Topic 3c - Ocean Colour overview (part 2) – techniques and applications in depth

So what makes the oceans blue? Water absorbs very weakly in the blue part of the spectrum and strongly in the red part. At the same time, water molecules scatter light very strongly towards the blue part of the spectrum. The combination of these two processes give water its characteristic blue colour if there is nothing else present in it.

In remote sensing of ocean colour though, we are also interested to learn how the colour changes with the amount of dissolved or particulate material that might be present in the water and also with respect to the type of material that is present in it.

For example, if you add a lot of white scattering material, as in this image here, the water turns progressively brighter and could take on a turquoise colour, for example, near coral reefs or even in the open ocean in the presence of a certain type of phytoplankton that have calcium carbonate cells in their outer sphere, which, when shed in large numbers into the water, turns the water a bright turquoise colour. But typically though, in the presence of phytoplankton that contain chlorophyll and other associated pigments, the water progressively green as you add more and more phytoplankton into the water.

We monitor these changes in the colour and then quantify them as concentration of chlorophyll a, for example. To do this quantification, typically we rely on more precise measurements of similar quantities from local in situ observation techniques.

The validation of the satellite products are typically undertaken using matched up observations from ships or other or observing devices right at the sea level since such observations can be more precise. And as shown in these examples here, the satellite observations are then compared with the in situ observations to determine the accuracy and precision of the satellite-retrieved quantities.

In ocean colour remote sensing, the signal for the sensing comes from the sun. In other words, the sun is the source of the light that we are observing. The sunlight passes through the atmosphere, reaches the ocean surface, and the part that is transmitted into the ocean interacts optically with the various substances that are present in it. And these interactions may be absorption or scattering.

Some of the scattered light then is retransmitted towards the surface of the ocean and, after transmission through the atmosphere, will be received by a satellite sensor that is passing over that location in outer space. So once the signal is corrected for the noise from the atmosphere, we have the spectrally-resolved water-leaving radians in the visible domain. And that light is our signal for inferring the properties of the material that are present in the water.

The idea here is that light, having interacted with absorbing and scattering material in the water, will carry optically-coded information to this satellite. Our task then is to interpret this signal in quantitative terms and to identify both the amount and the type of material that are present in the water.

A major focus of our work on remote sensing of ocean colour is on phytoplankton. Why is it important to study phytoplankton? These are microscopic plants that are free-floating and are present just about everywhere in the surface layers of the ocean. I say they are microscopic, but they occupy a very broad size range from less than one micron to more than 200 microns.

Phytoplankton, though microscopic, carry out all the tasks and duties of a plant, just like terrestrial plants. Notably, this includes photosynthesis. Through photosynthesis, in the presence of light, phytoplankton take up dissolved carbon dioxide in the ocean and convert it into organic material. The organic material produced by phytoplankton is the source of food for all the larger organisms present in the ocean.

It is a little known fact that net primary production of organic material by phytoplankton is comparable to that by all terrestrial plants. In fact, they are responsible for fixing some 50 gigatons of carbon as organic material globally and on an annual basis. Because of this large throughput of carbon dioxide through phytoplankton, they are major players in the global carbon cycle.

Phytoplankton have to absorb light to do photosynthesis. But photosynthesis is a very inefficient process and much of the absorbed light is dissipated as heat. Because of this, phytoplankton also play a key role in modulating the distribution of heat generated from sunlight in the surface layers of the ocean.

So in this regard, phytoplankton are important in two aspects of climate and climate change. One is carbon cycle. And the other is the heat budget of the ocean and, therefore, of the planet earth.

Phytoplankton are slightly negatively buoyant. That means that, left to themselves over time, they will sink out of the surface layers of the ocean, carrying with them the carbon that is assimilated into organic material. Therefore, phytoplankton are also important in carrying carbon from the surface layers into the deep ocean and even to the sediments of the ocean, wherein they are buried and out of contact with the atmosphere for very long time scales.

For all these reasons, phytoplankton-related chlorophyll concentration and ocean colour are recognised as essential climate variables by the Global Climate Observing System. In fact, ESA has launched a climate change initiative, in which they are generating climate quality time series information on all essential climate variables that are amenable to remote sensing. And ocean colour and chlorophyll concentration are part of this initiative.

And of all the ocean-related essential climate variables that are accessible to remote sensing, ocean colour and chlorophyll are the only ones that provide a window into the entire marine ecosystem. And after all, when we are studying climate, we want to know how life on the planet responds to change in the climate. And, therefore, this is a very important component of our climate studies.