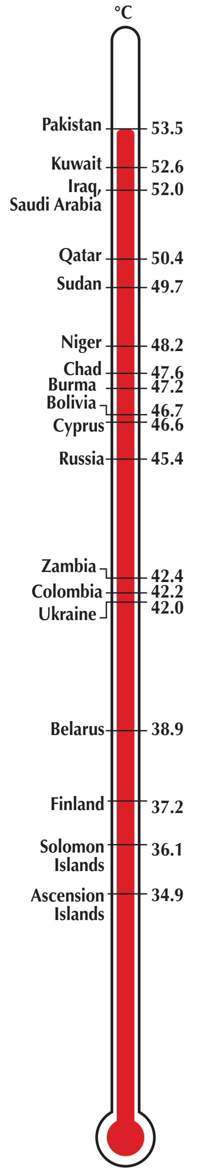
1 WARNING SIGNS

RECORD HIGHS

National temperature records set in 2010



Among the thousands of warning signs of climate change, the array of extreme events that took place in 2010 stand out.

Current climate change is affecting all continents and most oceans. Thousands of case studies of physical changes (such as reduced snow cover and ice melt) and changes in biological systems (such as earlier flowering dates and altered species distributions) have correlated with observed climate changes over the past three decades and more. Scientists have high confidence that these environmental changes are part of the early warning signs of climate change.

Effects on social and economic activities are harder to attribute to climate impacts, although major events attract considerable attention. From prolonged drought in Africa and Australia to the dire flooding in Australia, China, and Pakistan, livelihoods, economies, and politics are at risk.

A single extreme weather event or change in the natural environment does not prove that humans are changing the climate. However, the proven physical science, the history of recent observations, and the consistency in model assessments all support only one explanation: the emission of greenhouse gases by human activity is causing profound changes to the climate system and to the world we live in.

The pace of change appears to be accelerating. Reports of sea levels rising faster than previously expected, of new temperature records, of an increasing toll of weather-related disasters, and anecdotal stories of impacts on livelihoods are accumulating. The year 2010 tied as the warmest year since records began in the 1850s, and threw up an astonishing series of extreme events.

Increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising sea levels led the Intergovernmental Panel on Climate Change (IPCC) to report in 2007 that "warming of the climate system is unequivocal". As evidence continues to mount, that statement is even truer today.

USA: heat wave

In 2010, a very large area of the USA experienced high temperatures over an unusually long period. Downtown Los Angeles set an all-time record high temperature at 45°C in September 2010. Fires started in the hills and spread to residential areas.

Russia: state of emergency

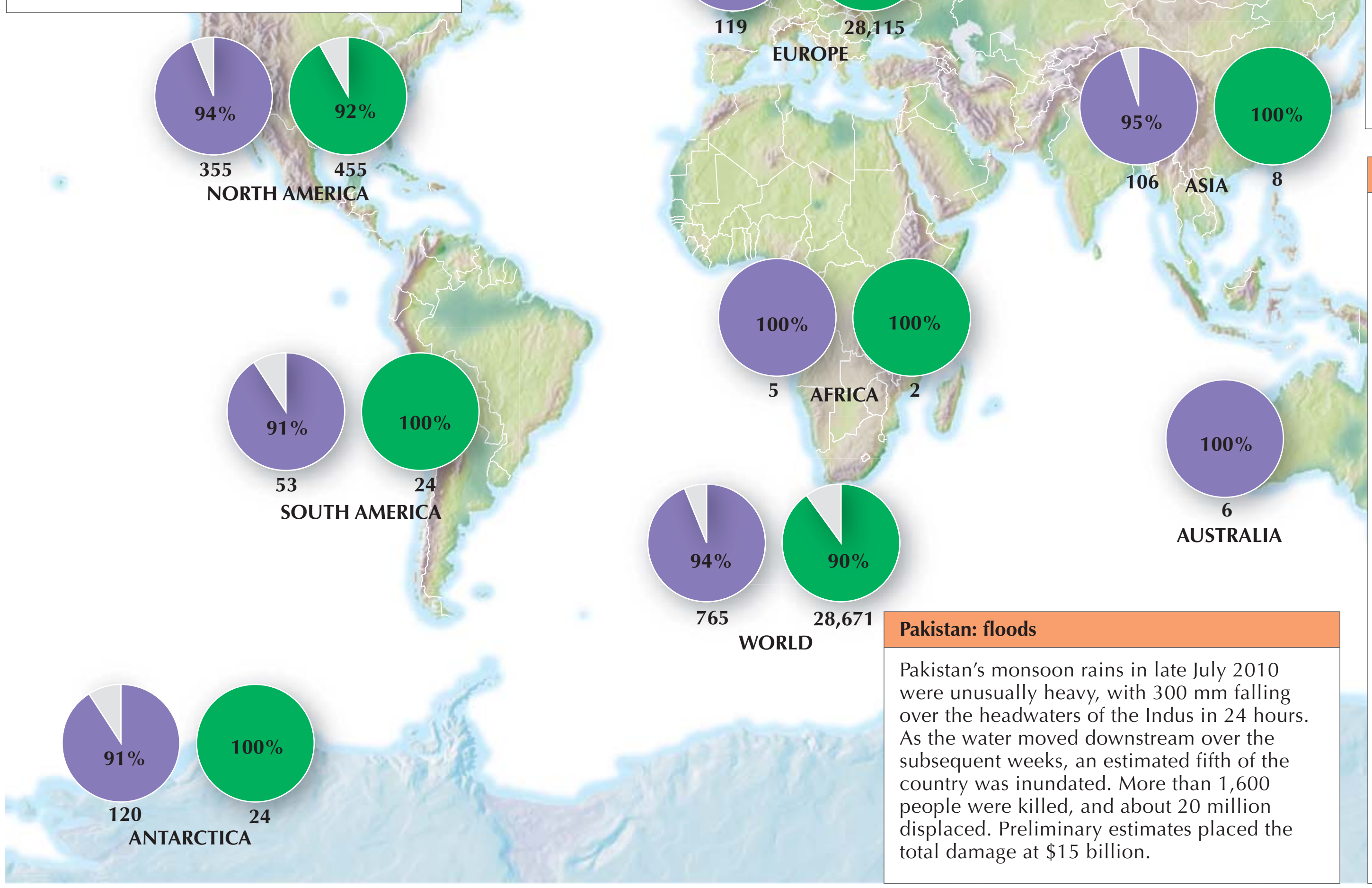
In 2010, a heat wave claimed 15,000 lives, with 7,000 deaths in Moscow alone. A state of emergency was declared in seven Russian regions, where tens of thousands of hectares of land was destroyed by fire, and hundreds of people were uprooted from their homes. As Russia's grain output was slashed by 40%, a grain export ban was imposed.

OBSERVED CLIMATE CHANGE IMPACTS

Number of significant observed changes and percentage of these changes that are consistent with climate change

1970–2004

- physical changes
- biological changes



China: floods

Flood waters from southwest to northeast China, including the municipality of Chongqing, shown here, led to the evacuation of 15 million people by the end of August 2010. Over 3,000 people died, and damage was estimated at over $50 billion.

Australia: floods

December 2010 was the wettest on record for Queensland. The floods that resulted in January 2011 led to at least 22 deaths and affected more than 200,000 people. Taking into account the impact on the Australian economy, the cost is estimated in the region of $30 billion.

Pakistan: floods

Pakistan's monsoon rains in late July 2010 were unusually heavy, with 300 mm falling over the headwaters of the Indus in 24 hours. As the water moved downstream over the subsequent weeks, an estimated fifth of the country was inundated. More than 1,600 people were killed, and about 20 million displaced. Preliminary estimates placed the total damage at $15 billion.

24–25 Polar Changes; 26–27 Shrinking Glaciers; 28–29 Ocean Changes; 30–31 Everyday Extremes

2 Polar Changes

Collapsing ice shelves
The collapse of the Larsen A Ice Shelf in 1995 was followed by that of the Larsen B Ice Shelf in 2002. Over the last century nearly 7,720 sq miles (20,000 sq km) of ice shelf was lost on the Antarctic Peninsula.

Warming in the Antarctic Peninsula and Arctic is driving large-scale melting of ice that will have both local and global consequences.

The presence of a hole in the ozone layer over the southern polar region has altered weather circulation patterns on Antarctica. It has brought more warm, moist, maritime air over the Antarctic Peninsula, contributing to warming and melting there, but has created a cooling effect in other areas. As the ozone hole recovers, that cooling effect is expected to diminish.

In East Antarctica, the changes are much less dramatic than those on the Peninsula, with some melting and thinning on coastal edges and some thickening in the interior. In West Antarctica, however, a coastal section of the ice sheet is now thinning quite rapidly.

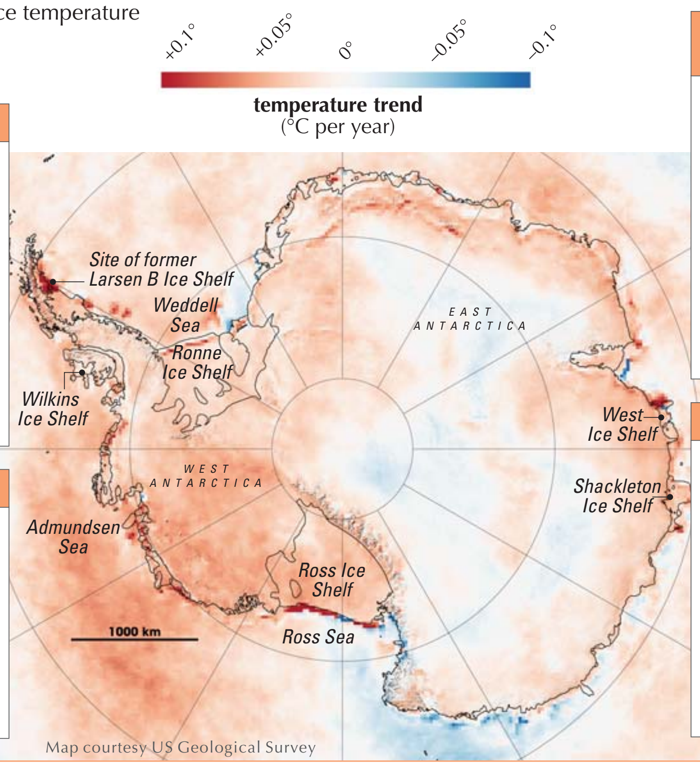
Floating Arctic ice has covered the North Pole for millions of years. Its extent fluctuates with the seasons, but eight of the ten lowest extents have occurred in the last decade. The remaining ice is also thinner, with approximately 50 percent of the maximum recorded thickness having been lost by 2008. Already, the North Pole is free of ice in some summers, and by the end of this century the ice may largely disappear for entire summers.

In September 2007, the Arctic ice cap shrank to its smallest recorded extent, opening up the possibility of commercial shipping routes operating for the first time along the northern coasts of Canada and Russia. Some projections suggest that sea ice will disappear completely in the summer months by 2080.

While an open Arctic sea would facilitate shorter trade routes, industrial-scale fishing and the exploitation of minerals, it would be at great cost to the environment and to traditional livelihoods. A delay in the formation of the winter ice, an earlier break-up of ice in the spring, and thinner ice year round makes it hard for indigenous people using largely traditional methods to make a living.

ANTARCTIC WARMING

Change in yearly surface temperature
1981–2007
degrees centigrade



Wilkins Ice Bridge

This 100-km long strip of ice, which broke apart in April 2009, is believed to have held the remnants of the Wilkins Ice Shelf in place since the shelf's retreat and collapse in the 1990s. The loss of the ice bridge may allow the ocean currents to disperse huge ice floes.

West Antarctic ice sheet

The Amundsen Sea area is the most rapidly changing section of the Antarctic ice sheet. The annual mass loss from glaciers represents a significant contribution to sea-level rise.

Melting ice and sea-level rise

Melting of floating sea ice and calving of glaciers into the ocean do not affect the sea level. Ice displaces about the same volume of water as it produces when it melts. However, thinning and retreat of glaciers on land does add water to the oceans.

Floral responses

Two native flowering plants *(Deschampsia antarctica* and *Colobanthus quitensis)* have increased in abundance at some sites in the maritime Antarctic, providing clear evidence of terrestrial species responding to climate change.

ARCTIC

Minimum extent of Arctic summer sea ice

- median for 1979–2000
- September 2007

Greenland ice cap

- area experiencing at least one melt day 2007

Potential shipping routes

- northwest passage
- northeast passage

What direction are we taking as an Inuit society? How is it we are going to deal with these monumental changes?

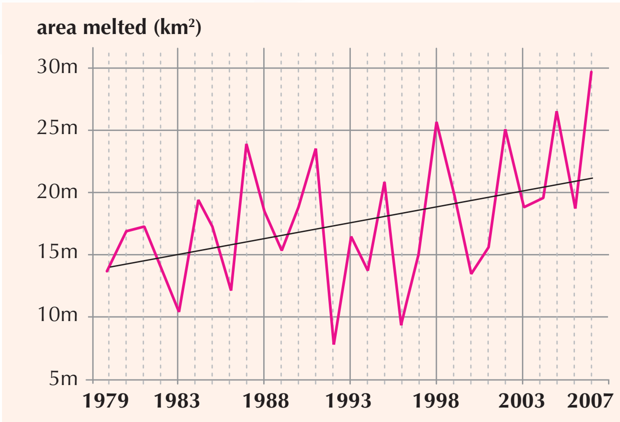
Sheila Watt-Cloutier, former Chair of Inuit Circumpolar Council

The permafrost around the Arctic is generally warming. In some areas, it is making a weakened coastline more prone to erosion, and causing subsidence, leading to the collapse of roads and buildings. It is also creating lakes of trapped melt water, which may increase carbon dioxide and methane emissions.

Each summer, parts of the Greenland ice sheet melt at the edges and on the surface. Although the melt area varies each year, the overall trend since 1979 has been upwards. Surface melt water finds its way through crevasses to the base of the ice, and forms a thin film between ice and bedrock. There are fears that this could increase the speed at which the ice sheet slides towards the sea.

