CLIMATE AND CLIMATE CHANGE

What is Climate *CHANGE*?

- **Climate change - A significant shift in the mean state and event frequency of the atmosphere.**
- **Climate change is a normal component of the Earth's natural variability.**
- **Climate change occurs on all time and space scales.**
- **A plethora of evidence exists that indicates the climate of the Earth has changed.**

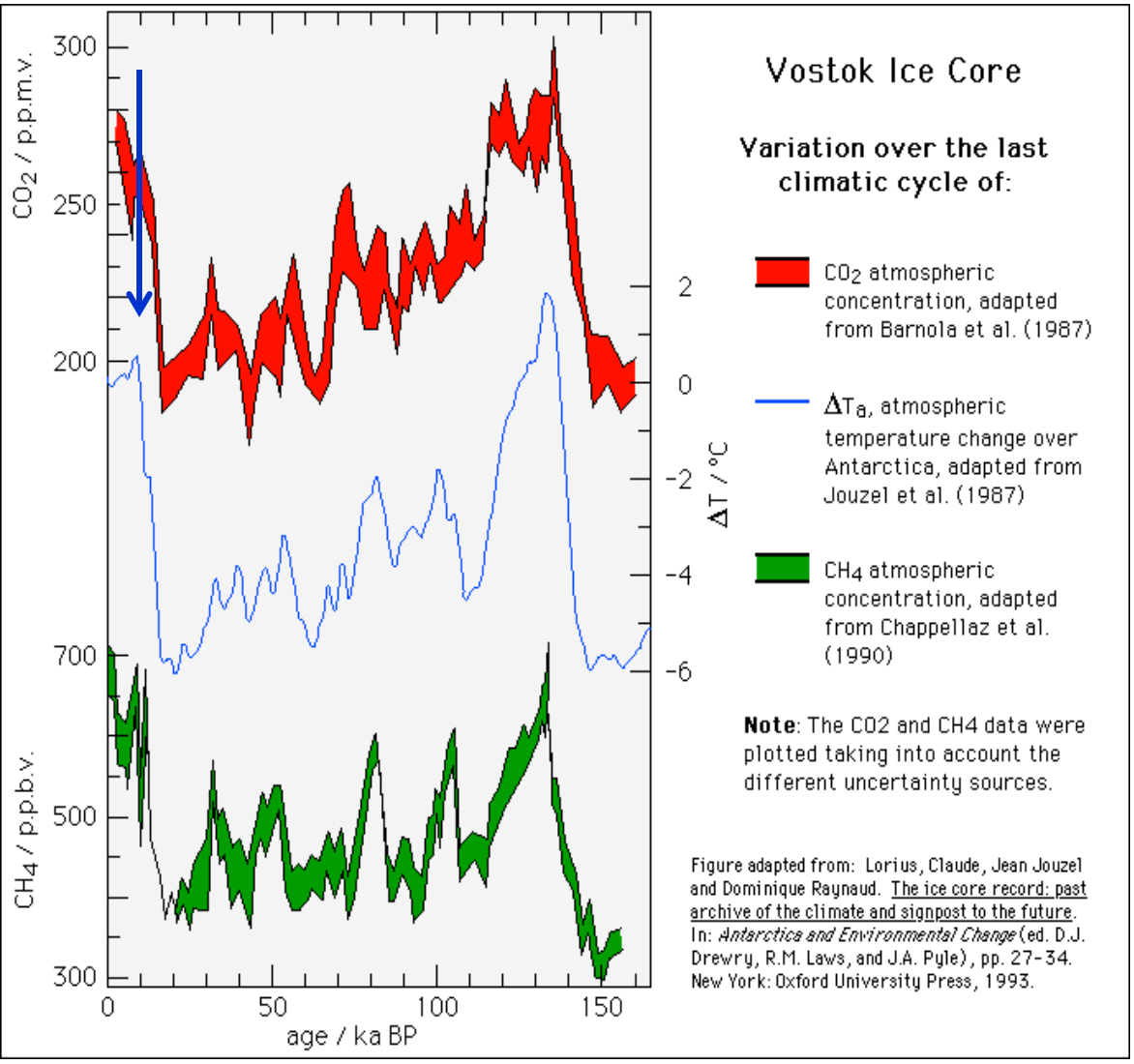
Determining the Past Climate

Paleoclimatology - the study of past climates.

- **Past 100-200 years (weather observations)**
- **Must use indirect climate measures, proxies, to examine further into the past. Some proxies:**

  - Tree rings (1,000+ years before present BP)

Ice Core from Vostok, Antarctica



During last ice age (>18,000 years ago)

Temps 6°C colder

CO_2 levels 30% lower

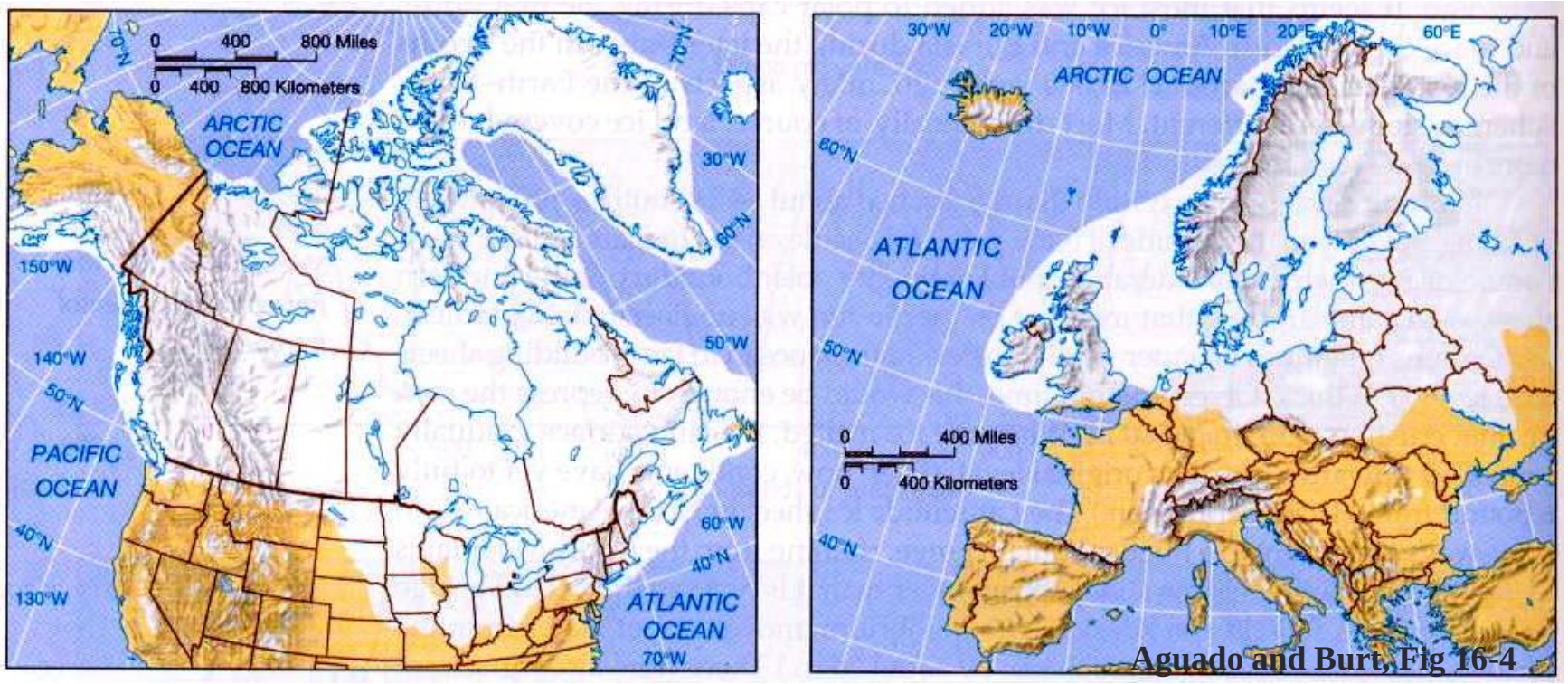
CH_4 levels 50% lower

H_2O levels were lower

than current interglacial.

What caused what?

Most Recent Ice Age



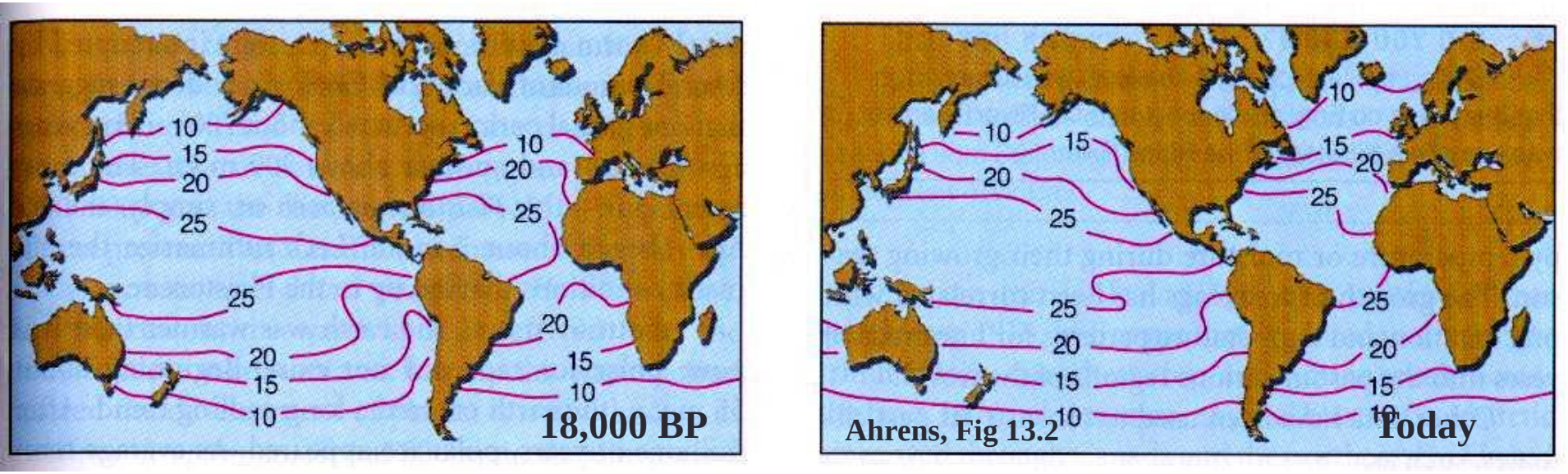
Aguado and Burt, Fig 16-4

Extend of continental glaciers 18,000 years BP.

Sea level was 100-125 m lower than present.

Bering land bridge between Siberia and Alaska.

