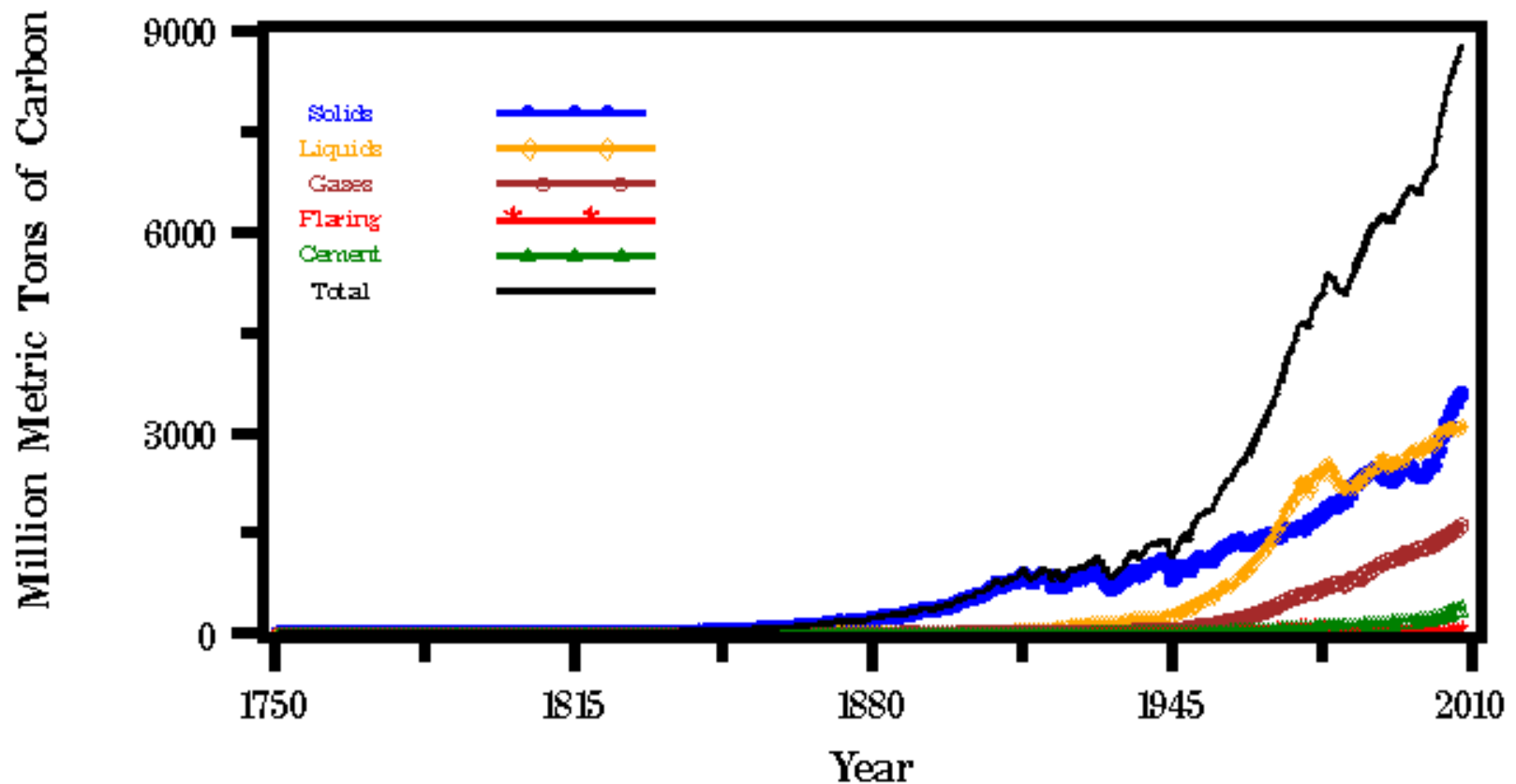


# Climate Change and Its Impacts: An Overview of the Science

Anthony J. Broccoli  
Director, Climate and Environmental Change Initiative  
Department of Environmental Sciences  
Rutgers University

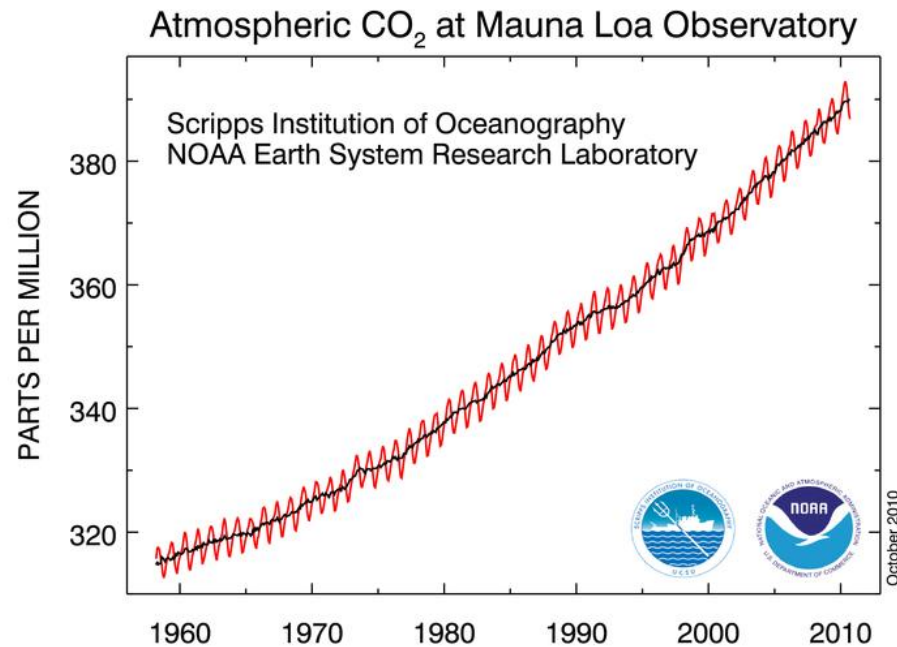
"Preparing New Jersey for Climate Change:  
A Workshop for Decision Makers"  
New Brunswick, NJ  
November 29, 2011

