Climate Change & You*

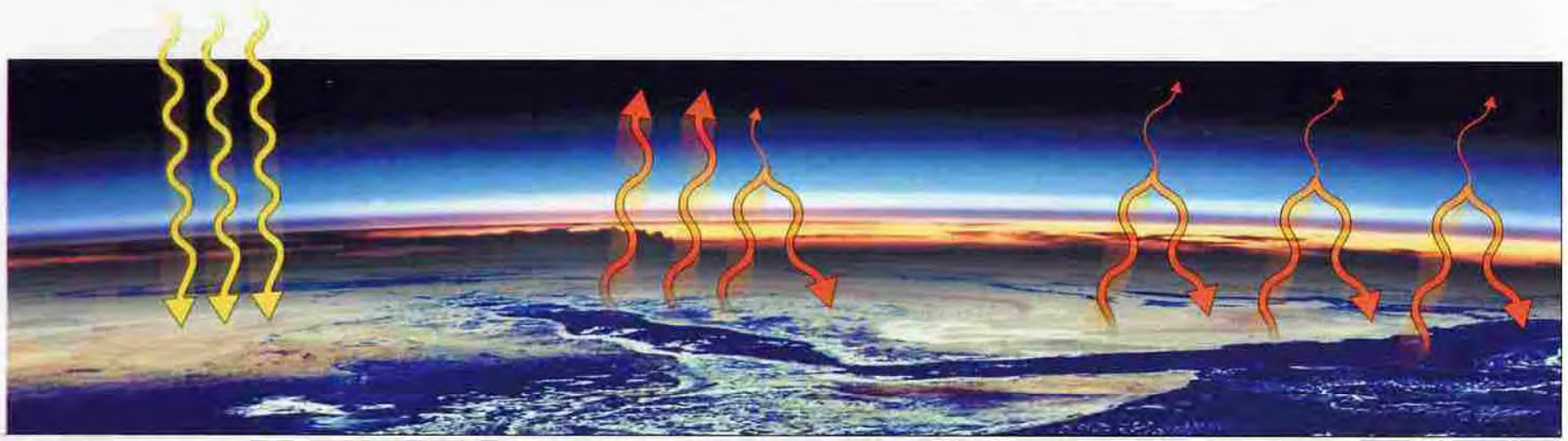
Climate Changes Over Time

- Over centuries and millennia, climate shifts somewhat.
- But usually expect little change on scale of human lifetime.
- Question now is whether that is a reasonable expectation given rapidly rising atmospheric levels of greenhouse gases.
- If climate does shift, how fast might it change, and what will those changes mean for environmental systems we depend on?
- Many scientists consider anthropogenic (human-caused) global climate change to be ***most important environmental issue of our times***.

Global Warming

- Concentrations of atmospheric gases affect average temperature near Earth's surface
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
- Surface temperature has enormous effect on global climate
- Gases act like pane of glass in greenhouse, hence the name greenhouse gases

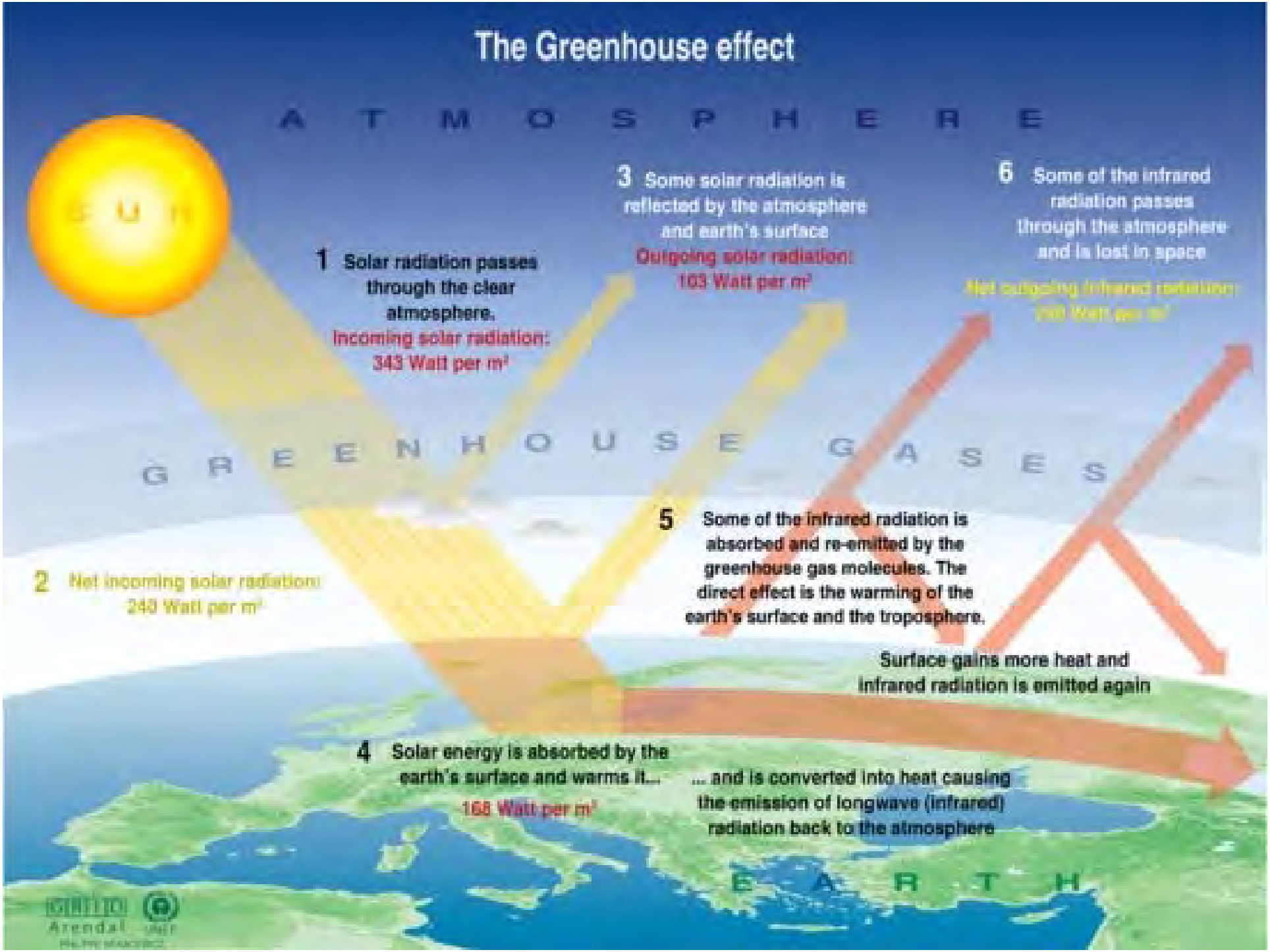
Gases pass sun's energy to Earth, but impede escape of longer infrared wavelengths of heat back into space



a The sun's rays penetrate the lower atmosphere, warm the Earth's surface.

b The surface radiates heat (infrared wavelengths) to the atmosphere. Some heat escapes into space. But greenhouse gases and water vapor absorb some infrared energy and radiate a portion of it back toward Earth.

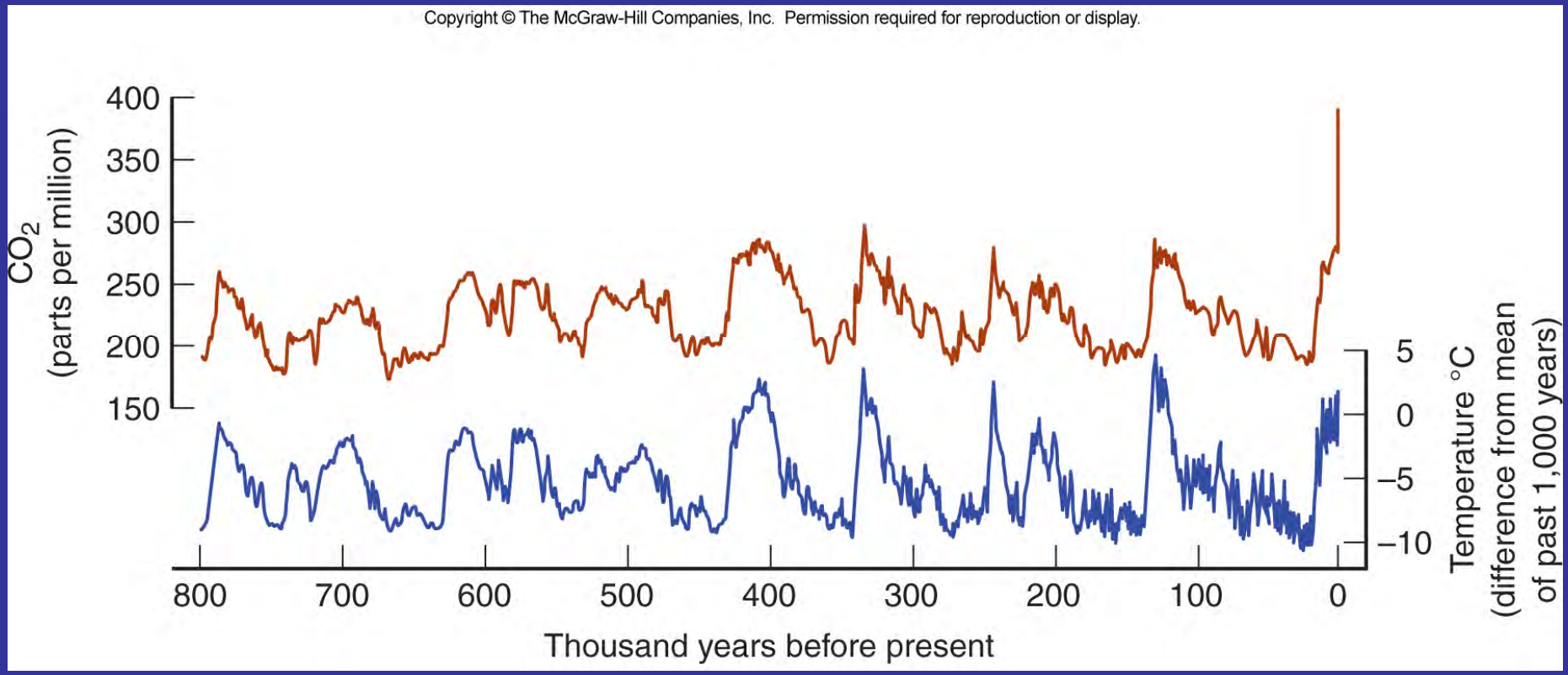
c Increased concentrations of greenhouse gases trap more heat near Earth's surface. Sea surface temperature rises, more water evaporates into atmosphere. Earth's surface temperature rises.


The Greenhouse effect
A T M O S P H E R E
S U N
1 Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m²
3 Some solar radiation is reflected by the atmosphere and earth's surface
Outgoing solar radiation: 103 Watt per m²
6 Some of the infrared radiation passes through the atmosphere and is lost in space
Net outgoing infrared radiation: 240 Watt per m²
G R E E N H O U S E G A S E S
2 Net incoming solar radiation: 240 Watt per m²
5 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.
Surface gains more heat and infrared radiation is emitted again
4 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
Arendal

Greenhouse Gases

- Some greenhouse warming necessary or Earth's surface too cold to support life
- But largely as result of human activities, greenhouse gas levels too high creating too much global warming
- Burning fossil fuels contributes most to global warming

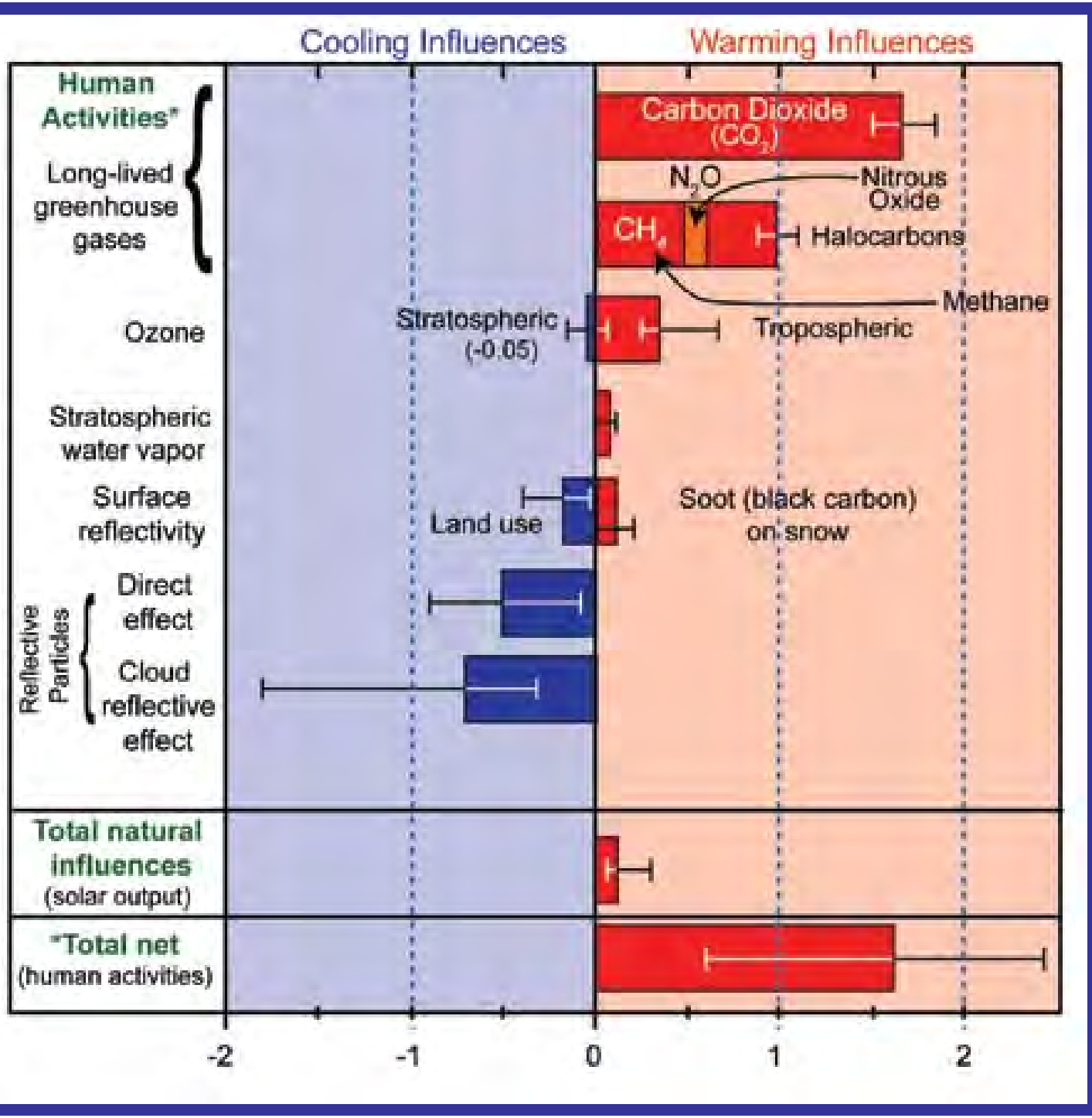
Correlation Between Historic CO_2 Levels and Historic Temperatures



Ice Cores Tell Us Much About Climate History

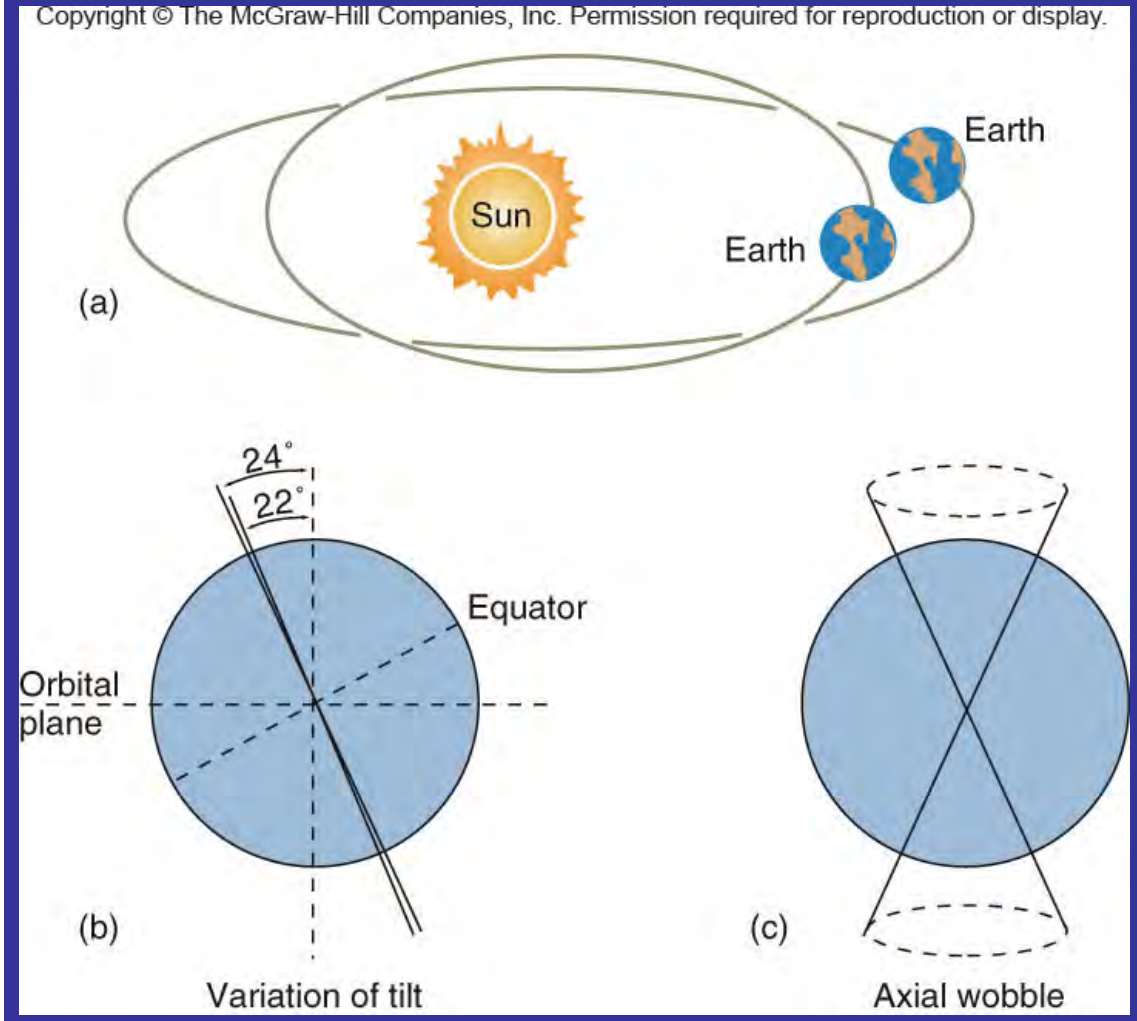
- Small amounts of air are trapped in snow layers.
- In polar regions, yearly snows slowly accumulate over centuries.
- Climatologists can extract ice cores, collect air-bubble samples
- Show how atmosphere has changed over time.

Courtesy Candace Kohl, University of California, San Diego



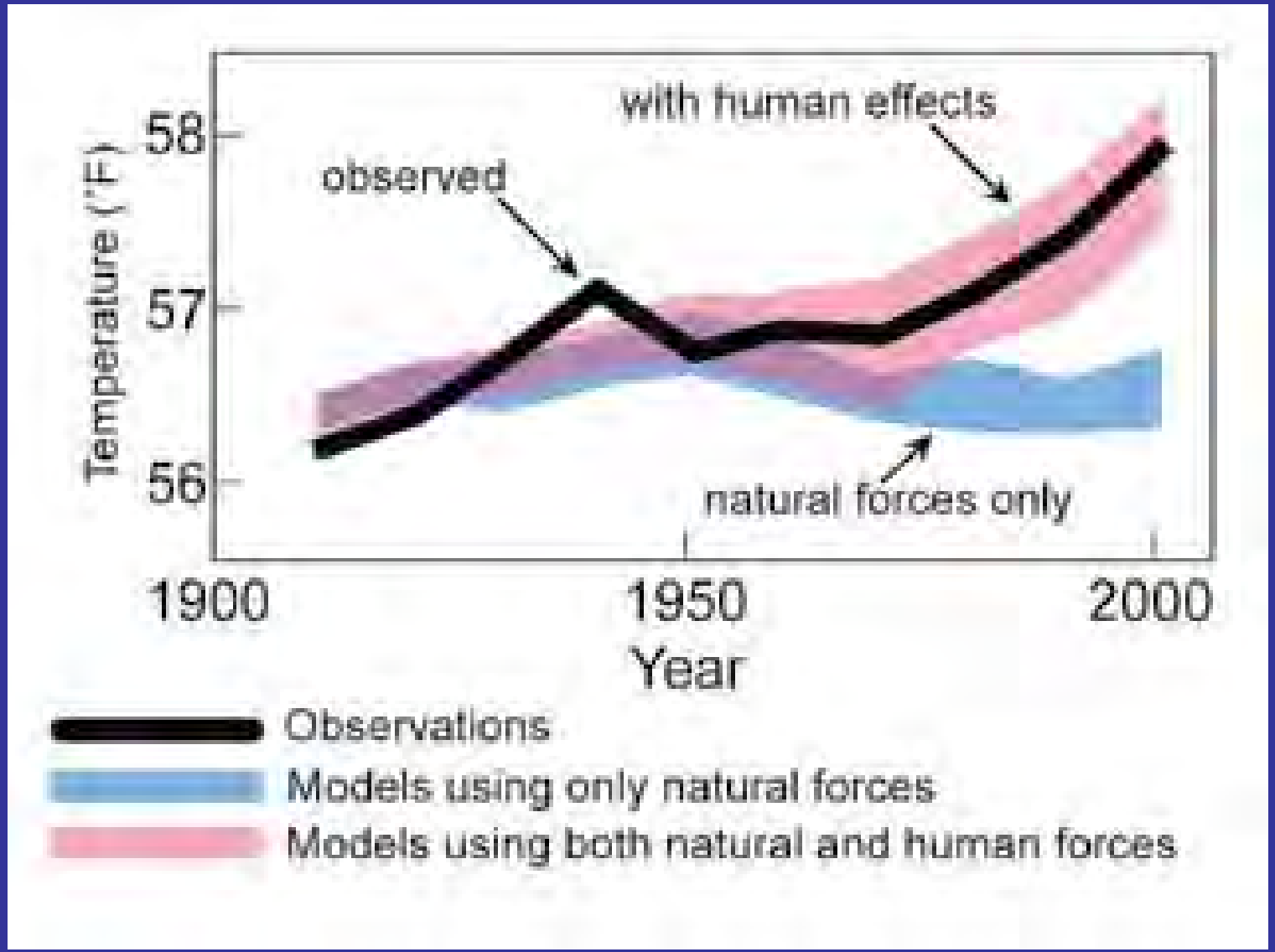
Major warming & cooling influences on climate (1750-2005)

What Causes Natural Climatic Swings?



