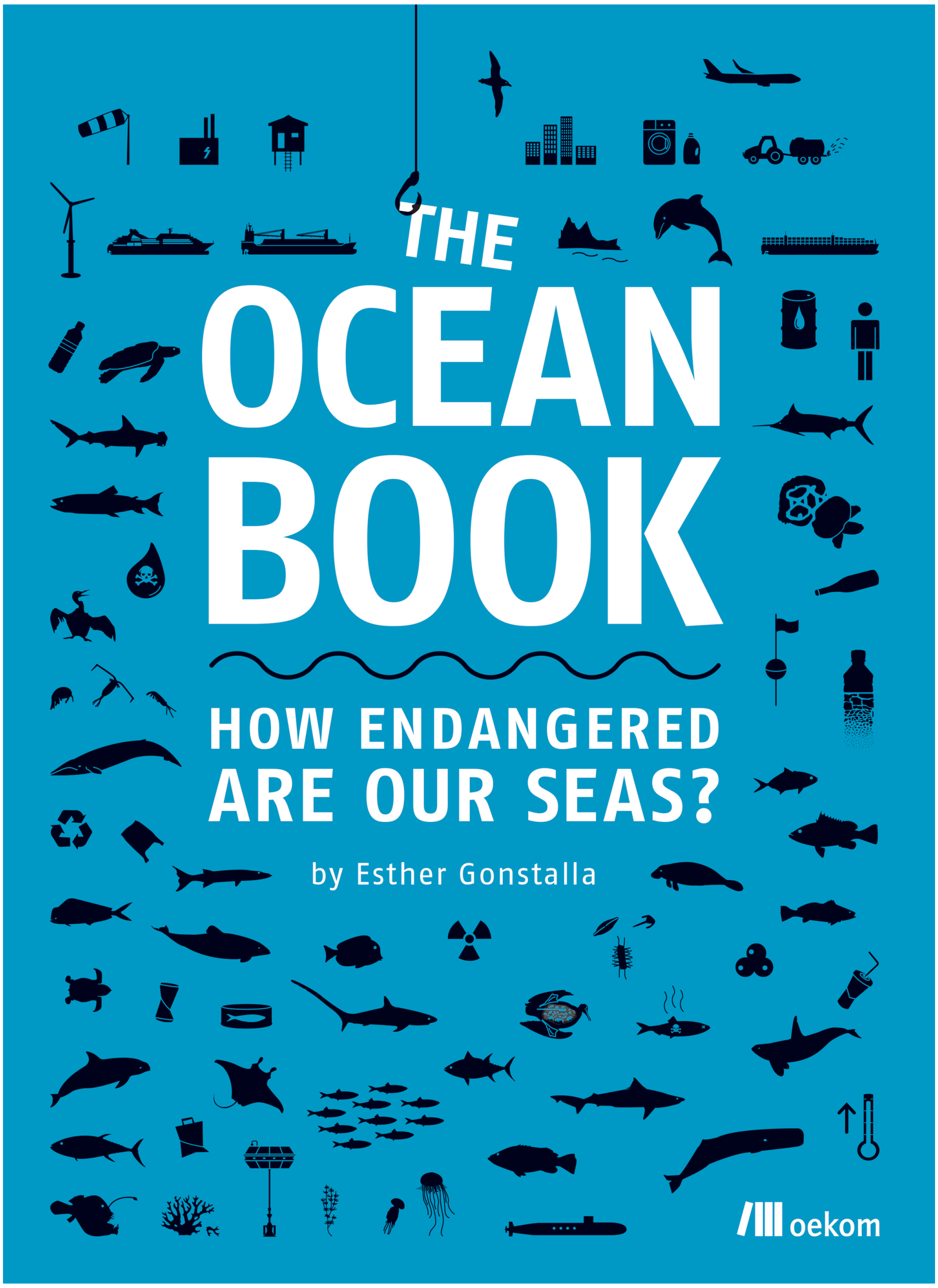

Esther Gonstalla
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