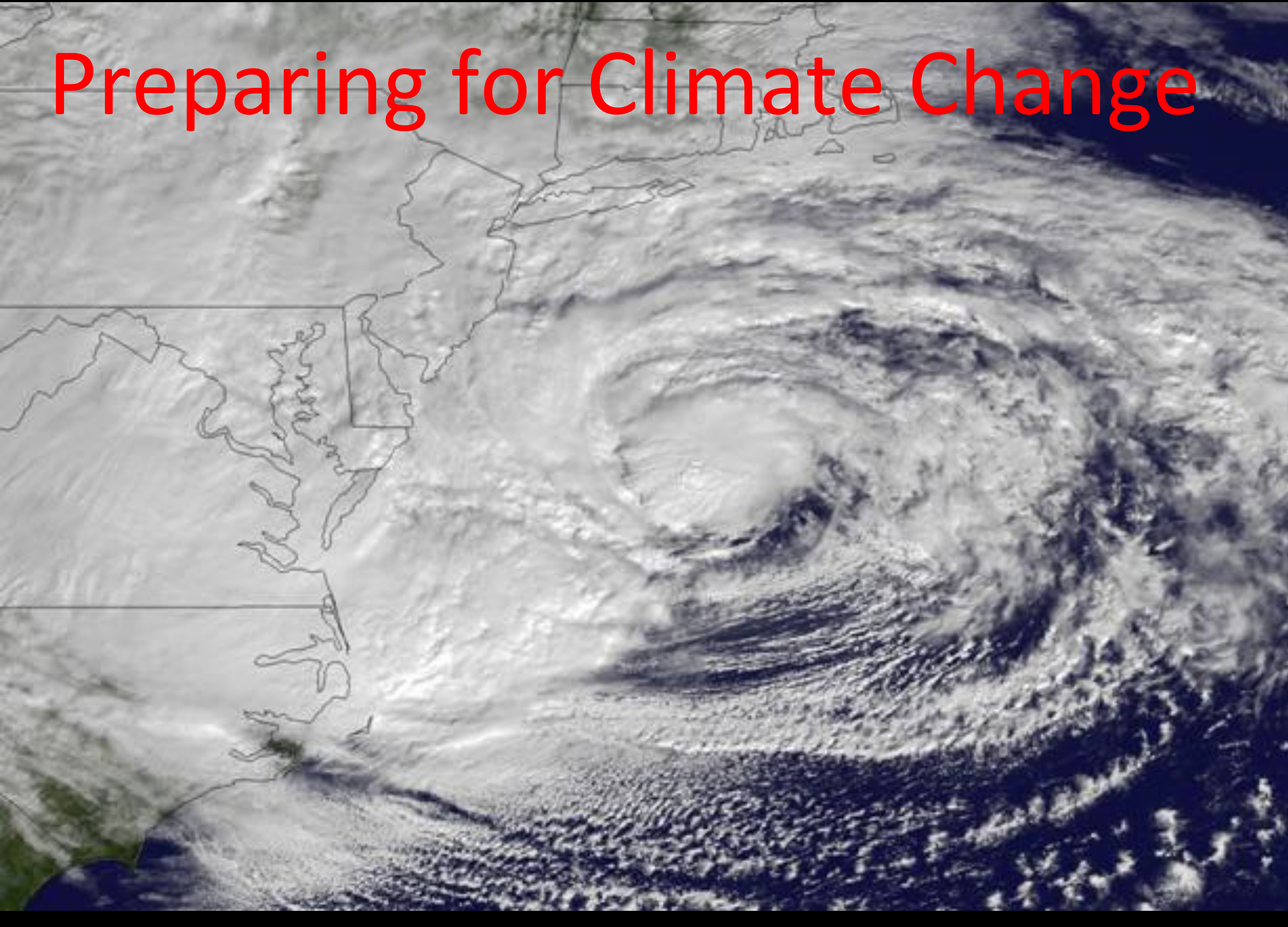
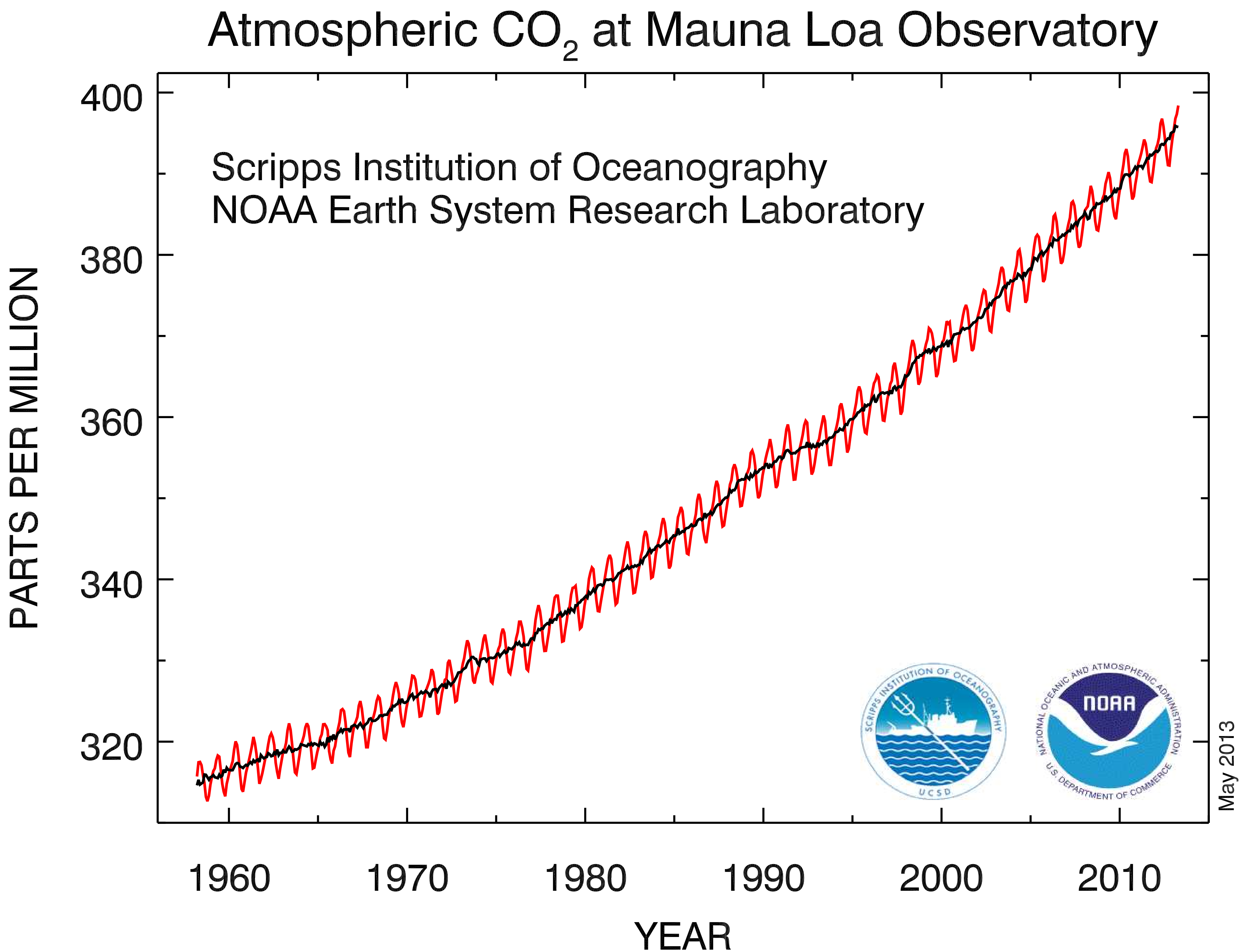

