Assessing the Future of Energy and Climate

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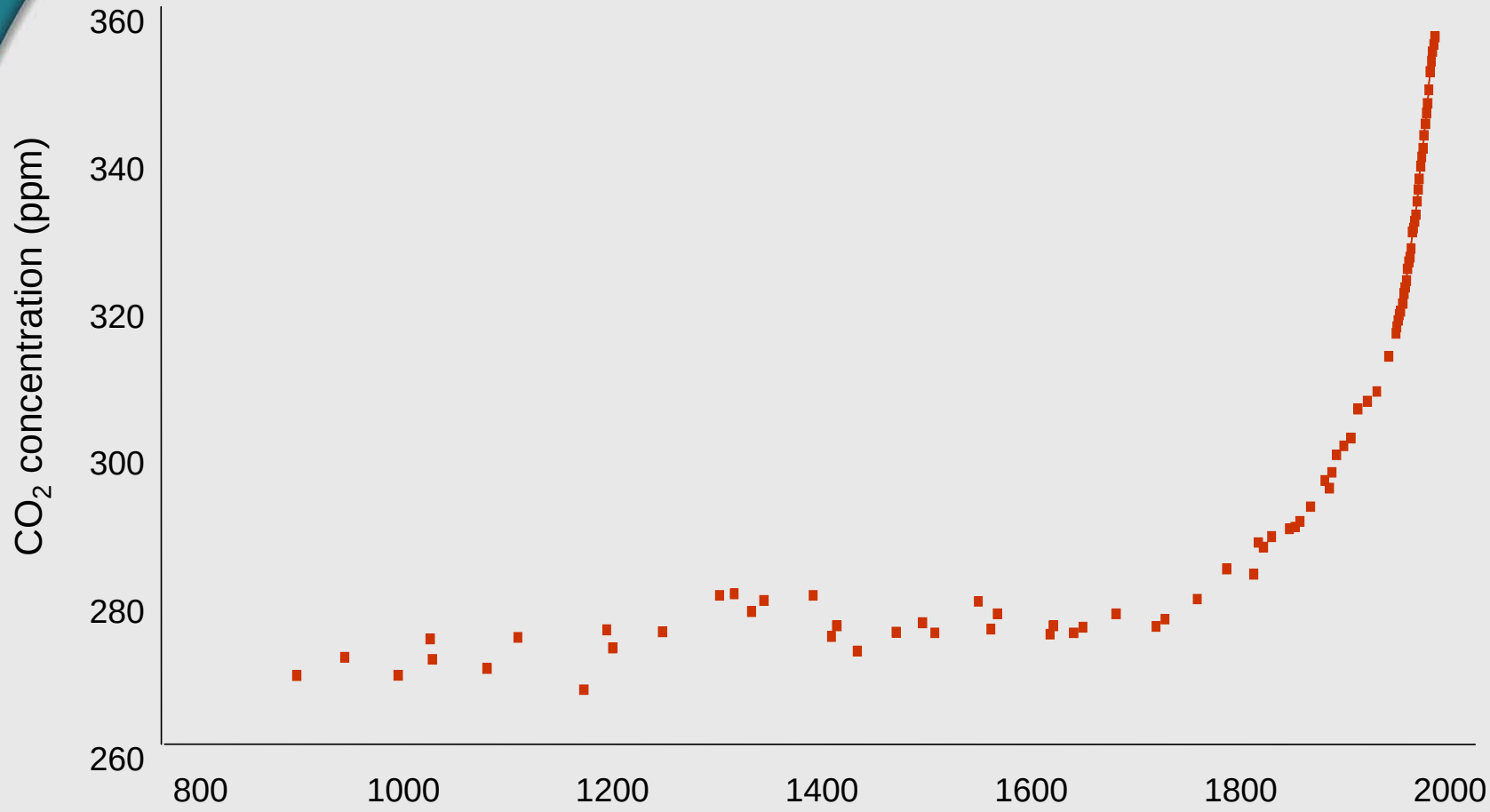