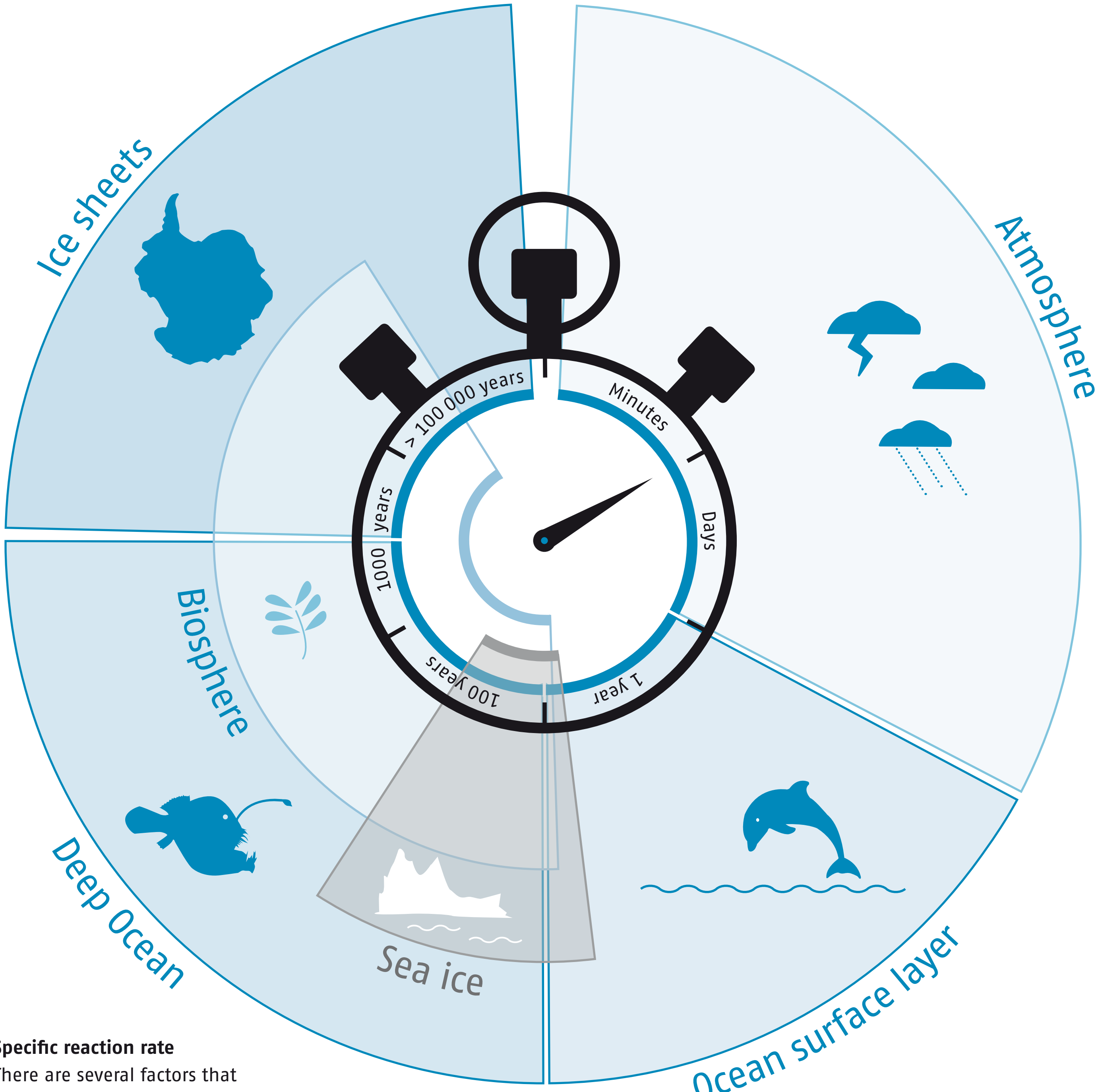
Climate change

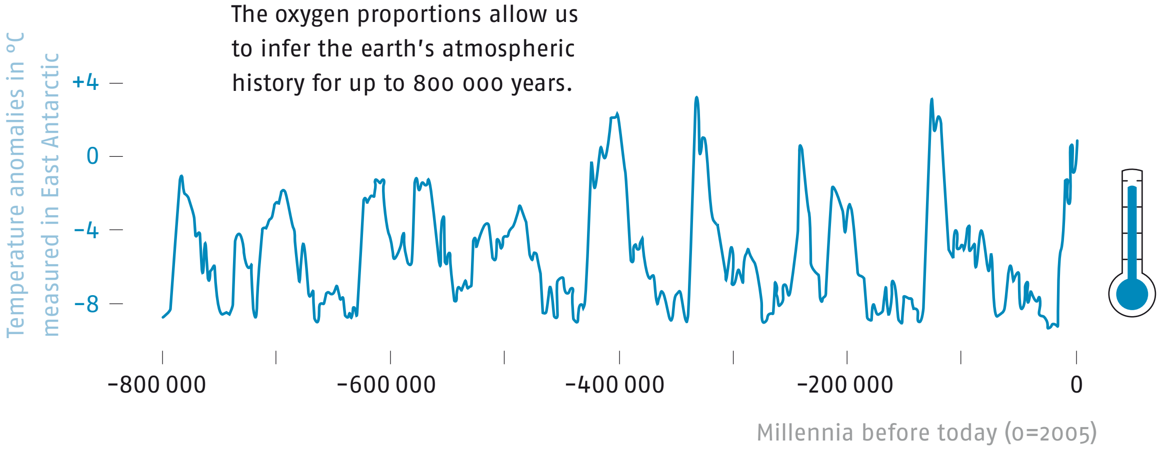
How does the climate work?



