GEOGRAPHY: WEATHER AND CLIMATE I

DEFINITION OF WEATHER AND CLIMATE

WEATHER

It is a physical condition, the state of the atmosphere at a given time & place. Variables are temperature, moisture, wind, velocity & barometric pressure.

CLIMATE

The behaviour of the atmosphere in a larger area, general/average weather conditions of a certain region, including rainfall, temperature & wind. To define a climate, it takes a period of 30 years (last one 1990-2020). It the periods are too long there is difficulties with data collection & there are not that many periods to compare.

There are different types of climate:

- seasonal vs. daytime climate
- continental vs. oceanic climate

GLOBAL RADIATION BUDGET

The Earth Radiation Budget is the balance between incoming energy from the sun and the outgoing longwave (thermal) and reflected shortwave energy from the Earth.

Only about half of the of the solar radiation that hits the outer edge of the atmosphere reaches the Earth's surface (either as direct or diffuse). The rest is lost in the atmosphere through reflection and absorption. About three percent of the shortwave radiation is immediately absorbed by the ozone layer (in the stratosphere) & is changed into longwave radiation (thermal radiation). This also happens in the Troposphere through water vapor (–> natural greenhouse effect), CO_2 (–> greenhouse effect) and other gases or aerosols (the finest solid particles suspended in air as smoke and dust). Almost ⅓ of all solar radiation is reflected straight into outer space.

LAYERS AND COMPOSITION OF THE ATMOSPHERE

TROPOSPHERE

It contains half of the Earth's atmosphere, weather occurs in this layer (clouds, wind, snow, rain). In the higher altitudes the sunlight isn't absorbed by the ground & therefore it is always around -50°C despite it is sunny. In the lower part wind speed and direction are influenced by friction with the Earth's surface (= planetary boundary layer).

STRATOSPHERE

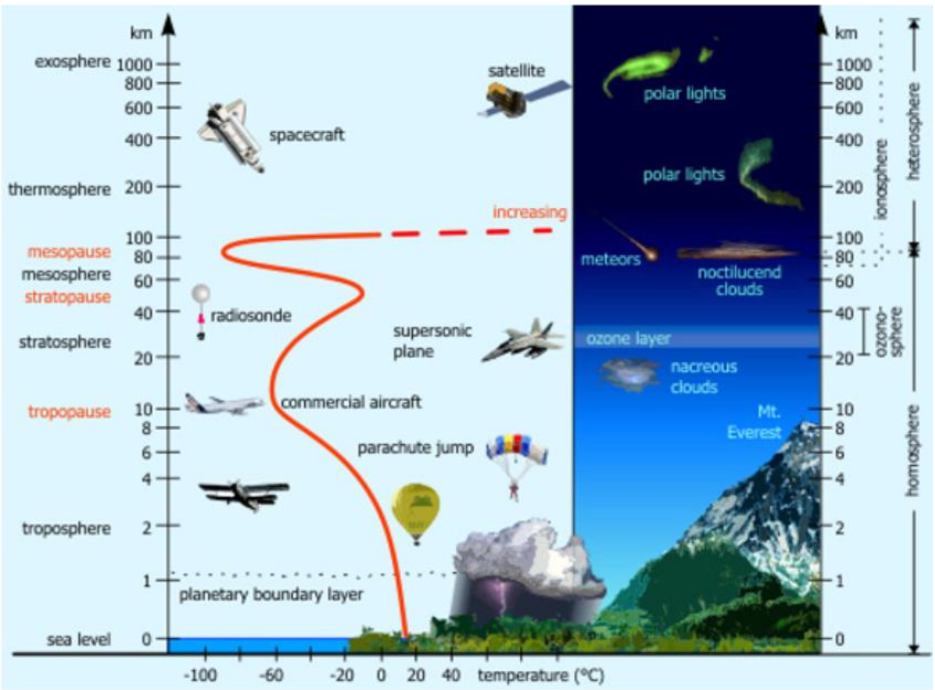
Because it is a very stable layer jet aircrafts fly in this area. Also, the ozone layer absorbs harmful UV rays from the sun and changes them into longwave radiation. This causes warming at the upper boundary of the ozone layer (–> temperature maximum at the stratosphere). With gaining of height the temperature rises.

