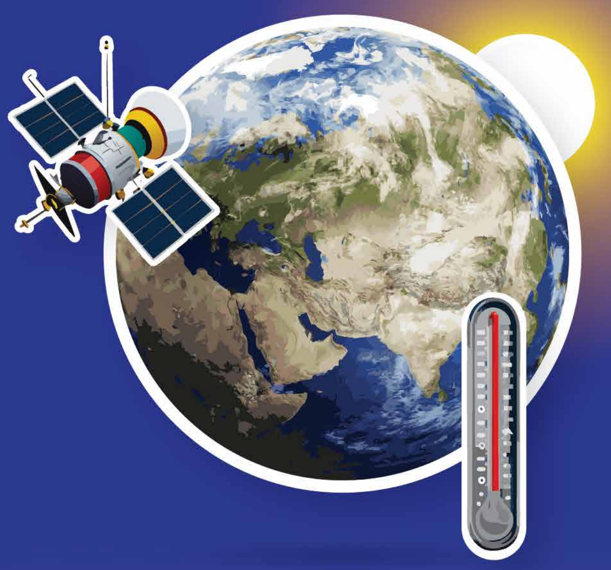


1

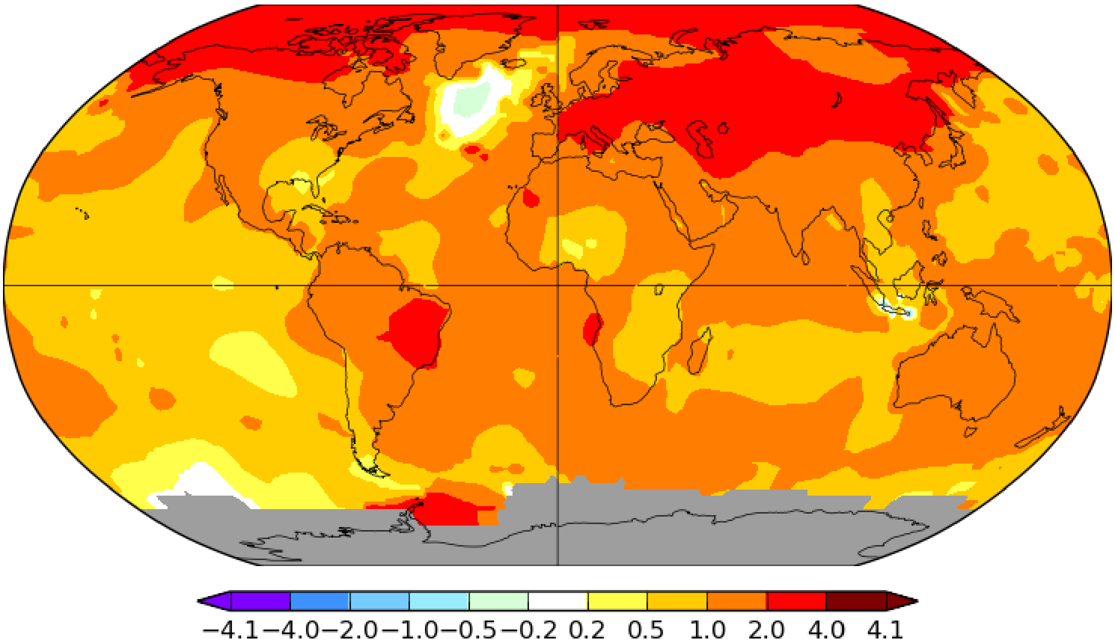
The problem of climate change

1 | The problem of climate change

Climate change is one of the most urgent global issues of our time. Thirty years ago, only scientists talked about climate change, but today it concerns most of us. We notice that the weather has become warmer and is increasingly hard to predict at any time of the year. We also notice the increased frequency and severity of extreme events, such as storms, hurricanes, heatwaves, precipitation, and droughts.

The fact that our planet's climate is changing, and changing rapidly, is clear beyond doubt. Judge for yourself: since the second half of the 19th century till this decade, the average temperature on Earth has risen by nearly 1.2°C. That may not seem like much, but on a global scale it poses a serious threat to all life on our planet, from plants to animals and to ourselves. And keep in mind that nearly 1.2°C is the world average, but warming is stronger over land than in ocean, and strongest in the Arctic. Warming is also stronger in the northern hemisphere than in the southern hemisphere, whose larger surface area absorbs more solar radiation and ocean circulation. Warming has also occurred at a faster rate after the 1970s than in the first half of the 21st century.

Figure 1.1 Map of observed changes in surface temperature on Earth between 1901 and 2022



Note: Gray areas signify missing data

The Earth is getting hotter

According to the World Meteorological Organization, the global average temperature on Earth in 2023 was about 1.4°C above the 1850-1900 average. This means that 2023 was the warmest year since record-keeping began in 1850.

The Greek philosopher Heraclitus coined the phrase '*panta rhey*' (everything flows) to express the concept of change. This also applies to the climate, which has been constantly changing for millions of years. Even 125 million years ago, global average temperatures were higher by about 1°C than they are today.

But the rapid rate of climate change in recent decades has perilous consequences for the planet and all its inhabitants.

'Climate change' is a more accurate term than 'global warming' because higher temperatures are only a part of what climate change means for Earth. Changes in climate lead to a loss of equilibrium throughout the natural world: glaciers and permafrost are melting, sea levels are rising, floods, droughts and hurricanes are more frequent, and the weather is harder to predict. Climate change leads to the extinction of many animals and plants, which cannot adapt to the new conditions, it hurts countries' economies and threatens the health and the lives of people.

There are different theories of why these changes are happening. Some researchers say they are due to the impact of astronomical processes (increased solar activity and changes in the slope of the Earth's axis), while others say that climate problems are a result of excessive human consumption of natural resources. What is certain is that solar activity and changes in the slope of the Earth's axis are beyond our control, while excessive consumption and the climate-harming greenhouse gases it causes are things we can do something about.

There is no country that is not experiencing the drastic effects of climate change. Greenhouse gas (GHG) emissions in the atmosphere are more than 50% higher than in 1990. Increasing GHG emissions are causing long-lasting changes to our climate system, which threatens irreversible consequences if we do not act.

13 CLIMATE ACTION

The climate action goal (Goal 13), one of the 17 Sustainable Development Goals adopted by the United Nations in 2015, aims to address the need to both adapt to climate change and invest in low-carbon development.

The Intergovernmental Panel on Climate Change and its most recent findings

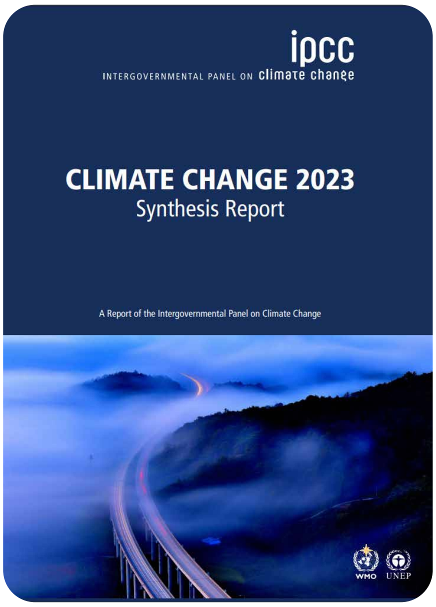
The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations. The IPCC was created in 1988 by the World Meteorological Organization and the United Nations Environment Programme to advance scientific knowledge and understanding of climate change, its drivers, and consequences, and how to deal with it.

The IPCC provides governments with the most updated scientific information on climate change. It does not conduct its own research but assesses all relevant scientific literature. This includes the observed changes in the climate system and their projections; natural, economic, and social impacts and risks stemming from climate change, and options and opportunities to mitigate climate change and adapt to its consequences. Thousands of scientists and other experts volunteer to review huge volumes of publications and reflect their findings in 'Assessment Reports' for policymakers and the public.

The IPCC is the most authoritative source of scientific information and assessment on climate change as leading climate scientists and governments endorse its findings. IPCC reports play a key role in the annual climate Conferences of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) that are known as COPs. Each of the six Assessment Reports (AR) published by the IPCC has led to major advances in UNFCCC negotiations. The First Assessment Report was critical to the negotiations that led to the adoption of the UNFCCC in 1992, the Second Assessment Report to negotiations of the Kyoto Protocol in 1997 and the Fifth Assessment Report to negotiations of the landmark Paris Agreement in 2015.

The most recent report by the IPCC is its Sixth Assessment Report (AR6) published in 2021-2023. Many of its findings are in this edition of the Climate Box (Fig. 1.2).

Figure 1.2 **Highlights of key messages from the IPCC AR6**



"It is indisputable that human activities are causing climate change, making extreme climate change events, including heat waves, heavy rainfall, and droughts, more frequent and severe."

"The evidence is clear: the time for action is now."

You can find more at:
https://www.ipcc.ch/assessment-report/ar6/

So, what is really happening to our weather and climate? How did the Earth's climate change in the past and how is it changing now? What is to blame for the changes that are happening? What are greenhouse gases and what can we do about them? Let's try to find some answers to these questions.

1.1 | Climate and weather

People often complain about the weather, but they hardly ever complain about the climate. For example: "October extinguished itself in a rush of howling winds and driving rain and November arrived, cold as frozen iron, with hard frosts every morning and icy drafts that bit at exposed hands and faces." (J.K. Rowling, *Harry Potter and the Order of the Phoenix*). Writers and poets don't write about the climate. And it's easy to understand why. You can see the weather just by looking out of the window. We must deal with the weather every day. But the climate is something much harder to grasp. Yet, everyone – from scientists to politicians and businesspeople – talks about how the climate is changing.

When you get back from a holiday with your parents somewhere far from home, the first thing people want to know is how the weather was. But when you recommend the same place to friends for a holiday, you will probably tell them: "The climate there is very good." So, what is the difference between weather and climate?

WEATHER

is the state of the atmosphere at a particular place at a particular time or for a limited period (for example, a day or a month).

The weather is the momentary state of what we call 'meteorological elements', things that we hear about every night on the TV weather forecast: temperature, humidity, atmospheric pressure, cloud cover, etc. When it turns cold for a week in the summer and rains so hard that you don't even want to poke your nose out of doors, that's bad weather.

