Climate Risks in America:
Process and Findings from the Fourth National Climate Assessment

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NASA CMS PSS
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U.S. Global Change Research Program

Outline

1. Background and Development of the Fourth National Climate Assessment (NCA4)
2. Overview of Findings
3. Some Topics of Relevance to the CMS Community
4. Regional Information
5. Additional Efforts & Next Steps

U.S. Global Change Research Program

- USGCRP began as a Presidential initiative in 1989
- Mandated by Congress in the U.S. Global Change Research Act (GCRA) of 1990 "to assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change"
- Overseen by Principals representing the 13 member agencies of the Committee on Environment's Subcommittee on Global Change Research (SGCR)

Legislative Origins for the NCA

Global Change Research Act of 1990, Section 106:

Not less frequently than every 4 years [USGCRP] shall prepare and submit to the President and Congress an assessment which:

- Integrates, evaluates, and interprets the findings of [USGCRP] and discusses the scientific uncertainties associated with such findings
- Analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity
- Analyzes current trends in global change, both human- induced and natural, and projects major trends for the subsequent 25 to 100 years.

NCA4: a two-volume effort

Congressional Mandate	Fourth National Climate Assessment (NCA4)	
	Vol I: Climate Science Special Report	Vol II: Impacts, Risks, and Adaptation in the U.S.
Integrates, evaluates, and interprets the findings of the Program (USGCRP) and discusses the scientific uncertainties associated with such findings	✓	✓
Analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity	✓	✓
Analyzes current trends in global change, both human- induced and natural, and projects major trends for the subsequent 25 to 100 years.	✓	✓

NCA4 Vol I:
Climate Science Special Report

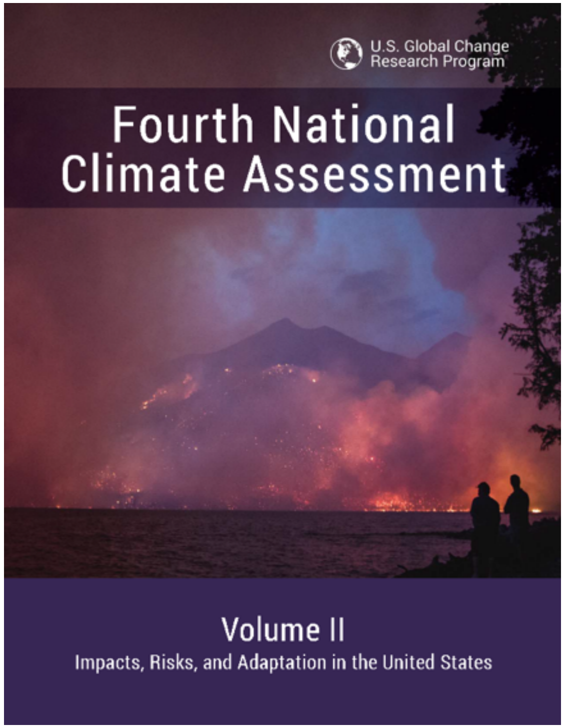
- Released Nov 3, 2017
- Key advances:
  - Detection and attribution
  - Extreme events (tropical cyclones, tornadoes, atmospheric rivers)
  - Downscaled information (including sea level rise)
  - Potential surprises
  - Climate model weighting
- Summarized in Ch. 2 (Our Changing Climate) of NCA4 Vol II

➢ Several chapters of relevance to CMS community (Ch. 2, 8, 10, 13, 14…)

Read and download the report at
science2017.globalchange.gov

NCA4 Vol II:
Impacts, Risks, & Adaptation in the U.S.

- Released Nov 23, 2018
- **Policy relevant**, but not policy prescriptive
- Assesses a **range of potential impacts**, helping decision makers better identify risks that could be avoided or reduced
- Places a strong emphasis on **regional information**
- Quantifies **impacts in economic** terms
- Integrates **international** considerations
- Uses **case studies** to provide additional context and to showcase community success stories



Read and download the report at **nca2018.globalchange.gov**

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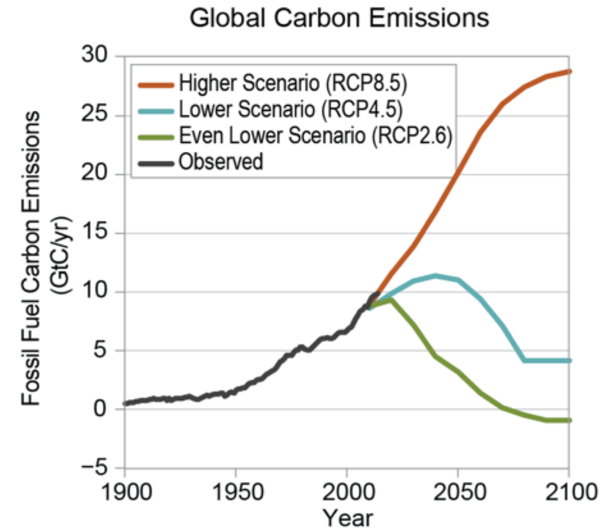
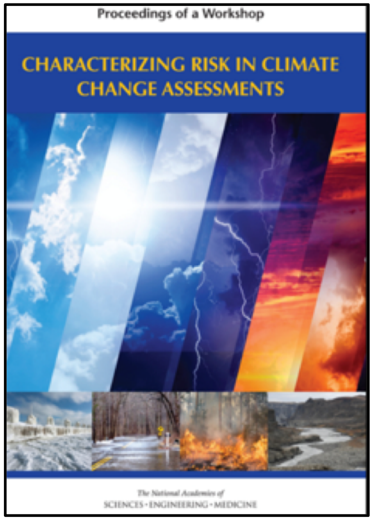
2. Overview of Findings

Risk Framing in Key Messages

- A **"risk-based framing"** is used to ensure NCA4 focuses on issues of high importance to decision-making and to help with communicating assessment outcomes
- In response to user needs and with guidance from a workshop of the National Academies, NCA4 Key Messages addressed:
  - ✓ What do stakeholders value/what is at risk in a given sector or region?
  - ✓ What outcomes do we wish to avoid with respect to these valued things?
  - ✓ What do we expect to happen in the absence of adaptive action and/or mitigation?
  - ✓ How bad could things plausibly get/are there important thresholds or tipping points in the unique context of a given region, sector, etc.?

