Physical Geography

Textbook for bilingual class

**“Tell me, and I will forget. Show me, and I may remember.
Involve me, and I will understand."
Confucius, 450BC**

Physical Geography

for English bilingual class

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Register

1. DISCIPLINE OF GEOGRAPHY

1.1 Definition of Geography

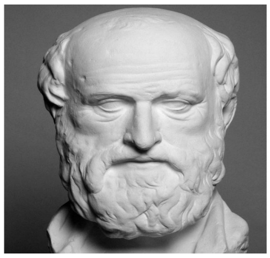
Geography – Latin language, G*eographia* – Greek language means **description of the earth's surface** (geo - "Earth" + graphia "description").

Many famous geographers and non-geographers have attempted to define the discipline in a few short words. The concept has also changed throughout the ages, making it difficult to create a concise, universal geography definition for such a dynamic and all-encompassing subject. After all, Earth is a big place with many facets to study. It affects and is affected by the people who live there and use its resources. But basically, **Geography** is a **study of environments and spaces of the Earth´s surface** and the study of **their interactions.** It is an **explanative science** – explains the interactions and relations between various parts of the Earth.

THE GEOGRAPHY IS THE WHY OF WHERE ☺

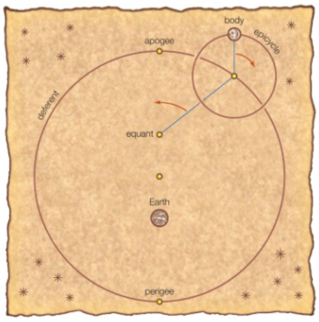
1.1.1 Origin of Geography

Geography, a study of Earth, its lands, and its people, started in ancient Greece, with the study's name defined by the scholar and scientist **Eratosthenes.** He is often called "Father of Geography".



1 – Eratosthenes.

A Greco-Roman astronomer, geographer, and mathematician **Ptolemy**, living in Alexandria, Egypt described the Universe with the Earth at the centre - **the geocentric model**, the Sun, the Moon, stars and planets all orbited the Earth. The geocentric model served as the predominant description of the cosmos in many ancient civilizations.



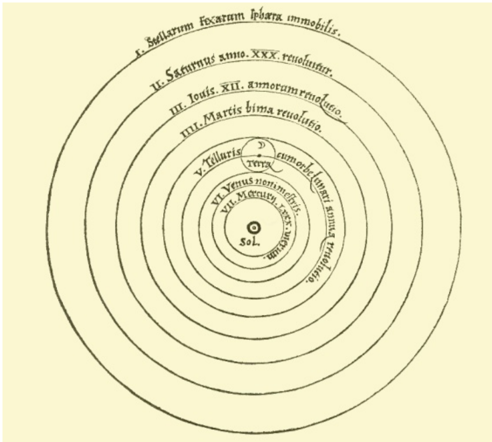
2 – Ptolemaic system.

Later, **Islamic scholars** developed the grid system to make maps more accurately and discovered more of the planet's lands. Then, another major development in geography included the use in **China** of the magnetic compass (invented for divination) for navigation, the earliest known recording of which is 1040. European explorers started using it in the century to follow.

3 Ancient Chinese compass.

Nicolaus Copernicus, a Polish mathematician and astronomer who formulated a model of the universe that placed the Sun rather than the Earth at the centre of the universe – **the heliocentric model** which was an important contribution to the Scientific Revolution.

4 Copernican heliocentrism.



Philosopher Immanuel **Kant** in the mid-1800s summed up the difference between history and geography as history as being when something happened and geography being where certain conditions and features are located. He thought of it more descriptive than a hard, empirical science. Halford Mackinder, a political geographer, included people in his definition of the discipline in 1887, as "man in society and local variations in environment." At the time members of Britain's Royal Geographic Society wanted to ensure that it was studied in schools as an academic discipline, and Mackinder's work aided that aim.

1.1.2 Origin of Geography

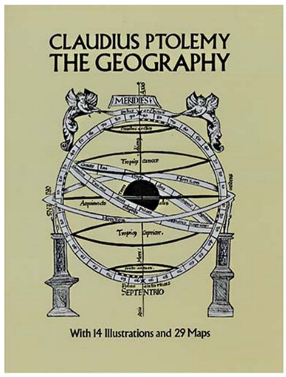
The first geographical studies focused on the knowledge of the lands discovered by explorers and travellers, elaborating new maps, identifying the course of rivers and explaining natural phenomena such as volcanism, droughts, floods and eclipses.

Ancient history

In the 3rd century BC **Eratosthenes of Cyrenes** summarized all available geographical knowledge of those times in his book ***Geographica*** – and he first used the term ***geography***.

However, **Aristotle**'s claims in the 4th century BC about the roundness of the Earth, based on the position of the stars, gravity and eclipses, can be considered as the first geographical remnant.

The first books of geography were written by **Strabo,** Greek historian and philosopher who wrote more than fifteen volumes describing in detail the territories of the Roman Empire.



5 Ptolemy´s Geography.

***The* Geography of Ptolemy** is an important work of geography in antiquity because he compiled all the information of the Greeks and designed varied maps. A key thing in geography is to know the exact location of a place on the Earth´s surface, so people tried to draw the first maps, using the first **latitude** and **longitude** data (cartography).

Medieval history

Geographic knowledge was not broadened much in the "dark ages".

6 Galileo Faced Science Deniers in the Catholic Church.

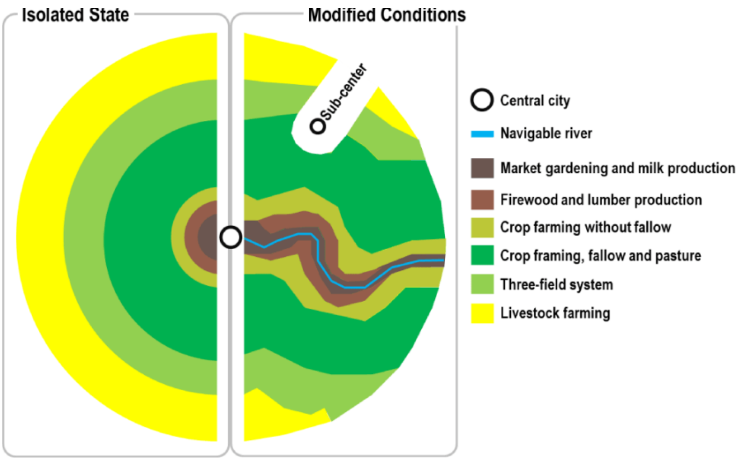
Modern history

For many centuries, geography was dedicated to the accumulation of geographic information. It was not until the 19th century that modern concepts of geography were introduced as a study of man's interaction with the environment. The promoters of these concepts were **Alejandro de Humboldt** and **Carl Ritte**.

Alejandro de Humboldt was born in Prussia to a wealthy family, Humboldt was drawn to the sciences from an early age. In 1799, he embarked on a five-year expedition to South America that would make him famous. His death-defying accounts of capsizing on the Orinoco river, scaling Chimborazo, and surviving all sorts of jungle diseases and predators won the world over. Humboldt's adventures and prestige led to more species and places being named after him than any other person. Yet while many have celebrated his achievements in founding or revolutionizing multiple fields of science, from ecology, meteorology, and mineralogy, to the social sciences such as anthropology, what is often taken for granted is how much of a pioneer Humboldt was in the realm of data visualizations. He measured everything (so much so that he had over a dozen mules just for carrying instruments on his expeditions), and always strove to explain the physical relationships in the world around him. Because of the enormous amount of data he collected, Humboldt worked at visualizing his data to make connections and correlations. As a result, he created some of the earliest precursors to what we would now call **infographics**.

7 Alejandro de Humboldt. His work Naturgemälde (1807) is considered by some as history's first infographic through its visualization of data beyond the charts and plots conceived by William Playfair. In this piece, Humboldt intuitively describes plant species at various elevational ranges, while also including detailed scientific observations on the wings.

Carl Ritte focused on the specific study of areas such as economic, historical and cultural phenomena. It was until the middle of the twentieth century when new trends and methodologies emerged in which quantitative methods were adopted in the demography and spatial location of which the protagonists were Heinrich Von **Thünen** and Walter **Christaller**.



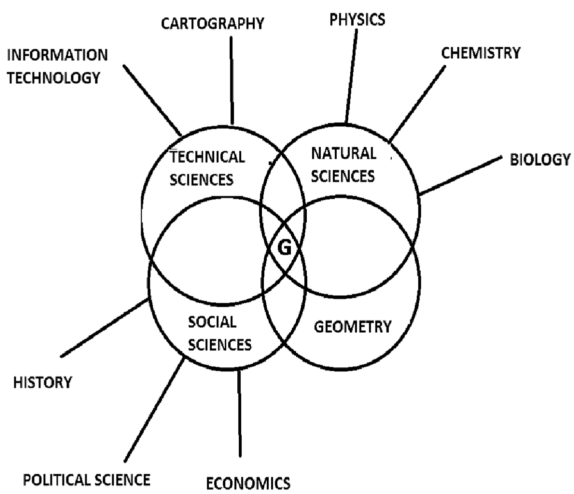
8 Von Thunen´s Regional Land Use Model .

1.1.4 Geographic techniques, past and present

Geographic techniques are important tools that help in interpreting data that geographers need for their particular work. Cartography leads in this respect as it precedes geography in their respective discovery and development. In 1500 BC, early **Polynesian** sailors utilized shells and sticks to determine their boats' positions in the ocean. Polynesian navigation was about star movements, ocean wave's speed and direction, sea and sky colour, cloud clusters above islands, and wildlife flights being observed based on seasons. At present, satellites orbiting above the earth help navigators pinpoint their exact location and destination anywhere on the planet. Other techniques involve sensors, satellite photographs, and computerized data information systems called **Geographic Information Systems (GIS)**. These are used by governments, institutions, and businesses.

1.1.5 Position of geography in the system of sciences

Geography is the science of place and space. Geographers ask where things are located on the surface of the earth, why they are located where they are, how places differ from one another, and how people interact with the environment. Geography is unique in linking the social sciences and natural sciences together. Geographers also study the relationships between human activity and natural systems.



1.2 Divisions of Geography

Geography is divided into two main branches: human geography and physical geography. There are additional branches in geography such as regional geography, cartography, and integrated geography.

Physical Geography – it studies physical spheres and relations among them.

Human Geography – it studies human sphere and relation between it and physical environment.

1.3 Spheres of the Earth

Earth is a very complex place. Although it looks like one large structure, it's actually got a lot going on that you may not see if you don't look closely. All of the processes on Earth are driven by concentric 'spheres,' which we describe individually, but are really all connected.

The main spheres of the Earth:

1. Atmosphere
2. Hydrosphere
3. Geosphere (Lithosphere)
4. Biosphere
5. Cryosphere (some approaches)

9 The Earth and its spheres.

The names of each of these spheres come from Greek words that describe what they're made of: '**Geo**' for 'ground,' '**hydro**' for 'water,' '**bio**' for 'life' and '**atmo**' for 'air.' Let's look at each of the four spheres in a bit more detail to gain a better understanding of how they help make up the earth.

Geosphere

Since 'geo' means 'ground,' the **geosphere** describes all of the rocks, minerals and ground that are found on and in the Earth. This includes all of the mountains on the surface, as well as all of the liquid rock in the mantle below us and the minerals and metals of the outer and inner cores.

Atmosphere

The atmosphere is the body of gasses that surrounds our planet, held in place by earth's gravity. Most of our atmosphere is located close to the earth's surface where it is most dense. The air of our planet is 79 percent nitrogen and just under 21 percent oxygen; the small amount remaining is composed of argon, carbon dioxide, and other trace gasses.

Hydrosphere

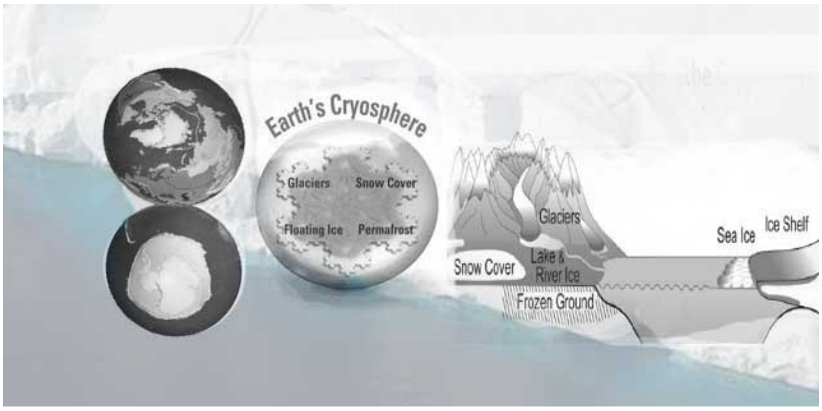
Knowing that 'hydro' means 'water,' you may have guessed that the **hydrosphere** is made up of all the water on Earth. This includes all of the rivers, lakes, streams, oceans, groundwater, polar ice caps, glaciers and moisture in the air (like rain and snow). The hydrosphere is found on the surface of Earth, but also extends down several miles below, as well as several miles up into the atmosphere.

Biosphere

The biosphere is composed of all living organisms: plants, animals and one-celled organisms alike. Most of the planet's terrestrial life is found in a zone that stretches from 3 meters below ground to 30 meters above it. In the oceans and seas, most aquatic life inhabits a zone that stretches from the surface to about 200 meters below. The biosphere is made up of biomes, or biophysical zones, filled with many ecosystems.

Cryosphere

The cryosphere is the part of the Earth system that includes solid precipitation, snow, sea ice, lake and river ice, icebergs, glaciers and ice caps, ice sheets and ice shelves, and permafrost and seasonally frozen ground. The cryosphere is global, existing not just in the Arctic, Antarctic and mountain regions, but at all latitudes and in approximately one hundred countries. The cryosphere provides some of the most useful indicators of climate change, yet is one the most under-sampled domains of the Earth System.



10 Earth´s Cryosphere.

Questions for discussion:

1. What is the most important thing about geography? Do you think learning geography will be interesting for you? What would you like to learn in geography lessons and why?
2. Explain how you understand the following geography definition: Geography is the why of where.
3. Which period in history do you think was the most important for geography concept development and why?
4. Do you know any explorers whose discoveries changed the world? Find out more information about the one who is the most interesting for you.
5. Find some geographical names or place names on the world map which are named after famous geographers or explorers.

2. MAPPING OF THE EARTH

2.1 History of mapping

Map - a scaled-down drawing or plan of a part of the Earth´s surface. It is a visual representation of an entire area or a part of an area, typically represented on a flat surface.

Cartography - from French „*cartographie*“ in the 1840s, based on Middle Latin *carta* "map".

Cartography, or mapmaking, has been an integral part of human history for thousands of years. From cave paintings to ancient maps of Babylon, Greece, and Asia, through the Age of Exploration, and on into the 21st century, people have created and used maps as essential tools to help them define, explain, and navigate their way through the world. Maps began as two-dimensional drawings but can also adopt three-dimensional shapes (globes, models) and be stored in purely numerical forms.

The history of mapping can be traced back to **prehistoric ages**.
These maps

- depicted small areas (a haunting ground, a military camp etc.)
- were pictorial more than mathematical in nature, were more works of art than maps
- had no rules relating to how they were oriented, modern maps usually have north at the top
- were not accurate

1 The map of Pavlovce in the Czech Republic, which shows the plan of a camp on a mammoth tusk. It is 27,000 years old.

The ancient era:

This was the time of growth of cartography. People started to measure the angles and distances on Earth, and they started to use the lines of longitude and latitude.
The masterpiece of those times is **Ptolemy´s map**, depicting the whole known world *(the first uses of longitudinal and latitudinal lines.*

2 Ptolemy´s map.

Middle ages:

The size of the known world grew, thanks to **sea-sailors**, but in general, there was only a little progress in the science of cartography.

During this middle age times, Muslim scholars continued and advanced on the mapmaking traditions of earlier cultures, mostly following Ptolemy's methods; but they also started using the knowledge, notes and writings of the explorers and merchants during their travels across the Muslim world. There were advances in a more accurate definition of the measure units, plus great efforts in trying to describe and define the calculations of the circumference of the earth. There were also numerous studies and methodologies to draw a system of meridians and parallels that helped greatly to the evolution of the science of Cartography

Tabula Rogeriana by Al Idrisi, isn't just a map of the world- it's an extensively researched geographical text that covers natural features, ethnic and cultural groups, socioeconomic features, and other characteristics of every area he mapped.

3 Tabula Rogeriana.

Renaissance:

This period brought a number of significant changes which affected the way of mapping:

- the discovery of America by Ch. Columbus and other discoveries
- new machines which made it easier to print maps (e.g. printing press)
- new devices to measure distances and angles = more accurate maps
- new cartographic projections
- first atlases
- maps show areas in different scales

Gerardus Mercator

- A German – Flemish cartographer, geographer and cosmographer
- He created the first world atlas called *Atlas Sive Cosmographicae* (1585 – 1589)

4 Mercator´s Atlas Sive Cosmographicae.

Age of Enlightenment:

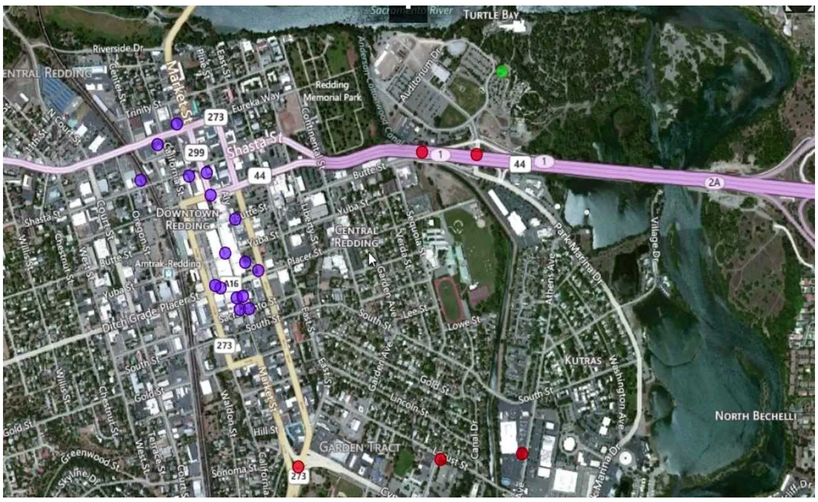
- New methods of measuring the distances and areas, first globes
- Army mapping, thematic mapping (maps of roads, maps of climates, etc.)
- The first Slovak cartographer – **Samuel Mikovíny**

5 Samuel Mikovíny – Bratislava´s meridian on the map.

6 Bratislava´s meridian and Samuel Mikovíny´s memorial board.

Modern Era:

- The use of photographs to create maps, GPS, satellite systems are used to locate objects on the Earth
- Maps have become very precise and accurate
- GIS (Geographic Information Systems) are PC programmes that are used to create
- Digital maps



7 An example of digital map made in GIS.

2.2 Types of maps

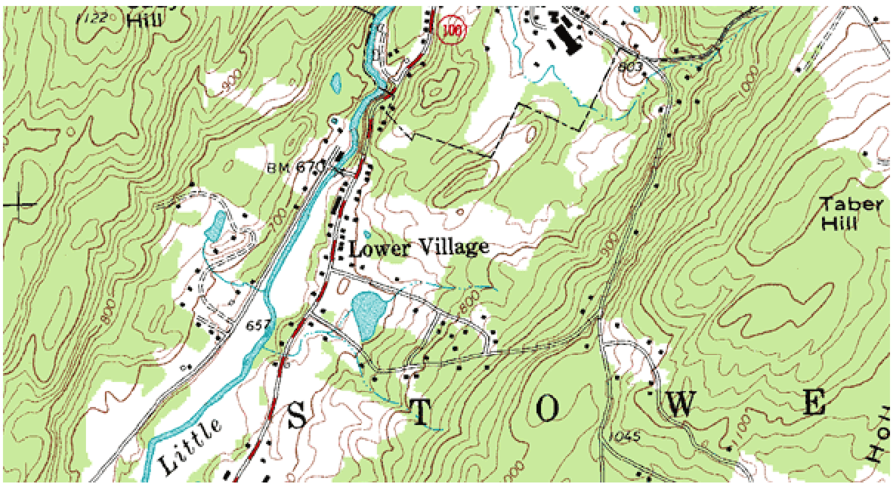
2.2.1 Physical map

- Show natural features such as mountains, lowlands, major rivers, seas, oceans and ecosystems like deserts and rainforests boundaries, mountains, rivers, lakes, etc.
- Different colours are used to show the elevation, the height above or below sea level.
  Water - different shades of blue.
  Land - green (for low elevation), brown (for high elevation).
- Physical maps use **cartograms**.

8 Physical map of the world.

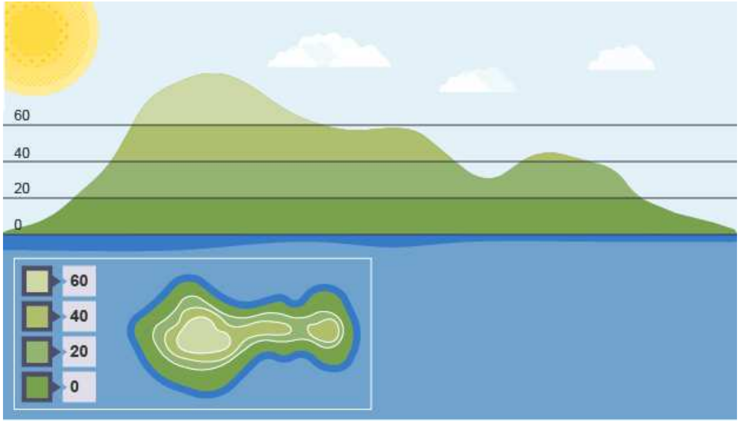
2.2.2 Topographic maps

They are graphical representation of the three dimensional shape of the earth´s surface.



9 An example of a topographic map.

- They show **elevation** change.
- They use **contour lines**. Contour lines connect the places with the same elevation spaced at regular intervals.
- The **closer** together are contour lines the **steeper** is the terrain.
- The **further** apart are the contour lines the **gentler** is the terrain.
- **Index contour lines** – thicker lines which have written elevation.
- Topographic maps also show the tops of mountains, rivers, roads, villages and towns etc.



10 The scheme of contour lines.

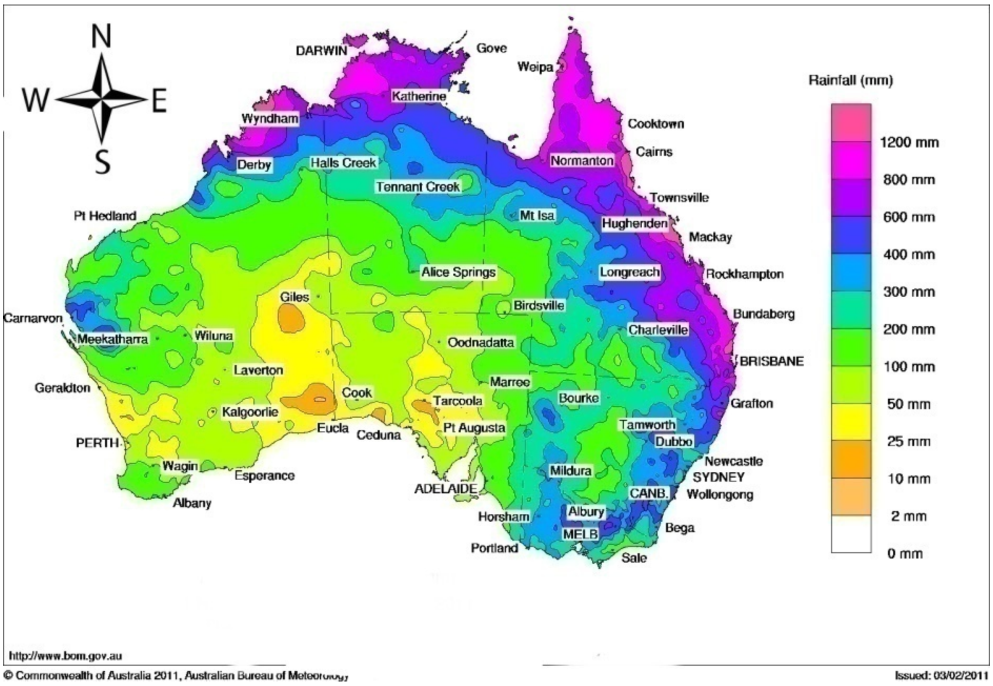
2.2.3 Human and political maps

- Show countries, boundaries between them and major cities
- Show **towns, cities, capital cities**.
- Do not show contour lines and mountains (elevation).
- Lakes, rivers, seas, oceans are sometimes named (depends on the map.)

11 Political map of the world.

2.2.4 Thematic map

- Focus on a particular theme.
- Always illustrate only theme, which can be connected with physical or human geography, e.g. geology, climate, ecosystems, population, economy.

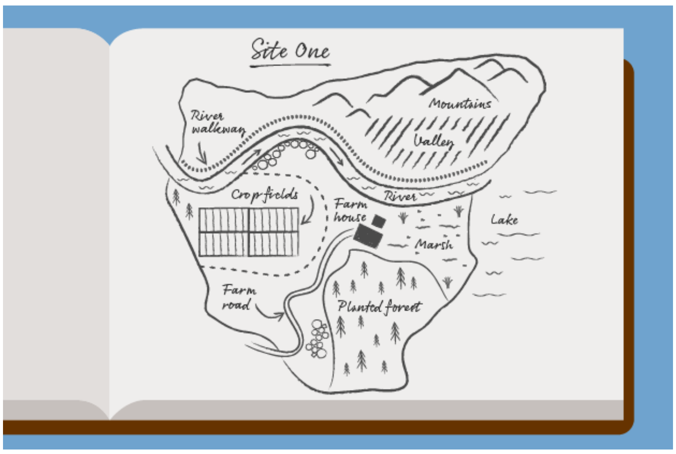


12 A thematic map showing rainfall in the U.S.A.

Other examples of maps:

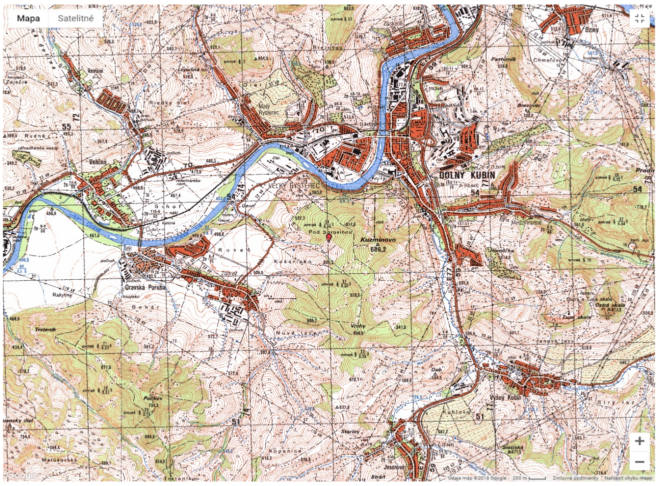
Sketch maps

Sketch maps are simple drawings of the landscape. They show things that are sometimes hidden in photographs or maps, e.g. the impact of tourists on a landscape.
Sketch maps may be shown as a bird's-eye view or as a drawing of the horizon. They can be drawn whilst on fieldwork or from a photograph. It is useful to annotate sketch maps or include a photograph alongside it.



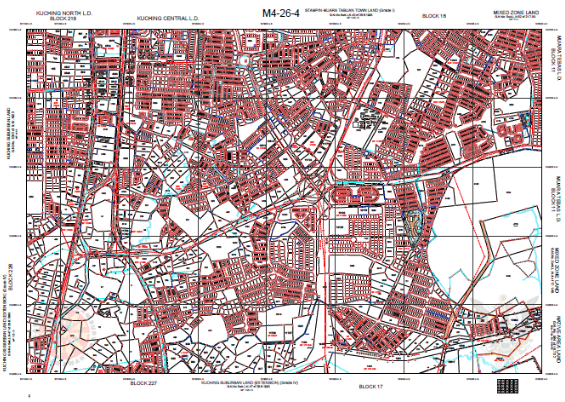
13 An example of a sketch map.

- Army map - ***The military map of Dolny Kubin (scale 1:2500)***



14 The military map of Dolny Kubin (scale 1:2500)

- Cadastral map – shows ownership of a land



15 An example of a cadastral map.

Photographs

Photographs can be taken from different locations:

- **Ground photographs** – these can be taken during fieldwork, using a camera or mobile device. They need to be annotated to show any features.
- **Aerial photographs** – these are usually taken from an aeroplane. They cover a wider area than ground photographs so they are useful in showing spatial patterns.
- **Satellite images** – these are high-resolution photographs taken from satellites in space. They show a very wide area, but in less detail than close-up images.

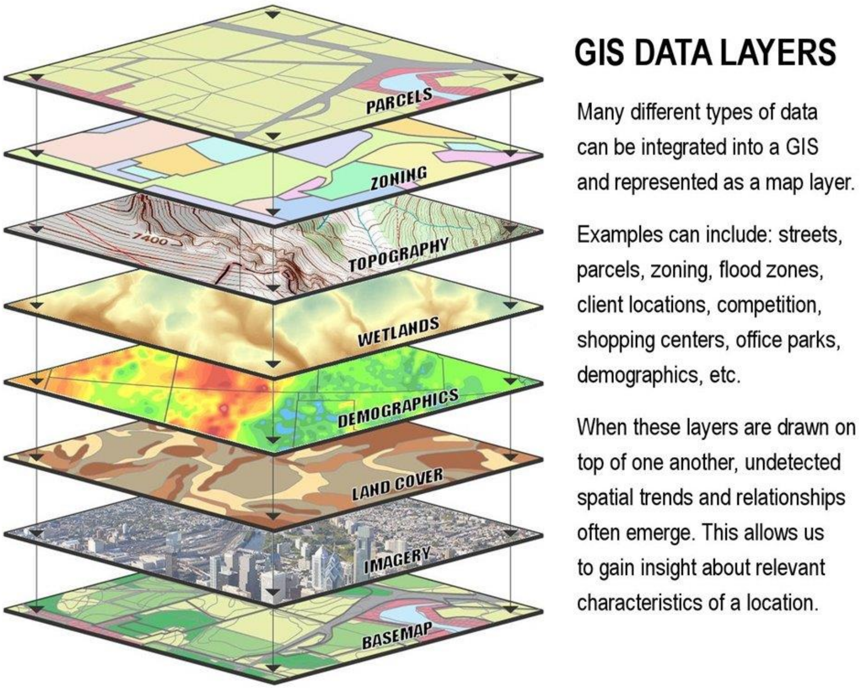
Satellite image showing the landscape before an earthquake:

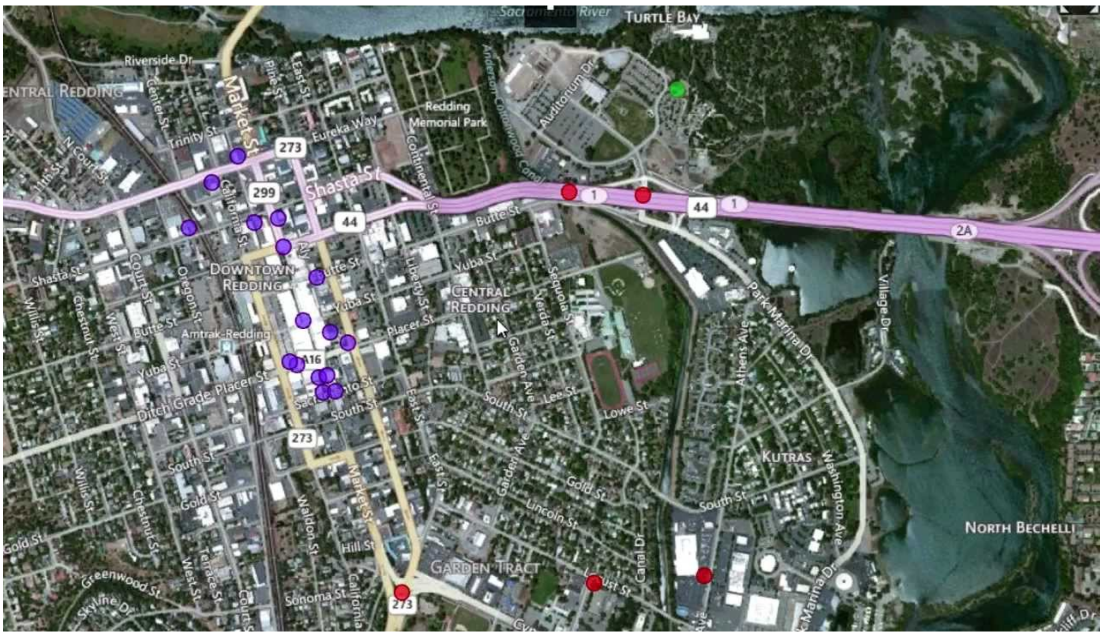
16 Examples of Arial photographs.

Geographical Information System (GIS maps)

Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. GIS applications are tools that allow users to create interactive user-created searches, analyze spatial information, edit data in maps, and present the results of all these operations. Locations in the Earth space- time can be recorded as dates/times of occurrence, and x, y, z coordinates representing, longitude, latitude, and elevation.

All Earth-based spatial–temporal location and extent references should be relatable to one another and ultimately to a "real" physical location or extent. This key characteristic of GIS has begun to open new avenues of scientific inquiry.

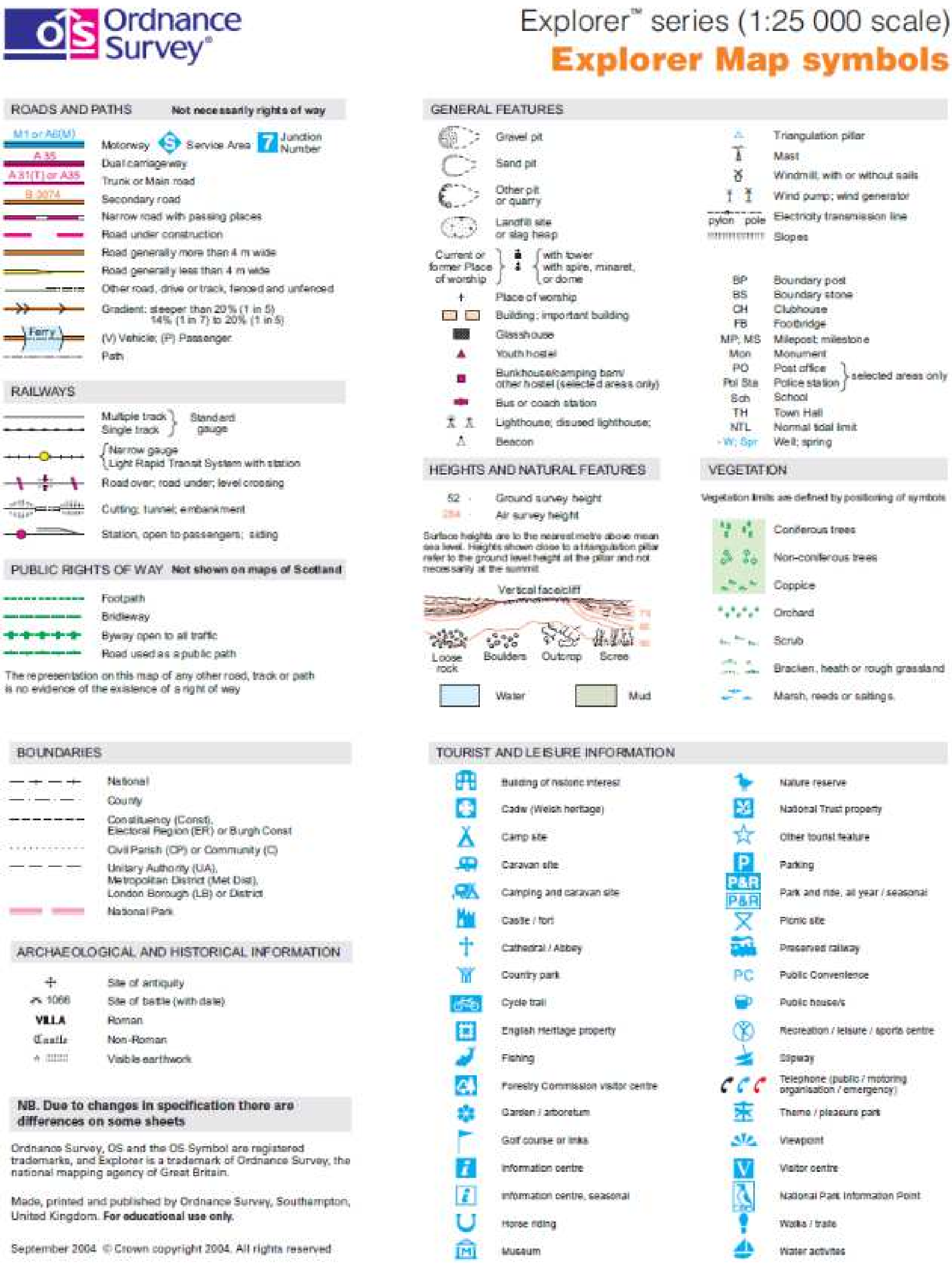




17 An example of digital map made in GIS.

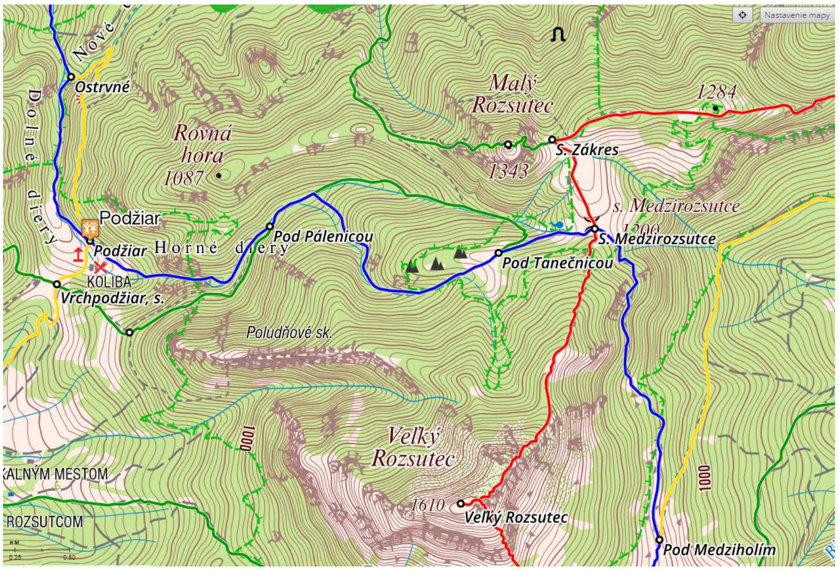
2.3 Map contents

Maps show features in a plan view as birds see it from above. It is impossible to label every single feature in words on a map, therefore we use map symbols. Every map is accompanied by a legend or key. The Key is essential since it contains what each symbol on the map stands for. Such symbols may be drawings, letters, lines, shortened words or coloured areas. Most map symbols are conventional signs as they are understood by everyone around the world.



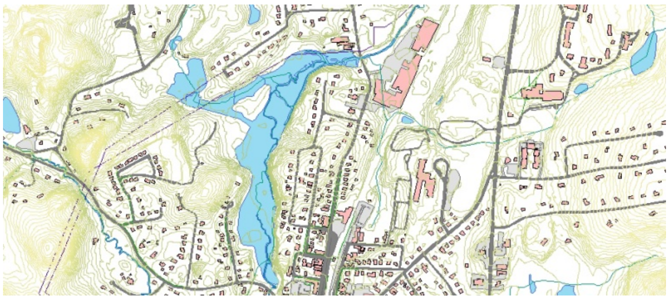
2.3.1 Topographic information

1. **The elevation of the terrain** – the figures of altitude, contour lines (isohypses/ isobaths), spot heights and shaded relief.



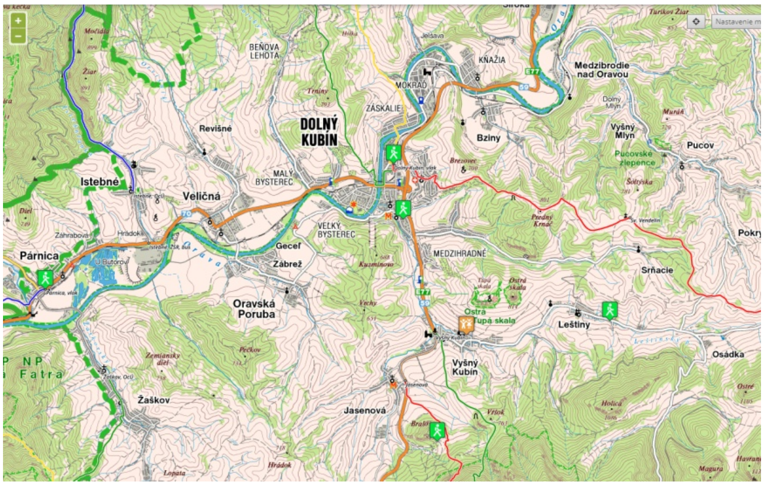
18 A topographic map of the Law Fatra Mountains, Slovakia.

2. **Planimetrics** – map symbols showing the **exact location** of various objects (buildings, borders, rivers, lakes, forests, etc.). These symbols could be ***pictograms*** (of an airport, bridge, cave, etc.), ***lines*** (of rivers, roads, etc.), or ***areas*** (of forests, deserts, etc.).



19 An example of planimetrics symbols on a map.

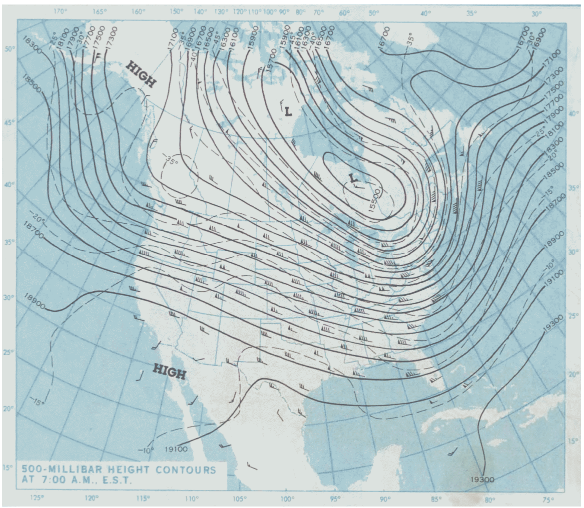
3. **Names and labels** of town and cities.



20 Names and labels on the map of Dolný Kubín, Slovakia.

2.3.2 Thematic information

It is some information about a **specific topic** which the map shows (e.g. the map of climate will have various colours representing various temperatures, or precipitation data, the map of cities´ population, etc.)



Topographic contents – **longitude and latitude lines, lines showing the states of the USA**

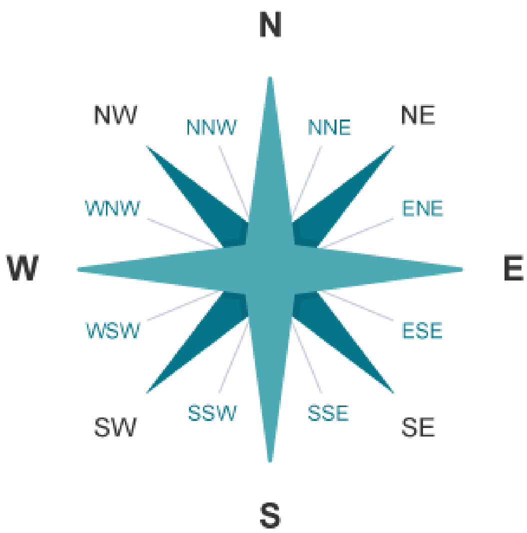
Thematic contents – **lines showing the barometric pressure, arrows showing the direction of the air masses,**
etc.

21 A thematic map showing barometric pressure in North America.

2.4 Geographic coordinate system

Direction

Maps should have a **direction** arrow to show which way is north. North is at the top of the globe and south is at the bottom. East is to the right and west is to the left. Compass points in between these four are shown as combinations, e.g. the point in between north and east is called north-east. If the point is slightly closer to the east, it is called east-north-east.



The compass directions are, in clockwise order from the top: North, East, South, and West. In between these are North-East, South-East, South-West and North-West.

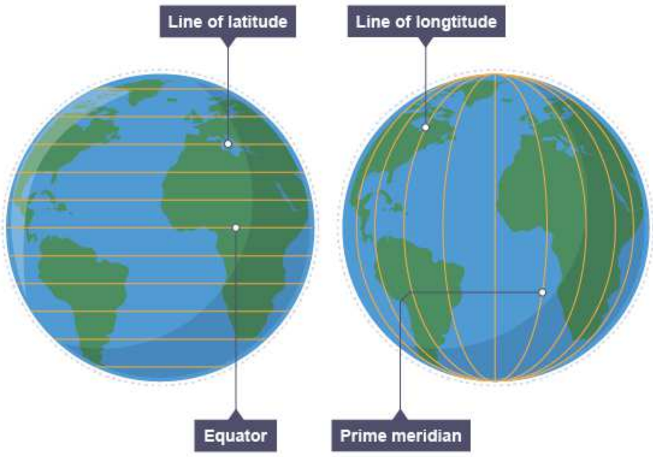
Longitude and latitude

The invention of a geographic coordinate system is generally credited to Eratosthenes of Cyrene, who composed his *Geography* at the Library of Alexandria in the 3rd century BC.
Coordinate system enables every location on Earth to be specified by a set of numbers, letters or symbols. The coordinates are often chosen such that one of the numbers represents a vertical position, and two or three of the numbers represent a horizontal position. A common choice of coordinates is **latitude**, **longitude** and **elevation**. The combination of latitude and longitude specifies the position of any location on the surface of Earth, without consideration of altitude or depth.

Latitude and longitude enable users to find locations.

- As the Earth is a sphere, lines of latitude and longitude are measured using degrees of a circle.
- Lines of **latitude** run from east to west. The **Equator** is a line of latitude that lies at 0°. Lines above this are shown as °N (north) and lines below this are shown as °S (south).
- Lines of **longitude** run from north to south. The **Prime** or **Greenwich Meridian** in London is a line of longitude at 0°. Lines to the right of this are shown as °E (east) and lines to the left of this are shown as °W (west).

Latitude is shown first and longitude is shown second, e.g. Manchester in the UK is at 53.5°N, 2.2°W.

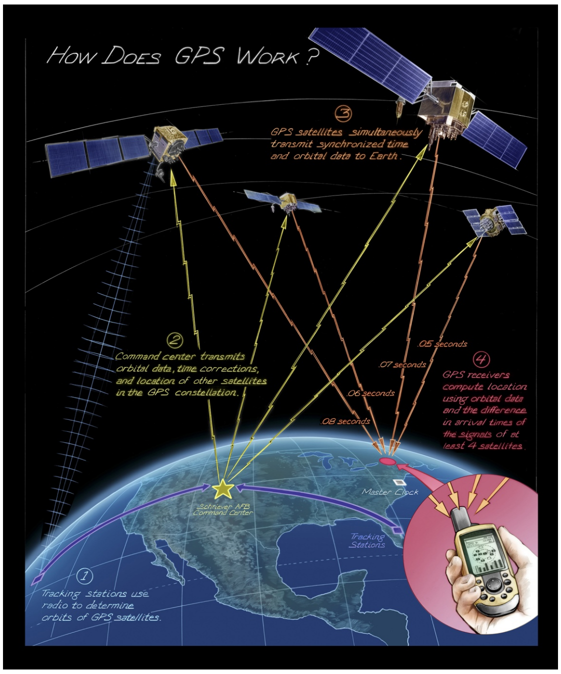


They completely specify a location of a topographical feature on, in, or above the Earth, and also have to specify the vertical distance from Earth's centre or surface.

Earth is not a sphere, but an irregular shape approximating a biaxial ellipsoid. It is nearly spherical, but has an equatorial bulge making the radius at the Equator about 0.3% larger than the radius measured through the poles. The shorter axis approximately coincides with the axis of rotation. Though early navigators thought of the sea as a flat surface that could be used as a vertical datum, this is not actually the case. Earth has a series of layers of equal potential energy within its gravitational field. Height is a measurement at right angles to this surface, roughly toward Earth's centre, but local variations make the equipotential layers irregular (though roughly ellipsoidal). The choice of which layer to use for defining height is arbitrary.

2.4.1 Global Positioning Systems (GPS)

Global Positioning System is a satellite navigation system used to determine the ground position of an object. GPS technology was first used by the United States military in the 1960s and expanded into civilian use over the next few decades. Today, GPS receivers are included in many commercial products, such as automobiles, smart phones, exercise watches, and GIS devices. Each GPS satellite broadcasts a message that includes the satellite's current position, orbit, and exact time. A GPS receiver combines the broadcasts from multiple satellites to calculate its exact position using a process called triangulation. Three satellites are required in order to determine a receiver's location, though a connection to four satellites is ideal since it provides greater accuracy.



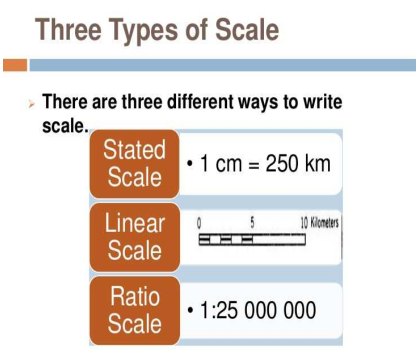
22 A scheme showing how GPS works.

2.5 Scale and distance

A **map** is a scaled-down drawing or plan of all part of the Earth´s surface. Maps are much smaller than the areas the show.
Maps are drawn to different scales, depending on the type of information that they need to show.

Scale is a relationship between a distance on a map and its corresponding distance on the ground. A few centimetres on the map stand for many kilometres on the ground.

Maps show objects as being much smaller than they are in real life. The relationship between the features on the map to the real size on the ground is called the scale. Scale is shown as a ratio, e.g. 1:25,000 means that 1 cm on a map represents 25,000 cm or 250 m in real life. **Small-scale maps** show **large areas** in little detail. **Large-scale maps** show **small areas** in greater detail.
Linear scale is a ruled line divided into kilometres and parts of a kilometre. It allows us to measure distance directly from the map. Scale could be given as a **ratio**. The ratio 1:25,000 means that any one unit of measurement on the map corresponds to 25,000 similar units on the ground.

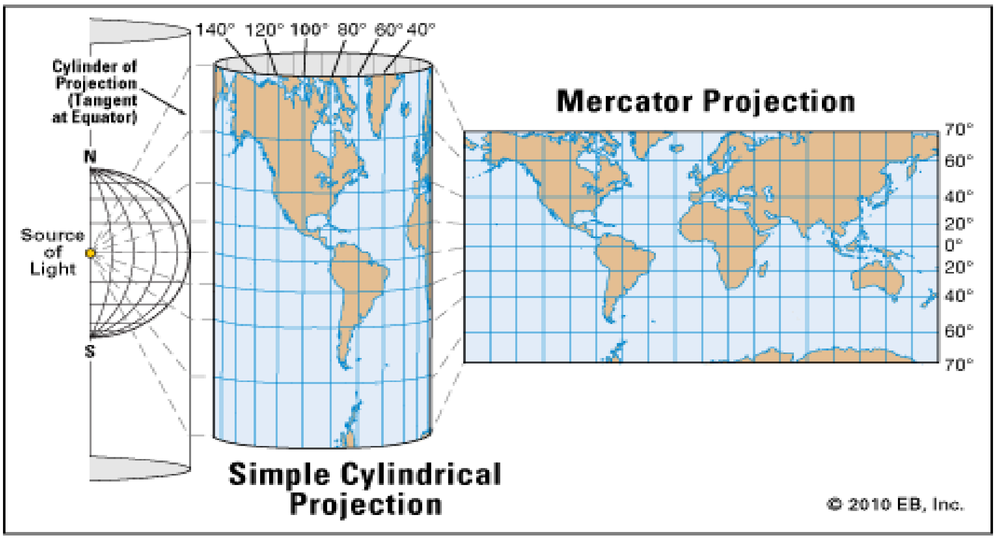


Types of Scale

	Area	Detail	Example
Large Scale Maps	Small	A lot (streets, schools, railways)	Topographic maps, road maps, city bus maps
Medium Scale Maps	Medium	In between (cities)	City of Toronto Map
Small Scale Maps	Large	A little (borders, lakes, large rivers, …)	Globes, world maps, atlases

2.6 Map projections

Maps miniaturized and symbolic depictions of the Earth´s surface. They are 2D representations of 3D space. The depicted area is always distorted. The real objects are represented by a set of map symbols.
When creating a map, the complicated surface of the Earth has to be miniaturized -> projected onto a 2D mapping plane -> primary (topographical) maps -> (topographical surveyors) further editing -> derived maps (cartographers)

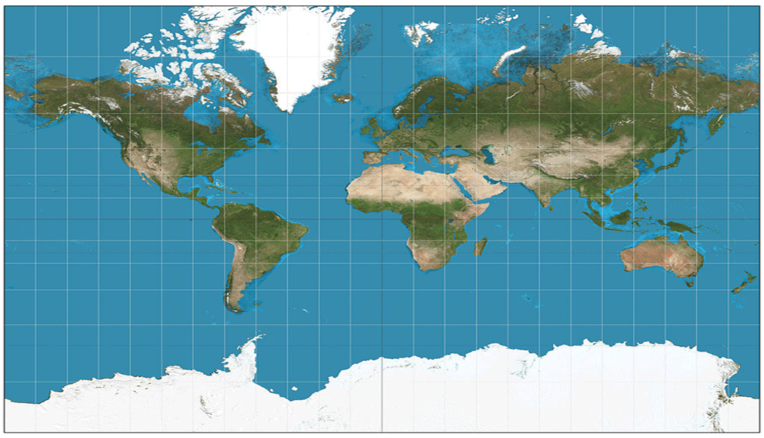


23 Examples of map projections.

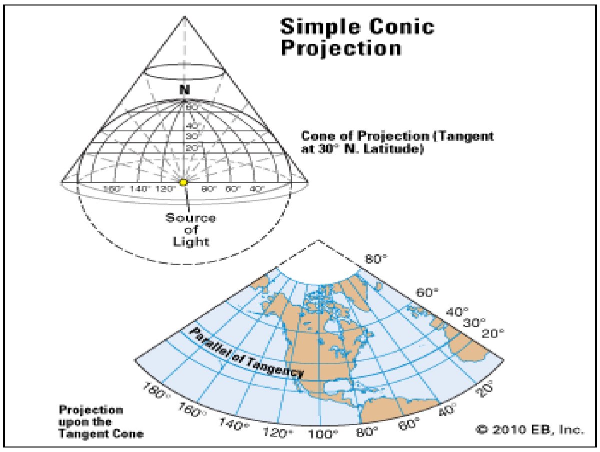
To avoid distortion, there are several map projections which we can use when creating a map:

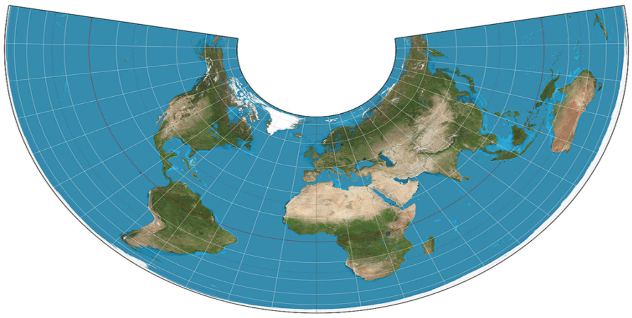
Cylindrical projection

- The 3D globe shape of the Earth is projected onto a **cylinder** this cylinder is wrapped around the Earth, projected onto, and then unrolled
- The longitude and latitude lines are at **right angles**
- Shows true direction
- Distorts high latitudes


21 A map based on the cylindrical projection.

Conic projection



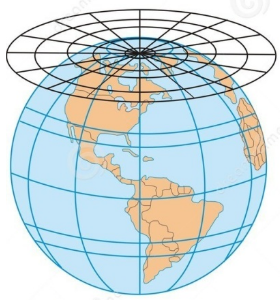


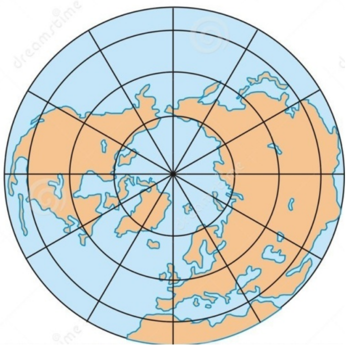
22 A map based on the conic projection.

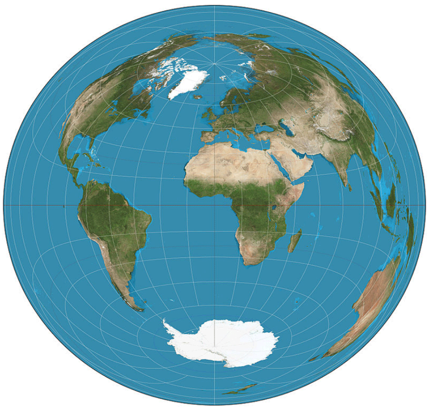
- The 3D globe shape of the Earth is projected onto a cone; this cone is wrapped around the Earth, projected onto, and then unrolled.
- The longitude lines all radiate from the top of the cone.
- The latitude lines form circles.
- Good for showing a small area accurately.

Azimuthally projection

- The 3D globe shape of the Earth is projected onto a plane, with one central contact point
- The longitude lines all radiate from the central point
- The latitude lines form circles
- Useful for showing polar regions





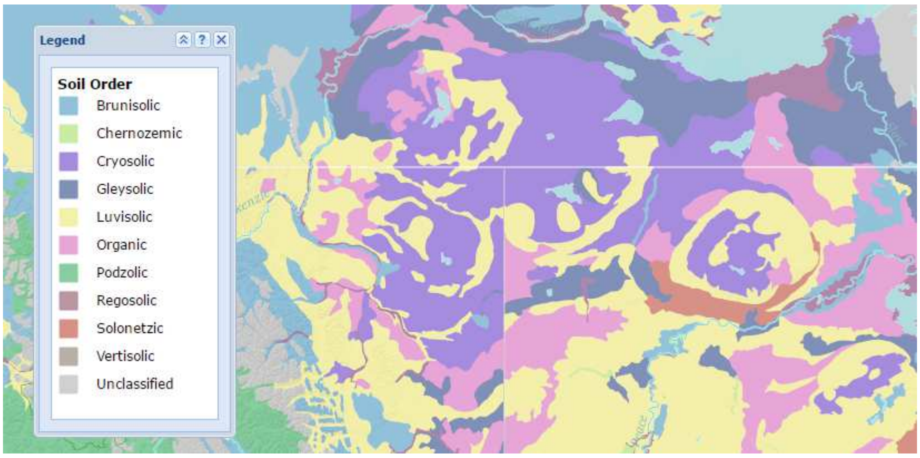


21 A world map based on the azimuthally projection.

2.6 Cartogram

2.6.1 Map legend

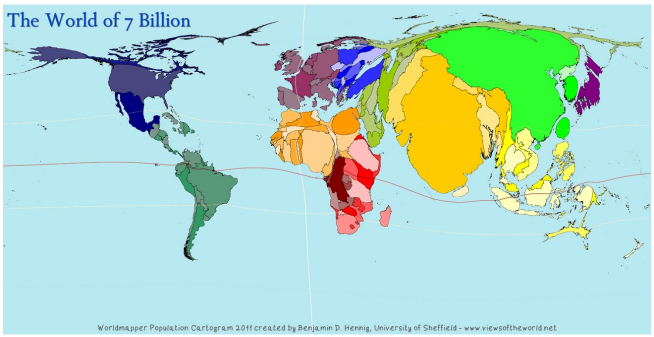
A map legend or a map key is an explanation of the symbols or pictorial language of the map.



1 A map showing soil spreading in Asia.

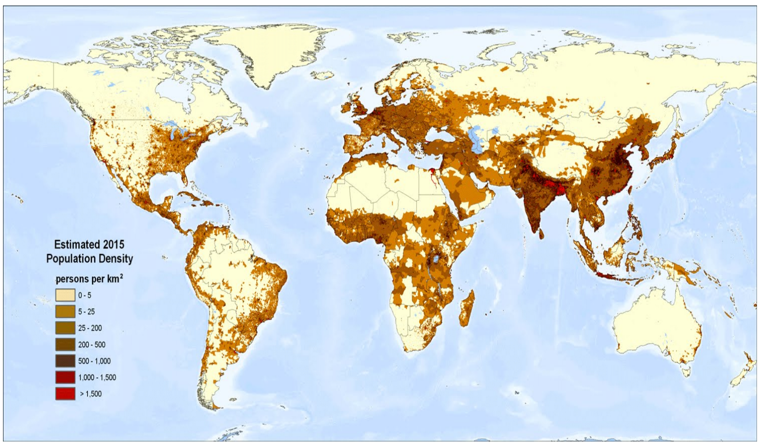
2.6.2 Cartogram

It is a unique **type of map** because it **combines statistical information** with **geographic location**.



2 The population of the world

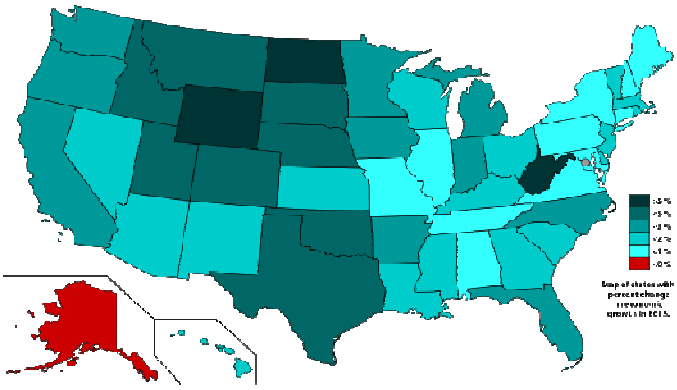
It is primarily used to display **quantity**, by using various colours or shapes.



