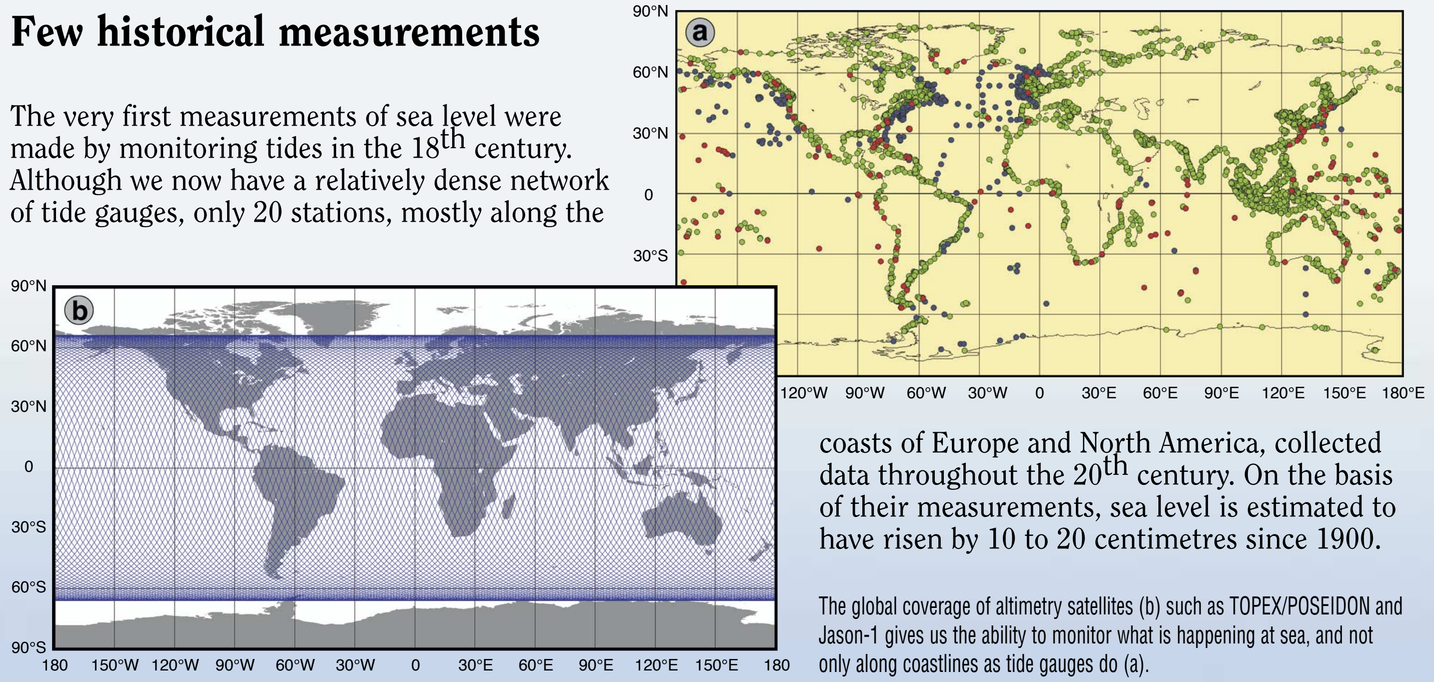
Global sea level on the rise

All indicators point to a rise in the mean level of the world's oceans. As far as we can tell from a few isolated measurements taken around 1900, this rise has been continuing for at least a century. Today, thanks to the global coverage of altimetry satellites, estimates of the rise in sea level—now running at 2.5 millimetres a year—have gained in accuracy.