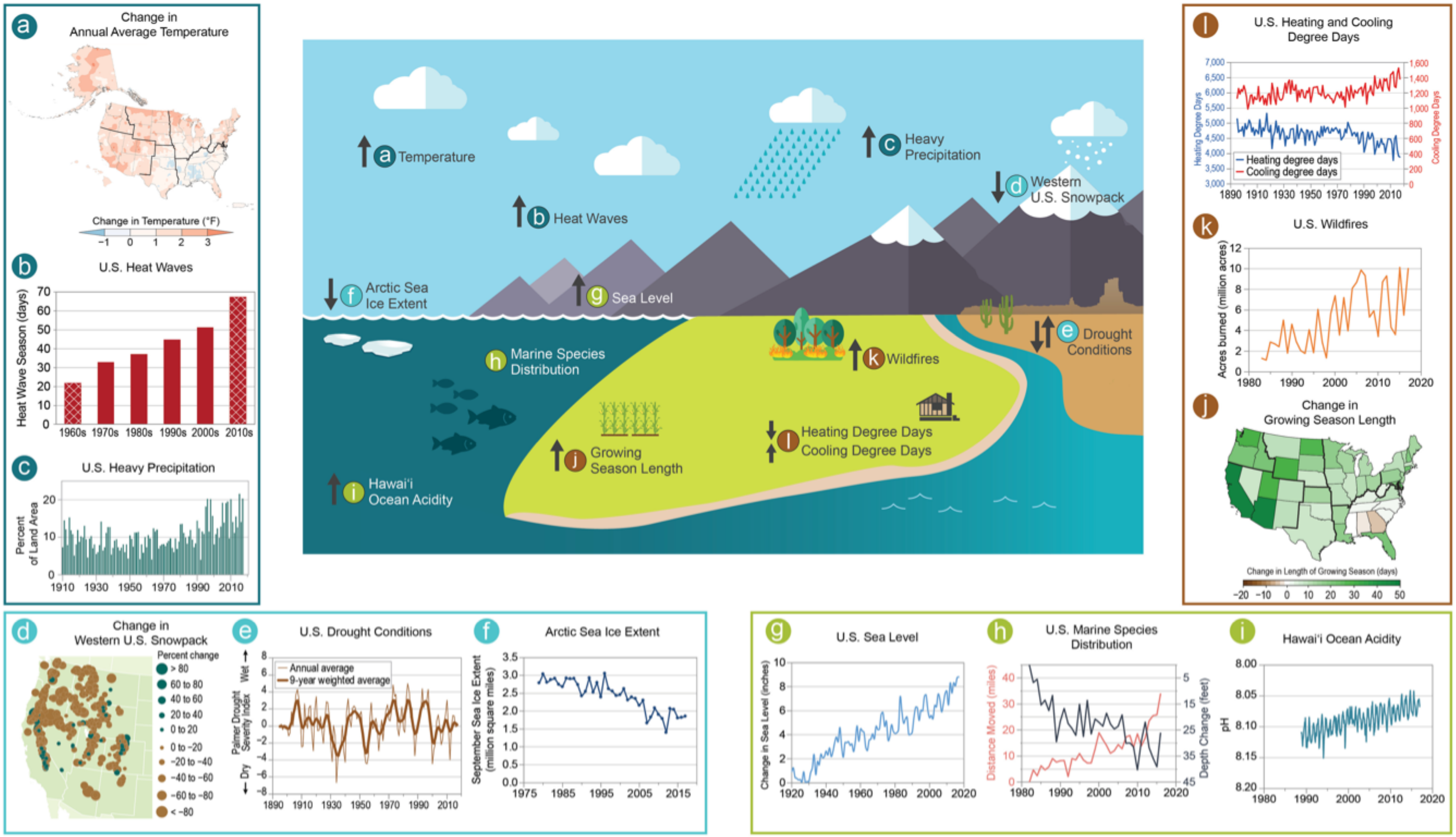




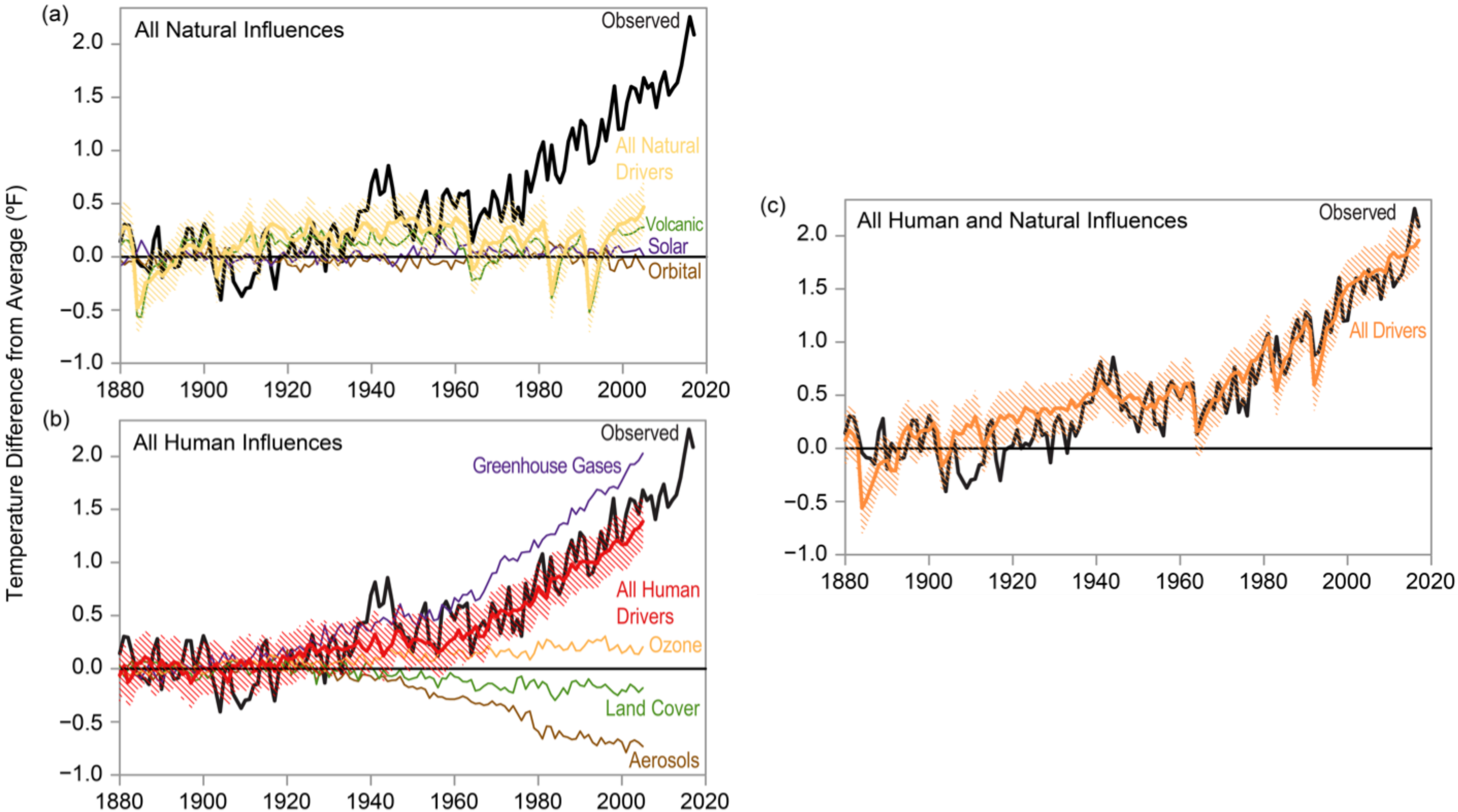
NCA4 Volume II in 5 Bullets

- Earth's **climate is now changing faster** than at any point in modern civilization.
- These changes are primarily the **result of human activities**, the evidence of which is overwhelming and continues to strengthen
- The impacts of climate change are **already being felt** across the country, and climate-related **threats** to Americans' physical, social, and economic well-being **are rising**
- **Americans are responding** in ways that can bolster resilience and improve livelihoods
- However**, neither global efforts to mitigate** the causes of climate change **nor regional efforts to adapt** to the impacts **currently approach the scales needed** to avoid substantial damages to the U.S. economy, environment, and human health and well-being over the coming decades

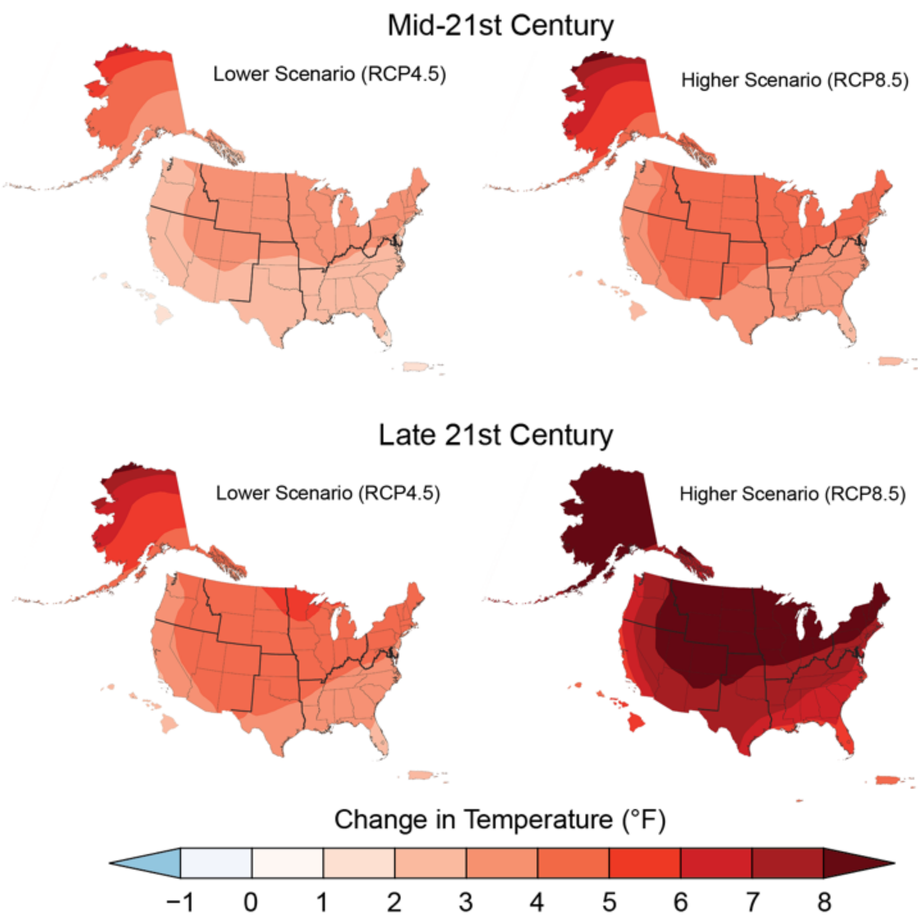
Observed Change

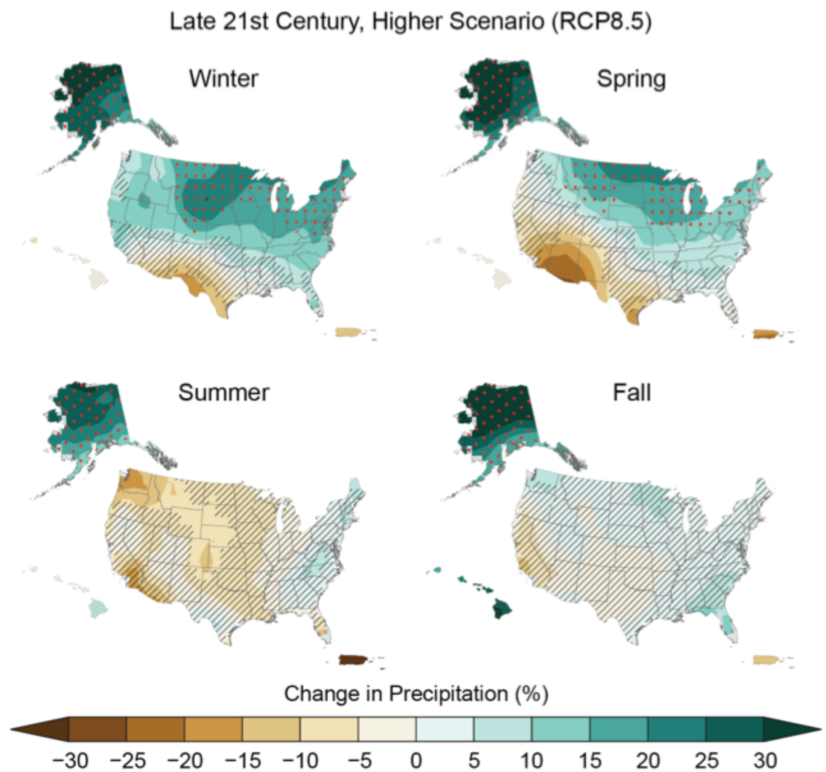


Attribution of Change



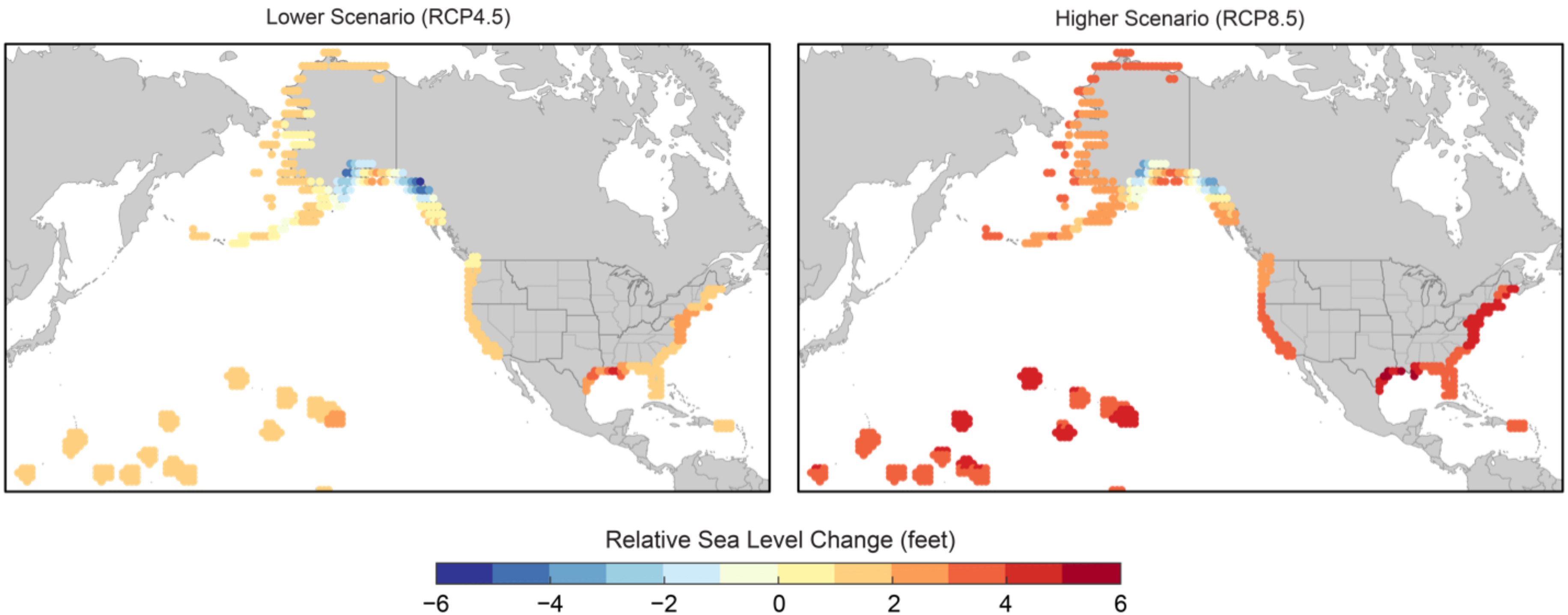
Projected Change:
Temperature & Precipitation





Areas with red dots show where projected changes are large compared to natural variations; areas that are hatched show where changes are small and relatively insignificant.

