Climate Change and Variability in the Carolinas

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Department of Geography

cisa
carolinas integrated sciences & assessments

cisa

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CISA's Core Focus Areas:

- Drought
- Climate & Watershed Modeling
- Coastal Management
- Public Health
- Adaptation

CISA works to be a regional resource for a variety of stakeholders to incorporate climate information into water and coastal management, public health, and related decision making processes.

Partner Organizations:

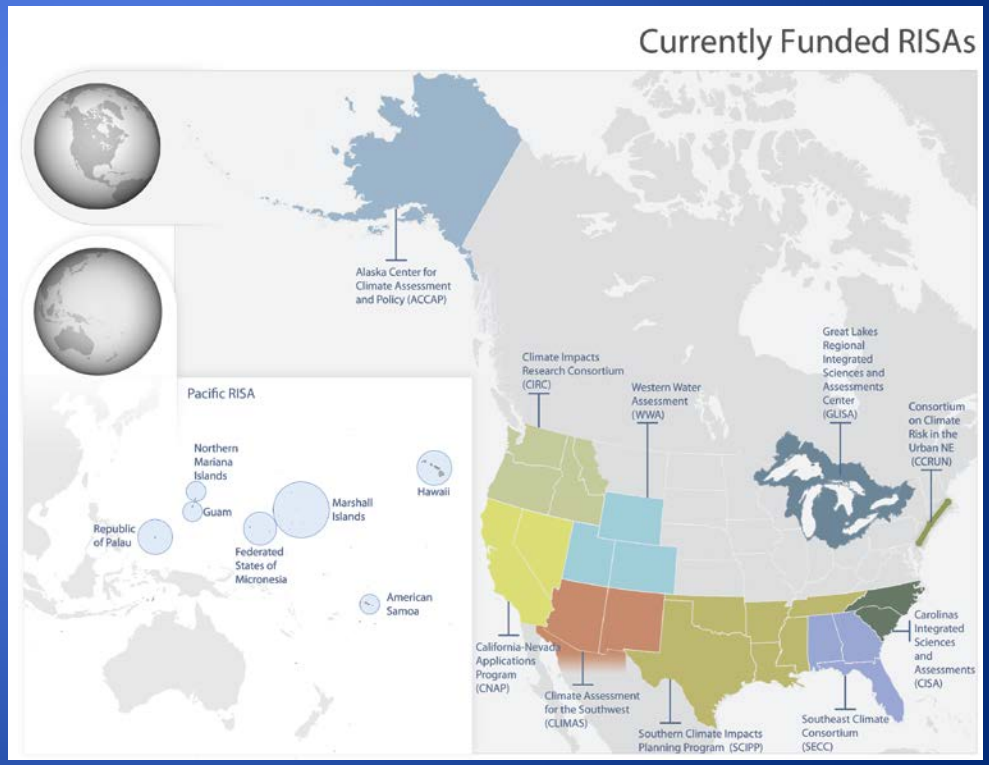
- Southeast Regional Climate Center
- NC Sea Grant
- SC Sea Grant Consortium
- NC & SC State Climate Offices
- Federal, State & Local Agencies
- Private Sector
- NGOs

Regional Integrated Sciences & Assessments

NOAA's RISA programs support research teams that help build the nation's capacity to prepare for and adapt to climate variability and change.

RISA teams work with public and private user communities to:

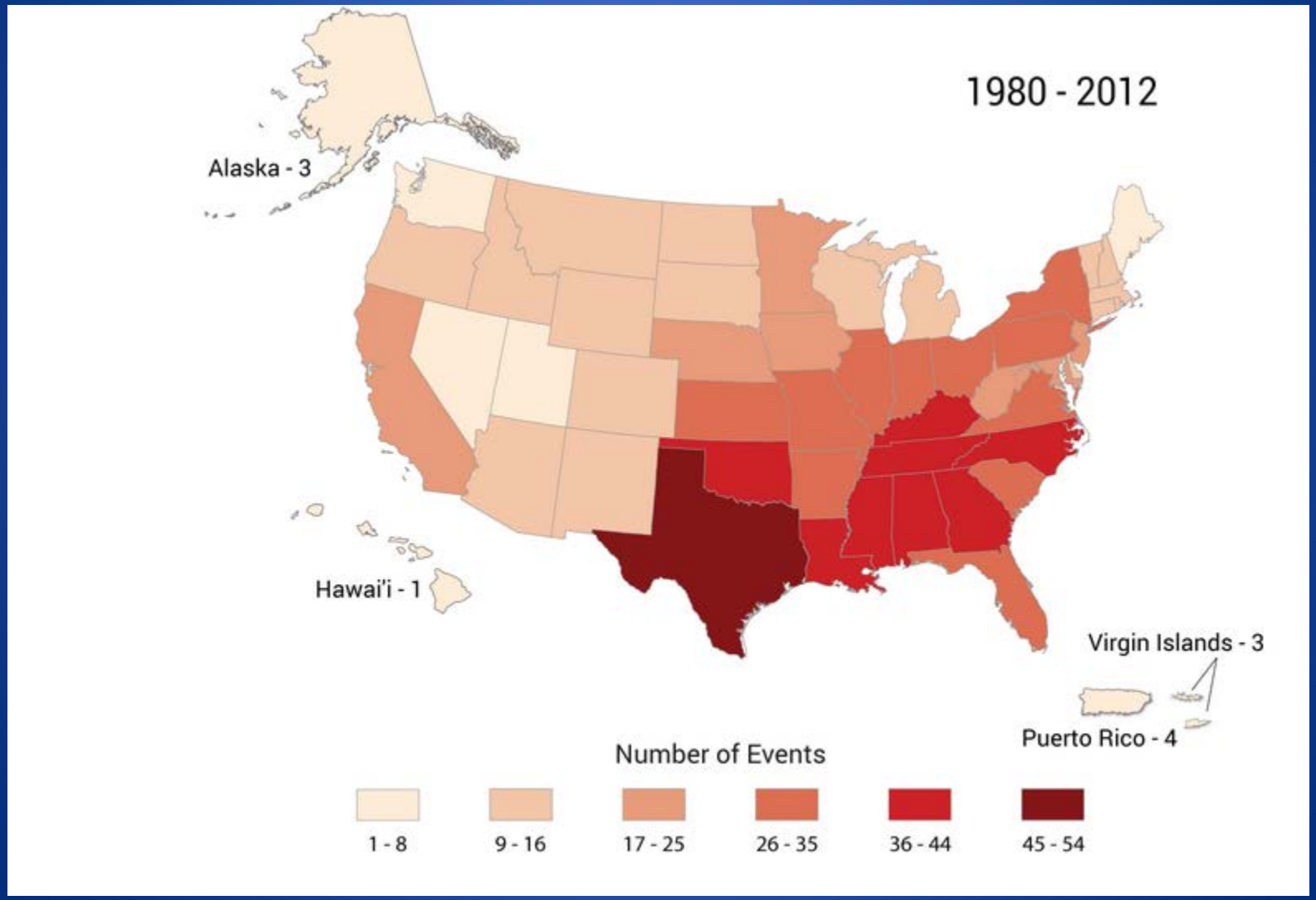
- Understand decision contexts
- Develop actionable knowledge
- Maintain diverse, flexible networks
- Innovate services to enhance the use of science in decision making



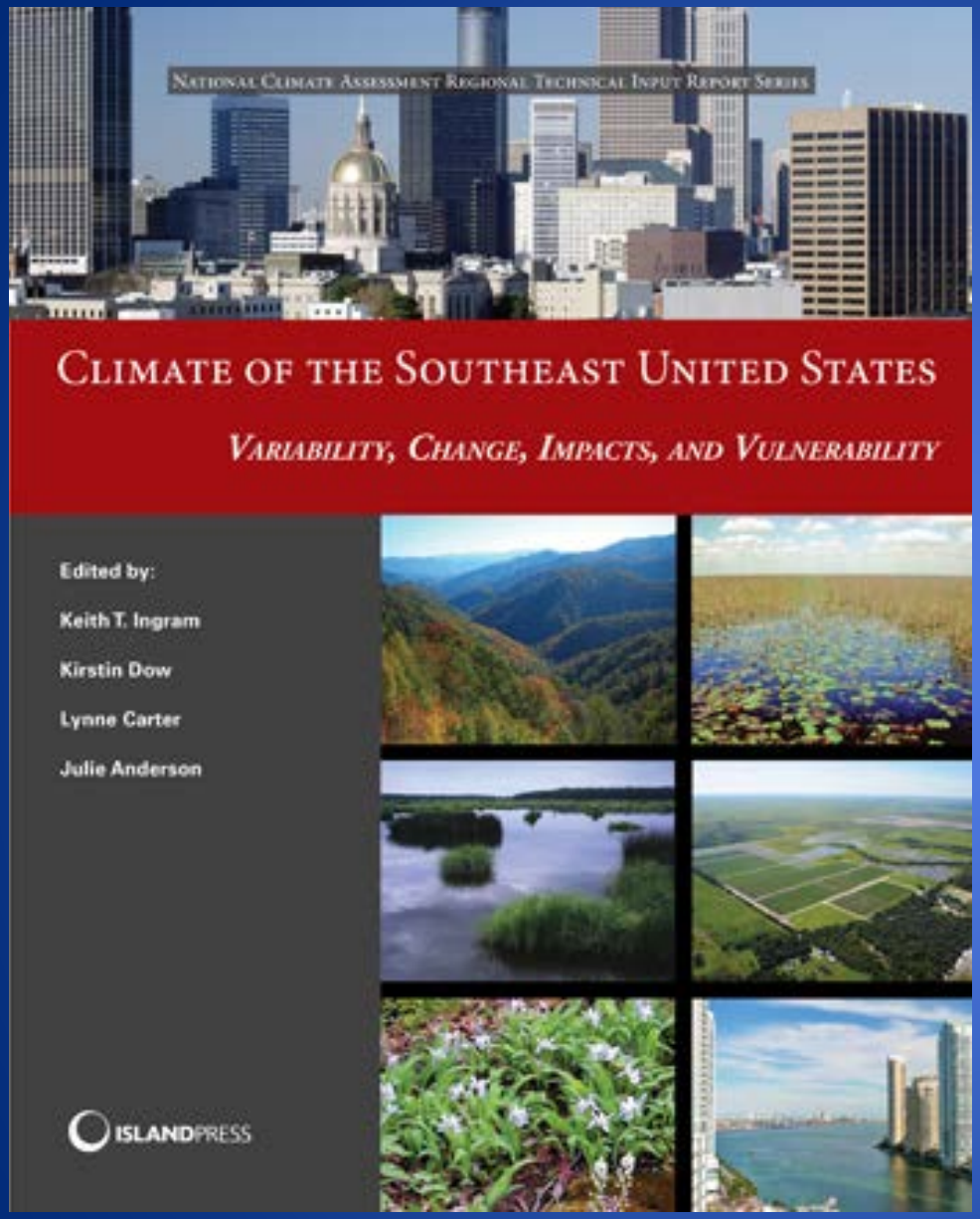
National Climate Assessment 2014

- Sea level rise poses widespread and continuing threats to the region's economy and environment.
- Extreme heat will affect health, energy, agriculture, and more.
- Decreased water availability will have economic and environmental impacts.

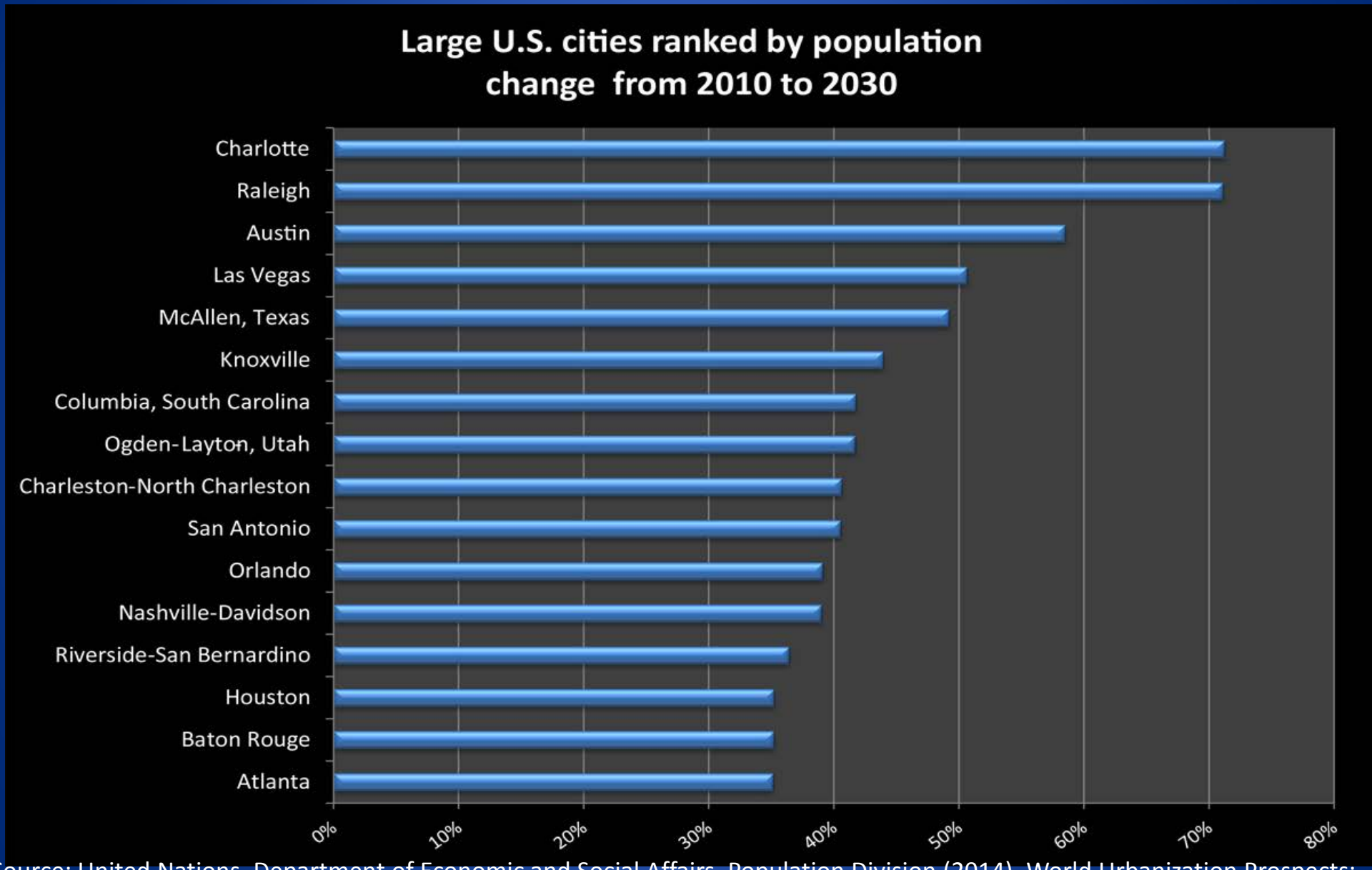
Billion Dollar Weather Disasters



- NC state. Ghost trees
- NCA search and SE themes
- Raleigh and Charlotte growth
- Energy water nexus


National Climate Assessment Regional Technical Input Report Series
Climate of the Southeast United States
Variability, Change, Impacts, and Vulnerability
Edited by:
Keith T. Ingram
Kirstin Dow
Lynne Carter
Julie Anderson
ISLANDPRESS

Raleigh and Charlotte Growth



Source: United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision.

Weather is what you get
Climate is what you expect – Mark Twain

Today: Progress in learning what to expect

Climate Change Means Changing…

Expectations based on current, historical, archaeological, and geologic records…

- Weather (Temp., Precip., storms, droughts)
- Water levels in rivers, oceans, and aquifers
- Melting snow, sea ice, permafrost, and glaciers
- Species ranges, communities, and life cycles
- Changes to human health, economy, security, natural hazards, agriculture, land use

Established Theory

Svante Arrhenius, Swedish scientist (1859-1927), in 1895 presented "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground."

Svante Arrhenius
Fotografi. 1893.

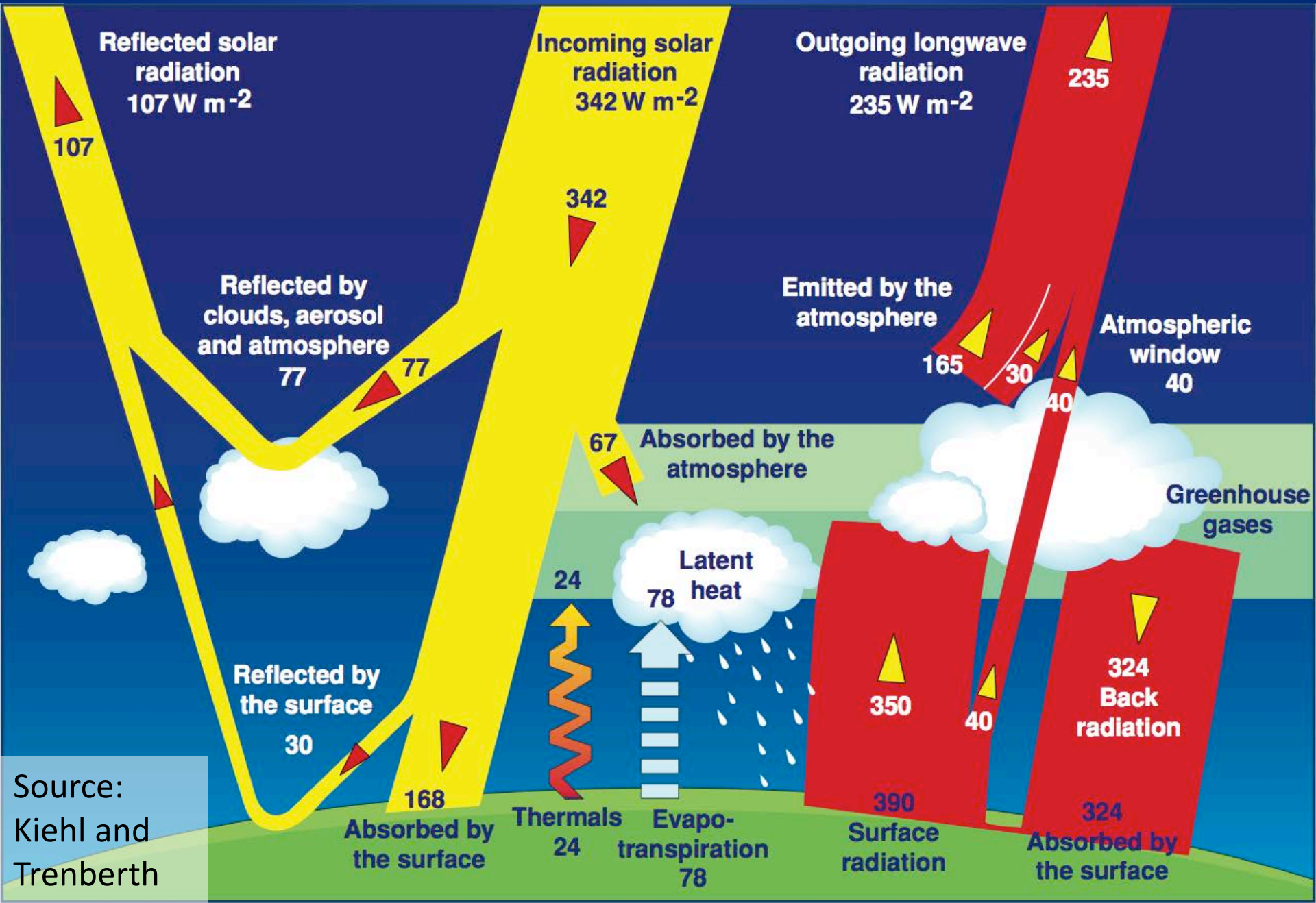
First presentation of the theory and calculations on the effect of carbon dioxide and other chemicals in the atmosphere on the heat budget of the Earth

STOCKHOLM. Strandvägen.

