AN OCEAN IN YOUR COMPUTER

4.2 THE BLUE-GREEN OCEAN FROM ABOVE: CHLOROPHYLL-A FROM SATELLITE OCEAN COLOUR VIDEO DURATION– 05:41

Satellite Ocean Colour observations have greatly increased our knowledge about the variability of phytoplankton in our oceans.

These organisms might be tiny and invisible to the naked eye, but they play an important role in our oceans. They form the first link in the marine food chain and are responsible for recycling a huge amount of carbon-dioxide through the marine ecosystem.

In this lecture, you will learn how Chlorophyll-a, an index of phytoplankton biomass, is obtained from satellite radiometer observations of ocean colour; and how to track the ocean's Chlorophyll-a variability from space.

The first proof-of-concept for satellite Ocean Colour sensors was the Coastal Zone Color Scanner which operated in the 1980s. Nearly a decade later, the launch of SeaWiFS in 1997 marked the start of the continuous Ocean Colour observing era. A series of missions such as MERIS, MODIS, VIIRS and the recent Sentinel-3 OLCI – have followed, providing scientists with more than 22 years of consistent global observations of Ocean Colour.

A Satellite Ocean Colour Radiometer flies around the Earth typically in a polar orbit, crossing the equator from south to north as shown here. As it moves along this orbit, the satellite sensor "sees" a certain portion of the Earth's surface, called the Swath, which has a width of the order of a thousand kilometres, and is measured with a spatial resolution ranging from 350 m to 4 km.

In 1 to 2 days the satellite instrument swath will have covered the entire surface of the Earth, measuring ocean colour from the reflectance of the ocean in the visible wavelength range of the Electromagnetic Spectrum. But this is only possible over the oceans when they are cloud free.

The cloud contamination can be overcome by combining composite images from different satellite sensors, on a regular grid typically at 1 or 4 km resolution, and on a daily or monthly basis. The result is the most complete view of global ocean Chlorophyll-a observations.

When we look at an imaged area from space, we see an array of colours over the ocean. There are white patches representing clouds. We also see many different shades of blue and green. In clear waters, the main constituent influencing the ocean colour is phytoplankton, which contain Chlorophyll-a, a green pigment. The higher the concentration of phytoplankton the greener the water. If the phytoplankton are absent, then the water will appear blue.

To be exact, what is being detected by the satellite ocean colour sensor is the spectral distribution of water-leaving radiance (or reflectance). However, because of the addition of light scattered by the atmosphere into the satellite sensor's view, we actually measure a signal reflected by both the ocean and the atmosphere. The atmosphere is 90% of the measured signal, so highly accurate atmospheric corrections are applied to retrieve the ocean signal.

This retrieved water-leaving radiance can then be linked to in-water properties, such as Chlorophyll-a, using a set of bio-optical algorithms.

For the open ocean, these algorithms typically take advantage of the decreased radiance in the blue (which is the 440–510nm band) and the increased radiance in the green (which is the 550–565nm band) by working in terms of the ratios in these two visible wavelength bands.

But for coastal waters, these ratios can vary in response to the presence of higher amounts of dissolved organic matter and suspended sediments. This introduces errors in pigment retrievals from the satellite data, and more specialised algorithms need to be applied to estimate the amount of Chlorophyll-a in the water.

The inferred satellite chlorophyll can then be used to monitor spatial and temporal changes of phytoplankton blooms.

This data visualization of the Chlorophyll-a distribution over the global ocean shows changes from 1998 to 2018. If we take a closer look at the animation, we notice extreme zones highlighted in Purple and Red:

- Purple patches are nearly devoid of any phytoplankton, just as a desert would be of vegetation, they are the ocean's deserts.

- The Red features indicate high levels of phytoplankton, like in the Northern hemisphere, which blooms every spring, just as plants in a garden might bloom in the spring. These spring blooms are easily detected in the Mediterranean Sea and the North Atlantic.

Near the coastlines, the Red patterns are likely due to the effect of another input contributing to ocean colour, such as suspended material.

More complex chlorophyll-a patterns due to seasonal variations can be observed, for example over the Agulhas Bank, off the coast of South Africa. In this monthly sequence of chlorophyll in 2015, we observe phytoplankton blooms from December to April with concentrations higher than 2 mg/m^3. During the rest of the year, the chlorophyll levels decrease to values lower than 1 mg/m^3 over the bank.

In this lecture of the Satellite oceanography module, we have explored how chlorophyll-a can be estimated from satellite Ocean Colour. We can also now appreciate using chlorophyll-a variability to inform us about the biological response of the ocean. In the next lecture, we will learn more about the physical aspects of the ocean as seen by satellite sensors from space.