Climate Adaptation Workshop

A Nebraska Silver Jackets Project
in association with the
Nebraska Floodplain and Stormwater Managers Association

Wednesday July 29, 2015
9:00am – 4:30pm
Nebraska City, NE
Lewis and Clark Missouri River Visitors Center
100 Valmont Drive

Nebraska Silver Jackets
Climate Change Workshop

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July 29th 2015

Agenda:

- Housekeeping
    - 9:00 – 9:15 Welcome and Introductions (Tony D. Krause, USACE-Omaha District)
- Context
    - 9:15 – 9:45 Climate Change / Science Lite (Dave Pearson, NWS-Valley Office)
    - 9:45 – 10:15 – Nebraska Climate Assessment (Clint Rowe, UNL Extension)
- **Break**
    - **10:15-10:30**
- Climate Change in Decision Processes
    - 10:30 – 11:00 – Climate Science Implications EO13690/FFRMS/HMP (Joe Chandler and Michelle Wolfe, FEMA-Region 7)
    - 11:00-11:30 – Agency Round Table
        - Decision making processes coming out of different state and federal agencies that include climate change or locations in different processes where climate informed decisions could be made.
        - Handouts covering and overview of different climate change tools.
- **Lunch**
    - **11:30-1:00**
- Technical Tools Part 1
    - 1:00 – 2:00 – USACE (Bryan Baker, USACE-Engineering Research & Design Center)
    - 2:00 – 2:45 – NWS (Barb Mayes, NWS-Valley Office)
- **Break**
    - **2:45-3:15**
- Technical Tools Part 2
    - 3:15 - 3:45 – USGS tools and data sources (Rick Wilson, USGS Nebraska Water Science Center)
    - 3:45 – 4:15 – EPA (Bob Dunlevy, EPA-Region 7)
- Closing / Question and Answer
    - 4:15 – 4:30

About the Speakers

Dave Pearson, NWS-Valley Office

Dave Pearson is the Senior Service Hydrologist at the National Weather Service Office in Omaha/Valley, Nebraska. Dave's background is in meteorology and hydrology. As the service hydrologist Dave oversees the flood warning operations for the Omaha office which serves much of eastern Nebraska and western Iowa.

Clint Rowe, UNL Extension

Clint Rowe is a Professor in the Meteorology-Climatology Program of the Department of Earth and Atmospheric Sciences at the University of Nebraska-Lincoln, where he has been on the faculty for over 25 years. Clint received his Ph.D. in Climatology from the University of Delaware in 1988. Clint co-authored the recent report "Understanding and Assessing Climate Change: Implications for Nebraska," a synthesis report for Nebraska to support decision making and natural resource management in a changing climate.

Joe Chandler, FEMA Region VII

As a the Senior Community Planner for FEMA Region VII, Joe Chandler is responsible for oversight and administration of the Multi-Hazard Mitigation Planning program for the 4 state region. This includes serving as lead planner for the review, evaluation, and approval of Disaster Mitigation Act multi-hazard mitigation plans; providing training and workshops to state, Local, and tribal officials with an emphasis on local mitigation planning; preparing and reviewing guidance on hazard mitigation plans; and providing technical assistance on the mitigation planning process.

Michelle Wolfe, FEMA Region VII

Michelle is a Hazard Mitigation Community Planner with FEMA and has over 14 years of professional experience with hazard mitigation, housing and community development in non-profit, private and public planning sectors. Michelle supports the review, evaluation and approval of Disaster Mitigation Act multi-hazard mitigation plans, and has presented educational and training sessions to affiliate professionals and colleagues on various planning topics in Kansas, Missouri and Nebraska.

Bryan Baker, USACE-Engineering Research & Design Center

Mr. Baker is the Inland Hydrology Lead for the Climate Preparedness and Resilience Community of Practice in the US Army Corps of Engineers. Mr. Baker started with the Corps in 1991 and has work at the District, Division and Labs in the Corps during that time as a hydraulics and hydrology engineer. In his current role, he works with the many aspects of the Climate Program and its implementation.

Barb Mayes, NWS-Valley Office

Dr. Barbara Mayes Boustead is a meteorologist and climate program manager at the National Weather Service Office in Omaha/Valley, Nebraska. Her background and research interests include exploring the intersection of weather and climate, communicating weather and climate concepts, and applying climate information to decision-making processes. A Michigan native, Barb lives in Omaha with her meteorologist husband, their infant son, a well-loved old dog, and her UNL-bound "adopted" niece.

Richard Wilson, USGS Nebraska Water Science Center

Rick Wilson is the U.S. Geological Survey (USGS) Nebraska Water Science Center Deputy Director, and he has served in that position for 13-years. Rick has been actively involved in scientific investigations ranging from surface-water and groundwater hydrologic modeling studies, hydrographic surveying, water-quality and ecological assessments, and geophysical surveys. Previously Rick served for 17 years at the U.S. Army Corps Northwestern Division and Omaha District. He is a registered Professional Engineer in Nebraska and Colorado. Rick received his B.S. and M.S. in Civil Engineering from the University of Nebraska-Lincoln, with a focus in water-resources and environmental engineering.

Bob Dunlevy, EPA-Region 7

Robert Dunlevy is an Environmental Engineer at the US Environmental Protection Agency Region 7, and has been with EPA for almost 25 years. He has primarily worked on Safe Drinking Water Act programs. These programs include wellhead and source water protection, Public Water System Supervision Program, and currently capacity development program and operator certification program. Robert is also the contact for the Region 7 Environmental Finance Center at Wichita State University. He graduated in 1981 from the Missouri University of Science and Technology with a Bachelor of Science degree in Geological Engineering. He still enjoys a good float trip on a river or taking his canoe on the lake.

Climate Change
Climate Science Lite

David Pearson

NOAA/National Weather Service, Omaha/Valley, NE

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July 29, 2015

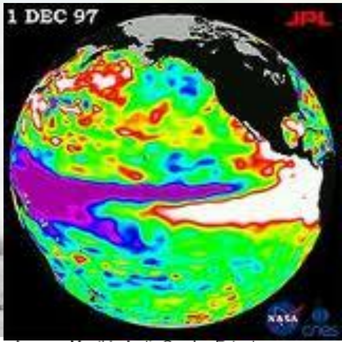
Nebraska City, NE

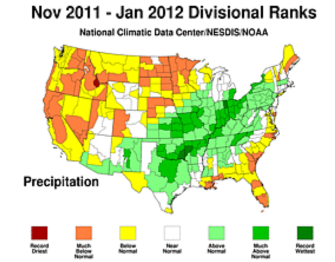
Weather vs. Climate

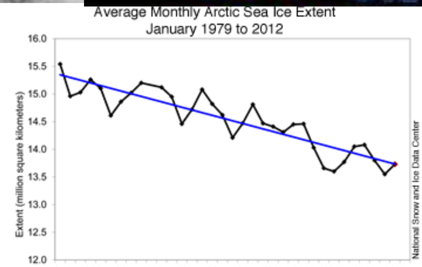
Weather

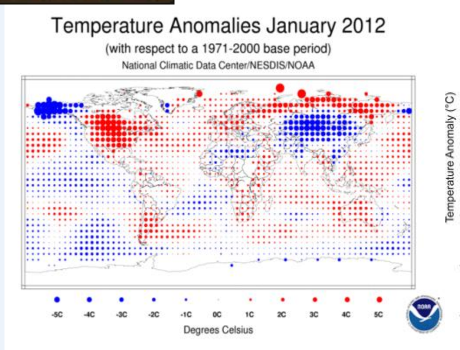


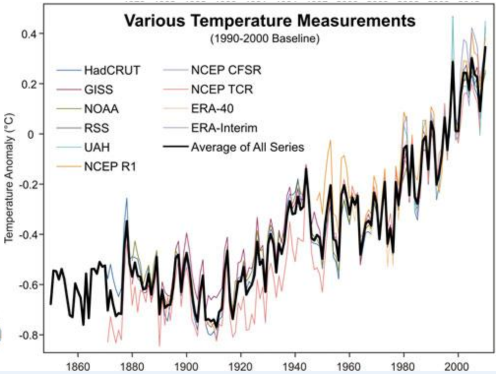

Climate



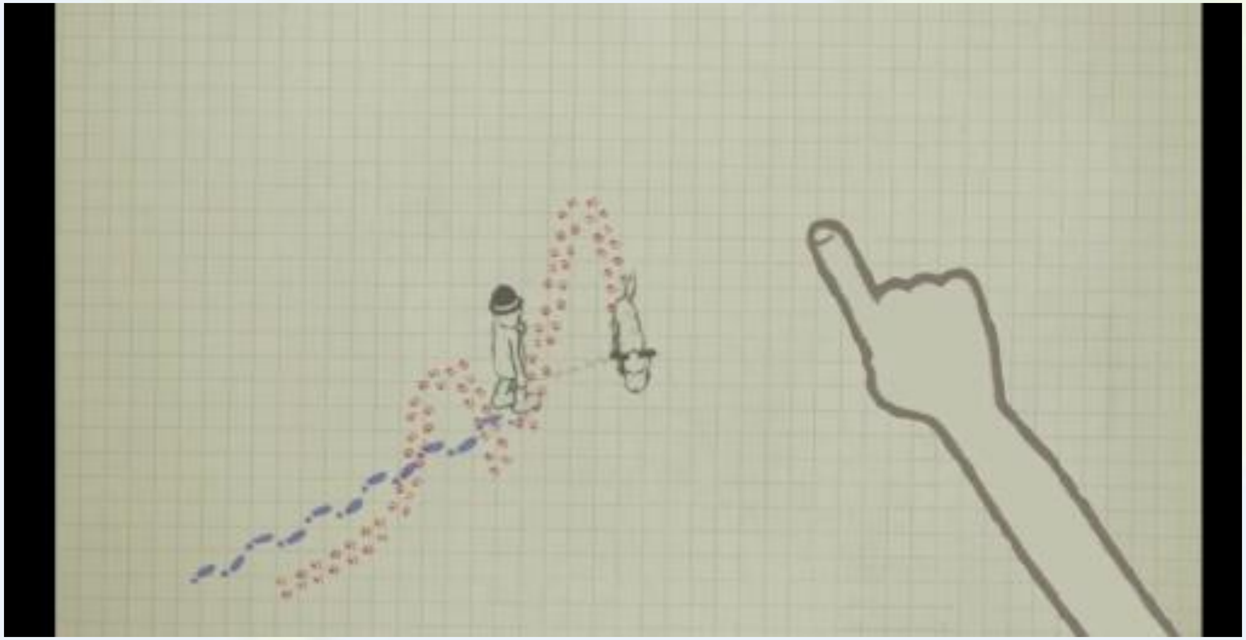






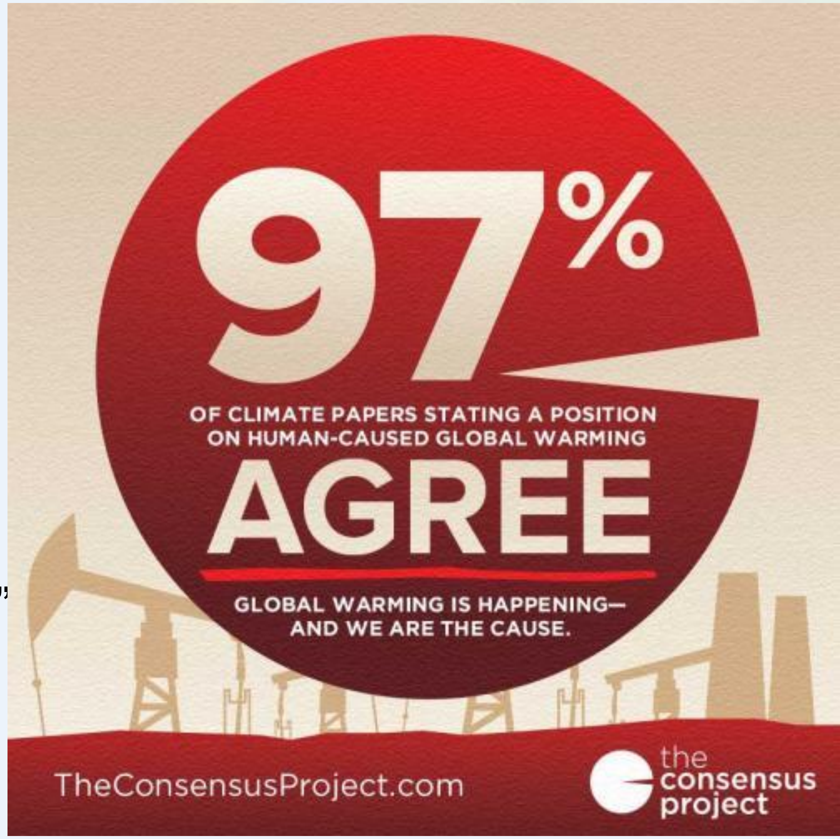
Weather vs. Climate: Like Walking a Dog!

http://spark.ucar.edu/video/dog-walking-weather-and-climate



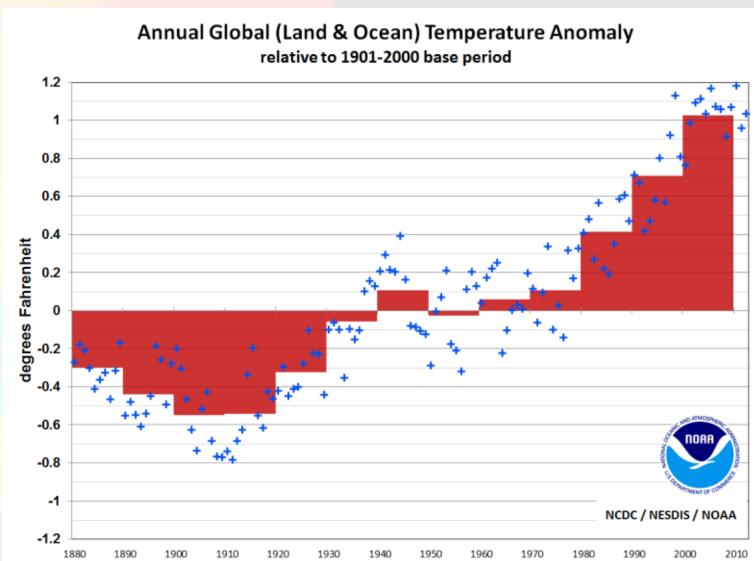
So, what's with this "global warming"/climate change stuff?

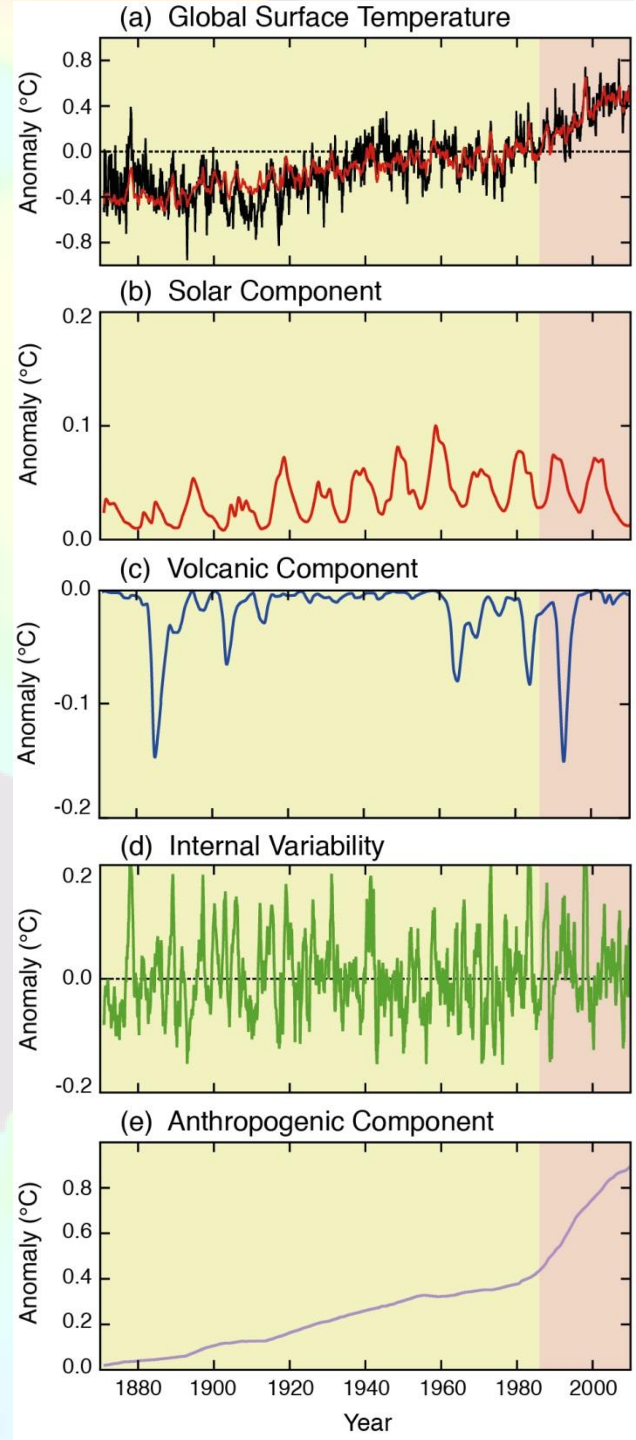
- First, let's cover terminology
  - ♦ The terms "climate change" and "global warming" are often used interchangeably
  - ♦ Scientists prefer "climate change" because it describes the changes to the whole system, not just temperatures
  - ♦ Many people still say "global warming"
- Be careful about your information sources!
  - ♦ Blogs, news commentators, politicians often not trained in climate
  - ♦ Would you go to a dentist to get heart surgery?



Introduction

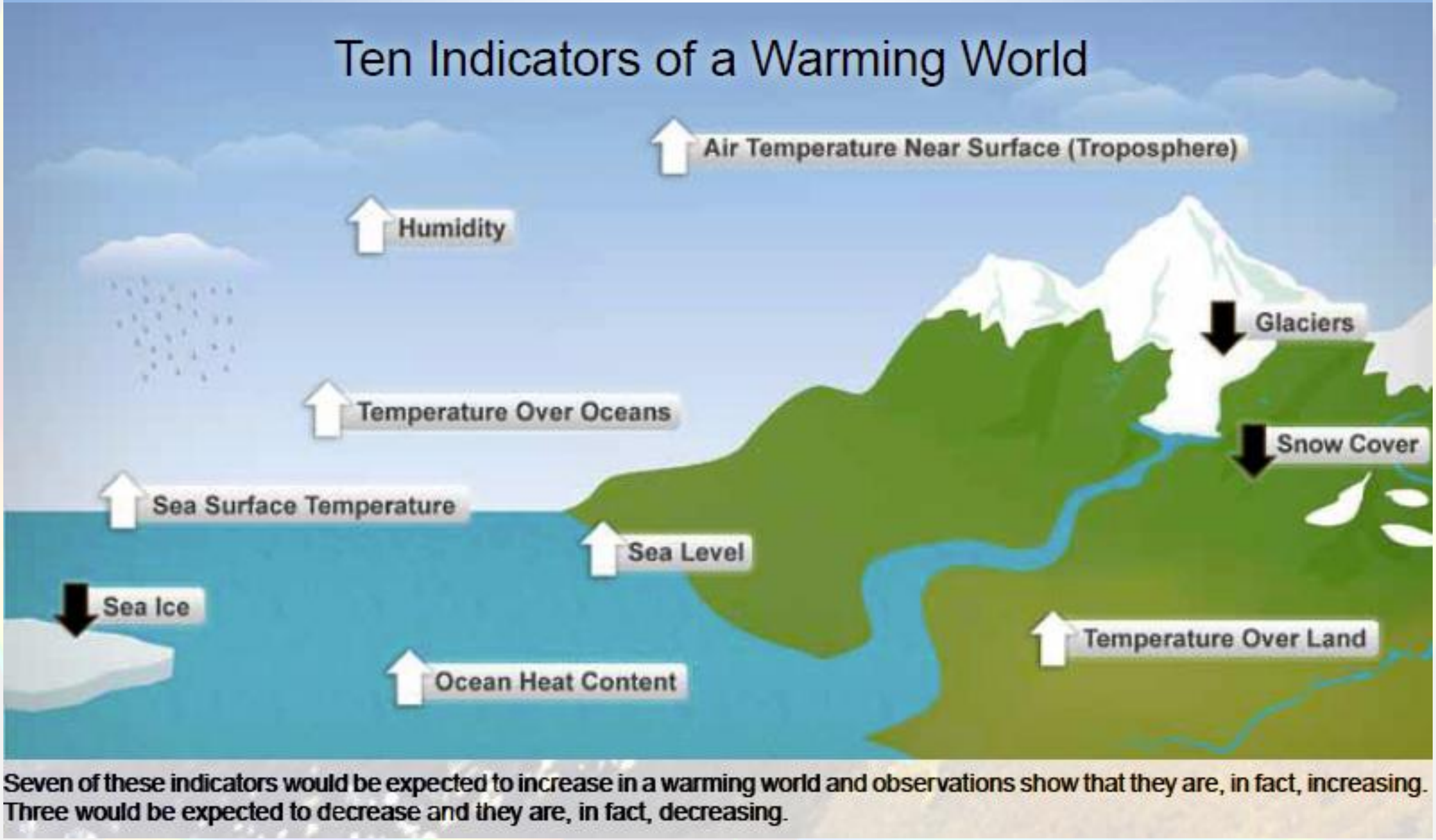
- Climate change/global warming – a "hot" topic!
- According to the IPCC, the Earth's surface temperature has risen by ~1.5 °F in the past ~130 years (0.2 to 0.4 °F in the past 30 years).
  - Accelerated warming during the past three decades.
  - 2000-09: Warmest decade since accurate instrument records began in 1880s.
- Evidence is conclusive that most of the warming over the last 50 years is attributable to human activities.





Indicators of a Warming World

The stratosphere (up here!) is cooling

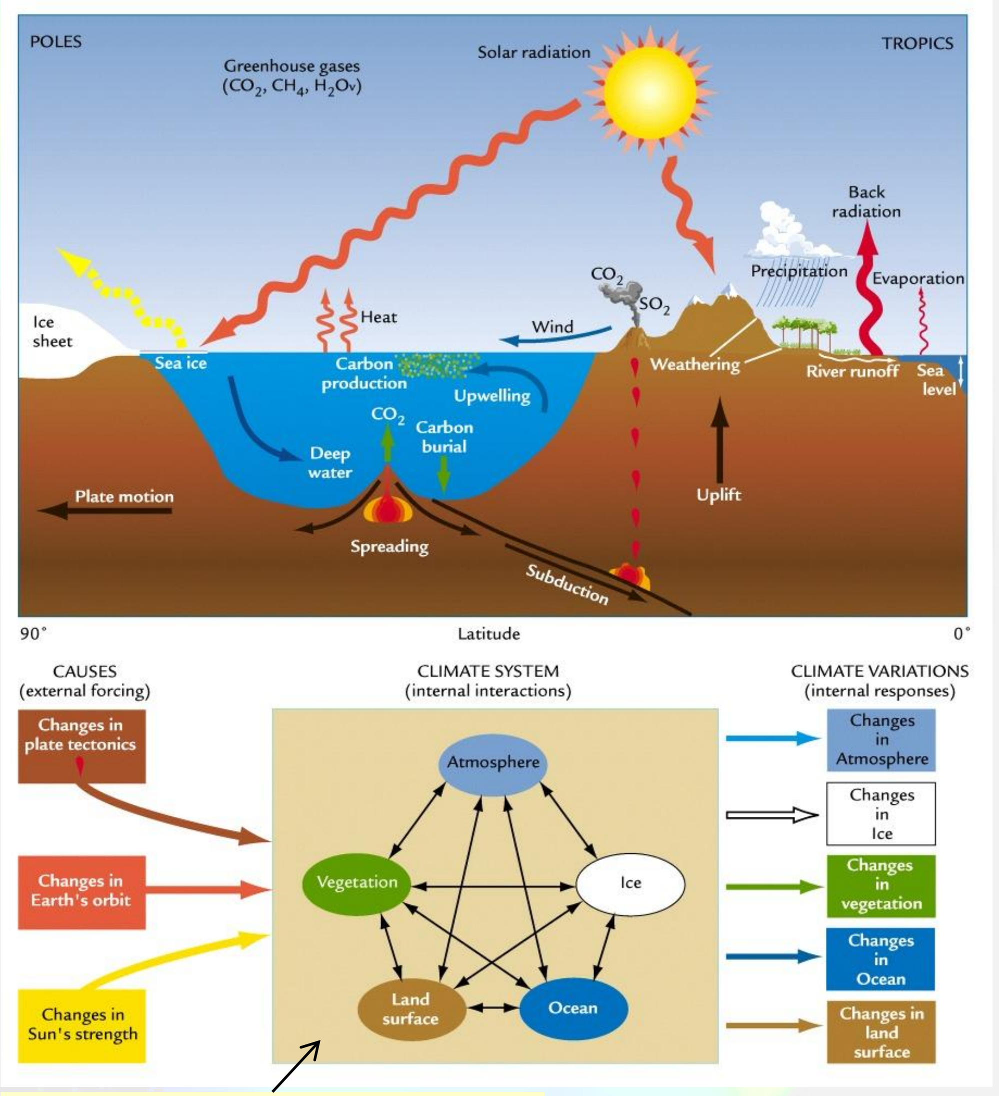


Download or order posters of this at http://cpo.noaa.gov/warmingworld/

Forcing and Response in the Earth's Climate System

- Forcings
  - Natural
    - Plate tectonics
    - Orbital cycles
    - Solar radiation
  - Human-caused
    - Increased greenhouse gases
    - Land use changes

- Responses: Changes to…
  - Atmosphere
  - Sea and land ice
  - Vegetation
  - Ocean
  - Land surface

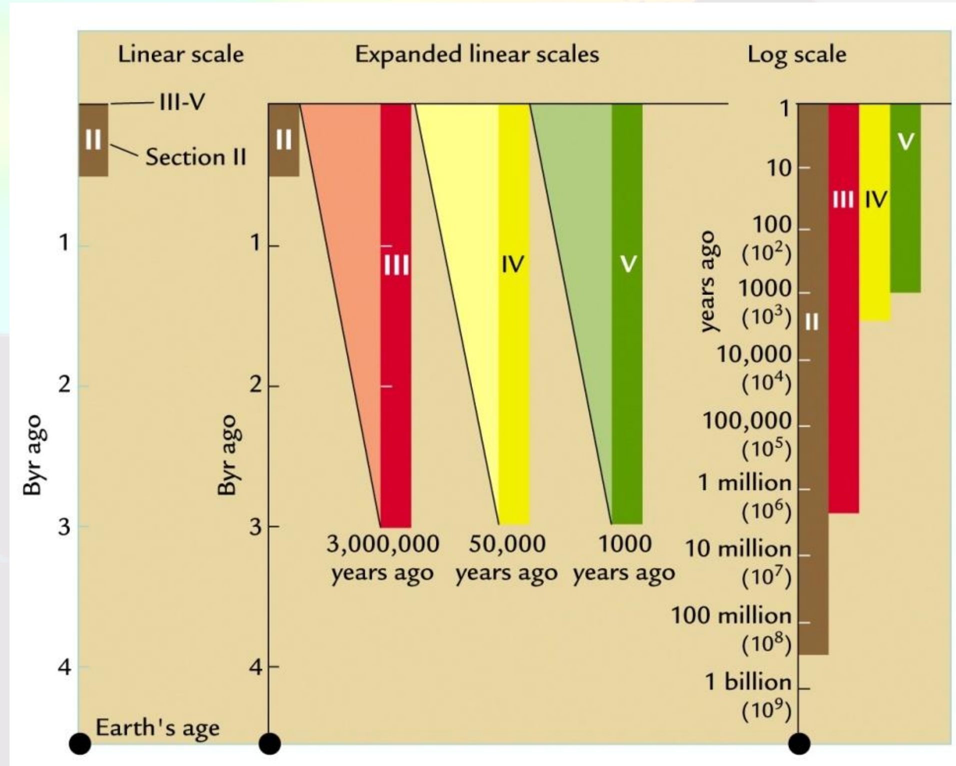


Changes in atmospheric composition, land use

Source: Ruddiman

Earth's Deep History

- Earth: 4.55 billion years old (and counting!)
  - Considerable uncertainty about the first 4 billion years
- Controls on climate have included:
  - Tectonic activity
  - Orbital cycles
  - Solar irradiance
  - Changes in atmospheric composition (especially CO_2)



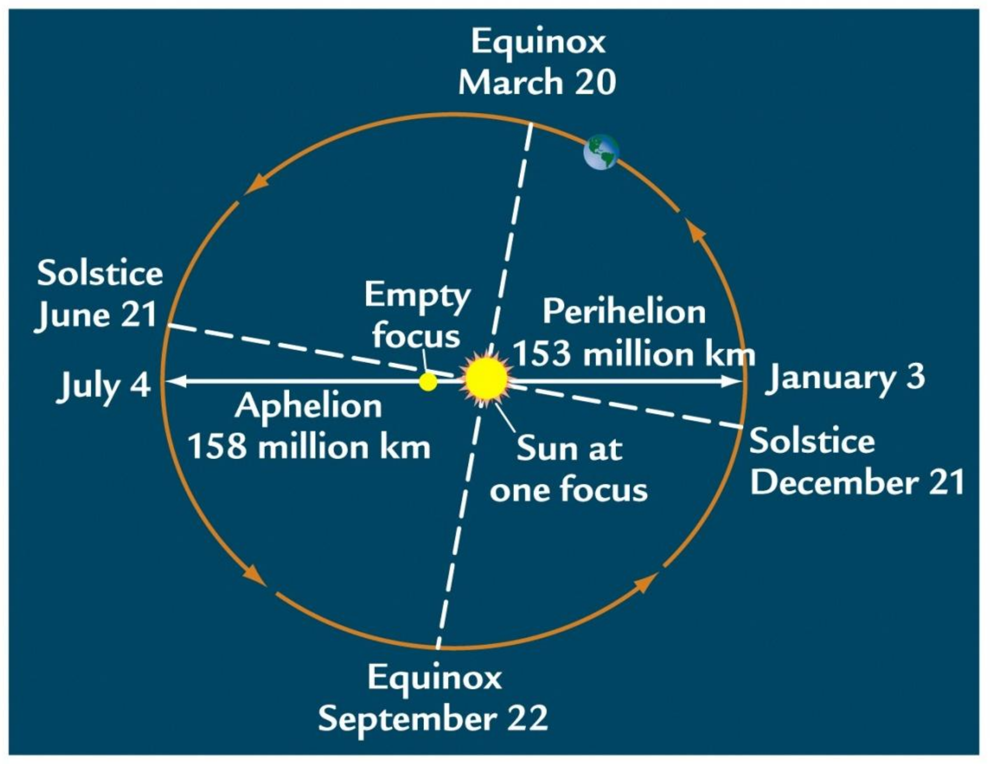
Time scales of climate change:

- II: Tectonic scale
- III: Orbital scale
- IV: Deglacial/millenial scale
- V: Historical scale

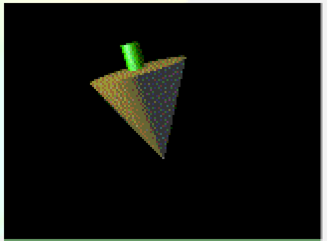
Source: Ruddiman

Earth's Orbit: Astronomy 101

- Elliptical orbit (not a perfect circle).
  - Shape changes on time scales from hundreds of thousands to millions of years, from more circular to more oval.
- Earth's position in the orbit relative to distance from the sun also changes, on a time scale of about 23,000 years.
- Tilt of Earth's axis changes, and direction the axis points also wobbles… like a spinning top that's slowing down.
- Combination of above factors: "Milankovitch cycle"
- Current orbital cycle:
  - More circular than oval-shaped
  - Winter solstice occurs when Earth is closer to the sun
    - Higher solar radiation
  - Summer solstice occurs near the farthest distance from the sun
    - Lower solar radiation
  - Common misconception that winter is because Earth is farther from the sun than summer. We know that seasons are caused by ___.

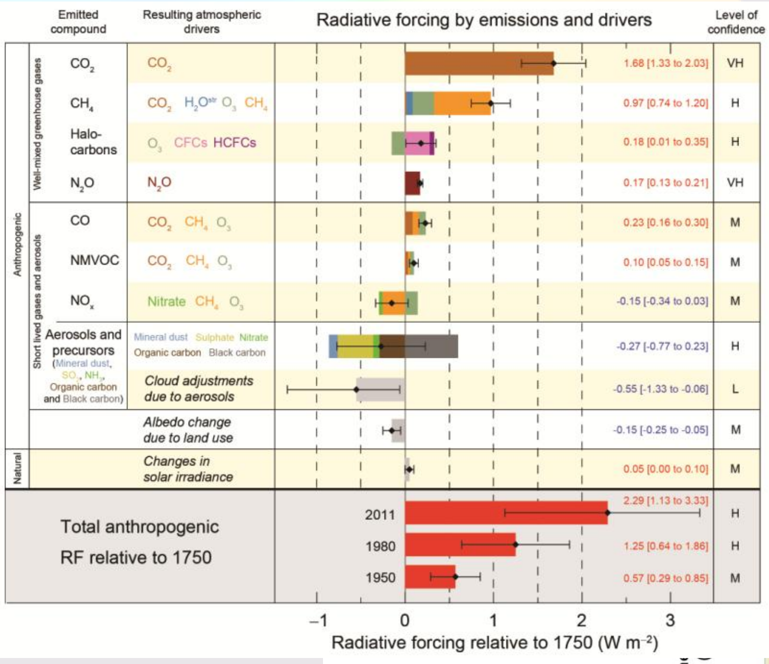


Source: Ruddiman



Source: NASA

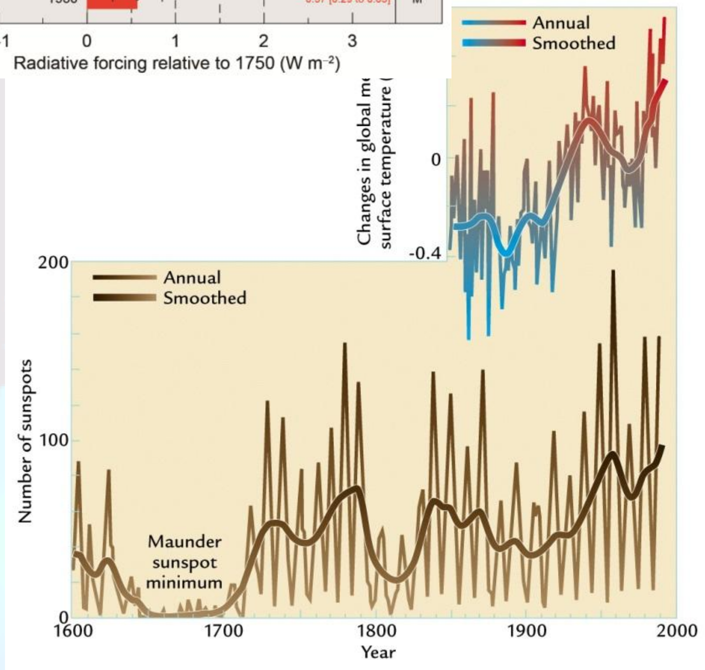
Sunspots and Solar Output Changes



Source: IPCC AR5

- Records from 1600 A.D. to present
- Sunspots: areas of intense magnetic activity
  - Visible dark spots on the Sun's surface
  - Correlates to solar radiation
- 11-year irradiance cycle
- Maunder Minimum
  - 1645-1715 A.D.
  - Very low sunspot activity
- Increasing activity could have increased temperatures by 0.07-0.2 °C in the 20th Century

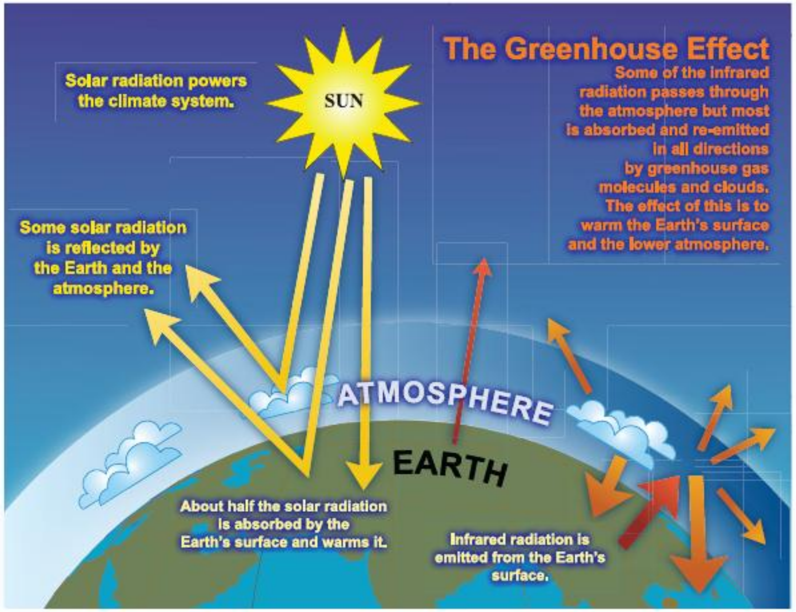
- Overall not believed to be a major player in climate change.



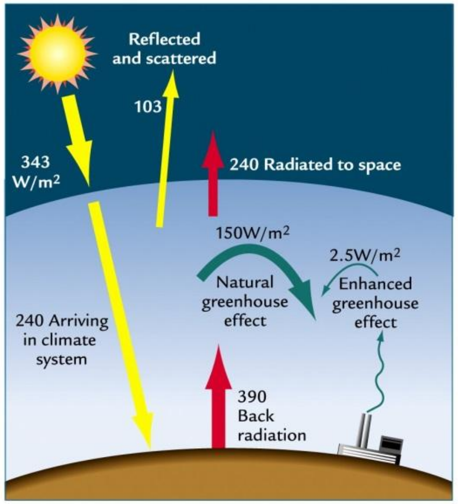
Source: Ruddiman

The Greenhouse Effect

- Gases in the Earth's atmosphere, like carbon dioxide (CO_2) and water vapor (H_2O), absorb and radiate energy (heat), which warms the Earth.
- Without a natural greenhouse effect, the temperature of the Earth would be about 0°F (-18°C) instead of its present 57°F (14°C).
- So, the concern is not with the fact that we have a greenhouse effect, but that human activities are leading to an *enhancement* of the greenhouse effect.



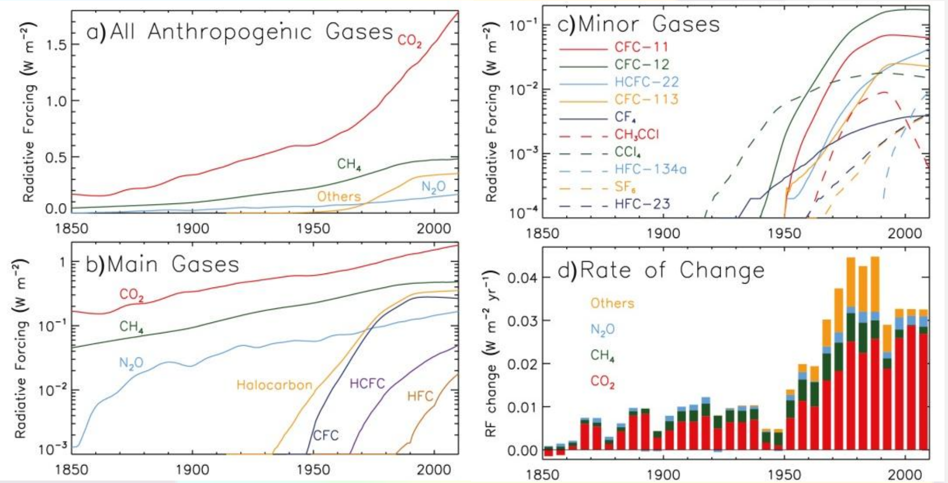
Source: IPCC AR4



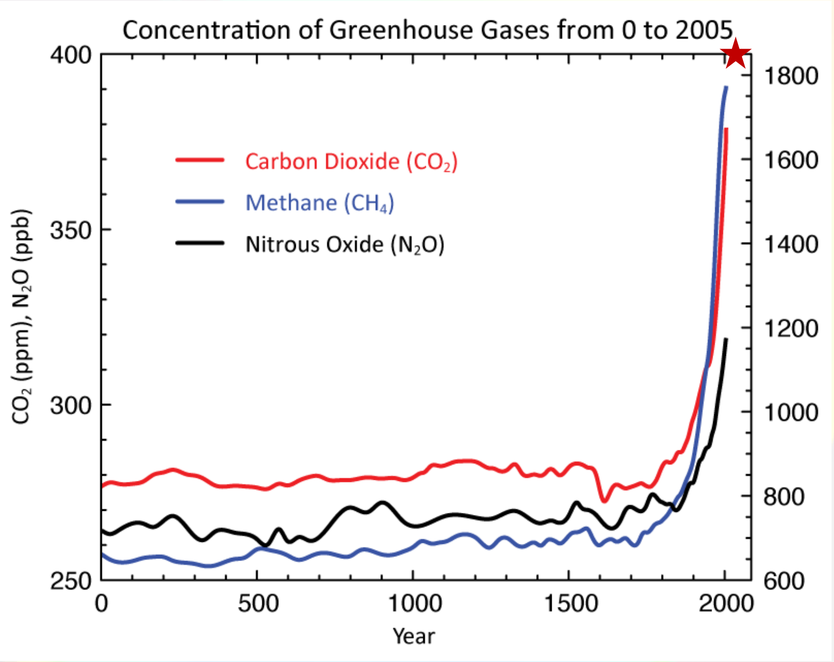
Source: Ruddiman

Primary Greenhouse Gases

- Water Vapor (H_2O)
  - Most abundant
  - Difficult to measure – short residence time (days) in atmosphere, unevenly distributed
  - Natural positive feedback loop: warming leads to more evaporation which leads to more water vapor and more potential warming
  - Clouds can regulate this feedback in a complex way
- Carbon Dioxide (CO_2)
  - Second most abundant
  - Longer residence time (years) and well-mixed
  - Strong impacts due to combination of abundance and radiative properties
  - Naturally produced and absorbed through the terrestrial biosphere and the ocean
  - Values have increased 43% since the industrial age began due to human activity.
- Methane (CH_4)
  - Lower concentration
  - Very strong effects
  - Residence time (years to decades)
  - Also produced both naturally and by human activities
- Other important gases include nitrous oxide (N_2O), tropospheric ozone (O_3), and CFCs.



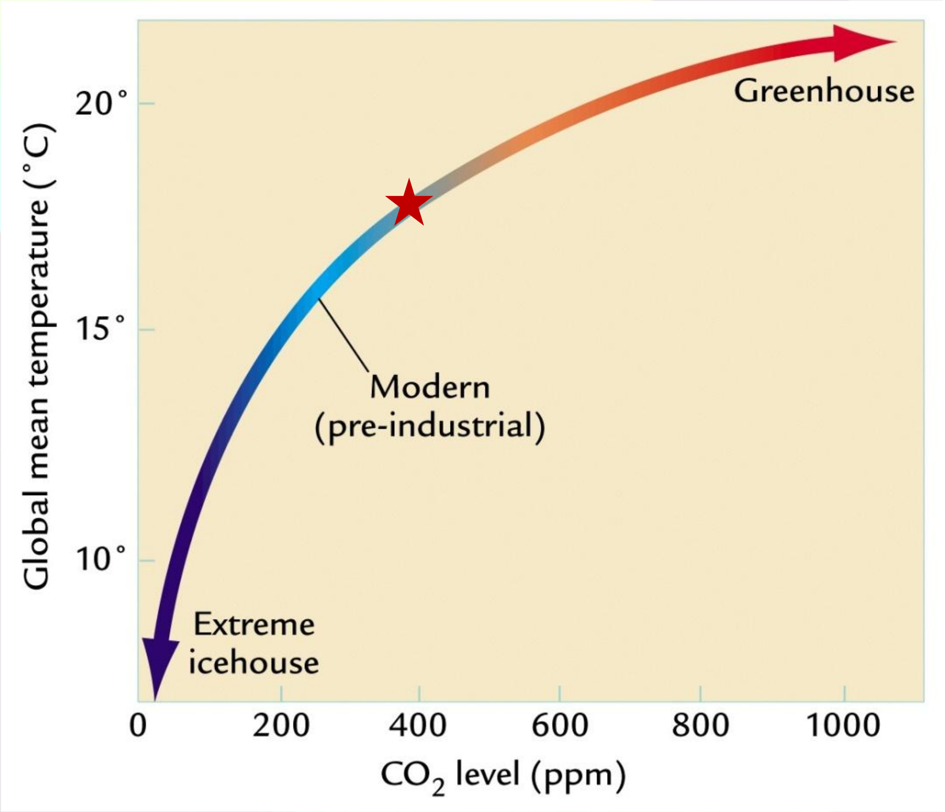
Source: IPCC AR5



Source: IPCC AR4

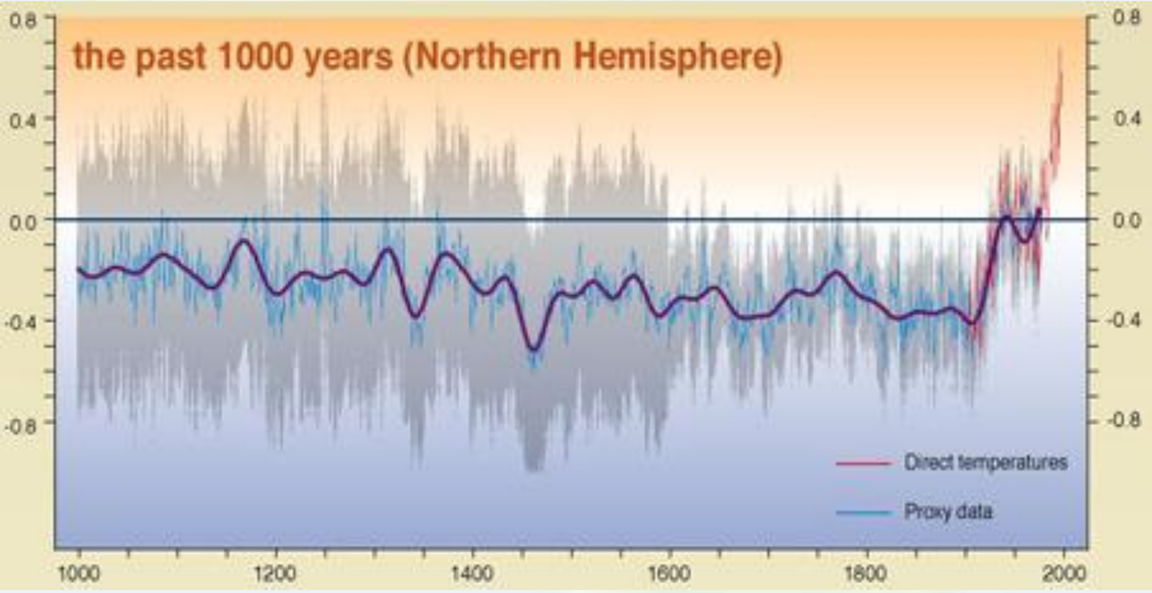
Sensitivity of Global Temperature to CO_2

- Earth's temperature most sensitive at low CO_2 concentrations
  - Snow and ice feedback
    - High albedo
  - At low CO_2, extent changes significantly
  - At high CO_2, once ice and snow are melted, further warming changes albedo very little
- Large ice sheets cannot exist with CO_2 concentration exceeding 1000 ppm
  - Demonstrated by sensitivity tests



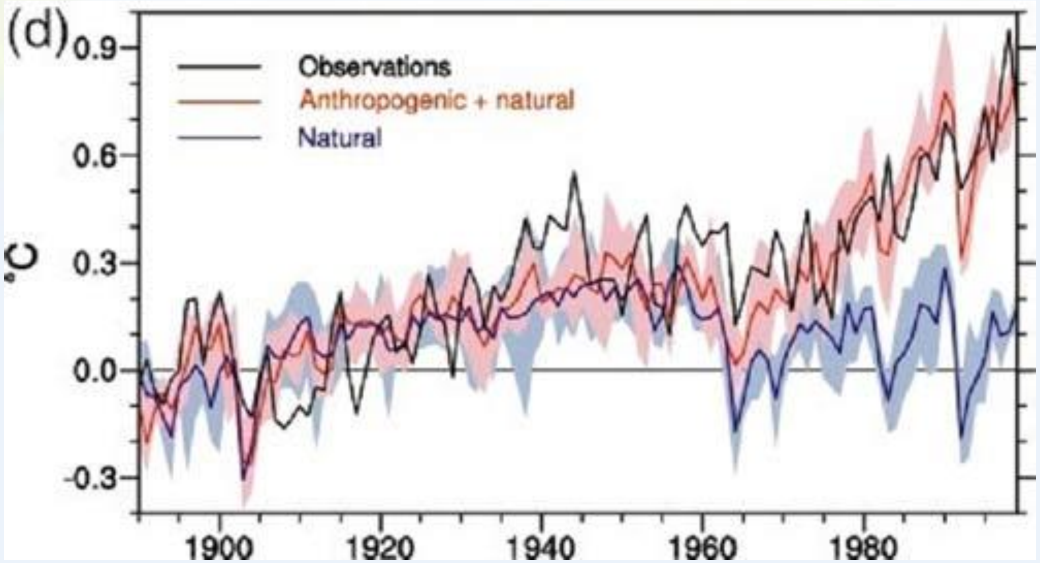
Source: Ruddiman

What We Know: Temperatures Increasing Because of CO_2



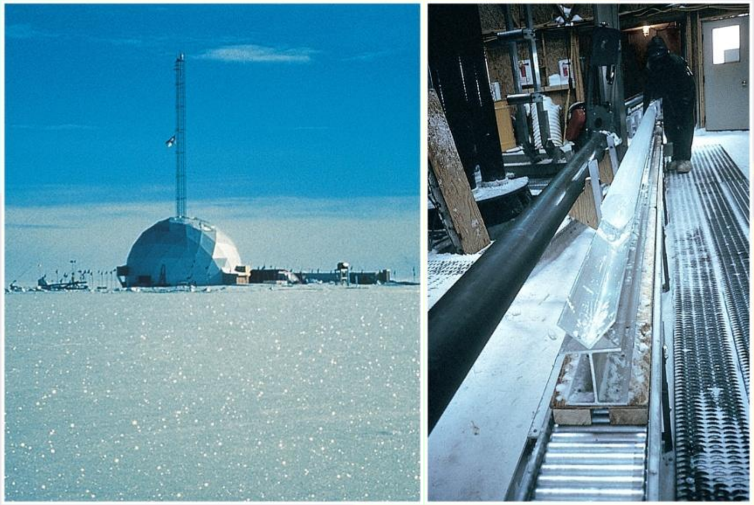
Temperature over the past 120 years. Black line is observed. Blue area is modeled with only natural forcing. Pink area is modeled with both human and natural forcing.

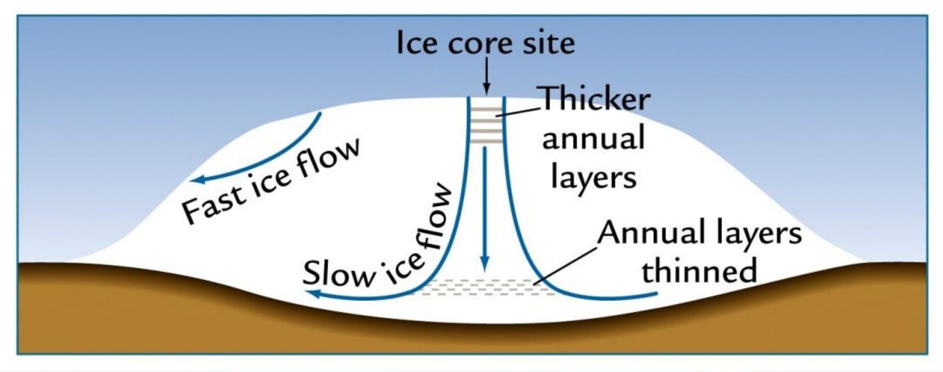
Temperature over the past 1000 years. Gray area is the range of possibilities. Blue line is based on "proxy" data (tree rings, corals, etc.). Red line is based on temperature measurements.



Ice Core Records

- Data in cores includes:
  - Atmospheric composition (air bubbles trapped in ice): CO_2, methane (CH_4), sulfates, nitrates, chlorides
  - Oxygen isotope $\delta^{18}O$ (proxy to temperatures)
  - Deposits of dust, ash
- Greenland
  - Well over 100,000 years of record
  - More than 20 °C warming since last glacial maximum
- Vostok, Antarctica
  - 800,000 years of record

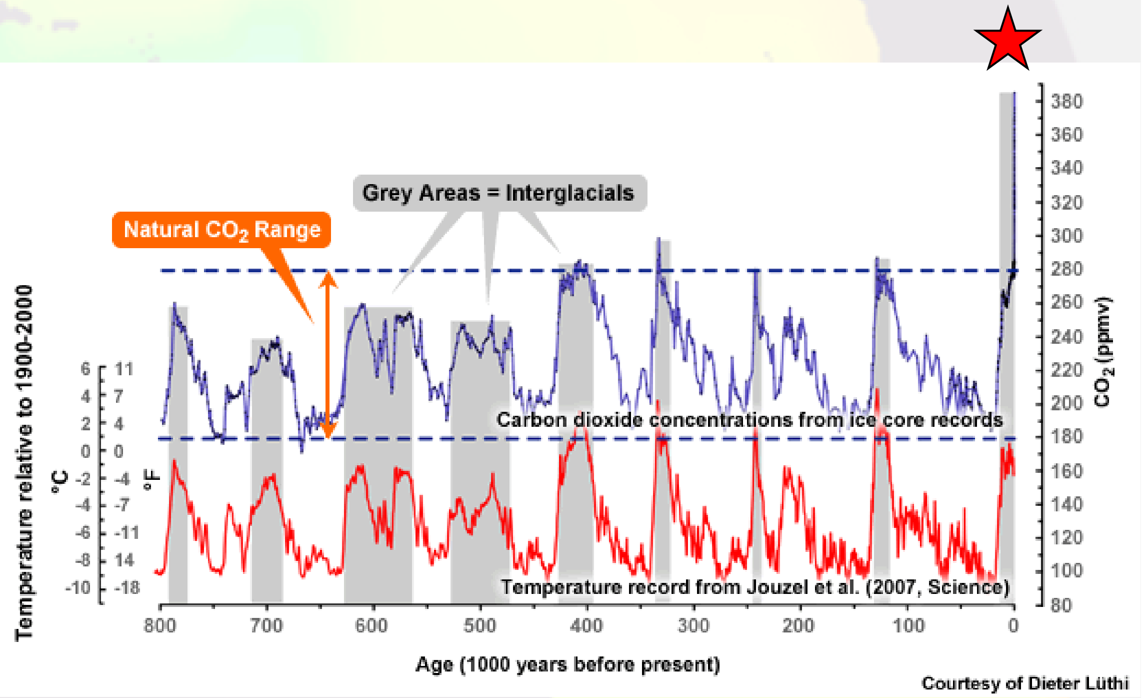




Source: Ruddiman

Carbon Dioxide (CO_2) and Global Temperature

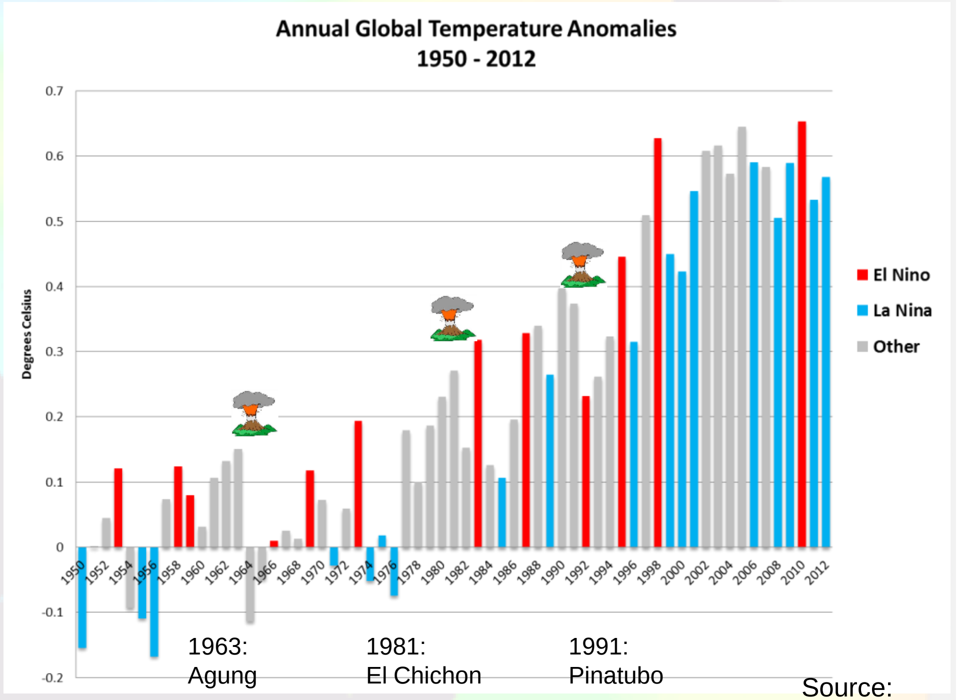
- Which changes first – carbon dioxide or temperature?
  - Both
  - Expected to correspond well if Earth is in radiative balance
  - Oceans store both heat and CO_2
  - CO_2 is not the only climate forcing
- Carbon dioxide changes can cause (lead) temperature changes
  - Energy balance of Earth changes
  - Extra greenhouse gas effect causes extra warmth
- Temperature changes can cause (lead) carbon dioxide changes
  - More complex, not as well understood
- Not a simple cause-and-effect relationship
  - Vegetation
  - Glaciation and ice sheet extent
  - Land surface characteristics



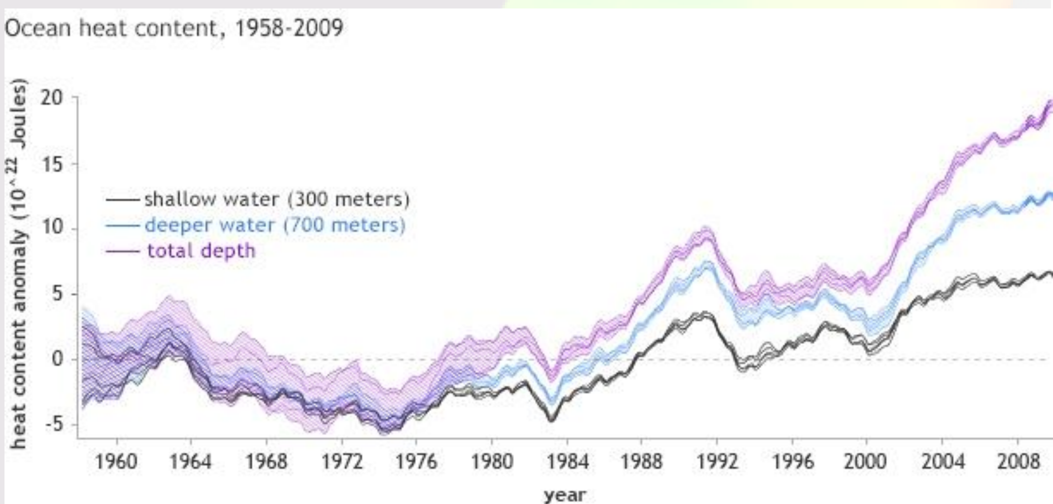
Source: NOAA
http://www.ncdc.noaa.gov/paleo/globalwarming/temperature-change.html
Source: GOES-R
http://www.goes-r.gov/education/comet/broadcastmet/climate/print.htm
Source: COMET
http://www.esrl.noaa.gov/gmd/ccgg/trends/history.html

The Instrumental Records

- Surface records
  - Dominated by North America and by land
  - Global average temperature increasing
    - +0.6 °C in the 20th Century
    - +0.75 °C from 1900-2009
    - 2000-09 warmest decade on record
    - Generally cooler in La Niña years than El Niño years
- Ocean records
  - Temperatures increasing at all depths



Source: NCDC

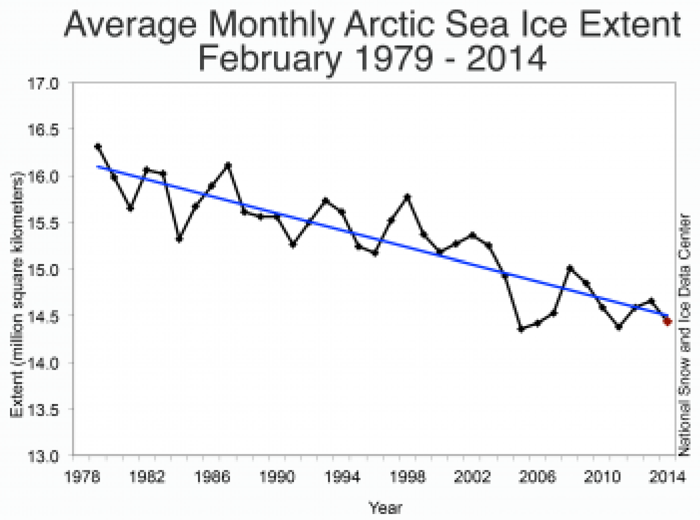


Other Signals: Ice

- Arctic sea ice has decreased by a rate of about 2.7%/decade.
- Antarctic sea ice extent has trended upward.
  - Why the difference?
  - Southern Ocean sea surface and surface air temperatures are warming
  - Antarctic land ice is decreasing
  - Decreasing ozone levels have caused increased winds around the Antarctic continent, which pushes sea ice around, leaving open areas that can be frozen into additional sea ice
  - Surface layer of water in the Southern Ocean is freshening due to increased snow and rain in the region as well as increased melting of Antarctic land ice

Alaska's Muir Glacier

August 13, 1941 **August 31, 2004**

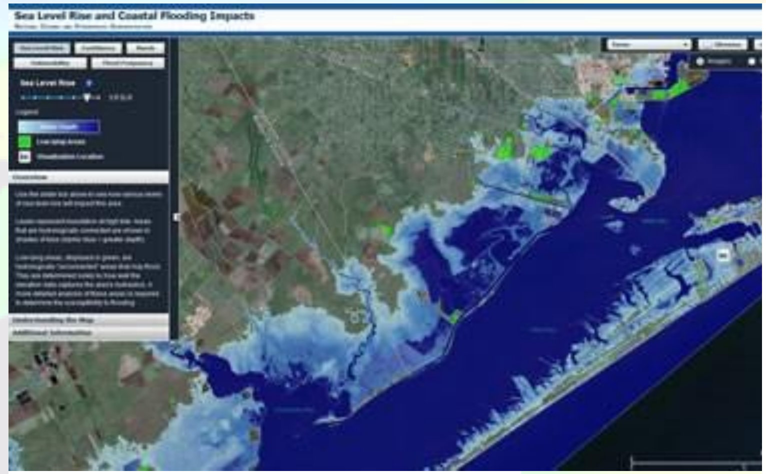


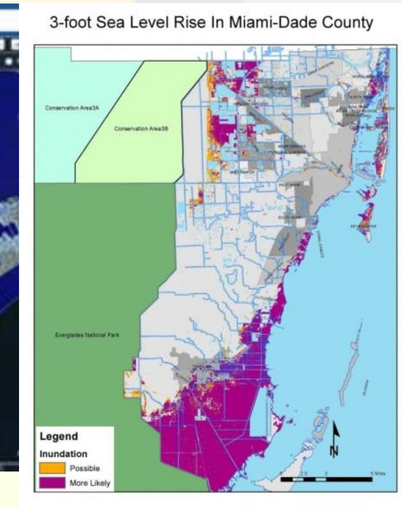
Source: NSIDC

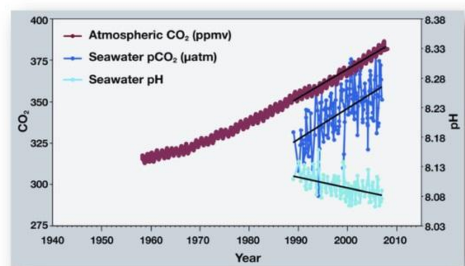
Other Signals: Sea Level and Chemistry

- Sea level rise
  - Water expands when heated
  - Fresh water runs off from melting land ice
  - Sea level trending higher just about everywhere (regional differences, just like with surface air temperature)

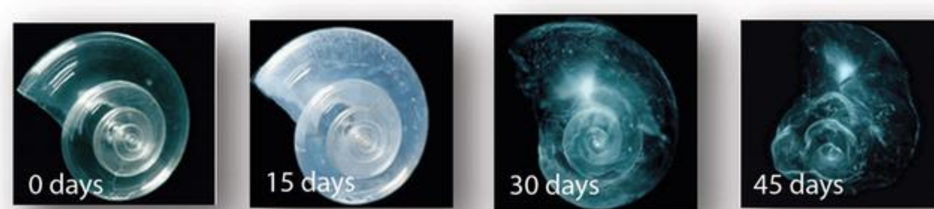
- Ocean acidification
  - Oceans absorb carbon dioxide. Chemical reaction with water produces carbonic acid.
  - Affects calcium carbonate in marine life
  - Causes coral bleaching
  - Causes weakening of shells and skeletons of some sea creatures







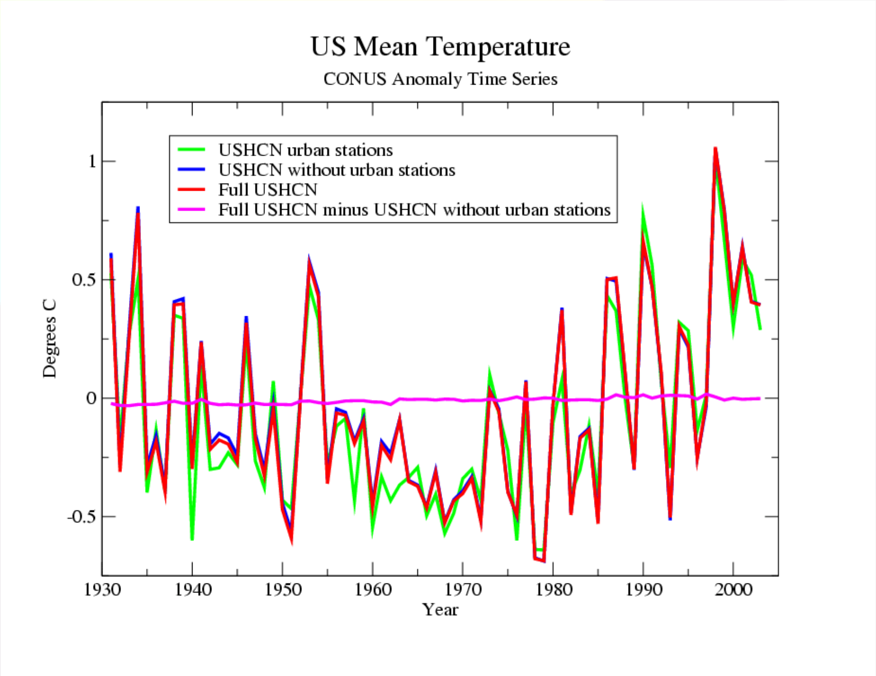
This graph shows the correlation between rising levels of carbon dioxide (CO_2) in the atmosphere at Mauna Loa with rising CO_2 levels in the nearby ocean at Station Aloha. As more CO_2 accumulates in the ocean, the pH of the ocean decreases. (Modified after R.A. Feely, Bulletin of the American Meteorological Society, July 2008)



Source: NOAA

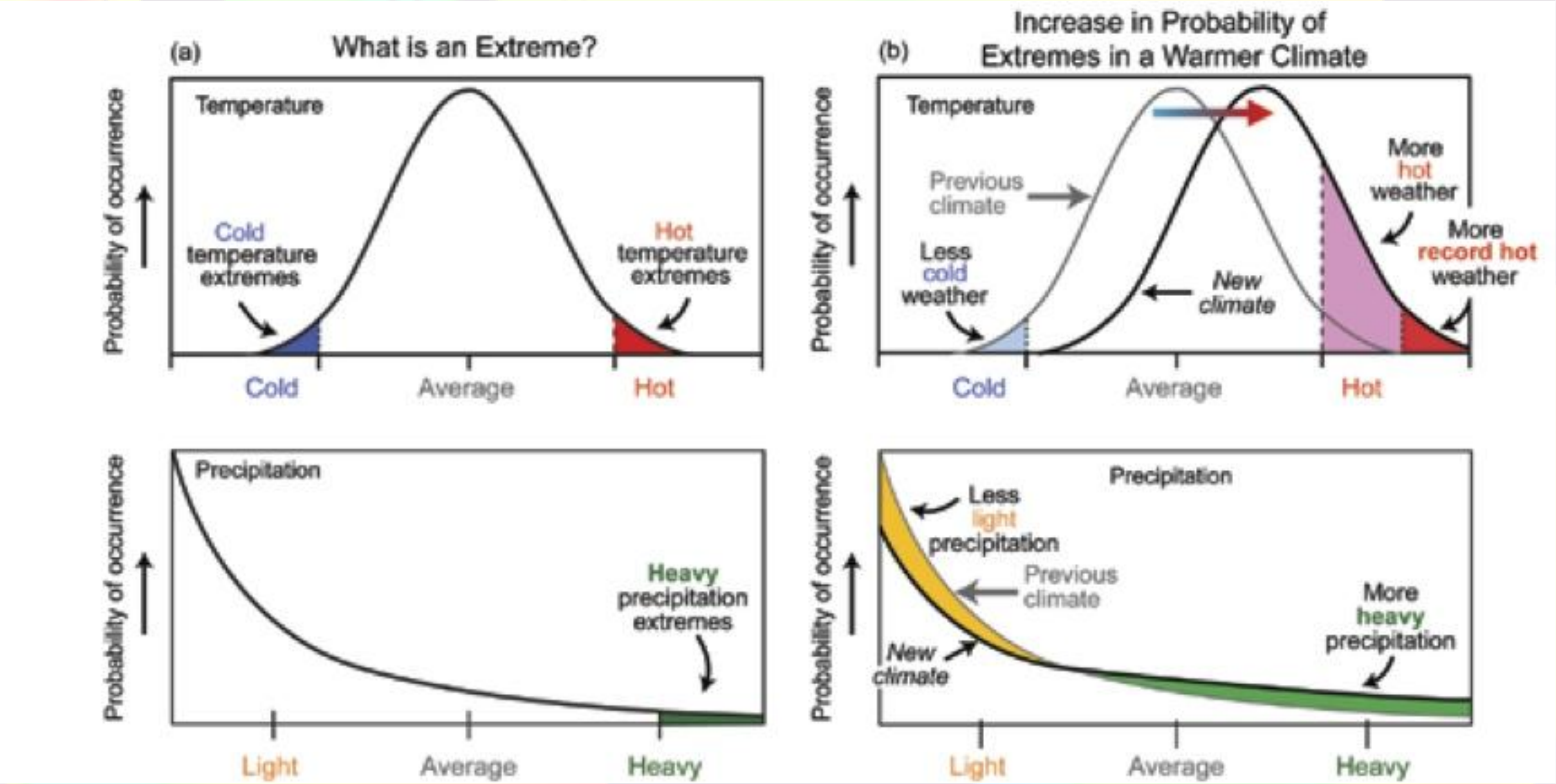
Isn't the temperature data tainted by changing stations and by the urban heat island effect?