MESOSPHERE

Meteors or rock fragments burn up in this layer

THERMOSPHERE
It is the layer with auroras (Polarlichter) and space shuttles orbit there (you see black skies). If too much air would be around the spacecrafts wouldn't stay up there.

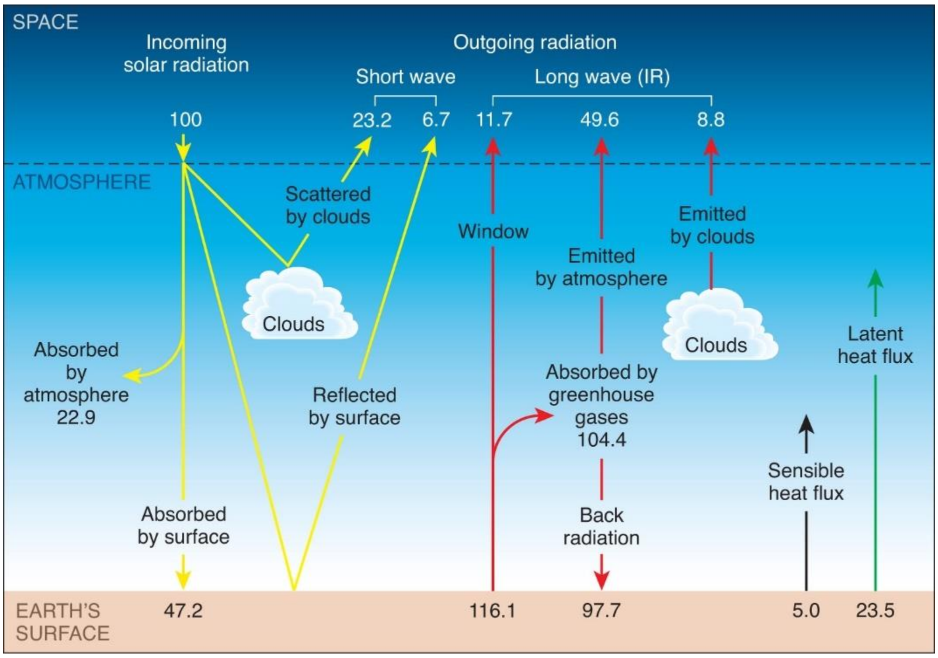
EXOSPHERE
This is the upper limit of the atmosphere, the layer where the atmosphere merges into space. It is extremely thin and has only a small number of molecules.



ALBEDO

The amount of radiation that is converted from shortwave to longwave (thermal radiation) depends on the features of the irradiated surface. The darker the surface is, the less radiation it reflects –> it absorbs the amounts of shortwave radiation and transform it into longwave radiation (ideal black body would have an albedo of 0%). Therefore, depending on the degree of reflection (the amount of albedo), the Earth's surface absorbs different amounts of shortwave radiation and is heated unevenly. Some of this heat is released into the soil and some is used in evaporation processes*.
A large proportion of longwave of thermal radiation is reflected back into the atmosphere. The converted radiation is supplemented by the Earth's own thermal radiation. Longwave radiation increases the movement of air molecules, generating warm air (sensible heat). Water vapor, CO_2, CH_4, O_3 and other trace gases absorb the majority of thermal energy on their way to escape the outer layers of the atmosphere and radiate it back to Earth –> natural greenhouse effect.

=> The albedo is quantified as the percentage of solar radiation of all wavelengths reflected by a body or surface to the amount incident upon it.



*The energy used in evaporation processes at the surface isn't lost, it just can't be felt because it is hidden (latent) in evaporated water, where it exists in the form of **latent heat**. When water vapor condenses the hidden heat is released and emitted into the environment –> movement of clouds transports water and energy. Inside a cloud a great amount of latent heat is stored. If it starts to rain this energy is visible as heat.
The same process is visible in our body if we sweat: Water in our body is evaporating and leaves our body which requires energy & is reducing the temperature inside.

=> Latent heat is the energy that is used to transform water into the different states. You can heat the water as much as you want but the temperature will stay at its maximum of 100°C –> latent heat is then responsible for the transformation from water to steam (steam has much more latent heat than boiling water).

