Future Climate Change: The Challenge Before Us

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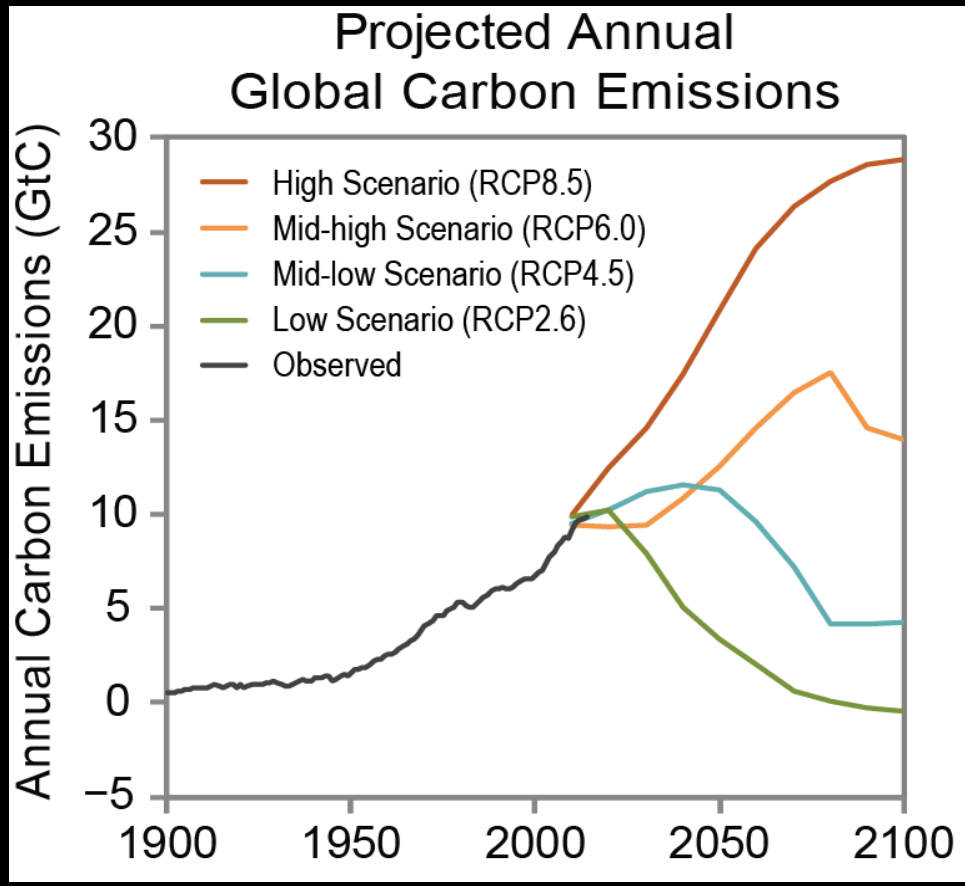
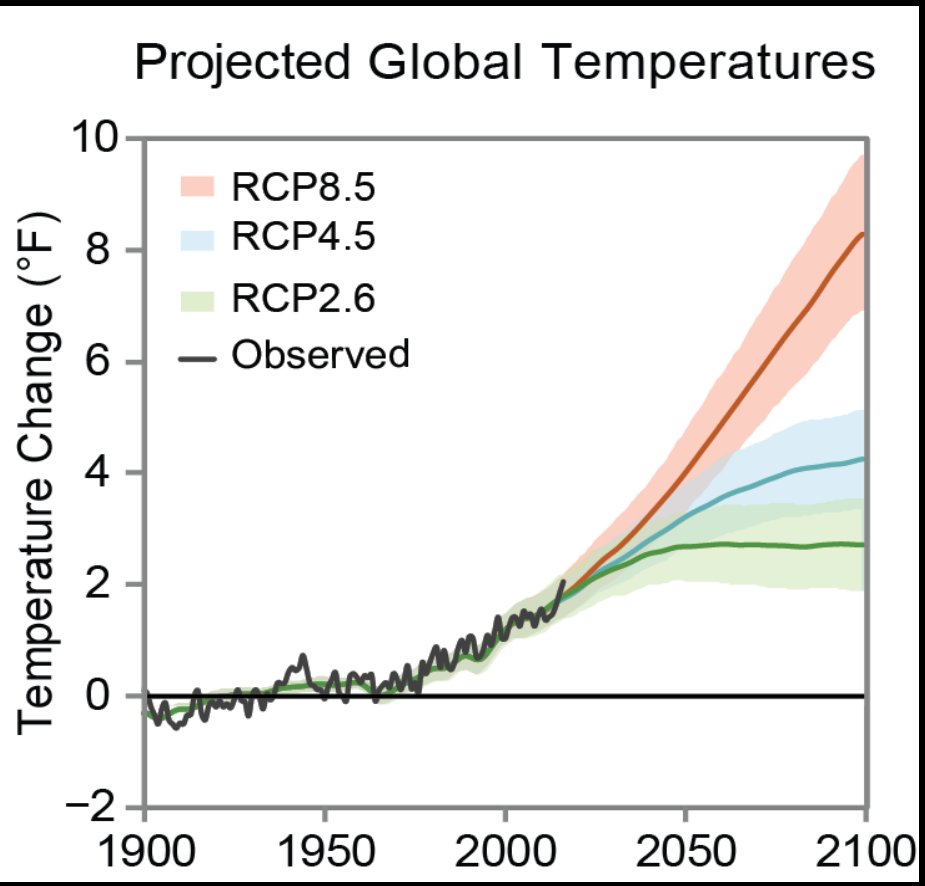
The Science: The Bottom Line