- The urban heat island effect is allowed for both by excluding as many affected sites as possible from the global temperature data and by increasing the error range.
- The error range decreases due to improvements in data quality and inclusion of satellites and other high quality data sources.
- Main temperature analysis is done with anomalies.



- Ocean data has no urban effect and shows warming
- Increasing temperatures supported by:
  - Plant bloom dates
  - Lake/river freeze/thaw dates
  - Glaciers melting
  - Etc.

Extreme Events

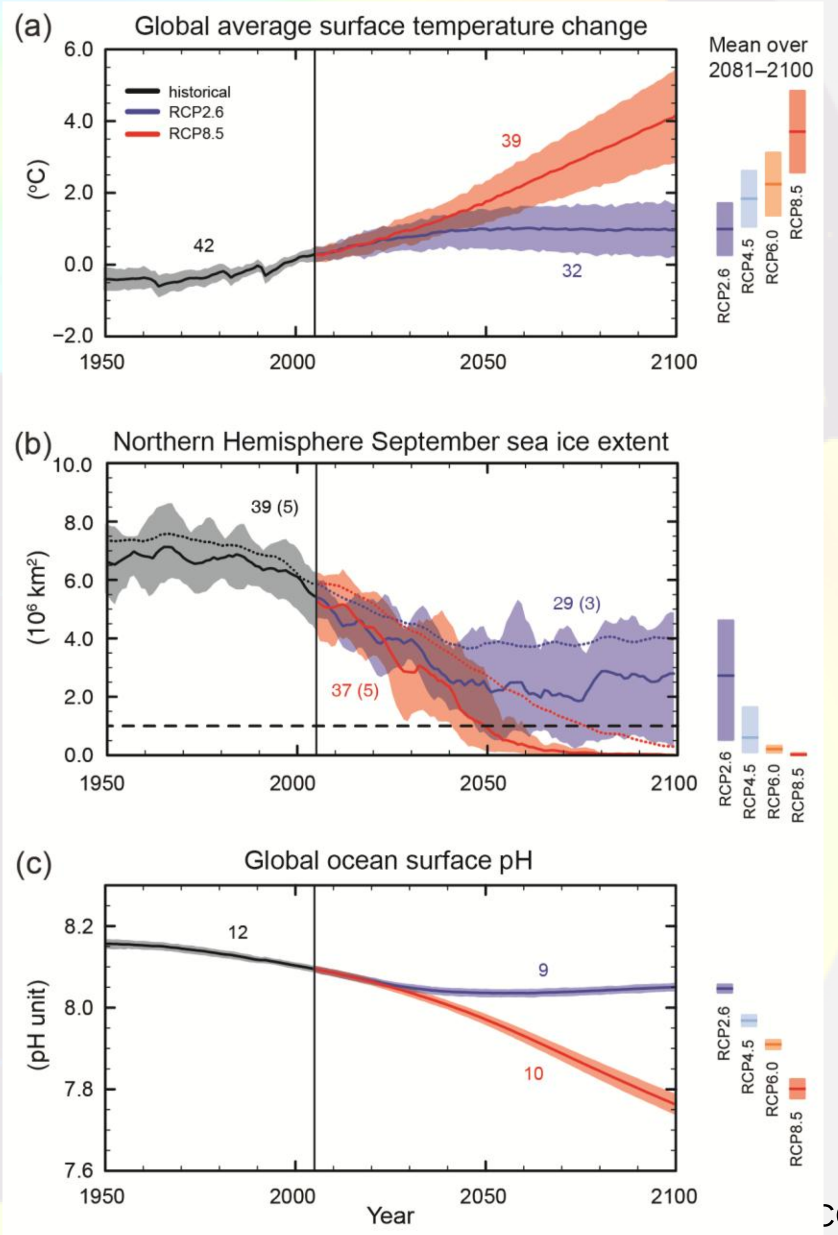


Source: IPCC AR5

Climate Change Projections

- Best estimate projections through the year 2100 for global surface temperature increases:
  - Lowest scenario: ~1.4 °C
  - Highest scenario: ~4.0 °C

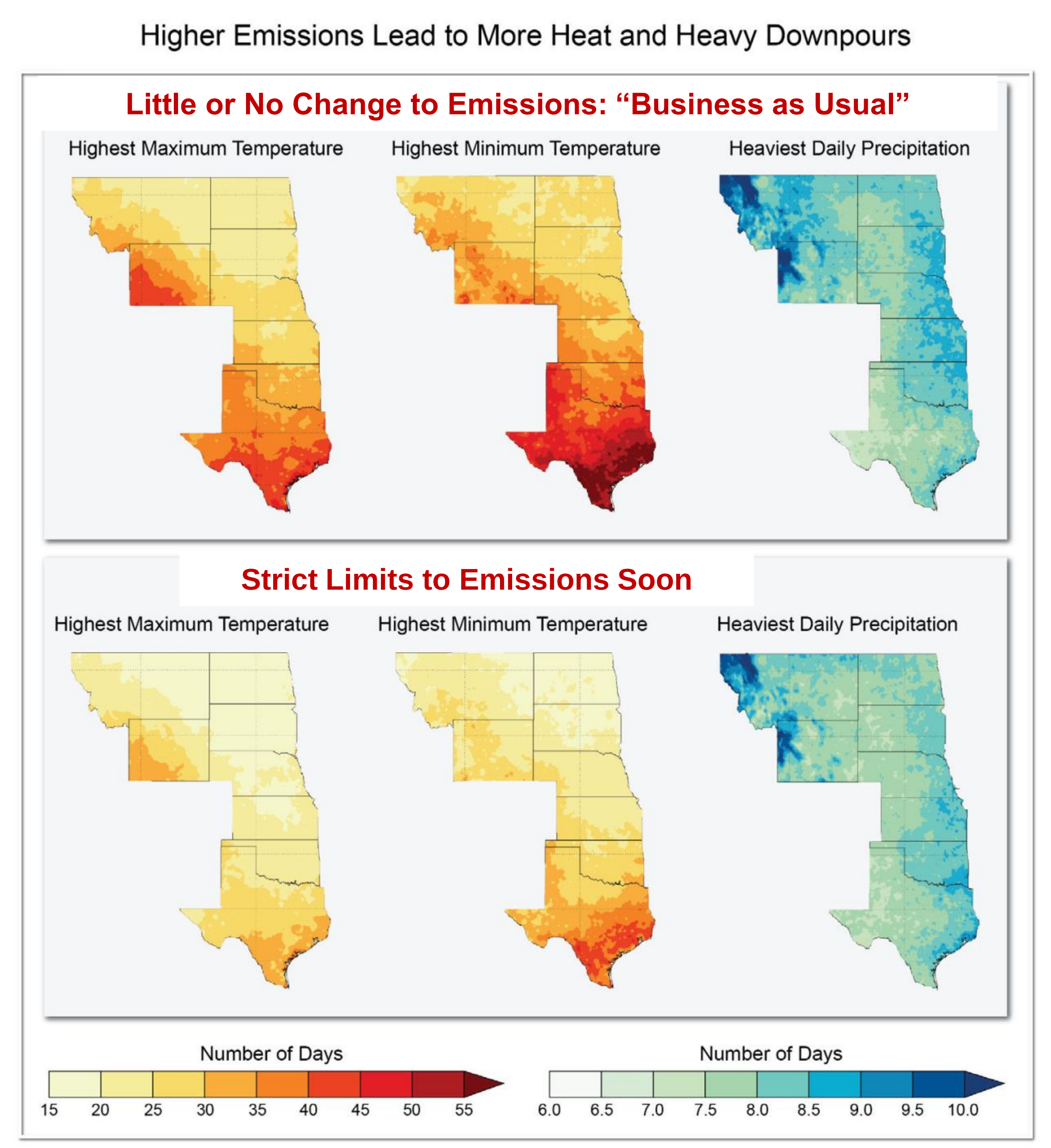
- Error bars go in both directions – toward both smaller and bigger changes than the middle



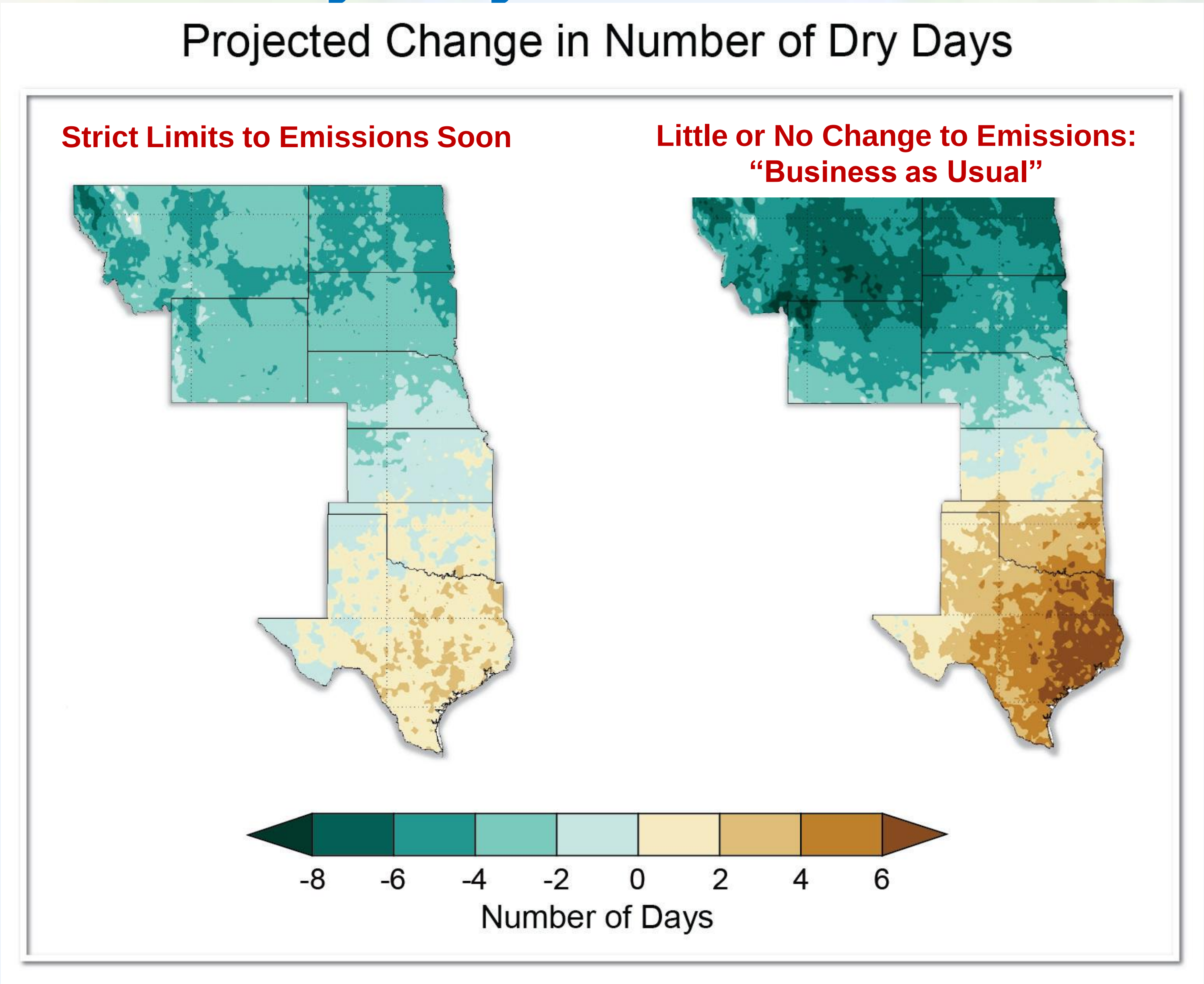
CC AR5

Climate Change:
Temperatures and Precipitation Increase

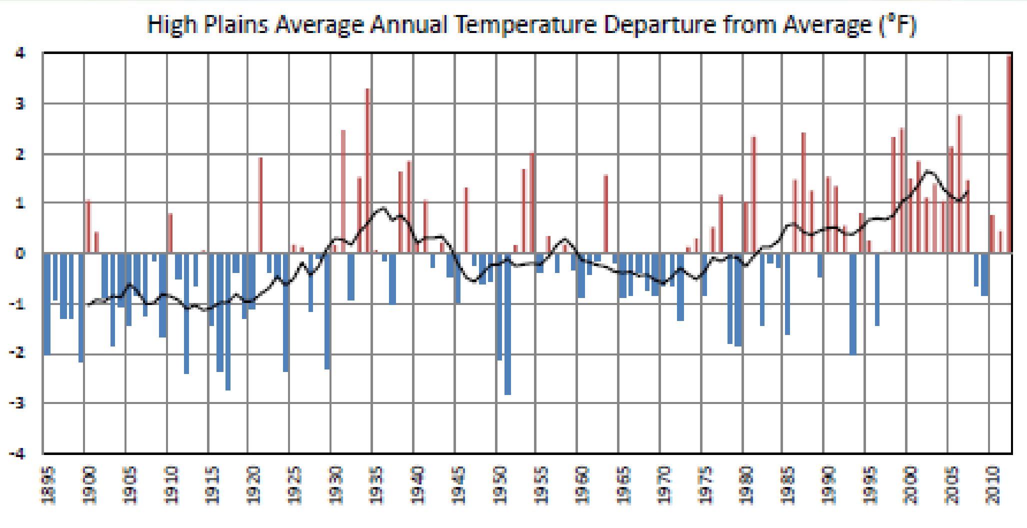
- Projections of changes in temperatures and days with precipitation in 2041-2070.
- Temperature changes depend on:
  - Time of day
    - Night warming faster than day
  - Time of year
    - Winter warming faster than summer
- Precipitation changes:
  - Depends on time of year
    - Spring increasing, fall decreasing
  - May include both longer droughts and more heavy rain events



Climate Change: Dry Days Decrease



Climate Change: Temperatures Already Rising

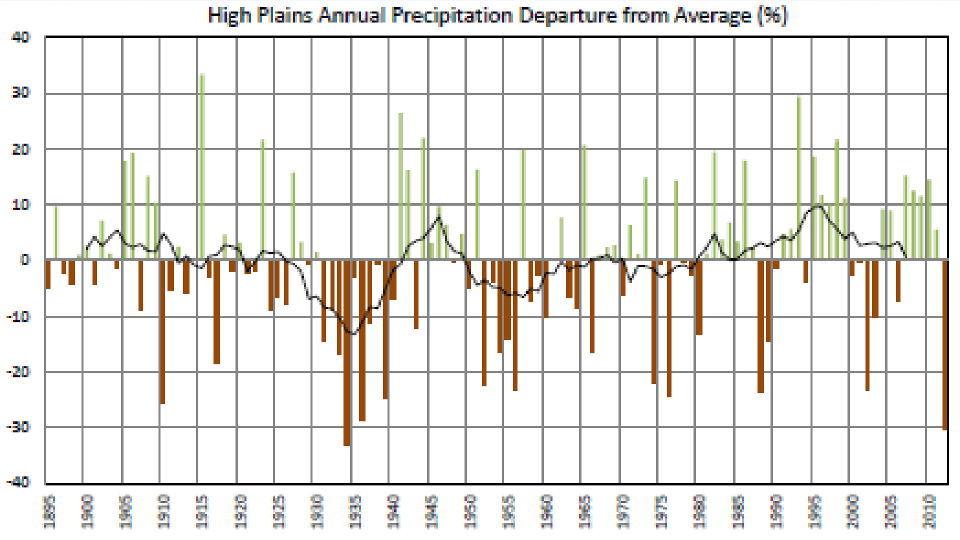


Statewide Average Temperature Change by Season (1895-2012) Temperature in degrees F				
State	**Spring**	**Summer**	**Autumn**	**Winter**
North Dakota	2.6	2.0	1.5	5.5
South Dakota	2.2	1.8	1.1	4.2
Nebraska	1.8	1.0	0.0	2.0
Kansas	1.7	1.0	-0.1	2.2
Wyoming	3.0	2.5	1.0	1.3
Colorado	2.0	1.1	0.4	1.9
Average	2.2	1.6	0.7	2.9

Departure of annual average temp. in the High Plains from the 118-year average

Source: High Plains Regional Climate Center

Climate Change: Precipitation Already Rising



Statewide Annual Climate Trends (1895-2012)

Temperature in degrees F, Precipitation in percent

State	Average Temperature	Maximum Temperature	Minimum Temperature	Precipitation
North Dakota	2.9	2.5	3.4	6%
South Dakota	2.4	1.6	3.2	3%
Nebraska	1.3	0.6	1.9	2%
Kansas	1.3	0.9	1.7	5%
Wyoming	2.0	2.7	1.3	-13%
Colorado	1.5	1.5	1.4	-1%
Average	1.9	1.6	2.2	1%

Departure of annual precipitation in the High Plains from the 118-year average

Source: High Plains Regional Climate Center

The Future…

- Global temperature increase of ~1.4-4.0 °C by 2100
- *Virtually certain* that extreme cold days and nights will be warmer and occur less often.
- *Virtually certain* that extreme hot days and nights will be warmer and occur more often.
- *Very likely* that frequency and duration of heat waves will increase.
- *Very likely* that heavy precipitation events (frequency, intensity, and/or amount) will increase over mid-latitude land areas and in wet tropical regions.
- *Likely* that drought will increase in duration and/or intensity.
- *More likely than not* that intense tropical cyclone activity will increase in the North Atlantic and Western North Pacific
- *Very likely* to have increased incidence/magnitude of extreme high sea level.

Links and Resources

National Weather Service, Omaha/Valley NE: http://www.crh.noaa.gov/oax/

NOAA Climate Services: http://www.climate.gov/

NOAA National Climatic Data Center: http://www.ncdc.noaa.gov/oa/ncdc.html

Global Change Impacts in the U.S.:
http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

International Panel on Climate Change: http://www.ipcc.ch/

HPRCC Climate Change: http://www.hprcc.unl.edu/climate_change.php

HPRCC "Climate Change on the Prairie":
http://www.hprcc.unl.edu/publications/files/HighPlainsClimateChangeGuide.pdf

USDA Plant Hardiness Zones: http://www.ars.usda.gov/is/pr/2012/120125.htm

For More (Local) Climate Info:

- David Pearson, National Weather Service in Omaha/Valley, Nebraska:

  david.pearson@noaa.gov or (402) 359-5732

- Dr. Barb Mayes Boustead, National Weather Service in Omaha/Valley, Nebraska: barbara.mayes@noaa.gov or (402) 359-5166

- High Plains Regional Climate Center in Lincoln, Nebraska: (402) 472-6706

Climate Change: Implications for Nebraska

CLINT ROWE

NEBRASKA SILVER JACKETS – CLIMATE CHANGE WORKSHOP

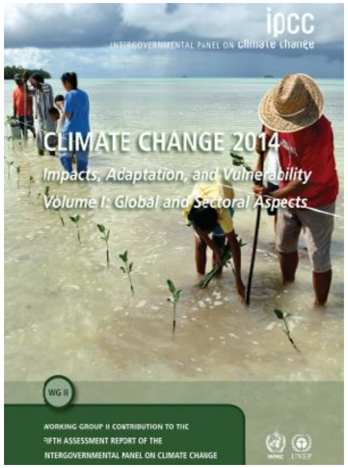
29 JULY 2015

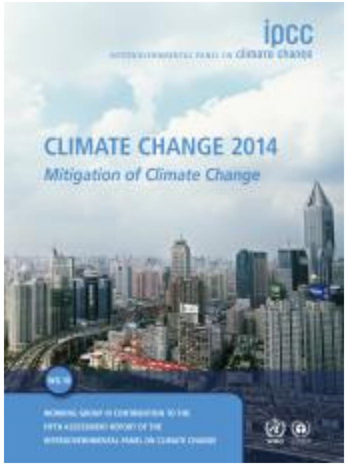
Introduction and Background

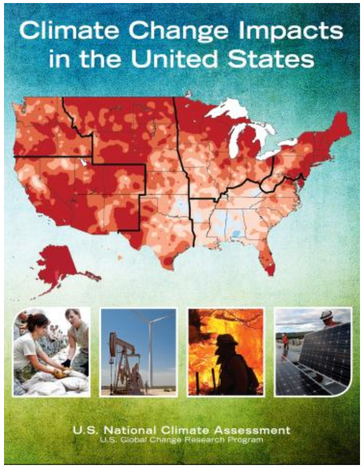
Report produced in response to legislation passed by the Nebraska Legislature.

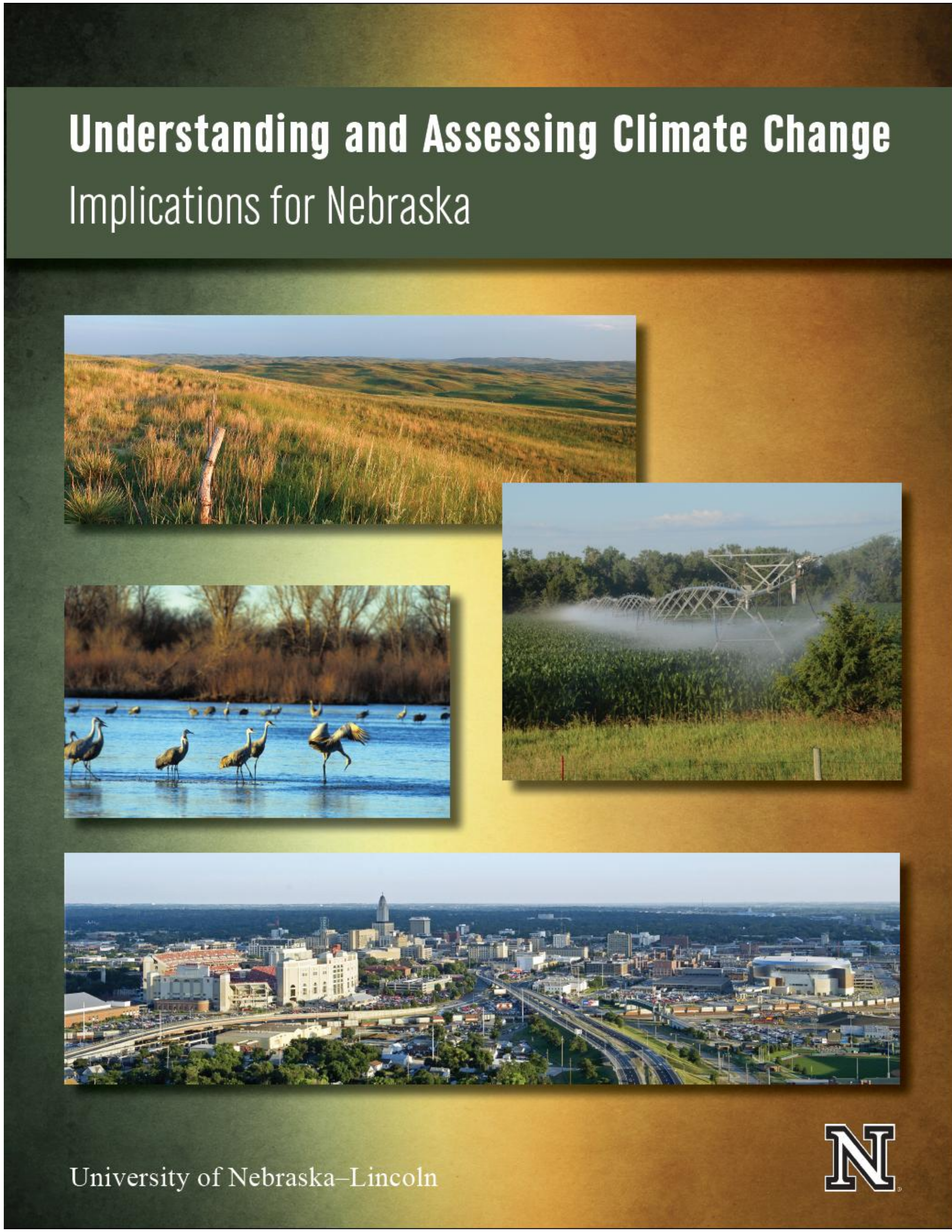
Review of available science to discern the implications for Nebraska

- IPCC Fifth Assessment Report (AR5), released Fall 2013 (Working group I) and Spring 2014 (Working groups II and III)
- Third National Climate Assessment (NCA), released Spring 2014









Report released in late September 2014

Lead Authors:

- Deb Bathke
- Bob Oglesby
- Clint Rowe
- Don Wilhite

More than a dozen other contributors from UNL, state and local agencies, NGOs

http://go.unl.edu/climatechange

Projections of future climates

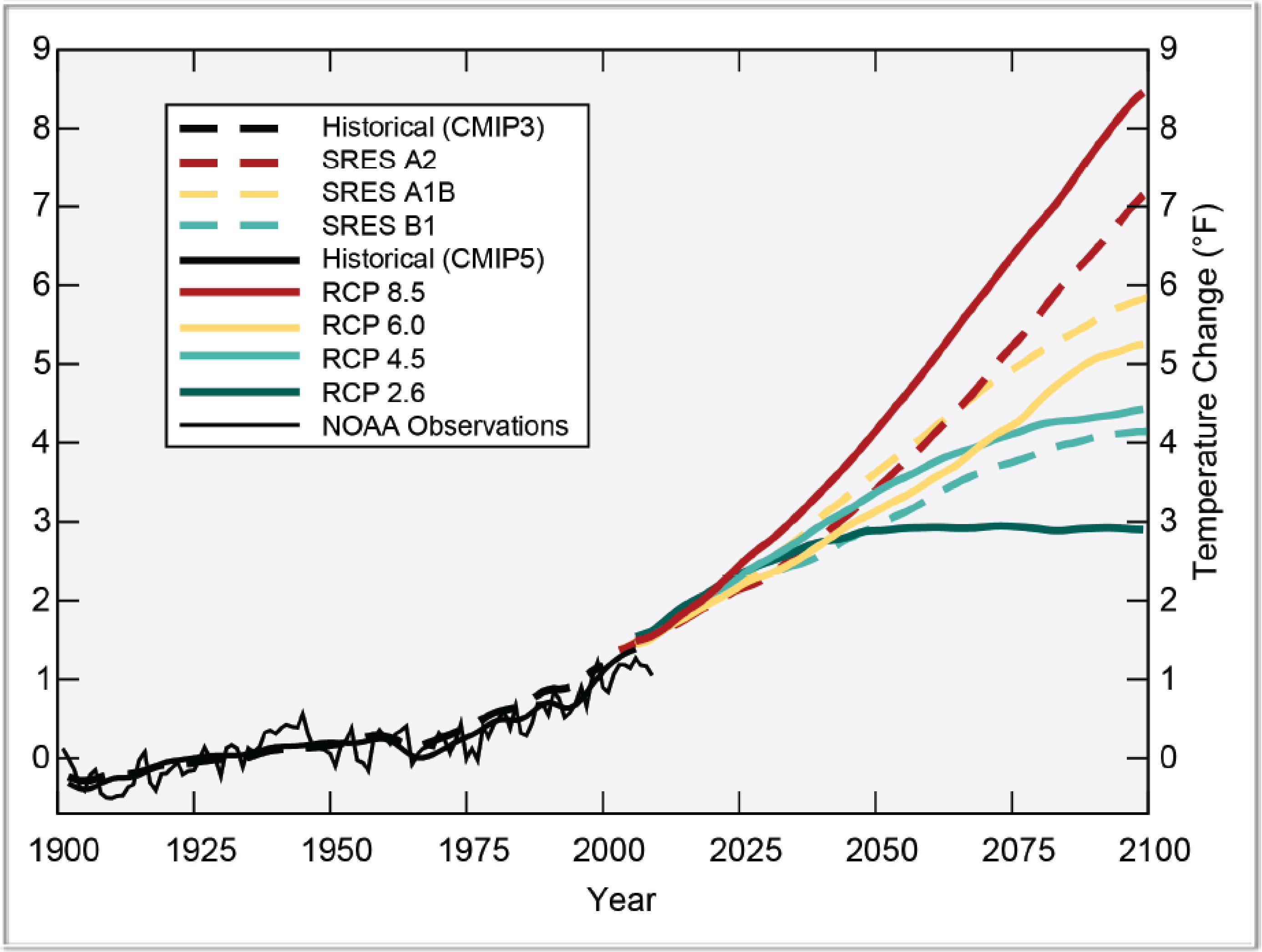
Global (average)

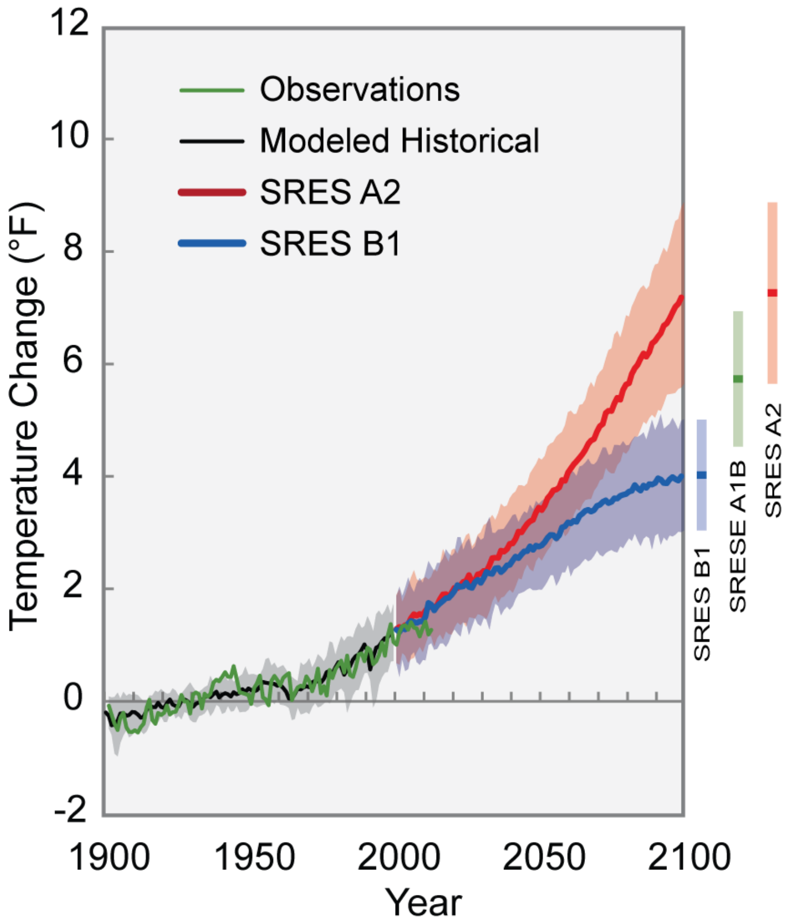
Global (geographic)

Regional

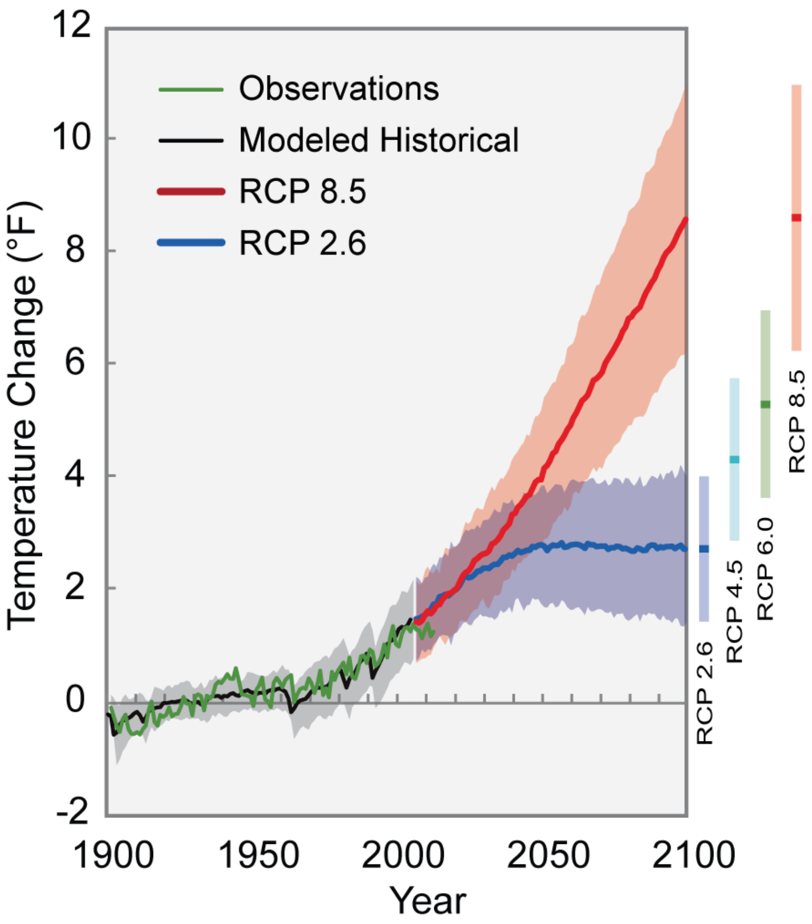
Local

Average Global Temperature Projections

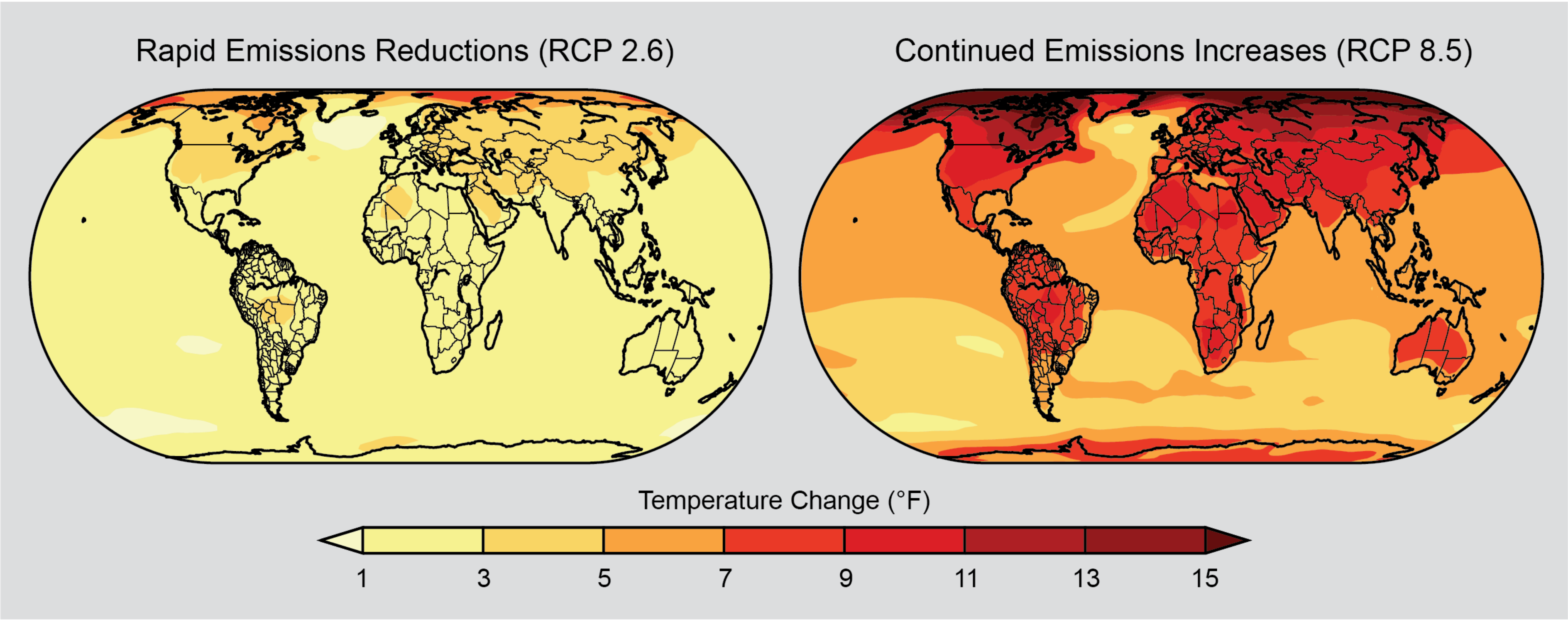


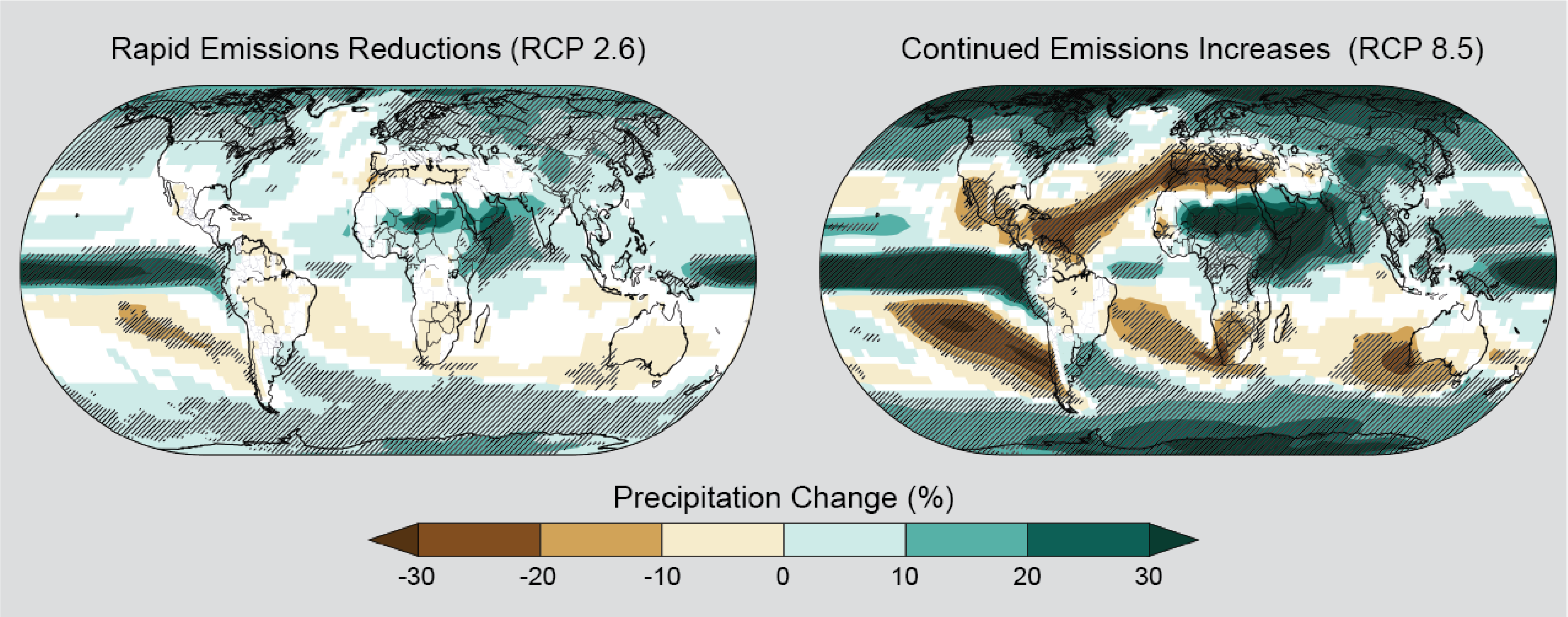


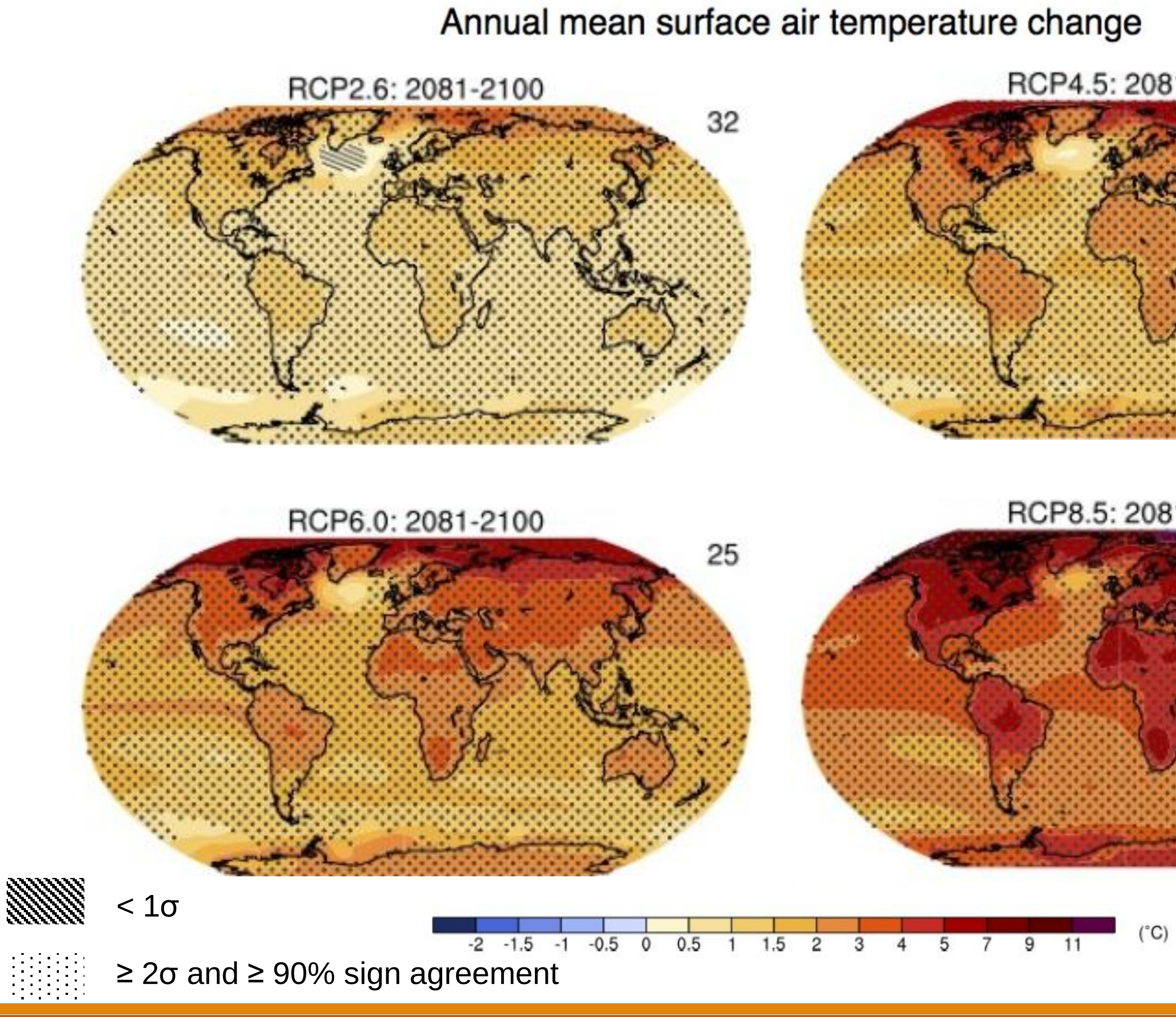
12
10
8
6
4
2
0
-2
Temperature Change (°F)
Observations
Modeled Historical
SRES A2
SRES B1
SRES B1
SRESE A1B
SRES A2
1900
1950
2000
2050
2100
Year



12
10
8
6
4
2
0
-2
Temperature Change (°F)
Observations
Modeled Historical
RCP 8.5
RCP 2.6
RCP 2.6
RCP 4.5
RCP 6.0
RCP 8.5
1900
1950
2000
2050
2100
Year


Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
Temperature Change (°F)
1
3
5
7
9
11
13
15


Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
Precipitation Change (%)
-30
-20
-10
0
10
20
30


Annual mean surface air temperature change
RCP2.6: 2081-2100
32
RCP4.5: 2081-2100
42
RCP6.0: 2081-2100
25
RCP8.5: 2081-2100
39
< 1σ
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)
≥ 2σ and ≥ 90% sign agreement

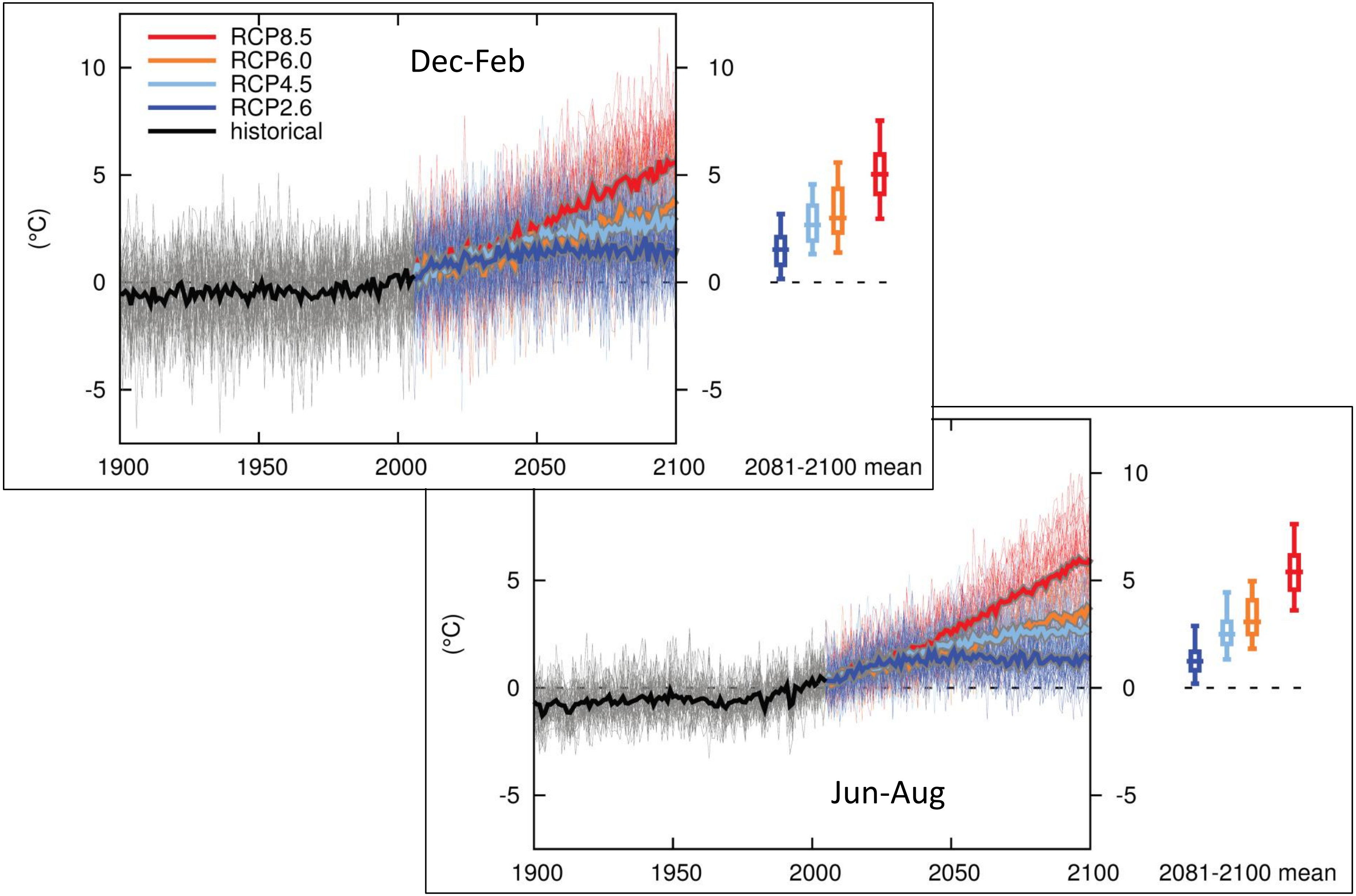
Projections of future climates

Nebraska

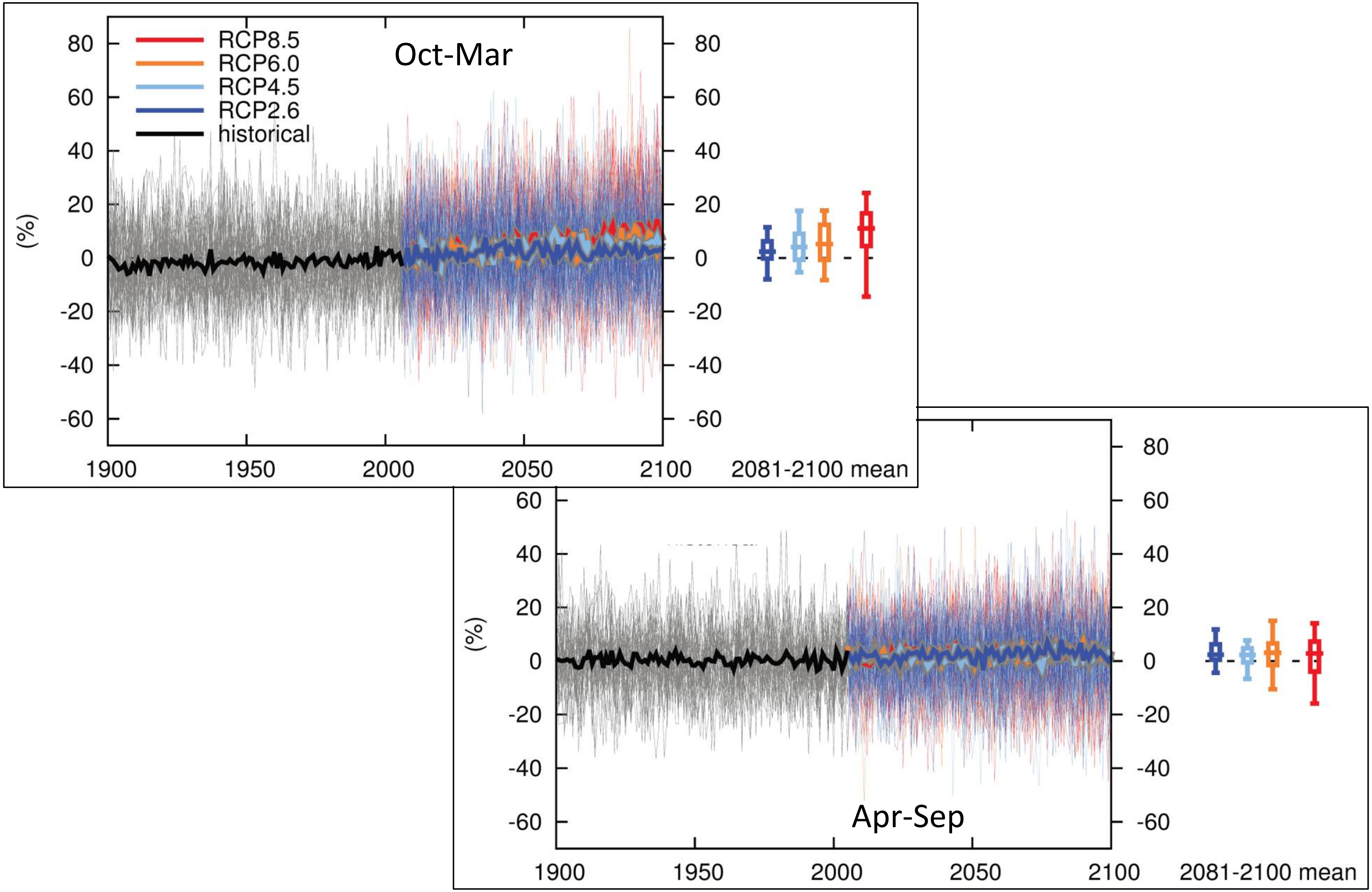
Temperature

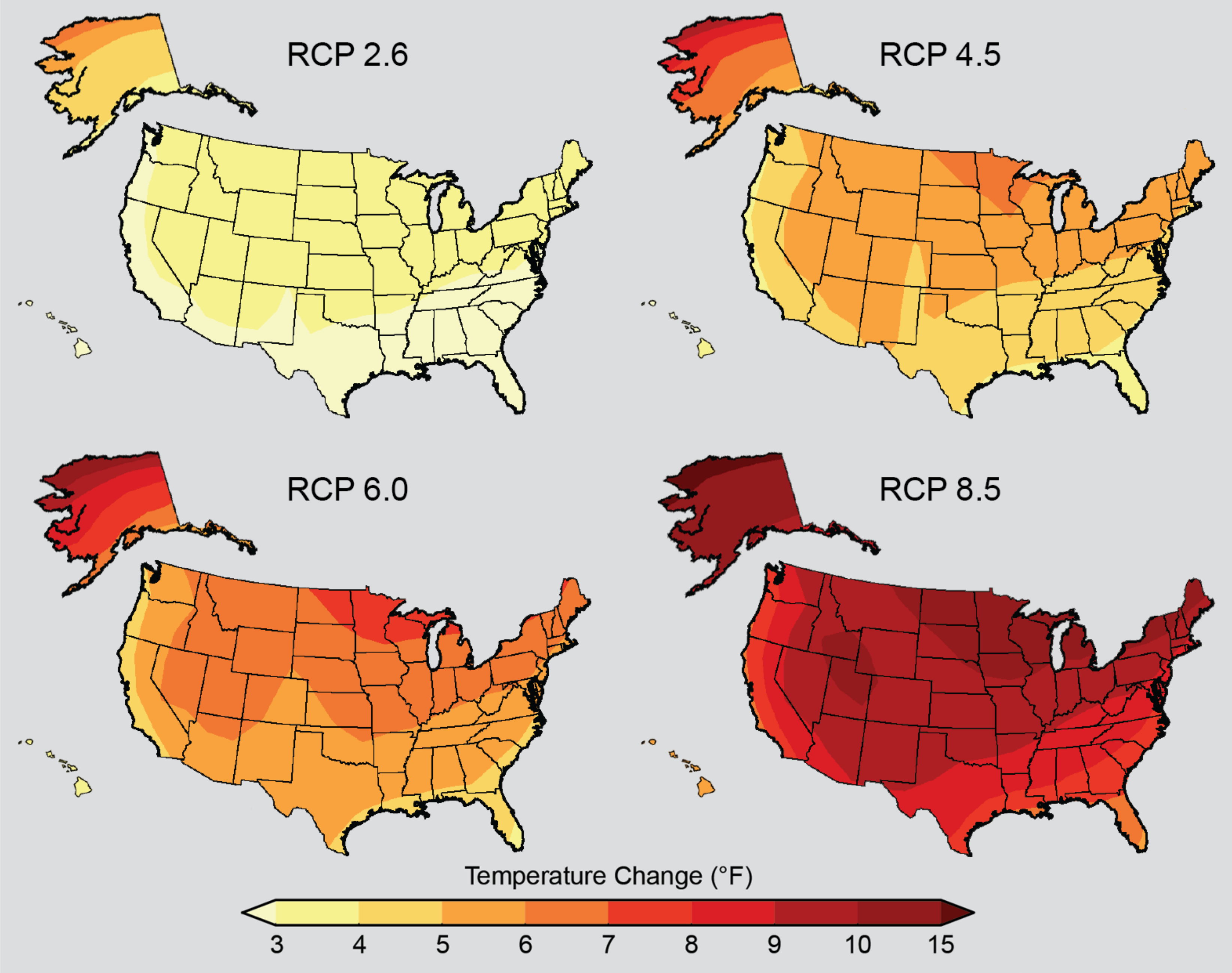
- Increases range from 4-5˚ to 8-9˚F by 2071-2099. The range is largely due to uncertainties in future emissions.
- Projected high temperature stress days (>100°F), increasing to 13-16 additional days (lower emissions) to 22-25 additional days (higher emissions).
- Number of warm nights increases.
- Frost-free season continues to increase by an additional 2 weeks by the end of the century.