SOLAR IRRADIATION AT THE SURFACE

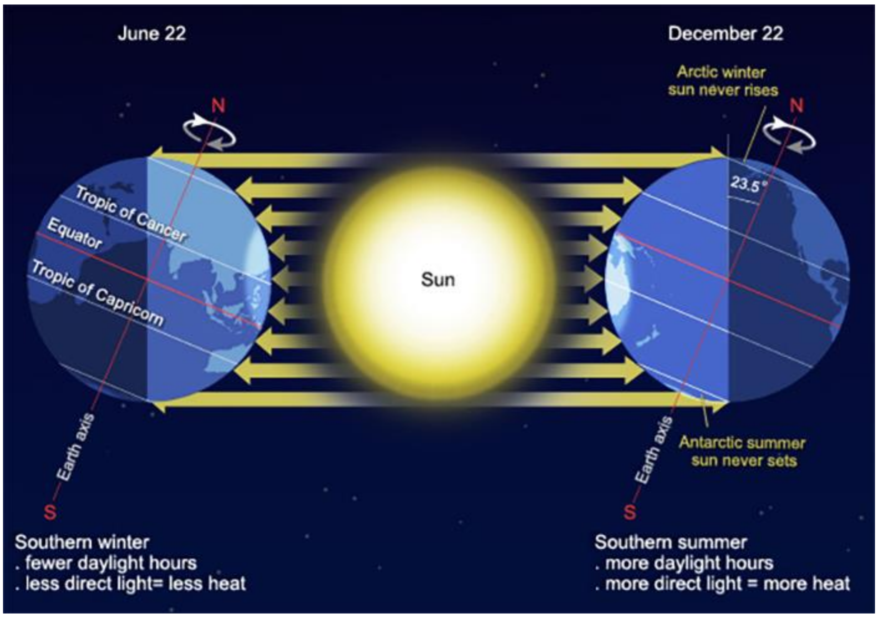
- ITC-sect along the equator is reducing the incoming radiation
- Trade wind coming from the east over the Andes blows away water from ocean –> colder water is coming up –> warm air from Andes meets the colder water –> foggy air –> less solar radiation

REGIONAL TEMPERATURE DIFFERENCES

All over the earth the total annual duration of sunshine is 50%. Factors that cause regional variations in temperature:

- spherical shape of the Earth
- position and movement of the Earth in the planetary system
- topography of the Earth's surface
- characteristics of the Earth's surface, particularly the distribution of water and land

Due to the spherical shape, temperature decreases as latitude increases: Rays of sunlight hit the Earth at a steeper angle in the tropics, the available radiant energy per square meter is greater there. Furthermore, incoming solar radiation in the polar regions travels longer through the atmosphere resulting in increased reflection and absorption. Finally, due to the high albedo in the ice and snow-covered polar regions very little incoming radiation is transformed into heat.



The position and movement of the Earth in our planetary system result in daily and seasonal changes in temperature. The Earth's rotation is responsible for night and day and for typical daily variations in temperature. The orbital movement around the sun in combination with the tilt of the Earth's axis results in seasonal differences in the insolation rates (zeniths of the sun, polar night and days).

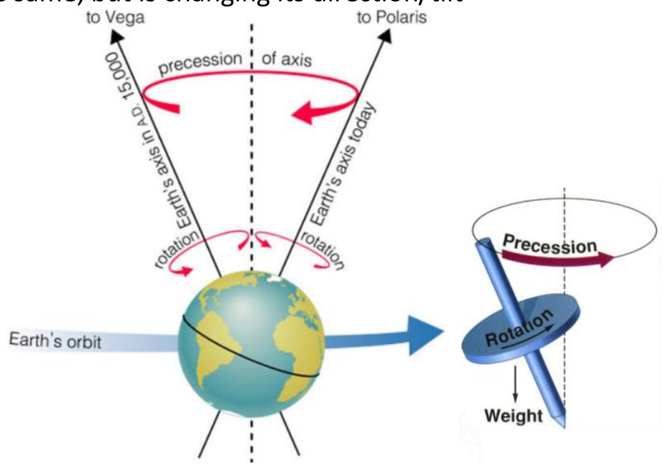
Differences in altitude and the distribution of land and sea can also cause completely different temperatures in locations with the same latitude. Large areas of water have an equalizing thermal effect (e.g. gulf stream and Norway/Greenland): In winter they act as a thermal store, in summer they cool. This is because water has a higher specific thermal capacity than land and the available energy is carried to great depths by turbulence. Landmass only warms on the surface and cools again quickly –> the greater the distance from the thermal energy story "ocean" the lower the average annual temperature is.
Other reasons that can influence local temperatures: Topography of the surface, wind streams, mountain ranges (cloud trap, wind…), lakes, location (north- or south-faced), valleys.