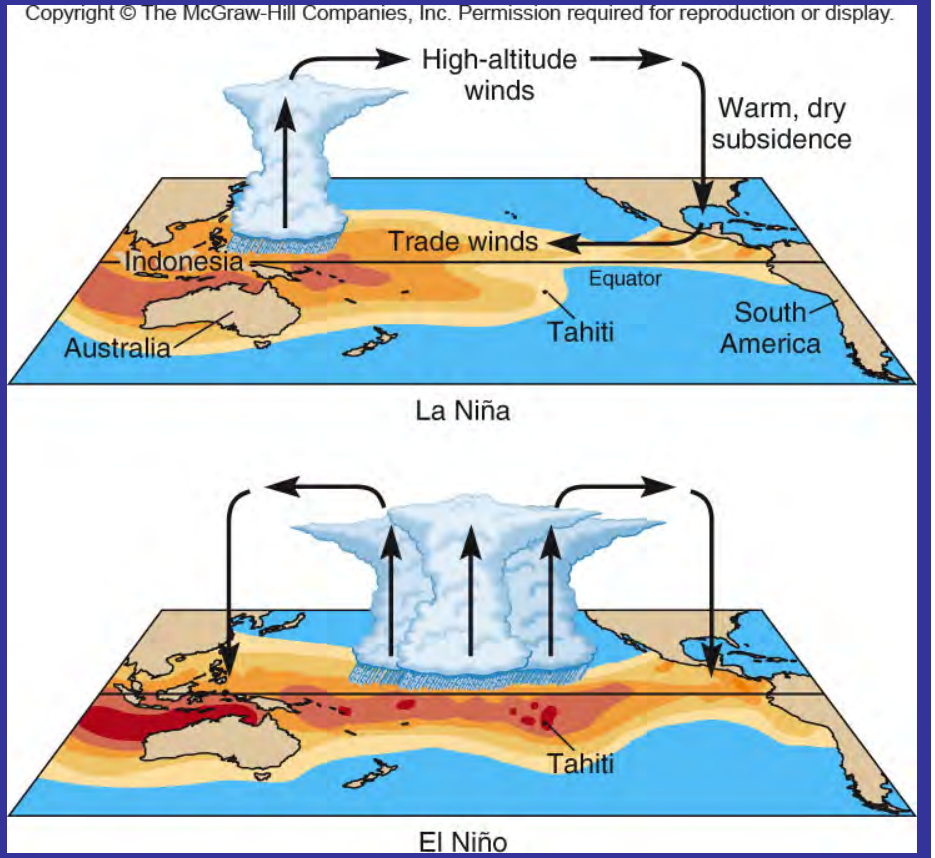
- Modest climate changes correspond to 11-year cycle in Sun's intensity called **Milankovitch Cycles.**
- Caused by changes in Earth's orbit, rotation, and wobble of its axis.

Separating Human and Natural Influences on Climate



The El Niño/Southern Oscillation Can Have Far-reaching Effects

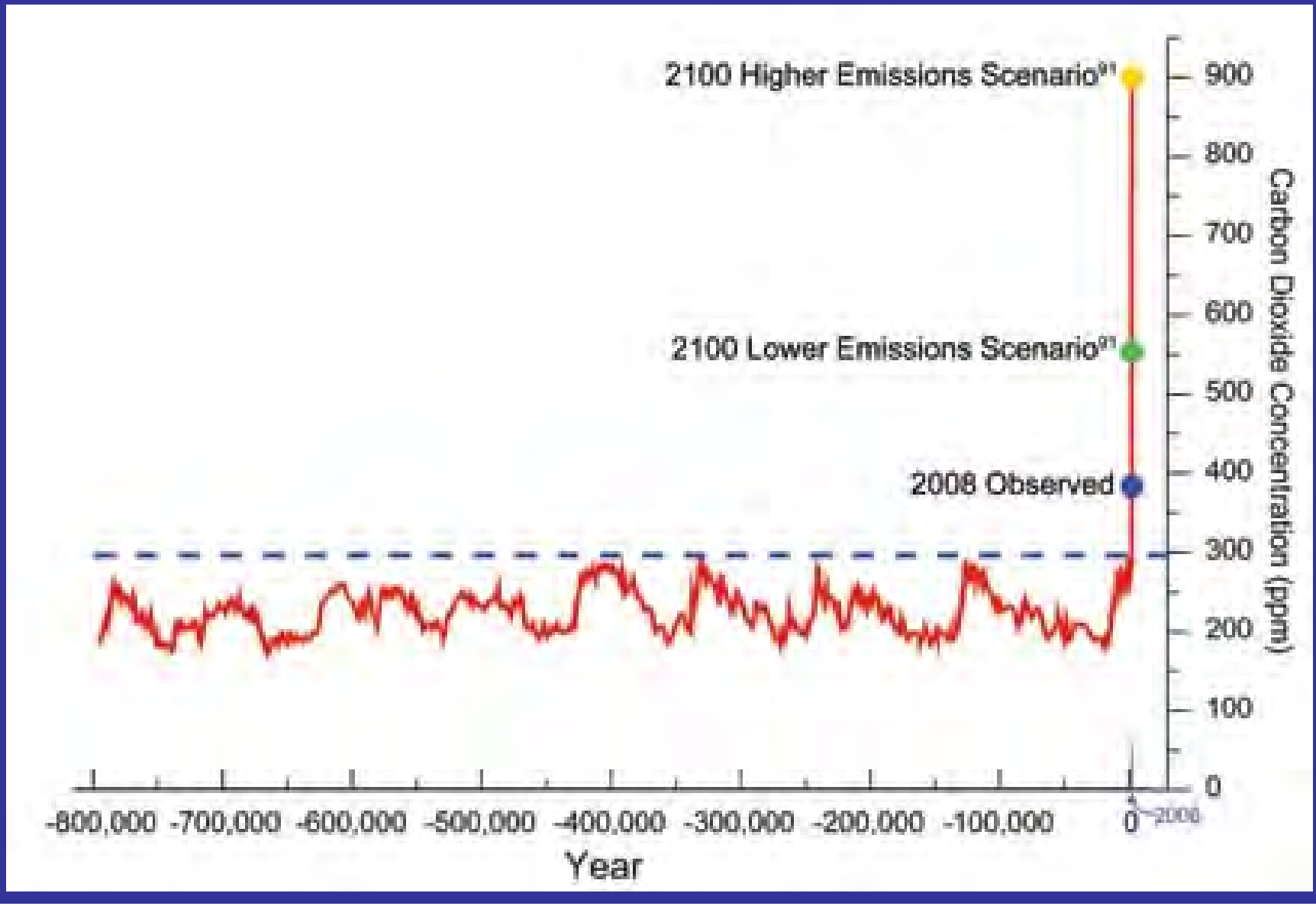
- Climate also changes according to oscillations in ocean and atmosphere.
- **El Niño/Southern Oscillation (ENSO)** is most famous.
- ENSO affects weather throughout Pacific, causing heavy monsoons or serious droughts.



The Main Greenhouse Gases are CO_2, CH_4, and N_2O

- Since pre-industrial times, atmospheric concentrations of CO_2, methane (CH_4), and nitrous oxide (N_2O) have climbed.
- Carbon dioxide by far most important because of its abundance and it lasts for decades or centuries in atmosphere.
- If current trends continue, CO_2 concentrations could reach about 500 ppm (approaching 2X the pre-industrial level of 280 ppm) by end of the 21st century.

Projected Exponential Increase in CO_2 Concentrations Above Levels Occurring Over Last 800,000 Years



Climatic Tipping Points

Arctic permafrost

Ocean CO_2 capacity

Ocean freshwater intrusion

Thawing permafrost: the Arctic's slow, giant carbon release

BY SABRINA SHANKMAN
INSIDECLIMATE NEWS

Permafrost — a vast, frozen subsurface layer of soil — covers nearly a quarter of the land in the Northern Hemisphere. It contains centuries worth of carbon in the form of plants that have died since the last ice age but remained frozen rather than decomposing.

Now scientists are learning that the "perma" part of its name may no longer be accurate.

As the Arctic heats up at a rate twice that of the rest of the globe and as sea ice and glaciers turn to water, the permafrost is also thawing. A recent review article in the journal Nature found that as the unfrozen organic matter decays, vast stores of carbon in the permafrost could be released into the atmosphere. This will trigger an irreversible feedback system and nullify existing calculations of just how much carbon humans can burn and keep the globe within a relatively safe degree of warming.

Kevin Schaefer, a permafrost scientist with the National Snow and Ice Data Center at the University of Colorado in Boulder and an author of the article, calls the thawing of the permafrost a "true climatic tipping point." Scientists are still trying to pinpoint when it will happen, but Schaefer said that a likely point is around the middle of this century, when the Arctic changes from a carbon sink to a carbon source. When that happens, it will trigger a centuries-long, unstoppable feedback system, in which warming will release carbon, which will trigger more warming, which will release more carbon.

The authors of the Nature article found that if humans continue on the current path of energy use, the permafrost could release 92 gigatons of carbon into the atmosphere by the end of this century. That represents nearly 18 percent of what the world has emitted since the start of the Industrial Revolution — or more than one third of what can be safely burned and still keep global warming within 2 degrees Celsius.

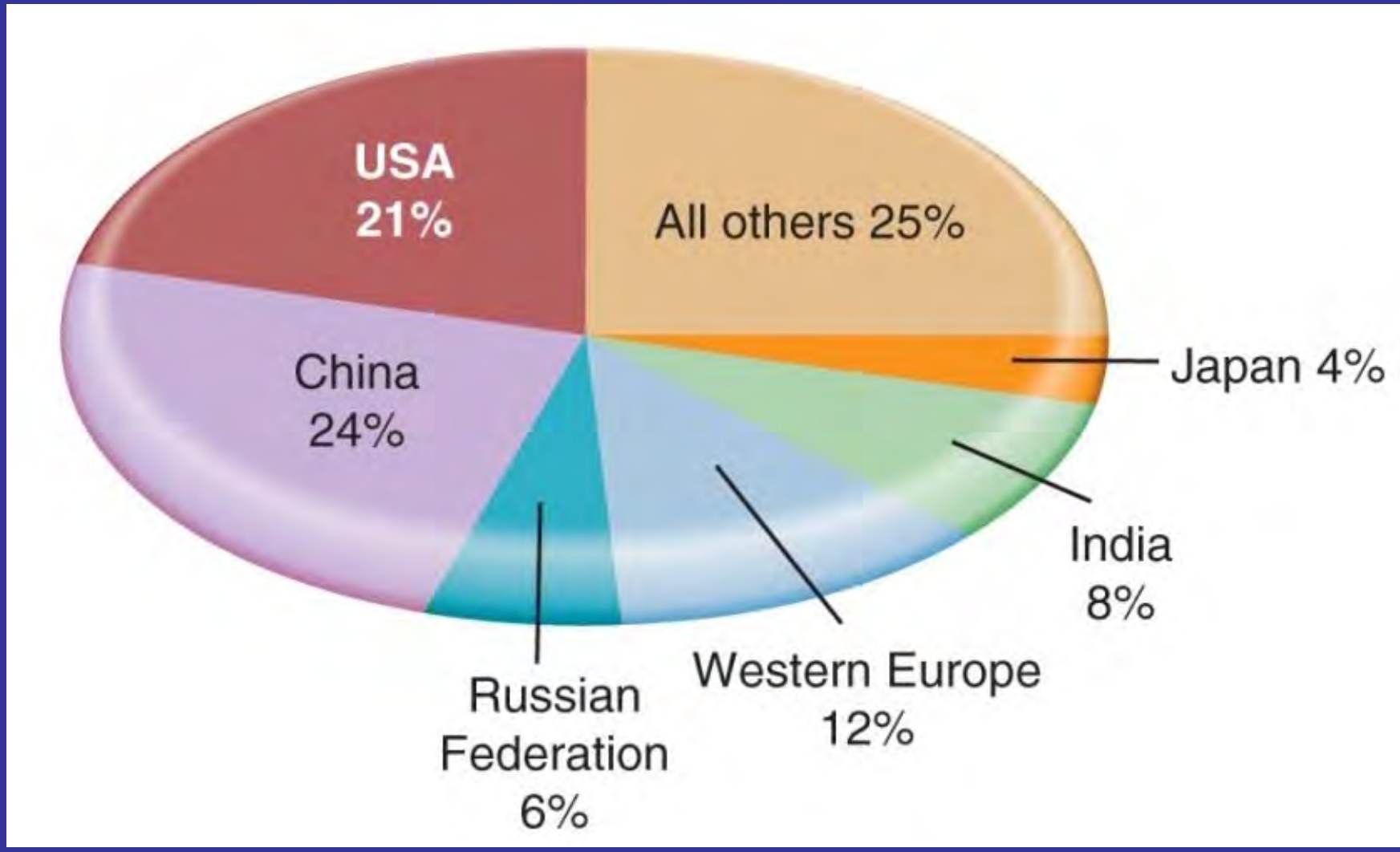
And that's only part of it. The authors reported that 59 percent of total permafrost emissions would occur after 2100.

The scientific understanding of the permafrost is new — so new, in fact, that it wasn't ready in time for the latest round of climate assessment reports from the Intergovernmental Panel on Climate Change, the world's largest scientific body on global warming.

The 2014 IPCC report estimated that to hold global warming below 2 degrees Celsius, worldwide carbon dioxide emissions would have to be cut by 40 percent to 70 percent by 2050, and then drop to nearly zero by the end of the century. This is a tall order on its own, and it does not take into account additional emissions from permafrost thawing.

"This is not a minor feedback," Schaefer said. "It's still small compared to fossil fuels, but it is not negligible either. If you don't account for it, you'll overshoot this 2 degree target."

Contributions to Global Warming From Different Countries



Scientific Consensus is Clear

- Because climate is so complex, climate scientists worldwide have collaborated in collecting and sharing data, and in programming models to describe how climate system works.
- Evidence shows minor differences among models, but no disagreement about direction of change.
- **Evidence shows *unequivocally*,** that *climate is changing*, and global average is warming because of increased retention of energy in lower atmosphere.

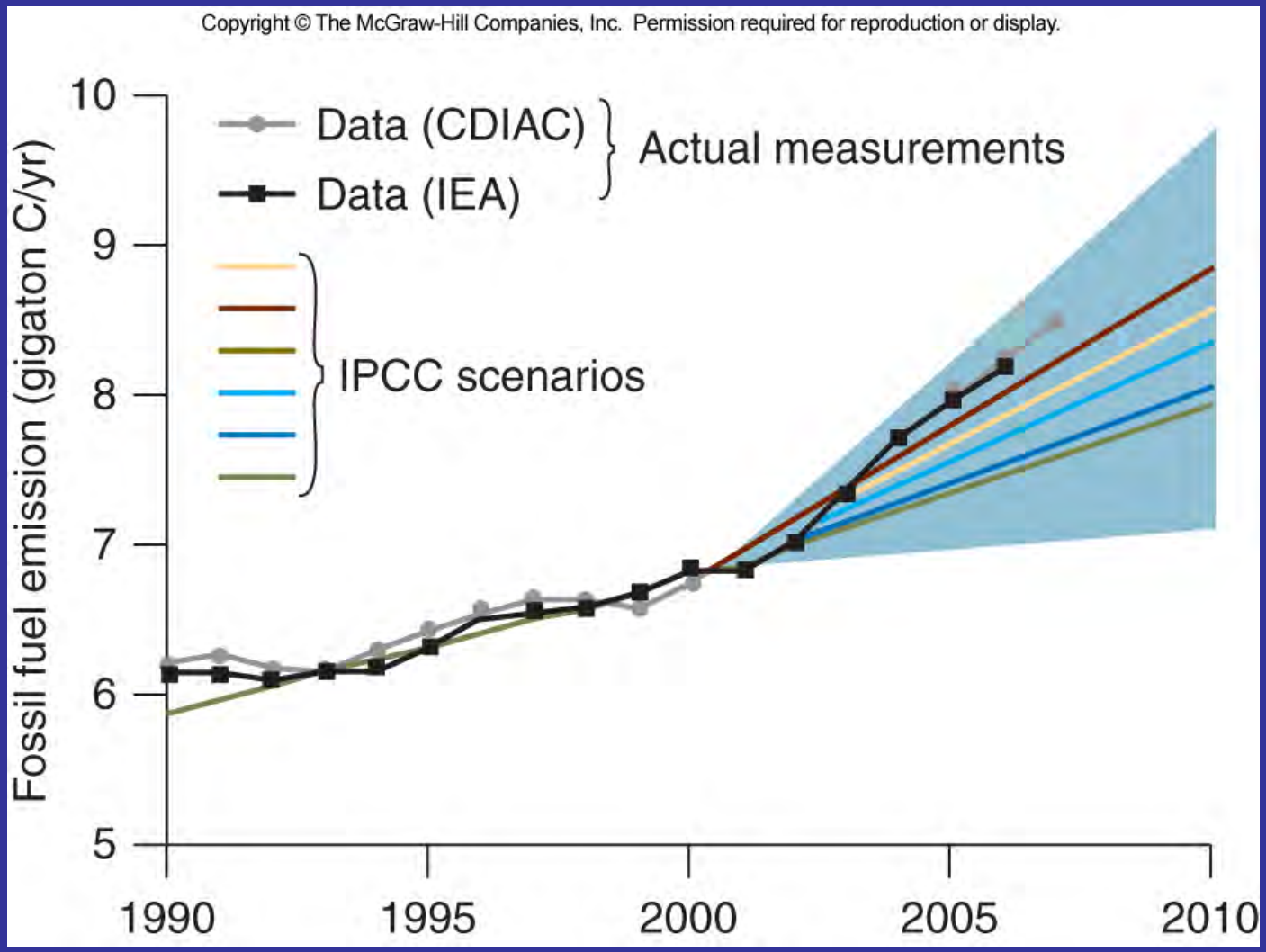
What is IPCC?

- Most comprehensive effort to describe state of climate knowledge is that of **Intergovernmental Panel on Climate Change (IPCC)**.
- IPCC brings together scientists and government representatives from 130 countries with aim to review scientific evidence on causes and likely effects of climate change.
- In 2007, IPCC issued its 4th Assessment Report.
- Conclusion was 90% certainty that observed climate change is caused by human activity.
- Subsequent reports raised that to 99% certainty.

Changes in Heat Waves, Sea Level, Storm Severity, etc., Occurring Faster than Expected

- 4th IPCC Report presents variety of climate scenarios for predicted emissions of greenhouse gases.
- For each scenario, IPCC modeled future emissions, starting in 2000.
- Observations since 2007 show that ***all*** the IPCC scenarios were too conservative – Greenhouse gas emissions, temperature rises, sea level, and energy use ***have accelerated faster than IPCC projections***.

Comparison of Emissions Projections and Actual Emissions



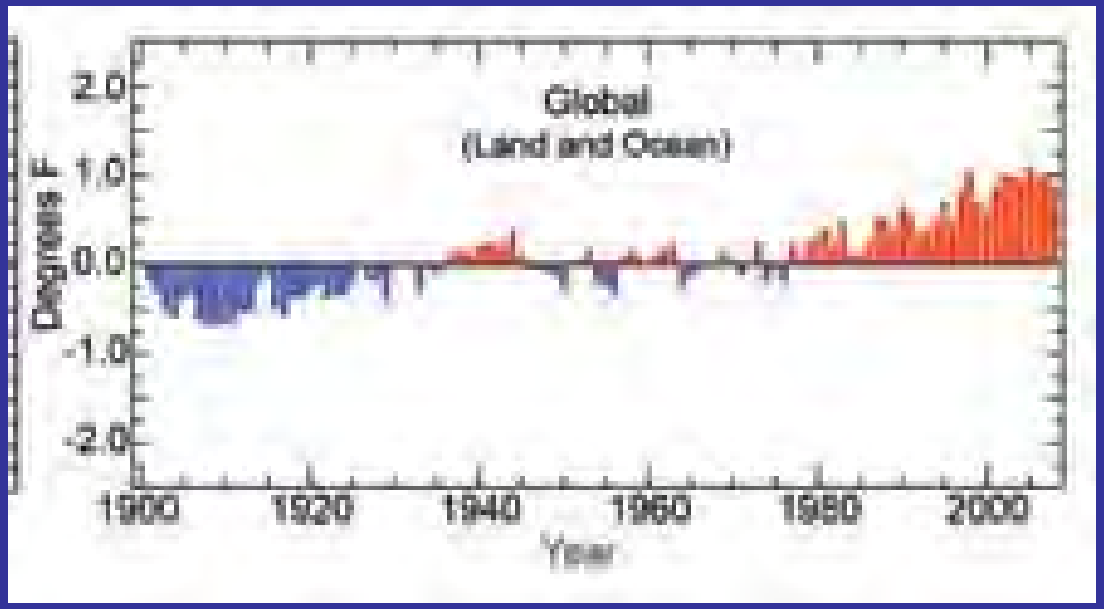
Why Should We Care?

Global Warming…

…and the Consequences

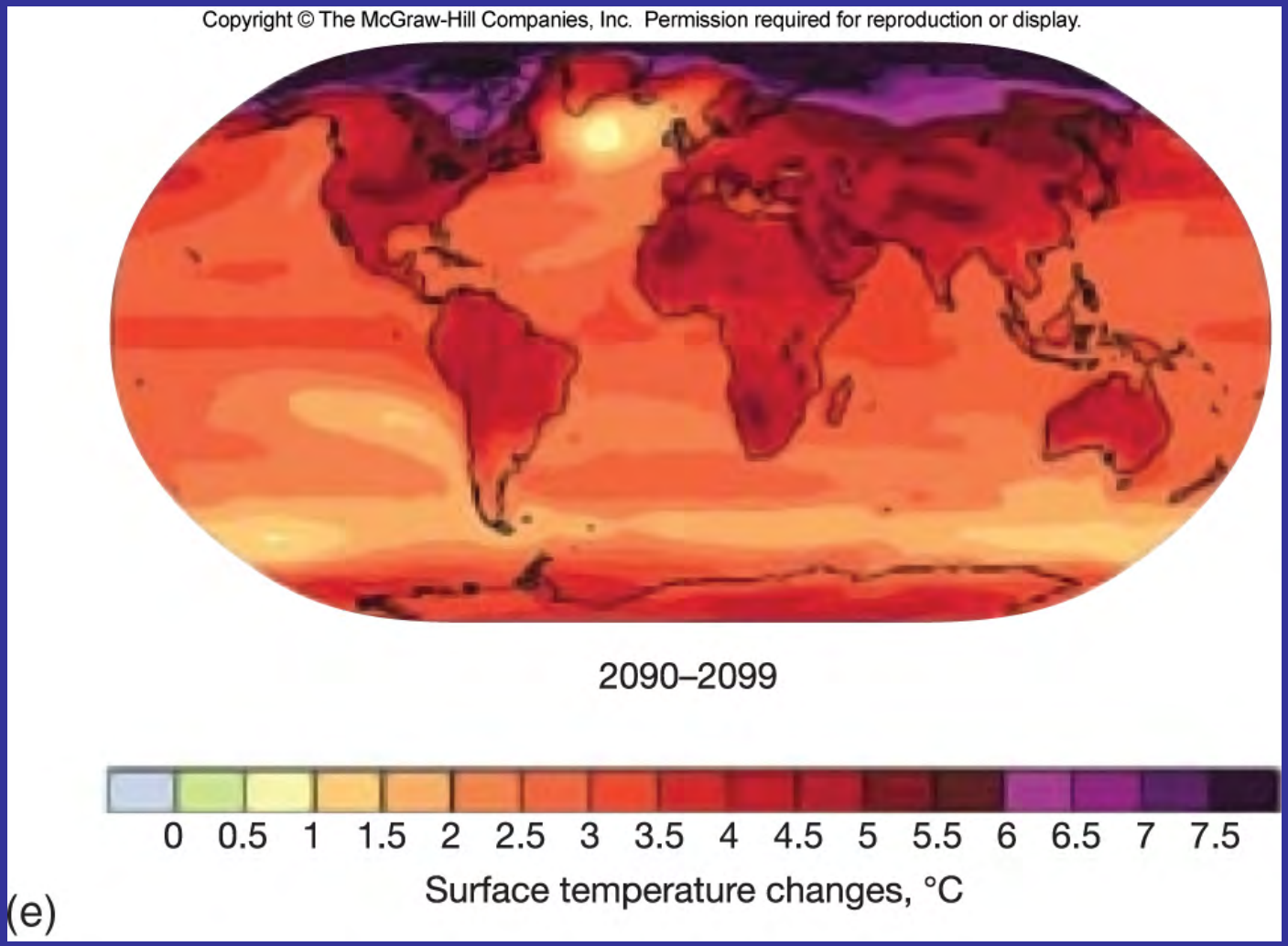
Global Temperature Increase

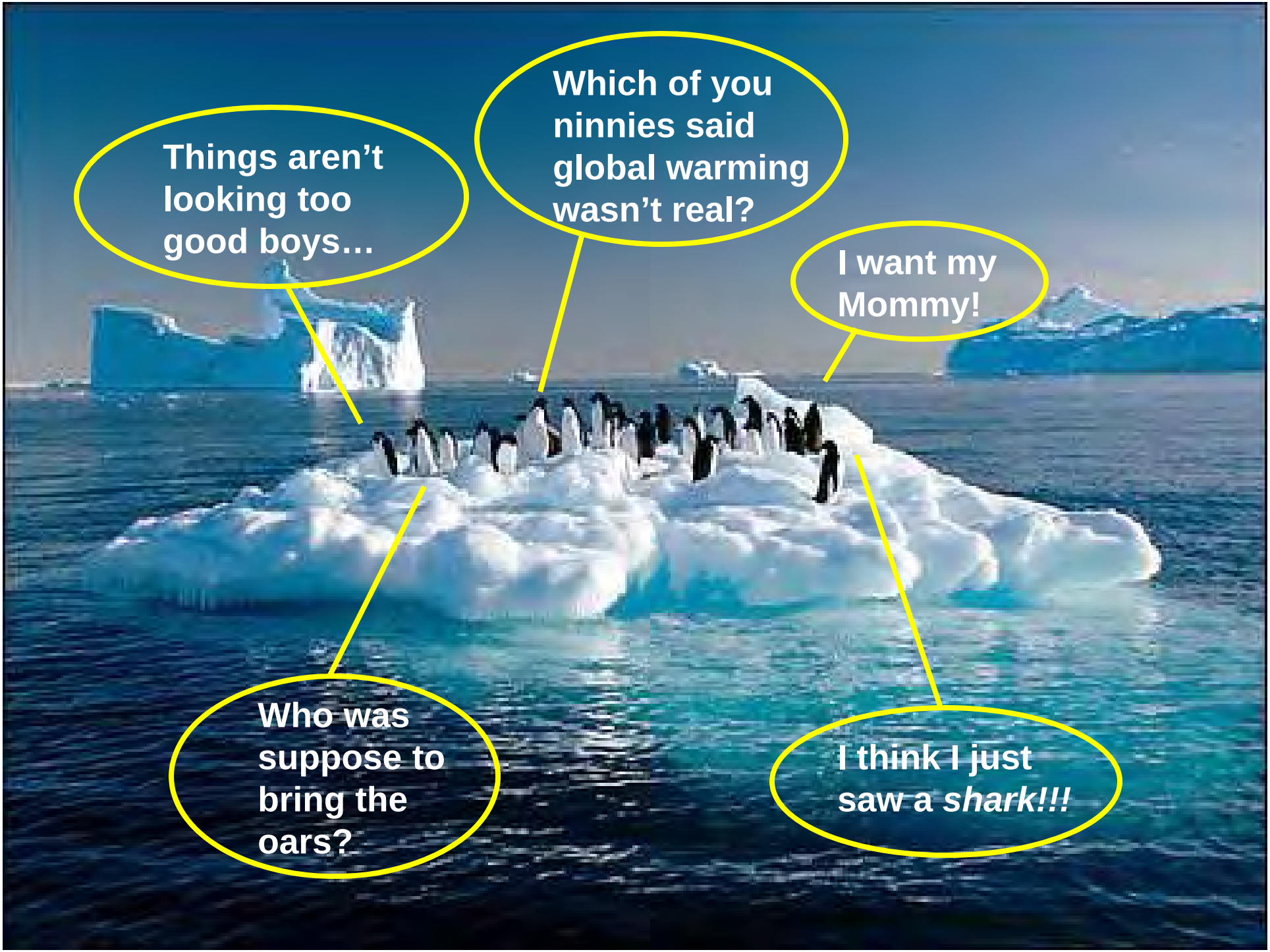
- Globally, last decade warmest on record