3 Estimated 2015 population density.

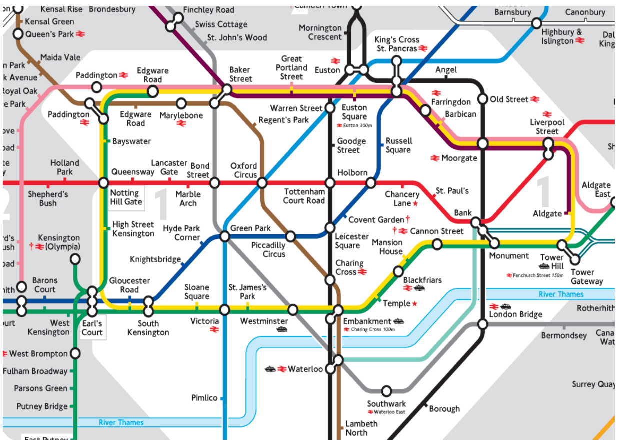
There are two main types of cartograms: **area cartograms** and **distance cartograms.**

An **area cartogram** is a map that changes an entire physical location by scaling a chosen economic, social, political, or environmental factor.



4 The economic growth percentage of U.S. states in 2013.

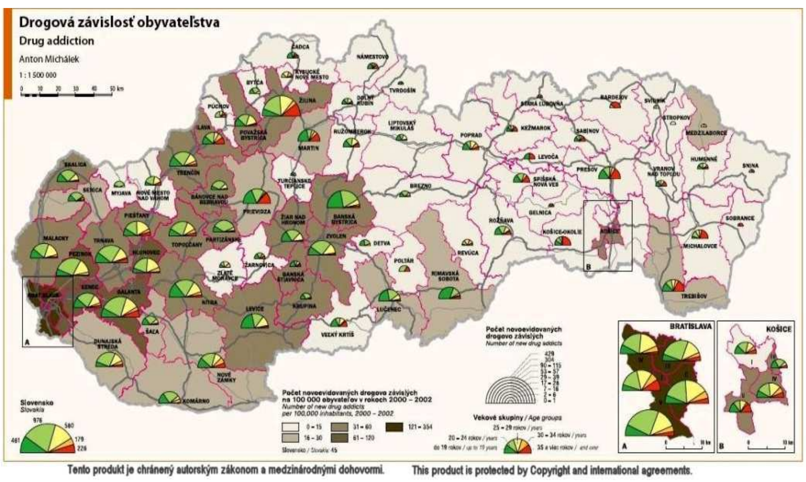
A **distance cartogram** is used to display the relative time and distance within a chosen network.



5 London Underground routes map.

2.6.3 Diagram

It is a pictorial representation of information, which shows **qualitative** data.



6 Drugs addiction of people in Slovakia.

Questions for discussion:

1. Nowadays at the era of digital and satellite photography do you think the maps are important?
2. Where and when is it necessary to use maps?
3. Do you think paper maps will disappear in the future?
4. Do you use maps? Why? Why not?
5. What are the three components of a map? What are the four cardinal directions?
6. What is meant by the term ‘the scale of the map’? Is it important to know the scale of a map?
7. How are maps more helpful than a globe?
8. Compare a map and a plan.
9. Which map provides the most detailed information?
10. Map of my travel dreams. Make your own map in Google Earth application, put there 5 places you would like to visit, use some pictures and support your choice with some arguments in the comment.

8 The map of Árva county in the Kingdom of Hungaria, 1891

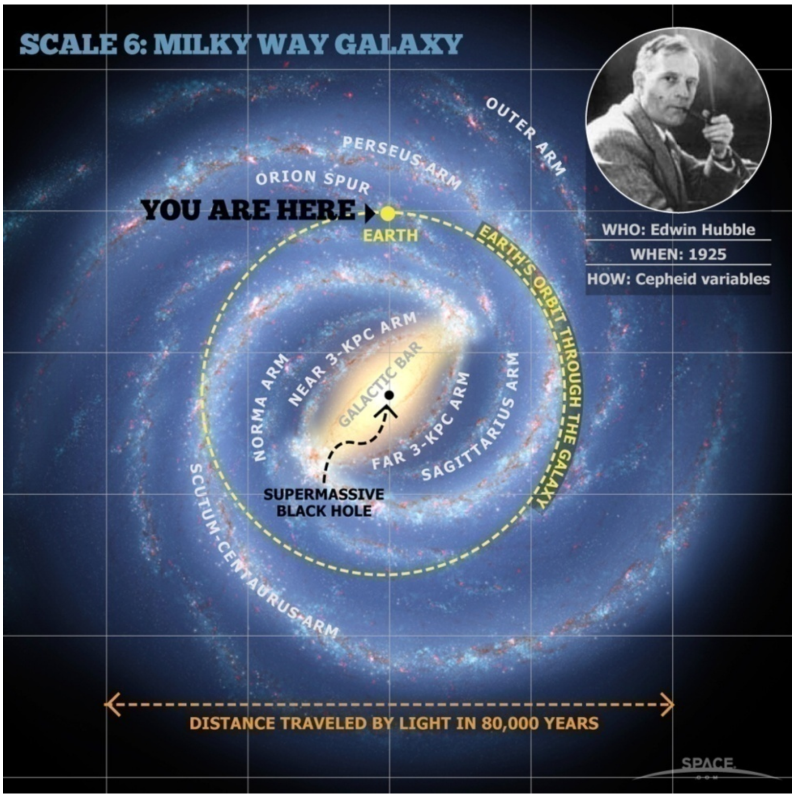
3. THE EARTH AS A PLANET

3.1 Solar System

The Big Bang Theory is the leading explanation about how the **universe** began. At its simplest, it says the universe as we know it started with a small singularity, and then inflated over the next 13.8 billion years to the cosmos that we know today.

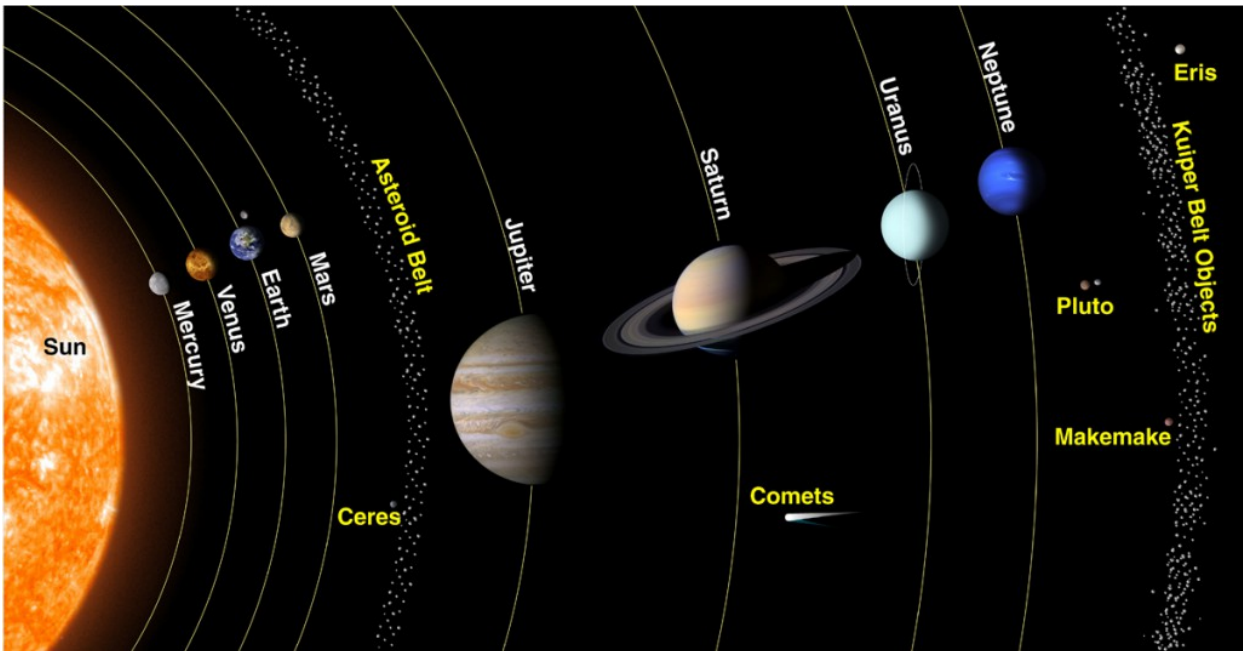
1 Milky Way Galaxy.

Our **solar system** is one of 500 known solar systems in the entire **Milky Way galaxy**. It was formed approximately 4.6 billion years ago when a cloud of interstellar dust and gas collapsed resulting in solar nebula, a swirling disk of material that collided to form our solar system. It is located in the Milky Way´s **Orion star** cluster and consists of **the Sun**, **planets** and countless smaller bodies such as **dwarf planets**, **asteroids** and **comets**. Our solar system orbits the centre of the Milky Way galaxy at about 828,000 kph. We are on the **galaxy´s spiral arms.** It takes our solar system about 230 million years one orbit around the galactic centre. Our solar System is a region of space. It has no atmosphere but it contains many worlds- including Earth – with many kinds of atmospheres. The planets of our solar system and even some asteroids hold more than 150 moons in their orbits. Our solar system is the only known to support life.



2 Milky Way Galaxy.

There are 8 planets in our solar system orbiting the Sun:



3 The planets of the Solar System.

The planets are divided in two categories based on their composition:

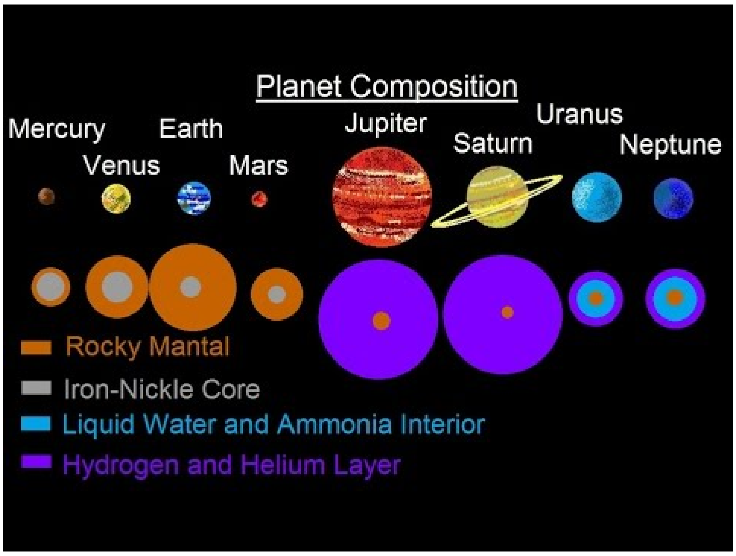
Terrestrial planets: *Mercury, Venus, Earth, Mars*

They are primarily made of rocky materials, their surface is solid and they don’t have ring.

Non-terrestrial or Jovian planets: *Jupiter, Saturn, Uranus, and Neptune*

These planets are found in the outer solar system. They are characterized by their massiveness and gaseous composition.

Dwarf planets: *Eris, Pluto, Haumea, Makemake, Ceres*.



4 Planets composition.

3.2 Evolution of the Earth

The Earth is **4,570,000,000** years old. We can date meteorites using radioactive isotopes and their decay products.

For the first half billion years of its existence, the surface of the Earth was repeatedly hit by asteroids and comets of all sizes. One of these collisions formed **the Moon**.

5 The Earth at the time of its origin.

Geosphere

The early Earth heats up. Soon after its formation the earth was completely melted. This melting was due to the decay of radioactive elements in the interior and heat left over from the collisions that formed the Earth.

Melting allowed the earth to separate into layers through a process known as *differentiation.*

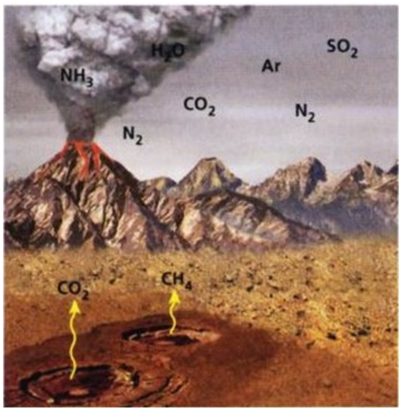
The first **crust** was thin and constantly changing due to wide spread volcanism tectonic activity

6 The origin of the Earth´s crust.

Atmosphere

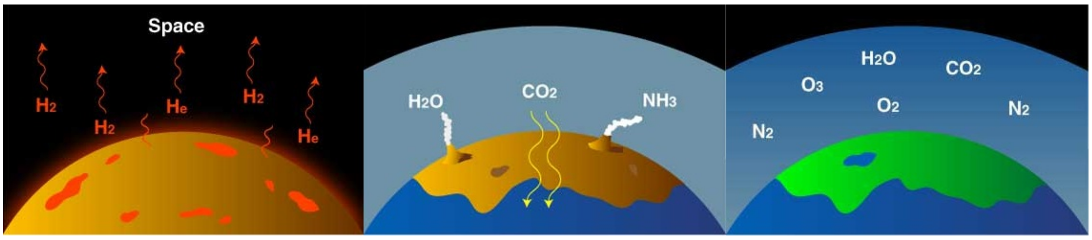
Right after its creation, the Earth is thought have had a thin atmosphere. Earth´s first atmosphere was mostly composed of **hydrogen (H)** and **helium (He).** The Earth´s gravity couldn´t hold these light gases and they easily escaped into outer space. Today these gases are very rare in our atmosphere. The early atmosphere was toxic and a human would not survive in it.

The second atmosphere was the result of out-gassing from wide spread volcanic activity. The early atmosphere was probably rich in **carbon dioxide (CO_2)**, **nitrogen (N_2)**, **methane (CH_4)**, **ammonia (NH_3)**, and **water vapour (H_2O)**. This atmosphere was void of free oxygen (O_2).

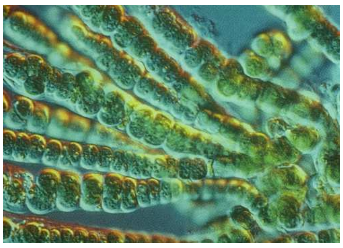


7 The origin of the atmosphere.

Simple organisms called *cyanobacteria (also known as Blue–green algae)* thrived in the acidic, carbon dioxide rich oceans and released oxygen to the atmosphere. Colonies of these organisms formed reef like structures called *stromatolites.* As life evolved, **photosynthesis** produced large quantities of oxygen that eventually led to the atmosphere with free oxygen that we have today.



One of the biggest differences between phases shown above (1 being the original atmosphere and 3 representing today), was the temperature of the surface material. Through the process of out-gassing, the outpouring of gasses from Earth´s interior, many other gases were injected into the atmosphere. Hot volcanic gases escaping Earth's interior built up the original atmosphere. Over a period of million years the atmosphere evolved to its current state.



8 Photosynthesis.

Hydrosphere

Water molecules were present in the nebula from which the solar system and the earth formed 4.567 billion years ago.
Scientists believe that the majority of water on Earth came from two sources:

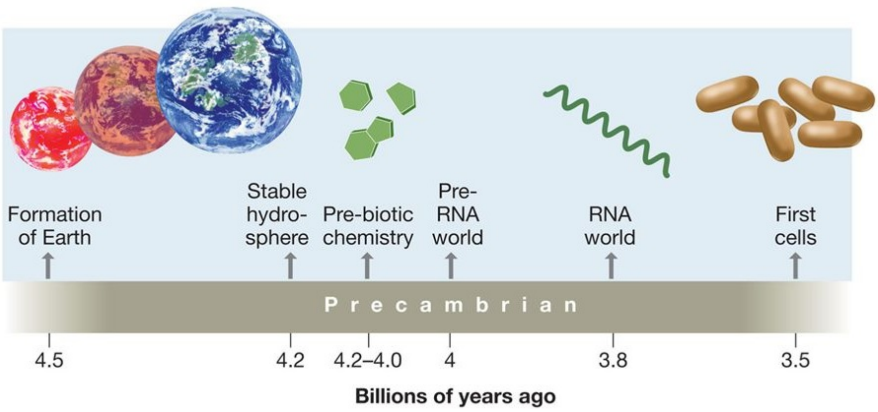
1) Meteor Impacts and Comet Impacts (about half)
2) Volcanic Out-gassing (release of water already trapped inside the Earth)

Volcanic activity released the trapped water to the atmosphere. As the Earth cooled, the water condensed and fell to the ground as precipitation.

9 The origin of hydrosphere.

Biosphere

Earth´s first life forms appeared 3.5 billion years ago. First vertebrates appeared in the ocean 500 million years ago. Land plants and coral reefs appeared 420 million years ago. Human began to evolve 1.4 million years ago.



10 The scheme showing how biosphere was created.

3.3 Shape and features of the Earth.

- EARTH provides us with life and protects us from space.
- EARTH is the third planet from the sun and the fifth largest in the Solar System.
- EARTH is 149,597,891 km away from the Sun.

1 astronomical unit – the Earth-sun distance => 1 AU = 150,000,000 km

A light beam takes 8.3 minutes to travel 150,000,000 km from the Sun to the Earth. The speed of the light in vacuum is 300,000 km/s**.** The distances in space are not in terms of kilometres or miles – but in *light years.*

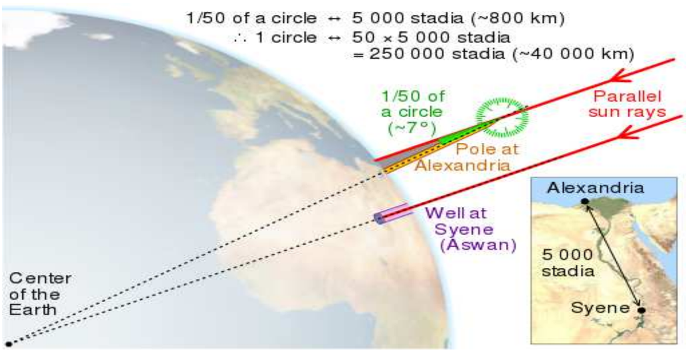
1 light year [ly] – distance that light travels in vacuum in one Julian year.

3.3.1 Earth´s shape

In the distant past people generally believed that the Earth is flat. But later on, there came scientifically valid evidence about shape of our planet.

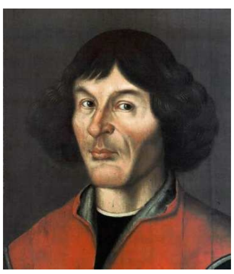
11 The idea of the flat Earth.

Eratosthenes – estimated radius and circumference of the Earth on the summer solstice.

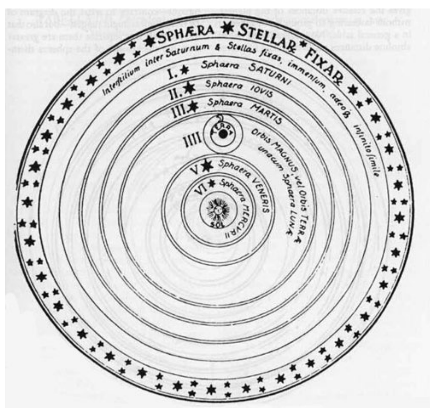


12 The estimation of the Earth´s radius.

Nicolaus Copernikus



He placed the Sun at the centre of the universe called Heliocentric theory.

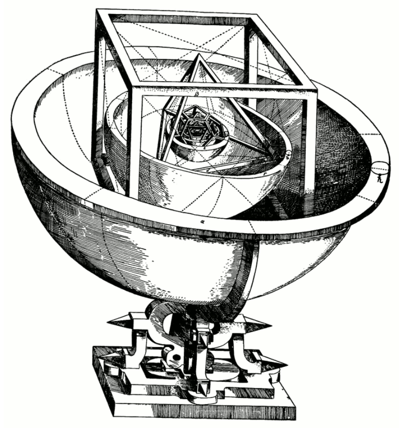


12 Heliocentric theory.

Johannes Kepler

The laws of planetary motion.

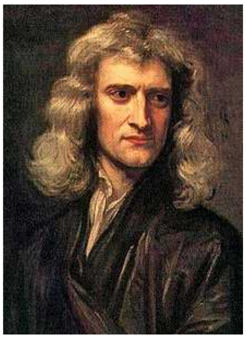
You can see Kepler´s Platnic solid model of the solar system from Mysterium Cosmographicum (1596).



13 Kepler´s model.

Isaac Newton

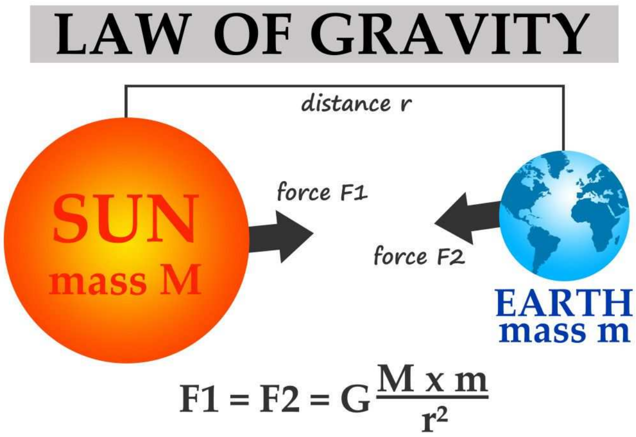
The laws of gravity.



Newton's Law of Gravity states that "there exists a universally attractive force between any two objects called gravity. The magnitude of this force is proportional to the product of the two masses, and inversely proportional to the square of the distance between their centres."

Newton's Law of Gravity explains why the Solar System sticks together, why there are tides, and why objects orbit other objects: it is the force of gravity that produces and maintains these results.

Newton's Law of Gravity, along with his Laws of Motion, explains why the Moon orbits the Earth. The Moon is a natural satellite of the Earth: as it moves "forward" in its orbit, it also falls "down" towards the centre of the Earth (due to gravity). This combined motion is balanced in such as way that the Moon stays the same height (more or less) off the surface of the Earth.

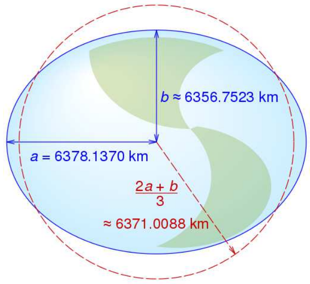


Some of the proofs showing the spherical shape of the Earth:

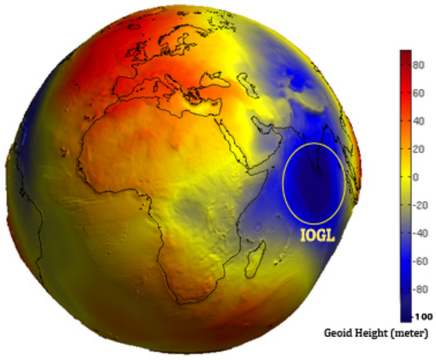
- A ship on its cruise dis (appears) slowly on the horizon.
- The position of stars changes when we go southward or northward.
- The shadow of the Earth on the Moon is circular during a moon eclipse.

Nowadays we know that Earth is a sphere. However, but not accurate sphere because of the rotation, earth is bulged around the Equator and flattened at its poles.

This forms a shape called an **ellipsoid** (an oblate spheroid).



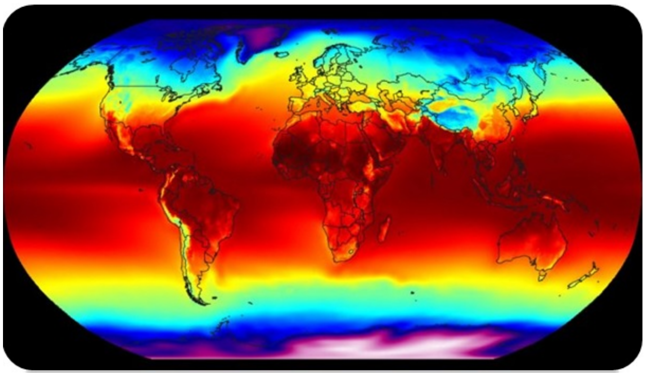
The real shape of Earth is **geoid,** see the following picture 14.



Geoid height (EGM2008, nmax=500)

3.3.2 Zonality

The fact that Earth is a sphere has significant impacts on life on Earth – the places on the Earth receive unequal amount of sunshine which results in zonality of climate, soils, flora and fauna



15 Climate zones.

3.3.3 Coriolis Effect

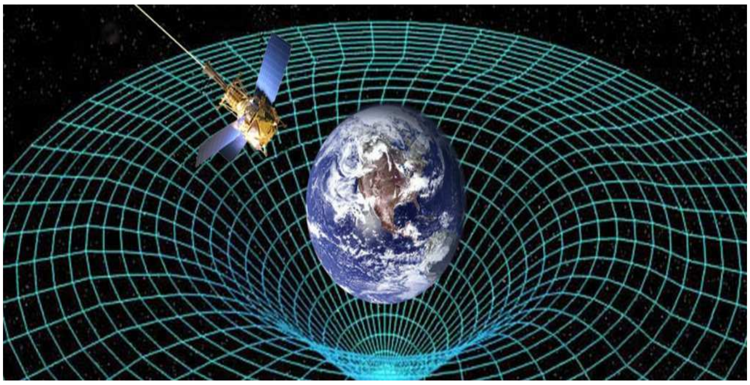
The **Coriolis force** is the internal force which causes a deflection in global wind patterns. The anticlockwise rotation of the Earth deflects winds to the right in the northern hemisphere and to the left in the southern hemisphere.

16 Coriolis Effect visible in the hurricane rotation.

3.3.3 Gravity

Gravity is natural phenomena in which all things that possess mass are brought towards one another – i.e. asteroids, planets, stars, galaxies, super clusters, etc.
The more mass an object has, the more gravity it will exert on objects around it. The gravitational force of an object is also dependent on distance – i.e. the amount it exerts on an object decreases with increased distance.

Gravity is also one of the four fundamental forces which govern all interactions in nature (along with weak nuclear force, strong nuclear force, and electromagnetism). Of these forces, gravity is the weakest, being approximately 10^{38} times weaker than the strong nuclear force, 10^{36} times weaker than the electromagnetic force and 10^{29} times weaker than the weak nuclear force.



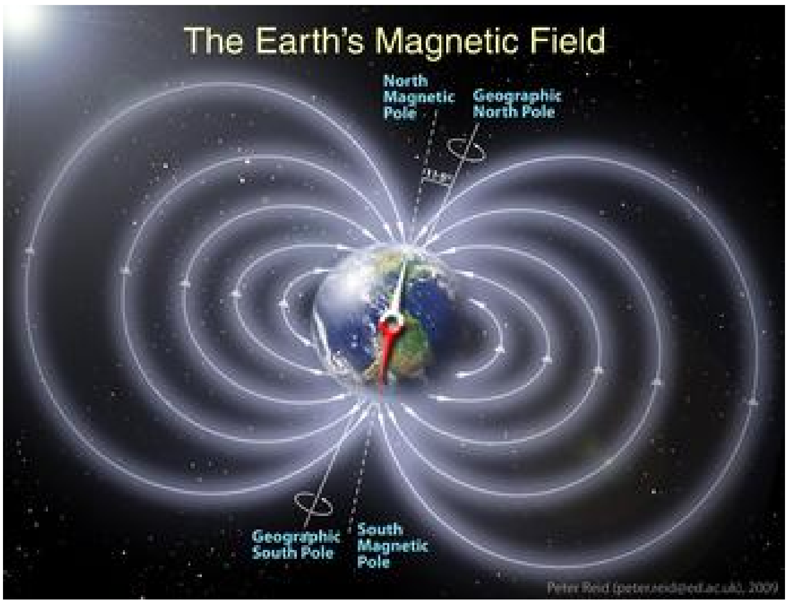
17 Gravitational field of the Earth.

3.3.4 Magnetism

Heat and the Earth's spin keep the outer core moving. This movement causes electrical currents in the core, which is mostly iron. The electrical currents create a magnetic field that extends into space (see the picture 18 below).

The magnetosphere is the magnetic force that extends into space. This force acts like a shield, protecting the Earth from harmful gases and charged particles that would destroy the atmosphere.

The North and South magnetic poles wander widely, but sufficiently slowly for ordinary compasses to remain useful for navigation. However, at irregular intervals averaging several hundred thousand years, the Earth's field reverses and the North and South Magnetic Poles relatively abruptly switch places.



3.3.5 Size of the Earth

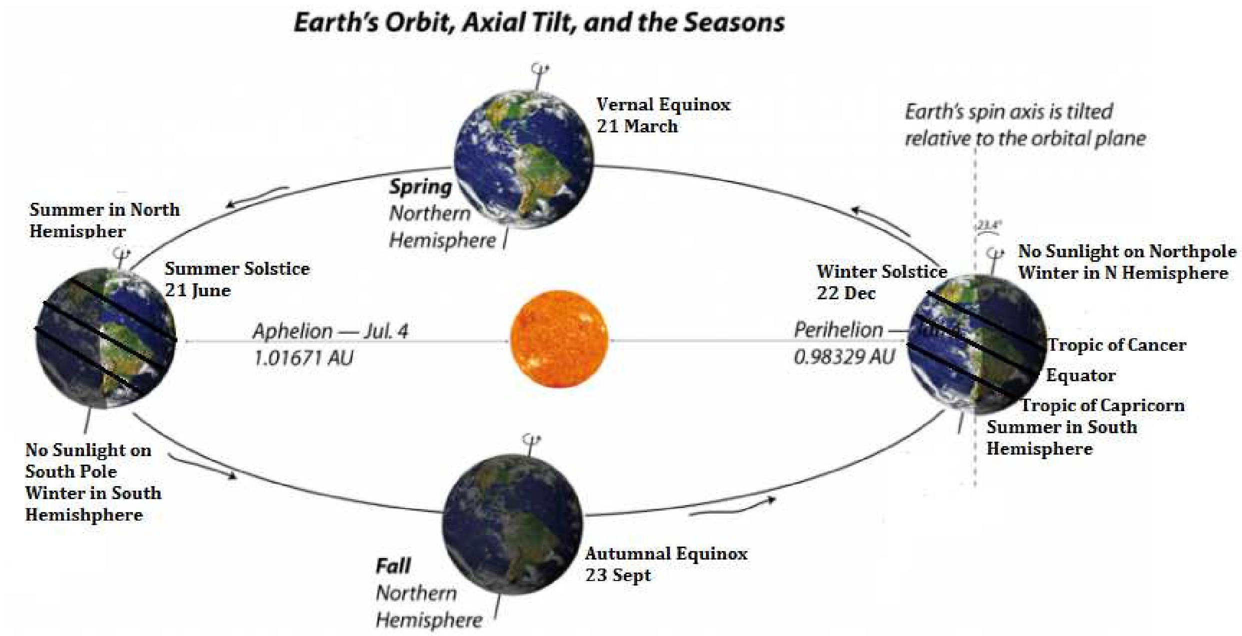
- **Diameter** of Earth at the Equator is 12,756 km.
- **Radius** of Earth is 6,378 km.
- **The total surface area** is about 510 million km^2.
- 149 million km^2 29% is represented by **land** (continents and islands), the remaining 361 million km^2 (71%) is covered by **oceans**.

3.4 Earth´s motions

The Earth is constantly in motion and does 2 cardinal motions – **revolution around the sun and rotation around its axis**. These motions are visible and obvious for people living on Earth. However, there are other 2 motions that are minor and not so important for us - nutation and precession.

3.4.1 Earth´s revolution around the Sun

For Earth to make one complete revolution around the Sun takes **365.24 days**. This amount of time is the definition of one year. The gravitational pull of the Sun keeps Earth and the other planets in orbit around the star. Like the other planets, Earth's orbital path is an ellipse so the planet is sometimes farther away from the Sun than at other times. The distance between Earth and the sun is 149.6 million kilometres, which equals **1 AU** (astronomical unit



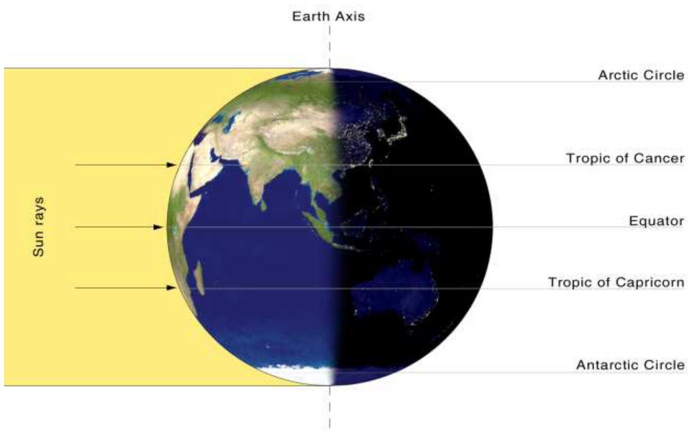
19 Earth´s Orbit.

The closest Earth gets to the Sun each year is at **perihelion** (147 million km) on about January 3rd and the furthest is at **aphelion** (152 million km) on July 4th. Earth's **elliptical orbit** has nothing to do with Earth's seasons. During one revolution around the Sun, Earth travels at an average distance of about 150 million km. Earth revolves around the Sun at an average speed of about 27 km per second, but the speed is not constant. The reason the Earth (or any planet) has seasons is that Earth **is tilted 23.5°** on its axis. During the Northern Hemisphere summer the North Pole points toward the Sun and in the Northern Hemisphere winter the North Pole is tilted away from the Sun.

The speed of the Earth changes during its journey, too. It moves the fastest **(30.3 km/s)** when it is closest to the Sun (perihelion), and it moves the most slowly **(29.9 km/s)** when it is furthest from the Sun (aphelion). The time taken for one complete revolution around the Sun is called **a tropical year**, and it corresponds to 365 days 5 hours 48 minutes and 7 seconds. However, practical reasons made people establish a calendar year, too, which lasts 365 days and every fourth year we have **a leap year** which has 366 days.

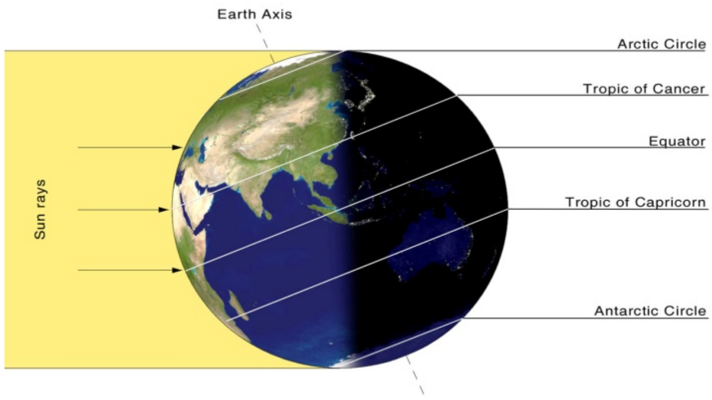
As the axis is tilted **23.5°**, it makes differences mainly between the **length of daylight** and **night** in particular places throughout the year. There are 4 special days during the year which are the result of the axis tilt – summer and winter **solstice**, spring and autumn **equinox.** If the axis were not tilted, there would be no seasons and inequality of daylight during the year.

On the spring (21st March) or autumn equinox (23rd September) the length of daylight and night all over the world is **equal** – 12 hours. It is because neither of the hemispheres is leaned towards the sun. At the Equator the sun is in the **zenith** at noon – directly overhead.



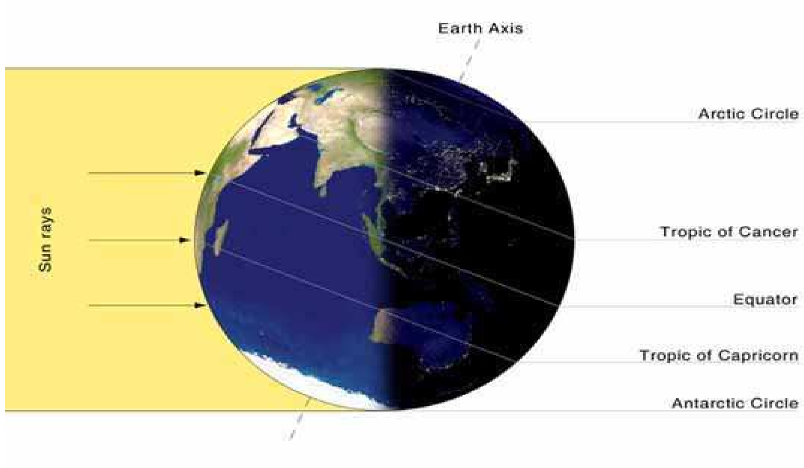
13 Spring/ Autumn equinox.

On the summer solstice (22nd June) the northern hemisphere is leaned most towards the sun. It has the longest daylight of the year and is considered to be the beginning of summer. Nights are the shortest. At the northern polar circle the sun does not set – it is **polar day.** At the Tropic of Cancer the sun is in the **zenith** (overhead). In the southern hemisphere which is leaned from the sun, conditions are reversed – it is the beginning of winter, nights are the longest and there is **polar night** at the southern polar circle.



14 Summer solstice.

On the winter solstice (22nd December) there is the longest daylight in the southern hemisphere which is leaned towards the sun and summer begins. At the Tropic of Capricorn the sun is in the **zenith** (overhead), at the southern polar circle there is **polar day.** In the northern hemisphere there is the beginning of winter, the shortest period of daylight and **polar night** at the northern polar circle.

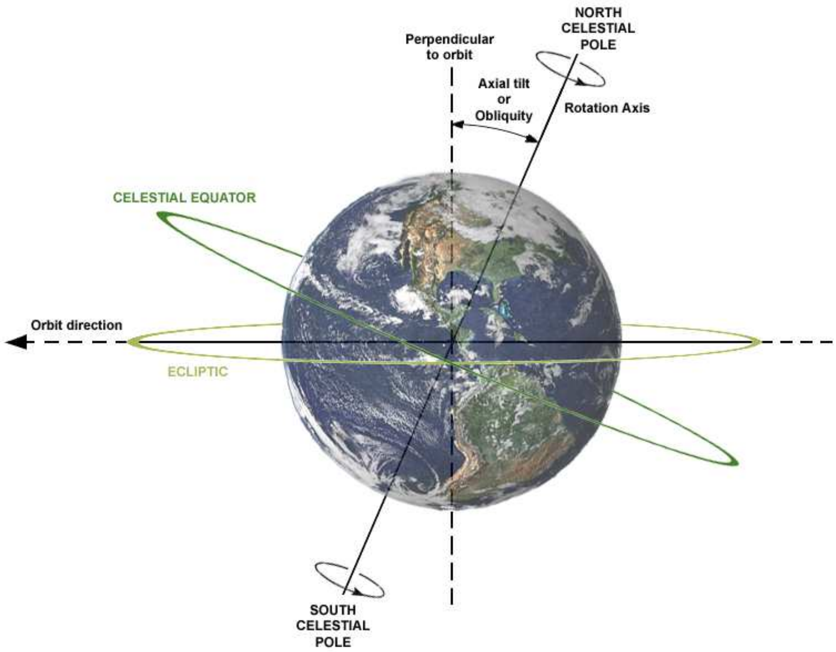


15 Winter solstice.

3.4.2 Earth´s rotation

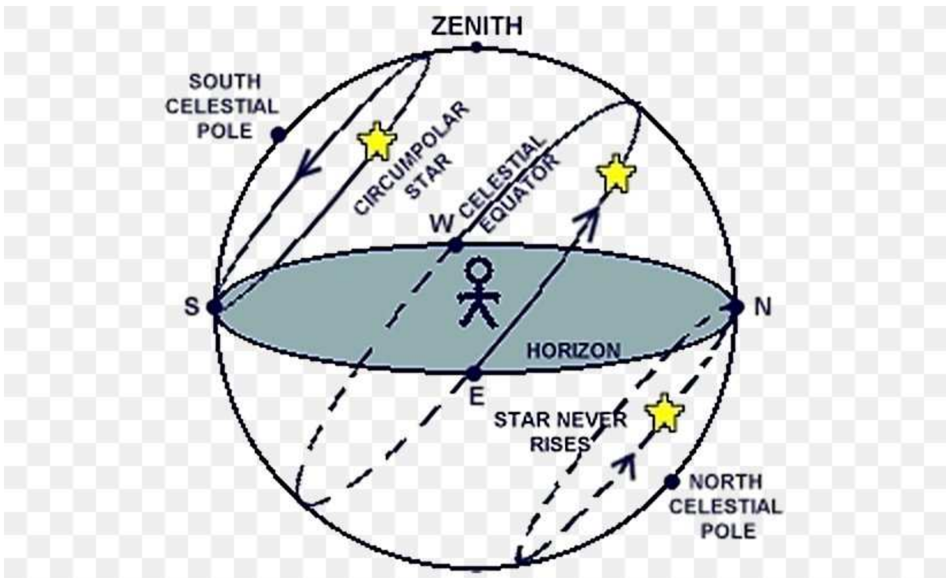
Imagine a line passing through the centre of Earth that goes through both the North Pole and the South Pole. This imaginary line is called an **axis**. Earth spins around its axis, just as a top spins around its spindle. This spinning movement is called Earth's **rotation**. At the same time that the Earth spins on its axis, it also orbits, or revolves around the Sun. This movement is called **revolution**, see the following figure 16.
The Earth rotates on its axis **from the West towards East**. This rotation when observed from the Earth´s surface is perceived as the Sun´**s daily rising in the East and setting in the West.**
One complete turn of the Earth takes **23 hours 56 minutes and 4 seconds** – a period which we call "A stellar day". Practically, a day is 24 hours long. It is a period of time when the Sun reaches twice its highest point in the sky – "A solar day".This difference of nearly 4 minutes is caused by the fact, that while the Earth rotates on its axis, at the same time it travels around the Sun.

At the equator, the Earth rotates at a speed of about 1,700 km per hour, but at the poles the movement speed is nearly nothing.



Celestial Sphere: A huge imaginary sphere around the Earth to which the stars appear to be attached.

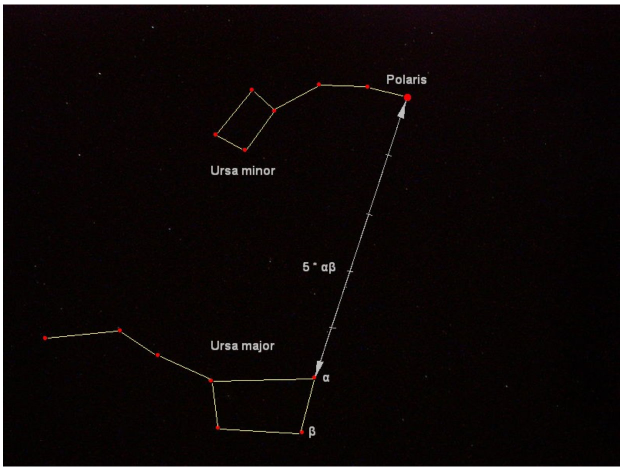
Celestial sphere is the apparent surface of the heavens, on which the stars seem to be fixed. For the purpose of establishing coordinate systems to mark the positions of heavenly bodies, it can be considered a real sphere at an infinite distance from the Earth. The Earth's axis, extended to infinity, touches this sphere at the north and south celestial poles, around which the heavens seem to turn. The plane of the Earth's Equator, extended to infinity, marks the celestial equator.



17 Celestial Sphere.

Celestial Equator: Projection of the Earth's Equator onto the Celestial Sphere.

Polaris, called the North Star or Pole Star, is the brightest star in the constellation of Ursa Minor. It is very close to the north celestial pole, making it the current northern pole star.

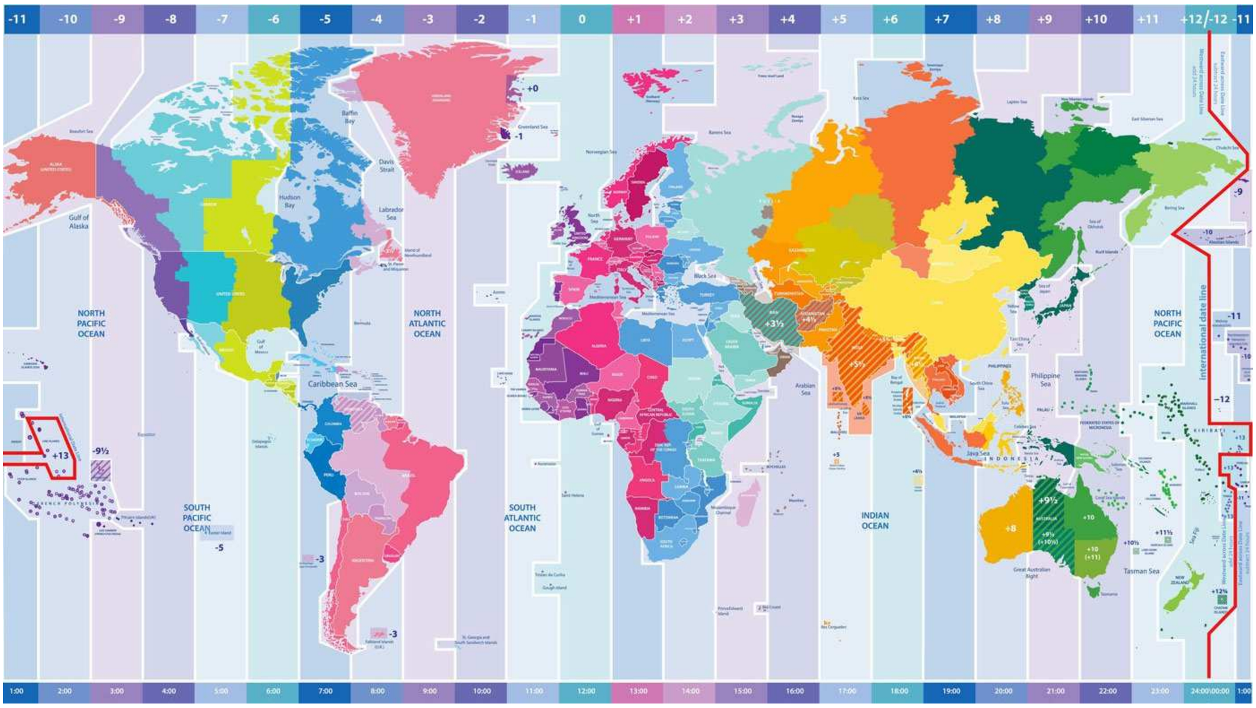


18 Ursa Minor constellation.

19 A photograph of the northern polar star.

3.4.3 Time zones

One complete turn means that the Earth turns **360°**.
Since the day has 24 hours, practical reasons made people divide the Earth into **24 time zones**.
One time zone is **15°** wide (360°: 24 hours = 15° → Width of a time zone.



20 World´s time zones.

The local time is the same in one time zone.

The local time at **0°** Greenwich meridian (**GMT – Greenwich meantime**) has been set as universal time, also known as the universal time coordinated (UTC).
When we travel eastward from the UTC zone, we have to add 1 hour in each time zone. When travelling westward, we have to **shift 1 hour back**.

In Slovakia, we use the time of **15^{th} eastern meridian** that is 1 hour ahead of London time. However, from late March to late October we use **Daylight saving time** (Summer time) in order to reduce the use of electricity for lightening.

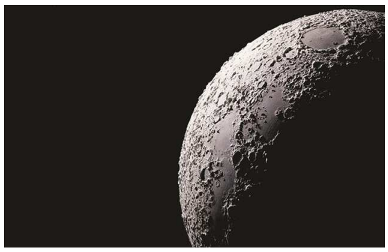
International dateline was established to prevent "date confusion". It is located at 180° meridian and entirely in the ocean. When crossing it **we have to change the date**. When we travel eastward across the date line (i.e. from Russia to the US, we have to **subtract 1 day**. When we travel westward across the date line, we have to **add 1 day**.

Consequences of the Earth´s rotation:

- The alternation of days and nights.
- The places of the same meridian have the same local time.
- The moving air masses are shifted to the right on the Northern Hemisphere, to the left on the Southern Hemisphere.

3.4.4 Moon

A **natural satellite** in astronomy is a smaller body which moves around a larger body. The smaller body is held in orbit by gravitation. The term is used for moons which go around planets, and it is also used for small galaxies which orbit larger galaxies. The Earth has only one moon. The Latin word for the moon is *Luna*, which is why the adjective used to talk about the moon is "lunar".



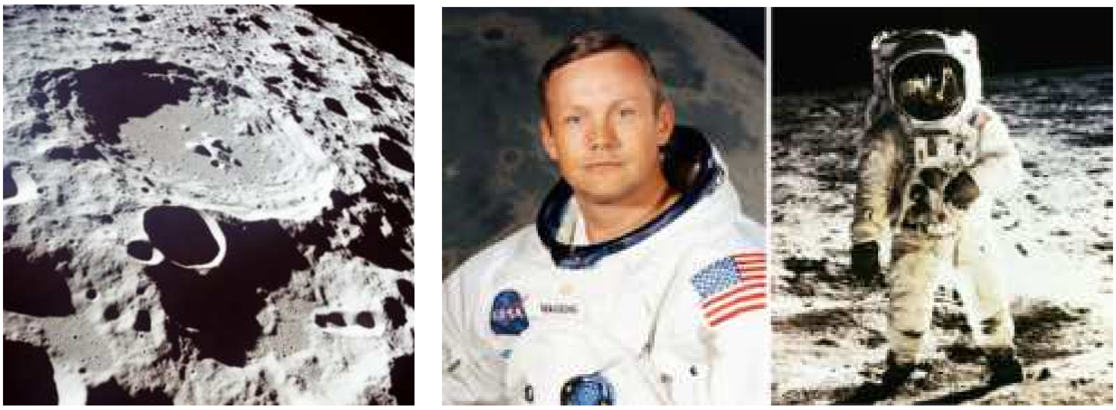
21 Moon.

Moons do not make their own light. We can see the Earth's moon because it acts like a mirror, and reflects the light of the Sun. **The same half of the moon faces toward Earth at all times**, no matter where it moves. But different parts of the moon are lit up by the Sun, so it looks different at different times of the month. This change as seen from Earth is called **the phases of the moon**, or lunar phases.

The average distance of it from the Earth is 384,400 km.
It revolves around the earth in a definite regular path. This path is called moon's orbit. It takes approximately **28 days** to complete one **revolution around the Earth**. It takes approximately **28 days** to complete one **rotation about its axis**. It is about 1/4 the size of the Earth and its weight is about 1/8 that of the earth.

Moon’s Surface

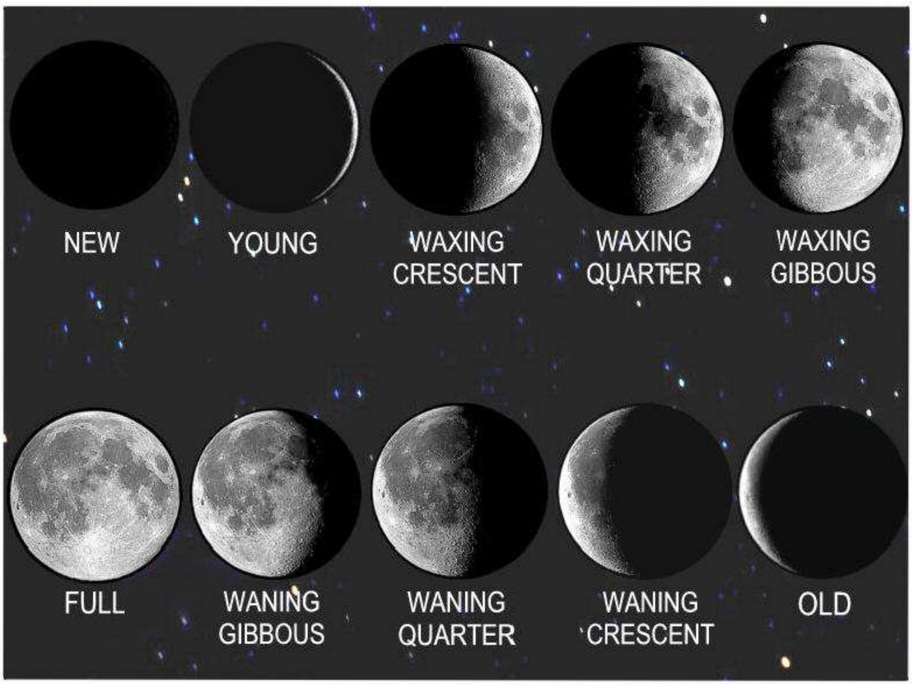
Its surface is dusty and barren. There are many craters of different sizes. It also has a large number of steep and high mountains. Some of these are as high as the highest mountains on the Earth. The gravity on its surface is much smaller, one-sixth that on the surface of the Earth. On it, the days are extremely hot and nights are extremely cold. It has no atmosphere. We can’t hear any sound on it.

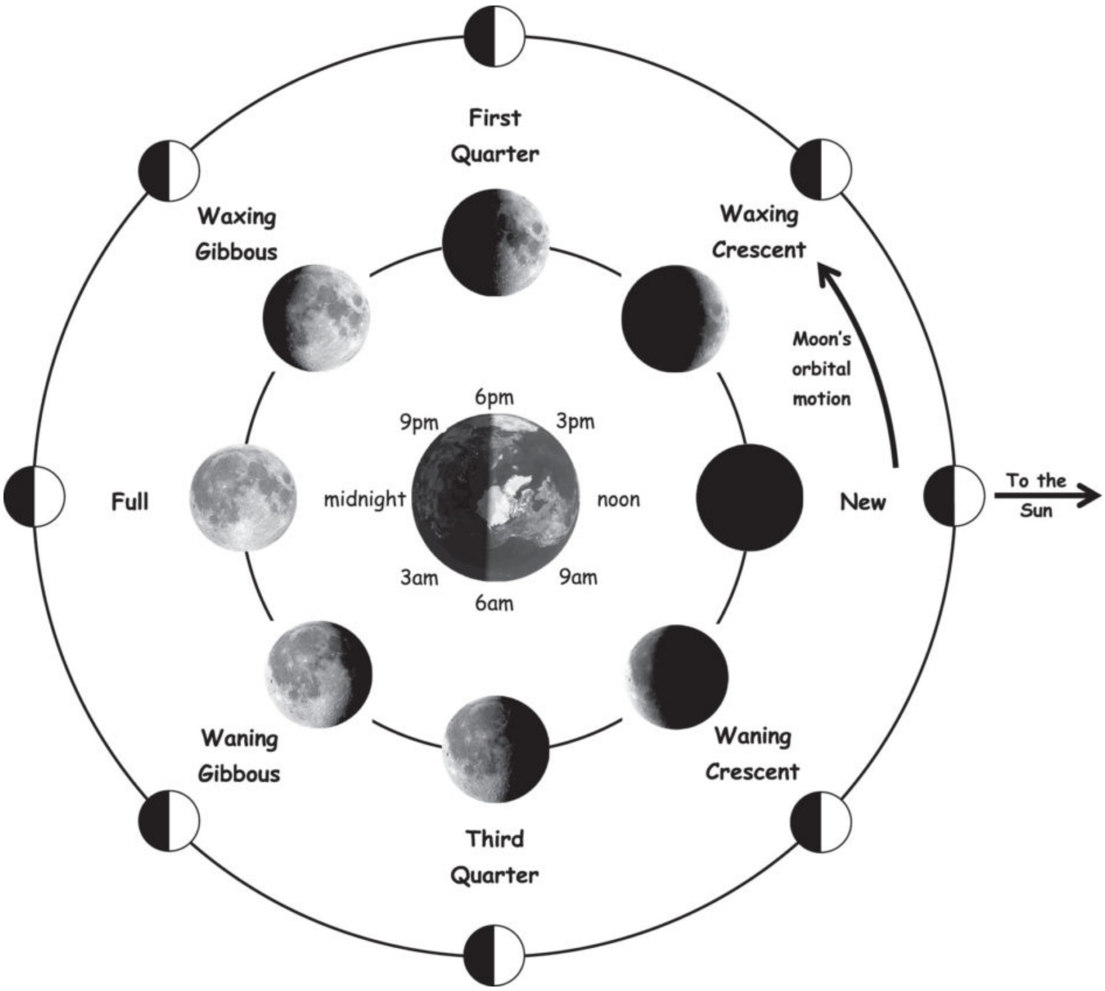


22 On July 21, 1969, the American astronaut Neil Armstrong landed on it for the first time. He was followed by Edwin Aldrin.

Moon’s Phases

The different sizes of the moon we see as it **waxes** and **wanes** are called its **phases**.
It does not produce its own light. We see it because the sunlight falling on it is reflected towards us. Also, the Earth revolves around the Sun and the moon revolves around the Earth. As a result of them the moon’s apparent shape and size of the change every day. Due to these reasons, we see moon’s phases in the following pictures:



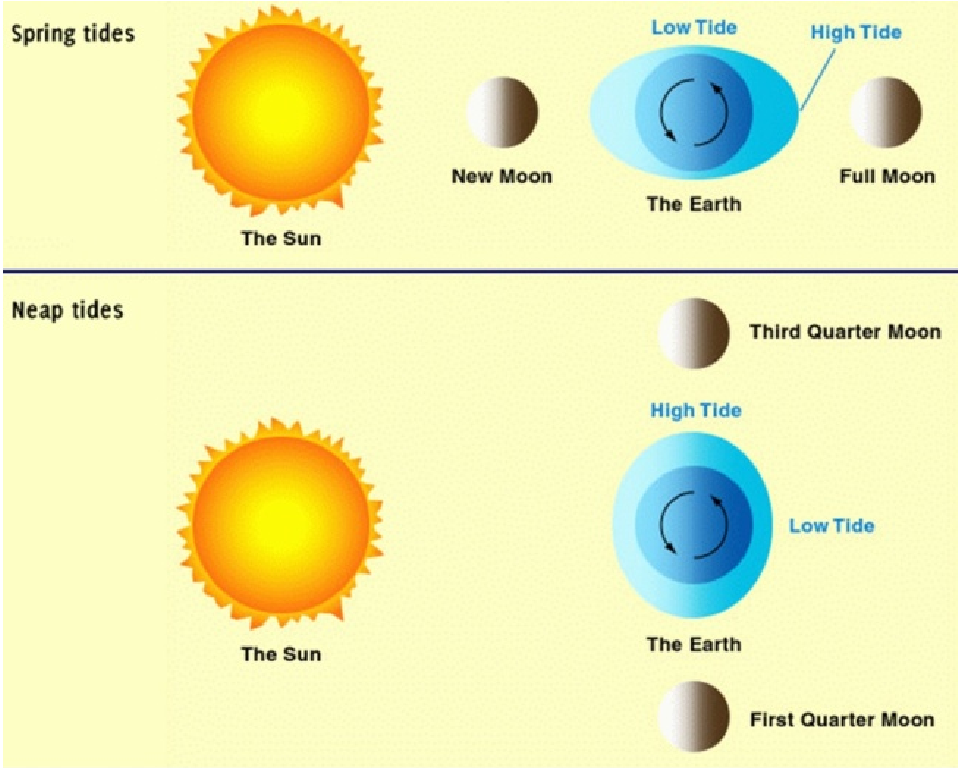


Special Days

- The day on which the whole disc of the moon is visible is known as the **full-moon** day.
- The day on which moon is not visible is known as **new-moon** day.
- On the next day of the new-moon day, a small portion of it is visible, it is called **crescent**.
- The period from one new-moon day to the next is of 29.5 days.

Tides

- Tides result from the moon's and sun's gravitational pull on the Earth's ocean.
- The major cause of tide is the Moon's gravitational force. There are two bulges one on the side of the Earth facing the moon and the other on the opposite side. As Earth's rotates each point on its surface passes through two high tides and low tides and low tides each day.
- The effect of the Sun's gravity on the oceans is only half that of the Moon's. However, when they are aligned (every 14.5 days) their pulls reinforce and create spring tides when the tidal range is the greatest. Thus spring tides occur on full moon day and new moon day.
- When the sun and moon are at right angles to Earth, their pulls offset each other and neap tides result. At this time the tidal range is the minimum.



14 Scheme of spring and neap tides.

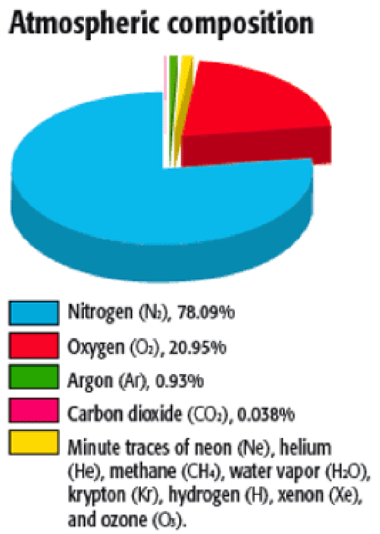
Questions for discussion:

1. What do you think about the origin, the past and the future of the Earth? Support your ideas with 3-4 arguments.
2. Do you think that people will colonize other planets in space? Why yes/ no? Are there any suitable planets with the best living conditions for humans?
3. Choose 2 planets in the Solar System and compare them. Do you know any places in Slovakia with not enough sunlight?
4. Do all places on the Earth have enough sun light? Why yes/ no? Give some examples. How can we use sunlight more efficiently?
5. What are the consequences of the Earth´s rotation? What is the direction of the Earth´s rotation? What would happen if the Earth rotated in the opposite direction? How would it affect life at your location?
6. What would happen if the Earth rotated different speed, faster or slower than it does now?
7. What would life on Earth be like if there was no gravitation?
8. Can we see or feel the Coriolis force? If yes, give some examples.
9. Does the Moon influence our lives? Do Moon phases affect human's life? Are there any special days in the year connected with some moon phases? Give some examples.
10. Why do you think the countries have lost interest in missions to the Moon? The last mission - of Apollo 17 - was in 1972 and the last person to be on the Moon was Eugen Cernan, an astronaut of Slovak origin. There is a famous quote connected with one of the missions to the Moon: “Houston, we have a problem.“ Which one was it? What was the problem they had?

