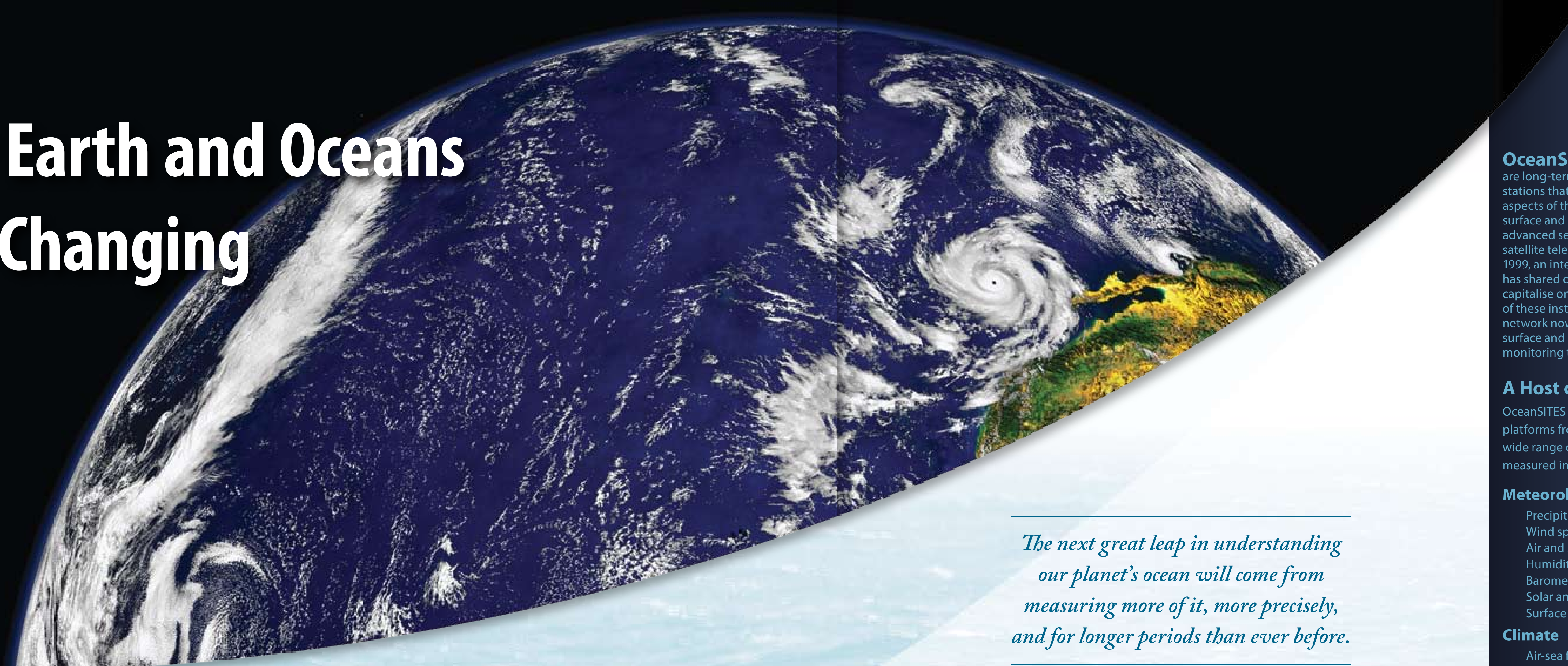
OceanSITES

Taking the pulse of the global ocean

Continuous measurements from the deep ocean in real time

Our Earth and Oceans are Changing



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.

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.