GREENLAND MELT

Rising trend in annual melt area
1979–2007



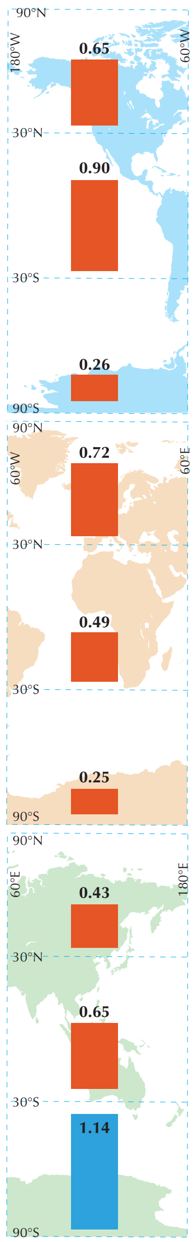
36–37 The Climate System; 42–43 Climate and Social Crises

3 Shrinking Glaciers

THINNING

Regional average annual change in mass balance
1996–2005
meters water equivalent

loss gain



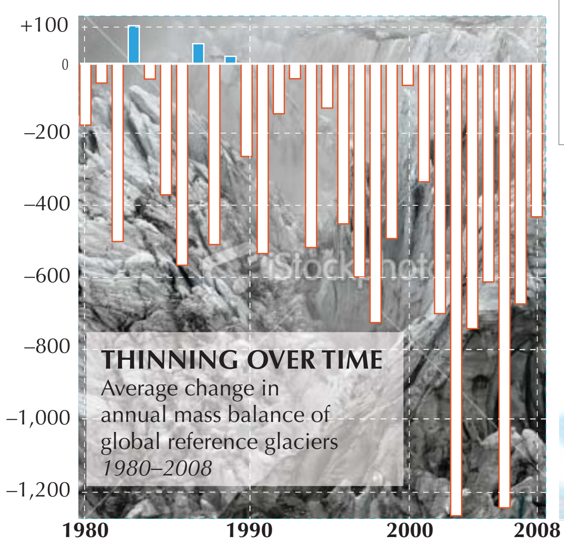
Around the world, glaciers are losing mass and are in retreat.

The mass and extent of glaciers responds to temperature and snowfall in the very local geography of mountains and polar regions. The changes in glaciers over time provide valuable evidence of long-term climate change. Because the tell-tale signs of their expansion and retraction are clearly visible, scientists are able to draw conclusions about climate change from periods well before instrumental records became widespread.

Globally, glaciers have lost an average of more than half a meter (water equivalent) during the past decade or so. This is twice the rate of loss in the previous decade, and over four times the rate of loss in the late 1970s.

The front of most glaciers is receding to higher altitudes, and at such a rate that glaciologists, mountaineers, tourists and local residents are astonished by the changes that have occurred in the past decade. Tree stumps and even, in 1991, human remains that have been preserved in the ice for thousands of years, are now being revealed. Changing landscapes affect local plants and animals that colonize the newly exposed areas.

Glacial melting changes the flow of rivers, adding to water stress for millions of people. Lakes formed from melting glaciers are unstable, prone to abrupt collapse and flooding, threatening property and lives downstream.



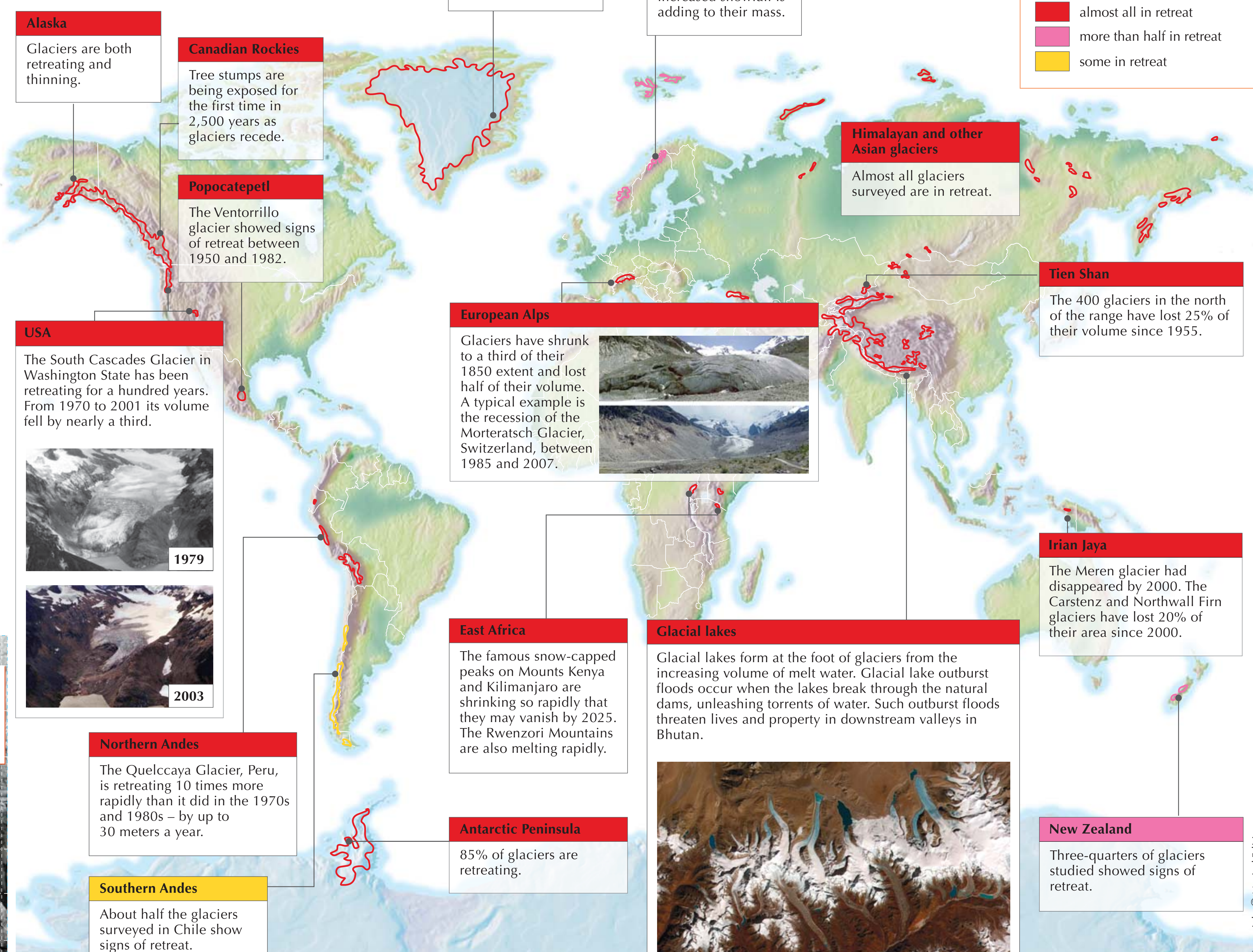
THINNING OVER TIME

Average change in annual mass balance of global reference glaciers
1980–2008

GLACIAL RETREAT

Extent to which fronts of glaciers have moved
since 1950s
selected glaciers

- almost all in retreat
- more than half in retreat
- some in retreat



Alaska

Glaciers are both retreating and thinning.

Canadian Rockies

Tree stumps are being exposed for the first time in 2,500 years as glaciers recede.

Popocatepetl

The Ventorrillo glacier showed signs of retreat between 1950 and 1982.

USA

The South Cascades Glacier in Washington State has been retreating for a hundred years. From 1970 to 2001 its volume fell by nearly a third.

Greenland

A rapid retreat and loss of ice mass in Greenland is giving cause for concern.

Scandinavia

Many glaciers are retreating, although increased snowfall is adding to their mass.

Himalayan and other Asian glaciers

Almost all glaciers surveyed are in retreat.

Tien Shan

The 400 glaciers in the north of the range have lost 25% of their volume since 1955.

European Alps

Glaciers have shrunk to a third of their 1850 extent and lost half of their volume. A typical example is the recession of the Morteratsch Glacier, Switzerland, between 1985 and 2007.

Irian Jaya

The Meren glacier had disappeared by 2000. The Carstenz and Northwall Firn glaciers have lost 20% of their area since 2000.

East Africa

The famous snow-capped peaks on Mounts Kenya and Kilimanjaro are shrinking so rapidly that they may vanish by 2025. The Rwenzori Mountains are also melting rapidly.

Glacial lakes

Glacial lakes form at the foot of glaciers from the increasing volume of melt water. Glacial lake outburst floods occur when the lakes break through the natural dams, unleashing torrents of water. Such outburst floods threaten lives and property in downstream valleys in Bhutan.

Northern Andes

The Quelccaya Glacier, Peru, is retreating 10 times more rapidly than it did in the 1970s and 1980s – by up to 30 meters a year.

Southern Andes

About half the glaciers surveyed in Chile show signs of retreat.

Antarctic Peninsula

85% of glaciers are retreating.

New Zealand

Three-quarters of glaciers studied showed signs of retreat.

4 Ocean Changes

Coral reef bleaching
Coral reefs are the foundation for one of the world's most productive and diverse habitats so their health affects that of many other species. Heat stress is a major factor in coral reef bleaching – a process during which coral polyps expel the algae with which they have a symbiotic relationship, turn white, and may die.

Around the world, oceans are getting warmer and more acidic, affecting marine life.

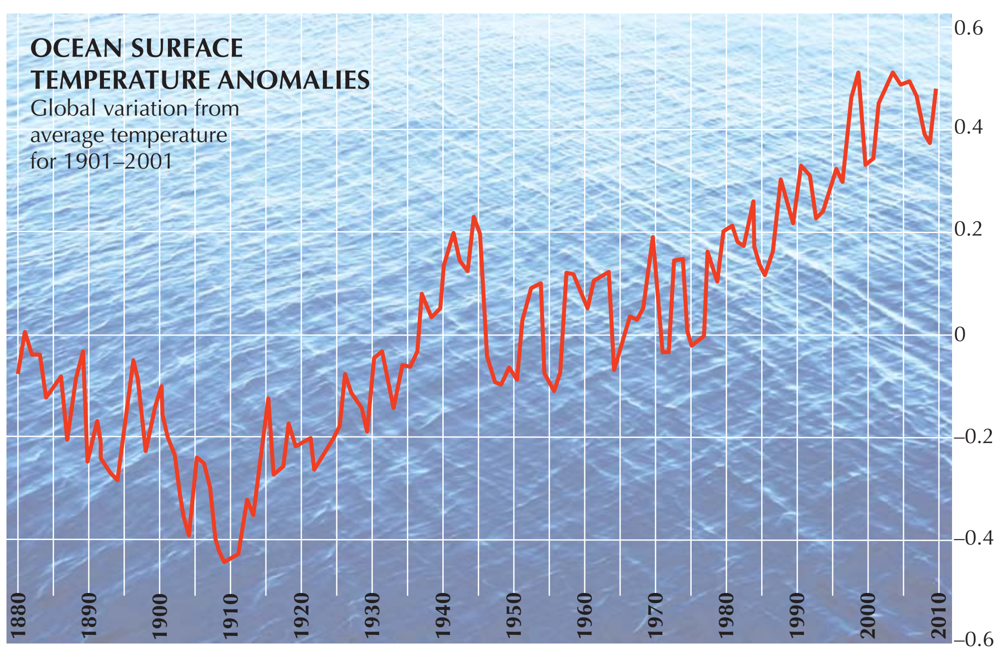
Ocean temperatures, from the surface down to a depth of 700 meters, increased 0.1°C between 1961 and 2003. Temperature is fundamental to the basic life processes of organisms. It can influence metabolic rates and population growth of individual species and have broad repercussions on entire ecosystems. Coral reefs are particularly sensitive to temperature increases. Episodes of higher temperatures increase the frequency of coral bleaching and mortality.

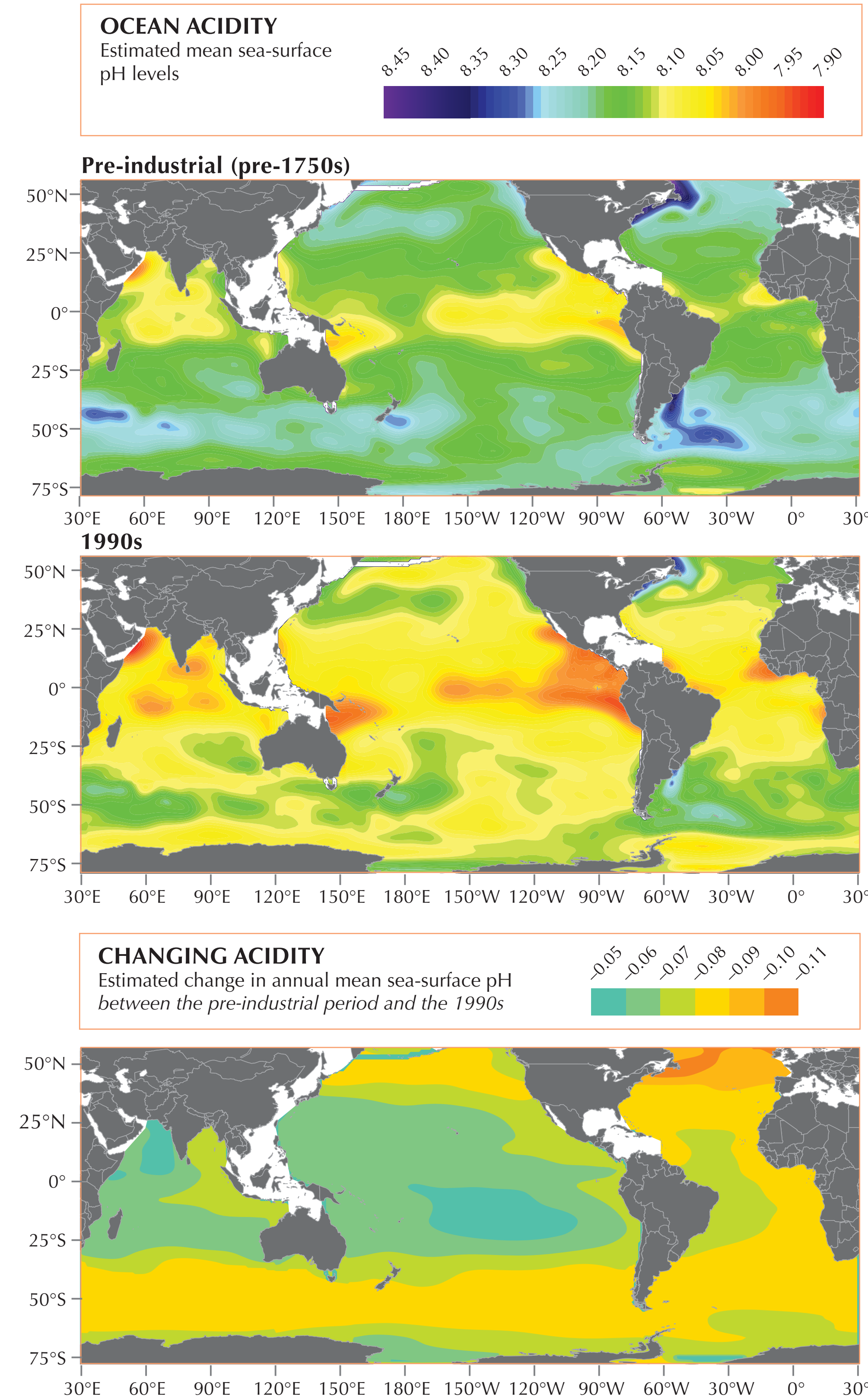
Sea levels rose at an average rate of 1.8 ± 0.5 mm a year from 1961 to 2003 due to thermal expansion and melting of land-based ice. The recorded rate for the more recent period, 1993 to 2010, is much higher (3.3 ± 0.4 mm a year), generating concern among scientists that sea levels will rise faster than previously expected.