4. ATMOSPHERE

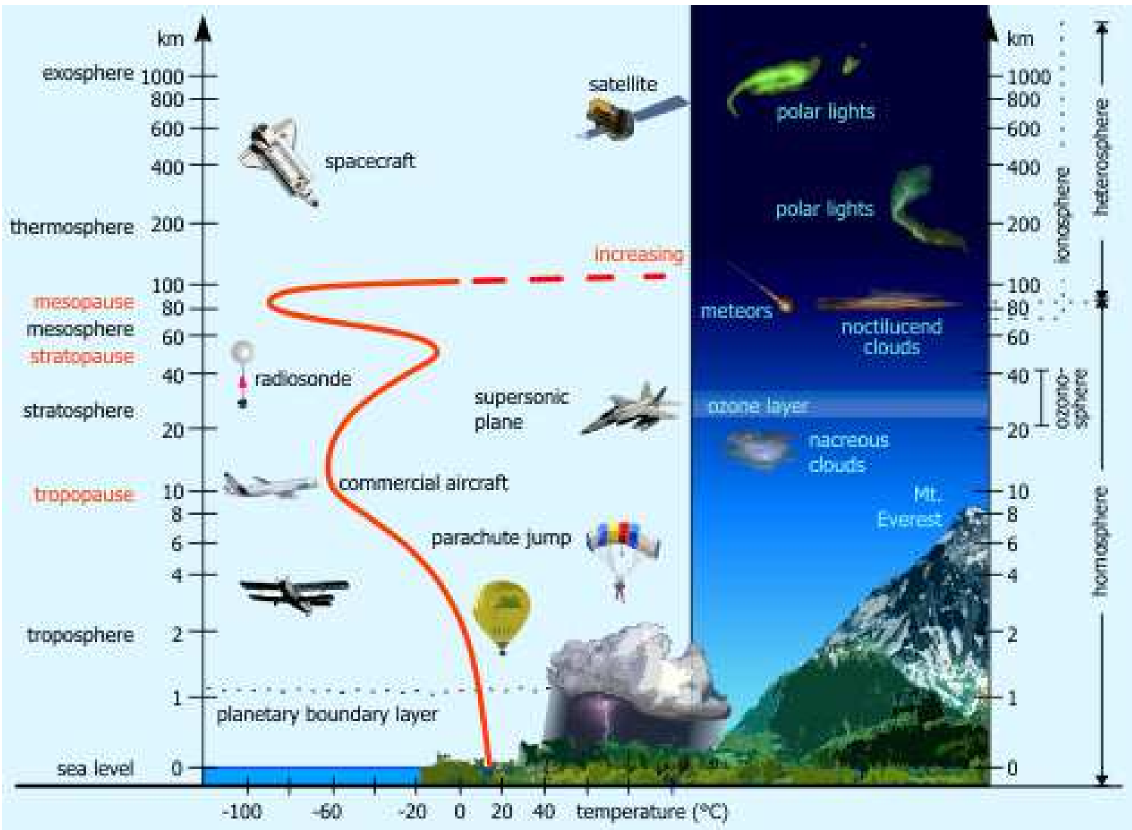
4.1 Composition of the Earth´s atmosphere

Atmosphere refers to the gases surrounding a star or planetary body held in place by gravity. A body is more likely to retain an atmosphere over time if gravity is high and the temperature of the atmosphere is low. The atmospheres of other planets have a different composition.



1. **Gases**: 78% nitrogen (N), 21% oxygen (O_2), 1% Argon (Ar), carbon dioxide (co_2), ozone (O_3), water vapour and other gases.
2. **Liquids:** water drops
3. **Solids**: dust, volcanic ash, soot

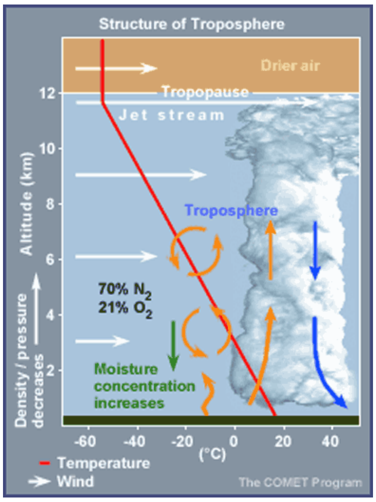
The atmosphere protects the planet and enables life. Most of our atmosphere is located close to Earth's surface, where it is most dense. It has five distinct layers:



1 Spheres of Atmosphere.

Troposphere

The layer of the atmosphere closest to the Earth is the troposphere. It is the layer where our day-to-day **weather takes place**. It begins at the surface of the Earth and extends out to about **6 to 20 km**. It's where weather happens and contains the air humans breathe. The bottom one third, that which is closest to us, contains **50% of all atmospheric gasses**. This is the only part of the whole make-up of the atmosphere that is breathable. Thanks to its air being heated from below by the earth's surface which absorbs the sun's heat energy, tropospheric temperatures decrease as you travel up into the layer.



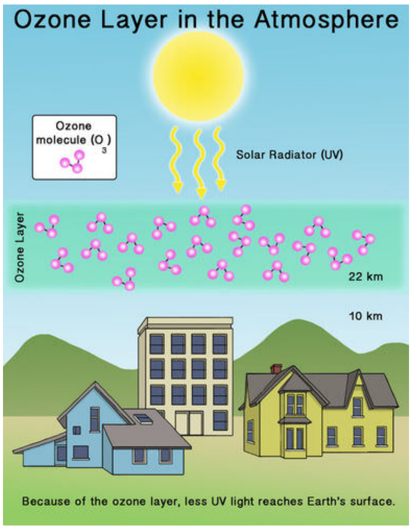
2 Structure of Troposphere.

At its top is a thin layer called the *tropopause*, which is just a buffer between the troposphere and the stratosphere.

Stratosphere

Above the troposphere is the stratosphere, **Ozone's home**, which extends to about **50 km** above the Earth's surface. This layer is where the ozone layer exists and scientists send weather balloons. This is the layer where most **commercial airliners and jets fly** to avoid turbulence in the troposphere. Temperature rises within the stratosphere but still remains well below freezing.

After the stratosphere, there is again a buffer layer, this time called the *stratopause*.



3 Ozone layer.

Mesosphere

From about **50 to 85 km** above the surface of the Earth lies the mesosphere, where the air is especially thin and molecules are great distances apart. Temperatures in the mesosphere reach a low of **-130 degrees Fahrenheit (-90°C).** This layer is difficult to study directly; weather balloons can't reach it, and weather satellites orbit above it. The stratosphere and the mesosphere are known as the middle atmospheres.


4 Mesosphere.

Thermosphere

The thermosphere raises several hundred kilometres above the Earth's surface, from **90 km** up to **500–1,000 km**. Temperature is very much affected by the sun here; it can be 360° Fahrenheit hotter (**500° C**) during the day than at night. Temperature increases with height and can rise to as high as 3,600° Fahrenheit (**2000° C**). Nonetheless, the air would feel cold because the hot molecules are so far apart. This layer is known as the upper atmosphere, and it is where the **auroras** occur (northern and southern lights).

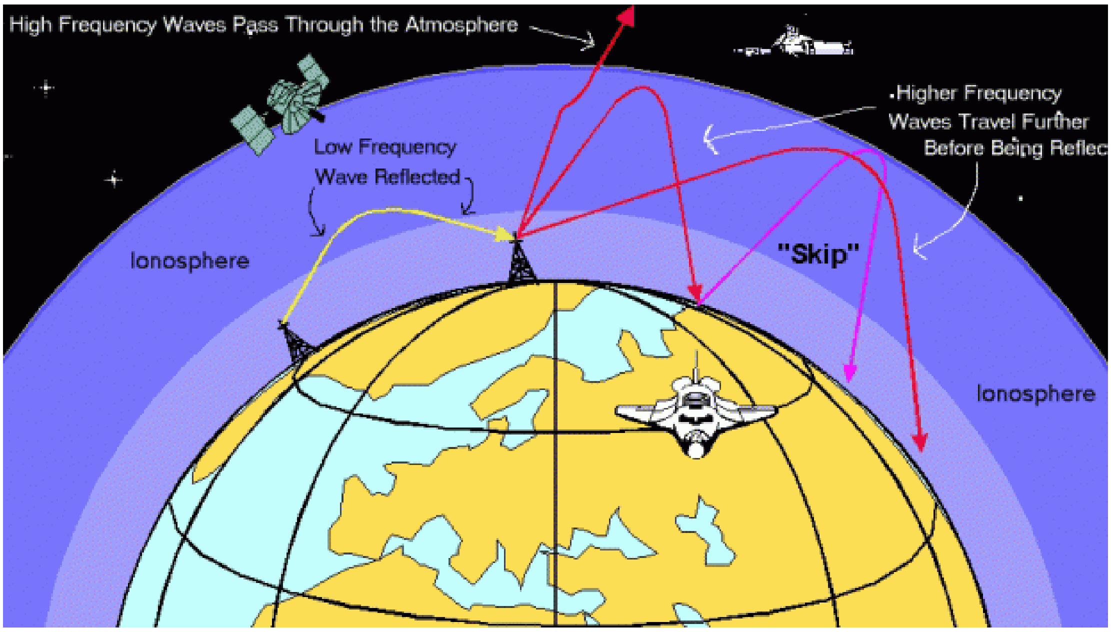
Exosphere

The exosphere is the layer where **Atmosphere and Outer space meet**. Some **10,000 km** above the earth is the exosphere -- the atmosphere's outer edge. It is where **weather satellites** orbit the earth.

5 Exosphere.

Ionosphere

The ionosphere **isn't its own separate layer** but is actually the name given to the atmosphere from about 60 km to 1,000 km high. (It includes the top-most parts of the mesosphere and all of the thermosphere and exosphere.) Gas atoms drift into space from here. It is called ionosphere because in this part of the atmosphere the sun's radiation is ionized, or pulled apart as it travels earth's magnetic fields to the north and south poles. This pulling apart is seen from earth as **auroras.**



6 Scheme of Ionosphere.

4.2 Heat transfer in the atmosphere

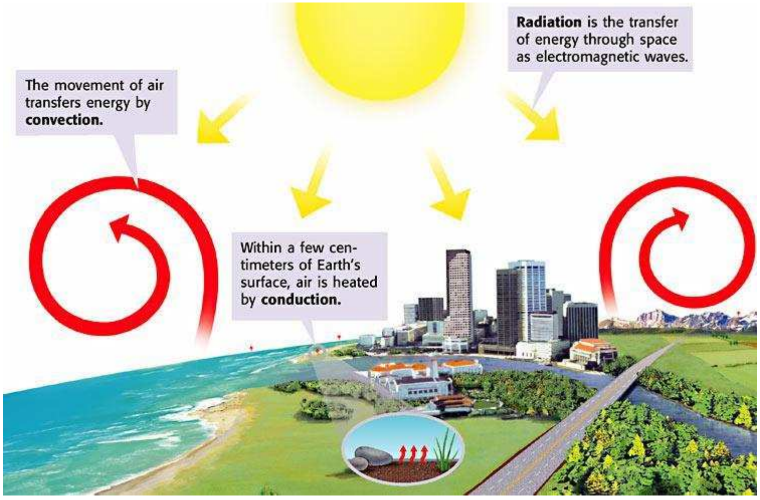
Most of the energy on the Earth comes from the Sun which releases number of different types of radiation. The sun sends to earth 2 kind of radiation, **ultraviolet radiation** (UV) which is invisible short wavelength, **and infrared radiation** (IR) that is invisible with long wavelength. The atmosphere is not heated directly by the sun radiation. Most of the radiation energy is absorbed. Some energy is reflected back into a space. It means that atmosphere is not heated directly by the sun radiation.

The energy coming from the Sun is transferred by **convection**, **conduction** and **radiation** taking place in the atmosphere and the surface of the Earth. The atmosphere and hydrosphere are the two essential parts of the climate system. They both are able to absorb and store thermal energy, so they act as heat sinks. Absorbing thermal (heat) energy and storing it helps regulate the temperature of the Earth.

Radiation – the energy transferred in a medium or space in the form of electromagnetic waves.

Absorption - turns energy into another type of energy, e.g. thermal energy.

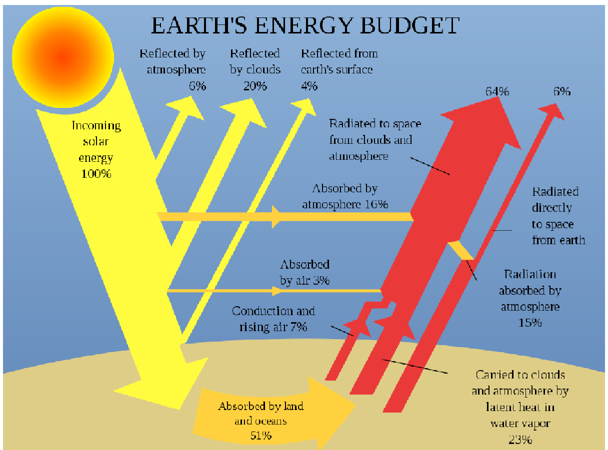
Conduction – the transfer of thermal energy through materials solids and fluids by molecules bumping into each other (by contact). Air molecules come in direct contact with warm earth surface and the thermal energy is transferred to the atmosphere.



7 Scheme of heat transfer.

Convection – the transfer of thermal energy by circulation or movement of molecules (heat) moves throughout a fluid, gas or liquid. Warm air is less dense than cold air and rises and cold air is denser, so it sinks. As cool air sinks, it pushes the warm air up. The cold air is eventually heated by the Earth´s surface and it begins to rise again. In this cycle of warm air rising and cooling causes a circular movement of air called **convection currents**.

8 Earth´s energy budget.



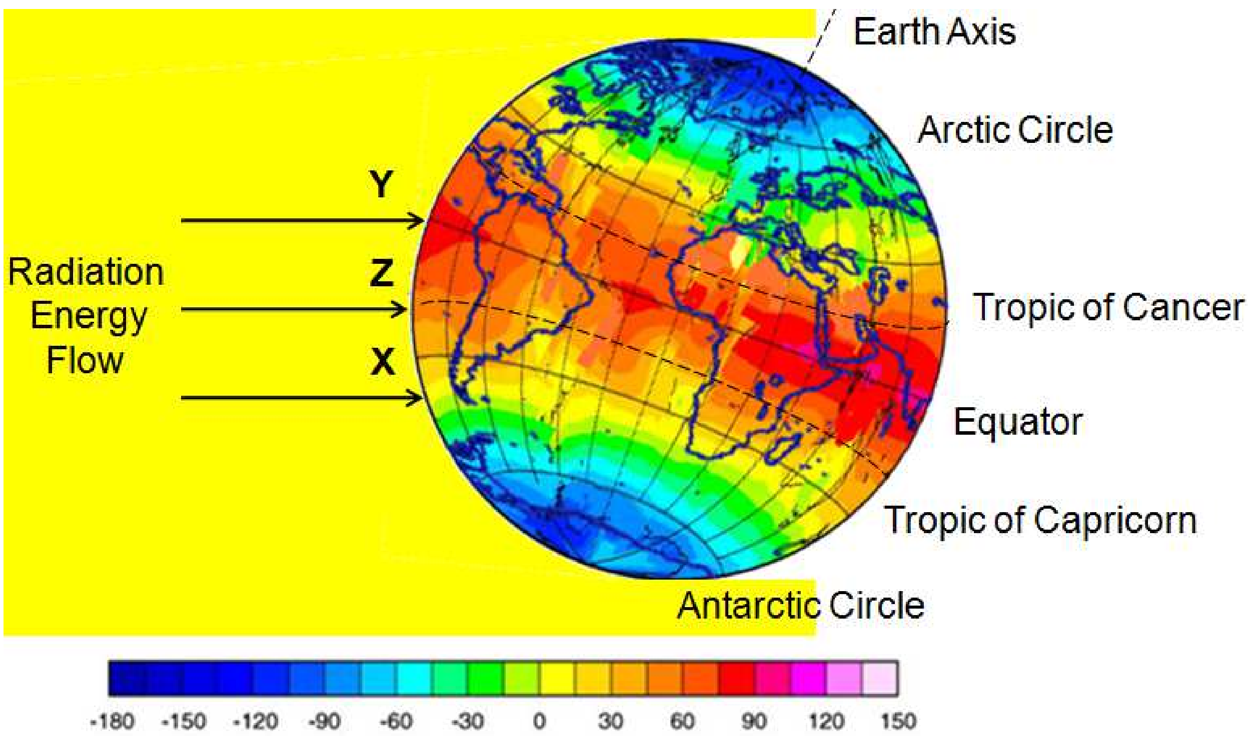
Totally, **30%** solar radiation is reflected and **70%** solar radiation is absorbed.

4.3 Climate control parameters

Weather – the state of the atmosphere from day to day. It includes temperature, atmospheric pressure, clouds, wind, and precipitation.
Meteorology – the scientific study of the atmosphere that focuses on weather processes and forecasting.
Climate – the long-term average of the weather. It is observed over periods of many years, decades, and centuries.
Climatology – the study of the Earth's weather patterns and the systems that cause them. From the ocean oscillations to trade winds, pressure systems that drive temperature, airborne particles that influence local conditions and even the phases of the moon and Earth's wobble all affect the climate. The word "climatology" comes from the Greek. *Klima* means "zone" or "area" and "logia" means "study". This means that climatology is the "study of zones" although in reality it is much more complicated than that.

The factors that affect a region's climate:

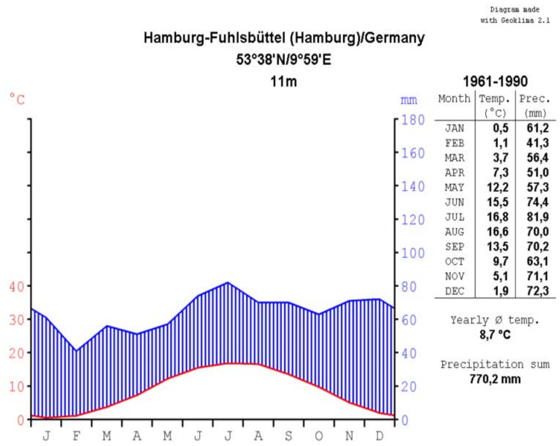
1. Latitude
As latitude increases, the sun shines more obliquely and provides less warming energy. The equator always faces the sun directly, so the climate is warm year-round., with the average day and night temperature hovering between 12.5 and 14.3°C. At the poles, however, winter and summer temperatures show a wider variation. The average temperature in the Arctic varies from 0°C in summer to -40° C in winter, while in the Antarctic, the temperature varies from -28.2° C in summer to -60° C in winter. The Antarctic is colder for two reasons: it's a landmass, and it's at a higher elevation than the Arctic.

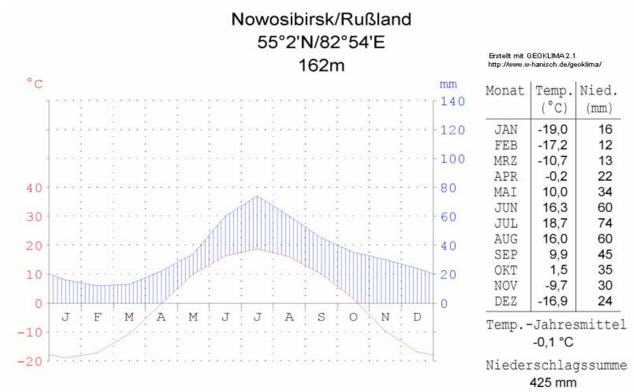


9 Sun radiation and energy flow on the Earth.

2. Proximity to large water bodies, mountains, or other surface features

Land areas near large bodies of water have more constant temperatures between summer and winter and between day and night compared to land areas far away from large bodies of water. Over interior continental regions there are often very large differences in temperature between summer and winter and between day and night.

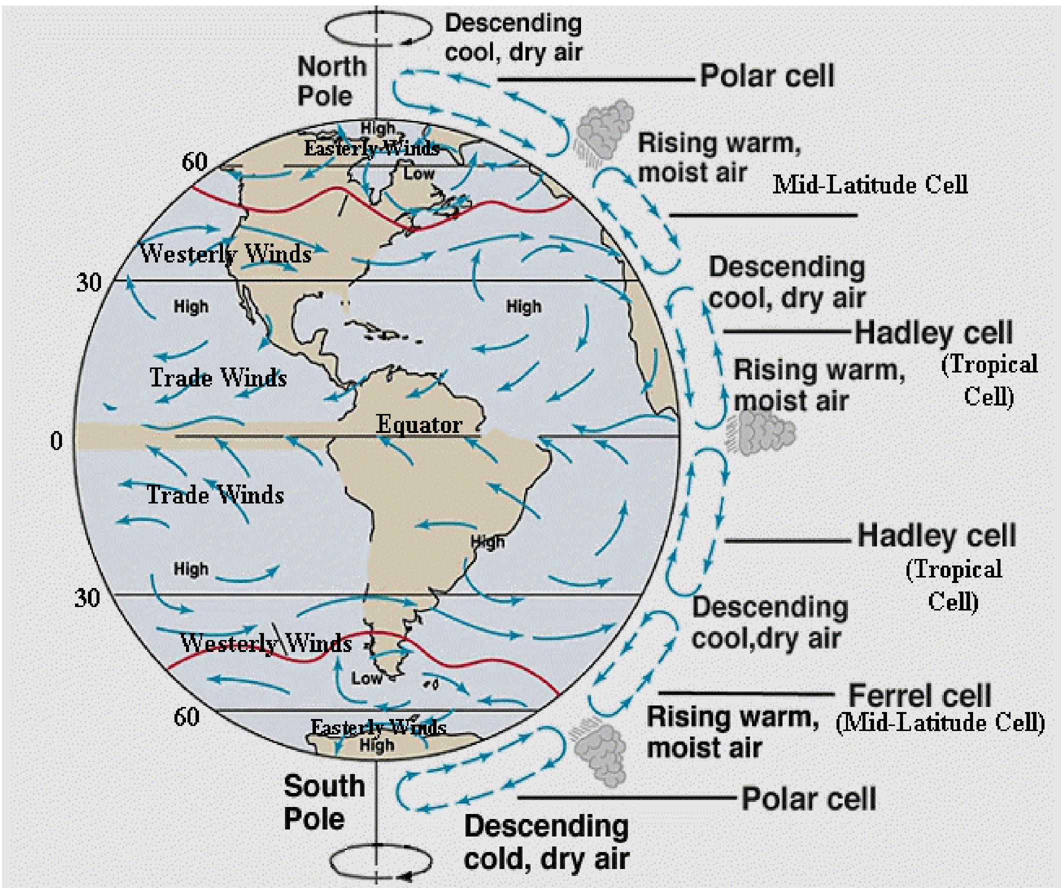




10 HAMBURG and NOVOSIBIRSK have the same latitude, but different temperature amplitudes and different precipitation

3. Long-term atmospheric circulation

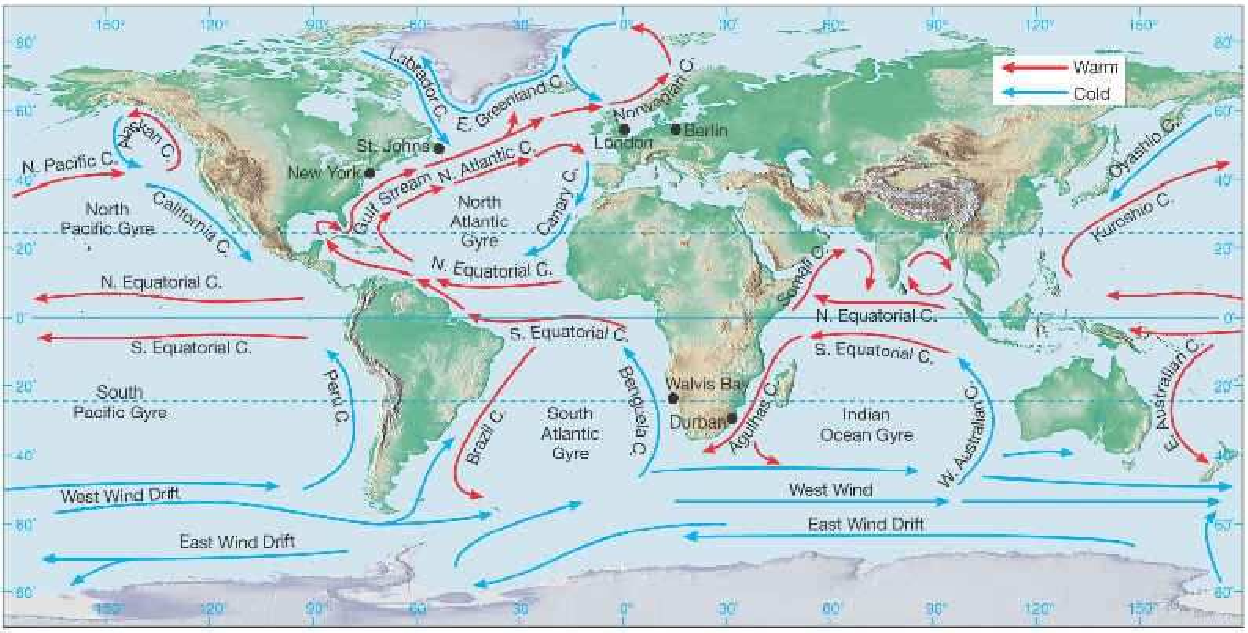
The movement of air across the planet occurs in a specific pattern.



11 Atmospheric air circulation.

4. Ocean currents (Ocean circulation patterns)

Ocean currents that have a northward or southward component, such as the warm Gulf Stream in the North Atlantic or the cold Humboldt Current off South America, effectively exchange heat between low and high latitudes.



12 World´s ocean currents.

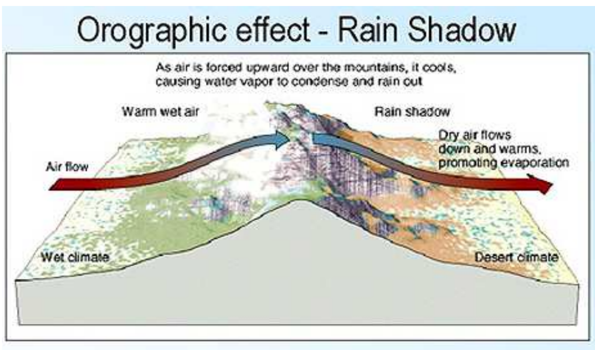
5. Elevation

Climates become cooler and the cold season lasts longer as elevation above sea level rises. As higher as you are, the temperature increases on average **0.6°C** each 100m height.

13 Ice cap on Mount Kilimanjaro, Tanzania.

6. Earth´s surface character

Variations in the slope of the ground affects the absorbed sunlight, exposure to winds, and run off, there are also different types of vegetation are favoured on the opposing slopes of a mountain. For mountains in the middle latitudes of the Northern Hemisphere, southward facing slopes face toward the midday sun, which results in more direct sunshine received and more heating, compared with northward facing slopes, which face away from the midday sun and remain cooler.



14 Scheme of relief rainfall.

7. Anthropogenic influences

Agriculture in places where forests are replaced with crops, less vegetation cover means the surface has less moisture available for evaporation. As a result, it experiences higher temperatures than a forested region. However, the opposite effect will be experienced when Urban areas become "heat islands", i.e., warmer than the surrounding countryside for two main reasons: The asphalt, bricks, roofing materials, etc. of which modern cities are constructed better absorb solar radiation than soils and vegetation and human activities (power generation, transportation, etc.) generate heat, which warms cities.

15 Brazilian rain forest lost.

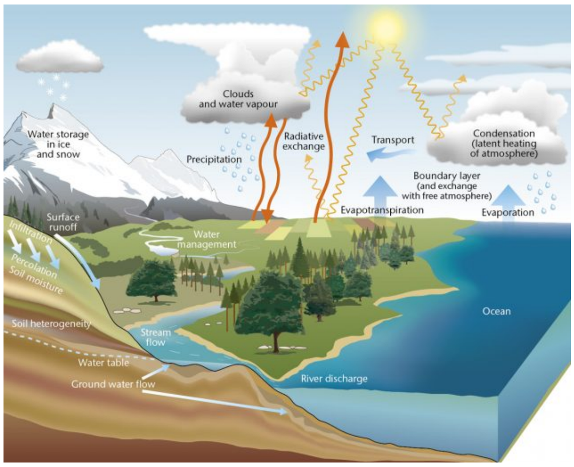
16 Palm oil plantations in Indonesia.

4.3 Weather determining factors

Weather is simply the current state of the atmosphere at a specific location at any given point in time. Weather can change very rapidly at times, varying hour to hour or even minute to minute. This is different than climate, which refers to the long-term average of the daily weather for that location. There are five main factors that determine the state and condition of the atmosphere and, therefore, influence and determine the weather:

1. **Temperature**
2. **Atmospheric pressure**
3. **Humidity**
4. **Cloudiness**
5. **Wind**

These factors can cause different properties in sections of the atmosphere or air masses. We often might think of the atmosphere as a large ball of air that encircles the Earth. While that is true, it is broken up into distinct sections with different physical properties. These properties are determined by the five factors just mentioned, and the differences in the properties between air masses are what cause the changes in our weather.



17 Weather determining factors.

4.3.1 Temperature

Temperature is the amount of heat contained in an object, in this case, the air. The amount of heat in the air determines the speed of the molecules in the air. The more heat, the faster the molecules move, raising the temperature. The heat in the atmosphere comes from the Sun and varies at different levels in the atmosphere. The layers of the atmosphere are determined generally by their temperature. Near the surface of the Earth, the temperature is a factor of how much sunlight an area receives, how much is changed into heat at the Earth's surface and how much of that heat is held near the surface by greenhouse gases or cloud cover. The higher the elevation above the ground, the cooler the air is. Temperature is measured using a thermometer in degrees **Fahrenheit (°F)** or **Celsius (°C).**

$$°C = \frac{°F - 32}{1.8000}$$

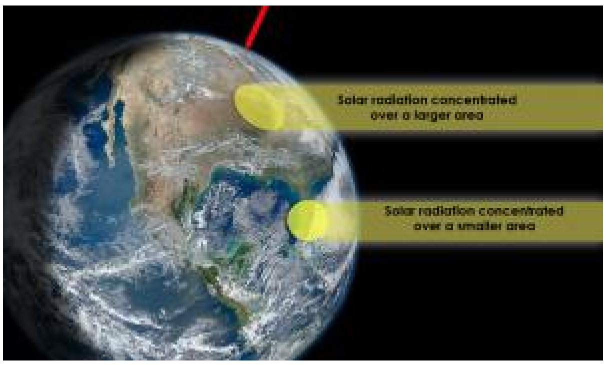
Absolute Zero	-459.67°F	-273.15°C
Parity	-40°F	-40°C
Zero	0°F	-17.78°C
Freezing point	32°F	0°C
Body Temperature	98.6°F	37°C

Isotherm - line drawn on a map or chart joining points with the same temperature.

Air temperature depends on **the angle of sun beams**, **elevation**, **a kind of the surface** (e.g. asphalt absorbs almost all solar energy and heats intensively but ice almost all solar energy reflects).

Angle of the solar radiation.

18 Scheme of solar radiation.



The angle of incoming solar radiation influences seasonal temperatures of locations at different latitudes. When the sun's rays strike Earth's surface near the equator, the incoming solar radiation is more direct (nearly perpendicular or closer to a 90˚ angle). Therefore, the solar radiation is concentrated over a smaller surface area, causing warmer temperatures. At higher latitudes, the angle of solar radiation is smaller, causing energy to be spread over a larger area of the surface and cooler temperatures. Because the angle of radiation varies depending on the latitude, surface temperatures on average are warmer at lower latitudes and cooler at higher latitudes (even though higher latitudes have more hours of daylight during the summer months).

Elevation

19 Choč mountain, Slovakia.

Air temperature is also affected by the elevation of a location. Temperature normally decreases as elevation or height increases, making locations at higher elevations colder. For **every 100-meter** increase in elevation, the average temperature decreases by **0.7°C**. Even in areas located near the equator, the temperature at higher elevations is cooler.

Temperature inversion

During an **inversion** episode, temperatures increase with increasing altitude. (Under normal conditions air temperature usually decreases with height.) The warm inversion layer then acts as a cap and stops atmospheric mixing. This is why inversion layers are called stable air masses. Temperature inversions are a result of other weather conditions in an area. They occur most often when a warm, less dense air mass moves over a dense, cold air mass. This can happen for example when the air near the ground rapidly loses its heat on a clear night. In this situation, the ground becomes cooled quickly while the air above it retains the heat the ground was holding during the day. Additionally, temperature inversions occur in some coastal areas because upwelling of cold water can decrease surface air temperature and the cold air mass stays under warmer ones.

20 Inversion on Kubínska Hoľa, Slovakia.

Smog

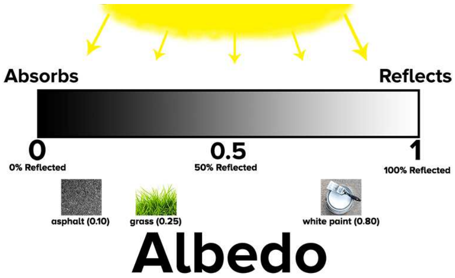
One of the most important things impacted by an inversion layer is **smog**. This is the brownish-gray haze that covers many of the world's largest cities and is a result of dust, auto exhaust, and industrial manufacturing. Smog is impacted by the inversion layer because it is in essence, capped when the warm air mass moves over an area. This happens because the warmer air layer sits over a city and prevents the normal mixing of cooler, denser air. The air instead becomes still and over time the lack of mixing causes pollutants to become trapped under the inversion, developing significant amounts of smog. During severe inversions that last over long periods, smog can cover entire metropolitan areas and cause respiratory problems for the inhabitants of those areas.

21 For five days in December 1952, the Great Smog of London smothered the city, wreaking havoc and killing 12,000 people.
A high-pressure weather system had stalled over southern England and caused a temperature inversion, in which a layer of warm air high above the surface trapped the stagnant, cold air at ground level.
The temperature inversion prevented London's sulphurous coal smoke from rising, and with nary a breeze to be found, there was no wind to disperse the soot-laden smog. The noxious, 30-mile-wide air mass, teeming with acrid sulphur particles, reeked like rotten eggs—and it was getting every day.

Albedo

Albedo can be defined as a way of quantifying how much radiation is reflected from the surface. It is a comparison between the reflection radiation from the surface to the amount of radiation that hits it. This term also refers to the quantity of radiation generated by electromagnetic rays which consequently reflects away.

Albedo is measured on a scale of **0-1**. A **0** means that the surface of a material absorbs all of the sunlight that hits it. A **1** means that a material reflects all of the light energy that hits it. In other words, a 1 on the albedo scale means 100% reflection. A 0 means no reflection.



Fresh asphalt, for example, has an albedo of around 0.05, which means that only 5% of the light is reflected. The rest, 95%, is absorbed. When a material absorbs solar radiation, some of that light energy is converted into heat energy, and the material warms up. That's why an asphalt parking lot will feel hot if you walk across it on a sunny day.

In general, lighter-coloured materials reflect more sunlight than darker colours and therefore have a higher albedo and that is why darker materials feel hotter than lighter ones when both are exposed to sunlight for a period of time.

4.3.2 Atmospheric pressure

Atmospheric or air pressure is the force per unit of area exerted on the Earth's surface by the weight of the air above the surface. The force exerted by an air mass is created by the molecules that make it up and their size, motion, and number present in the air. These factors are important because they determine the temperature and density of the air and thus its pressure. The number of air molecules above a surface determines air pressure. As the number of molecules increases, they exert more pressure on a surface and the total atmospheric pressure increases. By contrast, if the number of molecules decreases, so too does the air pressure.

Air pressure is greater at the sea level and decreases with increasing altitude.

Pressure measures force per unit area, with SI units of Pascals

(1 Pascal = 1 Newton per square metre, 1 N/m^2).

The unit of measurement:

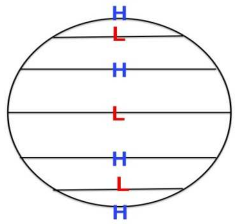
Standard atmosphere is defined as 1013.27 hPa.

Meteorological reports typically state atmospheric pressure in millibars.

Pressure measurement device is called **barometer**.

22 Barometer.

1. Low-pressure belt in equatorial areas.
2. High pressure belt in subtropical areas
3. Variable pressure in middle latitudes
4. High-pressure belt in polar areas.

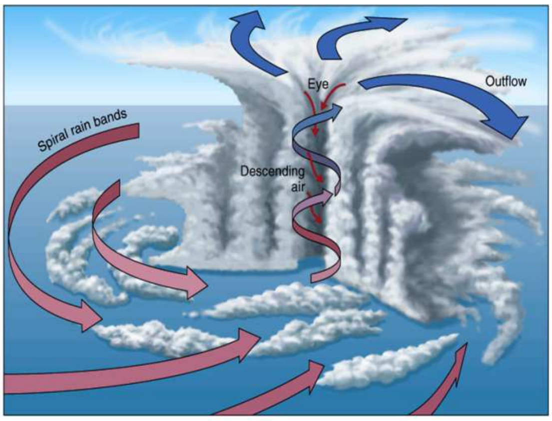


Low pressure system - Cyclone

A **cyclone** is a low pressure system of the atmosphere in which air pressure has dropped below the standard (normal) atmospheric pressure (1013.27 hPa) and winds rotate inward in a counter-clockwise direction in the northern hemisphere and clockwise direction in the southern hemisphere.

Tropical cyclones, which develop over tropical oceans, are commonly characterized by intense low-pressure system, high wind speeds, and storm surges.
Tropical cyclones are known by many names depending on their geographical location, but the following English terms are commonly used in three major cyclone zones:

Atlantic coasts of North America and Europe: **Hurricane**
Pacific coasts of East Asia and Pacific Islands: **Typhoon**
Indian Ocean coasts of South Asia and Australia: **Cyclone**

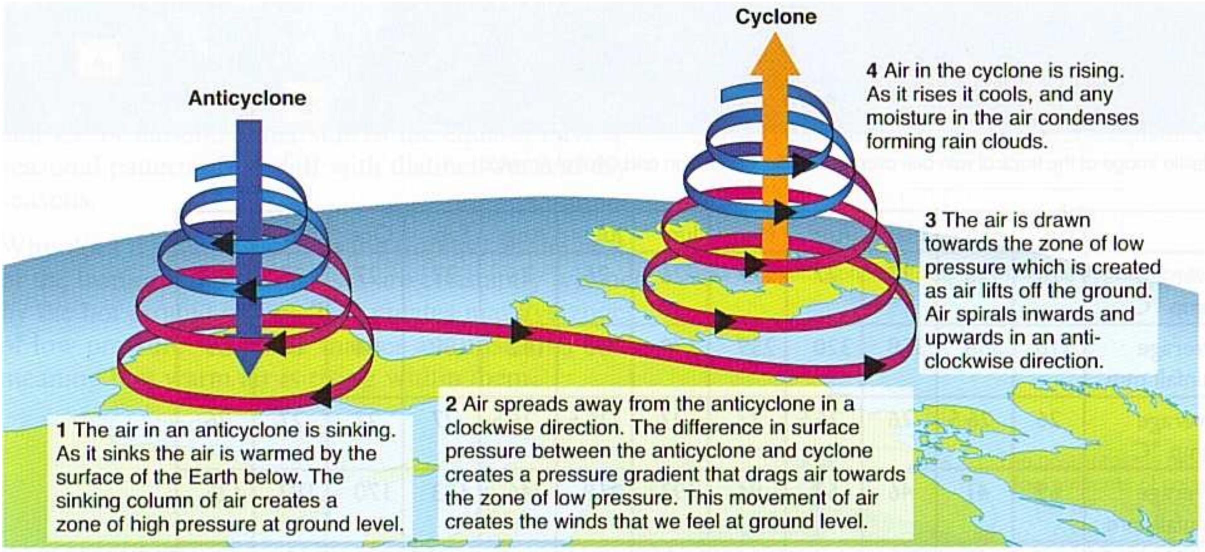


23 Cyclone.

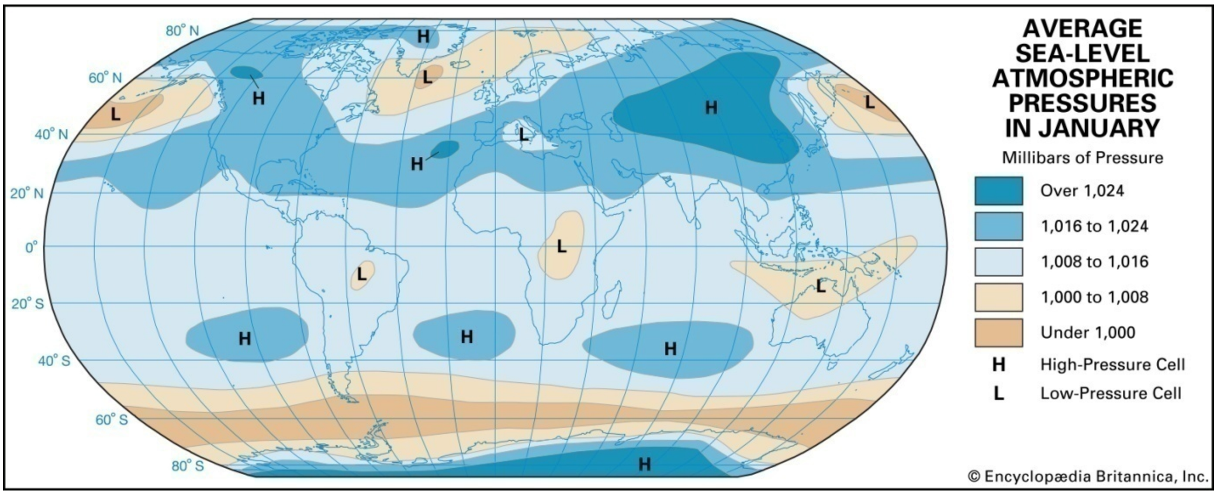
High pressure system - Anticyclone

An **anticyclone** is an area of high pressure which brings long periods of settled weather, dry and bright conditions. Warm air falls, clouds do not form because as the air sinks it warms, meaning it can hold more water.
In summer, high pressure usually results in clear skies, gentle breezes and fine weather. In cold conditions, anticyclones may also bring fog and mist. This is because the cold forces moisture in the air to condense at low altitudes.
In winter, high pressure leads to clear skies and colder conditions. The absence of fronts means winds may be very light.

23 Anticyclone.



24 Atmospheric pressure in the world.



4.3.3 Humidity

Humidity **says the amount of water vapour in the air.**
It is the most variable characteristic of the atmosphere and constitutes a major factor in climate and weather. Atmospheric water vapour is an important factor in weather for several reasons. It regulates air **temperature** by absorbing thermal radiation both from the Sun and the Earth. Moreover, the higher the vapour content of the atmosphere, the more latent energy is available for the generation of storms. In addition, water vapour is the ultimate source of all forms of **condensation** and precipitation.
Water vapour enters the atmosphere primarily by the **evaporation** of water from the Earth's surface, both land and sea. The water-vapour content of the atmosphere varies from place to place and from time to time because the humidity capacity of air is determined by temperature.

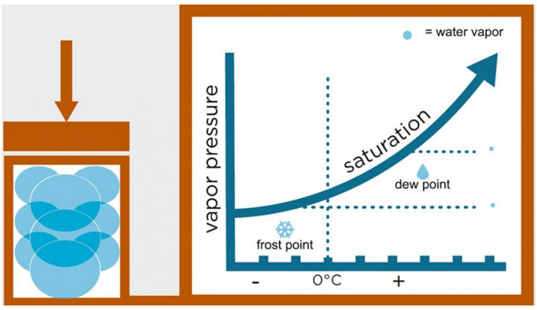
Relative humidity describes the water-vapour content of the air. It is expressed as a percentage, indicates a present state of absolute humidity relative to a maximum humidity given the same temperature.

Saturated air, for example, has a relative humidity of 100 % (e.g. fog). expressed as a percentage, indicates a present state of absolute humidity relative to a maximum humidity given the same temperature.

Absolute humidity is the measure of water vapour or moisture in the air, regardless of temperature. It's expressed as grams of moisture per cubic meter of air (g/m3). The warmer the air is, the more water it can absorb.

Dew point

The **dew point** is the temperature to which air must be cooled to become saturated with water vapour. When further cooled, the airborne water vapour will condense to form liquid water (dew). When air cools to its dew point through contact with a surface that is colder than the air, water will condense on the surface. When the temperature is below the freezing point of water, the dew point is called the **frost point**, as frost is formed rather than dew. The measurement of the dew point is related to humidity. A higher dew point means there will be more moisture in the air.



Dew

Dew is water in the form of droplets that appears on thin, exposed objects in the morning or evening due to condensation. As the exposed surface cools by radiating its heat, atmospheric moisture condenses at a rate greater than that at which it can evaporate, resulting in the formation of water droplets.

25 Morning dew

When temperatures are low enough, dew takes the form of ice; this form is called **frost**.

Because dew is related to the temperature of surfaces, in late summer it forms most easily on surfaces that are not warmed by conducted heat from deep ground, such as grass, leaves, railings, car roofs, and bridges.

26 Morning frost.

4.3.4 Cloudiness

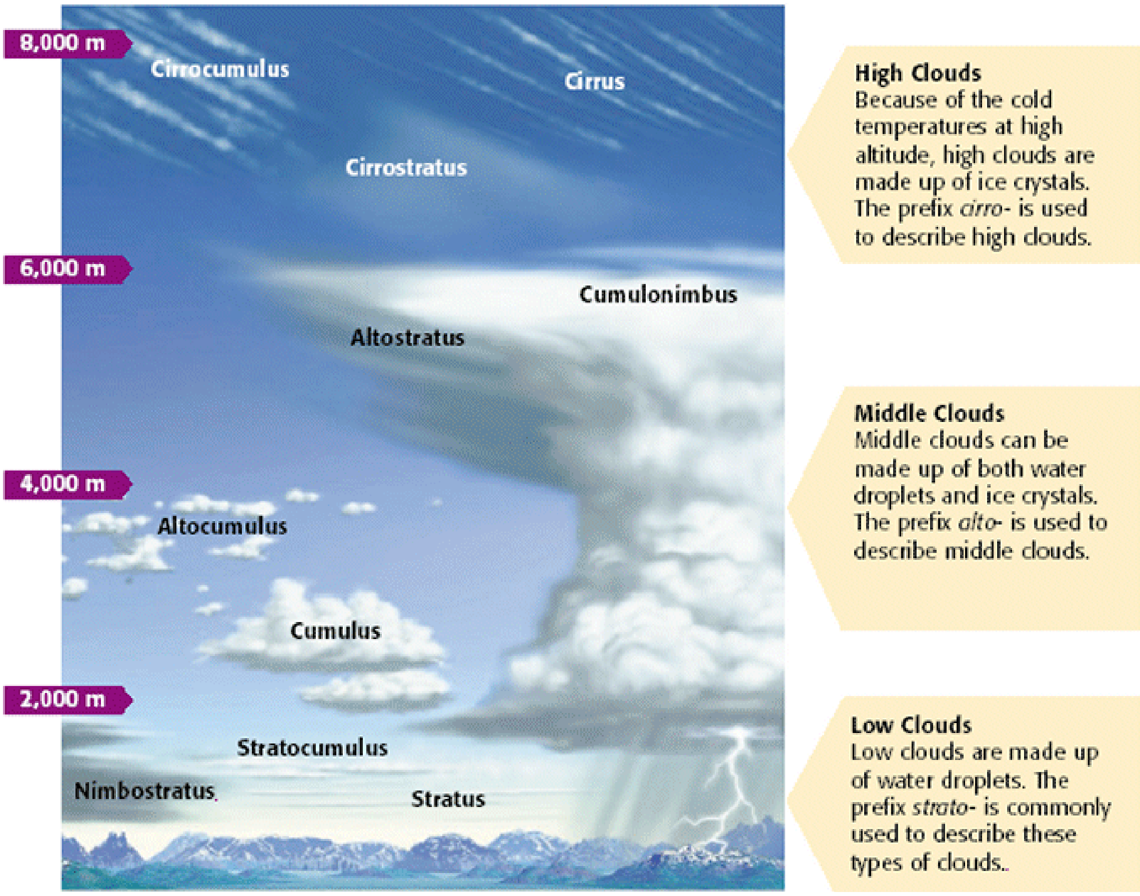
Clouds are visible accumulations of tiny water droplets or ice crystals in the atmosphere. Clouds form when air becomes saturated, or filled, with water vapour. Warm air can hold more water vapour than cold air, so lowering the temperature of an air mass is like squeezing a sponge. Clouds are the visible result of that squeeze of cooler, moist air. Moist air becomes cloudy with only slight cooling. With further cooling, the water or ice particles that make up the cloud can grow into bigger particles that fall to Earth as precipitation.

26 Cumulus Humilis.

Precipitation

When water on the Earth's surface is heated by the Sun, it evaporates and turns into water vapour which rises into the air. When the air cools it **condenses** around some dust or other particles in the air, called condensation nuclei. These small droplets then become visible as **clouds**.

Some droplets fall through the cloud and coalesce into raindrops on their way down. As more and more droplets join together, they become too heavy and fall from the cloud as rain. Warm air can hold more moisture than cool air, so when the warmer air is cooled and the moisture condenses, it often rains more heavily.



27 Different types of clouds and the heights they are created.

Clouds reflect radiation

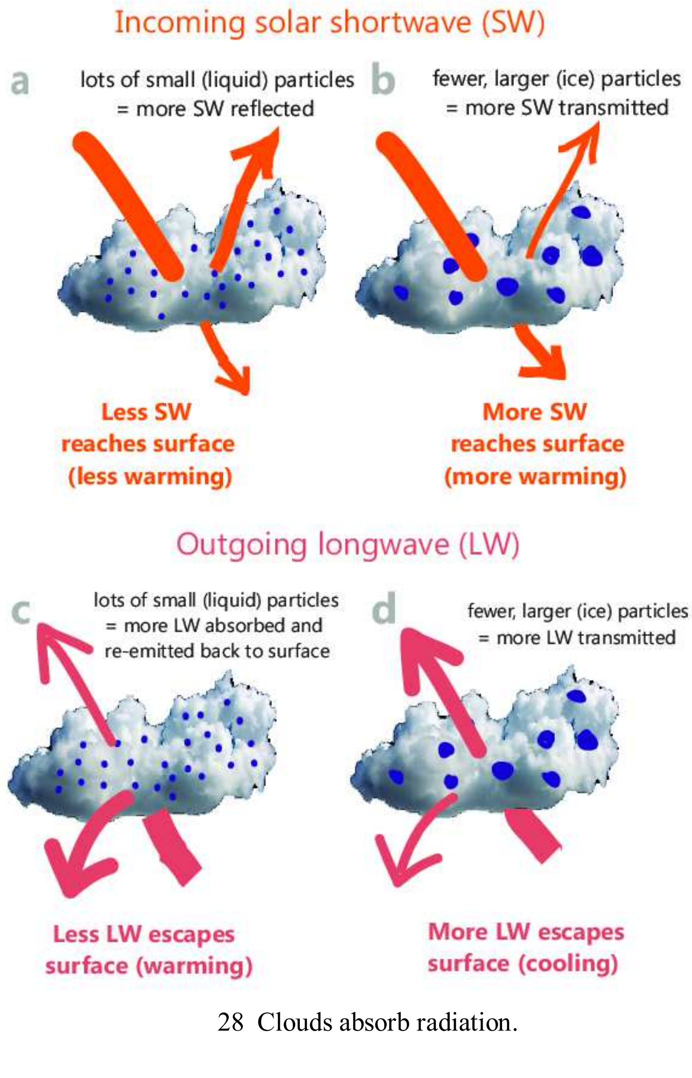
When the sun's energy enters the atmosphere, some of it is reflected off of clouds. This means that high cloud cover can contribute to a cooling effect: more radiation reflected means less heat present in the atmosphere.

But it's not just the presence or absence of clouds that affects temperature on the ground; it's also the duration and type of cloud cover. If it is overcast all day long, it will take longer for the ground to heat up because clouds are blocking incoming solar radiation. On the other hand, consistent cloud cover in a given area can also keep the ground relatively warm.

Even though clouds do reflect some radiation and contribute to overall climate cooling, clouds also trap some heat beneath them.

Clouds absorb radiation

Some of the sun's radiation passes through the clouds and heats up the ground below. The ground radiates that heat back up to the sky. If there is a thick blanket of clouds, often times, some of that heat is absorbed by the cloud layer and keeps the ground insulated. The absorption is due to the **greenhouse effect**, the warming of the ground due to the trapping of solar heat in the atmosphere. There are specific atmospheric gases that contribute significantly to this effect, such as carbon dioxide and water vapour. Clouds are comprised of water vapour, which act as a very strong greenhouse gas. Greenhouse gases cause about 50% of heat to be retained, contributing to warming.



28 Clouds absorb radiation.

4.3.5 Wind

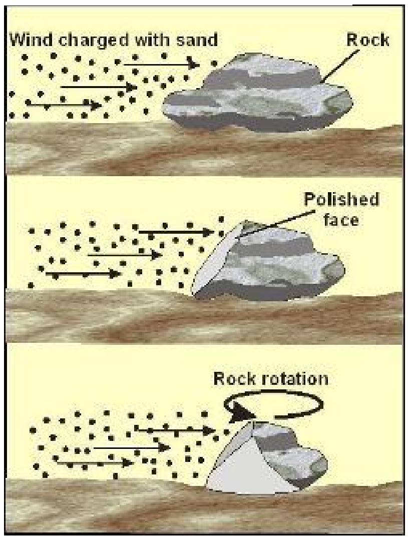
Wind is an important phenomenon that we have all experienced. Winds can range from a light breeze on a hot summer day to tornadoes and hurricanes with speeds of hundreds of kilometres per hour.
The atmosphere composed of air molecules. The air is free to move in every which way unless something is blocking it. For the purpose of our discussion, we define **wind** as the movement of air molecules in the atmosphere. However, it's important to note that more generally wind can be defined as the flow of any gases, not only air.

Wind formation
Air pressure, which you can think of as the amount of force that air molecules exert via their collective weight above a specified area, often differs from one location to another. To draw an analogy, think of a waterfall. The differences in altitudes cause the water to flow downward. Similarly, whenever there is a difference in air pressure over some geographic region, air flows from areas of higher pressure to areas of lower pressure.

Wind erosion

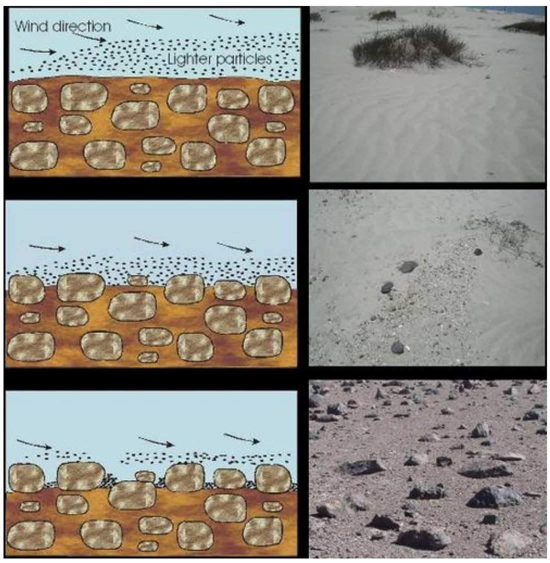
Erosion is defined as the set of natural processes that loosen, remove and transport weathered or unweathered solid material such as soil, sediment, mud, regolith, rock fragments and other particles from the landscape by downhill or downwind displacement. The mediums required to for material displacement can be wind, running water, waves, ice (glaciers), underground water, and gravity.

As erosion moves weathered solid material, it exposes fresh, unaltered rock to weathering. In some places, erosion is increased by human land use.



29,30 Wind erosion schemes.

Wind erosion is referred to as eolian erosion.



Differences in atmospheric pressure will cause the motion of air that can erode surface material when velocities are high enough to move particles. Eolian erosion is more pronounced in dry regions and in areas where there is insufficient rainfall to support vegetation and root systems.

Wind cannot carry as large particles as flowing water, but easily pickups dry particles of soil, sand and dust and carries them away. Wind generally causes erosion by deflation and/or abrasion. Wind breaks are often planted by farmers to reduce wind erosion.

Wind abrasion is the process of erosion produced by the suspended particles that impact on solid objects.

Windblown grains of sand, carried along at high speed, are a very effective tool that can sandblast away rocks by abrasion.

Wind deflation causes the lifting and transport of lighter particles from a dry soil, leaving behind a surface of coarse grained sand and rocks. The removed particles will be transported to another region where they may form sand dunes on a beach or in a desert.

31 Skalný budzogáň rock, Súľovské Vrchy Mountains

32 Tassili n´Ajjer, Sahara, Algeria, wind erosion of soft sandstone layers

33 The 'black' Hamada at Tademayt, Algeria

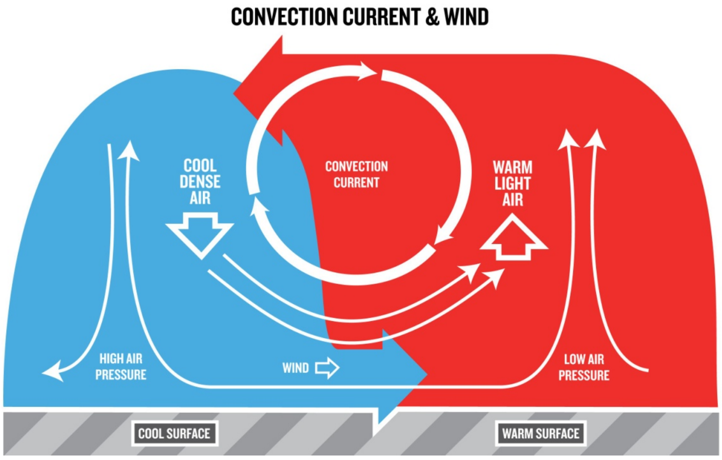
34 Erg Chebbi and the dunes of Merzouga, Morocco

4.4 Global atmospheric circulation

4.4.1 Wind

Wind is the flow of a huge amount of air, usually from a **high-pressure area** to a **low-pressure area.** The sun´s radiation is absorbed differently on the earth´s surface. The earth´s surface is heated differently because of cloud cover, mountains, valleys, water bodies, vegetation and desert lands. As a result of this uneven heating, there are bound to be earth´s surfaces that vary a lot in temperature. Air on surfaces with higher temperature begins to rise. As it rises, it creates low atmospheric pressure. Air on surfaces with cooler temperatures sinks. The sinking creates higher atmospheric pressure.

This behaviour or warm gases or liquids moving upward and being replaced by cooler particles is called **convection**. This brings spatial differences in atmospheric pressure, caused by uneven heating. The energy moving during convection is called **convectional current**.



35 Convection scheme.

Anywhere and each time there are differences in atmospheric (air) pressure, there will be a wind. As air will move from the high-pressure area to the low-pressure area, the wind may even be stronger where the difference in the air pressure is greater.

Winds can range from a light breeze on a hot summer day to tornadoes and hurricanes with speeds of hundreds of kilometres per hour.

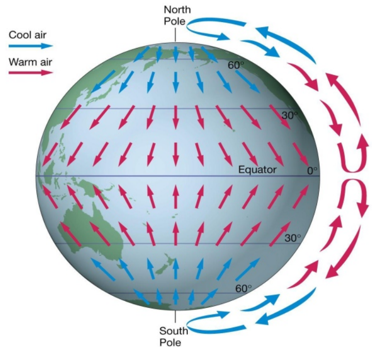
36 Tornado, South Moravia, Czech Republic

4.4.2 Global winds

Global winds are large air masses that are created mainly as a result of the earth´s rotation, the shape of the earth and the sun´s heating power.

1. **The Earth as a non-rotating sphere – Ideal situation**

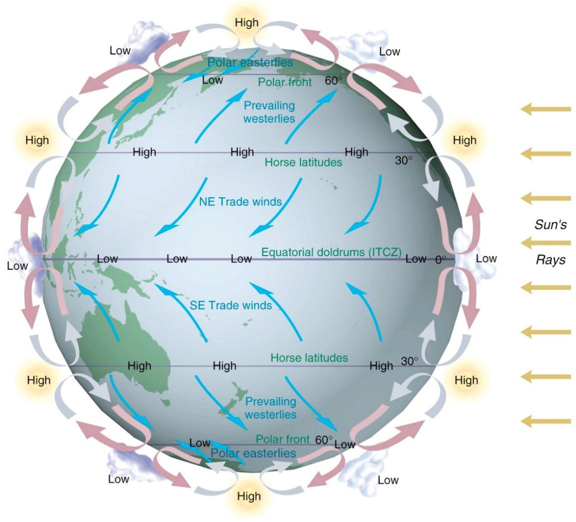
Imagine the Earth as a non-rotating sphere with uniform smooth surface characteristics. Assume that the sun heats the **equatorial regions much more than the polar regions**. In response to this, two huge convection cells develop. "**Single cell**" being either a single cell north or south of the equator. The air warms up at the Equator. It rises and moves towards the Poles. It is cooled and sinks. Cold winds move back to the Equator.



37 Non-rotating sphere scheme.

2. **The earth is a rotating sphere effected by Coriolis force – Real situation**

The Coriolis effect describes the pattern of deflection taken by objects not firmly connected to the ground as they travel long distances around and above the Earth. The Earth rotates faster at the Equator than it does at the poles. The Coriolis effect causes a deflection in global wind patterns. The anticlockwise rotation of the Earth deflects winds to the right in the northern hemisphere and to the left in the southern hemisphere. The Earth's rotation means that we experience an apparent force known as the Coriolis force. This deflects the direction of the wind to the right in the northern hemisphere and to the left in the southern hemisphere. This is why the wind-flow around low and high-pressure systems circulates in opposing directions in each hemisphere. The air´s direction is not straight but deflected because of the Coriolis force:



38 Real situation of global air circulation scheme.

1. **Equatorial area:**
   Air rises at the Equator because it is warm, creates pressure belt. The winds here are called **DOLDRUMS**. It is drawn towards the poles and it is turned towards west at around 30° latitude because of the Coriolis effect. The winds return to the equatorial area and are called **TRADE WINDS**. This circulation is called HADLEY CELL.

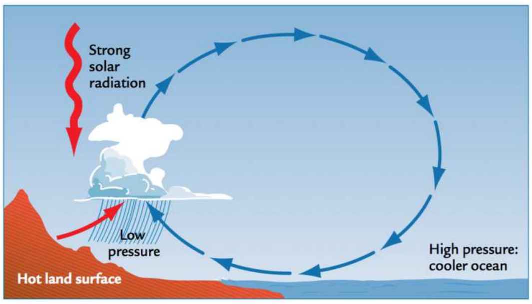
2. **Subtropical areas:**
   These are areas around 30°N and 30°S. The air from the equatorial areas sinks here, spirals outward and creates high-pressure belts. It is sunny and hot – most deserts are in these latitudes.

3. **Middle latitudes (30°- 60°):**
   Some winds from subtropical high-pressure belt moves towards middle latitudes. They are deflected because of the Coriolis effect. They blow from the west – we call them **WESTERLIES**. Middle latitudes lie between warm and cold regions and that is why the pressure here is variable. This circulation is called FERREL CELL.

4. **Polar areas (60°- 90°):**
   Winds are cold, they sink and create high-pressure belts. They blow from the east and we call them **POLAR EASTERLIES**. When they meet warmer middle latitude winds they create polar front. This circulation is called POLAR CELL.

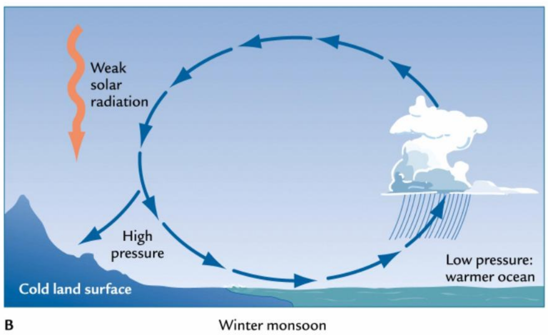
5. **Monsoons:**
   They occur in areas with big temperature differences of land and sea, mainly in East and South-East Asia.