- Our climate is changing,
  - It is happening now;
  - It is happening extremely rapidly;
- Severe weather is becoming more intense;
- Sea levels are rising and oceans affected;
- It is largely happening because of human activities and associated pollution;
- The climate will continue to change over the coming decades.

The Forecast: Climate will Continue to Change

Climate change beyond the next few decades depends primarily on the **heat-trapping gases emitted** and remaining uncertainty in the **sensitivity of Earth's climate** to those emissions.





Climate models are based on physics, chemistry, and biology

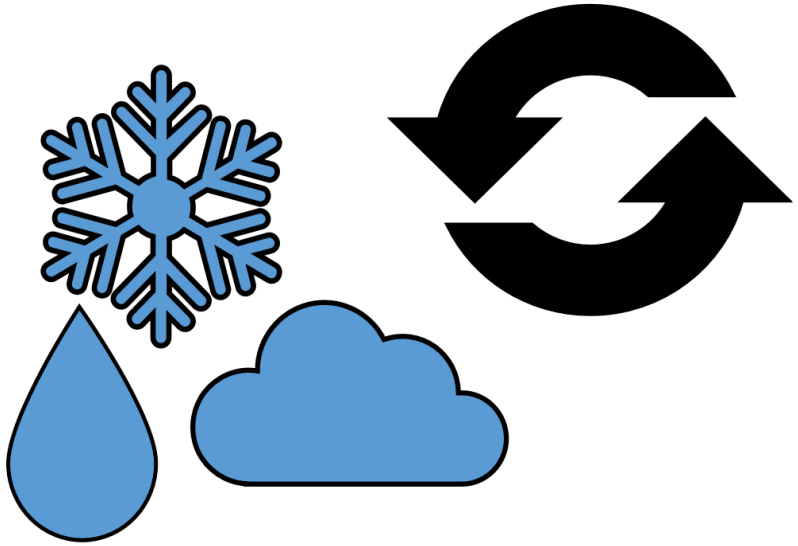
- Represents the atmosphere, the ocean, the hydrosphere, the biosphere, the cryosphere (ice and snow), and the lithosphere (soil, rocks)
- Use hundreds of mathematical equations to represent science for the different parts of the climate system *and* how these parts interact.
- These modelling tools do many things well, but they are not perfect. Nor should we expect them to be.

How will the planet respond?