Specific reaction rate
There are several factors that influence the climate, such as the atmosphere, cryosphere and biospheres on land and in the oceans. They react to changes at different rates, ranging from minutes to millennia.

Sources: Jouzel et al. (2007), Maribus (2010), NASA (2015)

The history of global climate
Changes in the average temperature and composition of the earth's atmosphere throughout the planet's history can be scientifically followed by analysing gas trapped in bubbles in the arctic ice sheets. The oxygen proportions allow us to infer the earth's atmospheric history for up to 800 000 years.



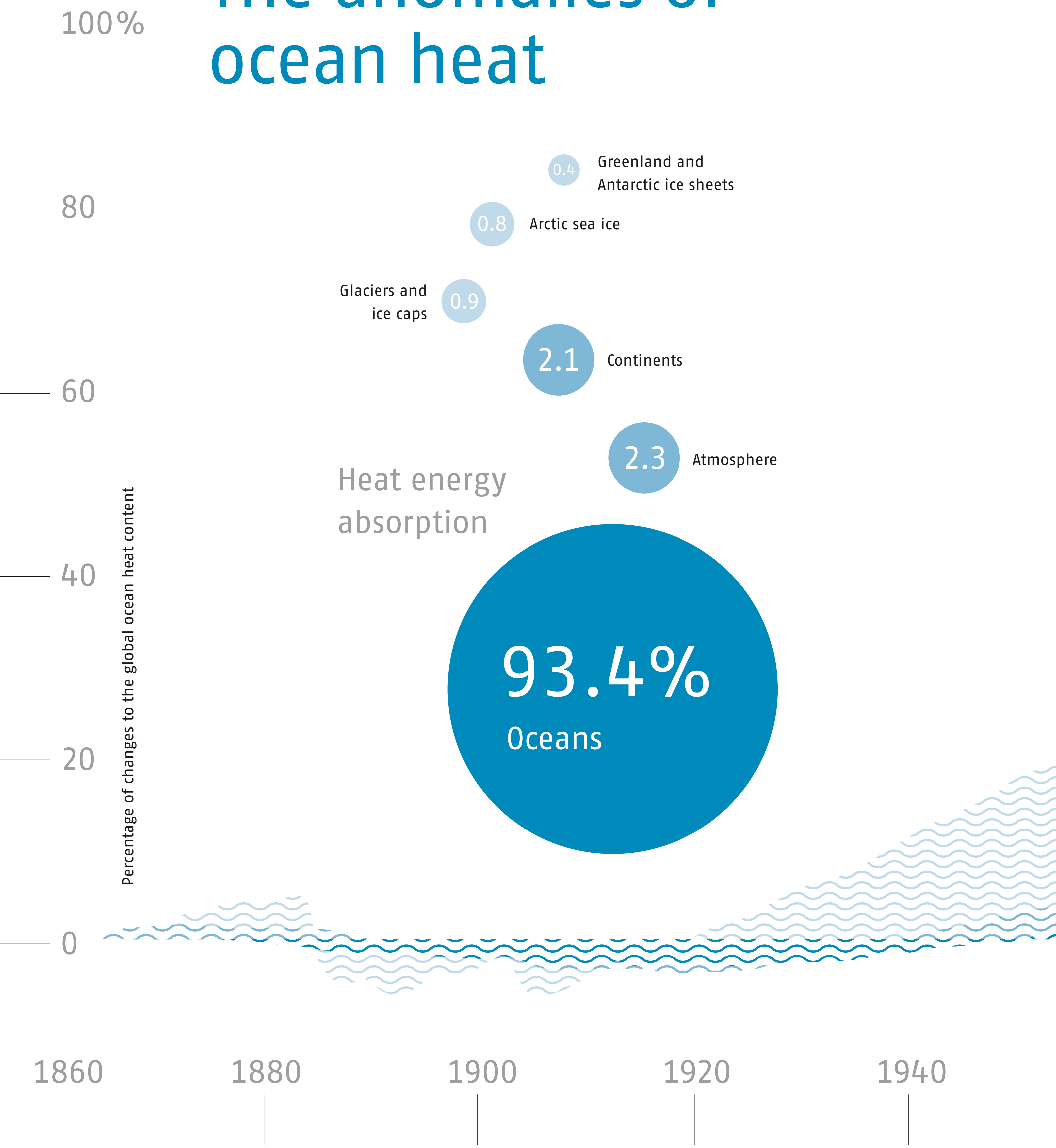
Our planet has warmed up and cooled down more than once in its long history. Subtle changes in the earth's angle to the sun, the planet's surface, the atmosphere and fluctuations in the sun's intensity have always caused the climate to vary steadily. The greenhouse effect, for instance, is in fact an important climate factor for our survival. If sunlight entering the earth's atmosphere were not converted into warmth after being reflected off the earth's surface and partially absorbed by the atmosphere, we would be experiencing sub-zero temperatures.

