THE OCEAN ENTERPRISE

NEW GEOSPATIAL TOOLS ARE NOT ONLY HELPING TO OBSERVE AND PRESERVE MARINE LIFE, THEY ARE CREATING INDUSTRIES AND REVENUES AROUND THE WORLD. KATHERINE ANDERSON REVEALS HOW

The market value of marine and coastal resources and industries is approximately US$3 trillion per year or 5% of global GDP. Rising sea levels, coral bleaching, mass die-off events – the news from the high seas is cause for concern, but how accurately can we measure oceans and biodiversity and how can we estimate their value? The oceans' immensity makes understanding them seem like an impossible task – but it is no longer as difficult as it once seemed, due to several recent innovations in marine biodiversity monitoring.

Ocean circulation to the full depth of the ocean is being measured through with a network of buoys around the world coordinated by the Global Ocean Observing System (or GOOS), while measurements of the world's ocean surface are monitored several times a day by satellites orbiting around the poles and above the equator. How and why temperature changes throughout the ocean can be explored using computer simulations. These tools can help detect when temperature deviates from the norm.

One example of how these data are used are the daily reports issued by the US National Oceanic and Atmospheric Administration (NOAA)'s Coral Reef Watch. Coral Reef Watch maps show temperatures that the ocean's surface today is up to 3ºC hotter than the average over the past three decades. In 2015 and 2016, the most expansive and persistent coral bleaching events ever occurred, in the areas where the ocean was warmest.

The living base layer of the ocean's food web is phytoplankton. These microscopic plants support nearly all marine life and supply half of breathable oxygen to the atmosphere and the ocean. The timing of the growth of phytoplankton is critical for the survival of fish and crustaceans. Space agencies around the world, including NASA, NOAA, and the European Space Agency (ESA), are investing in the study of phytoplankton phenology, the timing of plankton events. ESA just released the results of a new study of phenology of phytoplankton in the Red Sea, one of the warmest and saltiest bodies in the world.

ESA's Ocean Color Climate Change Initiative (OCCCI) uses satellite data to determine the level of phytoplankton during both winter and summer, and whether the phytoplankton is harmful or helpful to fish and other animals. Research such as this can provide vital inputs to inform decisions related to recreation, tourism and conservation in such countries as Egypt and Saudi Arabia.

Satellite imagery from space are typically paired up with in situ sampling to ground-truth the measurements before the data are used in biological computer simulations of the phytoplankton. Direct observations of species or group of phytoplankton, their abundance, phenology, and genomic composition give meaning to remote sensing data.

Satellite sensors provide insight on physical, biological and biogeochemical ocean parameters at different spatial resolutions and temporal scales (hourly/daily to multi-annual), helping to provide and complement (in conjunction with in situ measures and modelling/data assimilation activities) a nested global to basin-scale to regional to local ocean observing framework.

Ocean colour radiometry sensors on-board satellites map the abundance of phytoplankton (chlorophyll-a concentration) by measuring the light coming from the sea. Remote sensing of the ocean colour from space started in 1978 with the launch of NASA's

Coastal Zone Colour Scanner (CZCS) and has continued without significant interruptions since then. Both spatial and spectral resolutions have continually improved and today sensors can provide measurements of the reflexed solar radiation in up to 21 spectral bands at 300m resolution over 300km swaths (see ESA's Sentinel-3 OLCI).

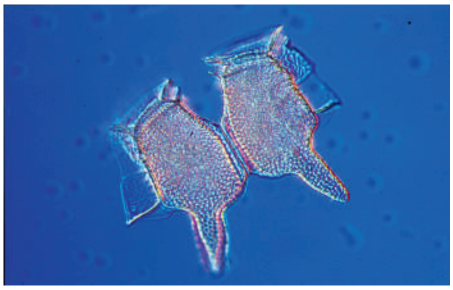
Sea surface temperature (SST) can be measured from space by using both infra-red and passive microwave sensors. Infra-red instruments can measure the skin SST at high spatial resolutions (<300m), but they are limited by the presence of clouds. Microwave instruments can measure [sub-skin] SST through cloudy conditions but at reduced spatial resolutions (<10km). Combined infra-red and microwave SST products also exist providing a multi-sensor SST product at a fine spatial and temporal resolution that is global and regularly distributed.

The temporal resolution and spatial coverage of satellite remote sensing products is a function of satellite orbit (geostationary or polar), sensor type and availability of satellite constellations. Nowadays, daily global satellite derived ocean colour and SST products are available at <300m resolution (L3 and L4 products). Regional and local satellite products are also available at the same resolution at higher frequencies, e.g. hourly (L2 products).

