Index

1. Climate change and its causes

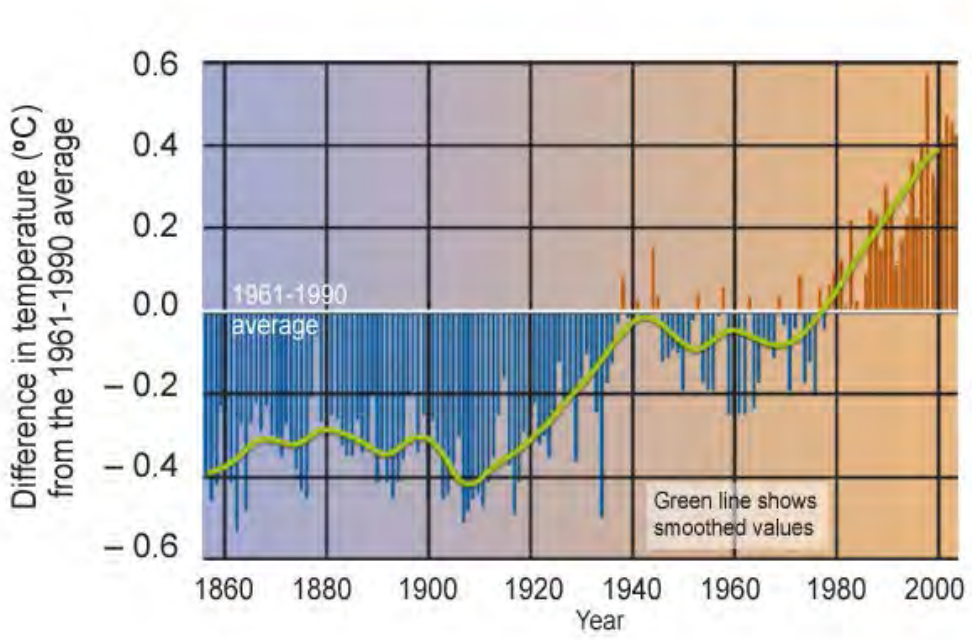
Climate change is on a variety of scales:

1. Short-term change

   Climate over the last few decades - hundred years e.g.El Nino, La Nina (very short)

2. Medium-term change

   Global climate over billions of years



3. Long-term change

   Climates from thousands / millions of years ago

Evidence for past climatic change

Climate varies on all time scales from the short –term *(the recent retreat of glaciers)* to the long-term *(deposition of desert sediments to form sandstone)* in response to random and periodic **forcing factors**.

Some of these could be due to short-term changes e.g. random variations ***(noise)*** in the climatic systems.

Present day ice limit

Extent of glacier retreat in little over 50 years

Ice limit in 1946

Past Climates

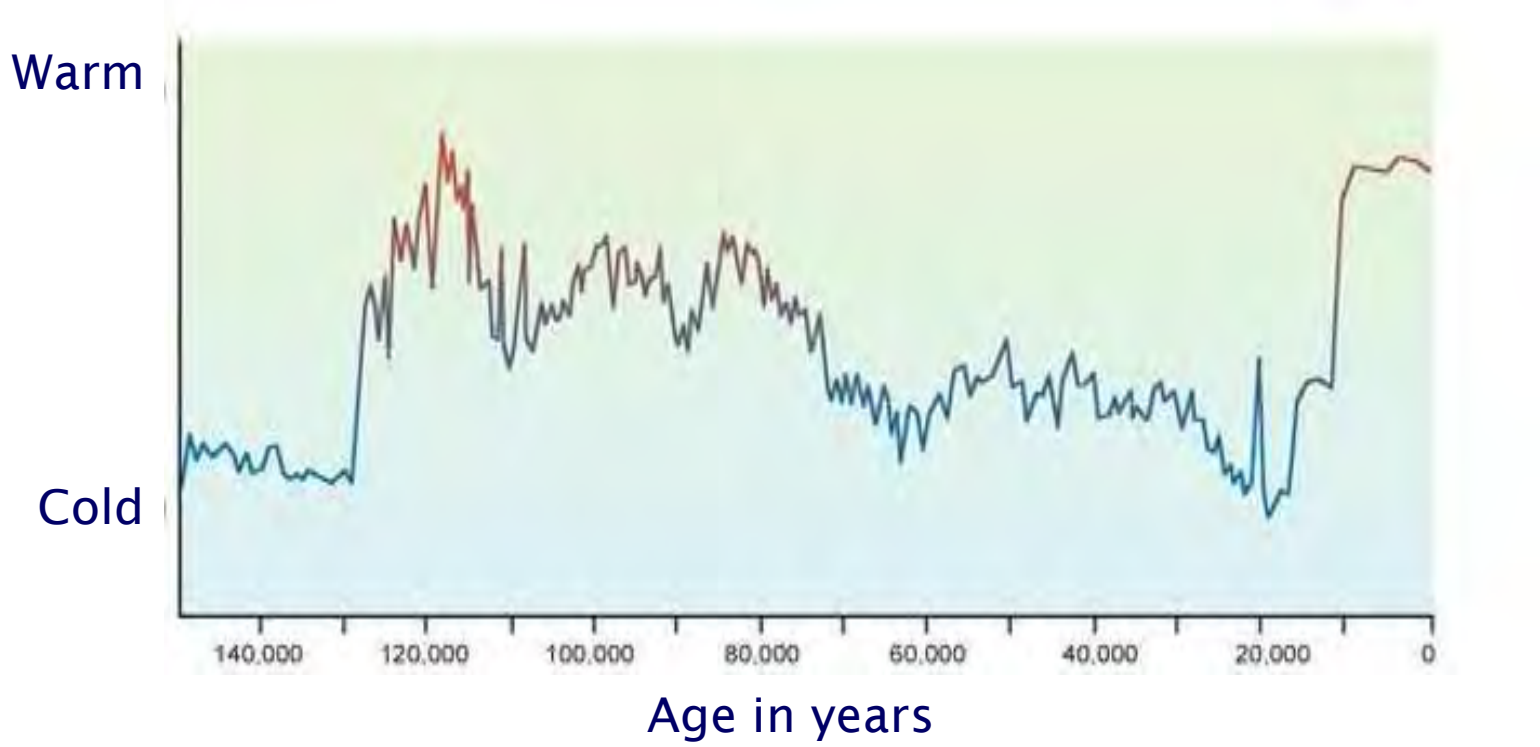
What was the climate like 740,000 years ago?

- Scientists extracted an Antarctic ice core 3000m long
- This represents 740,000 years of snow, with each year preserved like an annual growth ring in a tree.
- By analysing the gases in each year's deposit we can tell how much CO_2 there was in the atmosphere in that year
- Isotopes trapped in the ice can be used to calculate the atmospheric temperature for each year

Past Climates

Conclusions:

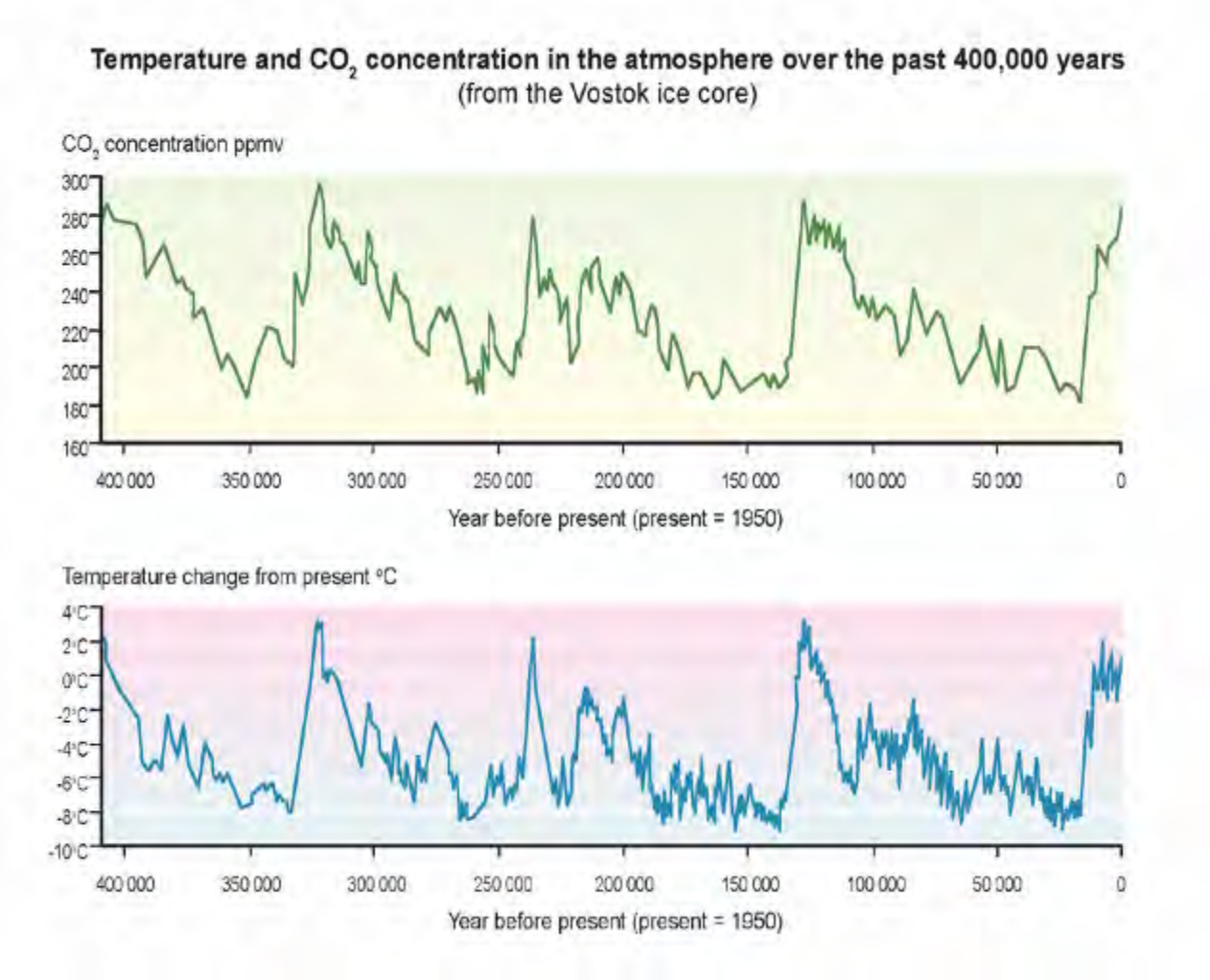
- There have been 8 ice ages and 8 warm periods over the last 740,000 years



Past Climates

Conclusions:

- Carbon dioxide and methane levels are now the highest they have been for 440,000 years
- There is a close match between CO_2 and air temperature



What are the reasons for past climatic changes?

