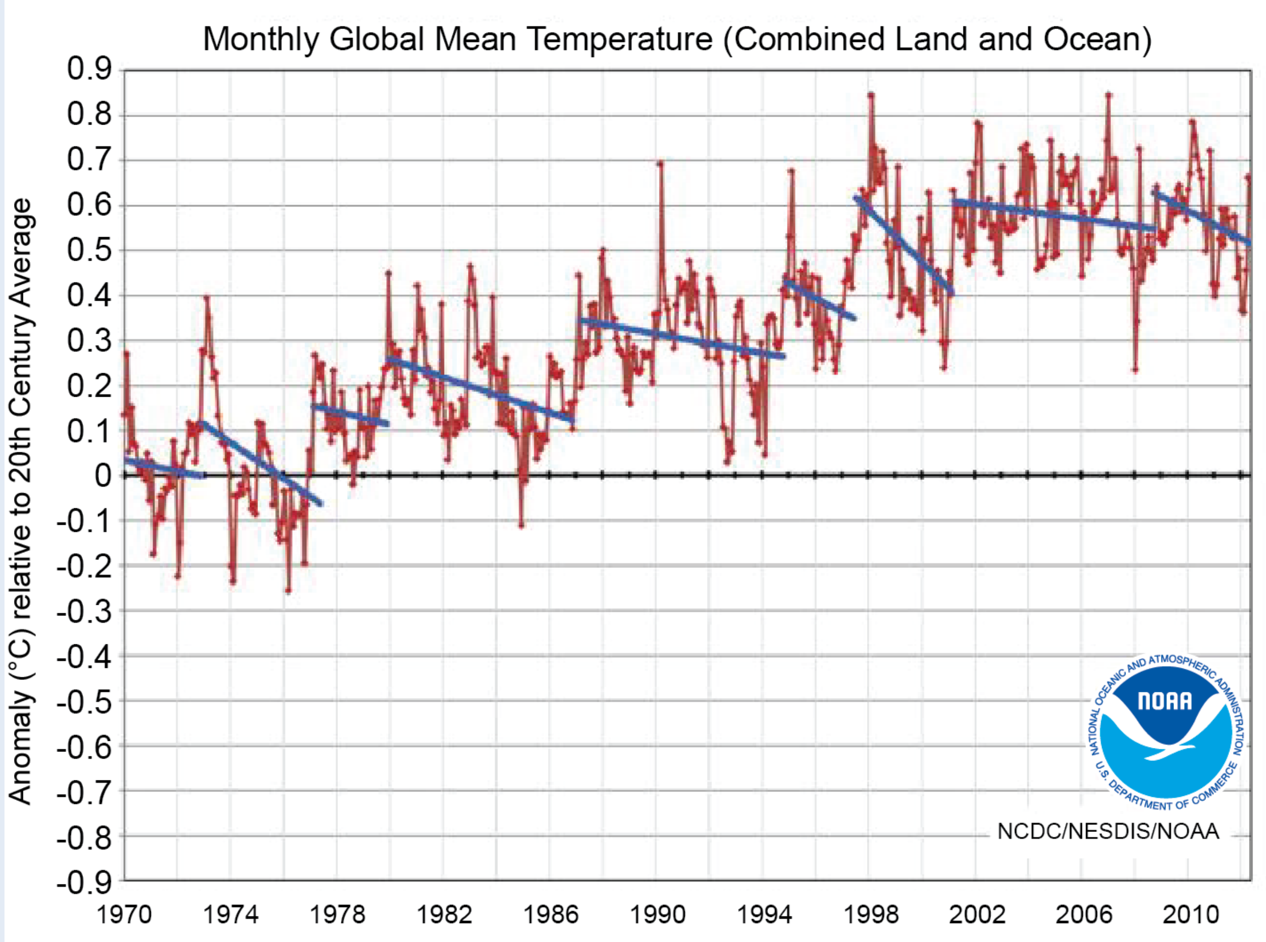
- 2010
  - Warmest year on record globally (tied with 2005)
- 2011
  - 11th warmest globally (tied with 1997)
- 2012
  - Likely to be in top 10 warmest globally
  - In the U.S.:
    - 2012 virtually certain to be warmest on record
    - July was warmest month on record



NOAA's National Climatic Data Center

Has global warming stopped?

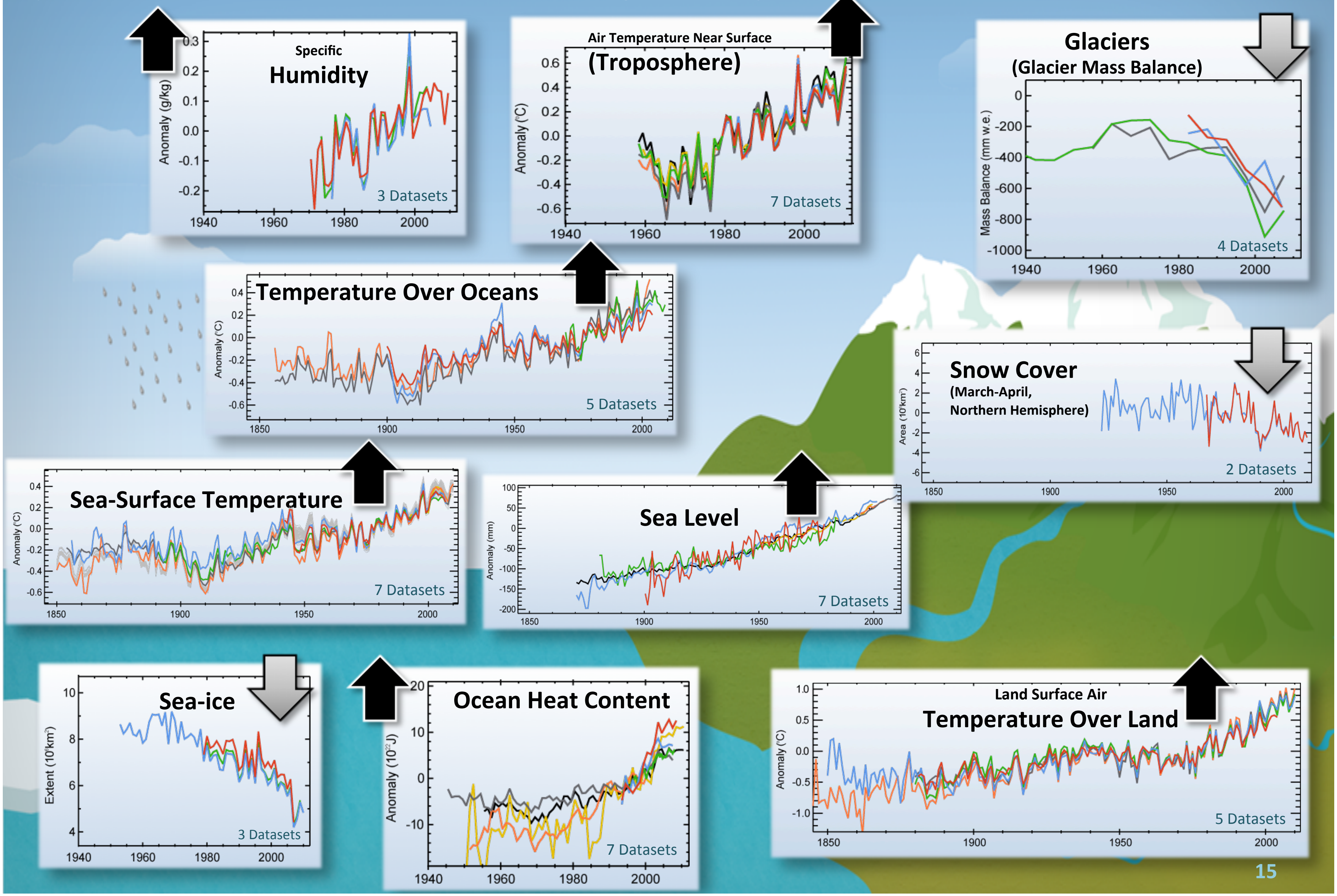
- Short-term cooling is possible within long-term warming
- Separating signal from noise requires long-term monitoring
  - Natural internal variability overwhelms trends at the decade scale