- If global temperatures rise only few degrees, can have devastating effects on world weather & ecology

Evidence of Climate Change: IPCC Surface Temperature Projections




Things aren't looking too good boys…
Which of you ninnies said global warming wasn't real?
I want my Mommy!
Who was suppose to bring the oars?
I think I just saw a *shark!!!*

Environmental Problems from Global Warming

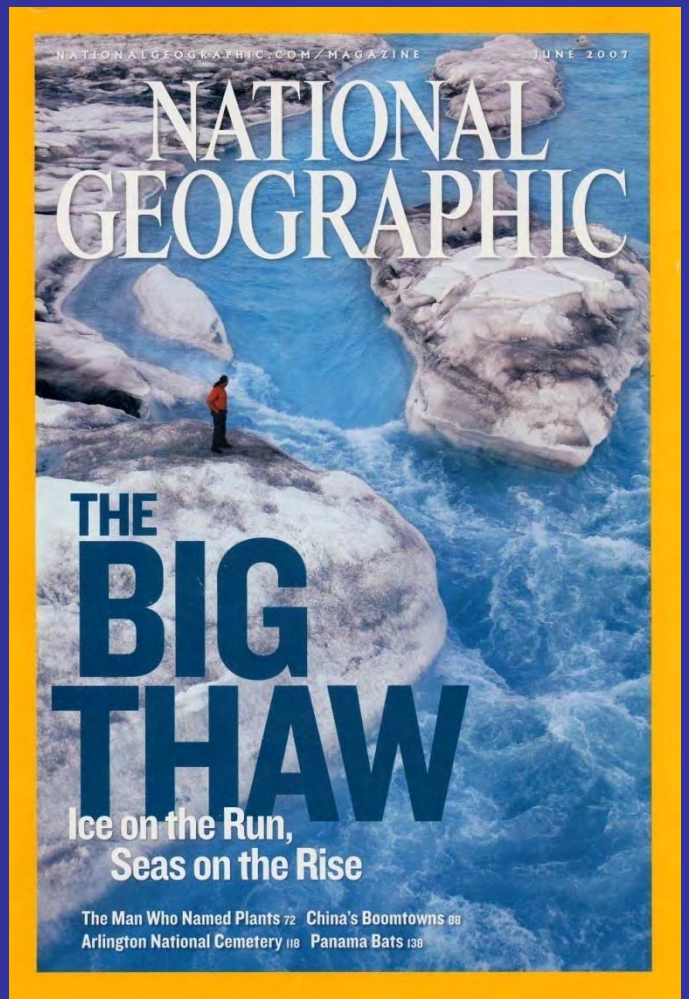
1. Rising sea levels
2. Severe weather events larger & more frequent
3. Increased rainfall & flooding
4. More intense heat waves, wildfires & droughts
5. Crop failures & drinking water shortages
6. New & increased pest and disease occurrences
7. Species loss & distribution range changes
8. Potential collapse of ocean current conveyor system

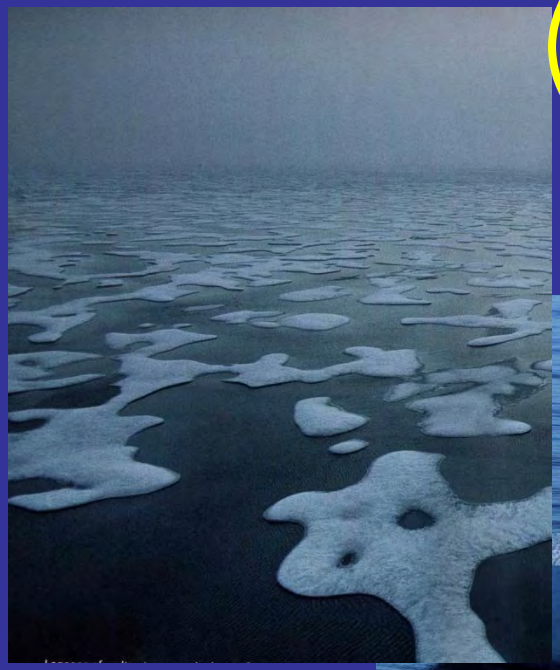
1. Rising Sea Levels

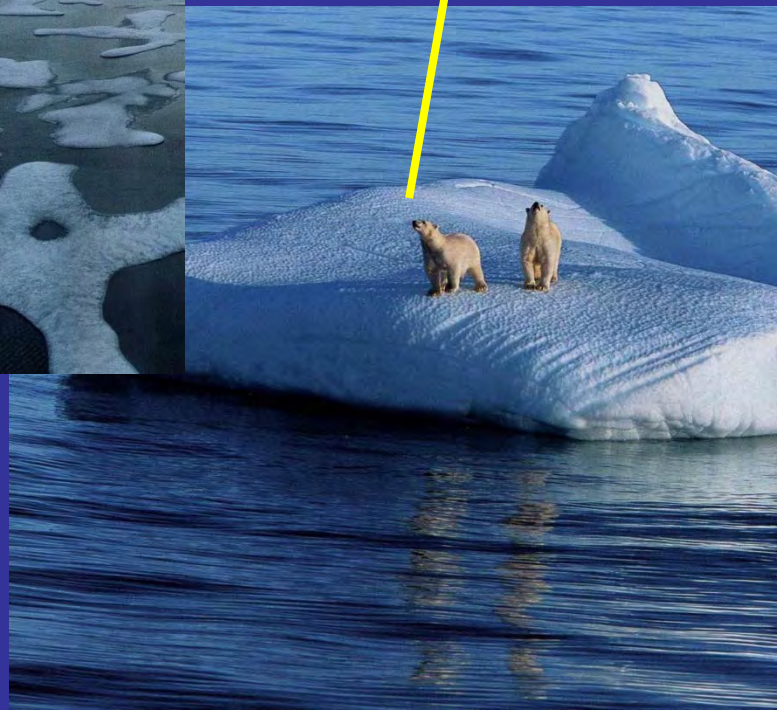
- Physical expansion of water from temperature increases
- Melting of glaciers, ice sheets, and arctic ice cap
- Seawater flooding of low coastal regions
- High tides & storm waves reach higher levels

Loss of Ice Worldwide

- Glaciers
- Greenland & Antarctica ice sheets
- Arctic sea ice







Evidence of Climate Change: Alpine Glaciers Retreating

Photographer Lisa McKeon, courtesy of Glacier National Park Archives

(c)

Photographer Lisa McKeon, courtesy of Glacier National Park Archives

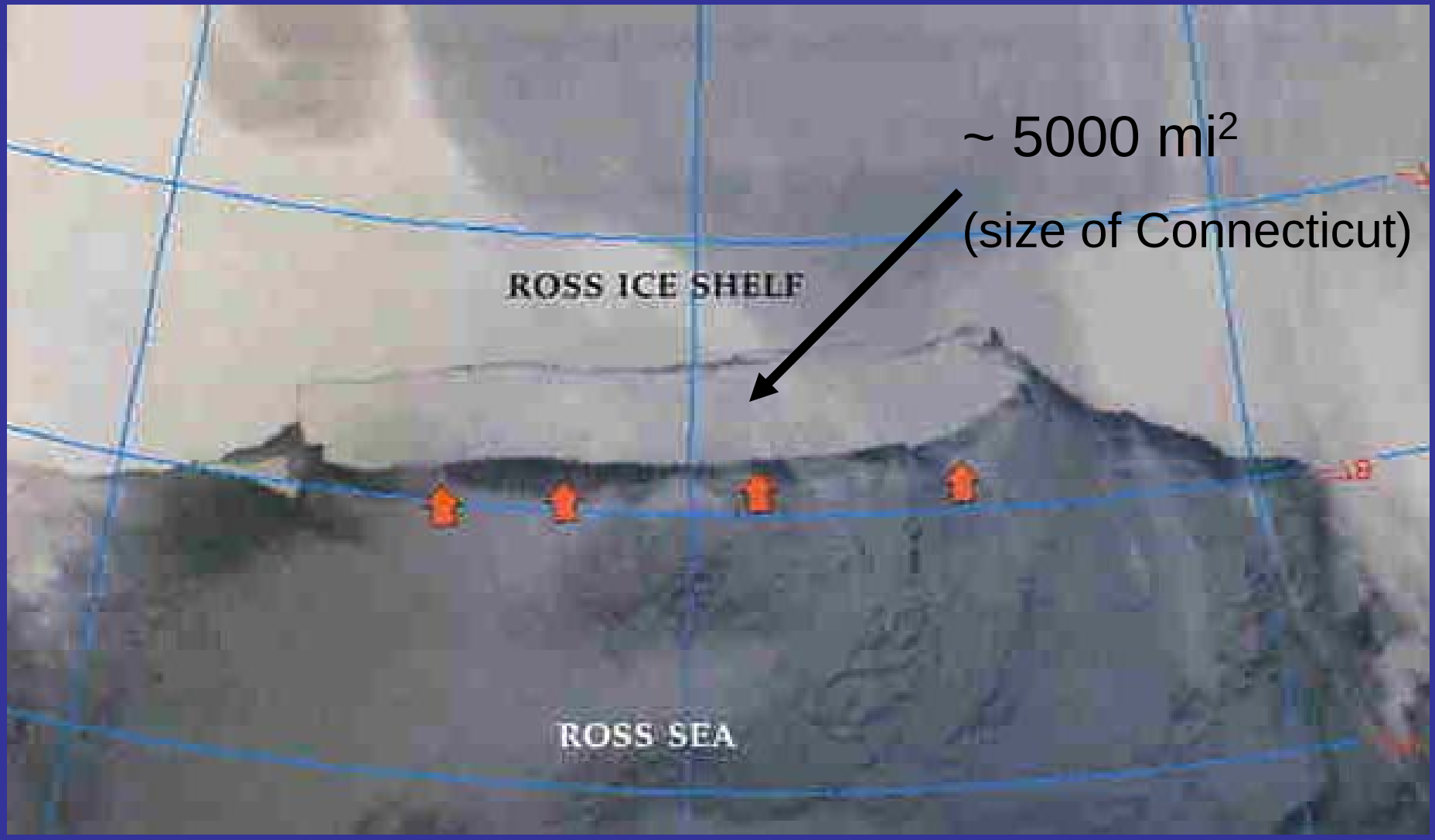
Glacier Melting in Glacier National Park

1938

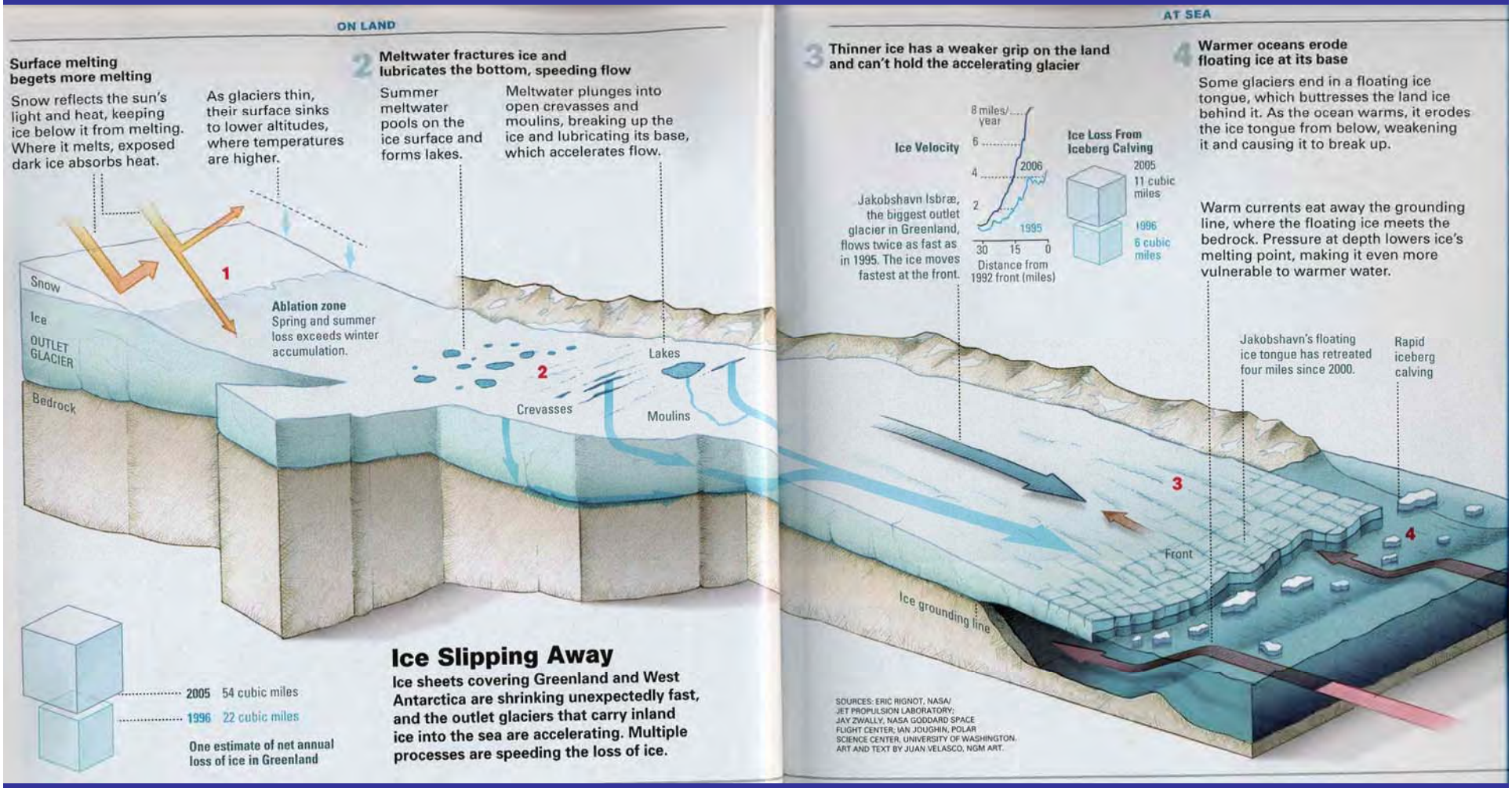
1981

2005

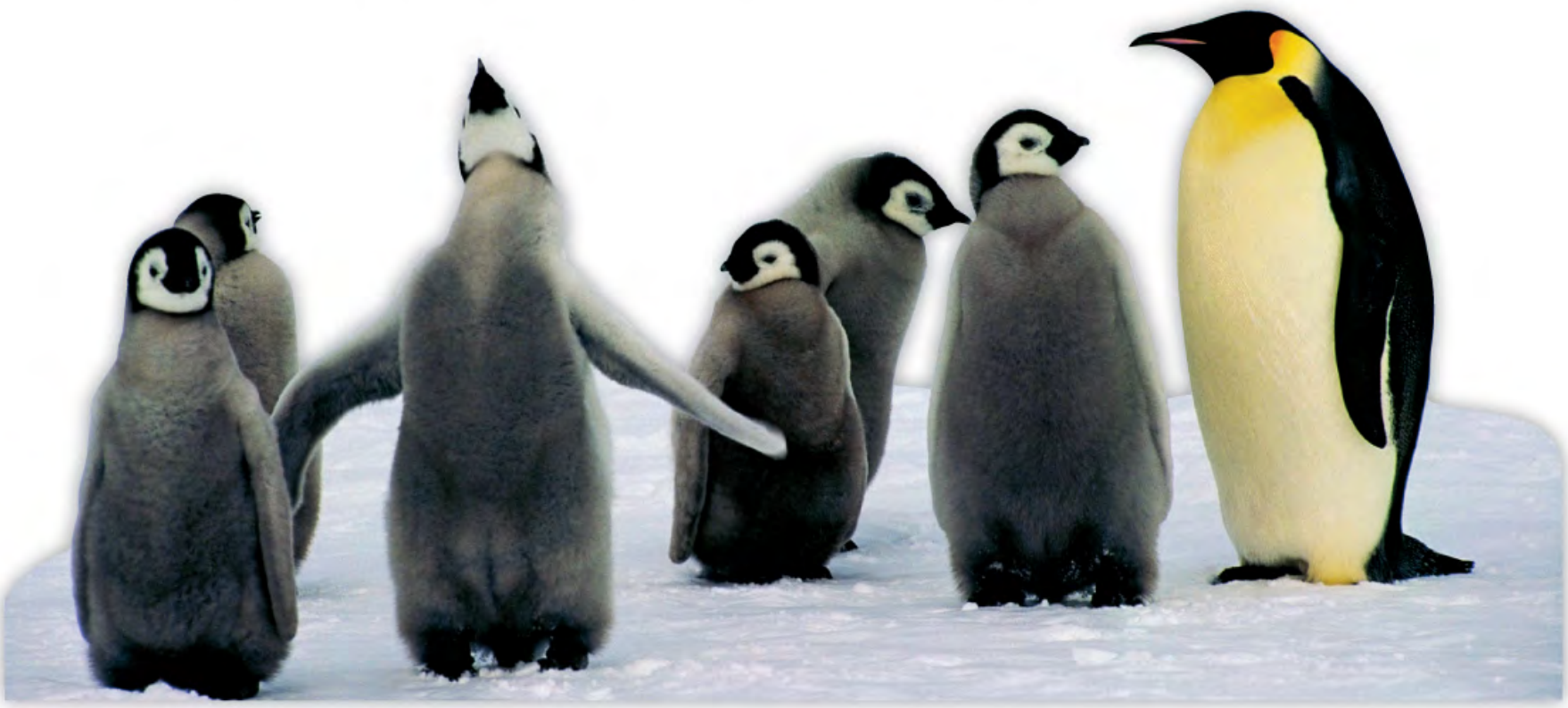
Unexpectedly rapid loss of large ice chunks from Greenland and Antarctica ice sheets



Antarctica & Greenland Ice Sheets



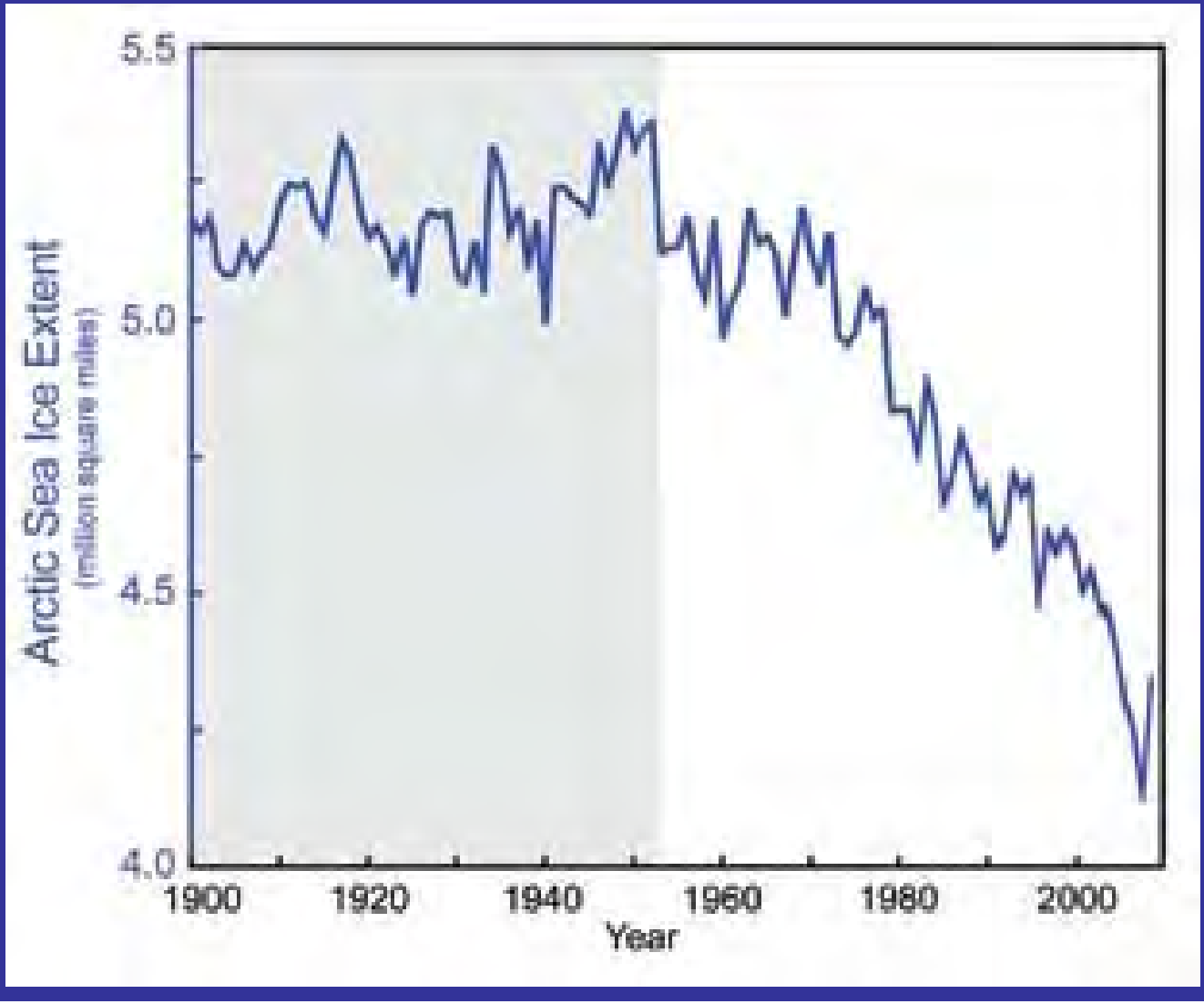
Evidence of Climate Change: Ice Dependent Penguins Declining



