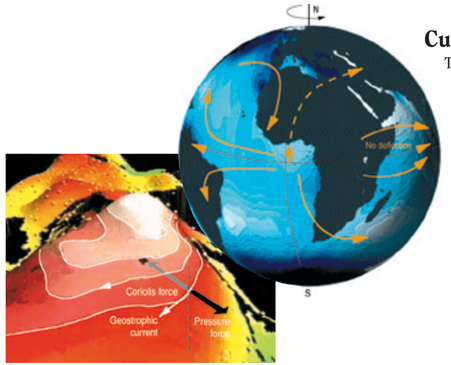
Current flow and climate fluctuations

By transporting heat and energy, ocean currents play a major role in shaping climate. Observing them from space is essential to further our understanding of the Earth.



The Coriolis force, generated by the Earth's rotation, diverts currents to the right of prevailing winds in the Northern Hemisphere, and to the left in the Southern Hemisphere. The higher the latitude, the larger the diverting force.

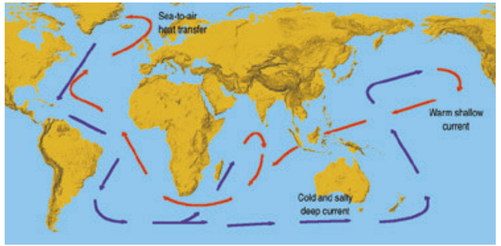
Current relief

The major ocean currents generated by prevailing winds are deflected from their course by the shoreline, and by the Earth's rotation. Ocean circulation thus causes water to accumulate at the western edge of ocean basins, forming reliefs in the ocean surface proportional to the speed of the currents.

By measuring sea level variations, altimetry satellites enable us to observe ocean currents.

Currents shape climate

Ocean movements have a strong influence on climate on land. Water is warmed by the Sun in the Tropics. Prevailing winds (easterly tropical tradewinds, westerly winds at medium latitudes) and temperature differences between water masses propel this water towards higher latitudes. On the way, it loses heat to the atmosphere and surrounding ocean. The heat thus distributed plays a key role in regulating different climatic regions around the globe.



Water from the Tropics cools as it flows into the Norway Sea. It then sinks to the bottom of the ocean where it propels the deep ocean circulation system before eventually welling up and warming again in the Tropics, some 1,000 years later.

Currents around the world

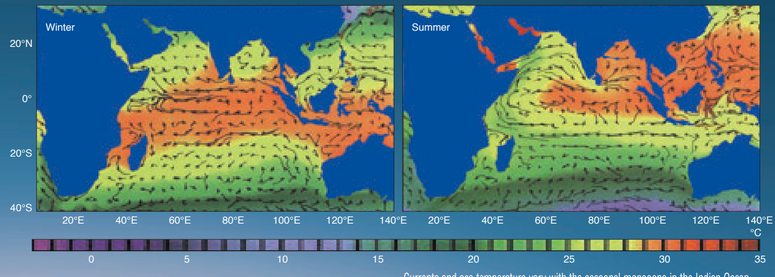
Dynamic topography and ocean currents viewed from space

A view of the global ocean circulation shows currents swirling around the hills and valleys in the sea surface. Currents flow around hills in a clockwise direction in the Northern Hemisphere, and in an anticlockwise direction around valleys (the opposite occurs in the Southern Hemisphere). These currents form loops on either side of the Equator. Sea surface heights also vary across the oceans: the largest difference and height between the Pacific and the Atlantic is due to variations in salinity.

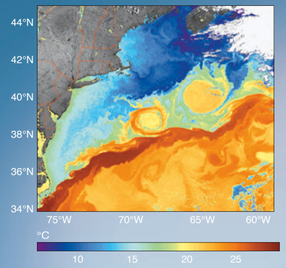
The Gulf Stream was first charted in 1777 to help ships crossing the Atlantic.