Projected Change:
Sea Level Rise (in 2100 vs. 2000)



Thermal Expansion + Land-Based Ice Melt + Vertical Land Movement + Ocean Circulation…

USGCRP Scenario Products: scenarios.globalchange.gov/sea-level-rise

NCA4 Vol. I (CSSR), Ch. 12: science2017.globalchange.gov/chapter/12/

Current & Future Risks: *Economy and Infrastructure*

- **Regional natural resource-based economies**
  - Crops, Tourism, Fisheries, Timber
- **Labor productivity in outdoor sectors**
  - Agriculture, Construction
- **Energy supply disruptions**
  - Heat waves, Drought, Extreme events
- **International considerations**
  - Supply chains, Commodity prices
- **Risks to airports, roads, ports, homes**
  - (High-tide) Flooding, Heat-induced buckling, Wildfires

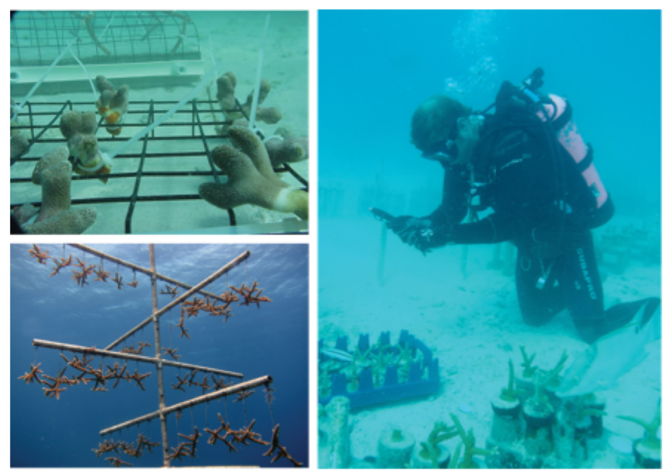
Increasing heavy rains cause more soil erosion and nutrient loss on cropland; integrating native prairie strips can reduce those loses while improving biodiversity.

Floodwaters from the Missouri River surround the Omaha Public Power District's Fort Calhoun Station, a nuclear power plant just north of Omaha, on June 20, 2011.

Current & Future Risks:
Natural Environment and Ecosystem Services

- **Safe and reliable water supplies**
  - ➢ Harmful algal blooms, Drought, Saltwater intrusion, Heavier downpours, Mountain snowpack
- **Protection from flooding and erosion**
  - ➢ Reef death, mangrove shifts
- **Changes in recreation and subsistence activities**
  - ➢ Species shifts, Wildfires, Pest & disease outbreaks, Ocean warming & acidification, Arctic sea ice declines

Razor clamming is a popular recreation activity in the Northwest, but is expected to decline due to ocean acidification, harmful algal blooms, warmer temperatures, and habitat degradation.

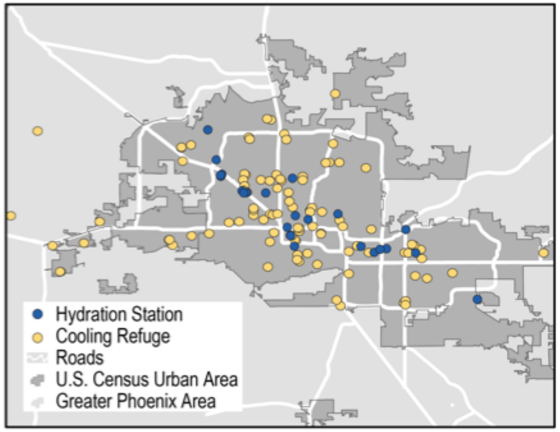


Coral farming (shown here in the U.S. Caribbean and Florida) is a strategy meant to improve the reef community and ecosystem function.

Current & Future Risks:
Human Health and Well-Being

- **Higher temperatures**
  - ➢ Heat exposure
- **Changes in air quality**
  - ➢ Asthma, Cardiovascular effects
- **Changes in extreme events**
  - ➢ Exposures to waterborne, vectorborne, and foodborne diseases
- **Food quality and availability**
  - ➢ Micronutrient levels, drought / flood-induced supply disruptions
- **Mental health**
  - ➢ Forced dislocation or relocation, Loss of traditional practices

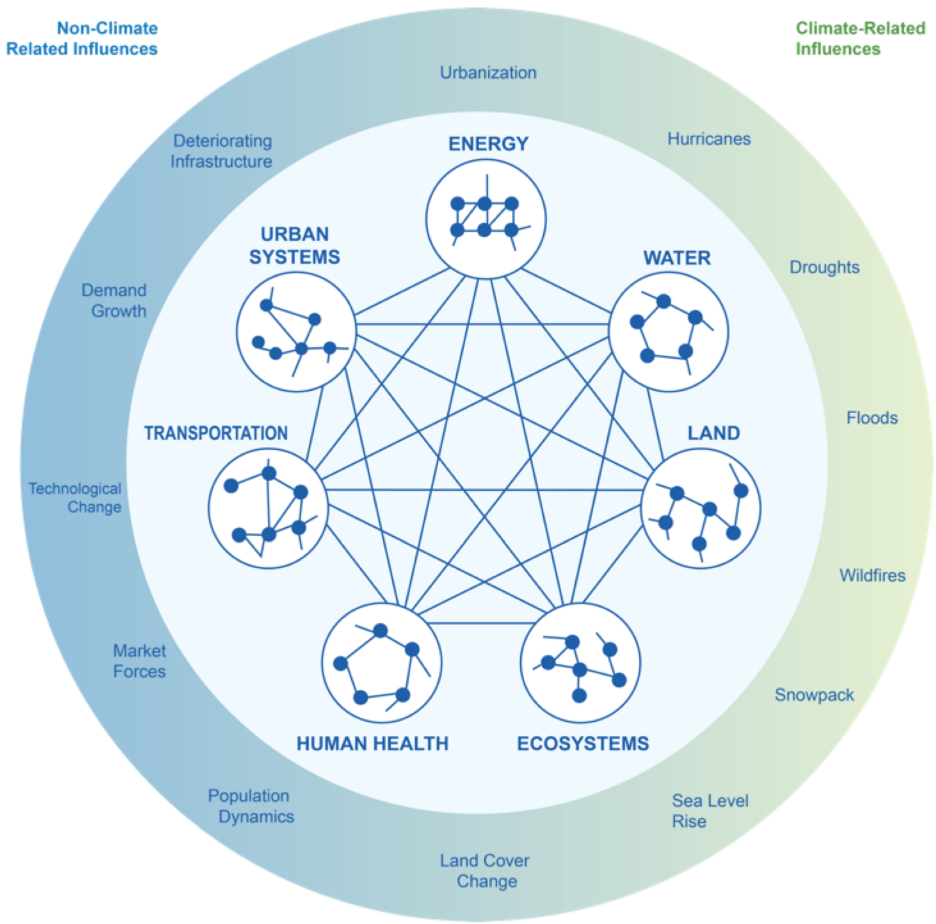
Hydration Stations and Cooling Refuges



Expansion of response measures for high heat events (as shown here in Phoenix) are expected to be needed at greater scales in the coming years.

State, local, and tribal leaders discuss the relocation of the tribal community of Isle de Jean Charles, LA, in response to severe land loss, sea level rise, and coastal flooding.

Interconnected Systems



- Sectors are interacting and interdependent through physical, social, institutional, environmental, and economic linkages.
- These sectors and the interactions among them are affected by a range of climate-related and non-climate influences.

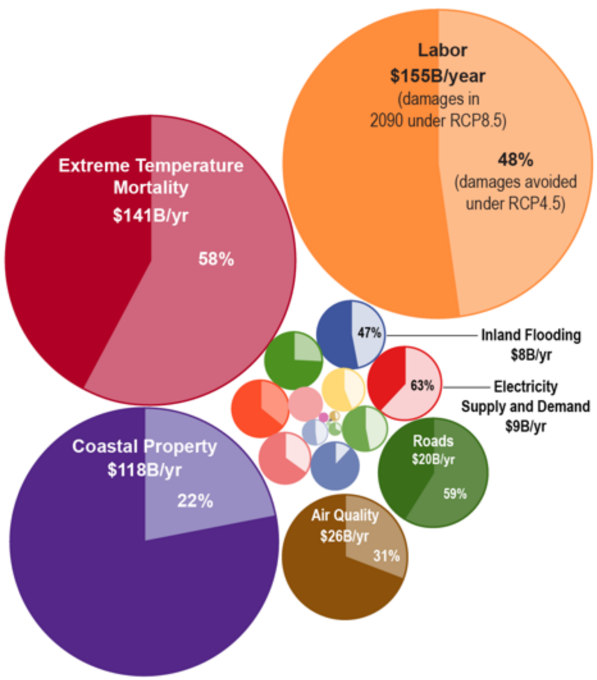
<u>Example</u>

1. Wildfire chars California hillside
2. Atmospheric river dumps heavy rain
3. Rainfall induces a landslide
4. Landslide cuts off roadways
5. Services and economic activity are disrupted

Reducing Risks: *Through Adaptation Action*

- Adaptation is an ongoing, iterative process
- Since NCA3, the scale and scope of adaptation implementation has increased
- Difficult to tally the extent of adaptation implementation (no common reporting systems; actions not labeled as climate adaptation)
- But, we know adaptation implementation is neither uniform nor commonplace across the U.S.

