Allianz Umweltstiftung

Information on the Topic of “Climate”: Fundamentals, History and Projections.

Wissen

Instead of a Preface.

For some time now, a heated debate has been raging in Germany and Europe on how - and even if - the climate is changing, who's responsible, and what can and must be done. Throughout this debate, facts, assumptions, and prognoses are often being interchanged at will. And buzzwords such as killer heat wave, monster tsunami, and horror climate are dominating the headlines.

With this brochure, the Allianz Foundation for Sustainability intends to add more objectivity to this controversial debate. The topic of climate change is divided into three parts. **"Fundamentals"** deals with the interrelationships and factors that influence the complex issue of climate. **"History"** depicts the dynamic developments in climate change over the years. And finally, **"Projections"** takes a look at the current and future world climate situation.

Allianz Foundation for Sustainability wishes you while reading an enriching and informative experience.

Contents.

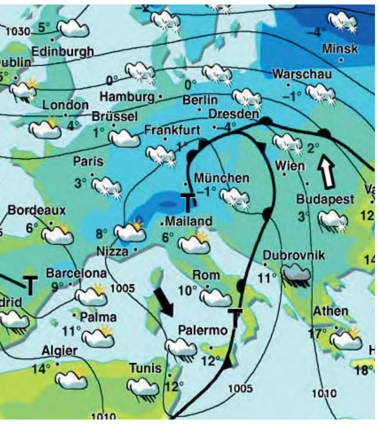
Information on the Topic of “Climate”:
Fundamentals, History and Projections.

From Weather to Climate.

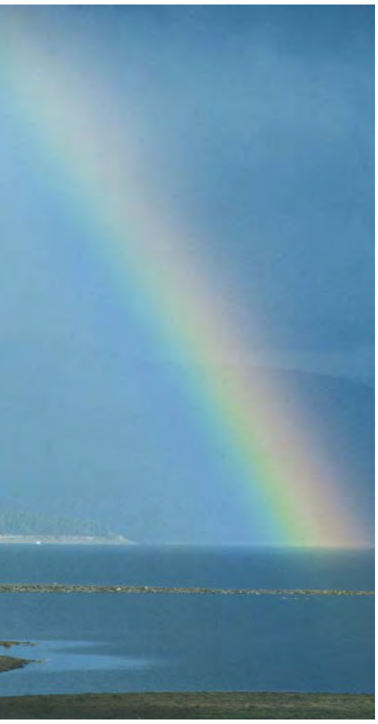
"The warm weather system Michaela continues to set record high temperatures. Yesterday was the hottest day in Germany since weather records began over a hundred years ago." Weather or climate?

This chapter explains:

- the difference between weather and climate
- how climate is defined.



Details of current weather conditions on a weather map.



Weather transformation between rain and sun.

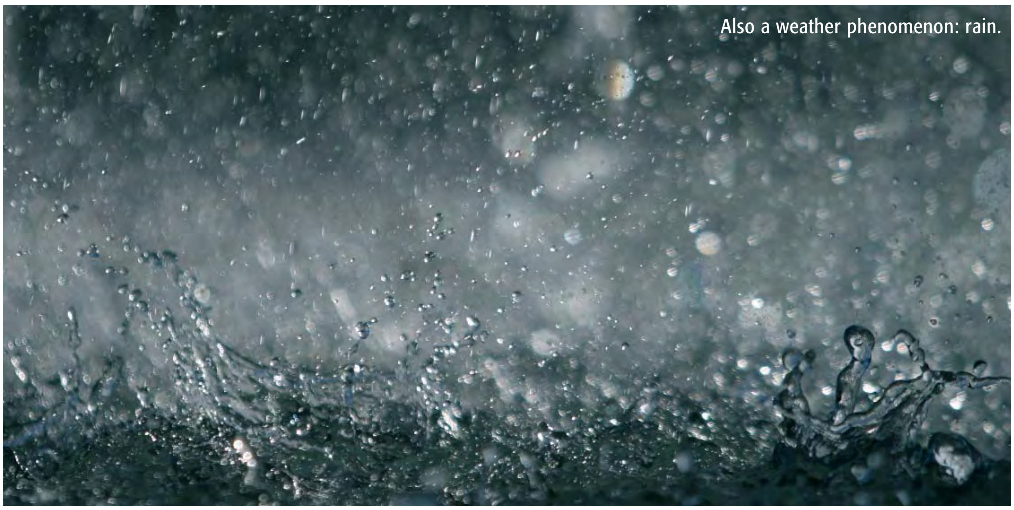
Weather, Weather, Everywhere!

When a fruit blossom freezes at night due to a late frost, this is the result of **weather**. But when a certain area continually experiences late night frosts during fruit blossoming, then the **climate** is not conducive to growing fruit.

Weather is the **short-term** and continually changing **conditions in the atmosphere** over a certain location that we experience on a daily basis. The current weather is the result of meteorological conditions that quickly emerge and dissipate like a low-pressure system or a prevailing warm weather front. Weather events or phenomena include rain, sunshine, thunderstorms, and blizzards. **General weather situations** are weather conditions over large areas such as Europe or East Asia. Observed atmospheric conditions over a few days is then known as weather. Weather forecasts are only possible for a few days up to a week.
Climate refers to the **characteristic developments in weather at a specific location** or area **over a longer period of time**. Climate is therefore a statistic of weather in which short-lived fluctuations have little bearing. But climate is not just the "average" weather. Climate also takes into

"Postcard weather."

account the frequency of extreme weather events. Climate always **refers to a concrete place and time**.



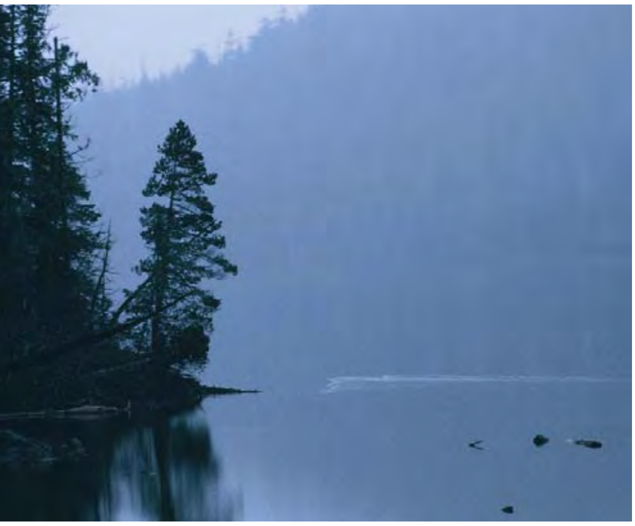
Also a weather phenomenon: rain.

Climate in Space ...

The microclimate describes climates of small areas, for example, of different vegetation types such as meadows or forests. Terrain or mesoclimate examines the climate of different landscape and terrain forms. Macro or global climate encompasses continental and global interrelationships. When comparing the climate of many different places across the globe, one discovers that relatively large areas have similar climate characteristics. These areas are put together to form climatic zones. (p. 8). This brochure deals solely with the global climate.

Climate
Climate comes from the Greek word *klíma*, meaning "inclination," referring to a geographical location. The angle of the sun is steeper at lower latitudes and flatter at higher ones. The various angles of incidence (the angle at which the sun's rays strike the earth) is the main factor for determining the different climatic zones.

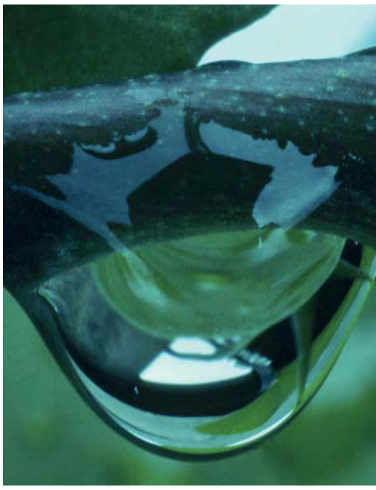
Climate on a grand scale: macro or global climate.



A lake in a basin – here is a mesoclimate.

... and Time.

To ensure that worldwide climatological data is compared on a uniform basis, reference periods of 30 years were established following a recommendation made by the World Meteorological Organization (WMO). 30-year periods for climate "normals" started in 1901-1930, from 1931–1960, etc. Currently, we are in the period covering 1991-2020. These fixed periods, however, are not rigid. Depending on the demands and needs of different climatological research objectives, this period may be shortened or extended. For example, when examining ice or heat ages, longer observations periods are necessary.



Microclimate: Different conditions are found under trees and bushes than in open spaces.

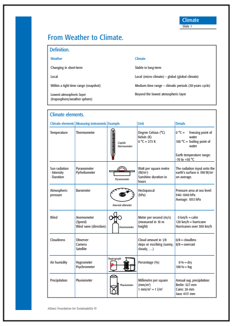
Overview of Important Points:

- Short-term and continuous changes in atmospheric conditions, affecting temperature, precipitation, etc., at a specific location are known as weather.
- Climates refers to weather conditions at a specific location or area over a longer period of time.
- Global climate encompasses the climate of the entire earth, respectively the continents. In order to assess changes in the earth's climate, observation periods of 30 years have been established - also known as climate normals or standard periods.

On Climate's Trail.

The weather station on the Hohenpeißen Mountain in the foothills of the Alps is considered to be the oldest mountain weather station in the world. This station has the longest continuous running record of weather in Germany, starting in 1871. Whoever wishes data before this time must rely on other sources: historical chronicles and paintings, water level markers on old bridge pillars, tree rings, and drilled cores from artic ice …

This chapter shows:
- what climate elements are
- how current climate data is gathered
- how past climate data can be reconstructed.



Climate
Slide 1

From Weather to Climate.

Definition.

Weather	Climate
Changing in short-term	Stable in long-term
Local	Local (micro climate) – global (global climate)
Within a tight time range (snapshot)	Medium time range – climatic periods (30-years cycle)
Lowest atmospheric layer (troposphere/weather sphere)	Beyond the lowest atmospheric layer

Climate elements.

Climate elements	Measuring instruments	Example	Unit	Details
Temperature	Thermometer	Liquids thermometer	Degree Celsius (°C) Kelvin (K) 0 °C = 273 K	0 °C = freezing point of water 100 °C = boiling point of water Earth temperature range: -70 to +50 °C
Sun radiation - Intensity - Duration	Pyranometer Pyrheliometer	Pyranometer	Watt per square metre (W/m²) Sunshine duration in hours	The radiation input onto the earth's surface is 198 W/m² on average.
Atmospheric pressure	Barometer	Aneroid altimeter	Hectopascal (hPa)	Pressure area at sea level: 940–1040 hPa Average: 1013 hPa
Wind	Anemometer (Speed) Wind vane (direction)	Anemometer	Meter per second (m/s) (measured in 10 m height)	0 km/h = calm 120 km/h = hurricane Hurricanes over 300 km/h
Cloudiness	Observer Camera Satellite		Cloud amount in 1/8 steps or escribing (sunny, cloudy, …)	0/8 = cloudless 8/8 = overcast
Air humidity	Hygrometer Psychrometer	Hygrograph	Percentage (%)	0 % = dry 100 % = fog
Precipitation	Pluviometer	Pluviometer	Millimetre per square (mm/m²) 1 mm/m² = 1 l/m²	Annual avg. precipitation: Berlin: 527 mm Cairo: 26 mm Java: 4117 mm

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From Weather to Climate.
Slide 1

Climate Is Measurable.

Measurable parameters that characterize climate are known as climate elements (Slide 1). In general, they are:
- temperature
- sunshine (duration, intensity)
- air pressure
- wind
- cloud cover
- humidity
- precipitation.

A weather station gathers weather data.

Weather elements are observed and recorded at different worldwide, networked weather stations and by weather and space satellites, according to international standards. A weather station houses various measuring instruments. At analogue stations, these instruments must be read manually by a weather observer. At weather stations that are manned around the clock, readings take place every hour. At digital (automatic) weather stations, sensors gather desired weather data and send these automatically back to a basis station by cable or wireless radio communication where they are then evaluated.

Anemometer measures wind speeds.

Observations Around the World.

A complete weather observation across oceans, rainforests, ice, deserts, and high mountains is hardly possible. Therefore, remote sensing from space is playing an ever greater role. Satellites detect and measure rays that are being either reflected and/or emitted from the earth and atmosphere. Satellite information alone, however, does not provide a complete picture of the complex weather events and climate events on earth. The exact determination of temperature,

Satellite picture.

humidity, and wind also necessitates the coordination with ground-based weather stations. Recorded data from weather stations and satellites are gathered and evaluated through numerical analysis by meteorologists. Calculated averages over longer periods of times characterize the climate of a certain area and are published in climate tables. Climate diagrams show the development of temperatures and precipitation (p. 8). Making a judgment about the world climate – and a possible climate change – is highly dependent upon the earth's annual average temperature. This average is calculated in a complex mathematical procedure from data gathered from worldwide network of weather stations. Basis for the calculation is the daily average temperature which is determined by the average of measured values on the hour, every hour. From the sum of the daily averages, monthly and yearly values are compiled.

Centuries of climate data is "saved" in the ice of Greenland's glaciers.

Climate Research Backwards.

Understanding the climate of the past is very important for climate researchers today. With data from the past, they try to discover long-term trends, deviations, and causes in order to make prudent forecasts about our climate in the future. The most important criterion for reliable climate forecasts is to have, if possible, a **continuous record of data over a long period of time** without any gaps.

There is, for example, **a continuous record** of temperatures near the ground over the last 100–150 years available for basically Europe, coastal zones of North America and East Asia as well as along major shipping routes. Some records even reach as far back as the 17th century. But before this, climate can only be reconstructed through so called proxies (= representatives). Proxies either come from "natural climate archives" or from other historical documents.

Natural climate archives that have "saved" climate information of the past include:

- the yearly rings in trees and coral reefs
- marine sediment cores
- ice cores from glaciers.

From natural proxy data, researchers can find out, for example, temperature, sun activity, insolation intensity, temperatures of dried up oceans, humidity and dryness of lost continents, and deduce the composition of the atmosphere, thereby being able to reconstruct climate events. In doing so, researchers also rely on the **historical depictions** and **chronicles** such as:

- reports of natural catastrophes, damn repairs, sailing times of ships, etc.
- protocols about water amounts and about icing over of rivers and lakes, and water level marks on houses and bridges
- weather diaries
- chronicles of worldly and religious institutions
- such as rogation processions against droughts
- paintings and pictures
- documents that records harvests, blossoming, and ripening of plants.

Climate reconstruction from historical data has the advantage over natural archives that dates can usually be exactly pinpointed.

Flood level marks on a house.

Overview of Important Points:

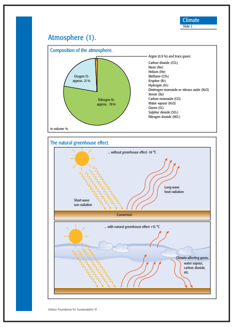
- Climate can be measured and determined through climate elements such as temperature, air pressure, humidity, wind, precipitation, etc.
- Continuous historical data over as a long a period of time as possible is very important for climate research. Currently, the longest periods of continual data are 100-150 years.
- For the time before this, climate can be reconstructed through proxy data. Besides being obtained from historical documents, natural climate archives play here an important role.

Earth’s Protective Shield.

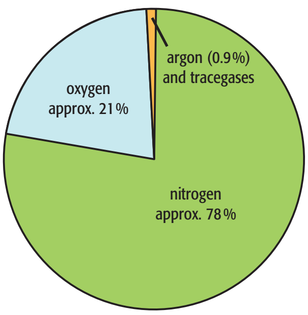
From a spaceship, the earth’s visible atmosphere appears as a deep royal blue seam across the curved horizon. Wonderfully magnificent. Yet, it looks ever so thin and extremely fragile. In relationship to the earth, our atmosphere is hardly thicker than the peel on an apple.

In this chapter read about:
- what is atmosphere
- what is “air” made of
- how is the atmosphere constructed
- how the atmosphere allows for and protects life on earth.

A small blue seam - our atmosphere.



Atmosphere (1).
Slide 2



Composition of the earth’s atmosphere (Fig 2.1).

Held by Gravity.

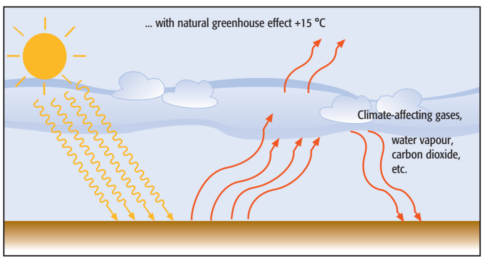
Atmosphere (Greek *atmós* = vapor, *sphaira* = sphere) is the layer of gases over the earth that plays a central role in our climate. It protects us against the powerful rays of the sun. It provides for an even temperature on the surface of the earth. And it contains the air we need to breathe, making life on earth possible. The atmosphere is between 1000 and 3000 kilometers thick. Near the earth’s surface, our atmosphere is the thickest, because it is “pulled” down by gravity. The higher we go, the thinner the atmosphere becomes.

In the course of earth’s history, the composition of our atmosphere has changed over and over again. Today, the atmosphere contains about 78% nitrogen, 21% oxygen, 1% argon, and numerous other so called trace gases (Slide 2, Fig 2.1). The amount of water vapor in the atmosphere varies between 0 and 7%, depending on the region.

Earth: A Greenhouse.

Although the **trace gases** only show up in very slight amounts, they have a substantial impact on climate: water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (laughing gas N_2O), and ozone (O_3) all have the similar effect as glass windows do in a greenhouse. They allow sun rays of shorter wavelengths to pass, while filtering longer wavelengths of radiant energy by partially changing the sun rays after reaching the surface. These gases are therefore known as **greenhouse gases** (Slide 2, Fig 2.2). They are responsible for the **“natural” greenhouse effect** that keeps the earth’s average temperature at about 15 °C – without them about -18 °C. The natural greenhouse effect is what makes life on earth possible.

Water vapor (60%) and **carbon dioxide** (20%) play the largest roles in creating the natural greenhouse effect. Another element of the atmosphere that plays a role in our climate is **aerosols**. These are tiny gaseous or solid particles suspended in the air that occur when volcanoes erupt, things are burned or from dust and ice crystals. In general, they have a cooling effect, because they reflect sunrays. Moreover, aerosols play an integral role in the formation of clouds, and some aerosols even absorb radiation.



The atmosphere functions like the glass windows in a greenhouse (Fig 2.2).

Layers of Cake: Air.

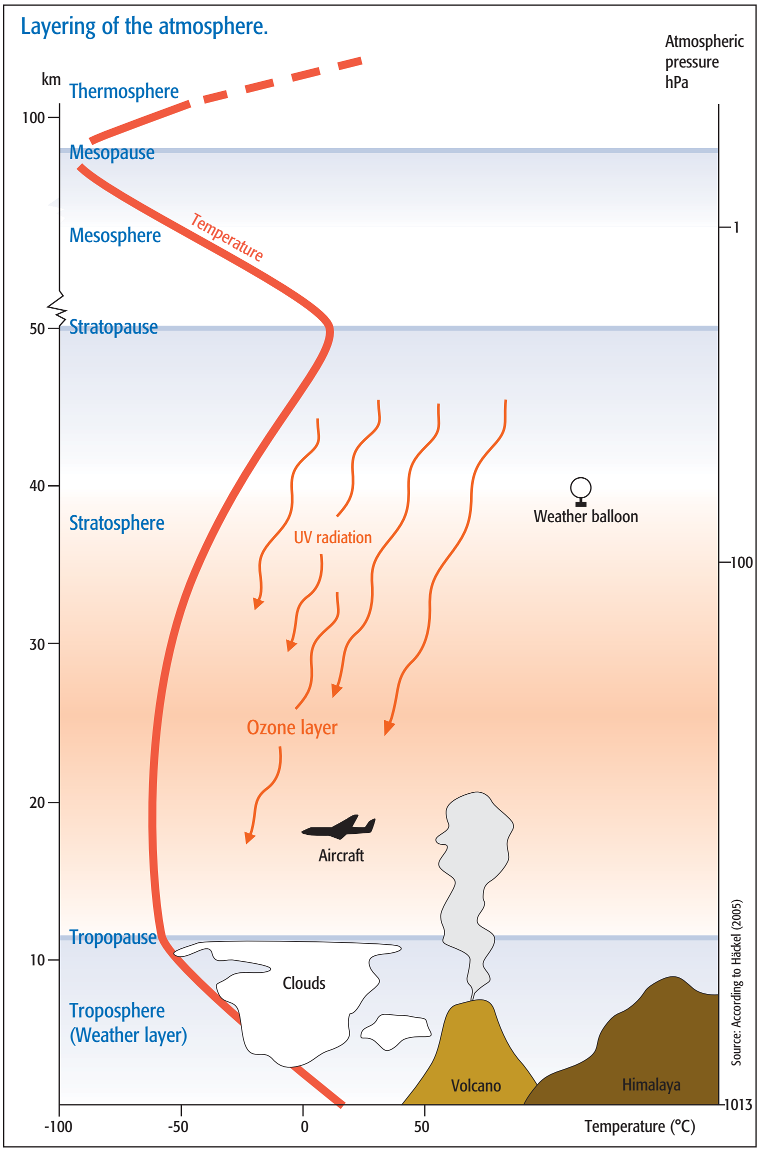
The atmosphere can be divided vertically into several distinct layers (Slide 3). In determining our weather and climate, the lowest layer of atmosphere, the **troposphere**, is the most important. It is known as the **"weather layer,"** because it holds about 90 % of the atmosphere's mass and water vapor. For each 1000 meters of altitude, the temperature sinks about 6.5 °C. The upper border of the troposphere is known as the **tropopause**.

The temperature in the dry and cloudless **stratosphere** – above the tropopause – remains almost unchanged, yet begins to rise as one approaches the **stratopause**. The exchange of air between the troposphere and stratosphere is relatively small. While the air in the troposphere can be replaced in days or within a few hours, this process in the stratosphere takes months if not years. Above the stratopause is the **mesosphere** with a mesopause. After this comes the thermosphere. And after the thermopause comes the **exosphere**, the atmosphere's outer most layer of gases.

Earth's Protective Shield.

For life on earth, the trace gas **ozone** plays a critical role. In the lower troposphere, it shows up only in small amounts and acts as a greenhouse gas. The stratosphere, however, contains about 90 % of all ozone molecules with a 75 % concentration in the altitude of 15 to 30 kilometers above the earth's surface. This is where the so called **ozone layer** is formed. This is where the powerful and potentially cell-damaging **ultraviolet (UV) light** from the sun is absorbed, letting only small amounts reach the earth's surface. Without this protective shield, life on earth would be in grave danger.

Weather takes place in the lowest layer of the atmosphere, the troposphere.



Layers in the atmosphere.
Slide 3

Overview of Important Points:

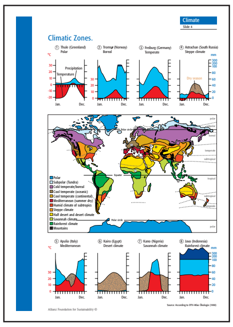
- Climate and atmosphere go hand-in-hand with one another.
- Atmosphere is made of up a gaseous mix, and can be divided vertically in different layers.
- Weather mainly takes place in the troposphere, the lowest layer of the atmosphere.
- Without the atmospheric gases that have an impact on the climate, the temperature of the earth would be about -18 °C, but is actually 15 °C due to the natural greenhouse effect.
- The ozone layer absorbs potentially cell-damaging UV radiation from the sun.

Climate Machine Earth.

Vostock, Antarctica, July 1983: minus 89.2 °C air temperature. El Azizia, Libya, August 1923: 57.3 °C air temperature. These are extreme values. But they show that the climate on earth is not the same everywhere and at the same time.

This chapter gives you an overview of:

- how diverse the earth's climate is
- what climate factors are
- how the climate machine earth is built.



Climatic Zones.
Slide 4

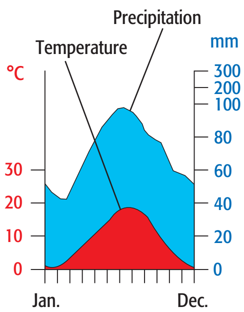
The Climate Today.

Climate conditions on earth today are very diverse. Our planet can be categorized into different **climatic zones** which have a characteristic progression from the poles to the equator: **polar, subpolar, boreal, temperate, subtropical**, and **tropical** (Slide 4). The borders between each of these zones, however, do not run parallel to the **geographical lines of latitude**. This is because of such phenomena as global wind belts and ocean currents in addition to the fact that larger masses of land react climactically different than oceans do. Oceans change their temperatures very slowly, conserve warmth, and affect neighboring land masses by tempering their weather. This is why Western Europe has a relatively temperate climate. Effects from the Atlantic provide for relatively mild winters and cool, humid summers. By contrast, the center of continents tend to cool off drastically in winter and heat up significantly in summer. Therefore, Eastern Europe has a more continental climate with cold winters and hot, dry summers.

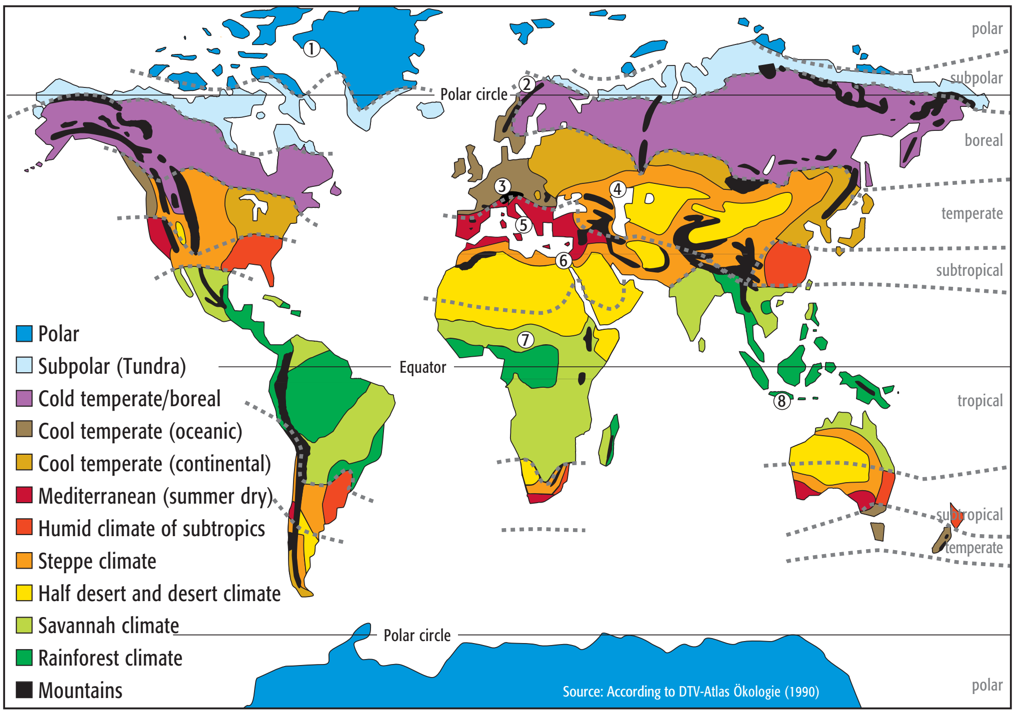
The differences between the various climate zones are easily discernable on a **climate diagram**. These diagrams describe the climate of a certain area over a long observation period by indicating temperatures and precipitation, days of frost, and dry spells. Slide 4 shows the earth's different climatic zones with their climate diagrams.

Between the Poles and the Equator.

Polar and **subpolar** climates are characterized by low average temperatures, where temperatures in the summer near the poles are hardly over 0 °C. Precipitation in these zones is also comparably low. In **boreal** and **temperate** climatic zones, more precipitation generally falls than can evaporate which leads to a **humid** climate. **Arid** and **semi-arid** climates on the other hand experience periods of dry spells. Less precipitation falls than ever could be evaporated by high temperatures. Climates with dry spells can be found the in steppe areas, around the Mediterranean, in the savannahs, and are very extreme in deserts and semideserts (mainly in the **tropics** and **subtropics**).



Climate diagram for Freiburg, Germany.



Climatic Zones (Fig 4.1).

The climate in tropical rain forests on the other hand is very humid. Here large amounts of precipitation fall and seasons are hardly existent. An exception are the tropical regions in the area of monsoons, where during certain times of the year rain fall increases exceptionally. Mountains represent a special case. Because air temperature in the atmosphere lowers 0.6 °C for every 100m increase in altitude, mountains in a way ascend through all climates zones. That’s why in the higher regions of mountains one can find conditions similar to those in polar zones – with the difference that incoming solar radiation (isolation) acts according to the geographical latitude.

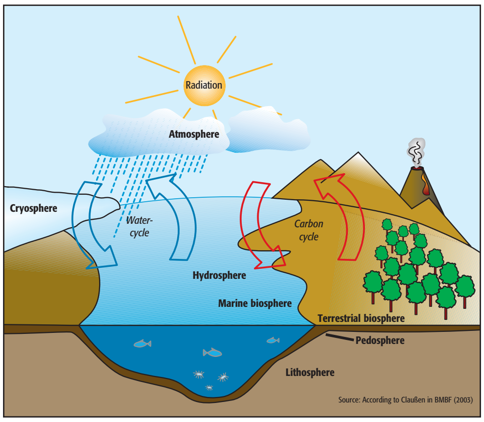
Determined by Climate.

The climatic zones are not only reflected in the vegetation on the surface of the earth but in the use of this vegetation as well. Whether a coniferous woodland or a rain forest can thrive depends on the climate. Climate also plays a critical role in the cultivation of agricultural crops. And the most “northerly crop cultivation point” - the border in the North at which agricultural is still possible – is defined primarily by the climate. This same is also true of the “dry timber line,” for example, the boundary zone Sahel in North Africa.

A Mammoth Climate Machine.

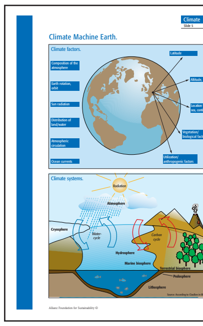
Climatic zones are not rigid, because the climate of the earth is constantly changing - even if on a grand time scale. This becomes evident when we look back over the history of climate (pp. 22). Climate is affected by different climate factors (Slide 5, Fig 5.1). These factors with global effects include phenomena like the composition of the atmosphere, deviations in earth’s orbit and solar radiation, distribution of land and water as well as the resulting atmospheric circulations (wind belts) and ocean currents.

Local factors are relevant in determining the climate at a certain location: geographical latitude, altitude above sea level, characteristics of the landscape with mountains, valleys, and plains (relief); and the proximity to oceans. In addition to these geophysical factors, there are also biological factors like vegetation and anthropogenic factors which are man-made. The global climate of the earth is a highly complex system with numerous and at times difficult to grasp interactions. The earth functions in this regard as a mammoth climate machine with the sun as its driving force (Slide 5, Fig 5.2).



Climate system (Fig 5.2).

The entire climate system consists of many subsystems. Besides the atmosphere and hydrosphere (oceans, rivers, precipitation, groundwater), the subsystems cyrospshere (ice masses, snow, permafrost), pedo- and lithosphere (earth’s crust and mantle) and the biosphere (living environment) also play a role. All these systems interact dynamically – this means a small change in one system can have a vast impact on another system or on the entire system.



Climate Machine Earth. Slide 5

Differences in climate determine what our world looks like.

Overview of Important Points:

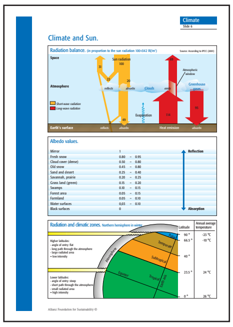
- ▶ The climate on earth is not the same everywhere, but does show common characteristics that are categorized into specific climatic zones that progress from the poles to the equator.
- ▶ Certain climate factors determine the climate. These can be divided into geophysical, biological, and anthropogenic factors.
- ▶ The earth’s climate system is extremely complex. The driving force is the sun.

Climate Motor: Sun.

The sun's energy warms. The sun drives the water cycle. And there wouldn't be any wind without the sun. Everything revolves around the sun - even climate.

In this chapter read about:

- how the sun drives the climate system
- how absorption and reflection affect climate
- why the angle of insolation and geographical latitude are important.



Climate and Sun.
Slide 6

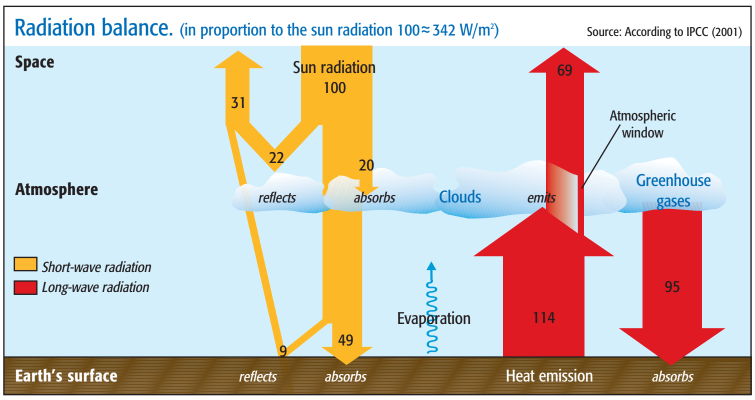
Solar Energy.

The sun is **the motor behind the climate machine on earth**. Each year, the earth receives **solar energy** amounting to 1.08 x 1010 kilowatt hours. (By comparison, this is almost 10,000 times more energy than humans consume yearly.)
Solar radiation or energy that reaches the earth varies in distribution. It differs – caused by the tilt of the earth's axis – according to the **seasons** and **geographical latitude**. In addition, incoming solar radiation changes upon entering the earth's gaseous atmosphere and after reaching the earth's surface. Here, the two most important processes are absorption and reflection (Slide 6, Fig 6.1).

Only Some Rays Make It.

In **absorption**, material takes in **short wavelengths** of solar radiation and transforms these into warmth (**long wavelengths**). Within the atmosphere, three gases are responsible for this: ozone, water vapor (clouds), and carbon dioxide. They absorb a large part of the sun's energy especially in the non-visible light spectrum, with ozone primarily absorbing light in the ultraviolet (UV) spectrum. **Reflection** is when solar energy is "thrown back" without any transformation. Light-colored objects reflect more rays than dark-colored ones. Degrees of reflection are expressed in terms of **albedo**.

Radiation ping-pong
(Fig 6.1).



The best reflectors in the atmosphere are clouds; the best reflectors on earth are the polar ice caps.

Reflected
The albedo (Latin *albus* = white) expresses the ratio of incident to reflected electromagnetic radiation. A theoretical albedo of 1 corresponds to 100% reflection. An albedo of 0 corresponds to 100% absorption. The albedo value is dependent upon the characteristic of the surface being radiated and at what angle. Slide 6, Fig 6.2 shows several examples for average albedos. The whole system of the earth and atmosphere has an albedo of 0.30.

Radiation Ping-Pong.