Variations in input

- variations in the Earth's orbit around the Sun
- variations in solar radiation

Variations in atmosphere

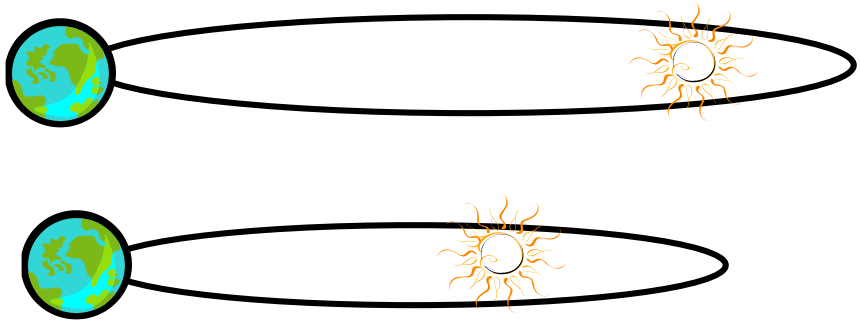
- volcanic activity
- meteorite impact
- changes in atmospheric composition

Paleoclimates

It has been suggested that Ice Ages have resulted from changes in Earth's orbit around the Sun.

Orbital changes occur over thousands of years, and the climate system may also take thousands of years to respond to orbital forcing.

Milankovitch has suggested that this cycle, termed the **eccentricity cycle**, occurs over a period of 100,000 years



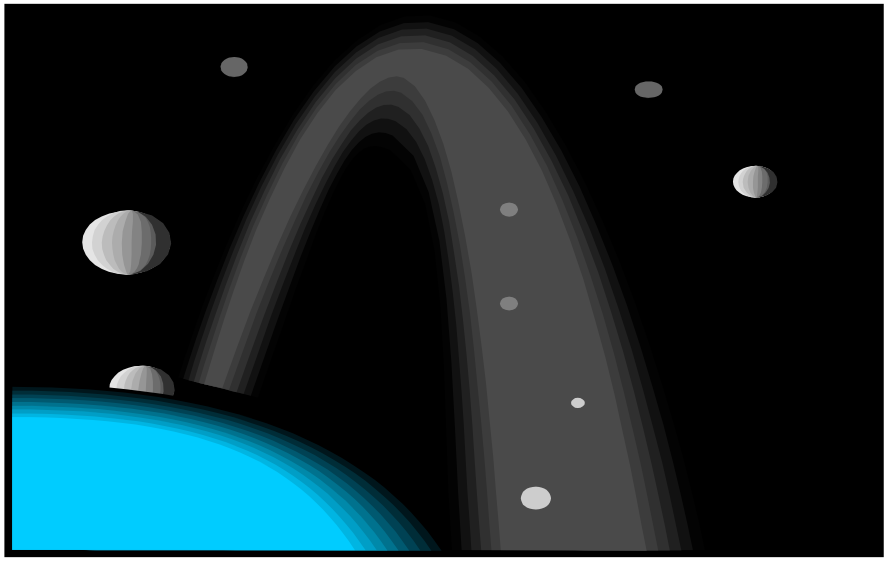
Other possible natural causes which could contribute to warming:

- variations in the Earth's orbit around the Sun
- variations in solar radiation
- volcanic activity
- meteorite impact
- changes in atmospheric composition

Natural causes of climate change

In 2006, a Russian scientist, Shaidurov, suggested that it was not the industrial revolution that caused the rise in temperature, but the effects of a meteorite on noctilucent clouds *(high atmosphere clouds thought to be composed of small ice-coated particles)* in the mesosphere.

The Tunguska meteorite exploded 8 km above the Tunguska River in Siberia in 1908. It released energy equivalent to that of a 15 megaton nuclear explosion.



Asteroid and meteorite activity may have been responsible for past climatic changes; for example farming areas scattered about the Sahara and the Dead Sea became deserts around 2350BC.

Evidence for past climatic change

Past sea levels

The ice ages brought **eustatic** change. Sea levels fell as huge volumes of water were transferred to glaciers and ice caps. Subsequent melting then causes an increase in sea level - **glacio-eustatic** change

Measuring sea level change

One or more of the following features can be used.

1. Shoreline deposits such as shells, wood and peat found in marine cores.
2. Exposed rock outcrops containing marine fossils.
3. Vegetated tidal flats above the high water mark.
4. Exposed coral reefs.
5. Marine rocks displaying evidence of wind-borne erosion

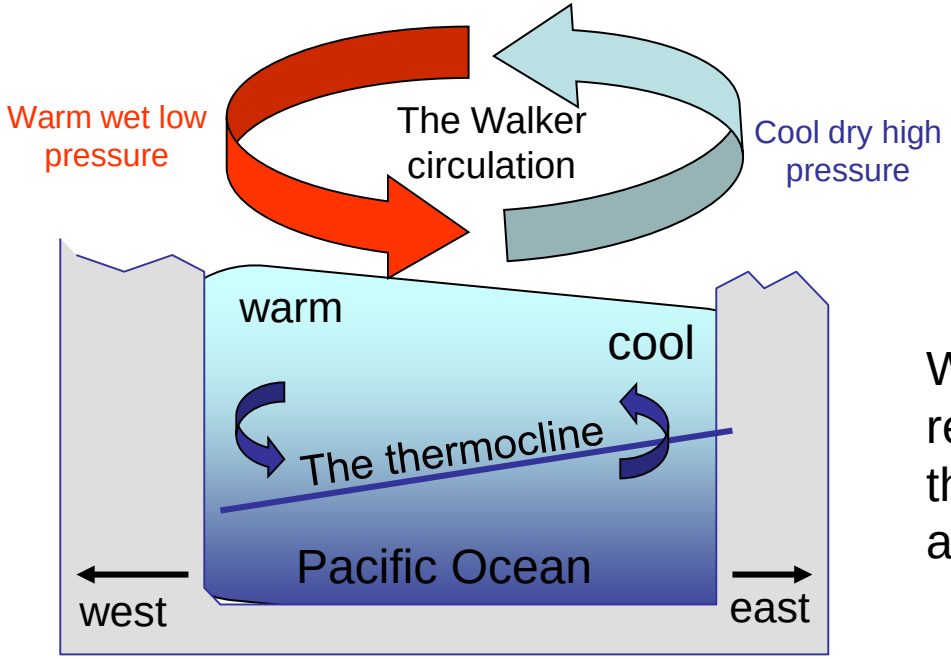
Past sea levels were up to 200m above present during interglacials and 100 -150m below present during glacials.

Other techniques include studying glacial advances/retreat, ice cores, isotope analysis, geology, pollen, dendrochronology and archaeological/historical data.

Short-term climate change - El Nino

El Nino is a shift in ocean temperatures and atmospheric conditions in the tropical Pacific that disrupts weather around the world.

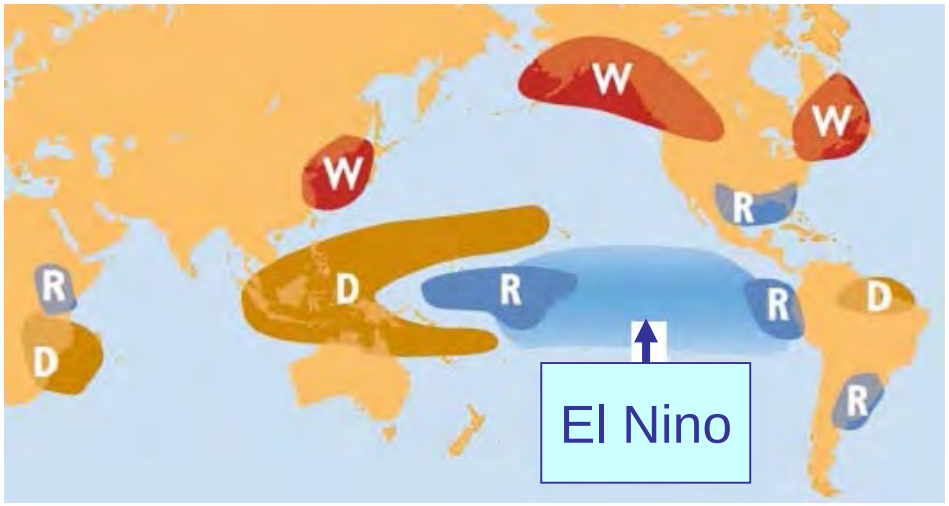
Its effect in the atmosphere, called the Southern Oscillation (SO), leads to the phenomenon being fully termed the ENSO *(El Nino Southern Oscillation).*



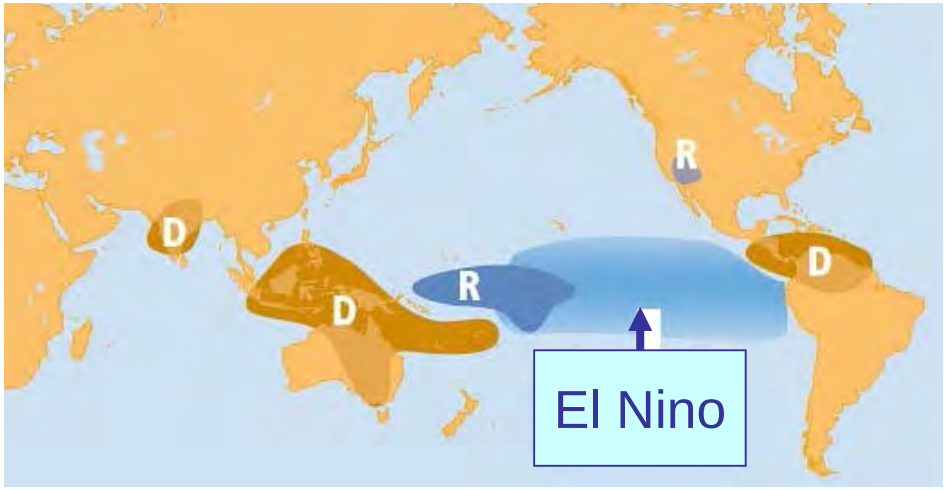
This diagram shows the **usual** situation

When the Walker circulation weakens or reverses, an El Nino results, causing the ocean surface to be warmer than average.

El Nino - The effects



October - March



April - September

What do W, D and R stand for on the maps?

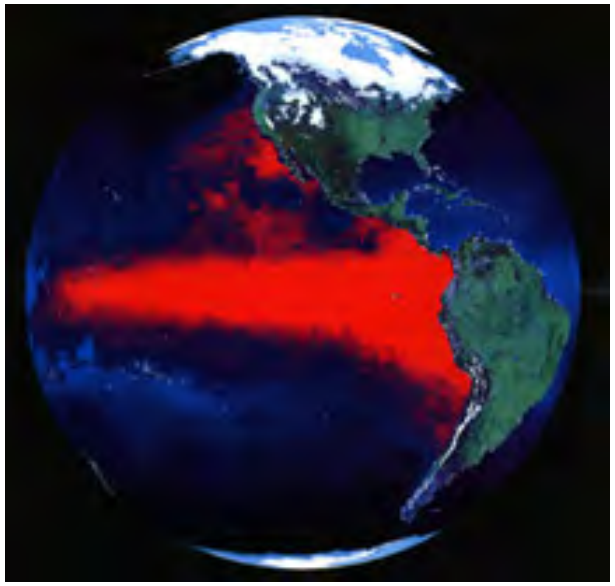
W = undue warmth

R = undue rainfall

D = undue drought

The 1982/83 El Niño, the strongest of the twentieth century, is estimated to have caused more than US$10 billion in weather-related damage worldwide.