ÄKTA FOTOGRAFI

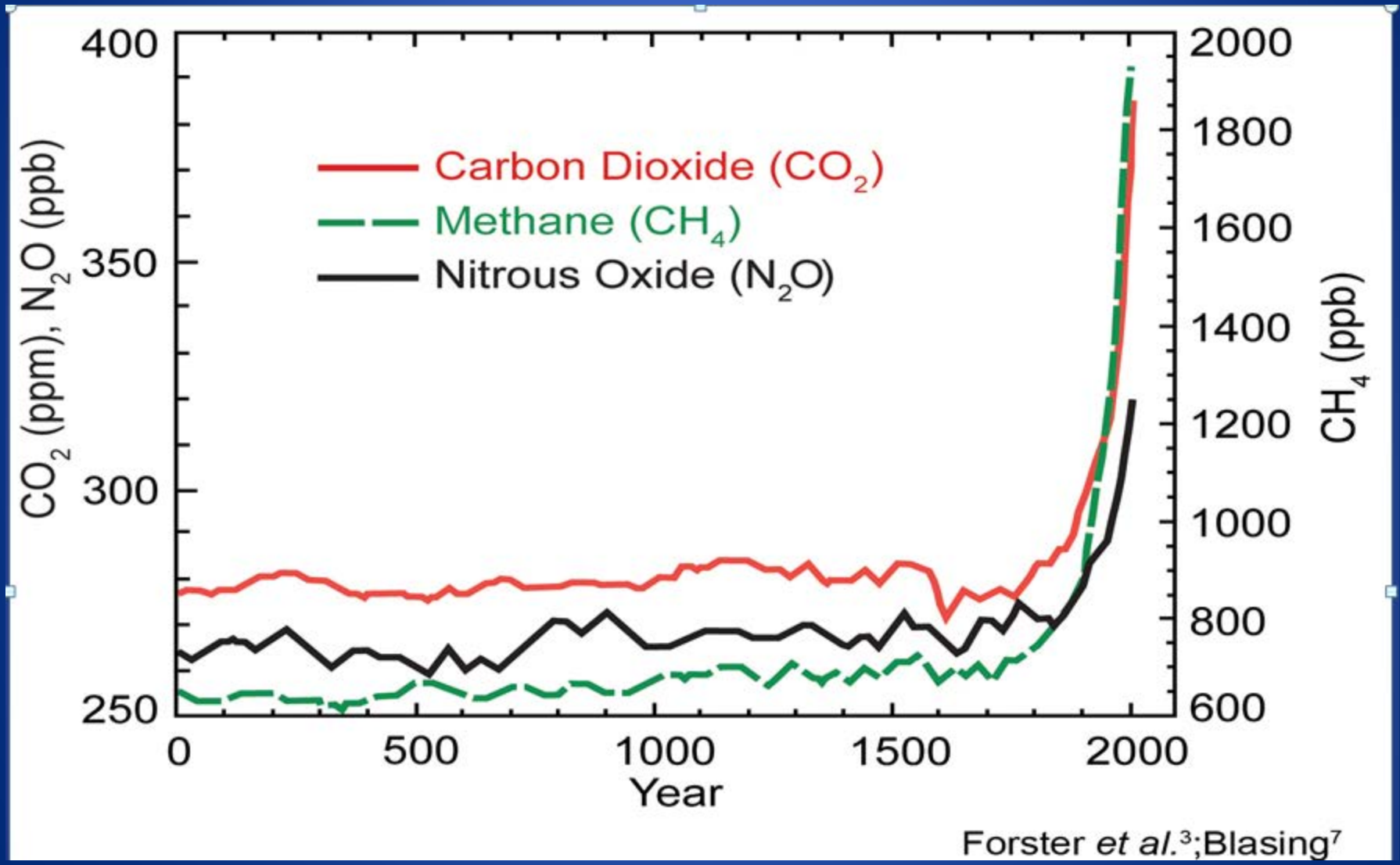
FÖRLAG NORDISK KONST STOCKHOLM

Measurements of the Earth's Radiation Budget

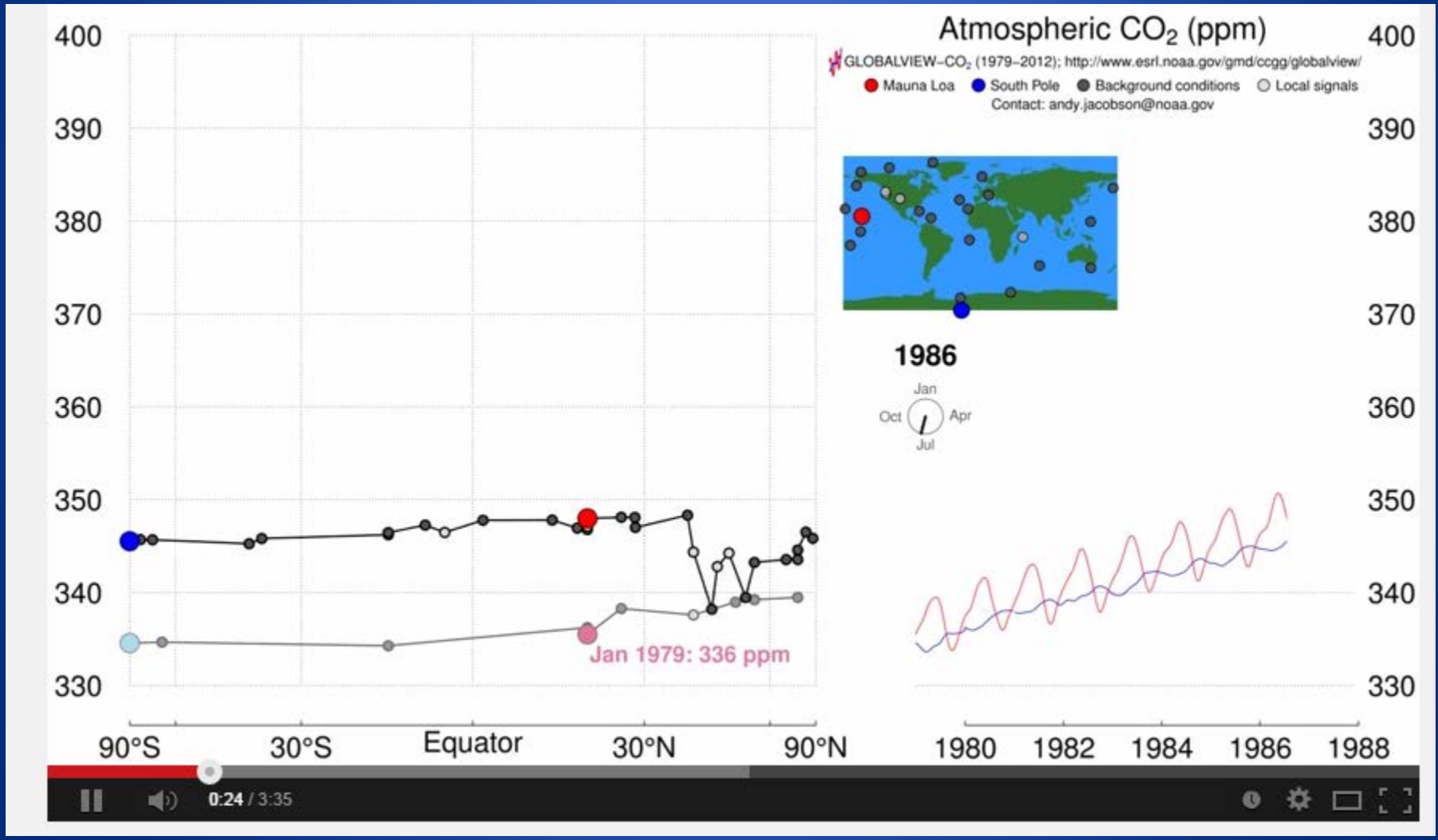


Source: Kiehl and Trenberth

Measurements of Greehouse Gases



In the context of planetary and human history

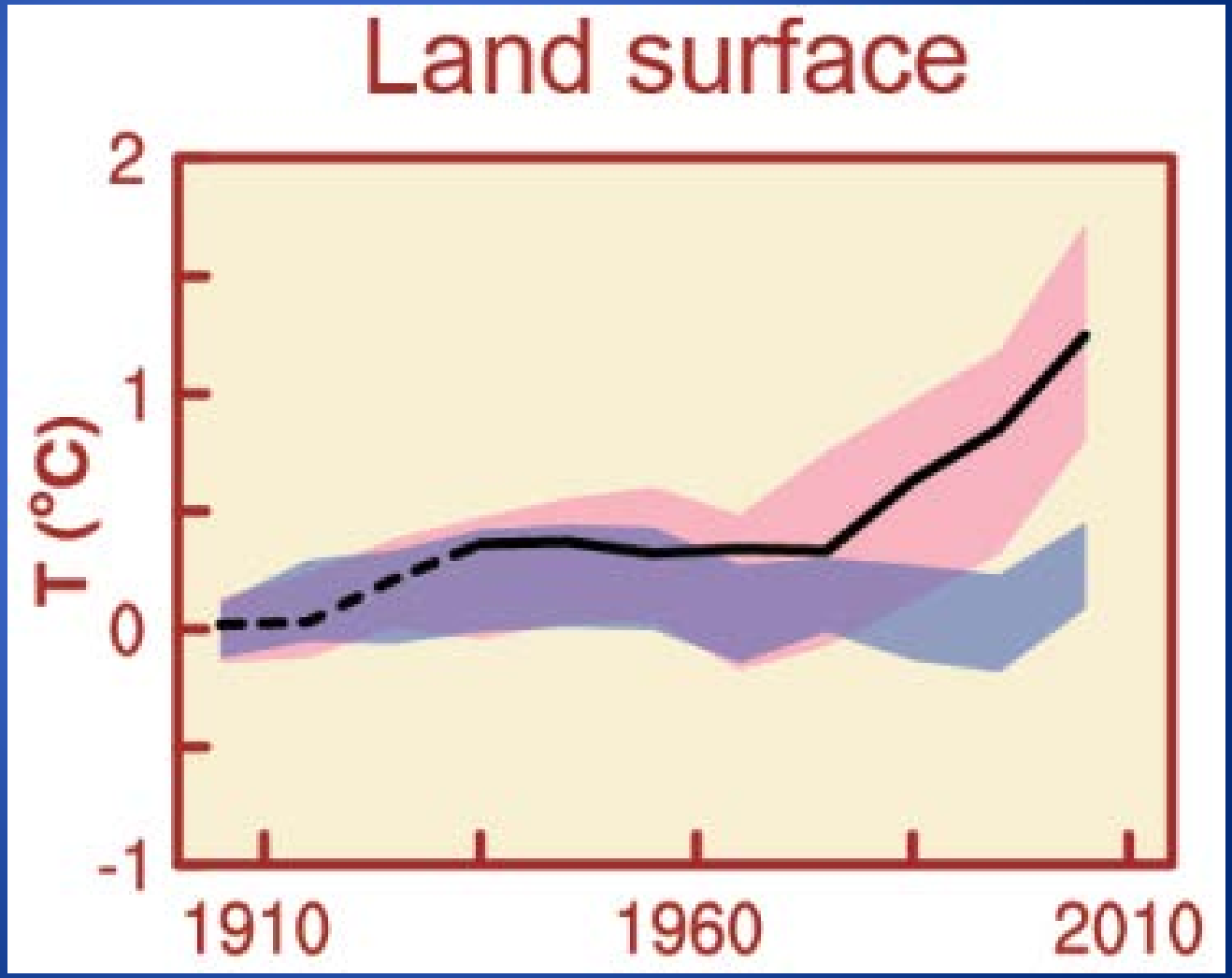


Models require greenhouse gas inputs to replicate observed changes

Temperature change relative to 1880-1919

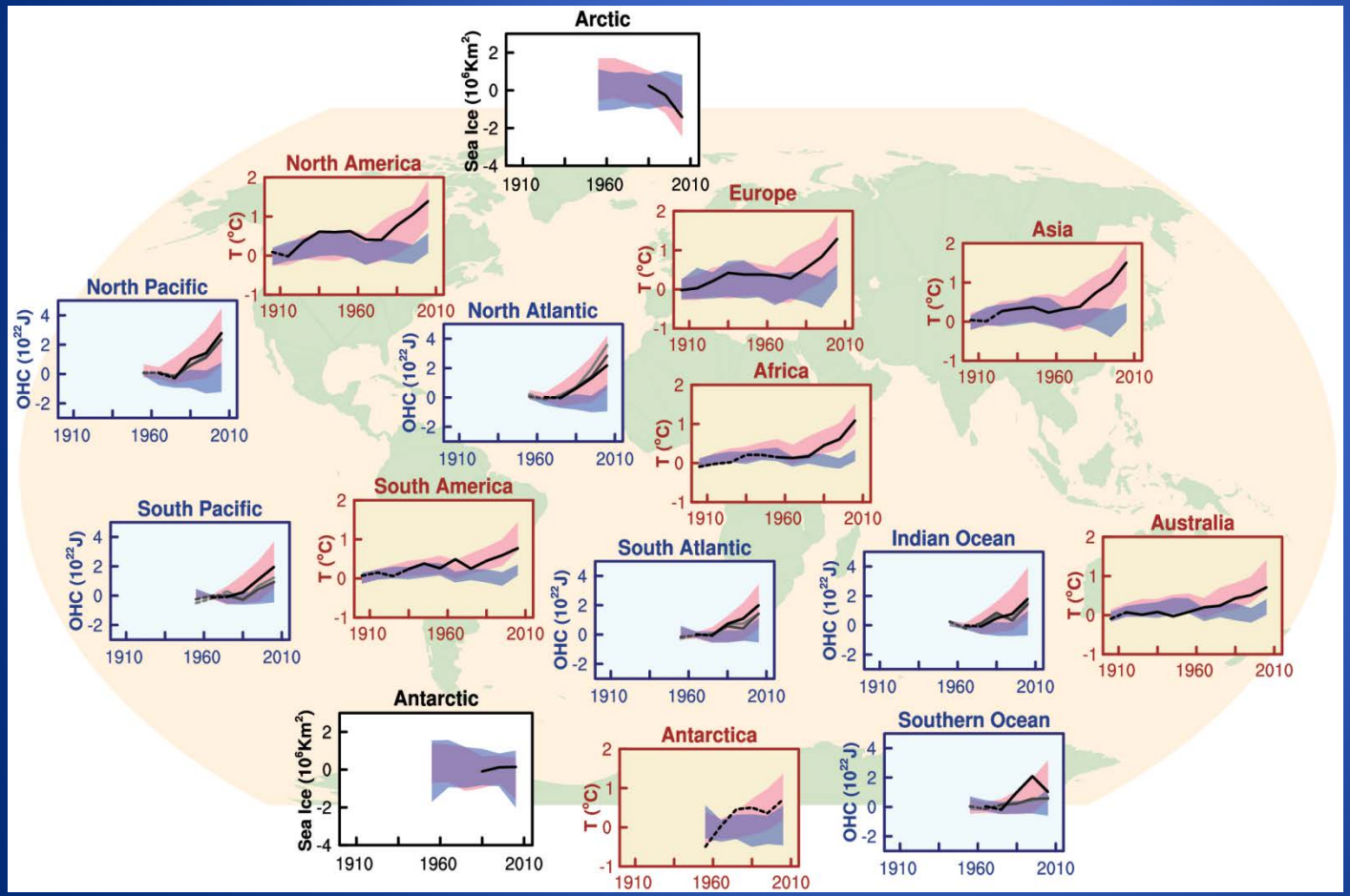
Models using Natural Forcings

Models using Natural & Human Forcings



IPCC 2013 SPM fig 6

Same relationship holds at the regional level
Gives some confidence in the models



