OceanSITES
Taking the pulse of the global ocean

Continuous measurements from the deep ocean in real time
OceanSITES are long-term buoy and ship stations that measure many aspects of the oceans’s surface and depths using advanced sensors and satellite telemetry. Since 1999, an international science team has shared data and costs in order to capitalise on the enormous potential of these instruments. The growing network now consists of about 10 surface and 30 subsurface OceanSITES monitoring the global ocean.

A Host of Sensors
OceanSITES stations offer stable platforms from which to deploy a wide range of instruments. Variables measured include:

**Meteorology**
- Precipitation
- Wind speed and direction
- Air and sea-surface temperature
- Humidity
- Barometric pressure
- Solar and infrared radiation
- Surface waves

**Climate**
- Air-sea fresh water exchange
- Air-sea heat exchange
- Air-sea gas exchange

**Physical oceanography**
- Current speed and direction
- Water temperature
- Salinity
- Transport of water
- Volume of deep ocean currents

**Biogeochemistry**
- Nutrients
- Organic sediments
- Dissolved inorganic carbon
- Oxygen
- Chlorophyll

**Carbon cycle**
- Carbon dioxide pressure in air and water

**Biology**
- Phytoplankton
- Zooplankton
- Fish stocks

**Geophysics**
- Seismic movements
- Magnetism

OceanSITES is watching... measuring... and looking forward.

Every year, more than 6 billion tonnes of carbon emissions flood into the atmosphere or dissolve into the ocean. Warm air billows from tropical waters, turning thunderstorms into raging hurricanes. Fish stocks seeking cold ocean waters retreat toward the poles. Arctic ice thins each summer, burying the salty northern oceans under a layer of fresh water. Earthquakes and volcanic eruptions jar the sea floor. As the world reacts to a changing ocean, scientists are working hard to find explanations and to predict what else lies in store. Thanks to the explosive pace of modern technology, many of the right tools are now in their hands. Satellites watch the sea surface; Argo drifters measure temperature and salinity in the upper ocean; automated samplers measure plankton and nutrients. But the major remaining challenge is also one of the most basic: the ocean is immense, inaccessible and always in motion. Tracking the key variables important to climate, ocean chemistry and fisheries as they change over seasons and decades is a longtime goal that is only now coming within reach.

At present fewer than 150 permanent deep-water observatories report air and sea conditions for the entire world’s oceans. Europe alone, at only 1/35th the size, has about 10 times that many weather stations on land.

It’s a critical challenge, because when it comes to shaping our planet, the open ocean is a far more powerful force than dry land. The ocean’s global influence extends from regulating climate, to feeding the fish that feed the world, to carrying the storms and tsunamis that threaten our mariners and coastlines. Monitoring the entire ocean over long time periods is an ambitious proposal. The OceanSITES team—more than 100 scientists from two dozen nations—puts planning at the forefront to make the work economically feasible. To deliver the maximum possible data out of each station, OceanSITES scientists plan to:

- Secure long-term support for existing OceanSITES stations;
- Upgrade stations with new sensors to record a host of physical, chemical and biological variables, enabling cross-discipline comparisons;
- Install new stations in key regions of the globe to collect long-term records for the first time;
- Rapidly distribute the data stream over the Web—for use by the OceanSITES team, the larger scientific community and the public;
- Refine existing sensors and develop new ones to usher in continuous surface measurements in even the most brutal sea conditions.

By studying key regions, OceanSITES scientists can unravel puzzles for the entire ocean. Long-term observations at these sites will give researchers the background they need to recognise complex patterns amid the ocean’s immense variability. With proper international support, it’s a fully achievable goal.

The next great leap in understanding our planet’s ocean will come from measuring more of it, more precisely, and for longer periods than ever before.
Oceanographers ask complex questions: What happens when the wind and sea trade heat, water and momentum? How much carbon dioxide do ocean plants use? How do fish stocks relate to nutrient cycles? Answering those interrelated questions requires tools to match. That’s the rationale behind the Global Ocean Observing System, after spending 30 years studying ships’ logs and ocean currents.