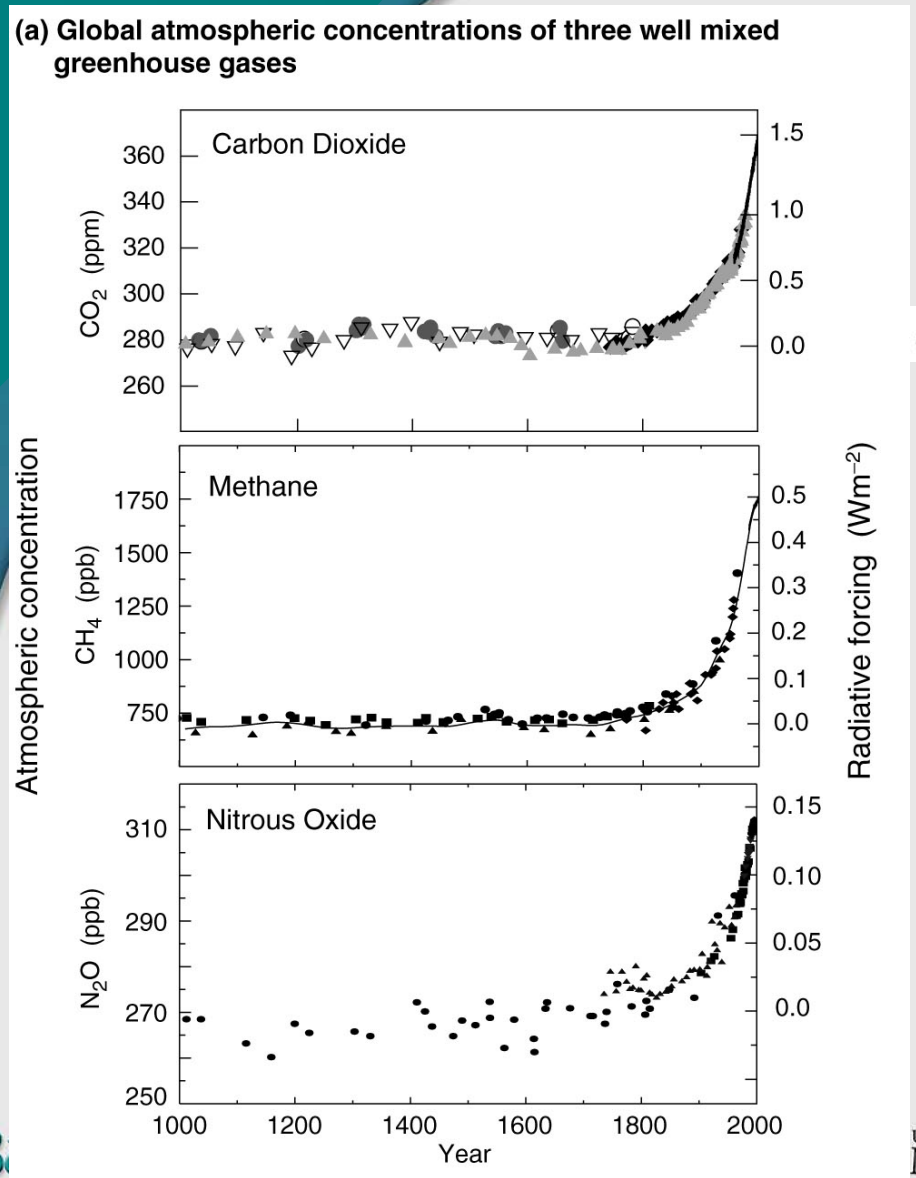
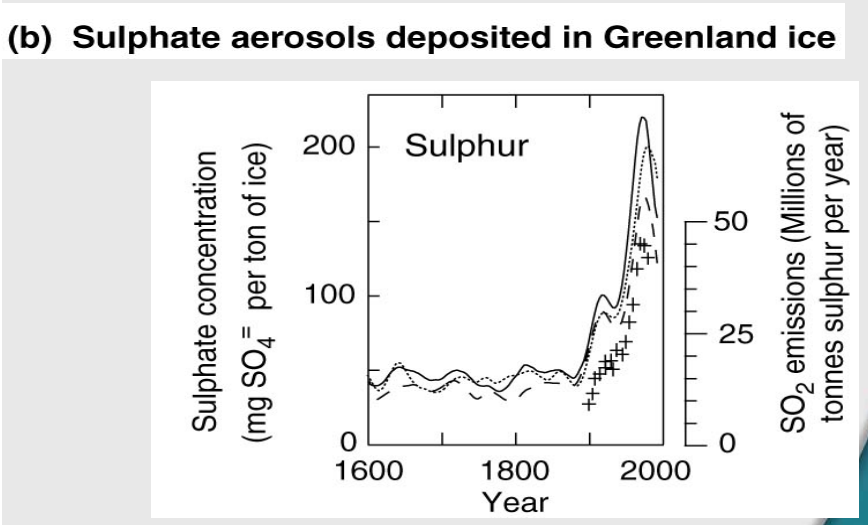
Global CO_2 Concentration