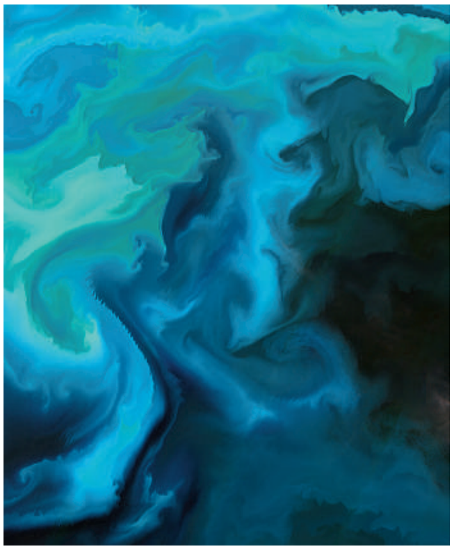
Characterising life

Sampling and characterising the types and abundance of life in the ocean, from microbes to whales, is difficult. Traditional sampling of the diversity of life in the ocean includes ships, bottles, nets, visual observations from a boat or by divers, hooks and lines, traps, dredges, submersibles, and remotely operated vehicles. Species are then counted using several tools, including microscopes and DNA analyses. Everywhere around the world, fish catch statistics or other methods like trawled nets are used for monitoring commercially important fish stocks. These data are used to analyse trends in the abundance, distribution and diversity of fish.

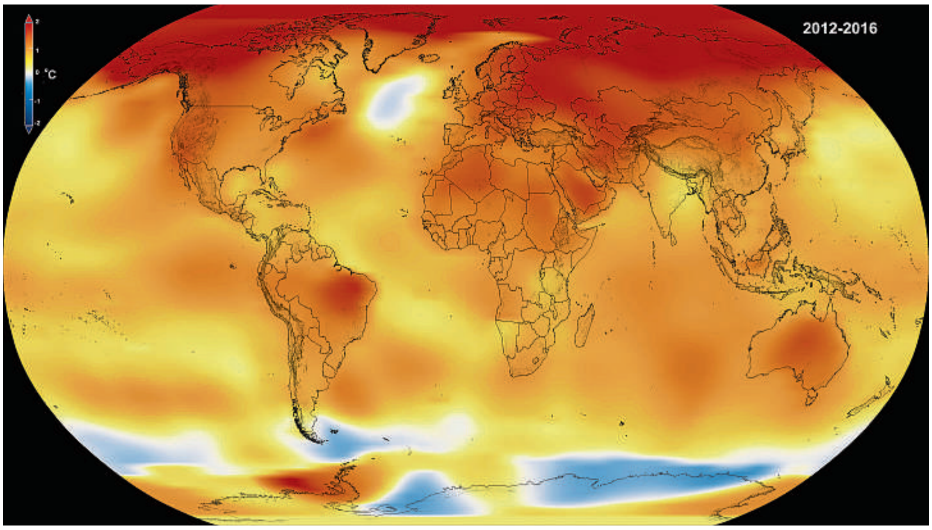
To understand a mass die-off of invertebrates including coral and sponges in about 10% of the area of the East Flower Garden Bank in the Gulf of Mexico in July last year, scientists turned to remote sensing. Sport divers reported coral and sponges covered in white mats and dead animals in the coral reefs near the surface of the National Marine Sanctuary. This is one of the healthiest coral communities in the northern Gulf of Mexico. Scientists from NOAA and the US Bureau of Ocean Energy Management used satellite imagery to estimate ocean salinity, by comparing various field measurements of the temperature and conductivity of seawater with microwave emissions by the ocean which can be measured by satellites. Salinity visualisations of the Gulf of Mexico showed an intrusion of freshwater from inland, due to extreme rainfall in the preceding months. The suspicion is that the run-off contained high levels of nutrients, which led to a bloom



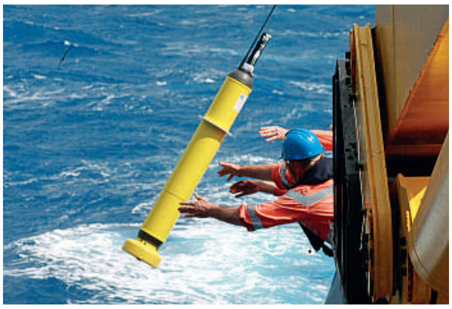
Phytoplankton, the basis of marine food webs, also produce half the oxygen we breathe. © IEO, Spain



