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*Serving UCAR, NCAR, and UOP*

# Climate Change and Health

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**National Center for Atmospheric Research**

NIEHS, February 27, 2003

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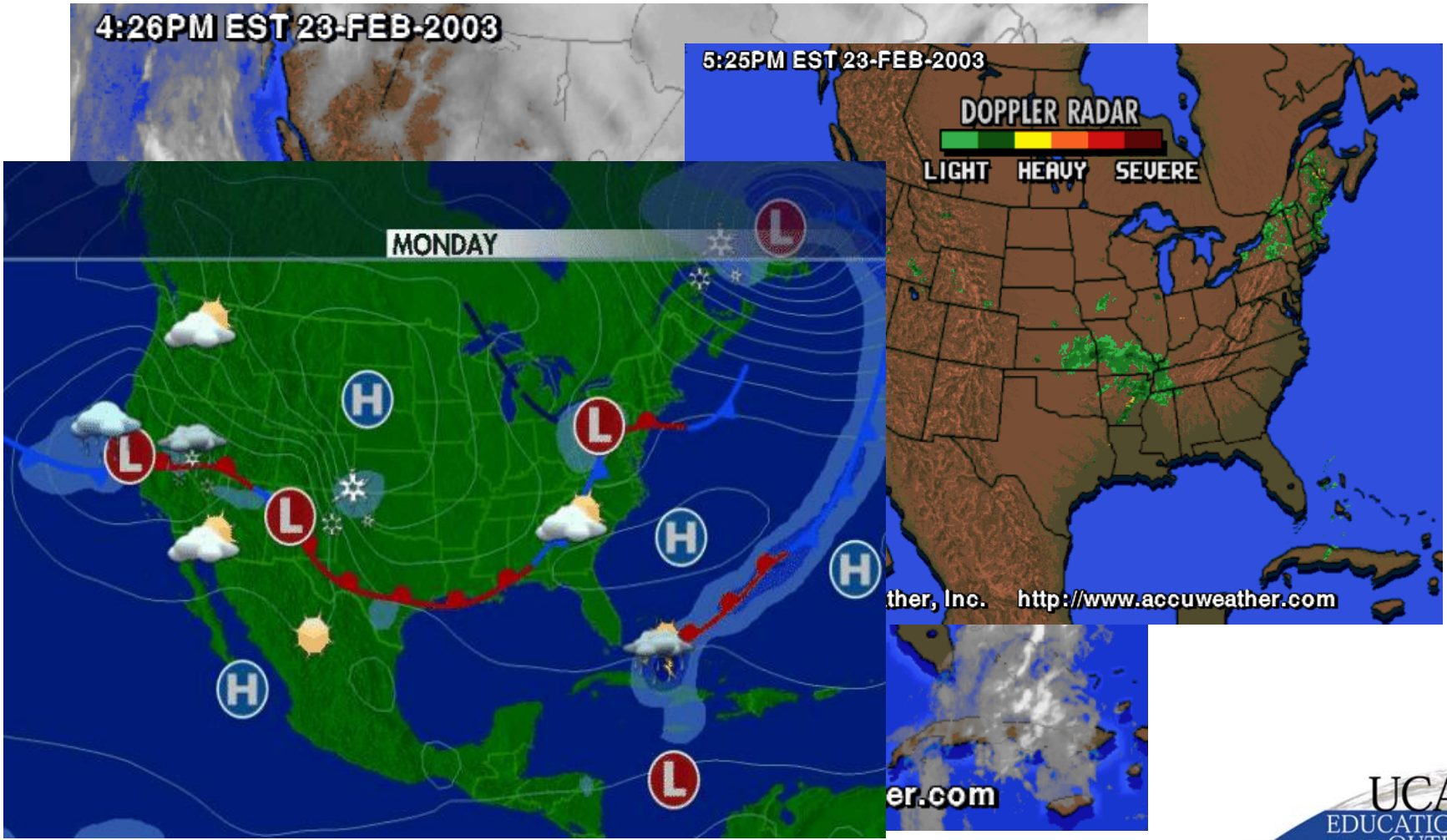
# Overview

- Climate versus Weather
- Is our climate changing?
- Climate and Health
- Curriculum Applications

# We're all familiar with the Weather



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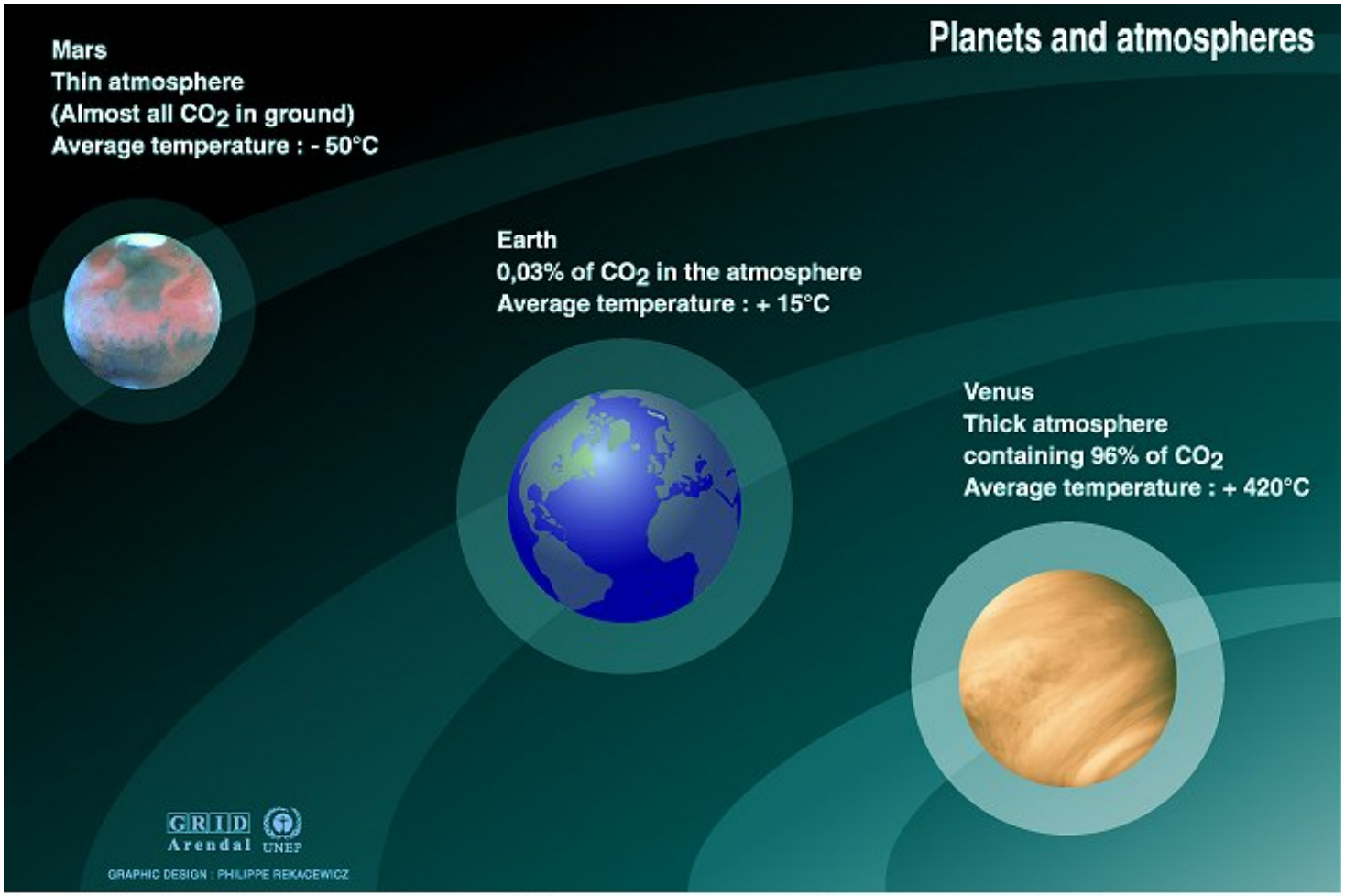
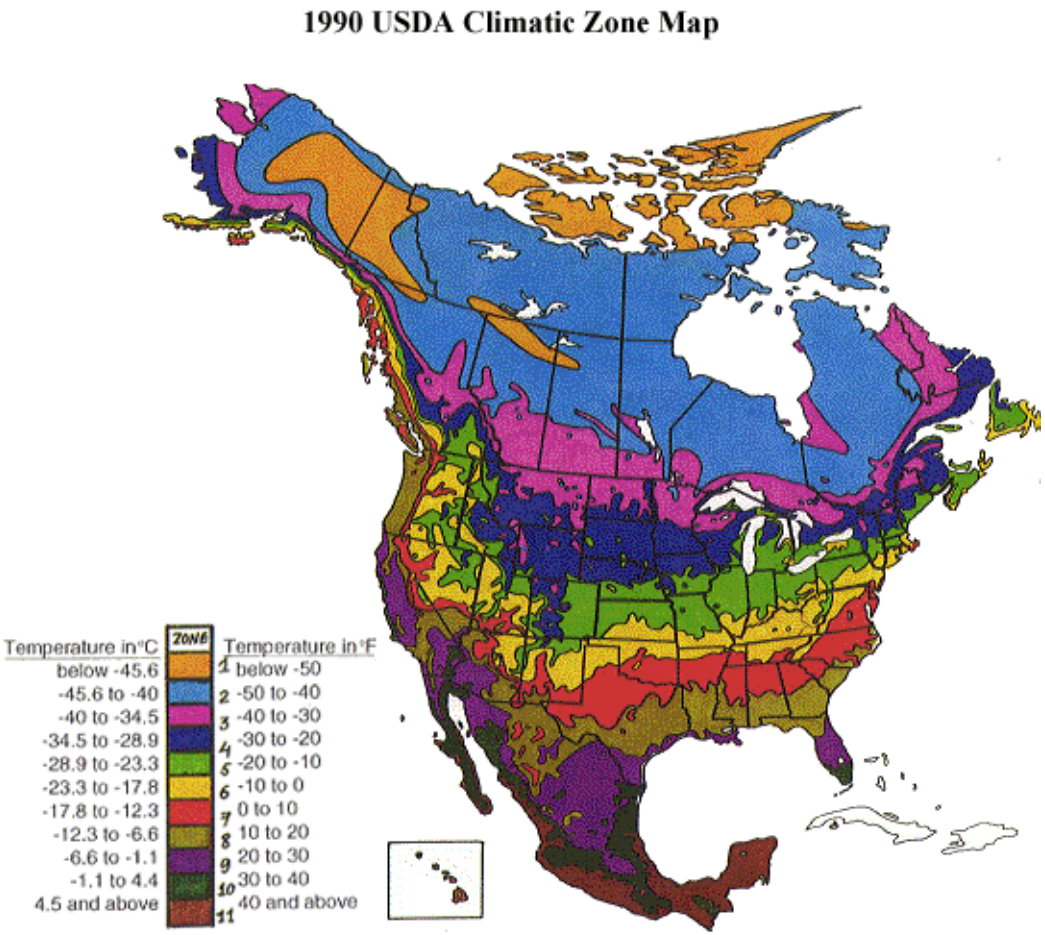
# Climate



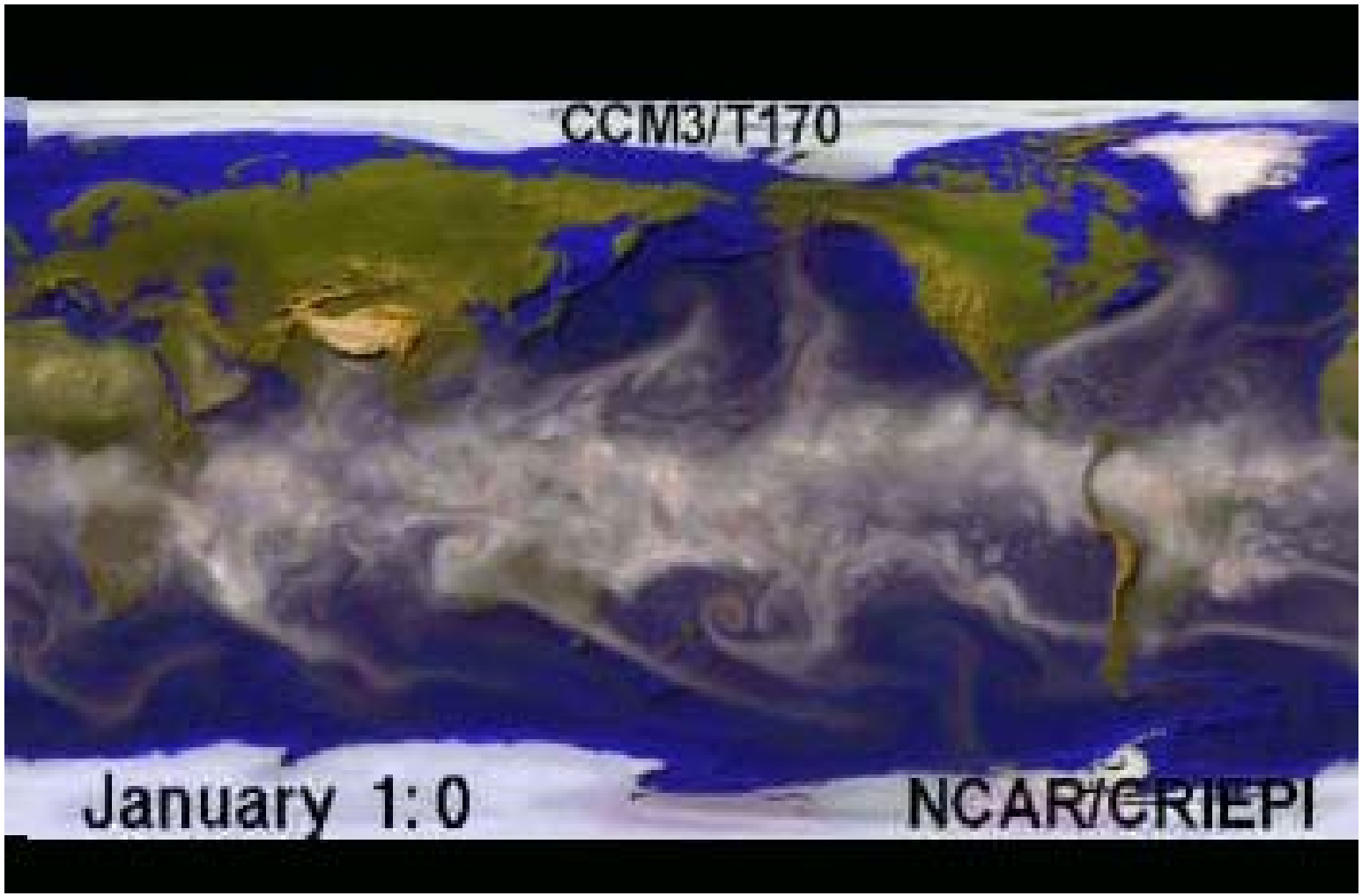

Sources: Calvin J. Hamilton, Views of the solar system, www.planetscapes.com; Bill Arnett , The nine planets, a multimedia tour of the solar system, www.seds.org/billa/tnp/nineplanets.html

- Global climate is driven by energy from the Sun and modulated by atmospheric composition




- The average weather for a region over a long period of time – 30 years or more
- Determined by latitude, altitude, topography, proximity to oceans/position in land mass
- Characterized by temperature, winds, and rainfall