Only about 50% of the sun's rays actually make it through the atmosphere and reach the earth's surface. They are transformed into heat radiation of long wavelengths that upon reaching the earths surface head back out into the earth's atmosphere. Only small amounts of this heat radiation in a specific wavelength can pass through the atmosphere and out into space again. Here, the talk is of an **atmospheric window**. The largest portion, however, is absorbed in the atmosphere especially by the greenhouse gases and emitted again in all directions – even back to the earth's surface. The earth's surface heats up and emits again heat radiation of long wavelengths back into the atmosphere. Some of the heat radiation escapes into space as explained above, and some is absorbed and emitted again as already described (greenhouse effect). Through this "radiation ping-pong," heat accumulates and the earth's surface receives more energy than the sun actually radiates. Seen on the whole, however, the earth is in a perfect energy balance with the universe. Of the 100% incoming solar radiation, about 3% is reflected and about 69% is absorbed and emitted as heat radiation of longer wavelengths (Fig 6.1).

The Climate Motor Is Running.

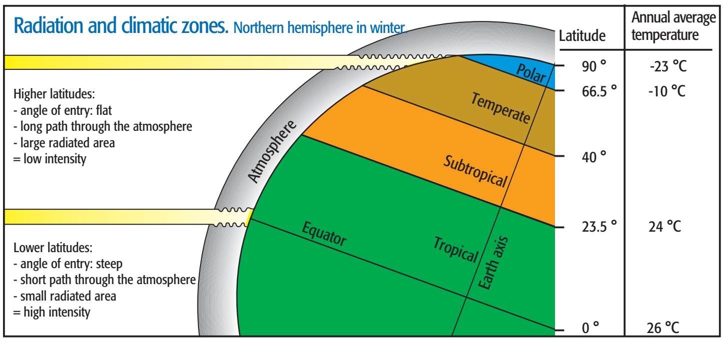
The aforementioned observations affect the earth as a whole. Regionally, though, the radiation balance can look quite different. Areas around the equator, for example, have a relatively constant annual insolation (incoming solar radiation), areas around the poles only for six months. Insolation at higher latitudes has a longer path through the atmosphere than at lower latitudes. Therefore, more radiation is absorbed. Moreover, because of the low angle of insolation, the radiation is distributed over a greater area. Both of these phenomena lead to a substantial reduction of radiation intensity at locations with higher latitudes (Slide 6, Fig 6.3). The form and structure of the earth's surface are also important factors with regard to radiation. Depending on whether radiation hits water, areas of land, light and dark surfaces, or vegetation or non-vegetated areas, it will be reflected or absorbed in varying degrees. This in turn has an effect on processes in the atmosphere.
Rises in temperatures lead to evaporation, clouds form. These in turn influence the incoming solar radiation. And the warming of the earth in varying degrees gives rise to global wind belts. There is even an exchange between warm water regions in the ocean (p. 12). Even life on earth is influenced by the effects that solar radiation has on climate: Through photosynthesis, plants bind carbon, thereby reducing CO_2 concentrations in the atmosphere (p. 18).

Light Variations.

Even seemingly universal givens such as solar radiation and the earth's orbit around the sun are subject to deviations, which have an impact on climate. One such deviation of importance are "Milankovitch Cycles," named after their discoverer, the Serbian mathematician and astronomer Milutin Milankovitch (1879-1958). Milankovitch found within every 100,000 years, the earth's orbit deviated between a near circle and light elliptical form (eccentricity) – affecting the distance between the earth and sun and subsequently the amount of solar radiation. Moreover, every 41,000 years, the earth's axial tilt changes slightly (obliquity) and the earth's axis completes one full cycle of precession approximately every 25,800 years. Both phenomena impact the distribution of solar radiation onto the surface of the earth. Today, Milankovitch cycles are considered to be what triggered the earth's most recent ice ages (p. 24).

Overview of Important Points:

- The sun is the motor of the climate machine earth. For the balance of radiation, absorption and reflection are the decisive factors.
- Only a portion of the sun's energy reaches the surface of the earth. In addition, different parts of the earth experience different radiation intensities.
- Once radiation reaches the earth's surface, it is either absorbed or reflected, depending on the characteristics of the surface. This affects the entire climate system, including wind belts and ocean currents.



Geographical latitude and solar radiation intensity (Fig 6.3).

Vegetation determines how much solar radiation reaches the earth's ground.

Snow and ice reflect almost 100% of sun light.

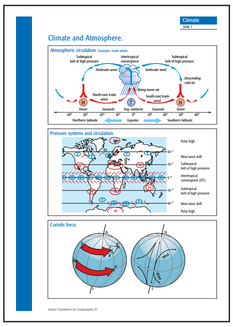
Even solar radiation is subject to deviation.

Climate Balance – Wind and Water.

The weather comes out of the Northwest. In the Bavarian forest during the winter, winds from the east bring arctic cold. At the coast, the winters are milder. Such short and succinct “weather rules” show that our climate is decisively impacted by wind and water.

This chapter explains:

- air pressure and wind systems (the weather makers)
- ocean currents and their effects on climate.



Climate and Atmosphere.
Slide 7

Distribution.

The sun is the “motor” that drives the climate machine earth. Different cogwheels and gears distribute that sun’s radiated energy. Wind and water, atmosphere and hydrosphere play a critical role here.

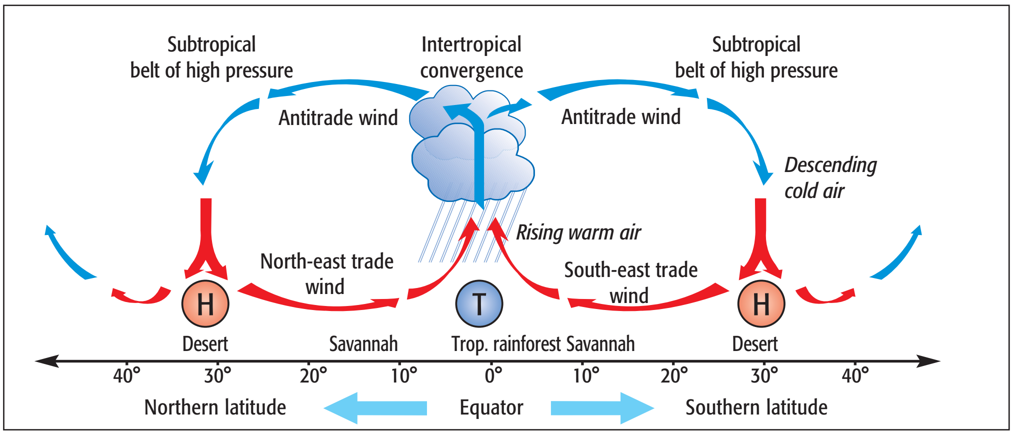
Highs and Lows.

In the atmosphere, many dynamic processes take place that determine weather and climate. One of these processes that has a major influence is air pressure. Cold air because of its higher density “presses” harder on the surface of the earth; warm air has lower density, presses down lighter on the earth and, therefore, creates less air pressure. Where cold air gathers is called a high pressure system. When air is heated strongly, we speak of low pressure systems or depressions. Differences in pressures are balanced out when air from high pressure systems flows to low pressures systems - giving us wind.

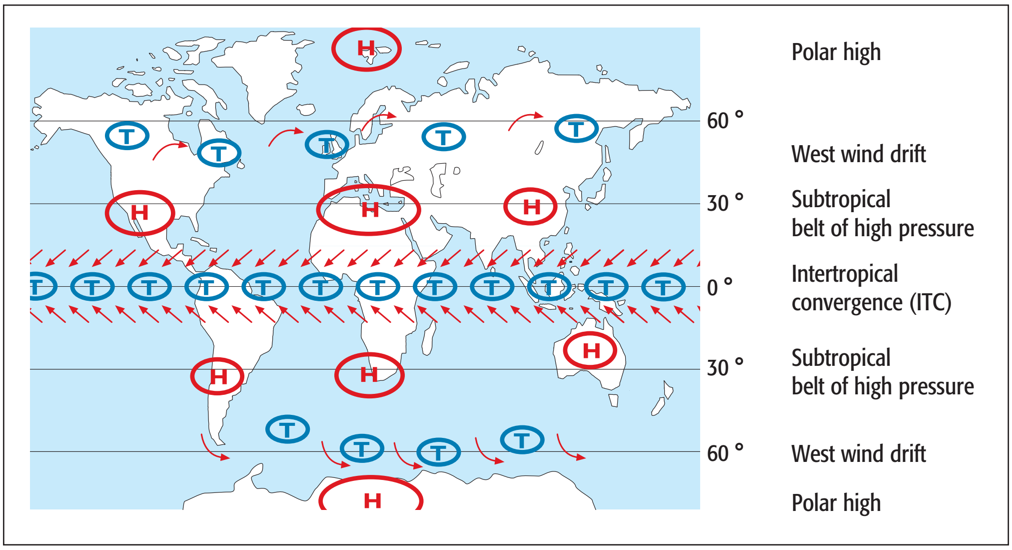
Global Wind Systems.

One example of wind systems are the trade and antitrade winds around the equator (Slide 7, Fig 7.1). Because of strong insolation at the equator,

air masses rise creating an intertropical convergence (ITC) zone. The rising air mass rains over the tropics and descends again in latitudes of about 30° North and South. Near the center of this descending air is a high pressure zone also known as the subtropical high pressure belt or horse latitudes. To balance out the fall in pressure, wind plays a crucial role. The trade winds flow out of the North and South towards the equator. Then the air mass shoots upwards to return as antitrade winds towards the poles again. Due to the spiral movement of air, excess warm air near the equator is transported to the North and the South, thereby subsequently sucking in colder air masses.



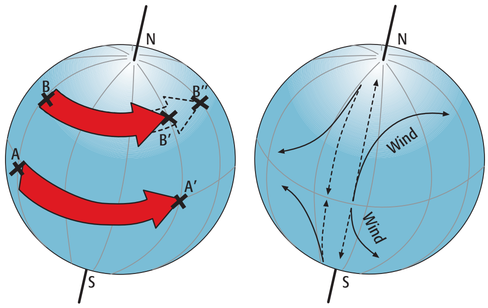
Atmospheric circulation (Fig 7.1).



Pressure systems of the earth (Fig 7.2).

When viewed globally, large connected pressure systems can be identified that run North and South of the ITC and along the subtropical high-pressure belt (Slide 7, Fig 7.2). At 60°N and 60°S warm and cold air masses meet, whereby the warm air rises, creating low pressures systems that due to the **Coriolis force** (see sidebar) drift eastwards (**west wind drift**). At the poles, the air falls again, creating high pressures areas (**polar highs**). In addition, because of the land and water distribution, so-called **thermal pressures system** also form. Hence, South Asia experiences high temperatures in the summer. The result is a constant thermal low. During winter, thermal highs arise as a result of Asia cooling off drastically, so much so that it almost encompasses the entire continent. The same holds true for the polar regions.

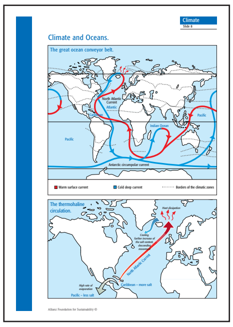
Depending on the season, the inner-tropical convergence sometimes swings outside of its equatorial zone. In summer, for example, the Asian thermal low pulls the ITC north across the Indian subcontinent. In this way, southeast trade winds cross the equator and due to the Coriolis force are turned into southwest winds. Fully saturated with moistures from the Indian Ocean, they drift up against the Himalayas and regularly cause heavy downpours of substantial rainfall – **monsoons**.



The principle of Coriolis force (Fig 7.3).

Coriolis Force (Slide 7, Fig 7.3)
Coriolis force is caused by the rotation of the earth and affects the movement of global air masses and ocean currents. Because of the spherical shape of the earth, places at different latitudes move at different speeds. A point along the equator moves at 1,667 km/h from West to East (A>A'). The closer we get to the poles, however, speed decreases because of less circumference (B>B'), eventually reaching zero directly at the poles. Now if an air mass leaves its geographical latitude, it retains the same speed. Should this mass travel from the equator northwards, it will enter latitudes of less speed than from where the air mass originated. The air mass is moving faster than the rotation of the earth under it. The air mass gains a lead (B") and is diverted towards the east. If the air mass travels from the northern hemisphere south, thereby entering a faster region and being slower itself, the air mass will be diverted to the west. The phenomena is exactly opposite for the southern hemisphere. Through this diversion of the air masses, pressure differences can gradually be balanced out and often remain so for days and even weeks.

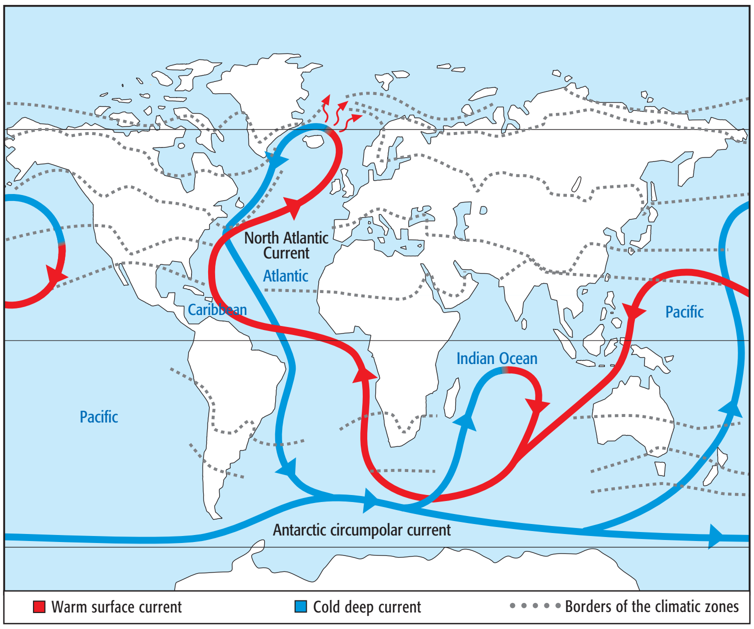
The Role of Oceans.



Climate and oceans.
Slide 8

Not only do the global wind systems provide for a distribution of energy, but above all else, **oceans** play a major role. Besides their function to **exchange heat across large areas**, they also influence the **amount of CO_2 in the atmosphere**. This occurs one the one hand by **direct intake of CO_2** out of the air into the water, whereby cold water can hold more CO_2 than warm water. For example, cold sinking ocean waters in the seas near Greenland and the Antarctic take in large amounts of dissolved CO_2, carrying these to the deep depths to be stored for many hundreds of years.
On the other hand, **phytoplankton extract CO_2 out of the water for photosynthesis** and in this way also from the atmospheric circulation (see p. 16 and 18).

The great ocean conveyor belt (Fig. 8.1).

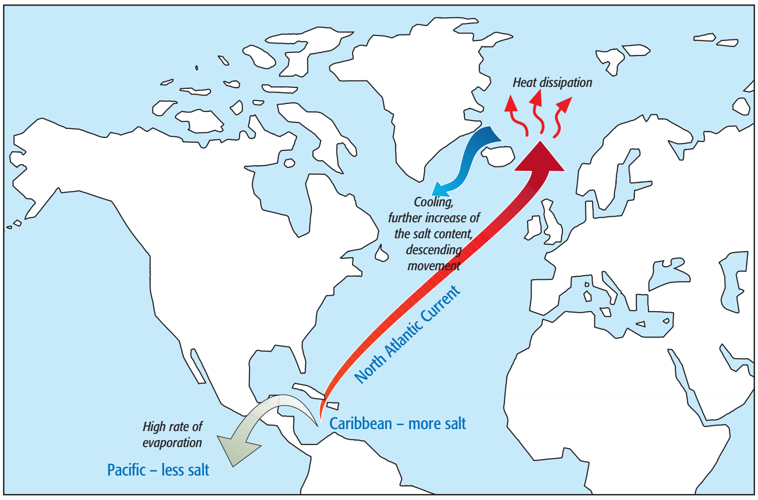


The Great Ocean Conveyor Belt.

The exchange of heat across large areas takes place on the **great ocean conveyor belt** that connects three oceans: the Atlantic, the Pacific, and the Indian (Slide 8, Fig. 8.1). Starting point for the global conveyor of currents is the **strong evaporation** that takes place **in the Caribbean** (Slide 8, Fig 8.2). Moisture from the evaporation is picked up by the North East trade winds and carried across the small land bridge in Middle America and exported westwards into the Pacific region. The freshwater lost from the Atlantic **is not replenished**, because further north in the area of the west winds, the Rocky Mountains stop the possible "return of clouds." This leads to a higher concentration of salt (**salinity**) in the water, making the waters of the Caribbean more dense than in the other oceans. The **North Atlantic drift** (partly of the gulf stream) and prevailing west winds transport the salty surface water of the Caribbean to the seas between Greenland and Norway. Once there, the water cools off, gets heavier, and sinks to the bottom. The sinking water and the vacuum it creates in turn pulls in salty water masses from the Caribbean, keeping the **heat pump** running. Because in the polar regions ocean water freezes to ice, salinity and density are increased even more. Differences in temperature and salinity create **thermohaline circulation** of the water masses (*thermos* = Greek for heat and *halos* = Greek for salt).

Then these water masses flow south as North Atlantic deep seawater and end up mostly in the **Antarctic circumpolar current** – the only current system in the world that circulates unhindered through all continental barriers.

From here the water is distributed as cold deep currents into the Pacific and Indian oceans. (Fig 8.1).
The effect of the global marine current system on the climate is significant. The "warm" North **Atlantic Drift** (current) creates for Western and Northern Europe a considerably more mild climate than would be expected from the geographical latitudes (Frankfurt, Germany is at the same latitude as Newfoundland and Stockholm, Sweden shares the same latitude as the southern tip of Greenland). On average, temperatures in North-west Europe are 9 °C over those places with a comparable geographical latitude!



The thermohaline circulation (Fig 8.2).

Massive Amounts of Water
In the "sinking zone" in the North Atlantic, over 17 million cubic meters of water plummet into the depths every second. This corresponds to about twenty times more water flowing out from all rivers in the world.

A Game of Interplay.

In the past, changes in oceans currents have had a massive impact on the climate occurrences. The tapering off of the North Atlantic current after the last ice age is a good example of this (pp. 24).
Another example of this is the **Antarctic circumpolar current** that vividly demonstrates how the different effects of the climate machine earth depend on and strengthen each other:
Through the detachment of Australia and South America, the Antarctic was probably completely surrounded by the South Polar Sea 30 million years ago. Prevailing west winds created the circumpolar current which since circles the Antarctic clockwise, preventing the exchange with warmer areas. This thermal isolation first of all led to the complete icing over of the continent. The huge snow and ice areas reflected almost all of the of the suns rays completely (high Albedo, p.10). As a result, the amount of the sun's energy being absorbed sank, leading to a worldwide cool down. This in combination with the growing ice crust led in turn to a temperature reduction in the South Polar Sea. And, because cold water can take in more CO_2 the warm water, the amount of CO_2 in the atmosphere was reduced which facilitated the fall in temperatures.

Wind and water affect our climate.

Overview of Important Points:

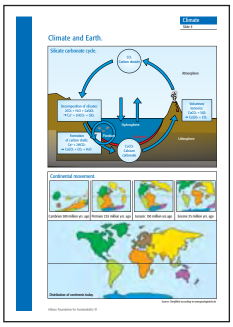
- Global wind and ocean current systems are responsible for the exchange of warmth between the tropics and the higher latitudes.
- The Great Ocean Conveyor Belt that connects the three oceans plays a decisive role. Part of the conveyor belt is the North Atlantic Drift (current), responsible for giving West and North Europe a mild climate
- Changes in atmospheric circulation as well as in oceans currents can have an impact on climate.

Climate in Motion.

That wind systems and oceans are important for climate makes sense. But what the earth's crust has to do with climate is often only understandable after a second glance. The seemingly solid ground under our feet is subject to constant change … change that also influences climate.

This chapter sheds light on:

- cycles in the climate system
- the role of the earth's crust as a reservoir for carbon
- effects of volcanism and tectonics on climate.



Climate and Earth.
Slide 9

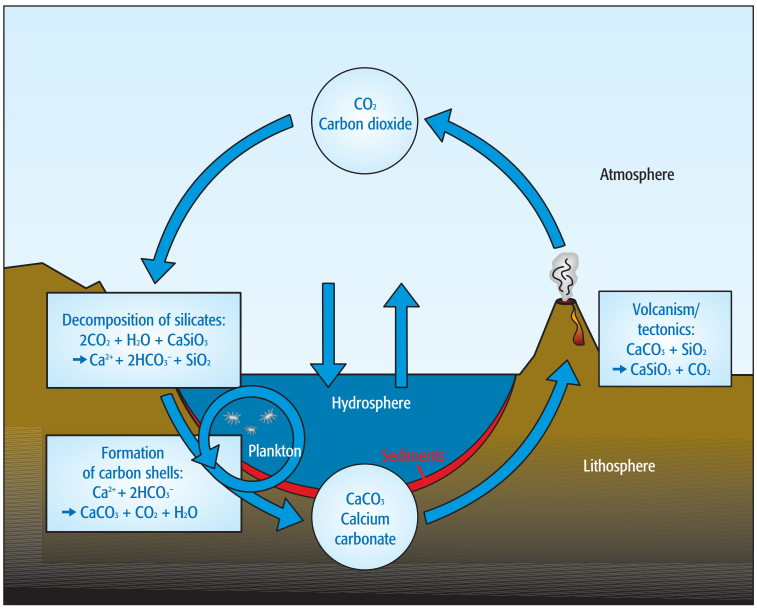
Getting to the Bottom of Climate.

The **lithosphere** (stone) as well as the **pedosphere** (soil) are in constant exchange with the other components of the climate machine. Decisive in this are decomposition processes, volcanism, and plate tectonic activities.

Decomposition – CO_2 in Circulation.

The **global carbon budget** plays an important role for climate. This circulation or cycle is for one dominated by living things in which atmospheric carbon dioxide interacts with organically bound carbon (p. 18) and two by the decomposition processes affected by the silicate-carbonate cycle. If carbon is depleted from the atmosphere in large amounts and over longer periods of time in sinks or reservoirs, this then has an impact on the CO_2 budget and in turn on the climate. Besides **silicate-carbonate weathering**, there is also the creation of coal (p. 18).

The Silicate-Carbonate Cycle (Fig 9.1).



Climate factor weathering.

Today's reservoirs of brown and black coal together with limestone and ocean sediment makes up the largest part of the earth's carbon (99.8 %).

The Silicate-Carbonate Cycle.
(Slide 9, Fig 9.1)
During the weathering of silicate rock (such as feldspar) silicon and calcium are dissolved in a multi-step chemical reaction. First, CO_2 is taken from the atmosphere. The simplified chemical equation for this process is: $2CO_2 + H_2O + CaSiO_3 \rightarrow Ca^{2+} + 2HCO_3^- + SiO_2$. The dissolved silicon is either deposited in the ground in clay mineral or quartz sediment (SiO_2). The remaining weathering products (Ca^{2+} und $2HCO_3^-$) are then transported to the oceans via rivers, where they are used by oceanic organisms to make marine carbonates such as shells and skeletons. ($Ca_{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$). After these organisms die, the carbonates in the form of shells and skeletons sink to the bottom of the ocean and become sediment.
Because the weathering of silicate rock "used" two molecules of CO_2 from the atmosphere, but only one molecule was freed in the formation of marine carbonates, silicate weathering transports carbon from the atmosphere as carbonate or calcium-rich sediment to the ocean's floor. Here the carbon remains in storage until it is released again through volcanism and plate tectonics in the form of CO_2 closing the cycle.

Volcanoes Heat Things Up …

Volcanism transports the stored carbon in the ground **back into the atmosphere**. Hence, in times of prevalent volcanic activity where increased amounts of gaseous carbon dioxide, methane, and steam are released, the earth experiences exceptionally warm periods.

… Or Cool Things Down

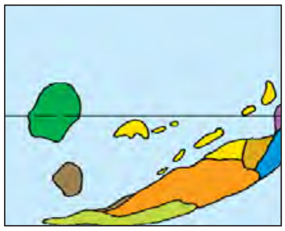
As a look back into the earth's history shows, intense volcanism has often been associated with the splitting up of huge mountain ranges. The increase in temperatures through the release of green house gases led simultaneously to an **intensification of the water cycle** (increased evaporation, more steam, more precipitation). This in turn accelerated **weathering** and **erosion** of these mountain ranges. Through the silicate-carbonate weathering, CO_2 was taken from the atmosphere – long-term this resulted in a **global cooling down**. This interplay between volcanism and weathering has frequently caused throughout the earth's history a seesawing of warm and cold phases (pp. 22). But volcanic eruptions even in the short term can have a cooling effect: Ash from the eruptions as well as gases are often blown several kilometers high into the atmosphere. Gases, such as sulfur dioxide, can be transformed into aerosols at certain altitudes which then reduce the sun rays, thus causing a cooling effect.

Climate factor volcano.

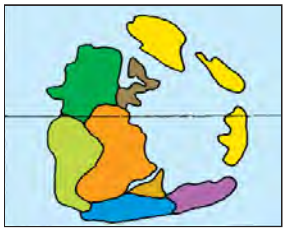
Ash: Natural Parasol.
During the eruption of Pinatubo on the Philippines in 1991, ash and gases were hurled up to 24 kilometers high. As a result of the eruption, the average global temperature sank 0.5 °C for about two years.

Changing Earth – Changing Climate.

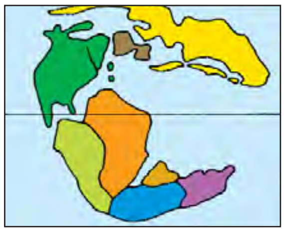
The **shape of the earth's surface** has been constantly changing throughout its history (Slide 9, Fig 9.2). According to the theory of the continental drift, parts of today's continents were once during the phases of earth's history near the poles, which led to an icing over of huge areas. In other phases, for example, "Central Europe" once was near the equator - with the corresponding climate effects. As a result, the land-water distribution also changed constantly, and thus had a bearing on the climate (pp. 22) as the following examples show:
About 290 – 250 million years ago (Permian/Triassic), there was only one land mass, the mega continent Pangaea. The simple circulation of the ocean and wind currents in combination with the one land mass created a very warm continental climate. By contrast, the drifting apart of the continents for about 2 – 3 million years ago has had a cooling effect. It set the great ocean conveyor in motion as we know it today.



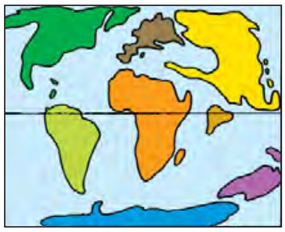
Cambrian (ca. 500 million yrs.)



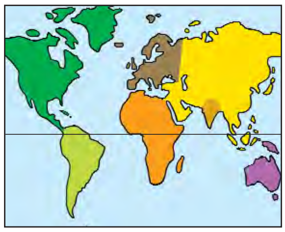
Permian (ca. 255 million yrs.)



Jurassic (ca. 150 million yrs.)



Eocere (ca. 35 million yrs.)



Today.

Continental drift.
Estimated position of land masses in the different geological epochs (Fig 9.2).

Source:
According to www.geologieinfo.de

Overview of Important Points:

- Through weathering and the formation of coal and oil, carbon is partly stored over the long term in ocean sediment and fossil reservoirs - thus taken from the atmosphere.
- Pronounced volcanism leads to the release of carbon dioxide and climate warming. The resulting increased activity in the water cycle strengthens, however, the effects of weathering and erosion; things cool off again.
- The earth is constantly changing. The drifting of the continents over earth's history has led to changes in the circulation of earth's atmosphere and ocean currents with corresponding effects to the climate.

Climate and Life.

Polar bears live at the North Pole. And street cafés are an invention of southern regions. Life reacts to climate – and vice versa?

This chapter reveals:

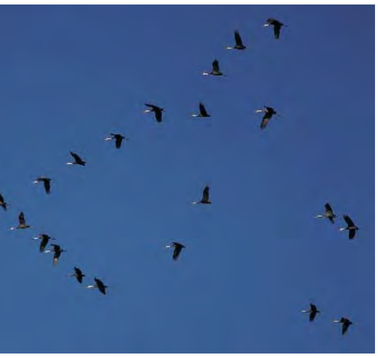
- the interplay between life and climate
- the circulation of carbon between the atmosphere and the biosphere.

Polar bears have adapted well to their climate.

Living Beings Adapt.

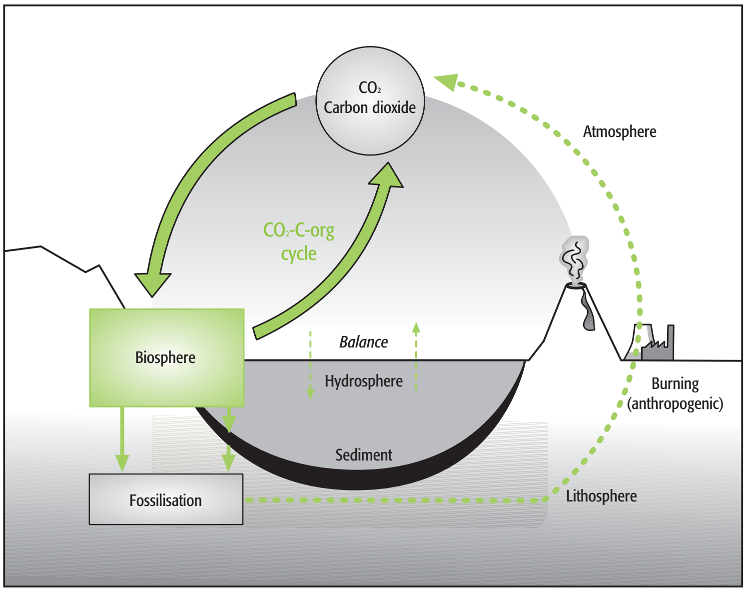
Life on earth is decisively impacted by the climate. Researchers surmise that different climate changes over the earth's history were conducive for developing entire species of plants and animals or were detrimental, leading to their extinction.

How plants and animals have adapted to the climate can be observed all over the earth today. For example, animals in colder regions are generally larger than their relatives from warmer regions (better relationship between volume and surface area). Thus polar bears or brown bears from Alaska are substantially larger than bears in other parts of the world. In addition, the migration patterns of many animal species is determined by the climate, for example, in birds. Plants prevail during droughts by conserving water like cactuses or by shedding their leaves. And even humans have adapted to different climate conditions. One need only to look at the nomads from the prairies. Vice versa is also true. Life has influenced the climate – and greatly.



Bird migration - an example of how animals react to climate.

The Carbon Cycle (Fig 10.1).



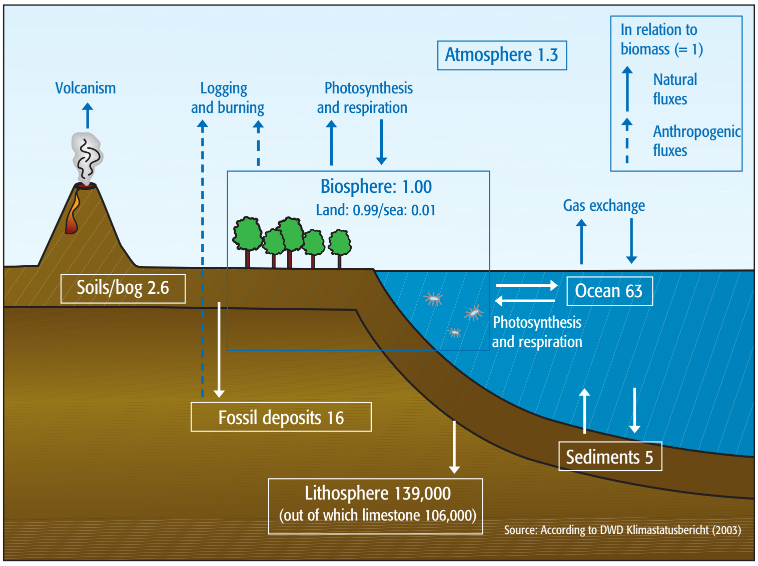
Growing trees bind CO_2 from the atmosphere and store it in their wood.

Living Beings Bind CO_2.

CO_2 is integrated into a cycle in which besides tectonics, volcanism, and silicate-carbonate weathering (p. 16), living beings also play an integral role.

Thus, plants bind carbon dioxide through the processes of photosynthesis, marine life uses carbon in their shells and skeletons, and the bones of land animals and humans also contain carbon (C-org). Usually, when organisms die, stored CO_2 is again largely released into the atmosphere through decay (carbon cycle; slide 10, Fig 10.1) – unless this cycle is hindered. Thus, diotomea, which make up three quarters of the ocean's phytoplankton, are very important to the climate, because when they die, their skeletons containing carbon sink down to the ocean sediment (p.16). Other examples for long-term binding of carbon from CO_2 are coal, oil, and natural gas.

Coal contains carbon from a plant world of long, long ago.



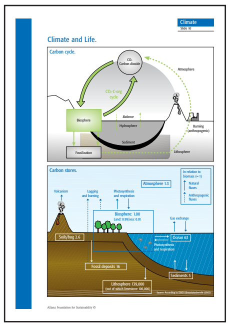
The earth's carbon reservoirs (Fig 10.2).

Reservoirs from the Past.

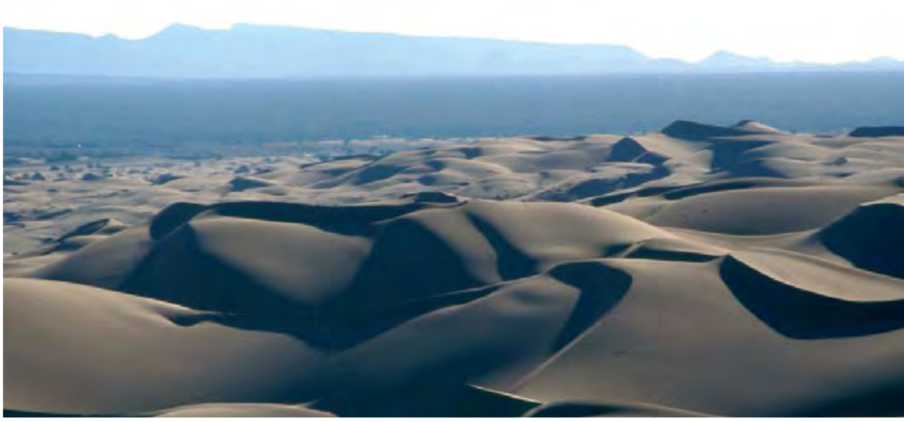
The fossil reservoirs of coal, oil, and natural gas are the remains of plants and animals from earlier generations in earth's history. In their creation, besides decay, high pressure and temperature, layers of covering material, and the absence of air all played a role. Coal comes from the swamp forests that once used to cover huge areas of land. Oil comes from marine sediment, mainly made up of dead animals and phytogenic micro-organisms (plankton).
Natural gas is on the one hand a decomposition product of coal and oil, formed in the depths of several 1000 meters and under high tempera-tures. On the other hand, natural gas was created at much lower depths under the influence of bacteria and organic remains.
Coal, oil, and natural gas are therefore fossil biomasses from long, long ago. Carbon stored in these masses are put back into the atmosphere as CO_2 when they are brought to the earth's surface and burned to create energy. (Slide 10, Fig 10.2).

The Impact of Vegetation.

The earth's different vegetation types reflect or absorb the suns radiation in varying degrees (Albedo Effect). Therefore, they have a certain impact on the amount of rays that reach the earth and consequently on the climate (compare also pp. 10). It is assumed that for about 5 million years ago, changes in vegetation caused progressive cooling and permanent icing over in the northern hemisphere. As a result, northerly forests (low Albedo) were replaced with tundra of higher Albedo. Inland on the continents, prairies and deserts (high Albedo) were the result.