El Nino



NOAA's satellite view of El Niño, 1997-8

El Nino is not totally predictable but on average occurs once every four years. It usually lasts for about 18 months after it begins

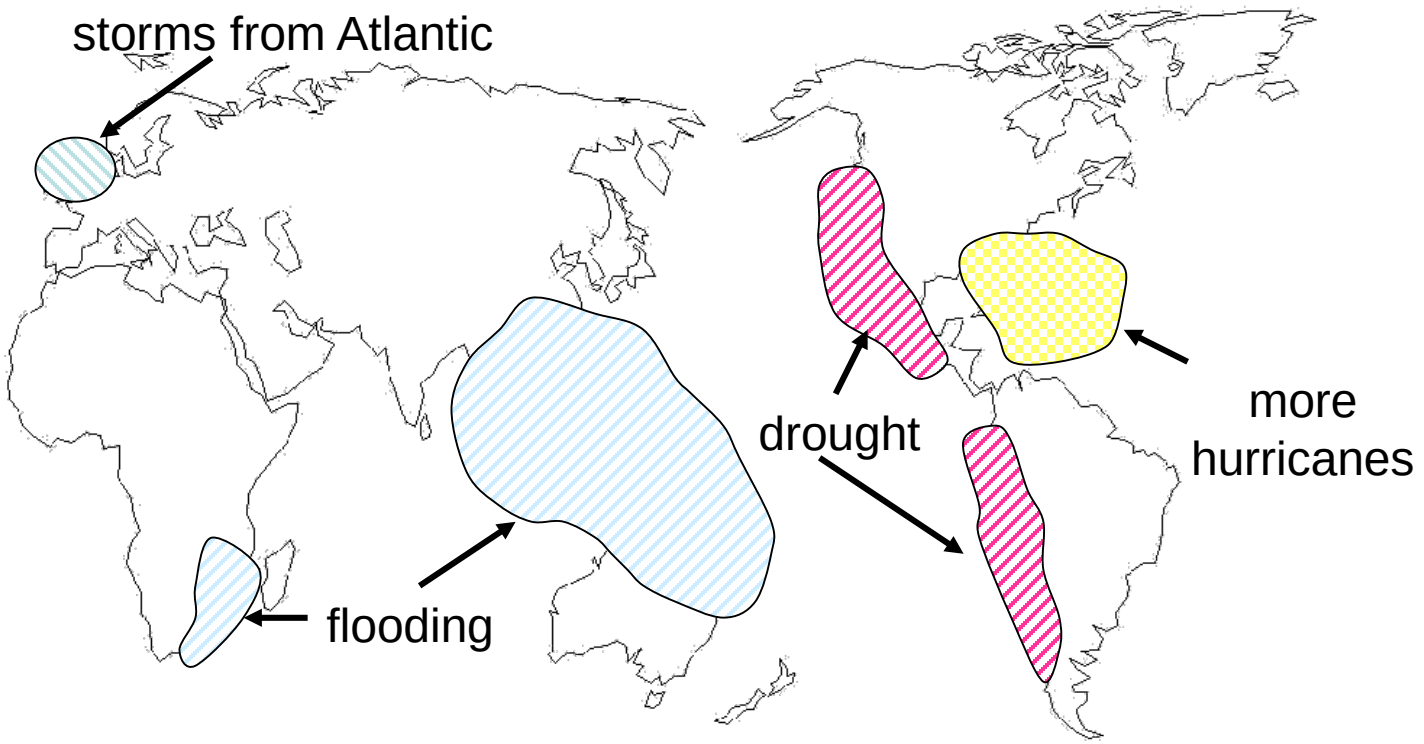
U.S. hurricane damage is affected by the phase of ENSO, with increased losses during **La Niña** events and reduced losses during El Niño events.

Number of damaging events that exceed certain thresholds by phase of the ENSO cycle, shown as years and percentages			
	La Nina	**Neutral**	**El Nino**
> $1 billion	77%	48%	32%
>$5 billion	36%	28%	14%
>$10 billion	18%	21%	14%

La Nina

La Nina is characterised by unusually cold ocean temperatures in the Equatorial Pacific, compared to El Nino, which is characterised by unusually warm ocean temperatures in the Equatorial Pacific.

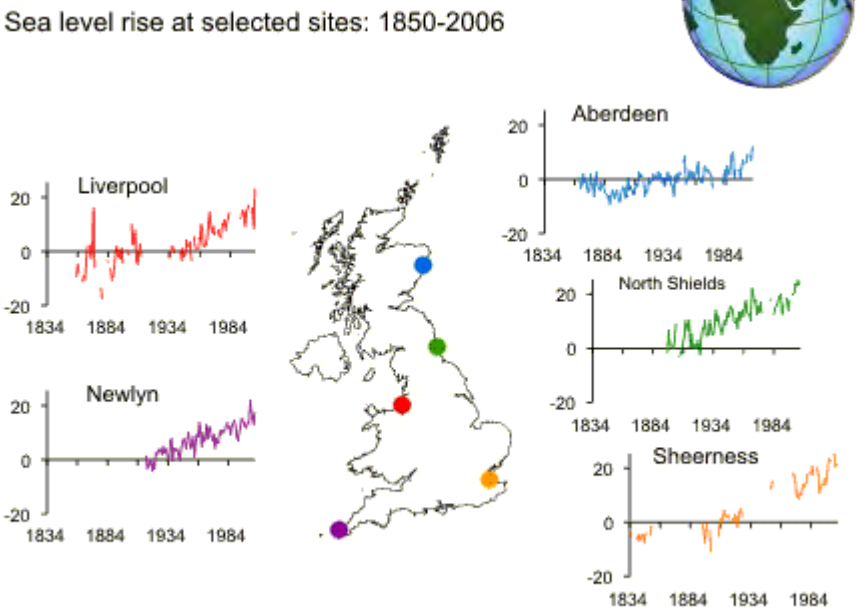
In general, La Nina events tend to cause less widespread weather extremes than El Nino.



Possible La Nina effects

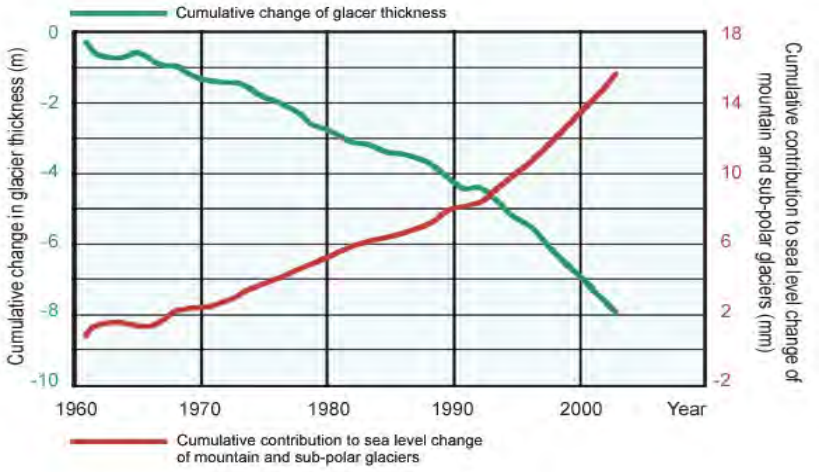
Evidence for recent global warming

1. Temperatures have risen by up to 1ºC globally in the last 150 years.
2. Greenhouse gases such as CFC's and CO_2 have increased significantly in this period and particularly in the last 50 years.
3. Extreme weather events are increasing in frequency outside of the *normal* trends.
4. Sea levels are rising at a rate of approximately 0.2m per century.



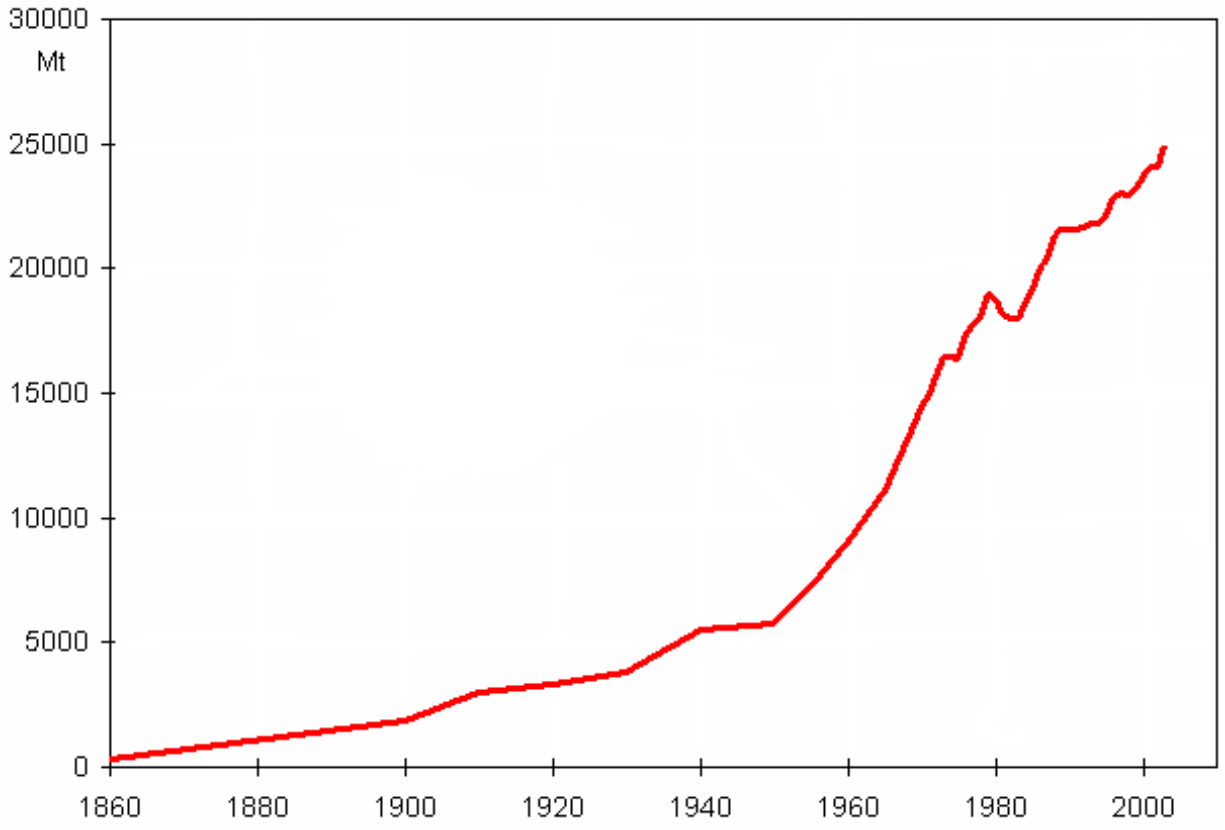
What is the main cause of rising sea-levels?

Thermal expansion. As the temperature of the oceans increase the water expands (and therefore takes up more space) due to the heat. The melting ice sheets are not yet that significant.



Global warming

Carbon dioxide emissions since 1840



What have been some of the major causes of this rapid rise?

- burning of fossil fuels
- deforestation

Global warming

Most scientists agree that global warming is being caused by human effects on the atmosphere, principally through carbon dioxide emissions.

