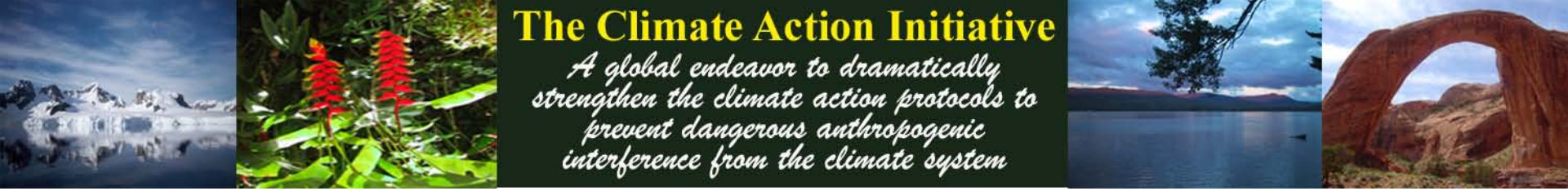
The Challenges of Climate in a Changing World

A Conversation with the New England Federal Partners

June 2, 2009

Dr. Robert W. Corell, Chair of the Climate Action Initiative



- **Framing the Issues among the Federal Agencies (NSTC Committees):**
  - **Committee on Environment and Natural Resources (CENR)**
  - **Committee on Homeland and National Security (CHNS)**
  - **Committee on Science (CoS)**
  - **Committee on Technology**
- **U.S. Global Change Research Act of 1990**

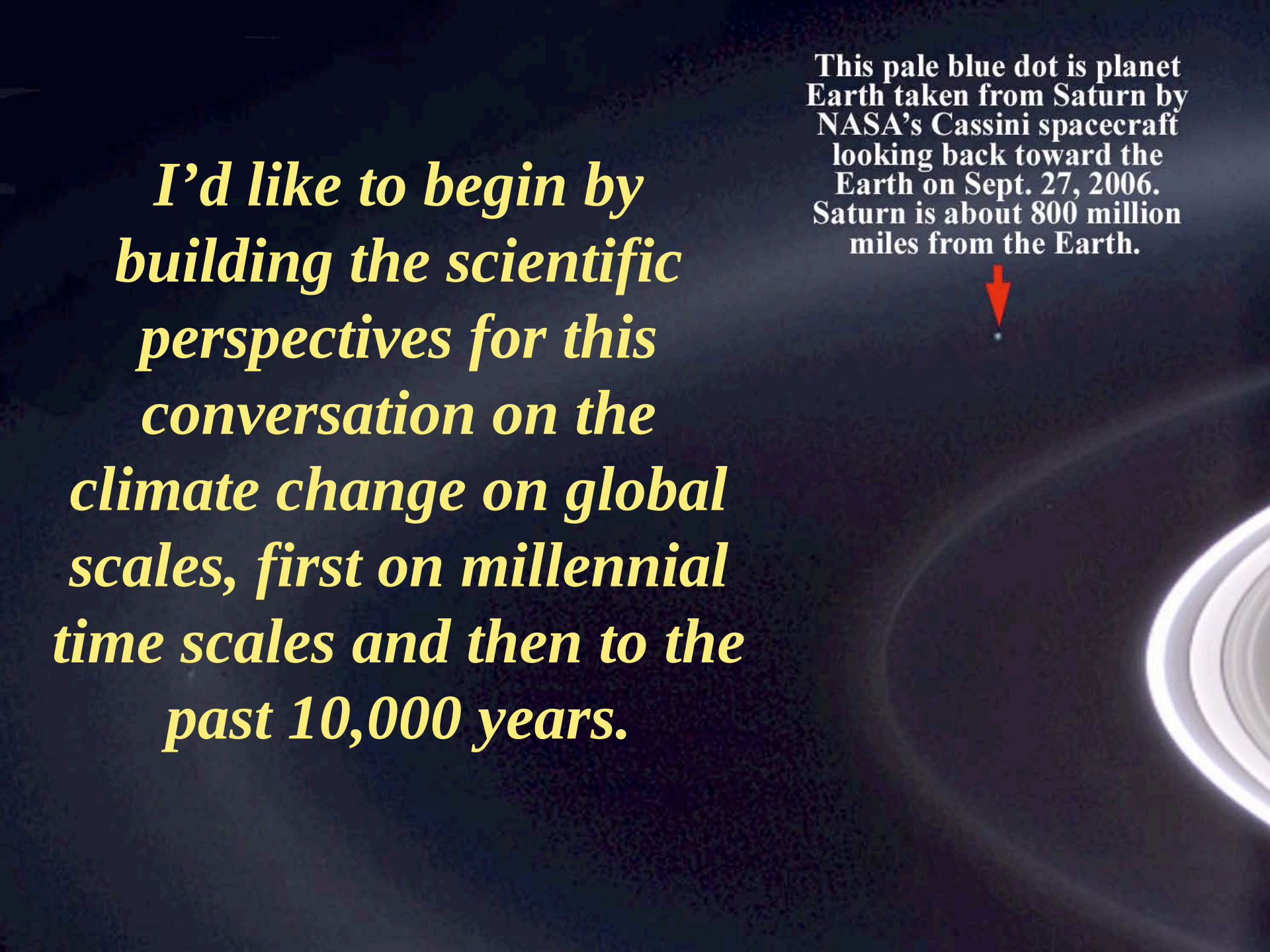
  (Public Law 101-606(11/16/90) 104 Stat. 3096-3104)
- **A Federal Initiative to Develop and Implement Strategies and Methods for Climate-related Decision Support**

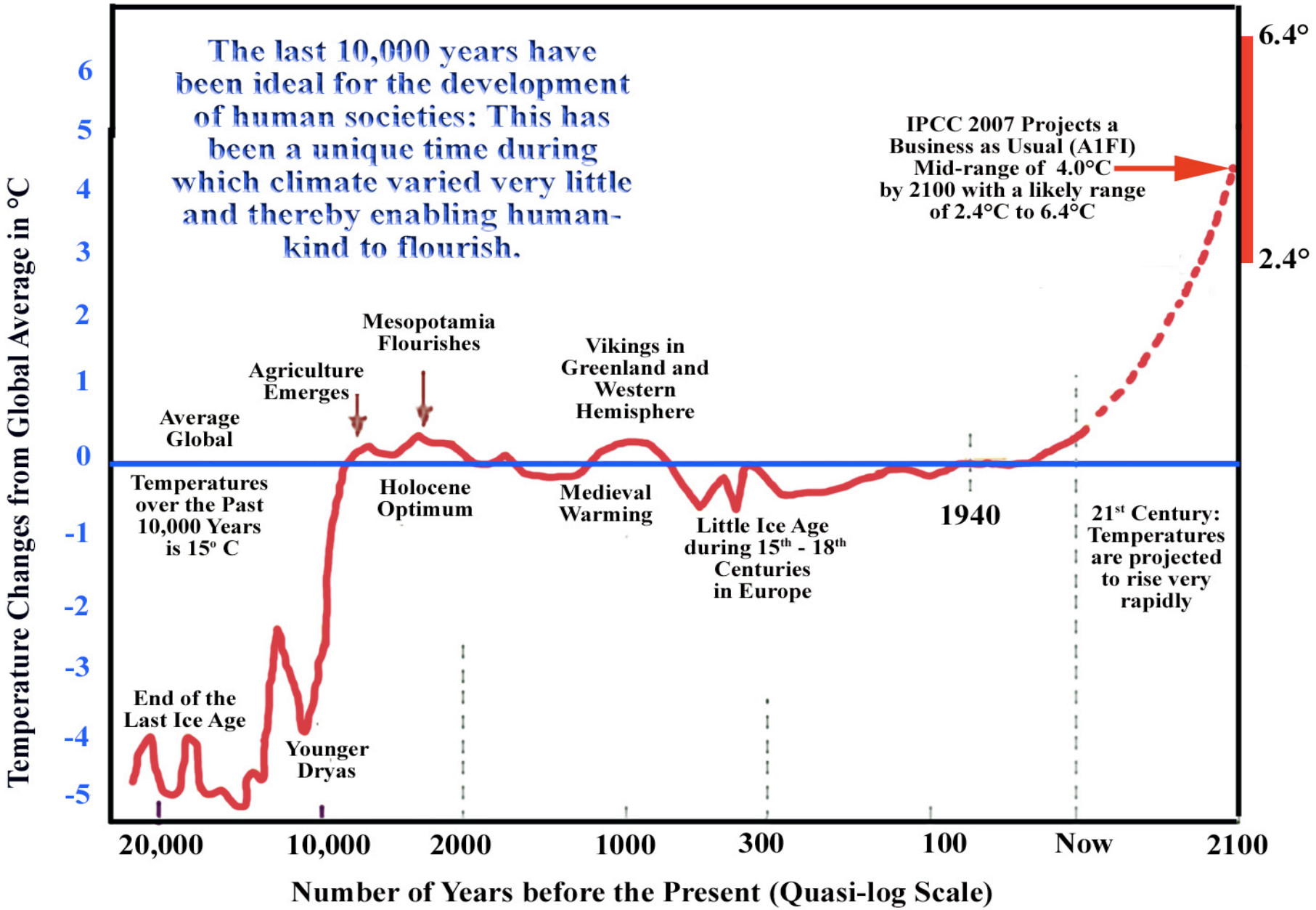
  (Legislation is currently under development in the House)
- **Framing the Conversations for Today**
  - **Emerging Issues in the Science of Climate Change**
  - **Prospects for the Global Deal in Copenhagen in December**
  - **Framing the Vulnerability, Resilience and Adaptation Issues**

“The stakes are high. Climate change has profound implications for virtually all aspects of human well being, from jobs and health to food security and peace within and among nations. Yet too often climate change is seen as an environmental problem when it should be part of the broader development and economic agenda. Until we acknowledge the all-encompassing nature of the threat, our response will fall short.”

Kofi Anan, Former Secretary General of the United Nations

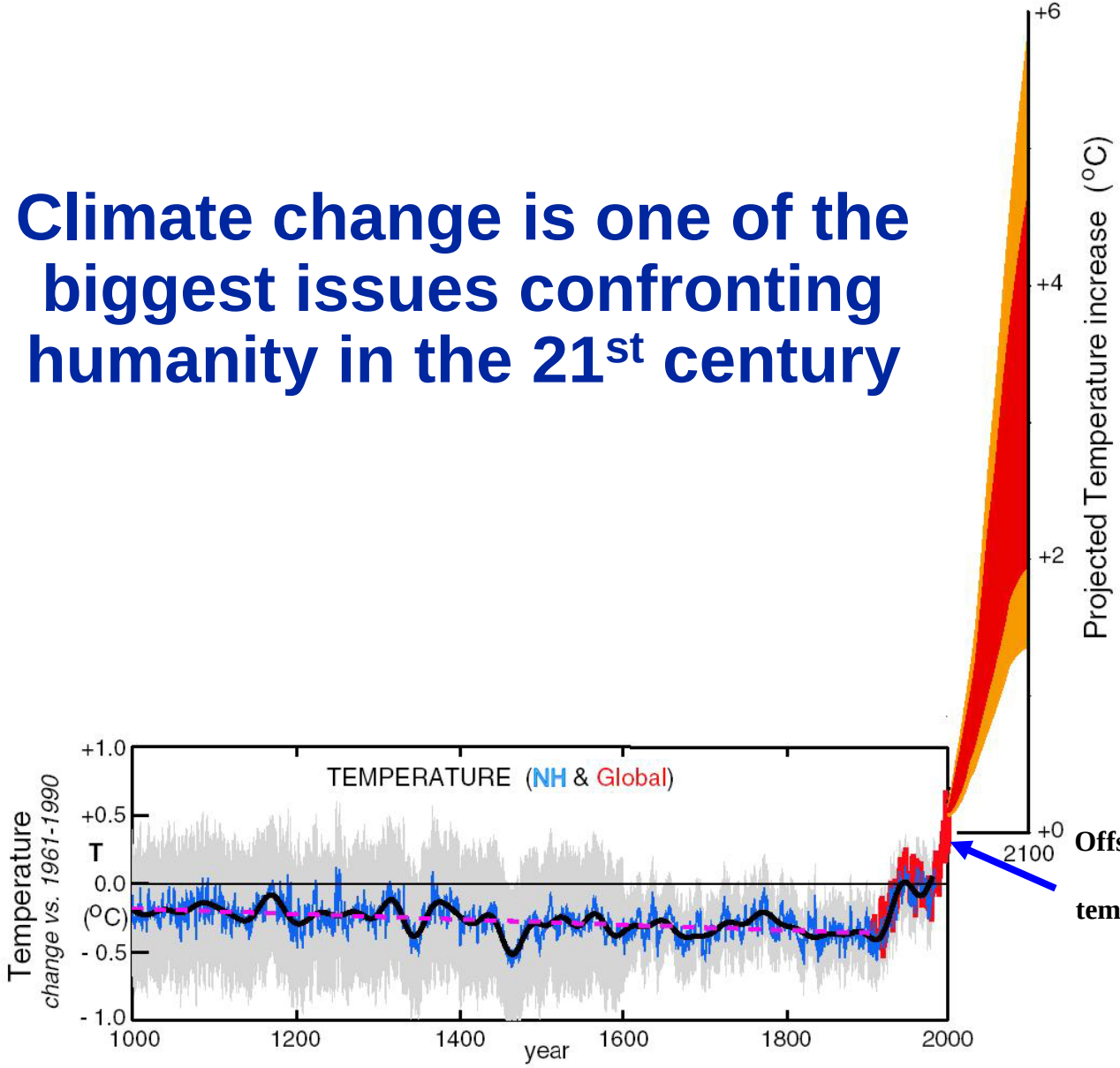
I'd like to begin by building the scientific perspectives for this conversation on the climate change on global scales, first on millennial time scales and then to the past 10,000 years.





Source: Adapted from "Climate change and human health - risks and responses" published by WHO in collaboration with UNEP and WMO 2003 and more recent data from IPCC 2007.

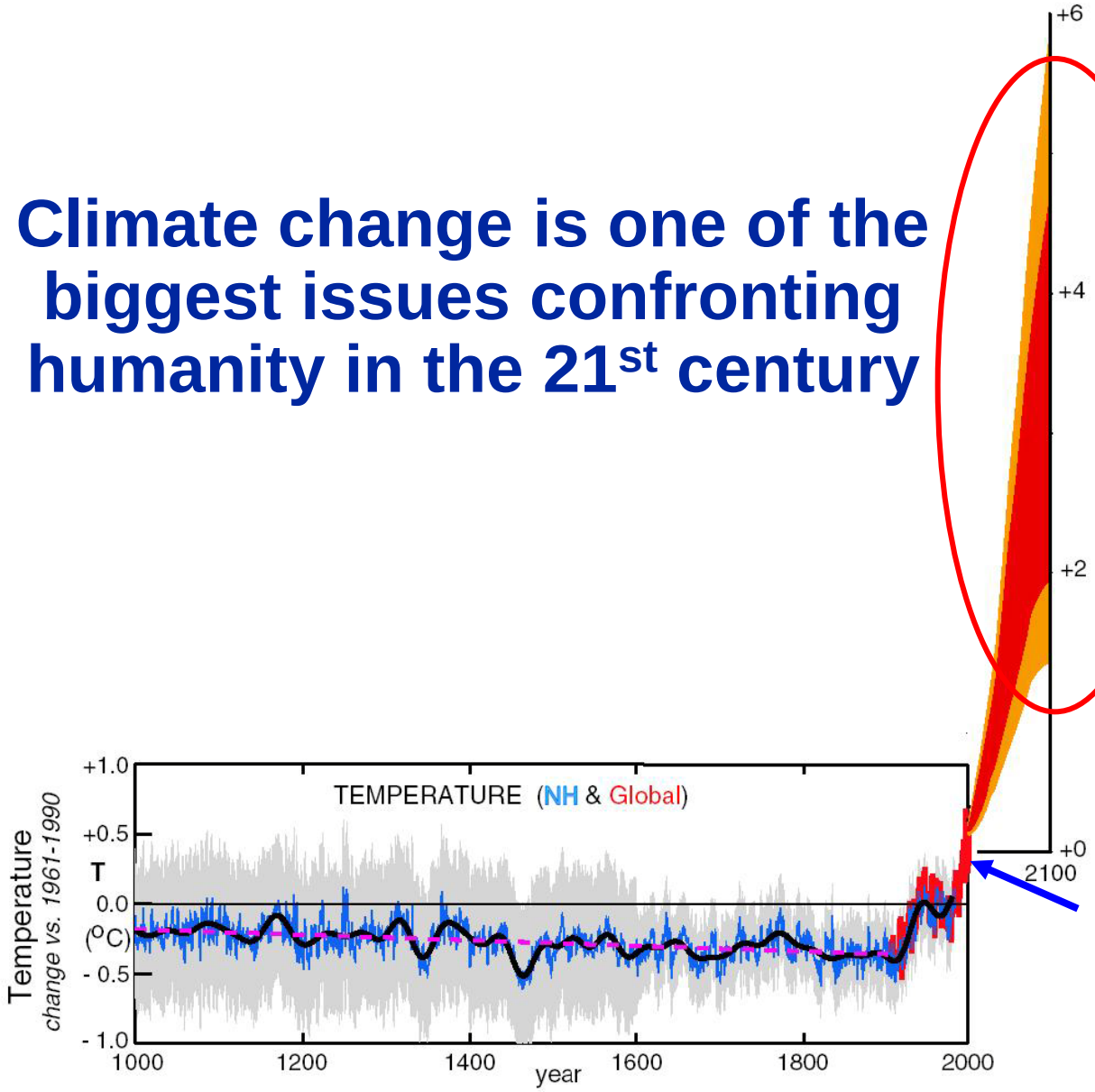
Climate change is one of the biggest issues confronting humanity in the 21st century



Projected IPCC Range of Temperatures

Offset to correct for increases to 2000 in global average temperatures since beginning of the industrial ear.

Climate change is one of the biggest issues confronting humanity in the 21st century



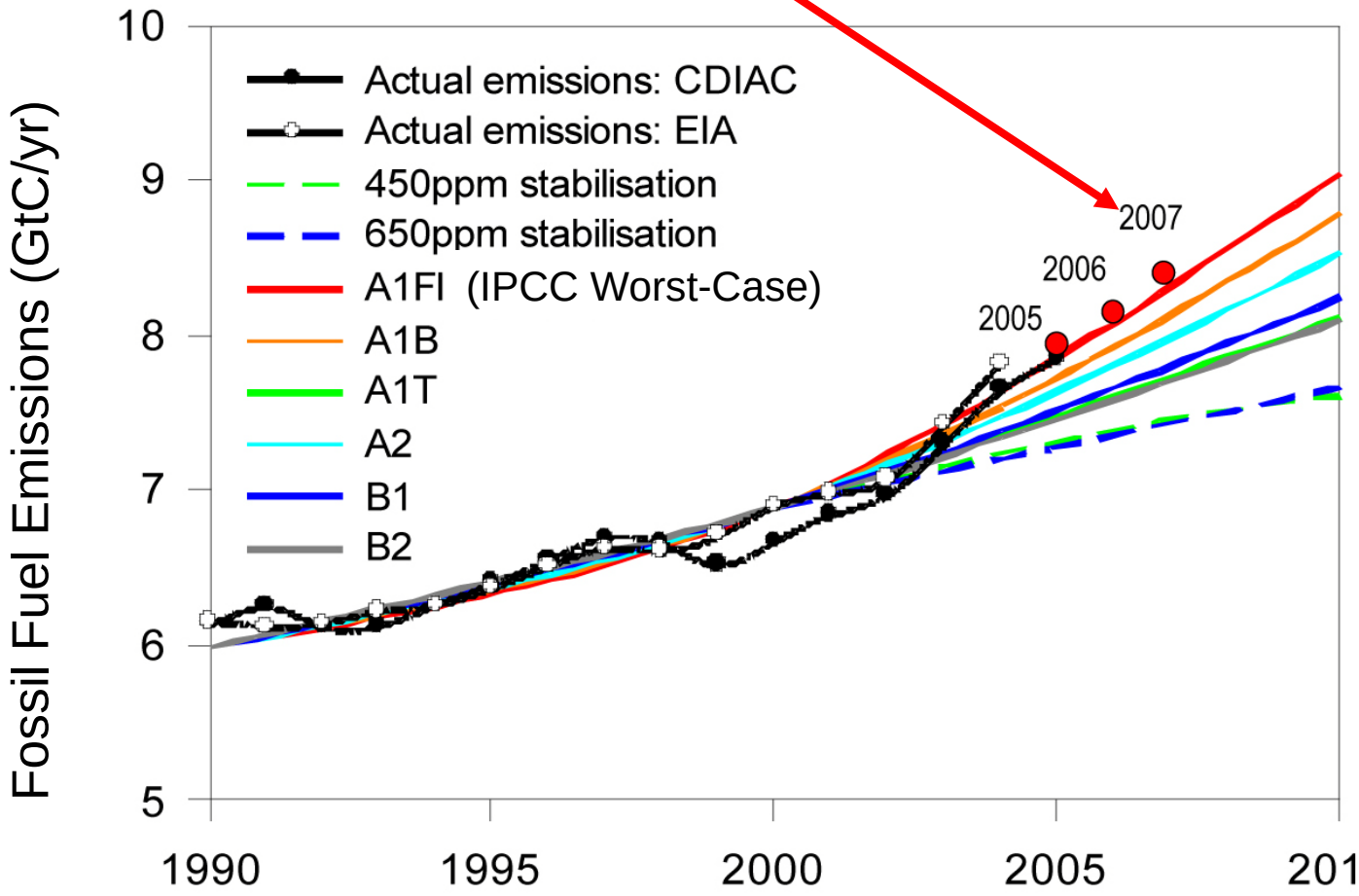
New (May 2009) Paper in the Journal of Climate suggests this Range may Low by up to a Factor of 2

Projected IPCC Range of Temperatures

Offset to correct for increases to 2000 in global average temperatures since beginning of the industrial ear.

Fossil Fuel Emissions: Actual vs. IPCC Scenarios

We face an incredible challenge: Emissions now exceed the IPCC Worst-case Scenario.



SRES (2000) aver. growth rates in % y^{-1} for 2000-2010:

A1B: 2.42
A1FI: 2.71
A1T: 1.63
A2: 2.13
B1: 1.79
B2: 1.61

Observed 2000-2007 3.5%

Raupach et al 2007, PNAS (updated)

New Data

Global Carbon Project October 2008 Report

- Since 2000, CO_2 emissions derived from human sources have been growing x4 faster than in the 1990s and are now above the worst case emission scenario of the Intergovernmental Panel on Climate Change.
- Despite 15 years of intense international climate negotiations, concentrations of CO_2 in the atmospheric have been growing 33% faster during the last 8 years than in the 1990s.
- These drivers of climate change are accelerating.

Atmospheric CO_2 Concentration

Year 2008

Atmospheric CO_2 Concentration:

387 ppm

~ 40% above pre-industrial

Growth in Atmospheric CO_2 Concentrations/Year

1970 - 1979: 1.3 ppm/year

1980 - 1989: 1.6 ppm/year

1990 - 1999: 1.5 ppm/year

2000 - 2007: 2.0 ppm/year

2007: 2.2 ppm/year

2008: 2.3.ppm/year

Accelerating

Data Source: Pieter Tans and Thomas Conway, NOAA/ESRL

New

Global Carbon Project October 2008 Report

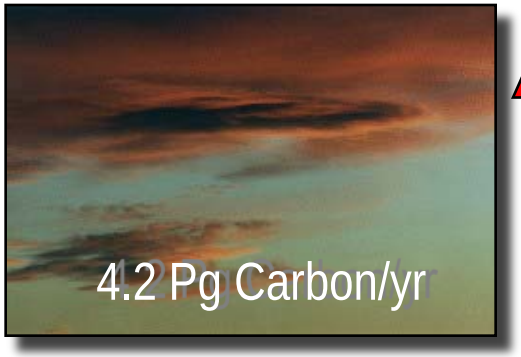
- There has been a complete shift in the share of regional emissions, now more than half of Fossil Fuel emissions are coming from developing countries.
- The efficiency of natural sinks has decreased by 5% over the last 50 years (and will continue to do so in the future), implying that the longer it takes to begin reducing emissions significantly, the larger the cuts needed to stabilize atmospheric CO_2

Fate of Anthropogenic CO_2 Emissions (2000-2007)

~ 20%

~ 80% +

Atmosphere
~ 46%



% is Going Up

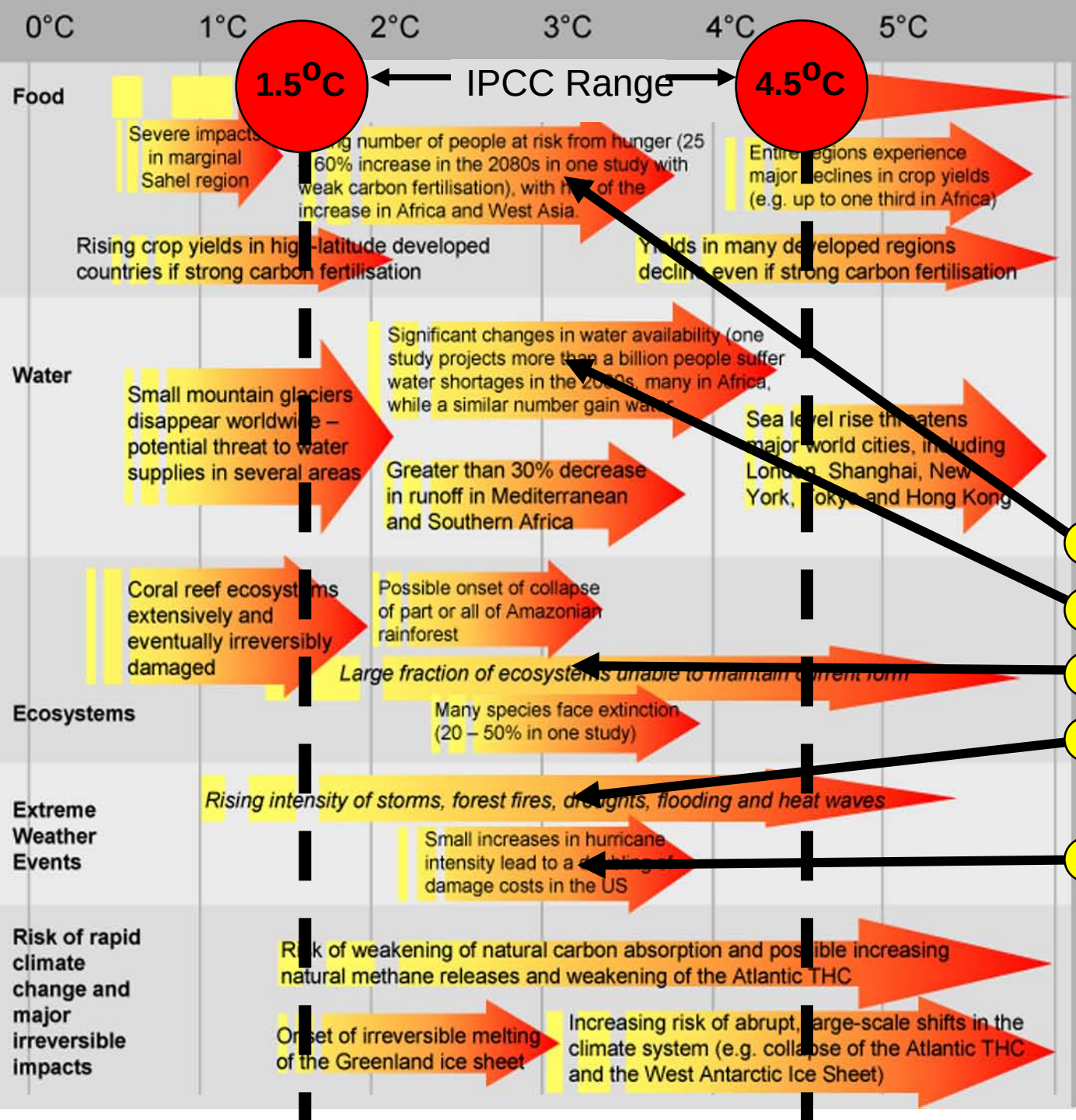
Land
~ 29%

Down ~ 5%

Oceans
~ 26%

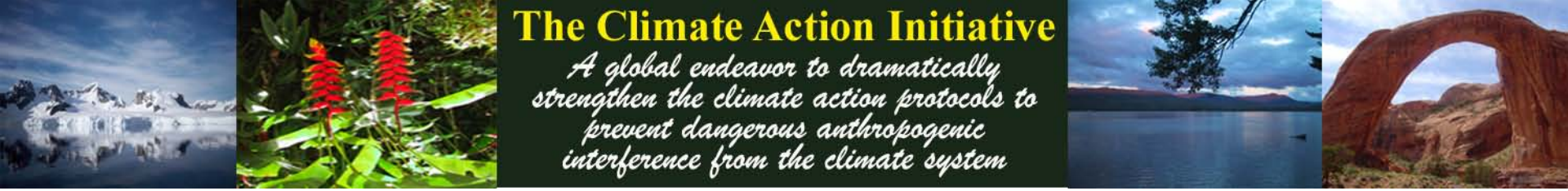
The Capacity of the Oceans and Lands to Absorb CO_2 is Down ~ 5% over the past several decades

Canadell et al. 2007, PNAS (updated)



Impacts and Consequence of the Projected Range of Temperatures towards the end of 21st Century for:

- *Food Security*
- *Water Issues*
- *Ecosystems*
- *Extreme Weather Events, and*
- *Risk of Rapid Climate Change and Irreversible Impacts.*



In Summary:

- ***Warming of the climate system is unequivocal,*** **as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.**
- ***There is now higher confidence in projected patterns of warming*** **and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and of ice.**
- ***Anthropogenic warming and sea level rise will continue for centuries*** **due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized.**