   Summer monsoon:
   It is a sea breeze in a bigger scale, the lands warms up quickly, the warm air rises and cooler and wet marine air blows it is place. It brings rains and floods. The summer monsoon blows from the sea towards the land and it brings wet, rainy weather.



39 Summer monsoon scheme.

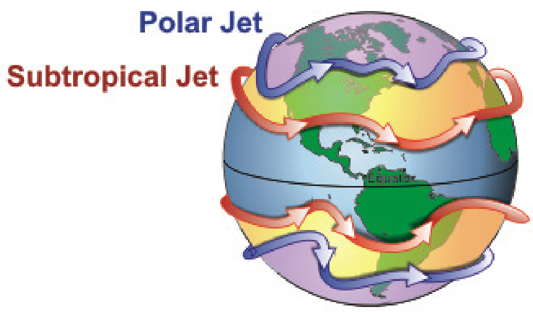
   Winter monsoon:
   It is a land breeze in a bigger scale, the lands cools down quickly, the air is cold and dry. The air above the ocean is warmer, it rises. Winter monsoon blows from the land towards the sea, it brings cold and dry weather.



39 Winter monsoon scheme.

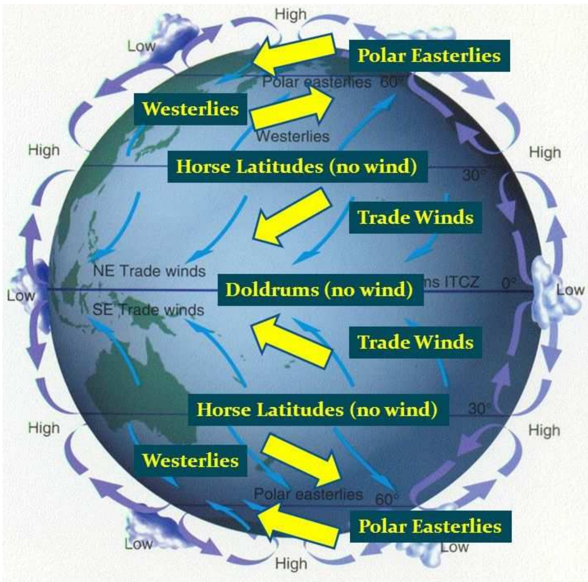
6. Jet streams

Jet streams will form at the approximate boundaries between the cells we've just discussed. So we should have a subtropical jet stream as well as a midlatitude jet stream. Since the locations of the midlatitude and subtropical jet streams are close to the cell boundaries, the jets will migrate with the seasons, like the doldrums.



40 Jet streams circulation.

WINDS:



41 Global winds scheme.

Doldrums

This is a very low-pressure area along the equator where prevailing winds are calmest. This low-pressure area is caused by the constant heating of the sun. Sailors noticed the stillness of the rising (and not blowing) air near the equator and gave the region the depressing name "doldrums." The doldrums, usually located between 5° north and 5° south of the equator. The doldrums are also called the intertropical convergence zone (ITCZ).

The trade winds converge in the region of the ITCZ, producing convectional storms that produce some of the world's heaviest precipitation regions.

Horse Latitudes

Between about 30° to 35° north and 30° to 35° south of the equator lays the region known as the horse latitudes or the subtropical high. This region of subsiding dry air and high pressure results in weak winds. Tradition states that sailors gave the region of the subtropical high the name "horse latitudes" because ships relying on wind power stalled; fearful of running out of food and water, sailors threw their horses and cattle overboard to save on provisions. Major deserts of the world, such as the Sahara and the Great Australian Desert, lie under the high pressure of the horse latitudes.

The region is also known as the Calms of Cancer in the northern hemisphere and the Calms of Capricorn in the southern hemisphere.

Tropical easterlies (Trade winds)

Blowing from the subtropical highs or horse latitudes toward the low pressure of the ITCZ are the trade winds. Named from their ability to quickly propel trading ships across the ocean, the trade winds between about 30° latitude and the equator are steady and blow about 11 to 13 miles per hour. In the Northern Hemisphere, the trade winds blow from the northeast and are known as the Northeast Trade Winds; in the Southern Hemisphere, the winds blow from the southeast and are called the Southeast Trade Winds.

Westerlies

They blow from subtropical areas in midlatitudes.

Polar easterlies

They blow from the Poles in polar areas.

Monsoons

Mainly in South-East and East Asia.

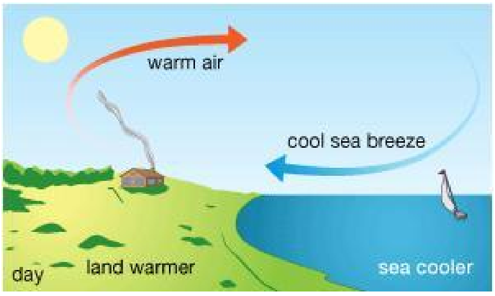
4.4.3 Local winds

Local winds are limited to smaller areas and blow for a certain time.

Sea breeze/ Land breeze

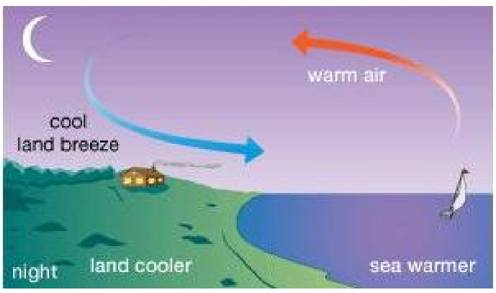
The same principle as monsoons, but the difference here is not between the summer and winter, but between the day and night and it occurs on seashores and lake shores.

During the day, the temperature of the sea surface changes only slowly, the shore is hotter than the sea/ lake. As the land warms up, the air above it also warms and rises, leaving a local area of low pressure. Cool air from the sea flows to the shore – **sea breeze (onshore breeze)**.



42 Sea breeze scheme.

During the night, the sea/lake is warmer than the shore, the land cools down faster than the sea, so the air above becomes denser than air over the sea and sinks down and flows from the shore to the sea/ lake – **land breeze (offshore breeze)**.



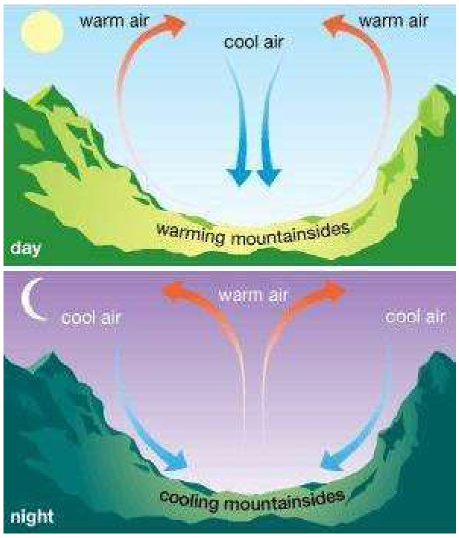
43 Land breeze scheme.

Mountain breeze/ Valley breeze

These are winds in mountains which occur in daily cycle.

During the day, the heated air in the valleys rises up the mountain slopes – **Valley breeze**.

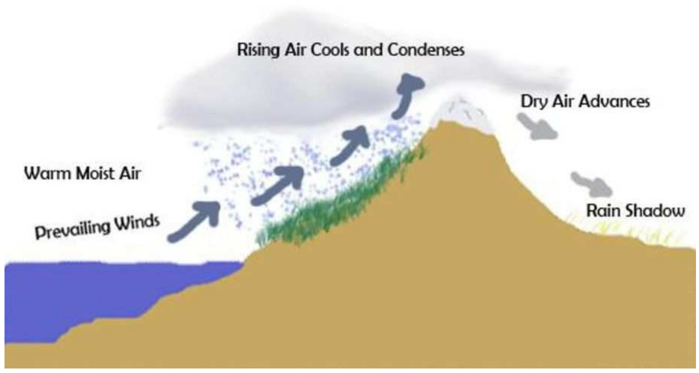
During the night, the wind descents down the mountain slopes – **Mountain breeze**.



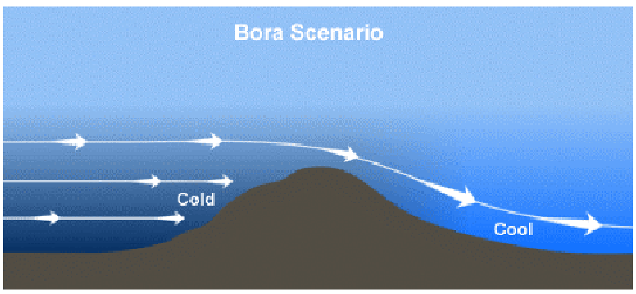
44/45 Mountain/Valley breeze scheme.

Foehn (FŐHN)

Föhn can be initiated when deep low-pressure systems move into Europe, drawing moist Mediterranean air over the Alps.
It is a rain shadow wind that results from the subsequent adiabatic warming of air that has dropped most of its moisture on windward slopes. As a consequence of the different adiabatic lapse rates of moist and dry air, the air on the leeward slopes becomes warmer than equivalent elevations on the windward slopes. Foehn winds can raise temperatures by as much as 14 °C (25 °F) in just a matter of hours. Switzerland, southern Germany and Austria have a warmer climate due to the Foehn, as moist winds off the Mediterranean Sea blow over the Alps.



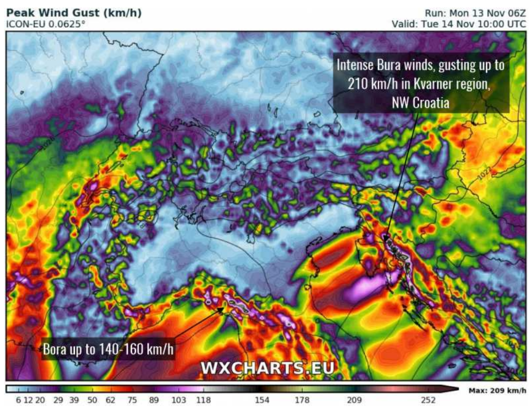
46 Satellite picture of Foehn.



47 Foehn scheme.

Bora

It is a **cold northern wind**, in Slovakia it occurs especially in winter seasons in the Tatra mountains and can be quite strong.
The Bora is most common blowing down the mountains on the eastern side of the Adriatic Sea (Croatia).



48 Expected wind gusts of Bora winds per ICON-EU model, Nov 14th 2017

The day that changed the Tatra mountains for good. (Spectator, 20. Nov 2017 at 13:35)

The windstorm damaged 12,000 hectares of woods on November 19, 2004. November 19, 2004 was a “Black Friday”, changing the image of the Tatras for good.
On that afternoon, a massive cold front arrived in the Tatra mountains, accompanied by extremely strong wind which amounted to a hurricane. This falling mountain wind is called **Bora**. Thirteen years ago, the **Bora** named Alžbeta (Elizabeth), which occurred in two succeeding phases, left fatal consequences on the Tatra vegetation and changed its image forever. The original forest ceased to exist. The Tatra forest in which spruces prevail, especially at the foot of the mountains, ceased to exist in just a few hours.
The wind uprooted or broke 12,000 hectares of woods, mostly in the Tatra National Park (TANAP), in a belt of more than 30 kilometres. A wind calamity of such an extent had not been recorded in Tatras previously though a similar one is mentioned in archives, dating back to 1915. People reacted very emotionally – the symbol of the Tatras, as well as the typical climate, was suddenly gone. Fundraising started immediately. Experts pointed out that a similar calamity should have been expected at one point or another: the man-made spruce could hardly resist a wind of such a force.
In the following years, it turned out that the whole landscape in and around the High Tatras changed.

49 The red belt affected by Bora wind in the High Tatras mountains.

50 Broken trees after disaster.

4.4.4 Clouds and precipitation

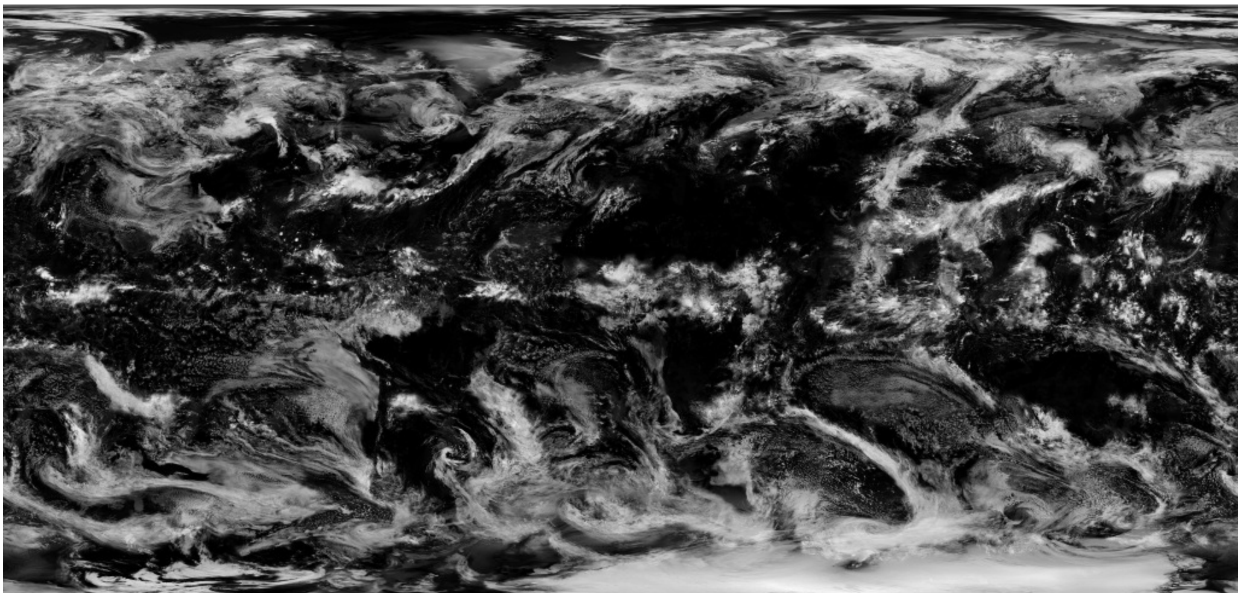
Clouds

Clouds are visible accumulations of tiny water droplets or ice crystals in the atmosphere. Clouds differ greatly in size, shape, and colour. Clouds usually appear white because the tiny water droplets inside them are tightly packed, reflecting most of the sunlight that hits them. White is how our eyes perceive all wavelengths of sunlight mixed together. When it's about to rain, clouds darken because the water vapour is clumping together into raindrops, leaving larger spaces between drops of water. Less light is reflected. The rain cloud appears black or gray. Clouds form when air becomes saturated, or filled, with water vapour. Warm air can hold more water vapour than cold air, so lowering the temperature of an air mass is like squeezing a sponge. Clouds are the visible result of that squeeze of cooler, moist air. Moist air becomes cloudy with only slight cooling. With further cooling, the water or ice particles that make up the cloud can grow into bigger particles that fall to Earth as precipitation.

Precipitation

When water on the Earth's surface is heated by the Sun, it evaporates and turns into water vapour which rises into the air. When the air cools it **condenses** around some dust or other particles in the air, called condensation nuclei. These small droplets then become visible as **clouds**.
Some droplets fall through the cloud and coalesce into raindrops on their way down. As more and more droplets join together, they become too heavy and fall from the cloud as rain. Warm air can hold more moisture than cool air, so when the warmer air is cooled and the moisture condenses, it often rains more heavily.

Any collection of particulate matter in the atmosphere dense enough could be perceptible to the eye, as a dust cloud or smoke cloud.

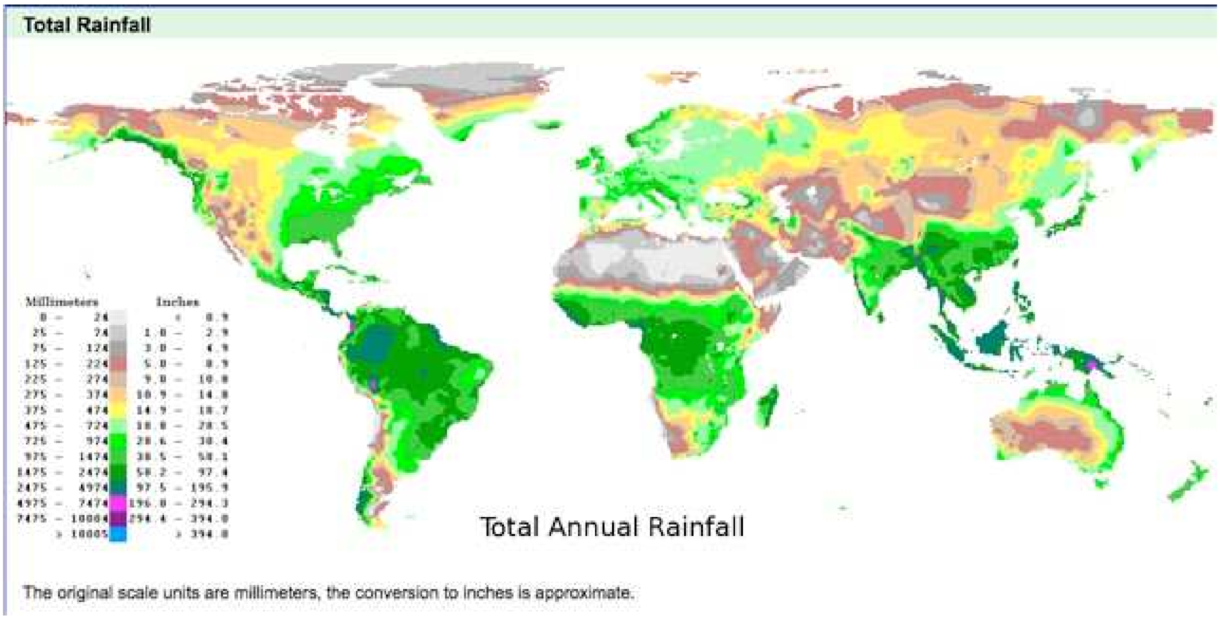


51 NASA satellite photograph of Earth´s clouds.

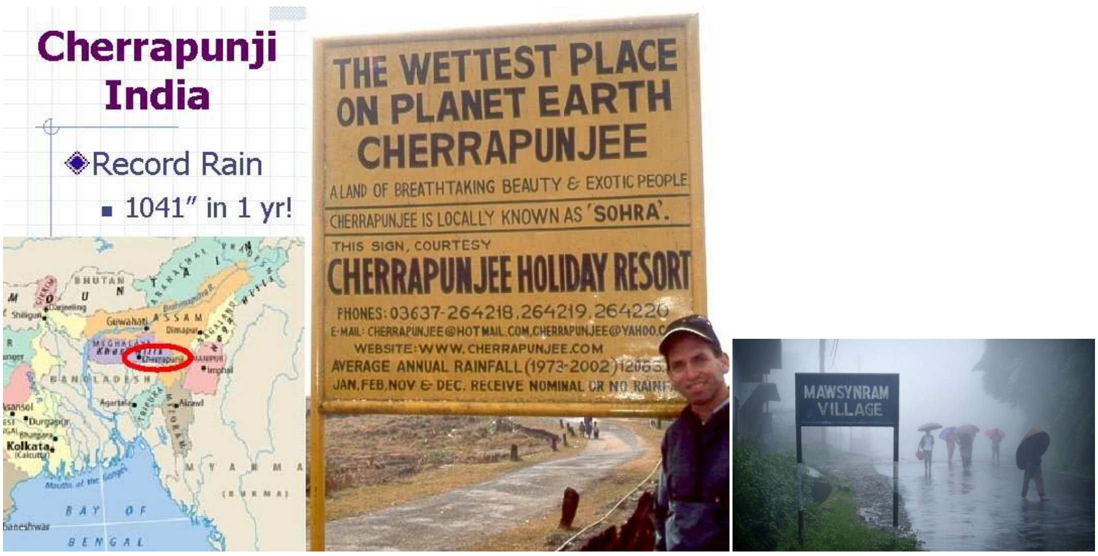
4.4.5 Rainfall zones

Based on how much precipitation a certain place on the earth gets throughout the year, we have defined 4 precipitation zones:

1. **Hot and humid zones**
   Between 0° and 20° latitudes (N ↑ S↓), average precipitation: *1,000 to 3,000 mm*
2. **Hot and dry zones**
   Between 20° and 30° latitudes (N ↑ S↓), average precipitation: *less than 250 mm*
3. **Cold and humid**
   Between 30° and 60° latitudes (N ↑ S↓), average precipitation: *about 1,000 mm, in the continental climate it can be lower than 250 mm*
4. **Cold and humid**
   From 60° LATITUDE TO THE POLES (N ↑ S↓, average precipitation: *less than 250* mm

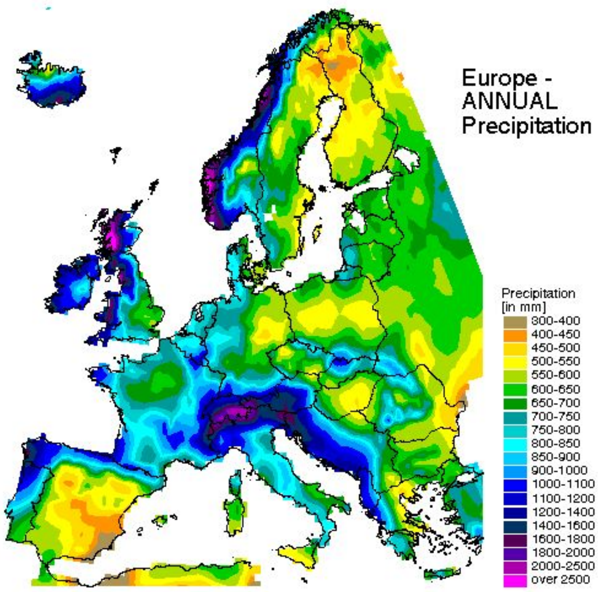


52 World´s total annual rainfall.



53 The wettest places on Earth, Mawsynram and nearby **Cherrapunji** in India.

Europe – Total annual rainfall in Europe:



54 The wettest place in Europe – Bergen, Norway.

Historical extremes in Slovakia (Slovak Hydrometerological Institute)

Hottest area: South-east part of Podunajská Nížina lowland, south and south-west slopes Kováčovské hills, Štúrovo

Absolute maximum, highest measured temperature: 40.3 °C, Hurbanovo, 20.7.2007

Coldest area: Peak location of the High Tatras

Absolute minimum, lowest measured air temperature: -41.0 °C, Vígľaš - part Pstruša, 11.2.1929

Highest yearly mean precipitation total, the most rainy place: 2130 mm yearly mean (period of observation 1901-1950) - Zbojnícka cottage at the High Tatras

55 Zbojnícka cottage at the High Tatras

Highest windy area: Chopok (2003 m a. s. l.), yearly mean wind speed 10 m/s

Highest measured wind speed: 78.6 m/s, (283 km/h), Skalnaté Pleso, 2nd January 1949

The most sunshine area: Middle of Podunajská lowland, Hurbanovo (2190 h yearly measured sum of 4447 h of astronomical possible sunshine duration)

Lowest sunshine area: Orava (Trstená - Ústie nad Priehradou, 1,052 h yearly sum

4.4 Climate system

4.4.1 Climate in general

Climate is the long-term pattern of weather in a particular area. **Weather** can change from hour-to-hour, day-to-day, month-to-month or even year-to-year. A region's weather patterns, usually tracked for at least 30 years, are considered its climate.

Different parts of the world have different climates. Some parts of the world are hot and rainy nearly every day. They have a tropical wet climate. Others are cold and snow-covered most of the year. They have a polar climate. Between the icy poles and the steamy tropics are many other climates that contribute to Earth's biodiversity and geologic heritage.

Climate is determined by a region's climate system. A **climate system** has five major components**: the atmosphere, the hydrosphere, the cryosphere, the land surface, and the biosphere**.

The **atmosphere** is the most variable part of the climate system. The composition and movement of gases surrounding the Earth can change radically, influenced by natural and human-made factors. Changes to the **hydrosphere**, which include variations in temperature and salinity, occur at much slower rates than changes to the atmosphere. The **cryosphere** is another generally consistent part of the climate system. Ice sheets and glaciers reflect sunlight, and the thermal conductivity of ice and **permafrost** profoundly influences temperature. The cryosphere also helps regulate thermohaline circulation. This "ocean conveyor belt" has an enormous influence on marine ecosystems and biodiversity. Topography and vegetation influence climate by helping determine how the Sun's energy is used on Earth. The abundance of plants and the type of land cover (such as soil, sand, or asphalt) impacts evaporation and ambient temperature. The **biosphere**, the sum total of living things on Earth, profoundly influences climate. Through photosynthesis, plants help regulate the flow of greenhouse gases in the atmosphere. Forests and oceans serve as "carbon sinks" that have a cooling impact on climate. Living organisms alter the landscape, through both natural growth and created structures such as burrows, dams, and mounds. These altered **landscapes** can influence weather patterns such as wind, erosion, and even temperature.

Climate Features

The most familiar features of a region's climate are probably **average temperature** and **precipitation**. Changes in day-to-day, day-to-night, and seasonal variations also help determine specific climates. For example, San Francisco, California, and Beijing, China, have similar yearly temperatures and precipitation. However, the daily and seasonal changes make San Francisco and Beijing very different. San Francisco's winters are not much cooler than its summers, while Beijing is hot in summer and cold in winter. San Francisco's summers are dry and its winters are wet. Wet and dry seasons are reversed in Beijing—it has rainy summers and dry winters.

Climate features also include **windiness**, **humidity**, **cloud cover**, **atmospheric pressure**, and **fogginess**. **Latitude** plays a huge factor in determining climate. Landscape can also help define regional climate. A region's **elevation**, proximity to the ocean or freshwater, and **land-use** patterns can all impact climate.

All climates are the product of many factors, including **latitude, elevation, topography, distance from the ocean, and location on a continent**. The rainy, tropical climate of West Africa, for example, is influenced by the region's location near the Equator (latitude) and its position on the western side of the continent. The area receives direct sunlight year-round, and sits at an area called the intertropical convergence zone (ITCZ, pronounced "itch"), where moist trade winds meet. As a result, the region's climate is warm and rainy.

Microclimates

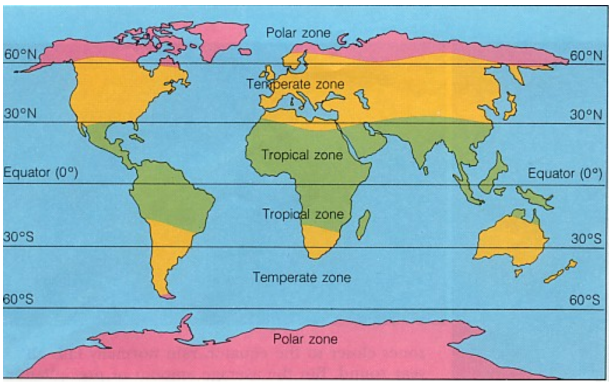
Of course, no climate is uniform. Small variations, called microclimates, exist in every climate region. Microclimates are largely influenced by topographic features such as lakes, vegetation, and cities. In large urban areas, for example, streets and buildings absorb heat from the Sun, raising the average temperature of the city higher than average temperatures of more open areas nearby. This is known as the "urban heat island effect."

Large bodies of water, such as the Great Lakes in the United States and Canada, can also have microclimates. Cities on the southern side of Lake Ontario, for example, are cloudier and receive much more snow than cities on the northern shore. This "lake effect" is a result of cold winds blowing across warmer lake water.

4.4.3 Climate classification

Geographers use a variety of methods to describe climate patterns. There are 3 major **climate zones**:

1. **Polar** – a dry climate with temperatures almost always below freezing.
2. **Temperate** – contains most of the Earth´s land masses with more moderate temperatures and rainfall year-round.
3. **Tropical** – has the warmest average temperatures and gets the most rain.

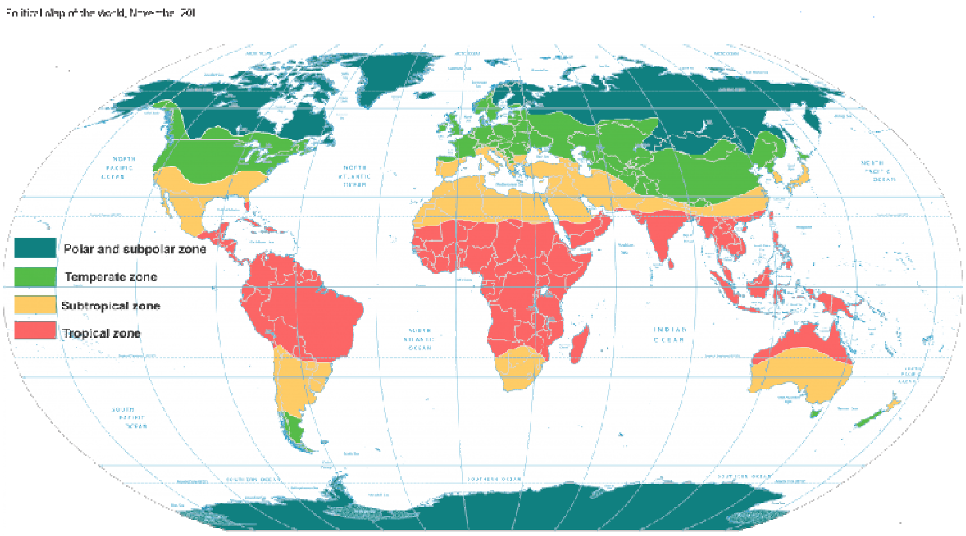


56 World´s main climate belts.

Temperatures in these three zones are determined mainly by the location and latitude.

4.4.2 Alisov climate classification

The classification developed by a Russian geographer and climatologist Boris. P. Alisov during the 1930s. This classification was used primarily by scientists in Russia.



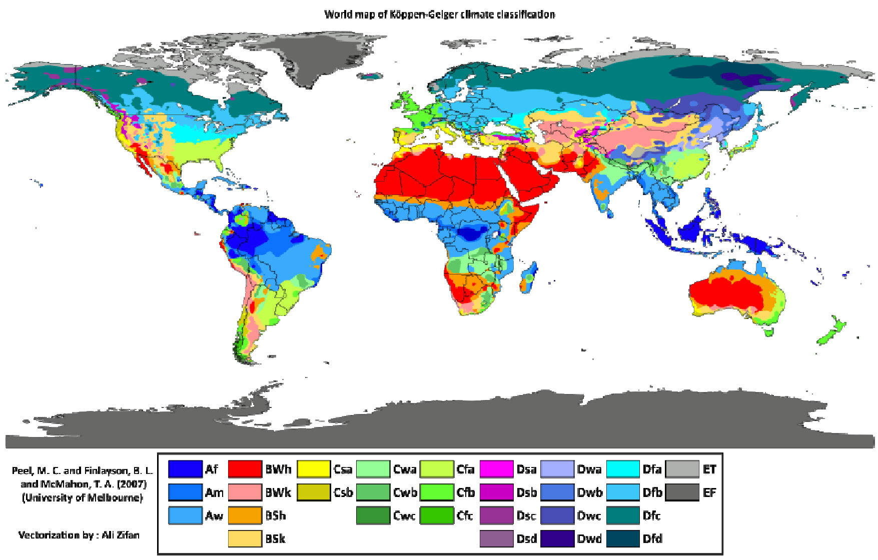
57 Alisov climate classification.

Alisov divided each hemisphere into 4 main bands and 3 subzones. The borders between these zones are determined by the climate fronts. A front describes the boundary between two air masses containing different temperature and/or water vapour content.

1. Equatorial
2. Sub-Equatorial
3. Tropical
4. Subtropical
5. Temperate
6. Subarctic/Subantarctic
   Arctic/Antarctic

4.4.3 Köppen climate classification

This is one of the most widely used climate classification systems.



58 Köppen climate classification.

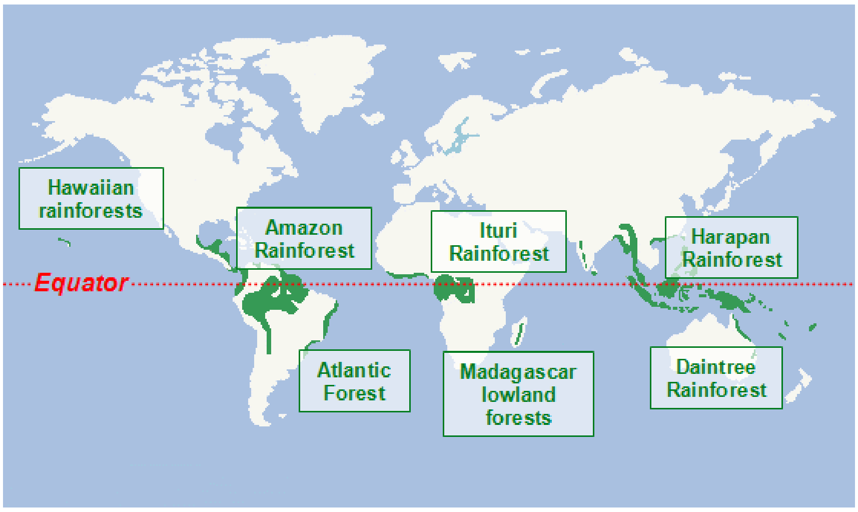
Köppen climate classification divides climates into five main climate groups, with each group being divided based on seasonal precipitation and temperature patterns. The five main groups are *A* (tropical), *B* (dry), *C* (temperate), *D* (continental), and *E* (polar). Each group and subgroup is represented by a letter. All climates are assigned a main group (the first letter). All climates except for those in the *E* group are assigned a seasonal precipitation subgroup (the second letter).

It is widely used, vegetation-based climate classification system developed by German botanist and climatologist Vladimir Köppen.
He defined climatic boundaries in such a way as to correspond to the vegetation zones (biomes) that were being mapped for the first time during his lifetime.

4.4.4 General features of climate zones

4.4.4.1 Tropical (Equatorial) climate zone

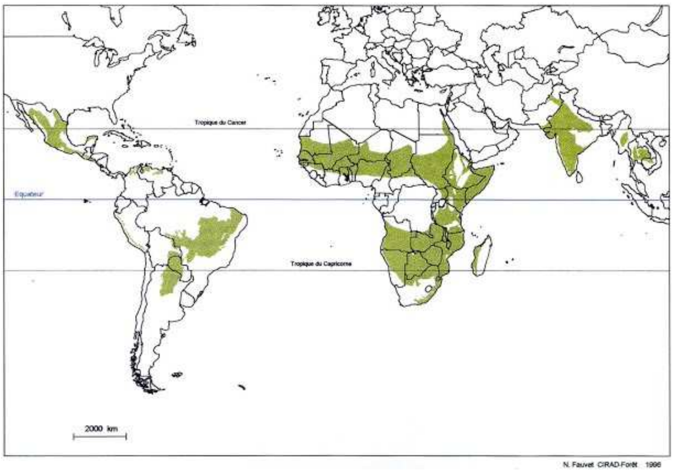
Tropical Wet
Equatorial regions are located in a band around the Equator and cover about 6% of the Earth's surface. They are often in lowland areas and have a climate that is hot and wet all year round. Tropical **rainforests** grow in the equatorial regions.
The tropical zone includes the Amazon Basin of Brazil, West Africa's Congo Basin and the rainforests of Malaysia and Indonesia. Large areas of South America, Africa and Asia, located between the Tropics of Cancer and Capricorn, have a tropical climate.



59 Rain forests zones.

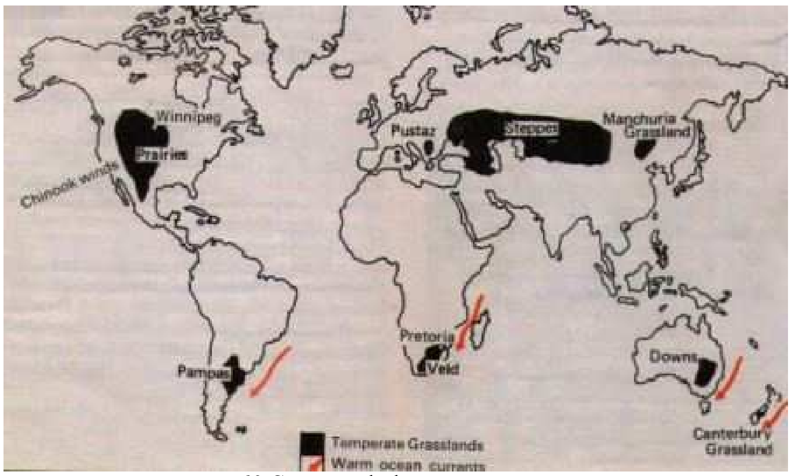
They are very wet and experience heavy rains almost every day. They do have warm nights and are very humid. They also **don't really have seasons** as the weather is basically the same every day.

Tropical Dry
Tropical climate zones are found on the land and oceans between the Tropics of Cancer and Capricorn. Trade winds carry seasonal rains -- **monsoons** -- to the east coasts of continents and irrigate lush vegetation in rain forests. Drier grasslands, such as **steppes** and **savannas**, occur on the northern and southern limits of this zone.



60 Tropical dry climate belts.

There is seasonality of the precipitations. The rain is usually in summer. The winters are hot, dry and sunny. There are **two seasons** – **dry** and **rainy**. In the dry season we can see higher daily and lower nightly temperatures in comparison with the equatorial climate. The vegetation is usually of type "**savanna**" with wide, grassy spaces and some trees. This kind of landscape can be seen in many places of the world, but most in the African savanna.



60 Savanna belts.

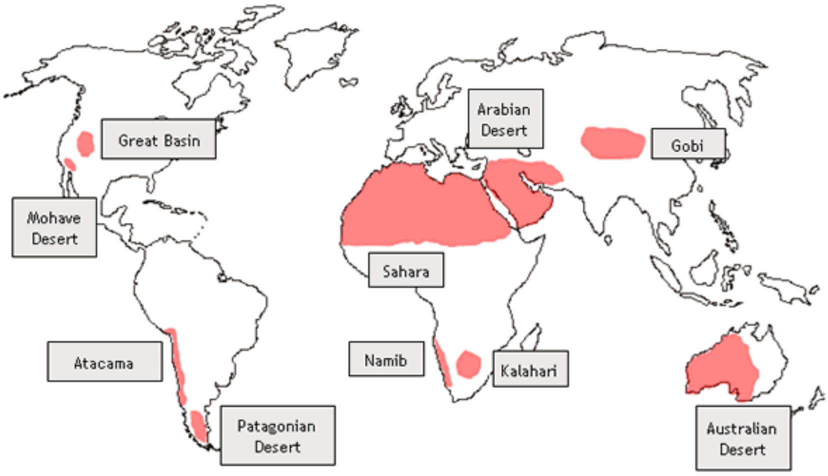
61 Savanna, South Africa.

4.4.4.2 Subtropical climate zone

62 Subtropical climate belts.

Arid zone - deserts

They have very **high day time temperatures** and **very low nighttime temperatures**. They have extremely **low amounts of precipitation** and therefore rivers cannot form, there is very little vegetation and usually very high winds.
Arid subtropical zones lie to the north and south of the tropical zone characterized by the absence of regular rainfall and high humidity.
There is only **250mm per year** and daily **temperature extremes**. Temperatures vary between freezing at nighttime and up to 43°C during the day. Subtropical regions include the Sahara Desert, southern Arabia, and parts of Jordan, Iraq, Iran, northwest India and Australia. A Mediterranean climate is a subdivision of this zone with rainfall of up to 35 inches annually. This zone lies around the Mediterranean Sea coast in Europe, the Pacific Northwest and most of California in the United States, Central Chile and western Australia.



63 Deserts zones.

64 Sahara Desert, Africa.

Mediterranean zone

The Mediterranean climate regime resembles the climate of the lands in the Mediterranean Basin, parts of coastal south-western North America, parts of Western and South Australia, in south-western South Africa and in parts of central Chile.

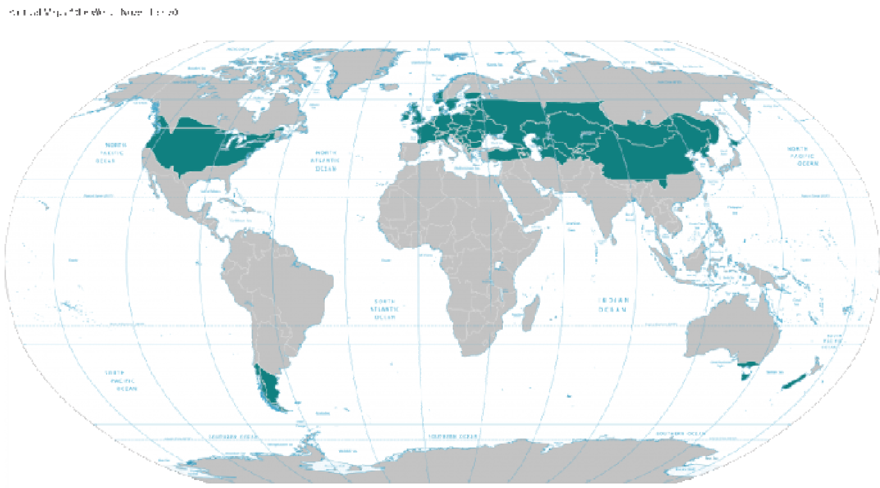
65 Mediterranean climate zones.

66 Cork Oak woodland, Spain.

The climate is characterized by **hot dry summers** and **cooler winters** with rainfall. In Europe, the northernmost Mediterranean climates are found along the French Riviera. A Mediterranean climate is a subdivision of this zone with rainfall of up to 35 inches annually. This zone lies around the Mediterranean Sea coast in Europe, the Pacific Northwest and most of California in the United States, Central Chile and west Australia. On the immediate

4.4.4.3 Temperate (mild) climate zone

Temperate climates are those without extremes of temperature and precipitation (rain and snow). The changes between summer and winter are generally invigorating without being extreme. **There are 4 seasons**: warm summers, wet springs, falls, and cold, snowy winters.



67 Temperate climate belts.

There are two types of temperate climate: **maritime** and **continental**.

1. The maritime (oceanic) climate

Region's climate is influenced by maritime airflow from the ocean cooler summers, warmer winters, smaller annual temperature change Water has higher heat capacity than soil or rock, thus seawater takes longer time to heat up during summer, but retains the energy for a long time, helping to moderate the climate Fairly humid with considerable amounts of precipitation British Isles, prevailing south-westerly winds from the Atlantic. Annual average temperature range is 10°C. Summer temperatures are generally cooler than further into Europe due to the cooling effect of the sea. Overall temperature is warmer than the rest of Europe and the temperature rarely drops below 0°C or goes above 21°C. Lowland areas tend to be warmer. Receives an average of 850 mm of rain in a year, which is relatively high.

68 Countryside, Australia.

2. Continental climate

It increases inland, with warmer summers and colder winters as the effect of land on heat receipt and loss increases. This is particularly true in North America, where the north-south aligned Rocky Mountains act as a climate barrier to the mild maritime air blowing from the west. Maritime climate, on the other hand, penetrates further into Europe where the major mountain range – the Alps – is orientated east-west.

69 Eastern Slovakia, Europe.

4.4.4.4 Subarctic climate zone

The subarctic area is transition climate zone between the temperate and polar climate zone. It occupies the area around and beyond the Arctic Circle. This climate zone is wide spread almost only in the North hemisphere because of the missing of mainland, in these latitudes, in the South hemisphere.

It is wide spread in the northern most parts North America (Alaska and North Canada), the northern part of Scandinavia and northern Asia (Siberia in Russia). Out of these areas this climate occupies the higher parts of the mountains (for example in the Alps can be found in the areas above 1500m.), the high parts of the Andes, Himalayas, Rocky mountains and so on. This climate is characterized by **long and very cold winters**. The temperatures can be negative more than six months in the year. Sometimes the temperatures can reach -40 °C. **The summer is short and cool**.

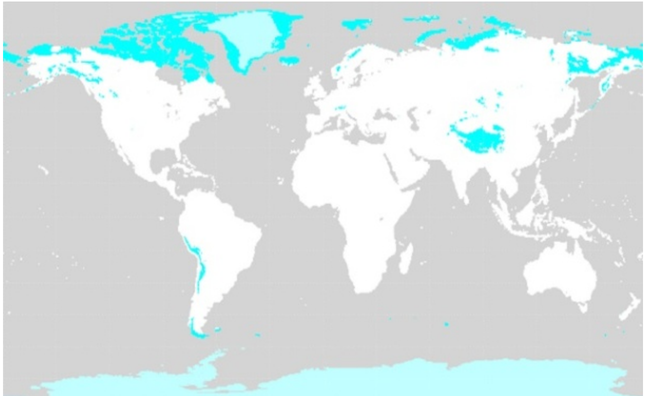
70 Alaska, USA.

4.4.4.5 Polar climate zone

The polar (arctic) climate zone occupies the ice caps of the planet. **The temperatures are below zero all year round.** In the South hemisphere this climate zone occupies the all territory of Antarctica and in the North hemisphere occupies the Arctic ocean.

The conditions of life are exceptionally hard. Because of this reason, these areas are unpopulated. Because of the fact, that our planet has permanent tilt of 23.5°, we can observe the occurrence of **the polar day and the polar night, that continue six months each**.

In the polar day the sun is never set beyond the horizon. During the polar night, just the contrary – it never rises.


71 Polar climate zones.


42 Greenland.

The polar (arctic) climate zone occupies the ice caps of the planet. **The temperatures are below zero all year round.** In the South hemisphere this climate zone occupies the all territory of Antarctica and in the North hemisphere occupies the Arctic ocean.

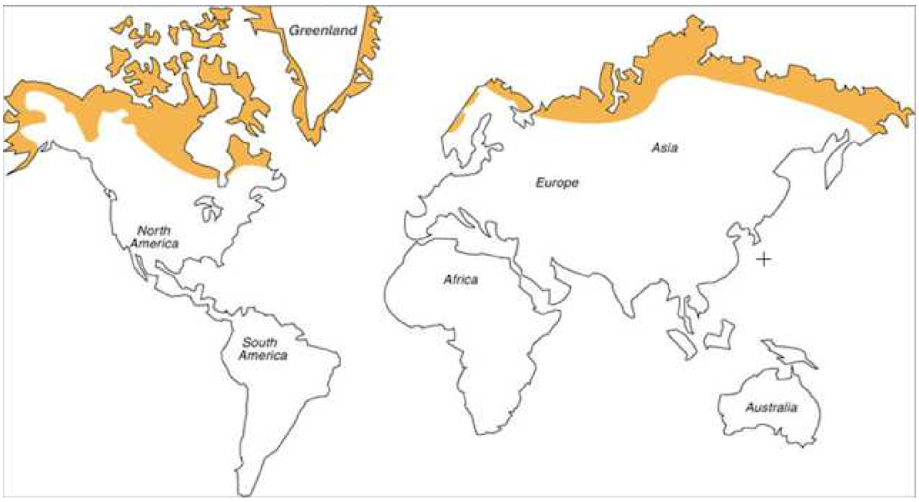
The conditions of life are exceptionally hard. Because of this reason, these areas are unpopulated. Because of the fact, that our planet has permanent tilt of 23.5°, we can observe the occurrence of **the polar day and the polar night, that continue six months each**.

In the polar day the sun is never set beyond the horizon. During the polar night, just the contrary – it never rises.

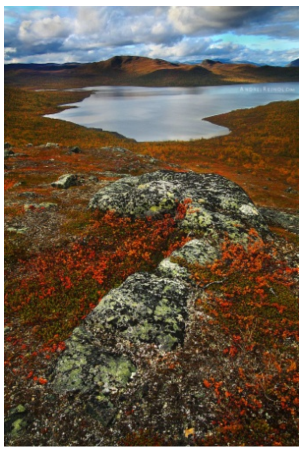
The lowest temperature ever recorded on Earth was **−89 °C**, measured at the Vostok Station in Antarctica. Polar climates also tend to be extremely dry since the descending cold air does not have a significant amount of moisture. Consequently, **no rain clouds are formed**. Some areas in polar regions receive an **annual rainfall of fewer than 250mm**.

If these areas were not covered with ice, they would be as dry as some of the Earth's hottest and driest **deserts**.

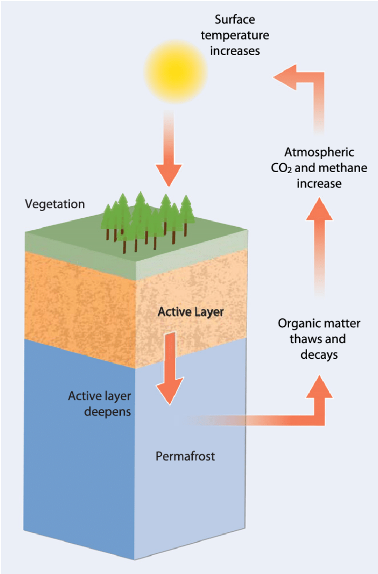
Tundra



73 Tundra belt.


74 Lapland, Finland.

Polar climates have some similarities to tundra climates but they are different.
The flat, treeless lands forming a ring around the Arctic Ocean are called **tundra**. It is almost exclusively located in the Northern Hemisphere. Very little precipitation falls here, usually less than 400mm per year.



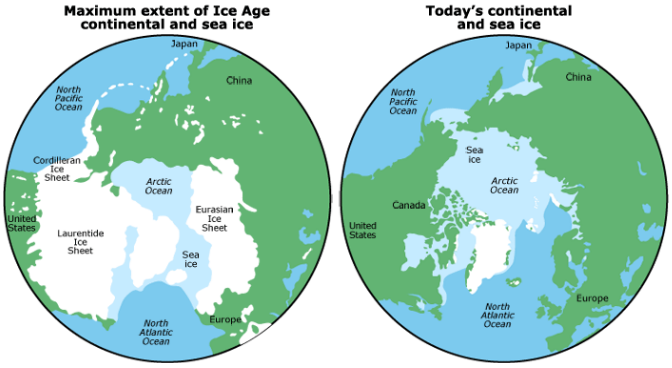
The land has **permafrost**, the subsoil is constantly frozen. In the summer, which lasts for only a few weeks, the temperature may reach slightly above 4 °C.
Tundra climates usually have a month in which the average temperature rises beyond the freezing point, while this does not occur in polar climates. When the permafrost melts, it releases carbon in the form of **carbon dioxide** and **methane**, both of which are **greenhouse gases**.

74 Permafrost, Siberia, Russia.

75 Methane bubbling up, Arctic permafrost.

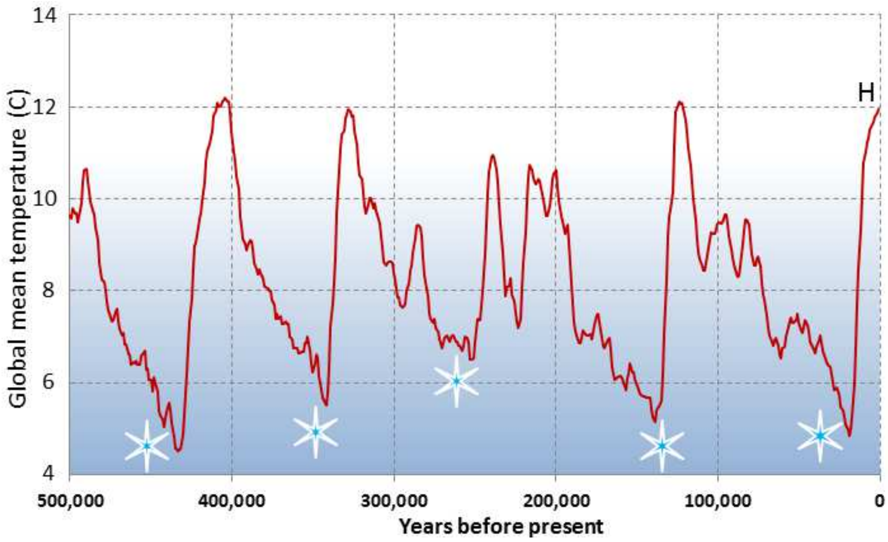
4.5 Climate change on the Earth

The planet's climate has constantly been changing over geological time. The global average temperature today is about **15°C**, though geological evidence suggests it has been much higher and lower in the past. We are facing the biggest environmental challenge our species has ever seen. No matter what we’re passionate about, something we care about will be affected by climate change.



76 Evidence of climate change, differences in ice cover of the same place during Ice Age and today.

The Ice Ages began 2.4 million years ago and lasted until 11,500 years ago. During this time, the earth's climate repeatedly changed between very cold periods, during which glaciers covered large parts of the world (see map below), and very warm periods during which many of the glaciers melted. The cold periods are called glacials (ice covering) and the warm periods are called interglacials.
There were at least 17 cycles between **glacial and interglacial periods**. The glacial periods lasted longer than the interglacial periods. The last glacial period began about 100,000 years ago and lasted until 11,500 years ago. **Today we are in a warm interglacial period**.



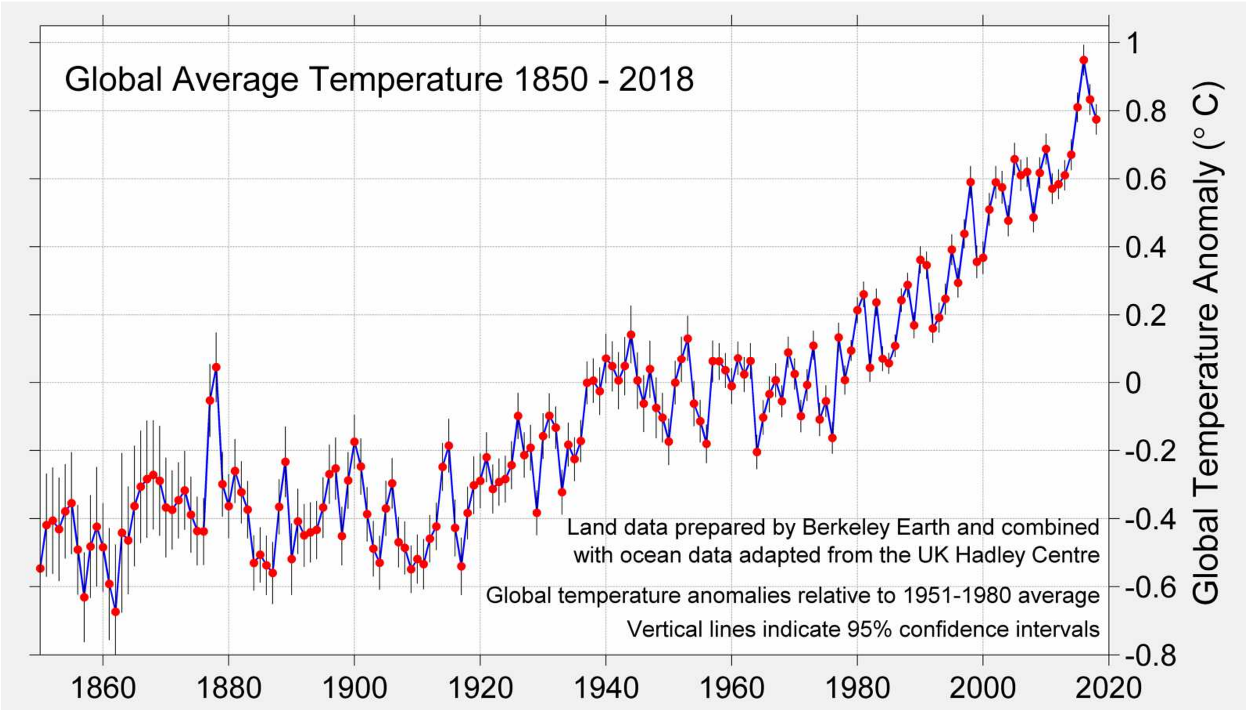
77 Changes in temperature over the past 500,000 years.

4.6 Global warming

Global warming describes **the current rise in the average temperature** of Earth's air and ocean. Glaciers are melting, sea levels are rising, cloud forests are dying, and wildlife is scrambling to keep pace. It's becoming clear that humans have caused most of the past century's warming by releasing heat-trapping gases as we power our modern lives. They are called **greenhouse gases (GHGs)**, their levels are higher now than in the last 650,000 years. The average global temperature and concentrations of **carbon dioxide** (CO_2), one of the major greenhouse gases, have fluctuated on a cycle of hundreds of thousands of years as the Earth's position relative to the sun has varied. As a result, ice ages have come and gone.

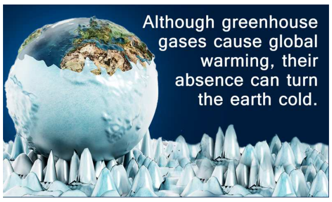
However, for thousands of years now, emissions of GHGs to the atmosphere have been **balanced out by GHGs that are naturally absorbed**. As a result, GHG concentrations and temperature have been fairly stable. This stability has allowed human civilization to develop within a consistent climate. Occasionally, other factors briefly influence global temperatures. Volcanic eruptions, for example, emit particles that temporarily cool the Earth's surface. But these have no lasting effect beyond a few years. Other cycles, such as El Niño, also work on fairly short and predictable cycles.
Now, humans have increased the amount of carbon dioxide in the atmosphere by more than a third since the industrial revolution. Changes this large have historically taken thousands of

years, but are now happening over the course of decades. Scientists worry that the climate is changing faster than some living things can adapt to it.

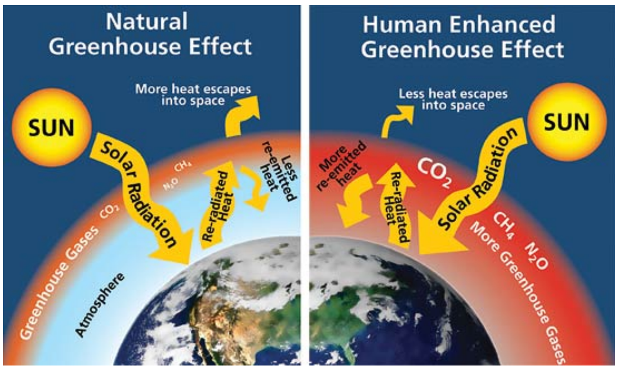


79 Global average temperature change .

4.7 Anthropogenic warming: Greenhouse effect



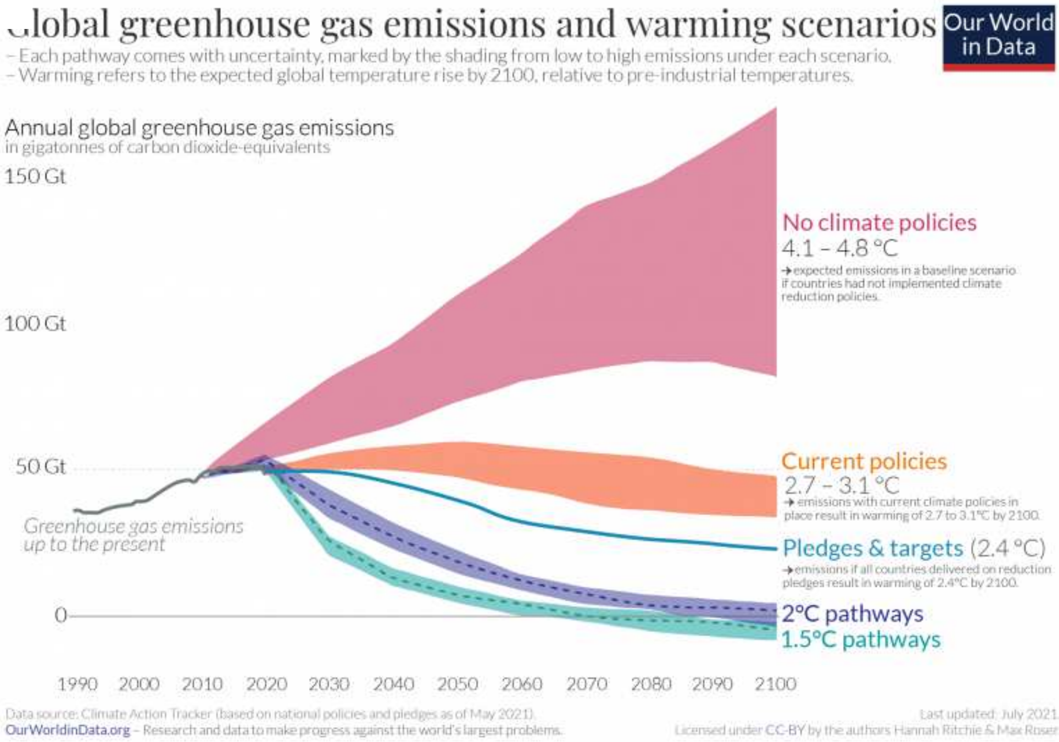
Greenhouse effect is a natural process whereby gases and clouds absorb infrared radiation emitted from earth´s surface and radiate it, heating the atmosphere and earth´s surface. Greenhouse gases warm the atmosphere by trapping heat. Some of the heat radiation out from the ground is trapped by greenhouse gases in the troposphere. The warming of the atmosphere because of insulation by greenhouse gases is called the **greenhouse effect**. Greenhouse gases are the component of the atmosphere that moderate Earth’s temperatures.



79 Natural and human contributions to greenhouse effect.

For several millennia—until the past two centuries—an average surface temperature of about **15°C** kept the sun and Earth in energy balance. That is, the same amount of infrared radiant energy was leaving the atmosphere as was being absorbed at the surface from the sun's radiant energy.

Anthropogenic warming:



80 Global greenhouse gas emissions graph.

4.8 Effects of global warming

1. Increase of average temperatures

The average global temperature has increased by about 0.8°C over the past 100 years. Scientists predict that earth´ s average temperature will increase by between 1.4 and 5.8°C by the year 2100. It will affect both the land and the ocean environments.

The biggest, most obvious effect is that glaciers and ice caps melt faster than usual. The melt water drains into the oceans, causing sea levels to rise and oceans to become less salty. Ice sheets and glaciers advance and retreat naturally. As Earth's temperature has changed, the ice sheets have grown and shrunk, and sea levels have fallen and risen.