Indicators of the Human Influence on the Atmosphere during the Industrial Era





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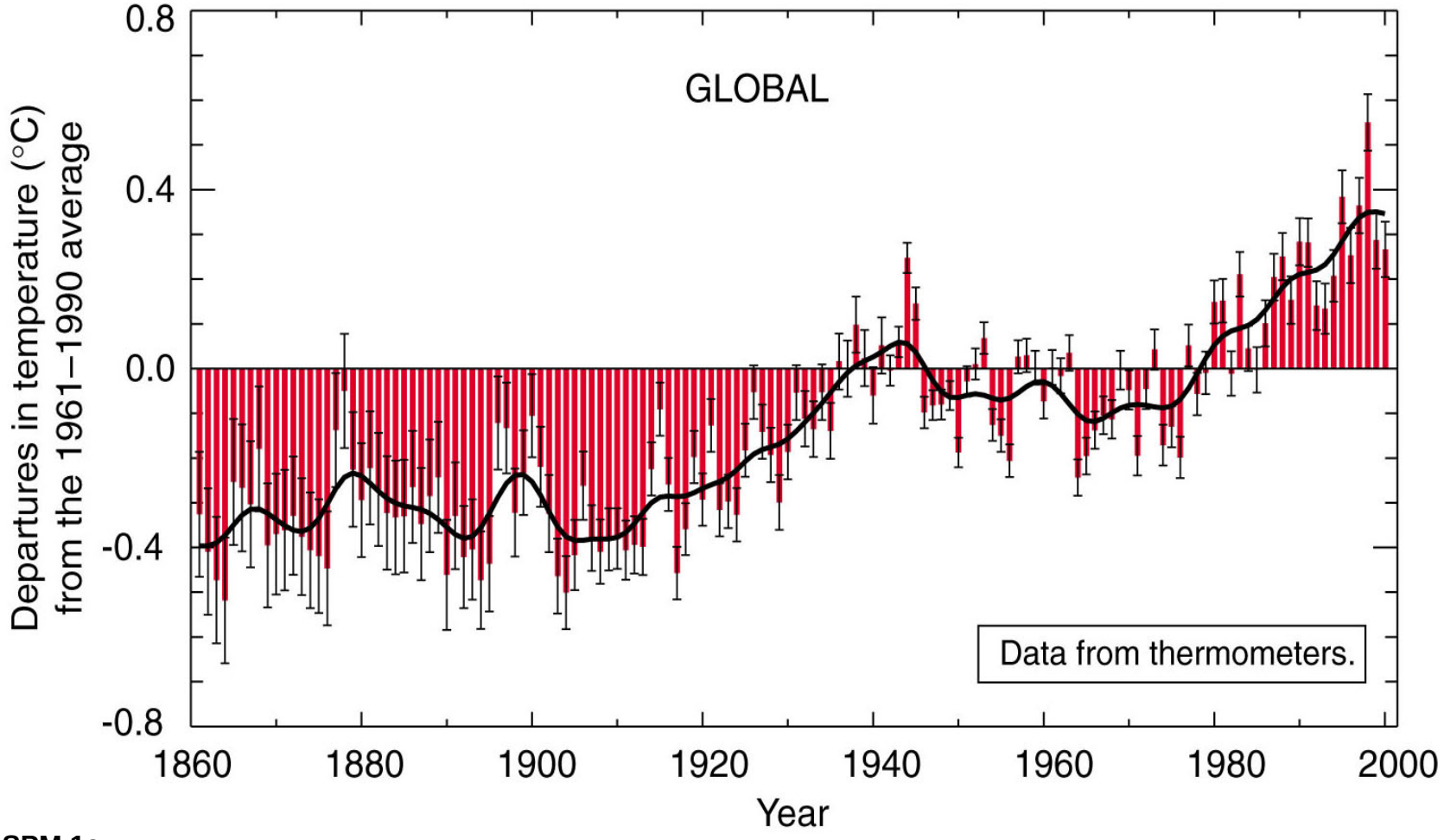
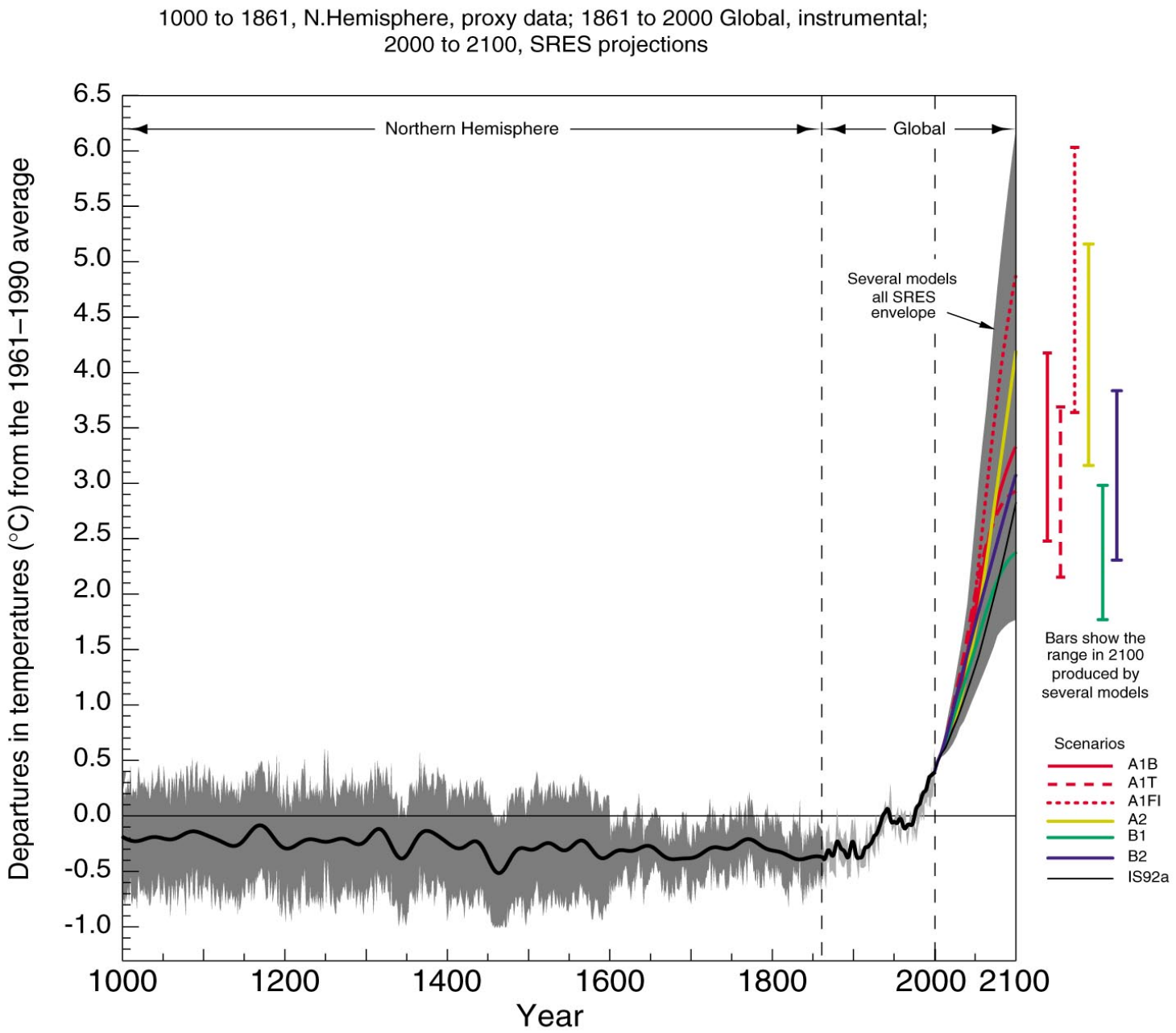
Variations of the Earth's surface temperature for the past 140 years



SPM 1a

Variations of the Earth's surface temperature: 1000 to 2100.