Few historical measurements

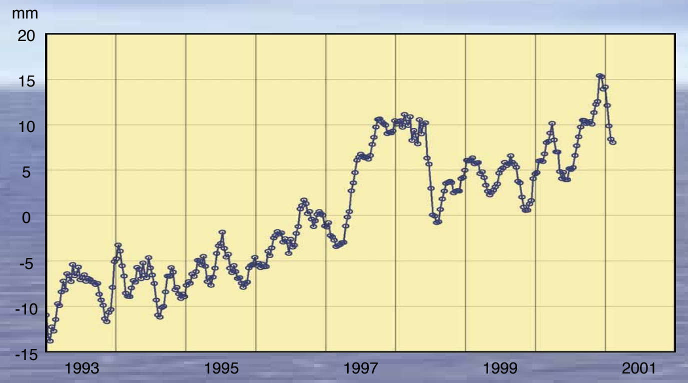
The very first measurements of sea level were made by monitoring tides in the 18th century. Although we now have a relatively dense network of tide gauges, only 20 stations, mostly along the coasts of Europe and North America, collected data throughout the 20th century. On the basis of their measurements, sea level is estimated to have risen by 10 to 20 centimetres since 1900.



The global coverage of altimetry satellites (b) such as TOPEX/POSEIDON and Jason-1 gives us the ability to monitor what is happening at sea, and not only along coastlines as tide gauges do (a).

Measuring oceans to the millimetre

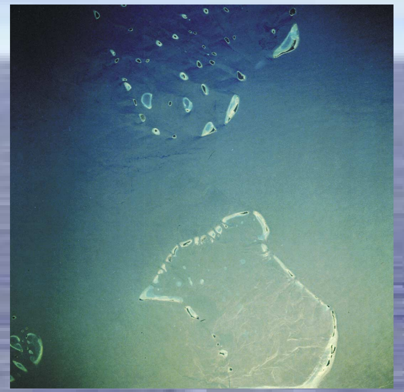
Since the early 1990s, altimetry satellites have been keeping a constant watch over the oceans. TOPEX/POSEIDON continuously measures sea level variations with an accuracy of about 0.5 millimetres over a year. These measurements reveal that the mean level of the oceans has been rising 2.5 millimetres a year since 1993.



Mean sea level variations seen by TOPEX/POSEIDON.

Regions under threat

A large proportion of the world's population lives in coastal areas vulnerable to rising sea level. Permanent submersion, repeated flooding, faster erosion of cliffs and beaches, and increasingly saline estuaries and salt contamination of groundwater are just some of the possible consequences of a big rise in sea level in low-lying regions.

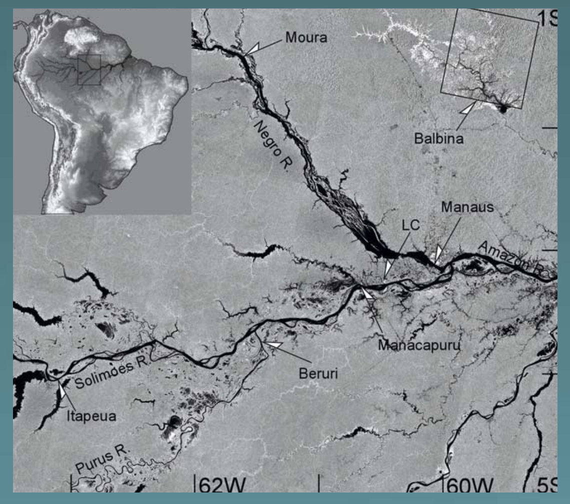


Islands such as the Maldives, where the highest point is often no more than 10 metres above sea level, are among those most under threat from rising sea level.

Rising seas are only part of the story

The rise in the level of the oceans is far from uniform. In fact, while in certain ocean regions the sea level has indeed risen (by up to 20 millimetres a year in places), in others it has fallen an equivalent amount. These regional differences, observed by TOPEX/POSEIDON since 1993, mostly reflect sea level fluctuations over several years.