A separate issue is the contribution made by higher levels of carbon dioxide in the atmosphere to the acidity of ocean surfaces since the Industrial Revolution. Carbon dioxide in the atmosphere dissolves into the oceans and forms carbonic acid. In some sea areas there has been a 0.1 unit change in pH – corresponding to a 30 percent increase in acidity over levels in the mid-eighteenth century.

Increased acidity is expected to affect the variety of marine organisms with shells of calcium or aragonite, decrease oxygen metabolism of animals, and alter nutrient availability. The expected consequences of this change are already being observed in marine life. Scientists have measured decreases in the weight of the shells of small marine snails (pteropods) as well as decreases in the calcification of corals in the Great Barrier Reef. Impacts on these small organisms, which are the base of the food chain and therefore the foundation of productive habitats, could ripple up to affect fisheries and therefore protein and food security for millions of poor people.

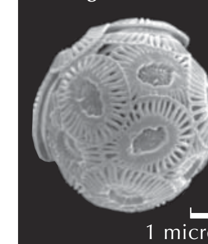
An initial calculation of possible economic losses associated with a 10 to 25 percent decline in mollusk catches in the USA alone estimates losses for the year 2060 at between $324 million and $5.1 billion at current values. Under scenarios of increasing emissions of carbon dioxide, surface ocean pH is projected to decrease further, by 0.4 ± 0.1 pH units, becoming increasingly acidic by 2100 relative to pre-industrial conditions.





Maps courtesy of NOAA Pacific Marine Environmental Laboratory

Shell growth



Incomplete shell due to acidity.

Malformed shell growth due to acidity.

Coccolithophorids are microscopic, one-celled organisms with calcareous shells vulnerable to increased acidity. They are the most abundant algal group in the world, and are important primary producers in marine foodwebs, serving as food for larger organisms such as snails and fish. As such, they are key parts of marine food webs, and their decline may have far-reaching consequences for ocean ecosystems.

46–47 Emissions Past and Present; 64–65 Food Security

5 Everyday Extremes

73%
of land area with adequate long-term records showed a significant increase in the number of warm night-time temperatures

The frequency of extreme events is increasing. A shift away from familiar patterns of climate variability is bringing changes in many aspects of climate.

In many parts of the world, the number of occasions on which precipitation is particularly heavy has increased. In China in 2010, heavy rains caused flooding and mudslides in 28 provinces. In Pakistan, unusually heavy rainfall over the watershed to the Indus River caused a large volume of water to move down the river over subsequent weeks, causing extensive flooding.

Since 1950, the number of heat waves has increased, affecting crop yields, human health, and the intensity of droughts. There has also been a widespread increase in the number of warm nights – a seemingly minor change, but one that reduces overnight relief from the day's heat.

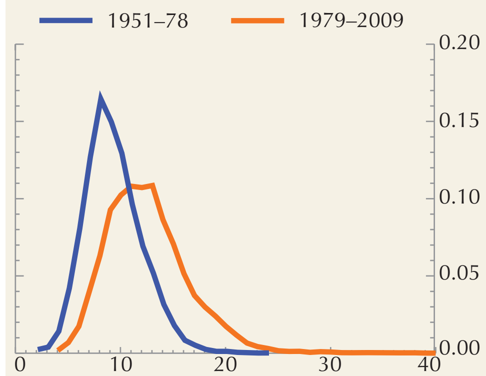
It is very difficult to attribute one particular extreme, such as a single heavy rainfall or a single severe hurricane, to human-induced climate change rather than the natural range of variability, but the increase in the probability of these events occurring can be linked to changes in the climate. In a sense, we can think of climate change as loading the dice in favor of these extreme events. That loading of the dice is easier to observe in large data sets, such as temperature and precipitation, which include decades of daily information from all over the world. It is much more difficult to detect change in trends of comparatively rare events. For instance, tropical cyclones and hurricanes wreak havoc around the world, yet there is only low confidence at present that their frequency and intensity have increased since the 1970s.

As examples of the impacts of recent extreme weather events, the still-recovering city of New Orleans or the rural population suffering the long-term effects of the Pakistan floods, can provide insight into the types of losses that might be increasingly experienced as the planet warms.

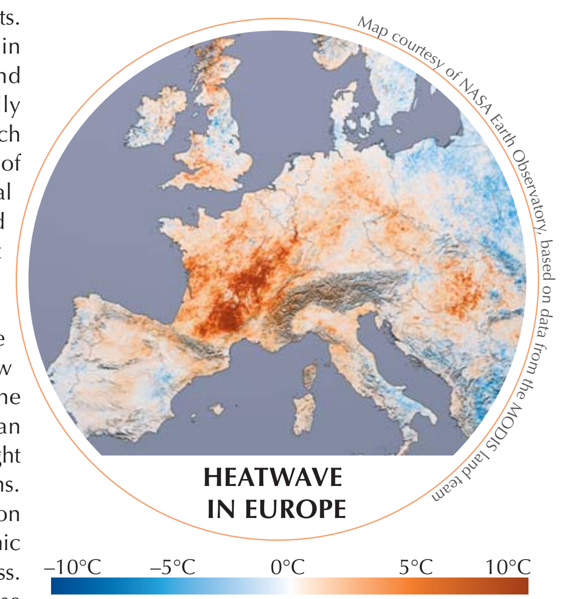
But these impacts cannot all be blamed on climate change. Many other social and economic factors contribute to hazard vulnerability and loss. Poverty, poor warning systems and land-use planning, inadequate shelter, and other issues of economics, education, household resources, and governance contribute to vulnerability to these extremes.

INCREASE IN WARM NIGHTS

Based on temperature records from 895 grids
1951–2003

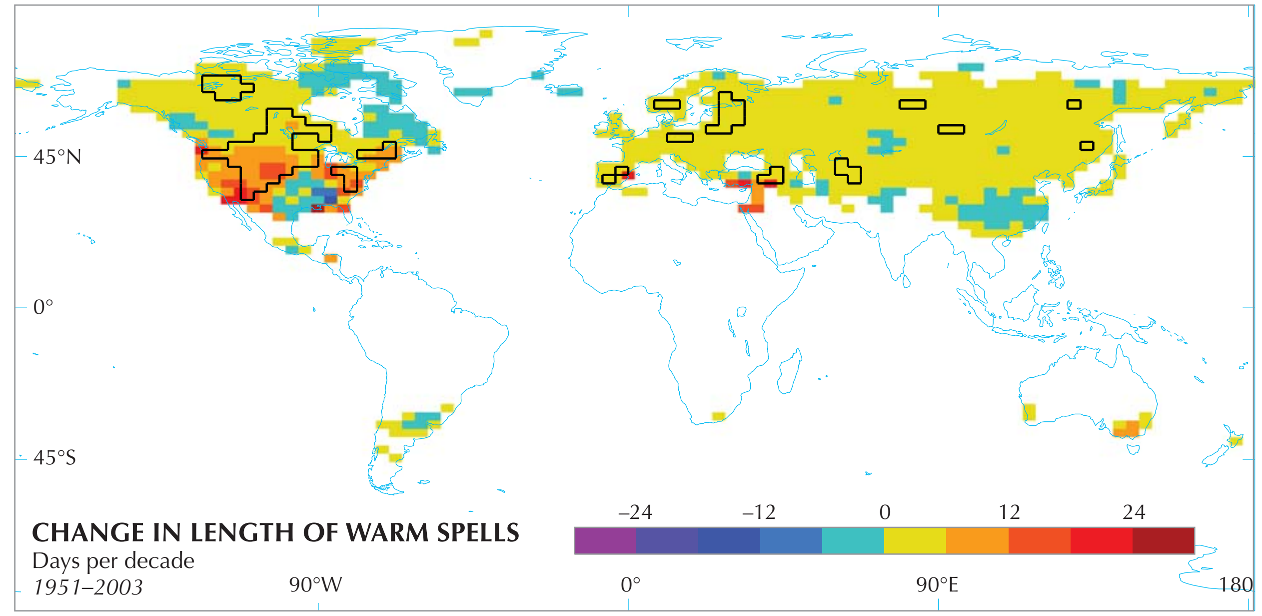


This probability density function compares the number of warm nights observed in two different periods, using gridded data for areas with adequate records. A warm night is defined as one with minimum temperatures in the top 10th percentile of temperatures for that location. In more recent decades, the likelihood of a year with more warm nights increased.



Difference between land surface temperatures *in July 2003 and July average for 2000–02*

Parts of Europe experienced a major heatwave in late July and early August 2003, which resulted in approximately 40,000 deaths.

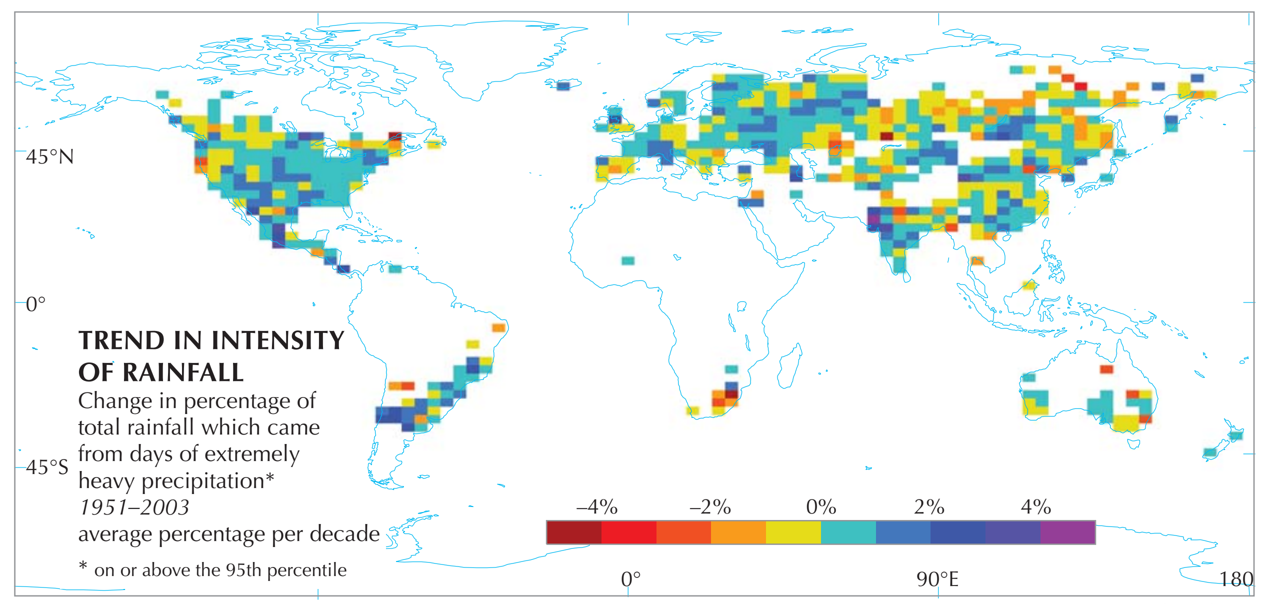


Climate models project that there will be more heat waves in the future. The above analysis of temperatures from 1951–2003 provides observational support for models. Here, heat waves, are termed "warm spells", which are defined as the number of days per year with at least six consecutive days of maximum temperatures in the top 10% of all maximum temperatures for that time of year.

Areas in the yellow to red shades indicate a trend to longer warm spells. Black lines enclose areas where statistical analysis indicates that the trend is significant at the 5% level.

Trends were not calculated for areas with less than 40 years of data, and data that ended before 1999, so we do not have information for much of Africa, South America, the Middle East, Asia, and Australia.

Map courtesy L. Alexander, Climate Change Research Centre, University of New South Wales



Climate models also project that, in many parts of the world, rain will tend to fall in more intense bouts. This map represents analysis indicating that in much of the USA, and Europe, as well as parts of Asia, the amount of total annual rainfall contributed by the heaviest 5% of rainy days has tended to increase by 1% or more per decade between 1951 and 2003. Areas in white show lack of adequate data sets for analysis.

There is less area with statistically significant trends in intense rainfall than in longer warm spells.

Map courtesy L. Alexander, Climate Change Research Centre, University of New South Wales

22–23 Warning Signs
76–77 Urgent Action to Adapt

6 The Greenhouse Effect

The intensification of the greenhouse effect is driving increases in temperature, and many other changes in the Earth's climate.