Climate and Life.
Slide 10



Dark forests absorb the sun's energy; desert areas reflect a large portion.

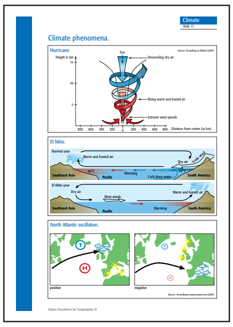
Overview of Important Points:

- Life is affected by climate and vice versa.
- Through the carbon cycle, life forms are connected to the atmospheric CO_2. Normally, the carbon taken in by organisms is subsequently released back into the atmosphere after death - unless it is depleted long term from the cycle through deposits in ocean sediment (plankton) or in fossil reservoirs (coal, oil, natural gas).
- And even the earth's surface vegetation affects climate by absorbing or reflecting the sun's radiation (Albedo).

Climate Phenomena and Extremes.

In ancient times, wind and other meteorological phenomena were looked at as godly – mysterious and unpredictable. But even though many things are explainable today, unpredictability still remains.

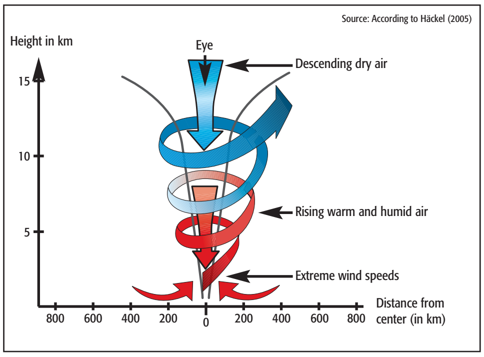
In this chapter you will get to know:
- how storms form
- what is behind El Niño and La Niña
- why some winters are more wet-warm and others more dry-cold.



Climate phenomena.
Slide 11

Exceptions Confirm the Rule.

By simple experiences with weather over a long period of time, climate was discovered. Over time, unique weather events have not been so important in the determining climate. However, these unique weather events or extremes are typical for certain weather zones.



Structure of a cyclone (Fig 11.1).

Tropical storm.

Thunderstorm.

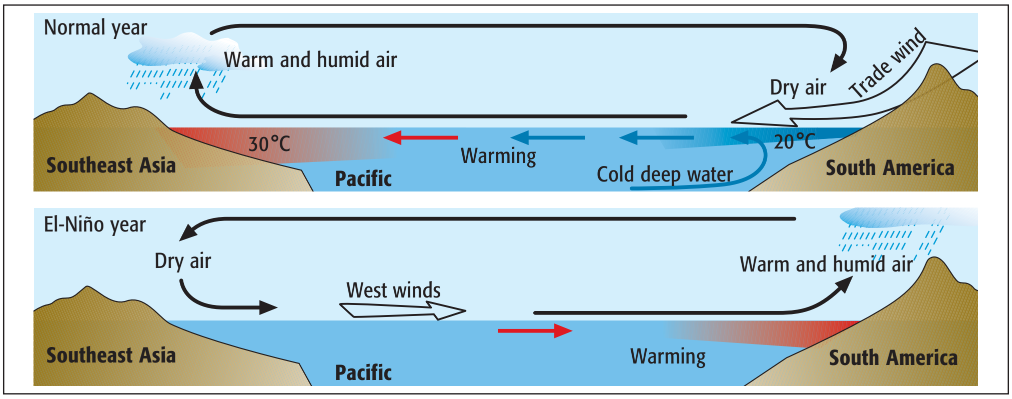
Tornado.

From Wind to Storm

Certain topographical features allow regional winds to form. Examples of this include the “foen” in the Alps, the “mistral” in the Rhone Valley, and the “sirocco,” a hot wind from the Sahara over the Mediterranean Sea. When there are large differences in air pressure, winds can turn into storms and can cause serious damage. In Central Europe, it is the “**Orkane**” or winter gales. They are, however, incomparable to **tropical storms** in their strength and intensity, since tropical storms need **warm sea water** to develop (Slide 11, Fig 11.1). Water begins to evaporate at 26 °C, and if there is a sufficient amount of water evaporating quickly, a spinning twister, also known as a **cyclone**, forms. You can constantly find these types of conditions over the West Atlantic in late summer and below the twentieth latitude in the Pacific and Indian Oceans.
The Coriolis Effect is responsible for the spinning motion of the cyclone (p. 13). Given that the Coriolis force has little or no influence at the equator, tropical storms only develop from the fifth northern and or southern latitudes.
At a water temperature of 34 °C, a **cyclone - hurricane** in the Atlantic or **typhoon** as in the West Pacific - can create wind speeds of up to 380 kilometers per hour. When reaching land, these cause devastating damage. Usually, a cyclone weakens when it reaches land with heavy rainfall, because the necessary supply with humid air is missing.
A temperature dependent cycle can be recognized in the Atlantic by the amount of tropical storms that appear, the so-called **Atlantic Multidecadal Oscillation** (AMO). The cycle appears in two phases and the entire oscillation period takes about 65 years. Right now, we are in a phase of above-average warm water temperatures.
A special weather occurrence with devastating effects are tornadoes. Typical for **tornadoes** is their form, which has the appearance of an elephant trunk. They usually have a radius of less then 100 meters but are famous for leaving paths of destruction. Tornadoes develop when extremely wet, unstable layers of warm air are crossed by cold, dry air. Because of the topographical situation, tornadoes are most often seen in North America. Around 700 tornadoes are reported every year in the United States. However, tornadoes can also form in Central Europe. Towards the end of March 2006, a tornado caused a large amount of damages in Hamburg; in July 2004, cranes were knocked down in the harbor of Duisburg by a tornado.

“Christ Child.”

Peruvian fishers have observed for sometime now that the surface water in front of the Pacific coast of Peru heats up every year at Christmas, which also marked the end of the fishing season. Peruvians called this observation “Christ Child” (Spanish “**El Niño**”). Today, El Nino is just a name for above-average hot temperatures which appear every 3-7 years and which usually remain about a year. Changes in rain periods in the Tropics, with dry periods in South-East Asia and floods in western South American can be linked with the “El Niño”



Climate phenomenon El Niño (Fig 11.2)

phenomenon. In "normal" years, the south east trade winds drive cold, nutrient-rich deep sea water from the Peruvian coast westwards. The surface of the waters warms up and the air absorbs the evaporated moisture. In the Australian-Indonesian region, the humid air rises, causing heavy precipitation. The air then flows back eastwards at high altitudes, sinking over the South American West Coast, and causing here a very dry climate (Slide 11, Fig 11.2).

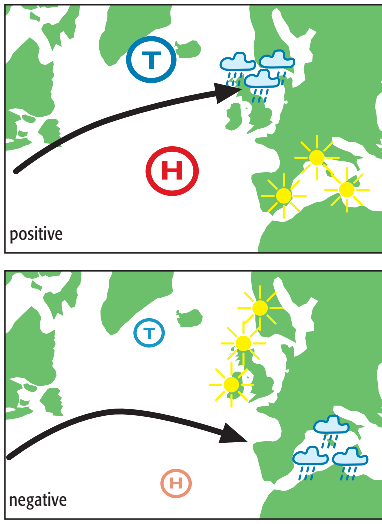
During an El Nino, changes in the differences in air pressures causes weaker than normal trade winds. Thus the upwelling of deep sea water from the Peruvian coast is also reduced. The water near the surface heats up greatly, finally bringing the whole wind circulation out of sync: Warm air rises over the South American coast and leads to heavy rainfall, while Southeast Asia, Indonesia, and Australia suffer from extreme dryness.

La Niña (Spanish=girl) occurs mostly after an El Niño, and is actually an increased phase of "normal" conditions with unusually cool temperatures in the East and Central Pacific and increased precipitation over the West Pacific. El Niño and La Niña have a far reaching impact on the regions mentioned. They affect the fishing-dependent coast of Peru, but also lead to crop shortfalls or the spread of tropical sicknesses all the way into southern Africa. Recent studies even suggest a connection between El Nino and the frequency of tropical storms in the North Atlantic. The hypothesis is that El Ninos lead to fewer storms and that La Ninas lead to an above average occurrence of storms.

Azores High and Iceland Low.

The North Atlantic Oscillation (NAO) originates in the pressures difference between the Azores and Iceland. It has two phases that are responsible for the typical winter weather in the North Atlantic region (Slide 11, Fig 11.3). Under positive NAO conditions the difference in pressures between the Azores high and Iceland low are greater than normal. Over the North Atlantic it is very stormy, bringing comparably warm, humid weather to Northern Europe with mild, precipitous winters. The Mediterranean is dominated by cold, dry air. Under negative NAO conditions, pressure differences are less than usual. There are fewer storms on the North Atlantic that primarily bring warm, humid air to the Mediterranean. Further north, sunny, but very dry and cold weather prevails. The NAO influences crop yields, fishing, and water and energy supplies.

Weather extremes: drenching rains and droughts.



North Atlantic Oscillation (Fig 11.3).

Overview of Important Points:

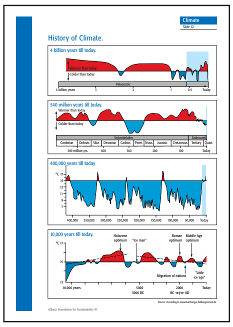
- Cyclones are part of tropical climate, extremes that require warm ocean areas before forming.
- The influence of climate phenomenon El Niño on the Peruvian Pacific coast reaches into areas in Southeast Asia and most likely into areas of southern Africa, too.
- Similar climate phenomena over large areas are also known in the North Atlantic through the North Atlantic Oscillation.

Climate History in Retrospect.

Alligators in Canada, palm trees in Siberia and temperatures fit for bathing at the North Pole? In the past, our climate was evidently always quite different than today – and good for surprises.

This chapter gives an overlook about:

- the progression of the world climate according to current knowledge.



History of Climate.
Slide 12

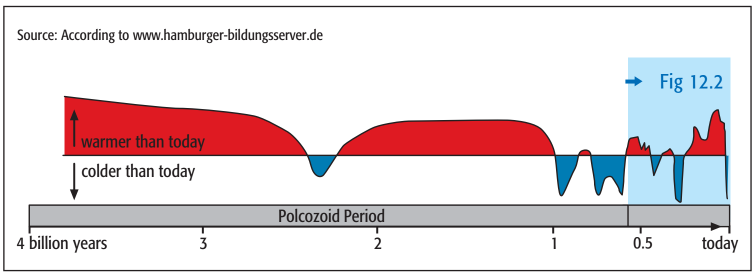
Up and Down.

The climate has always changed in the course of the earth's history. Very warm phases alternated with times of extensive glaciations. However, the various climates of the earth's history are not directly comparable with present day conditions because important factors such as the position of the continents, the height of the water level or the composition of the atmospheres have basically changed. Moreover the phases in the distant past can only be reconstructed to a certain limit.
The following illustrates (in time lapse) the events of the past climate according to the current scientific state (Slide 12):

Changes to the Atmosphere – Palcozoic Period.

During the Palcozoic period (up to about 545 million years before our time, Fig 12.1) there were extreme climatic conditions on the earth. The development of the climate was, above all, determined by the CO_2 content of the atmosphere. Astronomers presume that our solar system was created from rotating clouds of gas and dust about 4.6 billion years ago. Originally all planets were surrounded by atmospheres. While the largest outside planets could maintain their atmospheres up to the present due to their strong gravitational fields, the inside planets and the earth lost their initial atmospheres. Their gas envelopes disappeared into space.

Four billion years ago up to today (Fig 12.1).

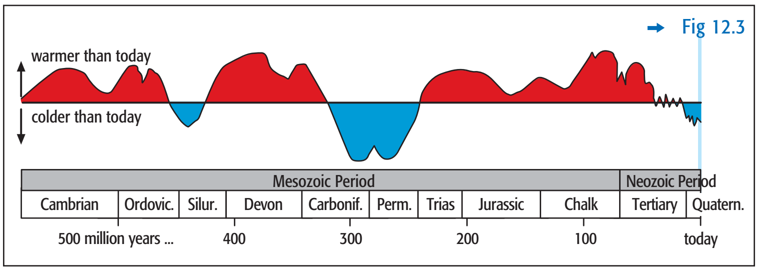


About 4 billion years ago an atmosphere was again formed around the earth due to gas emissions, mainly consisting of CO_2, Methane and Ammoniac. Owing to this it is likely that there was a "super greenhouse climate" with temperatures of over 50°C.
About 3.8 billion years ago the first signs of life were created in the oceans, presumably in the form of blue-green algae. While the blue-green algae bonded CO_2 and released oxygen by photosynthesis, the CO_2 content was reduced in the atmosphere and also the greenhouse effect. In addition to this, CO_2 was bonded by alteration (Page 16) and, therefore, the temperature sank until ice was formed in some regions.
Presumably between 2.5 and 2.3 billion years ago as well as between 900 and 600 million years ago there were two great icing phases. Some researchers even speak of a "snowball earth." As a result of the glaciations, the photosynthesis and the alteration largely succumbed. However due to the fact that CO_2 was continually returned into the atmosphere by volcanism, the earth thawed each time.

Mainly Warm – Mesozoic Period.

The period from the end of the Palcozoic period up until approximately 65 million years ago is characterized by three warm climate phases and two cold climate phases (Fig 12.2). Here the decisive climate factors were tectonics, volcanism as well as the change in CO_2 content in the interplay with vegetation on the one hand and rock alteration on the other hand.
From about 542 to 488 million years ago (Cambrian) it was warmer than today with a high level of CO_2. Owing to the interaction between the continental drift and the cold as well as warm ocean currents and air currents there was always a continual change in climate. Life only existed in water. About 440 million years ago (Ordovician/Silurian) an icing phase came which was presumably caused by the emergence of the first land plants. Due to photosynthesis they reduced the CO_2 content in the atmosphere which in turn caused a reduction in temperature and the for-

Land plants as a climate factor.



540 million years up to today (Fig. 12.2).

mation of a thick layer of polar ice. As a result of the bonded water in the ice, the ocean level sank by about up to 100 meters.

Owing to volcanism, the CO_2 content finally increased again thus increasing temperatures, until about 330 million years ago (Carboniferous) large areas of land were covered by tropical forests. The carbon that these plants continually detracted from the atmosphere was bonded into large coal deposits after these died (pp. 18). In doing this, the CO_2 content was reduced. Due to the fact that this concerned a phase with a low degree of volcanism, there was then a longer cold phase of about 80 million years.

In the course of several million years, all the continents fused together to form one mass of land (past continent Pangaea) which led to an extreme continental climate (p. 17) about 250 million years ago (Permian/Trias). The sea level increased by about 80 meters above the present level, the average temperature was 6 - 8°C warmer than today. Extensive tropical forests, in which the dinosaur lived, covered the gigantic continent. Pangaea began to break up 200 million years ago (Jurassic). The Atlantic Ocean was created, sea currents and atmospheric circulation basically changed. The extreme continental climate was replaced by a warm, humid tropical climate whereupon the warm period reached its peak in the Chalk Period about 100 million years ago.

About 65 million years ago (Chalk/Tertiary) there was a sudden climate change with a distinct cooling down of the atmosphere and the oceans as well as a reduction of the sea level. This break extinguished 70 percent of living forms, however mainly the dinosaur. The cause of this climatic catastrophe has long been the subject of controversial discussion. The most prevalent explanations are based on the meteorite theory which impacted the earth. The impact of a gigantic meteorite released great amounts of soot, ashes and gases into the atmosphere which covered the earth and extinguished light for months or even years. The Mesozoic Period ended with this event.

Cooling Trend – Neozoic Period.

The Neozoic Period, about 65 million years up to today, is characterized by a long trend of cooling down after a re-warming phase. The once ice-free poles are covered with ice caps. During the ice ages this ice extended deep into the south in the northern hemisphere. Various factors are responsible for this development: from CO_2 content of the atmosphere via the plate tectonics and volcanism up to the deviations of the earth´s orbit.

About 55 million years ago (Tertiary) another abrupt climate change happened. Within a relatively short period of time the temperature increased by 5° – 6°C. It has been discussed that the cause of this was, amongst other factors, the release of methane from the sea bed as well as an increase in volcanic activity. The heat wave “only” remained for a short period (relatively short for the earth) of 200,000 years. However, there were tropical temperatures even in the higher latitudes: in the Canadian polar region there were alligators, palm trees grew on the Kamchatka peninsula and the water temperature at the North Pole was approximately 20°C.

High tectonic activity finally caused a strong degree of volcanism which continued the relatively warm climate. The consequence of this tectonic agitation however was also the disengagement and isolation of the Antarctic up to about 35 million years ago. The incipient Antarctic circumpolar current caused icing of the South Pole and a sudden drop in temperature worldwide (p. 15).

About 25 million years ago the temperature again increased for a short period in a phase having very strong tectonics and volcanism. After that, the continuation of the cooling down trend (p. 16) is mainly due to the long effective silicate alteration.

Changes in ocean currents always caused changes in climate.

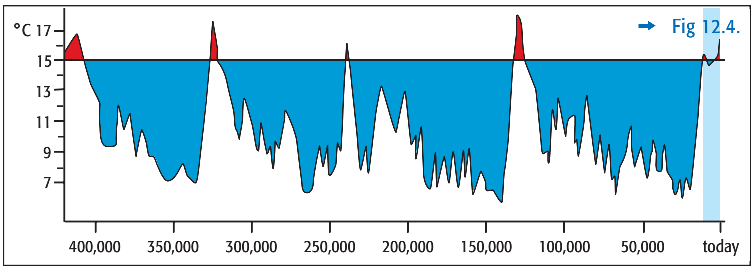
Tectonics and rock alteration – also a climate factor.

Glaciers are found in polar regions and high mountains.

"Ice-Age."

About 2 million years ago the continents, mountains and oceans basically took their present shape, the great marine conveyor was created (p. 14). Since this time the climate has been affected by cyclic repetitive ice ages. The reconstructed progression of temperature during the last 400,000 years (Fig 12.3) shows a change from marked cold periods with strong icing and warm phases (warm periods).
At the moment, we are in a warm period which, according to new calculations, will end probably in 30,000 to 50,000 years with an ice age.

400,000 years up to today (Fig 12.3).



The cause of the ice ages is attributed to the Milankovitch Cycles (p. 11). Due to the fact that they hardly influence the amount of radiation reaching the earth, but only the distribution over the seasons and latitudes, they only act as a trigger, as a catalyst. Another factor is, for example, the Albedo Effect (p. 10). Because when parts of the earth´s surface is covered with snow or ice then the cooling down tendency is reinforced by the reflection of the sun's rays.
The greatest glacial stage was during the Kansan (Mindel/Anglian) or Elster ice age, presumably 480,000 to 385,000 years ago, in which North America, Asia, Europe, and Great Britain were largely covered by glaciers of up to 3 km thick. Even in the Wisconsin, Würm, Vistula, Devensian cold periods (respectively for different regions of the earth), which began about 100,000 years ago and ended about 10,000 years ago, large parts of Europe and North America were glaciated. The sea level was about 130 meters lower than today owing to the water bonded in the glacier ice. Areas such as the English Channel and the Bering Straits were dry land.
The climate of the last 100,000 years was regionally characterized, partly by very rapid changes in temperature. Analyses of ice bore cores in Greenland report numerous jumps by a number of degrees (up to 10°C) within a few decades or even years! It is assumed that changes in sea currents are primarily responsible.

Names of the Ice Age Periods.

Due to the fact that in ice age periods glacial movements took place, classification is normally made according to geographical locations at which this left traces on the earth´s surface. It is for this reason that warm periods and cold periods have different names, depending on the region. Therefore the last cold period, which ended about 10,000 years ago, is called "Würm" in South Germany and "Weichsel" in North Germany, perhaps a little bit confusing for the layman, whereas in England the same period is called "Devensian", in North America "Wisconsin" and in Russia "Waldai."

High cultures – created in the Holocene Optimum.

Present Warm Period – The Holocene.

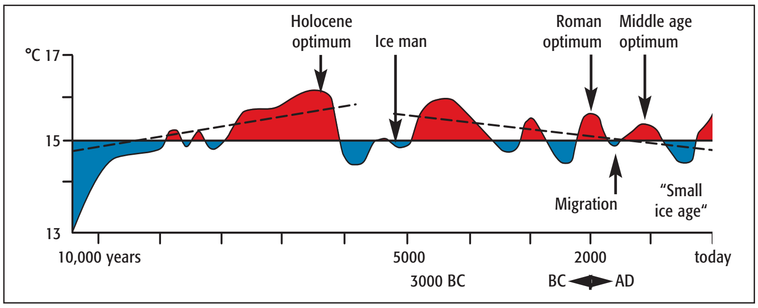
After the average temperature of the earth (which is currently about 15°C) had reached about 11°C, the lowest value of the Wisconsin cold period, after about 18,000 years ago, a transition took place into the **present warm period (the Holocene)**. This transition period was abruptly interrupted by a cold snap between 12,700 to 10,500 years ago. The trigger for this so-called **Younger Dryas** was, according to the established hypothesis, an intermission – or at least a **considerable weakening** – of the **North Atlantic current**, the warm water heating for Europe. This intermission was presumably caused by melting of the North American ice masses.
In doing this, the flow of fresh water diluted the salt content and density of the surface water in the North Atlantic and therefore stopped or weakened the North Atlantic current. The "remote heating" for Europe was only reactivated after the North American ice cap had completely melted.

The Holocene Optimum.

After an increase of the global average temperature to values which were even 2° to 2.5°C above the ones today, our present warm period reached its peak about 8000 to 6000 years ago (Fig 12.4). This climatic period, the **warmest since the last ice age period** – the so-called **Holocene Optimum** – brought far reaching shifts of climate and vegetation zones. In doing this, the humid climate reduced the desert areas in Africa, the Arab Peninsular and Asia. Parts of the Sahara were converted to savannah and the forest boundary shifted by up to 400 km to the north. The Alps were almost glacier-free, and the glacier melting in polar regions caused the sea level to rise until it reached one meter above the present level. The **first high cultures** in Mesopotamia and Egypt probably originate from the Holocene Optimum period.

The "Ice" Man.
About 5500 years ago there was a distinct intermediate cooling down. Evidence of this climatic change is the Ice Man out of the glacier who was discovered in 1991 in the Ötztaler Alpen, and who must have lived between 3350 and 3100 BC. He was presumably killed by an arrow. But after his death, his body remained preserved, because he was immediately covered by snow and ice.

The ice man.



10,000 years up to the present (Fig 12.4).

Overview of Important Points:

- A reconstruction of a journey through the history of the earth shows an ever changing climate in which there are more warm climates. The causes were partly due to the massive changes in climate factors.
- Drastic effects concerning the life on the earth were coupled together with the change in climate, for example,. the extinction of the dinosaur.
- The ice age began about 2 million years ago with a marked change from warm to cold periods. At present we are, according to the natural cycle, in the declining phase of a warm period.

Climate and Humans.

Dark skinned or light skinned, nomad or settler, siesta in the mid-day sun or sauna in the cold winter nights – the climate forms our appearance, our culture, our way of life. But how does our way of life influence the climate?

This chapter shows you:
- how greatly we human beings are dependent on the climate
- which "climate screws" we are turning.

People characterized by the climate.

Formed by the Climate.

Since the end of the Holocene Optimum period about 5000 years ago, various phases can be recognized in Europe and in the area of the North Atlantic in which it was warmer (**optima**) and colder (**pessima**) than today (Fig 12.4):

- 3500 – 2000 BC: Pessimum of the bronze age
- 400 BC – 200 AD: Roman Optimum
- 300 – 600: Pessimum of the migration age
- 800 – 1400: Middle age Optimum
- 1500 – 1850: Small ice age
- since approximately 1850: Modern Optimum.

These climate phases also had an **influence on history** concerning people and cultures:

- At the end of the year 218 BC, Hannibal advanced over the Alps with 37 elephants. This was possible because the alpine passes during the **Roman Optimum** could be gone through even in winter.
- Crop failures and the loss of pasture areas, caused by **long periods of draught or rain** resulted in repetitive **migration movement** of complete populations. An example of this is the drying out of the Mongolian steppe, which began in the 4th century and was the trigger for the conquest migration of nomadic people. The attack of the Black Huns through Southern Russia into the Danube Peninsular and further over Hungary up to France pushed the Germanic tribes to the south-west, whose migration had already started in the early 2nd century. This finally led to the downfall of the West Roman Empire.
- Already at about 875, in the starting phase of the **Middle Age Optimum**, the Vikings reached Greenland where they settled between 982 and 1500. As the name suggests "Greenland" is a green land. From the period of the Middle Age Optimum, there came many German and English place names suggestive of wine cultivation which no longer exist as such.
- During the **"Small Ice Age"** in the 16th and 17th centuries, there was a strong cooling down with humid, cool summers and long winters with much snow. Paintings from Dutch artists from this period show iced countrysides with people on ice skates and in the Alps the glaciers became larger. In middle Europe and England, there were repeated crop failures and hunger which triggered migration to the New World.

The cultivation of wine brought the Romans to middle Europe.

The "Small Ice Age" depicted in Dutch painting.

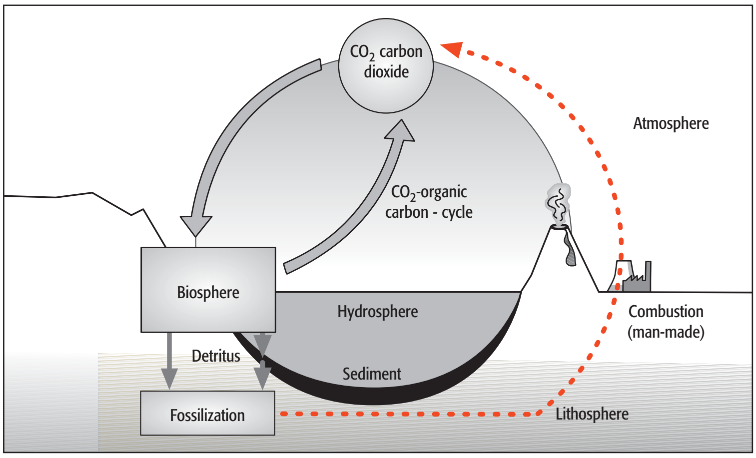
Low Temperature Deviations – Great Effect.

During the last 5000 years, the global average surface temperature has only deviated slightly. In some individual regions the values were up to 1.5° higher and lower than they are today. On the one hand, this shows how amazingly stable the climate for this period was and on the other hand, how life conditions for people can be profoundly affected by slight climate changes.
The triggering points for these climate changes were above all the deviations in the orbit parameters of the earth and the changes in sea currents. The temperature changes in the last 1000 years up to the 19th century can be well explained as a result of the deviations in the sun´s rays and volcanic activity.

Does Man Influence the Climate?

The form of the earth has changed due to settler activities and the use by people. Whether, and to what extent, one also changes the factors governing climate is a subject currently being hotly disputed.
Probably people in earlier times already influenced the climate. An example of this is the complete clearance of timberland areas in middle Europe by the Greeks, Phoenicians, and later mainly by the Romans (ship building). However, the influence on the climate remained regionally limited; global effects cannot be deduced from this.
But the basic changes were caused by the developments in the wake of the Industrial Revolution at the beginning of the 19th century. Up until this point in time, people for many centuries did not have many energy sources available. They used muscle power or draft animals, wind and water power (sailing boats, windmills, etc.) as well as firewood which were used as further sources of energy. The use of fossil fuels opened up a completely new dimension. Steam engines, combustion engines, the production and use of electricity as well as numerous other technical innovations replaced handicrafts, wind and water power, and caused an increasing need for energy. At first, coal was the most important provider of energy. Later came petroleum and natural gas.

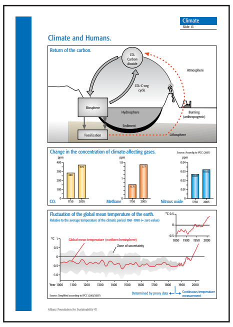
Strip mining – a carbon storage is opened.



The return of carbon (Fig. 13.1).

The Return of Carbon.

At the beginning of the 20th century the technical and economical development as well as the increasing population drove energy consumption higher and higher. This energy consumption is, to a great extent, covered by fossil fuels. Owing to this factor, carbon, which was once taken out of the atmosphere and bonded into underground storages, found its way back again into the atmosphere in the form of CO_2 (Slide 13, Fig 13.1).



Climate and Humans. Slide 13

Overview of Important Points:

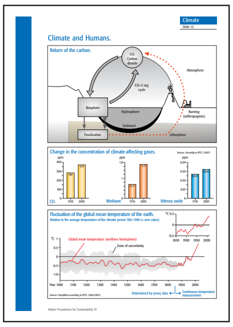
- The climate change (Optima and Pessima) during the past 5000 years can be connected to the prominent events in cultural history, although the deviations have been comparatively slight.
- The influence of people on the climate is firstly limited locally; however it looms to global dimensions at the beginning of industrialization.

Climate Change?

A few years ago, the subject of climate change was classified as being the invention of green moral apostles or self-appointed prophets of doom. Today it invokes heated debate. Is the climate changing? If yes, what influence do human beings have?

This chapter reveals:
- which climate trends can be currently observed.

What Do the Measurements Show?



Climate and Humans.
Slide 13

There are extensive records, especially concerning temperature, for the last 100 – 150 years from various stations, above all in Europe and North America (p. 5). In some cases, the wealth of data extends even further back.
Other climate data such as the concentration of greenhouse gases can be obtained from natural climate archives. Therefore direct **comparison possibilities** can be made between present climate data and those in the 18th and 19th centuries.

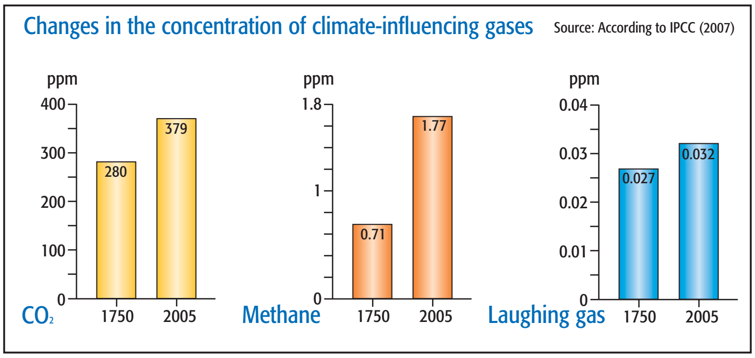
Air Changes.

The **concentration of climate-effecting green house gases** in the atmosphere show the following changes since 1750, i.e. before the industrialization (Slide 13, Fig 13.2, State 2005):

- The **carbon dioxide concentration** in the atmosphere **has increased 35%**, and is at its highest since 650,000 years, perhaps even since 20 million years. The annual rate of increase between 1995 and 2005 accelerated to 1.9 ppm.
- The **methane concentration** in the atmosphere **has increased 148%**, and is also at its highest level for at least 650,000. However, compared to the early nineties the increase has slowed down.
- The **laughing gas concentration** in the atmosphere **has increased 18%**, and is at its highest level since at least 1000 years. The rate of increase has been at a constant level since 1980.

In addition to this, there are other greenhouse gases, e.g. **halogen hydrocarbon**, also known as halogenated hydrocarbon. These do not come from natural sources but are exclusively generated by industry. The most well known being chlorofluorohydrocarbons (CFC), which were used for years as, amongst other things, a cooling agent, propellant, solvent, cleaning agent as well as a foaming agent for plastics. They act as greenhouse gases and destroy the ozone layer, causing holes in the ozone layer. Today, their use has been prohibited. Sulphur hexafluoride (SF_6) acts as a greenhouse gas with 23900 times the strength of carbon dioxide. Its concentration is currently on the increase.

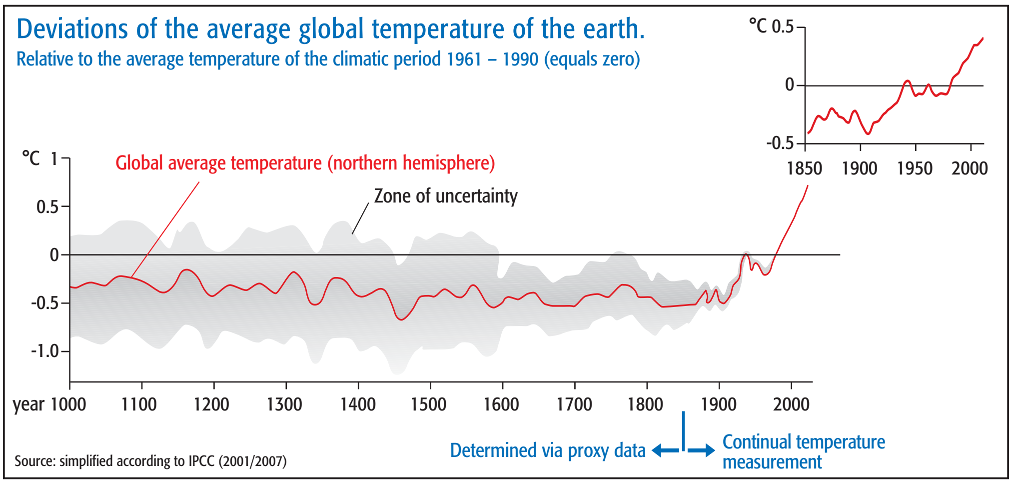
Air changes (Fig. 13.2).



It's Getting Warmer …

In parallel to these observations there is an **increase of the average global surface temperature**, recorded since the beginning of the systematic, approximate, area-coverage temperature measurements in 1861 and bearing various consequences (Slide 13, Fig 13.3):

- The global mean temperature (measured on the earth surface) **has increased** between 1906 and 2005 **by 0.74°C**, whereby the increase in temperature during the last 50 years is twice as high as in the past 100 years. 11 of the 12 warmest years since 1850 occur-



Rising Temperature (Fig. 13.3)

red in the past 12 years (1995 – 2006). The temperatures during the last 50 years are most likely higher than those occurring during the 500 years before, presumably even higher than the past 1300 years. The increase is especially high in the artic regions.