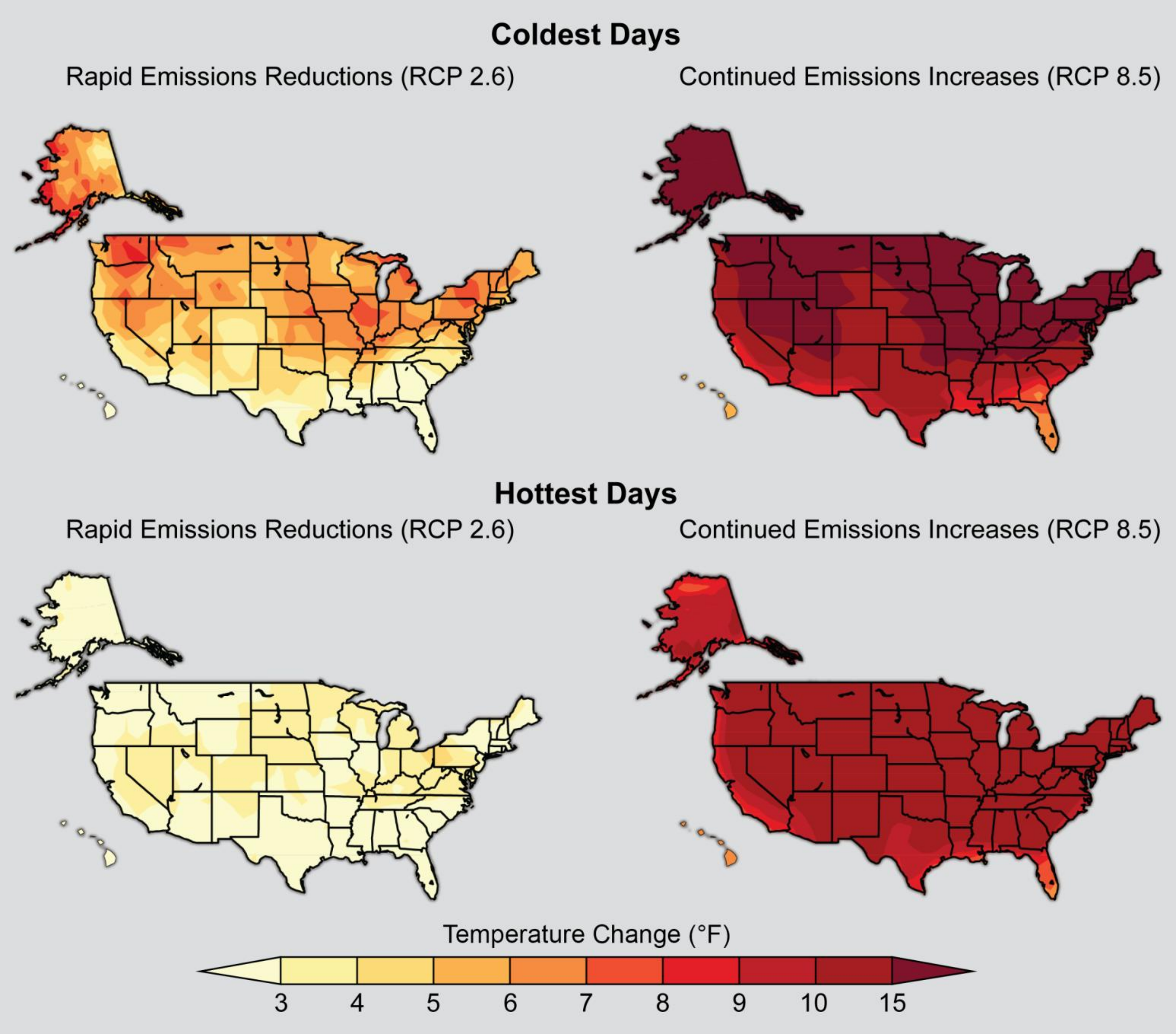
Temperature Change: Central North America



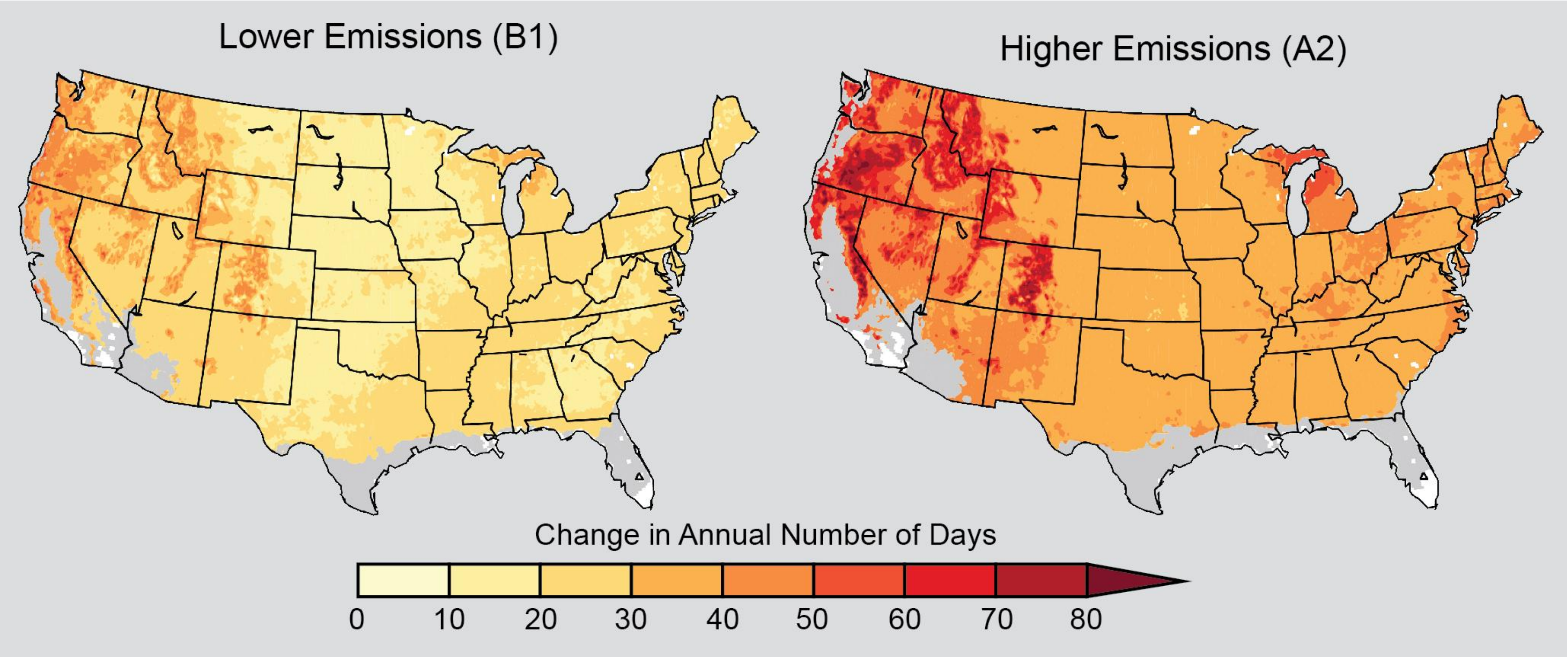
Precipitation Change: Central North America

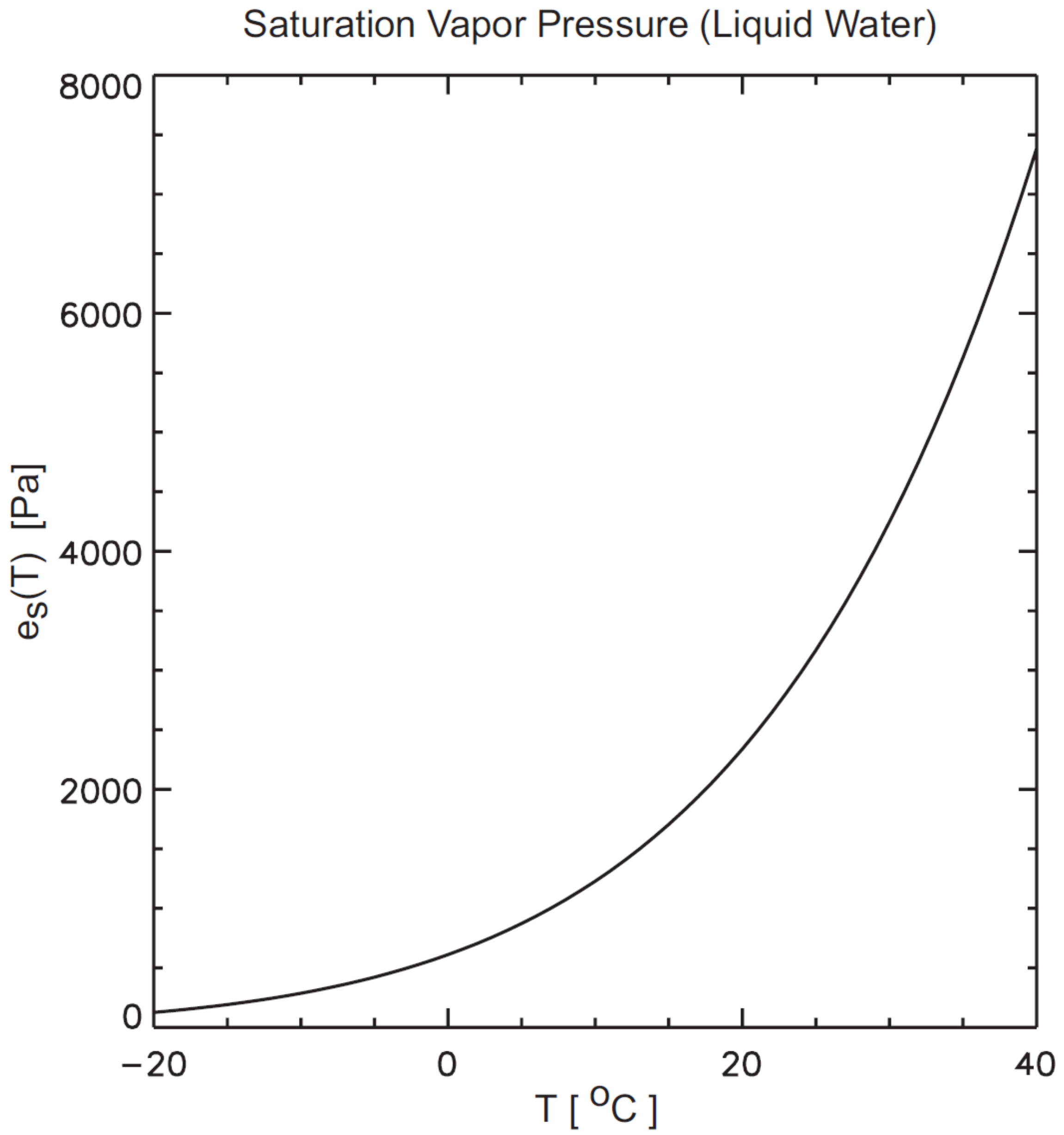



RCP 2.6
RCP 4.5
RCP 6.0
RCP 8.5
Temperature Change (°F)
3
4
5
6
7
8
9
10
15



Coldest Days
Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
Hottest Days
Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
Temperature Change (°F)
3
4
5
6
7
8
9
10
15


Lower Emissions (B1)
Higher Emissions (A2)
Change in Annual Number of Days
0
10
20
30
40
50
60
70
80


Saturation Vapor Pressure (Liquid Water)
8000
6000
4000
2000
0
−20
0
20
40
$e_s(T)$ [Pa]
T [^oC]

Projections of future climates

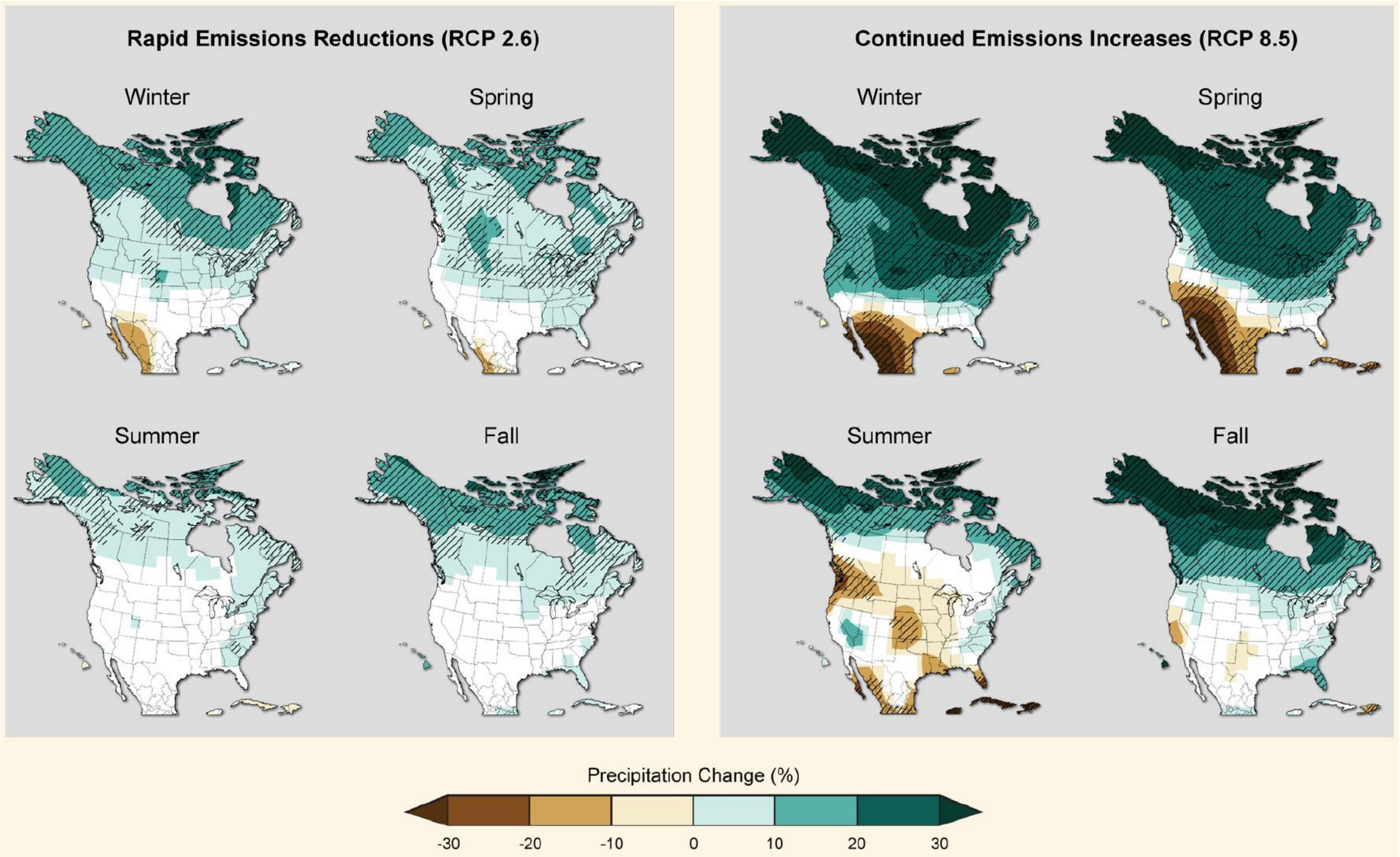
Nebraska

Precipitation

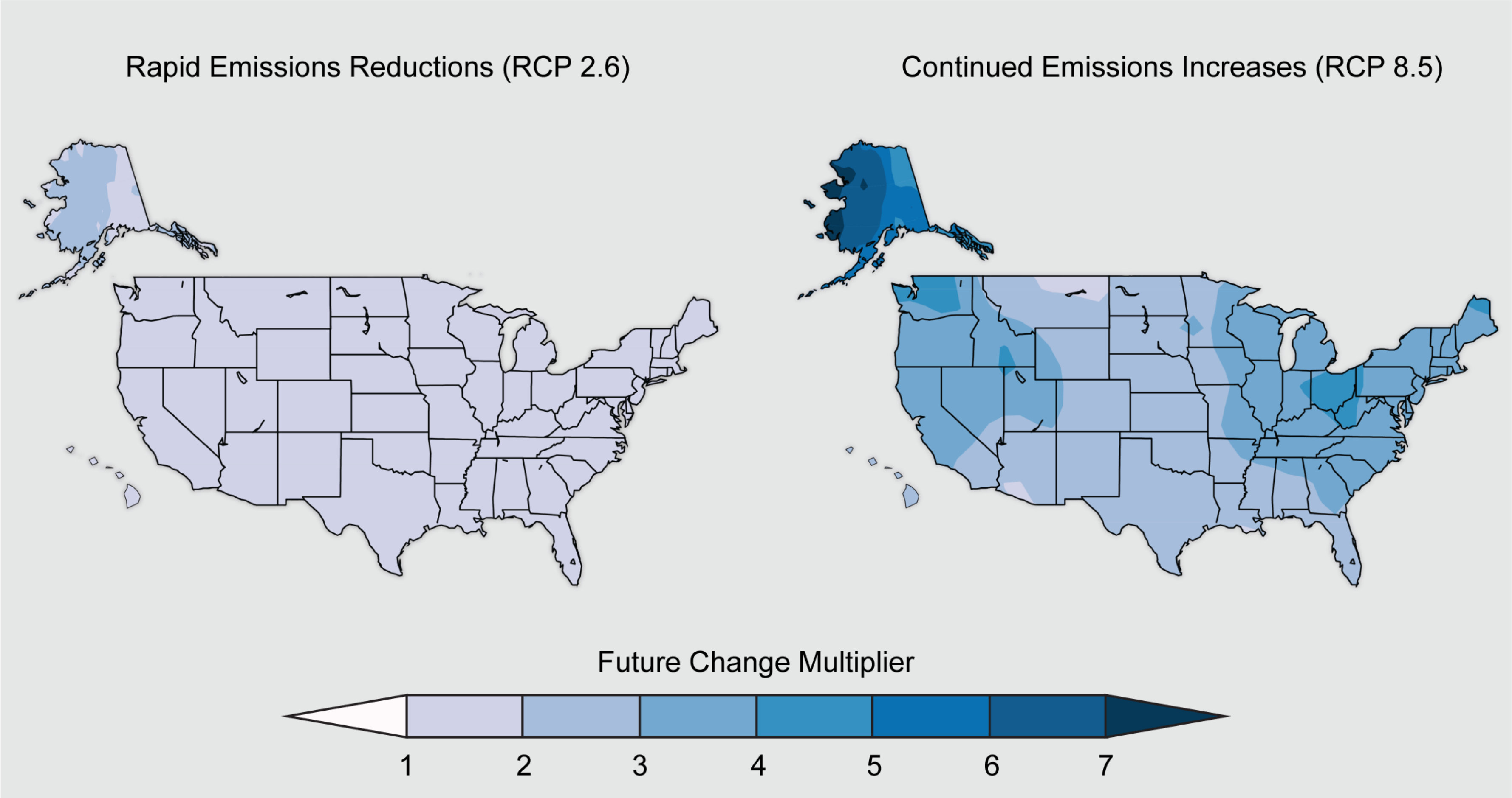
- model projections are highly uncertain, ranging from little change in annual precipitation totals (low emissions scenario) to continuing increases (high emissions scenario)
- percentage changes tend to be larger in winter and spring seasons and smaller in summer and fall, with summer projected to have decreasing precipitation in some scenarios
- increases in heavy precipitation events is expected to continue to increase and produce a greater proportion of total precipitation

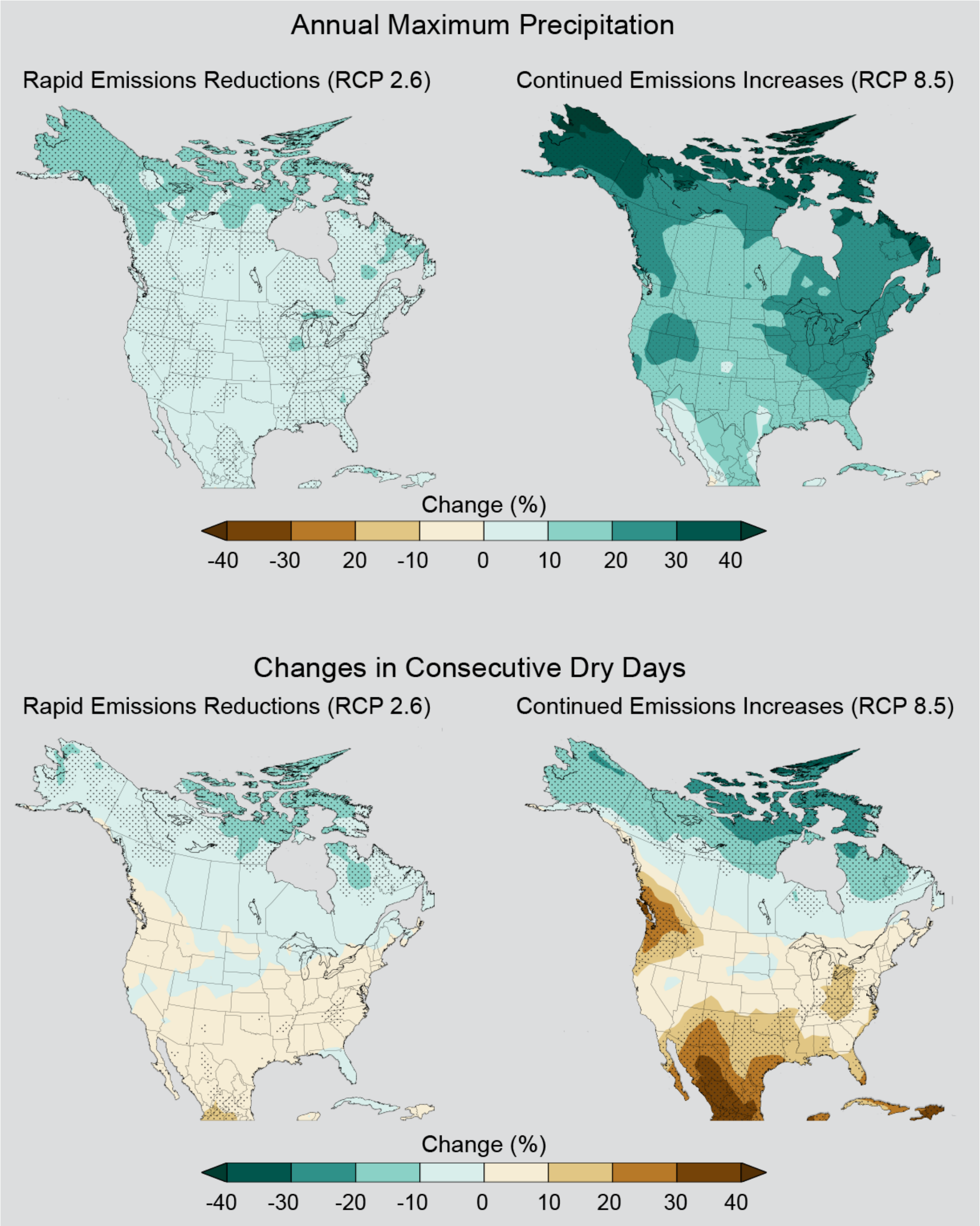
Soil moisture

- changes in soil moisture for Nebraska are for a decrease of 1-5% for the lower emissions scenario and 5-10% for the higher emissions scenario to the end of the twenty-first century

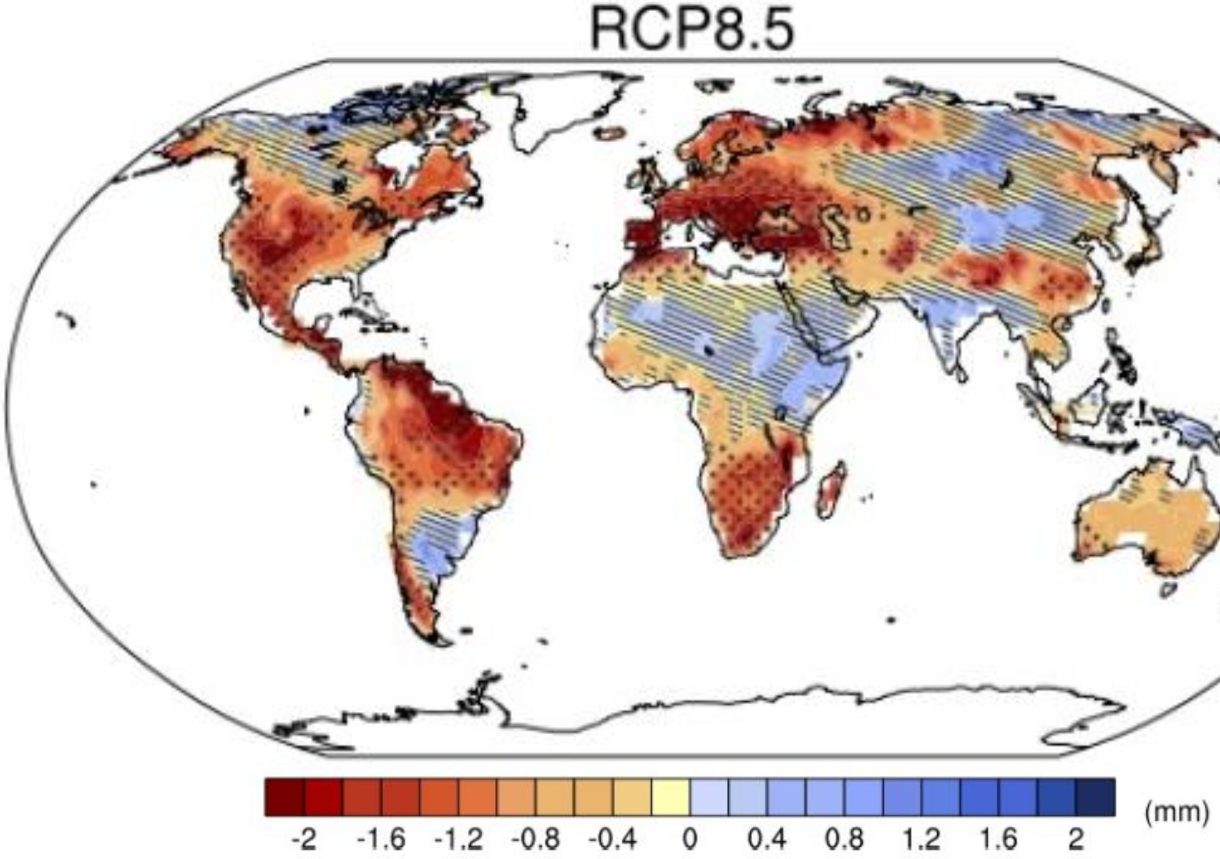

Rapid Emissions Reductions (RCP 2.6)
Winter
Spring
Summer
Fall
Continued Emissions Increases (RCP 8.5)
Winter
Spring
Summer
Fall
Precipitation Change (%)
-30
-20
-10
0
10
20
30

Projected Change in Heavy Precipitation Events



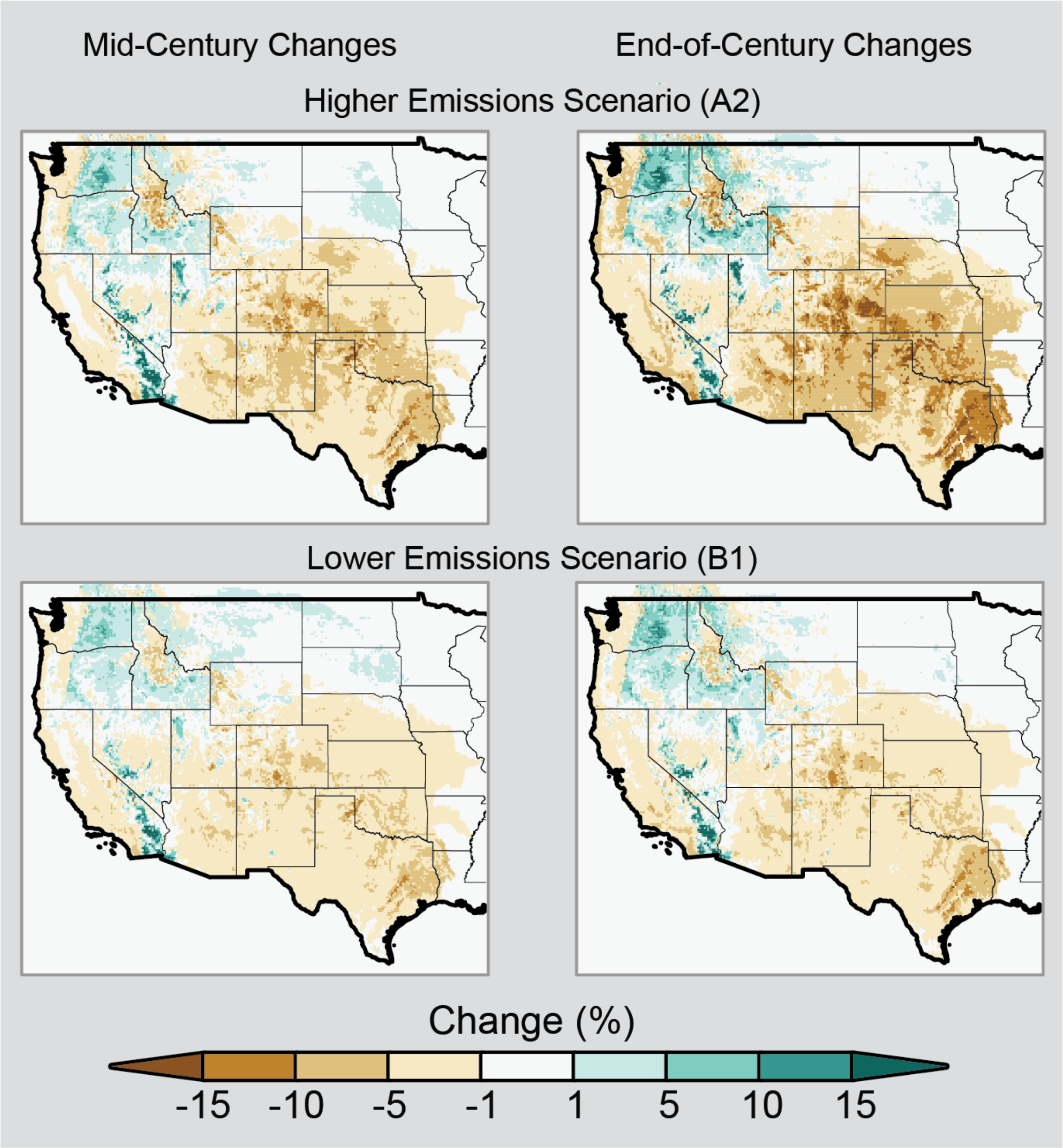

Annual Maximum Precipitation
Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
Change (%)
-40
-30
20
-10
0
10
20
30
40
Changes in Consecutive Dry Days
Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
Change (%)
-40
-30
-20
-10
0
10
20
30
40

Annual mean near-surface soil moisture change (2081-2100)

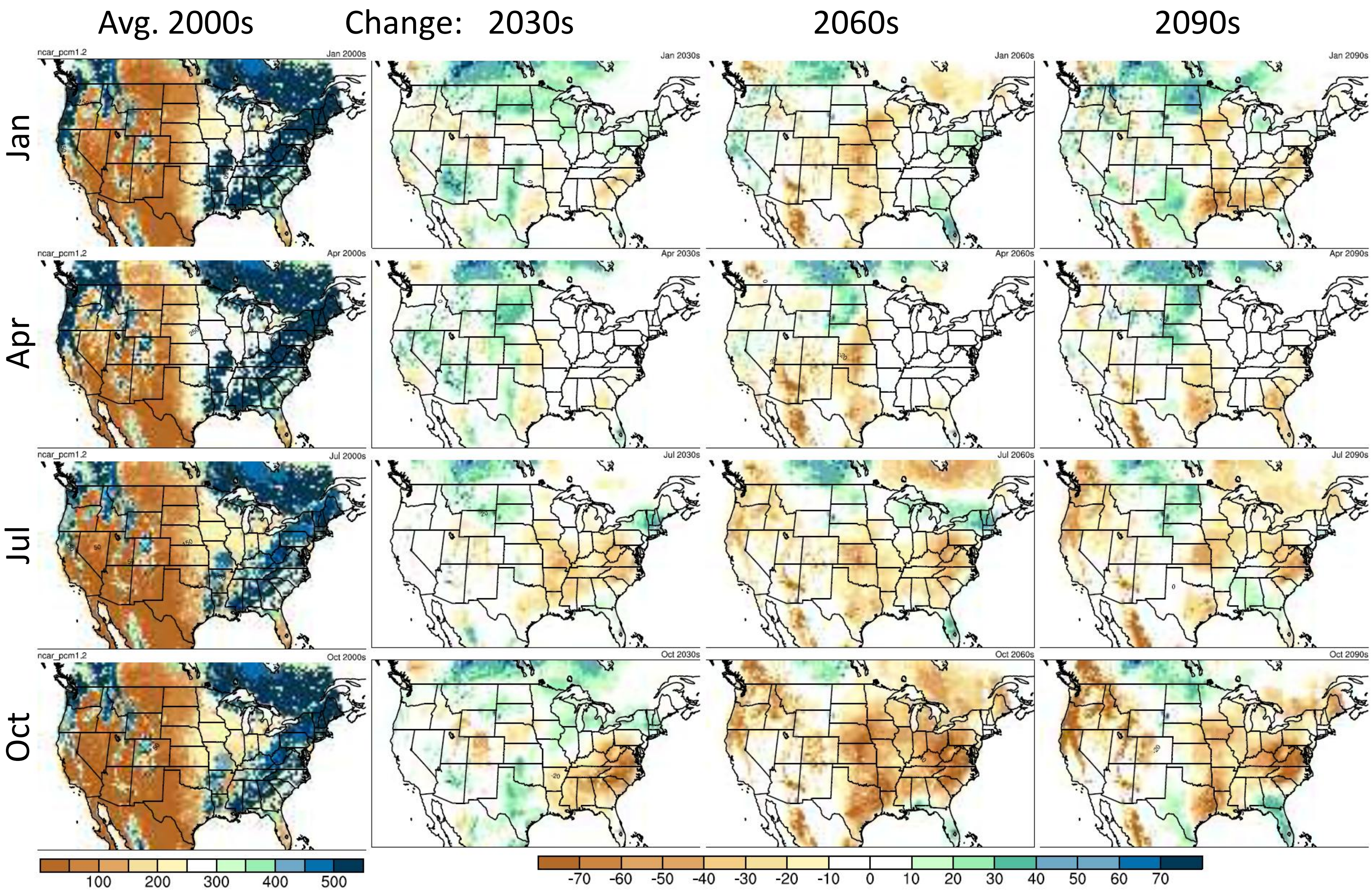


< 1σ

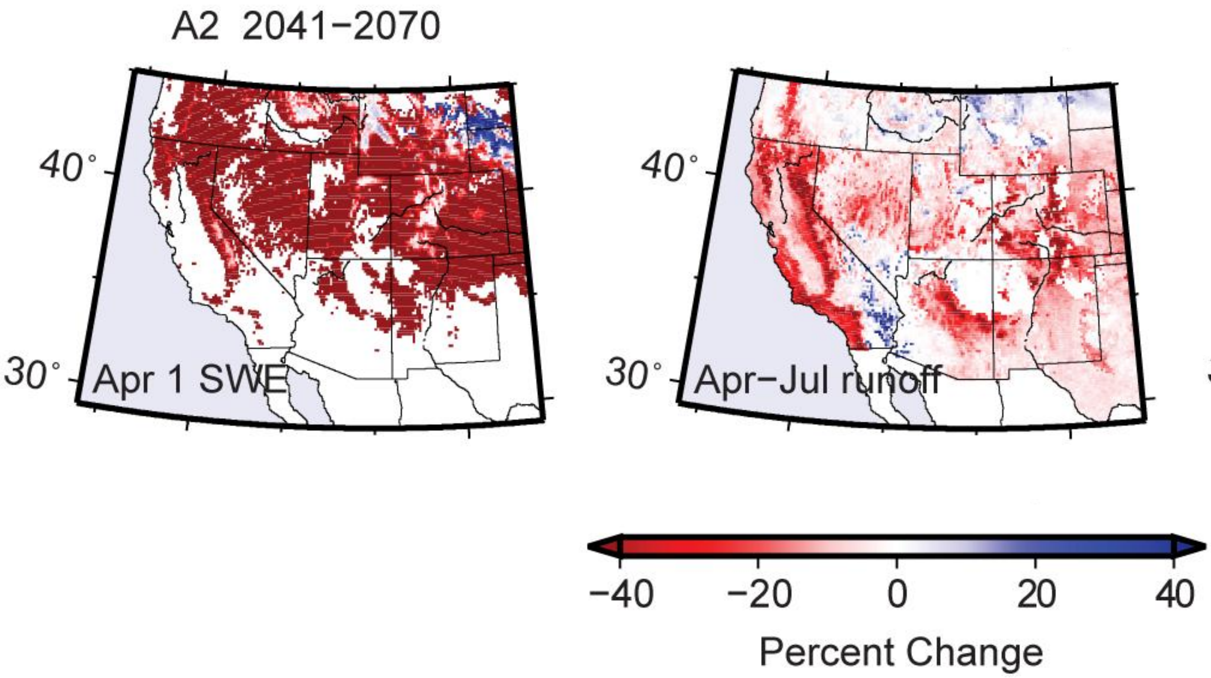
≥ 2σ and ≥ 90% sign agreement


Mid-Century Changes
End-of-Century Changes
Higher Emissions Scenario (A2)
Lower Emissions Scenario (B1)
Change (%)
-15
-10
-5
-1
1
5
10
15

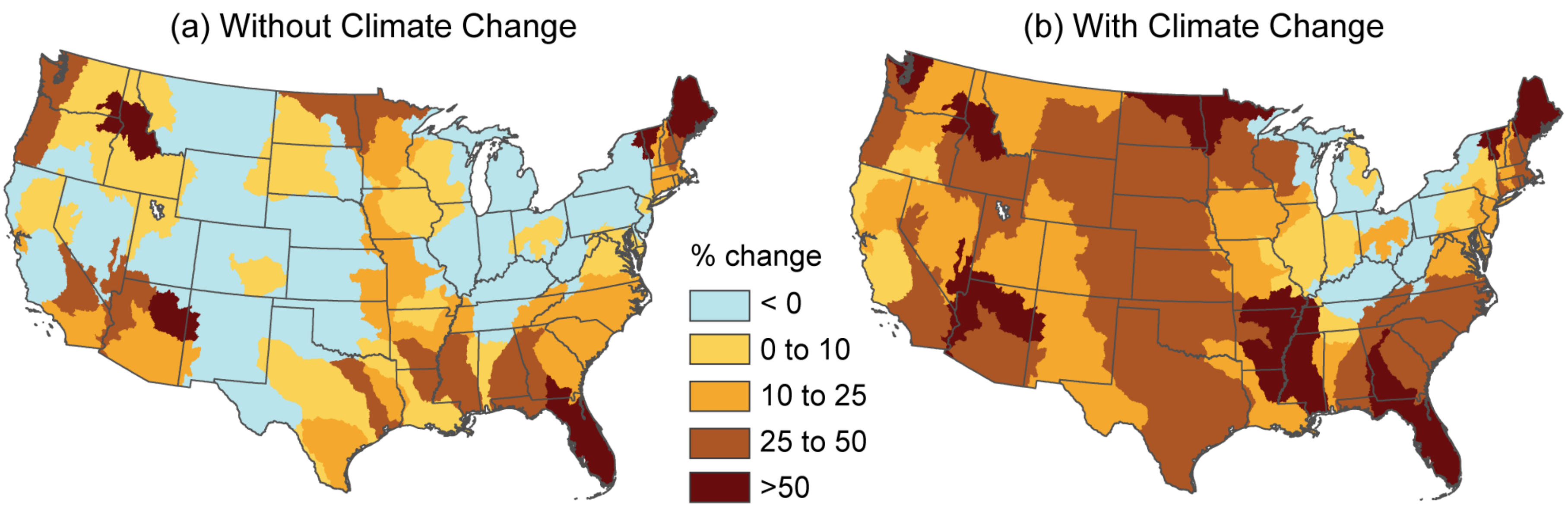
Projected Soil Moisture Changes



Projected Changes in Snow, Runoff, and Soil Moisture



Projected Changes in Water Withdrawals



Key Messages 3rd National Climate Assessment, Chapter 3

1. Annual precipitation and river-flow increases are observed now in the Midwest and the Northeast regions. Very heavy precipitation events have increased nationally and are projected to increase in all regions. The length of dry spells is projected to increase in most areas, especially the southern and northwestern portions of the contiguous United States.
2. Short-term (seasonal or shorter) droughts are expected to intensify in most U.S. regions. Longer-term droughts are expected to intensify in large areas of the Southwest, southern Great Plains, and Southeast.
3. Flooding may intensify in many U.S. regions, even in areas where total precipitation is projected to decline.
4. Climate change is expected to affect water demand, groundwater withdrawals, and aquifer recharge, reducing groundwater availability in some areas.
5. Sea level rise, storms and storm surges, and changes in surface and groundwater use patterns are expected to compromise the sustainability of coastal freshwater aquifers and wetlands.
6. Increasing air and water temperatures, more intense precipitation and runoff, and intensifying droughts can decrease river and lake water quality in many ways, including increases in sediment, nitrogen, and other pollutant loads.
7. Climate change affects water demand and the ways water is used within and across regions and economic sectors. The Southwest, Great Plains, and Southeast are particularly vulnerable to changes in water supply and demand.
8. Changes in precipitation and runoff, combined with changes in consumption and withdrawal, have reduced surface and groundwater supplies in many areas. These trends are expected to continue, increasing the likelihood of water shortages for many uses.
9. Increasing flooding risk affects human safety and health, property, infrastructure, economies, and ecology in many basins across the United States.
10. In most U.S. regions, water resources managers and planners will encounter new risks, vulnerabilities, and opportunities that may not be properly managed within existing practices.
11. Increasing resilience and enhancing adaptive capacity provide opportunities to strengthen water resources management and plan for climate change impacts. Many institutional, scientific, economic, and political barriers present challenges to implementing adaptive strategies.

Key Messages

3rd National Climate Assessment, Chapter 3

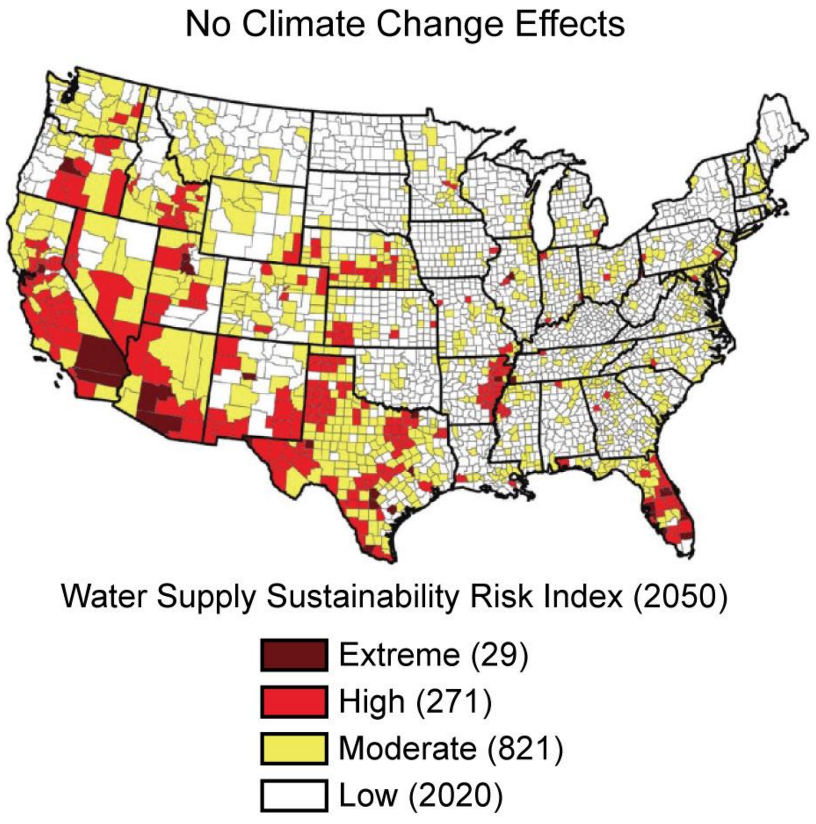
3. Flooding may intensify in many U.S. regions, even in areas where total precipitation is projected to decline.

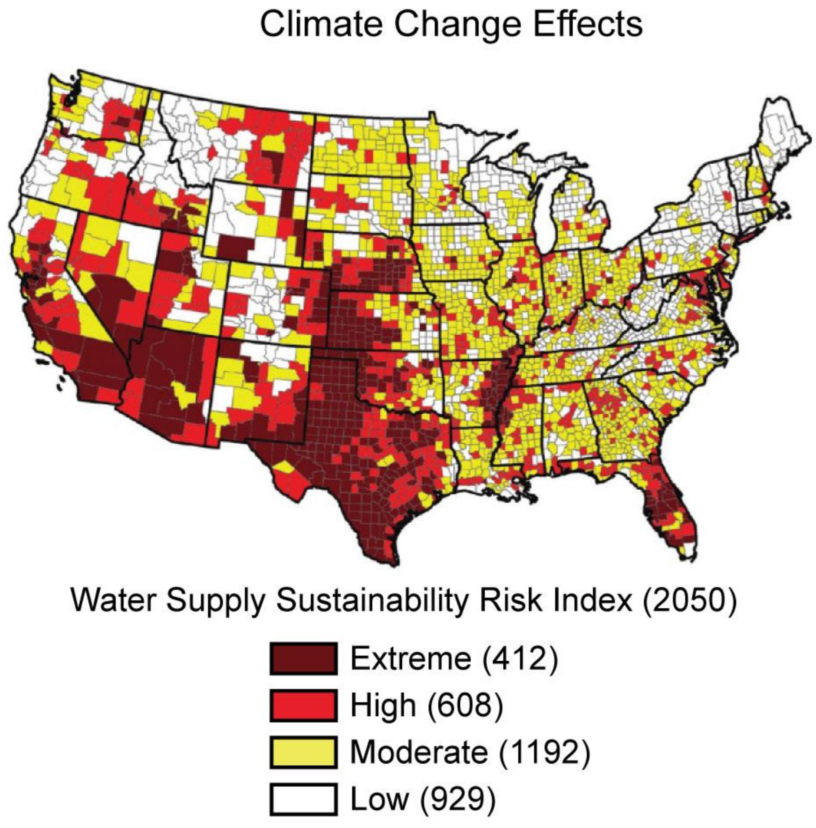
9. Increasing flooding risk affects human safety and health, property, infrastructure, economies, and ecology in many basins across the United States.

10. In most U.S. regions, water resources managers and planners will encounter new risks, vulnerabilities, and opportunities that may not be properly managed within existing practices.

11. Increasing resilience and enhancing adaptive capacity provide opportunities to strengthen water resources management and plan for climate change impacts. Many institutional, scientific, economic, and political barriers present challenges to implementing adaptive strategies.

water quality and quantity





In summary, expect increasing variability …

more flooding …

… and more drought

Questions?


©MATSON caglecartoons.com
ST. LOUIS POST-DISPATCH
"SHE'S BURNING UP FOSSIL FUELS AND RELEASING GREENHOUSE GASES... HOW LONG HAS SHE HAD HUMANS?"

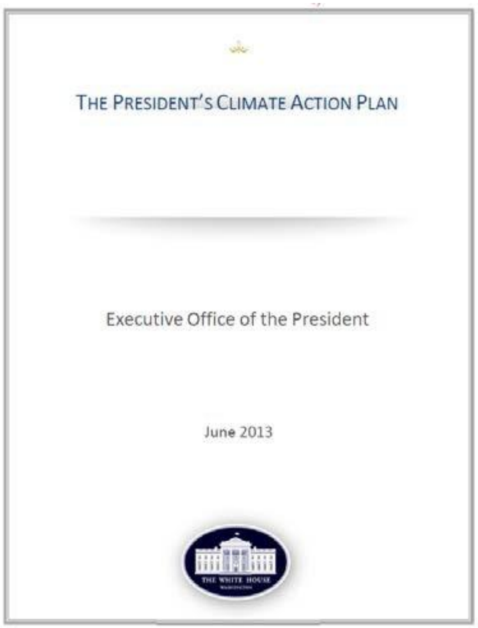
Implementing a Federal Flood Risk Management Standard

Updating Federal Flood Risk Management Standards

- The President has directed federal agencies to update their flood-risk reduction standards as part of the June 2013 President's Climate Action Plan.

- The new Federal Flood Risk Management Standard (FFRMS or the Standard) addresses this directive and will improve the nation's resilience to flooding and better prepare the United States for the impacts of climate change.

- The FFRMS builds on the work of the Hurricane Sandy Rebuilding Task Force and the State, Local & Tribal Leaders Task Force on Climate Preparedness and Resilience, both of which recommended that the federal government create a national flood risk standard for federally-funded projects beyond the Sandy-affected region.



Executive Order 11988

- Issued May 1977 governing federal actions in the floodplain
- Each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for
  (1) acquiring, managing, and disposing of federal lands, and facilities;
  (2) providing federally undertaken, financed, or assisted construction and improvements;
  (3)) conducting federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities.

Executive Order 13690

- On January 30th, the President signed Executive Order 13690, which amends Executive Order 11988 and establishes the Federal Flood Risk Management Standard (FFRMS or Standard).

- On February 5th, FEMA, on behalf of the Mitigation Federal Leadership Group (MitFLG), published in the Federal Register for notice and comment a draft of revisions to the 1978 Floodplain Management Guidelines. The draft Guidelines contain the basic interpretation of Executive Order 11988, as amended by the Executive Order 13690 and the FFRMS.

- Executive Order 13690 also requires agencies to develop Implementation Plans describing how each agency will update its existing policies, procedures and/or regulations to comply with the new requirements.

Goal to Increase Resilience to Flooding

- The FFRMS and Executive Order 13690 ensure that agencies expand management from the current base flood level to a higher vertical elevation and corresponding horizontal floodplain to address current and future flood risk and ensure that projects funded with taxpayer dollars last as long as intended.

Applying the Federal Flood Risk Management Standard

- Federal agencies will continue to implement Executive Order 11988, but replacing the 100-year base flood in the Executive Order with the process identified in the Federal Flood Risk Management Standard.

Applying the Federal Flood Risk Management Standard

- Executive Order 13690 does not prohibit building in the floodplains, but carries the same intent as Executive Order 11988 to avoid floodplains where possible and practical.

- Executive Order 13690 does not apply to private investments in structures, facilities, or homes. Executive Order 13690 applies to federal actions – such as where a private party is receiving federal funds or a federal decision for the construction activity that occurs in or affecting a floodplain.

- The Standard will not affect flood insurance premiums or the requirements for participation in the National Flood Insurance Program (NFIP). The revised standard will not change community floodplain management requirements, FEMA's flood mapping standard, or the rating practices of the NFIP.

Approaches in the Federal Flood Risk Management Standard

- Federal agencies have the flexibility to select the best approach for establishing the elevation and flood hazard area used when implementing Executive Order 11988 as amended by Executive Order 13690:
  - Utilizing best-available, actionable climate science data and methods that integrate current and future changes in flooding based on science;
  - Two or three feet of elevation, (depending on criticality), above the 100-year, or 1%-annual-chance, flood elevation; or
  - 500-year, or 0.2%-annual-chance, flood elevation.

Requirements of Executive Order 13690

- In addition to establishing the elevation and flood hazard area used when implementing Executive Order 11988, as amended by Executive Order 13690, there are also two other notable requirements:
  - The new Executive Order defines critical actions.
    - Although critical actions were not previously defined in the text of the Executive Order, FEMA's Floodplain Management Regulations at 44 CFR Part 9 have defined critical actions since 1980
    - The definition added to EO 11988 as amended by EO 13690 and the definition in 44 CFR Part 9 are the same.
  - The new Executive Order also states that agencies shall use natural systems, ecosystem processes, and nature-based approaches when developing alternatives for consideration.

Soliciting Input: Revised Implementing Guidelines

- The draft revised Guidelines were available for public comment through May 6, 2015.
- FEMA collected comments on the revised Guidelines and has provided them to the Mitigation Framework Leadership Group (MitFLG). The MitFLG is composed of agencies with programs and authorities designed to mitigate the impacts of disasters on communities.
- Agencies will use the final Guidelines to update policies, procedures, and/or regulations for implementing the Executive Orders. Those agency and program-specific updates are anticipated to provide for additional public engagement.

Key Themes from Public Comments

- Impact of Executive Order 13690 on permitting
- Impact of Executive Order 13690 on financial transactions
- A need for clarity on roles, definitions, and process
- A need for consistency across agencies
- Importance of leveraging existing programs and resources

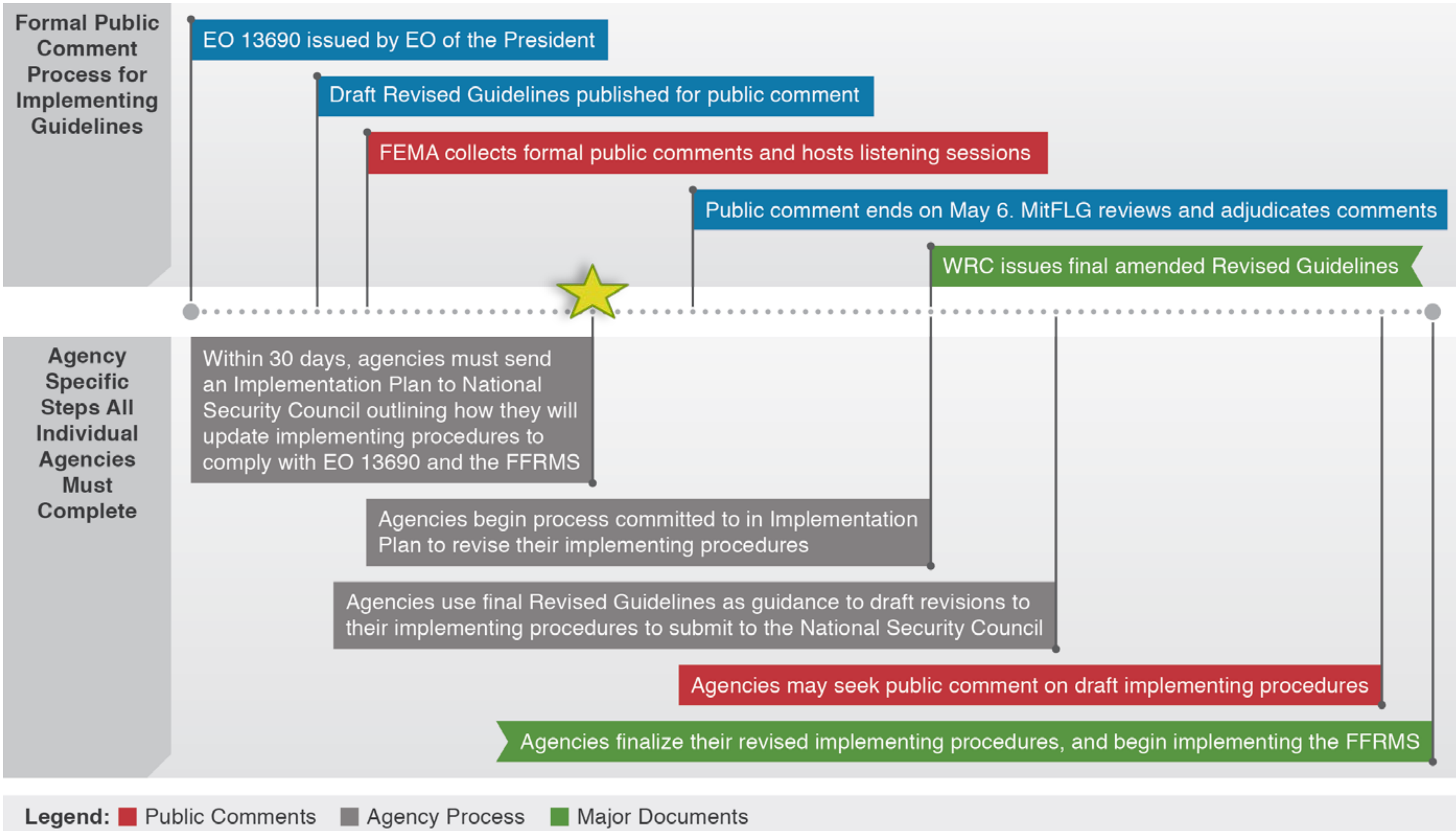
Revising and Finalizing the Guidelines

- FEMA collected the incoming public comments on the Guidelines and provided them to the MitFLG.
- The MitFLG is working to revise the Guidelines based on the input that is received.
- The MitFLG will provide recommendations on the Guidelines to the Water Resources Council to finalize and issue the Guidelines.
  - The Water Resources Council was established by the Water Resources Planning Act (79 Stat. 244), July 22, 1965.

After the Public Comment Period

- Comment period concluded on May 6, 2015.
- Post Public Comment Period Activities
  - Agencies will submit their Implementation Plan to the White House within 30 days of the close of the public comment period. The Implementation Plan will detail which policies, procedures, and/or regulations they plan to update along with the timeline and public engagement that may be necessary.
  - The Water Resources Council will finalize and issue the final Guidelines.
  - Agencies will revise policies, procedures, and/or regulations as necessary to implement the Standard and engage the public as required.

FFRMS and Implementing Guidelines Development Process



FEMA FFRMS Implementation Roles

- FEMA has two roles in the FFRMS Implementation Phase
  - FEMA will develop an Implementation Plan for our agency actions
  - FEMA serves an external role as a subject matter expert advisor in floodplain management for other federal agencies and provides consultation on other agencies implementation of the Executive Orders.

FEMA Implementation Plan

- The FEMA Implementation Plan was drafted by Office of Environmental Planning and Historic Preservation with support from the Office of the Chief Counsel.
- The Implementation Plan includes:
  - Revising 44 CFR Part 9- Floodplain Management and Protection of Wetlands
  - Drafting a Federal Flood Risk Management Standard Policy
  - Drafting a 44 CFR Part 9 Practitioners Guidance document
  - Updating the EO 11988 and EO 11990 Training Course for FEMA staff and field practitioners

Why create a new Policy?

- The Federal Flood Risk Management Standard offers three approaches to define the floodplain.
- The Federal Flood Risk Management Standard is intended to be updated periodically to incorporate the most current science that takes into account changing flood risk
- The Policy will identify which of the approaches FEMA will use to define the floodplain for the 8-step decision making process.
- The Policy will be able to be revised as experience is gained from implementation and for future revisions to the FFRMS

3 FFRMS Approach Options

- Three options under consideration are:

Option 1:

	Non-critical actions	Critical actions
Coastal	Climate Informed Science Approach	Climate Informed Science Approach, incorporating a higher SLC scenario and longer life span
Riverine	BFE + 2 feet	BFE + 3 feet

Option 2:

	Non-critical actions	Critical actions
Coastal	BFE + 2 feet	BFE + 3 feet
Riverine	BFE + 2 feet	BFE + 3 feet

Option 3:

	Non-critical actions	Critical actions
Coastal	BFE + 2 feet	BFE + 3 feet or 500 year (where available)*, whichever is higher
Riverine	BFE + 2 feet	BFE + 3 feet or 500 year (where available), whichever is higher

44 CFR Part 9 Guidance

- Some topics which will be addressed in the Practitioner's Guidance include:
  - How do I determine if a project is in the floodplain defined using the approaches defined in EO 13690?
  - What is “best available data”?
  - How are actions determined to be critical actions?

Flood Risk Management Standard and Project Design

- As under the original EO 11988, proposed actions will be evaluated for practicable alternatives to locating the action in the floodplain. If the action must be located in the floodplain, then mitigation opportunities should be identified to improve resilience of the action against flooding to the level of the FFRMS elevation

- Resilience to flooding can be accomplished with many methods

- For new construction and substantial improvement of structures, elevation or floodproofing may be appropriate. For non-structural projects, other methods to achieve resiliency may be needed.

Thank You

"It is the policy of the United States to improve the resilience of communities and federal assets against the impacts of flooding. These impacts are anticipated to increase over time due to the effects of climate change and other threats. Losses caused by flooding affect the environment, our economic prosperity, and public health and safety, each of which affects our national security."

- *Executive Order 13690*

US Army Corps of Engineers – Response to Climate Change Program

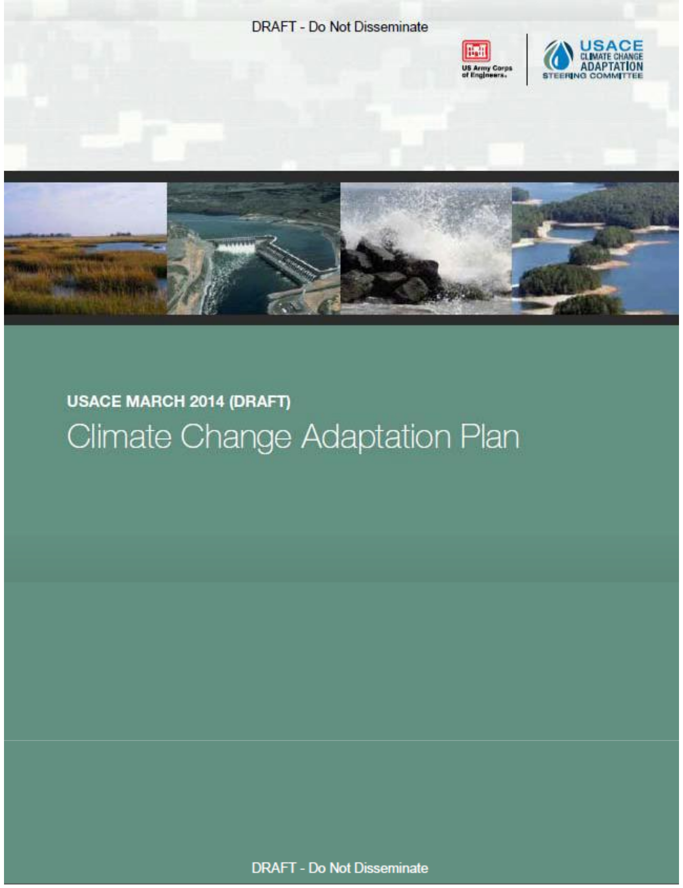
Bryan Baker, PE

Inland Hydrology Lead for Climate Preparedness and Resilience

16 June 2015

Bottom Line Up Front

- USACE is working with other agencies and experts to develop actionable science on which to base policies and guidance
- Collaboration improves the products and also ensures consistencies between Federal water management and science agencies
- Strategy for considering climate change in design for inland infrastructure
  - Start with qualitative guidance
  - Develop tools and methods to support
  - Then develop quantitative guidance



http://www.corpsclimate.us/adaptationpolicy.cfm

Executive Order 13653
"Preparing the US for the Impacts of Climate Change"

- USACE is one of 30 named agencies in new **Council on Climate Preparedness and Resilience,**
- EO 13653 requires agencies to build on recent progress and pursue new strategies to improve the Nation's climate preparedness and resilience, promoting:
  - Engaged and strong partnerships and information sharing at all levels of government
  - Risk-informed decision-making and the tools to facilitate it
  - Adaptive learning, in which experiences serve as opportunities to inform and adjust future actions
  - Preparedness planning

66819

Federal Register
Vol. 78, No. 215
Wednesday, November 6, 2013

Presidential Documents

Title 3—
The President

Executive Order 13653 of November 1, 2013

Preparing the United States for the Impacts of Climate Change

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to prepare the Nation for the impacts of climate change by undertaking actions to enhance climate preparedness and resilience, it is hereby ordered as follows:

Section 1. *Policy.* The impacts of climate change—including an increase in prolonged periods of excessively high temperatures, more heavy downpours, an increase in wildfires, more severe droughts, permafrost thawing, ocean acidification, and sea-level rise—are already affecting communities, natural resources, ecosystems, economies, and public health across the Nation. These impacts are often most significant for communities that already face economic or health-related challenges, and for species and habitats that are already facing other pressures. Managing these risks requires deliberate preparation, close cooperation, and coordinated planning by the Federal Government, as well as by stakeholders, to facilitate Federal, State, local, tribal, private-sector, and nonprofit-sector efforts to improve climate preparedness and resilience; help safeguard our economy, infrastructure, environment, and natural resources; and provide for the continuity of executive department and agency (agency) operations, services, and programs.

A foundation for coordinated action on climate change preparedness and resilience across the Federal Government was established by Executive Order 13514 of October 5, 2009 (Federal Leadership in Environmental, Energy, and Economic Performance), and the Interagency Climate Change Adaptation Task Force led by the Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA). In addition, through the U.S. Global Change Research Program (USGCRP), established by section 103 of the Global Change Research Act of 1990 (15 U.S.C. 2933), and agency programs and activities, the Federal Government will continue to support scientific research, observational capabilities, and assessments necessary to improve our understanding of and response to climate change and its impacts on the Nation.

The Federal Government must build on recent progress and pursue new strategies to improve the Nation's preparedness and resilience. In doing so, agencies should promote: (1) engaged and strong partnerships and information sharing at all levels of government; (2) risk-informed decisionmaking and the tools to facilitate it; (3) adaptive learning, in which experiences serve as opportunities to inform and adjust future actions; and (4) preparedness planning.