Preparing for Climate Change


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
May 2013

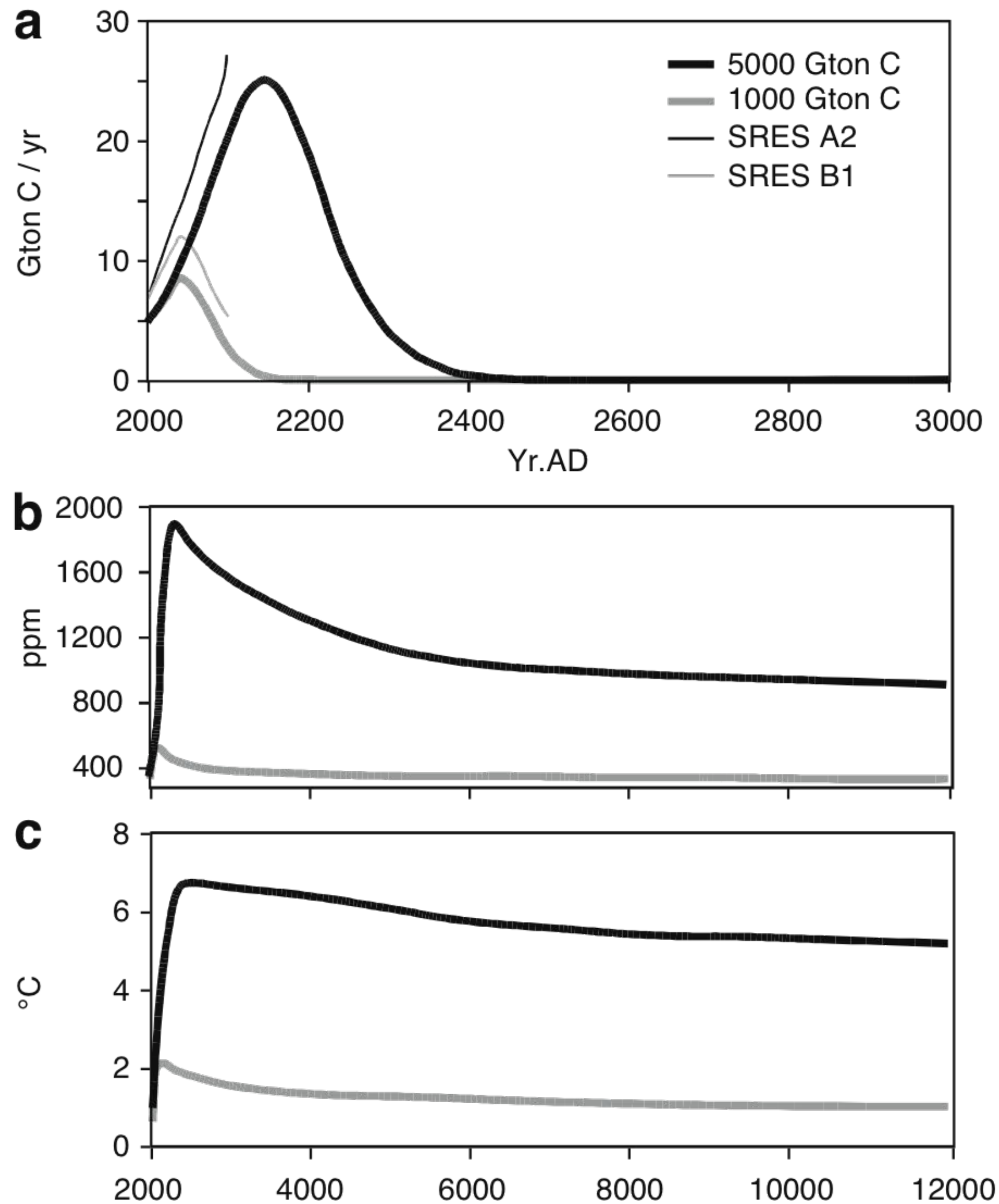


Fig. 2 A response of CLIMBER-2 model (Brovkin et al. 2002; Brovkin et al. 2007; Ganopolski et al. 1998) to Moderate (1,000 Gton C) and Large (5,000 Gton C) fossil fuel slugs. The equilibrium climate sensitivity of the model is 2.6°C. Temperatures were smoothed with a 250 filter to eliminate a spurious fluctuation of Antarctic sea ice caused by the low model resolution. The land carbon cycle was neglected in these simulations while deep sea sediments were explicitly simulated using a sediment diagenesis model (Archer 1991). **a** Emissions scenarios and reference IPCC SRES scenarios (B1 and A2). **b** Simulated atmospheric CO_2 (ppmv). **c** Simulated changes in global annual mean air surface temperature (°C)

What is the value of the distant future?

How do we think about decisions we are making today that will affect the Earth for tens of thousands of years?

Is there a moral argument for some threshold of environmental conditions that we must preserve for future generations?

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LETTERS

Warming caused by cumulative carbon emissions towards the trillionth tonne

Myles R. Allen[1], David J. Frame[1,2], Chris Huntingford[3], Chris D. Jones[4], Jason A. Lowe[5], Malte Meinshausen[6] & Nicolai Meinshausen[7]

Global efforts to mitigate climate change are guided by projections of future temperatures[1]. But the eventual equilibrium global mean temperature associated with a given stabilization level of atmospheric greenhouse gas concentrations remains uncertain[1–3], complicating the setting of stabilization targets to avoid potentially dangerous levels of global warming[4–8]. Similar problems apply to the carbon cycle: observations currently provide only a weak constraint on the response to future emissions[9–11]. Here we use ensemble simulations of simple climate-carbon-cycle models constrained by observations and projections from more comprehensive models to simulate the temperature response to a broad range of carbon dioxide emission pathways. We find that the peak warming caused by a given cumulative carbon dioxide emission is better constrained than the warming response to a stabilization scenario. Furthermore, the relationship between cumulative emissions and peak warming is remarkably insensitive to the emission pathway (timing of emissions or peak emission rate). Hence policy targets based on limiting cumulative emissions of carbon dioxide are likely to be more robust to scientific uncertainty than emission-rate or concentration targets. Total anthropogenic emissions of one trillion tonnes of carbon (3.67 trillion tonnes of CO_2), about half of which has already been emitted since industrialization began, results in a most likely peak carbon-dioxide-induced warming of 2 °C above pre-industrial temperatures, with a 5–95% confidence interval of 1.3–3.9 °C.