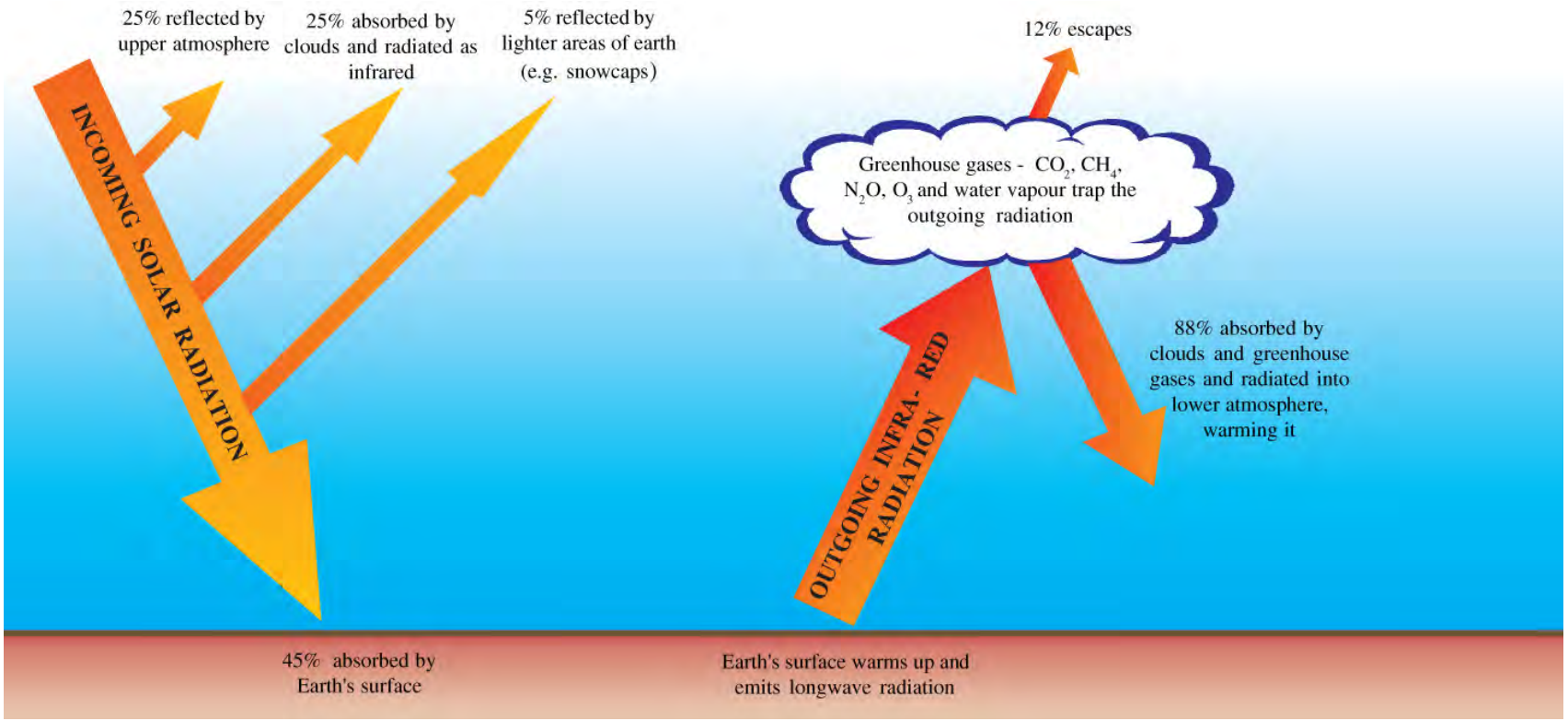
Which countries have the highest CO_2 emissions?
Rank the following (highest first) (*2004 data).*

1	Germany
2	Italy
3	UK
4	South Korea
5	Canada
6	USA
7	Japan
8	Russia
9	India
10	China

1	USA
2	China
3	Russia
4	Japan
5	India
6	Germany
7	Canada
8	UK
9	Italy
10	South Korea

Global warming – The greenhouse effect

The greenhouse effect is a natural process that is essential for life on Earth.



The enhanced greenhouse effect or *global warming* is a result of greater concentrations of greenhouse gases such as carbon dioxide, methane, nitrous oxides and CFC's being released into the atmosphere. These trap more long-wave radiation (heat) causing global atmospheric temperatures to rise.

2. The impacts of global warming

- Rising sea levels

During the 20th century, sea level rose 10-20 cm due to melting glacier ice and expansion of warmer sea water

- Melting ice caps and glaciers

The summer thickness of Arctic icebergs is about half of what it was 50 years ago.

- Severe weather events may be more common and stronger

Hurricanes & tornadoes have increased in number & scale in the last 20 years

- Sea-surface temperatures are warming

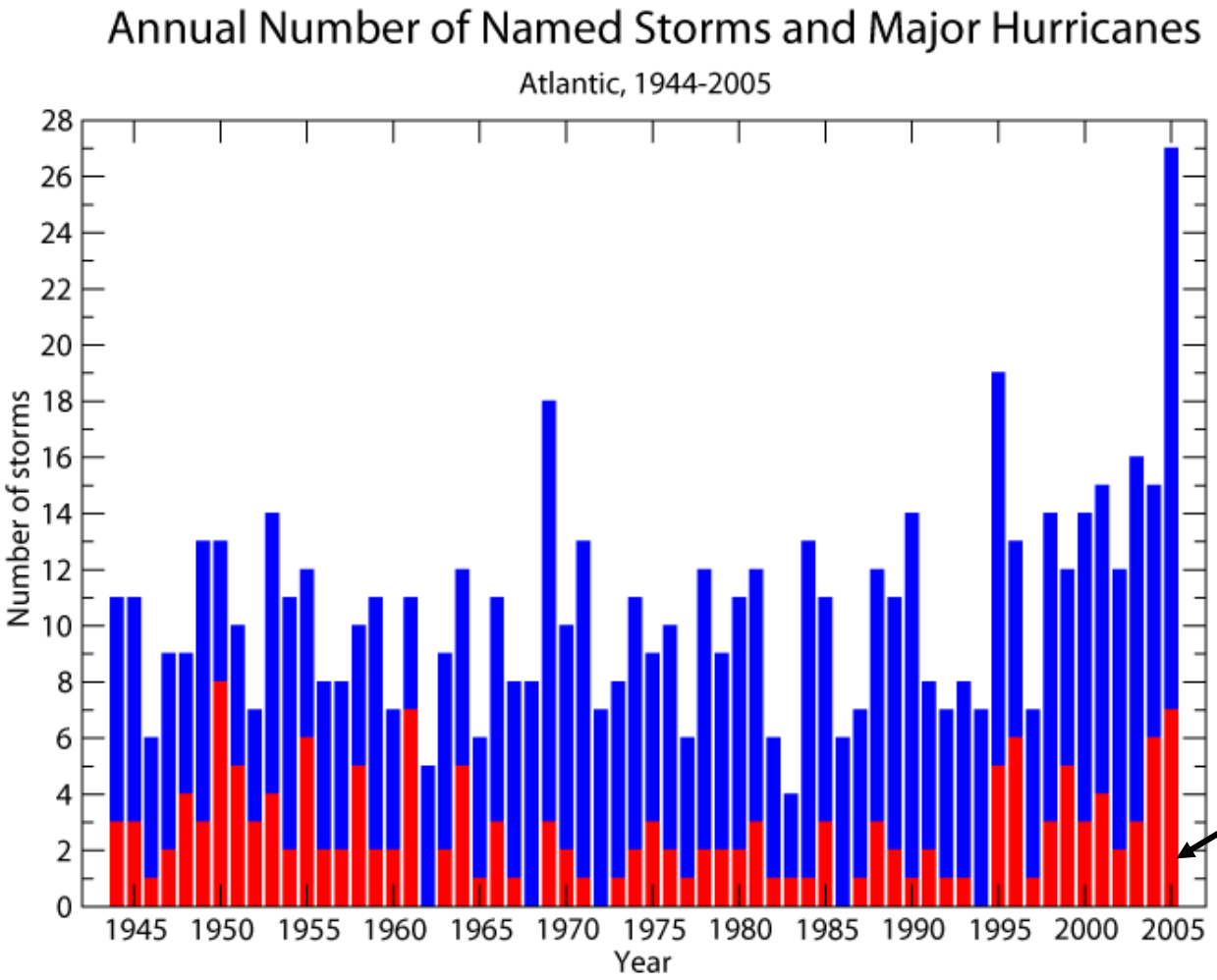
Over the past few decades, about a quarter of the world's coral reefs have died.

Devastating impact on ecosystems and populations throughout the world

LDCs hit hardest - health, food production, water supply and damage to property.

Decay and retreat of the Ross Ice Shelf

Impacts - Hurricanes



named storms

major hurricanes

2005 was the worst year on record for hurricanes

An average of 7.7 named storms and 3.6 major hurricanes since 1995 compares to 5 storms and 1.5 major hurricanes from 1970-1994.

Cause: Increasing ocean temperature?

Impacts - Disasters

The number of reported disasters rose from 1,110 to 2,742 1970 -2005.

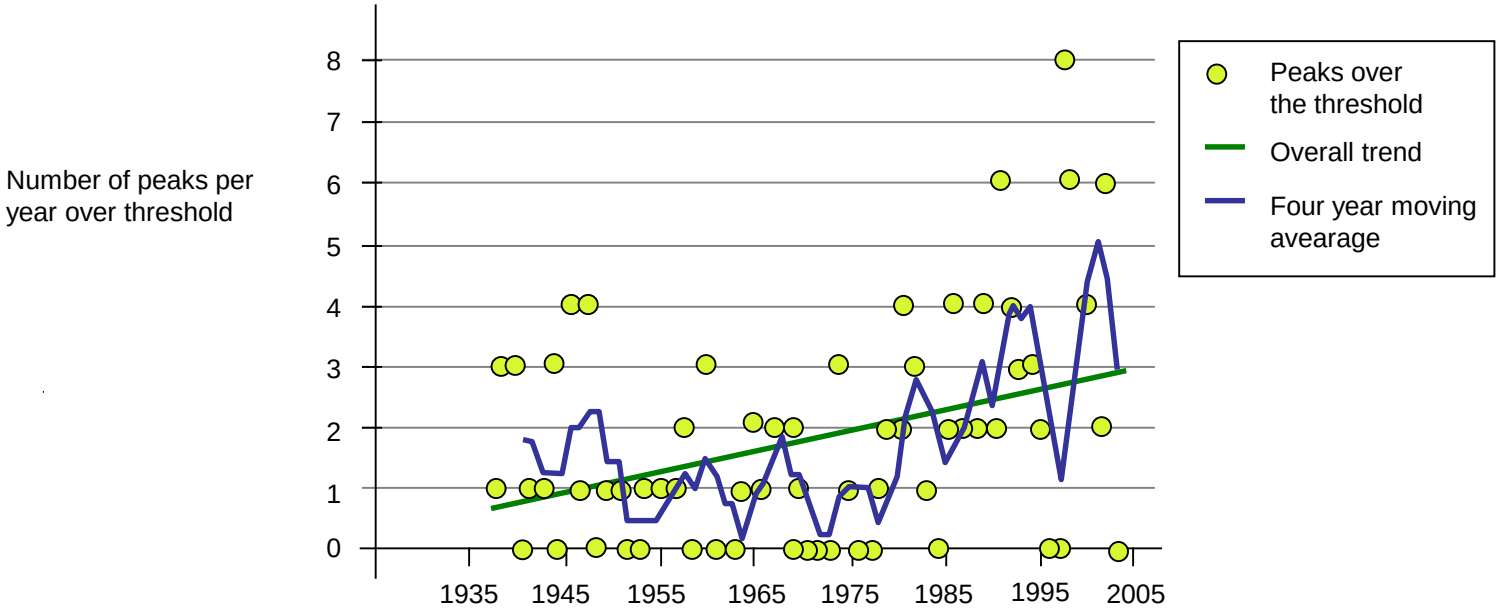
The number of people affected by disasters rose from 740 million in the 1970s to over two billion by 2005.