CLIMATE

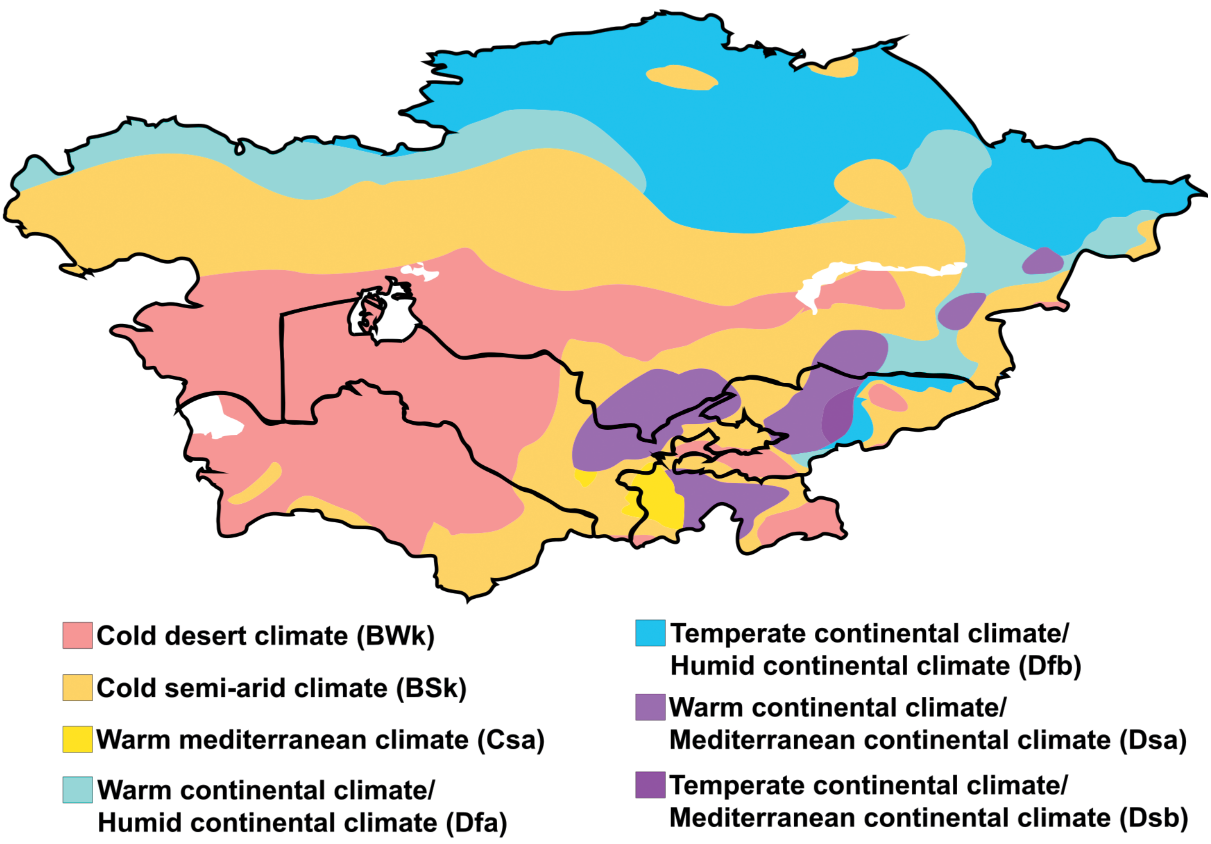
is the average state of the weather at a particular place over a long period (several decades).

For example: summers are hot and dry, while winters are cool and wet with very rare snowfalls. That is a brief description of the Mediterranean climate. As the proverb says: 'Climate is what we expect, weather is what we get'. You can't see the climate just by looking out of the window!

The main features of climate are:

- air temperature and its changes depending on the season;
- the amount and the time of precipitation (rain and snow) during the year;
- how air masses move;
- prevailing and other winds.

Figure 1.1.1 Example of a climate map of Central Asia (by W. Köppen)



AIR MASS

is a large piece of the atmosphere with roughly the same air temperature, pressure, and quantities of water vapour throughout.

The observation, study and forecasting of the weather is the subject of a branch of atmospheric sciences, called **meteorology**. **Climatology** is another branch of atmospheric sciences concerned with the description of the climate, the analysis of the causes of climatic differences and changes and their practical consequences.

People who live in Ireland say jokingly, “Ireland has a wonderful climate, but it’s spoilt by the weather.” Ireland is a country on a large island off the coast of Western Europe. Its weather is very changeable, but winters are mild, and the grass is green all year round. Because of this, Ireland is often called the ‘Emerald Isle’.

What meteorological elements determine the weather?

Air temperature may be positive or negative. The dividing point between positive and negative air temperature is 0°C when water freezes and turns to ice.

Air humidity depends on the amount of water vapour in the air. When humidity is higher in the winter, we feel colder. But when humidity is high and the air temperature is high, it feels stuffy.

Clouds are a cluster of tiny water droplets or ice crystals in the atmosphere.

Precipitation varies depending on whether it falls from clouds (rain, snow, frozen rain, hail) or forms on the surface of the ground and on objects (dew, frost, hoar frost, ice).

Visibility is the maximum distance beyond which an observed object blends into the distance and cannot be distinguished.

Fogs are a cluster formed by the condensation of water vapour close to the ground.

Atmospheric pressure is the pressure of air at a certain level in the atmosphere.

Wind is the horizontal movement of air caused by differences in atmospheric pressure.

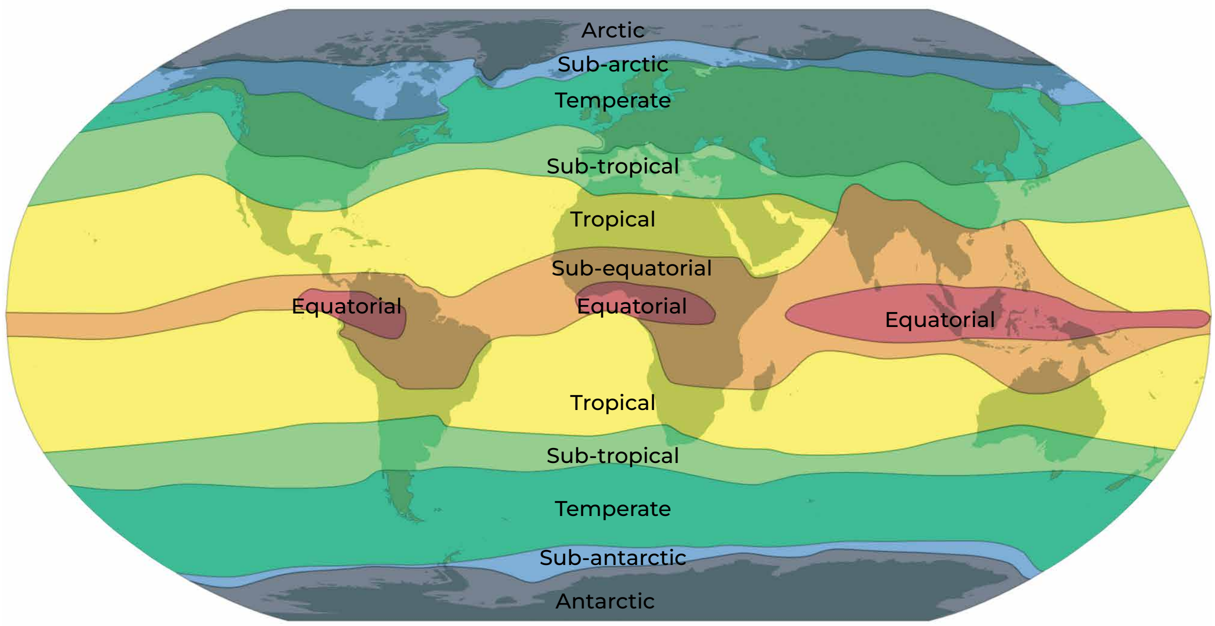
1.2 Types of climate and climate zones

Different parts of the globe have different climates. In northern countries, when people look out of the window during winter and see snow everywhere, they are keen to go on holiday to tropical countries, where one can enjoy hot weather and swim in the warm sea all year round.

Since ancient times, scientists have divided Earth into climate zones depending on the height of the sun above the horizon and the length of the day. The word 'climate' comes from the Greek language, in which it refers to the angle of inclination of the sun. Differences in the climate are primarily because the sun's heat is distributed unevenly over the Earth's surface. Proximity to the sea, atmospheric circulation, patterns of precipitation and other so-called 'climate-forming factors' also have a major role in determining climate, and they, in turn, depend much on geographical latitude and on the height above sea level.

Areas with similar climates are like broad stripes encircling the globe. They are what scientists call 'climate zones' and they turn colder the further away they are from the equator (Fig. 1.2.1).

Figure 1.2.1 The Earth's climates (by Boris Alisov)



CLIMATE ZONES

are areas with a relatively uniform climate.

The most well-known classification of climates was introduced by a German Russian climatologist Wladimir Köppen in 1884 (Fig. 1.1.1). He divided the climates into five main types: **A** – Tropical, **B** – Dry, **C** – Temperate, **D** – Continental, **E** – Polar and Alpine.

Another system of climate classification, commonly used in Eastern Europe, was created in the 1950s by the Russian scientist Boris Alisov (Fig. 1.2.1). It defines four main climate zones in each hemisphere and three transitional zones.

The main climate zones are **equatorial, tropical, temperate, and polar (Arctic in the Northern Hemisphere and Antarctic in the Southern Hemisphere)**. They are the main climate zones since each is dominated throughout the year by the same air masses.

Between the main climate zones are the transitional zones: **sub-equatorial, sub-tropical and sub-polar (sub-Arctic in the Northern Hemisphere, and sub-Antarctic in the Southern Hemisphere)**. All the names of transitional climate zones have the prefix 'sub', which in Latin means 'under'.

The air masses in transitional climate zones change with the seasons, entering them from neighbouring zones at various times of the year. For example, in a sub-tropical climate the summer is hot, like in the tropics, but the winter is cool, since the tropical air mass is displaced by an air mass from the temperate zone.

Some climate zones contain specific climate regions with a **continental, maritime or monsoon** climate (See Table 1.2.1).

The seasons in the southern and northern hemispheres are directly opposite: from December to February, when it is winter in the Northern Hemisphere, the Southern Hemisphere is in the midst of summer, and when the Northern Hemisphere is at its coldest, the Southern Hemisphere is at its hottest.

Table 1.2.1 **Climates of Earth (by Boris Alisov)**

Climate zone	Climate type	Average temperature		Time and amount of atmospheric precipitation	Circulation of the atmosphere and predominant winds	Territory
		Winter	Summer			
Equatorial	Equatorial	+26°C	+26°C	Throughout the year, 2000 mm	Warm, moist equatorial air masses are formed in a region of low atmospheric pressure	Equatorial regions of Africa, South America and Oceania
Sub-equatorial	Tropical monsoon	+20°C	+30°C	Mainly during the monsoon, 2000 mm	Monsoon	Southern and South-East Asia. West and Central Africa, Northern Australia
Tropical	Tropical dry	+12°C	+35°C	Throughout the year, 200 mm	Trade winds	North Africa, Central Australia
Sub-tropical	Mediterranean	+7°C	+22°C	Mainly at the cold time of the year, 500 mm	In summer, anticyclones with high atmospheric pressure; in winter, cyclones	Mediterranean, South Africa, South-West Australia, Western California
	Sub-tropical dry	0°C	+40°C	Throughout the year, 120 mm	Dry continental air masses	Interior of continents between 30 to 45° north and south of the equator
Temperate	Temperate maritime	+2°C	+17°C	Throughout the year, 1000 mm	West winds	Western parts of Eurasia and North America
	Temperate continental	-15°C	+20°C	Throughout the year, 400 mm	West winds	Interior of continents from 40–45° latitude to the polar circles
	Temperate monsoon	-20°C	+23°C	Mainly during the summer monsoon, 560 mm	Monsoon	Eastern fringes of Eurasia
Sub-polar (sub-arctic and sub-antarctic)	Sub-arctic	-25°C	+8°C	Throughout the year, 200 mm	Cyclones predominate	Northern fringes of Eurasia and North America
	Sub-antarctic	-20°C and below	About 0°C	Throughout the year, up to 500 mm	Cyclones predominate	Seas of the Southern Hemisphere from 60° southern latitude
Polar (Arctic or Antarctic)	Polar (Arctic or Antarctic)	-40°C	0°C	Throughout the year, 100 mm	Anticyclones predominate	Seas of the Arctic Ocean and the mainland of Antarctica

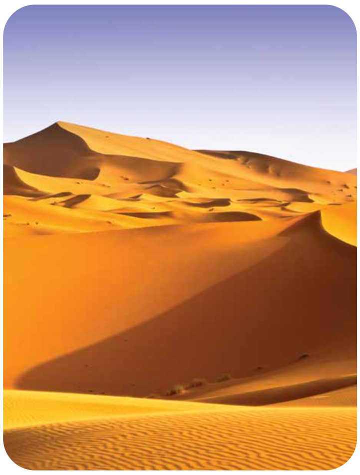
A brief description of different climates

Equatorial climate

An equatorial climate is marked by hot and moist equatorial air masses. Air temperature is constant (+24–28°C) and there is much rain throughout the year (from 1500 to 5000 mm). Rain falls faster than water can evaporate from the ground, so the soil in an equatorial climate is waterlogged and covered by a dense and high rainforest. An equatorial climate is found in northern parts of South America, the coast of the Gulf of Guinea, in the Congo River basin and the headwaters of the Nile in Africa, over the greater part of the Indonesian archipelago and the adjacent parts of the Indian and Pacific Oceans in Asia.