# Climate System Models

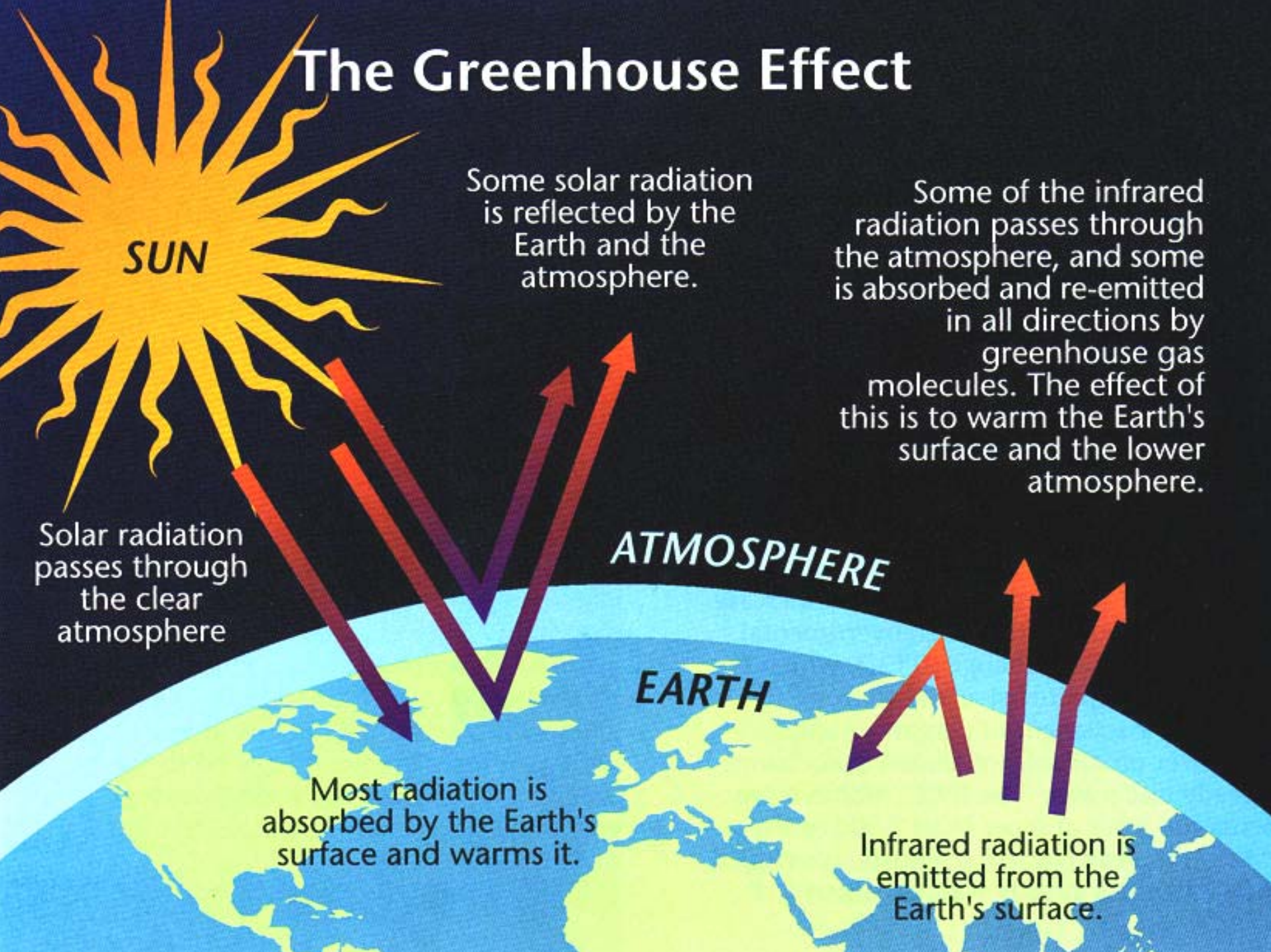


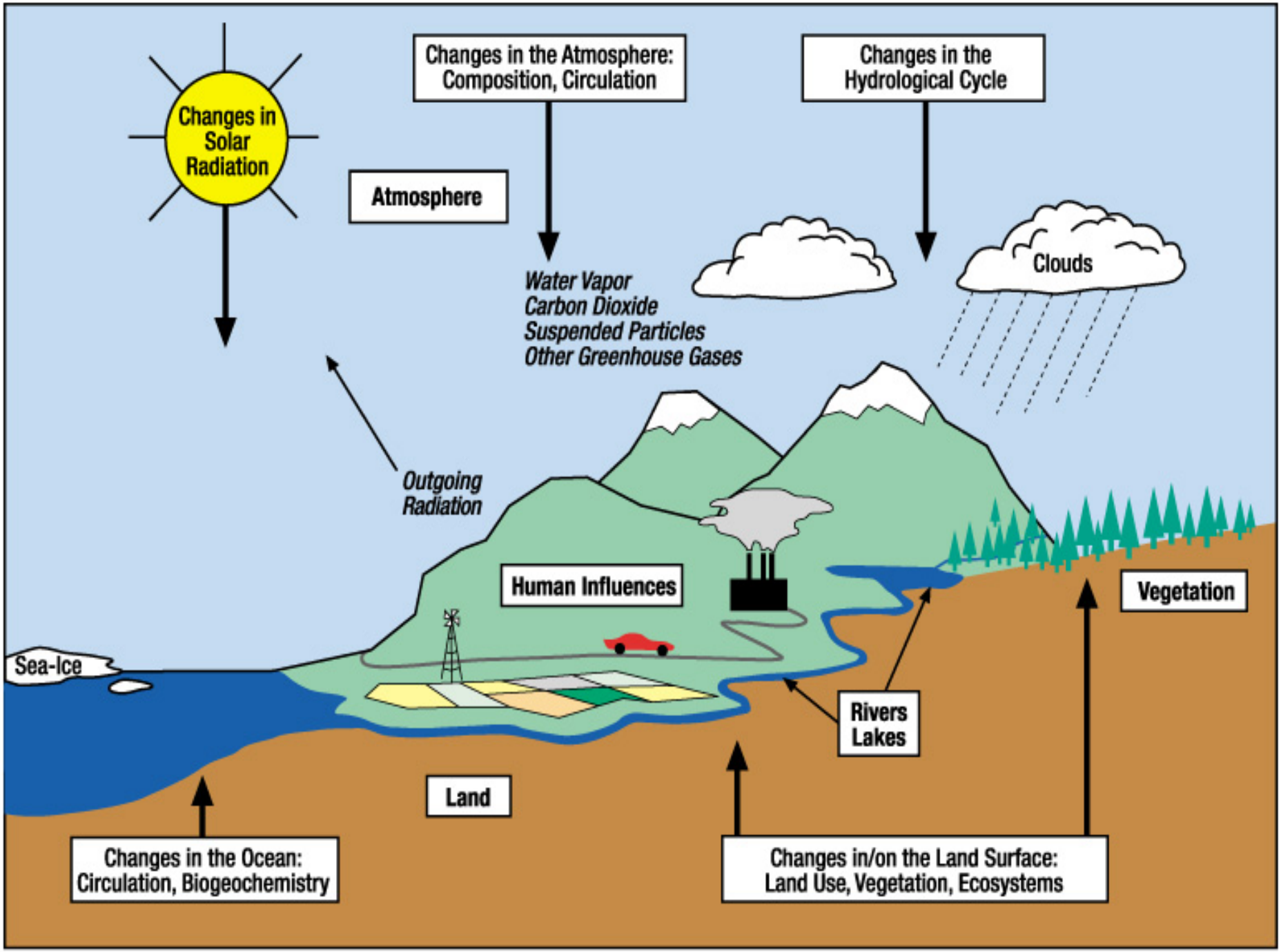
# But Climate varies with time…

- climate variability - seasonal to interannual
  - El Nino/La Nina
- climate fluctuations - decadal-scale
  - Dust bowl
- climate change - long-term changes in the average: centuries and longer
  - Little Ice Age, Medieval Warm Epoch,…

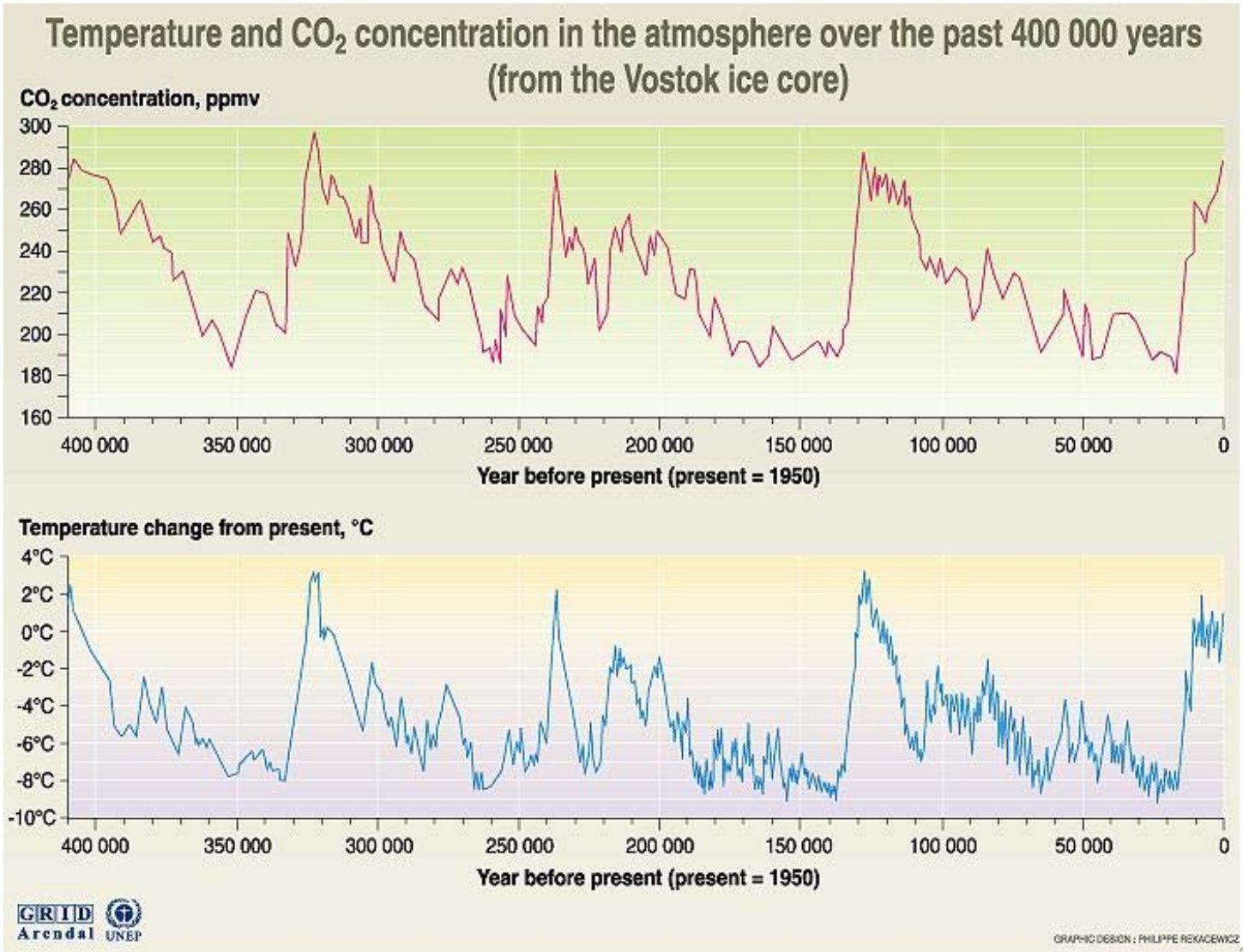
# Is Our Climate Changing?

- Greenhouse Effect
- Observations
  - What do we know about changes in our environment?
- Scientific Consensus
  - Model Results
  - Expected Climate Change


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

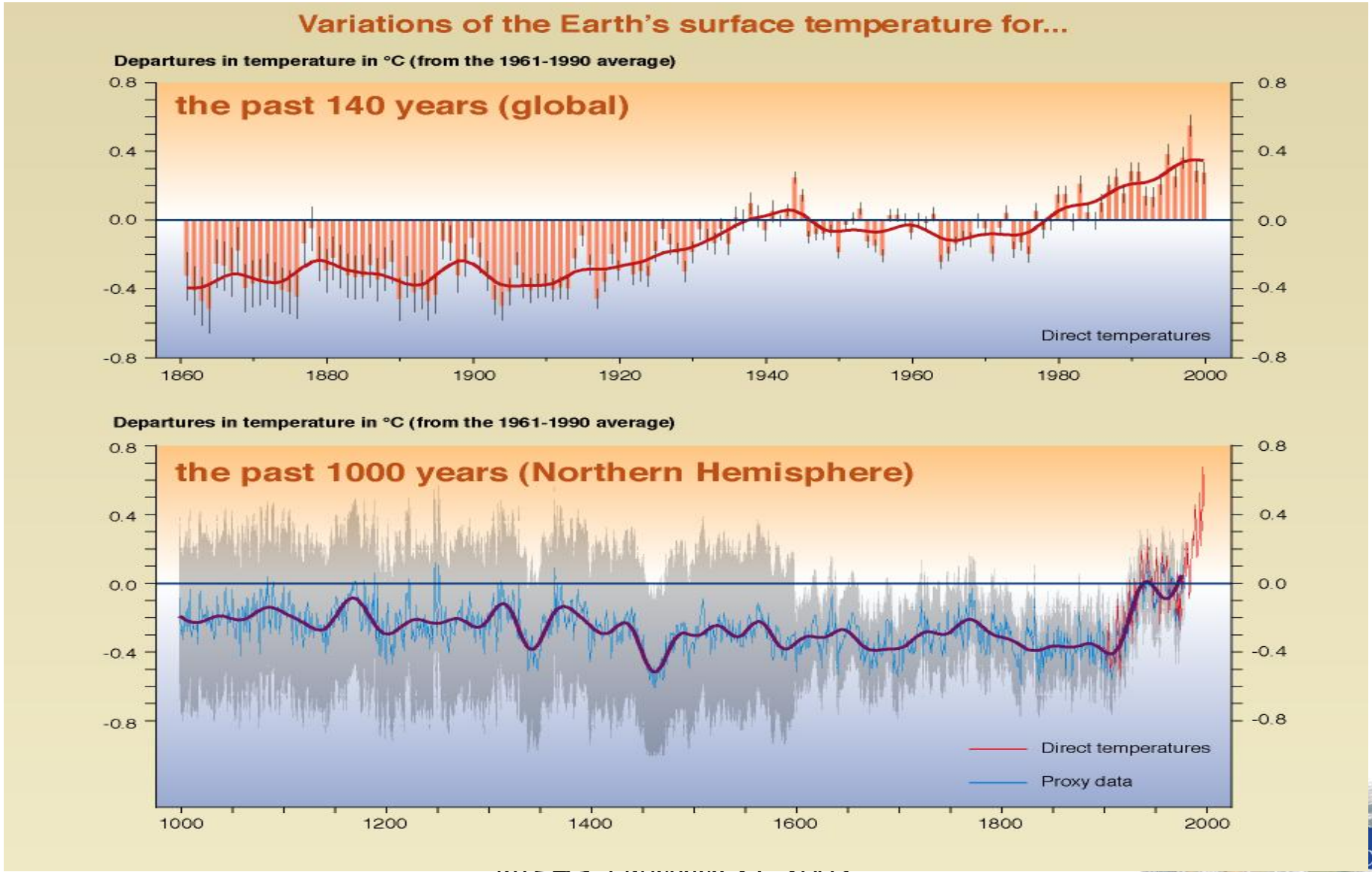

Changes in Solar Radiation
Changes in the Atmosphere: Composition, Circulation
Changes in the Hydrological Cycle
Atmosphere
Water Vapor
Carbon Dioxide
Suspended Particles
Other Greenhouse Gases
Clouds
Outgoing Radiation
Human Influences
Vegetation
Sea-Ice
Rivers
Lakes
Land
Changes in the Ocean: Circulation, Biogeochemistry
Changes in/on the Land Surface: Land Use, Vegetation, Ecosystems