Combustion of fossil fuels (coal, petroleum, natural gas) emits carbon dioxide into the atmosphere



Source: Carbon Dioxide Information Analysis Center, U.S. Dept. Of Energy

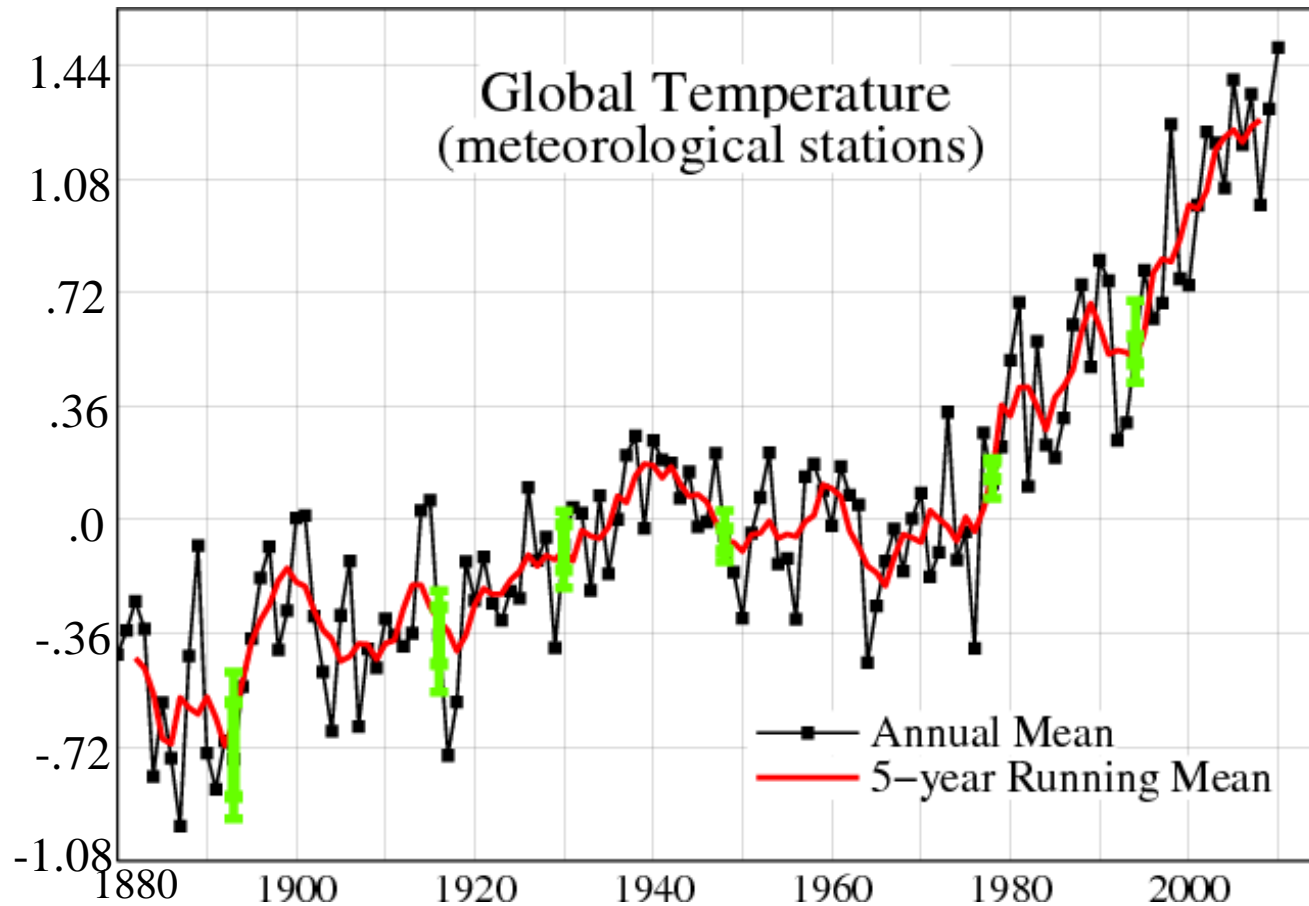
About half of the CO<sub>2</sub> remains in the atmosphere; most of the remainder goes into the ocean (causing ocean acidification)