Sub-equatorial climate

A sub-equatorial climate is marked by a rainy season in the summer, followed by a cool and dry season in the winter. Rainfall in a sub-equatorial climate is very uneven throughout the year. For example, Conakry (the capital of Guinea) receives just 15 mm of rain from December-March, but 3920 mm from June-September. This type of climate is found in some parts of the Indian Ocean, the western Pacific Ocean, as well as in South Asia and the tropical regions of Africa and South America.



Tropical climate

A tropical climate is dominated by anticyclones with high pressure, giving clear weather nearly all the year round. There are two seasons: warm and cold. Temperatures can vary from +20°C on the coast to +50°C in the interior. The temperature can also vary greatly within a single day: on a summer afternoon the air heats up to +40–45°C but cools down at night to +10–15°C. Deserts are often found in tropical climates, and the largest is the Sahara Desert in Africa. Deciduous forests (forests that lose their leaves in the winter) and savannas are common in wetter regions. Mexico, North and South Africa, Central Australia and the Arabian Peninsula have a tropical climate.

Sub-tropical climate

A sub-tropical climate is found in regions between tropical and temperate latitudes, from about 30° to 45° north and south of the equator. They are marked by hot, tropical summers and cool winters. The average temperature in summer is above +22°C and in winter above -3°C, but the arrival of air from polar regions in wintertime may cause temperatures to drop to -10 to -15°C, and occasionally even as low as -25°C. This type of climate is typical for the Mediterranean, South Africa, Southwestern Australia and Northwestern California.

Temperate climate

A temperate climate is found in so-called temperate latitudes (from 40°–45° north and south of the equator as far as the polar circles). In the northern hemisphere more than half of the temperate zone is occupied by land rather than the sea. But 98% of the temperate zone in the southern hemisphere consists of ocean. A temperate climate is marked by frequent and severe weather changes due to cyclones. A temperate climate is characterized by four seasons, of which one is cold (winter), one is warm (summer) and the other two (spring and autumn) are transitional. The average temperature in the coldest month is usually below 0°C, and in the warmest month it is above +15°C. The ground is covered with snow in the winter. Prevailing westerly winds bring rain and snow throughout the year, with rainfall and snowfall varying from 1,000 mm in coastal areas to 100 mm deep inland.

Sub-polar (sub-Arctic, sub-Antarctic) climate

A sub-Arctic climate is found between Arctic and temperate climate zones in the northern hemisphere. This climate is marked by air masses at moderate temperature in the summer and cold air masses from the Arctic in the winter. The summers are short and chilly, with air temperature in July rarely above +15°C by day and dropping to 0°–+3°C at night, and frosty nights likely through the summer. In winter the temperature by day and night is -35°–45°C. The landscape in a sub-Arctic climate consists of tundra and forest tundra, the soil is marked by permafrost, and there are few plants and animals. The north of Russia and Canada, Alaska (USA), South Greenland and the far north of Europe have a sub-Arctic climate.

A sub-Antarctic climate is found in the southern hemisphere between the temperate and Antarctic zones. The greater part of the sub-Antarctic zone consists of ocean, with annual rain and snowfall up to 500 mm.

Polar (Arctic, Antarctic) climate

A polar climate is found to the north of 70° latitude in the northern hemisphere (Arctic climate) and to the south of 65° latitude in the southern hemisphere (Antarctic climate). Polar air masses are dominant all year round. The sun does not appear above the horizon for several months (this period is called the 'polar night') and during some other months it does not set beyond the horizon ('midnight sun' or 'polar day'). Snow and ice reflect more heat than they absorb, so the air is very cold, and the snow never melts. Atmospheric pressure is high all year-round (anticyclone), so winds are weak and there are almost no clouds. There is very little snowfall, the air is full of small icy needles and a water haze often occurs in the summer. The average temperature in summer is below 0°C, and between -20°C and -40°C in winter.

Where are the coldest and hottest places on Earth?

The coldest place on Earth is the eastern plains of Antarctica. In August 2010, the US NASA Aqua satellite registered a new record low temperature there of -93.2°C (Figs. 1.2.2 and 1.2.3). However, this record is unlikely to be officially recognized because by current scientific standards air temperature must be measured on the Earth's surface, and not from outer space, to be declared accurate. More recent analysis by NASA scientists shows that temperatures at the same location fell lower, to -98°C. So, the internationally recognized low temperature record remains -89.2°C, registered at the Soviet (now Russian) Vostok research station in Antarctica on 21 July 1983 (Fig. 1.2.4). The village of Oymyakon in eastern Siberia is the coldest permanently inhabited place on Earth, with average winter temperatures of -50°C. The city's coldest day on record was in 1924, when temperatures plunged to -71.2°C.

The hottest place on our planet is Death Valley in the USA where an absolute record air temperature in the shade of +56.7°C was registered on 13 July 1913 (Fig. 1.2.5). WMO is currently verifying two temperature measurements of +54.4°C, recorded at the same place, on 16 August 2020 and on 9 July 2021. If validated, this would be the highest temperature on Earth since 1913.

Figure 1.2.2

The American satellite NASA Aqua was launched in 2002 to study physical processes on Earth.

Figure 1.2.3

Surface air temperature in Antarctica: data from the US satellites NASA Aqua in 2003–2013 and Landsat 8 in 2013.

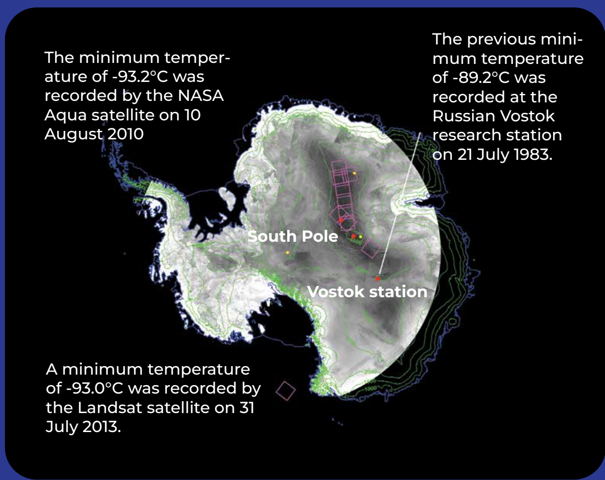


Figure 1.2.4 **Russian research station Vostok in Antarctica**

Figure 1.2.5 **Death Valley, USA**

QUESTIONS

1. When it is winter in the Northern Hemisphere, what time of year is it in the Southern Hemisphere?

2. What is wind? What types of winds do you know? What are the differences between them? In which climates do they predominate and why?

3. In which climate zone do you live? What do you know about the weather at different times of the year in your climate zone?

4. In which climate zones is it hardest for plants and animals to survive?

5. Where is it colder, at the North Pole or at the South Pole?

6. How fluent are you in climate terminology? Test yourself with the UNDP Climate Dictionary: https://www.undp.org/publications/climate-dictionary

TASKS

1

GAME

Materials: Cards showing various features of different types of climate: equatorial, tropical, temperate, polar. This is a game for 12–24 people. Each player receives one card with one climate feature.

Talk with other players and bring together all the features of one climate in one group of players. Mime to show the other groups what sort of climate you have.

2

The famous American writer Mark Twain once joked: “If you don’t like the weather in New England, just wait a few minutes.” What was it about the climate and weather in New England that the writer was making fun of?

Find New England on a map of the USA. Which climate zone is it in?

3

What are ‘favourable’ and ‘unfavourable’ climatic conditions?
Divide into groups and choose one type of climate.
Make up play-acting and jokes about the type of climate you choose.

4

GAME

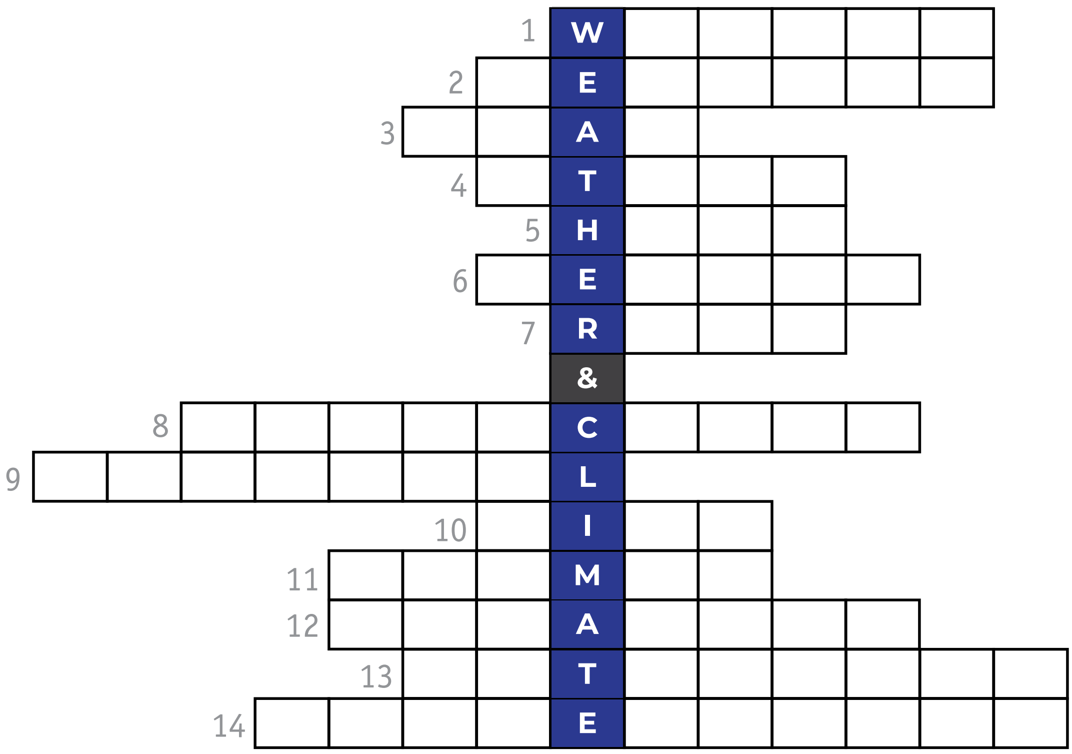
Point of the game: To feel as if you are in an equatorial climate and experience daily tropical rain.
How to play: Stand in a circle, with a leader in the centre. As the leader, you must show your movements to all the other players, turning slowly on your axis with each one. Begin a new movement after all the players in the circle have started to imitate your previous movement. Each player goes onto the next movement when you are opposite to them. Meanwhile the other players continue with the previous movement.

The sequence of movements: The leader and first player (then in turn the second, third player, etc.) join the palms of their hands and make slow circular circular motions with them. Then they click their fingers, then clap their hands, then slap their thighs and then stamp their feet. When the sequence ends, the actions are all repeated in the reverse order. The effect is to imitate the sounds of a downpour of rain from start to finish.