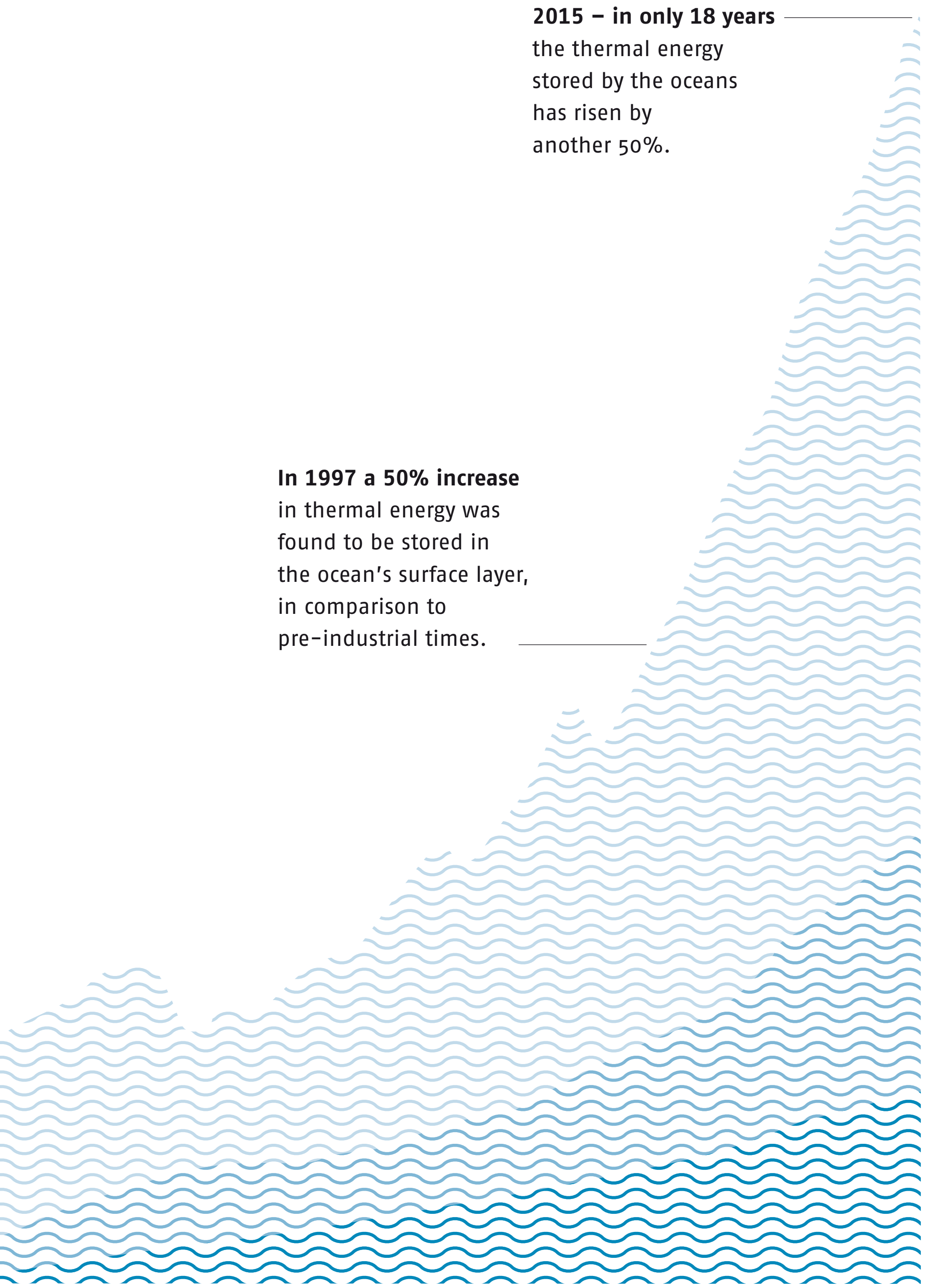
Since the beginnings of industrialisation in the 19th century, however, our emissions of CO_2 and other trace gases have contributed to an additional warming of the planet's surface. The more man-made CO_2 enters the atmosphere, the more thermal radiation remains trapped, leading to a more serious greenhouse situation. Scientists have been able to reconstruct the last 800 000 years of anomalies in the earth's temperature by analysing ice cores drilled in the Antarctic. This data, as well as other climate archives, show us that the current change to the climate is occurring much faster than instances of global warming in the past.