## Basic physics of CO<sub>2</sub> and climate

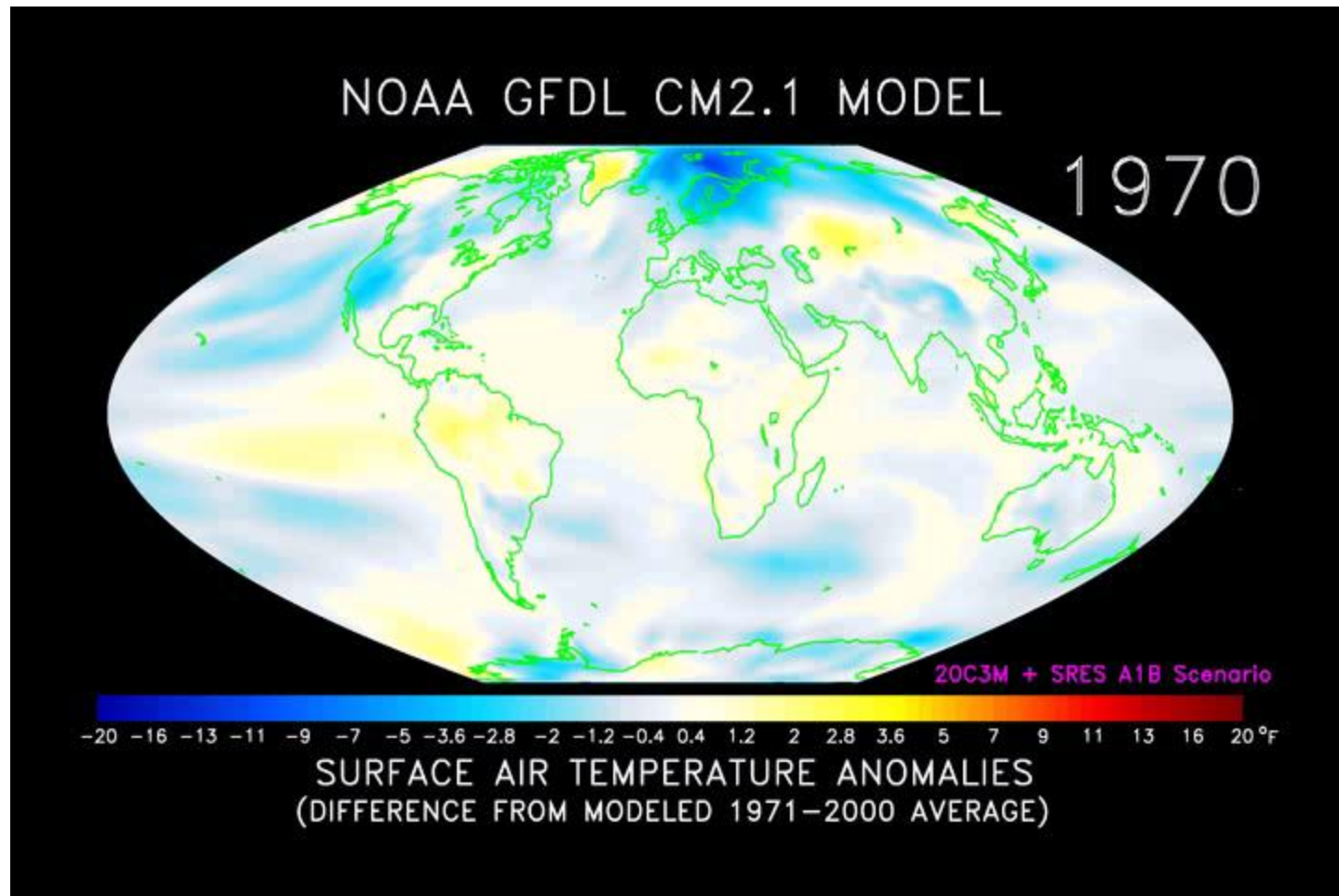
- The earth receives energy from the sun, mainly in the form of visible light.
- The earth also emits energy in the form of infrared light. This is the earth's cooling mechanism that balances the heating from the sun's visible light.
- CO<sub>2</sub> and water vapor are **greenhouse gases** that absorb infrared light, making it more difficult for energy to escape into space.
- Increasing amounts of greenhouse gases disrupt the balance between heating from the sun and cooling by infrared emission, causing the earth to warm.

Increasing CO<sub>2</sub> heats the earth; global temperatures have risen by about 1.5°F during the past century



