Climate Change is Here: Tipping Points & Rays of Hope

Evan Mills
Staff Scientist
U.S. Department of Energy
Lawrence Berkeley National Laboratory

The Scientific Consensus

Intergovernmental Panel on Climate Change

1300 Authors; 1100 Reviewers
Unanimously adopted by 100+ nations (including U.S.)

Federal Government

“By increasing the levels of greenhouse gases in the atmosphere, human activities are strengthening Earth's natural greenhouse effect.”

- U.S. Environmental Protection Agency

Local Governments

The mayors of more than 200 cities in 38 states have signed the "U.S. Mayors Climate Protection Agreement," urging Congress to pass federal climate legislation and pledging to meet or better Kyoto targets in their own communities.

The Business World

In a survey completed by 354 of the *Financial Times Global 500* companies, more than 90 percent cited climate change as posing commercial risks and/or opportunities

Insurance Industry

“We'd be out of our minds if we wrote weather insurance on the opinion global warming would have no effect at all.”

- Warren Buffett
2006 annual Shareholder meeting

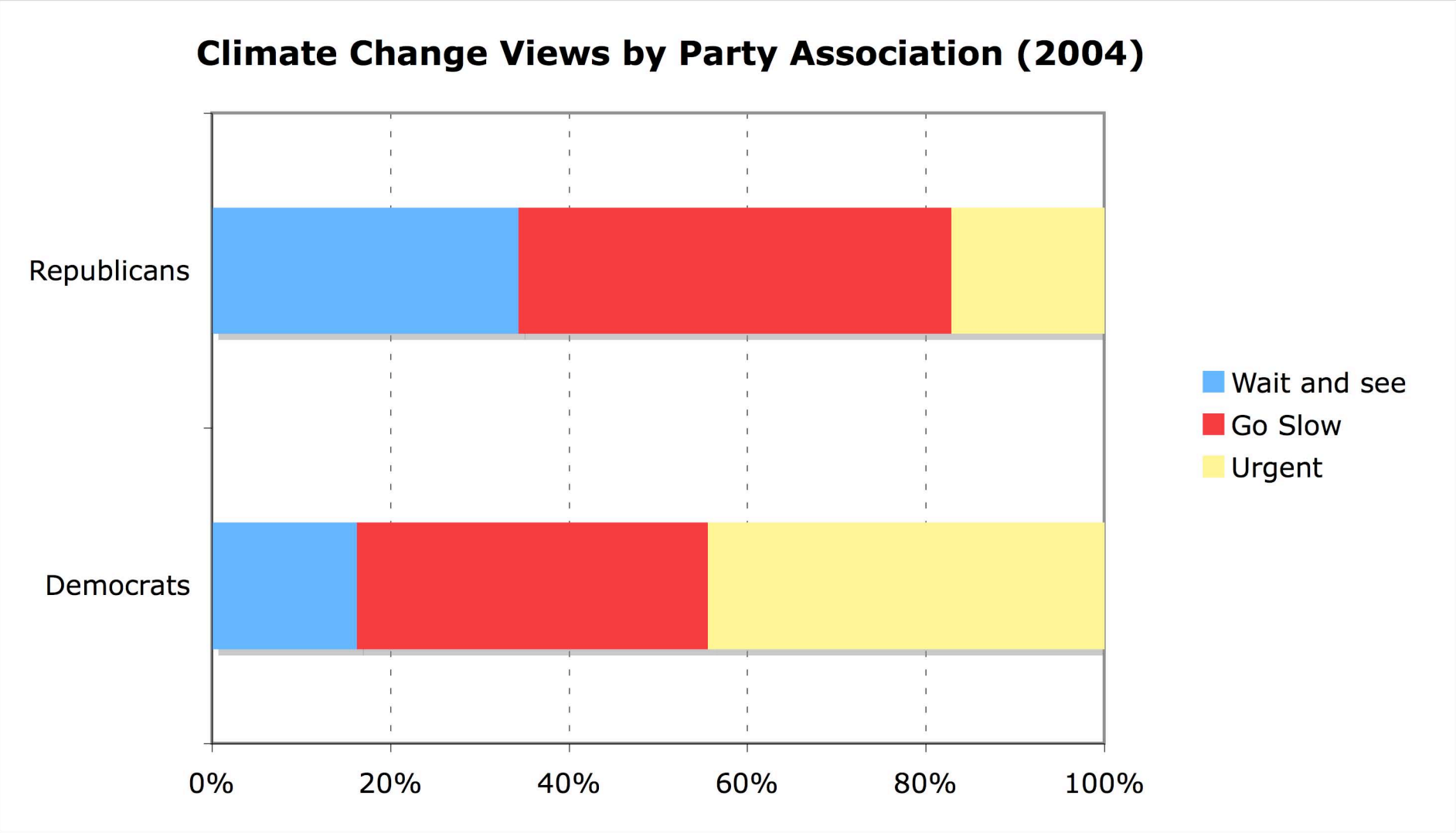
- James Woolsey - Former CIA Director

  Prius' bumper sticker reads:

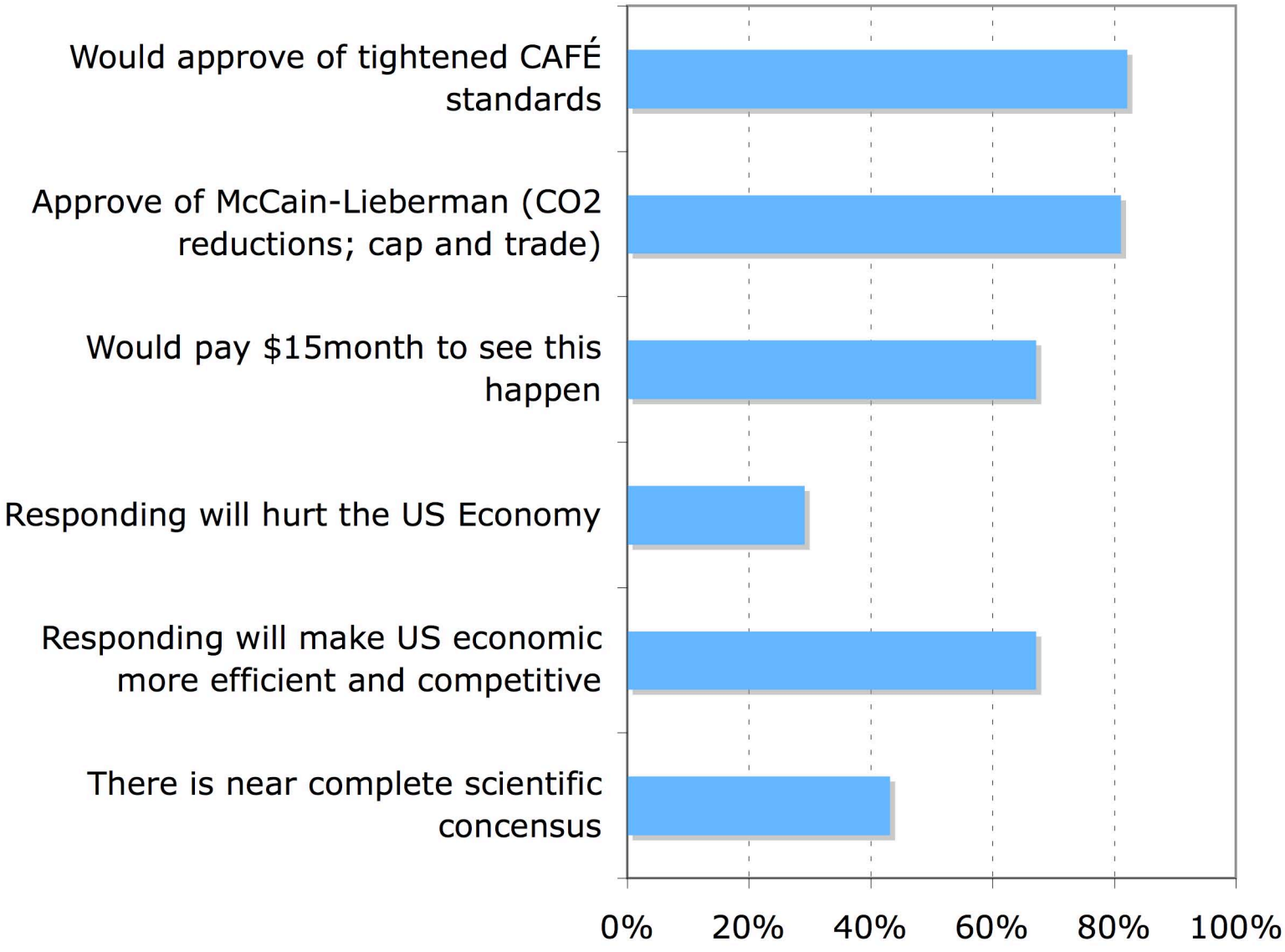
  "Osama bin laden hates this car."

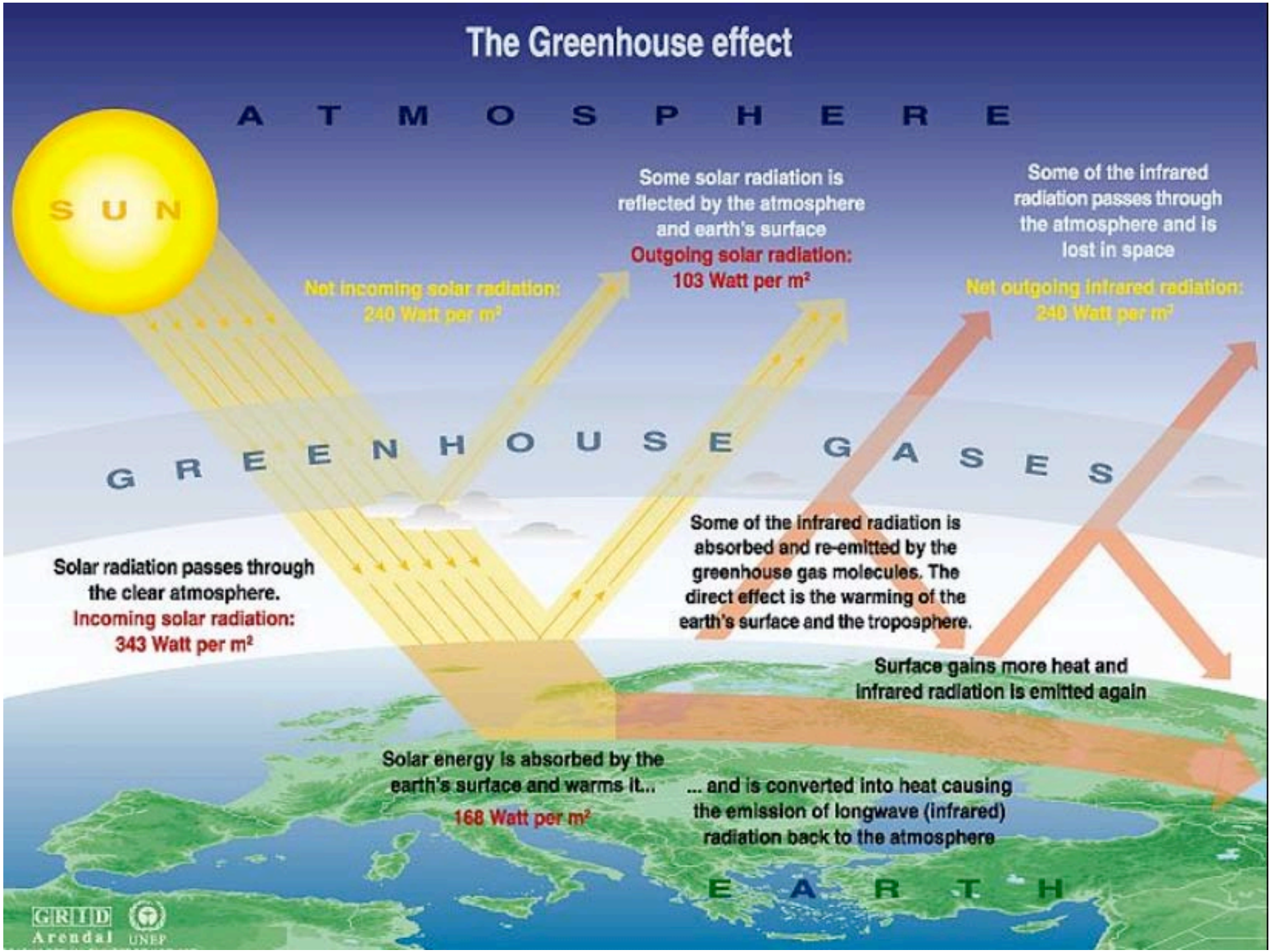
- Richard Cizik - National Assoc. of Evangelicals

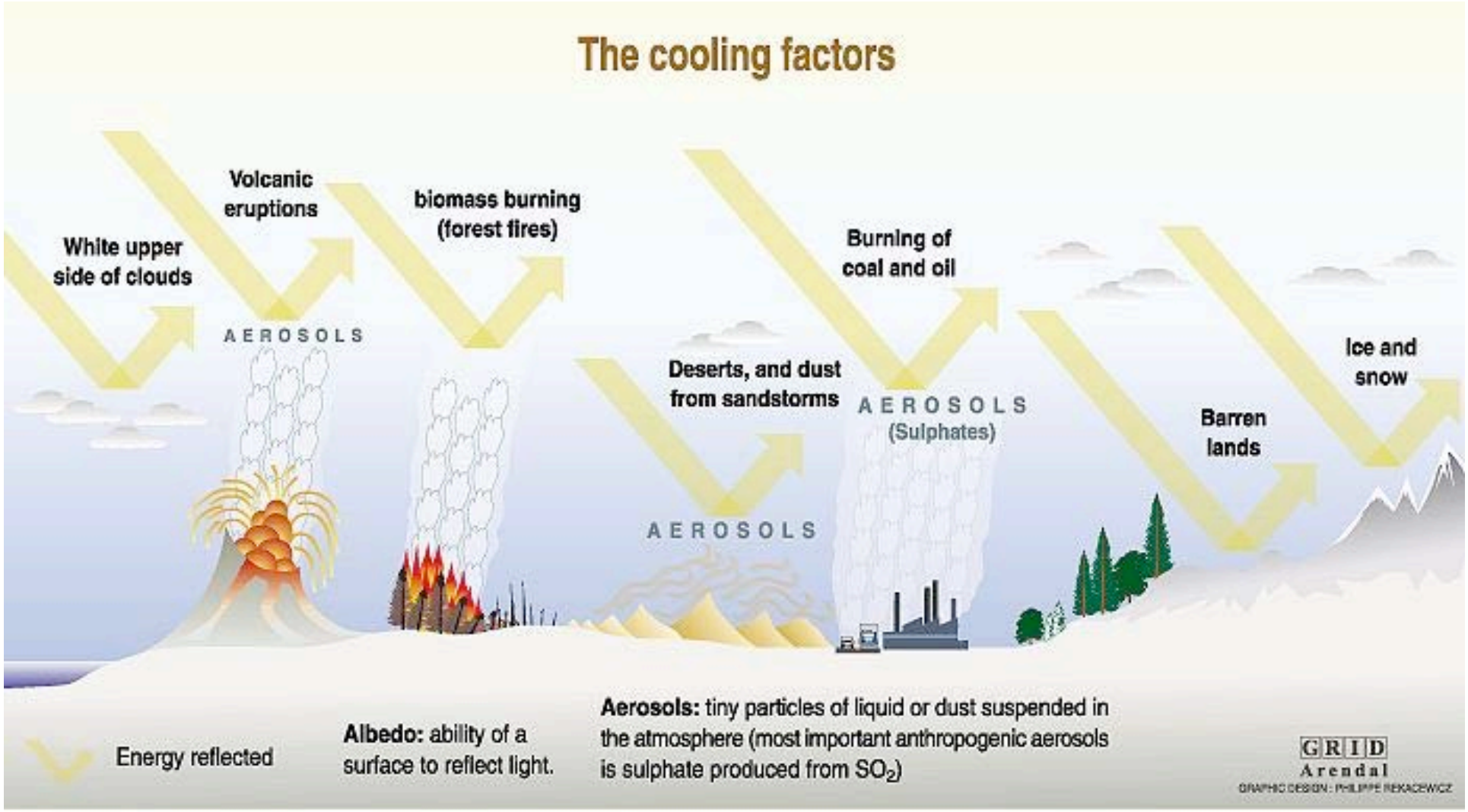
  "Pollution from cars and power plants is destroying God's creation… it violates sanctity of life."


Climate Change Views by Party Association (2004)
Republicans
Democrats
0%
20%
40%
60%
80%
100%
Wait and see
Go Slow
Urgent

Public Opinion on Climate Change (June 2004)




The Greenhouse effect
A T M O S P H E R E
S U N
Some solar radiation is reflected by the atmosphere and earth's surface
Outgoing solar radiation: 103 Watt per m²
Some of the infrared radiation passes through the atmosphere and is lost in space
Net incoming solar radiation: 240 Watt per m²
Net outgoing infrared radiation: 240 Watt per m²
G R E E N H O U S E G A S E S
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth's surface and the troposphere.
Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m²
Surface gains more heat and infrared radiation is emitted again
Solar energy is absorbed by the earth's surface and warms it...
168 Watt per m²
... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere
E A R T H
GRID Arendal
UNEP

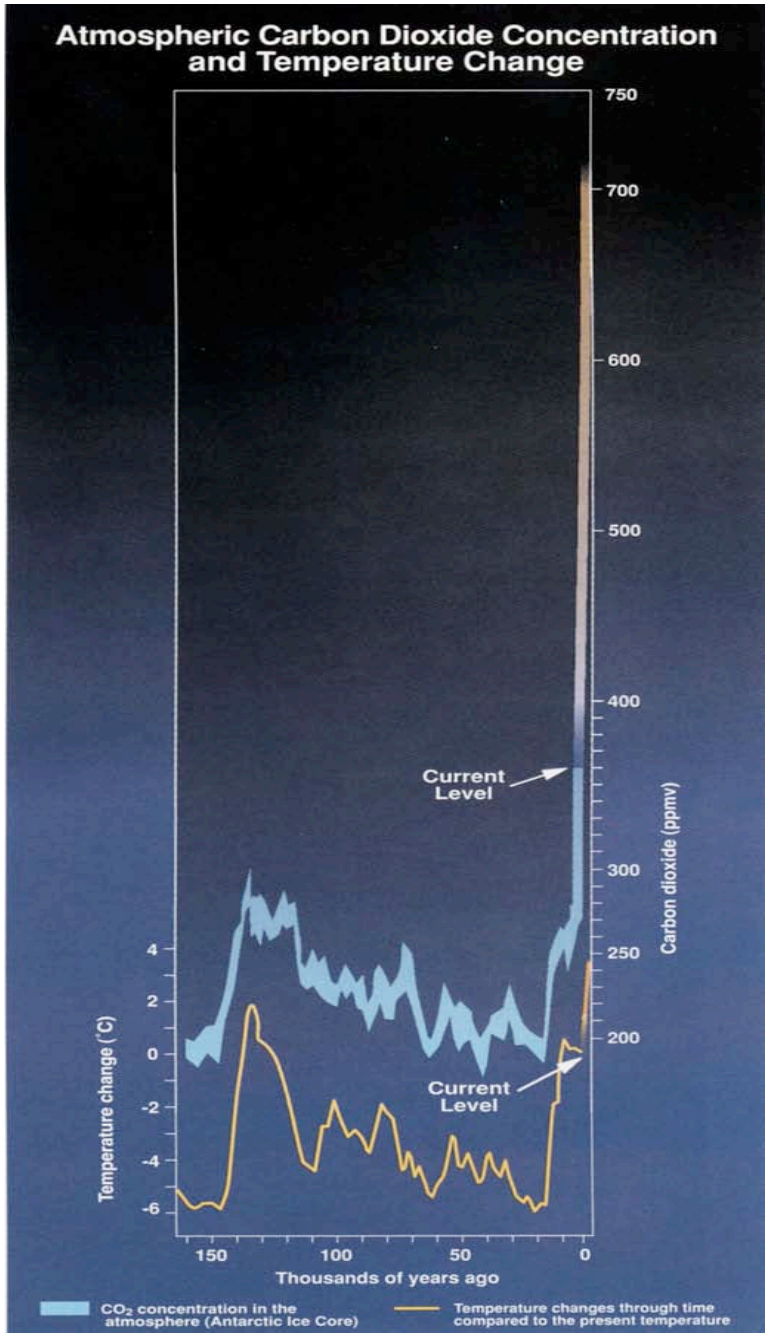


Sources: Radiative forcing of climate change, the 1994 report of the scientific assessment working group of IPCC, summary for policymakers, WMO, UNEP; L.D. Danny Harvey, Climate and global environmental change, Prentice Hall, pearson Education, Harlow, United Kingdom, 2000.