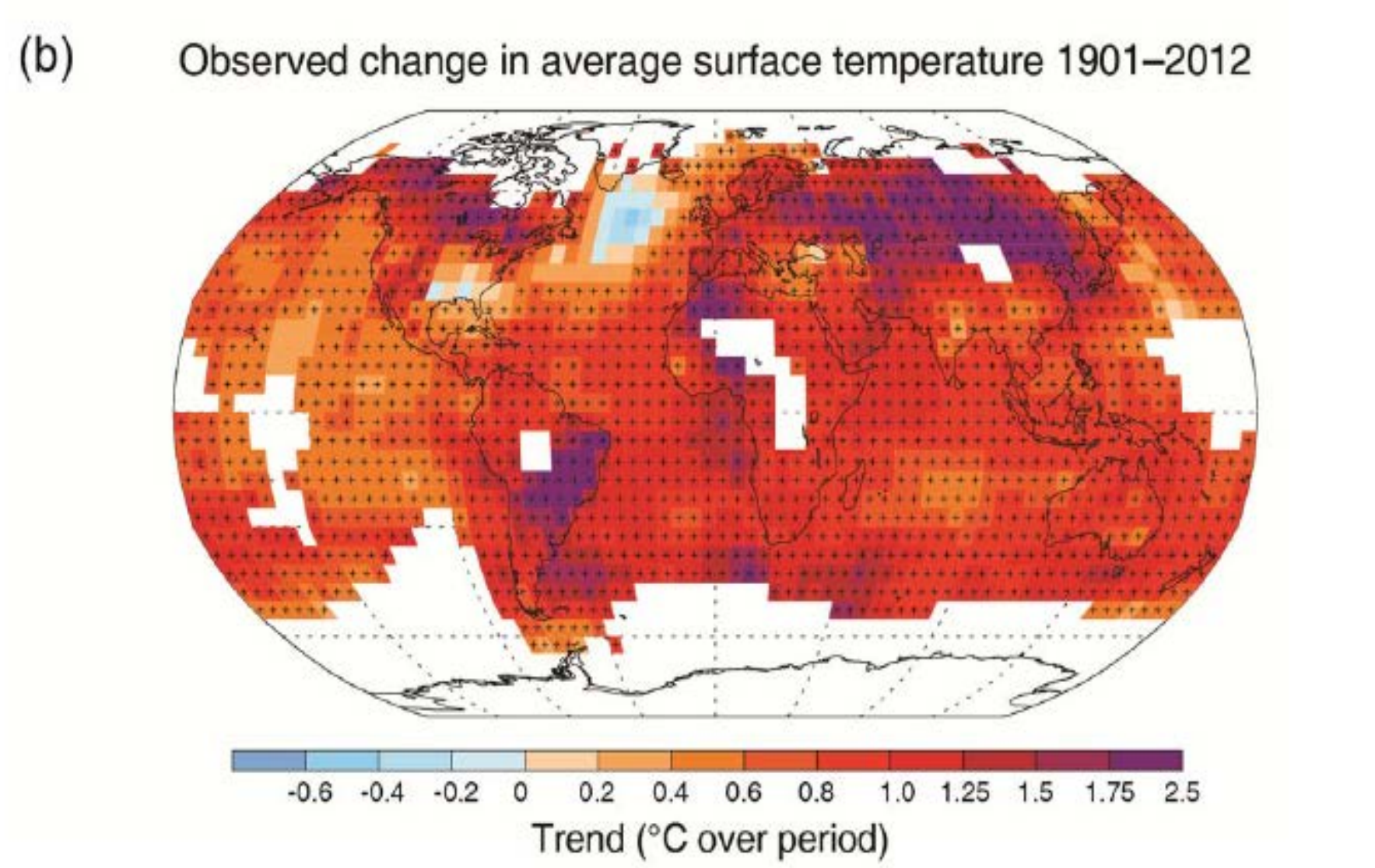
Temperature change
(Artic – sea ice area)

Models using Natural Forcings

Models using Natural & Human Forcings

IPCC 2013 SPM fig 6

Observations are consistent with theory

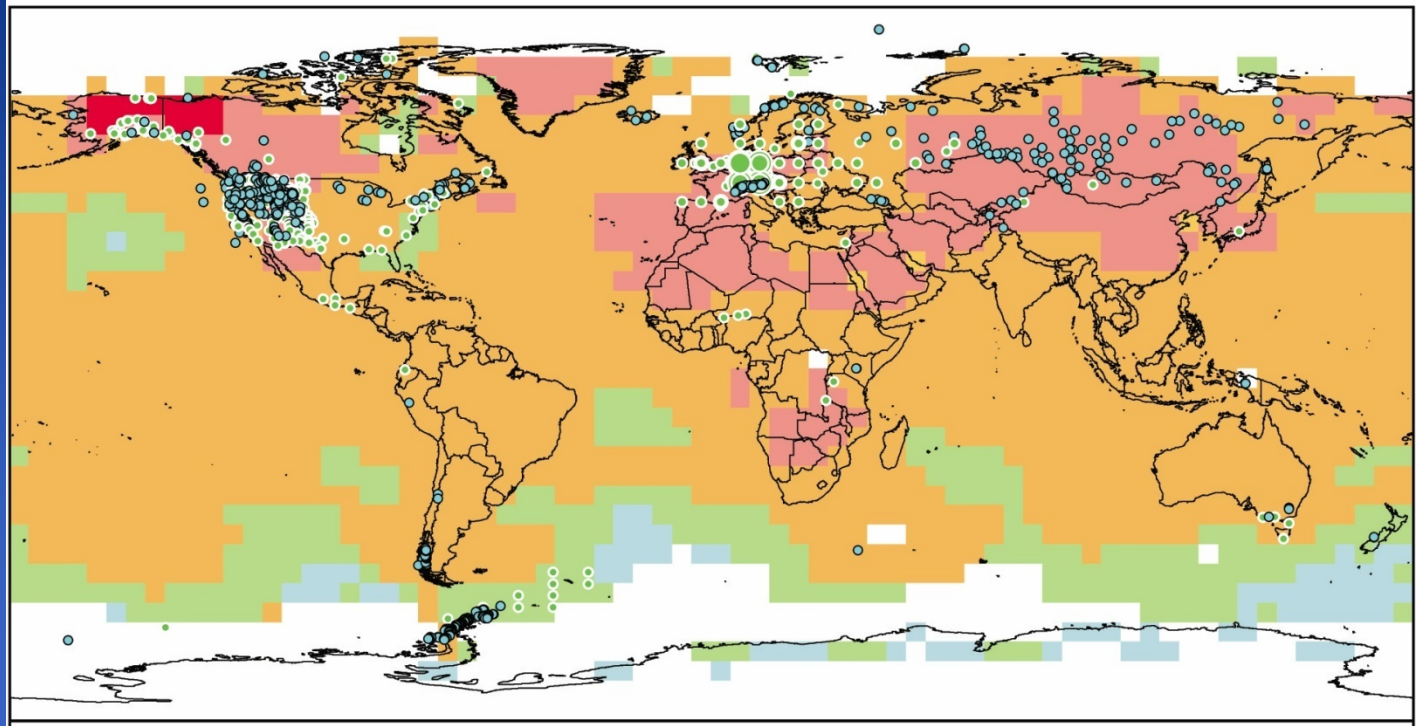


IPCC, 2013; Working Group 1, Figure 3.9 Summary for Policy Makers

Climate changes are being observed

- Temperature
- Physical systems
- Biological systems

- Source: IPCC 2007 Working Group 2, Summary for Policy Makers



NAM	LA	EUR (28,115)	AFR	AS	ANZ	PR*	TER (28,586)	MFW**	GLO (28,671)
355 455	53 5	119	5 2	106 8	6 0	120 24	764	1 85	765
94% 92%	98% 100%	94% 89%	100% 100%	96% 100%	100% –	91% 100%	94% 90%	100% 99%	94% 90%

Observations
- Physical systems (snow, ice and frozen ground; hydrology; coastal processes)
- Biological systems (terrestrial, marine, and freshwater)

Europe ***	
○	1-30
○	31-100
○	101-800
○	801-1200
○	1201 -7500

Temperature change °C
1970-2004
-1.0 -0.2 0.2 1.0 2.0 3.5

Physical	Biological
Number of significant observed changes	Number of significant observed changes
Percentage of significant changes consistent with warming	Percentage of significant changes consistent with warming

* Polar regions include also observed changes in marine and freshwater biological systems.
** Marine and freshwater includes observed changes at sites and large areas in oceans, small islands and continents.
*** Circles in Europe represent 1 to 7,500 data series.

Climate changes are being obs

- Ter
- Phy syst
- Bio syst

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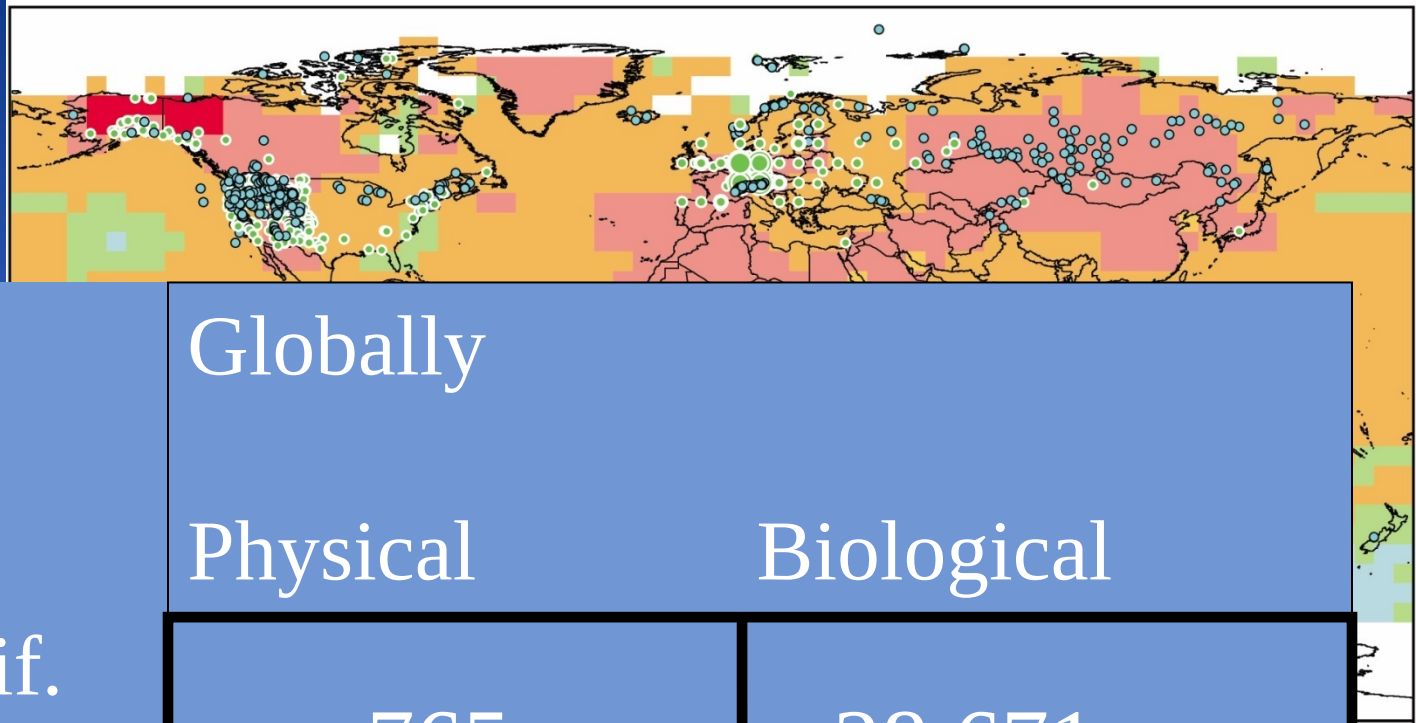

	Globally	
	Physical	Biological
# of signif. observed changes	765	28,671
% consistent with warming	94%	90%

1201 -7500

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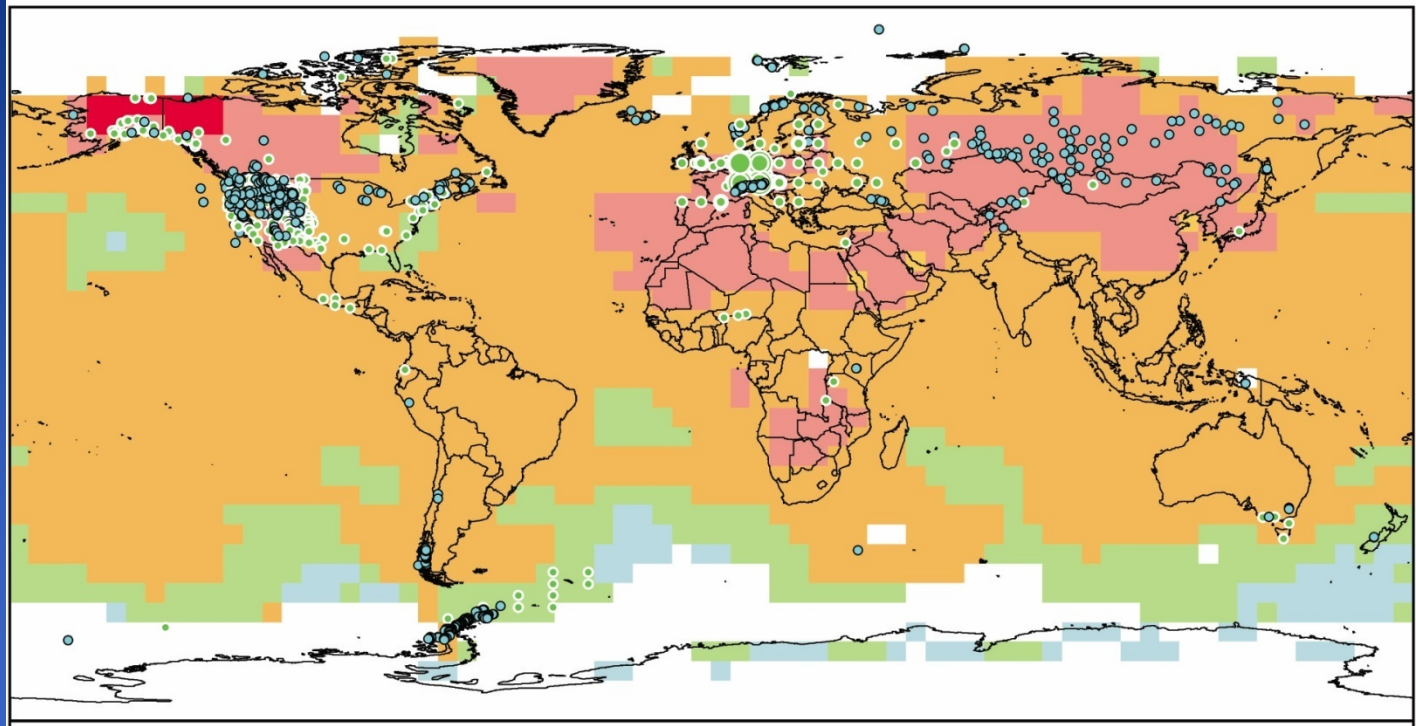
- Source: IPCC 2007 Working Group 2, Summary for Policy Makers



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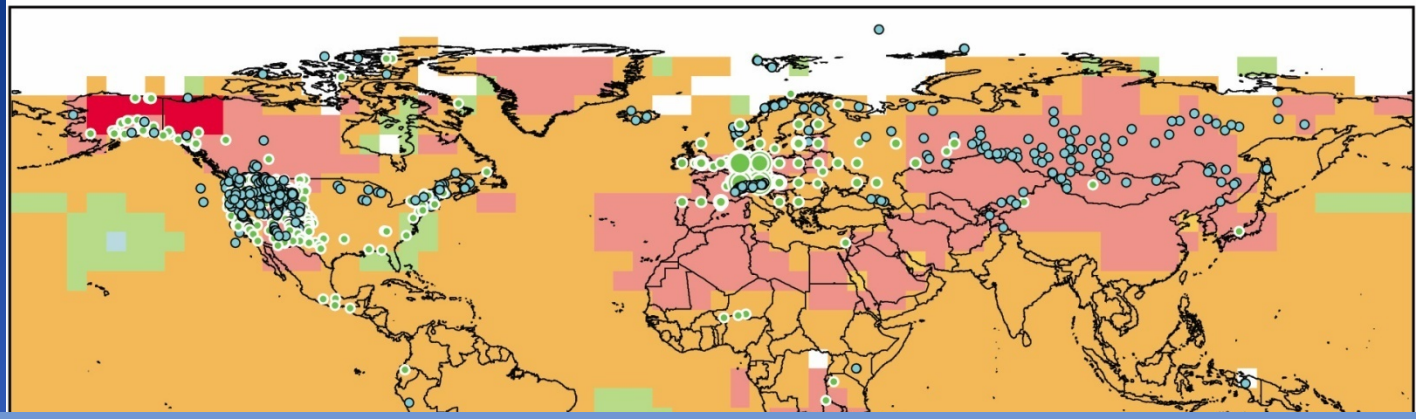
Climate changes are being observed



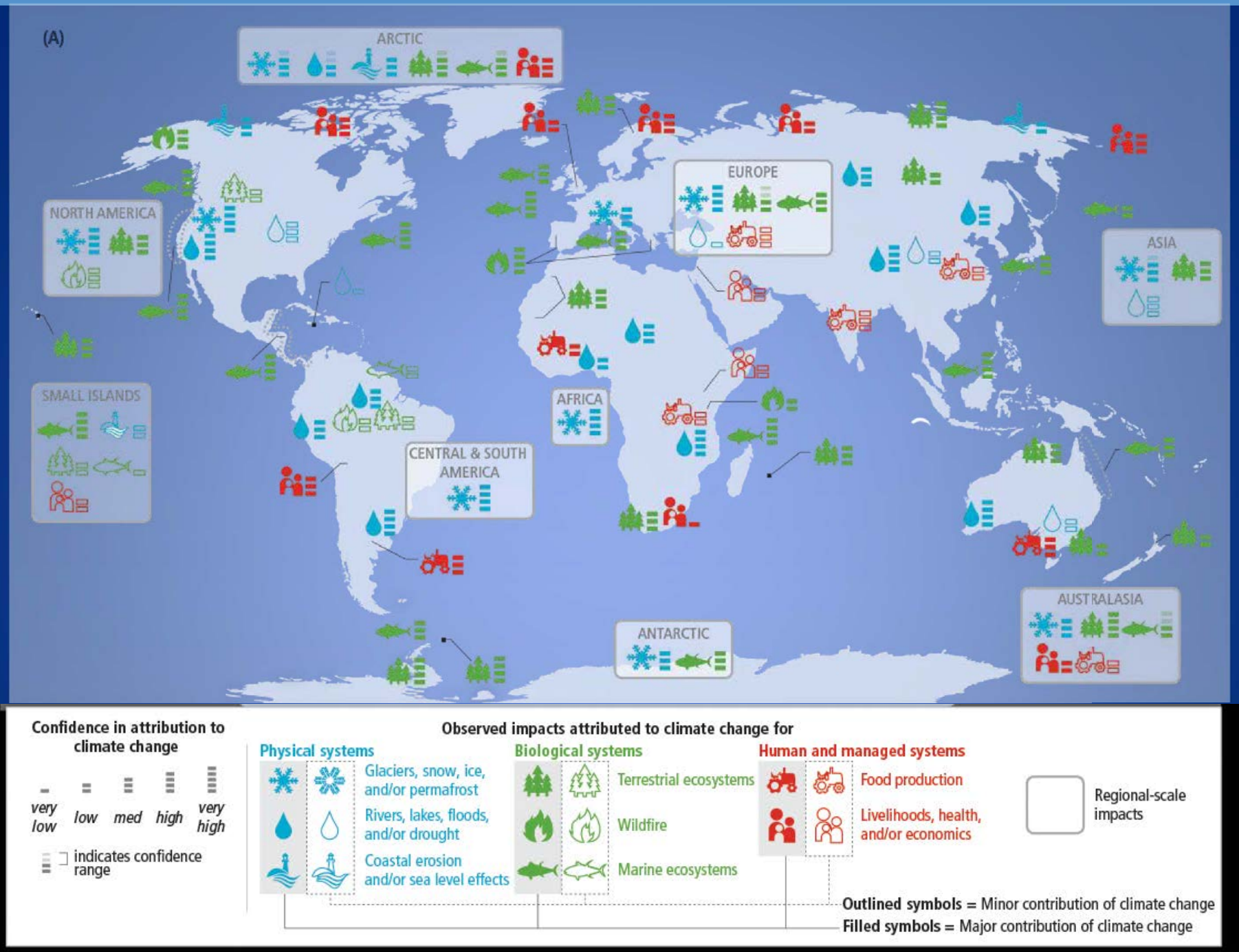
- Temp
- Phys syster
- Biolo syster

- Source: I Working G Summary Makers

North America

	Physical	Biological
# of signif. observed changes	355	455
% consistent with warming	94%	92%

Circles in Europe represent 1 to 7,500 data series.