This climate change has grave repercussions for the oceans. Because the surface of the sea is relatively dark, it absorbs considerable amounts of heat. Its slow ocean currents transport huge amounts of heat and CO_2. The sudden and extreme influx of CO_2 to the oceans is disturbing because the resulting acidification causes irreparable damage to ecosystems, ocean dwellers and coral reefs.

The ocean's climate responds relatively slowly to the greenhouse effect: the oceanic surface layer, stirred up by the wind, can react within months or years. It can take the deep sea centuries or even millennia to change. The ice sheets are the slowest, taking several hundreds and even thousands of years to show signs of change. Once they have begun, such far-reaching processes cannot be reversed by humankind. This is why global CO_2 emissions must be reduced as quickly as possible.

The anomalies of ocean heat





The ocean has the greatest thermal storage capacity on earth. While the atmosphere just keeps getting hotter and hotter, the ocean slows down our man-made rise in temperature levels considerably. The water gets warmer and thus expands, which contributes to rising sea levels. At first, the heat is mostly stored close to the surface, but then it later moves down into the deep sea. In this process heat is not only stored, but also released: most of the heat is bound close to the Equator. Surface currents such as the Gulf Stream then transport this warmth up north, where parts of the heat are released into the atmosphere.

Between 1997 and 2015 the temperature absorption of the ocean's surface layer has doubled, the medium depths have experienced an increase of 35%, while global warming has accelerated significantly in parallel.

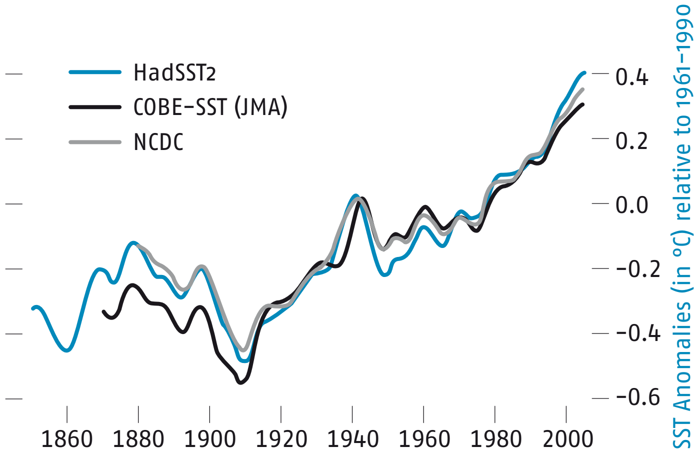
Alongside land-based biospheres, the ocean is currently our strongest climate fighting agent, but how much more heat can the ocean absorb?

Sources: EPA (2014), Gleckler et al. (2016), IPCC (2013)

Consequences of warming

1 The ocean temperature rises

The Sea Surface Temperature (SST) tends to rise. The ocean is about 0.4 degrees warmer compared to the years between 1961 and 1990, as three different scientific models prove.



2 Increasing numbers of coral reefs bleach and die off

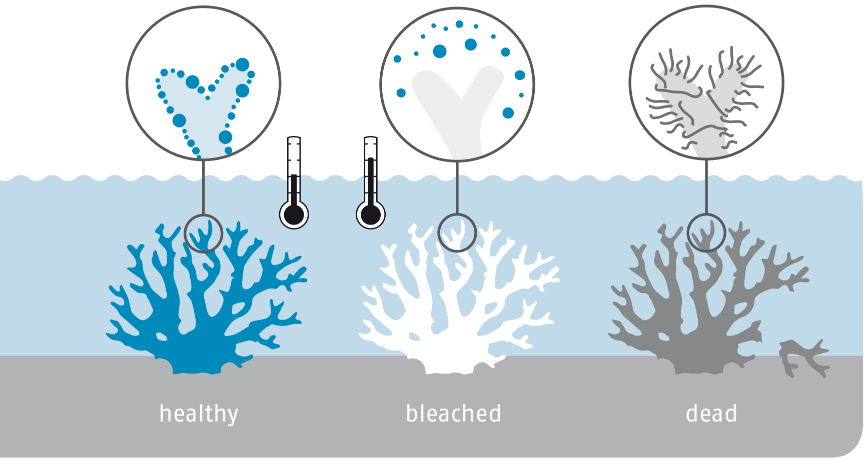
The El Niño phenomenon, which occurs approximately every four years and during which the eastern equatorial Pacific region shows an unusually strong increase in warmth, causes mass coral mortality. Global warming, and the resulting warming up of the oceans, carries the consequence that the El Niño phenomenon tends to be stronger and last longer. The shorter the warming lasts, the higher the chances that the corals survive. The longest coral bleaching event so far began in October 2015 and lasted until May 2016. 93% of Australia's Great Barrier Reef, the earth's largest coral reef, was affected by this. In the northern parts of the reef, 50% of the bleached corals died.