Source: United Nations - Intergovernmental Panel on Climate Change

Vostok Ice Cores:

150,000 years of carbon and temperature

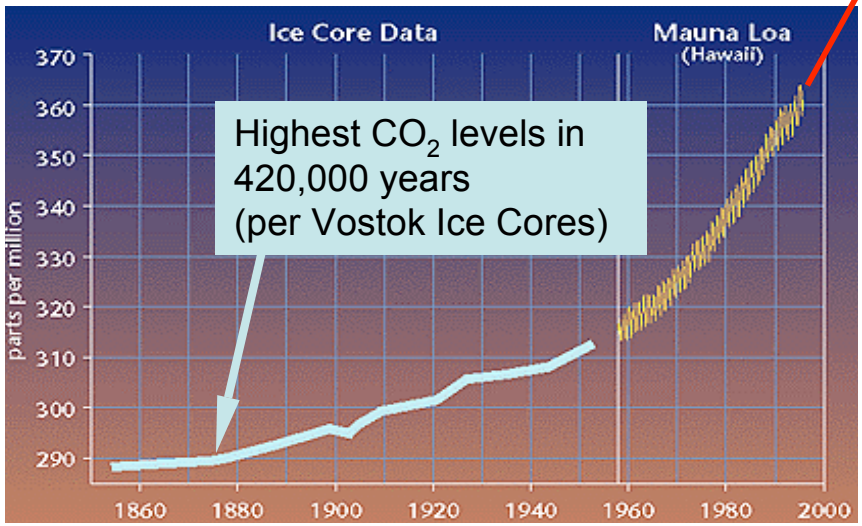


The Primary Human Influence is Fossil Fuels Combustion

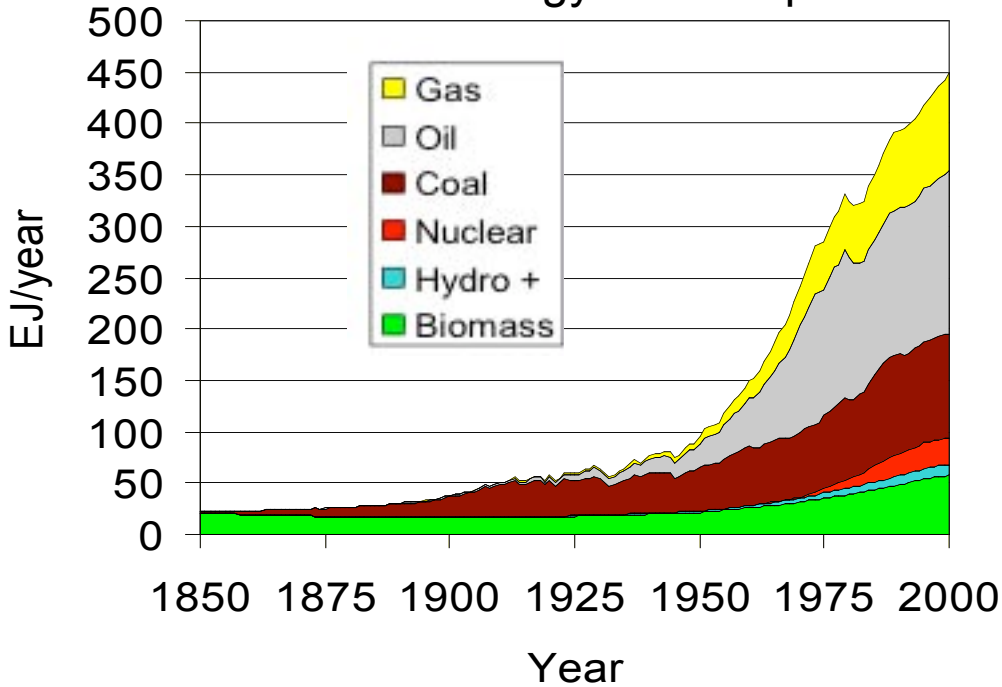
(Second is Deforestation)

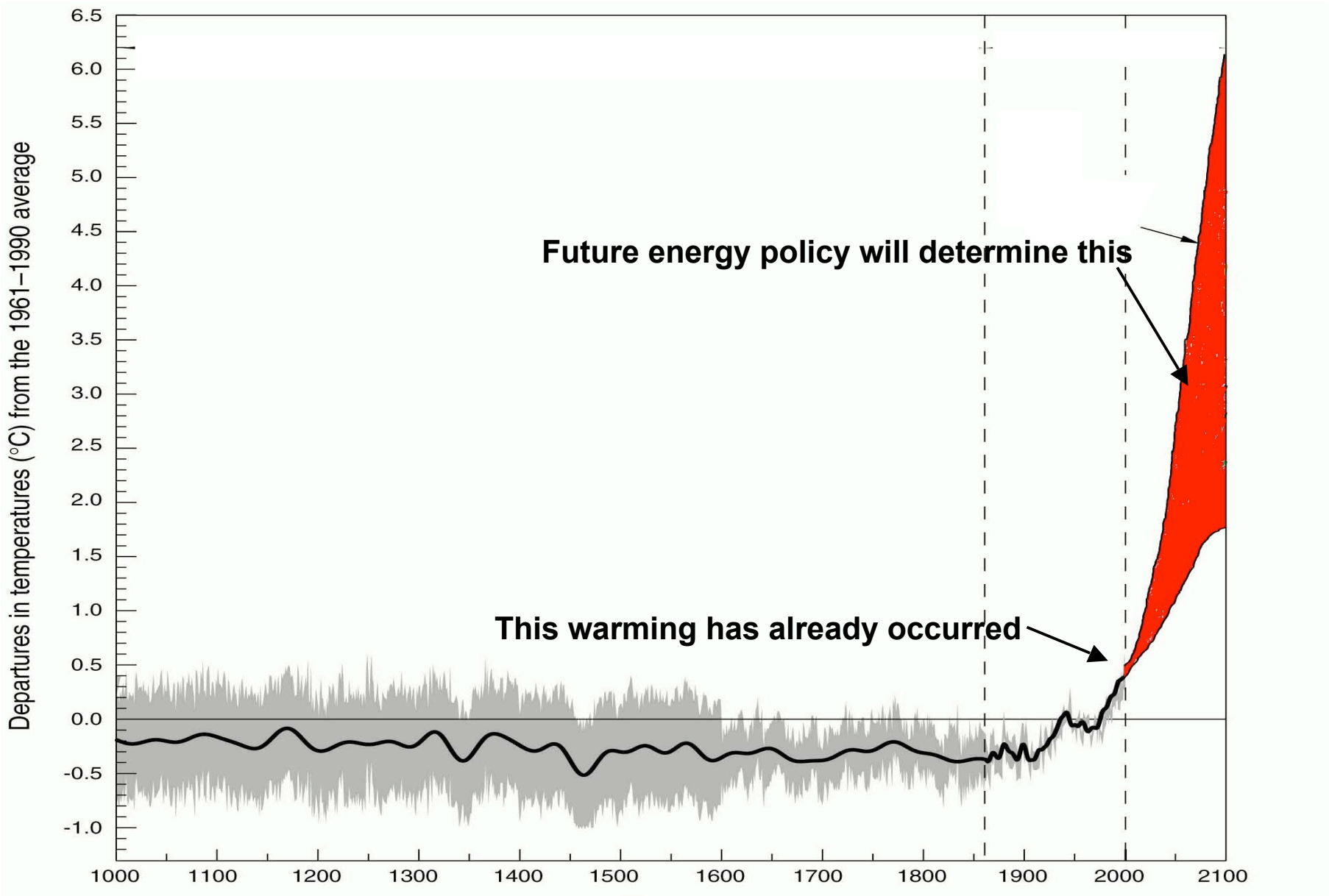
Today

World Carbon Dioxide Concentrations



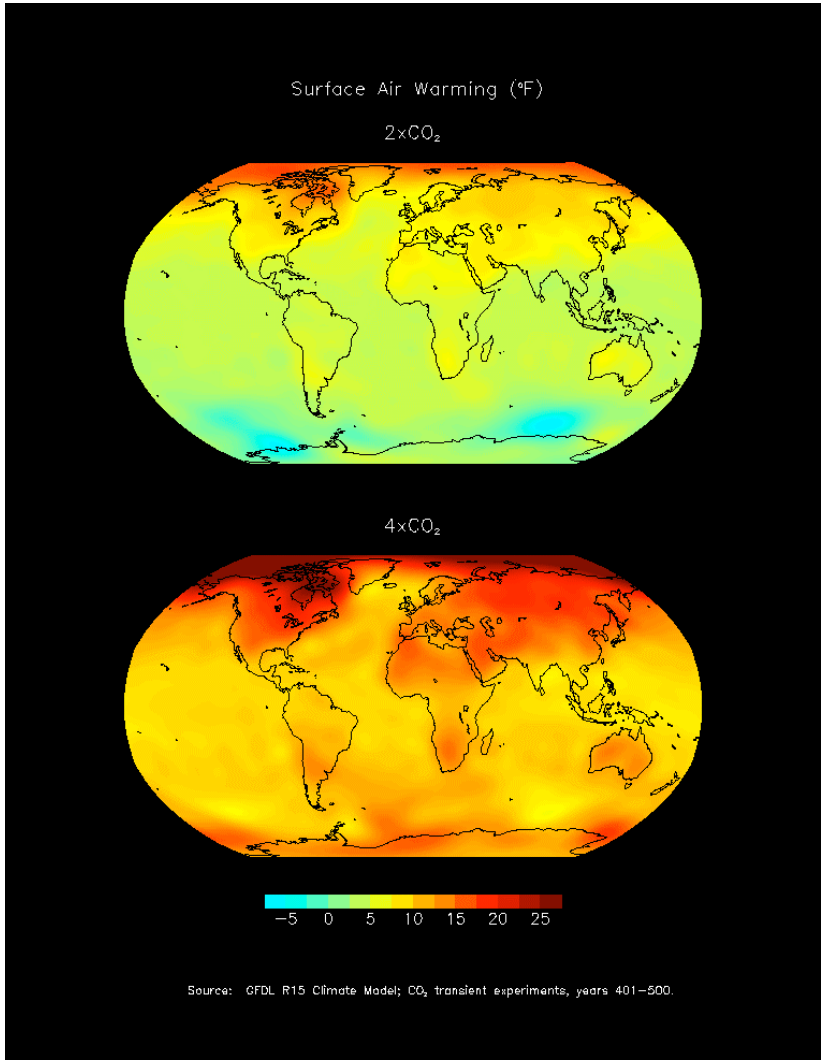
World Energy Consumption




Departures in temperatures (°C) from the 1961–1990 average
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Future energy policy will determine this
This warming has already occurred

We'll pass the $2xCO_2$ Milestone ~2050

Air Temperatures

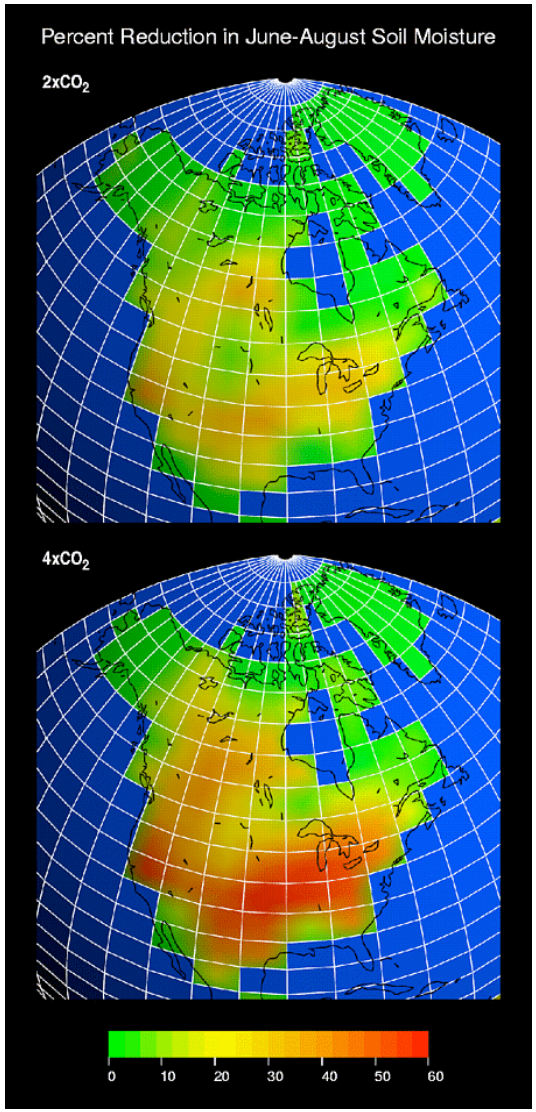


$2x\ CO_2$

$4x\ CO_2$

With increased warming, net impacts become increasingly negative

Soil Moisture



Source: NOAA (Geophysical Fluid Dynamics Laboratory)

Climate change affects all aspects of life

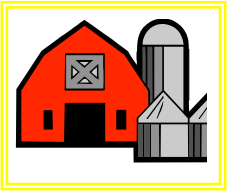
Physical Processes

- Air & water temperatures
- Ice
- Precipitation
- Soil moisture
- Ocean currents
- Sea level
- Permafrost
- Weather

Human Relevance

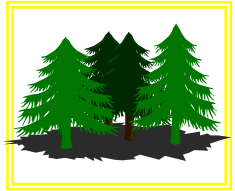
Health Impacts

Weather-related mortality/heat stress
Infectious diseases
Air quality-induced respiratory effects



Agriculture Impacts

Crop yields and commodity prices
Irrigation demands
Pests and weed



Forest Impacts

Change in forest composition
Shift geographic range of forests
Forest health and productivity

Water Resource Impacts

Changes in water supply and timing
Water quality
Increased competition for water

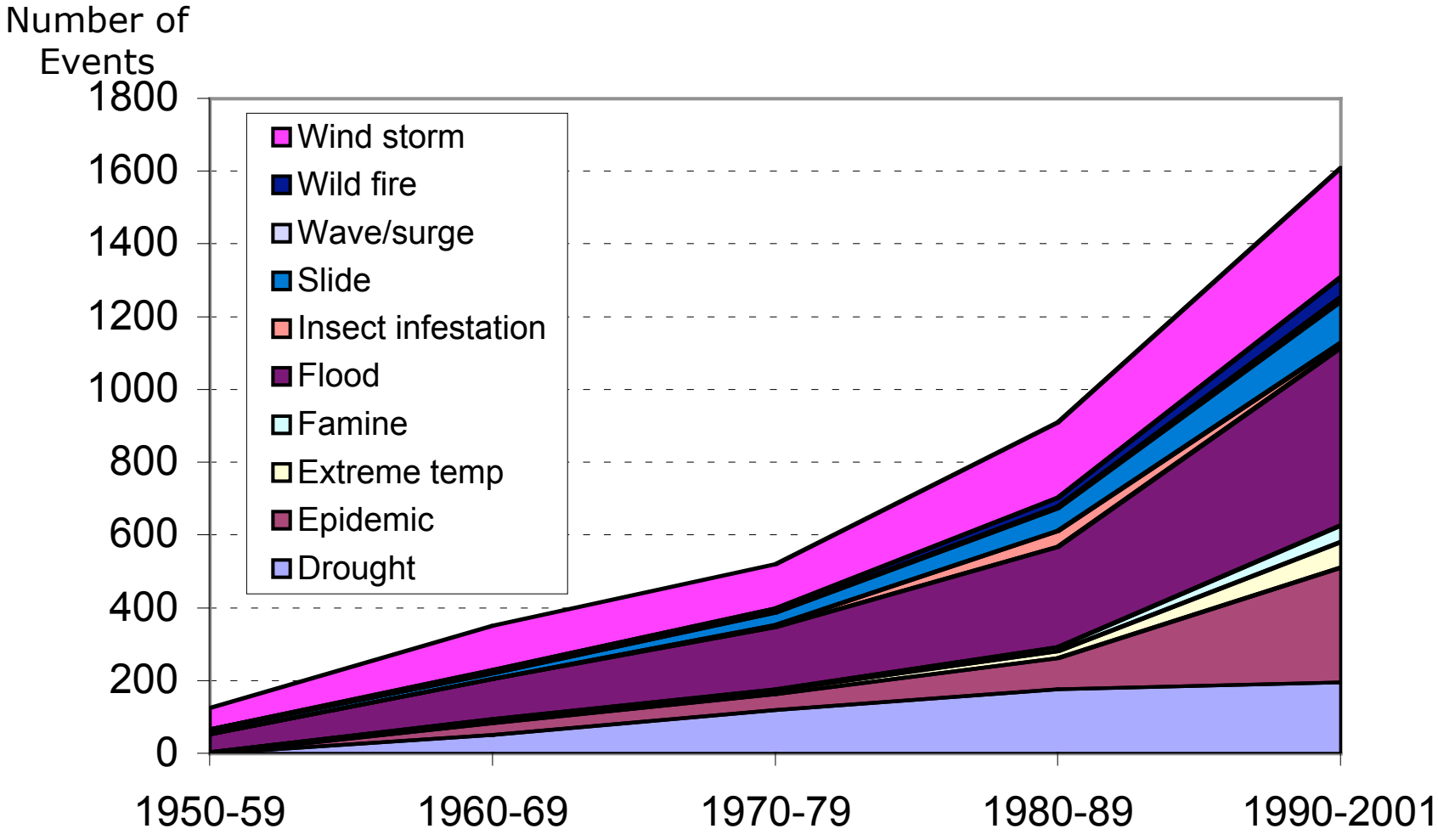
Coastal Area Impacts

Erosion of beaches
Inundation of coastal wetlands
Costs to defend coastal communities

Ecosystem Impacts

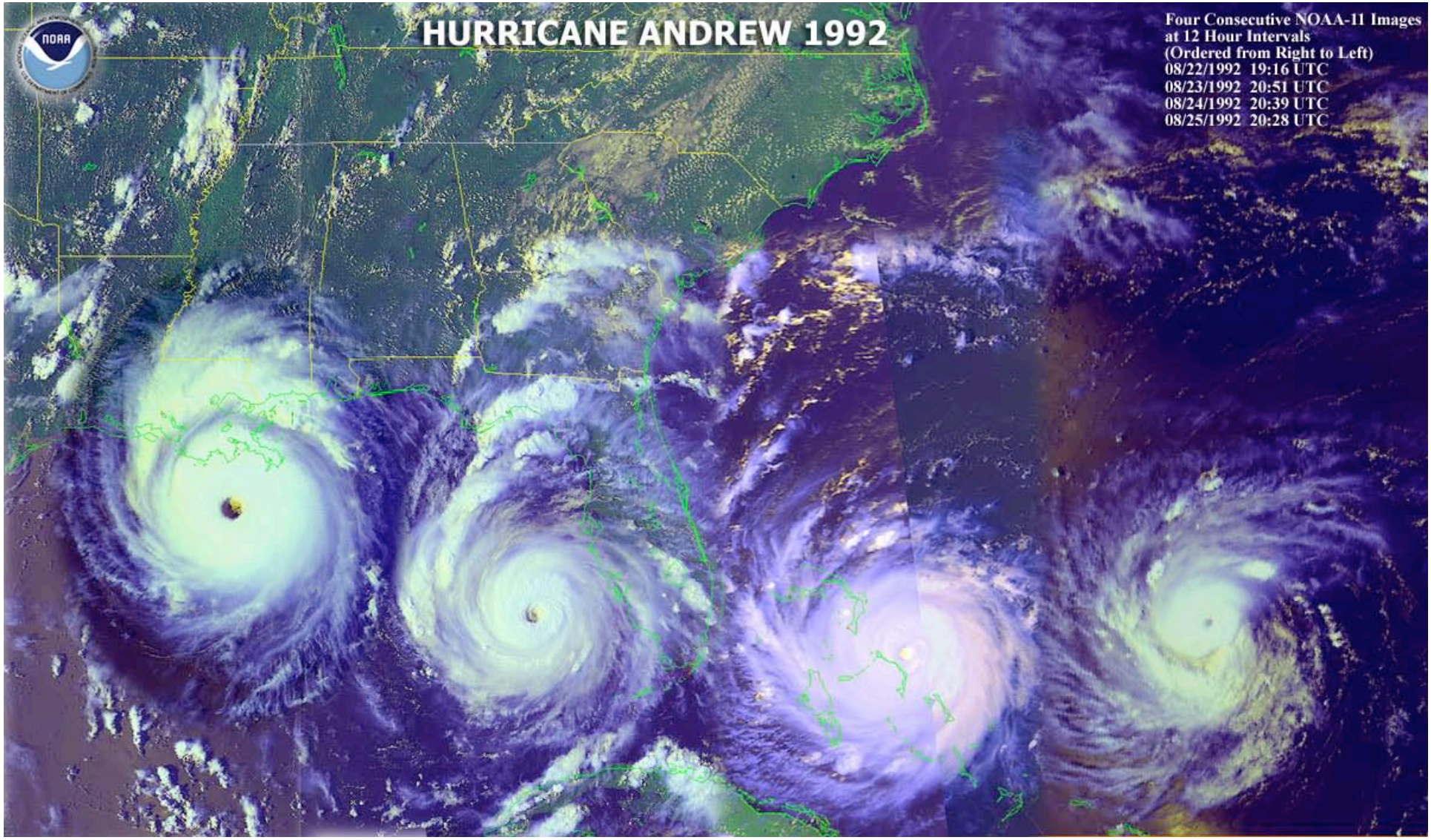
Shifts in ecological zones
Loss of habitat and species
Coral reefs threatened

Fingerprint: Rise in Number and Change in Mix of Weather/Climate Disasters

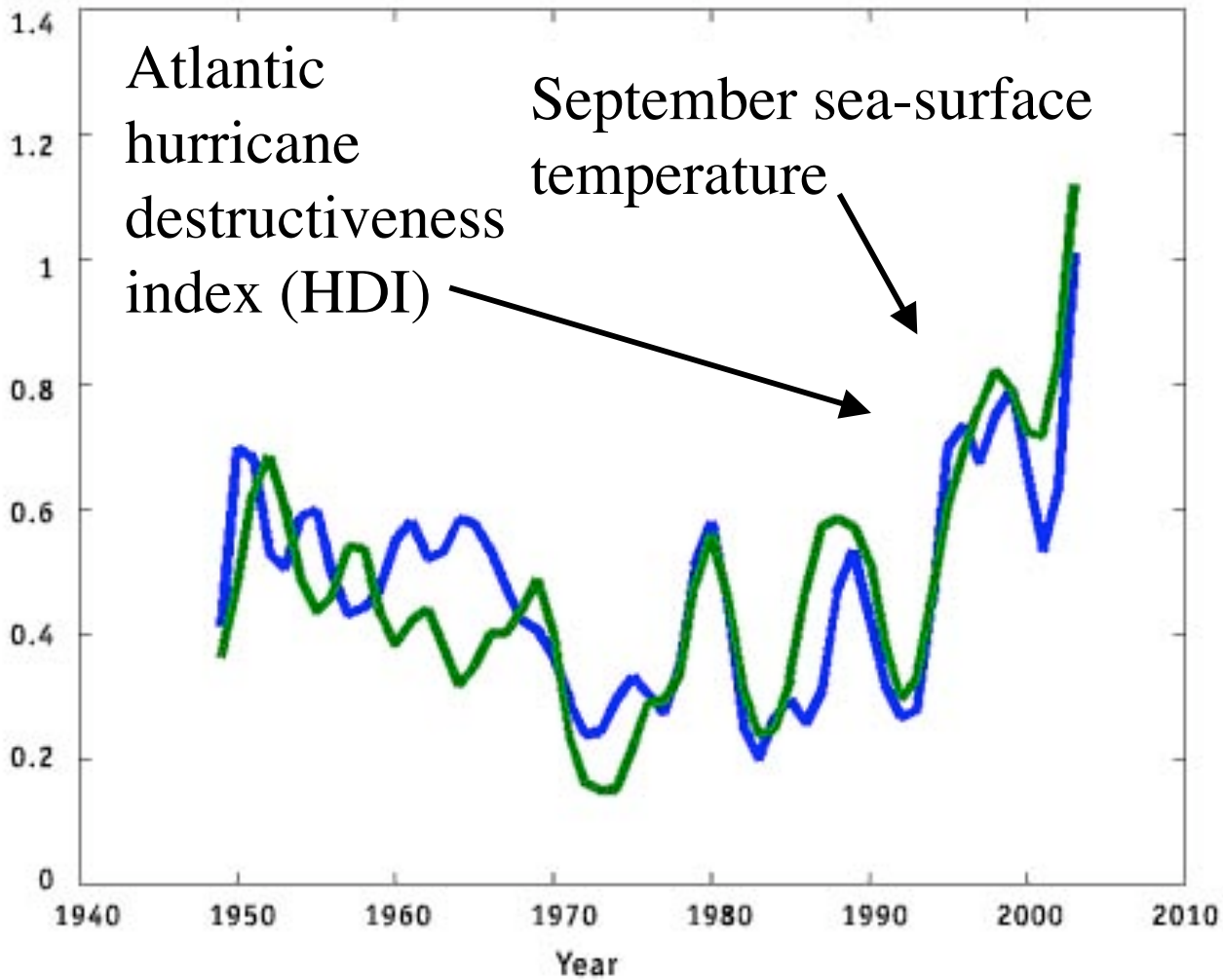


Source: Center for Research in the Epidemiology of Disasters (CRED)