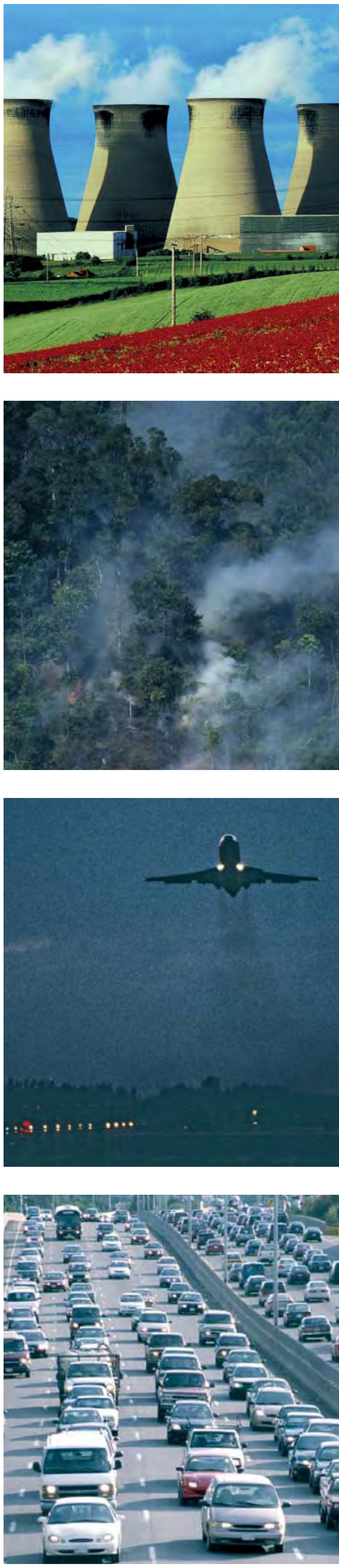
- Observations of the **oceans** since 1961 show that **temperatures have increased** on the global average up to a depth of 3000 m. It is assumed that the oceans have absorbed 80% of the additional warmth created by the climate system.
- In both hemispheres, the **mountain glaciers** as well as the **snow covered areas have been reduced**. The same applies to the permafrost soil. Since 1978, the **sea ice** of the Arctic has been depreciated by a yearly average of 8%. In summer it is even 22%. There is no record of a depletion in the Antarctic. The **ice shield** of the Antarctic however, especially that of Greenland, has been **reduced in mass** by the melting process and the break up of the glaciers.
- In many areas, **springtime comes earlier** as opposed to former times. Even the behavior of birds is different. At present, they migrate later and return earlier, or they don´t leave at all.
- The **sea level rose** in the 20th century **by 17 cm**, with increasing tendency (since 1993 alone it is 3 mm yearly). About half the increase was caused by thermal expansion of the warmer oceans, about 25% by melting mountain glaciers, and about 15% by the melting of the ice shield in the Arctic and Antactic.
- **Extreme weather conditions** such as tropical cyclones, strong rain with flooding or long dry periods have **increased** in the past years. In 2005 the Caribbean recorded the highest number of cyclones (ever recorded). One of these was the strongest on record as well as the most northerly cyclone ever observed. There are even changes with the accumulation of **extreme temperatures**. While extremely cold days and nights as well as frost periods are less frequent, hot days, tropical nights, and heat waves are increasing.

What Does This Mean?

During the past years it is becoming clearer that **human beings have a great influence on the earth´s climate machine** as supposed for a long time. Today, the change in climate can no longer be excluded from public discussion. In doing this, it is frequently overlooked that science has been engaged with this subject even longer and has to some extent given warnings at an early stage but never found a listener within the public or in the world of politics.

Overview Important Points:

- Compared to the time before or at the beginning of industrialization, there is a significant increase in certain greenhouse gases measured in the atmosphere, above all carbon dioxide.
- Parallel to this, an increase of the earth´s average temperature can be observed, accompanied by an increase in extreme weather conditions.

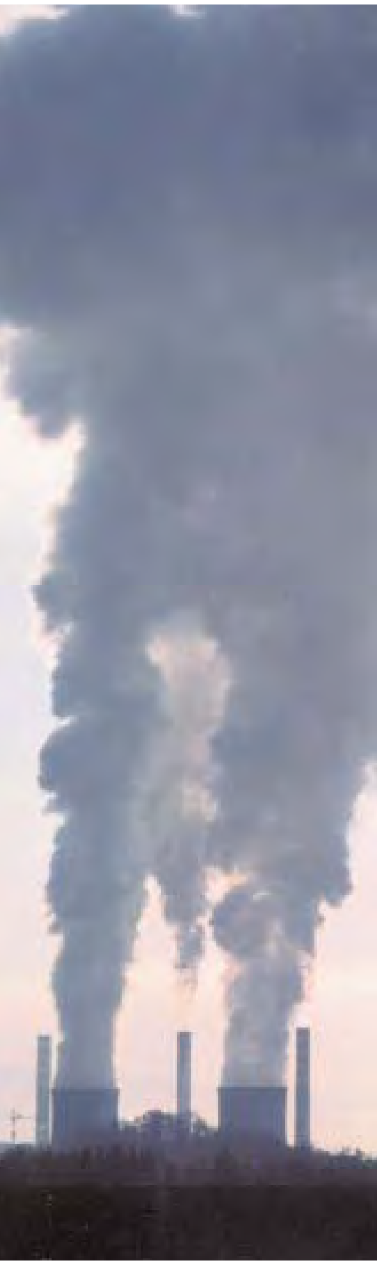


What influence do human beings have on the climate?

Climate Takes Center Stage.

In the past decades the earth's "climate machine" has been extensively researched. However, even the most detailed models of the complete system are not yet able to fully comprehend – and at some points there is a lack of knowledge.

This chapter shows you:
- the connections between climate changes and human activity
- how climate models are developed
- the problems involved
- how future prognoses about climate can be deduced using models.



The burning of fossil fuels contributes to three quarters of the increase in CO_2.

Conclusions.

A factor which is conspicuous in the observations made since the middle of the 19th century is the **almost simultaneous increase of CO_2 content of the atmosphere and the temperature**. The Swedish chemist Arrhenius (1859 – 1927) recognized that a continual increase of carbon dioxide concentration must lead to warming of the atmosphere. In 1896, he calculated a temperature increase of 4° – 6° if CO_2 is doubled. However, he evaluated the higher temperatures as being positive, because this would bring more stable and better climatic conditions, especially to colder areas of the earth.

Climate Takes Center Stage.

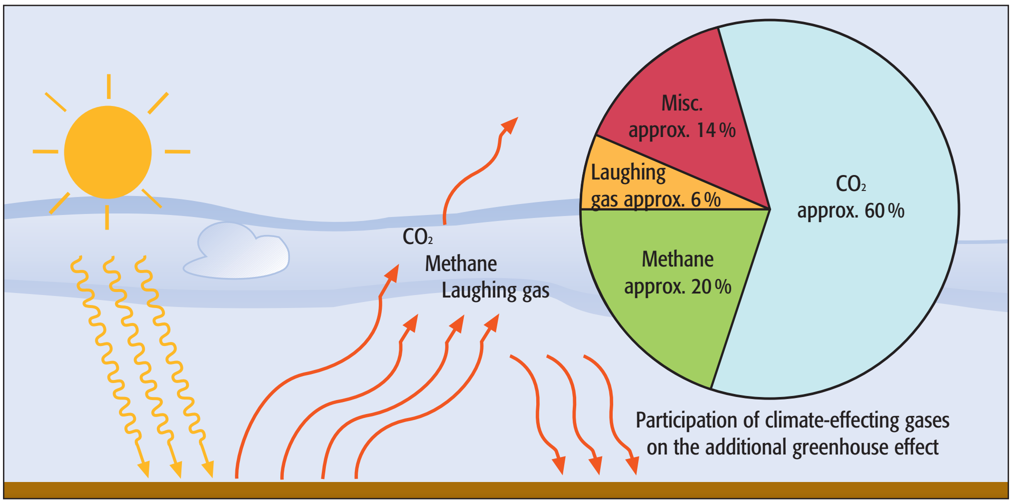
Intensive scientific work with the problems of **"climate change"** began in the second half of the sixties. This led to the first **Environmental Conference** (United Nations Conference on the Human Environment) in 1972 in Stockholm. Here, in addition to the environmental program of the UNO and the UNEP (United Nations Environment Programme) this also dealt with the starting up of a Global Environment Monitoring System (GEMS). In doing this, the influences of energy generation and consumption on the weather were to be monitored together with human health as well as animal and plant life. Measurement data collected worldwide showed that the CO_2 content of the atmosphere had already greatly increased, compared to the pre-industrial era.
In the final communiqué of the World Climate Conference in 1988 in Toronto, there was a clear warning given concerning the consequences of **global warming** and **immediate counteraction** was demanded.

On the Trail of Climate Change.

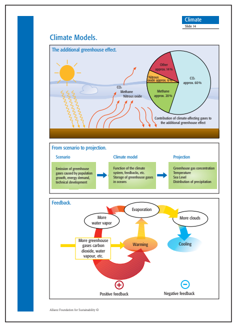
In order to bundle the acquired data about climate development, the World Meteorological Organization (WMO) and the **UNEP** founded the Intergovernmental Panel on Climate Change **(IPCC)**, based in Geneva. The IPCC collects the reports from scientists from different sectors in order to compile extensive, objective, and transparent report material concerning the **present scientific state of the complete climate and the whole field of climate research**. The reports are published every 5 – 6 years. The first report was issued in 1990.
In addition to monitoring climate changes as well as their evaluation, the tasks of the IPCC are, above all, to predicate future development. IPCC reports are therefore important information tools for decision makers in politics and business.

Man as Greenhouse Factor.

Already the first IPCC report in 1990 saw that a direct connection between the increase in greenhouse gas concentration and human activity is very likely. Therefore, it is referred to as an **additional or man-made greenhouse effect**. With regard to this, carbon dioxide plays a key role. Its participation in the man-made greenhouse effect is placed at approximately 60% (Slide 14, Fig 14.1). About three quarters of the man-made increase in CO_2 results from the burning of fossil fuels. The rest mainly results from slashing and burning of forest areas.
With regard to methane emission, about half comes from man-made sources (e.g. burning of fossil fuels, stock breeding, rice cultivation, and dumping grounds). They are responsible for about 20% of the man-made greenhouse effects.



The additional greenhouse effect (Fig 14.1).



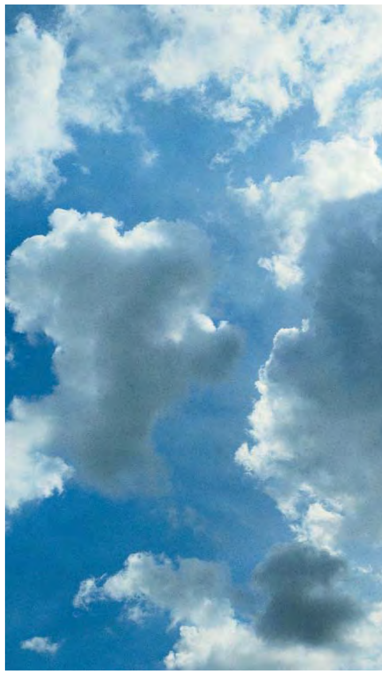
Climate Models.
Slide 14

Climate Models.

The **climate models** play an important part in research of climate change and its effects. These models try to present the real climate events **mathematically** and calculate the effect of changes with respect to climate factors. In doing this, the various climate mechanisms must be understood as far as possible together with their **feedback** and integrated into the model. In this connection, it is important to know the findings obtained from **climate history**. The climate from past eras can be simulated with the models and compared with actual known findings. In doing this the functional capabilities of the models can be checked.

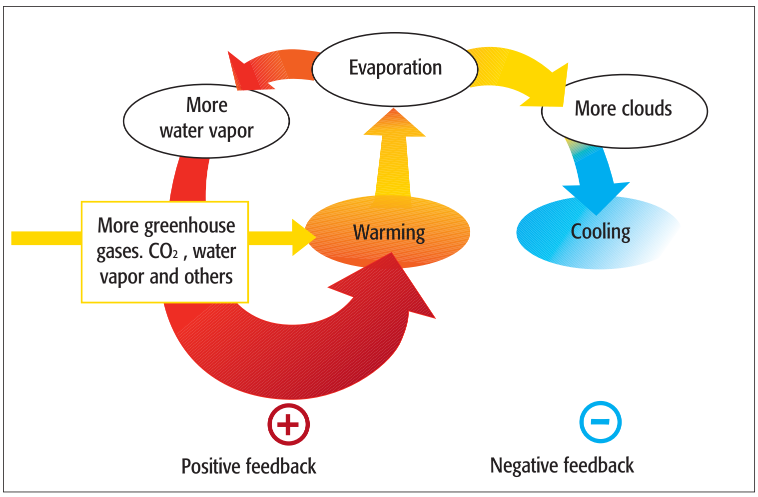
Interplay and Feedback.

Above all, it is the numerous **interplay effects** and feedback processes which make the climatic events, and therefore the presentation in the models, complicated and difficult to calculate. For instance, as a reaction to a warmer atmosphere, water vapor forms with increasing evaporation. Due to the fact that water vapor acts as a greenhouse gas, the warming process is reinforced and a **positive feedback** results. More water vapor also means more clouds. These reflect part of the sunlight (Albedo, Slide 6) and cause the tendency to cool – this is known as **negative feedback** (Slide 14, Fig 14.3). Which effect is the overriding one is of course the subject of intensive research. A similar complication involved in this are the effects involved in ocean warming.
Owing to the fact that cold water is able to absorb more CO_2 from the atmosphere than warm water, warming of the sea leads to a higher CO_2 content of the atmosphere and, therefore, an increase of the greenhouse effect (positive feedback).
Added to this, sea level rises due to thermal expansion of the water. This enlarges the surface of the sea and therefore the area of evaporation – water vapor content in the atmosphere increases. The ice area on the sea at the North and South Poles also play an important part in the models made by climate researchers. Because they reflect a great part of the sunlight (high Albedo) compared to the open surface of the water, a depletion of the ice surfaces lead to warming of the sea which in turn influences absorption of CO_2 .
It is also unclear about the development with aerosols which basically have a cooling effect (p. 6). Natural aerosols such as sea salt and dust can increase due to climate warming. As opposed to this, a decrease is to be expected with man-made aerosols due to the measures for maintaining clean air.



More warming, more water vapor, even more warming.

Feedback processes (Fig. 14.3).



How will the energy requirement be met in the future?

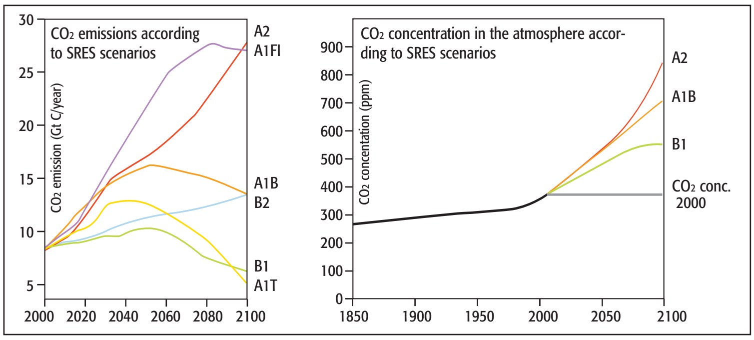
From Model to Forecast.

The realistic determination of the greenhouse emissions to be expected in the future are of importance in addition to exact climate models in order to estimate further climate development. In doing this, clarification of different questions play a part:

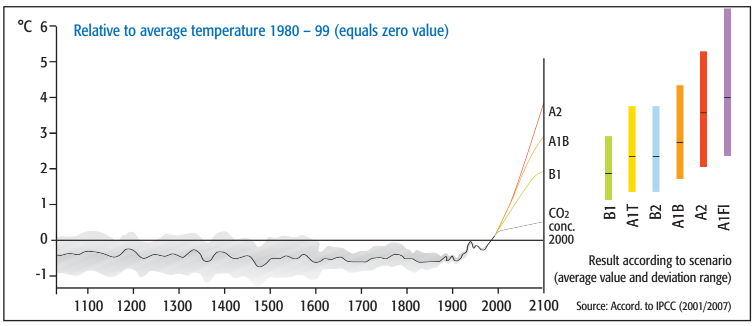
- How will the world population develop as well as the standard of living and the economy?
- What will be the energy requirement resulting from this development, and how can this be covered?
- What technical advances are to be expected and how can they influence the above points?

All these aspects have a direct or indirect influence on the amount of greenhouse gas emission and therefore on the future of our climate.
In order not to have to estimate the many possibilities to infinity, different scenarios were developed by IPCC which define the different development possibilities. The scenarios consist of four groups and are termed as SRES Scenarios (see box on the right) after the Second Report on Emissions.
Using these scenarios, scientists have calculated the greenhouse gas emissions resulting from this, which in turn were the basic data for the corresponding calculations of the climate model (Slide 15, Fig 15.1). Therefore a climate projection was calculated for each scenario.

Carbon dioxide emission and the possible consequences (Fig 15.1).



Development in temperature (Fig. 15.2).



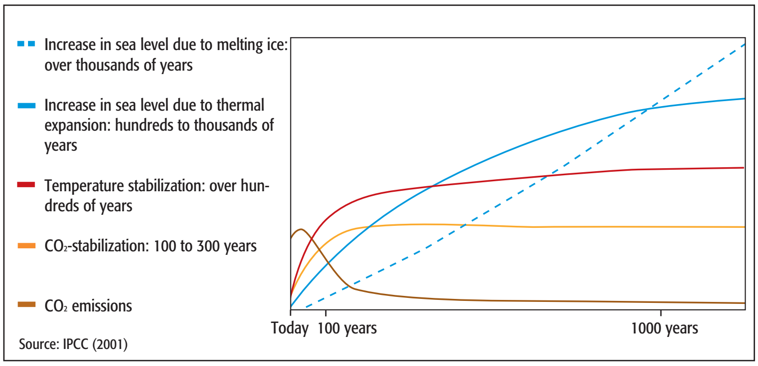
The SRES Scenarios

A1 defines a world with rapid economical growth, a world population which in 2050 reaches its maximum and decreases after this, plus the rapid introduction of new and more efficient technologies. Regional differences are compensated. The A1 family is subdivided into A1Fl (focused on fossil fuels), A1T (focused on non-fossil fuels) as well as A1B (a mixture of A1Fl and A1T).
A2 regards the world as very heterogeneous with the preservation of regional differences. The world population continually increases, the technical change only takes place slowly.
B1 calculates the world population the same as A1. The technical change is more concentrated on clean and efficient technologies with effective solutions in the economical, social and environmental areas.
B2 sees the world population the same as A2. Solutions to problems in the economical, social and environmental areas are found at a local level.

The different climate projections and bandwidths of the temperature increases to be expected (Slide 15, Fig 15.2) are the result of many possible developments and not the result of an inaccurate calculation. As a comparison, the scenario calculated in the IPCC Report for 2007 regards the CO_2 concentration for the year 2000 as constant, i.e. "frozen."

A View to Climate's Future?

With all the climate projects calculated from the SRES Scenarios there is almost the same level of increase in the annual average temperature globally up to 2030; however the curves deviate from each other after this (Slide 15; values related to the average value 1980-99). The range of the projected temperature increases up to 2100 are between 1.8 °C (1.1– 2.9 °C) for the favorable scenario B1 and 4 °C (2.4 – 6.4 °C) for the unfavorable scenario A1Fl (IPCC 2007). It is striking that even when freezing the CO_2 concentration to the state at the year 2000 (i.e. an immediate stop to all emissions) the temperature increase continues (by approximately 0.6 °C up to 2100). The reason can be found in the inertia of the climate system (Slide 15, Fig 15.3).The earth´s complicated climate machine is not easily unbalanced. It reacts rather slowly to changes in the

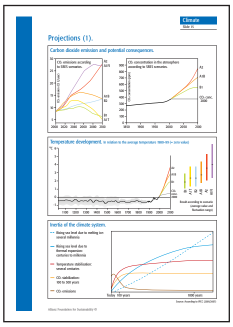


Inertia of the climate system (Fig 15.3).

climate factors and with a time delay. This also means when a development has started then any rerouting does not initially have any influence. Hundreds of years can pass until the CO_2 concentration in the atmosphere has stabilized or been reduced.
This effect is especially drastic concerning the presumed increase of the sea level. According to the projections, the sea level will increase up to 2100 (in relation to 1980 – 99) by "only" about 18-38 cm (Scenario B1) and 26 – 59 cm (Scenario A1FI). However, even if the CO_2 concentration has stabilized by then, the increase will continue by hundreds to thousands of years. The melting of the Greenland ice alone will cause the sea level to increase by approximately 7 m. Should the earth´s glaciers melt, then the sea level will increase by up to 80 m. The same rule applies here: Once the process has started, then up to a certain threshold value it can no longer be stopped and apparently is irreversible!

Everywhere Is Different.

The projections mentioned relate to general global development. The expected climate change will in all probability affect individual regions in very different ways. Already at present temperature monitoring indicates great differences – from very strong warming, especially in the arctic regions, to regional reductions in temperature. New climate models try to calculated these regional trends, because they are very important for on-site political decisions. Climate models with such a fine resolution require a high data density and necessitate immense expenditure in calculation.



Projections (1).
Slide 15

Overview of Important Points:

- The observed increase in the global average surface temperature most likely has man-made causes, whereby CO_2 emissions are especially the focal point.
- Climate research is intensively working on models which present the complicated climate events as accurately as possible and enable projection for future development.
- The IPCC has disclosed different development possibilities for the world as scenarios with respect to population and economical growth, energy requirement, etc.
  Using the climate models, the effects on world climate were calculated for each scenario (climate projection).
- All projections show a clear increase in temperature up to the end of the century. Depending on the scenario, an increase in average global temperature of 1.8 °C – 4.0 °C is to be expected compared to the same period between 1980 – 1999.
- The problem in this connection is the inertia of the climate system. Once started, many developments react very slowly to counter-measures or not at all.

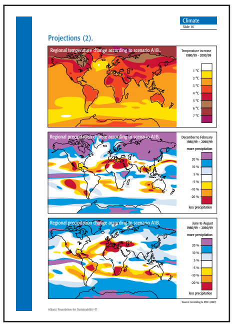
Climate Projections.

Climate change will not be the same everywhere. There will be winners and losers. But over a long period are the winners really the winners?

This chapter informs you about:

- the consequences of climate change
- the winners and losers.

Accumulation of extreme weather conditions.



Projections (2).
Slide 16

What Exactly Happens?

According to the present projections (IPCC 2001/ 2007) the future is to be calculated with the following effects:

Further increase in temperature.

The air temperature near the ground increases up to 2100, depending on the scenario, by a global average of **1.8 °C – 4.0 °C** (related to the average value 1980-99). Some regions display greater differences, but in general the warming over the land is higher than that over the sea (Slide 16, Fig 16.1).

More rainfalls.

Due to the fact that a warmer atmosphere produces more water vapor with increasing evaporation, it can be assumed that there is increased rainfall especially in higher degrees of latitude. However, in subtropical and tropical regions this can lead to a reduction (Slide 16, Figs 16.2 and 16.3).

The calm after the storm.

Accumulation of extreme weather conditions.

Even the length and intensity of rainfalls strongly deviate than previously. On the one hand, this means an **increase of strong rainfalls with flooding** and on the other hand **dry periods, heat waves**, and **draught**. The exchange of energy between a warm troposphere and the oceans leads to an **increase of water temperatures**. Therefore, the area in which cyclones can be created is larger. It is suspected that **cyclones will increase in intensity and strength**. If this trend overlaps with the cycle (AMO) mentioned on page 20, then the situation intensifies even more.
With climatic phenomena such as **El Nino**, an **increase in intensity** is expected. Even the North Atlantic oscillation will be obviously stronger, above all the positive NAO with mild winters in Central and Northern Europe. The paths of winter storms often run directly over central Europe instead of being deviated to the north or south.

Record harvests and crop failures.

Agriculture and forestry will be affected differently by climate change according to region. Forestry has the greatest problem with respect to reaction to climate change, because **forest reconstruction is only possible over the long term**. In some areas, agriculture must bear **crop failures due to dry periods and frequent rainfalls**. Other regions, at least in the short-term, will

Deserts on the advance?

The Pasterze Glacier at the Großglockner in 1900 and 100 years later.

profit. For instance, the boundaries for farming will shift to the north in the direction of the poles, and in the mountains it will shift upwards.

Decline of the ice.

The layer of snow and ice is declining, especially at the North Pole. When the permafrost soil thaws, which covers approximately 25% of the land surface, this could cause great amounts of CO_2 and methane to be released.

Changes in the animal and plant world.

According to estimations, about a quarter of all species could become extinct. Numerous species live in fragmented individual areas. Therefore there are hardly any possibilities to balance the shifting of climate zones by migration. The decisive factor is the speed at which the climate change is running. In the oceans, the climate change is leading to acidification of near-to-surface layers of water. It is here that a great portion of the plankton live. Damaging this first element of the marine food chain would have far reaching effects on sea life.

Propagation of illnesses.

The higher the temperature, the better the propagation for certain viruses. Therefore, even in Europe, illnesses are to be expected which were up to this point only known in southern countries, for example, malaria.

Weakening of the North Atlantic current.

In the Caribbean and in the Golf of Mexico, the higher air and water temperatures cause evaporation and therefore the salt content of the sea water increases. Compared to this, in the North Atlantic increased rainfalls and the inflow of melt water cause reduction of the salt content and therefore reduction of the water density. Water which has a low density sinks to a lesser degree, the wake weakens, and with it the thermohaline circulation. It is assumed that this will be reduced by 25% during the 21st century. However, researchers do not expect Europe to cool because the general warming trend is predominant. Complete demolishing of the current, similar to that at the beginning of the "Young Dryas" (refer to p. 25) is highly improbable for the next 100 years.

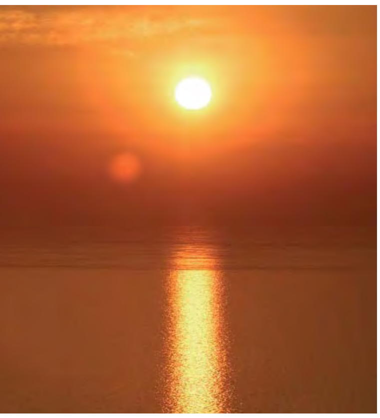
Malaria will also soon penetrate into moderate latitudes.

Tropical species – at danger through climate change.

Advantages for agriculture. Example: Canada.

The arctic and the polar bear-losers in the climate change.

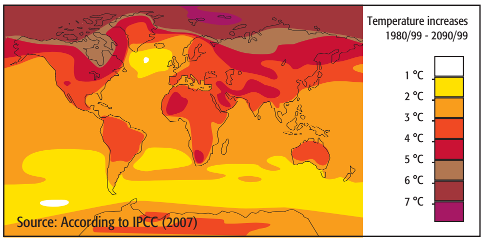
How high will the seas rise?



Sunshine every day? Weather – between a dream and a nightmare.

Winners and losers.

The consequences of climate change will **not affect all parts of the earth**. Some regions will be greatly affected. Others could, at least for some time, profit from it.
The decisive factor is whether and how humans, animals, and plants are able to adapt, and how much time is left for this process.



Temperature changes according to scenario A1B, Fig 16.1.

Rich countries have **better preconditions** than poor countries to adapt to the consequences of climate warming. This is the reason why the consequences of climate change will in all probability **clearly hit the poor countries harder**, although the developed industrial nations produce most of the greenhouse gases, and are therefore the main cause of the problem. However, in an ever shrinking world the problems of the "loser countries" also afflict the "winner countries." Moreover, the initial positive effects can turn to the contrary.
The following trends emerge:

Advantages:

- Increasing harvest in all parts of middle latitudes (with a temperature increase of less than 2°C in the next 100 years); strong tree growth
- South-East Asia – partly reduced lack of water
- Reduced energy requirement for heating in the higher latitudes.

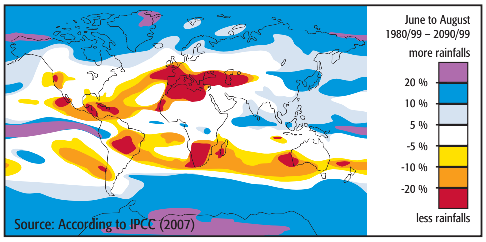
Disadvantages:

- Harvest reduction, above all in the tropics and subtropics
- Harvest reduction in the middle latitudes (with a temperature increase of more than 2°C within the next 100 years)
- Lack of water especially in subtropical regions
- Propagation of illnesses
- Increase of extreme weather conditions (storms, floods, etc.)
- Increase in energy requirement for cooling.

The following projections are made for the individual parts of the earth which greatly differ, according to scenario (Slide 16, Figs 16.1 – 16.3):

Europe

In Europe, the expected **problems are comparatively small** and can, to some degree, be solved by the rich countries.
In Middle Europe, the **summers will be dryer,** but the **winters will have more rainfalls**. The snow and tree boundaries will continue to rise in the Alps. **Glaciers will almost disappear** completely. Thawing of the permafrost soil will increasingly cause landslides and mudslides.
There will be **positive effects for agriculture mainly in the north**. In the south and east it will be more negative. In **Southern Europe**, there will be **partially long and more distinct dry periods**.



Changes in rainfall according to Scenario A1B, Fig. 16.3.

Asia.

In the warmer parts of Asia, **extreme weather conditions** such as cyclones and flooding will increase as well as dry periods and forest fires. **The increase in sea level** will threaten millions of people populated in coastal areas and their existence, e.g. Bangladesh, and additionally damage mangroves and coral reefs. While agriculture in the south is facing difficult re-circulations, **the agriculture in the north will propagate**. Above all, Russia will profit. On the other hand, the melting of the permafrost soil will damage the infrastructure (roads, supply routes).
In the tourist areas of South-East Asia, the heat and the increasing danger of **tropical diseases** will cause a reduction in the number of tourists, therefore causing heavy economical losses.

Africa

More frequent draughts, floods, and other extreme weather conditions will especially affect the agriculture from which very many people in Africa are dependent. The desert will expand further.
Another consequence will be the propagation of dangerous tropical diseases, e.g. malaria. As a continent with a mainly weak economy, Africa will probably be the **greatest loser in the climate change**. However, the number of so-called

environmental refugees will increase, thus posing a problem for the whole world.

Australia and New Zealand.

In this area more dry periods and forest fires are to be expected as well as the increase in tropical storms. The further progression of climate change will have negative consequences for the agricultural sector, above all, due to the lack of water. Many species of the unique animals and plants will presumably not survive climate change.

America.

Agriculture in the north (Canada) will profit by the shift in the agricultural boundary. In the southern parts of the USA, tropical storms will increase in severity and, therefore, the damage caused by weather will also increase.
Unique ecological systems such as prairies, marshes, and arctic tundra are on the loser side as well as the original inhabitants who live there.
The problem is graver for Mid and South America where the poorer countries will be greatly affected by climate change (cyclones, floods, draughts, problems with water and food supplies).

Polar Regions.

While the effects of global warming is less dramatic in the Antarctic, climatic change will especially be stronger and quicker in the Arctic. It is feared that animals such as the polar bear will not adapt quickly enough to the changed conditions. It will affect the life style of many of the local inhabitants. At the end of the century the ice on the Arctic Sea could completely disappear in summer. One advantage: The seaway between Europe and Japan will be shorter ...

Storm damage in Germany.

Island Countries.

Many island countries are on the loser side. The main problem is the imminent increase of the sea level, acutely threatening the freshwater supplies of many islands and flooding the coasts. This will also have consequences for the fishing industry. The important tourist industry must also expect clear losses. Some islands will completely disappear from the world map.

Islands – threatened paradises.

What Can Germany Expect?

More likely, hot dry summers; rather humid, mild winters. Extreme weather conditions as those experienced in the dry year 2003, the flooding of the river Elbe 2002 or storms such as Lothar, Wiebke and Kyrill will occur more frequently.
Only the high altitude of the Alps (from 1500 m) and the low mountain range (from 800 – 1000 m) are certain to have snow. The North Sea and the Baltic Sea will become more popular as vacation regions compared to Southern Europe.
Because forest alteration will take decades, the climate change will, above all, affect forestry.
Agriculture will possibly profit for some period of time. There will be less cooling water available for power plants and industry (summer 2003). Shipping will be affected by the extremely low water levels.
The low rainfalls in the North-East German lowlands, the warm Upper Rhine Valley and the Alpine regions are areas in Germany which are mostly affected by the climate change.

Overview of Important Points:

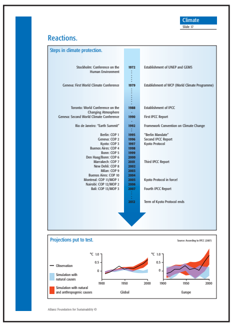
- The climate change predicted by scientists will have worldwide effects.
- In addition to an altered rainfall distribution and an increase of extreme weather conditions, there are considerable effects to be expected on the animal and plant world as well as on agriculture and forestry. Other economical sectors such as tourism will also be affected.
- The aftermath of climate warming will affect the individual continents very differently.

Climate Policy.

Summer of the century, climate shock, monster hurricanes – during the past years, the climate has always reached headline news and public discussion. On a political level, it has been the subject of a long-standing debate.

In this chapter you can read something about:

- the first steps towards international climate protection
- climate conferences and their results.



Reactions.
Slide 17

First Steps Towards Climate Protection.

International agreements for protection of the climate were initially made at the Conference on Human Environment at Stockholm in 1972. It founded the "Earthwatch" program whose objective was to collect and evaluate all the environmental data compiled by institutions working in the complete system of the UN. By doing this, any changes to the environment could be recognized in good time and fundamental measures produced for environmental policies.
The first World Climate Conference in 1979 in Geneva marked, with the World Climate Programme (WCP), the beginning of intense international efforts to scientifically understand climate changes.
The follow-up to this was the World Climate Conference in 1988 in Toronto which dealt with changes to the atmosphere and which founded the IPCC. The second World Climate Conference was held in Geneva in 1990 also concerned itself with the protection of the ozone layer. The first climax in international climate protection was the United Nations Conference on Environment and Development (UNCED) in 1992 in Rio de Janeiro (Slide 17, Fig 17.1).

Earth Summit in Rio.

At the "Earth Summit" in Rio, in which about 10,000 delegates from 178 countries participated, a number of important documents were passed – amongst others, the United Nations Framework Convention on Climate Change, UNFCCC. Although this is vaguely formulated and not binding from a statutory point of view, it produces the framework for all future international efforts concerning climate protection: Since 1995 the contractual countries annually meet for the Conference of the Parties, COP.

Climate Protection - A Global Task

The Climate Framework Convention 1992
"The ultimate objective of this Convention ... is to achieve ... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

From Rio to Kyoto.

COP 1, which took place in Berlin in 1995, passed the "Berlin Mandate" as the most important result. In this, it was stated that the details in Rio were insufficient and the industrial countries be assigned the main responsibility for climate protection.
At the COP 2 in Geneva the following year, the majority of participants officially recognized the results of the second IPCC report, in which it stated that "there is a recognizable human influence on the global climate," in the form of the "Geneva Declaration." The COP 3 in Japan 1997 produced the "Kyoto Protocol," so far the biggest step in climate protection.

The Kyoto Protocol.

In the Kyoto Protocol, the industrial countries oblige themselves as a group to reduce emissions of important greenhouse gases (carbon dioxide, methane, laughing gas, and others) between 2008 and 2012 by an average of 5.2% below the value of 1990. The EU set this value to 8%, Germany to 21%, the USA to 7%, Japan and Canada each at 6%, whereas Russia and the Ukraine agree not to exceed the 1990 level. The developing countries, including India and China, did not accept any limitation.
Three flexible mechanisms were developed in order to achieve fixed objectives for reduction of emission:

1. Emission Trading.

The permitted emissions of a country is divided into certificates similar to how the value of companies is divided into shares. The countries distribute these certificates individually to companies according to their emissions existing up until now. Companies who are not able to meet their reduction obligations must purchase certificates from companies who have already reduced their emission. Those who save emission can even earn money! Therefore, free-enterprise capital shall contribute to reducing toxic emissions and assert environmental technologies. The system, limited to industrial countries, also enables inter-country trading of emission.

2. Joint Implementation.

If an industrial country finances measures of emission reduction in another industrial country, then it has the right to have this emission reduction imputed as a saving and is correspondingly allowed to emit more.