Arctic Sea Ice Conditions on September 15th 2008

Ave.
2005
2007

The Climate Action Initiative

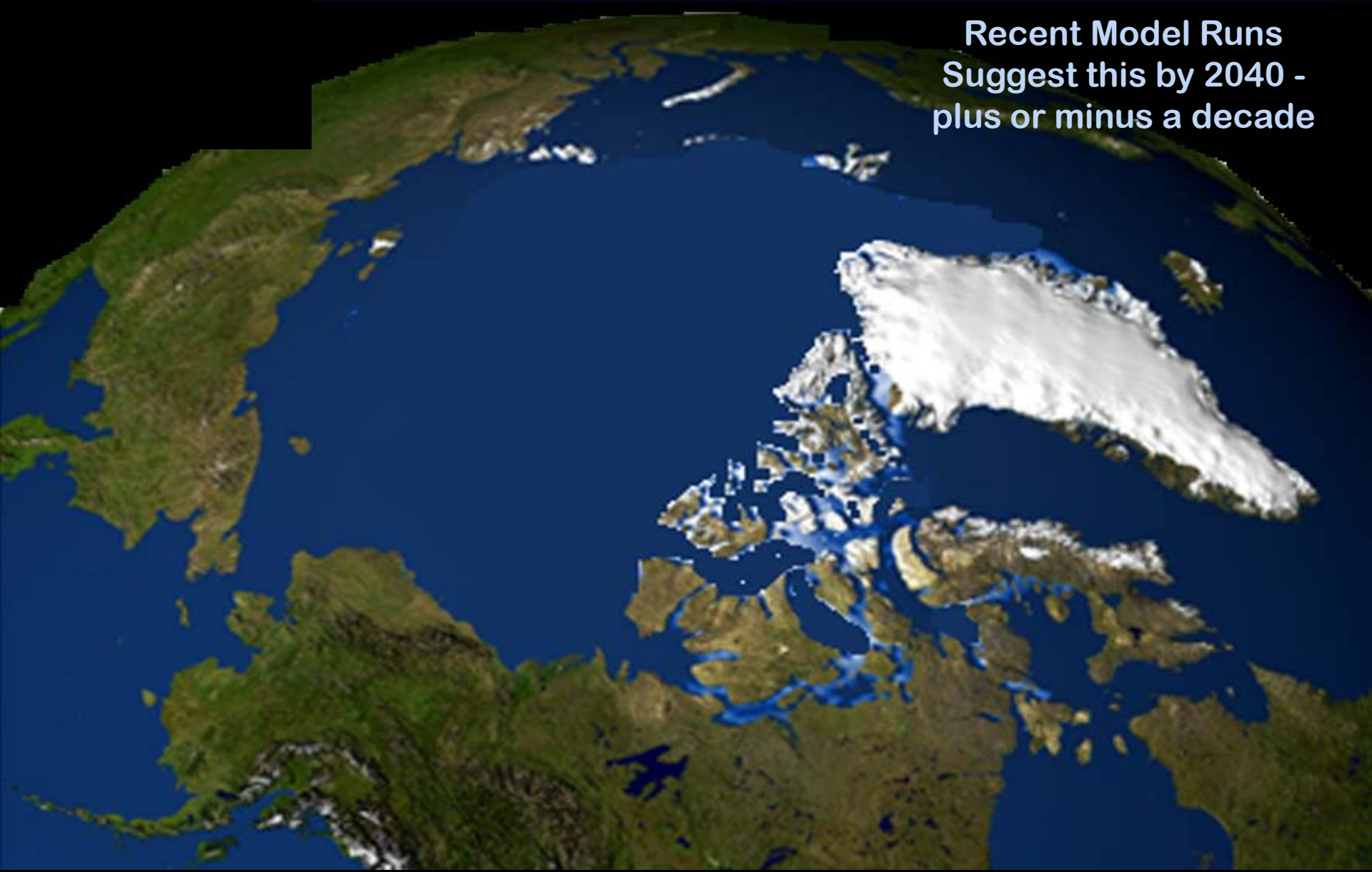
A global endeavor to dramatically strengthen the climate action protocols to prevent dangerous anthropogenic interference from the climate system

1980

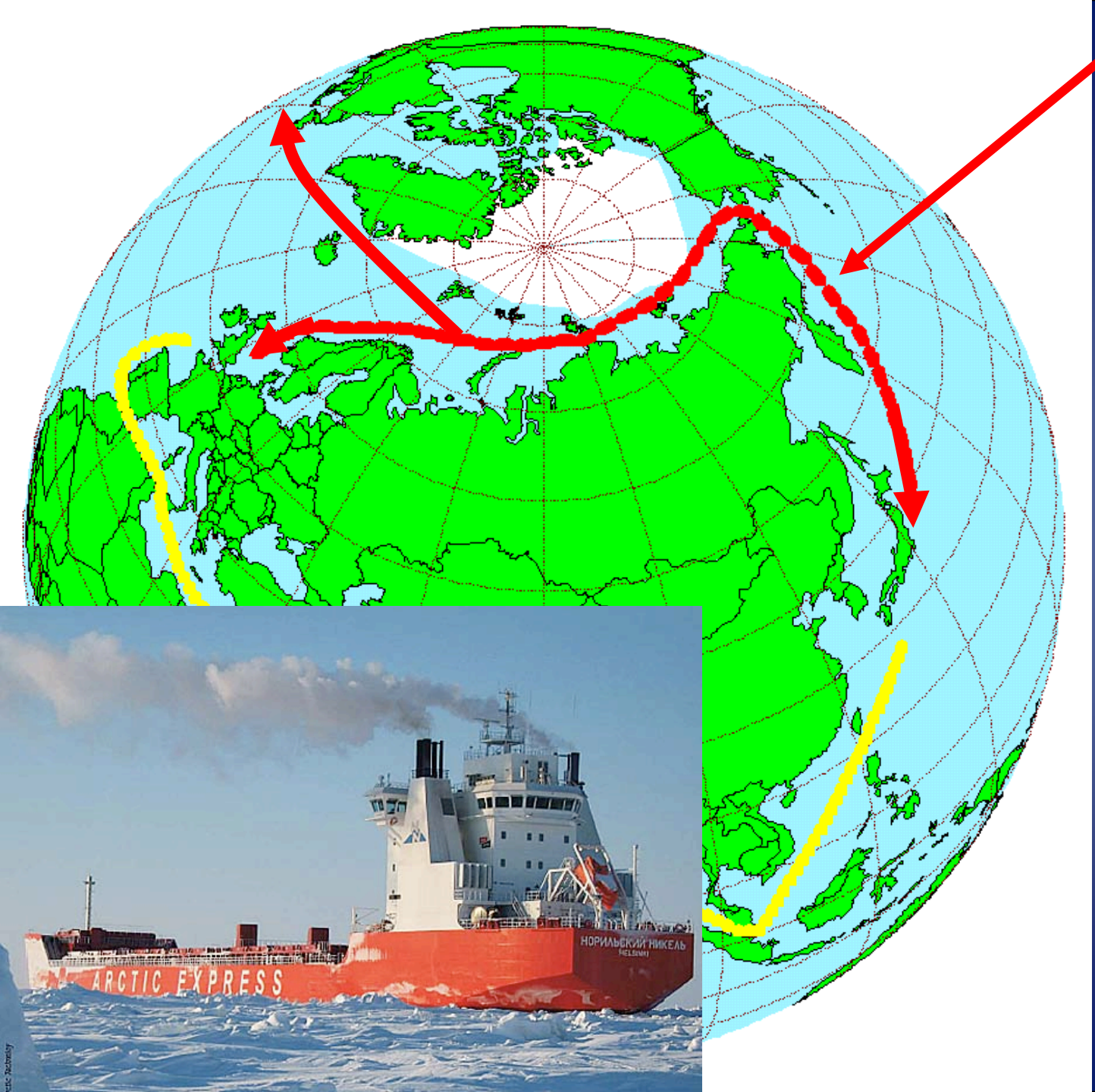
2005

2007

Models Project Sea Ice Extent for Mid-September



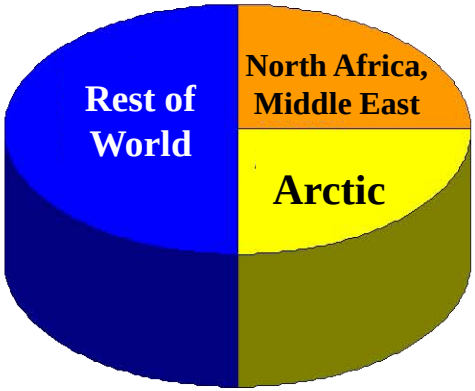
Recent Model Runs Suggest this by 2040 - plus or minus a decade



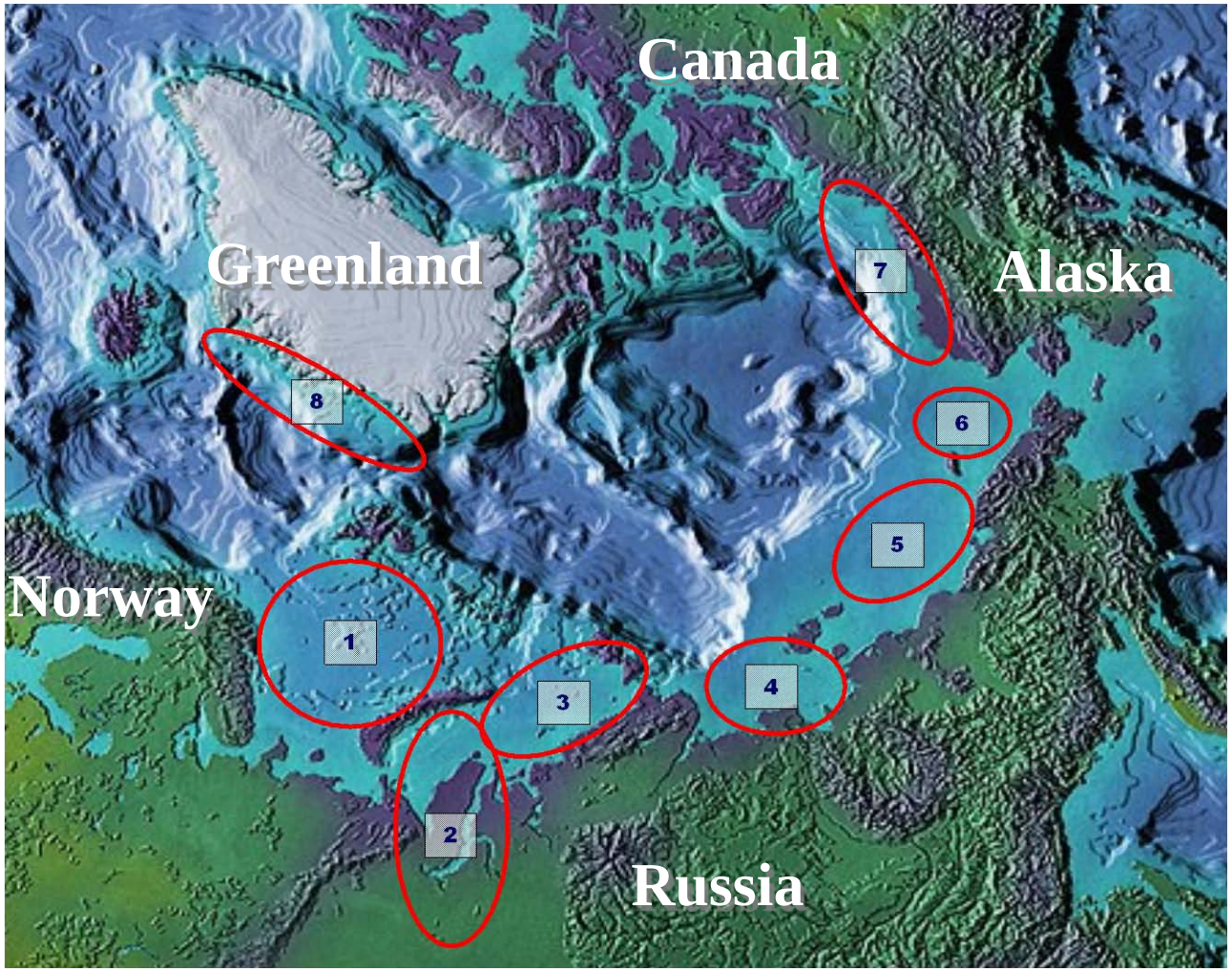
Northern Sea Route is 45% Shorter than through the Suez Canal

The ACIA models projects that the current navigation season of 20-30 days per year will increase to 3-6 months/yr by 2080, with one model indicating an ice-free summer by 2040

World's Petroleum Potential



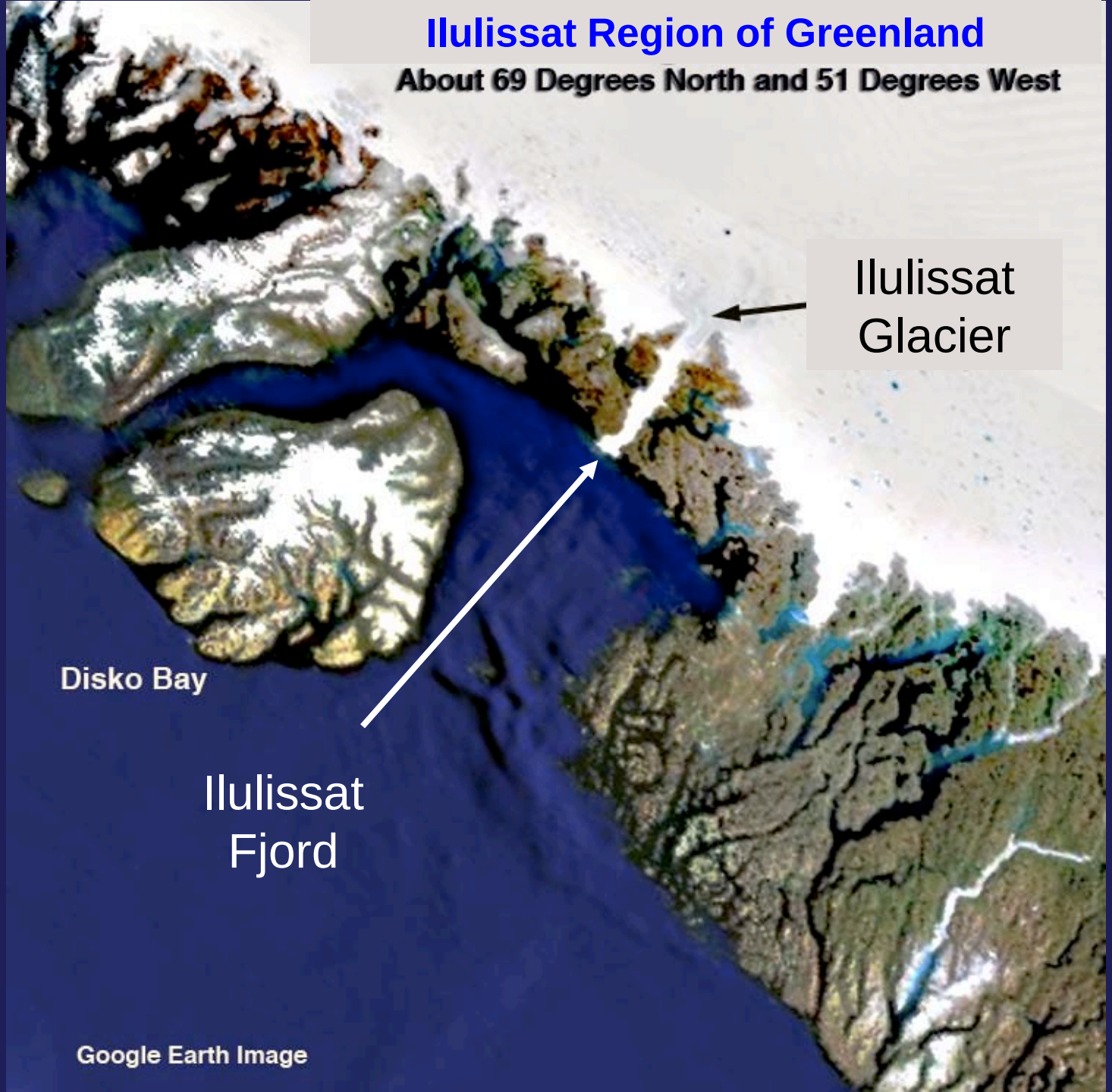
1. Barents Sea
2. Southern Kara Sea and Western Siberia
3. Northern Kara Sea
4. Laptev Sea
5. East Siberian Sea
6. Chukchi Sea
7. Alaska North Slope
8. East Greenland



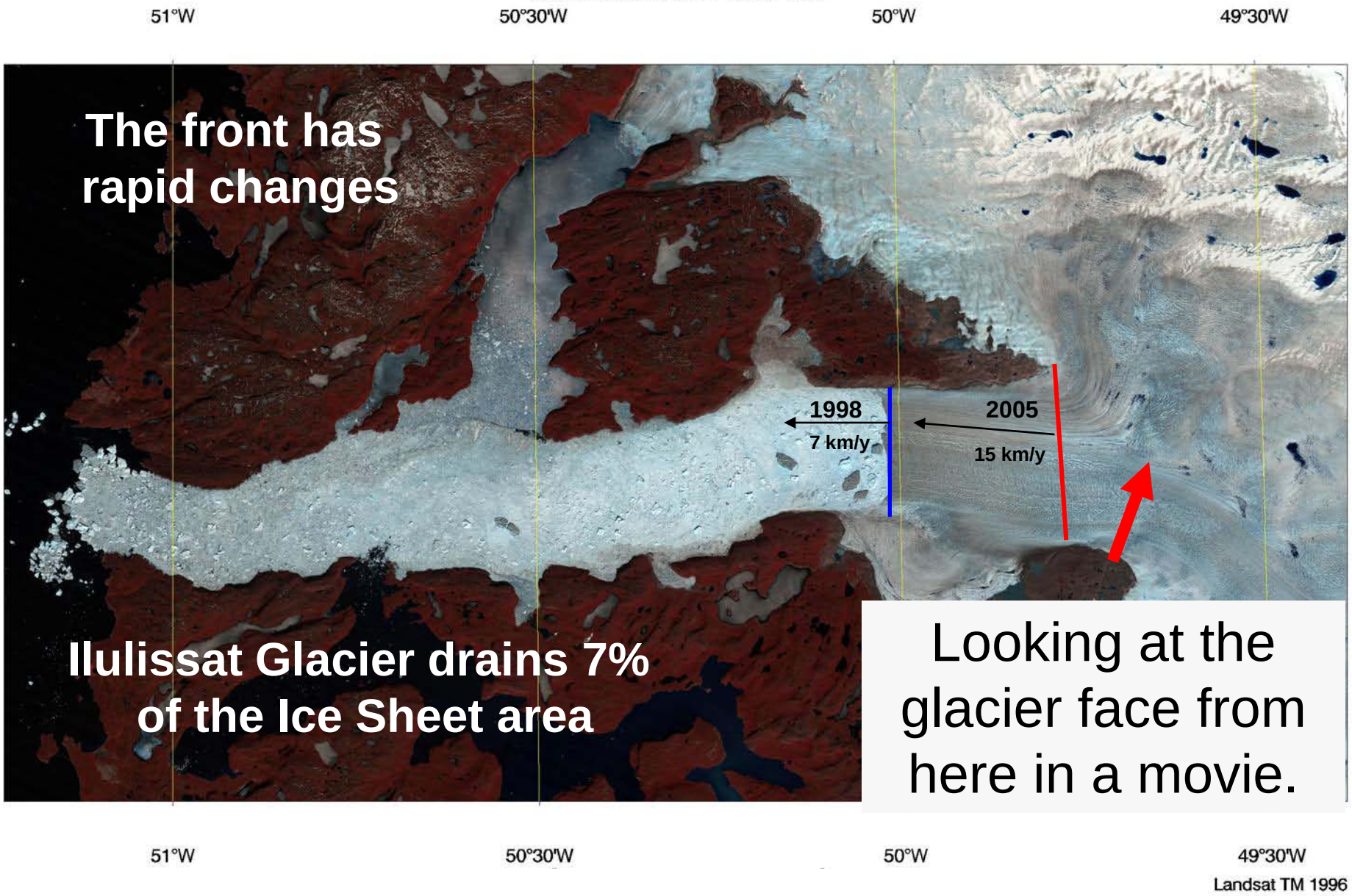
Polar Front
Cold polar water
Mixed cold water
Warm water of the Irminger Current and the North Atlantic Drift
Mixed cool water

Ilulissat Region of Greenland

About 69 Degrees North and 51 Degrees West



Ilulissat Glacier Retreat 1998-2005



The Climate Action Initiative

A global endeavor to dramatically strengthen the climate action protocols to prevent dangerous anthropogenic interference from the climate system

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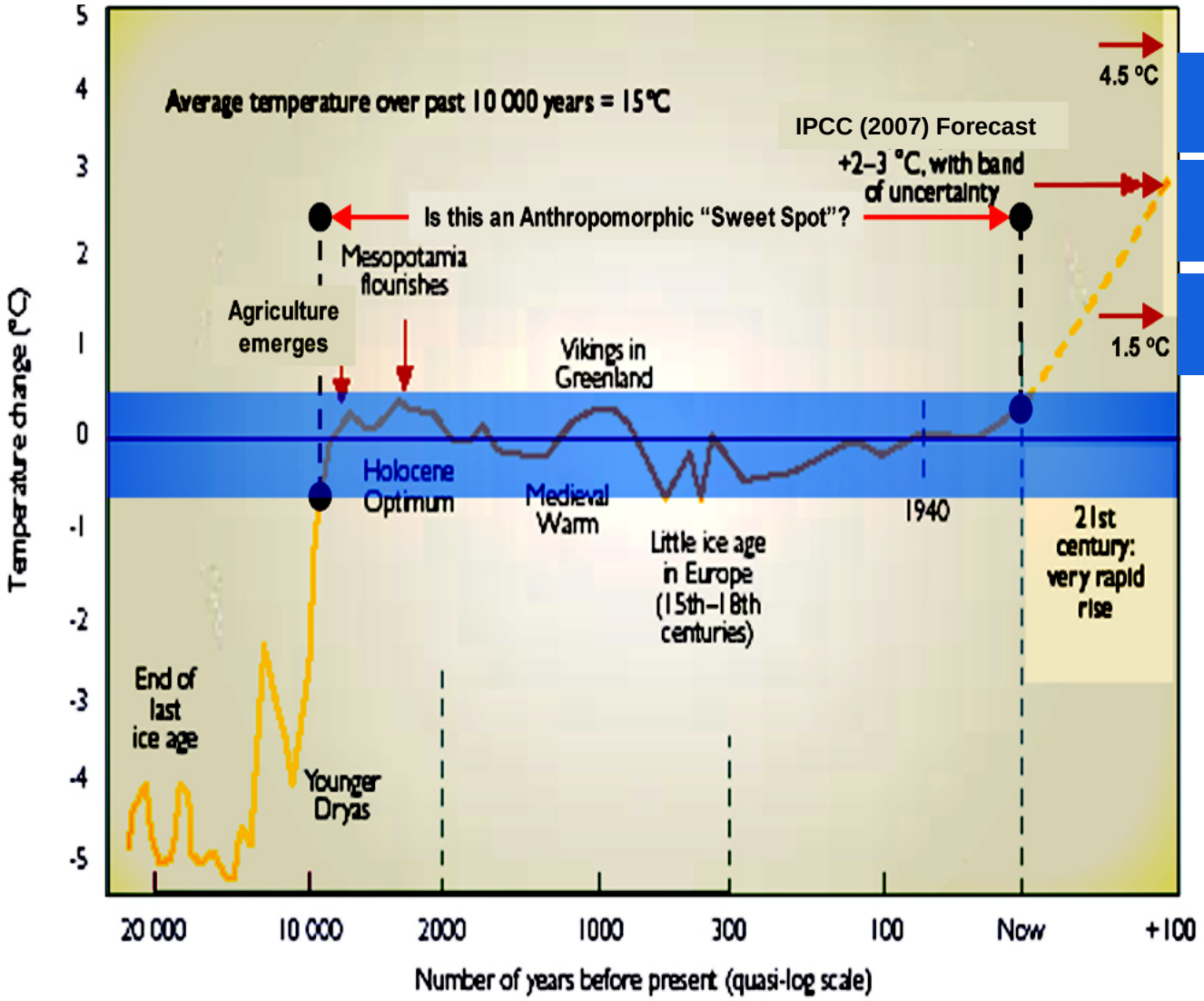
A global endeavor to dramatically strengthen the climate action protocols to prevent dangerous anthropogenic interference from the climate system

Jackson
LOUISIANA
Alexandria
MISSISSIPPI
TEXAS
Hattiesburg
Baton Rouge
Hammond
Lake Charles
Beaumont
Slidell
Lafayette
New Orleans
Houma
+ 1 meter
USA: Louisiana
Gulf of Mexico
Weiss and Overpeck
0
100 km

The question is: At what temperature will we stabilize?



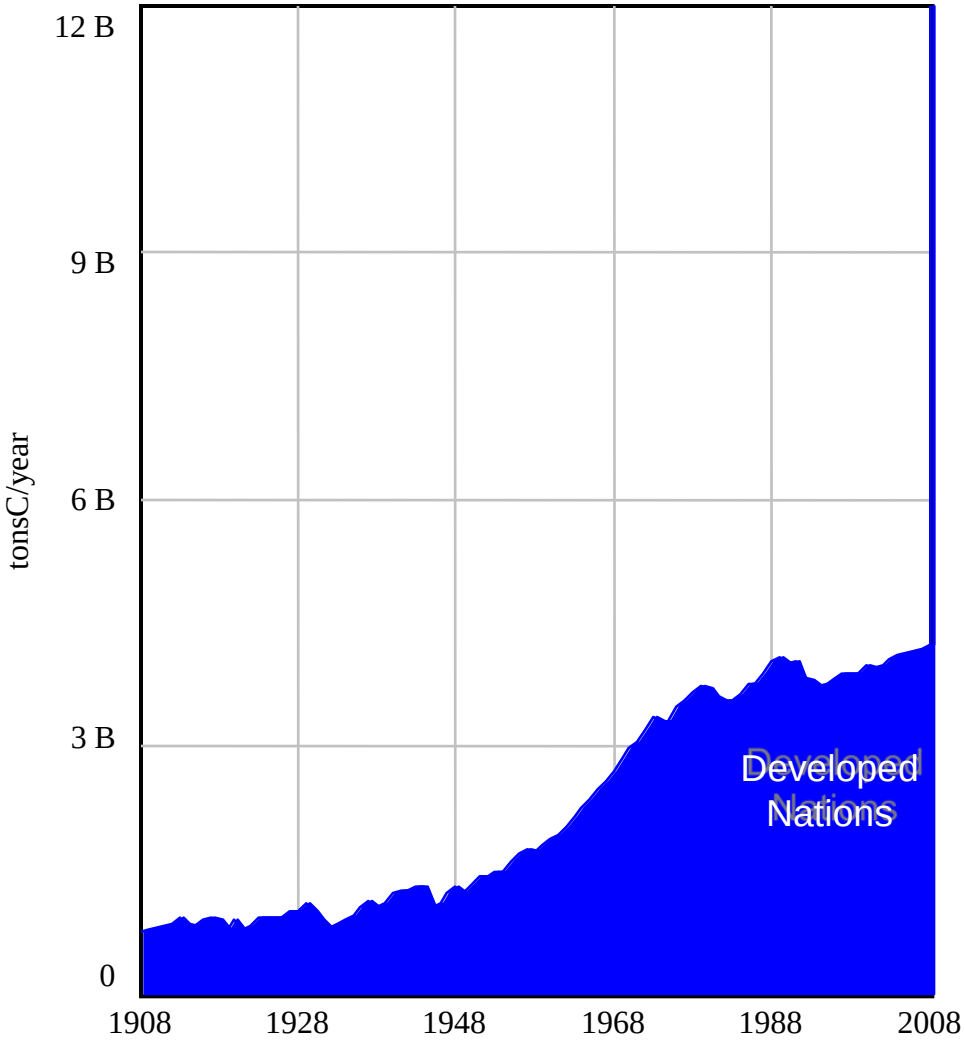
750 ppm ~ 4.3 ^{0}C

550 ppm ~ 3 ^{0}C

450 ppm ~ 2 ^{0}C

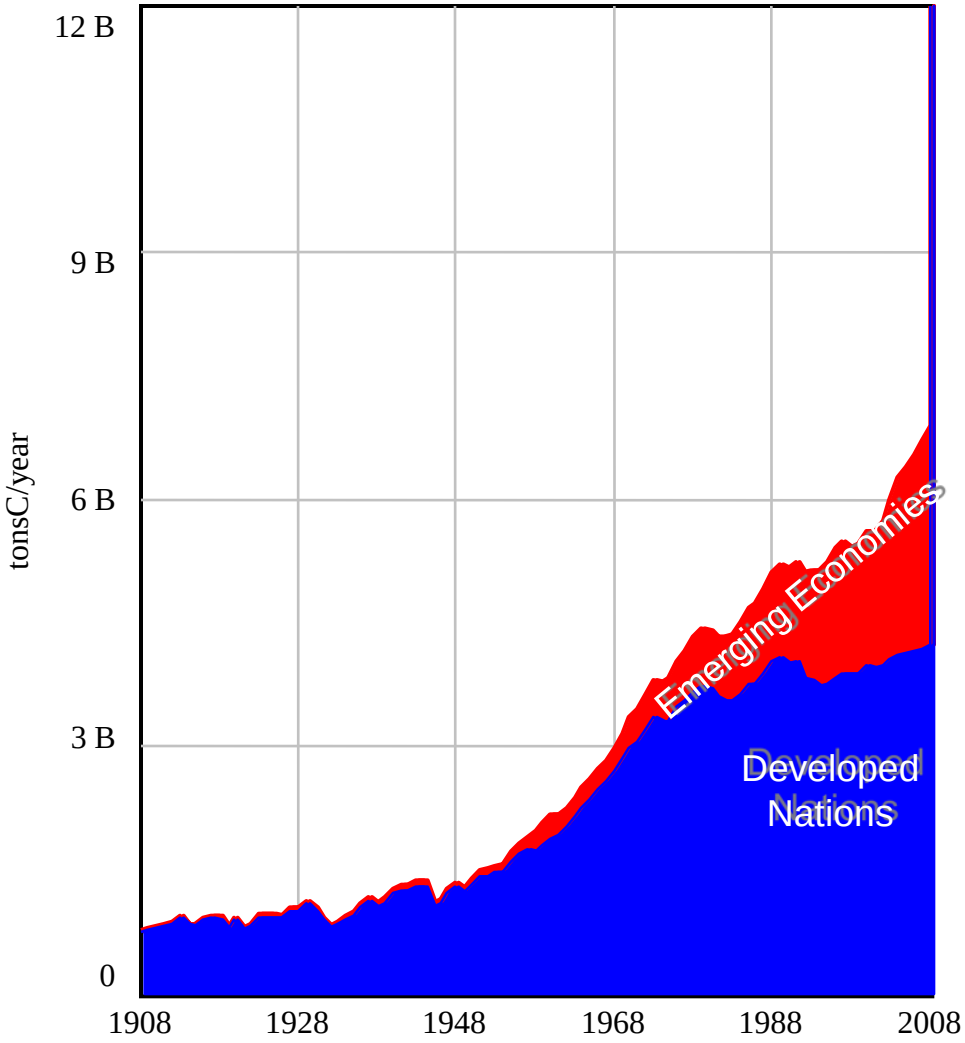
There is the potential that the climate is likely, as projected by the IPCC, to take humankind where it has never been