Fingerprints


HURRICANE ANDREW 1992
Four Consecutive NOAA-11 Images
at 12 Hour Intervals
(Ordered from Right to Left)
08/22/1992 19:16 UTC
08/23/1992 20:51 UTC
08/24/1992 20:39 UTC
08/25/1992 20:28 UTC

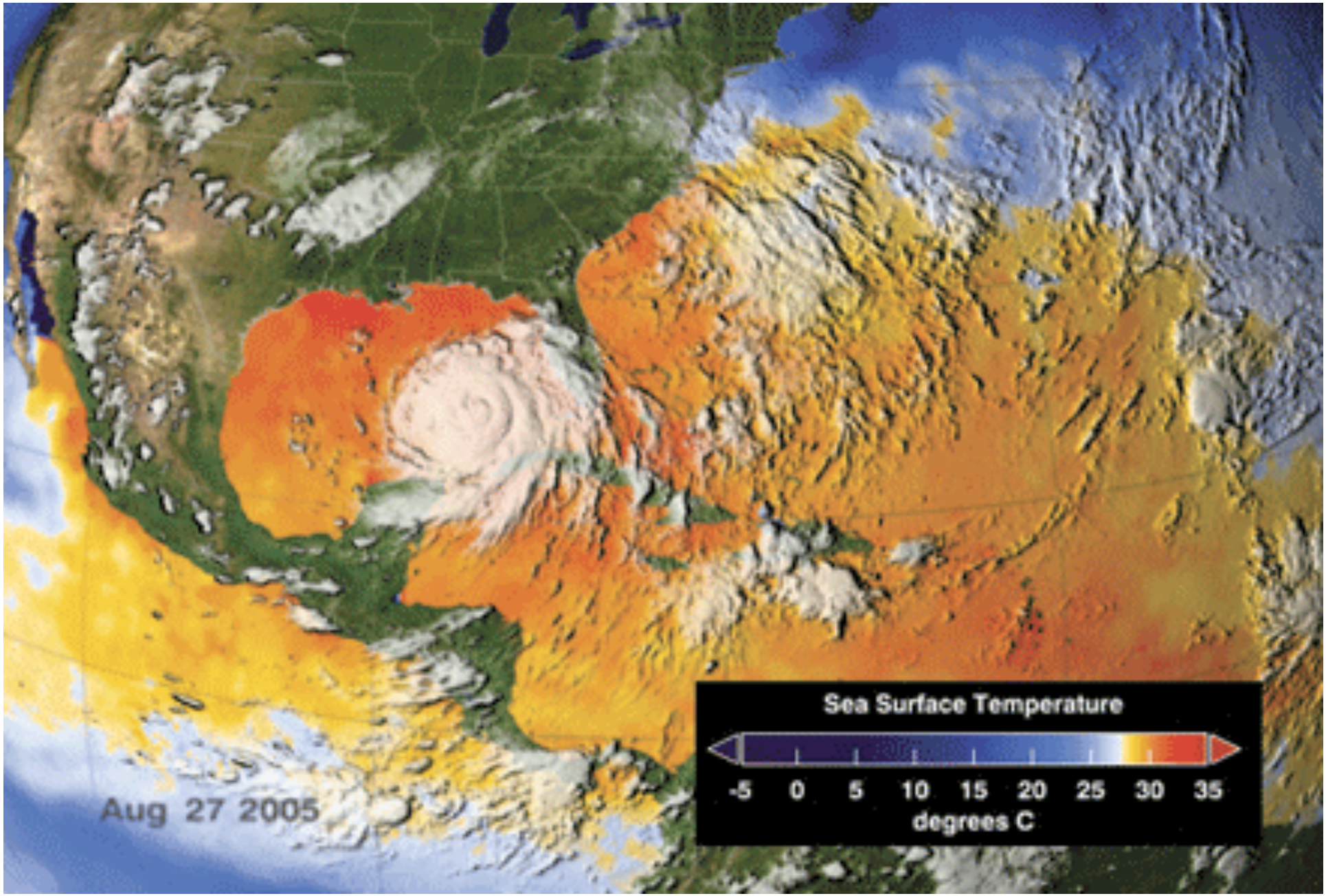
Hurricane destructiveness increasing in lockstep with ocean temperatures

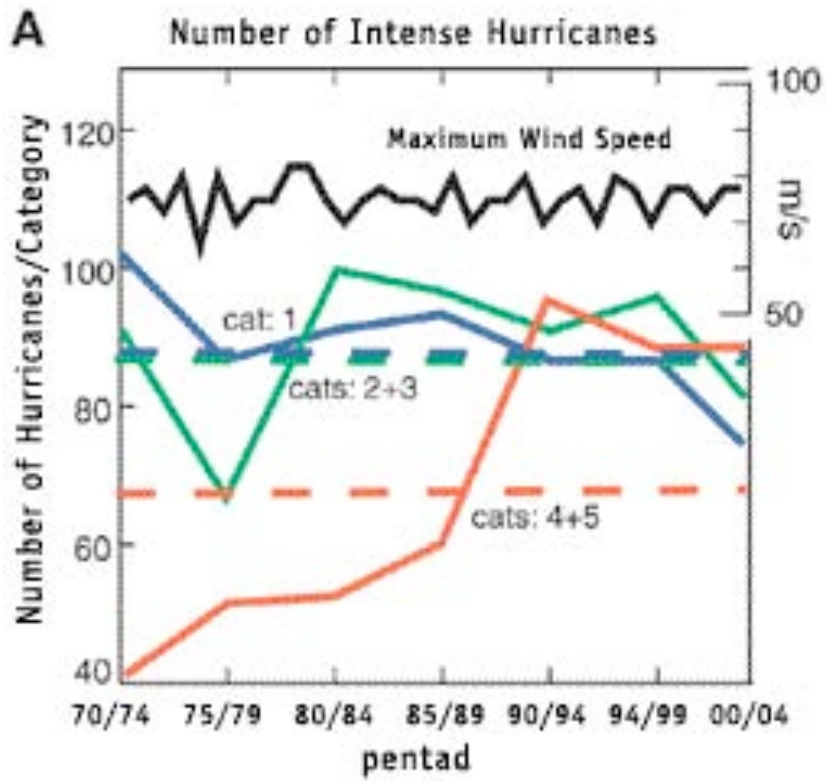


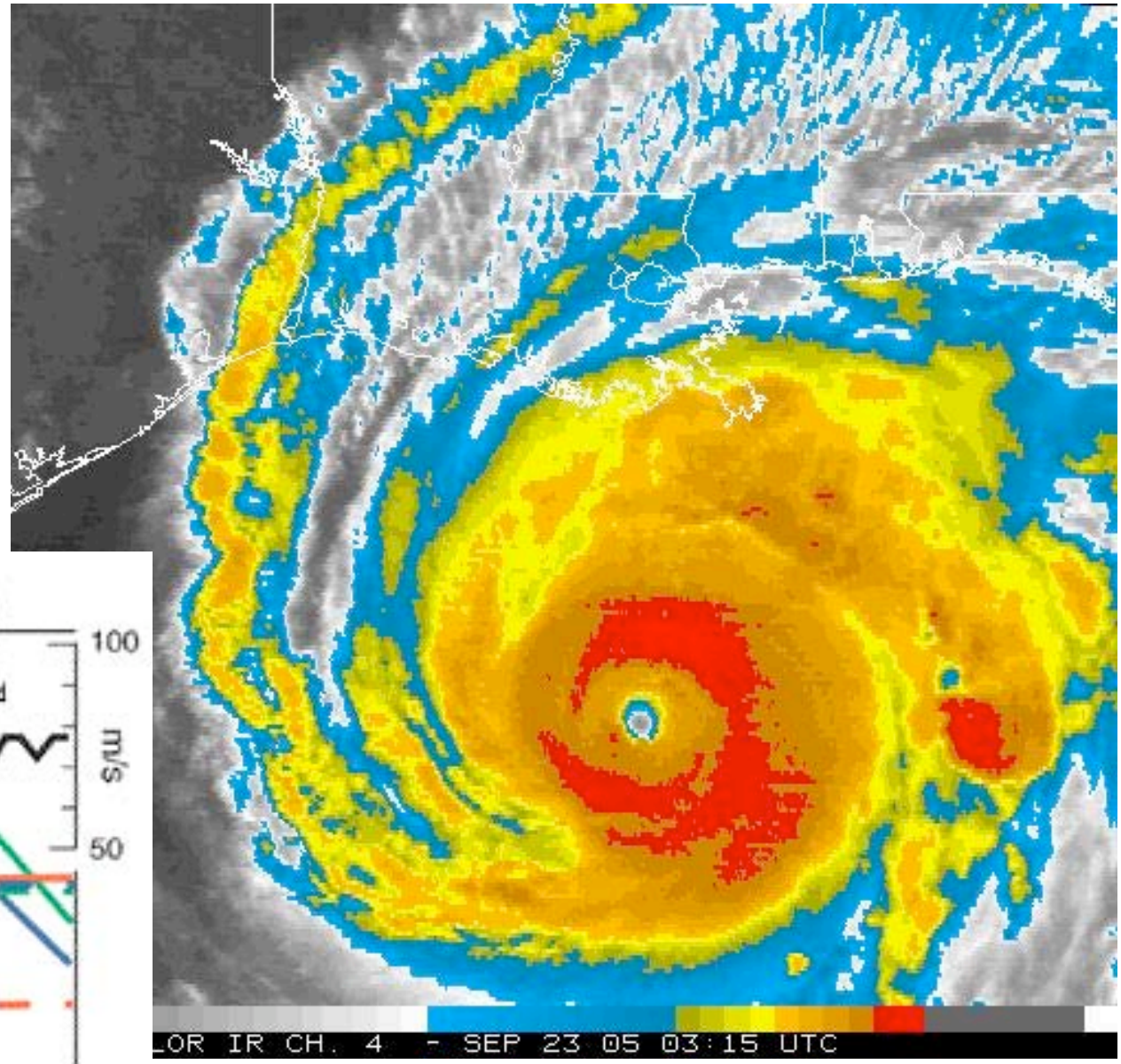
2005 broke most records

- Number
- Strongest storm
- Physical size
- Storm duration
- Season duration
- Southernmost landfall

Source: Kerry Emanuel, MIT *Nature* (former "climate skeptic")


Sea Surface Temperature
-5 0 5 10 15 20 25 30 35
degrees C
Aug 27 2005

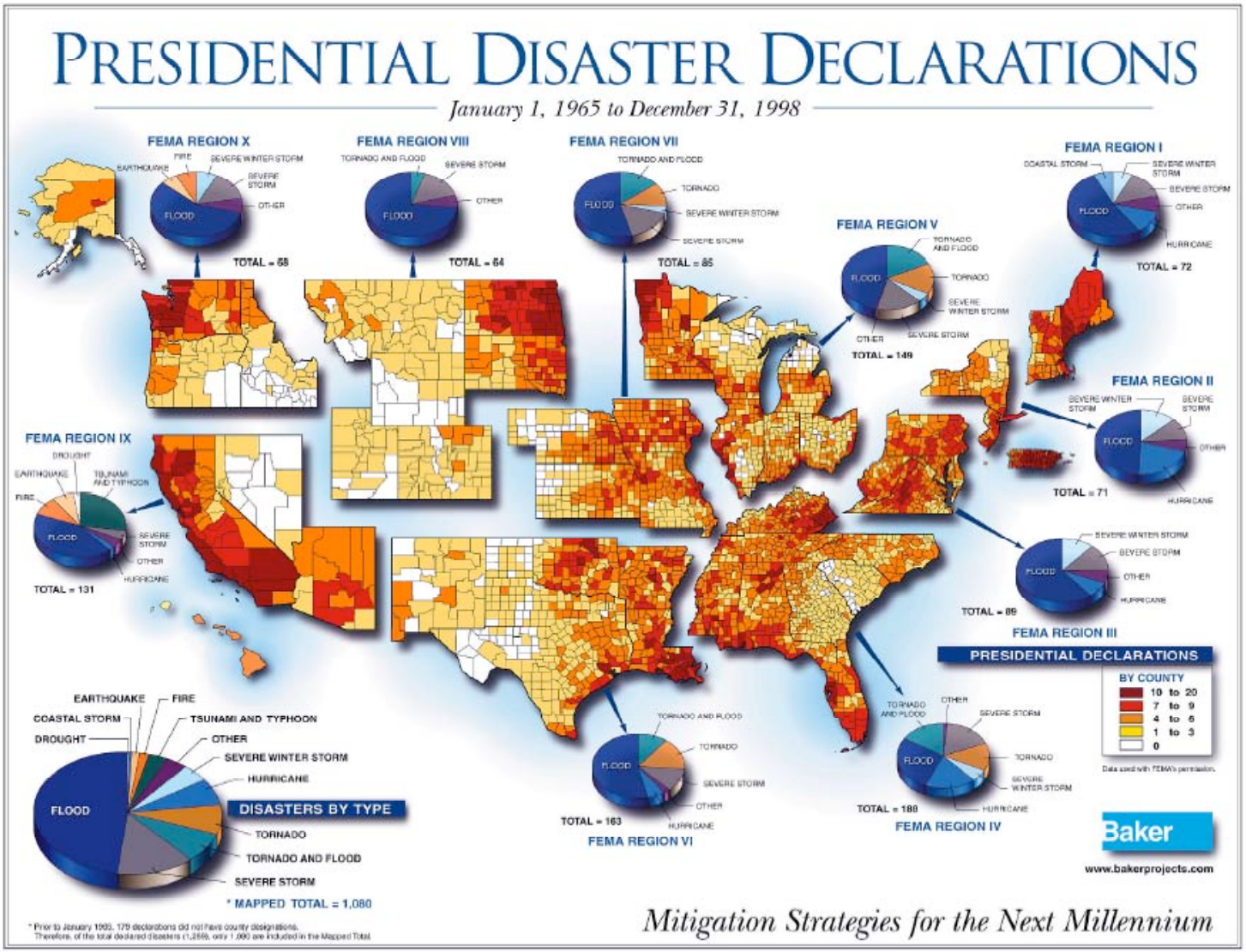

A
Number of Intense Hurricanes
Maximum Wind Speed
cat: 1
cats: 2+3
cats: 4+5
Number of Hurricanes/Category
m/s
120
100
80
60
40
100
50
70/74
75/79
80/84
85/89
90/94
94/99
00/04
pentad


LOR IR CH. 4 - SEP 23 05 03:15 UTC

refineries
oil rigs
Hurricane Katrina's Path

Disasters Not Just a "Coastal" Issue

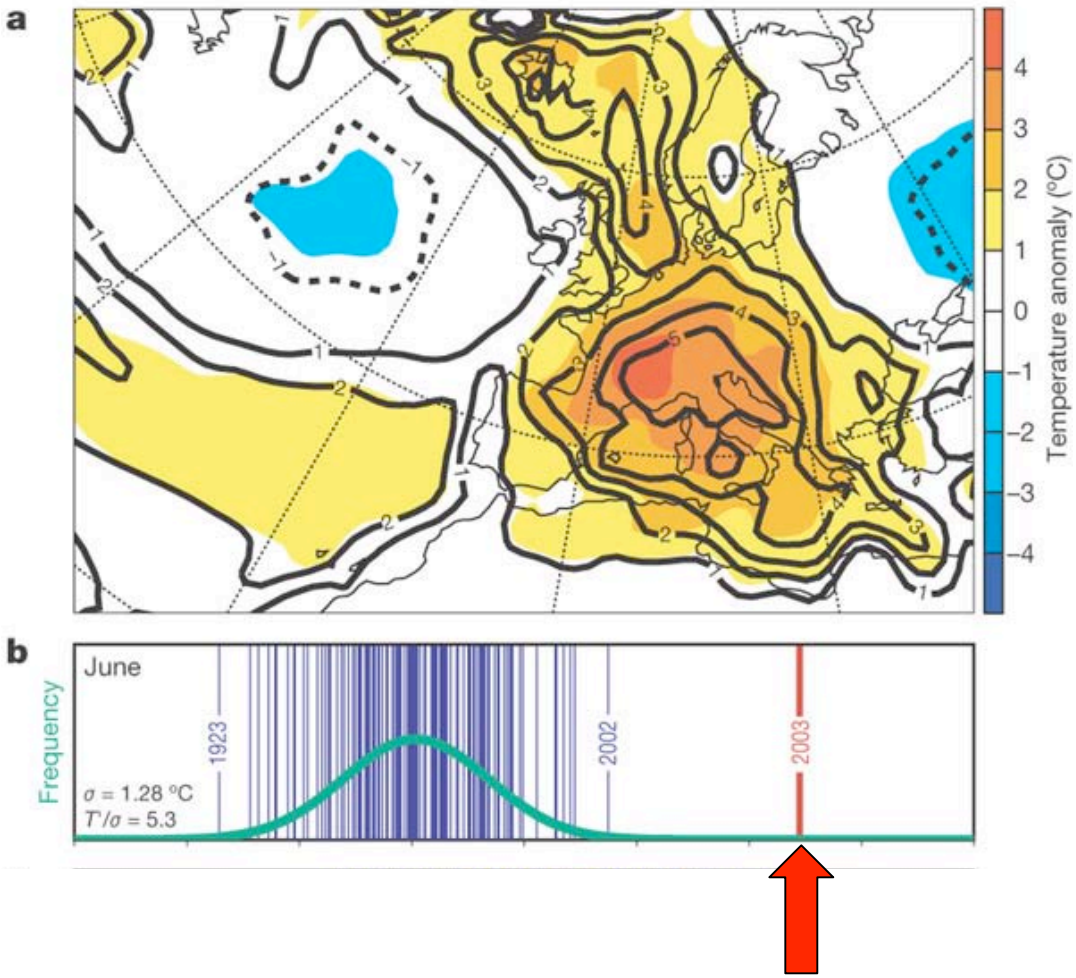
~99% Weather Related



More Frequent Extremes: For a 1.5 °F temperature increase, the *1-in-300 year heatwave* comes *every 10 years*.

