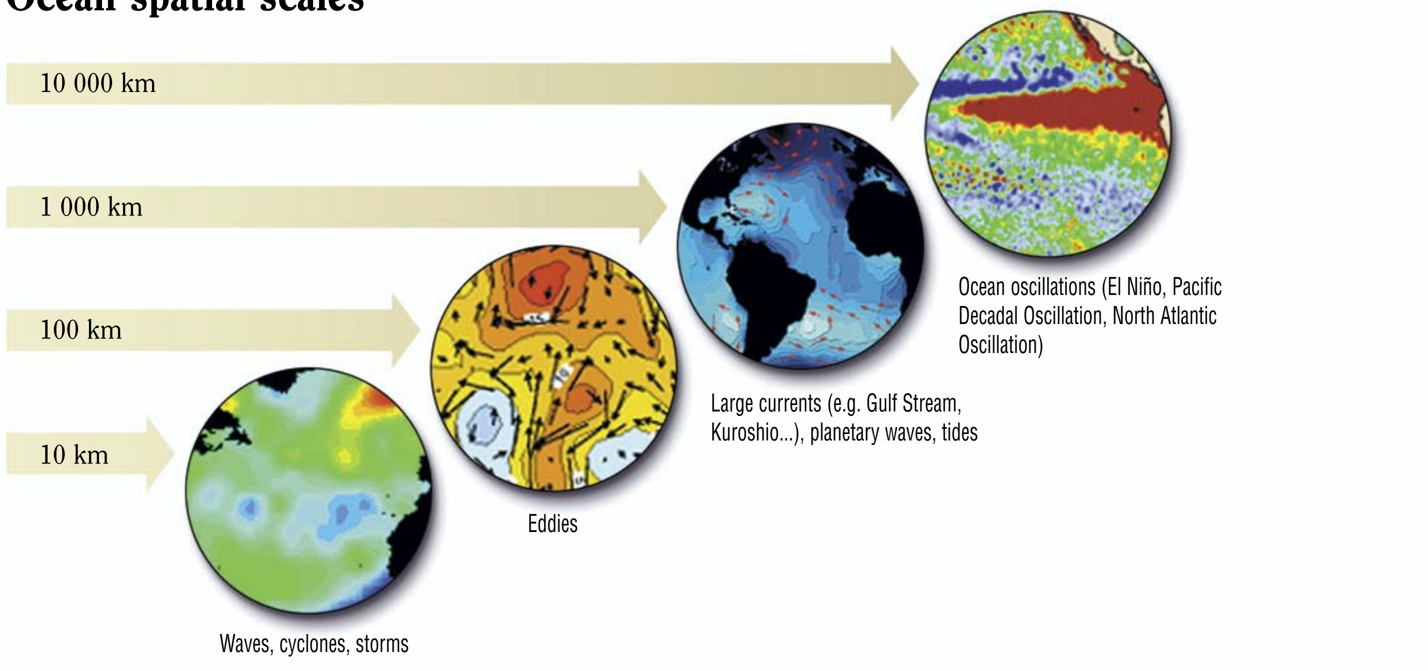
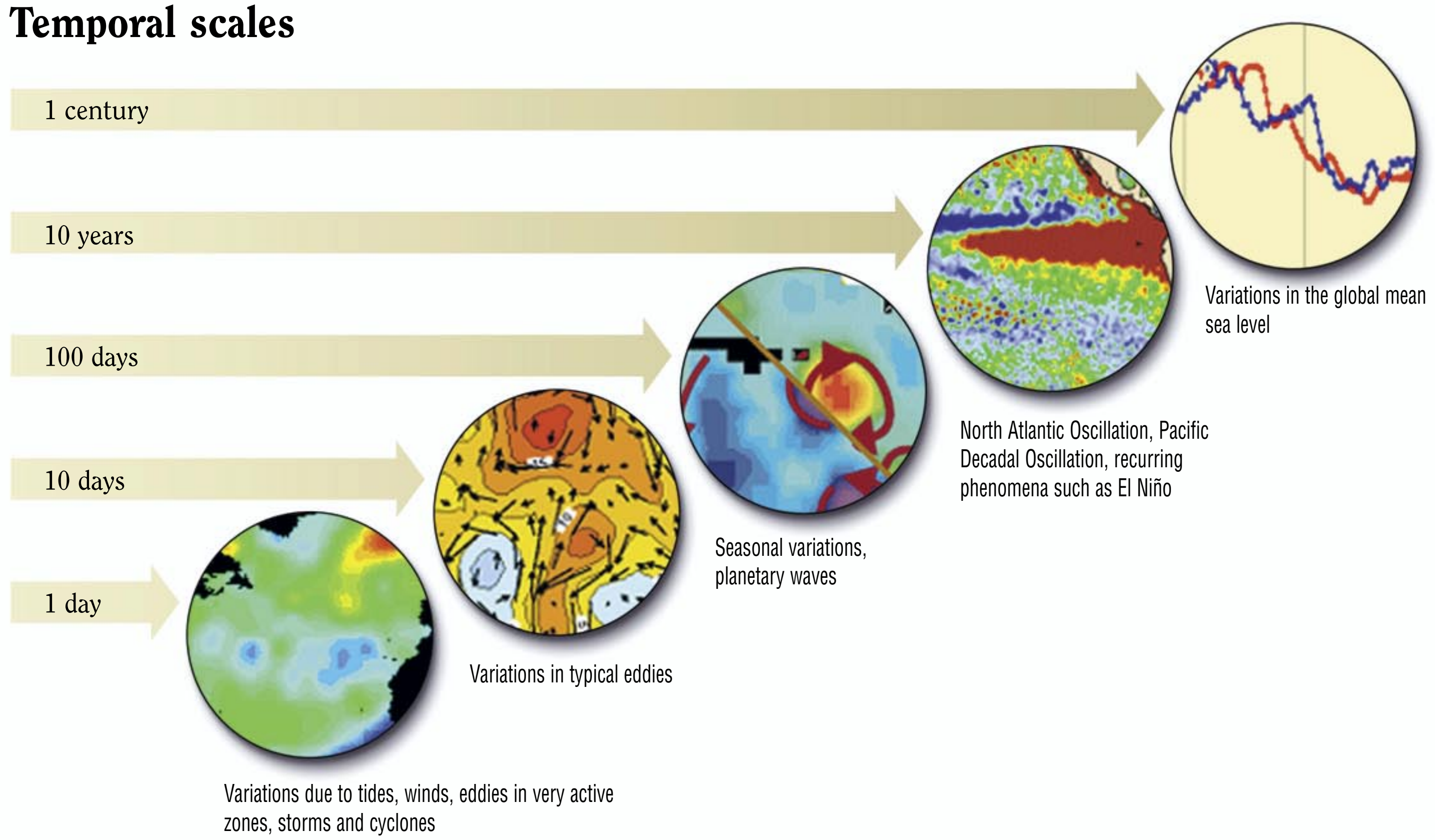
A multi-faceted ocean