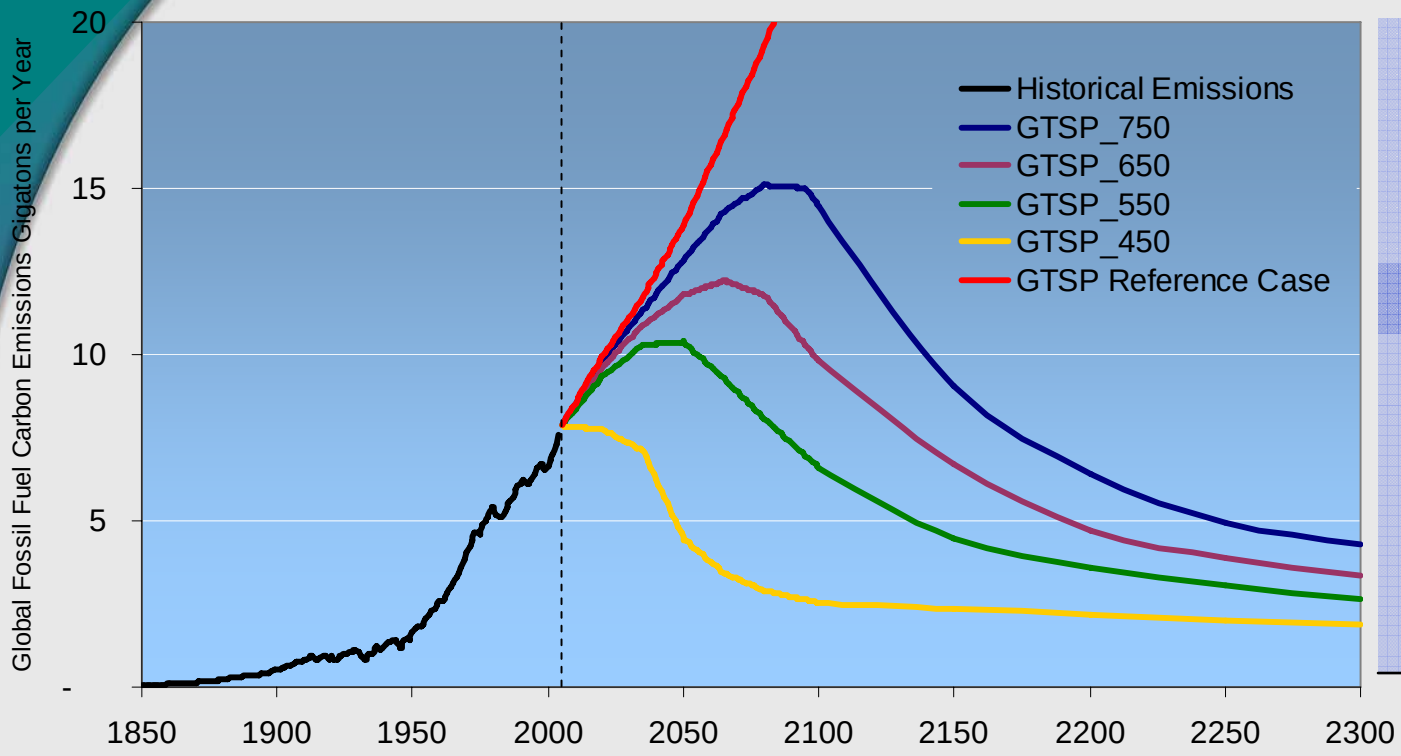
Two Focuses of IA

- The traditional focus of IA research has been on providing data and models relevant to understanding the scale and timing of the drivers of climate change over decades to century time scales.
  - What are potential long-term, future emissions trajectories of fossil fuel CO_2, land-use change CO_2, non-CO_2 greenhouse gases, chemically active gases and aerosols?
  - What would stabilizing radiative forcing imply?

Two Focuses of IA

- The second role of Integrated Assessment Research is to bring the pieces of climate research together in a way that can provide insights that would not otherwise be available from the pursuit of focused disciplinary research.
  - In principle this means being able to go all the way from the anthropogenic emissions to climate impacts, with everything in between.
  - It means pulling together state-of-the-art science and drawing implications.
  - It means being capable of representing more than one climate sensitivity, more than one carbon cycle behavior, etc.

Climate change is a long-term strategic problem with implications for today

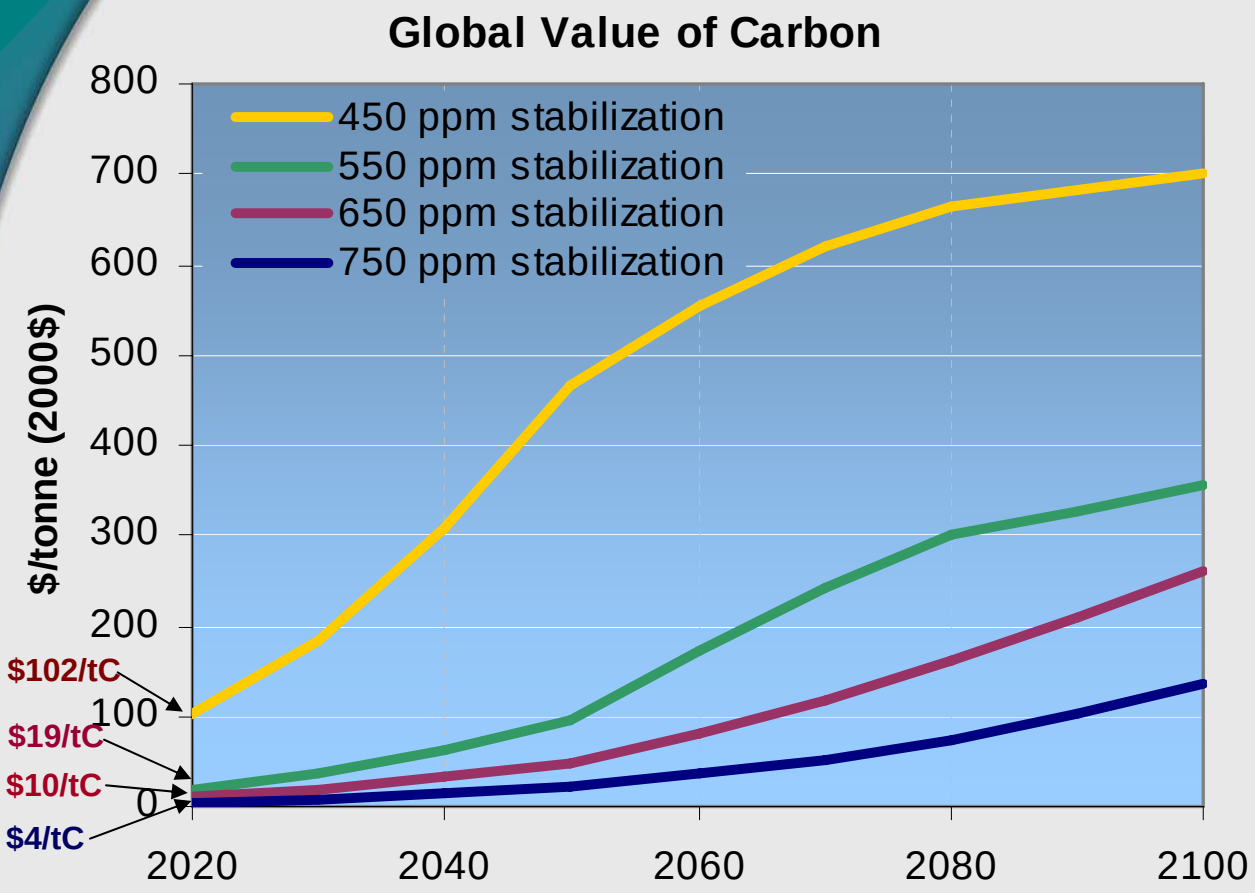


Fossil Fuel Carbon Emissions
Historic & 2005 to 2100

1750-2005	300 GtC
GTSP Ref	1430 GtC
750 ppm	1200 GtC
650 ppm	1040 GtC
550 ppm	862 GtC
450 ppm	480 GtC