Fingerprint: the 2003 European Heat Wave

(hottest summer since 1500 AD)



The European heat wave of Summer 2003

Source: Schar 2004 (*Nature*)

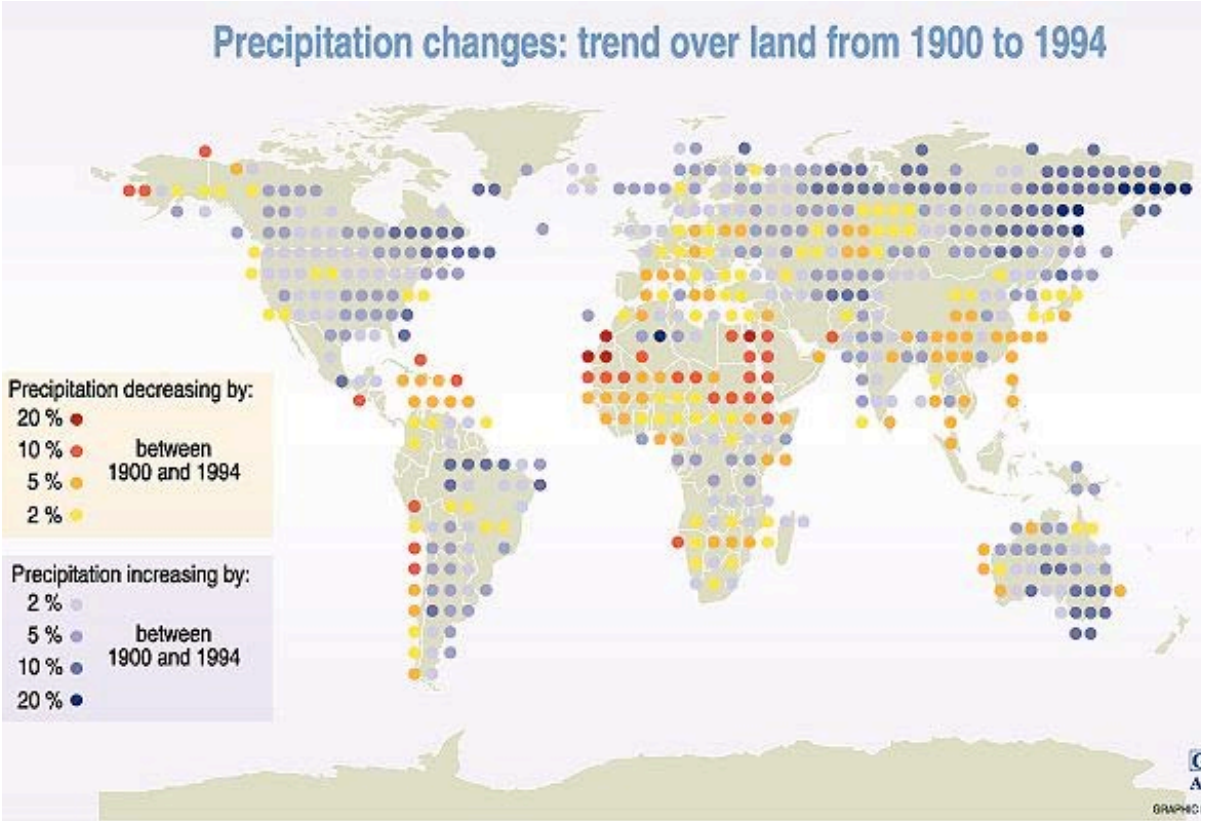
Multiple correlated, impacts:

- 22,000-35,000 human fatalities (+unhealthy air masses)
- $13.6B in crop/livestock losses
- 25,000 fires; 1.2 million acres. $1.7B in wildfires in Portugal alone + respiratory illness
- Nuclear power plant curtailment (insufficient cooling water)
- Electricity prices 20x US average
- Avalanches (melting permafrost)
- Unhealthy air masses (smog, particulate)

Small-scale, Gradual, Diffuse, and Indirect Events Often Overlooked

Greater combined impacts than CATs in an average year

- Blackouts
- Crop damages
- Equipment breakdown
- Eroded air quality
- Eroded water quality
- Hail
- Ice Storms
- Infectious diseases
- Lightning
- Mudslides
- Permafrost melt
- Sea-level rise & coastal erosion
- Sinkholes
- Subsidence
- Thunderstorms
- Tornados
- Vehicle damages/injuries
- Wildfire
- Winterstorms

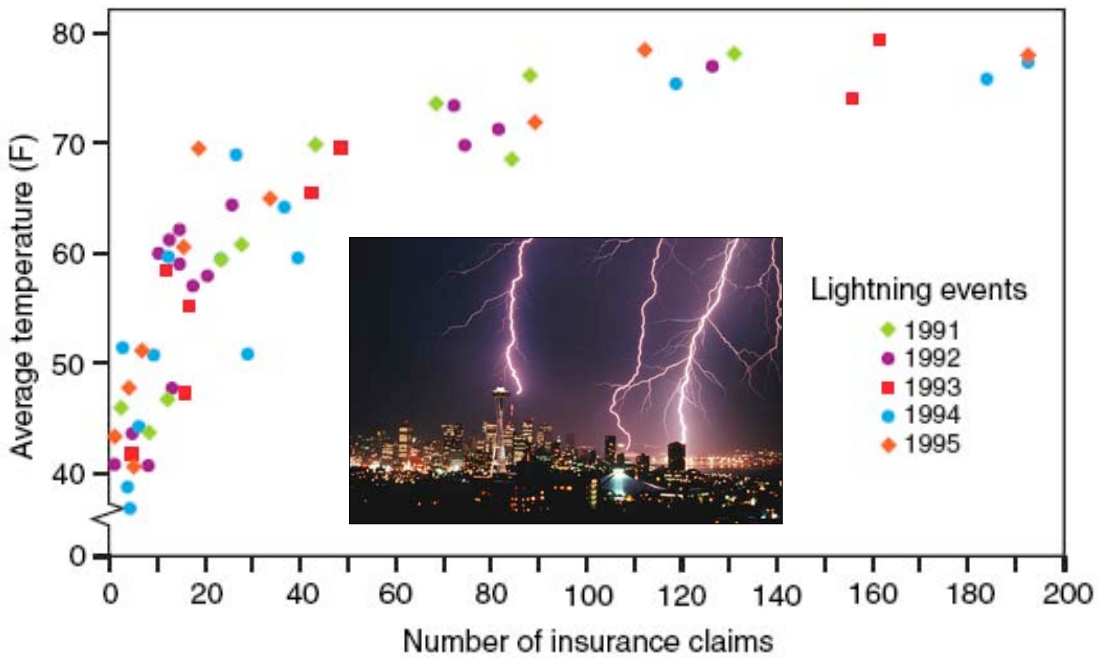


: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP an
y, 1996; Hulme et al., 1991 and 1994; Global Historical Climate Network (GHCN), Vose et al., 1995 and Eischeid et al., 1995)

Mudslide in El Salvador (2001)

Fingerprint: Lightning

Lightning-related damages *accelerate* with temperature



Source: Hartford Steam Boiler Inspection and Insurance Co.

Examples of Losses:

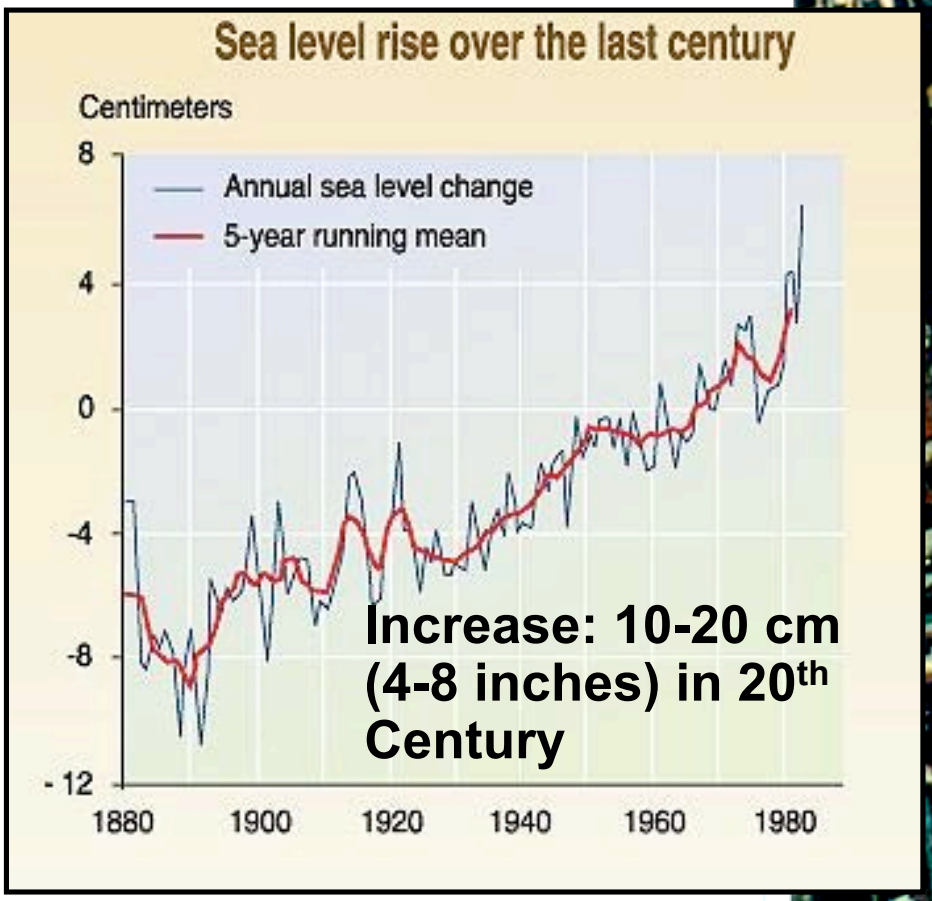
State Farm: $330M/year in claims

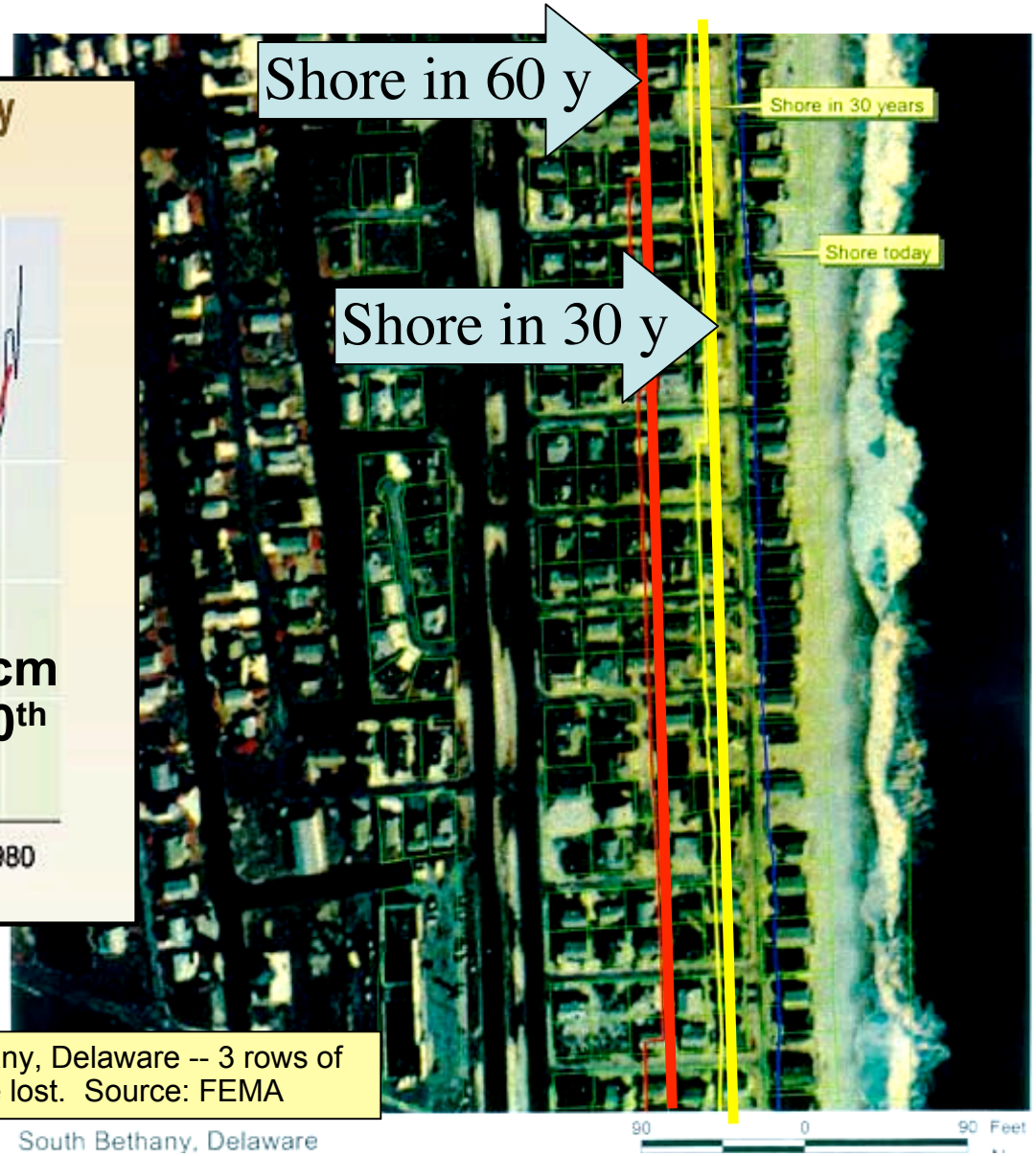
Factory Mutual: 3-4% of claims

- 50% wildfires in western US
- >3000/year: structural, vehicle fires
- 30% of power outages
- 80% of petroleum storage accidents
- 346 incidents, 81 nuclear sites: 1990s
- $2B/year: airline operating costs
- 100,000/y: desktop computer losses
- Traffic signal outages

Source: www.lightningsafety.com

Fingerprint: Sea Level Rise

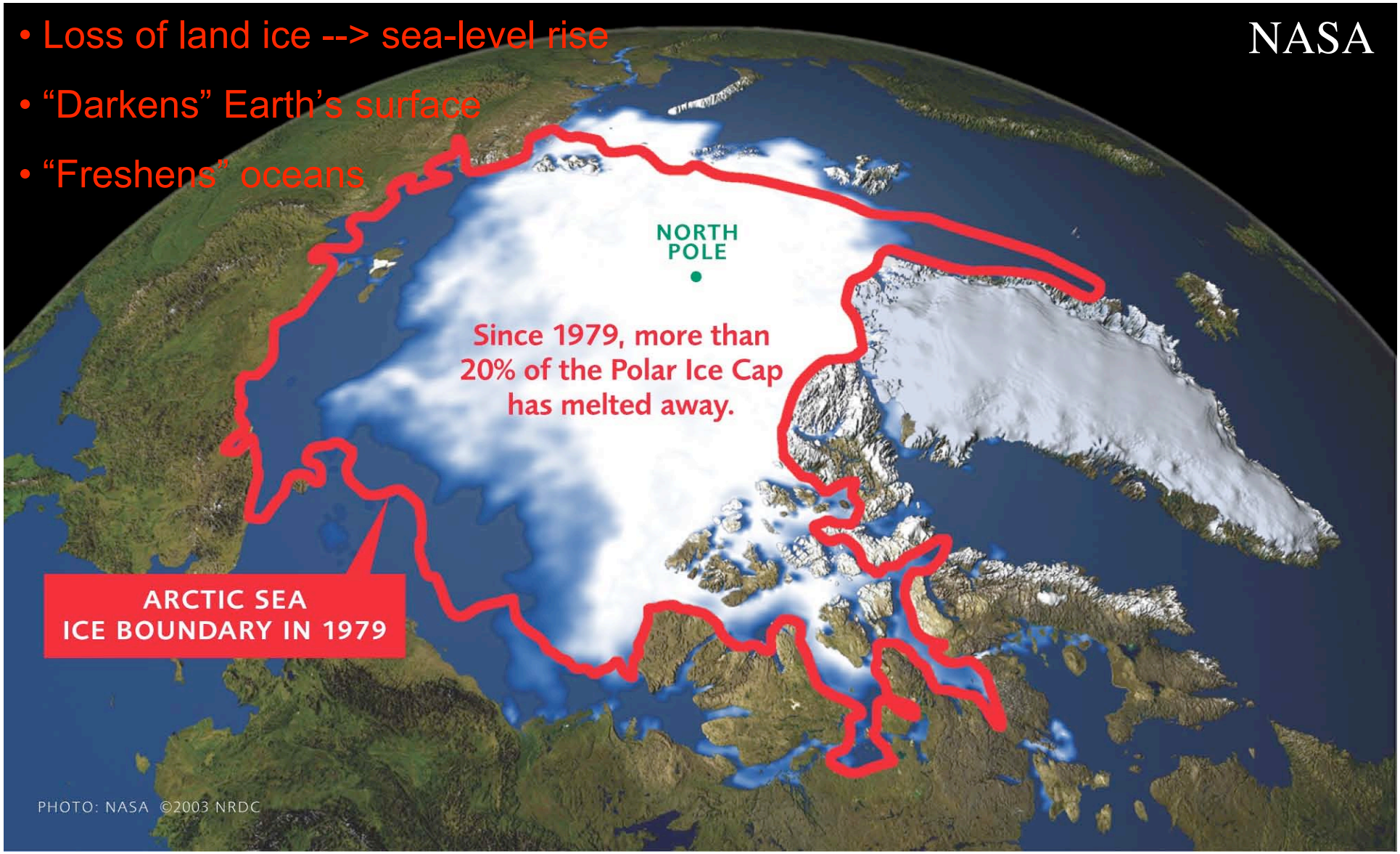




3 feet displaces 200 million people globally

South Bethany, Delaware -- 3 rows of homes to be lost. Source: FEMA

Fingerprint: Loss of Ice & Snow Cover



- Loss of land ice --> sea-level rise
- “Darkens” Earth’s surface
- “Freshens” oceans

Harvard Expedition to North Pole

Polar Bears are the Canaries in the Mineshaft

- Polar bears drowning in unprecedented numbers
- Reduced birth rates
- Extinction projected this century
- (Inuit hunters also impacted)

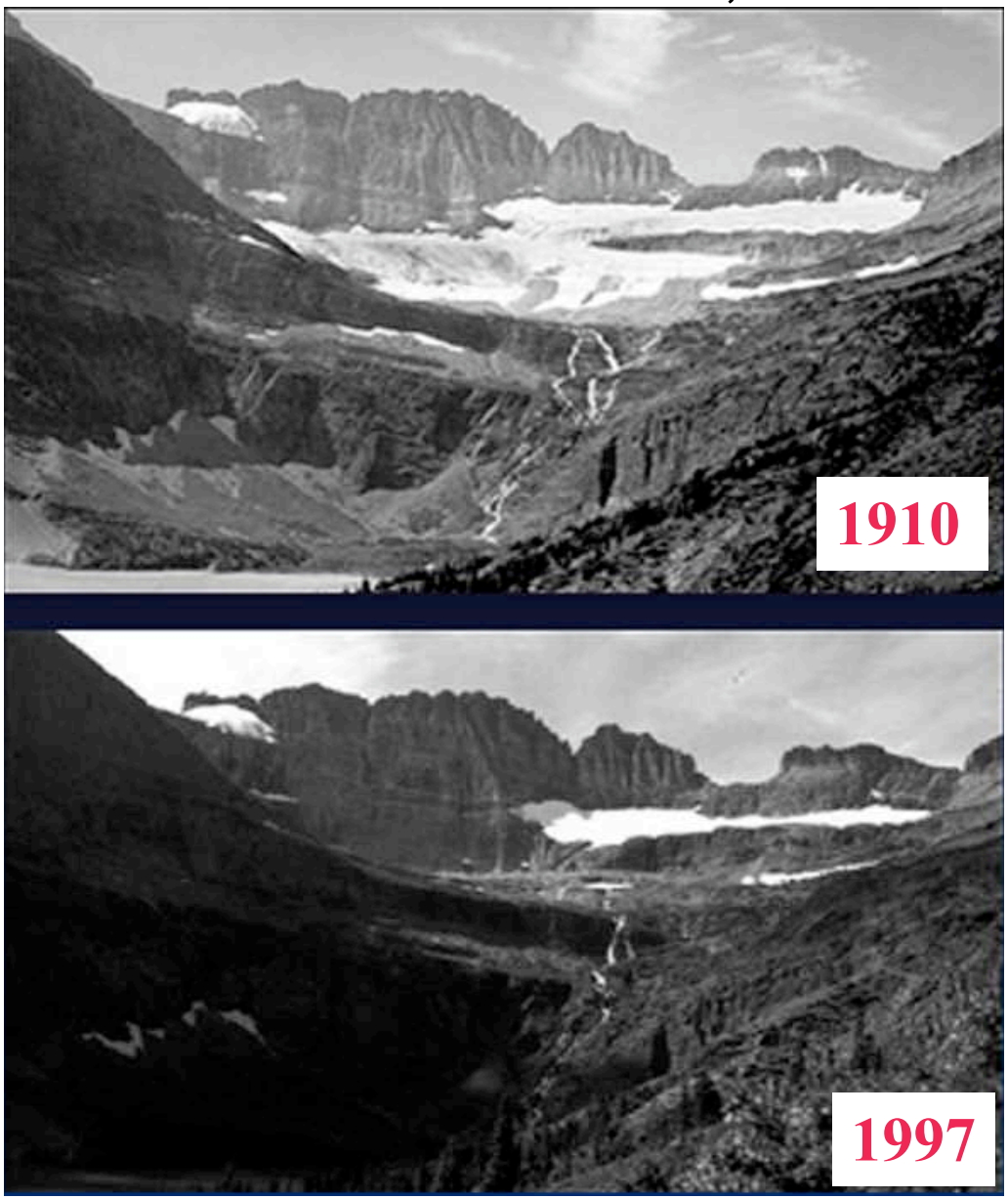
Photo Credit/Crédit photographique: Dan Crosbie

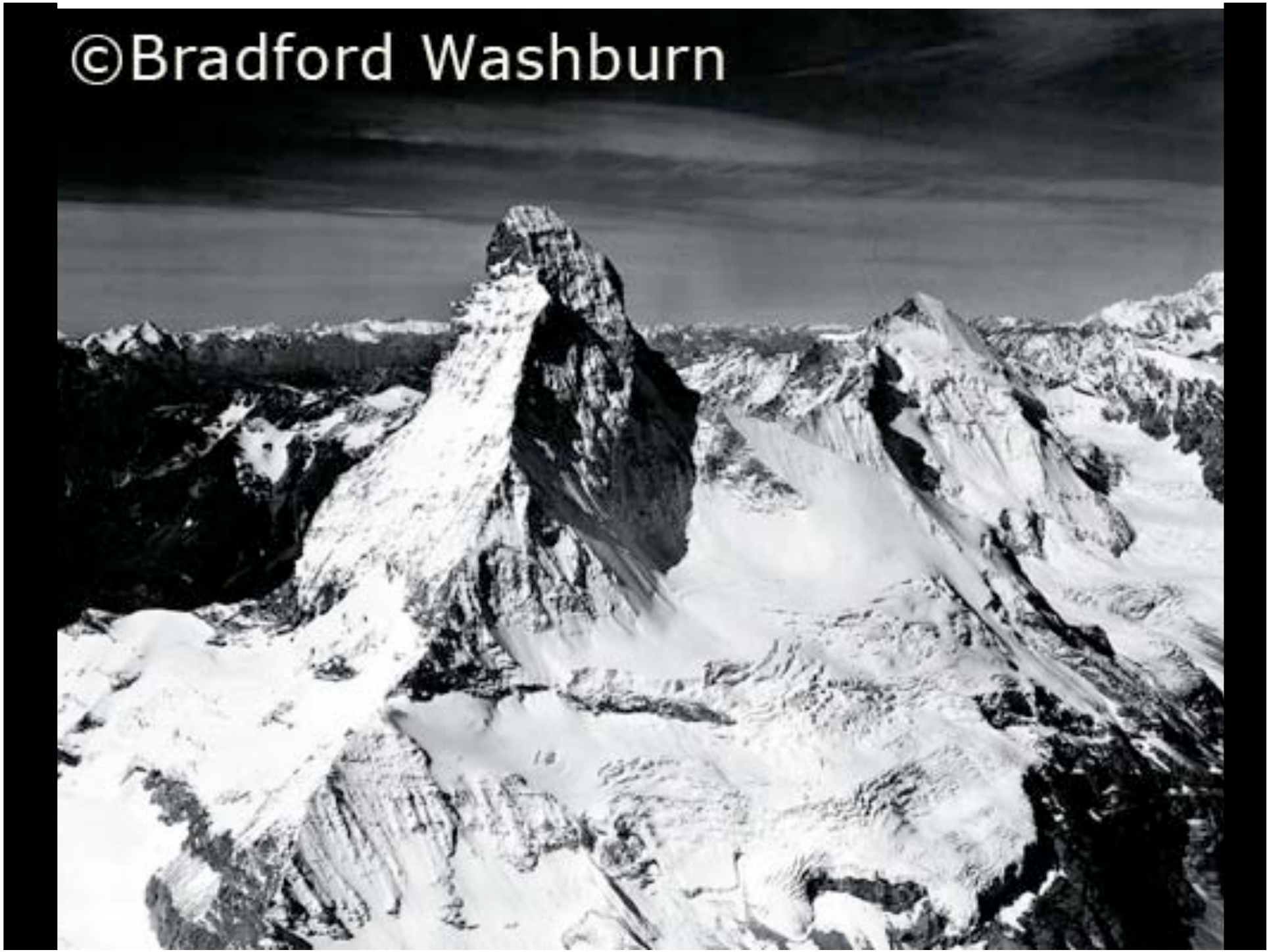
Fingerprint: Systematic Worldwide Glacier Retreat