IPCC 2014; WG2 SPM

Increased flooding: $200 million in flood control underway in C'ton

Kayaking through the Charleston City Market, August 28, 2012

Sea Level Rise and Cypress

Source: FWS

3 Lines of Evidence

1. **The fundamental process is well established**
2. **Climate models show some ability to replicate observations indicating they are capable of representing some processes**
3. **Observations of many impacts are consistent with theory**

Other Connections

Protecting the Lincoln Reflection Pond

estimate approximately $7 million

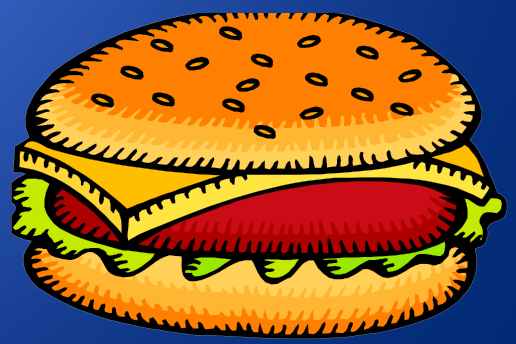
Source:blog.recovery.gov

Western Drought and Beef Prices

"Beef prices hit all-time high in U.S."

8 April 2014 LA Times

- October 2013 McDonald's Dollar Menu becomes a "Dollar Menu & More"
- January 2013 Wendy's "Dollar Menu" be came the "right price, right size"



Vulnerability of global supply chains

"Thailand Flooding Cripples Hard-Drive Suppliers"
***New York Times*; 6 November 2011**

Anticipated 10% increase in consumer prices
Slow down in Honda and Toyota car production

WIDESPREAD OBSERVED IMPACTS

A CHANGING WORLD

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WIDESPREAD OBSERVED IMPACTS

A CHANGING WORLD

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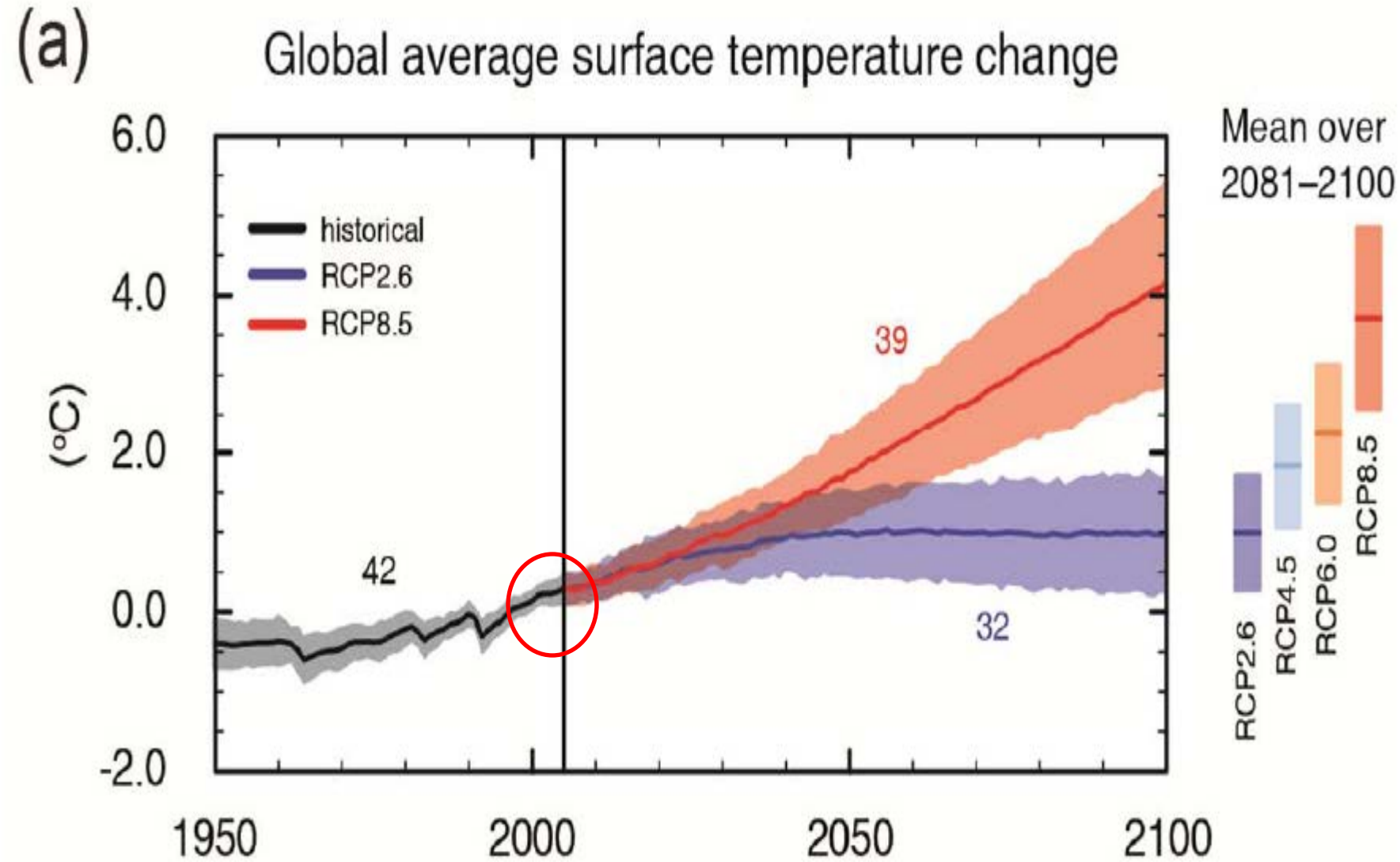
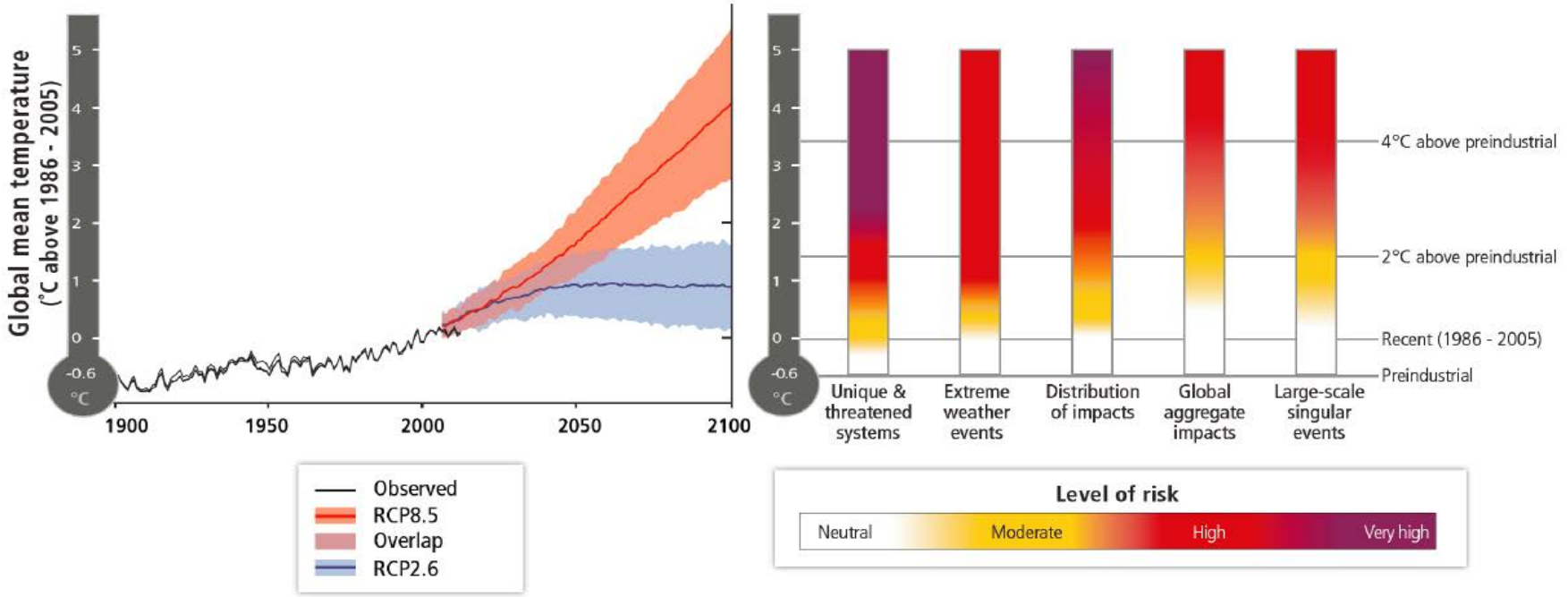
INTERGOVERNMENTAL PANEL ON climate change