5

CROSSWORD

1. One of the main seasons.
2. The state of the atmosphere at a given time in a given place.
3. Seasons come and go in one...
4. Severe weather conditions with strong wind.
5. Frozen rain that falls in the form of small ice balls or lumps.
6. A long-term weather pattern at a certain period of the year.
7. One of the main features of weather.
8. The main character of children's winter holidays, the old man whose arrival is always welcome.
9. One of the climate types.
10. Horizontal movement of the air, caused by a difference in atmospheric pressure.
11. The time of year that school children in Northern Europe like the most.
12. A famous Italian composer who wrote a series of works called The Four Seasons.
13. The coldest continent.
14. The main factor that determines climate.

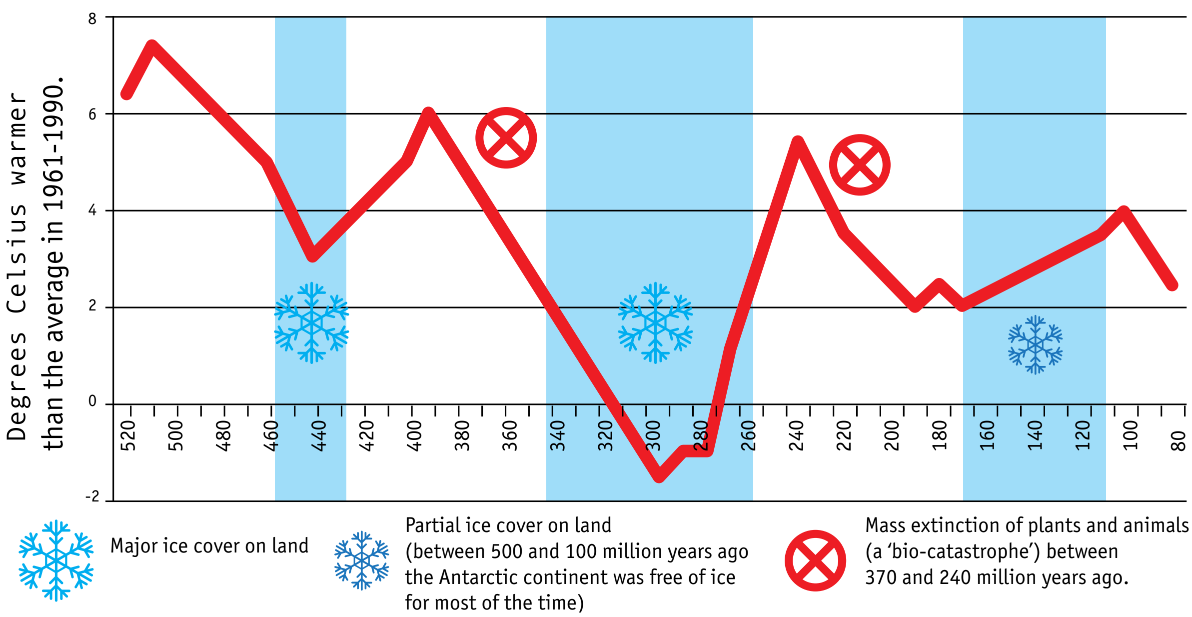


1.3 How and why the climate changed in the past

It is not hard to show that the Earth's climate has always been changing. Of course, the heroes of cartoons and computer games about dinosaurs and the ice age are made up, but dinosaurs really did exist, as we know from finding dinosaur bones and eggs. When these animals were alive, the climate on our planet on earth was much warmer than it is now. But there were cold periods, when the climate was much colder than now, and when glaciers reached as far south as Berlin or Chicago and were as high as a multi-storey building!

Over the hundreds of millions of years in the Earth's history, the temperature has varied greatly – by about 10°C (Fig. 1.3.1). That's a lot! If temperatures today were 10°C warmer, then the climate in Stockholm would be quite different: the average temperature during the year in the Swedish capital would be what it is now at the Mediterranean coast, for example in Barcelona or Marseille. That would be nice, you think. But then southern Europe would be as hot as in Dubai. And on the Arabian Peninsula, it would probably too hot for people to live.

Figure 1.3.1 **The temperature on Earth over the past 500 million years**



How do scientists know what the climate was like in the past?

Scientists assess what the temperature on Earth was in the past by studying rocks, sediments at the bottom of lakes, seas, and oceans. Ice leaves traces on rocks, while sediments from what used to be ancient seas contain the remains of plants, which could only survive at certain temperatures.

Scientists have an even better source of data to assess temperatures in the last million years: they use the ice of Antarctica. The ice contains air bubbles that give evidence of the gas composition in the atmosphere and the temperature on Earth in the past (Fig. 1.3.2). The longest data series (about 800,000 years) has been obtained at the Russian Antarctic station, Vostok.

Tree rings are a good source of information on climate change in past centuries. The rings from warm years are wider, but those from cold years are narrower. The shells of marine and freshwater molluscs are another good indicator of climate in the past.

The science that deals with the study of past climate is called **paleoclimatology**.

Figure 1.3.2 **Scientists extract a column of Antarctic ice, from which they determine the air temperature and carbon dioxide content in the atmosphere over hundreds of thousands of years**

1.3.1 | Causes of climate change: millions of years

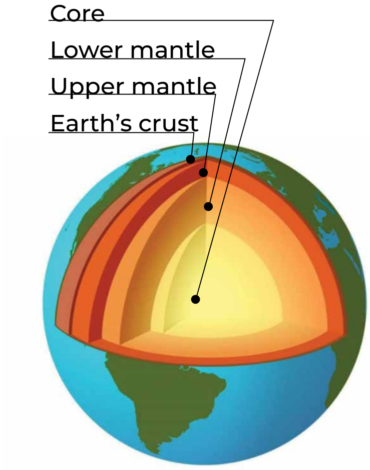
Seeking to explain the major changes of the Earth's climate that have occurred in the past half a billion years, scientists have looked at various geological, astronomical, biological, geomagnetic, and cosmic factors. They have even considered the possibility of visitors from other planets, who might have used some sort of climate weapons. But scientists found no trace of action by aliens. What they found was that the temperature on our planet in the last few hundred million years was determined by the location of its continents.

Moving continents

The Earth's crust is only the thin top layer of our planet (Fig. 1.3.3). Beneath it begins the mantle, which is the main part of the planet and which becomes a very hot and sticky liquid deeper down. The crust and top layers of the mantle consist of relatively hard ('lithospheric') plates, which can crack, move apart or come together, shifting just a few centimetres each year, but covering thousands of kilometers over millions of years! This is called 'continental drift'. The single, ancient continent of Pangaea gradually divided into separate continents, which moved apart and collided with one another (Fig. 1.3.4). If you look at the western side of Africa and the eastern side of South America, you can see that they fit together like pieces of a jigsaw puzzle, and the reason for this is that they were once part of one single continent that split apart.

Figure 1.3.3

Layers of the Earth



Continents that are close to the equator do not accumulate ice, but if they are close to the poles, then they are soon buried under the glaciers (ice masses) that we now see in Antarctica and Greenland. The white surface of ice and snow reflects solar radiation back into space, ensuring that the ice and snow remain cold, while the dark surfaces of earth or water almost completely absorb solar radiation and therefore heat up.

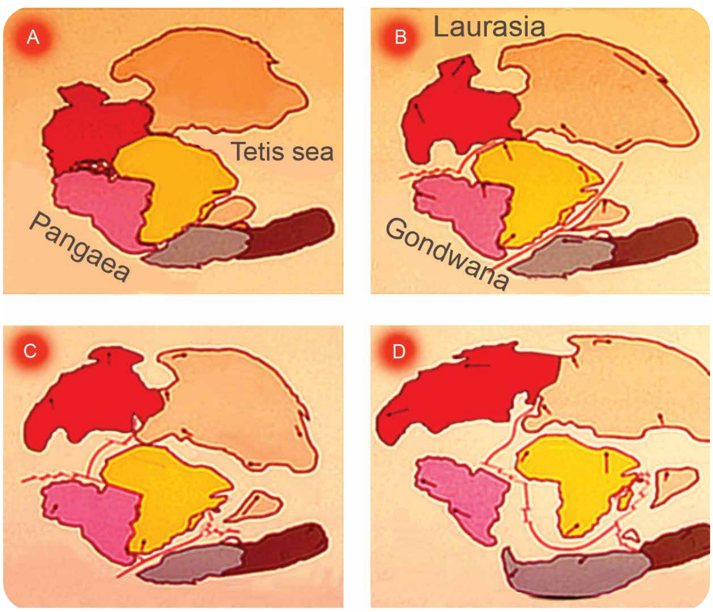


Figure 1.3.4

Continental drift over the past 500 million years.

A – the formation of Pangaea
B – the division of Pangaea, formation of Laurasia and Gondwana
C – the splitting of Gondwana, formation of Hindustan, Australia and Antarctica
D – the formation of South America, beginning of the division of Laurasia

When this occurs over a large area, it becomes the main factor influencing the climate of the entire planet. For most of the time in the last half a billion years the continents had less ice cover than they have now, so the earth's climate was warmer.

The white surface of ice and snow reflects solar radiation back into space, ensuring that the ice and snow remain cold, while the dark surfaces of earth or water almost completely absorb solar radiation and therefore heat up.

When there was a major change of climate, particularly when there was a cooling, so-called 'bio-catastrophes' occurred: whole species of living organisms died out and only those survived which were best suited to the new conditions.

One of these cold spells about 60 million years ago led to the disappearance of the last dinosaurs. This must have been a gradual process lasting more than a thousand years. The exact cause of the extinction of the dinosaurs is unknown, and there may have been several and not just one cause.

Why did the dinosaurs become extinct?

Dinosaurs finally died out on Earth around 60 million years ago. Scientists are still unsure exactly why.

One theory is that the dinosaurs were unable to compete with more 'sophisticated' living organisms. For example, with warm-blooded mammals, that were no larger than a squirrel, but which could eat the dinosaurs' eggs or attack them by night, when the cold-blooded dinosaurs were unable to move.

According to another theory, a huge meteorite struck Earth around the present Caribbean Sea, causing gigantic amounts of dust to spread through the atmosphere, blotting out the rays of the sun for a considerable period. Birds, mammals, and many other organisms adapted to the new temperatures, but dinosaurs did not.

There is one other version. It is known that for some reptiles (crocodiles, turtles) the ground temperature determines whether males or females will hatch from eggs laid in the sand along riverbanks and coasts. Biologists suggest that this dependence might also have applied to dinosaurs, which were also reptiles, only very large ones. If the temperature was such that only females (or males) hatched from dinosaur eggs, the species would have quickly disappeared without any need for disasters or falling meteorites.

The change from an invariable, moist climate to one with seasonal changes (even small changes) could produce short periods of cold nights when the huge reptile bodies of the dinosaurs could not retain sufficient warmth. Many of the animals would weaken and finally die.

But the most important climate event happened 50 million years ago, when the continents moved away from the poles. Snow and ice cover shrank, and temperatures rose to a level about 12°C higher than nowadays. Then, 'suddenly', India, which had previously been a small, separate lithospheric plate, crashed into Eurasia. The Himalaya mountains emerged at the place of the collision. The other plates moved around so that Antarctica took its place at the South Pole and was covered with a layer of ice (30–40 million years ago). The temperature on Earth began to fall sharply as the white ice of Antarctica began to reflect solar radiation back into space.