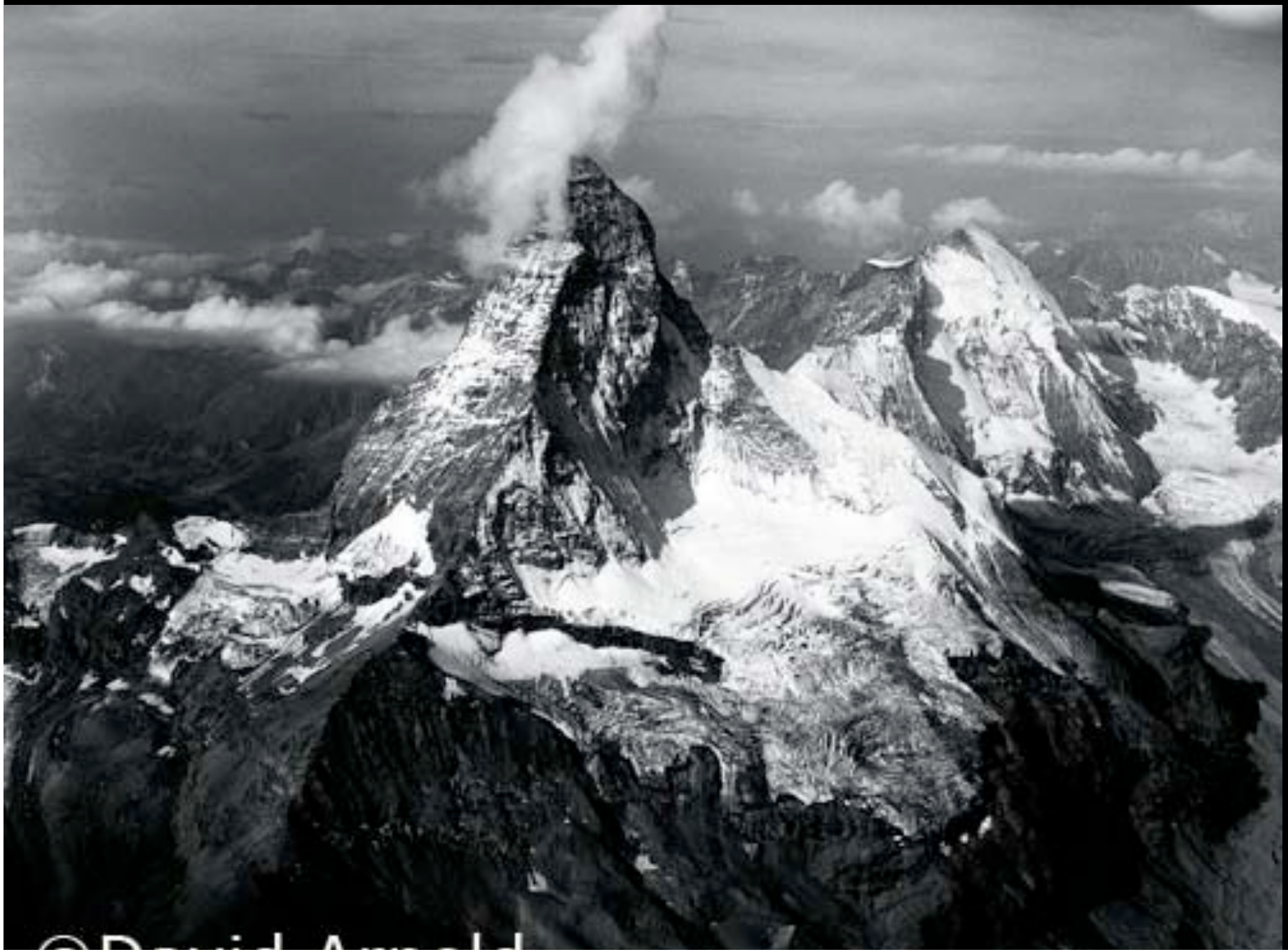
Americas
Europe
Asia
Africa
Australasia

Loss of world's glaciers = 1 1/2 foot sea level rise

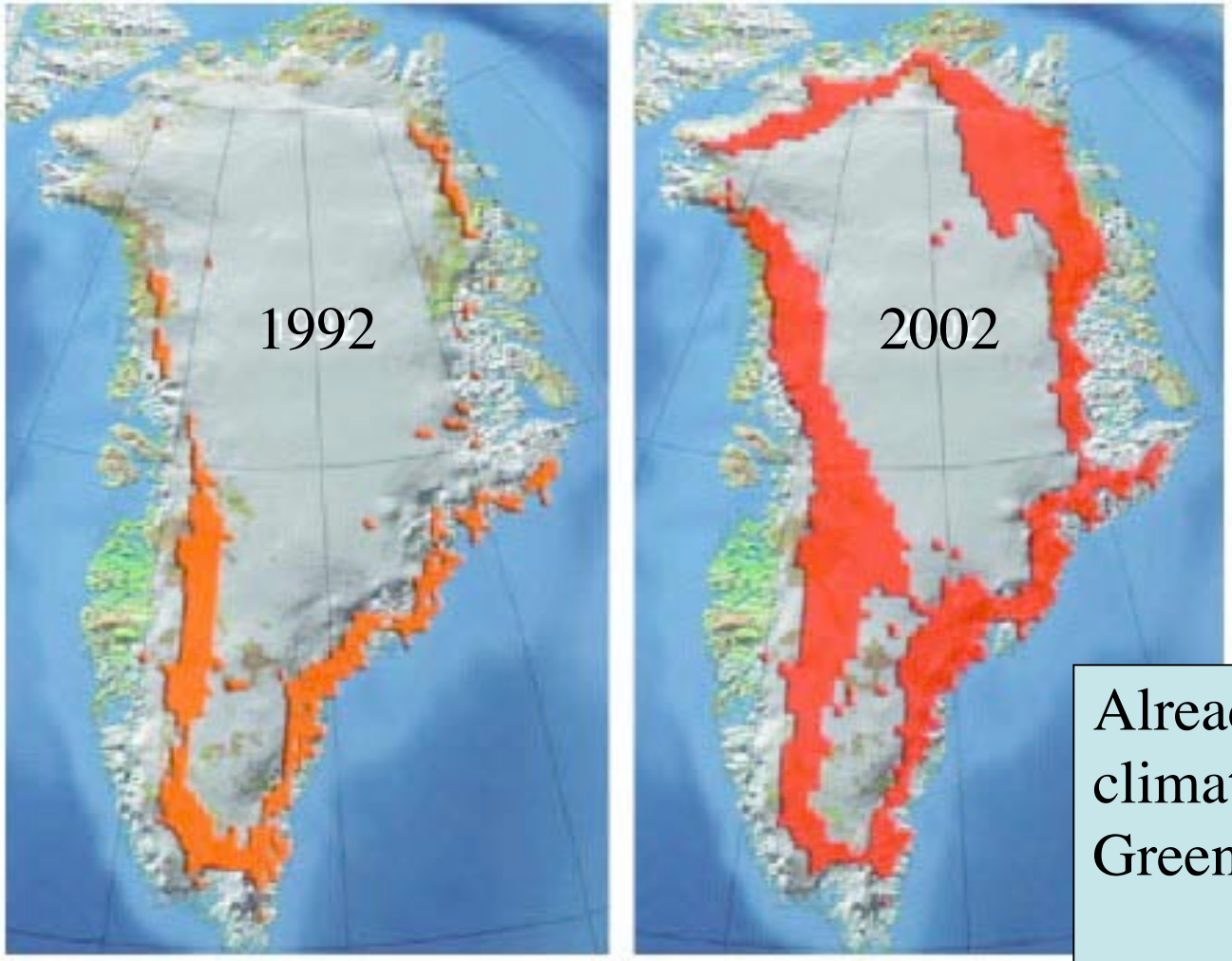
Grinell Glacier
"Glacier" National Park, USA




©Bradford Washburn


©David Arnold

The Greening of Greenland: 50 cubic miles of ice lost each year

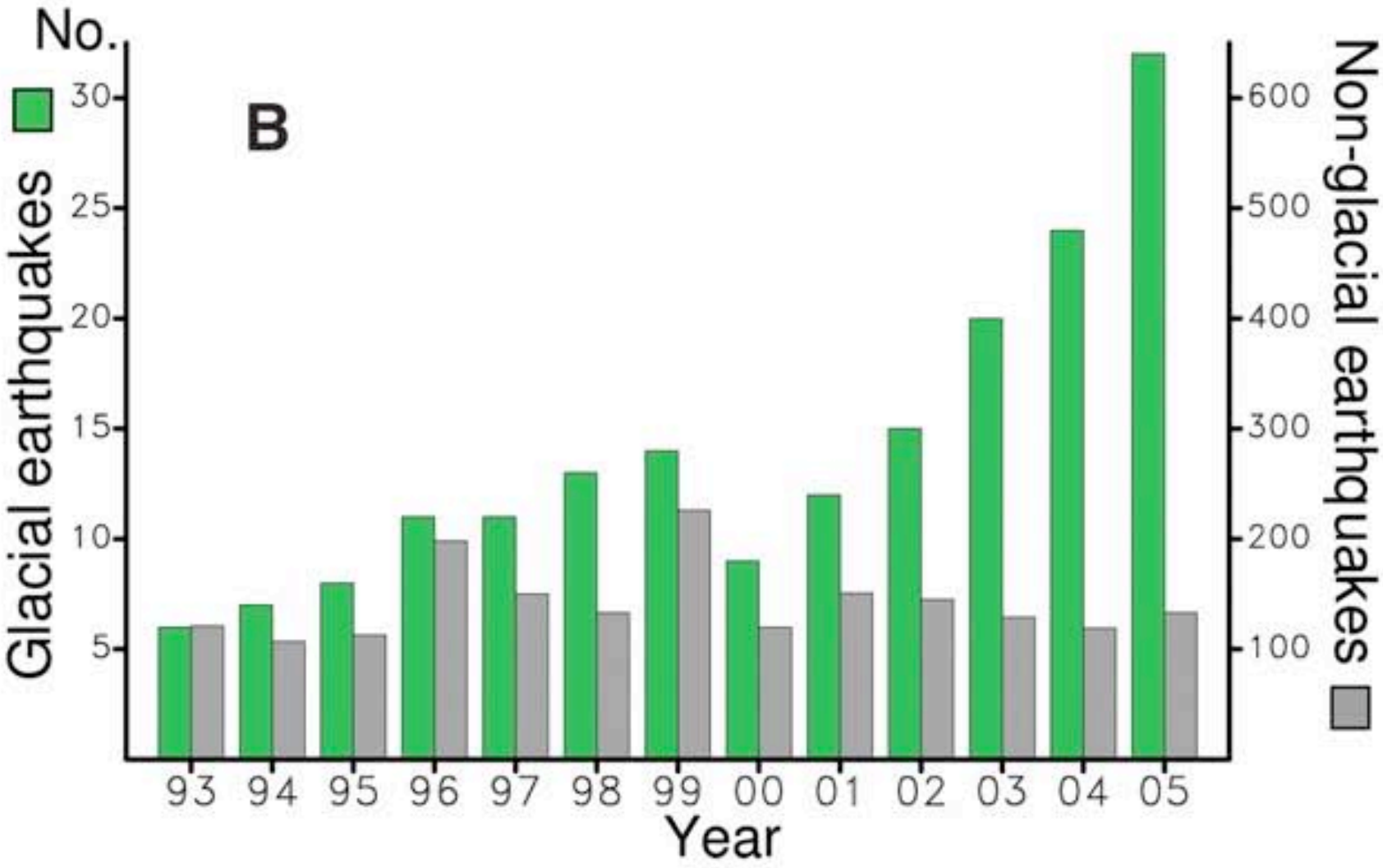


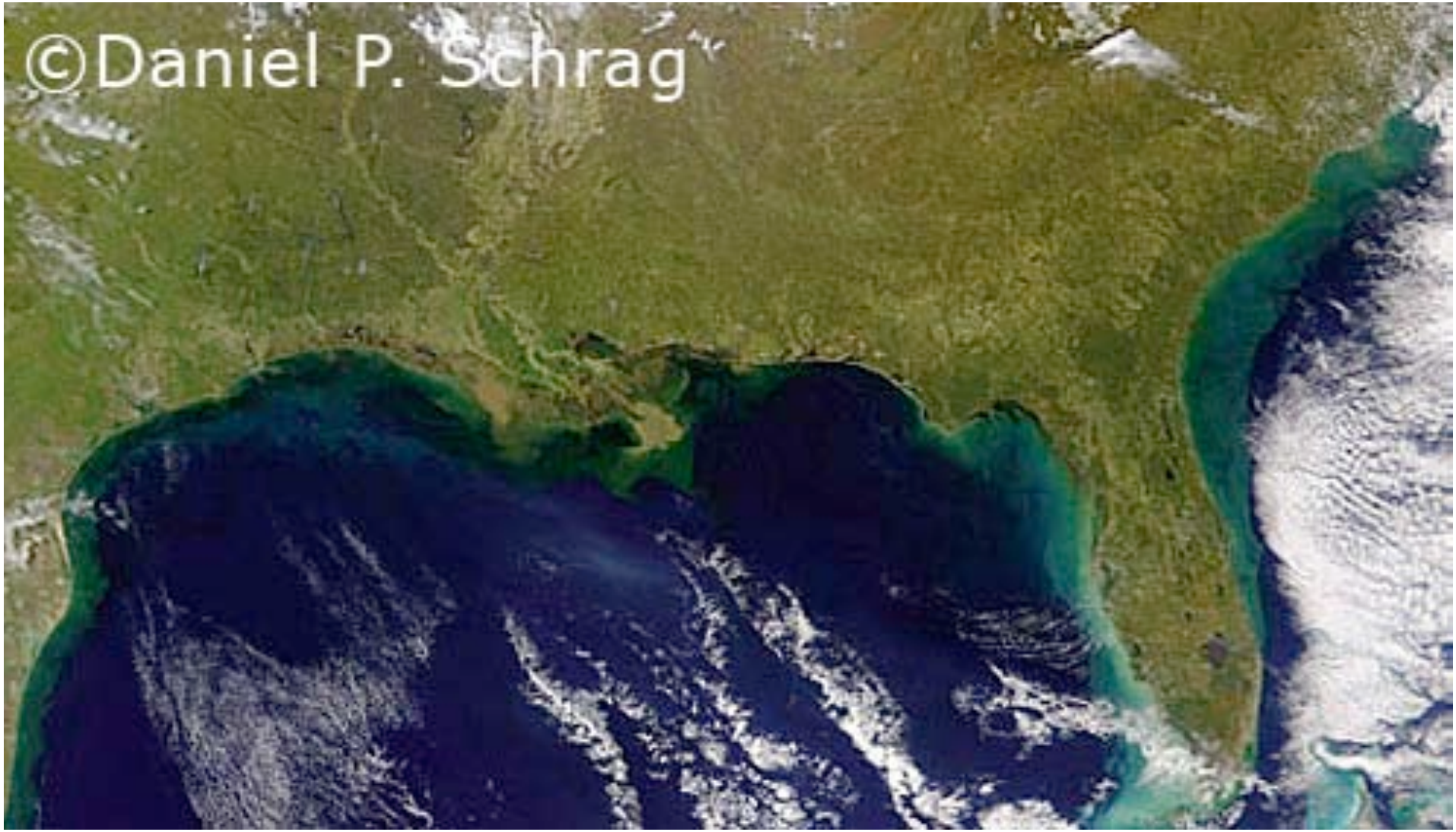
Source: Alley et al. *Science* (21 October 2005)

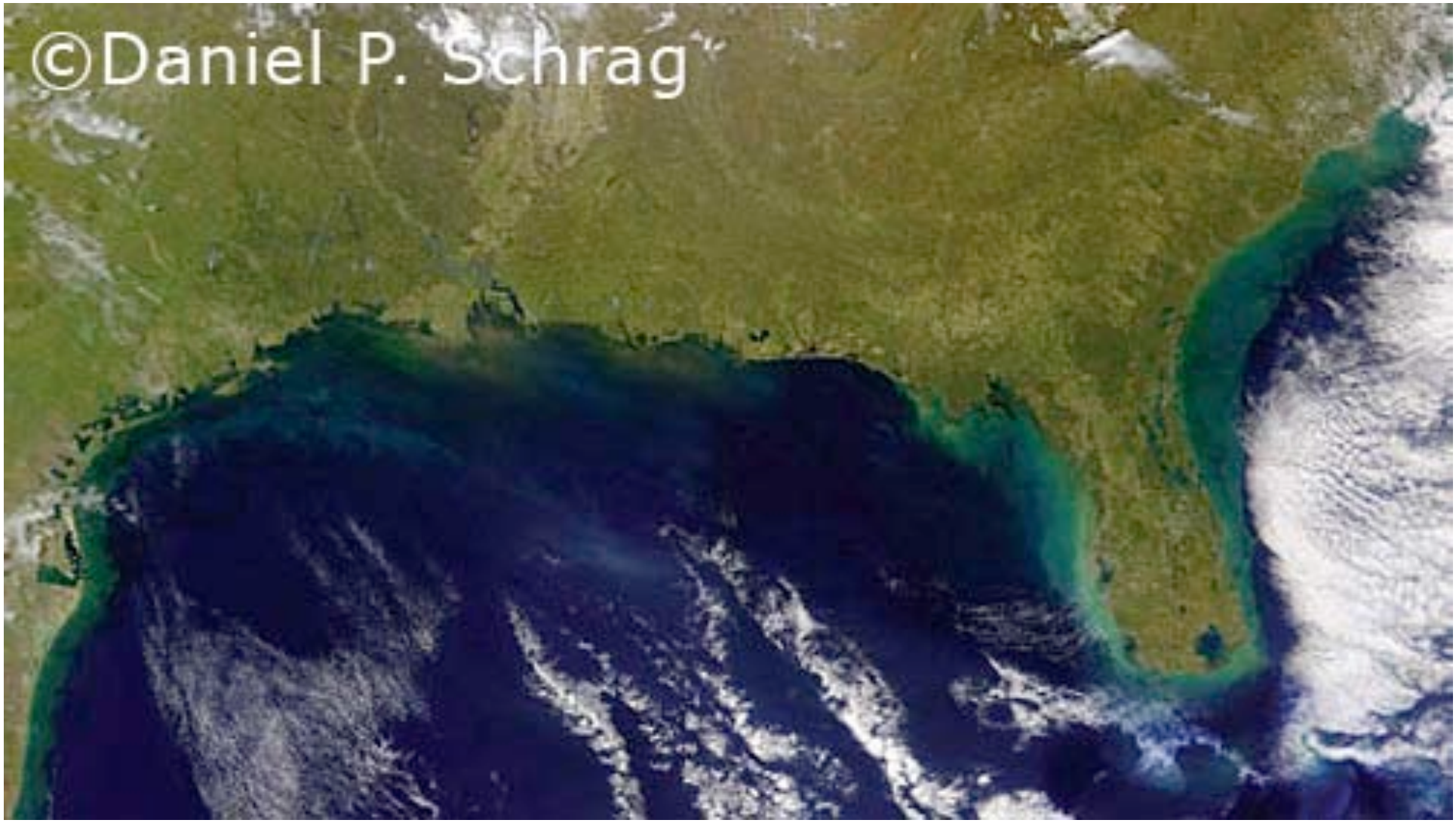
Already enough climate change to melt Greenland

= 10 feet sea level rise

Glacial Earthquakes on the Rise




©Daniel P. Schrag



Sea-level Rise for Half of Greenland Melting: ~2100
(Source: Harvard University)

©Daniel P. Schrag

Harvard University
Sea-level Rise for Half of Greenland Melting: ~2100

Mt. Kilimanjaro (Tanzania)