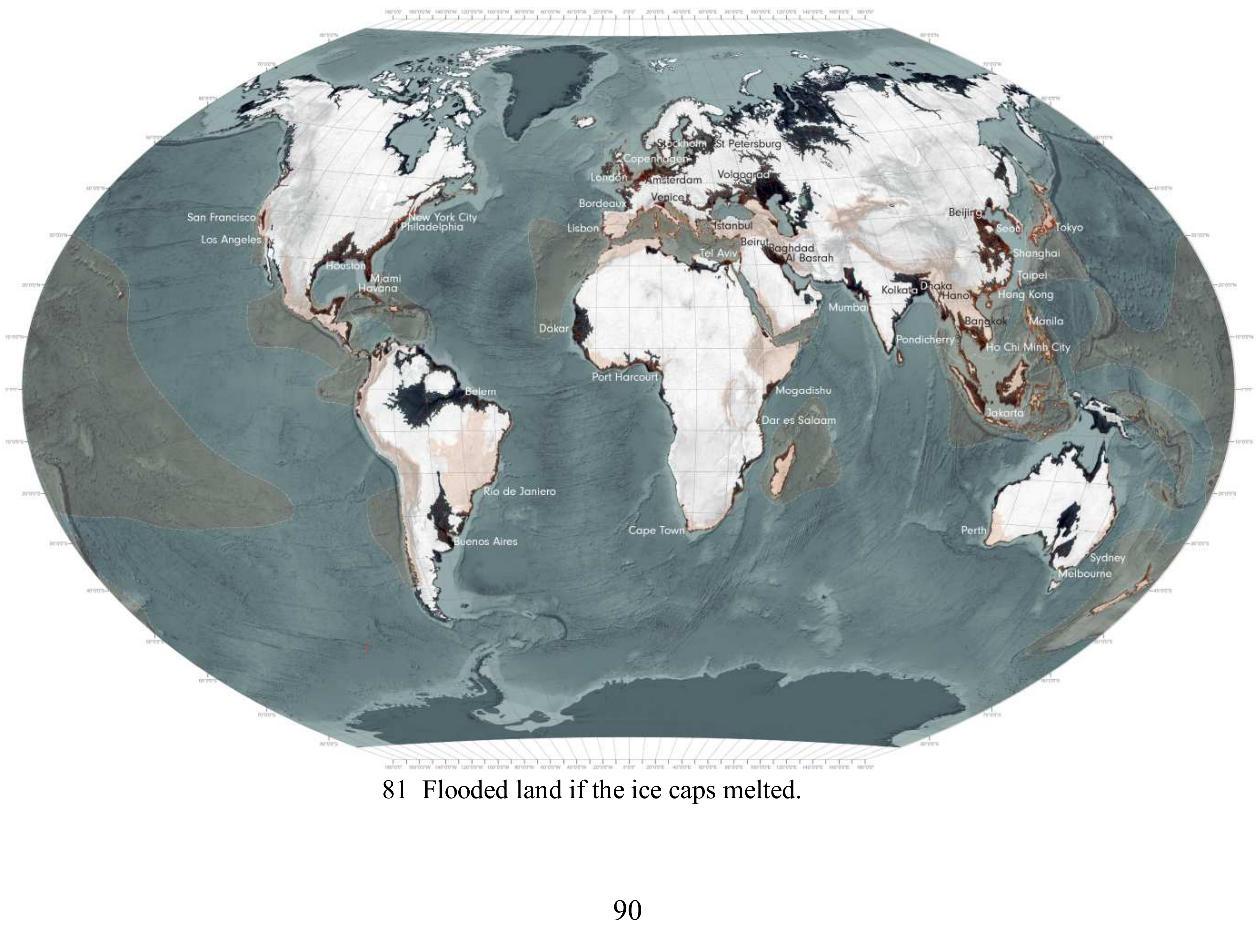
2. Rise in sea levels

Glaciers and ice caps cover about 10 % of the world's landmass today. **They hold about 75 % of the world's fresh water**. If all of this ice melted, sea levels would rise by about 70 m.

Rising sea levels could flood coastal communities, displacing millions of people in areas such as Bangladesh, the Netherlands, and the U.S. state of Florida. Forced migration would impact not only those areas, but the regions to which the “climate refugees” flee. Millions more people in countries like Bolivia, Peru, and India depend on glacial melt water for drinking, irrigation, and hydroelectric power. Many scientists use the term “climate change” instead of “global warming.” This is because greenhouse gas emissions affect more than just temperature. Another effect involves changes in precipitation like rain and snow. Patterns in precipitation may change or become more extreme. Over the course of the 20th century, precipitation increased in eastern parts of North and South America, northern Europe, and northern and central Asia. However, it has decreased in parts of Africa, the Mediterranean, and parts of southern Asia. When the ocean water gets warm, the algae in the ocean tends to produce toxic oxygen compounds called superoxide which are damaging for the corals.

The climate has always been changing and the oceans have risen and fallen accordingly. Sea level is now 120 meters higher than it was 20,000 years ago; a world of more ice and land bridges unrecognizable to us now. Inversely, in warmer periods the oceans have been anywhere between 6 to 30 meters higher than where they are currently. The difference now is that we are both causal to and threatened by the changes taking place.

The following map shows the land which would be flooded if the ice caps melt in entirety, in which case the sea level would rise by 80.32 meters. 1 In this scenario, vast new coastlines and inland seas will be created and 50 of the world's major cities would become architectural reefs. Even if sea level rises only 0.74 meters by 2100 as is conservatively predicted some 115 million people will likely be displaced and 420,000 km^2 of land will be lost to the encroaching seas.



81 Flooded land if the ice caps melted.

3. Ocean Acidification

As levels of atmospheric carbon dioxide increase, the oceans absorb some of it. This increases the acidity of seawater. Since the Industrial Revolution began in the early 1700s, the acidity of the oceans has increased about 25%. Because acids dissolve calcium carbonate, seawater that is more acidic has a drastic effect on organisms with shells made of calcium carbonate, such as corals, molluscs, shellfish and plankton. Change in ocean acidity will also affect fish and other aquatic animals and plants.

82 Dying corals on the Great Barrier Reef.

4. Climatic hazards

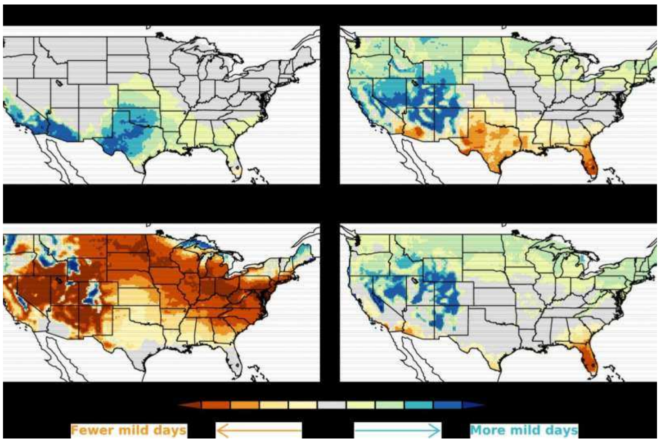
Extreme weather events include record-breaking **high or low temperatures, floods or intense storms, droughts, heat waves, hurricanes and tornadoes**, etc.
The others weather extremes are higher or lower agricultural yields, melting of arctic ice and snowcaps which causes landslides, flash slides and glacial lakes. It will cause extinction of some animal and plant spices and increase diseases caused by e.g. mosquitoes.

83 A man walking in front of a fire at Le Capannine beach in Catania, Sicily, Italy, July 30, 2021. A roundup of the wildfires sweeping southern Europe.

5. **Change in world´s climate patterns**

Climate change resulting from increasing temperatures will likely include changes in wind patterns, annual precipitation and seasonal temperature variations. Climatic patterns in most parts of the world have already changed. Rains fall when least expected and at irregular intervals. This has greatly affected the timing of planting and harvesting activities. Sometimes the rains fall so heavily to cause floods, or too little leading to drought.

Most of the arable land that once used to be productive is slowly turning arid. With time, farmers will run short of the land for cultivation, a fact that will result in famine.



84 Climate change to shift global pattern of mild weather in the U.S.A., tropics are losing mild days.

6. **Effects on plants and animals**

Many spices of plants and animals are already moving their range northward or higher altitudes as a result of warming temperatures. Additionally, migratory birds and insects are now arriving in their summer feeding and nesting grounds several days or weeks earlier than they did in 20th century.

Warmer temperatures will also expand the range of many disease-causing pathogens that were once confined to tropical and subtropical areas, killing off plant and animal spices that formerly were protected from diseases. These and another impacts of global warming will likely contribute to disappearance of up to one-half of the earth´s plants and one-third of animals from their current range by 2050.

85 The heat is melting glaciers and sea ice, shifting precipitation patterns, and setting animals on the move.

7. Effects on humans

As dramatic as the effects of climate change are expected to be on the natural world, the projected changes to human society may be even more devastating.

Agricultural systems will likely be dealt a crippling blow. Though growing seasons in some areas will expand, the combined impacts of drought, severe weather, lack of accumulated snowmelt, greater number and diversity of pests, lower groundwater tables and a loss of arable land could cause severe crop failures and livestock shortages worldwide. Carbon dioxide is affecting plant growth. Though CO2 can increase the growth of plants, the plants may become less nutritious.

This loss of food security may, in turn, create havoc in international food markets and could spark **famines**, **food riots**, **political instability** and **civil unrest** worldwide.

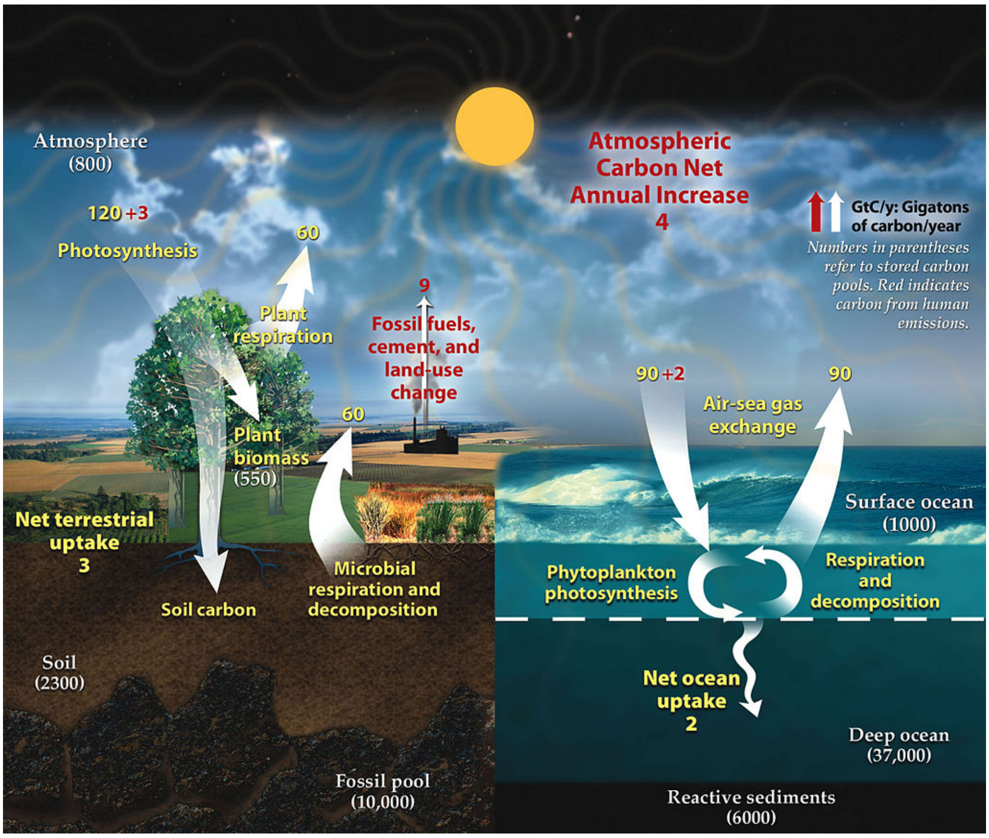
In addition to less nutritious food, the effect of global warming on human health is also expected to be serious. The scientist has reported an increase in mosquito-borne diseases like **malaria** and **dengue fever**, as well as a rise in cases of chronic conditions like asthma, most likely as a direct result of global warming. The 2016 outbreak of **Zika virus**, **a mosquito-borne illness**, highlighted the dangers of climate change. The disease causes devastating birth defects in foetuses when pregnant women are infected, and climate change could make higher-latitude areas habitable for the mosquitoes that spread the disease. Longer, hotter summers could also lead to the spread of **tick-borne illnesses**.

86 Madagascar famine becomes worst in history to be caused solely by climate crisis.

4.9 Carbon cycle

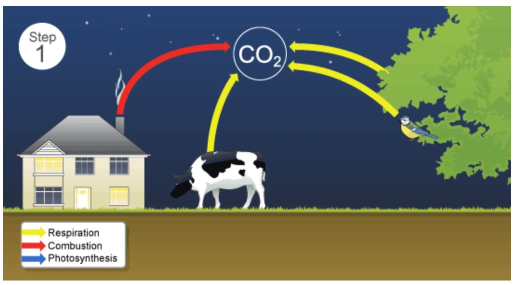
All living things are made of carbon. **Carbon** is also a part of the ocean, air, and even rocks. Because the Earth is a dynamic place, carbon does not stay still. It is on the move.
In the atmosphere, carbon is attached to some oxygen in a gas called carbon dioxide. Plants use carbon dioxide and sunlight to make their own food and grow. The carbon becomes part of the plant. Plants that die and are buried may turn into fossil fuels made of carbon like coal and oil over millions of years. When humans burn fossil fuels, most of the carbon quickly enters the atmosphere as carbon dioxide.

Carbon dioxide is a greenhouse gas and traps heat in the atmosphere. Without it and other greenhouse gases, Earth would be a frozen world. But humans have burned so much fuel that there is about 30% more carbon dioxide in the air today than there was about 150 years ago, and Earth is becoming a warmer place. In fact, ice cores show us that there is now more carbon dioxide in the atmosphere than there has been in the last 420,000 years.

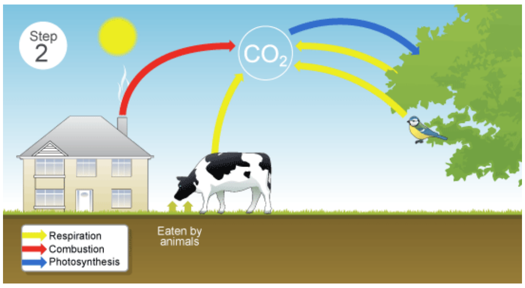


87 Carbon cycle scheme.

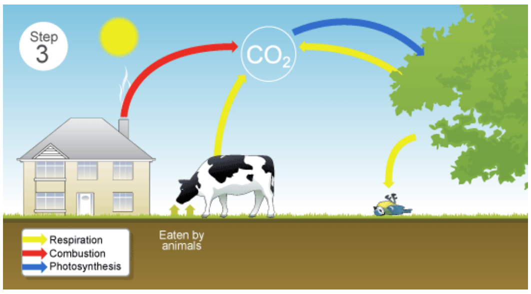
1. Carbon enters the atmosphere as carbon dioxide from respiration and combustion.



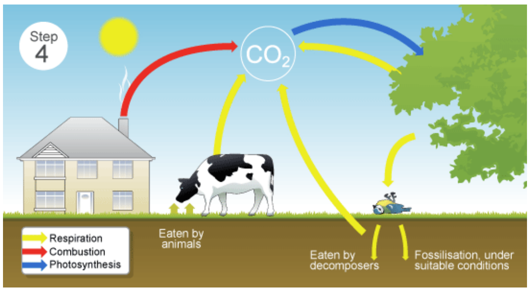
2. Carbon dioxide is absorbed by producers to make carbohydrates in photosynthesis.



3. Animals feed on the plant passing the carbon compounds along the food chain. Most of the carbon they consume is exhaled as carbon dioxide formed during respiration. The animals and plants eventually die.



4. The dead organisms are eaten by decomposers and the carbon in their bodies is returned to the atmosphere as carbon dioxide. In some conditions decomposition is blocked. The plant and animal material may then be available as fossil fuel in the future for combustion.



4.9 Human contribution to climate change

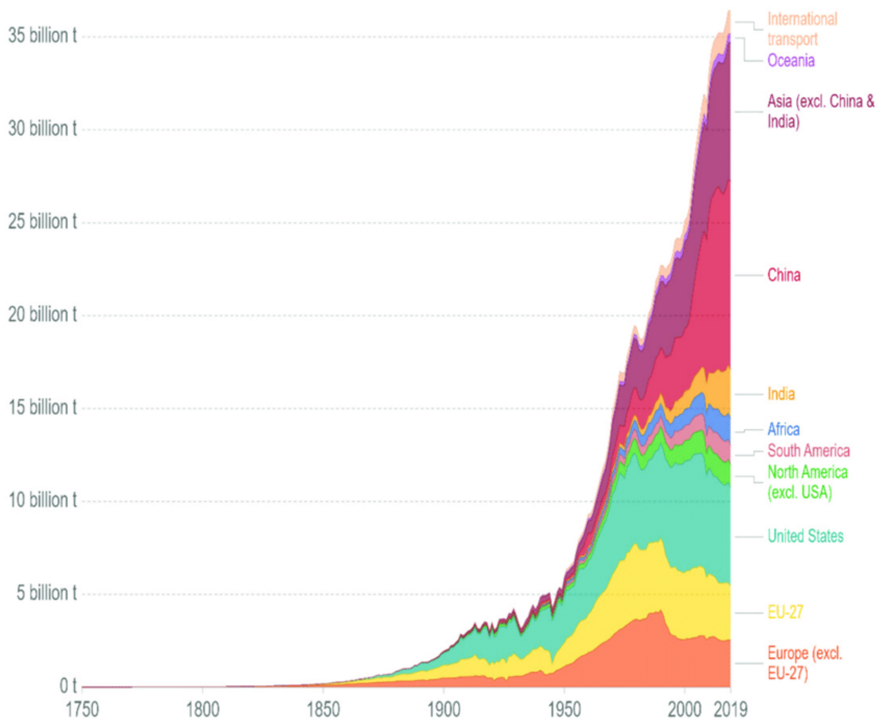
1. Deforestation

Green plants absorb carbon dioxide gas from the atmosphere and use it to manufacture their food through the process of photosynthesis. Cutting down trees means that a few trees are left to absorb carbon dioxide from the air. This led to increase in the amount of it in the atmosphere.

88 Over 17 percent of the Amazon rainforest has been destroyed over the past 50 years

2. Increasing carbon dioxide levels

Humans burn fossil fuels to power cars and other machines, to generate electricity, and to keep buildings warm. Waste gases are released during combustion, including carbon dioxide. As the human population increases, more fuel is used, and more carbon dioxide is released.



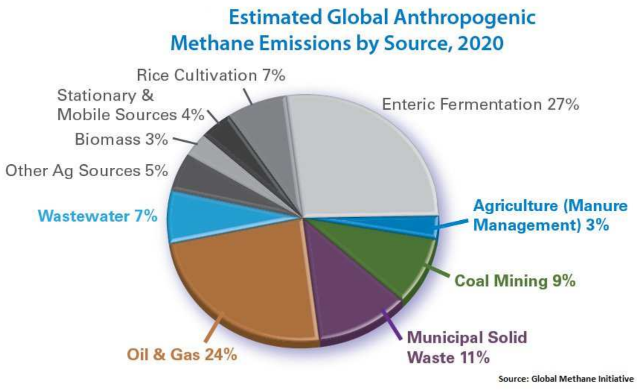
89 Annual total CO_2 emissions, by world regions

3. Methane

Methane is caused by emissions from **landfills**, **livestock**, **rice farming** (which uses methane-emitting bacteria), **septic processes**, and **fertilizers**.

Herbivorous livestock guts are full of them. Cows, sheep, goats, even camels have methanogenic bacteria in their stomach to help digest plant material, which means they collectively pass very large quantities of methane gas.
Another agricultural source of methane is **the production of rice**. Rice paddies contain methane-producing microorganisms as well, and the soggy fields release about 1.5% of global methane emissions.

Methane emissions come also from the fossil fuel industry. Methane is not released when we burn fossil fuels, like carbon dioxide does, but rather during the extraction, processing, and distribution of fossil fuels. Methane is much more efficient at absorbing heat than carbon dioxide (as much as 86 times more), making it a very potent greenhouse gas. Fortunately, methane can only last about 10 to 12 years in the atmosphere before it gets oxidized and turns into water and carbon dioxide. Carbon dioxide lasts for centuries.

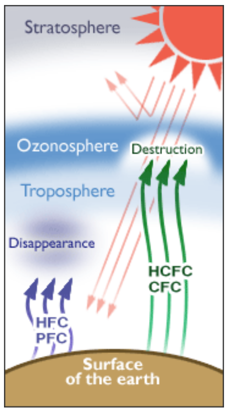


90 Global anthropogenic methane emissions.

4. Nitrous oxide

This gas is produced from both man-made and natural processes. Human activities which produce dinitrogen oxide include **combustion of fossil fuels** in vehicles and power stations, use of **nitrogenous fertilizers**, **burning vegetation** and **animal waste**. The gas is also produced by **digesting bacteria**, and is part of the nitrogen cycle, one of the most important natural processes on earth.

5. Chlorofluorocarbons (CFCs – freons)



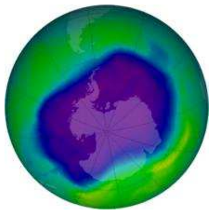
The sources of CFCs in the atmosphere include refrigerators, air conditioners and aerosols. CFCs are extremely effective greenhouse gases. **One CFC molecule is about 10,000 times more effective than carbon dioxide molecule**.

Ozone is a gas made up of molecules that are formed by three oxygen atoms. Its molecule formula is O3. Ozone is formed when the sunlight hits oxygen molecules (O2) and breaks them up into individual atoms. These individual atoms then join up with O2 molecules and make O3, or ozone.

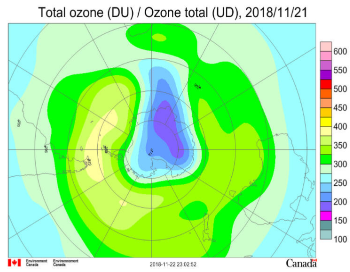
Ozone molecules in the atmosphere provide us with important protection from the rays of the sun. Specifically, these molecules are good at absorbing certain ultraviolet rays that can cause sunburn and skin cancer. It turns out that certain types of molecules can cause a chemical reaction when they come in contact with ozone molecules. This causes the ozone to break up and become unable to absorb ultraviolet light. The main molecules that are destroying the ozone layer are called **chlorofluorocarbons** or **CFCs**.

Chlorofluorocarbons are a group of chemicals which are made up of only **chlorine**, **fluorine**, **carbon**, and **hydrogen**. They were used as refrigerants to keep things cold, in a variety of products including air conditioners, spray cans, fire extinguishers, and in manufacturing foams.

In 1974 was formed a treaty called called Montreal Protocol to try and stop the manufacture and use of CFCs throughout the world. CFCs were to be banned and completely eliminated in developing countries by the year 2000.



91 A hole in the ozone over the Antarctic in 1974.

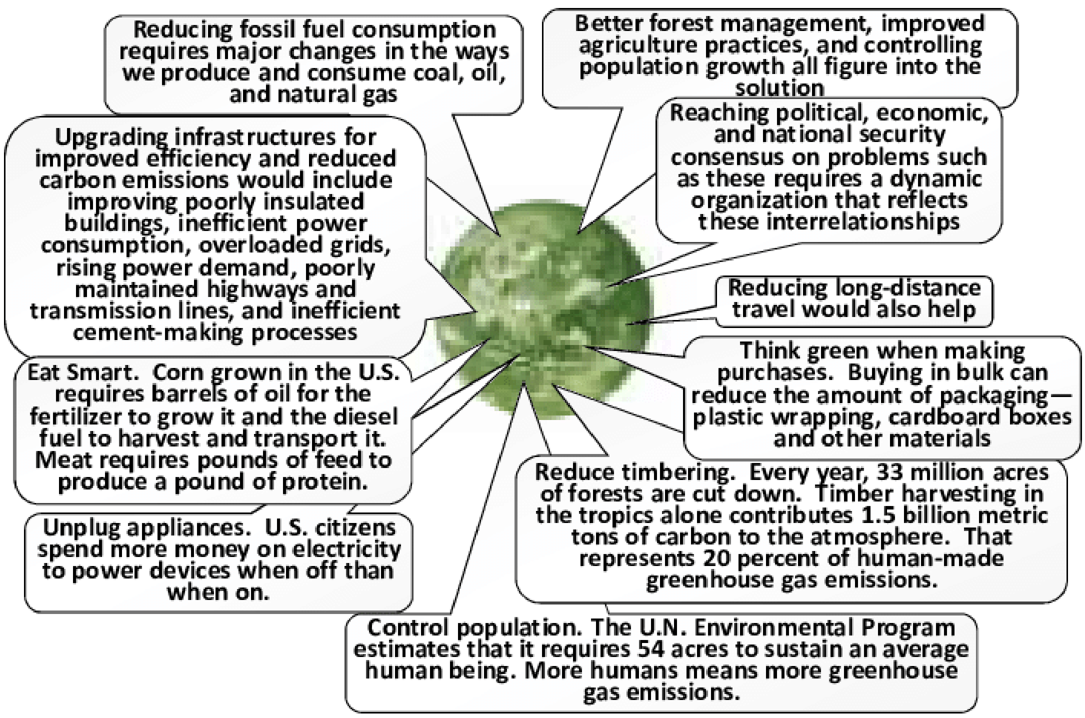


92 A hole in the ozone over the Antarctic in 2018 is almost over.

CFC molecules are highly stable and can last for up to 100 years. Unfortunately, this gives them plenty of time to find their way to the ozone layer. One chlorine molecule from a CFC can destroy up to 100,000 ozone molecules.

Possible ways of solving climatic problems:

- **Education**
- **Avoidance of bad method of farming**
- **Application of appropriate technologies**
- **Land reforms**
- **Afforestation**
- **Laws and rules**
- **Reduction of carbon dioxide emissions from industries**



Questions for discussion:

1. What would life on Earth look like if the atmosphere did not exist?
2. Do you think the Ice Age could come on the Earth? Why yes/ not?
3. Which of the climate control parameters influence the climate in Europe and Slovakia? Give some examples.
4. Imagine that you are a presenter of weather forecast on TV and prepare the weather forecast for next day. Prepare also a suitable picture.
5. Search the Internet for temperature extremes (the lowes and the highest temperature ever measured on the Earth and explain why they occurred in their particular locations.
6. What climate zone does Slovakia belong to? What are its typical features? Name other places on the Earth with the same climate, compare to Slovakia and talk about similarities and differences.
7. Explain what a tornado is and name some locations where this hazard has been a problem. Find as much information as you can about the deadly tornado in South Moravia in the Czech Republic on 24 June 2021. Discuss why the hazard occurred. Do you think tornado can occur also in Slovakia?
   Draw a labelled sketch map of the tornado. Explain why the hazard happened there. Describe how it affected people in the area.
8. Find information about extreme weather in Europe and Slovakia. Discuss why the hazards happened there.
9. Find 3 places on the earth which are best to live in. Take into account criteria such as climate, fresh water sources, fertile soil etc.
10. What is the evidence of global warming? What causes the greenhouse effect? Explain some effects of global warming. Which of the effects of global warming influence your life? Discuss the future of Slovakia if global warming continues.

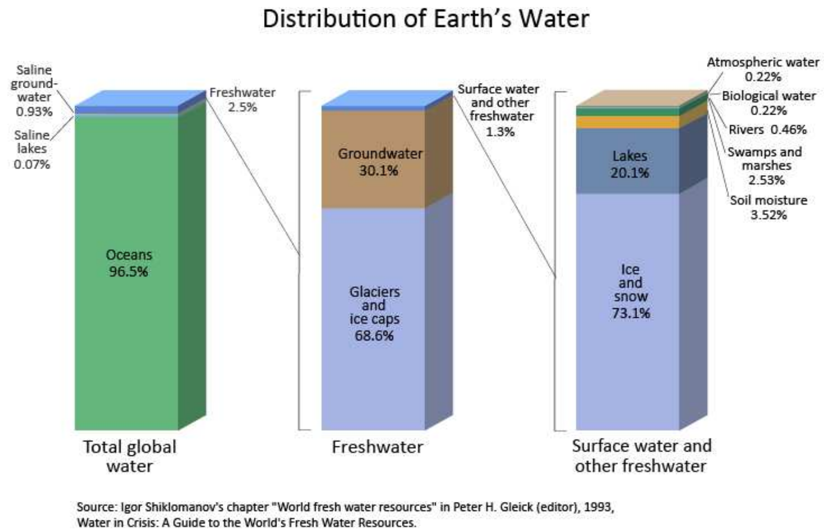
93 Slovakia faces climate change, water shortage and deforestation

5. HYDROSPHERE

The hydrosphere (from Greek *hydór*, “water „and *sphaira*, “sphere“) is the combined **mass of water** in all its forms found **on**, **under**, and **above** the surface of a planet.

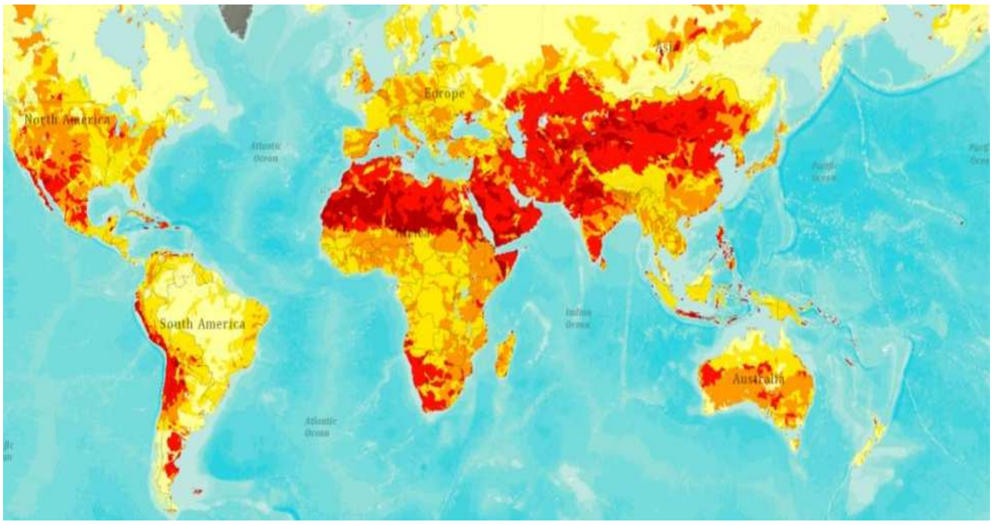
It is the whole water mass concentrated on Earth. Water can be found in various forms – in the **sea** and o**ceans, rivers, lakes, moors, soils, glaciers, under the surface and in the atmosphere.** It is one of the most important resources and inevitable for life. Its amount varies from place to place. There are places that have too little water available, whereas in some places water can cause serious disasters.

- 70% of Earth´s surface is covered by water:
- **97.47%** of water is concentrated in the oceans, **salt water.**
- **2.53%** represents **fresh water** (drinking water) on the land.
- 2/3 of fresh water is frozen into huge glaciers of Antarctica, Greenland and mountain regions.
- Only small amount of water is used as fresh liquid water (rivers, lakes and underground water).



The chart below sums up global distribution of water in some of country elements.

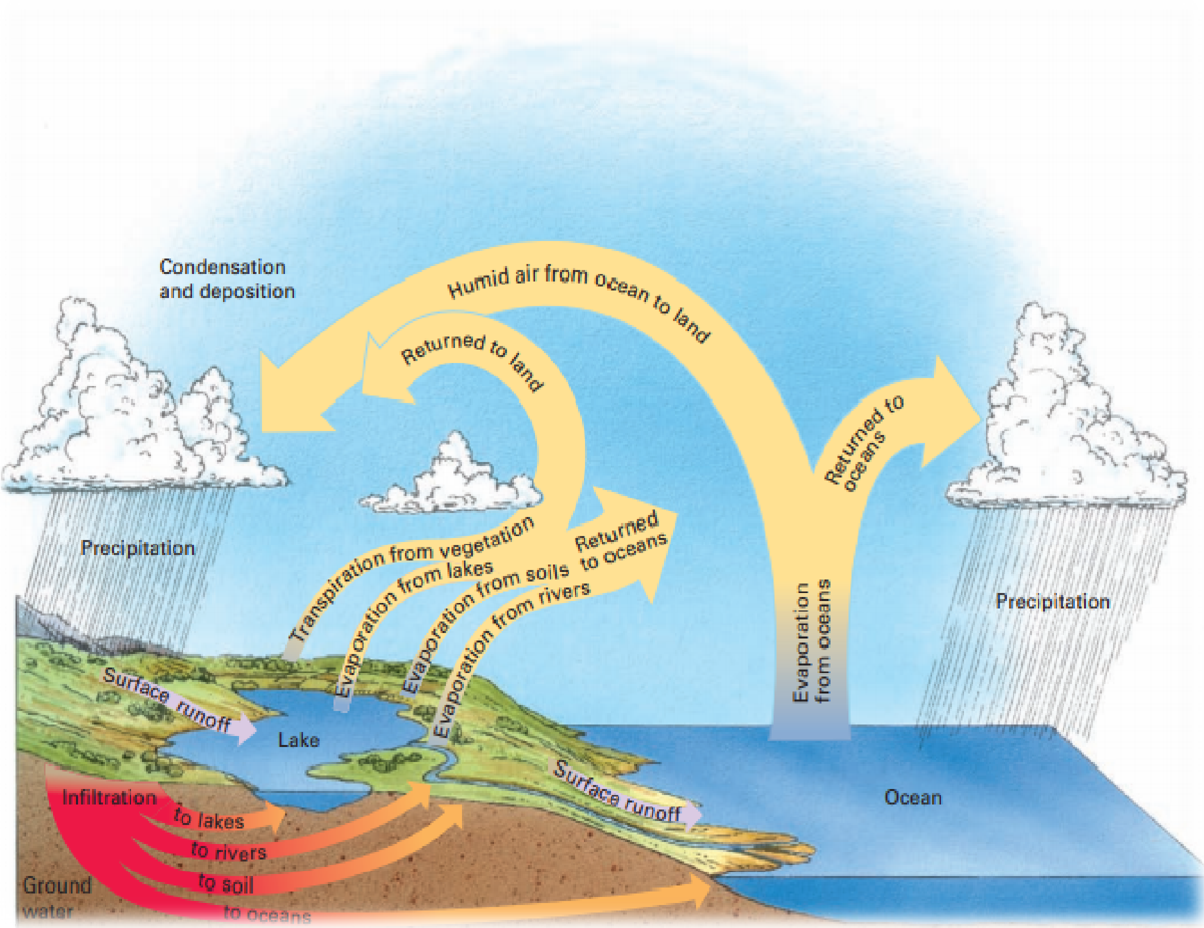
Water source	Water volume, in km	Percentage of total water
Oceans, Seas, & Bays	1,338,000,000	96.54 %
Ice caps, glaciers, permane Snow	24,064,000	1.74 %
Groundwater	23,400,000	1,69 %
Ground ice, permafrost	300,000	0,022 %
Lakes	176,400	0,013 %
Soil Moisture	16,500	0,001 %
Atmosphere	12,900	0,001 %



2 Water risks in the world.

5.1 Hydrological cycle on the Earth

The global **hydrological cycle (or the water cycle)** is the continuous movement of water between the seam the atmosphere and the land. It is a closed system, i.e. **no water is lost or gained.**



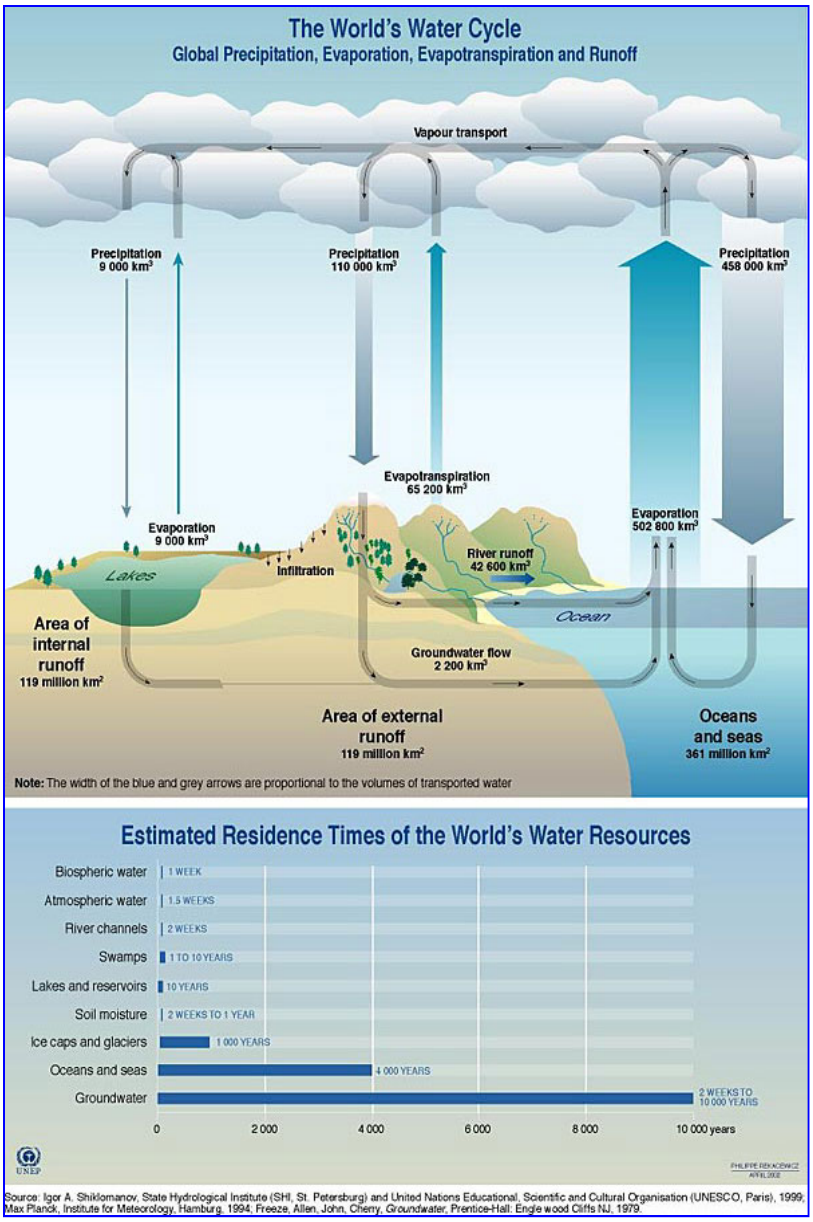
3 Hydrological cycle scheme.

When waterfalls as precipitation on land, it has two possible pathways:

1. Returns to the hydrosphere by flowing as runoff from the land surface into streams, rivers lakes, and eventually the ocean.
2. Returns to the lithosphere by infiltration into the ground becoming water or ground water.

Hydrological cycle:

1. **Precipitation** – any form of water falling from the atmosphere to the ground
2. **Condensation** – the process of changing from gas to liquid
3. **Evaporation** – the transformation of water liquid to gas as it moves from the ground or water into the atmosphere. The source of energy for evaporation is primarily solar radiation.
4. **Transpiration** – the release of water vapour from plants into the atmosphere
5. **Evapotranspiratio**n – evaporation + transpiration



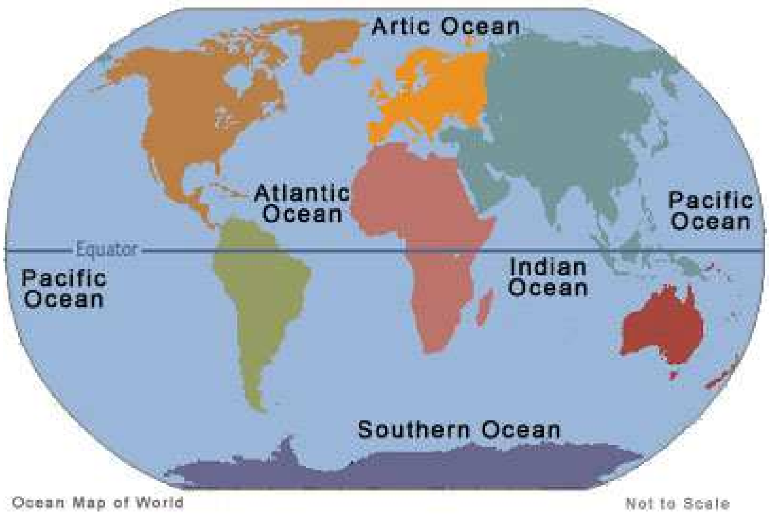
4 Global water cycle scheme.

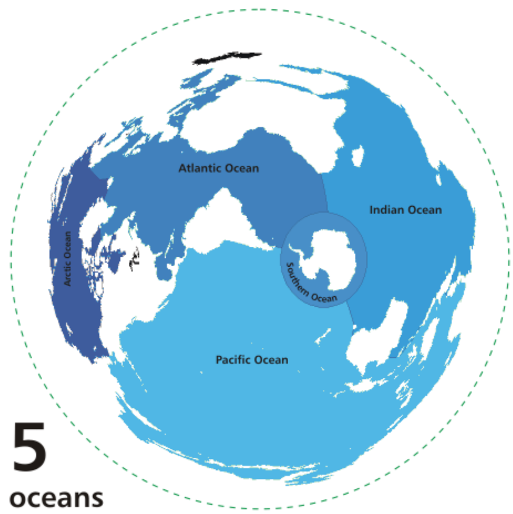
5.2 World Ocean

All the oceans and seas are actually one continuous body of water, which creates the **World Ocean**. Roughly **71%** of Earth`s surface is covered by oceans. Its average depth is about 4 km. Smaller parts of the world ocean are called oceans and seas. It is a huge heat accumulator – only 10m layer of the ocean´s water absorbs more heat than the whole atmosphere.

The world ocean is divided into **5 oceans** that spread between continents:

1. **Pacific ocean**
2. **Atlantic ocean**
3. **Indian ocean**
4. **Southern (Antarctic) ocean (of 60° southern latitude).**
5. **Arctic ocean**





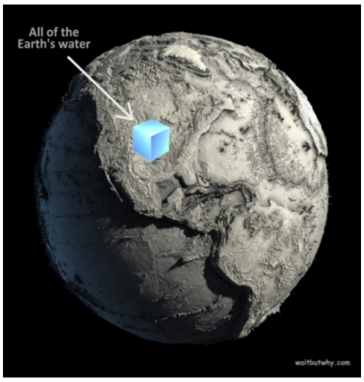
5/6 Maps of world oceans.

Some interesting facts about the oceans:

- The largest ocean on Earth is the **Pacific Ocean**, covering around **30%** of the Earth's surface.
- The deepest known area of the Earth's oceans is known as the **Mariana Trench**. It's deepest point measures 11km. That's a long dive down!
- The longest mountain range in the world is found under water. Stretching over **56,000 km**, the **Mid-Oceanic Ridge** is a mountain chain that runs along the centre of the ocean basins.
- About **70%** of the oxygen we breathe is produced by the oceans.
- The sea is home to the world's largest living structure – the **Great Barrier Reef**. Measuring around 2,300 km, it can even be seen from the **Moon**!
- We have only explored about **5%** of the world's oceans. There's a lot more to be discovered!

- The sea can be described as the planet's mega museum. There are more artefacts and remnants of history in the ocean than in all of the world's museums combined!

7 If the Earth would not be covered by oceans, it would look like the one in the picture.



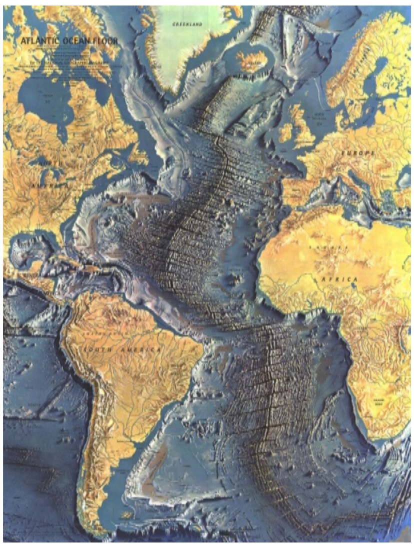
5.2.1 Pacific Ocean

The Pacific Ocean is by far the world's largest ocean at 155,557,000 km^2. It covers 28% of the Earth and is equal in size to nearly all of the land area on the Earth. The Pacific Ocean is located between the Southern Ocean, Asia, and Australia in the Western Hemisphere. It has an average depth of **4,028 meters** but its deepest point is the Challenger Deep within the **Mariana Trench** near Japan. This area is also the deepest point in the world at **-10,924 m**.
The Pacific Ocean is important to geography not only because of its size but also because it has been a major historical route of exploration and migration.

8 Great Coral Reef

5.2.2 Atlantic Ocean

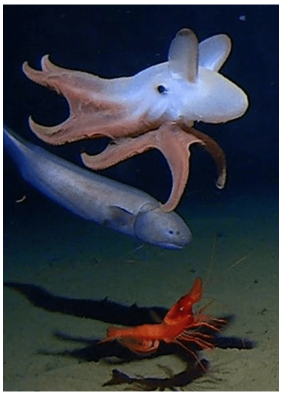
9 Mid-Atlantic Ridge.



The Atlantic Ocean is the world's second-largest ocean with an area of 76,762,000 km^2. It is located between Africa, Europe, the Southern Ocean in the Western Hemisphere. It includes the includes other water bodies such as the Baltic Sea, Black Sea, Caribbean Sea, Gulf of Mexico, Mediterranean Sea and the North Sea. The average depth of the Atlantic Ocean is 3,926 meters) and the deepest point is the **Puerto Rico Trench** -8,605 m. The Atlantic Ocean is important to the world's weather (as are all oceans) because strong Atlantic hurricanes often develop off the coast of Cape Verde, Africa and move toward the Caribbean Sea from August to November.

5.2.3 Indian Ocean

The Indian Ocean is the world's third-largest ocean and it has an area of 68,566,000 km^2. It is located between Africa, the Southern Ocean, Asia, and Australia. The Indian Ocean has an average depth of 3,963 meters and the **Java Trench** is its deepest point at -7,258 meters). The waters of the Indian Ocean also include water bodies such as the Andaman, Arabian, Flores, Java and Red Seas as well as the Bay of Bengal, Great Australian Bight, Gulf of Aden, Gulf of Oman, Mozambique Channel and the Persian Gulf. The Indian Ocean is known for causing the monsoonal weather patterns that dominate much of southeast of Asia and for having waters that have been historical chokepoints (narrow international waterways).



10 Elusive Dumbo octopus filmed in Java Trench 23,000 feet below the ocean surface.

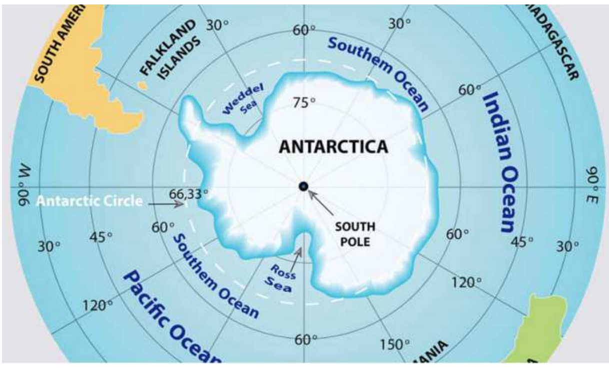
5.2.4 Arctic Ocean

The Arctic Ocean is the **world's smallest** with an area of 14,056,000 km^2. It extends between Europe, Asia and North America and most of its waters are north of the Arctic Circle. Its average depth is 1,205 meters and its deepest point is the Fram Basin at -4,665 m. Throughout most of the year, much of the Arctic Ocean is covered by a drifting polar icepack that is an average of 3 m thick. However, as the Earth's climate changes, the polar regions are warming and much of the icepack melts during the summer months. The Northwest Passage and the Northern Sea Route have been important areas of trade and exploration.

11 Sea ice in the Arctic Ocean has been melting faster in recent years due to a rise in global temperatures, which has implications for the rest of the planet and is a driver of climate change.

5.2.5 Southern Ocean

The Southern Ocean is **the world's newest** and fourth-largest ocean. In the spring of 2000, the International Hydrographical Organization decided to delimit a fifth ocean. In doing so, boundaries were taken from the Pacific, Atlantic and Indian Oceans. The Southern Ocean extends from the coast of Antarctica to 60° South latitude. It has a total area of 20,327,000 km^2 and an average depth ranging from 4,000 to 5,000 m. The deepest point in the Southern Ocean is unnamed but it is in the south end of the South Sandwich Trench and has a depth of -7,235 meters. The world's largest ocean current, the Antarctic Circumpolar Current moves east and is 21,000 km in length.



12 Everything south of 60 degrees latitudes is called the ´Southern Ocean´.

5.3 Seas

A sea is the part of an ocean that is **near to land.** It has its own circulation, is influenced by the rivers and is often shallower than oceans. According to the position, we can classify seas as:

1. **Nearly enclosed seas** – they reach deeply into continents and they are connected with the open ocean by narrow waterways called **straits**. (i.e. the Mediterranean Sea, the Baltic Sea...)

2. **Partly enclosed seas** – These seas are like the open oceans, especially in the circulation of their waters. (i.e. the Sea of Okhotsk, The North Sea...)

3. **Archipelago seas** – they are located between islands and archipelagoes (i.e. the South China Sea, the Sulu Sea...)

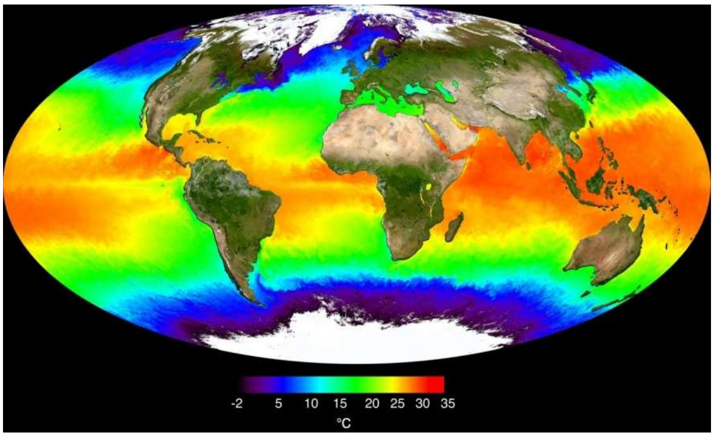
4. **Hypersaline lakes** - they were part of prehistoric oceans or seas. Tectonic shifts blocked their access to larger bodies of water and they have become completely surrounded by land (i.e. the Caspian Sea, the Dead Sea...)

5.4 Physical and chemical features of sea water.

The temperature of the oceanic water is impor-tant for marine organisms including plants (phytoplanktons) and animals (zooplanktons). The temperature of sea water also affects the climate of coastal lands and plants and animals therein. The surface temperature of the ocean water mainly depends on the latitude and season. It is to be noted that water is heated and cooled rather slowly. Moreover, the water of the ocean is constantly moving and mixing by the action of waves and currents. The most notable features include **temperature**, **salinity**, and **colour**.

5.4.1 Temperature of sea water

The ocean is heated by the sun. However, sunlight does not penetrate too deep. In fact, most of its heat rays are absorbed in the top few meters of water. Here the temperature is usually the highest. The average sea water temperature is **4°C**. At the bottom of the deepest areas in all the oceans the temperature is about 2°C. There is another difference between fresh water and sea water. Sea water freezes at **-2°C**, because it contains far more minerals than fresh water.**The more minerals, the lower the freezing point.**

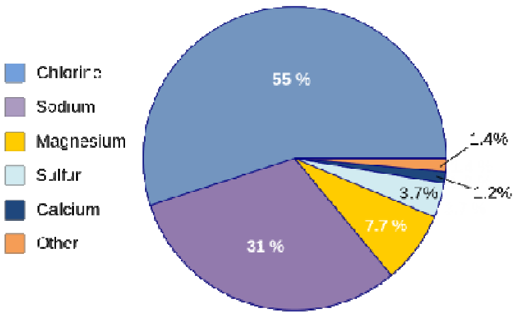


13 World´s sea temperature map.

The temperature of the ocean water decreases from the equator to the polar regions. The average water temperature at the equator reaches more than 26°C. Thus, the average surface temperature of ocean water in the equatorial region is 27°-28°C; at latitude 44°-55°, the temperature is 10°-13°C; at latitude 60°, it is 0°C; and it is below the freezing point in the polar areas. In fact, the surface water 60° latitude to the polar seas remains permanently frozen. The temperature of the sea water decreases with depth. Temperature of the water of the polar seas increases with the increase in depth. The surface water of this region forms extensive ice-fields.
The **highest** temperatures of the sea water are in **the Indian Ocean**.

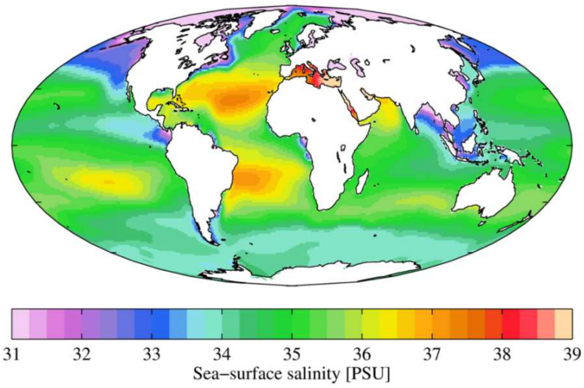
5.4.2 Salinity of sea water

We know that sea water is salty. It is seen from the chemical analysis that the sea water on the average contains 3.5% of salt it means every **1,000 grams** of sea water contains nearly **35 g** of salt. Of the total salt content in sea water, about 77 % is sodium chloride or common salt.



The term "**salinity**" means what amount of minerals (salts) 1 kg of sea water contains. In other words, how many grams of salts can be found in 1 kg of sea water if we boiled it away and water would be evaporated. Salinity is measured in **parts per thousand - per mile (‰).** The average salinity of the ocean is **35‰**. However, salinity varies. It is influenced by temperature (evaporation), rainfall, river water, freezing and melting, ocean currents etc.

The areas of lower salinity (below average) are located where large amount of fresh water enter the ocean – around the mouth of a river called estuary. **A mix of fresh water and sea water** is called **brackish water**. Salinity is lower around the Equator, too, because of heavy rainfall. Similarly, areas of lower salinity can be found in cold waters around polar circles.



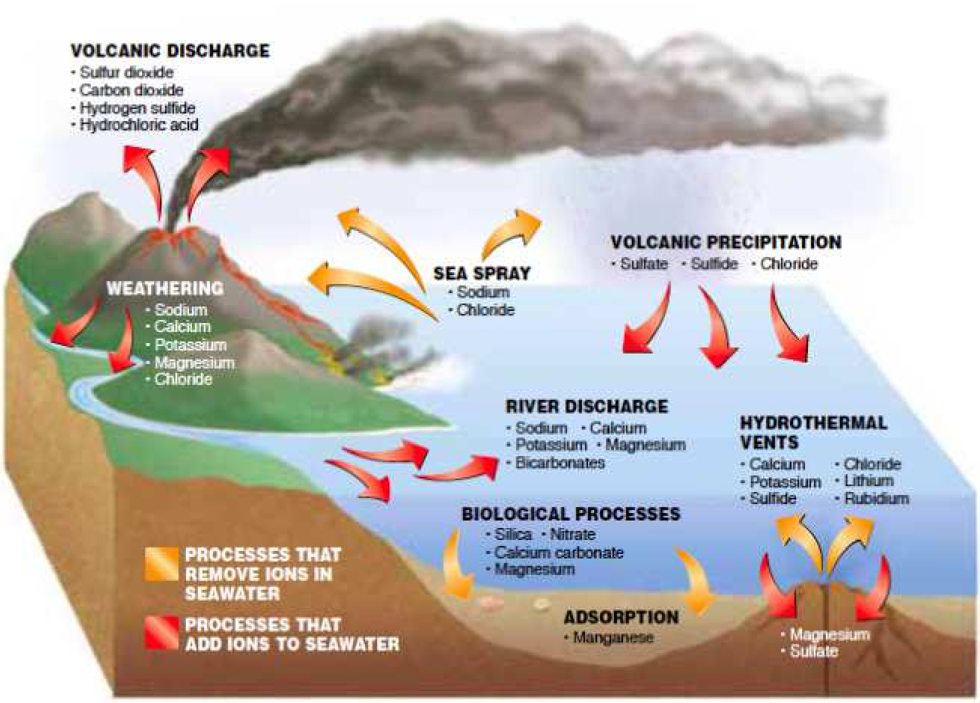
14 World´s sea-surface salinity map..

The higher figures of salinity occur in hot and dry climate. Here oceans lose much water by rapid evaporation. These areas lie between 20° and 30° of latitudes (dry tropics).

The Dead Sea has the highest salinity in the world – **up to 350 ‰**. nearly nine times the average salinity of ocean water. It is called the Dead Sea because nearly nothing can survive within it because of its salinity. Differences in water density are responsible for deep ocean currents.

15 Swimming in the Dead Sea.

Where does the salt in seawater come from?



16 Processes and substances which cause salinity of sea water.

As water moves through rock and soil on land it picks up ions. This is the flip side of weathering. Salts comprise about 3.5 percent of the mass of ocean water, but the salt content or salinity is different in different locations. In places like estuaries, seawater mixes with fresh water, causing **salinity** to be much lower than average. Where there is lots of evaporation but little circulation of water, salinity can be much higher.

5.4.3 Colour of sea water

Thought many people think that water in the oceans is blue, it is not always correct. The colour of water varies from place to place. In general, the basic water colour is blue, but in some places it can have shades of green, green-blue, brown, and white. It depends on the **distance from land**, **the depth of water**, **its temperature**, **the environment it is in**, and a kind of **material concentrated** in it.

17

Different colours of sea water.

5.5 Ocean water movement

Ocean waters are never still. They are in **permanent motion** that is caused by various factors (effect of the Sun and the Moon, temperature differences, winds, plate tectonics etc).

5.5.1 Tides

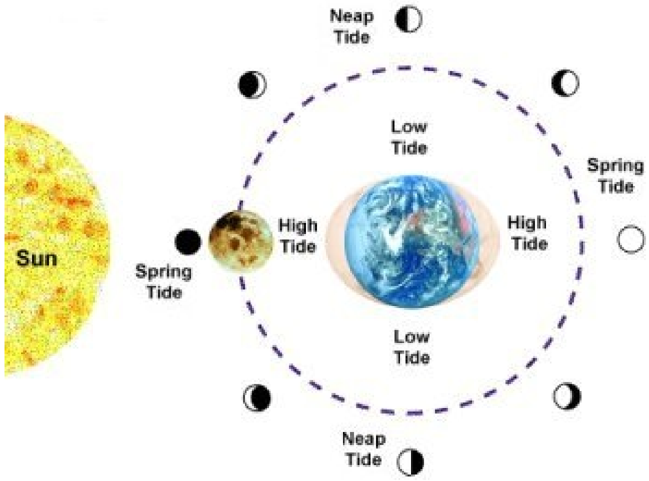
Vertical movements of water caused by the gravitational force of the Moon and the Sun. When water level lowers a low tide occurs, when level of water is rising there is a high tide.

19 Mont Saint. Michel, France – High tide

20 Mont Saint. Michele, France – Low tide

- **High** tides are when the water reaches its **highest** point. In places where there are tidal bulges, high tide is occurring along the coastlines.
- **Low** tides are when the water reaches its **lowest** point.
- **Spring** tides occur **2** times a month, during a **full** and **new** moon when the Earth, Sun, and Moon are lined up. Spring tides are **higher** and **lower** than normal tides.
- **Neap** tides occur in between spring tides, at the **first** and **third** quarters of the Moon when the Sun and Moon pull at **right** angles to each other. Neap tides are **not** as high or low as normal tides. They are **weak** tides.

21 Scheme of tides.



5.5.2 Waves

A kind of horizontal movements of water. It is transfer of energy in water itself caused by wind. Waves originate on the open ocean, approach the shore and form **swash**. Some waves are formed as a result of an undersea earthquake. We call it **tsunami** waves. They have destructive effect and cause severe disasters of the places that are hit by it.

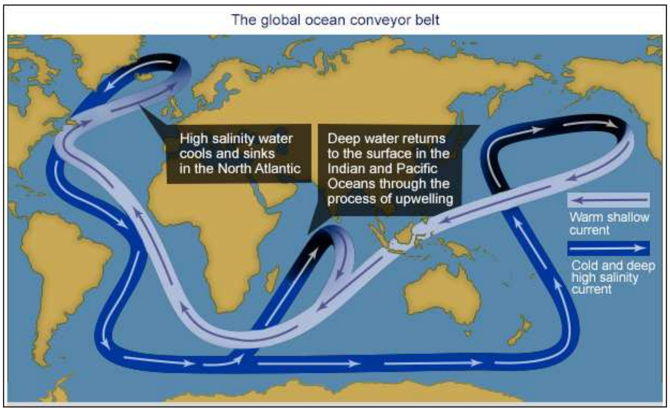
22 Tsunami, Japan

5.5.3 Ocean currents

The oceans not only have waves, tides and surface currents — they also have a constantly moving system of deep-ocean circulation driven by temperature and salinity known as the

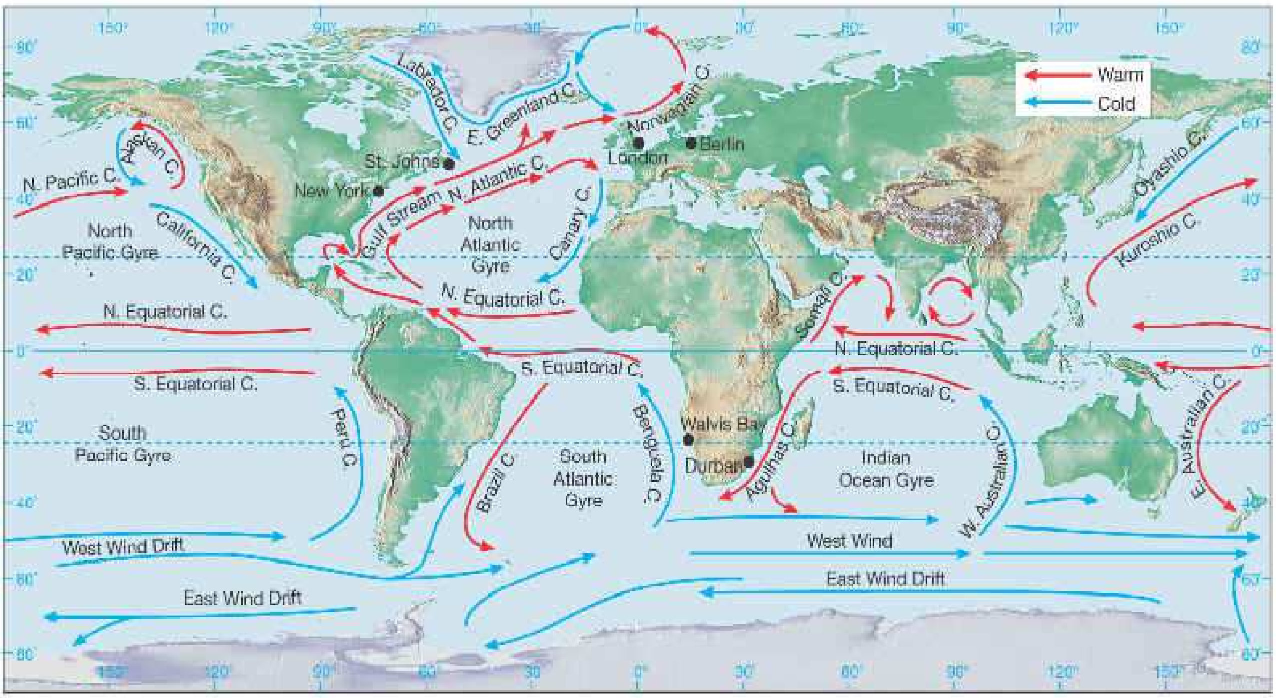
Global ocean conveyor belt. This deep ocean current gets one of its "starts" in the polar region near Norway. As sea ice forms, the water left behind becomes saltier and denser and begins to sink, making room for warmer and less dense incoming surface water, which in turn eventually becomes cold and salty enough to sink.