Flooding in Bangladesh has intensified as a result of heavier monsoon rain and rising sea levels.

Predicted Impacts – UK by 2020s

- Temperatures increase by 0.2^{o}C per decade.
- Annual precipitation over the UK as a whole is expected to increase by 5% by the 2020s and by nearly 10% by the 2050s.
- The contrast in the UK's climate is likely to become exaggerated, e.g. the currently dry SE will tend to become drier and the moist NW will get wetter.
- More storm surges, gales, intense rainfall events, flooding and extreme wind speeds, especially in the North.

Flood levels in the river Wye at Erwood, Wales



Impacts - UK

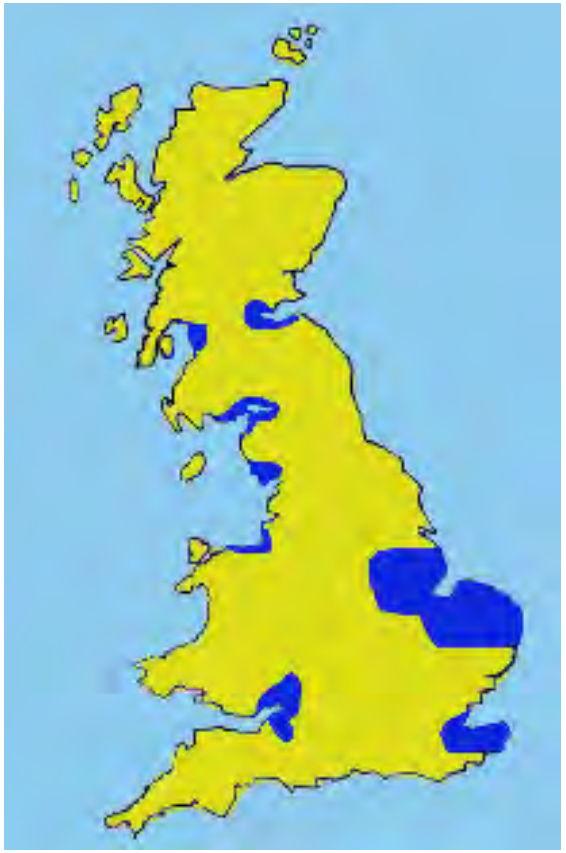
The areas shaded are < 5m above sea-level and are therefore at risk of flooding. They also contain major road and rail links as well as important strategic facilities such as power stations.

Positive effects

- increased timber yields (up to 25% by 2050s) especially the north of the UK (with perhaps some decrease in the south)
- a northward shift of farming zones by about 200-300 km per degree centigrade of warming
- enhanced potential for tourism and recreation as a result of increased temperatures/ reduced precipitation in the summer, especially in the southern UK.

Negative effects

- increased soil aridity, soil erosion and the shrinkage of clay soils
- increased animal, especially insect, species as a result of northward migration from the continent and a small decrease in the number of plant species due to the loss of northern and montane sp.
- decreased crop yields in the SE.
- increased river flow in winter/ decrease in summer, esp. in the south
- an increase in public and agricultural demand for water
- increased damage from storms, flooding and erosion
- increased incidence of infectious diseases & heat-related syndromes.



Areas at risk of flooding

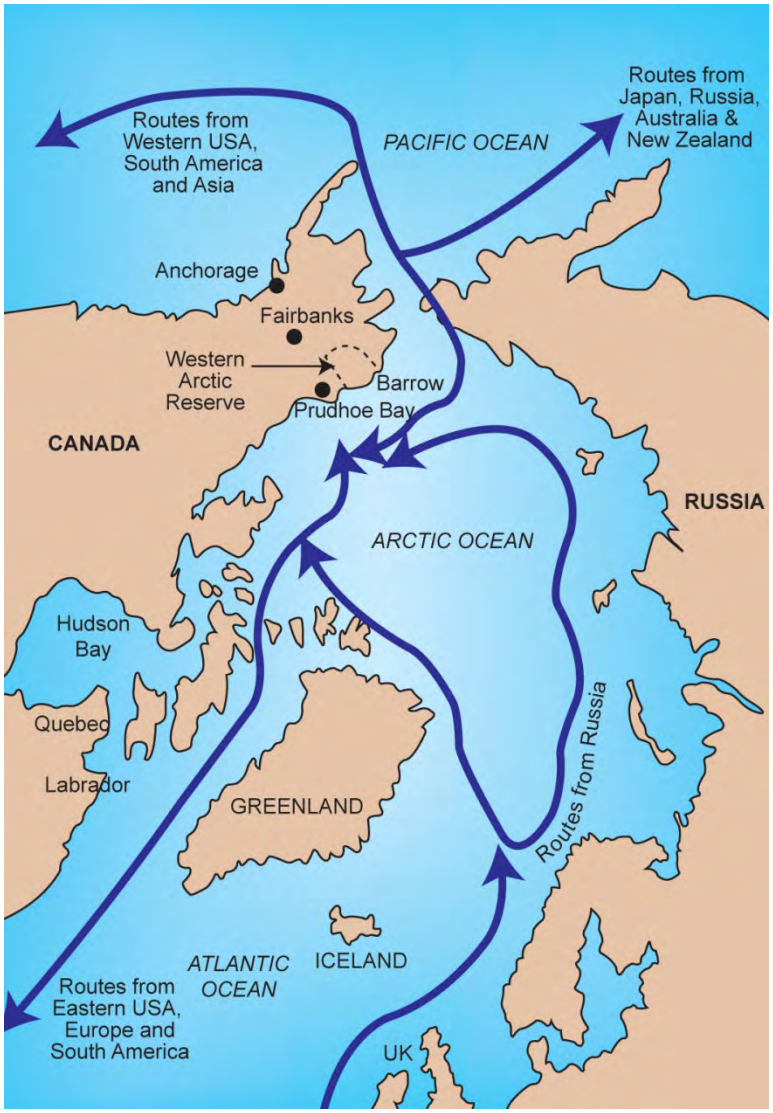
Retreating Arctic ice

As average global temperatures have risen the actual rise at the poles is higher than lower latitudes.

2007: successful navigation of the NW passage, a fabled sea route from the Atlantic to the Pacific ocean, made possible by the melting of blocking sea ice.

