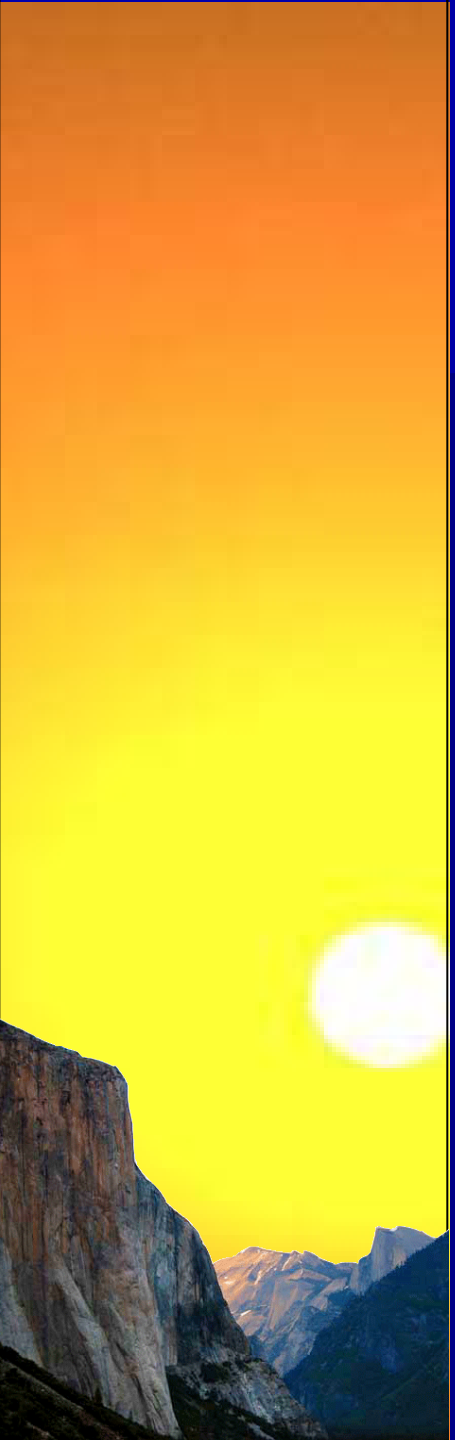
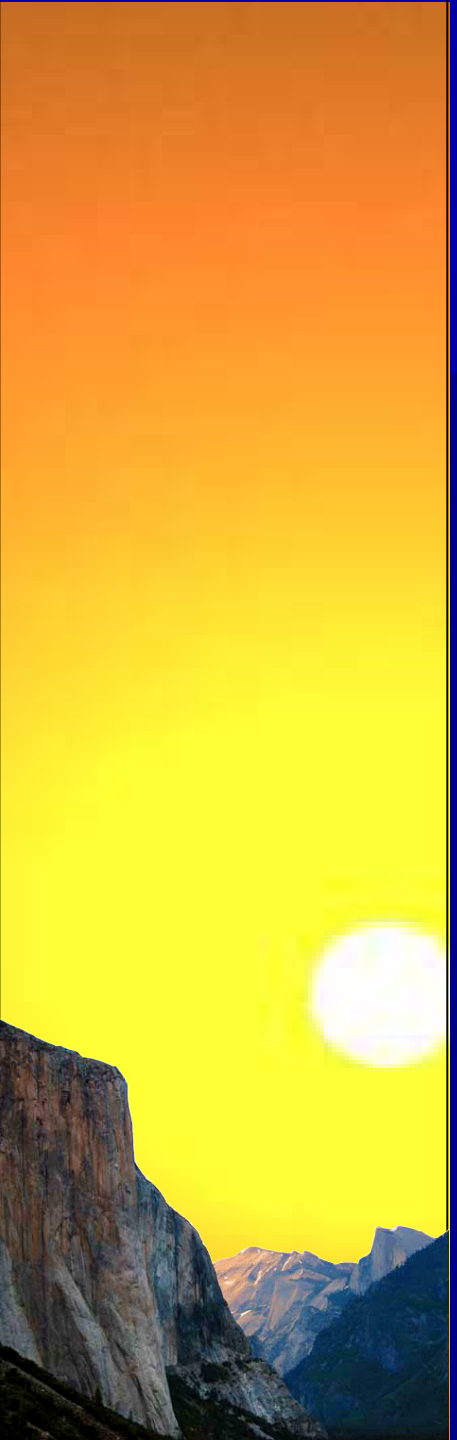


# Climate Change

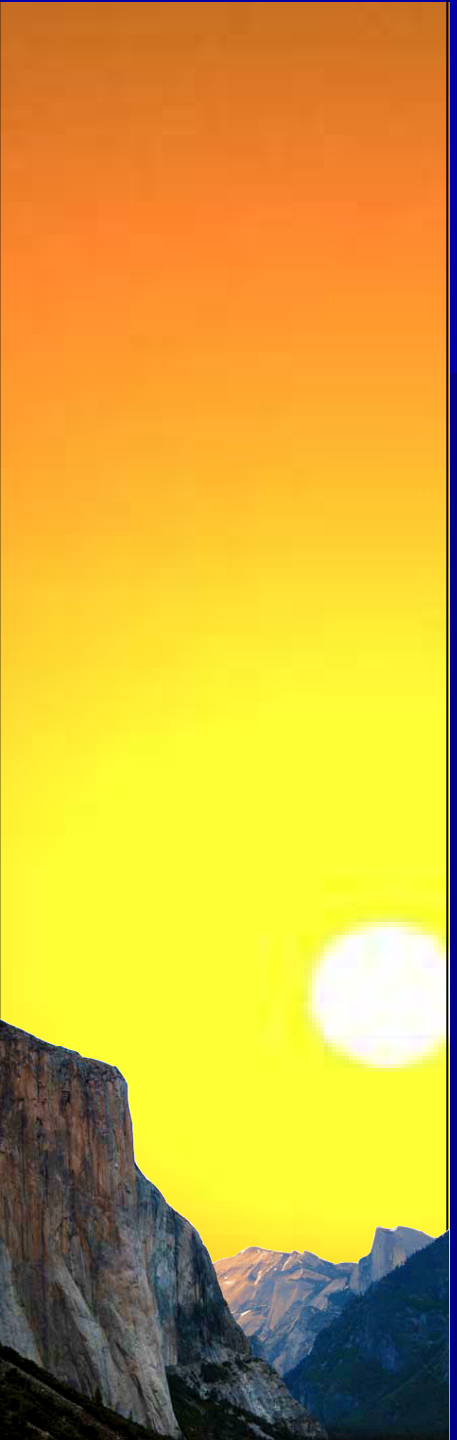
*in the National Parks*

July 2006



"The overwhelming majority of scientific experts, while recognizing that scientific uncertainties exist, nonetheless believe that human-induced climate change is already occurring."

*- Intergovernmental Panel on Climate Change (2001)*



"An increasing body of observations gives a collective picture of a warming world and other changes in the climate system."

*- Intergovernmental Panel on Climate Change (2001)*

March 17, 2005

US NSF - News - Climate Change Inevitable in 21st Century - Microsoft Internet Explorer

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Press Release 05-043

# Climate Change Inevitable in 21st Century

**Rise of sea level to outpace temperature increase**

Scientists are studying the interaction between global climate and human influence.
Credit and Larger Version

**March 17, 2005**

Even if all greenhouse gases had somehow been stabilized back in the year 2000, we would still be committed to a warmer Earth and greater sea level rise in the present century, according to a new study performed by a team of climate modelers at the National Center for Atmospheric Research (NCAR) in Boulder, Colo.

June 7, 2005

# Joint science academies' statement: Global response to climate change

## Climate change is real

There will always be uncertainty in understanding a system as complex as the world's climate. However there is now strong evidence that significant global warming is occurring[1]. The evidence comes from direct measurements of rising surface air temperatures and subsurface ocean temperatures and from phenomena such as increases in average global sea levels, retreating glaciers, and changes to many physical and biological systems. It is likely that most of the warming in recent decades can be attributed to human activities (IPCC 2001)[2]. This warming has already led to changes in the Earth's climate.

The existence of greenhouse gases in the atmosphere is vital to life on Earth – in their absence average temperatures would be about 30 centigrade degrees lower than they are today. But human activities are now causing atmospheric concentrations of greenhouse gases – including carbon dioxide, methane, tropospheric ozone, and nitrous oxide – to rise well above pre-industrial levels. Carbon dioxide levels have increased from 280 ppm in 1750 to over 375 ppm today – higher than any previous

potentially cost-effective technological options th
contribute to stabilising greenhouse gas concentr
These are at various stages of research and devel
However barriers to their broad deployment still
overcome.

Carbon dioxide can remain in the atmosphere f
decades. Even with possible lowered emission r
be experiencing the impacts of climate change
the 21st century and beyond. Failure to implem
significant reductions in net greenhouse gas em
now, will make the job much harder in the futu

## Prepare for the consequences of climate change

Major parts of the climate system respond slow
changes in greenhouse gas concentrations. Eve
greenhouse gas emissions were stabilised instan
today's levels, the climate would still continue t
it adapts to the increased emission of recent de
Further changes in climate are therefore unavoi
Nations must prepare for them.

## June 7, 2005

Academia Brasiliera de Ciências
Brazil

Royal Society of Canada,
Canada

Chinese Academy of Sciences,
China

Académie des Sciences,
France

Deutsche Akademie der Naturforscher
Leopoldina, Germany

Indian National Science Academy,
India

Accademia dei Lincei,
Italy

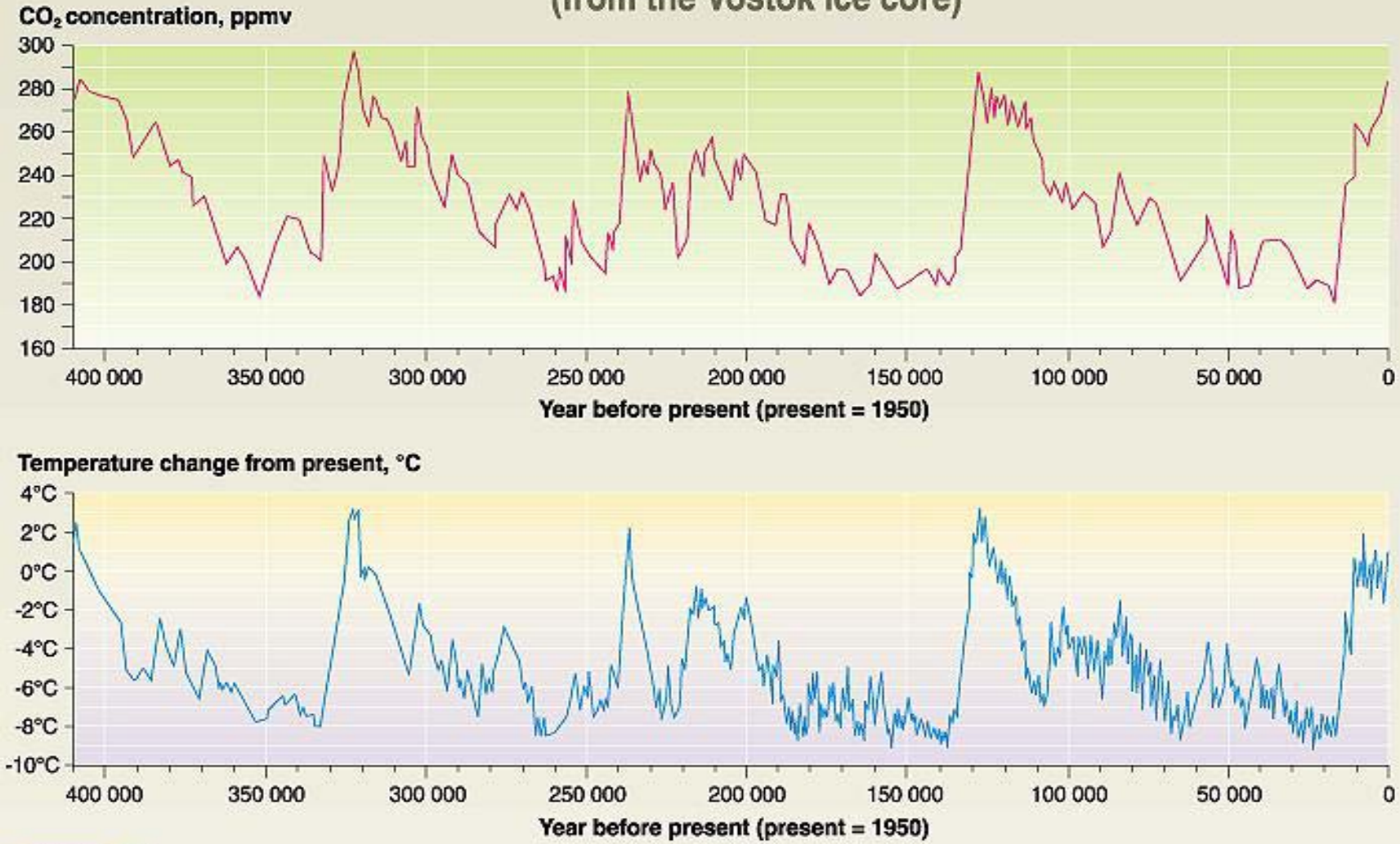
Science Council of Japan,
Japan

Russian Academy of Sciences,
Russia

Royal Society,
United Kingdom

National Academy of Sciences,
United States of America

# Temperature and $CO_2$ concentration in the atmosphere over the past 400 000 years (from the Vostok ice core)

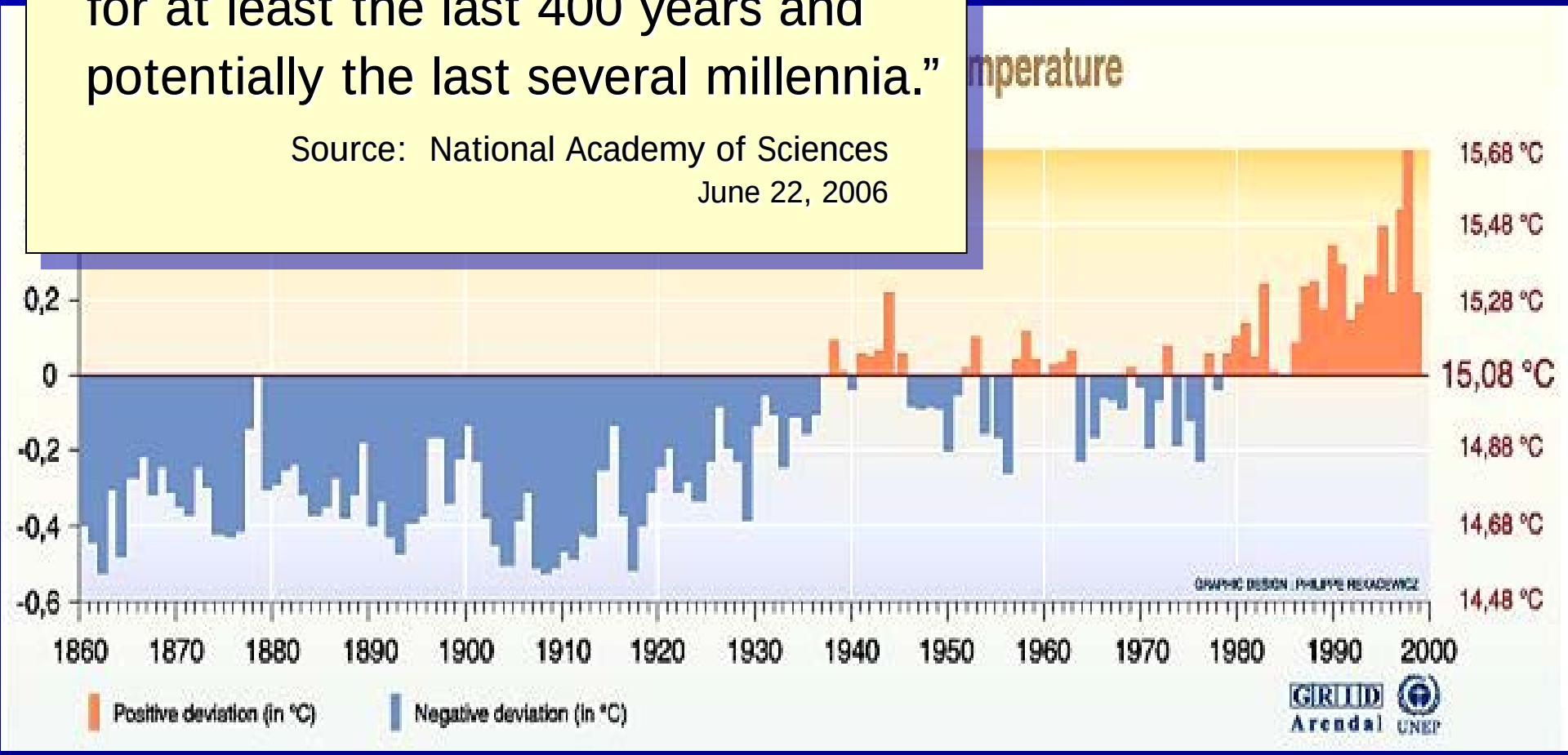



GRID Arendal UNEP

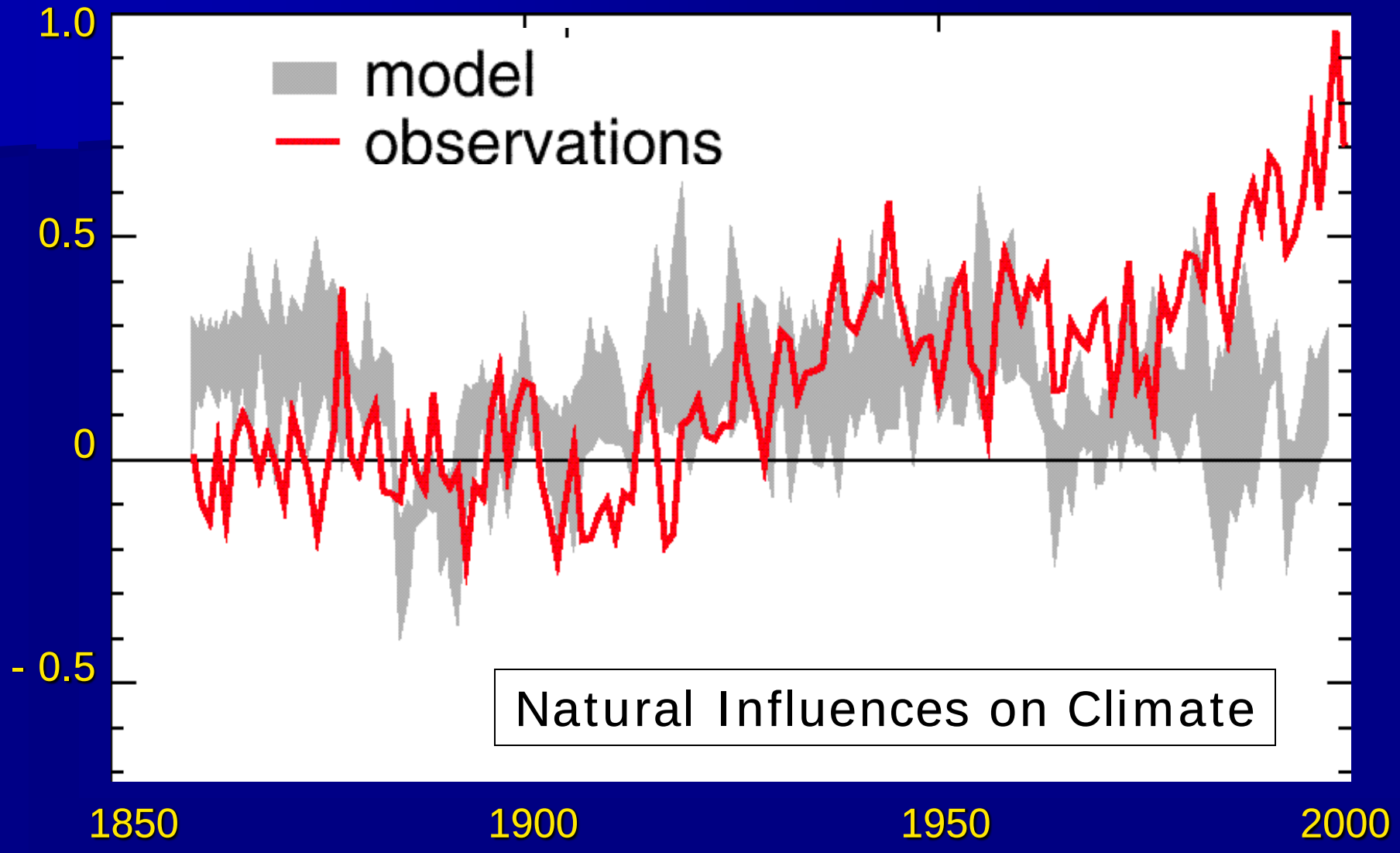
GRAPHIC DESIGN : PHILIPPE REKACEWICZ

" Recent warmth is unprecedented for at least the last 400 years and potentially the last several millennia."