Scientists sound the rhythms and variations of an ocean in perpetual motion through continuous observation. These variations impact zones both large and small. Altimetry reveals many of the ocean's underlying mechanisms by supplying frequent measurements of sea surface height across the globe, accurate to within a few centimetres.

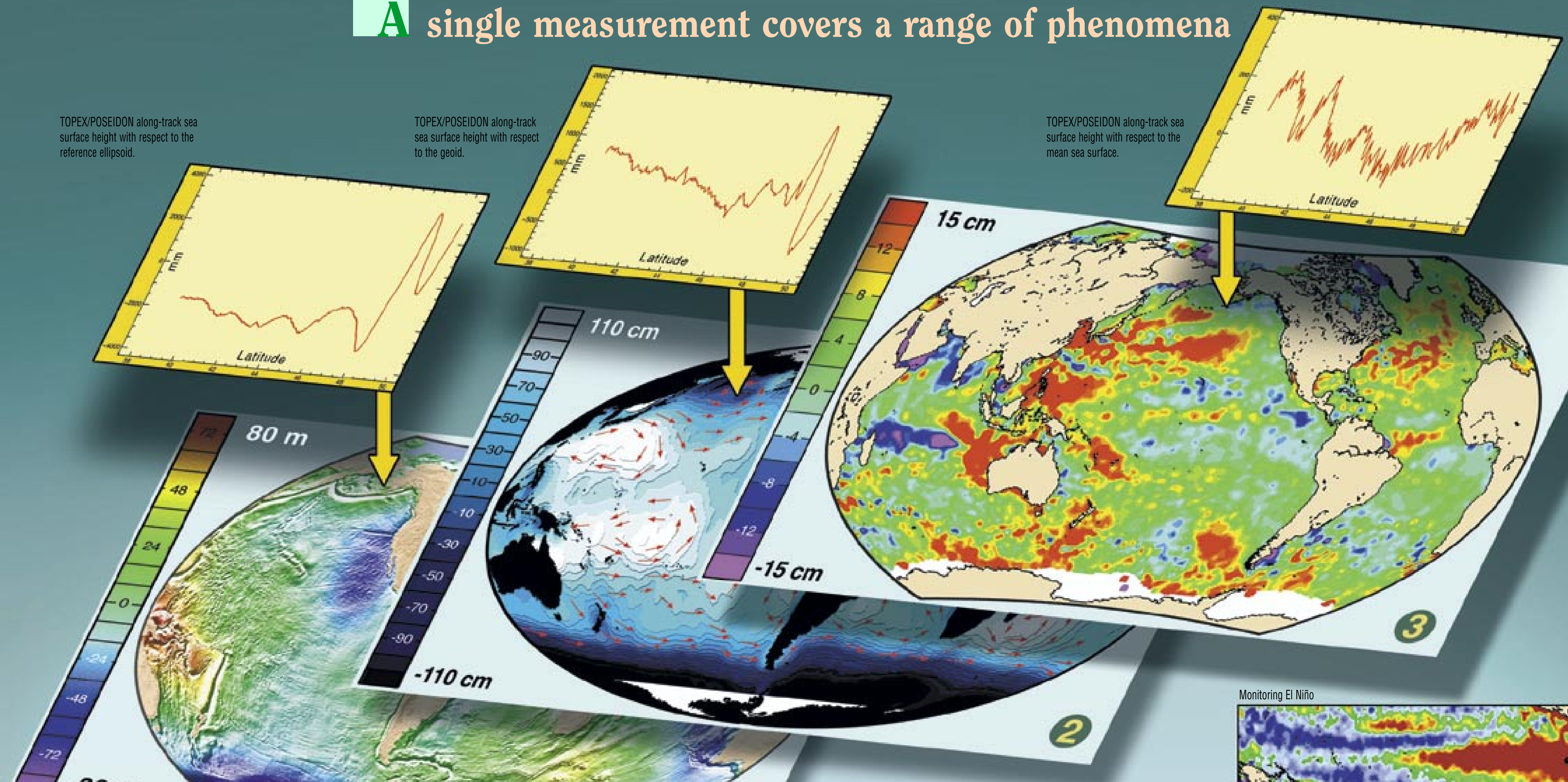
Ocean spatial scales

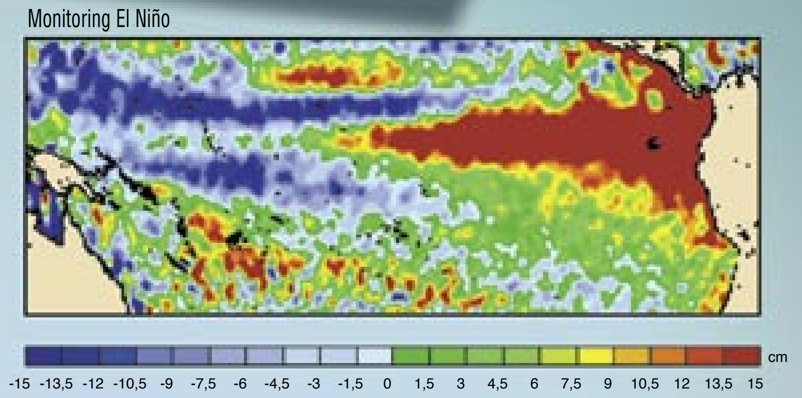


Temporal scales



A single measurement covers a range of phenomena

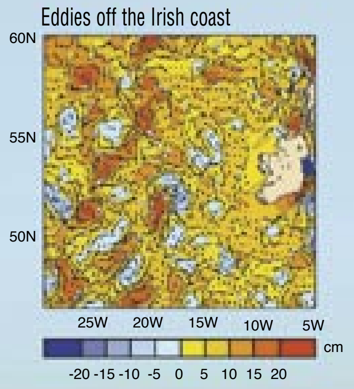


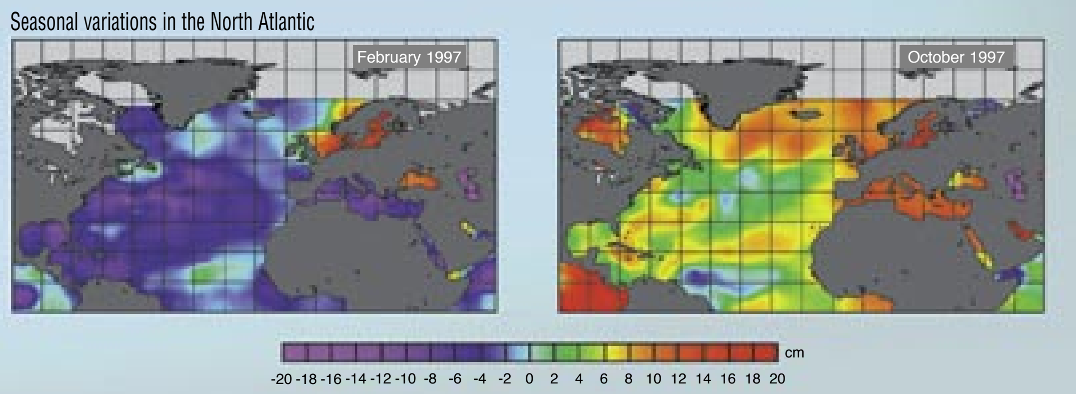