Source: NASA/Goddard Institute for Space Studies

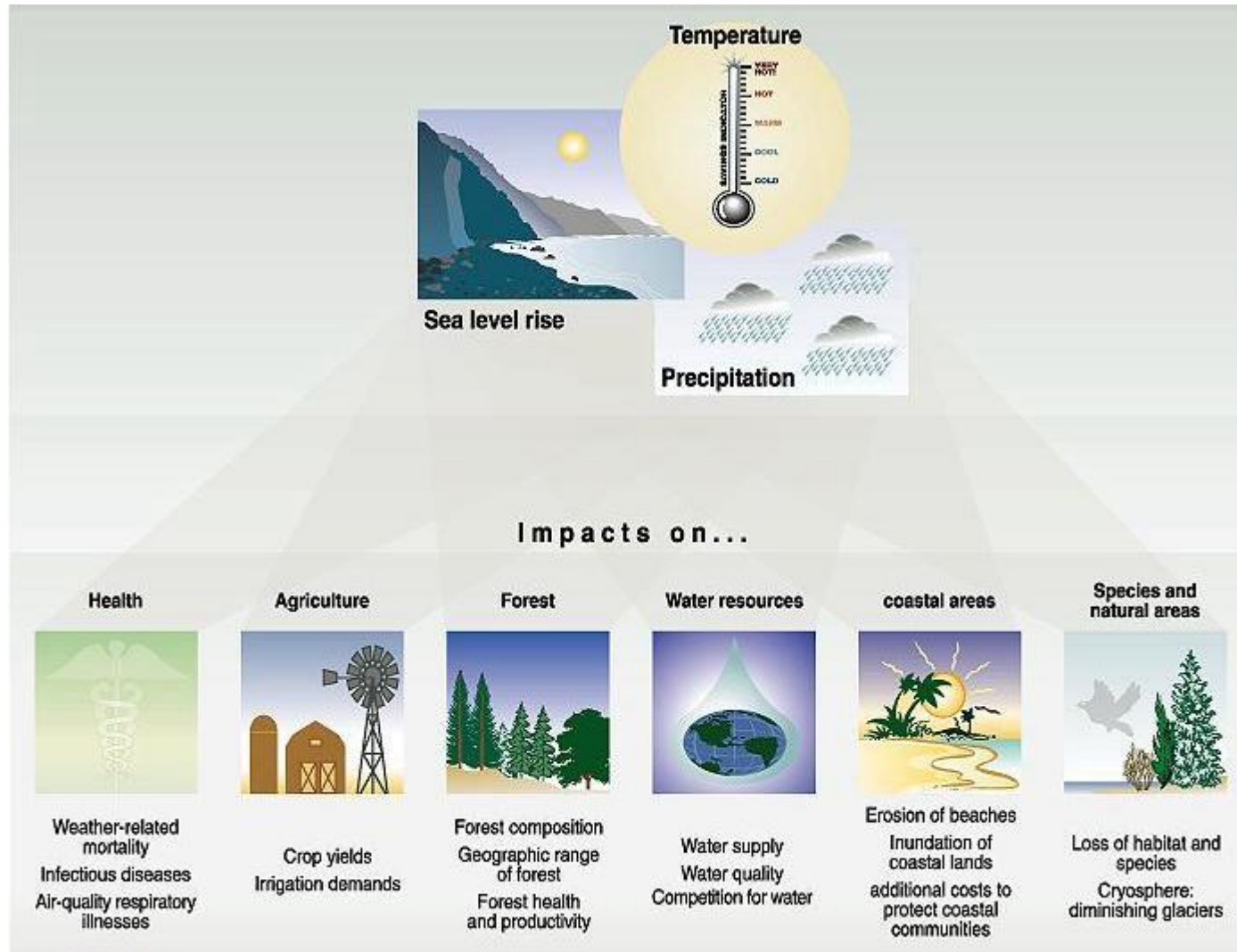
# Simulating Future Climate Change



Source: NOAA Geophysical Fluid Dynamics Laboratory



# Potential Climate Change Impacts



## Sea Level Rise







# Why Is Global Sea Level Rising?

- Thermal expansion of ocean

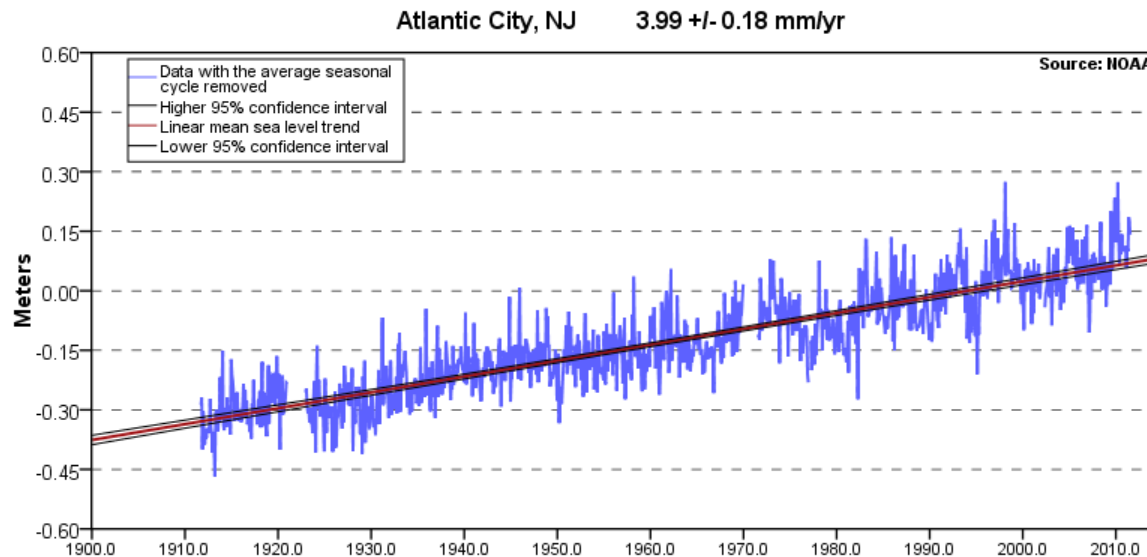
Warmer water is less dense than colder water.

- Melting of mountain glaciers and ice caps

Water released by the melting of ice on land adds to the volume of the oceans.

- Melting and calving of Greenland and Antarctic ice sheets

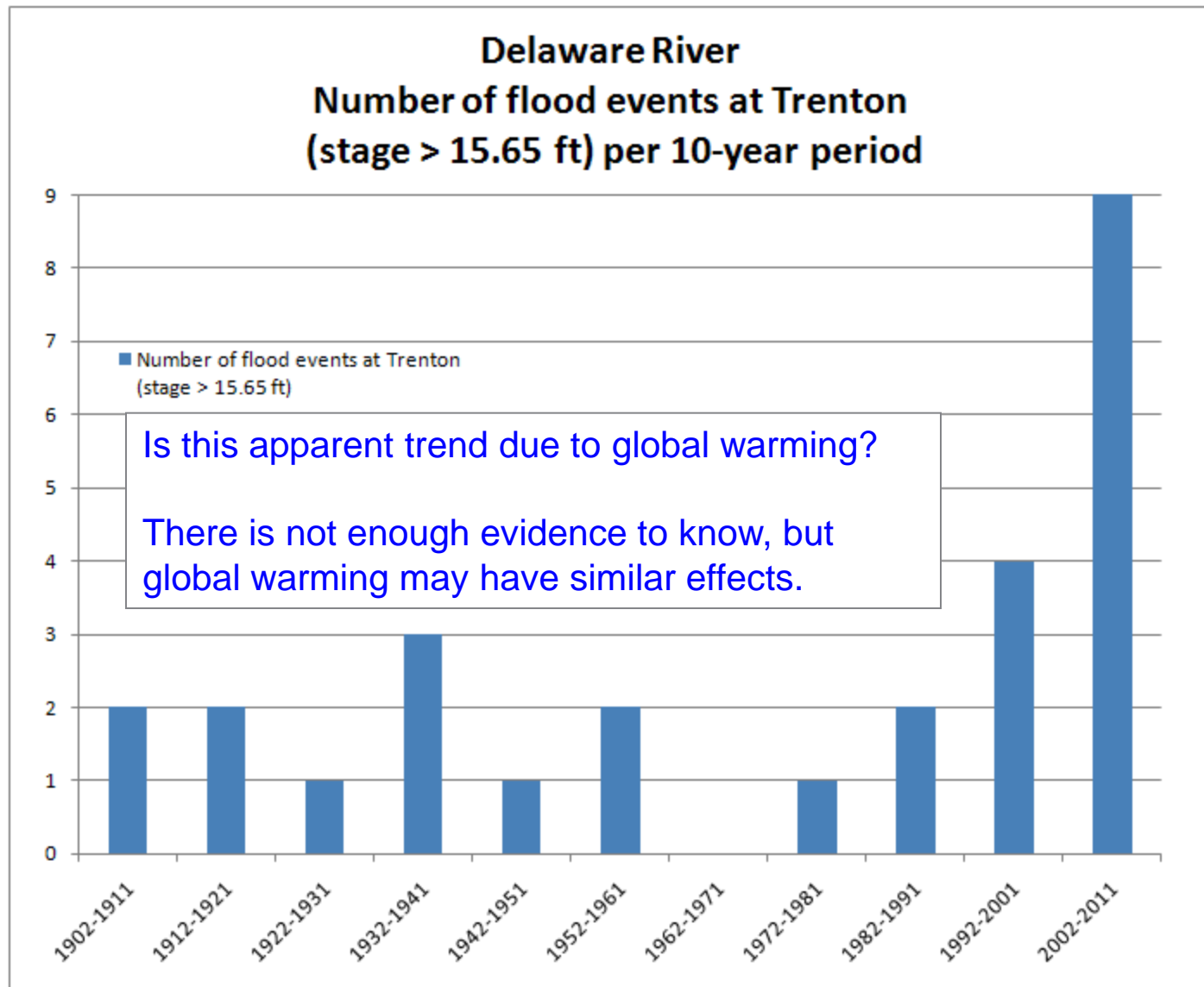
Depends on ice sheet dynamics (how the ice flows).