↓

Corals engage in a symbiosis with certain algae, the zooxanthellae, which are indispensable to life. They are fed by the algae and gain their colour through them.

Starting at a 1°C rise in temperature, the algae go into a state of shock and produce toxins instead of sugars. The coral then rejects its partners and loses its colour.

The corals starve as a result of this. After their death, a dangerous process of algae and sponge coverage begins, making the return of zooxanthellae virtually impossible.



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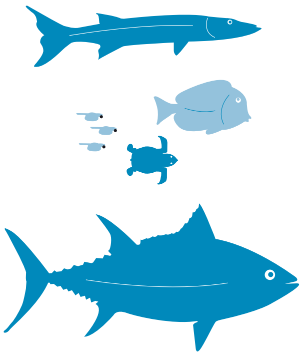
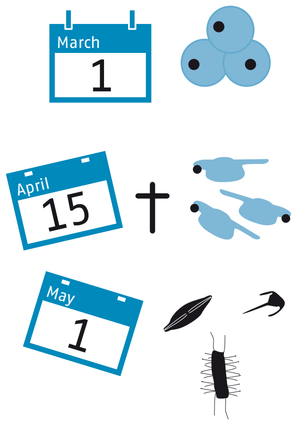


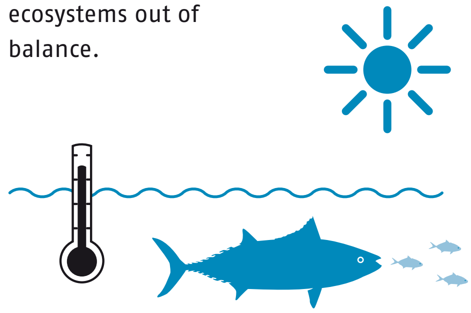
25% of the ocean's inhabitants are directly dependent on coral reefs

3 Many marine creatures change their behaviour

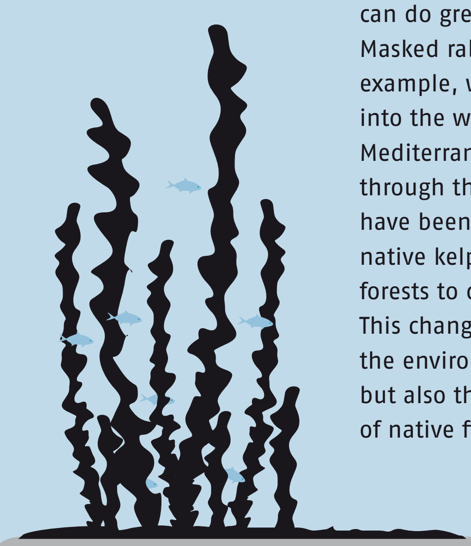
When the waters are warmer than usual in the spring, many fish lay their eggs early. The food sources the larvae are used to may not be available yet at this point, since plankton are highly dependent on sunlight and the seasons. The consequence: larvae starve and the fish population diminishes.