Sec. 2. *Modernizing Federal Programs to Support Climate Resilient Investment.* (a) To support the efforts of regions, States, local communities, and tribes, all agencies, consistent with their missions and in coordination with the Council on Climate Preparedness and Resilience (Council) established in section 6 of this order, shall:

(i) identify and seek to remove or reform barriers that discourage investments or other actions to increase the Nation's resilience to climate change while ensuring continued protection of public health and the environment;

Climate Hydrology – A Work in Progress

- Actions and Science with climate hydrology
  - What do we know
  - What don't we know (uncertainty)
  - What do we think we know
  - What don't we know that we don't know
- Appreciate it is a complex system
  - We can never predict with certainty the exact response
  - Absorbing disturbances; undergoing change yet retain same function = Resilience
- Evaluation of future changes
  - Frequency
  - Duration
- Future efforts

Overall Approach

- USACE climate change adaptation planning and implementation for new and existing, built and natural infrastructure relies on
  - Policy and guidance based on consistent approaches due to collaboration with aligned agencies and partners
  - Science translation to inform decision-makers, based on best available and actionable science
  - Tools and methods for use at working staff level
  - Screening level assessments of vulnerability to climate change that will be refined over time
  - Training and capacity building
- Geospatial tools supporting knowledge transfer
- Approach consistent with1 Nov 2013 EO "Preparing the United States for the Impacts of Climate Change“ and the President’s Climate Action Plan

Adaptation Policy and Guidance Related to Flood Risk

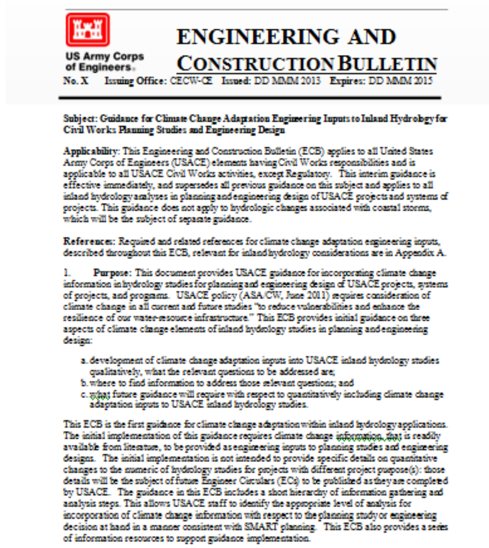
- Consistent Datums:
  - ER 1110-2-8160 Policies for Referencing Project Evaluation Grades to Nationwide Vertical Datums
  - EM 1110-2-6056 Standards and Procedures for Referencing Project Evaluation Grades to Nationwide Vertical Datums
- Sea Level Change:
  - 2000, ER 1105-2-100 – sensitivity to historic and NRC high rate sea level change
  - 2013, ER 1100-2-8162 (supersedes 2009 and 2011's EC 1165-2-211 and 1165-2-212) – use 3 scenarios
  - 2014 ETL 1100-2-1, adaptation, signed Feb 2014, awaiting publication via ACE-IT – uses tiered approach with level of effort commensurate with scale of decision and consequences
- Post-Sandy Flood Risk Recovery Standard:
  - 2013 ECB 2013-33, Application of Flood Risk Reduction Standard for Sandy Rebuilding Projects
- Total Water Levels:
  - In progress: ETL on Procedures to Evaluate the Magnitudes and Effects of Total Water Levels at USACE Projects

6

Developing Guidance for Inland Hydrology

- Method and approach briefed internally and externally (e.g., ACWI)
- Information needed to support inland hydrology qualitative guidance:
  - HUC-4 basin runoff 2014
  - Nonstationarity bibliography underway

    Guidance for detection and attribution of climate-related nonstationarity underway
  - Regional climate syntheses at HUC-2 level in progress
  - Screening-level vulnerability assessments by business line, roll-out summer 2014
  - Routed unregulated streamflow, 2015



US Army Corps of Engineers

ENGINEERING AND CONSTRUCTION BULLETIN

No. X Issuing Office: CECW-CE Issued: DD MMM 2013 Expires: DD MMM 2015

Subject: Guidance for Climate Change Adaptation Engineering Inputs to Inland Hydrology for Civil Works Planning Studies and Engineering Design

Applicability: This Engineering and Construction Bulletin (ECB) applies to all United States Army Corps of Engineers (USACE) elements having Civil Works responsibilities and is applicable to all USACE Civil Works activities, except Regulatory. This interim guidance is effective immediately, and supersedes all previous guidance on this subject and applies to all inland hydrology analyses in planning and engineering design of USACE projects and systems of projects. This guidance does not apply to hydrologic changes associated with coastal storms, which will be the subject of separate guidance.

References: Required and related references for climate change adaptation engineering inputs, described throughout this ECB, relevant for inland hydrology considerations are in Appendix A.

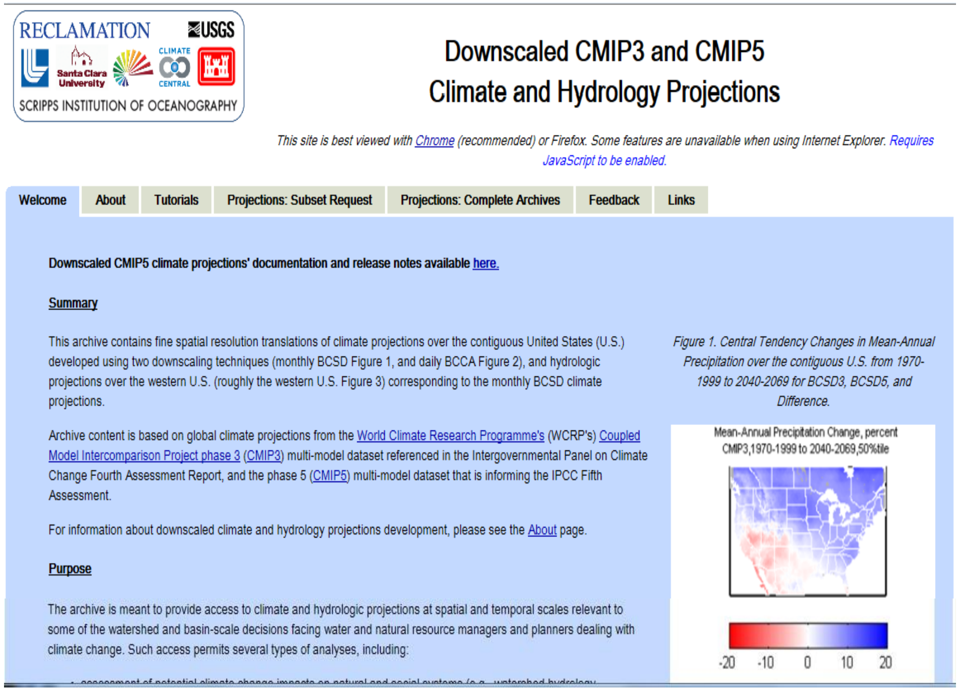
1. **Purpose**: This document provides USACE guidance for incorporating climate change information in hydrology studies for planning and engineering design of USACE projects, systems of projects, and programs. USACE policy (ASA/CW, June 2011) requires consideration of climate change in all current and future studies "to reduce vulnerabilities and enhance the resilience of our water-resource infrastructure." This ECB provides initial guidance on three aspects of climate change elements of inland hydrology studies in planning and engineering design:

    a. development of climate change adaptation inputs into USACE inland hydrology studies qualitatively, what the relevant questions to be addressed are;
    b. where to find information to address those relevant questions; and
    c. what future guidance will require with respect to quantitatively including climate change adaptation inputs to USACE inland hydrology studies.

This ECB is the first guidance for climate change adaptation within inland hydrology applications. The initial implementation of this guidance requires climate change information, that is readily available from literature, to be provided as engineering inputs to planning studies and engineering designs. The initial implementation is not intended to provide specific details on quantitative changes to the numeric of hydrology studies for projects with different project purpose(s): those details will be the subject of future Engineer Circulars (ECs) to be published as they are completed by USACE. The guidance in this ECB includes a short hierarchy of information gathering and analysis steps. This allows USACE staff to identify the appropriate level of analysis for incorporation of climate change information with respect to the planning study or engineering decision at hand in a manner consistent with SMART planning. This ECB also provides a series of information resources to support guidance implementation.

Climate Hydrology

- Collaborative agency team produced a consistent set of statistically downscaled climate hydrology March 2013
- CMIP5, BCSD, VIC (unregulated) hydrology
- Various combinations of GCMs and RCPs resulting in 100 traces per watershed per time period



USACE Hydrology and Tools

- ECB 2014-10, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects
  - Qualitative approach, 2 phases
- Screening Level Vulnerability Assessment
- Draft ETL on Appropriate Application of Paleoflood Information for Hydrology and Hydraulics Decision-Making
  - Based on 2013 report that received IEPR-lite
  - In HQ review
- Draft ETL on Guidance for Detection of Nonstationarities in Annual Maximum Peak Discharge
  - Expected CY 2015
- Frequency/Duration
- Drought

Qualitative Analysis Per ECB 2014-10

- Required for all projects to consider potential impacts and vulnerabilities impacting project goals and engineering designs
- Level of detail to be scaled to the decision and its consequences
- Relies on readily available information from peer reviewed literature and data
- Can potentially use a first-order statistical analysis
- No direct numerical change to hydrology

Phase II: First-Order Statistical Analyses

- Example provided in ECB 2014-10 for flood risk reduction project, flows, HUC 1027

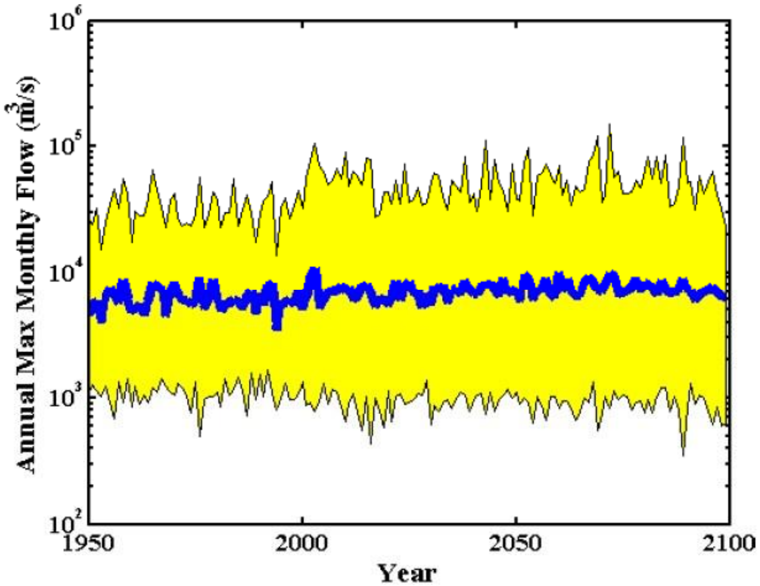


Figure C-3. Projections of climate-changed hydrology for HUC 4 1027. The mean of 100 projections of annual maximum monthly flow is in blue and the range of those 100 projections is in yellow.

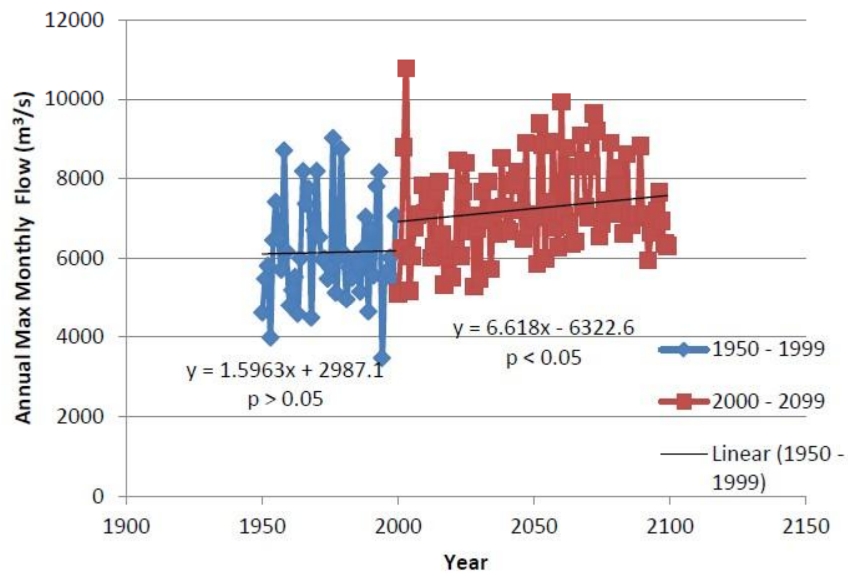
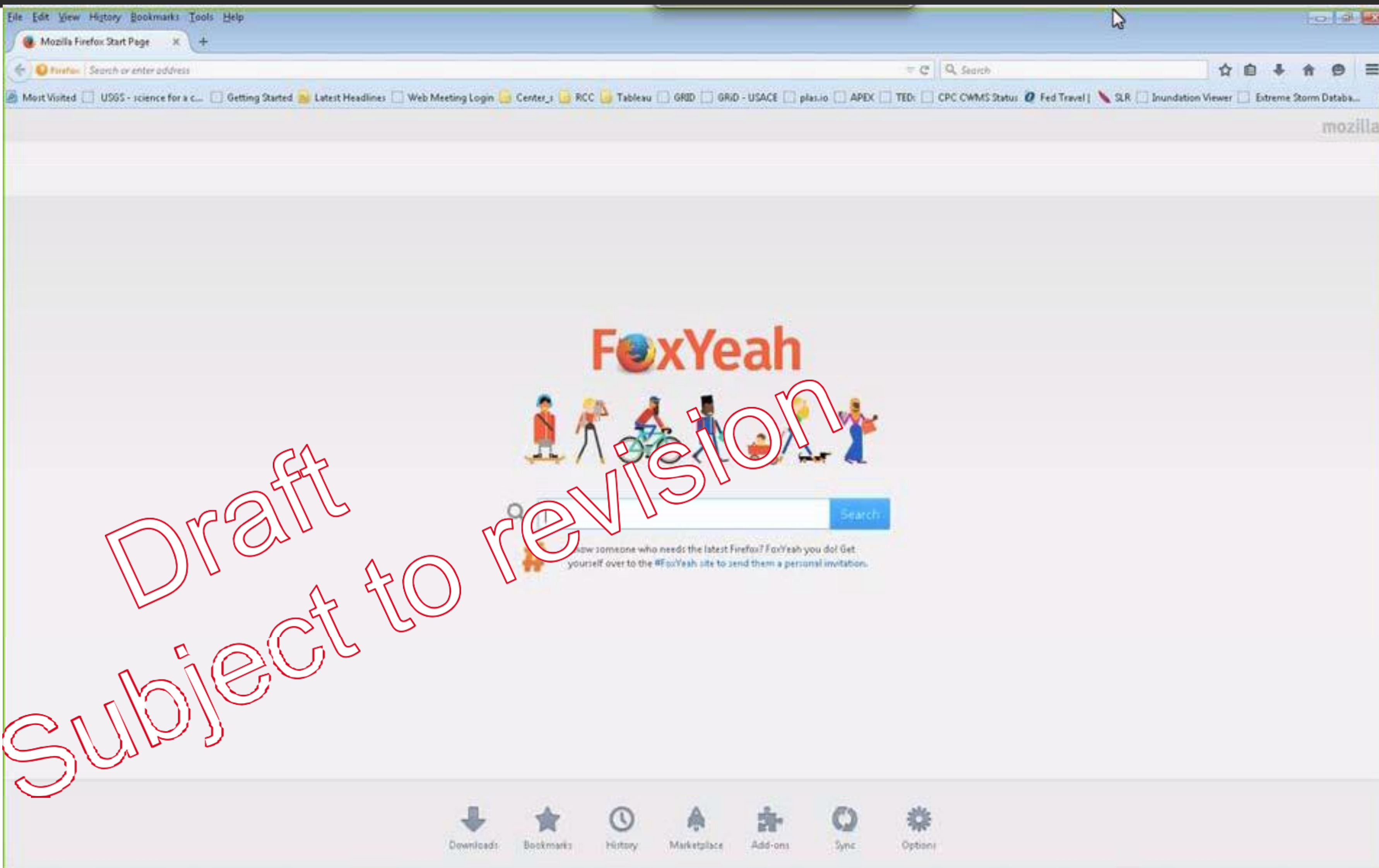


Figure C-4. Statistical analysis of the mean of the annual maximum monthly flow projections. The 1950–1999 period has no statistically significant trend, but the trend for 2000–2100 is statistically significant at the $p<0.05$ level.

ECB with PPT – about 4 minutes



Adaptation Policy and Guidance: Hydrology and Tools

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Watershed Vulnerability: Climate Hydrology

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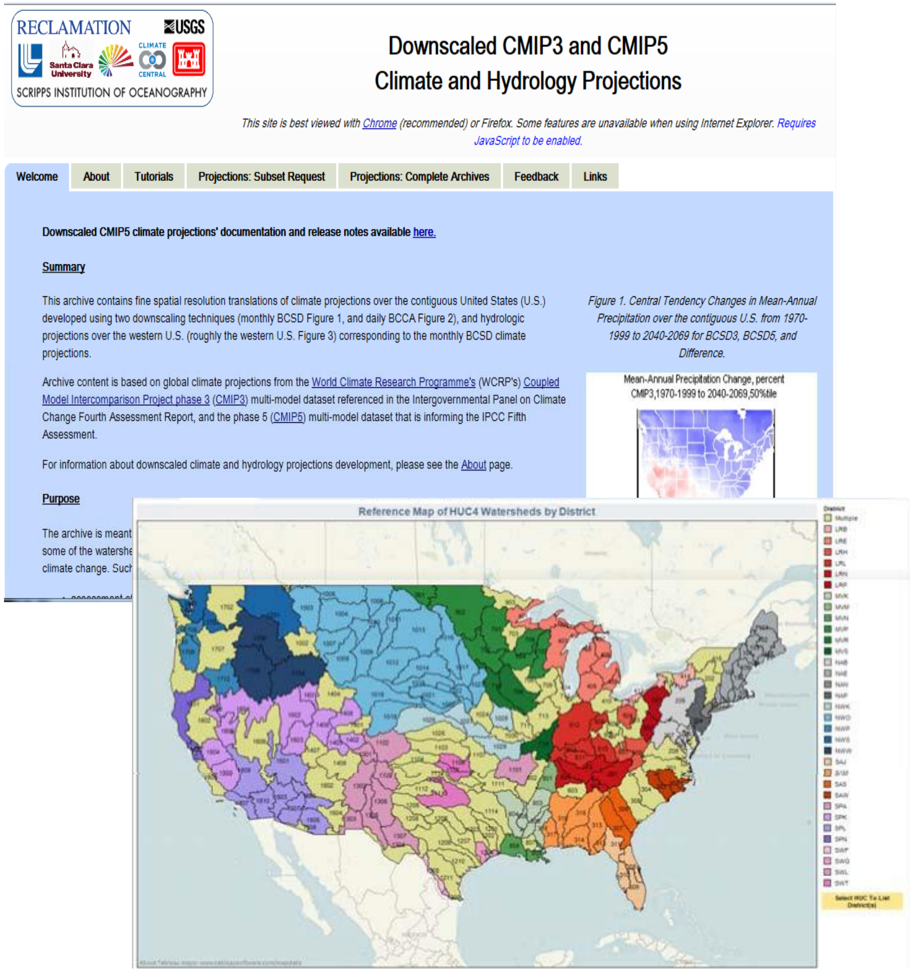
- CMIP5, BCSD, VIC (unregulated) hydrology
- Various combinations of GCMs and RCPs resulting in 100 traces per watershed per time period



"It's impossible, irresponsible even, to be more precise than you can be accurate,"

Screening-Level Climate Vulnerability Assessment Tool at Watershed-Scale: Summary

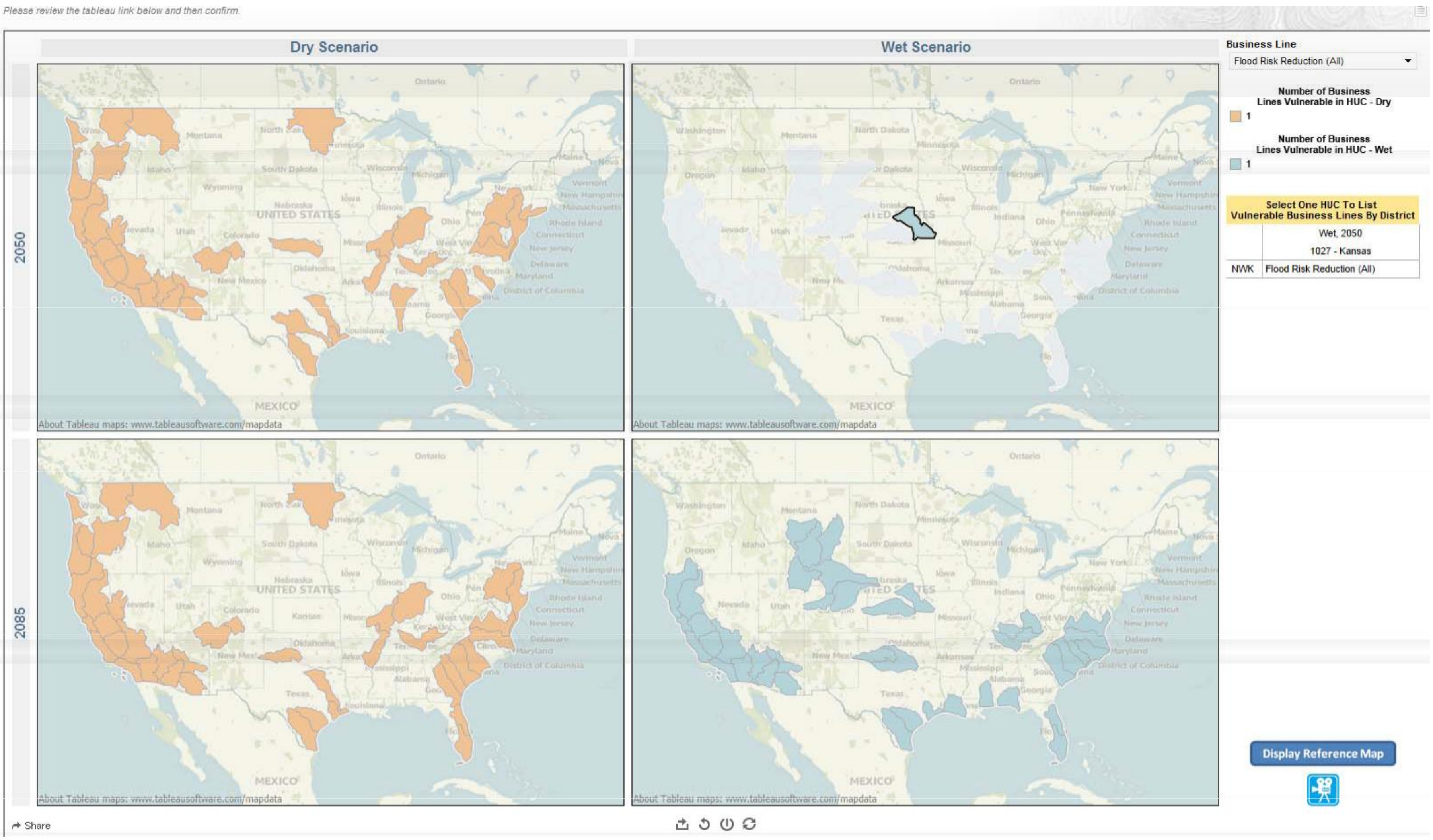
Objective: Assess the vulnerability of USACE's missions, operations, and programs to climate change impacts

- Easily accessible, usable, and risk-informed decision-support tool with associated data
- Support USACE's climate change adaptation planning activities
- Can be adapted and used by other federal agencies

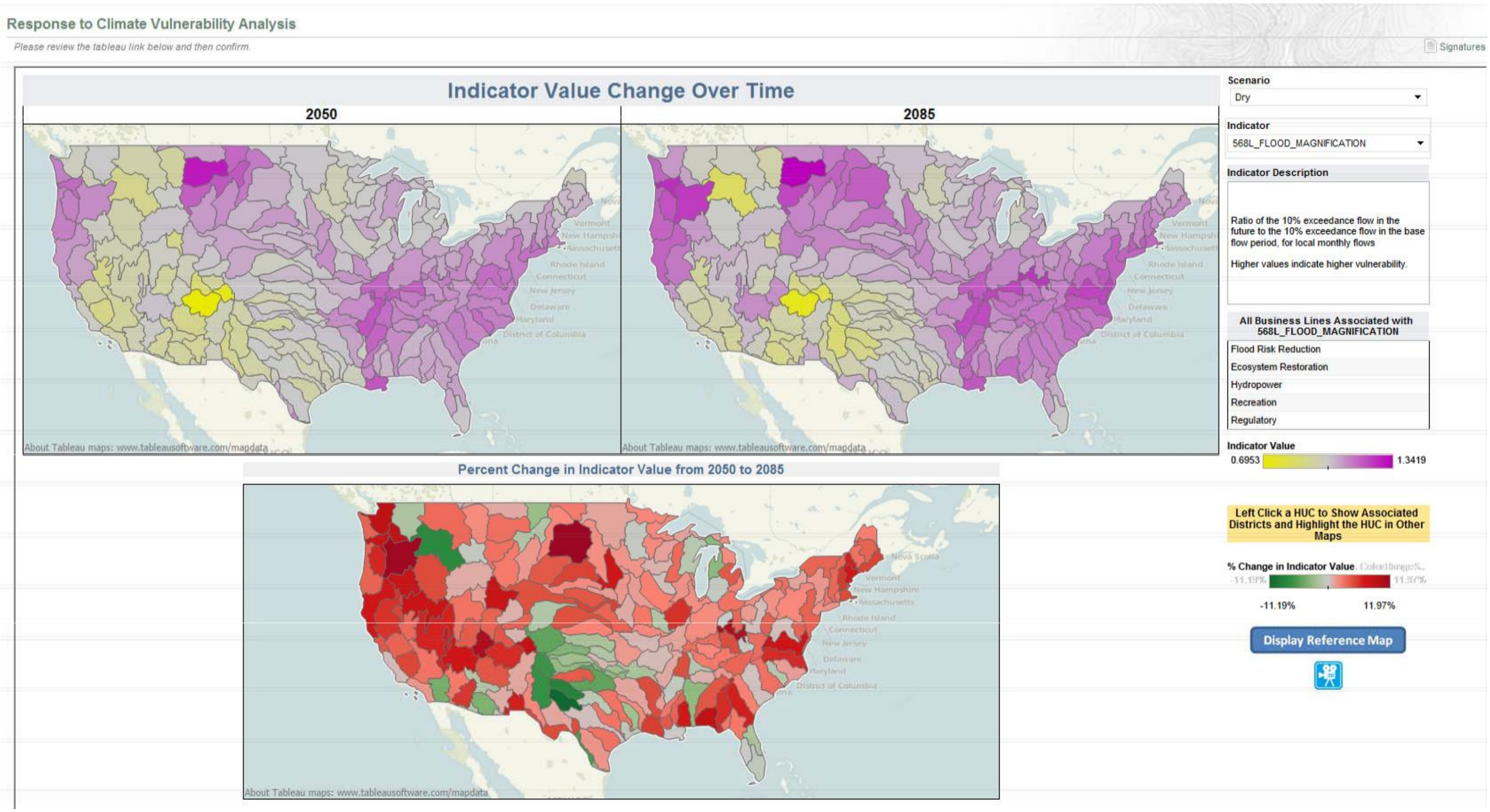
Our tool examines the vulnerability of 8 USACE Business Lines

Navigation	Flood Risk Reduction	Ecosystem Restoration	Hydropower
Regulatory	Recreation	Water Supply	Emergency Management

HUC 1027, USACE Screening-Level Watershed Vulnerability Assessment: Wet Only



HUC 1027 Flood Magnification Factor > 1.0 Even in Dry



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- Frequency/Duration
- Drought

Preview of Analysis

- Detection
  - Can we detect a statistically significant change in the observed climate?
- Attribution
  - Can we attribute that change to anthropogenic climate change?
    - This almost always involves comparisons to model outputs
    - Do the models with increases in greenhouse gases show this change while models run with no change in greenhouse gas concentrations not show it?

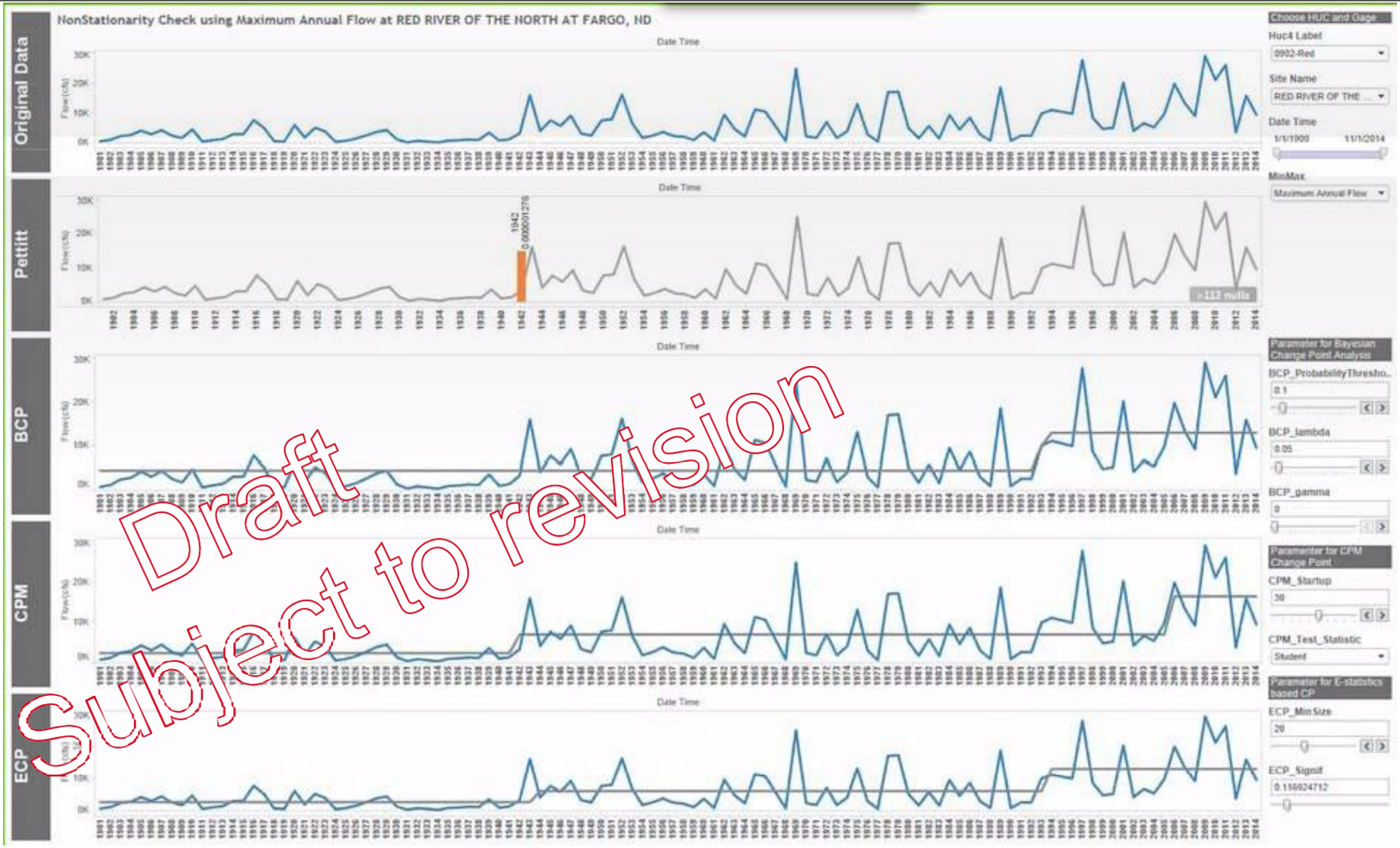
What Does Detection Mean

- We are interested in understanding how indices of risk or return periods are bound to change in a dynamic world
- Why?
  – Under nonstationary conditions of critical importance to hydrologic design and planning is an understanding of changes in the annual exceedance probability associated with future hydrologic events
  – Such changes in the annual exceedance probability are paramount to risk based decision making under nonstationary conditions

What Does Detection Mean Continued

- Traditional probabilistic approaches for defining risk, reliability and return periods under stationary hydrologic conditions assume that extreme events arise from a serially independent time series with a probability distribution whose moments and parameters are fixed.
- Most existing hydrology texts and handbooks provide a review of hydrologic design procedures assuming stationary conditions.

Detection Tool



Change Was Detected

- What is the significance of the change?
- What is the attribution of the change
  - Human?
  - Environment?
- Evaluate the appropriate period of record to use

Adaptation Policy and Guidance: Hydrology and Tools

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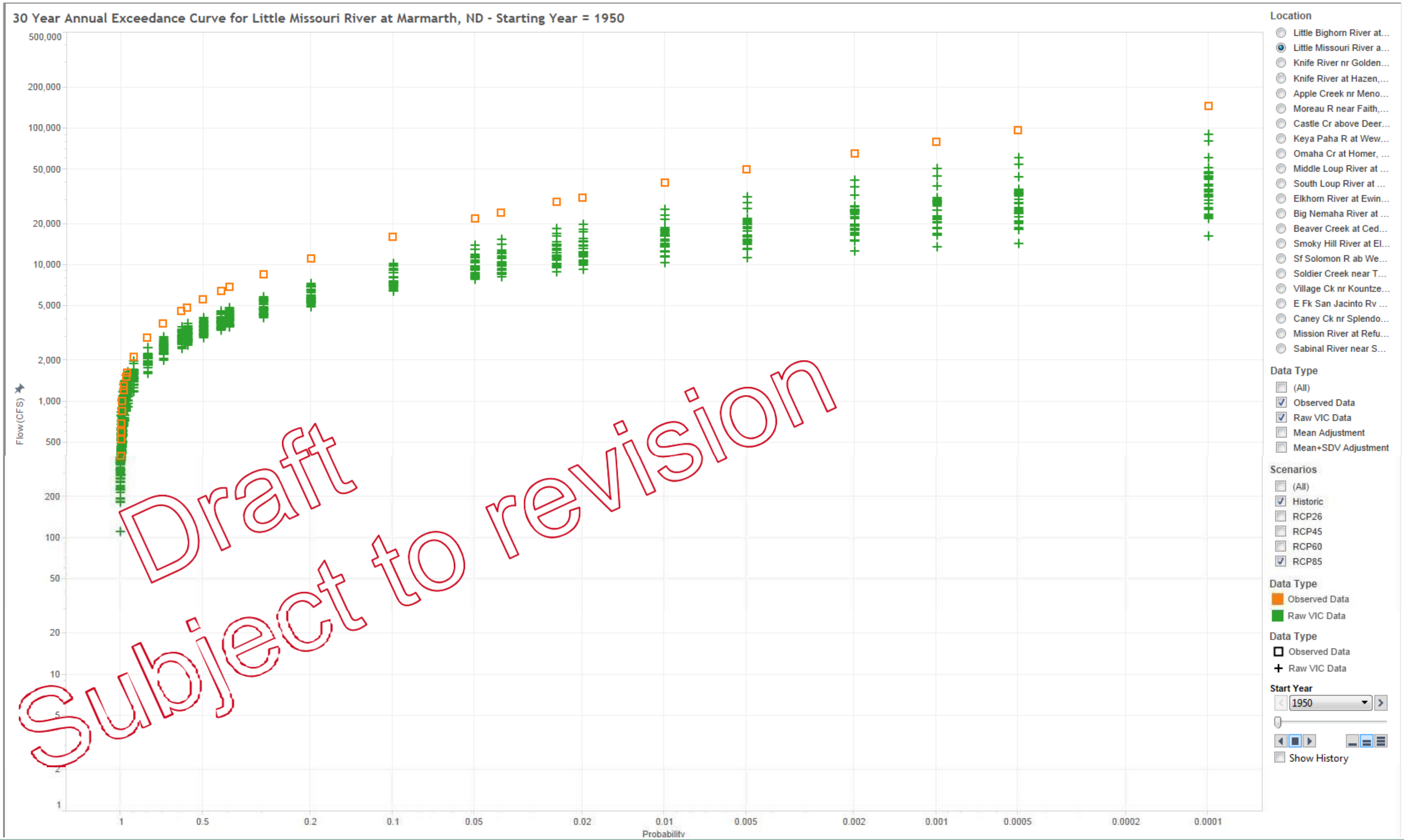
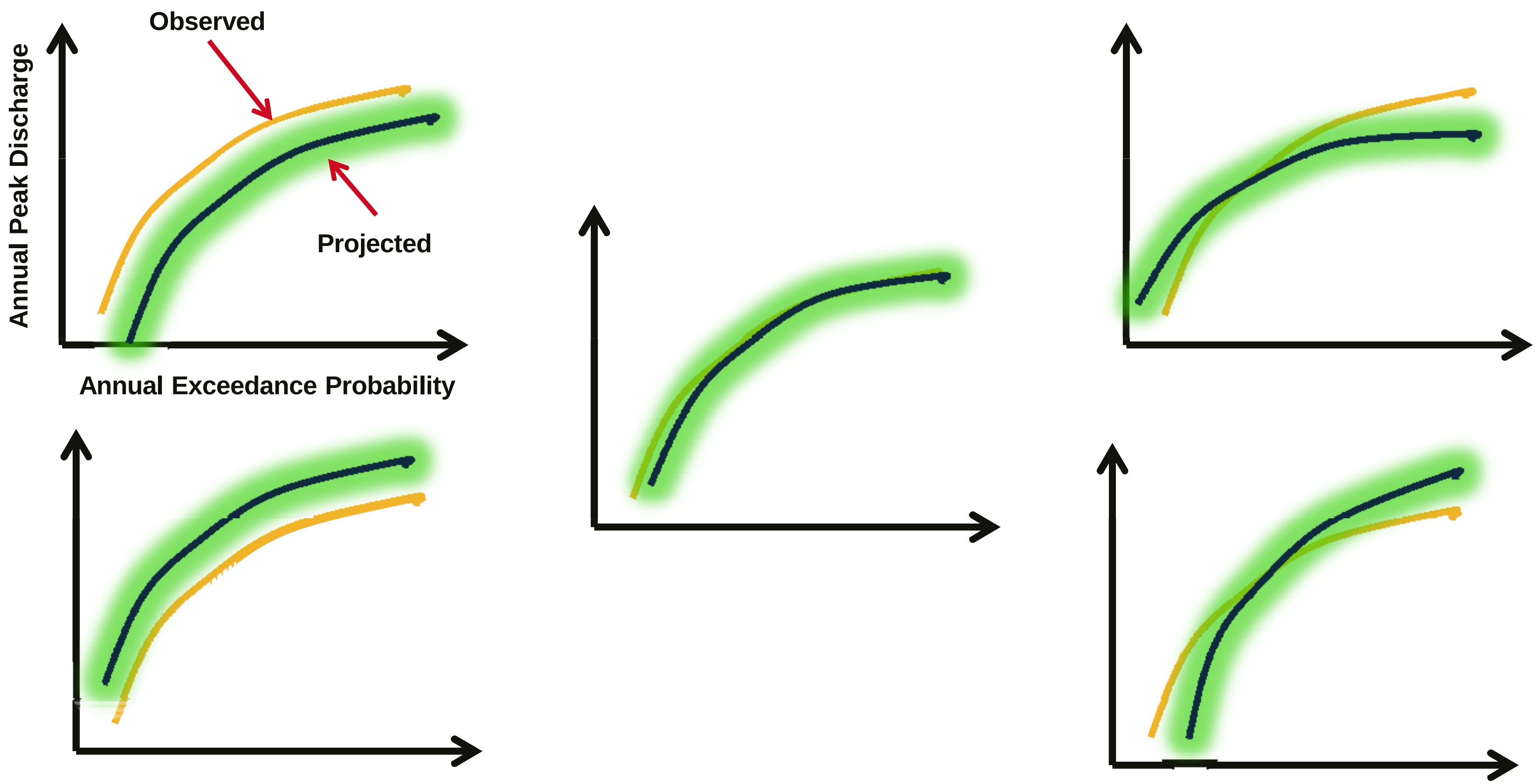
- Frequency/Duration
- SPI/SPEI

Observed Frequency Curve (30 year Orange) and raw Climate derived data (green) for Little Missouri River at Marmarth, ND

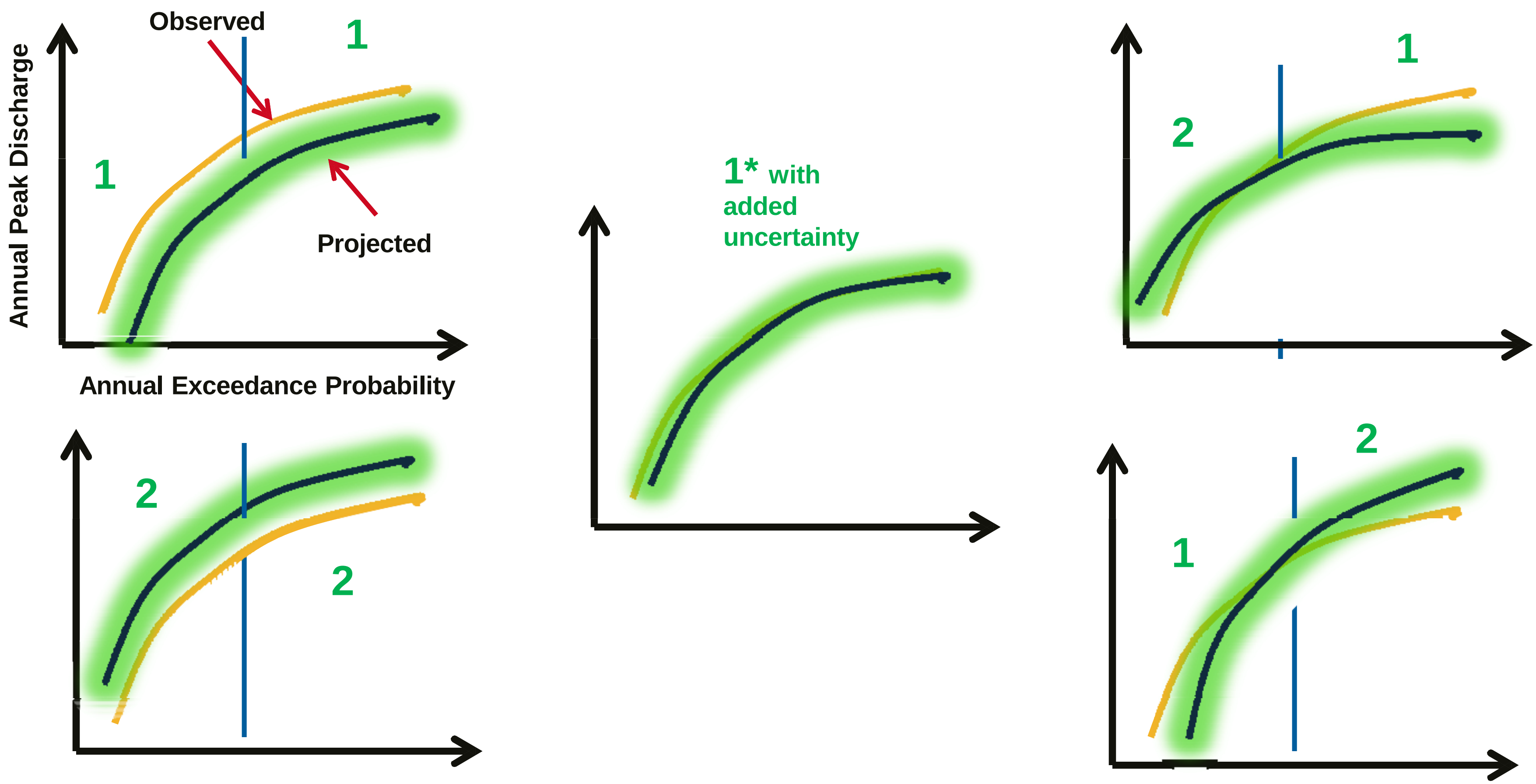


Notional – Based on Current Information: Five Basic Frequency Cases Can Inform Adaptation



Journal paper in prep White & Baker

Example: Inform Adaptation For Flood Risk Reduction Business Line

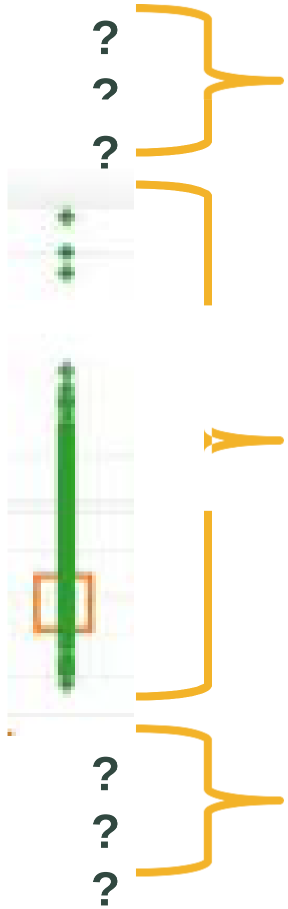


1 = use current methods

2 = identify adaptation measures for increased future flow

*** Update after additional information becomes available Summer 2015**

Allow for Unknown Unknowns

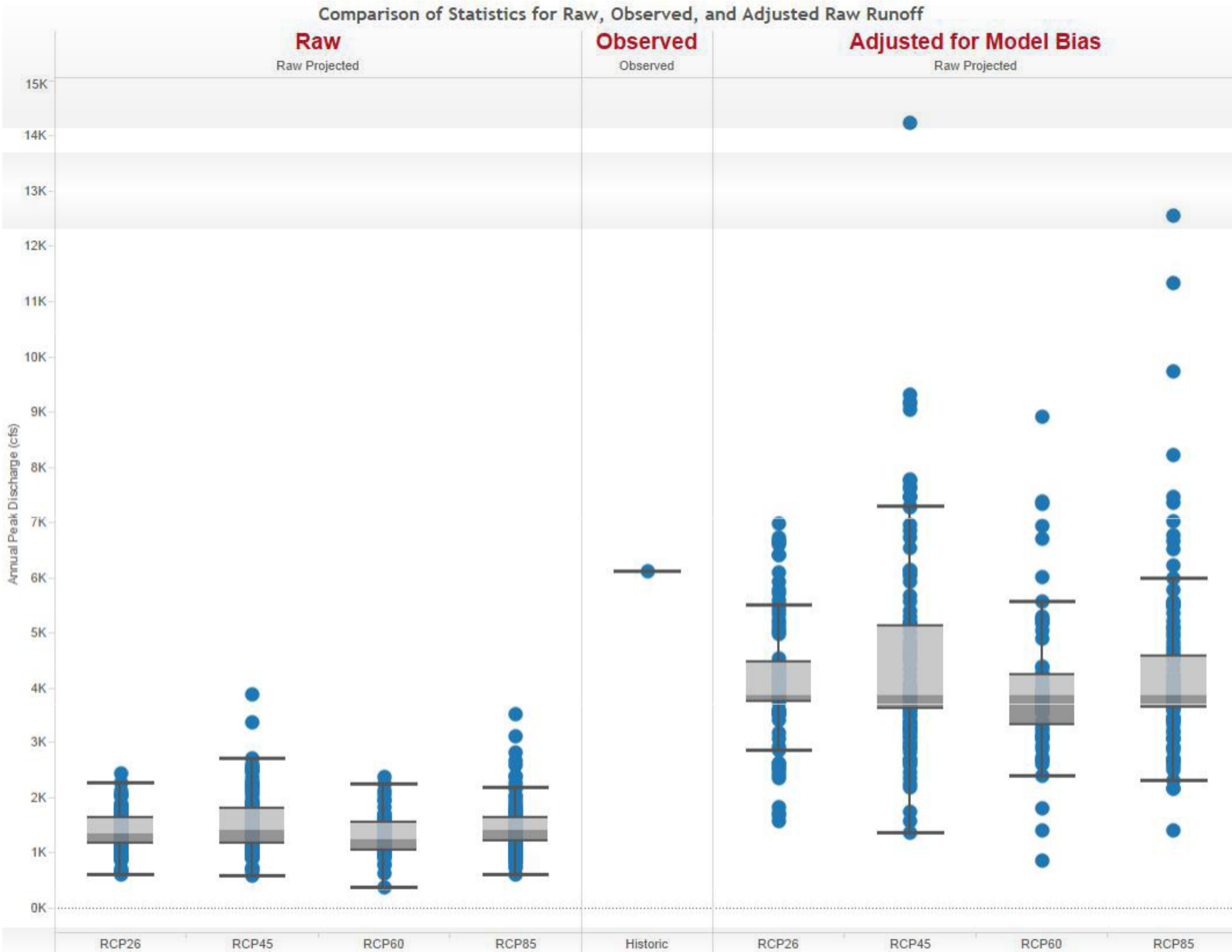


Unknown unknowns:
Other downscaling, other hydrologic models, other unknowns

Known unknowns:
Most GCM/RCP BCSD VIC

Unknown unknowns:
Other downscaling, other hydrologic models, other unknowns

Observed and GCM Box Plots for .9 Probability Exceedance (Raw and Adjusted)



Gage Name
Cottonwood Creek near Olinda, CA

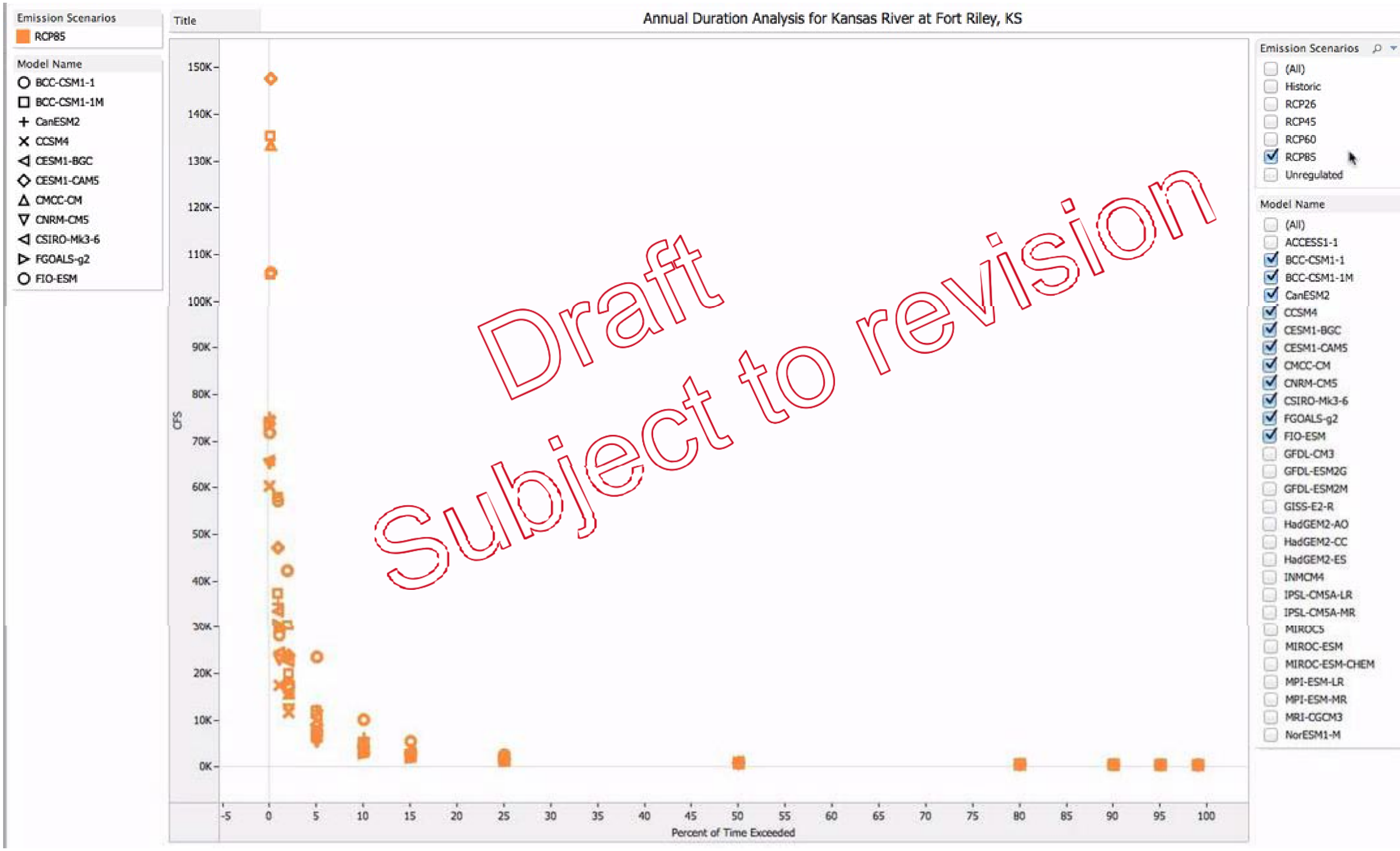
Representative Concentratin Pat..
All

Exceedance Probability, PCT
0.9

Box plots for projected flow are for the selected epochs, Representative Concentration Pathways (RCPs), General Circulation Models (GCMs), and exceedance probability(s). The chart on the left illustrates the raw projections processed throught Bulletin 17B compared to the observed runoff from Bulletin 17B, and the chart on the right represents the statistics when the raw projected data is adjusted to reflect model bias.

The adjustment is made by the following equation per exceedence plot ordinate: Qap/(Qbp/Qo) where Qap = projected runoff adjusted for model bias, Qbp = GCM runoff for the base period 1950-2014, and Qo = observed runoff for the period of record ending 2014. There will always be some uncertainty remaining because of the various methods, initial conditions, and boundary conditions of the GCMs and the assumptions driving the RCPs. However, you should see that when adjusted for model bias, there is less difference between the projected and observed runoff.

Duration Curves at Fort Riley, Kansas River, KS



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- Frequency/Duration
- Drought

Work in Progress

- Actions and Science
  - Uncertainty
    - We have limited national downscaling and hydrology which means that we have not yet revealed all of the uncertainty
    - Work in progress to add hydrologic models and parameters – and downscaling – in FY15-16 to move toward quantitative guidance
    - Model Democracy
  - Flow frequency
    - Despite the uncertainties, we are making progress on understanding future changes to flow frequency
    - Working to simplify

Some Drought Index Definitions

- Standardized Precipitation Index
  - Primarily for defining and monitoring drought
  - Determines the rarity of a drought at a given resolution
  - Different from the Palmer Drought Index (PDI)
  - SPI considers only precipitation

- Standardized Precipitation Evapotranspiration Index (SPEI)
  - Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land to the atmosphere
  - The Standardized Precipitation Evapotranspiration Index (SPEI) is an extension of the widely used Standardized Precipitation Index (SPI)
    - The SPEI is designed to take into account both precipitation and potential evapotranspiration (PET) in determining drought.
    - Thus, unlike the SPI, the SPEI captures the main impact of increased temperatures on water demand.

- IT IS NOT A PREDICTION TOOL WHEN DROUGHTS HAPPEN

Standardized Precipitation Index

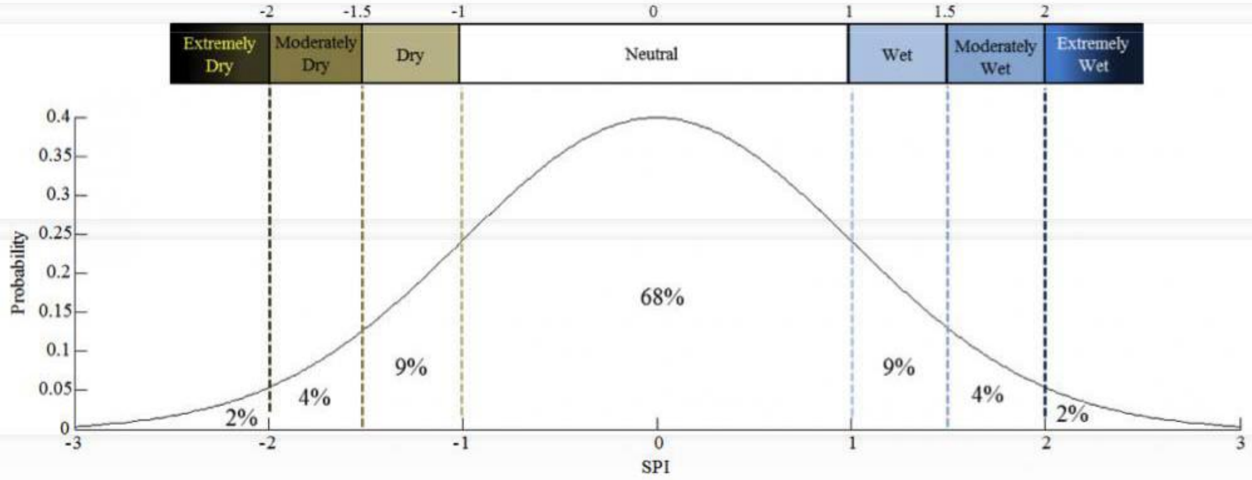
Text from NCAR website
More at https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi

The **Standardized Precipitation Index (SPI)** is a probability index that gives a better representation of abnormal wetness and dryness than the **Palmer Severe Drought Index (PSDI)**. The World Meteorological Organization (WMO) **recommends**, that all national meteorological and hydrological services should use the SPI for monitoring of dry spells. Some advantages of the SPI:
It requires only monthly precipitation.

It can be compared across regions with markedly different climates.
The standardization of the SPI allows the index to determine the rarity of a current drought.
It can be created for differing periods of 1-to-36 months.

A shortcoming of the SPI, as noted by Trenbert et al (2014): "the SPI are based on precipitation alone and provide a measure only for water supply. They are very useful as a measure of precipitation deficits or meteorological drought but are limited because they do not deal with the ET [evapotranspiration] side of the issue."

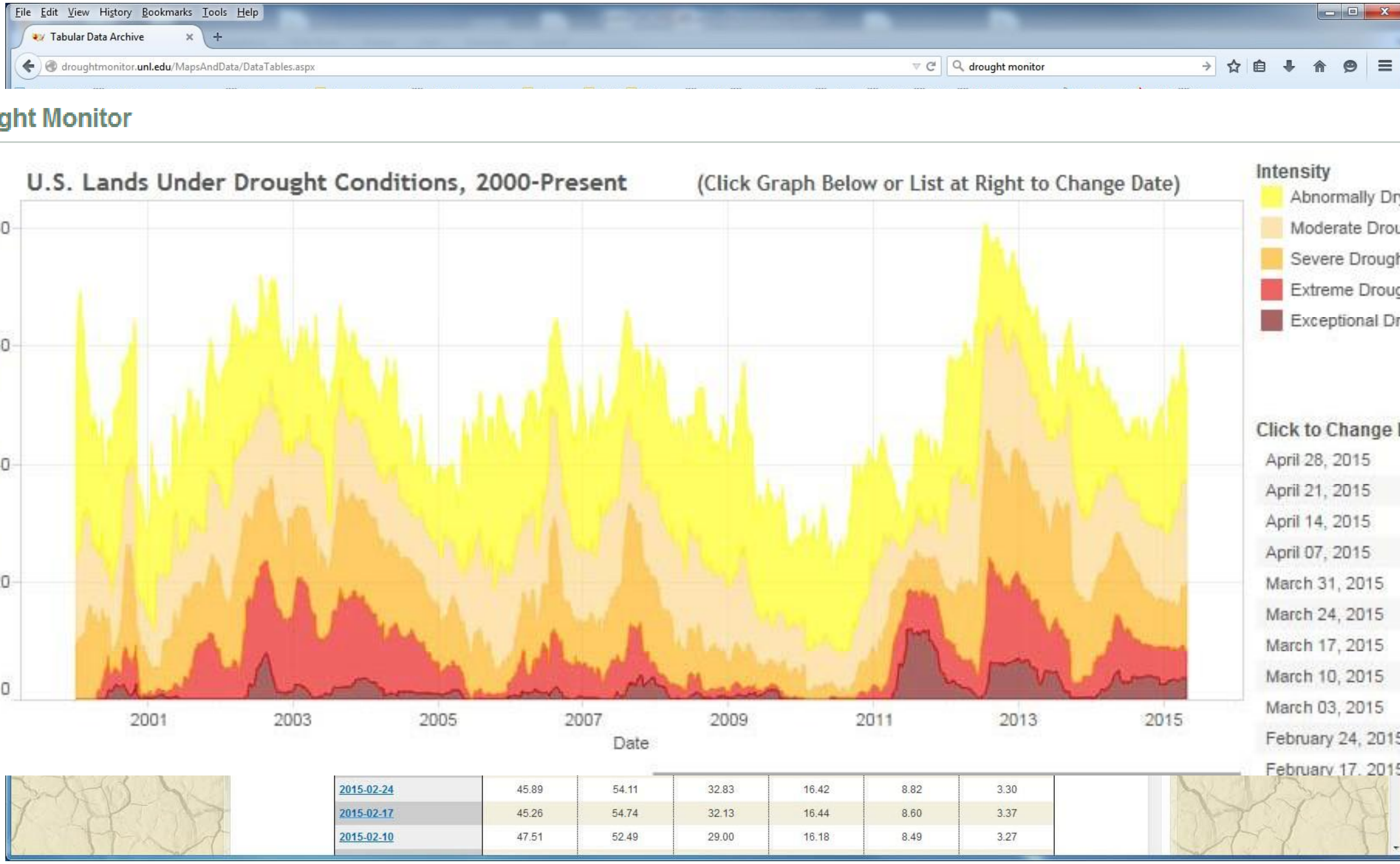
The SPI is obtained by fitting a gamma or a Pearson Type III distribution to monthly precipitation values.