Developed Nations: Steady Growth in Emissions



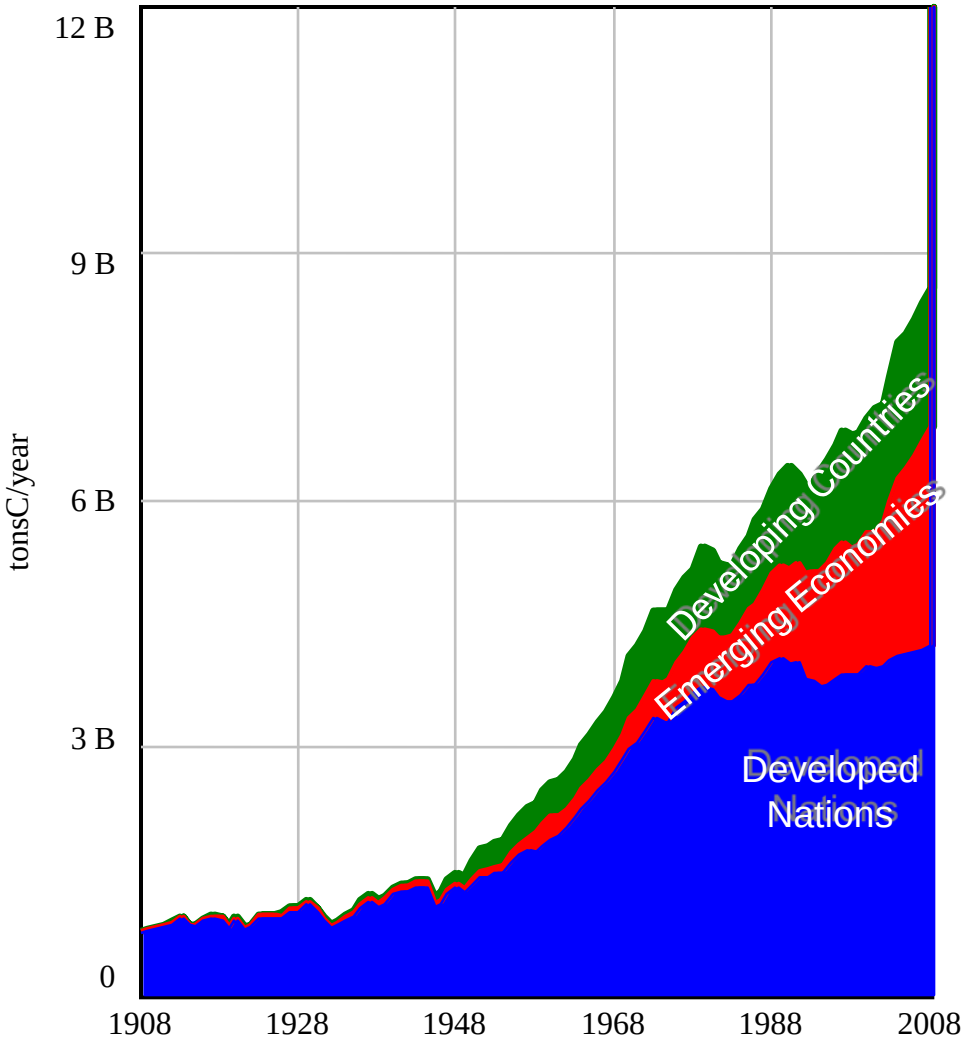
Source: CDIAC, WEO, C-ROADS

Emerging Economies: Emissions Rising



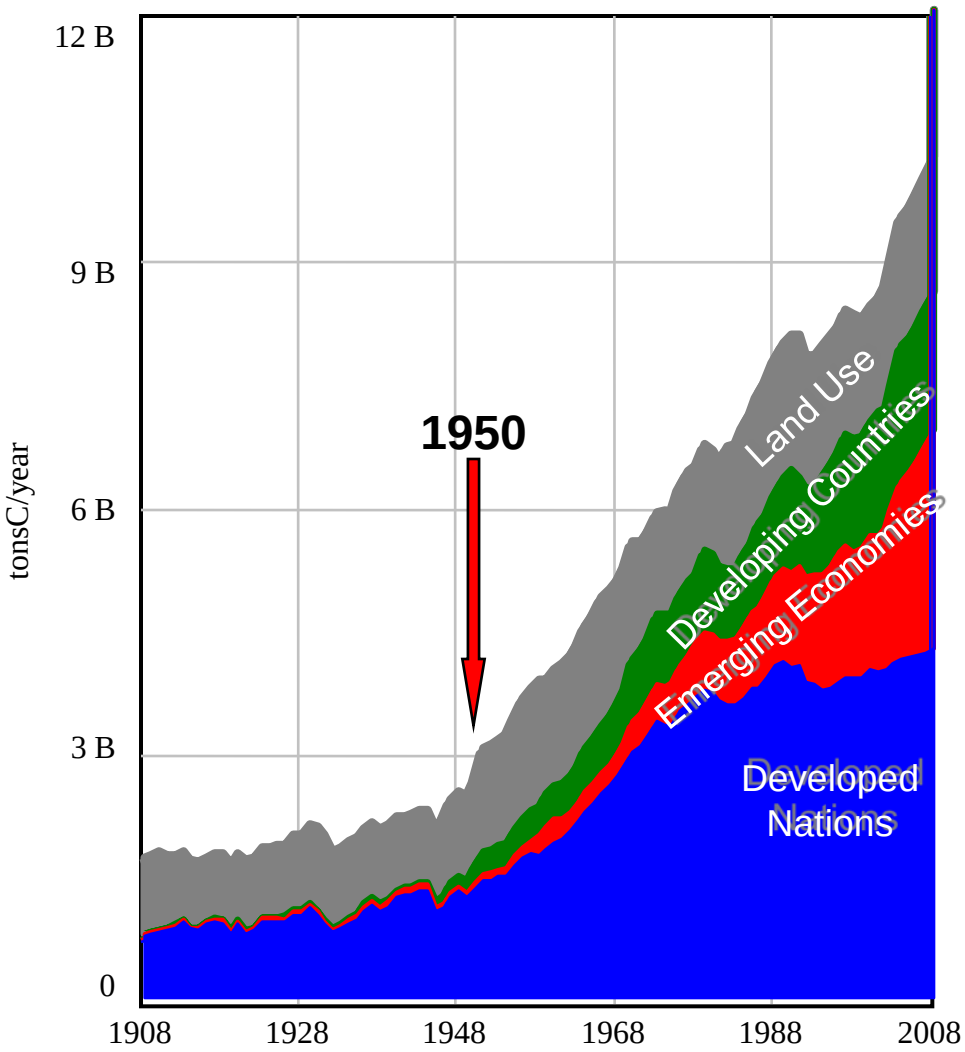
Source: CDIAC, WEO, C-ROADS

Developing Countries Emissions Rising



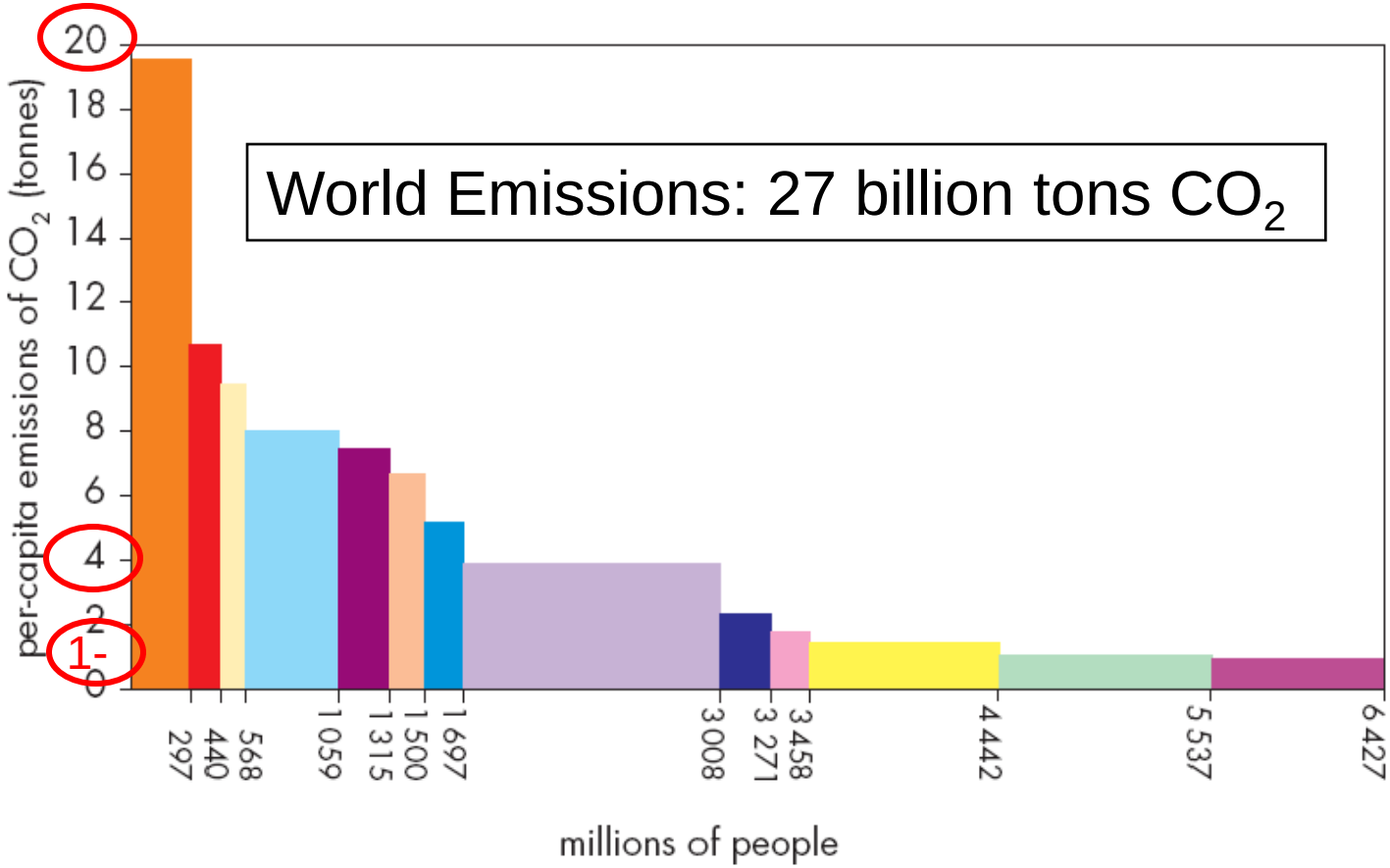
Source: CDIAC, WEO, C-ROADS

Fossil Fuel and Global Deforestation



Source: CDIAC, WEO, C-ROADS

Per-capita Fossil-Fuel CO_2 Emissions

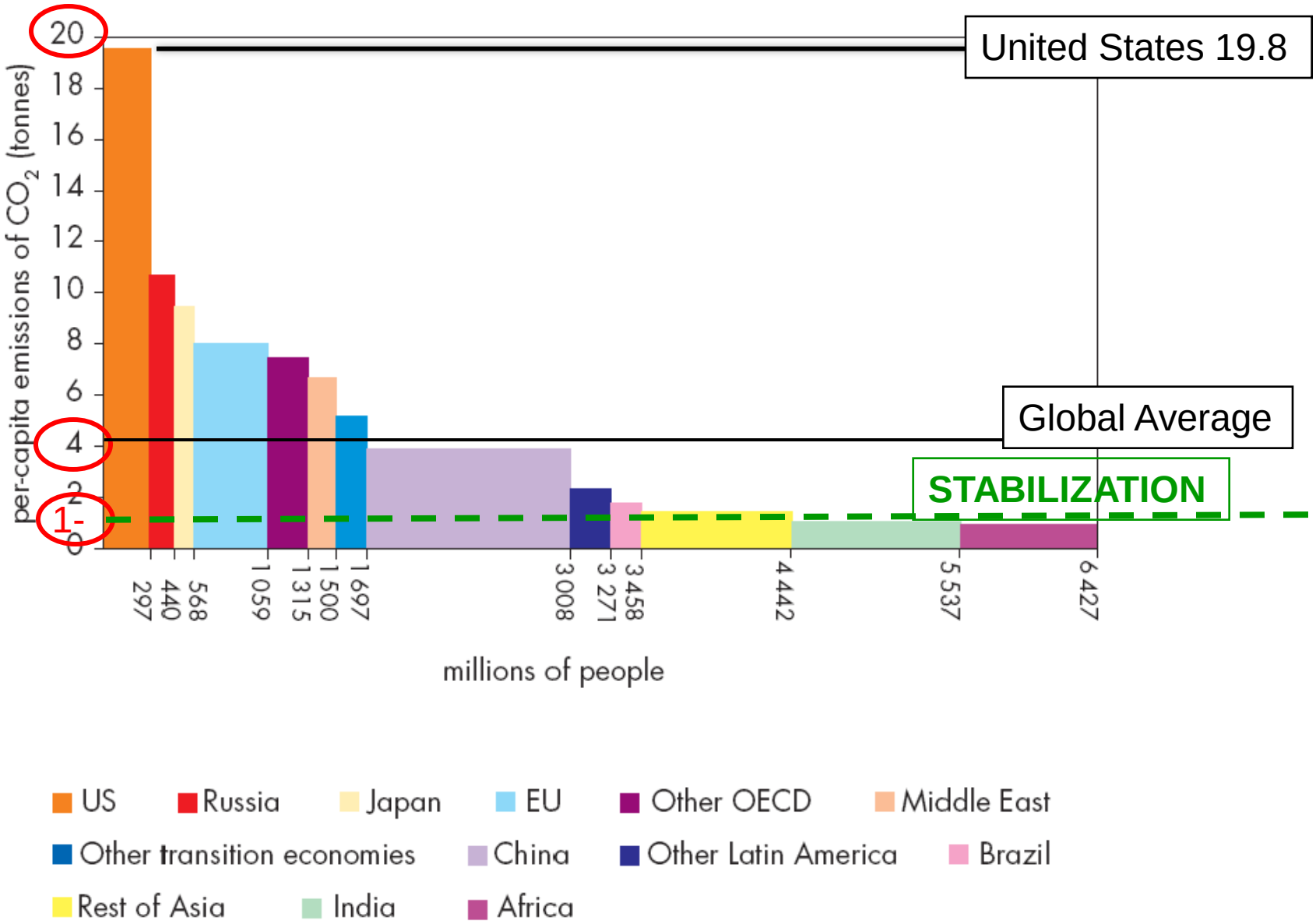


2005 Data

US, Russia, Japan, EU, Other OECD, Middle East, Other transition economies, China, Other Latin America, Brazil, Rest of Asia, India, Africa

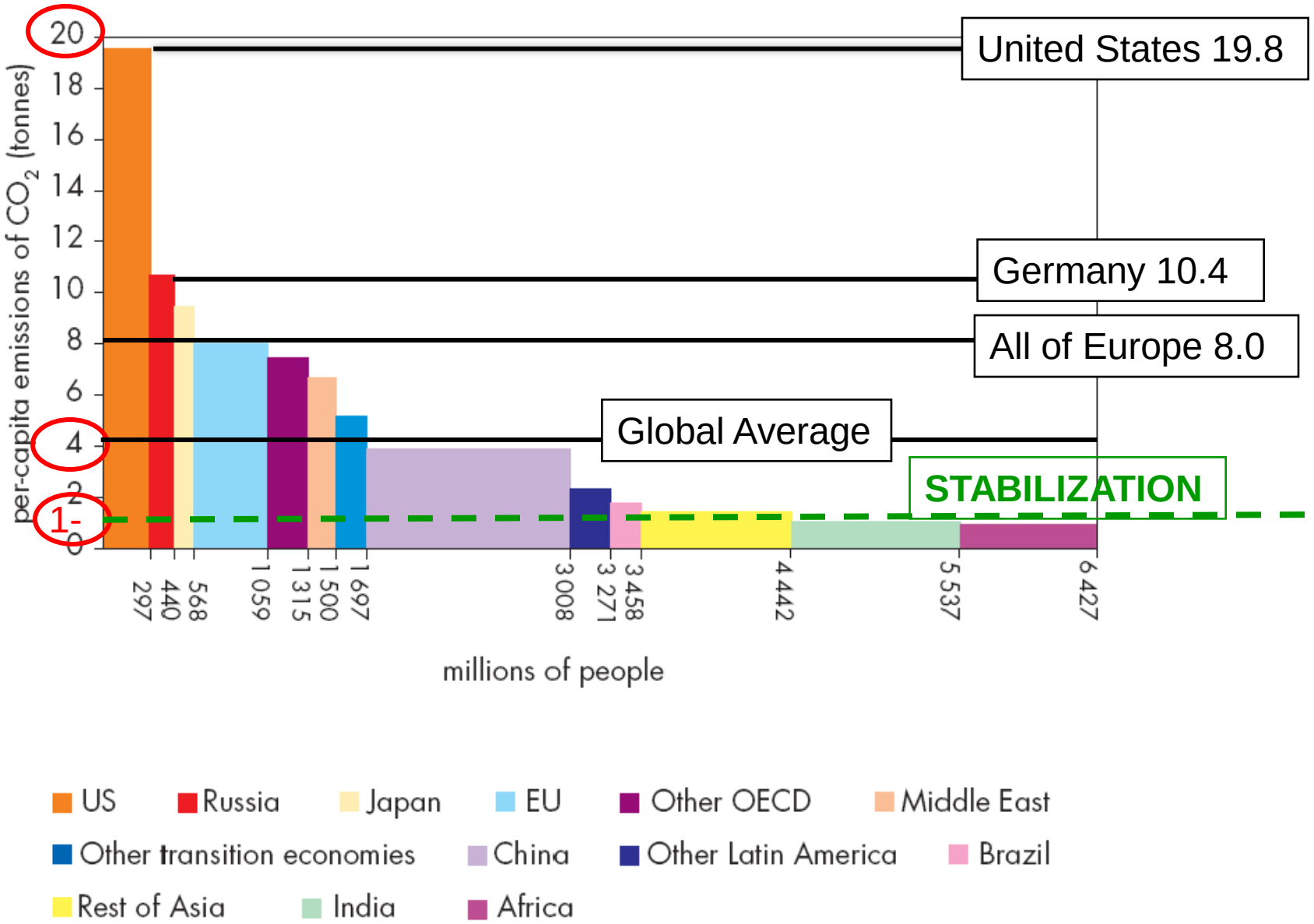
Source: IEA WEO 2007

Per-capita Fossil-Fuel CO_2 Emissions

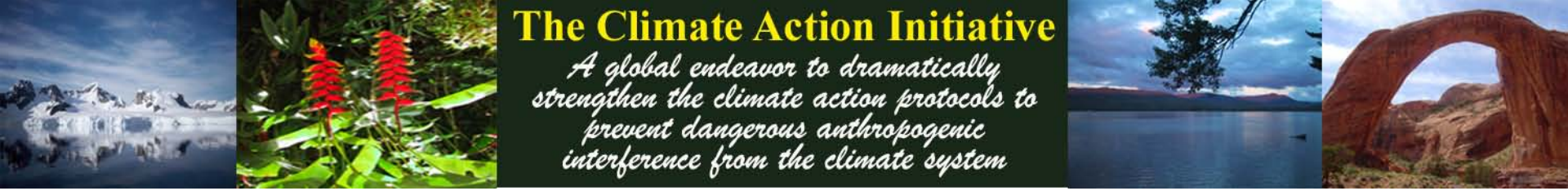


Source: IEA WEO 2007

Per-capita Fossil-Fuel CO_2 Emissions

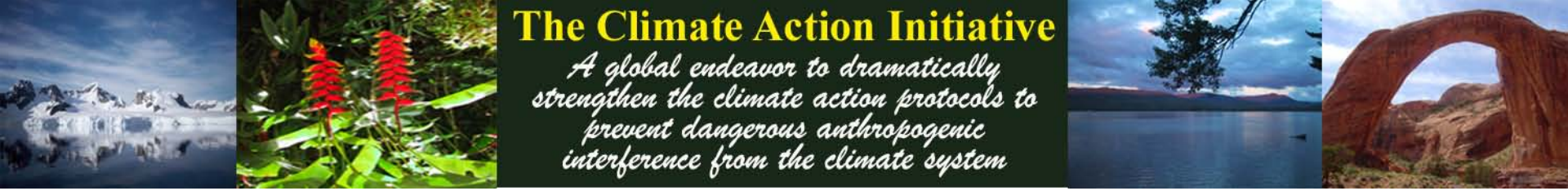


Source: IEA WEO 2007



Four Ways to Emit 4 Tons Co_2/yr (Today's Global Per-capita Average)

Activity	**Amount producing 4 ton CO_2/yr emissions**
a) Drive	10,000 miles/yr, 30 miles per gallon
b) Fly	10,000 miles/yr
c) Heat home	Natural gas, average house, average climate
d) Lights	300 kWh/month when all coal-power (600 kWh/month, natural-gas-power)

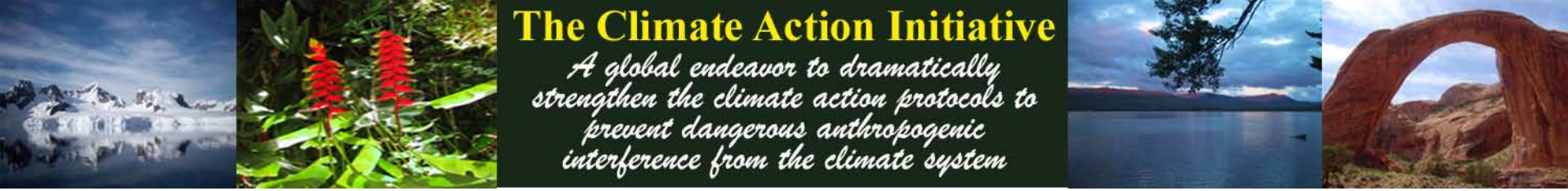


The Climate Action Initiative

The Challenge: It is now clear that there is a need to dramatically change the negotiation process for a Post-Kyoto Protocol. It is also increasingly clear that to address the root causes of climate change, ***Heads of State are the most likely individuals who can affect the necessary agreements*** to accomplish this end in the same way that they have done so in such arenas as trade, global financial agreements, nuclear disarmament, foreign policy, human rights, national security, etc.

The Initiative Strategy: To engage CEOs from global industries and selected global NGOs who then jointly work to re-engage Heads of State in the upcoming CoP 15 and beyond negotiations of the UNFCCC. It is posited that "***Climate Policy Exercises***" that employ "***Climate Policy Simulations***" of the climate system will substantively facilitate the process.

CAI
Climate Action Initiative



Target Audience and Stakeholders:

- ✓ Heads of State of the G8 Plus 5 Countries (to include also Sweden and Denmark) in the world the emit over 70 % of the CO_2 emissions, the top five of which emit almost 60% of the emissions, who in order are China, US, Russian Federation, India, and Japan.
- ✓ Selected global industry CEOs whose corporations have substantial knowledge and/or interests in these CO_2 emitting countries which includes CEOs from companies in Europe, US, China and India.
- ✓ Key CEOs of global NGOs who are impacted by climate change and have a vested interest in controlling climate change (e.g., Oxfam, CARE and Save the Children).
- ✓ Potential partners among other NGOs, industry, and scientific community.

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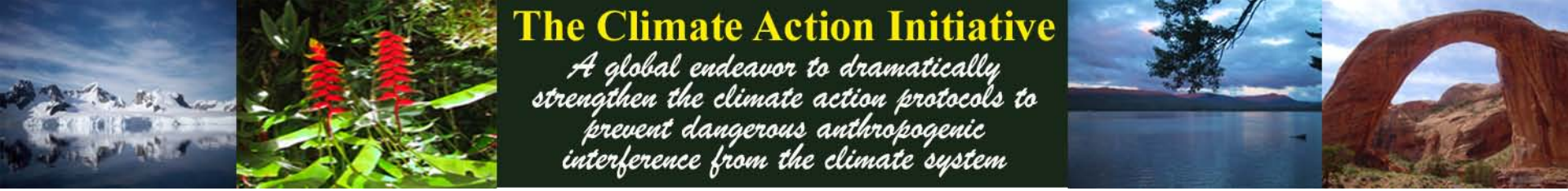

The Initiative Steering Committee:

- **Dr. Robert W. Corell**, Chair of the Initiative (United States)
- **Mr. Tom Cummings**, Executive Learning Partnership (The Netherlands)
- **Mr. Andrew P. Jones**, Sustainability Institute (United States)
- **Dr. Christine Loh**, Civic Exchange (China)
- **Dr. Anne Marsh**, The Heinz Center (United States)
- **Dr. Jacqueline McGlade**, European Environment Agency (Denmark & EU)
- **Dr. Felicity von Peter**, Forum for Active Philanthropy (Germany)
- **Dr. Elizabeth Sawin**, Sustainability Institute (United States)
- **Dr. Peter M. Senge**, Society of Organizational Learning (United States)
- **Dr. John D. Sterman**, MIT System Dynamics Group (United States)
- **Ms. Tranice Watts**, The Heinz Center (United States)

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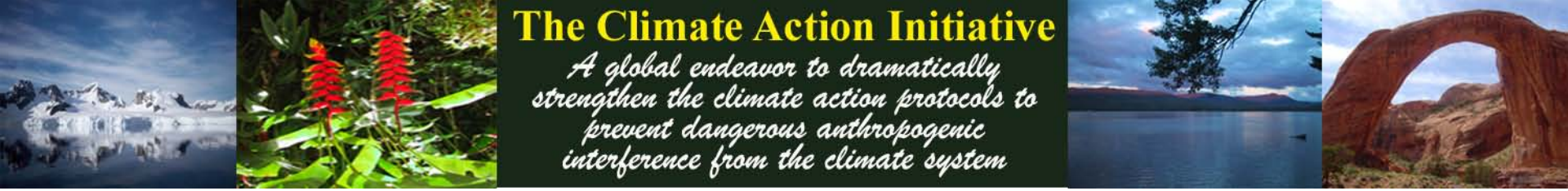


Purpose of C-ROADS

(Climate Rapid Overview And Decision Support)

- **Improve understanding of important climate dynamics among:**
  - ✓ **Policymakers**
  - ✓ **Educators**
  - ✓ **The public**
- **A climate model that is designed to help ensure that climate policy is informed by accepted, peer-reviewed science**

C-ROADS designed to be:

- **Fast**
  - Simulates in <1 second
- **Accessible**
  - Used easily on a laptop by non-modelers
  - Flexible, intuitive interface
- **Transparent**
  - Open-box; assumptions available for review
  - Causal tracing permits auditing of behavior
- **Grounded in and consistent with accepted climate science**
  - Calibrated to/tested against AR4, other models and data
  - Enables rapid and flexible sensitivity analysis
  - Reviewed by distinguished panel of scientists

Climate Policy Exercises and C-Roads to Facilitate Decision-making by Understand Dynamics of Climate Change

Inputs

- Fossil fuel emissions by countries or "economy group"
- Land use emissions
- Additional sequestration from aforestation
- Other greenhouse gas emissions

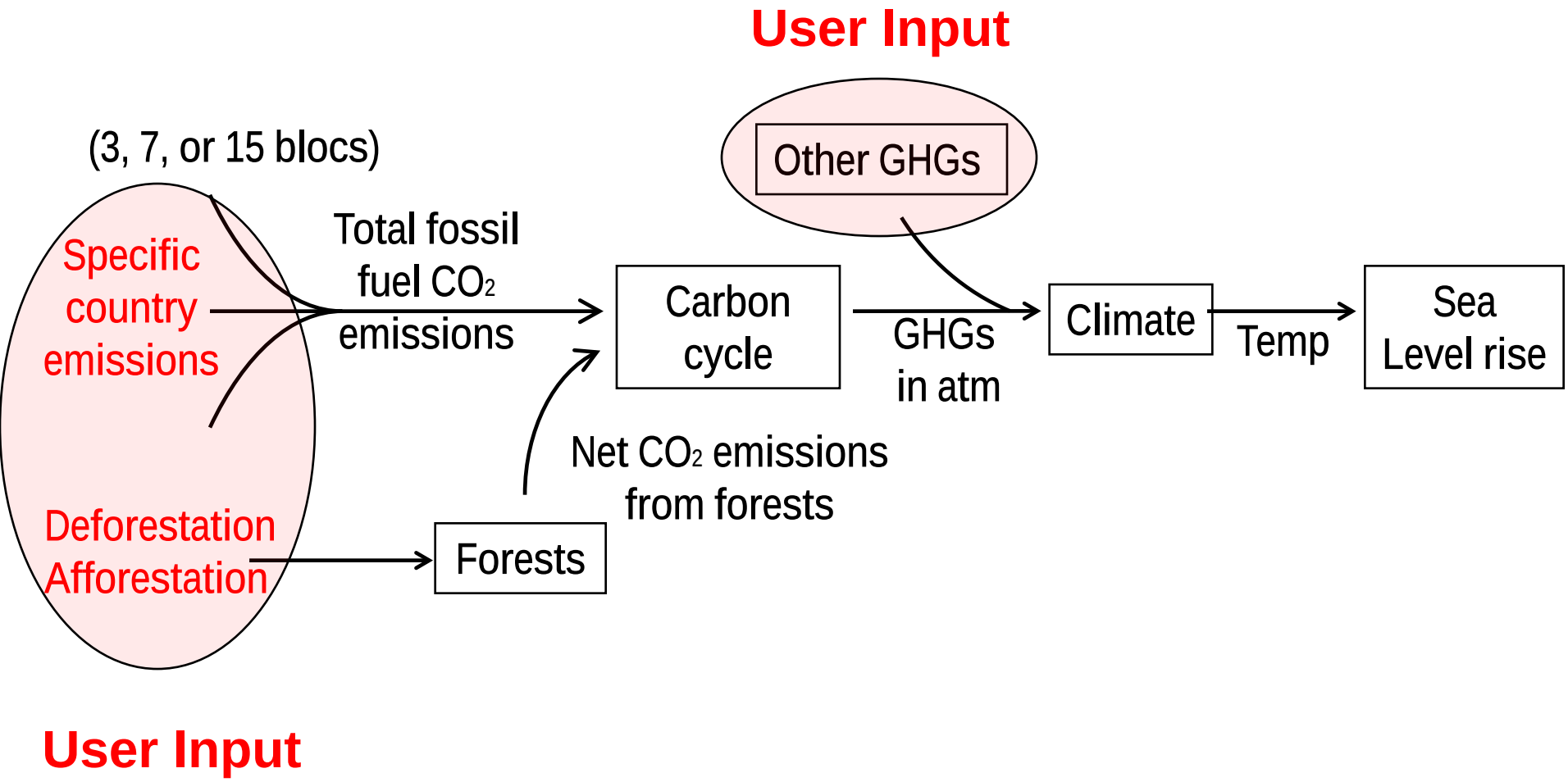
Simulation

Outputs

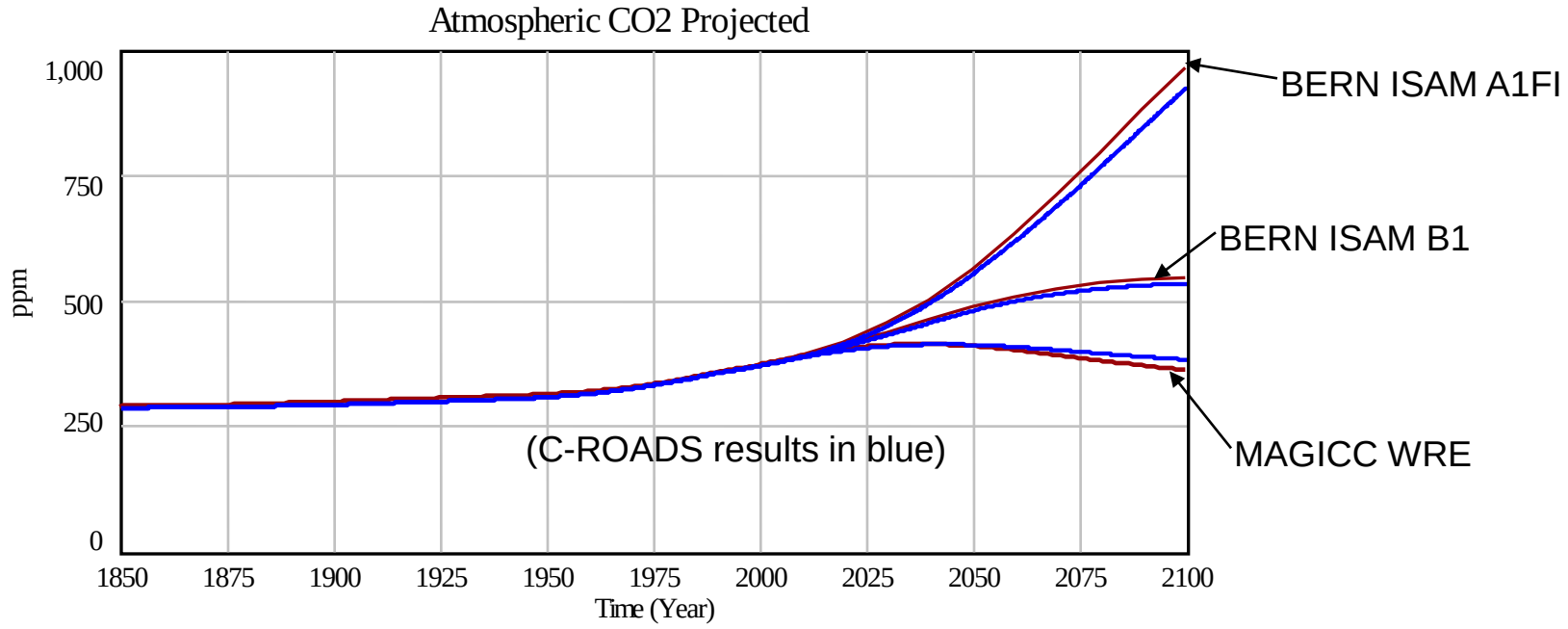
- CO_2 in the atmosphere
- Global temperature
- Total emissions
- Total removals to oceans, biomass etc.