NOAA's National Climatic Data Center

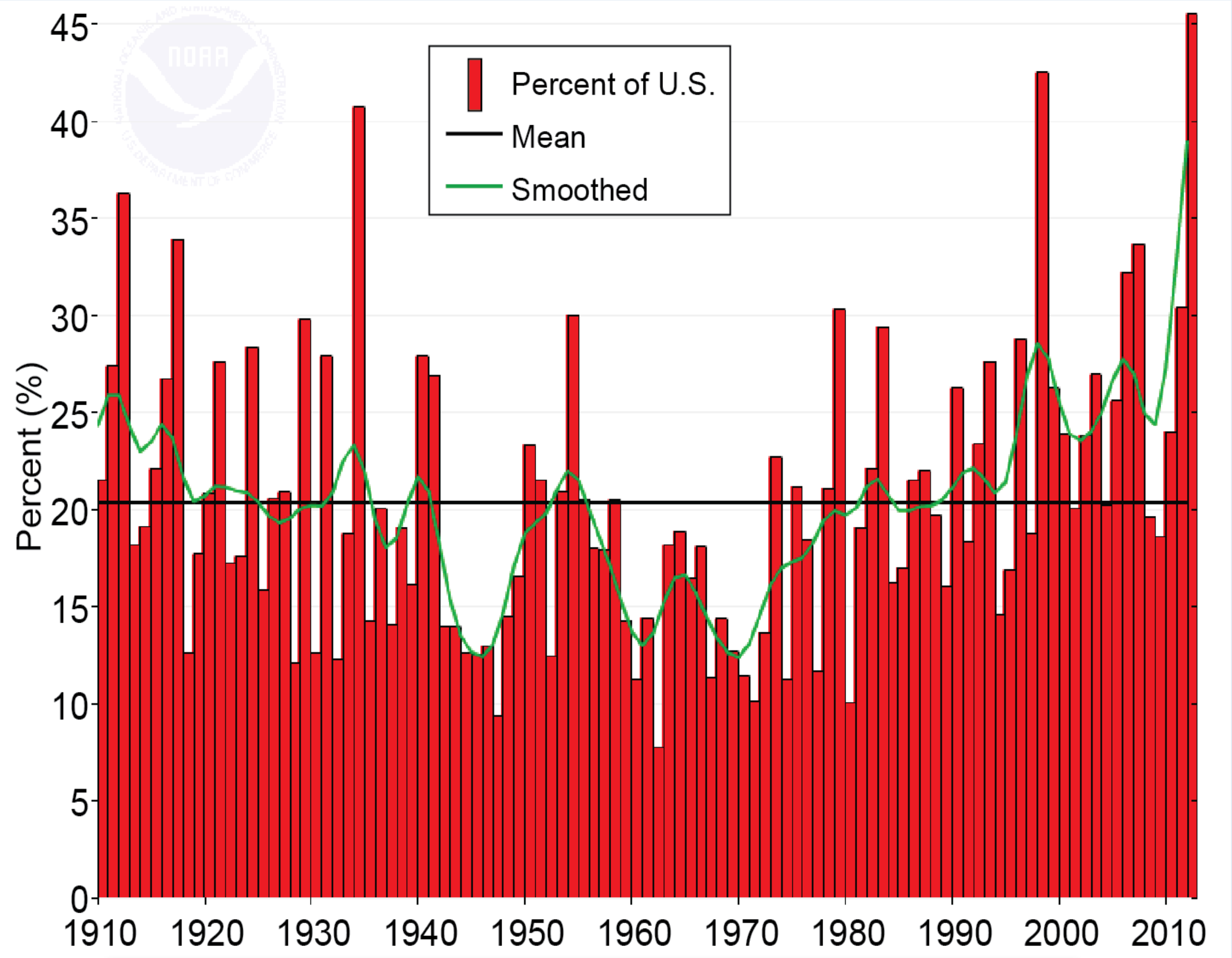
The Changing State of the Climate

Updated from Bulletin of the American Meteorological Society, 2010-12



NOAA U.S. Climate Extremes Index

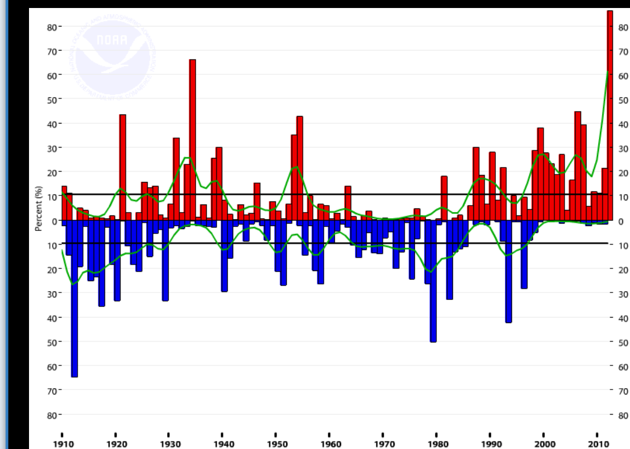
- The index is sensitive to climate extremes in
  - Monthly maximum and minimum temperature
  - Daily precipitation and runs of dry days
  - Monthly Palmer Drought Severity Index: indicates too little or too much soil water
  - Landfalling tropical storm and hurricane wind velocity



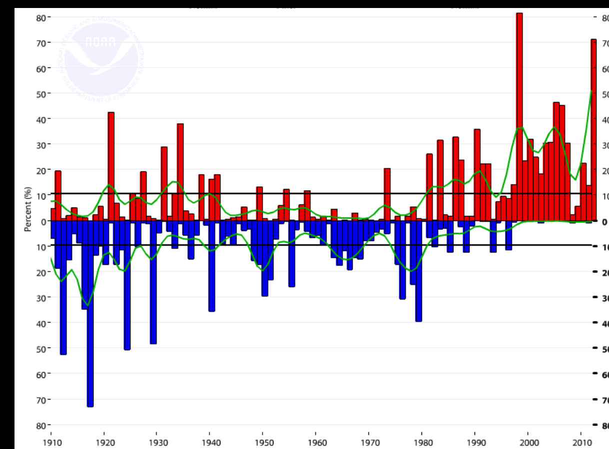
Year-to-date (Jan – Nov) 1910 to 2012

What's Driving the Increase Since the 1970s?