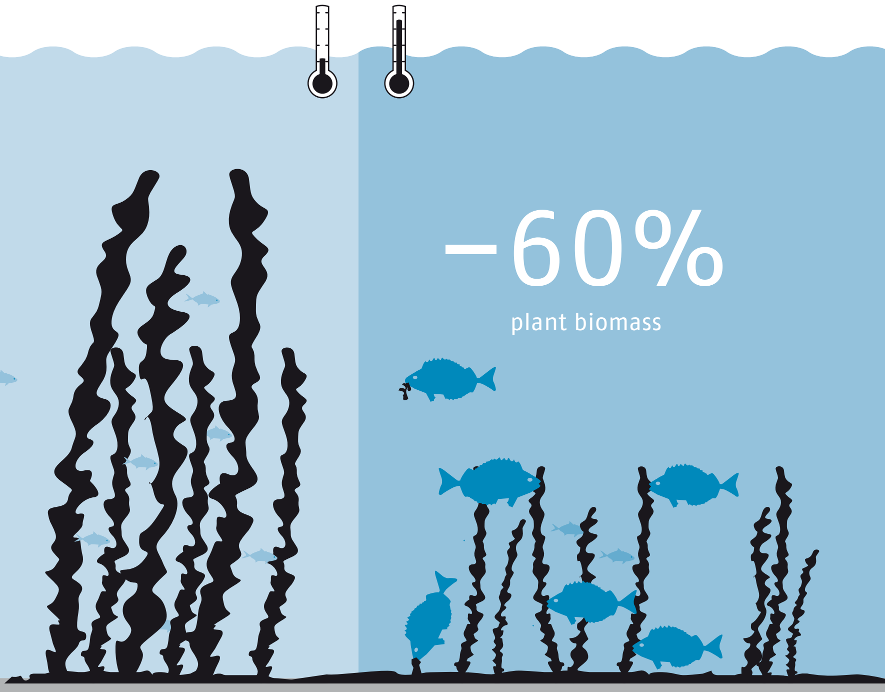
Natural signs, such as the intensification of sunlight in spring and rising water temperatures in the summer, can trigger fishes to change their feeding and mating habits. Climate change can thus warp the natural behaviour of marine creatures, throwing ecosystems out of balance.



4 Invasive species spread out and alter ecosystems



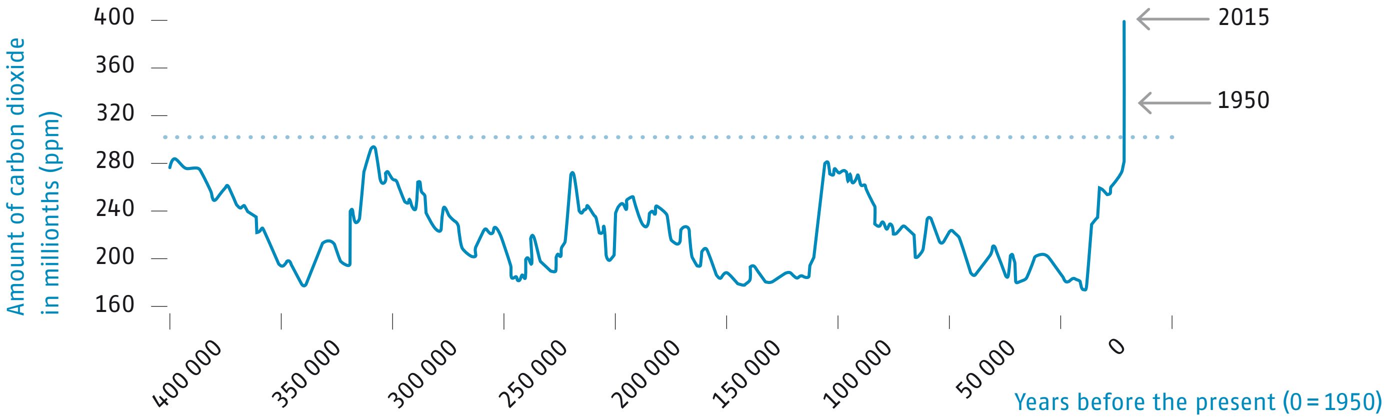
Herbivorous tropical fish can do great damage. Masked rabbit fish, for example, which moved into the warming Mediterranean waters through the Suez canal, have been eating the native kelp and algae forests to destruction. This changes not only the environment, but also the behaviour of native fish.



Sources: ARC (2016), IPCC (2014), Neuheimer et al. (2015), Vergers et al. (2014), XL Catlin (2016)