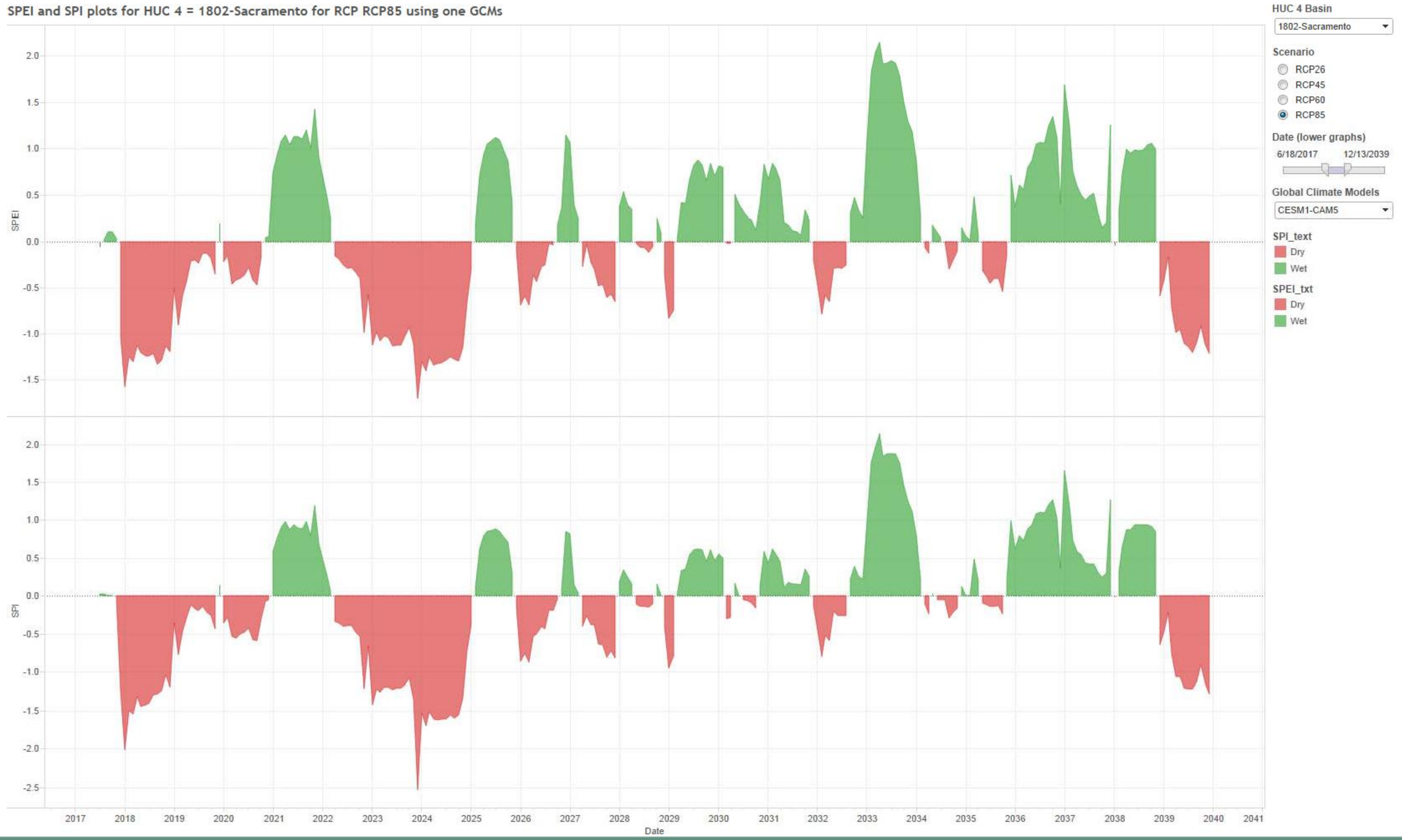
Concepts

- What can we reveal
  - What do we know
  - What don’t we know
  - What don’t we know we don’t know
  - What do we think we know that just isn’t so
- Appreciate it is a complex system
  - We can never predict with certainty the exact response
  - Absorbing disturbances; undergoing change yet retain same function = resilience

Drought Monitor



SPI ad SPEI for HUC 4 Basin = Sacramento
One Climate Model, Concentration Path is 8.5



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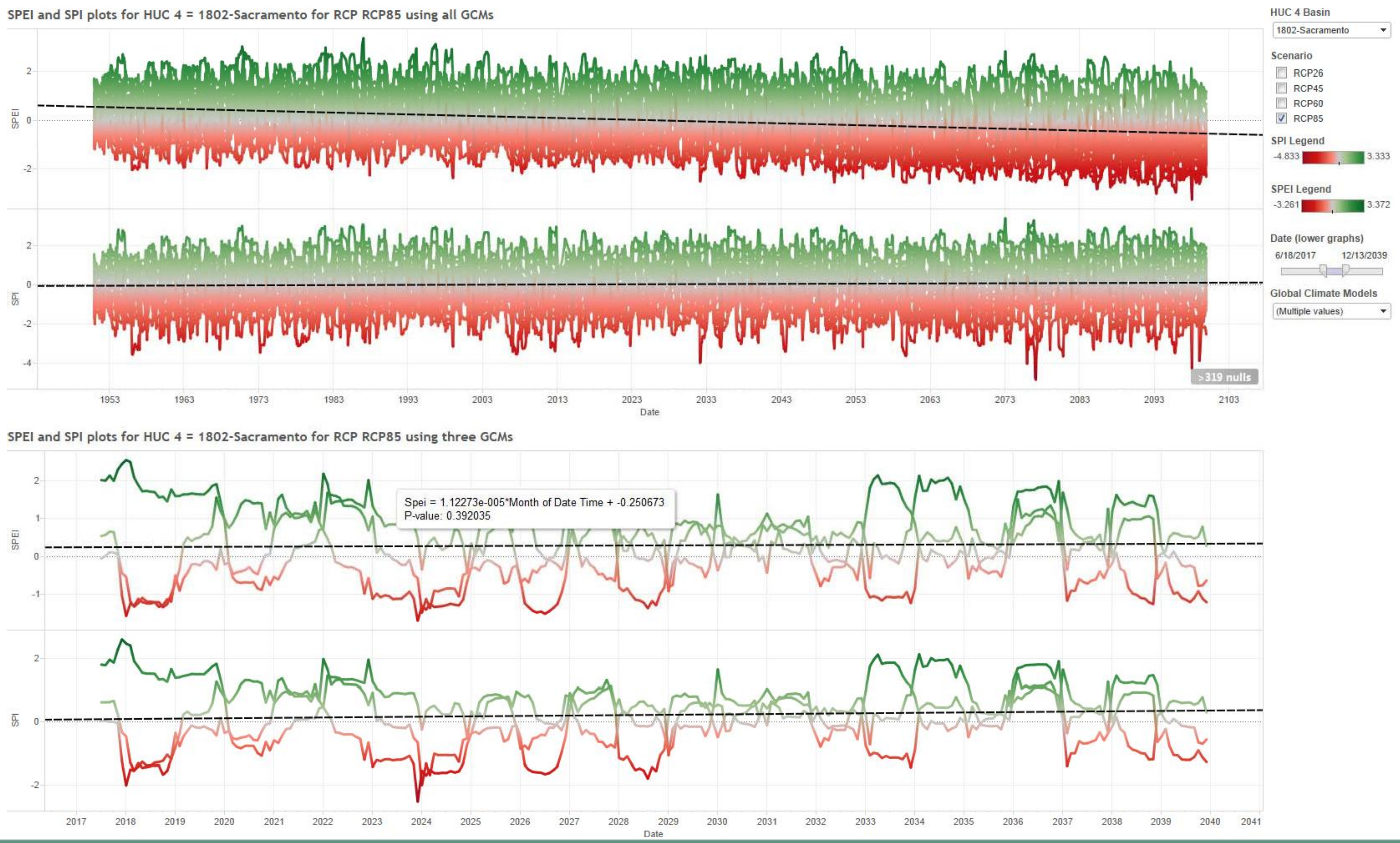
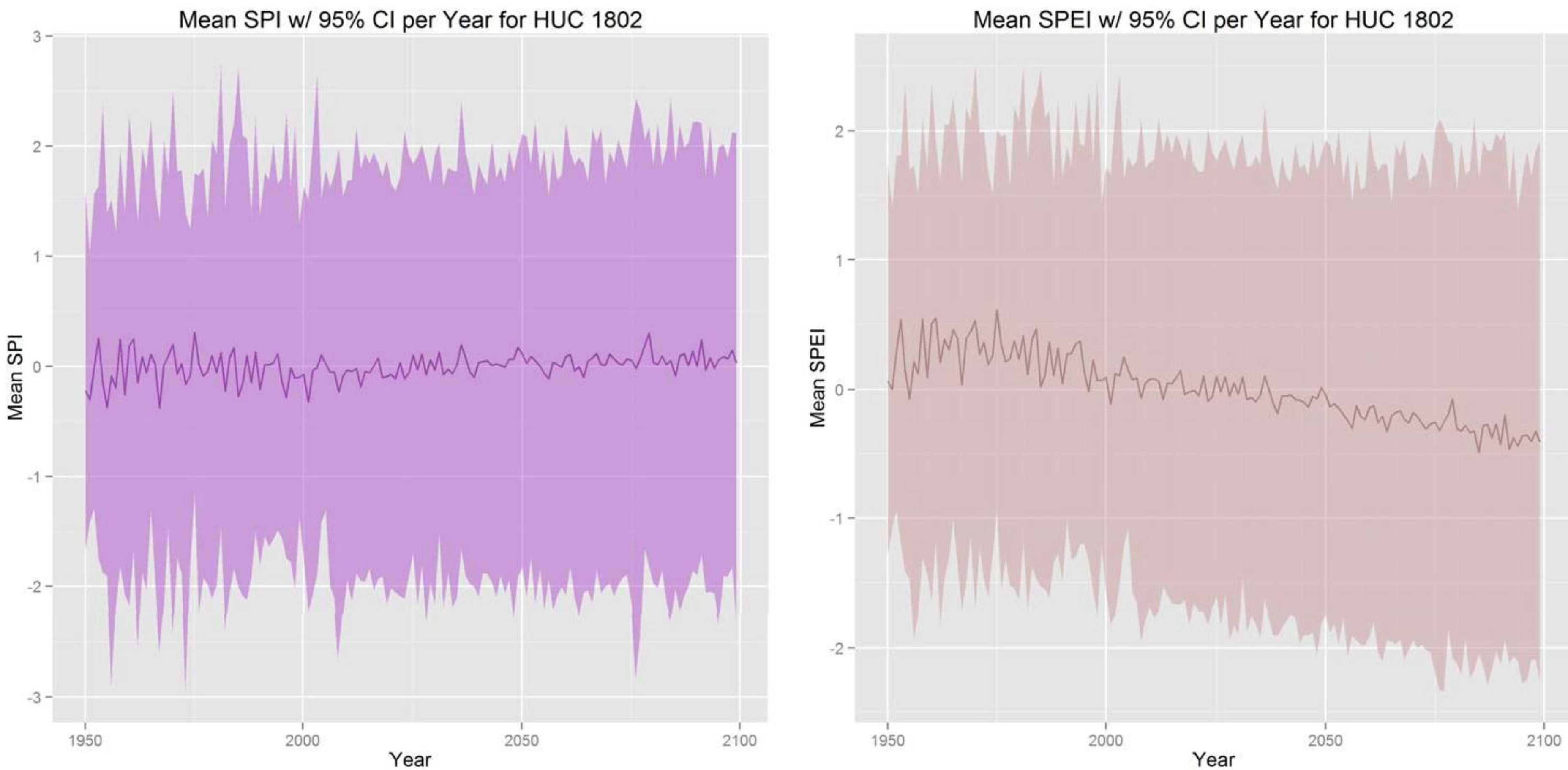
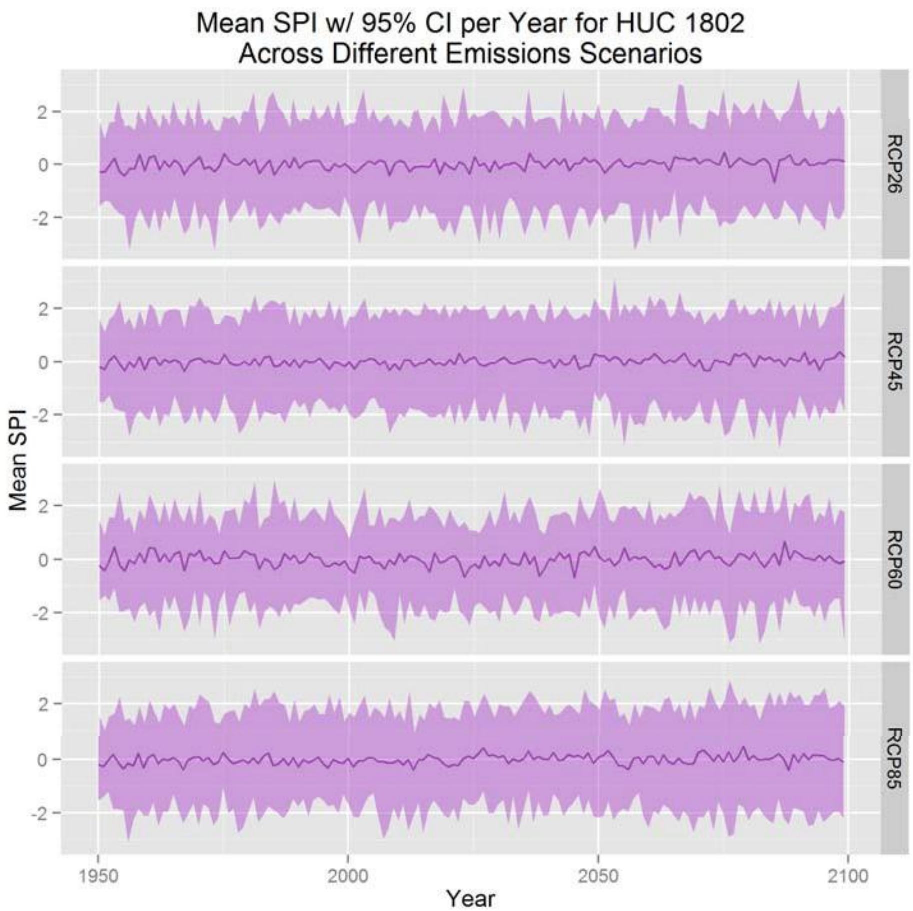
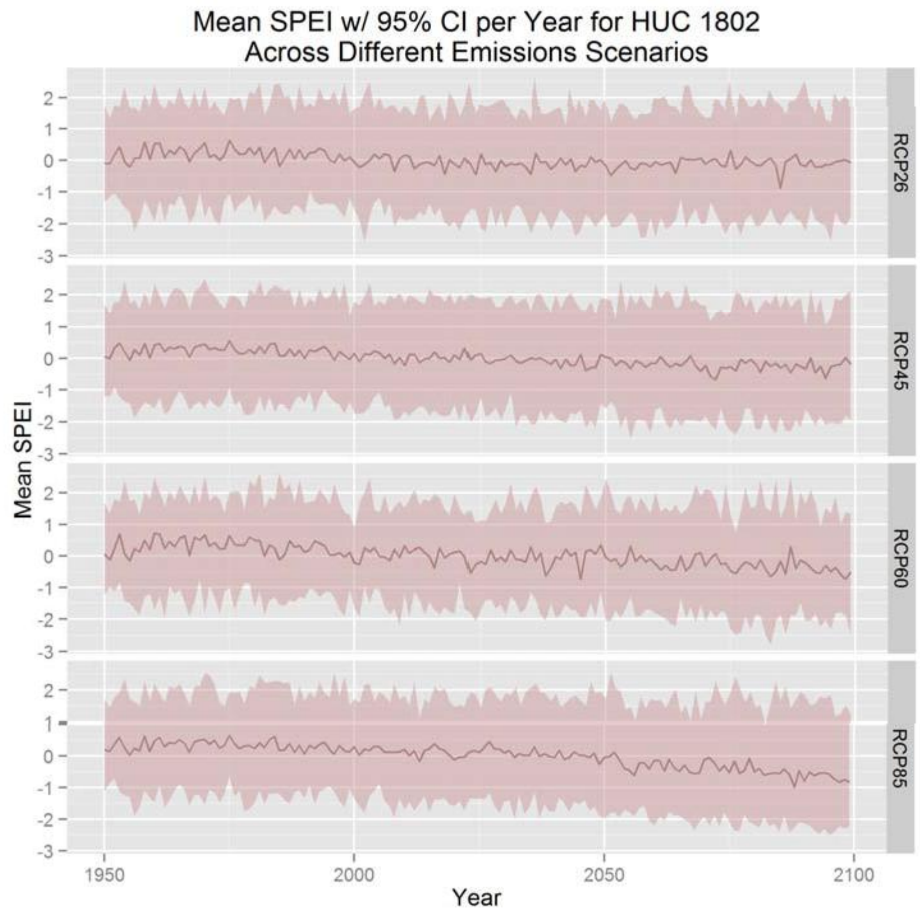


95% Confidence Interval for SPI & SPEI



95% Confidence Interval for SPI & SPEI broken out by Representative Concentration Pathways

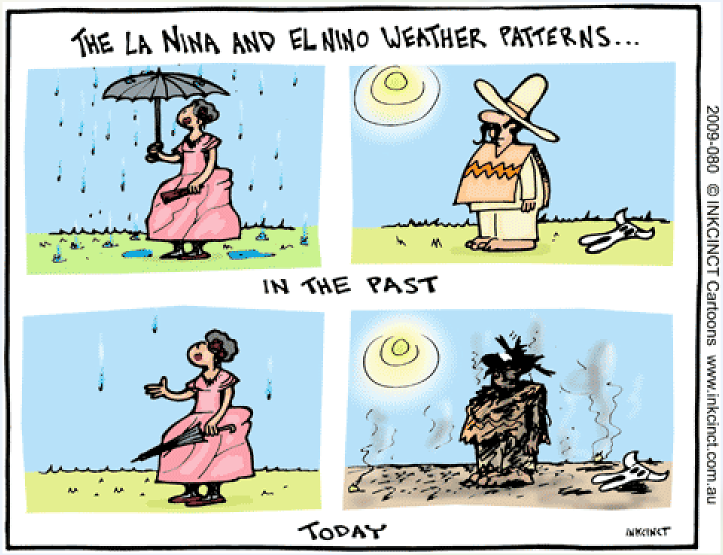




Capstone

- We embrace uncertainty
- Don’t pre-select
  - A GCM
  - A RCP
  - An Index
  - Etc
- Trend lines and model democracy
- Visualize the data.
  - Visual data analysis is key
  - Graphical methods for data analysis.
- The more we look at it and questions it, the more we learn, we can be better prepared (better discussions)

Climate Tools and Outlooks



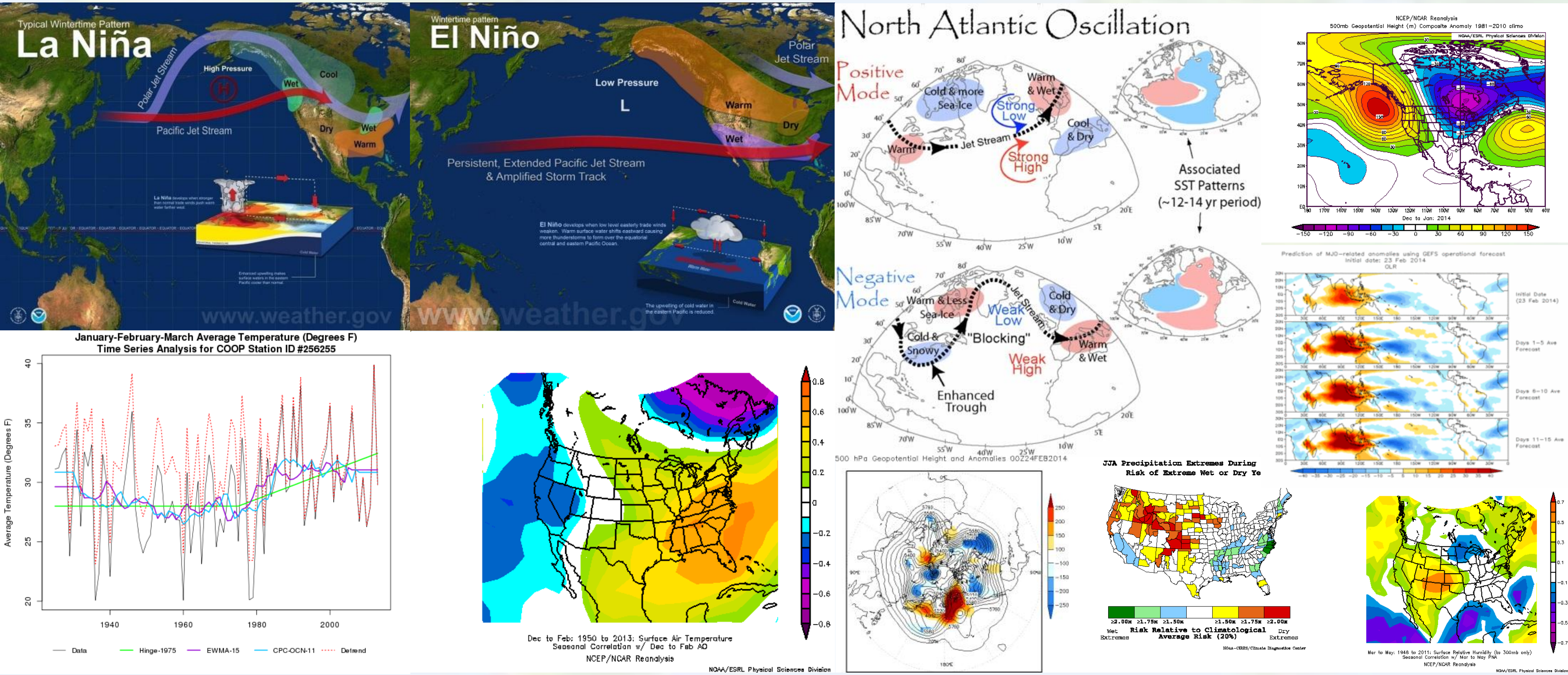
Nebraska Silver Jackets Climate Change Workshop

July 29, 2015

Barb Mayes Boustead, Ph.D.

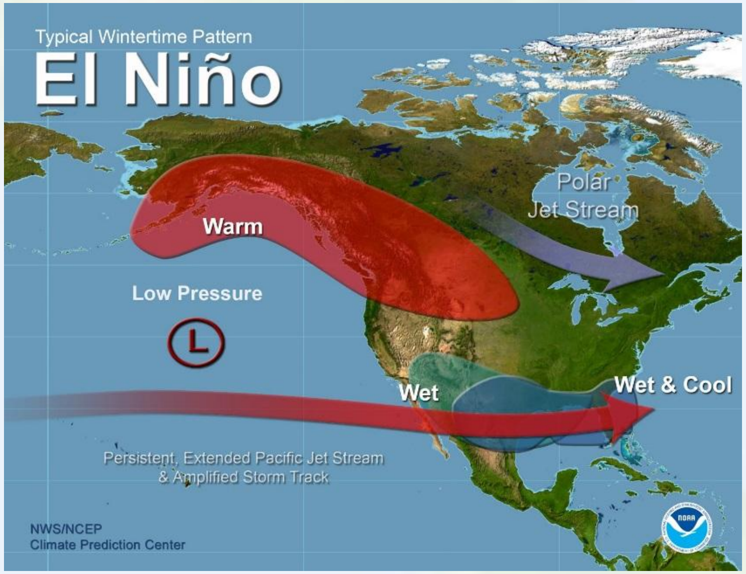
National Weather Service, Omaha/Valley, NE

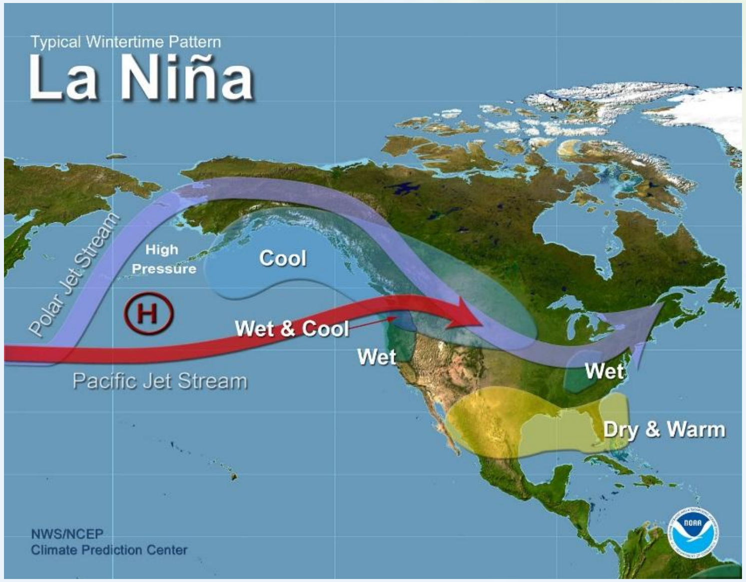
Climate Forecasting: Players in Regional Climate

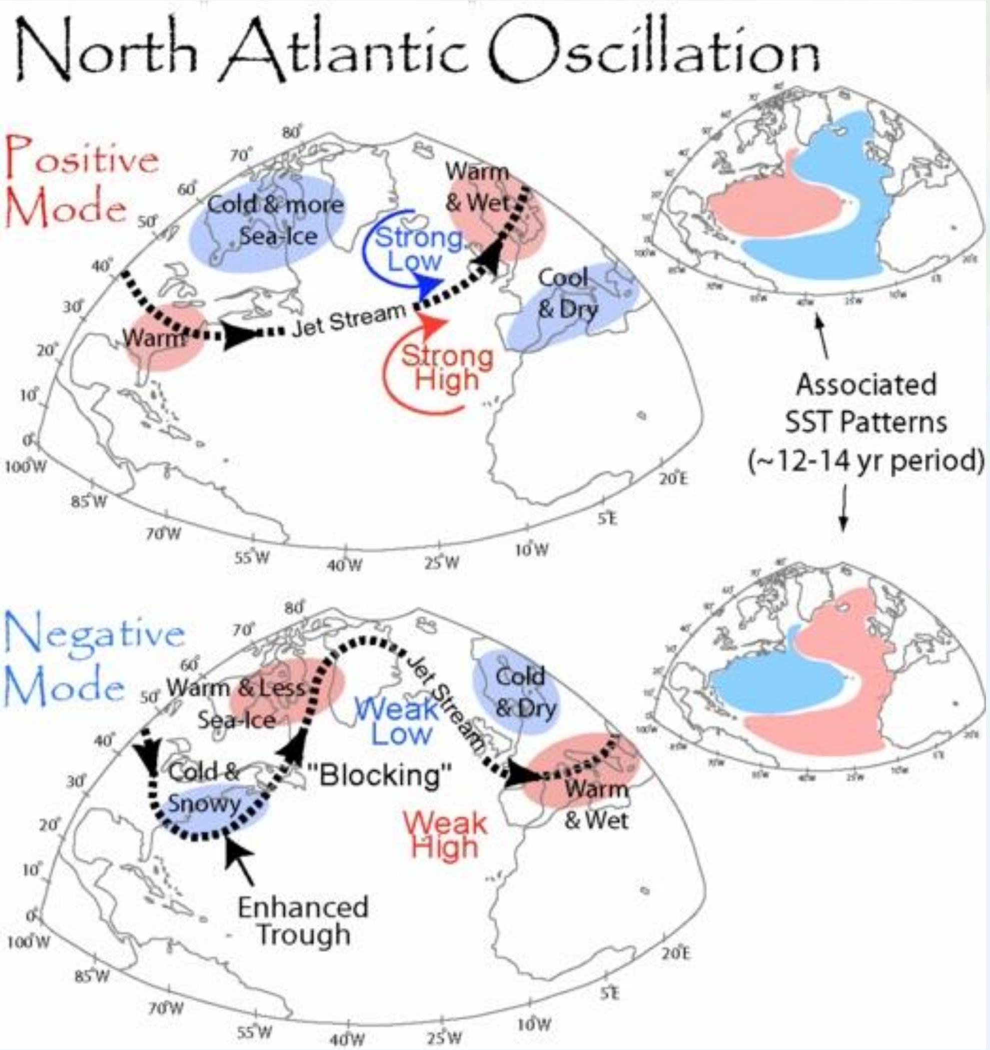


- Climate teleconnection patterns: El Niño/Southern Oscillation, North Atlantic Oscillation, Arctic Oscillation, Madden-Julian Oscillation, etc.
- Trends
- Persistent weather patterns: Blocking highs

Climate Variability: Influencing Seasons

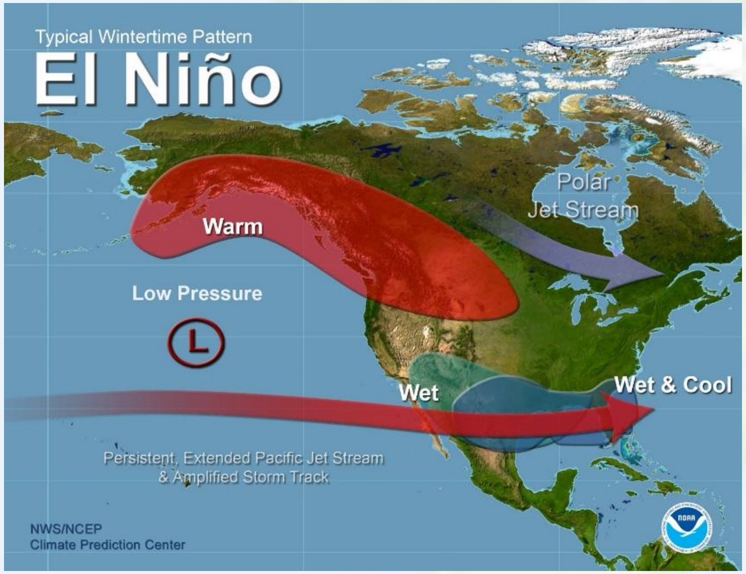






Climate Variability: El Niño—Southern Oscillation (ENSO)

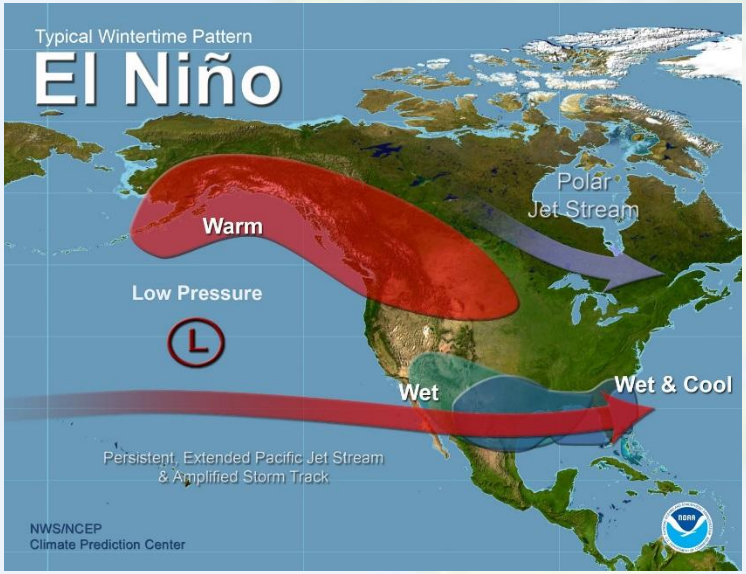
- El Niño typical impacts:
  - Strong jet suppressed south across the Gulf
  - Northern Plains high and dry
  - Southern states cool and wet
  - North Atlantic tropical activity suppressed

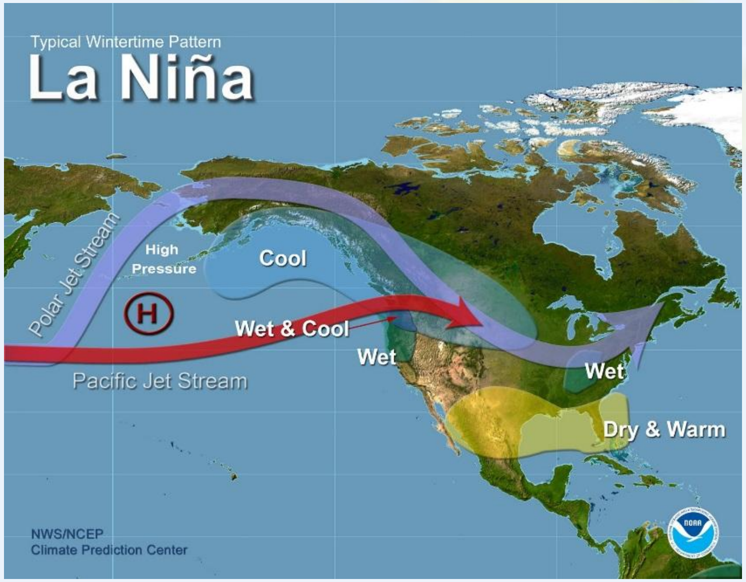


Climate Variability:
El Niño—Southern Oscillation (ENSO)

- El Niño typical impacts:
  - Strong jet suppressed south across the Gulf
  - Northern Plains high and dry
  - Southern states cool and wet
  - North Atlantic tropical activity suppressed

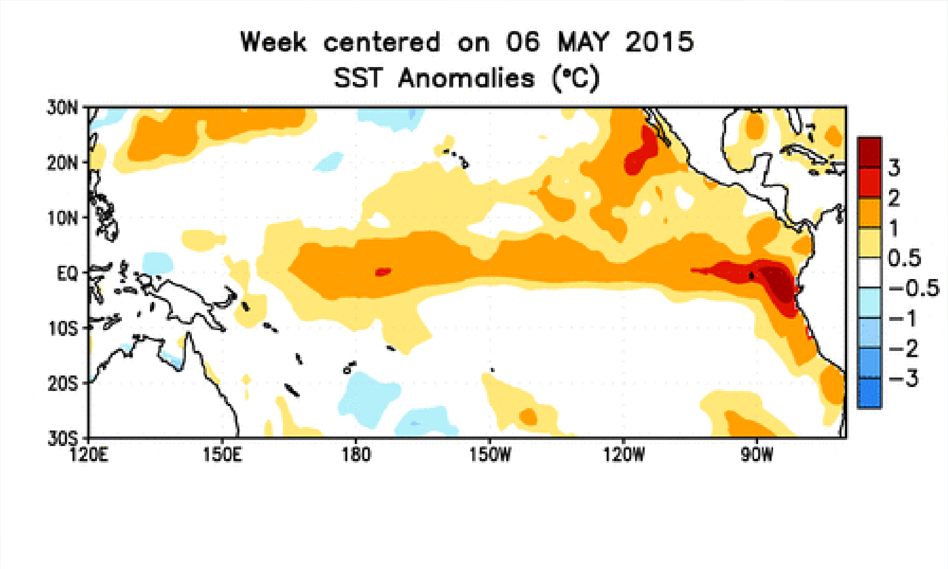
- La Niña typical impacts:
  - Amplified and variable jet
  - Northern Plains taking cold air dumps
  - Southern states high and dry
  - Ohio Valley wet
  - North Atlantic tropical activity enhanced



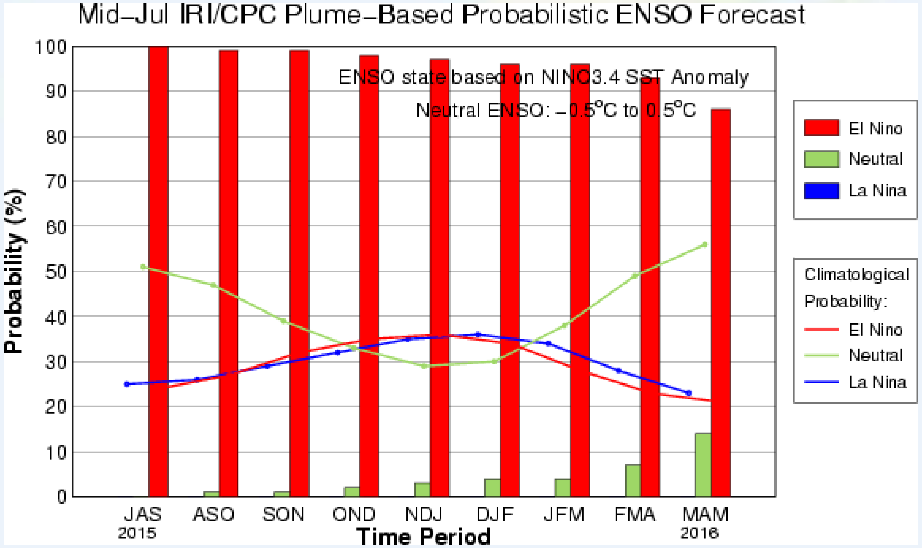


Current ENSO State and Outlook

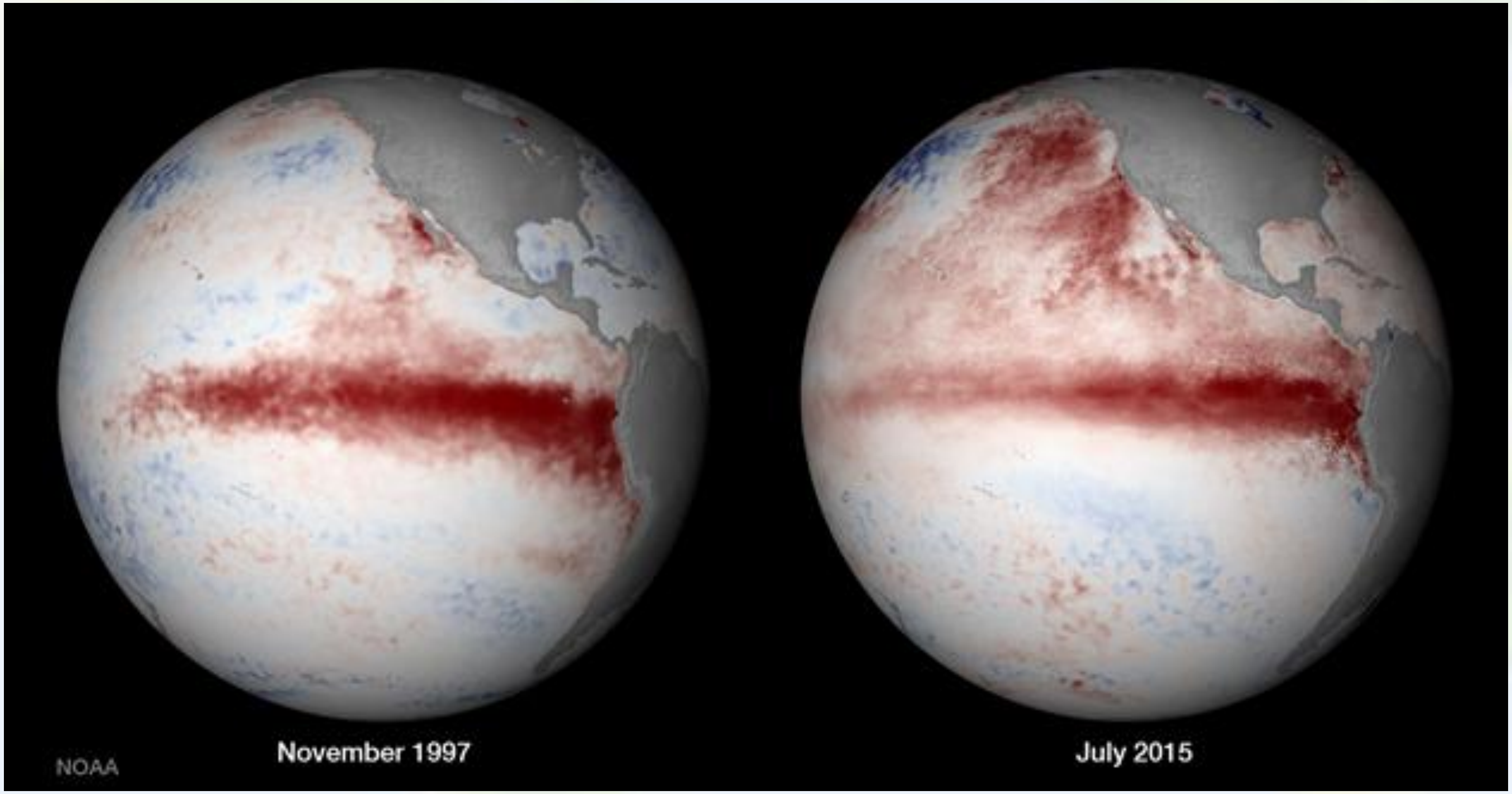
- Current state:
  - ♦ Moderate El Niño conditions
  - ♦ Atmosphere responding to ocean temperatures



- Outlook:
  - ♦ El Niño will continue through winter
  - ♦ Strong El Niño event is more likely than not



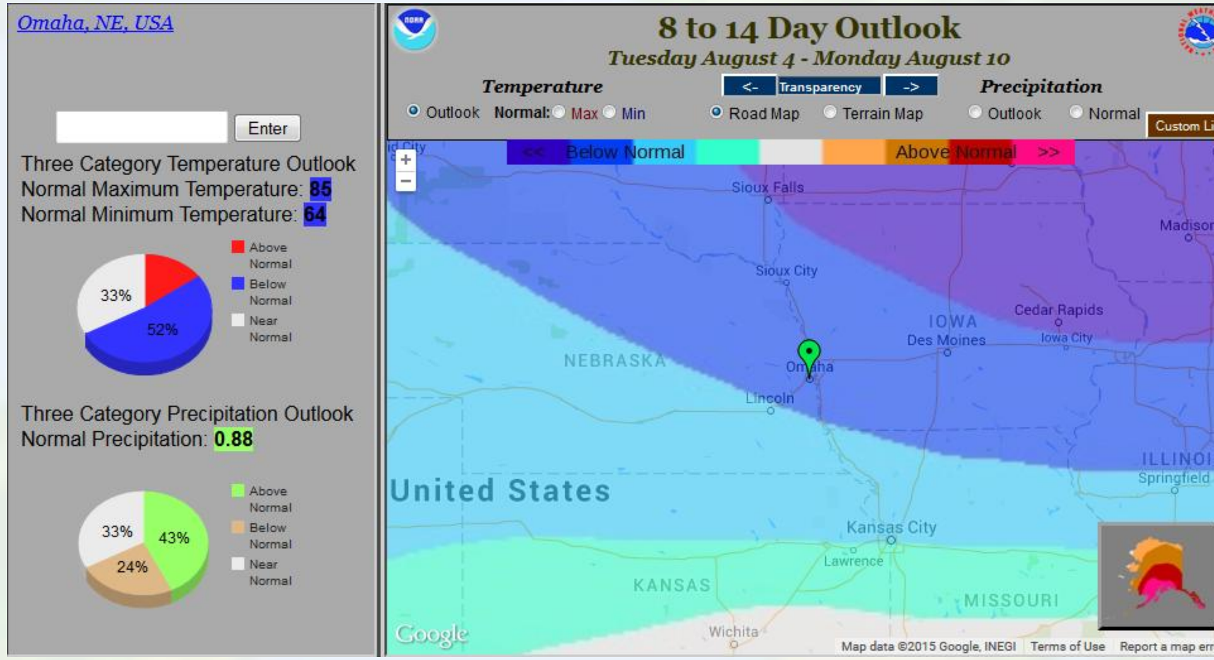
Is This El Niño Going to Be the “Big One”?

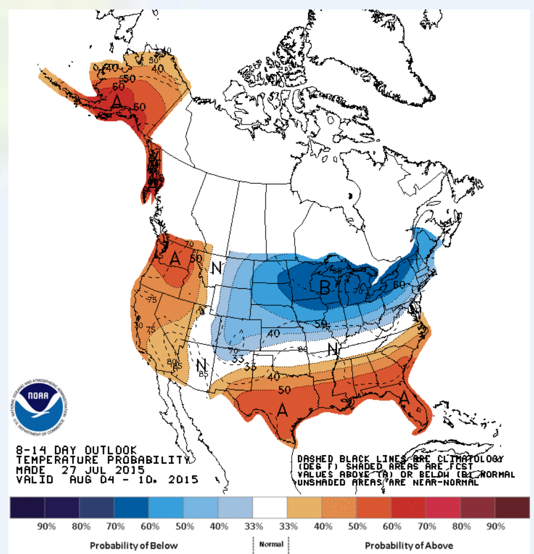


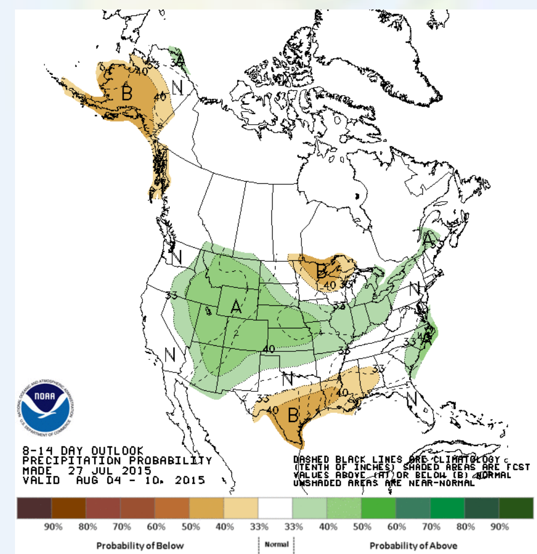
- Strong warm anomalies for this time of year
  - Typical peak: Dec/Jan
- “The Blob”

CPC Outlooks:
6- to 10-Day and 8- to 14-Day

- Predicting chances for *temperatures* and *precipitation* to fall in the *upper, middle, and lowest thirds*.
  - "50%" = 50-60% chance of that category (instead of the usual 33%)
- Issued every afternoon
  - Automated on weekends
- Mainly based on weather and climate models
- New: Interactive display

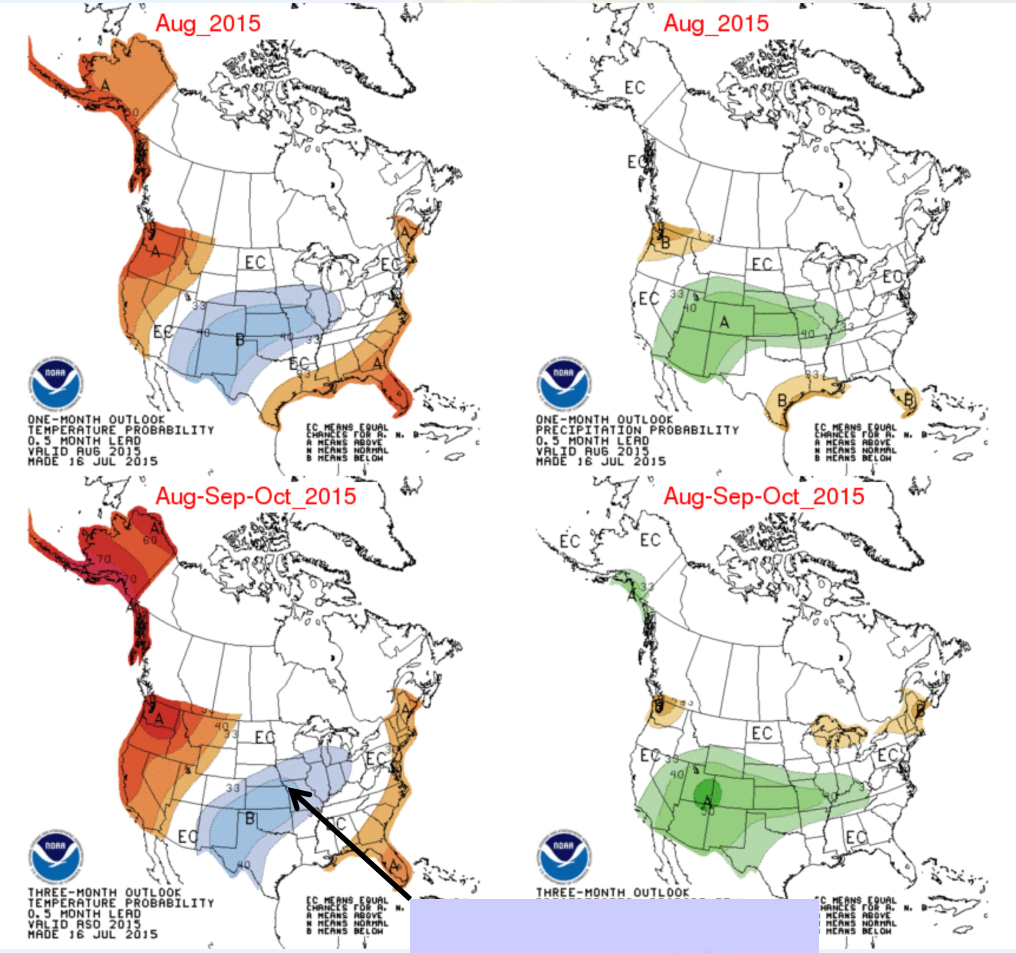


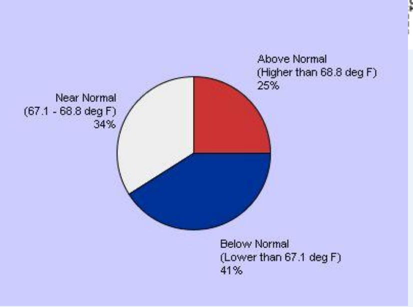




CPC Outlooks: One-Month and Three-Month

- Predicting chances for *temperatures* and *precipitation* to fall in the *upper, middle, and lowest thirds*.
    - “EC” (Equal Chances) = odds of each category match climatology
    - “40%” = 40-50% chance of that category (instead of the usual 33%)
- Issued 3rd Thursday of each month
- Based on ENSO, trends, climate models, soil moisture
- Local 3-Month Temperature Outlook: downscaled to single points





Activity:
Interpreting Climate Outlooks

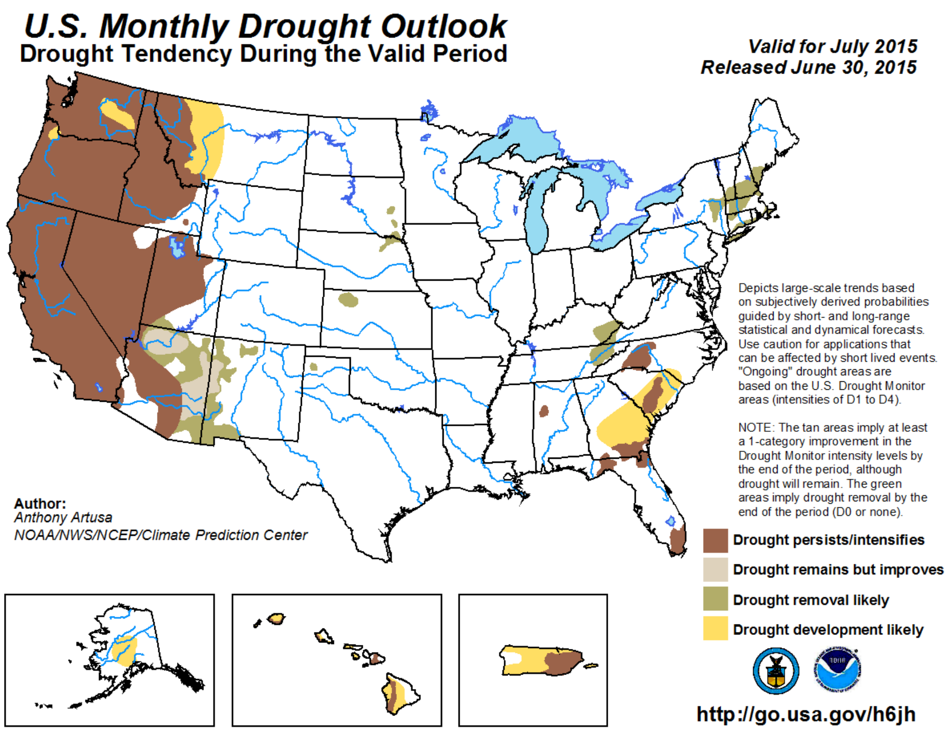
Will loading the dice guarantee a result, or just make it more likely than chance?

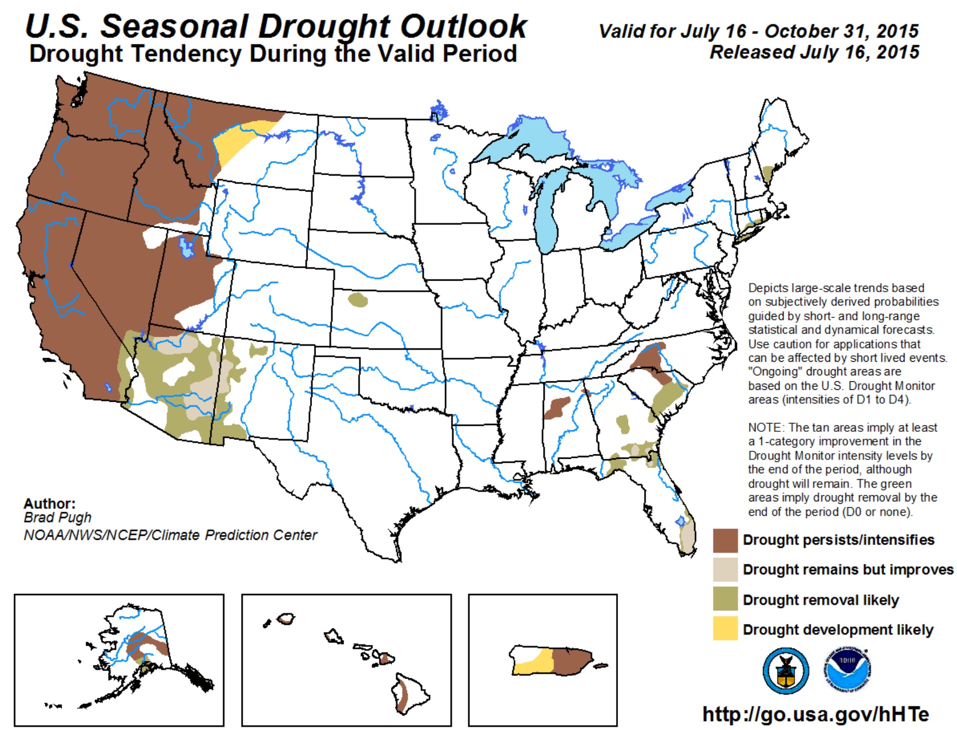
Roll the dice with and without weights. Roll the set at least 10 times each.

Record the results of each roll. How does the weighted set compare to the set without weights?

How does this apply to climate outlooks?

CPC Outlooks:
Drought (One-Month and Three-Month)

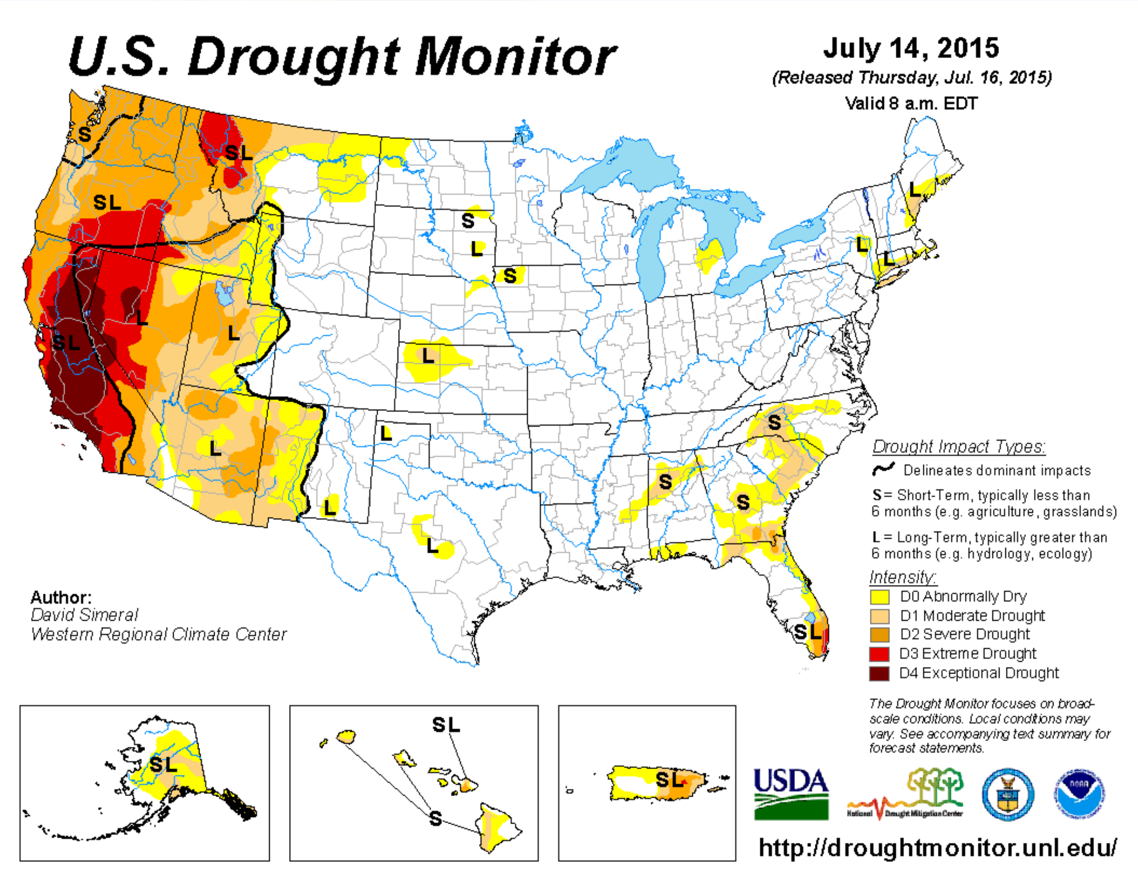


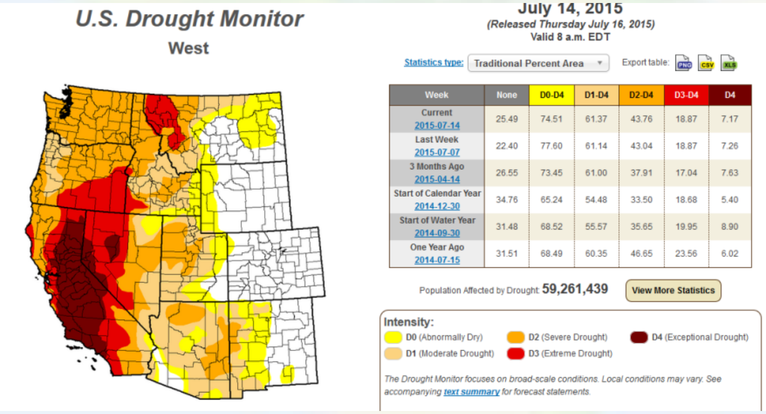


- Predicting changes to Drought Monitor categories during the valid period.
- New: monthly outlook updated at the end of the previous month.
- Seasonal (3-month) outlook updated on the 3rd Thursday of the month with the rest of the 3-month outlook package.

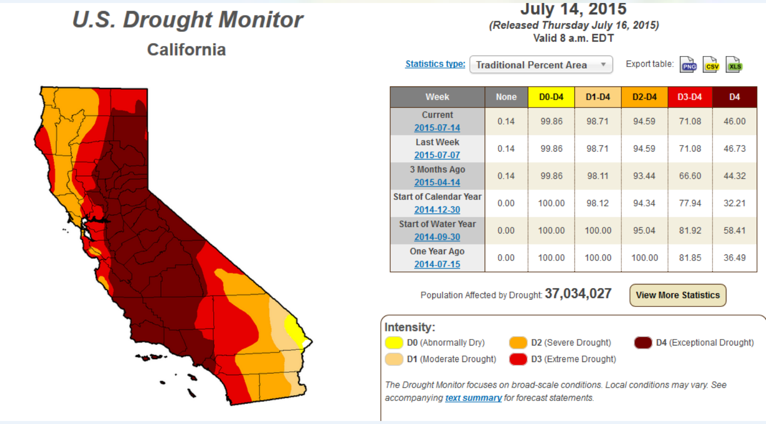
Drought Monitor

- Objective (measurable) and subjective (analysis and opinion) input





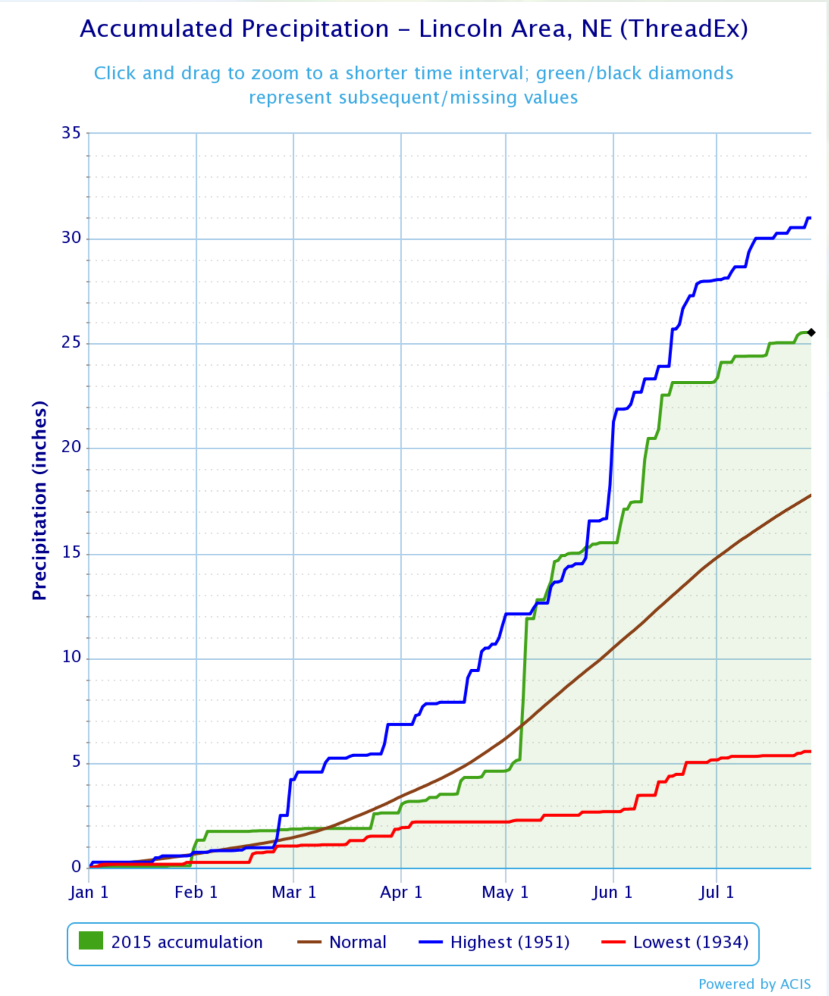
Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current 2015-07-14	25.49	74.51	61.37	43.76	18.87	7.17
Last Week 2015-07-07	22.40	77.60	61.14	43.04	18.87	7.26
3 Months Ago 2015-04-14	26.55	73.45	61.00	37.91	17.04	7.63
Start of Calendar Year 2014-12-30	34.76	65.24	54.48	33.50	18.68	5.40
Start of Water Year 2014-09-30	31.48	68.52	55.57	35.65	19.95	8.90
One Year Ago 2014-07-15	31.51	68.49	60.35	46.65	23.56	6.02



Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current 2015-07-14	0.14	99.86	98.71	94.59	71.08	46.00
Last Week 2015-07-07	0.14	99.86	98.71	94.59	71.08	46.73
3 Months Ago 2015-04-14	0.14	99.86	98.11	93.44	66.60	44.32
Start of Calendar Year 2014-12-30	0.00	100.00	98.12	94.34	77.94	32.21
Start of Water Year 2014-09-30	0.00	100.00	100.00	95.04	81.92	58.41
One Year Ago 2014-07-15	0.00	100.00	100.00	100.00	81.85	36.49

http://droughtmonitor.unl.edu/

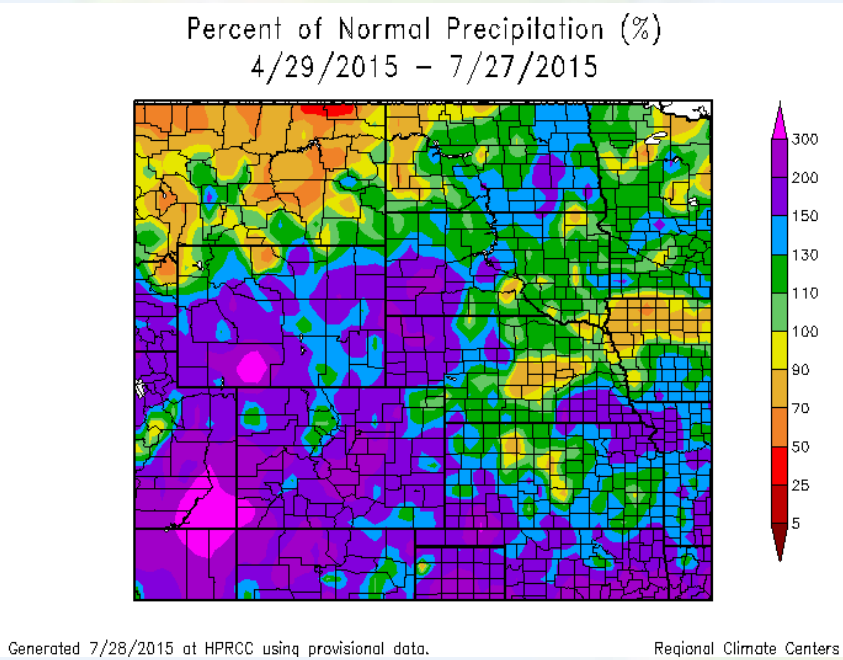
Climatological Context: NOWData

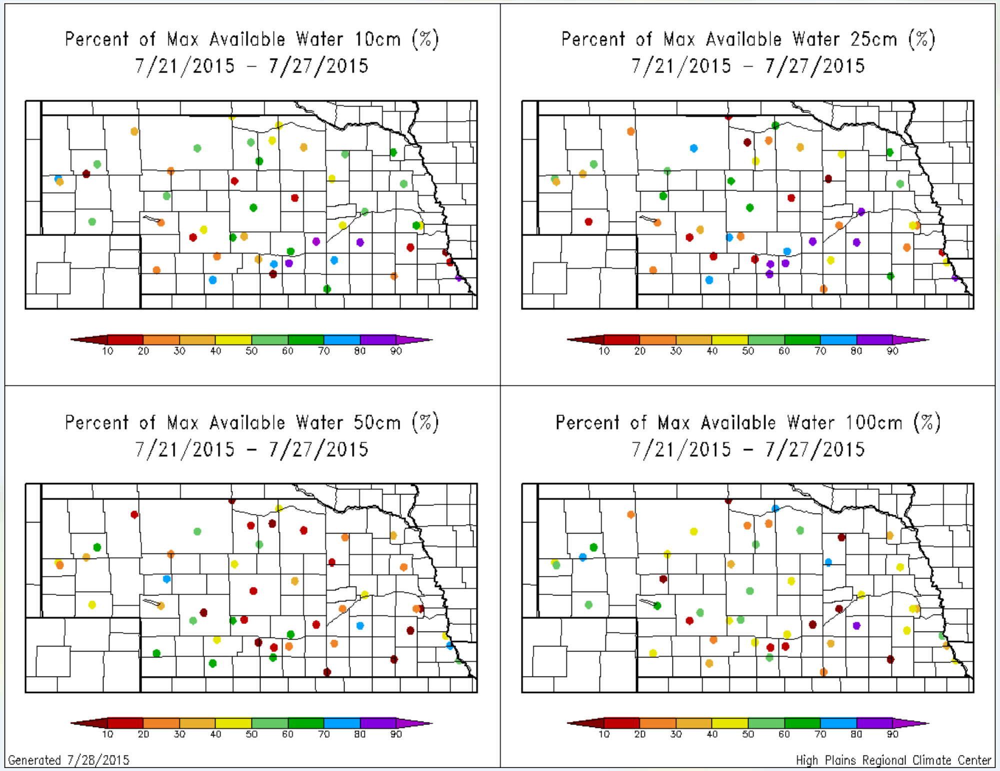


- Place events into historical context for frequency, rankings, local to regional coverage, etc.