3. Clean Development Mechanism.

Industrial countries can procure the right to emit more greenhouse gases if they finance the measures for emission reduction in developing countries who have not agreed to any obligation to reduce emission. However, these measures must assist the sustainable development of the corresponding country.

What comes after Kyoto?

The development after Kyoto is an example of how difficult it is to come to worldwide agreement on climate protection. The Kyoto Protocol could only come into effect after ratification by at least 55 countries who were responsible for at least 55% of the CO_2 emitted in 1990 – which was the case only in 2005 after ratification by Russia. In the meantime, 141 countries ratified who are responsible for 62% of CO_2 emission and who represent 85% of the world´s population. At the same time, there are four countries who are not in the process: Australia, Croatia, Monaco, and the USA – the greatest emitter of CO_2 with a quarter of the world´s discharge.
COP 11 (2005) in **Montreal**, with participants from 188 countries, was the first conference after the Kyoto Protocol came into effect and therefore at the same time the first Meeting of the Parties of the Protocol, MOP 1. Although at the conference in **Nairobi** (2006) the climate change was identified as being the greatest challenge in history of civilization, no concrete steps could be established over and beyond 2012.

Where is the way out?

Success Story?

That international agreements can produce success is proven by the development around the so-called ozone hole. In 1974 scientists indicated for the first time about the destruction of the ozone layer by chlorine from industrial greenhouse gases (CFCs). The hole in the ozone layer became larger over the poles in the following years. At the same time pressure was brought to bear on politicians to find a solution.
In Montreal (1987) a milestone was reached at the International Conference for Protection of the Ozone Layer in which 48 countries obliged themselves to drastically reduce the substances responsible for ozone destruction. The regulations were continually intensified up to 1999.
In 1990, Multilateral Ozone Bonds were set up that finance developing countries to exclude the use of CFCs.
In the meantime, studies have concluded that the ozone hole over the Antarctic will close by 2070. An encouraging example of how something can be done to protect the environment and climate by common action.
However, it was fundamentally sufficient to ban just a few and relatively easy to replace chemical substances.

Climate protection is everybody's concern.

Overview of Important Points:

- ▶ Since 1972 the international community of states regularly meet for climate conferences.
- ▶ Milestones in climate policy were achieved at the "Earth summit" in Rio (1992) and the Kyoto Protocol (1997) which specified the mandatory reduction of gases up to 2012 that affect climate.
- ▶ Efforts to protect the ozone are a promising example of how international agreements can achieve success.

Climate Change: Fact, Fiction, Panic Maker?

"It is not half so bad!" "The human race is not at fault." Such opinions circulate through the media. But how reliable are the prognoses? Will climate change fail to take place?

This chapter describes:

- skeptics' arguments concerning climate change.

The Facts.

Each look into the future is inevitably afflicted with uncertainties. This also applies to the prognoses about climate change. Without doubt, there are aspects which are not fully understood and are the object of current research. But certain core assertions are regarded as being backed up overwhelmingly by the majority of climate researchers:

- ▶ The concentration of CO_2 in the atmosphere has clearly increased since 1850 (from 280 ppm to 379 ppm).
- ▶ The burning of fossil fuels and the slashing and burning of the forests are mainly responsible for this increase, and therefore clearly points the finger of blame towards humans.
- ▶ CO_2 is a gas affecting the climate and boosting the greenhouse effect.
- ▶ The global climate has warmed up significantly. Natural causes for this increase cannot be solely substantiated.

Despite these facts, climate change and its consequences are often played down. The following arguments are mostly asserted by "skeptics":

"Man Is Not at Fault."

"Warming of the earth has other causes than greenhouse gases."

- ▶ The climate is influenced by different factors. The influencing factors over a long period (changes in the earth's orbit, continent drift, etc.) cannot be responsible for global warming over the past 100 years. Even the briefly impactful period of volcanism cannot be given as an explanation, owing to the lack of volcanic eruptions in the recent past. The sun then?

Less dangerous then once thought?

"The earth's warming is triggered by a change in the sun's activity."

- ▶ It is undisputed that the deviations in the sun's activity has contributed to climate changes in the past. Climate deviations of the last millennium can even be well presented. However, the warming during the 20th century cannot be alleged to come from sun activity alone; it has been relatively stable since 1940.

"The increase in CO_2 is a result of earth warming and not its cause."

- ▶ The earth's history shows a close connection between CO_2 content and temperature. An increase or decrease in temperature (e.g. caused by changes in the earth's orbit) will be followed by a delayed increase or decrease of the CO_2 content. However, if we look at this inversely, we will see that an increase or decrease of CO_2 will also lead to a corresponding change of temperature. Therefore, it is only dependent on which factor changes first, and in which direction. Currently the temperature is following, with a delay, the increasing CO_2 content.

Isn't a warmer climate nice?

"The warming does not depend on the carbon dioxide content of the atmosphere."

▶ In fact, carbon dioxide is not solely responsible for global warming, but in combination with other greenhouse gases (pp. 30). But 60 % of it account for carbon dioxide.

"Humans have nothing to do with the increase of carbon dioxide."

▶ There are exact figures available on how many fossil fuels have been mined and burned in the past, and how much carbon dioxide has thereby been released into the atmosphere. Approximately half of it was absorbed by the oceans and the biosphere. The rest corresponds almost exactly to the measured increase in carbon dioxide concentration. The isotopic composition, moreover, clearly indicates that the major part of the additional carbon dioxide (approximately 75 %) comes from fossil fuels. Slash and burn cultivation is mainly responsible for the rest.

The observed temperature profile since 1850 can neither be explained by natural factors (solar activity, volcanism), nor by anthropogenic factors (greenhouse gases) alone. The best depiction of reality is achieved through model simulations which superimpose natural and anthropogenic causes. These model calculations also prove the significant influence of humans on the global warming of the last 30 years (slide 17, Fig 17.2).

"It Won't Be so Bad …"

… argue climate skeptics who downplay the consequences of climate warming or mainly find positive effects in it:

"Various feedback mechanisms will stop or reverse the warming!"

▶ A number of mechanisms is not yet sufficiently researched, as shown on page 31. Feedback that would be able to compensate or reverse the observed warming are unknown at present. When looking at the climatic history, one clearly sees that these mechanisms probably never existed. On the contrary, once a certain threshold value is reached, the system becomes unbalanced, and one can expect strong cataclysms.

"The climate has always been changing."

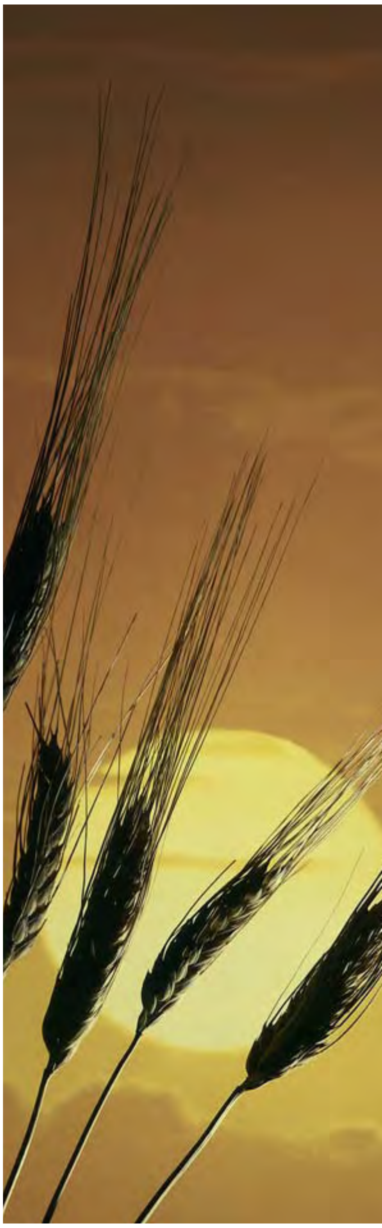
▶ This argument is rather an indication of the system's sensitivity and does not contribute anything to an all-clear message. The current speed at which global warming takes place is unheard of in history.

"Carbon dioxide is good for plant growth and therefore for world nutrition."

▶ Carbon dioxide enhances plant growth. Therefore there will be initially a fertilizing effect indeed – mainly in the higher latitudes. With an increasing and accelerated climate change, negative consequences like drought stress and others will probably have the upper hand. One example is the "millennium summer" in 2003. According to measurements for that period, plant growth in Europe was 30 % below the usual values!

"Humans will come up in time with the required technical inventions."

▶ In the meantime a number of – partially bizarre – proposals have been made. Some proposals require such drastic actions that the consequences would be most probably completely unforeseeable. Other considerations, like the deposition and storage of carbon dioxide in combustion processes, are seriously discussed. Whether they are a solution at all is uncertain at the moment (p. 45).



Carbon dioxide – good for plant growth?

Overview of Important Points:

- ▶ Human influence on climate warming of the last 100 years can be considered as proven.
- ▶ Nonetheless, fundamental connections are time and again denied or doubted by the so-called climate skeptics. The arguments of these climate skeptics, however, do not usually hold water when scrutinized more closely.

Reacting to Climate Change.

After us, the flood? The climate change has already begun – but it is not too late to counteract.

This chapter tries:
- to give an assessment of the future development that is as realistic as possible
- to show how climate change can be countered.

We're Already in the Midst ...

According to the current state of research, one can expect a further increase in the carbon dioxide concentration in the near future, even based on the most positive scenarios. Even if all emissions would be immediately stopped, climate change could not be halted (p. 33). Initially the temperature will keep on increasing and the rise in sea levels might even continue over a period of several centuries. On the part of the cause, the emissions, a remarkable reduction of gases relevant to climate is met with considerable resistance. The USA, at present contributing ¼ of the current carbon dioxide emissions, did not ratify the Kyoto Protocol. China, the second largest emission source, considers the demand for climate protection measures as hindrance to its economic development, and will soon overtake the US as main polluter. Other emerging nations with large populations like India or Brazil see these measures mainly as a duty of the industrialized nations. With the worldwide population growth one can expect a continually increasing energy demand and therefore rising greenhouse gas emissions.

Keep Going?

A simple "keep going" attitude is however not acceptable, as an accelerated climate change bears too many risks – an experiment with unknown result! With the increasing progression of climate change it becomes more and more difficult, if not impossible, to carry out countermeasures.
Measures for climate protection clearly present a financial effort. But even today, climate change causes high financial expenditures – which might considerably increase in the future. A report by the Umweltbundesamt dated 2005 states that by 2050, the economic damage will have reached several trillion euros worldwide. Germany alone would have to shoulder annual costs of around 100 billion euros (By comparison: Germany's federal budget in 2006 consisted of 260 billion euros in total). Even though one should be careful with such figures, there is one thing that is clear: The longer we wait, the costlier it will become ...

What Now?

Therefore we should focus on stabilizing and/or reducing the concentration of important greenhouse gases in the atmosphere – first of all carbon dioxide – as fast as possible, as formulated in the United Nations Framework Convention on Climate Change (p. 38). According to most experts, the measures of the Kyoto Protocol are a first step in the right direction, but will be barely able to slow down the increase of the carbon dioxide concentration and the global average temperature, even if the resolutions are fully implemented. More significant objectives for reduction will be required beyond 2012.

Guard Rails.

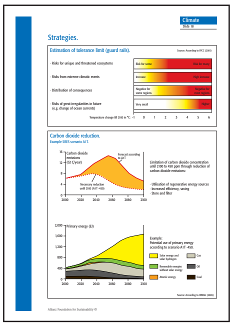
The more slowly climate change takes place, the more time is available to react to changes. Therefore researchers try to determine tolerance levels – **guard rails**, so that the climate does not start skidding: How much can the carbon dioxide content of the atmosphere grow to make consequences of the climate changes controllable? How much can the temperature maximally rise so that irreversible events – like the breakaway of the gulf stream – do not occur? Within these guard rails the future development can be guided in relatively secure **corridors**. Such threshold values are however difficult to define, as the reaction of the climate system has inherent insecurities and the climate risks are of varying severity. In certain ecosystems, the risk of damages rises with every degree of temperature increase. The change of ocean currents becomes only probable after a significant temperature increase (Slide 18, Fig 18.1).

The WBGU (German Advisory Council on Global Change) recommends for instance not to let the carbon dioxide rate in the atmosphere increase over 450 ppm within the next 100 years. Compared to the pre-industrial value, this would correspond to a rise of the global average temperature by **2°C** until 2100. Other bodies also consider this tolerance value and a warming speed of max. 0.2°C per decade to be hardly bearable. These values have been deducted from the fluctuation range and speed of climatic changes of the last 100,000 years. They take into account the costs of adjustment to climate change that are barely endurable for the international community.

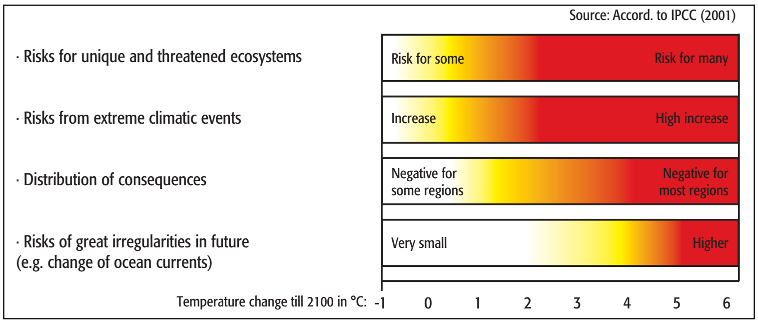
On Twin Paths.

To stay within the 2°C guard rails, the emissions of the greenhouse gases, carbon dioxide, methane, and nitrous oxide need to be significantly reduced. As the global average annual temperature is today already approximately 0.8°C higher than the pre-industrial value, the worldwide carbon dioxide emissions would require a reduction by 45-60% till 2050 – with reference to the status in 1990. As climate change is a **global problem**, solutions also have to be global. The required measures have to take into account the differing conditions in the individual countries and their capability. To include developing countries and first of all emerging nations like India or Brazil, per capita emission rights are discussed as a basis for international agreements. This means that the industrialized countries with correspondingly high per capita values will have to reduce their emissions more, whereas developing countries with low emissions might be even able to increase them a little.

According to the opinion of many experts, a secondary path must be chosen besides the reduction of emissions, namely the **adaptation** to the consequences of climate change. An adaptation however is only possible if it doesn't have to occur too quickly. Therefore, the secondary path cannot be realized without the primary path.



Strategies.
Slide 18



Risks of climate change (Fig 18.1).

Overview of Important Points:

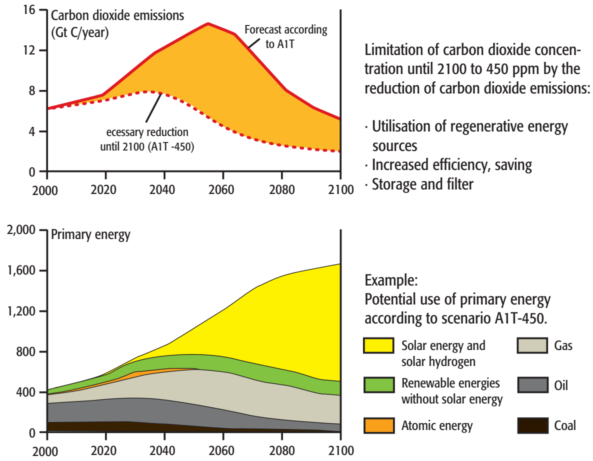
- We are in the midst of a climate change.
- Even if we change course immediately, we have to expect a further increase in global average temperatures and corresponding consequences.
- To keep climate warming in a bearable frame, “guard rails” are determined – maximum values for carbon dioxide content, temperature rise, and global temperature.
- To remain within these guard rails and keep the impact for humans and the environment bearable, the reduction of emissions and adaptations to the consequences of climate changes are necessary.

Between Back-pedalling and Adaptation.

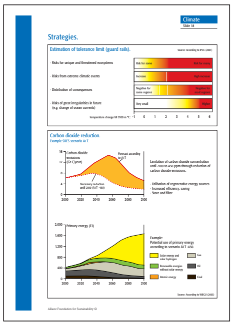
Climate experts consider the next 10 to 20 years as the crucial period in which effective measures against climate change must be taken.

This chapter shows:

- what are the possibilities to reduce emissions
- which of them are realistic
- what an adaptation to the consequences of climate change looks like.



Reduction of carbon dioxide (Fig. 18.2). Source: According to WBGU (2003)



Strategies.
Slide 18

Strategies for Emissions Reduction.

The energy demand of the world is one of the major reasons for the high carbon dioxide emissions. All forecasts say that it will continue to rise in future. The major emission sources are plants for power and heat generation (around 40%) as well as traffic (around 24%). To significantly reduce emissions till 2100 (p. 43), the following solutions (Slide 18, Fig 18.2) exist:

- ▶ Conversion of power supply from fossil energy sources to regenerative energies
- ▶ Energy saving through efficiency increase and production that requires less energy
- ▶ Carbon dioxide deposition and storage (mainly as interim solution).

More energy from regenerative energy sources?

Using Alternative Energies.

It should be our aim to increasingly replace fossil energy sources by carbon dioxide-free and/or reduced alternatives while the primary energy demand increases (Fig 18.2 below):

The regenerative sources.

The regenerative energies include solar thermal systems and photovoltaics, wind and hydropower, geothermic energy and the use of biomass. Carbon dioxide is only created in the utilization of biomass, but only as much as was absorbed from the atmosphere by plants. The use of biomass is therefore described as carbon dioxide-neutral.

There is a very controversial and also emotional discussion going on, if and when regenerative energies will be able to replace fossil energy sources. But even now they can help to gradually decrease the dependence on fossil energy sources. As fossil energy sources won't last forever, a change of track is in any case advisable.

Atomic energy – oh, sure?

Since nuclear power plants do not emit carbon dioxide during operation, atomic energy is advocated by its supporters as a solution to the climate problem. At present, about 440 nuclear power plants operate worldwide. But to effectively replace fossil energy sources, several thousand new nuclear power plants would be required.
It is highly disputed whether this is a viable solution considering the potential risks of operation and permanent disposal of nuclear waste that has so far not been solved satisfactorily. Moreover, the uranium deposits of the world are also limited.

Gas instead of coal.

An effective alternative for the short term is the increased utilization of natural gas. Compared to coal and oil, the burning of gas emits considerably less carbon dioxide. This would be an intermediate solution, as long as the conversion to regenerative alternatives has not been carried out to a sufficient extent.

Saving Energy.

Unused energy does not cause carbon dioxide emissions. Therefore, the improvement of energy efficiency has possibly the highest potential to efficiently contribute to climate protection. There exists a large number of possibilities to save energy through modern technology: in the generation and distribution of power and heat, in industrial production, in residential building, and in traffic.

Storing and Filtering.

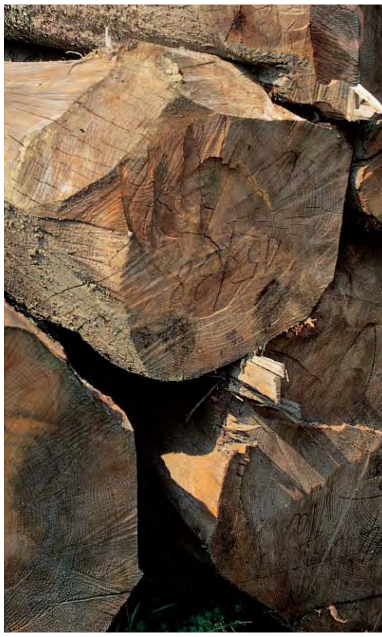
The storage of carbon in biomass can also contribute to the decrease of carbon dioxide concentration. Here the storage function of forests is highly important. Therefore, the Kyoto Protocol contains the possibility to offset the carbon storage in so-called terrestrial sinks (forests, grounds, etc.) with the emission commitments. Carbon storage in forests, however, occurs slowly and only from a certain age of the forests. In addition, a forest can quickly turn from a carbon dioxide sink into a source, e.g., when growth decreases due to dryness or if the forest is cut and its wood is burned. An effective storage effect is achieved when wood is turned into durable products, e.g., in building houses or furniture. The idea to trigger plankton growth through the fertilization of the oceans and thereby remove carbon dioxide from the atmosphere, did not prove a very suitable solution according to a few experiments. Only a minimal portion of the carbon initially bonded to the plankton was stored for a long time, while the major part was soon released again via the food chain. It is difficult to estimate which other side effects might occur in addition.

Another possibility is to deposit carbon dioxide during combustion and press it into subterraneous cavities (e.g. exploited coal and oil deposits) or corresponding rock formations and thereby remove them from the atmosphere over the long term.
Supporters of this technology say that the carbon dioxide released by the burning of coal, oil, and gas would thereby be returned to the lithosphere. But the costs of such procedures are not yet known. And the deposition as well as the transport would require a lot of energy. This technology is only interesting for large emission sources like power plants or industrial facilities. The first pilot plants are being built and tested. But the carbon dioxide that adds up to large volumes from small sources – like cars, aircrafts, domestic heating, etc. – cannot be collected with this method. As there exists a number of open questions when it comes to storage (capacity limits, leakages in the rock, etc.), this method can only be an intermediate solution.

Besides carbon dioxide, a reduction of emissions should also be affected for other greenhouse gases. Methane and nitrous oxide are mainly produced in farming: Particularly intensive livestock farming and an expansion of rice cultivation contribute to increased emissions. They can only be reduced by changed husbandry and cultivation methods. Another source is leaky landfills. They require technical measures.

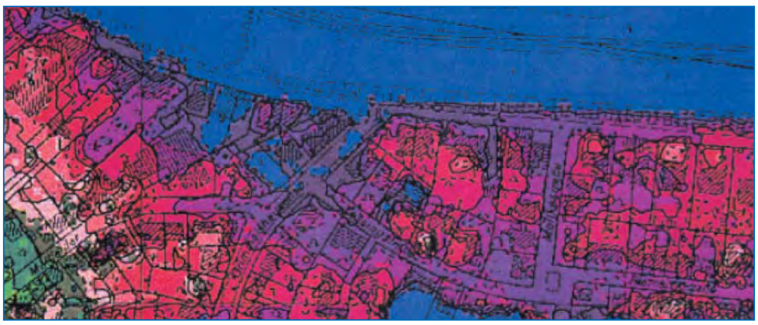
Reacting Through Adapting.

Besides all efforts to reduce the emission of greenhouse gases, it is also important to prepare for the imminent effects of climate warming in time. The earlier, the better applies here as well.
In agriculture, the selection of varieties of species and cultivation methods will have to adapt to changing conditions. This concerns first of all irrigation, where more efficient methods must clearly be developed in the future, as the availability of water will become a limiting factor in many regions. This applies first of all to those worldwide regions that already face water shortage. In these areas, the dependence of humans on agriculture is often particularly high. The predicted increase of precipitation and extreme weather requires greater efforts for the protection from floods, landslides, and storms. This concerns the relevant forecast and early warning systems in the same way as direct protective measures (dykes, dams, protective walls, …). But also indirect and prophylactic measures like the creation of large flood areas and a corresponding building and settlement planning are part and parcel of an anticipatory adaptation strategy. In this context, coastal areas are in the focus: They belong to the most densely populated regions and are particularly affected by a rising sea level and storms.



Wood stores carbon dioxide – especially when made into durable products.

In the future, efficient irrigation methods will become increasingly important for agriculture.



Maps with risk areas on large rivers show danger zones, so that measures can be carried out in time.

Low adaptability – a coral reef.

Concrete measures with respect to the health care for the population are also important, particularly in underdeveloped countries. In the near future, immense help and a science transfer from the industrialized nations are necessary.
The reactions to the summer of 2003, which led to a large number of deaths in Europe due to prolonged high temperatures (experts estimate that the number of additional deaths throughout Europe was 30,000), is a good example of what an adaptation can look like: The affected countries developed corresponding emergency plans, so that they were much better prepared for the situation when the heat wave struck in July 2006.
Animals and plants are also affected by climate change. Coral reefs for instance react very sensitively to temperature changes. Many other ecosystems will be able to adapt to the new conditions only to a certain extent. Therefore it is important to develop relevant concepts early on. Planning, management, and networking of protected areas have to be designed in such a way that different species have a chance to migrate. Special attention is turned to the so-called hot spots – regions or protected areas that have a particularly large or unique biodiversity.
It is decisive in all measures that poorer nations can also muster the necessary financial resources. Here the installation of climate funds could help, as already discussed during the Climate Conference in Nairobi in 2006.

Chances and Challenges.

Besides measures for the reduction and prevention of emissions, more and more technologies and methods that facilitate the handling of changing conditions are required in the future. The climate change also offers opportunities here, because the use of new technologies can give additional economic incentives. Adaptive and preventive processes can become the motor of sustainable economic development. A climate-friendly energy concept mitigates imbalances and can avoid conflicts for resources like water and oil.
When informing the public about climate change, its opportunities should be emphasized more strongly. The creation of a catastrophe mood rather leads to fatalistic reactions, where people think that they won't be able to change anything anyway and, thus, just let the process continue unhindered.

More Research.

Due to the mentioned insecurities of the presented predictions, further research is necessary. The better the contexts of the climate machine Earth are understood, the faster climate protection measures can be modified and threatening damages prevented or lessened.

Adaption Strategies in Germany

Agriculture and forestry, particularly in Eastern Germany will have to switch to other agricultural products. The same applies for instance to the area around Lake Constance. Here farmers increasingly plant apple trees that had previously only grown in South Tyrol.
Special attention is given to the people living close to rivers. To prevent floods and/or minimize the damages, large enough flooding areas have to be created. Threatened areas should be kept free of buildings and flood forecasts must be optimized.
Many tourist centres in the low mountain ranges, but also in the Bavarian Alps have to find new concepts that incorporate tourism apart from the classic winter sport activities.

Overview of Important Points:

- It is possible to reduce greenhouse gas emissions: An increasing utilization of regenerative energy sources, a more efficient utilisation of energy, and consequent saving of energy.
- The storage of carbon dioxide is only an intermediate solution that at best gains time to develop adaptation strategies.
- It is one of the most important challenges for the future to live with climate change and adapt to inevitable changes. Climate change in this context should also be understood as an opportunity to develop new sustainable technologies.

Glossary.

Absorption
Here: assimilation of radiant energy and conversion into long wave heat radiation (p. 10). Opposite of > reflexion.

Aerosols
Small particles in the air, compact or liquid (dust, salt crystals, ashes, etc). Act cooling on the climate, as they reflect sun radiation (p. 6).

Albedo
Reflective ability of a surface (p. 10, Slide 6).

Atmosphere
A layer of gases around the earth (pp. 6).

Biomass
The entire material built by living creatures.

Biosphere
Animate environment (Greek “bios”= life and “sfaira”= sphere).

Carbon dioxide
Trace gas of the atmosphere, important > greenhouse gas. Is mainly linked to the additional > greenhouse effect and thereby with climate change.

Circumpolar current
Ocean current, that flows clockwise around the Antarctic (pp. 14).

Climate
Characteristic progression of the weather in a place or in an area over a longer period (pp. 2).

Climate elements
Describe the climate. These include temperature, precipitation, wind, etc. (p. 4).

Climate factor
Factor that is decisive for the climate. For instance, rotation of the earth, vegetation, anthropogenic factors (p. 9, Slide 5).

Climate graph
Shows average climate data like temperature and precipitation of a certain place and thus enables the comparability of different climate stations (p. 8).

Climate model
Rendering of the climate in mathematical models (p. 31).

Climate record
Contains saved climate data of the past. Natural climate records: e.g. annual rings of trees, layering in the ice of glaciers (cores). Historical climate records: chronicles or historical measured data (p. 5).

Climatic zone
Division of the earth in areas with similar climate: tropical, subtropical, temperate, boreal, subpolar, polar. There are transitional areas in between, and the division also varies (p. 8).

Continental drift
The earth’s crust consists of several shelves on which the continents slowly drift towards and/or away from each other.

Coriolis force
A force that is generated by the earth’s rotation and which influences the wind systems and ocean currents (p. 13, Slide 7).

Cryosphere
Part of the environment which consists of ice (sea ice, inland ice, mountain glaciers, > permafrost soils).

El Niño/La Niña
El Niño (Spanish “the christ child”) describes a periodical change of sea and wind circulations in the southern Pacific. La Niña (“The girl”) is the counteractive part (pp. 20).

Emission
Release of substances, gases, etc. into the environment (lat. “emittere” = to emit), e.g. of > carbon dioxide in combustion processes.

Feedback
Interaction that strengthens (positive f.) or weakens (negative f.) an effect (p. 31).

Fossil energy sources
Created by biological and/or chemical and geological processes in the course of earth’s history (coal, oil, natural gas). They do not newly form in reasonable periods.

Global annual average temperature
Determined close to the ground, basis to assess global climate (p. 4).

Great Ocean Conveyor Belt
Globally active ocean current that connects Atlantic, Pacific and Indian Ocean (p. 14).

Greenhouse effect
Certain gases in the atmosphere act similar to the panes in a greenhouse, e.g. water vapor, > carbon dioxide and > methane. They let the sunlight pass through unhindered, but not the heat emission of the earth's surface. The medium temperature of the earth is therefore not -18°C, but +15°C (natural greenhouse effect, p. 6). Human activities, e.g. the burning of fossil energy sources, increase the concentration of climate-affecting gases and enhance the effect (additional or anthropogenic greenhouse effect, p. 30).

Greenhouse gases
Gases that partially prevent the heat emission of the earth's surface into space (like the glass pane in a greenhouse). E.g. water vapor, > carbon dioxide and > methane.

Gulf Stream
Warm ocean current in the Atlantic, Part of the > North Atlantic Current.

High pressure area
Area where high air pressure is prevalent (p. 12).

Holocene
Most recent epoch of the Earth's history. It started after the end of the last ice age (approx. 12,000 years ago).

Hydrosphere
The entire water resources of the earth (Greek "hydor"= water and "sfaira"= sphere).

Industrial Revolution
Period at the end of the 18th/beginning of the 19th century, in which groundbreaking inventions (e.g. steam engine) introduced the industrial mass production of goods. It was based on the utilisation of fossil energy sources (coal, later oil) in large quantities.

Lithosphere
Outer area of the earth's mantle with earth crust, the rocks, but also subterraneous deposits of coal, oil, natural gas, etc. (Greek "lithos"= stone and "sfaira"= sphere).

Low pressure area
Area where low air pressure is prevalent (p. 12).

Meteorology
Science that deals with weather and climate.

Methane (CH_4)
Climate-affecting trace gas of the atmosphere (20 to 30 times more effective than carbon dioxide). Is mainly linked to the additional > greenhouse effect (p. 31).

Milankovitch cycles
Cyclical fluctuations of the earth's rotation and orbit around the sun (p. 11).

Nitrous oxide, dinitrogen monoxide (N_2O)
Climate-affecting trace gas of the atmosphere. Is mainly linked to the additional > greenhouse effect (p. 31).

North Atlantic Current
Ocean current in the North Atlantic, which transports warm water from the Caribbean to Northern Europe ("Warm water heating of Europe," p. 14).

Ozone/ozone layer
Molecular compound made of three oxygen atoms. In the upper atmospheric layers ozone works as a protection from the UV radiation of the sun. In the lower atmospheric layer, however, ozone is a > greenhouse gas.

Pedosphere
Outermost layer of the Earth (Greek "pedon"= soil, earth and "sfaira"= sphere).

Permafrost soil
Permafrost soil (25% of all continents' surface, in Scandinavia up to 20 m, in Siberia up to 1.5 km deep). There are concerns that wide areas of these soils might defrost and thereby additionally release carbon dioxide and/or methane.

Photosynthesis
Process in which green plants build up > biomass from sunlight, > carbon dioxide and water and release oxygen.

Phytoplankton
Plant plankton (algae) floating in the oceans. First link in the marine food chain.

Primary energy
Direct energy content of coal, crude oil or wind, without conversion losses, into electricity.

Proxy data
Data that helps to deduce climatic events in the past (p. 5).

Reflection
Reflection of radiation energy (p. 10). Opposite of > absorption (also see > albedo).

Renewable/regenerative energy sources
Fed by sources that are inexhaustible according to the human time scale (e.g. the sun).

Scenario
Here: assumptions on the future economic and technological development of our world that are used in > climate models (p. 32).

Silicate carbonate cycle
Part of the global carbon cycle (p. 16).

Sustainability
Economic principle that guarantees that future generations can lead a life worth living by the protection of natural resources.

Tectonics (plate tectonics)
Mobile forces prevalent in the earth's interior that lead to > continental drift.

Thermohaline circulation
Drive of the > Great Ocean Conveyor Belt, triggered by differences in temperature (Greek "thermos"= heat) and salt content (Greek "halos"= salt) of sea water, (p. 14).

Troposphere
Lowest atmospheric layer, approx. 10 – 12 km wide, also called weather layer (p. 7, Slide 3).

Tundra
Vegetation of the subpolar climatic zone with mosses, lichens and low shrubs. No trees.

United Nations Framework Convention on Climate Change (UNFCCC)
Drafted at the "Earth Summit" in Rio de Janeiro in 1992. Non-binding declaration of community of states, to limit the global warming in such a way that no irreversible damages occur.

UV radiation
Short-wave, ultraviolet wavelength range of the sun radiation, not harmful for most organisms. UV radiation is partially absorbed by the ozone layer in 15 – 30 km height.

Weather
Short-term and continually changing state of the atmosphere in a specific place (p. 2).

Abbreviations mentioned in the text:

COP/MOP (Conference of the Parties, Meeting of the Parties) Annual meeting of the contractual nations of the > United Nations Framework Convention on Climate Change (first in 1995).

GEMS (Global Environmental Monitoring System) Global monitoring system to detect the human impact of energy generation and consumption, was formed in 1972 with the > UNEP.

IPCC (Intergovernmental Panel on Climate Change) Interdisciplinary circle of scientists that pools the current state of climate research and publishes the findings in reports every 6 – 7 years. Founded in Toronto in 1988.

Ppm (Parts per million) Numeric value widely used in chemistry, physics and environmental sciences. The portion of carbon dioxide in the atmosphere for instance is at present around 380 ppm.

SRES (Second Report on Emissions Scenarios) Possible development scenarios of the world that were agreed upon by the scientific world in the second IPCC report to enable comparisons.

UNCED
United Nations Conference on Environment and Development in Rio de Janeiro (1992).

UNEP
United Nations Environment Programme, founded in 1972.

UNFCCC
United Nations Framework Convention on Climate Change (1992 in Rio de Janeiro).

UNO United Nations Organization.

WBGU
German Advisory Council on Global Change.

WCP
World Climate Programme, founded in 1979 in Geneva.

WMO
World Meteorological Organization under the UN's roof, headquartered in Geneva. Promotes the standardisation and international exchange of climate relevant data.

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Allianz Foundation for Sustainability.

Environmental protection is fun if it goes beyond bans and finger-pointing – this is clearly visible in the projects of the Allianz Foundation for Sustainability.

"Contribute to a life worth living in a safe future."

This dictum is part of the articles of the Allianz Foundation for Sustainability. By founding the foundation in 1990, the Allianz set another example for taking on social responsibility.

Goals.

The activities of the foundation aim to promote creativity, enable innovation, and impart delight in nature. Humans are therefore at the center of the foundation's activities – as their action form the environment and their dreams and visions define our future.

Funding Principles.