The Model

C-ROADS Model Structure



The Simulation Produces Atmospheric CO_2 Levels Consistent with IPCC and other Scenarios



The Simulation Produces Temperature Output Consistent with the Models in the 2007 IPCC's

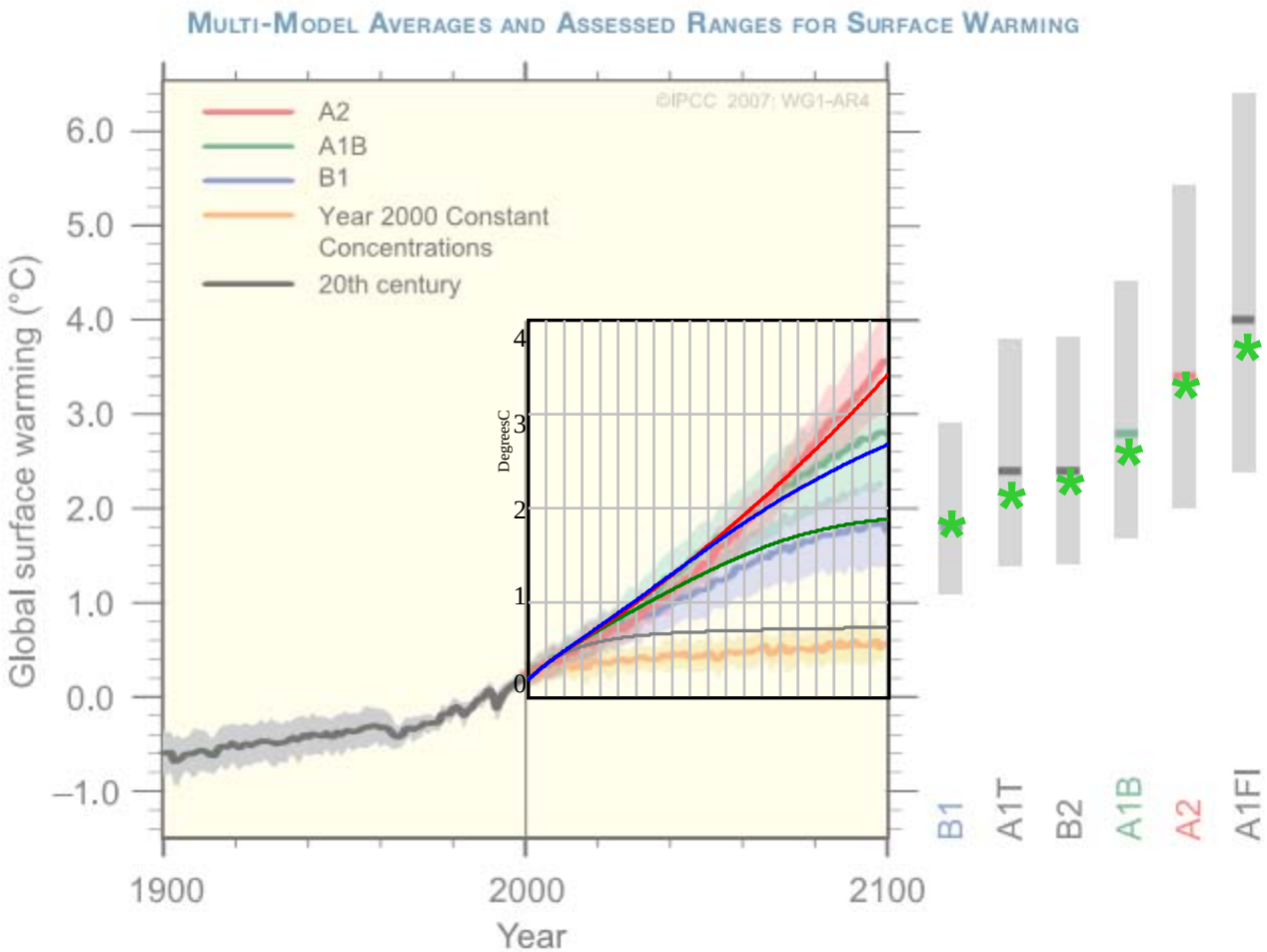


Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

C-ROADS Scientific Review Panel
March 2009

• Dr. Robert Watson (Chair)	Department for Environment, Food and Rural Affairs (DEFRA) and former chair, IPCC
• Mr. Eric Beinhocker	McKinsey Global Institute
• Dr. Klaus Hasselmann	Max-Planck Institut für Meteorologie
• Dr. David Lane	London School of Economics
• Dr. Jørgen Randers	Norwegian School of Management (BI)
• Dr. Stephen Schneider	Stanford University
• Dr. Bert de Vries	Netherlands Environmental Assessment Agency, RIVM

Conclusion of Scientific Review Panel

The C-ROADS model:

- **"reproduces the response properties of state-of- the-art three dimensional climate models very well"**

- **"is a *sensitivity* tool, rather than a tool to provide precise quantitative estimates of projected emissions, CO_2 concentrations, and temperature and sea level responses."**

- **"Given the model's capabilities and its close alignment with a range of scenarios published in the Fourth Assessment Report of the IPCC we support its widespread use among a broad range of users and recommend that it be considered as an official United Nations tool."**

A Climate Policy Exercise

2009
Simulating the UN Climate Negotiations leading the CoP-15

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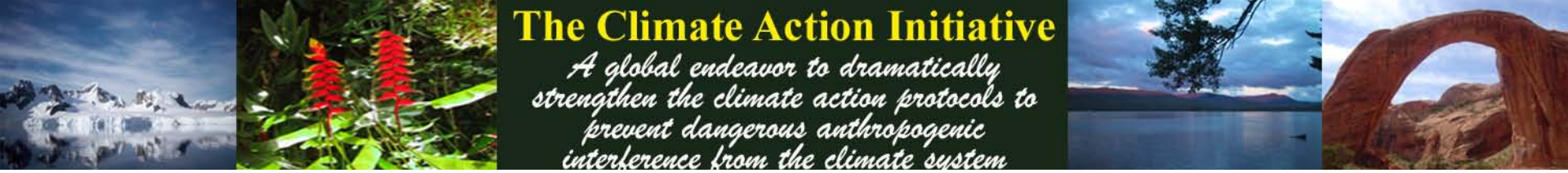
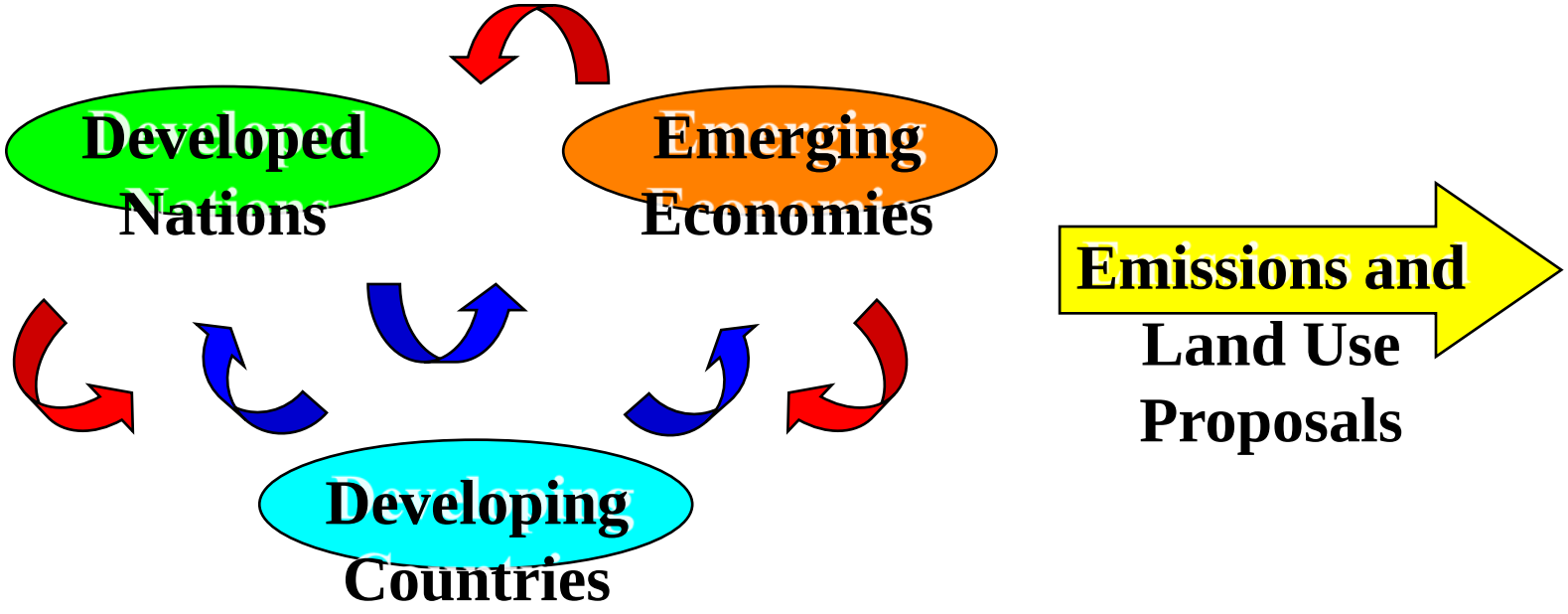


Your Goal in this Policy Exercise

Achieve emissions reduction commitments that stabilize CO_2 levels about 350 to 400 ppm by 2100

Climate Policy Exercise in Three Country Groupings Develop Emission and Land Use Proposals

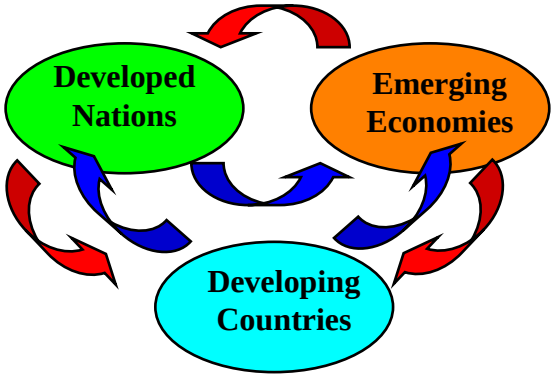


Role-Playing (Mock)
Negotiating for Three (3) Country Groups
or
Up to 15 Regions of
Countries and Individual Countries (EU, US, China, India, etc.)

Climate Policy Exercise in Three Country Groupings Develop Emission and Land Use Proposals

Negotiation Targets for:

- Fossil fuel emissions by countries or "economy group"
- Land use emissions
- Additional sequestration from aforestation
- Other greenhouse gas emissions



Role-Playing (Mock) Negotiating Country Groups or Up to 14 Regions of Countries and Individual Countries (EU, US, China, India, etc.)

Produce → **Inputs** → **C-ROADS** → **Outputs**

A Dynamic Policy-Relevant Decision-support Simulation of the Climate System

Climate Policy Exercises and C-Roads to Facilitate Decision-making by Understand Dynamics of Climate Change

Inputs

- Fossil fuel emissions by countries or "economy group"
- Land use emissions
- Additional sequestration from aforestation
- Other greenhouse gas emissions

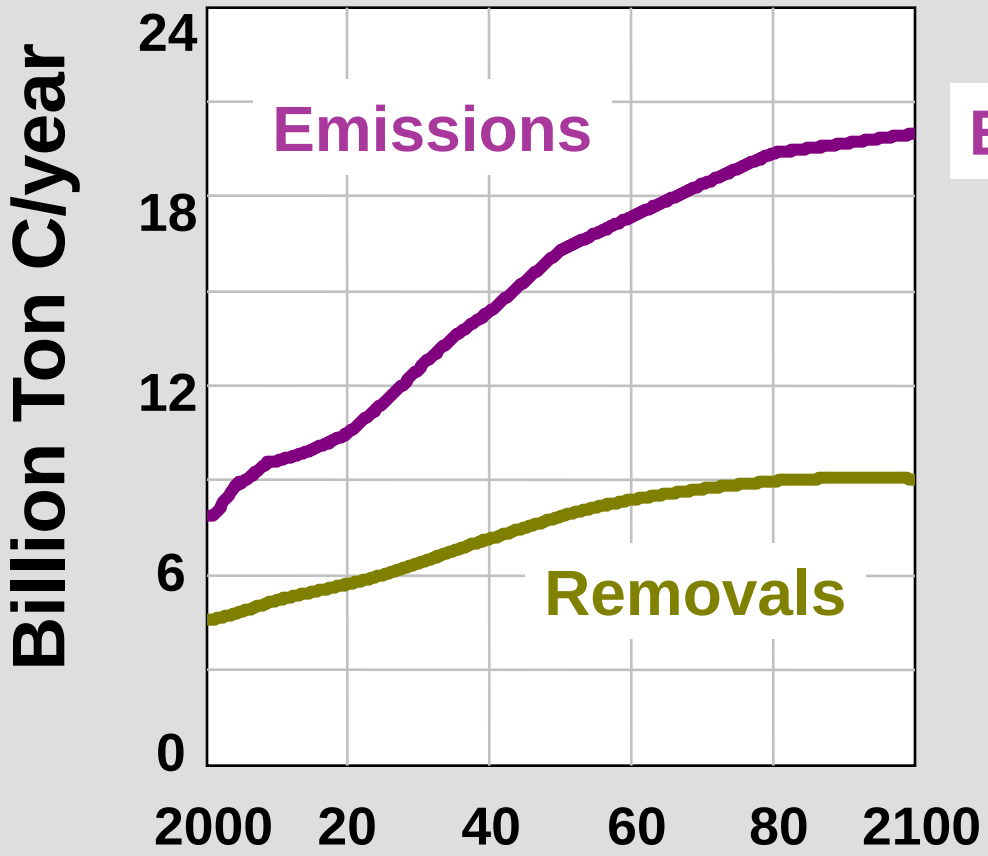
Simulation

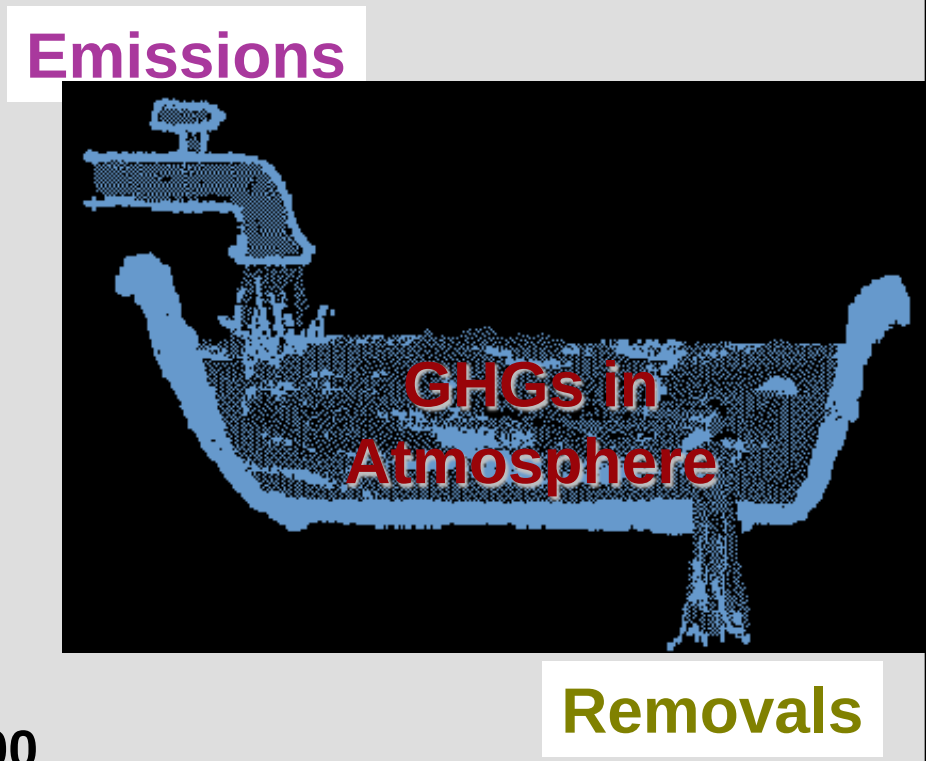
Outputs

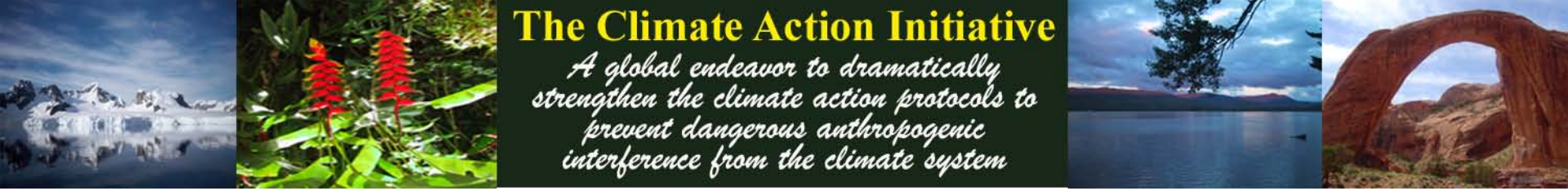
- CO_2 in the atmosphere
- Global temperature
- Total emissions
- Total removals to oceans, biomass etc.

Use the C-ROADS to characterize issues of societal importance and in terms policy makers understand.

GHG Emissions Under Current Proposals Continue to Exceed Removal from Atmosphere





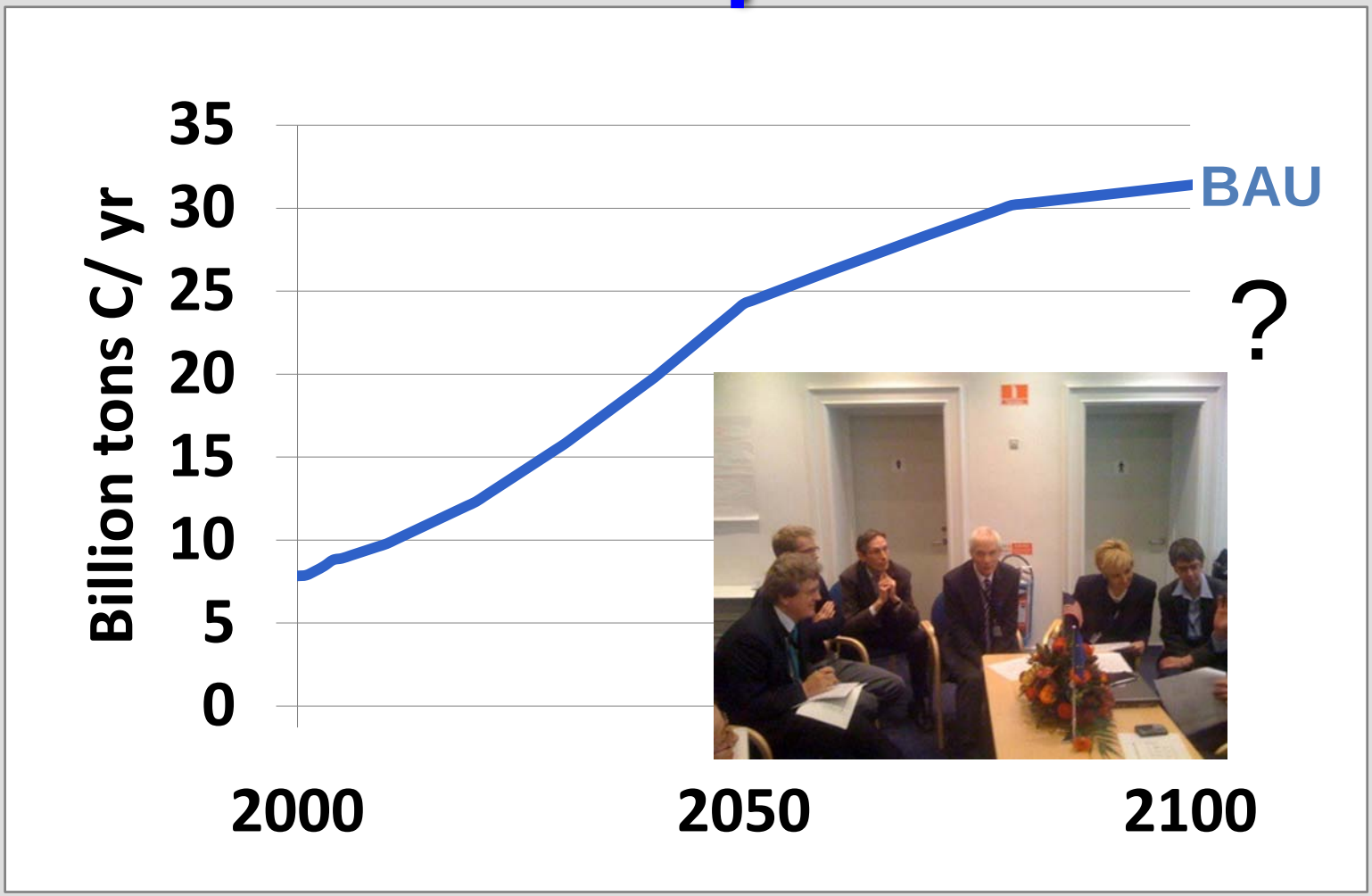


What would happen if the Negotiations on Climate Change were based on the currently known “positions” of the 192 UNFCCC nations on the issue of emissions Reductions and changes in deforestation and other land use changes?

Our Understanding of the Current Emission Reduction Proposals

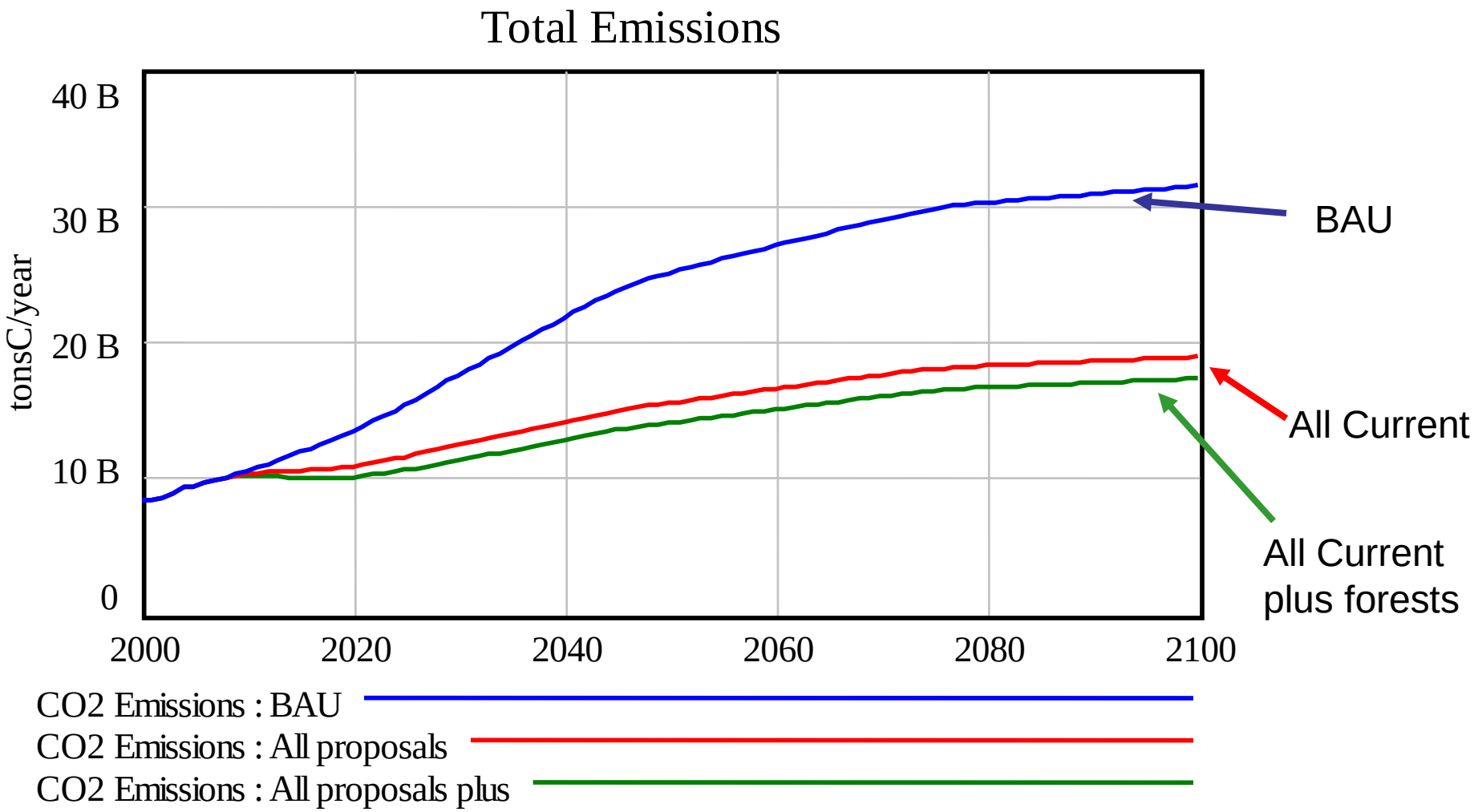
Brazil Eliminate deforestation by 2050	Canada 70% below 2006 by 2050	China	Europe 80% below 1990 levels by 2050	India BAU rate until 2035 and then constant emissions
Middle East	Mexico 50% below 2002 levels by 2050	OECD Pacific 60% below 2000 by 2050	Other Africa	Other Large Asia
Other Latin Am.	Other Small Asia	Russia/FSU 1990 levels by 2012	South Africa BAU until 2022; emissions constant until 2032, then 1% per year annual decline	US 80% below 1990 by 2050

What Might We Expect From "Your Proposals"?