Effective Climate Sensitivity: 2 x CO2 → 2.0-4.5 ℃

Climate sensitivity

$= CO_2 +$



Initial warming

Feedbacks

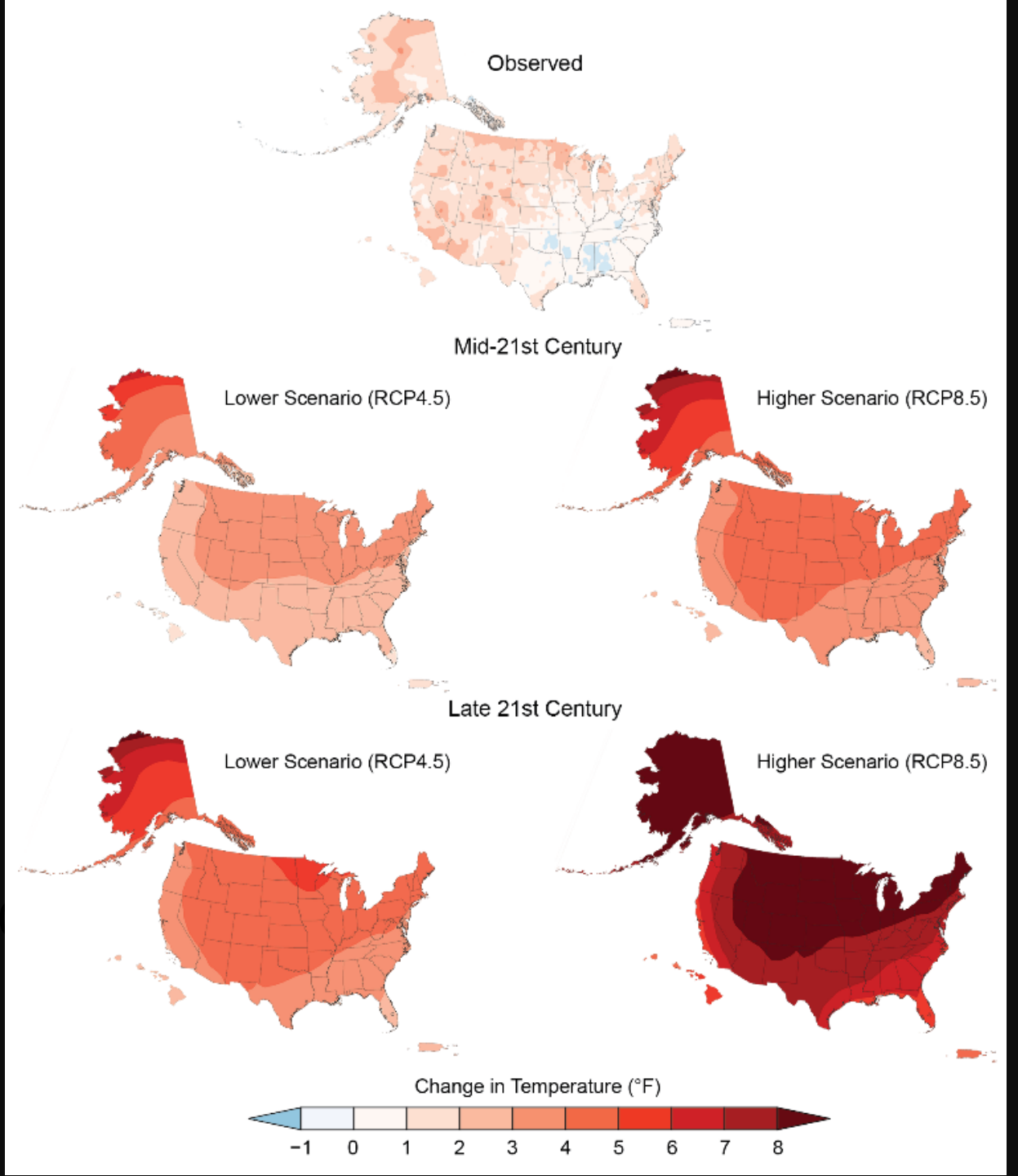
What about uncertainty?

- Use climate projections over 20-30 year periods.
- Climate models typically represent the range of climate sensitivity.
- Future scenarios are driven by human activities which we can't predict, so we always look at the future as an "if/then" – *if* we do this, *then* this is likely to happen
- Because we're conducting a truly unprecedented experiment with our planet, there is always the chance of surprise
  - NCA4: Surprise likely weighted towards larger impacts