SOLAR CONSTANT

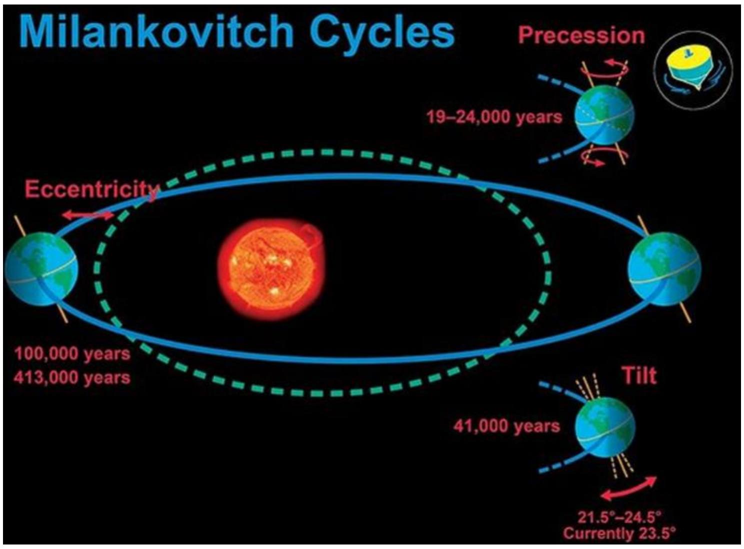
Solar constant is the amount of incoming solar electromagnetic radiation per square meter. It includes all types of solar radiation, not just the visible lights. This radiation is about 50% infrared, 40% visible and about 10% ultraviolet at the top of the atmosphere. One square meter (on top of the atmosphere) of solar radiation would be enough to run a vacuum cleaner (in Switzerland about 20 square meters). But this amount of energy isn't constant because of four reasons:

1. **Eccentricity**: Change of the Earth's orbit around the sun (cycle of ca. 100'000 years)
   In winter we are closer to the sun, but because of the Earth's angle the sun inclination is lower → the more elliptical the orbit is the lower the solar radiation is
2. **Nutation**: The tilt of the Earth's axis which varies by some degrees (over period of ca. 40'000 years)

3. **Precession:** The Earth's axis is shifting its orientation (cycle of 22'000 to 26'000 years)
   The angle stays the same, but is changing its direction/tilt



4. **Changes of solar radiation**: visible by the number of sun spots (cycle of 11 years)
   More solar spots –> more solar activity. Since the 50s the activity of the sun is decreasing



Possible causes for ice ages:

- Variation of solar radiation: Positive feedback –> less radiation, more ice can form in polar region –> more reflection (higher albedo) –> less heat –> more ice… => **Viciuos cycle**
- Changes in atmosphere, aerosols from volcanoes, altered ocean currents

There is no large chance that there will be another ice age because of man kind.

NATURAL AND ANTHROPOGENIC GREENHOUSE EFFECT

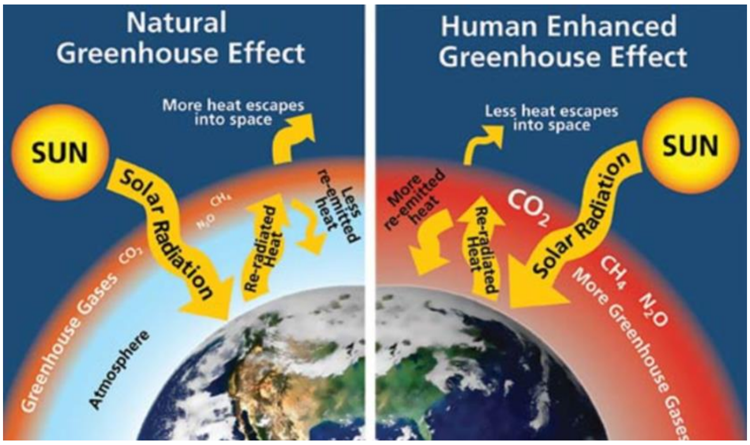
NATURAL GREENHOUSE EFFECT

CO_2 + greenhouse gases are invisible for the shortwave radiation (about 40%) –> it can get into the atmosphere & there it is transformed into longwave radiation that can't get out => are rereflected back to Earth. Without this counter-radiation the average global temperature would be minus 18°C.