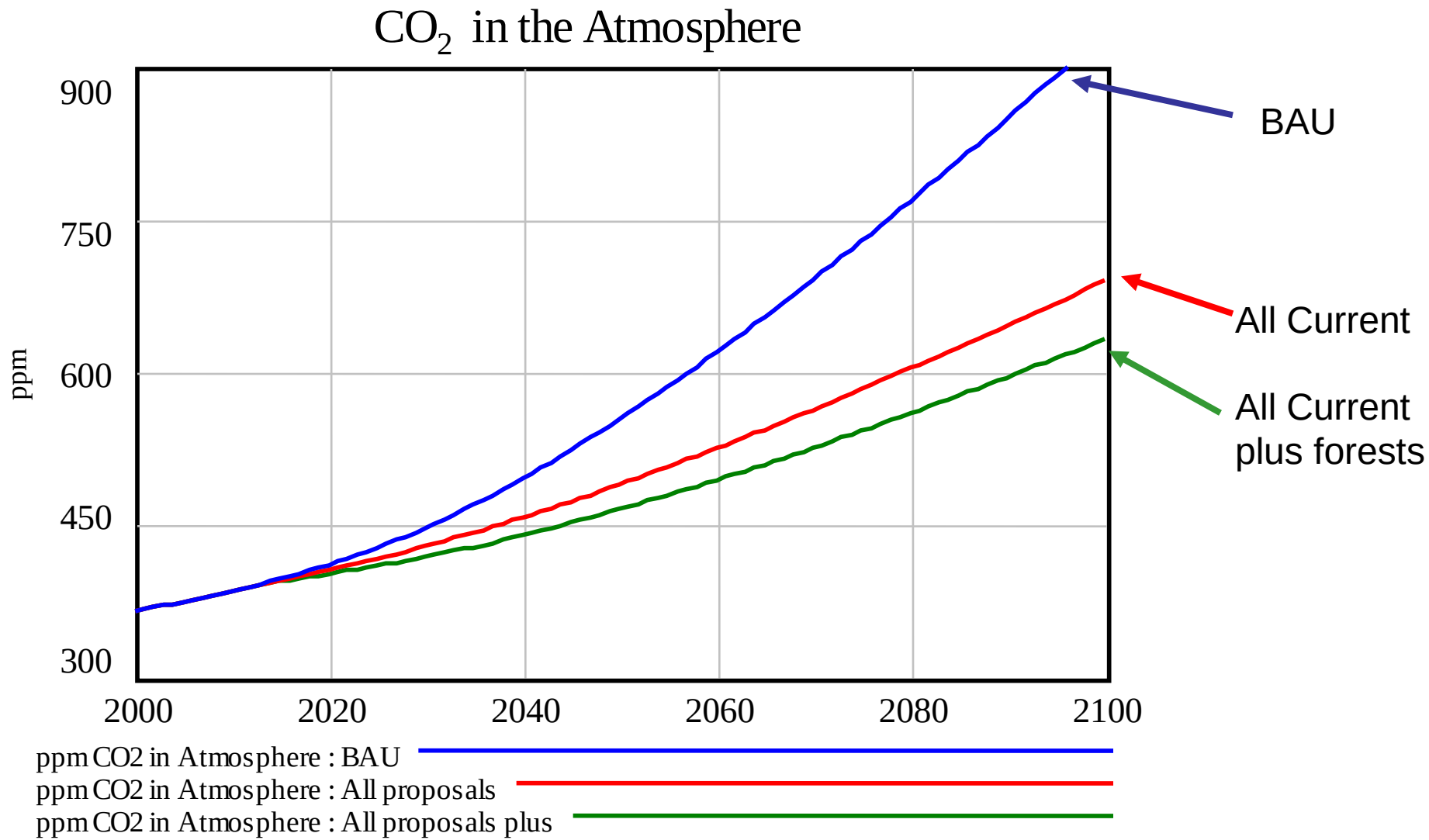


BAU = Business As Usual (A1FI)

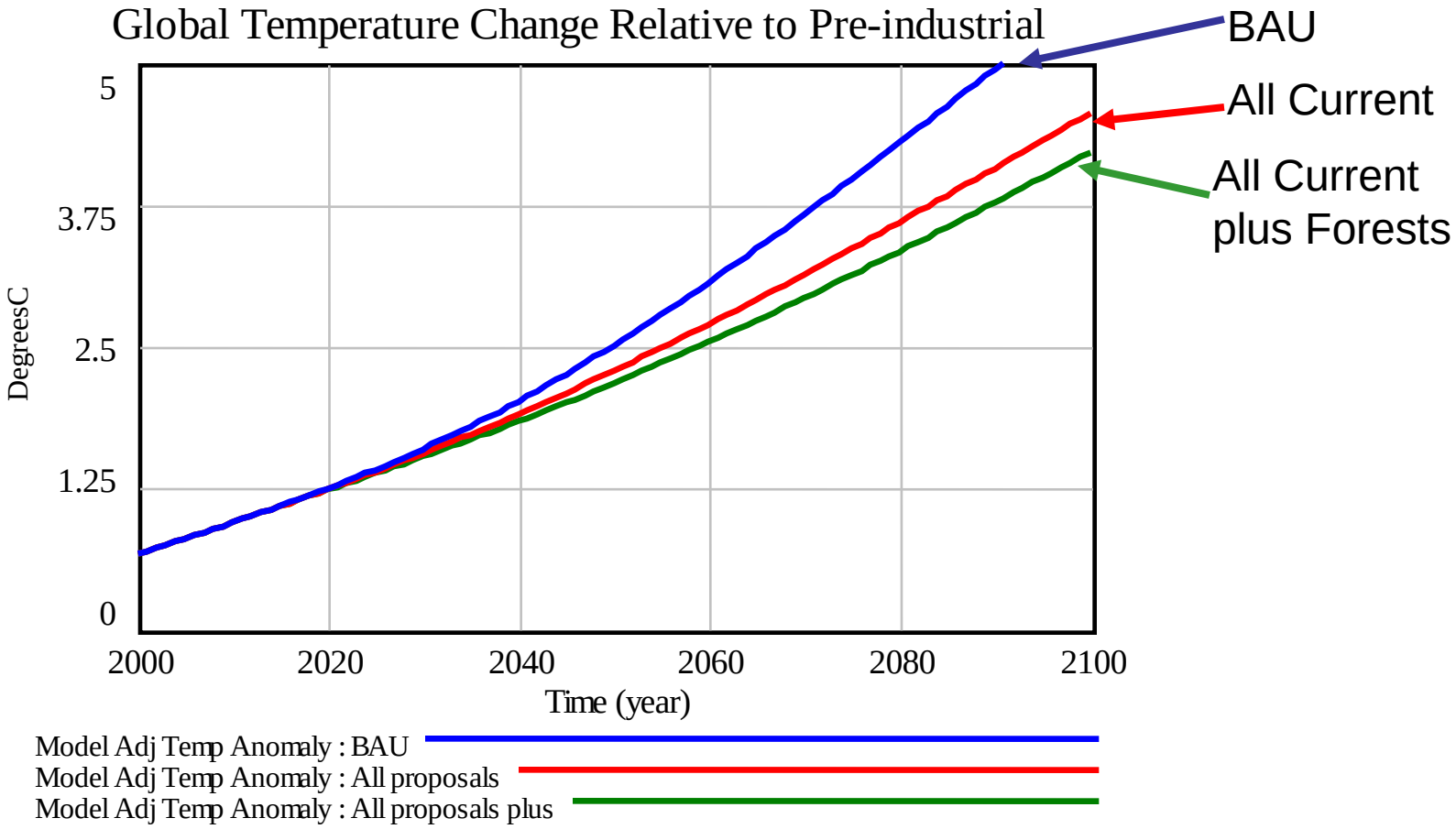
Total Fossil Fuel CO_2 Emissions



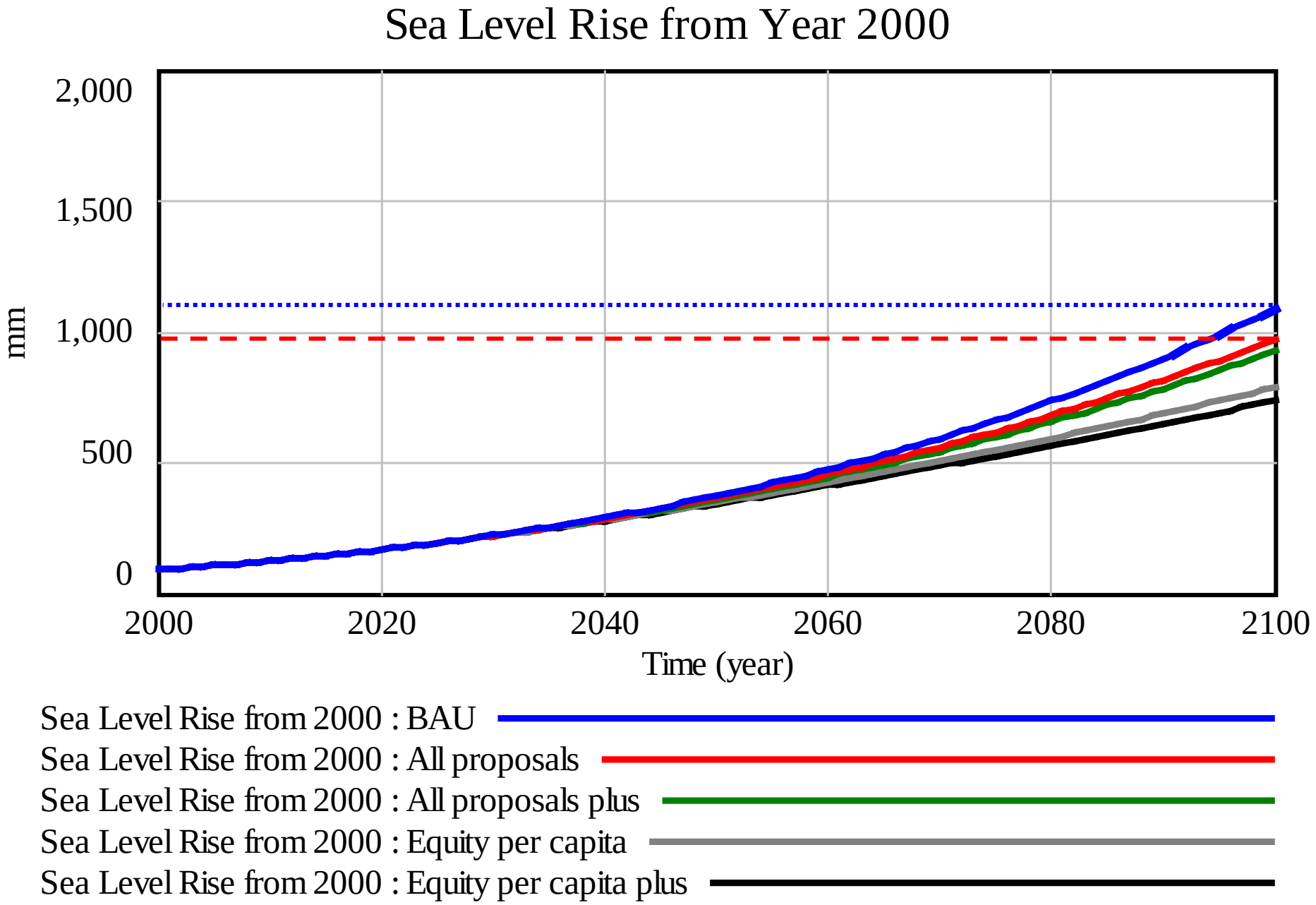
CO_2 in Atmosphere Would Continue to Increase



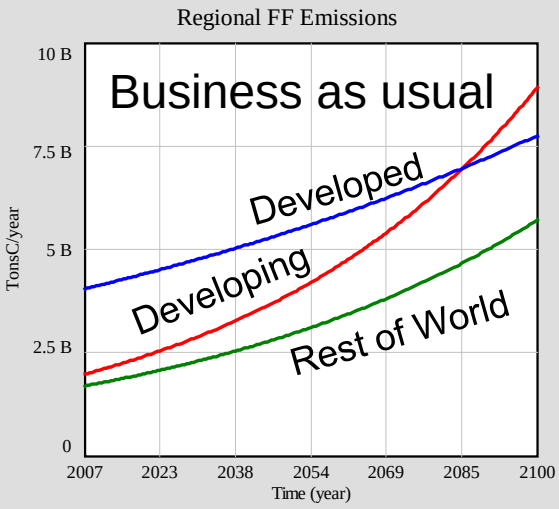
Global Temperature Change

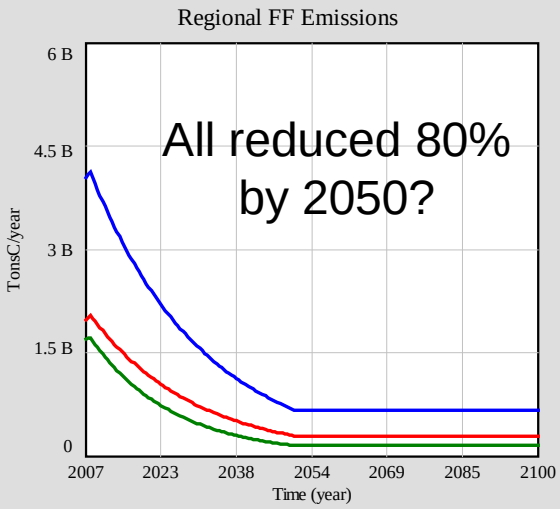


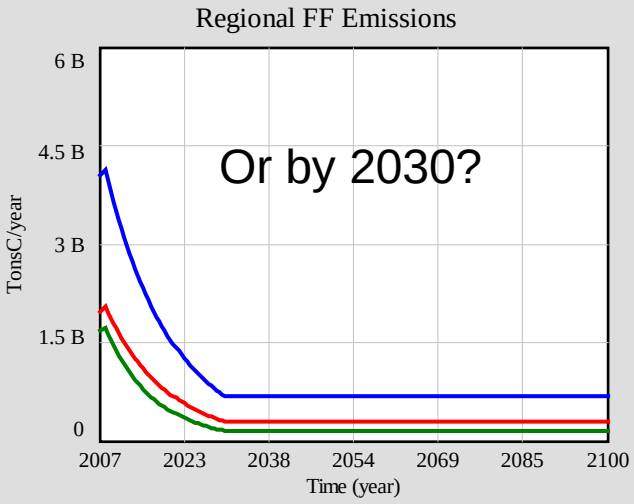
Sea Level Rise

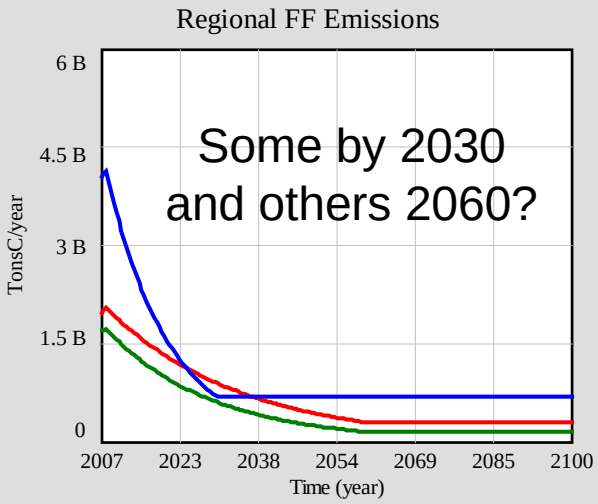


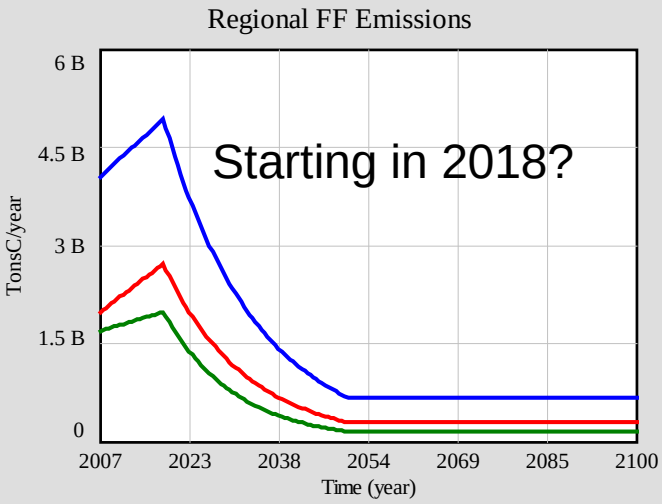
Simulator Helps Users Conduct Customized Tests: What If…..?

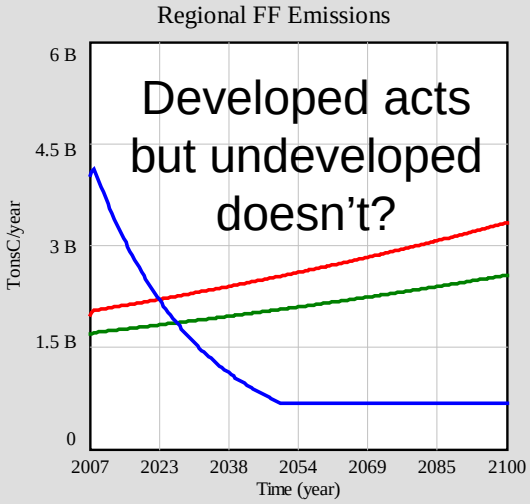






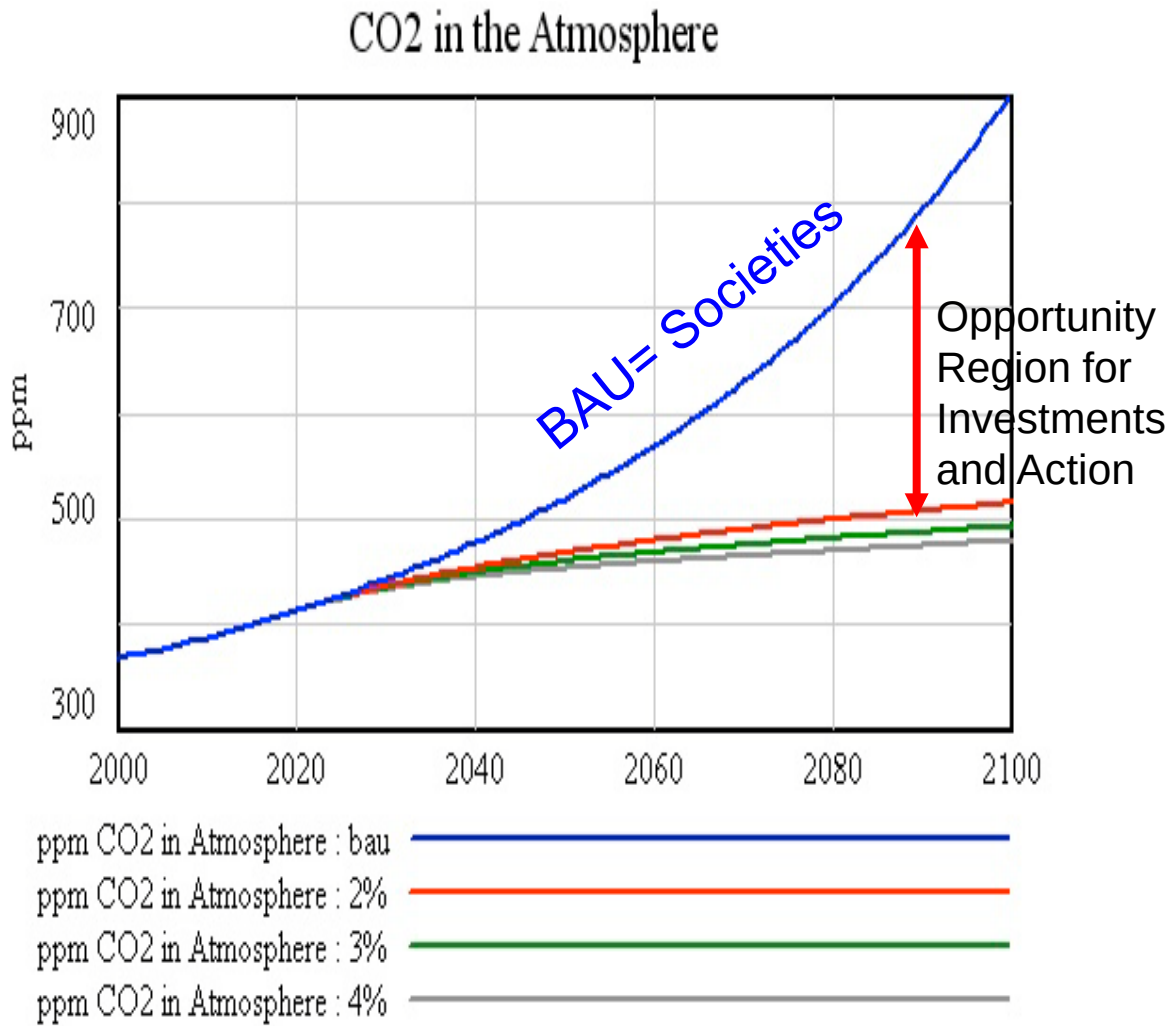


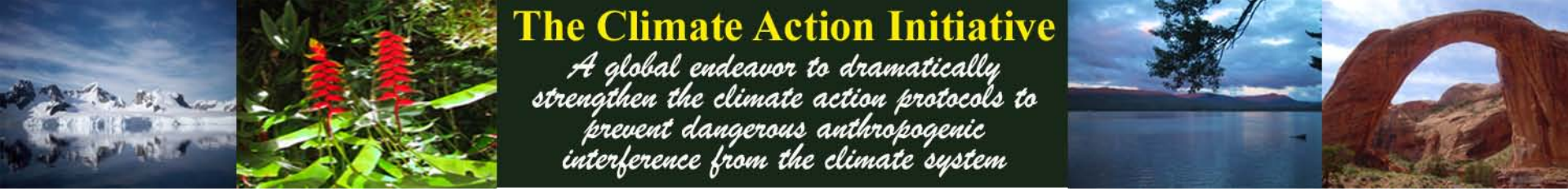




(all graphs fossil fuel emissions)

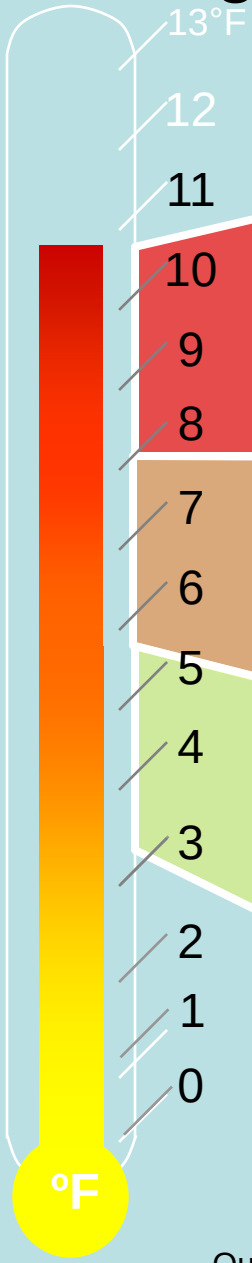
Atmospheric CO_2 Levels In the Three Scenarios





Thus, the issue of the UNFCCC negotiations and national actions must include adaptation measures at many levels of government and civil society

Linking Global Warming Impacts with Climate Action



Higher Warming Range (8 – 10.5 °F)

3 - 4 times as many heat wave days
22 - 30 inches of sea level rise
90% loss in Sierra snowpack
20% increase in energy demand

Medium Warming Range (5.5 – 8 °F)

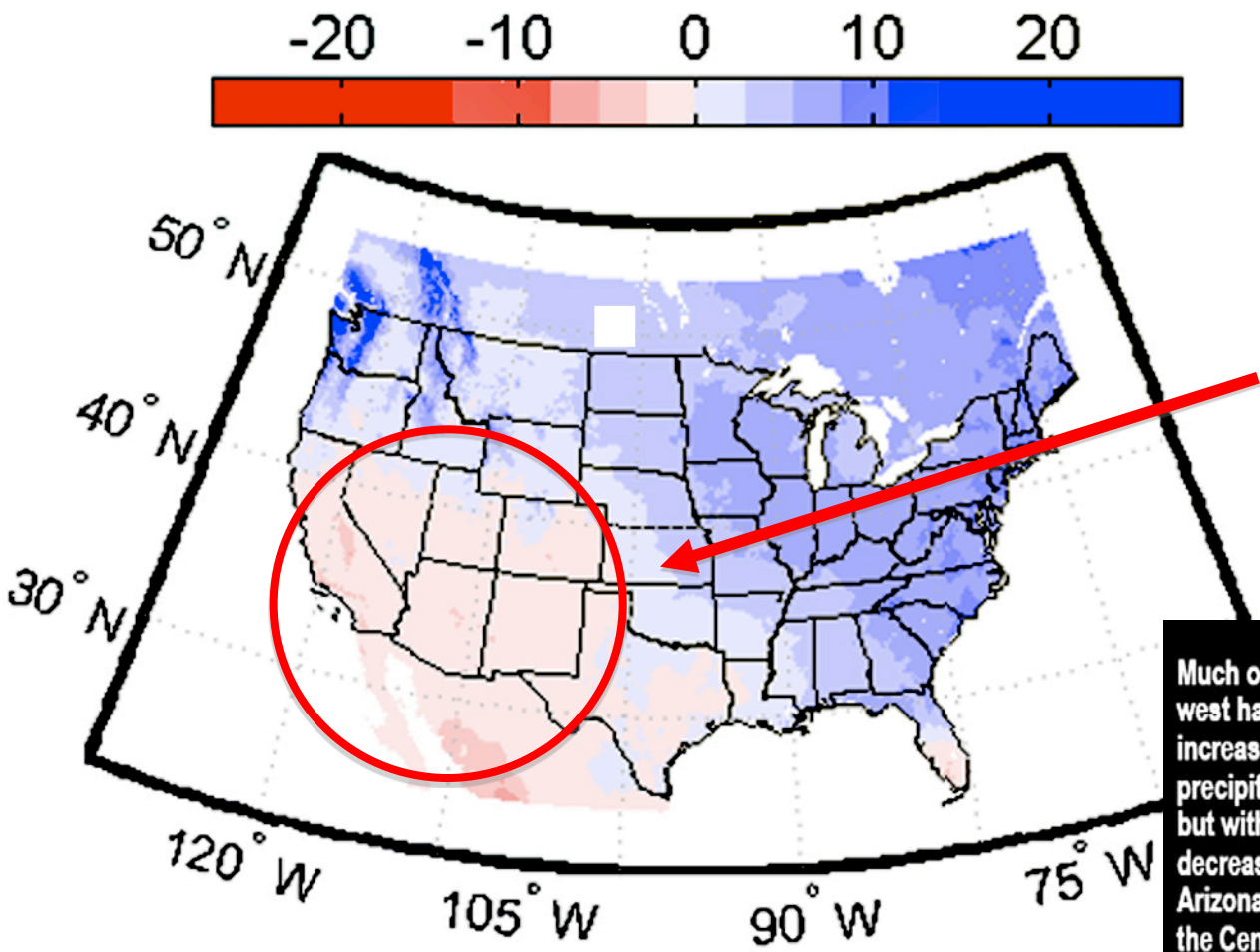
2.5 - 4 times as many heat wave days
14 - 22 inches of sea level rise
70 - 80% loss in Sierra snowpack
30% decrease in forest yields (pine)
55% increased risk of large forest fires
10% increase in energy demand

Lower Warming Range (3 – 5.5 °F)

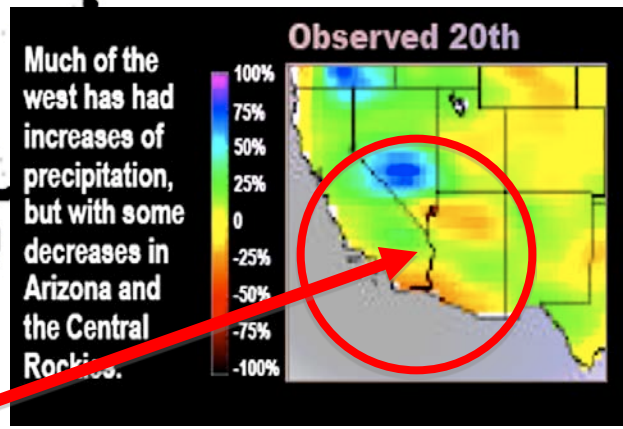
2 - 2.5 times as many heat wave days
6 - 14 inches of sea level rise
30 - 60% loss in Sierra snowpack
7 - 14% decrease in forest yields (pine)
10 - 35% increased risk of large forest fires
3 - 6% increase in energy demand

Our Changing Climate: Assessing the Risks to California (2006), *www.climatechange.ca.gov*

Median Annual Precipitation Change between an Average for 1971 and 2000 and by Downscaling of Climate Projected for 2041 to 2070

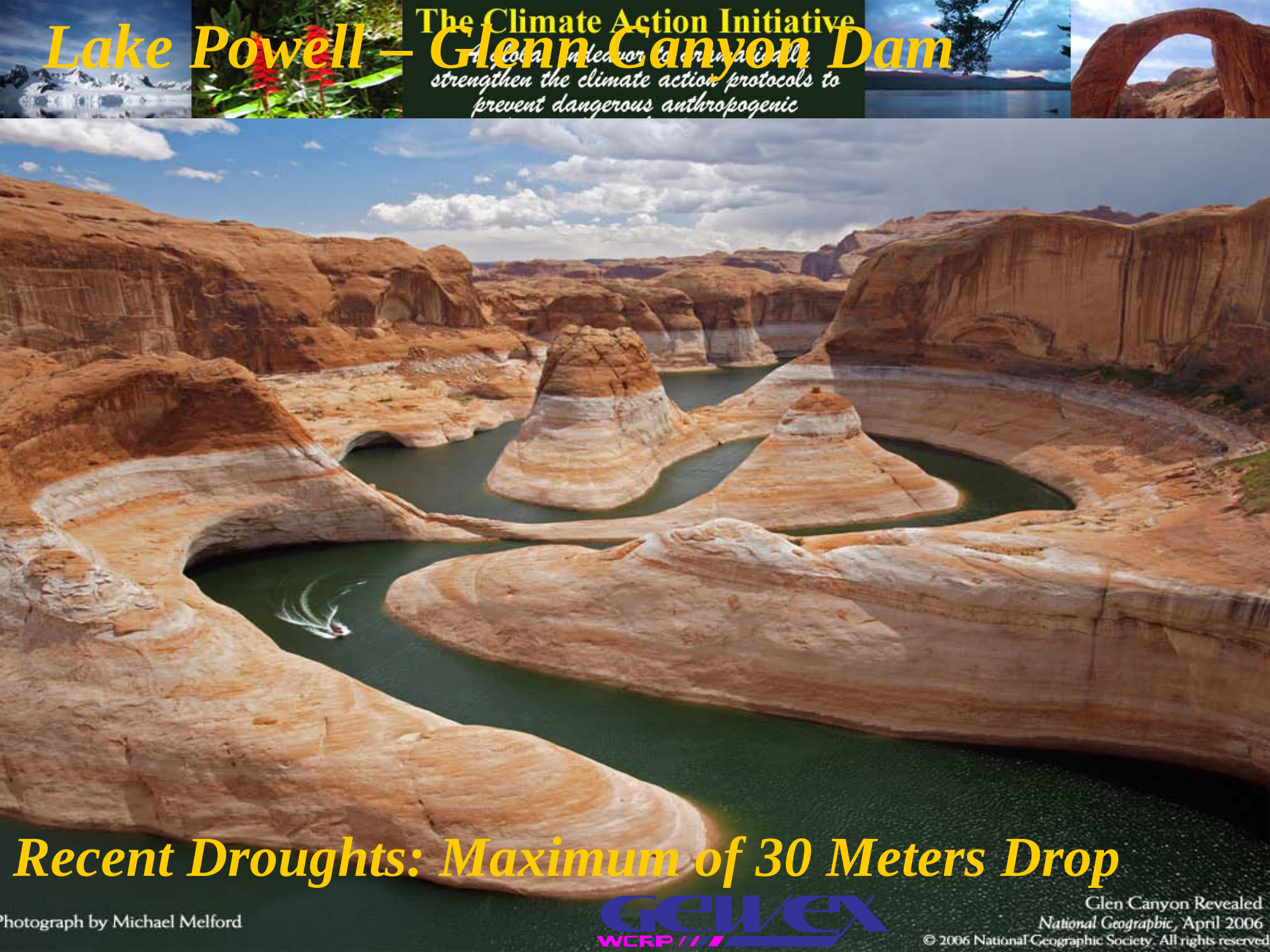


Multi-Decadal Droughts are Projected for the US Southwest through at least Mid-Century



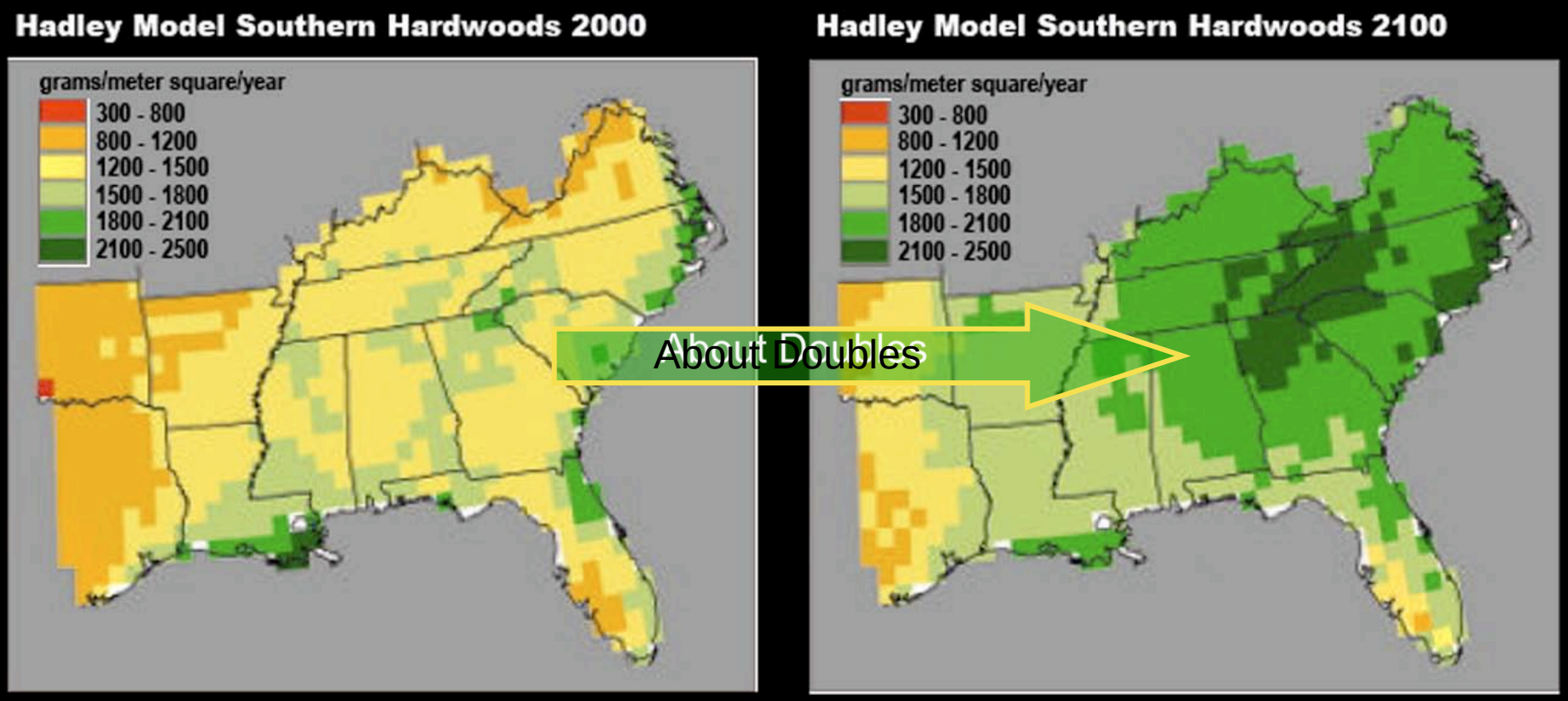
Compared to 2008, the region was comparatively wet during much of the latter part of the 20th century.