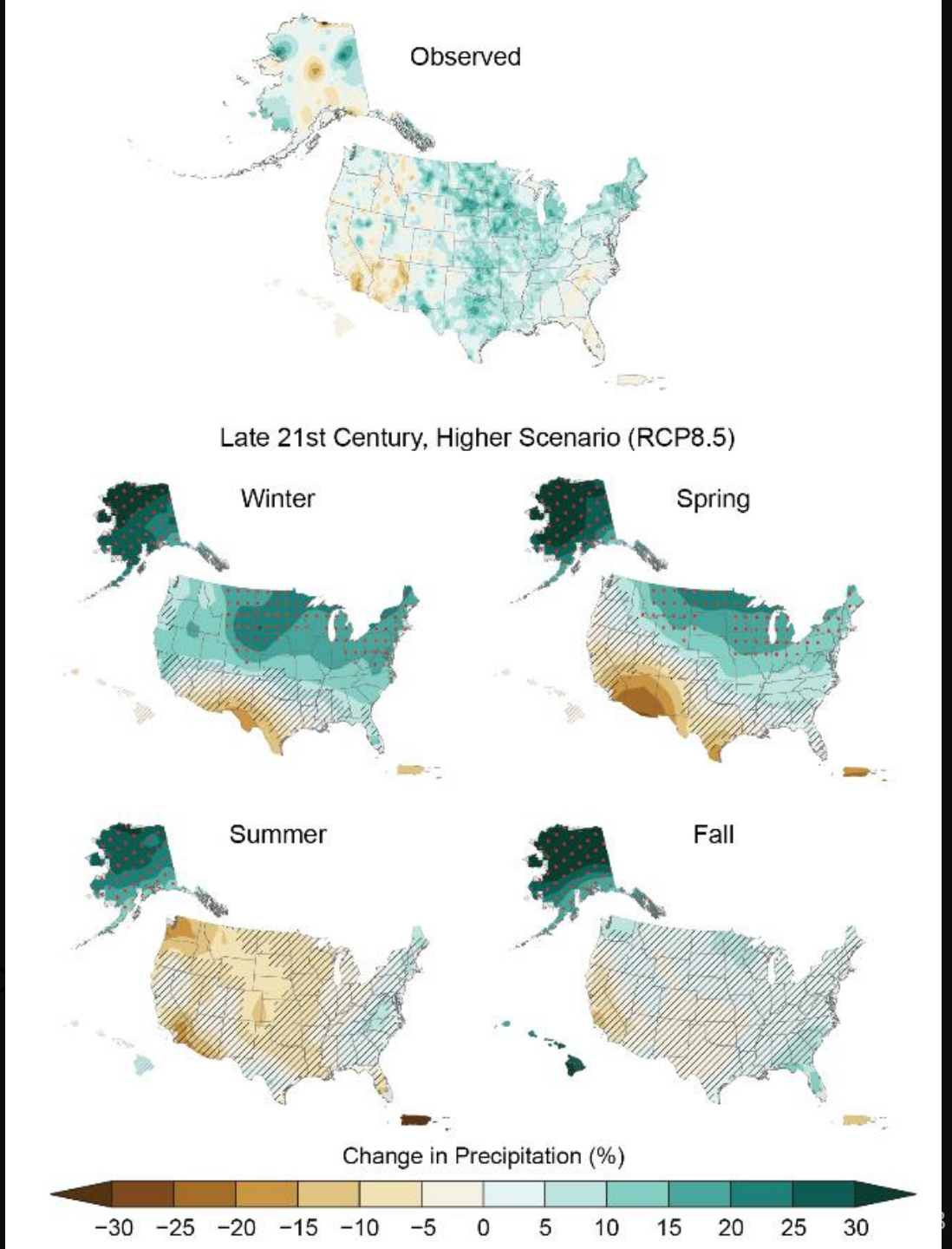
Observed and Projected U.S. Annually-Averaged Temperature Change