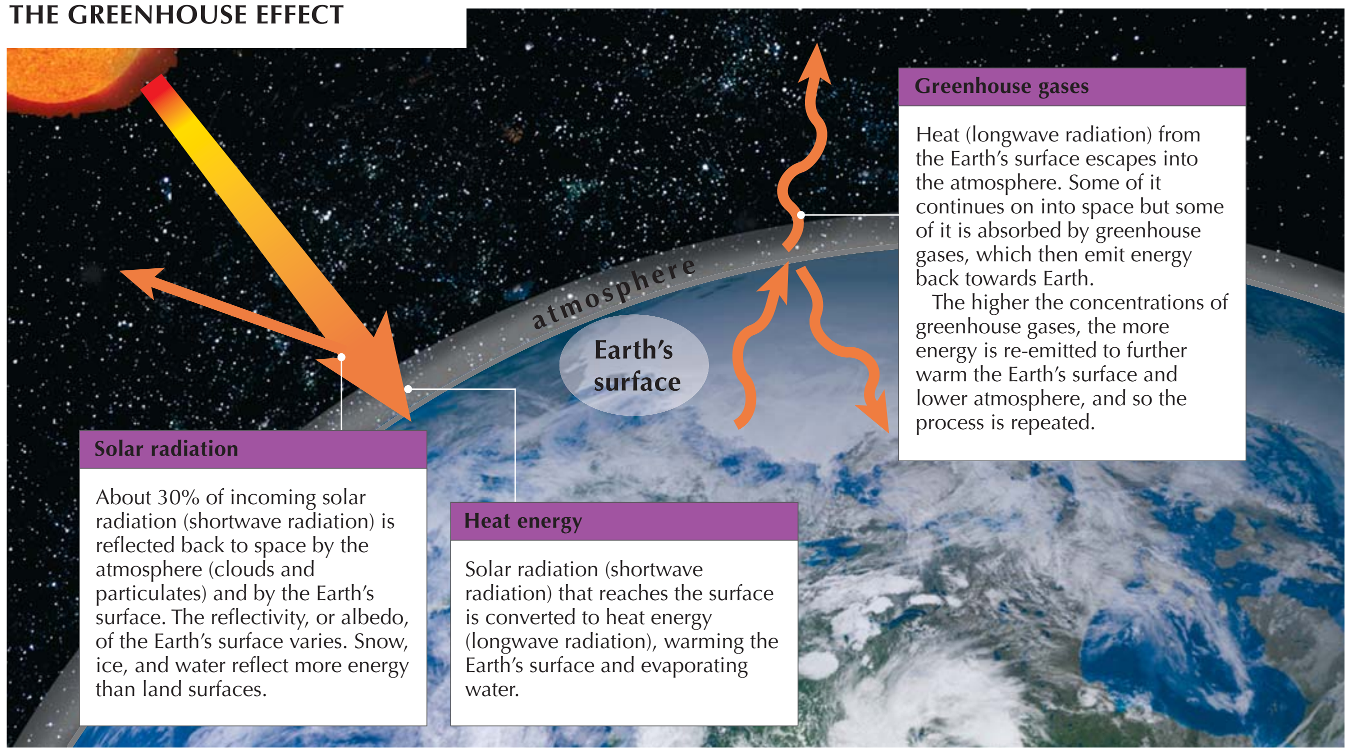
Without the natural atmospheric greenhouse effect, which captures and holds some of the sun's heat, humans and most other life-forms would not have evolved on Earth. The average temperature would be –18°C, rather than 15°C.

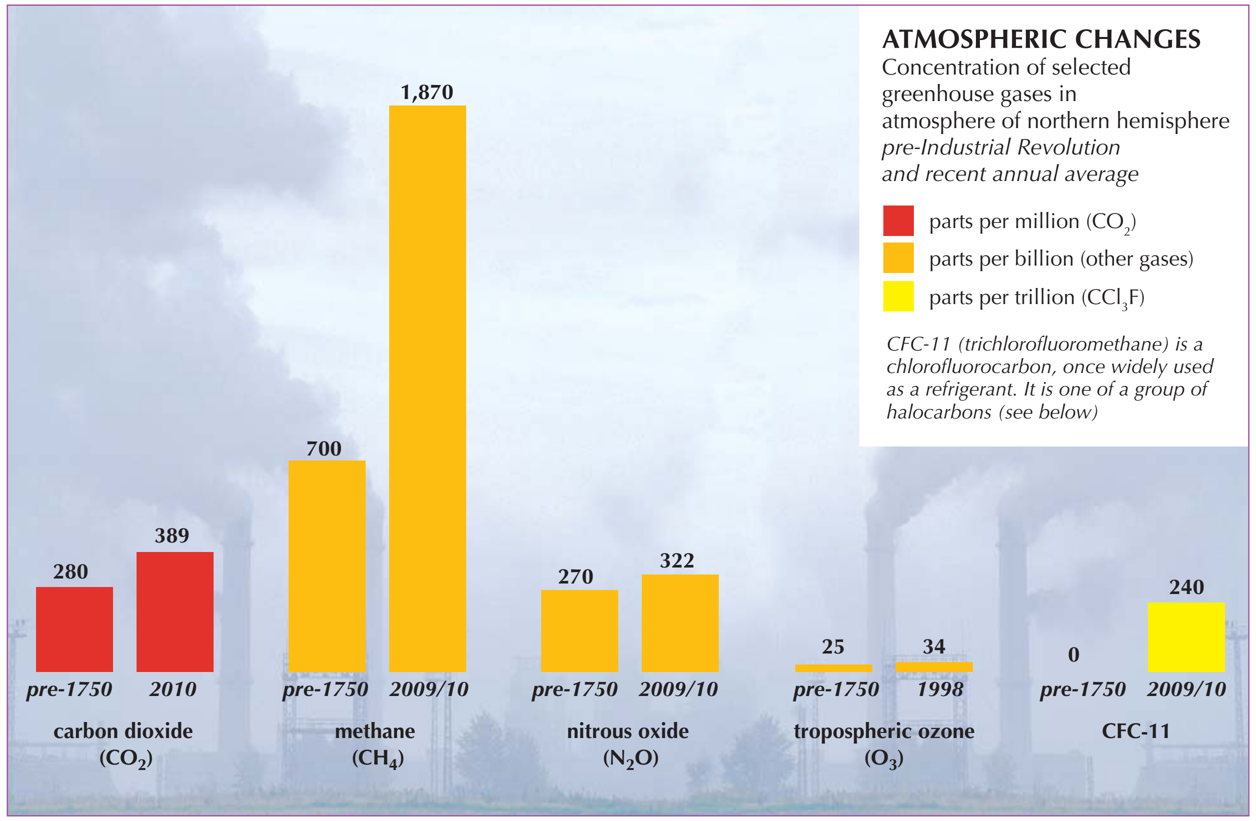
The greenhouse effect operates in the following way. Solar radiation passes through the atmosphere, and heats the surface of the Earth. Some of that energy returns to the atmosphere as long-wave radiation or heat energy. Another portion of that energy is captured by the layer of gases that surrounds the Earth like the glass of a greenhouse, while the rest passes into space. Changes to the composition of this layer of gases are central to climate change.

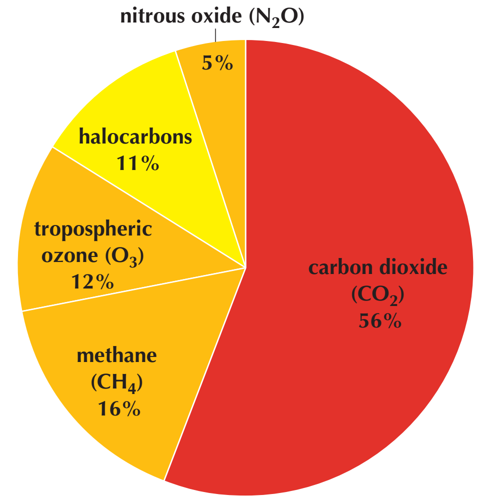
Over the last 250 years or so, human activity – such as extensive burning of fossil fuels, the release of industrial chemicals, the removal of forests that would otherwise absorb carbon dioxide, and their replacement with intensive livestock ranching – has changed the types and amounts of gases in the atmosphere, and substantially increased the capacity of the atmosphere to absorb heat energy and emit it back to Earth. The major greenhouse gases augmented by human activities are carbon dioxide, tropospheric ozone, nitrous oxide, and methane. Other industrial chemicals, including many halocarbons, also add to the effect.

Some of these gases only stay in the atmosphere for a few hours or days, but others remain for decades, centuries, or millennia. Greenhouse gases emitted today will drive climate change long into the future, and the process cannot be quickly reversed. In addition, warming may cause changes, or "feedbacks", that further accelerate the greenhouse effect. For instance, if the highly reflective snow cover decreases, more solar radiation will warm the Earth's surface. The warmer the Earth, the more heat energy is emitted back to the atmosphere. And if warming leads to extensive thawing of permafrost, there may be a large release of methane, a potent greenhouse gas.

THE GREENHOUSE EFFECT

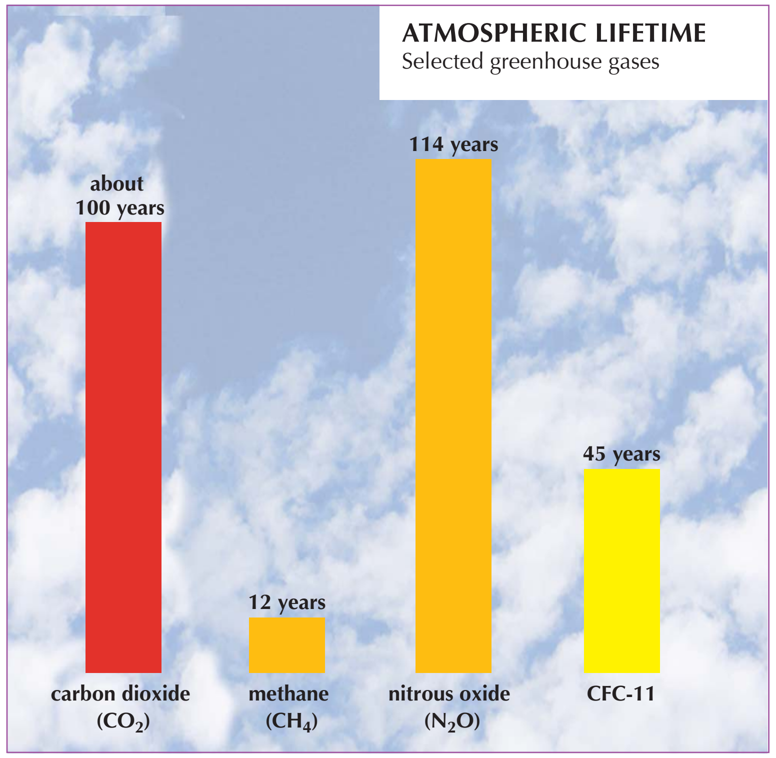






APPROXIMATE CONTRIBUTION OF GHGS
To positive radiative forcing of the atmosphere
post 1750

Halocarbons, are a group of climate-forcing gases that includes CFCs, and their replacement compounds HCFCs and HFCs.



42–43 Climate and Social Crises

7 The Climate System

> The climate system is the highly complex system consisting of the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings.
>
> IPCC

The climate system is adjusting to an increase in the heat trapped in the Earth's atmosphere caused by greenhouse gases.

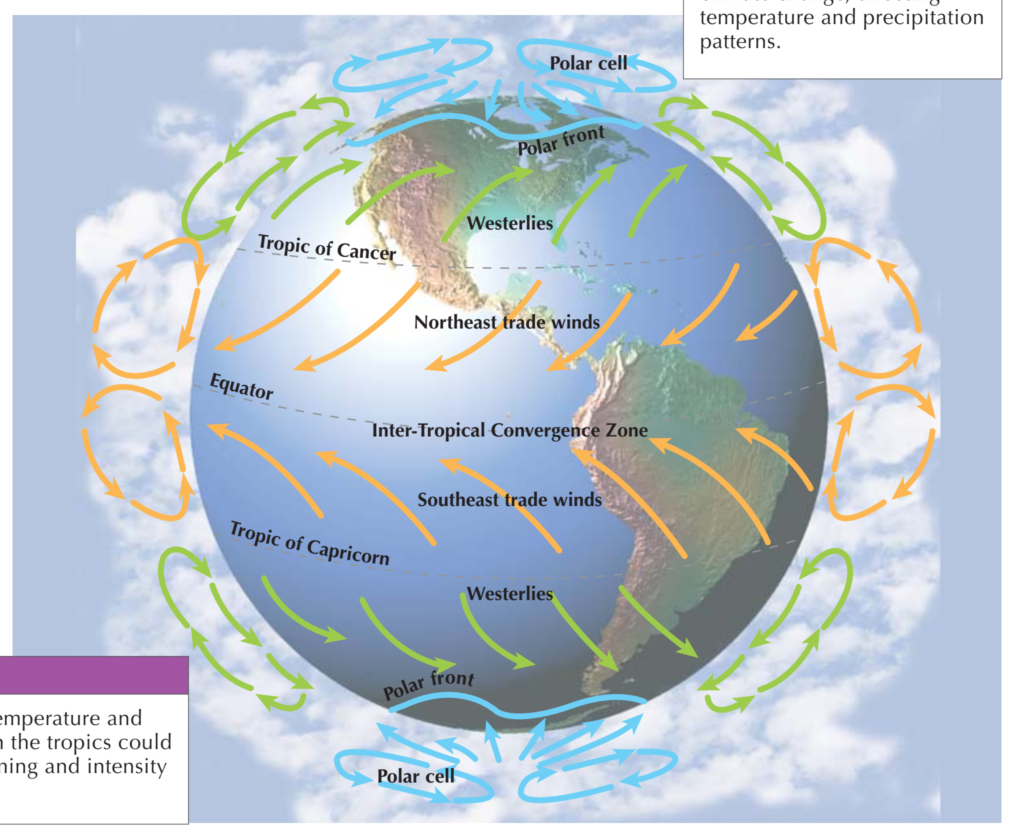
The Earth's climate system functions as a giant "heat distribution engine." Atmospheric and oceanic circulations move heat energy around the world, in an effort to distribute it more equally. This creates the long-term average conditions referred to as "climate", within which we experience the short-term, day-to-day variability of "weather." The addition of more heat energy to the atmosphere and the Earth's surface is expected to alter the climate system's heat distribution patterns, to change many average climate conditions and thus create more variation in the weather.