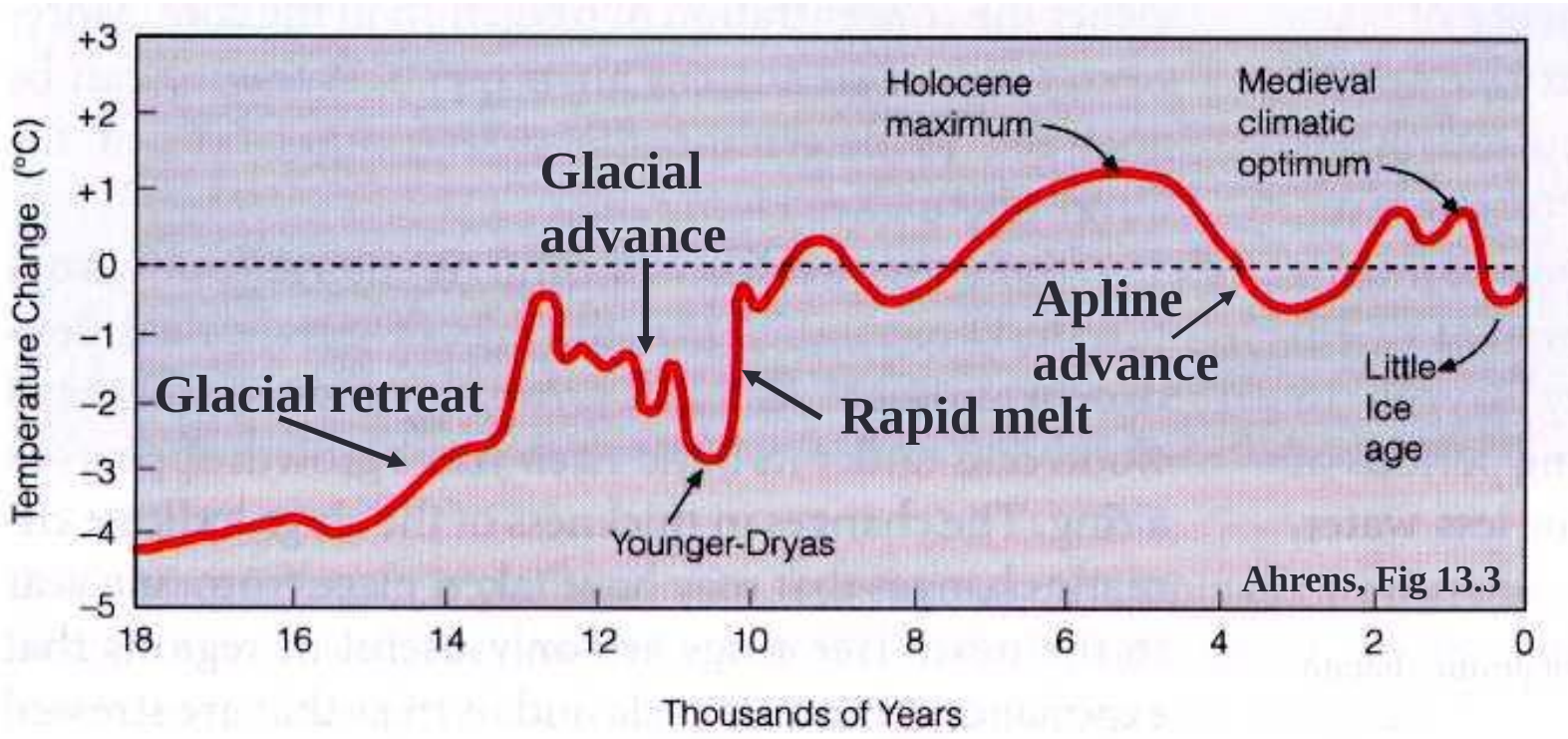
18,000 years BP



Much cooler over the North Atlantic Ocean.

Ocean currents were undoubtedly different.

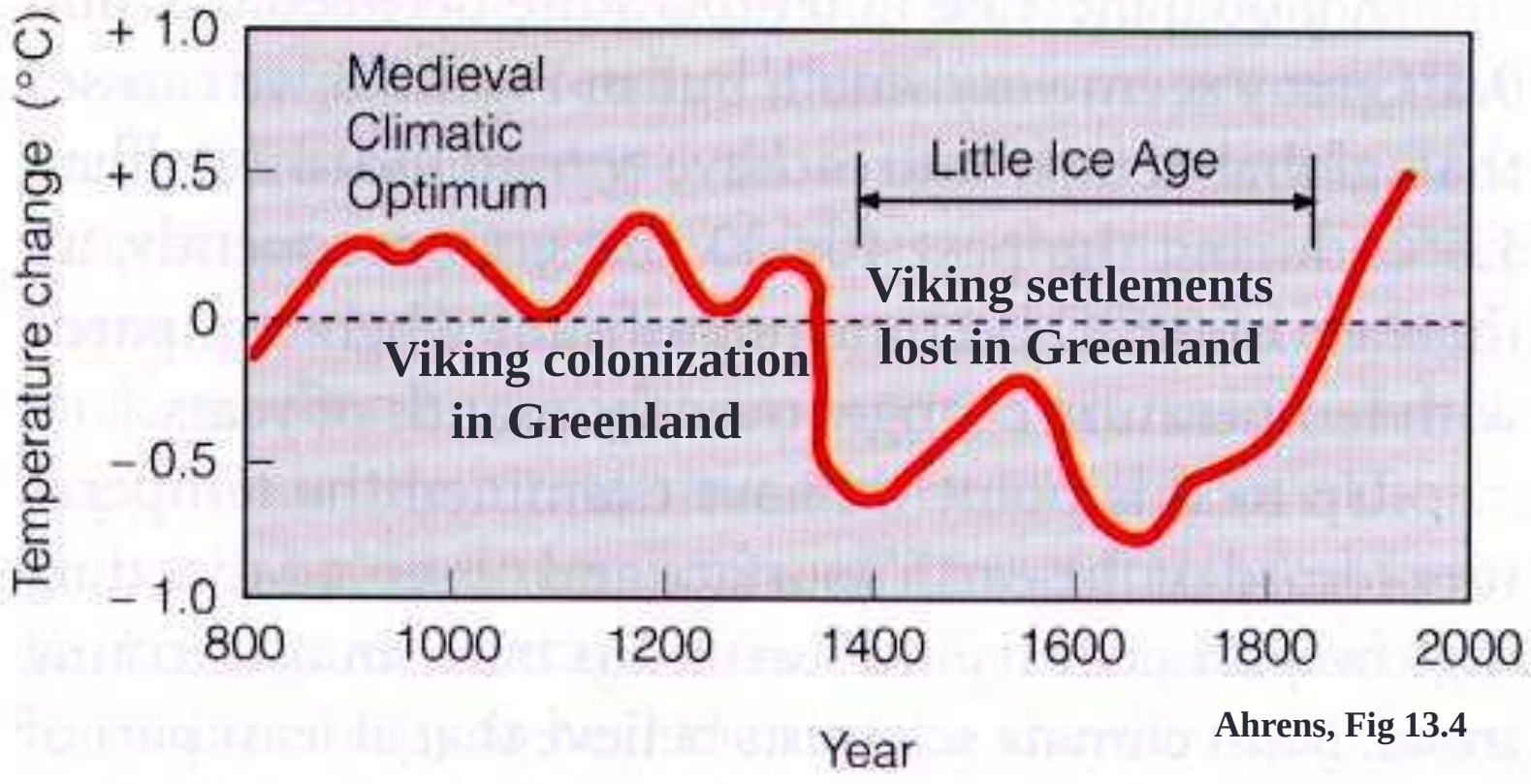
Temperatures Since Last Ice Age



Rapid warming occurred at end of Younger-Dryas period.

Ice cores indicate that Ice Age conditions ended in 3 years!

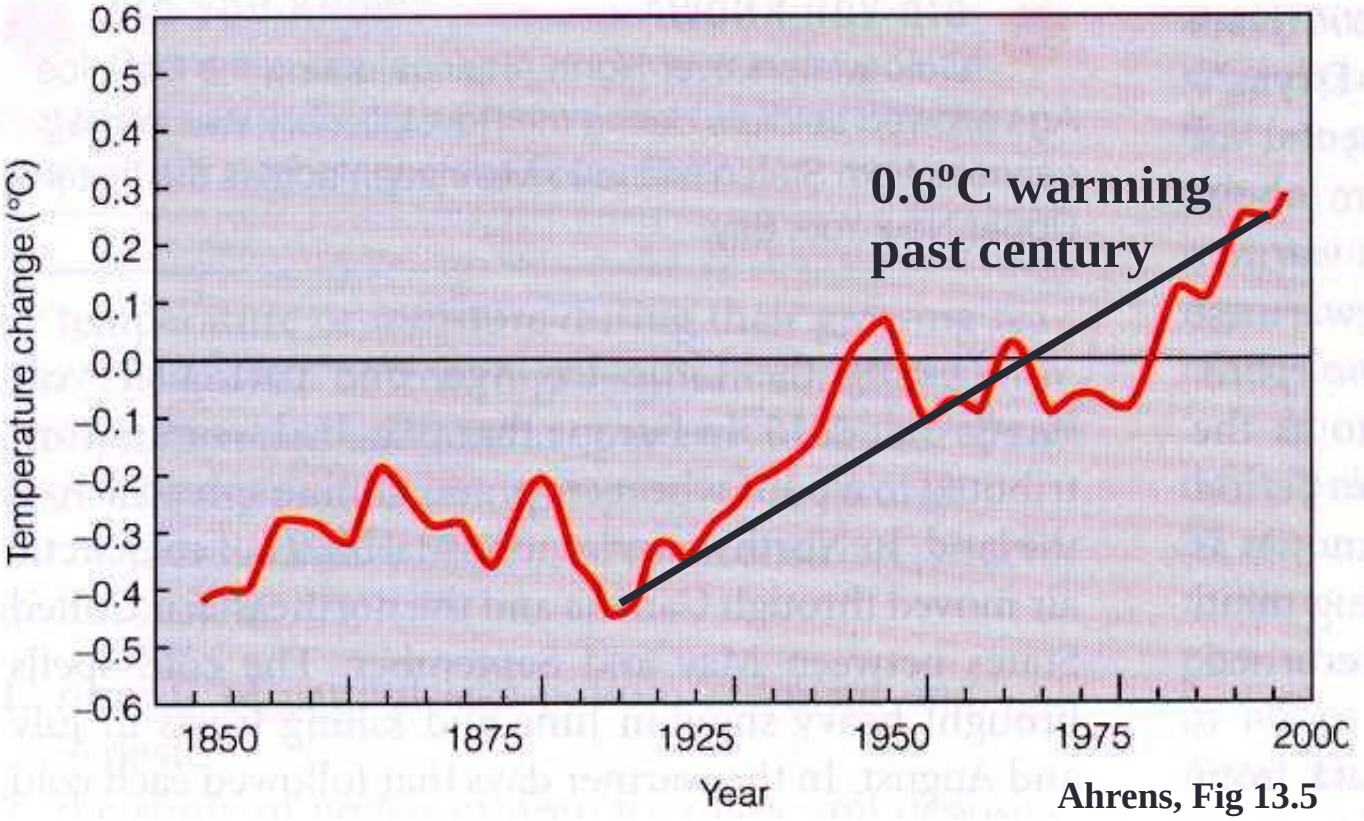
Climate Changes Affect Mankind



Ahrens, Fig 13.4

Temperatures for eastern Europe during the last 1200 years.

Evidence of Climate Change



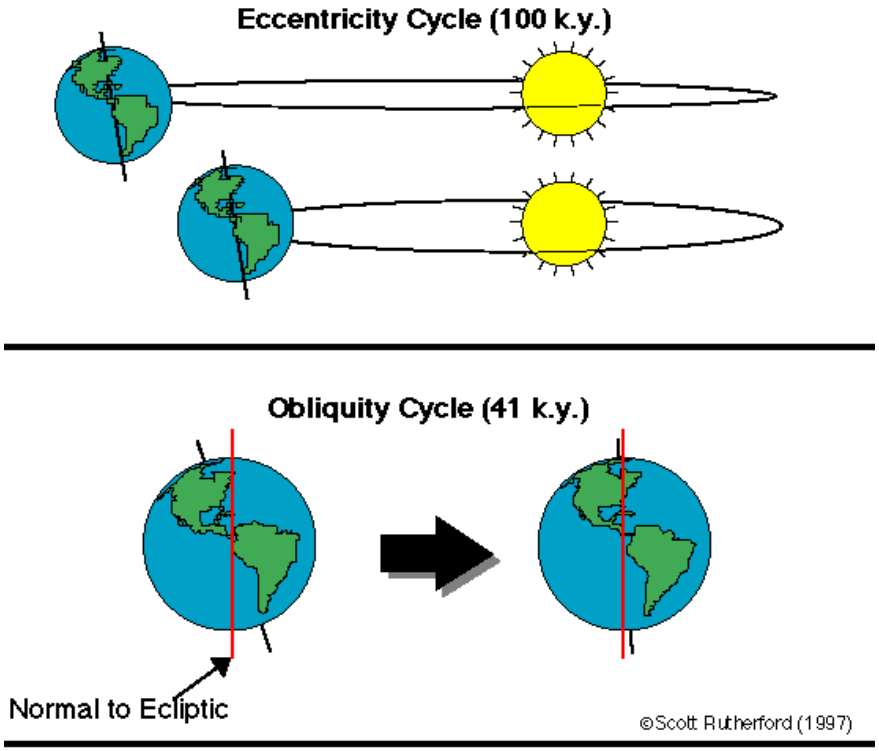
Ahrens, Fig 13.5

Surface temperatures based on meteorological observations. Is the warming of the past century due to human activities?