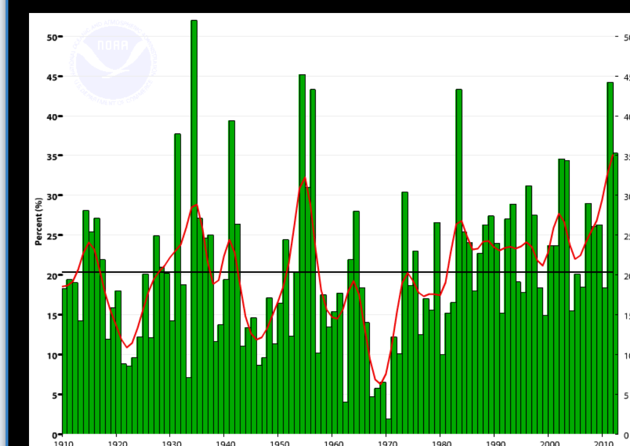
Extremes in Maximum Temperature



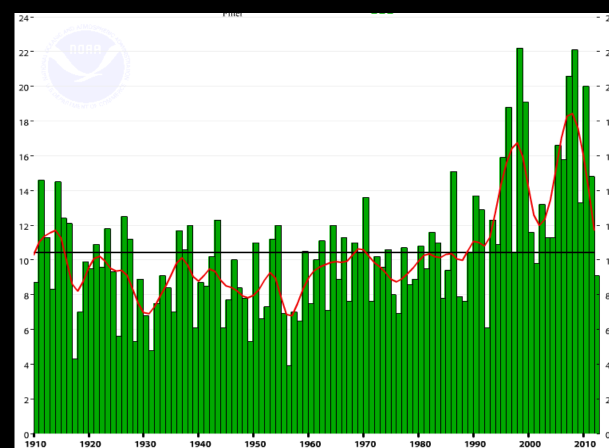
Extremes in Minimum Temperature



Drought Severity and Water Surplus



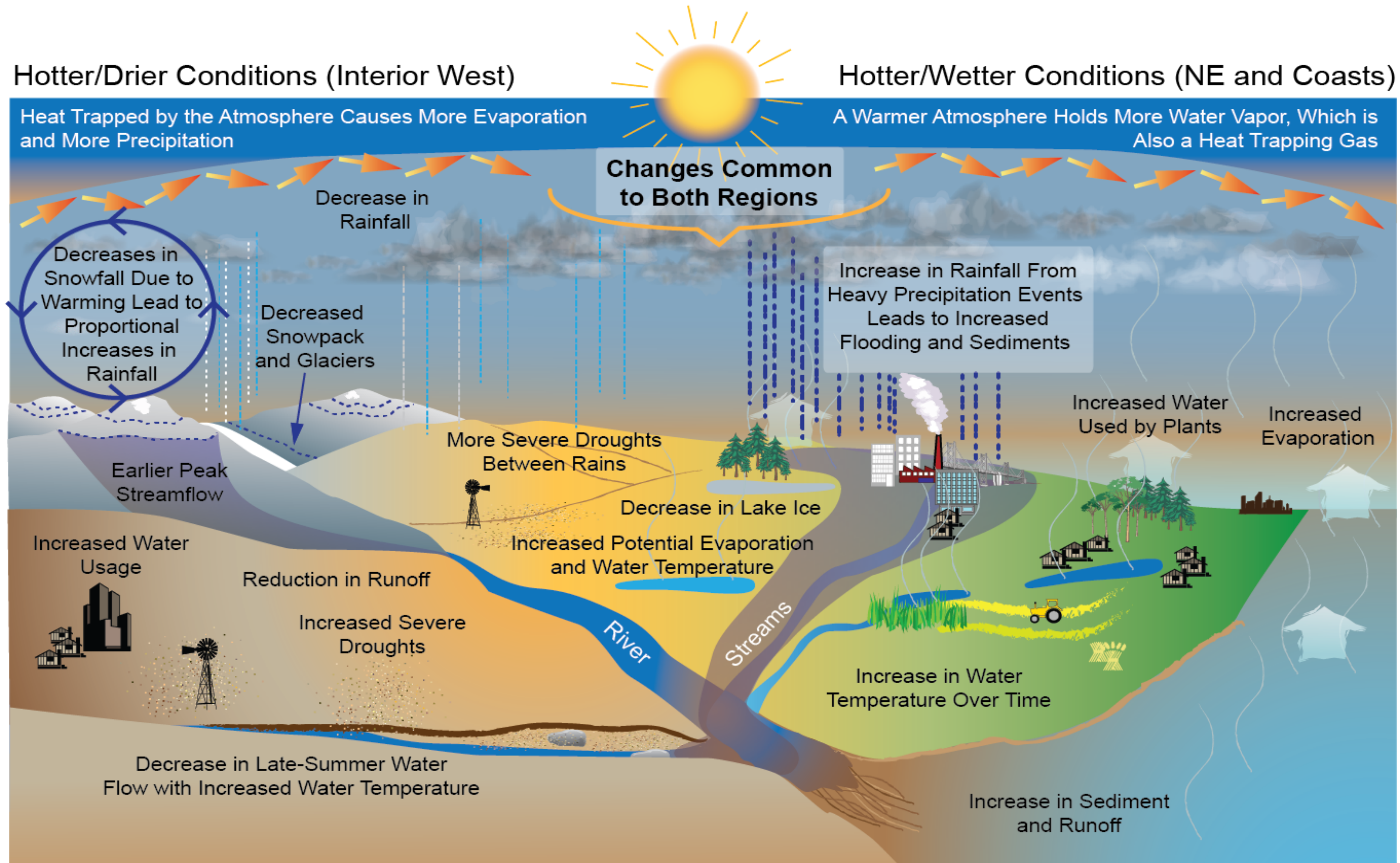
Extremes in 1-Day Heavy Precipitation



All graphs are year-to-date (Jan – Nov) 1910 to 2012

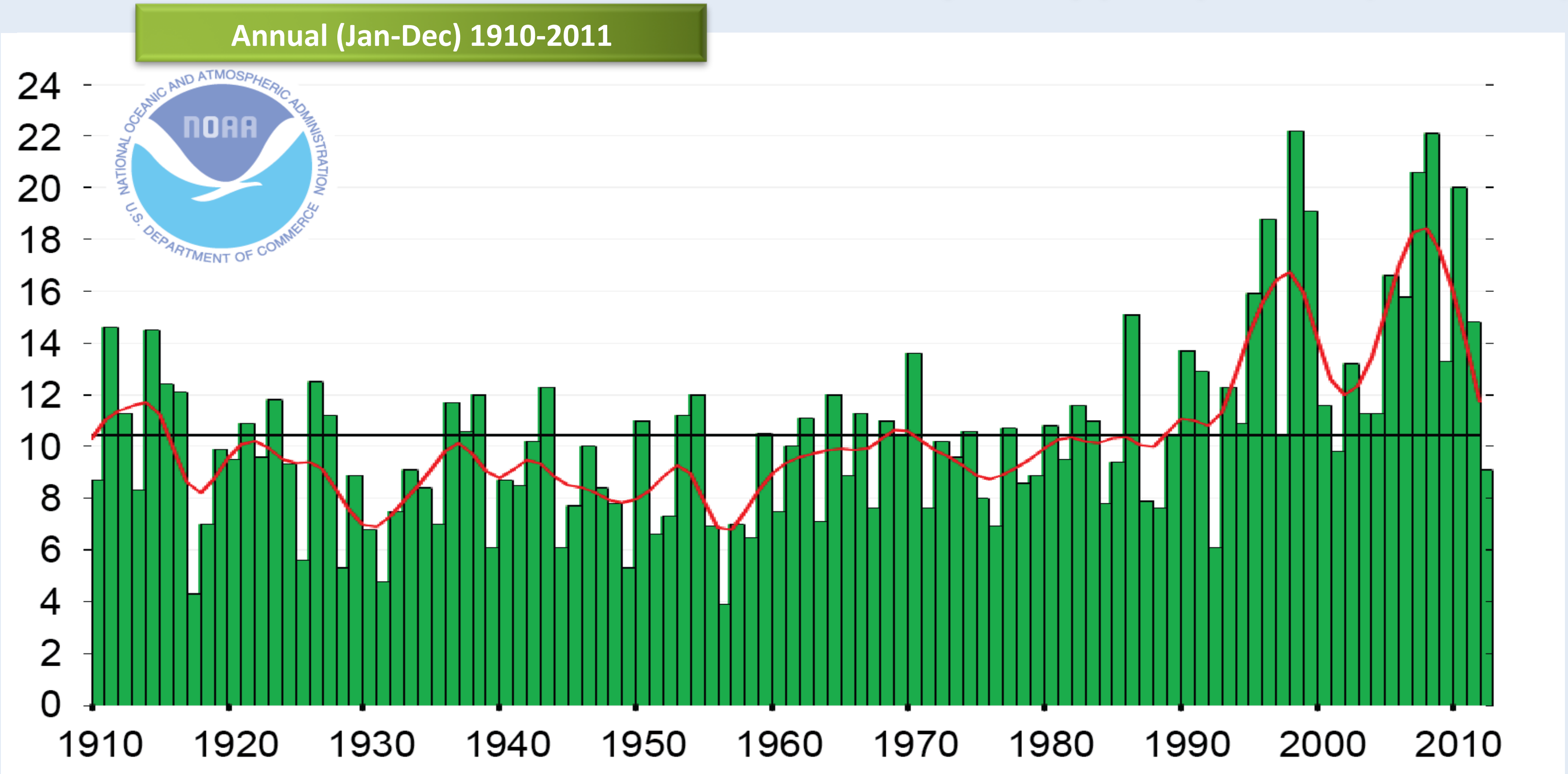
NOAA U.S. Climate Extremes Index
http://www.ncdc.noaa.gov/extremes/cei/

