City of Cambridge
Climate Change Vulnerability Assessment and Adaptation Plan

January 22, 2013

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Today's Agenda

Introduction
John Bolduc

Climate Change Projections [3:00-4:00]
Paul Kirshen, Katharine Hayhoe

Economic Vulnerability Assessment [4:00-4:30]
Sam Merrill

Public Health Vulnerability Assessment [4:30-5:00]
Pat Kinney

Next Steps
Lisa Dickson

Climate Change Projections

Katharine Hayhoe

How do we translate global projections into local climate?

The scientific “crystal ball”

Human society: demographics, technology, energy, economy

Emissions of greenhouse gases and other activities that affect climate

Global and continental-scale climate and change

Regional to local-scale climate and change

SOCIO-ECONOMIC MODELS

GLOBAL CLIMATE MODELS

DOWNSCALING MODELS

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Why are future projections uncertain?

1. On-going natural variations in climate are chaotic, making it difficult to predict conditions over time scales shorter than a decade.

Why are future projections uncertain?

1. On-going natural variations in climate are chaotic, making it difficult to predict conditions over time scales shorter than a decade

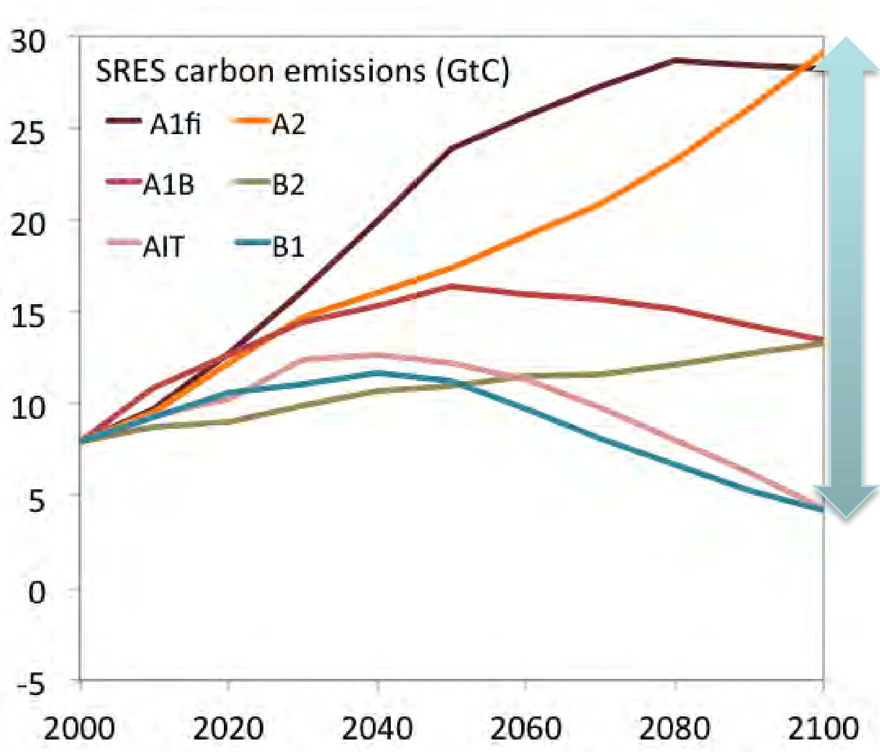
What can we do about it?

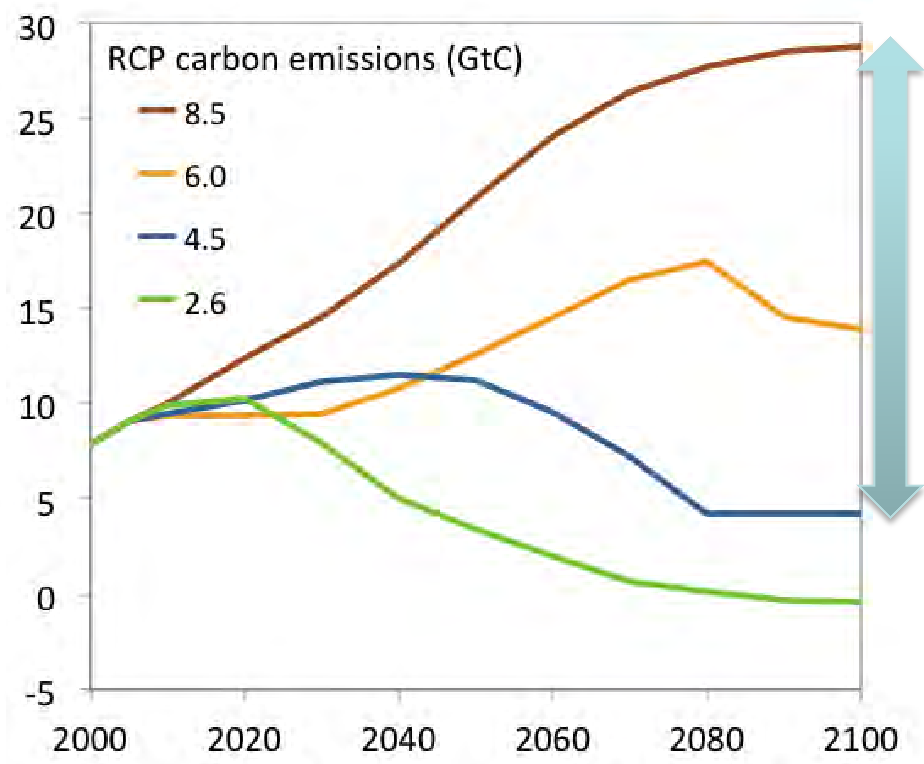
Our projections will be averaged over climate time scales (e.g., 2015-2044 for 2030 and 2055-2084 for 2070). Over time scales of 20 years or more, the effects of most natural variations (like the NAO) tend to average out.

Why are future projections uncertain?

2. We don’t know what future emissions from human activities will be. So how can we predict future climate change?

Two sets of IPCC scenarios





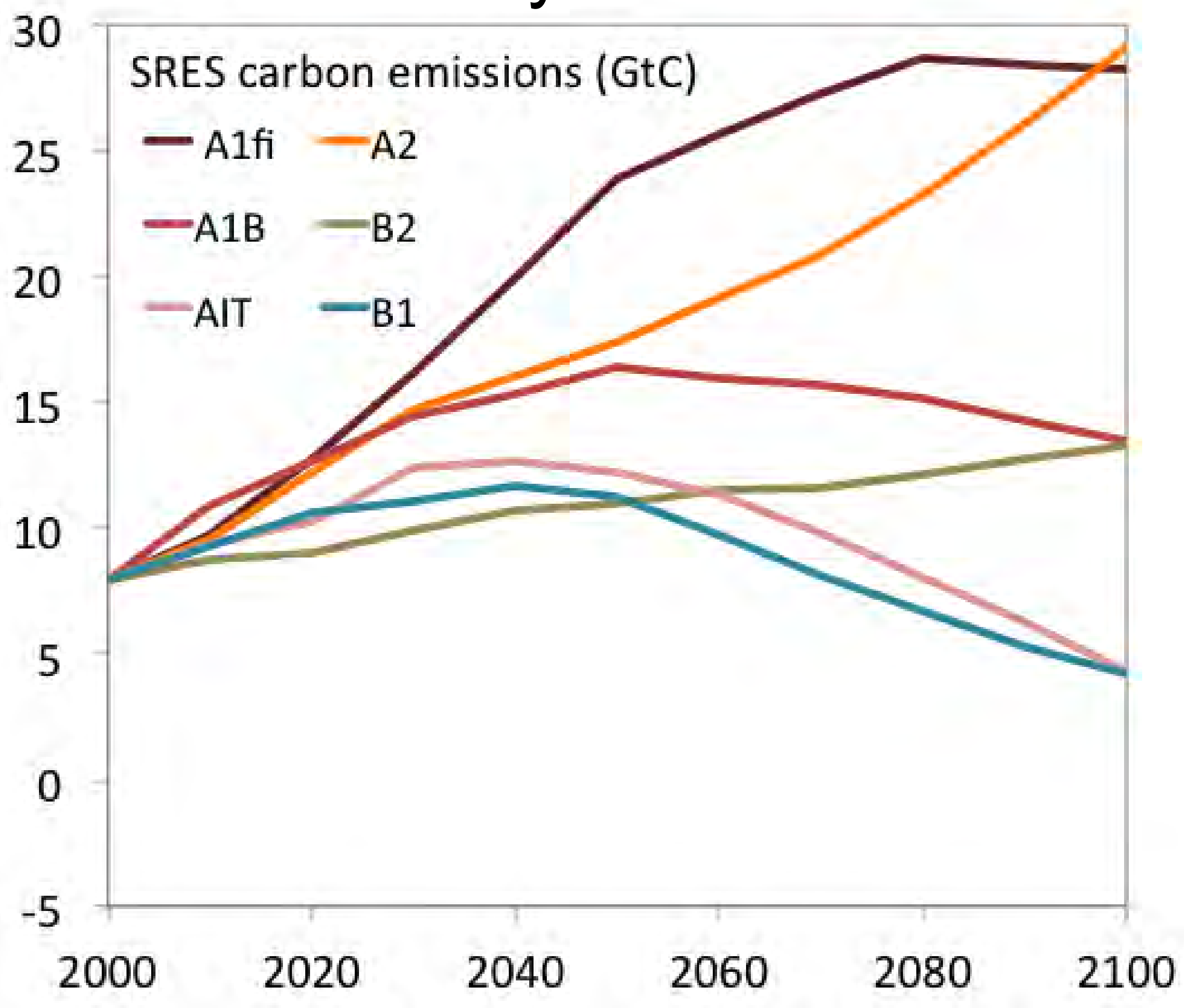
2000 Special Report on Emission Scenarios

IPCC (2007), NECIA (2007), NCA (2009)

2010 Representative Concentration Pathways

IPCC (2013), NCA (2014)

Which is more likely?



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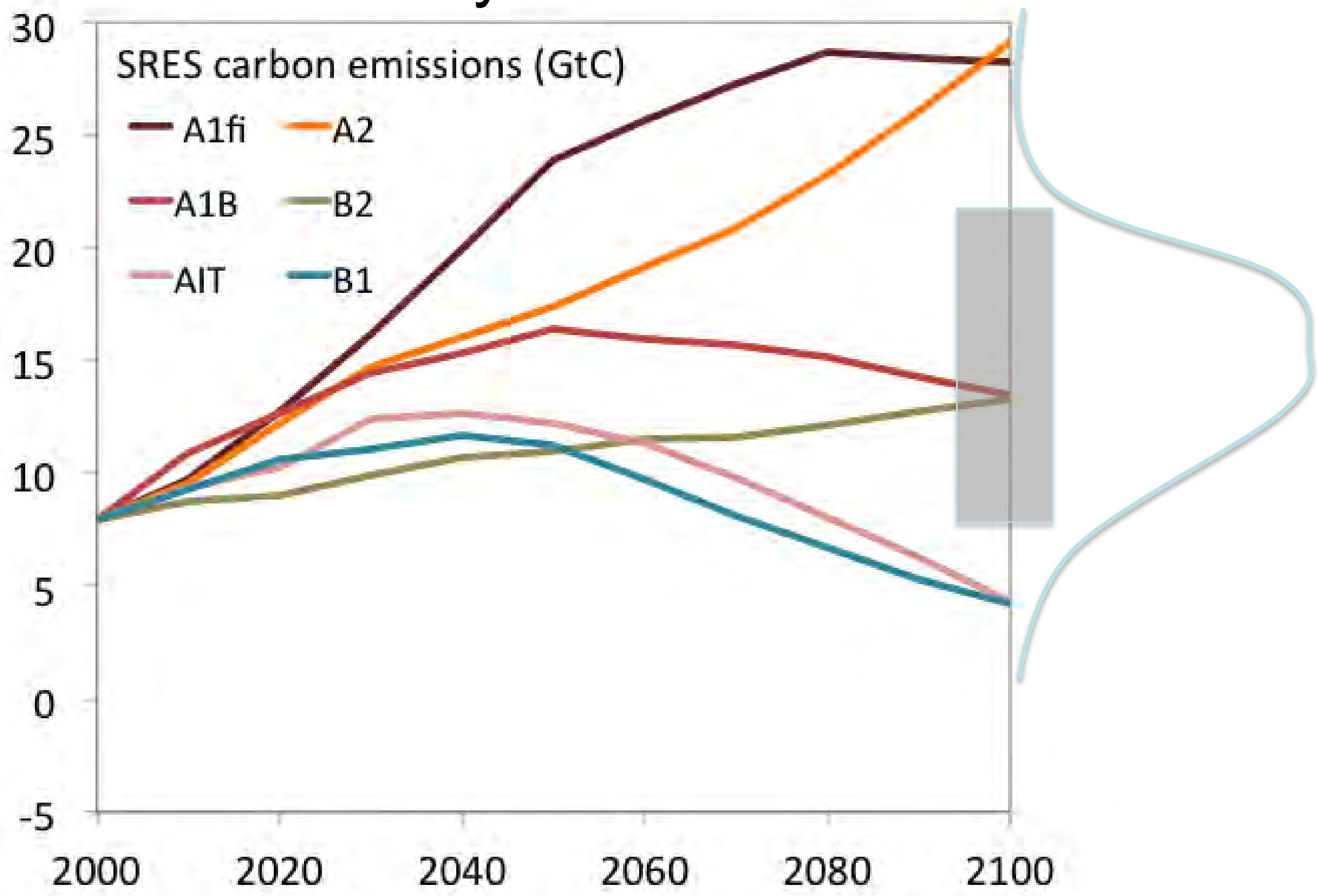