1991-2

Relative to 1976–2005

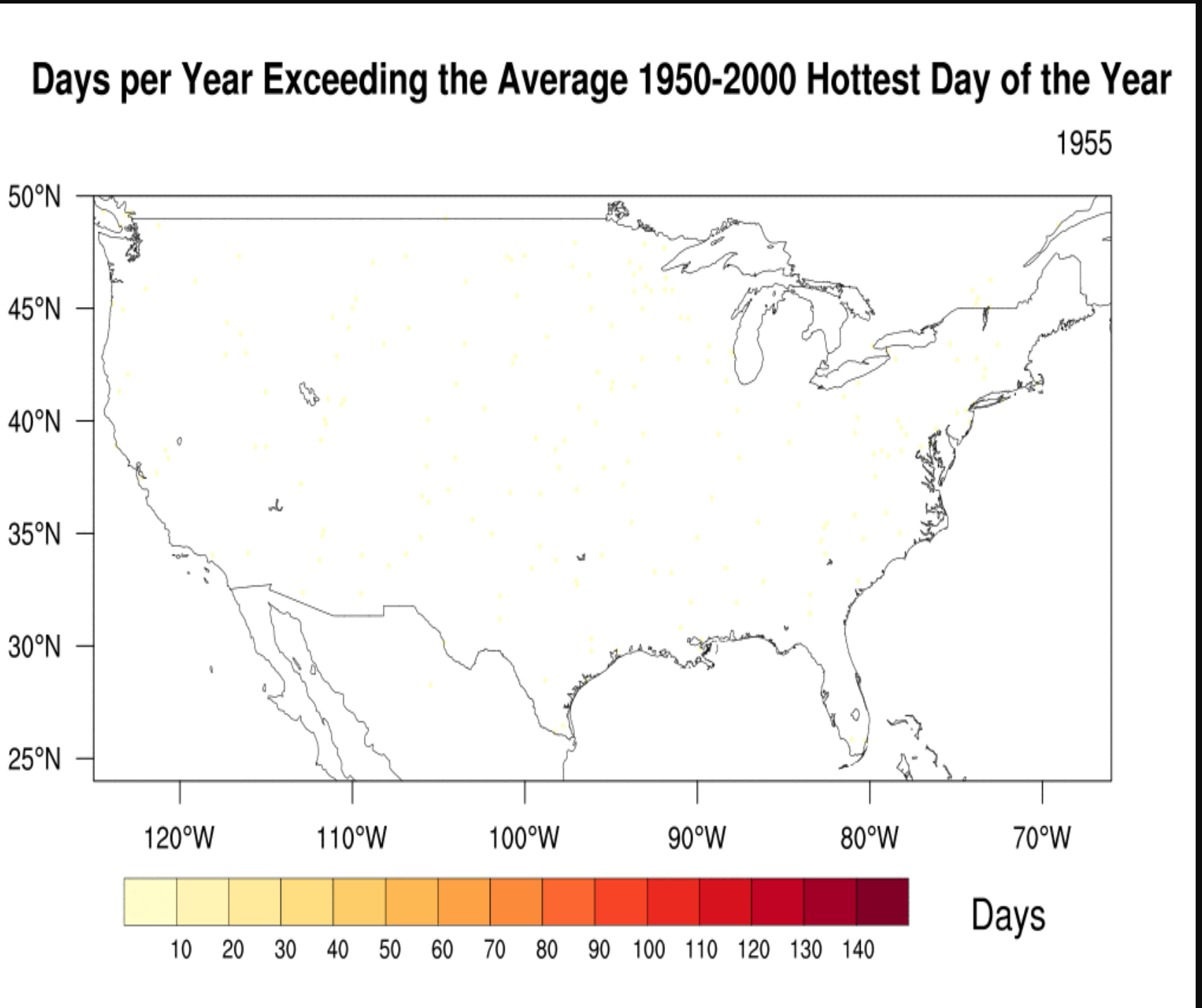


Observed and Projected U.S. Precipitation Change



1991-2012 c

2070-2099 relative to 1975-2005
For RCP8.5 (High scenario)