Rising acidity

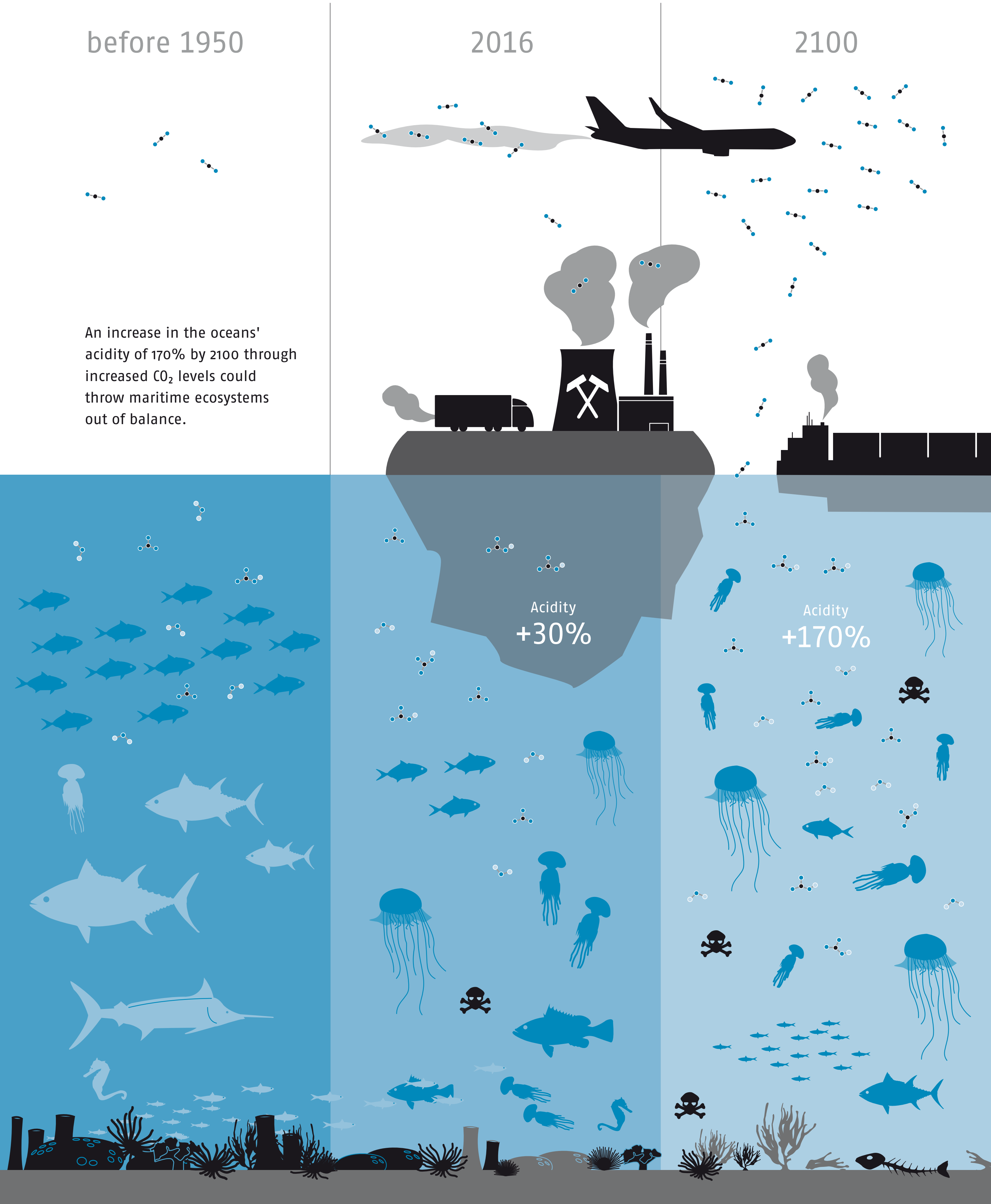
For 650 000 years, CO_2 levels in the atmosphere oscillated below 300 ppm. Then came the industrial revolution.



Since the age of industrialisation, humanity has been burning massive amounts of fossil fuels and engaging in unprecedented scales of deforestation, causing the steady rise of carbon dioxide levels in the atmosphere and, consequently, in the ocean as well. Since then, the levels of CO_2 in the ocean have been increasing faster than in the previous 60 million years. The ocean's pH value has gone from 8.2 to 8.1 since 1950, meaning that the ocean's acidity is approximately 30% higher. It is estimated that if the rate of CO_2 emissions continues at the current level, it would cause a further increase of 140% by 2100. Ocean water is generally alkaline and only acidifies when it absorbs carbon dioxide and partially bonds to create carbonic acid. Marine plants such as algae take the carbon which has been dissolved in the water and metabolise it into sugars and starches through photosynthesis. Higher CO_2 levels also help jellyfish grow faster. But a continued drop in the ocean's pH balance would harm coral reefs and some invertebrate species, whose vital lime formation processes become impaired. We can only guess at how the entire ocean ecosystem would change with this continued drop in its pH levels, because, so far, there have not been sufficient long-term studies to provide us with data.

- Carbon dioxide (CO_2)
- Water (H_2O)
- Carbonat ions (CO_3^{2-})
- Bicarbonate ($2HCO_3^-$)

Sources: IGBP, IOC, SCOR (2013), Maribus (2010), CC (2010), NOAA (2016)



An increase in the oceans' acidity of 170% by 2100 through increased CO_2 levels could throw maritime ecosystems out of balance.