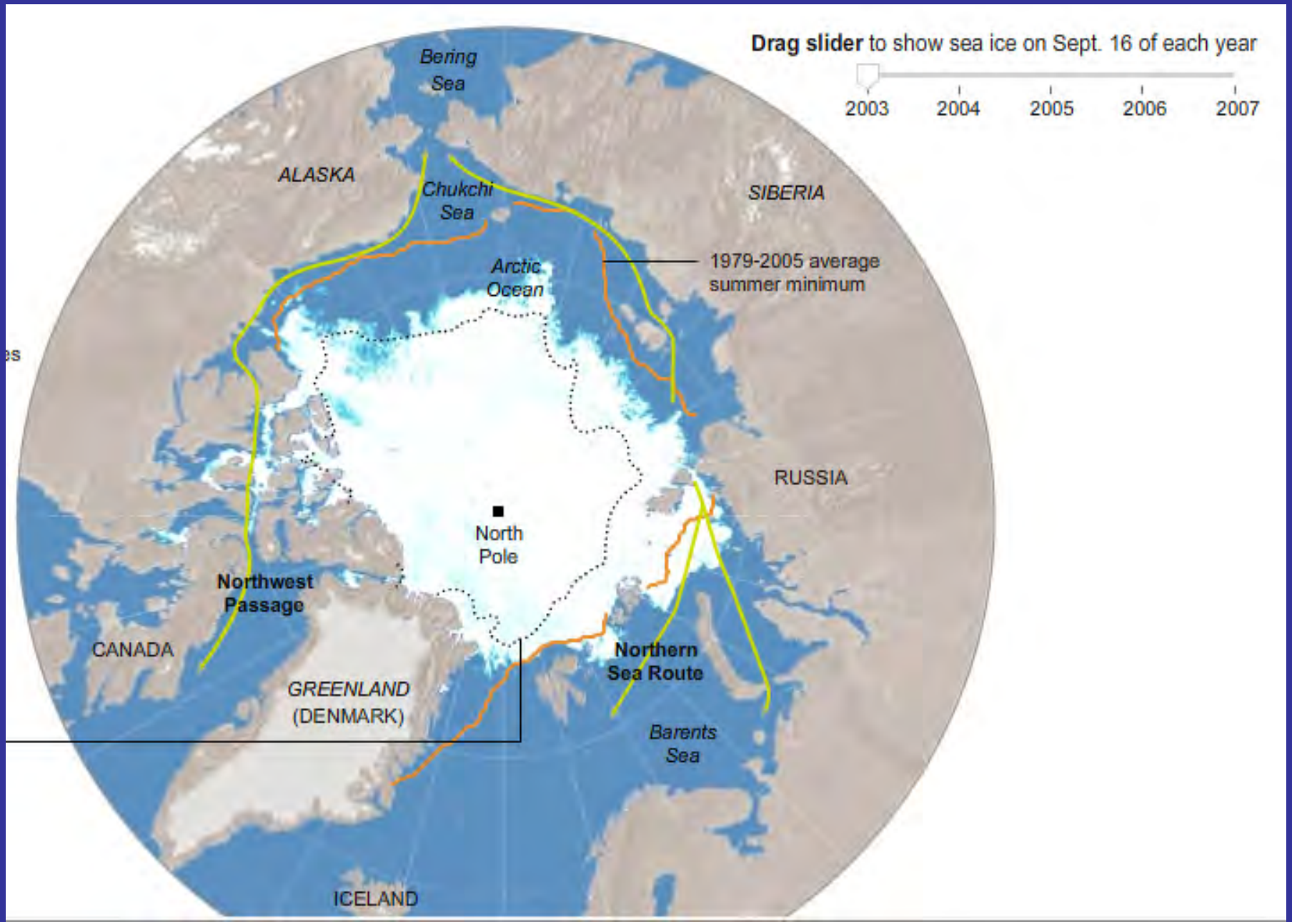
(b)

Retreat of Arctic Polar Ice Cap

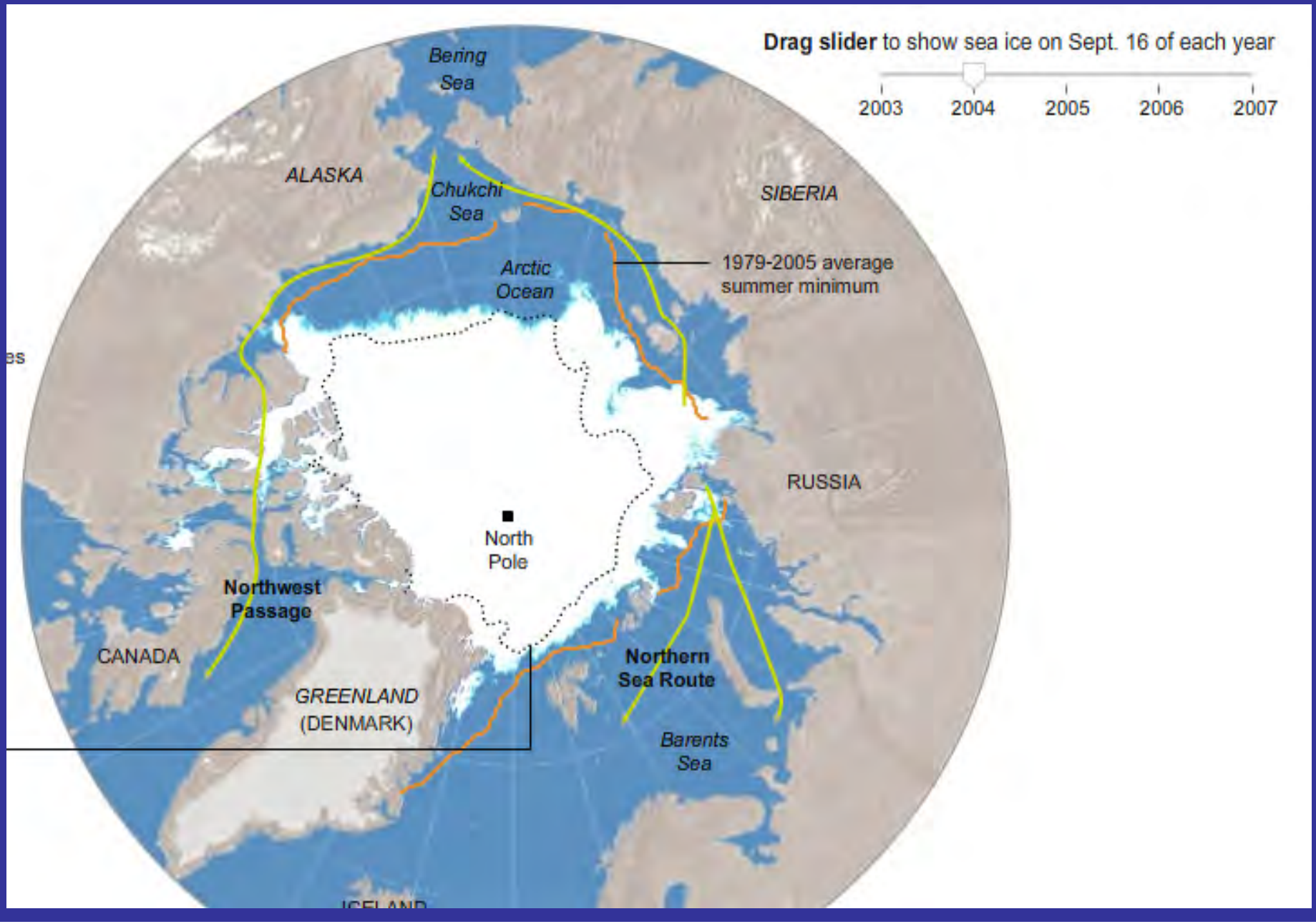
- Also melting much faster than projected



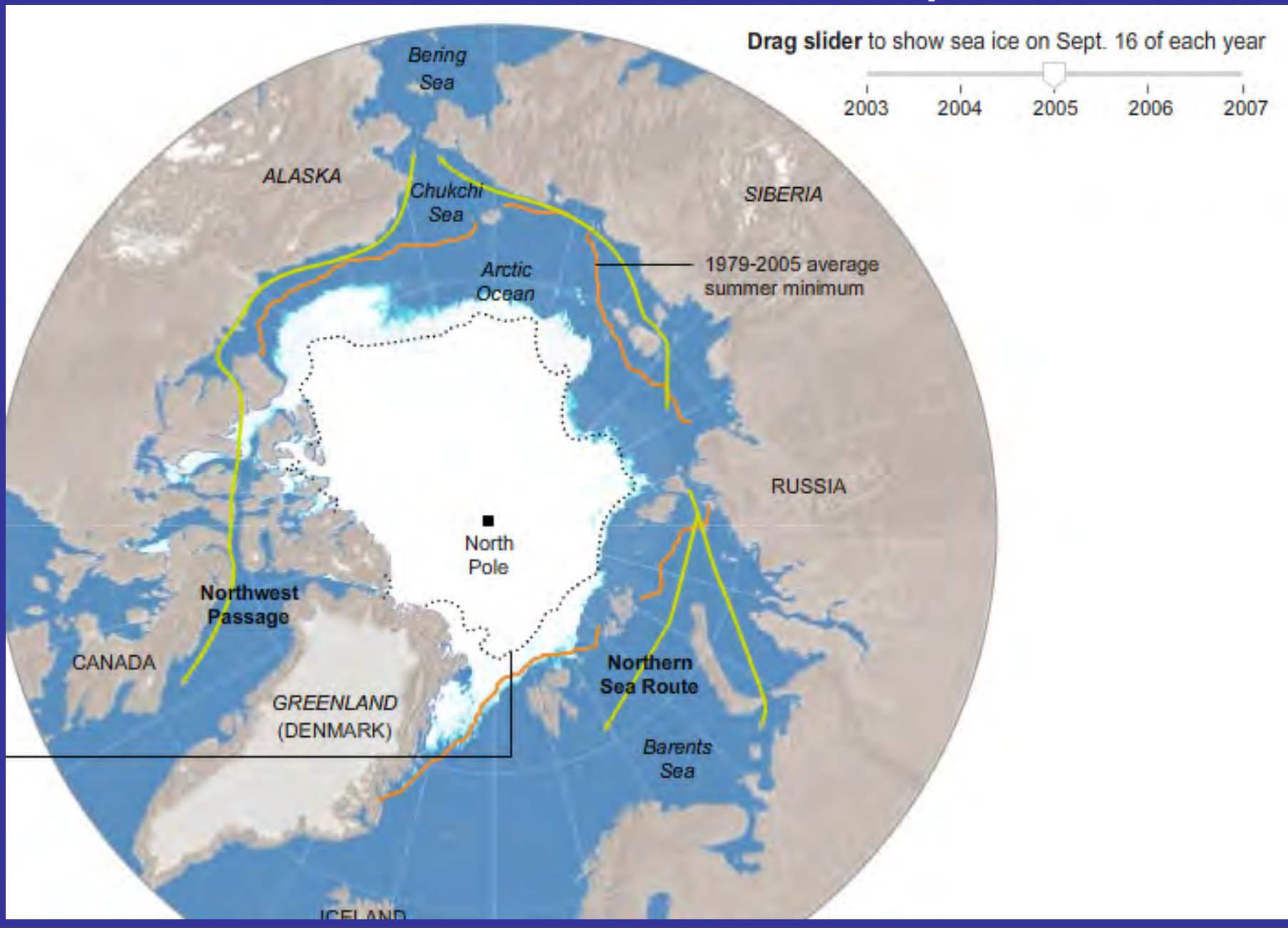
Retreat of Arctic Polar Ice Cap -- 2003



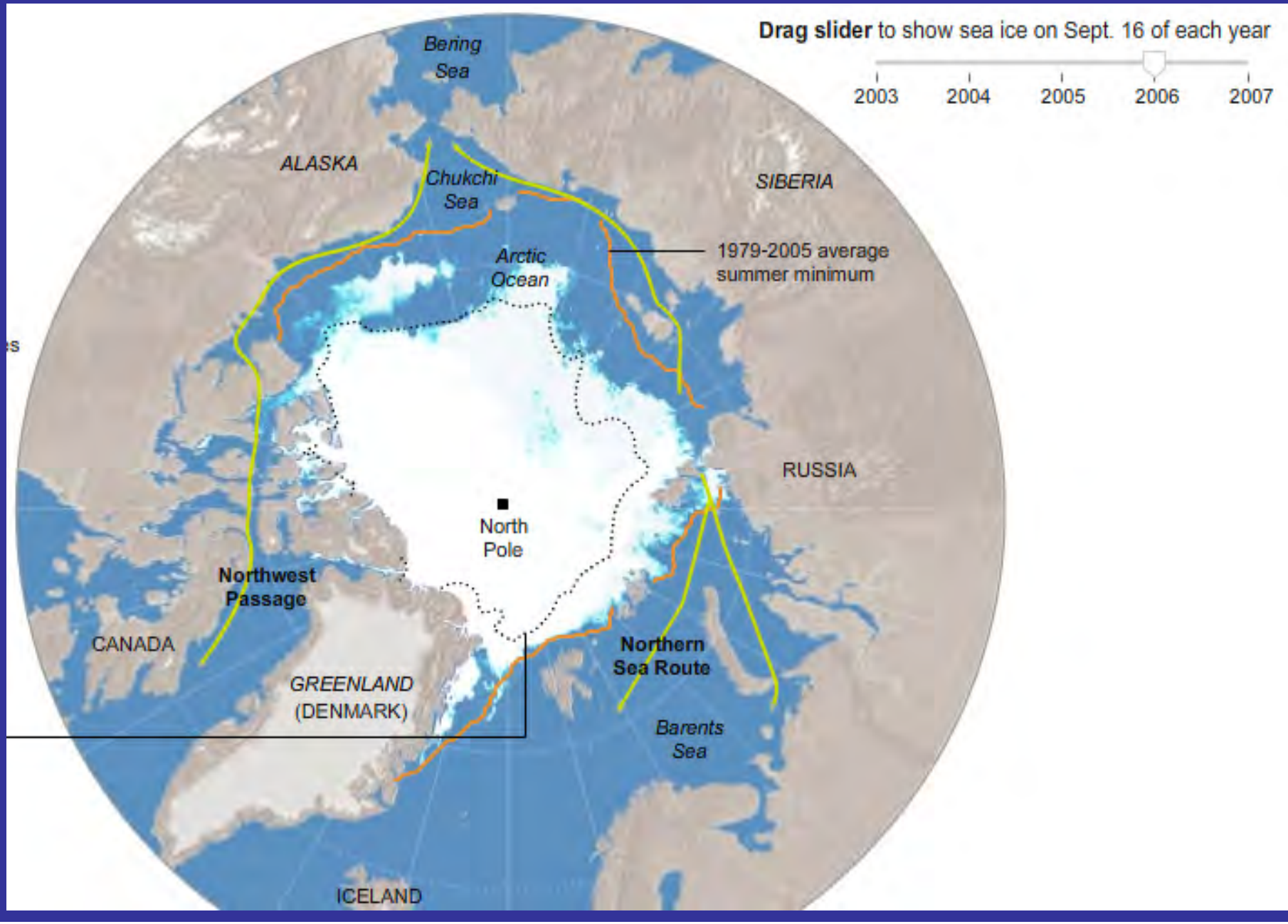
Retreat of Arctic Polar Ice Cap -- 2004



Retreat of Arctic Polar Ice Cap -- 2005

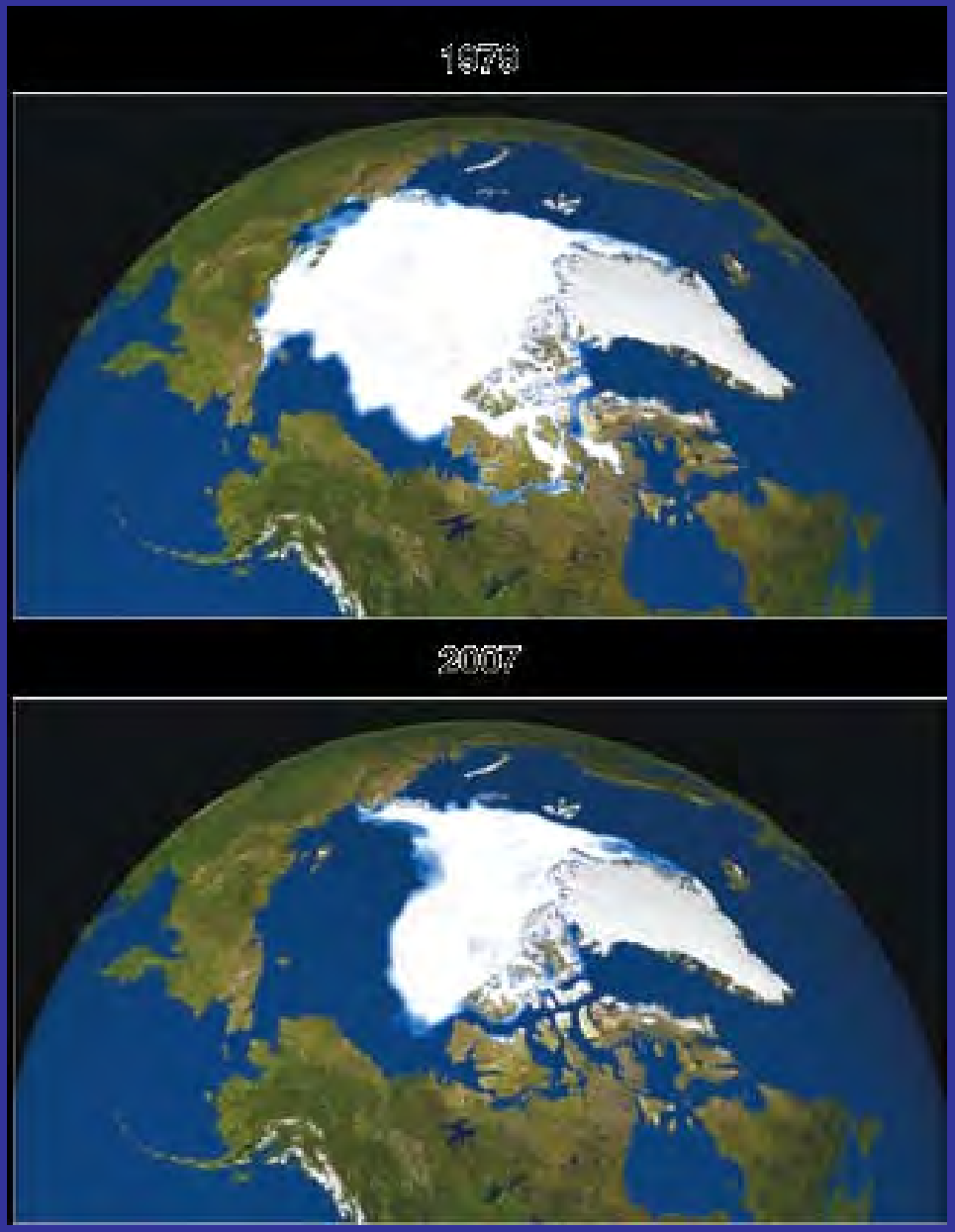


Retreat of Arctic Polar Ice Cap -- 2006



Retreat of Arctic Polar Ice Cap -- 2007

Retreat of Arctic Polar Ice Cap

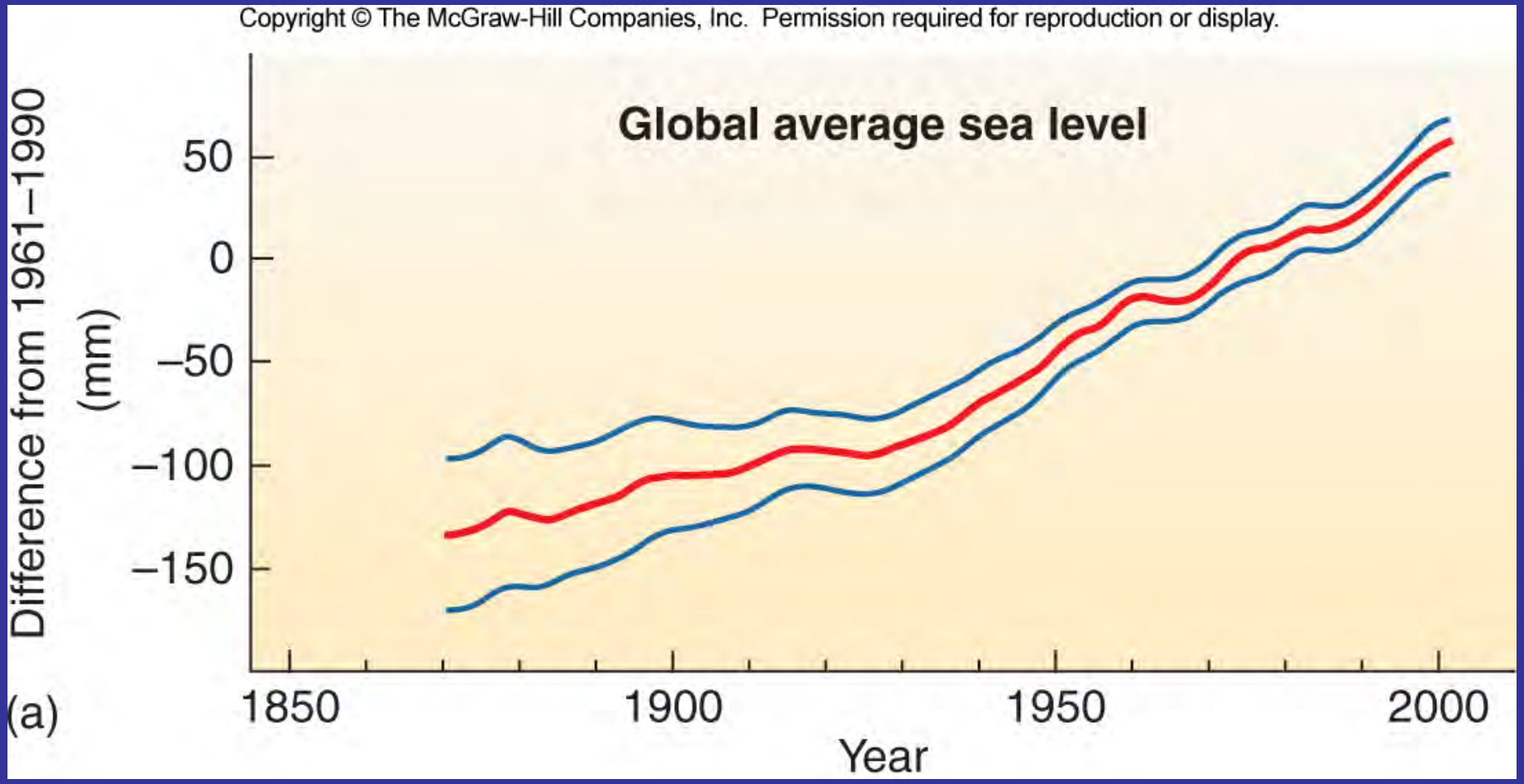


More sun energy absorbed by ocean instead of being reflected out to space

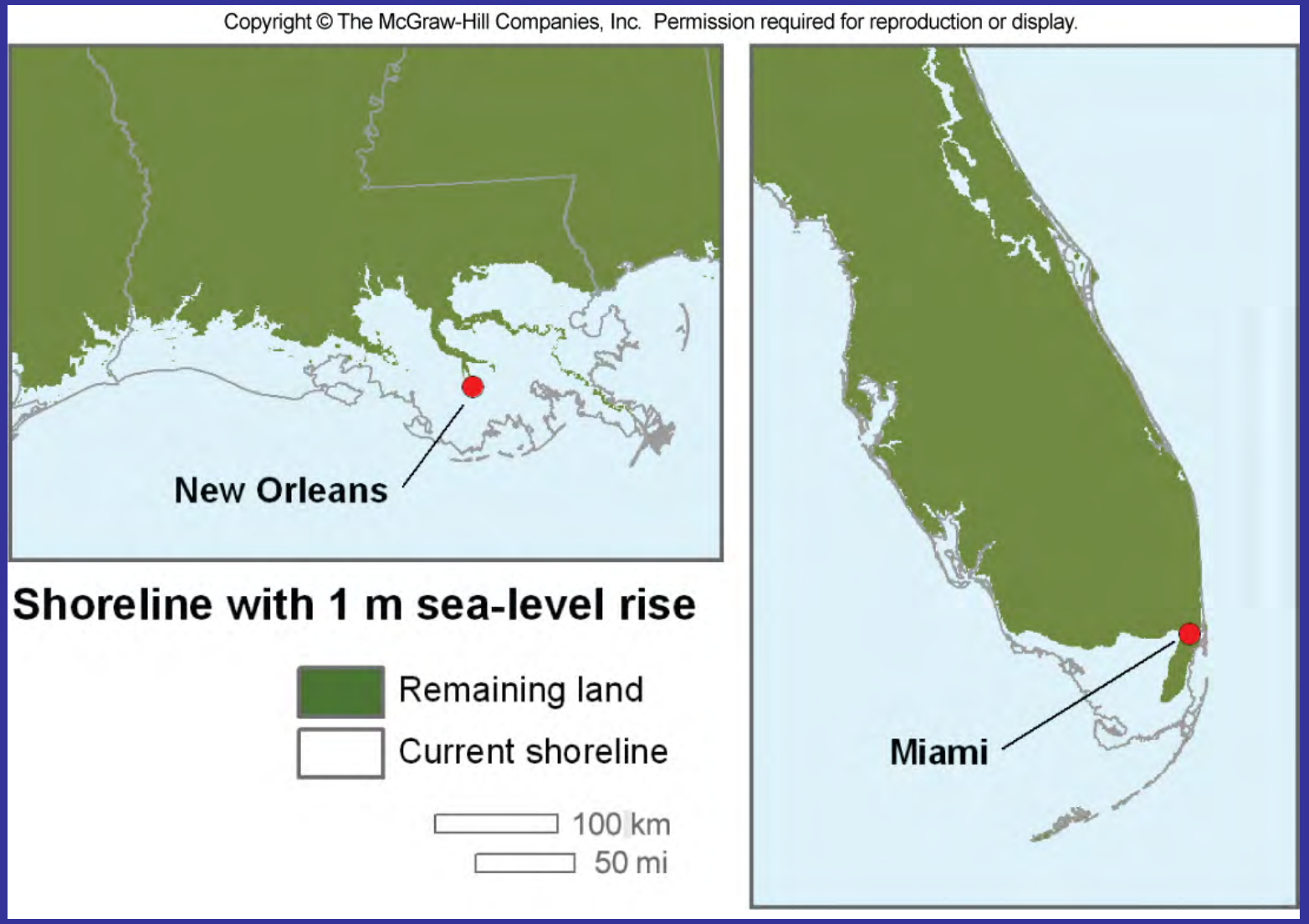
Further increases rate of global warming