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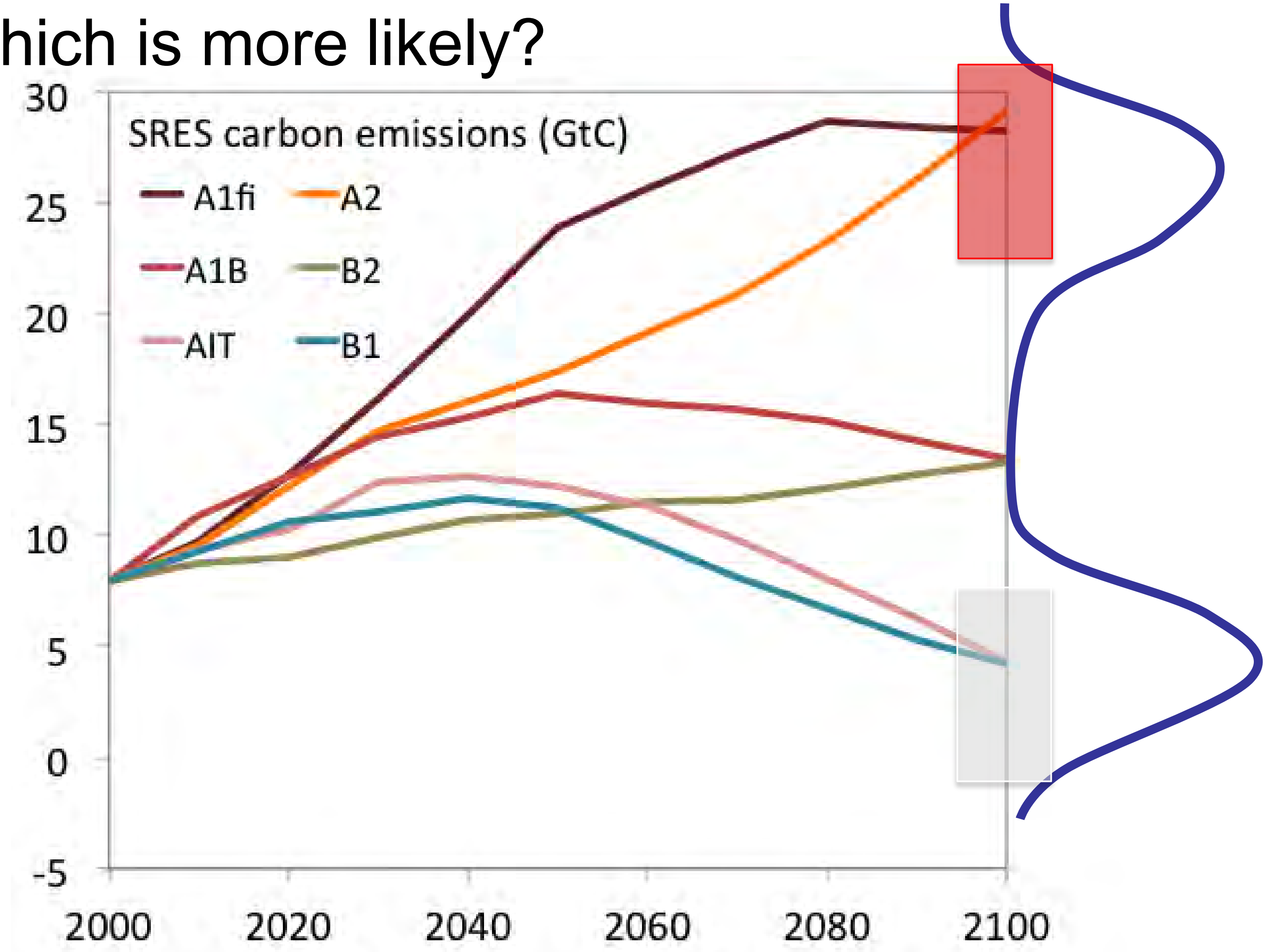
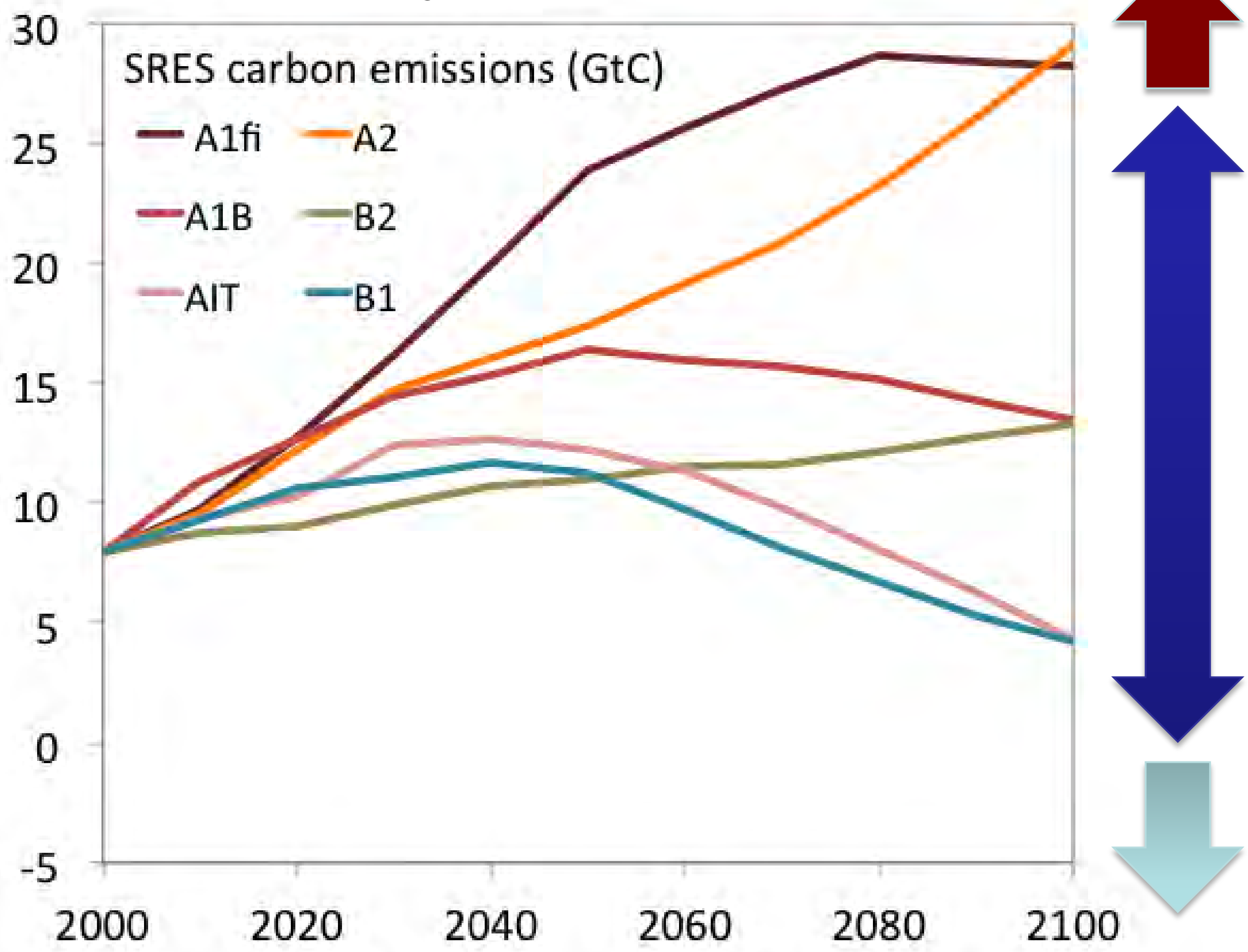
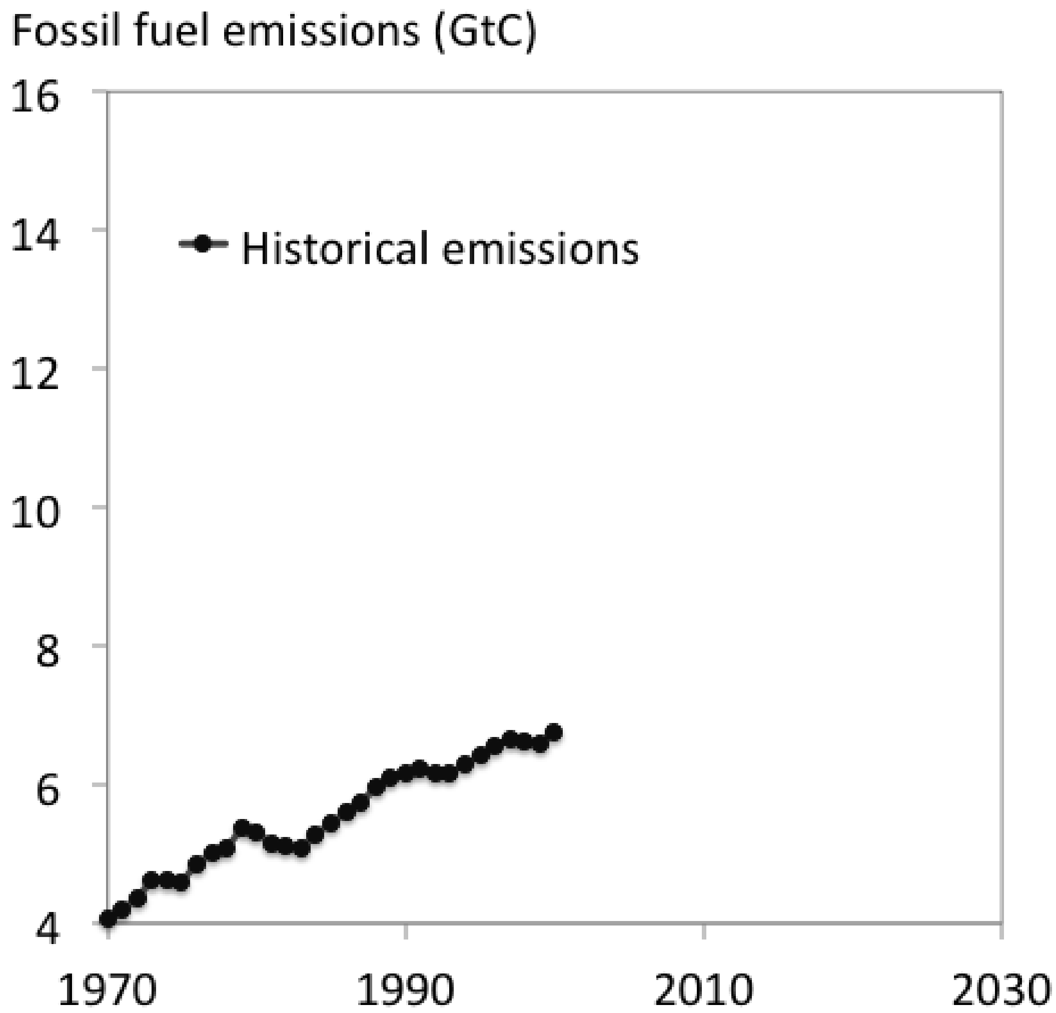