What is the timescale of decarbonizing the U.S.?

The challenge: Try to construct a low-carbon U.S. economy by mid-century, assuming increases in demand are balanced by increased energy efficiency.

U.S. Transportation Sector, 2008

	Energy (GWy)	CO_2 (Gt/y)
Coal	0	0
Oil	884	1.9
Natural Gas	23	0
Biomass	28	0
Electricity	1	0

- Electrify as much as possible (whether electric cars or fuel-cell cars with hydrogen from renewables). Motor gasoline is roughly 50% of U.S. petroleum use, so replacing that would add ~450 GWy of electricity demand.

- Remainder provided by advanced biofuels, which requires CCS on a scale of ~2 Gt/y.

U.S. Residential and Commercial Sectors, 2008

	Energy (GWy)	CO_2 (Gt/y)
Coal	3	0.0
Oil	62	0.1
Natural Gas	274	0.4
Biomass	19	0.0
Electricity	312	1.6

- Electrify as much as possible. (adding ~300 GWy of demand)

U.S. Industrial Sector, 2008

	Energy (GWy)	CO_2 (Gt/y)
Coal	61	0.2
Oil	286	0.6
Natural Gas	270	0.4
Biomass	68	0.0
Electricity	112	0.6

- Electrify as much as possible (unclear how much is feasible), adding ~250 GWy of electricity demand.

- Replace petroleum with advanced biofuels, requiring additional CCS on a scale of ~2 Gt/y.

U.S. Electricity Sector, 2008

(~1,100 GW of generating capacity)

	Energy (GWy)	CO_2 (Gt/y)
Coal	227	1.9
Oil	5	0.0
Natural Gas	101	0.4
Biomass	6	
Nuclear	92	
Hydro	28	
Wind	6	
Solar	2	
Geothermal	2	

- Creating a non-fossil electricity sector to replace existing system (450 GWy of demand) requires building at least 1500 GW of new capacity (because of low capacity factors of renewables).

- Additional demand of ~1000 GWy requires an additional 2500 to 3000 GW of capacity.

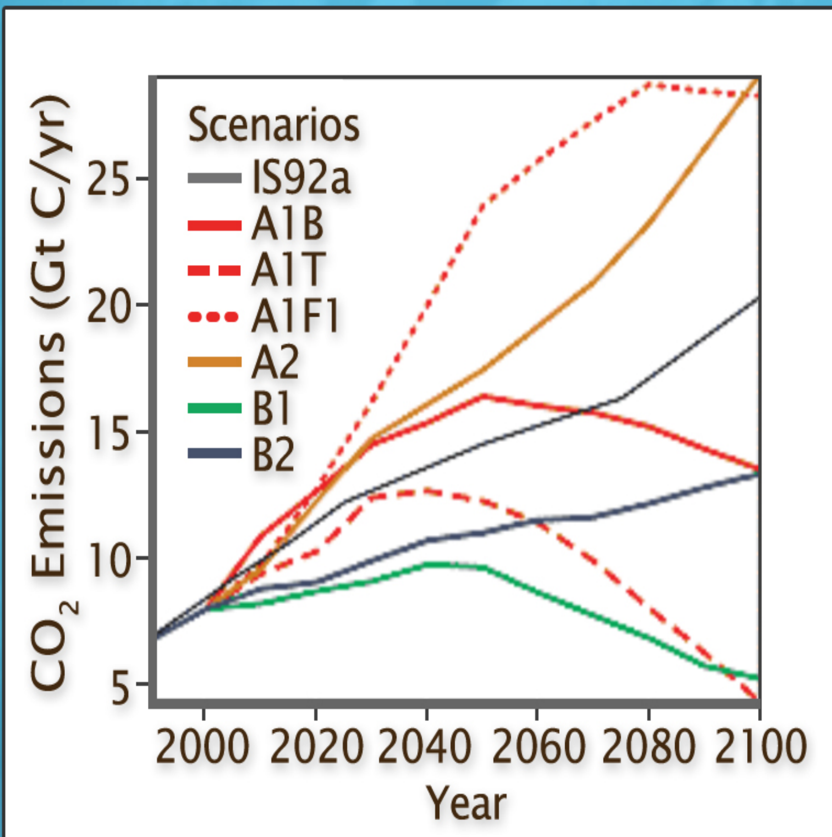
What can we say about timescale?

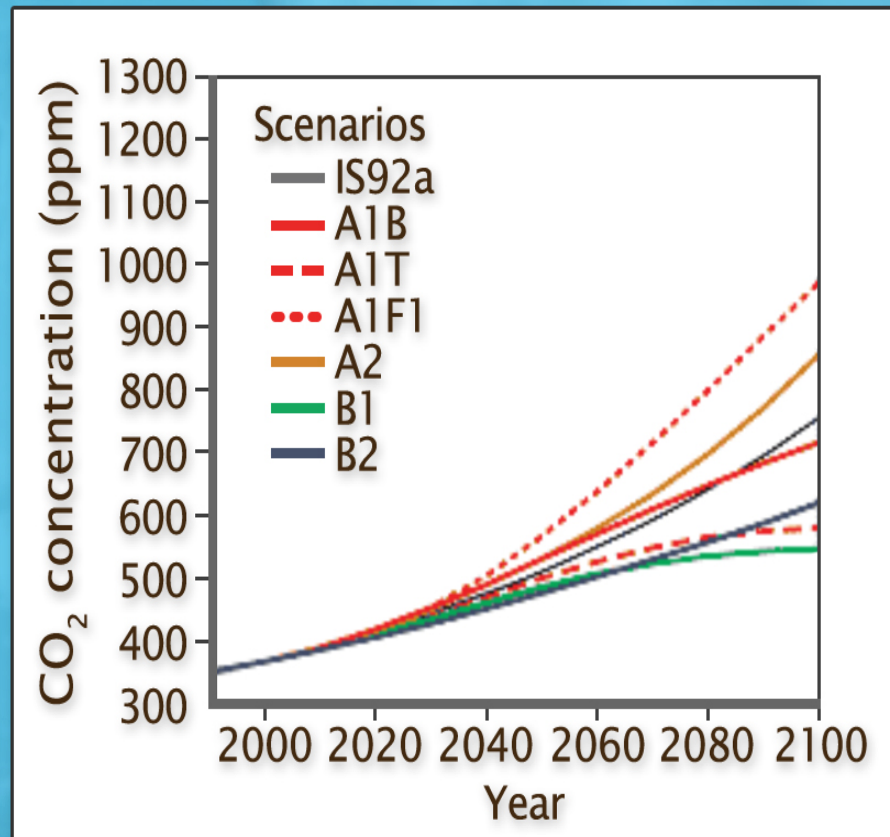
In addition to massive infrastructure for non-fossil transportation and industrial systems, we need to build 4000 to 5000 GW of non-fossil generation capacity in the U.S. The current rate of gross construction is ~20 GW per year. (For China, it is ~100 GW/y).