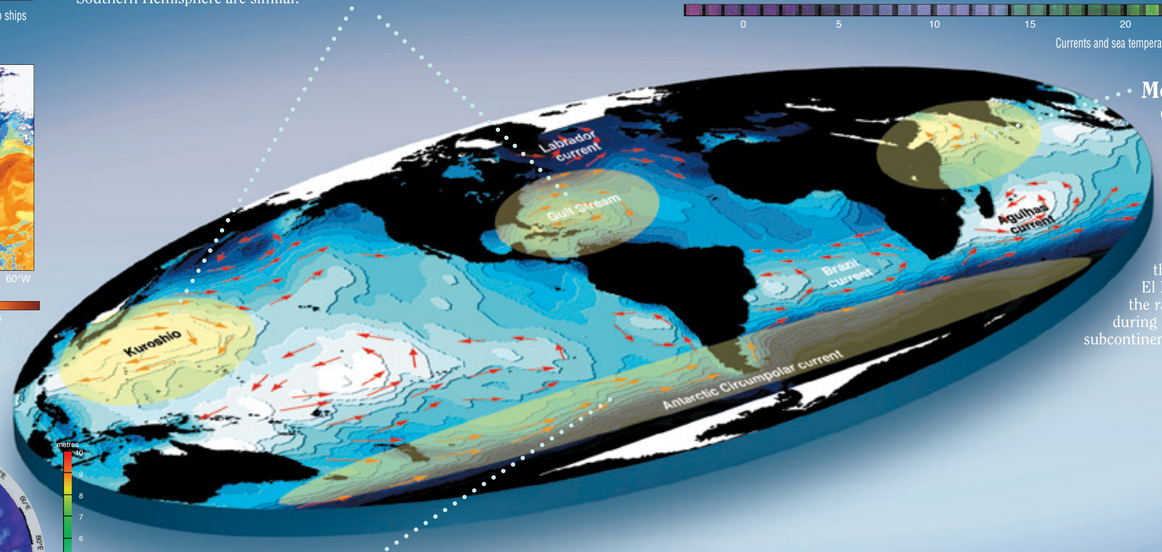
Boundary currents: the Gulf Stream and the Kuroshio

The Gulf Stream, which flows from the Caribbean to the Grand Bank off Newfoundland, is one of the first currents to have been studied scientifically, due to its importance for transatlantic shipping. Its temperature drops from 25° to 2°C during its course as it warms the ocean and releases heat and water vapour into the atmosphere. Like the Kuroshio Current, its counterpart in the Pacific Ocean, the Gulf Stream is a warm, western boundary current formed by easterly winds. It is very turbulent and exhibits sharp variations in direction, speed and temperature. The Agulhas and Brazil Currents in the Southern Hemisphere are similar.



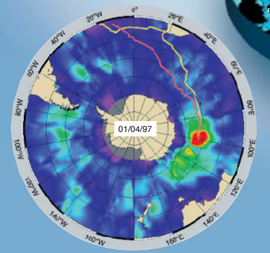
Currents and sea temperature vary with the seasonal monsoons in the Indian Ocean.





Monsoon currents

Currents near the Persian Gulf vary with the seasons. Winds blow from the land or off the sea (monsoons) and may be dry or carry the rains that farmers need for their crops. These changing winds drive the ocean currents, which in turn affect the winds. Large-scale ocean variations also affect the monsoons: during El Niño episodes off the coast of Peru, the rains are late coming; conversely, during a cold La Niña event the Indian subcontinent experiences flooding.



Wave heights around Antarctica during the 1996-97 Vendée Globe yacht race.

Antarctic Circumpolar current

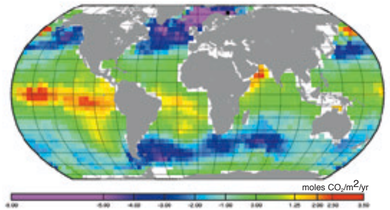
Antarctica is one of the most remote regions on Earth. Here, winds and waves are often of an intensity seldom equalled anywhere, and icebergs make these waters very treacherous places ships, which is why they are popularly known among sailors as the "roaring forties". Such severe ocean conditions have conspired to make the Antarctic Circumpolar Current one of the least studied of all. It is also unique in many ways, since it is the only current not bounded by a continent, thus allowing water to flow between oceans.

Greenhouse effect and global warming

The relationship between oceans and climate is more complex than just the transport of heat. The oceans also play a role in the carbon cycle, which is a crucial factor affecting climate due to the greenhouse effect. In turn, climatic variations have an impact on the oceans, where sea level and circulation vary as water temperature rises and falls.

CO_2 in the water

Climate is a complex system driven by many underlying oceanic and atmospheric parameters. A key factor is the amount of greenhouse gases (water vapour, carbon dioxide, etc.) in the atmosphere.
The greenhouse effect is essential—without it, all the Sun's energy would be reflected back into space and temperatures on the surface of the Earth would be too low to sustain life (–18°C on average). But this effect only needs to be amplified slightly by a few



Carbon dioxide in the atmosphere is absorbed by the oceans and redistributed by the currents (moles CO_2 per m^2 and per year).

