Japan

JAMSTEC
Japan Agency for Marine-Earth Science and Technology

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Partnership for Observation of the Global Ocean

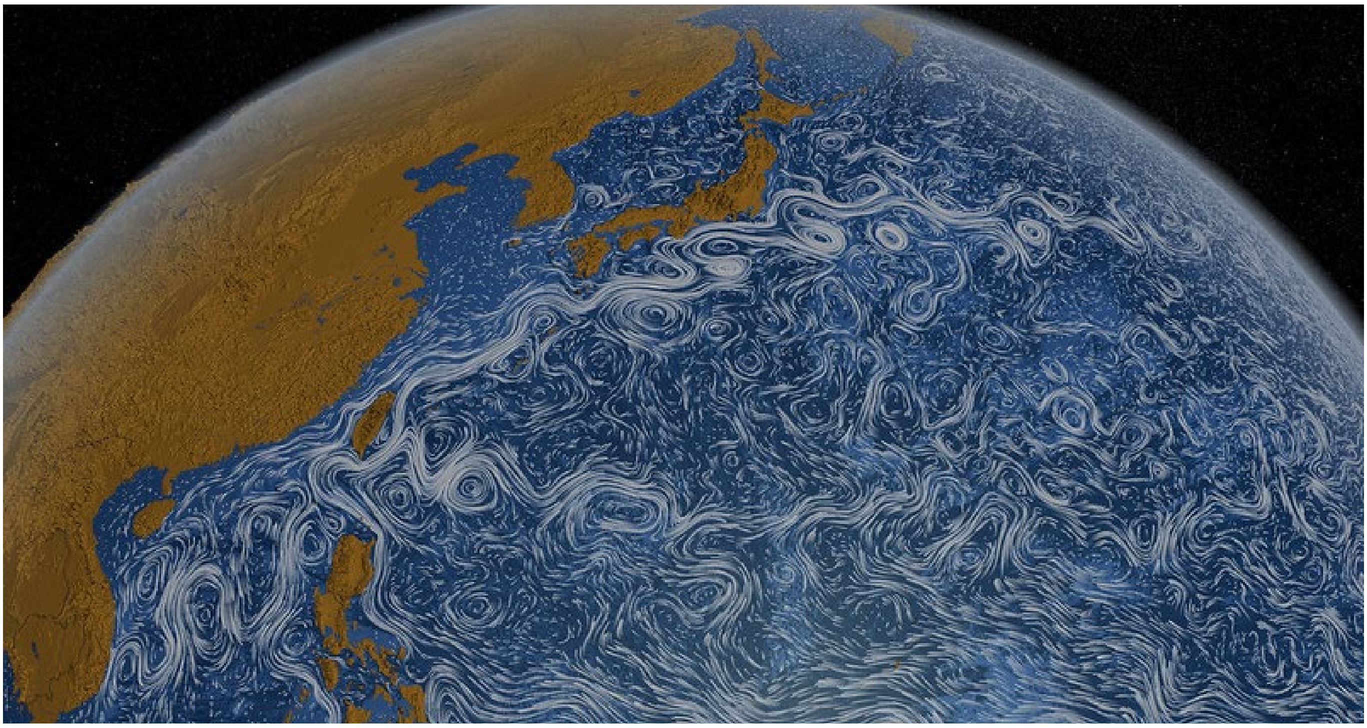
OCEAN OBSERVATIONS TO SHINE LIGHT ON THE PACIFIC'S VITAL MICROBIAL MICROCOSMOS

Researchers at the Japan Agency for Marine-Earth Science and Technology want to learn how communities of hidden but essential plankton populations are changing as the ocean warms and acidifies.