# Ice Cores show us…

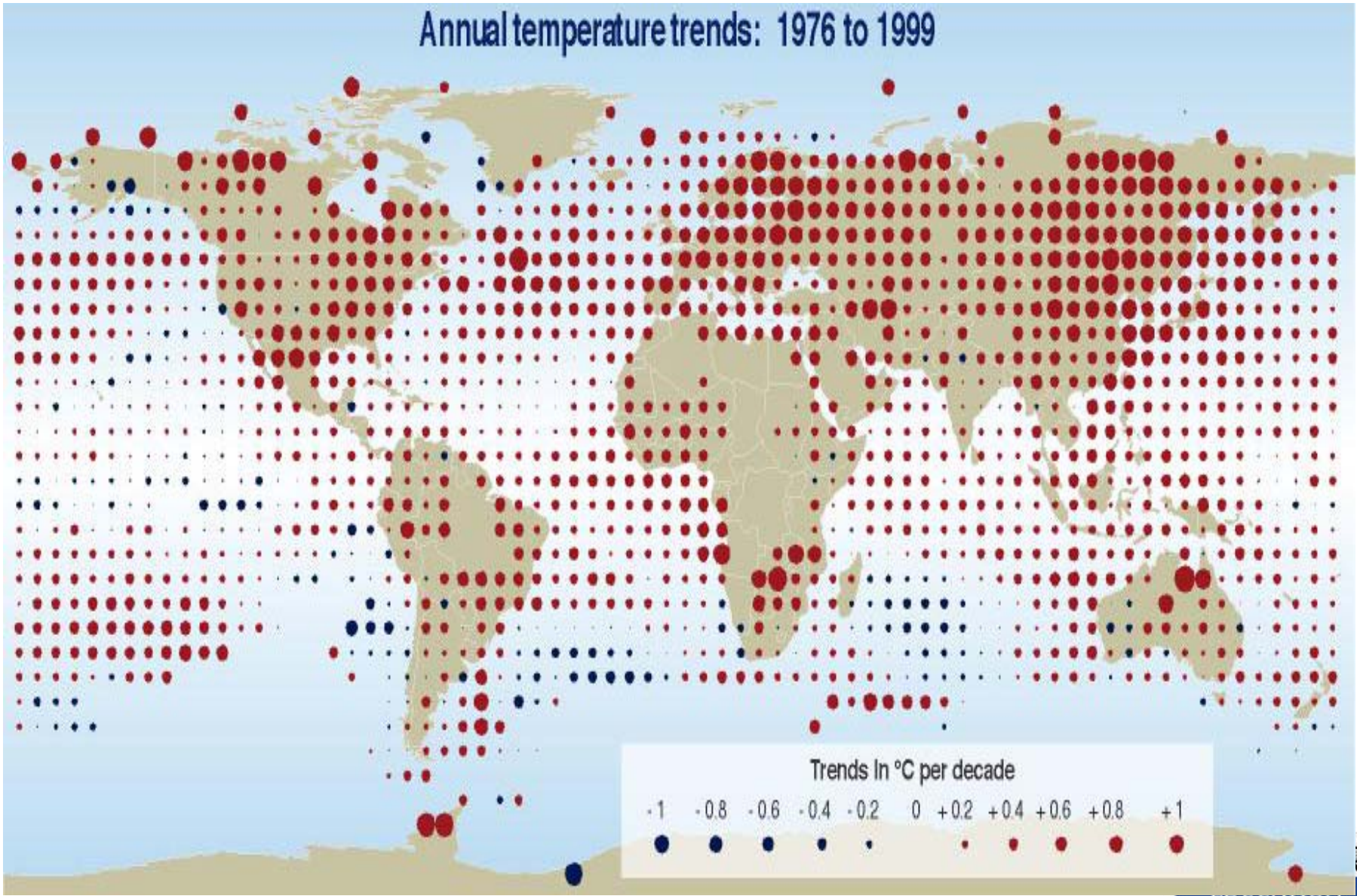



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

# Global mean surface temperatures have increased



# The Land and Oceans have warmed

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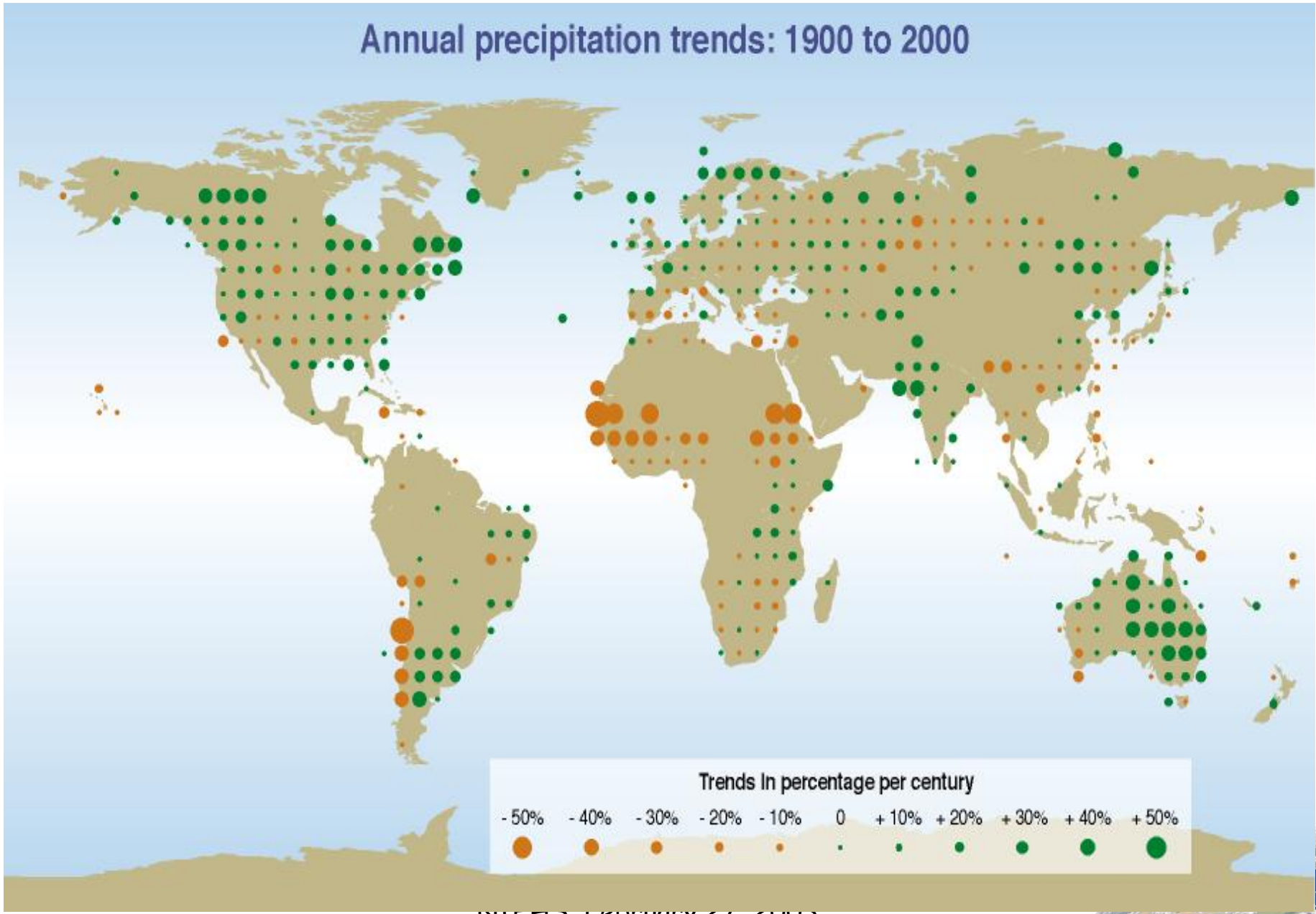
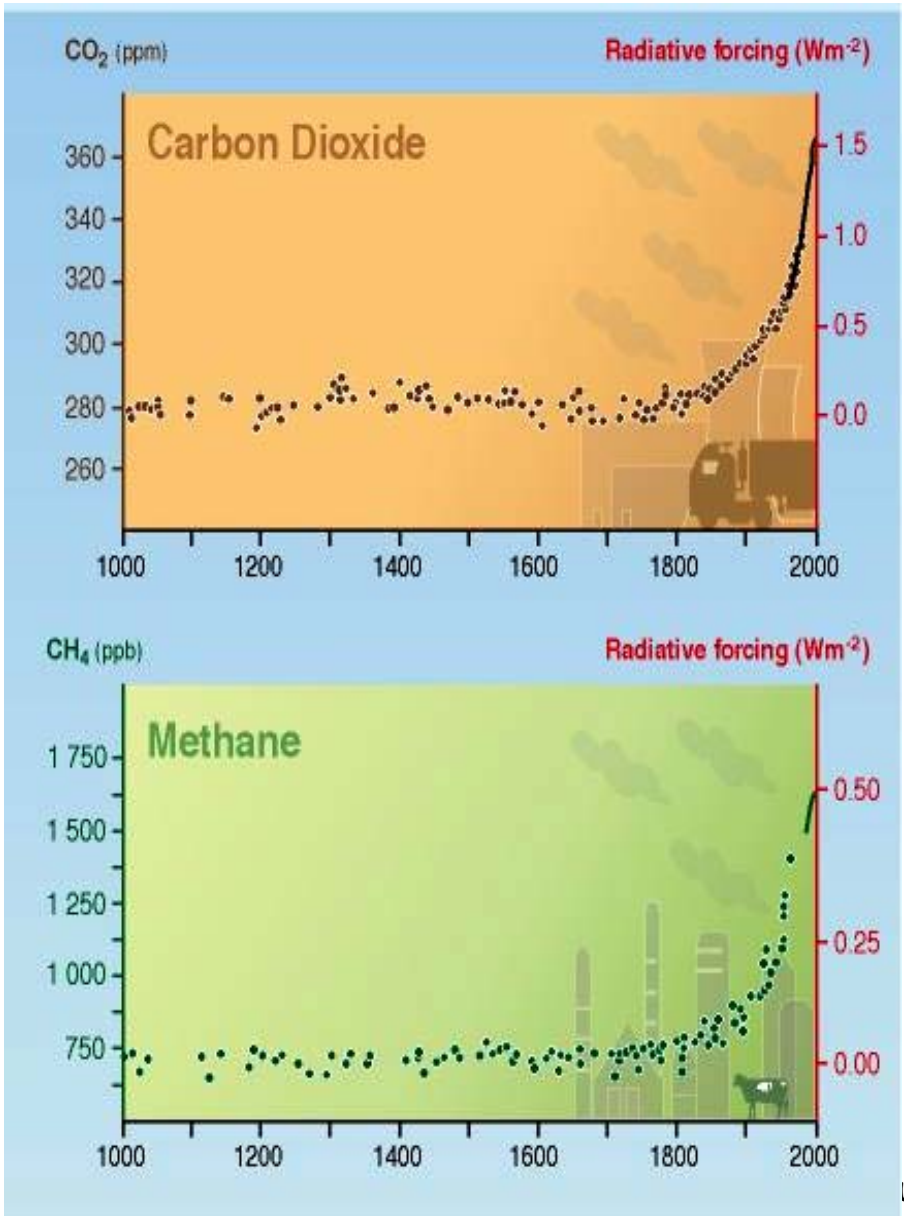
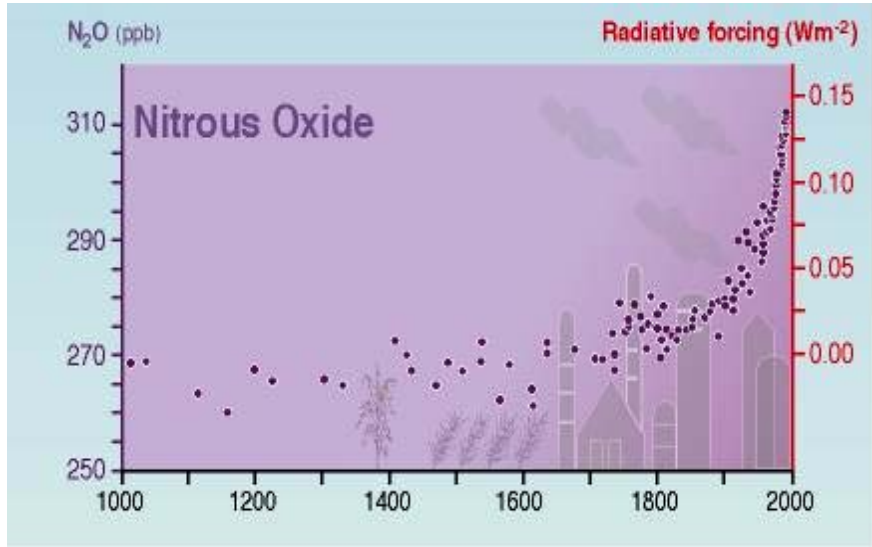
# Precipitation patterns have changed

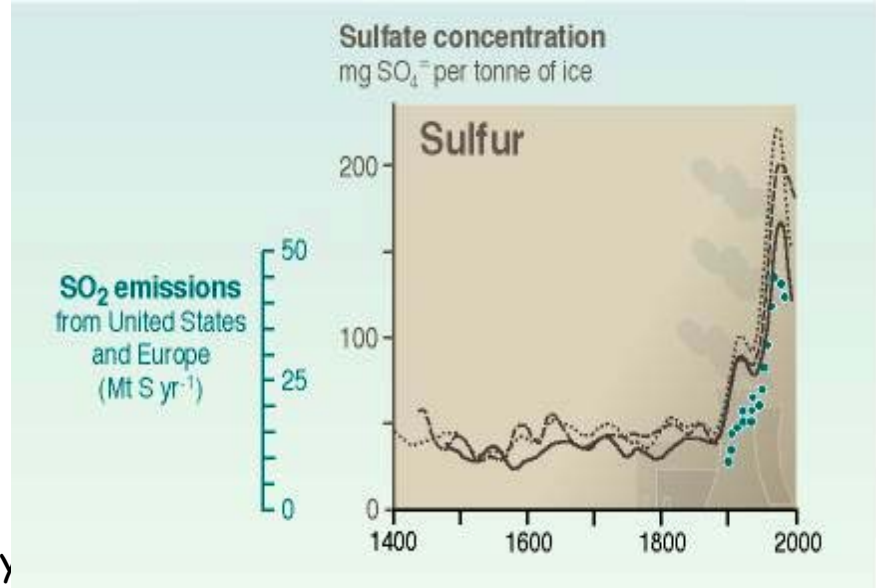


# Human activities have changed the composition of the atmosphere since the pre-industrial era

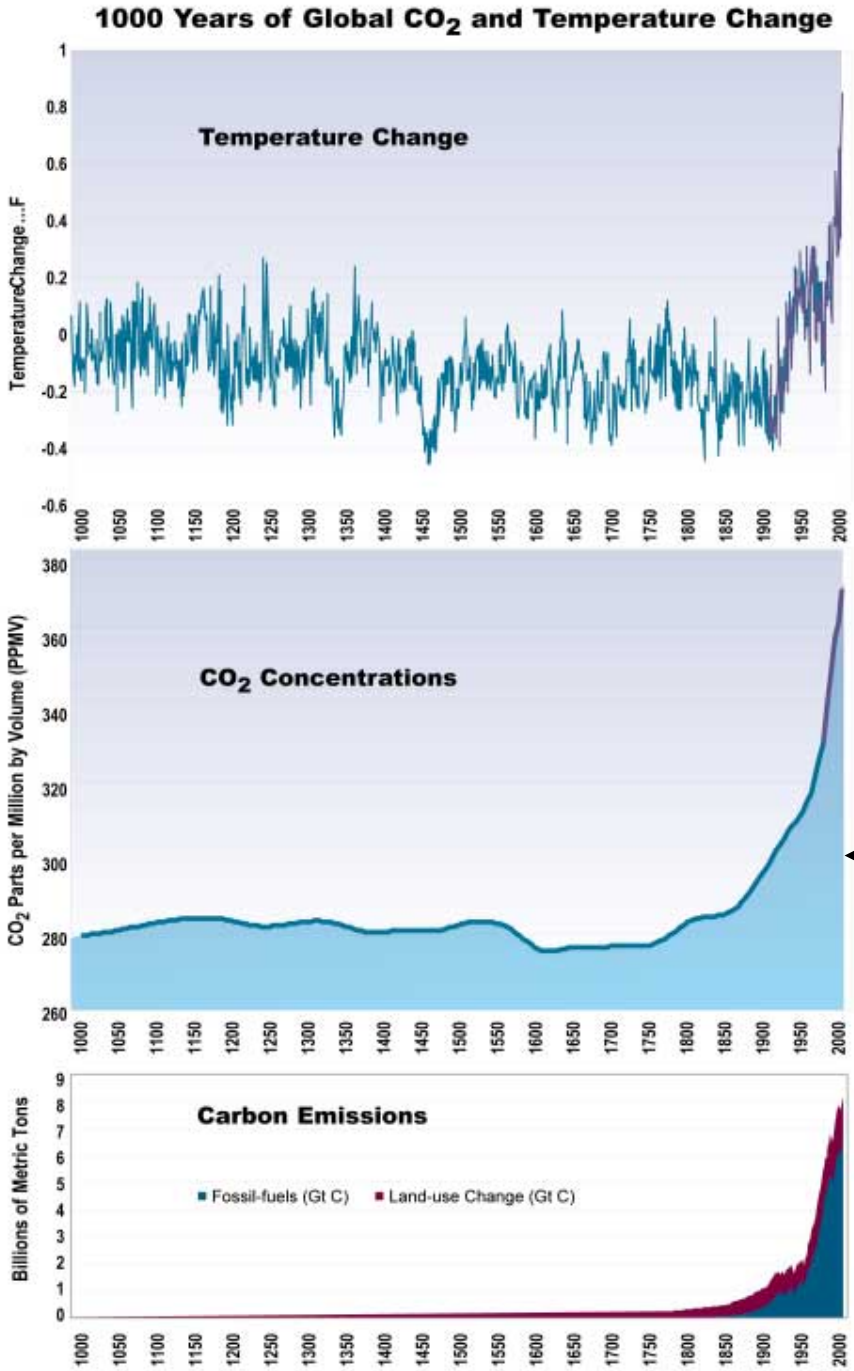



Sulfate aerosols deposited in Greenland ice



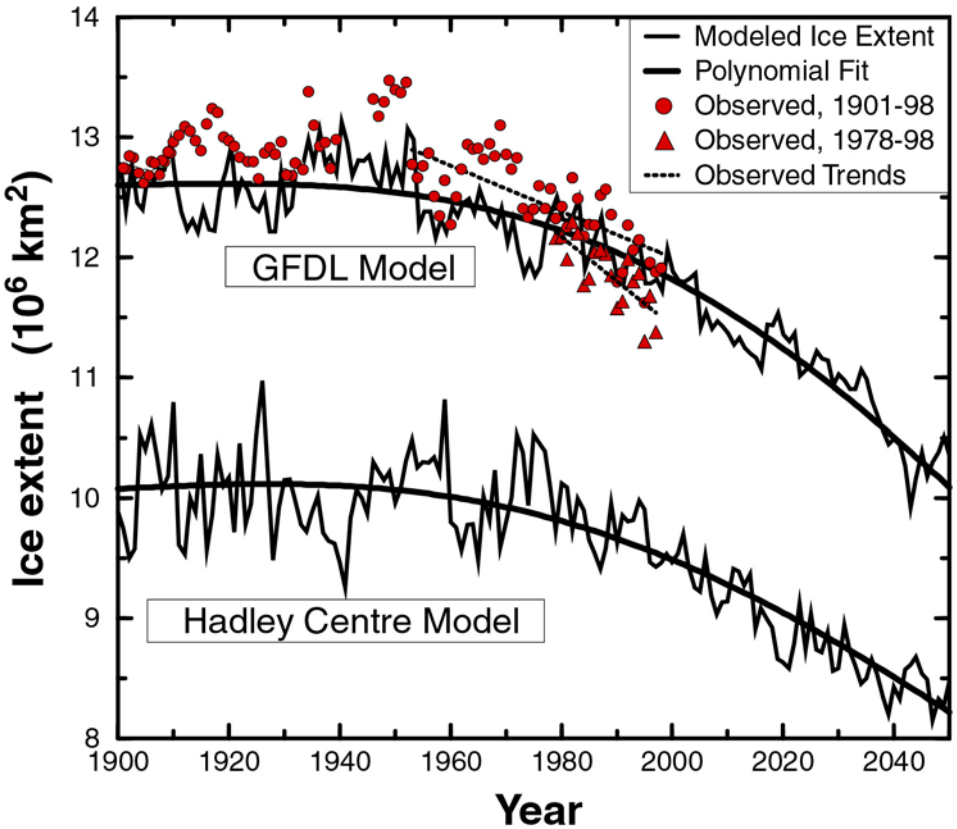
Increase in temperature tracks carbon emissions and $CO_2$