Lake Powell – Glenn Canyon Dam

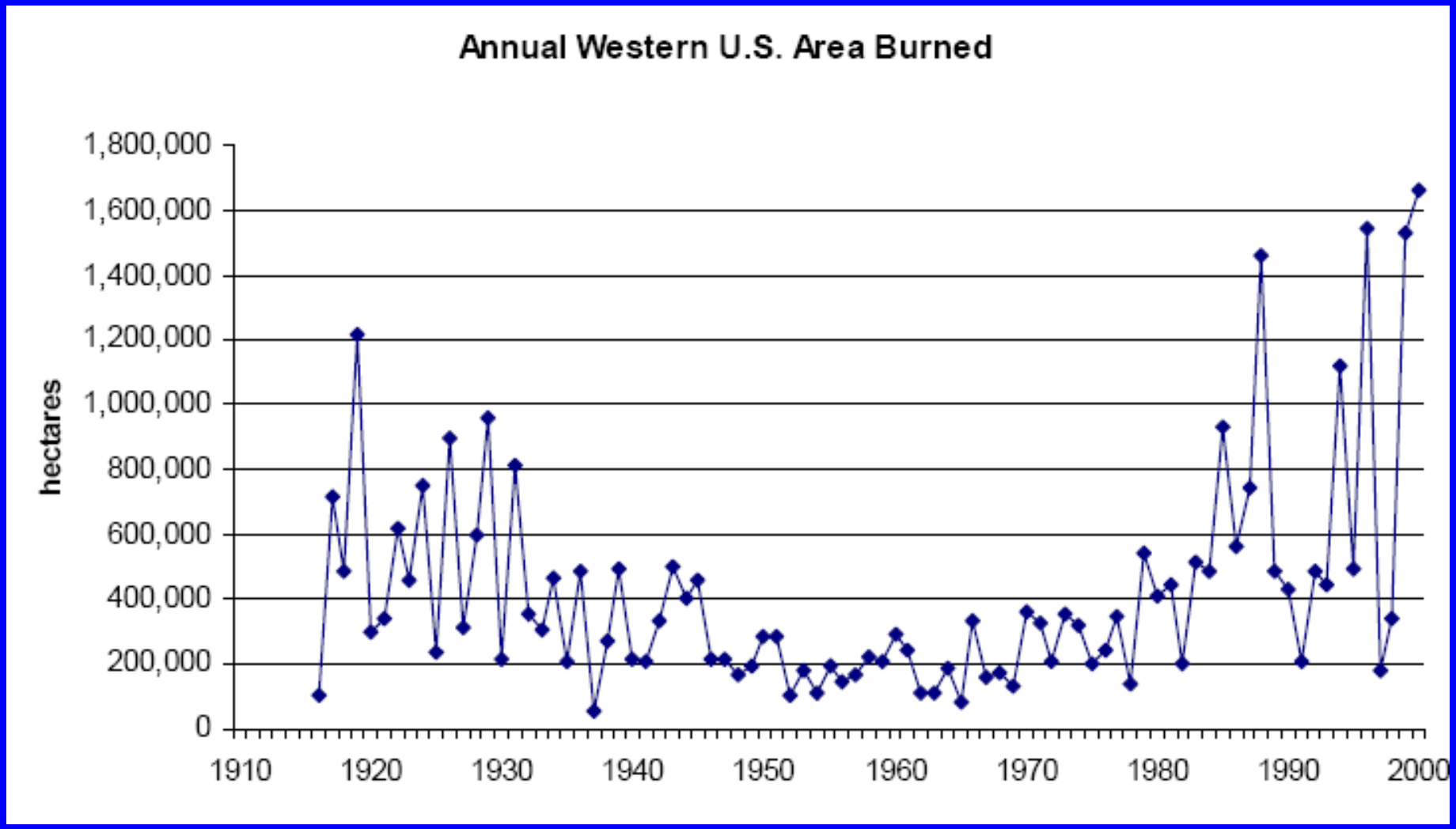


Recent Droughts: Maximum of 30 Meters Drop

Model Projections of Changes in Southern Hardwoods 2000 to 2100



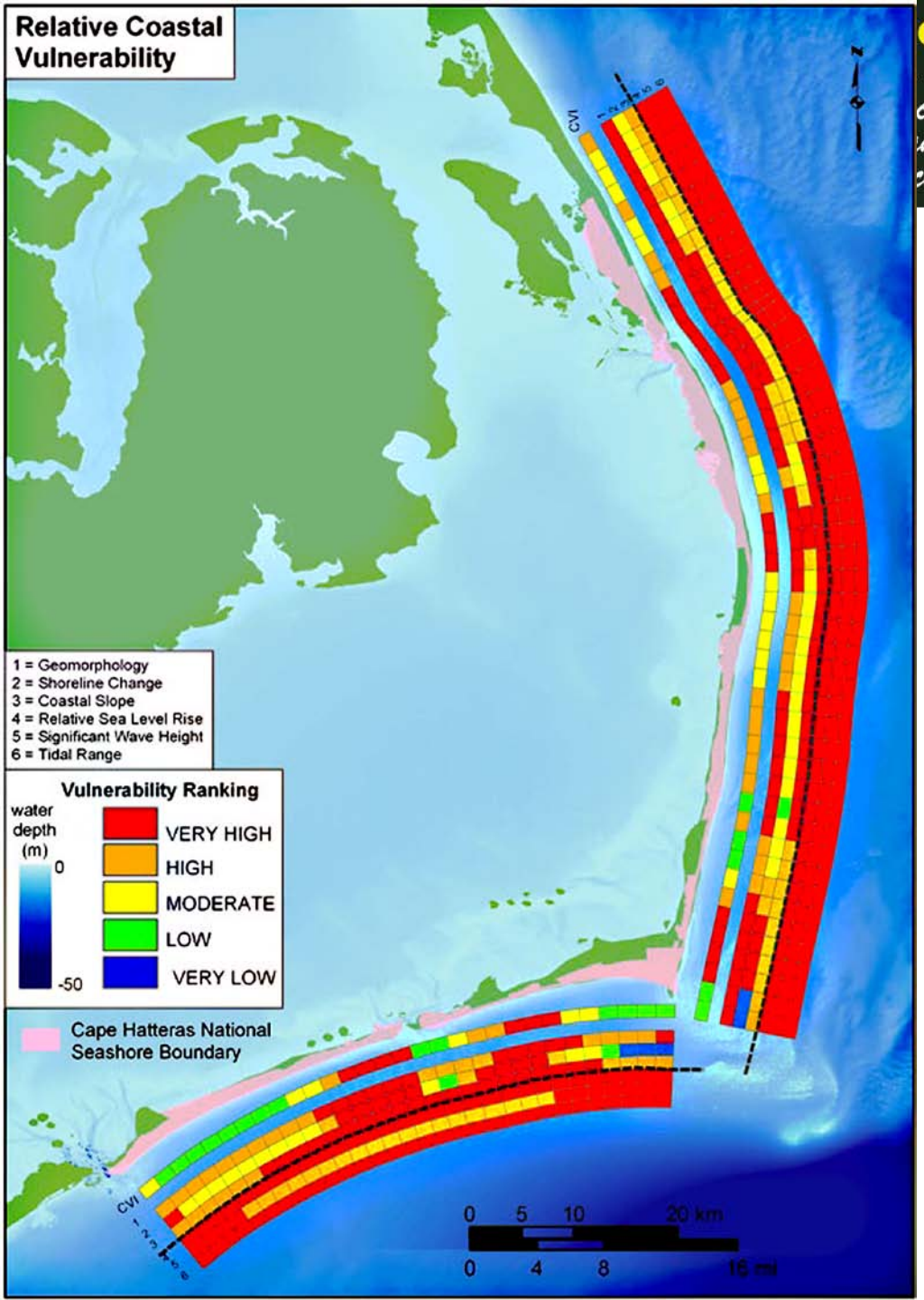
20th Century Wildfire



Courtesy of Dr. Anthony Westerling, Scripps Institution of Oceanography

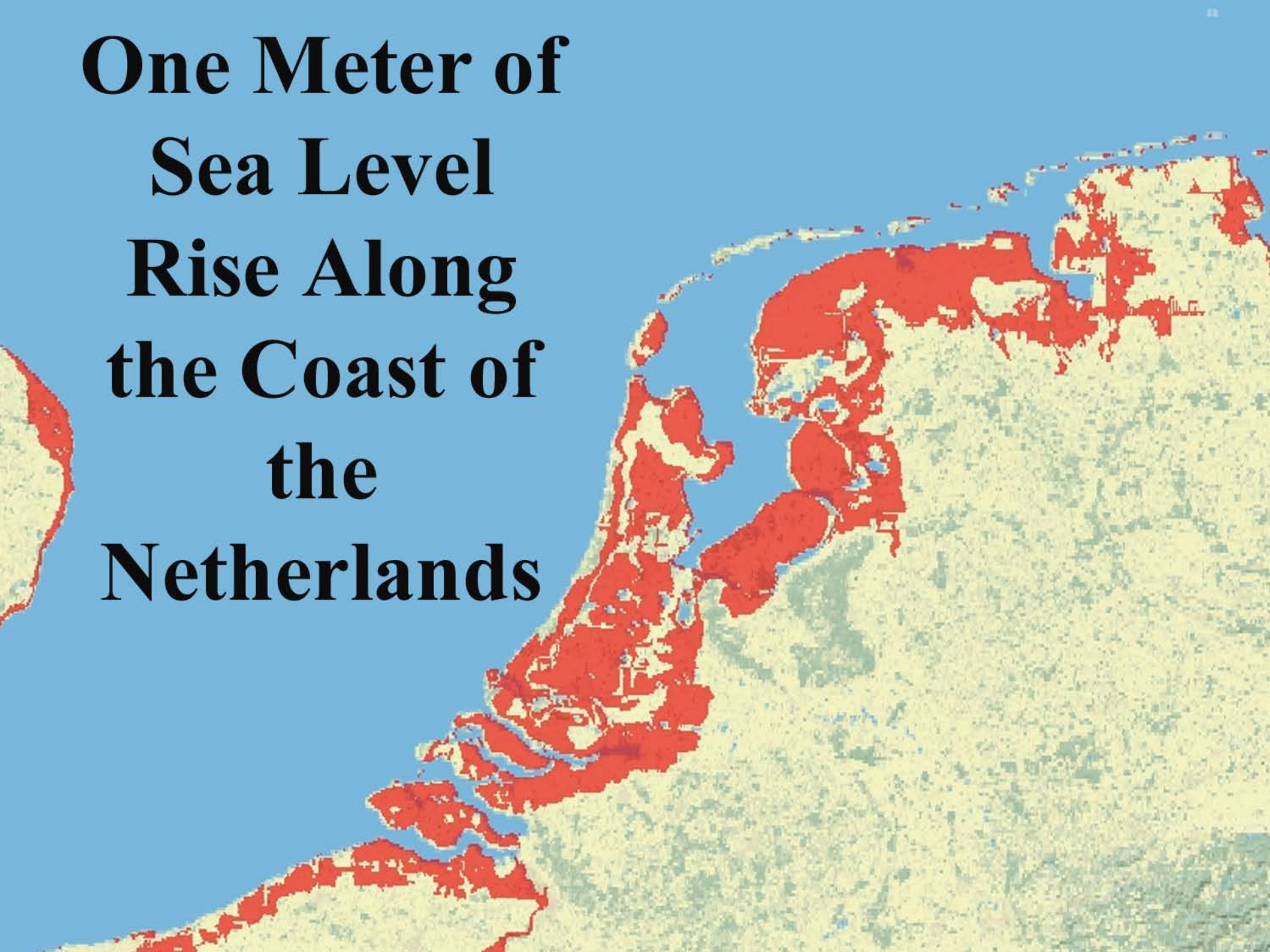
East Coast Regions Vulnerable to Sea Level Rise of 1 Meter

- New York City
- Chesapeake Bay
- Outer Islands
- Georgia Coast

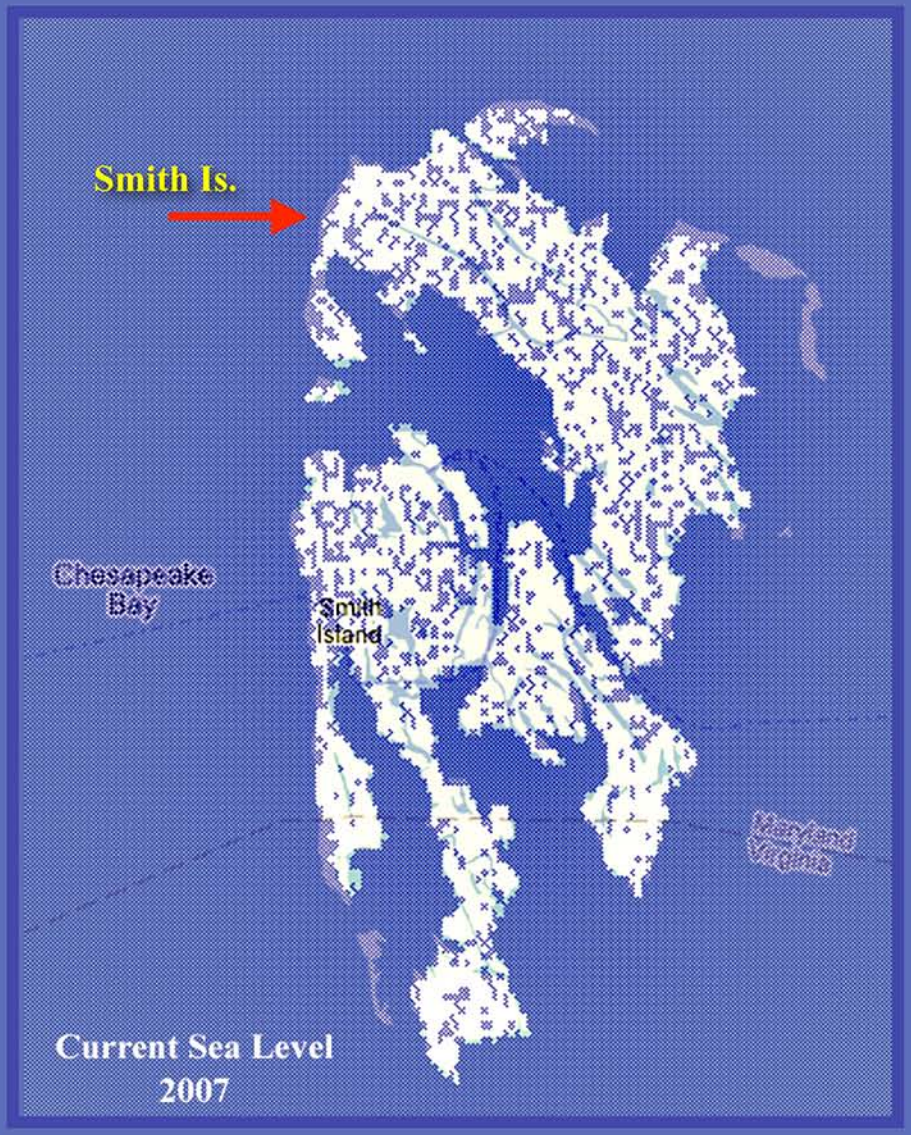


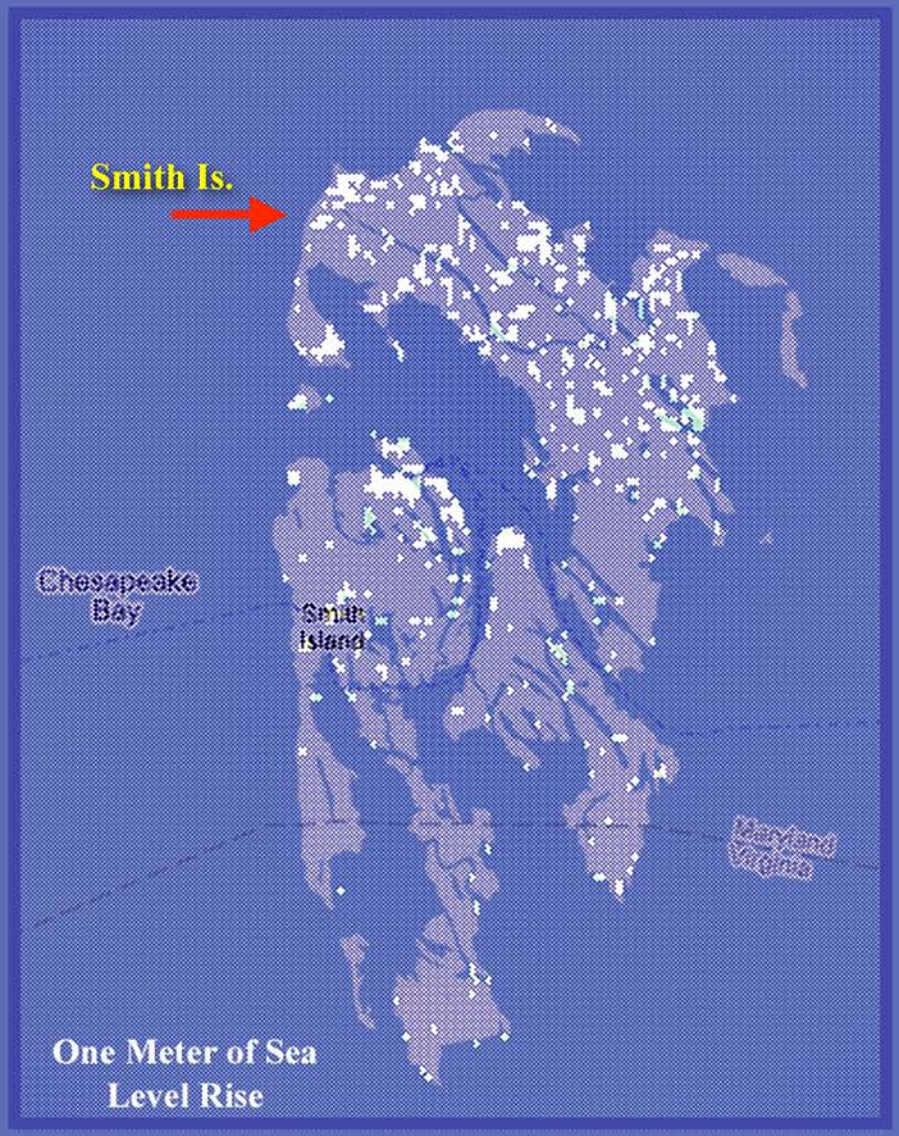
The Coastal Vulnerability Index (CVI) has been developed by USGS to assess the potential vulnerabilities of many of the Nation's National Seashores. The CVI goes from very high ____ to very low ____

One Meter of Sea Level Rise Along the Coast of the Netherlands



Changes in the Topography of Smith Island and Environs to One Meter of Sea Level Rise





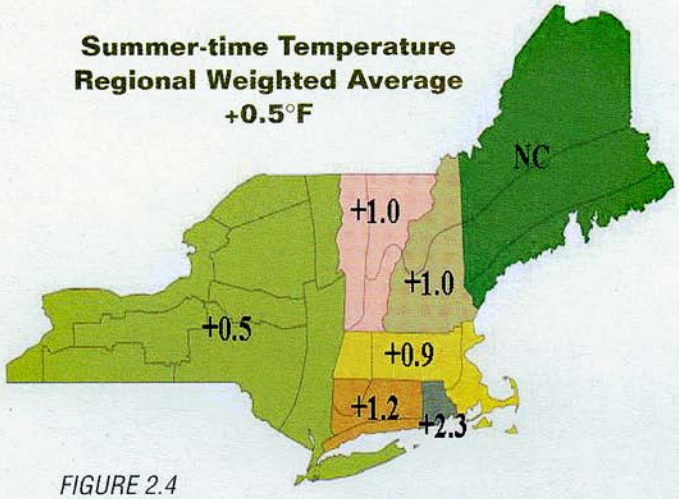


FIGURE 2.4
New England and New York summer-time temperature changes (°F) between 1895 and 1999. The faint lines within each state represent NCDC climate zones.

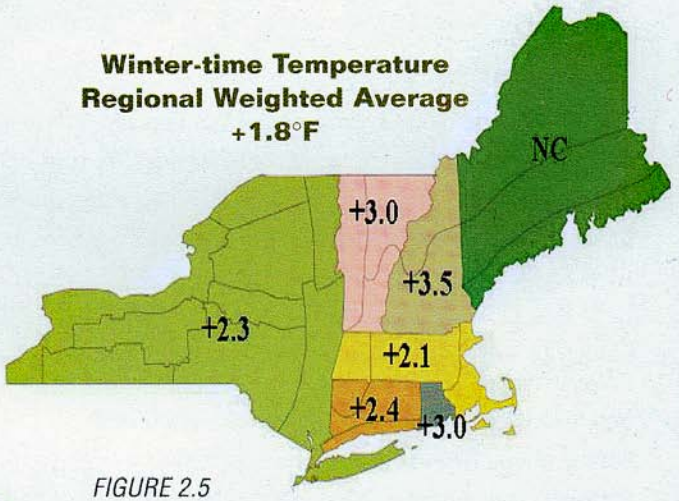


FIGURE 2.5
New England and New York winter-time temperature changes (°F) between 1895 and 1999. The faint lines within each state represent NCDC climate zones.

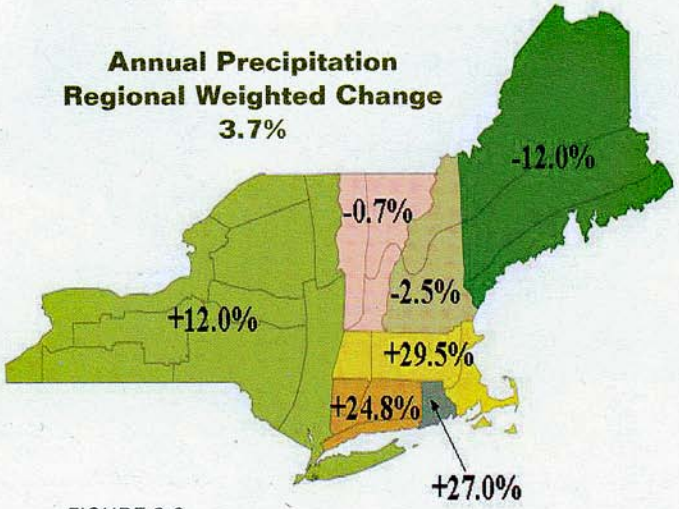
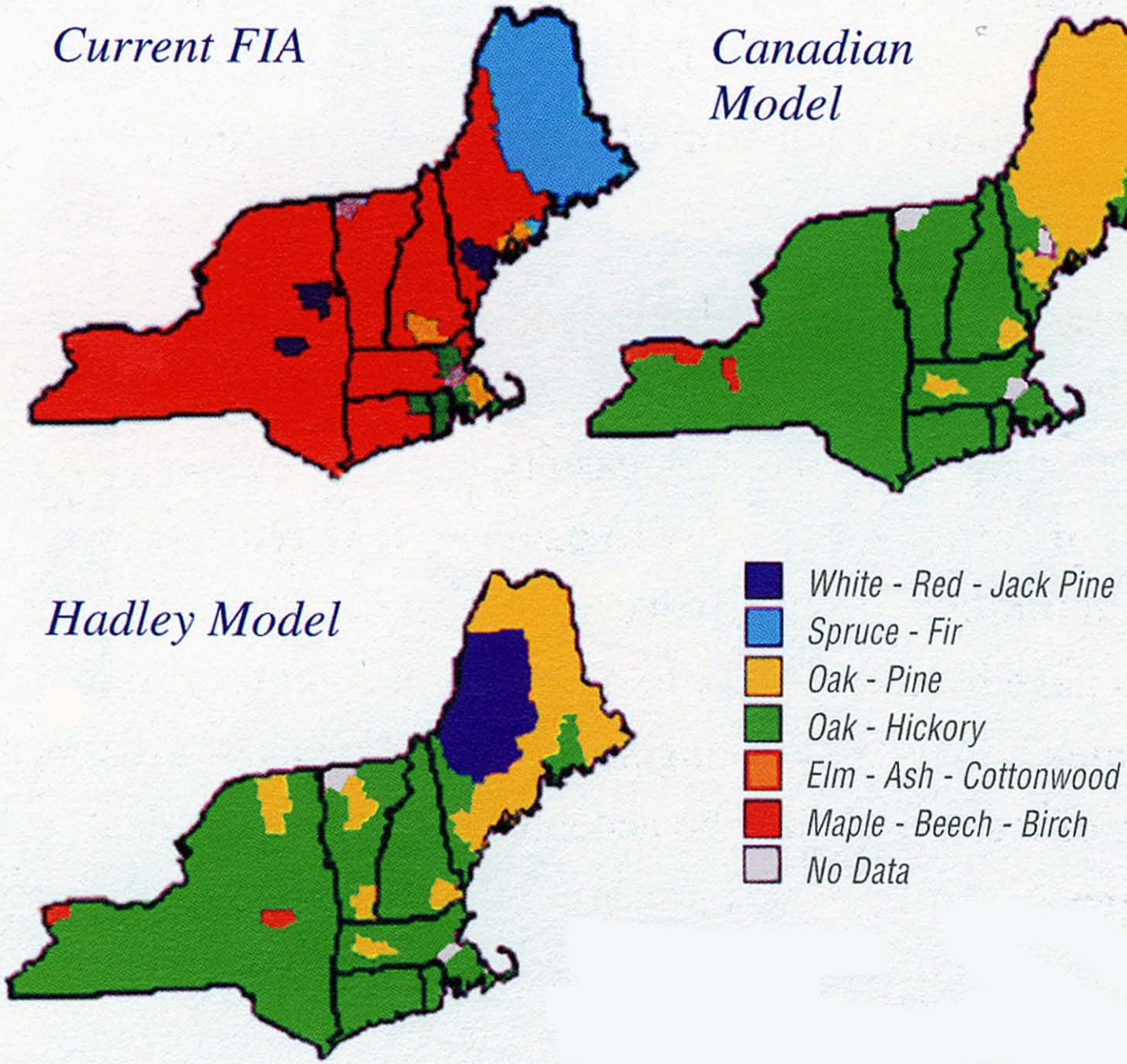


FIGURE 2.6
New England and New York annual precipitation changes (%) between 1895 and 1999. The faint lines within each state represent NCDC climate zones.