ANTHROPOGENIC GREENHOUSE EFFECT

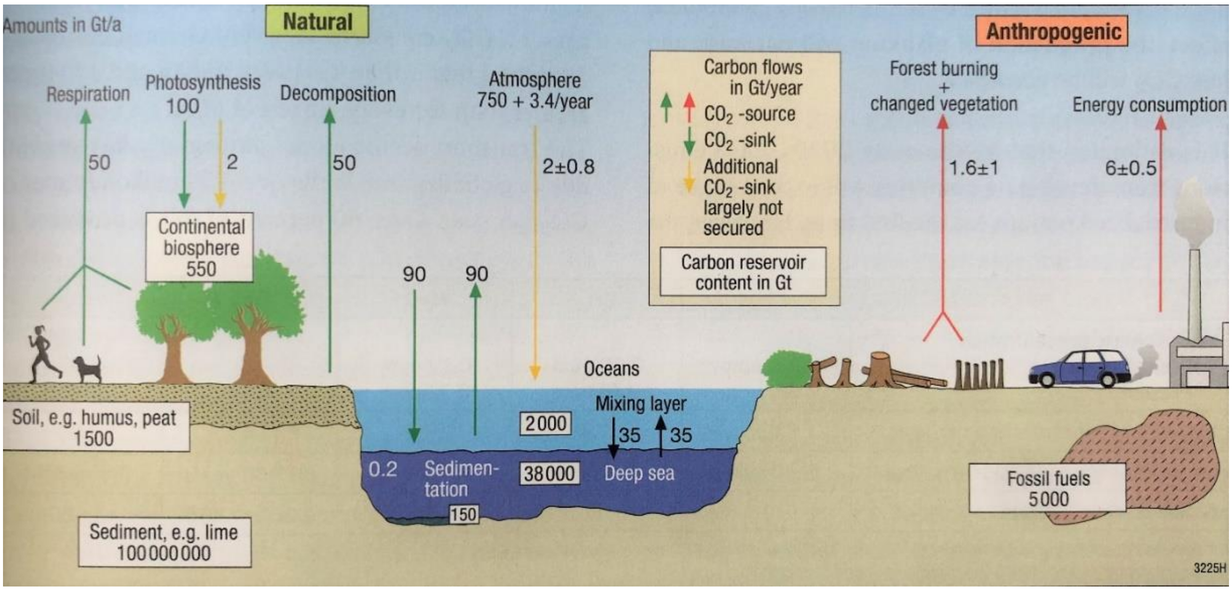
It is caused by an increased man-made concentration of greenhouse gases in the atmosphere.

CO_2 is the main contributor and accounts for over 60% of the anthropogenic greenhouse effect. Methane (CH_4) is produced by factory farming, rice cultivation, flaring of natural gas and landfills. As the temperature rises methane is also emitted from thawing permafrost soils and the ocean floor. Nitrogen oxides are produced by agricultural fertilization and through burning processes. HFCs, PFCs and Sulphur hexafluoride are further greenhouse gases. Because these gas molecules have a much longer atmospheric residence time, their impact is much more significant.