Similar situation with loss of glaciers and ice sheets

Evidence of Climate Change



Impact of 1 Meter Rise in Sea Level



When ice melts, seas rise

Southern Florida with sea level 16 feet higher than now

Continental U.S. if Present Ice Sheets Melt

2. Severe Weather Events

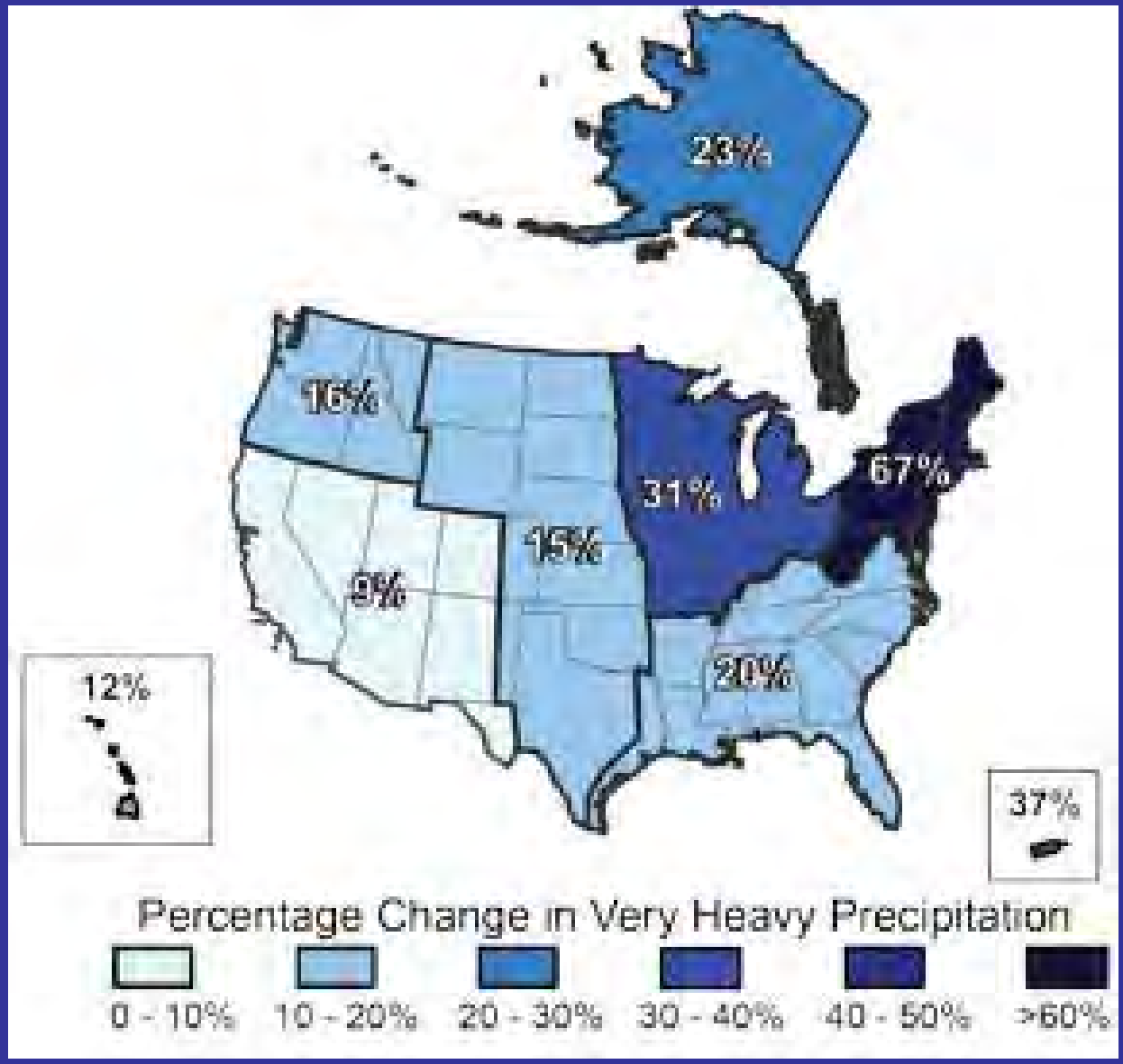
- *Frequency* of severe weather events increases
  - Hurricanes
  - Tornados
  - Floods
  - Fires
  - Blizzards

- *Magnitude* of severe weather events also increases

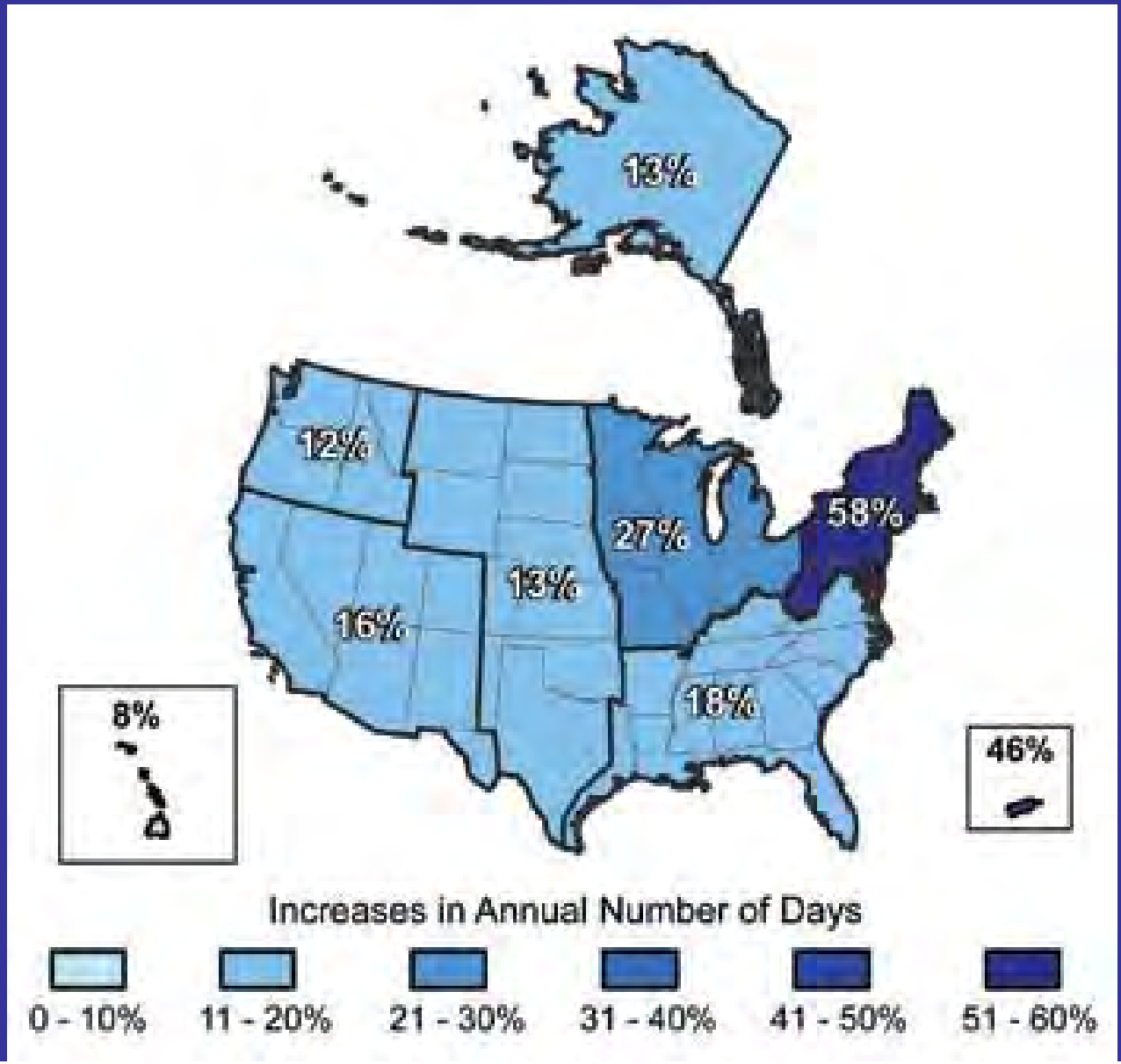
3. Increased Rainfall & Flooding

- Regional rainfall patterns change
- Much of northern hemisphere will get more rain
- But interior of continents will get drier & deserts will expand
- Snow will melt faster in mountain regions
  - Higher spring runoff (flooding)
  - Summer droughts more severe

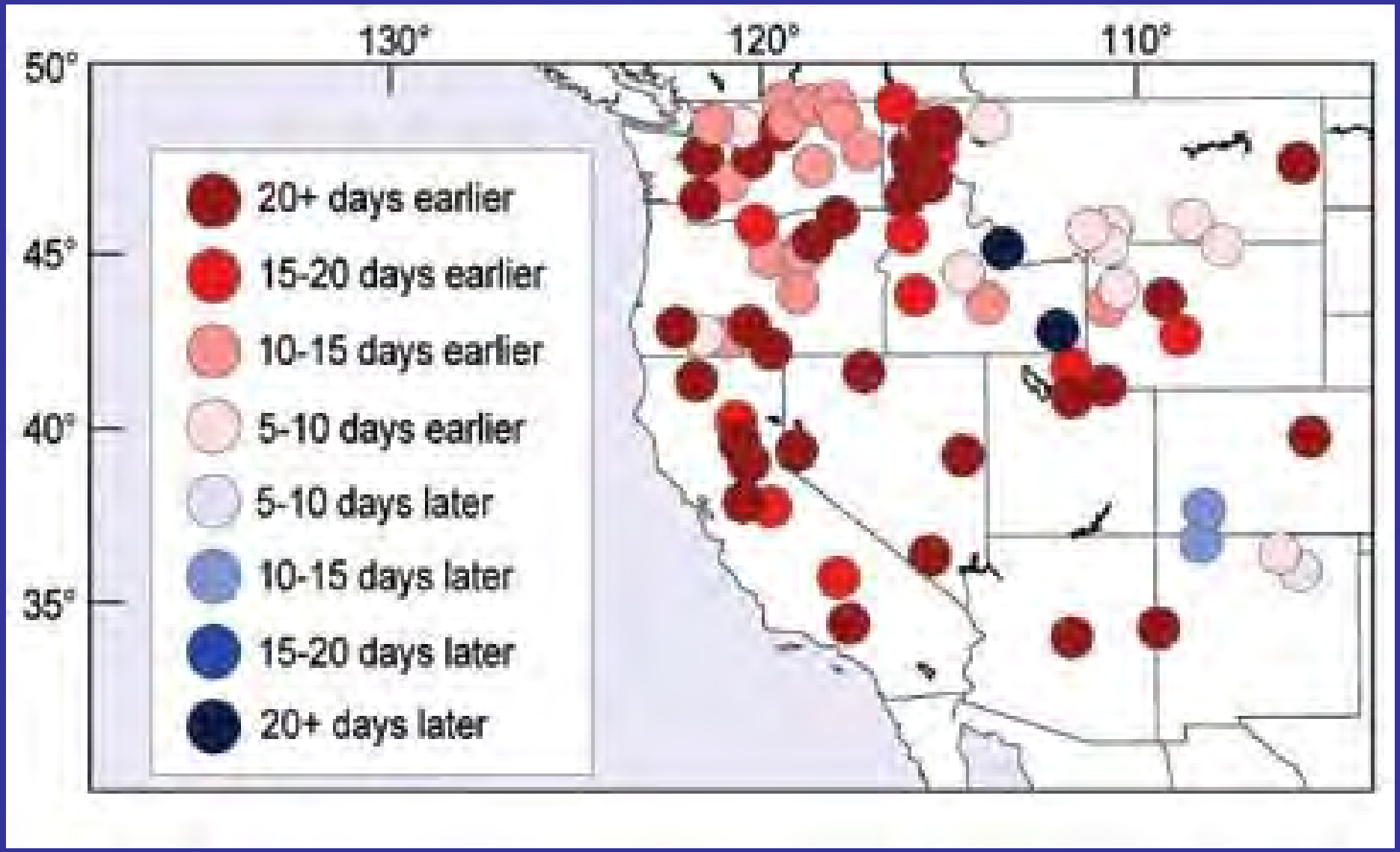
Increases in Amounts of Very Heavy Precipitation (1958-2007)



Increases in Number of Days with Very Heavy Precipitation (1958-2007)



Observed Changes in Spring Snowmelt Dates



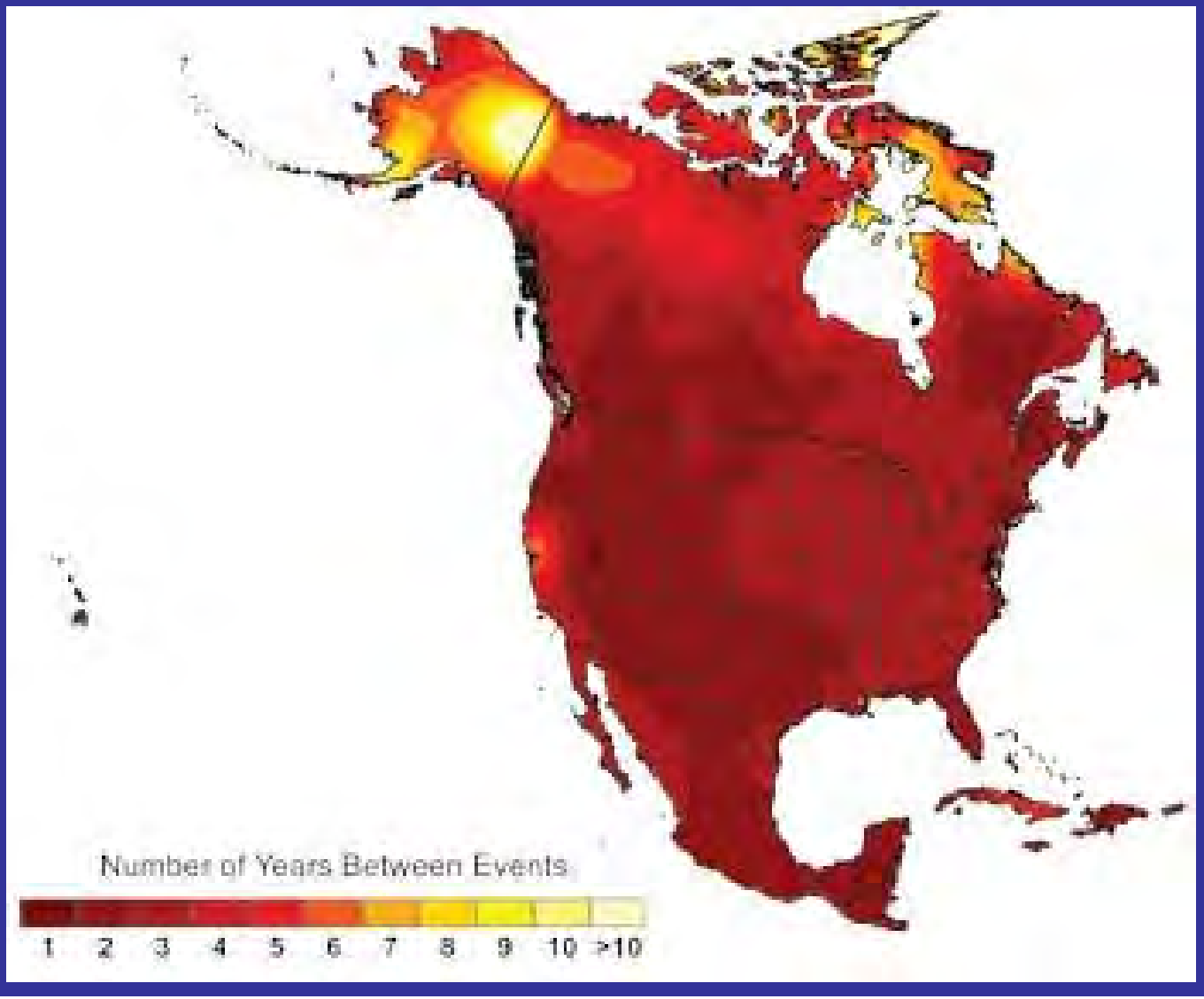
Flooding events more frequent and severe

Chalmette, Louisiana After Hurricane Katrina

4. More Intense Heat Waves

- Heat waves will intensify in northern hemisphere
- Hotter, drier summers will create more wildfires

Projected Increase in Number of Very Hot Days That Are Now Experienced Once Every 20 Years (2080-2099 Average)

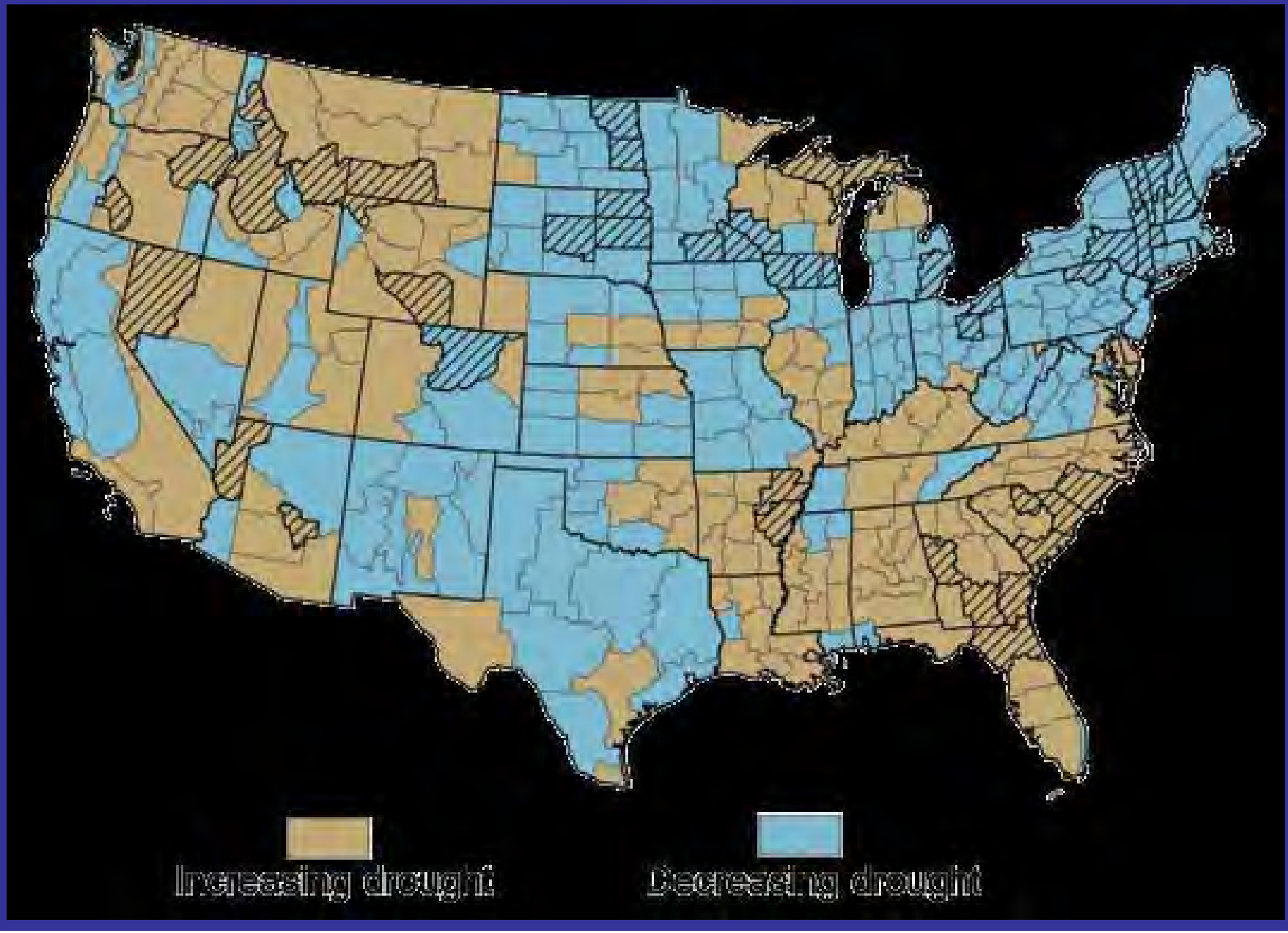


5. Crop Failures & Drinking Water Shortages

- Droughts will intensify in much of northern hemisphere including
  - **U.S.**
  - **Europe**
  - **Asia**
  - **Africa**

- Major agricultural crop losses will occur (hybrids)
- Increases in global malnutrition & famine

Drought Projections for U.S.