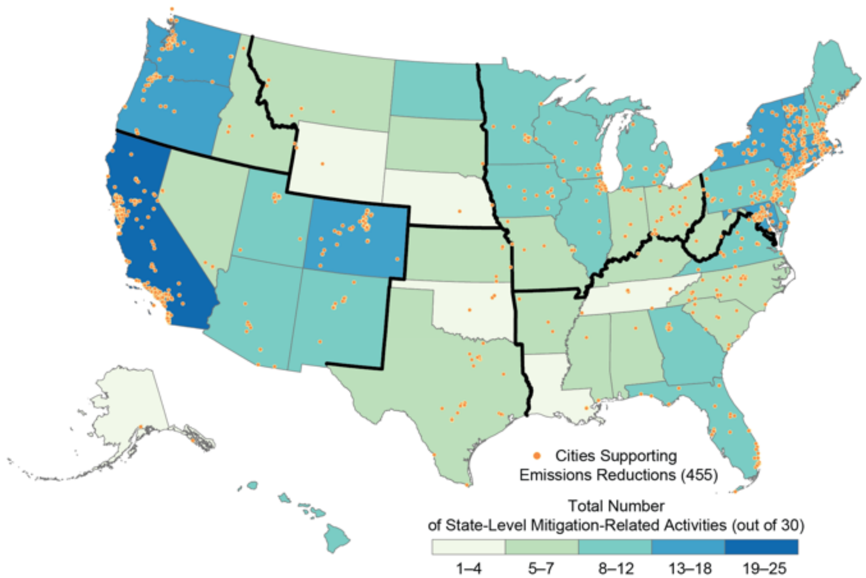
Reducing Risks:
Through Emissions Mitigation



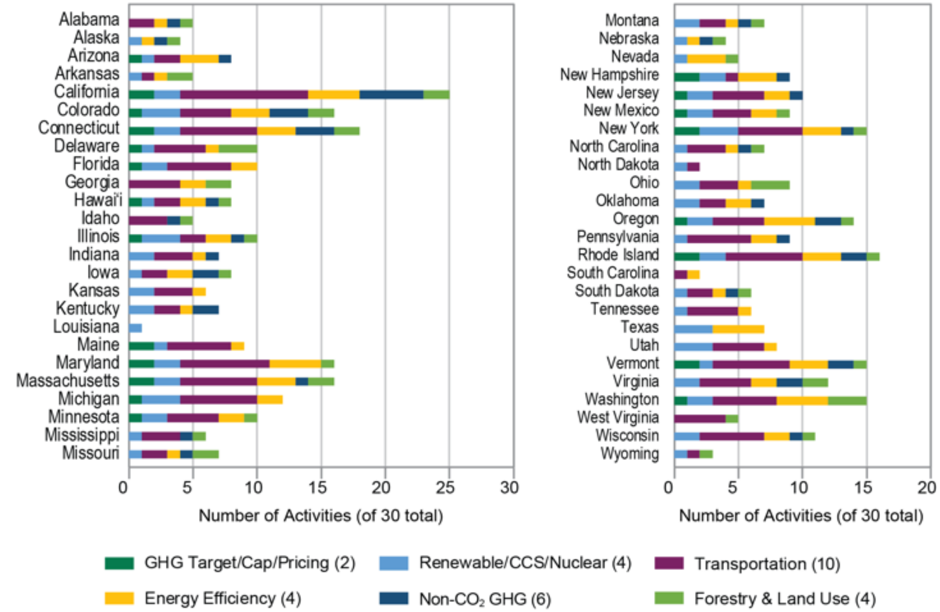
Annual Economic Damages in 2090		
Sector	**Annual damages under RCP8.5**	**Damages avoided under RCP4.5**
Labor	$155B	48%
Extreme Temperature Mortality◊	$141B	58%
Coastal Property◊	$118B	22%
Air Quality	$26B	31%
Roads◊	$20B	59%
Electricity Supply and Demand	$9B	63%
Inland Flooding	$8B	47%
Urban Drainage	$6B	26%
Rail◊	$6B	36%
Water Quality	$5B	35%
Coral Reefs	$4B	12%
West Nile Virus	$3B	47%
Freshwater Fish	$3B	44%
Winter Recreation	$2B	107%
Bridges	$1B	48%
Munic. and Industrial Water Supply	$316M	33%
Harmful Algal Blooms	$199M	45%
Alaska Infrastructure◊	$174M	53%
Shellfish*	$23M	57%
Agriculture*	$12M	11%
Aeroallergens*	$1M	57%
Wildfire	–$106M	–134%

- The total area of each circle represents the projected annual economic damages under a higher warming scenario (RCP8.5) in 2090 relative to a no-change scenario.
- The decrease in damages under a lower warming scenario (RCP4.5) compared to RCP8.5 is shown in the lighter-shaded area of each circle.

Reducing Risks:
Through Emissions Mitigation



Source: EPA



Source: America's Pledge 2017

- Sub-national mitigation-related activities are growing across all sectors of the economy
- The magnitude and rate of these activities (both domestically and abroad) do not yet approach the scale needed to avoid the worst impacts

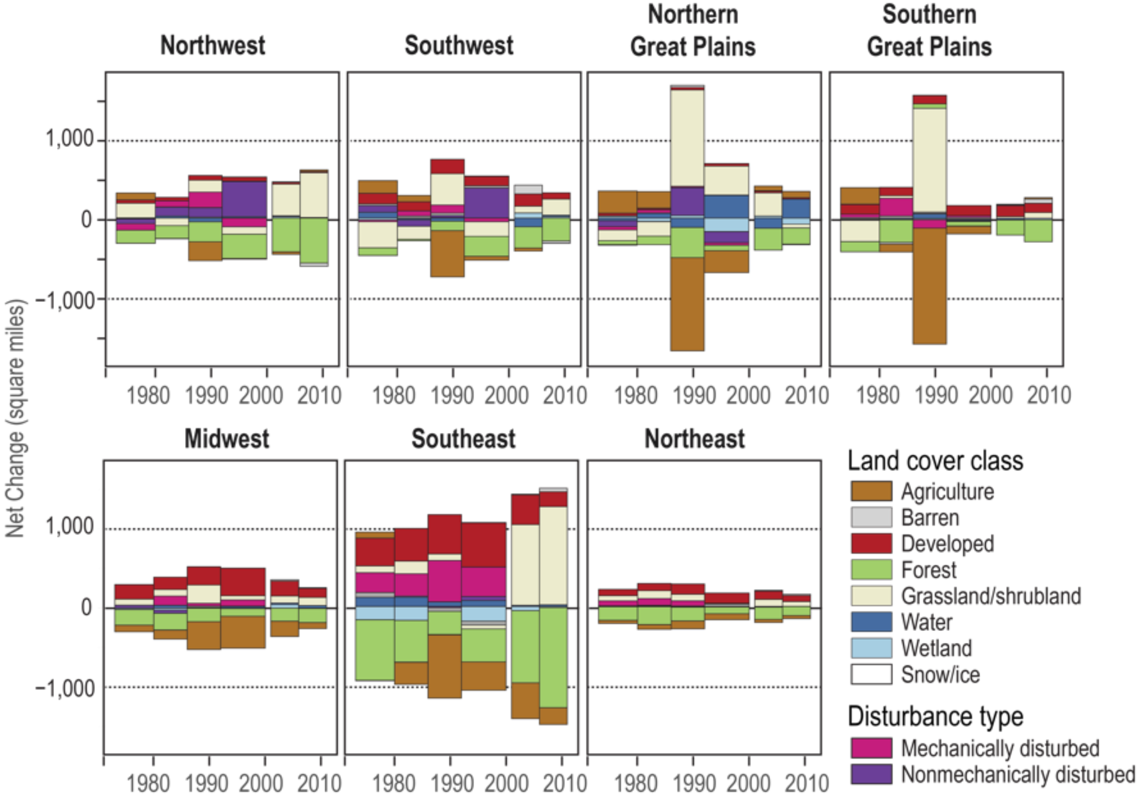
3. Some Topics of Relevance to the CMS Community

Lead Authors / Potential Collaborators

- **Ch. 5: LCLUC** – Tom Loveland and Ben Sleeter (USGS)
- **Ch. 6: Forests** – Dave Peterson and Jim Vose (USFS)
- **Ch. 7: Ecosystems** – Shawn Carter, Madeleine Rubenstein, Sarah Weiskopf (USGS) and Jay Peterson, Doug Lipton (NOAA)
- **Ch. 8: Coastal Effects** – Beth Fleming (USACE), Billy Sweet and Jeff Payne (NOAA)
- **Ch. 9: Oceans & Marine Resources** – Andy Pershing (GMRI), Libby Jewett and Roger Griffis (NOAA)
- **Ch. 10: Agriculture & Rural Communities** – Carolyn Olson (USDA/USGS), Jean Steiner and Prasanna Gowda (USDA)
- **Ch. 11: Built Environment** – Susan Julius and Keely Maxwell (EPA)
- **Ch. 12: Transportation** – Jennifer Jacobs (UNH) and Mike Culp (DOT)
- **Ch. 13: Air Quality** – Chris Nolte (EPA)

Land Cover & Land-Use Change: *Key Messages*

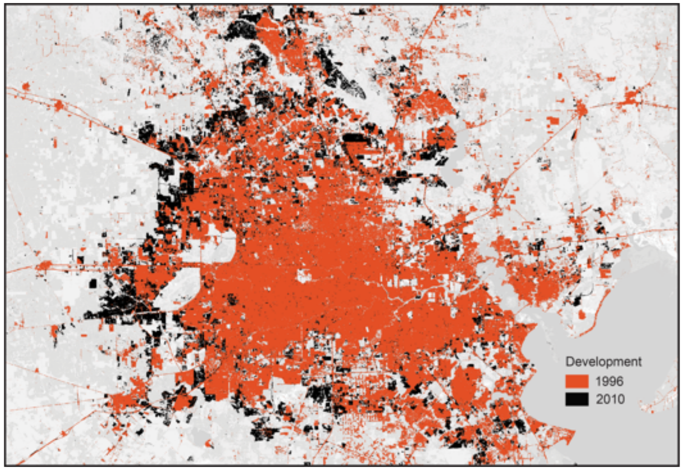
- Land cover change influences weather and climate
- Climate change alters disturbance patterns, species distribution, and the suitability of land for specific uses



Net change in land cover reveals the trajectory of a class over time. A dramatic example is the large decline in agricultural lands in the two Great Plains regions beginning in the mid-1980s, which resulted in large part from the establishment of the Conservation Reserve Program. Over the same period, agriculture also declined in the Southwest region; however, the net decline was largely attributable to prolonged drought conditions, as opposed to changes in federal policy.

Land Cover & Land-Use Change: *Some Remaining Uncertainties*

- Higher confidence in the **role of deforestation as a warming agent** in the U.S. requires more research on how to treat:
  - sensible and latent **heat fluxes** in coupled GCM–LSM models
  - the relationship of **albedo to forest density** in the presence of snow
  - the timing, persistence, and extent of **snow cover**
  - real-world comparisons of the **response of albedo to land-cover change**
- Influence of **urbanization on precipitation** patterns and storm tracks



Development-related changes surrounding Houston, from 1996 to 2010, as mapped by NOAA's Coastal Change and Analysis Program (C-CAP).

Forests: *Key Messages*

- **Extreme events** increase severe ecological disturbances, driving rapid changes in forest structure and function across large landscapes
- Alterations to forest productivity, health, and species distribution are expected over **longer timescales**
- Climate change (i.e., temps, drought, disturbance) will inhibit many forest ecosystems from providing important **ecosystem services** (e.g., tree growth, carbon storage).
- **Management activities** that increase forest resilience of are being implemented, but the future pace of adaptation will depend on how effectively social, organizational, and economic conditions support implementation.

The 2011-16 California drought led to western pine beetle outbreaks, which contributed to the mortality of 129 million trees. As a result, the structure and function of these forests are changing rapidly.