Intensified Water Cycle



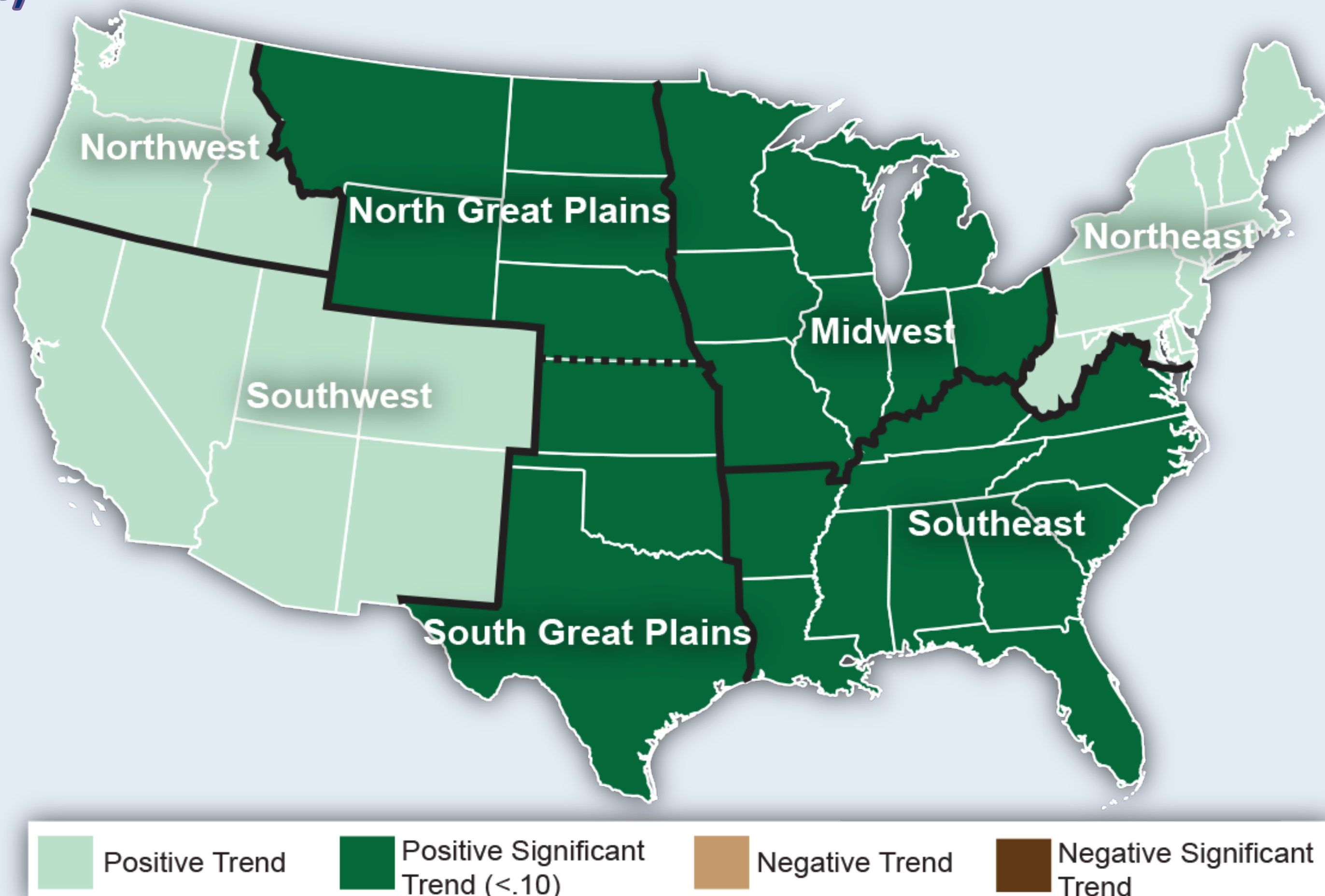
1-Day Heavy Precipitation Events

Percent of the U.S. with much above normal 1-day heavy precipitation (>50.8mm)



- A statistically significant increase in extremes

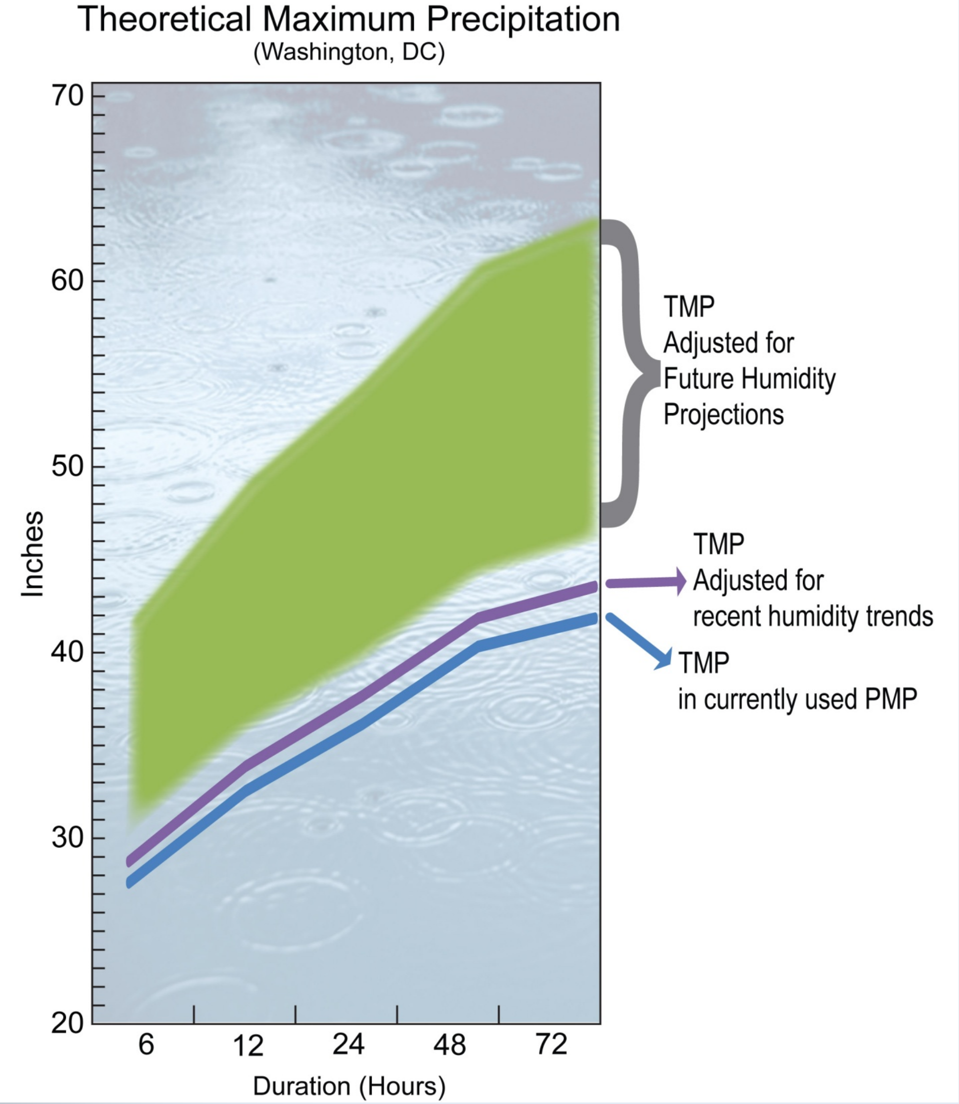
Precipitable Water Difference
(Percent)



Difference between 1990-2009 minus 1971-1989 for daily, 1-in-5-year extreme events

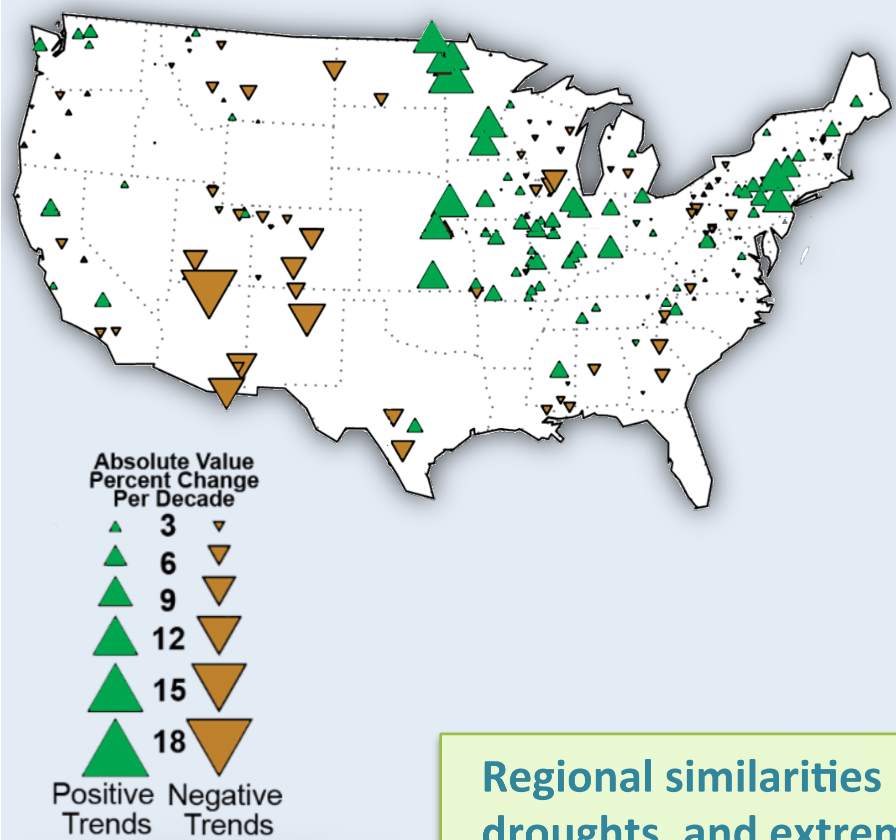
Adapted from Kunkel, K.E. et al., 2012 (In Review). Monitoring and Understanding Changes in Extreme Storm Statistics: State of Knowledge. *BAMS.*