http://w2.weather.gov/climate/xmacis.php?wfo=oax

Climate Tools:
High Plains Regional Climate Center

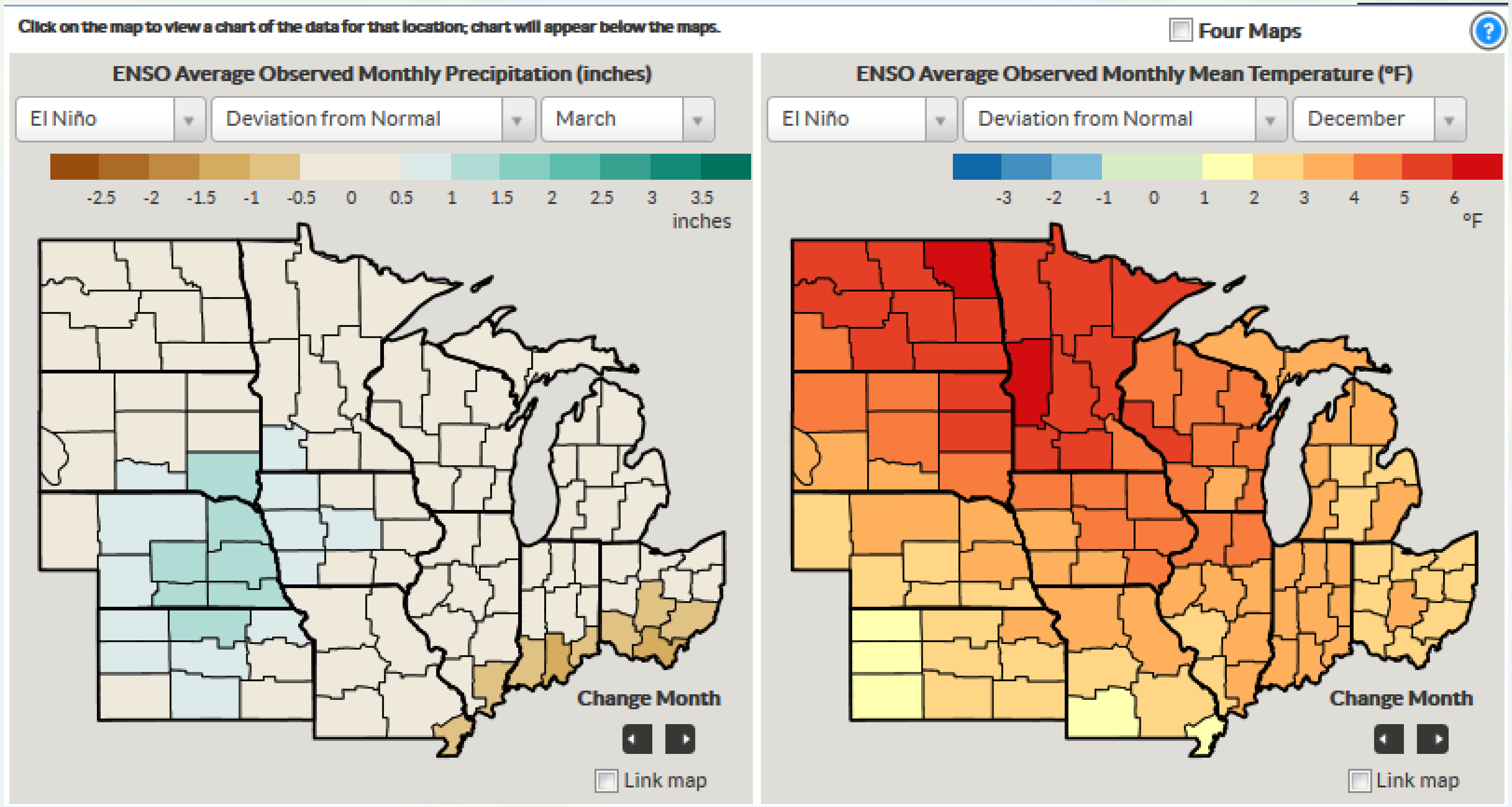




- Maps of temperature, precipitation, soil moisture.
- Adjustable by geographical region (state, regional, or national) and time (last 7 days to previous year)

http://www.hprcc.unl.edu/products/

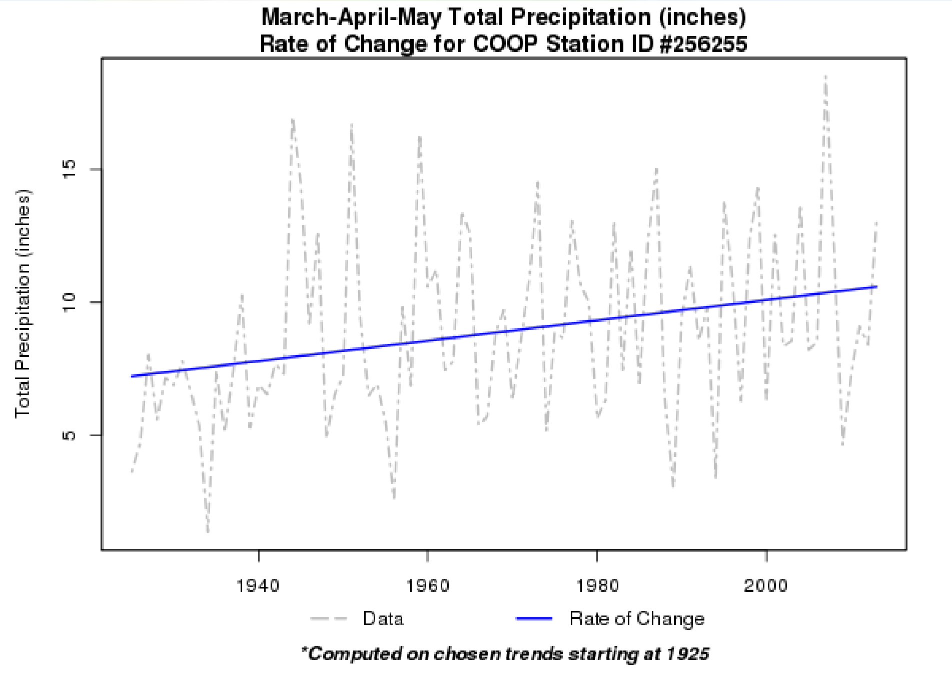
Climate Tools:
Useful to Usable (U2U) Patterns Viewer

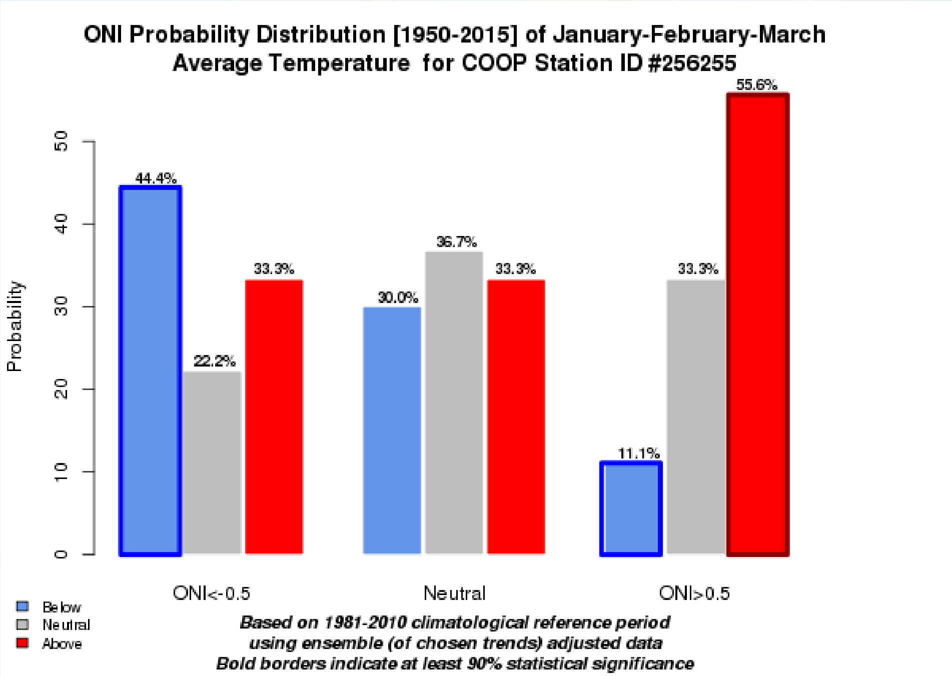


- Shows effects of ENSO and AO by month on temperatures, precipitation, and corn yield.

https://mygeohub.org/groups/u2u/cpv

Climate Tools:
Local Climate Analysis Tool (LCAT)

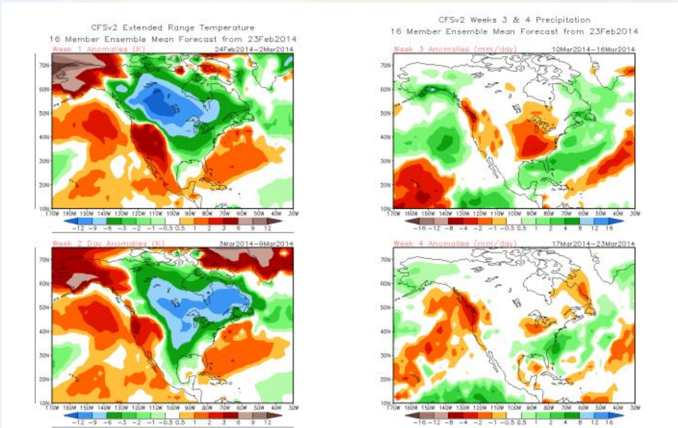


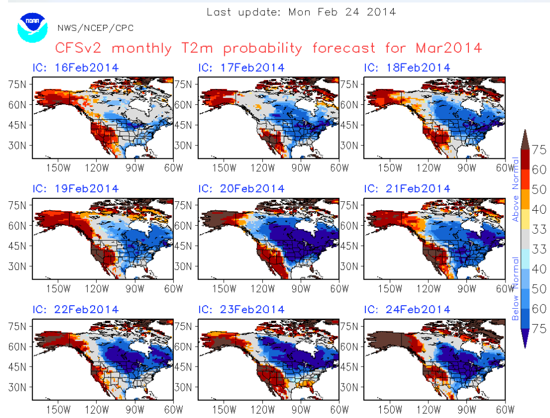


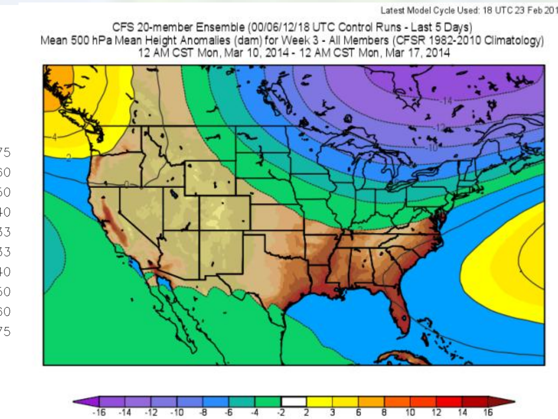
- Analyze climate change trends, climate variability signals (ENSO for now).
- Interpreting these results:
  - Mar-Apr-May precipitation at Omaha is rising by 0.38 inches per decade.
  - El Niño is associated with a significantly higher chance of average temperatures like the warmest third of 1981-2010 climatology in Jan-Feb-Mar at Omaha.

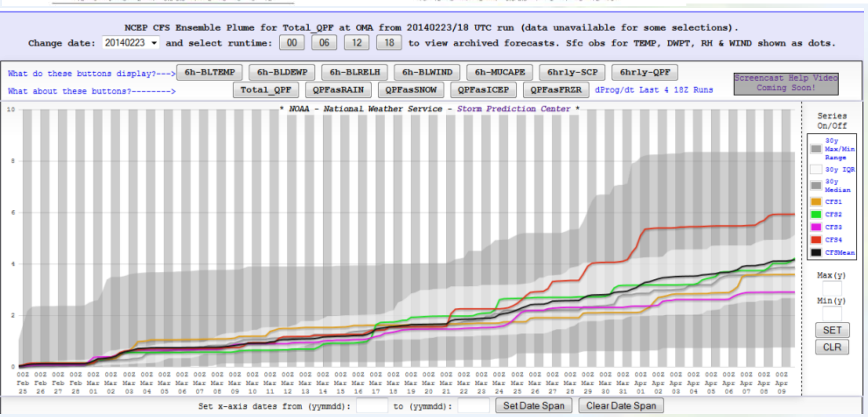
http://nws.weather.gov/lcat/

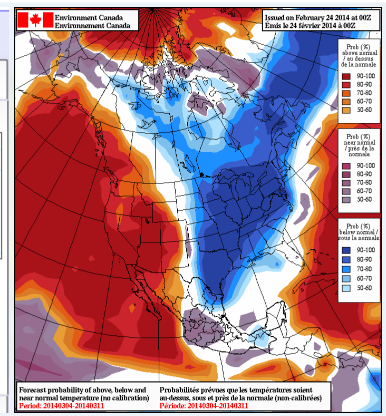
Climate Forecasting: Model Displays

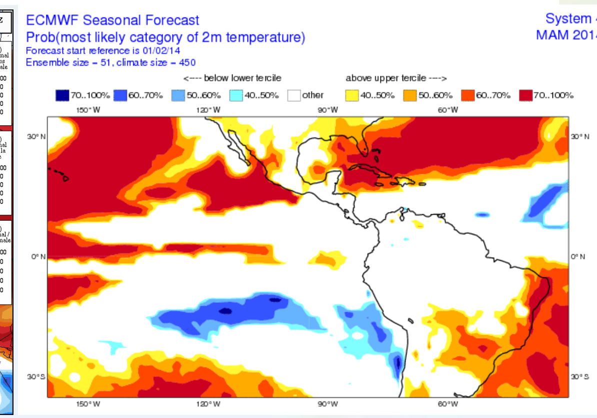












- NCEP's Climate Forecast System version 2 (CFSv2) – several pages to access
- North American Ensemble Forecast System
- European Center for Medium-Range Weather Forecasting
- Requires expertise to interpret and assess (just like with weather models)

Decision Support Services:

Building a Weather-Ready (and Climate-Ready) Nation

- What are “decision support services”?
  - NWS has always provided decision support! We are just streamlining how we offer support by communication with our partners to identify critical events or situations that are weather- and climate-sensitive.
  - Usually takes the form of prepared briefings or participation on teleconferences. Rarely, can include on-site assistance.
  - Can be one-time or periodic.
- Who can request assistance?
  - Core partners – including federal, state, and local government agencies, emergency managers, law enforcement, and other public entities.
- What situations might be appropriate?
  - Support of events where weather or climate could create an impact.
- Who do we contact?
  - Just email me. I’ll either take care of you or refer you to the right person in NWS if I’m not it.

Links and Resources

National Weather Service, Omaha/Valley NE: http://www.weather.gov/oax/

NOAA Climate Services: http://www.climate.gov/

NOAA ENSO Blog: https://www.climate.gov/news-features/department/enso-blog

NOAA National Climatic Data Center: http://www.ncdc.noaa.gov/oa/ncdc.html

Global Change Impacts in the U.S.:
http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

International Panel on Climate Change: http://www.ipcc.ch/

HPRCC Climate Change: http://www.hprcc.unl.edu/climate_change.php

HPRCC "Climate Change on the Prairie":
http://www.hprcc.unl.edu/publications/files/HighPlainsClimateChangeGuide.pdf

National Climate Assessment: http://ncadac.globalchange.gov/

NWS Weather-Ready Nation Roadmap:
http://www.nws.noaa.gov/com/weatherreadynation/files/nws_wrn_roadmap_final_april17.pdf

Thank you!

Barbara Mayes Boustead, Ph.D.

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National Weather Service, Omaha/Valley, NE

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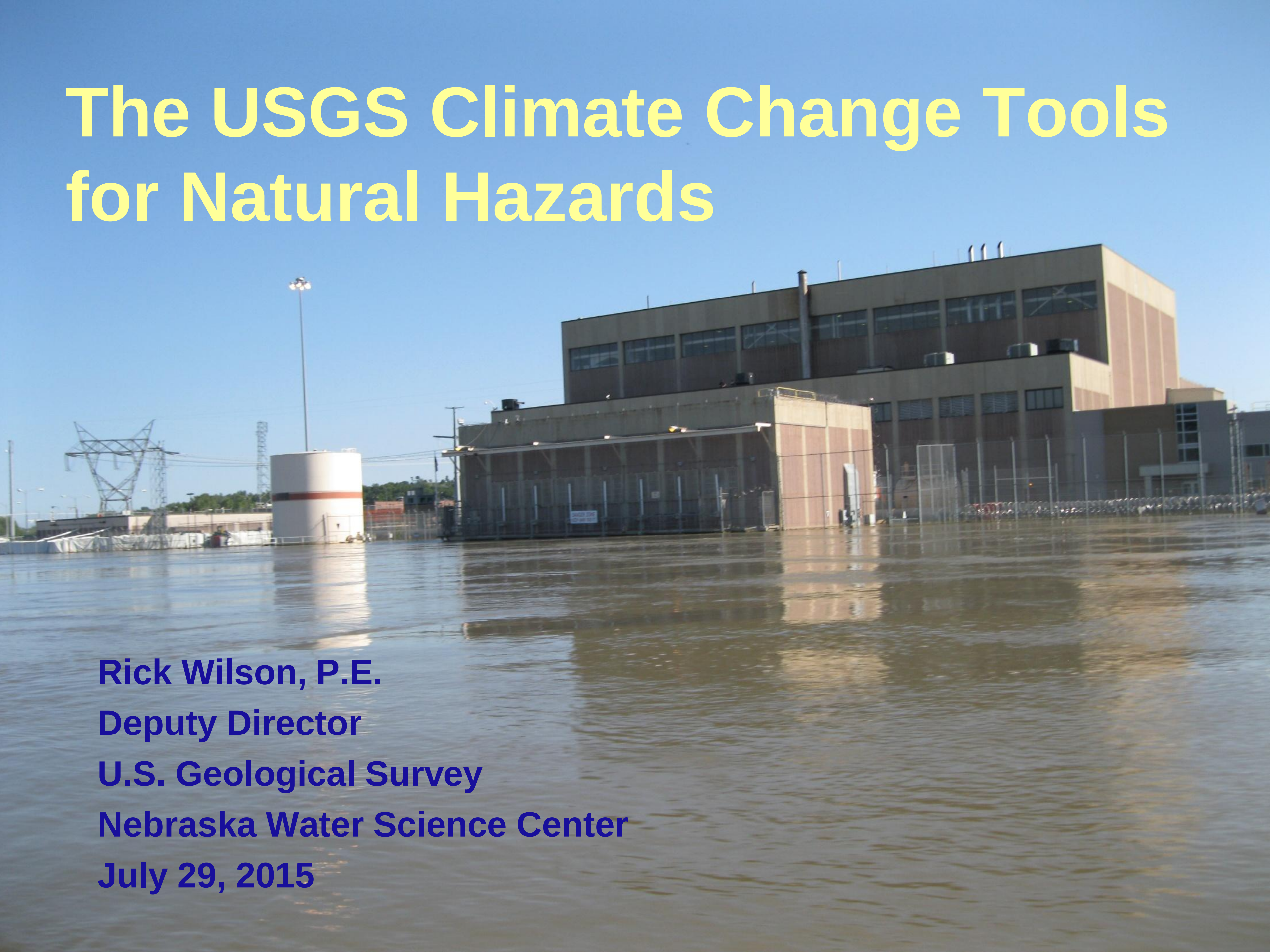
The USGS Climate Change Tools for Natural Hazards



Rick Wilson, P.E.
Deputy Director
U.S. Geological Survey
Nebraska Water Science Center
July 29, 2015

This presentation

- Today, we have had quite a bit of discussion regarding climate change science
- Now, this presentation will focus on USGS tools, primarily monitoring/measurement

Climate Change and Uncertainty

2007

“We never have 100 percent certainty. We never have it. If you wait until you have 100 percent certainty, something bad is going to happen on the battlefield. That’s what we know. You have to act with incomplete information.”

Source: General Gordon S. Sullivan, Chairman, Military Advisory Board, Center for Naval Analyses National Security and the Threat of Climate Change (2007)

http://www.cna.org/reports/climate

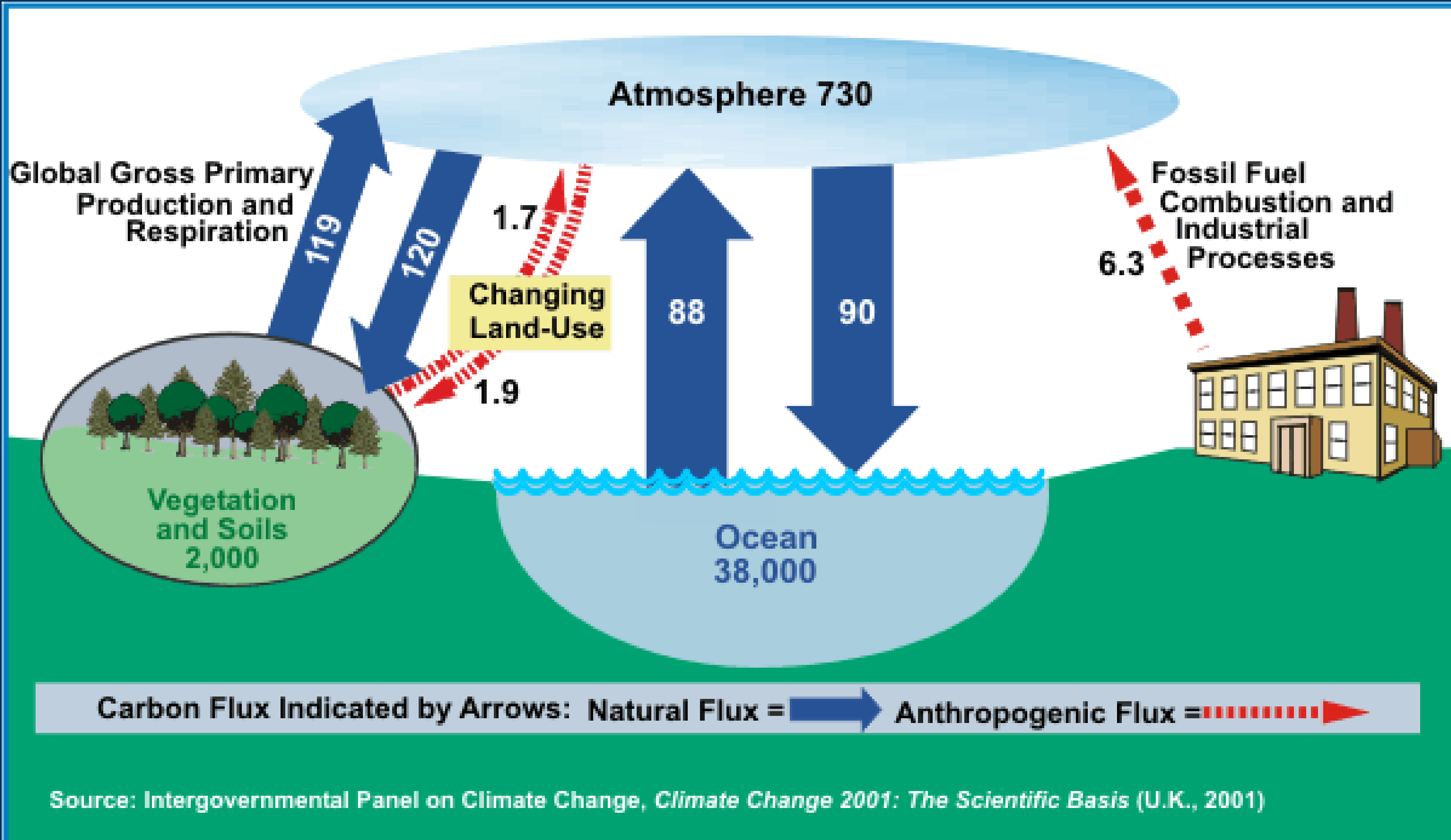
2013

Scientists now are 95 percent to 100 percent certain that human activity is the primary cause of the warming that has occurred since the 1950s

Source: United Nations, Intergovernmental Panel on Climate Change, September 2013

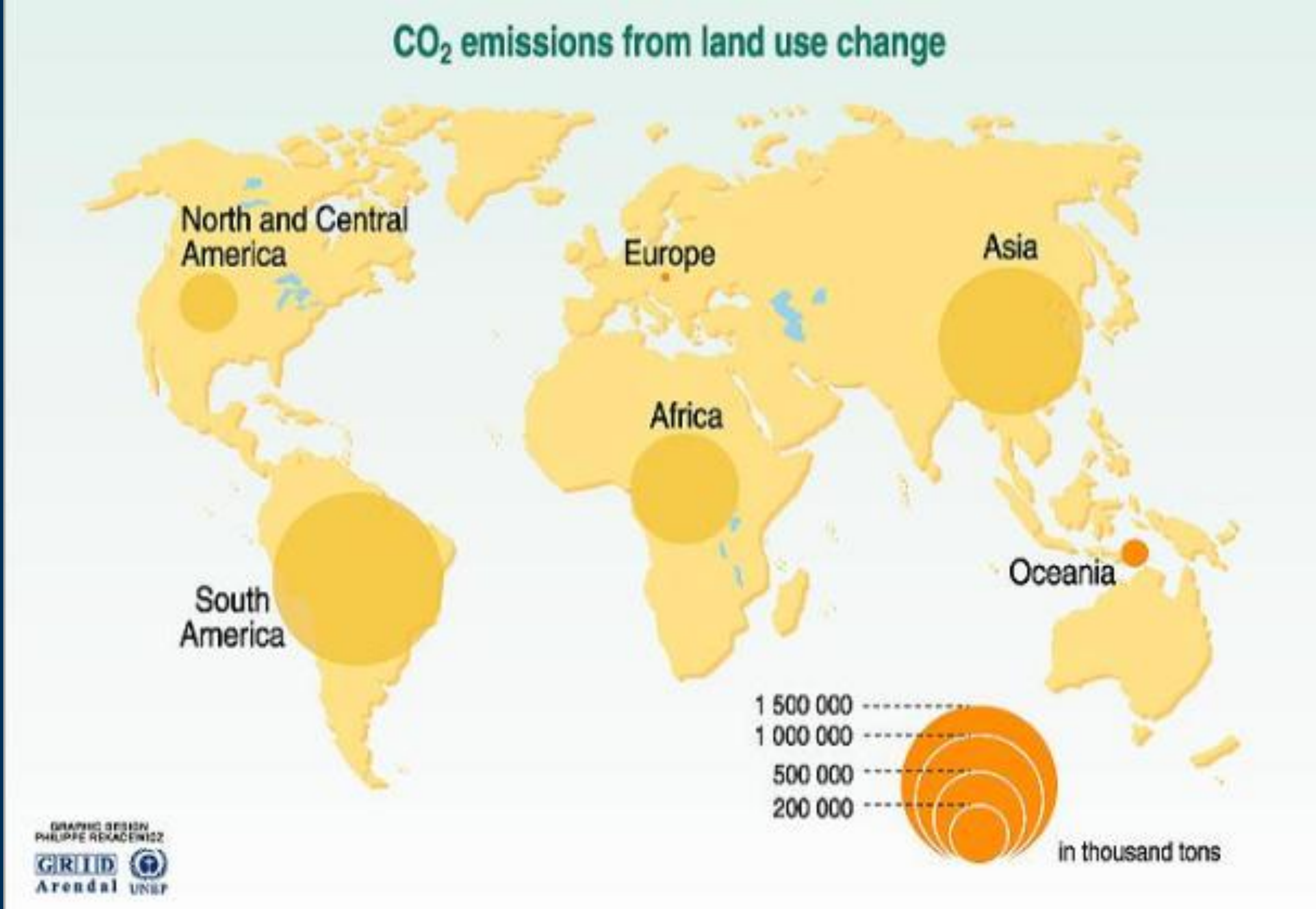
USGS

Global Carbon Cycle

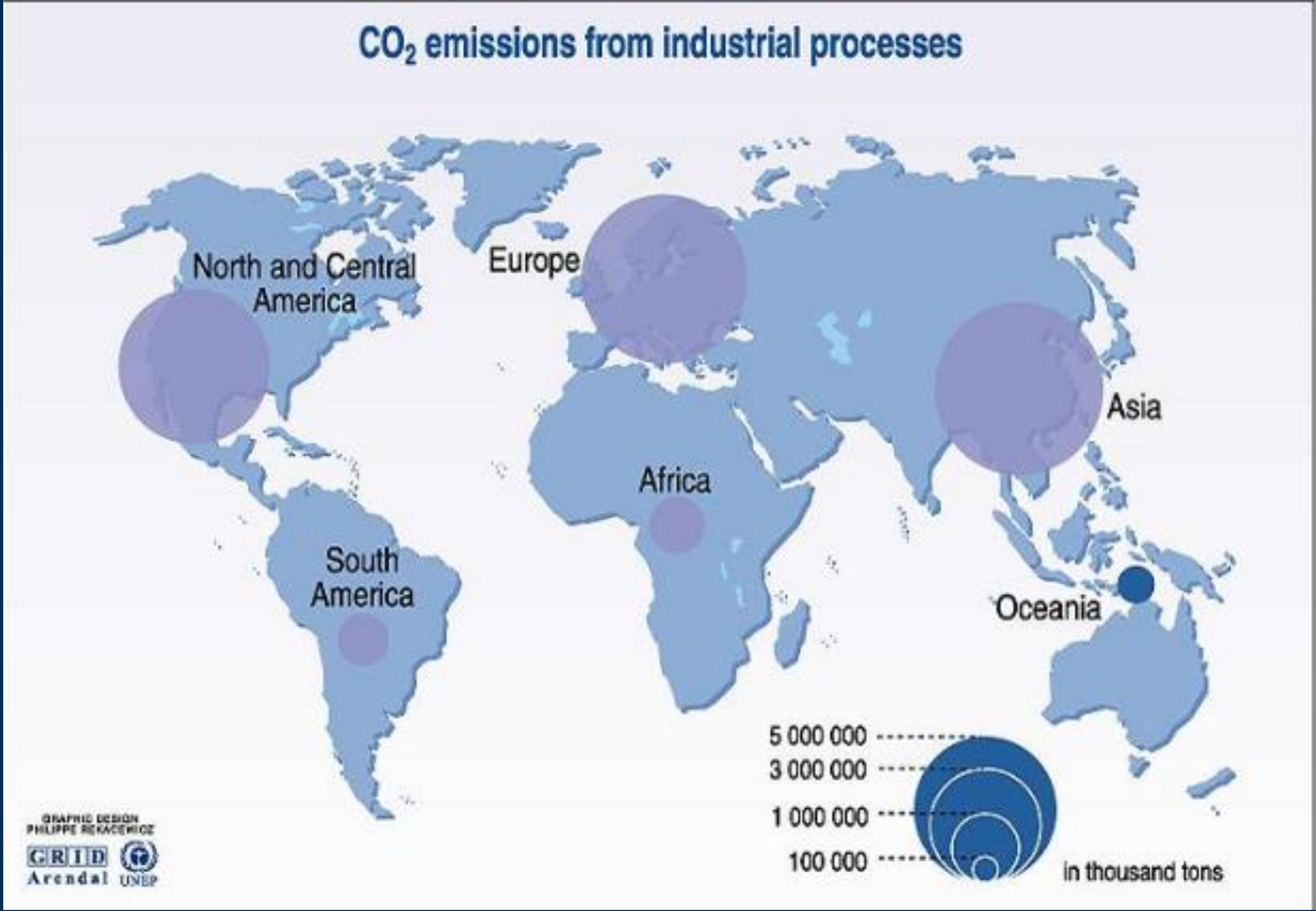


USGS

Units: Billion Metric Tons Carbon



Source: Climate Change Information Kit, United Nations Environmental Programs, 1997

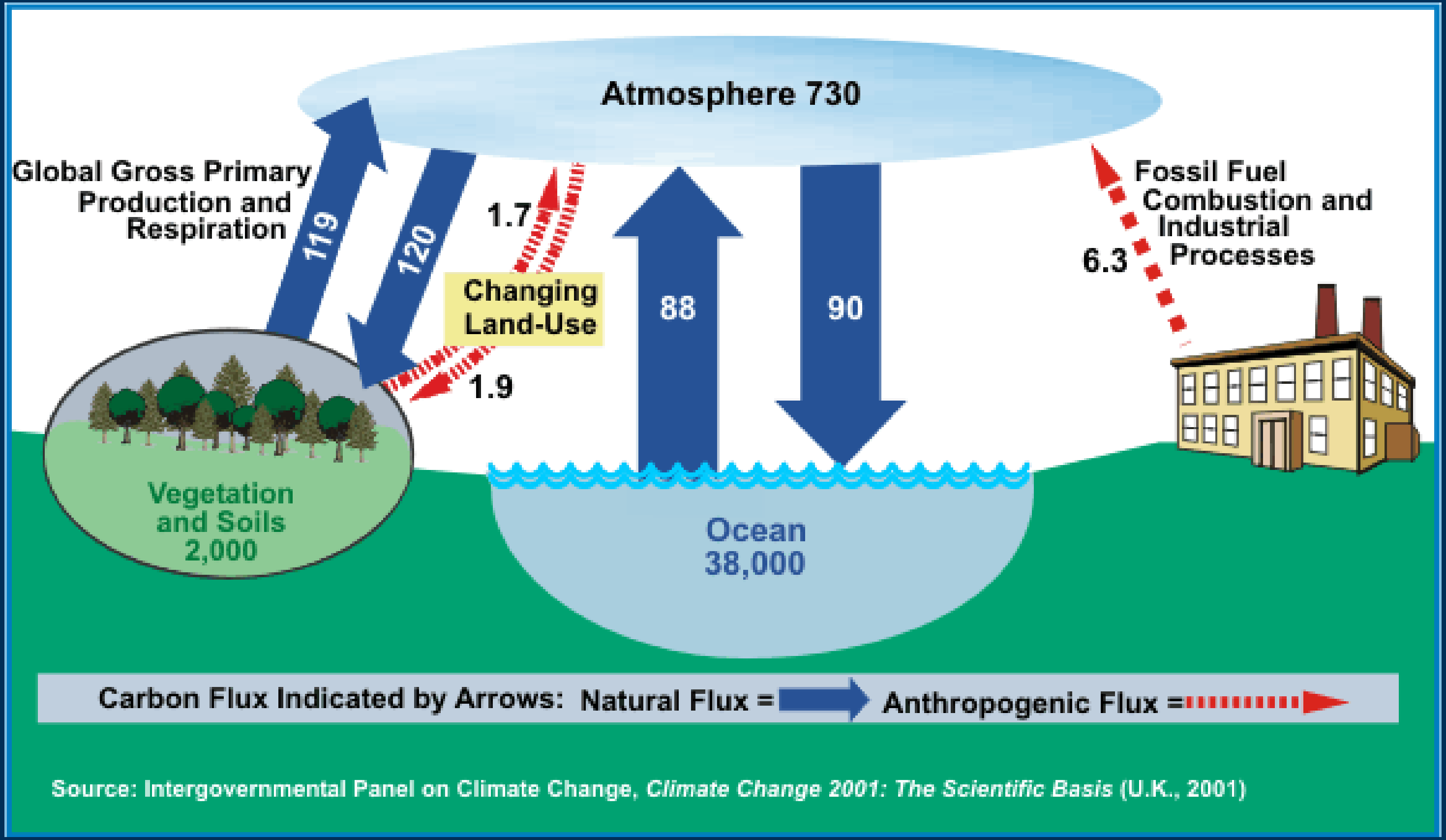


USGS

Source: Climate Change Information Kit, United Nations Environmental Programs , 1997

Take Home Point

- Focus efforts
  - Land use
  - Fossil fuels, production of gas-house gases



USGS

Climate Change: What have we already observed?

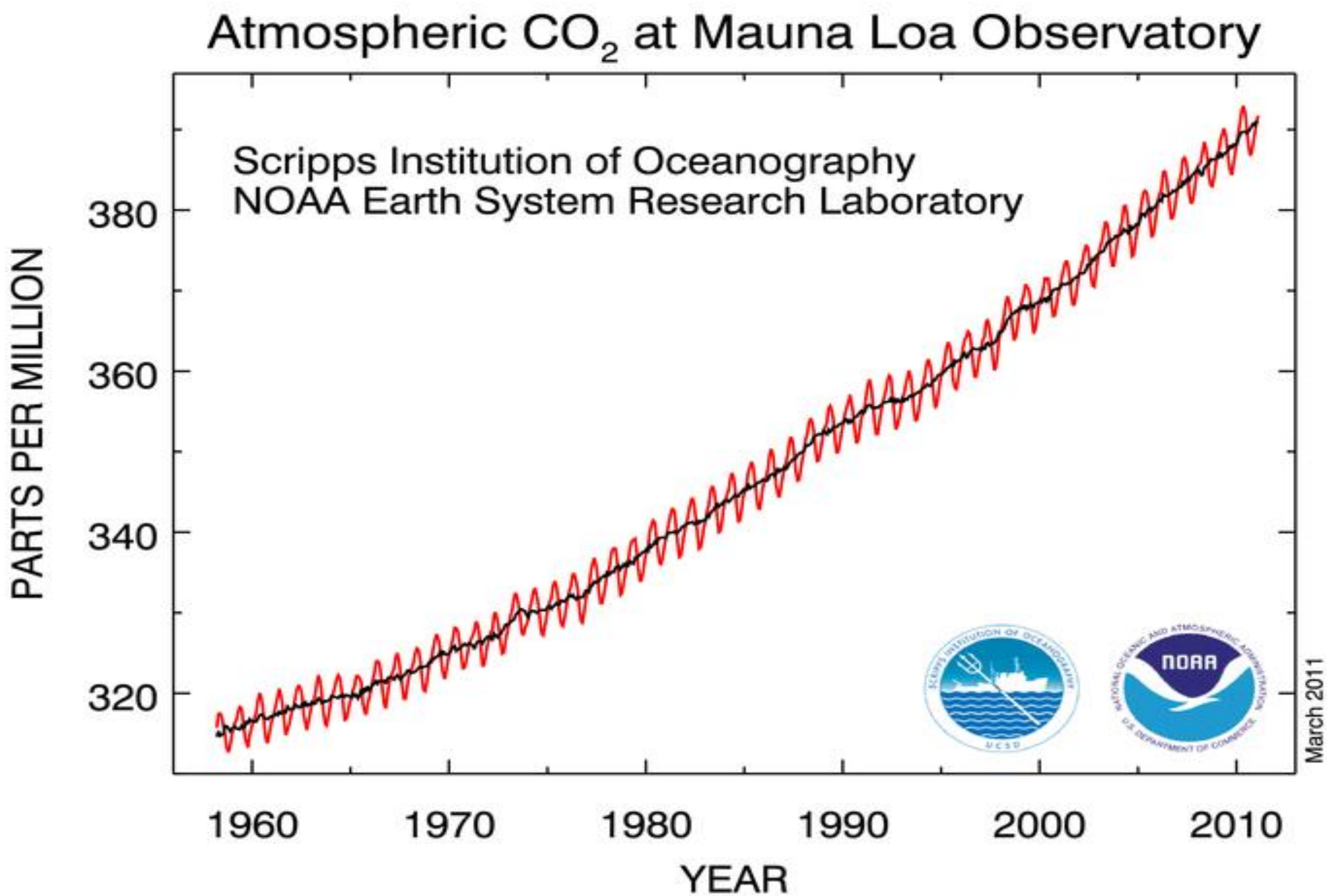
During the past 50 years:

- **Average temperature in the U.S. increased more than 2º F (1ºC)**
- **Precipitation in the U.S. increased average of 5%, and the intensity of precipitation events increased**
- **Extreme weather events increased in frequency and intensity**
- **Sea level increased along most the U.S. coast**
- **Artic sea ice extent decreased 3 to 4% per decade**

Source: USGCRP, 2009 Global Climate Change Impacts in the U.S.

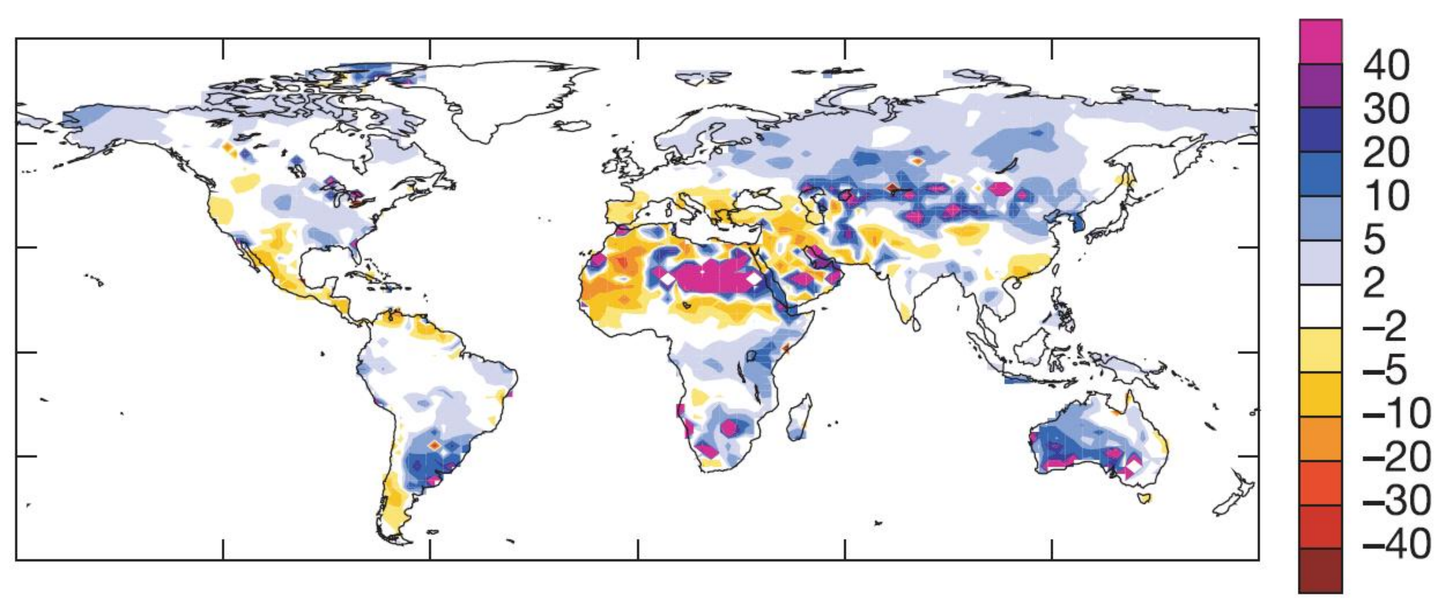
USGS

The Importance of Monitoring

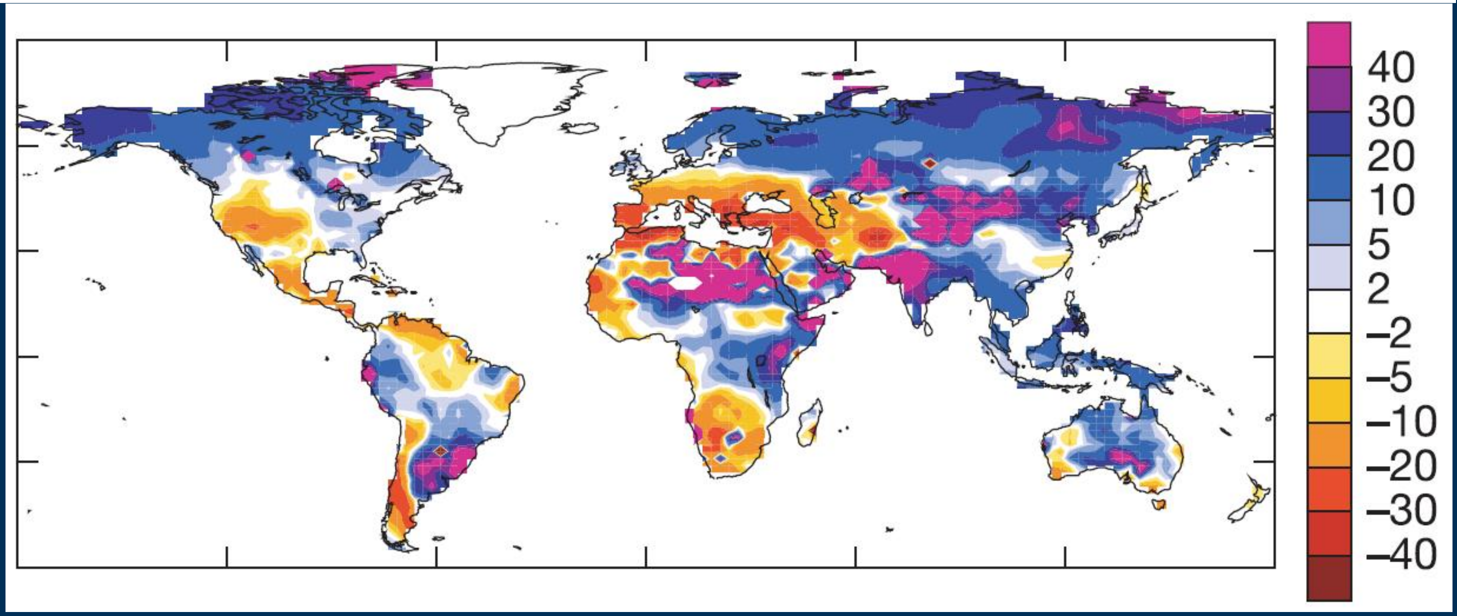


http://www.esrl.noaa.gov/gmd/ccgg/trends/

Relative Change in Surface Runoff (%)



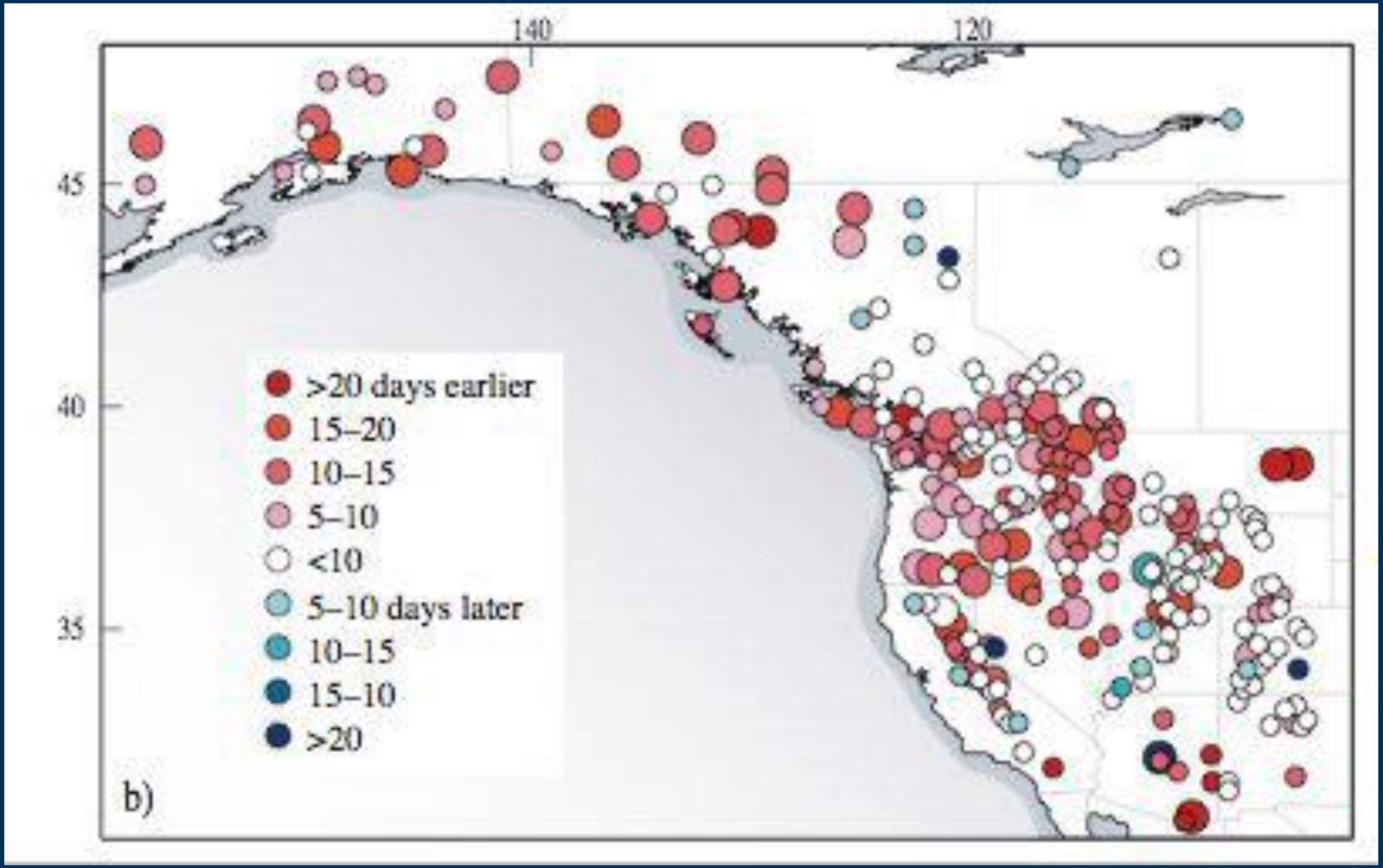
20th Century



21st Century

Source: Milly, Dunne, and Vecchia, Nature, 2005

Western North America Streamflow - arriving earlier in the year



Source: Dettinger and Cayan, 1995; Cayan et al., 2001; Stewart et al., 2005

Similar trends have been observed in snow-melt-affected rivers in northeast.

Climate Change National Policy

USGS

National Policy
Six Priority Recommendations

- Establish Planning Process
- Strengthen Water Data and Information
- Provide Tools to Assess Vulnerability
- Improve Water Use Efficiency
- Promote Integrated Water Resources Management
- Support Training/Outreach to Build Response Capability

USGS

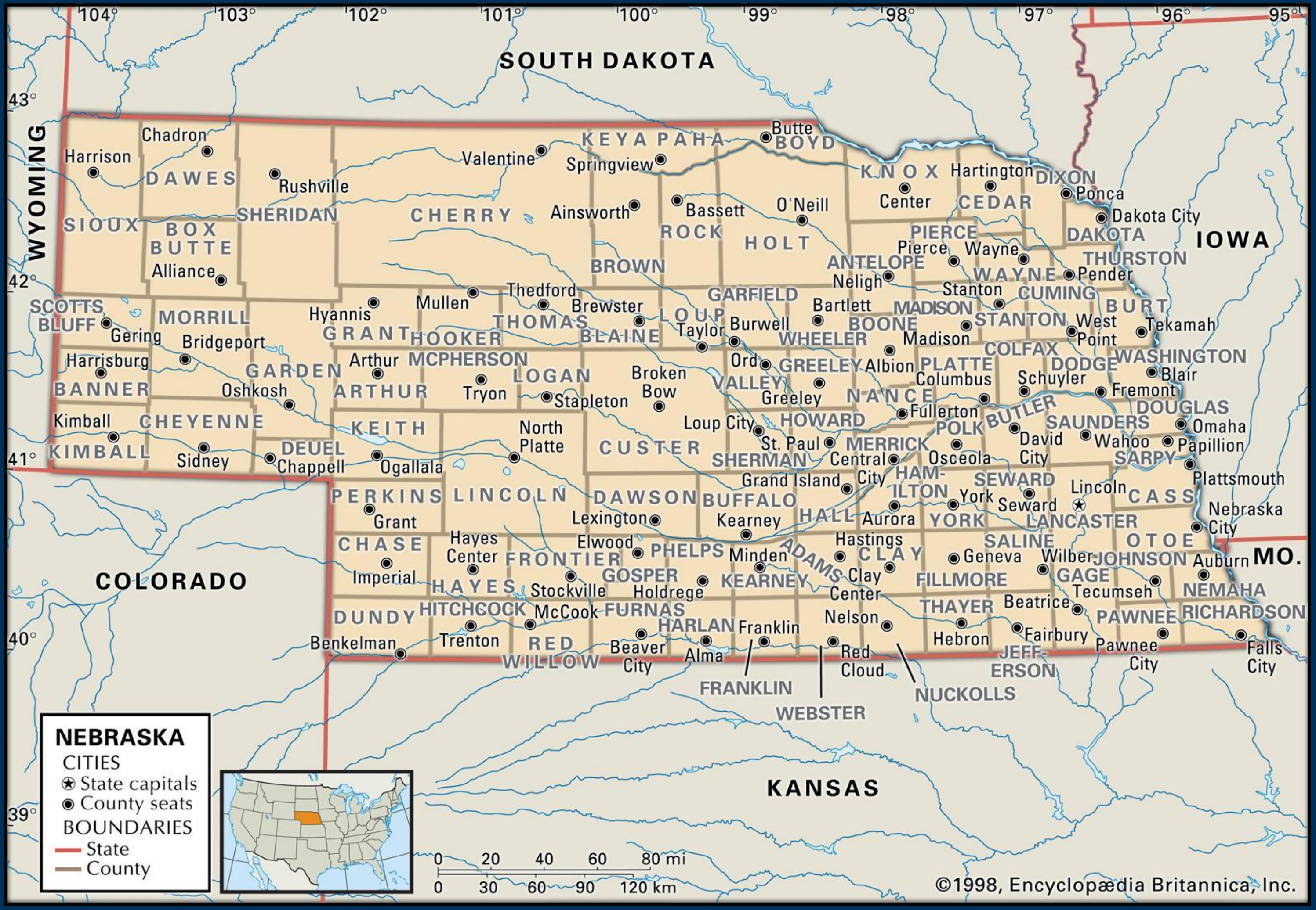
National Policy
Specific Supporting Actions

Recommendations:

- Strengthen water data/information systems
- Strengthen tracking of waterborne disease
- Expedite wetlands mapping
- Pilot water vulnerability index
- Develop national metrics for water use efficiency
- Create toolbox of water efficiency practices
- Strengthen climate role of river basin commissions
- Add climate to Federal water project planning principles and requirements
- Establish core training for water and climate change adaptation
- Focus youth outreach on climate/water

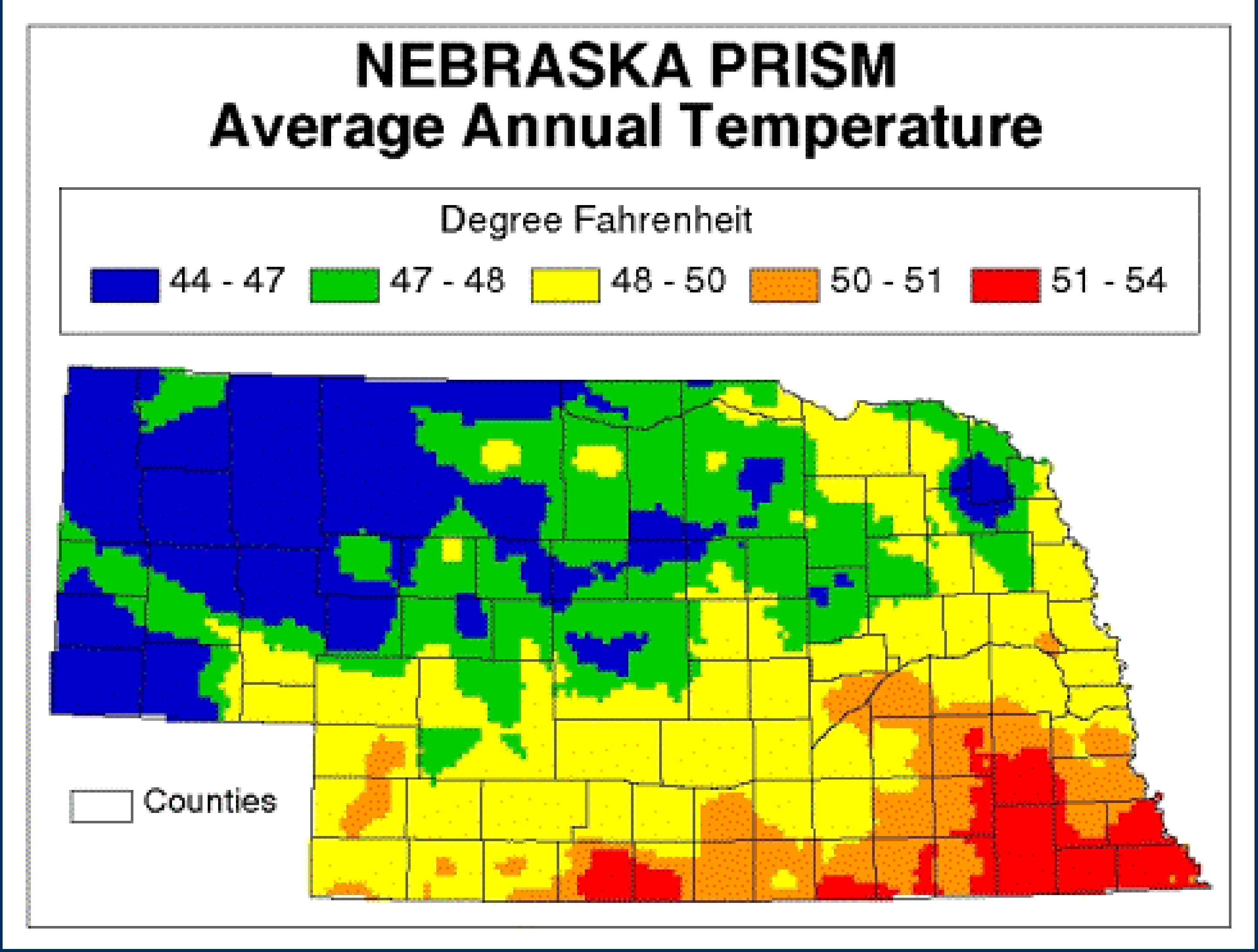
USGS

Climate Change in Nebraska



USGS

Nebraska Temperature, 1961-1990



Source: USDA-NRCS, 2001

Climate Forecasts for Nebraska - Temperature

- **Predictions based on a composite of model simulations for future climate in Nebraska**
- **Annual avg. warming of 4ºF by 2050**
- **Annual avg. warming of 8ºF by 2090**
- **Greatest amount of change predicted in the summer**
- **Least amount of change predicted in the spring**

USGS

Source: UNL, NebGuide G2208, 2013

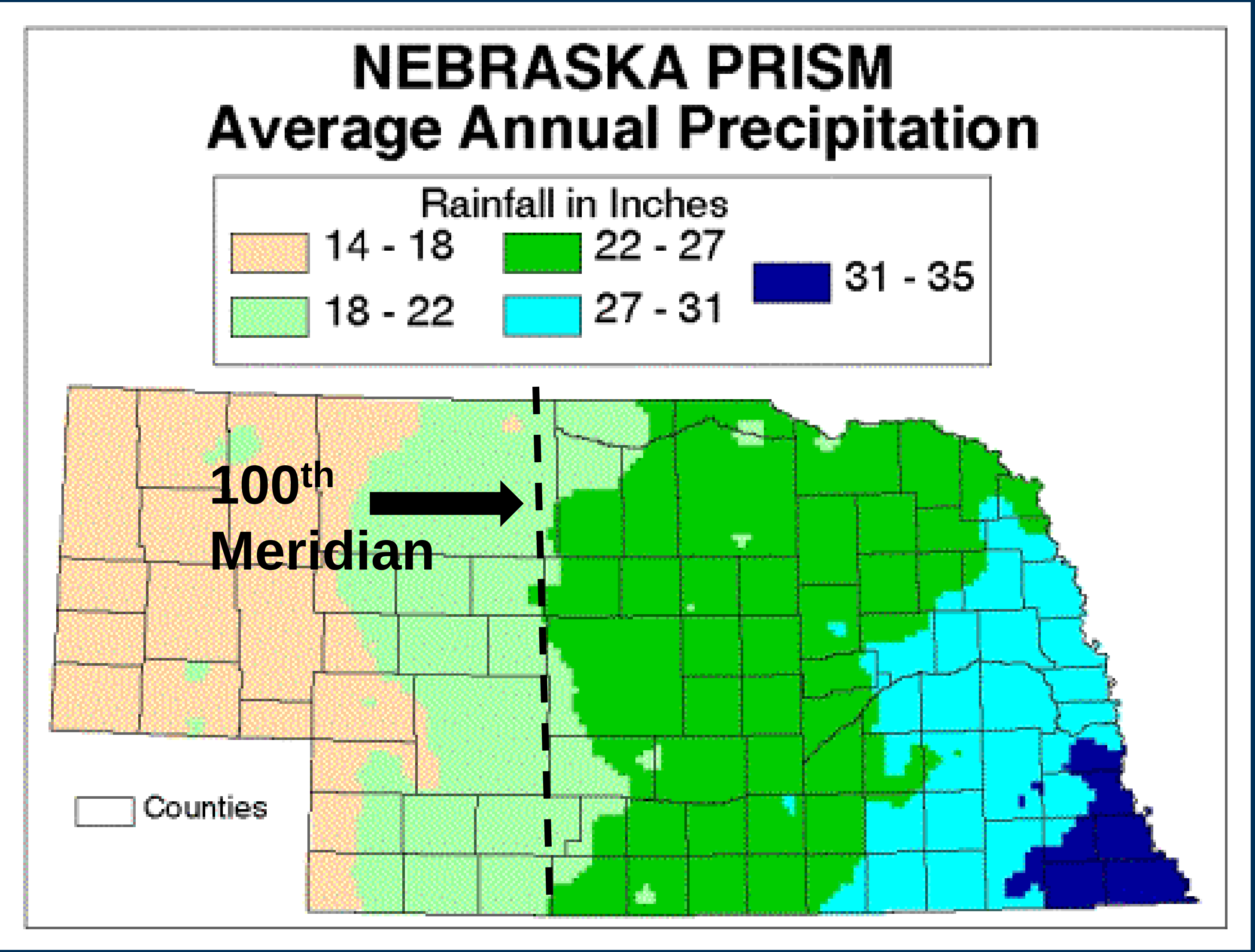
Climate Forecasts for Nebraska - Temperature

- By 2050 the number of days per year with daytime highs greater than 95ºF is expected to increase by about 15
- By 2050 the number of days per year with daytime lows less than 10ºF is expected to decrease by about 10
- Increase in the frequency and severity of extreme events such as heat waves and heavy precipitation

USGS

Source: UNL, NebGuide G2208, 2013

Nebraska Precipitation 1961-1990



Source: USDA-NRCS, 2001

Climate Forecasts for Nebraska - Precipitation

- Composite model simulations for precipitation is less certain than temperature
- The 100th Meridian the dividing line btw the moist air from the gulf to the semi-arid climate to the west
- In the future more seasonal variability is expected, wetter conditions north & east, drier conditions in the south & west
- Drier in the summer and wetter in the winter

USGS

Source: UNL, NebGuide G2208, 2013

How will I be affected?

Currently, scientific knowledge and forecasting techniques can not accurately answer this question

USGS

What is needed is expanded monitoring and improved analytical tools

USGS

http://landsat.usgs.gov/

What is needed is expanded monitoring and improved analytical tools

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National Water Information System: Web Interface

USGS Water Resources

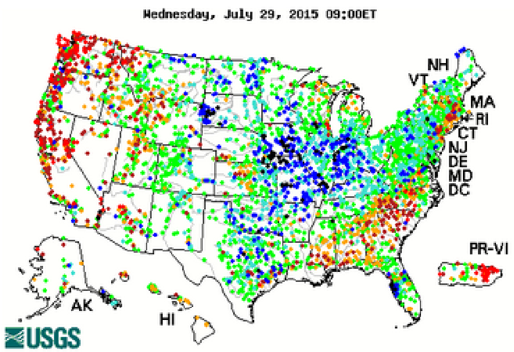
Data Category: Current Conditions | Geographic Area: United States | GO

Click for News Bulletins

USGS Current Water Data for the Nation

— Predefined displays — Introduction | go

Daily Streamflow Conditions



Explanation

- High
- > 90th percentile
- 76th - 90th percentile
- 25th - 75th percentile
- 10th - 24th percentile
- < 10th percentile

The colored dots on this map depict streamflow conditions as a percentile, which is computed from the period of record for the current day of the year. Only stations with at least 30 years of record are used.
The **gray circles** indicate other stations that were not ranked in percentiles either because they have fewer than 30 years of record or because they report parameters other than streamflow. Some stations, for example, measure stage only.

Select a state from the map to access real-time data

Current data typically are recorded at 15- to 60-minute intervals, stored onsite, and then transmitted to USGS offices every 1 to 4 hours, depending on the data relay technique used. Recording and transmission times may be more frequent during critical events. Data from current sites are relayed to USGS offices via satellite, telephone, and/or radio telemetry and are available for viewing within minutes of arrival.