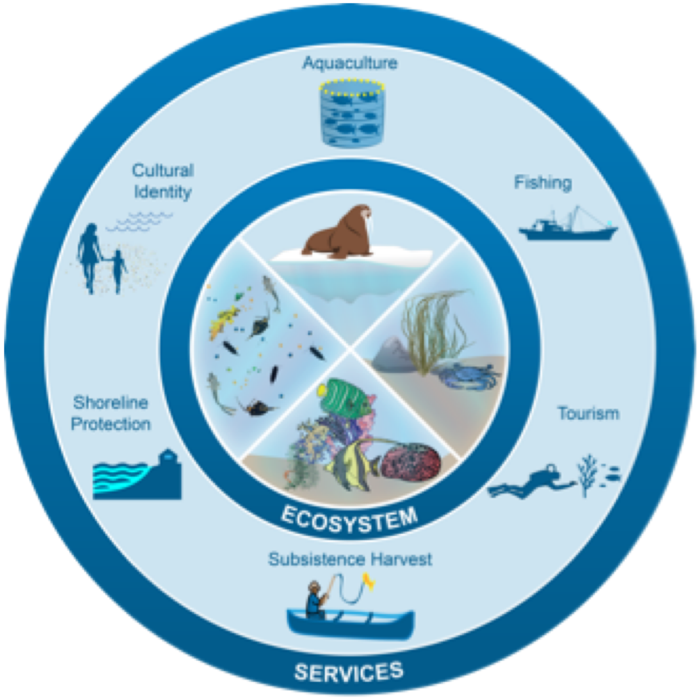
Forests:
Some Remaining Uncertainties

- Wildfire-related information gaps include:
  - **Sub-regional scale projections** of spatial and temporal fire changes
  - effects of long-term thermal changes on most **insect species** and their community associates
  - effects of climate change **on fungal pathogens** is sparse, making projections of forest diseases uncertain
- **Species distribution and abundance** are likely to change in a warmer climate, but magnitude, geographic specificity, and rate of future changes are uncertain

In autumn 2016, a prolonged dry period and arson in the southern Appalachian region resulted in 50 major wildfires. If drought or prolonged dry periods increase in this region as expected, fire risk will increase in both forests and local communities.

Oceans & Marine Resources: *Key Messages*

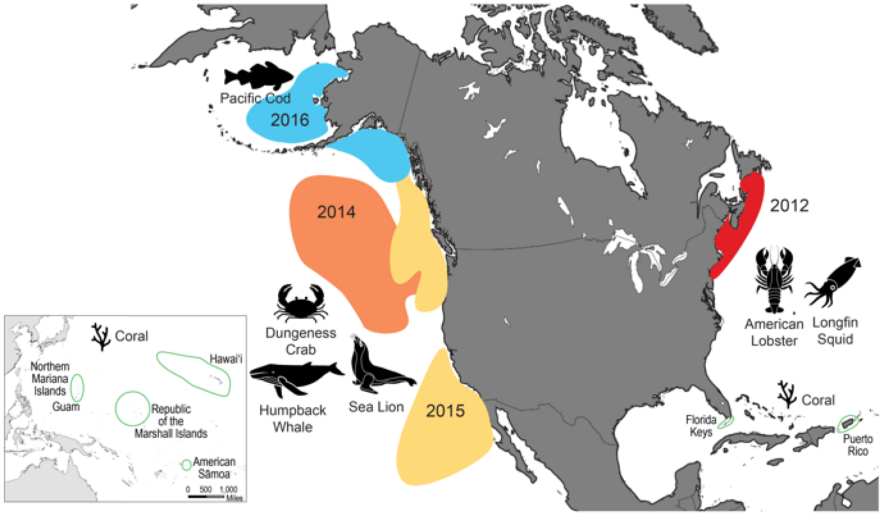
- Ocean ecosystems are increasingly being disrupted by **warming, acidification, and deoxygenation**
- Marine **fisheries and communities reliant on them are at risk** from climate-driven changes in the distribution, timing, and productivity of fishery-related species, **challenging effective management** of fisheries and protected species
- **Extreme maritime events** are projected to become more common and severe, exposing vulnerabilities that **can motivate change**, including technological innovations to detect, forecast, and mitigate adverse conditions



Marine ecosystems (center) and the services they provide to human communities

Oceans & Marine Resources: *Some Remaining Uncertainties*

- Species' adaptive capacity and whether the **rate of adaptation** is fast enough to keep up with unprecedented rates of change to the environment
- **Interacting stressors** of warming, acidification, and deoxygenation on marine ecosystems
  - **Scaling of results** from individual to population or community levels
- How **natural modes of climate variability** will function in an altered climate

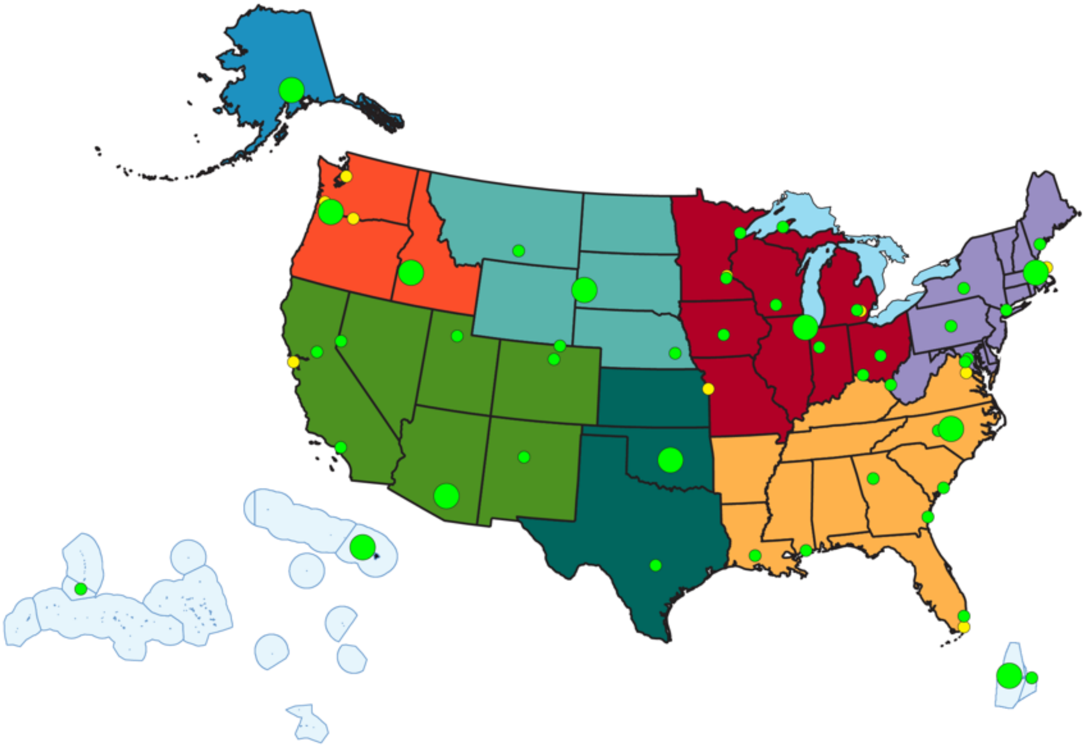


Extreme events in U.S. waters since 2012 (heat waves, "the Blob", mass bleaching)

4. Regional Information

Regional Chapters:
An Opportunity for Engagement

- The "main course" of NCA4
- Engagement with stakeholders identified what is of value to a given region
- Key Messages were framed around how those things of value are at risk from climate change
- Highlight options, challenges, opportunities, and success stories for addressing climate risk



Value of the regional chapters

- What do communities value about the places they live?
- How are those values impacted for better or worse by climate change?
- Local governments need information NOW to help guide future policy frameworks

Using NCA4 to Inform Policy

For NCA4 to support local management decisions, it must be:

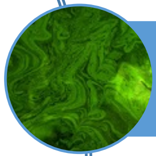
- Authoritative
- Transparent
- Comprehensive
- Inclusive

Ch. 18: King tide flooding in Annapolis, Maryland in 2012


Ch. 24: No-till fields in Oregon build climate resilience

Key Message Themes Across Regions

10 / 10 discuss **adaptation actions**



9 / 10 mention the **economy, ecosystems, and human health**

8 / 10 talk about **rural livelihoods, natural resources, and infrastructure**

7 / 10 focus on **vulnerable communities**, extremes, or heat

Regional Information Empowers Cities and States to Act

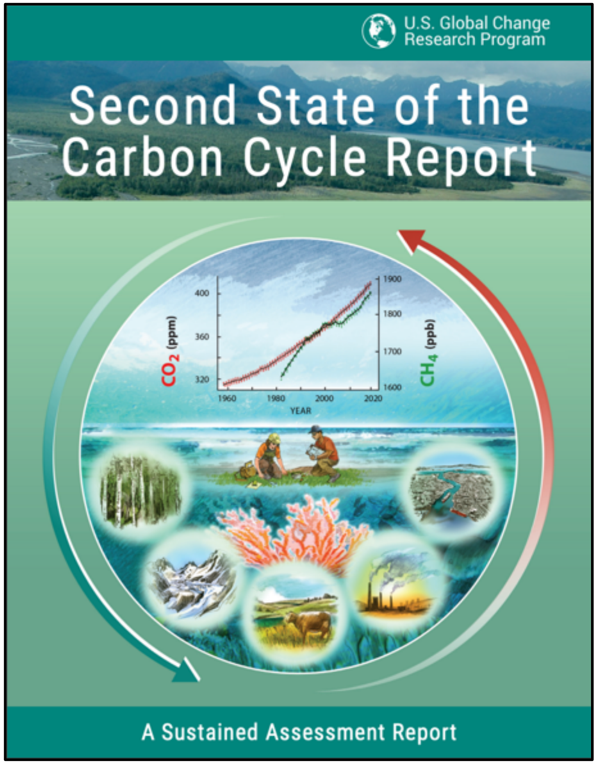
Honolulu Mayor Kirk Caldwell, NCA4 Authors Chip Fletcher and Victoria Keener, and CRO Josh Stanbro on Monday, November 26, 2018

- Cities and states need authoritative climate projections
- Legitimate debate about how best to adapt to impacts, make tradeoffs
- Regional chapters provide examples of communities and organizations across the country adapting

5. Additional Efforts & Next Steps

2nd State of the C Cycle Report (SOCCR-2)

- Authoritative decadal assessment of carbon cycle science across North America:
    - carbon cycle processes
    - stocks
    - fluxes
    - interactions with global-scale carbon budgets
    - climate change impacts in managed and unmanaged systems
- 200+ authors, 19 chapters & 7 appendices, 880-pages



Read and download the report at
carbon2018.globalchange.gov

Planning for NCA5

- Ongoing interagency conversations under auspices of USGCRP's "Sustained Assessment Working Group"
  - Meeting since early 2017 to discuss best practices on various elements of the NCA process
  - Recommendations being translated into an "Implementation Roadmap"
- OSTP Leadership in place, informed, and engaged

➢ ***Contact me if you're interested in learning more about participating in NCA5!***

THANK YOU!

