EUMETSAT

Ocean Extras: Models and future missions for phytoplankton and biodiversity

Phytoplankton represent the base of the marine food web, such that any changes in their health and productivity can have a bottom up effect on the marine ecosystem. From space, we use chlorophyll a as a proxy for phytoplankton biomass.

One of the instruments that we use to assess chlorophyll a or phytoplankton biomass is the Moderate Resolution Imaging Spectra Radiometer, or MODIS instrument, that's onboard NASA's Aqua satellite. The visualisation that you're seeing behind me is monthly MODIS Aqua sea surface chlorophyll a concentrations, basically from July of 2002 to February of 2016.

The darker regions indicate elevated chlorophyll a concentrations, or higher phytoplankton biomass, where in the blue or darker blue regions indicate lower chlorophyll a or reduced chlorophyll a and therefore reduced phytoplankton biomass.

Like plants on land, phytoplankton in the ocean need nutrients and sunlight in order to bloom. So the majority of these regions in which you're seeing a lot of phytoplankton productivity are in these regions of upwelling zones, which are largely driven by ocean circulation and the atmosphere.

And these upwelling zones as you can see are really sort of dominated within the subpolar gyres, along the equator, the West coast of continents, and Western boundary currents, such as the Gulf Stream and Kuroshio current.

Other sources of nutrients include runoff from land, as well as atmospheric deposition from minerals, such as dust from the Sahara and African region that comes over and deposits iron. And you can get phytoplankton blooms in association with that deposition.

Phytoplankton patterns that you see here can also change with respect to short term weather systems, such as tropical cyclones. Also they vary with season, and they can also vary with long term climate systems, such as El Nino.

Phytoplankton are crucial players within Earth's carbon cycle. From space, we can only see chlorophyll a, which is an indication of phytoplankton biomass. But different phytoplankton species have different contributions to the carbon cycle, whether you're a larger phytoplankton such as a diatom, or a smaller phytoplankton such as cyanococcus.

Right now, we don't have the capabilities from space to tease out these different phytoplankton species or sizes, if you will, phytoplankton functional types. But with upcoming satellites, such as NASA's Pre-Aerosols Clouds and ocean Ecosystems mission, or PACE, we will be able to start assessing those phytoplankton species themselves.

In the meantime, while we're waiting for that mission to be launched, we rely upon model simulations, such as the one that you see behind me in this animation. So this is a model solution generated by the Darwin Project at the Massachusetts Institute of Technology.

And you're seeing the dominant phytoplankton groups worldwide, where you basically go from large to small . So diatoms being the largest phytoplankton, prochlorococcus, which are green, being the smallest. So you can sort of see where they reside with respect to global distributions. And mainly that's limited by or governed by how much light and nutrients there are, what these different phytoplankton groups like to and need in order to grow.

So you can see the diatoms mainly reside within the subpolar region. They like a lot of silica. This is mainly a region in which it happens. Prochlorococcus and cyanococcus, the smaller species, really reside within the tropics, since they are nutrient-limited regions. And they flourish within these environments.

So through model solutions such as Darwin, we're able to assess how these phytoplankton groups, how they're distributed worldwide, and again, how they're changing with respect to climate change, short term weather events such as cyclones, tropical cyclones, as well as longer term climate events, such as El Nino. Phytoplankton diversity is an extremely important variable that we need to measure. And we will with future missions such as NASA's PACE mission.

Oceans cover more than 2/3 of the Earth's surface. As humans, we rely upon the ocean for multiple things. For recreation, for tourism, for food. And as you're seeing here, this is phytoplankton diversity. This impacts higher trophic levels. As humans, we eat fish. Fish eat phytoplankton, so changes within them actually impacts fish, which impacts people. So having a better understanding of this lowest level of the marine food web is extremely important to the Earth's system and to human survival.

Coral Reef Airborne Laboratory or Coral Mission is a three year NASA campaign that utilises state-of-the-art airborne and in-water instruments to assess the condition of a portion of world wide coral reefs, specifically going to portions of Australia's Great Barrier Reef, Guam, the Marianas Islands, and the Hawaiian island chains.

Why are corals important? We know if we had to put a value on the ecosystem goods and services that coral reefs provide worldwide, that value is in fact estimate around $400 billion, whether it's through tourism, food, coastal protection, and one that's emerging being the biotechnology industry through different cancer therapies as well as painkillers that are in local hospitals.

Aside from their global importance, coral reefs are also the true canary in the coal mine scenario, in which they are one of the first ecosystems to respond both critically, dramatically, and globally, not only to local environmental degradation, but also global climate change.

Current estimates say that 33% to 50% of coral reefs worldwide are threatened, with that number only increasing in the coming years. However, these predictions are based upon extremely sparse data. The current methodology for these coral reef assessments rely heavily upon in-water techniques that are expensive, labor-intensive, and limited in spatial scope.

This is what we're trying to address. We're trying to take it at a much larger scale to say something about the whole ecosystem. We are using aircraft instruments. In fact, we're using the portable remote imaging spectrometer aboard the Tempus Applied Solutions. Gulf Stream floor, as you can see here. And the instrument is observing whole coral reef ecosystems.

We also do have in-water teams that are doing validation for the aircraft. And it's the two of these together that really are providing the assessment of coral reef condition so that we can say something about how corals are changing with respect to their environments. So how they're changing with respect to increasing temperature, significant wave height, marine pollution just being some of the functions that we're going to be looking at.

The great thing about instruments such as Prism, these being imaging spectrometers, is they provide an entire spectrum of data. So current satellites really from ocean colour perspectives are multiband. So if you have a spectrum, they're taking specific bands within that entire spectrum.

Whereas imaging spectrometers are getting that entire-- every single wave band. Let's say every for Prism, it's about every three nanometers within 350 all the way out to 1050 nanometers. So you can imagine that's a lot of data. That's a lot of information that we can understand about a system.

We're just assessing coral reef condition, which is the ratio of coral algae in sand, to say something. So what you see here is in fact a flight line. So this is a true colour image from Prism overlaid. On top is in fact the coral reef map that you will get that shows the benthic cover.

So how much coral, how much sand, how much algae is there? And that provides us with an indication of coral reef condition. That as well as looking at primary productivity and calcification of the reef systems.

Once that light hits the sensor, it actually breaks out that signal into colours or spectra. And how we do that, how it breaks that out, is these different signatures that both coral, algae, and sand have. So you can see how each has very distinctive signatures, and that is how we are in fact looking at benthic cover.

What's next? What can happen with regards to long term monitoring of coral reef condition? For coral, we are assessing four different sites. But we would like to look at a longer term monitoring worldwide. And in order to do that, you need to go spaceborne.

So imaging spectroscopy is going in that direction. Not only through potential missions that look at coral reef condition, but also terrestrial biodiversity through missions such as ECOSTRESS and HyspIRI, as well as NASA's PACE mission. So there are multiple satellites being developed using imaging spectroscopy to assess biodiversity and take us to that next level in understanding our Earth's system as a whole.