To achieve the most within its means, the Allianz Foundation for Sustainability observes the following principles for the selection of projects. It funds projects that:

- consider nature and/or the environment, and also include humans and their requirements,
- aim at a sustainable improvement of the environmental situation,
- connect environmental aspects to social, cultural and educational concerns,
- give a stimulus as model projects and thus give an incentive to other institutions to continue or imitate them,
- convert research into practical action and thereby further develop nature and environmental protection.

Here the Allianz Foundation for Sustainability also takes initiative: through the determination of areas to be funded and active participation in the projects.

Funding Areas.

There are many areas where commitment to the environment is worthwhile. To prevent arbitrariness and develop its own profile, the Allianz Foundation for Sustainability has established several funding areas:

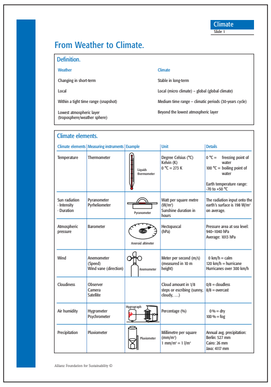
- Nature conservation, wildlife protection and landscape management
- Living waters
- Green in cities
- Gardening arts
- Environmental communication.

Besides the funding of these areas, the foundation is also active in the Benediktbeuern Symposium and the campaign "The Blue Eagle."

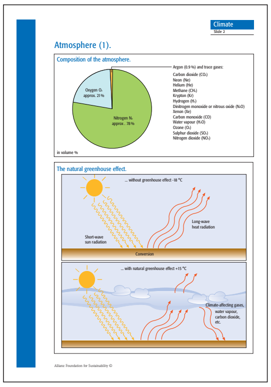
The Allianz Foundation for Sustainability is only active in Germany.

Allianz Umweltstiftung

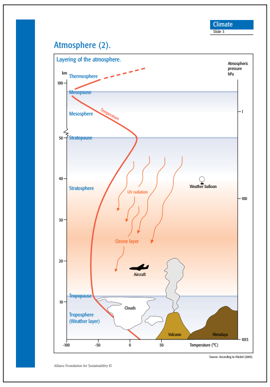
Slides.



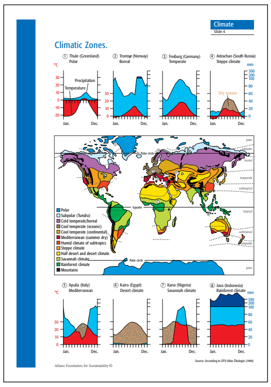
Slide 1
From Weather to Climate.



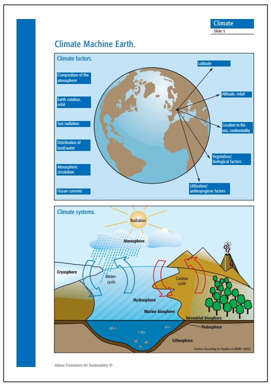
Slide 2
Atmosphere (1).



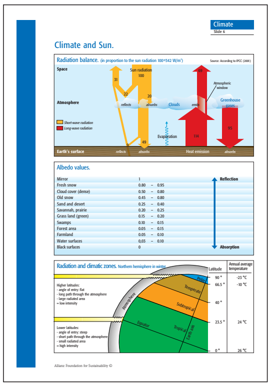
Slide 3
Atmosphere (2).



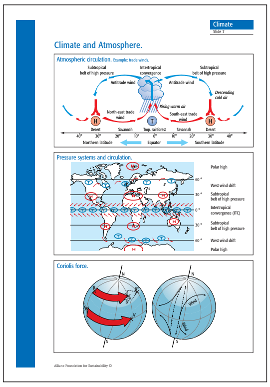
Slide 4
Climatic Zones.



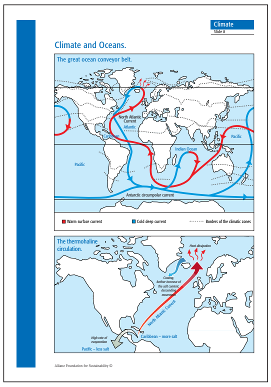
Slide 5
Climate Machine Earth.



Slide 6
Climate and Sun.



Slide 7
Climate and Atmosphere.



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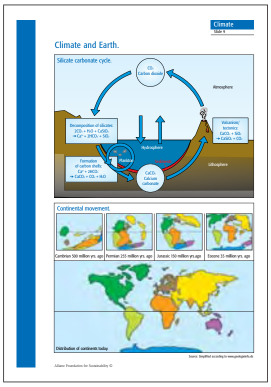
Climate and Oceans.



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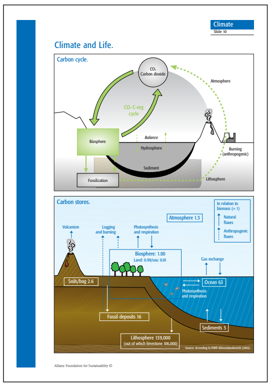
Climate and Earth.



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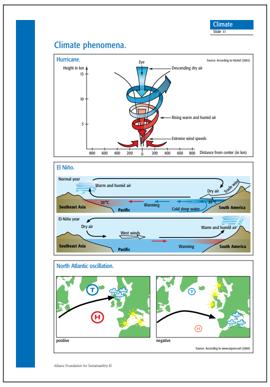
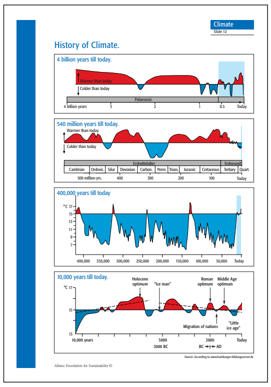
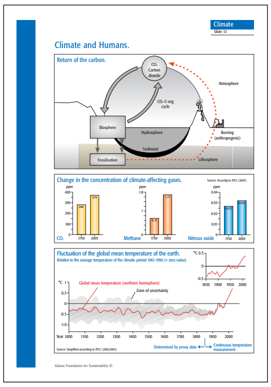
Climate and Life.



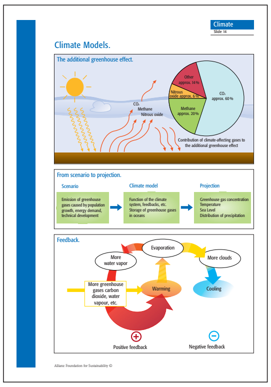
Slide 11
Climate Phenomena.



Slide 12
History of Climate.



Slide 13
Climate and Humans.



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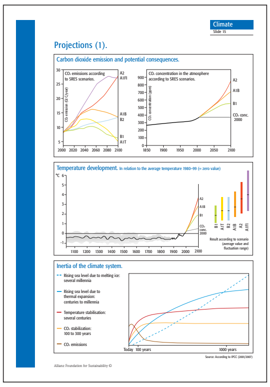
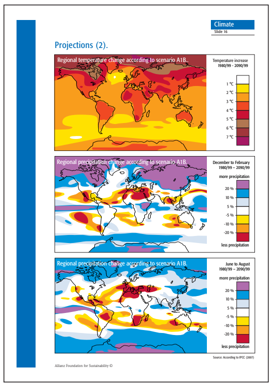
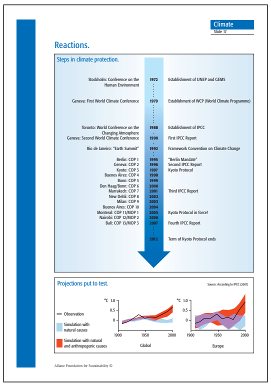
Climate Models.



Slide 15
Projections (1).

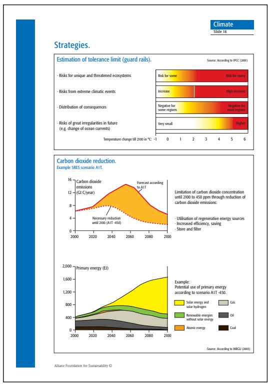


Slide 16
Projections (2).



Slide 17

Reactions.



Slide 18

Strategies.

Imprint.

Photos

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(r: right; l: left; u: up; d: down; m: middle; S: Slide; C: Cover)

Graphic Art and Drawings

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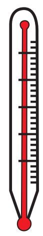
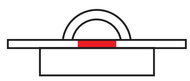
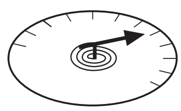
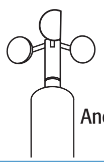
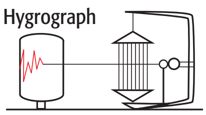
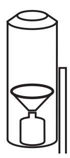
1. Edition

From Weather to Climate.

Definition.

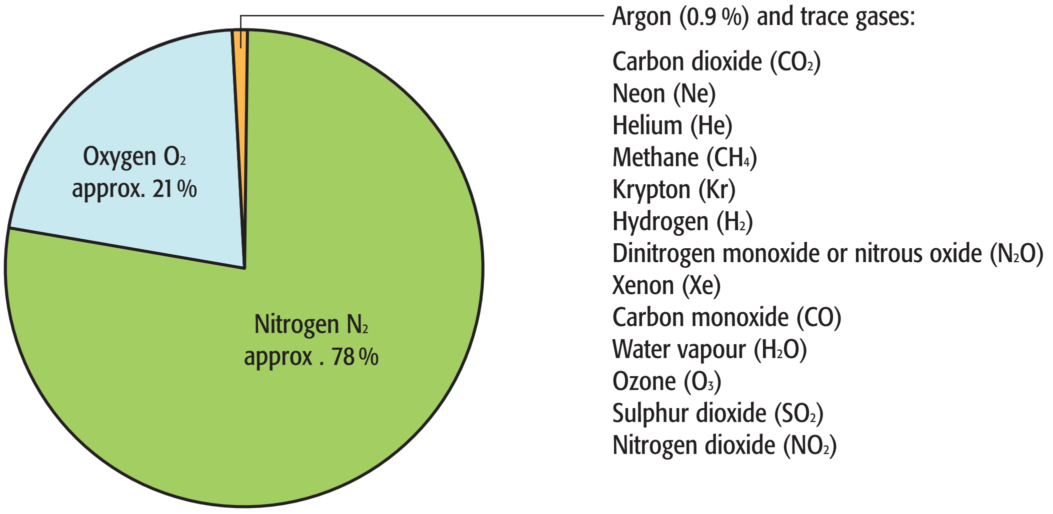
Weather	Climate
Changing in short-term	Stable in long-term
Local	Local (micro climate) – global (global climate)
Within a tight time range (snapshot)	Medium time range – climatic periods (30-years cycle)
Lowest atmospheric layer (troposphere/weather sphere)	Beyond the lowest atmospheric layer

Climate elements.

Climate elements	Measuring instruments	Example	Unit	Details
Temperature	Thermometer		Degree Celsius (°C) Kelvin (K) 0 °C = 273 K	0 °C = freezing point of water 100 °C = boiling point of water Earth temperature range: -70 to +50 °C
Sun radiation · Intensity · Duration	Pyranometer Pyrheliometer		Watt per square metre (W/m^2) Sunshine duration in hours	The radiation input onto the earth's surface is 198 W/m^2 on average.
Atmospheric pressure	Barometer		Hectopascal (hPa)	Pressure area at sea level: 940–1040 hPa Average: 1013 hPa
Wind	Anemometer (Speed) Wind vane (direction)		Meter per second (m/s) (measured in 10 m height)	0 km/h = calm 120 km/h = hurricane Hurricanes over 300 km/h
Cloudiness	Observer Camera Satellite		Cloud amount in 1/8 steps or escribing (sunny, cloudy, …)	0/8 = cloudless 8/8 = overcast
Air humidity	Hygrometer Psychrometer		Percentage (%)	0 % = dry 100 % = fog
Precipitation	Pluviometer		Millimetre per square (mm/m^2) 1 mm/m^2 = 1 l/m^2	Annual avg. precipitation: Berlin: 527 mm Cairo: 26 mm Java: 4117 mm

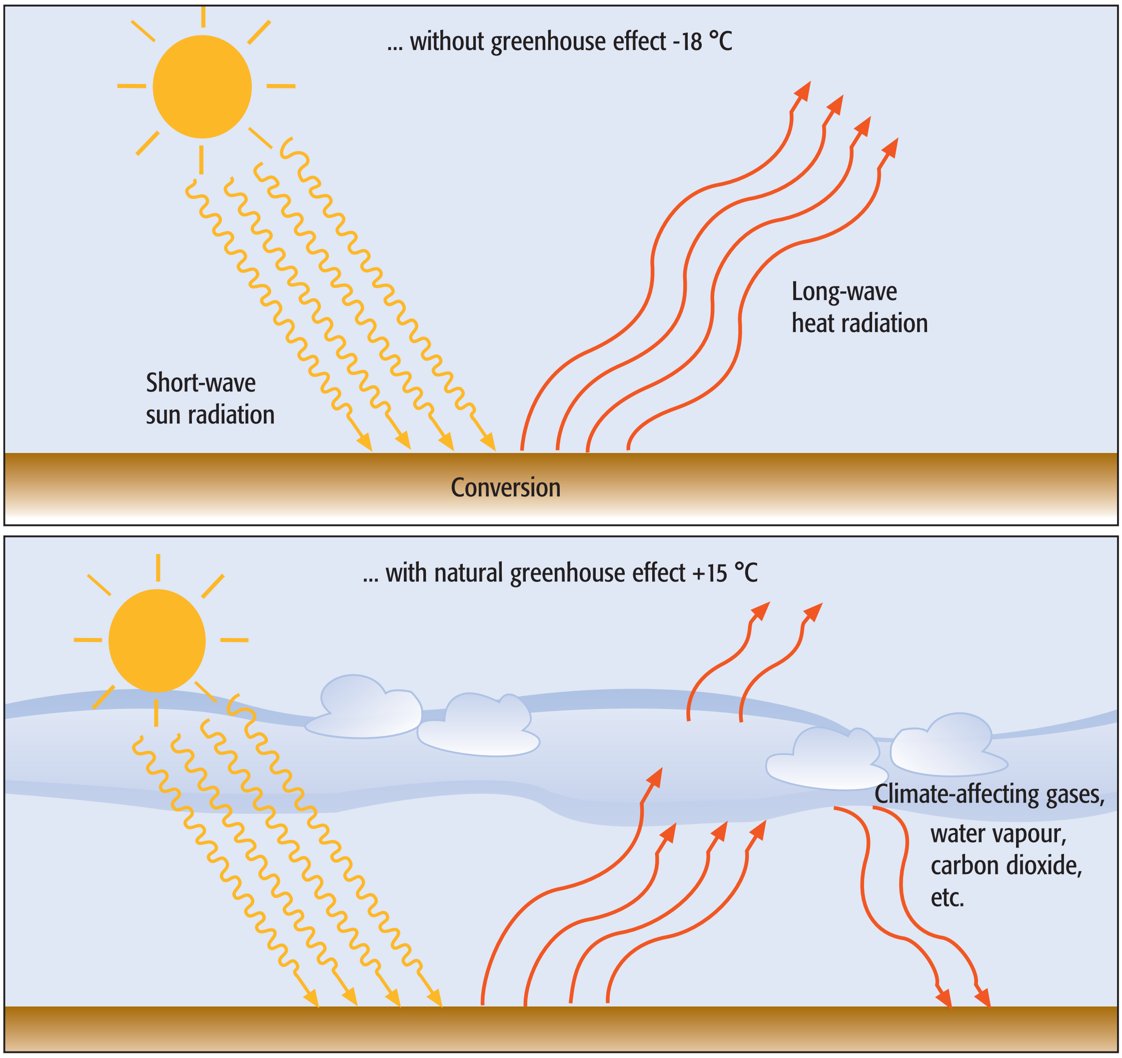
Atmosphere (1).

Composition of the atmosphere.

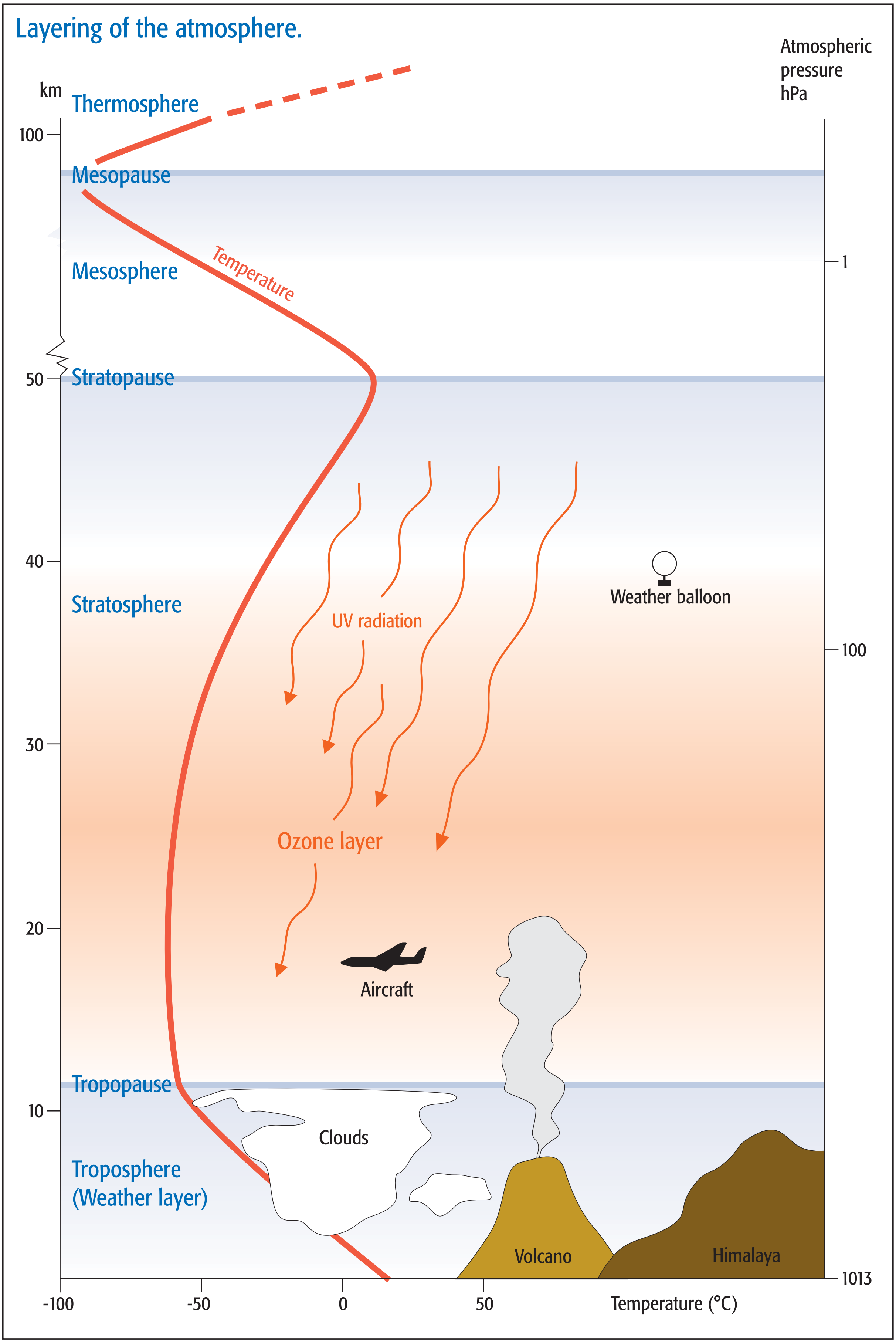


in volume %

The natural greenhouse effect.

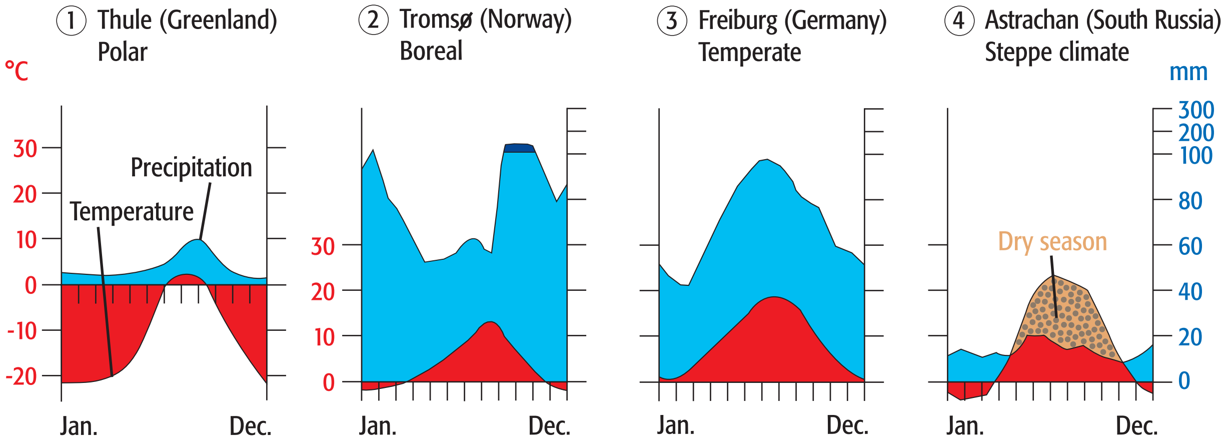


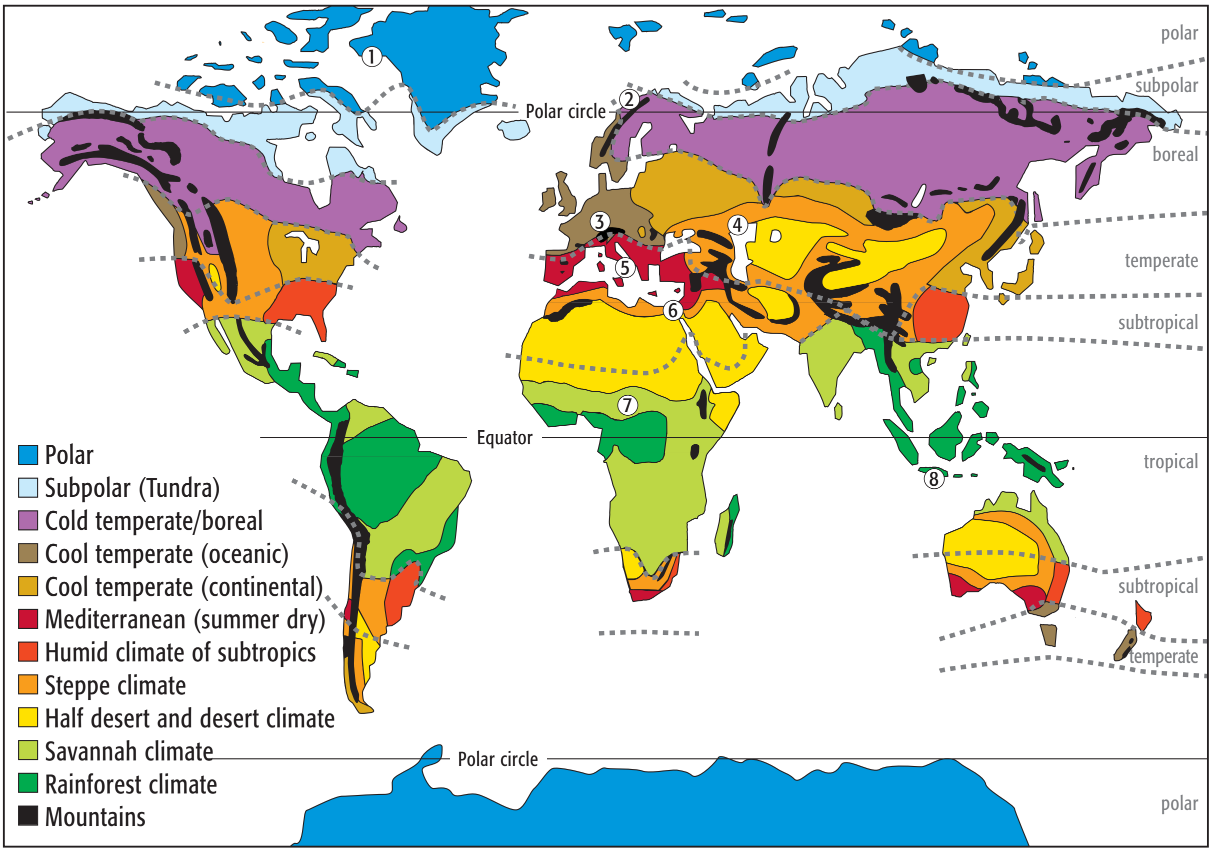
Atmosphere (2).

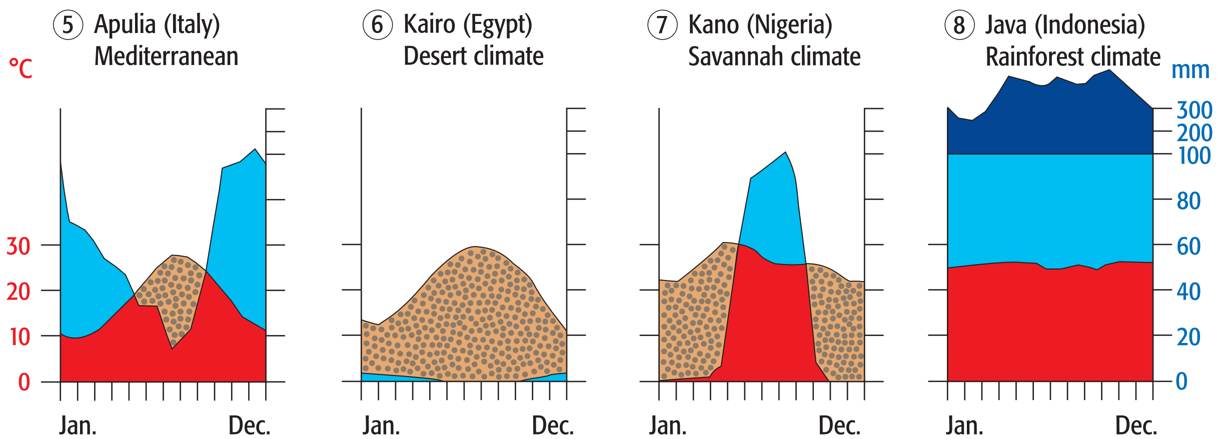


Source: According to Häckel (2005)

Climatic Zones.

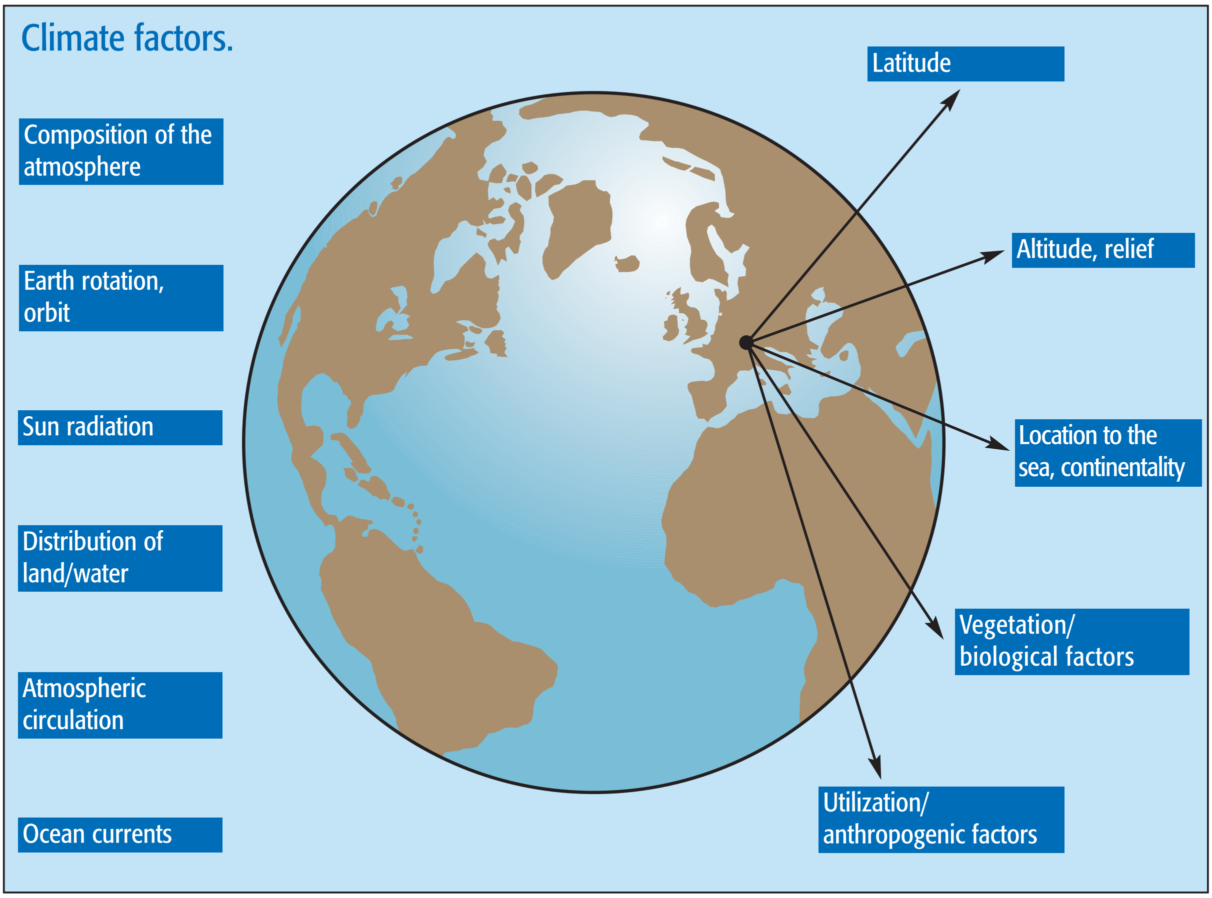


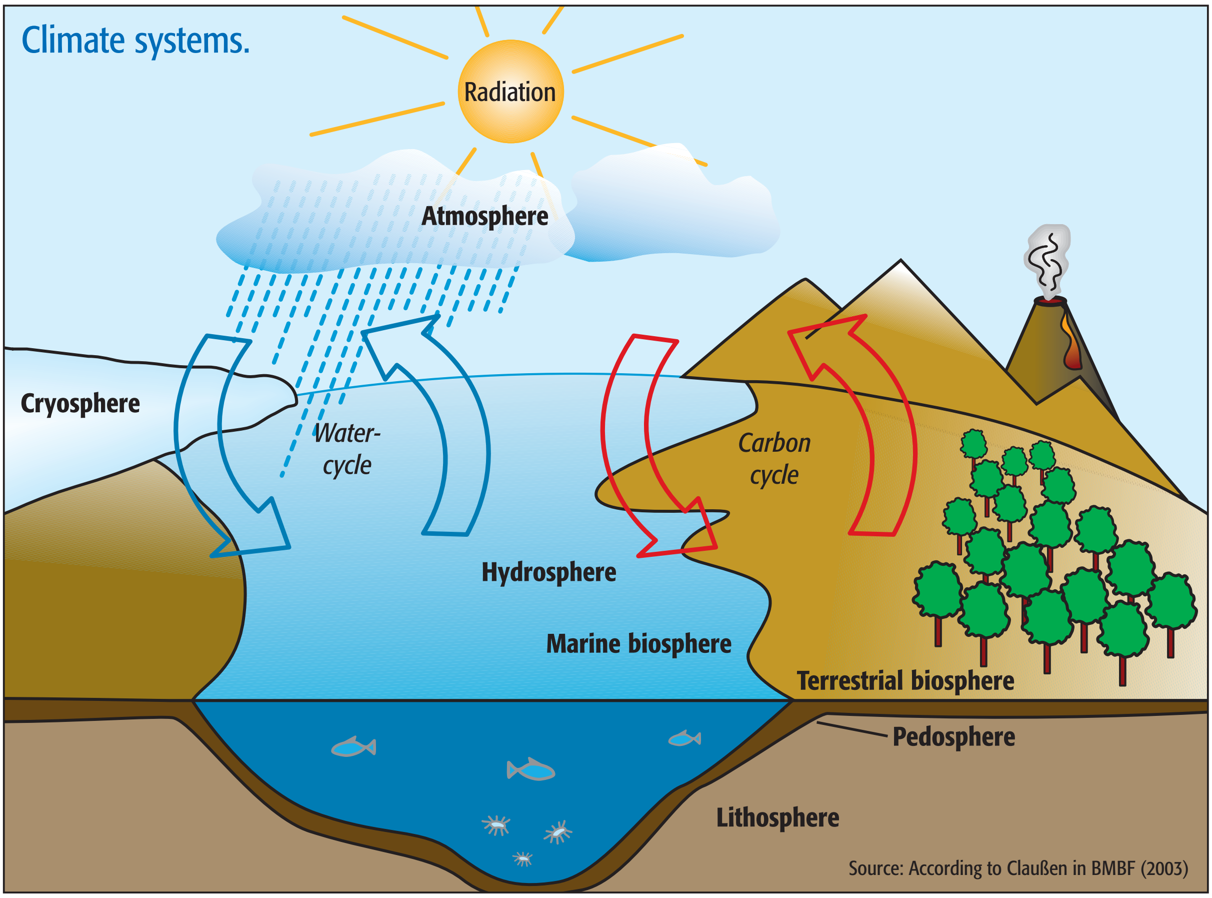




Source: According to DTV-Atlas Ökologie (1990)

Climate Machine Earth.

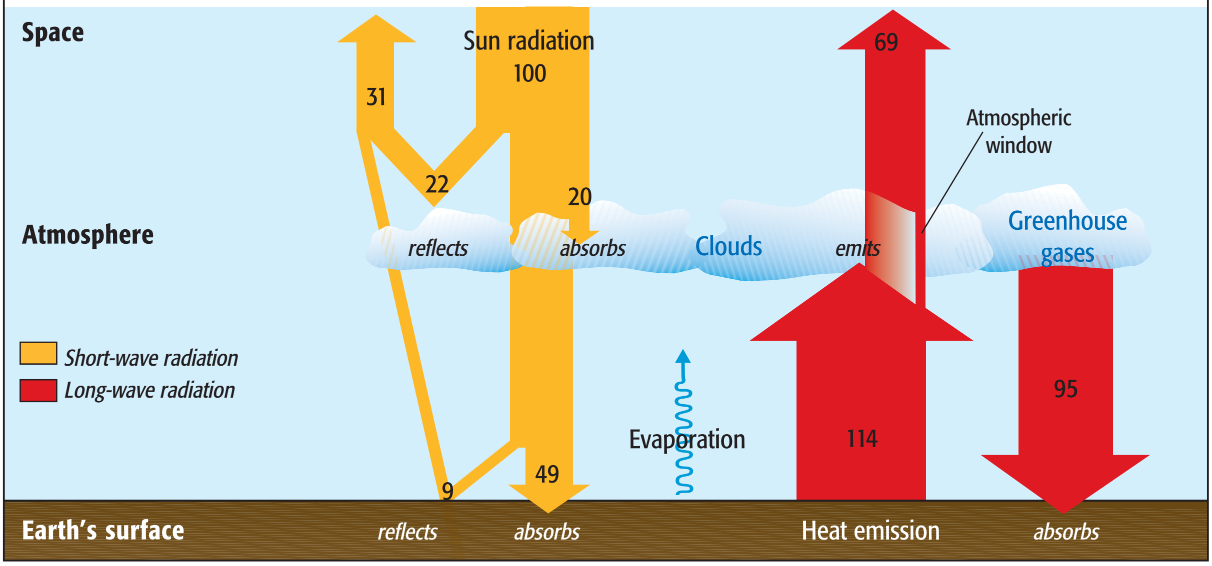




Climate and Sun.