1 The radar beam from the satellite scans the ocean surface, detecting variations in relief of up to 80 metres in places. Ocean relief, which is stable, is shaped by the geoid—the surface normal to the direction of the Earth's gravity field. At smaller scales, but still included within the geoid, hills and valleys on the sea surface of the order of one metre reflect peaks and trenches as high and as deep as one kilometre on the seafloor.

2 In addition to the geoid's impact on sea level, the major ocean currents such as the Gulf Stream, Kuroshio and Antarctic Circumpolar Current generate variations in ocean relief of about one metre.

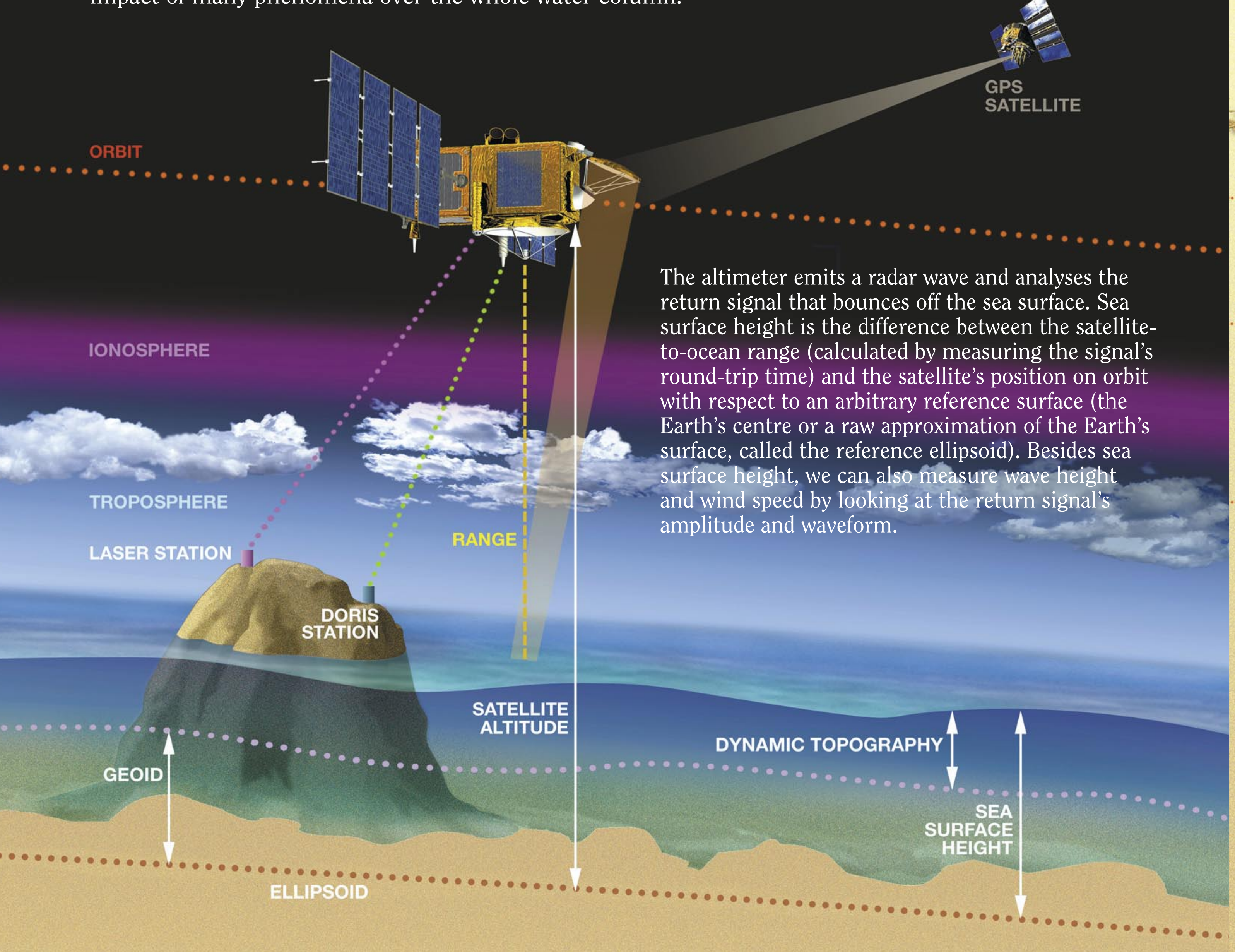
3 The geoid and the major ocean currents form what is termed the mean sea surface (MSS), which varies very little. But sea level around the globe is far from constant, exhibiting anomalies of about ten centimetres with respect to the MSS that we can detect from altimetry measurements. These sea level anomalies (SLAs), driven by eddies, seasons or phenomena such as El Niño spanning several years, are the main focus of attention for physical oceanographers today.