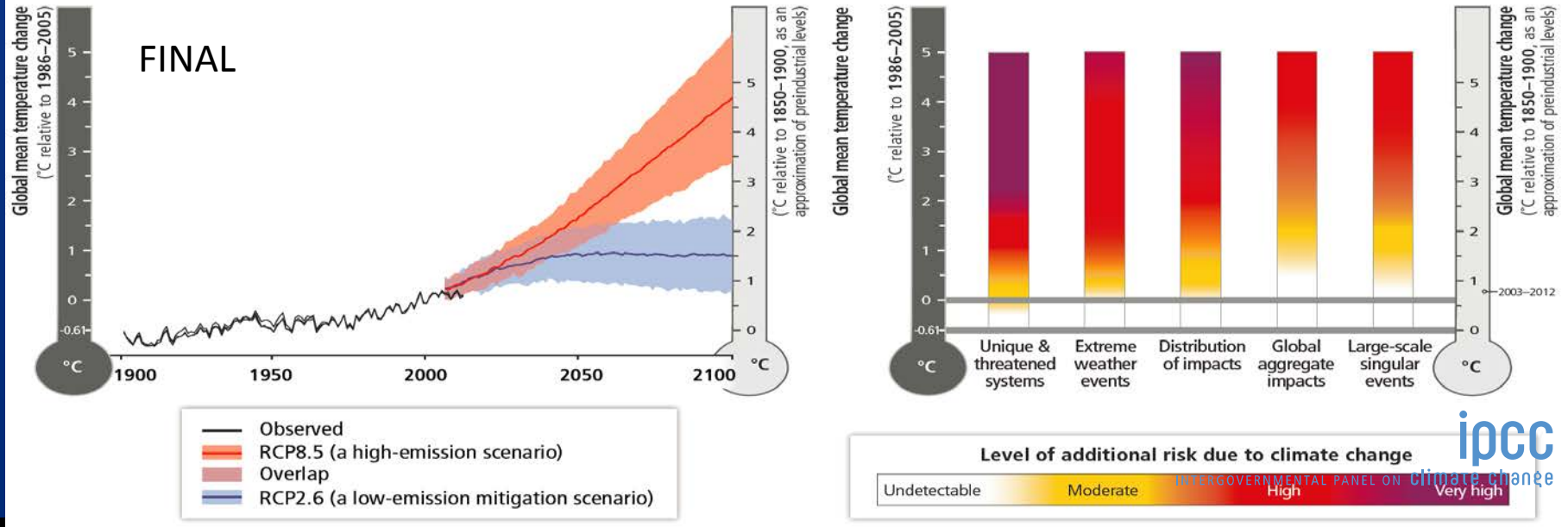
The choice of paths



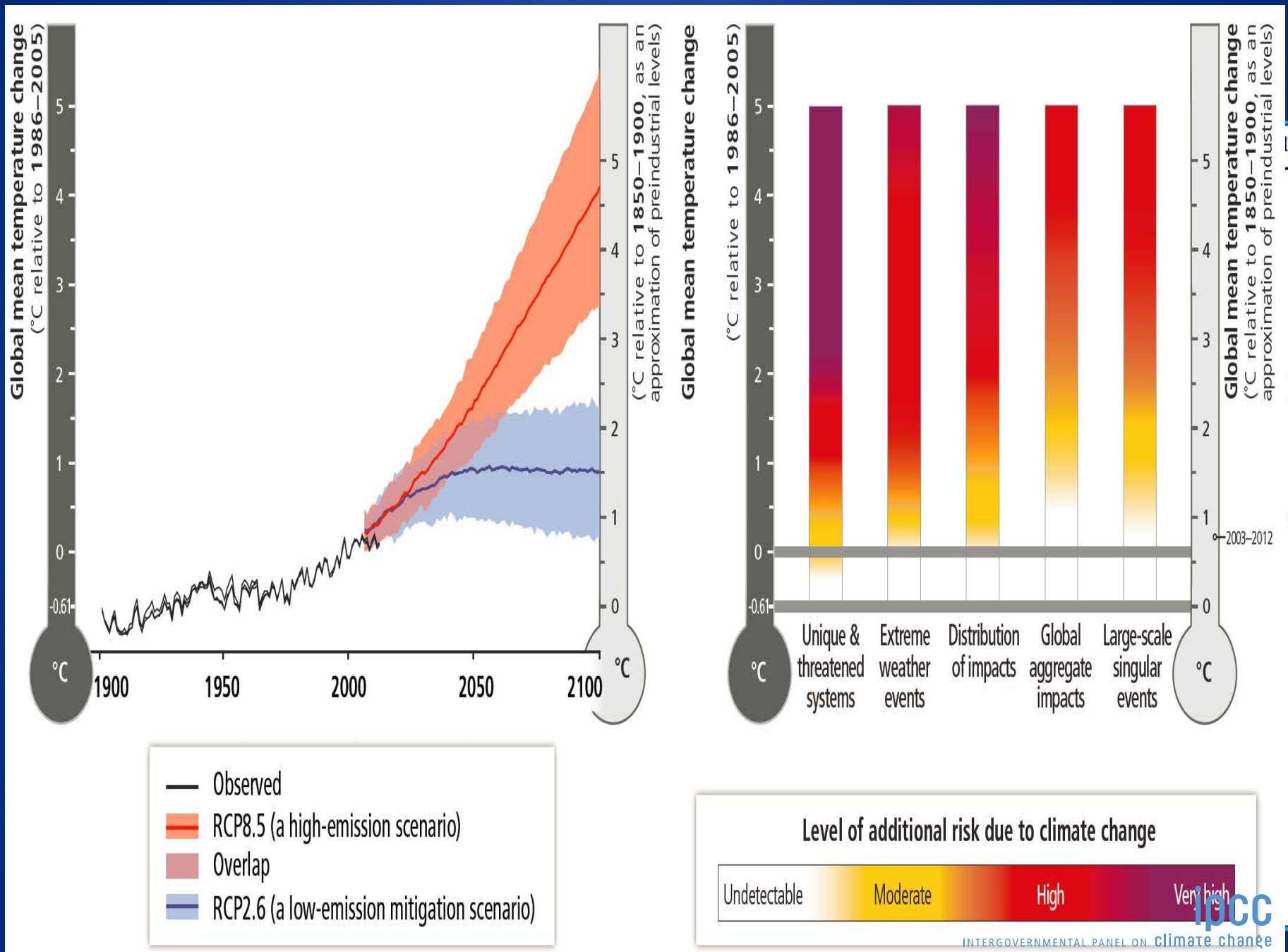
IPCC WG1: SPM 2013



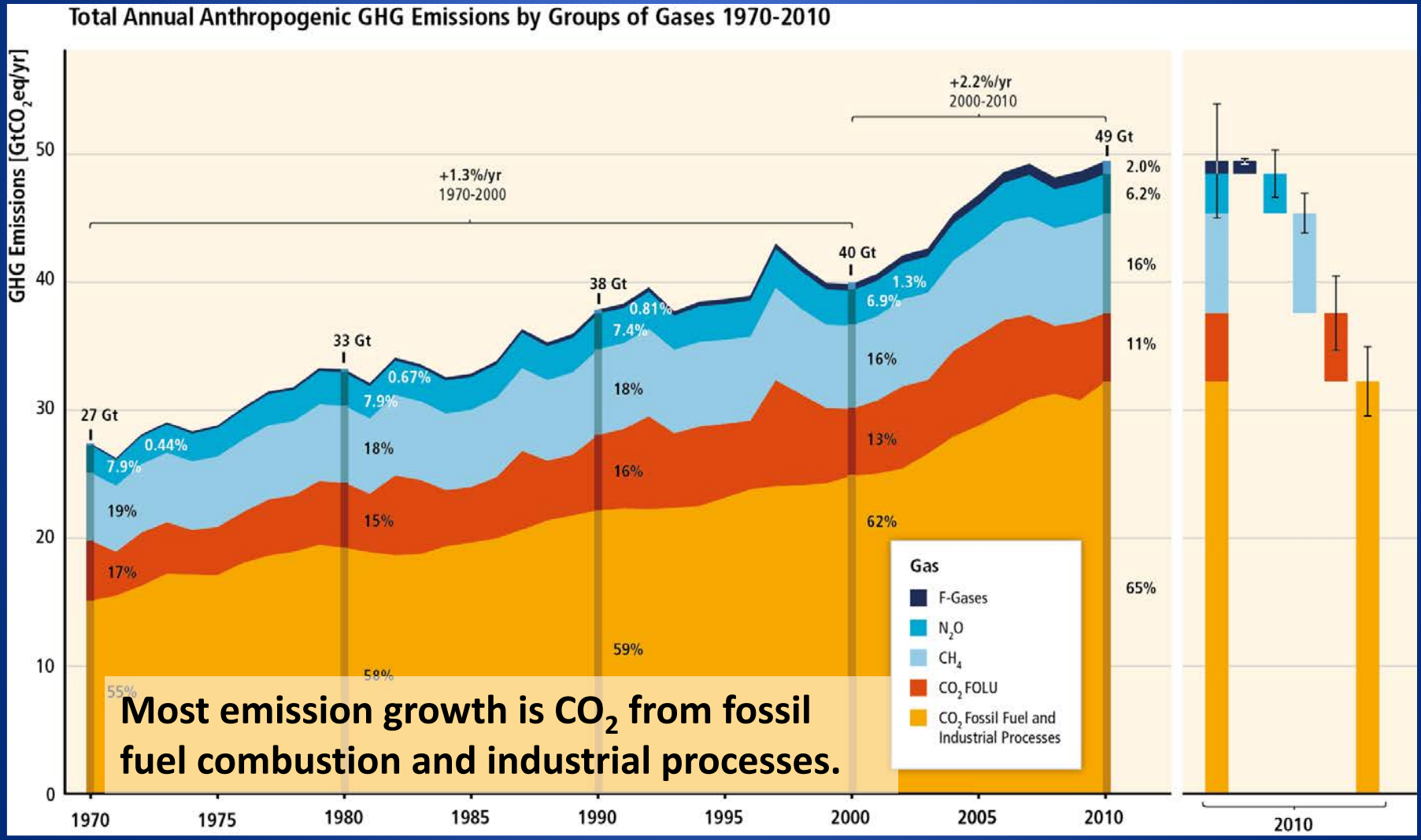
FINAL



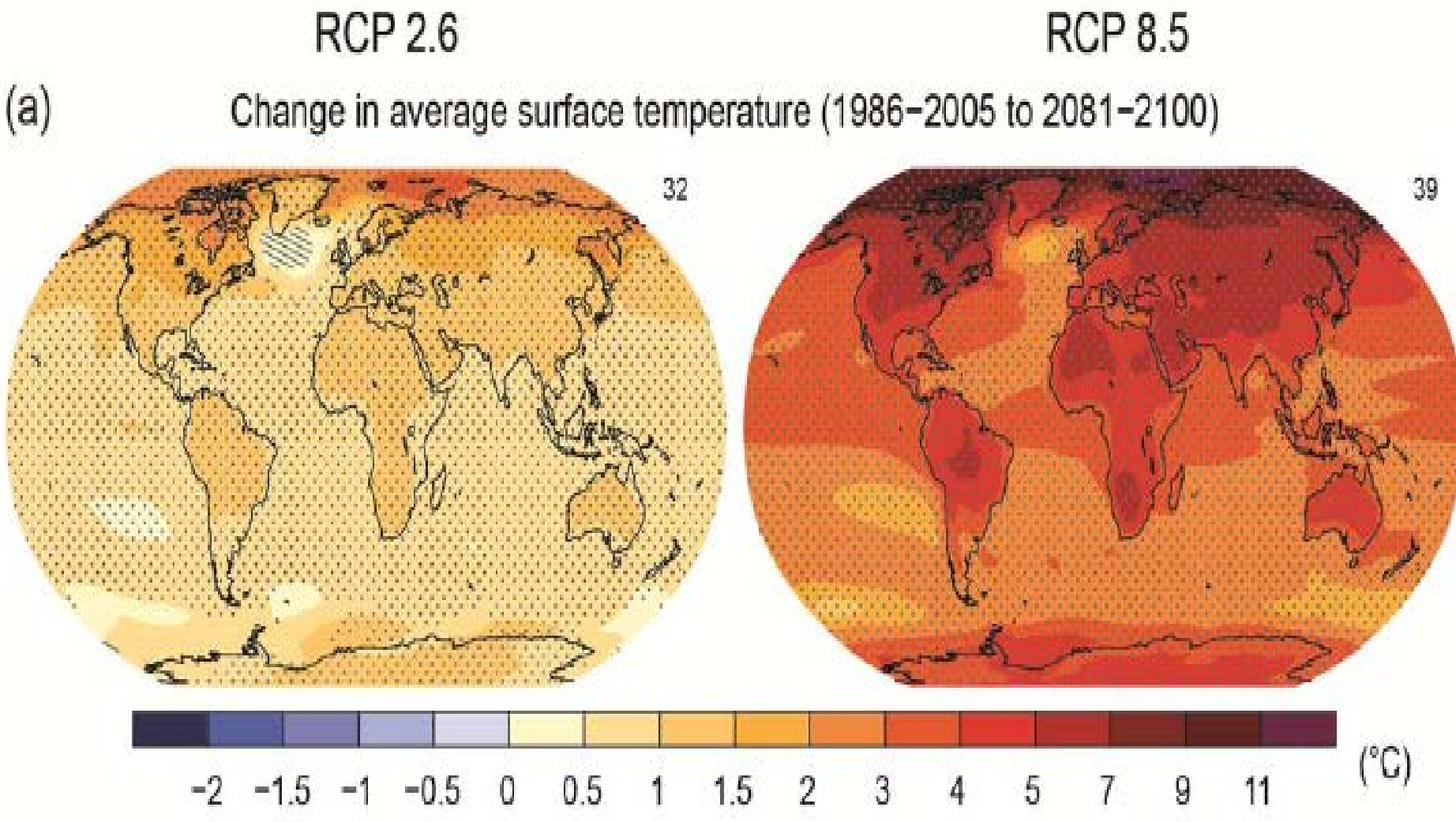
ipcc
INTERGOVERNMENTAL PANEL ON climate change


Global mean temperature change
(°C relative to 1986–2005)
Global mean temperature change
(°C relative to 1850–1900, as an approximation of preindustrial levels)
°C
1900
1950
2000
2050
2100
Observed
RCP8.5 (a high-emission scenario)
Overlap
RCP2.6 (a low-emission mitigation scenario)
Unique & threatened systems
Extreme weather events
Distribution of impacts
Global aggregate impacts
Large-scale singular events
2003–2012
Level of additional risk due to climate change
Undetectable
Moderate
High
Very high
ipcc
INTERGOVERNMENTAL PANEL ON climate change

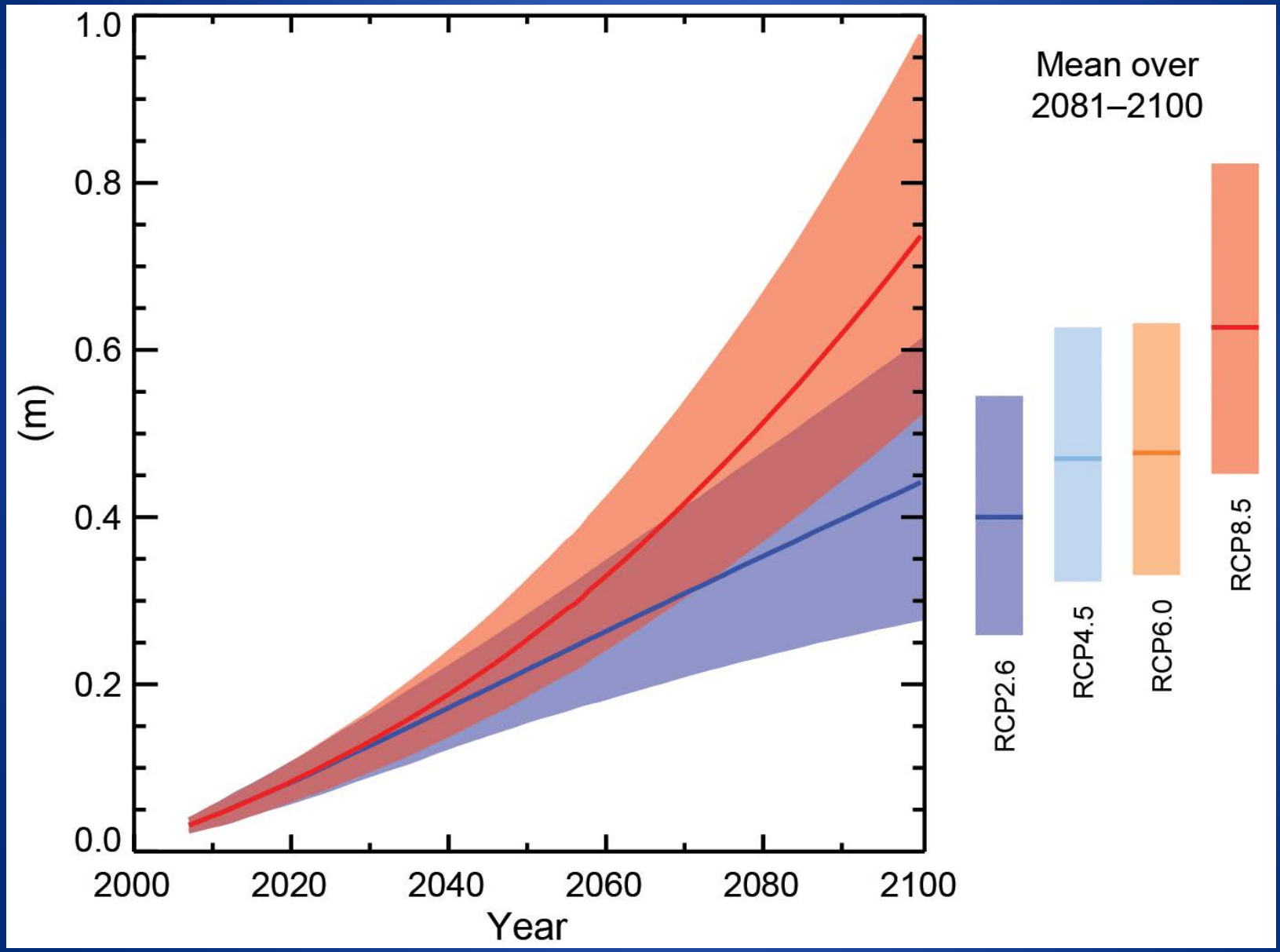
Currently, GHG emissions accelerate despite reduction efforts.



High and low projections for 2081-2100



Projected Global Mean Sea Level Rise



High and low projections: Arctic sea ice

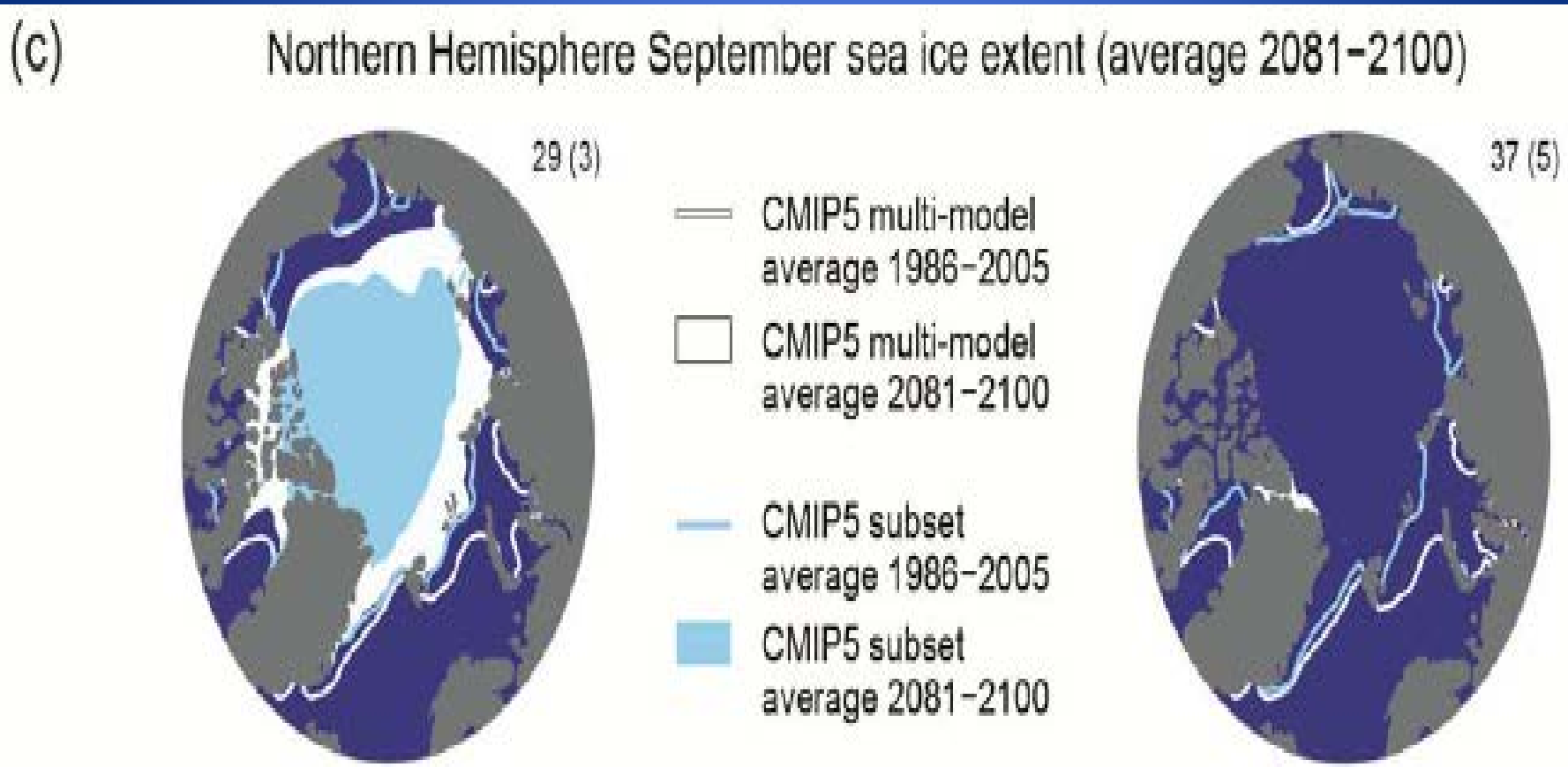
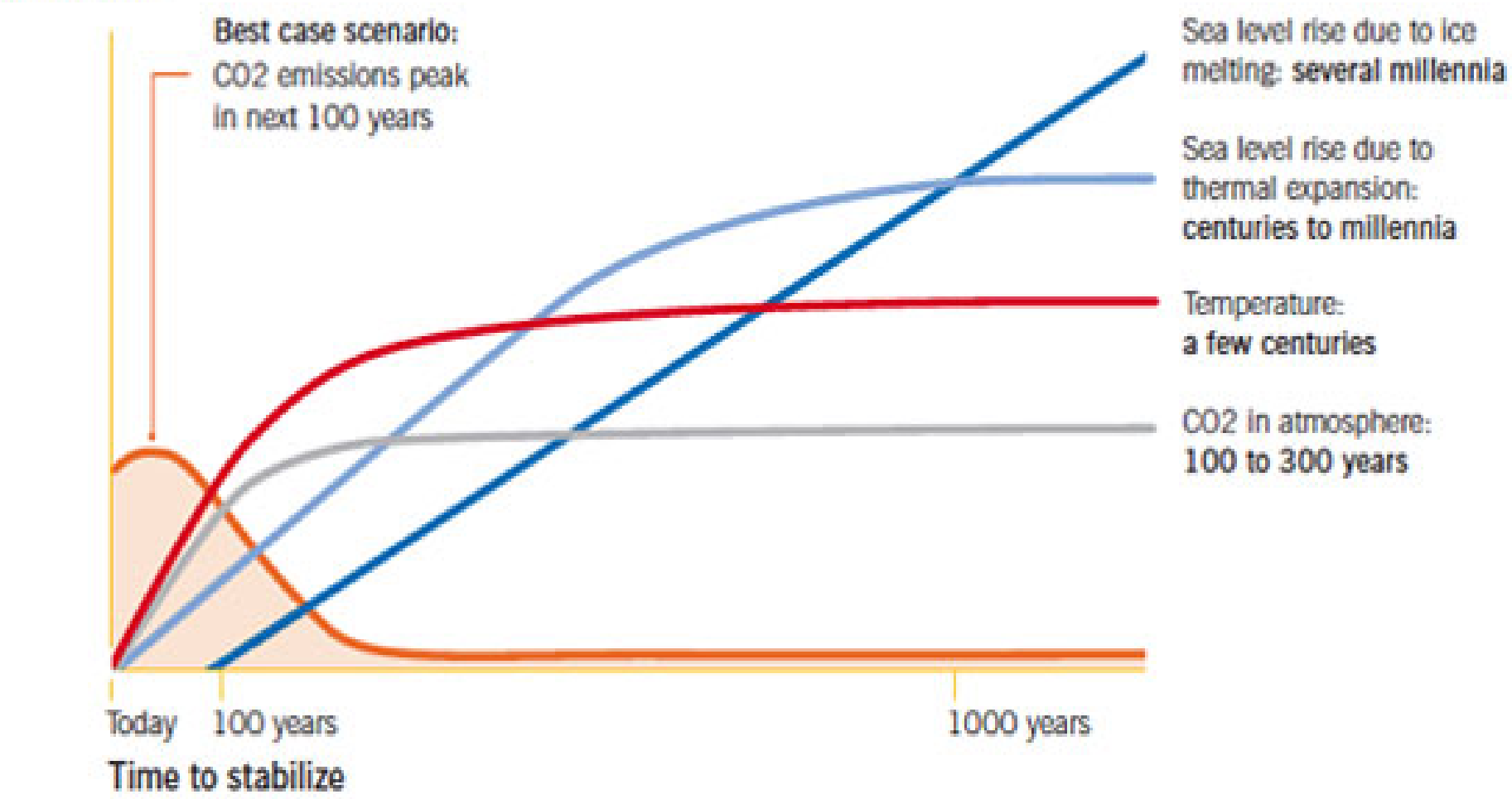
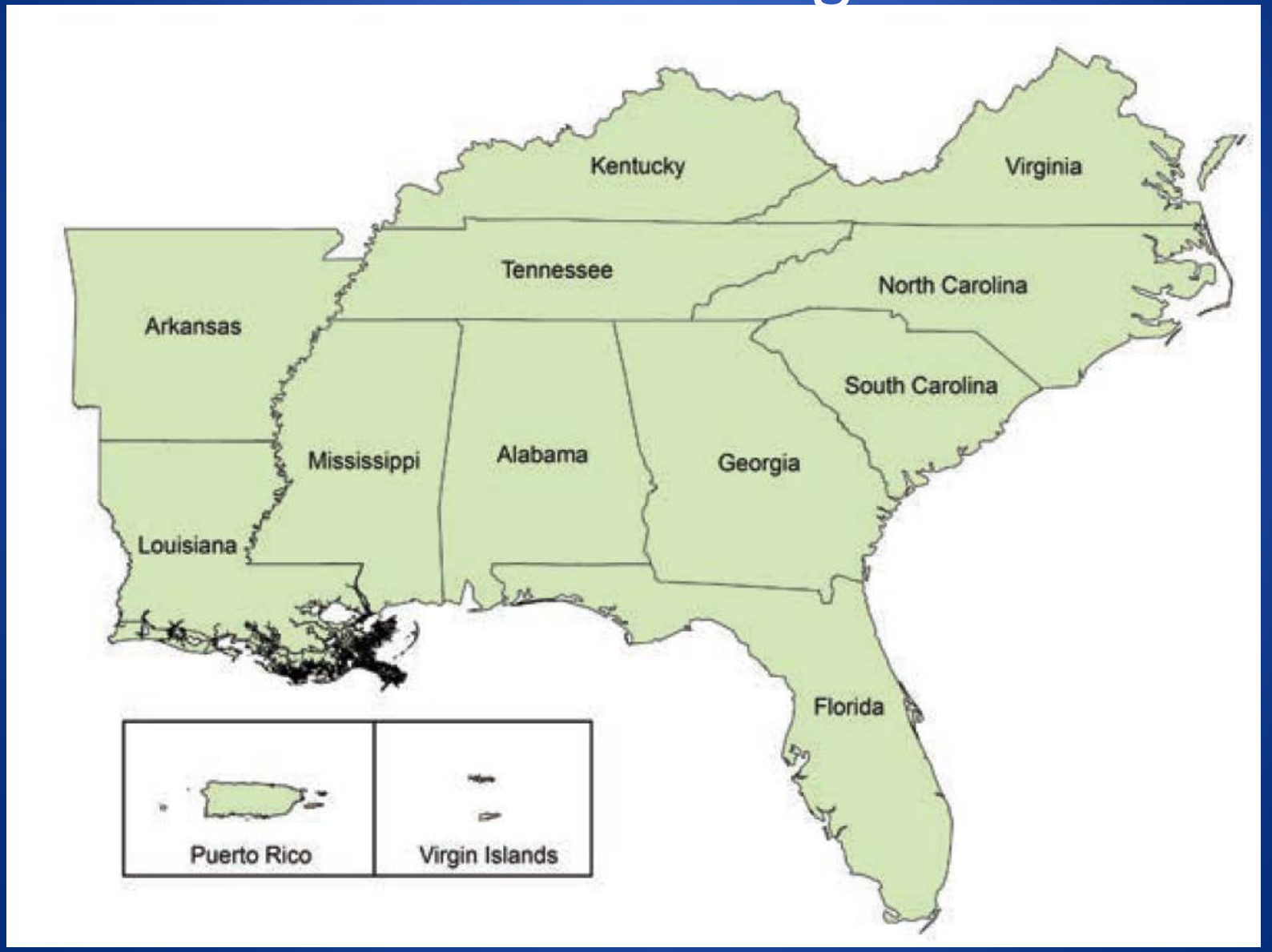