Between 1980-2007 the ice has retreated from 7.8mkm^2 to 4.2mkm^2

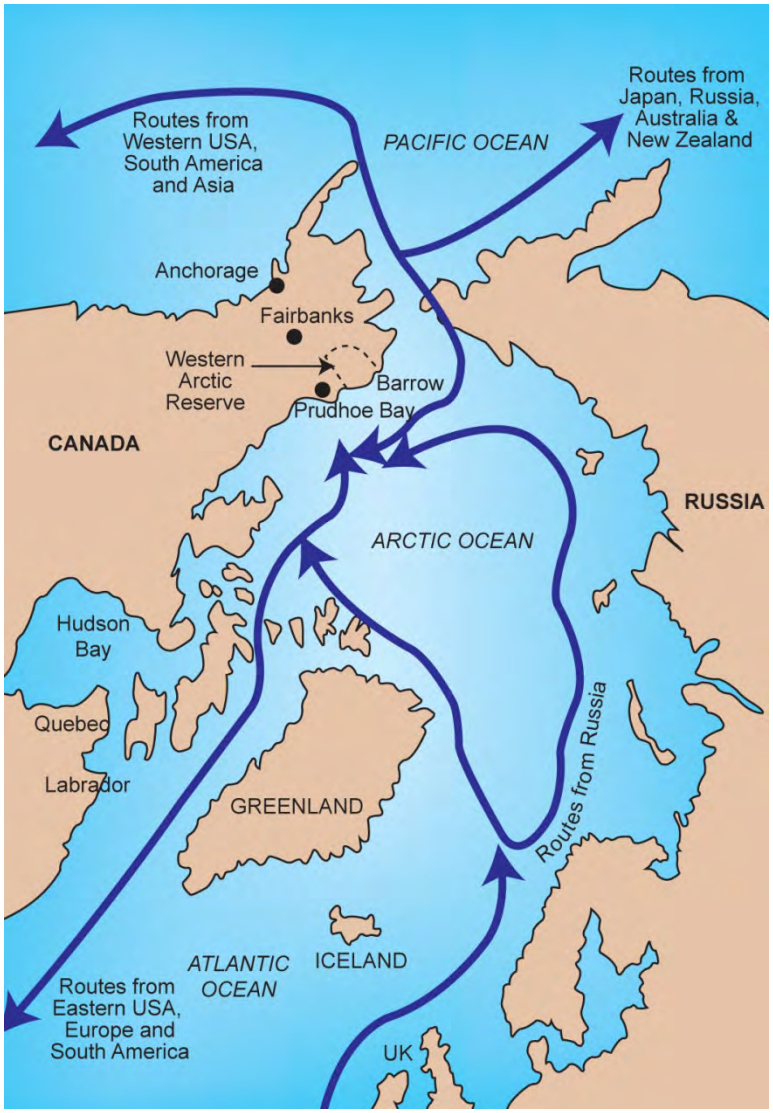
Possible sea routes



Implications

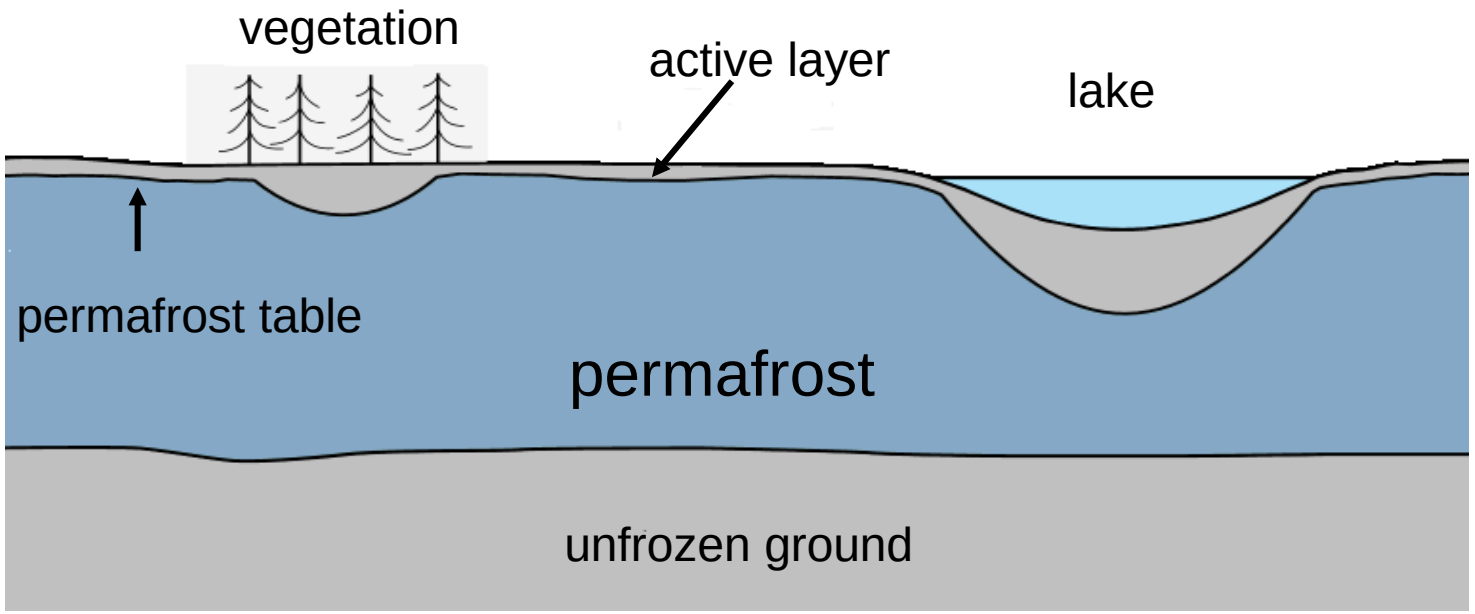
- Increased output of the Alaskan oilfields which are environmentally sensitive. Areas that were previously uneconomic could now be profitable.
- Greater exploitation of previously inaccessible fishing grounds/mineral deposits.
- Traditional Inuit hunting and fishing grounds no longer accessible due to reduction in sea ice.
- Threat to Polar bears as routes to seals on ice no longer available. Having to swim increasingly long distances. US gov. predict 2/3 of 25000 population will disappear by 2050.
- Ice shelf collapse. 20km^2 of the Ward Hunt shelf has recently broken off from Ellesmere Island. Carbon dating shows it has been in place for 3000 years.
- Permafrost thaws

Possible sea routes



Retreating Arctic ice

Periglacial conditions have affected a large proportion of the continents in recent geological time. Currently, permafrost underlies about 20% of the Earth's land surface, including about 50% of Canada.



Permafrost

Permafrost is defined as **cryotic** ground i.e. ground below <0ºC which often, but not always contains ice. As the Arctic ice retreats areas ahead of it are warmer and so the ground is subsequently frozen for shorter periods throughout the year.

Retreating Arctic ice

Annual thaw-related damage to structures and infrastructure in Alaska $35m: repair of permafrost-damaged roads is the largest component. Roads unusable for longer periods as the winter season shortens.

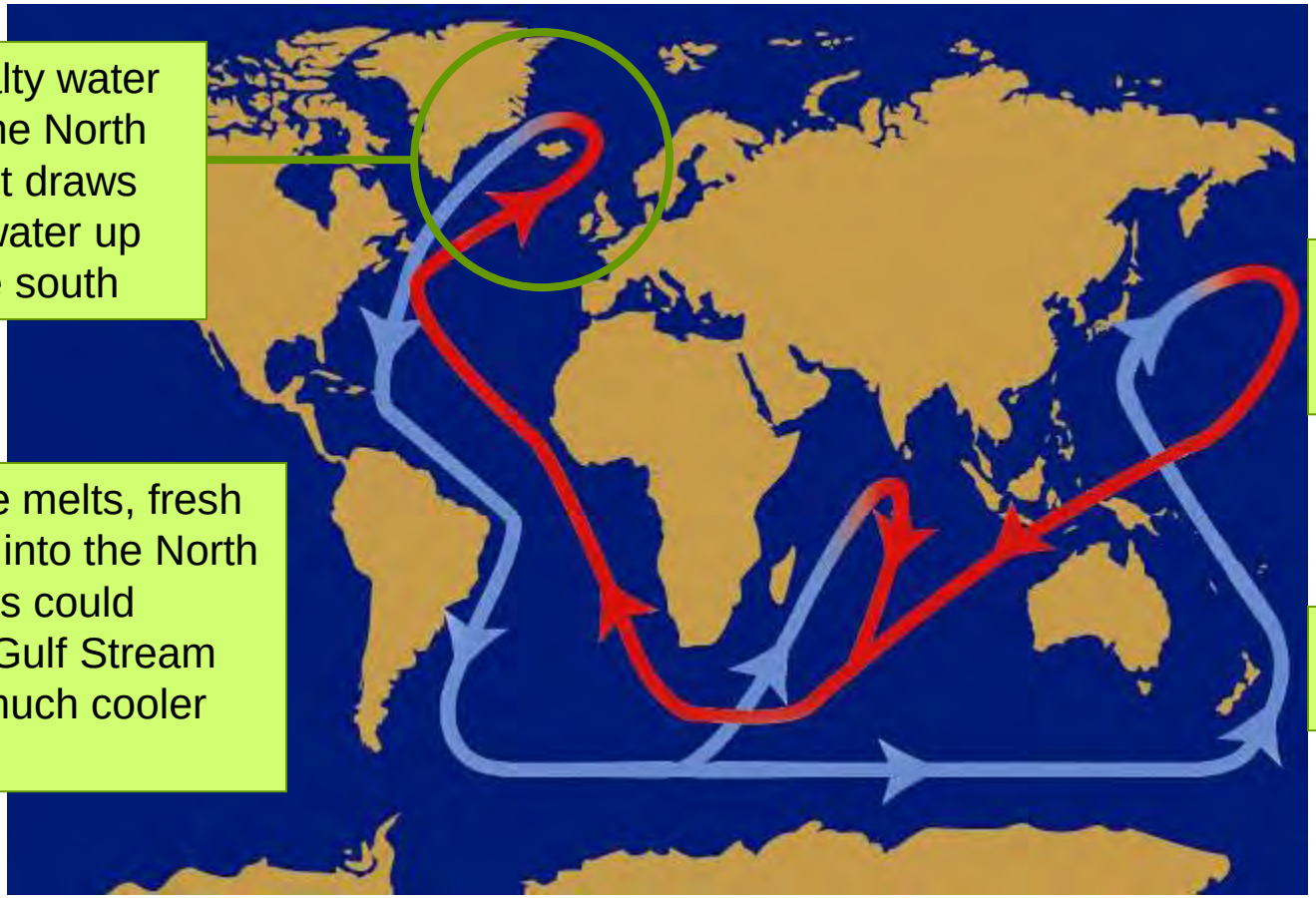
Catastrophic events caused by mudslides can destroy housing and disrupt communications

400 miles of the Trans-Alaska pipeline were elevated on piles (to keep the ground frozen), at an additional cost of $800 million.

Ocean circulation system

- These movements of air and water have huge effects upon climate and ocean productivity
- Global Climate Change may change these currents with potentially dramatic changes in the average temperatures, rainfall, agricultural productivity and fisheries productivity for many countries

As cold salty water sinks in the North Atlantic, it draws warmer water up from the south



Warm surface currents

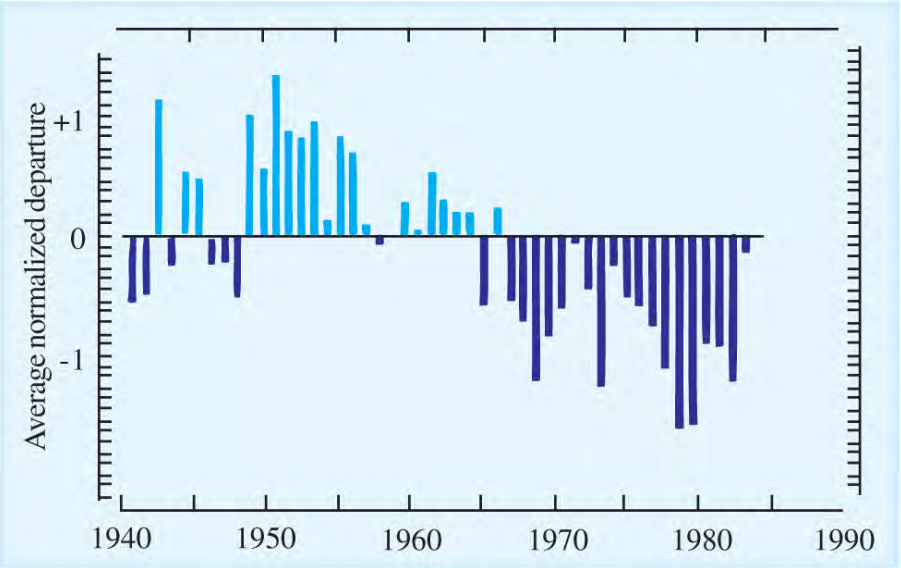
As Arctic ice melts, fresh water flows into the North Atlantic. This could disrupt the Gulf Stream leading to much cooler waters

Cold deep currents

Impacts - Africa

- The IPCC predicts that, by 2020,75-250m Africans could face water shortages.
- Increased droughts and floods
- Temperatures have risen by 0.7^{o}C over most of the land mass and rainfall has decreased over much of the Sahel region (but increased in east central Africa), contributing to the problems of desertification.
- The World Bank predicts that nations will need to spend between $10 billion-$40 billion per year just to adapt to the changes.

Rainfall trends in the Sahel 1941-84



Impacts - Africa

70% of the population is involved in rain-fed agriculture, of which 1/3 of total income is derived. 40% of all exports are agricultural.

North Atlantic Oscillation a key factor in international climate vulnerability with impacts on fisheries industries

Egypt/Cairo/The Nile: Coastal areas threatened by sea-level rise

Sudan – Desert has migrated Southwards by 100km in the last 40 years

Ethiopia – R. Boco has dried up due to lack of rainfall and over-extraction. It used to be the main source of irrigation.

Sahel expands

Horn of Africa heavily affected by recent droughts

High proportion of population concentrated in coastal areas in West African cities e.g. Lagos and Banjul, vulnerable to sea-level rise

Important commercial agriculture adapted to bimodal rainfall; shifts in rainfall patterns would have huge impacts

Regional climate modelling experiments show deforestation in Central Africa will impact climate in distant south (teleconnections)

Change storage in East Africa lakes and reservoirs

Rwanda – in the Bugasera region yields are down by 40%.

Coastal marine fishery likely to be negatively affected by changes in Bangwuela current

Burundi – 2m people (25% pop.) affected by 2007 floods require assistance. This follows drought in 2006. Most people already exist on $1 per day.

Complete loss or displacement of Succulent Karpo biome

Diseases such as cholera and Rift Valley fever have reappeared

Intensity of extreme events increased significantly over South Africa; biome shifts will favour horticulture over plantation forestry; malaria expands southward

Floods in 1999 severely affected coastal population and infrastructure

Impacts – Eustatic rise in sea level

More than 60% of the global population lives on or within 60km of the coast.