The cold dense water flows along the ocean bottom all the way from the northern hemisphere to the Southern Ocean where it merges with more cold dense water from Antarctica and is swept into the Indian and Pacific Oceans.
Eventually it mixes with warmer water and rises to the surface before finding its way back to the Atlantic. It can take 1000 years to complete this cycle.



23 The global ocean conveyor belt.

Currents are streams of water running through a larger body of water. The ocean's salinity and temperature and the coastal geographic features determine an ocean current's behaviour. The Earth's rotation and wind also influence ocean currents. Currents flowing near the surface transport heat from the tropics to the poles and move cooler water back toward the Equator. This keeps the ocean from becoming extremely hot or cold. The paths of ocean currents are partially determined by the Earth's rotation. This is known as the Coriolis effect. It causes large systems, such as winds and ocean currents that would normally move in a straight line, to veer to the right in the northern hemisphere and to the left in the southern hemisphere.



24 World map of ocean currents.

There are two types of them, **warm and cold** ones. All the currents have a certain direction. The driving force of their movement is **wind**.

Warm ocean currents - the Gulf Stream, the Kuroshio Current, the Brazil Current... are formed around the Equator and flow towards colder areas around the poles.

Cold ocean currents - the West Wind Drift, the Humboldt Current, the Benguela Current... have the reversed direction – they flow from higher latitudes towards the Equator.

Both types of currents significantly influence climate of a region. Warm currents make climate more temperate and bring precipitation.

25 Atacama Desert (Chile)

Gulf Stream

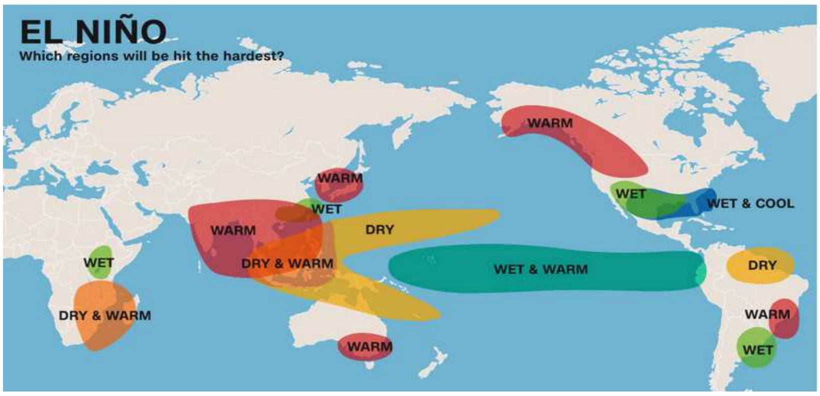
It positively influences climate of northern Europe (Iceland, Scandinavia, British Isles), whereas the places at the same latitude as Iceland (i.e. Greenland, Canada regions.) have harsher climate without much rainfall, low temperatures and glaciers. A warm surface current originates in the tropical Caribbean Sea and flows northeast along the eastern coast of the United States. The Gulf Stream is up to 80 km wide and is more than 1 km deep.

Like other ocean currents, the Gulf Stream plays a major role in climate. As the current travels north, it transfers moisture from its warm tropical waters to the air above. Westerly, or prevailing, winds carry the warm, moist air to the British Isles and to Scandinavia, causing them to have milder winters than they otherwise would experience at their northern latitudes. Northern parts of Norway are near the Arctic Circle but remain ice-free for most of the year.

26 Gulf stream map.

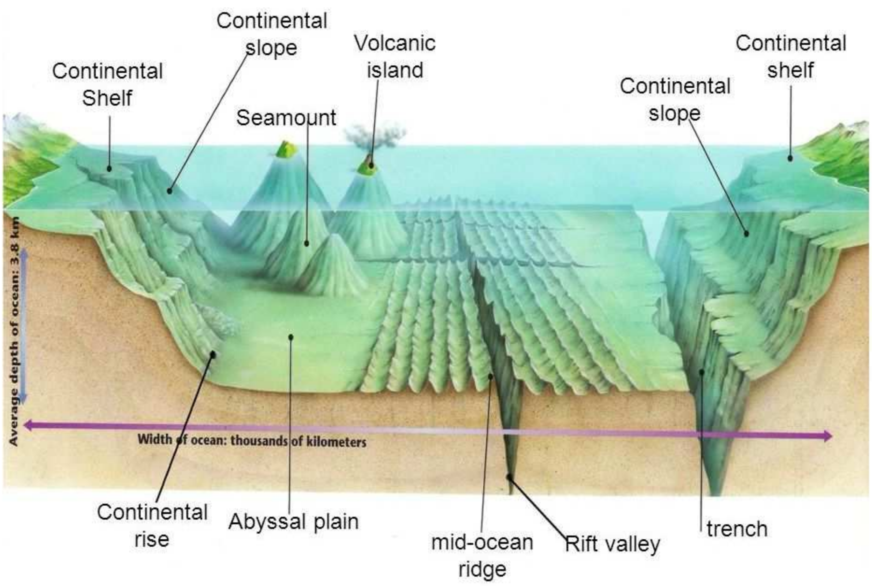
El Niño

Episodic shifts in winds and water currents across the equatorial Pacific can cause floods in the South American desert while stalling and drying up the monsoon in Indonesia and India. Atmospheric circulation patterns that promote hurricanes and typhoons in the Pacific can also knock them down over the Atlantic. Fish populations in one part of the ocean might crash, while others thrive and spread well beyond their usual territory.



27 El Niño stream map.

5.6 Features of the Ocean Floor



28 Ocean floor scheme.

As you can see from the picture, under the water level there are parts that are represented by shapes of the ocean relief. Among them we can identify:

1. **Continental shelf** – an area closest to land and up to 200 m below the water level. It gently slopes into the ocean and differs greatly in width, see the map. The shelf ends where the continental slope begins.
   A continental shelf is a portion of a continent that is submerged under an area of relatively shallow water known as a shelf sea. Much of the shelves were exposed during glacial periods and interglacial periods.

2. **Continental slope** – begins at the outer edges of the continental shelf. It is a considerably steep area. Continental slope goes down to an average depth of about 3 km.

3. **Continental rise** – is a part of the continental slope that continues gently downward. It is covered by mud and sand.

4. **Abbysal plains** – are huge areas of the ocean floor at a depth of 4000 m or more. They are flat, much flatter than any other plains on land.

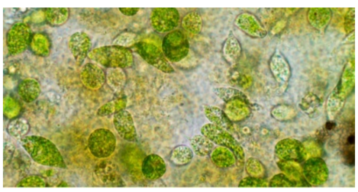
5. **Ocean ridges** – are undersea mountains. They form a nearly continuous chain that is 65 000 km long. The longest ridge is situated in the middle of the Atlantic ocean, known as the Mid-Atlantic ridge. In places where the highest peaks of ridges reach above the water level, islands are formed.

6. **Ocean trenches** – are the deepest parts of the ocean floor. They can reach the depth of a few kilometres below the usual level of the ocean floor. The most known trenches are the Marianas Trench (11 034 m), the Philippine Trench (10 545 m), the Puerto Rico Trench (8 800 m), and others.

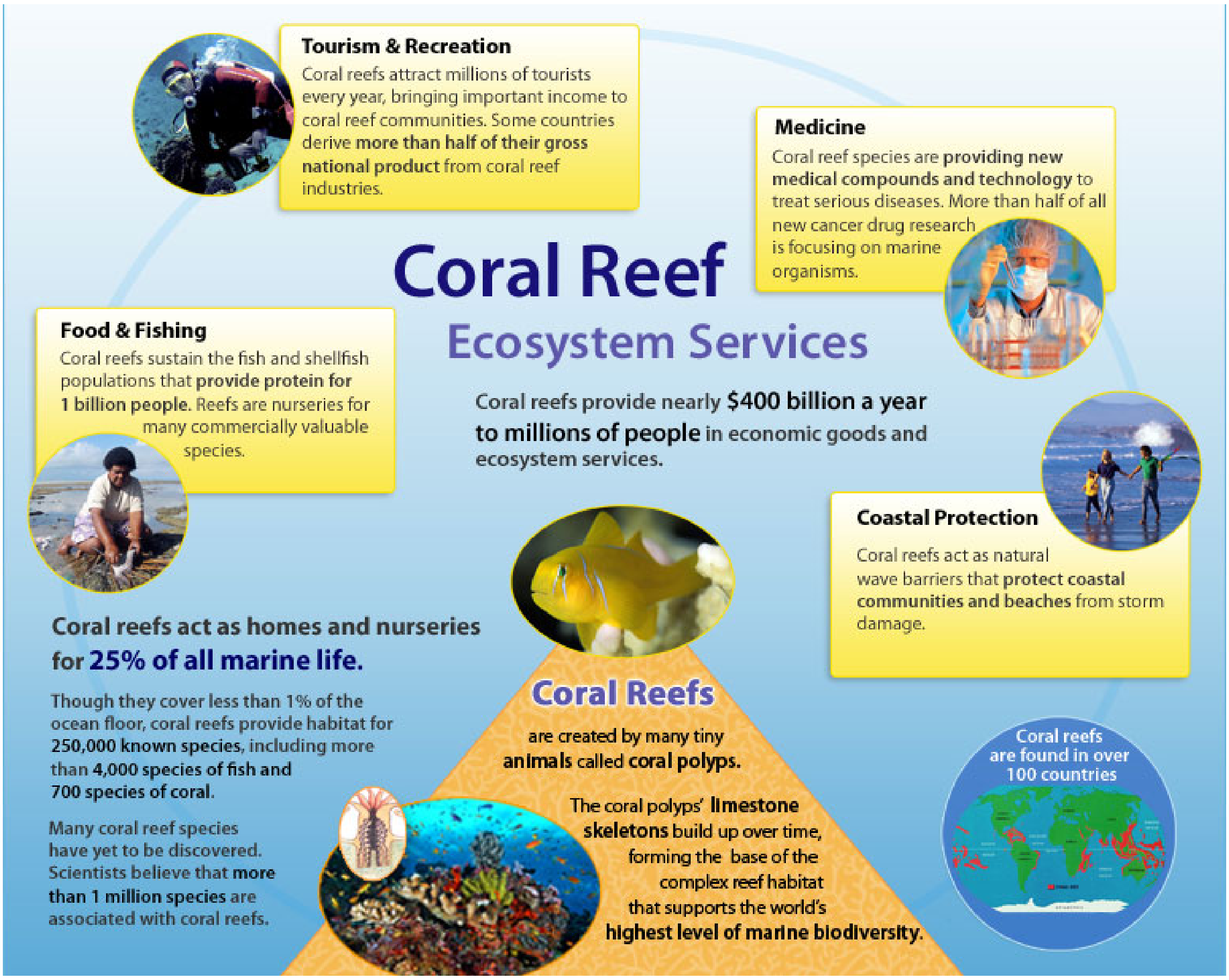
5.7 The importance of the ocean for the humans

For thousands of years, people have depended on the ocean as a source of food and as a route for trade and exploration. Today people continue to travel on the ocean and rely on the resources it contains. Ships still carry most of the world´s freight, particularly bulky goods such a s machinery, grain, and oil. Ocean ports are areas of commerce and culture. Scientists hope the ocean will be used more widely as a source of renewable energy. Some countries have already hamessed the energy of ocean waves, temperature, currents, or tides to power turbines and generate electricity.

1. The ocean regulates the Earth climate.
2. The Ocean produces more oxygen than the Amazons.
3. The source of food – fishing, seaweeds usage
4. Freight transport
5. Mining and drilling – sea salt, oil, natural gas
6. Holiday industry, tourism
7. Source of renewable energy
8. The important source of food.
9. The majority of life on the Earth..
10. The Ocean has therapeutic properties.



29 Microorganisms that drift near the surface of water tanks produce about 80% of oxygen on Earth during photosynthesis.



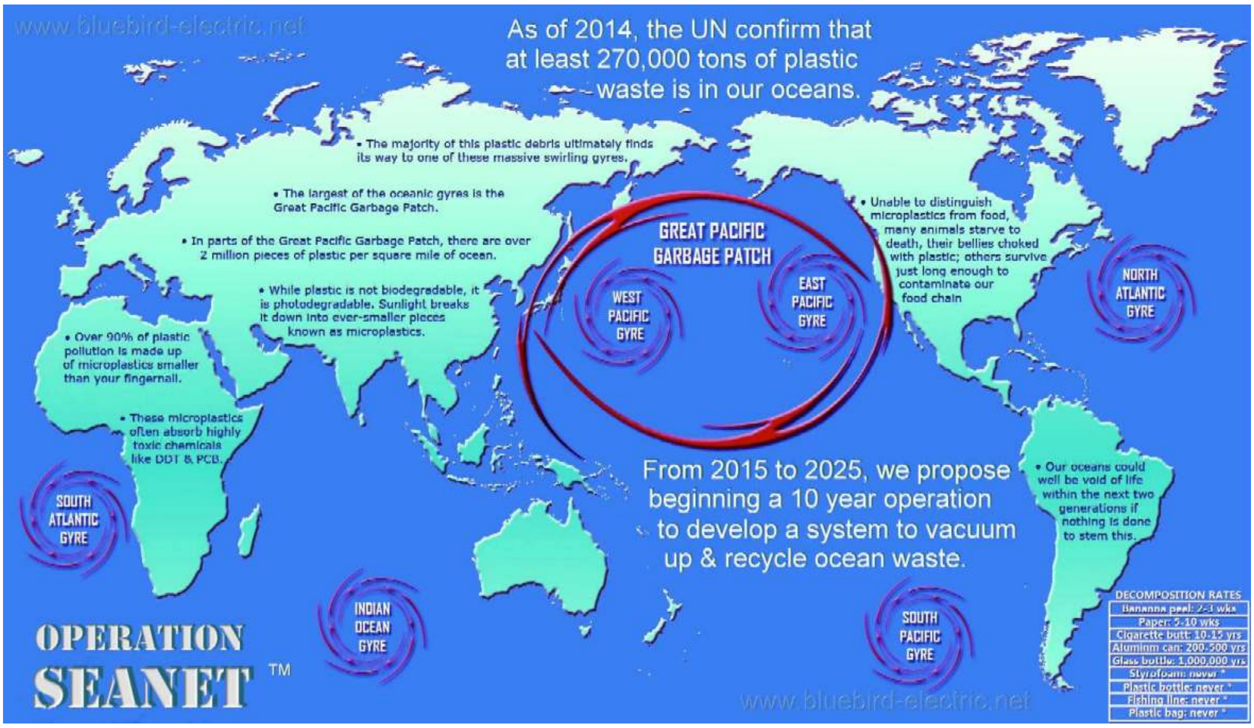
30 Importance of Coral Reef for humans.

5.7.1 Pollution of the oceans

Each year, billions of pounds of trash and other pollutants enter the ocean. **Some of the debris ends up on our beaches, washed in with the waves and tides**, some sinks, some is eaten by marine animals that mistake it for food, and some accumulates in ocean gyres. Other forms of pollution that impact the health of the ocean come from a single, known sources, such as **oil spills**, or from accumulation of many dispersed sources, such as **fertilizer from our yards**.

Another source of pollution is **plastics**. Most ocean debris, or garbage, is plastic thrown out by consumers. Plastics such as water bottles, bags, six-pack rings, and packing material put marine life at risk. Sea animals are harmed by the plastic either by getting tangled in it or by eating it.

An example of marine pollution consisting mainly of plastics is the Great Pacific Garbage Patch. The **Great Pacific Garbage Patch** is a floating dump in the North Pacific Ocean. It's about twice the size of Texas and probably contains about 100 million tons of debris. Most of this debris comes from the western coast of North America (the U.S. and Canada) and the eastern coast of Asia (Japan, China, Russia, North Korea, and South Korea). Because of ocean currents and weather patterns, the patch is a relatively stable formation and contains new and disintegrating debris. The smaller pieces of plastic debris are eaten by jellyfish or other organisms, and are then consumed by larger predators in the food web. These plastic chemicals may then enter a human's diet through fish or shellfish.



31 Great Pacific Garbage Gyre Patch.

Another source of pollution is **carbon dioxide**. The ocean absorbs most carbon dioxide from the atmosphere. Carbon dioxide, which is necessary for life, is known as a greenhouse gas and traps radiation in the Earth's atmosphere. Carbon dioxide forms many acids, called carbonic acids, in the ocean. Ocean ecosystems have adapted to the presence of certain levels of carbonic acids, but the increase in carbon dioxide has led to **an increase in ocean acids**. This ocean acidification erodes the shells of animals such as clams, crabs, and corals.

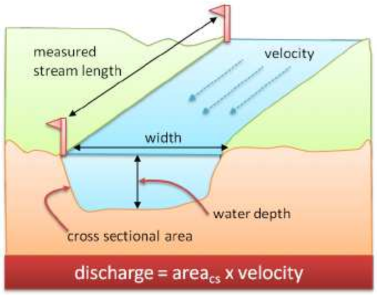
Global warming contributes to rising ocean temperatures and sea levels. Warmer oceans radically alter the ecosystem. Global warming causes cold-water habitats to shrink, meaning there is less room for animals such as penguins, seals, or whales. Plankton, the base of the ocean food chain, thrives in cold water. Warming water means there will be **less plankton available for marine life to eat**.

Melting glaciers and ice sheets contribute to **sea level rise**. Rising sea levels threaten coastal ecosystems and property. River deltas and estuaries are put at risk for flooding. Coasts are more likely to suffer erosion. Seawater more often contaminates sources of fresh water. All these consequences—**flooding, erosion, water contamination**—put low-lying island nations, such as the Maldives in the Indian Ocean, at high risk for disaster.

To find ways to protect the ocean from pollution and the effects of climate change, scientists from all over the world are cooperating in studies of ocean waters and marine life. They are also working together to control pollution and limit global warming.

5.8 Water on land

Water on land is all the water concentrated on land, especially in rivers, lakes, marshes, reservoirs, glaciers, snow, soil, and underground.

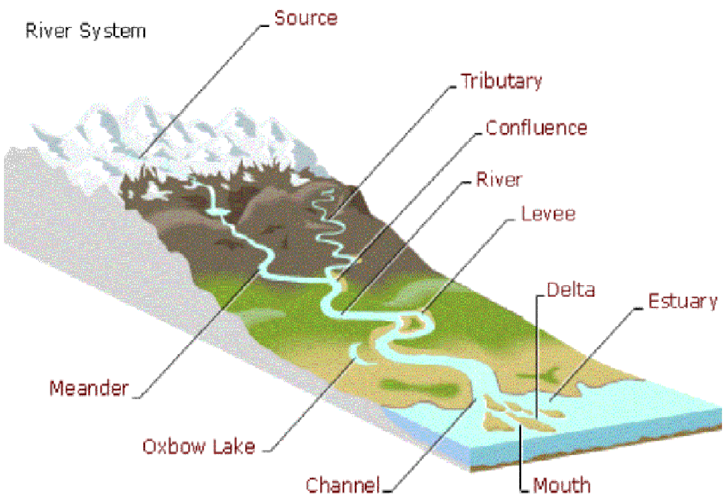


Discharge
Discharge is the volume or amount of water that river contains at any time. The greater the discharge, the more effectively a river will be able to erode and transport material.

Velocity
The greater river velocity or speed , the more effectively a river will be able to erode and transport materials. River velocity depends on **slope gradient**, **discharge**, **shape and roughness** of the river channel. The steeper the river course, the faster a river will flows as well the greater the amount of water, the faster a river flows.

5.8.1 River processes

Water is one of the most important modifiers of the landscape. Both, rivers and seas/ oceans model the shape of the earth´s surface. They create fluvial and coastal landforms.



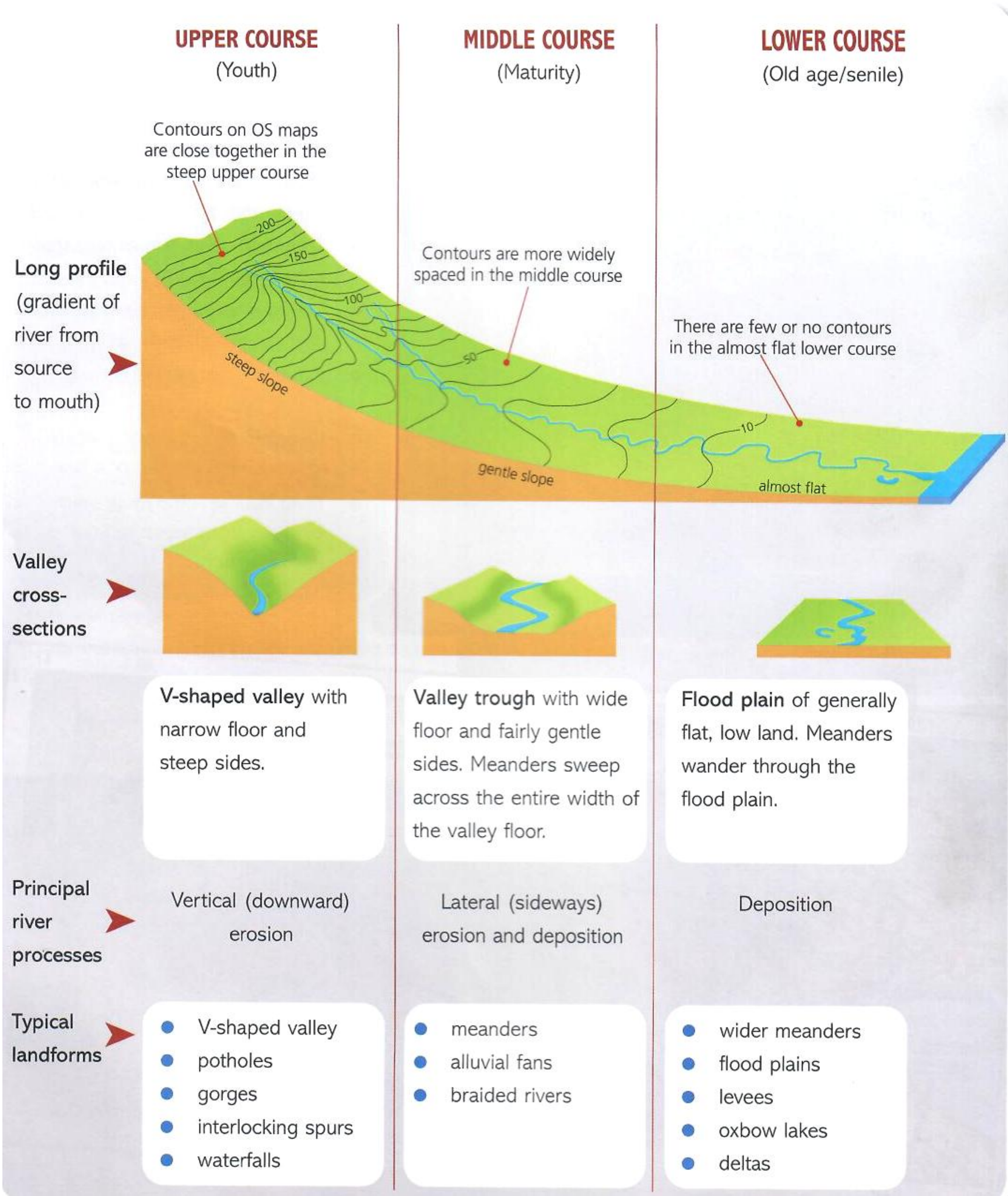
32 Parts of the river system.

Rivers are natural systems filled with running water. A stream (a creek, a brook) is a small body of water, smaller than a river. Both rivers and streams have their tributaries that flow into them. The area that is drained by a river and its tributaries, altogether with ground water is called a drainage basin. The borderline between two basins is called watershed or divide. It is like a top of a roof dividing water between two sides of it. Rivers with streams and lakes create a hydrographical network of an area.

Erosion, **transportation** and **deposition** all occur in a river. Moving from the upper course to the lower course, the rates of erosion, transportation and deposition change.

The Three Stages of a River

The courses of some rivers show three distinct stages: the **upper** or **youthful** course; the **middle** or **mature** course and the **lower** or **old age** course. The main characteristics of each of these stages are shown below.



33 Stages of the river.

5.8.2 Fluvial landforms

V-shaped Valleys and Interlocking Spurs

V-shaped valleys are found in a river's upper course where vertical erosion is dominant. The river will erode (cut) downwards while the sides are weathered (attacked by the weather e.g. rain, wind and the sun). The weathered material will then fall into the river and be transported away leaving a v-shaped valley.
Interlocking spurs are the areas of the valley (hills) that stick out into the river forcing it to meander around them.

Deltas

When a river meets the sea its velocity suddenly reduces. This reduction in velocity means that much of the rivers load is deposited at the mouth of the river. If the river deposits quicker than the sea can erode then a delta starts to develop. Deposition can mean that the main river channel gets blocked, forcing the water to find alternative routes to the sea by making distributaries. Deltas have very fertile soil and tend to be excellent for farming.

34 The Ganges Delta is the largest delta in the world.

Levees

A levee is a natural or artificial wall that blocks water from going where we don't want it to go. Levees may be used to increase available land for habitation or divert a body of water so the fertile soil of a river or sea bed may be used for agriculture. They prevent rivers from flooding cities in a storm surge. But if a levee breaks, the consequences can be disastrous.

35 Natural levees of the river.

Meanders and Ox-bow lakes

Meanders: A meander is simply a bend in the river. If a river is very bendy it is said to be sinuous. A meander starts to form when the thawed moves to one side of the river channel. This causes greater erosion on one side of the channel and deposition on the other. Over time the erosion and deposition will cause the river to bend. Meanders are constantly moving and over long periods of time widen the floodplain.

36 Domašínsky meander, Slovakia

Oxbow lakes: Oxbow lakes are created when two meanders join. The river will often finally connect the two meanders during a flood event when the river is more powerful. The thawed then shifts to the centre of the river (and does not travel around the old meander) causing deposition on the outside of the river channel cutting off the old meander and creating an oxbow lake.

37 Oxbow lake, India

Floodplains

Floodplains are simply the areas of land that rivers flood onto when they exceed bank full discharge. The constant movement of meanders creates floodplains. Because horizontal erosion is more dominant in a rivers lower course, floodplains tend to be a lot wider in a river's lower course. If you live on a floodplain you are at risk of being flooded. However, they also make great farmland because of alluvial deposits.

37 Northampton plain, England

Alluvium: Mineral rich load that is deposited on floodplains in times of flood. Alluvium is essential to keep farmland fertile.

Terraces

Bench or step that extends along the side of a valley represents a former level of the valley floor. A terrace results from any hydrological or climatic shift that causes renewed down cutting. It generally has a flat top made up of sedimentary deposits and a steep fore edge and it may be the remains of an old floodplain, cut through by the river and left standing above the present floodplain level. Another type of terrace is cut into bedrock and may have a thin veneer of alluvium, or sedimentary deposits. In paired terraces, the terrace features on each side of a valley correspond.

38Terraces of the river.

Alluvial fan

Alluvial fans are usually created as flowing water interacts with mountains, hills, or the steep walls of canyons. Streams carrying alluvium can be trickles of rainwater, a fast-moving creek, a powerful river, or even runoff from agriculture or industry. As a stream flows down a hill, it picks up sand and other particles - alluvium.

39 Bad Water, Death Valley, USA.

Canyons

The movement of rivers, the processes of weathering and erosion, and tectonic activity create canyons. The water pressure of a river can cut deep into a river bed. Sediments from the river bed are carried downstream, creating a deep, narrow channel.

40 Grand Canyon, USA.

Gorge

Gorge is a deep, narrow passage that usually has a river running through it.

41 Veľký Sokol gorge, Slovakia

Potholes

Potholes are cylindrical holes drilled into the bed of a river that vary in depth & diameter from a few centimetres to several metres.

41 Pothole landforms.

Waterfalls

A waterfall is a sudden drop along the river course. It forms when there are horizontal bands of resistant rock (hard rock) positioned over exposed, less resistant rock (soft rock).

42 Angel Falls, Venezuela, the world’s highest uninterrupted waterfall

5.8.3 Water on the land

43 Moorland, Scotland

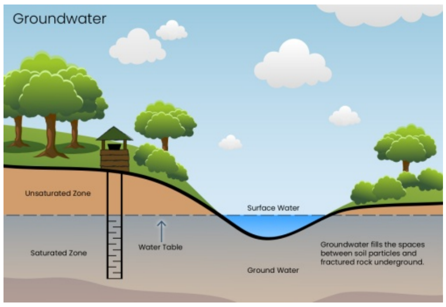
Rainfall – the only source of water on the Earth.

Surface water:

- rivers, streams, brooks
- lakes
- dams
- moors
- glaciers
- snow

Groundwater:

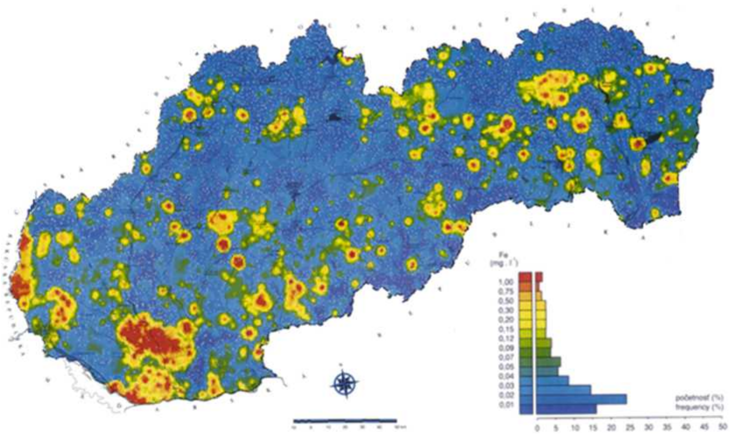
- undergroundwater
- soil water



Rivers are very important humans as well for biodiversity. They keep water drain to the seas and oceans:

79% of land – drained zones

21% of land – endorheic zones

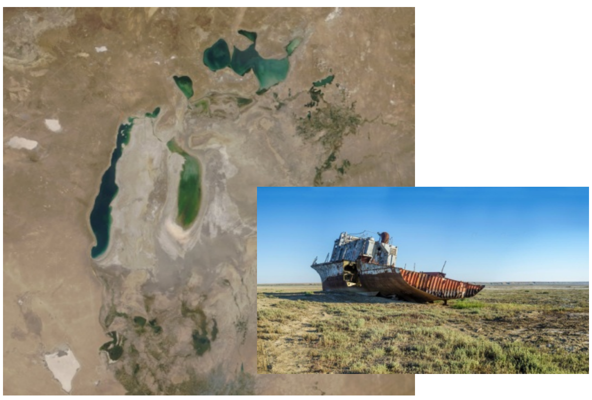


44 Groundwater – The important source of drinking water in Slovakia .

Endorheic zones are the zones without outflows:

45 Caspian Sea

46 Aral Sea



47 Dead Sea

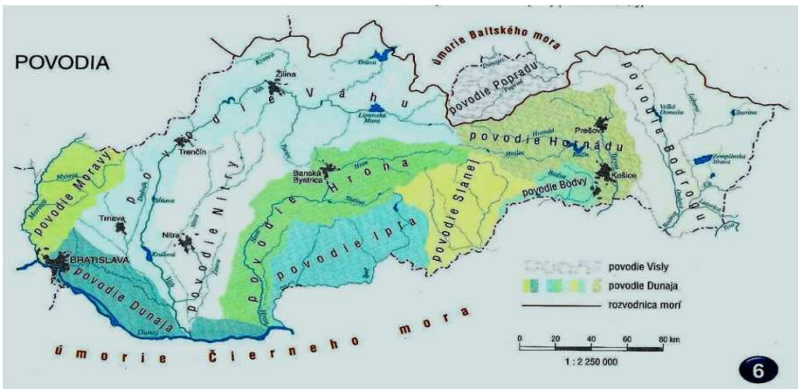
5.8.4 The drainage basin

The drainage basin is any area of land where precipitation collects and drains off into a common outlet, such as into a river, bay, or other body of water as well underground water.

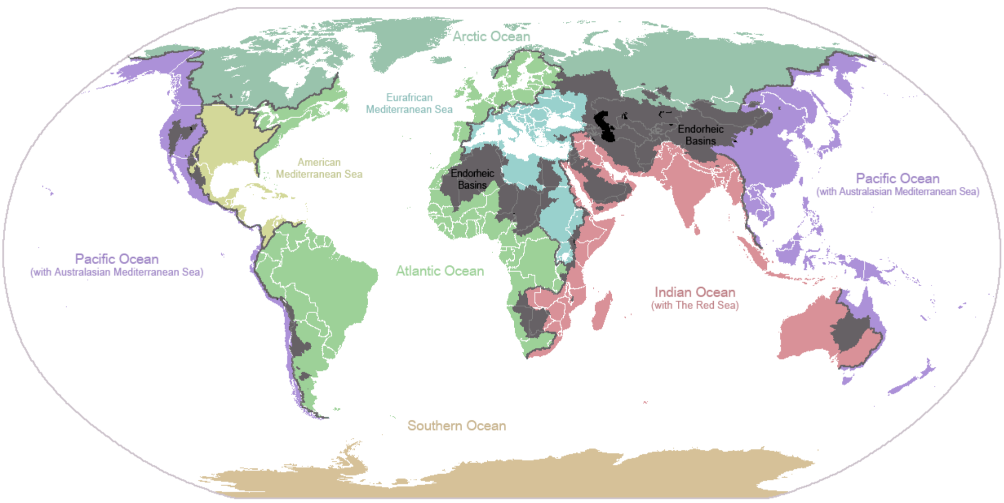
The Black Sea Basin

49 The Danube basin

50 Drainage basins of Slovakia



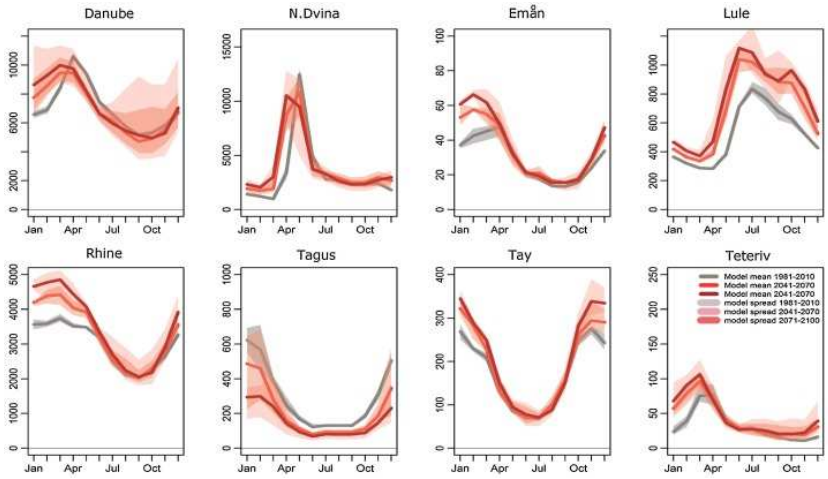
51 World drainage zones.



5.8.5 Hydrological regime of a river

River regime is the variation discharge (cubic metres per second (passing a certain point in the river) throughout a year. The amount of water in rivers throughout the year is not the same. It is influences by a few factors, for example **the amount and intensity of rain**, **snow**, **infiltration of rocks and soils**, **vegetation** etc.

- **Equatorial** (Amazon, Congo) **–** the same amount of the water for whole year
- **Seasonal / monsoonal** (Mekong) **-** large discharge in summer, minimum in winter
- **Snowy-rainy –** Siberian and Canadian rivers **–** water mainly from melting snow – Ob, Yenisei
- **Oceanic-** Thames
- **Rainy** – maximum discharge in the end of winter
- **Mountain snowmelt- rainy** (Danube) **–** maximum in April and May (melting snow)
- **Glacial (**Rhone) – maximum discharge in summer (melting snow and ice)
- **Snowy lowland rivers of Eastern Europe rivers**



52 Hydrological regimes of rivers.

5.8.6 The world longest rivers

53 The Amazon river – the river with the largest drainage basin.

The largest rivers in the world with catchment areas (uploaded by R. Berndtsson, ReaserchGate internet source):

River	*Catchment area (km^2)*	*Annual average discharge (m^3/s)*
Amazon	7,180,000	220,000
Kongo	4,014,500	39,600
Yangtze	1,942,500	22,000
Brahmaputra	935,000	19,800
Ganges	1,059,300	18,700
Jenisej	2,590,000	17,400
Mississippi	3,221,400	17,300
Orinoco	880,600	17,000
Lena	2,424,200	15,500
Parana	2,305,100	14,900
St. Lawrence	1,289,800	14,200
Irrawaddy	429,900	13,600
Ob	2,483,800	12,500
Mekong	802,900	11,000

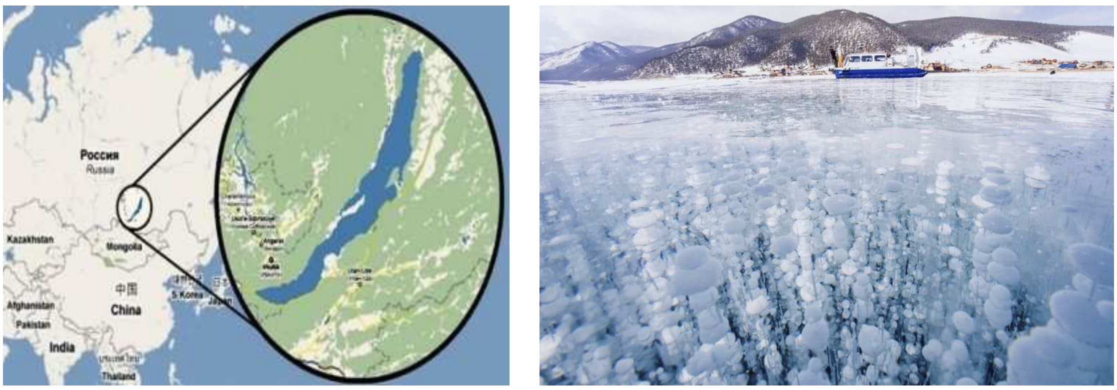
5.8.7 Lakes

A lake can be classified as a **natural depression filled with water.** It is not part of the ocean and is surrounded by land. Most of the lakes are fresh water, but there are some that contain salty water (i.e. The Dead Sea, The Caspian Sea).

There are several **types of lakes** according to how they originated:

1. **Tectonic lakes** – Lake Baikal, Lake Tanganyika, Lake Balaton, Dead Sea, Loch Ness etc.

   They were formed by tectonic processes, for example uplift of a mountain range, depression in the earth`s crust, areas of rifts etc.



54 Lake **Baikal**, a rift lake, Russia, the world´s deepest lake, max. depth 1,642m

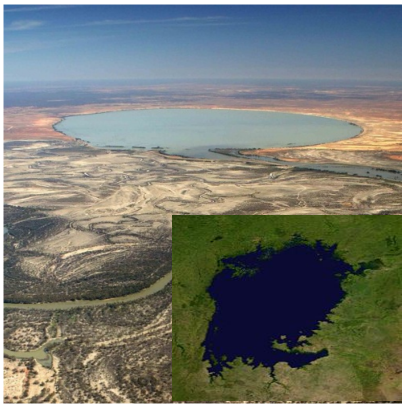

55 **Tanganyika**, East African rift – contiguous geographic trench, the world´s second largest, deepest and oldest, – max. depth 1,470m

2. **Glacial lakes – tarns**, lakes in Finland, Canada, Siberia, Slovakia etc.
   They were created by advancing glaciers that made a depression and those were filled with fresh water.

56 **Veľké Hincovo pleso**, the biggest and deepest mountain lake of glacial origin in the High Tatras, Slovakia. The maximum depth is 53m.

3. **Volcanic lakes** – Lake Victoria (Ukerewe), Crater Lake, etc.
   They are situated in volcanic craters and were created by volcanic eruptions.

57 **Crater Lake**, south-central Oregon, the United States



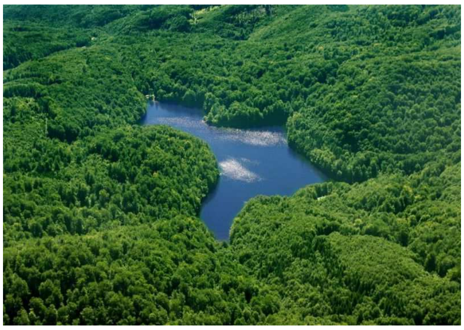
58 **Victoria lake**, Eastern Africa

4. **Oxbow lakes** – were formed as a river created meanders that were later detached from the river. They often have the shape of "U".


59 Oxbow lakes

5. **Landslide lakes** – Landslide Lake, Morské oko in Vihorlat, etc.
   These lakes originated when a mass of land slided down and blocked a river or stream.

60 Morské Oko Lake, Vihorlat, Slovakia



5.8.8 Artificial water reservoirs

They were created by man to store water. Their typical feature is **a dam**. They have different **functions**, for example water supply, irrigation, production of electricity, flood control, fishing or recreation.

1. **Taichy – artificial water reservoirs of Banská Štiavnica**

First water reservoirs were created as early as the beginning of the 16th century. Miners built an incredible water scheme composed of sixty interconnected water reservoirs, supplying energy for prosperous mining. Twenty-four of them remained, conjoined with nature.

61 Taich Klinger

62 Kopanický Mderštôlniacky taich

2. **Dams**

Structure built across a stream, a river, or an estuary to retain water. Dams are built to provide water for human consumption, for irrigating arid and semiarid lands, or for use in industrial processes. They are used to increase the amount of water available for generating hydroelectric power, to reduce peak discharge of floodwater created by large storms or heavy snowmelt, or to increase the depth of water in a river in order to improve navigation and allow barges and ships to travel more easily. Many dams are built for more than one purpose; for example, water in a single reservoir can be used for fishing, to generate hydroelectric power, and to support an irrigation system. Water-control structures of this type are often designated multipurpose dams.

63 **Three Gorges** Dam, the Yangtze River, China, the most efficient hydroelectric power station in the world

64 Gabčíkovo Dam and hydroelectric power station, the Danube River, Slovakia

65 **Starina** reservoir is a water reservoir in eastern Slovakia, Snina District, located in the Poloniny National Park. It is the most important source of **drinking water** in the area.

3. Ponds

Lakes and ponds are a great place for fishing.

66 Skalica ponds, Slovakia

4. Recreation areas

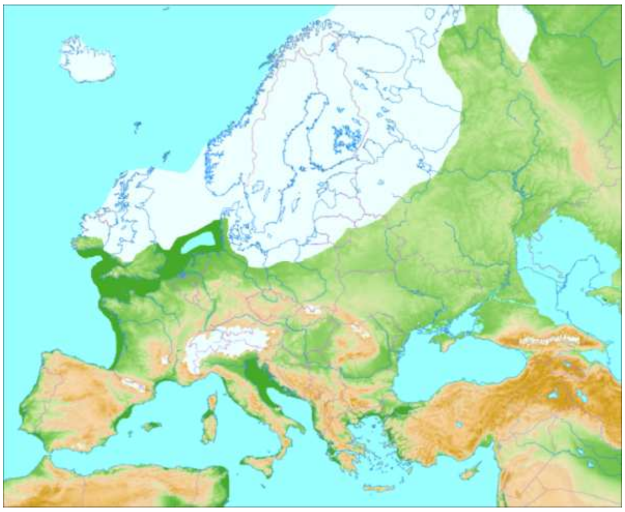
Recreation areas are lakes used as a natural swimming pool.

66 The largest Slovak recreational and sporting resort is **Zlat**é **Piesky** in Bratislava.

67 Liptovská Mara dam

5.8.9 Glaciers

About 20,000 years ago, ice covered much of the continent of Europe, including most of the United Kingdom. Ice joined the UK to the rest of Northern Europe. Ice spreads out during glacial periods and gets smaller during warm interglacials. Glaciers also grow and shrink with seasonal changes in temperature. About 20,000 years ago, ice covered much of the continent of Europe, including most of the United Kingdom. Ice joined the UK to the rest of Northern Europe and it has covered different areas in the past due to glacial periods and interglacials. Ice spreads out during glacial periods and gets smaller during warm interglacials. Glaciers also grow and shrink with seasonal changes in temperature.



68 Ice cover of Europe 20,000 years ago

Glaciers develop over many years in places where snow has fallen but not melted. Snow is compacted and turns to ice. The weight of the ice means that it starts to slip down mountain sides over time. A **glacier** is a large mass of ice often shaped like a river that flows very slowly, under the force of gravity. Together with snow cover, glaciers are the most important **source of fresh water** in the world. The area of glaciers is smaller every year because of the **global warming**. Thus, glaciers are among the most sensitive indicators of climate changes and have a serious impact on some coastal regions.

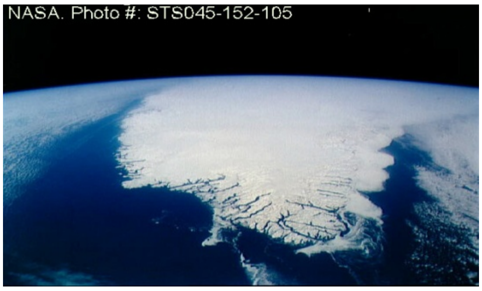
There are 2 types of glaciers:

1. **Mountain (Alpine) glaciers**
   They are located above the snow line – an area where snow does not melt during the year, it is permanent. We can find them in the highest mountain ranges in the world, for example the Himalayas, the Alps, the Andes, the Rocky Mountains etc. In Slovakia, we have no permanent glaciers.

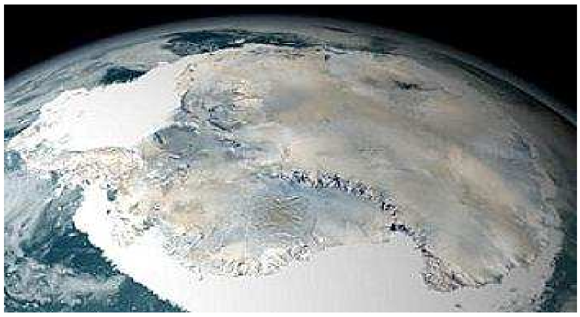
69 The Baltoro Glacier in the Karakoram, Baltistan, Northern Pakistan. At 62 kilometres in length, it is one of the longest alpine glaciers on earth.

70 Alpine glacier.

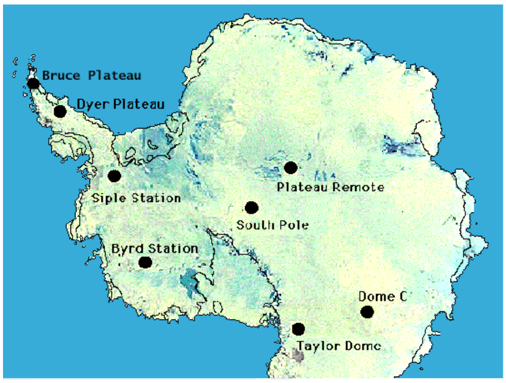
2. **Continental glaciers - ice sheets**
   They include 97% of all the glaciers on Earth. They are located in polar regions and form vast areas of glacial regions. The only current ice sheets can be found in **Antarctica and Greenland.**



71 Ice sheet in Greenland.

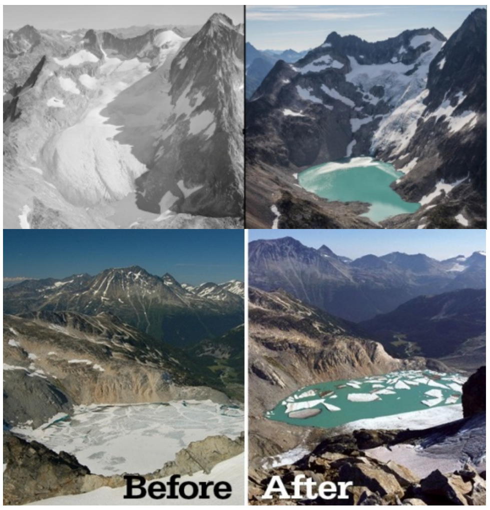


72 Ice sheet in Antarctica.



73 The world´s largest glacier is Lambert Glacier, located in Antarctica, measuring approximately 100km wide, 400km long and 2.5km deep.

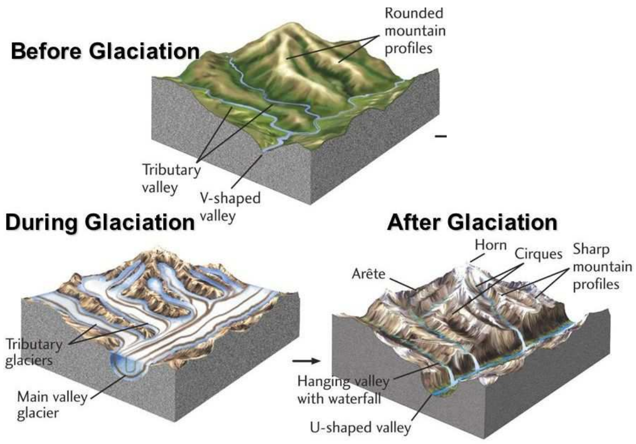
Global warming consequences:



74 Melting glacier, before and after.

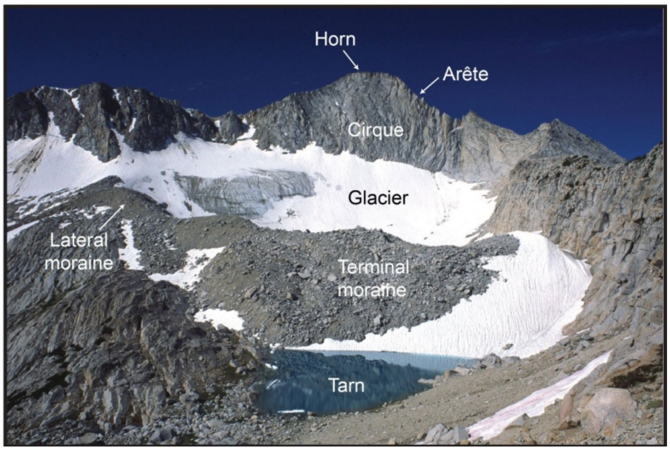
5.8.9.1 Glacial processes and landforms

Glaciers shape the land through processes of weathering, erosion, transportation and deposition, creating distinct landforms.



75 Glacial processes and landforms scheme.

Glacial landform is any product of flowing ice and melt water. Such landforms are being produced today in glaciated areas, such as Greenland, Antarctica, and many of the world's higher mountain ranges. In addition, large expansions of present-day glaciers have recurred during the course of Earth history. Glaciers carve a set of distinctive, steep-walled, flat-bottomed valleys. U-shaped valleys, fjords, and hanging valleys are examples of the kinds of valleys glaciers can erode.



76 Some glacial landforms.

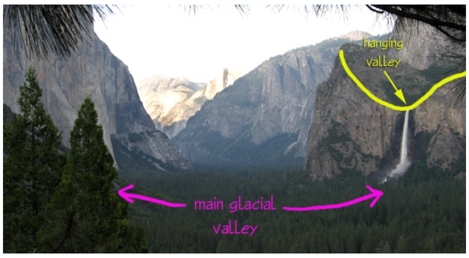


77 Arete landform

78 Cirque with turn

79 Erratic landform

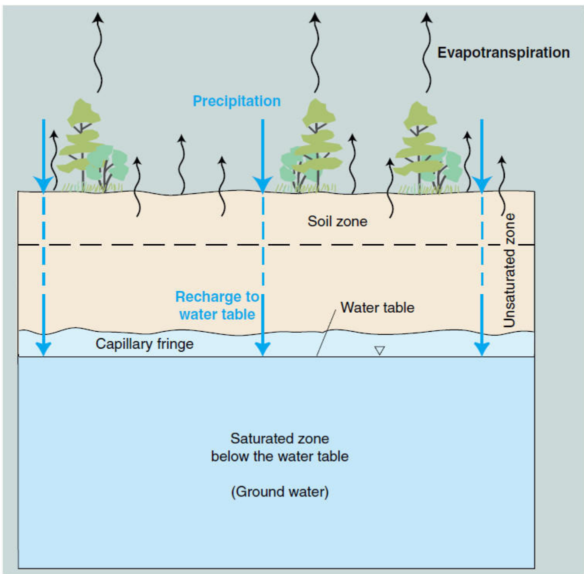
80 Hanging valley with waterfall



81 Fjords (Norway)

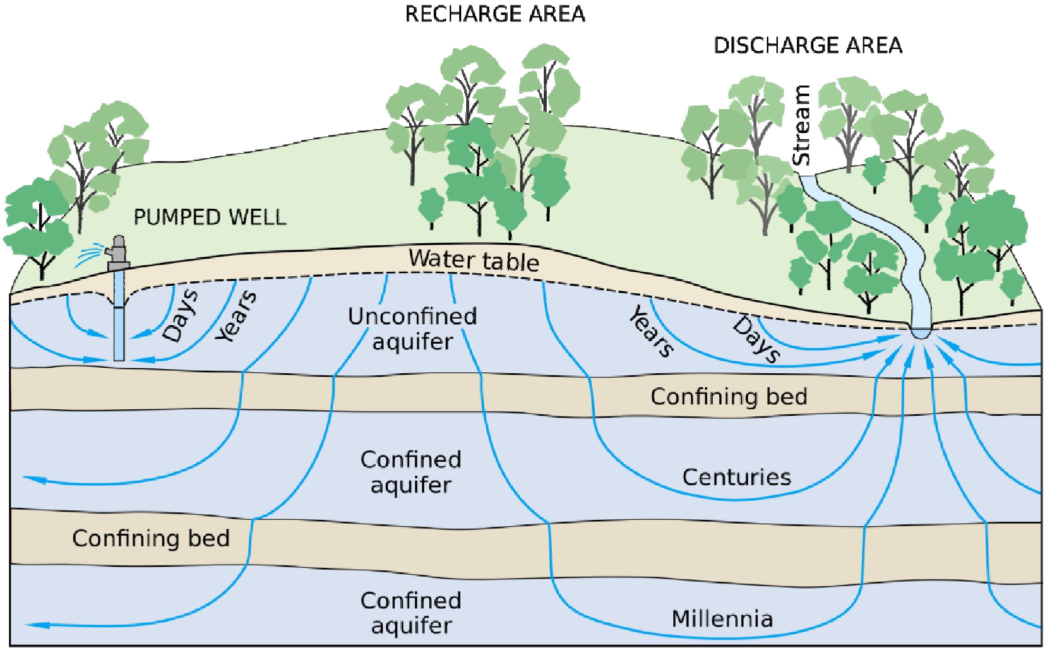
5.8.10 Groundwater

Groundwater is a part of the natural **water cycle**. Some part of the precipitation that lands on the ground surface infiltrates into the subsurface. The part that continues downward through the soil until it reaches rock material that is saturated is groundwater recharge. Water in the saturated groundwater system moves slowly and may eventually discharge into streams, lakes, and oceans. The top of the surface where groundwater occurs is called the **water table**. In the diagram (picture 82), you can see how the ground below the water table is saturated with water (the saturated zone). Aquifers are replenished by the seepage of precipitation that falls on the land, but there are many geologic, meteorologic, topographic, and human factors that determine the extent and rate to which aquifers are refilled with water. Rocks have different porosity and permeability characteristics which means that water does not move around the same way in all rocks. Thus, the characteristics of groundwater recharge vary all over the world.



82 Diagram of groundwater

Water concentrated in **soil** and in **rocks** underground is known as **groundwater**.
Rocks contain space between the crystals of grains, which are called pores. Water is often kept in rocks that have a large percentage of pore space. Groundwater exists everywhere there is **porosity**. Another factor that influences amount of groundwater is **permeability** of rock material. Materials such as sand, gravel, and sandstone have a high level of permeability, therefore there are **permeable**. Materials such as clay, shale, granite are **impermeable**.
An **aquifer** is a body of rock or unconsolidated sediment with sufficient permeability to allow water to flow through it. Unconsolidated materials like gravel, sand, and even silt make relatively good aquifers, as do rocks like sandstone. Other rocks can be suitable aquifers if they are well fractured. An **aquitard** is a body that does not transmit a significant amount of water, such as clay, a till, or a poorly fractured igneous or metamorphic rock. These are relative terms, not absolute, and are usually defined based on someone's desire to pump groundwater; an aquifer to someone who does not need much water may be an aquitard to someone else who does. An aquifer that is exposed at the ground surface is called an unconfined aquifer. An aquifer where there is a lower permeability material between the aquifer and the ground surface is known as a confined aquifer, and the aquitard separating the ground surface, and the aquifer is known as the confining layer.
If a person were to go out into their garden or a forest or a park and start digging, they would find that the soil is moist (unless you are in a desert), but it is not saturated with water. This means that some of the pore space in the soil is occupied by water, and some of the pore space is occupied by air (unless you are in a swamp). This is known as the **unsaturated zone**. If a person were to dig down far enough, they would get to the point where all the pore spaces are 100 percent filled with water (**saturated**), and the bottom of your hole would fill up with water. The level of water in the hole represents the **water table**, which is the surface of the saturated zone.

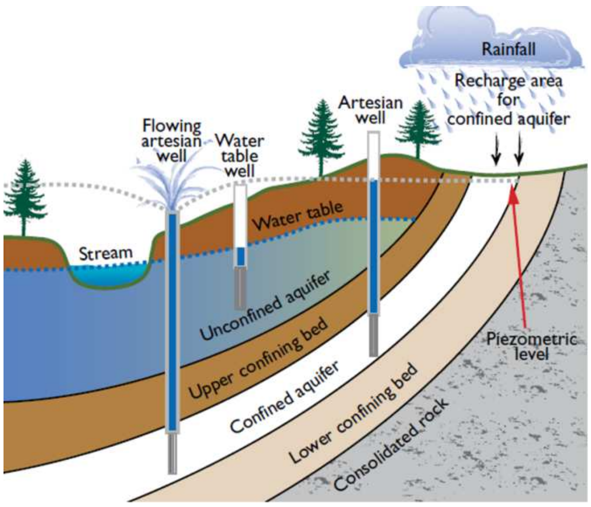


83 Groundwater and its sources depth

The place in which groundwater flows out on the earth´s surface is called **a spring**. Springs are classified by how many litres of water they can produce by a second.

Artesian water

Groundwater in aquifers between layers of poorly permeable **rock**, such as clay or shale, may be confined under pressure. If such a confined aquifer is tapped by a well, water will rise above the top of the aquifer and may even flow from the well onto the land surface. Water confined in this way is said to be under **artesian pressure**, and the aquifer is called an **artesian aquifer**. The word artesian comes from the town of Artois in France, the old Roman city of Artesium, where the best known flowing artesian wells were drilled in the Middle Ages. The level to which water will rise in tightly cased wells in artesian aquifers is called the potentiometric surface.



84 Geological and topographical control affecting artesian and flowing artedian wells.

Mineral water

Water is a solvent and dissolves minerals from the **rocks** with which it comes in contact. Groundwater may contain dissolved minerals and gases. The amount of minerals (i.e. calcium, magnesium, iron etc.) depends on the kind of rock through which it passes, the distance it travels underground, and its temperature. Genuine mineral water is the kind of water that contains at least **1 gram of minerals** in a litre of it. Slovakia is pretty rich in mineral waters.

There are more than 1300 mineral water sources in Slovakia that are used as curative water and high quality mineral water for drinking.

1. Natural table mineral water - is water, which by its chemical composition, physical properties and taste is suitable as a refreshing drink, which contains in 1 liter of at least 1000 mg of dissolved carbon dioxide and maximum 6000 mg of dissolved solids which neither individually nor together do not have significant pharmacological effects.
2. Natural mineral water - is water in natural springs and artificial catchments which in place of groundwater withdrawal contains in 1 litter of water more than 1000 mg of dissolved solids or 1,000 mg dissolved CO2.
3. Natural healing (spa) water - is water, which due to its chemical composition and physical properties as positive, scientifically proven effects on human health has, that it is in the public interest to use the water in medical therapy.

Hot springs

A **hot spring**, hydrothermal spring, or geothermal spring is a spring produced by the emergence of geothermally heated groundwater onto the surface of the Earth. The groundwater is heated either by shallow bodies of magma (molten rock) or by circulation through faults to hot rock deep in the Earth's crust.