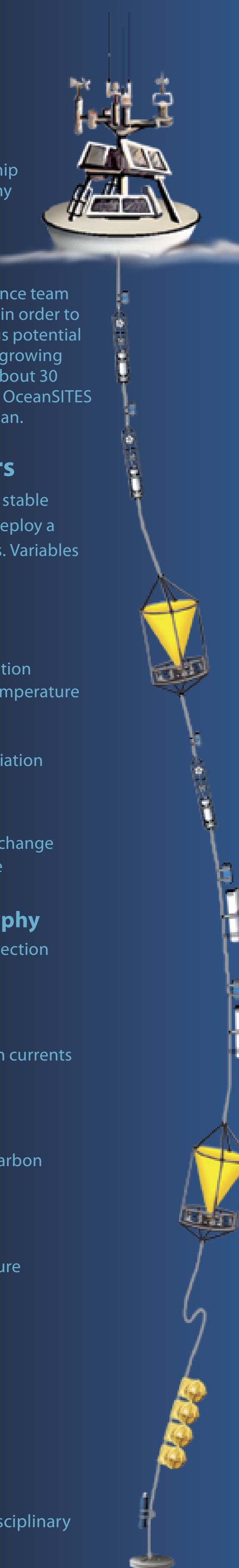
Monitoring the entire ocean over long time periods is an ambitious proposal. The OceanSITES team—more than 100 scientists from two dozen nations—puts planning at the forefront to make the work economically feasible. To deliver the maximum possible data out of each station, OceanSITES scientists plan 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.

OceanSITES*

are long-term buoy and ship stations that measure many aspects of the ocean'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 30 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

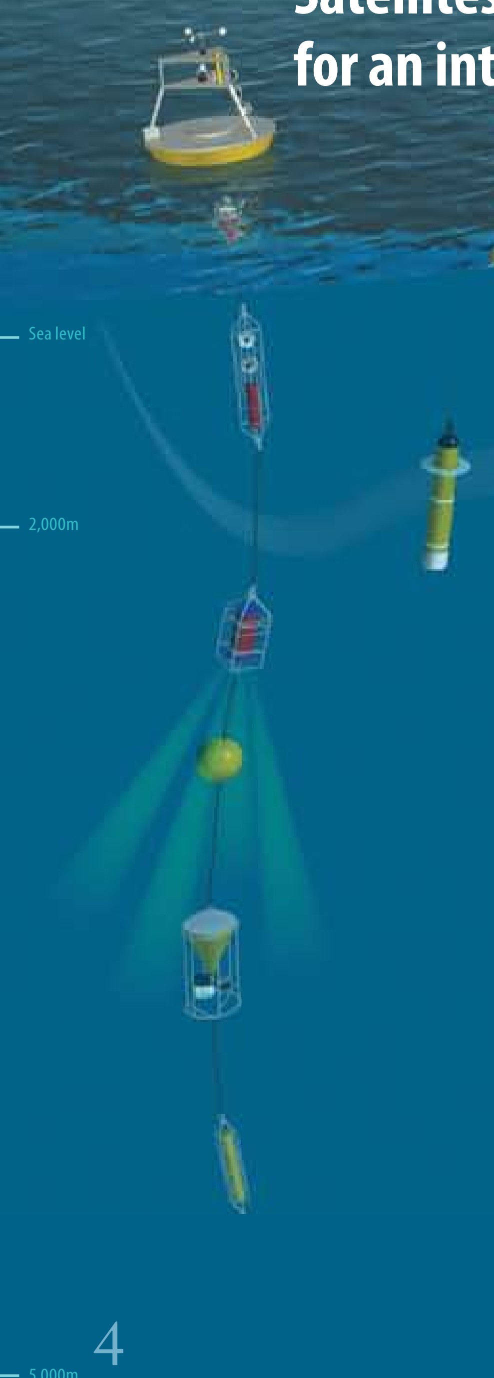
Biology
- Phytoplankton
- Zooplankton
- Fish stocks

Geophysics
- Seismic movements
- Magnetism

*Ocean Sustained Interdisciplinary Timeseries Environment observation System

OceanSITES covers the ocean from whitecaps to bedrock

Satellites, drifters and OceanSITES combine for an integrated observing system



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, an international effort to study the ocean from at least three overlapping perspectives: satellites, drifters and fixed reference stations, including OceanSITES.