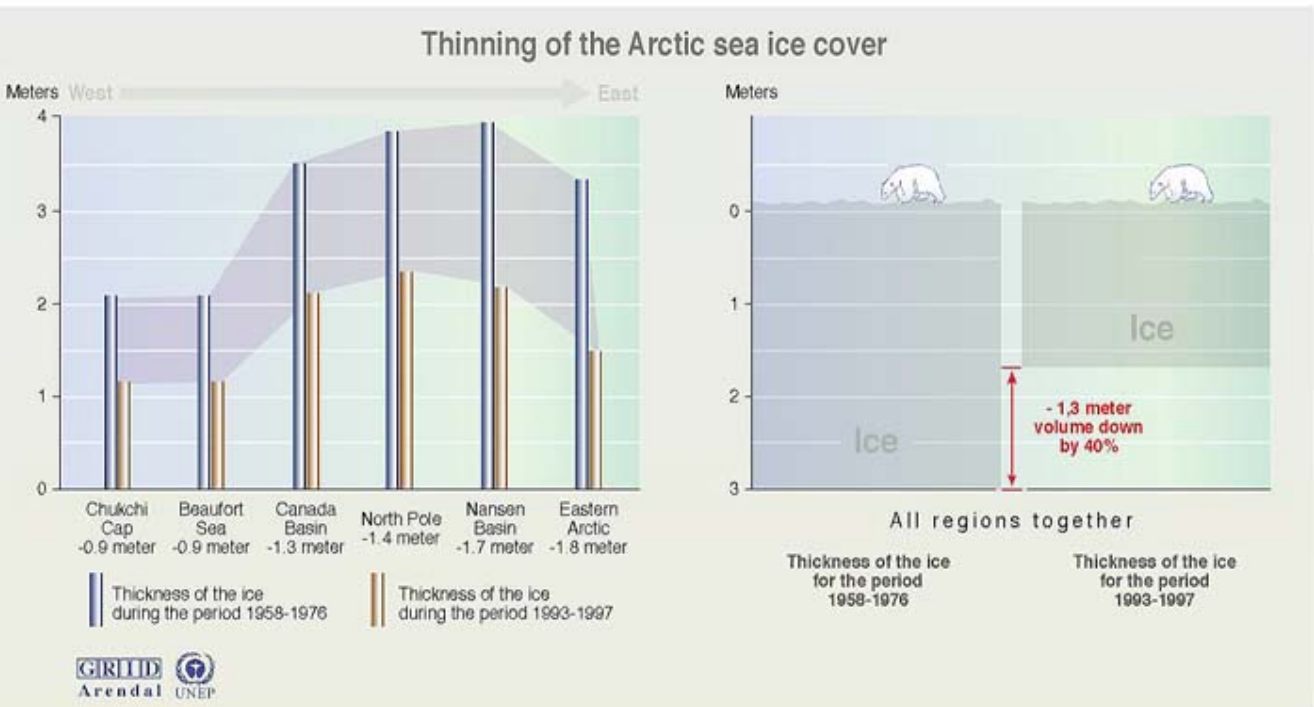

~ highest level of $CO_2$ over past 400 Kyrs

# Sea Ice Areal Extent Decreasing

- Both models predict decrease in sea ice extent
- Both models, and observations, show that the decrease in sea ice extent is accelerating




*(Vinnikov et al., 1999, Science; Chapter 7)*


Note: comparison of sea-ice draft data acquired on submarine cruises betwen 1993 and 1997 with data from 1958-1976 indicates that mean ice draft at the end of the melt season has decreased by 1,3 m (from 3,1 m to 1,8 m). Value is down by 40%

Sources: D.A. Rothrock, Y.Yu and G.A. Maykut, Thinning of the Arctic sea-ice cover, University of Washington, Seattle, 1999.

# Arctic Ice is thinning

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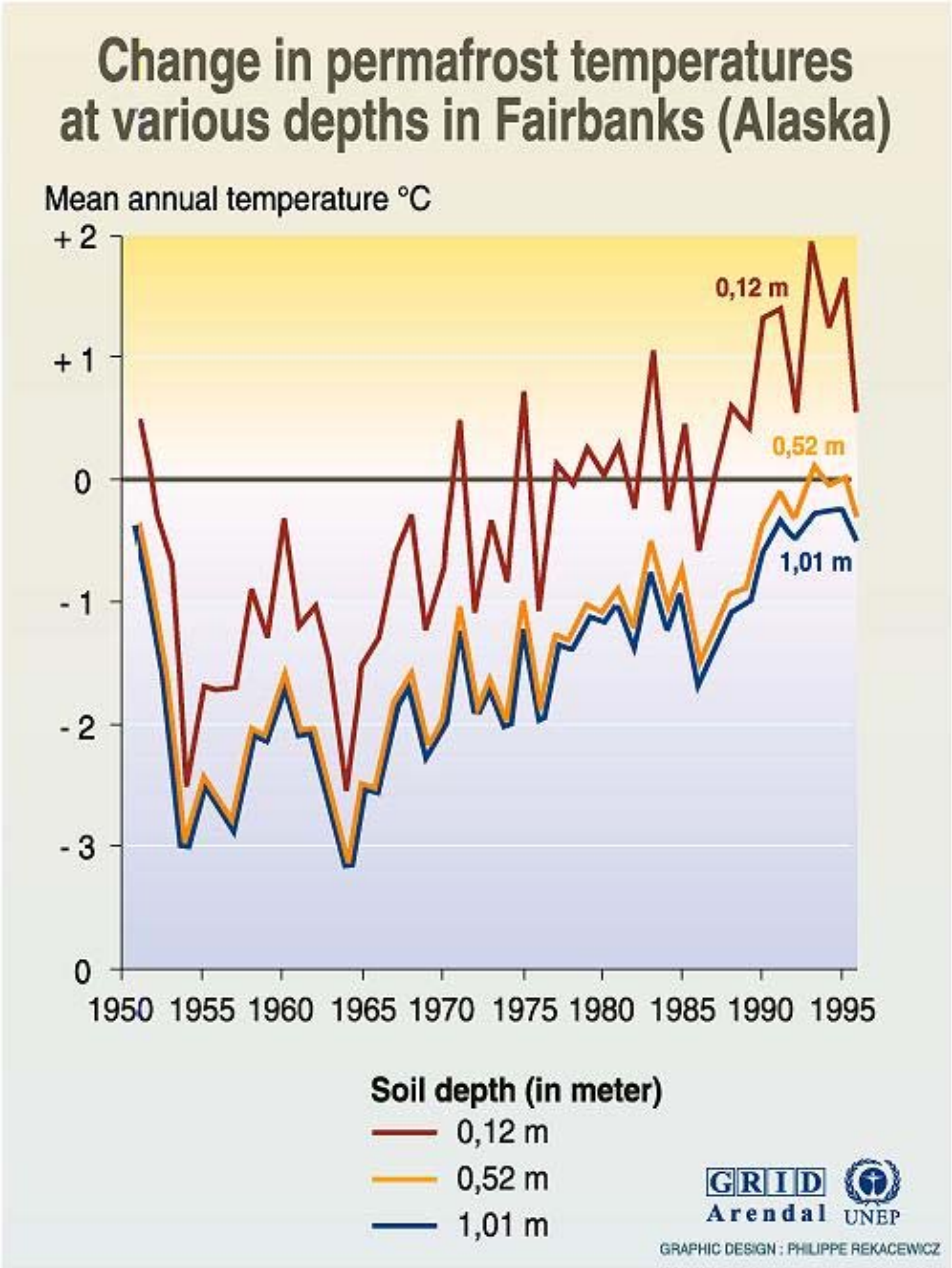
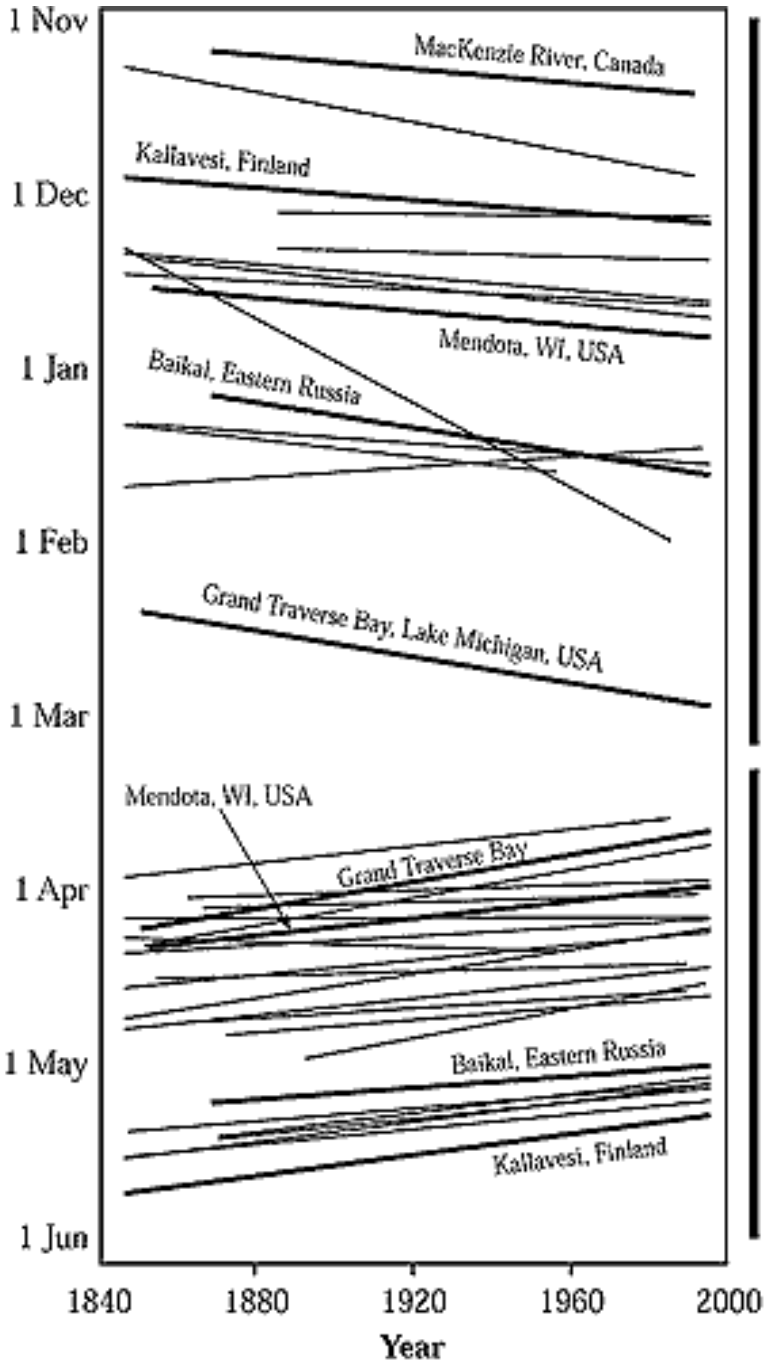
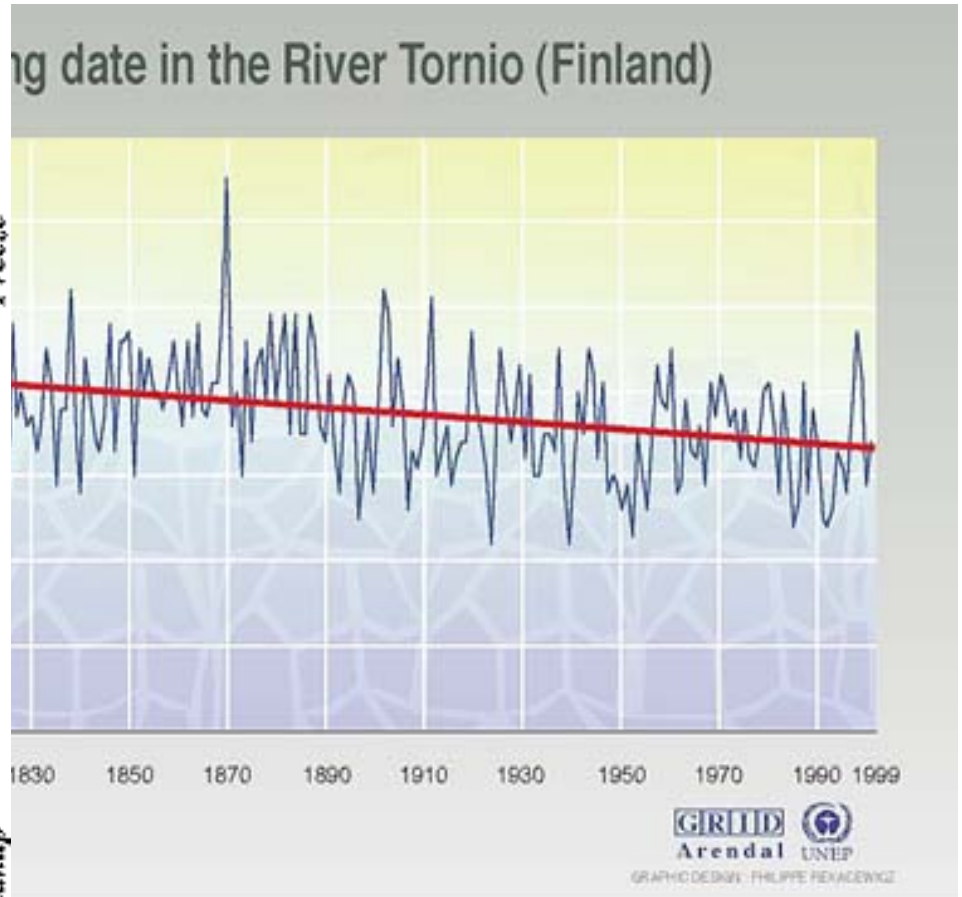



Source: Romanovsky, in Impacts of global climate change in the Arctic regions, IASC, Tromsø, April 1999.