Radiation balance. (in proportion to the sun radiation 100≈342 W/m²)

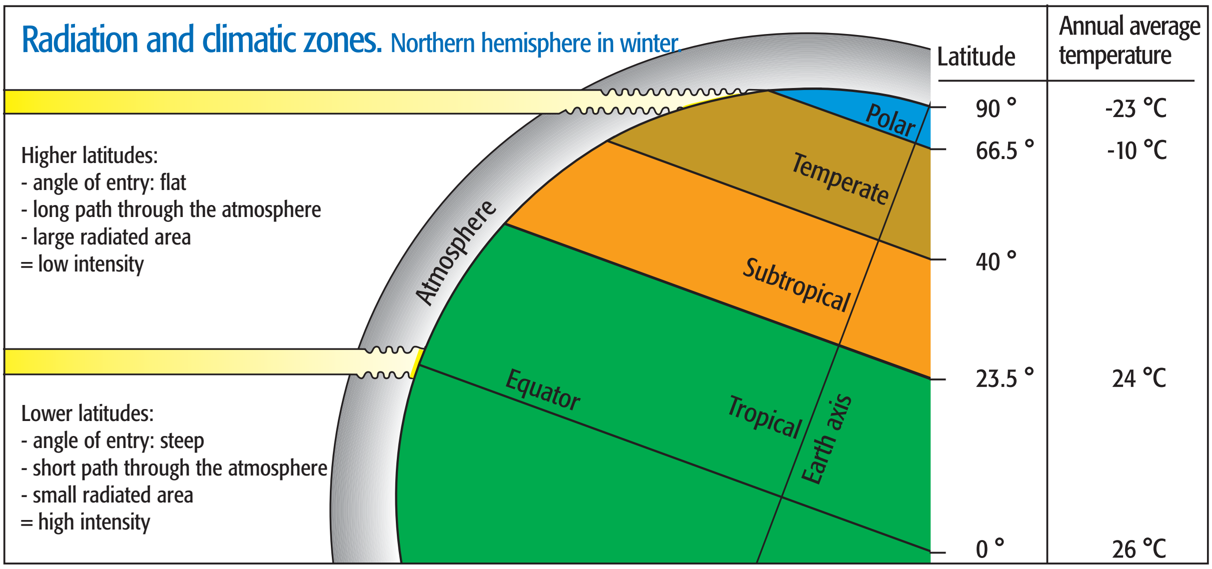
Source: According to IPCC (2001)



Albedo values.

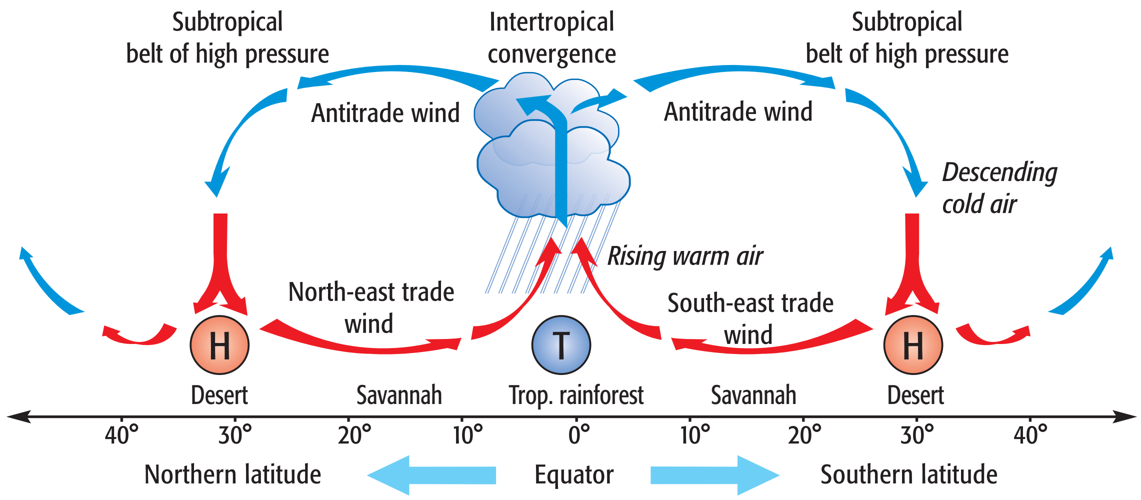
Mirror	1		**Reflection**
Fresh snow	0.80	– 0.95	
Cloud cover (dense)	0.50	– 0.80	
Old snow	0.45	– 0.80	
Sand and desert	0.25	– 0.40	
Savannah, prairie	0.20	– 0.25	
Grass land (green)	0.15	– 0.20	
Swamps	0.10	– 0.15	
Forest area	0.05	– 0.15	
Farmland	0.05	– 0.10	
Water surfaces	0,03	– 0.10	
Black surfaces	0		**Absorption**

Radiation and climatic zones. Northern hemisphere in winter

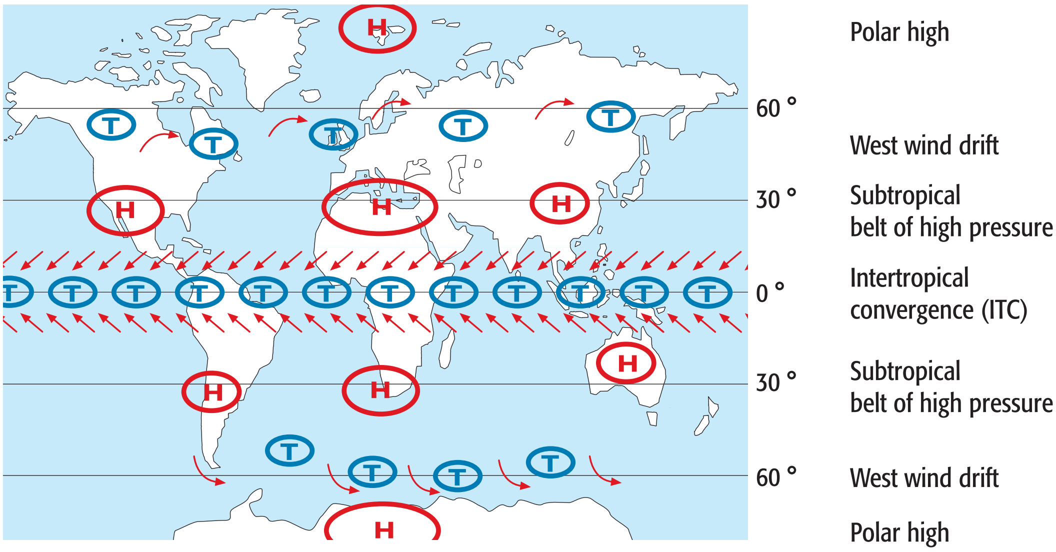


Climate and Atmosphere.

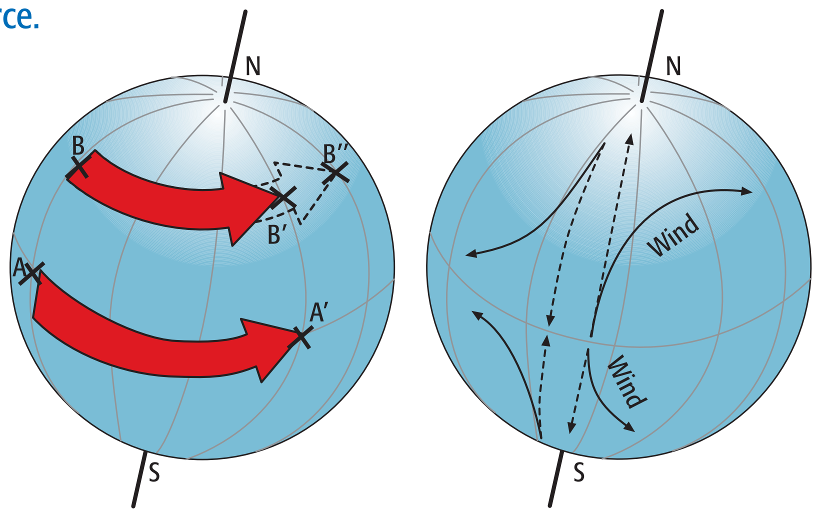
Atmospheric circulation. Example: trade winds.



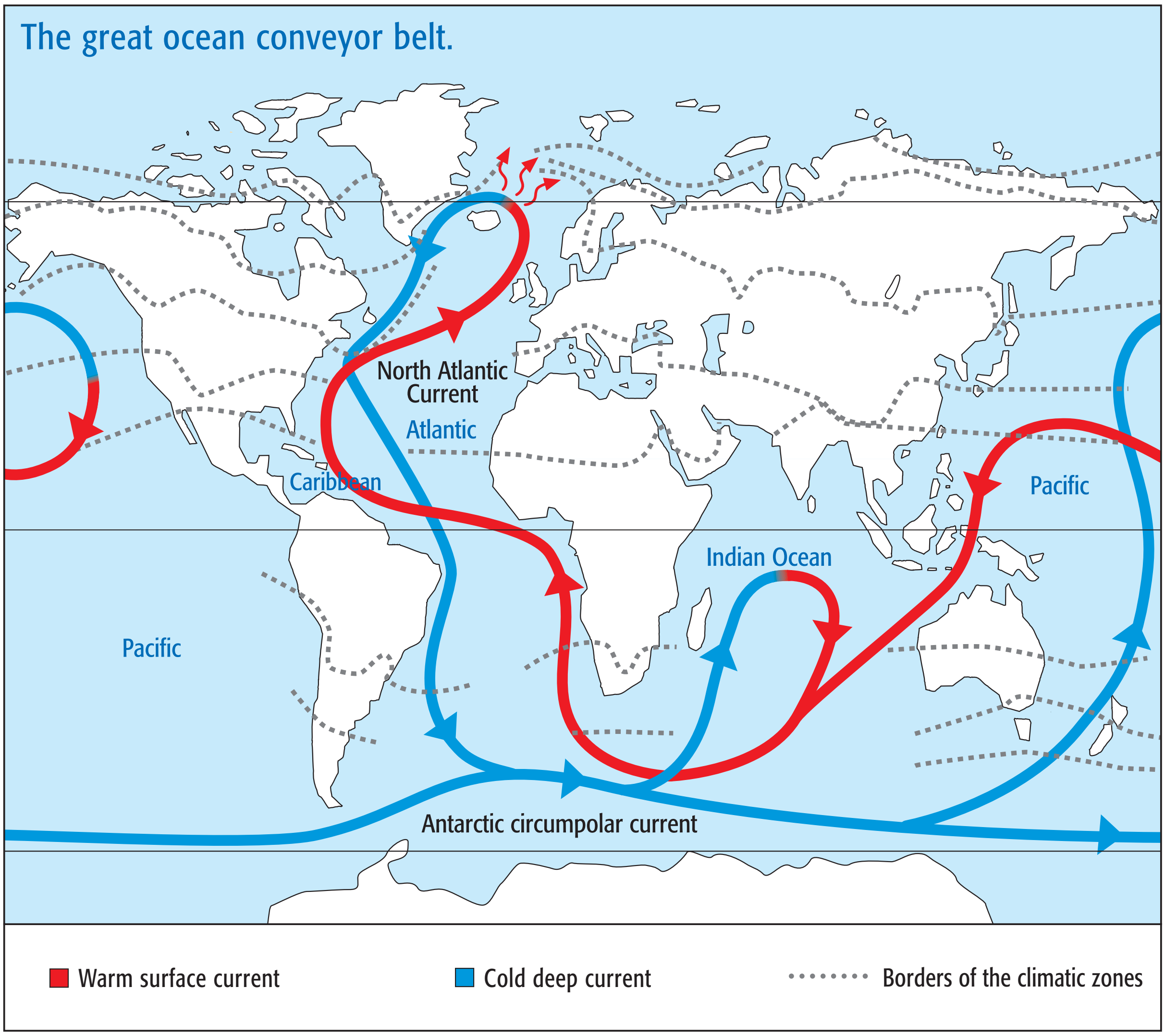
Pressure systems and circulation.

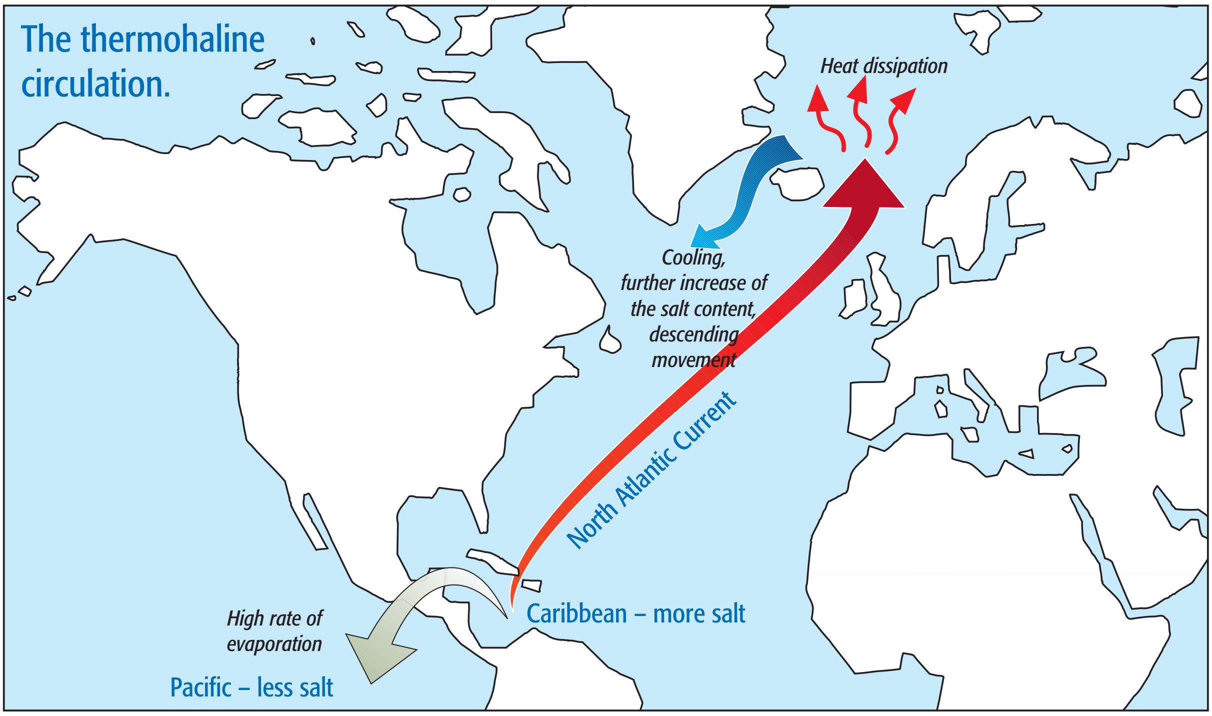


Coriolis force.



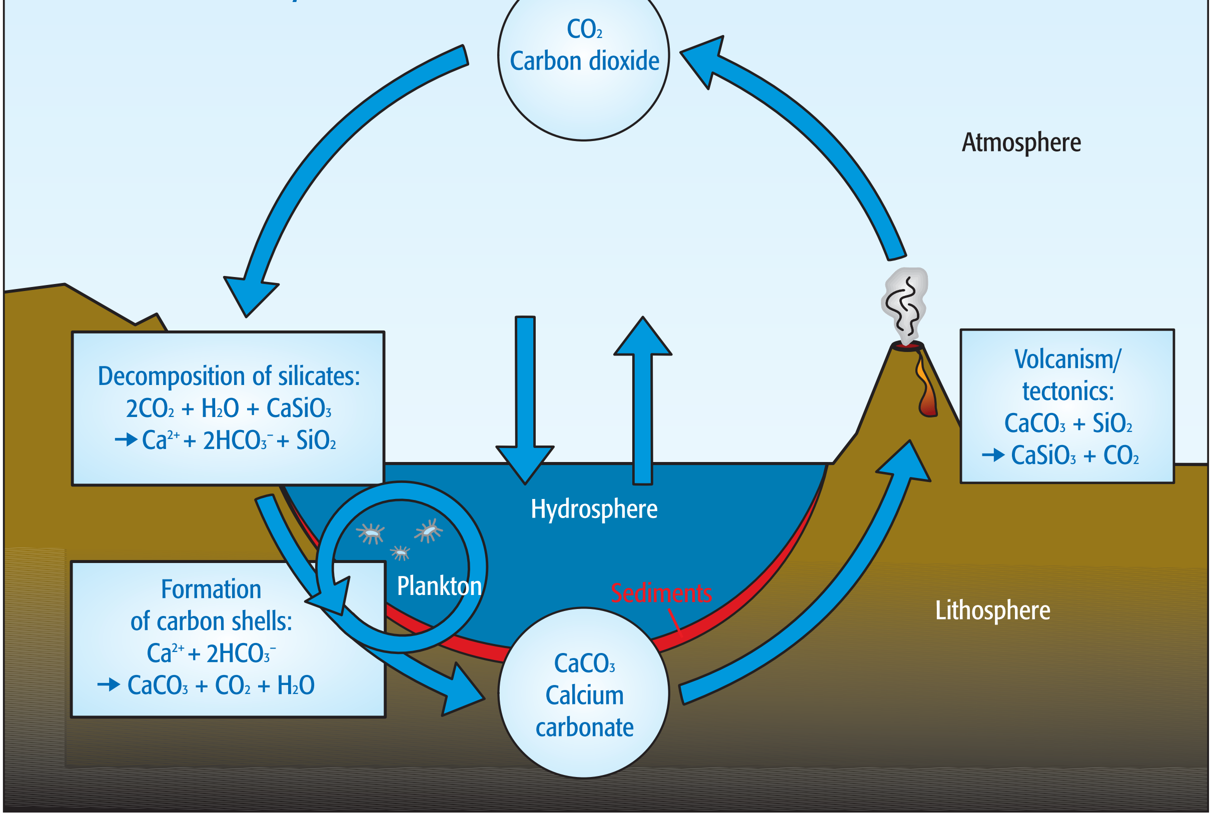
Climate and Oceans.



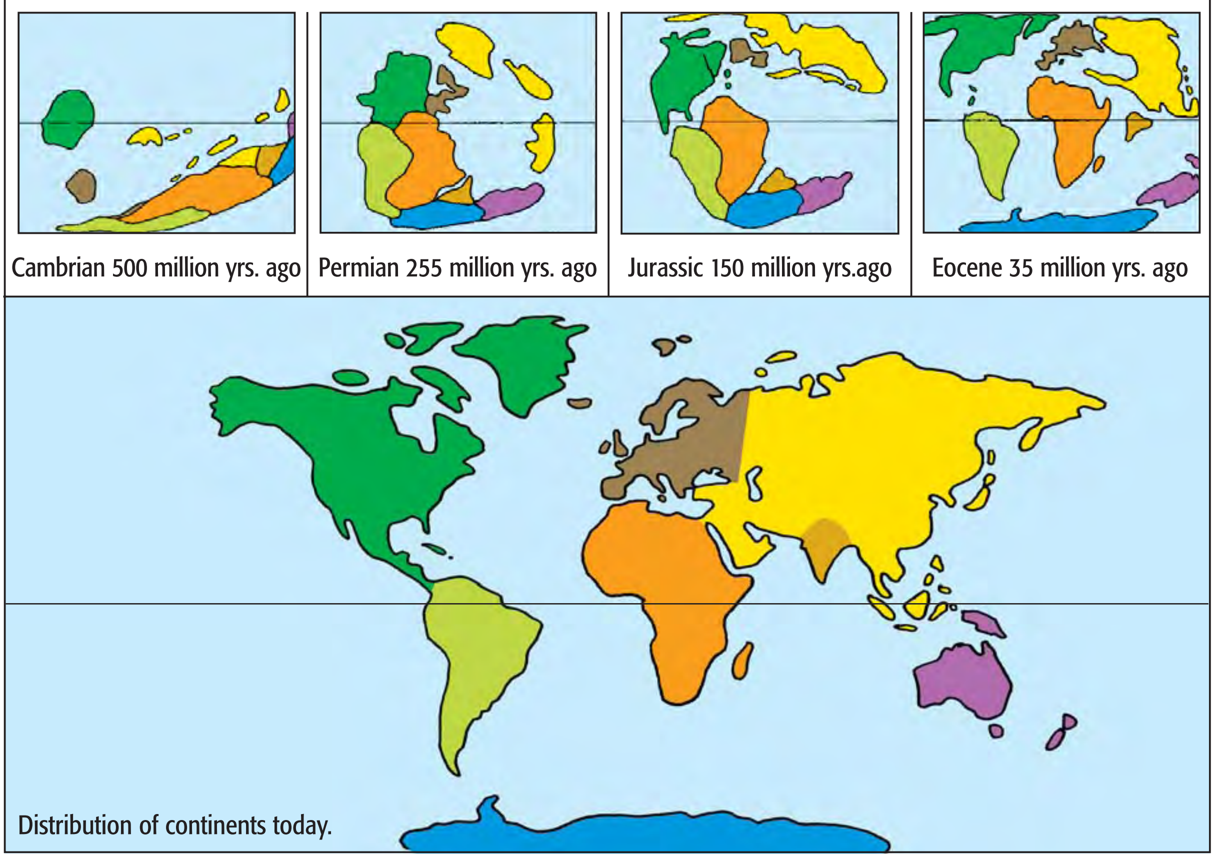


Climate and Earth.

Silicate carbonate cycle.



Continental movement.



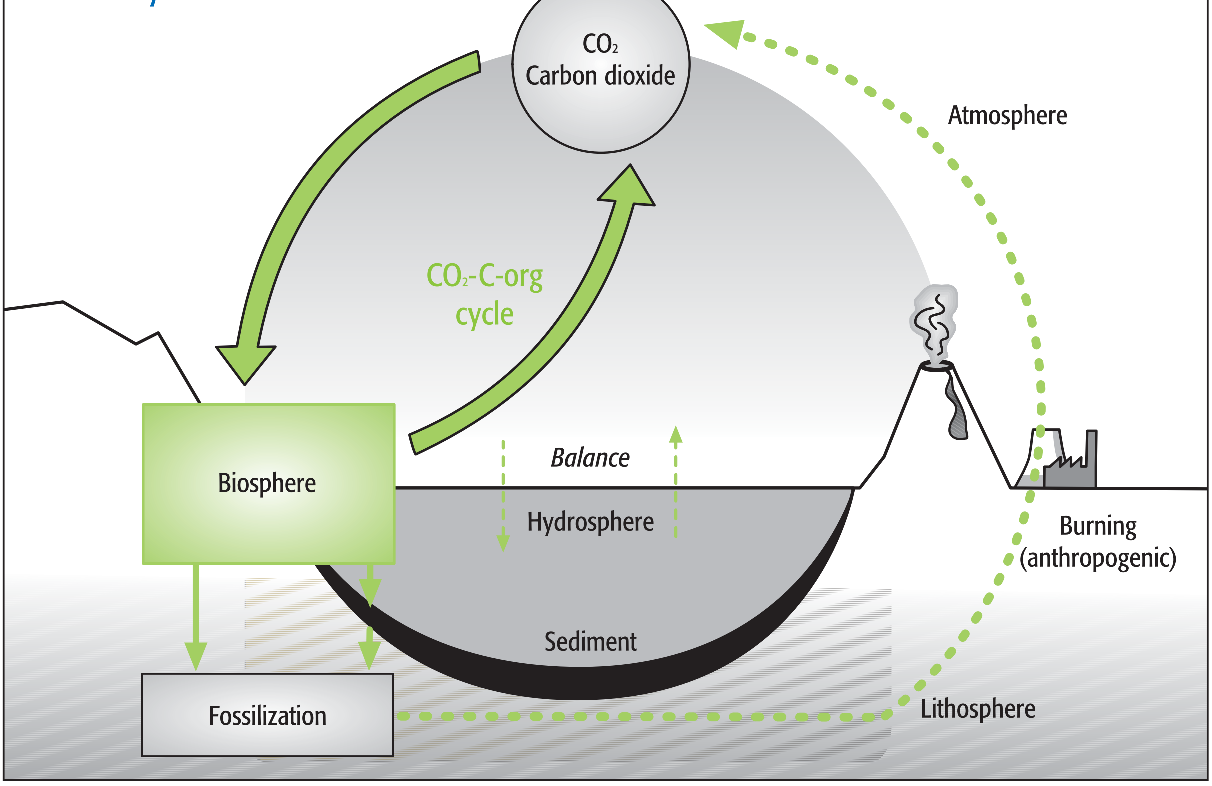
Cambrian 500 million yrs. ago | Permian 255 million yrs. ago | Jurassic 150 million yrs.ago | Eocene 35 million yrs. ago

Distribution of continents today.

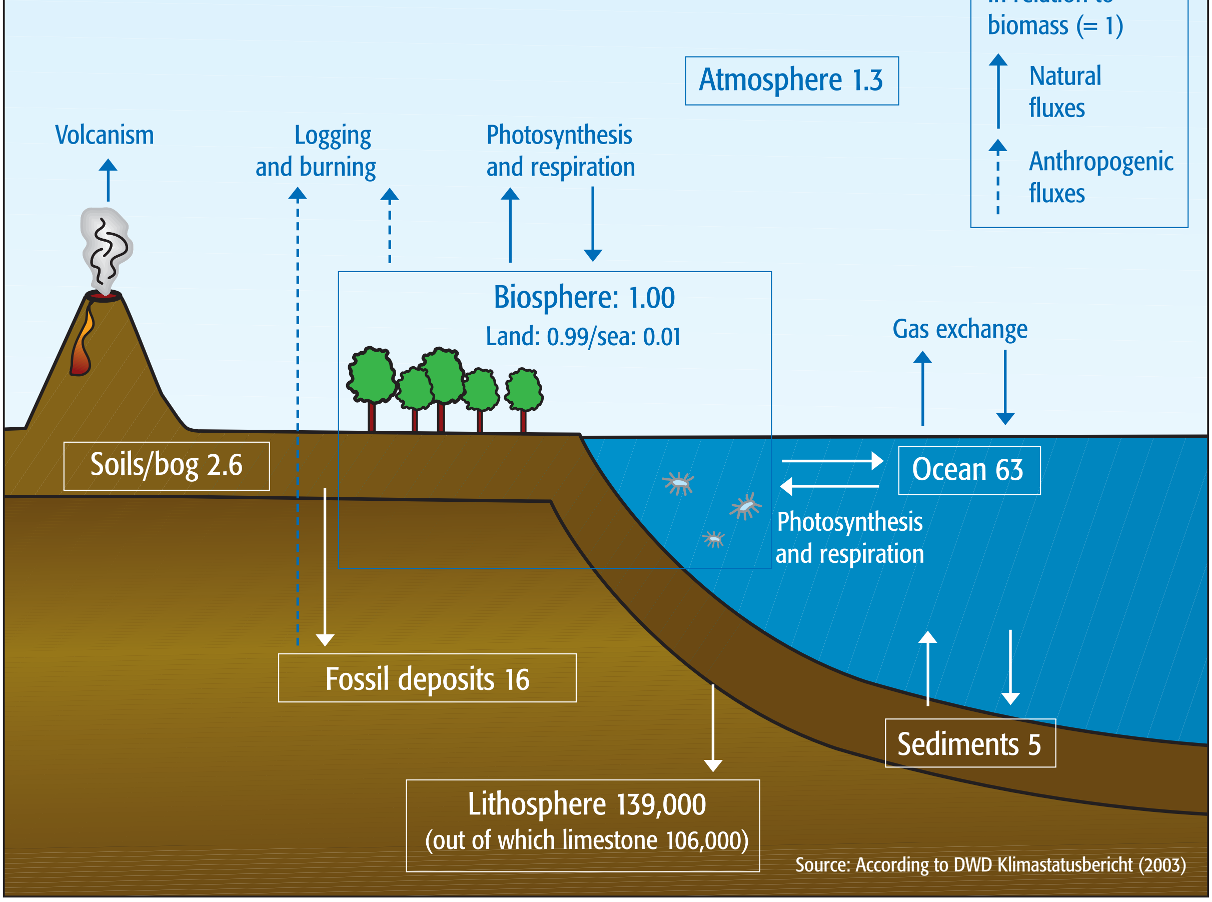
Source: Simplified according to www.geologieinfo.de

Climate and Life.

Carbon cycle.



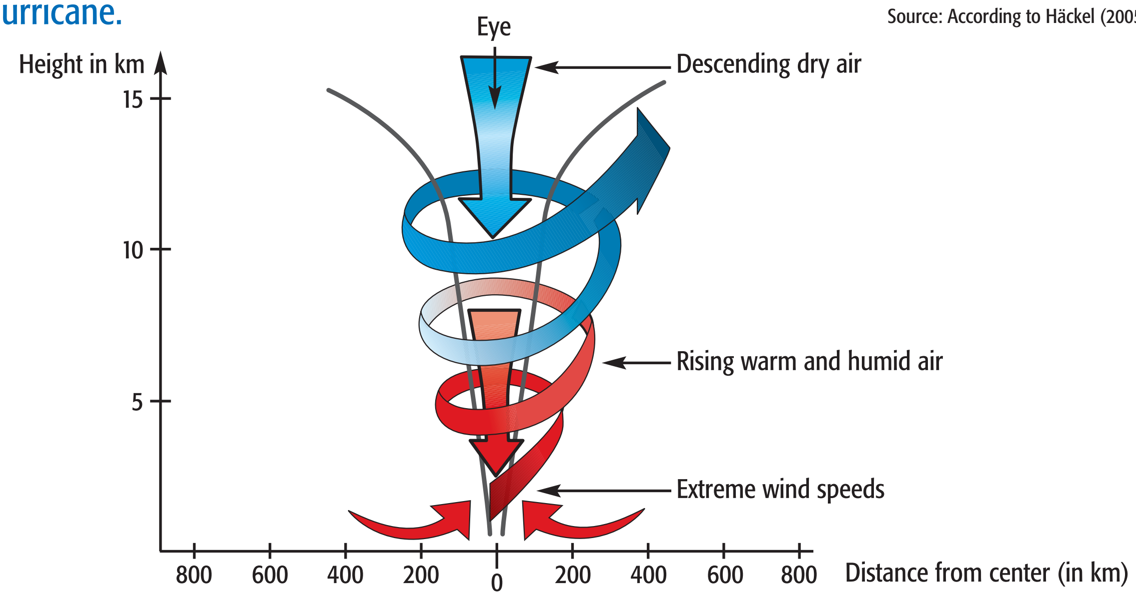
Carbon stores.



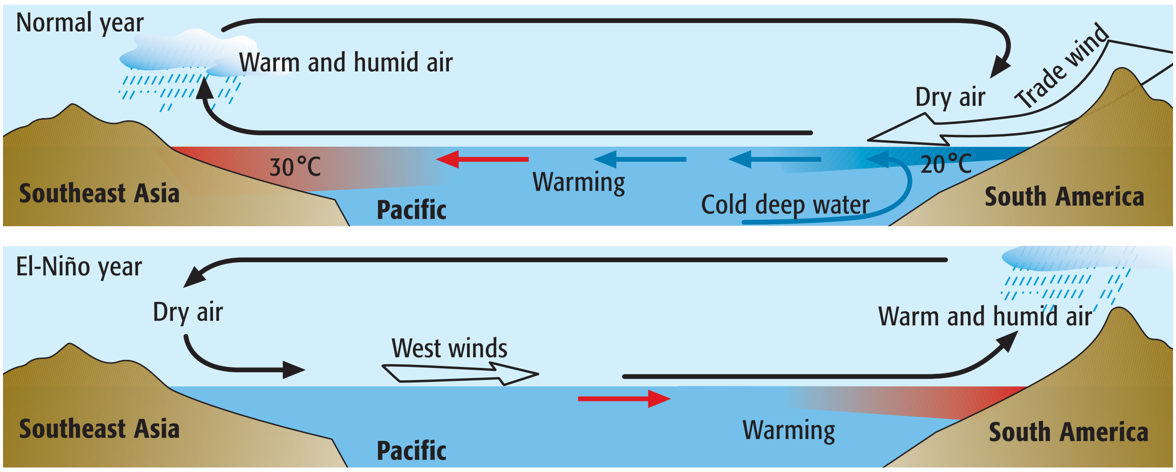
Climate phenomena.

Hurricane.

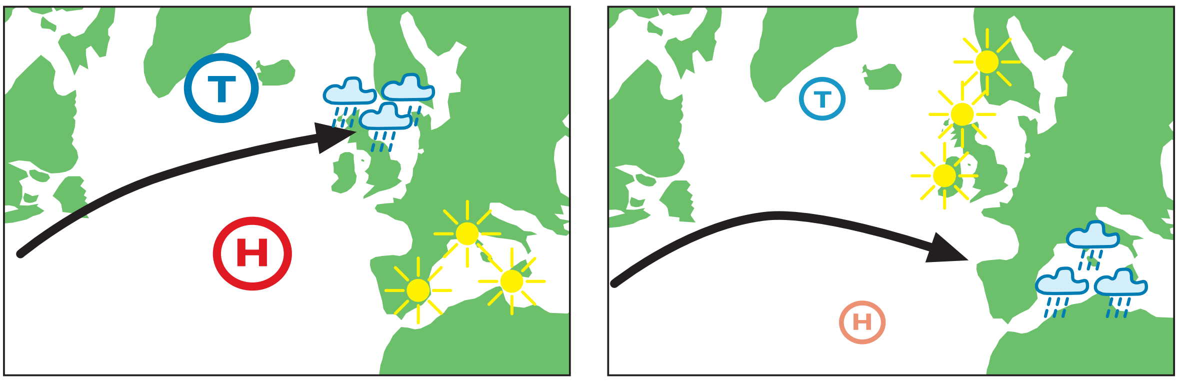
Source: According to Häckel (2005)



El Niño.



North Atlantic oscillation.

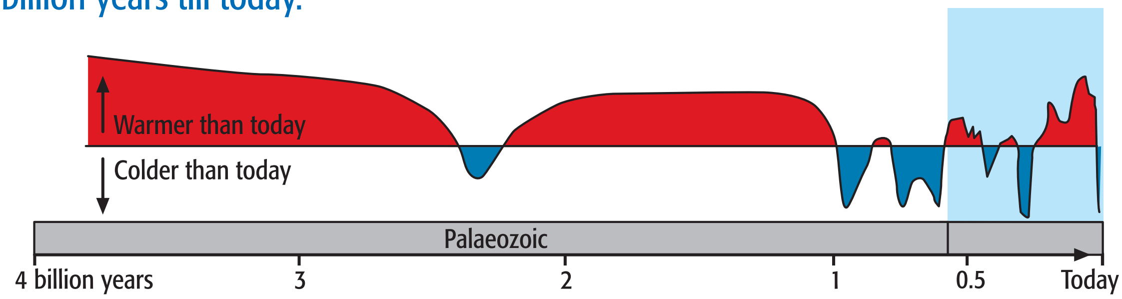


positive negative

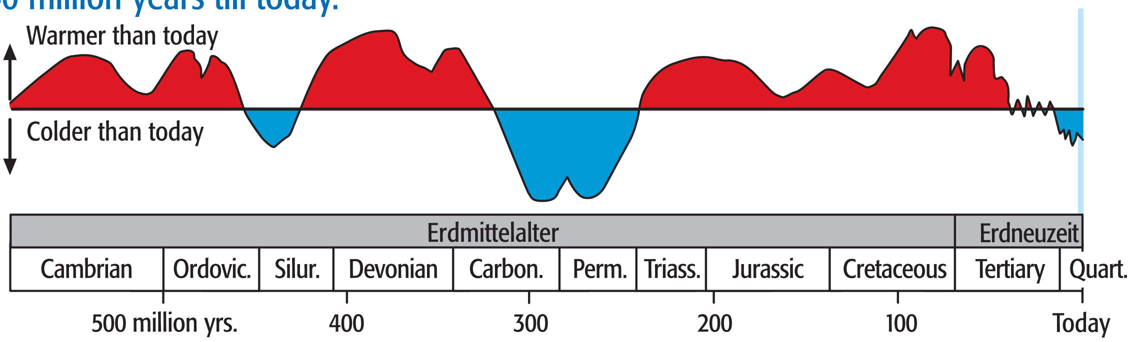
Source: According to www.espere.net (2004)

History of Climate.