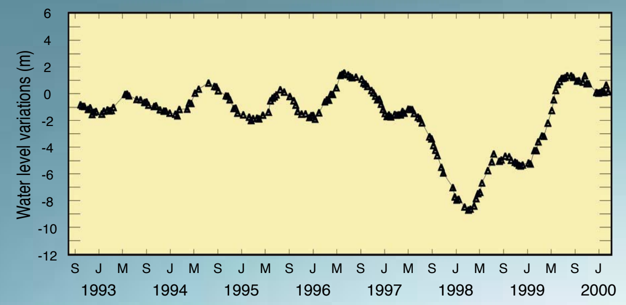
The Amazon under close surveillance



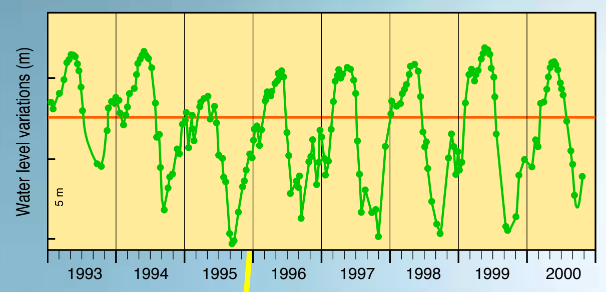
Radar mapping of the Amazon basin

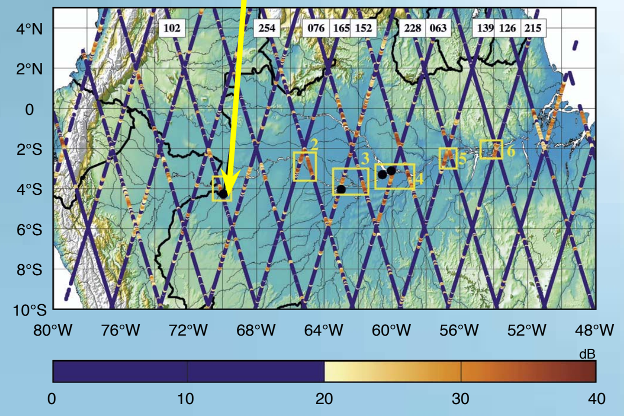
The Amazon is the world's largest river system, but it is poorly understood because few in-situ measurements from its remote regions are available. Altimetry satellites are now being used to monitor its water level variations, permanent and temporary flood zones, and various other parameters. Artificial dams such as Balbina reservoir are also being monitored. For example, in 1997 drought brought on by the strong El Niño event that year led to a big drop in water levels in the Amazon Basin.

Variations of the Balbina reservoir. During the strong El Niño 1997-98, drought conditions in the northeastern regions lead to a marked fall of water level, and to the break-out of forest fires (International Program LBA).