Most solar radiation and surface heating occurs at the equator, where the sun's rays are nearly perpendicular to the surface all year round. The poles receive much less radiation because of the Earth's orbit and tilt relative to the sun. Atmospheric and oceanic circulations contribute equally in moving energy from the equator towards the poles. The large-scale weather systems that generate the migrating warm and cold fronts, and their associated storms, are part of this process. The climate is also influenced by processes that contribute to multidecadal variability, such as El Niño and others in the Atlantic and Pacific.

The process of heat energy distribution by the global climate system is largely responsible for regional climates, and an increase in temperature differentials between the tropics and the poles could disrupt the climate in many ways. Warmer summers, heat waves, drier winters, less snowfall, and changing frequency and intensity of storms, are all possible results.

ATMOSPHERIC CIRCULATION

At the equator, solar radiation heats the land and the oceans, evaporating water. Warm air rises, carrying water vapor and creating heavy rainfall in the atmosphere. The resulting drier, colder air is pushed away from the equator and descends to Earth in the Tropics of Cancer and Capricorn, where deserts form. Trade winds blow back to the equator to complete the circulation. Similar circulation cells exist over the mid-latitudes and polar regions.



Jet stream

The typical flow of the mid-latitude jet stream or polar front may be altered by climate change, affecting temperature and precipitation patterns.

Tropics

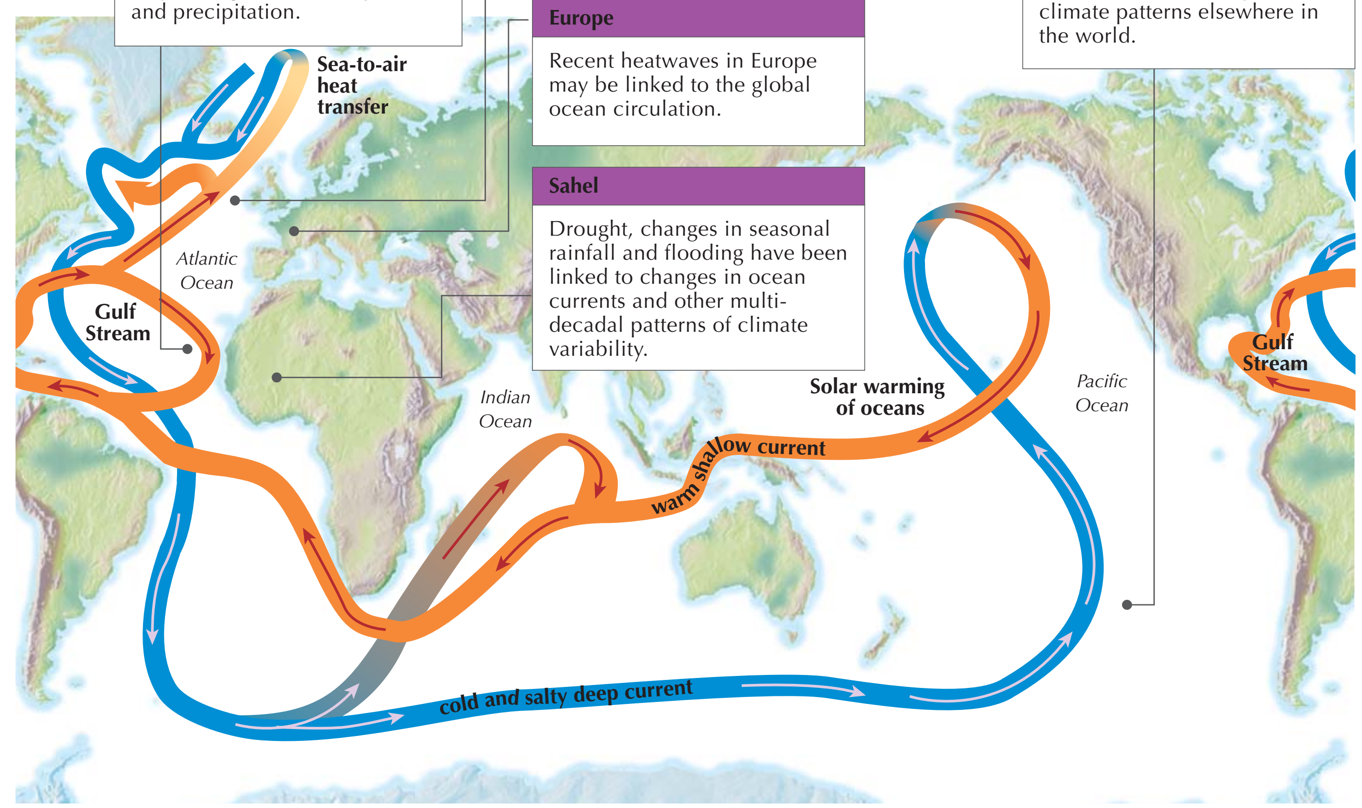
Increases in temperature and evaporation in the tropics could change the timing and intensity of monsoons.

OCEAN CIRCULATION

The ocean currents distribute energy from solar heating. Some currents are mainly driven by winds and tides, but others are primarily driven by differences in ocean temperature and salt concentration that affect the density of seawater. Water naturally mixes to even out the distribution of heat and salt. Circulation occurs as the denser, colder, saltier water drops below the warmer, fresher water. This drives the "thermohaline circulation", or the "ocean conveyor belt", although that metaphor doesn't fully capture the complexity of mixing processes.

If climate change warms the polar waters and/or decreases their salinity by adding fresher water from melting glaciers, the difference in water density will decline and the circulation pattern is expected to slow down or even collapse. Based on current models, many scientists view the potential collapse as a "low-probability, high-impact" scenario in the 21st century, although some see greater probabilities and potential in the 22nd century.

Even a slowing of the circulation is likely to have a wide-ranging impact. Descending cold waters carry carbon dioxide into deep water, away from the atmosphere. Elsewhere, parts of the world rely on upwelling waters to bring nutrients from the bottom of the ocean to the surface, where they help support the local ecology and fisheries. Temperature and rainfall patterns are also expected to change with alterations to this circulation pattern.



Storms

Increased temperatures and water vapor in the air over tropical oceans will create improved spawning conditions for cyclones, hurricanes and typhoons, although other climate circulation features are required for formation. Modeling studies suggest storms may have greater wind speeds and precipitation.

Northern Europe

Europe has a mean annual surface air temperature some 5°–7°C warmer than regions at the same latitude in the Pacific. A collapse, or even a slowing, of the Gulf Stream would reduce the amount of warm, tropical water brought north. Although this cooling might be offset by atmospheric warming, the consequences could be severe.

Europe

Recent heatwaves in Europe may be linked to the global ocean circulation.

Sahel

Drought, changes in seasonal rainfall and flooding have been linked to changes in ocean currents and other multi-decadal patterns of climate variability.

El Niño

The frequency and intensity of El Niño events, triggered when warm water in the Pacific extends east, may be affected by changes in climate systems. During El Niño years, rainfall follows the warm water, typically leading to flooding in Peru, drought in Indonesia and Australia, and a disruption to climate patterns elsewhere in the world.

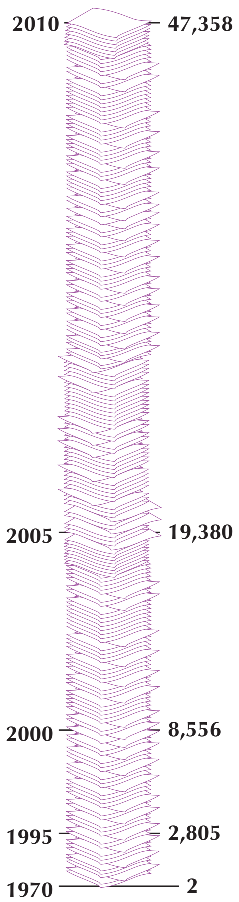
22–23 Polar Changes; 30–31 Everyday Extremes

8 Interpreting Past Climates

ACCUMULATED KNOWLEDGE

Total number of scientific articles referring to climate change and published in journals indexed in Web of Science

1970–2010



The science of climate change is well established, with over 5,000 articles now appearing every year in peer-reviewed journals. Over 3,000 scientists in the Intergovernmental Panel on Climate Change (IPCC) collect and review this knowledge.

Concentrations of carbon dioxide and methane are higher than they have ever been in the last 800,000 years. The Earth is warmer than at any time in the past 1,000 years.

Records of the Earth's past climates, reconstructed from ice cores, tree rings, paleoclimatic fingerprints in ocean and lake sediments, cave deposits, glaciers, and even ship records of sea-surface temperatures, confirm that global warming is real and unprecedented. The Earth is warmer than in the past millennium, and the commitment to future warming is evident in the record levels of carbon dioxide (CO_2) in the atmosphere. Modern human societies and economies have never faced such conditions.

A physical explanation of the greenhouse effect was already well developed 100 years ago, and since then scientists have identified trends in atmospheric composition and temperature extending over hundreds of thousands of years. The concentrations of carbon dioxide and methane in the atmosphere are now at the highest levels for over 800,000 years. The atmospheric concentration of carbon dioxide has risen from 315 parts per million (ppm) in the 1950s to just over 388 ppm in 2010. Paleoclimate records indicate that the pattern of global temperature fluctuations has been similar to the pattern of change in CO_2 levels.

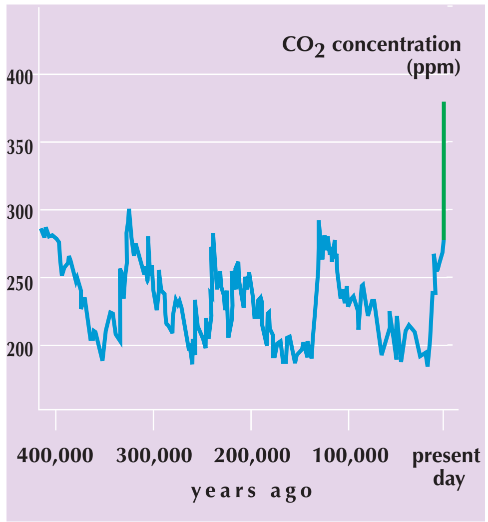
The physical understanding of the climate system, with its many variables, is captured in computer models. Their efficacy is tested against the record of past climates, and many have managed to reconstruct past climates reasonably accurately. Fluctuations in past temperatures have been shown to be caused by natural forces, such as cycles of solar energy, changes in the Earth's orbit, and volcanic eruptions that send gases and dust into the atmosphere. However, the variability and trends in historical global temperatures can only be explained if both natural forces and greenhouse gas emissions from human activity are included in the models. This validation of models of the physics of the climate system gives scientists the confidence to use these models to project future climate change.

CO_2 FLUCTUATIONS

400,000 years ago to present day

concentration in ice-core samples

concentration in atmosphere

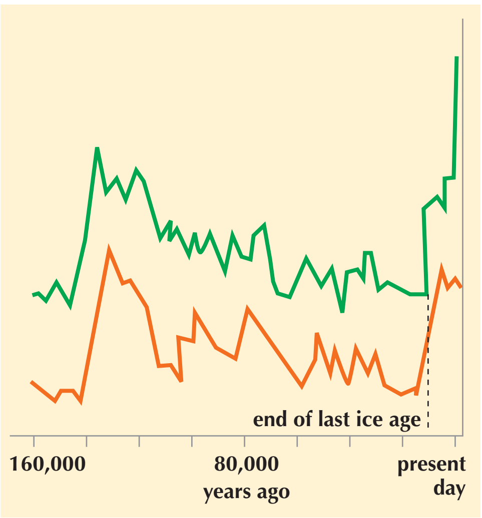


LINK BETWEEN CO_2 AND TEMPERATURE

160,000 years ago to present day

CO_2 concentration in atmosphere

global temperature



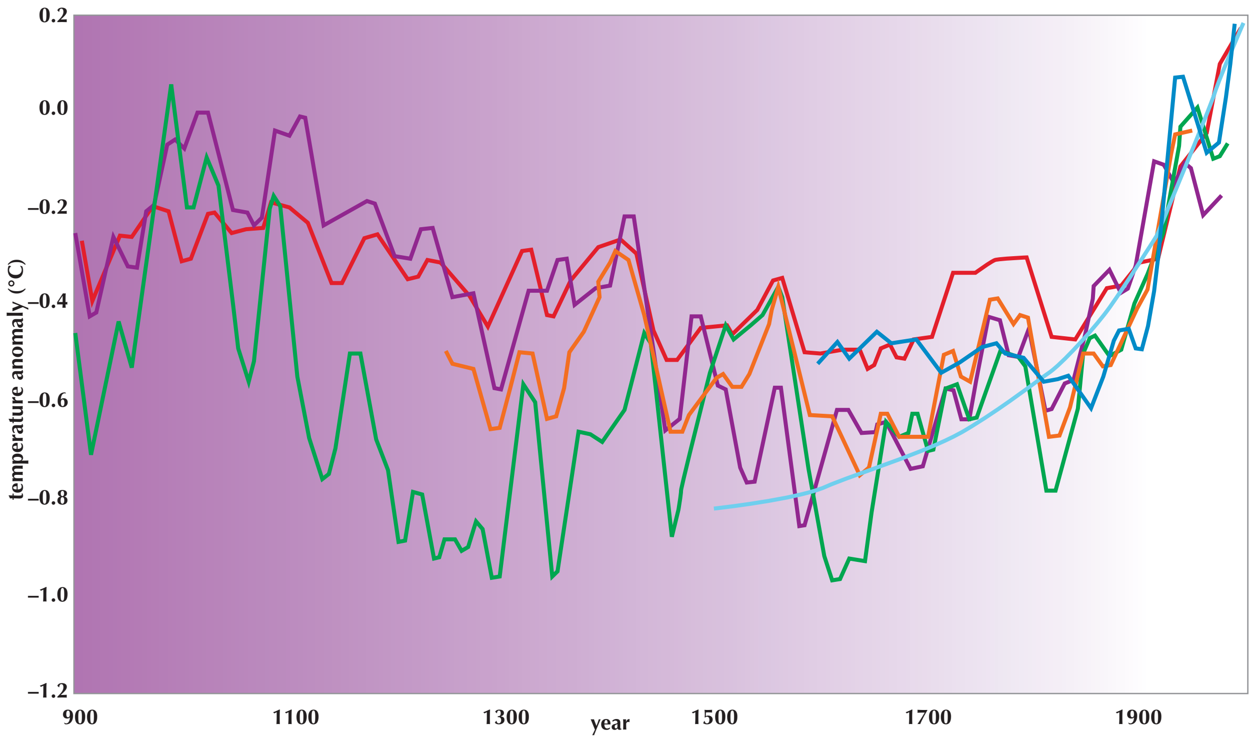
SURFACE TEMPERATURES

Information from a range of measurements

last 1,100 years

- combined proxy data set 1
- combined proxy data set 2
- tree rings
- combined proxy data set 3
- borehole temperatures
- glacier lengths
- increasing certainty

Efforts to reconstruct the history of past surface temperatures for the Earth have generated considerable controversy. The long period of less variability followed by an upturn in the last century, shown in a figure known as the "hockey stick curve", was taken as definitive evidence of human-induced climate change. In response to the controversy, the US Academy of Sciences was asked to assess the state of science in this area. A key figure summarizing part of the assessment illustrates their conclusion that multiple sets of proxy information provide a qualitatively consistent view of temperature changes over the past 1,100 years. The last 400 years show particularly strong agreement. Note that the background shading of the diagram indicates increasing levels of certainty.