Natural-colour capture of a plankton bloom in the Barents Sea by the Sentinel-2A satellite. Contains modified Copernicus Sentinel data (2016), processed by ESA

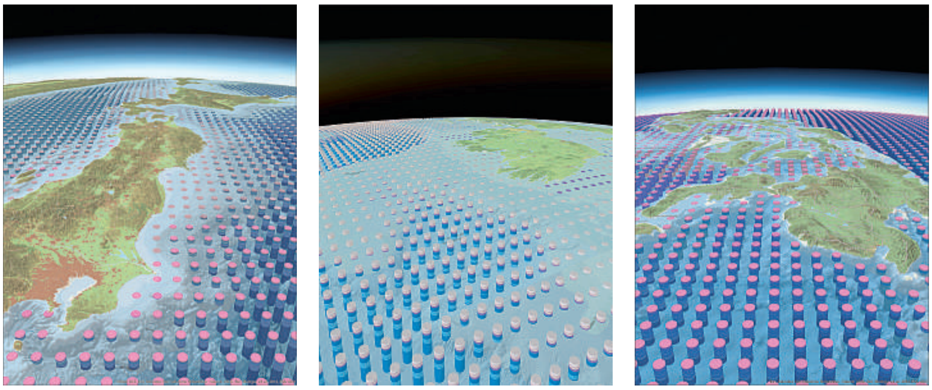


Global temperatures 2012-2016 © NASA



An Argo float being deployed ©GOOS

The small-scale fishing industry is an important contribution to the 'Blue Economy' in small island developing states, such as Mauritius. © POGO



Ecological marine units (EMUs) represented in three dimensions. Although the EMUs are mapped as a continuous surface, the use of columnar stacks allows them to be visualised at point locations. There are few EMUs In the coastal zone, whereas offshore there are more and deeper EMUs. The colour of EMUs highlights temperature gradients © Esri

of phytoplankton in the brackish plumes that were carried offshore. The decay of the plankton at the bottom of this brackish lens of water likely led to low oxygen concentrations that suffocated the animals, covered them with a layer of bacteria, and caused the die-off.

Remote sensing combined with in situ measurements are analysed in a contextual framework. They provide historical data, near-real-time data, and cover large geographic scales. This helps form a more complete picture of time and space variation in the ocean.

Working together

But it also results in a new challenge: large amounts of data. NOAA alone produces 20TB of data a day from satellite measurements. Packing that information in a way that is useful to decision makers is quite daunting.

A public-private collaboration on mapping and visualising standardised data was recently unveiled by NOAA and Esri. The Ecological Marine Units Explorer has an interface which shows data layers at several depths for physical and chemical characteristics of the ocean including salinity, temperature, dissolved oxygen and phosphate, as well as producing visual representations for fish census and other data. The ecological marine units (EMUs) mash 50 years of field data archived by NOAA into a set of thematic classes. While already in use in the US, global adoption would require agreement on classification of the marine environment. The next step – to merge these EMUs with dynamic satellite data – is now under way as part of the Marine Biodiversity Observation Network.

The Argo programme is an example of what can be achieved when the global community comes together. Argo is a global array of 3,800 free-drifting profiling floats that measure a limited number ocean variables. These buoys allow continuous monitoring of the temperature, salinity, and velocity of the upper ocean. All data are relayed globally and made publicly available within hours after collection.

Such routine observations of the global subsurface ocean have revolutionised our understanding of the role of the ocean in the climate system. An important addition would be to add sensors that detect changes in the diversity and abundance of life in the ocean. We are still some way from that but prototyping of technologies is now underway.

Value in observations

There is more to this than simple philanthropy. A new study shows the industry conducting the measurements also has value. A US report measuring the scale and scope of business activity in ocean observations shows the economic and non-for-profit interaction in this distinct sector for the first time, coining the description 'Ocean Enterprise'.

The study reveals the Ocean Enterprise of ocean observations alone today generates US$7bn in revenue annually. The study also finds 86% of these businesses have been operating five or more years in the Ocean Enterprise and more than 54% of them expect growth in the next year.

The study provides a baseline against which to measure the development of the ocean observation enterprise and gives stimulus to its future development and direction. Business activity that underpins making ocean measurements, observations and forecasts, and their subsequent use to deliver economic and societal benefits is an important industry cluster of the 'Blue Economy' – the use of the oceans. As the Blue Economy expands in the coming decades, so too will the need for ocean data and information.

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