1876 After 4 years, the HMS Challenger finishes the first oceanographic research voyage. The final report takes 50 volumes and 20 years to write.
1900 On the Atlantis, Alexander Agassiz maps unknown parts of the Pacific, sampling the sea floor and water column along the way.
1925-27 Georg Wüst explores the Atlantic, aboard the Argo, mapping deep currents, salinity and temperature in unprecedented detail.
1940 Ships in the Ocean Weather Station program begin collecting continuous data from 46 spots in the open ocean. The program lasts until 1980, when satellite imagery replaces it.
1960-70s First subsurface moorings, then surface moorings begin to appear in the deep ocean.
1972 The Goethes voyages begin. Over 6 years, researchers make the first maps of radioisotopes in the Atlantic, Pacific and Indian oceans.
1982 Devastating El Niño weather causes $13 billion in damages and spurs governments to build a long-term buoy array across the equatorial Pacific.
1990 Scientists and ships from 10 nations pitch in for the World Ocean Circulation Experiment (WOCE), a decade-long effort to map ocean circulation.
1991 UNESCO forms the Global Ocean Observing System to promote international work on ocean observations.
1999 St. Raphael, France: oceanographers envision a global system of “Eulerian observatories,” eventually renamed OceanSITES.
2000 The Argos satellite kicks off with a global system of 3,000 drifting Argo drifters to map ocean currents.
2004 The devastating Indian Ocean Tsunami highlights the need for improved tsunami warning.
2015 The Global Earth-Observing System of Systems (GEOSS) finishes implementing its 61-nation vision of advanced sensors and modems to study the ocean in new ways.

Milestones in Ocean Observations

OceanSITES is part of a long history of oceanic exploration. Technological advances along with our need to preserve and protect ocean resources makes sustained support of OceanSITES an important choice for our future.
Putting eyes in the deep ocean

OceanSITES buoys stay fixed in place for a year or more between maintenance visits. During that time, their cargo of instruments automatically collects the kind of data that a shipful of scientists would normally measure.

Under the waves, the buoy’s mooring line carries more instruments. Wiring embedded in the line carries data back to the surface and out to a satellite. Scientists choose from sensors like the ones drawn here and use surface or subsurface buoys, research ships or robotic vehicles based on their specific research goals.

Instruments in the hull record sea temperature, salinity, oxygen content and carbon dioxide. Current meters record current speed, direction, temperature and salinity to produce a motion picture of flow and mixing in the water column.

Acoustic Doppler current profilers emit high-pitched pings and measure their echoes to calculate current speed at regular intervals in the water column.

Other systems record dissolved oxygen, light levels, photosynthetic activity and nutrients like nitrogen, phosphorus and silica.

Engineers build an S-bend in the mooring line to reduce the tension between anchor and buoy during heavy seas.

Bottom pressure recorders can sense the pressure from a passing tsunami wave, then beam a warning to a surface buoy.

Seismometers measure earthquakes in the sea floor.

Meteorological sensors atop a surface buoy provide data for calculating heat, water and momentum exchange between air and ocean. The self-reliant buoys carry batteries, solar panels, two satellite transmitters (in case one fails) and a GPS locator.

Data centres receive buoy data, check quality and serve calibrated data to the Internet.

Research ships sample water for in-depth biogeochemical analyses.

Subsurface buoys are good choices for studying the deep ocean. These moorings aren’t exposed to surface waves, so they get much less wear and tear than surface buoys.

Submersible incubation devices incubate sea water samples to measure phytoplankton productivity.

Remote access samplers automatically do routine prep work, like filtering sea water, and then store the samples in individual jars to be analysed for nutrients, phytoplankton or zooplankton.

Acoustic tomography sends sound waves long distances to calculate temperature and track warming across entire ocean basins.

Subsurface moorings are often deployed in pairs. One line supports a moored profiler, which crawls up and down the cable measuring temperature, salinity and currents. Instruments on the outer mooring measure different variables at fixed depths.

Sediment traps collect falling “marine snow” (dead organic matter). They provide key data on how carbon cycles in the ocean.

Magnetometers measure changes in the Earth’s magnetic field during earthquakes.

Transport sites measure water moving in important ocean currents. Rows of buoys placed in the deep ocean measure currents, temperature and salinity. The data help scientists calculate how much water is moving from one ocean basin to another.

Robotic gliders monitor precise locations on the fly, without requiring ship time or mooring hardware.

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The ocean and air constantly trade heat, water and chemistry

In 1954, ships monitoring “Station S” off Bermuda began recording basic ocean data twice per month. Fifty years later, the assembled data reveal a 0.5°C increase in ocean temperature per century more than a kilometre beneath the surface. The change would be imperceptible without decades of precise time-series measurements. The warmer deep waters, which are blanketed from the effects of transient warm spells, are vital evidence that our planet is warming.

The 1990s saw the realisation of the multi-national TAO array, spanning the entire breadth of the tropical Pacific. Just three years after its completion, the array paid off. Climatologists predicted impacts of the severe 1997-98 El Niño six months in advance. California alone saved more than $1 billion.