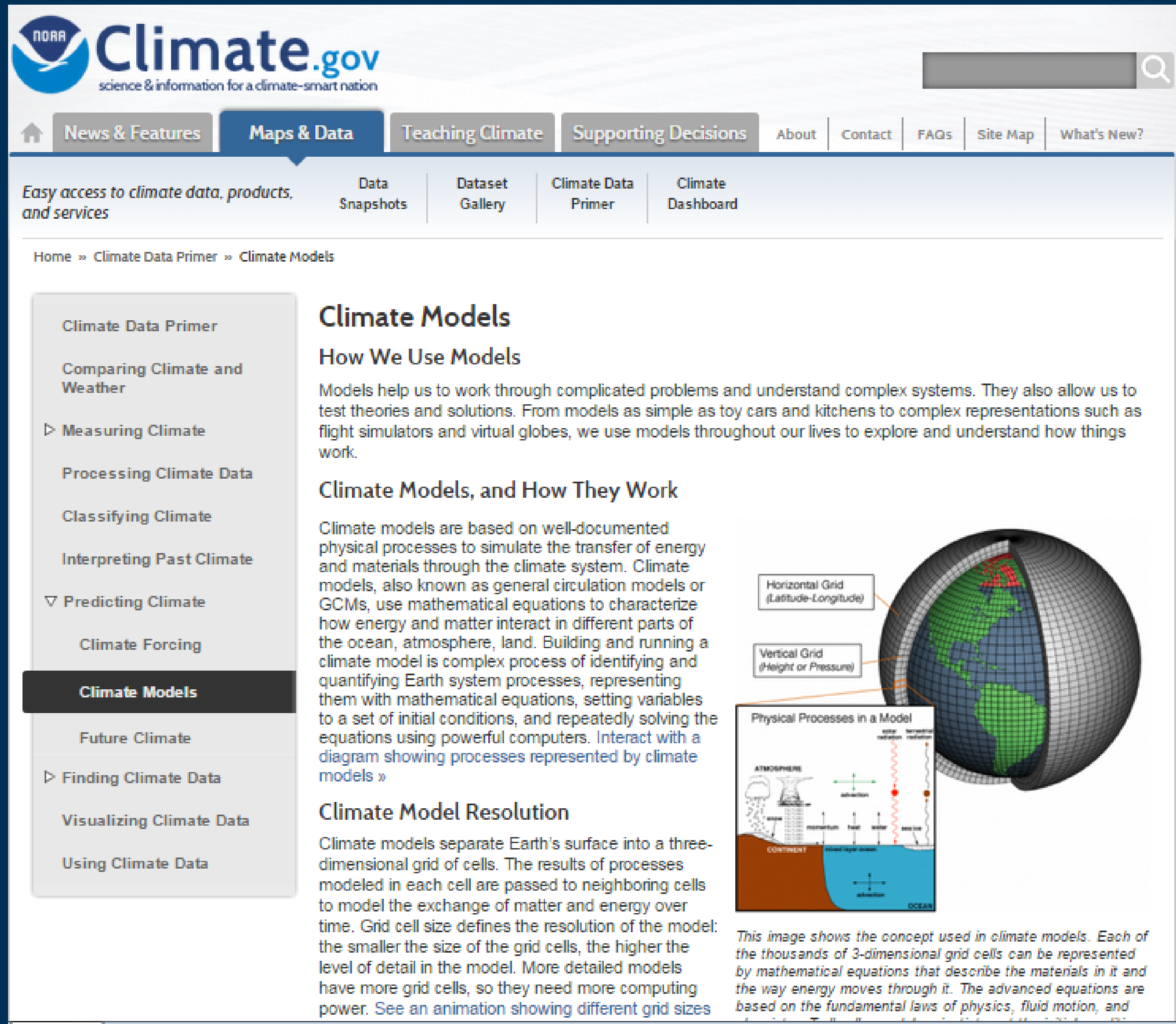
All real-time data are provisional and subject to revision.

Build Current Conditions Table	Show a custom current conditions summary table for one or more stations.
Build Time Series	Show custom graphs or tables for a series of recent data for one or more stations.

USGS

http://waterdata.usgs.gov/nwis/rt

What is needed is expanded monitoring and improved analytical tools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- Climate Data Primer
- Comparing Climate and Weather
- Measuring Climate
- Processing Climate Data
- Classifying Climate
- Interpreting Past Climate
- Predicting Climate
  - Climate Forcing
  - **Climate Models**
  - Future Climate
- Finding Climate Data
- Visualizing Climate Data
- Using Climate Data

Climate Models

How We Use Models

Models help us to work through complicated problems and understand complex systems. They also allow us to test theories and solutions. From models as simple as toy cars and kitchens to complex representations such as flight simulators and virtual globes, we use models throughout our lives to explore and understand how things work.

Climate Models, and How They Work

Climate models are based on well-documented physical processes to simulate the transfer of energy and materials through the climate system. Climate models, also known as general circulation models or GCMs, use mathematical equations to characterize how energy and matter interact in different parts of the ocean, atmosphere, land. Building and running a climate model is complex process of identifying and quantifying Earth system processes, representing them with mathematical equations, setting variables to a set of initial conditions, and repeatedly solving the equations using powerful computers. Interact with a diagram showing processes represented by climate models »

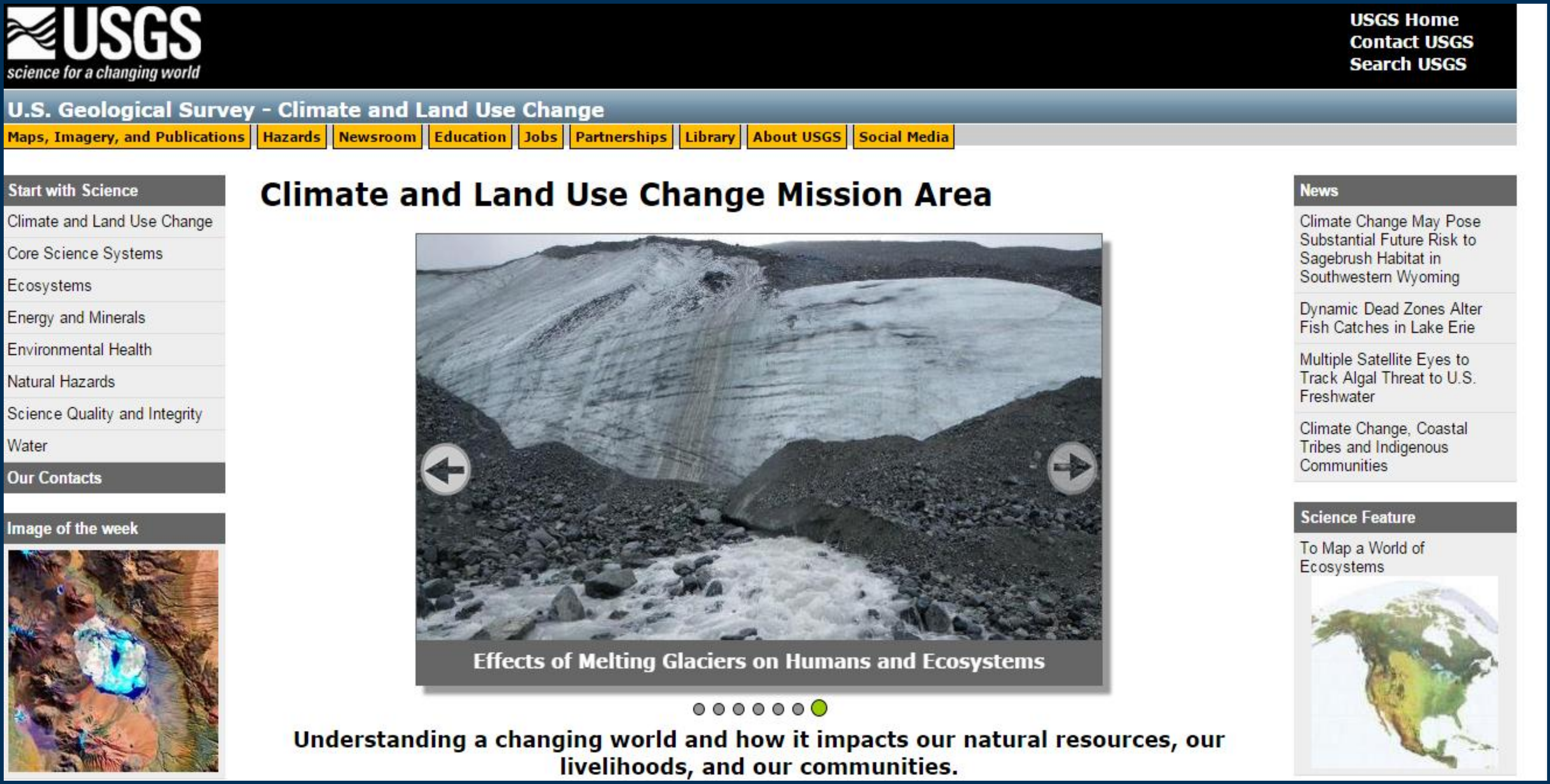
This image shows the concept used in climate models. Each of the thousands of 3-dimensional grid cells can be represented by mathematical equations that describe the materials in it and the way energy moves through it. The advanced equations are based on the fundamental laws of physics, fluid motion, and

Climate Model Resolution

Climate models separate Earth's surface into a three-dimensional grid of cells. The results of processes modeled in each cell are passed to neighboring cells to model the exchange of matter and energy over time. Grid cell size defines the resolution of the model: the smaller the size of the grid cells, the higher the level of detail in the model. More detailed models have more grid cells, so they need more computing power. See an animation showing different grid sizes

USGS

USGS Mission Area



http://www.usgs.gov/climate_landuse/

USGS

Start with Science
- Climate and Land Use Change
- Core Science Systems
- Ecosystems
- Energy and Minerals
- Environmental Health
- Natural Hazards
- Science Quality and Integrity
- Water

Our Contacts

Climate and Land Use Change

The USGS undertakes scientific research, monitoring, remote sensing, modeling, synthesis, and forecasting to address the effects of climate and land use change on the Nation's resources. The resulting research and products are provided as the scientific foundation upon which policymakers, natural resource managers, and the public make informed decisions about the management of natural resources on which they and others depend.

Climate and Land Use Change Programs

Land Change Science (LCS)

The goal of the USGS Land Change Science (LCS) Program, formerly Geographic Analysis and Monitoring, is to understand the patterns, processes, and consequences of changes in land use, land condition, and land cover at multiple spatial and temporal scales, resulting from the interactions between human activities and natural systems.

Land Remote Sensing (LRS)

The Land Remote Sensing Program operates the Landsat satellites and provides the Nation's portal to the largest archive of remotely sensed land data in the world, supplying access to current and historical images. These images serve many purposes from assessing the impact of natural disasters to monitoring global agricultural production.

National Climate Change and Wildlife Science Center (NCCWSC)

The National Climate Change and Wildlife Science Center responds to the research and management needs of partners and provides science and technical support regarding the impacts of climate change on fish, wildlife and ecological process. The Center is taking the lead on establishing the Department of the Interior regional Climate Science Centers.

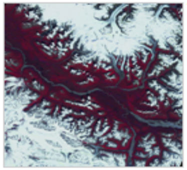
Research and Development Program (R&D)

The USGS Climate and Land Use Change Research and Development Program supports fundamental scientific research to: 1) understand processes controlling Earth system responses to global change over broad temporal and spatial scales; and 2) understand and model impacts of climate and land-cover change on ecosystems and other natural resources.

Carbon Sequestration

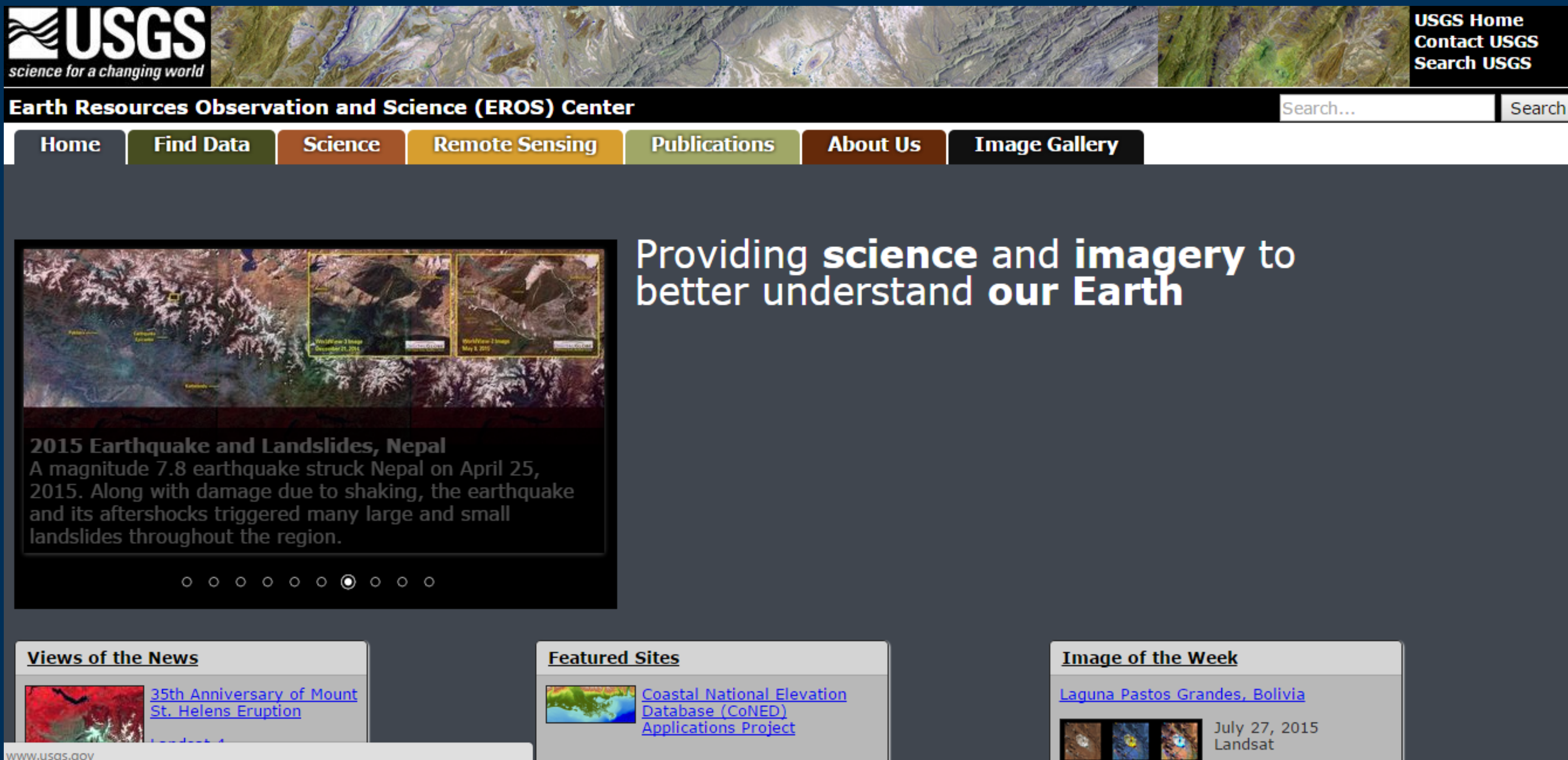
Scientists at the U.S. Geological Survey (USGS) are working to assess both the potential capacities and the potential limitations of the various forms of carbon sequestration and to evaluate their geologic, hydrologic, and ecological consequences. In accordance with the Energy Independence and Security Act of 2007, the USGS has developed scientifically based methods for assessment of biologic and geologic carbon sequestration.

Earth Resources Observation and Science Center (EROS)



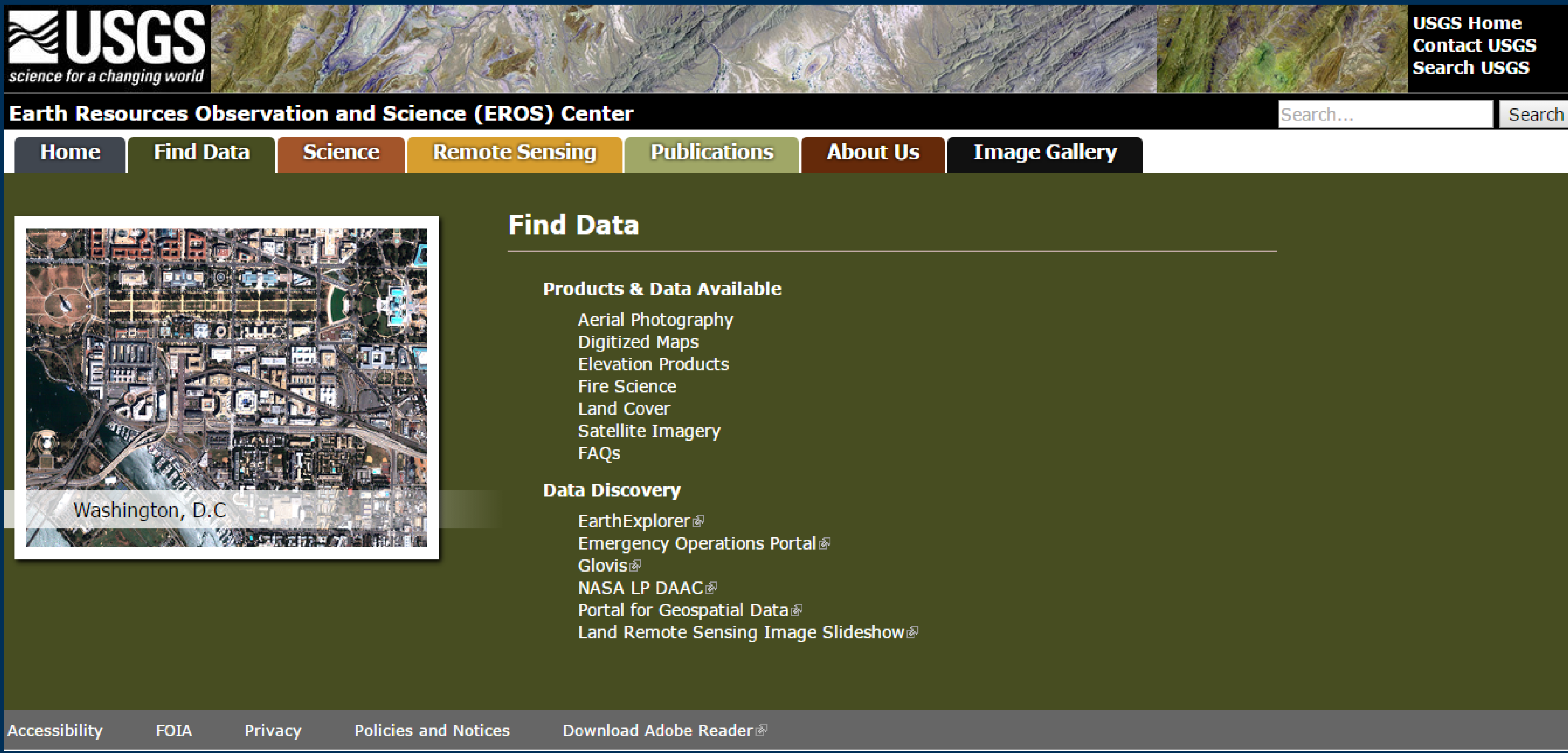
The USGS Earth Resources Observation and Science Center (EROS) contributes to the Climate and Land Use Change Mission Area through research and operational activities that enable the understanding of local to global land change. The EROS multidisciplinary staff uses their unique expertise in remote sensing-based science and technologies to carry out basic and applied research, data acquisition, systems engineering, information access and management, and archive preservation to address the Nation's most critical needs.

Earth Resources Observation and Science (EROS) Center



http://eros.usgs.gov

EROS - Data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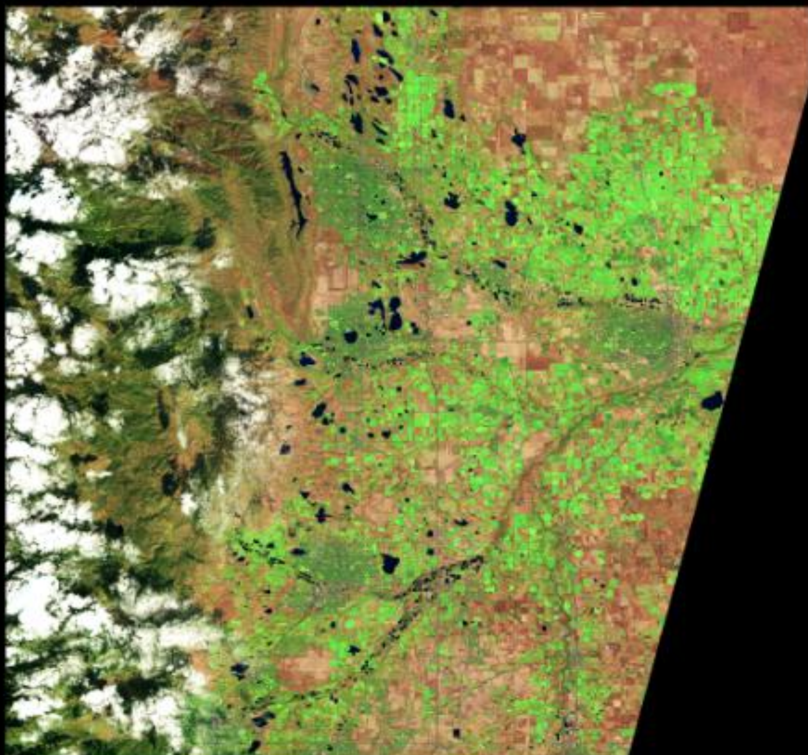
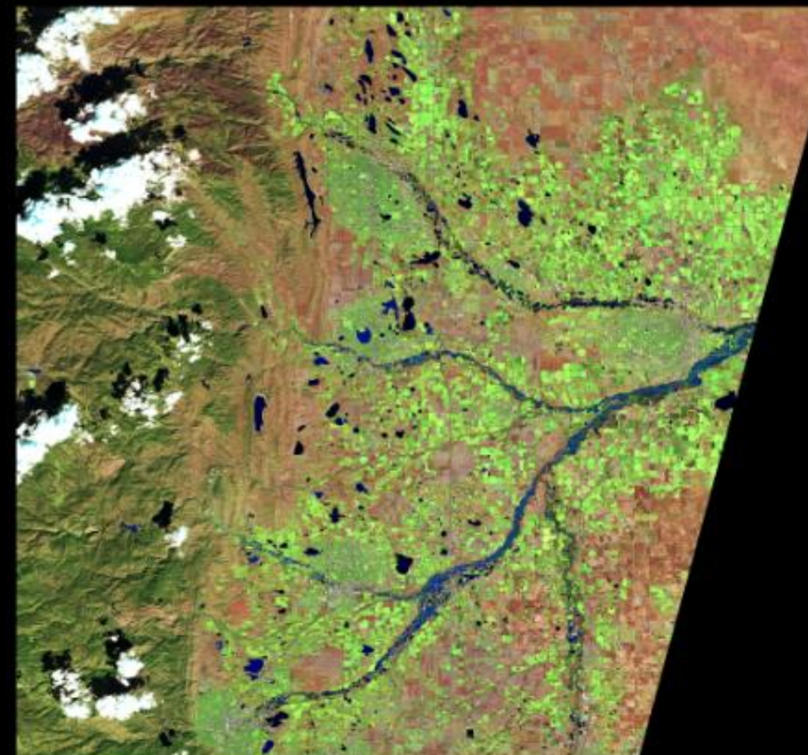
Land Remote Sensing Network



Landsat 8
August 16, 2013

0 4 8 Miles



Landsat 8
September 17, 2013

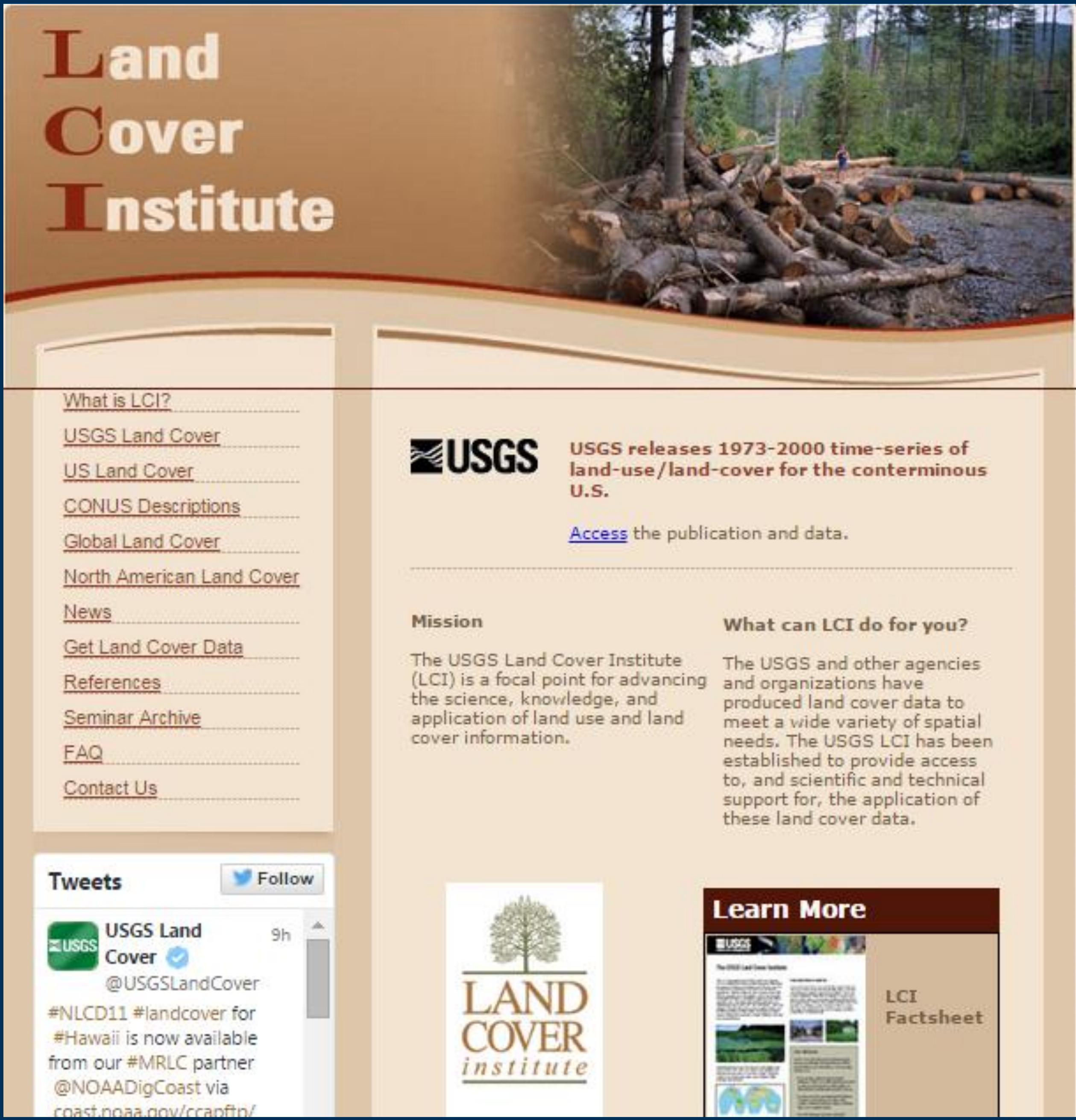
0 4 8 Miles

Colorado Flooding

Some parts of Colorado received nearly a year's worth of rain in just one week in September 2013. This pair of Landsat 8 images from August 16 (left) and September 17, 2013 (right) shows the flooded South Platte River as it flows by Greeley, Colorado, which is on the right side of the images.

Along the Front Range of the Rocky Mountains are Fort Collins, Loveland, Longmont, and Boulder, all affected by the flooding. Flooded rivers flow from the mountains, through each of these cities, and into the South Platte.

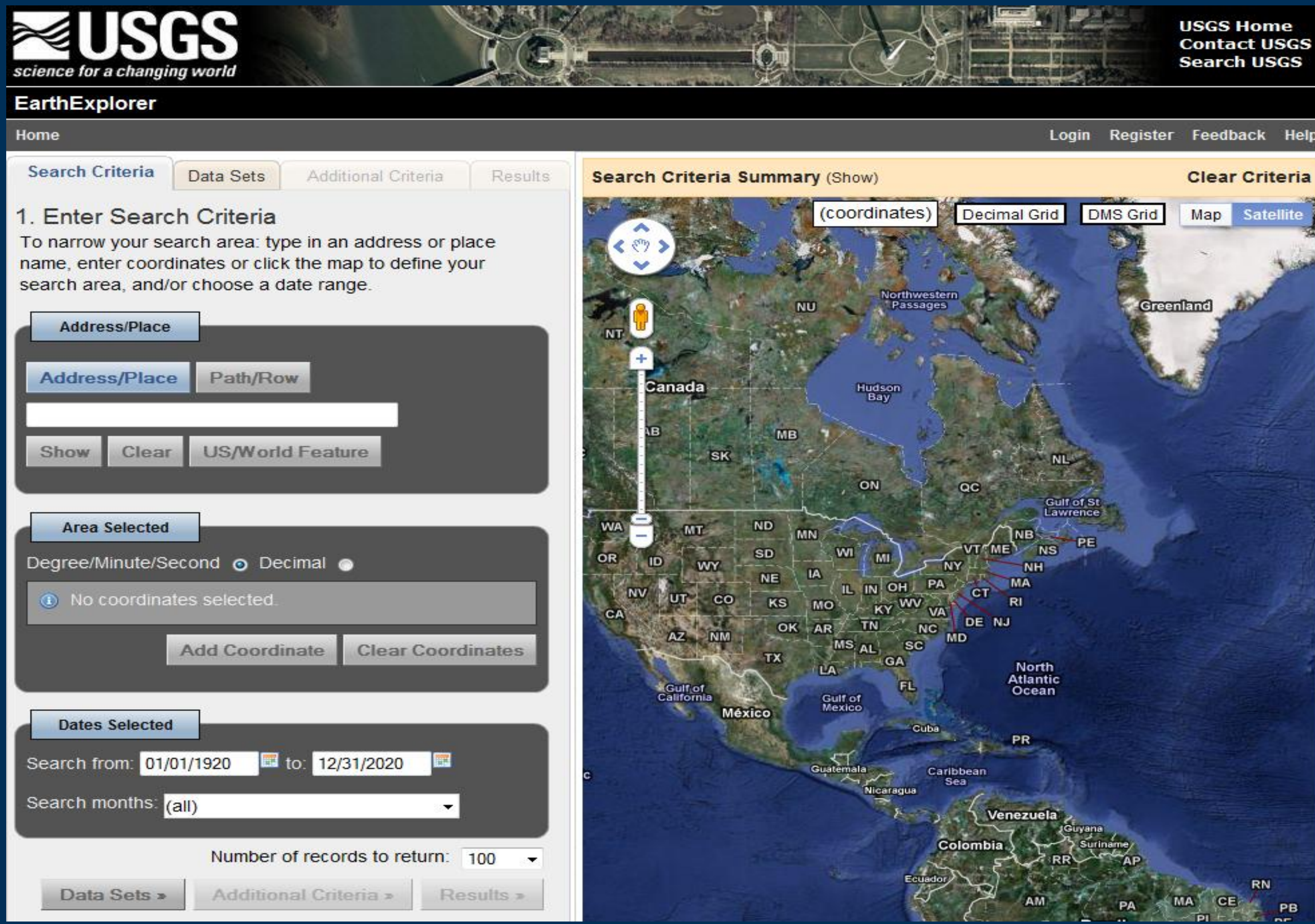
EROS - Land Cover



USGS

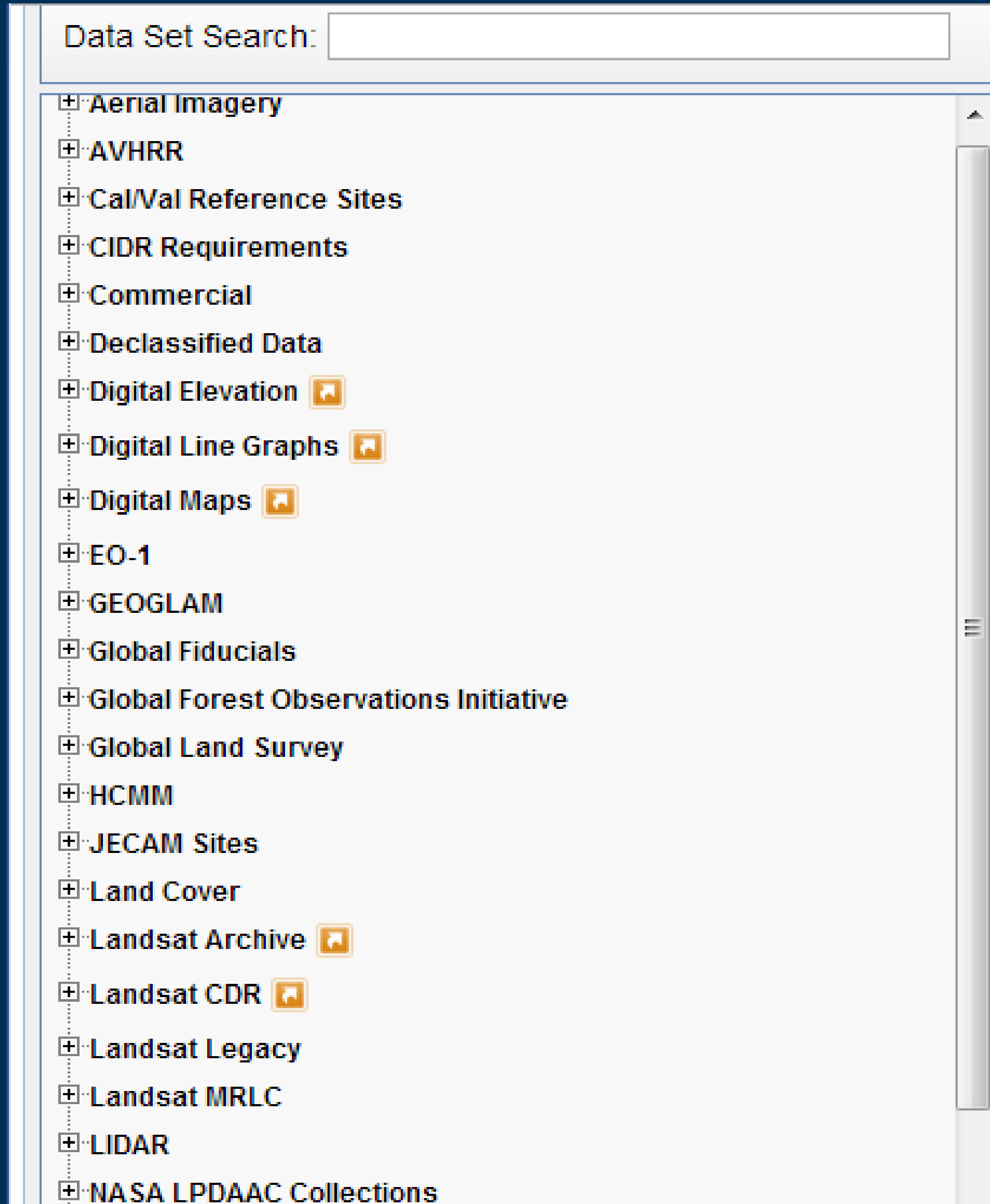
http://landcover.usgs.gov/landcoverdata.php

EROS - EarthExplorer

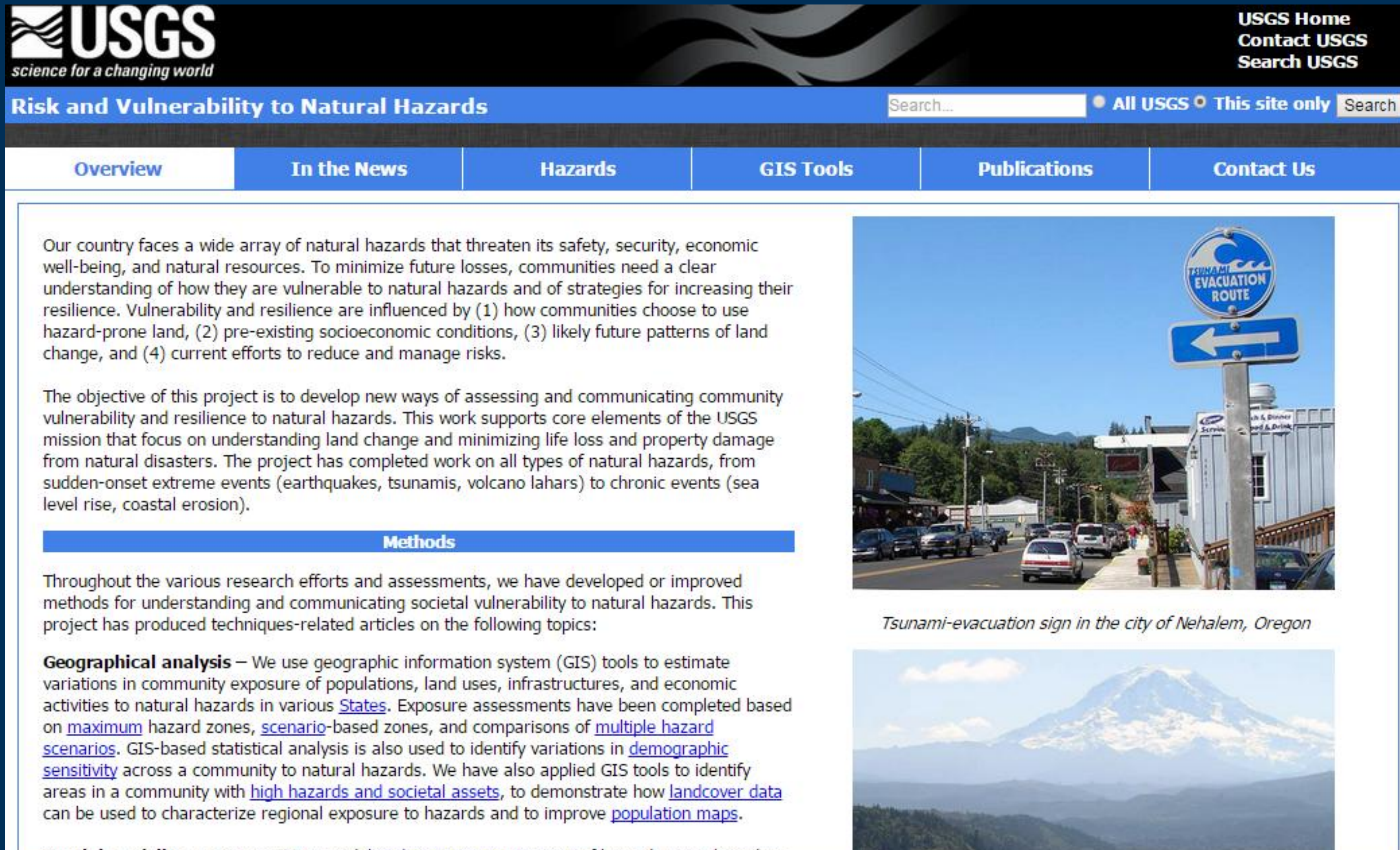


http://earthexplorer.usgs.gov/

EROS - Earth Explorer Data Sets



Risk & Vulnerability to Natural Hazards



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science for a changing world

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Risk and Vulnerability to Natural Hazards

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Our country faces a wide array of natural hazards that threaten its safety, security, economic well-being, and natural resources. To minimize future losses, communities need a clear understanding of how they are vulnerable to natural hazards and of strategies for increasing their resilience. Vulnerability and resilience are influenced by (1) how communities choose to use hazard-prone land, (2) pre-existing socioeconomic conditions, (3) likely future patterns of land change, and (4) current efforts to reduce and manage risks.

The objective of this project is to develop new ways of assessing and communicating community vulnerability and resilience to natural hazards. This work supports core elements of the USGS mission that focus on understanding land change and minimizing life loss and property damage from natural disasters. The project has completed work on all types of natural hazards, from sudden-onset extreme events (earthquakes, tsunamis, volcano lahars) to chronic events (sea level rise, coastal erosion).

Methods

Throughout the various research efforts and assessments, we have developed or improved methods for understanding and communicating societal vulnerability to natural hazards. This project has produced techniques-related articles on the following topics:

Geographical analysis – We use geographic information system (GIS) tools to estimate variations in community exposure of populations, land uses, infrastructures, and economic activities to natural hazards in various States. Exposure assessments have been completed based on maximum hazard zones, scenario-based zones, and comparisons of multiple hazard scenarios. GIS-based statistical analysis is also used to identify variations in demographic sensitivity across a community to natural hazards. We have also applied GIS tools to identify areas in a community with high hazards and societal assets, to demonstrate how landcover data can be used to characterize regional exposure to hazards and to improve population maps.

Spatial modeling – We use GIS to model pedestrian evacuation out of hazard zones, based on

Tsunami-evacuation sign in the city of Nehalem, Oregon

USGS

http://geography.wr.usgs.gov/science/vulnerability/

USGS - National Water Information System

USGS Current Water Data for Nebraska

Click to hide state-specific text

- **NEW!** Sign up for custom Water Alerts by text or email

--- Predefined displays ---
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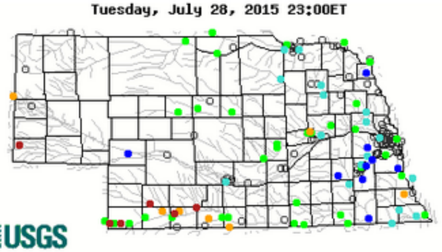
Daily Streamflow Conditions

Select a site to retrieve data and station information.

Tuesday, July 28, 2015 23:00ET



Explanation

- High
- > 90th percentile
- 76th - 90th percentile
- 25th - 75th percentile
- 10th - 24th percentile
- < 10th percentile
- Low
- Not ranked

The colored dots on this map depict streamflow conditions as a percentile, which is computed from the period of record for the current day of the year. Only stations with at least 30 years of record are used.
The **gray circles** indicate other stations that were not ranked in percentiles either because they have fewer than 30 years of record or because they report parameters other than streamflow. Some stations, for example, measure stage only.

Statewide Streamflow Real-Time Table

USGS water-resources monitoring has been recently threatened or discontinued at the following streamgages.

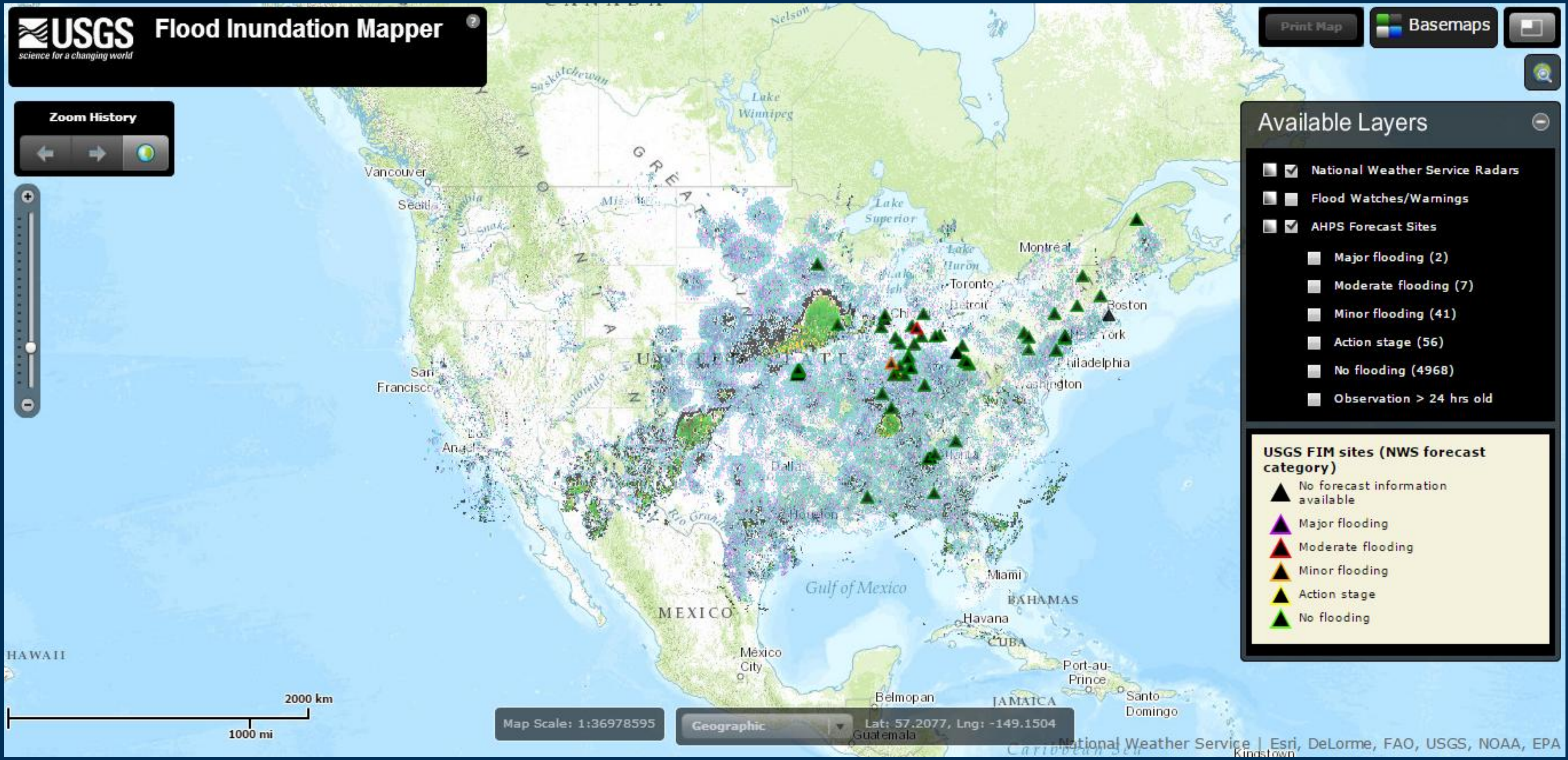
Real-time data typically are recorded at 15 minute intervals, stored onsite, and then transmitted to USGS offices every hour. Recording and transmission times may be more frequent during critical events. Data from real-time sites are relayed to USGS offices via satellite, telephone, and/or radio and are available for viewing within minutes of arrival.

All real-time data are **provisional and subject to revision**.

Build Real-Time Table	Show a custom real-time summary table for one or more stations.
Build Time Series	Build a custom sequence of graphical or tabular data for one or more stations.

http://waterdata.usgs.gov/ne/nwis/rt

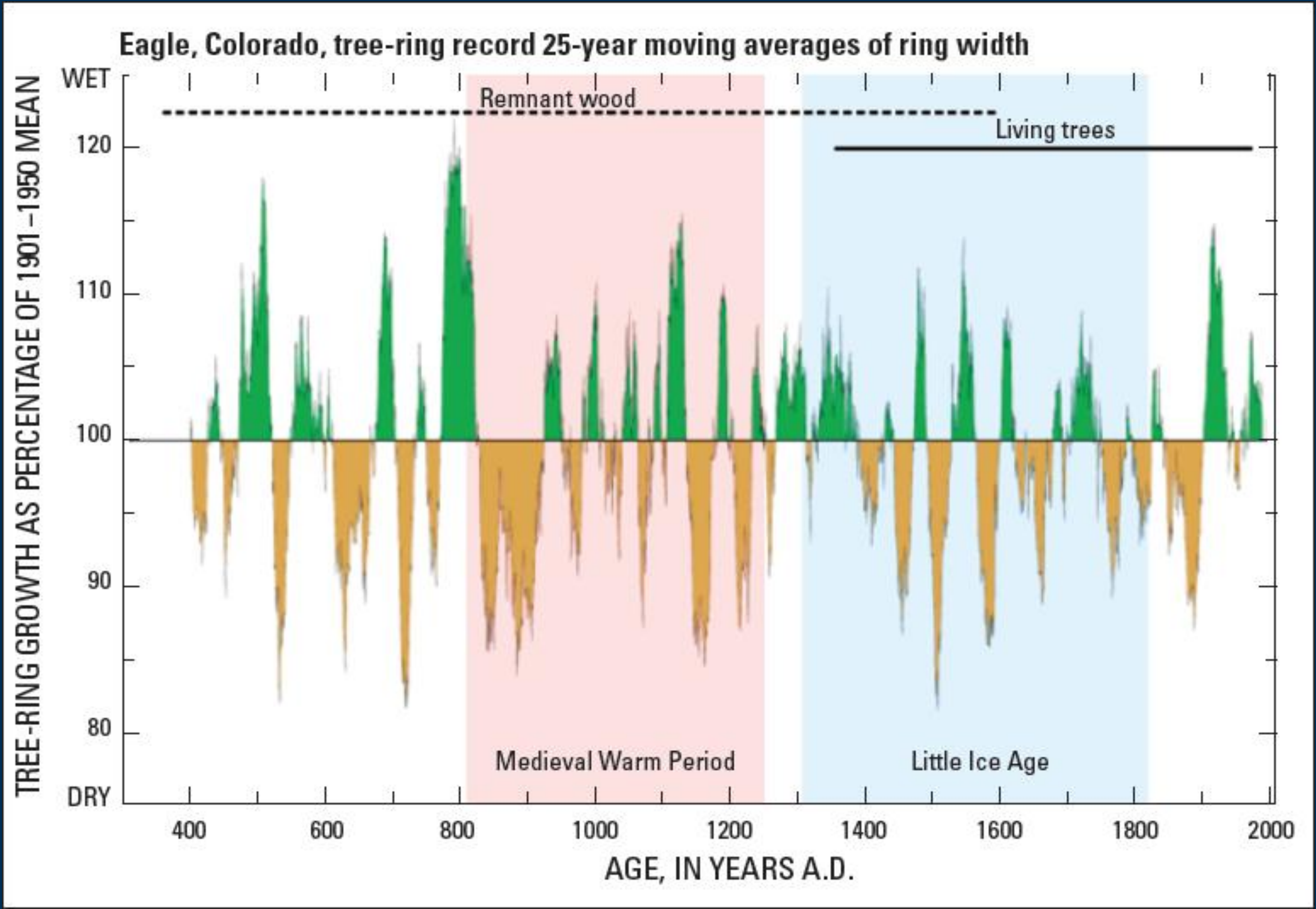
USGS - Flood Inundation Mapping



http://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html

Look Back to Predict the Future
Reconstructed Paleoclimatic Records

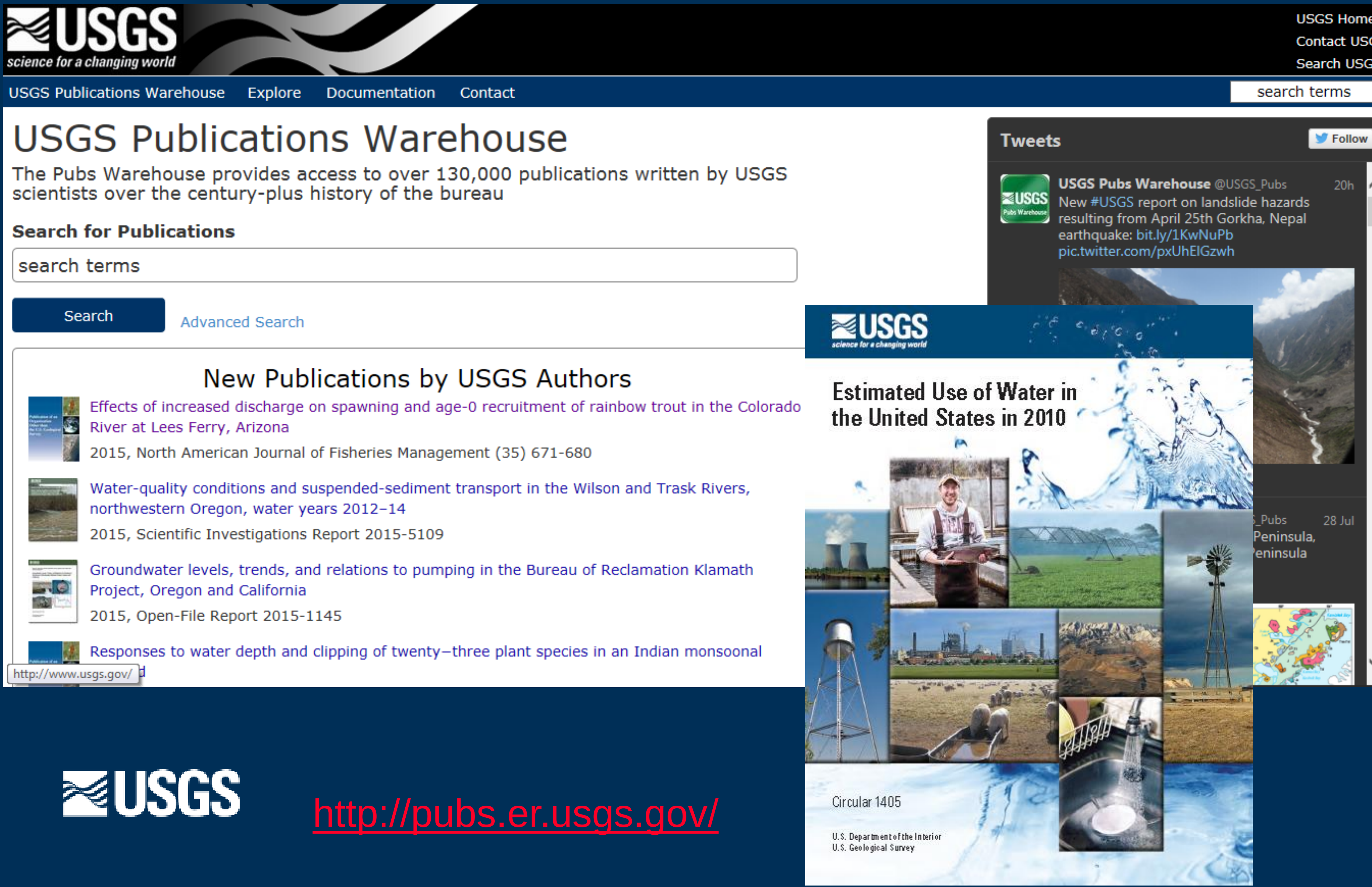
Source: USGS Fact Sheet 2010-1323, January 2011



USGS

Source: USGS Fact Sheet 2010-1323, January 2011

USGS Publications



USGS

http://pubs.er.usgs.gov/

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New Tools
CREAT 2.0

Climate Resiliency Evaluation and Awareness Tool

Robert Dunlevy

Nebraska Silver Jackets Climate Change Workshop

Nebraska City, NE

July 29, 2015

Other New Tools

- http://water.epa.gov/scitech/climatechange/index.cfm
- http://water.epa.gov/infrastructure/greeninfrastructure
- http://water.epa.gov/infrastructure/watersecurity

Other New Tools

Water Infrastructure and Resiliency Finance Center

- Stormwater and green infrastructure
- Public/private partnerships
- Financing predevelopment
- Affordability
- Small systems

Overview of CREAT

United States Environmental Protection Agency

CREAT 2.0

- Risk assessment and scenario-based planning application
- Guides utility owners and operators through information on potential climate-related threats and assessment of potential risks for their utilities
- Provides users with access to basic national and regional climate science information, and a framework to compare current climate-related risks before and after implementing adaptation strategies
- Results from assessments of potential scenarios can be used to incorporate climate change into planning and asset management frameworks

CREAT Pilot Projects - FY 2015
Region 7

Name	City, State	Type: Drinking Water, Wastewater, or Combo	Size: Estimate of the population served	Primary climate change concern (if known): Drought, Flooding, Water Quality, Ecosystem Changes, etc.
Blair Water Department	Blair, NE	Combo	8,000	Flooding, Drought, Water Quality
Fredericktown Water Treatment Plant	Fredericktown, MO	Drinking Water or Combo	4,024	Drought and Water Quality
Hillsboro Water Dept.	Hillsboro, KS	Drinking Water	3,000	Blue/Green Algae & Drought

Climate Change and Associated Risks in the Great Plains

EPA United States Environmental Protection Agency

Local Observations and Future Climate Concerns

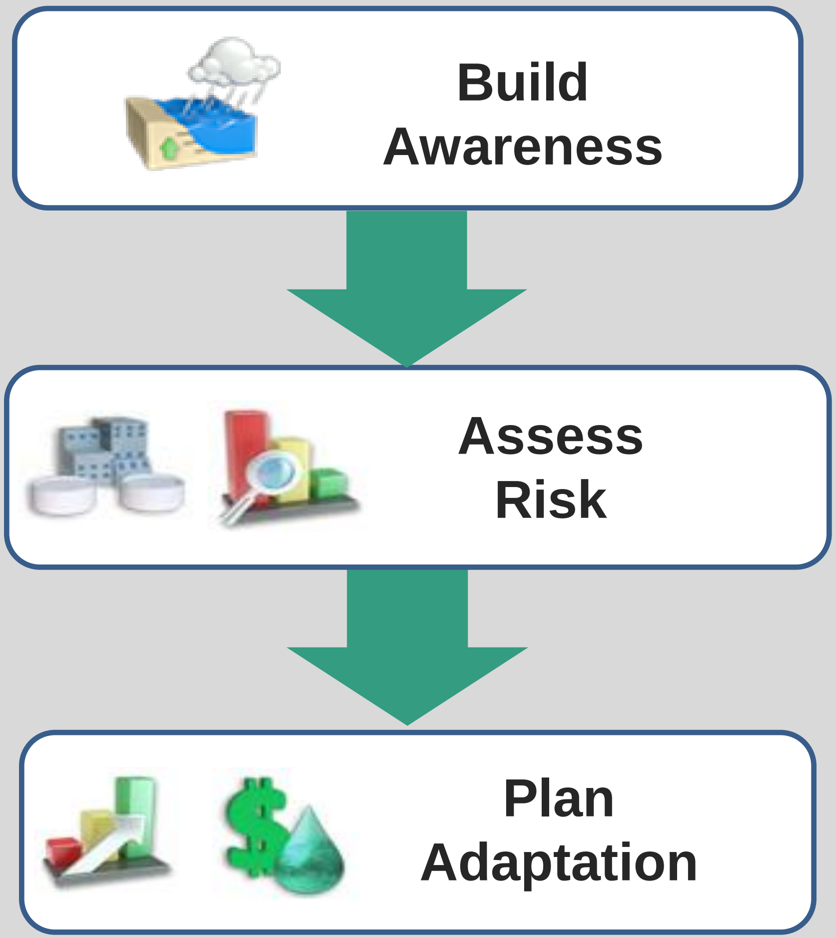
- Local climate observations
  - Temperature rise
  - Shifts in precipitation patterns and timing
- Future climate concerns
  - Increased frequency and severity of droughts
  - Increased precipitation and more frequent and intense precipitation events
  - Rapid spring warming and intense rainfall

Utility Risk Concerns

- Current utility experiences and concerns with observed climate conditions
  - Drought affecting water availability
  - Treatment challenges from intense precipitation and temperature extremes impacting water quality (e.g., high turbidity, NPDES permit)
- Future utility concerns with potential climate changes
  - More frequent and intense drought conditions
  - More frequent and intense precipitation events

CREAT Process

Using CREAT



- Setup
- Threats
- Assets

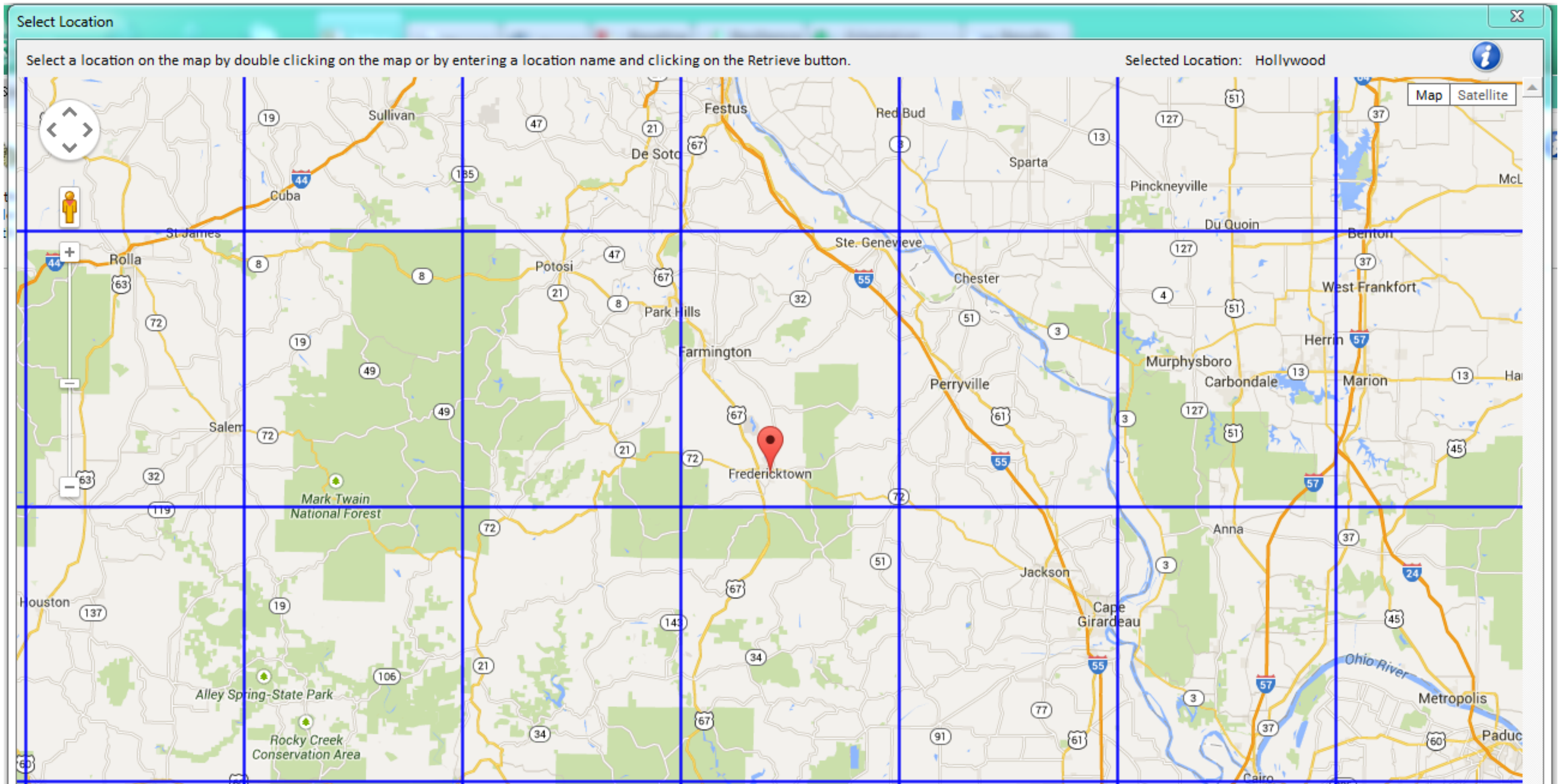
- Baseline Analysis
- Resilience Analysis

- Adaptation Planning
- Results & Reports

CREAT Setup

- Utility/system information – used in reporting
- Analysis parameters
  - Locations
  - Climate data
  - Likelihood
  - Time periods
  - Consequence weighting

Defining Location(s)



Key Questions: Where are climate impacts relevant to my utility? Are there specific areas of my service system or watershed that I want detailed climate data for?

United States Environmental Protection Agency

Historical Data

- CREAT-provided or use your own, if preferred
- Selection of climate station provides historical data on storm events (e.g., 1 in 100 year storm)

Navajo Reservoir (L1) | **Fredericktown, MO (L2)** | Location 3 (L3) | Location 4 (L4)

					Intense Precipitation (inches per 24-hour event)					
Selected	Climate Dataset Description	Average Annual Temperature (F)	Total Annual Precipitation (inches)	Climate Station	5 Year	10 Year	15 Year	30 Year	50 Year	100 Year
☑	CREAT provided data	55.22	43.92	FREDERICKTOWN	3.86	4.49	4.84	5.47	5.91	6.50

Type	ANNUAL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
Average Temp (F	55.22	31.44	35.56	44.91	55.85	64.33	72.84	77.20	75.67	68.02	56.95	45.12	34.81
Total Precip (inch	43.92	2.52	2.56	4.05	4.27	4.57	3.90	3.82	3.74	3.25	3.11	4.55	3.57

Intense Precipitation	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Autumn (SON)
5 Year	3.86	2.20	2.87	2.99	2.80
10 Year	4.49	2.68	3.54	3.54	3.39
15 Year	4.84	2.95	3.94	3.90	3.74
30 Year	5.47	3.39	4.69	4.45	4.37
50 Year	5.91	3.70	5.24	4.84	4.84
100 Year	6.50	4.13	6.02	5.39	5.51

Key Question: Does my utility (or city) have data that I should incorporate into my assessment (e.g., preferred weather stations, accepted historical datasets)?