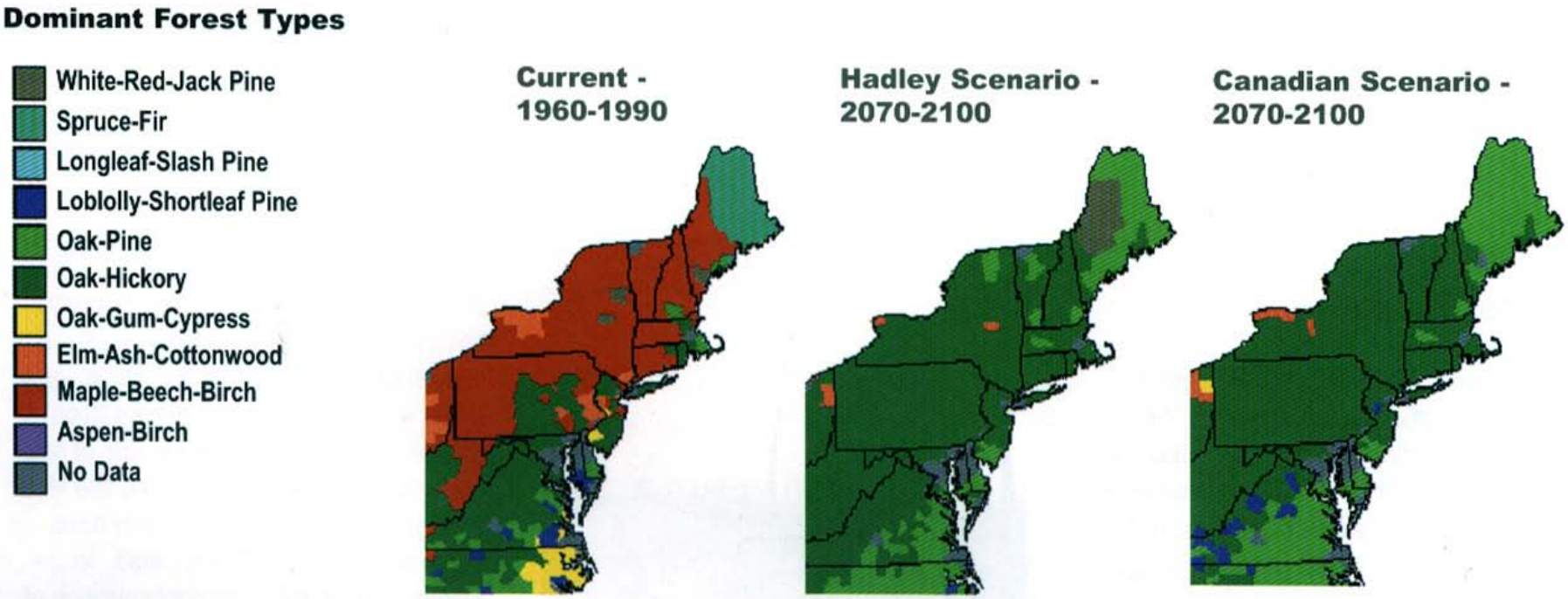
Averages of Precipitation or Temperatures can often misleading at local scales



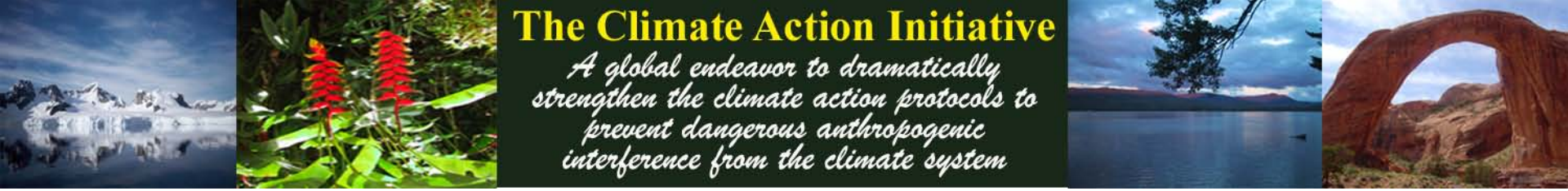
Projections of Changes in Tree Species for New England **(2000 to 2100)**

Dominant Forest Types for the Northeast

Present and Projections Over the Next 100 Years



The maps above show current and projected forest types for the Northeast, based on the DISTRIB model (see Forest sector). Note that Maple-Beech-Birch, currently a dominant forest type in the region, is completely displaced by other forest types in both the Hadley and Canadian climate scenarios.



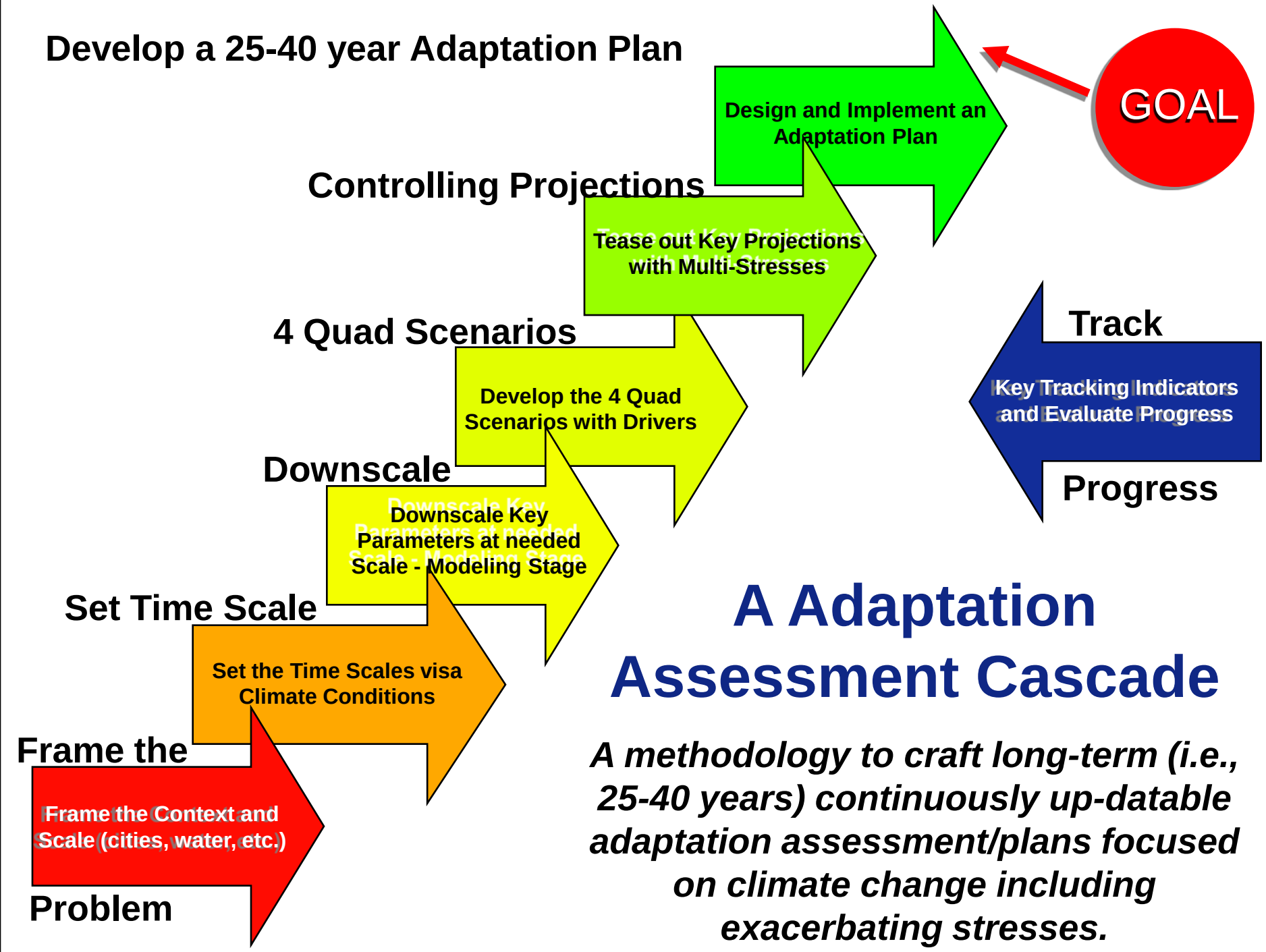
Place-Based (Local)

Place-Based (Local)

Place-Based (Local)

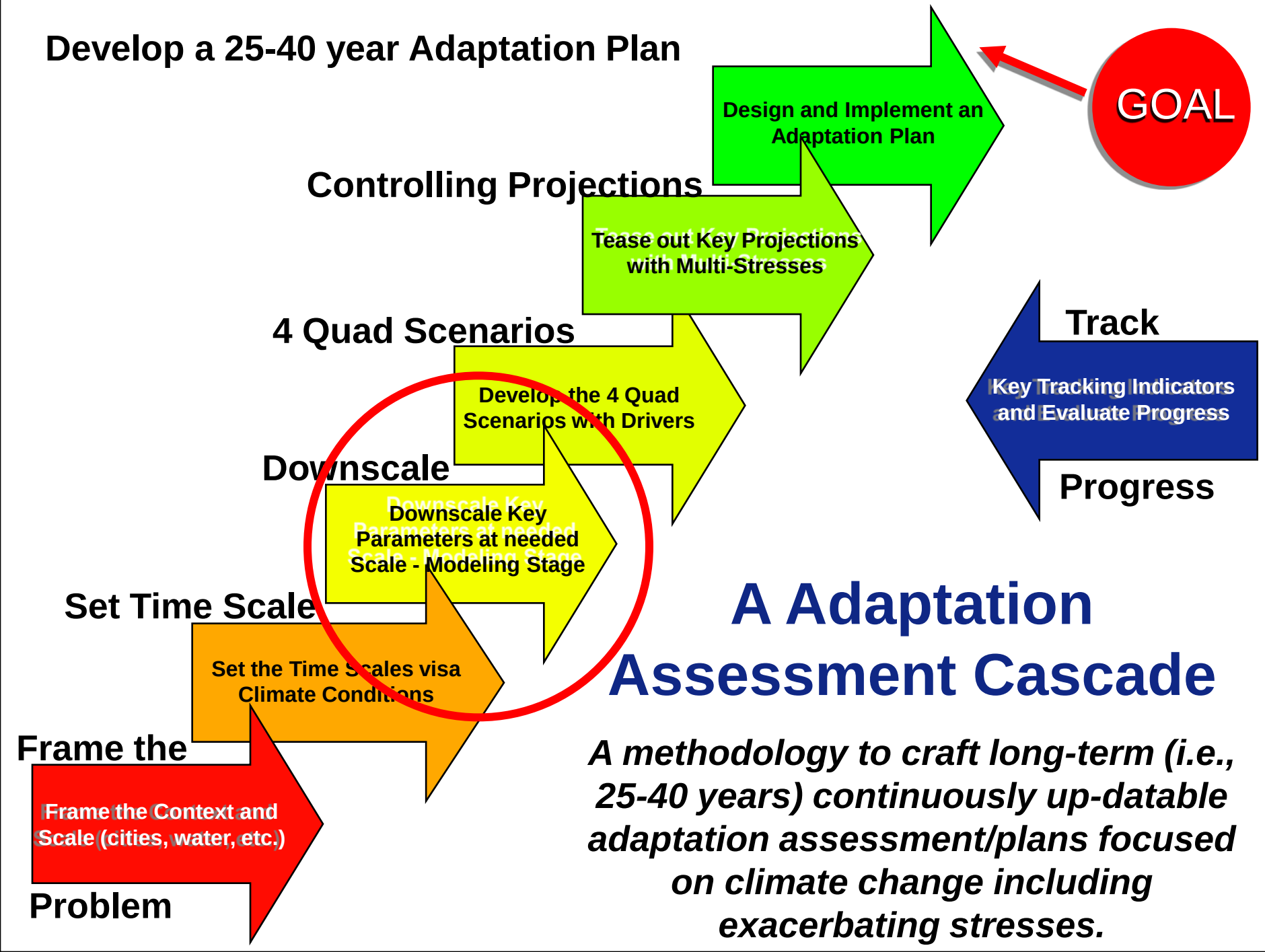
Vulnerability = Impacts - Adaptive Capacity

Clearly, coping/adaptation is at local scales !



A Adaptation Assessment Cascade

A methodology to craft long-term (i.e., 25-40 years) continuously up-datable adaptation assessment/plans focused on climate change including exacerbating stresses.


Develop a 25-40 year Adaptation Plan
Design and Implement an Adaptation Plan
GOAL
Controlling Projections
Tease out Key Projections with Multi-Stresses
4 Quad Scenarios
Develop the 4 Quad Scenarios with Drivers
Track
Key Tracking Indicators and Evaluate Progress
Progress
Downscale
Downscale Key Parameters at needed Scale - Modeling Stage
Set Time Scale
Set the Time Scales visa Climate Conditions
Frame the
Frame the Context and Scale (cities, water, etc.)
Problem
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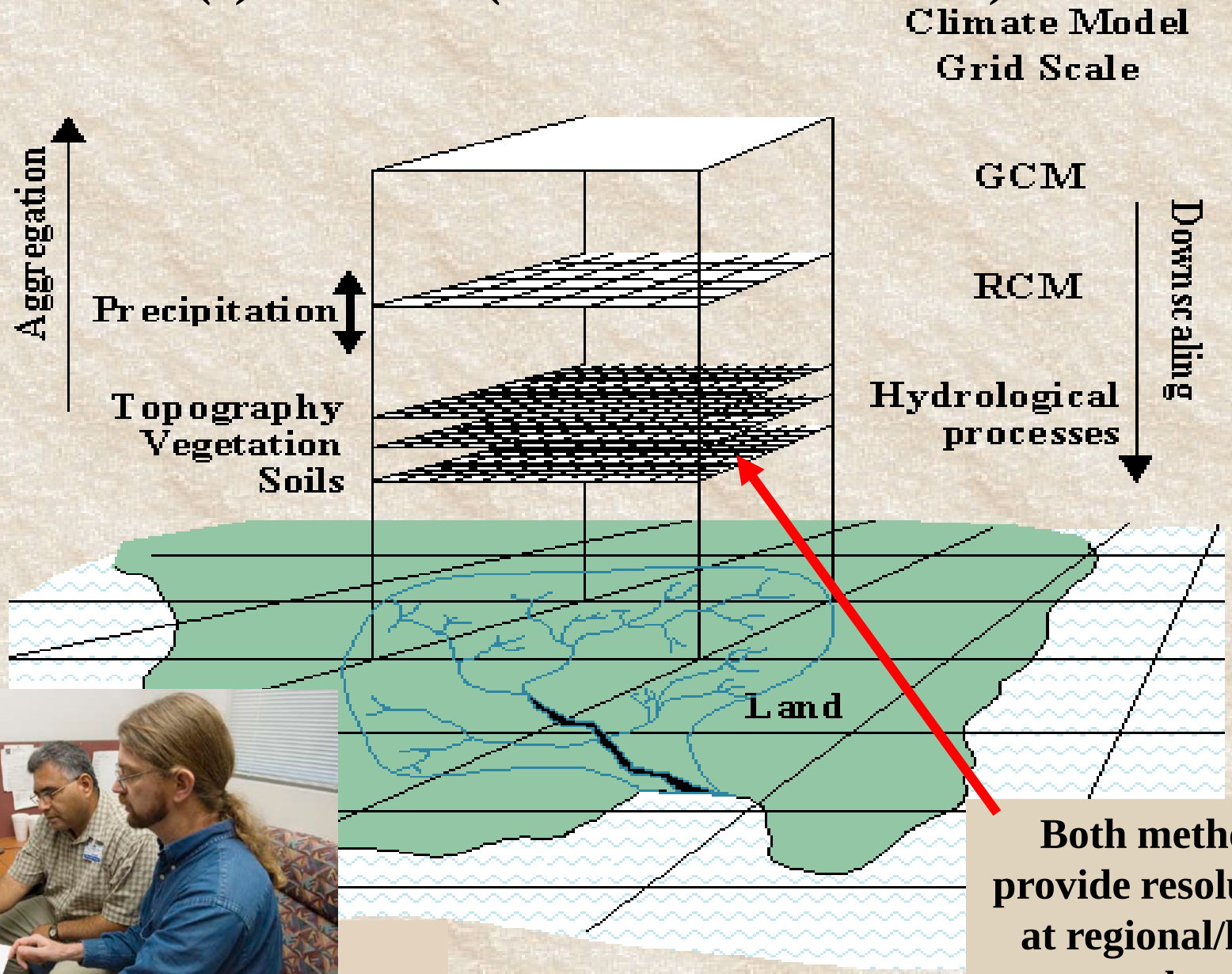
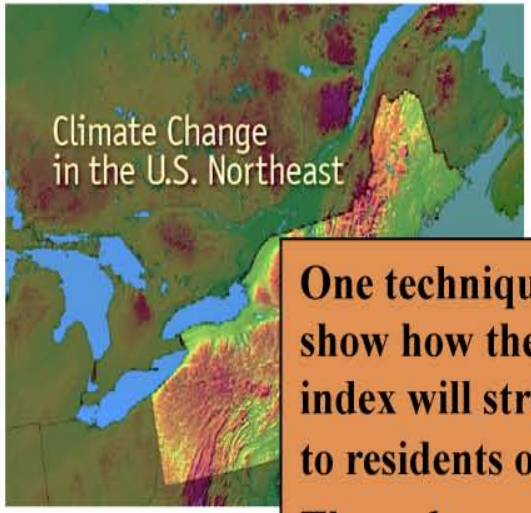
Downscaling: (a) Dynamic (needs super computer) and/or (b) Statistical (uses GCM data and PC)



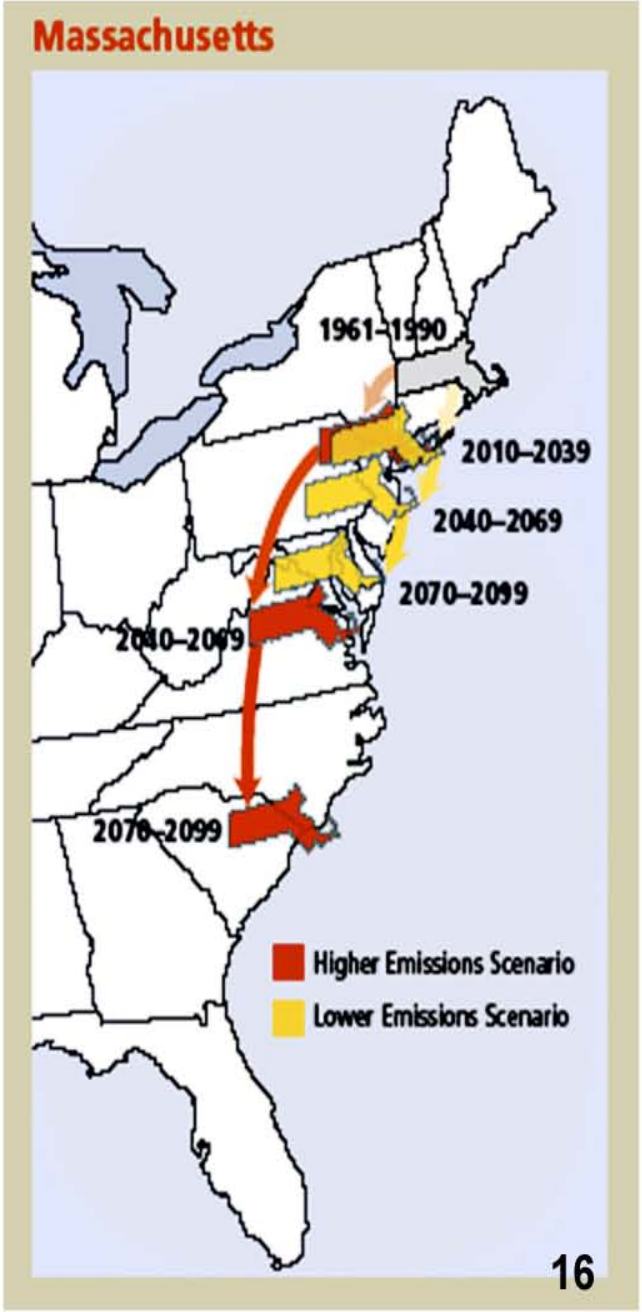
Both methods provide resolutions at regional/local scales.

Regional Downscaling Climate Modeling Project
Changes in the Climate of the U.S. Northeast



One technique used in the assessment was to show how the changes in average summer heat index will strongly alter how the summer feels to residents of the Northeast.

The *red arrows* track suggests that summers in the Massachusetts toward the end of this century are likely to feel like current summer heat indices in northern parts of South Carolina. The yellow arrows track suggests that summers in the Massachusetts toward the end of this century are likely to feel like current summer heat indices in the Washington, D.C. area.

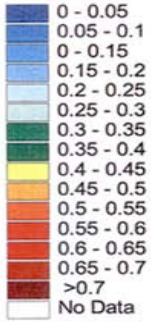


The Climate Action Initiative

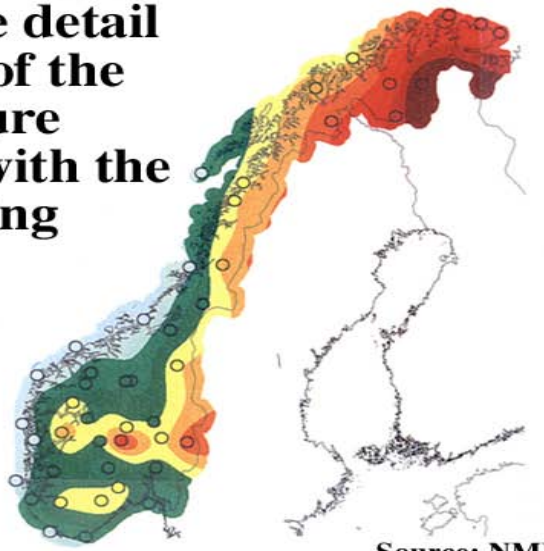
A global endeavor to dramatically strengthen the climate action protocols to prevent dangerous anthropogenic interference from the climate system

Norway Temperatures depicted in GCM for 2075

Increases in Temperatures per decade from a 1964-1990 base to 2020-2049

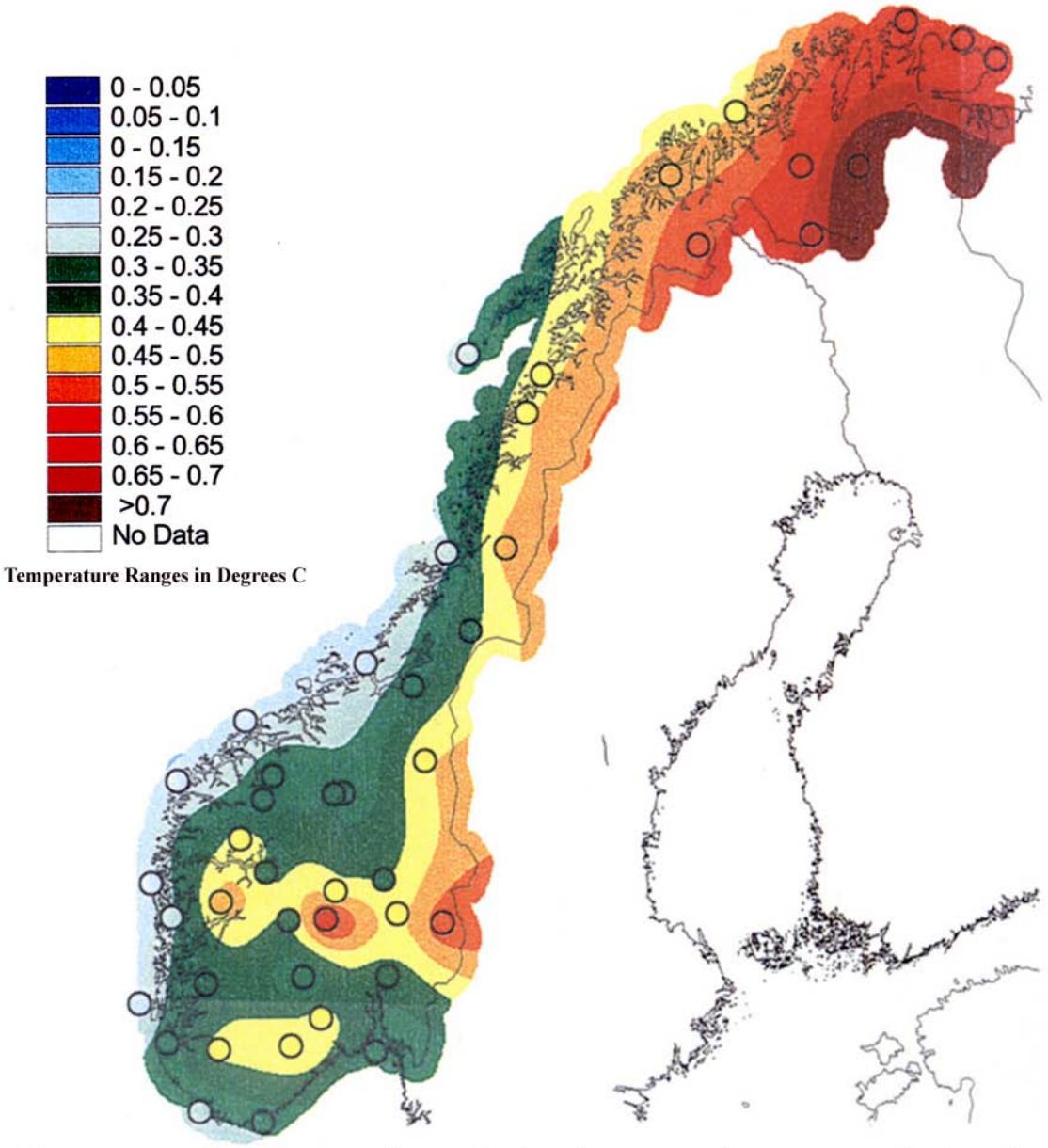


Note the dramatic increase in the detail and texture of the temperature distributions with the downscaling



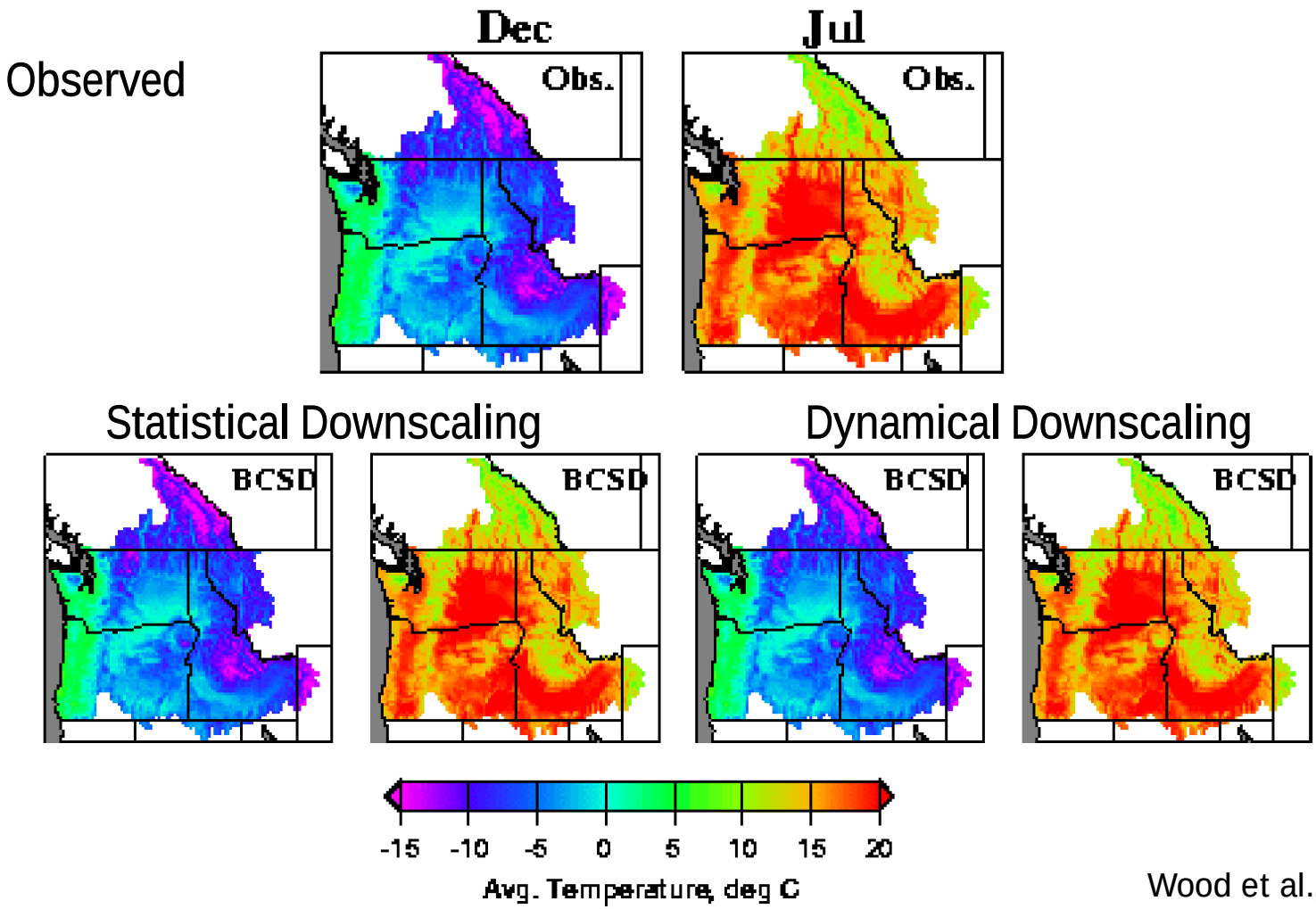
Downscaled Image

Source: NMI



Increases in Norwegianwinter temperatures per dedcade from the period of 1961-1990 to the period 2020-2049