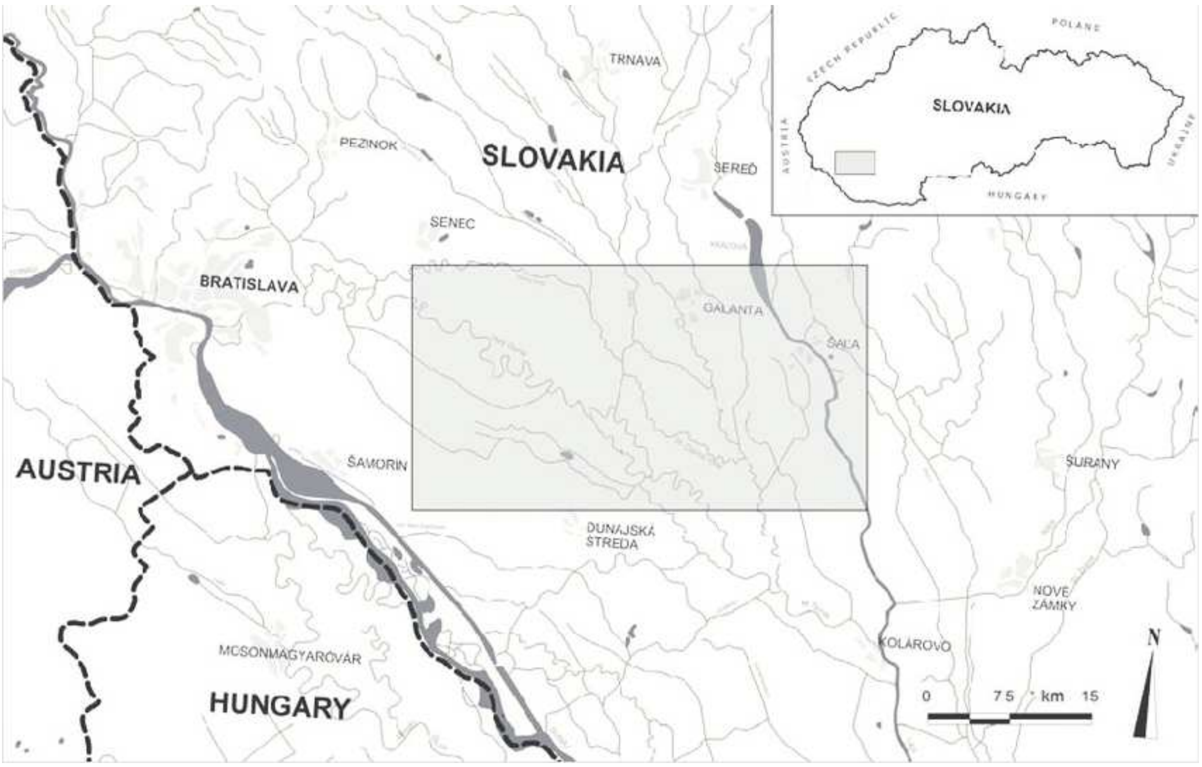
Thermal water is groundwater heated by geothermal energy. Its temperature is **higher than 25°C**, although there are many definitions of hot springs that vary in the temperature rate.

85 Hot spring in Oravice, Slovakia

Fresh water

About 96 percent of all unfrozen fresh water is found below the Earth's surface and is known as **groundwater**. Groundwater systems globally provide 25 to 40 percent of the world's drinking water.

Žitný Ostrov Island with the area of 1886 km^2 covers the territory of the Danube Plane. Žitný ostrov is the biggest natural groundwater source in the Slovak Republic (SR) and in Central Europe with app. 20 400 l.s-1 capacity. It is the largest reservoir of groundwater in the Central Europe.



86 Žitný ostrov location

Questions for discussion:

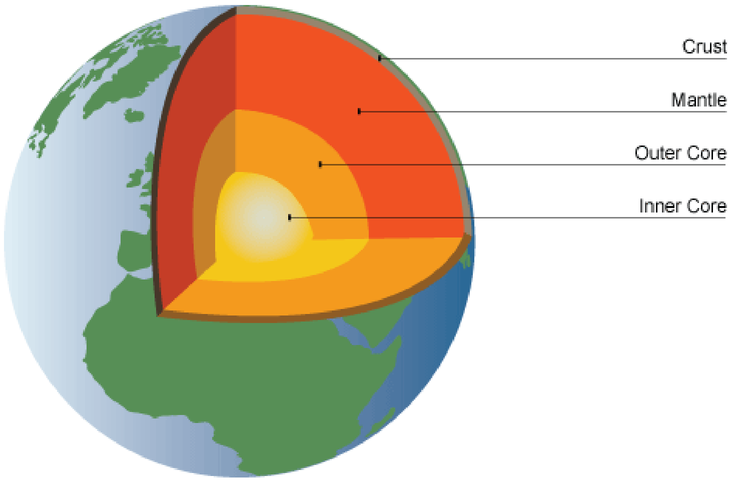
1. Do you think you can live without water? What about food? Support your ideas with some arguments. Where do you take water at home from? Find information about its source.
2. 1.1 billion people worldwide lack access to water, and a total of 2.7 billion find water scarce for at least one month of the year. Where are such places located? What are the reasons for water scarcity in these regions?
3. What about Slovakia? Do we have enough fresh water? Find as much information as possible on the Internet about this issue.
4. There are more than 1300 mineral water sources in Slovakia that are used as curative water and high quality mineral water for drinking. There are 21 thermal spas built on these mineral springs. Explain why and support your opinion with facts/ arguments.
5. Would you like to live in a country with a sea or ocean? Why yes/ not? Why is the sea salty? Do you think Slovakia has never had a sea? If yes, provide some facts on how to prove it.
6. What are the reasons why people build dams? Name some dams in Slovakia and talk about their functions. What are the advantages and disadvantages of dams? Support your opinion with facts/arguments.
7. The world is experiencing a dramatic increase in disasters related to precipitation. More and more people are at risk of flooding. Why is it so? How can we prevent them? What about Slovakia? Find some records of the latest flood in your area.
8. As the climate warms, how much, and how quickly, will Earth's glaciers melt? Are glaciers important for us? How will life on the earth change if all glaciers melt?
9. There are a lot of water conflicts in the world. Search on the Internet and find some conflict regions as well as the reasons for the conflicts.
10. What is sustainable water management? What is its aim? Find out some methods of water management in Slovakia.

6. LITOSPHERE

6.1 Structure of the Earth

The interior of the Earth, like that of the other terrestrial planets, is chemically divided into layers. The Earth has an outer silicate solid crust, a highly viscous mantle, a liquid outer core that is much less viscous than the mantle, and a solid inner core. Many of the rocks now making up the Earth's crust formed less than 100 million years ago; however the oldest known mineral grains are 4.4 billion years old, indicating that the Earth has had a solid crust for at least that long. The Earth consists of four concentric layers: **inner core**, **outer core**, **mantle** and **crust**.

1Internal structure of the Earth.



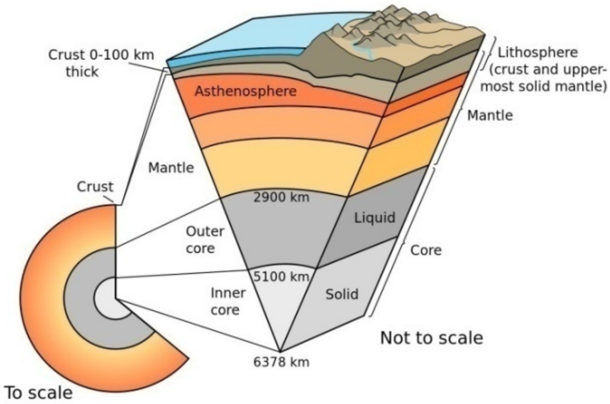
The inner core
The centre of the Earth and it is the hottest part of the Earth. It is solid and made up of **iron** and **nickel** with temperatures of up to 5,500°C. With its immense heat energy, the inner core is like the engine room of the Earth.

The outer core
The outer core is surrounding the inner core. It is a liquid layer, also made up of **iron** and **nickel**. It is still extremely hot, with temperatures similar to the inner core.

The mantle
The mantle is the widest section of the Earth lying between the crust and the core of the Earth. It has a diameter of approximately 2,900 km. The mantle is made up of semi–molten rock called magma. In the upper parts of the mantle the rock is hard, but lower down the rock is soft and beginning to melt. Although it is very hot, most of the mantle remains solid. The mantle consists mostly of **oxygen, magnesium, silicon, iron, calcium** and **aluminium**.
Asthenosphere - the part of the mantle close to the crust. It can sometimes become semi–molten and capable of flowing in very slow–moving currents called **convection currents** of semi–molten underground rocks called **magma**.

The crust is the outer layer of the Earth. It is a thin layer between 0–100km thick. The crust is made of solid rocks and minerals. The crust and upper portion of the mantle are part of a single geologic unit called the **lithosphere – up to 200km**. The lithosphere's depth varies. Earth's crust is made of young oceanic material and older, thicker continental material.

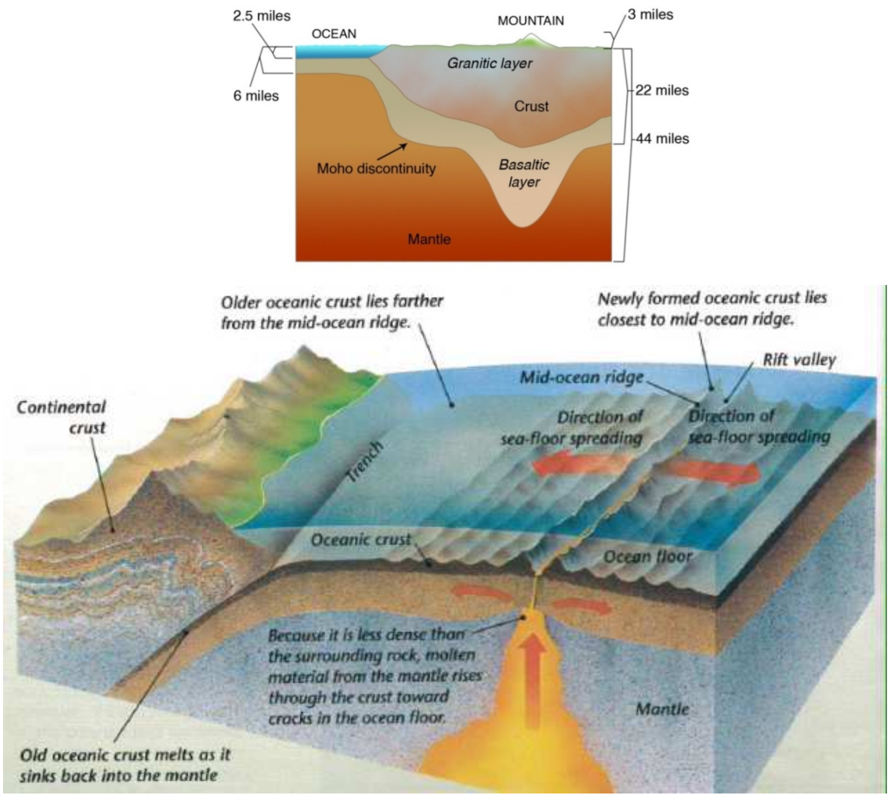
Mohorovicic discontinuity (the Moho) – the boundary between the mantle and crust.
Gutenberg discontinuity - the mantle-core boundary. There is an abrupt change in the seismic waves generated by earthquakes or explosions that travel through Earth.



2 Detailed internal structure of the Earth.

Continental crust – it carries land masses, it is thickest part of the crust **up to 70 km** thick. The thickness of continental crust in the territory of Slovakia is **30–40 km**. The continental crust is the layer of **granitic, sedimentary and metamorphic rocks** which form the continents and the areas of shallow seabed close to their shores, known as continental shelves.

Oceanic crust – it lies under our oceans and carries water, it is very **thin 5 – 10 km** and it is made of very **old rocks** such as **basalt**. The oceanic crust is constantly formed at **mid–ocean ridges**, where tectonic plates are tearing apart from each other. As magma that wells up from these rifts in Earth's surface cools, it becomes young oceanic crust. The age and density of the oceanic crust increase with distance from mid – ocean ridges.



3 Scheme of Earth´s crust

6.2 Plate tectonics

The Earth´s crust is broken into seven large slabs and a dozen or more minor ones called **tectonic plates**. These plates float on the magma of the lower mantle and are moved around slow but powerful convection currents of magma beneath them. This movement causes plates to collide, to move apart and to slide past each other in different parts of the world. Plate tectonics theory is a combination of two separate theories:

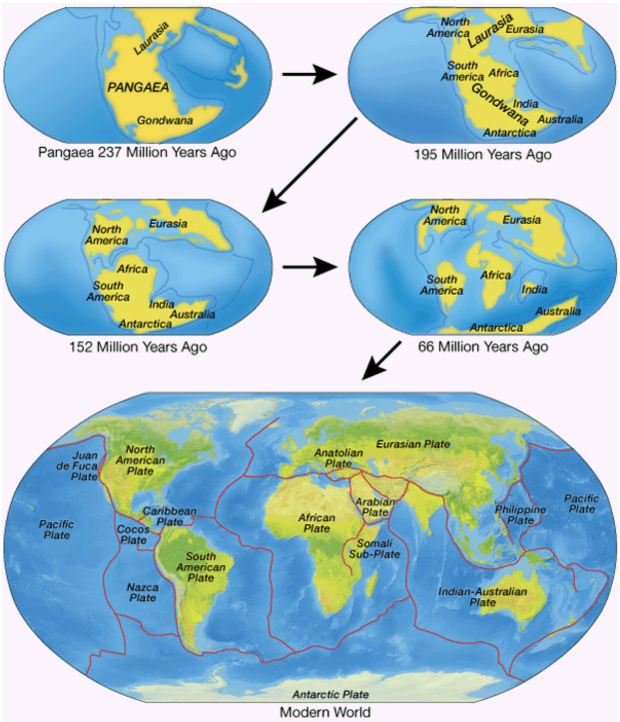
1. Continental drift theory
2. Sea-floor spreading theory

6.2.1 Continental drift theory

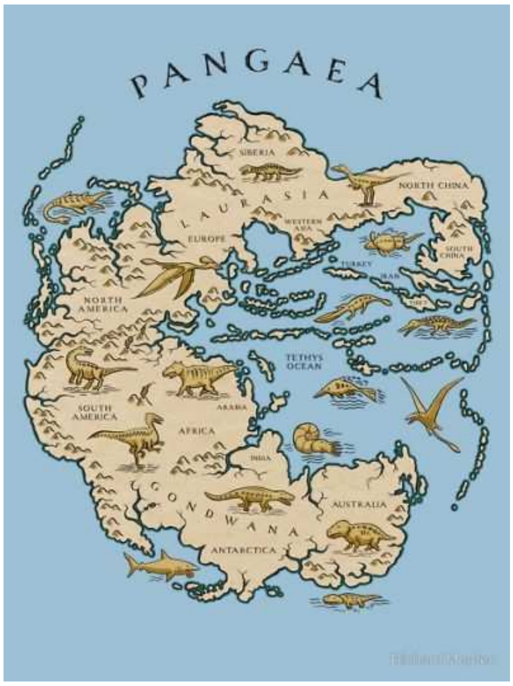
In 1912 a scientist named *Alfred Wegener* made some interesting discoveries.

- He noticed that coastlines of Africa and South America matched as if they once fitted together
- He discovered exact matches between seams of rocks and rare fossils in South Africa and Brazil.

These discoveries led Wegener to come up with the theory of **continental drift**. He said that all continents of the world once formed a single landmass (which called *Pangea*). About 200 million years ago, this landmass began to break up into two huge continents (which called *Laurasia* and *Gondwanaland*).



4 Continental drift of crustal plates.

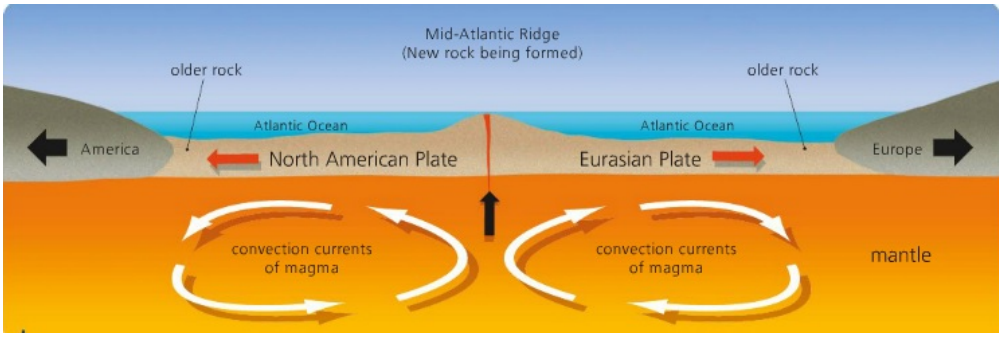


5 Single landmass called Pangea.

At first, most experts rejected the theory of continental drift because Wegener could not explain how continents could move. The mystery of moving continents was later solved by the theory of sea-floor spreading.

6.2.2 Sea-floor spreading theory

In 1948, the Mid-Atlantic Ridge was discovered. This is a huge mountain range that runs roughly north-south along the floor of the Atlantic Ocean. It consists of volcanic rock that emerged from Earth´s mantle. Similar mid-**ocean ridges** were discovered on the floor of the Pacific and other oceans.

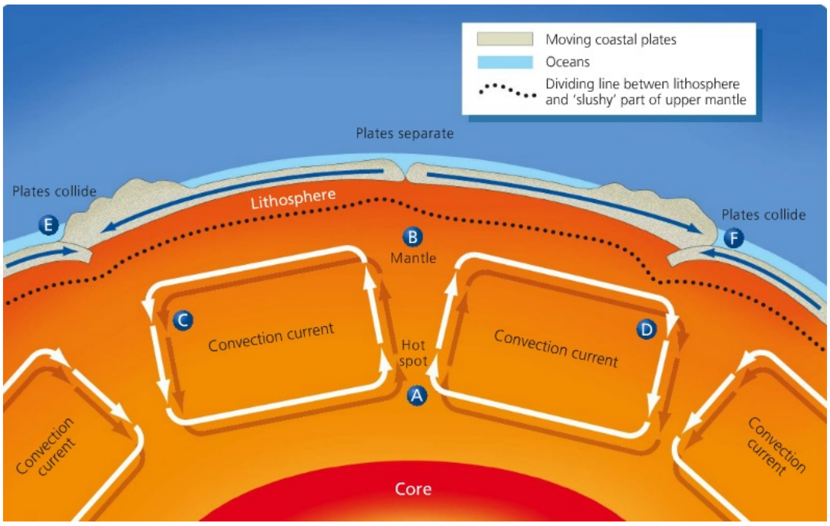


6 Sea-floor spreading is making the Atlantic Ocean wider. Scientist calculate that sea-floor spreading is pushing America and Europe further apart by about 2.5 centimetres per year.

In the 1960s, a geologist named Harry Hess studied the ages of rocks on seabed of the Atlantic Ocean and discovered that rocks were youngest in the **Mid-Atlantic Ridge** and that they became gradually older as one moved away from the ridge towards the shores of America or Europe.
This discovery was very important. It suggested that, as new volcanic rock emerged to form the Mid-Atlantic Ridge, it pushed the older existing rocks apart. This caused the sea floor to get wider and wider. It also caused the continents of North and South America to drift slowly away from the continents of Europe and Africa. Harry Hess theory of seafloor spreading supported the earlier theory of continental drift. These two theories together form the basis of the theory of plate tectonics, which scientists now accept as fact.

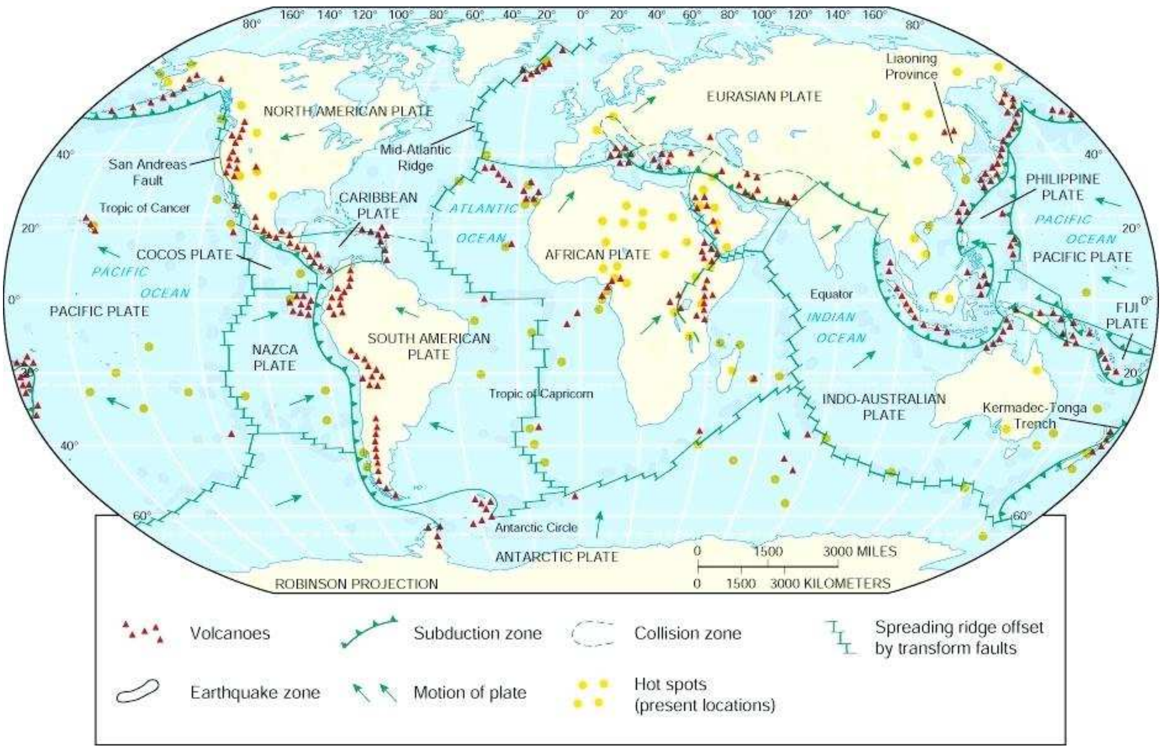
6.2.3 How the plate tectonics work

The following picture 7 below explains the **causes of crustal plate movements**.



- Parts of the Earth´s upper mantle are so hot that rock there takes the form of semi-molten magma. But some parts of the upper mantle are even hotter than other parts. These extra hot parts such as the place labelled are sometimes referred to as hot spots. The magma in these hot spots is less dense and so tends to rise slowly towards the lithosphere.

- When the rising slushy magma approaches the solid lithosphere it is forced to spread our horizontally. As it does so it creates enough tension to eventually tear the lithosphere apart. This causes the Earth´s crust to break up into plates that diverge (separate from each other), for example at the place labelled B.
- Temperatures near the lithosphere are cooler that they are deeper down in the mantle. The horizontally moving magma near the lithosphere must therefore eventually cool down. When it does so, it becomes denser and sinks down into the mantle at C and D and eventually returns to its original position. In this way, a circular convection current of magma is completed.
- Different convection currents move towards each other beneath some parts of the lithosphere. Where this happens, plates converge (move together) and collide with each other. This happen at the places labelled E and F.



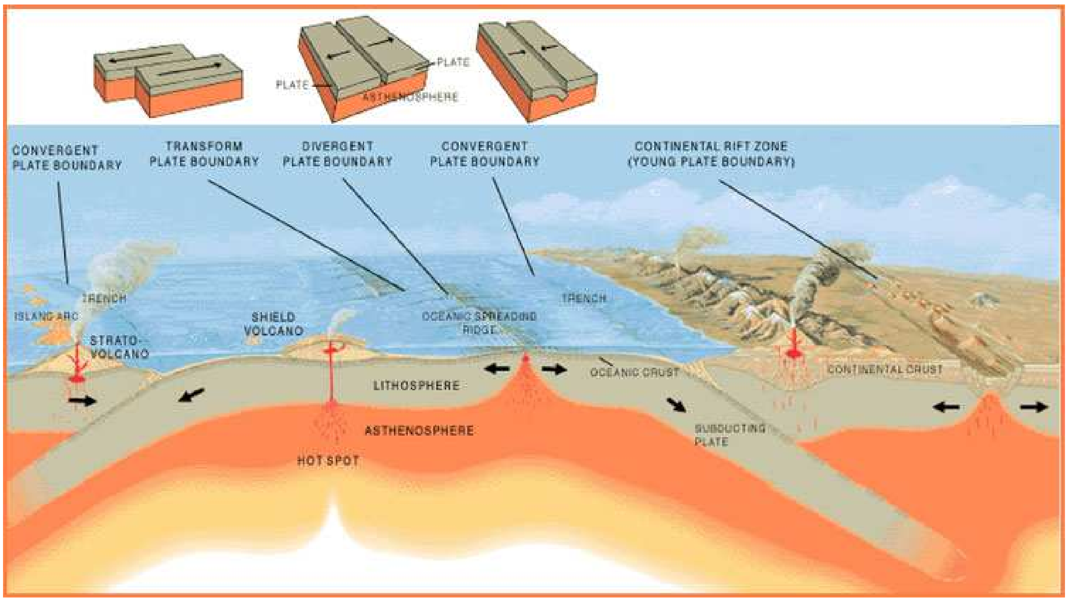
8 The Earth´s crustal plates, types of boundaries and the direction of movement.

The lithosphere is divided into 15 major tectonic plates:

North American, Caribbean, South American, Scotia, Antarctic, Eurasian, Arabian, African, Indian, Philippine, Australian, Pacific, Juan de Fuca, Cocos, and **Nazca**.

Most tectonic activity takes place at the boundaries of these plates, where tectonic plates are shifting apart from one another. At these zones, the lithosphere is only as thick as the crust.
The movement of tectonic plates is made possible by **thermal energy** (heat) from the mantle part of the lithosphere. Thermal energy makes the rocks of the lithosphere more elastic.
Tectonic activity is responsible for some of Earth's most dramatic geologic events: **earthquakes**, **volcanoes**, **orogeny** (mountain-building).

6.2.4 Plate boundaries

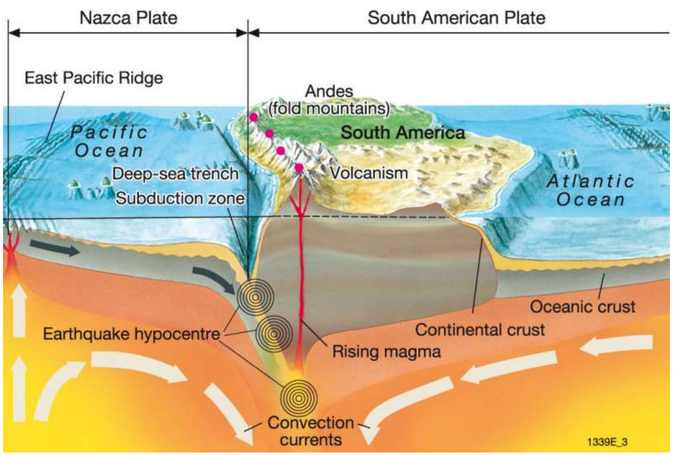


9 Main types of plate boundaries: divergent, convergent, and transform.

6.2.4.1 Destructive (convergent) plate boundaries

The plates move towards one another and this movement can cause Earthquakes. As the plates collide, the oceanic plate is forced beneath the continental plate. This is known as **subduction**. This happens because the oceanic plate is denser (heavier) than the continental plate. When the plate sinks into the mantle it melts to form magma. The pressure of the magma builds up beneath the Earth's surface. The magma escapes through weaknesses in the rock and rises up through a **composite volcano**. The volcanic eruptions are often violent, with lots of steam, gas and ash. If two continental plates collide, neither can sink and so the land buckles upwards to form **fold mountains**. Earthquakes can also occur.

One example of a destructive plate boundary occurs along the western edge of South America, where the South American Plate collides with the Nazca Plate. Part of the oceanic Nazca Plate melts and sinks beneath the mainly continental South American Plate.



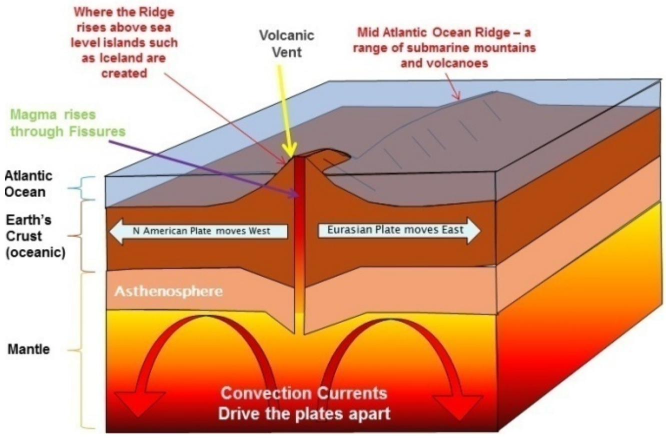
10 Nazca and South American plate boundaries.

6.2.4.2 Constructive (divergent) plate boundaries

At a constructive plate margin the plates move **apart** from one another, they **diverge**. When this happens the magma from the mantle rises up to make (or construct) new land in the form of a **shield volcano**. The movement of the plates over the mantle can cause Earthquakes. A constructive plate boundary occurs in the mid-Atlantic area where the American plates move away from the Eurasian and African plates

Iceland is a volcanic island created by the 130 volcanic mountains that make up the island. Eighteen of these volcanoes have erupted since the island was settled in 874 AD. The three most active and deadly mountains are Grimsvotn volcano, Katia volcano and Hekla volcano. Each of these volcanoes is a hot spot volcano that lies along a divergent boundary.

Convection currents in the Earth´s mantle pull opposite directions and create tension (stretching) on Earth´s crust. This tension is so great that the crust is torn apart. Numerous cracks called fault lines and fissures appear on the crust. Earthquakes are common as fault lines and fissures are formed.



11 Constructive plate boundaries scheme.

Mid-Atlantic Ridge

Submarine ridge lying along the north-south axis of the Atlantic Ocean; it occupies the central part of the basin between a series of flat abyssal plains that continue to the margins of the continental coasts. The Mid-Atlantic Ridge is in effect an immensely long mountain chain extending for about 16,000 km in a curving path from the Arctic Ocean to near the southern tip of Africa. The ridge is equidistant between the continents on either side of it. The mountains forming the ridge reach a width of 1,000 miles. These mountains sometimes reach above sea level, thus forming the islands or island groups of the Azores, Ascension, St. Helena, and Tristan da Cunha, among others.

12 Mid-Atlantic Ridge.

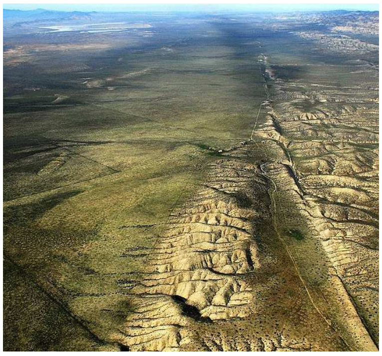
13 The Mid-Atlantic ridge which crosses Iceland. Iceland was formed as the result of sea floor spreading in the North Atlantic


14 The Mid-Atlantic ridge which crosses Iceland. Iceland was formed as the result of sea floor spreading in the North Atlantic.

15 The bridge joining two continents, rift valley Alfagja, Island.

6.2.4.3 Conservative transverse plate boundaries

The plates move **past each other** or are **side by side** moving at different speeds. As the plates move, friction occurs and plates become stuck. Pressure builds up because the plates are still trying to move. When the pressure is released, it sends out huge amounts of energy, causing an Earthquake. The Earthquakes at a conservative plate boundary can be very destructive as they occur close to the Earth's surface. There are no volcanoes at a conservative plate margin. These boundaries are also called *passive*.



15 San Andreas fault in California, the USA.

- Great fissures or fault lines mark the places where plates move paste each other. They are called **transverse faults** or **tear faults**. The world´s most famous transform fault is the San Andreas Fault in California in the USA. This 1,300km long fault marks the boundary where the Pacific and the North American plates move in a north-westerly.
- Both of these plates move in north-westerly direction. But the Pacific Plate moves about six times faster than North American Plate, and this causes cracks and fissures to occur in the Earth´s crust. The slippage between the two plates is not smooth. Tension builds u pas underground rocks jam against each other. When the rocks eventually snap, the plates suddenly lurch paste each other. Shock waves are then released and they cause tremors or Earthquakes when they reach the Earth´s surface. The city of San Francisco in California suffered from severe Earthquakes in 1906 and 1989.

6.3 Endogenic forces

The Earth is shaped by many different geological processes. The forces that cause these processes come from both above and beneath the Earth's surface. Processes that are caused by forces from within the Earth are **endogenic** processes. By contrast, **exogenic** processes come from forces on or above the Earth's surface. Endo is a prefix meaning "in" while Exo is a prefix meaning "out".

They take place mainly along the plate boundaries, which are the zones that lay on the edges of plates. These zones are weak. Endogenic processes cause many major landform features.
Many **exogenic (extra-terrestrial) forces** are as a result of other bodies in space. For example, the Moon causes tides in the Earth's oceans and other big bodies of water. Impacts from comets and meteoroids change the surface of the Earth. When they strike the Earth, they create craters which are holes, which can be very big or small, in the ground. Radiation from the Sun can cause aurora, which are lights that can be seen at night near the poles. An example of an exogenic process that is not as a result of bodies in space is erosion. Erosion happens as a result of wind, water, ice, or people, animals, or plants digging in the Earth.
Some other examples of exogenous process are rainfall, snowfall, hailstorm, erosion, tsunamis, avalanches, winds, wave currents etc.

There are three main **endogenic processes**: **folding, faulting** and **volcanism**.

16 Folded rocks.

17 San Andreas fault in California, the USA.

18 Mount Etna, Sicily, Italy.

6.3.1. Volcanoes

6.3.1.1 Volcanoes at destructive plate boundaries

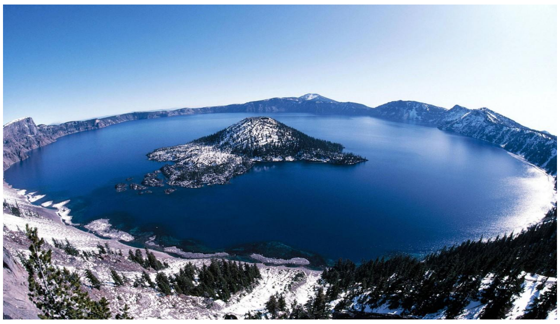
Most of the world´s great volcanoes occur at **destructive plate boundaries**. Crustal plates converge at such boundaries, for example near the west coast of South America where the *Nazca* and *South American plates* collide. **Subduction** takes place there. The denser oceanic Nazca Plate is pushed under the lighter (mainly continental) South American Plate. As the subductional plate descends into the upper mantle it reaches temperatures of more than 1000°C. It then begins to melt and form molten **magma**.

Molten magma begins to force its way upward towards the Earth´s surface. It often accumulate in huge underground masses or magma "magma chambers" called batholiths, before erupting to the surface through holes called **vents** or **pipes**. Such eruptions are usually violent because the vents through which magma erupts are usually quite small. This increases pressure on the moving magma. The magma usually contains explosive, super-heated *steam and gases*.
Magma derived from crustal plates is usually viscous (thick and sticky), so gases often need to explode in order to escape from it. Once the magma reaches the Earth´s surface the gases in it escape and it is called **lava**.
The lava which is usually as dense as thick toothpaste does not flow far and cool down quickly. Layers upon layers of lava gradually build up to form **cone-shaped mountains**. These mountains are usually **steep-sided** because the thick, viscous lava cannot run very far from the mouth of the vent.

19 Mount Etna in Sicily has a symmetrical volcanic cone and it lies at destructive plate boundaries.

6.3.1.2 Calderas

Calderas are huge crater- like depressions, often several kilometres wide. They are the remaining outer shell of volcanic mountains. They are formed when the top of a mountain is blown off or collapses inwards following particularly violent volcanic eruptions.
Mount Vesuvius is a sleeping stratovolcano in southern Italy, which is located 15 km from Naples, the Campania region. It is a part of the Apennine mountain system which has a height of 1281 meters, and the crater about 750 meters in diameter. It is located at the junction of combining African and Eurasian plates, was formed as a result from the displacement African plate under the Eurasian one. The hot and the solid surface layer melted, becoming a liquid rock, but because the magma was less dense than the surrounding rock, it came out to the top, forming a volcano.



20 Crater Lake, Oregon
(It is not a crater, it is a caldera).

21 The lake in the caldera of the Quilotoa volcano in Ecuador.

6.3.1.3 Volcanoes at constructive plate margins

A great deal of volcanic activity also happens at **constructive plate boundaries**. These volcanic mountains and hot spots are described as **shield volcanoes**. Crustal plates separate from each other at such boundaries, for example beneath the middle of the Atlantic Ocean. Where plates separate, magma emerges from the Earth´s mantle through long **fissures** or cracks in the Earth´s crust. These eruptions are often relatively gentle because the magma derived from the Earth´s mantle is usually quite runny, so gases can escape from it easily. The fissures through which the magma emerges are usually large. This reduces pressure on the moving magma. The lava that emerges at constructive plate margins may build up gently sloping mountains because it is extremely hot and runny. This lava can flow great distances before it cools down and hardens.

22 Kilauea in Hawaii, shield volcano as well hot spot erupted nearly continuously from 1983 to 2018, causing considerable property damage, including the destruction of the towns of Kalapana in 1990, and Vacation land Hawaii and Kapoho in 2018.

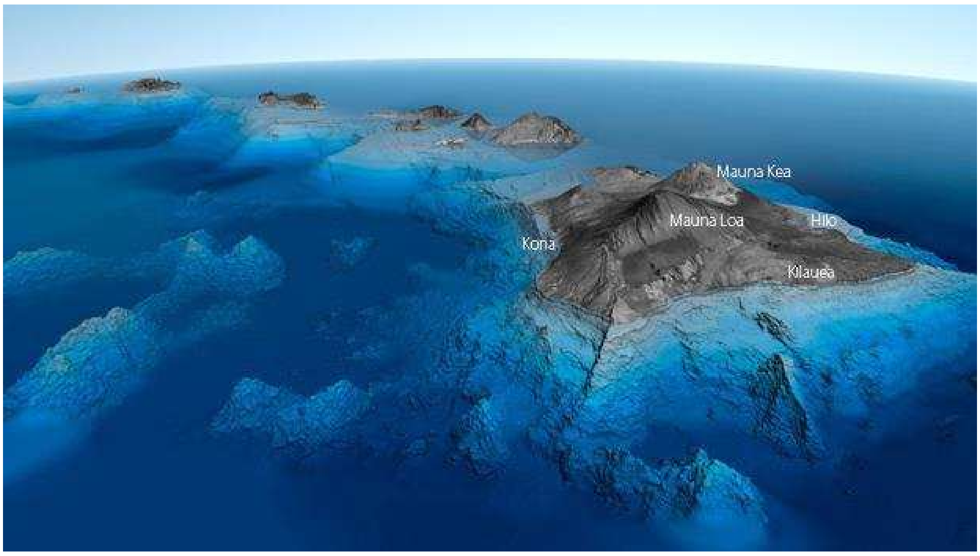
6.3.1.4 Hot spots

Some parts of the Earth´s mantle are particularly hot. These places are called hot spots. They are about 120 known hot spots in the world. They are stationary and most of them are situated far from the plate boundaries. A narrow column of extra hot molten magma called a plume rises up from each hot post and may force its way up through the Earth´s crust. When magma reaches the surface, it forms a volcanic mountain or sometimes a volcanic island. Hawaii, Iceland and the Canary Islands are all volcanic islands situated over hot spots.

The Hawaiian Islands are a line of volcanic islands. Each active volcano was formed over the same stationary hot spot. As the Pacific Plate moved, each older volcano was carried away from the hot post and so become inactive.

Hawaii's most active shield volcano has produced the world's largest mountain. Although Mount Everest is the highest mountain in the world at 8,850m, the highest peak of Hawaii, Mauna Kea is **10,2108m** tall. This takes into account the 6,096m below water that it had to grow to even reach the ocean's surface. Hawaii's hot spot has produced an incredible amount of basalt and continues to erupt daily. This is one of the few places you can walk right up to lava and wonder at its destructive power. Mauna Kea is about a million years old, and has thus passed the most active shield stage of life hundreds of thousands of years ago. In its current post-shield state, its lava is more viscous, resulting in a steeper profile.

23 Mauna Loa, Hawaii. The largest sub aerial volcano in both mass and volume, has historically been considered the largest volcano on Earth.



24 Volcanoes in Hawaii.

6.3.1.5 The products of volcanic eruptions

- **Steam and gases**
  Steam and poisonous gases such as chlorine are often ejected in volcanic eruptions. Hot and heavy gases sometimes tumble down the sides of volcanic mountains in the form of fiery clouds. Such clouds travel at up 10 metres per second. They bring instant death to anyone in their path.

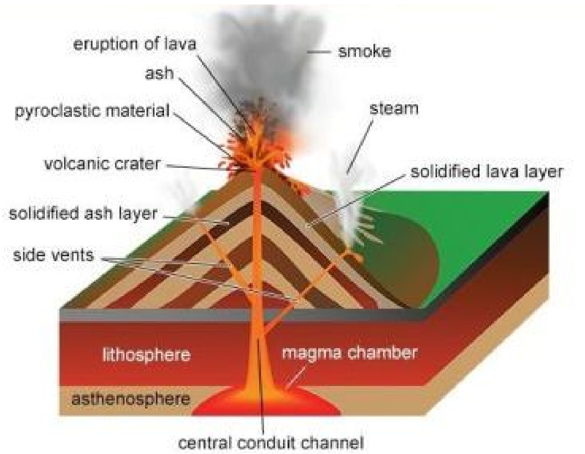
- **Ash**
  Fine ash may also be ejected. This was once rock that was pulverised by the violent explosion. It can be thrown several kilometres into the sky and may be carried away by the winds.
- **Pyroclasts**
  Rock particles are also hurtled into the air. These particles, in general, are called **pyroclasts** or **tephra**, though they may sometimes have a specific name. Some pyroclasts, for example, are about the size of a pea and are called **cinders**. Others are thrown into the air as spatters of boiling mud, but cool instantly to fall as red-hot pieces of rock. They are called **volcanic bombs** and can range from only 3cm across to the size of a large car.
- **Lava**
  One of the main products of volcanic eruptions is lava, which is magma after it reaches the surface and releases its gases. Acid lava is produced at destructive plate boundaries. It is runny and can flow quickly and over greater distances.
- **Lahar**
  Lahars are rivers of mud that flow down the sides of volcanic mountains. They are made up of soil or rock fragments.


25 Lahar flow covering the old city of Playmouth on the Caribbean island of Montserrat.

6.3.2 Main types of volcanoes

1. Composite or stratovolcanoes

They are created by eruptions and following effusions of lava. Composite volcanoes called also stratovolcanoes are made of layers of lava, volcanic fragments of different size (e.g. ash, sand, volcanic bombs). Mount Vesuvius in Italy and Mt. St. Helen in North America are stratovolcanoes.



26 The scheme shows the structure of a composite volcano.

Pyroclastic flows as a fast moving current of hot gas and rock, which reaches speeds moving away from a volcano of up to 700km/h together with **explosive eruptions** result in rocks, lava and ask exploding from the volcano. This mixes with gas and steam and causes **pyroclastic** flows. Layers of **lava** and ash gather around the vent, which creates a Composite volcano. The viscosity is very high, stickier, more viscous, which plugs up the volcano, causing increased pressure over time. The magma type is **Andesitic** (name from the Andes) lower temperature, higher silica, lots of gas.

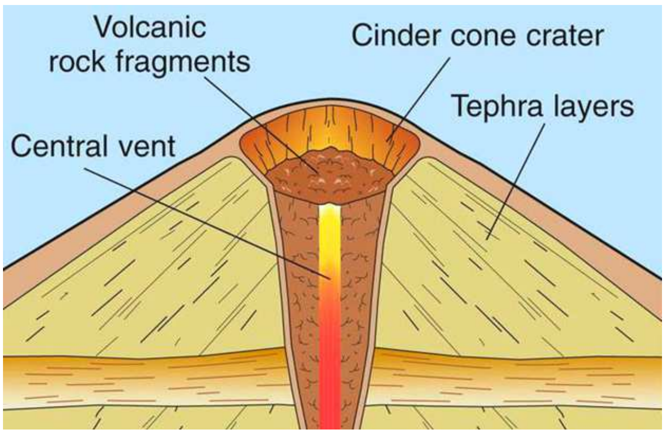
27 Mount St. Helens, The U.S.A.

28 Mount Vesuvius, Italy

29 Etna, Italy

2. Cinder cone volcanoes

Cinder cone volcanoes are created by accumulating of loose volcanic material of different size (Cerro Negro in Nicaragua). They are built from particles and blobs of congealed lava ejected from a single vent. As the gas-charged lava is blown violently into the air, it breaks into small fragments that solidify and fall as cinders around the vent to form a circular or oval cone. Most cinder cones have a bowl-shaped crater at the summit and rarely rise more than a thousand feet or so above their surroundings. Cinder cones are numerous in western North America as well as throughout other volcanic terrains of the world.



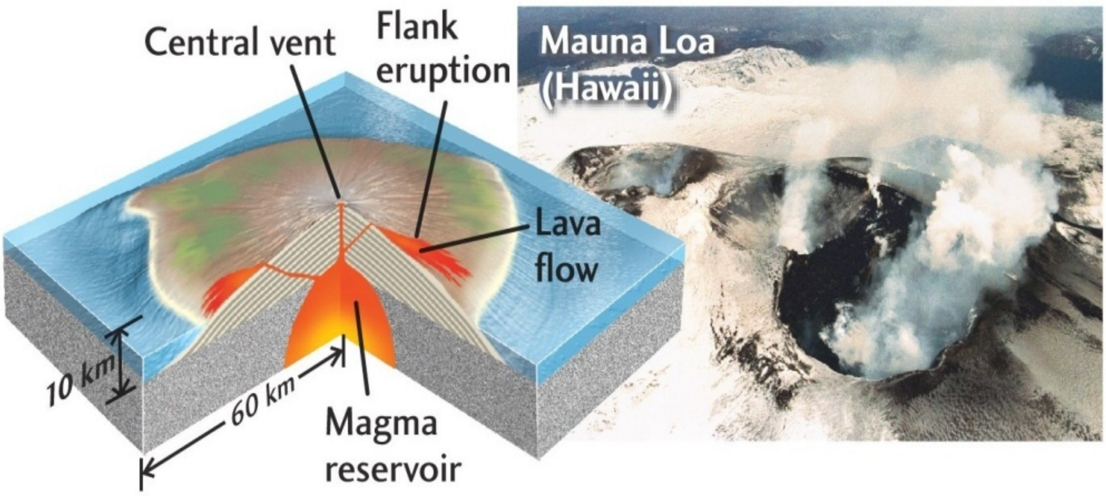
30 The scheme of cinder volcano.

32Kula volcano, Turkey

31 Cerro Negro on 20th August 2011 is an active volcano in the Cordillera de los Maribios mountain range in Nicaragua, about 10 km from the village of Malpaisillo. It is a very new volcano, the youngest in Central America.

3. Shield cone volcanoes

Shield volcanoes (on Iceland, Hawaii) produce only lava. It is named for its low profile, resembling a warrior's shield lying on the ground. This is caused by the highly fluid (low viscosity) lava erupted, which travels farther than lava erupted from a stratovolcano, and results in the steady accumulation of broad sheets of lava, building up the shield volcano's distinctive form.



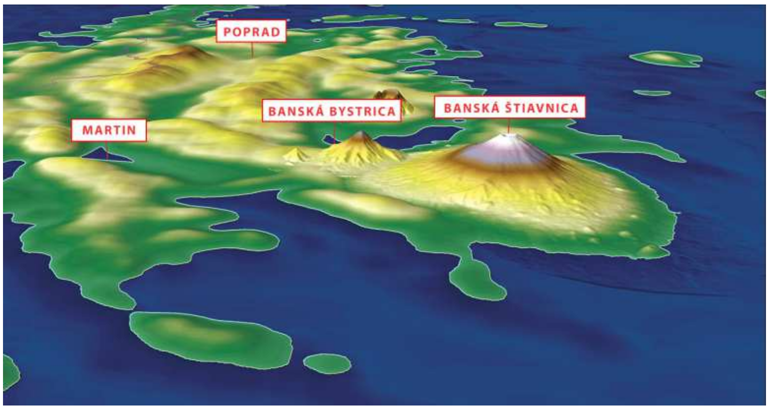
33 The scheme and picture of shield volcano.

34 The Hawaiian volcano. The Hawaiian Volcano is at the top of giant undersea shield volcanoes that formed at the Hawaiian hotspot.

35 Erta Ale is a continuously active basaltic shield volcano in the Afar Region of north-eastern Ethiopia. Ale is the most active volcano in Ethiopia.

6.3.3 Volcanism in Slovakia

Slovakia is a country of extinct volcanoes. 20 million years ago, a warm sea spread over this area. Through deep cracks, hot magma surged to the surface. In the Tertiary period, Banská Štiavnica was the territory of the largest stratovolcano in Europe. About 16.5 million years ago, countless eruptions formed the volcanic cone of a gigantic stratovolcano. It was about 4 kilometres tall and covered the area from Levice to Zvolen, and from Nová Baňa to Krupina. This stratovolcano had the diameter of 50 km The southern part of the stratovolcano bathed in central Europe, for no Europe existed at that time. With its dimensions, the Štiavnica stratovolcano is the highest volcano in the whole area of the Carpathian Mountains, i.e. from Slovakia via Ukraine to Romania.



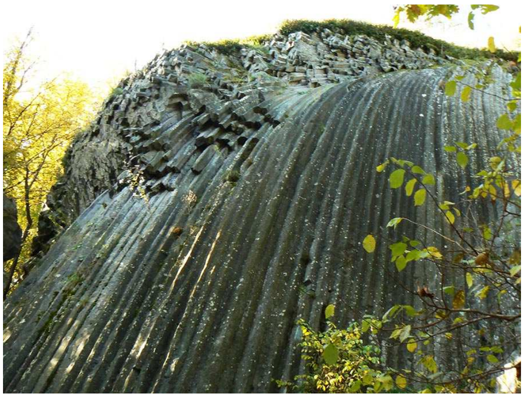
36 When the series volcanic eruptions occurred in the shallow warm sea which covered our region, a ring of volcanic mountains arose. Today, this ring spreads from the Kremnické vrchy hills, through Štiavnické vrchy hills, the Poľana and Cerova vrchovina mountains in Slovakia, the Matra, Bukk, and Tokaj mountains in Hungary and ends again in Slovakia in the area of the Slanské vrchy hills.

37 Contours of the caldera, 18 x 20 km.

Pútikov Vŕšok Mt. is the youngest volcano in Central Europe. The Central Slovakia volcanic field consists of small basaltic shield volcanoes and cinder cones of Pliocene-to-Pleistocene age.

38 Nová Baňa - Brehy: basalt lava flows from the youngest volcano in the Carpathians Putikov vŕšok Mt., dated about 100,000 years ago

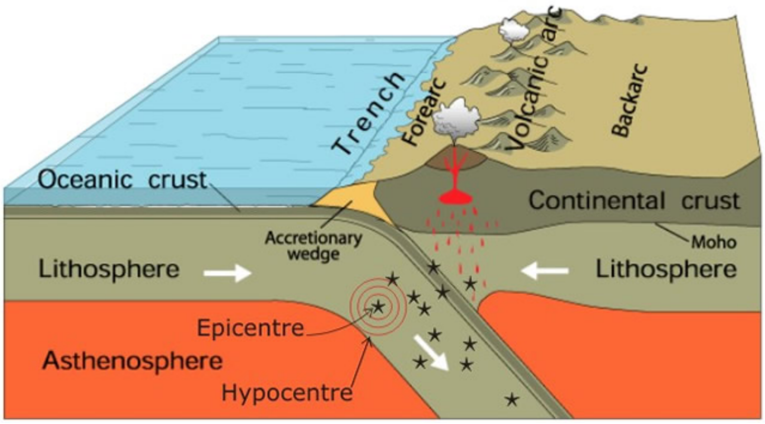
The Slovak National Nature Reserve Šomoška is located on the border with Hungary near Fiľakovo in the Cerova vrchovina hills. There is a volcanic stone waterfall 9 m high and about 4 million years old. Magma of the volcanoes, after touching the surface of the earth, changed to gradually setting lava and we can still look at the result to this day.



39 A volcanic stone waterfall in Šomoška, Slovakia.

6.3.2 Earthquakes

Earthquakes are unexpected uncontrollable shaking of the ground found along all types of plate margins. They occur where plate converge, separate or slide past each other. They also happen in places such as *the African Rif Valley*, where rifting is creating a new plate boundary.



40 Earthquakes occurring at the destructive plate boundaries.

Most earthquakes happen where plates collide at **destructive plate** boundaries. They are particularly common at the zones of **subduction** where convection currents in the Earth´s mantle force heavy oceanic plates to descent beneath lighter continental plate. This descent is not smooth. As an oceanic plate sinks it may become jammed against the continental plate. Convention currents will continue to try to force the oceanic plate downwards. This will cause the jammed rocks to bend under stress and will result in a build-up of stored energy in the bent rocks. Eventually the stress becomes so great that the jammed plates will jolt forward suddenly or the belt rocks will snap along a fault line. Where this happens, the stored energy is released suddenly and **seismic waves** radiate outwards in all directions. When the seismic waves reach the surface, they cause it to tremble and sometimes to crack in what we call an **earthquake**.

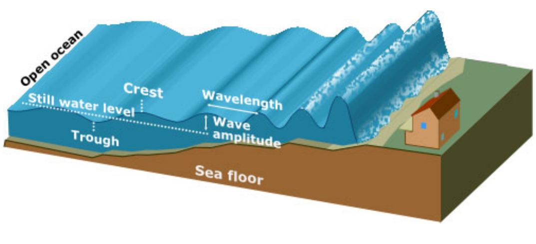
Earthquakes are also very common at **conservative (passive) plate boundaries** where one plate tries to slide horizontally past another. Here again the moving plates become jammed and stored energy builds up. That seismic energy is suddenly released when the jammed rocks snap along a transverse fault such as *the San Andreas Fault* in California. Plates separate also **at constructive plate boundaries**. This separation causes rock to split along fault lines and this too causes Earth tremors. Such tremors are common beneath the mid-Atlantic area where the American plate separates from the Eurasian and African plates.

The point inside the Earth's crust where the Earthquake begins is called the **focus**. The Earthquake's energy is released in seismic waves which spread out in all directions from the focus. The seismic waves are most powerful at the **epicentre**. This is the point on the Earth's surface directly above the focus. The focus can be shallow or deep inside the crust. Shallow-focus Earthquakes are more destructive because they make the ground shake more at the surface.

For example, the 2015 Nepalese Earthquake's focus depth was only 15 km, but measured 7.8 on the Richter scale and it did tremendous damage. By contrast, the deep-focus 2013 Okhotsk Sea Earthquake west of Japan, at a depth of 609 km measured 8.3 on the Richter scale but was not intense at the surface.

6.3.2.1 Tsunami

Earthquakes happen under a seabed can give rise to destructive giant sea waves. An undersea Earthquake displaces water and triggers a powerful ripple effect in all directions. Water waves rush towards the shore up to 1000 kilometres per hour. On approaching shallow water the waves become slower and much higher. They can be up to 30m high on reaching the shore. They rush island with devastating power. Nearly a quarter of a million people died and more than one million were made homeless by a tsunami that struck Indonesia, Thailand and other Southeast Asian countries in 2004.



41 The scheme show how the tsunami wave creates and spreads.

6.3.4 Natural hazards and measurements

6.3.3.1 Life cycles of volcanoes

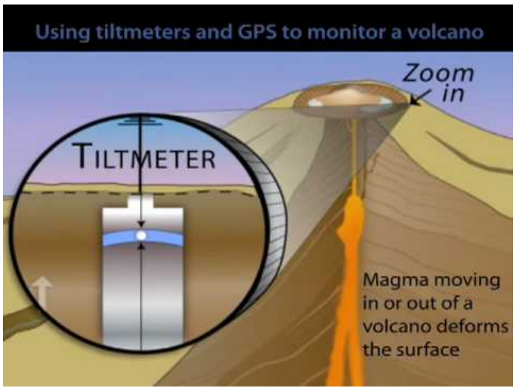
Life cycles of volcanoes

- **Active** volcanoes are those that erupt regularly, examples include Mount Etna or Mount Vesuvius in Italy.
- **Dormant** are those that volcanoes have not erupted for a long time, but they erupt again, examples include Mount St Helens in the USA. It erupted in 1980 after a dormant period of more than 120 years.
- **Extinct** volcanoes are those that have not erupted in historic times. Slemish in Co Antrim is an example.

Can we predict volcanic eruptions?

Volcanologists try to predict when and where volcanic eruptions are likely to take place. They also try to predict the dangers that eruptions might bring. Particular attention is given to active volcanoes that are located close to densely populated areas. Many such volcanoes are under constant daily surveillance.

- **Changes in ground level**
  Magma builds up inside a volcano before an eruption. This makes the volcano swell and so causes the slopes of the sides of the volcano to change. Instruments called **tiltmeters** are used to measure these changes in the slopes. The swelling of a volcano might also result in changes in the water levels of nearby lakes, which can sometimes be detected by satellite.



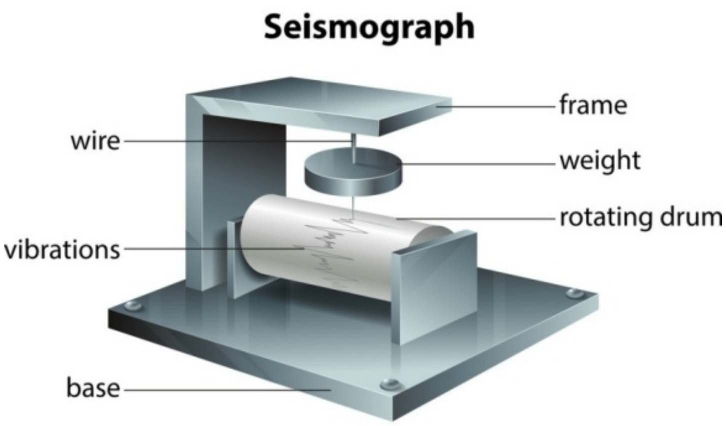
42 Tiltmeter in practice.

Volcano deformation of Mountain St. Helen can provide clues about what is happening deep below the surface. Two techniques used to monitor deformation include Tiltmeters and GPS. Like a carpenter level, an electronic tiltmeter uses a small container filled with a conducting fluid and a bubble to measure a change in slope. Tiltmeters measure the amount of tilt in microradians, which is the angle turned by raising one end of a beam one kilometre long the width of a dime (equivalent to 0.00006 degree!). GPS measures the distance between two points to determine if they are moving further apart, as they might if magma was entering the system.

- **History**
  Some volcanoes erupt at fairly regular intervals. By studying past patterns of volcanic eruptions, volcanologists can sometimes predict when future eruptions are likely to take place. Studies of past eruptions can also provide clues as to how destructive future eruptions are likely to be.
- **Earthquakes**
  Frequent, small Earthquakes usually take place before a major volcanic eruption. Instruments called **seismometers** can detect these Earthquakes. They are placed around the slopes of a volcano being investigated and relay information to a monitoring base. **Seismographs** record the findings of seismometers.
- **Gases**
  Increased amount of gases such a sulphur dioxide, carbon dioxide and radon are often emitted from a volcano before a volcanic eruption. The temperature of emitted gases also increases prior to an eruption. Helicopters are used to collect gas samples and to measure gas temperatures above the crater of a volcano being investigated.

6.3.3.2 Measuring earthquakes

Sensitive instruments called seismographs are used for tremors measurements of Earthquakes (Figure 3.45):

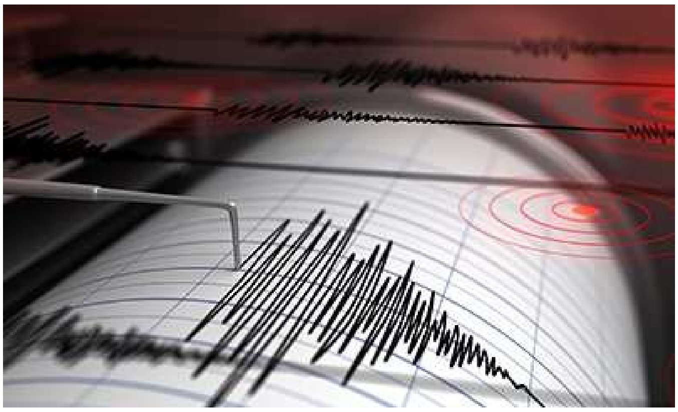


43 Seismograph for tremors measurements.

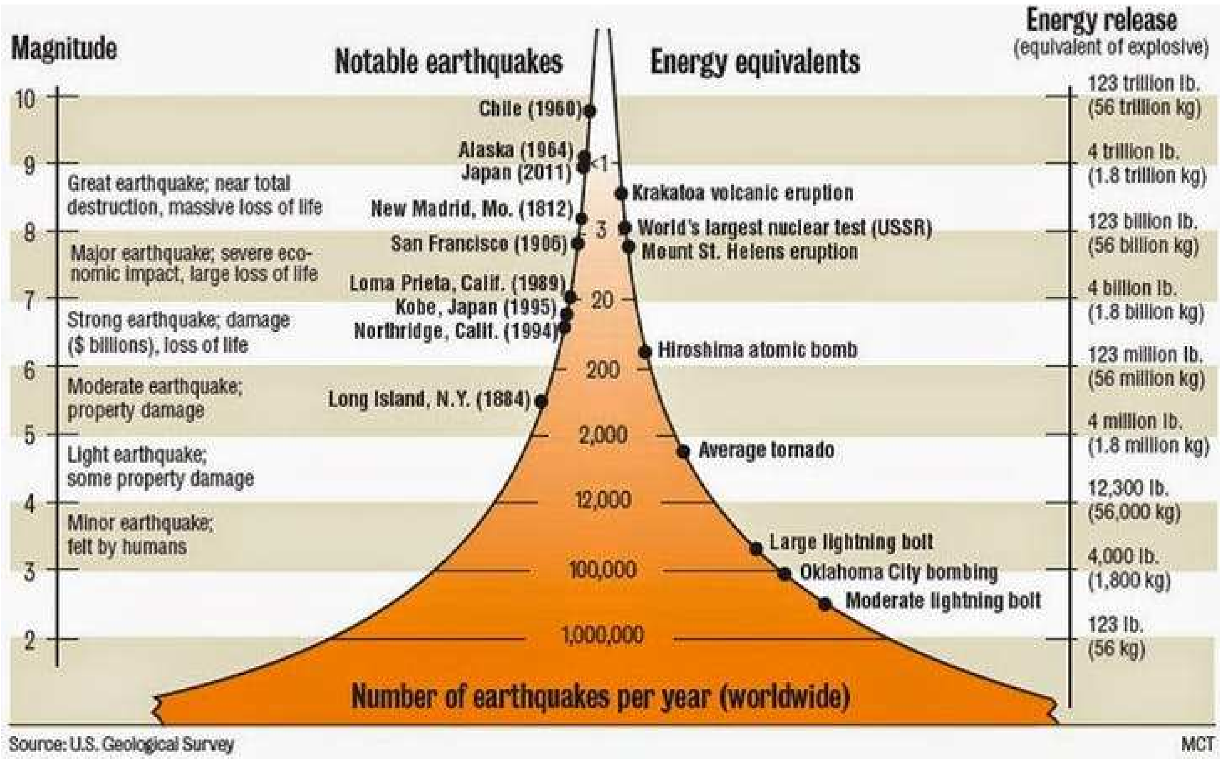
They are designed to measure the magnitude (energy) of Earthquakes. Some seismographs are designed to measure horizontal tremors on the ground, while others measure vertical tremors.