Causes of Climate Change

- **Atmospheric Composition - Anything that changes the radiative properties of the atmosphere (volcanic aerosols, carbon dioxide).**
- **Astronomical - Anything that alters the amount or distribution of solar energy intercepted by the Earth (solar variations, orbital variations).**
- **Earth’s Surface - Anything that alters the flow of energy at the Earth's surface or changes its distribution (desertification, continental drift).**

Milankovitch Theory of Ice Ages



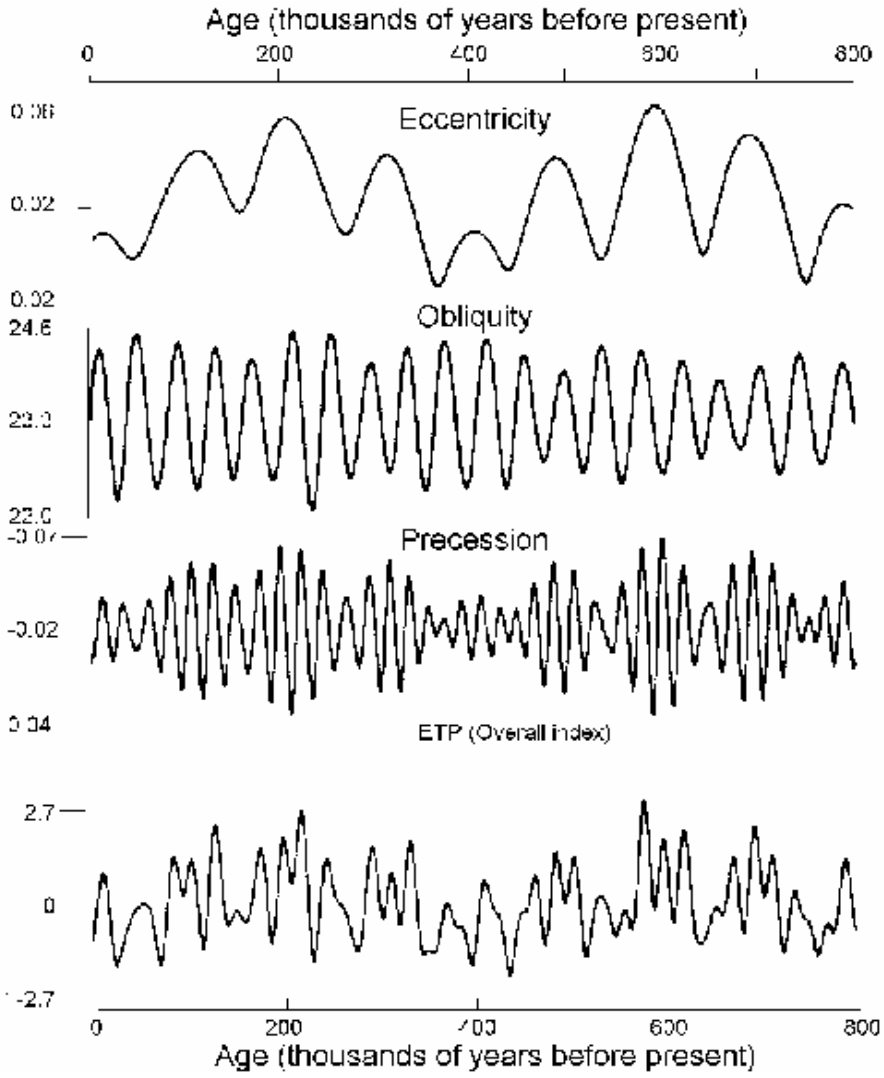
- **Attempts to explain ice ages by variations in orbital parameters**
- **Three cycles:**

  Eccentricity (100,000 yrs)

  Tilt (41,000 yrs)

  Precession (23,000 yrs)
- **Changes the latitudinal and seasonal distributions of solar radiation.**

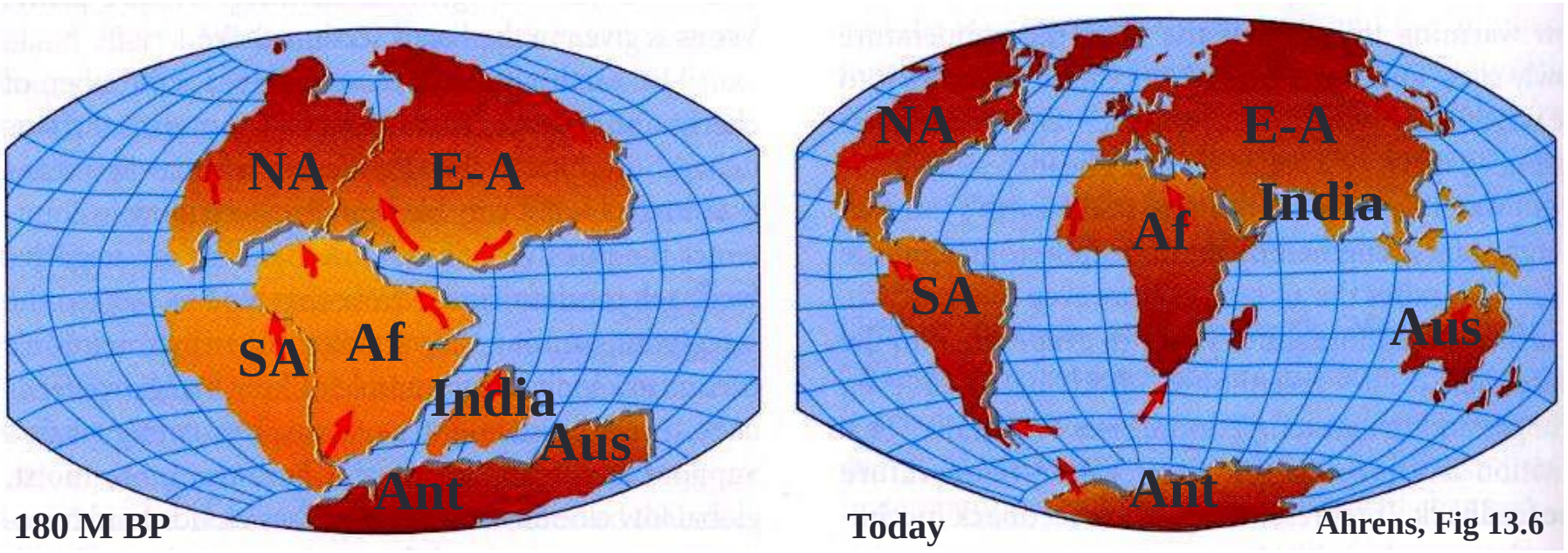
Milankovitch Theory of Ice Ages



- **Ice ages occur when there is less radiation in summer to melt snow.**
- **Partially agrees with observations, but many questions unanswered.**

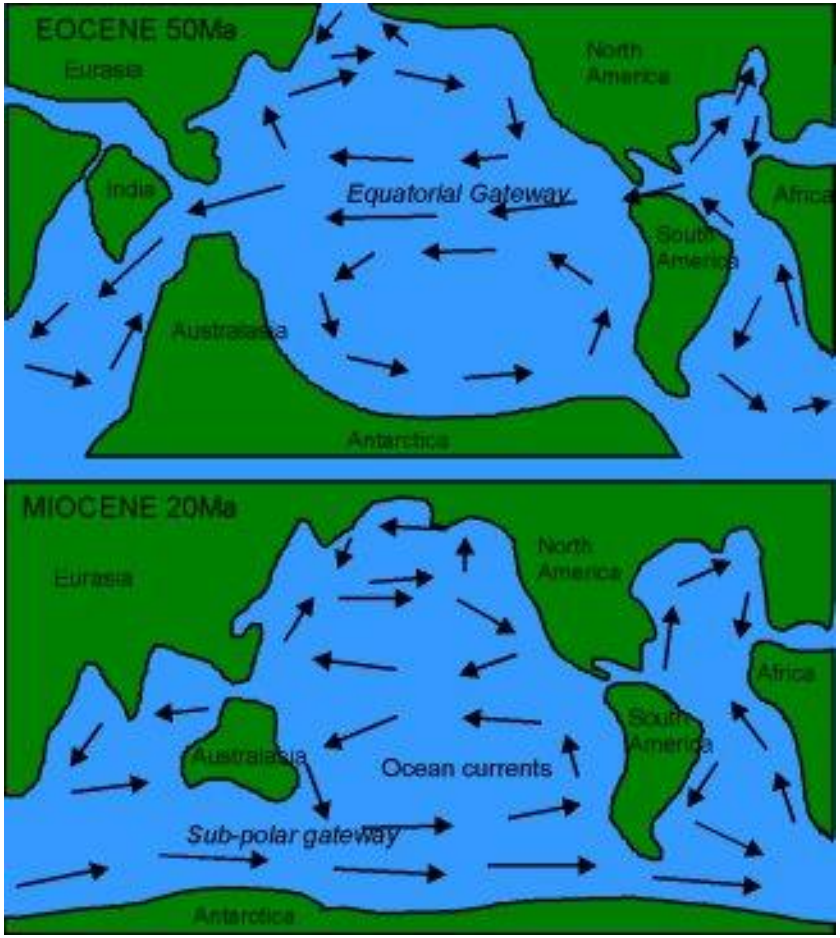
What caused the onset of the first Ice Age?

Long-Term Climate Change



- 250 million years ago, the world's landmasses were joined together and formed a super continent termed Pangea.
- As today's continents drifted apart, they moved into different latitude bands.
- This altered prevailing winds and ocean currents.

Long-Term Climate Change

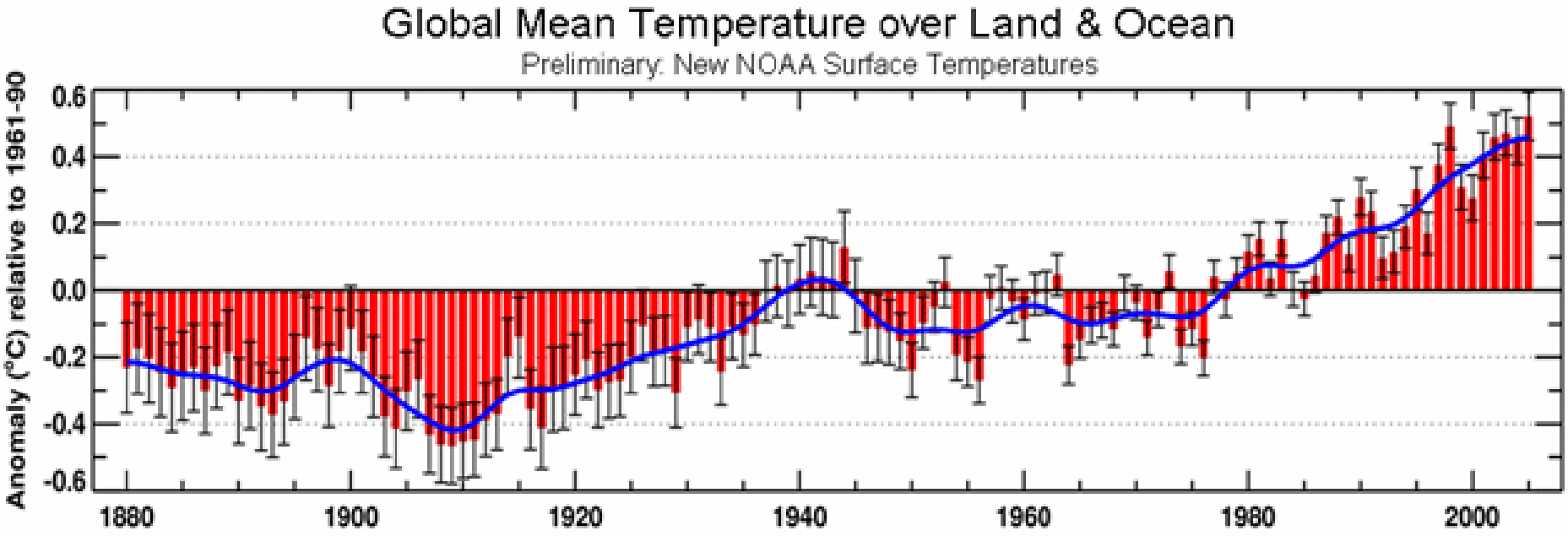


- **Circumpolar ocean current formed around Antarctica 40-55 *MY* ago once Antarctica and Australia separated.**
- **This prevented warm air from warmer latitudes to penetrate into Antarctica.**
- **Absence of warm air accelerated growth of the Antarctic ice sheet.**