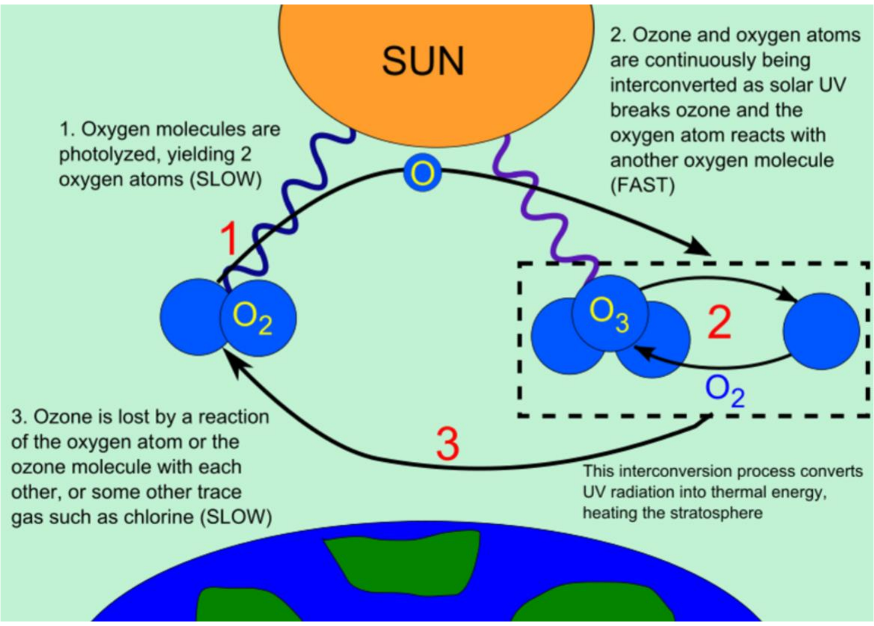


CARBON CYCLE

There are two main causes for the increased concentration of CO_2: Increase of CO_2 sources and the reduction of CO_2 sinks. Most CO_2 emissions are created by the burning of fossil fuels. Also the demand for energy is increasing because of an increasing world population. Burning forests to clear land in the tropics contributes to the increase of the atmospheric CO_2 content: Resulting emissions and the decreased absorption of CO_2 by vegetation. Oceans (main CO_2 sinks) are capable of absorbing 50% of the CO_2 that additionally enters the atmosphere due to human activity.
Plankton absorbs CO_2 through the process of photosynthesis (–> biological pump). But if the oceans are warmed by the increasing greenhouse effect, the production of plankton will decrease and less CO_2 will be absorbed.

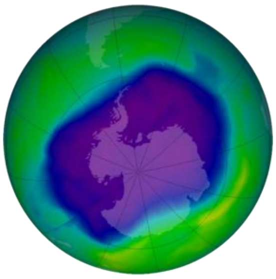


OZONE LAYER



Depending on what layer of the atmosphere the triatomic oxygen molecule O_3 occurs, or is absent, it is either harmful of beneficial. In the summer months the concentration of ozone in the lower atmosphere increases (–> **summer smog**). Summer smog is caused by nitrogen oxides and organic compounds and is often a main problem on afternoons in early summer.

The highest concentrations are outside towns. The harmful gas (to humans and inorganic substances) is created when numerous air pollutants mix with oxygen at high temperature and strong sunlight and can cause respiratory problems.



Concentration of ozone over 20km altitude protects against UV-radiation. The large quantities of CFC that have been emitted in recent decades destroy the ozone –> **ozone hole** over the polar regions has developed and levels of UV-radiation have increased. This results in health and material damage as well as damage to phytoplankton, one of the most important CO_2 sinks. Problem: CFC has a very long atmospheric residence time due to its chemical inertness. But the UNO imposed a halt of CFC production at the climate conference in 1987. Since then the ozone hole over Antarctica appears to be closing.

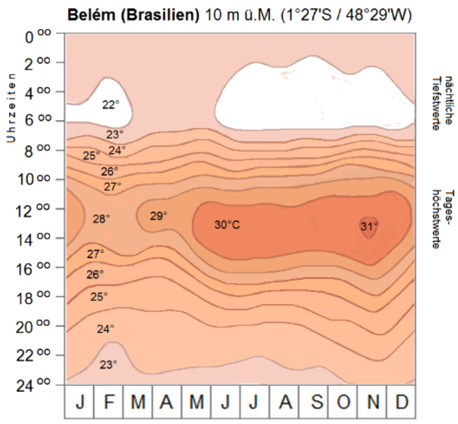
Sources of CFC:

- aerosol propellants
- sterilization of medical equipment
- production of plastic foam and insulation products
- air conditions and refrigerators
- solvent cleaning of metal
- fire extinguisher

