Monitoring ocean acidification from space

What is ocean acidification?

Since the industrial revolution the oceans have absorbed approximately **50%** of the CO_2 produced by human activities (The Royal Society, 2005). Scientists previously saw this oceanic absorption as advantageous, however ocean observations in recent decades have shown it has caused a profound change in the ocean chemistry – resulting in **ocean acidification (OA**); as CO_2 dissolves into the oceans it forms carbonic acid, lowering the pH and moving the oceans into a more acidic state. According to the National Oceanic Atmospheric Administration (NOAA) ocean pH has **already decreased** by about **30%** and some studies suggest that if no changes are made, **by 2100**, ocean pH will decrease by **150%**.

Impacts of OA

It's anticipated OA will impact many marine species. For example, it's expected it will have a harmful effect on some calcifying species such as corals, oysters, crustaceans, and calcareous plankton e.g. **coccolithophores**.

OA can significantly reduce the ability of reef-building corals to produce their skeletons and can cause the dissolution of oyster's and crustacean's protective shells, making them more susceptible to predation and death. This in turn would affect the entire food web, the wider environment and would have many socio-economic impacts.

Calcifying phytoplankton, such as coccolithophores, are thought to be especially vulnerable to OA. They are the most abundant type of calcifying phytoplankton in the ocean, and are important for the global biogeochemical cycling of carbon and are the base of many marine food webs. It's projected that OA may disrupt the formation and/or dissolution of coccolithophores, **calcium carbonate ($CaCO_3$) shell**s, impacting future populations. Thus, changes in their abundance due to OA could have far-reaching effects.

Unlike other phytoplankton, coccolithophores are highly effective light scatterers relative to their surroundings due to their production of highly reflective calcium carbonate plates. This allows them to be easily seen on satellite imagery. The figure at the top of this page shows multiple coccolithophore blooms, in light blue, off the coast of the United Kingdom on 24th March 2016.

Current OA monitoring methods

Presently, the monitoring of OA and its effects are predominantly carried out by **in situ observations** from ships and moorings using **buoys** and **wave gliders** for example. Although vital, in situ data is notoriously **spatially sparse** as it is difficult to take measurements in certain areas of the world, especially in hostile regions (e.g. Polar Oceans). On their own they do not provide a comprehensive and cost-effective way to monitor OA globally. Consequently, this has driven the development of satellite-based sensors.

How can OA be monitored from space?

Although it is difficult to directly monitor changes in ocean pH using remote sensing, satellites can measure **sea surface temperature and salinity (SST & SSS)** and **surface chlorophyll-a**, from which ocean pH can be estimated using empirical relationships derived from in situ data. Although surface measurements may not be representative of deeper biological processes, surface observations are important for OA because the change in pH occurs at the surface ?rst.

In 2015 researchers at the University of Exeter, UK became the first scientists to use remote sensing to develop a worldwide map of the ocean's acidity using satellite imagery from the European Space Agency's Soil Moisture and Ocean Salinity (SMOS) satellite that was launched in 2009 and NASA's Aquarius satellite that was launched in 2011; both are still currently in operation. **Thermal mounted sensors** on the satellites measure the SST while the **microwave sensors** measure SSS; there are also microwave SST sensors, but they have a coarse spatial resolution.

Future Opportunities - The Copernicus Program

The **European Union's Copernicus Programme** is in the process of launching a series of satellites, known as **Sentinel satellites**, which will improve understanding of large scale global dynamics and climate change. Of all the Sentinel satellite types, Sentinels 2 and 3 are most appropriate for assessment of the marine carbonate system. The **Sentinel-3** satellite was launched in February this year andwill be mainly focussing on ocean measurements, including SST, ocean colour and chlorophyll-a.

Overall, OA is a relatively new field of research, with most of the studies being conducted over the last decade. It's certain that remote sensing will have an **exciting and important role** to play in the future monitoring of this issue and its effects on the marine environment.

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