



The ocean circulation

Key words of this unit:

Water distribution, oceans as energy storage, ocean circulation, thermohaline circulation, Gulf Stream, North Atlantic Drift

for students



Fig 1: The polar ocean between liquid water and ice plays an important role for the global ocean circulation. Photo: John Boyer

Water on our planet

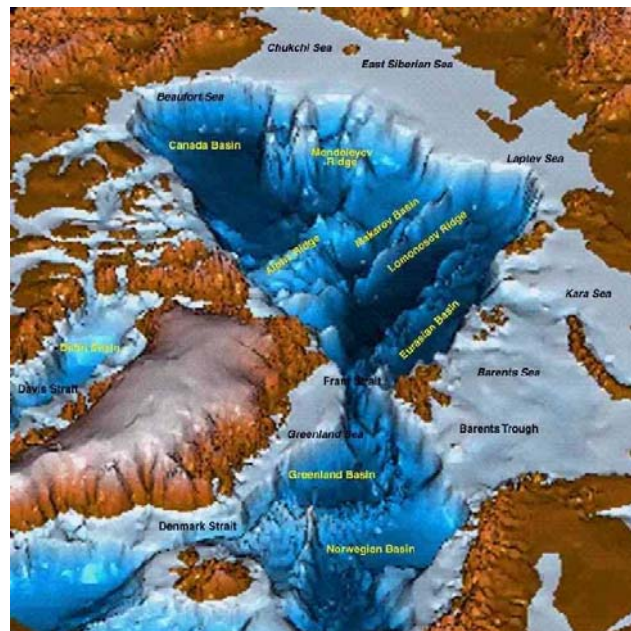
The oceans cover 71% of the Earth's surface. They are at some points deeper than the highest mountains are high, and over wide areas 2000 to 4000 m deep. This is an enormous amount of water: about 96.5% of all water on Earth. Unfortunately, due to its salinity, this water can neither serve as a potable water for humans nor for irrigation of crops. Therefore, with the expansion of the oceans caused by climate change, we lose valuable living space.

Fig 2: The graph on the right shows strongly super elevated the structure of the sea floor in the area of the Northern polar sea and North pole. We see mountains and valleys on the ocean floor similar to the ones existing on land.

Please click the image in order to enlarge.

Source:

www.cyberspaceorbit.com/northpolefloor.jpg





Water distribution

We see in the graph on the left that most of the fresh water (1.74%, cyan) is stored as ice shields or glaciers, primarily in Antarctica and Greenland. Here, we can certainly not make much use of it. About the same amount (1.7%) is available as ground water. But only little less than half of it (0.76% of all water, light green) is not salty. Only a tiny fraction of the world-wide water resources are allotted to lakes (turquoise) and an even tinier fraction is related to the little hardly visible light yellow square bottom right - this is how much is stored in rivers and the atmosphere together.

Fig 3 (above): The area shows the relative distribution of water on the oceans (marine blue) and other water resources. At the very bottom right hand corner those small fractions are represented in light grey, turquoise and light yellow, which do not belong to ice (ice shields, glaciers) and ground water. The distribution is a visualisation based on data on the following [USGS Website](#). Graph: Elmar Uherek



Fig 4 (right): Collage water distribution. Main photo: Simeon Eichmann (sxc)

The oceans as energy storage

When the Earth is seen from space, the oceans appear dark blue. They absorb the major fraction of the sunlight and reflect only a little: about 4% at clear sky, 7% if the sky is cloudy.

In this way the oceans take up large amounts of energy from the Sun and store it. You know that it takes a long time until a pot with water on the stove begins to boil, although the plate is very hot the whole time. Water takes its time absorbing energy. If you remove the pot from the stove and switch off the hot plate, it will cool down quickly. However, the water will still remain hot for a long time. Water also takes its time in releasing energy.



Fig 5: The Earth seen from space © NASA

We know this phenomenon from bathing resorts at the sea. On March 21st and September 22nd the solar radiation is about equal. But in March the sea is still cold from the winter, while in September it is warm after the summer - much better for bathing.