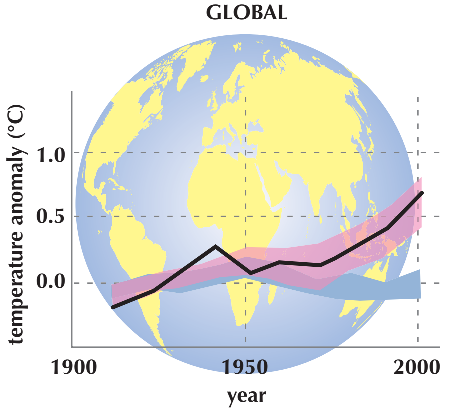


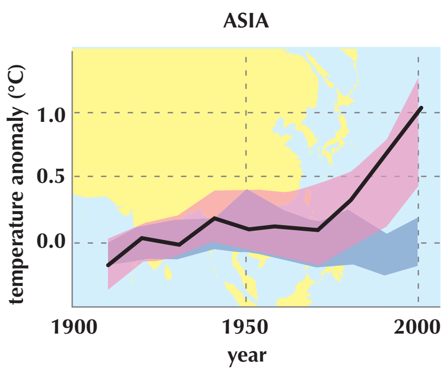
ACCOUNTING FOR WARMING

Comparison of observed changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings

1906–2005

- decadal averages of observations
- 5%–95% range for climate models using only natural forcings
- 5%–95% range for climate models using both natural and anthropogenic forcings





34–35 The Greenhouse Effect
46–47 Emissions Past & Present

13 Methane & Other Gases

Methane hydrates
An estimated 20 million trillion cubic meters of methane is trapped in permafrost ice and under-sea sediments in a form known as methane hydrates or clathrates. Its release into the atmosphere would be catastrophic, but there is uncertainty about what would trigger a mass release and how much of the gas would be transformed into CO_2 by sea water before it reached the atmosphere. Recent research reports that methane believed to be trapped by under-sea permafrost in part of the Arctic Shelf is being released to the atmosphere.

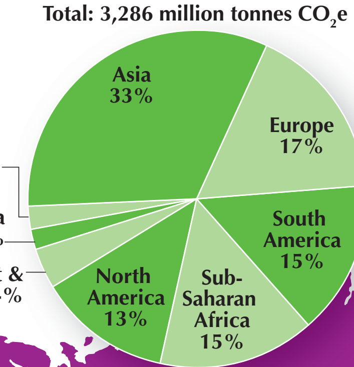
A range of greenhouse gases contribute to climate change. Methane, nitrous oxide, and other greenhouse gases are more efficient at warming the atmosphere than carbon dioxide, but are present in much smaller quantities, and their overall contribution to global warming is less.

Methane is about 25 times more effective than carbon dioxide at trapping heat in the atmosphere. As its average atmospheric lifetime is 12 years, a reduction in emissions would have a rapid effect. Methane is produced by rice cultivation, coal mining, energy production and the rearing of livestock. In the industrial world, landfill sites are a major contributor. It is also produced in the natural environment, as bacteria break down organic material in anaerobic conditions. About 70% of nitrous oxide emissions in industrialized countries in 2005 were contributed by agriculture

Nitrous oxide is 300 times more effective than carbon dioxide at trapping heat in the atmosphere. The great majority of emissions are from agriculture – nitrogen-based fertilizers and livestock manure – with additional releases in waste, industrial processes and energy use.

Manufactured gases such as halocarbons – including chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) – and compounds such as sulfur hexafluoride (SF6) have long lifetimes in the atmosphere. Sulfur hexafluoride is used as an insulator for circuit breakers, and to stop oxidation of molten magnesium during processing. HFCs are used in refrigeration units, in place of CFCs.

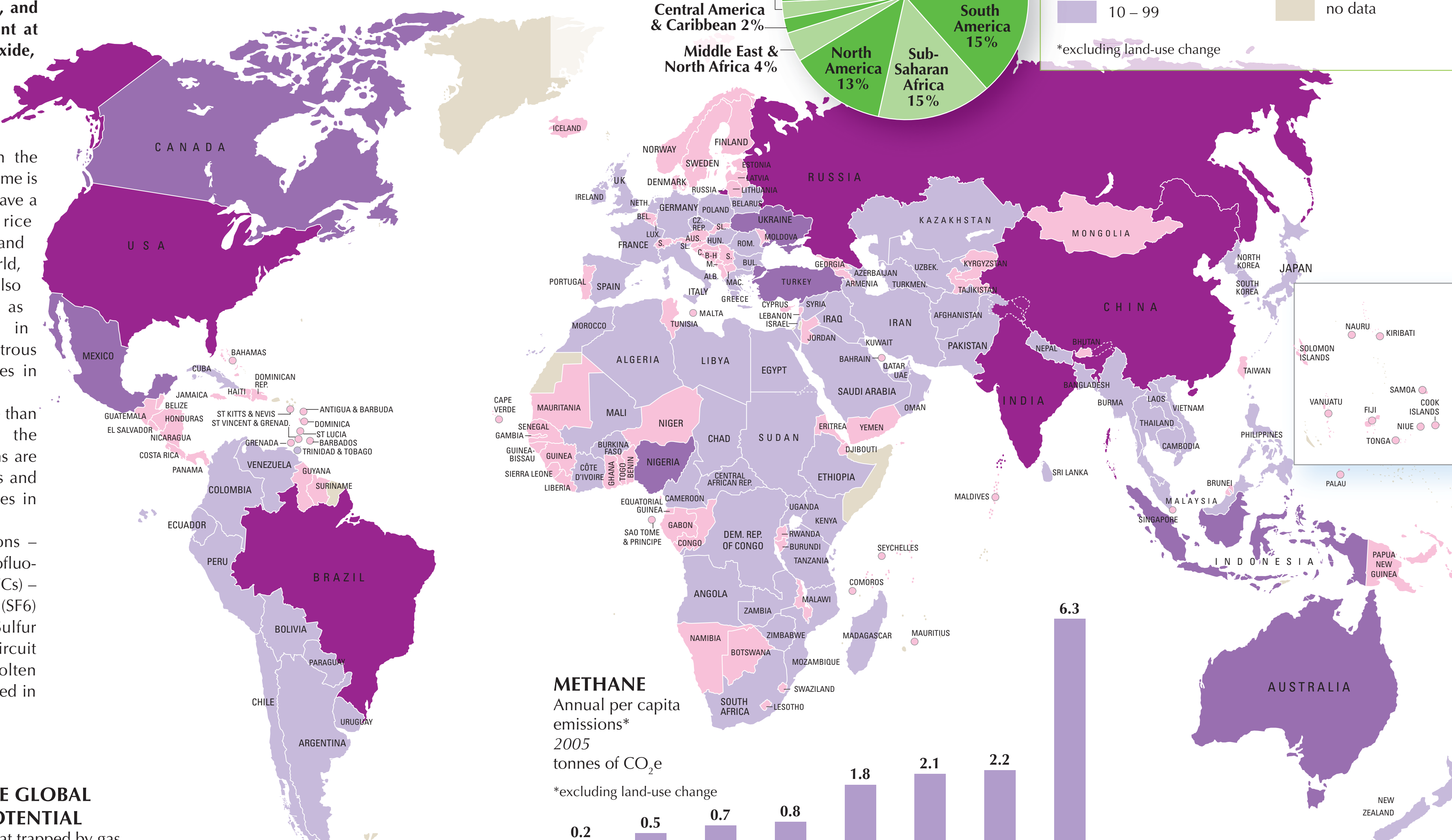
NITROUS OXIDE
Regional share of total emissions*
2005
* includes land-use change



METHANE
Annual emissions*
2005
million metric tonnes of CO_2e

315 – 853
100 – 200
10 – 99
fewer than 10
no data

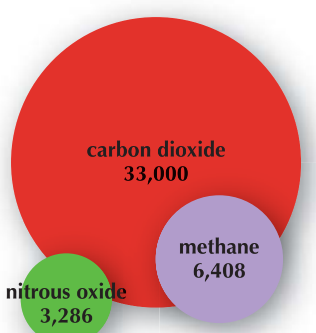
*excluding land-use change



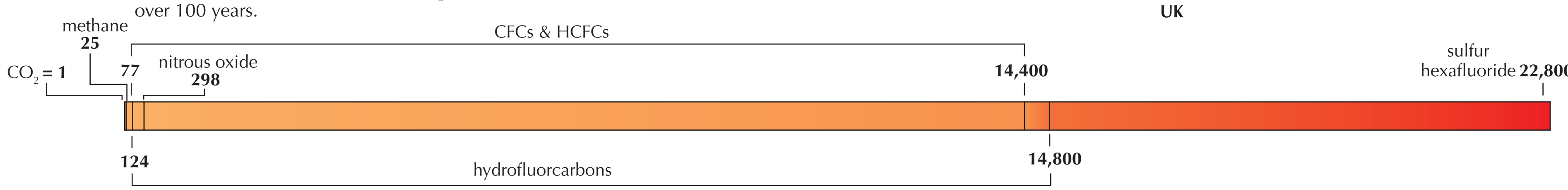
METHANE
Annual per capita emissions*
2005
tonnes of CO_2e
*excluding land-use change

0.2 Japan
0.5 India
0.7 China
0.8 Germany Indonesia UK
1.8 USA
2.1 Brazil
2.2 Russia
6.3 Australia

COMPARATIVE GHG EMISSIONS
Annual emissions including those from land-use change
2005
million tonnes of CO_2e



COMPARATIVE GLOBAL WARMING POTENTIAL
The amount of heat trapped by gas over a standard period of time.
The reference unit is the GWP for CO_2 over 100 years.



18 Threatened Water Security

Up to **5 billion** *people may live in water-stressed areas by 2050*

Nearly **3 billion** *people live in areas where water demand outstrips supply*

Water scarcity is already a major threat in some regions. Climate change raises the level of threat in some places and increases the urgency for global action.

Water is a vital resource, often taken for granted, but rising demand from expanding populations, and an increasing risk of drought are causing concern in many countries. It is now apparent that climate change is making the situation worse.

Higher temperatures result in more evaporation from surface water and evapotranspiration from plants, reducing supply and increasing demand, especially for irrigation water. Warmer and longer summers cause snow packs and glaciers to melt more quickly, which increases river flows in the spring, but may reduce summer flows. Over the long term, a reduction in snow and ice may seriously threaten many river basins. For example, in northern India 500 million people rely on the Indus and Ganges, which are fed largely by glacial melt waters.

Some areas will experience less annual rainfall; in others it will be less predictable, with seasonal rains failing to materialize, or arriving with such ferocity that they create dangerous floods. Other threats to freshwater supplies include sea-level rise, which leads to saline intrusion in coastal aquifers, and damage to water infrastructure from coast storms.

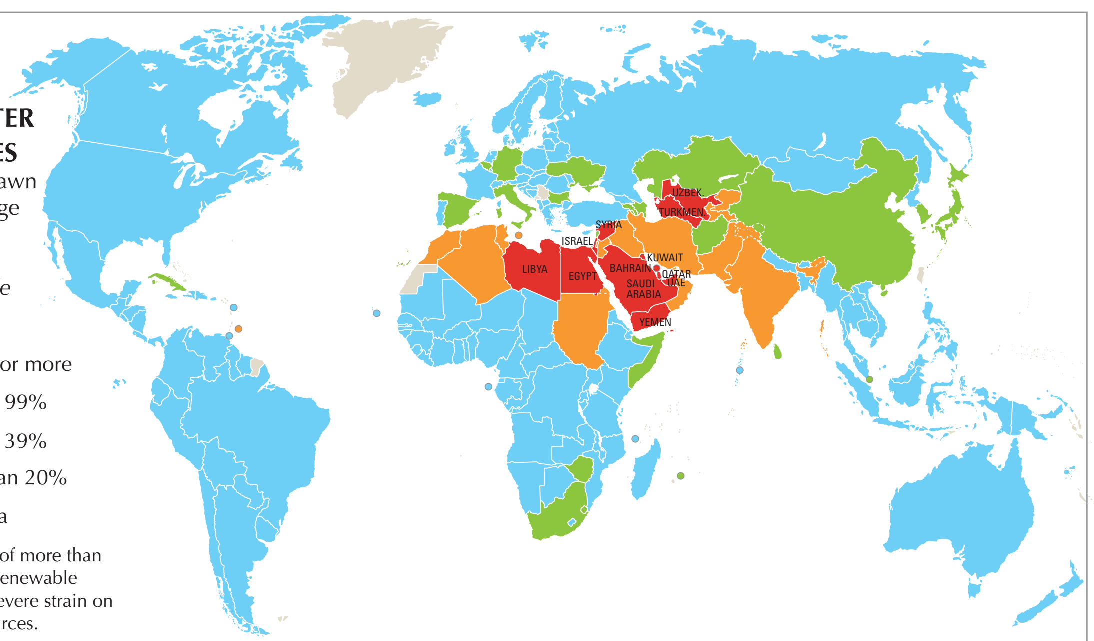
Rapid changes in weather patterns – from seasonal crises to a decade of low flows – leave people little time to adapt. Regions reliant on heavily irrigated agriculture may be forced to import more food, or even to import water itself. International water imports have been suggested as urgent options in the Mediterranean and southeast England. Water-intensive industries, such as paper and electronics manufacturing, will be unable to function, and economies will suffer as a consequence. If water supplies fail completely, contaminated water, lack of hygiene and thirst will take their toll.