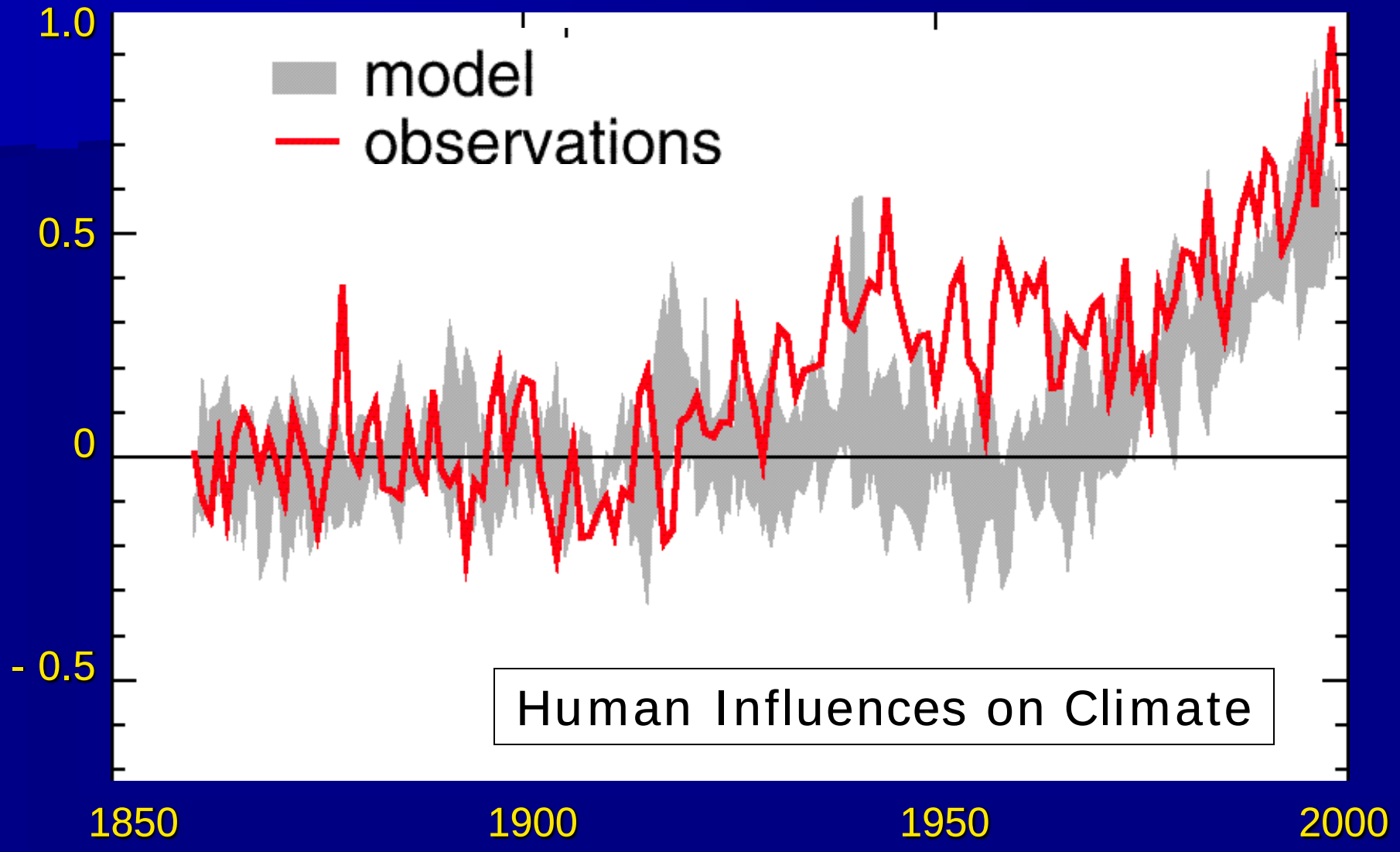
Source: National Academy of Sciences
June 22, 2006



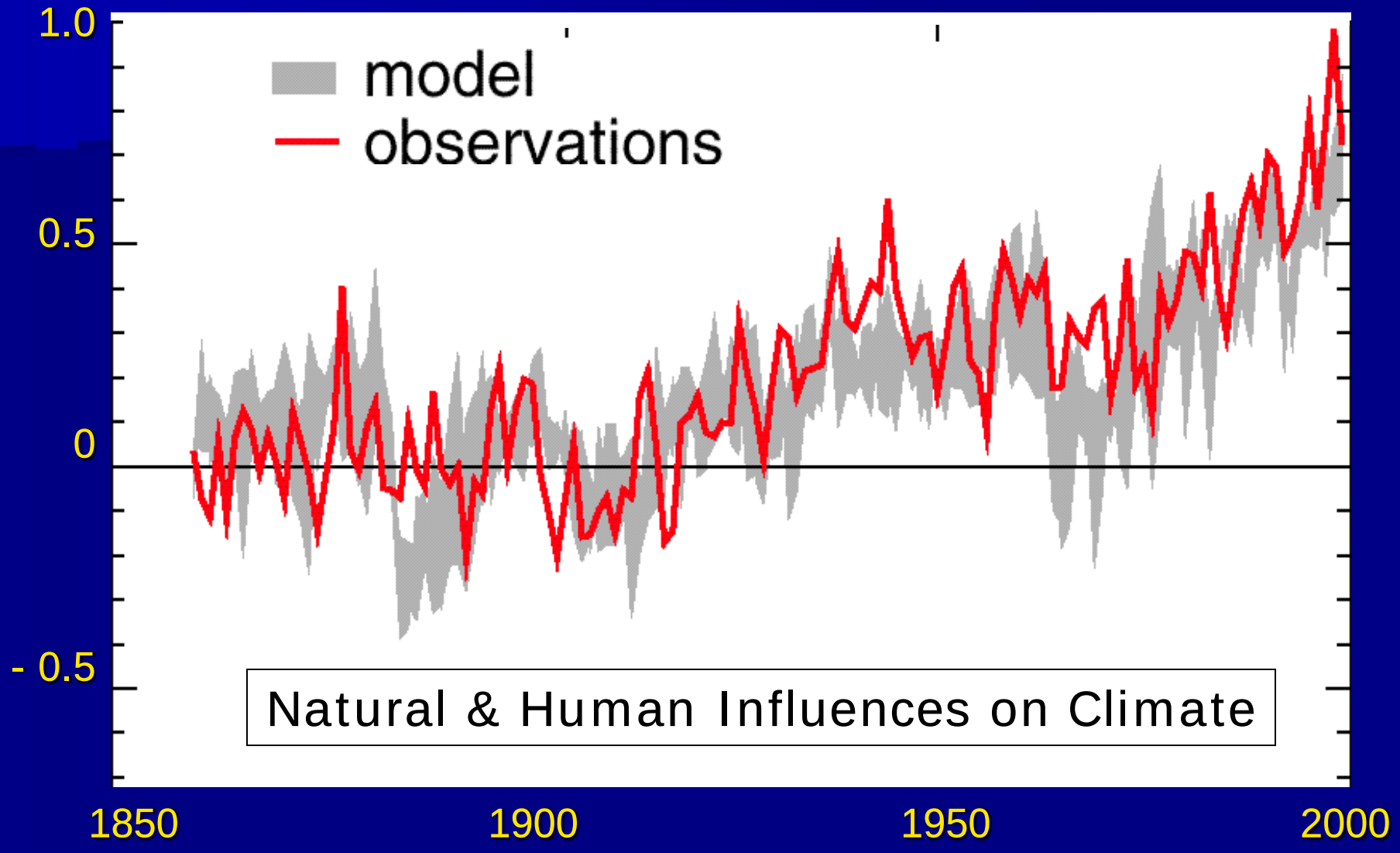
# *Global Temperature Change*



# *Global Temperature Change*

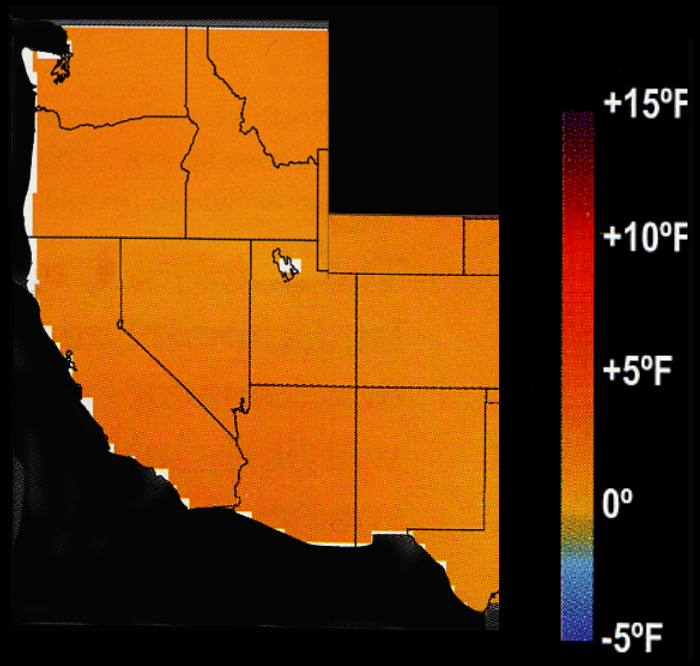


# *Global Temperature Change*

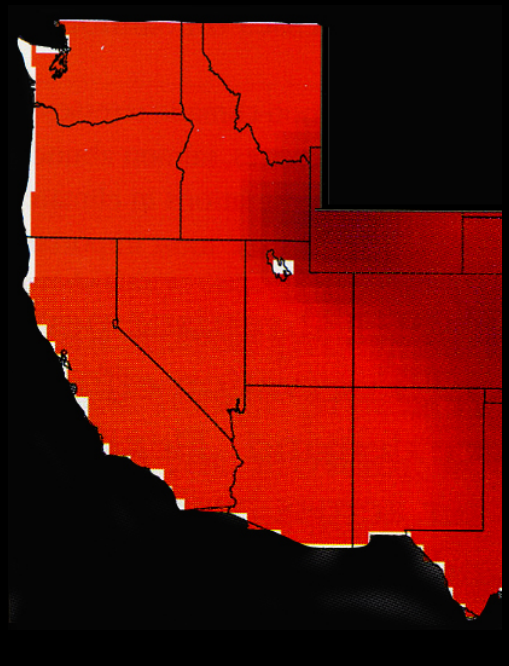


# *Changing Temperatures*

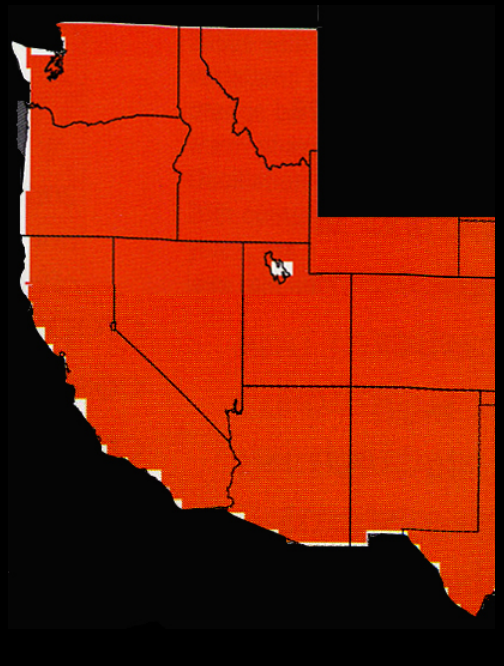
20th Century




Predicted 21st Century



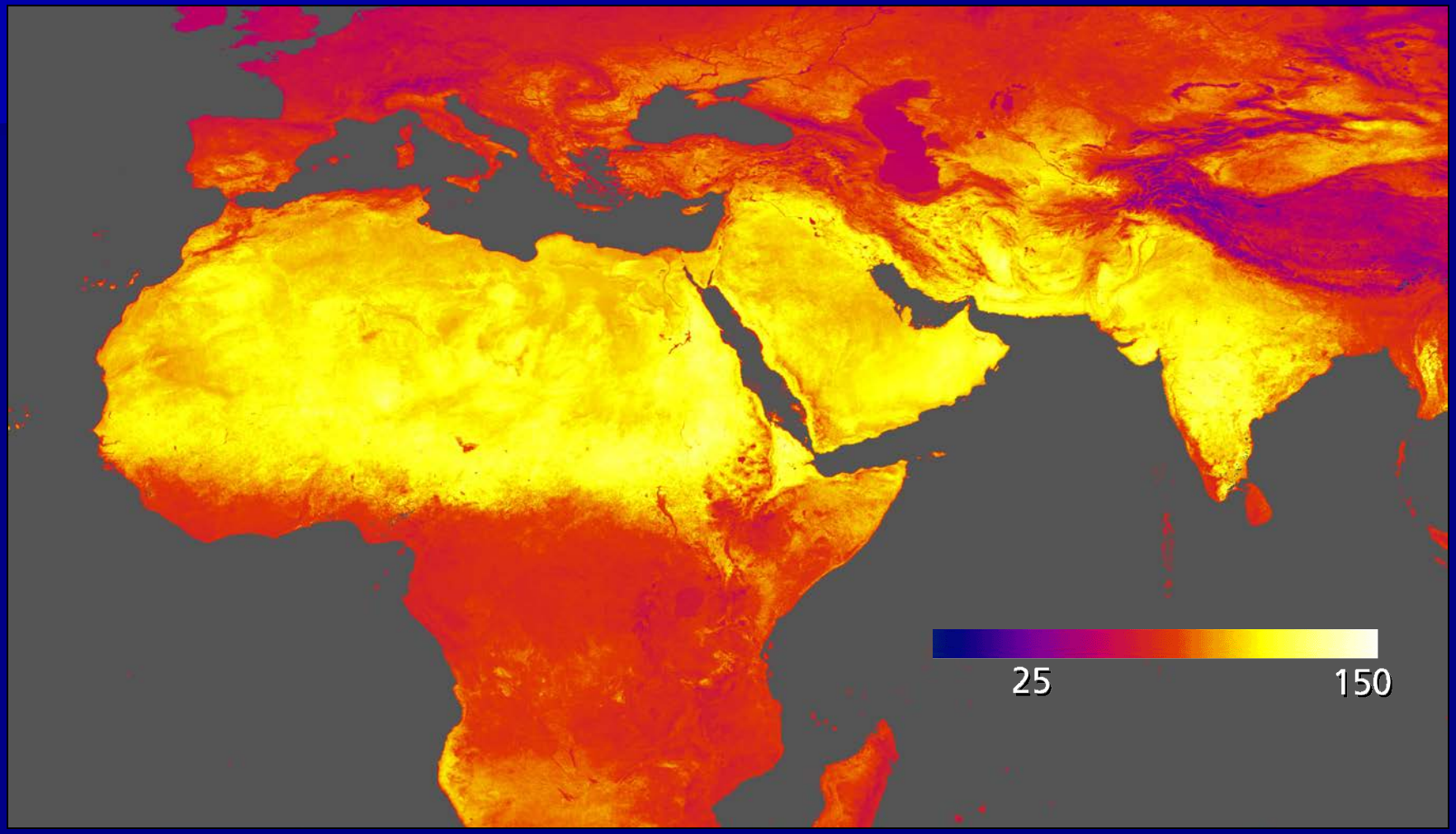
Canadian Model



Hadley Model

Source: U.S. Global Change Research Program
National Assessment Synthesis Team
(2000)

# *Changing Temperatures*

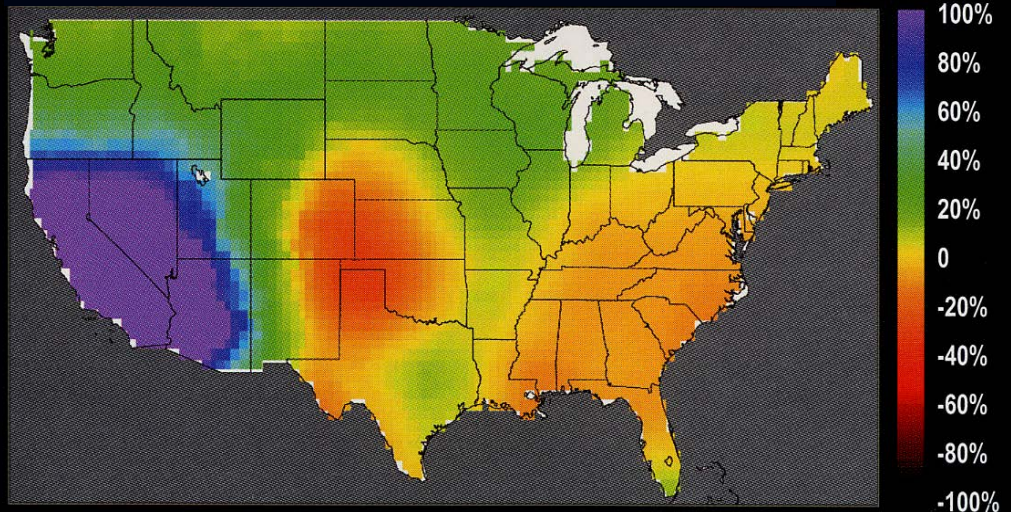



Heat Wave in India and Africa
May 2003

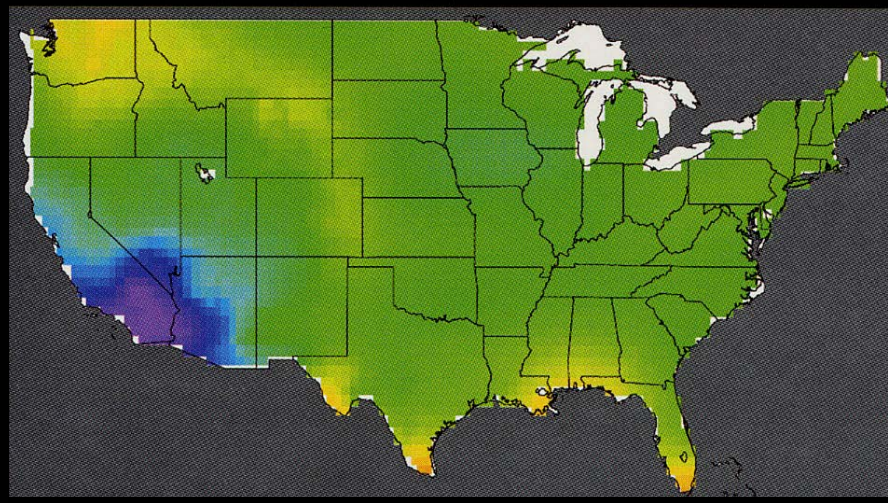
NASA Image

# *Changing Precipitation Patterns*

Predicted: Canadian Model



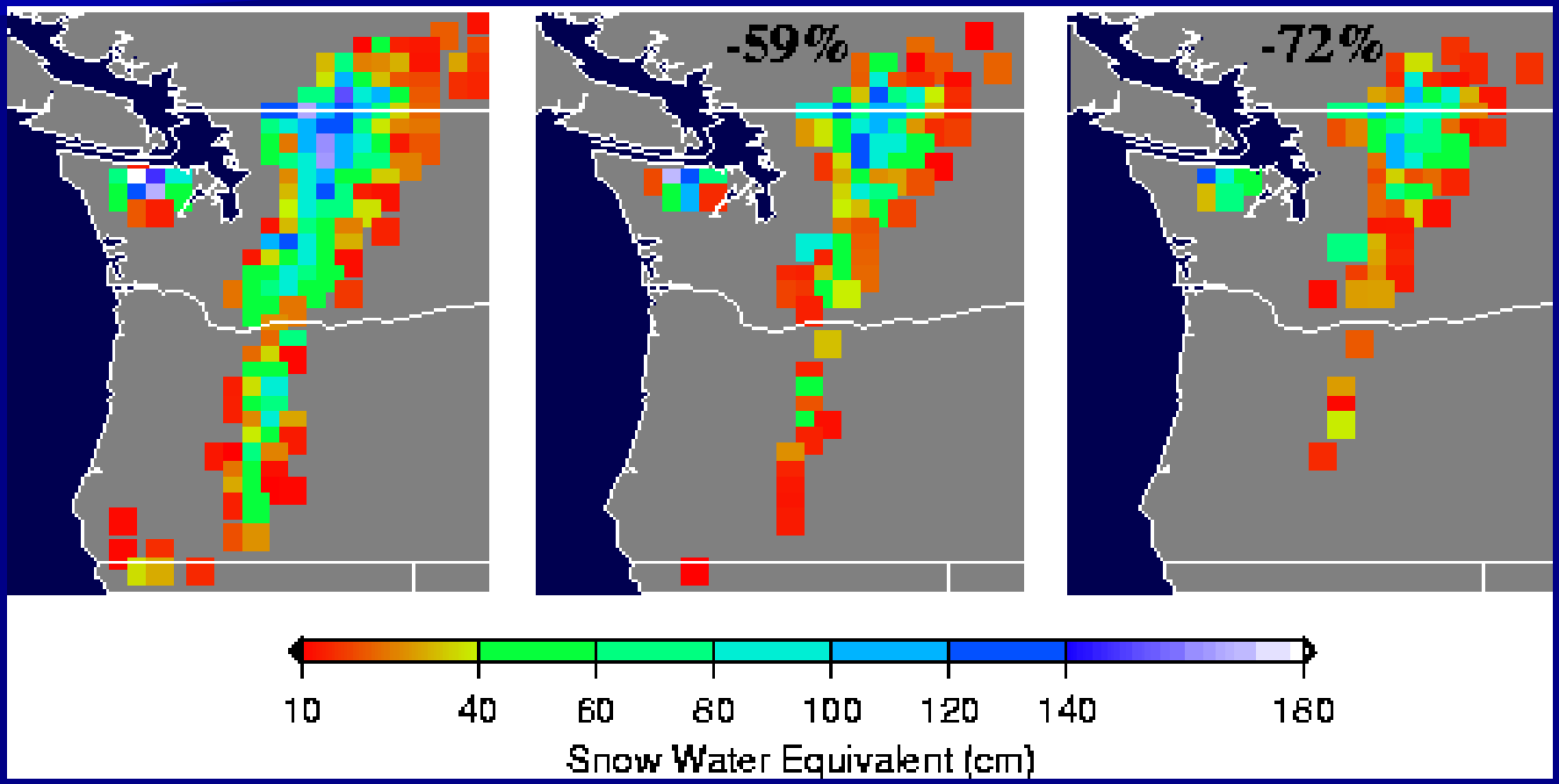

Predicted: Hadley Model



Source: U.S. Global Change Research Program
National Assessment Synthesis Team
(2000)