Satellites watch the entire globe but can't see below the ocean surface. Drifters such as Argo follow ocean currents and profile the upper ocean (left).

OceanSITES buoy and ship stations complete the picture by continually measuring a suite of variables along a single column from atmosphere to deep ocean.

The long-term data let scientists factor out everyday variation and detect other phenomena (see box). As the planet moves, we get regular changes like sunrise, sunset, tides and seasons. These recurring patterns dominate the signal on any ocean graph, obscuring subtler trends. To look past the noise requires the perspective of a long time series.

Climate and ocean researchers work with wide-coverage satellite and drifter data, but they need fixed reference points that add time and depth to their models. OceanSITES sustained observations, recorded by calibrated sensors as often as once per minute, are a cornerstone for this effort.

By recording data over the long term, OceanSITES stations let scientists identify natural patterns of ocean variability and new changes to the ocean.

In the open ocean, what do you measure?

OceanSITES give scientists long-term data about basic ocean processes. Those same data stations give us immediate insight on a suite of globally important phenomena:

Weather forecasts predict where **hurricanes** will go, but we need ocean data to predict how punishing they will be when they arrive.

Large-scale **climatic fluctuations** like El Niño change weather patterns, threaten crops and cause floods and droughts.

Burgeoning human populations demand ever more from **declining fisheries**. Managing the stocks starts with measuring ocean productivity at the base of the food chain.

Some of our global **carbon emissions** get locked away in deep ocean currents. We need to know how much the waters can hold, and for how long.

Tsunamis travel at deadly speeds. The key to safety is rapid detection and early warning.

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.

1500 Lighthouse keepers in Europe begin accruing continuous records of coastal ocean conditions.

1855 Matthew Fontaine Maury publishes *The Physical Oceanography of the Seas*, the first textbook in oceanography, 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 *Albatross*, 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 *Meteor*, 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.

1960s-70s First subsurface moorings, then surface moorings begin to appear in the deep ocean.

1972 The GEOSECS voyages begin. Over 6 years, researchers make the first maps of radioisotopes in the Atlantic, Pacific and Indian oceans.

1978 NASA launches satellites equipped with Advanced Very High Resolution Radar (AVHRR). The digital sensors record global weather patterns and sea surface temperature.

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 30 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 observatories.

1999 St. Raphael, France: oceanographers envision a global system of "Eulerian observatories," eventually renamed "OceanSITES."

2000 The first of 3,000 Argo drifters is set loose in the water worldwide. They ride ocean currents and report upper-ocean conditions to satellites every 10 days.

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: advanced sensors and moorings to study the ocean in new ways.