- Stabilization of greenhouse gas **concentrations** is the goal of the Framework Convention on Climate Change.
- Stabilizing CO_2 **concentrations** at any level means that **global**, CO_2 emissions must peak and then decline forever.

A global commitment to stabilizing CO_2 concentrations requires a carbon price that escalates over time



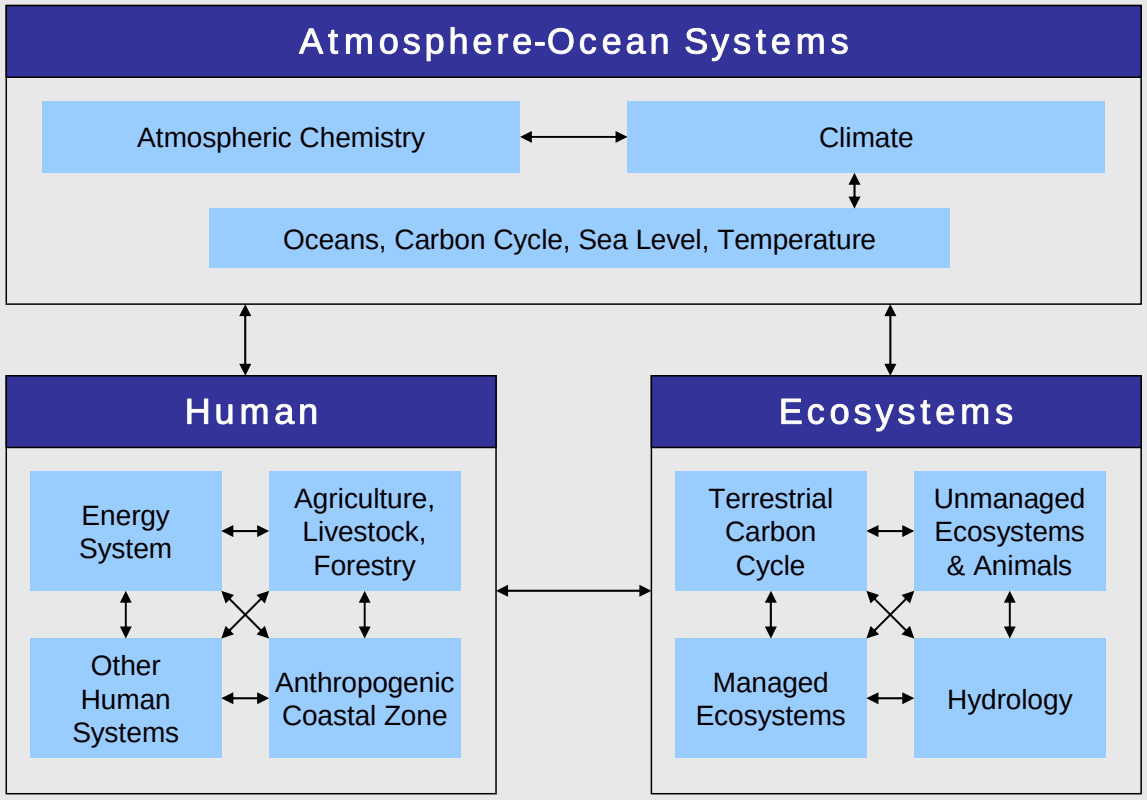
- Price of carbon should start low and rise steadily to minimize society's costs.
- Eventually all nations and economic sectors need to be covered as the atmosphere is indifferent as to the source of CO_2 emissions.
- The response to this escalating price of carbon will vary across economic sectors and regions.

Elements of Integrated Assessment Research

IA research at PNNL reflects, and in some areas pushes, the most recent climate sciences.

The development of Earth Systems Models will place increasing demands on IA.

Extending IA research to include the consequences of climate change will force IA models to "close".