# *Changing Precipitation Patterns*

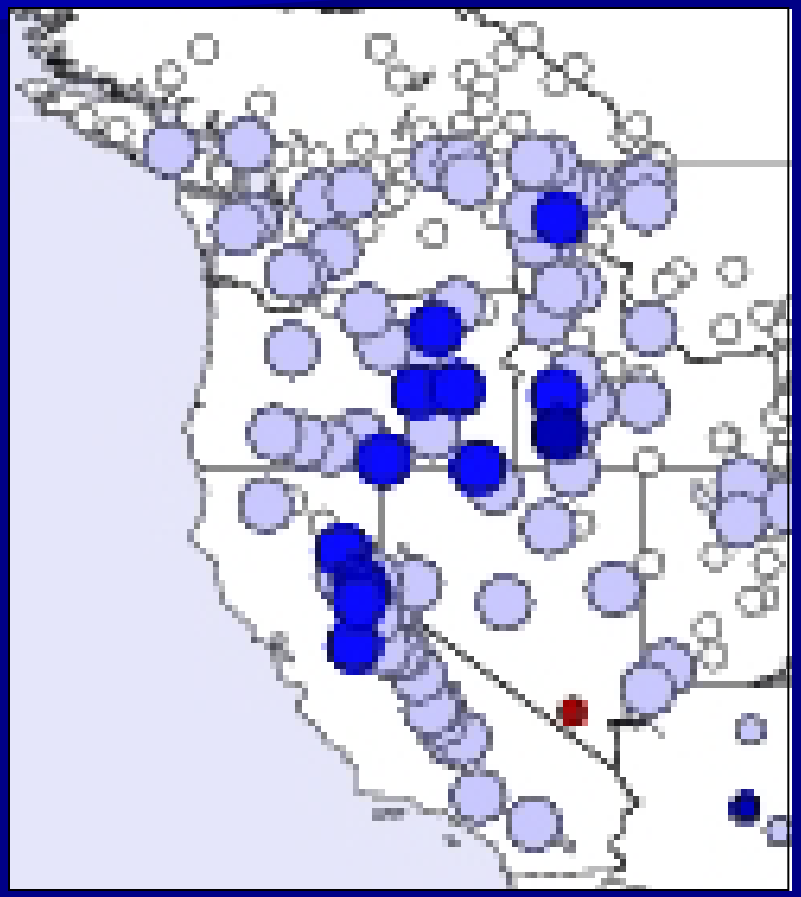
**Snowpack on April 1**




***10 cm ≈ 4 inches***

# *Changing Streamflow*

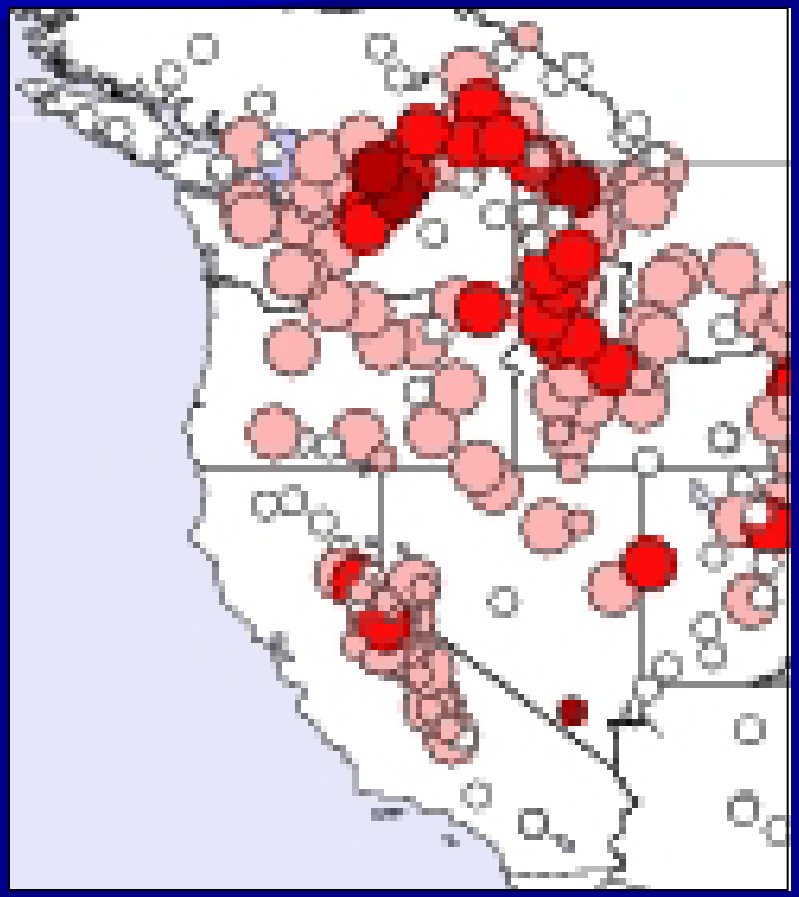
**March: Change from 1948 to 2000**



< -20%
-20 to -10%
-10 to -3%
-3 to +3%
+3 to +10%
+10 to +20%
> +20%

# *Changing Streamflow*

**June: Change from 1948 to 2000**

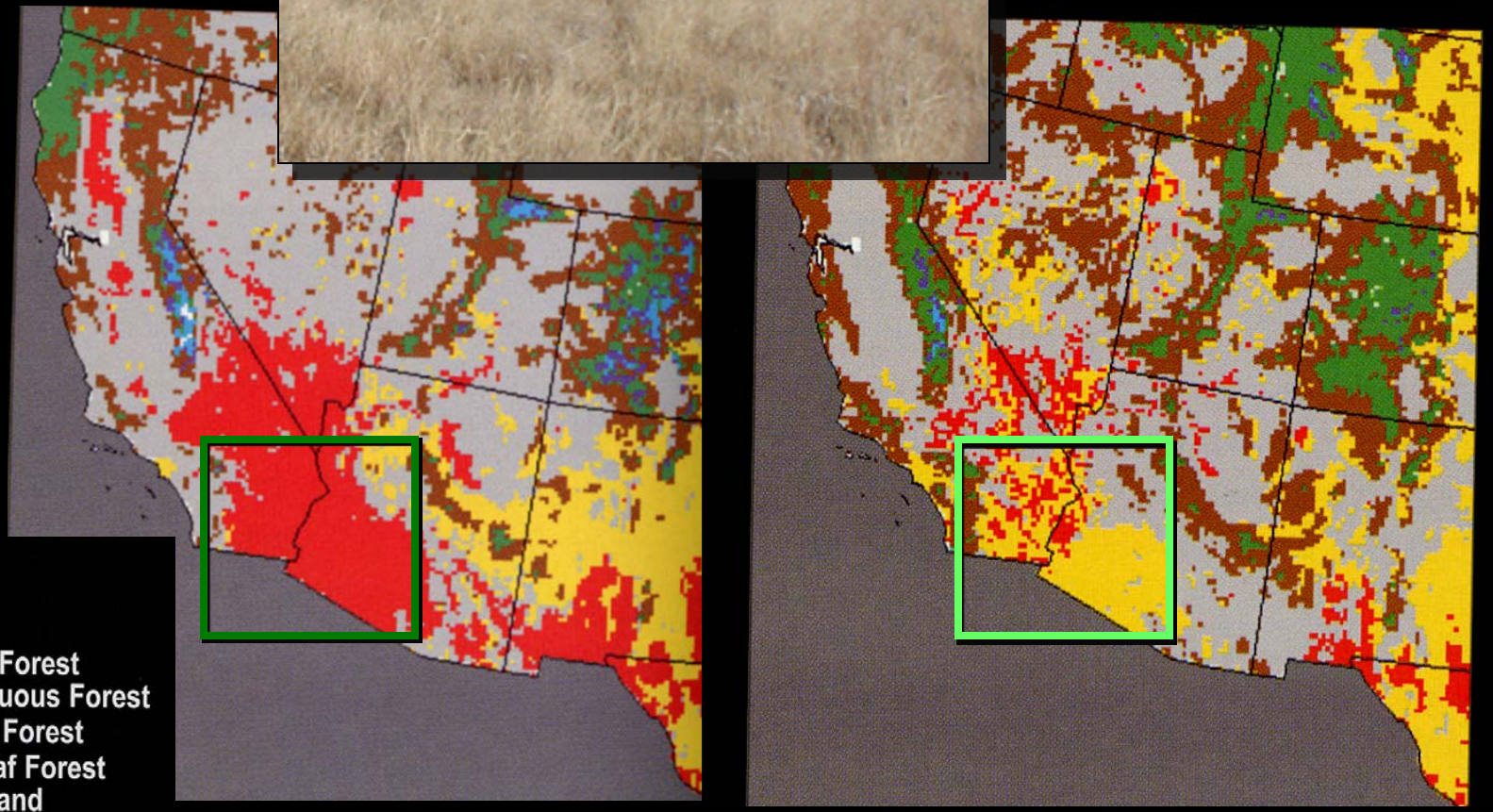


< -20%
-20 to -10%
-10 to -3%
-3 to +3%
+3 to +10%
+10 to +20%
> +20%

Bonneville Power Administration, a federal agency with approximately
$15 billion in outstanding debt, provides over half the power for the Pacific Northwest.

# *Changing Ecos*

Current

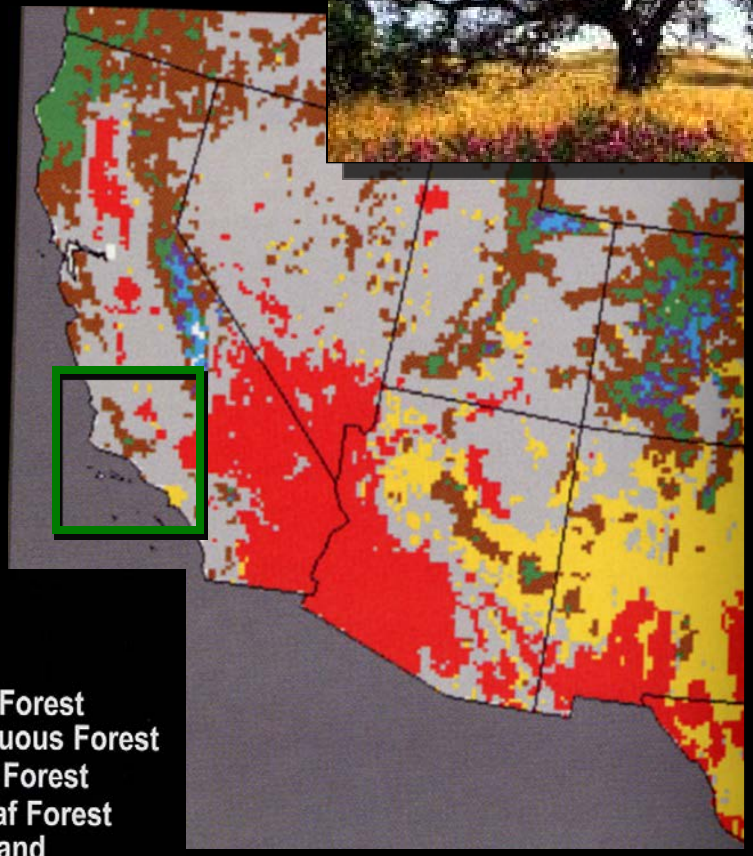


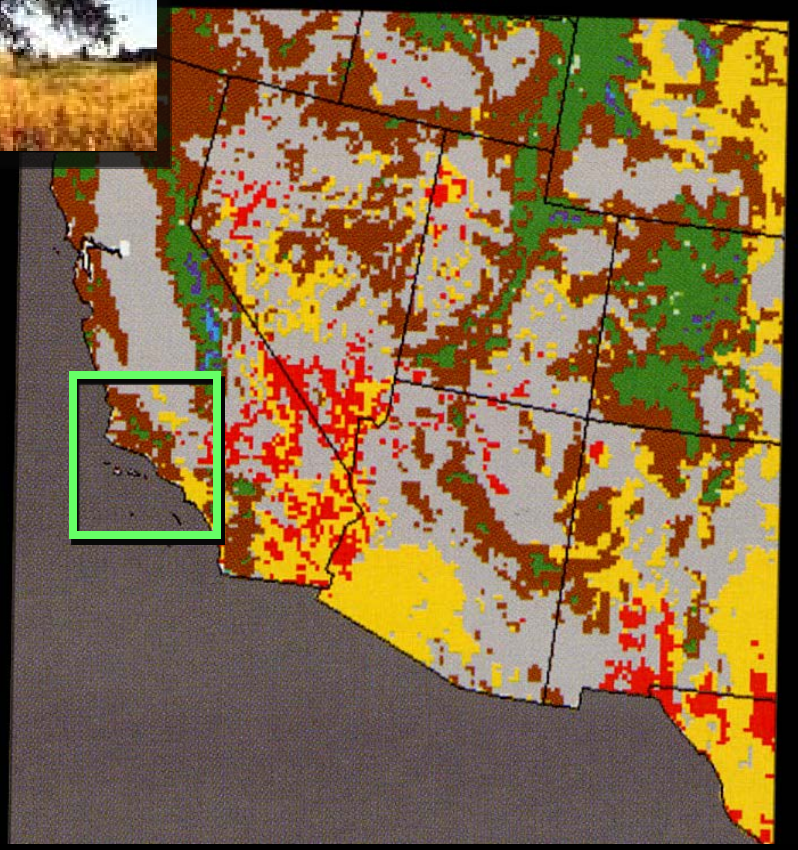

Source: U.S. Global Change Research Program
National Assessment Synthesis Team

# *Changing Ecosy*

Current

cted

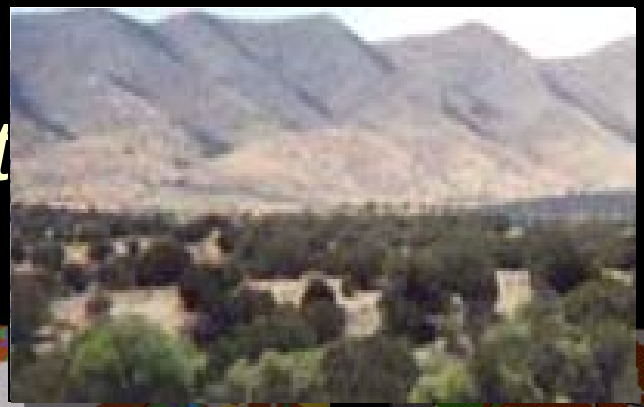




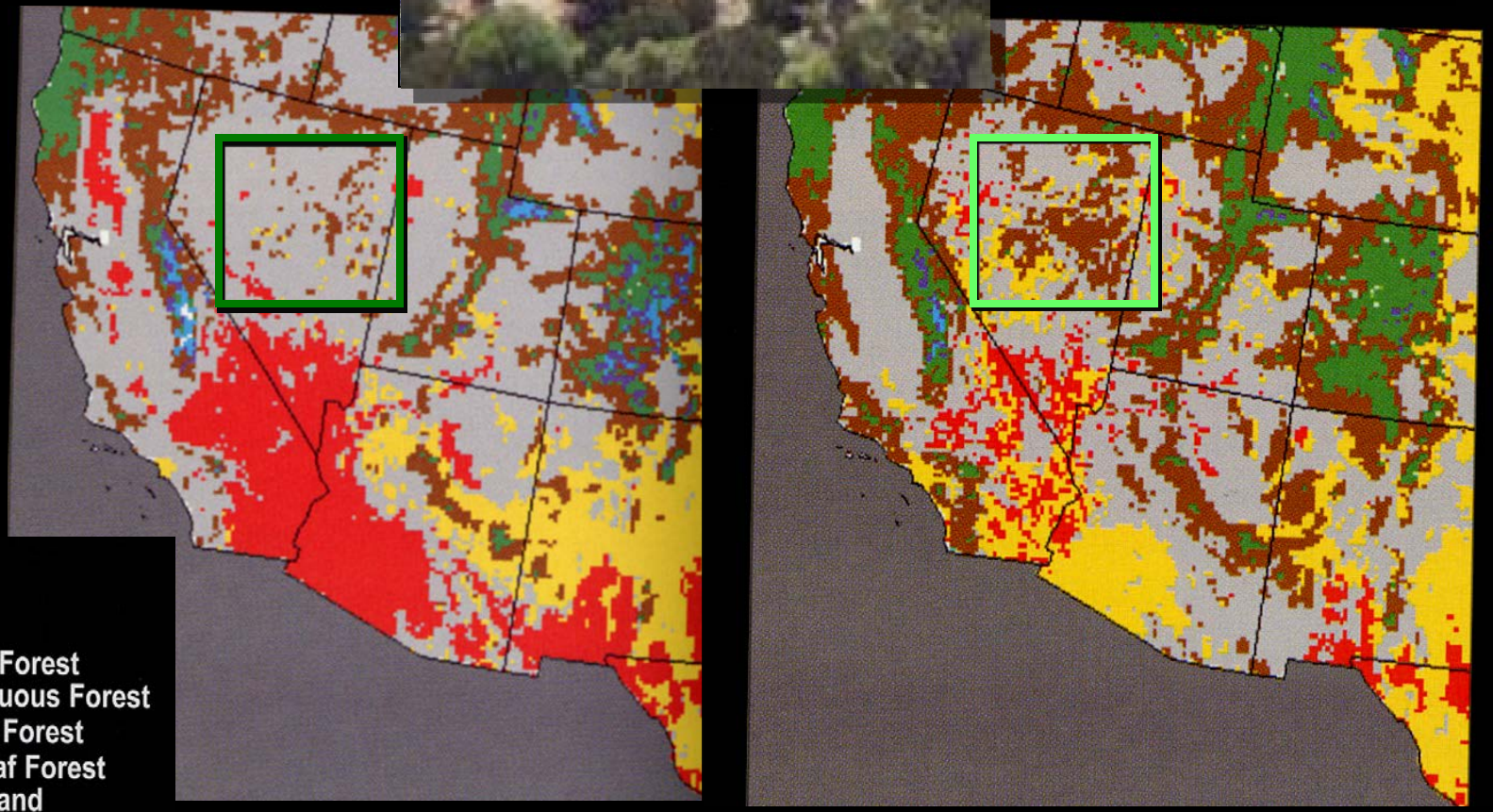
- Tundra
- Taiga / Tundra
- Conifer Forest
- Northeast Mixed Forest
- Temperate Deciduous Forest
- Southeast Mixed Forest
- Tropical Broadleaf Forest
- Savanna / Woodland
- Shrub / Woodland
- Grassland
- Arid Lands

Source: U.S. Global Change Research Program
National Assessment Synthesis Team

# *Changing Ecosyst*



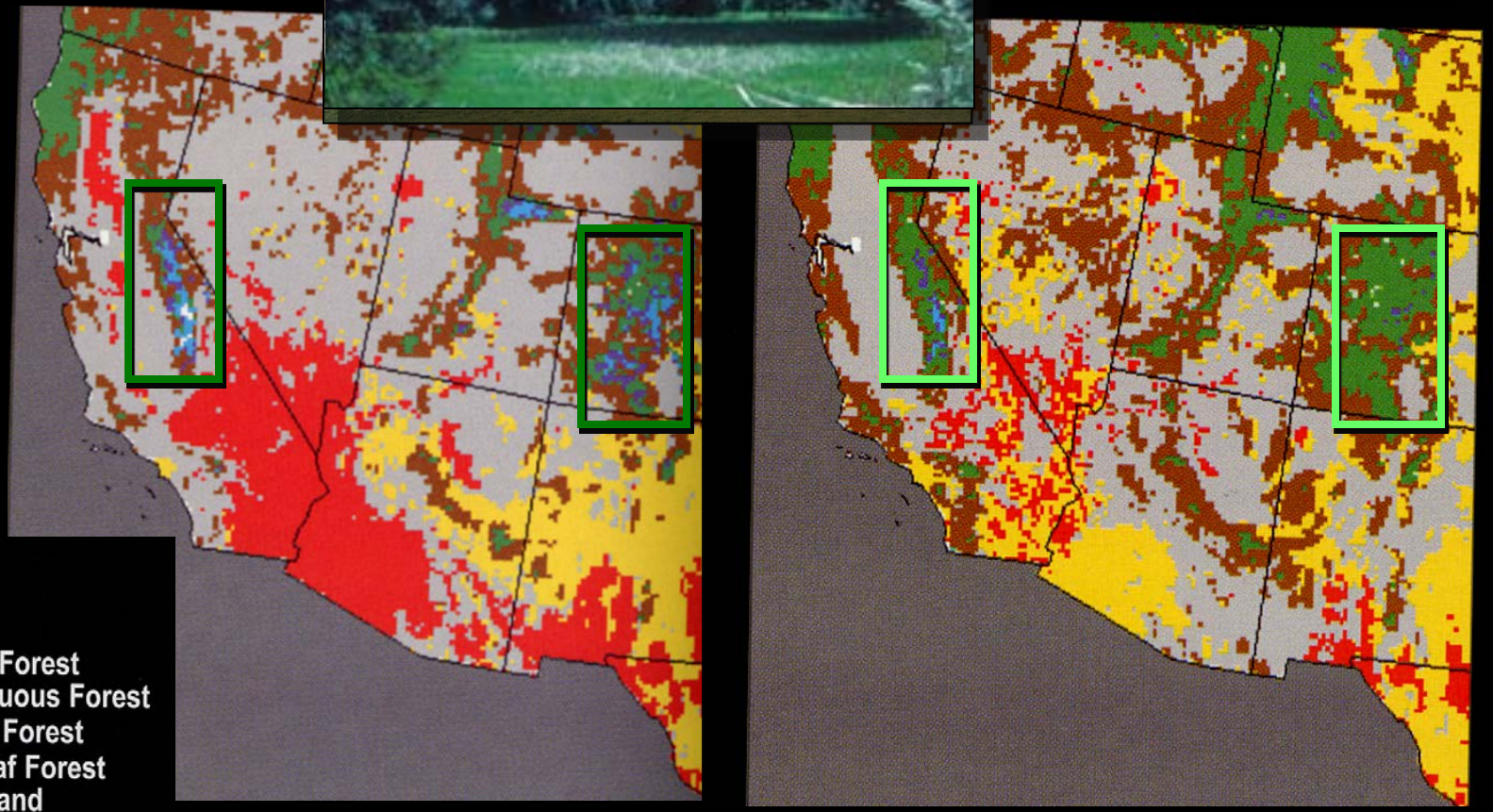
Current



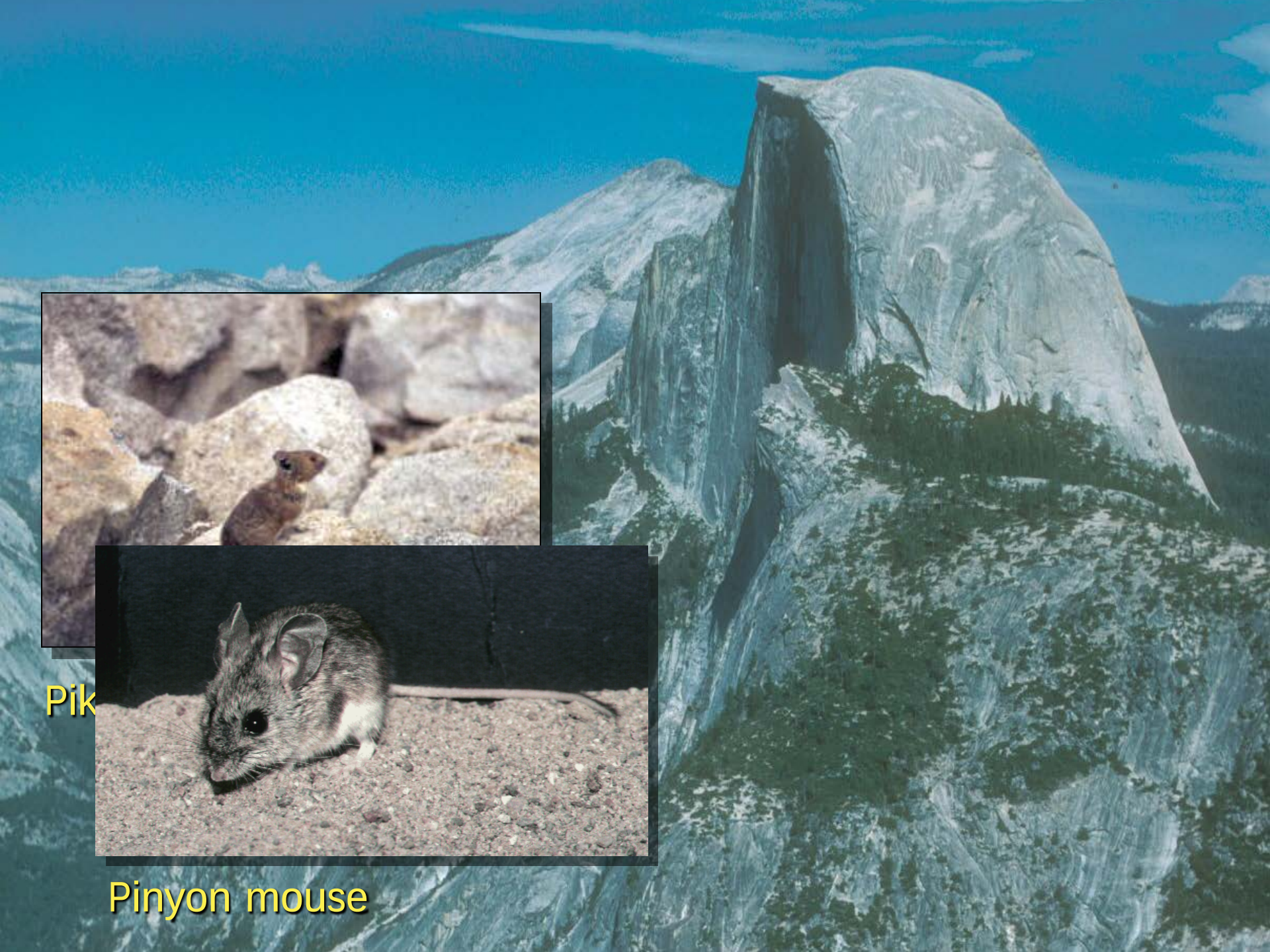

Source: U.S. Global Change Research Program
National Assessment Synthesis Team

# *Changing Ecosy*

Current



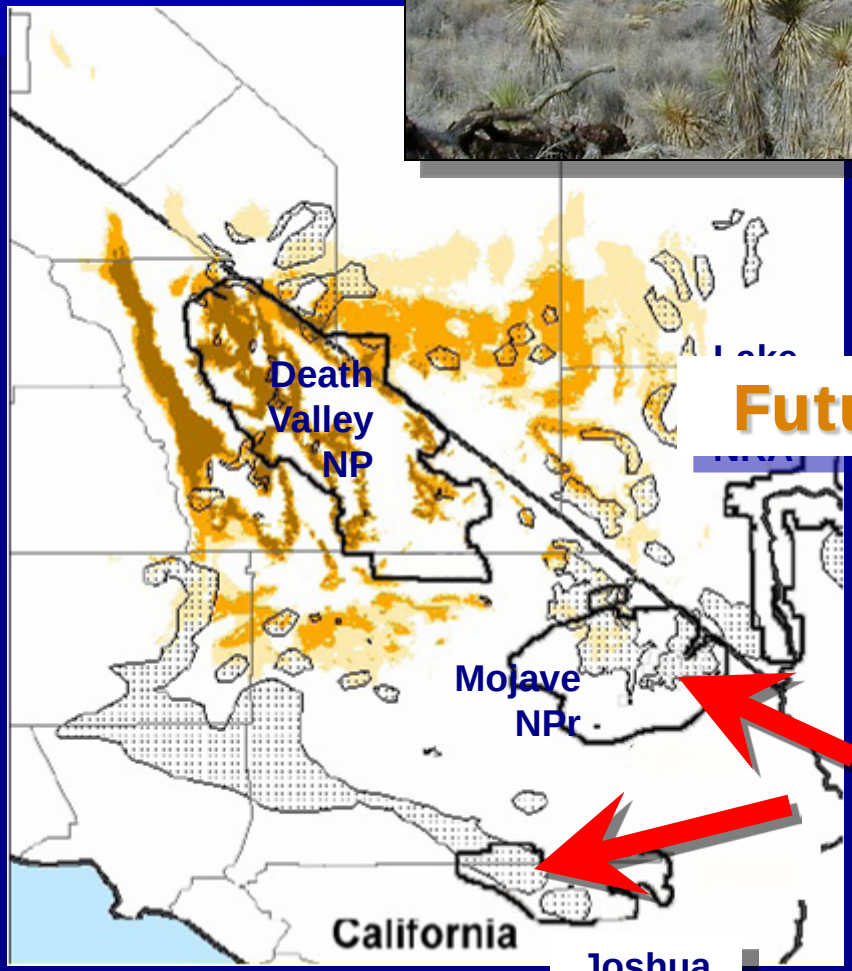

Source: U.S. Global Change Research Program
National Assessment Synthesis Team



Pik



Pinyon mouse




Future Range

Current Range

Oregon Silverspot Butterfly

Santa Cruz Island bush-mallow

Silversword

Spotted Knapweed

# Western Wildfires

- Summer warming
- Changing precipitation
- Moisture stress

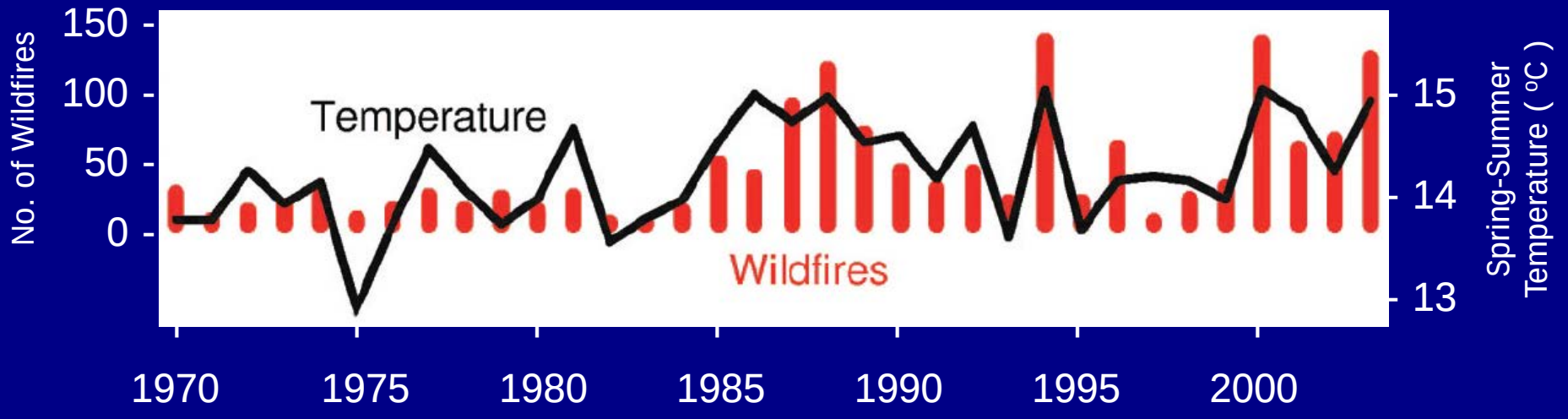
Arctic Climate Impact Assessment:

Natural Resources Defense Council:

Lawrence Berkeley National Laboratory:

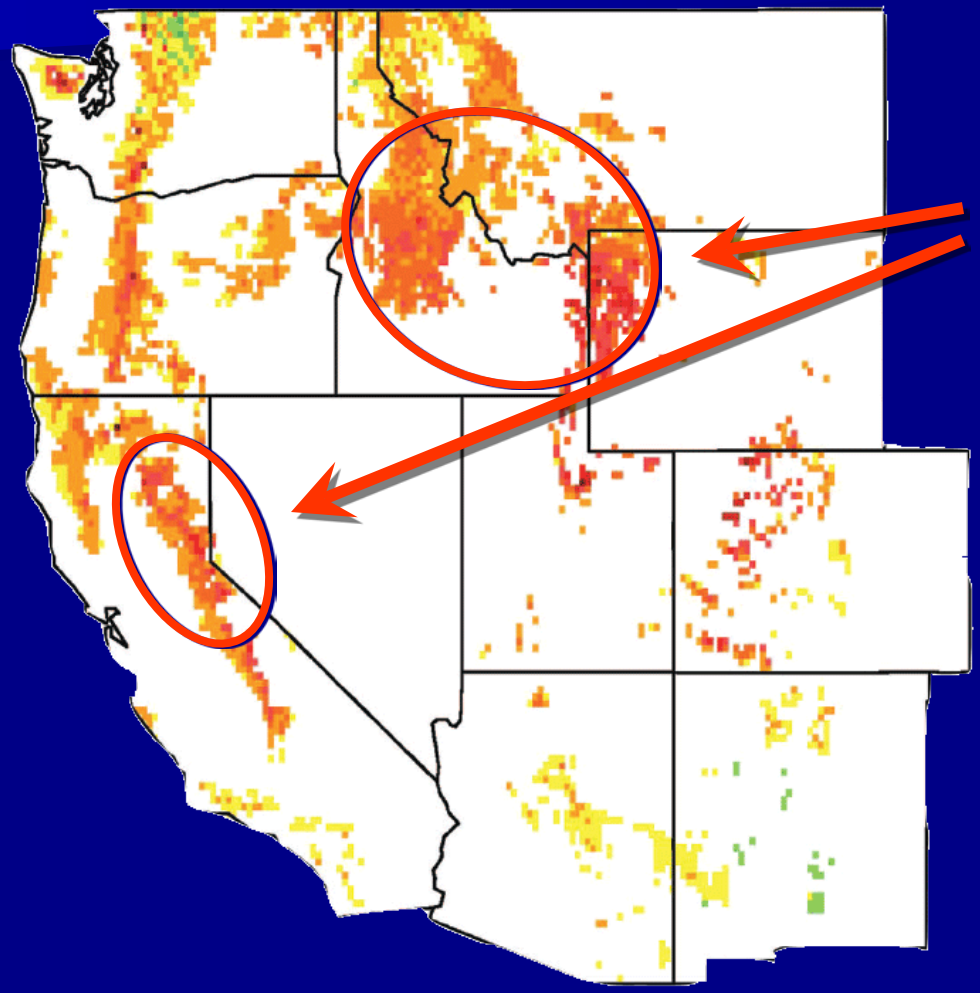
"Climate change could double the area burned by wildfire each year in the western United States by the end of the century, according to a new study. Using a high-resolution computer model, researchers found that the area burned by wildfire has increased by 400 percent in the past 30 years, and could increase by another 200 percent by the end of the century. The study's lead author, Anthony Westerling, said the increase is driven by a combination of warmer temperatures and changes in precipitation patterns. 'We're projecting a 54 percent increase in the area burned by wildfire for each degree Celsius of warming,' he said. 'That's a big deal.' The study also found that the length of the fire season could increase by 10 to 30 days, depending on the region. Westerling said the longer fire season would put more pressure on firefighting resources and could lead to more frequent and larger fires. 'We're going to have to rethink how we manage fire in the West,' he said. 'We're going to have to be more proactive and less reactive.' The study was published in the journal Science."

# *Western Wildfires and Spring-Summer Temperature*




Source: Westerling et al. (2006)

# *Western Wildfires and Moisture Deficit*



¾ of the increased wildfire frequency since the mid-1980s

Moisture Deficit: Potential Evapotranspiration vs. Available Moisture

Source: Westerling et al. (2006)

# *Melting Glaciers*

Riggs Glacier
Glacier Bay NP
2004

## *Melting Glaciers*

- Changed hydrologic patterns of glacier-fed streams
- Warmer water temperatures
- Changed water chemistry
- Some streams dry up in summer
- Loss of aquatic species
- Impacts on riparian zones and uplands

## *Melting Glaciers*

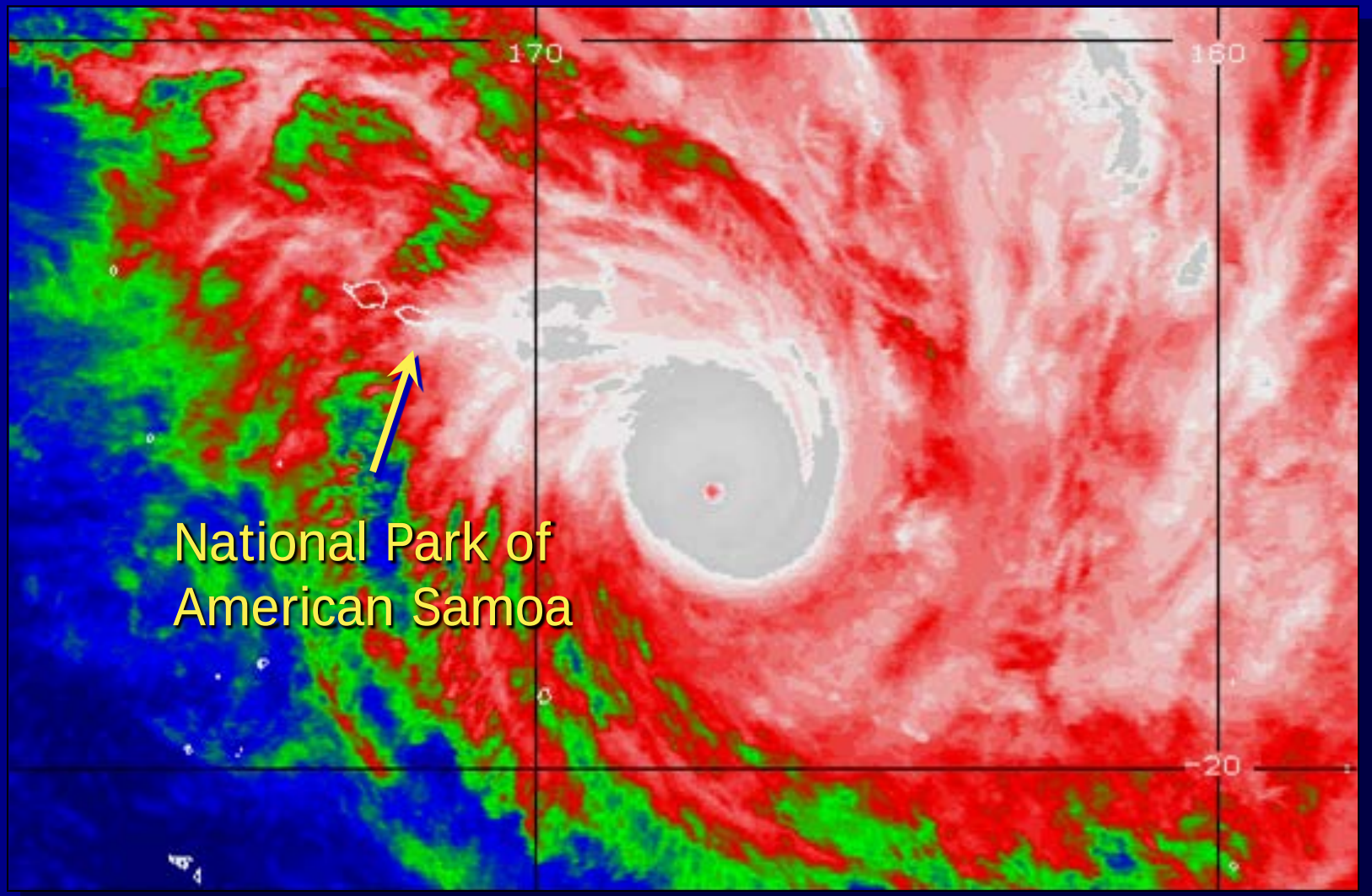
With more than one-sixth
of the Earth's population
relying on glaciers and
seasonal snow packs
for their water supply,
the consequences of
these hydrological changes
for future water availability --
predicted with high confidence
and already diagnosed
in some regions --
are likely to be severe.

Barnett, T. P., J. C. Adams, and D. P. Lettenmaier. 2005. Potential Impacts of a Warming Climate on Water Availability in Snow-Dominated Regions. *Nature* 430(4066):303-309.

## *Warming Oceans*

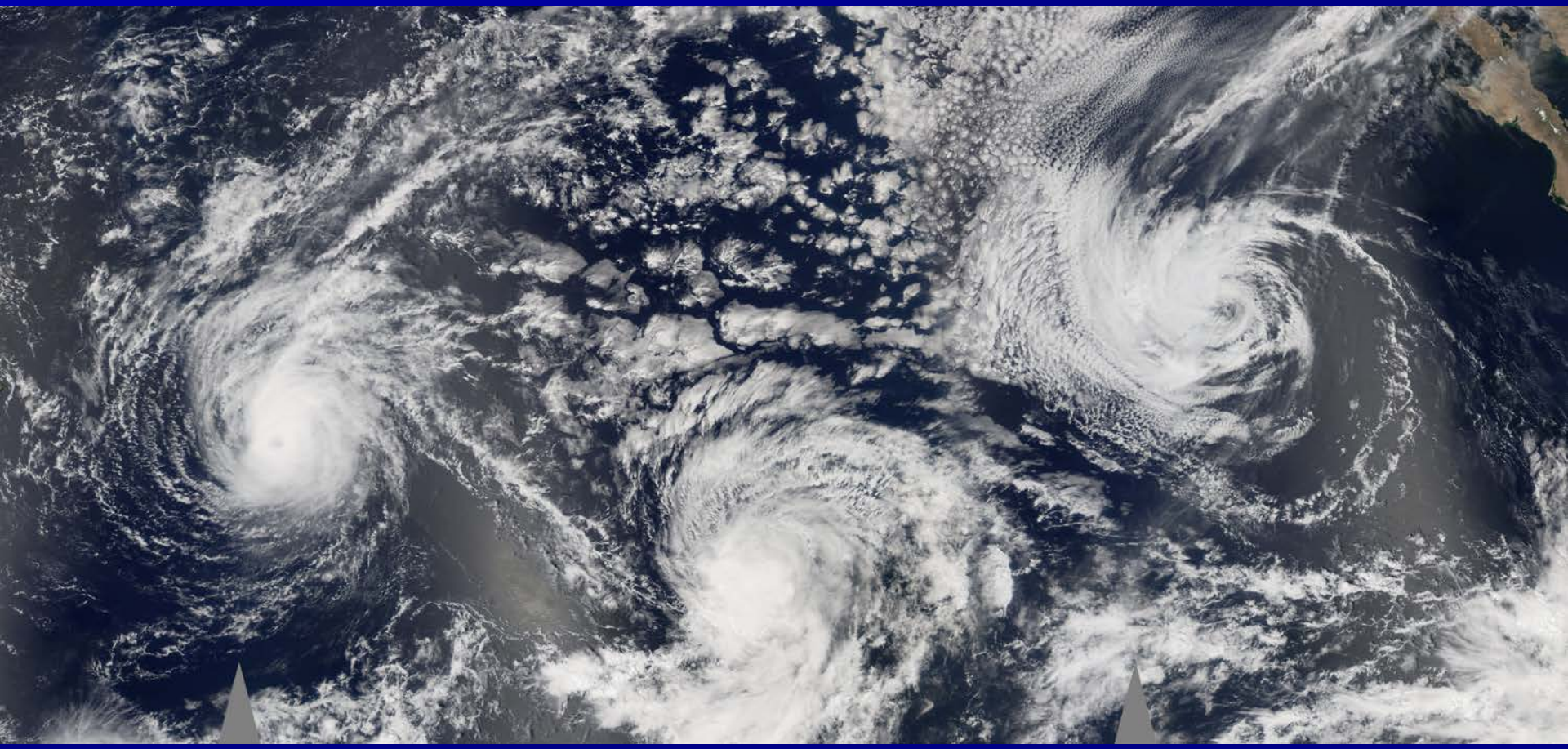
- Coral bleaching
- Reduced calcification of corals
- Increased intensity of storms

# *Warming Oceans*




Cyclone Olaf - Feb. 17, 2005

# *Warming Oceans*



Hurricanes Jova and Kenneth, Tropical Storm Max,
and the developing Tropical Storm Norma in the Pacific

September 21, 2005

NASA photo

## *Warming Oceans*

- Increased damage by hurricanes and typhoons, as well as tornadoes and other storms.