nca2018.globalchange.gov

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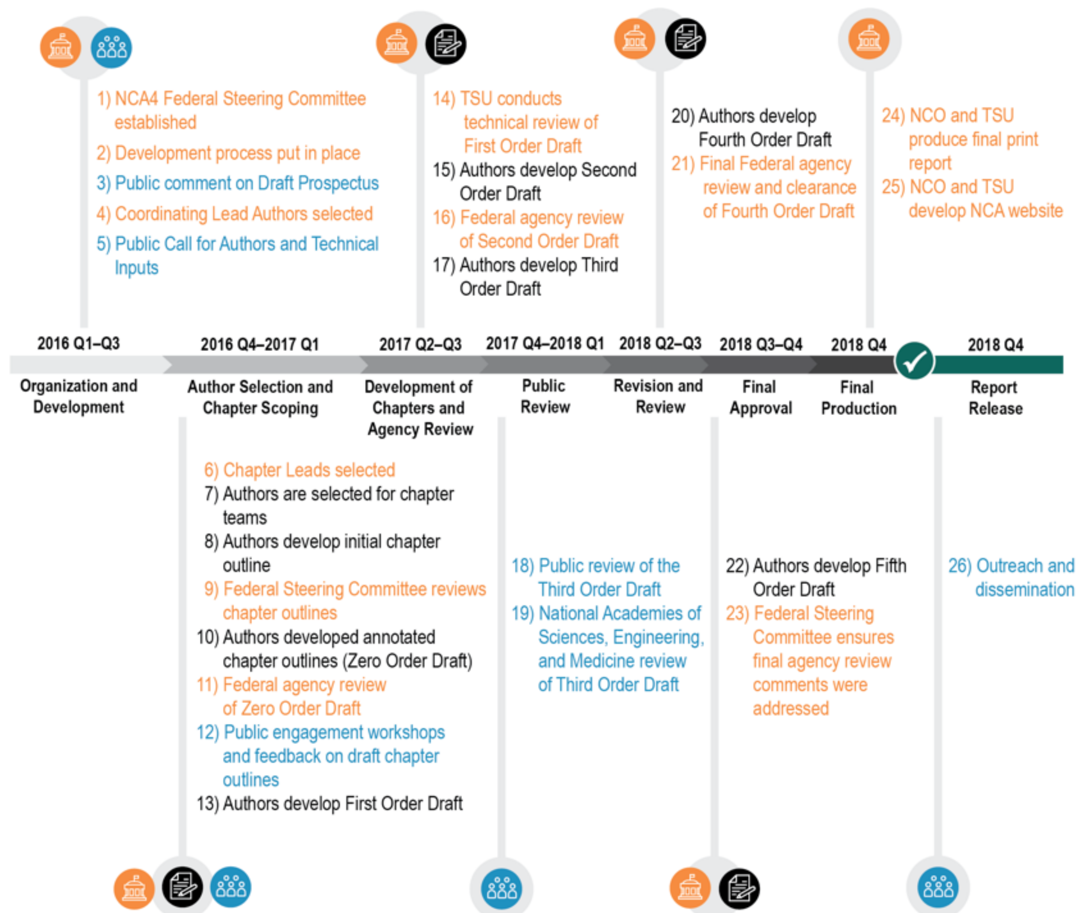
GlobalChange.gov

Thank you to the hundreds of volunteer federal and non-federal authors, review editors, and technical contributors to NCA4

U.S. Global Change Research Program

Report Development Process

- Multiple points of **federal review and decision** *(orange icons)* were present throughout the process.
- In addition, **public engagement** *(blue icons)* was a cornerstone of the NCA4 development process.
- Authors used these feedback mechanisms to inform their **chapter's development** *(black icons)*.



Ecosystems, Ecosystem Services & Biodiversity

- Organisms are altering individual characteristics, the timing of biological events, and their geographic ranges.
- Altered ecosystem productivity, spread of invasives, and changes to species interactions
- Changes in agricultural and fisheries production, the supply of clean water, protection from extreme events, and culturally valuable resources
- Challenges to traditional natural resource management strategies
- Mainstreaming adaptation planning into natural resource management progressing slowly

Range of invasive lionfish projected to expand closer to Atlantic coast

White snowshoe hares stand out in stark contrast against snowless backgrounds, leaving them more vulnerable to predators than their brown counterparts.

Coastal Effects

- America's trillion-dollar coastal property market and public infrastructure are threatened by tidal flooding, with cascading impacts to the larger economy
- Healthy coastal ecosystems are being transformed, degraded, or lost; Restoring and conserving them and adopting nature-based infrastructure solutions can enhance community and ecosystem resilience
- Coastal impacts often exacerbate preexisting social inequities

Natural and nature-based infrastructure habitats include seagrass meadows (not shown), (a) coastal wetlands, (b) barrier islands, (c) beaches, (d) corals, (e) oyster reefs, and (f) dunes. Each of these habitats provides storm and erosion risk reduction by causing waves to break or slow as they roll over the ecosystem.

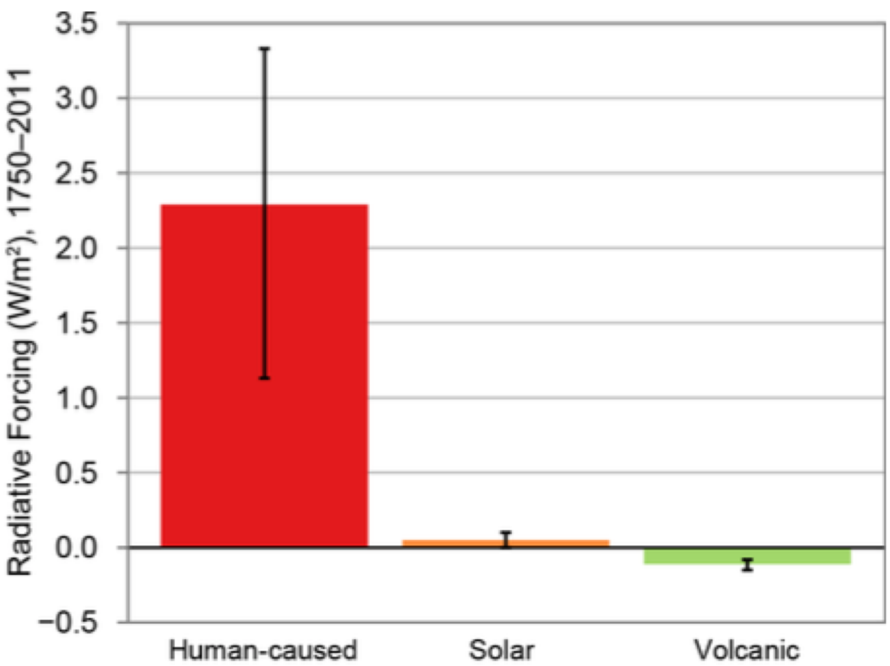
Key Advances in Climate Science (NCA4 Vol. I)

NCA4 Vol. I (CSSR) Table of Contents

Main CSSR Findings

- Thousands of studies conducted by researchers around the world have **documented changes in many parameters**, including: surface, atmospheric, and oceanic temperatures; melting glaciers; diminishing snow cover; shrinking sea ice; rising sea levels; ocean acidification; and increasing atmospheric water vapor.
- It is extremely likely that **human activities**, especially emissions of greenhouse gases, are the **dominant cause of the observed warming** since the mid-20th century. For the warming over the last century, there is **no convincing alternative explanation** supported by the extent of the observational evidence.
- The **science of event attribution is rapidly advancing** through improved understanding of the mechanisms that produce extreme events and the marked progress in development of methods that are used for event attribution.
- There is broad consensus that **the further and the faster the Earth system warms, the greater the risk of unanticipated changes** and impacts, some of which are large and irreversible.

Key Advance:
Detection & Attribution



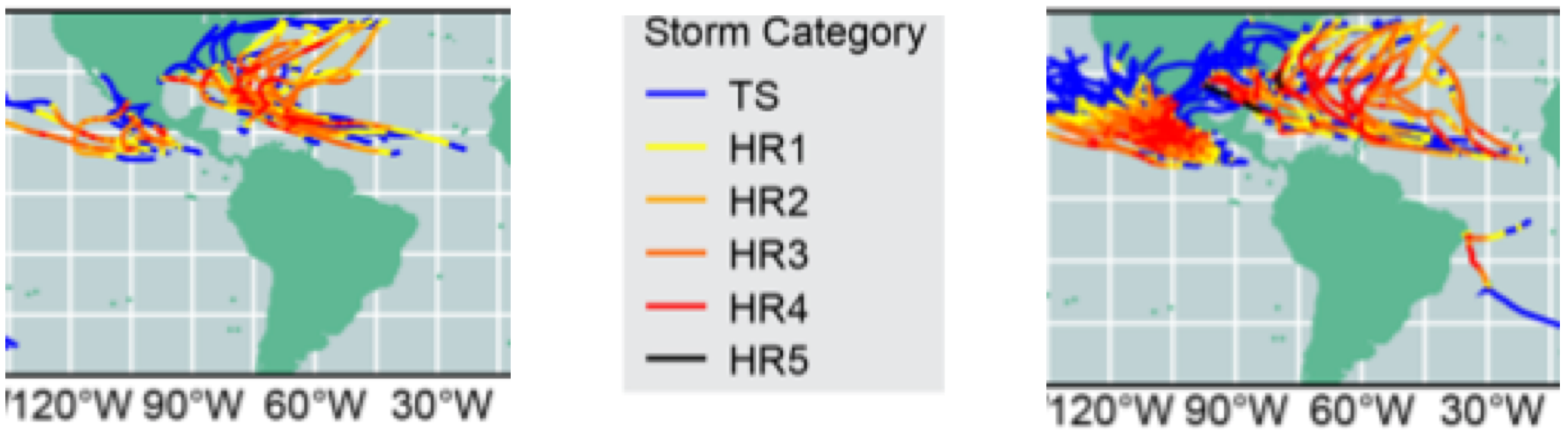
- The *likely* range of the human contribution to the global mean temperature increase over the period 1951–2010 is 1.1° to 1.4°F (*high confidence*). This translates to a likely human contribution of 93%–123% of the observed 1951–2010 change.
- It is *extremely likely* that more than half of the global mean temperature increase since 1951 was caused by human influence on climate (*high confidence*).

- The likely contributions of natural forcing and internal variability to global temperature change over that period are minor (*high confid*ence).