Many of the effects of climate change can be countered by prioritizing the most urgent uses, adopting water-saving technology and more efficient irrigation methods. The cost of adaptation in developing countries has been estimated as up to $20 billion a year. However, the finance, technology, and infrastructure necessary to effectively manage current water resources are significant barriers.

FRESHWATER RESOURCES
Water withdrawn as a percentage of renewable resources
latest available 2002–10

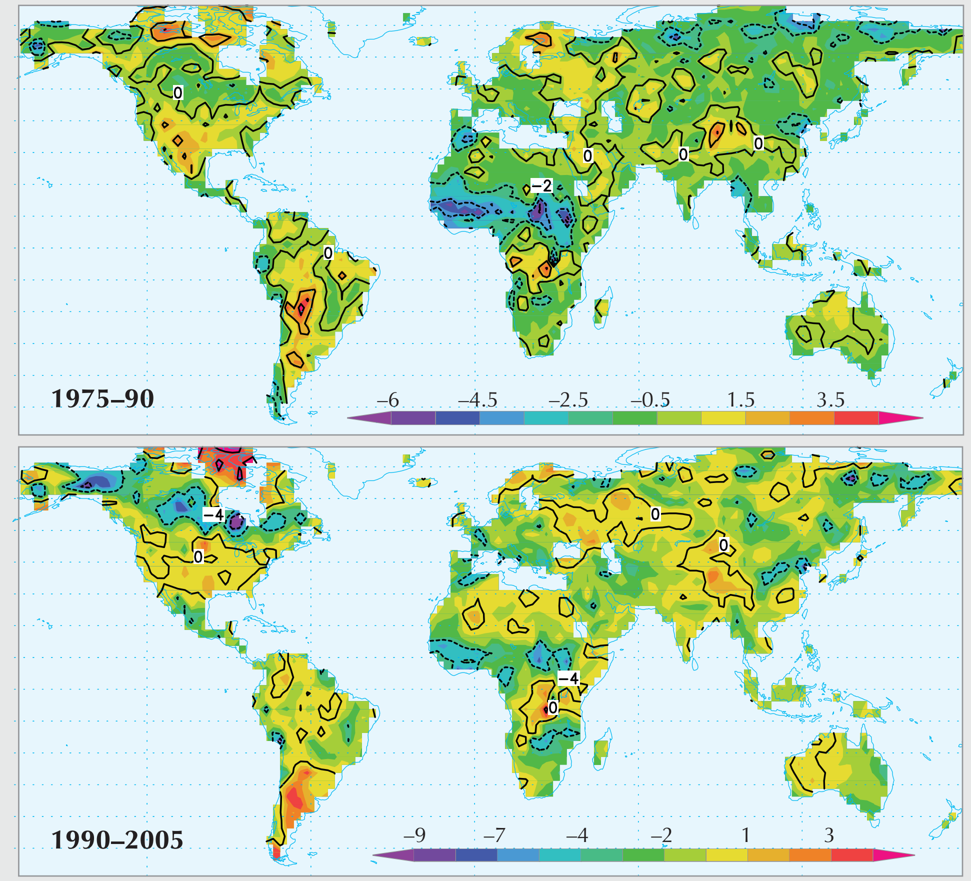
- 100% or more
- 40% – 99%
- 20% – 39%
- less than 20%
- no data

The withdrawal of more than 40% of annual renewable sources puts a severe strain on freshwater resources.



INCREASING DROUGHT RISK
Average Palmer Drought Severity Index

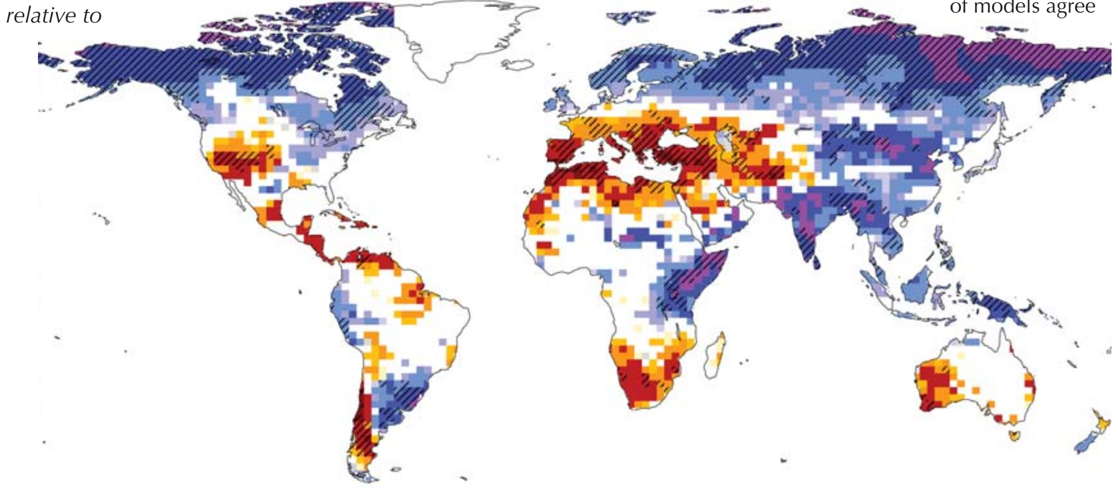
Tom – can we please have about 130 words of explanation in this column. thanks



POTENTIAL CHANGE IN RUN-OFF
Possible large-scale changes in annual water run-off
2090–99 relative to 1980–99

Decrease
- 40% or more
- 20% – 39%
- 10% – 19%
- 5% – 9%
- 2% – 4%
- little change

Increase
- 2% – 4%
- 5% – 9%
- 10% – 19%
- 20% – 39%
- 40% or more
- fewer than 66% of models agree
- more than 90% of models agree



20 Threats to Health

Over **70,000** *people died in weather-related disasters in 2010*

Under-nutrition is the underlying cause of death for at least **30%** *of all under-fives*

People already suffer from a variety of weather-related health effects. The number of victims and the economic costs have increased in the past decade, possibly a sign of future threats to health.

Exposure to weather-related disasters, such as heat waves and cyclones, and changes in resources, such as sea-level rise, ocean acidification, and altered growing seasons, means everyone is potentially at risk of one health consequence or another as a result of climate change.

Diseases transmitted by vectors, such as mosquitoes and ticks, and pests that destroy crops, are affected by rising temperatures and humidity, and by altered rainfall patterns. The areas affected by diseases may expand in some regions, contract in others, or the disease may become more common throughout the year. The absence of pest-killing sub-zero temperatures increases year-round populations of pests.

While fewer people may die from cold, warmer weather leads to increased heat stress. It may also lead to higher levels of air pollutants from forest fires in rural areas, and from the formation of ozone and volatile organic compounds in urban areas. The number of deaths related to respiratory conditions will rise.

Intense rainfall and flooding increases the risk of waterborne diseases such as cholera, typhoid, and dysentery, and of mosquito-borne diseases, including malaria and yellow fever. Heavy rainfall often leads to contamination of the environment and water supplies: poor sanitation is a major health risk in crowded urban areas.

Drought and disasters reduce food supplies, with direct effects on malnutrition in vulnerable people. Poor nutrition is a significant factor in the ability to fight off infections and reduces the effectiveness of many medical treatments (including for HIV/AIDS).

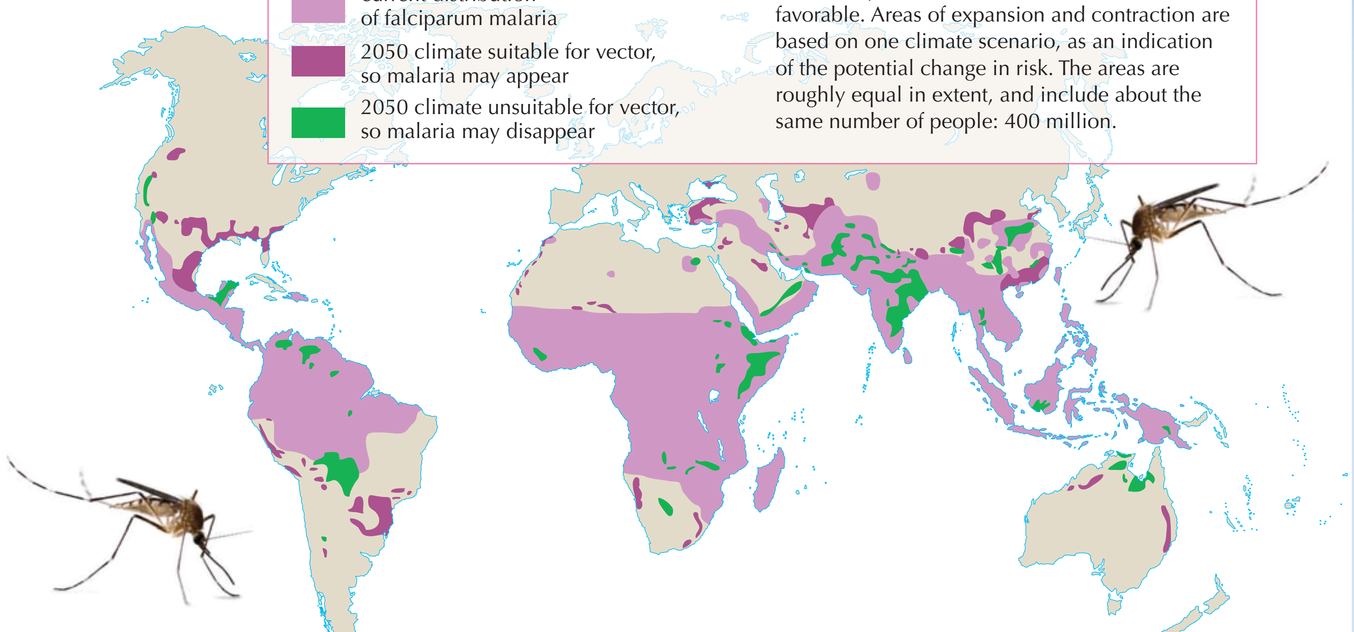
The effects of disasters and changing environments on mental health are a growing concern. Increased suicide rates in drought-affected areas have been noted. Anxiety has been caused by new risks such as coastal erosion and the need to relocate communities.

POTENTIAL FUTURE MALARIA RISK

Scenario of malaria distribution
projected 2050

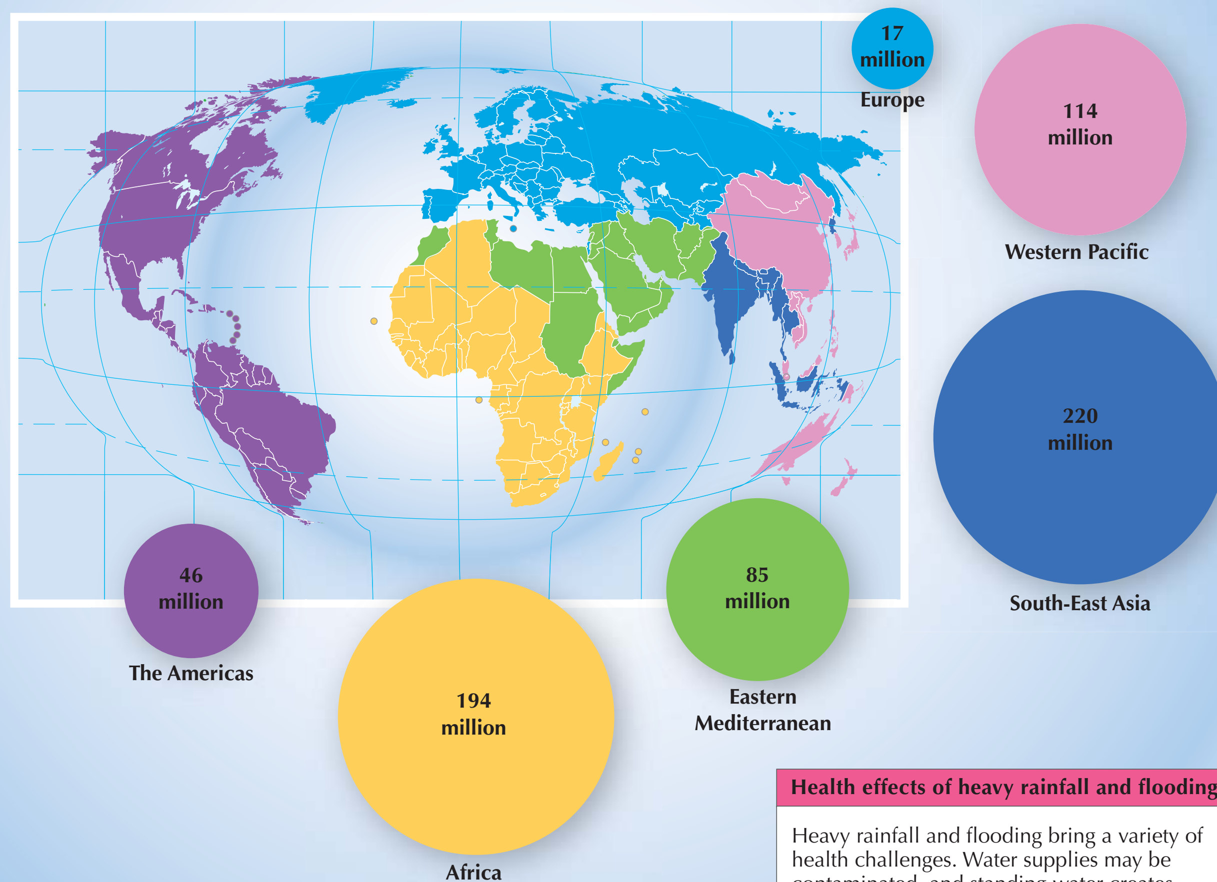
- current distribution of falciparum malaria
- 2050 climate suitable for vector, so malaria may appear
- 2050 climate unsuitable for vector, so malaria may disappear

The map shows the distribution of the parasite that causes malaria in humans: *Plasmodium falciparum*, carried by the *Anopheles* mosquito. It is currently distributed wherever conditions are favorable. Areas of expansion and contraction are based on one climate scenario, as an indication of the potential change in risk. The areas are roughly equal in extent, and include about the same number of people: 400 million.