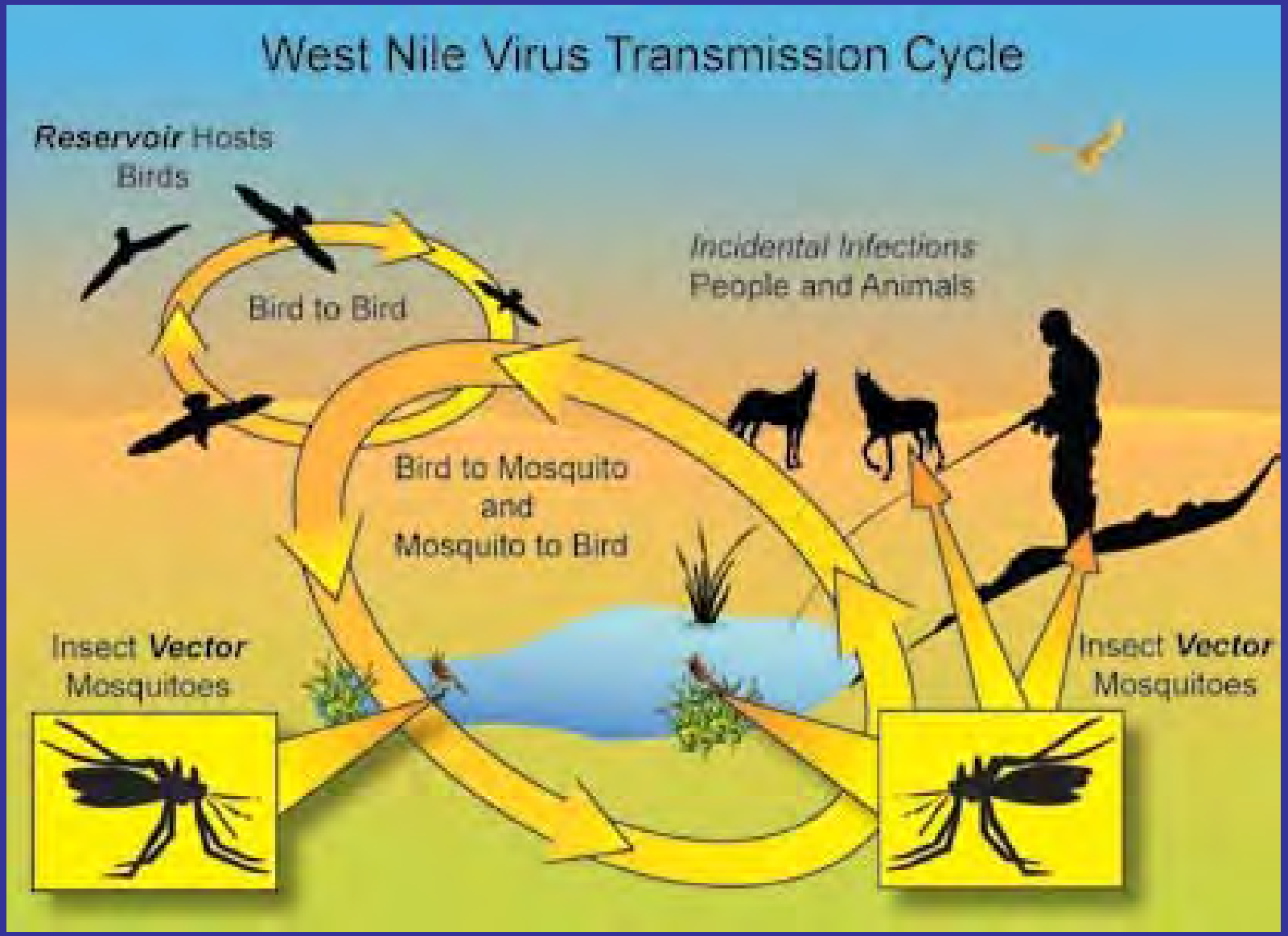


Desertification of Arid Grassland (Arizona)

6. Increased Pests & Diseases

- Pest species & diseases common in southern climates migrate northward
- More widespread distribution of pathogenic organisms & disease
- Some organisms exposed to new pathogens or diseases will not have adequate defenses

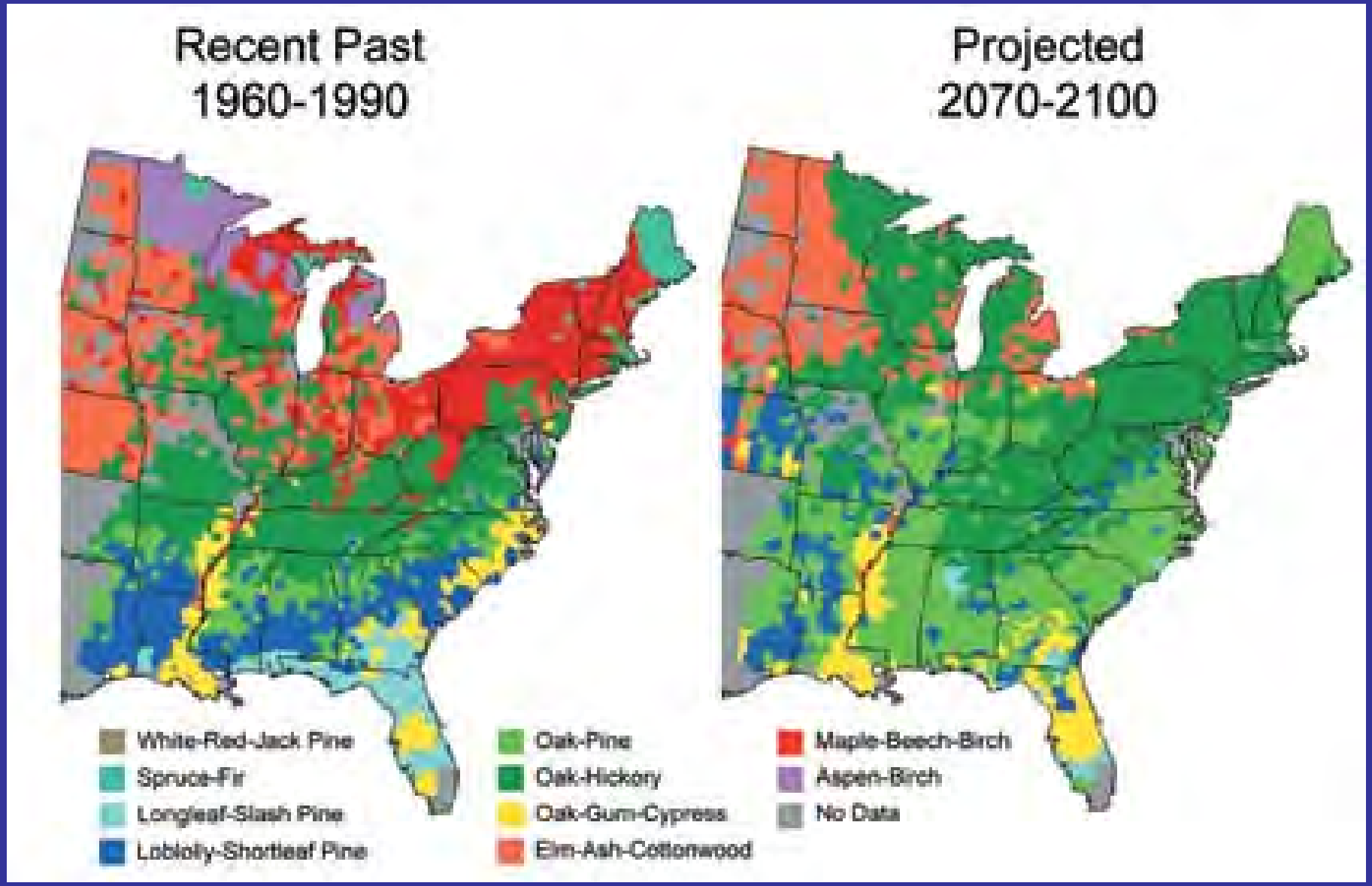
First outbreak of West Nile virus in U.S. occurred in 1999, now has spread throughout country



7. Species Loss & Distribution Range Changes

- Species migrating northward as climate changes
  - Breeding sooner, offspring hatch before traditional food sources available
  - Young die for lack of food
  - Predator/prey relationships disrupted
- Coral reef loss from coral bleaching brought about by warmer water temps
  - Loss of coral reefs associated with overall decline in marine fish populations since mid-1990s
- Acidification of oceans from CO_2 adsorption
  - Marine animals can not make shells

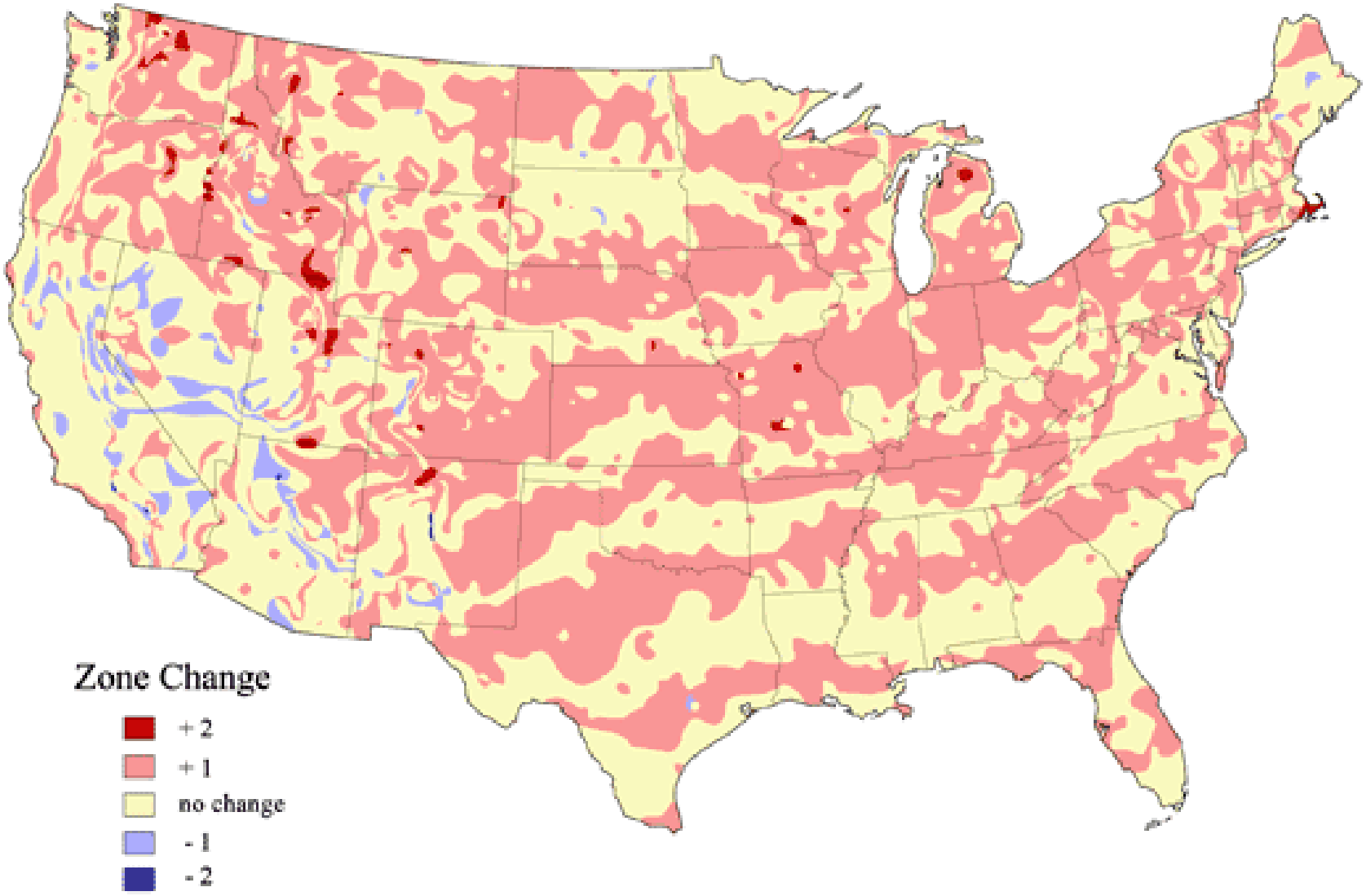
Projected Shifts in Forest Types



Forest Species Shift Upslope

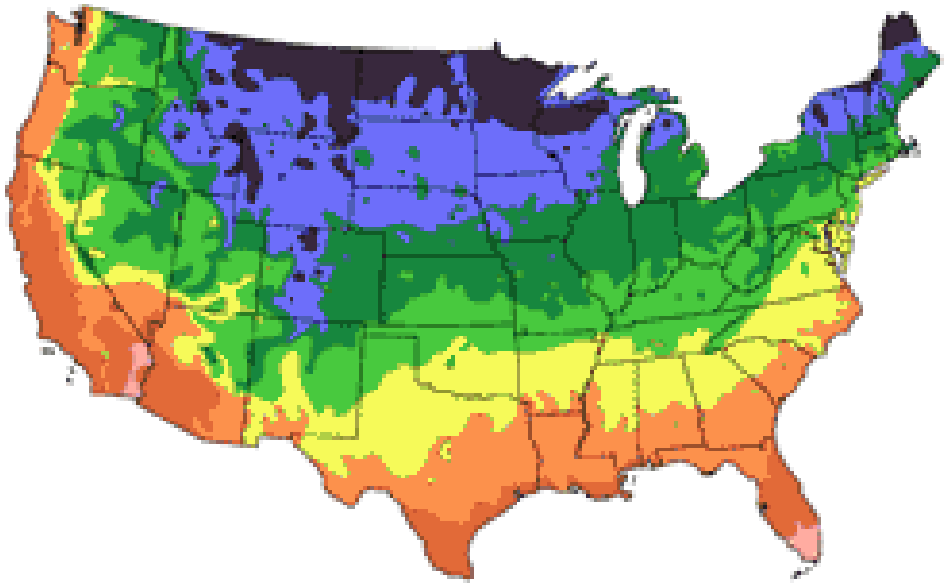
- As climate warms, hardwood trees out-compete evergreen trees adapted to colder conditions

Differences between 1990 USDA hardiness zones and 2006 arborday.org hardiness zones reflect warmer climate



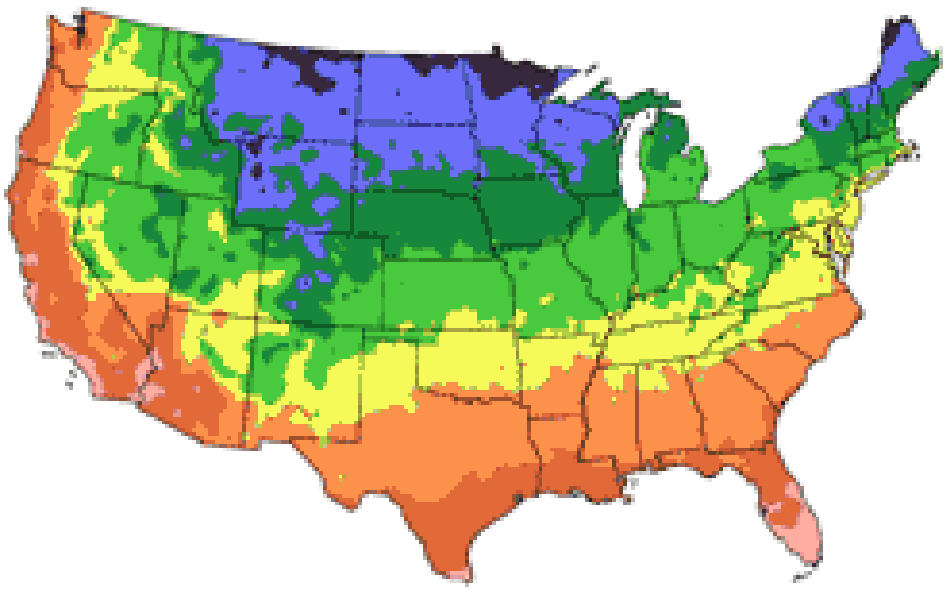
Shift in Plant Hardiness Zones

1990 Map



After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990.

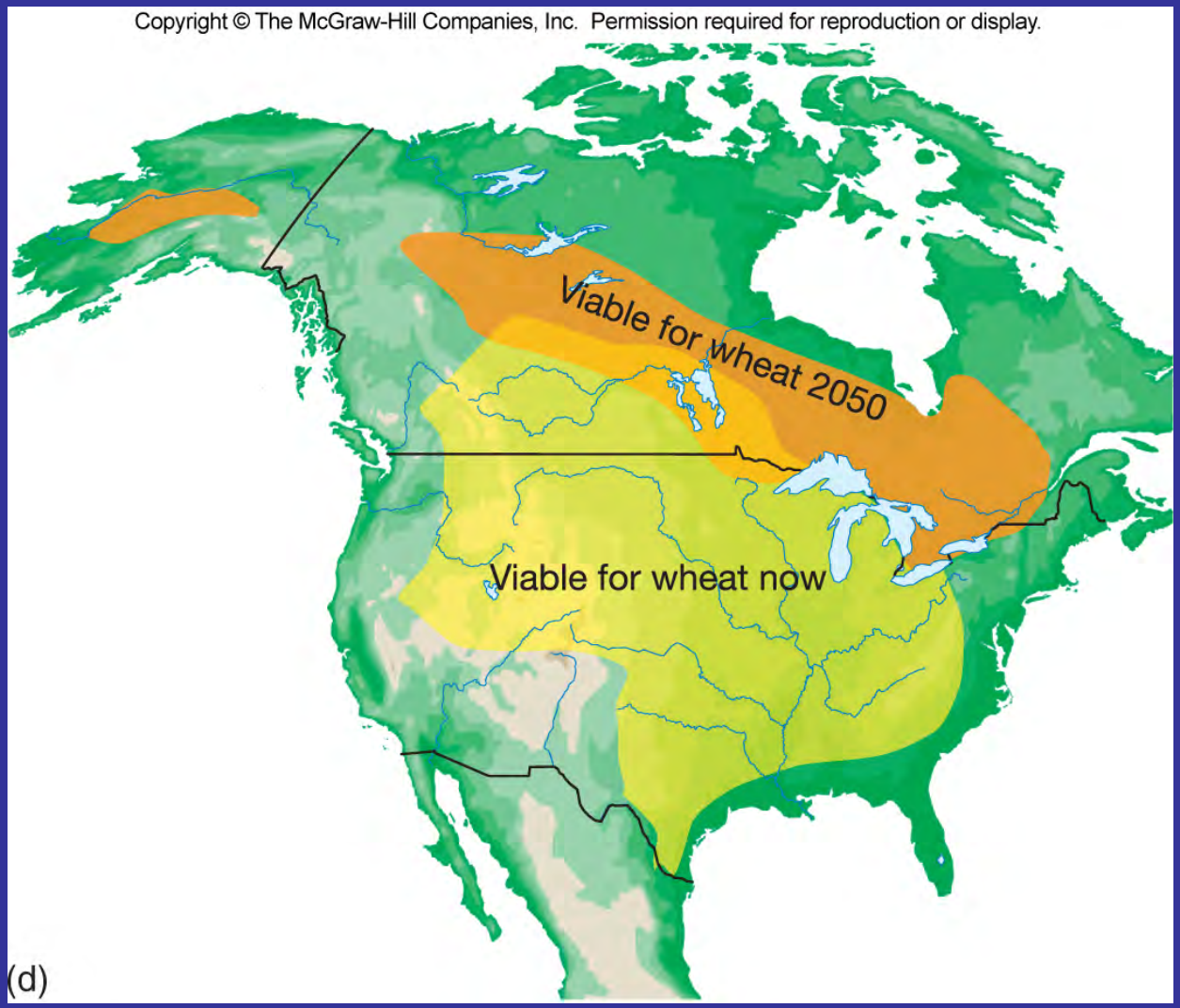
2006 Map



National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.

Zone

Evidence of Climate Change: Changing Climactic Range for Growing Wheat



Era	Period	MASS EXTINCTION UNDER WAY
CENOZOIC	QUATERNARY	With high population growth rates and cultural practices (e.g., agriculture, deforestation), humans become major agents of extinction.
	1 mya	
	TERTIARY	
	65	MASS EXTINCTION
MESOZOIC	CRETACEOUS	Slow recovery after Permian extinction, then adaptive radiations of some marine groups and plants and animals on land. Asteroid impact at K–T boundary, 85% of all species disappear from land and seas.
	138	
	JURASSIC	
	205	
	TRIASSIC	
	240	MASS EXTINCTION
PALEOZOIC	PERMIAN	Pangea forms; Land area exceeds ocean surface area for first time. Asteroid impact? Major glaciation, colossal lava outpourings, 90%–95% of all species lost
	290	
	CARBONIFEROUS	
	360	MASS EXTINCTION
	DEVONIAN	More than 70% of marine groups lost. Reef builders, trilobites, jawless fishes, and placoderms severely affected. Meteorite impact, sea level decline, global cooling?
	410	
	SILURIAN	
	435	MASS EXTINCTION
	ORDOVICIAN	Second most devastating extinction in seas; nearly 100 families of marine invertebrates lost
	505	
	CAMBRIAN	
	570	MASS EXTINCTION
	(precambrian)	Massive glaciation, 79% of all species lost including most marine microorganisms

Loss of Species

- Significant problem for human survival
- We benefit from other organisms in many ways, some of which we don't appreciate until a particular species or community disappears.
- Even seemingly obscure and insignificant organisms can play irreplaceable roles in ecological systems or be source of genes or drugs that someday may be indispensable.

Biodiversity Provides Food and Medicines

- Wild plant species could make important contributions to human food supplies. Genetic material from wild plants has been used to improve domestic crops.
- Wild bees, moths, bats, and other organisms provide pollination for most of world's agricultural crops.
- Pharmaceutical products derived from developing world plants, animals, and microbes bring in more than $30 billion per year.

TABLE 5.2

Some Natural Medicinal Products

Product	Source	Use
Penicillin	Fungus	Antibiotic
Bacitracin	Bacterium	Antibiotic
Tetracycline	Bacterium	Antibiotic
Erythromycin	Bacterium	Antibiotic
Digitalis	Foxglove	Heart stimulant
Quinine	Chincona bark	Malaria treatment
Diosgenin	Mexican yam	Birth control drug
Cortisone	Mexican yam	Anti-inflammation treatment
Cytarabine	Sponge	Leukemia cure
Vinblastine, vincristine	Periwinkle plant	Anticancer drugs
Reserpine	Rauwolfia	Hypertension drug
Bee venom	Bee	Arthritis relief
Allantoin	Blowfly larva	Wound healer
Morphine	Poppy	Analgesic

Biodiversity Can Support Ecosystem Stability

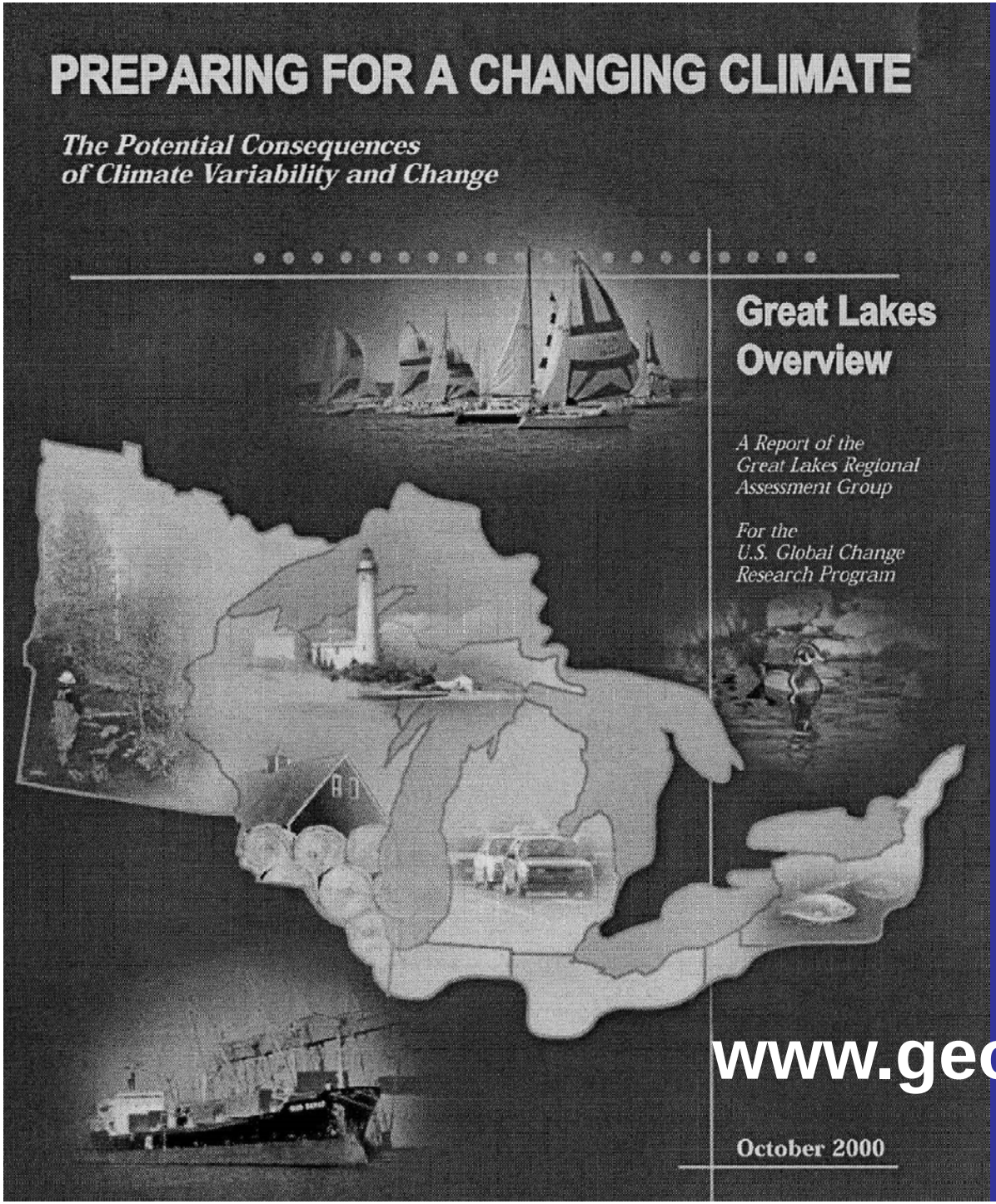
- High diversity may help biological communities withstand environmental stress better and recover more quickly than those with fewer species.
- Because we don't fully understand the complex interrelationships between organisms, we often are surprised and dismayed at the effects of removing seemingly insignificant members of biological communities.
- Maintaining biodiversity is essential to preserving ecological services.