Which is more likely? **We don't know.**



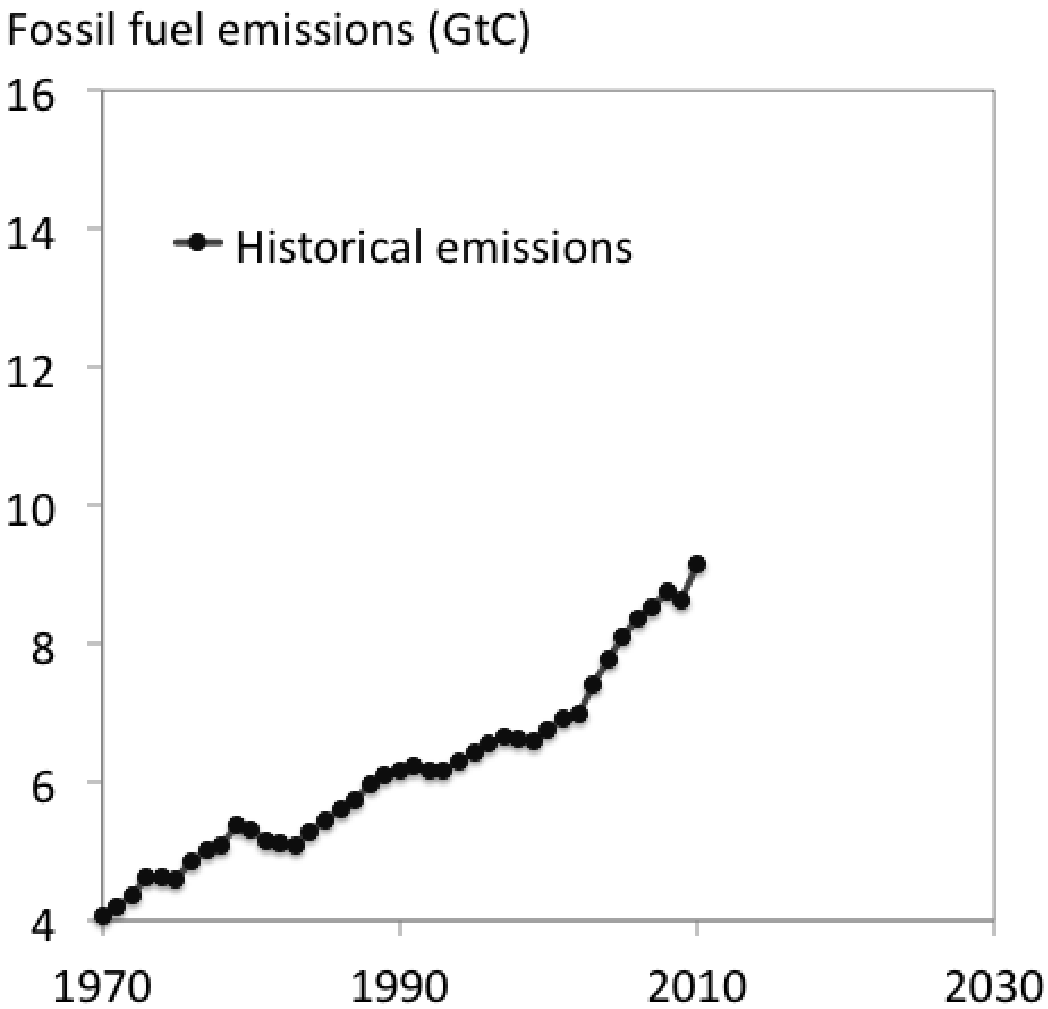
How are we doing so far?



1990s – Emissions growing at 1%

Hayhoe for FWS, 2013

How are we doing so far?



1990s – Emissions growing at 1%

2000s – emissions growing at 3%

Hayhoe for FWS, 2013

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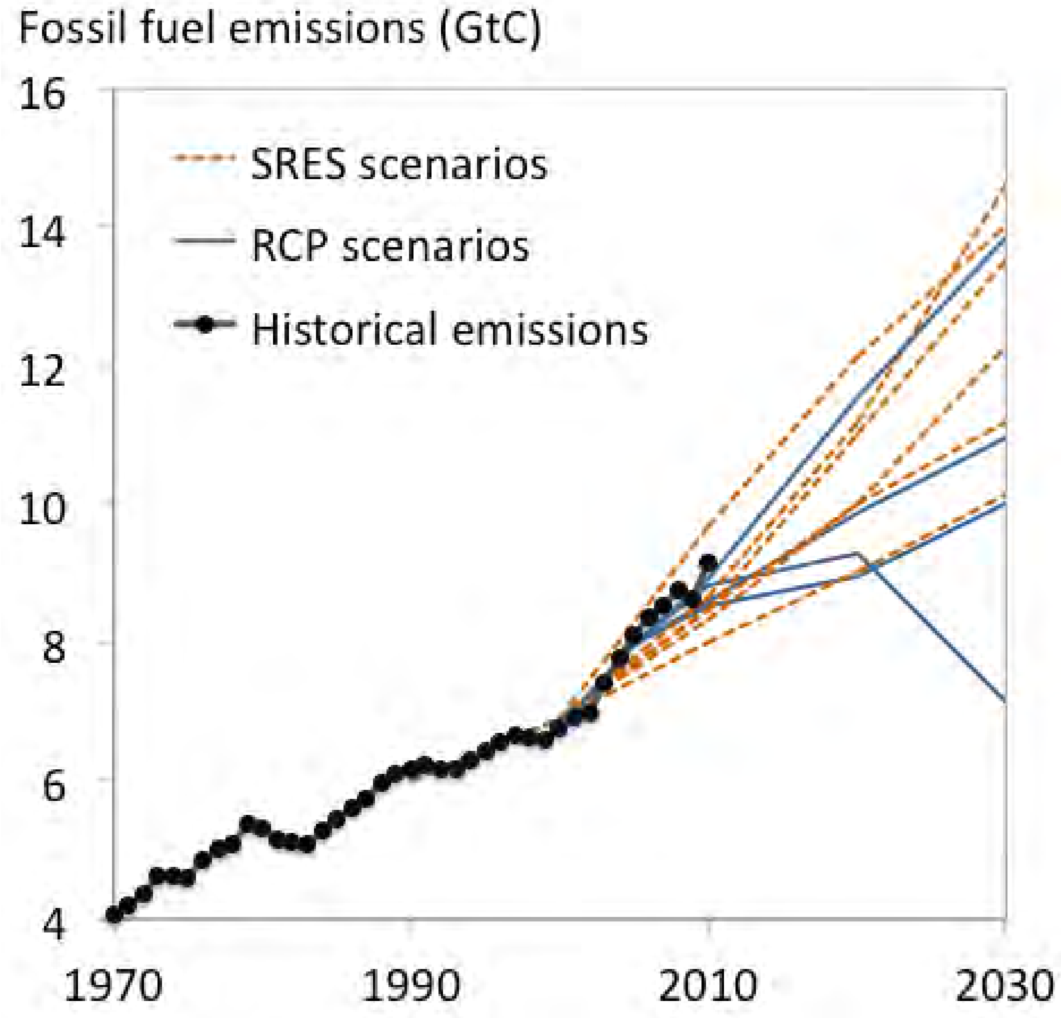

1990s – Emissions growing at 1%

2000s – emissions growing at 3%

2010 – heading on up

Why are future projections uncertain?

2. We don’t know what future emissions from human activities will be. So how can we predict future climate change?

What can we do about it?

We are developing projections for both the SRES and the RCP **higher** and **lower** scenarios, to cover a range of possible futures.

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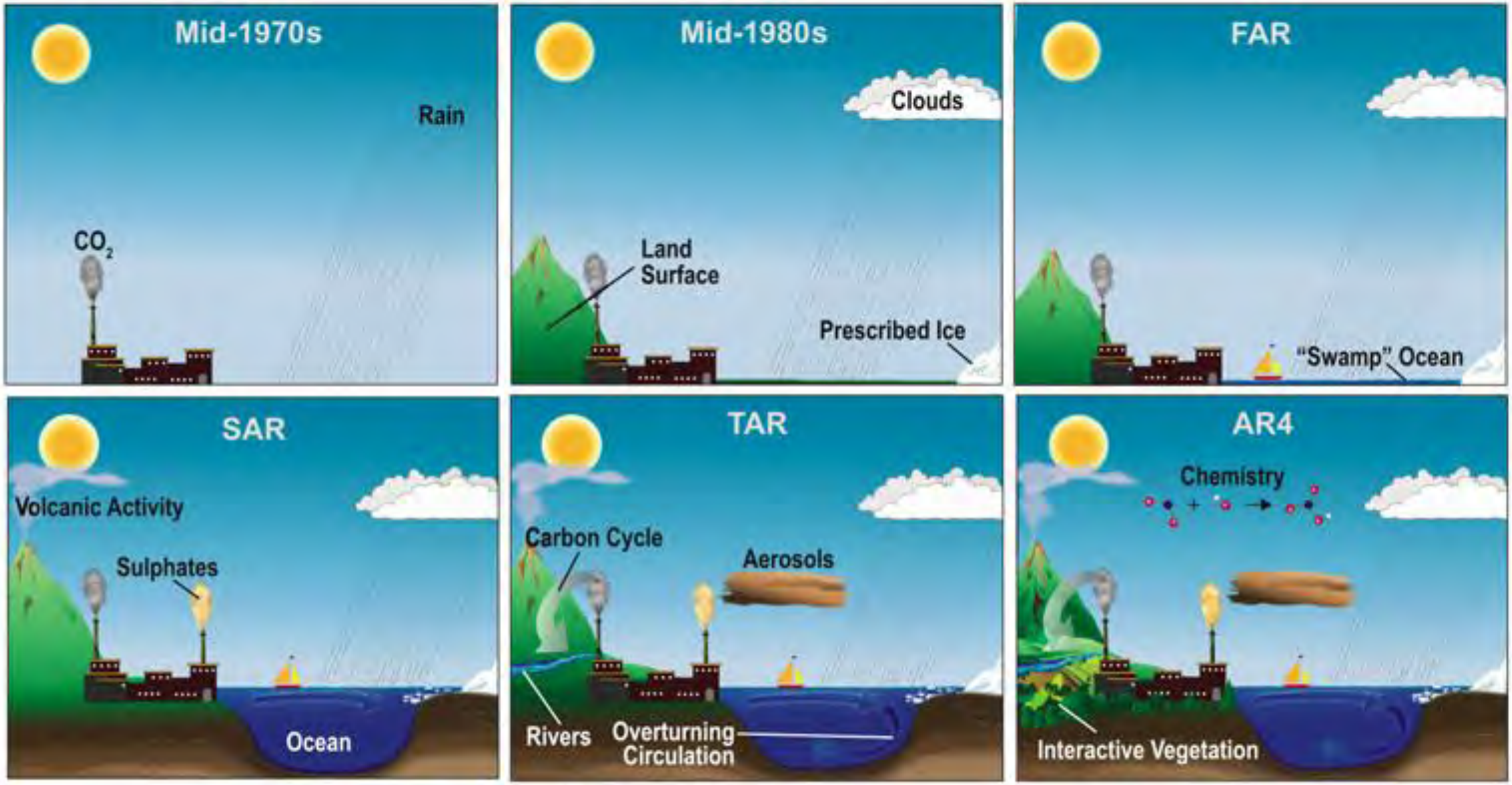
Why are future projections uncertain?