Probable Max Precipitation

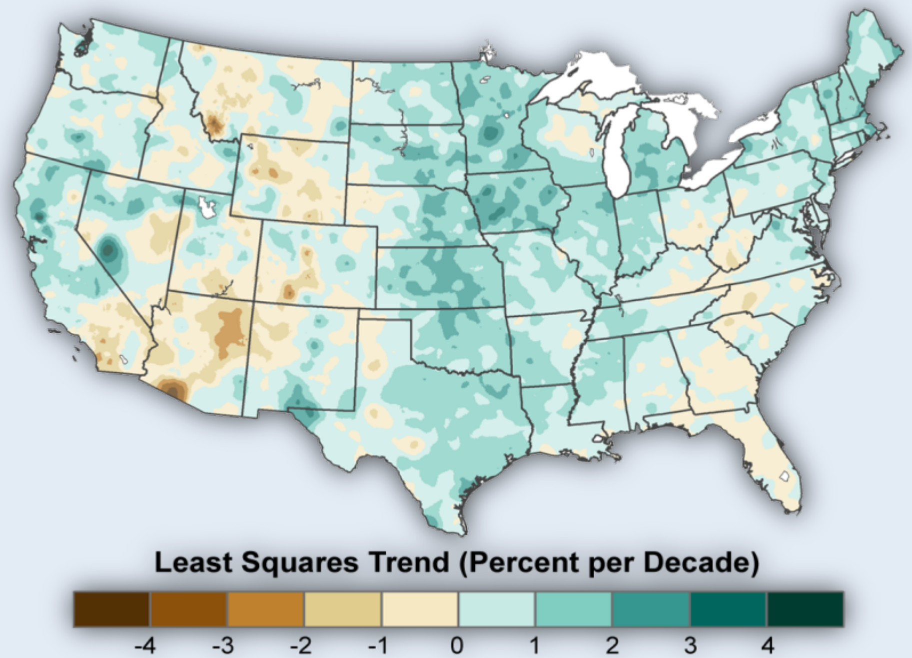


Flooding and Precipitation

River-Flow Trends in Annual Maximum: 85-127 years ending 2008

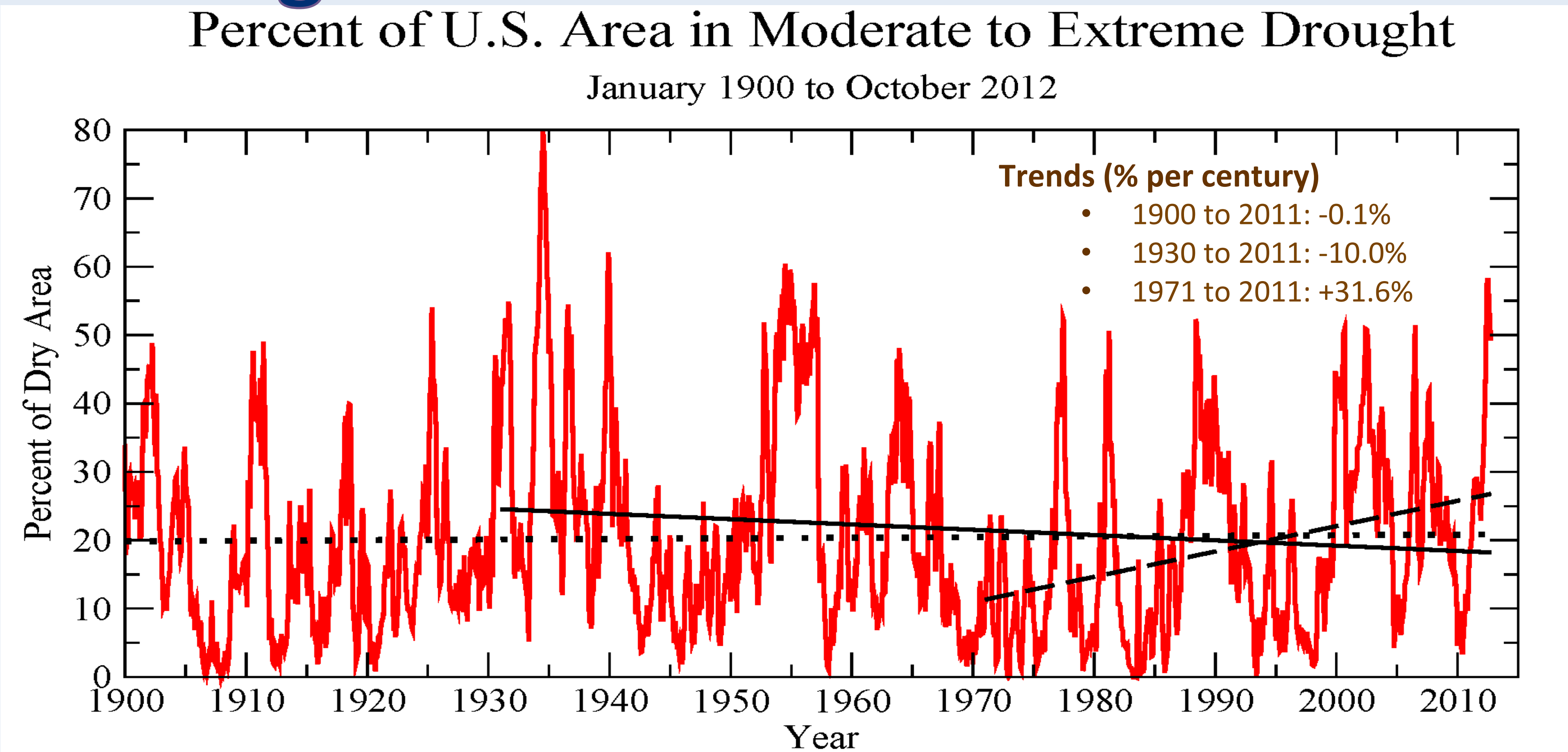


Trends in Total Annual Precipitation: 1909-2008



Regional similarities between trends of annual precipitation, droughts, and extremes of river flooding