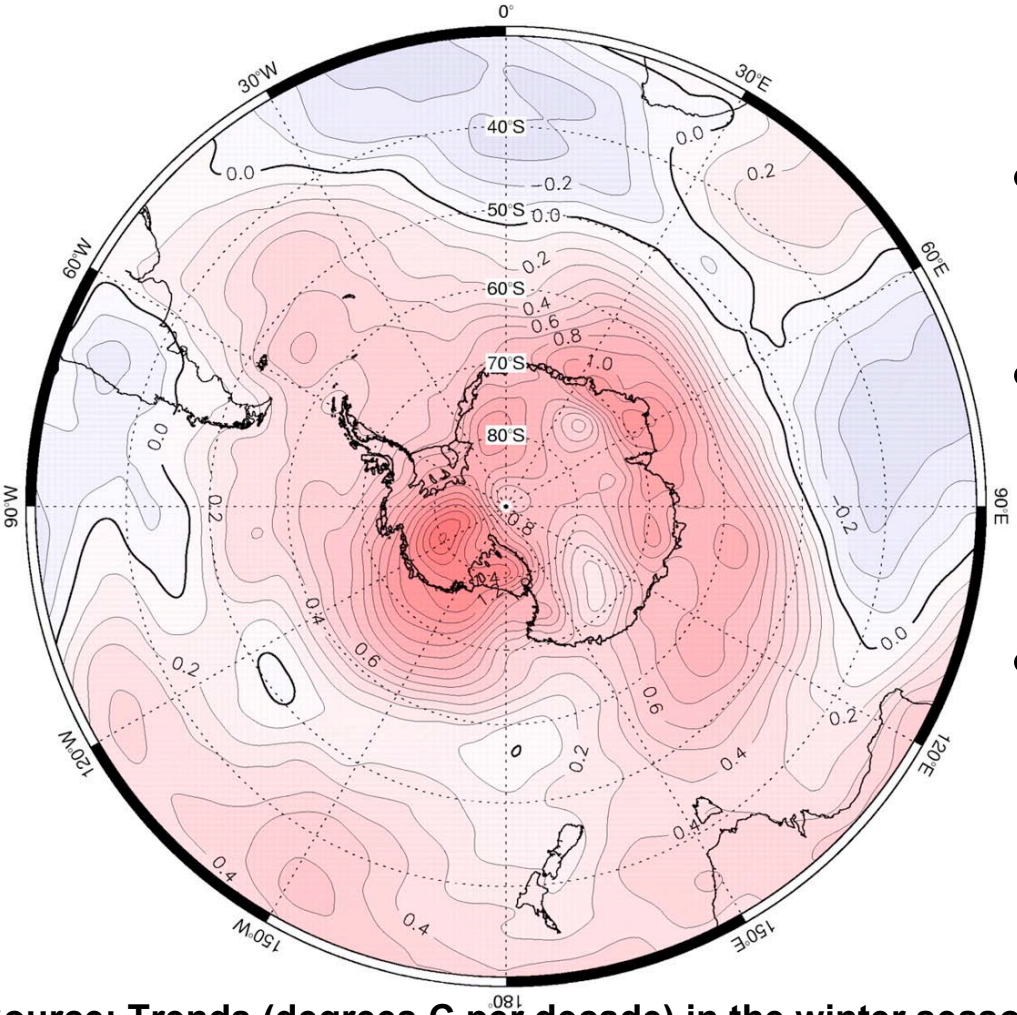
1990

2000

The snows will be gone in 15 years

Permafrost Disintegration

Rapid Antarctic Warming



- First Antarctica-wide warming picture
- 1 degree Warming per Decade over past 30 years
- Warming 3x faster than world average

Source: Trends (degrees C per decade) in the winter season 500-hPa temperatures from 1979 to 2001

from the ECMWF reanalysis British Antarctic Survey J. Turner et al., *Science* 311, 1914 -1917 (2006)

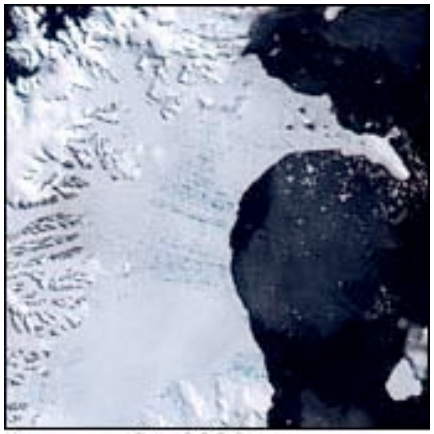
Abrupt Climate Change

In the largest single ice sheet disintegration event in recorded history, **approximately 3,250 square kilometers of the Larsen B ice sheet shattered in a *five-week* period in 2002**.

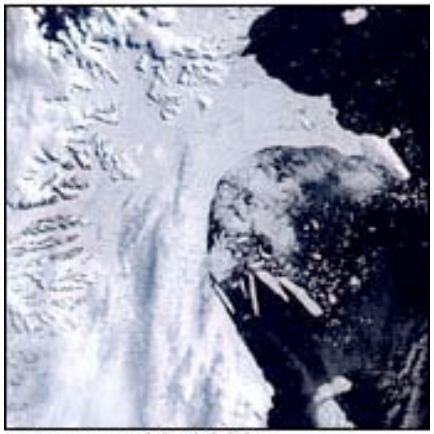
The disintegration released 720 billion tons of ice into the Weddell Sea.

Equal to area of Los Angeles Basin

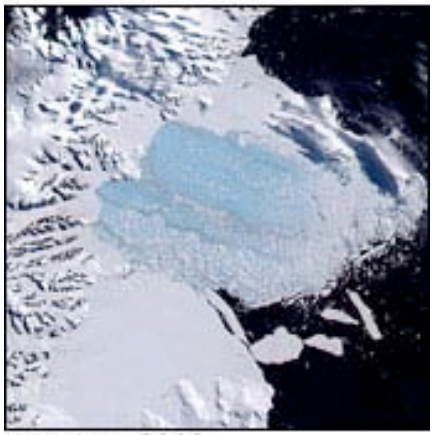
Source: National Snow and Ice Data Center



January 31, 2002



February 23, 2002

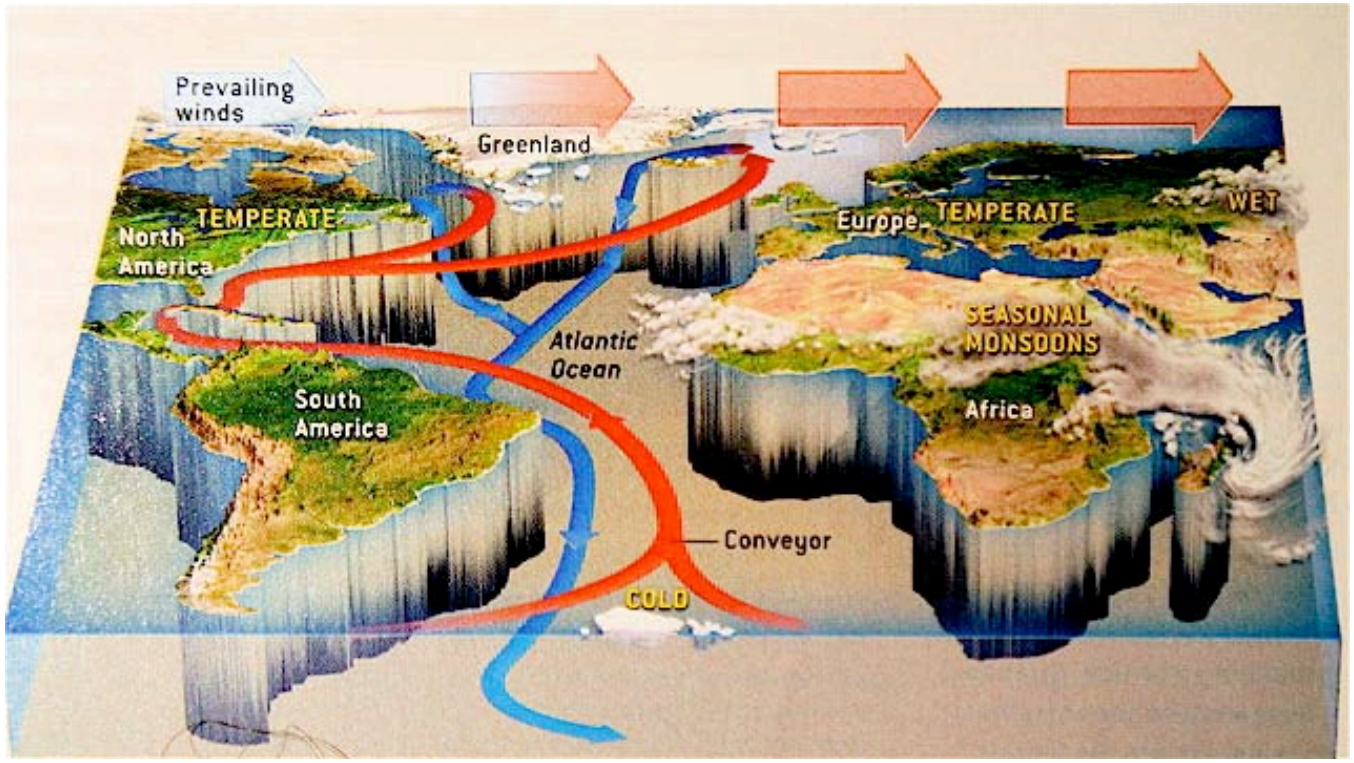


March 7, 2002

Abrupt Climate Change

The Ocean Conveyor Belt

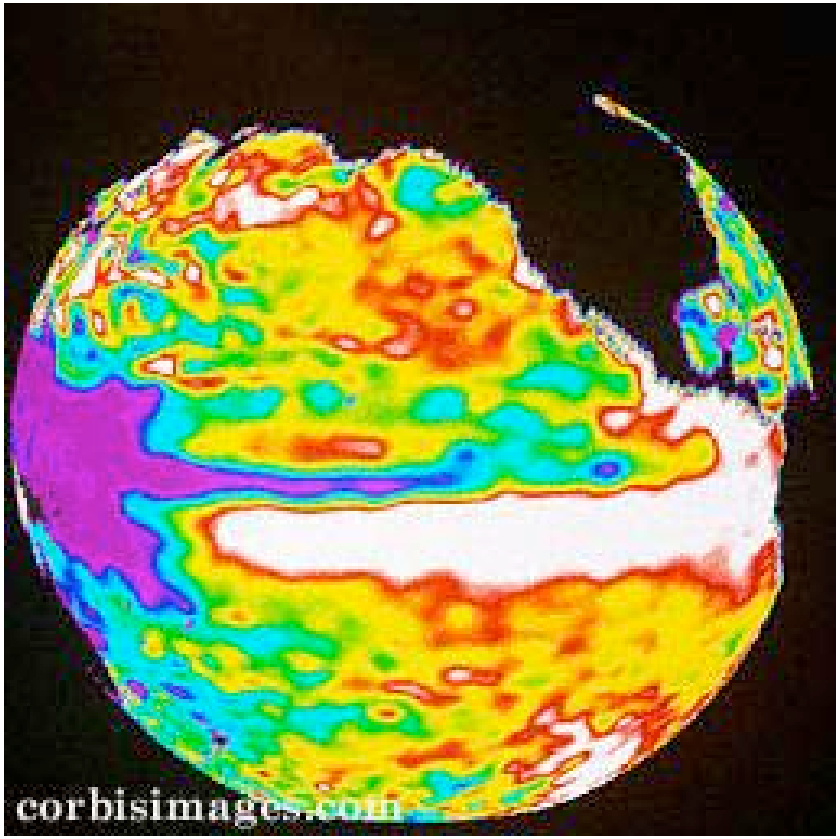
Labrador and South England are same latitude



1998-2004 30% reduction in observed flow@ 25°NL
= Heat equivalent of 500,000 power plants (Source: Bryden et al. *Nature*)

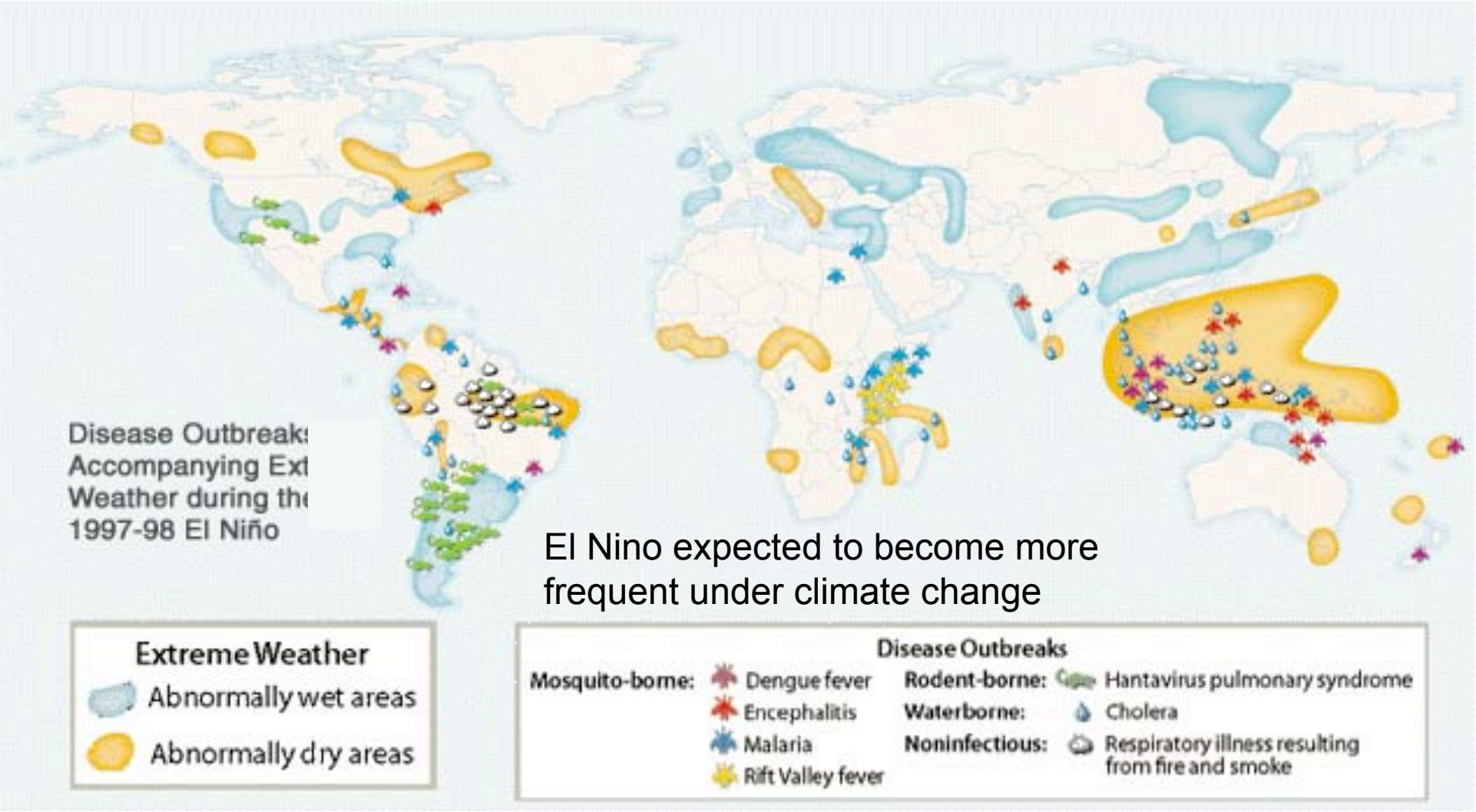
Human Health Impacts

- **Human Systems**
  - Heat stress
  - Respiratory disease
    - Pollen
    - Mold
    - Smoke and particulates
    - Urban air pollution
  - Infectious diseases
  - Food poisoning
  - Water quality
  - Injury/death from disasters
  - Environmental contamination



WHO estimates 150,000 human mortalities each year due to current climate change

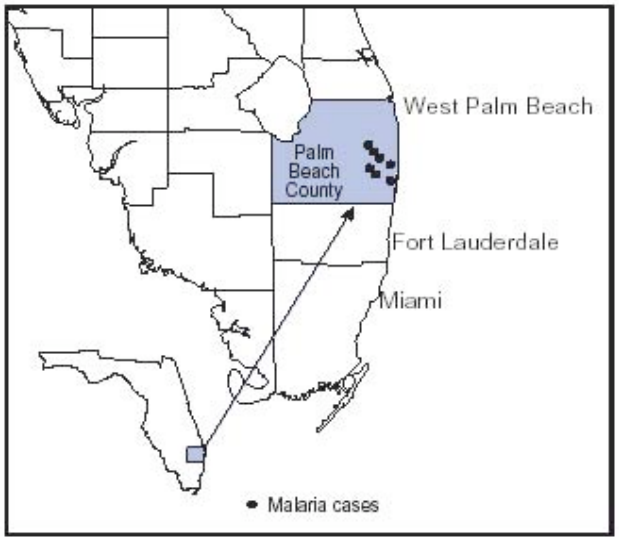
Correlation of Disease Clusters with the 1997-1998 El Nino Weather Extremes



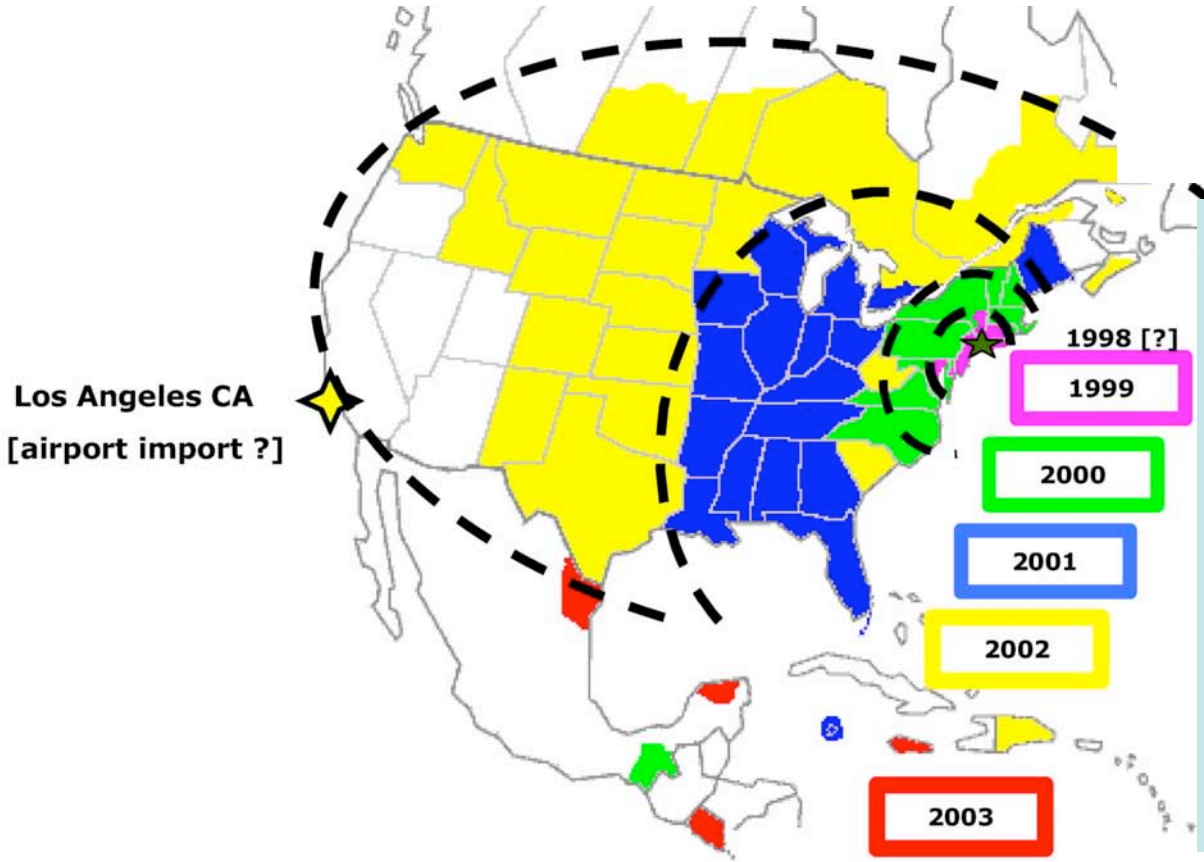
Source: Harvard Medical School, Center for Health and the Global Environment (*Science*)

Malaria in Florida (2003)

FIGURE. Location of cases of Malaria — Palm Beach County, Florida, July–August, 2003



Spread of West Nile Virus in North America: 1999-2002



Drought-Mosquito-Bird Vector chain

Human Impacts:

2001: 66 cases; 9 deaths
2002: 4161 cases; 284 deaths
***Science* 2002:297:1988**

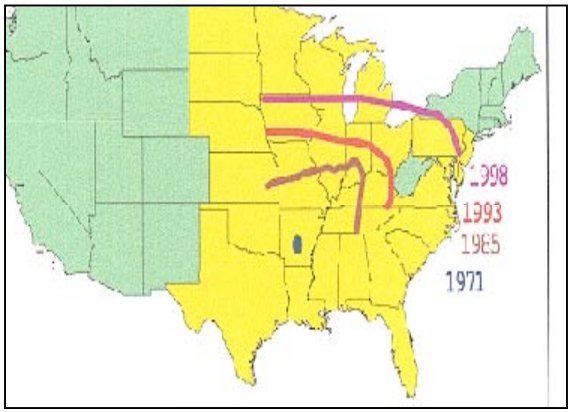
233 Other species

Sources: U.S. Army Environmental Programs Directorate, from Centers for Disease Control, Health Canada, USGS, and ProMED-mail as of 14 May 2003)