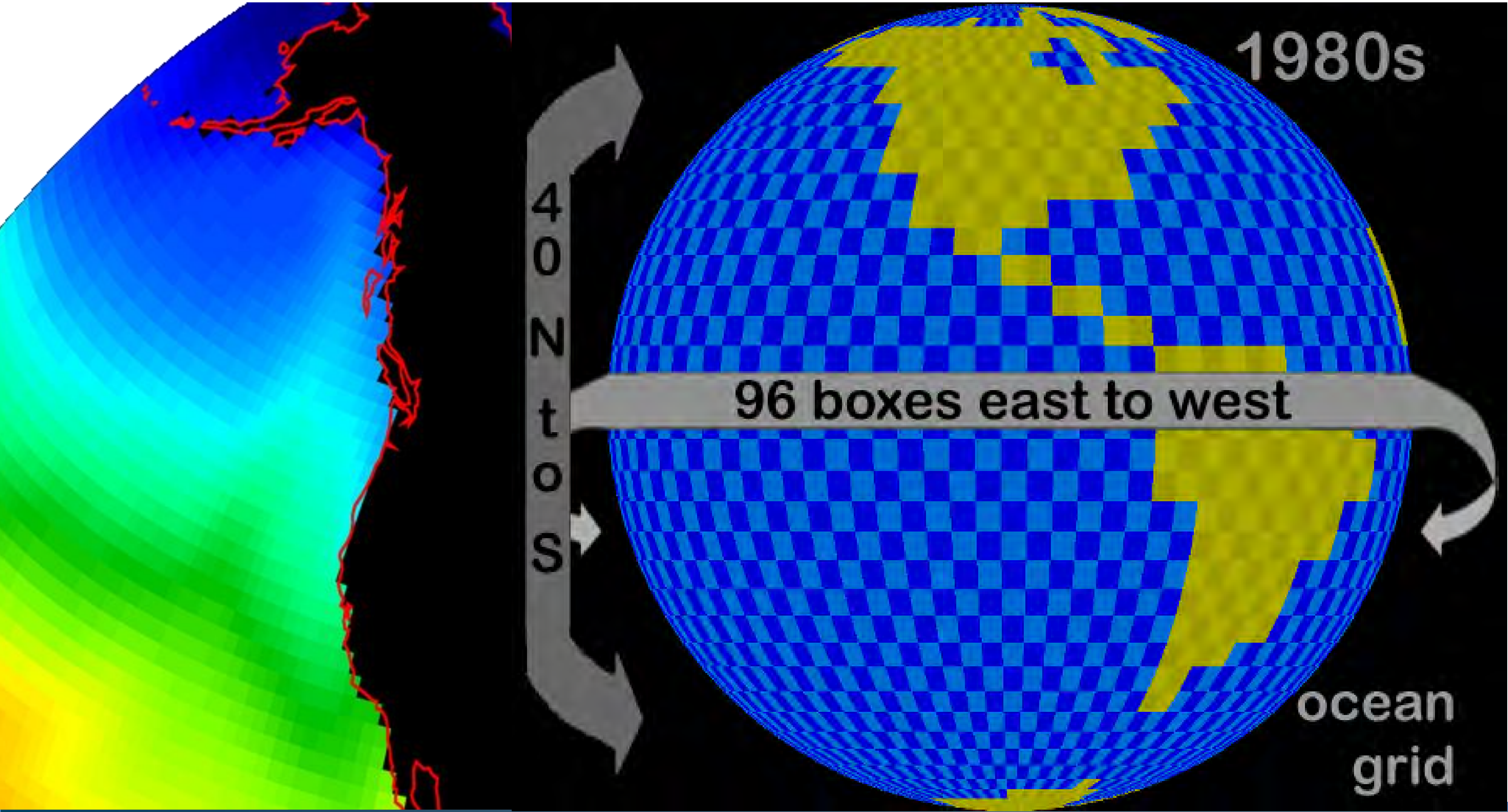
3. Our scientific knowledge is limited

We don’t know exactly how sensitive the climate system is to human activities, and our ability to simulate the climate system is limited and incomplete, particularly at the local to regional scale.

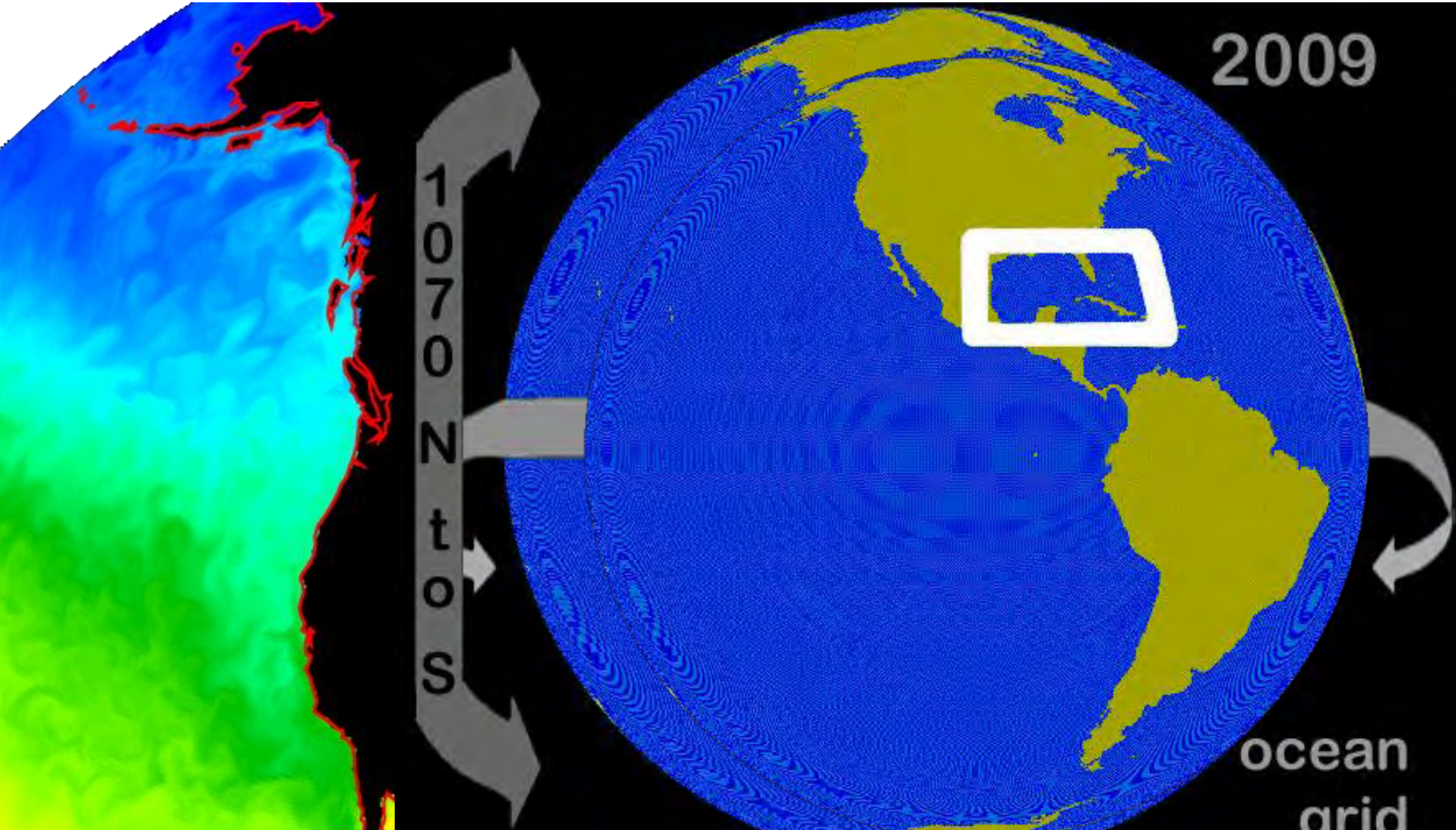
The evolution of climate models: adding more components over time



The evolution of climate models: increasing resolution over time



The evolution of climate models: increasing resolution over time



The bottom line on climate models

- There is no one “perfect” or “best” model for Cambridge (or for anywhere)
- Understanding model limitations and abilities is key to their appropriate use
- Using multiple, well-established models nearly always gives us a result that is closer to reality than any individual model

Why are future projections uncertain?

3. Our scientific knowledge is limited

What can we do about it?

We are using multiple global climate models from the CMIP3 (2006) and CMIP5 (2012) archives. Models cover a range of uncertainties and have been thoroughly analyzed and evaluated in the scientific literature.

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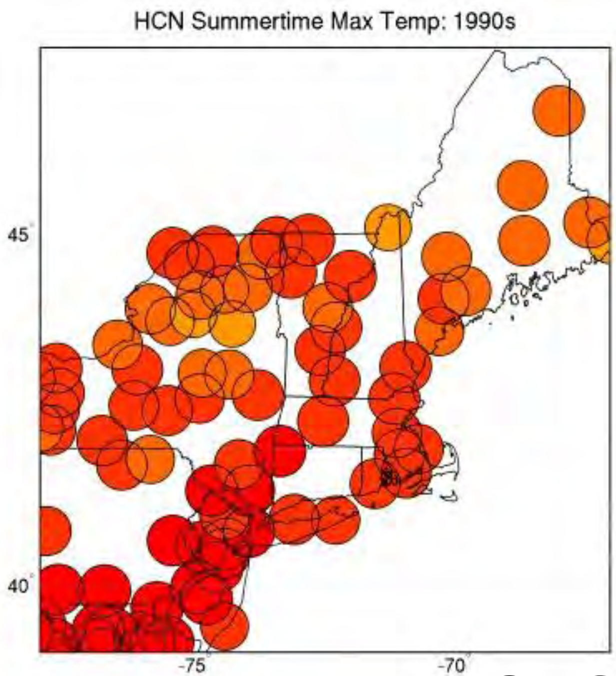
Why are future projections uncertain?

4. Translating the impacts of global change down to the regional scale is complicated!

What is downscaling?

Generating high-resolution projections from coarser-resolution fields **by introducing new information**: here, from long-term observations



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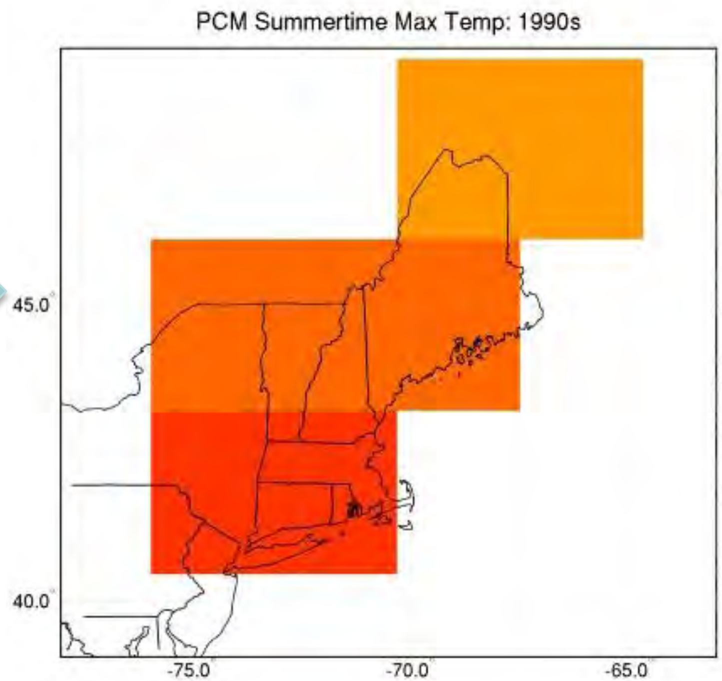
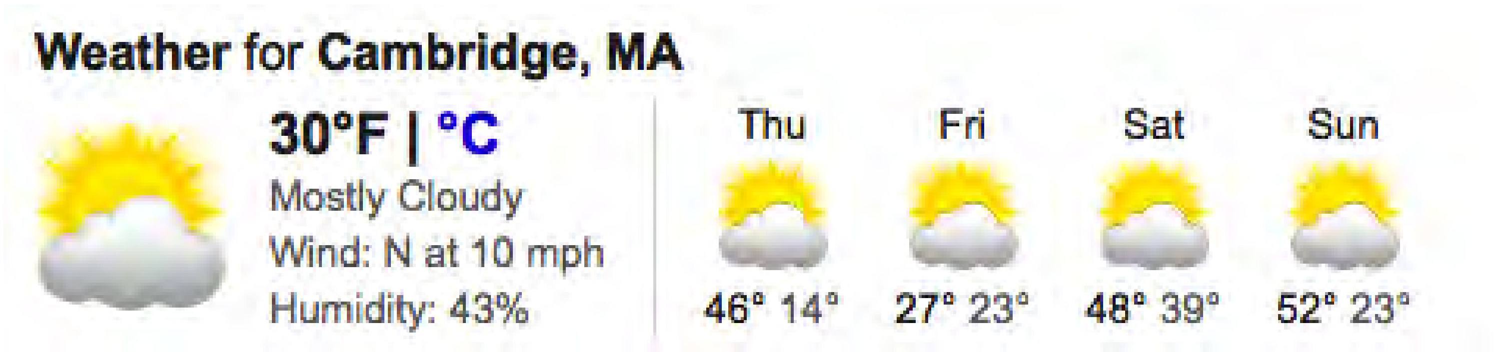