INCREASED DISEASE BURDEN

Number of extra cases of diarrhea, malaria, and malnutrition, assuming a business-as-usual scenario of climate change
projected 2030



Health effects of heavy rainfall and flooding

Heavy rainfall and flooding bring a variety of health challenges. Water supplies may be contaminated, and standing water creates breeding grounds for disease- carrying organisms such as mosquitoes. Soil transported by flood waters may move soil-borne diseases such as anthrax, and toxic contaminants such as heavy metals and organic chemicals, to previously unexposed areas. Mold developing on flooded property may contribute to respiratory problems. Cholera is related to wetter seasons.

Tick-borne diseases

Lyme disease, which can cause long-term disability, is spreading in the USA and Europe as winter temperatures warm and daily temperatures rise. The habitat favorable to the **deer ticks** that carry the disease is likely to spread. Rocky Mountain spotted fever, Q fever, and, especially in Europe, tick-borne encephalitis are among other diseases that may also spread as the climate changes.

35 Personal Action

REDUCE, REUSE, RECYCLE

Actions in order of effectiveness:

1. Buy things to last, such as clothes, and appliances, so you buy less.
2. Reuse items, such as shopping bags or water bottles.
3. Recycle what cannot be reused.

These actions cut the amount of GHGs emitted during resource extraction or harvest, manufacturing, transport, and disposal, as well as saving energy and reducing pollution.

People around the world are making lifestyle changes to reduce the greenhouse gas emissions associated with their everyday activities. From the way we run our homes, to the ways we use collective spaces for work, play, and worship, there is plenty of advice on how to live more sustainably.

In addition to benefiting the climate, most of the recommended actions also result in households making long-term financial savings. Some savings are immediate, involving low-cost or no-cost adjustments; others require long-term investment. Many of the decisions taken to save energy will also improve people's quality of life and health.

Together, the actions of millions of people could add up to considerable savings in greenhouse gases, but they will not, on their own, be sufficient to halt climate change. Individuals also need to put pressure on government representatives and companies to take the larger-scale collective action necessary to achieve a reduction in emissions of 60 to 80 percent.

TRANSPORTATION

Choosing to live near your work and cutting the length of your daily commute will reduce your carbon footprint and save you time, especially if you live close enough to cycle, take public transport, or walk to work.

Purchasing a more energy-efficient car is an effective long-term investment option, but there are many immediate low-cost and no-cost energy saving actions you can take to reduce the emissions of any vehicle.

CAR USE

Possible savings in total US energy use if measures were adopted by all US households

2008

Potential saving: 17.6% of current US total energy use

improve driving technique: smoother acceleration and no sudden stops	3.2%
reduce top speed from 70 mph to 60 mph	2.4%
tune engine more frequently, including air filter changes	3.9%
maintain correct tire pressure	1.2%
share car to work with one other person	4.2%
reduce mileage by half by combining errands	2.7%

REDUCING EMISSIONS AT HOME

Use energy efficient appliances and lighting.

Insulate and seal ducts and windows.

Insulate wall cavities and loft spaces.

Turn the heating thermostat down, and the air conditioning up.

Use water efficiently. It is very energy intensive to purify and distribute water.

Increase use of renewable energy sources.

Be a carbon-conscious shopper. Buy local, used, and recycled goods.

ENGAGE GOVERNMENT, COMMUNITIES, AND COMPANIES

There are many ways you can influence changes that will have an impact beyond your immediate household or workplace:

- Challenge your political representatives to take climate change seriously.
- Take part in a day of action in your community, campus, or church.
- Bring your neighbors together to discuss climate change.
- Choose investment funds that support low carbon futures, such as renewable energy sources.
- Ask businesses to disclose any risks they might face due to climate change.
- As a corporate shareholder, encourage sustainability plans that reduce the carbon footprint of production processes and supply chains.
- Encourage your community to incorporate climate change mitigation and adaptation in growth and renewal plans.

Don't ignore the elephant in the room – the message of an artwork created by 3,000 students and teachers at the Ryan International School in New Delhi, and volunteers from the Indian Youth Climate Network. It was photographed by aerial artist Daniel Dancer in November 2010, as part of the 350 EARTH project, which used aerial art to send messages to governments around the world.

ENERGY SAVINGS AT WORK

- Choose energy-efficient equipment and energy-efficient settings.
- Turn off computers and photocopiers at the end of the day.
- Unplug appliances that drain energy when not in use.
- Save paper and always use both sides of the paper.
- Establish an anti-idling policy for the vehicle fleet.
- Use natural lighting when possible.
- Coordinate with vending machine vendor to turn off advertising lights.
- Consider alternative work schedules and telecommuting to reduce GHG from commuting.
- Use coffee cups instead of disposable cups.

CONSIDER BECOMING CARBON NEUTRAL

Calculate your carbon emissions, and make changes that allow you to reduce your emissions as much as possible. Emissions that cannot be reduced can be compensated or offset by paying one of many firms to support renewable energy production or carbon sequestration projects, such as tree planting.

Carbon calculators can be found at the following:
US Environmental Protection Agency: Household Emissions Calculator, Office Carbon Footprint Tool: www.epa.gov
Act on CO_2: www.carboncalculator.direct.gov.uk
Redefining Progress: www.myfootprint.org

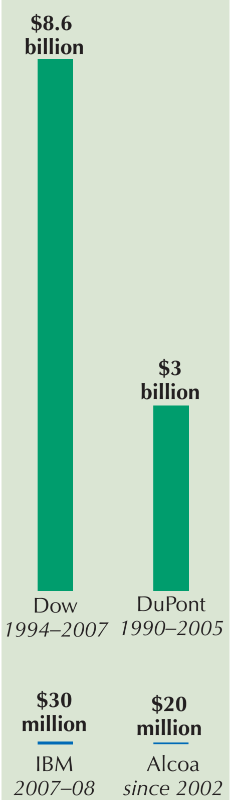
104–05 Public Action

36 Public Action

Toyota reduced its CO_2 emissions by **20%** *per vehicle produced 2001–08*

CORPORATE ENERGY REDUCTION SAVES MONEY

Estimates of savings from increased efficiency



The policies, practices, and investments of governments and businesses will have the greatest impact on our future. Individuals can seek to influence those decisions.

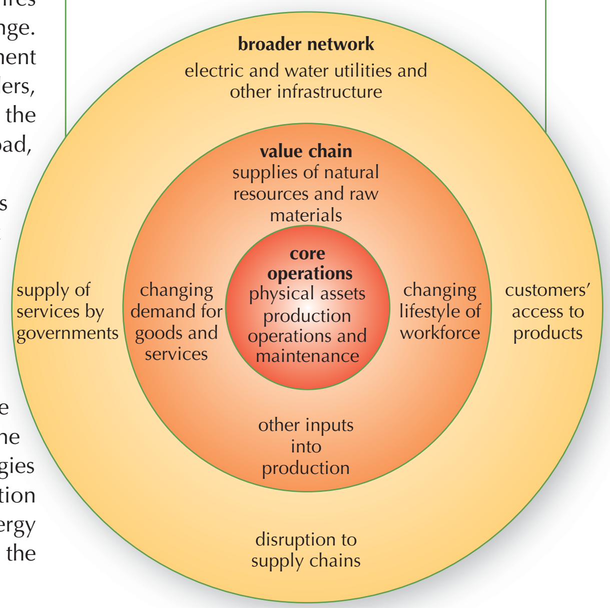
Climate change presents a central challenge: how to shift from the current path of social, economic, and technological development to one that reduces emissions and prepares us for future climates. The necessary reduction in emissions of between 60 and 80 percent requires large-scale investment, policy development, and implementation. The control of these areas rests largely with governments and businesses, but the adaptation and mitigation effort requires champions within organizations to lead change. These people, in turn, need the encouragement and support of voters, shareholders, and others to convene the dialogues, identify the risks and opportunities, and promote a broad, long-term vision of sustainability.

Major corporations and government leaders at all levels have already brought about substantial reductions in greenhouse gas emissions, and made timely adaptations to climate change – in some cases in response to citizen and shareholder calls for action. Many of the changes made have provided substantial economic and other benefits. Indeed, the increasing international competition to be the leader in emerging climate-friendly technologies and green jobs, reflects a growing recognition of the multiple advantages of increasing energy efficiency, reducing emissions, and decreasing the risks associated with climate change.

ASSESSING THE RISK TO BUSINESS

Businesses will be affected by climate change both directly and indirectly, not only in terms of their core operations, but the resources they depend on, the parts they buy, the transportation and other services they use, and the social and environmental conditions that make their product attractive to the customer. In today's global markets, companies are likely to feel the impact that climate change is having on the other side of the world.

Aspects of business on which climate change may impact



ONLINE TOOLS AND RESOURCES

A growing number of websites are being set up to help organizations develop strategies to deal with climate change and reduce their emissions. These include:

- US EPA Energy Star provide customized support for diverse types of enterprises, including government, healthcare, higher education, hospitality/entertainment, retail, small businesses, congregations, service and products providers www.energystar.gov
- UKCIP Business Areas Climate Impacts Assessment Tool (BACLIAT) offers a structured examination of threats and opportunities associated with climate change www.ukcip.org.uk/bacliat
- Global Framework for Climate Risk Disclosure www.unepfi.org
- Cool California supports planning by local governments and CalAdapt leads sectoral adaptation planning: www.CoolCalifornia.org, www.climatechange.ca.gov/

MEETING THE SCALE OF ACTION REQUIRED

Action by governments and larger organizations is necessary to achieving mitigation and adaptation goals. Individual households cannot achieve necessary emissions reductions or adaptations.

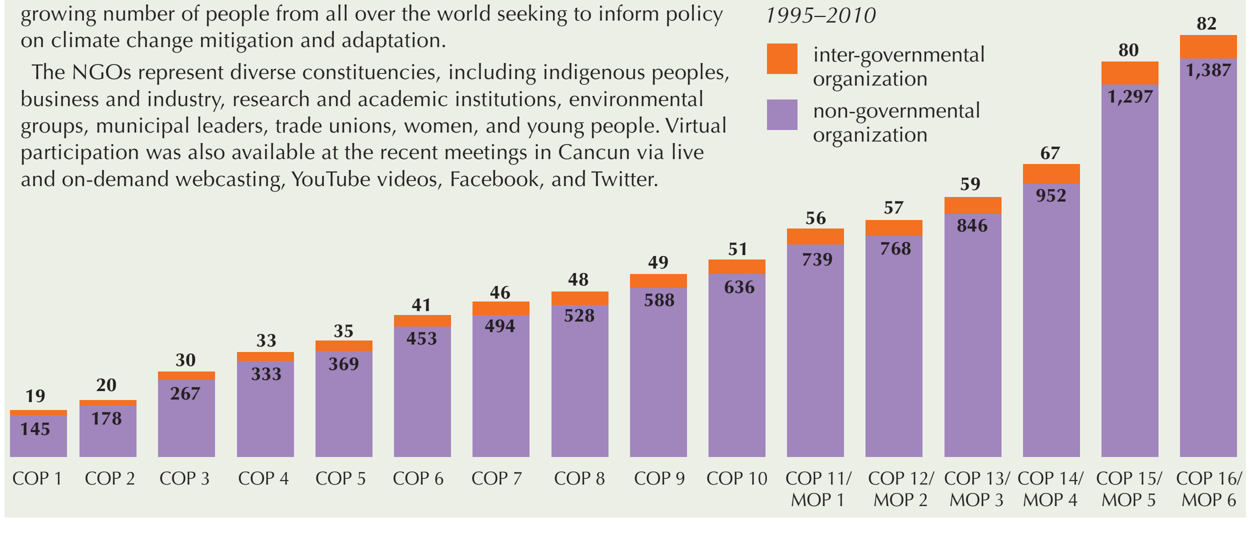
- **National Governments** can push for more rapid progress on international emissions reduction commitments and support for adaptation. They can revise laws, regulations, and rules to remove barriers to reducing emissions and increasing adaptation.
- **Local government representatives** are key to implementation of many actions involving construction, land use, infrastructure, and urban design. See Local Governments for Sustainability: www.iclei.org/index.php?id=800 . And, in the absence of national and international action, regional and local action is more important.
- **Workplaces, schools, and places of worship** can adopt numerous strategies to reduce emissions and improve adaptation.
- **Companies and governing bodies** can invest in energy conservation measures, renewable energy, demonstration projects and sharing lessons and innovations. They can also set standards and certifications that allow consumers to make informed choices.
- **Corporations** can develop a greenhouse gas registry, conduct life-cycle analysis to minimize carbon emissions throughout supply chain. They can also assess, report, and improve adaptation to the risks of climate change to operations and financial plans.

PARTICIPATION IN POLICY MAKING

The participation of Non-Governmental Organizations at the UNFCCC Conference of Parties (COP) and Meeting of Parties (MOP) events reflects the growing number of people from all over the world seeking to inform policy on climate change mitigation and adaptation.

The NGOs represent diverse constituencies, including indigenous peoples, business and industry, research and academic institutions, environmental groups, municipal leaders, trade unions, women, and young people. Virtual participation was also available at the recent meetings in Cancun via live and on-demand webcasting, YouTube videos, Facebook, and Twitter.

Number of observer organizations at COP/MOP events
1995–2010



 102–03 Private Action