Assuming massive political will and highly favorable economics (neither yet exists…), a huge industrial effort (building at the rate of China) requires at least 70 years to reach our goal. (just for the U.S.!)

This will be a LONG war…

Projected CO_2 Emissions and Concentrations





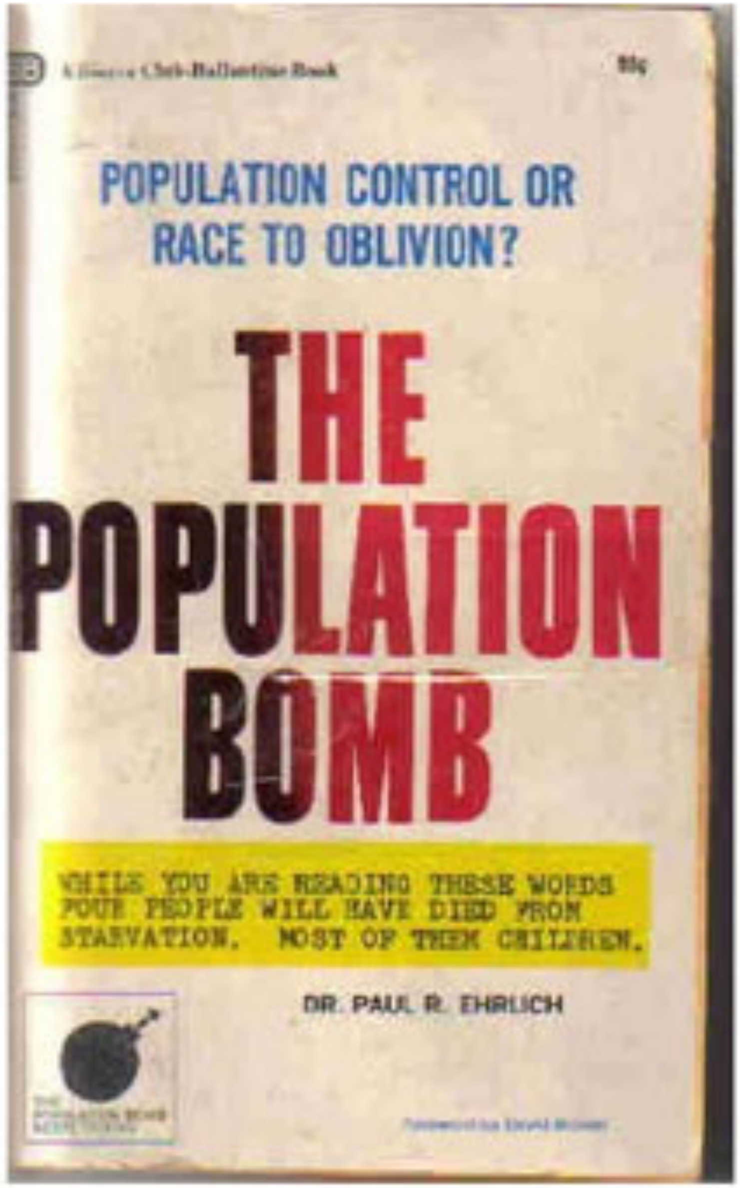
An honest (albeit depressing) view of action on climate change:

We are asking people (in general) to bear costs (sometimes significant costs) for benefits that will have virtually no impact on their experience of climate change in their lifetime. (i.e., they will suffer the impacts of climate change regardless of what they do). The benefits will go to their children and mostly to their grandchildren and beyond…

What is a solution?

Three views:

- develop new technology
- change our behavior
- money and power



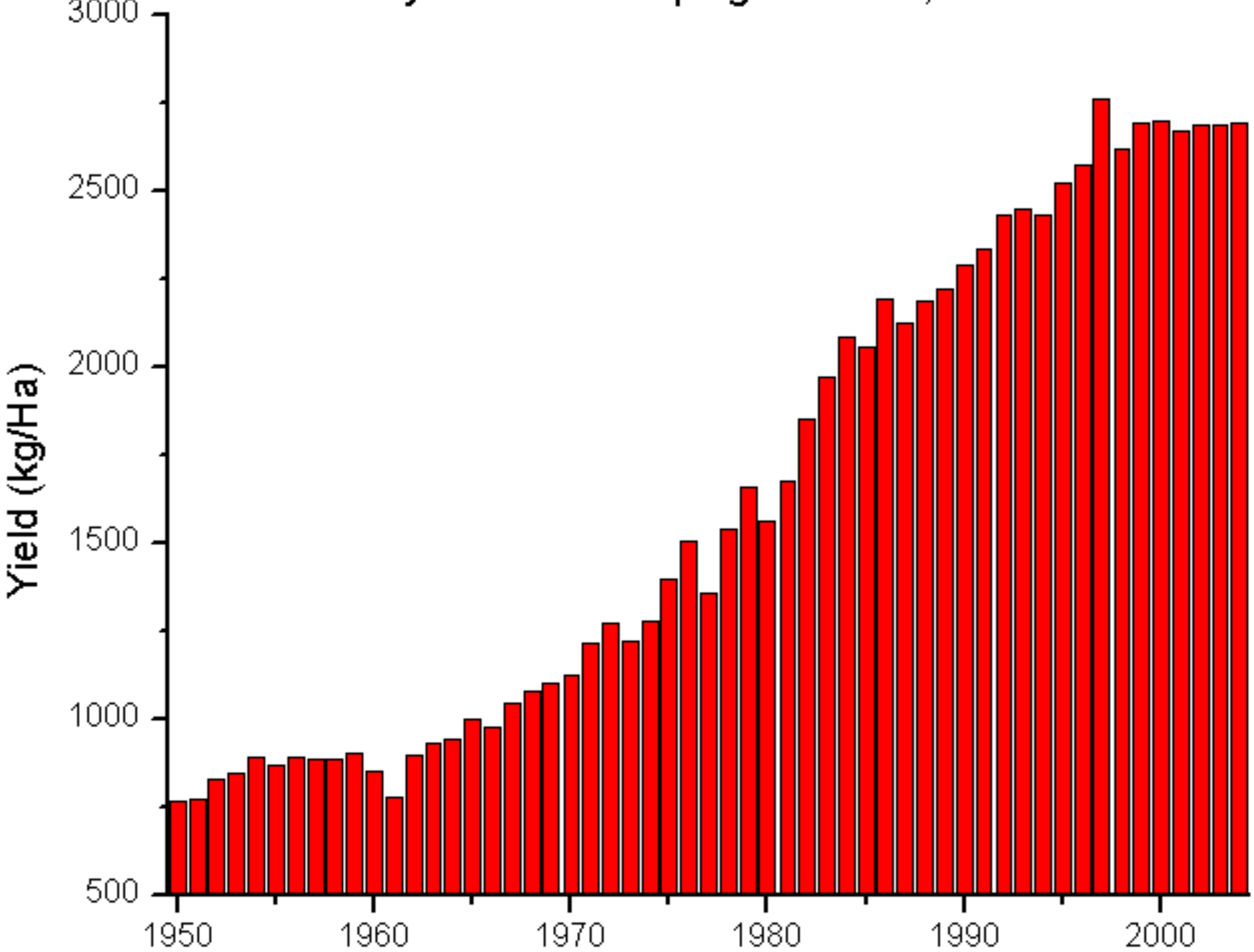
Written by Paul and Ann Ehrlich in 1968.