Areas threatened by rising sea level

1. Gulf and Atlantic coast, Mexico and United States
2. Orinoco delta
3. Amazon delta
4. Gulf of La Plata, Argentina
5. Southern and eastern England
6. Northern Germany, The Netherlands, Belgium and France
7. Guadalquavir delta, Spain
8. Ebro delta, Spain
9. Northern Adriatic from Rimini to Venice and Grado
10. Danube delta, Romania
11. North-east Tunisia
12. Nile delta
13. Nigerian delta and coast
14. Zambezi delta
15. Ganges-Brahmaputra delta
16. Eastern Sumatra
17. Northern Java

Impacts - Bangladesh

- Bangladesh is very densely populated.
- Many fresh water fishing resources are under threat.
- Fishing generates substantial income and any intrusion of salt water would disrupt the economy.
- Storm surges are also a threat; cyclonic storms occur frequently and with devastating effects.

Sea level threats to Bangladesh

	1m (2050)	3m (2100)
Bangladesh		
Total sea level rise	0.83m	3.4m
(Global)	(0.13m)	(2.2m)
(Local subsidence)	(0.70m)	(1.2m)
Loss of habitable land	7%	26%
Population	5%	27%
GDP	5%	20%

Impacts of global climate change: Summary

Melting glaciers & thermal expansion →
↑mean sea level → ↑flood risk
↘ ↑coastal erosion
↑threat of extinction,
e.g. Arctic polar bear

↑t° →
↓rainfall →
↓crops yields in Africa

↑CO_2 →
↑t° → ↑ Incidence of vector-borne diseases, e.g. malaria & dengue fever

↑Bleaching of coral reefs → disruption of food chains + ↓fishery productivity

Positive feedback
↑CO_2 →↑ t° →↓ rainfall → drying of Amazon →
↓ biodiversity
↓ forest cover

Global climate change

△Wind patterns →
△Ocean currents →
△Ocean productivity

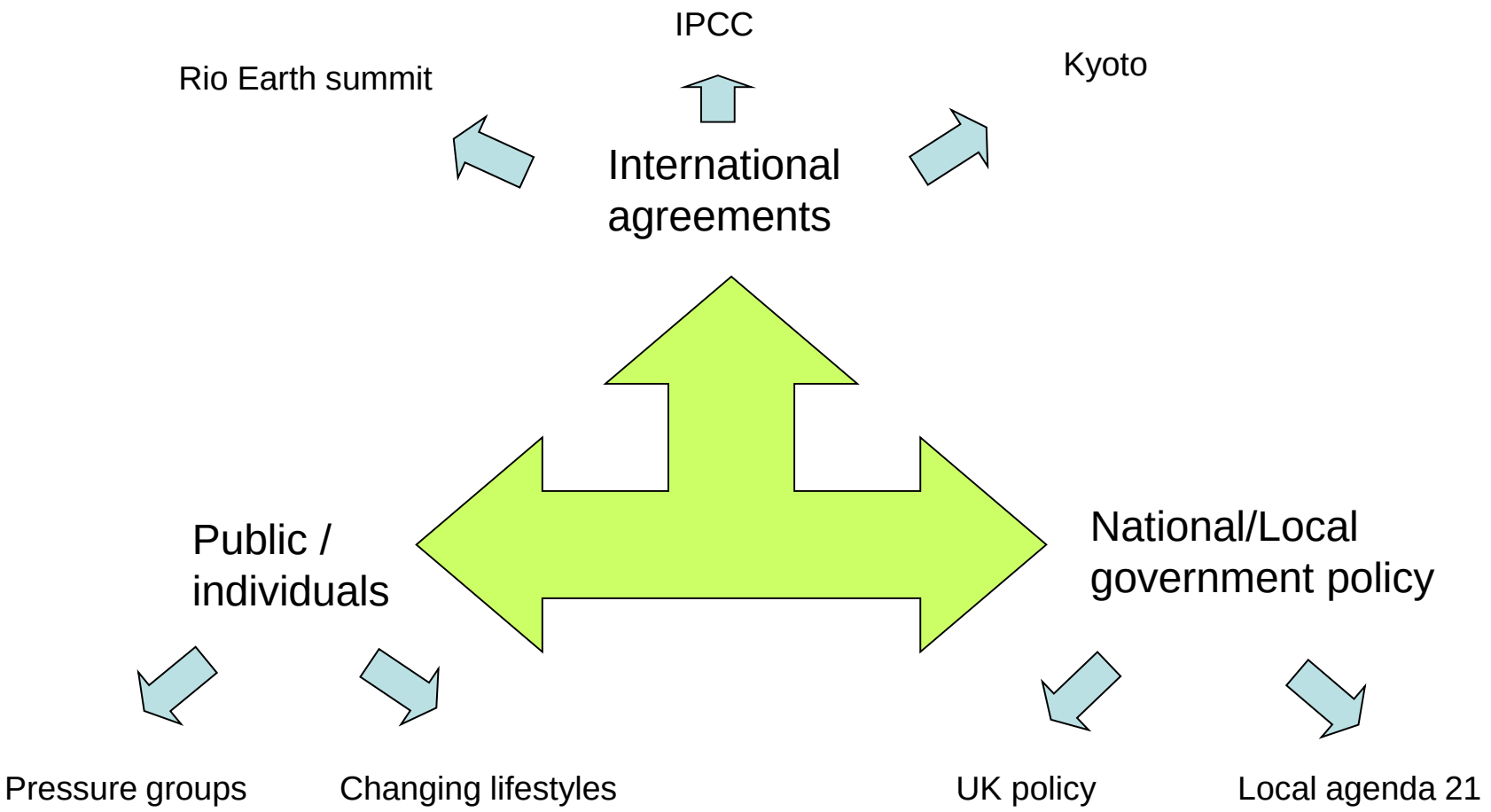
↑t° → ↑N migration of insects, plants & bird species

↑ t° → ↑ crops yields in some temperate areas

↗↓Ability of organisms to form $CaCO_3$ shells
↑CO_2 → ↓pH oceans →↓ phytoplankton → ↓ fish stocks
↘ damage to other food chains

Key:
↑ Increasing
↓ Decreasing
t° Temperature
△ Changing

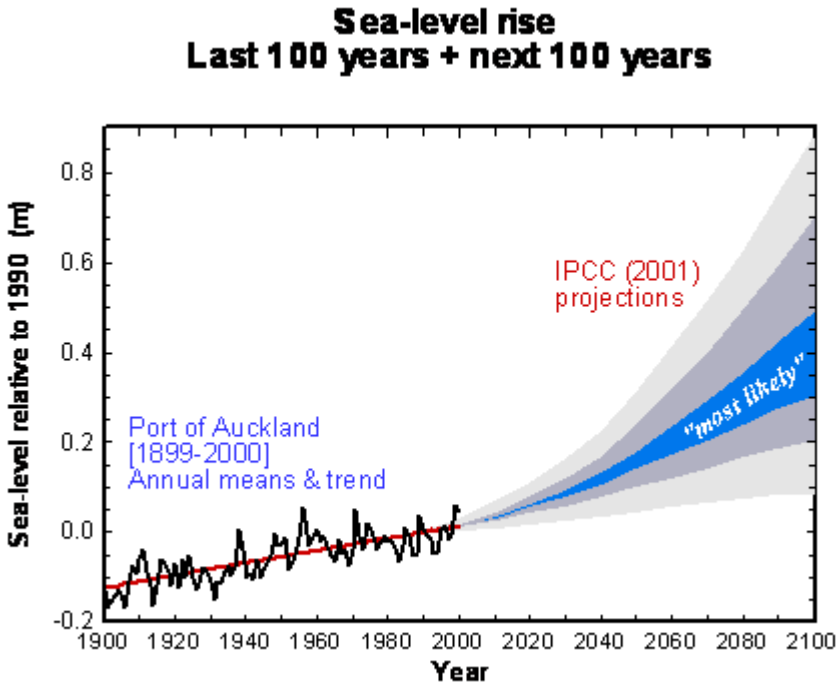
3. Coping with climate change



Coping with climate change – IPCC

The **Intergovernmental Panel on Climate Change** (IPCC) was set up to assess date on climate change and the impact on the planet. IPCC carries out the following activities:

- Remote observation of the atmosphere at surface and troposphere level
- Monitoring and measuring ocean temperatures
- Monitoring and measuring greenhouse gas levels in the atmosphere
- Monitoring sea-level rise and glacial and ice sheet retreat



The IPCC make predictions about temperature increases, sea level increases etc. But there are huge uncertainties e.g. ghg emissions, negative and positive feedback loops etc.

Coping with climate change – Earth summit

1992 Rio de Janeiro (Rio Earth Summit) attracted more than 30,000 people and over 100 heads of state. The aim of the conference was to address the growing global environmental problems and to agree major treaties on climate change, forest management and bio-diversity.

Key principles agreed:

- Development today must not threaten the needs of present and future generations.
- Nations have the right to exploit their own resources, but without causing environmental damage beyond their borders.
- Environmental protection shall constitute an integral part of the development process.
- The polluter should, in principle, pay for the cost of pollution.

A key outcome was **The Framework Convention on Climate Change.**

Coping with climate change – Kyoto Protocol

In 2005 the 1997 Kyoto Protocol became international law. Industrialised nations who sign the treaty are legally bound to reduce worldwide emissions of six greenhouse gases by an average of 5.2% below their 1990 levels by the period 2008-2012.

The USA (the largest polluter) remains the only developed nation not to have signed the treaty

Each country has developed its own strategies to meet the targets. The EU has created a market where 12,000 factories and power stations are given a carbon dioxide quota. If they use more than this amount they can purchase extra allowances or pay a fine. If they use below their quota they can trade the remaining credits.

Kyoto Protocol

- An international agreement to reduce emissions of carbon dioxide and other greenhouse gases
- Countries which sign agree to reduce their greenhouse gas emissions
- Gases covered include CO_2, CH_4, N_2O, HFCs, PFCs, SF_6

Coping with climate change – Kyoto Protocol

1. **Emissions trading**
   - Each country puts a 'cap' (an upper limit) – on CO_2 emissions from large industries
   - Any industry/country unable to stay within their designated can buy emissions credits from a company that is well within its limit
     - e.g. Cap = 20Mt CO_2/yr
     - **Country 1** gets its emissions down to 24 Mt CO_2/yr
     - **Country 2** gets its 16 Mt CO_2/yr
     - **Country 1** buys 4 Mt of credits from **Country 2** (or pays a fine)
   - The scheme tries to ensure that reductions are made at the least cost
2. **Joint Implementation**
   - Country A can help country B reduce its emissions and claim some of the reduction as it's own
3. **Joint fulfillment**
   - EU countries can add up their total targets and re-allocate them so that countries that are going to find it difficult can be helped out by another country doing more
4. **Clean development mechanism**
   - Signatories can help any other country anywhere (even non-signatories) to reduce emissions and claim the reductions as their own