http://www.ace.mmu.ac.uk/eae/Climate_Change/Older/Continental_Drift.html

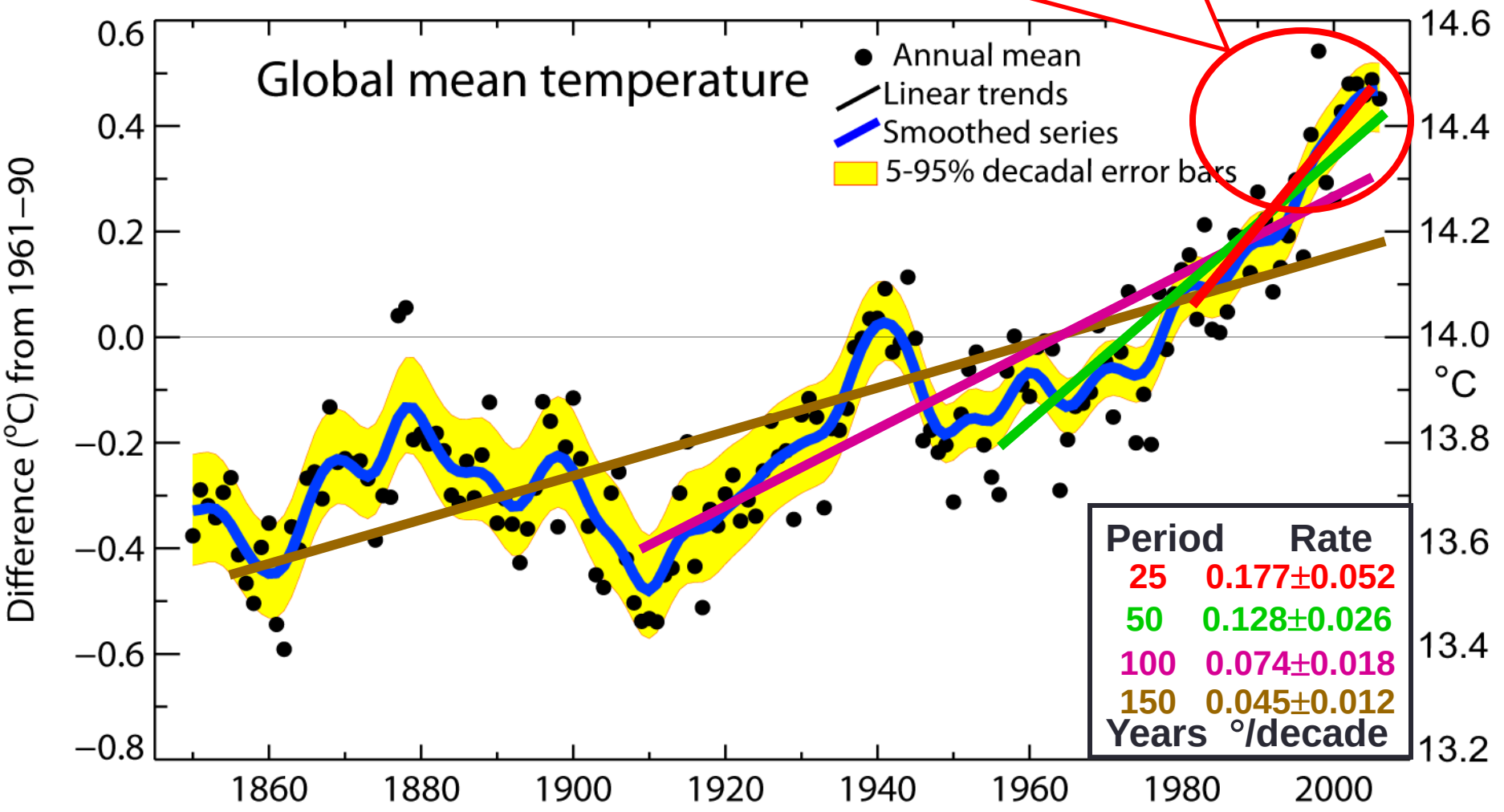
Our changing climate

- **Our climate is changing.**
- **In particular, surface temperatures are increasing. => 1998 or 2005 is the warmest year in the past 400 years, and perhaps much longer**



Global mean temper…ime

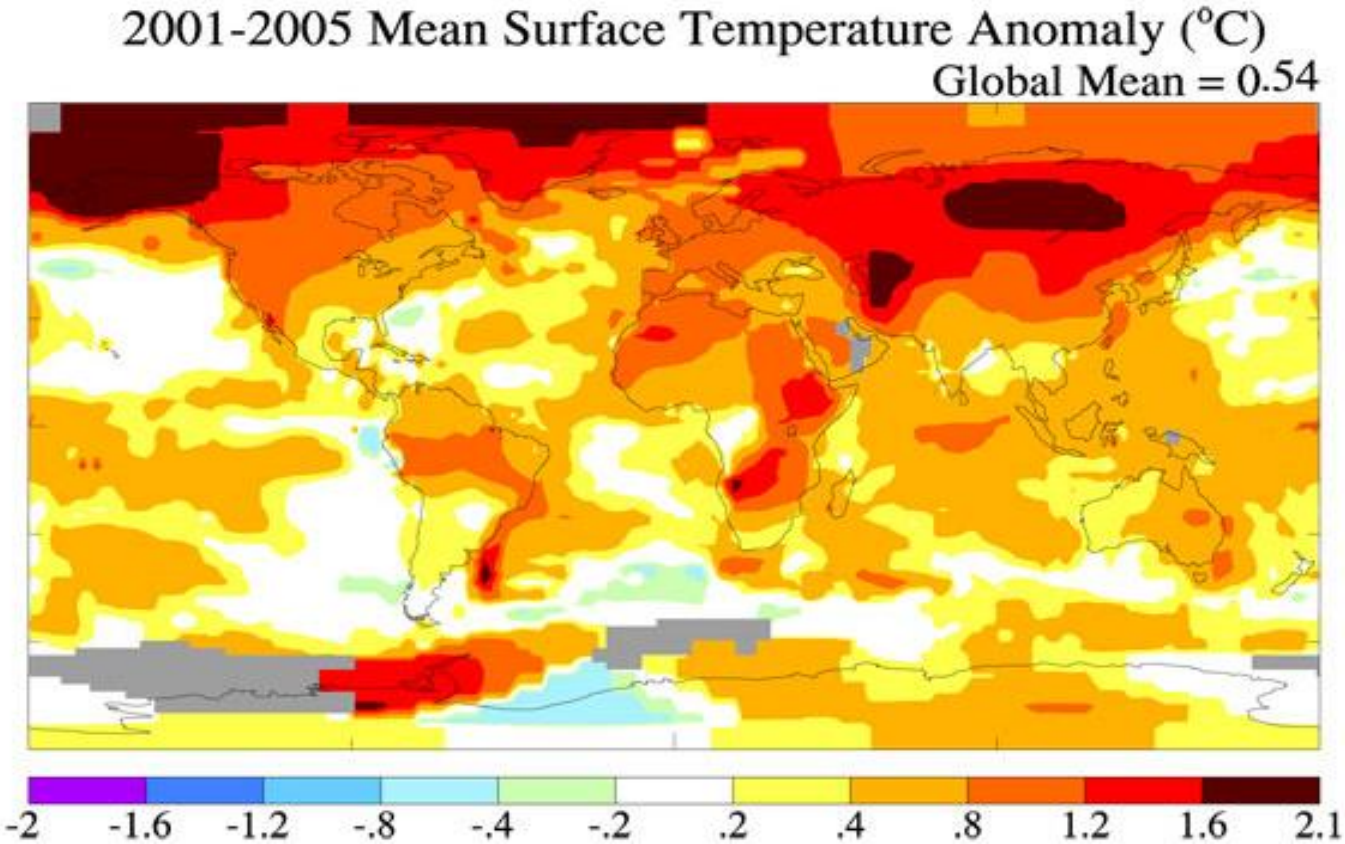
Warmest 12 years:
1998,2005,2003,2002,2004,2006,
2001,1997,1995,1999,1990,2000



IPCC

Our changing climate

- Arctic is warming faster than most other regions, largely as predicted by climate models
- This raises questions about ice melt and sea level rise
- Western US may warm and dry significantly (8ºF in 50-100 years?)

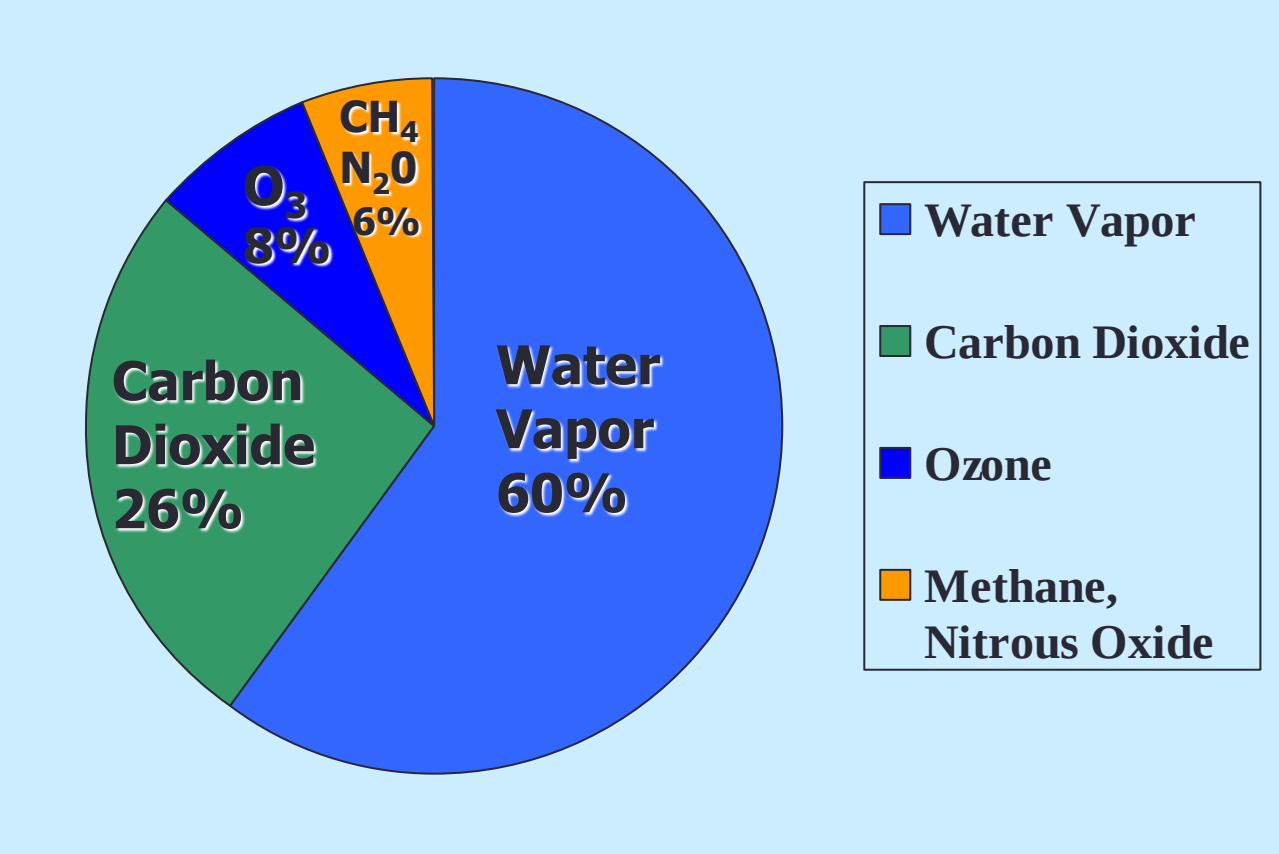


Our changing climate:
Key Questions

- Climate modelers have predicted the Earth's surface will warm because of manmade greenhouse gas (GHG) emissions

- So how much of the warming is manmade?
- How serious are the problems this is creating?
- What, if anything, can and should we do?