					Intense Precipitation (inches per 24-hour event)					
Selected	Climate Dataset Description	Average Annual Temperature (F)	Total Annual Precipitation (inches)	Climate Station	5 Year	10 Year	15 Year	30 Year	50 Year	100 Year
☐	User 1									

CREAT Process

Likelihood

Two options in CREAT:

– Conditional: consider "what-if" scenarios

– Assess likelihood: qualitatively assess the likelihood of threats under each climate scenario

Key Questions: Do I feel comfortable making an assessment of likelihood? Or am I OK just looking at potential "what-if" climate scenarios?

Time Periods

- CREAT provides two default time periods
- For each of these time periods, CREAT provides climate projection data
- To use other time periods, you must provide your own climate projection data

CREAT-Provided 2035	CREAT-Provided 2060
2035	2060
Represents mid-century time period (2021 to 2050) for planning in response to climate change. Projected changes in temperature, precipitation, and sea level (for coastal locations) provided in CREAT for this time period.	Represents late-century time period (2046 to 2075) for planning in response to climate change. Projected changes in temperature, precipitation, and sea level (for coastal locations) provided in CREAT for this time period.

Key Question: Do the CREAT-provided time periods align with my assessment goals?

EPA United States Environmental Protection Agency

Consequences

- Assessment within CREAT will consider the consequences of climate change impacts on assets
- Five categories of consequences

	Utility Business Impacts	Utility Equipment Damage	Source/Receiving Water Impacts	Environmental Impacts	Community Public Health Impact
	Revenue or operating income loss evaluated in terms of the magnitude and recurrence of service interruptions.	Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of the magnitude of damage (minimal, minor,	Degradation or loss of source water or receiving water quality and/or quantity evaluated in terms of the recurrence." (minimal, temporary, seasonal or episodic,	Evaluated in terms of environmental damage or loss (aside from source water or other assets) and compliance with environmental regulations (minimal, short term,	Evaluated in terms of the duration (short or long-term) and extent (minimal, minor, localized, or widespread)
Weight	20 %	20 %	20 %	20 %	20 %

United States Environmental Protection Agency

Consequences

Categories and their definitions can be edited to reflect a utility's priorities.

	Category 1	Category 2	Category 3	Category 4	Category 5
Title	Utility Business Impacts	Utility Equipment Damage	Source/Receiving Water Impacts	Environmental Impacts	Community Public Health Impact
Description	Revenue or operating income loss evaluated in terms of the magnitude and recurrence of service interruptions.	Costs of replacing the service equivalent provided by a utility or piece of equipment evaluated in terms of the magnitude of damage (minimal, minor, significant, complete loss) and financial impacts (flexible cost scale, "$X," can be customized by each user)	Degradation or loss of source water or receiving water quality and/or quantity evaluated in terms of the recurrence." (minimal, temporary, seasonal or episodic, long-term)	Evaluated in terms of environmental damage or loss (aside from source water or other assets) and compliance with environmental regulations (minimal, short term, persistent / permit violations significant impact and/or regulatory enforcement and actions)	Evaluated in terms of the duration (short or long-term) and extent (minimal, minor, localized, or widespread)
Very High	Long-term and/or significant loss of expected revenue or operating income	Complete loss of asset; replacement costs of $X++	Long-term compromise of source water quality and/or quantity	Significant environmental damage - may incur regulatory action	Long-term and/or widespread public health impacts
High	Seasonal or episodic - but minor - compromise of expected revenue or operating income	Significant damage to equipment; costs estimated at <$X+	Seasonal or episodic compromise of source water quality and/or quantity	Persistent environmental damage - may incur regulatory action	Short-term and localized public health impacts
Medium	Minor and short-term reductions in expected revenue or operating income	Minor damage to equipment; costs estimated at <$X	Temporary impact on source water quality and/or quantity	Short-term environmental damage, compliance can be quickly restored	Minor public health impacts
Low	Minimal potential for any attributable loss of revenue or operating income	Minimal damage to equipment	No more than minimal changes to source water quality and/or quantity	No impact or environmental damage	No impact on public health
Weight (%)	20	20	20	20	20

United States
Environmental Protection
Agency

CREAT Process

Baseline Analysis

- Current capabilities to withstand a future threat.
- Library of over 100 existing adaptive measures.
- Consider the consequences of identified threats on utility assets.
- Assessments made for each individual scenario and time period.
- Benefit through adaptation measured as difference between baseline analysis and second assessment.

United States Environmental Protection Agency

Resilience Analysis

- Reconsider assessments in baseline analysis with the addition of new adaptive measures to increase utility resilience.
- Adaptive measures can be modified to show improvement or new adaptive measure can be developed.
- Consider cost and approach.

United States Environmental Protection Agency

Adaptive Planning

- Develop adaptation packages to apply results from baseline and resilience assessments.
- Measures designed to reflect the relative reduction in risk associated with implementing adaptive measures.
- Addition of costs into the tool.
- Generate Report.

United States Environmental Protection Agency

Act

- Share with partners.
- Build support team.
- Report to decision makers.
- Choose action.

CREAT Process

United States Environmental Protection Agency

Additional Resources

- CREAT training videos
  - Focus on individual steps of the tool (3-5 min. each)
  - Demonstrate mechanics and illustrate use-case/rationale via fictional narratives
- CREAT worksheets
  - Available on the first sub-tab of Setup
  - May be helpful when collaborating with others

United States Environmental Protection Agency

NEW

CREAT tool Pilot Communities

- Fredericktown, MO: https://www.youtube.com/watch?v=acVgr7qdkMU
- Camden, NJ: https://www.youtube.com/watch?v=_w9Omq3ZMQg
- Harrisburg, PA: https://www.youtube.com/watch?v=H-n2UVZhFbk
- Manchester by-the-Sea, MA: https://www.youtube.com/watch?v=MsNuIgFgoso
- Faribault, MN: https://www.youtube.com/watch?v=qhka0Xm-hNw

United States Environmental Protection Agency

Questions?

Up Next: Web-based 3.0

Contact

EPA Region 7

Robert Dunlevy

(913) 551-7798

dunlevy.robert@epa.gov

EPA Region 7 Community Resiliency Climate Change Tools

EPA R7 can provide climate resiliency assistance in the following general areas: guidance documents, relationships with partnering agencies, public relations, web based water and wastewater utility assistance tools and water efficiency tools/guidance. This document summarizes the major tools, including links for additional information, EPA can offer other agencies, cities and communities.

Climate Resilience Evaluation & Awareness Tool (CREAT)

This software tool assists drinking water and wastewater utility owners and operators in understanding potential climate change impacts and in assessing the related risks at their utilities.

⟹ http://water.epa.gov/infrastructure/watersecurity/climate/index.cfm

National Stormwater Calculator

EPA's National Stormwater Calculator (SWC) is a desktop application that estimates the annual amount of rainwater and frequency of runoff from a specific site anywhere in the United States (including Puerto Rico). Estimates are based on local soil conditions, land cover, and historic rainfall records.

⟹ http://www2.epa.gov/water-research/national-stormwater-calculator

Community Flood Resilience Checklist

This checklist is intended to help state agencies review their program structure and state policies to improve floodplain management and plan for more responsible future growth.

⟹ http://www.epa.gov/smartgrowth/pdf/Flood-Resilience-Checklist.pdf

Workshop Planner for the Water Sector

The workshop Planner contains all of the materials needed to plan and conduct a customized workshop focused on planning for frequent and intense extreme events.

⟹ http://www.epa.gov/climatereadyutilities

Adaptation Strategies Guide

This interactive guide assists drinking water and wastewater utilities in gaining a better understanding of what climate-related impacts they may face in their region, and what adaptation strategies can be used to prepare their system for those impacts. The guide now also includes information on how utilities can incorporate sustainability into their adaptation planning.

⟹ http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817k13001.pdf

Flood Resilience: A Basic Guide for Water and Waste Water Utilities

EPA's Flood Resilience Guide is your one-stop resource to know your flooding threat and identify practical mitigation options to protect your critical assets.

⟹ http://water.epa.gov/infrastructure/watersecurity/emerplan/upload/epa817b14006.pdf

Enhancing Sustainable Communities With Green Infrastructure: A Guide To Help Communities Better Manage Stormwater While Achieving Other Environmental, Public Health, Social, And Economic Benefits

This guide aims to help local governments, water utilities, nonprofit organizations, neighborhood groups, and other stakeholders integrate green infrastructure strategies into plans that can transform their communities.

⟹ http://www.epa.gov/smartgrowth/green-infrastructure.html

Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans

This workbook helps users to create a vulnerability assessment and identify adaptation actions to address their vulnerabilities. The Workbook will assist organizations that manage environmental resources to prepare a broad, risk-based vulnerability assessment and adaptation plan.

⟹ http://www2.epa.gov/sites/production/files/2014-09/documents/being_prepared_workbook_508.pdf

Adaptive Response Framework for Drinking Water and Wastewater Utilities

This report includes 11 findings and 12 recommendations to guide climate ready activities and the identification of needed resources and possible incentives to support and encourage utility climate readiness.

⟹ http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817f12009.pdf

EPA Region 7 Communities Digest

The purpose of the EPA Region 7 Communities Information Digest is to provide communities in the 4-state region and other interested areas the latest news, webinars, conferences, funding, and other community-based activities going on in the region and country related to human health and the environment.

⟹ Email to be added: R7_POIS_Communities_Mailbox@epa.gov

For further information regarding the EPA Region 7 Community Resiliency Team, contact Amy Shields at 913-551-7396 or shields.amy@epa.gov.

United States
Environmental Protection
Agency

Climate Resilience Evaluation and Awareness Tool Version 2.0
A Climate Risk Assessment Tool for Water Utilities

Purpose

The Climate Resilience Evaluation and Awareness Tool (CREAT), developed under EPA's Climate Ready Water Utilities initiative, assists drinking water, wastewater, and stormwater utility owners and operators in assessing risks to utility assets and operations. Extreme weather events, sea-level rise, shifting precipitation patterns, and temperature changes will affect water quality and availability. Managing these events will pose significant challenges to water sector utilities in fulfilling their public health and environmental mission. Version 2.0 of CREAT provides access to the most current scientific understanding of climate change, including downscaled climate model projections, that will increase user awareness of projected changes in climate, related impacts , and potential adaptation options.

CREAT has a flexible and customizable risk assessment framework that organizes available climate data and guides users through a process of identifying threats, vulnerable assets, and adaptation options to help reduce risk. CREAT supports utilities in considering impacts at multiple locations, assessing multiple climate scenarios, and documenting the implications of adaptation on energy use. To support more robust decision-making, CREAT encourages users to compare the performance of adaptation options in multiple time periods across climate scenarios.

FEATURES

Scenarios of climate change are provided at local scales to support identification of threats that affect utilities.

Pre-loaded data contains libraries of drinking water and wastewater utility assets (e.g., treatment plants, reservoirs, pump stations) and customizable adaptation strategies for implementation.

Climate change information and data at regional and local levels is included to support the assessment of threat likelihood and potential asset, environmental, community and economic consequences.

Results support implementation of climate change adaptation options and assessment of their effectiveness in reducing risk to climate change impacts.

Reports on climate data, risk reduction, and costs can be generated from the tool to evaluate various adaptation options.

Data and process can be customized over time as new information becomes available, enabling updates to adaptation strategies in the future.

Process: Adaptation, Planning & Use

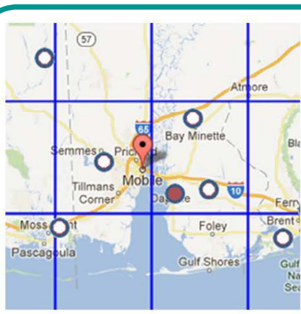
In CREAT 2.0, water utility owners and operators use information about their utility to identify climate change threats, assess potential consequences, and evaluate adaptation options. This approach allows utilities to assess impacts based on established thresholds when utility operations are disrupted and assets are impacted. Complementing other tools and resources already employed in risk management practices (e.g., models of hydrology and projected demand), utilities can use climate science data to evaluate the plausibility of climate-related impacts and how soon these impacts may affect the utility.

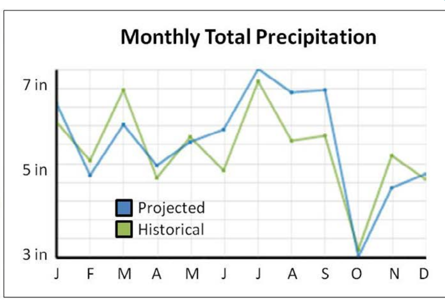
continued on page 2

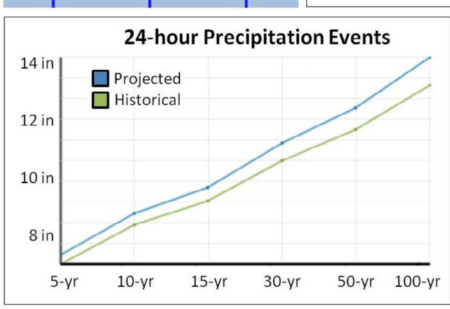
CREAT Process: Application of climate information and utility knowledge to assess risks and challenges presented by climate change.

The CREAT 2.0 framework incorporates available qualitative regional and quantitative (downscaled) local climate information to help inform the utility planning process. The software does not attempt to forecast climate change (e.g., temperature and precipitation changes), but offers a range of potential conditions to consider. Users can consider these scenarios of projected climate change to help identify related impacts important to operations, maintenance, and management.

Example: Projected changes in intense precipitation will likely increase the frequency of flood events and the peak influent flows into collection systems following storm events. CREAT provides pre-loaded historical precipitation data and projected changes based on model outputs to help users understand how these events will differ as climate changes. Utility experience regarding how storms have impacted utility assets and operation in the past is key to interpreting the potential impact of these changes in the future. CREAT guides the user through a detailed risk assessment including the selection of adaptation options to reduce consequences from floods and higher peak influent flows. By evaluating benefits (i.e., reduction in risk) of different adaptation options, users can develop effective adaptation plans to prepare for projected changes in storm conditions.







CREAT provides data and plots for comparing local historical conditions with downscaled climate model projections for each grid cell.

Benefits of CREAT

CREAT helps utilities organize and communicate risks from climate impacts and potential gains from adaptation to decision makers, stakeholders and citizens. Incorporating CREAT results with overall utility planning builds customer confidence that a utility is being proactive in identifying significant risks or gaps where additional planning may be needed.

For More Information: CREAT 2.0 is available for download at www.epa.gov/climatereadyutilities. For more information, email CRWUhelp@epa.gov.

CLIMATE READY WATER UTILITIES EPA

Climate Change on the Prairie:
A Basic Guide to Climate Change in the High Plains Region

Global Climate Change

Why does the climate change?

The Earth's climate has changed throughout history and will continue to change in the future. Global climate change can be attributed to one of two causes, natural or anthropogenic (human-induced), and can occur on different time scales, both short-term and long-term.

A volcanic eruption is an example of natural short-term climate change. When ash is ejected high into the atmosphere, it temporarily blocks the sunlight and subsequently cools the Earth. El Niño is another example of natural short-term change. When the sea surface temperatures in the equatorial Pacific are warmer than normal, global wind patterns can change which affects temperature and precipitation patterns. Long-term climate change, on the order of thousands of years, are due to changes in solar radiation receipt, slight changes in the Earth's orbit, continental drift, formation or loss of ice sheets, and changing ocean currents.

Human activities can also influence climate. The human influence that is most responsible for recent changes in global temperature is the burning of fossil fuels which increases the levels of greenhouse gases in the atmosphere, such as carbon dioxide and methane. Increases in greenhouse gases contribute to a general warming of the Earth because as their concentrations increase so does the temperature.

As the Earth's climate changes, many different sectors will be impacted. The impacts on Earth's ecosystems are already apparent from the tundra to the tropical waters. For example, in the high northern latitudes, permafrost is thawing which is increasing coastal erosion and damaging infrastructure of the towns which are built upon the permafrost. Rising sea temperatures already threaten the coral reefs of the world which is having an impact on tourism and fisheries.

What are the current trends and projections?

Surface temperature measurements of both the land and the ocean indicate a warming trend since the early 20th century and especially in the last 50 years (see Figure 1).

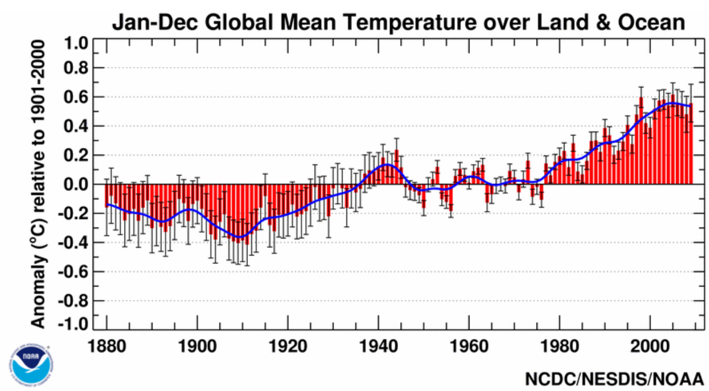


Figure 1: Departure from 1901-2000 average temperature. Figure courtesy National Climatic Data Center.

According to the U.S. Global Change Research Program (USGCRP), models which incorporate different greenhouse gas emission scenarios project global temperatures to increase by 2°F-11.5°F by 2100. If the rate of greenhouse gas emissions is reduced, the temperature increase is projected to be on the lower end of the range and if emission rates continue at or near current rates the temperature increase is projected to be at the higher end of the range.

Climate Change in the United States

Historical trends and projections - temperature

Overall, temperatures across the United States have been warming over the past 100 years and the average temperature has increased by 2°F in the past 50 years (USGCRP). Areas of the southeast show a slight cooling over the past century, however, these areas have begun to show a warming trend over the past 30 years. The warming trend is occurring in both the daily maximum and minimum temperatures, however the minimum temperatures are increasing at a faster rate than maximum temperatures. Climate models are projecting that temperatures will continue to increase now through 2100. Because of the residence time of greenhouse gases in the atmosphere, model projections of the near future temperature changes do not vary much. However, by 2100, in the lower emissions scenarios, the increase could range from 4°F-6.5°F and in the higher emissions scenarios the increase could range from 7°F-11°F (USGCRP).

Historical trends and projections - precipitation

According to the USGCRP, shifts in global precipitation patterns are already occurring and has resulted in increases in precipitation in some areas and decresases in others. Here in the US, the total annual precipitation has increased by 5% over the past 50 years (USGCRP). This increase has occurred for the most part due to an increase in the frequency and intensity of heavy downpours. All areas of the US have shown to have an increase in heavy downpours over the last 50 years, but the areas with the highest increases are the Northeast and the Midwest. While precipitation changes are much more difficult to predict in the long term, climate models do show indications that northern areas of the US will become wetter, particularly in the winter and spring, and areas of the south and west will become drier. Models are also projecting an increase in heavy downpours and a decrease in light precipitation over the next 100 years.

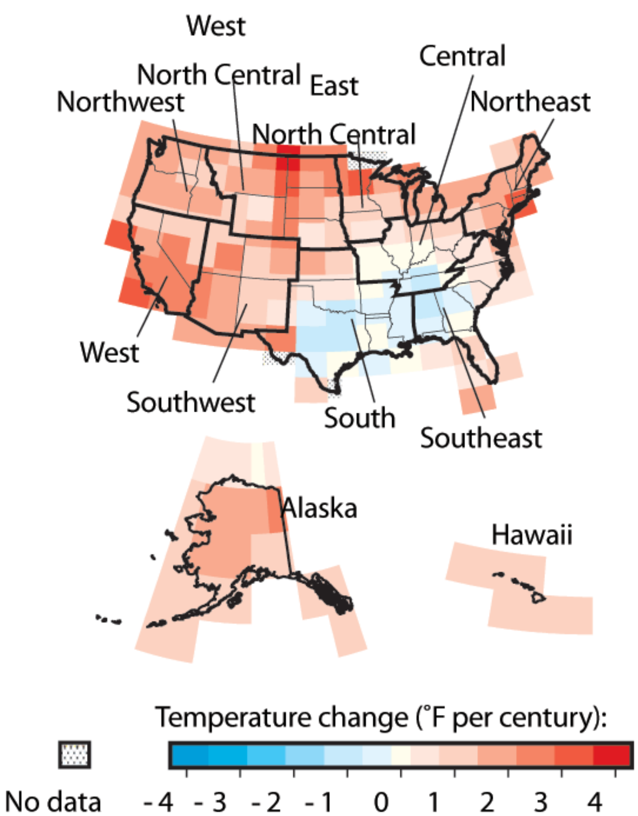


Figure 2: Annual Temperature Trends 1901-2005. Figure courtesy United States Environmental Protection Agency.

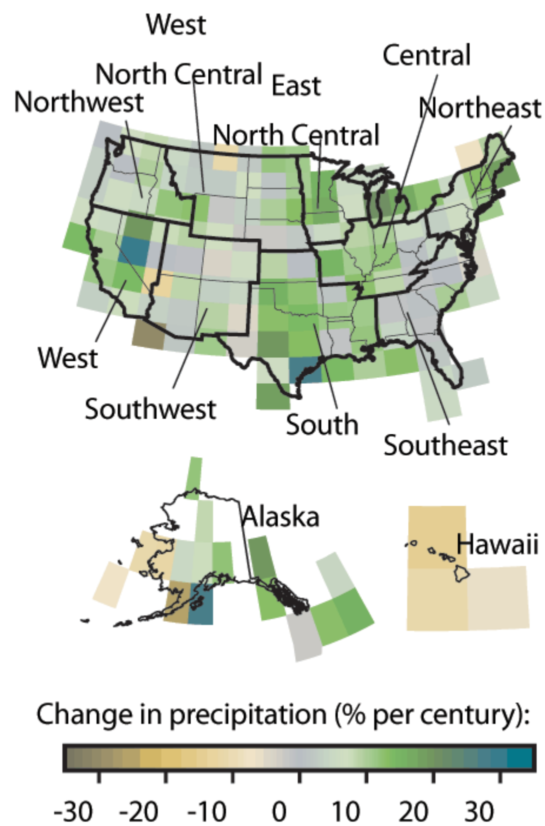


Figure 3: Annual Precipitation Trends 1901-2005. Figure courtesy United States Environmental Protection Agency.

Historical Climate Trends in the High Plains Region

Temperature

There are more than 100 years of climate data for the High Plains states with records that date back to the 19th century. A look into the historical datasets reveals the variability and trends in climate over time.

The trend in average annual temperature for the six-state region shows a warming of 1.7°F over a 115 year period. Temperatures show cooler than normal conditions early in the record, followed by significant warmth during the 1930's dust bowl era, and warmer than normal conditions since the 1970's, especially over the last 10 years. The greatest amount of warming on an annual basis is found in North Dakota (2.9°F) and the least amount is in Colorado (0.9°F).

Overall, the annual warming trend is greater for nighttime low temperatures than for daytime high temperatures. This is the case for much of the globe with lows warming more than highs. One reason for this difference is thought to be an increase in the amount of moisture in the air, which affect minimum temperatures much more than maximum temperatures. If broken down by season, the warming is strongest in winter (2.5°F) and weakest in autumn (0.5°F) for the region. This seasonal variability is also reflected in the global trends, particularly for land masses in the Northern Hemisphere.

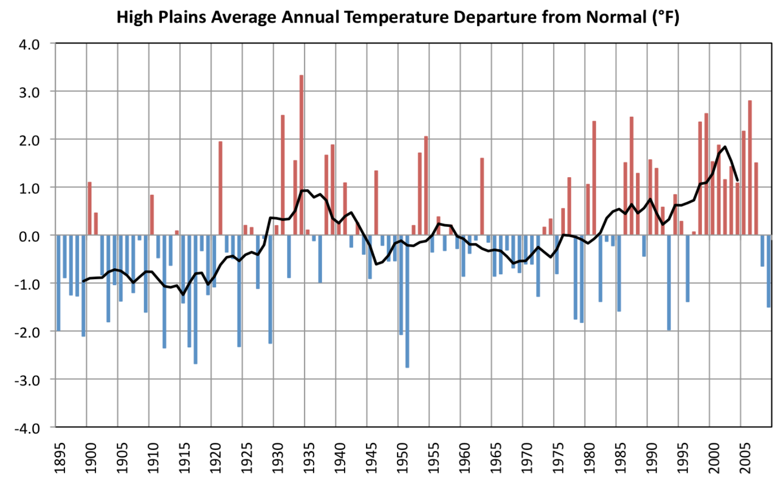


Figure 4: Average Annual Temperature Departure from Normal (˚F) in the High Plains Region. Data courtesy National Climatic Data Center.

Global climate change quick facts:

According to the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center's 2009 State of the Climate Report:

- the 2000-2009 decade was the warmest on record
- the average global surface temperature for 2009 was 0.96˚F above the 20th century average
- the years 2001-2009 each rank in the top ten warmest years on record (period of record 1880-2009)

Statewide Average Temperature Change by Season (1895-2009)

Temperature in degrees F

State	Spring	Summer	Autumn	Winter
North Dakota	2.2	1.8	1.5	5.0
South Dakota	1.8	1.6	0.9	3.9
Nebraska	1.5	0.7	0.0	1.8
Kansas	1.2	0.6	-0.2	2.0
Wyoming	2.7	2.3	0.6	0.8
Colorado	1.4	0.6	0.1	1.5
Average	1.8	1.3	0.5	2.5

Historical Climate Trends in the High Plains Region

Precipitation

Precipitation shows a much weaker trend than temperature with essentially no change for the annual average in the High Plains Region. There is high year-to-year variability throughout the century long dataset, which is typical for the continental type climate of the region. The dry years of the 1930s and 1950s stand out in the record with periods of below normal rainfall. Over the last several decades the region has been overall in a wet period. There are, however, seasonal differences in the precipitation pattern with most states experiencing a drying for the winter (14% decrease on average) and wetter during autumn (16% increase). The overall trends for spring and summer are on average small.

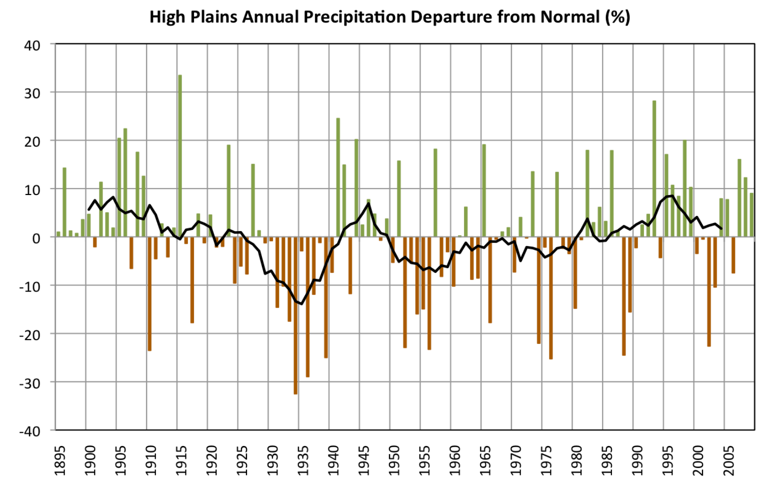


Figure 5: Average Annual Precipitation Departure from Normal (%) in the High Plains Region. Data courtesy National Climatic Data Center.

Statewide Annual Climate Trends (1895-2009)
Temperature in degrees F, Precipitation in percent

State	Average Temperature	Maximum Temperature	Minimum Temperature	Precipitation
North Dakota	2.9	2.4	3.2	4%
South Dakota	2.2	1.3	3.0	2%
Nebraska	1.2	0.3	1.8	3%
Kansas	1.1	0.6	1.5	7%
Wyoming	1.8	2.6	1.1	-14%
Colorado	0.9	0.9	0.9	1%
Average	1.7	1.4	1.9	0%

Climate Change Projections and Possible Impacts

Through the use of climate models, scientists have the ability to project future climate based on scenarios of anthropogenic and natural forcings. One of the primary forcings is enhanced greenhouse gas emissions, which alters the amount of radiation we receive and influences temperature. Several research groups across the globe run models using scenarios to simulate future climate, both at the global and regional scale. A composite of the various climate models projects a warming in the High Plains region of about 4°F by 2050 and 8°F or higher by 2090. The individual models show a range of temperature increases, although they all point to a warming. Model projections of changes in precipitation vary by season, showing a general drying in summer and autumn with wetter conditions in winter. Spring is projected to be wetter in the northern part of the region and drier in the south. The summer drying trend is compounded by increased evaporation rates due to the projected warming. With approximately 70% of the land in the High Plains Region being used for agricultural or rangeland purposes, this region is acutely sensitive to these types of changes.

Climate Change Projections and Possible Impacts

Key climate change impacts in this region include the following:

- **Water Resources:** An increase in temperature, especially in the summer months, can lead to an increase in evapotranspiration and decrease in soil moisture. This can lead to an increase in irrigation demands, which is heavily relied upon to avoid plant water stress. Increased water use is already putting a strain on water resources in the region, such as the Ogallala Aquifer.

> **"Warming of the climate system is unequivocal."**
>
> Fourth Assessment of the Intergovernmental Panel on Climate Change

- **Extreme Events:** There are expected to be changes in the frequency and severity of extreme events in a warmer climate. This includes more days with heavy precipitation, extreme cold, and growing season frosts. These can affect urban and rural landscapes alike, and often the extreme events have a significant and immediate economic and social impact.
- **Ecosystems:** The likelihood of invasive species and pests is expected to increase in a warmer climate with associated shifts in temperature and precipitation patterns. Productivity and yields of agricultural land will be impacted by such a change. Adding in human-caused stress factors, such as fragmentation of habitat, native species will also become more vulnerable to climate change.

Nebraska Farmland. Picture courtesy Ken Dewey.

- **Demographics:** Current population trends in the region are toward the growth of urban areas and a depopulation of the rural areas. This demographic trend brings a corresponding shift in the needed services and economic base. As such, rural areas are expected to have an increase in vulnerability to climate change. In addition, Native Americans are particularly vulnerable to climate change stresses, such those on water resources, which is expected to increase further in a changing climate.

* Projections and impacts information courtesy of the U.S. Global Change Research Program

For more information, please contact the High Plains Regional Climate Center:

High Plains Regional Climate Center

Providing Timely Climate Data and Information to the Public for Cost Effective Decision Making

High Plains Regional Climate Center
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3310 Holdrege Street
Lincoln, NE 68583-0997

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http://www.hprcc.unl.edu

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Pioneering new frontiers.

New Guidance Available for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects

Posted 5/29/2014

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Photos 1 of 1

HARTWELL, Ga. - Water rushes through 12 spillway gates at the U.S. Army Corps of Engineers' Hartwell Dam in the early morning hours of July 9, 2013. The Corps activated the spillway gates to release excess water after heavy rainfall the night before caused the reservoir to reach its maximum flood storage capacity of 665 feet per mean sea level. During peak discharge, the Corps released 74,000 cubic feet per second (cfs) of water through the Hartwell Dam. This amount includes 32,000 cfs passing through the five turbines (for hydropower generation) and 42,000 cfs passing through 12 spillway gates. Other than routine spillway gate tests, it was the first time the spillway gates had been opened at the Hartwell Dam since Aug. 18, 1994. The only other occasion was on March 8, 1964. Photo by Doug Young. (Photo by Doug Young)

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ALEXANDRIA, VIRGINIA. The U.S. Army Corps of Engineers (USACE) has released new guidance on how to incorporate climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaptation policy. USACE policy requires consideration of climate change in all current and future studies to reduce vulnerabilities and enhance the resilience of our water-resource infrastructure.

The Engineering and Construction Bulletin (ECB) 2014-10 (pdf, 195 KB), issued 2 May 2014 and expiring 2 May 2016, outlines concepts and goals, provides guidance and provides an example to support incorporation of new science and engineering products and other relevant information about specific climate change and associated impacts in hydrologic analyses for new and existing USACE projects.

The bulletin establishes a procedure to perform a qualitative analysis of potential climate threats and impacts to USACE hydrology-related projects and operations. The method consists of a two phase process that first conducts an initial screening-level qualitative analysis to identify whether climate change is relevant to the project goals or design. If climate change is relevant to the project goals or designs, the second phase requires an evaluation of information gathered about impacts to the important hydrologic variables and the underlying physical processes such as changes in processes governing rainfall runoff or snowmelt. The information should be used to help identify opportunities to reduce potential vulnerabilities and increase resilience as a part of the project's authorized operations and also identify any caveats or particular issues associated with the data. The information gathered in the second phase can be included either in risk registers or separately in a manner consistent with risk characterization in planning and design studies, depending on the project phase.

The guidance applies to all Civil Works applies to all hydrologic analyses supporting planning and engineering decisions having an extended decision time frame, except for operational hydrologic studies for water management or to dam safety. Changes other than climate threats that affect inland hydrology will continue to be evaluated in the manner described in current USACE guidance.

The ECB was issued by Mr. James Dalton, Chief of the HQUSACE Engineering & Construction Community of Practice and was prepared under the direction of Mr. Jerry Webb, leader of the Hydrologic, Hydraulic & Coastal Engineering Community of Practice. The authors of the bulletin included Dr. David Raff (formerly of USACE IWR, now with the U.S. Bureau of Reclamation), and Dr. Kate White and Dr. Jeff Arnold of USACE IWR.

ENGINEERING AND CONSTRUCTION BULLETIN

US Army Corps of Engineers®

No. 2014-10 **Issuing Office:** CECW-CE **Issued:** 2 May 2014 **Expires:** 2 May 2016

Subject: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects

Applicability: Guidance.

References: Required and related references are provided in Appendix A.

1. Purpose. This ECB provides USACE with initial guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaptation policy. USACE policy requires consideration of climate change in all current and future studies to reduce vulnerabilities and enhance the resilience of our water-resource infrastructure. The guidance in this ECB is also in accordance with the President's Climate Action Plan released in June 2013 and with Executive Order 13653.

2. Objective. The objective of this ECB is to support incorporation of new science and engineering products and other relevant information about specific climate change and associated impacts in hydrologic analyses for new and existing USACE projects to enhance USACE climate preparedness and resilience.

a. This ECB is effective immediately and applies to all hydrologic analyses supporting planning and engineering decisions having an extended decision time frame. However, this guidance does not apply to operational hydrologic studies for water management or to dam safety.

b. Changes other than climate threats that affect inland hydrology will continue to be evaluated in the manner described in current USACE guidance (e.g., Chapter 18, Evaluating Change in EM 1110-2-1417, *Flood-Runoff Analysis*; and EM 1110-2-1413, *Hydrologic Analysis of Interior Areas*).

3. Introduction. USACE projects, programs, missions, and operations have generally proven to be robust enough to accommodate the range of natural climate variability over their operating life spans. Recent scientific evidence shows, however, that in some places and for some impacts relevant to USACE operations, climate change is shifting the climatological baseline about which that natural climate variability occurs, and may be changing the range of that variability as well. This is relevant to USACE because the assumptions of stationary climatic baselines and a fixed range of natural variability as captured in the historical hydrologic record may no longer be appropriate for long-term projections of the climatologic parameters, which are important in hydrologic assessments for inland watersheds. However, projections of the specific climate changes and associated impacts to local-scale project hydrology that may occur far in the future due to changing baselines and ranges of variability as reported in the recent literature are uncertain enough to require guidance on their interpretation and use. This ECB helps support the interpretation and use of climate change information for hydrologic analyses supporting planning and engineering decisions in three specific areas:

a. A qualitative assessment of potential climate change threats and impacts potentially relevant to the particular USACE hydrologic analysis being performed.

b. Resources to support the qualitative assessment of climate threats and impacts specific to those analyses.

c. An early overview of future planned guidance for additional quantitative assessments of potential climate change threats and impacts for use in future hydrologic analyses.

4. Incorporating Climate Change and Variability in Hydrologic Analyses.

a. Climate change information for hydrologic analyses includes direct changes to hydrology through changes in temperature, precipitation, and other climate variables, as well as subsequent basin responses such as sedimentation loadings potentially altered by changes in those primary climate drivers. The qualitative analysis required by this ECB includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant hydrologic inputs. The results of this qualitative analysis can indicate the direction of change but not necessarily the magnitude of that change. For this reason, the qualitative analysis does not alter the numerical results of the calculations made for the other, non-climate aspects of the required hydrologic analyses. However, the climate change information synthesized and evaluated during the qualitative analysis can inform the decision process related to future without project conditions, formulation and evaluation of the performance of alternative plans, or other decisions related to project planning, engineering, operation, and maintenance.

b. The qualitative analysis is the only approach currently required for hydrologic studies for inland watersheds at the time of issuance of this ECB.

c. The qualitative analysis will be required for projects except for the following cases:

(1) Feasibility Phase: The Tentatively Selected Plan (TSP) milestone has been completed as of the date of issuance of this ECB.

(2) Preconstruction Engineering and Design (PED): The required hydrology and hydraulics components of the PED phase are more than 50% complete, as of the date of issuance of this ECB.

d. A first-order statistical analysis of the potential impacts to particular hydrologic elements of the study can be included as supplemental input to this qualitative assessment, but is not required.

e. Appendix B provides a flow chart of the guidance provided in this ECB.

f. Appendix C provides detailed guidance on how to perform the qualitative analysis, as well as an example with a first-order statistical analysis.

5. Future Expansion of Support Documents for Implementation of this ECB. A series of guidance documents will be published in the future to support quantitative analyses of climate threats and impacts to specific project types. Appendix D provides a preview of planned future quantitative guidance.

6. HQUSACE POC. The HQUSACE POC for this action is Mr. Jerry Webb, Leader of the Hydrology, Hydraulics, and Coastal Community of Practice, 202-761-0673.

//S//

Encls

JAMES C. DALTON, P.E., SES
Chief, Engineering and Construction
U.S. Army Corps of Engineers

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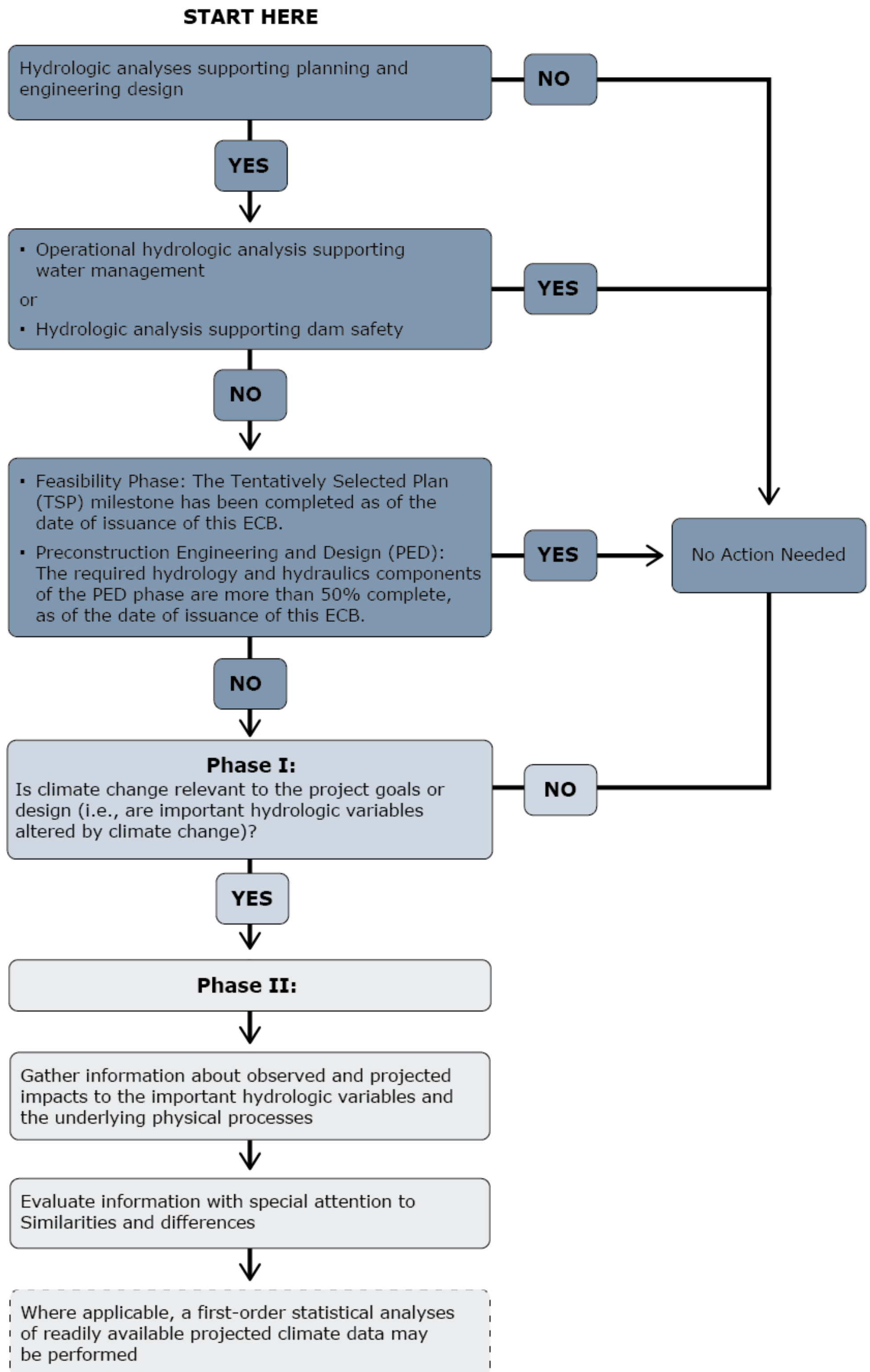
Appendix B: Flow Chart



Appendix C: Qualitative Analysis Requirements and Example.

1. Qualitative Climate Change Analysis for Hydrologic Analyses in Planning and Engineering Design Studies. The goal of a qualitative analysis of potential climate threats and impacts to USACE hydrology-related projects and operations is to describe the observed present and possible future climate threats, vulnerabilities, and impacts specific to the study goals or engineering designs. The qualitative approach on its own will not produce binding numerical outputs, but it can identify the direction of change where change is detected in climate variables relevant to elements of the hydrology study. In some cases, it may be possible to calculate an order of magnitude range of the relevant climate threats and impacts that can be considered in the context of project goals or design vulnerabilities and impacts. This, in turn, can be used to describe future without project conditions or inform decisions during the alternative formulation and selection phase, when one project alternative can be judged to reduce vulnerabilities or enhance resilience more than the others. The qualitative analysis is intended to answer a linked series of questions related to key decision components:

a. Is climate change is relevant to the project (Phase I)?

b. If yes, what is the direction of the potential climate change in the variables that may affect the hydrology of the project, and potentially impact project goals and designs (Phase II)?

2. Qualitative Analysis Framework.

a. To improve preparedness and resilience to climate change threats, USACE requires actionable science and strategies supporting informed decision-making in studies, designs, projects, and groups of projects. The certainty and applicability of the available science on climate change and hydrology that is ready for consideration in decisions varies strongly with location and spatial scale. The important consideration here is selecting information for the qualitative analysis at the appropriate scale of the study. This does not mean that the broad, global or continental-scale analyses presented with substantial expert agreement and explicit confidence estimates such as those presented in the Intergovernmental Panel on Climate Change (IPCC) synthesis documents (e.g., IPCC 2007) are not useful at the scale of USACE projects, nor that the changes in current climate and hydrologic responses observed and measured at very fine scales like those of the the Sacramento–San Joaquin [Vanrheenen et al. 2004], Upper Mississippi [Jha et al. 2006], Florida Everglades [Sklar et al. 2001], or Hudson, James, and Ungava Bays [Déry et al. 2005] cannot be used for this analysis. Rather, a successful qualitative analysis will combine the most useful information for the decisions in the hydrology study it is supporting from a range of sources, noting the differences in information types – projections and observations, e.g. – and the differences in uncertainty or confidence in the data and information deployed for the analysis.

b. The current state of actionable climate science, regardless of its scale of analysis, results in large uncertainties about projected future conditions relevant to USACE projects and programs. In some cases, these uncertainties may be comparable in scale to existing sources of uncertainty, such as future changes in land use and land cover, though the climate-related uncertainties can also be larger or smaller than the ones more often considered in hydrologic analyses previously. Uncertainties are different for different climate variables and in different locations and these differences should be noted in the qualitative assessment. But the climate uncertainties must be put into context with the other uncertainties relevant to the hydrologic analysis.

c. The framework of the qualitative analysis has two phases:

(1) Phase I. An initial screening-level qualitative analysis will be completed to identify whether climate change is relevant to the project goals or design in accordance with SMART Planning (i.e., are important hydrologic variables altered by climate change).

(2) Phase II. If climate change is relevant to the project goals or designs, an evaluation is made of information gathered about impacts to the important hydrologic variables and the underlying physical processes such as changes in processes governing rainfall runoff or snowmelt. The information should be used to help identify opportunities to reduce potential vulnerabilities and increase resilience as a part of the project's authorized operations and also identify any caveats or particular issues associated with the data (e.g., different literature sources may project different outcomes). The information gathered in Phase II can be included either in risk registers or separately in a manner consistent with risk characterization in planning and design studies, depending on the project phase.

3. Information Included in Phase II Qualitative Analysis. Information to support the qualitative assessment will be compiled from available, established, and reputable, scientific and engineering research literature. Where non-peer-reviewed literature is used, the assessment must include justification for its use and its peer-review equivalence. Examples of sources of peer-reviewed information on which the qualitative analyses can draw include the West-Wide Climate Risk Assessments and Basin-Wide Studies prepared by the Bureau of Reclamation (see http://www.usbr.gov/WaterSMART/wcra/), the relevant regional and sector information in the US Global Research Program's Third National Climate Assessment (see http://www.globalchange.gov/what-we-do/assessment) and subsequent updates, reports prepared for USACE climate change adaptation pilots, and reputable and peer-reviewed journal papers describing regional climate impacts to water resources. Regional synthesis information on either observations of change or projections of future change can be supplemented by additional information as described below where available.

a. Regional and Watershed Synthesis Information.

(1) Regionalized scenarios of possible future climate, as well as historic trends, are available in the National Oceanic and Atmospheric Administration (NOAA)'s Technical Report NESDIS 142, *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment* (NOAA 2013). The report has sections for eight regions of the U.S., including for Alaska and for the Pacific Islands, and a ninth section for the contiguous U.S. as a whole.

(2) Regional and sector-specific information for the United States can be obtained from the United States Global Change Research Program (USGCRP, www.globalchange.gov) and specifically the Third National Climate Assessment (NCA) released in 2014 (http://ncadac.globalchange.gov), as well as the various technical support documents to the National Climate Assessment (http://www.globalchange.gov/what-we-do/assessment/nca-activities/available-technical-inputs).

(3) Regional synthesis information for the western United States can be obtained from the Department of the Interior, Bureau of Reclamation's *Literature Synthesis on Climate Change Implications for Water and Environmental Resources* (Bureau of Reclamation 2011a)

(4) The USACE is currently in the process of developing regional climate change literature syntheses at the two-digit Hydrologic Unit Code (HUC2) scale.

(5) Other sources of peer-reviewed information that are available at regional or local scales should be explored and included if appropriate to the particular scales and variables of the hydrologic study.

b. Hydrologic simulations using the bias-corrected, spatially disaggregated (BCSD) archive and the Variable Infiltration Capacity (VIC) hydrologic model are appropriate and available through http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html. These data were produced by USACE in conjunction with Lawrence Livermore National Laboratory, the Bureau of Reclamation, the U.S. Geological Survey, Climate Central, Scripps Oceanographic Institute, and Santa Clara University as described at the online archive.

c. Hydrologic information developed for the USACE screening-level watershed-scale vulnerability assessments at the HUC-4 scale.

d. If available in the region, other USACE analyses that include climate change information can also be used. For example, USACE climate change adaptation pilots may have developed regional to local information that addresses climate change hazards or vulnerabilities.

4. Evaluation of Phase II Information. A robust evaluation of available information encompasses present patterns of climate change as well as future projected climate changes expected to impact watershed hydrology in the project region.

a. The literature evaluation should include a description of each source along with:

(1) The length and quality of the observed record;

(2) Any statistically significant trends in the observed record for the hydrologic variables of interest or underlying physical processes;

(3) The type and quality of the projected climate information related to the hydrologic variables of interest or underlying physical processes;

(4) The direction and (if available) magnitude of the projected relevant changes, as well as any projected trends.

b. Similarities and differences in the literature should be noted, with a discussion about how these might be considered in project planning and design. In cases where information from the literature conflicts, these results could be considered to provide a range of potential future conditions without assigning weights or expected probabilities to those potential futures. It is important that the qualitative analyses do not inject false precision by prematurely down-selecting to a limited set of the available projected future conditions.

c. Where applicable, a first-order statistical analyses of readily available projected climate data may be performed using standard statistical methods to characterize the data and identify trends for variables relevant and at a scale appropriate to the hydrologic study.

5. <u>Example Qualitative Analysis</u>. The example qualitative analysis is for a Flood Risk Management project in northeastern Kansas, in HUC 1027 (Kansas: The Kansas River Basin, excluding the Republican and Smoky Hill River Basins. Kansas, Nebraska, Missouri).

a. Project Description. A system of levees currently in place is being studied for possible modifications to achieve additional project goals for flood risk reduction. The no-action alternative is to maintain the levee system as it currently exists. A study is being conducted to evaluate the feasibility of raising levee heights at certain locations to provide additional flood risk reduction. The hydrologic analysis is directed at updating estimates of flood frequency. The existing flood frequency information was last investigated for a period of record ending in the 1960s. Since that time, several floods have occurred, including the 1993 flood of record. Increases in projected future flood magnitude and frequency could impact both the future with- and without-project conditions, and may result in different benefits compared to the without-climate change analysis. Increases in future flood magnitude or frequency could also alter project performance, including increased maintenance costs or repairs associated with overtopping events that are potentially more frequent than originally assumed.

b. Phase I Qualitative Assessment. The flood reduction project is intended to reduce damage associated with flood events in northeastern Kansas in the vicinity of the Big Blue River. Any future conditions which increase the magnitude or frequency of flood flows would impact the project. Therefore, climate change is a consideration for this project.

c. Phase II Identification of Climate Threats and Impacts.

(1) Observed Record. For the period of record from 22 July 1959 through 21 January 2010, daily observations of discharge for inflow at the project site were analyzed in two ways. The first method involved performing a linear regression of the annual maximum daily discharge from the record to determine if there is a statistically significant slope (Figure C-1). Simple linear regression with test statistics can be performed using the method of least squared errors in a variety of software programs, including Microsoft Excel's "Analysis Toolpack" -

"Regression" macro. The second method involves performing a linear regression of the largest annual three-day maximum discharge to determine if there is a statistically significant slope (Figure C-2). Both analyses resulted in a relatively small but statistically significant trend at the $p<0.05$ level towards smaller annual maximum daily discharges and smaller annual maximum three-day average discharges.

(2) Projected Future. The NOAA National Environmental Satellite, Data and Information Service (NESDIS) released a report in January 2013 that assessed climate trends and scenarios into the next 50–100 years for the Great Plains region (NOAA 2013). The report indicates that over the period of hydroclimatological record for northeast Kansas, both temperature and precipitation have trended above normal, especially over the last 50 years. To account for climate change, the forecast of future meteorological conditions in the region considers the past temperature and precipitation records, as well as the modeled future conditions in the area through 2070. According to the NESDIS report, a warming trend of about 3–5°F and a precipitation trend toward slightly wetter conditions can be expected over the next 50 years, although these estimates have significant uncertainty. Numerous reputable and peer-reviewed climate change syntheses, including Kunkel et al. (2013), suggest that a warming climate can increase the risk of very heavy precipitation and flooding. The USACE screening-level watershed vulnerability assessment for HUC 1027 showed that this watershed is in the 20% most vulnerable for the flood risk reduction business line for the wet scenarios, primarily due to the cumulative flood magnification factor (FMF, Vogel et al 2011). The cumulative and local FMF computed for the watershed (as of March 2014) are greater than 1.0 for both wet and dry future conditions (i.e., flood magnitudes are expected to increase in the future).

(3) An additional analysis was performed to provide first-order detection of any changes in floods for both the observed record and the projected future based on bias-corrected and spatially downscaled data from simulations developed for the Coupled Model Intercomparison Project Phase 5 (CMIP5) data, with hydrologic response simulated by the Variable Infiltration Capacity (VIC) model (Liang et al. 1994) at http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html

(i) The first-order statistical analysis for the 100 simulations for 1950 to 1999 indicates no statistically significant linear trend for potential realizations of runoff for the 20th century (Figure C-3). Note that this is simply a review of modeled conditions and does not use actual measurements for that time period. The actual measurements are shown in Figure C-1.

(ii) A statistical analysis of the projected hydrology for 2000 to 2099 indicates a statistically significant linear trend of increasing average annual maximum monthly flows (Figure C-4). This trend is consistent with the literature, which indicates that floods may increase in this area in future.

d. Conclusion of Phase II Evaluation: Although the observed trend indicates a slight decrease in runoff for the period of record at the example location, the literature consistently projects a trend toward increasing runoff. The USACE screening-level watershed vulnerability assessment indicates that the FMF is slightly greater than 1.0 even in a drier future. The first-order analysis of projected future conditions indicates that climate change in the next 50 years may increase flood flow frequency in the study basin. Based on the assessment, which shows differing but relatively small signals, the recommendation is to treat the potential increases in flood magnitude as occurring within the uncertainty range calculated for the current hydrologic analysis.

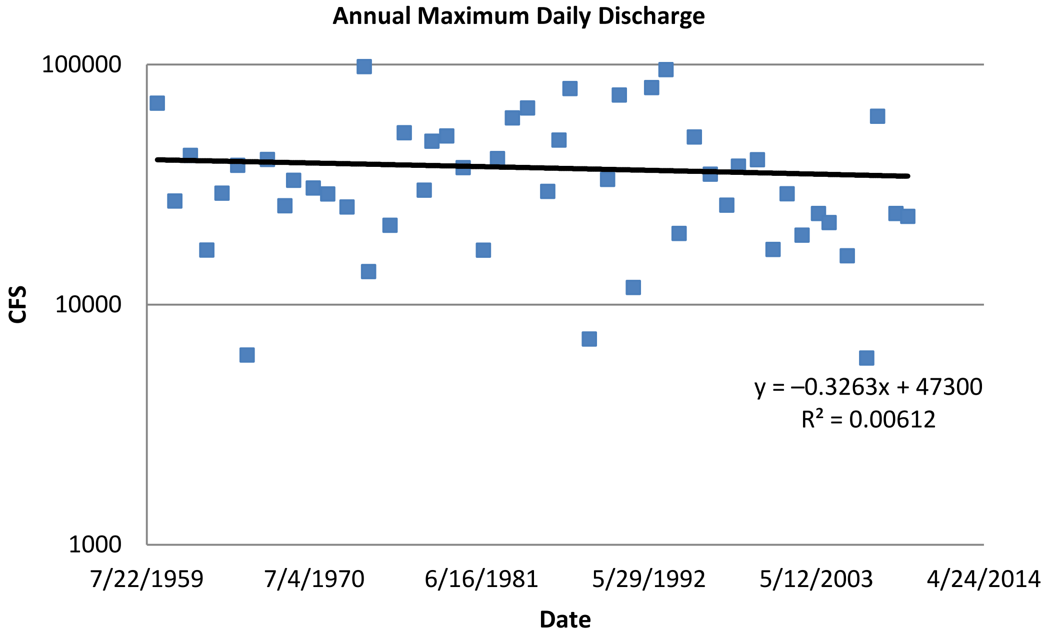


Figure C-1. First-order trend detection for observed annual maximum daily inflows in the example region of northeastern Kansas. A negative slope is determined to be statistically significant at the $p<0.05$ level.

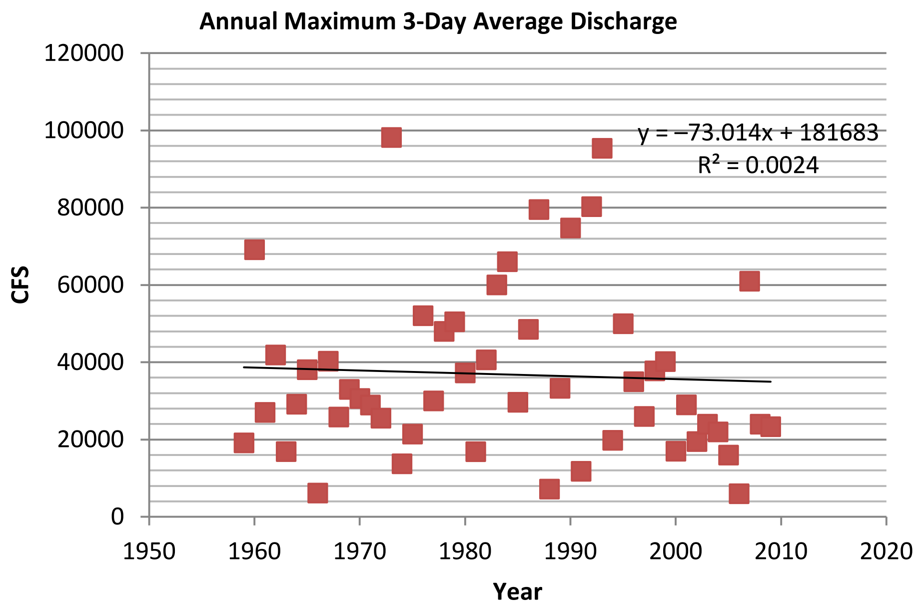


Figure C-2. First-order trend detection on observed annual three-day maximum daily inflows in the example region of northeastern Kansas. A negative slope is determined to be statistically significant at the $p<0.05$ level.

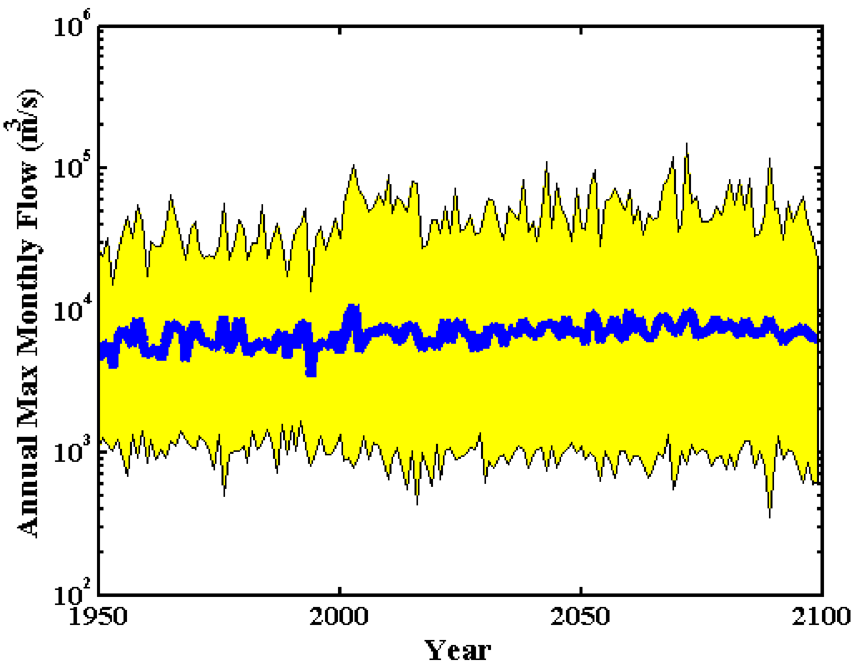


Figure C-3. Projections of climate-changed hydrology for HUC 4 1027. The mean of 100 projections of annual maximum monthly flow is in blue and the range of those 100 projections is in yellow.

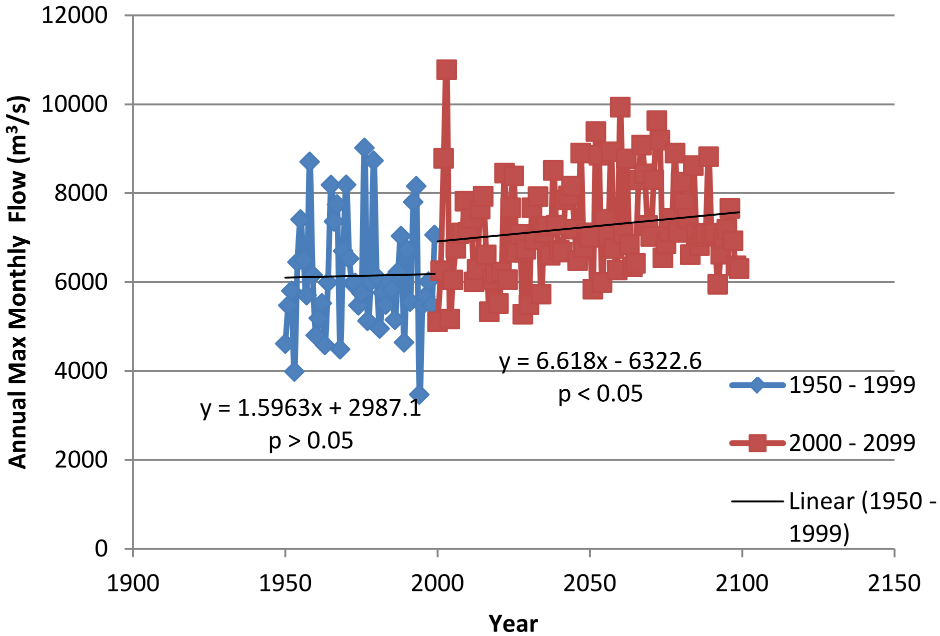


Figure C-4. Statistical analysis of the mean of the annual maximum monthly flow projections. The 1950–1999 period has no statistically significant trend, but the trend for 2000–2100 is statistically significant at the p<0.05 level.

Appendix D: Preview of Quantitative Analysis Requirements.

1. Quantitative Climate Change Analysis for Hydrologic Analyses in Planning and Engineering Design Studies. Quantitative assessments are necessarily project-specific and will be conducted explicitly for impacts to the authorized purposes of the project. The outputs from a quantitative analysis can directly alter the numerical calculations and results in the hydrologic analysis. The amount of alteration is determined by the amount of evidence indicating that climate change is affecting the hydrologic metric of interest in the present and future. These changes to numerical results can alter calculations of project benefits and costs, thus directly informing the decision process. The quantitative assessment to be required in future will require different processes for uncertainty assessment. These will be described in future additions to this guidance along with new information for considering those climate-related uncertainties in the context of other uncertainties associated with the hydrologic estimates under future conditions.

a. Specific guidance for implementing quantitative analyses will be provided as methods are developed. This guidance will be developed based on project type (e.g., Flood Risk Management, Navigation, Water Management, Levee Safety). Once additional guidance is provided for specific project types, a quantitative analysis will be required in addition to the qualitative analysis when at least one of the following is true:

(1) The qualitative analysis indicates an expectation that consideration of climate change will alter hydrologic analyses and potentially affect the decision outcome, OR

(2) Feasibility Phase: The TSP milestone has not yet been completed, OR

(3) PED Phase: The required hydrology and hydraulics components of the PED phase are less than 50% complete, as of the date of issuance of project-type quantitative guidance ECs.

b. The three primary components of any future quantitative guidance will be detection of trends, attribution of these trends to climate change, and projection of future trends.

(1) Detection. The first step in a quantitative analysis is to attempt to detect changes in the observed hydrologic record for the metric relevant to the study, such as increases or decreases in variability or magnitude (see Kundzewicz and Robson (2000) for examples). If no change is detected, no further quantitative analysis will be necessary. USACE is developing information and inputs to forthcoming guidance which will support methods of detection to be required in the quantitative analyses at a later date. This information will be distributed together with the future guidance requirements as described above.

(2) Attribution. If a change is detected through statistical analysis, the next step is to attempt to attribute the change to one or more causes, primarily by evaluating additional information about changes in the watershed, searching the supporting literature, and in some cases using results from experiments with numerical climate simulation models already performed – no new numerical climate simulations will be required. Hegerl and Zwiers (2011)

provide a review of possible attribution strategies and discuss the difficulties in attributing changes using only observational data. As with the detection methods, for attribution, USACE is developing information to support its application in the quantitative analyses to be required in future. This information will be distributed together with the future guidance requirements as described above.

(3) Projection. Finally, projected hydrologic changes are analyzed. Climate projections such as those available at http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/ can be used in concert with hydrologic simulation tools to obtain projections of specific hydrologic variables. Well-documented and peer-reviewed models have been applied to assess climate change impacts in many locations and at many scales in the US. These applications include use of HEC-HMS, the Variable Infiltration Capacity Model (VIC) (Christensen et al. 2004; Payne et al. 2004; Christensen and Lettenmaier 2007; Maurer 2007; Barnett et al. 2008; McGuire and Hamlet 2010; Bureau of Reclamation 2011b), the Sacramento Model (SAC-SMA) (Brekke et al. 2009; Raff et al. 2009; Maurer et al. 2010), and others.