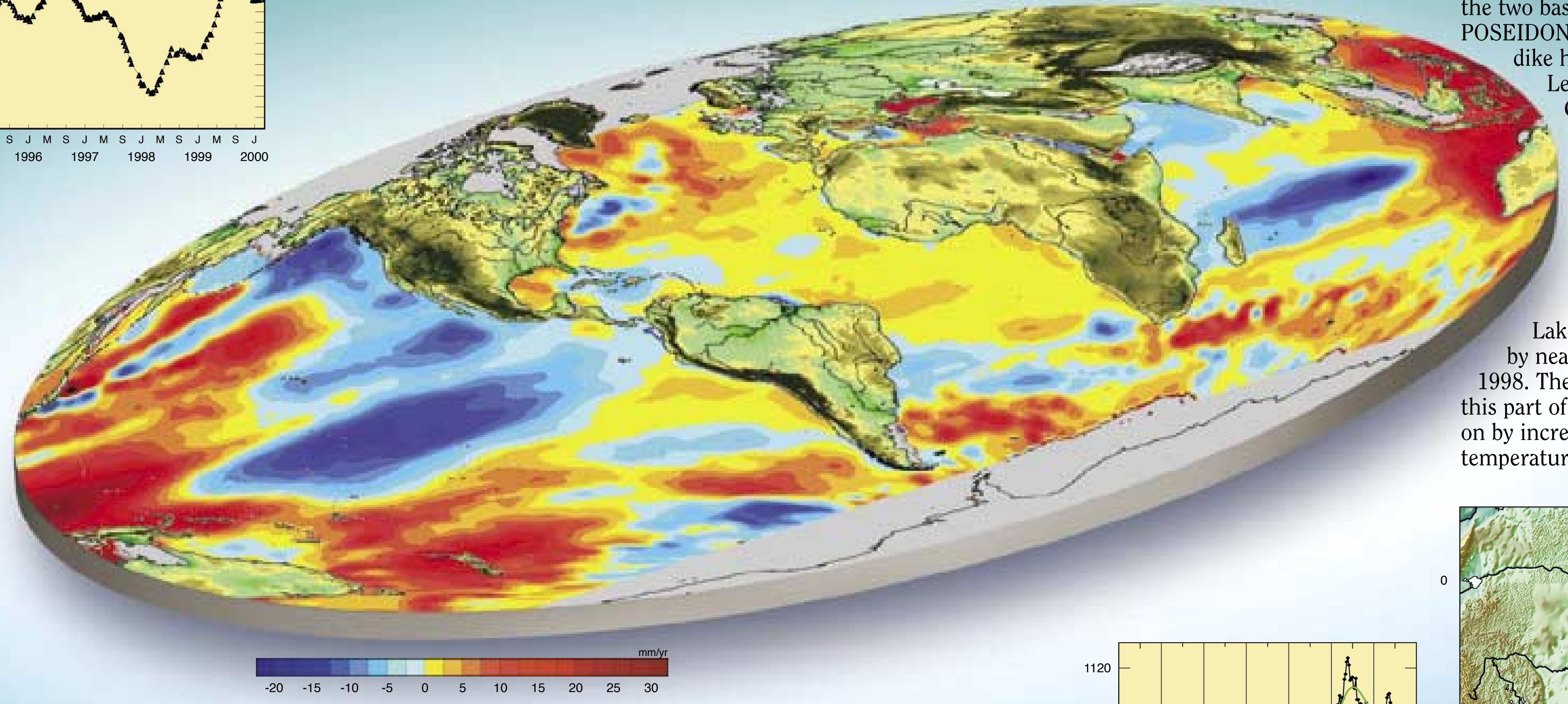


Water level variations since 1993 on the upper part of the Amazon, over the TOPEX/POSEIDON ground track #102



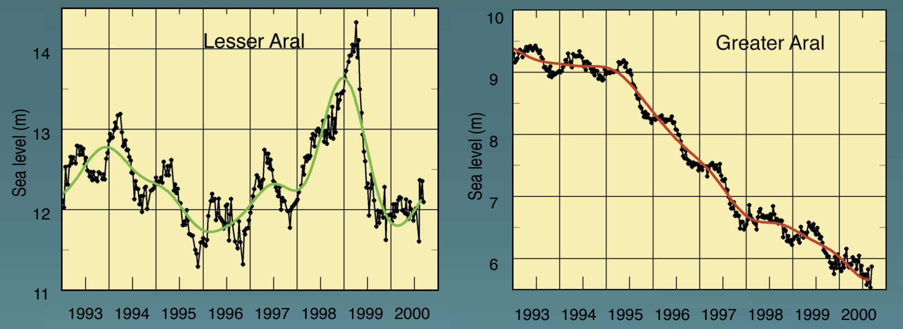


TOPEX/POSEIDON ground tracks over the Amazon basin. Yellow and red indicate flooded regions, where the altimeter radar beam is well reflected.



Map of differences in sea level variations between 1993 and 2000, seen by TOPEX/POSEIDON

The shrinking Aral Sea

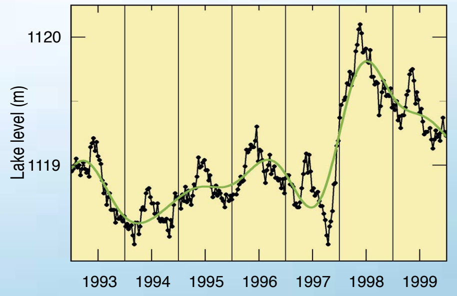


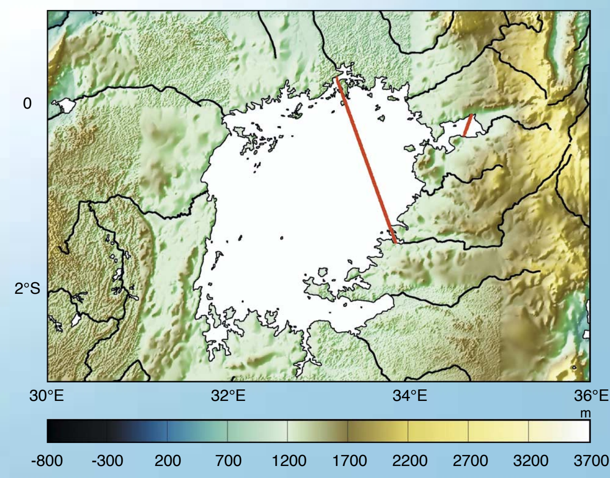
The Aral Sea, currently split into two basins and the water level variations of those basins (left, the Lesser Aral, right, the Greater Aral).