Permafrost in the Arctic is melting, leading to infrastructure damage as well as disrupting subsistence life styles




Ice is breaking up earlier on rivers and lakes in the spring around the world

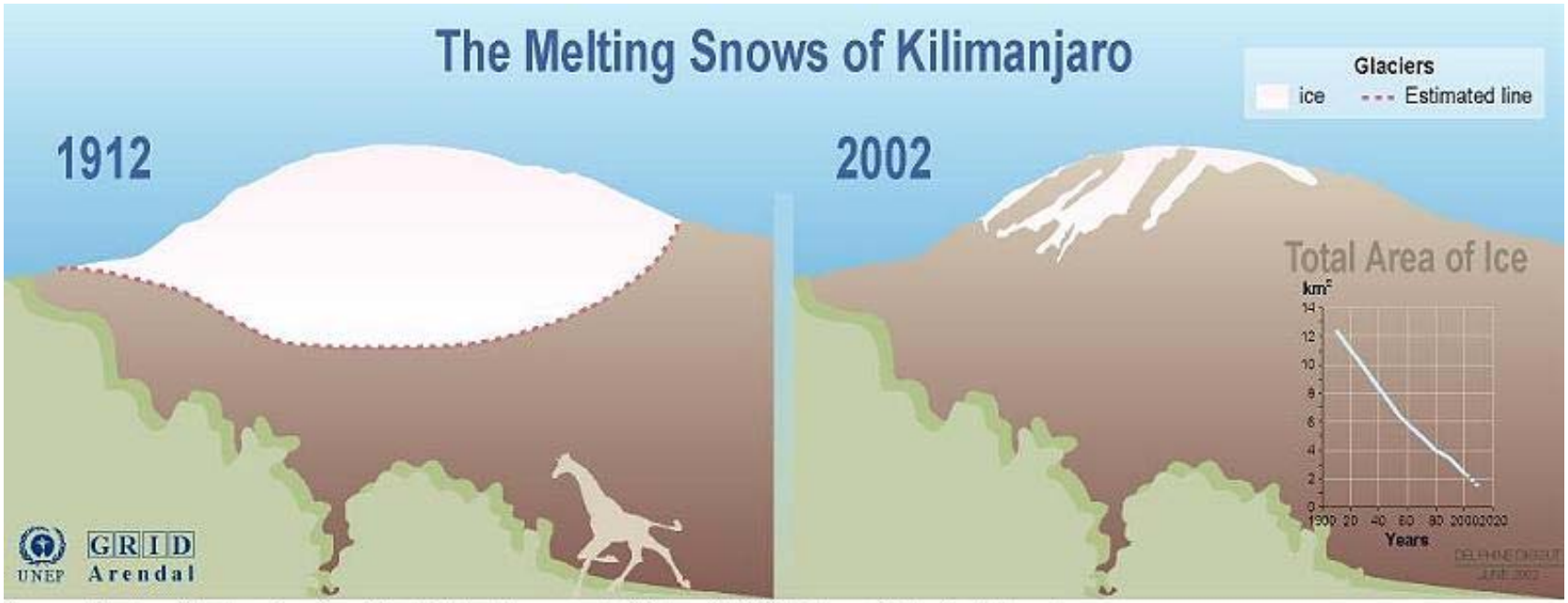
# Glaciers are Retreating Globally

## In Switzerland...

from "Rhone-Glacier and its Ice Grotto" M. Carlen & Fotohaus Geiger

## In Alaska...

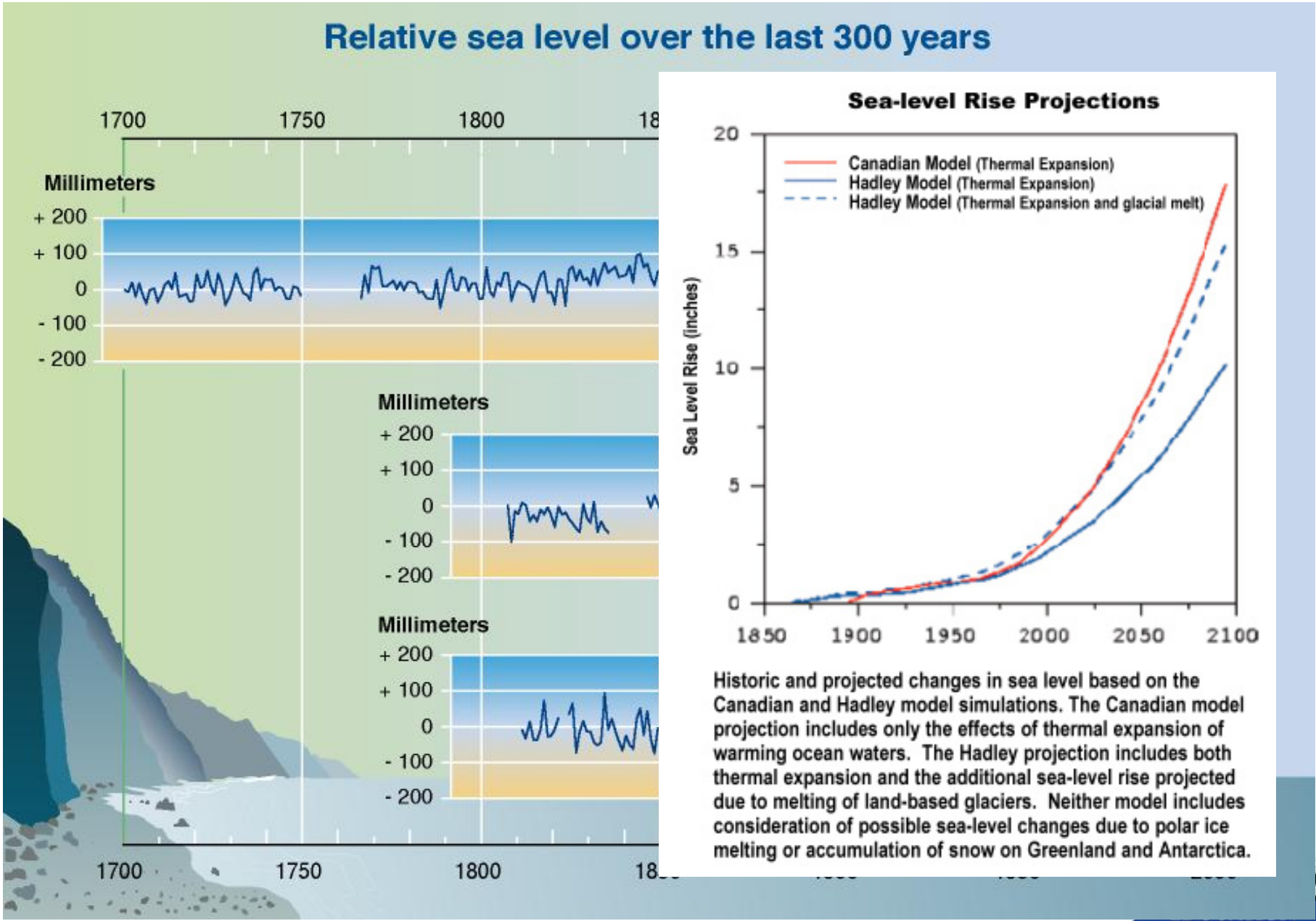





Sources: Meeting of the American Association for the Advancement of Science (AAAS), February 2001 ; Earthobservatory.nasa.gov.

# And in Africa

# Sea Levels have risen



# Potential impact of sea-level rise on Bangladesh


## Today

Total population: 112 Million

Total land area: 134,000 $km^2$


## 1.5 m - Impact

Total population affected: 17 Million (15%)

Total land area affected: 22,000 $km^2$ (16%)

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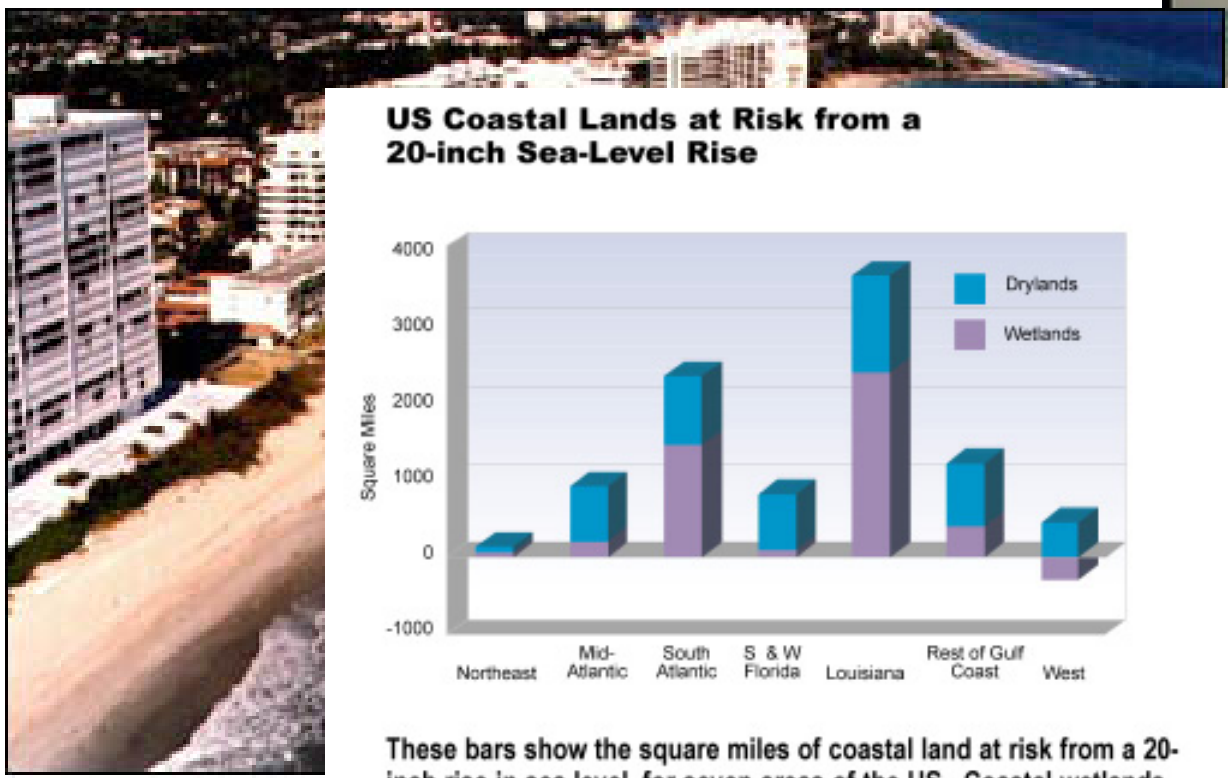
Source : UNEP/GRID Geneva; University of Dacca; JRO Munich; The World Bank; World Resources Institute, Washington D.C.

# Endangering coastal properties




**US Coastal Lands at Risk from a 20-inch Sea-Level Rise**

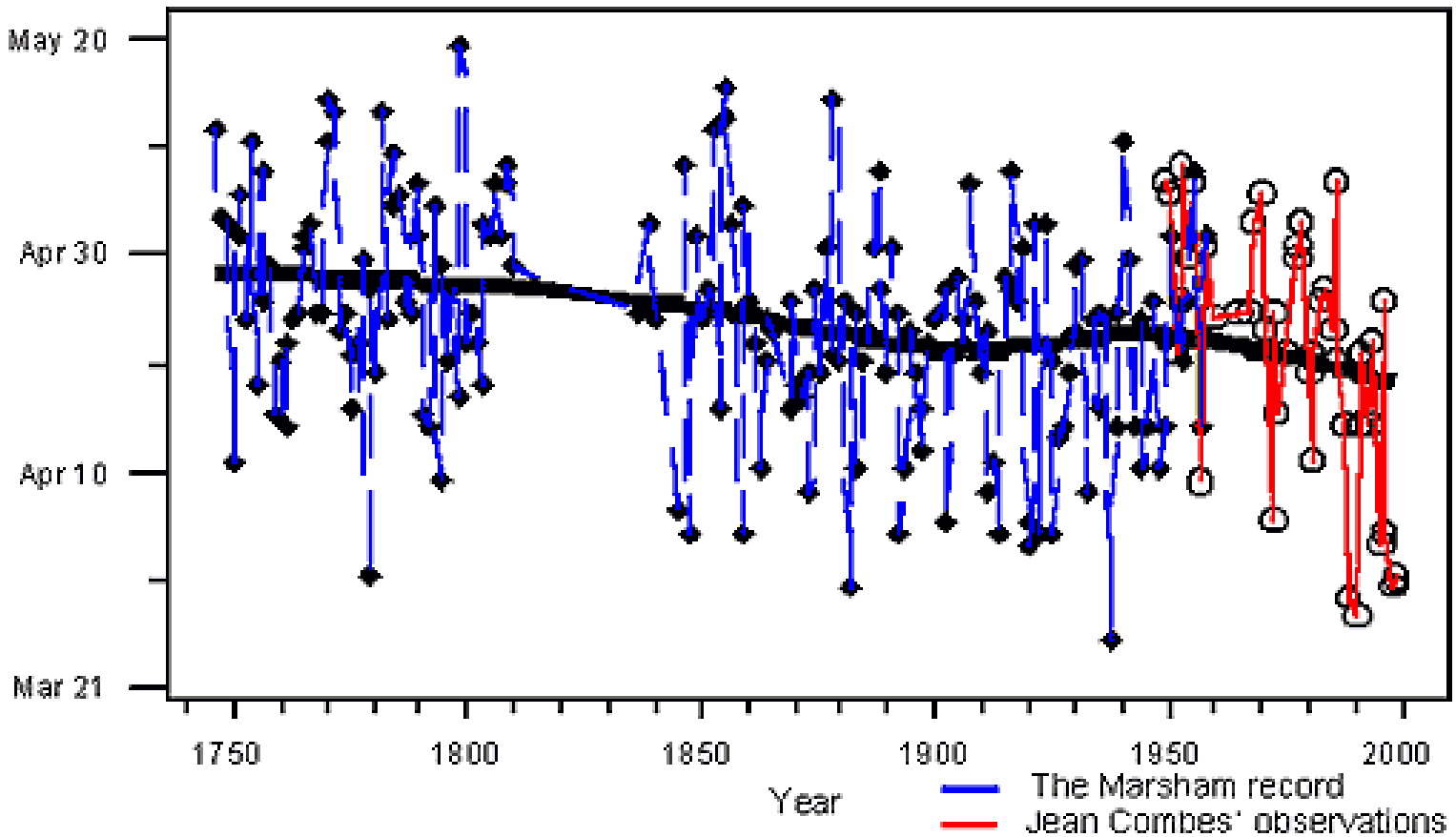



These bars show the square miles of coastal land at risk from a 20-inch rise in sea level, for seven areas of the US. Coastal wetlands projected to be inundated are shown in yellow while drylands projected to be inundated are shown in blue.

# Effects in Biological Systems

- Range shifts (latitudinal or altitudinal)
- Abundance changes
- Change in growing season length
- Earlier flowering; emergence of insects; earlier mating; loss of habitat, shorter hibernation

# 250 Year Record of Leafing Out Date of English Oaks



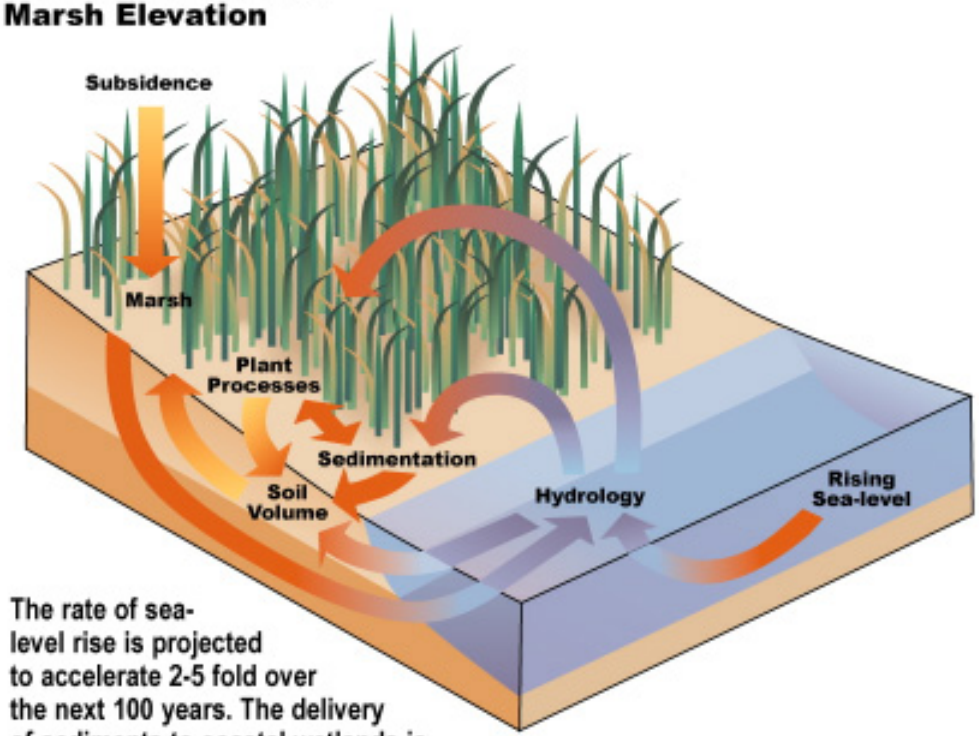
# Climate Change effects on Coral

**Coral reef bleaching has been detected around the world**

Caribbean - Florida Keys, Bermuda, Bahamas
Pacific - Mexico, the Philippines, Panama, the Galapagos, Australia, Papua New Guinea, American Samoa, Fiji
Persian Gulf
Indian Ocean – Seychelles, Kenya, Reunion, Mauritius, Somalia, Madagascar, Maldives, Indonesia, Sri Lanka, Gulf of Thailand, Andaman Islands, Malaysia, Oman, India, and Cambodia

- Increasing $CO_2$ reduces alkalinity of surface waters, reducing coral calcification, producing weaker and smaller skeletons
- Warmer ocean temperatures cause corals to expel color-producing algae that live inside them and are crucial to their survival - a process called coral bleaching
- Coral can recover after a short episode of warmer water, but if it persists, the coral die

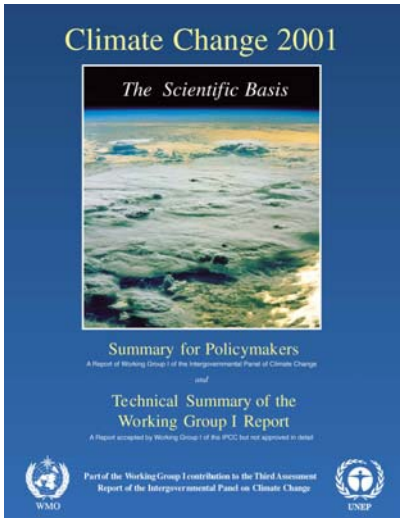
**Processes Affecting Marsh Elevation**

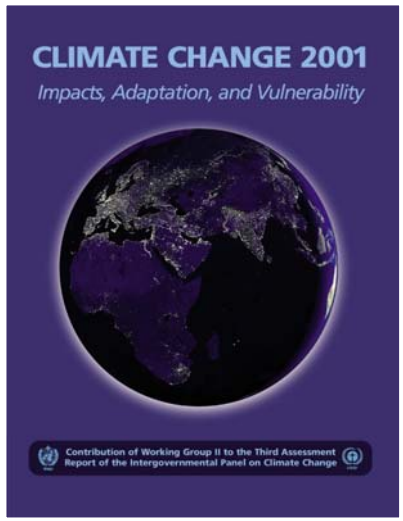


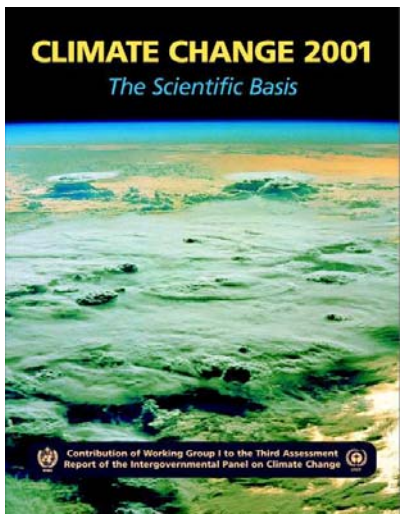

The rate of sea-level rise is projected to accelerate 2-5 fold over the next 100 years. The delivery of sediments to coastal wetlands is extremely important in determining the potential of these systems to maintain themselves in the face of current and future sea-level changes.