Richter scale

The Richter scale measures the **ground movement** caused by an Earthquake and the **magnitude** (amount of energy) that is produced. The scale used is *logarithmic*. This means that each unit increase on the scale represents a ten-fold increase in ground movement. It means that an Earthquake measuring 7 on the Richter scale would produce ground movements that are 10 times greater than an Earthquake that measured 6 on the scale. The Richter scale is very accurate. It makes use of seismographs to gather information.



44 The picture show how the seismograph works.



44 Richter scale and energy release, Earthquakes are assigned a class. An increase of one number means the quake´s magnitude is ten times greater than the number prior.

Modified Mercalli scale

The modified Mercalli scale (Figure 3.48) measures the intensity (the observed effects) of an Earthquake. The intensity values are given in Roman numerals from i to xii. The modified Mercalli scale uses observation but no instruments in its measurements. It is therefore much less accurate than the Richter scale.

Modified Mercalli Intensity Scale

I	Instrumental: detected only by instruments	VII	Very strong: noticed by people in autos Damage to poor construction
II	Very feeble: noticed only by people at rest	VIII	Destructive: chimneys fall, much damage in substantial buildings, heavy furniture overturned
III	Slight: felt by people at rest Like passing of a truck	IX	Ruinous: great damage to substantial structures Ground cracked, pipes broken
IV	Moderate: generally perceptible by people in motion Loose objects disturbed	X	Disastrous: many buildings destroyed
V	Rather strong: dishes broken, bells rung, pendulum clocks stopped People awakened	XI	Very disastrous: few structures left standing
VI	Strong: felt by all, some people frightened Damage slight, some plaster cracked	XII	Catastrophic: total destruction

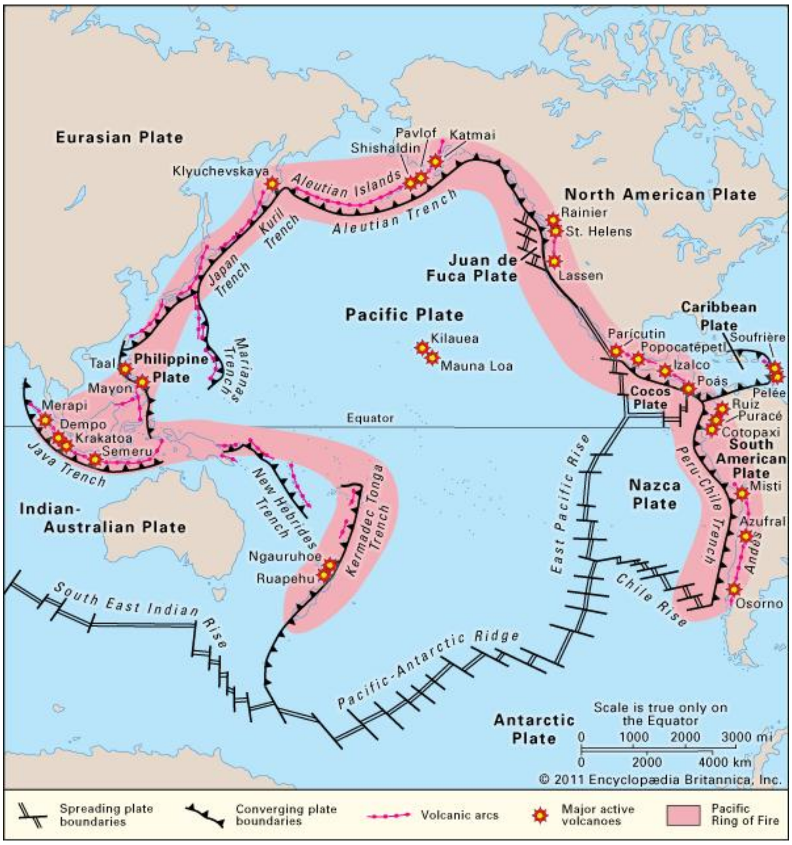
45 Modified Mercalli scale.

Can we predict Earthquake?

It is easy to predict where serious Earthquakes are likely to occur. They almost all happen on fault lines or near plate boundaries. It has proved almost impossible, however, to predict precisely when Earthquakes will occur.

- Seismographs are used to record vibration in the Earth´s crust. Such vibrations may be foreshocks that occur before the main tremors of an Earthquake.
- The land surface sometimes bulges or tilts before major Earthquakes. Instruments called tiltmeters are used to measure such bulging.
- Laser beams from satellites are used to measure even the slightest rock movements in areas prone to Earthquakes. Rock movements are sign of plate movements that can cause Earthquakes.
- By studying history of Earthquakes in given area, scientists try to discover patterns in the seismic gaps (the length of time) between Earthquakes. Where clear seismic gap pattern exist, it may be possible to predict future Earthquake approximately.
- A gas called radon is emitted from the Earth´s crust. Radon gas emissions from wells are sometimes monitored, as they tend to increase prior to Earthquakes.
- Water levels in wells are sometimes monitored. These water levels sometimes rise when the ground is under stress prior to an Earthquake.
- Some people believe that changes in animal behaviour might be a sign of a coming Earthquake. Snakes, for example, have been known to abandon their nests prior to Earthquakes.

6.3.3.3 Pacific Ring of Fire



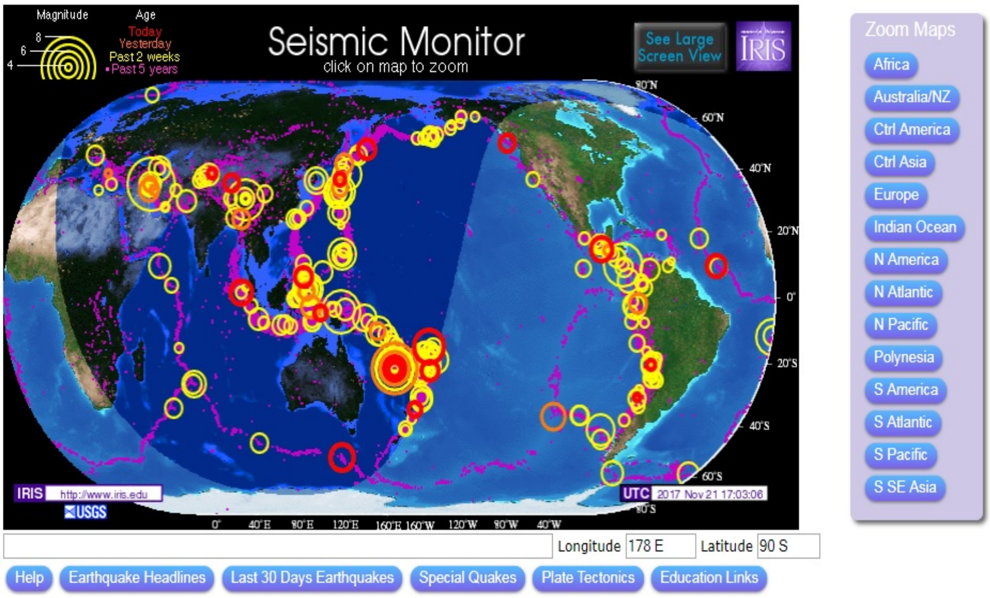
46 Pacific Ring of Fire.

It is a zone of frequent Earthquakes and volcanic eruptions that encircles the basin of the Pacific Ocean. It is shaped like a horseshoe and it is 40,000 km long. It is associated with a nearly continuous series of oceanic trenches, island arcs, and volcanic mountain ranges and/or plate movements. It shows that Earthquakes and active volcanoes occur near the meeting places of the Earth´s great crustal plates known as the Pacific Ring of Fire. There are 50 per cent of world active and sleeping volcanoes and 90 per cent of world Earthquakes.

47 Indonesia, one of the places with the most active volcanoes per kilometre square.

Monitoring of Earthquakes

IRIS is a non profit organization in the state of Delaware with its headquarters office in Washington, DC. It is a consortium over 120 US universities dedicated to the operation of science facilities for the acquisition, management and distribution of seismological data.
Figure 27 shows continuous Earthquakes monitoring at IRIS Earthquake channel which is free.

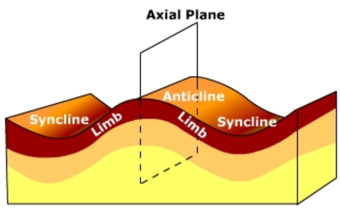


48 IRIS online monitoring of Earthquakes, print screen

6.3.4 Folding, dorming, faulting

6.3.4.1 Folding

When crustal plates collide, tremendous compression (horizontal squeezing) occurs. This compression results in layers of rock being buckled or wrinkled into folds that can range in size from a few centimetres to several kilometres:



A general diagram of a fold.

49 Folds in the valley of the Gods, Utah, the U.S.A.

Fold mountain ranges has been developed at destructive plate boundaries and we can find found all over the world with most of the world's tallest peaks such as the Himalayas, the Andes, the Rocky Mountains, the Alps etc. **The Alpine folding began about 35 million years ago and still continues**. The Himalayas were formed by the collision of the Eurasian tectonic plate and the Indian tectonic plate less than 15 million years ago. All of these mountain ranges are very high because they have not yet been worn down as much as older mountains.

50 Barandovská skala, Czech Republic.

A syncline is a concave fold in which the younger layers are closer to the centre. Synclines are typically a downward fold, pointing upwards. The top can also be eroded, so you only see the edges of the formation.

51 Syncline.

An anticline is like a syncline but in reverse. An anticline is a fold that is convex up and has its oldest beds at its core. Anticlines are often flanked by synclines, although in real life, additional faulting and erosion can mask the relationship between the two. Anticlines form many excellent hydrocarbon traps and so are very interesting for oil prospectors.

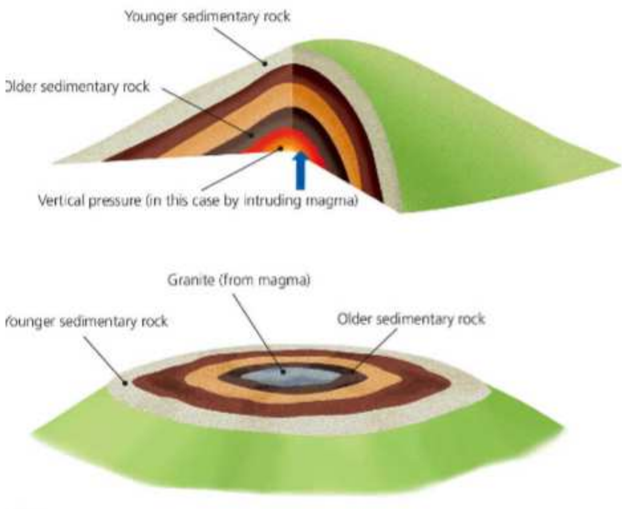
52 Anticline.

A **monocline** is a geological structure in which all the layers are bent in one direction. There are several ways through which a monocline can be formed, but the most common one is by differential compaction over an underlying structure.

53 Monocline.

Dorming

Doming happens when vertical (upward) pressure creates large rounded mounds. The magma forces its way under sedimentary rocks and causes them to bulge at the surface. (Figure 31). Weathering and erosion sometimes removes the outer rock layers of domes and eposes the inner and older sedimentary layers. The shape of such mountains is formed millions of years when magma forced its way under sedimentary rocks and caused them to bulge at the surface.



54 A diagram of the dome mountain.

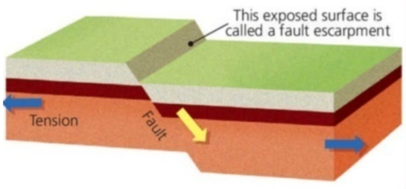
Large globs of magma float up from beneath the crust and push up surface rocks, creating a rounded swelling in the crust. Once the magma cools, it creates a large dome of harder rock under the surface, which erosion sometimes reveals.

55 A dome mountain.

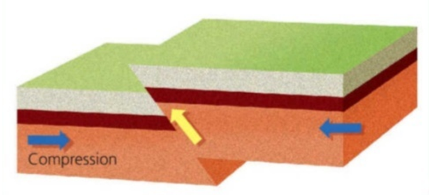
Faulting

Plate movements create compression (pushing together) and tension (pulling apart) on the rocks of the Earth´s surface. These rocks may crack of fracture under such pressure. The fractures are called faults when rock on either side of them moves.

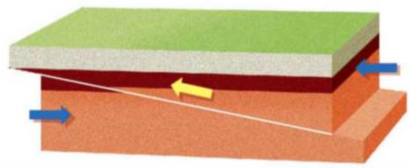
1. **Normal fault** – caused by tension (pulling apart)



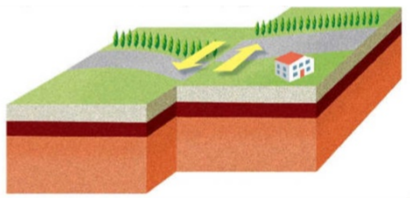
2. **Reverse fault** – caused by compression (pushing together)



3. **Thrust fault** – a typo of reverse fault in which the angle is almost horizontal

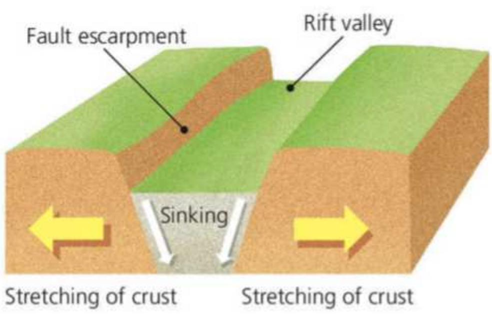


4. **Tear (transverse) fault** – the land on one side of the fault is displaced horizontally



Rift valleys

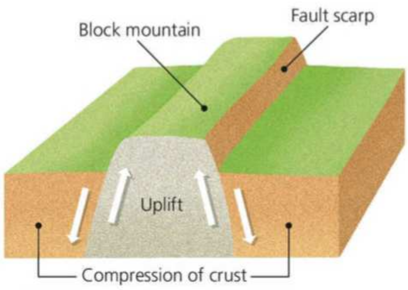
Where two normal faults are parallel to each other, the land between them may slip downward as tension pulls the crust apart this creates a rift valley between the parallel faults.



56 East African Rift Valley.

Block mountains

They form between parallel faults. They can result from uplift between the faults (due to compression) or downward movement of land on either side of the faults (due to tension)



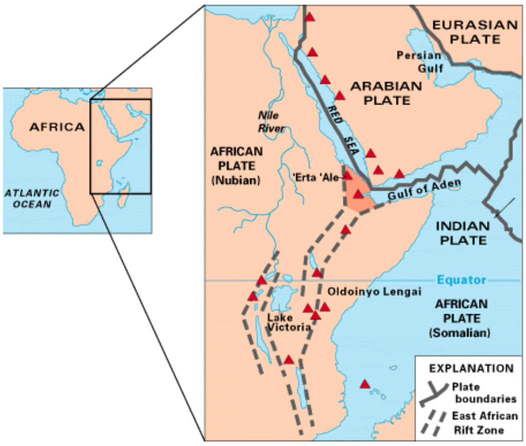
Examples of different ways of faulting.

57 Block mountain in Iceland.

The African Rift Valley

A huge rift valley stretches 4,800km through East Africa. Long lakes such as Lake Malawi occupy parts of this great valley. A long line of hot spots lies beneath the African Rift Valley. Convections currents of magma from this line of hot spots create crust, which caused tension on the crust, which caused huge parallel faults slipped downwards as tension pulled the crust apart. Valley split apart and a new constructive plate boundary will form. The sea already occupies parts of the widening valley as a new ocean. These parts make up the Red sea and the Gulf of Aden.

The map shows
the African Rift Valley.

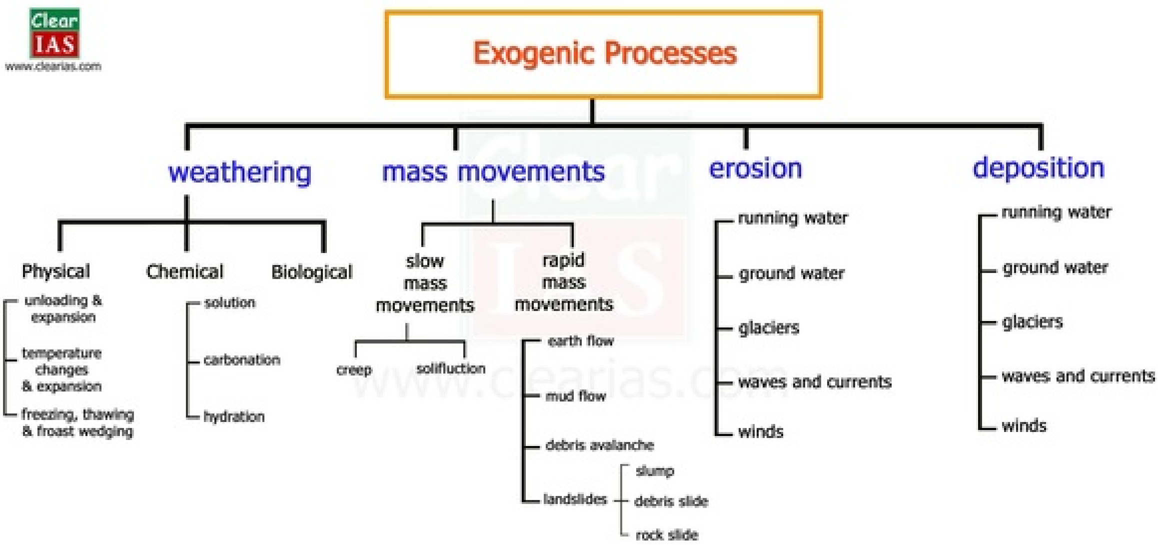


58 The African Rift Valley, a place the long annals of human coexistence with volcanoes on Earth.

6.4 Endogenic forces

The processes which occur on earth's surface due to the influence of exogenic forces are called as exogenic processes. Exogenic processes modify relief.

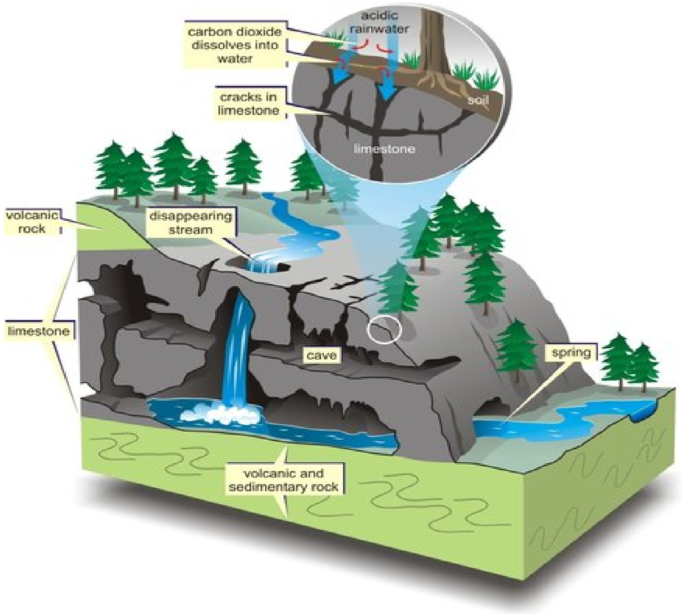
Geomorphic agents: gravity, solar energy, flowing water (rivers), moving ice (glaciers), waves and tides (oceans and lakes), wind, plants, organisms, animals and humans.



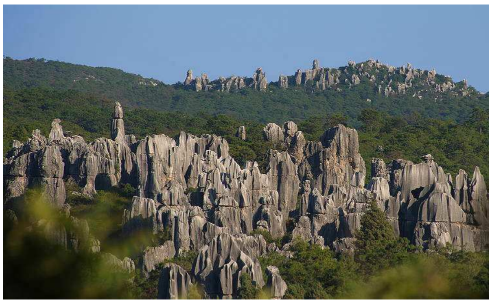
6.4.1 Chemical weathering by rainwater in limestone areas

Carbonation – Rain water dissolves soluble limestone.

Karst is a topography formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum. It is characterized by underground drainage systems with sinkholes and caves.
As rainwater passes through the atmosphere, it takes in carbon dioxide and then becomes a weak carbonic acid. This acid reacts with calcium carbonate in limestone, causing the limestone to be dissolved slowly. Limestone is permeable, it allows water to pass through and karst landforms are created.



59 Demänovská Cave of Liberty, Slovakia

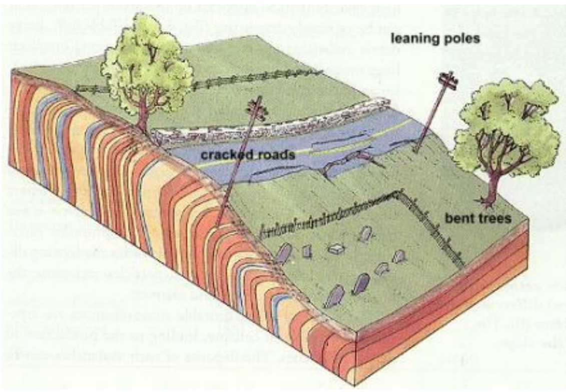


60 Limestone forest, Madagascar

6.4.2 Mass movement

The weathering loosens and breaks up the rocks of the earth´s surface. This loose, weathered material is called **regolith**. Regolith moves down slopes under the influence of gravity. This action is known as **mass movement**.

Soil creep occurs on gentle slopes and it is very slow.



61 Expansive solid creep down slopes.

Bogbursts, **mudflows** occur on steeper slopes and could be rapid, see the following pictures 62, 63.

Landslide occurs on very steep slopes and it is also very rapid as you can see in the following pictures 64, 65.

6.4.3 Processes of rivers

Erosion

Erosion is the process that wears away the river bed and banks. Erosion also breaks up the rocks that are carried by the river. Hydraulic action - This is the sheer power of the water as it smashes against the river banks. Air becomes trapped in the cracks of the river bank and bed, and causes the rock to break apart.

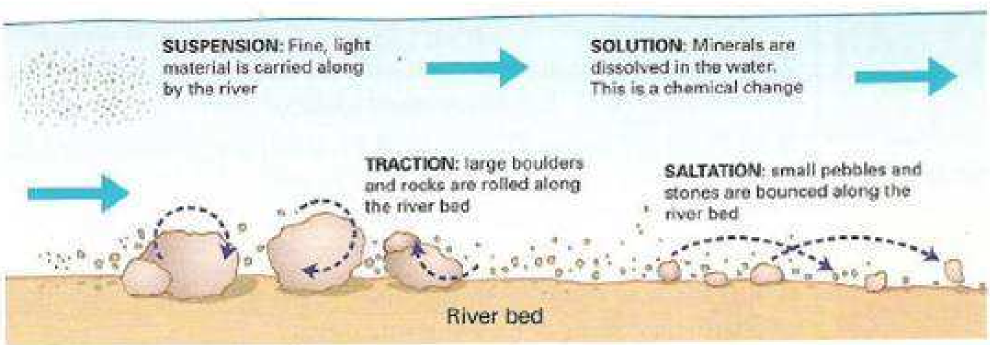
Streams erode and transport sediment. As the loose sediments are moved along the bottom of the river channel, small bed forms (formations of sediment on the bottom of the stream bed) can develop, such as ripples and sand dunes. the bed load - materials bounced along the stream bottom

66 One example of river erosion is the Grand Canyon which was formed by the Colorado River.

67 Kraľovianska dolina valley was formed by the Orava river.

Transportation

The river picks up sediment and carries it downstream in different ways.



68 Transportation of sediments in the river.

Deposition

When the river loses energy, it drops any of the material it has been carrying.

Factors leading to deposition:

- shallow water
- at the end of the river's journey, at the river's mouth
- when the volume of the water decreases

69 Fluvial deposition.

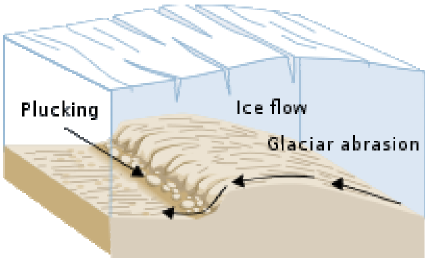
6.4.4 Processes of moving ice - erosion

Plucking

As ice moves, its base rubs against the ground and creates friction. This may cause some ice to melt intocraqcks in the rock. When the ice stops for a while, the melt water refreezes and sticks to the rock. When the ice moves forward again, it can pull or ´pluck´ chunks of rock out of the ground.

Abrasion

The plucked rocks become embedded in the base of the glacier. As the glacier moves, these rocks scrape and smooth the surface over which they pass.



69 Glacial erosion – High Tatras, Slovakia.

6.4.5 Work of the sea

Erosion

It is the removal of rocks and soil by the sea from the coast. It is carried out most effectively by strong waves (usually carried by strong winds across large sea areas) on exposed shorelines made of soft rock such as **bays, beaches, cliffs, sea caves, sea arch or lagoons**.

60 White Cliffs of Dover.

61 Lagoon and limestone cliffs of Coron, Parawan, Philippines.

6.4.6 Biogenic landforms created by organism

Plants and animals are other factors influencing the Earth´s relief. Their activities - biogenic processes create smaller forms such as **moorlands (moors), termite mounds, burrows, coral reefs, coral islands etc.**

62 Coral Island


63Termite mound.


64 Burrows.

6.4.7 Aeolian landforms created by wind

Aeolian landforms are features of the earth´s surface produced by either the erosive or reconstructive actions of the wind.
Erosion is defined as the set of natural processes that loosen, remove and transport weathered or unweathered solid material such as soil, sediment, mud, regolith, rock fragments and other particles from the landscape by downhill or downwind displacement. The mediums required to for material displacement can be wind, running water, waves, ice (glaciers), underground water, and gravity.

As erosion moves weathered solid material, it exposes fresh, unaltered rock to weathering. In some places, erosion is increased by human land use.

Wind erosion is referred to as **Aeolian erosion**.

Differences in atmospheric pressure will cause the motion of air that can erode surface material when velocities are high enough to move particles. Eolian erosion is more pronounced in dry regions and in areas where there is insufficient rainfall to support vegetation and root systems.

Wind cannot carry as large particles as flowing water, but easily pickups dry particles of soil, sand and dust and carries them away. Wind generally causes erosion by deflation and/or abrasion. Wind breaks are often planted by farmers to reduce wind erosion.

65 Aeolian deposition.

66 Skalný budzogáň stone, Súľovské Vrchy Mountains

67 Algeria, Tassili n´Ajjer, Sahara, wind erosion of soft sandstone layers

68 Huduma Ya Afya

69 Erg desert Chebbi, Marocco

70 Hamada desert

6.4.8 Human effects on land formation

Human activities affect landforms by causing erosion (e.g., farming) that reduces surface soil and is carried down rivers to increase river deltas, removing parts of mountains or hills or filling in valleys for , by strip mining, by drilling, etc. Human activities affect landforms by building hills, digging canals, etc.

71 Mirnii diamond mine, Siberia, Russia

72 Artificial islands in Dubai, UAE

Questions for discussion:

1. What keeps the continents floating on a sea of molten rock? Can we feel it? Where exactly are you floating? Look around your surroundings and explain what everything in the lithosphere is on the move right now and why.
2. Study continental drift of prehistoric continents as well as Pangea, Gondwana and Laurasia. Make a simple sketch of a prehistoric world map, put Pangea on it and label the movement of Europe and Slovakia till now. Which of the two world largest rivers was one and flew to the west?
3. What are the consequences of continental drift nowadays? What will the position of continents look like in the future? How does the movement of continents influence Europe? Support your ideas with some arguments.
4. Find out some information about the 5 largest volcano eruptions in history, their consequences and their impacts on the people's lives. Which are the locations of the most frequent hazards in the world?
5. Find out as much information as you can about the 5 most active volcanoes in Europe and talk about their locations and why they are placed there. Do you think there were any volcanoes in the region of Orava in the past? Why yes/ no?
6. Have there ever been any earthquakes in Slovakia? Why yes/ no. Support your ideas with some arguments.
7. Which of the relief forms created by exogenic processes can we find in Slovakia? Find pictures and talk about details.
8. Find 5 examples of weathering, take a picture of them and explain the process they have been made by.
9. Kars areas are also located in Slovakia. Find out more information about them and explain their origin. Do you know any in your area?
10. Travertine is a form of terrestrial limestone deposited around mineral springs, especially hot springs. Find some information about some famous travertine locations in the world. Are there any travertine locations in Slovakia? If yes, talk about their locations and explain why we should protect them.

73 Travertine cascades in Lúčky, Slovakia

7. PEDOSPHERE

7.1 Our Living Soil

The Earth's structure consists of three major parts: the crust, the mantle, and the innermost part known as the core. The crust forms the surface of the Earth and is also constituted by several parts, one of which is the **pedosphere**.

The pedosphere is the part of the crust that is made up of soil and where the soil-forming processes are still active.

This part of the crust co-exists with other parts of the Earth’s structure including the atmosphere, hydrosphere, biosphere, and lithosphere. The pedosphere forms the foundation of all terrestrial life on the planet.

Soil is formed as a result of the breakdown of rocks either by water, air, or other factors of erosion. Rocks that form the crust of the Earth today are millions of years old. However, some mineral particles found in the soil are estimated to be as old as 4.4 billion years. This suggests that the Earth has had solid ground for at least 4.4 billion years. Soil development is determined by the chemical composition found in the rocks that will eventually result in the formation of soil. The different types of rocks that often underlie the soil profile are sedimentary, igneous, or volcanic rock. These rocks are exposed to the Earth’s surface as a result of tectonic activity.

1 Soil profile

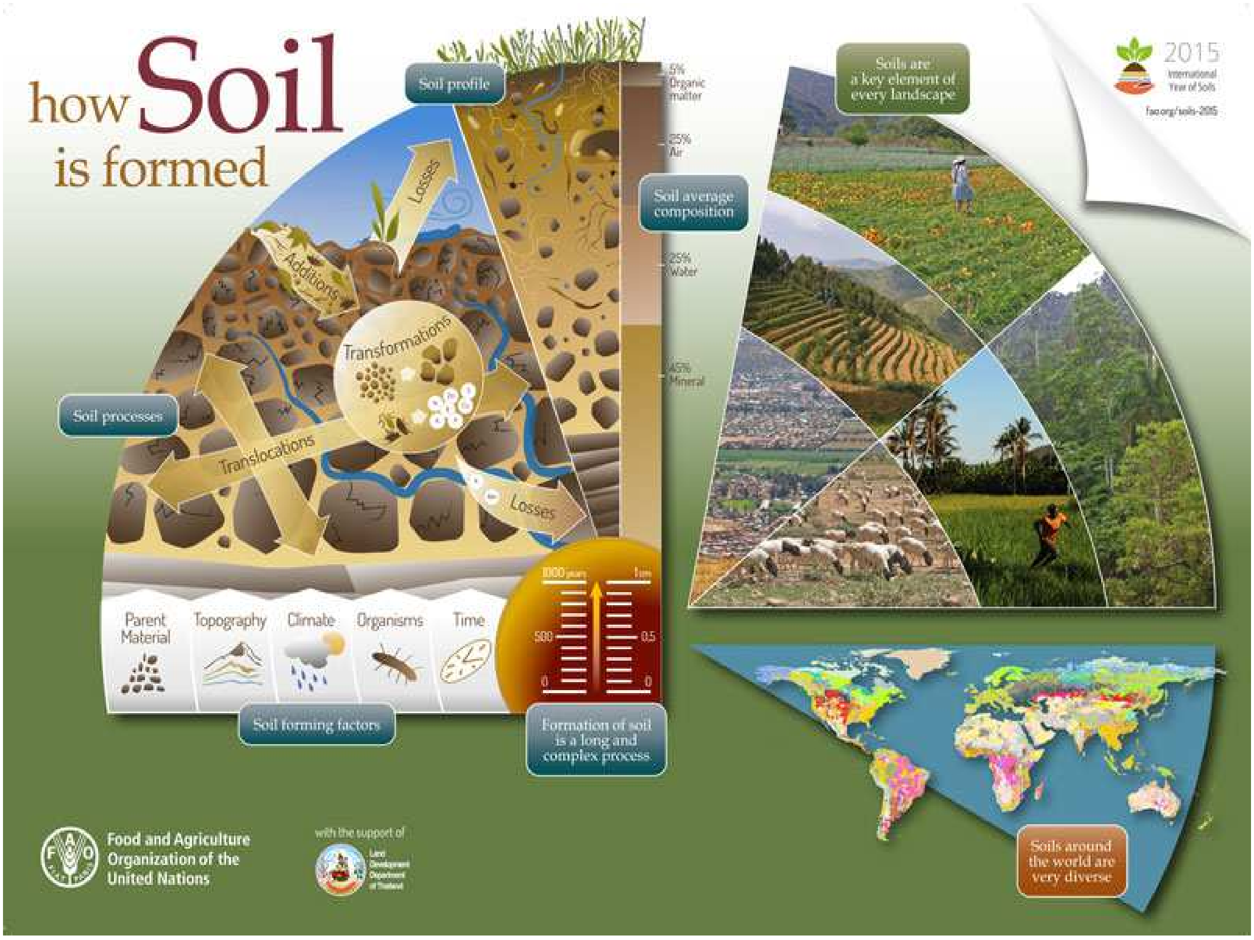
The environment determines the structure and composition of the pedosphere. Forests have the thickest humus layers as a result of the diverse plants and animals that inhabit them. In the tropics, rainforests receive heavier precipitation than any other type of environment, as well as more insulation than forests outside the tropics. These higher temperatures and large amounts of water result in increased rates of chemical weathering. Deserts and grasslands have the lowest rates of chemical weathering due to the significantly low levels of precipitation, and therefore soil development is heavily dependent on other agents of weathering such as wind.

Human activity has dramatically changed the structure of the pedosphere over time. In regions where there is industrial or construction activity, soils are more likely to contain significant amounts of chemicals which leach nutrients in the soils, leaving them barren and unusable for agricultural activity. Agricultural activities have also affected the structure of the pedosphere, leading to massive erosion in some parts of the Earth.

Without soil, plants could not grow and there would be no food for land animals – including people. Soil, therefore, is an essential **natural resource**.

7.2 How Soil is Formed

Soils are dynamic, forming a very long time period with lots of variables. Soil formation is a procedure. It is projected that a inch of dirt carries 500 to 1000 years to shape. Soil types differ, depending on the parent materials from which they came and from the surrounding environment.



2 Soil formation scheme.

The way in which soil forms depends on:

1. **parent material**
2. **climate**
3. **topography**
4. **living organisms**
5. **time**

First of all the forces of rain, wind, freezing and freezing water, earthquakes, volcanoes work to gradually pulverize stones into smaller particles that may compose a soil. This is the early stage of what we might call soil. Here we add some life, specifically lichens. Now the small pockets of land have shaped to the extent that a bigger plants, plants with roots may take a look steadily.
At closing phase , the lands have been developed enough to encourage thick vegetation.

7.3 Composition of Soil

Soil is a living thing. It contains five main ingredients. All thesew work together to make the soil ferile.

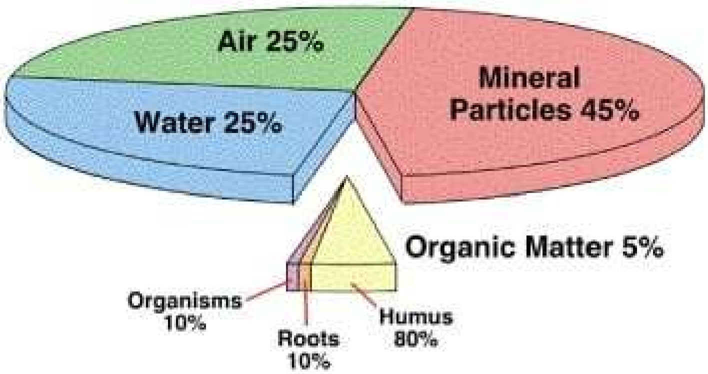
Mineral particles are the biggest ingredient of soil. They are the *remains of rock* that have been broken down by weathering and erosion. They include stones and tiny particles of sand, clay, silt and gravel.

Air is found in the spaces between soil particles. Ot provides the *oxygen* and *nitrogen* that plants and living organisms need to survive.

Water helps to bind the soil together. It also *dissolves minerals* so that plant roots can soak them up in liquid form.

Living organisms range from visible creatures such as earthworms to tiny micro-organisms that can be seen only with the aid of a microscope. They all help to break down plant and animal remains into humus. As worms move through the soil, they also help air and water to *circulate* through it.

Plant remains or ´plant litter´, such as leaves, and twigs tirn into **humus** when they decay in the soil. Humus is a dark, jelly-like substance that mourishes living plants. Dead animals in the soil also form humus.



3 Soil composition.

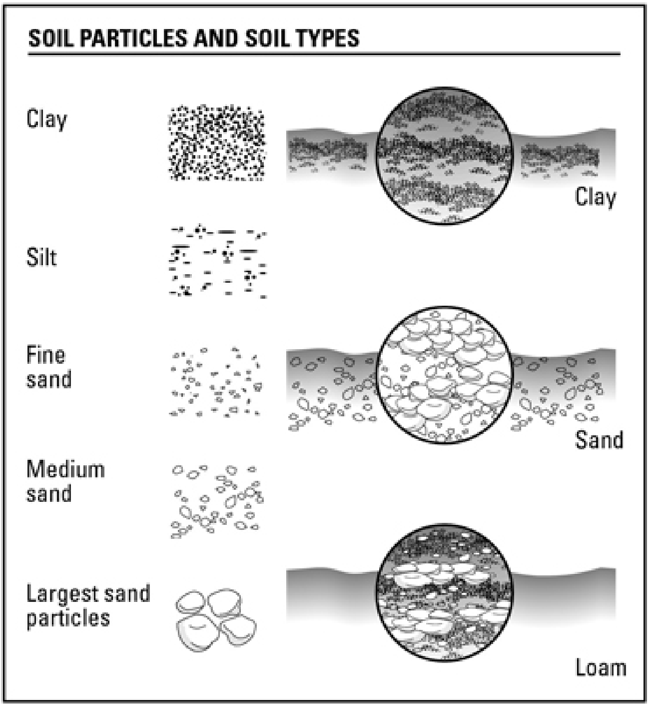
7.5 Soil particles

Soils vary enormously in characteristics, but the size of the particles that make up a soil defines its gardening characteristics:

Clay: less than 0.002mm
Silt: 0.002-0.05mm
Sand: 0.05-2mm
Stones: bigger than 2mm in size

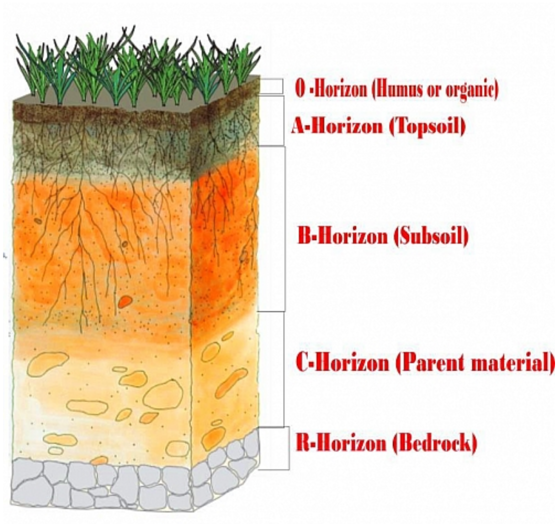
Chalky soils also contain calcium carbonate or lime.

4 Soil particles.



7.4 Soil profiles

A vertical section of the soil from the surface downwards is called a soil profile. Different soil types have different soil profiles. Each profile contains a number of layers. These layers are called horizons, because they occur more or less horizontally.

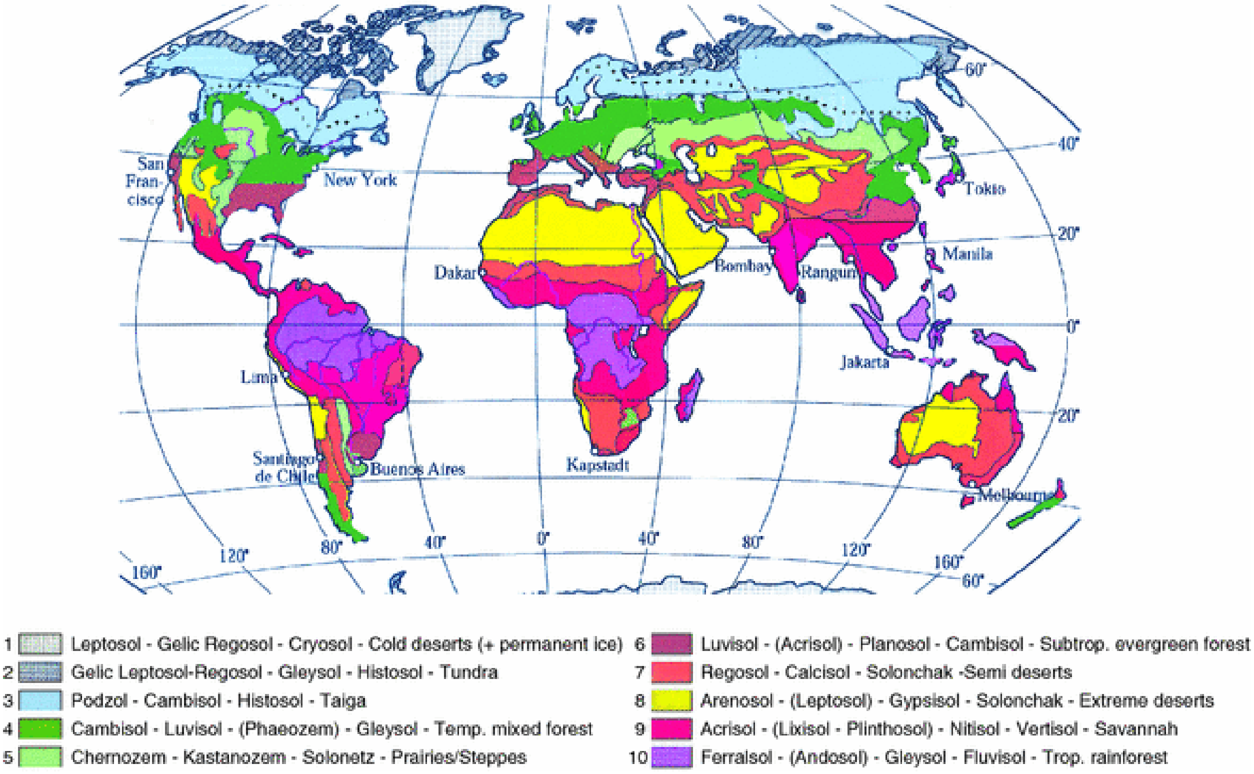


The **A horizon** – sometimes called *topsoil* or the *humus horizon* – is closest to the surface. It is usually dark in colour because it contains dark-coloured humus as well as plant litter. It is the most *fertile* horizon.

The **B horizon** or *subsoil* lies just below the A horizon. It may contain less humus and so be lighter in colour. It may be more *stony* than the A horizon, because it is closer to the underlying bedrock.

The **C horizon** consists of the underlying *bedrock* that is the soil´s *´parent rock´*. The top part of this horizon may be broken into particles, but the lower part is solid rock.

7.5 Different soil types



5 World map of soils.

Chernozems

Soil having a very dark brown or blackish surface horizon with a significant accumulation of organic matter, a high pH and having calcium carbonate deposits within 50 cm of the lower limit of the humus rich horizon. Chernozems show high biological activity and are typically found in the long-grass steppe regions of the world, especially in **Eastern Europe, Ukraine, Russia, Canada and the USA**. Chernozems are amongst the **most productive** soil types in the world.

6 Chernozem (Black soil), Krasnodar and Stavropol territories, Russia.

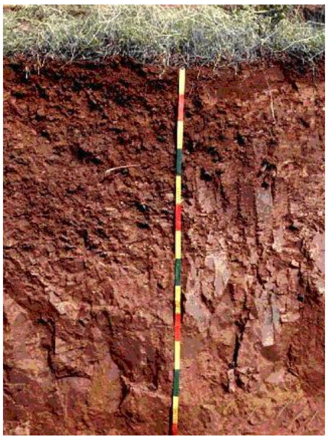
Brown soils

They are common in lowland areas (below 1,000 feet) on permeable parent material. The most common vegetation types are deciduous woodland and grassland. Due to the reasonable natural fertility of brown earths, large tracts of deciduous woodland have been cut down and the land is now used for farming. The largest expanses cover **western and central Europe**, large areas of western and **Trans-Uralian Russia**, the **east coast of America and eastern Asia**. Here, areas of brown earth soil types are found particularly in **Japan, Korea, China**, eastern **Australia** and **New Zealand**. Brown earths cover 45% of the land in **England and Wales**.

7 Brown soil, England.

Luvisol

Luvisols generally occur on well drained landscapes. The mixed mineralogy, high nutrient content, and good drainage of these soils make them suitable for a wide range of agriculture, from grains to orchards to vineyards. Luvisols form on flat or gently sloping landscapes under climatic regimes that range from cool temperate to warm Mediterranean. Occupying just over 5 percent of the total continental land area on Earth, they are found typically in **west-central Russia**, **the United States, central Europe, the Mediterranean basin, and southern Australia**.



8 Luvisol, Belgium.

Stagnosols

Stagnosols are periodically wet and mottled in the topsoil and subsoil, with or without concretions and/or bleaching. The topsoil can also be completely bleached (albic horizon). The agricultural suitability of Stagnosols is limited because of their oxygen deficiency resulting from stagnating water above dense subsoil. Therefore, they have to be drained. They are developed in a wide variety of unconsolidated materials like glacial till, and loamy aeolian, alluvial and colluvial deposits and physically weathered siltstone. Stagnosols occur on flat to gently sloping land in cool temperate to subtropical regions with humid to perhumid climate conditions. They are found in **temperate regions of West and Central Europe, North America, southeast Australia and Argentina.**

9 Stagnosol, Slovakia.

Cambisoles

A cambisol is a young soil. Most of these soils make good agricultural land and are intensively used. Cambisoles in temperate climates are among the most productive soils on earth. Camisoles occur in a wide variety of environments around the world and under all many kinds of vegetation. Cambisoles are the second most extensive soil group on Earth, occupying 12 percent of the total continental land area—mainly in **boreal polar regions** in landscapes with high rates of erosion, and in regions of parent material resistant to clay movement. They are most spread soils in **Slovakia**.

10 Cambisol, Slovakia.

Podzols

Podzols are common under vegetation with acidic litter. There are dominant soil types in Europe. Cover 14 % of Europe, the dominant soil of the northern latitudes. Podzols usually defy cultivation because of their acidity and climatic environment. They range from **Scandinavia to Russia and Canada in the Northern Hemisphere, to The Guianas near the Equator, to Australia and Indonesia in the Southern Hemisphere**, **Slovakia** (but not from carbonate and limestone rocks).

10 Podzol, Slovakia.

Rendzina soils
They are humus-rich shallow soils that are usually formed from carbonate- or occasionally sulphate-rich parent material. Rendzina soils are often found in karst and mountainous regions. Rendzina soils are a very important component of the Tatra ecosystems. These soils develop from **carbonate rocks** and occur in **all regions of the Tatra Mountains, the Low Fatra, the High Fatra, and the Slovak Paradise**.

11 Rendzina, Kláštorská roklina, Slovak Paradise, Slovakia.

Fluvisols
Fluvisols are common in periodically flooded areas such as alluvial plains, river fans, valleys and tidal marshes, on all continents and in all climate zones. Fluvisols develop due to the deposition of sediments following flood events - the picture shows a typical flood event where the river has overflowed its banks; Below: the profiles of Fluvisols show a layering of the sediments indicating deposition by water; The map shows the location of areas in Europe where Fluvisols are the dominant soil type. Cover 5 % of Europe. Their characteristics and fertility depend on the nature and sequence of the sediments and length of periods of soil formation **after or between flood events**.

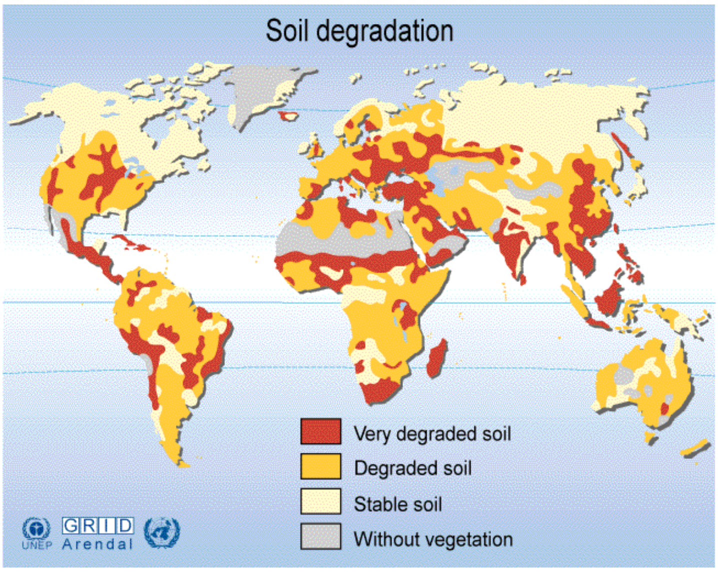
12 Fluvisol, Germany.

7.6 Soil degradation

1. Soil can be degraded in different ways, the main types of soil degradation are:

Wind and water: Rain or wind blowing away topsoil and causing degradation.
Biological: The loss of humus and or plant/animal life.
Physical: The loss of soil structure or change in permeability.
Chemical: The change in the chemical composition of soil. This could be acidification, salinisation or chemical pollution or loss of nutrients.

The world's soils are rapidly deteriorating due to soil erosion, nutrient depletion, loss of soil organic carbon, soil sealing and other threats, but this trend can be reversed provided countries take the lead in promoting sustainable management practices and the use of appropriate technologies.



13 Estimates of the level of soil degradation at a global level

The following factors are linked to soil degradation:

a. **Desertification (fertile land turning into desert)**
b. Dust storms
c. Topsoil erosion
d. Famine & starvation
e. Conflicts

Soil provides ecosystem services critical for life: soil acts as a water filter and a growing medium. Soil also provides habitat for billions of organisms, contributing to biodiversity; and supplies most of the antibiotics used to fight diseases. Humans use soil as a holding facility for solid waste, filter for wastewater, and foundation for our cities and towns. Finally, soil is the basis of our national agro ecosystems which provide us with feed, fibber, food and fuel.

Questions for discussion:

1. Explain what soil erosion is and how it changes the land.
2. What do you think which of the causes of soil degradation you have learned we can find and experience in Slovakia?
3. Explain what soil erosion is and how it changes the land. Find some events such as avalanches, landslides or mud flows on the Internet and talk about them. Try to find some examples in Slovakia.
4. Explain how soil is connected with climate problems.
5. Provide a conclusion of all information you have already known and suggest a solution to keep soil stable with water and comment on its suitability for future population growth and use.

14 Slovakia struggles with extremely dry weather.

8. BIOSPHERE

8.1 Definition

The biosphere is a global ecosystem composed of living organisms (biota) and the abiotic (nonliving) factors from which they derive energy and nutrients.

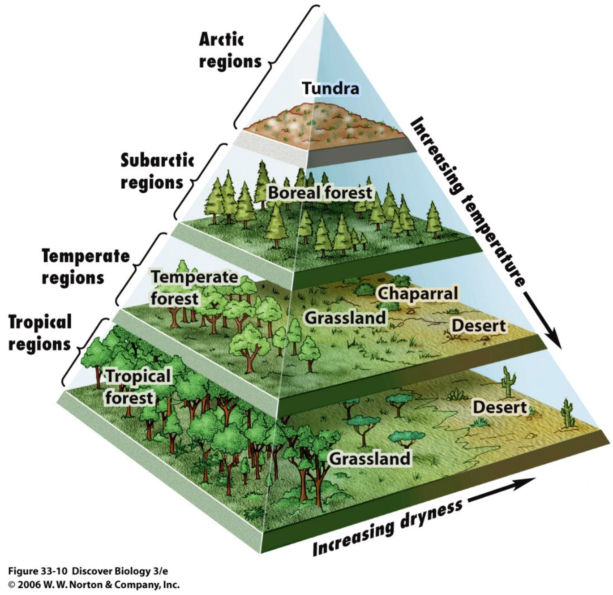
Before the coming of life, Earth was a bleak place, a rocky globe with shallow seas and a thin band of gases—largely carbon dioxide, carbon monoxide, molecular nitrogen, hydrogen sulphide, and water vapour. It was a hostile and barren planet. This strictly inorganic state of Earth is called the geosphere; it consists of the lithosphere (the rock and soil), the hydrosphere (the water), and the atmosphere (the air). Energy from the Sun relentlessly bombarded the surface of the primitive Earth, and in time—millions of years—chemical and physical actions produced the first evidence of life: formless, jellylike blobs that could collect energy from the environment and produce more of their own kind. This generation of life in the thin outer layer of the geosphere established what is called the biosphere, the "zone of life," an energy-diverting skin that uses the matter of Earth to make living substance.

The biosphere is a system characterized by the continuous cycling of matter and an accompanying flow of solar energy in which certain large molecules and cells are self-reproducing. Water is a major predisposing factor, for all life depends on it. The elements carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur, when combined as proteins, lipids, carbohydrates, and nucleic acids, provide the building blocks, the fuel, and the direction for the creation of life. Energy flow is required to maintain the structure of organisms by the formation and splitting of phosphate bonds. Organisms are cellular in nature and always contain some sort of enclosing membrane structure, and all have nucleic acids that store and transmit genetic information.

1 Low Fatra mountains, Slovakia

8.2 Biomes

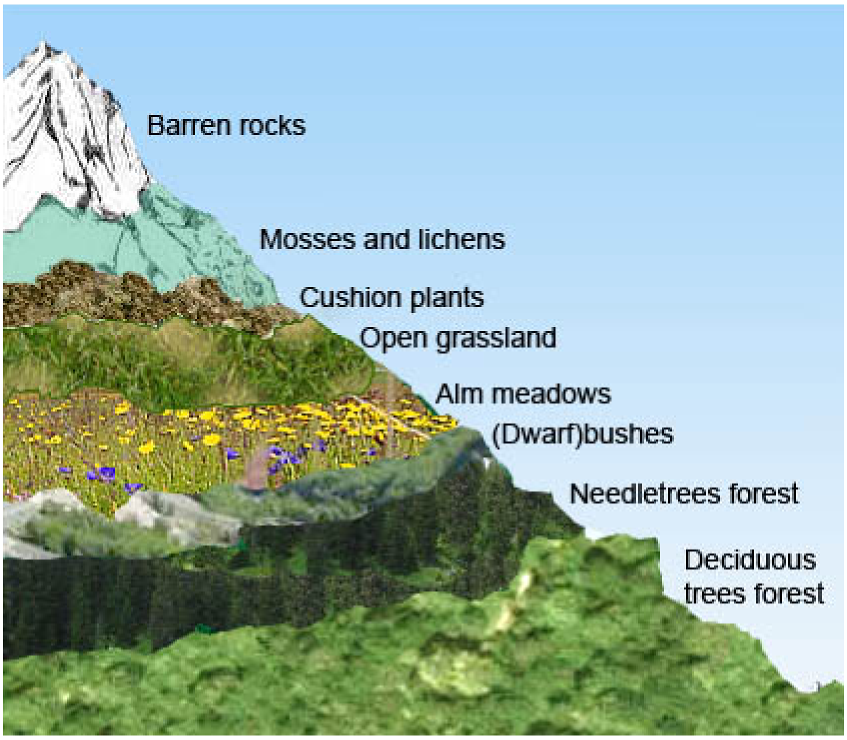
Ecosystem is a small scale community of living things that interact with each other and their non-living environment, and may be as large as a desert or as small as a puddle. It requires energy from an external source – this is usually the sun.



Biome is a very large ecological area on the earth's surface, with fauna and flora (animals and plants) adapting to their environment. It is often defined by abiotic factors such as climate, relief, geology, soils and vegetation.

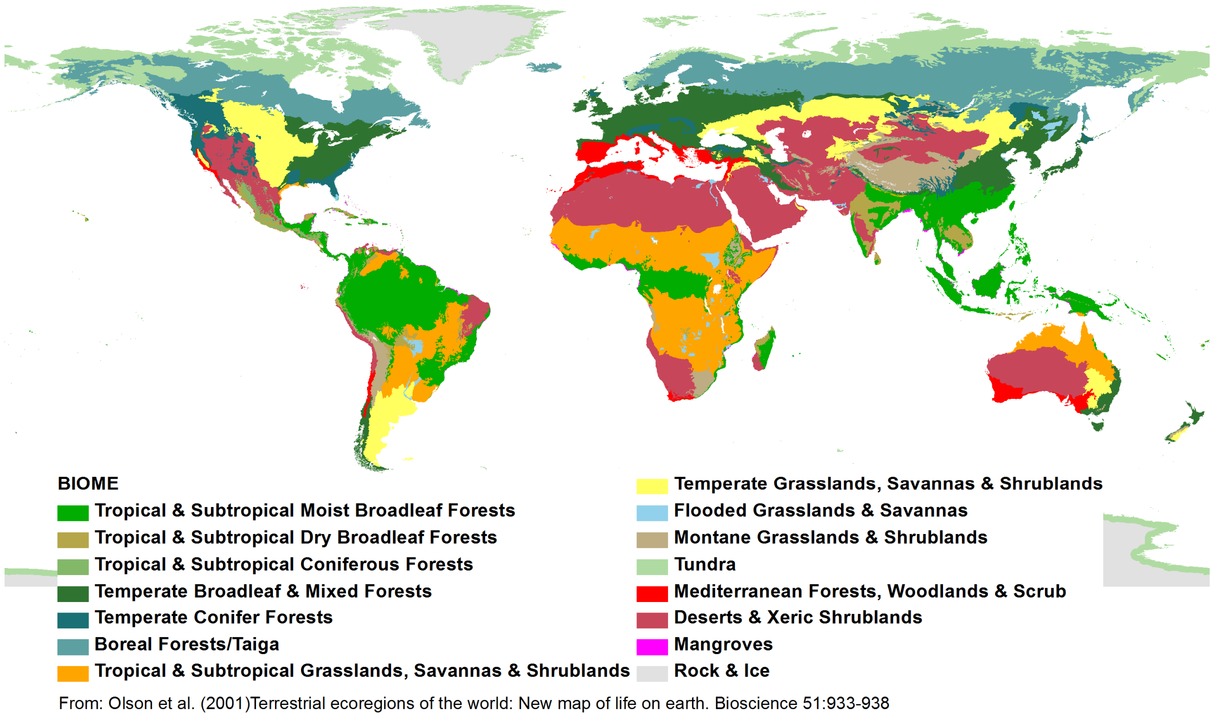
Abiotic factors refer to non-living physical and chemical elements in the ecosystem such as **rocks, relief, atmosphere (gases) and climate, soil, water, solar radiation, fire, gravity**.

Biotic factors are living or once-living organisms in the ecosystem. These are obtained from the biosphere and are capable of reproduction such as plants, animals, detritivores (fungi, microbes etc.), and people.



3 Vegetation zonation in mountains.

The distribution of large-scale ecosystems (biomes) is determined by **climate**. Latitude, air pressure and winds are important factors that determine the climate of a place. The map shows the distribution of the global ecosystems or biomes.



4 World biomes map.

Biome characteristics:

- **Tropical forests** are found near the equator in Central and South America, parts of Africa and Asia. They are hot and humid and contain a huge variety of plants and animals - around half of all the world's species. The trees are mostly hardwood. The climate is called equatorial.
- **Savannas** or tropical grasslands are hot and dry, dominated by grass, scrub and occasional trees. They have two distinct seasons - a dry season when much of the vegetation dies back, and a rainy season when it grows rapidly. They are found in central Africa (Kenya, Zambia, and Tanzania), northern Australia and central South America (Venezuela and Brazil).
- **Desert** is the driest and hottest of areas. The world's largest desert is the Sahara in North Africa. Areas of scrub land that border the desert are called **desert scrub**.
- **Mediterranean** climates are not too hot or cold. They are found around the Mediterranean Sea, near Cape Town in South Africa and Melbourne in Australia.
- **Temperate** grasslands are dominated by grass and trees and large bushes are scarce. They have a temperate continental climate - the weather is mild with moderate rainfall. Grasslands include the Puszta in Hungary, the Veldt in South Africa, the Pampas in Argentina and the Prairies in the USA.
- **Temperate deciduous forests** contain trees that lose their leaves and are found across Europe and USA. The weather is mild and wet. The climate is called temperate maritime.
- **Coniferous forests**, containing evergreen trees, are found in Scandinavia, Russia and Canada. They have a cool climate with moderate rainfall called cool temperate.
- **Mountain** areas can be very cold at night and during winter. The growing season is short and at higher levels trees will not grow.
- **Tundra** surrounds the North and South poles. They have an extremely cold climate, with limited numbers of plants and animals able to survive there.

Questions for discussion:

1. Name the largest ecosystems on the earth, talk about their locations and discuss their importance for humanity. Talk about human's impact on them and its connection with climate change.
2. Explain what endemic and relict species are. Find 5 animal and plant endemic and relict species we can find in Slovakia and talk about them and why we have to protect them.
3. Search some information about the Galapagos Islands, their locations and discuss why they are designated a UNESCO World Heritage site. Name 5 endemic animal and plant species living there. Which factors allowed their evolution?
4. Which biomes are typical for Slovakia? What kind of zonality can we see in Slovakia? Talk about the differences between each belt and give examples of some of the animals and plants. Why are there no coniferous (boreal) forests in the Southern Hemisphere?
5. Explain why National Parks are important for us and the reasons we have them. Name all National parks in Slovakia and their locations. Explain why it is important to protect these areas.
6. Why is tundra often discussed in connection with climate change?
7. Find out current information about endangered species, name 10 most endangered of them and explain the reasons why they are going extinct.
8. Find an interesting place in the world and analyse all its physical features you have learnt about in geography this year.

Acknowledgement

I would like to express my gratitude to all those authors whose works gave me the possibility to complete this textbook.

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