Aesthetic and Existence Values are Important

- Nature appreciation is economically important. The U.S. Fish and Wildlife Service estimates that Americans spend $104 billion every year on wildlife-related recreation. This is 25% more than the $81 billion spent each year on new automobiles.
- For many people, just the idea that wildlife exists has value. This idea is termed "existence value." Even if they will never see a tiger or a blue whale, many find it gratifying to know they exist.

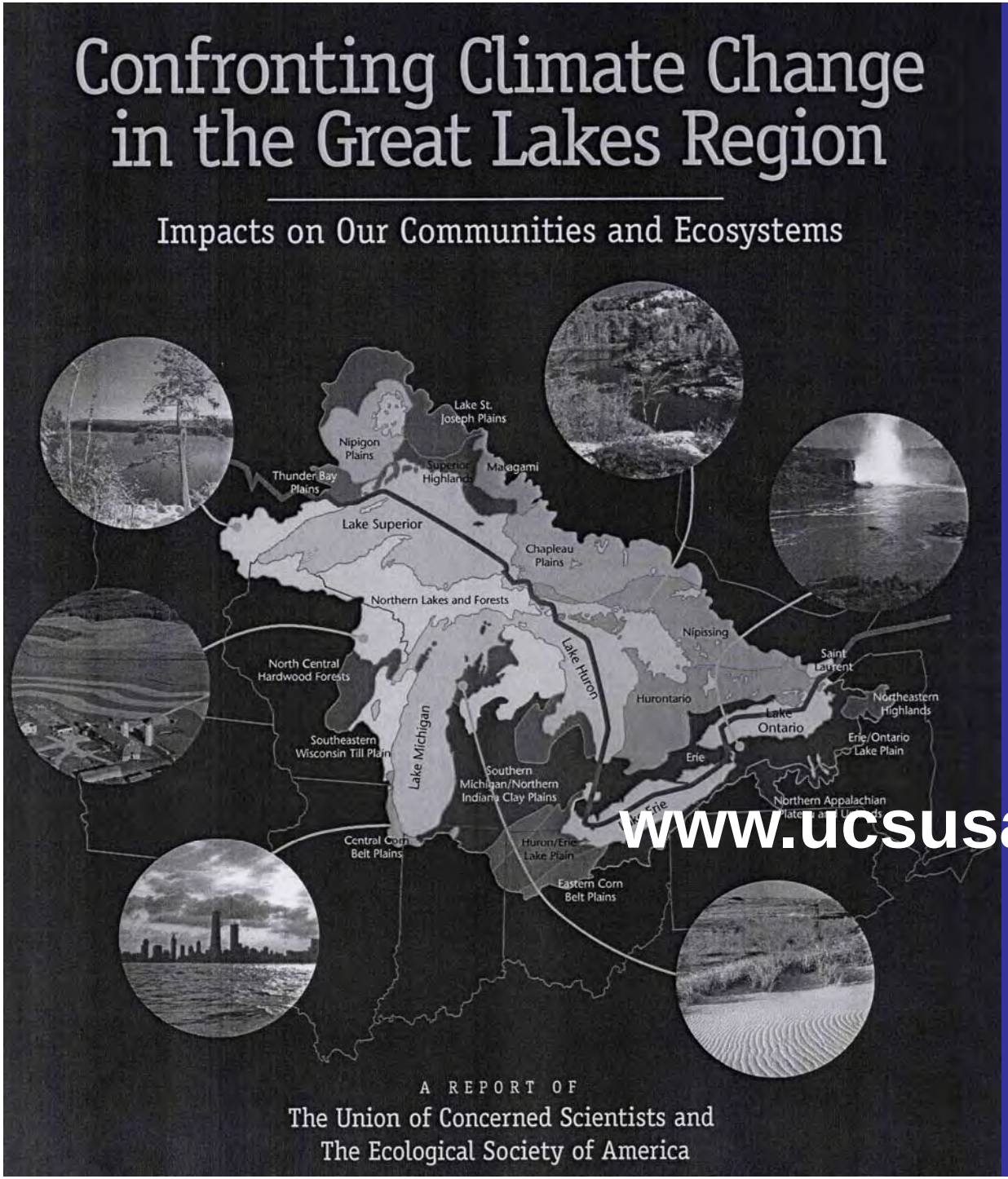
Aesthetic and cultural benefits

Bird watching and other wildlife observation alone contribute more than $29 billion each year to the U.S. economy.



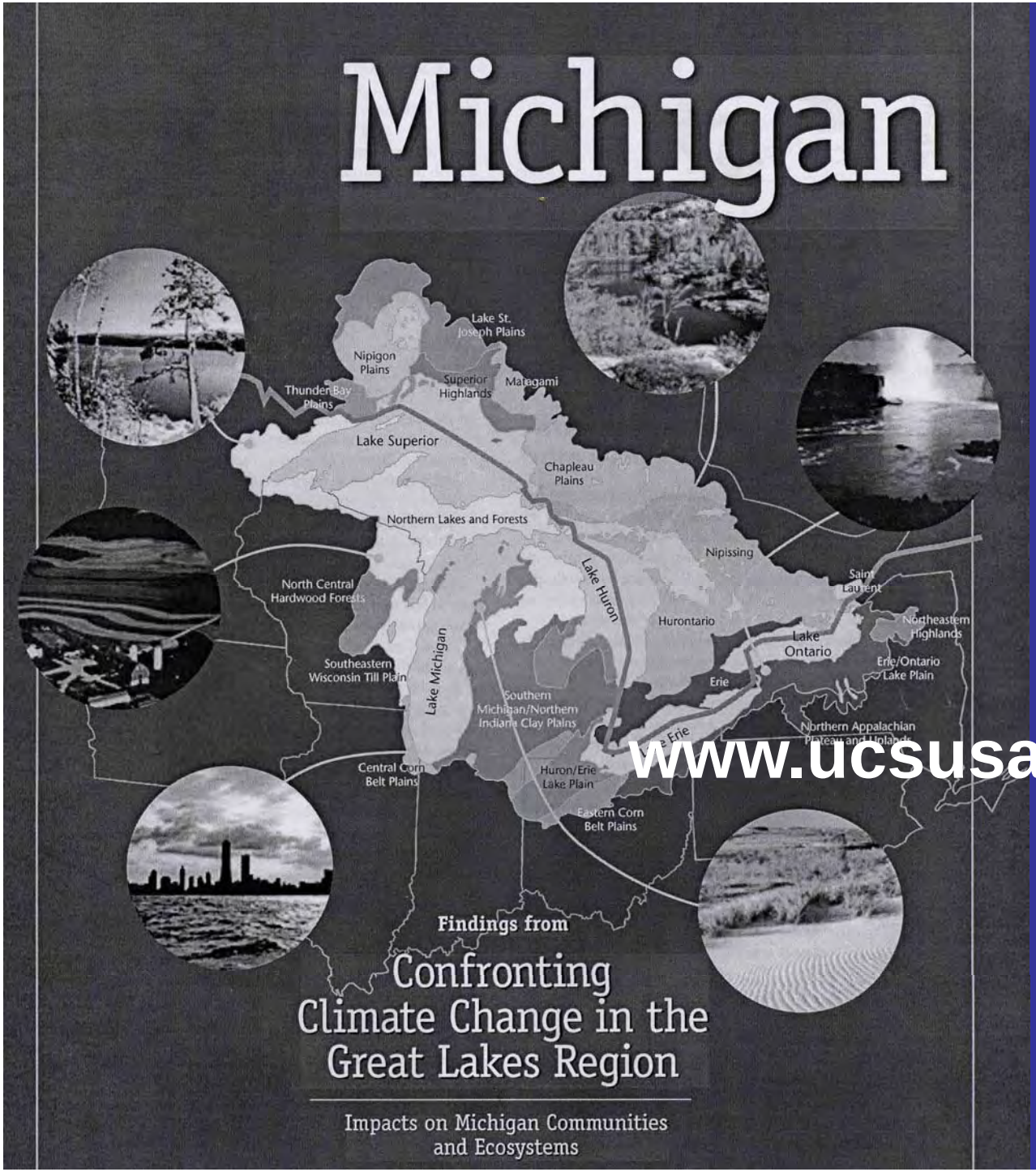
Effects of global warming in Great Lakes Region

www.geo.msu.edu/glra



Effects of global warming in Great Lakes Region

www.ucsusa.org/greatlakes

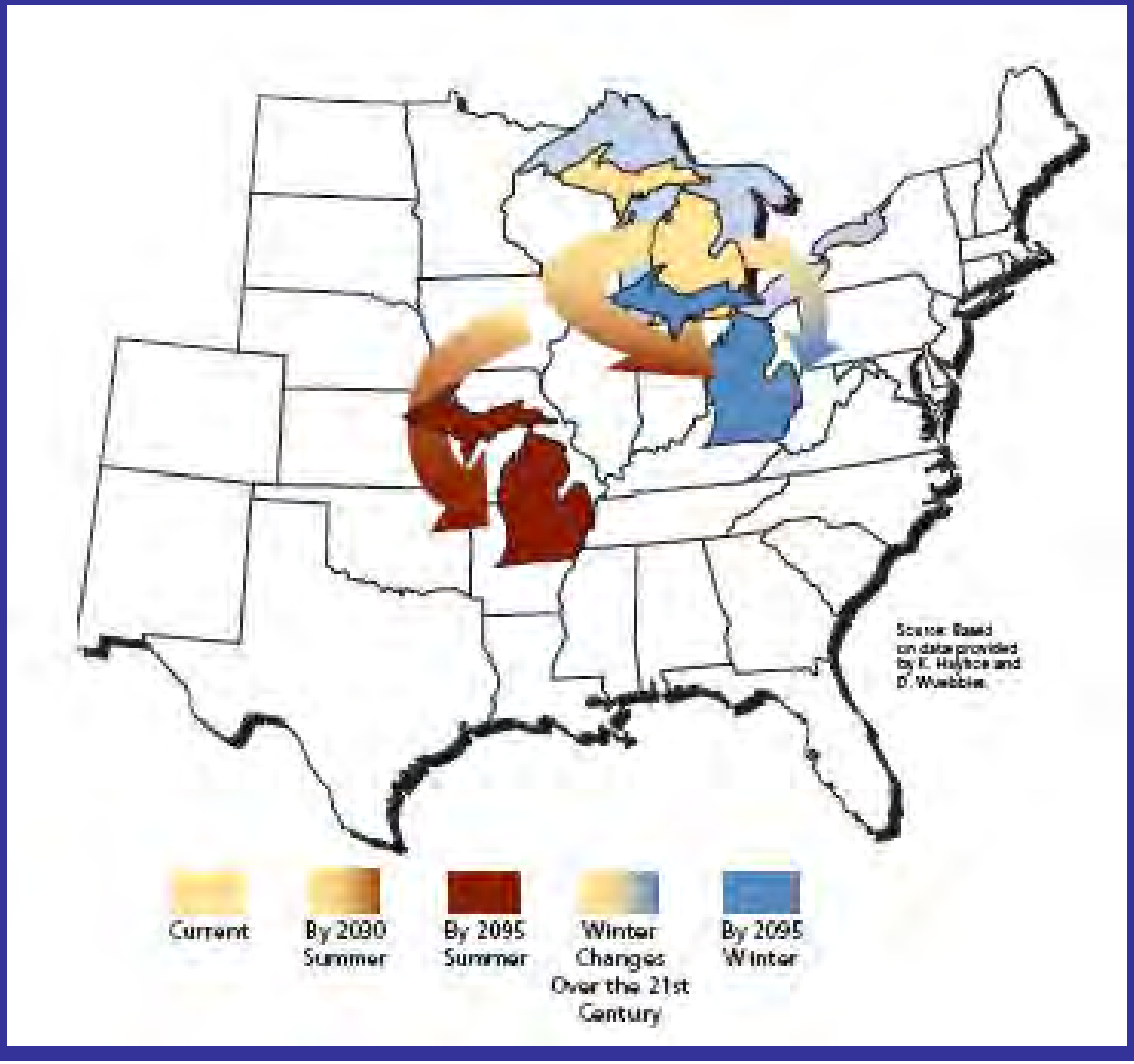


Effects of global warming in Michigan

www.ucsusa.org/greatlakes

Projected Climate Shift in Michigan

By end of century, temperature will rise 6-10°F in winter and 7-13°F in summer



Summer climate will resemble that of current-day Arkansas

Winter climate will resemble that of current-day Ohio

Projected Climate Shift in Michigan

Climate changes more dramatically under high emissions scenario

By end of century, climate would resemble that of current-day western Oklahoma or northern Texas

Dramatic warming exceeds amount that has occurred since last ice age

Precipitation Changes in Michigan

- Annual *average* precipitation may not change, but seasonal changes are likely
  - Increasing in winter 10-25% (more as rain)
  - Summer -5% to +20%, but generally drier with declining soil moisture & more droughts
  - Overall, rainfall will not fully compensate for drying effects of warmer climate
- Frequency of heavy rainstorms, both 24-hour and multiday, will continue to increase
  - Could be 50-100% higher than now

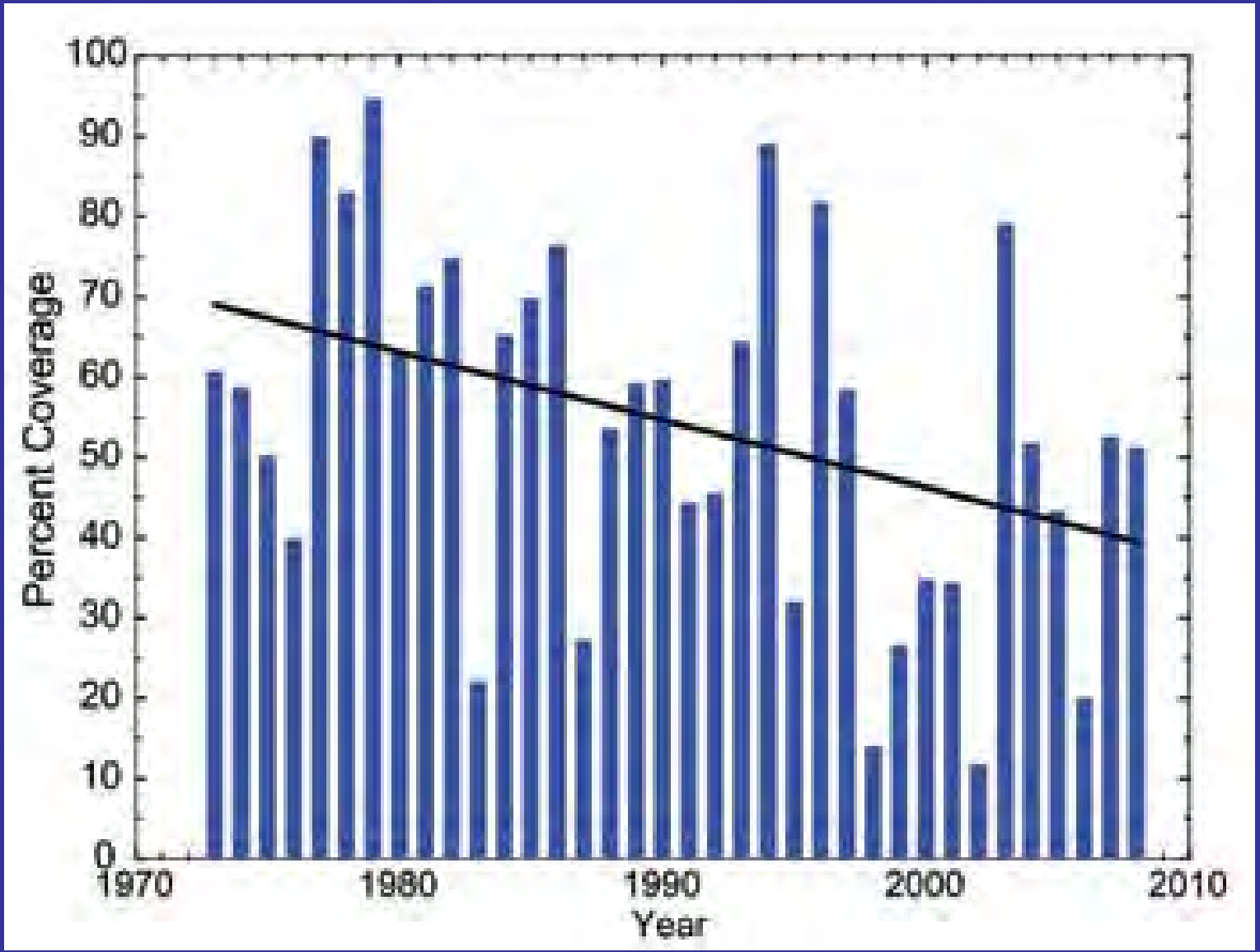
Water Level Changes in Michigan

- Water levels in Great Lakes and inland lakes drop as moisture evaporates from warmer climate and less ice cover
- Less summer groundwater recharge to streams
  - Stream flows decrease or stop
  - Water temperatures increase (loss of coldwater fish)
  - Reduced wetland area & less habitat for wildlife
- Pressure to increase water extraction amounts increase

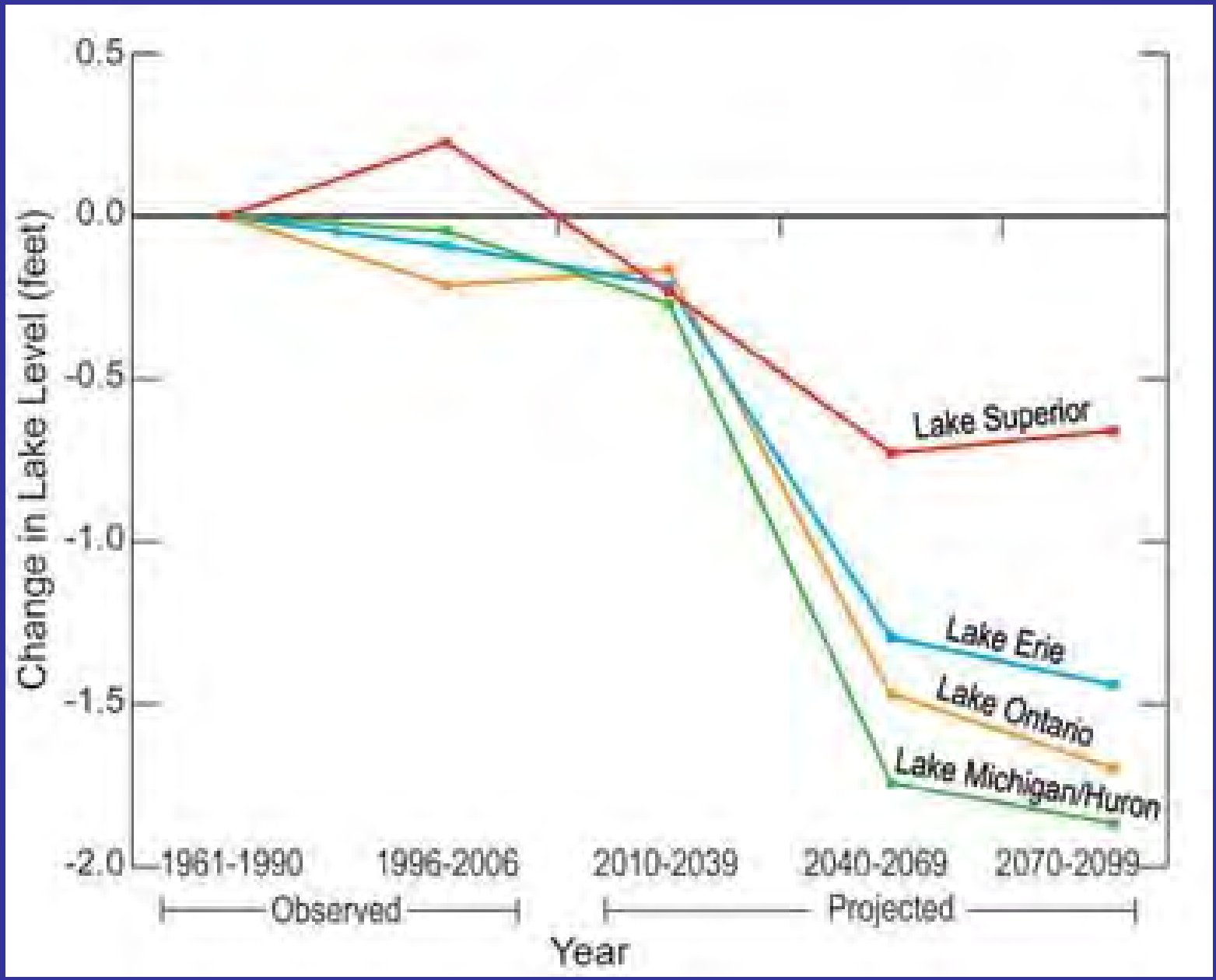
Water Quality Problems Increase

- Greater number of intense rainfall events challenge flood-absorbing capacities of decreased wetlands/floodplains and increase stormwater pollutant inputs
- Lower water levels & warmer water temps may accelerate accumulation of mercury (and other contaminants) in food chain
  - Probable increase in nuisance plant abundance
- Increased length of summer stratification in lakes adds greater risk of oxygen depletion
  - Organisms die from lack of oxygen, but winterkill events likely to decrease
  - Anoxic conditions mobilize sediment bound phosphorous and some metals

Observed Changes in Great Lakes Ice Cover



Projected Changes in Great Lakes Water Levels



Increased World Conflict

- Currently world has wars for numerous reasons
  - **Religious beliefs**
  - **Political positions**
  - **Land or natural resources**
  - **Energy**
  - **Egos**
- Global warming will add “Water Wars” to list
- Estimated that as early as a few years from now, 3 billion people will run out of fresh water

An Abrupt Climate Change Scenario and Its Implications for United States National Security

October 2003

By Peter Schwartz and Doug Randall

Imagining the Unthinkable

The purpose of this report is to imagine the unthinkable – to push the boundaries of current research on climate change so we may better understand the potential implications on United States national security.