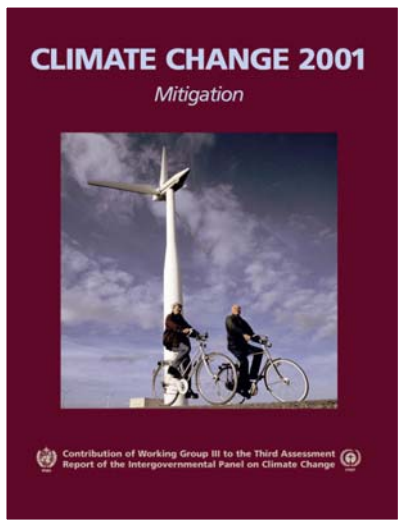
# Marshes and Mangroves - Wetland systems stressed by rising sea level and changing land-use

# IPCC Third Assessment: Climate Change 2001




- IPCC founded in 1988 by UN Environment Program and World Meteorological Association
  - to assess scientific, technical and socio- economic information
  - relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation
- Third Assessment - An update on previous assessments by the international scientific community
- Drafted by teams of hundreds of scientists from around the world
- Referencing thousands of peer-reviewed research studies

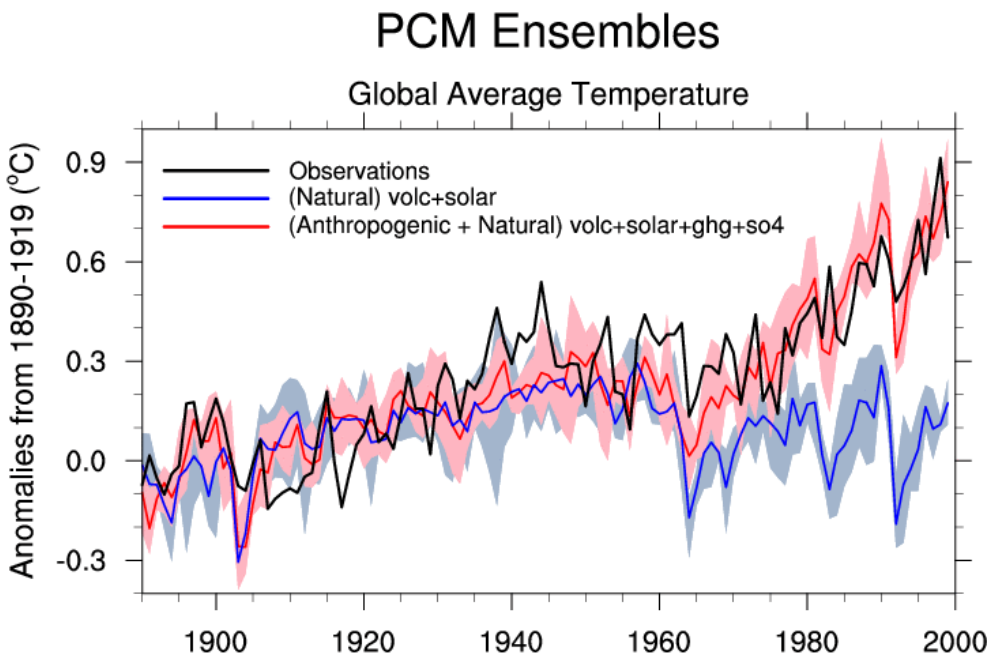
# Scientific Consensus

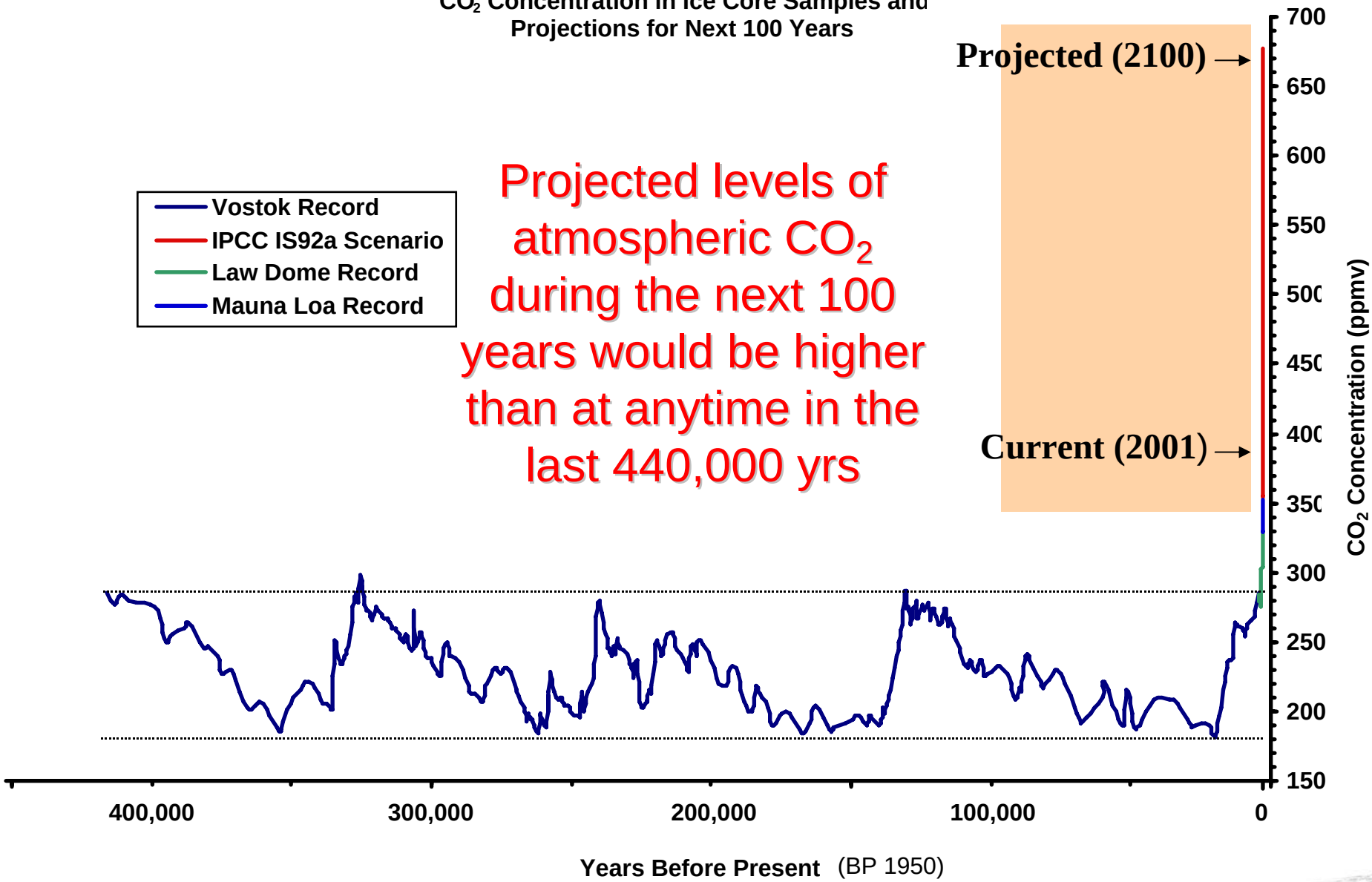
"An increasing body of observations gives a collective picture of a warming world and other changes in the climate system"

- Global average surface temperature has increased over the 20th century by about 0.6°C
- The last decade of the 20th century was the warmest decade of the past millennium
- Temperatures have risen during the past four decades in the lowest 8 kilometers of the atmosphere
- Snow cover and ice extent have decreased.
- Global average sea level has risen and ocean heat content has increased

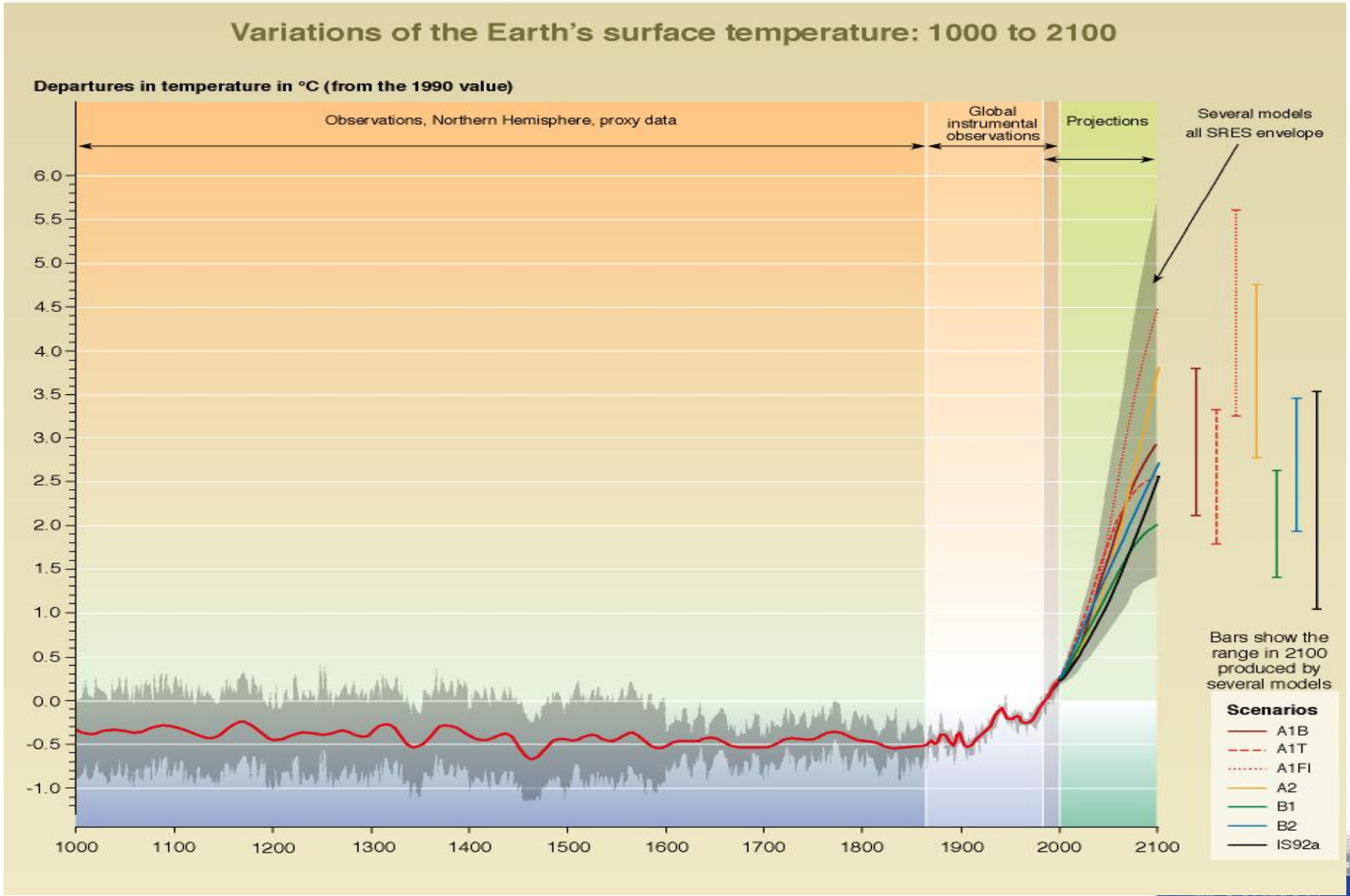
# Natural Variations do not explain observed climatic change

- Climate models with natural forcing (including volcanic and solar) do not reproduce warming
- When increase in greenhouse gases is included, models do reproduce warming
- Addition of increase in aerosols (cooling) improves agreement





# Climate models estimate global temperatures will rise by 1.4 to 5.8 C by the year 2100, including the effect of aerosols



# What this means in the US - Temperature

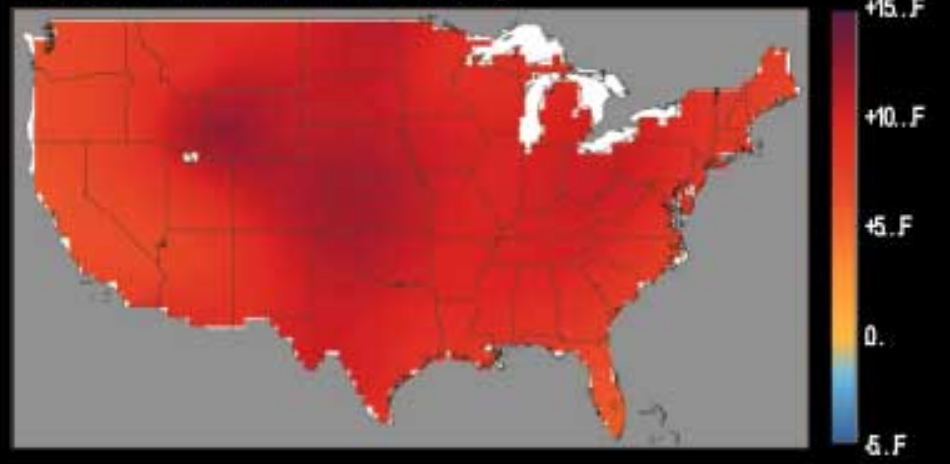
## Temperature Change

How to read these maps: The color scale indicates changes in temperature in …F over a 100 year period. For example, at 0…F there is no change; at +10…F there is a 10…F increase from the begining to the end of the century.

Observed 20th Century

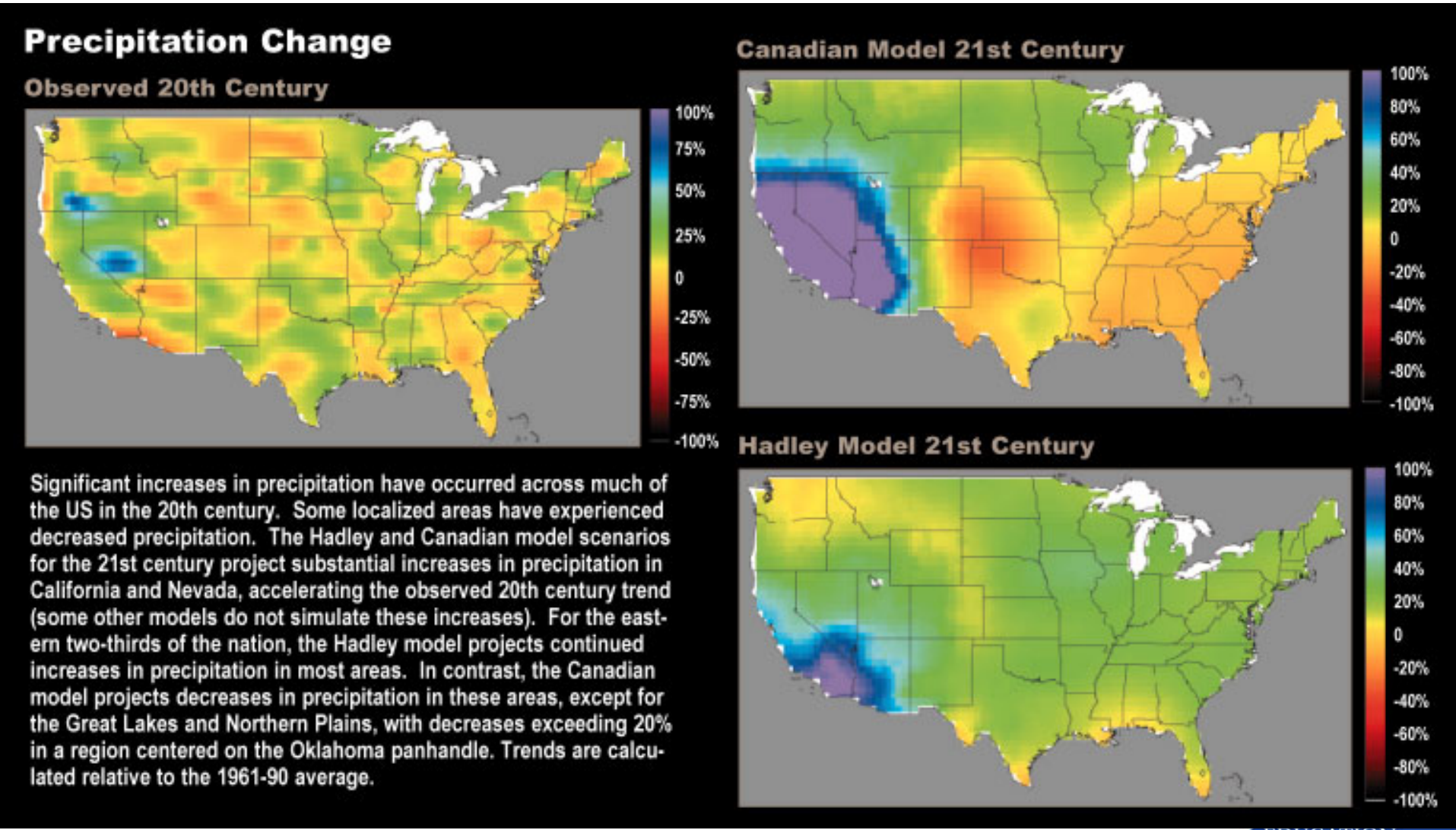

The change in the annual average temperature over the 20th century has a distinctive pattern. Most of the US has warmed, in some areas by as much as 4ßF. Only portions of the southeastern US have experienced cooling, and this was primarily due to the cool decades of the 1960s and 1970s. Temperatures since then have reached some of the highest levels of the century.