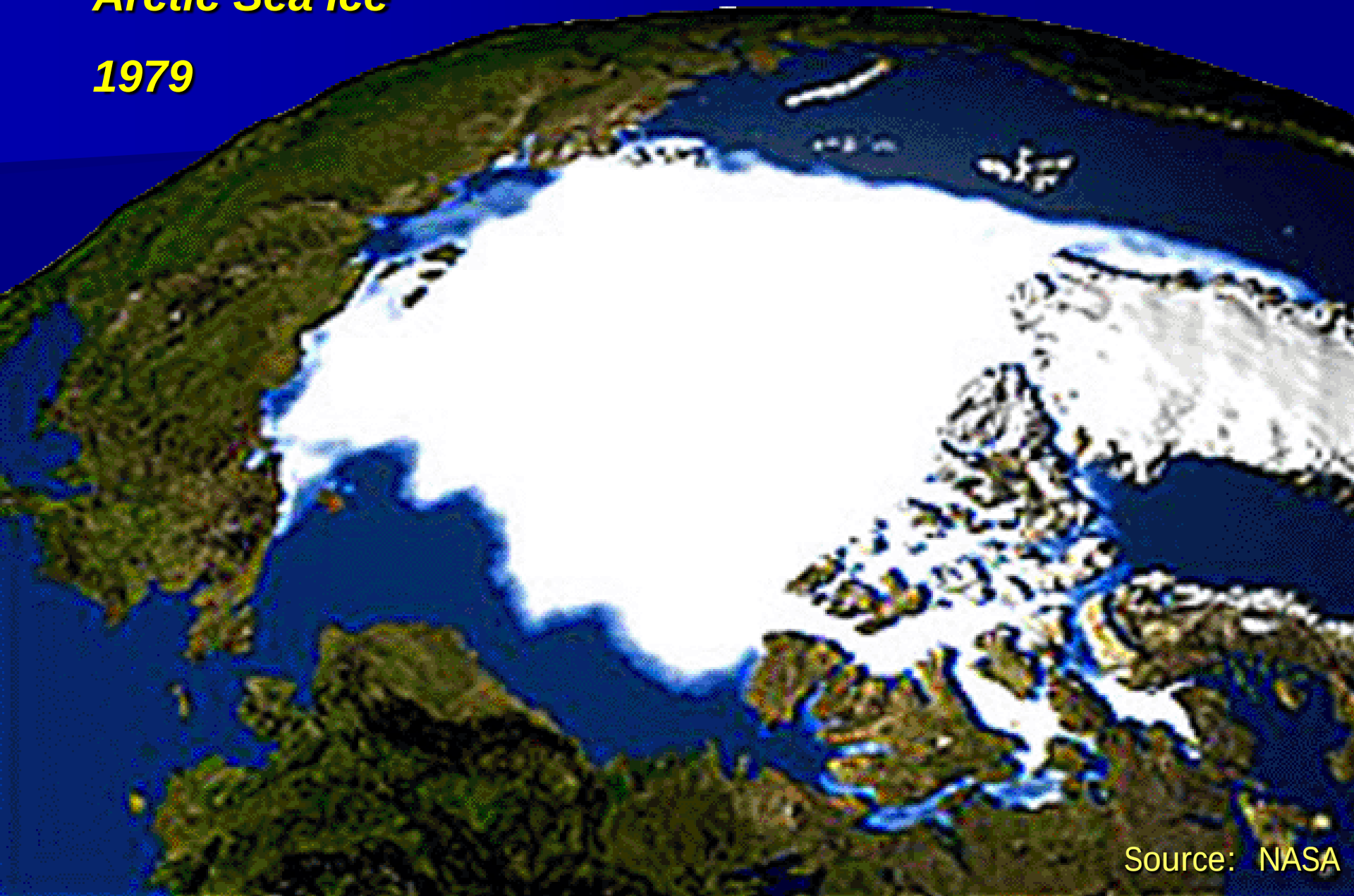
# *Warming Oceans & Atmosphere*

- Sea ice thins
- Polar ice sheets melt
- Ice shelves collapse

Photo by World Wildlife Fund

***Arctic Sea Ice***

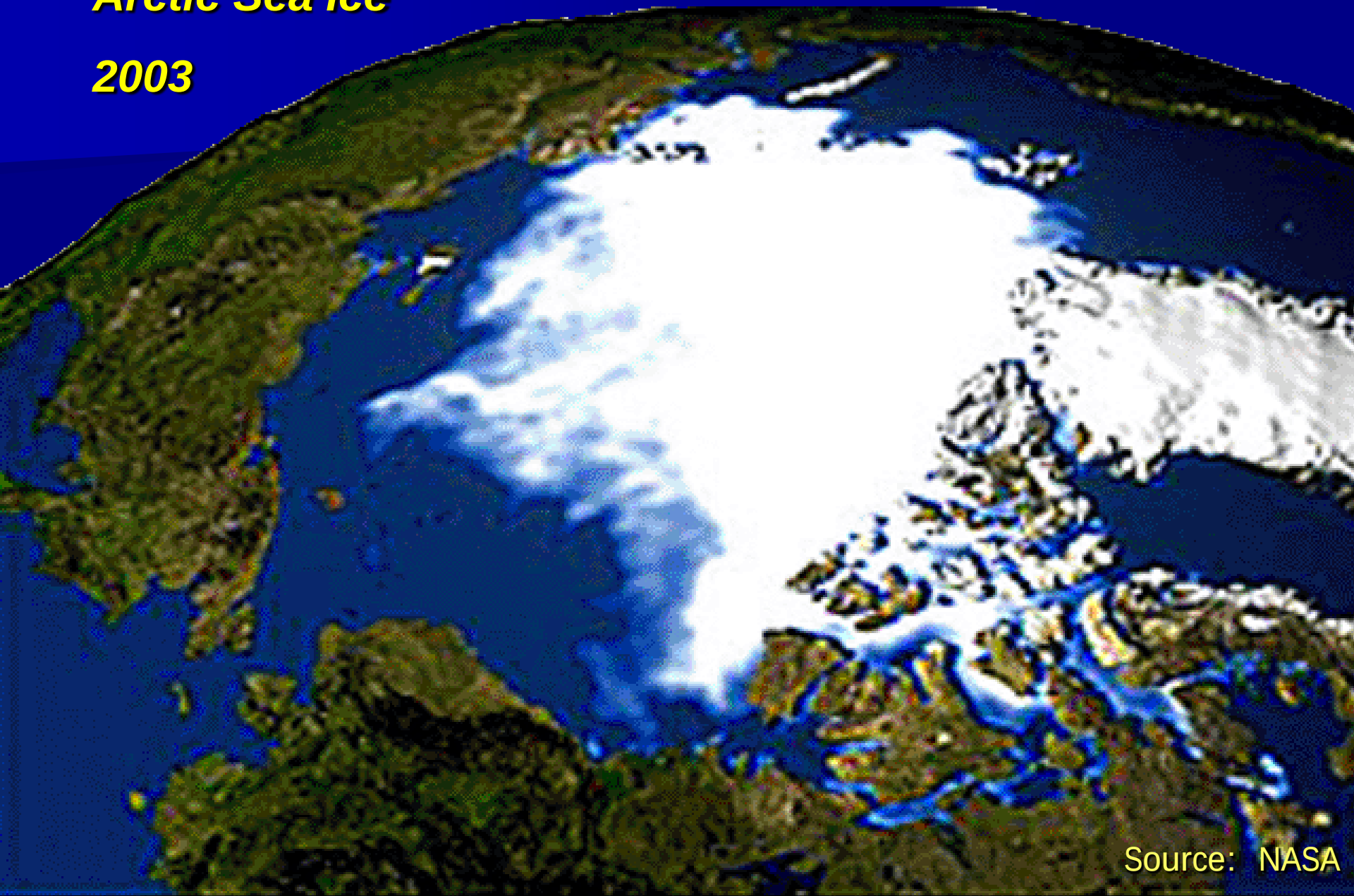
***1979***



Source: NASA

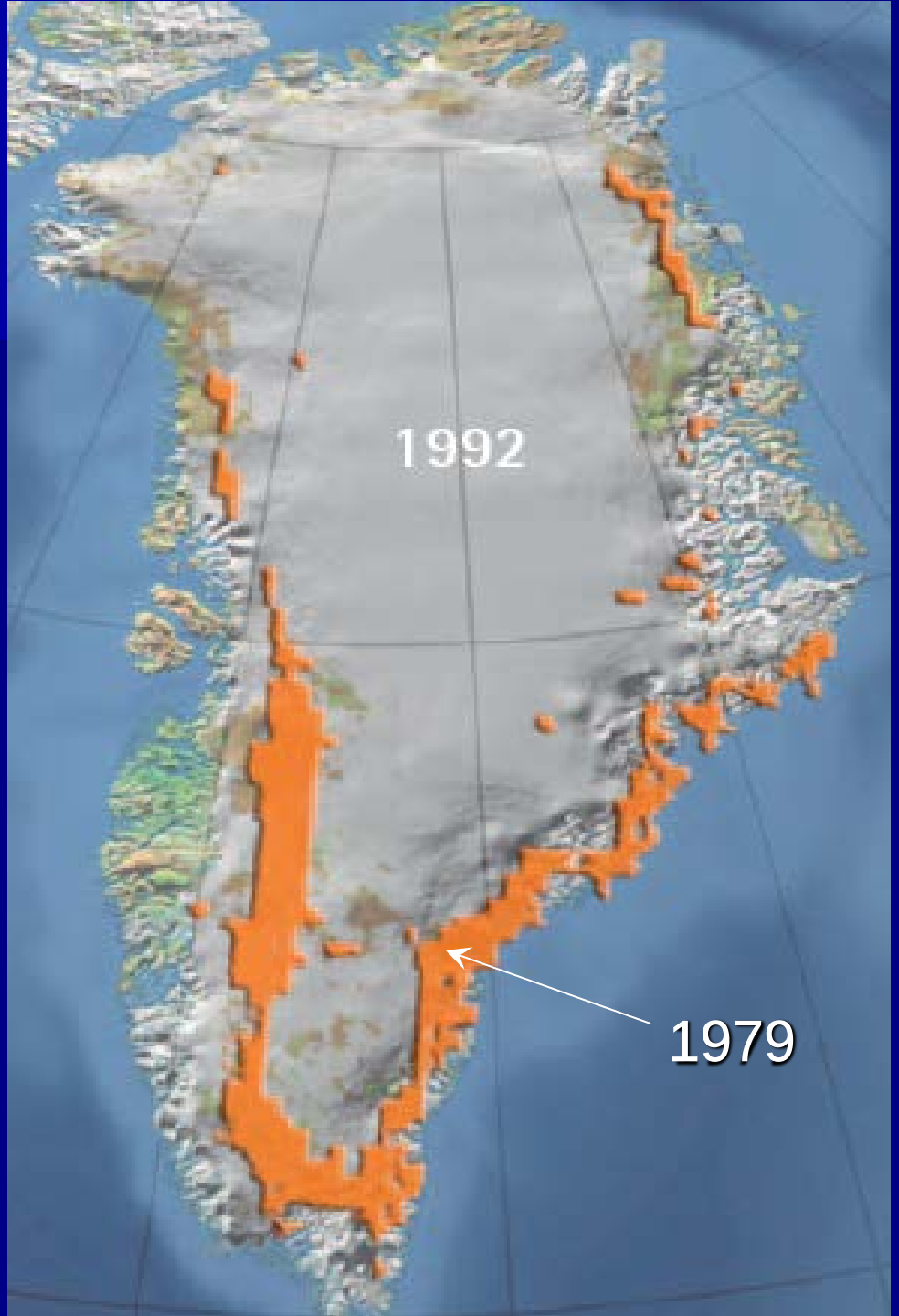
***Arctic Sea Ice***

***2003***



Source: NASA

## *Greenland*




5° F ➔ Complete melting?

- Sea ice thins
- Ice shelves collapse
- Polar ice sheets melt
- Sea levels rise

Shishmaref, Alaska

- Sea ice thins
- Ice shelves collapse
- Polar ice sheets melt
- Sea levels rise

Maldive Islands

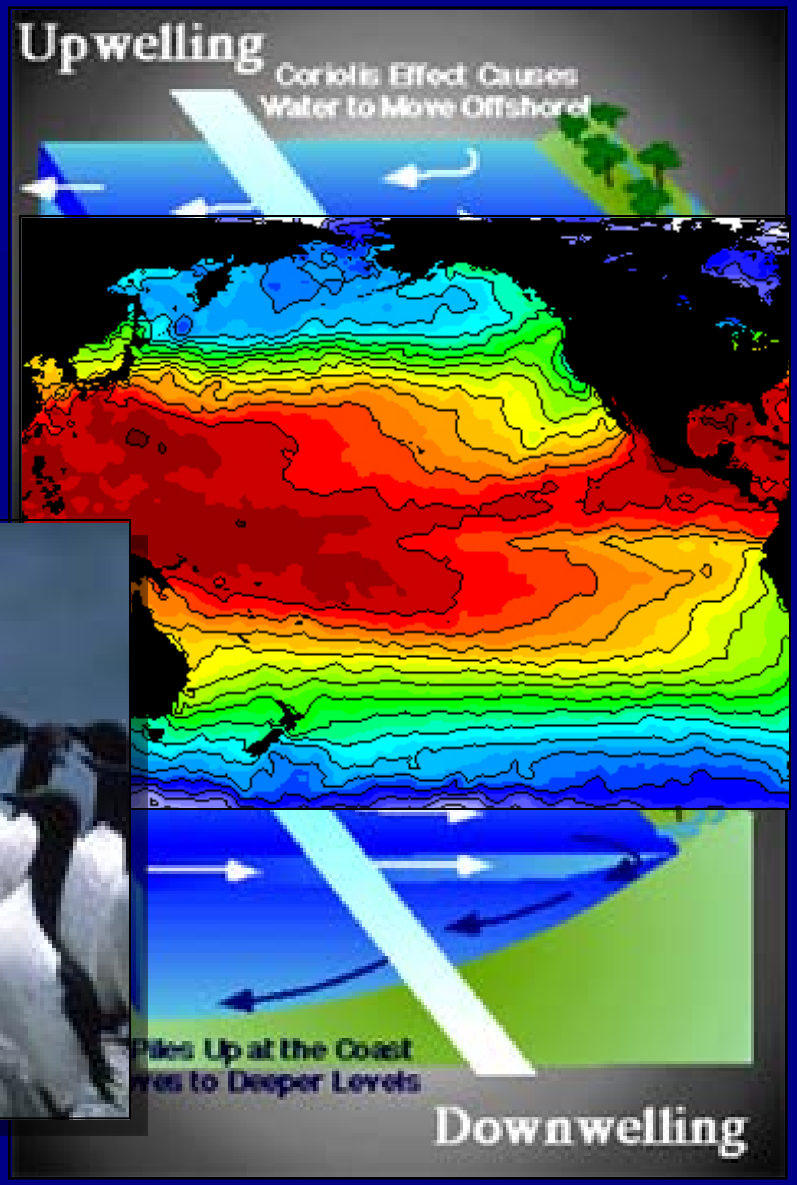
80% of the area is under 1 meter in elevation.

- Sea ice thins
- Ice shelves collapse
- Polar ice sheets melt
- Sea levels rise

Bangladesh

Population: 144 million

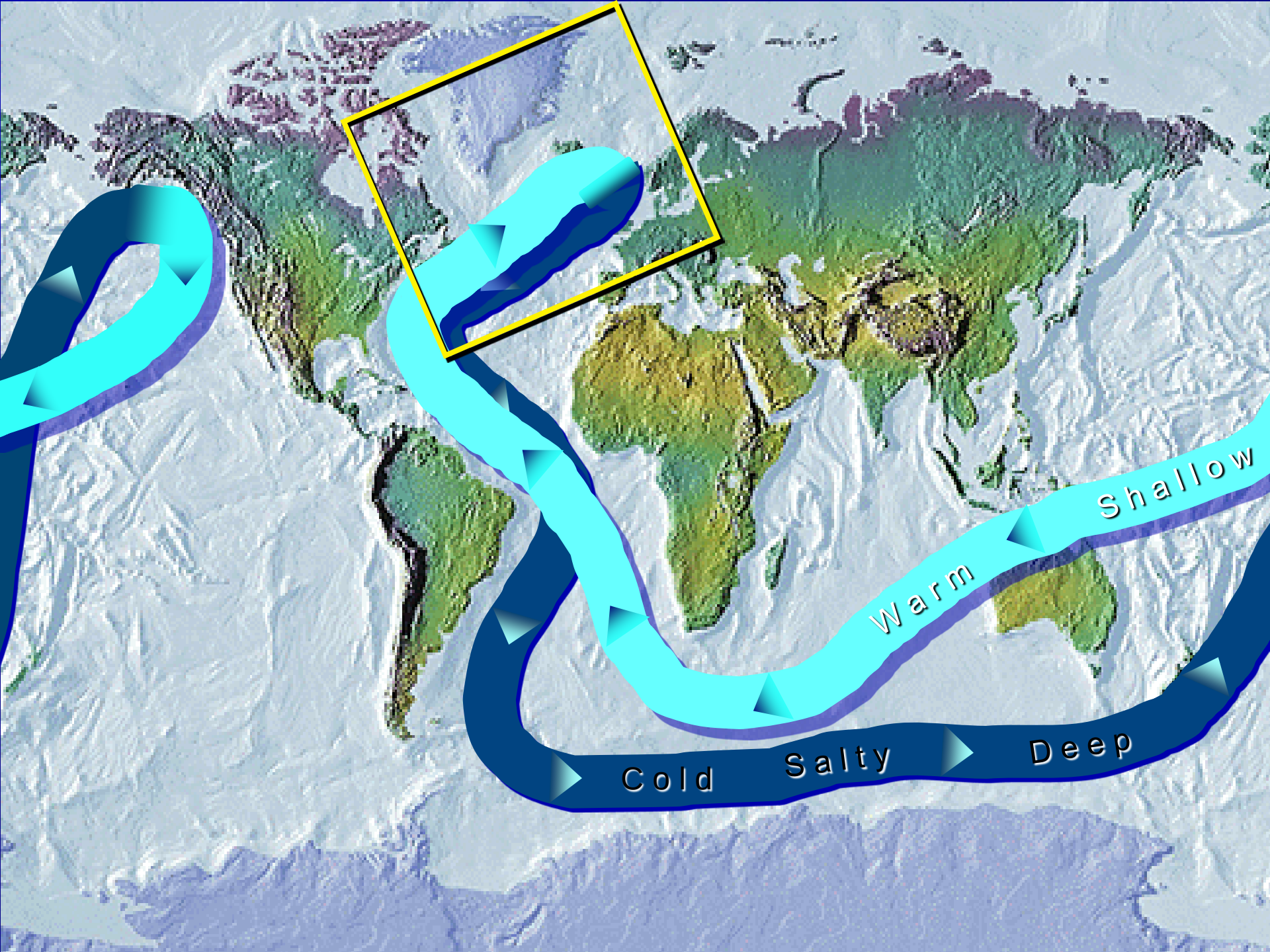
- Sea ice thins
- Ice shelves collapse
- Polar ice sheets melt
- Sea levels rise
- Ocean currents shift




Graphic from: University of Washington

- Sea ice thins
- Ice shelves collapse
- Polar ice sheets melt
- Sea levels rise
- Ocean currents shift
- Dead zones

NASA image


Warm
Shallow
Cold
Salty
Deep

## *Why Isn't this Common Knowledge?*

928 scientific studies of climate change:

Not a single paper disagreed with the consensus position of the Inter-Governmental Panel on Climate Change (IPCC), the National Academy of Sciences, and the public statements of professional scientific societies that global warming is occurring, and the primary cause is human activities.

Source: Kerr, Richard A. 2004. Climate Change: Three Degrees of Consensus. *Science* 305(5686):932-934.

## *Why Isn't this Common Knowledge?*

636 articles on climate change
in 4 major U.S. newspapers:

- 52.7% presented the story as a matter of conflicting viewpoints.
- One-third emphasized the role of humans.

"Politicians, economists, journalists, and others may have the impression of confusion, disagreement, or discord among climate scientists, but that impression is incorrect."

Source: Boykoff, Maxwell T., and Jules M. Boykoff A. 2004. Balance as Bias: Global Warming and the US Prestige Press. *Global Environmental Change* 14(2):125-136.

# an inconvenient truth

A GLOBAL WARNING

# *Global Warming in the Media*

April
2006

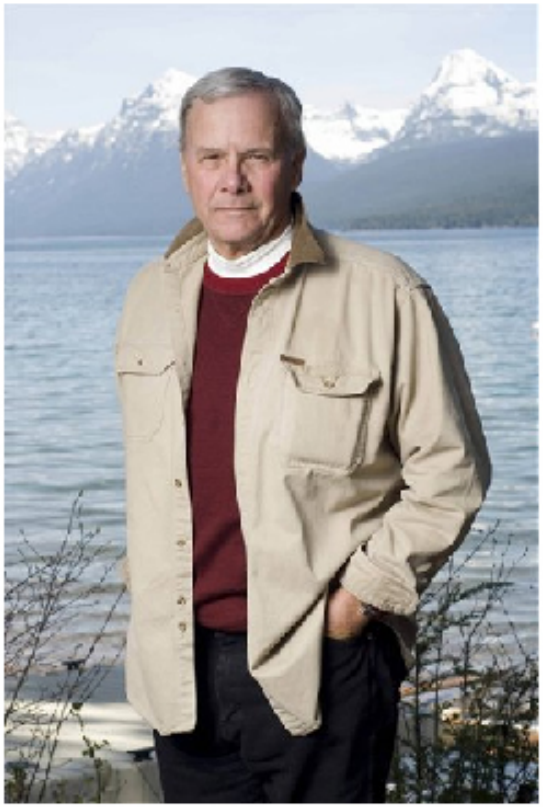
# *Global Warming in the Media*

July
2006

## Brokaw Joins Fight Against Global Warming

**Former NBC anchorman Tom Brokaw joins battle against global warming with Discovery show**

NEW YORK, Jul. 9, 2006
By DAVID BAUDER AP Television Writer



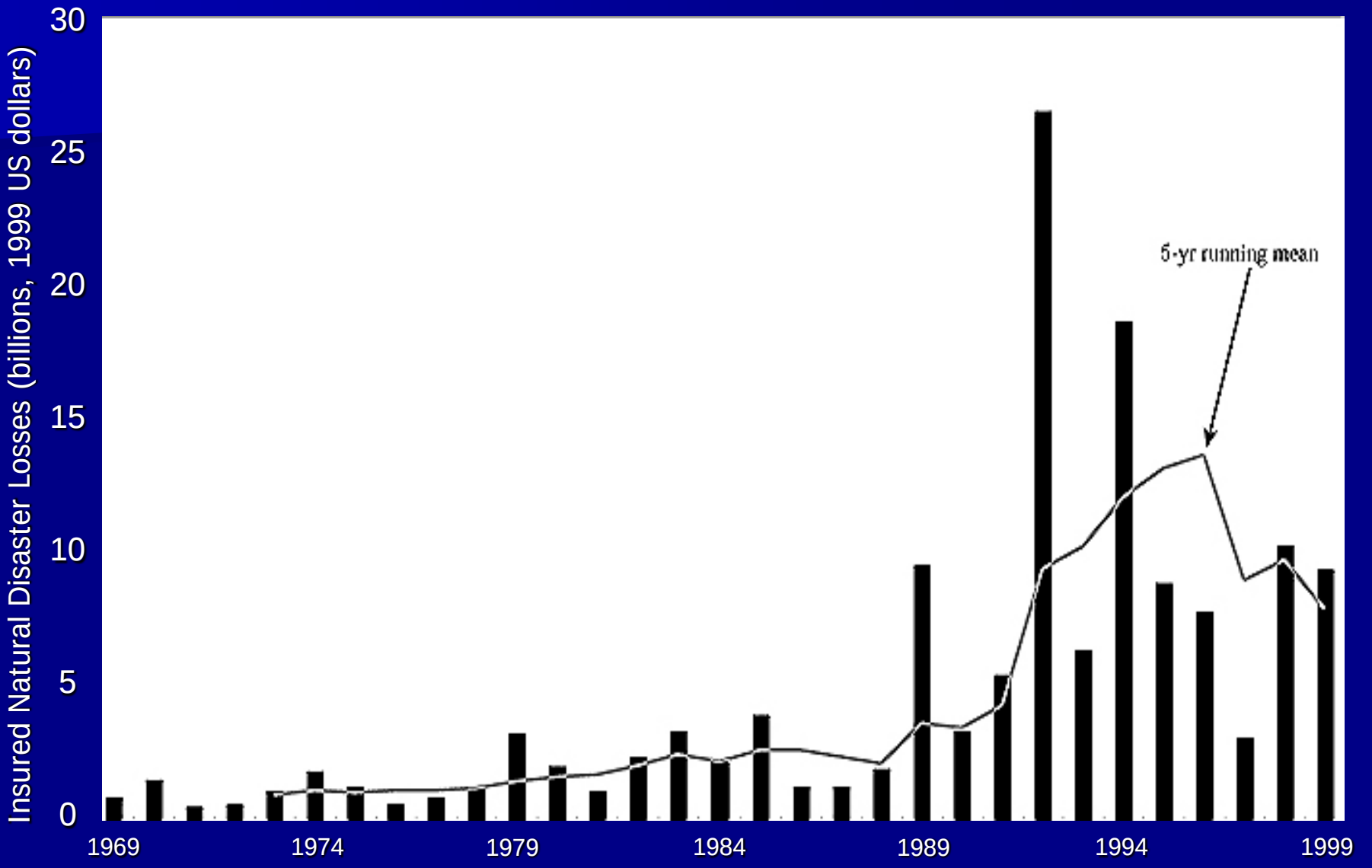
(AP)

**(AP)** Tom Brokaw is giving Al Gore some company in the effort to raise awareness of global warming. The former NBC anchorman is host of "Global Warming: What You Need to Know," which doubles as an explainer and call to action for average Americans. It premieres Sunday at 9 p.m. on the Discovery Channel.

Brokaw said he has seen and was impressed by "An Inconvenient Truth," Gore's documentary on the subject.

"It's the same science that we are drawing upon and it's irrefutable," he said. "I thought there was too much of Gore, but that's not my call. I thought it was very effectively done. To give credit to him, he's been on this issue for a long period of time."

# Businesses Are Taking Action




Source: Intergovernmental Panel on Climate Change

# CLIMATE CHANGE
## ADAPT OR BUST

**Until recently, world opinion has been divided: are current weather trends the result of long-term climate change or not? And what role, if any, has climate change played in the recent spate of weather-related catastrophes?**

The facts are often confused by politics and by a wealth of different – and sometimes conflicting – evidence from a range of scientific and other sources.

However, a growing body of expert opinion now agrees that the climate is changing – and that human activity is playing a major role. Most worryingly, the latest science suggests that future climate change may take place quicker than previously anticipated.

There will continue to be much argument, over both the extent of future climate change and its likely impact on society. But whatever the facts, there could hardly be a debate of greater importance to the insurance industry.

The past few years highlight bluntly the cost of weather-related catastrophes for the global economy and the insurance industry in particular. The industry's response has proven that it is financially strong and well-equipped to respond to these financial shocks.

It is equally clear that, so far, the industry has not taken changing catastrophe trends seriously enough. Climate change is likely to bring us all an even more uncertain future. If we do not take action now to understand the risks and their impact, the changing climate could kill us.

In publishing this report, it is not Lloyd's intention to take a particular position, or to support a specific scenario. We simply aim to present the facts from the most reliable sources in a way which we hope will be helpful for those who trade in, and with, our market. We also want to generate debate about the specific steps which we might take as an industry to prepare for the increasing volatility of the climate.

# FACT:

## IF THE SEA LEVEL WERE TO RISE JUST FOUR METRES DUE TO CLIMATE CHANGE, ALMOST EVERY COASTAL CITY IN THE WORLD WOULD BE INUNDATED.

Population Reference Bureau, www.prb.org, 2006

360

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# EXECUTIVE SUMMARY

## 2 RECENT EVENTS HAVE SHOWN CAPITAL AND PRICING MODELS TO BE WANTING. WE MUST REGULARLY UPDATE AND RECALIBRATE OUR MODELS TO KEEP PACE WITH REALITY.

Catastrophe modelers have now reacted to criticisms following the recent record US hurricane seasons. However, much of this work could and should have been done prior to these events.

Going forward, the industry must take a new approach to underwriting, looking ahead and not simply basing decisions on historical patterns. Insurer pricing and capital allocation models must be updated regularly – and not just *in extremis* – to reflect the latest scientific evidence.

# EXECUTIVE SUMMARY

## 4 CLIMATE CHANGE MEANS EXPOSURES ARE CHANGING AND NEW ONES EMERGING. INSURERS MUST REGULARLY REVIEW AND COMMUNICATE CONDITIONS OF COVERAGE.

We foresee an increasing possibility of attributing weather losses to man-made factors, with courts seeking to assign liability and compensation for claims of damage.

Exposures can also be expected to increase in respect of property, business interruption, and political risks, demanding the same response.

That means the insurance industry will want to regularly review conditions of coverage against risk, appetite, and do more to educate the public about changing exposures .

The industry can help by creating incentives for policy holders to reduce risk. Opportunities for those insurance markets which are flexible and innovative will emerge too. As society

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# EXECUTIVE SUMMARY

## 6 EFFECTIVE PARTNERSHIP WITH BUSINESS AND GOVERNMENT WILL BE KEY TO MANAGING RISK. THE INSURANCE INDUSTRY MUST ENGAGE NOW.

Based on long experience, Lloyd's believes that insurance markets operate most efficiently when left to free-market forces, and the vast majority of natural perils are insurable – as long as the market is free to price risk adequately.

However, if this freedom is removed, or if the pace of climate change grows faster than expected, this could change our view. Industry strategists will want to consider the long-term insurability of weather-related risk.

We believe that a meaningful partnership with government and business, supported by a series of practical actions, has the best chance of providing solutions. In particular, this should address the issue of increasing concentrations of population and economic wealth in high-risk areas, for example on coasts. This report focuses on adaptation, but we recognise that mitigation of the risk itself (i.e. the reduction of $CO_2$ emissions) is critical.

## *State and Local Governments Are Taking Action*

July 2005:

U.S. Conference of Mayors agreed to implement the provisions of the Kyoto Protocol, including a reduction in emissions to 6% below the 1990 levels by the year 2012.

Thus far, 169 cities have agreed to these standards.