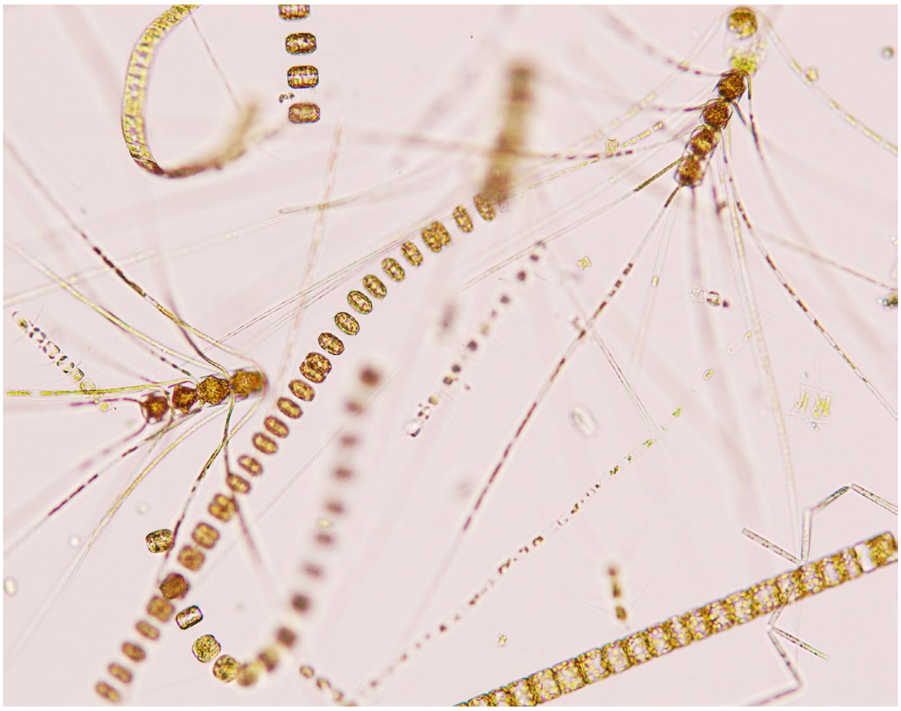
The western North Pacific is home to one of the great terminals of global ocean circulation. Two major ocean currents collide, creating a dramatic mix of warm and cold waters that influence marine habitats, ocean chemistry, and nurture some of the world's most immense fishing grounds (see figure one). This vibrant mixing of waters also has a profound impact on communities of phytoplankton, tiny plants that drift in the ocean and, perhaps more than any other organisms, are crucial to life on Earth.

Like trees in a rainforest, phytoplankton such as glass-shelled diatoms, spindly dinoflagellates, and chalk-plated coccolithophores capture the sun's energy and use it to convert carbon dioxide, water, and minerals into organic carbon-based matter through photosynthesis. This primary production underpins all life in the ocean, and as they live out their lives these remarkable microalgae also perform roles that benefit the wider ocean and planet. They produce roughly half of the oxygen in the atmosphere, underpin essential nutrient cycles, and shuttle vast quantities of carbon to the deep ocean.

In the western North Pacific, two massive boundary currents have a major influence on the ocean environment and its planktonic inhabitants. One of these currents brings warm, subtropical waters northwards. Kuroshio – meaning "black stream" in Japanese –, has a very low nutrient content, its waters dominated by downwelling processes that move from the surface to the deep ocean. A second boundary current draws cold, subpolar waters southwards. Oyashio – meaning "parent stream" – is dominated by upwellings that bring fertile waters from the deep ocean to the surface.



Due to the effects of human greenhouse gas emissions, many parts of the ocean are undergoing unprecedented warming, freshening, and acidification. Scientists are concerned that these changes will undermine the essential functions of microalgae and other plankton such as viruses, bacteria, archaea, and tiny creatures called zooplankton. Climate models indicate that these multiple threats will affect different ocean regions in different ways, and researchers at the Japanese Agency for Marine-Earth Science and Technology (JAMSTEC) realised it was a race against time to better characterise plankton communities in the western North Pacific before its environment changed forever.



PLANKTON: A HIDDEN MICROCOSMOS

"Plankton have been studied for centuries, yet because of their tiny size and the vastness of the ocean environment, it is only recently that we have begun to fully appreciate their intricate roles in the wider Earth system," says Koji Sugie, a research scientist at JAMSTEC, whose group wants to understand how microorganisms are responding to stressors such as warming, acidification, and deoxygenation of seawater. "Plankton collectively make up around 70% of the biomass in the ocean: they form the base of the ocean food chain, produce vast amounts of oxygen, and assimilate similar amounts of carbon dioxide. Therefore, it is very important to learn more about them and how their populations might be impacted by global change."