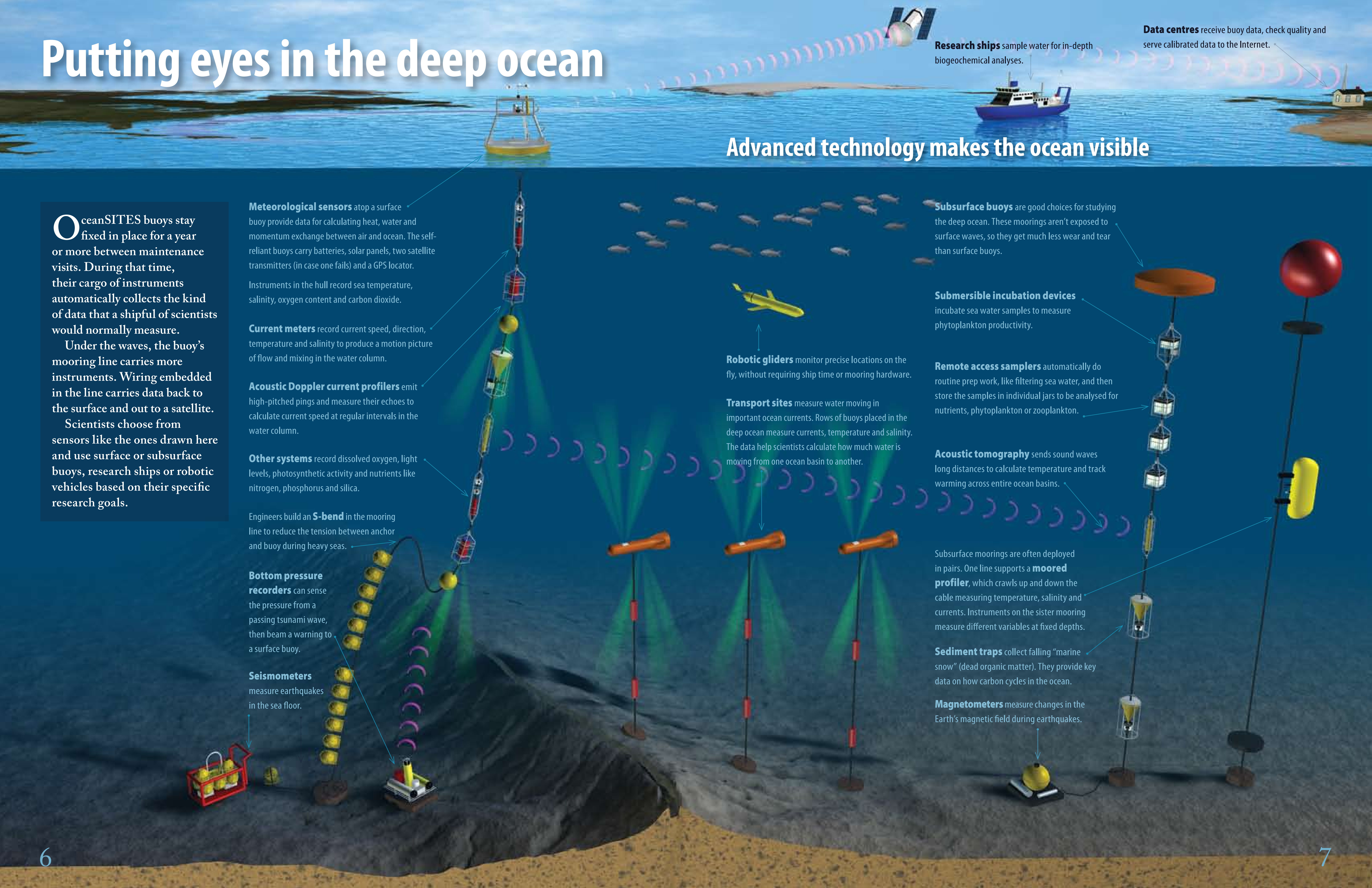
Putting eyes in the deep ocean

Advanced technology makes the ocean visible

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.



Tracking Global Ocean Processes

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.

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, a system of more than 70 stations 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 poles and trade it back into the cooler atmosphere along the way.

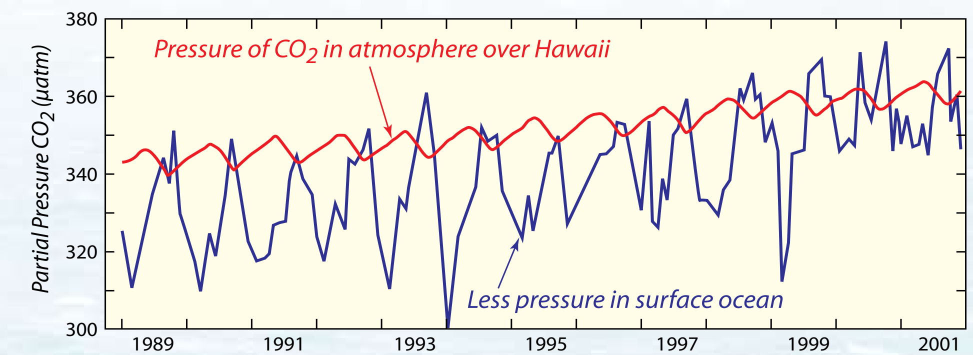
Now, climate scientists are turning their attention to the cold, stormy seas of the north and south. The moorings that enable year-long buoy deployments in the tropics can't yet stand up to a Southern Ocean winter. Building on the success of equatorial buoys, OceanSITES scientists are engineering a system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