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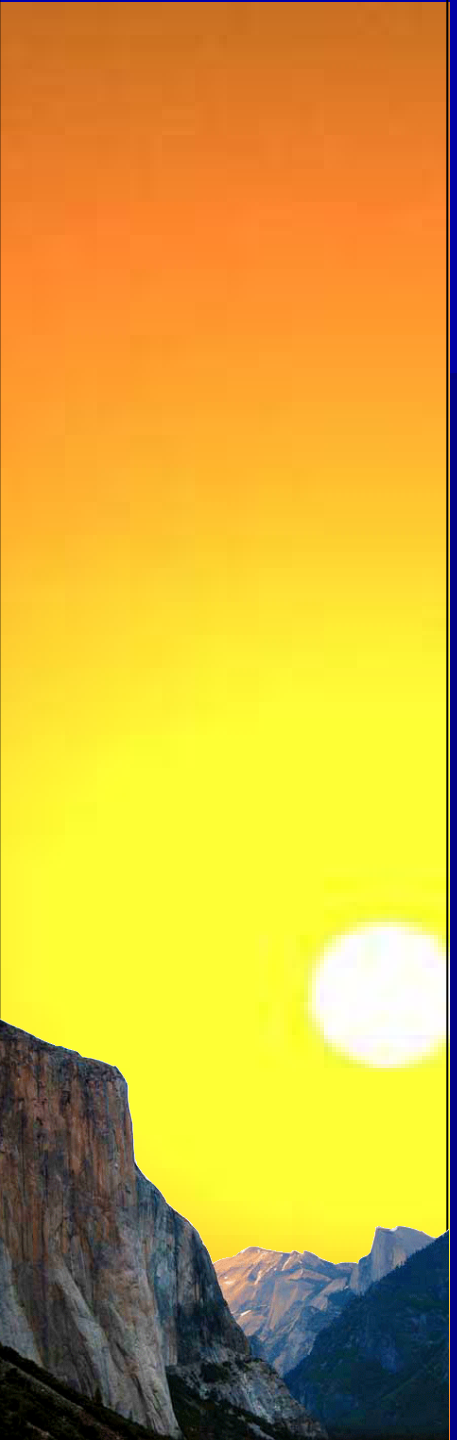
# State and Local Governments Are Taking Action



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Oregon Department of Energy

## West Coast States Strengthen Joint Climate Protection Strategy

**November 18, 2004**

**The Governors of Washington, Oregon, and California today approved a series of recommendations for action to combat global warming, and directed their staffs to continue working on state and regional goals and strategies to combat global warming over the coming year. A staff report to the three governors stated:**

**"Global warming will have serious adverse consequences on the economy, health and environment of the West Coast states. These**

The folowing documents are in PDF format and require the Adobe® Reader.® The free Reader can be downloaded from the Adobe Web site by clicking here. Get Adobe Reader

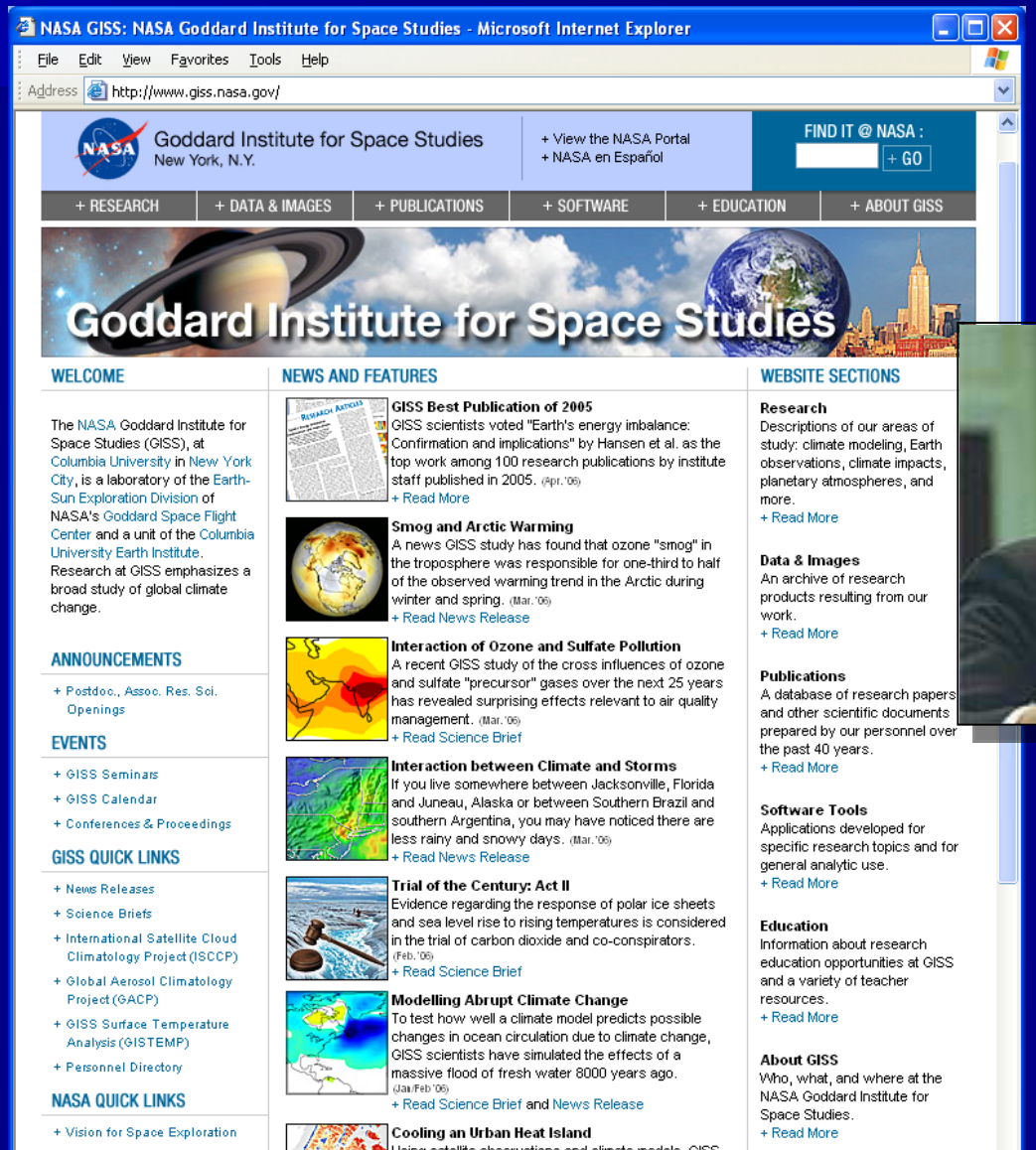
Main Report (Regional)

Appendix A

Appendix B

Appendix C

# *Some Federal Agencies Are Taking Action*



Dr. James E. Hansen
Director

# Some Federal Agencies Are Taking Action

EPA : Global Warming : Resource Center : Tools - Microsoft Internet Explorer

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Address http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterTools.html

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## Tools

Many individuals, communities, and states are interested in estimating emissions or calculating the emissions savings associated with specifi strategies. Others are interested in conducting in-depth analyses of en comparing the energy and cost savings of emission reduction options, successful greenhouse gas mitigation projects. EPA's State and Local compiled the following online tools and resources to meet these needs.

### Calculators

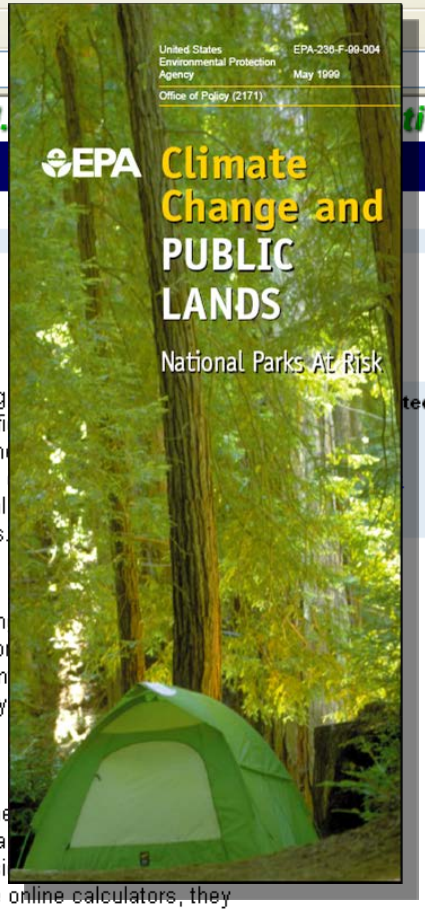
Interactive calculators are available online for assistance with estimatin emissions of specific activities and evaluating emission reduction oppo calculators presented here vary greatly in complexity, scope, and inten arranged by sector, and a brief description of each is provided to help y best suit your needs.

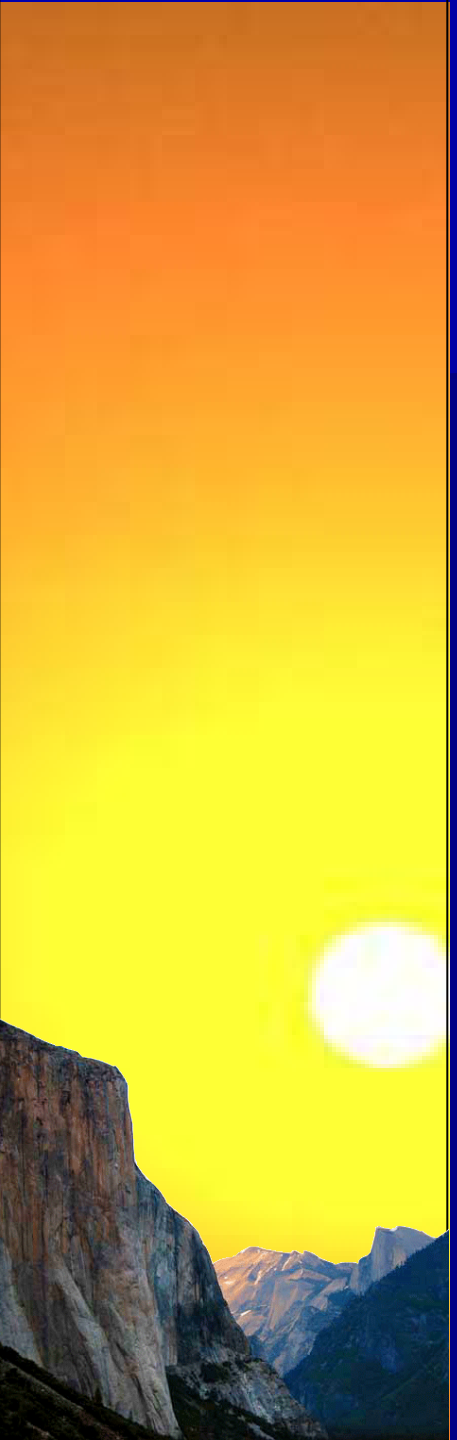
### Software

Computer software packages are available to measure and analyze ene emission reduction opportunities. They also may be used to verify data scenarios, and calculate the energy and cost savings of various emissi software packages are more rigorous in examining emissions than the online calculators, they should provide a higher degree of confidence in the results. A description of each software package is provided.

### Case Studies

Real world examples are useful in evaluating emission reduction options. These case studies





# *What Should the NPS Do?*

# What Should the NPS Do?

US NSF - News - Climate Change Inevitable in 21st Century - Microsoft Internet Explorer

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Press Release 05-043

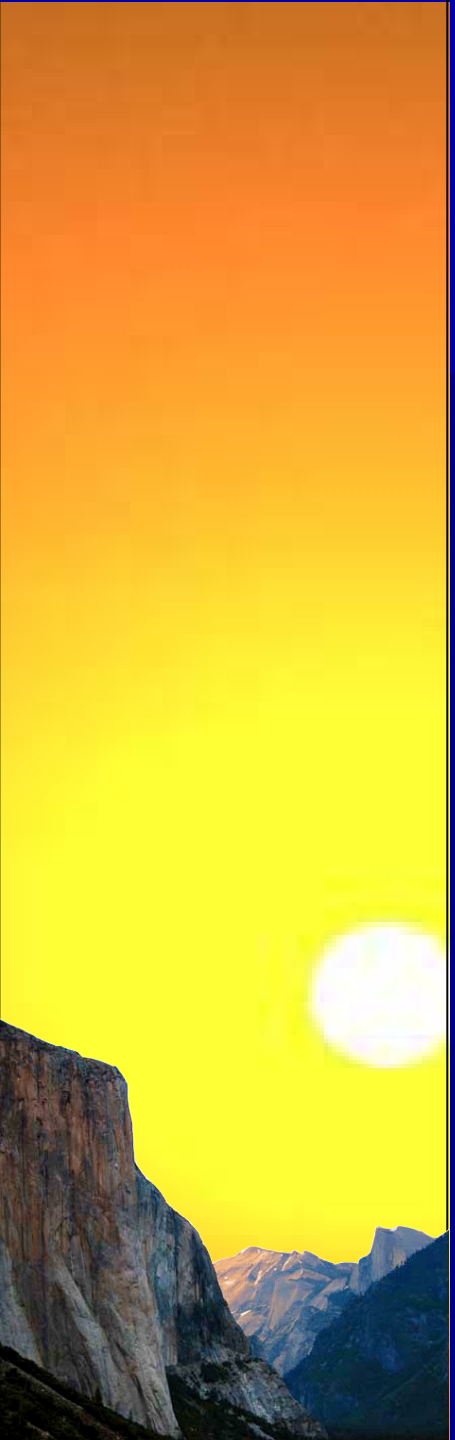
## Climate Change Inevitable in 21st Century

**Rise of sea level to outpace temperature increase**

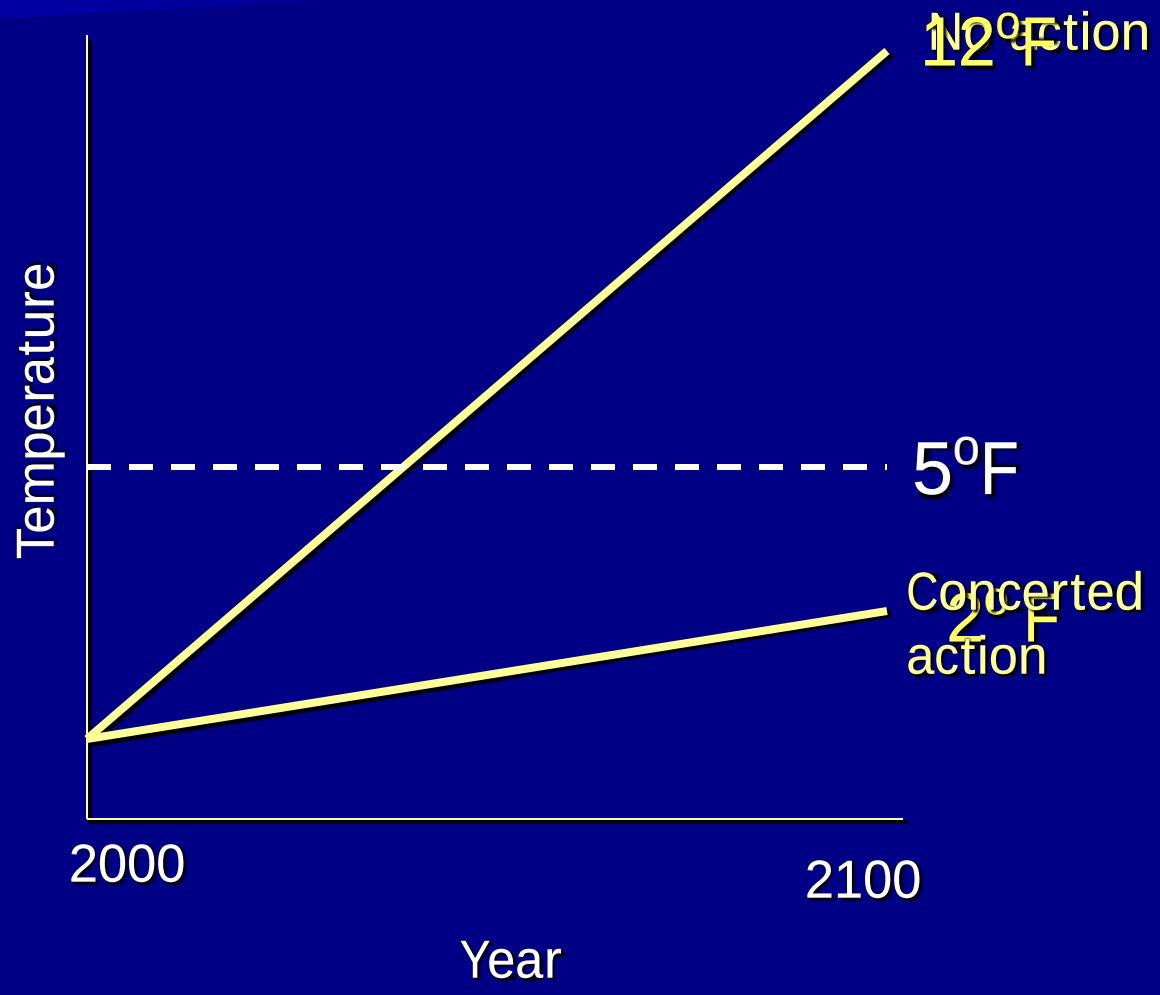
Scientists are studying the interaction between global climate and human influence.
Credit and Larger Version

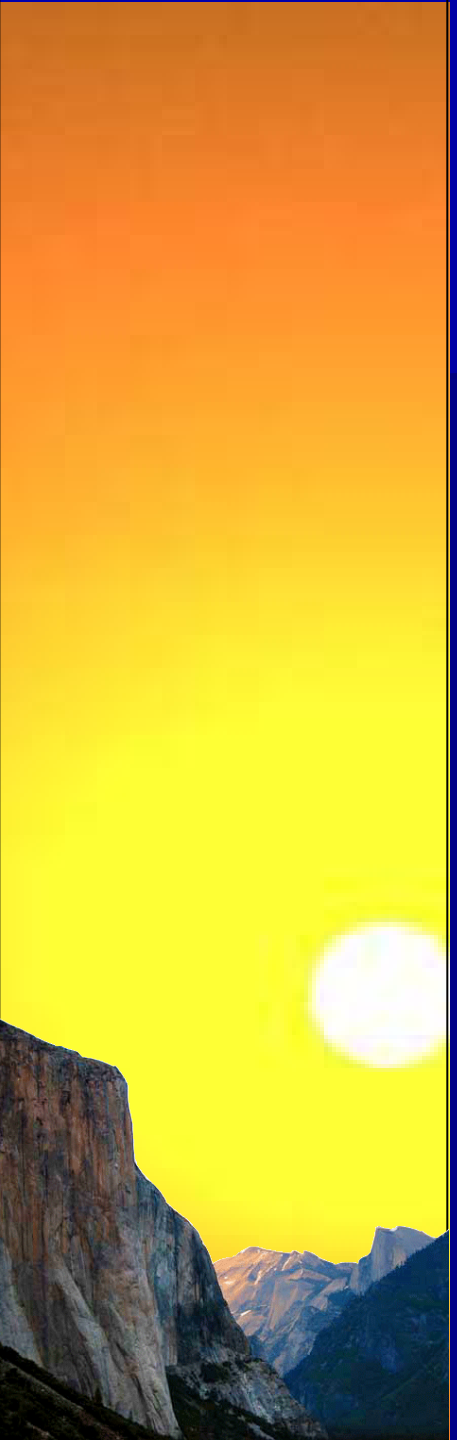
**March 17, 2005**

Even if all greenhouse gases had somehow been stabilized back in the year 2000, we would still be committed to a warmer Earth and greater sea level



## *What Should the NPS Do?*





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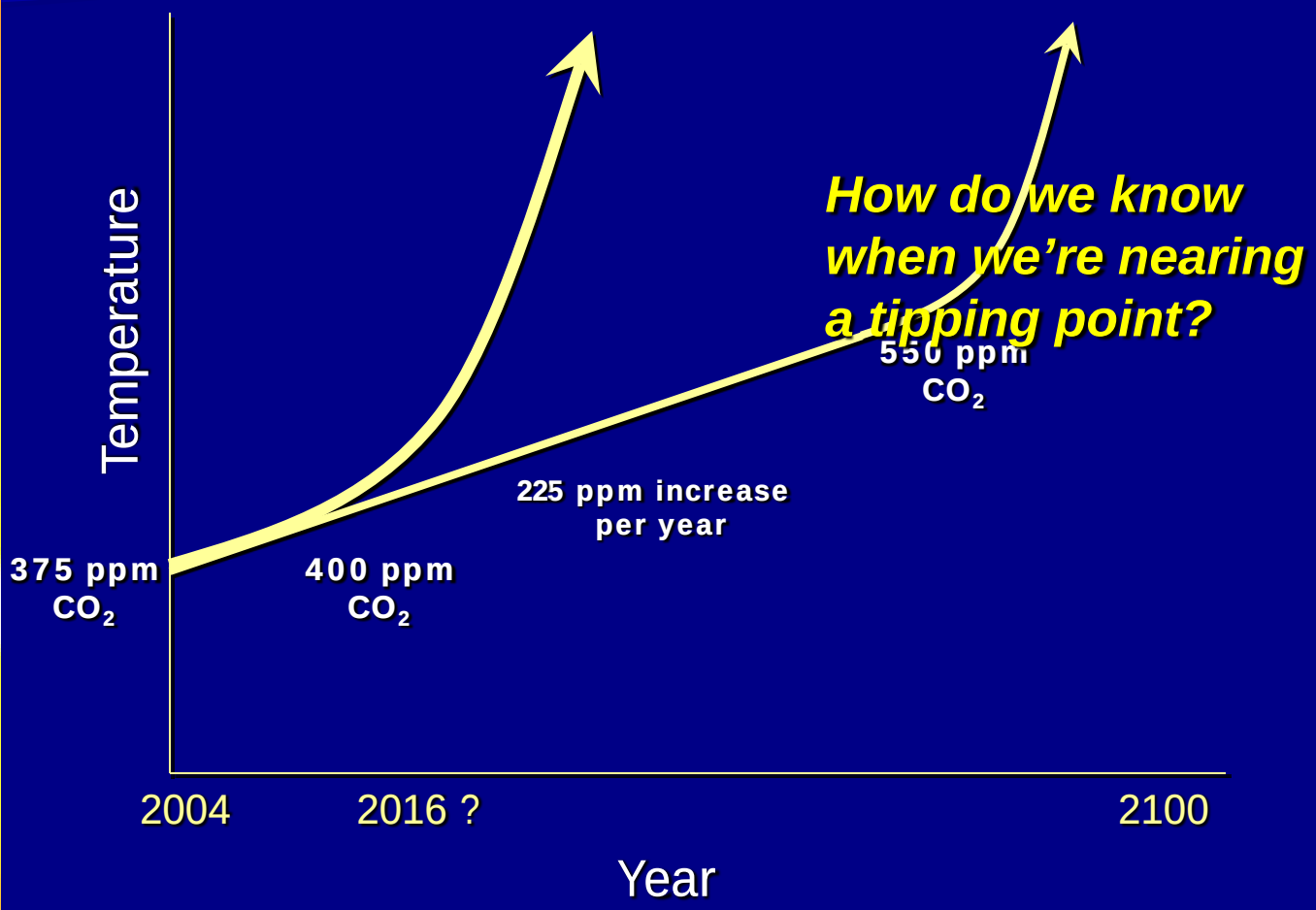
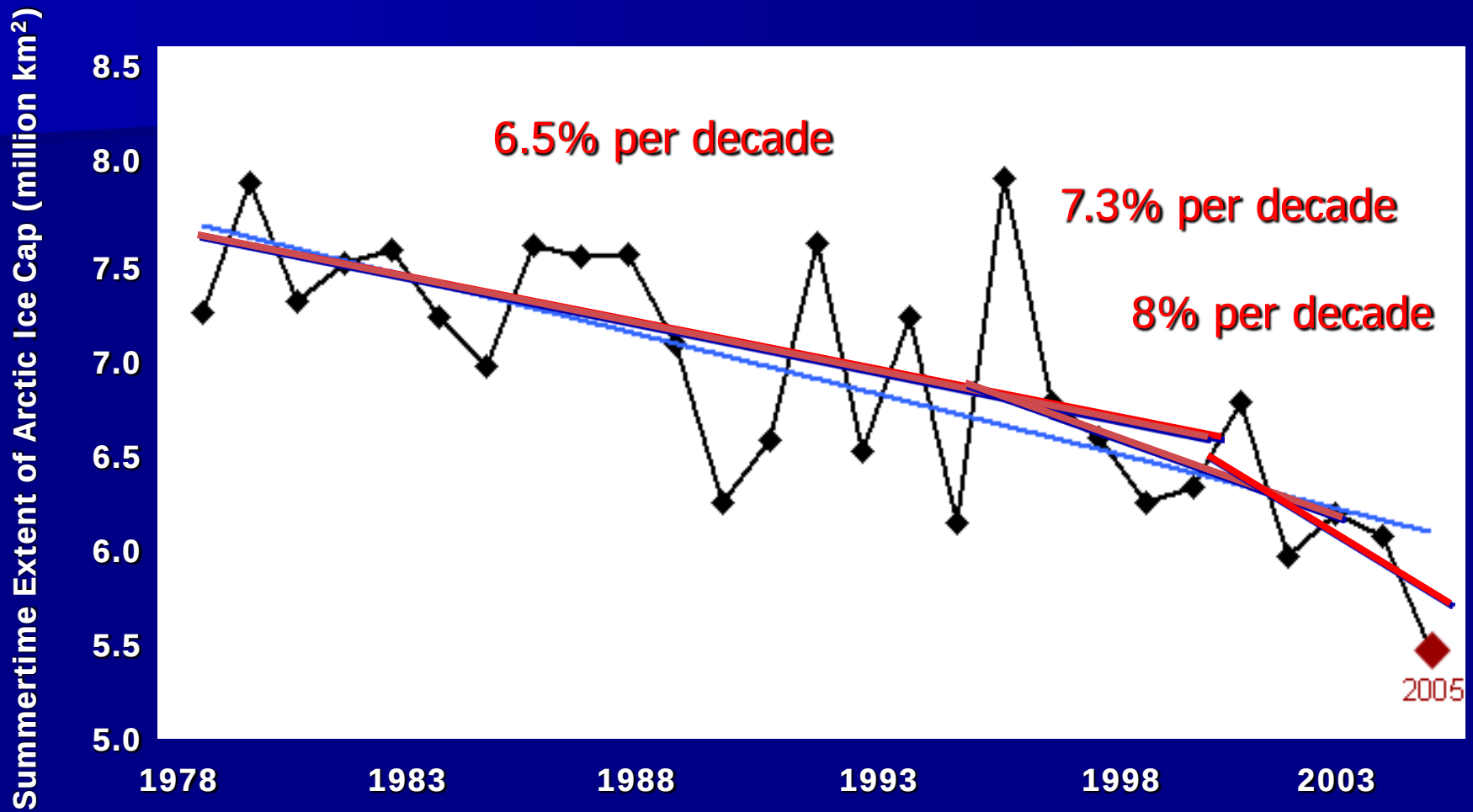