Drought



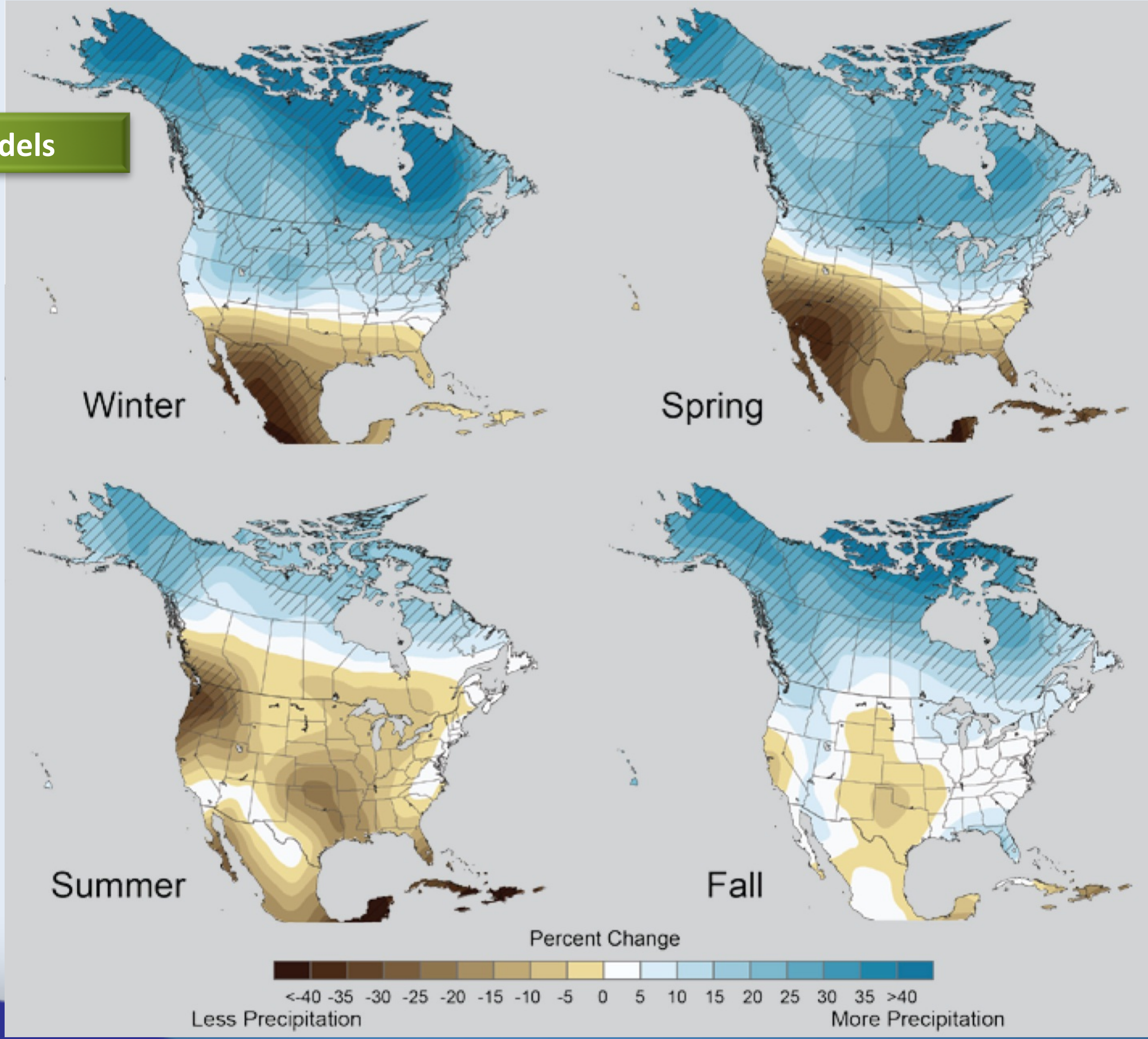
Widespread persistent drought

- 1930s (Central and Northern Great Plains, Northwest, Great Lakes)
- 1950s (Southern Plains, Southwest), 1980s (West, Southeast)
- First decade of the 21st century (West, Southeast)

Peterson, T. C. et al., 2012 (In Review).

Projected Change (A2 Scenarios – "Higher Emissions") in North American Precipitation (Late 21st Century)

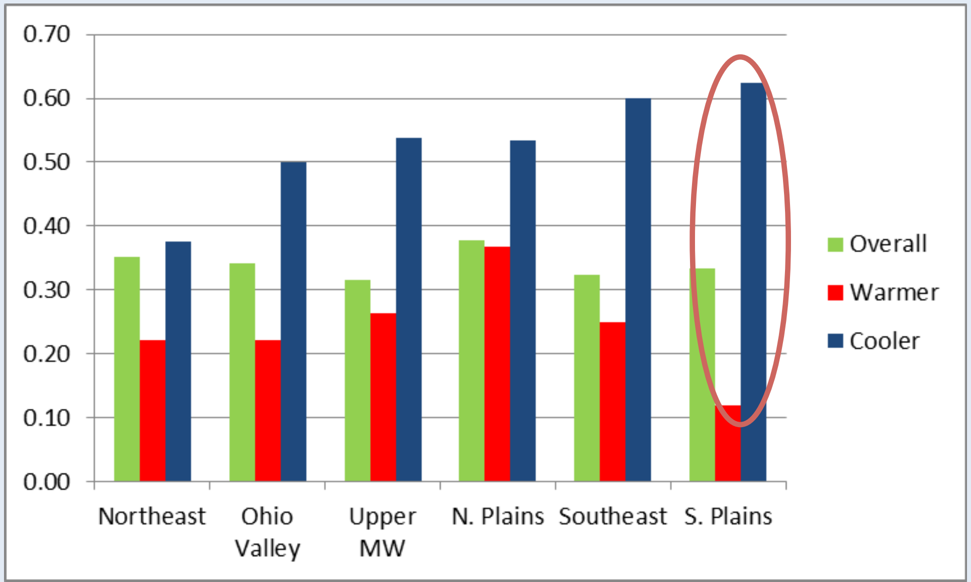
15 Climate Models

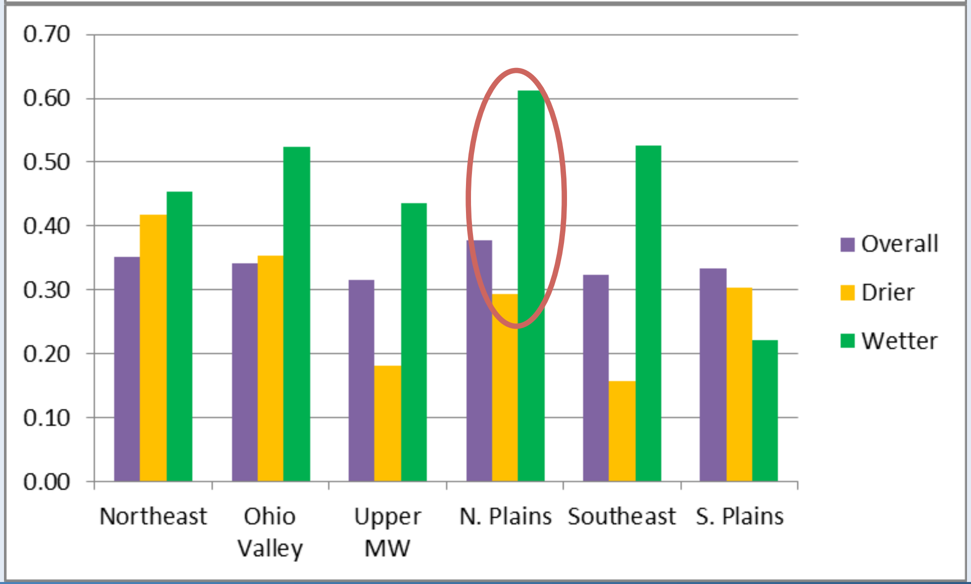


Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

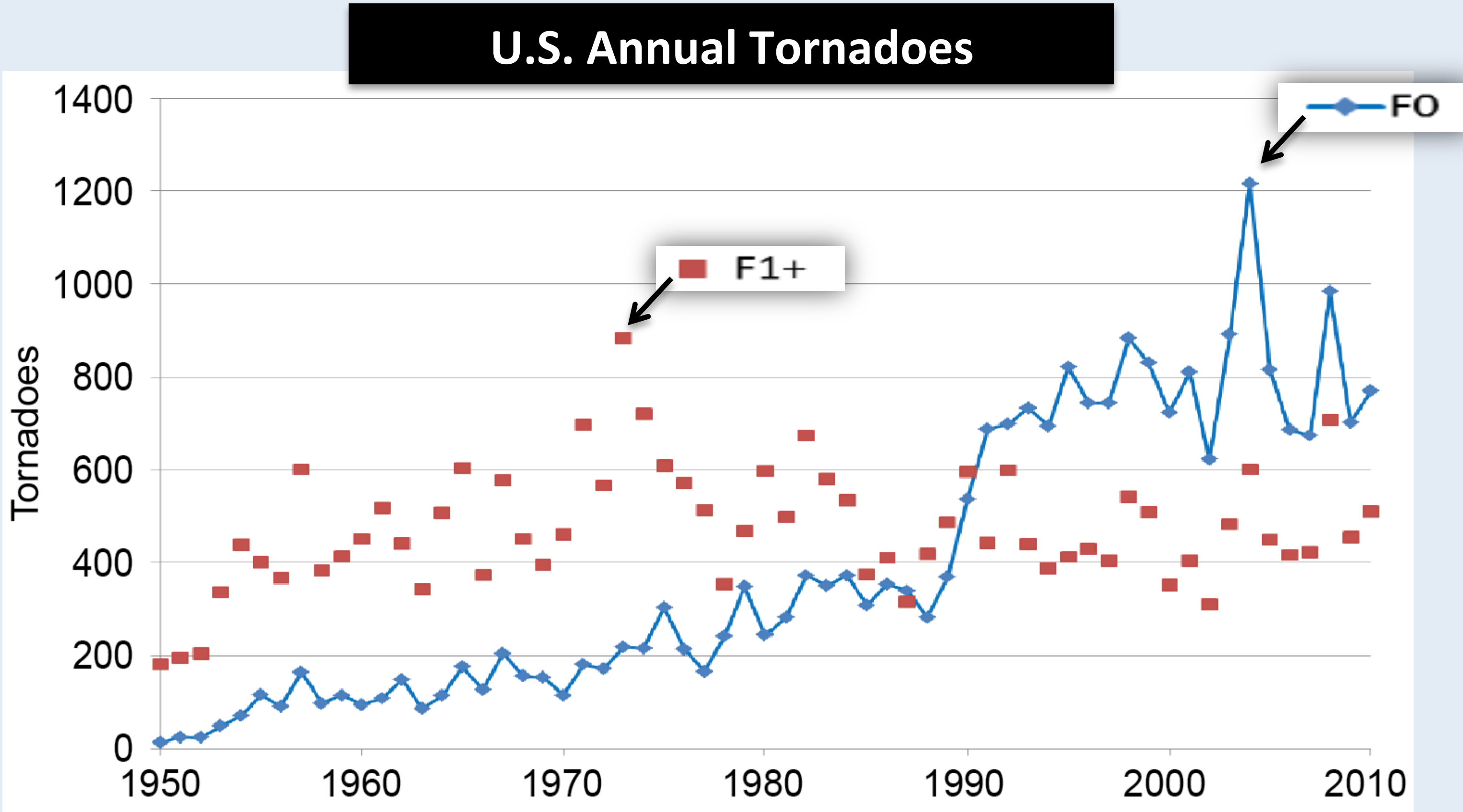
Extreme Snowstorms

- Would changes in temperature and precipitation favor more or fewer extreme snowstorms?
- For the top 50 snowstorms during unusually warm, cool, dry and wet seasons, it varies:
  - E.g. Southern Plains much snowier when cool
  - Northern Plains much snowier when wet