The Natural Greenhouse Effect: clear sky



Kiehl and Trenberth 1997

Our changing climate:
Increasing CO_2 concentrations

- Man is modifying the CO_2 concentrations via burning fossil fuels

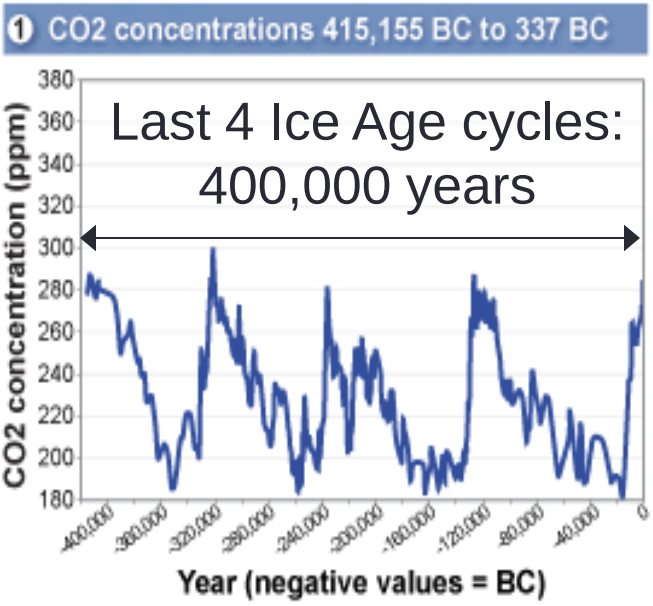
NOAA site

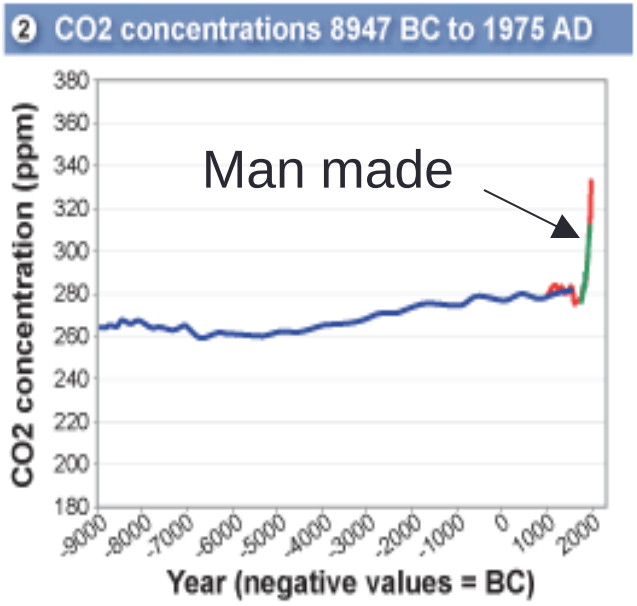
  - Amounts are now beyond the range of natural variations experienced over the past 700,000 years

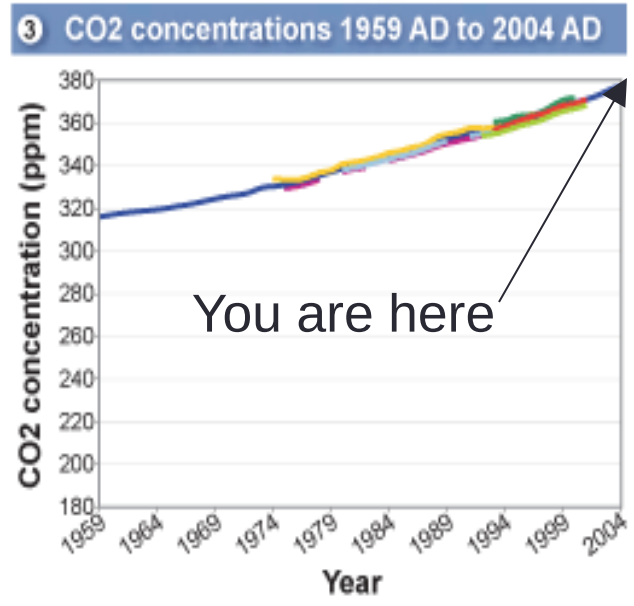
NOAA site

Changing CO_2 concentrations

- CO_2 concentrations have varied naturally by a factor of 2 over the past few hundred thousand years
- Fossil fuel burning since the industrial revolution has created a sharp increase in CO_2 concentrations
- CO_2 concentrations are now higher than at any time in past few hundred thousand years
- And concentrations are increasing faster with time

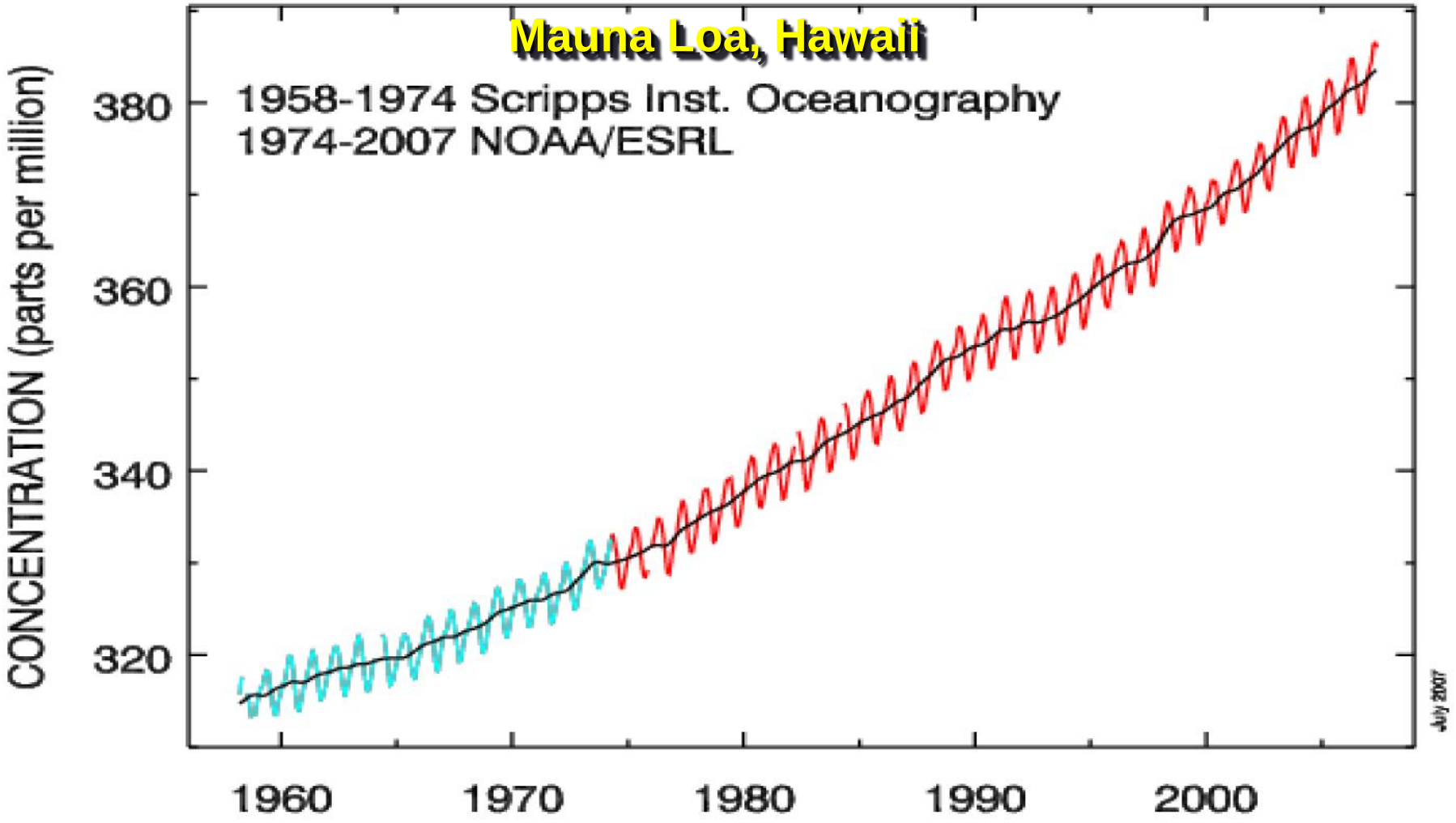






See http://epa.gov/climatechange/science/recentac.html

Changing atmospheric composition: CO_2



Change in IR Emission to Space

- **Notice that because of Earth's greenhouse gases, 91% (=64/70) [195/235 = 83%] of the IR emitted to space comes from the atmosphere and only 9% (=6/70) [40/235 = 17%] comes from the surface**
- **When GHG's are added to the atmosphere, the altitude of IR emission to space rises**
- **In the troposphere, air temperature decreases with altitude**
- **So the temperature of the emission to space decreases**
- **So the energy emission to space decreases because the emission energy decreases with decreasing temperature**

Positive and Negative Feedbacks

- Assume that the Earth is warming.

  - Warming leads to more evaporation from oceans, which increases water vapor in atmosphere.

  -More water vapor increases absorption of IR, which strengthens the greenhouse effect.

  -This raises temperatures further, which leads to more evaporation, more water vapor, warming…

  “Runaway Greenhouse Effect”

  Positive Feedback Mechanism

Positive and Negative Feedbacks

- Again assume that the Earth is warming.

  - Suppose as the atmosphere warms and moistens, more low clouds form.

  - More low clouds reflect more solar radiation, which decreases solar heating at the surface.

  - This slows the warming, which would counteract a runaway greenhouse effect on Earth.