Fritz Haber

Carl Bosch

Norman Ernest Borlaug (March 25, 1914 – September 12, 2009)

Wheat yields in developing countries, 1950-2004



Source: FAO

Is Technology the Answer?

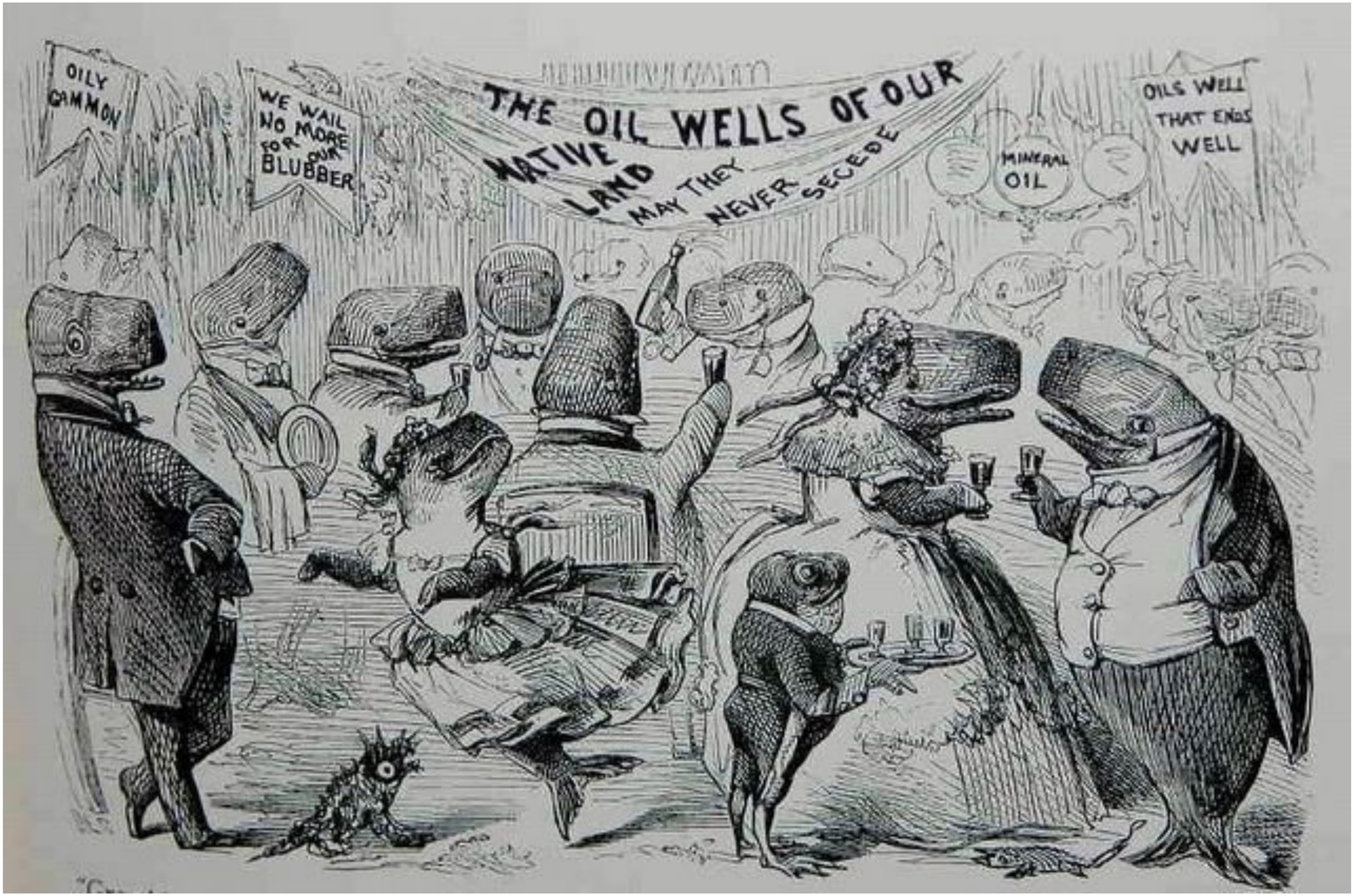
"The green revolution has won a temporary success in man's war against hunger and deprivation; it has given man a breathing space. If fully implemented, the revolution can provide sufficient food for sustenance during the next three decades. But the frightening power of human reproduction must also be curbed; otherwise the success of the green revolution will be ephemeral only."

Norman Borlaug, 1970
Nobel Peace Prize acceptance speech

Is Technology the Answer?

"Just as few people saw a moral problem with slavery in the 18th century, few people in the 21st century see a moral problem with the burning of fossil fuels. Will people in 100 years look at us with the same incomprehension we feel towards 18th-century defenders of slavery? If we are to address the problem adequately, the answer to that question must be yes--our common atmosphere will no longer be seen as a free dumping ground for greenhouse gases and other pollutants."