Canadian Model 21st Century

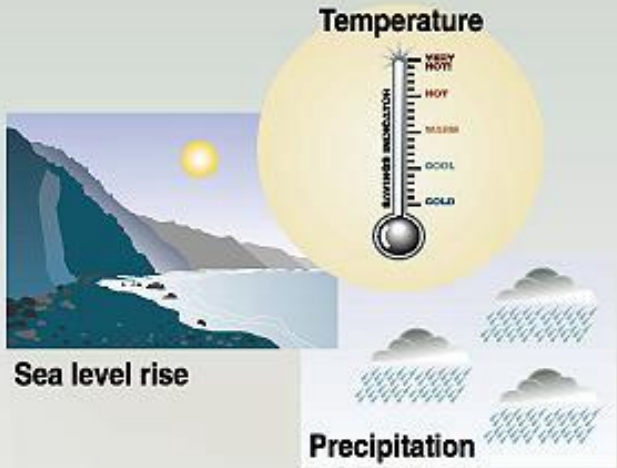



Hadley Model 21st Century

# What this means in the US - Precipitation



# Potential climate changes impact




## Impacts on...

| Health | Agriculture | Forest | Water resources | coastal areas | Species and natural areas |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
| Weather-related mortality<br>Infectious diseases<br>Air-quality respiratory illnesses | Crop yields<br>Irrigation demands | Forest composition<br>Geographic range of forest<br>Forest health and productivity | Water supply<br>Water quality<br>Competition for water | Erosion of beaches<br>Inundation of coastal lands<br>additional costs to protect coastal communities | Loss of habitat and species<br>Cryosphere: diminishing glaciers |

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GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Source: United States environmental protection agency (EPA).

# Global Warming Health Impacts

- Changes in mortality due to heat stress
- Changes in geographic ranges and seasonality of transmission of vector-borne infectious diseases
- Increasing frequency of extreme events (storms, floods, droughts, cyclones)
- Environmental degradation

# Projected changes in global temperature:

## global average 1856-1999 and projection estimates to 2100

Global average temperature in °centigrade

IPCC estimate

High

ILLINOIS, 1999 — CHICAGO HEAT INDEX HITS RECORD 119°F. HEAT WAVE KILLS 250 ACROSS EASTERN U.S.

20° 19,8 19,6 19,4 19,2 19° 18,8 18,6 18,4 18,2 18° 17,8 17,6 17,4 17,2 17° 16,8 16,6 16,4 16,2 16° 15,8 15,6 15,4 15,2 15° 14,8 14,6 14,4 14,2 14°

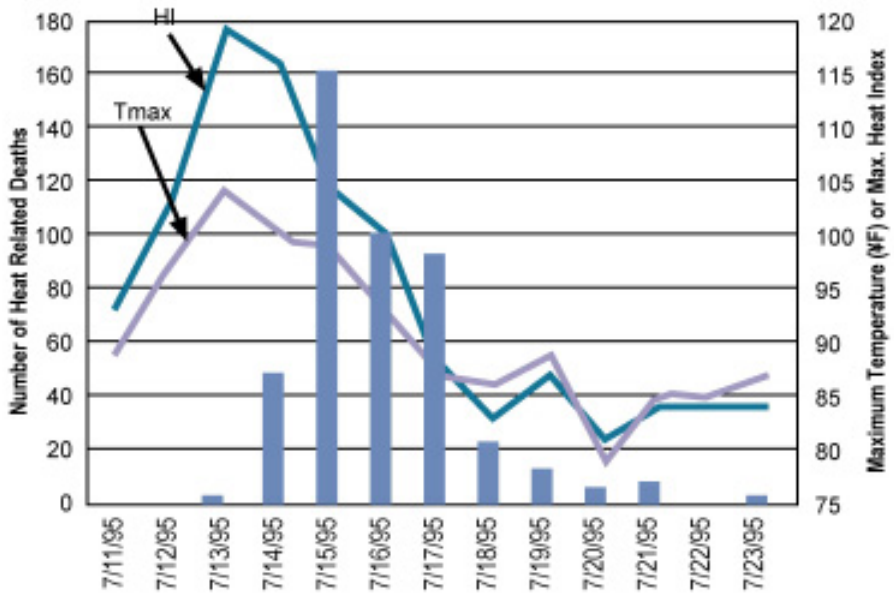
1999

1850 1870 1890 1910 1930 1950 1970 1990 2010 2030 2050 2070 2090

1900 2000 2100

## Heat Related Deaths - Chicago, July 1995

Maximum Temperature and Heat Index




This graph tracks maximum temperature (Tmax), heat index (HI), and heat-related deaths in Chicago each day from July 11 to 23, 1995. The gray line shows maximum daily temperature, the blue line shows the heat index, and the bars indicate number of deaths for the day.

GRID Arendal UNEP

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Source : Temperatures 1856 - 1999: Climatic Research Unit, University at East Anglia, Norwich UK. Projections: IPCC report 95.

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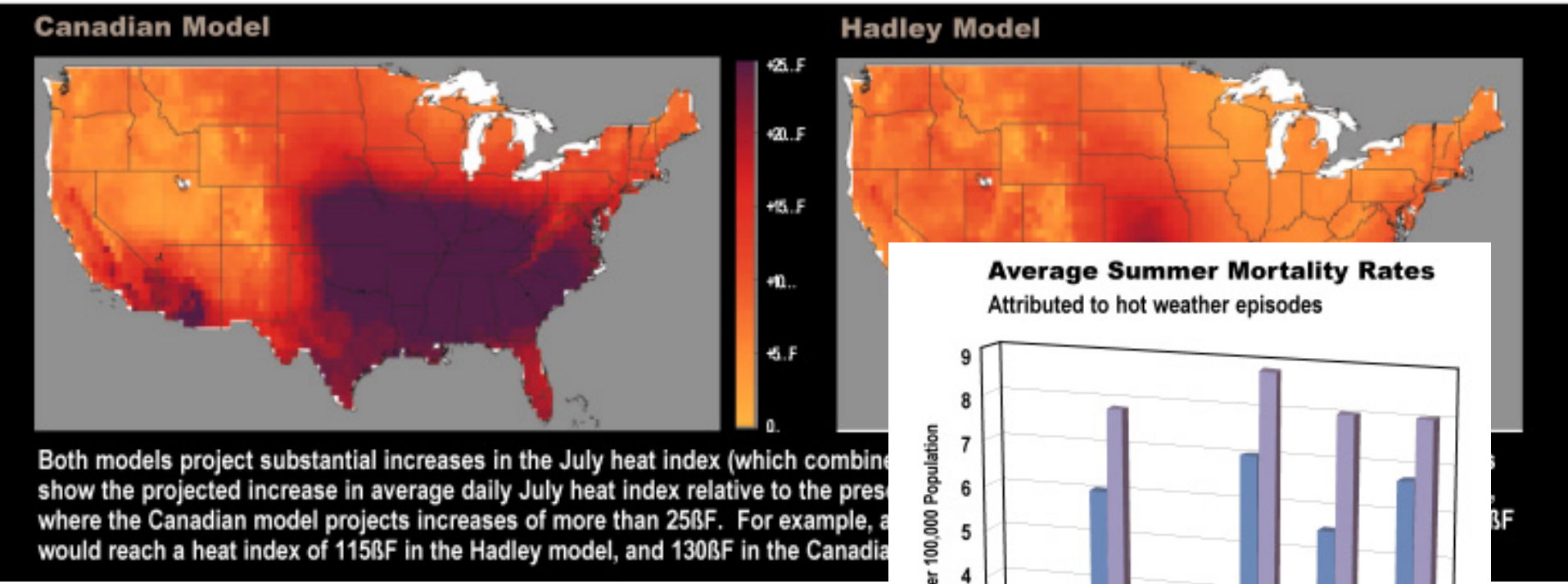
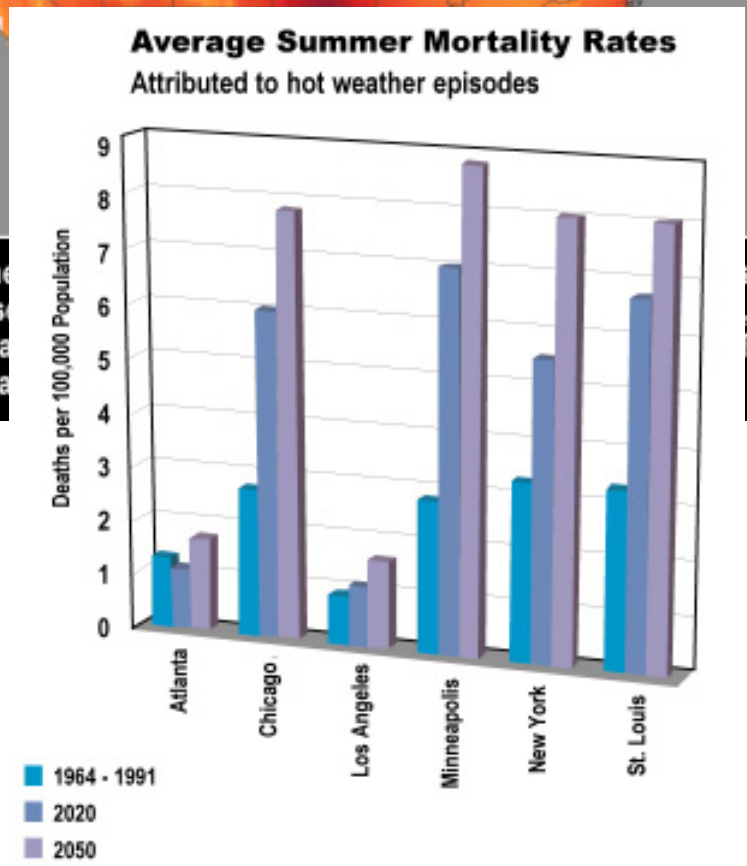
## July Heat Index Change - 21st century




- Risk of death and serious illness increases, principally for older age groups and the urban poor
- Exacerbated by increased humidity and air pollution
- Greatest impact in mid- to high latitude cities
- Warmer winters will decrease winter mortality, but balance is unknown

| Disease | Vector | Population at risk (million)[1] | Number of people currently infected or new cases per year | Present distribution | Likelihood of altered distribution |
|---|---|---|---|---|---|
| Malaria | Mosquito | 2,400[2] | 300-500 million | Tropics and Subtropics | |
| Schistosomiasis | Water snail | 600 | 200 million | Tropics and Subtropics | |
| Lymphatic Filariasis | Mosquito | 1 094[3] | 117 million | Tropics and Subtropics | |
| African Trypanosomiasis (Sleeping sickness) | Tsetse fly | 55[4] | 250 000 to 300 000 cases per year | Tropical Africa | |
| Dracunculiasis (Guinea worm) | Crustacean (Copepod) | 100[5] | 100 000 per year | South Asia, Arabian Peninsula, Central-West Africa | |
| Leishmaniasis | Phlebotomine sand fly | 350 | 12 million infected, 500 000 new cases per year[6] | Asia, Southern Europe Africa, Americas | |
| Onchocerciasis (River blindness) | Black fly | 123 | 17.5 million | Africa, Latin America | |
| American Trypanosomiasis (Chagas disease) | Triatomine bug | 100[7] | 18 million | Central and South America | |
| Dengue | Mosquito | 1,800 | 10-30 million per year | All Tropical countries | |
| Yellow Fever | Mosquito | 450 | more than 5 000 cases per year | Tropical South America Africa | |

1. Top three entries are population-prorated projections, based on 1989 estimates.
2. WHO, 1994.
3. Michael and Bundy, 1995.
4. WHO, 1994.
5. Ranque, personal communication.
6. Annual incidence of visceral leishmaniasis; annual incidence of cutaneous leishmaniasis is 1-1.5 million cases/yr (PAHO, 1994).
7. WHO, 1995.

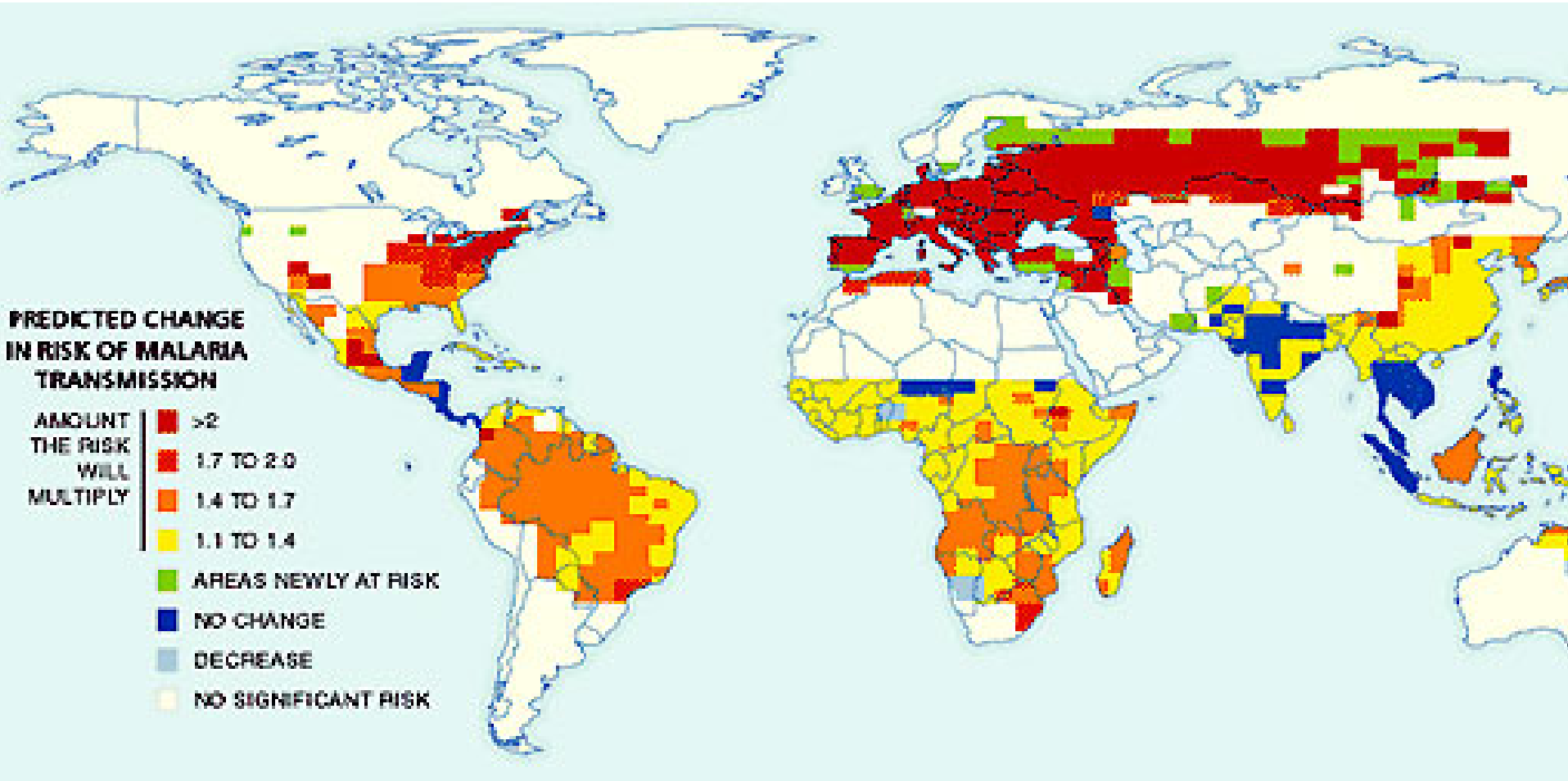
Highly likely  Very likely  Likely  Unknown