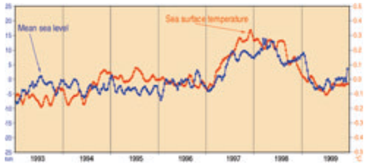
degrees to cause global warming and upset climate. Today, anthropogenic carbon dioxide emissions generated by burning of oil and other fossil fuels are constantly rising. There are no easy answers to this problem, because we still do not fully understand just how much gas the ocean is capable of storing. Studying ocean circulation will help us to gauge this capacity more accurately.

Water rising

Global warming affects the oceans, where sea level rises due to the melting of continental ice sheets and expanding warmer waters. With 50% of the world's population living less than 100 kilometres inland, a

How Europe's coastline would be reshaped if all continental ice melted (sea level would rise 80 metres).

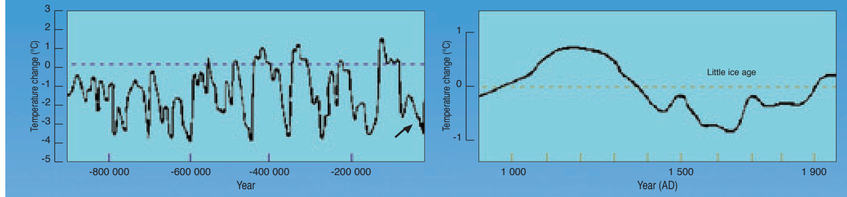
rise in sea level would have catastrophic consequences, particularly for atolls in the Pacific Ocean or for Bangladesh, where lands are barely above current sea level.
Variations in water temperature and salinity can also lead to changes in the global ocean circulation, which in turn affect climate—and so the cycle begins all over again.



Mean sea level measured by TOPEX/POSEIDON. We can see that sea levels have risen by about 1.5 millimetres per year since 1992.

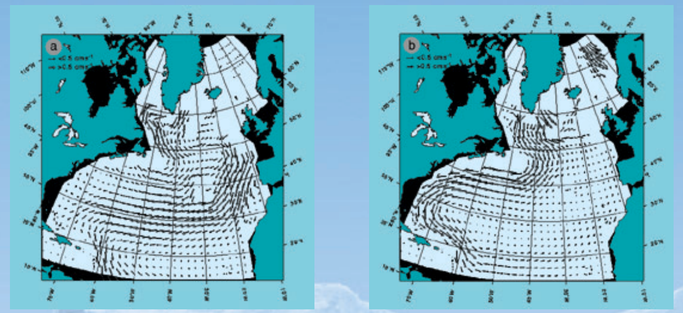
A trip back in time

Through the ages, the Earth's climate has undergone many, sometimes extreme, variations. During the Quaternary Period, the planet underwent several glaciations. During the most recent ice age, reindeer roamed through southern Europe—as cave paintings show—and a sheet of ice joined Asia to America where the Bering Strait in Alaska is today.



Temperature variations during the Quaternary Period show alternating periods of cooling and warming.

During these ice ages, ocean circulation was not the same as it is in a warmer cycle. We can also trace small variations by looking through historical records. For example Greenland, today a frozen landscape, was indeed a "green land" at the time of the Vikings; and the Little Ice Age reached its peak between the 17th and 18th centuries when solar activity was at a minimum. Each time, changes in ocean circulation would not have been the direct cause of cooling, but they may have amplified it.



Currents in the North Atlantic at the height of the last ice age, 18,000 years ago (a), and today (b).

For more information:

AVISO/Altimetry: http://www-aviso.cnes.fr
Climatology: http://www.clivar.org
Paleoclimatology: http://www.ngdc.noaa.gov/paleo/

Sources:

CLS, CNES, CNRS/LEGOS, CNRS/LSCE, LDEO, Météo-France, NASA,NOAA, Universität Kiel, WHOI

Observing the oceans from space

Ocean and climate: who leads the dance?

The oceans cool and warm the Earth. Ocean currents warm colder zones, transporting heat from warmer zones and distributing the Sun's energy. But this balance between hot and cold is constantly changing. Glaciations and warmer interglacial periods have alternated through the ages, and the effects of climate variations have always been felt at human scale. The oceans too are affected, as the sea level rises and falls in response to these fluctuations.
Permanent, global observation of the oceans and their movements is vital for us to predict climate variations and their socio-economic impact. Satellites give us the wider picture we need to achieve this. In particular, altimetry satellites such as TOPEX/POSEIDON and Jason-1 enable us to measure sea level and gain a closer insight into the processes of ocean circulation.