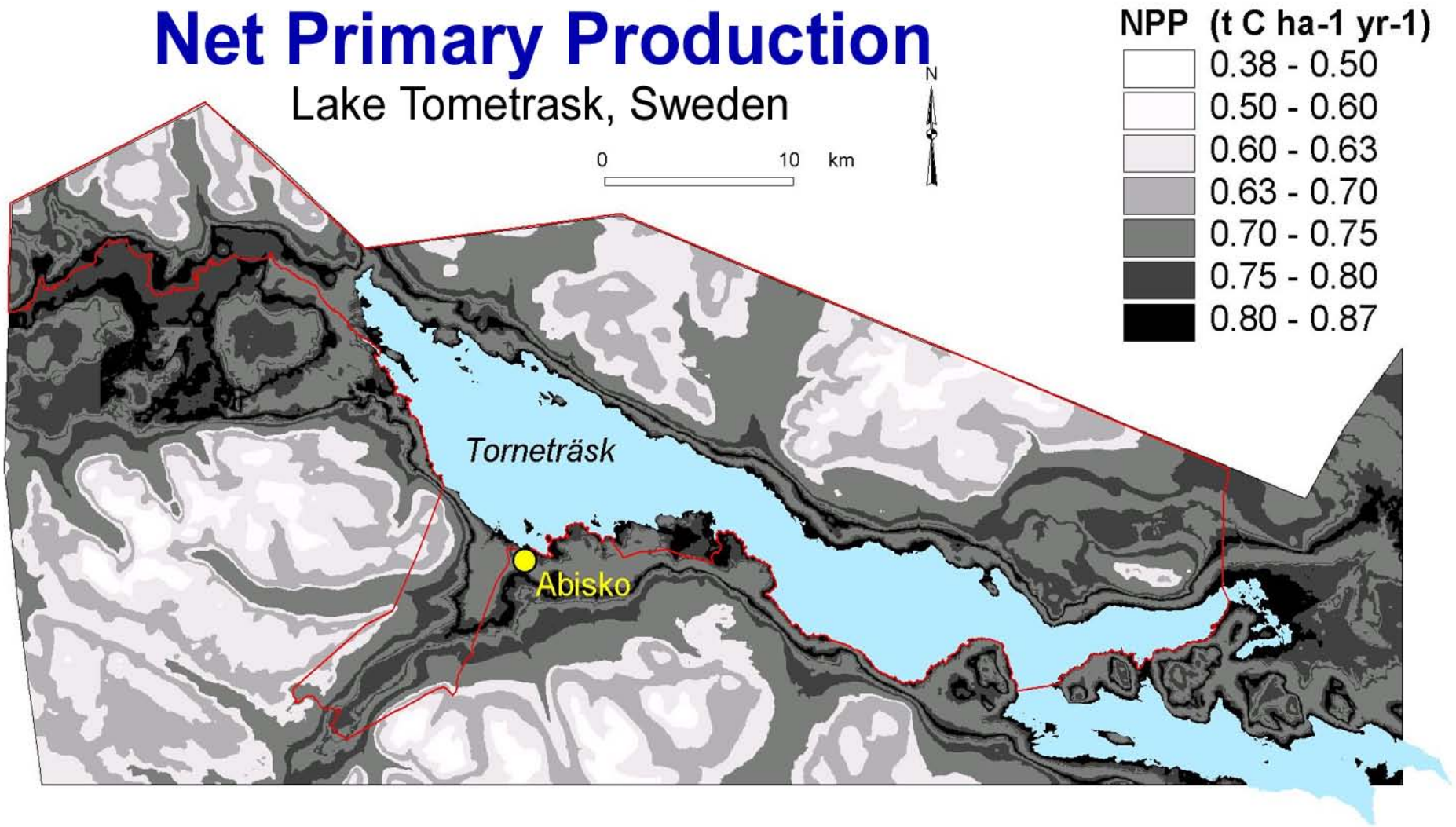
Reproducing Observed Spatial Distributions through Downscaling TEMPERATURE



Wood et al., 2003

Downscaling of Net Primary Production

Lake Tometrask, Sweden

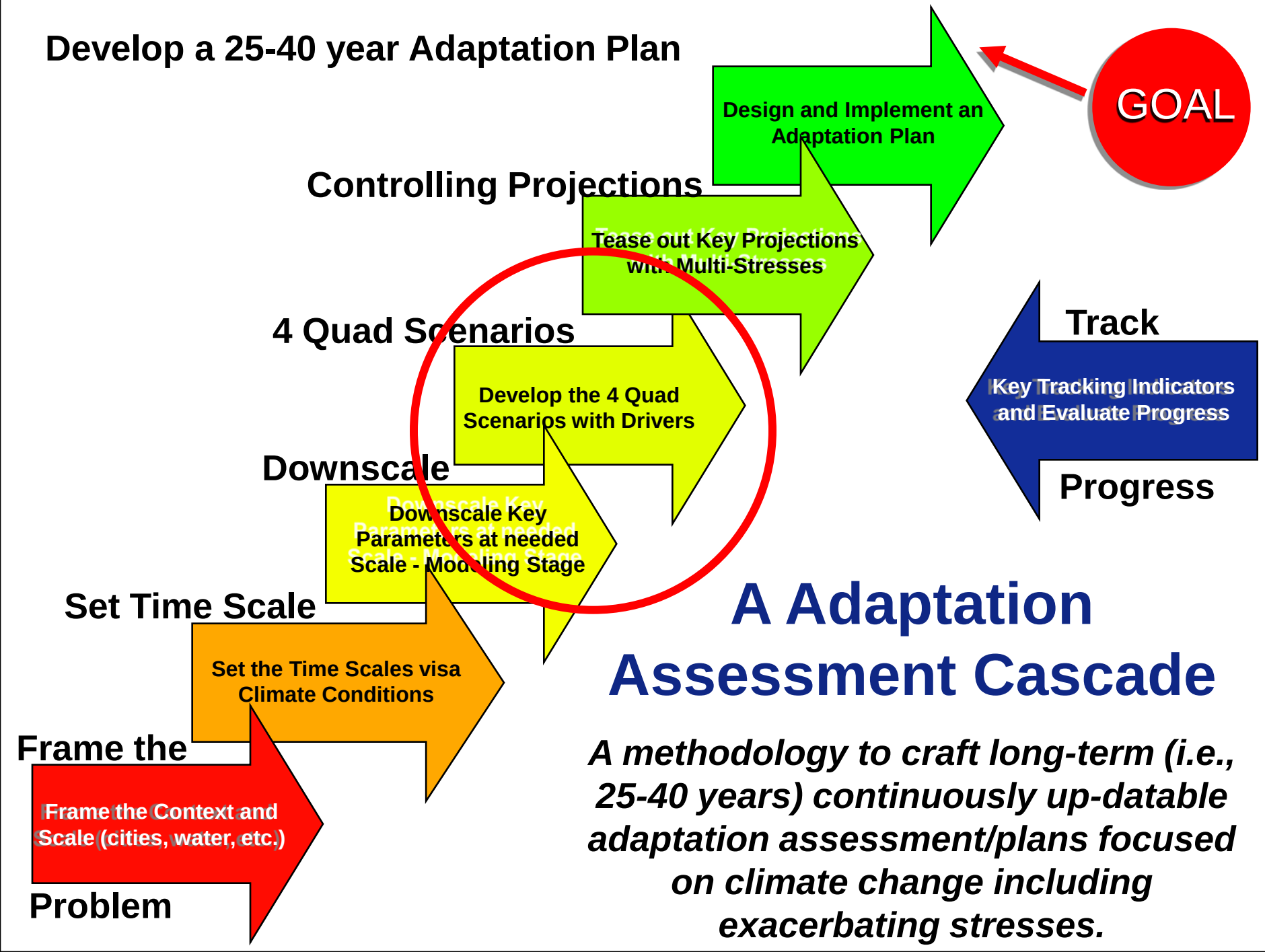


LAKE TORNE AREA BIOSPHERE RESERVE

Abisko Scientific Research Station

Sheffield Centre for Arctic Ecology

Göteborg University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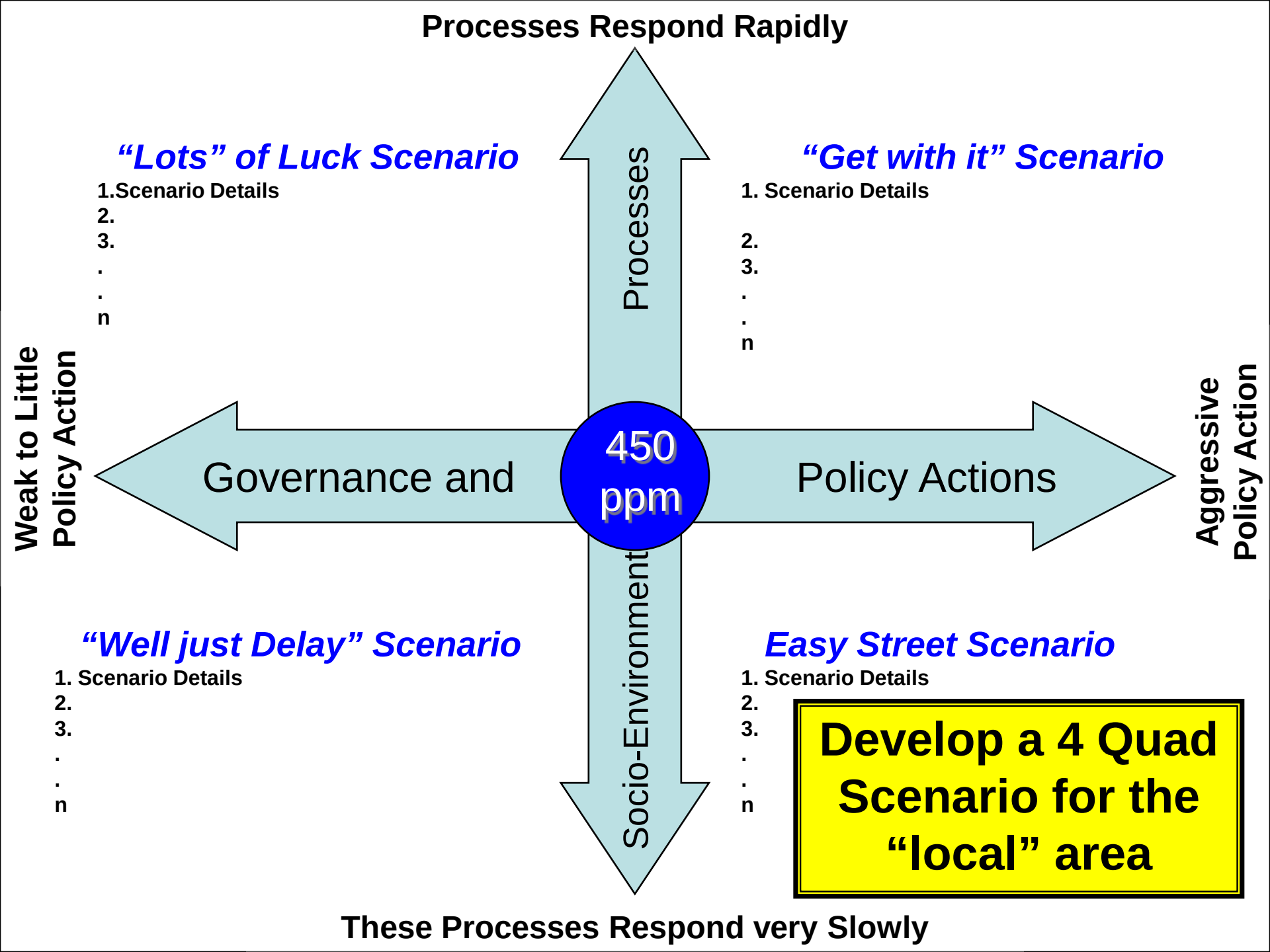
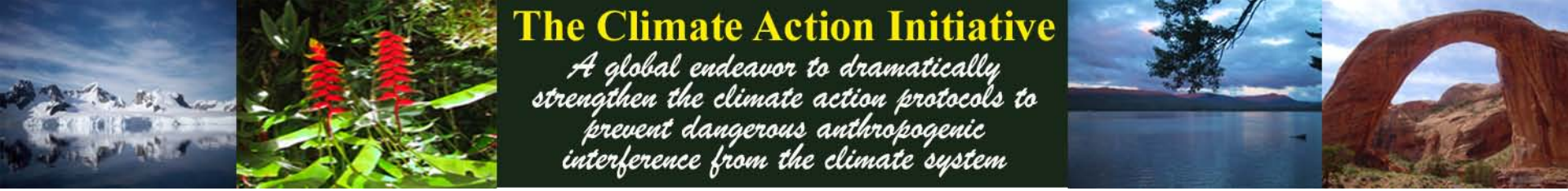

Processes Respond Rapidly
Processes
"Lots" of Luck Scenario
1.Scenario Details
2.
3.
.
.
n
"Get with it" Scenario
1. Scenario Details
2.
3.
.
.
n
Weak to Little Policy Action
Governance and
450 ppm
Policy Actions
Aggressive Policy Action
Socio-Environment
"Well just Delay" Scenario
1. Scenario Details
2.
3.
.
.
n
Easy Street Scenario
1. Scenario Details
2.
3.
.
.
n
Develop a 4 Quad Scenario for the "local" area
These Processes Respond very Slowly

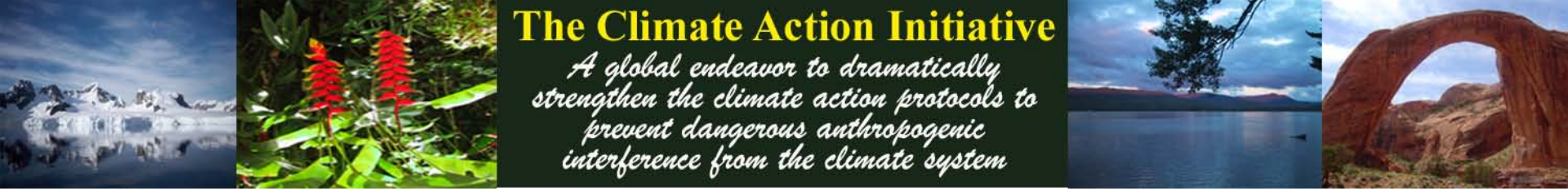


Informing Decisions in a Changing Climate

National Research Council, 2009

Background

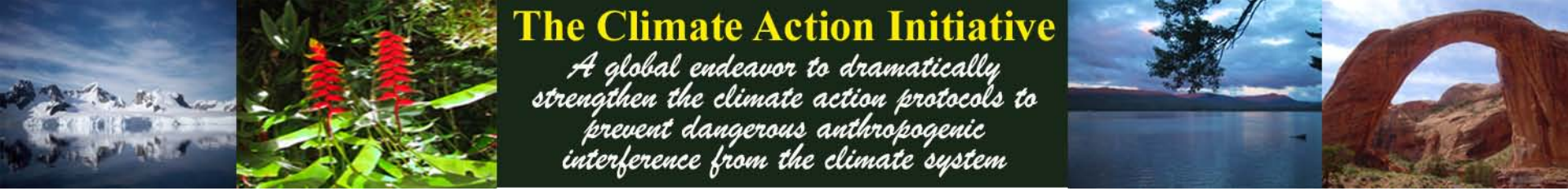
- Several Federal agencies noted a growing demand for climate-related decision support.
- They saw that they and other agencies generally would benefit from a clearer conceptual and operational framework for designing and evaluating decision support activities.



Task

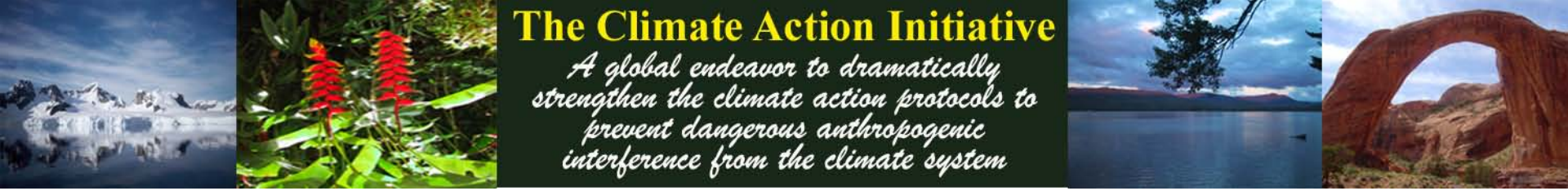
- The National Academies were asked to provide a framework for organizing and evaluating decision support activities for the U.S. Climate Change Science Program, with special attention to sectors and issues of concern to the sponsors.

- The National Academies created the Panel on Strategies and Methods for Climate-Related Decision Support, operating under the NAS standing Committee on the Human Dimensions of Global Change.



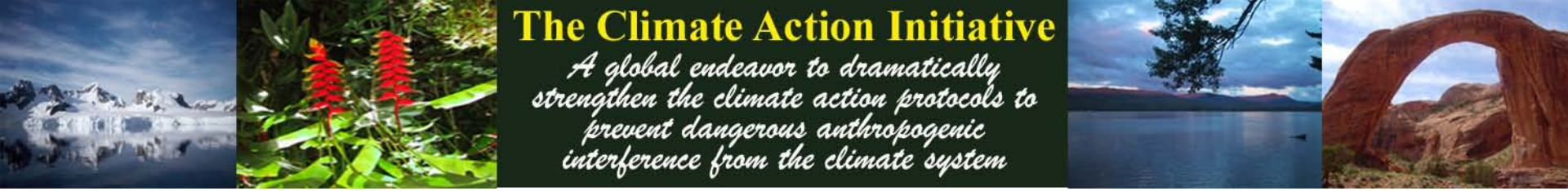
Conclusion 1: The end of "***Climate Stationarity***" requires that organizations and individuals alter their standard practices and decision routines to take climate change into account. Scientific priorities and practices need to change so that the scientific community can provide better support to decision makers in managing emerging climate risks.

- Decision makers must expect to be surprised—probably with increasing frequency (e.g., the hundred-year storms may recur every decade) because of the nature of climate change and the incompleteness of scientific understanding of its consequences.
- An uncertainty management framework should be used because of the inadequacies of predictive capability.



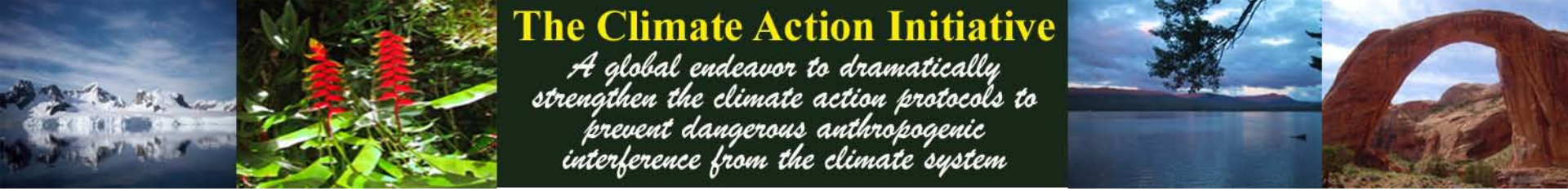
Federal Roles in Decision Support:

- Serving the constituencies of federal agencies
- Participating in international efforts related to decision support
- Providing decision support services and products that would not otherwise be provided, e.g., for states and local governments, regional organizations, and others
- Facilitating distributed responses to climate change



Early Observations on Services

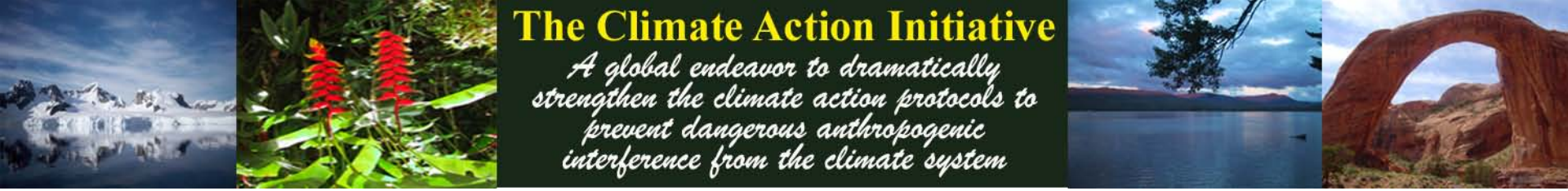
- Good decisions depend not only in the quality and availability of information, but also on the ways people — working individually or in groups — process information and evaluate options.
- Climate-affected decision makers can be treated as ***constituencies***: collections of decision makers facing similar choices and having similar information needs
- Decision support is largely dependent on decision support systems, which are ***networks*** that link information producers and users
- Decision-relevant information is not only climate information



The Six Principles for Effective Decision Support Capabilities

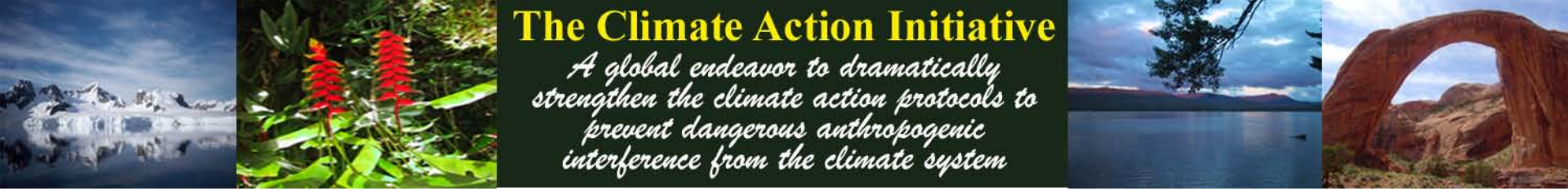
(Based on research in the decision sciences and practical experience with decision support)

1. **Begin with users' needs:** Decision support activities should be driven by users' needs, not by scientific research priorities. These needs are not always known in advance, and should be identified collaboratively and iteratively in ongoing two-way communication between knowledge producers and decision makers. The latter can usefully be thought of as *constituencies*—sets of decision makers who face similar climate-related choices and have similar information needs.
2. **Give priority to processes over products:** To get the right products, start with the right process. Decision support is not merely about producing the right kinds of information products. Without attention to process, products are likely to be inferior—although excessive attention to process without delivery of useful products can be equally ineffective.
3. **Link information producers and users:** Decision support systems require networks and institutions linking information producers and users. The cultures and incentives of science and practice are different, for good reason, and those differences need to be respected if a productive and durable relationship is to be built.



The Six Principles for Effective Decision Support Capabilities (continued):

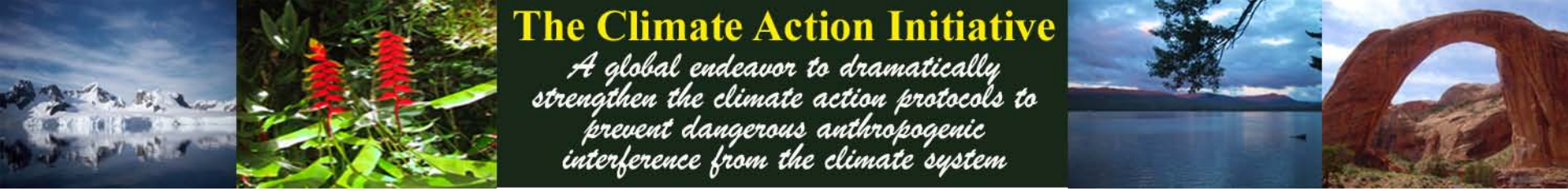
4. **Build connections across disciplines and organizations:** Decision support services and products must account for the multidisciplinary character of the needed information, the many organizations that share decision arenas, and the wider decision context.
5. **Seek institutional stability:** Decision support systems need stable support. This can be achieved through formal institutionalization, less formal but long-lasting network building, establishing new decision routines, and mandates, along with committed funding and personnel. Stable decision support systems are able to obtain greater visibility, stature, longevity, and effectiveness.
6. **Design for learning:** Decision support systems should be structured for flexibility, adaptability, and learning from experience.



Four Modes of Learning

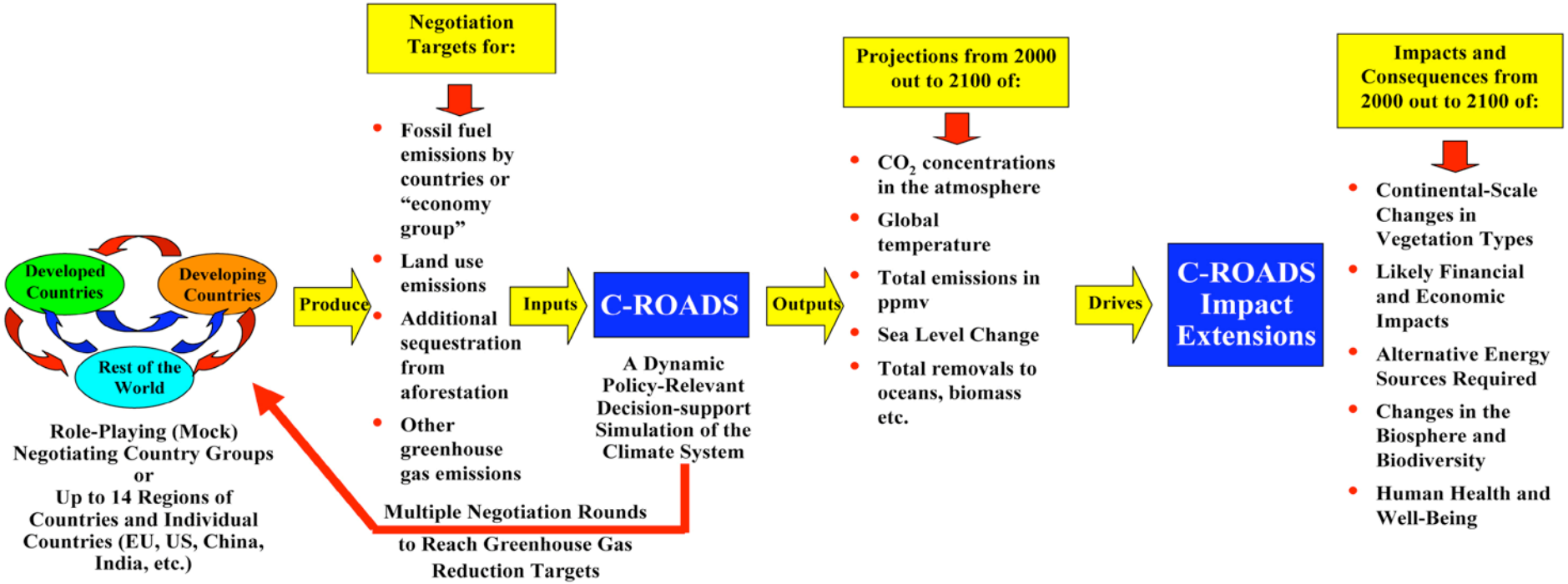
Climate change is a "***wicked problem***" with multiple decision makers, different value priorities, and changing and uncertain information. Decision makers will need to learn and adapt. Four learning modes are available:

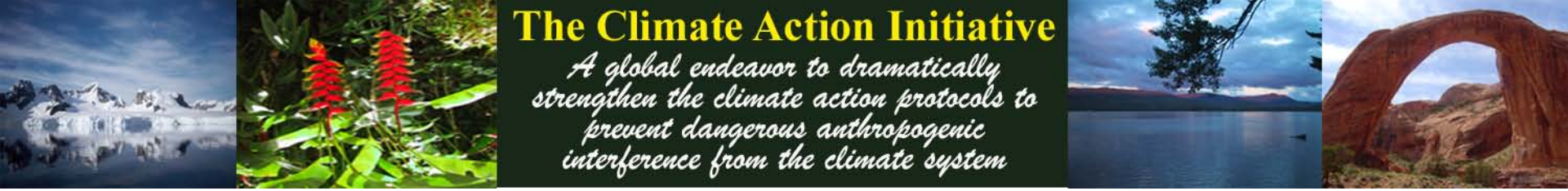
1. ***Unplanned learning***
2. ***Program evaluation***
3. ***Adaptive management***
4. ***Deliberation with analysis***



A Central Proposition from the Study: Deliberation with Analysis is the most appropriate strategy for meeting the challenges of response to climate change. It is central to decision support because it enables continuing learning in a constantly changing environment.

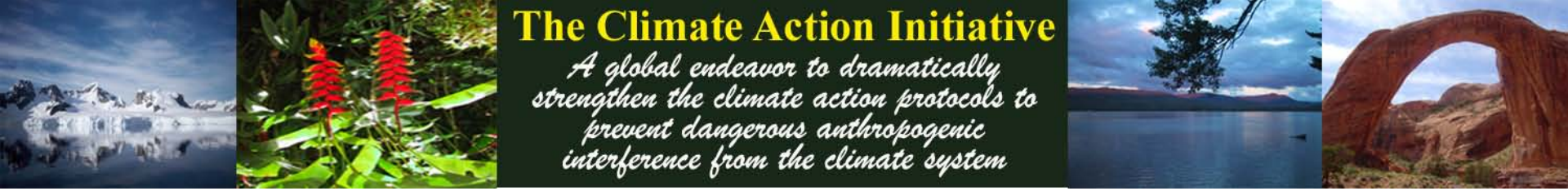
An Example: Climate Policy Exercises of the Climate Action Initiative





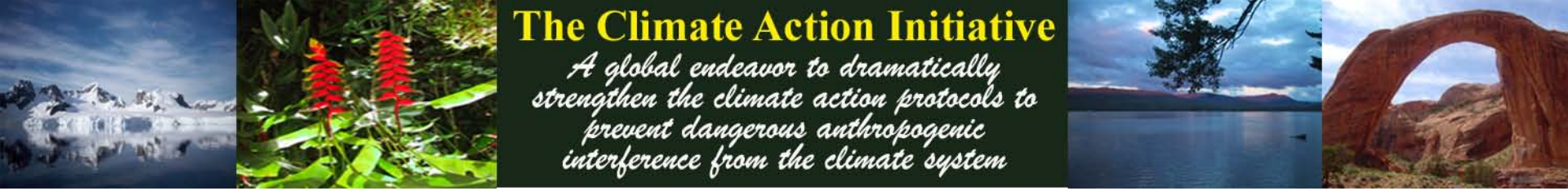
Science Priorities *for* Decision Support

1. **Understanding climate change vulnerabilities,** human development scenarios for potentially affected regions, populations, and sectors.
2. **Understanding the potential for mitigation**, including anthropogenic driving forces, capacities for change, possible limits of change, and consequences of mitigation options.
3. **Understanding adaptation contexts and capacities**, including possible limits of change and consequences of various adaptive responses.
4. **Understanding how mitigation and adaptation interact** with each other and with climatic and ecological changes in determining human system risks, vulnerabilities, and response challenges.
5. **Understanding and taking advantage of emerging opportunities** associated with climate variability and change.



Priorities for the Science *of* Decision Support

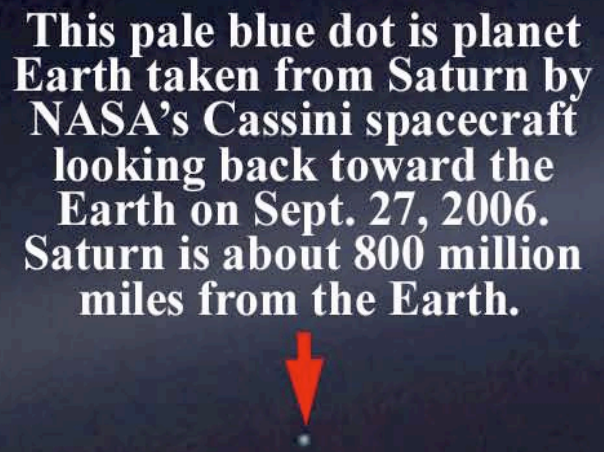
1. **Understanding stakeholders' information needs**
2. **Characterizing and understanding climate risk and uncertainty**
3. **Understanding and improving processes related to decision support; including decision support processes and networks and methods for structuring decisions**
4. **Developing and disseminating decision support products**
5. **Assessing decision support "experiments"**



How to Fulfill the Federal Roles:

Recommendation: The federal government should undertake a ***national initiative for climate-related decision support*** under the mandate of the U.S. Global Change Research Act (USGCRA of 1990) and other existing legal authority. This initiative should include a service element to support and catalyze processes to inform climate-related decisions and a research element to develop the science of climate response to inform climate-related decisions and to promote systematic improvement of decision support processes and products in all relevant sectors of U.S. society and beyond.

Climate change and global warming are no longer simply an environmental issue, it is an issue of economic security and human well-being !



Thank You !