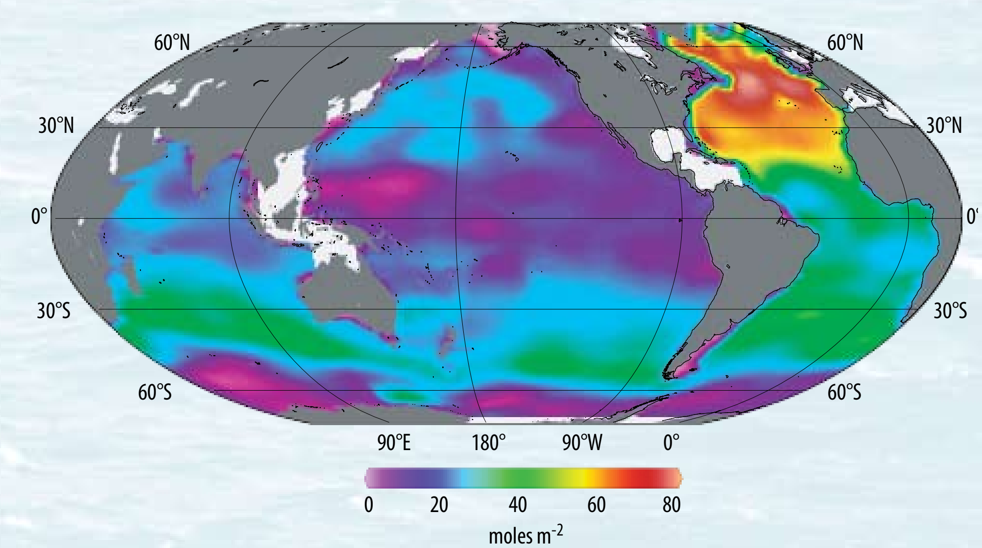
As well as simply dissolving into ocean water, carbon dioxide can enter the ocean when tiny plants and animals use the carbon to grow. As they die, the carbon in their bodies sinks to the sea floor, where it may lie for centuries. Biologists are now using OceanSITES to measure the rate at which these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