# Hydrologic Extremes





Source: U. S. Geological Survey, personal communication



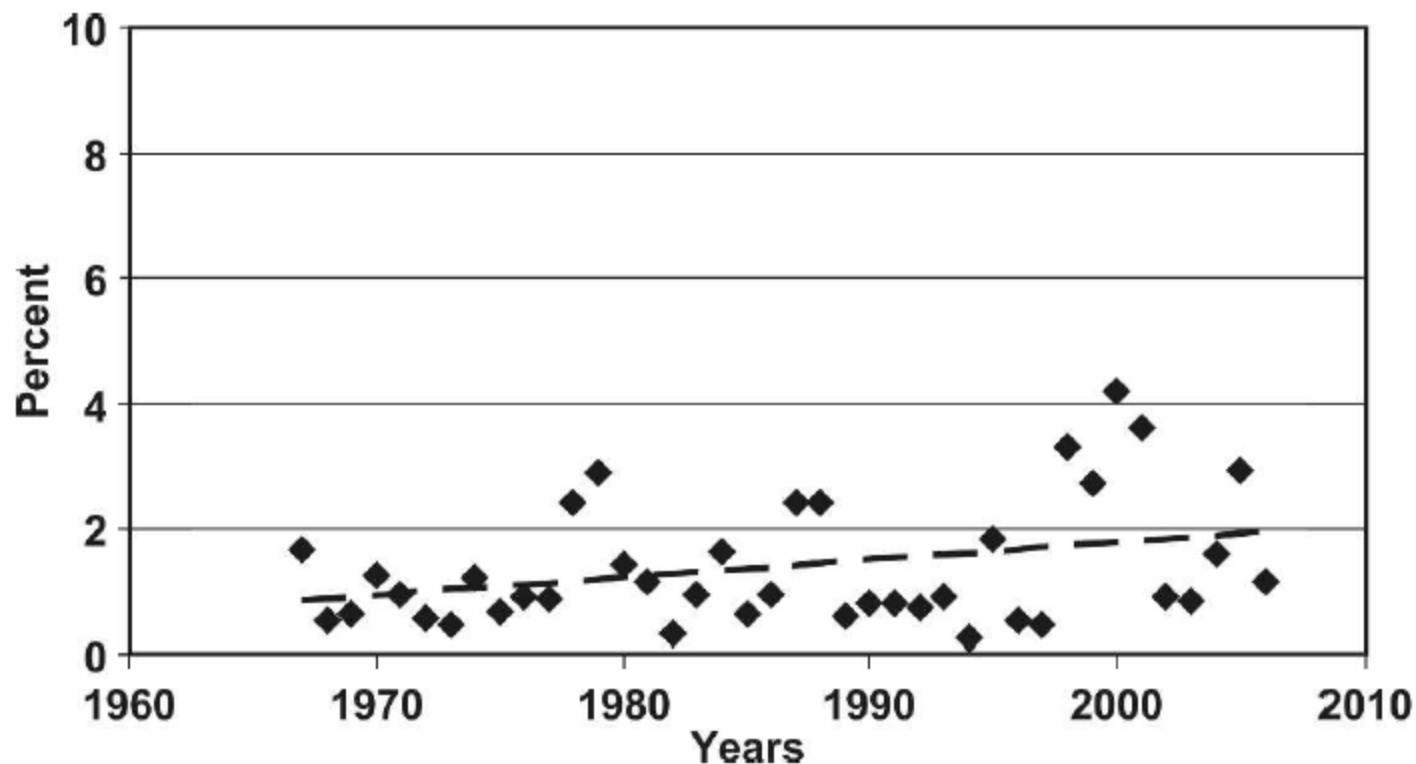
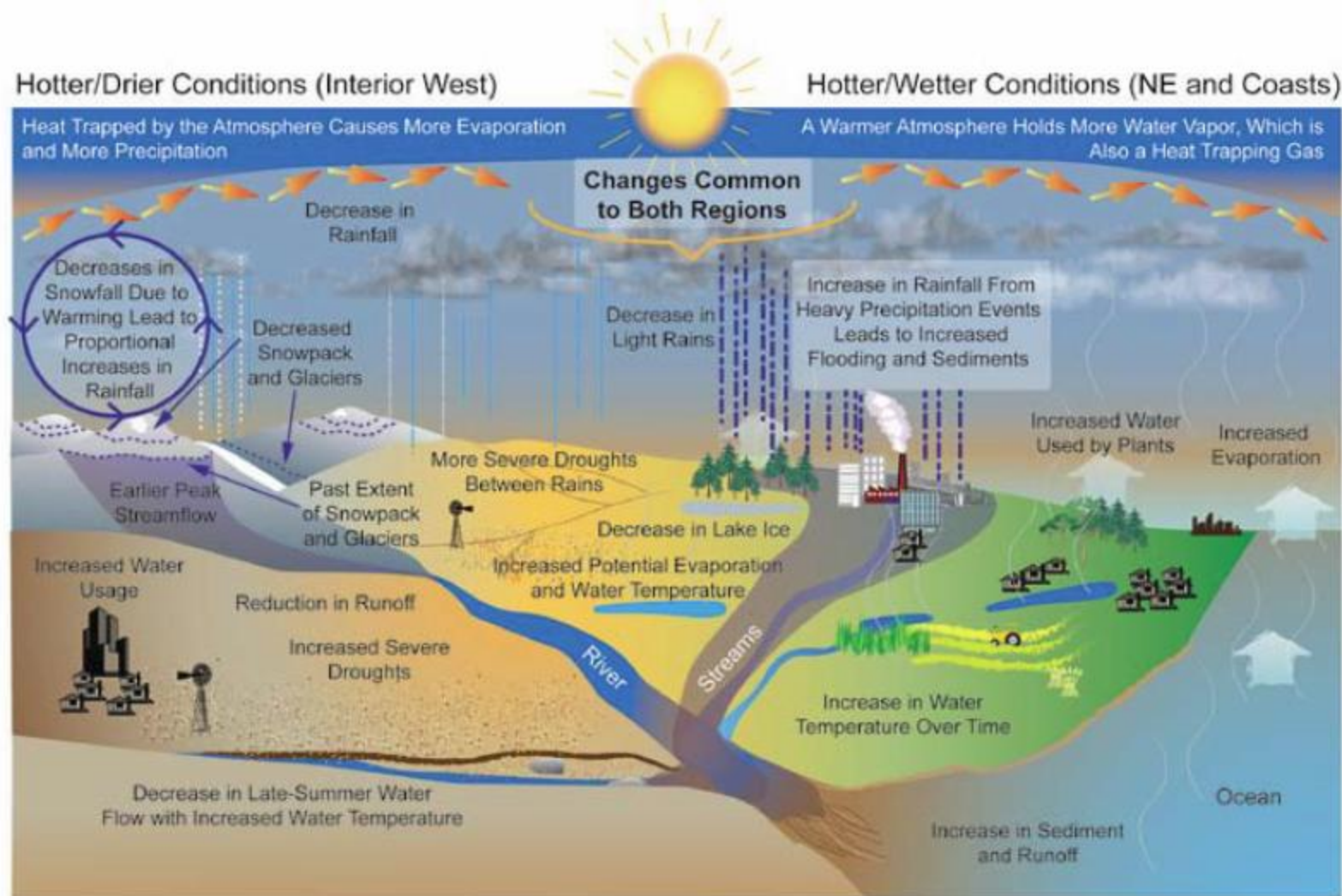