Figure 1: How long will it take our climate to stabilize?

Even if we succeed at reducing our emissions, it will take centuries for the climate—and the effects of global warming and sea level rise—to stabilize.

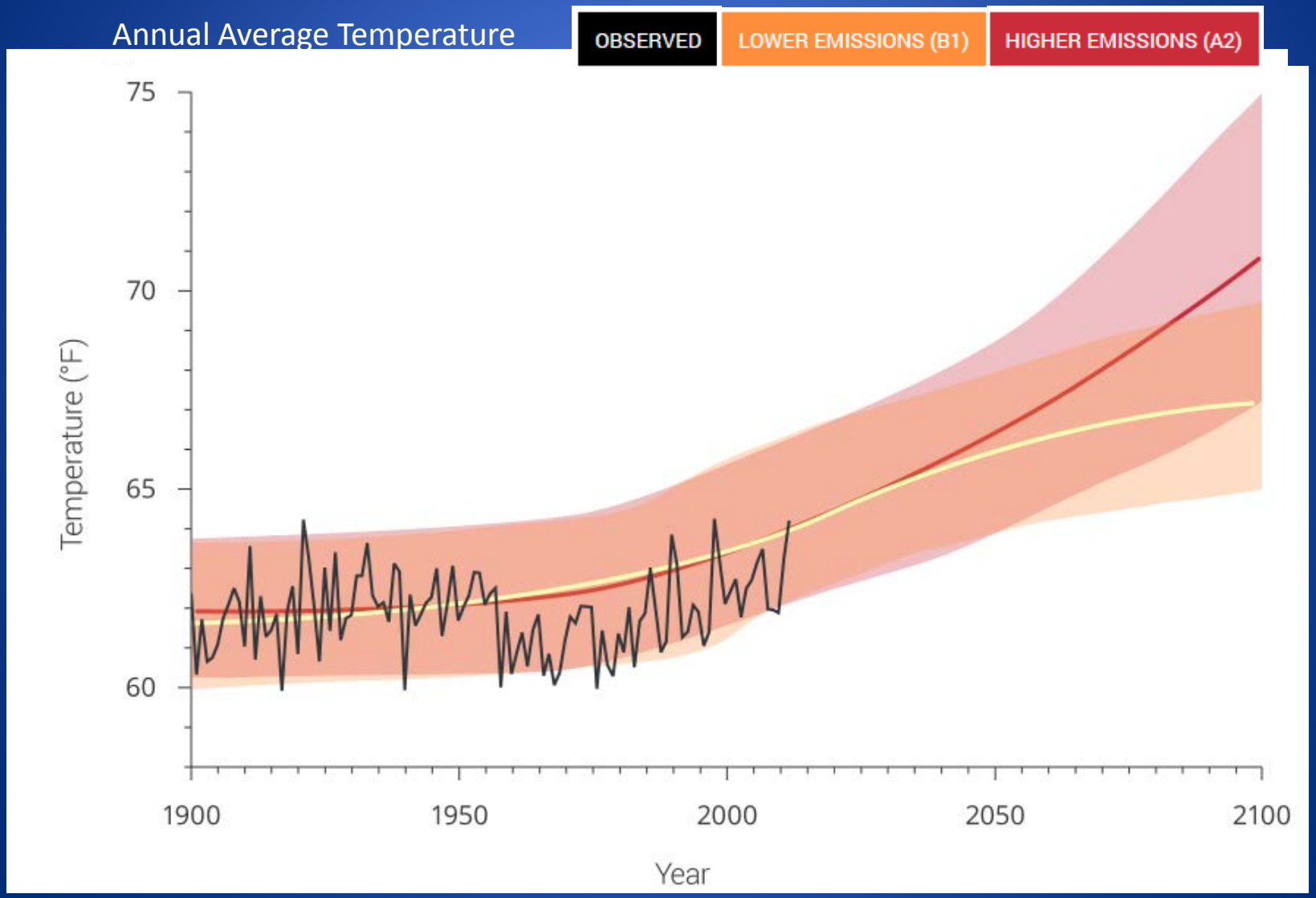


US National Climate Assessment
Southeast Region



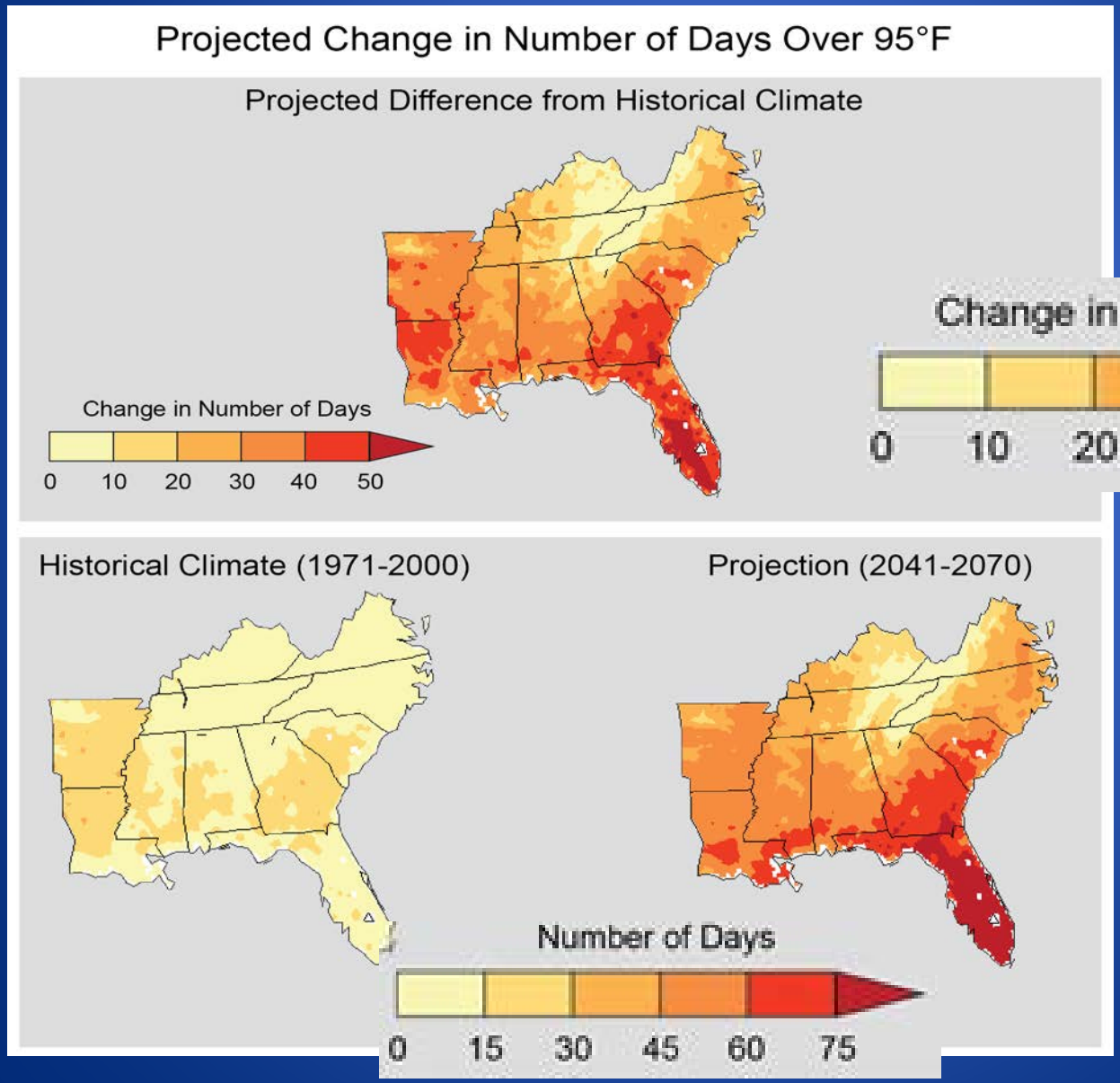
Southeast U.S. Temperature

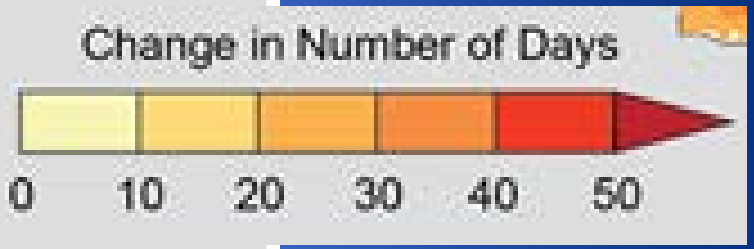
Annual Average Temperature



Source: 3rd NCA, adapted from Kunkel et al. 2013

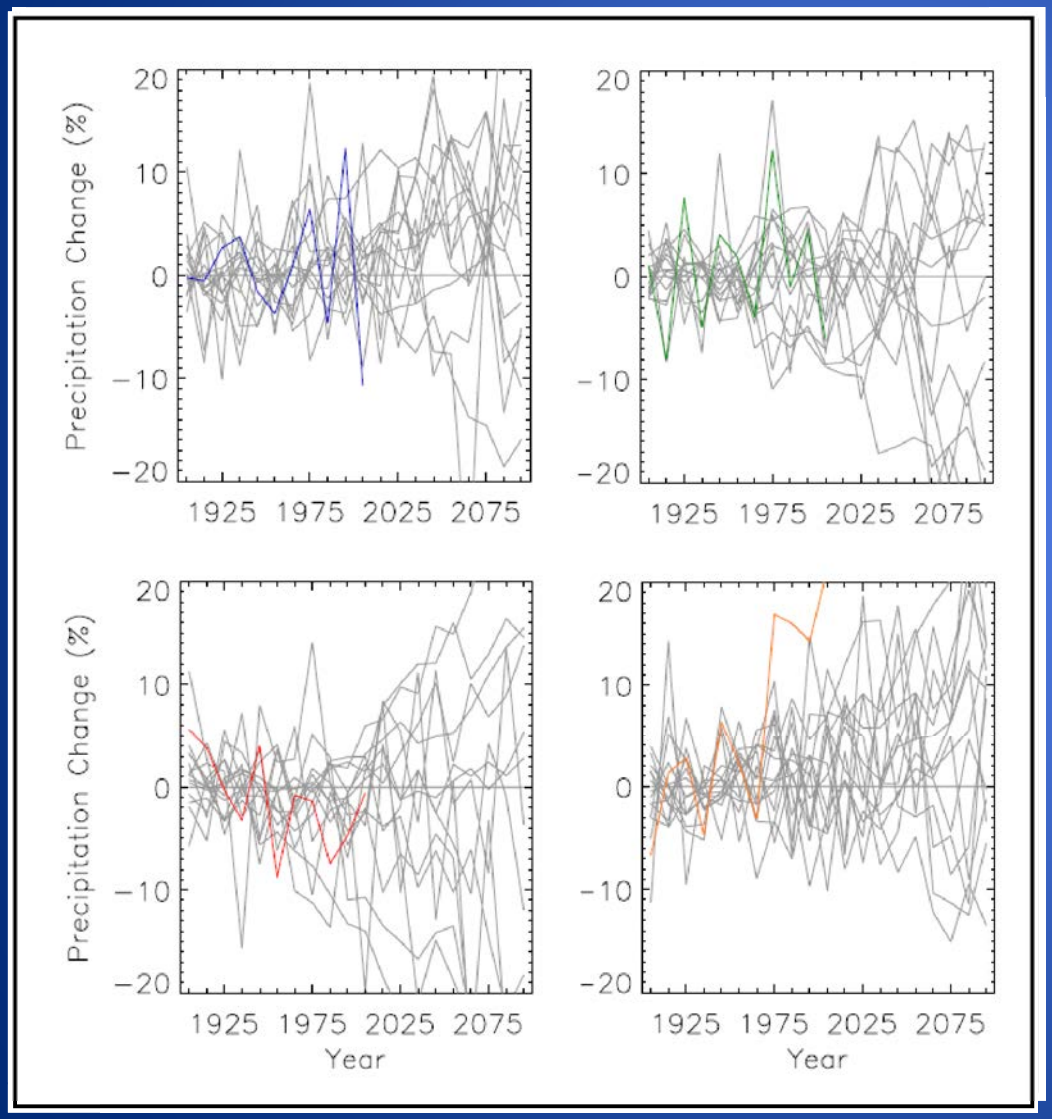
Southeast U.S. Days over 95F





Source: NOAA NCDC / CICS-NC

Southeast U.S. Precipitation Projections



Black line – Observed decadal mean annual precipitation change

Colored lines – Observed decadal mean annual precipitation change

Gray lines – Model simulations from 15 CMIP3 models for the high (A2) emissions scenario.

Source: Kunkel et al. 2013

Two Adaptation Issues

- Increased temperatures and longer duration of warm periods – heat threats
- Changing timing and distribution of public health issues

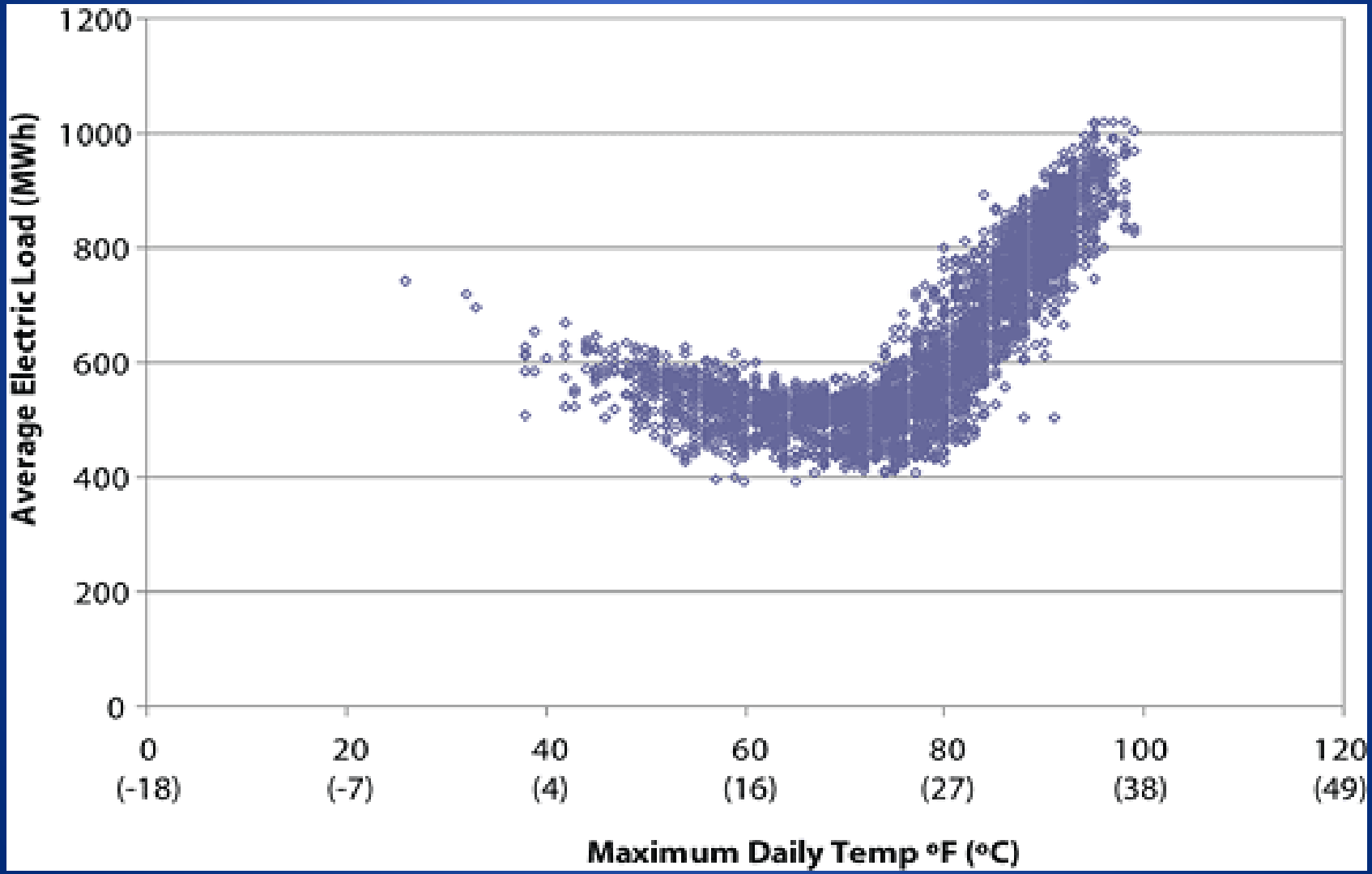
Adaptation Strategies and Considerations