We have interviewed leading climate change scientists, conducted additional research, and reviewed several iterations of the scenario with these experts. The scientists support this project, but caution that the scenario depicted is extreme in two fundamental ways. First, they suggest the occurrences we outline would most likely happen in a few regions, rather than on globally. Second, they say the magnitude of the event may be considerably smaller.

We have created a climate change scenario that although not the most likely, is plausible, and would challenge United States national security in ways that should be considered immediately.

Sudden Impact?

- Recent worry that global warming estimates are too low & problems will be much worse than anticipated
- Was thought effects would be felt slowly, as climate gradually warmed, but is happening much more quickly than projected
- Plus, now fear may be near significant single event that would cause sudden climate shift all at once

8. Ocean Thermohaline Conveyor

- Recent evidence suggests that present gradual global warming could lead to the abrupt slowing or collapse of ocean's thermohaline conveyor system of currents
- These currents keep many continental coasts warm and recycle deep ocean nutrients needed for world food web
  - Phytoplankton main source O_2
- Ironically, collapse of these currents brought about by global warming could usher in a *new Ice Age*
  - Has happened 6 times in recent geological past
  - Could be well into new ice age in as little as 10 years

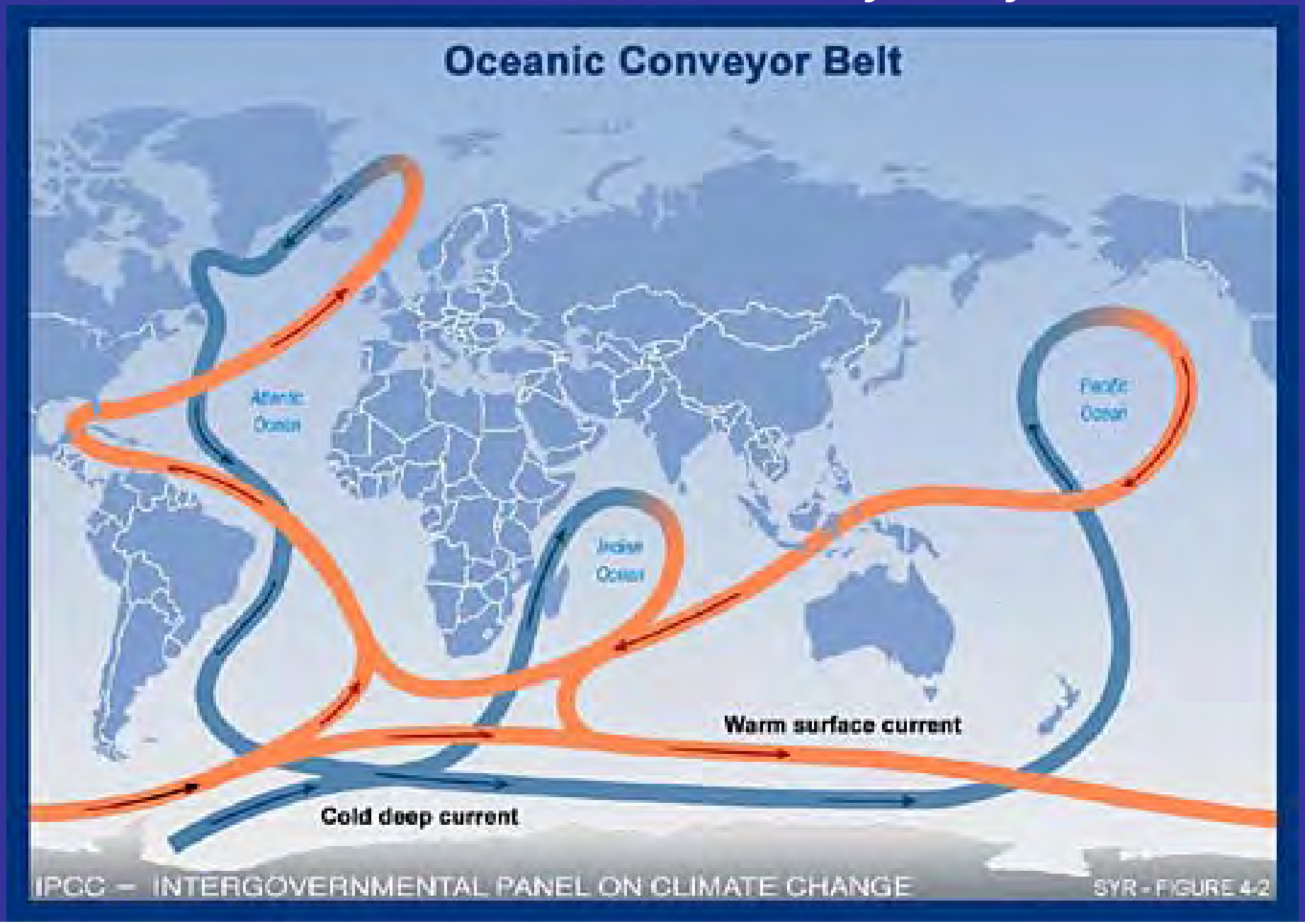
How Does Conveyor Work?

- Thermohaline currents driven by temperature & salinity differences
  - Warm water less dense than cold water, rises while denser cool water sinks
  - Similarly fresh water less dense than salt water & when mixed with ocean water decreases seawater density

How Does Conveyor Collapse?

- Melting polar ice caps increase amount of fresh water entering oceans, changing seawater density
- Though warm salt water from equator has cooled in temperate latitudes, no longer dense enough to sink – driving process of conveyor system
- Warm equatorial water stops flowing to temperate latitudes & continents cool

World Thermohaline Conveyor System



How Soon?

- Some indications global warming has *already* reached threshold where thermohaline circulation could start to be significantly impacted
- North Atlantic being increasingly freshened by melting glaciers, has become substantially less salty over past 40 years
- Floating ice in northern polar seas lost 40% of its mass between 1970 and 2000, all expected to be gone soon
  - No more icebergs

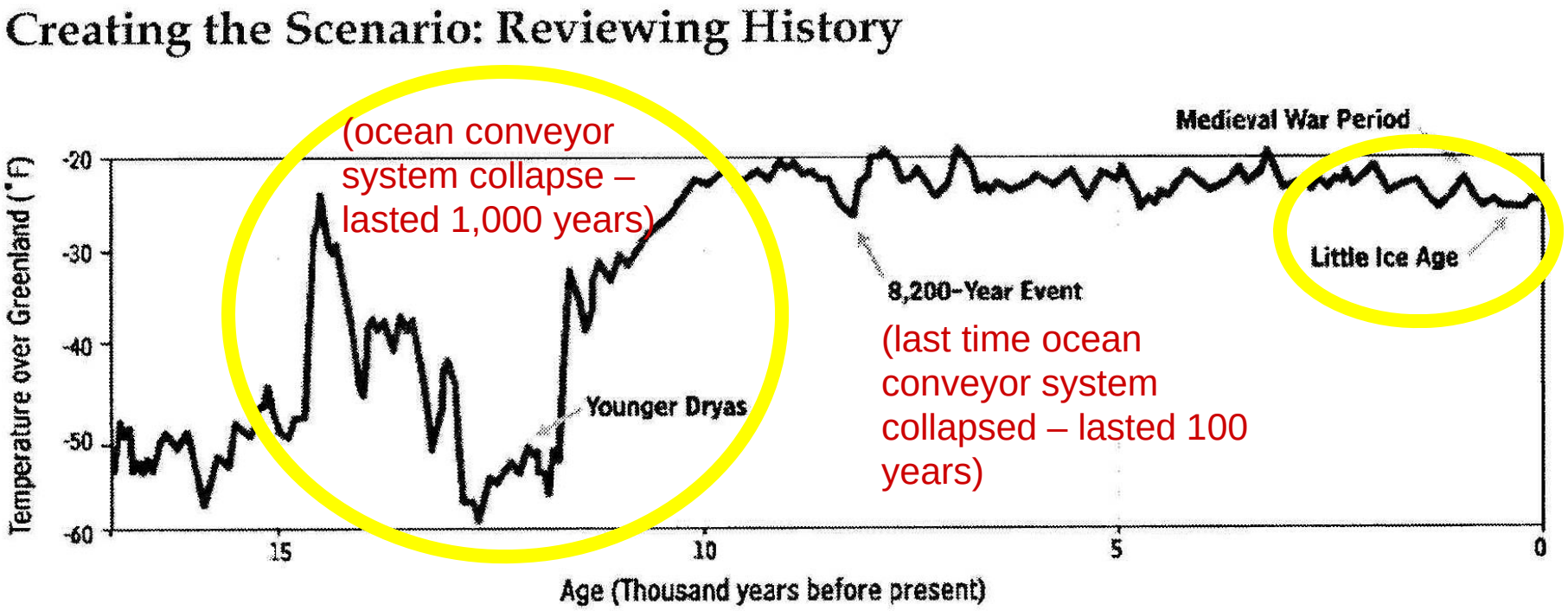
What Will be Immediate Impact?

- Northern Europe and eastern North America no longer warmed by northern flows of equatorial water from Gulf Stream
- Result is significantly cooler temperatures in Europe & throughout much of Northern Hemisphere
- Weather patterns change with dramatic drop in rainfall for many key agricultural & populated areas reducing water supplies & food production

Global temperatures could drop significantly, causing increased snowfall & glaciation of northern areas

– Michigan land surface still rebounding from last glaciers up to 1.2 miles thick (up to 2 miles thick parts of North America)

Temperatures over Greenland dropped more than 27°F during Younger Dryas



Lasts How Long?

- Paleoclimatic evidence suggests altered climate patterns could last as little as 100 years, as they did during last thermohaline conveyor collapse 8,200 year ago
- Or over 1,000 years, as they did during Younger Dryas 12,700 years ago
- Or perhaps even for geological timeframe

Summary: Evidence of Climate Change is Overwhelming

- Over last century, average global temperature has climbed about 0.6 degree C (1 degree F).
- Permafrost is melting; houses, roads, pipelines, sewage systems, and transmission lines are being damaged as ground sinks beneath them.
- Arctic sea ice is only half as thick now as it was 30 years ago.

Summary: Evidence of Climate Change is Overwhelming

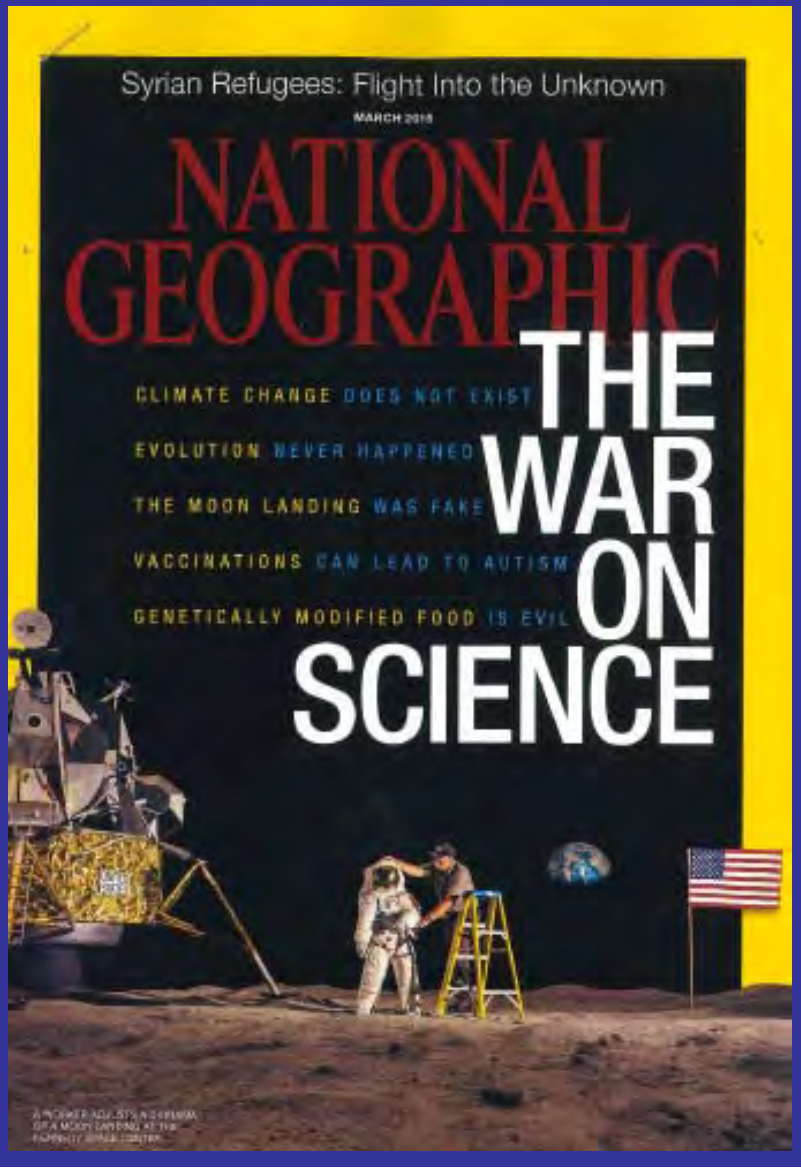
- Alpine glaciers everywhere are retreating rapidly.
  - Mount Kilimanjaro has lost 85% of its famous ice cap since 1915.
- Higher levels of CO_2 being absorbed are acidifying oceans, and could have adverse effects on sea life.
- Sea level has risen worldwide approximately 15–20 cm (6–8 inches) in past century.

Summary: Evidence of Climate Change is Overwhelming

- Satellite images and surface measurements show that growing seasons are now as much as three weeks longer in a band across northern Eurasia and North America than they were 30 years ago.
- Droughts are becoming more frequent and widespread.
- Biologists report that many animals are breeding earlier or extending their range into new territory as the climate changes.
- Coral reefs worldwide are “bleaching,” losing key algae and resident organisms.

Summary: Evidence of Climate Change is Overwhelming

Yet climate deniers persist with their obstruction and misinformation campaigns



Despite All Evidence, Policy Makers Have Made *Little Progress* in Finding Solutions

- Climate control is classic free-rider problem, in which nobody wants to take action for fear that someone else might benefit from their sacrifices.
- Question is whether sacrifices need necessarily be as big as some policy makers suggest.
- Climate scientists point out that shifting our energy strategy from coal to wind, solar, and greater efficiency, could produce millions of new jobs and save billions in health care costs associated with coal burning.

Controlling Emissions is Cheap Compared to Climate Change

- 2010 study by Pew Trust estimates cost of lost ecological services by 2100.
- Costs included factors such as:
  - lost agricultural productivity from drought
  - damage to infrastructure from flooding and storms
  - lost biological productivity
  - health costs from heat stress
  - lost water supplies.

Controlling Emissions is Cheap Compared to Climate Change

- The Pew report found that climate change is likely to cost between $5 trillion and $90 trillion by 2100.
- Stern report estimates a cost of only about 1% of global GDP to avoid worst impacts of climate change.
- Former president Bill Clinton has argued that combating climate change doesn't have to mean economic hardship.
- It could be biggest development stimulus since World War II, creating millions of jobs and saving trillions of dollars in foreign fuel imports.

Responses to Disputes Over Climate Change

- Climate scientists offer following responses to some of claims in popular media:
  - *Reducing climate change requires abandoning our current way of life* (no, but it does require we use different energy sources).
  - *There is no alternative to current energy systems* (Europe and China are showing this to be false).
  - *A comfortable lifestyle requires high CO_2 output* (data show this is false).

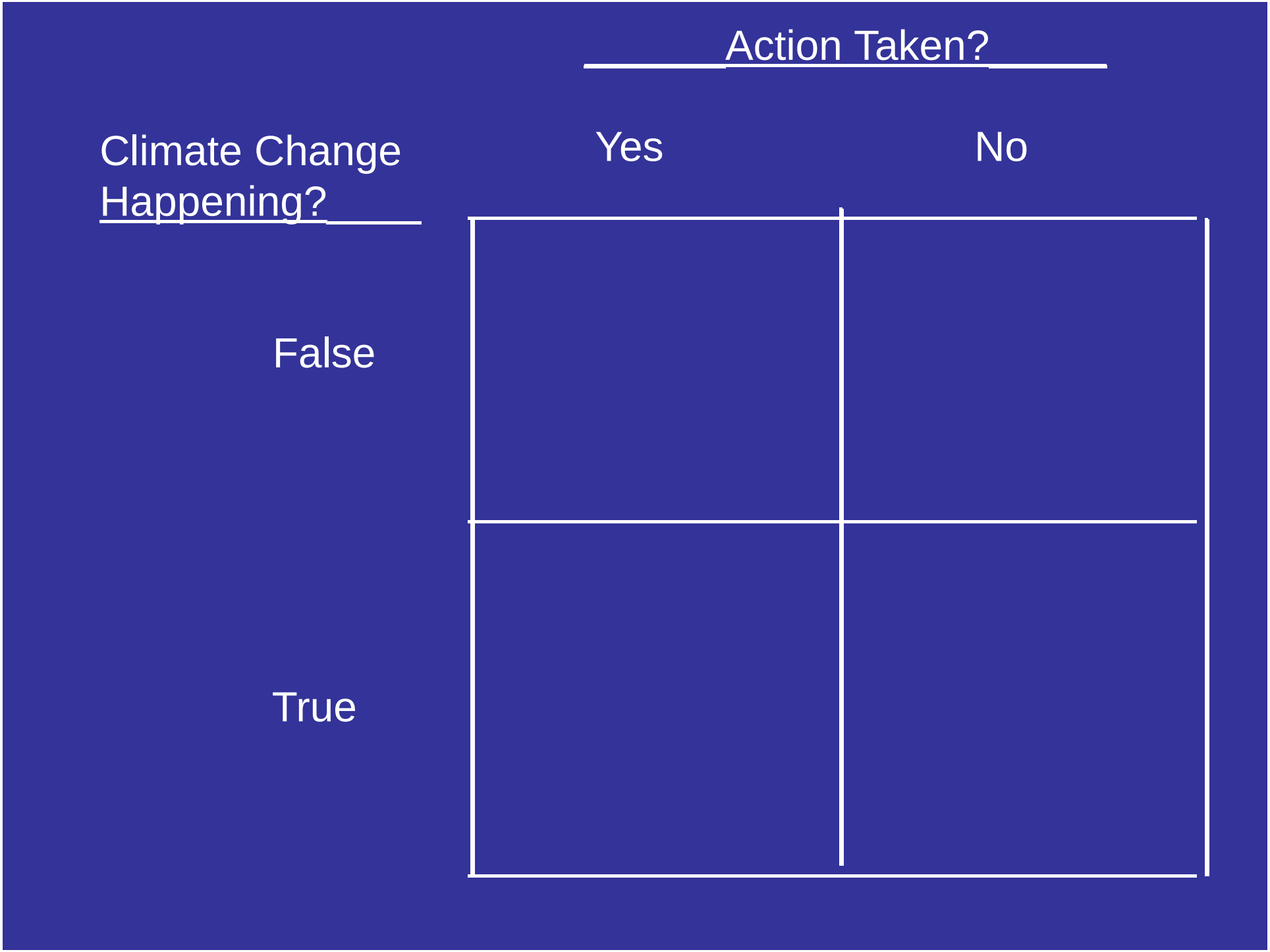
Responses to Disputes Over Climate Change

- *Natural changes such as solar variation can explain observed warming* (changes are slight and do not coincide with climate changes).
- *The climate has changed before, so this is nothing new* (Today's CO_2 level exceeds anything the Earth has seen for nearly a million years).
- *Temperature changes are leveling off* (True on short time frames sometimes, but over decades trends in surface air temperatures and in sea level continue to rise).

Responses to Disputes Over Climate Change

- *We had cool temperatures and snowstorms last year, not heat and drought* (Regional differences in temperature and precipitation trends are predicted by climate models).

- *Climate scientists don't know everything, and they have made errors and misstatements* (fraud in data collection is almost unheard of in science).


Action Taken?
Climate Change Happening?
Yes
No
False
True

Climate Change Happening?	Action Taken? Yes	No
False		
True		

Climate Change Happening?	Action Taken? Yes	No
False	Cost $ Global Economic Depression	
True		

Climate Change Happening?	Action Taken? Yes	No
False	Cost $ Global Economic Depression	
True		Global Catastrophes Economic Political Social Environmental Health

How Can We Mitigate Climate Change Impacts?

Temperature Change Mitigation

Expand use of green infrastructure and low impact development

- Reduce *summer* stormwater runoff of warm water into surface waters
- Enhance groundwater recharge to provide more coolwater input to surface waters.

Increase riparian tree canopies to decrease amount of direct solar radiation heating surface waters, wetlands and floodplains.

How Can We Mitigate Climate Change Impacts?

Temperature Change Mitigation (cont)

Remove dams that no longer serve their purpose:

- Reduces surface area of impounded river water warmed by solar radiation in summer.

Protect and restore wetlands and floodplains:

- Absorbs stormwater runoff to increase amount of groundwater recharge of cool water to streams during summer.

How Can We Mitigate Climate Change Impacts?

Precipitation Change Mitigation

Utilize more low-impact development techniques to reduce stormwater runoff and increase groundwater recharge.

Install larger-sized stormwater infrastructure to accommodate increased stormwater and river flows from bigger precipitation events

- Particularly important for transportation river crossings and municipal stormwater systems.

Expand use and size of greenbelts to filter increased stormwater runoff before it reaches surface waters.

How Can We Mitigate Climate Change Impacts?

Precipitation Change Mitigation (cont)

Protect, restore, and minimize development/conversion of, wetlands and floodplains to rivers absorb stormwater runoff

- minimize the magnitude of streambank erosion from high flow stream events
- increase the amount of groundwater recharge to streams during the low-flow summer period.

Install rain barrels at buildings to provide irrigation water for nearby vegetation, particularly during the summer.

How Can We Mitigate Climate Change Impacts?

Precipitation Change Mitigation (cont)

Reuse gray water for irrigation where feasible to minimize water withdrawals from both surface water and ground water.

Convert sprinkler, spray and open trough irrigation systems to underground drip lines to minimize evaporative loss of irrigation water, particularly during the summer.

Increase conservation easements on forested lands to protect forested land cover and thereby reduce stormwater runoff and soil erosion, while preserving groundwater recharge functions of these ecosystems.

How Can We Mitigate Climate Change Impacts?

Vegetation Change Mitigation

When installing new greenbelt or enhancing/expanding an existing one, use diverse set of plant species

- Ability to survive warmer, longer and drier summers
- Able to withstand longer periods of saturated spring soil
- Mitigates impacts of anticipated increases in pest populations and arrival of new pests due to warming environment

How Can We Mitigate Climate Change Impacts?

Vegetation Change Mitigation

Use xeriscape landscaping in dry or exceptionally sunny locations to minimize need for summer irrigation water.

Plant more trees to increase acreage of forested land cover

- Protects against soil erosion
- Mminimizes stormwater runoff
- Enhances groundwater recharge
- Sequesters carbon from atmosphere.

What Can I do to Minimize Climate Change Impacts?

- ❖ Call/write local, state, and federal elected officials
- ❖ Reduce your carbon footprint (reduce energy consumption)
  (Google "reduce carbon footprint")
- Buy local and eliminate unnecessary trips to the store
  Bike, walk or use public transportation when possible
- Shop online
  If live 9 miles or more from store, online purchases use less energy to get the product
- Eat locally (restaurants, farmers markets, your garden)
  Average food item in U.S. travels 1,500 miles from farm to table
- Eat less meat, plant trees
- Drive fuel-efficient vehicles and use energy saving driving practices

What Can I do to Minimize Climate Change Impacts?

- Use less water
- Reduce, Reuse and Recycle
  Purchase environmentally friendly products
- Insulate and seal your home or business, adjust thermostat
- Have an energy audit done on your home or business
- Use energy saving light bulbs and appliances in your home or business
- Encourage your local government and local power utility to decrease their fossil fuel use by increasing their use of alternative energy sources (wind, solar, geothermal)
- If investing in energy companies, choose alternative energy companies rather than those dealing with fossil fuels (oil, coal, natural gas, propane, etc.)
- Google “climate change actions”

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The End?