From the perspective of satellite images, multicoloured swarms of phytoplankton resemble post-impressionist paintings, and can be seen stretching for hundreds of kilometres across the ocean. But zoom beneath the surface, and you will find a rich multi-species forest of miniature plants populating the waters. Understanding this diversity is very important to learning their broader function, Sugie says. "While plankton are undoubtedly very small, they have a huge range in terms of shape, genetics, and size," he explains. "There are up to five orders of magnitude between the smallest marine virus and the largest zooplankton species: that's similar to the difference between a bed bug and a blue whale.

"Phytoplankton at the base of the food chain are typically at the smaller end of this scale, but again their sizes can vary wildly. Changes in the environment could reduce the average size of microalgae at the base of the food chain in some parts of the ocean. This matters. Approximately 80 to 90 percent of energy is lost at each level of transfer, for instance when a copepod eats some microalgae, when a fish eats a copepod, or when a shark eats a fish.

"These impacts in turn could have dramatic effects that cascade up the food chain, affecting everything from the size of zooplankton, to the extent of fisheries, to the amount of carbon held in the deep ocean."

INTRICACIES OF THE BIOLOGICAL CARBON PUMP

But up until the turn of the millennium, a lack of direct ocean observations meant that relatively little was known about the western North Pacific's plankton communities. In response JAMSTEC established long-term research stations, one located in the cold waters of the region's subarctic (since 2001) and others based in the relatively warmer waters of the region's subtropics (since 2010).

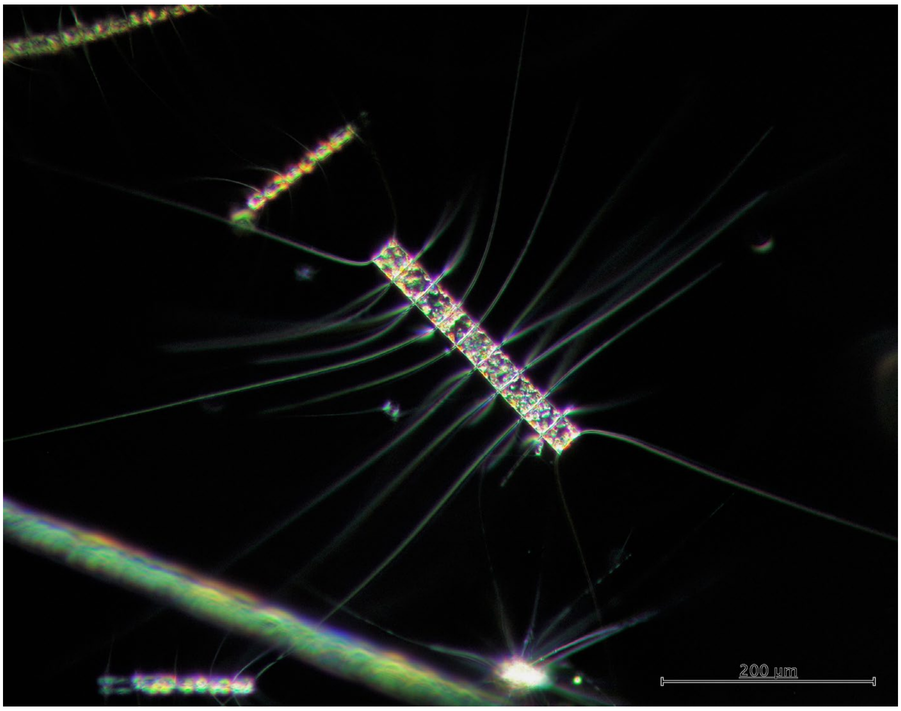
At these sites, an array of instrumentation is used to monitor water temperature, salinity, air-sea exchanges of heat and moisture, wind speeds, carbon dioxide, and ocean pH levels. Sediment traps and filters at various depths, on the other hand, lie in wait for plankton-related detritus that allows researchers to follow the transport of carbon from the sea surface to the ocean floor. The observations are complemented by seasonal cruises that collect additional baseline data.