- No Regrets Strategies – will provide benefits under existing conditions as well as potential future conditions
- Low Regrets Strategies
- Lock-in – making investments that will commit us to a pathway that may address a current problem but not future conditions
- Multiple Stresses – not just climate
- Timing of investments
  - Building adaptive capacity – preparing to act effectively

Increased Temperatures and Longer Duration of Warm Periods

- Health threats to those with limited access to cooling
  - Poor, elderly, socially isolated
  - People working outdoors
  - Athletes
- Budget expense
- Particular issue in urban areas due to the urban heat island effect

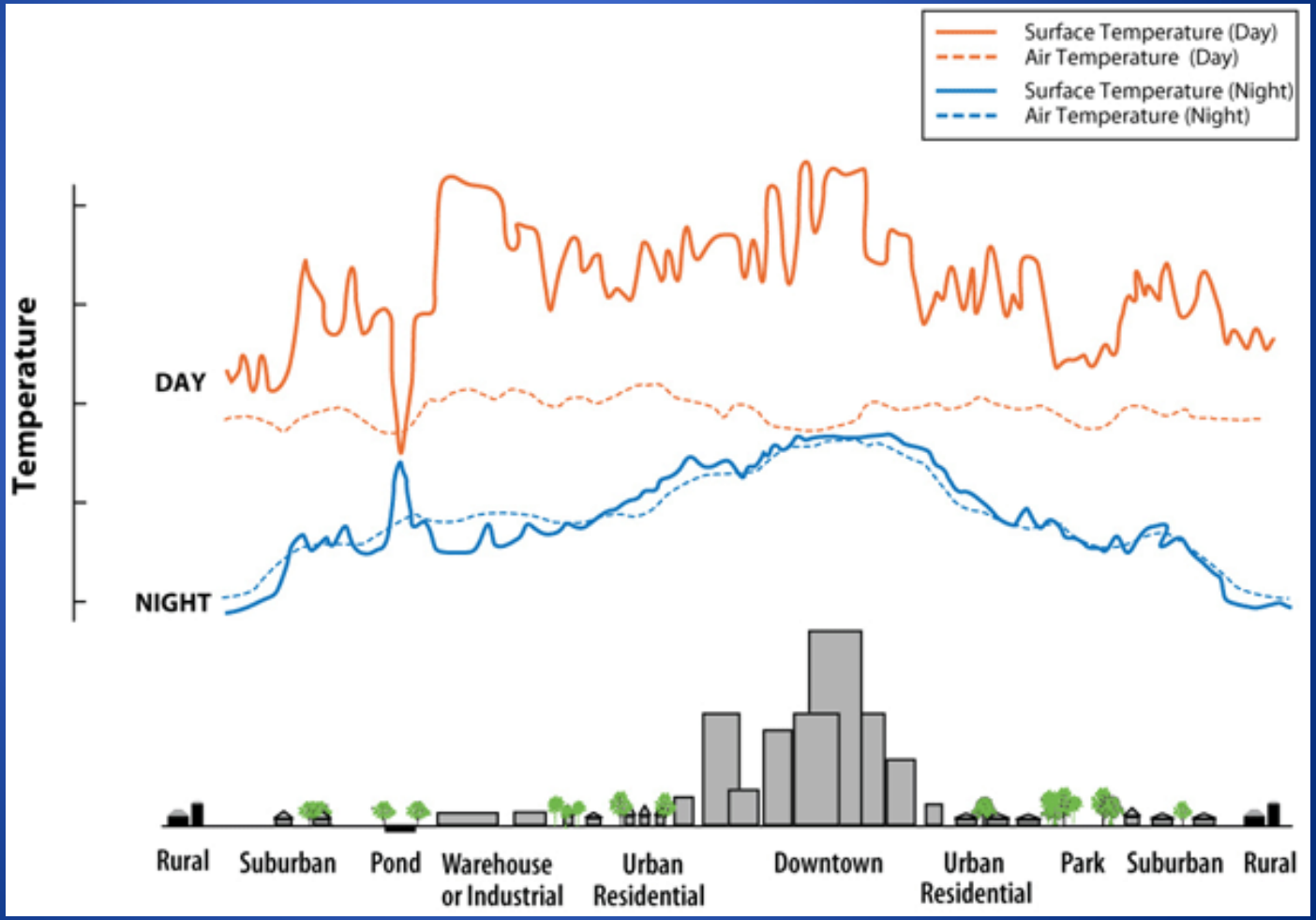
Energy demand increases with daily temperature



Urban Heat Island

Can raise temperature from 2-10^{o}F

Many cities in South Carolina will also have aging populations



Source: US EPA

Ozone Impacts

- Ground-level ozone is formed when Nitrous oxides (often fossil fuel emissions) and volatile organic compounds (VOCs) react in the presence of sunlight and hot weather.

- Hotter, sunnier conditions will result in greater levels of ground-level ozone production

- Increased Asthma incidences

Water Quality Impacts

- Pavement and rooftops at over 100 ^{o}F can raise rainfall temperature from 70^{o}F to 95 ^{o}F .

- This drains to storm sewers and then to water bodies where it can result in fast increases in water temperatures and harm to aquatic life
  - metabolism
  - reproduction

Adaptation Options

- Green spaces
- Planting trees
- Green roofs

Adaptation Option

- Urban tree planting
  - Lower summer temperatures by shading concrete and returning humidity to the air through evaporative cooling
  - ALSO
    - Improved air quality
      - Removing dust and pollutants
    - Capture carbon dioxide
    - Protect water quality
      - Capturing and retaining stormwater

Million Tree Programs

- New York City
- Baltimore
- Chicago
- Los Angeles
- Others

Green Roofs

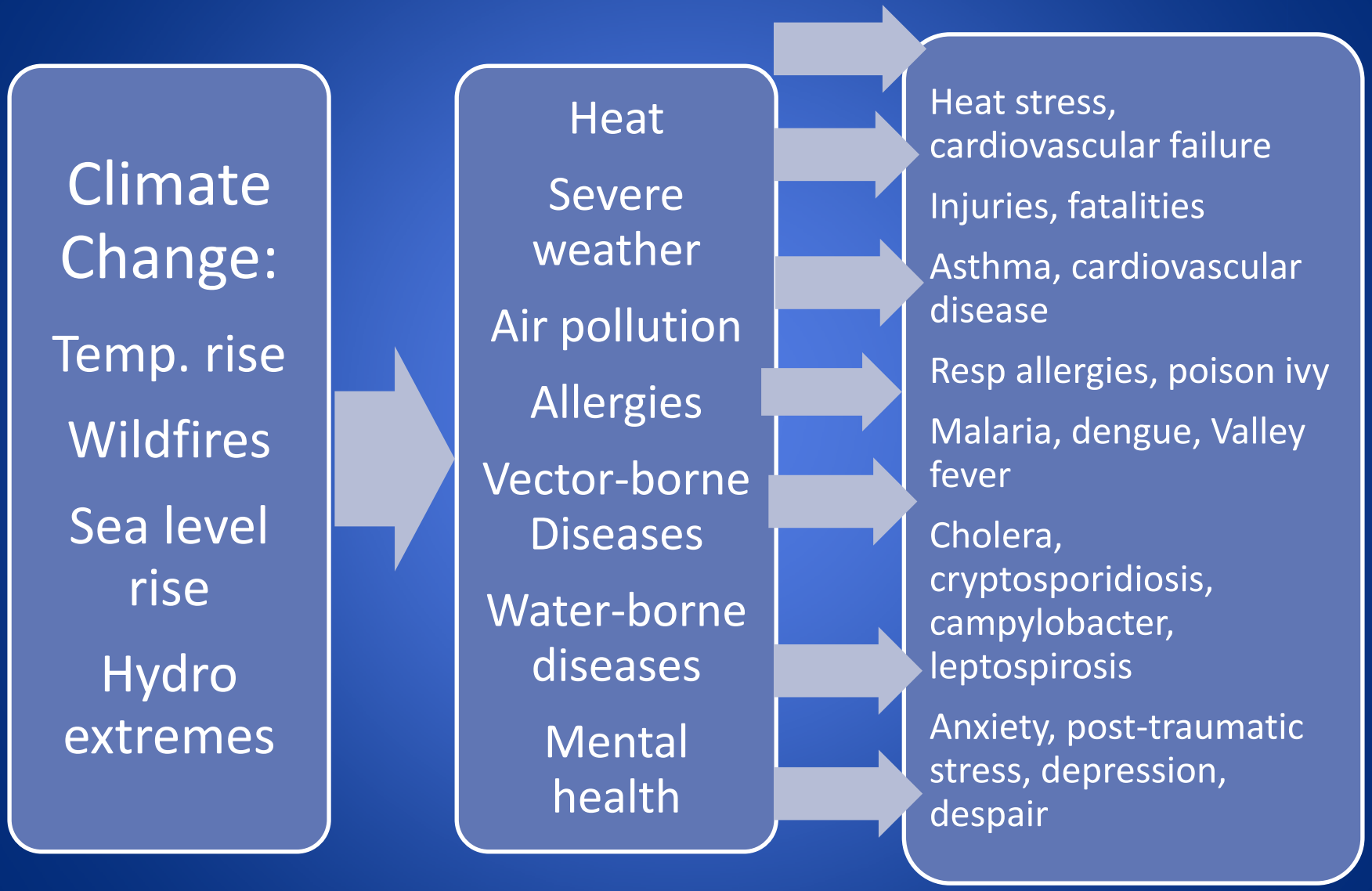
- Heat sensing pictures illustrate the major temperature difference between green roofing on

Chicago's City Hall (left) and traditional roofing (right)

USC West Quad

- See Greenroofs.org

Public Health and Climate Change



Source: Frumpkin, CDC

Local Specifics

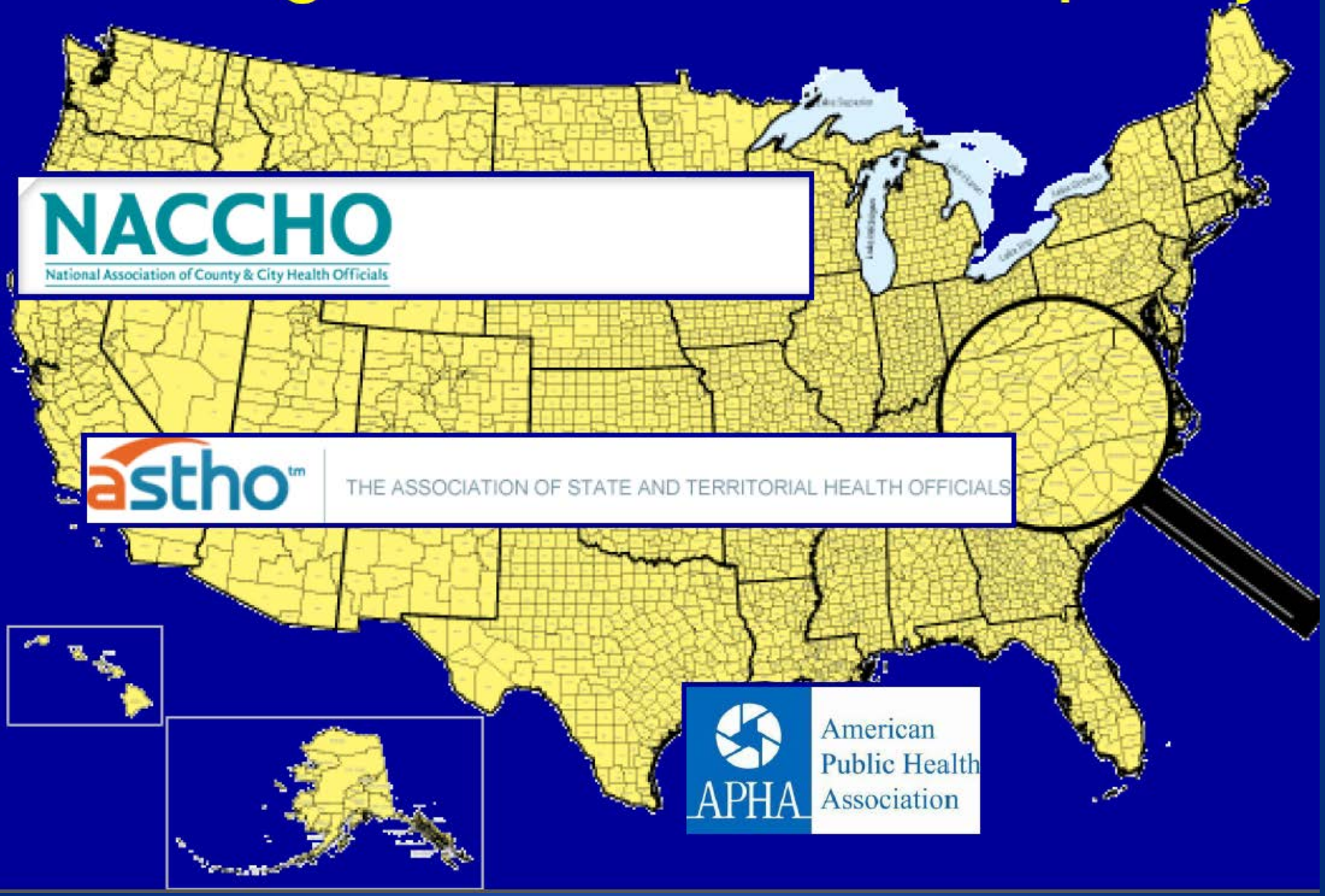
- Earlier springs, longer pollen seasons
- Warmer conditions favoring pathogens
  - Observations of *Vibrio* in Gulf Coast show cases earlier and later than usual

- Harmful Algae Blooms
  - Favored by warmer temperatures and changes in lake warming
  - Some can become air-borne and cause respiratory problems
  - Other spread into new areas as habitat conditions change
    - Red tide
    - *Aedes aegypti*

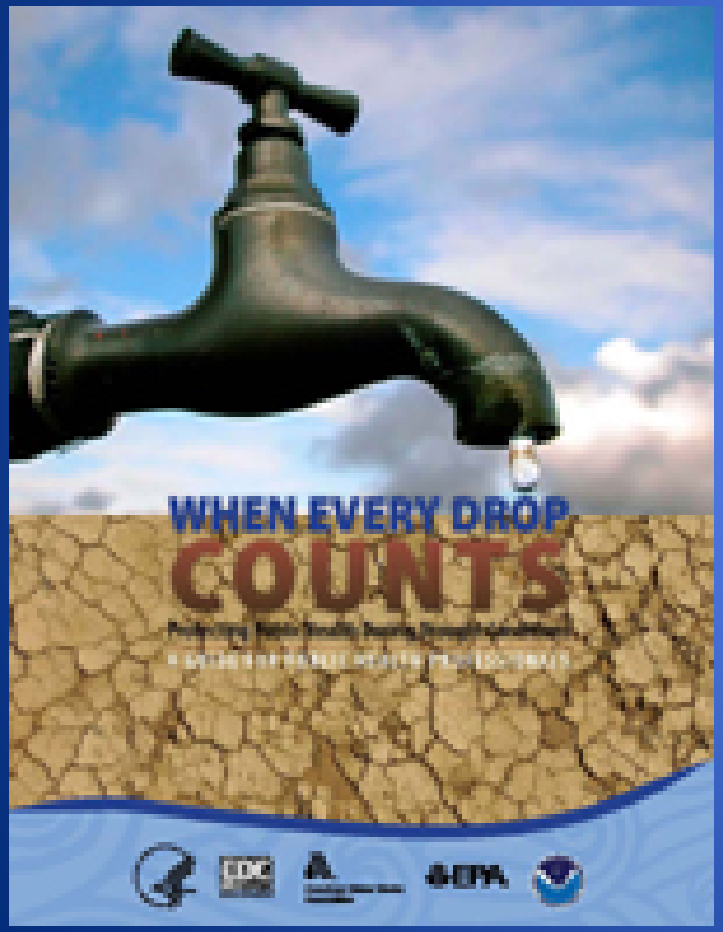
Vector-Borne and Zoonotic Disease

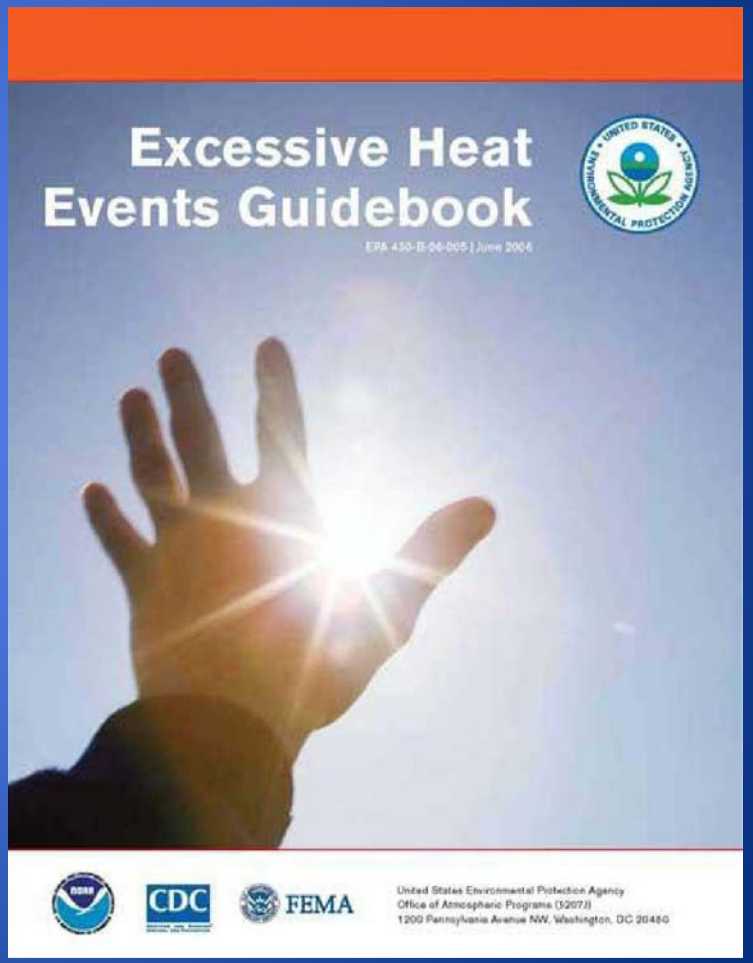
- Very Uncertain
- Spread is dependent on many factors, not just climate
- Mosquito, *Aedes aegypti* and *A. albopictus*
  - very adaptable to urban conditions
  - can transmit dengue and malaria
  - Chikungunya – 1st case in SC identified July 2014 – travel relate

Building State and Local Capacity



More resources are becoming available





General Resources

- In addition to federal agencies mentioned,

- CAKE – Community Adaptation Knowledge Exchange
- ICLEI – Local Governments for Sustainability
- Georgetown Climate Center Adaptation Clearinghouse

Thank You

Adaptation Limits

- Risk –based approach
- Related to actors' **objectives, values and needs**
- Differ **across scales**
  - a limit for an individual is not a limit for a group or a system
- Linked to the **rate and magnitude** of climate change, in context of other risks
- **Dynamic** and changing over time. Therefore need to be assessed within a given **time-frame**
  - For a social actor, a decision time-frame
  - For natural systems, the speed of system response

How do actors appraise risks?