The level of the Aral Sea has fallen 17 metres since the start of the 1960s as the two rivers draining into it have been diverted to irrigate cotton fields. Today, the Aral Sea has split into two basins: the Greater Aral to the south, and the Lesser Aral to the north. Between 1996 and 1999, the Lesser Aral began to rise following the construction of a dike between the two basins. But in 1999, TOPEX/POSEIDON again observed a sharp drop: the dike had given way and water from the Lesser Aral was flowing into the Greater Aral.

Lakes swollen by rains

Lake Victoria, in East Africa, rose by nearly one metre between 1997 and 1998. The rise that affected all lakes in this part of the continent was brought on by increased rainfall due to higher temperatures in the Indian Ocean.





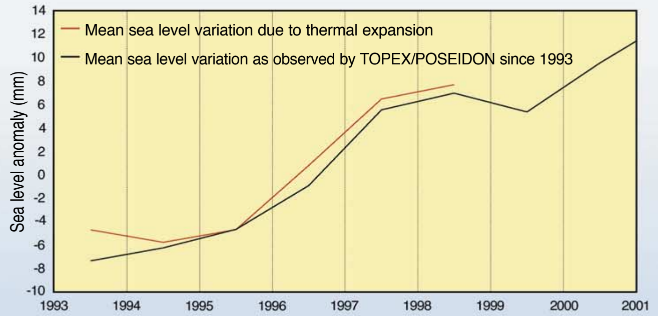
Lake Victoria (red line: TOPEX/POSEIDON ground track) and its water level variations.

What is causing sea level to rise?

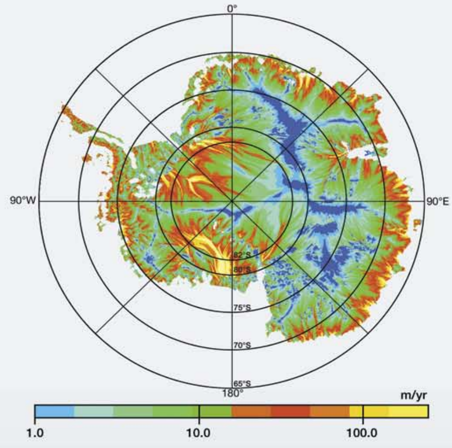
Variations in the global mean sea level, as well as local variations in lakes and landlocked seas, are mostly due to climate fluctuations. A rising trend linked to global warming is emerging.

Temperature variations

Sea level variations closely mirror changes in water temperature. As water warms, it expands and its volume increases, causing levels to rise. The effects of global warming thus make themselves felt in the oceans within a few years.



Ocean temperature fluctuations are by far the biggest factor explaining variations in the global mean sea level measured by TOPEX/POSEIDON since 1993.