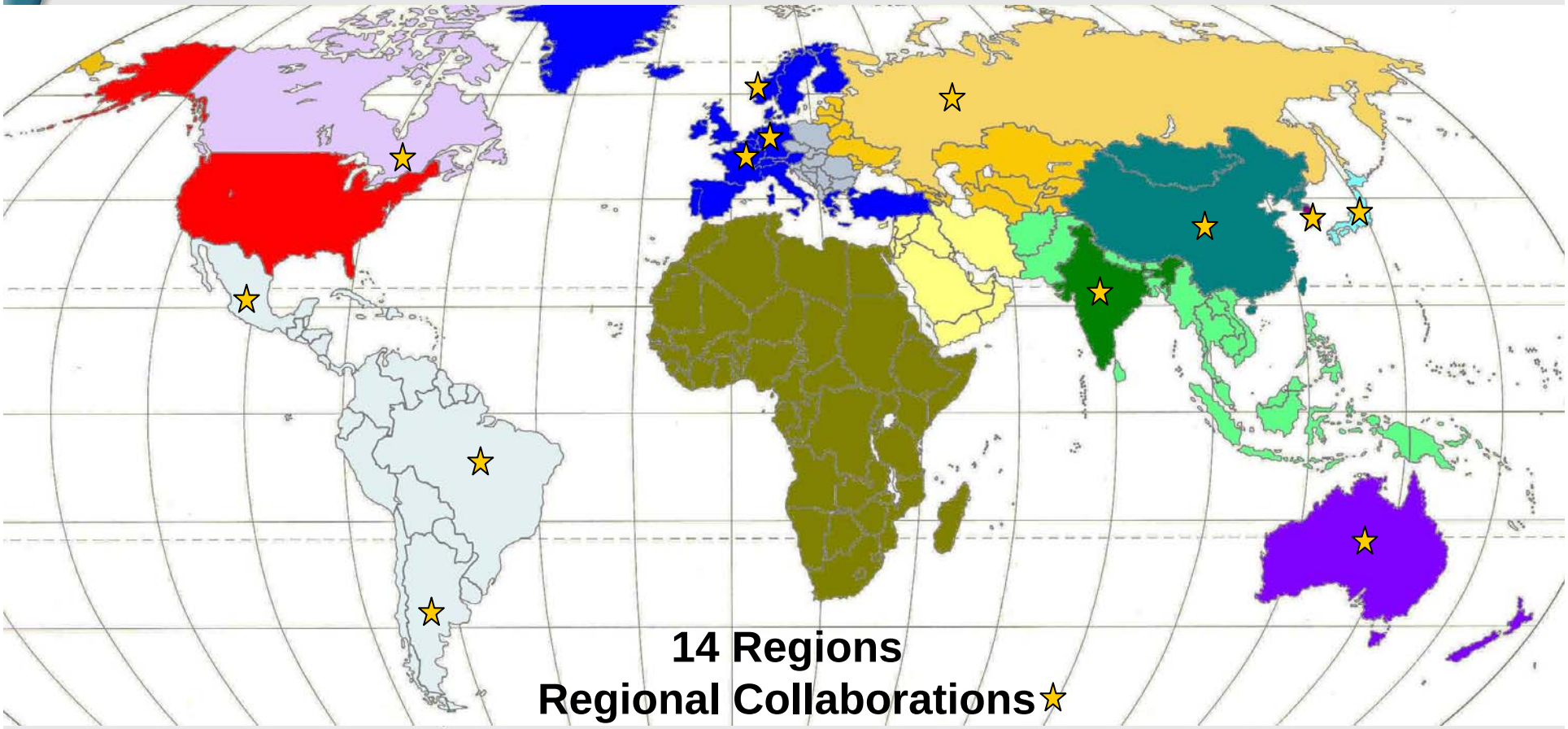
MiniCAM
An Integrated Assessment Model

Emissions, Atmosphere, Climate

Emissions: Energy-economy-agriculture-land-use model

15 gaseous emissions—linked to associated human activities

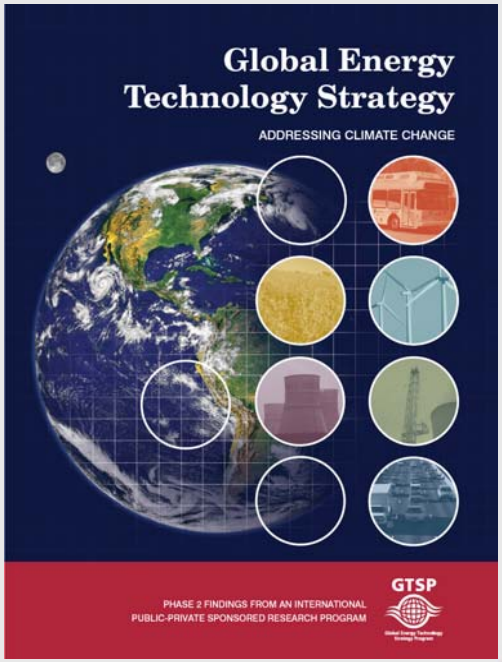
2095 time horizon



14 Regions

Regional Collaborations ☆

The Global Energy Technology Strategy Program



Biofuels/Overview of Technology

Findings from the First Decade of Research—GTSP Phases 1&2

Jae Edmonds

May 30, 2007

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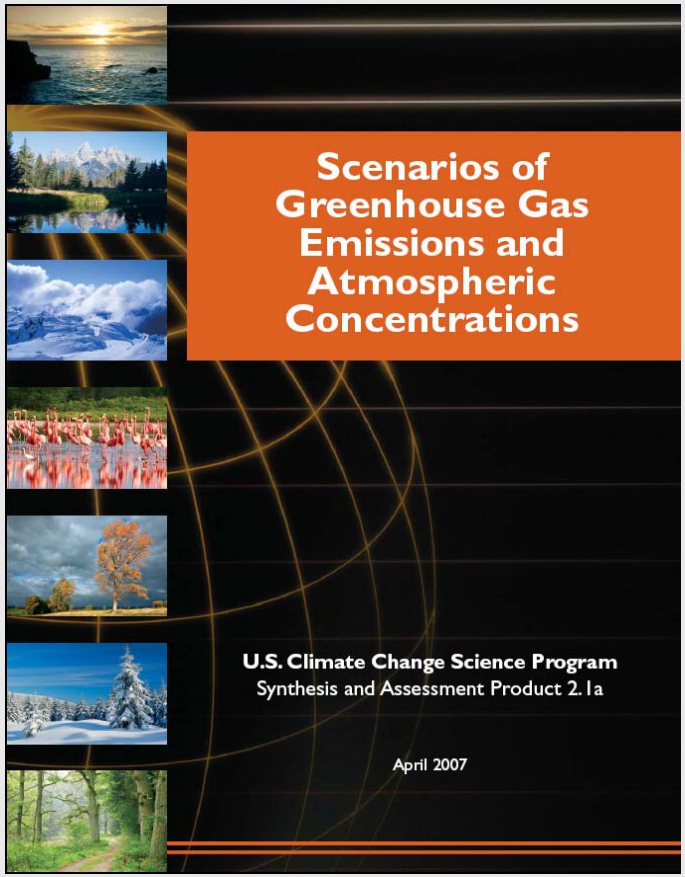
Key Findings of the GTSP

- Climate is a long-term problem, with implications for actions today.
- Stabilizing the concentration of CO_2 means fundamental change to the global energy system.
- Technology will play a central role in addressing a growing mitigation challenge in the near-, mid- and long-term.
- Six technology systems could play dramatically greater roles in a climate constrained world.