Health Impacts on Non-Human Systems Are Economically Important

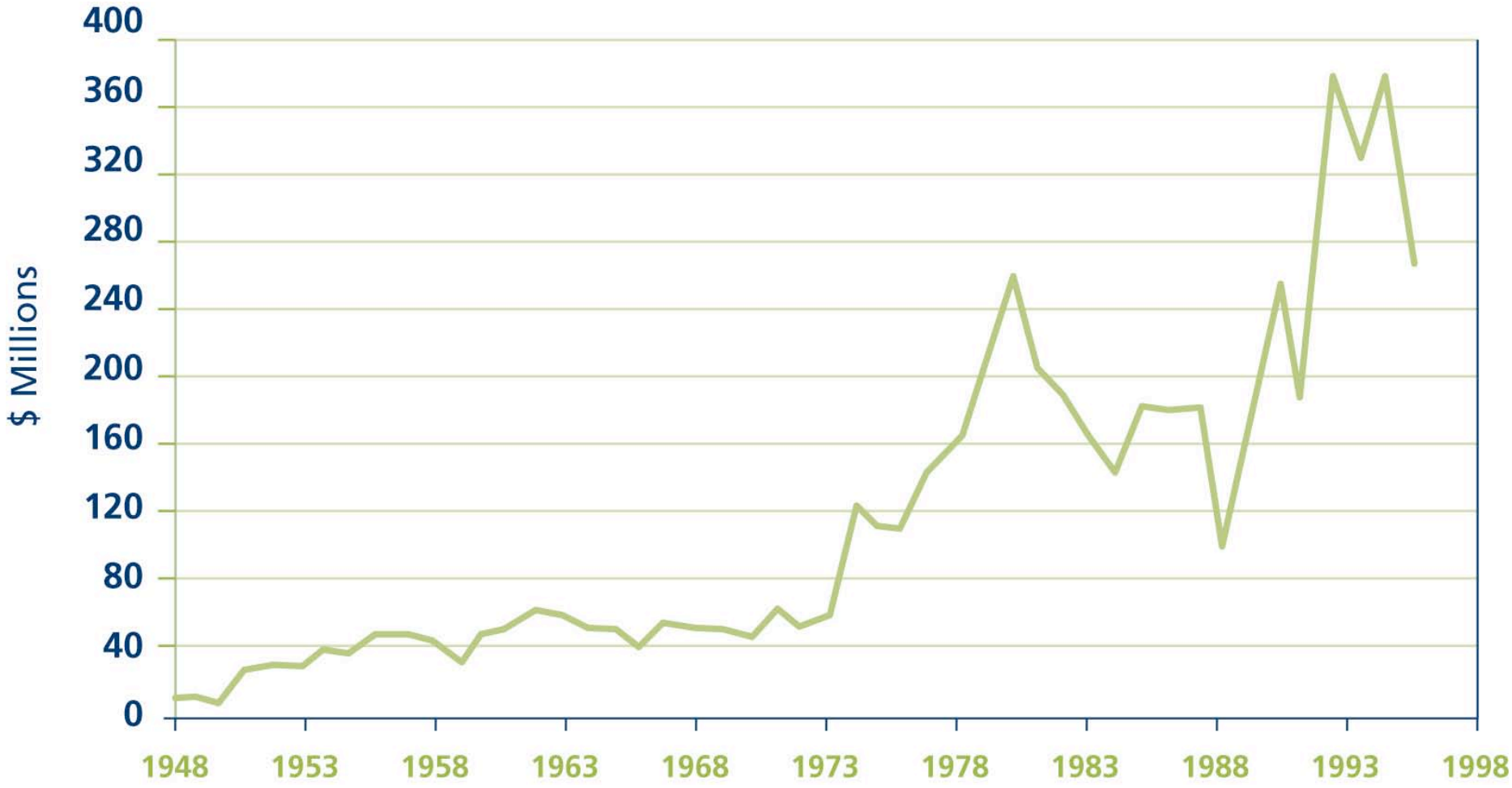
Pine beetle super-infestations: wildfire, lumber products, tourism/recreation, mudslides

Crop Diseases: e.g. Expanding range of soybean rust: 1971-1998

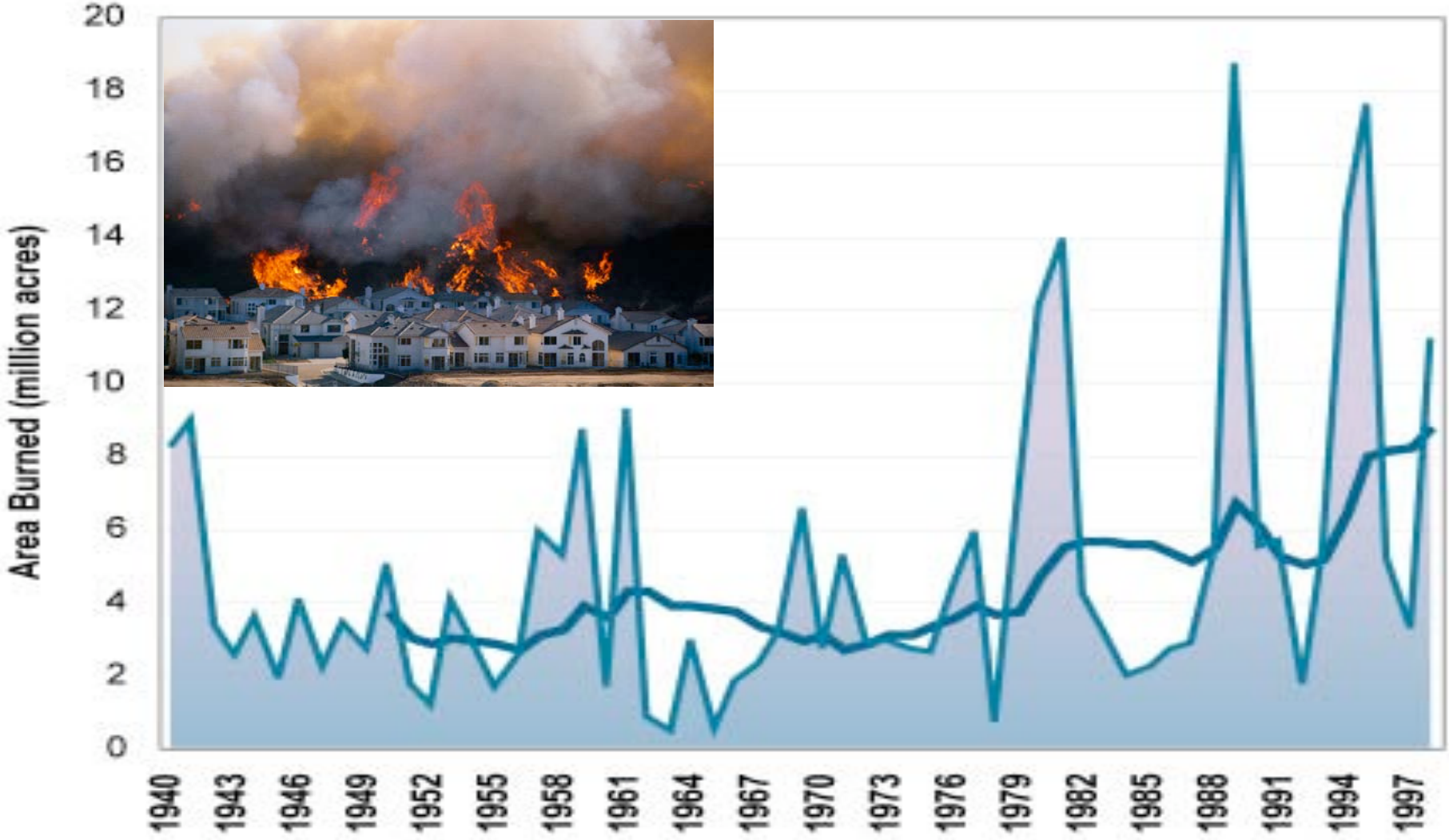


Coral bleaching: loss of pharmaceutical resources; coastal protection; freshwater salinization; fisheries

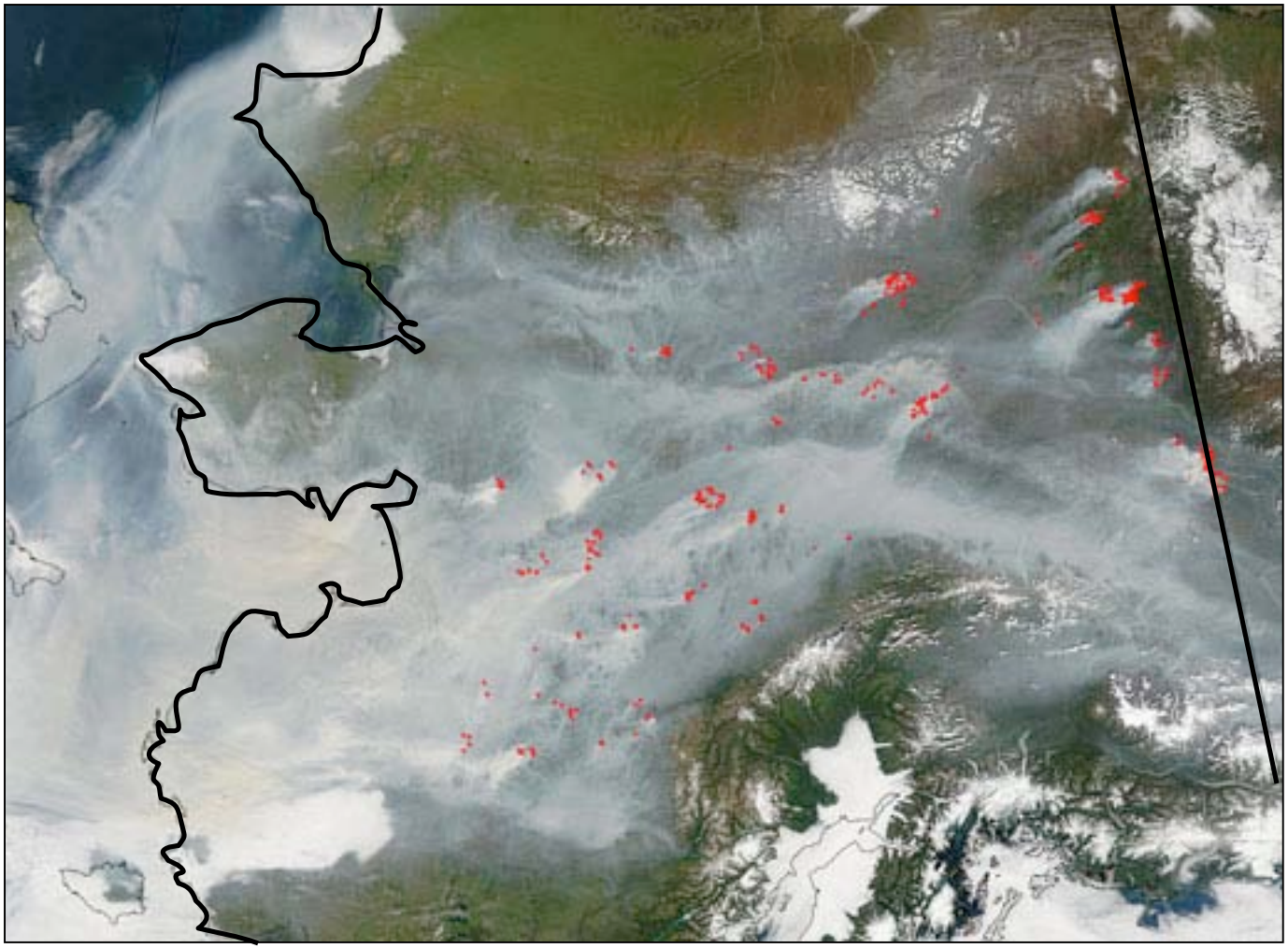
Crop


$ Millions
400
360
320
280
240
200
160
120
80
40
0
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998

Fingerprints: North America wildfire - area burned has doubled since 1970



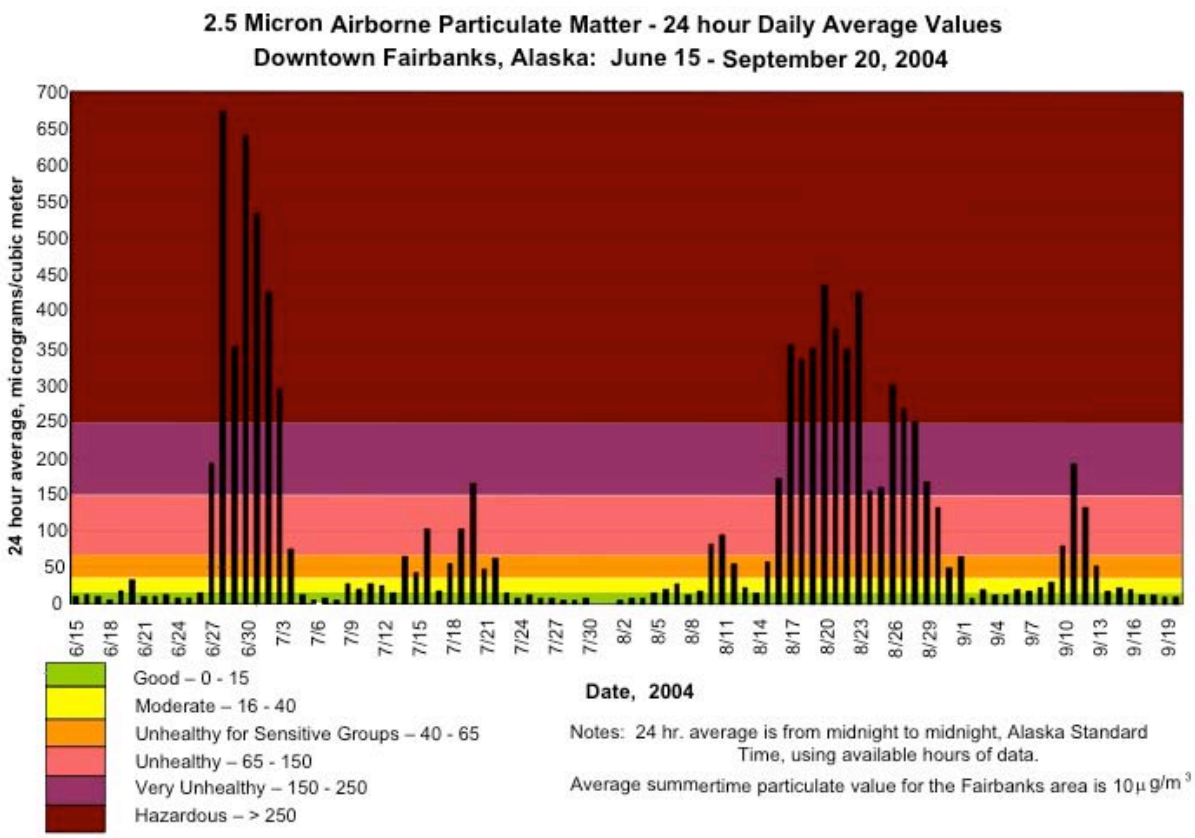
Alaska: Summer 2004



800 miles

Unhealthful air conditions over most of state

Wildfire & Air-Quality Links: Alaska: Summer 2004



Fairbanks June 28, 2004

July 6, 2004

- *October was dry, hot. 85-100°*
- *Fierce Santa Ana winds, up to 70 mph*
- *Humidity below 10-15% in many places*

- *14 fires*
- *Over 750,000 acres*
- *24 deaths, 246 injured*
- *3600 houses burned*
- *Cost over $2 billion*
- *15,000 firefighters*

Copyright

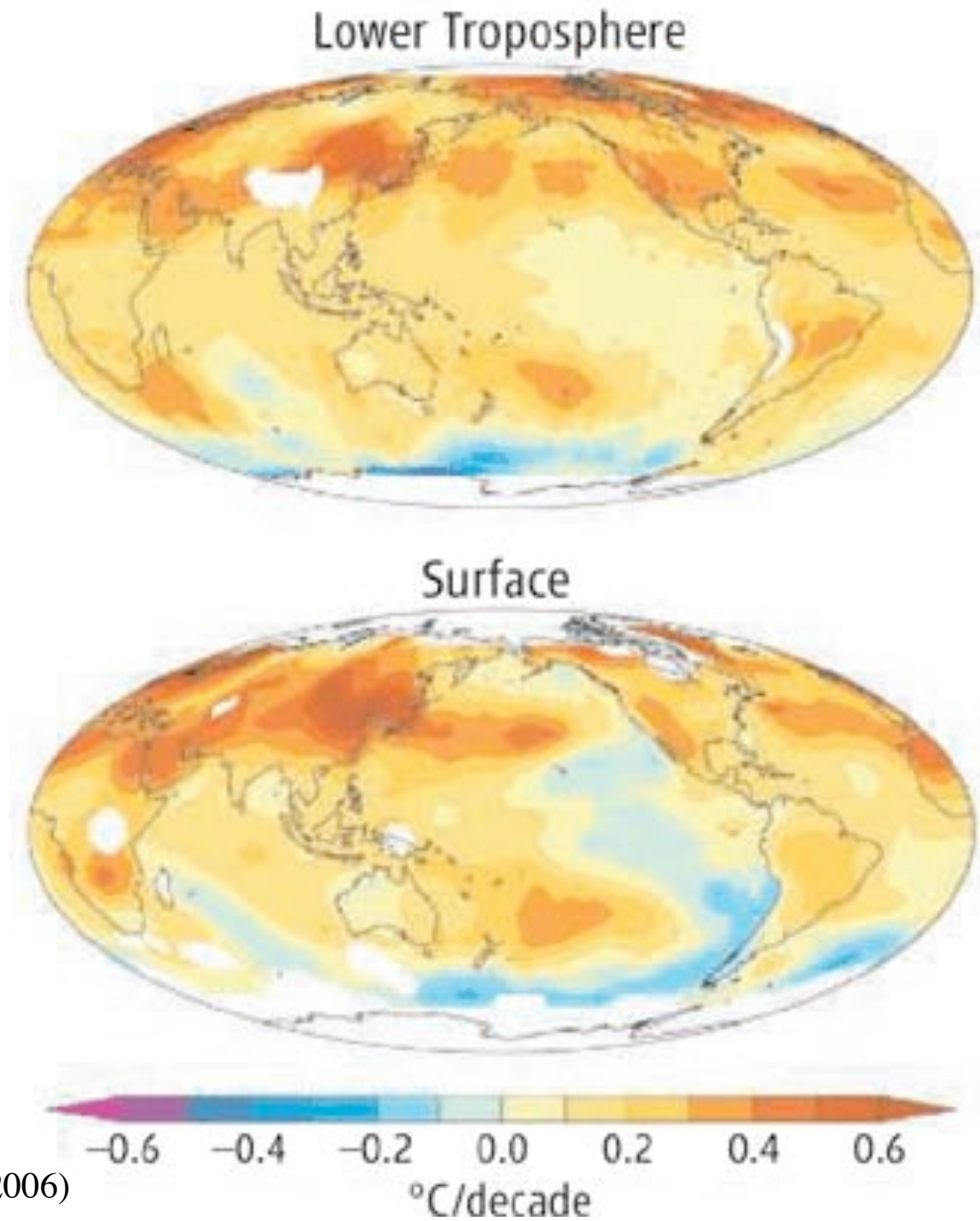
Idyllwild is More Vulnerable to Climate Change Impacts than Most Places

- Water quality/quantity
- Wildfire
- Power outages
- Forest loss/change
- Air pollution
- Loss of tourism
- Sensitive species

Climate Skeptics are an Endangered Species

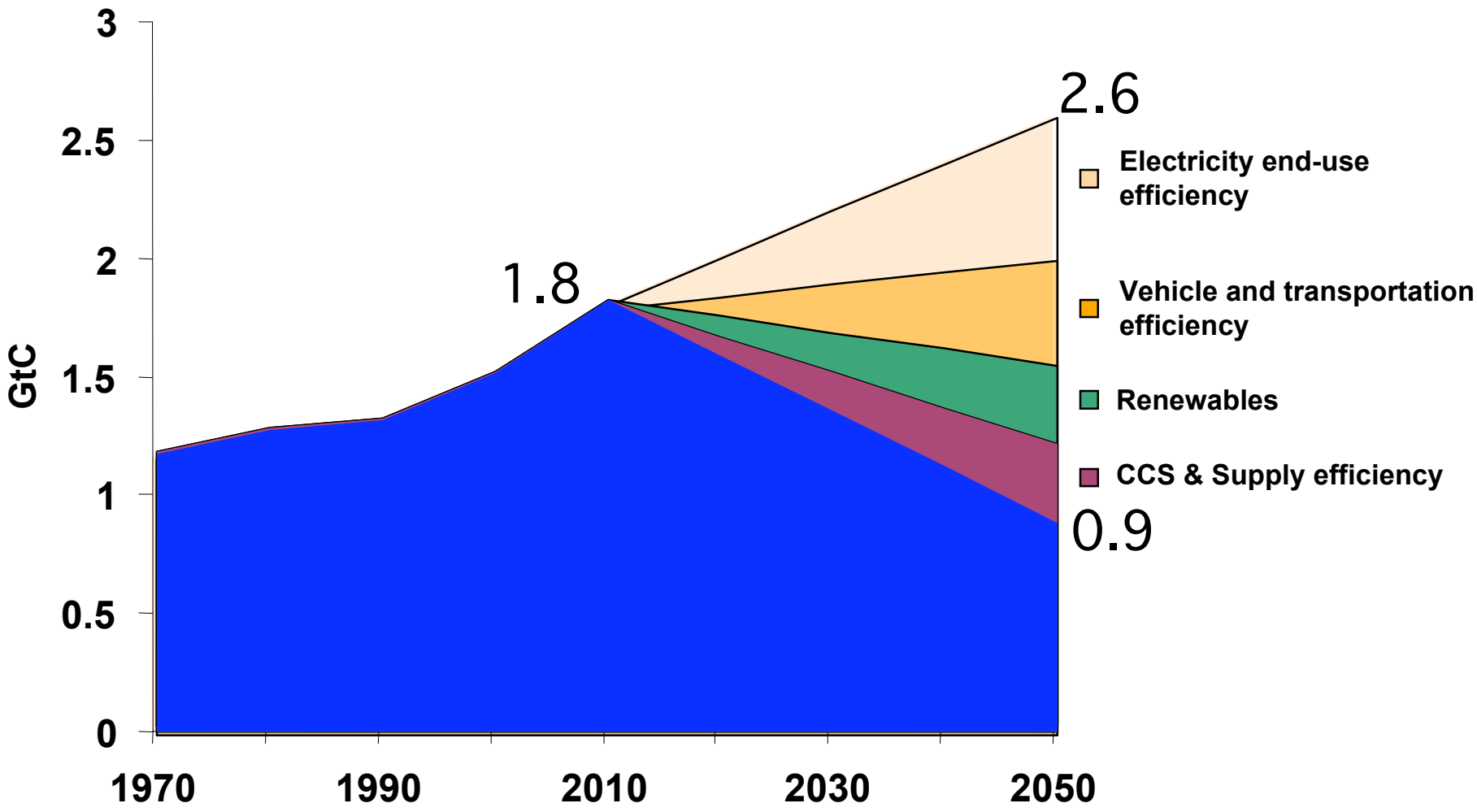
- Variability is a fact of life; but the dice are loaded
- No better alternative theory has been advanced
- Models predict past climate very well
- Risk management is the appropriate response

Satellite data controversy resolved (May 2006)



Source: Kerr, Science v312:825 (12 May 2006)