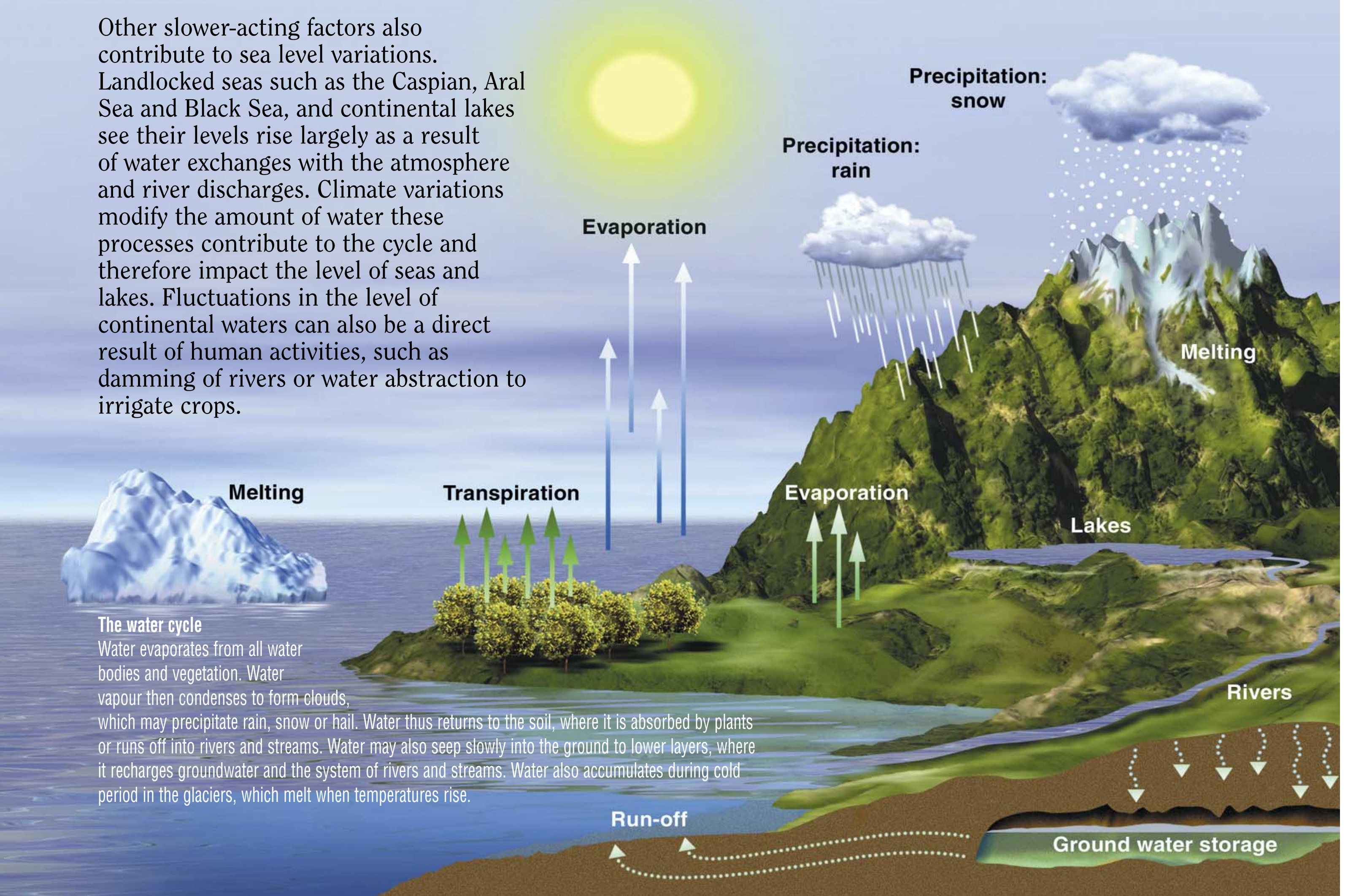


Ice flow velocities in Antarctica, derived from ERS-1 topography measurements. Very-fast-flowing "rivers of ice"—reaching velocities of up to one kilometre a year, comparable to the speed at which glaciers are moving in the Alps and the Andes—have been observed deep inside the continent.

Variations in the mass of the polar ice caps in Greenland and Antarctica also affect sea level. For the time being, increased snowfall caused by rising temperatures seems to be offsetting faster melting of ice along the coasts. However, most mountain glaciers are receding. Melting glaciers were a significant factor in rising sea levels observed over the 20th century.

Water exchanges

Other slower-acting factors also contribute to sea level variations. Landlocked seas such as the Caspian, Aral Sea and Black Sea, and continental lakes see their levels rise largely as a result of water exchanges with the atmosphere and river discharges. Climate variations modify the amount of water these processes contribute to the cycle and therefore impact the level of seas and lakes. Fluctuations in the level of continental waters can also be a direct result of human activities, such as damming of rivers or water abstraction to irrigate crops.