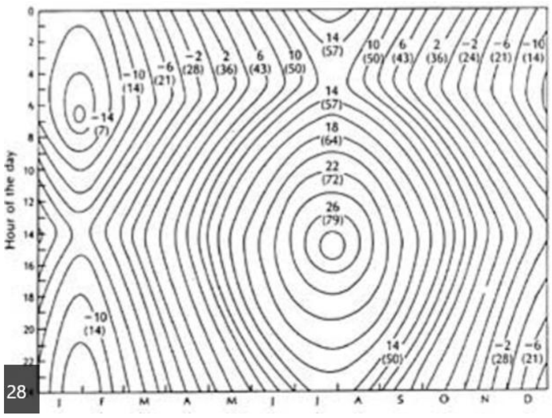
THERMOISOPLETHIC DIAGRAM

SEASONAL VS. DAYTIME CLIMATE

- In the daytime climate of the tropics, the daily range of temperature is always greater than the annual range of temperature

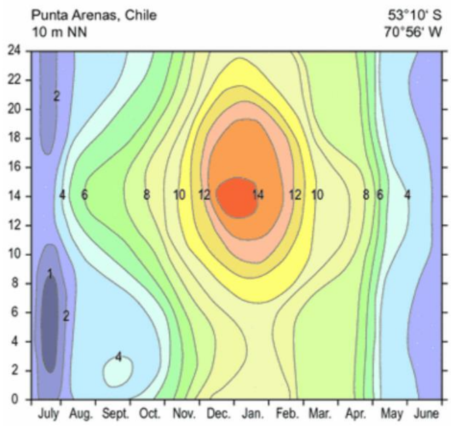


- The seasonal climate has a wide range of annual temperatures and is typical for outer tropical regions



CONTINENTAL VS. OCEANIC CLIMATE

- The continental climate is characterized by low average annual temperature and a wide range of minimum and maximum temperatures –> change between summer & winter >20°



- Oceanic climate typically has higher average temperatures, more balanced annual patterns –> narrower range of annual temperature and a seasonal lag in minimum and maximum temperatures

PRESSURE DIFFERENCES

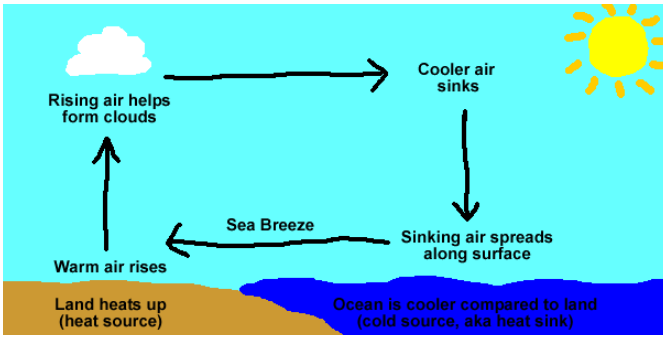
Pressure difference means that the weight of the column of air pressing down on the Earth's surface varies at the same height above sea level which results in airflow / wind. The main engine of the wind is temperature differences caused by the solar radiation –> wind is stronger during daytime. During night the wind changes: It turns from the ground towards the sea, but the wind is less strong because of the smaller temperature differences. The wind is cold, because it comes from the colder land. Also in winter there is more wind because of the bigger temperature difference between the polar and the tropical regions.

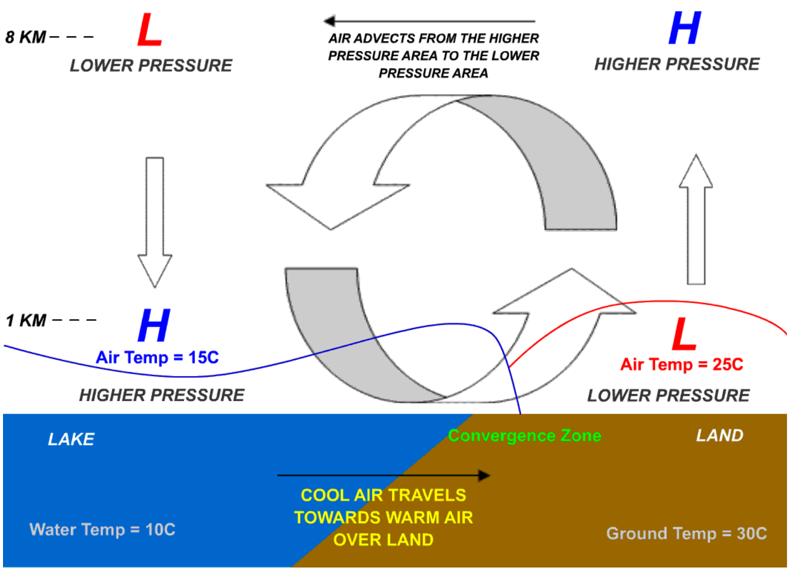
The **high pressure gradient** implies temperature differences. The greater the differences in pressure, the higher the pressure gradient, the stronger the wind.