FIG. 4. Percentage of the dry day episodes with 1-month or longer duration during the warm season during the past 40 yr area averaged over the eastern United States. Linear trend (dashed line; 1.1% per 40 yr) is statistically significant at the 0.05 level.

Source: Groisman and Knight, *J. Climate*, 2008

## Projected Changes in the Water Cycle



The water cycle exhibits many changes as the Earth warms. Wet and dry areas respond differently.

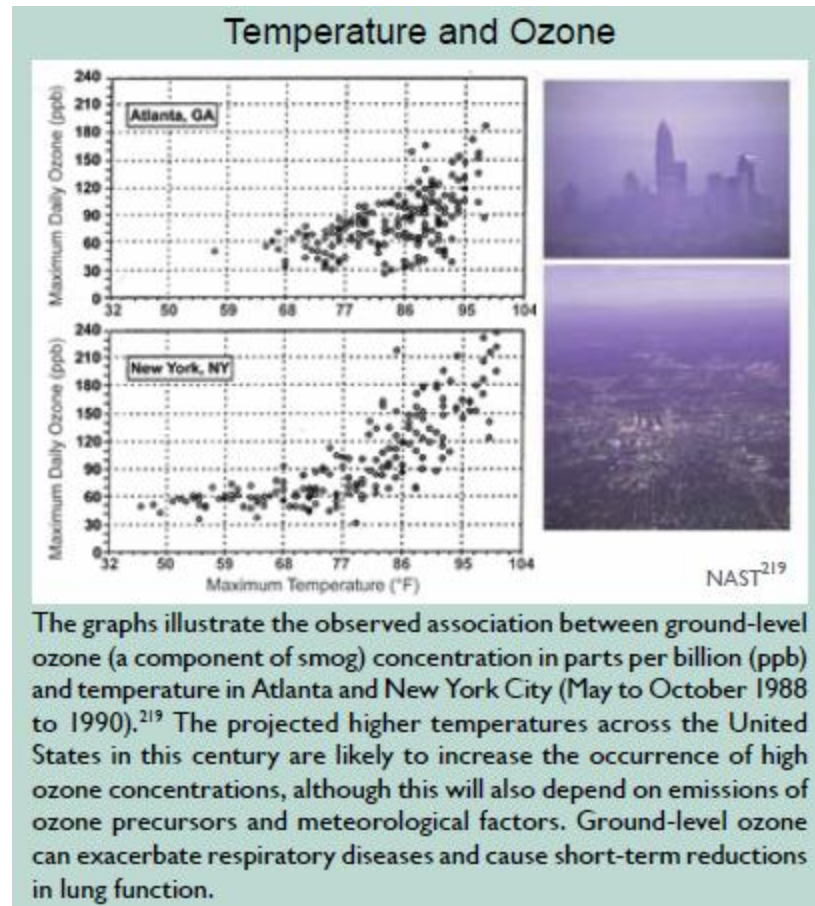
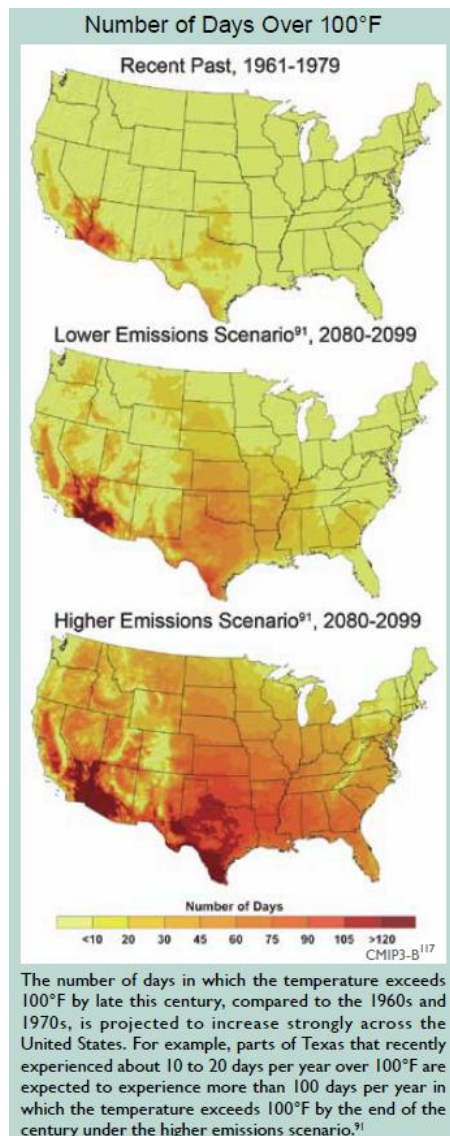
NOAA/NCDC