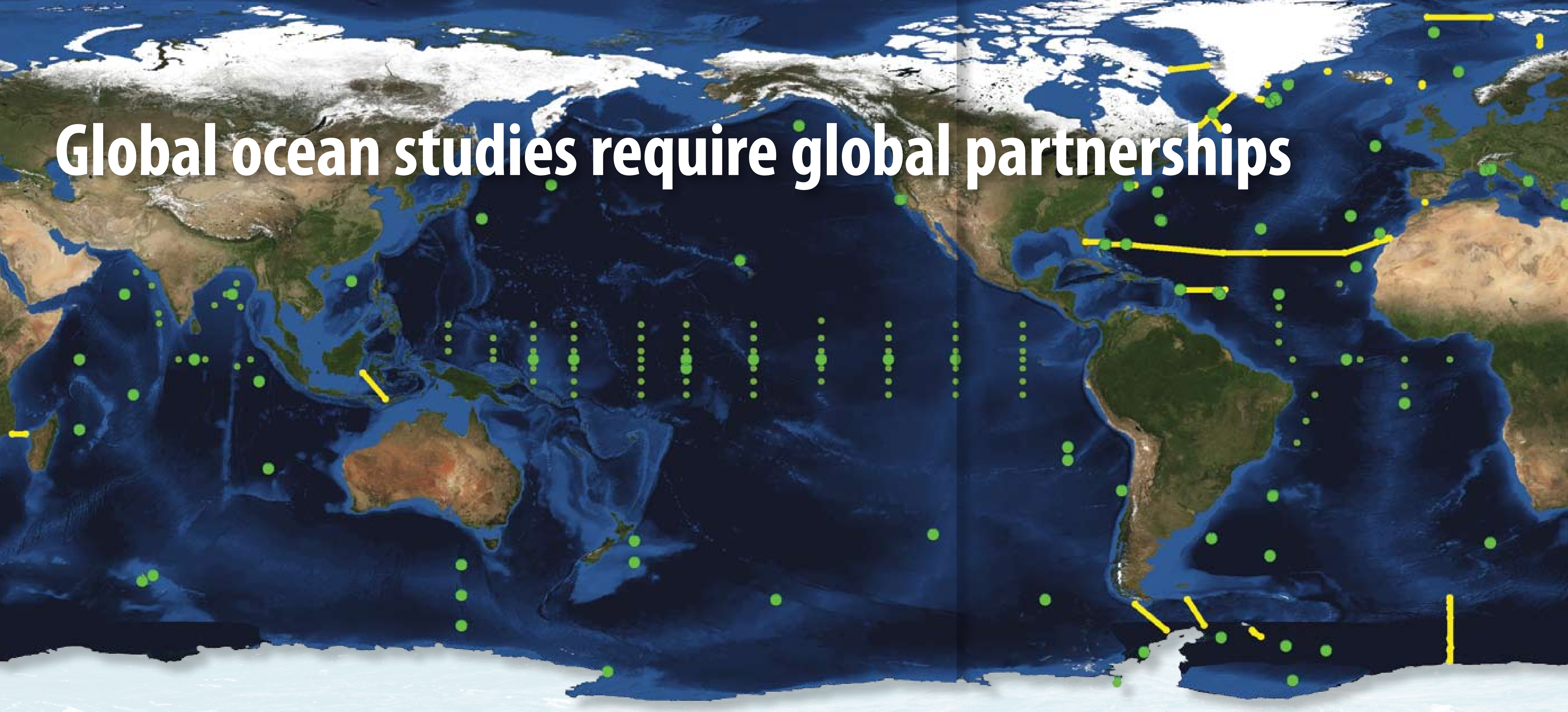


▲ Near Hawaii, the ocean's ability to absorb carbon dioxide (CO_2) from the atmosphere is diminishing. CO_2 pressure in the air (red) has long been higher than in the ocean (blue). When the blue line is below the red line, CO_2 dissolves into the water. This gap is narrowing, and could vanish as early as 2008 (graph courtesy Hawaii Ocean Time Series).

▼ Time-series data like the above graph help climate modelers sketch in the details of the global carbon cycle. The world map below estimates how much anthropogenic carbon—from autos, factories and energy production—winds up stored in the world's oceans. Red and green indicate relatively high amounts of carbon storage; purple and blue areas contain less carbon (graph courtesy Chris Sabine, NOAA).



Global ocean studies require global partnerships



◄ The OceanSITES network of existing and planned data stations. Large dots are multidisciplinary surface and subsurface stations. Small dots are moorings collecting a limited set of surface observations. Yellow lines are transport sites (see p. 7). As of March 2006, 64 multidisciplinary stations are operating in addition to more than 80 buoys monitoring the equatorial oceans.

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 34 surface and 30 subsurface arrays that comprise the OceanSITES initiative.

OceanSITES research contributes to larger projects like UNESCO's Global Ocean Observing System (GOOS) and the Global Earth Observing 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.

Ocean observation is moving beyond spot estimates of basic physical properties, toward long-term records of dozens of variables. As we track the ways our planet is changing, research teams need data precise enough to inform global models of climate change, nutrient chemistry and ocean food chains. OceanSITES is an indispensable part of the campaign.

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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.


TAO project, NOAA

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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GCOS · GOOS · WCRP OOPC Ocean Observations Panel for Climate

CLIVAR Climate Variability & Predictability World Climate Research Programme

pogo

jcomm Oceanography & Marine Meteorology