Key Advance:
Extreme Events – Tropical Cyclones

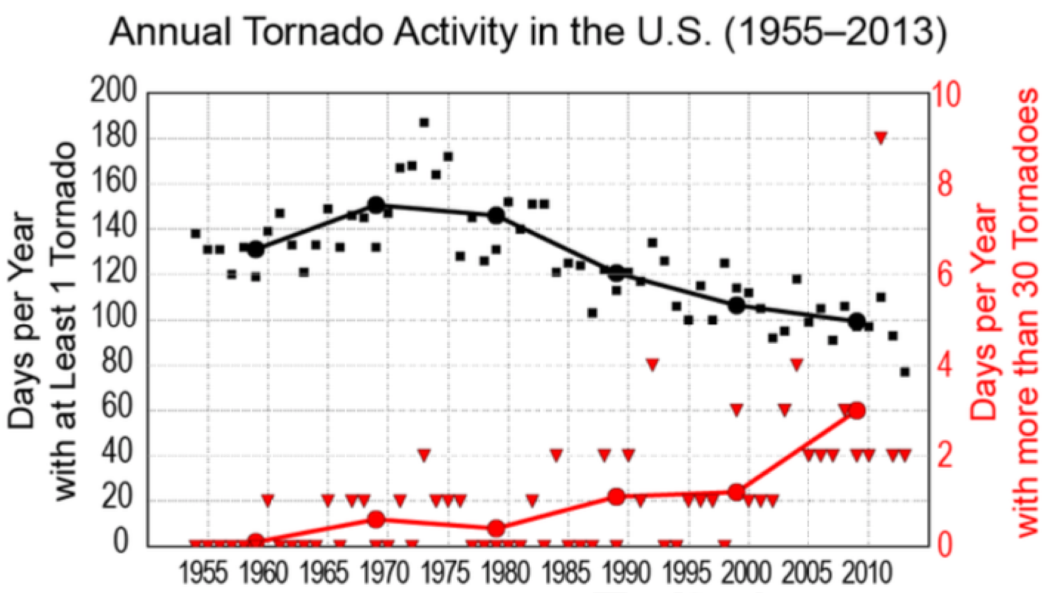
Present-day simulation
244 Cat 4-5 storms

RCP4.5 Late 21st century
313 Cat 4-5 storms



- Models generally show an increase in the number of very intense tropical cyclones in a warmer world.
- Increases are projected in precipitation rates (*high confidence*) and intensity (*medium confidence*).
- The frequency of the most intense of these storms is projected to increase in the Atlantic and western North Pacific (*low confidence*) and in the eastern North Pacific (*medium confidence*).

Key Advance:
Extreme Events – Tornadoes & Atmospheric Rivers

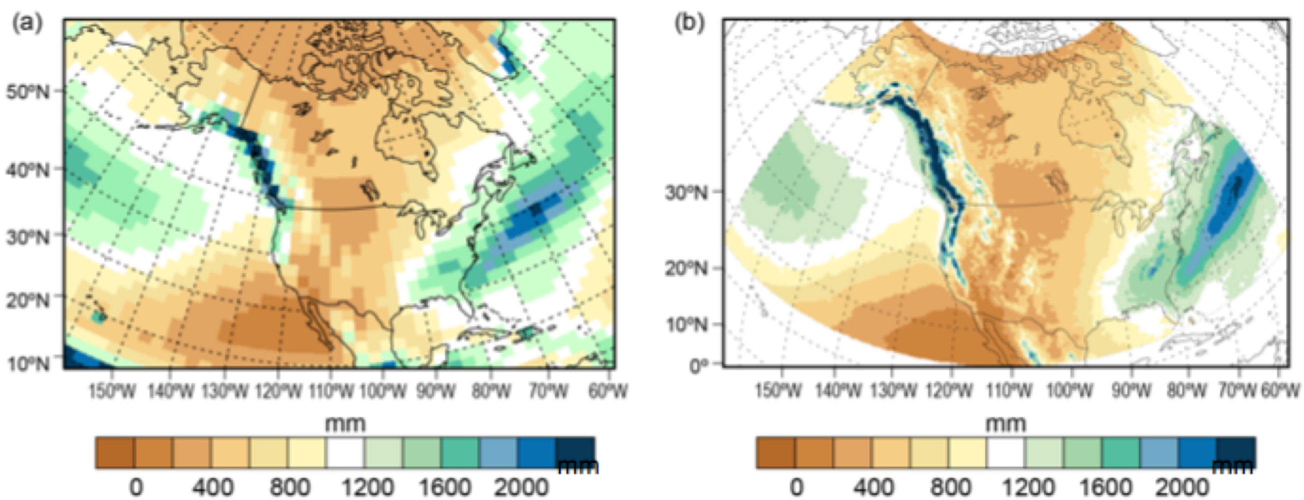


- Tornado activity in the United States has become more variable, particularly over the 2000s, with a decrease in the number of days per year with tornadoes and an increase in the number of tornadoes on these days (*medium confidence*)

- The frequency and severity of landfalling "atmospheric rivers" on the U.S. West Coast will increase with increasing temperature. (*Medium confidence*)

Key Advance:
Downscaled Information

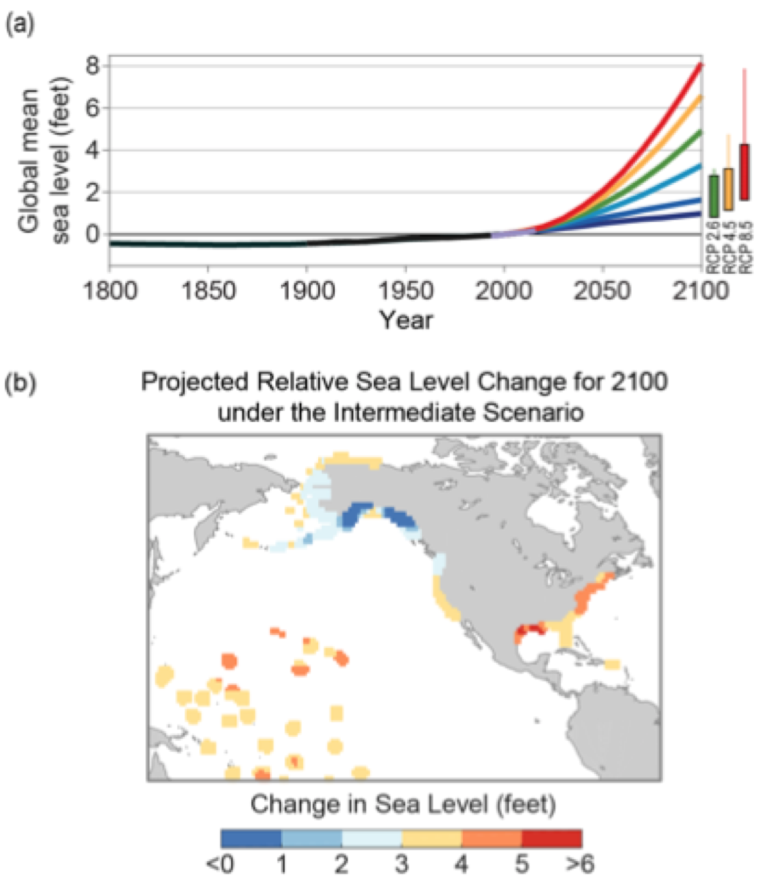
- Combining output from global climate models and dynamical and statistical downscaling models can result in more relevant and robust future projections. For some regions, sectors, and impacts, these techniques are increasing the ability of the scientific community to provide guidance on the use of climate projections for quantifying regional-scale changes and impacts (*medium to high confidence*).



50-300 km resolution

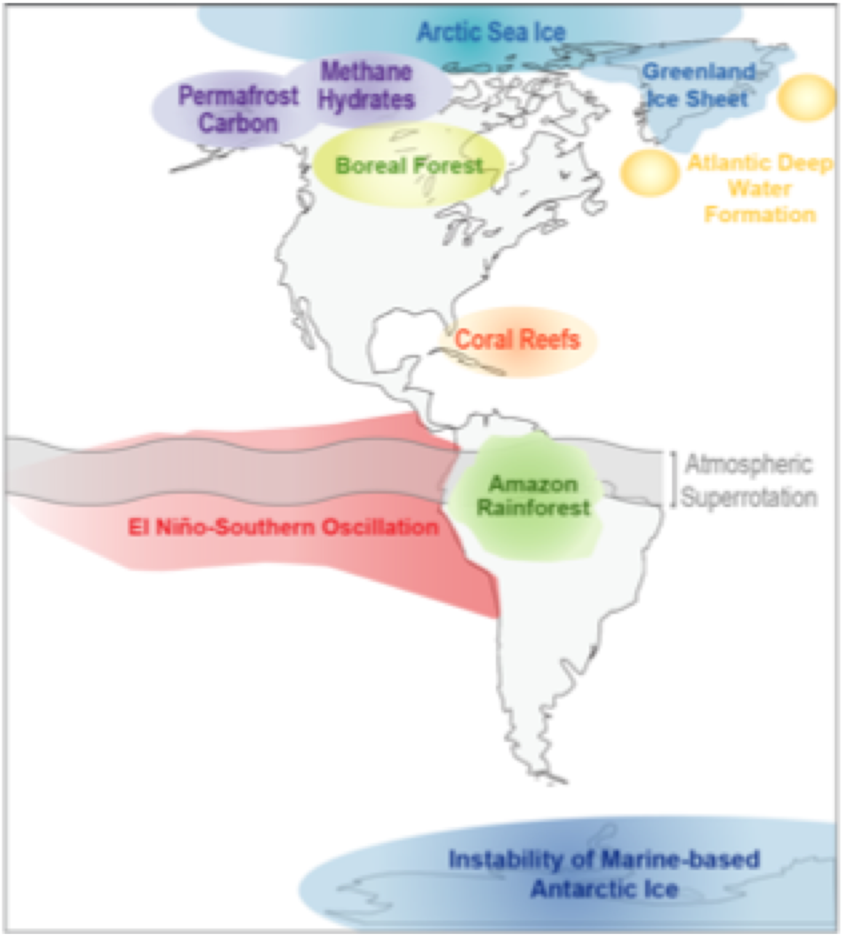
10-50 km resolution

Key Advance: *Sea-Level Rise*



- Global mean sea level (GMSL) has risen by about 7–8 inches since 1900, with about 3 of those inches occurring since 1993 (*very high confidence*).
- Relative to 2000, GMSL is *very likely* to rise by 0.3–0.6 feet by 2030, 0.5–1.2 feet by 2050, and 1.0–4.3 feet by 2100.
- A GMSL rise >8 feet by 2100 is physically possible, although the probability cannot currently be assessed.
- Relative sea level (RSL) rise will vary along U.S. coastlines (*very high confidence*), and is *likely* to be greater than the global average in the Northeast and the western Gulf of Mexico.
- “Nuisance floods” have increased 5- to 10-fold since the 1960s in several U.S. coastal cities (*very high confidence*). Rates of increase are accelerating in over 25 Atlantic and Gulf Coast cities (*very high confidence*).

Key Advance: *Potential Surprises*



- Positive feedbacks (self-reinforcing cycles) within the climate system have the potential to accelerate human-induced climate change. Some feedbacks are probably still unknown.
- The physical and socioeconomic impacts of compound extreme events can be greater than the sum of the parts (*very high confidence*). Few analyses consider the spatial or temporal correlation between extreme events.
- Future changes outside the range projected by climate models cannot be ruled out (*very high confidence*).