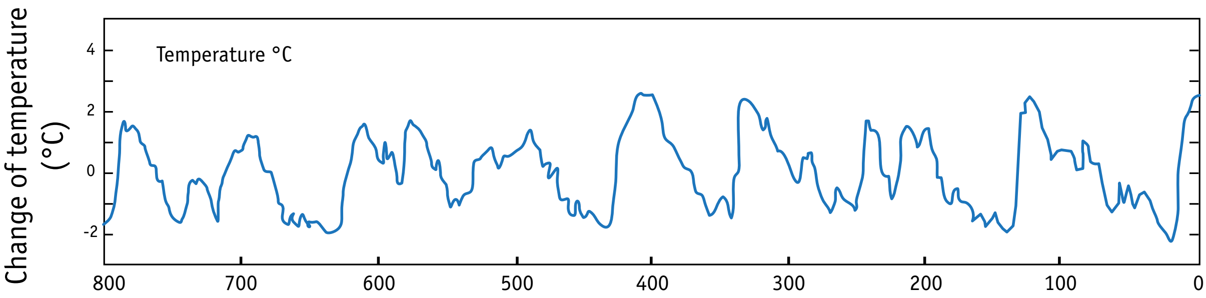
About 10 million years ago Greenland reached its present location and was covered by a layer of ice that lowered the temperature still further, to levels close to those we have today.

It was much warmer on Earth 100 million years ago than it is today. Antarctica became covered with ice 30–40 million years ago and Greenland 10 million years ago, causing temperatures to drop to their current levels.

1.3.2 Causes of climate change: tens and hundreds of thousands of years

We know that the temperature on Earth changes every million years. It has been found that, about every 100,000 years, we experience a relatively short warm period, while for the rest of the time the climate is much colder (so-called 'glacial periods' or 'ice ages'). At present we are living in a warm period.

Figure 1.3.5 **Change in temperature on Earth over the last 800,000 years relative to the average temperature**



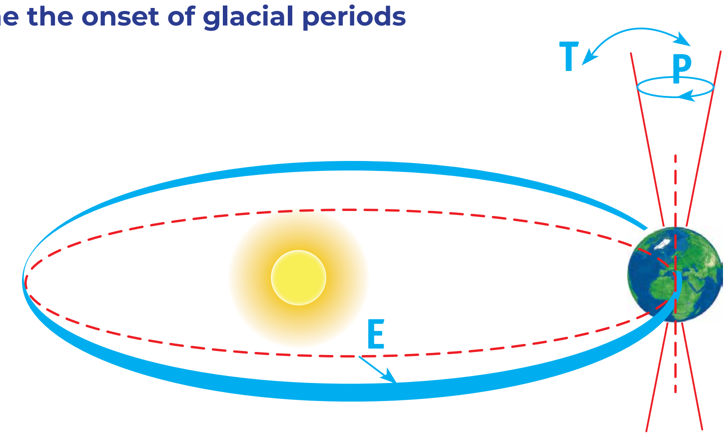
Why does this happen? Scientists think that the alternation of ice ages and warm periods has astronomical causes (Fig. 1.3.6).

Every 41,000 years the tilt of the Earth's axis alters in a range between 22° and 24.5° (it is currently at 23.5°). This variation makes the duration of the polar night in polar regions longer in some periods and shorter in others. Although this makes no difference to the total amount of heat reaching the Earth from the Sun, it affects the severity and duration of the winter season.

Figure 1.3.6

Changes in the Earth's orbit and its rotation around its own axis, which determine the onset of glacial periods

T — tilt of the Earth's axis
E — changes in the Earth's orbit (deviation of the orbit from a circle)
P — change in direction of the Earth's axis of rotation



The Earth's axis completes a circular path every 19,000–23,000 years. When you spin a top, its tip points straight upwards to begin with, but then starts to make circles, and then the top stops spinning and falls. The Earth is like a spinning top. There is no chance that it will stop rotating in the next few million years, but there has been a slowing down, and the axis of the earth is not fixed on the same spot in the heavens. The circles described by the axis of the Earth's rotation have no impact on the amount of heat reaching it from the Sun (no more than the tilt of the axis), but they do influence the severity and duration of the cold season in polar latitudes.

The Earth's orbit around the Sun changes about every 400,000 and 100,000 years. When it is close to circular, seasonal changes in the flow of heat from the Sun are less than when the orbit has an elliptic shape.

When winters in polar regions are longer and more severe, and snowfall is greater, less snow melts in the summer, and the accumulation forms glaciers. These white glaciers, unlike the dark surface of the ground or water, reflect nearly all the solar radiation that reaches them. As a result, the cold intensifies and the glaciers continue to grow, moving from the poles into temperate latitudes. A glacial period then begins (Fig. 1.3.7).

After a few tens of thousands of years, the conditions change in a way that causes the winters in polar and temperate regions to become shorter and warmer. The glaciers start to retreat, and the climate returns to what it was before. This is what happened 13,000 years ago, when the last glacial period ended.

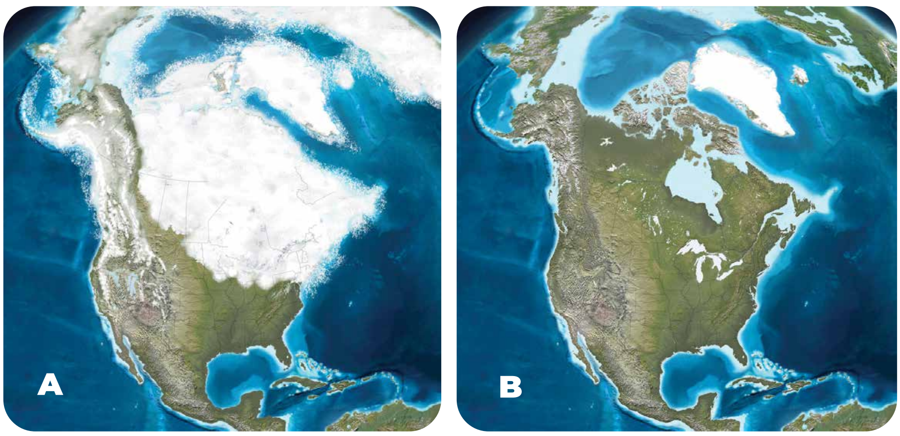


Figure 1.3.7

North America during:
A - the glacial period 125,000 years ago
B - at present

About 5,000-7,000 years ago, the climate was warmer and wetter than it is now, and that created conditions favourable for the development of human civilization, but it would be a mistake to think that warming by a couple of degrees will be good for modern civilization. Human beings today have different needs and different conditions of life: an abundance of grass for domestic animals and plenty of game to hunt in the forests are no longer enough for our societies to function properly.

The level of the Earth's oceans has changed with the coming and going of glacial periods. During cold periods the sea level was 50–100m below its level today. Those were the times when ancient people moved from Eurasia to America, mainly on land and for part of the way across a narrow strait covered by ice. In warmer periods during the last few hundreds of thousands of years, the ocean was at its present level or 5–10m higher.

How many tens of thousands of years remain until the next glacial period on Earth? The complexity of periods of change of the Earth's orbit and rotation around its axis make it impossible for scientists to predict whether it will happen in 15,000, 20,000 or 30,000 years.

Two things, though, are clear. First, that it will happen. Probably our distant descendants will be able to adapt because the climate in central and tropical latitudes will not be much colder than it is now. Second, the next glacial period will not come soon, not in even in hundred years, but the glacial movement will take hundreds and thousands of years. The prospect of a glacial period is therefore of no significance to the climate in the last millennium or the next few centuries to come.

The climate history of Earth for the past million years is characterized by the coming and going of glacial periods. Roughly every 100,000 years, the climate warms up. The warm period lasts for 20,000–40,000 years and then there is another cooling. A new glacial period is inevitable, but it will not happen for the next 15,000 or 30,000 years. The prospects of a new ice age are of no significance to the climate change happening now and that will happen in the next few centuries.

1.3.3 | Causes of climate change: centuries

Different parts of Earth have been warmer and colder at various times during the last thousand years. There were several decades when air temperature varied by a palpable 3°–4°C. Of course, there were no thermometers a thousand years ago (people have only been able to measure the temperature for the last 300 years) but surviving records of fertile (warm) and less fertile (cold) periods are evidence of significant climate fluctuations. Scientists have also drawn conclusions about temperature in the past from deposits at the bottom of seas and rivers and by using other signs. The annual growth rings of trees are a particularly good source of information.

Scientists explain periodic temperature fluctuations over decades by changes in solar activity, volcanic eruptions and processes occurring in the world's oceans.

Variations in solar activity

The intensity of solar radiation varies periodically and has 11-year cycles. But observations that began as early as the 17th century also show cycles of change in solar activity lasting 40–45, 60–70, and 100-200 years.

Variations in solar radiation are usually slight, but when several periods of low solar activity come one after the other, the temperature on Earth falls substantially. This occurred, for example, from 1640 to 1715, a period referred to as the 'Little Ice Age'.

That was when people in the Netherlands used to skate along the frozen canals of Amsterdam in the wintertime. Soon afterward the cold snap came to an end and the use of skates became much less common (Fig. 1.3.8).

Figure 1.3.8

Dutch people skating on a frozen canal. Engravings from the series *Fashionable characters* by Romeyn de Hooghe (Netherlands, 1682–1702)

Volcanic eruptions

What natural phenomenon amazes us most by its power and energy? The answer, surely, is the eruption of a volcano. Do you think that volcanoes heat up the Earth's atmosphere or cool it down? At first glance, it seems that they must heat up the atmosphere. It is true that the hot lava and burning-hot gases raise the air temperature, but only near the volcano. What has the biggest impact on climate is not hot lava or gas, but volcanic ash. The eruption sends it high into the stratosphere, to altitudes of 10–15 km, where it stays for a long time. The ash blocks out some of the sun's rays, because of which the whole planet gets colder.

Any powerful volcanic eruption, in which a column of ash reaches the stratosphere, causes short-term cooling a year later. For example, after the Napoleonic Wars in Europe, people wondered why the climate turned cold for several years. The reason was the eruption of the Mount Tambora volcano in what is now Indonesia (Fig. 1.3.9). The same thing happened in 1983 after the eruption of El Chichon in Mexico, and in 1992 after the eruption of Mount Pinatubo in the Philippines.

After two or three years the ash settles, and volcanoes cease to have an impact on the Earth's climate until the next major eruption throws ash into the stratosphere.

Such huge eruptions are rare, and most of those we hear about do not affect the Earth's climate. For example, the eruption of the volcano with the hard-to-pronounce name, Eyyafyad-layëkyudl, in Iceland in 2010 spewed a lot of ash, but only into the lower atmosphere. Aircraft all over Europe were grounded, but the ash settled quickly and did not spread around the globe.

Figure 1.3.9

Mount Tambora volcano on the island of Sumbawa in Indonesia. The massive eruption of 1815 caused its top part to collapse, forming a crater six km wide and one km deep

Ocean currents

It has been shown that the discovery a thousand years ago by Norwegian Vikings of Greenland coincided with a warm period. Hence the choice of name by the discoverers. Of course, even then Greenland was not completely green: glaciers covered the greater part of the island, as they do now, but the southern edge was ice-free and relatively warm. The reason for this was changes in ocean currents: when they are stronger the local climate becomes a little warmer; when they are weaker it gets colder. This behaviour by ocean currents has caused warmer and colder periods in various parts of the world.

The Earth's climate has changed several times in the past. But never has the average temperature of the planet changed as fast as it is changing now: by nearly 1.2°C in 130 years. This unprecedented speed is not usual for natural processes. The fastest natural changes have always taken hundreds or thousands of years, which is a very slow rate of change by the measure of human life. Catastrophes where climate changes drastically in the space of one or two years might be the subject of a disaster movie, but they are far from reality and from what any scientist would forecast.