GLOBAL MODEL

Underlying Assumptions



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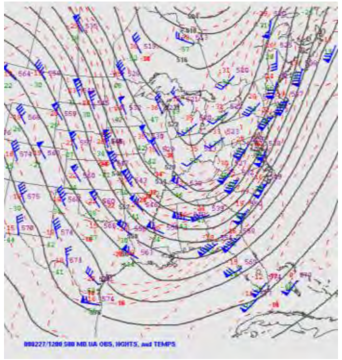

Large-scale weather systems

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Local orography and other time-invariant features

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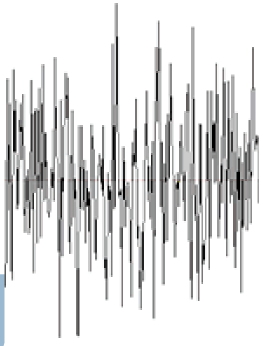

Stochastic noise

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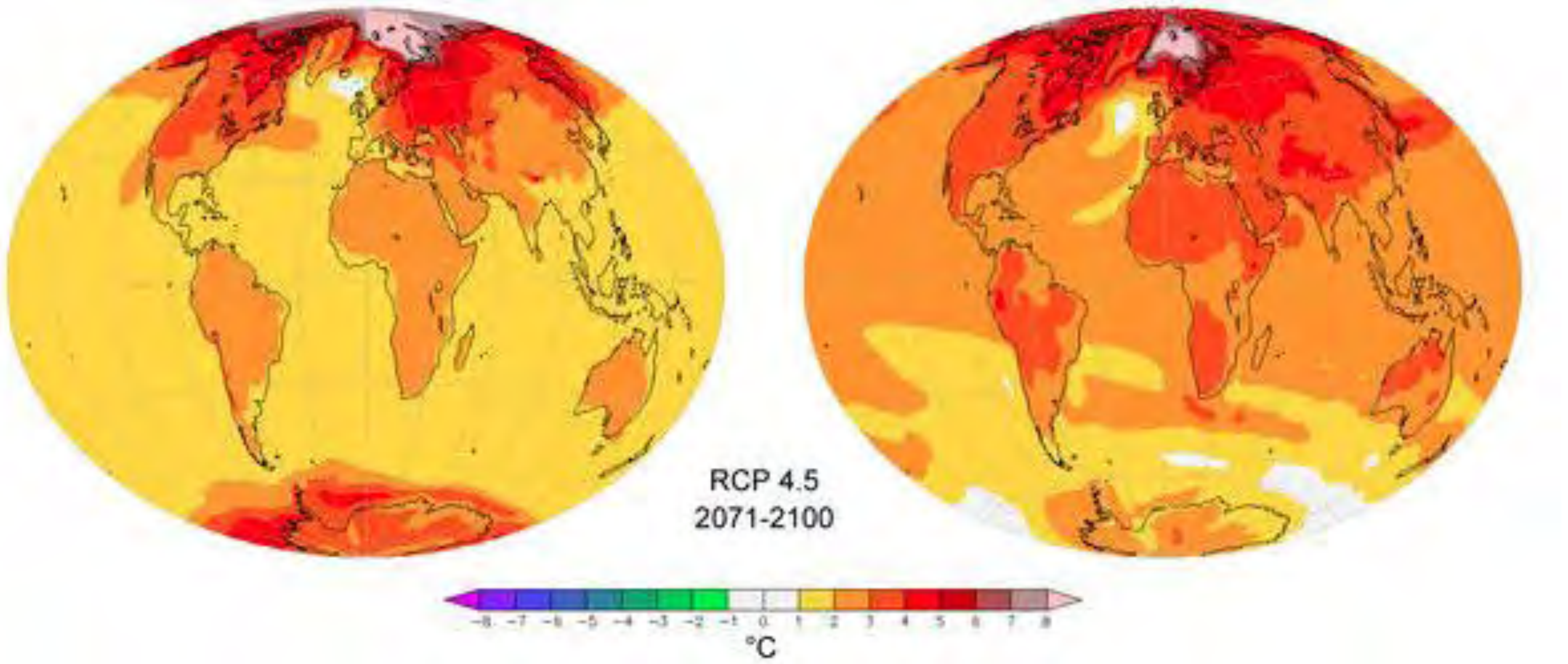
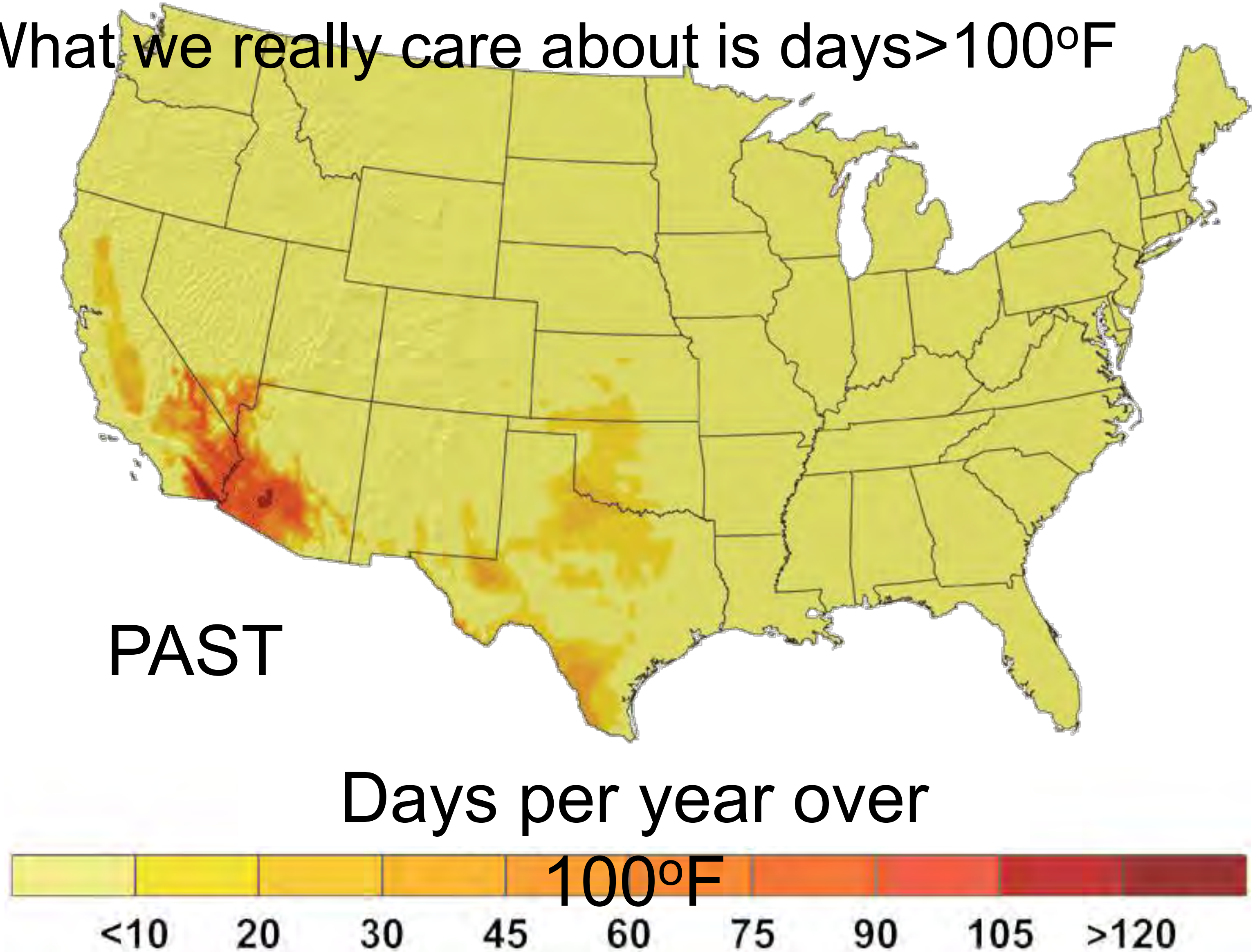
Climate models give us global average temperature, for example…