"JAMSTEC's observation stations have provided data that have enabled a wide range of plankton-related discoveries in the western North Pacific," says Makio Honda, a senior principal scientist at JAMSTEC. "For example, while the multicoloured ocean waters seen in satellite images indicated high levels of primary productivity in subpolar regions, the cobalt blue waters seen in the subtropical areas were thought to be largely devoid of planktonic life. Yet to our surprise, studies have revealed substantial levels of primary production at both of our sites.

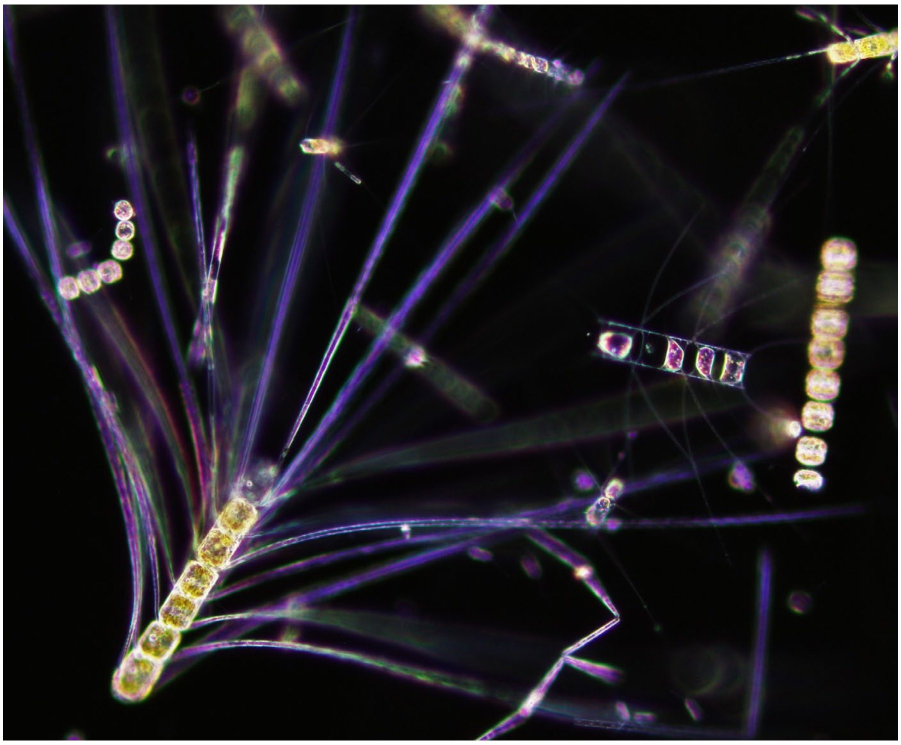
"Using our suite of observations, JAMSTEC researchers identified unexpected nutrient sources in the waters at our subtropical site, including eddy-driven upwellings, weather events, and dust clouds. Eddies can draw nutrients from the deep ocean to the ocean surface, fuelling subsurface phytoplankton blooms that were not detected by satellites. Such a fundamental discovery underscores how much there still is to learn about the roles plankton play in the ocean."

And it is not just living plankton researchers are interested in, but also carbon-packed organic particles created when microscopic organisms die, defecate, decompose, or simply happen to be messy eaters. "When collected and analysed over long time periods, this fall out, known as 'marine snow', can provide an indication of the amount of carbon being transferred to the deep ocean by sea life," explains Honda, whose group carries out time series observations of this phenomenon, which researchers call the biological carbon pump.

As it descends, some marine snow decomposes, releasing carbon and nitrogen back into the water. As a result, deeper ocean waters are often much more fertile than upper layers of the ocean. If marine snow is transported far enough below the surface, beyond a key ocean layer called the thermocline, it can be centuries before carbon particles see the light of day again. A small proportion – roughly 0.1% of organic carbon found in the surface layer – settles right at the bottom as seafloor sediment, and can eventually become fossil fuel deposits.