QUESTIONS

1. What has been the main factor of climate change over billions of years?

2. What ice-cream flavour melts slower in the sun: white vanilla or dark chocolate? Why? How does this illustrate processes that occur on Earth?

3. What major shift of lithospheric plates occurred 50 million years ago? What impact did it have on Earth as we now know it?

4. What do scientists use to find out the temperature and chemical composition of the atmosphere over the last 800,000 years?

5. Why do glacial periods occur?

6. When did the last glacial period end? Will there be another? Could it begin next year?

7. How did ancient people cross from Eurasia to America? They had no boats, and the width of the Bering Strait is now 86km (you cannot see from one side to the other).

8. Do volcanoes heat up or cool down the Earth's atmosphere?

TASKS

1

Lay a sheet of tracing paper on a map of the world, trace the outlines of Africa and South America and cut them out. Join up the cut-out continents.

Does it look as if they were once a single piece of land?
What was that land called? What happened to it?
How did that affect the Earth's climate? Why?

2

Experiment
Materials: Two small sheets of paper (white and black); two pieces of plasticine 4 cm long and 0.5 cm thick.

The experiment: Glue the pieces of paper together, so that the left half is white, and the right half is black. Stick the pieces of plasticine perpendicular to the sheet on its rear side, one piece on the white part and the other on the black. Place the sheet on its edge and hold it close to a lamp (preferably a strong lamp). The lamp will illuminate the paper.

Which piece of plasticine fell first as the lamp heated the sheet of paper? Why? Give an example of a similar process that occurs on Earth.

3

You already know that the climate on Earth at the time of the dinosaurs was warmer than it is now. For the world to be as warm again as when the dinosaurs lived, Antarctica would have to move far enough away from the South Pole for all its ice to melt.

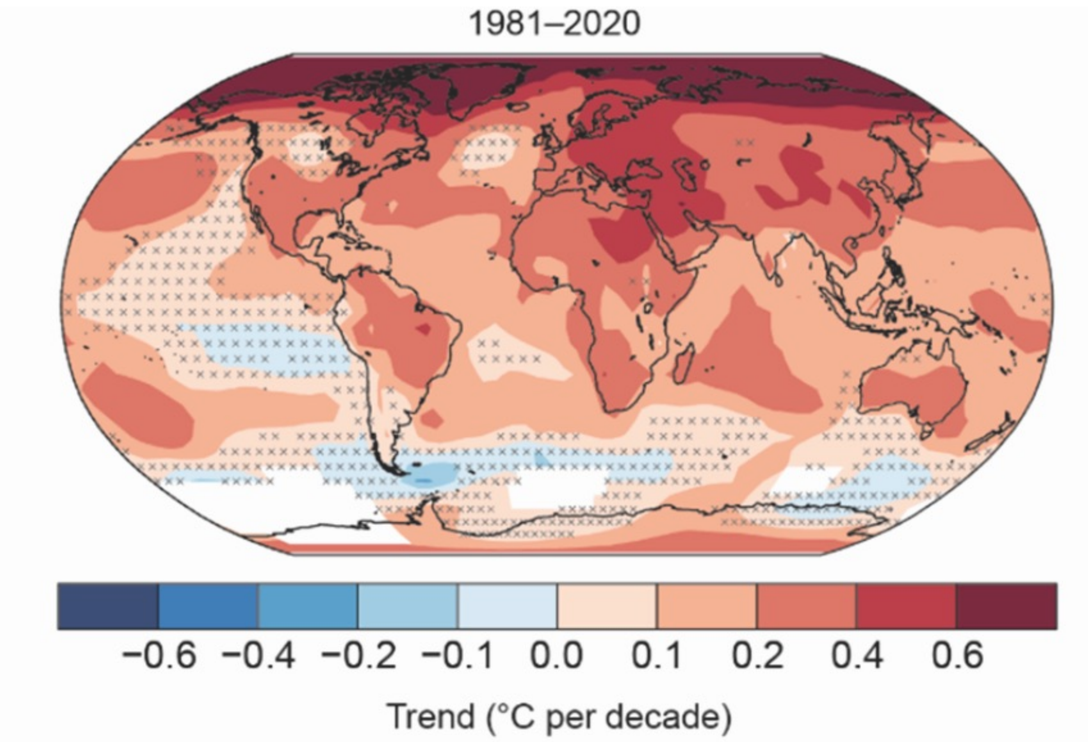
Take a physical map of the world and given its scale, calculate how far in kilometres Antarctica would have to move before its centre is at 40° southern latitude.

Suppose that Antarctica moves at a speed of 2 cm per year. How many years would it take for a warming of the earth caused only by the motion of Antarctica that would be sufficient for dinosaurs to live on earth again?

1.4 Climate change today

During the last century, the temperature on Earth began to rise in a way that could not be explained by natural phenomena. In 130 years, the planet became nearly 1.2°C warmer! According to the IPCC AR6, over the last 50 years, global temperature has increased at a rate unprecedented in at least the last 2,000 years. Global surface temperatures have not been warmer in the past 125,000 years. Observed and projected warming are stronger over land than oceans, and strongest in the Arctic.

Figure 1.4.1 Map of comparative trends in decadal changes in temperature in different regions of the world (1981-2020 and 1850-1900)

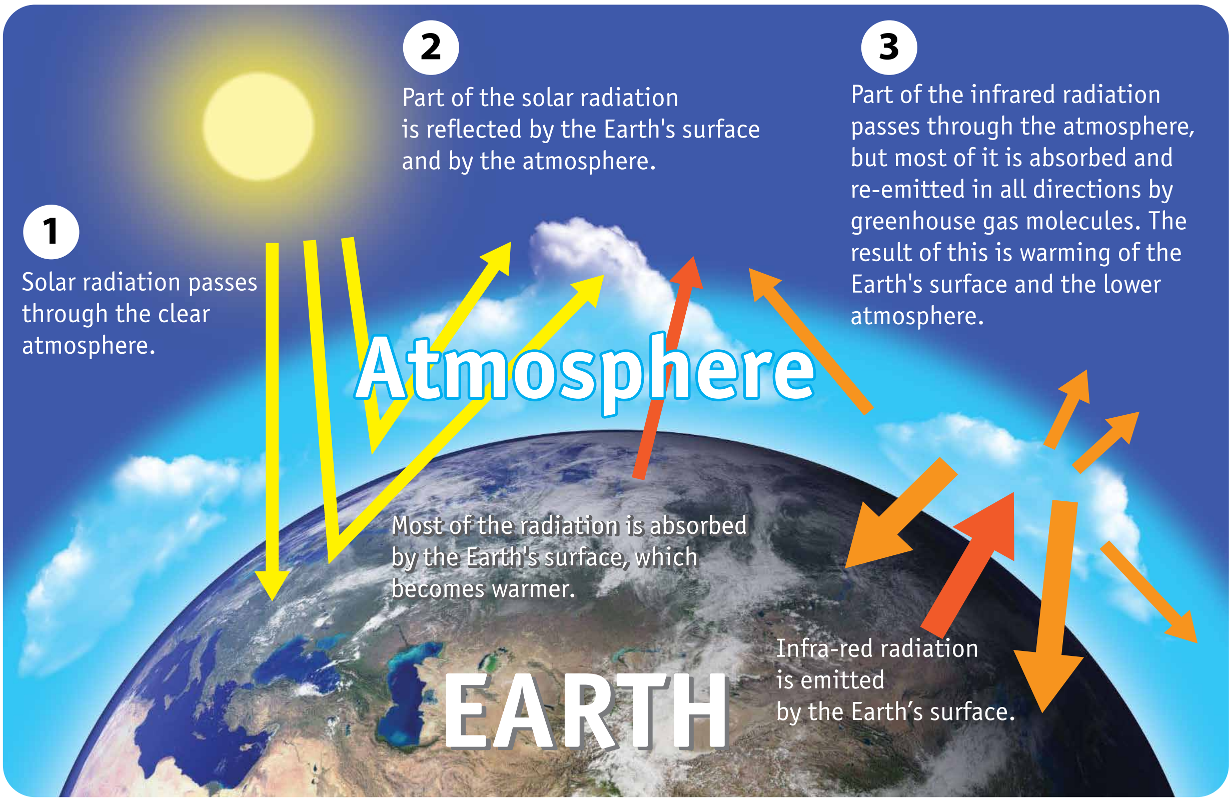


Scientists explain the current warming of the planet by an increase of what is called the 'greenhouse effect'.

The greenhouse effect

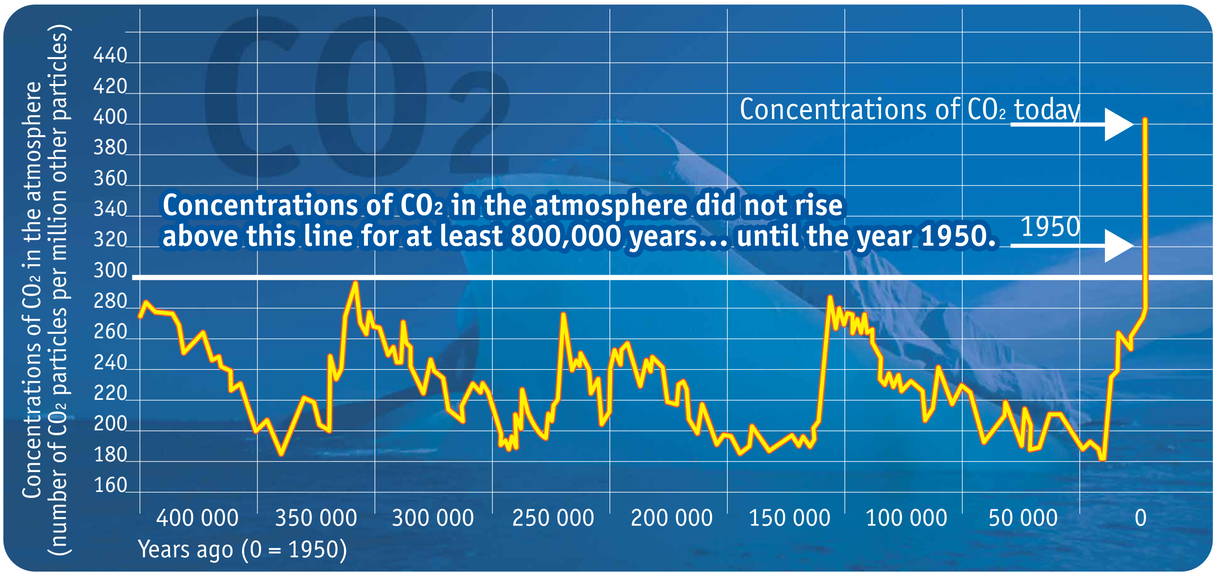
The greenhouse effect is the process by which gases, dust and water vapour in the atmosphere absorb the Earth's heat and hinder its reflection from the surface of the Earth. When scientists first described this effect 200 years ago, they noted how the Earth's atmosphere acts like a greenhouse for growing vegetables. So, the gases that absorb the Earth's thermal radiation were called 'greenhouse gases'. The main greenhouse gases in the atmosphere are carbon dioxide, methane, and nitrous oxide (for convenience, we will refer to them by their chemical formulas, CO_2, CH_4 and N_2O) and some others, as well as water vapour. They obstruct infrared radiation from the Earth's surface. As a result, the lower atmosphere warms up. Without the greenhouse effect, the average air temperature on the Earth's surface would not be +14°C, as now, but -19°C. The heat of the Earth would dispel into space without warming the atmosphere. This would make it hard for life to exist on our planet.