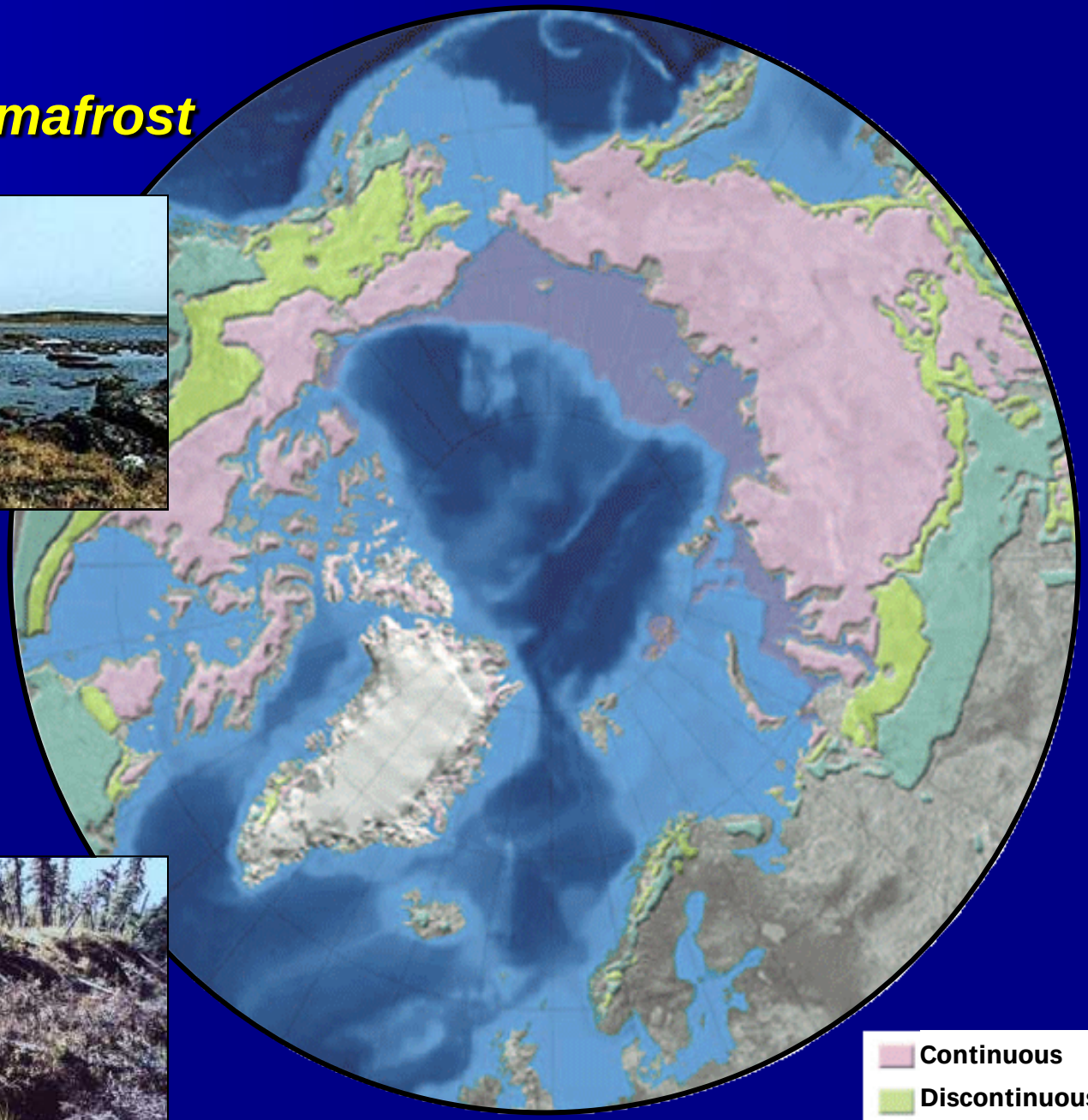

***How do we know when we're nearing a tipping point?***

# *Decline in the Arctic Ice Cap*

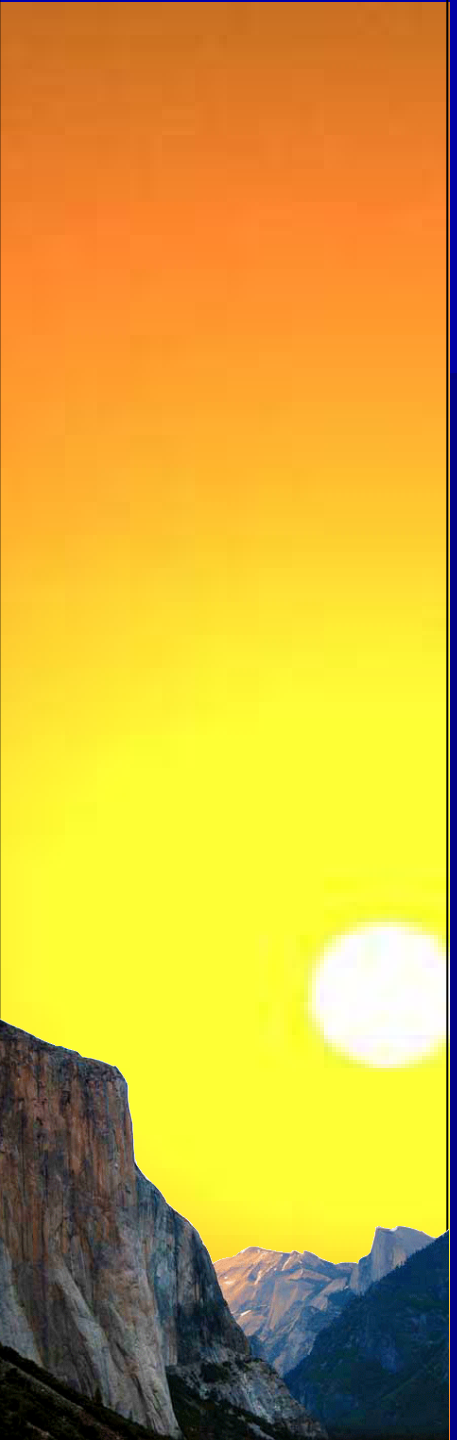


# *Melting Permafrost*

USGS photo

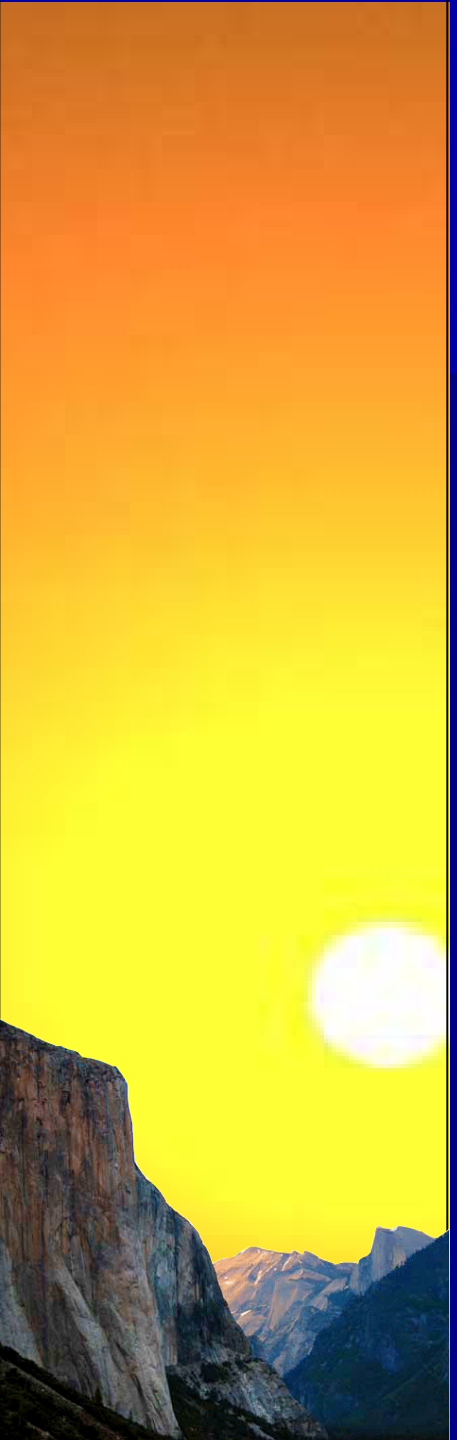



Graphic: Arctic Climate Impact Assessment



# *What Should the NPS Do?*

- Research?



## *What Should the NPS Do?*

"An increasing number of climate impact studies of a range of species, habitats and regions, as well as cross-taxonomic review articles, provide compelling evidence that climate change is already affecting the behavior and distribution of species and the composition and structure of communities and ecosystems.

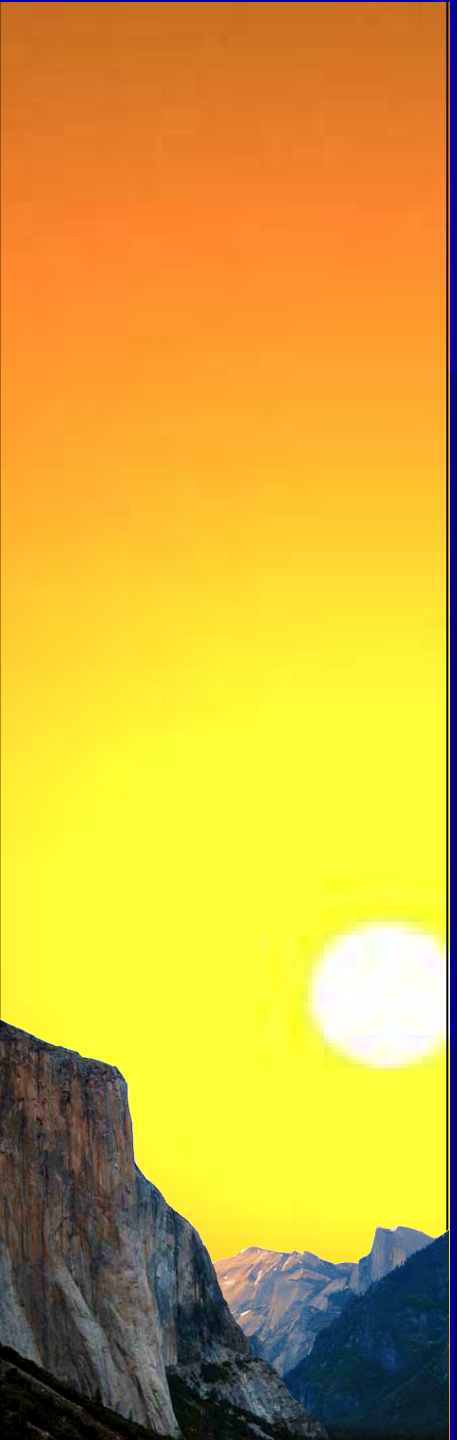

Gian-Reto Walther
*University of Hanover*

Lesley Hughes
*Macquarie University*

Peter Vitousek
*Stanford University*

Nils C. Stenseth
*University of Oslo*


*[2005]*



# *What Should the NPS Do?*

"More research will be valuable, but is not needed to show that climate change is already affecting the Earth in multiple ways."


Gian-Reto Walther
*University of Hanover*

Lesley Hughes
*Macquarie University*

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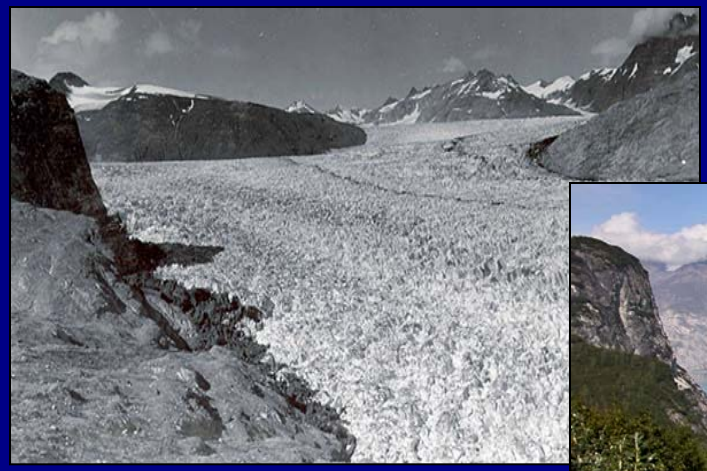
*Stanford University*

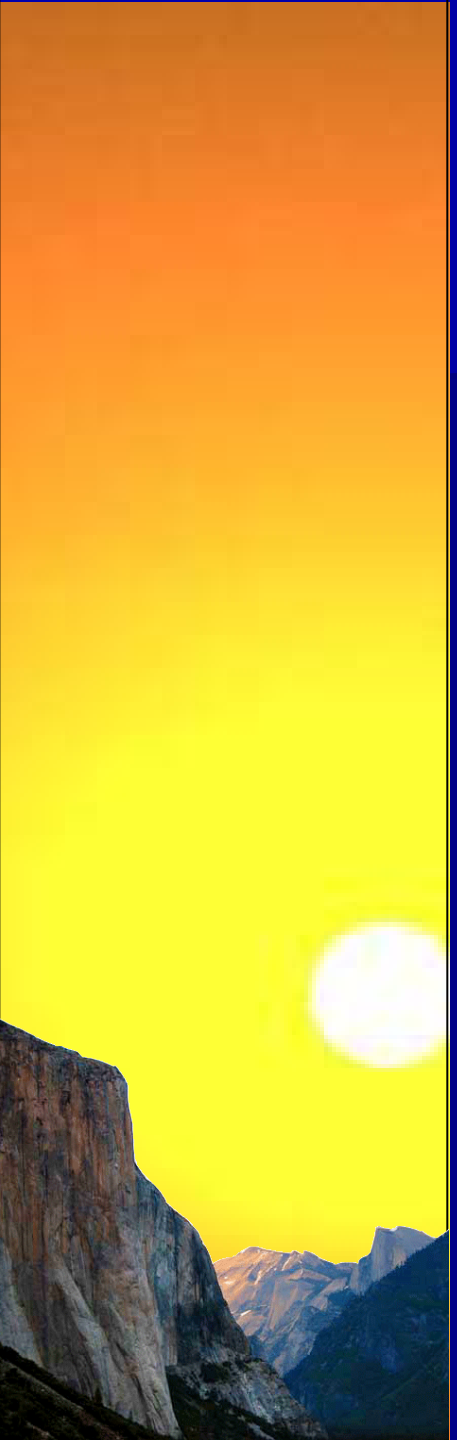
Nils C. Stenseth
*University of Oslo*


*[2005]*

# *What Should the NPS Do?*

- Monitoring?

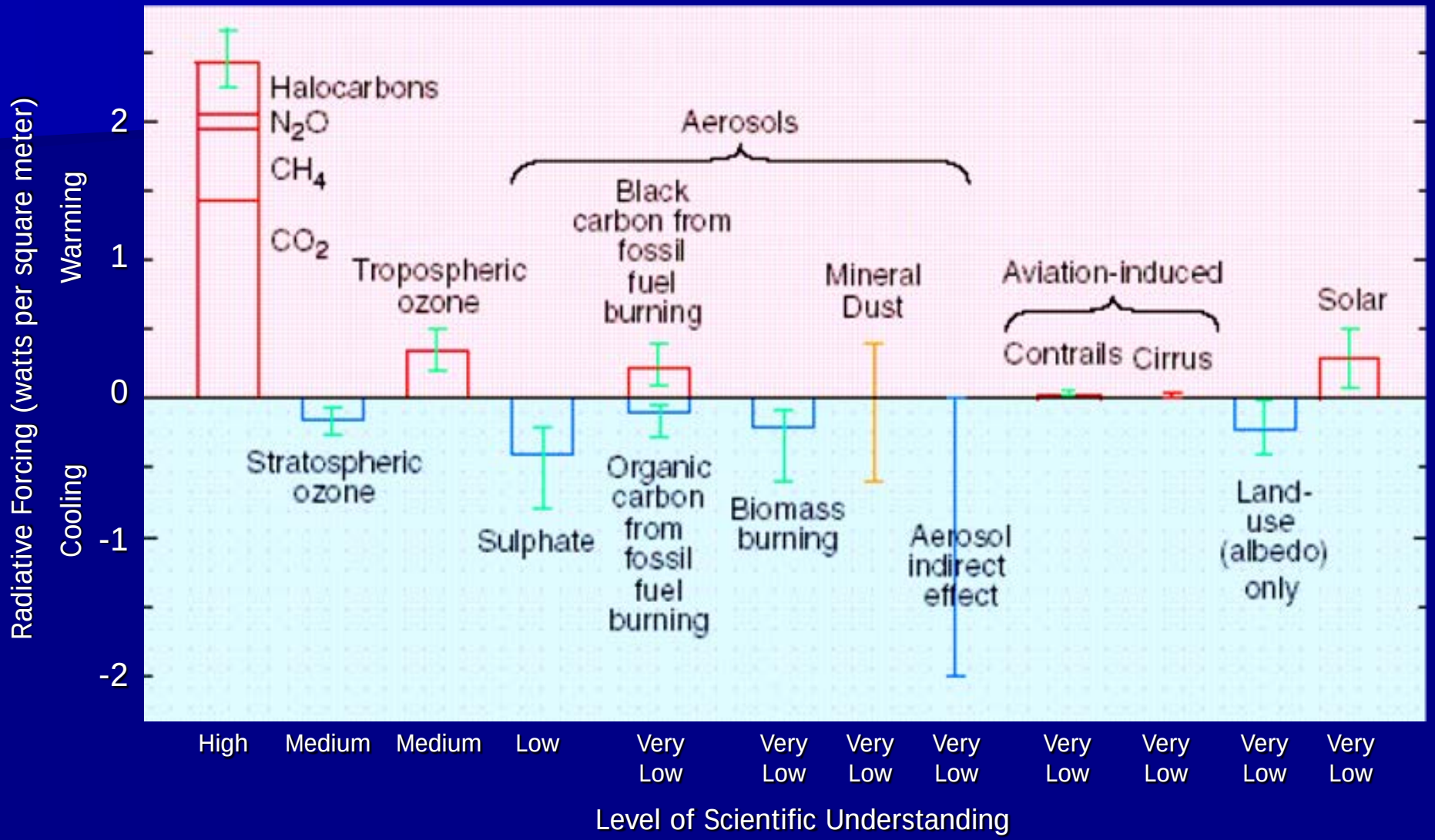




# *What Should the NPS Do?*

- Reduce greenhouse gas emissions

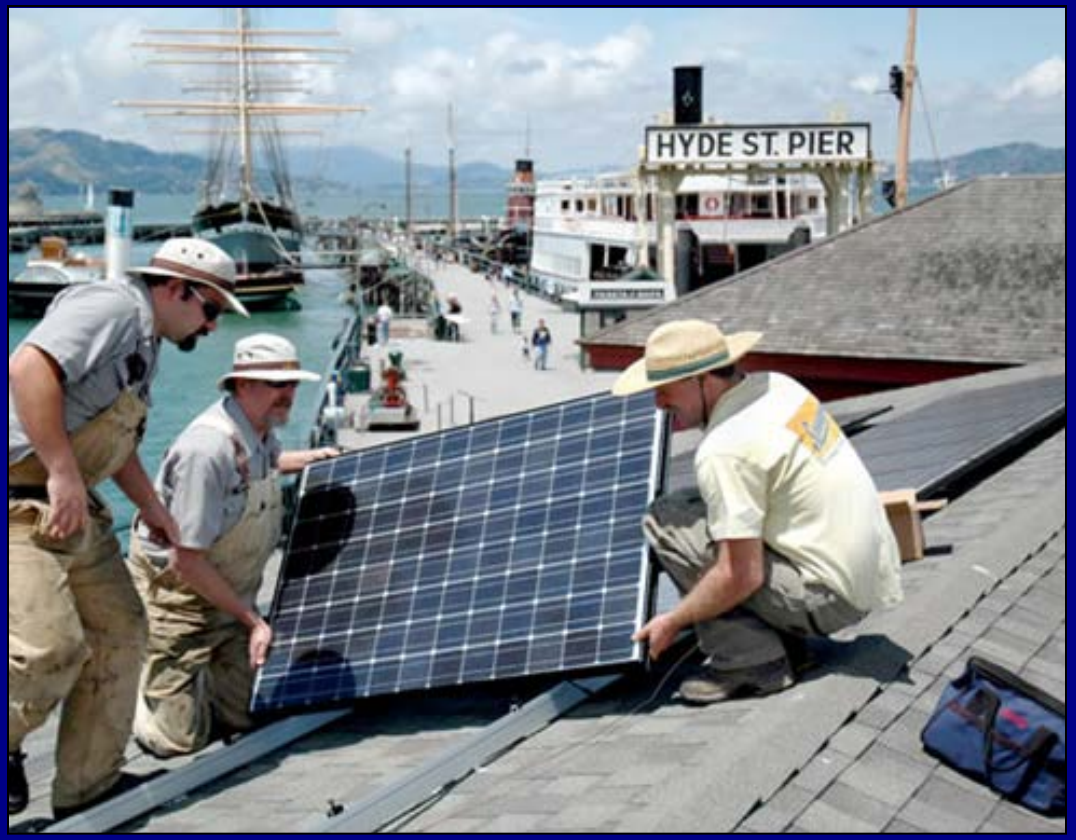
# *Factors Affecting Climate Change (1750-2000)*