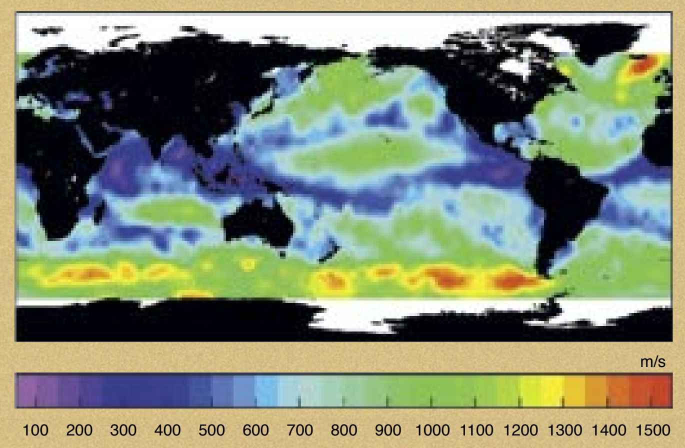


How altimetry works

The one major drawback of observing the oceans from space is that electromagnetic waves emitted and received by the satellite do not penetrate far beneath the sea surface. Altimetry satellites do measure range from the satellite to the surface, but the estimated sea surface height also comprises the cumulative impact of many phenomena over the whole water column.



The altimeter emits a radar wave and analyses the return signal that bounces off the sea surface. Sea surface height is the difference between the satellite-to-ocean range (calculated by measuring the signal's round-trip time) and the satellite's position on orbit with respect to an arbitrary reference surface (the Earth's centre or a raw approximation of the Earth's surface, called the reference ellipsoid). Besides sea surface height, we can also measure wave height and wind speed by looking at the return signal's amplitude and waveform.