Figure 1.4.2 The Earth's energy balance and the greenhouse effect



Scientists have long predicted that by producing and burning coal, oil and gas, human beings would emit large amounts of CO_2 and CH_4, increasing the greenhouse effect. In the mid-20th century, the prediction was confirmed: the concentration of these gases all over the world began to increase rapidly (Fig. 1.4.3).

Figure 1.4.3 **Concentrations of CO_2 in the atmosphere over the past 400,000 years**



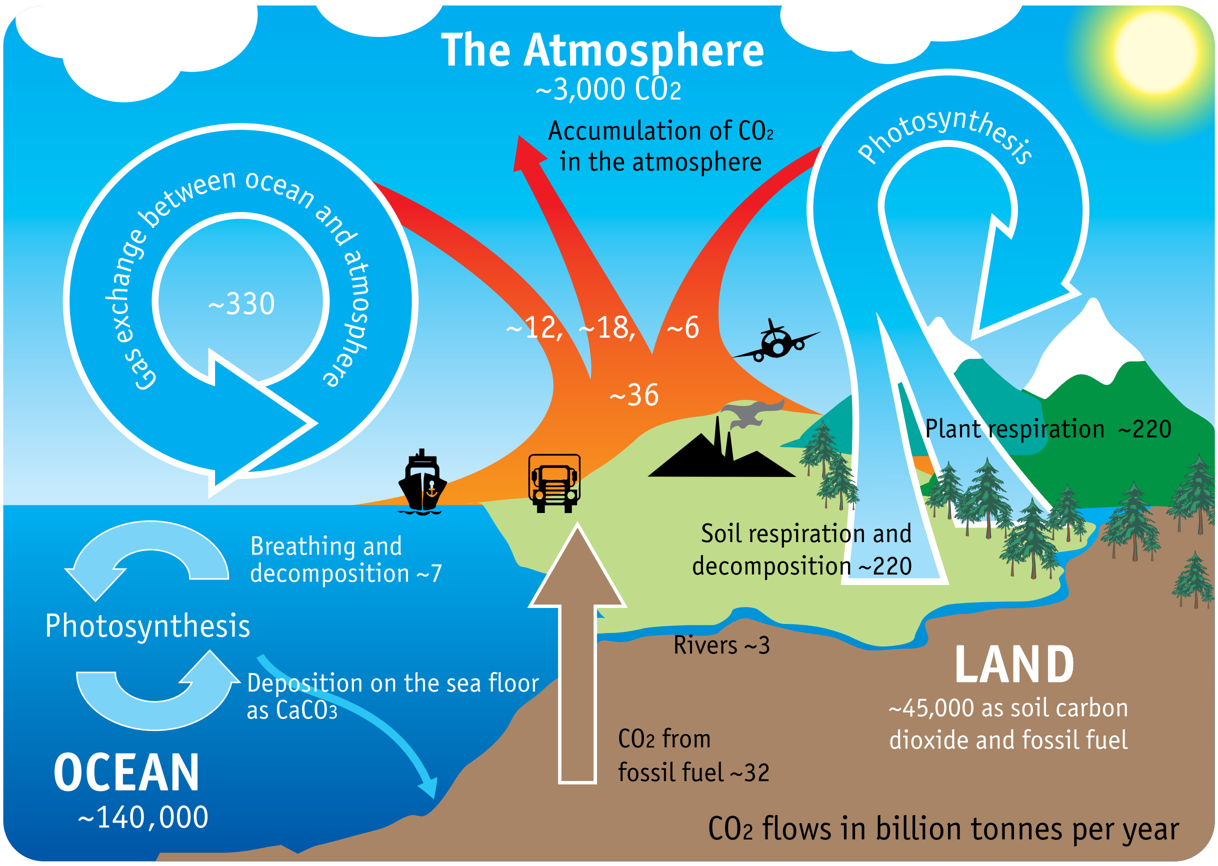
Greenhouse gases are the main cause of climate change today. As a result of human activities, primarily the burning of fossil fuels, and the development of transport and deforestation, atmospheric concentrations of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have reached record levels – higher than at any time in the last 800,000 years. The natural concentration of carbon dioxide in the atmosphere varied throughout history between 180 and 300 parts per million (ppm) other particles. The latest analysis of observations from the WMO shows that the globally averaged surface concentrations for CO_2, CH_4 and N_2O reached new highs in 2022, with CO_2 at 418 ppm, CH_4 at 1923 ppb and N_2O at 336 ppb. These values constitute, respectively, increases of 150%, 264% and 124% relative to pre-industrial levels. The suggestion that human activity strengthens the greenhouse effect was first put forward by the Swedish scientist, Svante Arrhenius, as early as 1896.

Is the increase in concentrations of CO_2 due only to human activity or is it a natural process?

Natural processes like respiration in living organisms, decomposition, ocean-atmosphere exchange, volcanic activity, and wildfires release CO_2 into the atmosphere, playing key roles in the Earth's carbon cycle (Fig. 1.4.4). However, isotope analysis reveals that the recent rise in atmospheric CO_2 primarily stems from human activities, such as burning fossil fuels, which is distinctively different in molecular composition from CO_2 released by these natural processes.

ISOTOPE ANALYSIS
Atoms of the same substance may contain different amounts of certain particles, called neutrons. The number of neutrons in an atom indicates whether atmospheric CO_2 comes from the respiration of living organisms or from the combustion of coal, oil, and natural gas.

Figure 1.4.4 The CO_2 cycle in nature



The ocean, forests, and soils of our planet 'help' human beings by absorbing half of all their CO_2, but the other half accumulates in the atmosphere (Fig. 1.4.4) and increases the greenhouse effect. This causes the atmosphere (Fig. 1.4.5) and then the ocean to warm up (Fig. 1.4.6). The increase in the global mean average temperature between 1850 and 2023 (Fig. 1.4.5) illustrates the WMO finding, based on data from different meteorological centres, that the past nine years between 2015 and 2023 were the warmest years on record. A similar trend is observed in oceans. People have cut down a large share of the world's forests, so their ability to absorb CO_2 from the atmosphere is now less than it was in the past.

Figure 1.4.5 Increase in the global mean temperature on Earth between 1850 and 2023 as shown by different meteorological centres

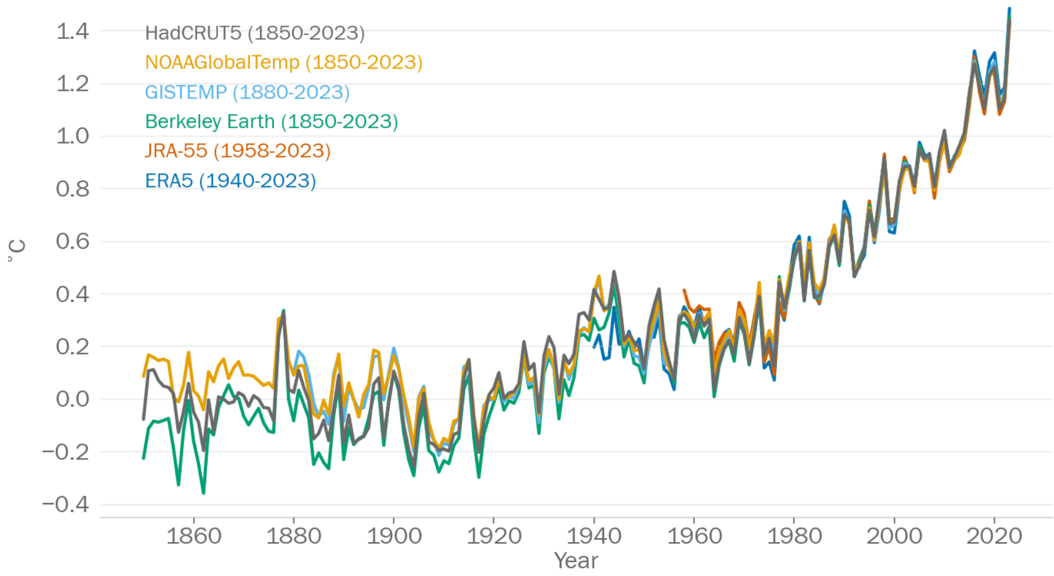
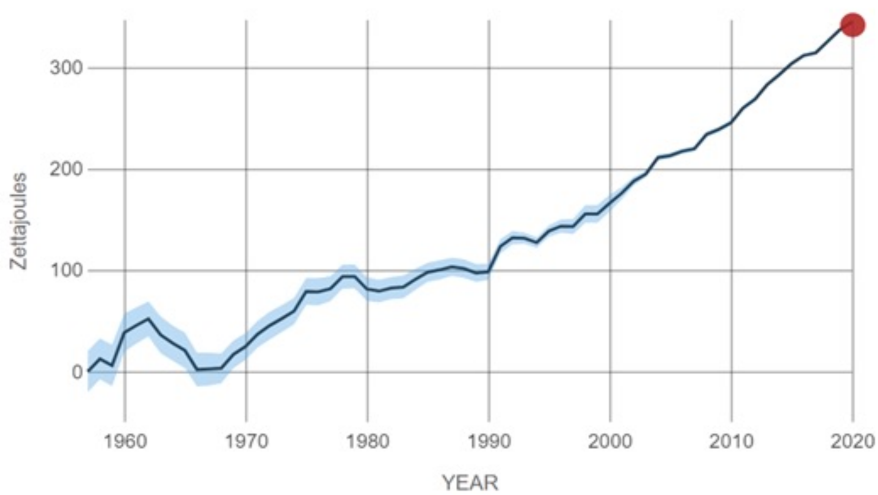


Figure 1.4.6 Increase in ocean heat content between 1955 and 2020



Note: Ocean heat content is the heat absorbed and stored by oceans.

The **ocean** plays the most important role of all in shaping the Earth's climate. It contains more than 90% of the energy of the planet's climate system. If only the atmospheric temperature, but not that of the ocean, was rising, there would be much less cause for alarm. This would mean that the main link in the climate system remained unaffected. Unfortunately, the temperature of the oceans is also rising year by year. The annual estimates for warming of the ocean for its first 2,000 metres between 1955, the year when modern recordkeeping began, and 2022 (Fig 1.4.6) present the average over five years – for example, the 2020 value is the average for 2018-2022. So, climatologists believe that instances of cold winters or even a cooling of the air all over the planet cannot signal a halt to global warming, because the amount of heat in the Earth's climate system continues to rise year by year, with most of the increase occurring in the ocean.

Aerosols are yet another factor with sizeable impact on our climate. Aerosols are small particles that come in many forms. They can be natural, like wildfire smoke, volcanic gases, or salty sea spray. Human activities can also generate aerosols, such as particles of air pollution or soot.

Figure 1.4.7 **Aerosols emitted by natural and human activities**

The role of aerosols in climate science is complex. In general, light-coloured particles in the atmosphere will reflect incoming sunlight and cause cooling. Light-coloured aerosols are those formed from sulphur dioxide (SO_2) gas emitted from volcano eruption, which combines with water in the atmosphere to form tiny particles that can circle the globe and stay in the air for a few years. Burning fossil fuels releases sulphate particles and SO_2 which, like volcanic aerosols, can reflect sunlight and make the atmosphere cooler. Dark-coloured particles absorb sunlight and make the atmosphere warmer. An example of dark-coloured particles is soot, made up of particles of carbon from burning fossil fuels, wood or other plant matter. Because different types of particles have different effects, aerosols are a hot topic in climate research.