Prof. Andy Hoffman, U. of Michigan



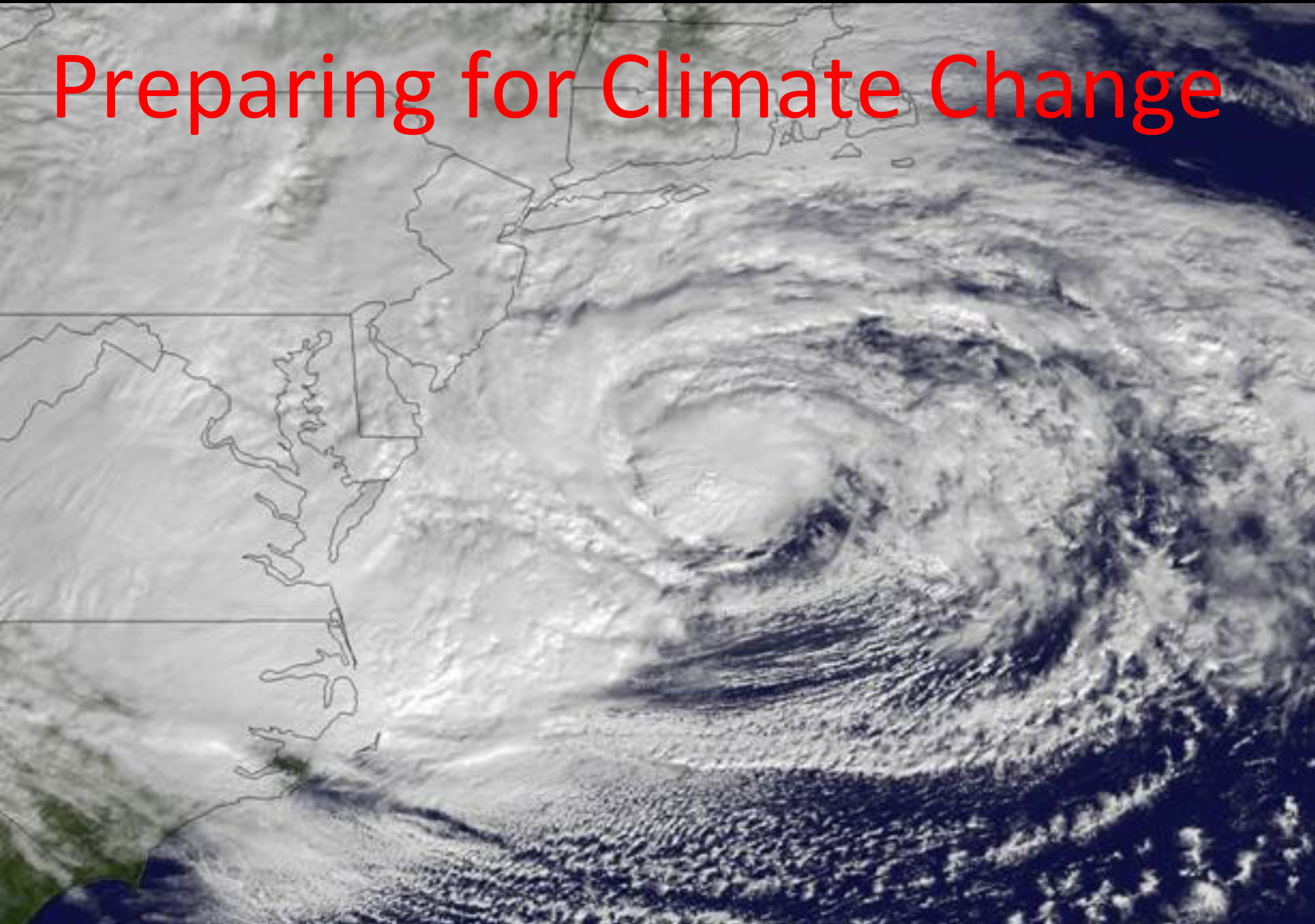
Cartoon from an 1861 *Vanity Fair*: "Grand ball given by the whales in honor of the discovery of the oil wells in Pennsylvania."

Collective action is easiest if one can frame the action as aligned with core cultural values.

These core cultural values can change, driven by technology, by economic forces, or by social forces, but this generally takes a long time.

The relationship between technology, behavior, values, culture and political action is complex and worthy of much more attention (Thank you, Garrison Institute!)

Preparing for Climate Change



There are three ways to deal with climate change:

We can mitigate (reduce our emissions).

We can adapt (manage the impacts).

We can suffer.

(We are likely to do all three)

Adaptation versus Preparedness

A “preparedness” framing aligns public action on climate change with core community values (protecting our families, protecting our homes, protecting our communities…)

Adaptation versus Preparedness

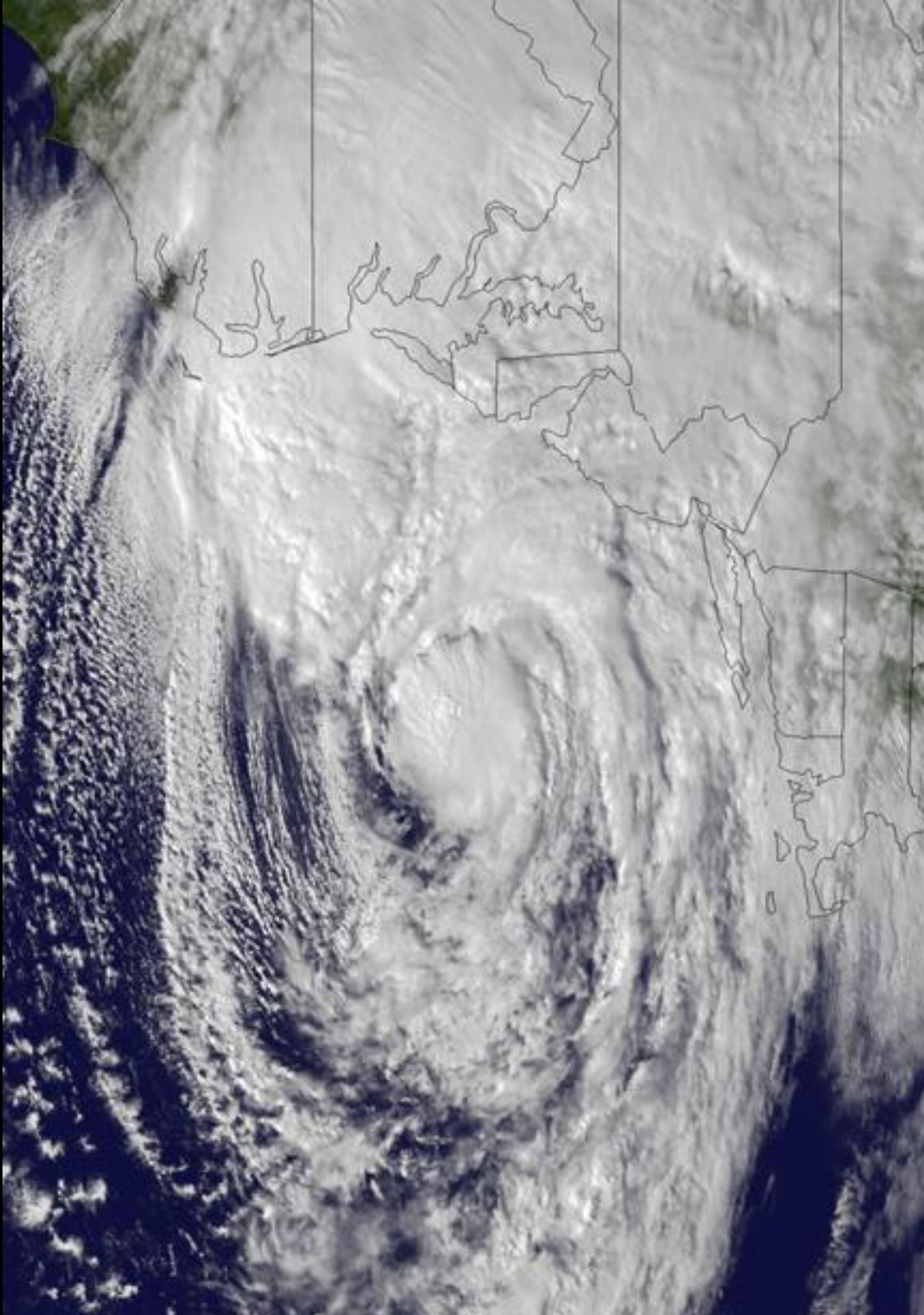
“This issue is lost. I don't care what the Supreme Court does, this is now inevitable -- and it's inevitable because we lost the language on this.”