Source: Intergovernmental Panel on Climate Change (2001)

# *What Should the NPS Do?*

- Reduce greenhouse gas emissions




Installing solar panels at Hyde Street Pier
San Francisco Maritime NHP

# *What Should the NPS Do?*

- Reduce greenhouse gas emissions

Electric vehicle
Point Reyes NS

# *What Should the NPS Do?*

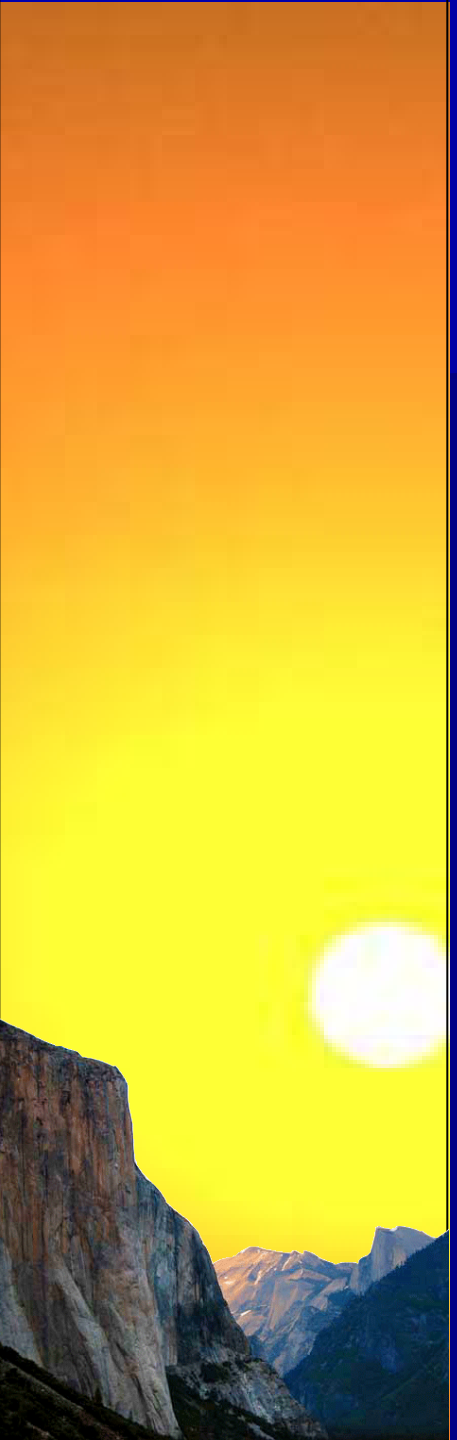
- Reduce greenhouse gas emissions

Contract for “Solar Sail” ferries

Alcatraz Island • Golden Gate NRA

# *What Should the NPS Do?*

- Reduce greenhouse gas emissions



# *What Should the NPS Do?*

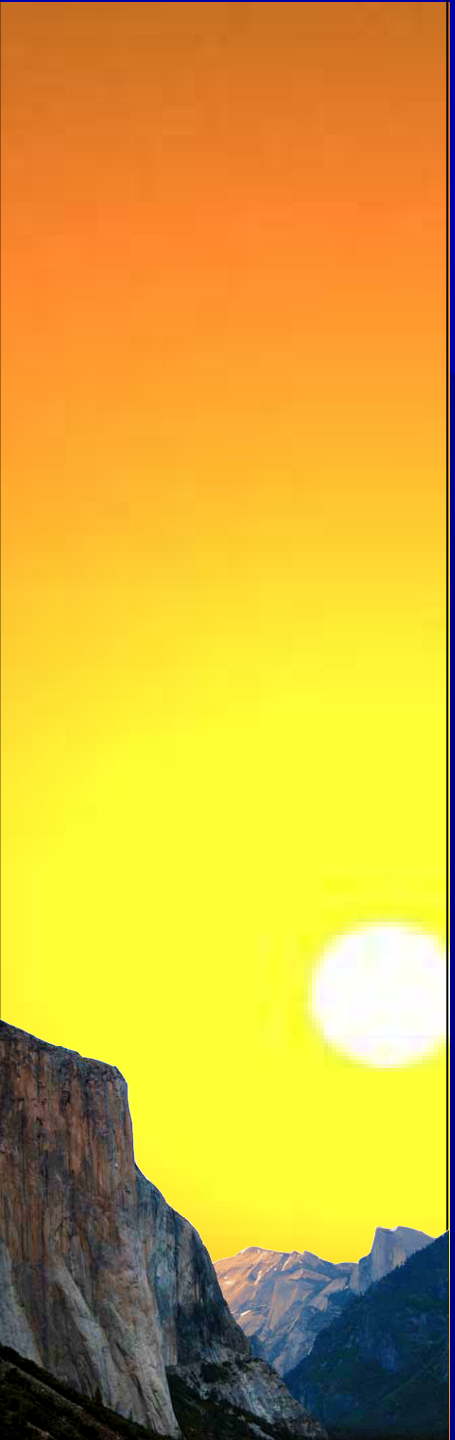
- Reduce greenhouse gas emissions

GREEN TAGS

Carbonfund.org
TOWARD A ZERO CARBON WORLD

# *Are We Doing Enough?*

- Reduce greenhouse gas emissions



# *What Should the NPS Do?*

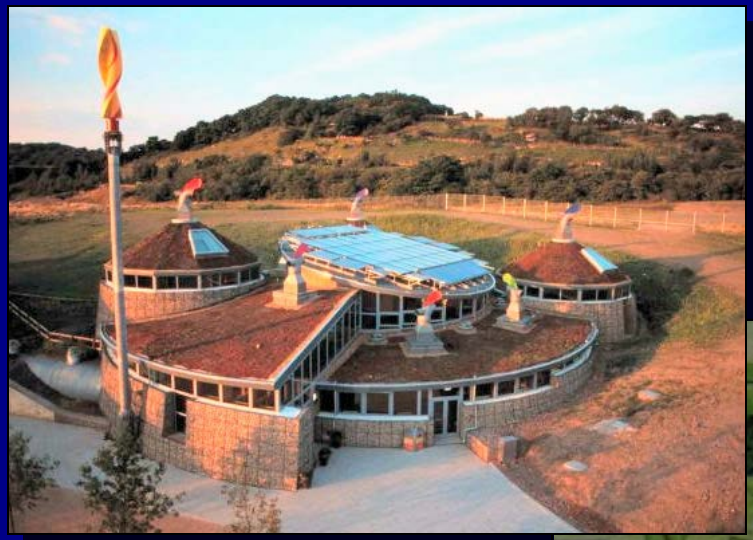
- Plan for the future

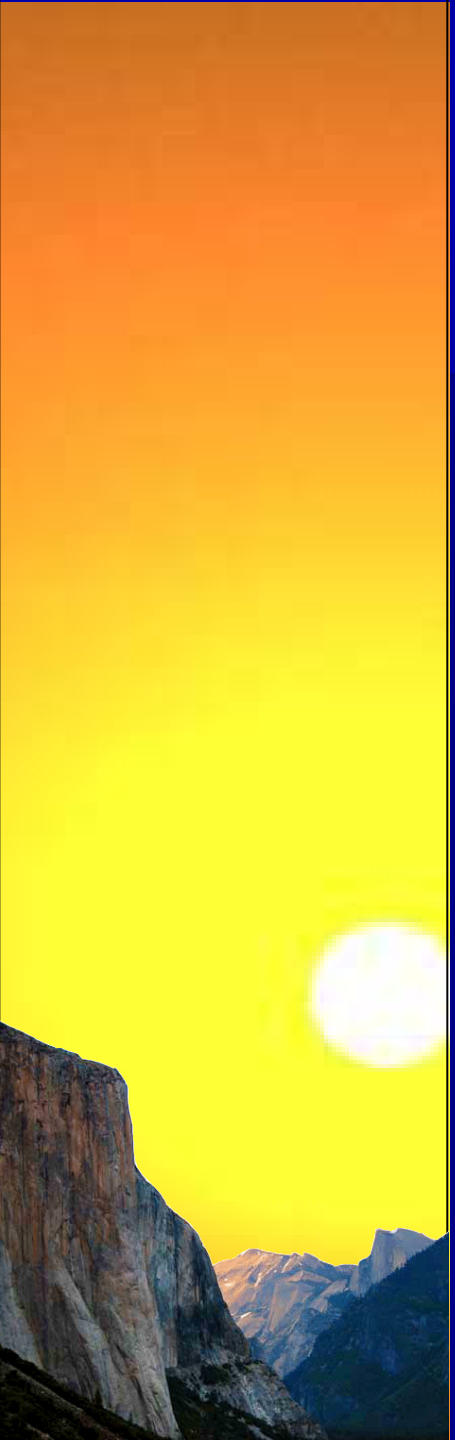
# What Should the NPS Do?

Pu'uhonua o Honaunau NHP

# *Are We Doing Enough?*

- Plan for the future





# *What Should the NPS Do?*

- Build public understanding

# What Should the NPS Do?

- Build public understanding

## Climate Change

Pictured Rocks National Lakeshore
National Park Service
U.S. Department of the Interior

### What Does The Future Hold For Great Lakes National Parks?

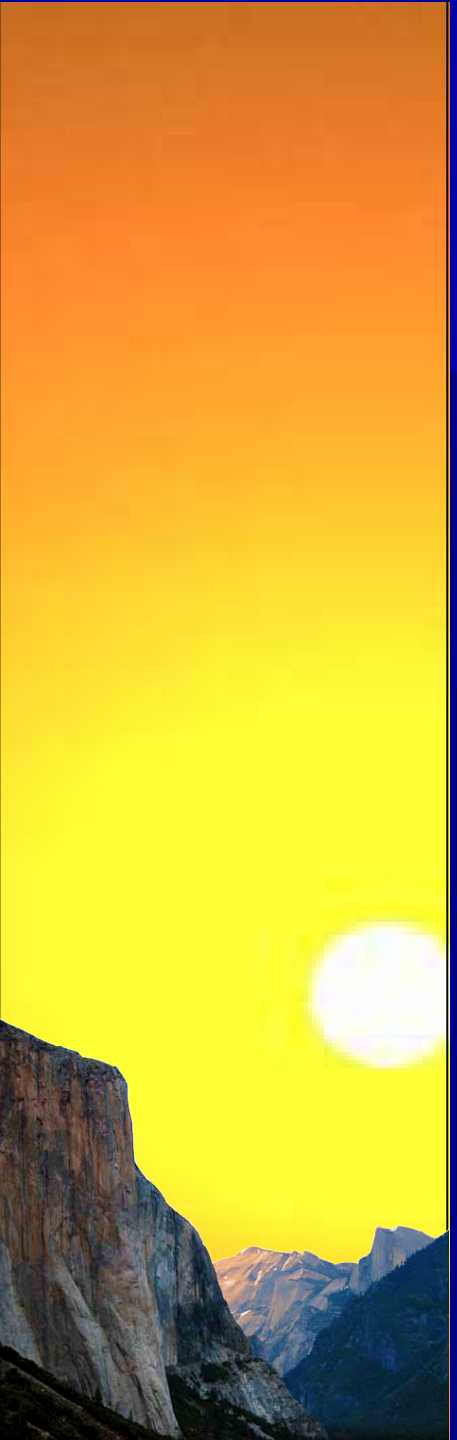
Although numerous theories are being advanced to explain or predict changes in the earth's climate, scientists are reaching a growing consensus that the earth's climate is in fact getting warmer, and will continue to warm in the coming decades and centuries, as a direct result of human activities. No one is sure how this global warming will affect regional climate and weather patterns or how long it will take for the effects to be seen. Most agree that impacts will include a rearrangement of temperature and precipitation patterns across the globe, a rearrangement of the distributions of plants and animals, rising sea levels, and potentially critical stress on the major agricultural systems that currently feed the world's growing human populations.

Global warming may seriously affect our ability to protect the species and habitats that are now encompassed by national parks,

2,000,000 years before present [ybp] until 9,500 ybp in upper Michigan) evidence shows that the global climate went through many cycles of cooling and warming, each averaging about 100,000 years in length - perhaps caused by cycles in the earth's orbital pattern called the Milankovich Cycle (Broecker 1989). Average temperatures fluctuated about 5°C (9°F) as the earth oscillated through a series of glacial (ice age) and interglacial periods. When the last glacial period (the Wisconsin) peaked about 22,000 ybp, the earth was about 3°C (5.4°F) cooler than it is today. The Wisconsin age glaciers (which carved much of the topography seen in Pictured Rocks National Lakeshore today) were gone by around 9,500 ybp. The interglacial period (which we are still in) peaked around 5,900 ybp when temperatures averaged about 2°C (3.6°F) warmer than today's.

Where plants live is largely determined by climate and where animals live depends largely on where the plants are. Reflecting climate change, the distribution of plants and animals across the globe has also radically changed over time.

Fossil records show that climate changes during the Pleistocene caused species distributions to shift both in latitude and in elevation (Brubaker 1988). During several Pleistocene interglacial periods, when temperatures in North America were 2-3°C (3.6-5.4°F) higher than today, species were found several hundreds of kilometers north of their present distributions. Osage oranges and pawpaws grew near Toronto, manatees swam in New Jersey, and tapirs and peccaries foraged in



# *What Should the NPS Do?*

- Build public understanding

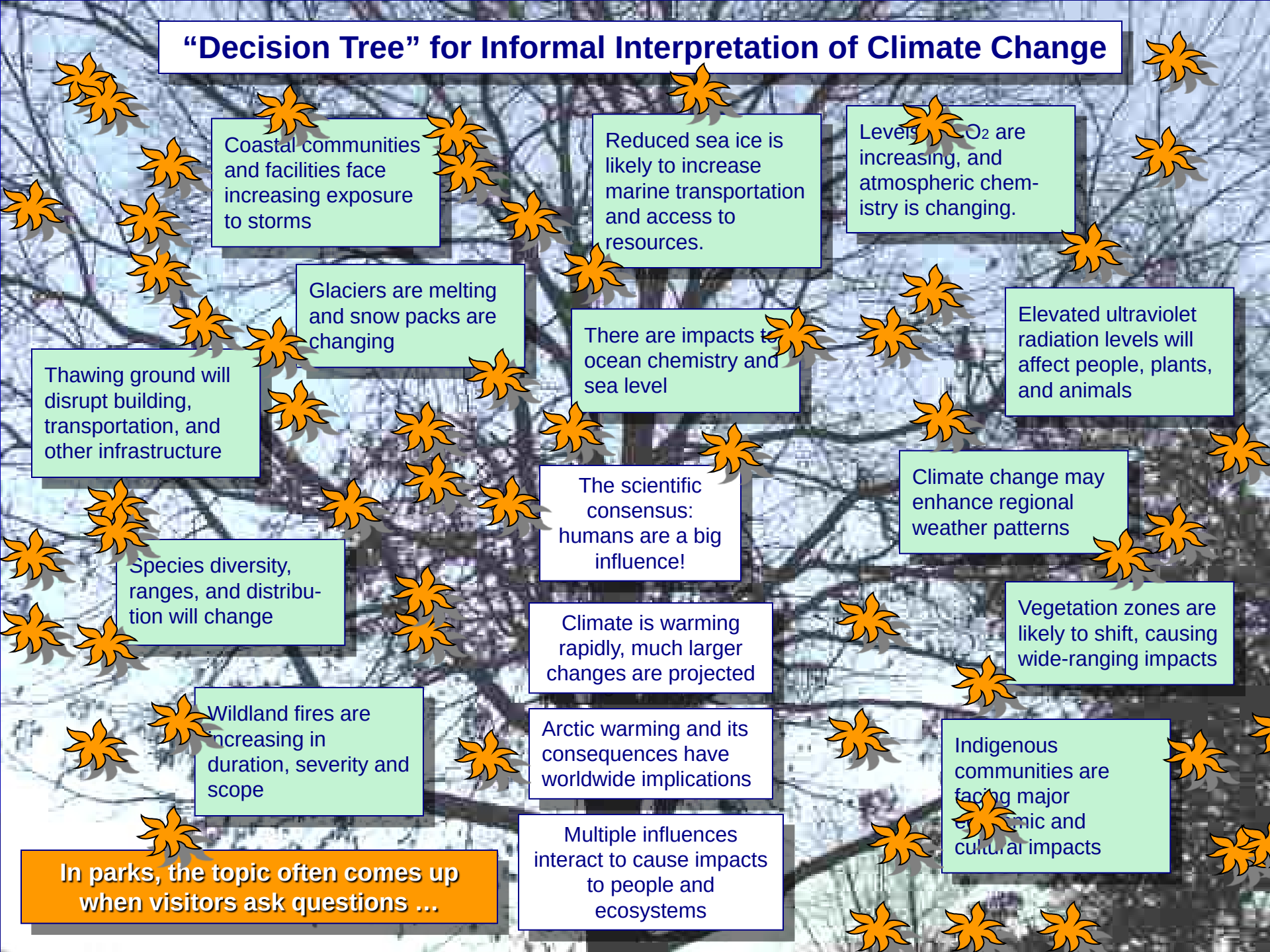
NASA Earth to Sky Project:

"Climate Change in the National Parks" training project

Goddard Institute for Space Studies

John Morris
Alaska Regional Office

# "Decision Tree" for Informal Interpretation of Climate Change



Coastal communities and facilities face increasing exposure to storms

Reduced sea ice is likely to increase marine transportation and access to resources.

Levels of $CO_2$ are increasing, and atmospheric chemistry is changing.

Glaciers are melting and snow packs are changing

There are impacts to ocean chemistry and sea level

Elevated ultraviolet radiation levels will affect people, plants, and animals

Thawing ground will disrupt building, transportation, and other infrastructure

The scientific consensus: humans are a big influence!

Climate change may enhance regional weather patterns

Species diversity, ranges, and distribution will change

Climate is warming rapidly, much larger changes are projected

Vegetation zones are likely to shift, causing wide-ranging impacts

Wildland fires are increasing in duration, severity and scope

Arctic warming and its consequences have worldwide implications

Indigenous communities are facing major economic and cultural impacts

Multiple influences interact to cause impacts to people and ecosystems

**In parks, the topic often comes up when visitors ask questions …**

# Are glaciers melting … how do we know?

A few of the interpreter's options and why to choose them:

| | |
|---|---|
| Explain laser-altimetry glacier studies | Explanation: USGS and UAF scientists are using airplanes equipped with altimeters and lasers to fly over and determine changes in ice thickness and extent. (Favors Intellectual connection – new insight or deeper understanding) |
| Describe / illustrate changes on map | Illustration: Using historic and recent photographs, show the visitor how the glacier has retreated over time. (Favors intellectual or Emotional connection – new insight, or surprise.) |
| Ask visitor how they think we might know… | Questioning: See if the visitor can figure it out for themselves; perhaps by giving them some clues and encouraging them. (Favors intellectual connection – deduction or reasoning.) |
| Create analogy comparing this area to other parks | Analogy: Describe what Yosemite looked like before all the ice melted (u-shaped valley, glacial erratics, unsorted outwash in river beds, etc. (Favors emotional connection, new awareness.) |
| Give them a brochure | Provide reference: Perhaps the visitor is indicating they must depart soon; it may be better to give them something to read that will explain it. (Favors intellectual connection, deeper understanding or recognition.) |

# *Are We Doing Enough?*

- Reduce greenhouse gas emissions
- Plan for the future
- Build public understanding

# *Are We Doing Enough?*

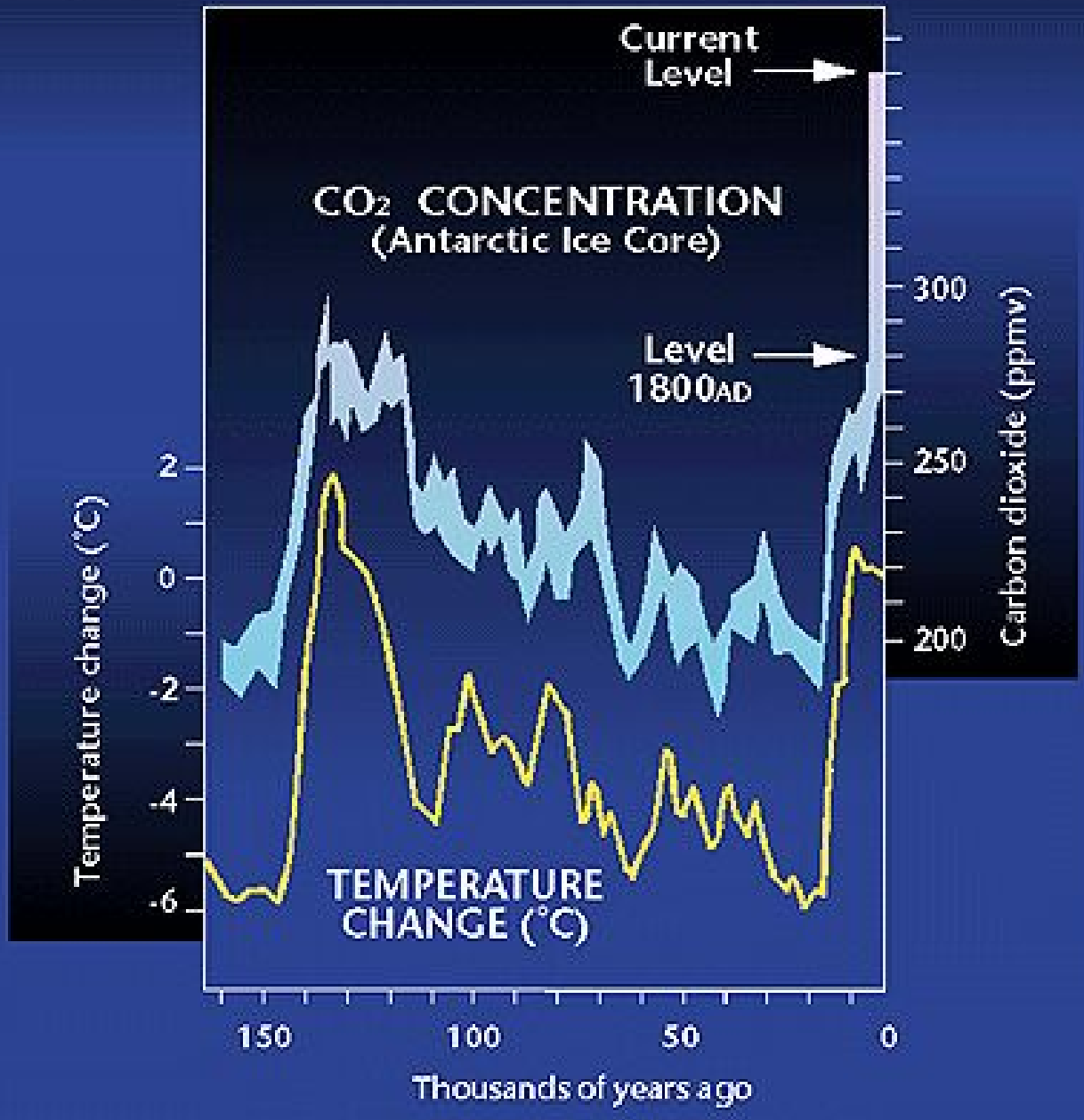
"The era of procrastination,
of half measures,
of soothing and
baffling expedients
is coming to a close.

In its place
we are entering
a period of
consequences.

*-- Winston Churchill*

The sooner we act, the
more options we will have.

NATIONAL
PARK
SERVICE

The truth is incontrovertible; malice may attack it, ignorance may deride it, but in the end there it is. - Winston Churchill

# Atmospheric Carbon Dioxide Concentration and Temperature Change