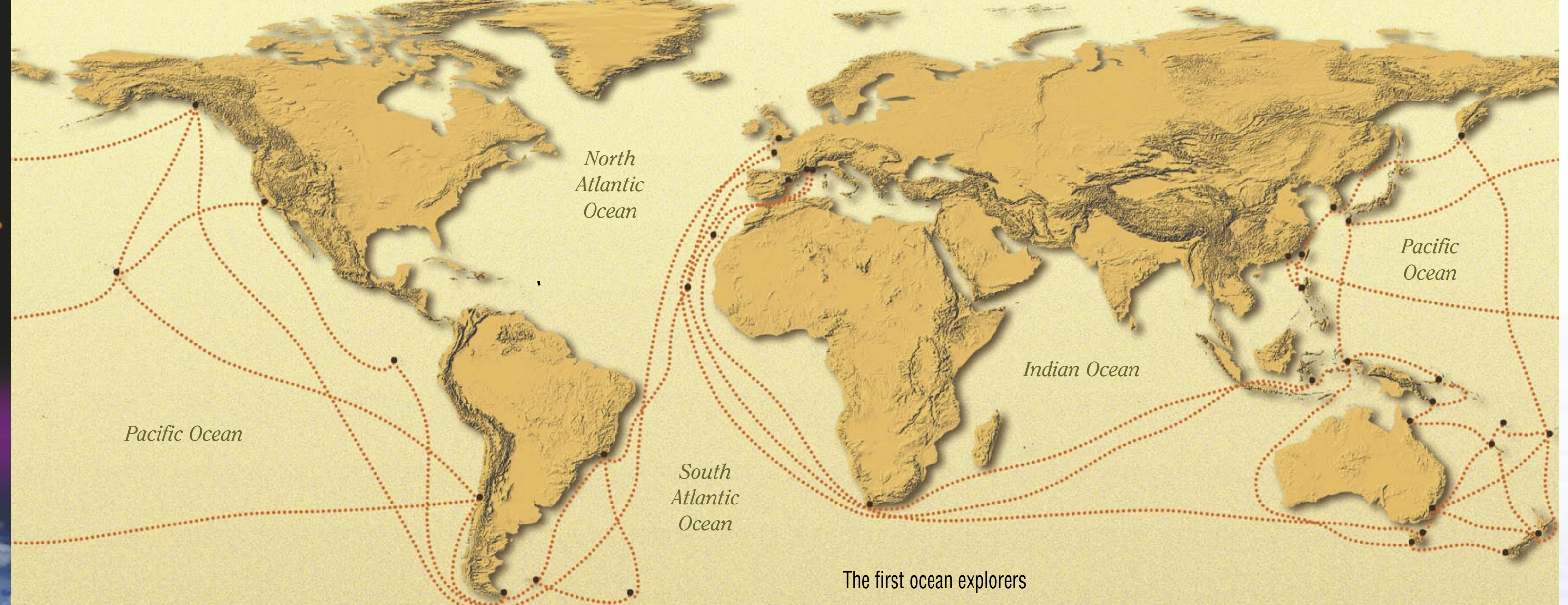


Wind speed measured by TOPEX/POSEIDON

Performing all these measurements and calculations may look easy on paper, but in practice things are more complex. To obtain measurements accurate to within centimetres over a range of several hundred kilometres requires an extremely precise knowledge of the satellite's orbital position. Location systems such as DORIS can reduce the uncertainty on positional data to just two centimetres. Any perturbation on the radar signal also needs to be taken into account. Water vapour and electrons in the atmosphere, sea state and a range of other parameters can affect the signal round-trip time, thus distorting range measurements. We can correct for these perturbing effects on the altimeter signal by measuring them with supporting instruments or at several frequencies, or by modelling them.

Securing the future of satellite altimetry

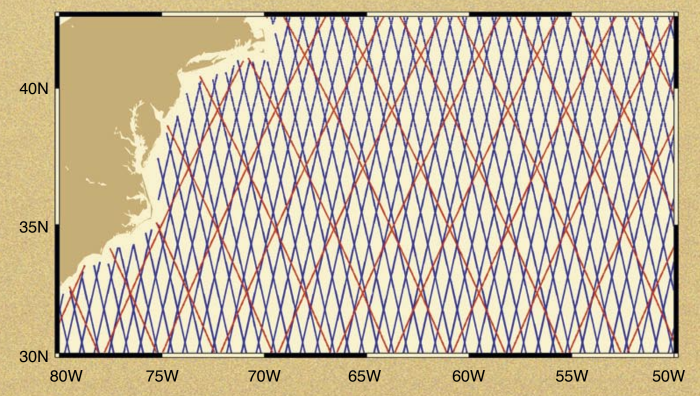
Satellite altimetry started out in the 1970s and 1980s, but it was not until the launch of TOPEX/POSEIDON in 1992 that the technique really came of age, delivering sea surface height measurements accurate to a few centimetres. The Jason series of satellites now poised to take over from TOPEX/POSEIDON and continue its mission is based on a new design and miniaturized instruments. Other missions scheduled or in development will operate alongside Jason to give us a truly permanent ocean observatory.