Source: U.S. Global Change Research Program

# Human Health





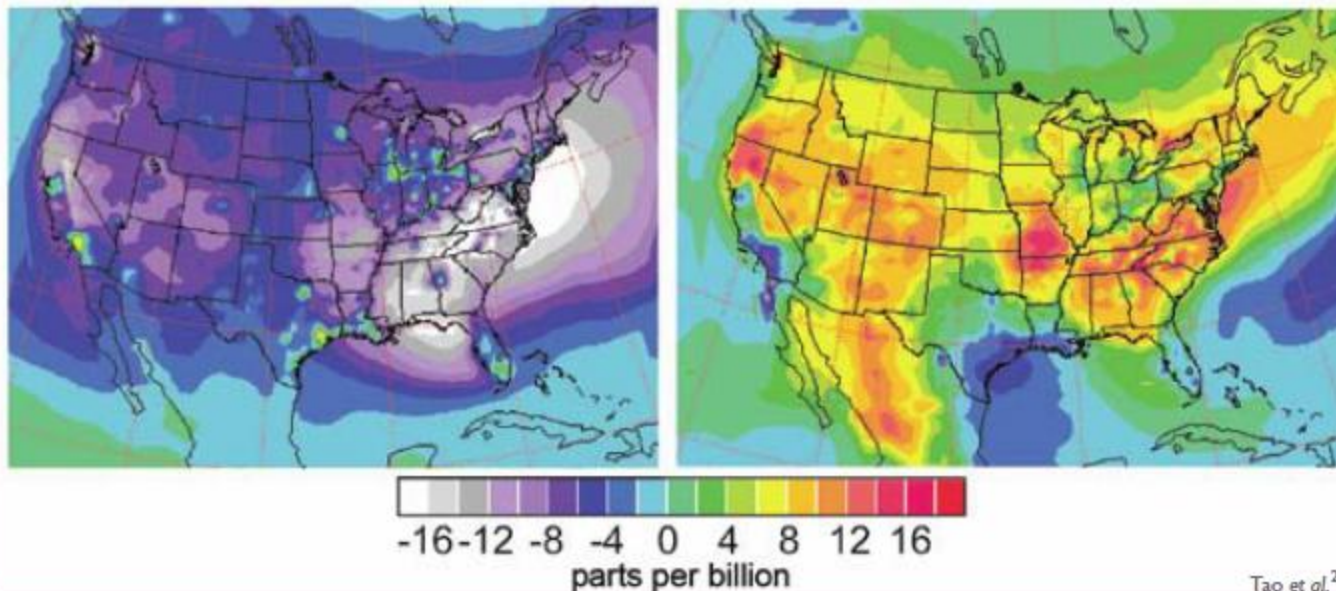




## Projected Change in Ground-Level Ozone, 2090s

### Lower Emissions Scenario<sup>91</sup>

### Higher Emissions Scenario<sup>91</sup>



Tao et al.<sup>291</sup>

The maps show projected changes in ground-level ozone (a component of smog) for the 2090s, averaged over the summer months (June through August), relative to 1996-2000, under lower and higher emissions scenarios, which include both greenhouse gases and emissions that lead to ozone formation (some of which decrease under the lower emissions scenario).<sup>91</sup> By themselves, higher temperatures and other projected climate changes would increase ozone levels under both scenarios. However, the maps indicate that future projections of ozone depend heavily on emissions, with the higher emissions scenario<sup>91</sup> increasing ozone by large amounts, while the lower emissions scenario<sup>91</sup> results in an overall decrease in ground-level ozone by the end of the century.<sup>291</sup>

# Agriculture





## Climate science efforts heat up at A.D. Makepeace in Wareham

Brook and bog sites are new testing grounds

Photos

 Zoom




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### Wicked Local Wareham

Posted Oct 28, 2011 @ 10:20 AM

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WAREHAM — Red Brook and Century Bog on the Wareham-Plymouth border are now home to research on climate change.

The brook and bog, which are owned by A.D. Makepeace, will be the testing grounds for experiments and new farming techniques to overcome the effects of climate change in Southeastern Massachusetts.

They will also help researchers learn how climate change will affect ecological restoration, and conservation, officials said.