  Negative Feedback Mechanism

Positive and Negative Feedbacks

- **Atmosphere has a numerous checks and balances that counteract climate changes.**
- **All feedback mechanisms operate simultaneously.**
- **All feedback mechanisms work in both directions.**
- **The dominant effect is difficult to predict.**
- **Cause and effect is very difficult to prove at the “beyond a shadow of a doubt” level.**

Key Points: Climate Change

- **Proxy data are used to infer the past climate.**
- **Data show that the Earth's Climate**

  Has changed in the past

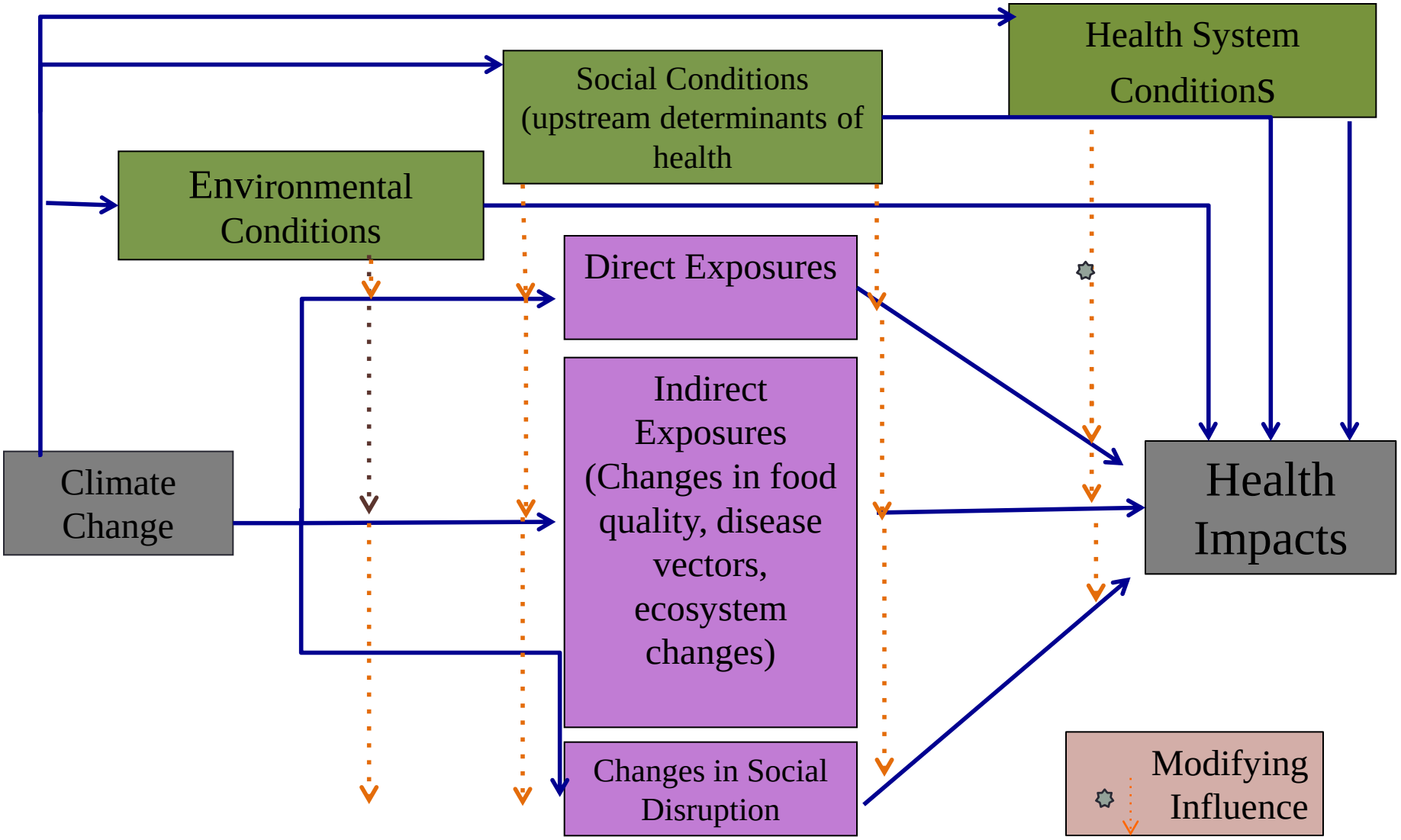
  Is changing now

  And will continue to change
- **Key question is determining whether recent changes are due to natural causes or man.**

Key Points: Climate Change

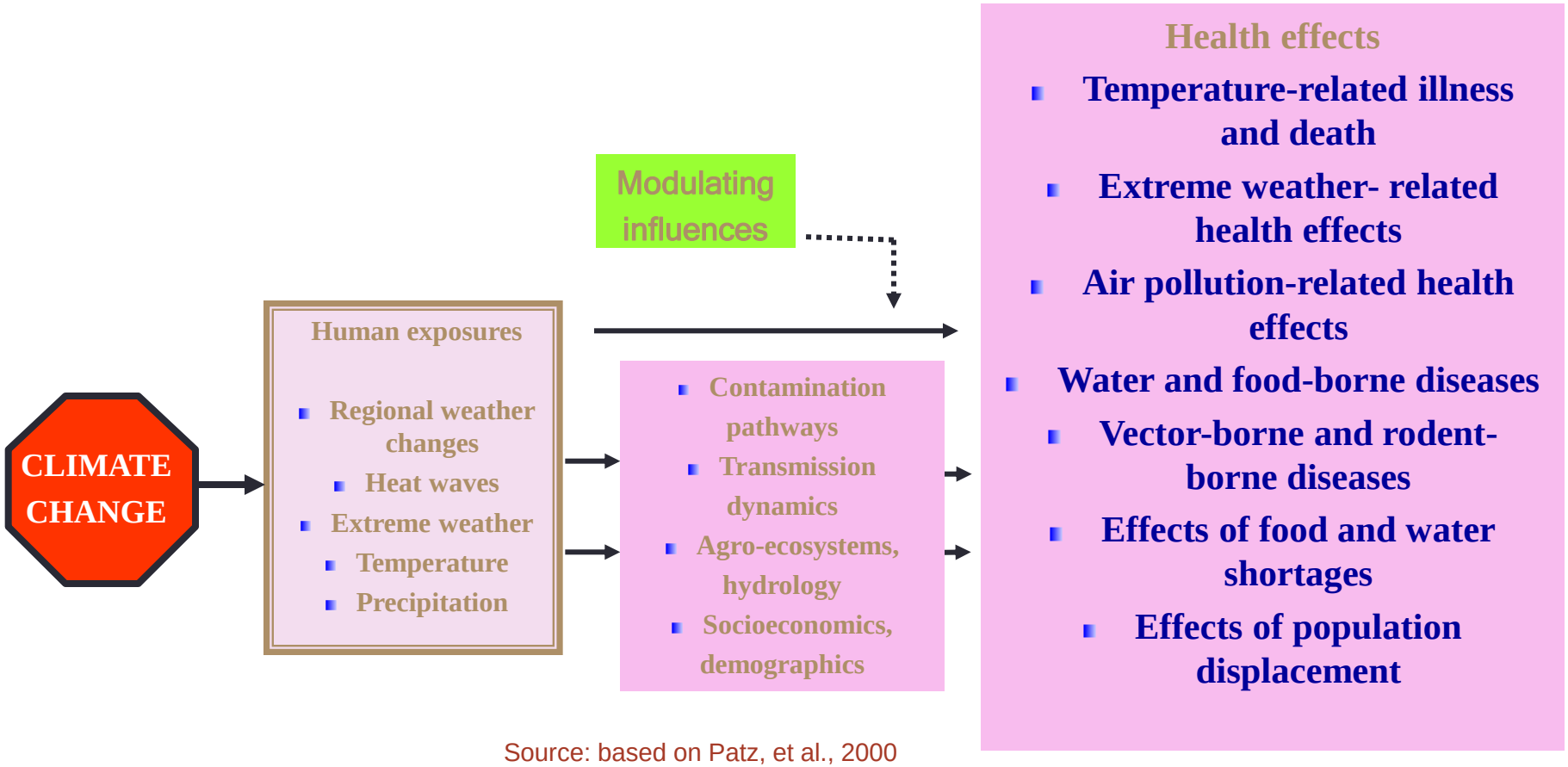
- **The climate system is very complex.**
  Contains hundreds of feedback mechanisms
  All feedbacks are not totally understood.
- **Three general climate change mechanisms:**
  Astronomical
  Atmospheric composition
  Earth's surface

Pathways for Weather to Affect Health



Mapping Links Between Climate Change and Health

- Most expected impacts will be adverse but some will be beneficial.
- Expectations are not for new health risks, but rather changes in frequency or severity of familiar health risks



Source: based on Patz, et al., 2000

POTENTIAL HEALTH IMPACTS FROM ENVIRONMENTAL CHANGES

TEMPERATURE

Temperature

Table 3.2. Projected temperature changes for Asia/Pacific subregions[c]					
	2030 (℃)				
Subregion	Annual	DJF	MAM	JJA	SON
Arid and Semi-Arid Asia	1.2 (0.6–2.3)	1.3 (0.6–2.7)	1.2 (0.5–2.4)	1.2 (0.5–2.3)	1.2 (0.6–2.2)
Temperate Asia	0.9 (0.4–1.9)	1.0 (0.4–2.5)	0.8 (0.3–1.3)	0.8 (0.4–1.7)	0.9 (0.4–1.8)
North Tropical Asia	0.8 (0.4–1.3)	0.8 (0.4–1.4)	0.8 (0.4–1.4)	0.8 (0.4–1.4)	0.8 (0.4–1.3)
South Tropical Asia	0.8 (0.4–1.3)	0.8 (0.4–1.3)	0.8 (0.4–1.4)	0.8 (0.4–1.3)	0.8 (0.4–1.3)
	2070 (℃)				
Arid and Semi-Arid Asia	3.2 (1.3–7.1)	3.4 (1.3–8.3)	3.2 (1.0–7.3)	3.1(1.1–7.1)	3.1 (1.2–6.8)
Temperate Asia	2.4 (0.9–5.7)	2.8 (0.9–7.7)	2.3 (0.8–5.5)	2.2(0.8–5.3)	2.4 (0.9–5.6)
North Tropical Asia	2.1 (0.9–4.0)	2.1(0.8–4.1)	2.1 (0.9–4.2)	2.0(0.8–4.1)	2.0 (0.8–4.0)
South Tropical Asia	2.1 (0.9–4.0)	2.0 (0.9–4.1)	2.1(0.9–4.2)	2.1(0.8–4.1)	2.1(0.8–4.1)

CSIRO 2006: Climate Change in the Asia/Pacific Region

Temperature

Direct Impacts to Health from Heat

- The human body maintains body temperature in ambient temperatures not exceeding 32 degrees C
- Above this temperature, heat lost through the skin and sweating
- Heat-related illness occurs when the body unable to adequately cool
- Minimum ambient temperatures are also important:
    a) Difficulties cooling when minimum temperature is greater than 22 degrees C
- High humidity reduces effectiveness of sweating and increases the risk of heat-related illness at any given temperature.

Relative Atmospheric Temperature (°C)

Humidity(%) and Temperature	26	28	30	32	34	36	38	40	42	44
0%	25	27	28	30	32	33	35	36	37	38
10%	25	27	28	30	32	33	35	37	39	41
20%	26	27	28	30	32	34	37	39	42	46
30%	26	27	29	31	33	36	39	43	47	52
40%	26	28	30	32	35	39	43	48	54	60
50%	27	28	31	34	38	43	49	55	62	
60%	27	29	33	37	42	48	55	62		
70%	27	31	35	40	47	54	63			
80%	28	32	38	44	52	61				
90%	28	34	41	49	58					
100%	28	36	44	56						

At an apparent temperature, (T_a) of:

32–40°C Heat cramps or heat exhaustion possible

41–54°C Heat cramps or heat exhaustion likely, heat stroke possible

54°C< Heat stroke highly likely

Exposure to full sunshine can increase the heat index value by up to 8°C

Impacts to Health from Increased Temperatures

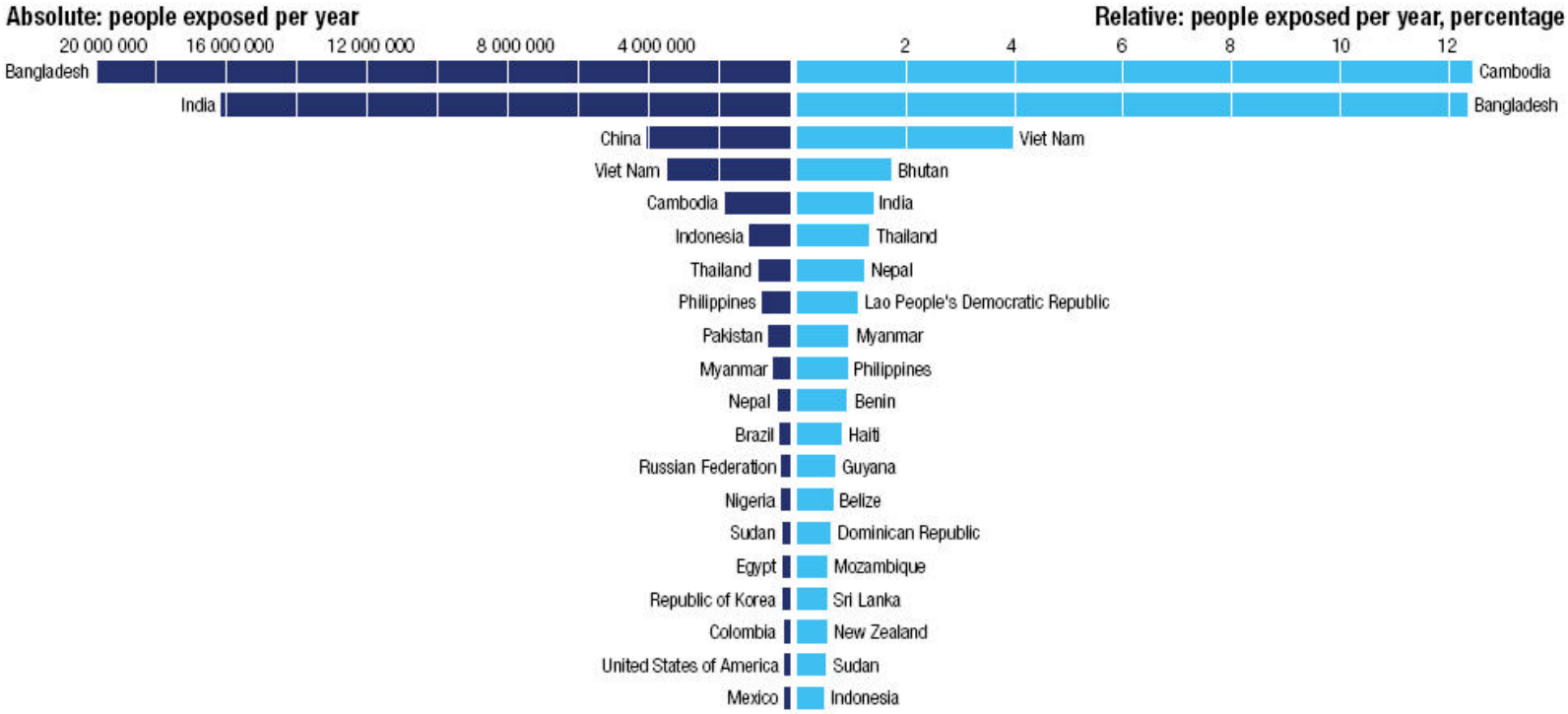
- Direct impacts to health:
  a) **Heat cramps** – muscular pains and spasms
  b) **Heat exhaustion** – body fluids are lost through heavy sweating
  c) **Heat stroke** – is life threatening.
- Indirect impacts:
  a) Range of areas that can potentially be affected with gradual and extreme temperature increases
  b) Includes impacts on ecosystems, water, food, disease-carrying vectors, lifestyle, community resilience.

STORMS/FLOODS

Storms/Flooding

Flooding is heavily concentrated in Asia

Most human exposure to flood is in Asia. The top ten countries – in absolute and relative terms - are in south and south east Asia.



Source: 2009 Global Assessment report on Disaster Risk Reduction From: Environment Solutions: www.environmentsolutions.dk

2012 Flood in Pakistan (September)

- Monsoon floods in Pakistan during September, killed more than 400 people and affected more than 4.5 million others:
  - Tens of thousands have been made homeless by heavy flooding in the provinces of Balochistan and Sindh – where 2.8 million were affected.
  - Pakistan has suffered devastating floods in the past two years.
  - The worst floods were in 2010, when almost 1,800 people were killed and 21 million were affected.
- During 2011, many Asian countries experienced flooding, including Bangladesh, China, India, Japan, Laos, North Korea, Pakistan, Thailand, the Philippines and Singapore.

BBC news: 28 Sept 2012

Health Impacts of Floods

- Immediate deaths and injuries
- Non-specific increases in mortality
- Infectious diseases – leptospirosis, hepatitis, diarrhoeal, respiratory, and vector-borne diseases
- Exposure to toxic substances
- Mental health effects
- Indirect effects
- Increased demands on health systems.

Flooding: Direct Health Effects

Causes	Health Implications
Stream flow velocity; topographic land features; absence of warning; rapid speed of flood onset; deep floodwaters; landslides; risk behaviour; fast flowing waters carrying boulders and fallen trees	Drowning Injuries
Contact with water	Respiratory diseases; shock; hypothermia; cardiac arrest
Contact with polluted water	Wound infections; dermatitis; conjunctivitis; gastrointestinal illness; ear, nose and throat infections; possible serious waterborne diseases
Increase of physical and emotional stress	Increase of susceptibility to psychosocial disturbances and cardiovascular incidents

Flooding: Indirect Health Effects

Causes	Health Implications
Damage to water supply systems; sewage and sewage disposal damage; insufficient supply of drinking water; insufficient water supply for washing	Possible waterborne infections (enterogenic *E.coli*, shigella, hepatitis A, Leptospirosis, giardiasis, camplylobacter) dermatitis, and conjunctivitis
Disruption of transport systems	Food shortage; disruption of emergency response
Underground pipe disruption; dislodgement of storage tanks; overflow of toxic waste sites; release of chemicals; rupture of gasoline storage tanks may lead to fires	Potential acute or chronic effects of chemical pollution
Standing waters; heavy rainfalls; expanded range of vector habitats	Vector-borne diseases
Rodent and other pest migration	Possible diseases caused by rodents or other pests
Disruption of social networks; loss of property, jobs and family members and friends	Possible psychosocial disturbances
Clean-up activities following floods	Electrocutions; injuries; lacerations; skin punctures
Destruction of primary food products	Food shortage
Damage to health services; disruption of “normal” health service activities	Decrease of “normal” health care services, insufficient access to medical care

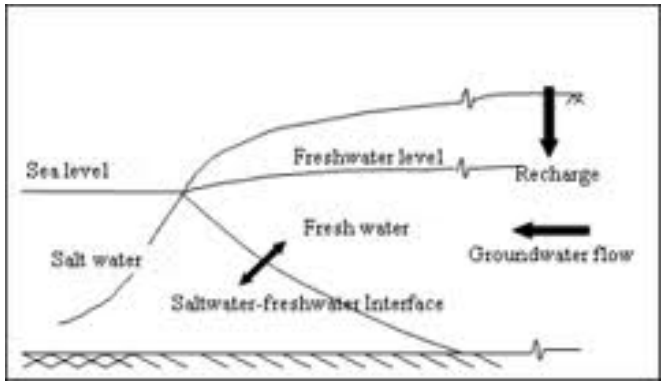
DRINKING WATER

Climatic Change: Drinking Water Supply

- Drying climate causes:
  - Changes to land cover and run-off patterns (erosion)
  - Increased bushfire risk
  - Increased sediment, nutrient and debris.
- Flooding can also affect drinking water supplies:
  - Coastal intrusion
  - Contamination.

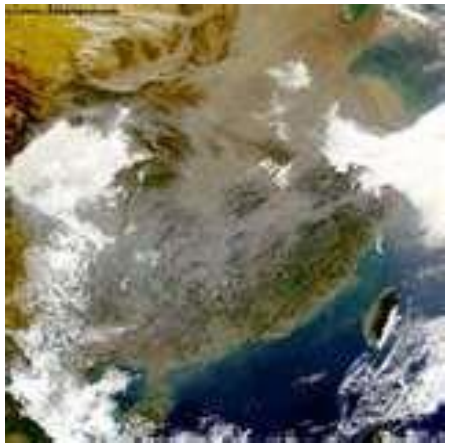
Climatic Change: Drinking Water Supply

- Reduction in flows to dams and groundwater aquifers
- Increased evaporation from surface water storages
- Salt water intrusion into coastal aquifers
- Acidification of susceptible inland aquifers
- Increased risk from the:
  a) Concentration of nutrient and chemical contaminants
  b) Formation of toxic algal bloom

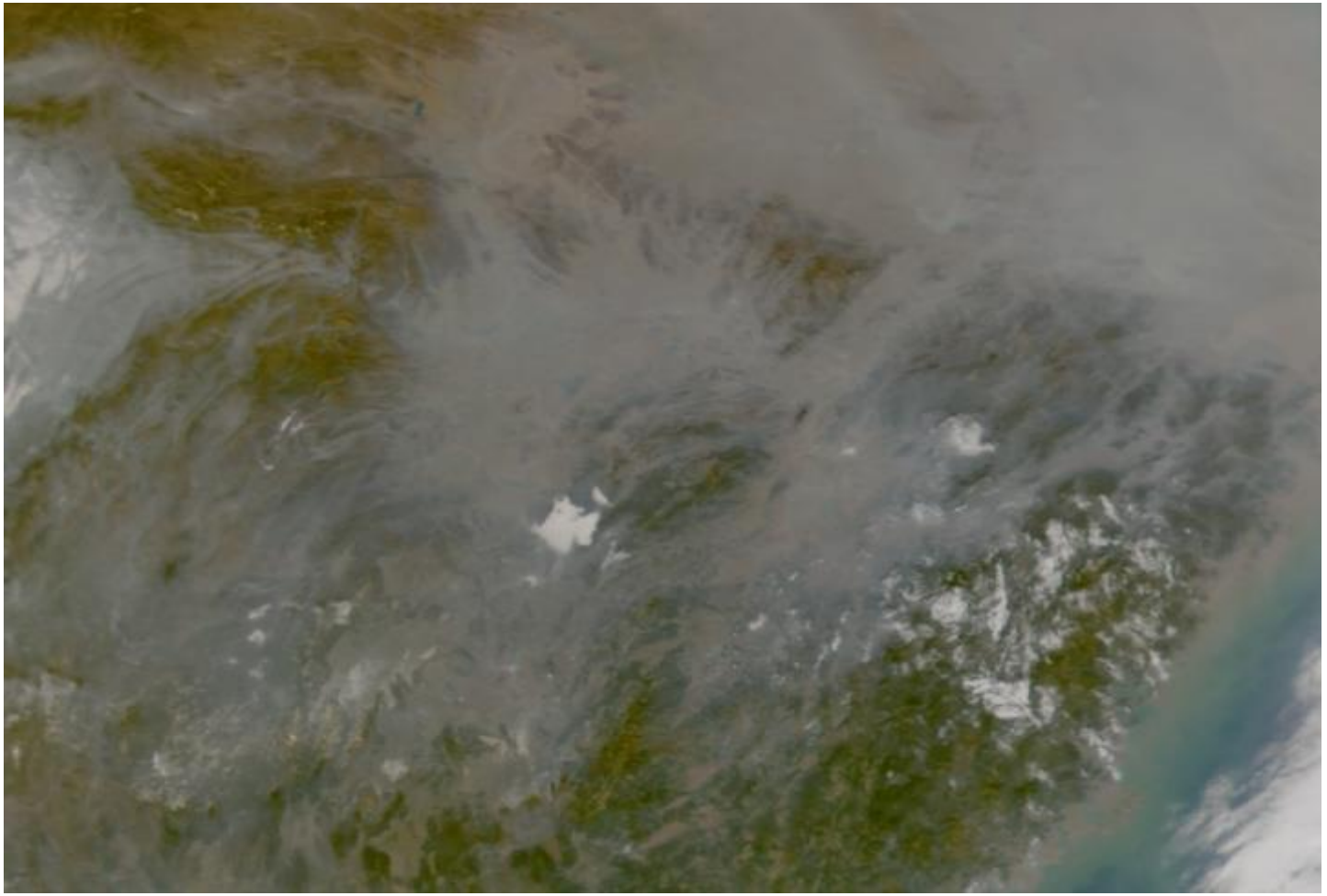


AIR QUALITY

Air quality



China Haze 10 January 2003



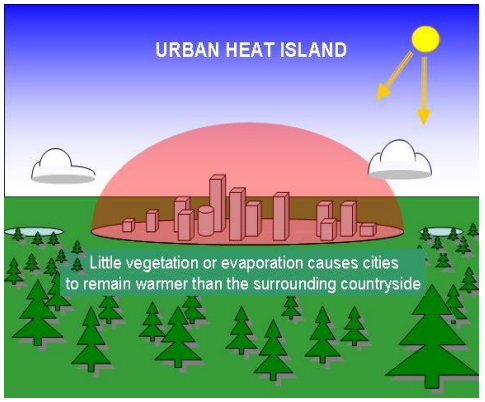
Source: NASA

Climatic Change: Air Quality

- Weather has a major role in the development, transport, dispersion and deposition of air pollutants
- Air pollution episodes are often associated with stationary or slowly moving air masses
- Air pollutants and fine particulate matter may change in response to climate change.