Coping with climate change – NGOs

Friends of the Earth – www.foe.co.uk

The Climate Group – www.theclimategroup.org

The Carbon Trust – www.thecarbontrust.co.uk

Greenpeace – www.greenpeace.org

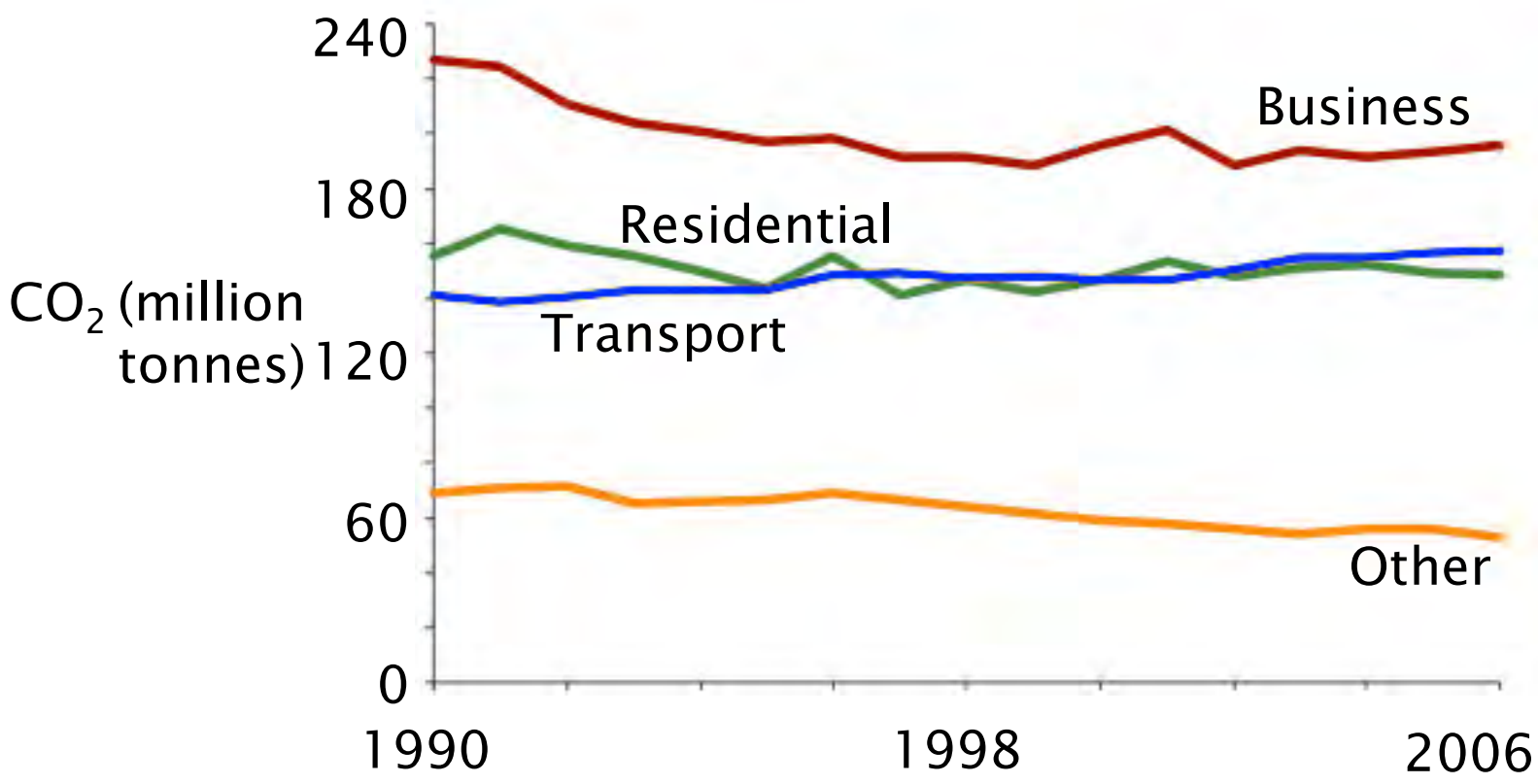
The Global Climate Coalition (guided USA against Kyoto) - www.globalclimate.org

World Wildlife Fund – www.wwf.org.uk

Coping with Climate Change – UK Policy

UK progress

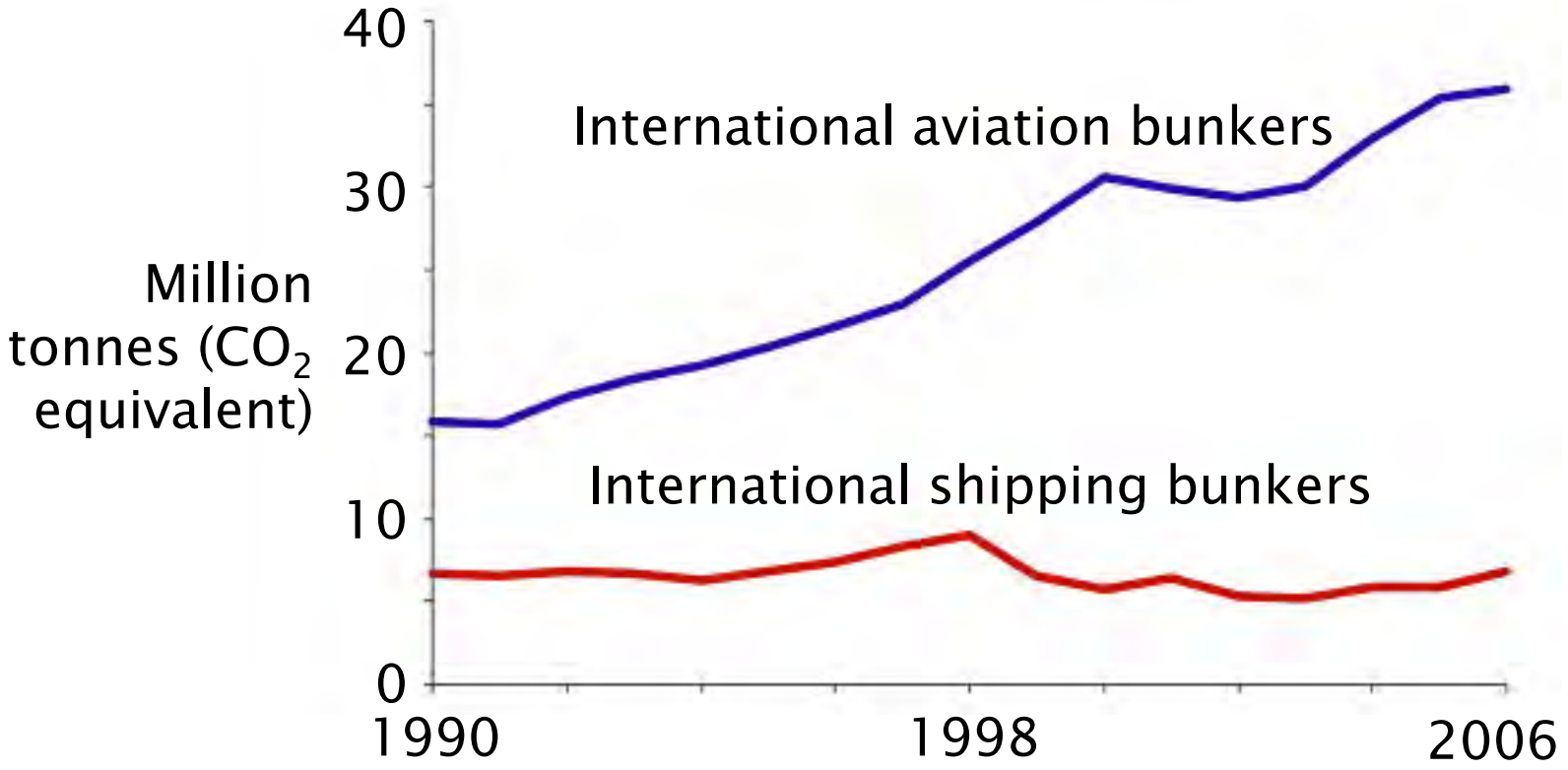
- CO_2 emissions from industry, domestic, transport sectors (excluding international aviation and shipping) 1990 to 2005



Coping with Climate Change – UK Policy

But the UK government exclude emissions from aviation – the fastest growing source, and from shipping!

Greenhouse gases from UK-based international aviation and shipping fuel bunkers 1990 to 2006:



Tackling climate change – UK policy

- The **UK Energy White Paper** 2003: “energy, the environment and economic growth are properly and sustainably integrated”. Tony Blair pledged the UK government would cut emissions by 60% by 2050. But by 2004, according to Friends of the Earth, the “sad reality” was the UK had not progressed since 1997, being only one fifth of 1% lower in carbon dioxide emissions than when Labour came to power.

- **Sustainable energy usage**, energy conserving houses, grants for efficient gas boilers etc
- **Waste strategies** including recycling to avoid methane from landfill.
- Move to **renewable sources of power**, **combined heat & power systems** and cleaner coal.
- **Green transport strategies** lean burn car engines, fuel efficiency, new fuels, car parking (e.g Winchester’s extended Park & Ride and MIRACLES project) working patterns, public transport. Indirectly, London’s Congestion Charging will help.

Tackling climate change – UK policy

- **Air quality regulation**- strict Environment Agency & EU requirements
- **Planning regulations:** encouragement of compact cities and avoidance of urban sprawl e.g. through the Green Belt policy.
- **Carbon emissions trading scheme** - setting caps on emissions in industry to “provide clear incentives for investment in energy efficiency and cleaner technologies”.
- **Technological innovation** - supporting research and development into new long term options (e.g. hydrogen economy) and allowing current renewable energy supplies to “demonstrate their potential”. In March 2001, the **Carbon Trust** was launched as a new, independent, not for profit company, funded by the Government and the Devolved Administrations to promote low-carbon technology and innovation in the UK.

- The Climate Change Levy (CCL) is a tax on the use of energy in industry, commerce and the public sector, with offsetting cuts in employers’ National Insurance Contributions and support for energy efficiency schemes and renewable sources of energy.

Methods to reduce greenhouse gas emissions

Gas	Technique
CO_2	Reduce use of fossil fuels in power stations and use renewables instead C tax / Aviation tax Stripping carbon from flue gases and storing beneath oceans or geological repositories or worked-out gas and oil fields
CH_4	Reduce use of landfill or capture at landfill Reduce livestock populations Encourage composting (aerobic decomposition) of organic wastes Breeding rice varieties that can grow in dry soil
NOx	Reducing the peak temperature of fossil fuel combustion in power station or vehicles In vehicles, increasing the percentage of fuel to air Flue-gas denitrification Catalytic converters (although they increase CO_2)
Tropospheric O_3	Reduce release of precursors NOx, CO and NMVOCs – all by reducing vehicle use NMVOCs can be reduced by capturing leaking gases at petrol stations
CFCs	Ban their use in all developing countries Substitutes Kyoto Protocol highly successful

Coping with climate change – Local agenda 21

Established during the 1992 Rio Earth Summit. A framework for future action on global sustainable development was agreed. However, sustainable development cannot be achieved on a global scale unless it is tackled at a local level, with all local authorities adopting Local Agenda 21 into their strategies. 'Think Globally, Act Locally.'

To put sustainable development into practice at a local level each local authority must create a strategy. All local authorities must incorporate sustainable development into every aspect of their work. The strategies should not be designed to work along side projects, they should inform what the project should be.

With the cooperation of local business, schools, transport companies and the wider community Oxford County Council has attempted to reduce road traffic intensity along with its associated pollution. The city of Oxford has been the main focus.

Strategies aim to reduce the 60% car use within the city and involve two action plans – Travelwise and the Transport Action Plan. These include:

- Funding for the *Sustrans* cycle network across the county
- Increased funding for rural bus services
- Green commuter plans from employers such as car share / bus provision
- Walk to school week
- Provision of sustainable transport seminars for business
- Car free days

Methods to reduce greenhouse gas emissions