“Individually, particles can be too small to sink more than a couple of metres. However, they often aggregate together to create ghostly flakes of marine snow, which can sometimes be visible under the beam of a diver’s headlamp. Generally, the deeper marine snow sinks, the less likely it will see the light of day in the foreseeable future. This means that more carbon is held from the atmosphere.



“Through our ocean observations, we want to learn the answers to fundamental puzzles about this biological carbon pump. How much carbon is absorbed by the ocean? Where does it happen? How do different conditions affect these processes? And, crucially, how might this change in future?”

To answer these questions, Honda says that understanding multiple factors that control where marine snow ends up – such as temperature, oxygen levels, and the ecosystem’s structure – is essential for determining carbon export. “Plankton communities are very dynamic and can vary dramatically on a daily, seasonal, yearly, or even decadal basis,” he explains. “Therefore, a single trip to the ocean each year is not enough: continuous, long-term observations are needed in order to distinguish natural variations from human-driven change.

“By making observations over a multi-year timescale, JAMSTEC researchers have found that in the cooler, low-oxygen, nutrient-rich waters of the subarctic station, the levels of marine snow recorded in deeper ocean layers was markedly higher than in the subtropical region. This is despite similar levels of primary productivity closer to the surface.

“One reason for this is because the two ocean regions have very different compositions of phytoplankton species. The cooler waters around our subarctic station are rich in silicate, which diatoms – one of the largest kinds of microalgae – can use to construct their glassy shells. On the other hand, our subtropical site appears to be dominated by smaller phytoplankton, whose small size may limit their descent to the deep ocean.”

UNDERSTANDING THE EFFECTS OF GLOBAL CHANGE

Thanks to the years-long datasets, JAMSTEC researchers are also learning about the effects of human-driven changes on plankton communities. Observations are conducted under the umbrella of the international time series observation programme (OceanSITES) and the global ocean acidification observation network (GOA-ON).

“Warming ocean temperatures can create stratification where surface waters warm faster than the deeper ocean layers,” explains Koji Sugie. “Large differences in temperatures can reduce the mixing of waters between upper and lower parts of the ocean. This can block the flow of nutrients such as silicate and iron from the deep ocean to where plankton need them on the surface. For phytoplankton species that thrive on these nutrients, this presents a major problem.

“On the other hand, as the ocean absorbs some of the excess carbon from human emissions – a process known as the solubility pump – a natural chemical response is that the waters can become more acidic. We have recorded this at both our subarctic and subtropical sites in the western North Pacific. This is particularly bad news for common phytoplankton species such as coccolithophores, whose calcium carbonate shells can dissolve in acidic waters – species may grow smaller or may be eradicated all together.

This could have ramifications not only for carbon export to the deep ocean, but the entire marine food web.

“If phytoplankton become smaller on average, it will likely have negative impacts on trophic transfer – or even result in the growth of a new trophic layer dominated by smaller zooplankton species,” Sugie explains. “This could reduce energy transfers between prey and predator that scale upwards through the whole ecosystem. In turn, this could dramatically reduce the productivity of fisheries, which have huge social and cultural importance in Japan.

“There are other problems, too. For instance, there are signs of dramatic changes in the ocean’s ability to redistribute excess emissions. That’s because warmer waters can reduce the ocean’s ability to absorb atmospheric carbon dioxide, potentially driving further heating at a global level. The feedbacks between climate, the ocean, and its ecosystems need to be better understood in order to learn how the ocean environment may change in the future.

“Therefore, one of the urgent questions in biological oceanography is to clarify what kind of phytoplankton trait would be a benefit or disadvantage against future climate change,” Sugie adds.

“If we can better understand the conditions that allow essential plankton communities to thrive, we will be better placed to do something about it if their ecosystems fall out of balance.”

Written by Adam Gristwood

With thanks to Koji Sugie and Makio Honda (JAMSTEC)