GRID Arendal  UNEP

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

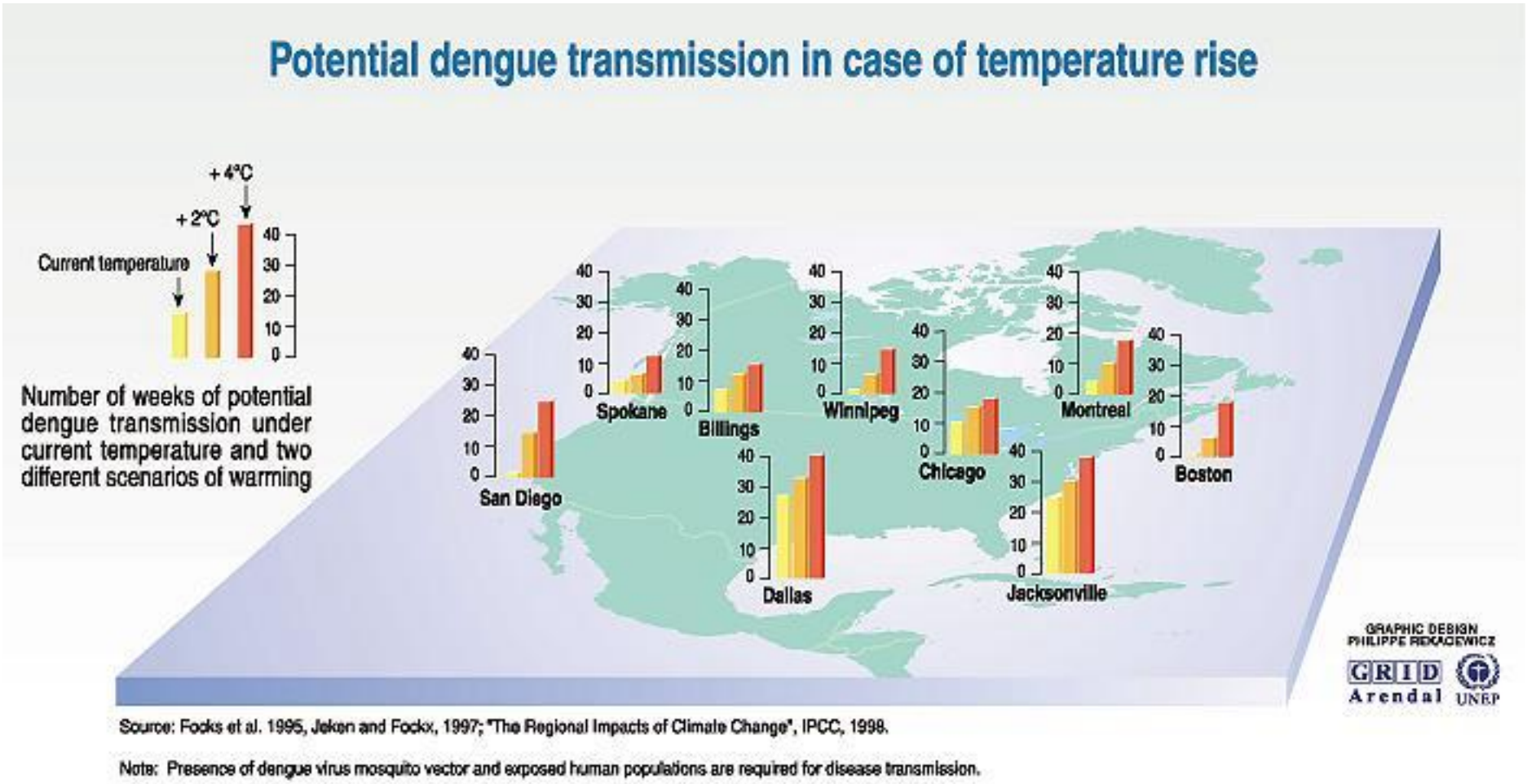
Source: Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

# Malaria




NIEHS, February 27, 2003

# Dengue



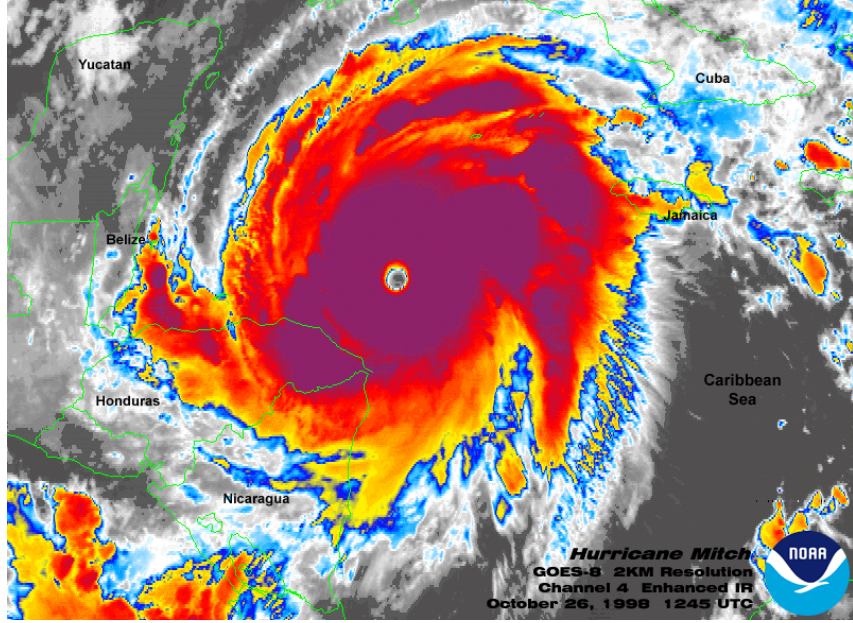
# Documented Cases

- Dengue fever spreads to higher elevations
  - Mexico, Central America
- Malaria spreads to high elevations
  - Indonesia (highlands of Irian Jaya)
  - Kenya highlands (deadly outbreak in 1997)
  - Tanzania (Usamabara mountains)
- Mosquitoes
  - *Aedes aegypti* (dengue and yellow fever) recently appeared at 7,200 ft in Columbia (Andes mountains)
  - Genetic adaptation to global warming in *Wyeomyia smithii* mosquito observed in North America – 9 days later winter dormancy, increasing chance of disease transmission
- Cholera
  - Link between stronger El Niño events and cholera prevalence found in Bangladesh

# Extreme Events
# Storms, Floods, Droughts, Cyclones

- More frequent droughts and periods of intense precipitation
- Direct loss of life and injury
- Indirect effects
  - Loss of shelter
  - Population displacement
  - Contamination of water supplies
  - Loss of food production
  - Increased risk of infectious disease epidemics (diarrhoeal and respiratory)
  - Damage to infrastructure for provision of health services

# Hurricane Mitch




- Category 5 hurricane
- Oct 26 - Nov 4, 1998
- Central America: Honduras, Nicaragua
- Most deadly hurricane to hit western hemisphere in 2 centuries
- Over 11,000 killed, thousands missing
- Over 3 million made homeless

# Impacts on People

- Critical food, medicine, and water shortages
- Hunger and near-starvation widespread in many villages
- Epidemics feared as malaria, dengue, and cholera make appearance
- Fever and respiratory illnesses widespread
- Whole villages washed away
- Estimated 70 - 80 percent of transportation infrastructure destroyed

# Wastewater System Failure

- Wastewater systems that combine storm drains, sewage, and industrial waste are still common (Northeast, Great Lakes, Northwest)
- During storms and snowmelt, these systems spill over sewage into surface waters
- Increased precipitation and frequency of extreme events likely to increase health risks

**Combined Wastewater Systems**

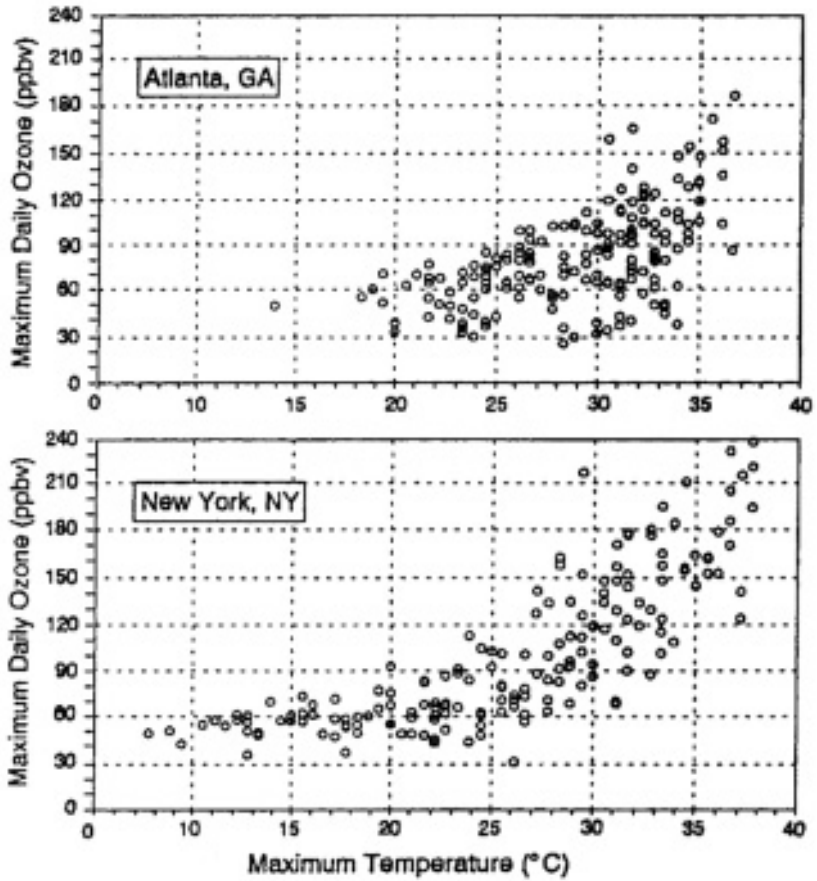
# Environmental Degradation

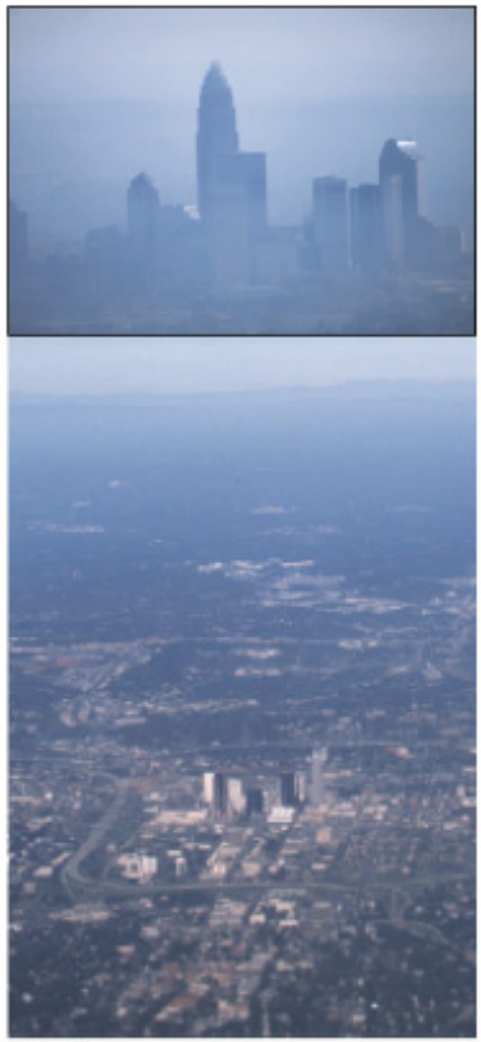
- Decrease air quality in urban areas with air pollution problems
- Salt-water incursion in freshwater systems leading to contamination
- Changes in marine environment that will increase risks of human poisoning and disease

# Ozone

These graphs illustrate the observed association between ground-level ozone concentrations and temperature in Atlanta and New York City (May to October 1988-1990). The projected higher temperatures across the US in the 21st century are likely to increase the occurence of high ozone concentrations, especially since extremely hot days frequently have stagnant air circulation patterns, although this will also depend on emissions of ozone precursors and meteorological factors. Ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function.

**Maximum Daily Ozone Concentrations**
and Maximum Daily Temperature - Atlanta & New York



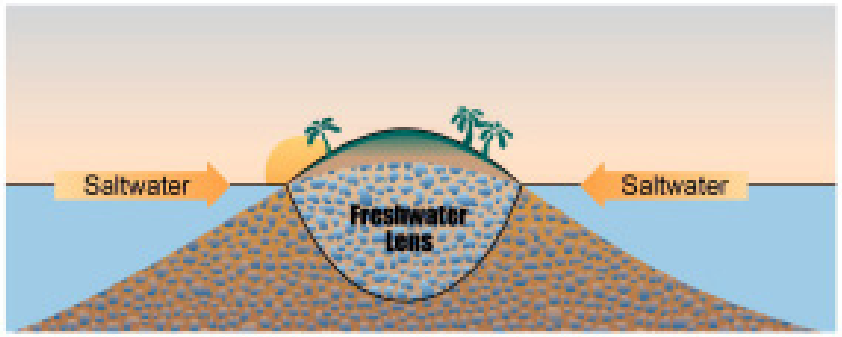



Atlanta

# Salt Water Incursions in Island Water Tables

- Underground freshwater is typically a critical source of water for islands
- Freshwater lens is suspended by saltwater
- As sea level rises, salt water intrudes, making the water unsuitable for many uses (drinking, watering, etc)
- Compounded by extraction of water due to increased development pressures
- Most critical for small islands

**Freshwater Lens Effect in Island Hydrology**



# Poisons in the Sea

- Pathogens enter marine environment from human and terrestrial animal sources through sewage and runoff
  - warmer seas are likely to lead to a change in the survival and persistence of marine pathogens, leading to poleward expansion of these pathogens
- Harmful algal blooms cause a variety of acute, sub-acute, and chronic diseases in humans, other mammals, fish, and birds
  - warmer seas are likely to lead to an increase in intensity, duration, and extent of harmful algal blooms
- Therefore, anticipated global warming and an increase in extreme events is likely to lead to an increase in disease/poisoning associated with
  - human consumption of fish and shellfish
  - inhalation of sea spray
  - recreational contact with sea water (swimming, surfing)

# Relevance of Climate Change and Health to the National Science Education Standards

## Grades 5-8

### Life Science

- Populations and ecosystems
- Diversity and adaptations of organisms

### Science in Personal and Social Perspectives

- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

## Grades 9 – 12

### Life Science

- Biological evolution
- Interdependence of organisms
- Behavior of organisms

### Science in Personal and Social Perspectives

- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

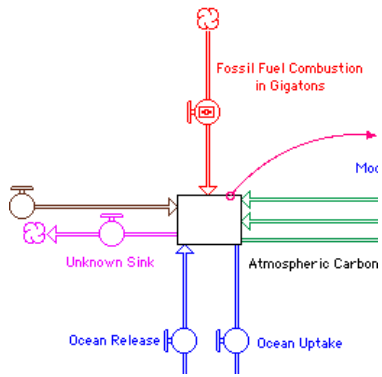
# Curriculum Resources

- The Potential Consequences of Climate Variability and Change: Human Health*
- See http://www.strategies.org/climate.html
  - Climate and Disease: A Critical Connection
    - Grades 9-12
    - Climate variability impacts on food chain, animal population, and relationship to disease
  - Beyond the Bite: Mosquitoes and Malaria
    - Grades 5-8, 9-12
    - How a warming climate may affect the distribution of malaria
  - Both with 2001 Seal of Approval from the NASA Earth Science Enterprise
- USGCRP Education Resources - http://www.usgcrp.gov/usgcrp/education/default.htm

*Developed by the Institute for Global Environmental Strategies in support of the US Global Change Research Program, with sponsorship from NASA

# Professional Development for Educators

- Participants selected from national pool of master with significant training experience
- High impact through waterfall training model
- Middle/high school teachers
  - NCAR Workshop on Climate and Global Change, July 21-Aug 1
    - 20 participants, 2 weeks
    - science content, activities, field work, standards, technology, and training support
    - leading scientists and professional development specialists
    - **http://www.ucar.edu/educ_outreach/gew**
  - Modeling in the Geoscience Workshop, June 16-27
    - Funded by NASA through Earth System Modeling Framework
    - 2 weeks, focus on use of models in geoscience education
    - **http://www.ucar.edu/educ_outreach/mgw/**



# Some Great Websites on Climate

- Intergovernmental Panel on Climate Change (IPCC)- http://www.ipcc.ch/index.html
- US Global Change Research Program (lots of good stuff)- http://www.usgcrp.gov/usgcrp/default.htm
- World Health Organization (WHO) - http://www.who.int/peh/climate/climate_and_health.htm
- US Environmental Protection Agency (EPA) – http://yosemite.epa.gov/oar/globalwarming.nsf/content/Climate.html
- National Snow and Ice Data Center (great cryosphere data)- http://nsidc.org/noaa/
- National Center for Atmospheric Research Climate and Global Dynamics - http://www.cgd.ucar.edu/
- Climate HotSpots Map (AMAZING!)- http://www.climatehotmap.org/index.html
- Vital Climate Graphics (Great ppt Graphics)- http://www.grida.no/climate/vital/index.htm
- World View of Global Warming (photos)- http://www.worldviewofglobalwarming.org/
- Exploratorium Global Change Research Explorer - http://www.exploratorium.edu/climate/index.html