5. Additional Resources

New USGCRP Tools to Inform NCA4

Greater regional focus *[next slides]*

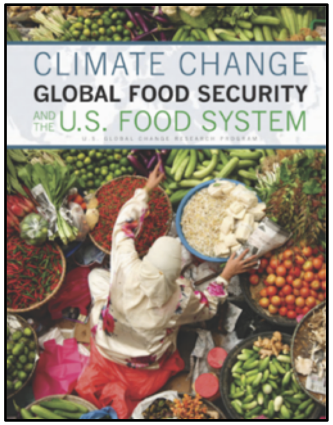
- NOAA State Climate Summaries
- EPA State Climate fact sheets
- Case studies

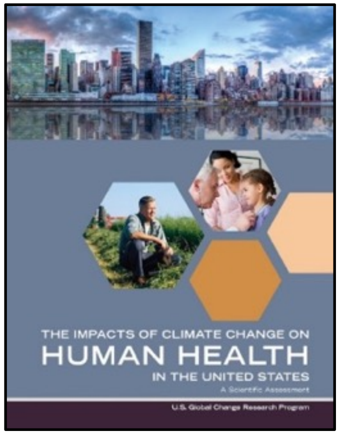
Science advances

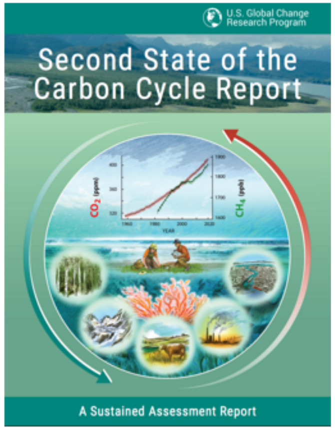
- Special Reports *[at right]*
- Scenario products (SLR, Land Use & Population): scenarios.globalchange.gov
- Downscaled LOCA projections: scenarios.globalchange.gov/loca-viewer/
- Indicators: globalchange.gov/explore/indicators

Economic impacts by sector & region

- CIRA2.0: www.epa.gov/cira



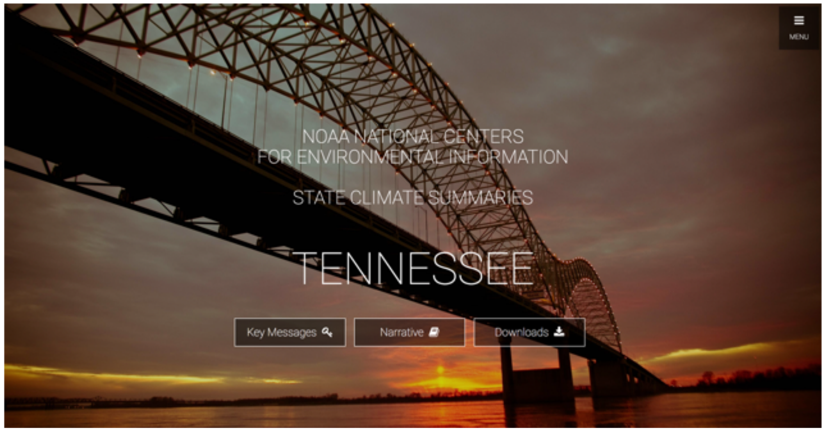


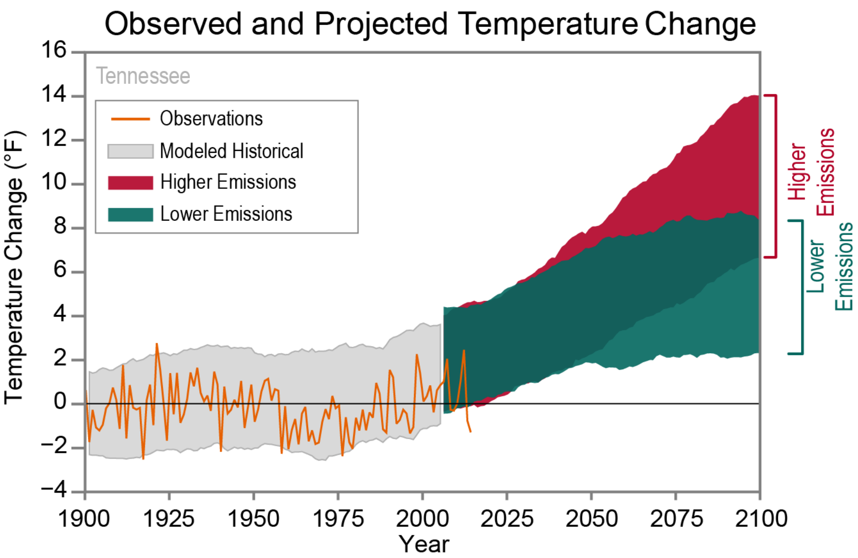


NOAA State Climate Summaries

- Developed in response to demand for more local information after NCA3
- Three Key Messages for each state on observed and projected climate trends
- Also includes 7-10 figures tailored to each state
- Available for all 50 states, as well as Puerto Rico & the U.S. Virgin Islands
- Supplemental figures (n = ~1500) also available online (e.g., hot days, warm nights, days below freezing, etc.)

stateclimatesummaries.globalchange.gov





EPA State Climate Fact Sheets

EPA United States Environmental Protection Agency

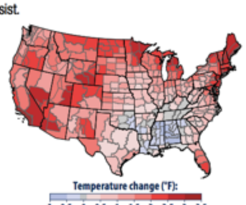
August 2016
EPA 430-F-16-044

What Climate Change Means for Tennessee

Tennessee's climate is changing. Although the average temperature did not change much during the 20th century, the state has warmed in the last 20 years. Average annual rainfall is increasing, and a rising percentage of that rain is falling on the four wettest days of the year. In the coming decades, the changing climate is likely to reduce crop yields, threaten some aquatic ecosystems, and increase some risks to human health. Floods may be more frequent, and droughts may be longer, which would increase the difficulty of meeting the competing demands for water in the Tennessee and Cumberland rivers.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree (F) during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Natural cycles and sulfates in the air prevented much of Tennessee from warming during the last century. Sulfates are air pollutants that reflect sunlight back into space. Now sulfate emissions are declining, and the factors that once prevented Tennessee from warming are unlikely to persist.



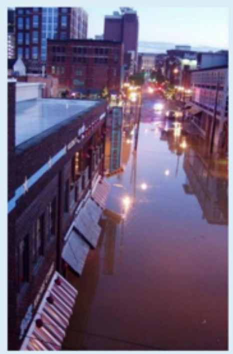
Rising temperatures in the last century. Tennessee has warmed less than most of the United States. Source: EPA, Climate Change Indicators in the United States.

Changing Water Availability

Annual precipitation in Tennessee has increased approximately 5 percent since the first half of the 20th century. But rising temperatures increase evaporation, which dries the soil and decreases the amount of rain that runs off into rivers. Although rainfall during spring is likely to increase during the next 40 to 50 years, the total amount of water running off into rivers or recharging ground water each year is likely to decline 2.5 to 5 percent, as increased evaporation offsets the greater rainfall. Droughts are likely to be more severe, because periods without rain will be longer and very hot days will be more frequent.

Increased Flooding

Flooding is becoming more severe in the Southeast. Since 1958, the amount of precipitation falling during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue. To prevent serious floods, the Tennessee Valley Authority (TVA) and the U.S. Army Corps of Engineers release water from the reservoirs behind dams they operate before the winter flood season. Doing so lowers water levels and provides a greater capacity for the reservoirs behind those dams to prevent flooding. Nevertheless, the dams cannot prevent all floods. In May 2003, for example, heavy rains exceeded TVA's dam capacity, flooding low-lying areas in Chattanooga and other parts of Hamilton County; in 2010, high flows in the Cumberland River flooded Nashville.



The Cumberland River flooded parts of Nashville in 2010, damaging many businesses, including the Grand Ole Opry. Credit: USGS.

Droughts, Navigation, and Hydroelectric Power

Droughts also pose challenges for water management. If the spring is unexpectedly dry, reservoirs may have too little water during summer. During droughts, TVA and the Corps of Engineers release water from dams to keep the Tennessee and Cumberland rivers navigable. These rivers support $35 billion in annual shipping. The agencies try to keep channels at least eleven feet deep, because lower river levels can force barges to carry smaller loads, which increases transportation costs. During the drought of 2007, however, TVA could only release enough water to keep some channels nine feet deep. This release meant that lake levels were lowered tens of feet, which caused problems for recreational swimming and boating. If droughts become more severe, TVA and the Corps of Engineers will face this type of problem more often.

Dry years diminish the amount of electricity that TVA can produce from its 19 hydroelectric dams in Tennessee, which provide 12 to 15 percent of the electricity produced in the state. During the 2007 drought, TVA's hydroelectric plants produced 30 percent less than normal, which forced TVA to meet demand by using more expensive fuel-burning power plants.

Two views of a boat ramp in Douglas Lake during the 2007 drought. The lake is nearly dry and the 330-foot ramp is completely out of the water. Credit: NOAA.

Aquatic Ecosystems

Changing the climate can harm aquatic ecosystems. Warmer water lowers the level of dissolved oxygen in surface water, which can severely limit fish populations. Because fish cannot regulate their body temperatures, warmer water can make a stream uninhabitable for fish that require cooler water. Warmer temperatures can also increase the frequency of algal blooms, which can be toxic and further reduce dissolved oxygen. Summer droughts may amplify these effects, while periods of extreme rainfall can increase the impacts of pollution on streams.

Agriculture

Changing the climate will have both beneficial and harmful effects on agriculture. Longer frost-free growing seasons and increased concentrations of atmospheric carbon dioxide tend to increase yields for many crops during an average year. But more severe droughts and more hot days are likely to reduce yields, especially in the western half of Tennessee: 70 years from now, that part of the state is likely to have 15 to 30 more days with temperatures above 95°F than it has today. Even on irrigated fields, higher temperatures are likely to reduce yields of corn, and possibly soybeans. Warmer temperatures are also likely to reduce the productivity of dairy and other cattle farms.

Forest Resources

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Tennessee, but the composition of those forests may change. Forests cover about half the state, dominated by oak and hickory trees, and the forest products industry employs 180,000 people. Although more droughts would reduce productivity, longer growing seasons and increased carbon dioxide concentrations could more than offset those losses. Nevertheless, climate change is likely to increase the damage that certain insects and diseases cause in Tennessee's forests.

Human Health

Hot days can be unhealthy—even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. Warmer air can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Tennessee Department of Environment and Conservation have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

The Smoky Mountains have always had a natural blue haze. But air pollution has increased that haze, and higher ozone levels could increase it further. This photo shows how haze obscures the view from the Look Rock Tower in Great Smoky Mountains National Park. Credit: National Park Service.

The sources of information about climate and the impacts of climate change in this publication are: the national climate assessments by the U.S. Global Change Research Program, synthesis and assessment products by the U.S. Climate Change Science Program, assessment reports by the Intergovernmental Panel on Climate Change, and EPA's *Climate Change Indicators in the United States*. Mention of a particular season, location, species, or any other aspect of an impact does not imply anything about the likelihood or importance of aspects that are not mentioned. For more information about climate change science, impacts, responses, and what you can do, visit EPA's Climate Change website at www.epa.gov/climatechange.

https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-tn.pdf

Case Studies – Learning by Doing

- Mitigation and adaptation activities in various sectors or regions
- Give national visibility to local-level actions
- Facilitate community-to-community learning

Climate Resilience Toolkit
https://toolkit.climate.gov/#case-studies

CASE STUDIES
Users can explore case studies to see how people are building resilience for their businesses and in their communities.