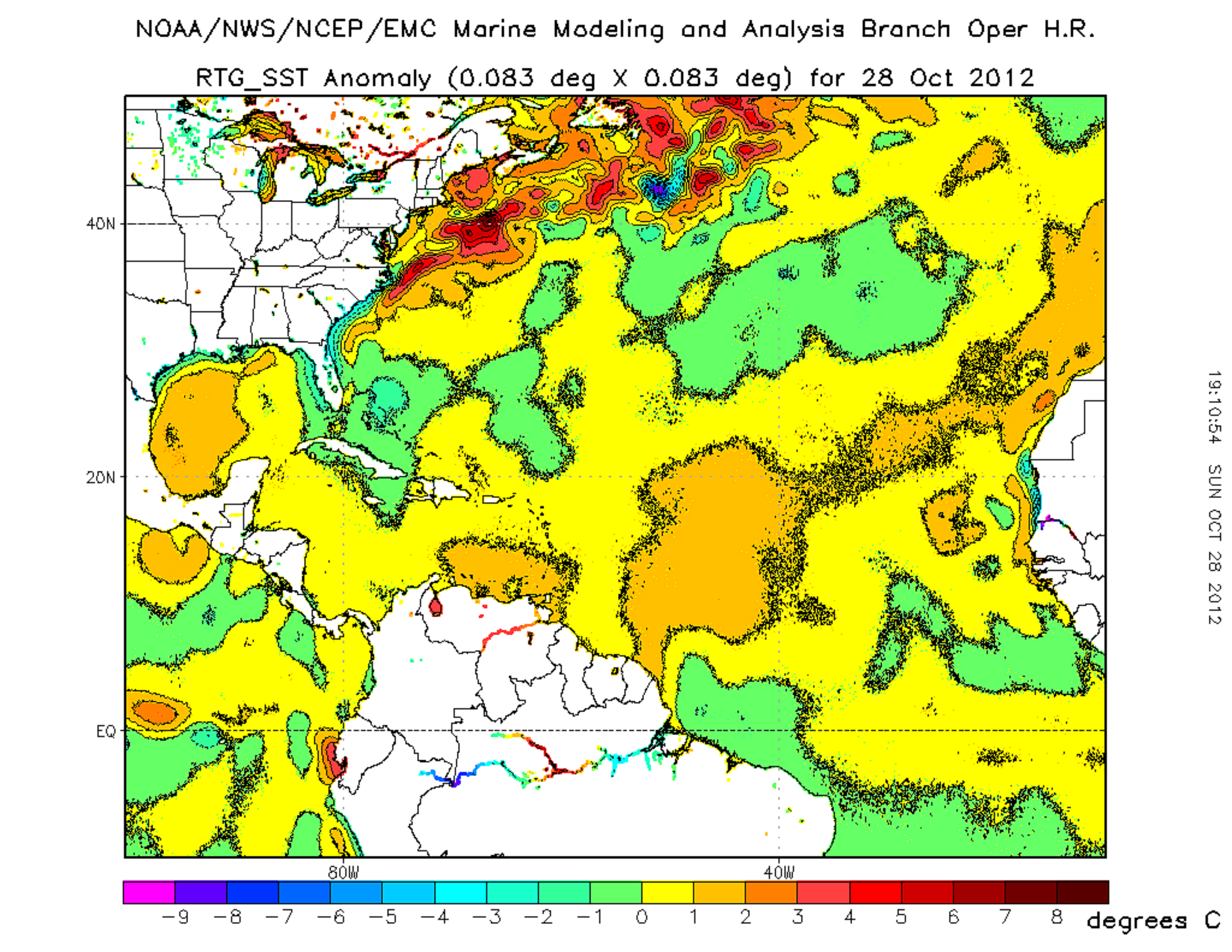
- *Rush Limbaugh on gay marriage*

Adaptation versus Preparedness

A “preparedness” framing aligns public action on climate change with core community values (protecting our families, protecting our homes, protecting our communities…)

A focus on preparedness finesses the complex question about attribution. It doesn’t matter whether a specific weather event was “caused” by climate change or not.




NOAA/NWS/NCEP/EMC Marine Modeling and Analysis Branch Oper H.R.
RTG_SST Anomaly (0.083 deg X 0.083 deg) for 28 Oct 2012
40N
20N
EQ
80W
40W
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8
degrees C
19:10:54 SUN OCT 28 2012


HAMweather.com
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Cabo San Antonio
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Guantanamo
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Veracruz
Jamaica
Isla Saona
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11 AM Mon Oct 22
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Tobago

EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

March 2013

Dear Mr. President:

When you met with your Council of Advisors on Science and Technology (PCAST) at the end of November, you noted that your Administration was in the process of developing a strategy for addressing climate change during your second term and you asked for our input.

In this letter, we suggest six key components for consideration that we deem central to your climate change strategy and policy:

(1) focus on national preparedness for climate change;

(2) continue efforts to decarbonize the economy, with emphasis on the electricity sector;

(3) level the playing field for clean-energy and energy-efficiency technologies by removing regulatory obstacles, addressing market failures, adjusting tax policies, and providing time-limited subsidies for clean energy when appropriate;

(4) sustain research on next-generation clean-energy technologies and remove obstacles for their eventual deployment;

(5) take additional steps to establish U.S. leadership on climate change internationally; and

(6) conduct an initial Quadrennial Energy Review (QER).