Cutting U.S. Emissions in Half



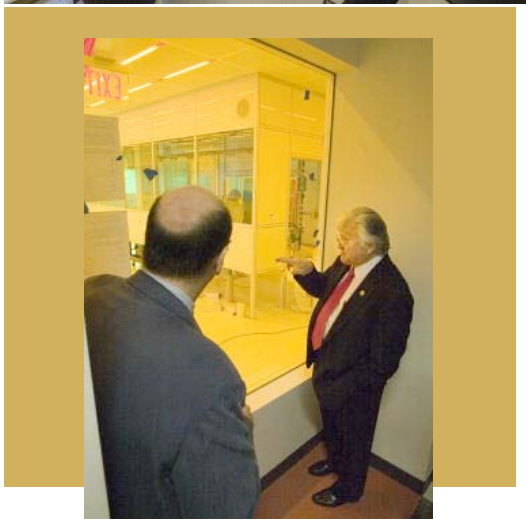
After Pacala and Socolow (*Science*)

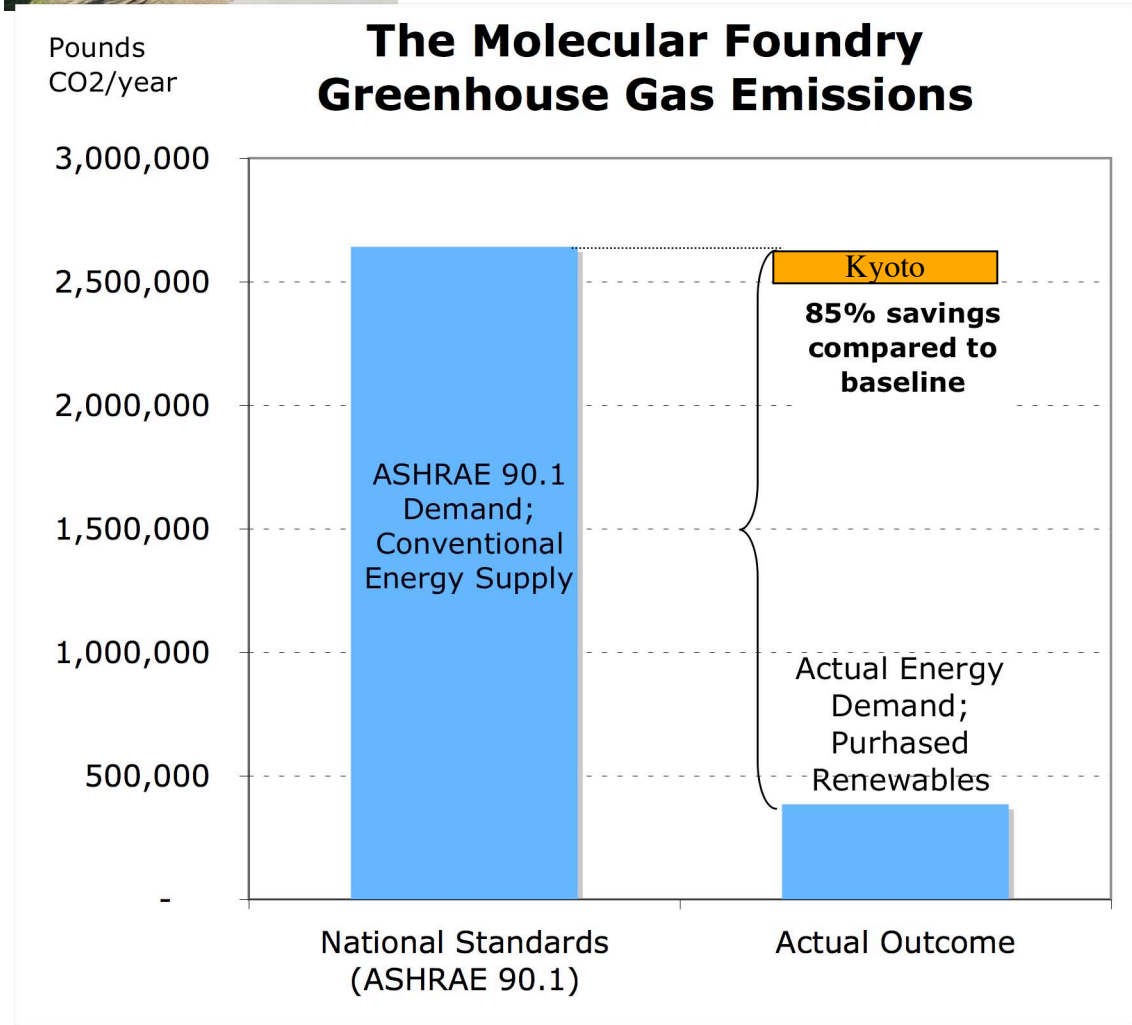
Energy Efficiency is Mainstream

Increased fuel economy will *"save jobs, save lives and save fuel."*

Bush Administration: April 27, 2006

The Molecular Foundry -- High-tech can be green

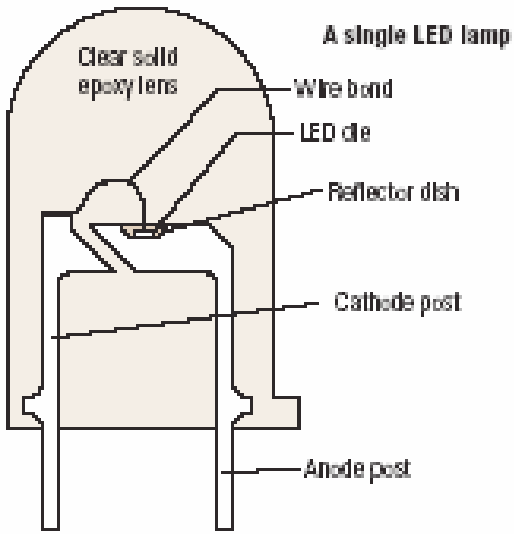




Scorecard:

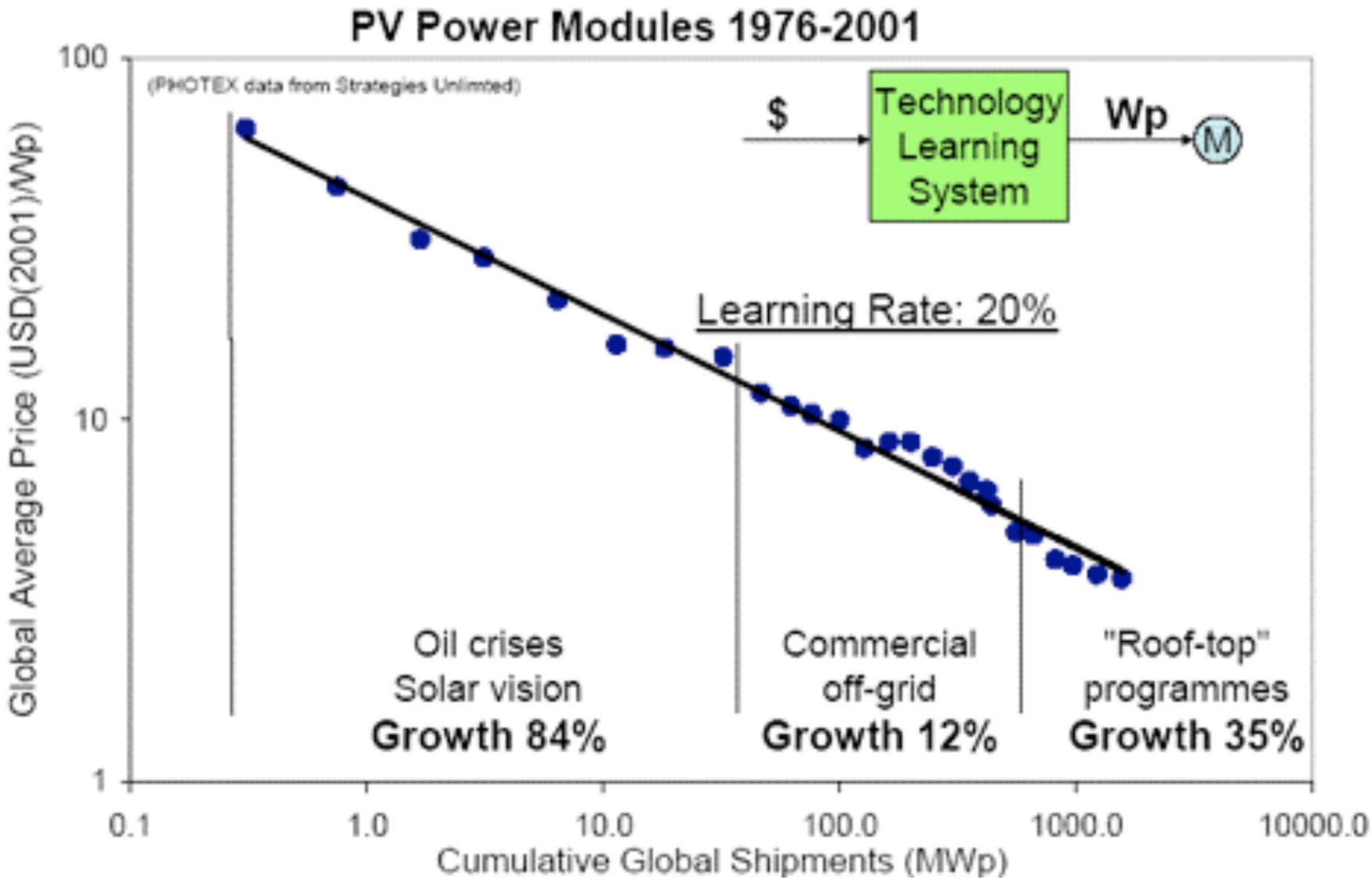
- ❑ **37% energy savings**
- ❑ **92% of electricity purchased from renewables**
- ❑ **85% greenhouse-gas reduction [Kyoto = 5%]**
- ❑ **35% indoor water savings and 65% outdoor savings**
- ❑ **Renewably grown bamboo floors**
- ❑ **Low-emission building materials**
- ❑ **LEED Silver (pending)**

Light Emitting Diodes



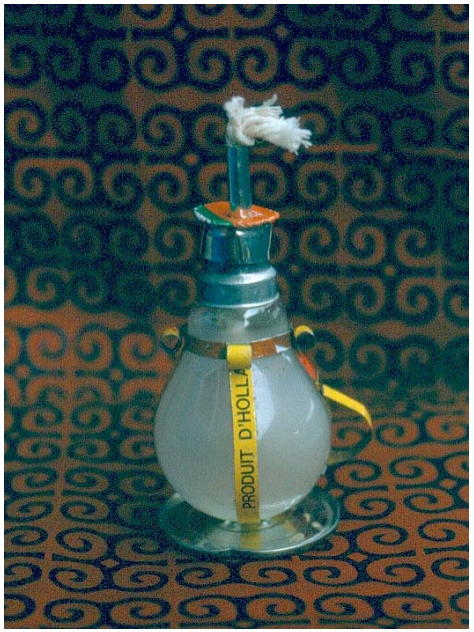
Source: Hewlett-Packard

Stable Technology Learning over three decades and four orders of magnitude in spite of a deployment roller-coaster



Fuel-based Lighting

India: street vendor

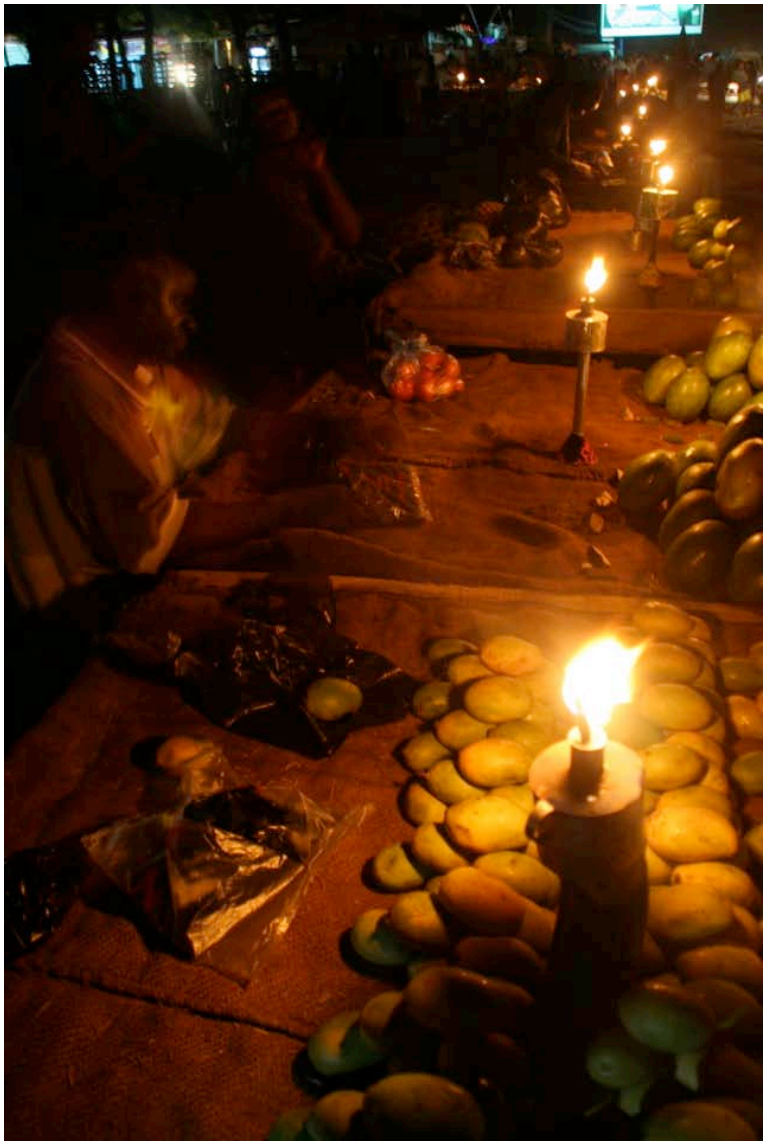


Ghana: lamp

India: propane lamp

Bhutan: merchant

India: sweat shop



Tanzania: night market

China: kerosene porter

China: kitchen

- **Kenya**: classroom light levels as low as 2% of western standards

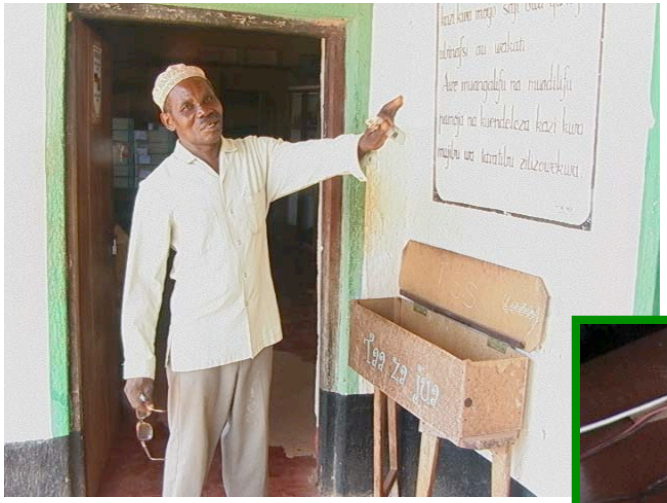
- **Tanzania**: teachers grading homework with light levels 1% of western standards

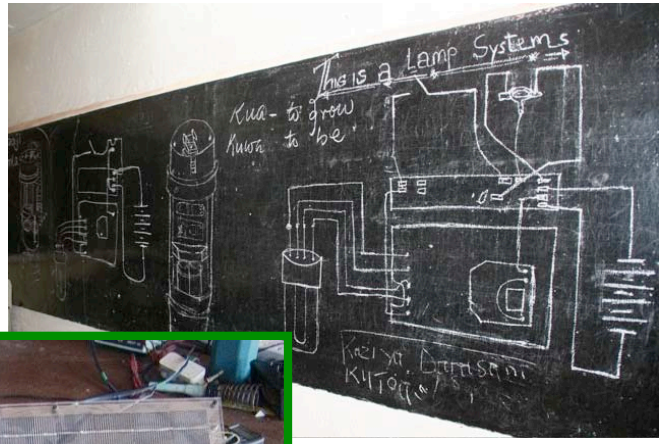
million points of light

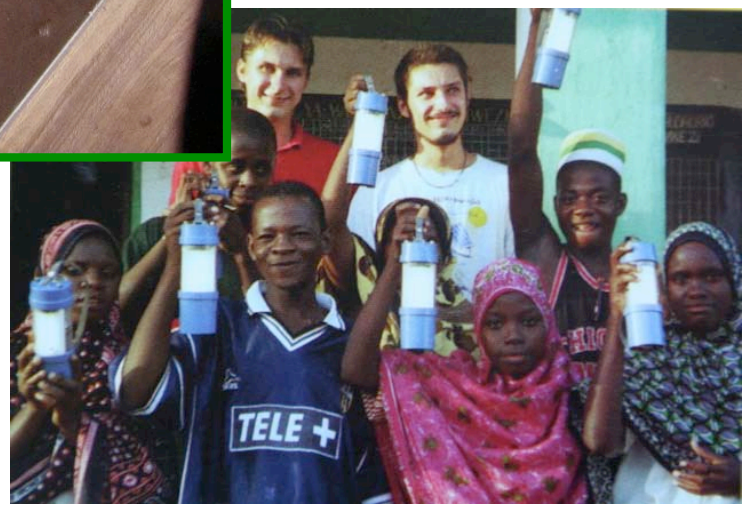
SOLIO
plug into the sun

Kenya: vegetable stand in Kibera slum

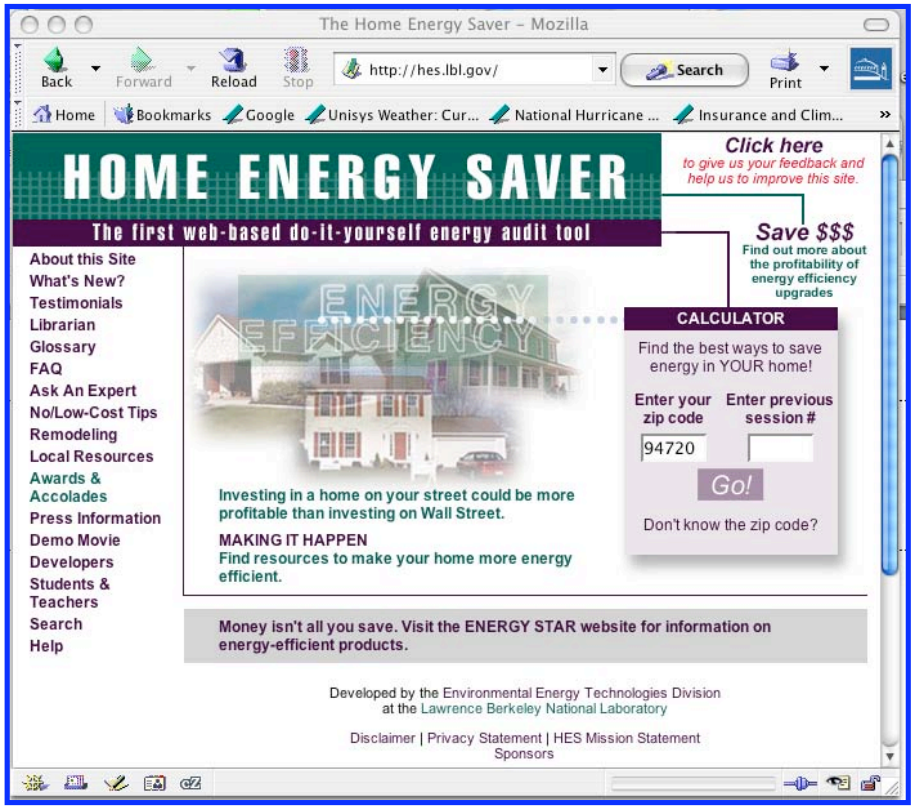
Tanzania: shoe seller - flame [left]; white LED [right]

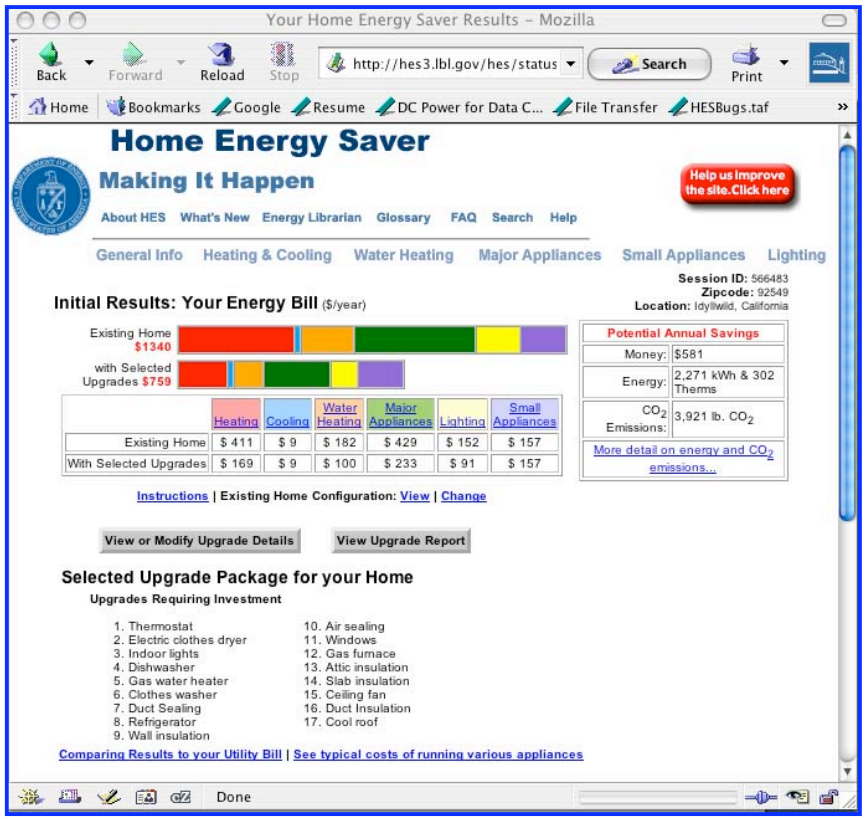



This is a Lamp Systems
Kua - to grow
Kuisa to be


TELE +

http://HomeEnergySaver.lbl.gov





Thank You

EMills@lbl.gov

Thank You

EMills@lbl.gov