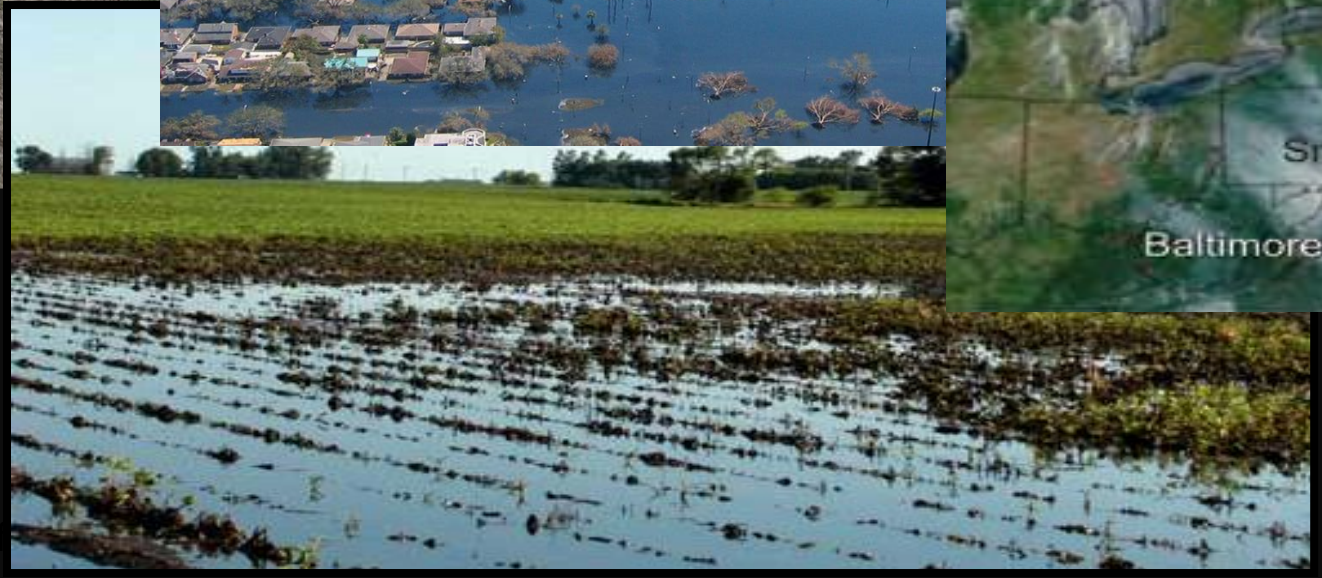
These animations are based on CMIP5 simulations for 200 weather stations under the RCP8.5 scenario.

The CHANGING OCEAN

- Sea levels have risen 7-8 inches since 1900
- Highest Rate of Sea Level Rise in over 2800 years
- Sea levels expected to rise another 1-4 feet over this century
- The acidification of the oceans
- Changing ocean circulation
- Declining oxygen concentrations in many coastal areas

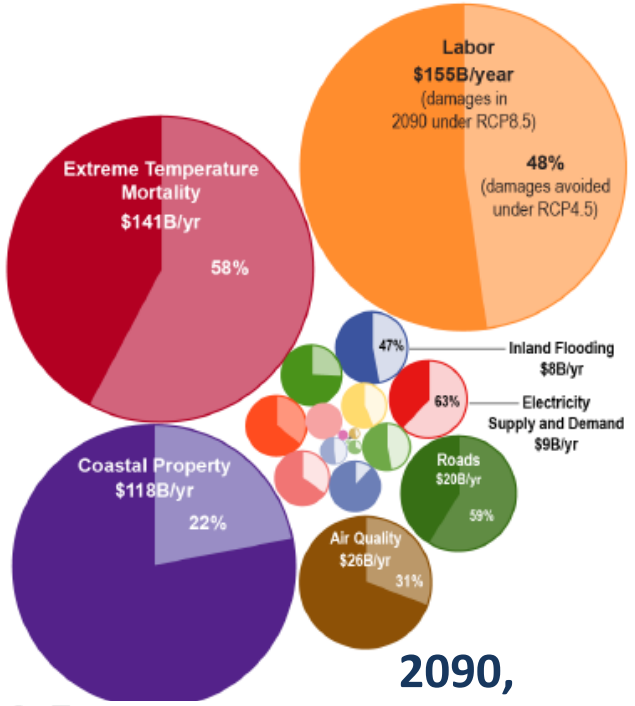
ipcc
INTERGOVERNMENTAL PANEL ON climate change

Impacts are already apparent in every region and in important sectors, e.g., health, water, agriculture, energy, and more.



Potential for Significant Economic Impacts on the U.S. (and Globally)