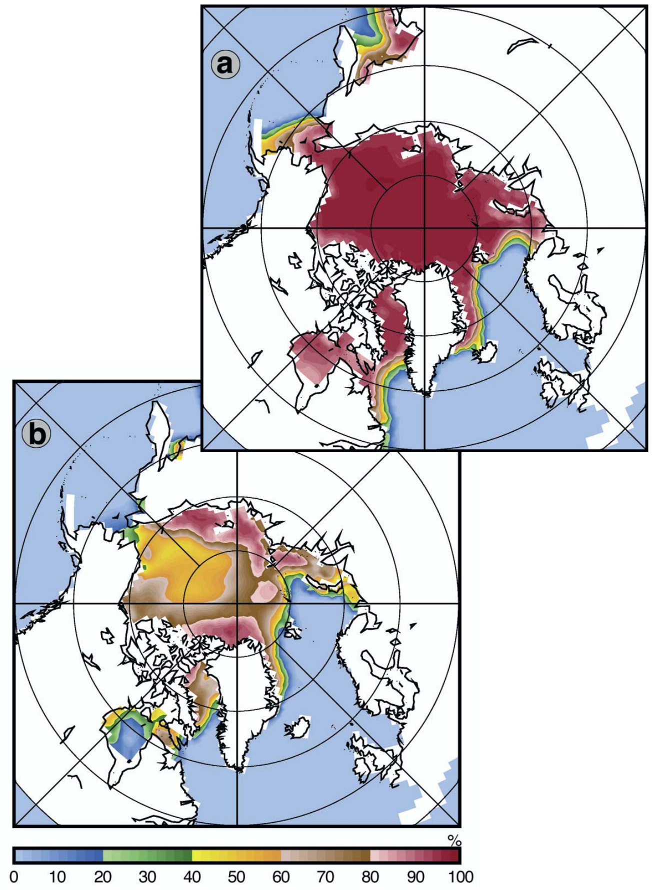
The water cycle
Water evaporates from all water bodies and vegetation. Water vapour then condenses to form clouds, which may precipitate rain, snow or hail. Water thus returns to the soil, where it is absorbed by plants or runs off into rivers and streams. Water may also seep slowly into the ground to lower layers, where it recharges groundwater and the system of rivers and streams. Water also accumulates during cold period in the glaciers, which melt when temperatures rise.

Long-term climate prediction

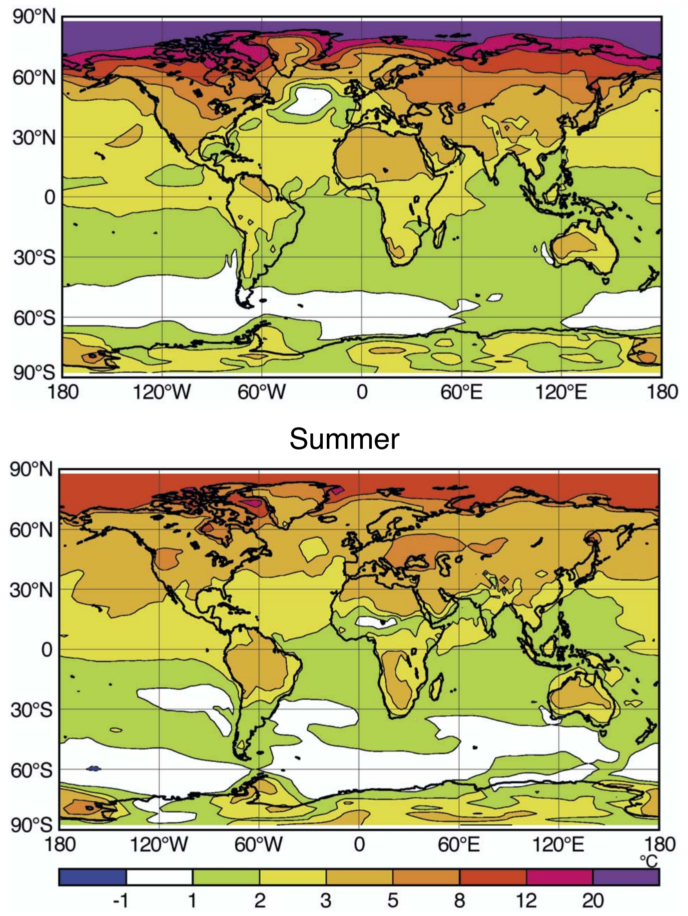
How far sea level will vary in the future is a vital question that is closely linked to climate change. Long-term climate prediction models are now being developed to provide answers.