Tornadoes & Convective Storms

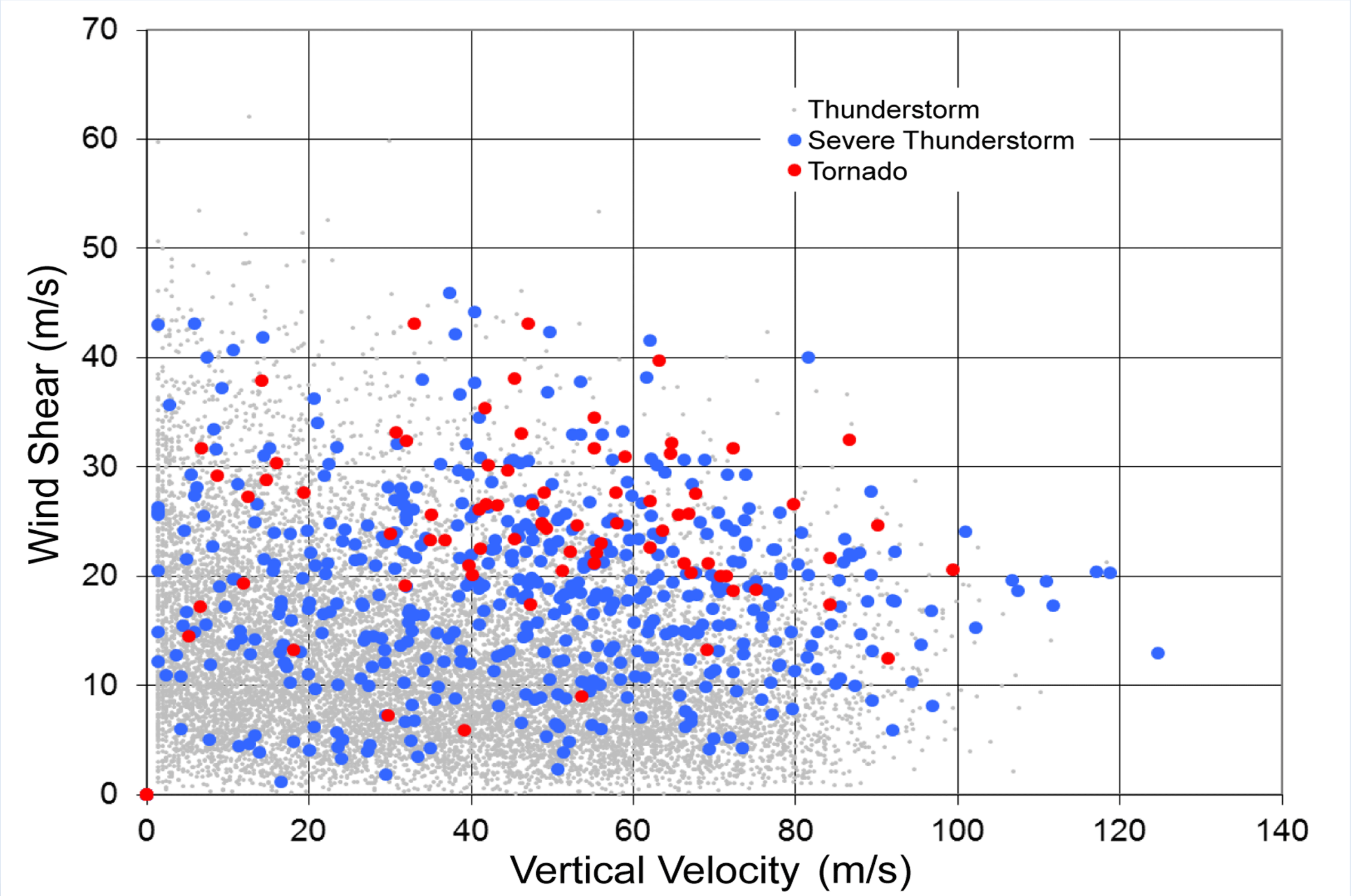


- Although some ingredients that are favorable for severe thunderstorms have increased over the years, others have not
- Overall, changes in the frequency of environments favorable for severe convective storms have not been statistically significant

Kunkel, K.E., et al., 2012 (In Review). *BAMS*.

Tornadoes & Convective Storms

Wind Shear vs. Vertical Velocity–6km proximity values



Each cell is best viewed as a conditional probability

Kunkel, K.E., et al., 2012 (In Review). *BAMS*.

Assess the Earth's Climate:

International, National, Annual Assessments

International Assessments

- Fourth Assessment Report
- Fifth Assessment Report
- Special Report on Extremes

National Assessments

- Global Climate Change Impact in the United States 2009
- National Climate Assessment 2013
- Sustained Assessment Process

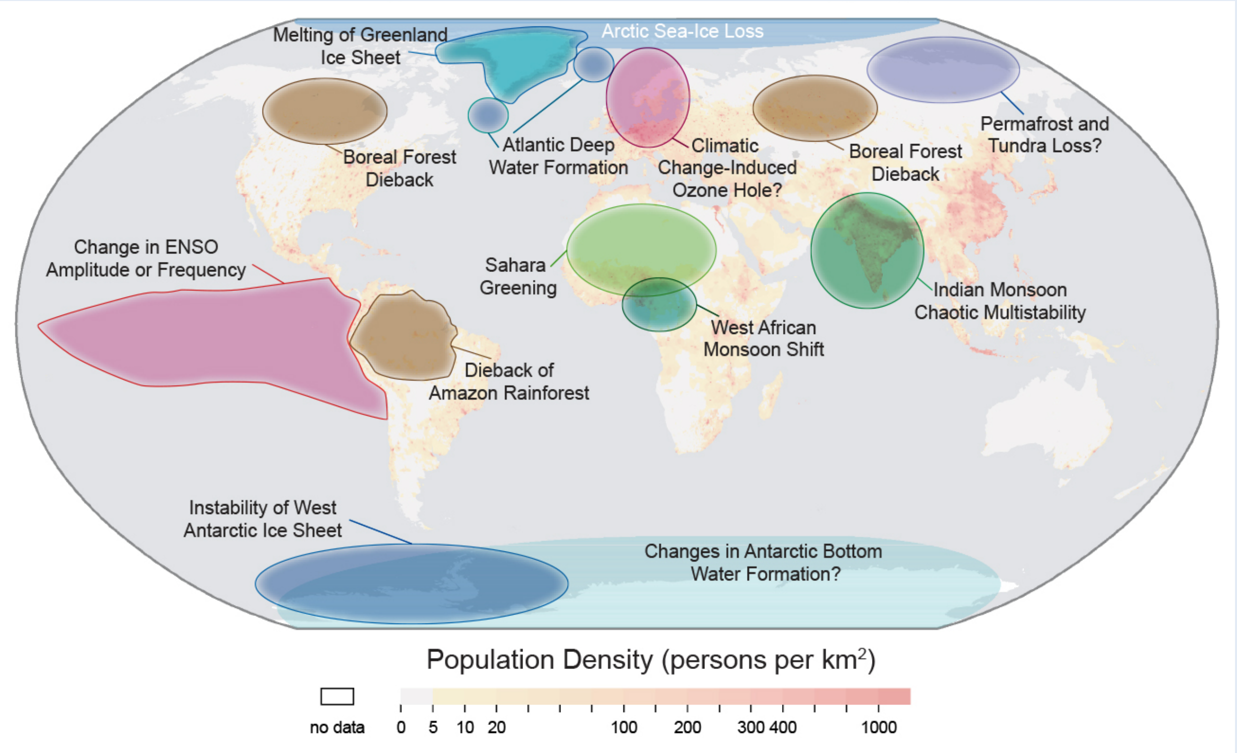
Annual Assessments

- State of the Climate
- Explaining Extremes

Are there tipping points or thresholds in the climate system we should be concerned about?