A conference was held at Makepeace's Tihonet Village Market recently to address the future of conservation with state Sen. Marc Pacheco, D-Taunton, and researchers from the Manomet Center for Conservation Sciences, and the Mass. Department of Fish and Game.

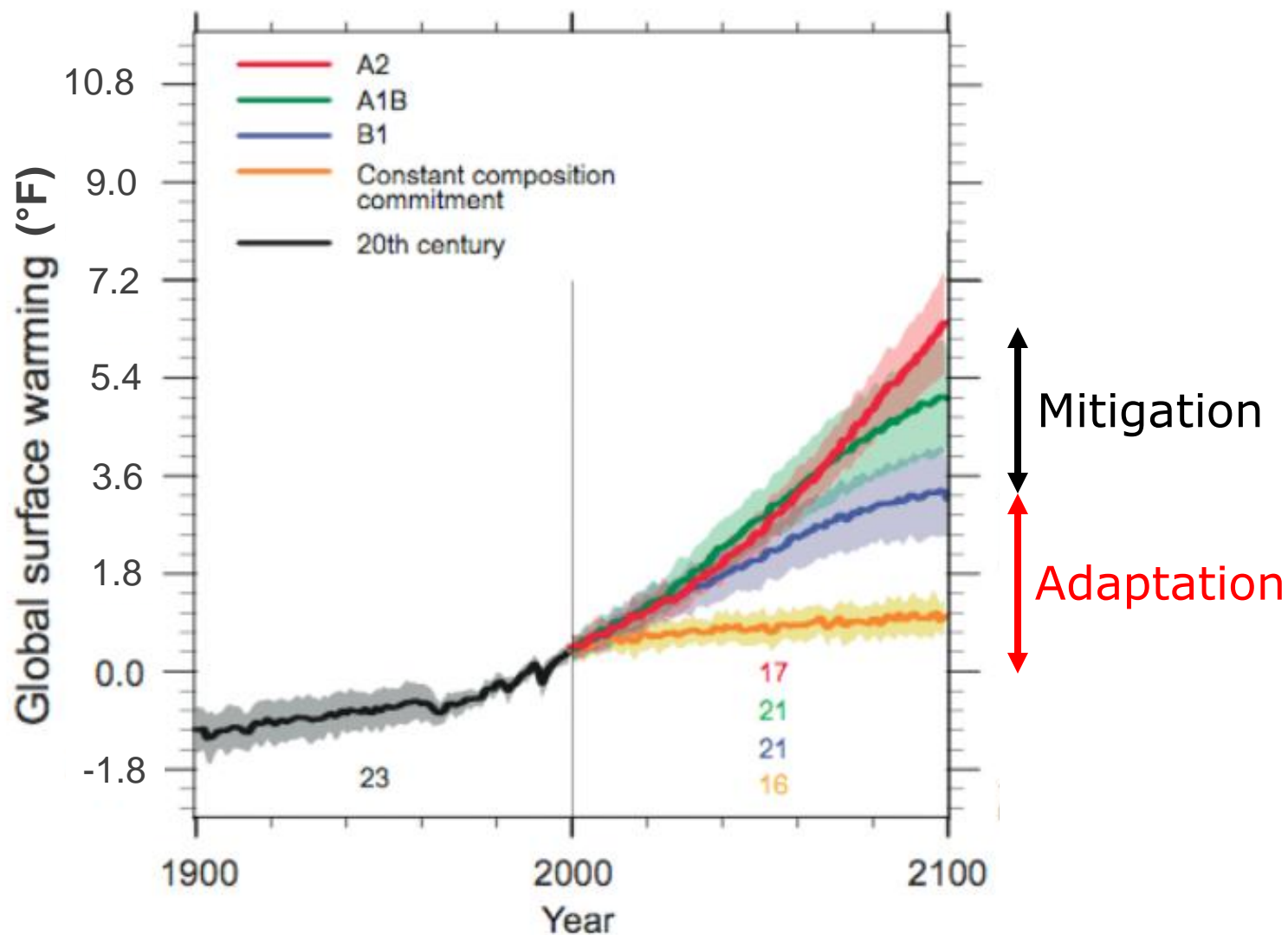
Hector Galbraith, from the Manomet Center for Conservation Sciences, said the research goal at Red Brook is to lead the way in addressing global warming. "Hopefully, Red Brook will be the source of inspiration for the rest of the country in five years," Galbraith said.

The climate is already changing in Massachusetts, according to data collected during the past 100 years. In the last 50 years the annual average temperature of the state has increased by about 1.6 degrees Fahrenheit, and the rate of warming has also accelerated, along with precipitation and rising sea levels, officials at the conference said. The sea levels are changing due to heat-induced expansion of the ocean water, and melting glaciers and icecaps, they said.

Pacheco said, "We are not talking about potential global warming and potential climate change. This is a reality, and it is here right now."

Source: Wareham Courier, Wareham, MA

## Adaptation vs. Mitigation: A False Choice







#### ADAPTATION TO CLIMATE CHANGE

## Time to Adapt to a Warming World, But Where's the Science?

With dangerous global warming seemingly inevitable, users of climate information—from water utilities to international aid workers—are turning to climate scientists for guidance. But usable knowledge is in short supply

ing.” More concisely, climatologist Bruce Hewitson of the University of Cape Town in South Africa said that a result is actionable science if you would spend your own money on it.

Behar said he finds the uncertainties surrounding actionable climate information “fairly overwhelming” these days. And he’s having trouble coming up with intermediaries between users and scientists who can at least put the uncertainties into perspec-

## Some challenges of adaptation planning

- “Actionable” science is needed—processed information that can be readily used by engineers, planners, decision makers.
- Spatial scales are mismatched—local information is desired for planning but climate projections are most valid on larger scales.
- Uncertainties will remain, requiring a risk assessment approach.
- Known unknowns: How will nor’easters, hurricanes, severe storms respond? Are there “tipping points” in the climate system?
- More effective communication between climate research community and potential users of climate information is required.