Without aerosol pollution, Earth would be around 0.4°C warmer than it already is according to the 2021 IPCC AR6 report. This is compared to the warming coming from the greenhouse gas emissions estimated at around 1.5°C. So, human activity both warms and cools the planet, but its impact on global warming (by strengthening the greenhouse effect) is about three times greater than the cooling effect of aerosols. Therefore, there is every reason to speak of 'climate change' caused by human beings.

As early as the 1970s, the climatologist Mikhail Budyko, who made accurate forecasts of climate change, predicted that human beings would face problems by 2000 in the form of new and 'strange' changes in climate. He was right.

Since the time people began to burn coal, the air temperature on the Earth's surface has risen by nearly 1.2°C, with 0.85°C of that growth occurring in the last 50 years (Fig. 1.4.5). At first glance, the change seems modest and does not seem to pose a threat. But we must remember that this is the average change for the whole planet and for all seasons of the year. The change in certain places has been much greater. Scientists found that the Earth's poles are warming faster than the global average, a phenomenon known as **polar amplification**. This phenomenon is already being seen in the Arctic, which has warmed nearly four times faster than the global average over the past four decades. Recent studies show that the Antarctic is warming twice as fast as the global average.

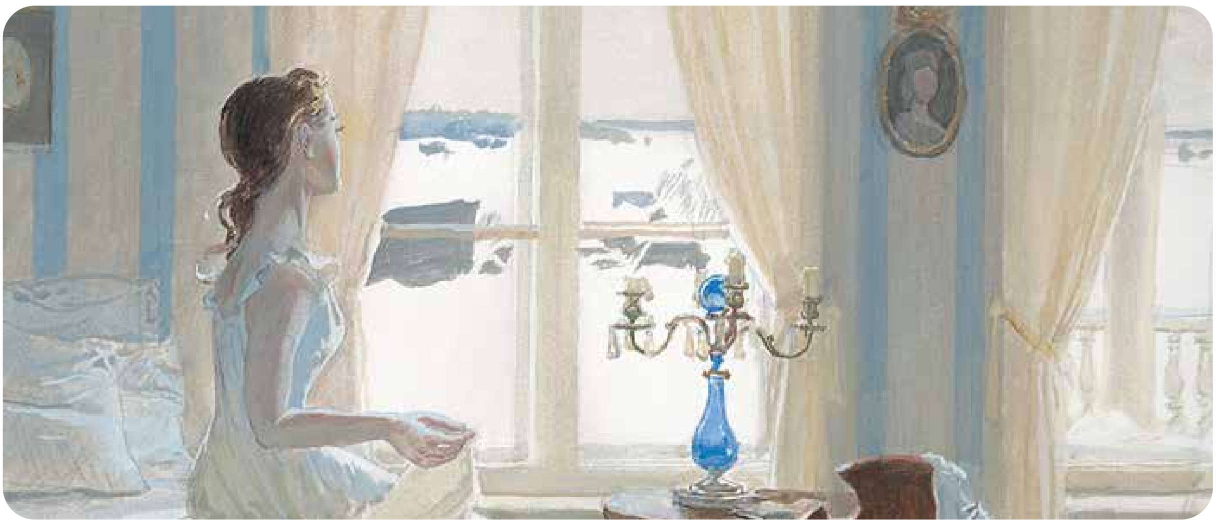
In some northern parts of Europe, North America and Asia, winters have become colder and not warmer. Looking at weeks and months, we find that the temperature might be 10°C warmer for two to three weeks and then 9°C colder than the average for that time of year in that region in the second half of the twentieth century, with an overall warming of 1–2°C. What is most striking is not the overall change, but the fact that the weather has become much more changeable, with storm winds and heavy rainfall or snowfall.

Didn't the weather behave strangely in the past as well? It certainly did. Alexander Pushkin, the famous Russian poet, wrote in his masterpiece, *Eugene Onegin* (1833):

"That year, the autumn lingered,
In yards and fields, loath to go.
Nature waited, icy-fingered
Winter stalled its fall of snow
Till January the third, at night..."

Pushkin uses Russia's 'old style' Julian calendar, so his 3 January is our 20 December. But that is still very late for the first snow in the central part of European Russia, where it usually starts snowing at the end of October.

Figure 1.4.8 **Tatiana sitting on the bed. *Winter***
Illustration from *Eugene Onegin* by D. Belyukin (Russia, 1999)



In the 19th century too, there were warm days in the wintertime and cold spells in summer, storms and floods, heavy snowfalls and droughts, and even frozen rain that covered everything with a thick crust of ice.

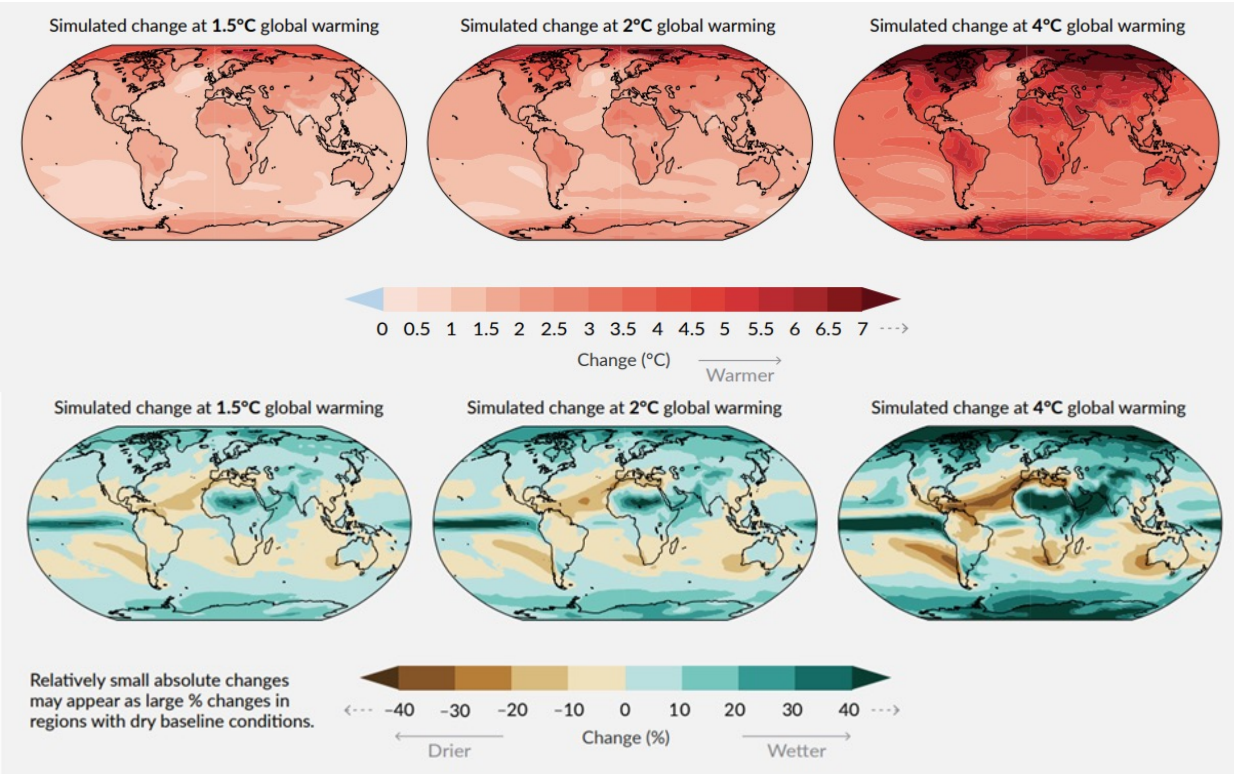
The key point is that such dangerous natural phenomena are now happening more often, and they will become even more frequent in the future. We will continue to experience periods of very cold weather, although, over time, they are likely to become less common. There will be some positive effects from global warming, but at present we see more negative effects.

Using computer models that take account of all the effects (both natural and human-induced), climatologists can explain what is happening now and make a forecast for the entire 21st century. Depending on the level of greenhouse gas emissions, the temperature on Earth could rise dramatically during the current century. In a favourable scenario, the changes compared to the beginning of the 20th century will be 1.5–2°C. But in the worst case the climate could become more than 5°C warmer. Northern Europe is expected to warm more rapidly. Also, the Arctic has warmed nearly four times faster than the global average over the past four decades and it is expected that this warming trend will continue to be more pronounced over the 21st century. This will have a major impact on the levels of precipitation, the sea level, and the frequency and severity of extreme weather events. How the 21st century ends will depend largely on human activity and the actions that we take now. Of course, the influence of the sun, volcanoes, ocean currents and other natural processes is also very significant. But the climate changes they cause are of a short duration and their role over long periods is small.

Scientists stress that every fraction of a degree of global warming results in exponential changes in regional mean temperature, precipitation, and soil moisture. The scientists used a database with hundreds of scenarios to assess how global warming will impact indicators of the climate, such as global temperatures, precipitation, and soil moisture. Because of improvements in global models, they were able to come up with more accurate regional assessments.

Modelling studies now tell us about changes in the annual mean temperature and precipitation resulting from global average temperature increases of 1.5°, 2° and 4°C (Fig. 1.4.9). They suggest that across warming levels, land areas warm more than ocean areas, and the Arctic and Antarctic warm more than the tropics. These results also suggest that precipitation is projected to increase over high latitudes, the equatorial Pacific, and parts of the monsoon region, but decrease over parts of the sub-tropics and in limited areas of the tropics. Many changes in the climate system are projected to become larger in direct relation to increasing global warming, including ocean acidification, melting of ice in the Arctic and Antarctic, and the rise in sea levels.

Figure 1.4.9 **Modelled changes in the annual mean temperature (above, °C) and annual precipitation (below, %) relative to 1850-1900 for global average temperature increases of 1.5°, 2° and 4°C**



So, most scientists agree that humanity has most probably played the biggest role in the climate change taking place on Earth for the last 70 years (since the mid-20th century) and which will continue in the coming century. They strongly emphasize the urgent need to reduce greenhouse gas emissions in the current decade if we are to have a fair chance of keeping the rise in temperature well below 2°C and 1.5°C.

The biggest human impact on the climate system is from greenhouse gas emissions caused by the combustion of fossil fuels: coal, natural gas and petroleum products. Reducing the use of fossil fuels by power plants, transport, industry and in everyday life will reduce human impact on the climate. But the combustion of fossil fuels is not the only factor. Human beings influence the climate by cutting down forests, which absorb CO_2 from the atmosphere, by allowing major leakage of methane gas from pipelines, and by applying new synthetic and potent greenhouse gases in industry. This is what makes it so difficult to solve the problem of climate change: what is needed is a transformation of our societies and the entire world economy, to make it ‘green’ and climate safe, so that it can work to the benefit of both people and the planet. Scientists stress on the urgent need for such transformation to have a fair chance of stabilizing the temperature increase at safe levels.

QUESTIONS

1 Was there a greenhouse effect in the past? How was it caused?

2 Why has the temperature on Earth risen so much in the last 100 years?

3 Has the growth of CO_2 concentrations in the atmosphere been due to natural causes or to human activity?
How has this been proved?

4 How do we know that human beings both heat and cool the planet?
Which of the two effects is greater?

5 By how many degrees have temperatures risen over the past 130 years?
Has the increase in northern Europe been greater or less than in the world as a whole?

TASK

Find a thick, cleanly sawn log or a large tree stump.

Look at the annual growth rings: you will see that some are narrower than others.

The oldest growth rings are at the centre of the log or stump and the youngest are at the edge.

Wide rings mark warm years and narrow rings mark cold years. Count how many of the last 20 years were warm and how many were cold.