Climatic Change: Air Quality

- Airflow on edges of a high-pressure system can transport ozone precursors. Ozone levels are increasing in many areas
- An increase in fire events will mean increased toxic gases and particulates
- Changes in wind pattern may increase long-range transport of air pollutants
- Weather patterns can enhance urban “heat islands” which can lead to elevated pollution levels.



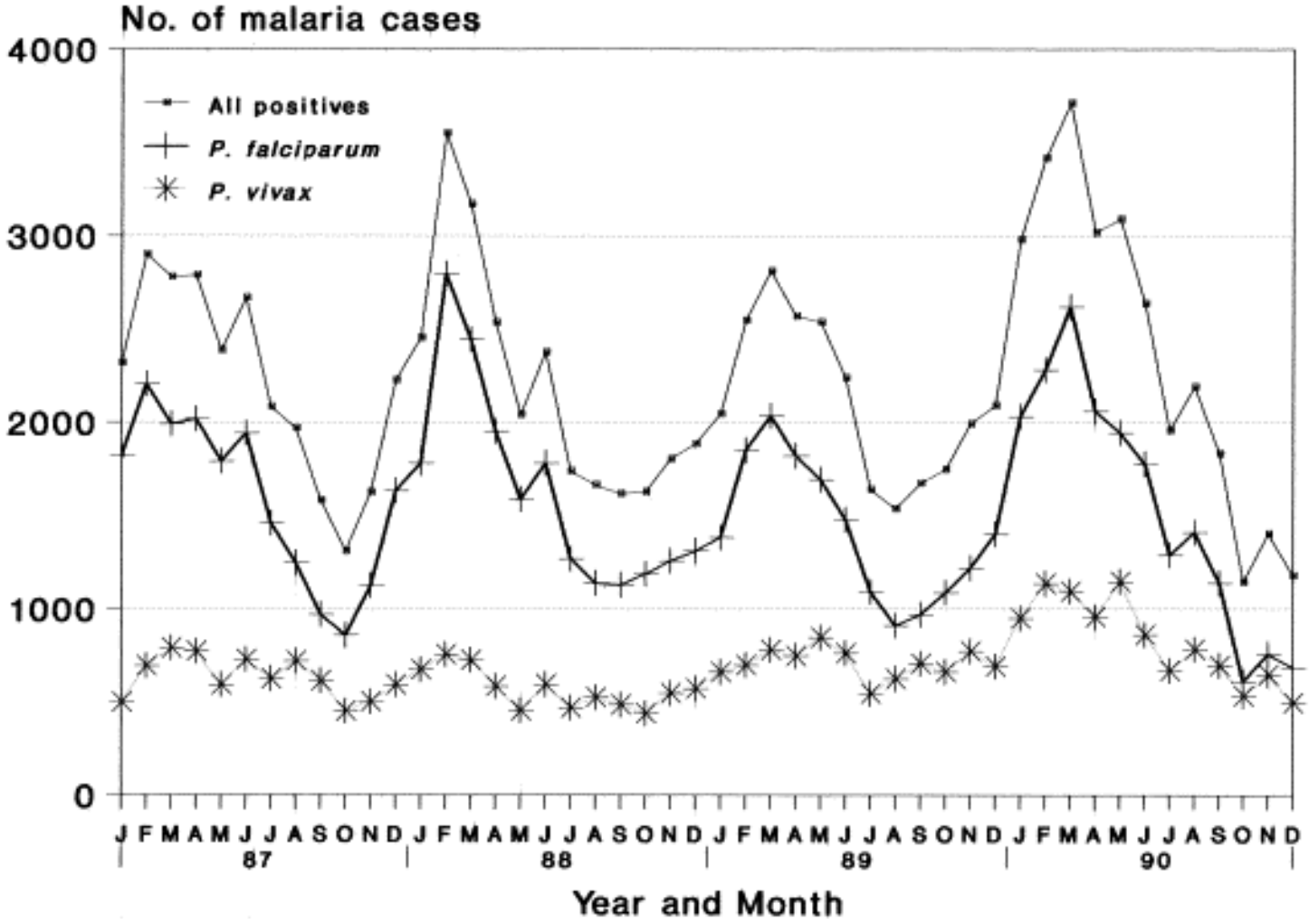
Potential health Impacts

- Ozone – pneumonia, COPD, asthma, allergic rhinitis and others – premature mortality
- Particulate matter (PM) – known to affect morbidity and mortality
- Toxic gases and PM from fires contribute to acute and chronic respiratory illness. Evidence from 1997 Indonesia fires – transboundary impacts
- Wind blown dust (respirable particles, trace elements) from desert regions can affect populations in remote areas. Evidence that mortality is

A fire in a tropical peat forest on Sumatra in Indonesia

VECTOR-BORNE DISEASE

Malaria in Vanuatu

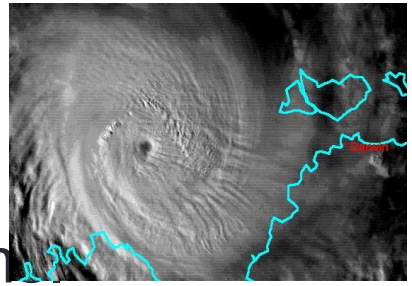


Wet season in Vanuatu is from November until April, temperatures very between 24 to 30^{o}C

Mosquito-borne-disease: Environmental Changes

Distribution of vectors will change arising from:

- Increasing temperature
- Changing rainfall:
  a) Increase or decrease
  b) Seasonality
- Cyclones, flooding
- Changes in animal host/reservoir populations
- Rising sea levels
- Extreme tides
- Loss of coastal margin



Mosquito-borne-disease: Human Factors

Location of population:

- Geographic location
- Proximity to water bodies

Urban environment:

- Peri-domestic breeding

Mobility of population

- Arrival of infected people
  a) International
  b) Interstate
  c) Intrastate

Living standards:

- Insect screens, air conditioning
- Social/political breakdown.

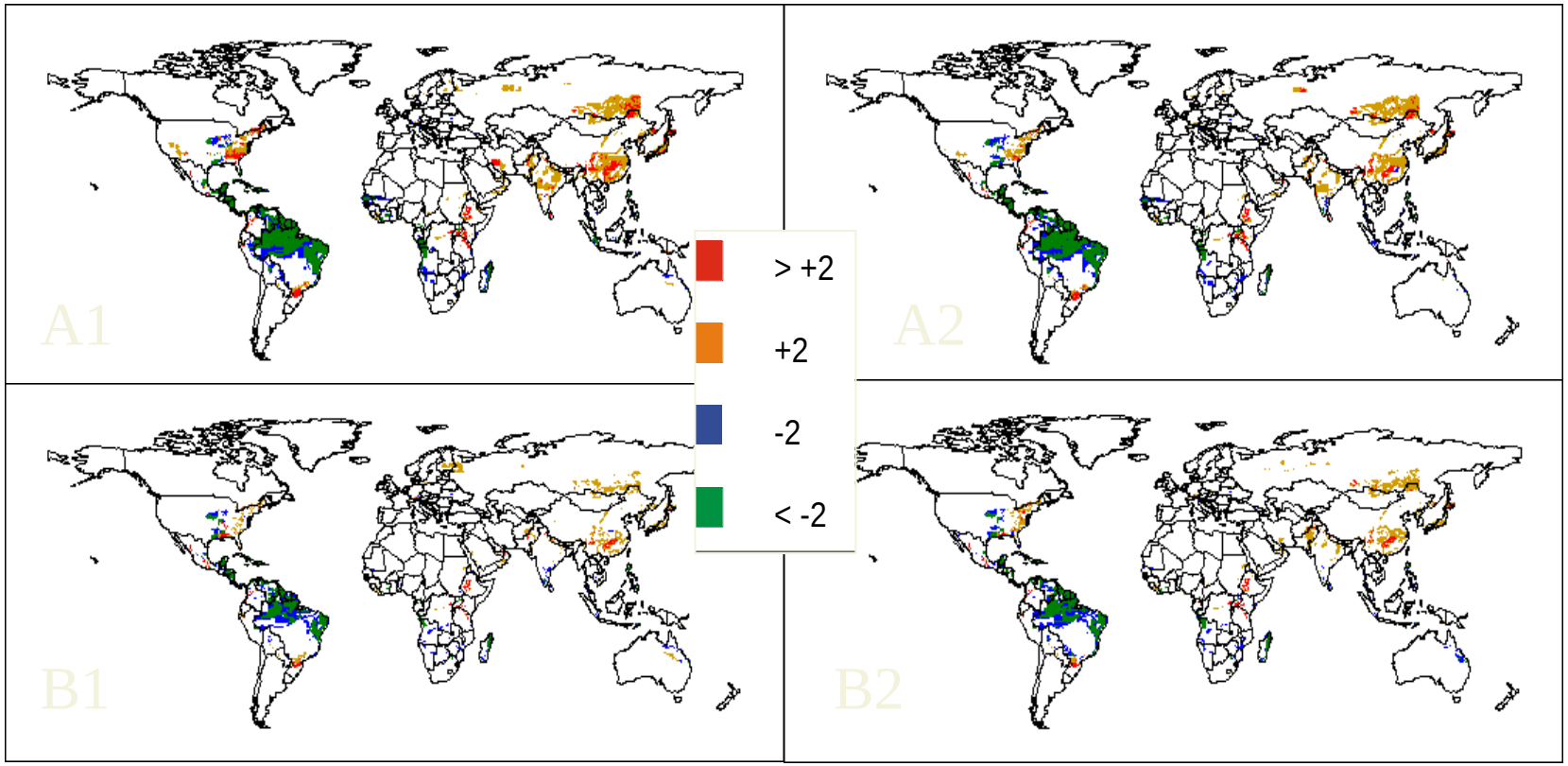
Mosquito-borne-disease: Water Management

Breeding is also influenced by:

- Water hoarding/storage:
  a) Rainwater tanks
  b) Uncovered containers
- Dams
- Irrigation
- Groundwater recharge.

Climate Change and Malaria under Different Scenarios (2080)

- Increase: East Africa, Central Asia, Russian Federation
- Decrease: Central America, Amazon [within current vector limits.



FOOD SECURITY

Food Production: Land

Land based agriculture:

- Food production, loss of soil fertility, erosion and salinization:
  - Changes in crop yields and protein levels (+/-)
  - Effects on feed intakes and animal reproduction
  - Changes to pests, weeds and diseases
  - Changes to use of agrochemicals
- Dietary and nutritional changes

Food Production: Fisheries

Oceanic and coastal fisheries:

- A change in coastal circulation patterns can affect:
  - Nutrient supply
  - Lagoon flushing
  - Coastal erosion
  - Ocean acidity and coral bleaching
  - Decline in productivity.

Screening the Theoretical Range of Response Options – Malaria

Theoretical Range of Choice	Technically feasible?	Effective?	Environmentally acceptable?	Financially Feasible?	Socially and Legally Acceptable?	Closed/Open (Practical Range of Choice)
Improved public health infrastructure	Yes	Low	Yes	Sometimes	Yes	Open
Forecasting & early warning systems	Yes	Medium	Yes	Often	Yes	Open
Public information & education	Yes	Low	Yes	Yes	Yes	Open
Control of vector breeding sites	Yes	Yes	Spraying - no	Yes	Sometimes	Open
Impregnated bed nets	Yes	Yes	Yes	Yes	Yes	Open
Prophylaxis	Yes	Yes	Yes	Only for the few	Yes	Closed for many
Vaccination	No					Closed

Source: Ebi and Burton, 2008

Where are we?

Since pre-industrial times, human activities have caused approximately 1.0°C of global warming.

- Already seeing consequences for people, nature and livelihoods
- At current rate, would reach 1.5°C between 2030 and 2052
- Past emissions alone do not commit the world to 1.5°C