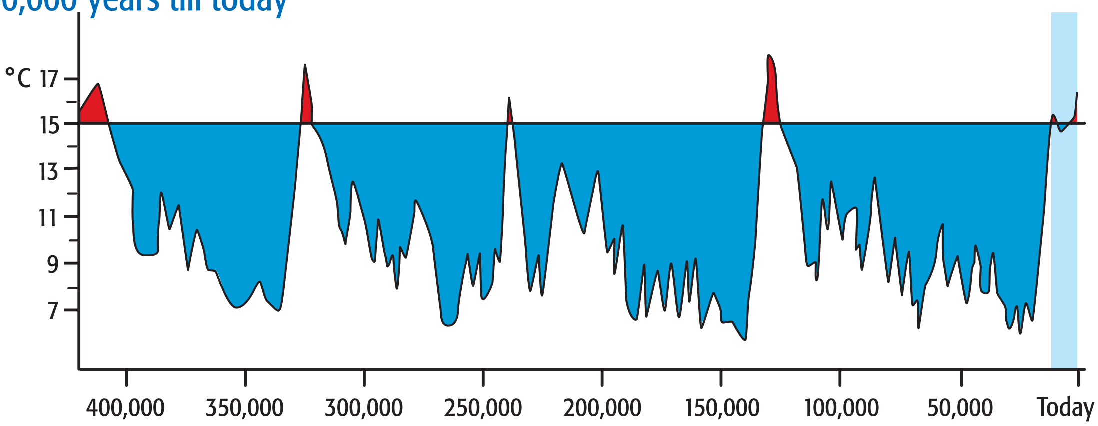
4 billion years till today.



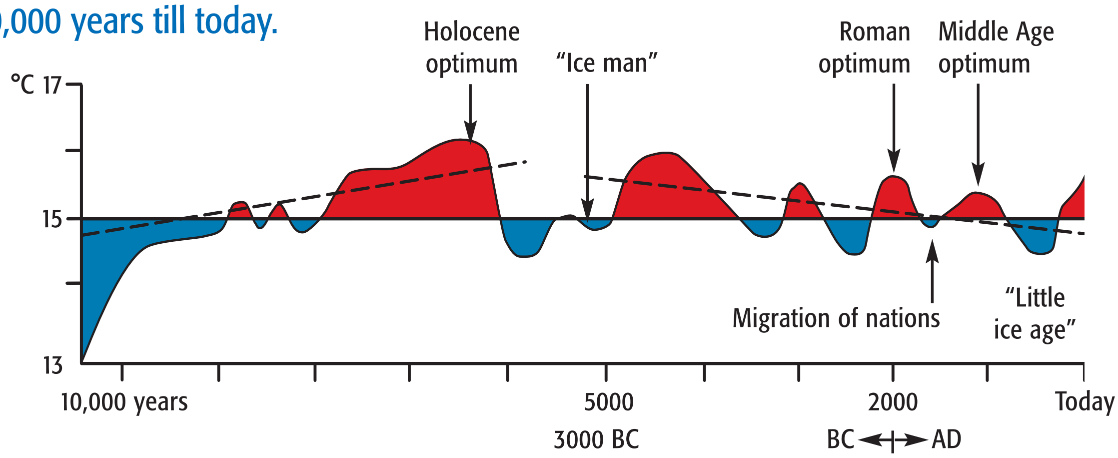
540 million years till today.



400,000 years till today



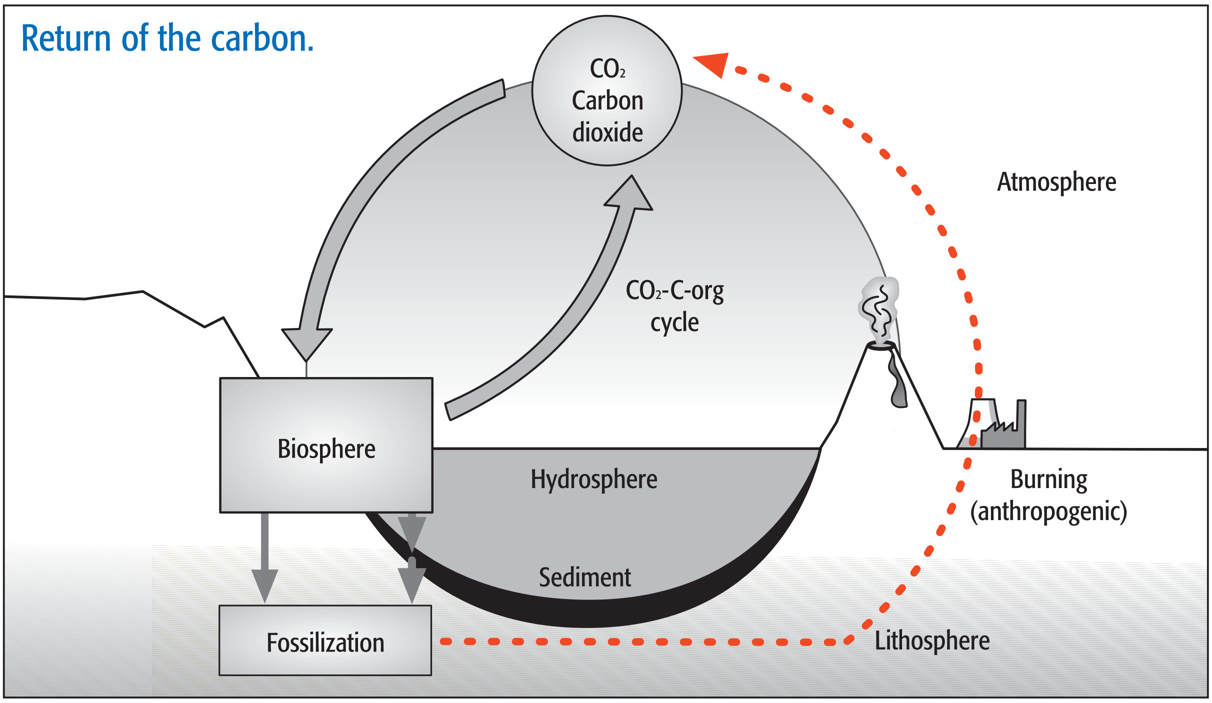
10,000 years till today.



Source: According to www.hamburger-bildungsserver.de

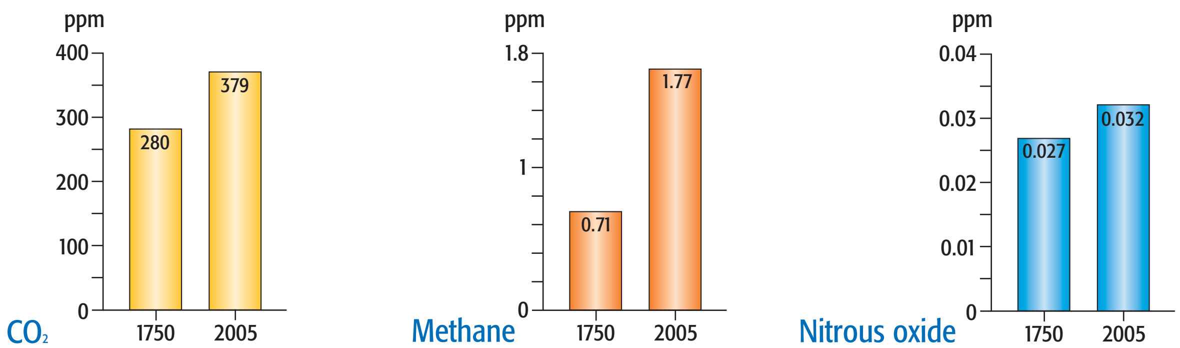
Climate and Humans.

Return of the carbon.



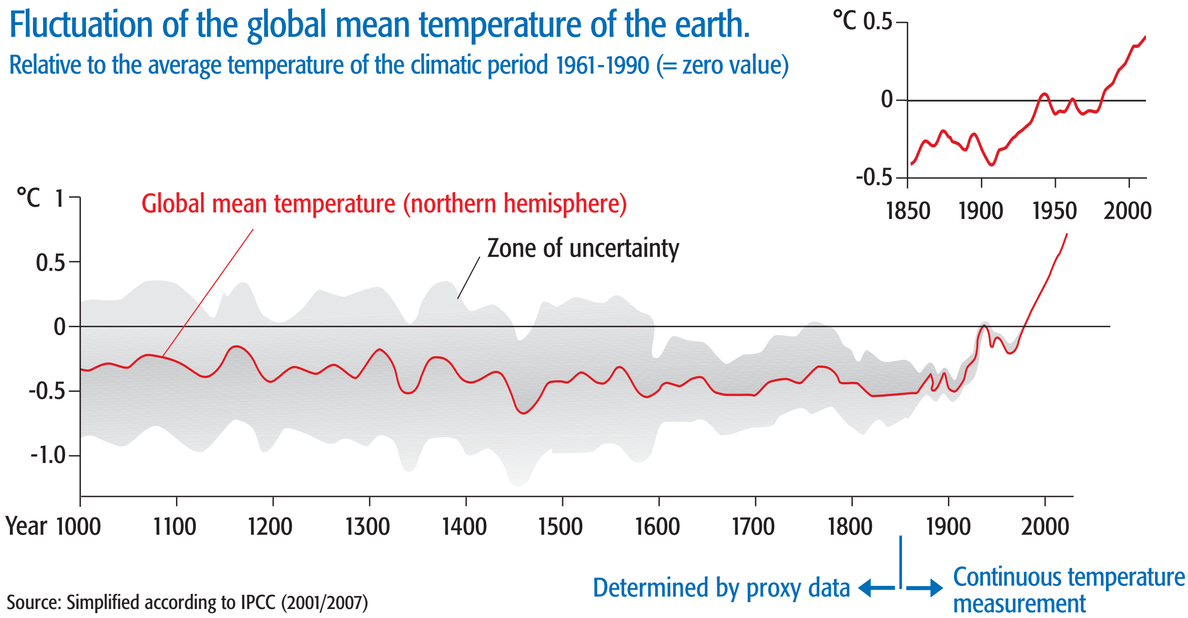
Change in the concentration of climate-affecting gases.

Source: Accordig to IPCC (2007)



Fluctuation of the global mean temperature of the earth.

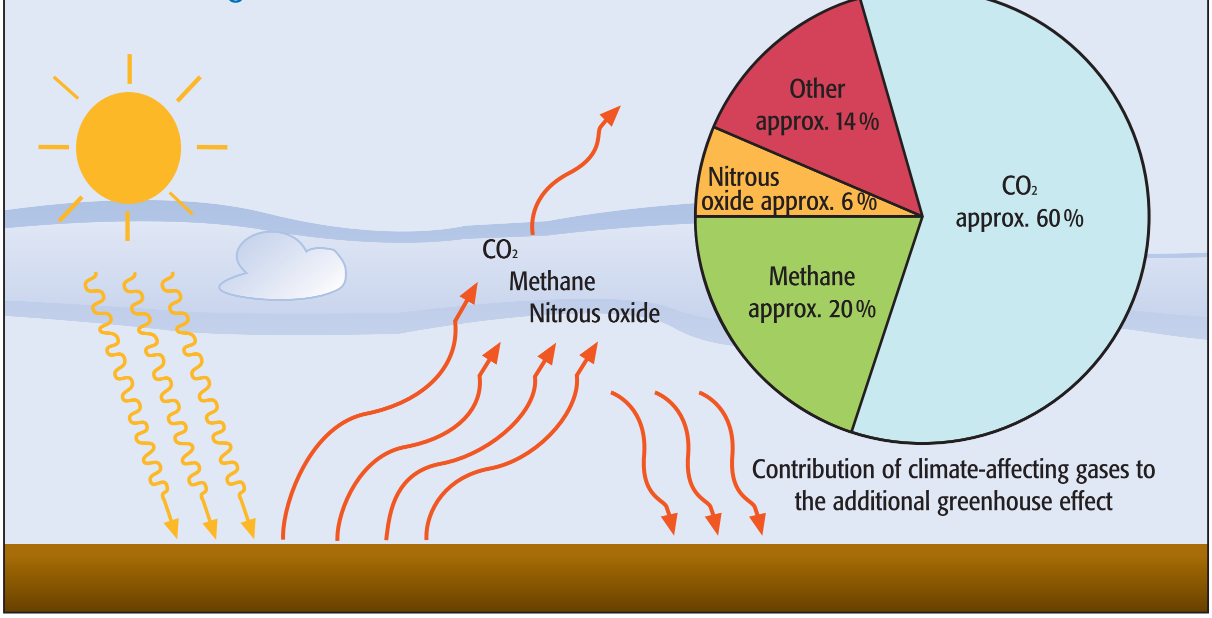
Relative to the average temperature of the climatic period 1961-1990 (= zero value)



Source: Simplified according to IPCC (2001/2007)

Climate Models.

The additional greenhouse effect.



From scenario to projection.

Scenario

Emission of greenhouse gases caused by population growth, energy demand, technical development

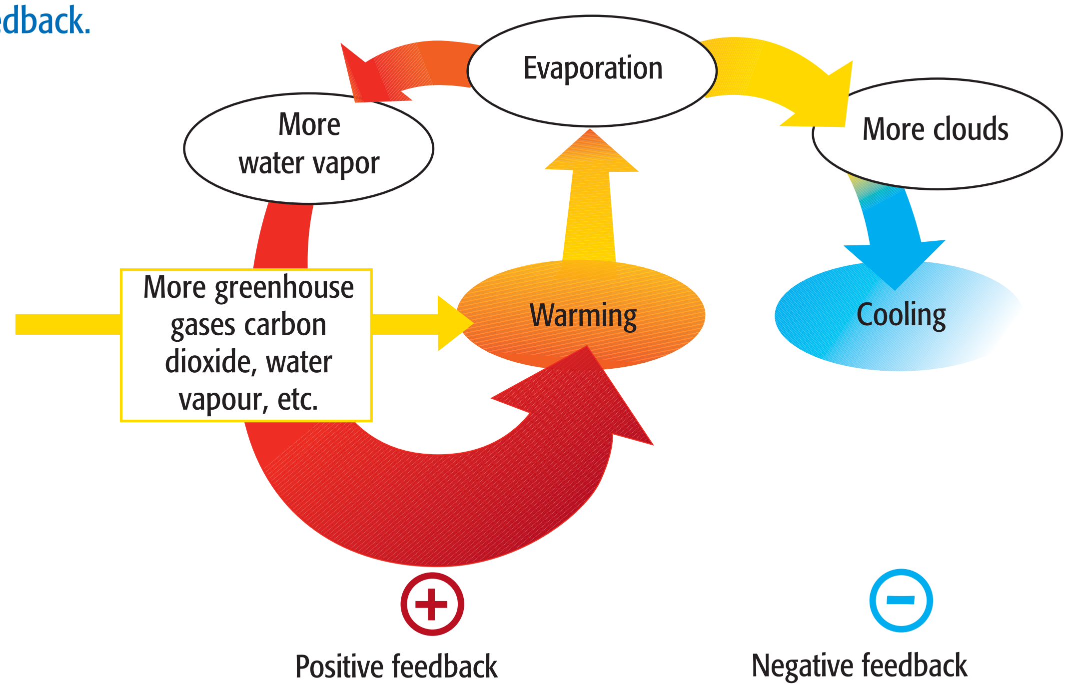
Climate model

Function of the climate system, feedbacks, etc.
Storage of greenhouse gases in oceans

Projection

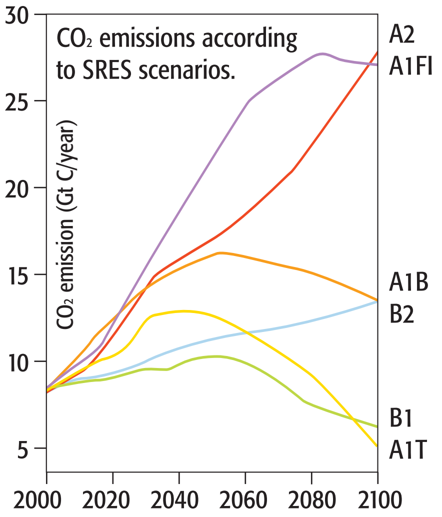
Greenhouse gas concentration
Temperature
Sea Level
Distribution of precipitation

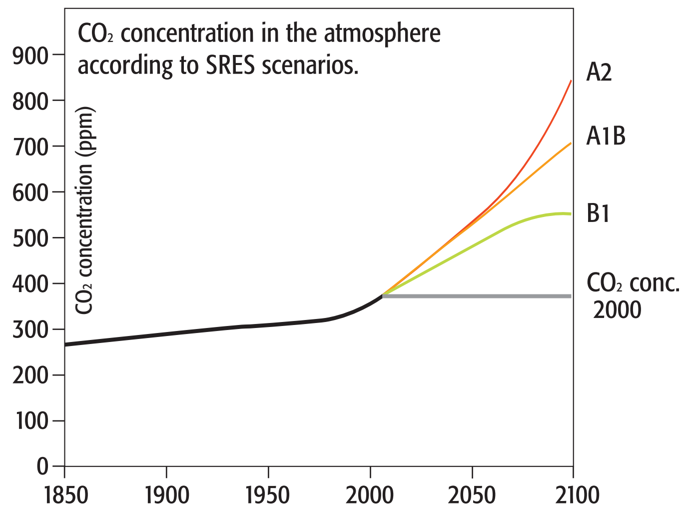
Feedback.



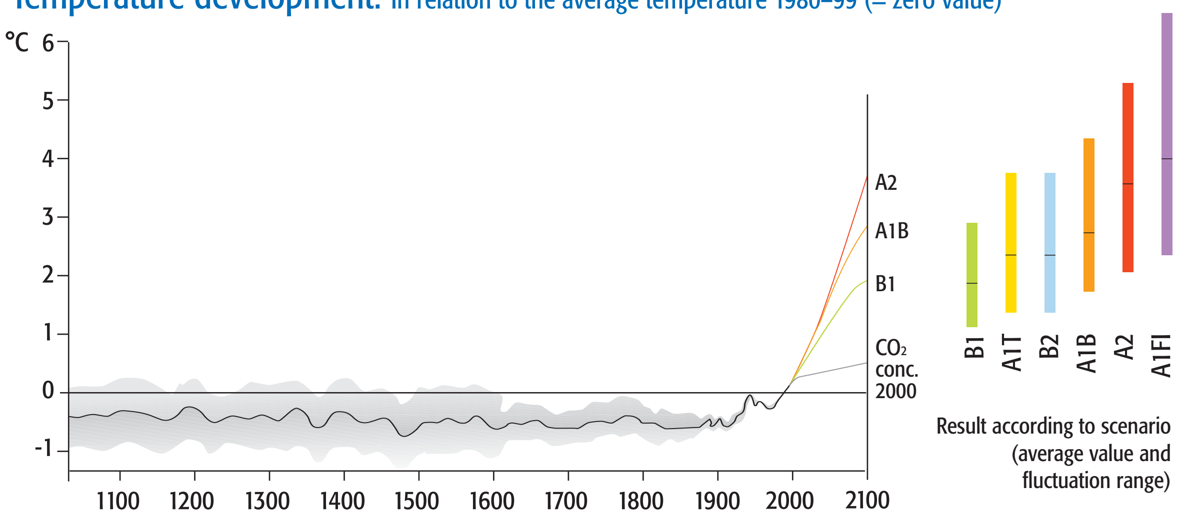
Projections (1).

Carbon dioxide emission and potential consequences.

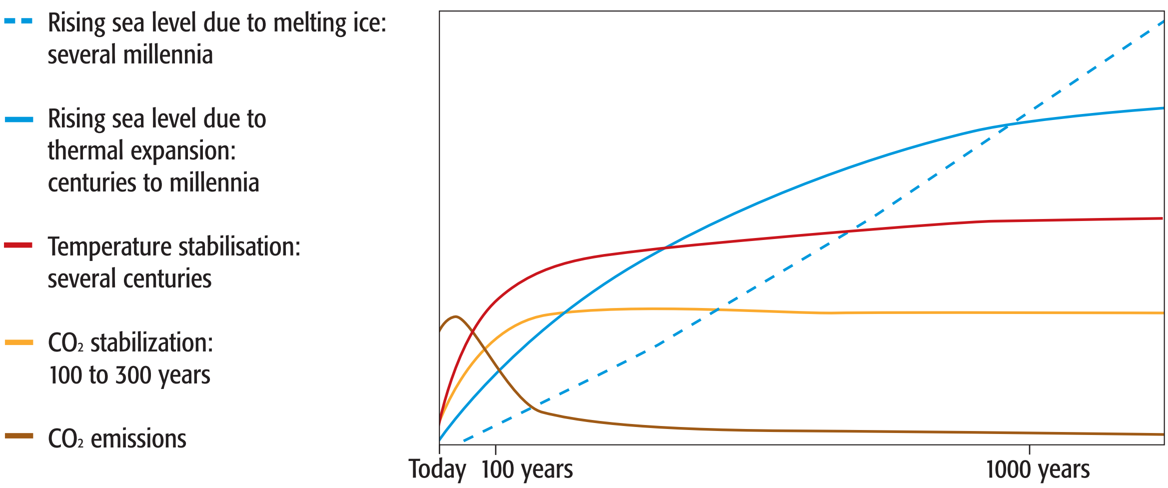




Temperature development. In relation to the average temperature 1980–99 (= zero value)

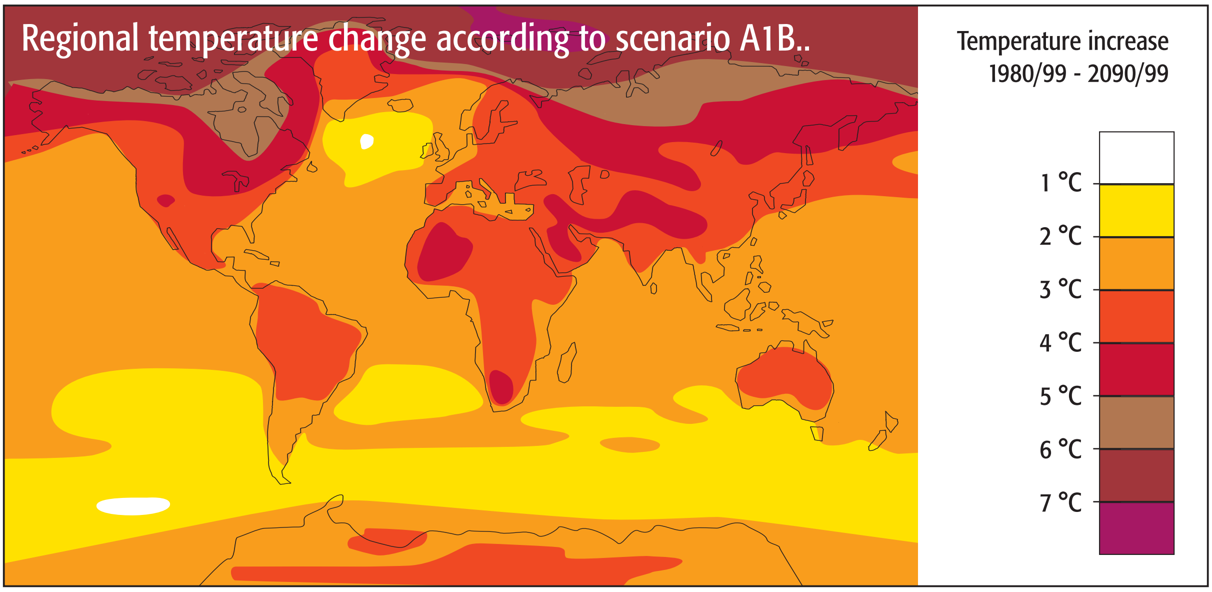


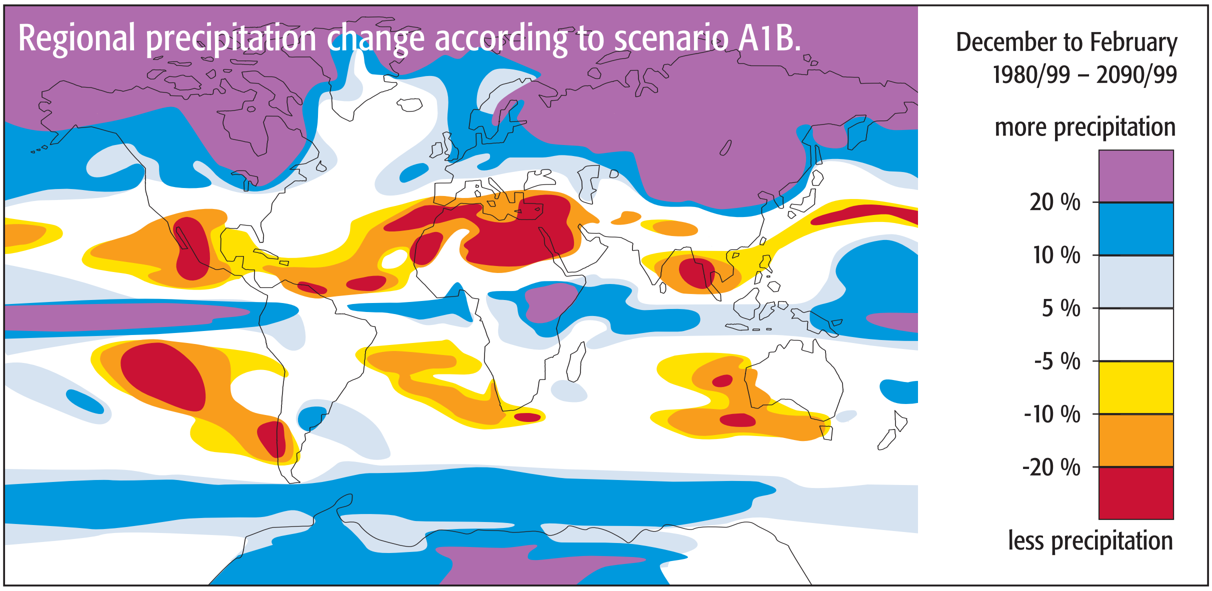
Inertia of the climate system.

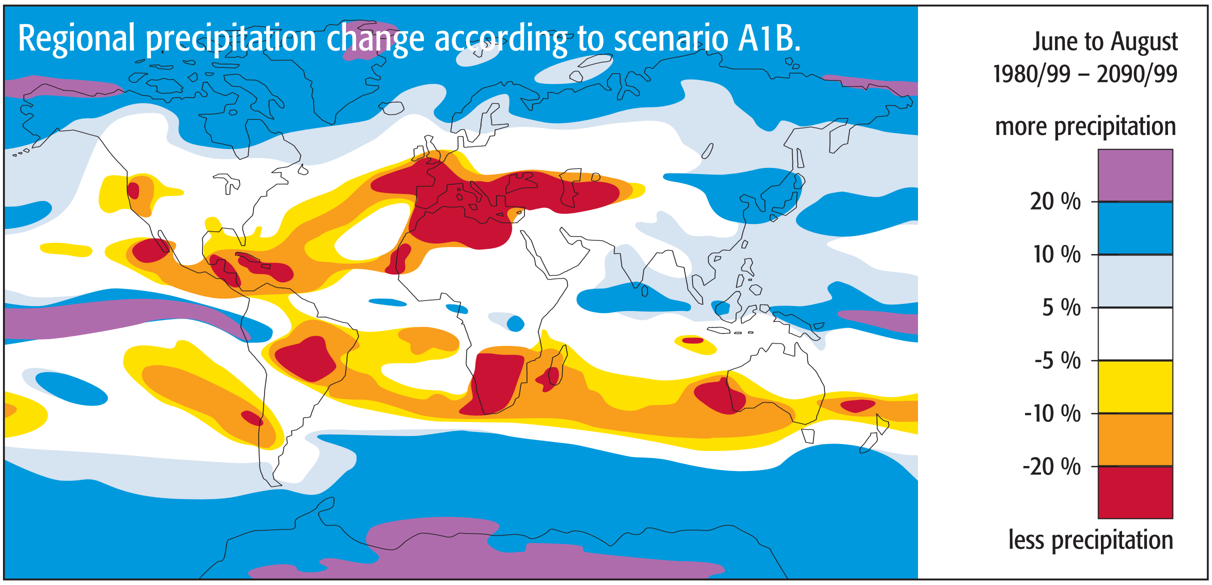


Source: According to IPCC (2001/2007)

Projections (2).







Source: According to IPCC (2007)

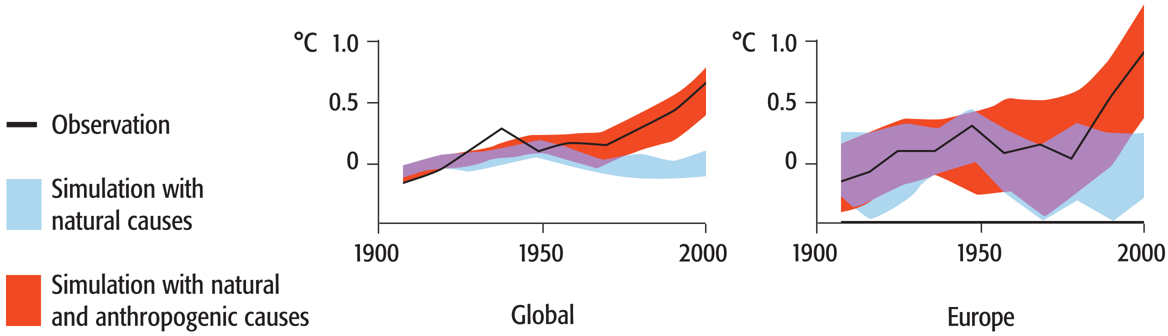
Reactions.

Steps in climate protection.

Stockholm: Conference on the Human Environment	1972	Establishment of UNEP and GEMS
Geneva: First World Climate Conference	1979	Establishment of WCP (World Climate Programme)
Toronto: World Conference on the Changing Atmosphere	1988	Establishment of IPCC
Geneva: Second World Climate Conference	1990	First IPCC Report
Rio de Janeiro: "Earth Summit"	1992	Framework Convention on Climate Change
Berlin: COP 1	1995	"Berlin Mandate"
Geneva: COP 2	1996	Second IPCC Report
Kyoto: COP 3	1997	Kyoto Protocol
Buenos Aires: COP 4	1998	
Bonn: COP 5	1999	
Den Haag/Bonn: COP 6	2000	
Marrakech: COP 7	2001	Third IPCC Report
New Dehli: COP 8	2002	
Milan: COP 9	2003	
Buenos Aires: COP 10	2004	
Montreal: COP 11/MOP 1	2005	Kyoto Protocol in force!
Nairobi: COP 12/MOP 2	2006	
Bali: COP 13/MOP 3	2007	Fourth IPCC Report
	2012	Term of Kyoto Protocol ends

Projections put to test.

Source: According to IPCC (2007)



Strategies.

Estimation of tolerance limit (guard rails).

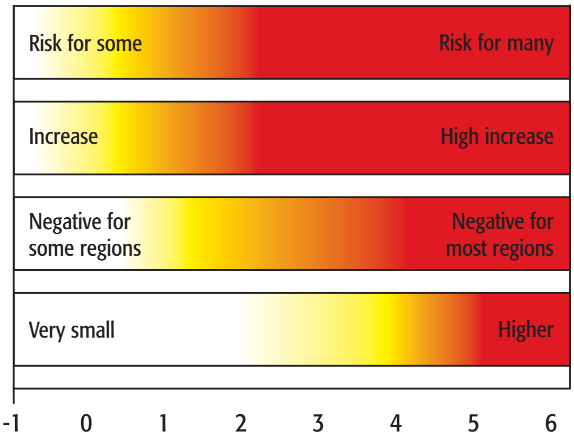
Source: According to IPCC (2001)

· Risks for unique and threatened ecosystems

· Risks from extreme climatic events

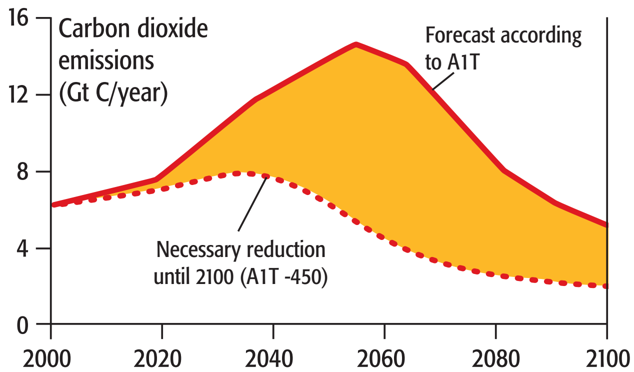
· Distribution of consequences

· Risks of great irregularities in future (e.g. change of ocean currents)



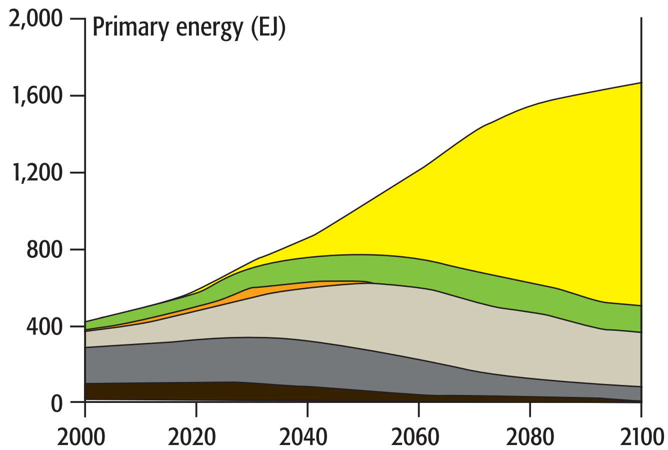
Carbon dioxide reduction.

Example SRES scenario A1T.

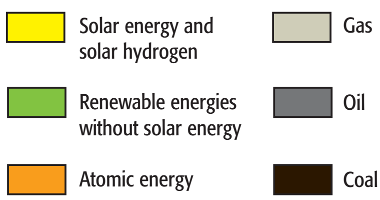


Limitation of carbon dioxide concentration until 2100 to 450 ppm through reduction of carbon dioxide emissions:

· Utilisation of regenerative energy sources
· Increased efficiency, saving
· Store and filter



Example:
Potential use of primary energy according to scenario A1T -450.



Source: According to WBGU (2003)

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