OCCURRENCE OF LAND AND SEA BREEZE

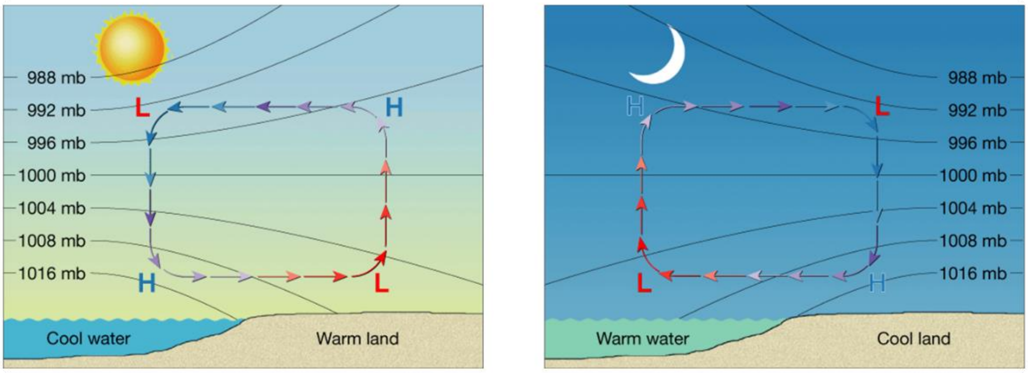
In coastal areas, during daytime, land becomes hotter than water. The air above the land starts to rise causing a low pressure at the surface. Because the isobar planes are uneven*, this warm air is flowing towards the sea (from high-pressure to low-pressure area) and convection takes place. Over the sea the air starts to cool down and sinks. Because of the water the air stays cool and is therefore denser, the total amount of air is greater (it gets attracted by the gravity of Earth) and if it accumulates in higher levels a high-pressure area develops. From the high-pressure area over the sea the cool air rushes to the low-pressure area in the coastal area (–> the wind tries to equalize the air mass). This causes a **sea breeze**. In cold air, the molecules are closer packed together than in warm air, so cold air is denser than warm air because the weight of cold air is bigger –> cold air causes high-pressure.

=> Cold air at the surface is always associated with high pressure and warm air with low pressure.





The opposite occurs during night: The air above the water is warmer than air above the land, so it rises up and cool air from land takes its place causing **land breeze**.



*__Isobar planes__ are the levels of same pressure in the atmosphere. They become uneven on a sunny coast because the land is heated faster than the sea by solar radiation and the air over this region expands. A high-pressure area develops and causes the isobars to rise, because the density of hot air is lower. The isobar planes in the cooler region are still lower –> lower pressure prevails at the same altitude –> airflow.
Because there are less air molecules in the high-pressure area, the weight of air molecules on top of the ground is lower and a low-pressure area develops.

If you travel from a high to a low-pressure region the number of isobars will decrease (you always need to compare the isolines at the same level). The closer the isolines are, the stronger the wind.

Low pressure is generally associated with cloudy, rainy, or snowy weather: Air rises and gets cooler because of the lower pressure around it –> condensation pressure –> rain

MORE SITUATIONS WITH PRESSURE DIFFERENCES

- In glaciers (in comparison to the nearby rocks)
- In mountain ranges
- Albedo (high albedo –> high pressure vs. low albedo –> low pressure)

MAP WITH ISOBARS

- The average pressure on sea level is 1013 mbar
- A low-pressure area has a pressure lower than 1013 mbar
- A high-pressure are has a pressure higher than 1013 mbar