What we really care about is days>100^{o}F



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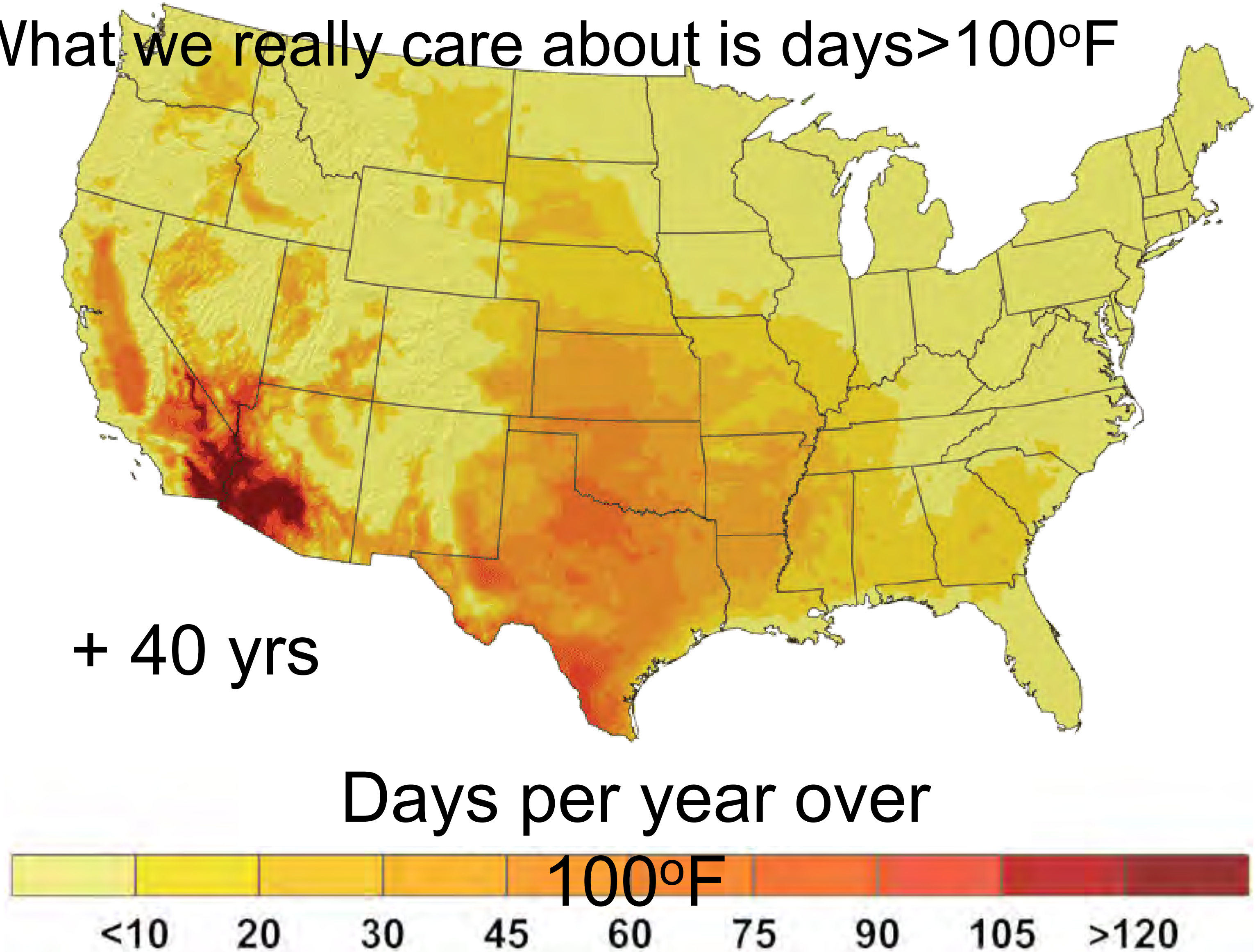
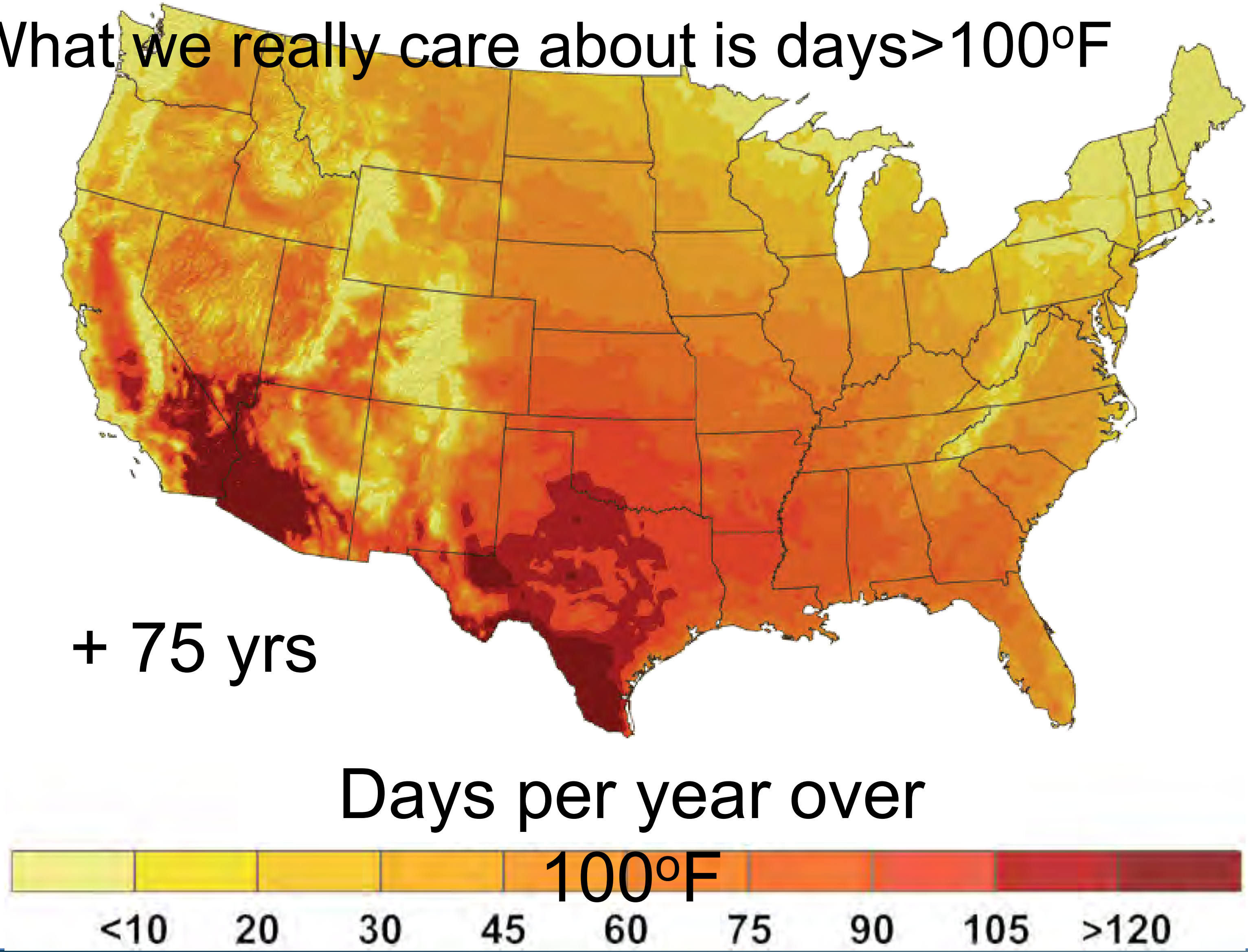


+ 40 yrs

Days per year over 100^{o}F

What we really care about is days>100ºF



Days per year over 100ºF

Why are future projections uncertain?

4. Translating the impacts of global change down to the regional scale is complicated!

What can we do about it?

We will use an advanced statistical downscaling model combined with long-term **station** observations to generate daily maximum and minimum temperature and precipitation from 1960 to 2100.

This information can be used to derive all kinds of indicators: days over 95°F, demand for air conditioning, risk of flood conditions, etc.

Compatibility with other assessments

- We need to use station-based downscaling for Cambridge because it is a very small spatial area and it is close to the coast. Gridded datasets do not perform well in either situation.
- Projections based on older CMIP3 models and SRES scenarios will be compatible with NECIA (2007) and the 2009 US National Climate Assessment.
- Projections based on new CMIP5 models and RCP scenarios will be compatible with new 2014 US National Climate Assessment and the latest scientific literature.

Final products

- Daily maximum and minimum temperature and 24h cumulative precipitation for 1960 to 2099
- Corresponding to SRES and RCP higher and lower scenarios
- Generated using daily output from CMIP3 and CMIP5 global climate models.
- For 3 long-term weather stations nearest to Cambridge

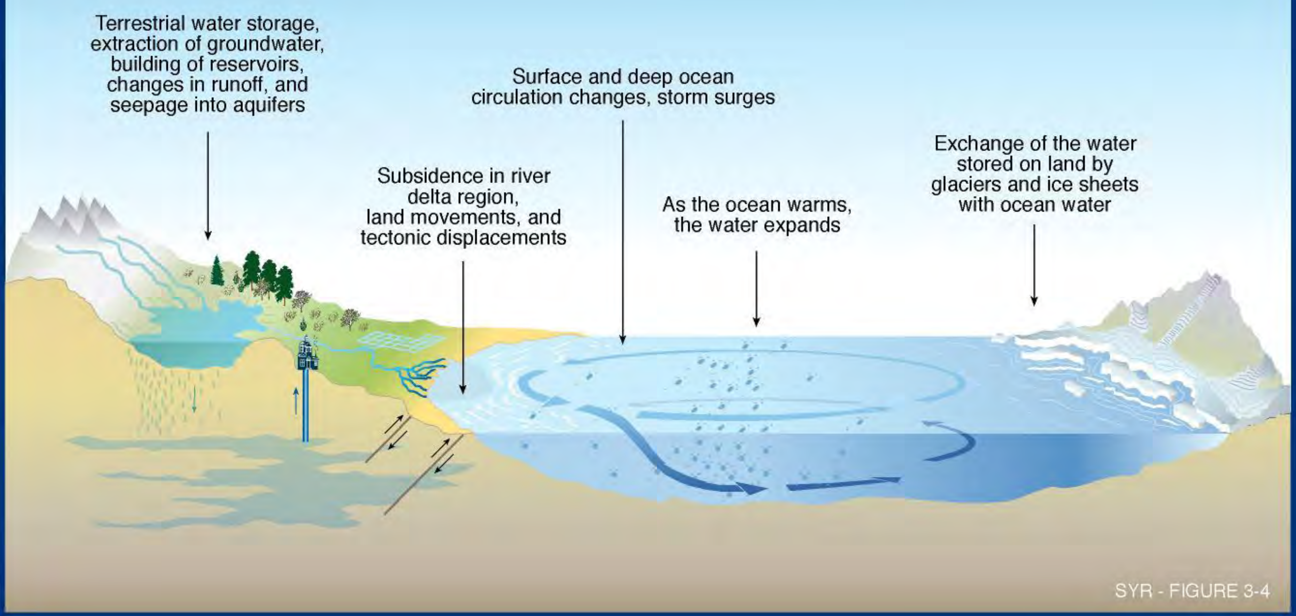
This information can be used to interpolate to short-term weather stations in Cambridge, to analyze observed and projected trends in climate, and to generate a host of climate indicator projections.

Questions / Discussion

Relative Sea Level Rise

Paul Kirshen

What causes the sea level to change?



SYR - FIGURE 3-4

Scenario Projections for Global SLR

(Vermeer & Rahmstorf, 2009)

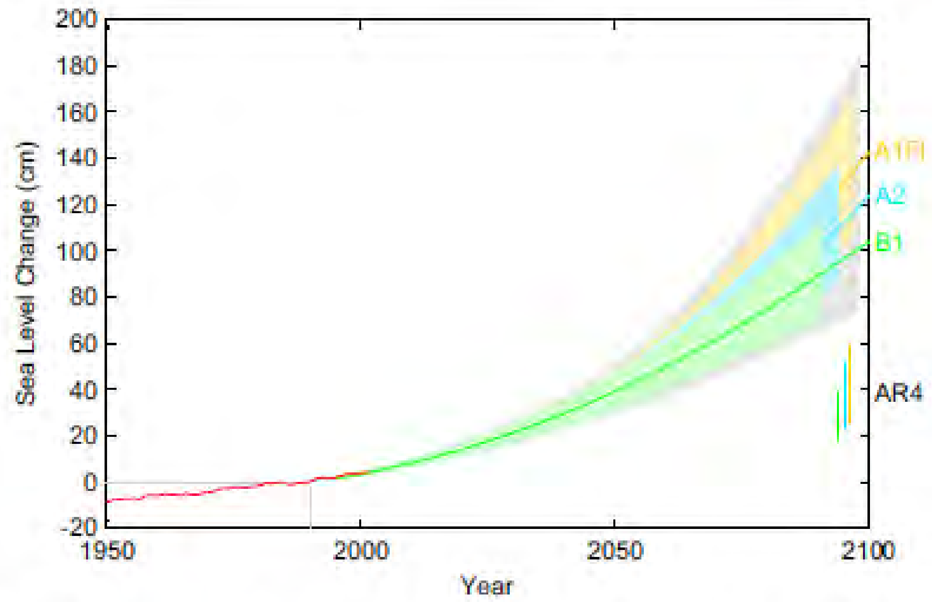


Fig. 6. Projection of sea-level rise from 1990 to 2100, based on IPCC temperature projections for three different emission scenarios (labeled on right, see Projections of Future Sea Level for explanation of uncertainty ranges). The sea-level range projected in the IPCC AR4 (2) for these scenarios is shown for comparison in the bars on the bottom right. Also shown is the observations-based annual global sea-level data (18) (red) including artificial reservoir correction (22).