- Tipping points
  - Greenland ice melt, Arctic sea ice
  - Permafrost thaw, methane release
- Thresholds
  - Coral reefs – Ocean acidification & thermal stresses
  - Pine bark beetles – min temps
  - Invasive species
  - We know the thresholds for some species. E.g. 70-degree threshold for coldwater fish leading to decreasing habitat.
- Potential areas of research
  - Economic & ecosystems
    - Most systems, we don't know threshold for disequilibrium

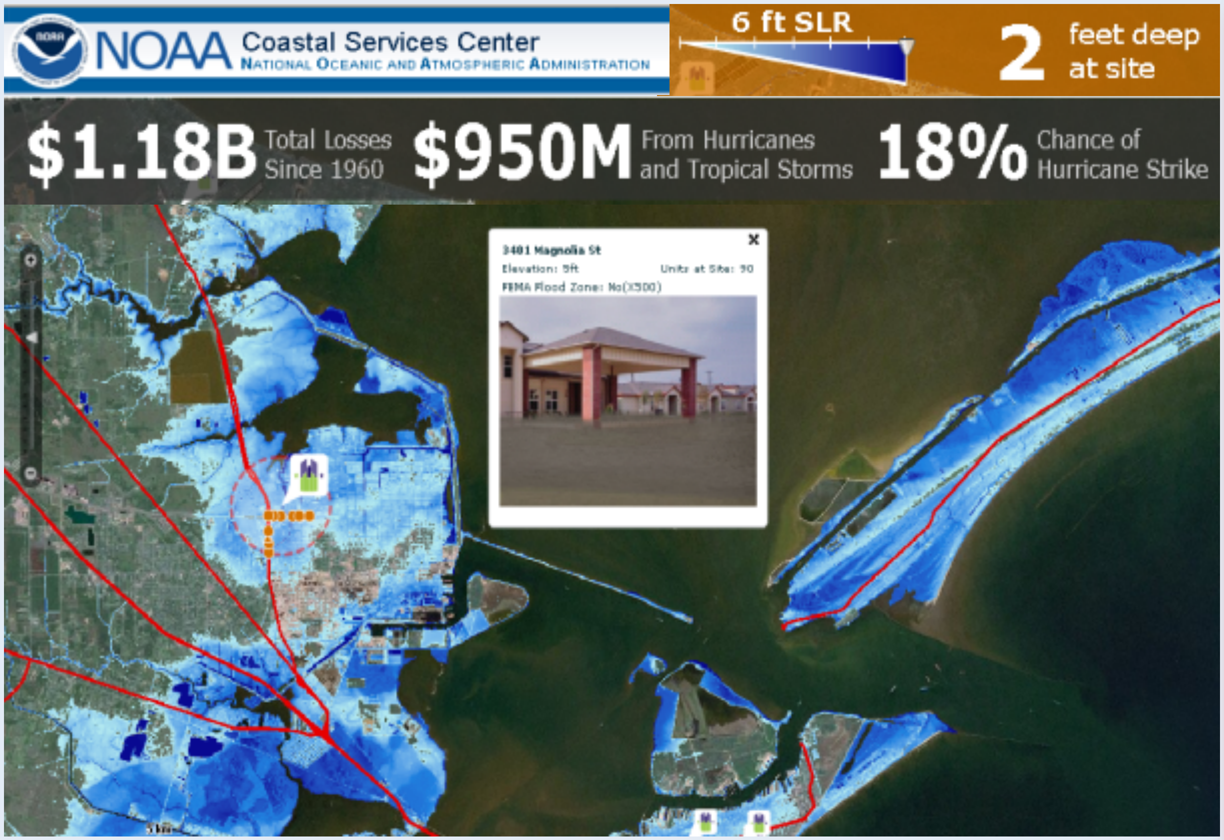
Tipping Points
Potential Areas of Research



U.S. National Climate Assessment work in progress

DIGITAL COAST

Sea Level Rise Viewer

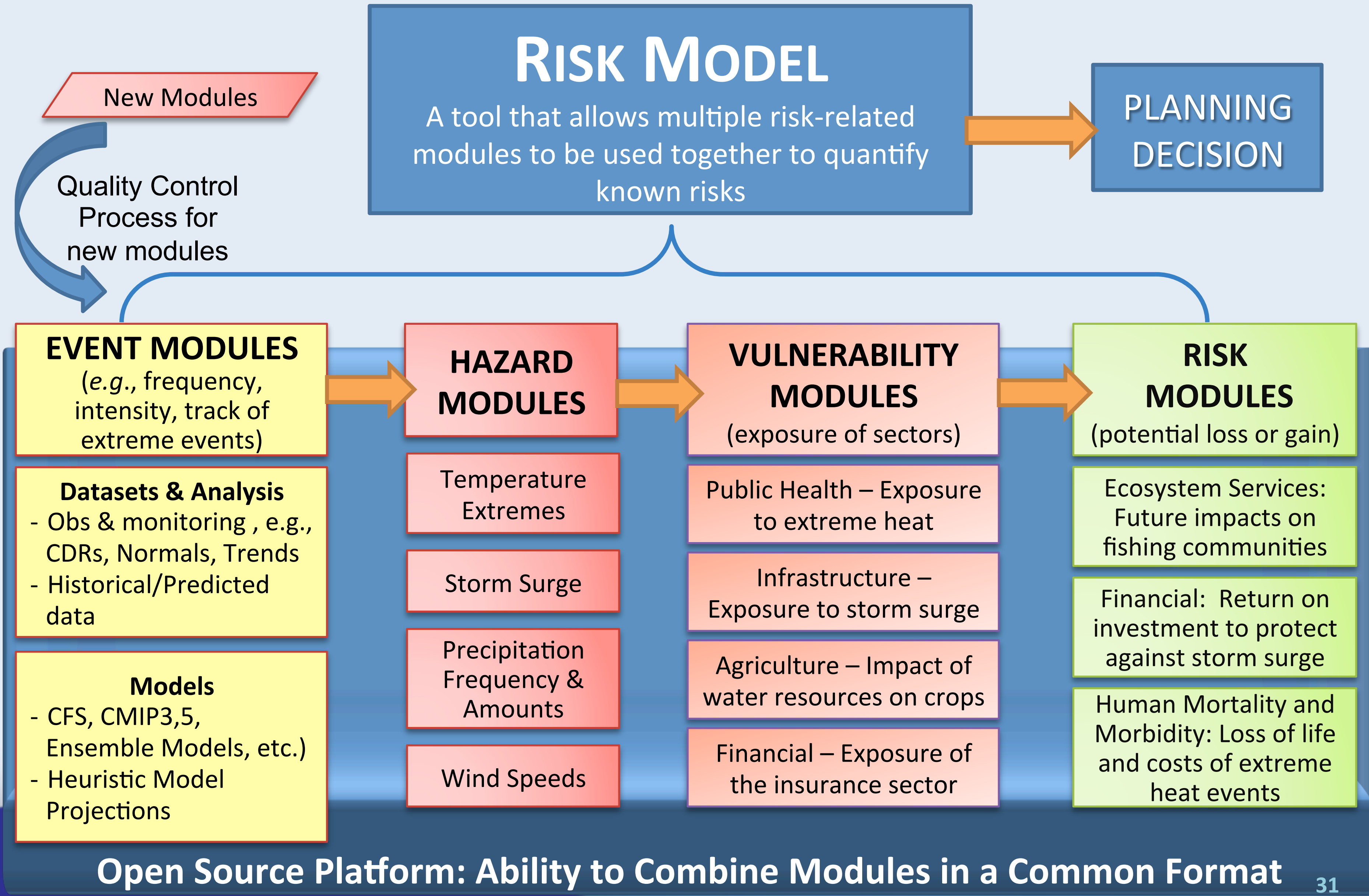


http://www.csc.noaa.gov/digitalcoast/tools/slrviewer

Features

- **Displays** potential future sea levels
- **Provides** simulations of sea level rise at local landmarks
- **Communicates** the spatial uncertainty of mapped sea levels
- **Models** potential marsh migration due to sea level rise
- **Overlays** social and economic data onto potential sea level rise
- **Examines** how tidal flooding will become more frequent with sea level rise

Risk Modeling Framework



Questions?