Rising sea level is a major consequence of the rising global temperatures observed in recent decades. Climate prediction models indicate that the planet's mean temperature will continue to climb in the century ahead, as a result of probable higher concentrations of greenhouse gases—carbon dioxide, methane and water vapour—in the atmosphere. These same models forecast that by 2100 the mean sea level will be about 40 centimetres higher than it is today, although with a sizeable error margin of 20 centimetres either way. They also predict that this rise will not be uniform across the globe, occurring faster in some regions than others. However, there are still some significant disagreements between models surrounding regional sea level variations in the coming decades.

Altimetry satellites are pursuing their constant watch over the world's oceans alongside scientists working to model the impacts of global warming on sea level.



Mean percentage of Arctic sea ice cover in March for 1950-1979 (a) and 2070-2099 (b), calculated by the Météo-France climate model. Warming is amplified by varying reflection of the Sun's rays. Receding ice cover reduces surface reflectivity in summer, which in turn increases the amount of solar energy absorbed by the ocean surface, thus delaying winter ice formation.



Sea surface temperature variation for 2070-2099 in comparison with 1961-1990, in winter and summer, calculated by the Météo-France climate model. Temperature could rise by 10°C in some zones, while remaining stable in others. This fact is explained partly by changes in ocean circulation reducing the transport of warm water from the Equator.

Creation-conception: CLS / Design: Active Design / Publisher: CNES 2001

For more information:
AVISO/Altimetry: http://www-aviso.cnes.fr
Climate change (IPCC) : http://www.ipcc.ch/

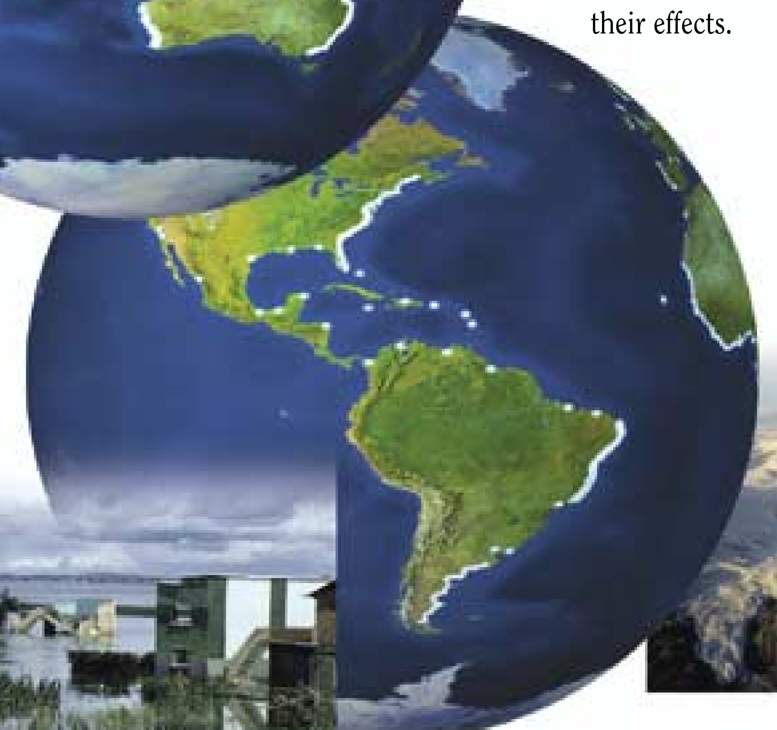
Sources:
CLS, CNES, CNRM/Météo-France, CNRS/LEGOS, IPCC, NASA/GSFC, UCLA/D. Alsfdorf

Observing the oceans from space

Altimeters chart water levels

Are we in danger of being flooded out in the not-too-distant future? As global temperatures rise, mean sea level is rising with them to threaten low-lying regions around the world. At local scale, there are fears that lakes and seas could begin to shrink like the Aral Sea. Whatever the underlying trends, we must prepare for the significant human, ecological and economic impacts of these variations.

Altimetry satellites such as TOPEX/POSEIDON and Jason-1, providing sea level measurements stables within 0,5 mm over a year, are a crucial aid for observing variations in mean sea level. With time series of ten years of data and more, we can confirm trends and attempt to mitigate their effects.



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