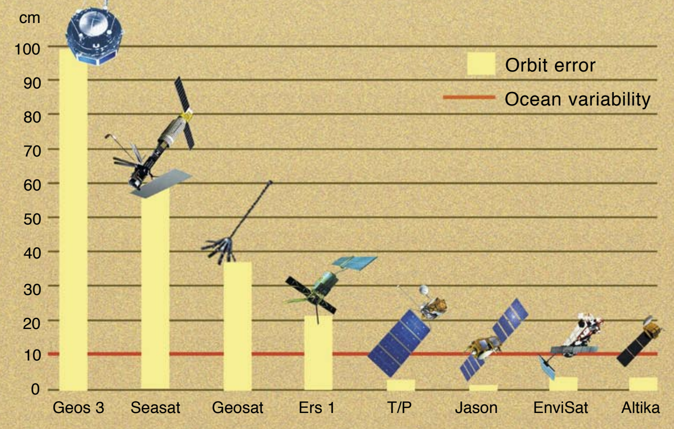
The first ocean explorers

Ocean observation has a long history. In fact, it probably all started with the very first boat to take to the seas. Today, an altimetry satellite such as TOPEX/POSEIDON can gather more data on ocean circulation in ten days than sailors were able to compile over several centuries. And because a satellite revisits the same point on the globe every ten days, we can even track ocean variations in near-real time.

Thanks to its superb accuracy, TOPEX/POSEIDON has made it possible to observe phenomena with an amplitude of no more than one centimetre across entire ocean basins. With the Jason series now ready to assume its mantle, continuity of observations is assured. But we still need to observe more of the ocean, more often. The combination of the TOPEX/POSEIDON and ERS satellites has moved us closer to this goal by acquiring more measurements and increasing spatial coverage. In the years ahead, Jason-1 and ENVISAT will continue to pursue this combined mission. Possible solutions now being studied for the future could deploy constellations of low-cost altimetry satellites and employ new instrument concepts.



Combined measurements from two altimeters, one (Jason-1, in red) with a short revisit cycle and a widely spaced grid of measurement points, the other (EnviSat, in blue) with a tighter grid but a longer revisit interval of 35 days.



Improvements in measurement accuracy since the first satellite altimetry missions now allow us to observe ocean variations at close quarters.

To find out more:

AVISO/Altimetry: http://www-aviso.cnes.fr

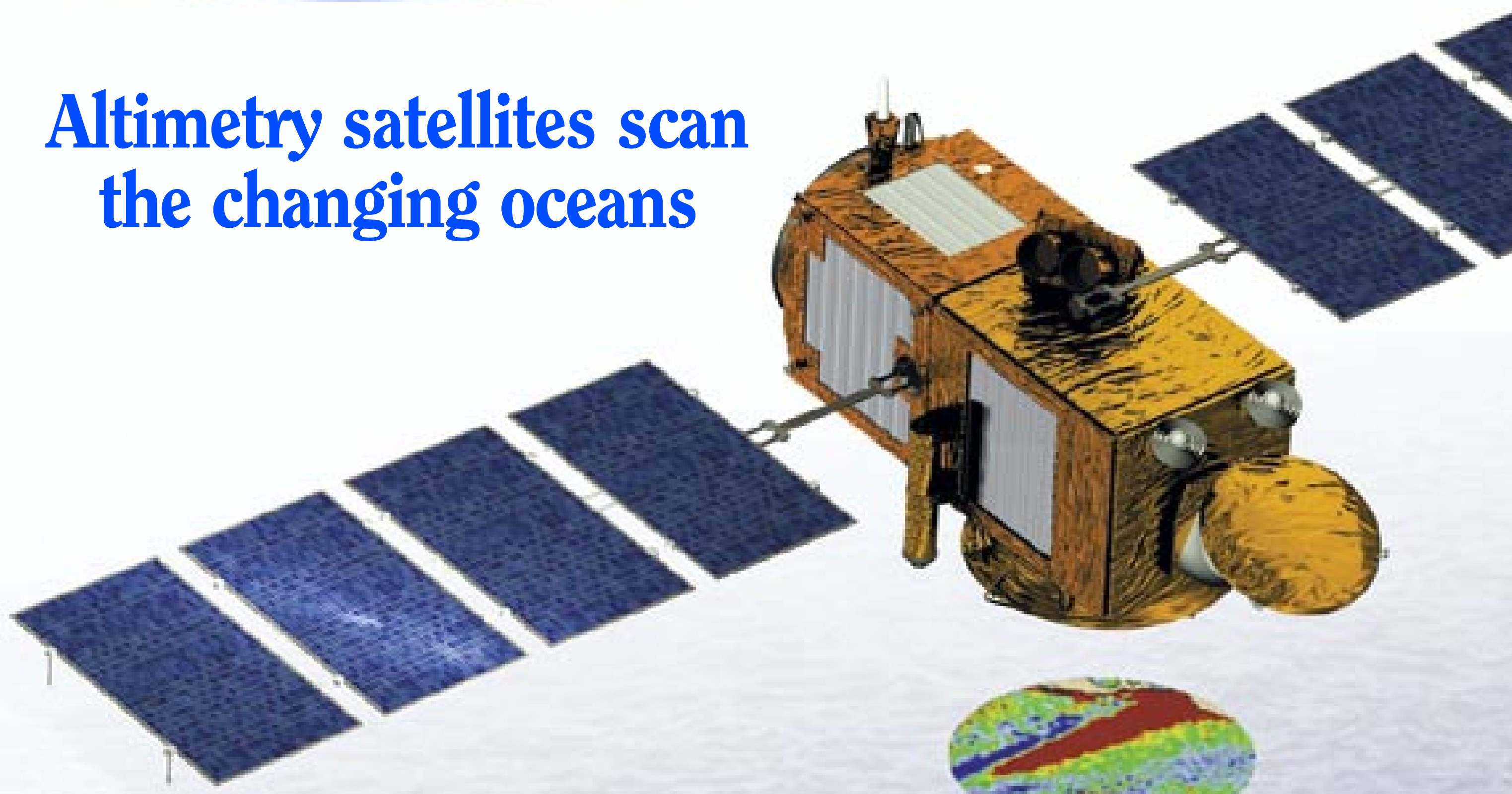
Sources:

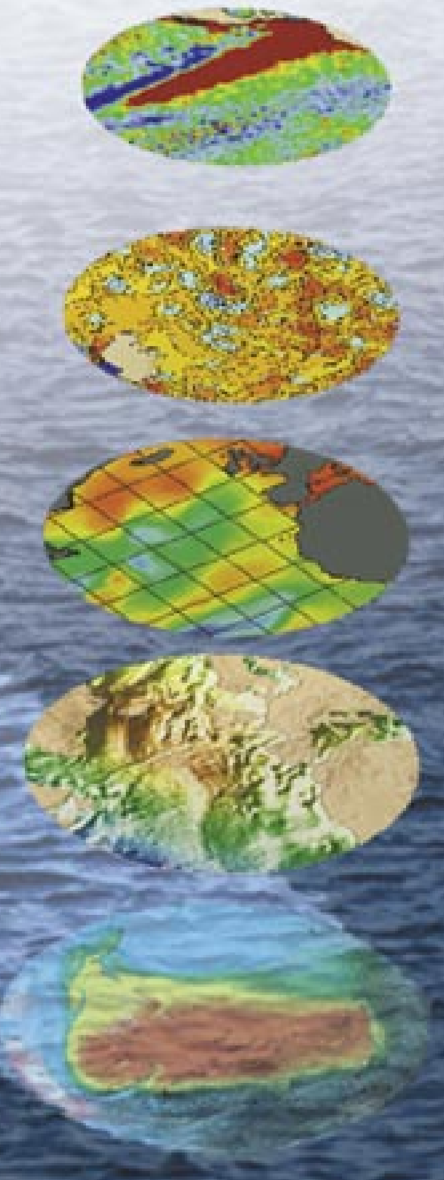
CLS, CNES, CNRS/LEGOS, NASA

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

Observing the oceans from space

Altimetry satellites scan the changing oceans





The unfathomable depths of the oceans have always fascinated humankind. Today, we are beginning to unravel the mysteries that lie behind the oceans' shifting patterns, in particular thanks to radar altimeters scanning the sea from space. Radar altimetry allows us to measure sea surface height very accurately and thus obtain a wealth of information about ocean dynamics. Ocean circulation variations, wave heights, wind speed and tides are key indicators that are helping us to better understand the oceans and predict trends.

The first altimetry satellites launched in the 1970s and 1980s proved that radar altimetry was a workable concept. But it was their successors in the 1990s that revealed the full potential of this technique, taking measurement accuracy to new levels. The challenge facing us now is to conceive new missions which, together or alone, will give us the capability to monitor the oceans even more closely.

National Aeronautics and Space Administration Jet Propulsion Laboratory

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