  CO_2 capture and storage, Biotechnology, Hydrogen systems, Nuclear energy, Wind and solar, and End-use energy technologies, though none is a "silver bullet."
- A strategy to develop and deploy technology should be part of a larger program—including scientific research, emissions limitation, and adaptation to climate change.

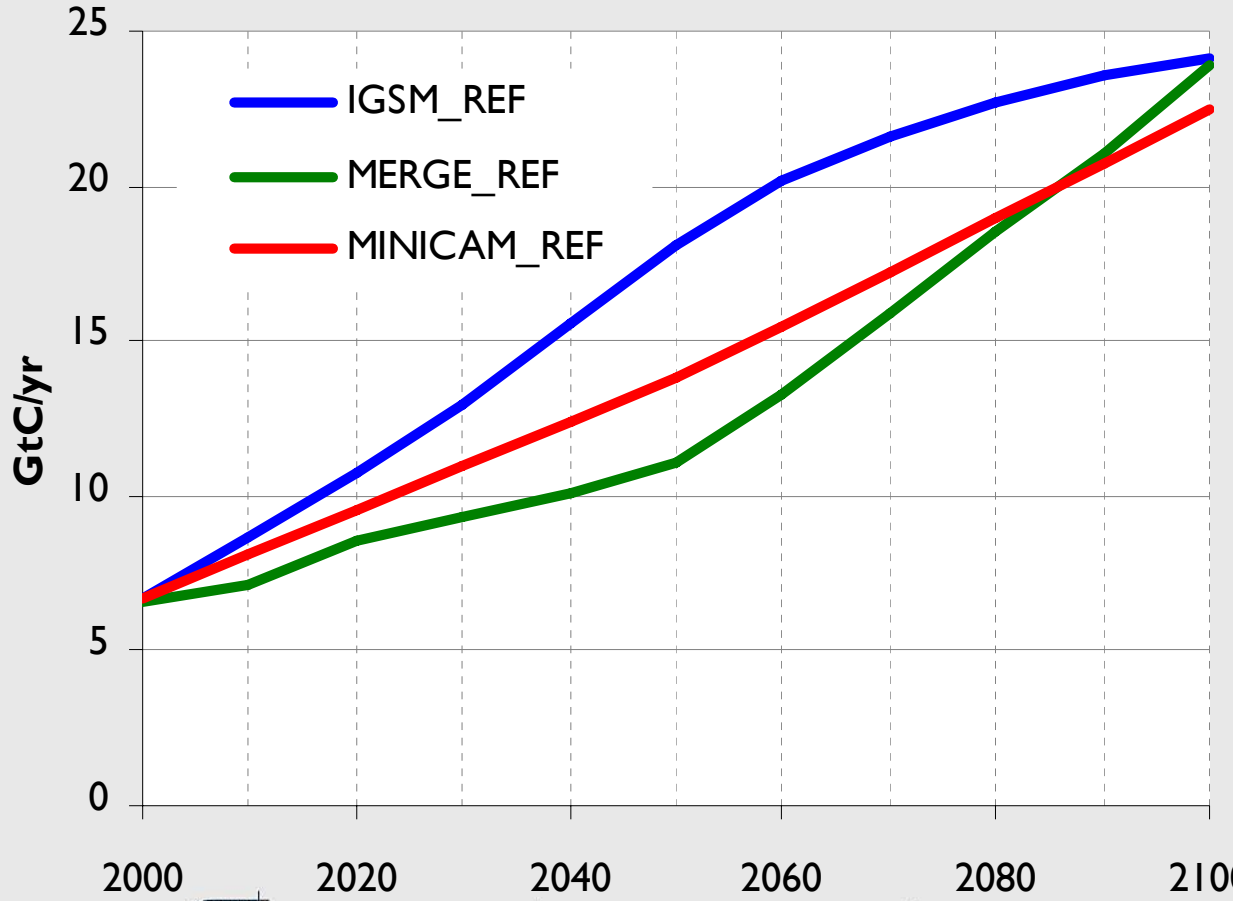
The SAP 2.1a

- It is finally out!
- An AR5?
  - The nature of scenarios to drive the new Earth System Models will be different.



Carrying on the Traditional Role of IA Research

Annual Fossil Fuel CO_2 Emissions, SAP 2.1a



How do we respond?

- Portfolio of greenhouse gas mitigation to reduce climate forcing through carbon management and energy technology development and deployment
- Adaptation to changes that we cannot avoid
  - Need tools to know how effective mitigation is likely to be
  - Need tools to know what to adapt to and how effective coping strategies might be
  - Key is to have an integrated analysis of both parts of portfolio