National preparedness should be a central pillar of climate change policy

A primary goal of a national climate strategy should be to help the Nation prepare for impacts from climate change in ways that decrease the damage from extreme weather and other climate-related phenomena (i.e., increase robustness) and ways that speed recovery from damage that nonetheless occurs (i.e., increase resilience). Recent disasters involving extreme weather events (including Hurricane Sandy, extreme drought, and rampant wildfires) have underscored the Nation's vulnerability and the urgent need for preparedness.

“Preparedness against major threats is a critical responsibility of the Federal Government, working with the States. An ongoing focus on preparedness, moreover, will help Americans understand that climate change is a clear and present threat, whose effects are already visible, expensive, and worsening (rather than a distant issue with impacts many decades hence). A preparedness strategy that engages state and local officials, as it must given the geographic variation in climate-change effects and vulnerabilities and the need for state and local actions to address them, will also strengthen the national constituency for the comprehensive approach to climate change — mitigation as well as adaptation — that is needed.”

Resilience (from Merriam-Webster)
re·sil·ience *noun* \ri-ˈzil-yən(t)s\

1: the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress .
2: an ability to recover from or adjust easily to misfortune or change.

Robustness is defined as "the ability of a [system] to resist change without adapting its initial stable configuration.”

robust

resilie
nt

Some thoughts on resilience and robustness…

1) Distinguish investments in robustness from investments in resilience (i.e., sea walls versus pumps and waterproof systems).

2) Distinguish "hard" versus "soft" investments in robustness (i.e., wetlands versus sea walls).

3) The most effective policy measures will align economic incentives with individual and societal decisions to put people in harm's way.

Thoughts for the U.S. (not necessarily relevant for the rest of the world…)

1) The most important policy levers for increasing resilience to climate-related impacts are at the state and local levels (i.e., building codes, zoning laws).

2) Deregulation of the insurance industry (and reform of some programs like federal flood insurance and crop insurance) can be an effective way to encourage responsible investments in robustness and resilience. Inclusion of risk in housing markets (e.g., Fannie, Freddie) would also be effective.

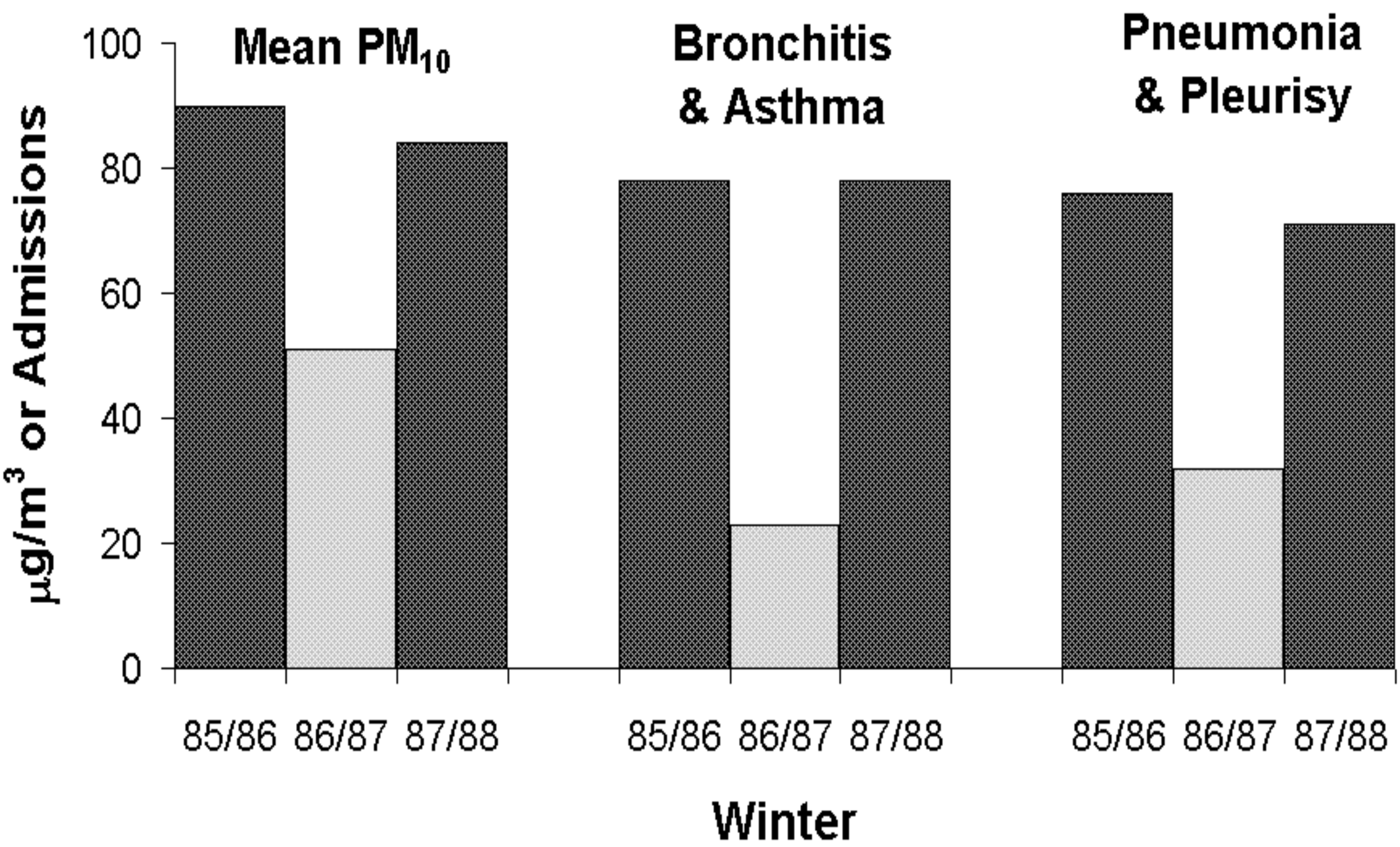
3) The U.S. political system is unlikely to support large infrastructure investments required to provide “hard” protection from climate change. Investments in controlled migration, “soft” robustness, and resilience are more likely to receive the necessary political support.

Climate preparedness requires a focus on local scales of climate change (i.e., different places have different vulnerabilities). This allows communities to focus on things that matter most to them.

But beware the urge to misuse climate models to produce “downscaled” forecasts of future conditions, as these look pretty (and authoritative) but have very little predictive value.

As the Nation continues to address the challenges of preparing for the impacts of climate change, we cannot lose sight of the overarching importance of mitigating the pace and ultimate magnitude of the changes in climate that will occur. Without very substantial mitigation, which must occur worldwide, adaptation efforts will ultimately be overwhelmed and will be extremely costly.

Utah Hospital Admissions
Children 0-17 Year



Pope, Amer J Public Health 1989; 79: 623