- **Acceptable risks** are risks deemed so low that additional risk reduction efforts are not seen as necessary.
- **Tolerable risks** relate to activities seen as worth pursuing for their benefits, but where additional efforts (adaptations) are required for risk reduction within reasonable levels.
- **Intolerable risks** are those which exceed a socially negotiated norm (e.g. the availability of clean drinking water) or a value (e.g. continuity of a way of life) despite adaptive action.

Based on Renn 2008

Adaptation limits

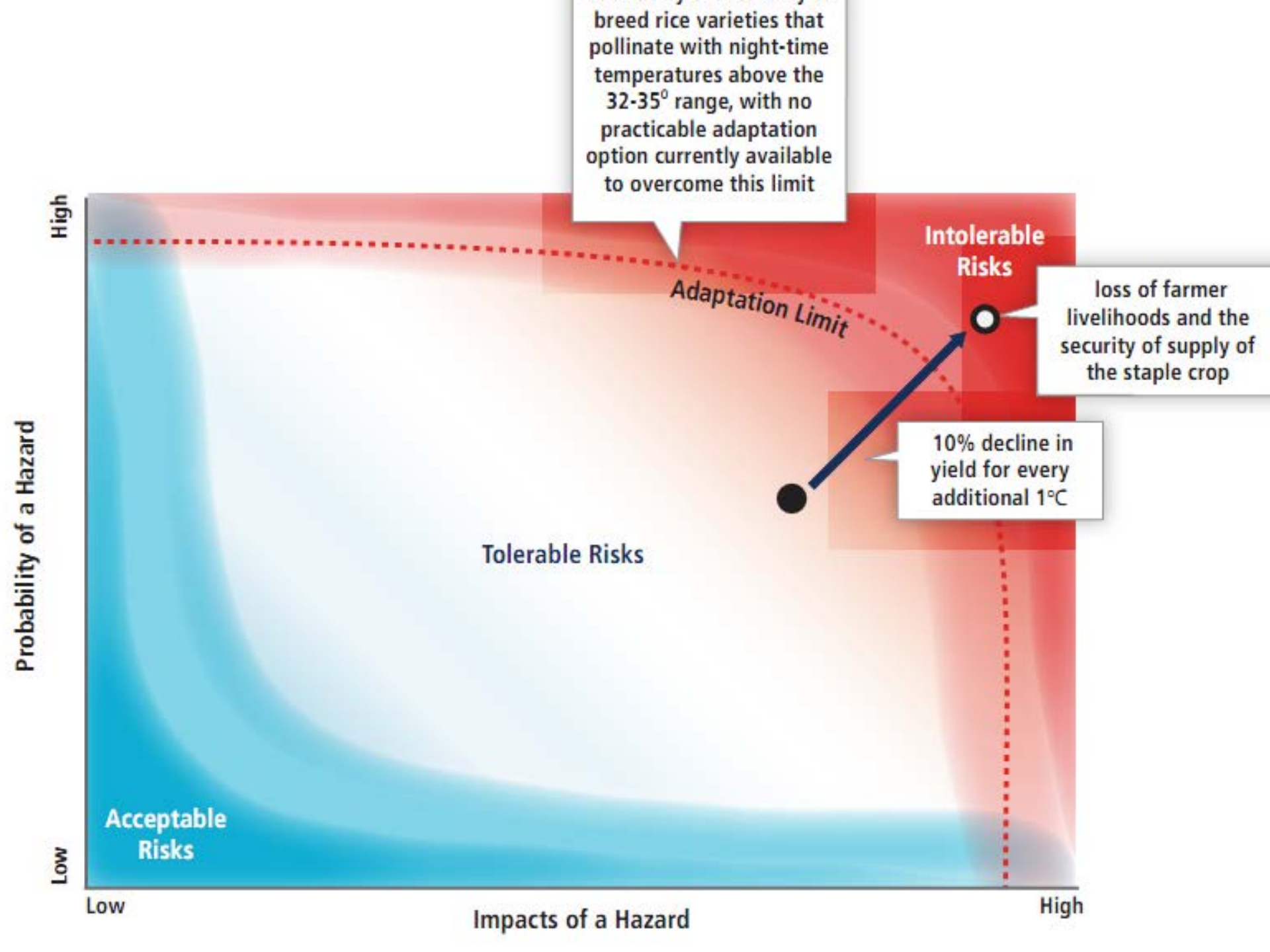
Focus on adaptation OBJECTIVES

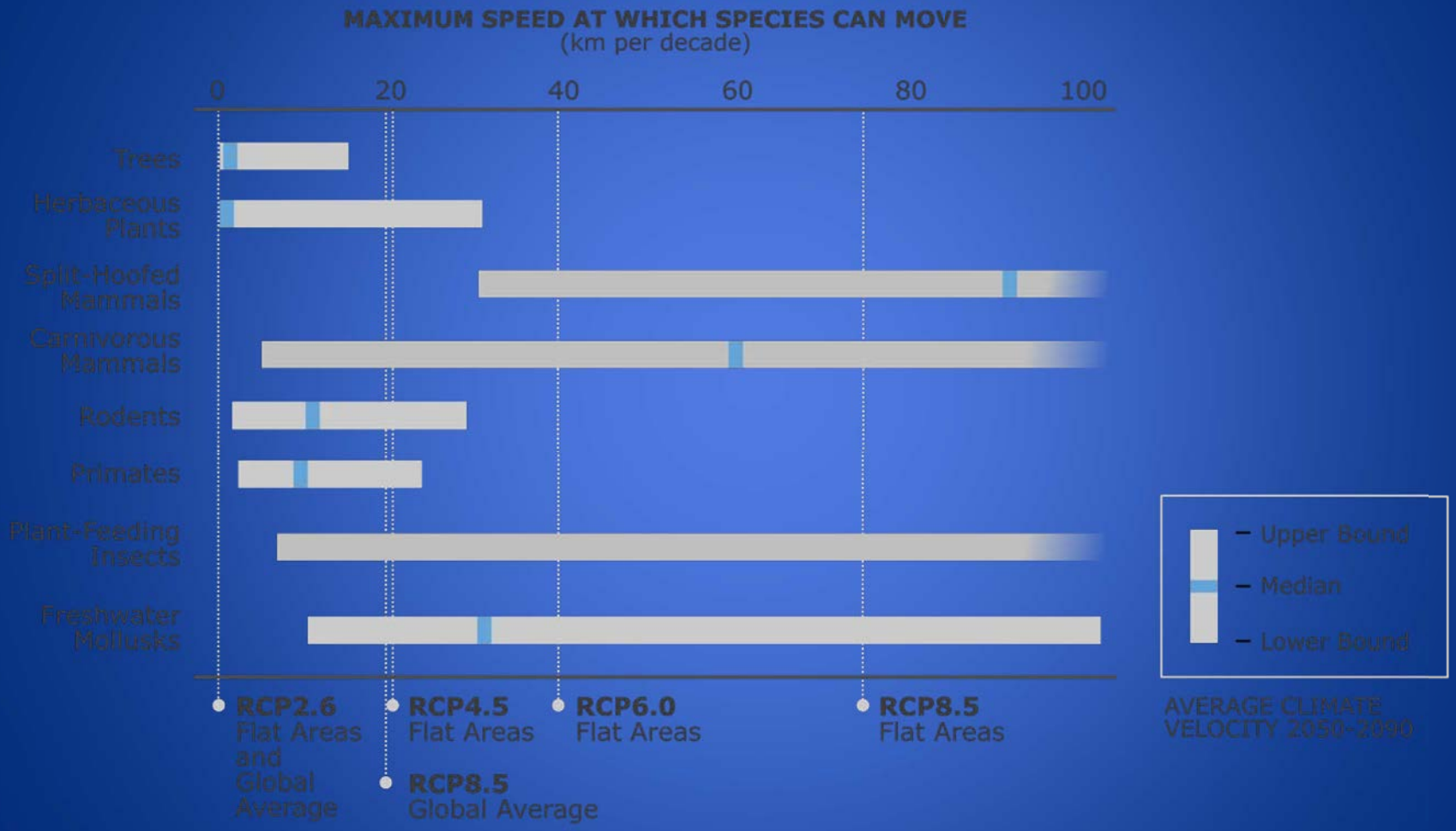
Definition

- the point at which an actor is unable to secure objectives from **intolerable risks** through adaptive action

At a limit there are three options:

1. Live with escalating losses
2. Change objectives (role of values and norms)
3. Transformative responses


breed rice varieties that pollinate with night-time temperatures above the 32-35⁰ range, with no practicable adaptation option currently available to overcome this limit
Intolerable Risks
Adaptation Limit
loss of farmer livelihoods and the security of supply of the staple crop
10% decline in yield for every additional 1°C
Tolerable Risks
Acceptable Risks
High
Low
Probability of a Hazard
Low
High
Impacts of a Hazard



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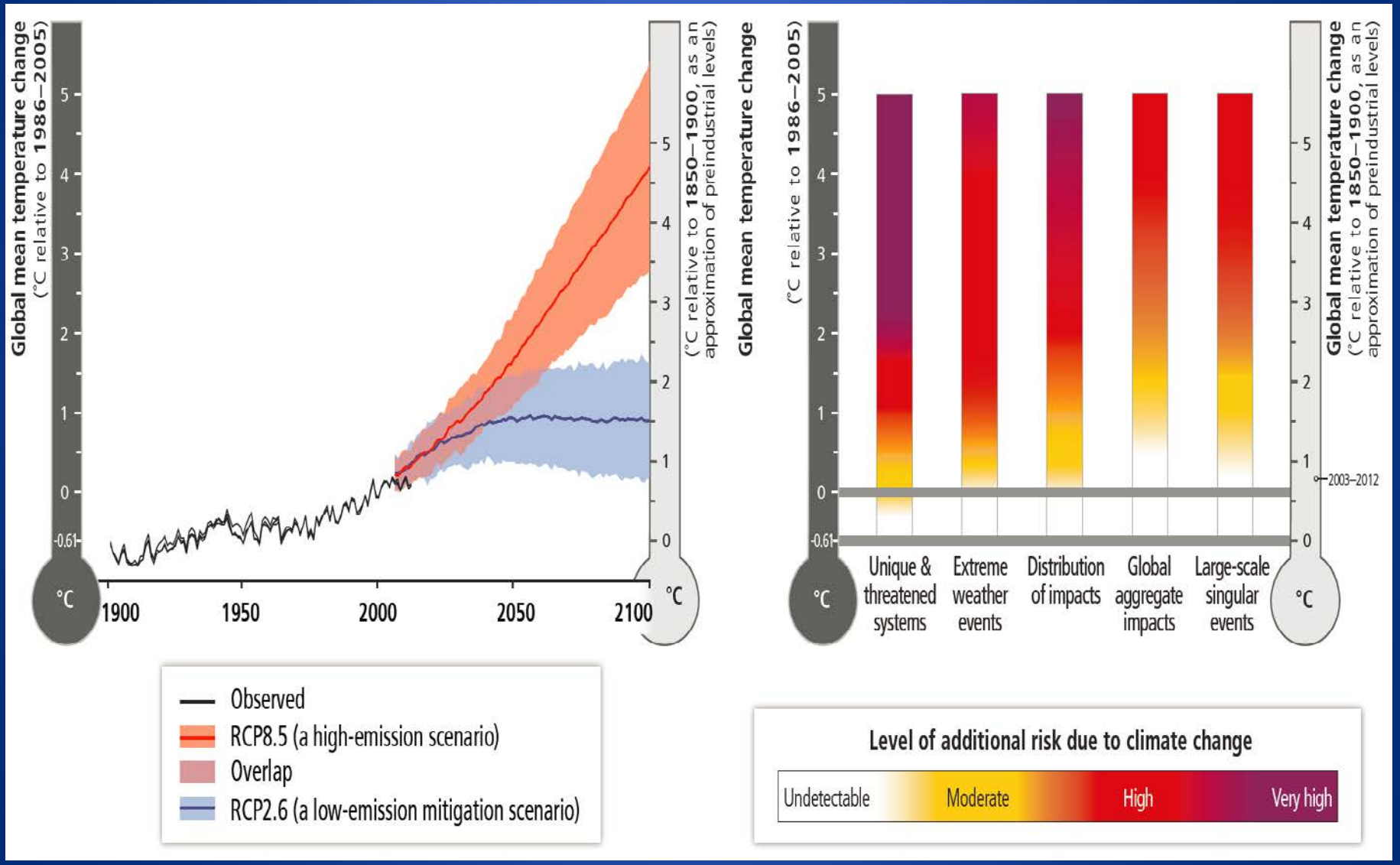
INTERGOVERNMENTAL PANEL ON Climate Change

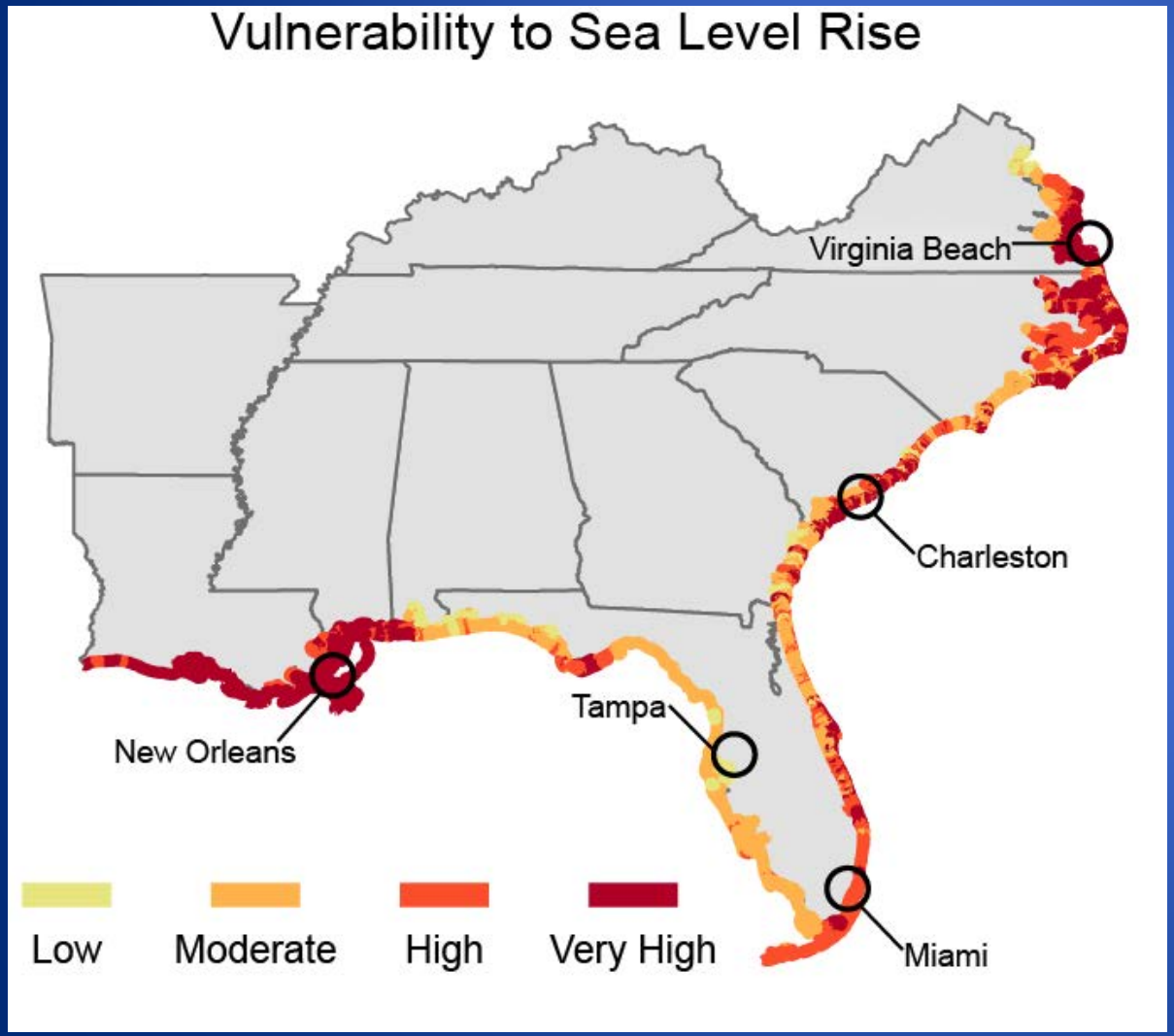
Two questions about the implications of climate adaptation limits

- Given that adaptations will not be able to secure all objectives and limits will be reached,
  - What are the implications for defining "success" of transformative adaptations
    - Context of the Warsaw Mechanism on Loss and Damage
- There are likely to be conflicts over differing objectives and tradeoffs.
  - What types of risk governance processes are needed to anticipate limits and develop response strategies

Climate Choices



Sea Level Rise: Differences in Vulnerability



Causes of differences

- Tidal range
- Wave height
- Coastal slope
- Shoreline change, landforms, and processes
- Historical rate of sea level rise

Source: Third NCA, Data from Hammar-Klose and Thieler 2001)