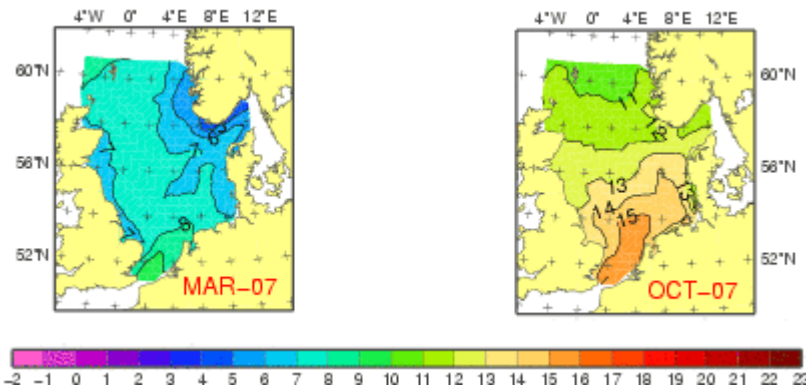


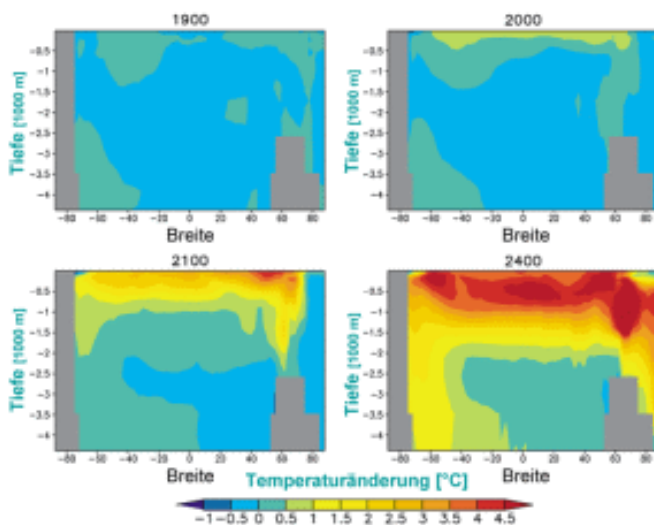
Fig 6: The North Sea two weeks before spring begins and two weeks after autumn started. The astronomical position of the sun is the same. But water temperatures are clearly different. Source: Bundesamt für Seeschifffahrt und Hydrographie. Please click on the figure in order to see an overview of all months.

The heat of the surface water of the oceans is still transported to us with the wind and brings us warm late summer and early autumn days. The quick warming of the land compared to a slow warming and cooling of the sea leads to sea breeze and land breeze near the coast. (The sea breeze is explained on this [ESPERE page](#).)

Sometimes we find bays with shallow water. At such places the energy of a hot day can warm up the water and it will cool down again during the night. The surface water of the ocean however reacts more to seasonal temperature changes and warms up in summer and cools down in winter. This is different again for the deep water in the ocean in several hundreds or even thousands of metres of depth. The deep sea does not really feel the seasons. Only if the average temperature of the air over the ocean increases for decades to centuries, the heat will slowly be transported to the deep sea.



Fig 7: The solar radiation of one day is sufficient to warm up shallow waters near the coast. Photo: Auro Queiroz (Taipús coral reef / Brazil)



This process will be started with climate change. The deep sea is going to store the global warming for a long time and will hand it over to the next generations, even if humankind is able to reduce the fraction of greenhouse gases in the air.

Fig. 8: The model calculation shows how the ocean temperature would react to an extreme increase in the amount of carbon dioxide to three times those of preindustrial values ($3 \times 280 = 840$ ppm). The effect would not reach the deep sea until centuries later. Source: IPCC 2001

Temperature differences and ocean currents.

The oceans are in a state of continuous slow motion. They transport heat, which is given by the Sun primarily to the equatorial regions, towards the poles. One of the surface currents is the Gulf Stream. Warm and cold surface currents lead to different climates in the regions in the vicinity of the coasts. We call it maritime climate. But oceans are not only in motion close to the surface.



Fig 9: The map shows important surface currents in the oceans. Source: [Windows to the Universe](#) / UCAR

The deep water is also slowly exchanged. Cold and dense surface water sinks in the North and South polar region and flows back in deeper layers towards the equator. We can simulate this motion in a little [experiment](#). But the exchange of deep water is extremely slow. A complete turnover of the oceans lasts about 1000 years.

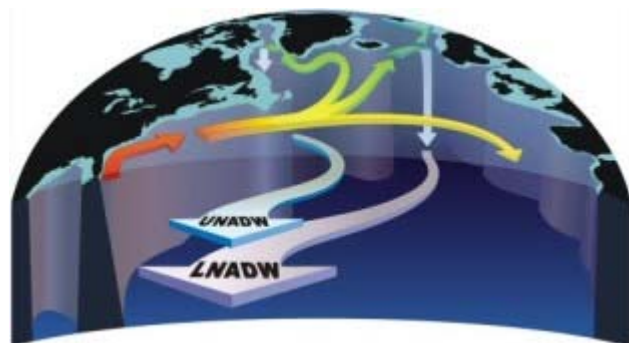


Fig 10: Deep water is formed at two locations in the Northern Atlantic, in the Labrador Sea and in the Greenland Sea. Since the water in the Greenland Sea is colder and sinks deeper, the back flowing water masses form two different layers in the ocean. Source: V.Byfield / British National Oceanography Centre, Southampton

Salinity

The ocean water is salty. This has important consequences for the ocean streams. Salty water is heavier than fresh water. And due to the salt the density anomaly of the water changes. Salty water of 1°C is denser than salty water of 4°C.

In contrast, fresh water has its highest density at 4°C. Next to the North pole and the South pole it is so cold that ocean water begins to freeze. But the ice consists only of fresh water since the salt is excluded from the freezing process. Consequently, the remaining liquid surface water with the ice swimming on top is saltier and denser than deep water layers of the same temperature would be. We can conclude that the surface water does not only sink due to its lower temperature, but also due to its salinity. According to the Greek terms for heat (thermos) and salt (hals) we call the ocean conveyor belt a "thermohaline circulation".