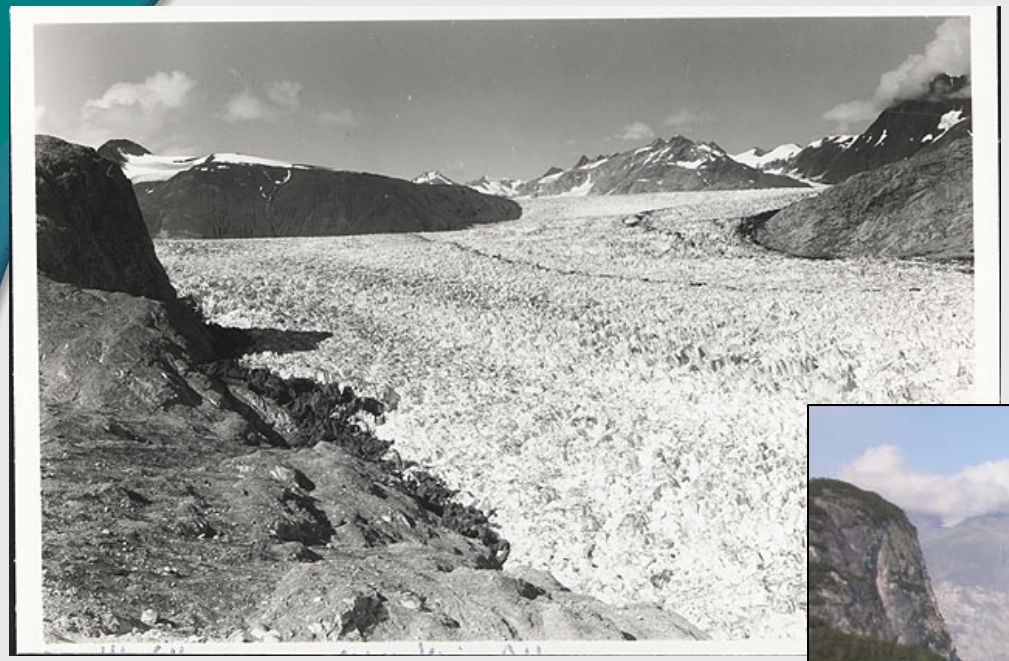
Greenhouse Gas Mitigation

- Human activities are biggest single perturbation to physical climate system through addition of greenhouse gases
- Expectation that in absence of policy, growth in global demand for energy will dwarf today's levels
- Influence of technology is biggest single lever we have to reduce climate impact of energy use at acceptable economic and environmental costs
- Directly relevant to DOE OSC long term goal for climate change research: data and models for policy makers to decide on "safe" levels of greenhouse gases

Adaptation and Coping

- Because changes occurring now, have both coping to current circumstances and questions about planning for future circumstances to consider
- Requires some knowledge of regional climate changes and environmental consequences
- Requires information on current practices for coping and understanding of factors that control vulnerability
- Requires ability to model effectiveness of adaptation strategies as part of integrated response portfolio

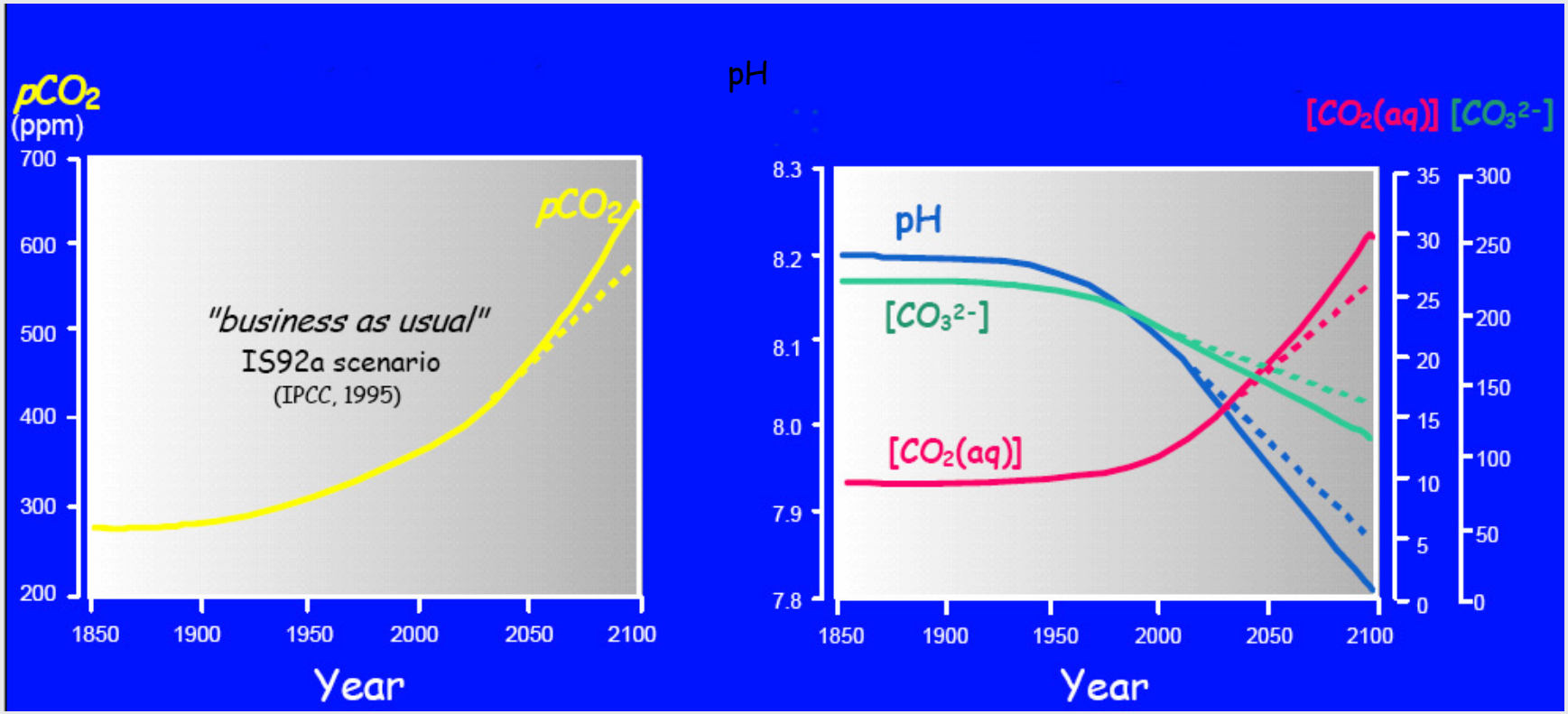
Muir Glacier, Alaska
August 1941 (left) and August 2004 (right)



Source: National Snow and Ice Data Center (www.nsidc.org)

Rising atmospheric CO_2 is changing the chemistry of the ocean

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow$$
$$HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2H^+$$



After Turley et al., 2005

Importance of Thresholds and Rapid Change

- But what if change is rapid or discontinuous?
  - Substantially complicates management and policy responses
  - Raises difficult scientific questions about predictability and links to climate drivers
- Need to understand better the role that such events play in decision making and calculations of costs and/or benefits
- What if change cannot be successfully coped with?

Analytical Context

- What is our capacity to adapt to or manage threshold changes?
- How would a better monitoring and/or predictive capacity affect that capacity?
- How might we mitigate stresses so we don't go through tipping points?

Summary

- A very real issue with challenges now
- Assessments examine two-pronged response:
  - Mitigation of emissions
  - Coping with impacts
- Technology investment, development and deployment incredibly important
- Must begin to understand rapid changes