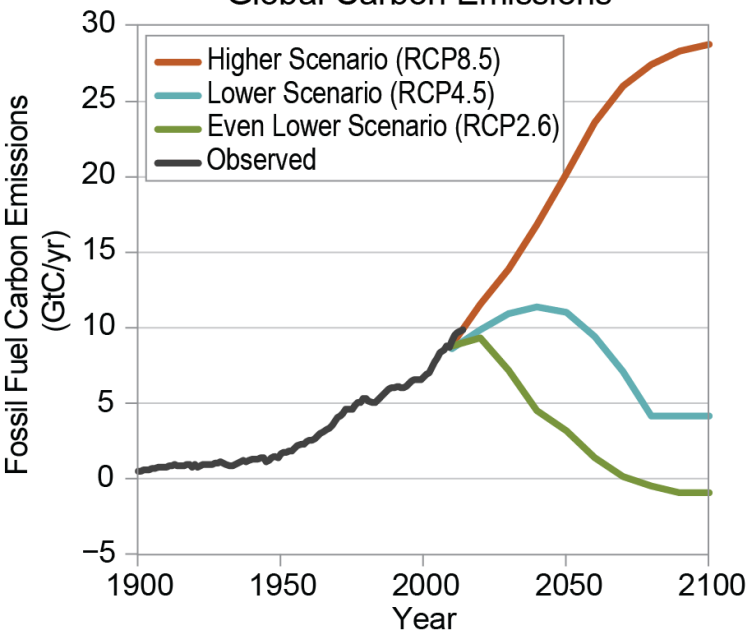
Projected Damages and Potential for Risk Reduction by Sector



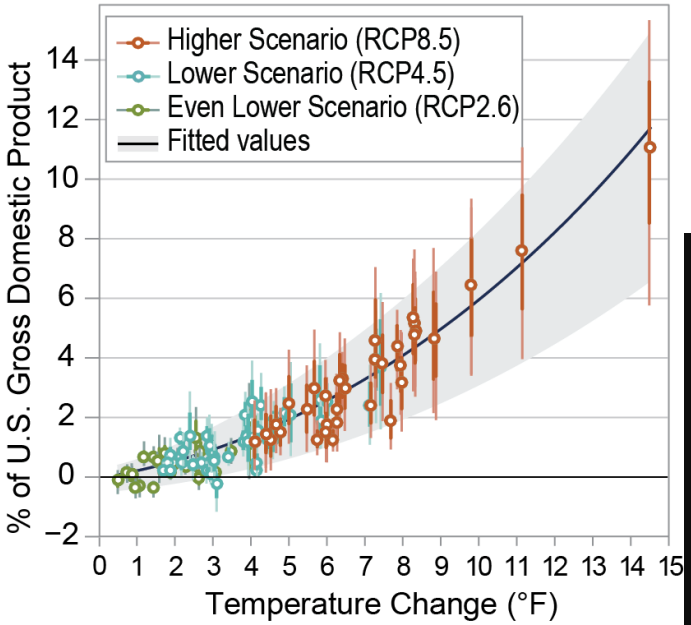
Annual Economic Damages in 2090		
Sector	Annual damages under RCP8.5	Damages avoided under RCP4.5
Labor	$155B	48%
Extreme Temperature Mortality◊	$141B	58%
Coastal Property◊	$118B	22%
Air Quality	$26B	31%
Roads◊	$20B	59%
Electricity Supply and Demand	$9B	63%
Inland Flooding	$8B	47%
Urban Drainage	$6B	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%

2090, Based on EPA (2017) in 2015 $

Global Carbon Emissions



Direct Damage to U.S. Economy



These analyses underestimate some major impacts

What should we do?

There are three options:

- **Mitigation**: measures to reduce the pace & magnitude of the changes in climate.
- **Adaptation**: measures to reduce the adverse impacts on human well-being resulting from climate change.
- **Suffering**: the adverse impacts and societal disruption not avoided by mitigation or adaptation.

Enough mitigation is needed to avoid the unmanageable, and enough adaptation to manage the unavoidable.

Maintaining a Sense of Hope

- Our future depends on how we act to limit climate change.
- Adaptation is not a choice – our choice is whether to adapt proactively or respond to the consequences.
- Adaptation requires focusing on managing risks.
- We must draw on our long history of responding to changing conditions on our planet in facing the challenges of climate change.

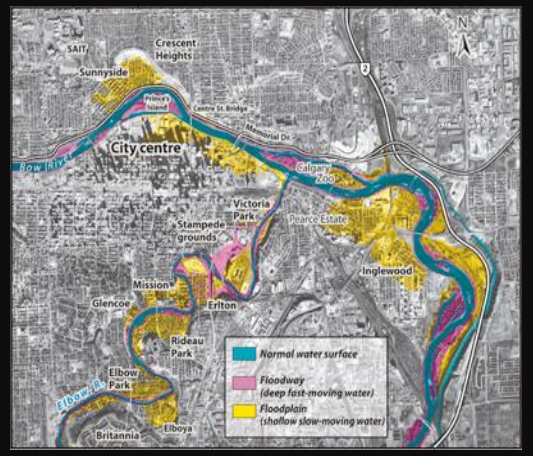
Thank You!