Consistent with US National Climate Assessment SLR Scenario Report (2013)

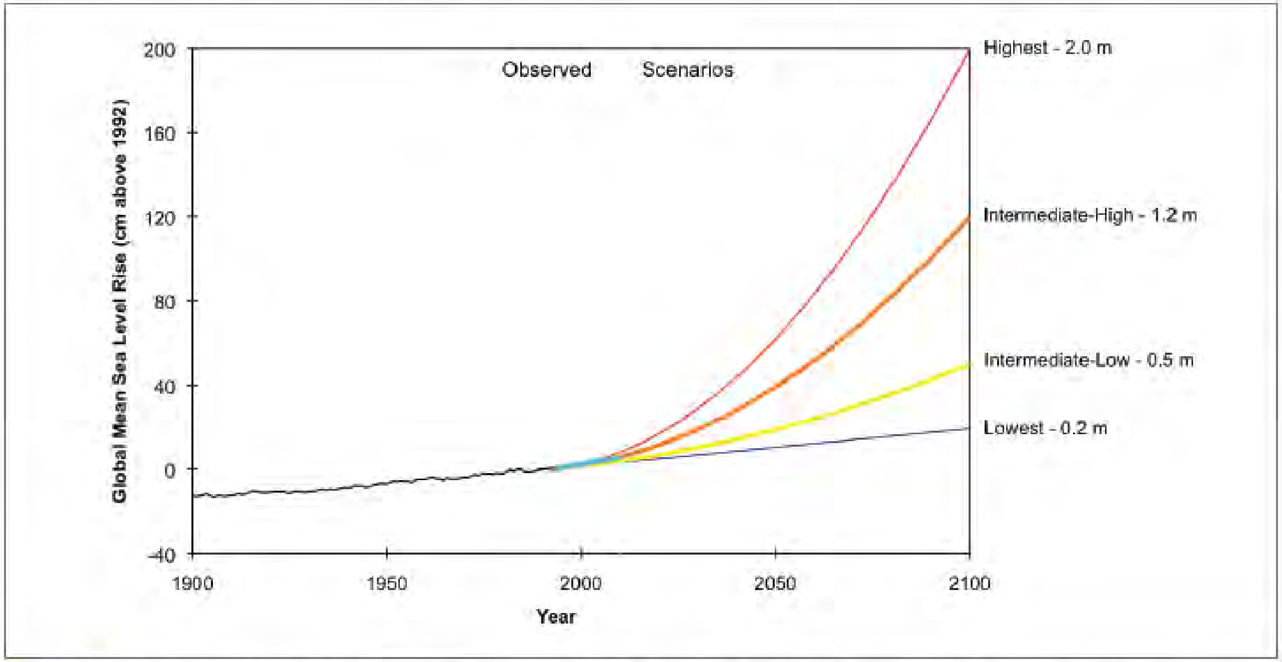


Figure 10. Global mean sea level rise scenarios. Present Mean Sea Level (MSL) for the US coasts is determined from the National Tidal Datum Epoch (NTDE) provided by NOAA. The NTDE is calculated using tide gauge observations from 1983 – 2001. Therefore, we use 1992, the mid-point of the NTDE, as a starting point for the projected curves. The Intermediate High Scenario is an average of the high end of ranges of global mean SLR reported by several studies using semi-empirical approaches. The Intermediate Low Scenario is the global mean SLR projection from the IPCC AR4 at 95% confidence interval.

12 | November 2012

Component	Source
Global SLR (m)	Vermeer, M., and Rahmstorf, S., Global Sea Level Linked to Global Temperature,www.pnas.org_cgi_doi_10.1073_pnas.0907765106, 2009. Low B1, High A1fi
Local (m)	Kirshen, P., Watson, C., Douglas, E., Gontz, A., Lee, J., and Tian, Y., Coastal Flooding in the Northeastern USA due to Climate Change, Mitigation and Adaptation Strategies for Global Change, 13(5-6), June 2008. (1.1 mm/year)
Regional (m)	Yin, J., Schlesinger, M., and Stouffer, R., Model Projections of Rapid Sea-Level Rise in the Northeast Coast of the United States, Nature Geoscience, 2(4):262-266, 2009. (20 cm by 2100 for high scenario)

Questions / Discussion

Economic Vulnerability Assessment

Sam Merrill

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Data for Decision-Making

Damage Functions for Single Family
Residential Structures with Basement

Depth (feet)	Mean of Damage
0	25.5%
1	32.0%
2	38.7%
3	45.5%
4	52.2%
5	58.6%
6	64.5%

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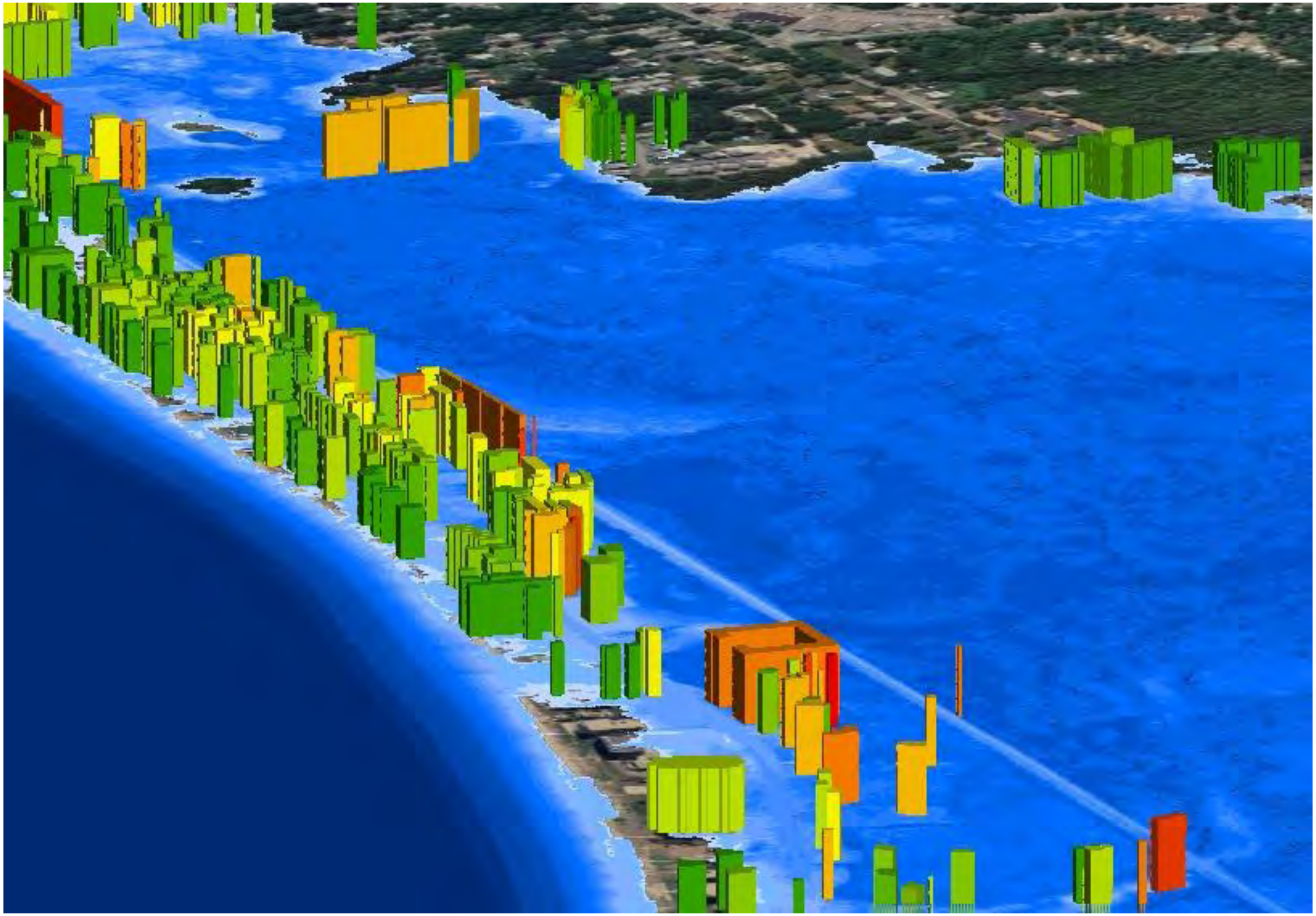

Expected costs and damages, 2010 - 2050

SLR Scenario	Adaptation	Residual Damages ($ million)	Adaptation Cost ($ million)	Total Damages and Costs ($ million)
No SLR	No Action	680	0	680
	50 yr flood	3.4	52.4	55.8
	100 yr flood	0	60	60
Low	No Action	899.3	0	899.3
	50 yr flood	28.3	52.4	80.7
	100 yr flood	0	60	60
High	No Action	1016.6	0	1016.6
	50 yr flood	67.8	52.4	120.2
	100 yr flood	37.6	60	97.6

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Possible Assets to Model

- Real estate values
- Economic output
- Public health impacts
- Displaced persons, vulnerable demographics
- Natural resources values
- Cultural resources values
- Community impacts
- Infrastructure (transportation, energy, facilities, telecommunications)

Impact Modeling Parameters

Under Low and High climate change scenarios developed by the Kleinfelder team, for the years 2030 and 2070, model expected damages for:

1) Lost real estate value from flooding.
2) Economic impact.

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Vulnerable Assets

Lost real estate values:

- Assessor's tables

Economic impacts:

- Combined proxy metrics including
  - Numbers of employees
  - Combined $ value of retail goods and services
  - Ridership at T-stations (or use other transportation/mobility data as appropriate).

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Economic impacts

- Will be developed and assigned in collaboration with City representatives (across the identified high-impact building clusters), so that assumptions about business interruption thresholds are agreed upon.

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Questions / Discussion

Public Health & Vulnerability

Pat Kinney

Proposed Health Activities

Primary focus in three areas:

- Direct effects of temperature
- Regional air quality
- Vector-borne diseases

Also review potential vulnerabilities related to:

- Waterborne diseases
- Indoor air quality
- Health infrastructure and flooding
- Pollen and allergic diseases

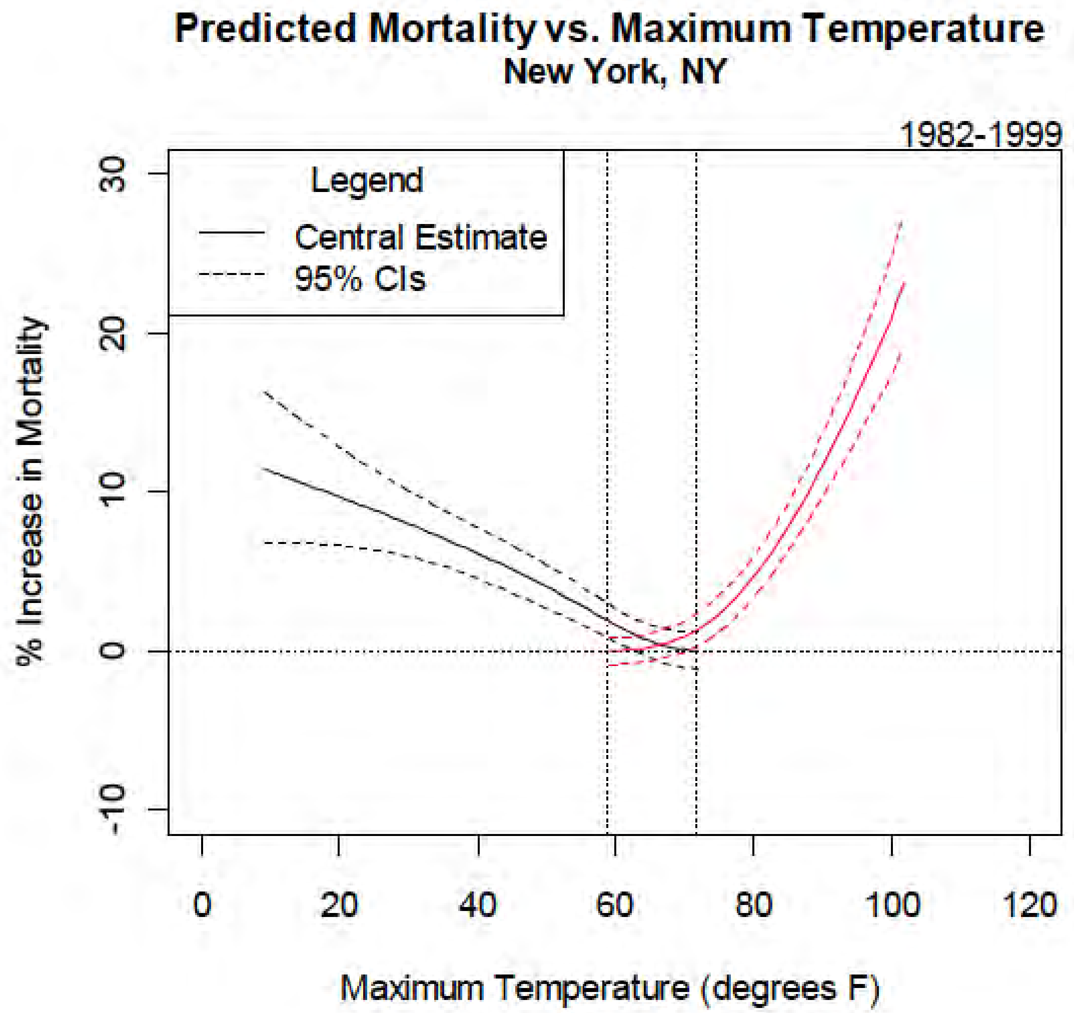
Direct Effects of Temperature

Quantitative Analyses:

- Obtain records of daily deaths and temperatures in Cambridge and Boston
- Statistical analyses of exposure-response
- Projections of future effects under climate change

Vulnerability Mapping:

- Obtain and map data related to old age, social isolation, poverty, non-white race, green space, access to cooling centers, air conditioner prevalence, and surface temperatures (Landsat)
- Overlay data and assign vulnerability scores to census blocks

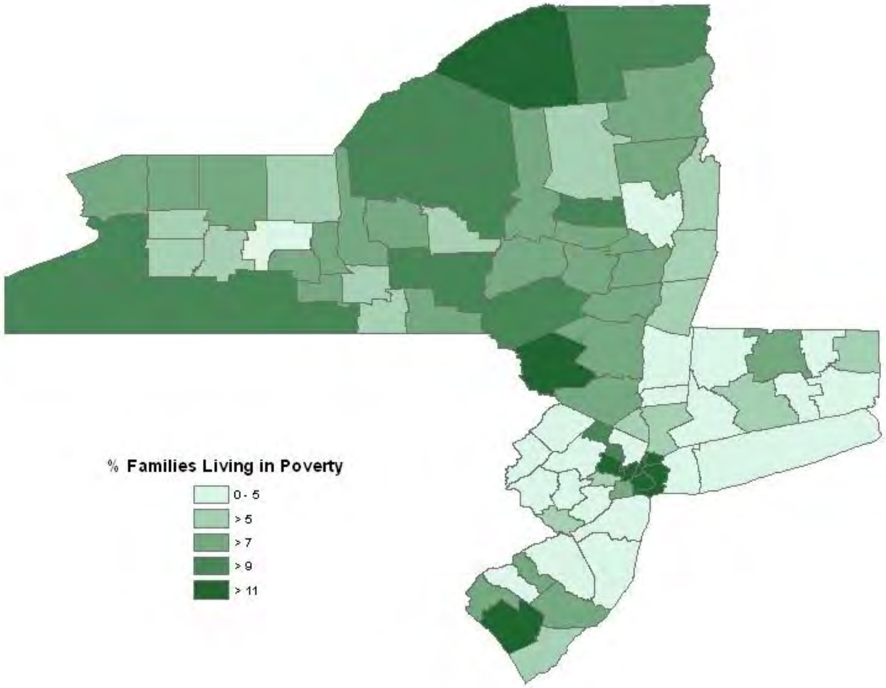


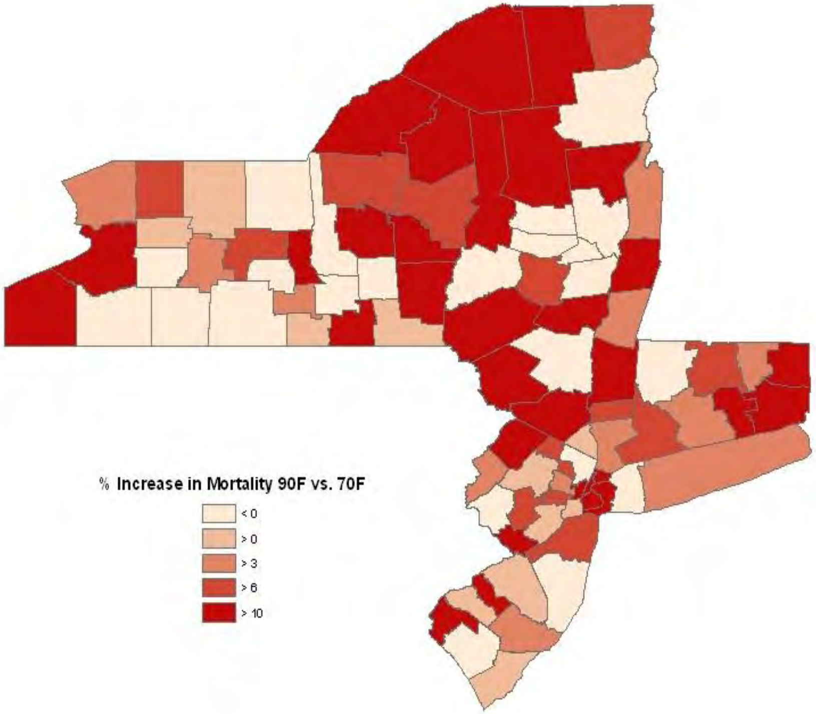
The lines show the effects of changes in daily max temperature on the risk of death on that day (warm temps) or mean of today and yesterday (cold temps)

% Poverty (left) and Heat Impact (right)

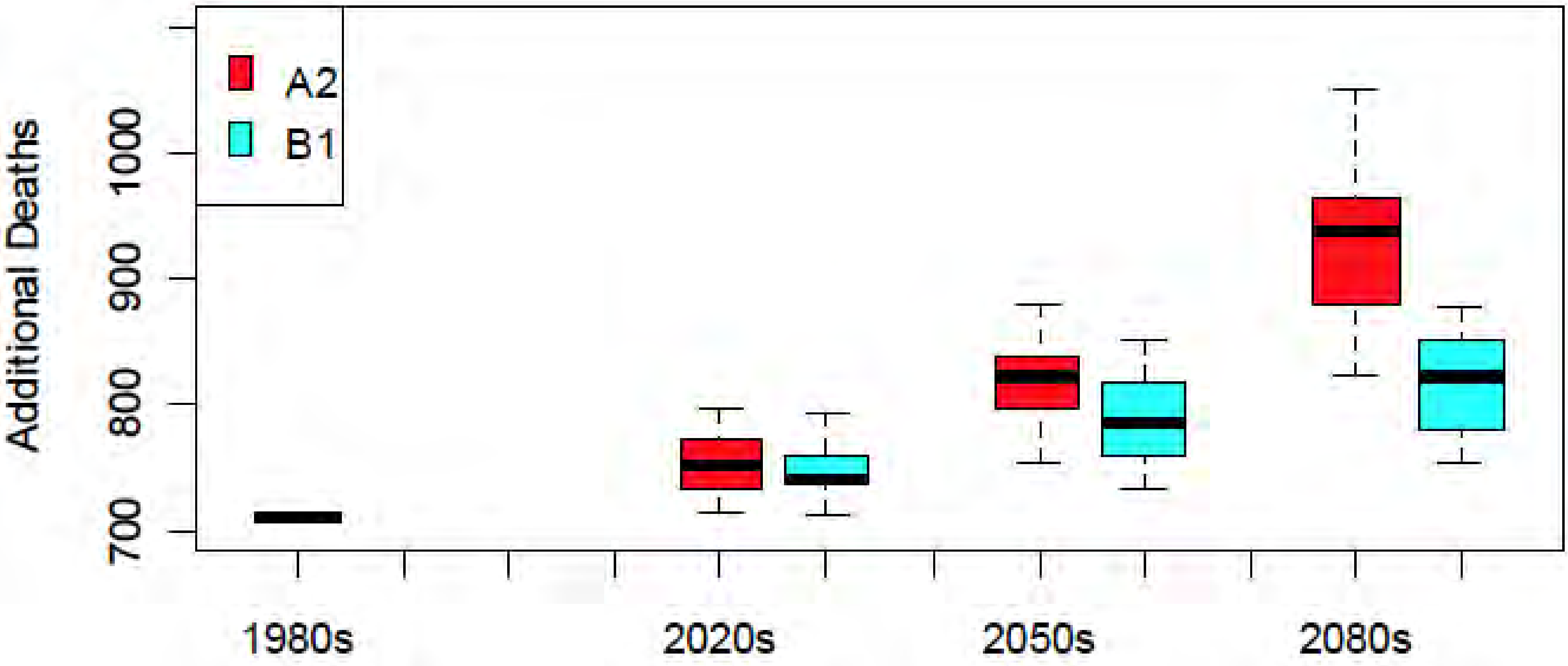
Percent of families living in poverty

Percent change in daily deaths at 90 F vs. 70 F (right)





Projections of Future Deaths in Manhattan
(distributions across 16 models, for 2 scenarios)



Li, Horton and Kinney, in review at Nature Climate Change

Regional Air Quality

Ozone:

- Review findings from studies that have modeled ozone (and PM2.5) in the NE US under a range of future climate and emissions scenarios

Pollen:

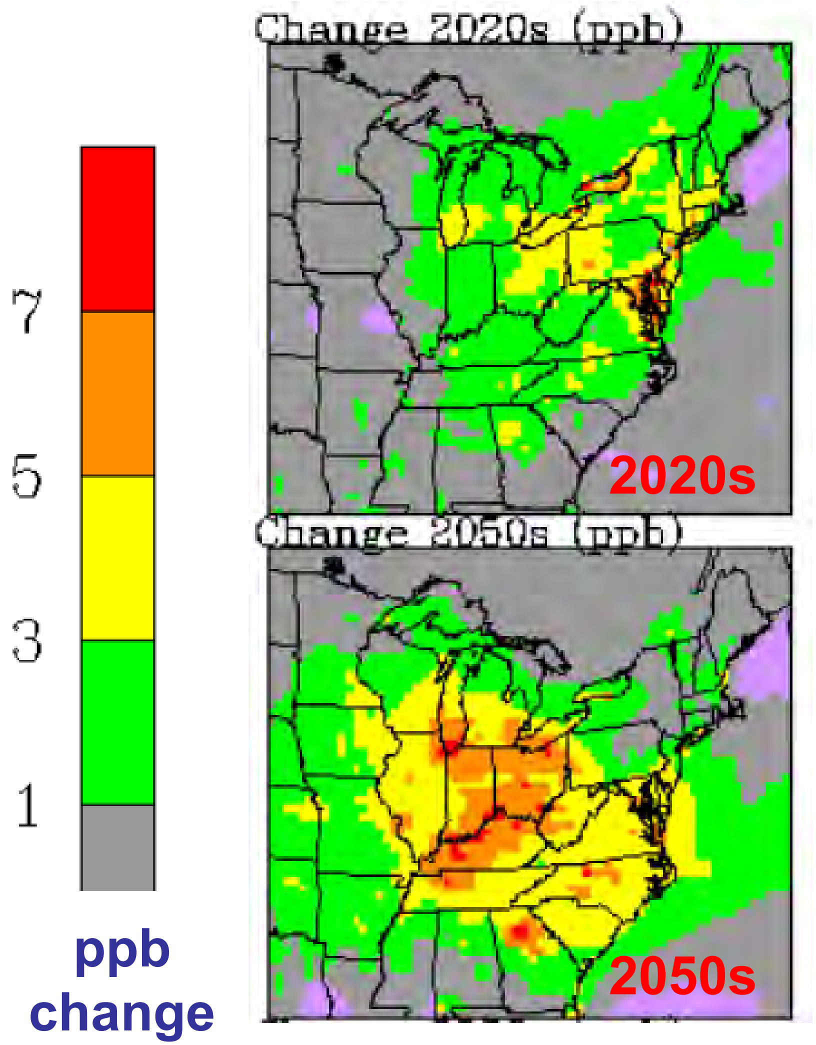
- Qualitative review of emerging literature on pollen responses to warming and CO_2 rise

Indoor moisture:

- Examine flooding projections associated with storm events

Modeled changes in ozone pollution from the 1990s to the 2020s and 2050s

(parts per billion)



From: New York Climate and Health Project, developed and led by P. Kinney

Vector Borne Diseases

Qualitative review for:

- West Nile Virus, dengue fever, Lyme disease, Eastern Equine Encephalitis
- Summarize past trends in surveillance data for region
- Review evidence for potential future trends related to climate

Other Health Vulnerabilities

Qualitative assessment of:

- Water-borne disease and climate extremes

Spatial analysis of future flood projections in relation to key health infrastructure:

- Hospitals
- Clinics
- Nursing homes

Questions / Discussion

Next Steps