Climate work has focused on the equatorial oceans because they are a major engine in Earth’s climate machine. Tropical waters soak up enough energy each day to keep a high-output light bulb burning for every metre of ocean surface in all directions. Ocean currents born in the tropics carry heat toward the cooler atmosphere along the way.

Now, climate scientists are turning their attention to the cold, stormy seas of the north and south. The moorings that enable year-long buoy deployments in the tropics can’t yet stand up to a Southern Ocean winter. Building on the success of equatorial buoys, OceanSITES scientists are engineering a system of surface buoys that will be deployed in the challenging northern and southern oceans.

Heat isn’t the only commodity that ocean and air trade back and forth. Billions of tonnes of carbon dioxide dissolve into the ocean from the atmosphere every year. At select OceanSITES stations, scientists are now measuring the net transfer of carbon and other elements between the two systems. When carbon dioxide dissolves into the ocean, it stops adding to greenhouse warming. (About half of the world’s carbon dioxide emissions find their way into the ocean each year.) But ocean circulation is constantly bringing carbon-dioxide-rich deep water to the surface, where the gas re-enters the air. For scientists to know the net effect, they need precise measurements collected over years.

As well as simply dissolving into ocean water, carbon dioxide can enter the ocean when tiny plants and animals use the carbon to grow. As they die, the carbon in their bodies sinks to the sea floor, where it may lie for centuries. Biologists are now using OceanSITES to measure the rate at which these creatures grow, die and settle out.

By tracking plankton growth at these reference stations, biologists are also learning about the staple food of the ocean. Phytoplankton numbers promise to be crucial data for researchers assessing commercial fisheries. Giving scientists the ability to know key variables from across the spectrum of ocean sciences—all measured simultaneously—is part of the power of the OceanSITES program.

To understand the climate in any one location, scientists must calculate four crucial air-sea exchange rates: water, heat, momentum and carbon dioxide. For OceanSITES surface stations, measuring these variables is just part of the daily routine.
Ocean observation is moving beyond spot estimates of basic physical properties, toward long-term records of dozens of variables. OceanSITES is an indispensable part of the campaign.

OceanSITES involves more than 60 institutions in 22 countries

When a research question has a global scope or spans a broad range of disciplines, OceanSITES has relevant experts already at the table. More than 60 institutions and 22 countries bear the cost and upkeep of the current 64 multidisciplinary surface and subsurface arrays that comprise the OceanSITES initiative.

OceanSITES research contributes to larger projects like UNESCO’s Global Ocean Observing System (GOOS) and the Earth Observation System of Systems (GEOSS). Guidance is provided by the Climate Variability and Predictability project (CLIVAR) of the World Climate Research Programme (WCRP), the Partnership for Observation of the Global Oceans (POGO) and the Ocean Observations Panel for Climate (OOPC).

The OceanSITES data management team aims at distributing quality-controlled data through a streamlined network. Lead scientists submit calibrated data to local data centres. The centres double-check the data and serve it to the OceanSITES website for free global access.

Technical challenges still complicate the goal of long-term, open-ocean measurements (see What’s So Complicated?, at right). But OceanSITES engineers are solving these problems as they invent the next wave of ocean technology. The decisive vision of projects like GEOSS and the Ocean Research Interactive Observatory Networks (ORION) provide key support.

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What’s so complicated?

- About measuring a column of water and air in the open ocean, 5 km deep or more and totally at the mercy of open-ocean weather?
- Radio silence. Space communication is easy: Colour pictures of Saturn’s moons reach Earth in about 90 minutes. But just a metre of ocean water stops radio and radar dead.
- Very long cables. Just sinking a mooring line is a major undertaking. The rope, chain and cable can be 5 km long, weigh 10 tonnes and take up much of a ship’s deck.
- Slimy instruments. For some reason, ocean life loves new instruments. While OceanSITES has nothing against sea creatures, “biofouling” is a major cause of instrument failure.
- No elbow room. OceanSITES engineers have to pack dozens of sensors onto each station. And they also have to find room for backups, spare batteries and prototypes of next-generation equipment.
- Needles in a haystack. OceanSITES platforms carry radar reflectors so ships can avoid them—and stay clear of the water the buoy is measuring.
- Gremlins in the data. When OceanSITES data go live on the Web, they’re free to the world. Before that happens, data managers spend hours calibrating, organising and formatting the data stream.
OceanSITES is an international programme working to discover new knowledge about the ocean and make it publicly available. The programme employs a global system of reference stations recording diverse measurements from the sea floor to the atmosphere. State-of-the-art communications relay data to the Internet as soon as it is measured. The rugged, technologically advanced stations operate for years at a time, allowing scientists to compile long-term profiles of the ocean in key regions of the globe.

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