Climate Change Affects Many Societal Sectors

RESIDENTIAL + COMMERCIAL BUILDING CODES

WHAT TYPES OF CROPS WE GROW, AND WHERE

THE ENERGY DEMAND WE PLAN FOR



100-YR FLOOD ZONES

INVESTMENT IN SNOW REMOVAL CAPACITY

WATER PLANNING

But many engineering and policy studies still depend on past data

AND Many Others…

Key mitigation realities

- Human CO_2 emissions are the biggest piece of the problem (50% and growing)
  - About 85% comes from burning coal, oil, & natural gas (which provide >80% of world energy)
  - Most of the rest comes from deforestation & burning in the tropics
- Developing countries now exceed industrialized ones in total CO_2 emissions (but not per capita).
- Global energy system can't be changed quickly: ~$20T is invested in it; normal turnover is ~40 yrs.
- Deforestation also isn't easy to change: forces driving it are deeply embedded in the economics of food, fuel, timber, trade, & development.

POLICY SOLUTIONS: Modernize Energy Sources

- **Accelerate development of renewable energy** in order to reduce greenhouse gases and other pollutants from fossil fuel plants, create jobs and grow the clean energy economy
- **Develop a more decentralized electricity system** based on more distributed renewable energy.
- **Accelerate implementation of energy efficiency** in order to reduce greenhouse gases, create jobs, reduce the energy dollar outflow from the region, and grow the regional clean energy economy
- **Accelerate adoption of electric and other alternative fueled vehicles** across the region and in business, state, municipal and school bus fleets. Power electric vehicle charging stations with clean renewable solar energy and wind energy

What Can We Do?

June 28, 2016

Dear Members of Congress,

We, as leaders of major scientific organizations, write to remind you of the consensus scientific view of climate change.

Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research concludes that the greenhouse gases emitted by human activities are the primary driver. This conclusion is based on multiple independent lines of evidence and the vast body of peer-reviewed science.

There is strong evidence that ongoing climate change is having broad negative impacts on society, including the global economy, natural resources, and human health. For the United States, climate change impacts include greater threats of extreme weather events, sea level rise, and increased risk of regional water scarcity, heat waves, wildfires, and the disturbance of biological systems. The severity of climate change impacts is increasing and is expected to increase substantially in the coming decades.[1]

To reduce the risk of the most severe impacts of climate change, greenhouse gas emissions must be substantially reduced. In addition, adaptation is necessary to address unavoidable consequences for human health and safety, food security, water availability, and national security, among others.

We, in the scientific community, are prepared to work with you on the scientific issues important to your deliberations as you seek to address the challenges of our changing climate.

American Association for the Advancement of Science
American Chemical Society
American Geophysical Union
American Institute of Biological Sciences
American Meteorological Society
American Public Health Association
American Society of Agronomy
American Society of Ichthyologists and Herpetologists
American Society of Naturalists

[1] The conclusions in this and the preceding paragraph reflect the scientific consensus represented by, for example, the U.S. Global Change Research Program, the U.S. National Academies, and Intergovernmental Panel on Climate Change. Many scientific societies have endorsed these findings in their own statements, including the American Association for the Advancement of Science, American Chemical Society, American Geophysical Union, American Meteorological Society, American Statistical Association,

There is much we can each do:

- Speak up!
- Write your representatives
- Vote with care
- Be energy efficient
- Change to LED light bulbs
- Get efficient appliances
- Use cold water in washer
- Be water efficient
- Eat organic
- Eat less meat
- Buy local
- Use mass transit, walk, etc.
- Drive a fuel efficient vehicle
- Use solar or other renewable energy

Science underpins climate policy

Science provides:

- the motivation for developing a cost-effective plan to reduce impacts;
- the sense of urgency for doing so now rather than waiting;
- the awareness that such a plan must include both mitigation and adaptation;
- the knowledge of the causes and the character of society's vulnerabilities that allows appropriate specificity in designing a plan; and
- the recognition that any U.S. plan must include a component designed to bring other countries along.

Adaptation

Americans are Responding to the Impacts of Climate Change

This map shows climate-related impacts that have occurred in each region since the Third National Climate Assessment in 2014 and response actions that are helping the region address related risks and costs. These examples are illustrative.