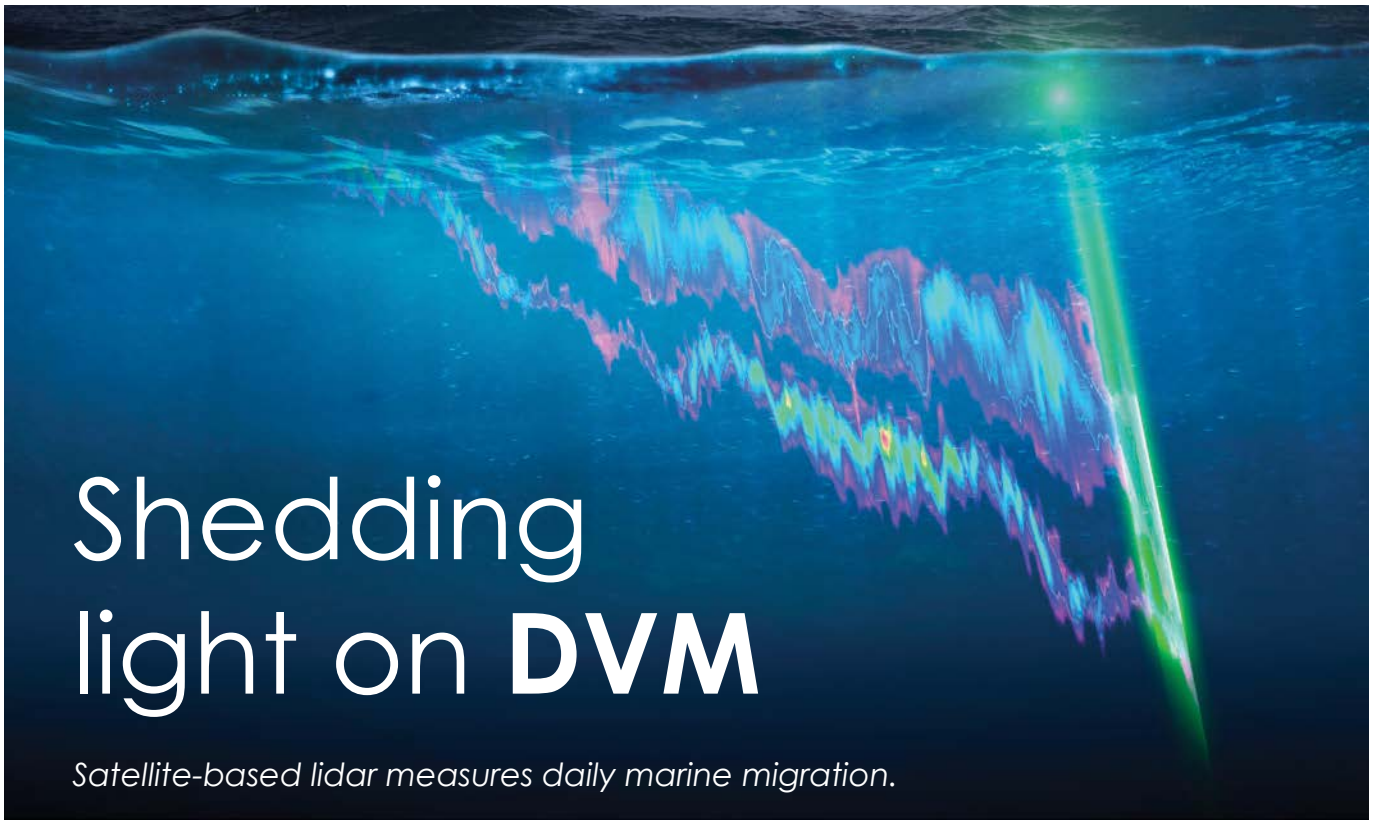


Shedding light on **DVM**

Satellite-based lidar measures daily marine migration.

NASA/Timothy Marvel

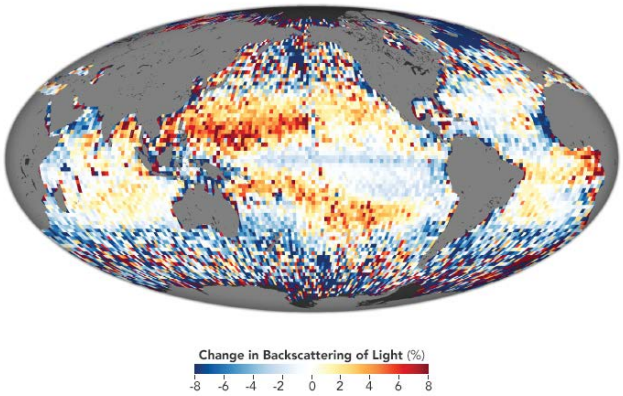
NASA/Timothy Marvel

The CALIPSO satellite's lidar was used to measure diel vertical migration (DVM), the daily movement of small marine organisms into the surface waters at sunset to feed under cover of darkness, before descending back into the depths just before sunrise.

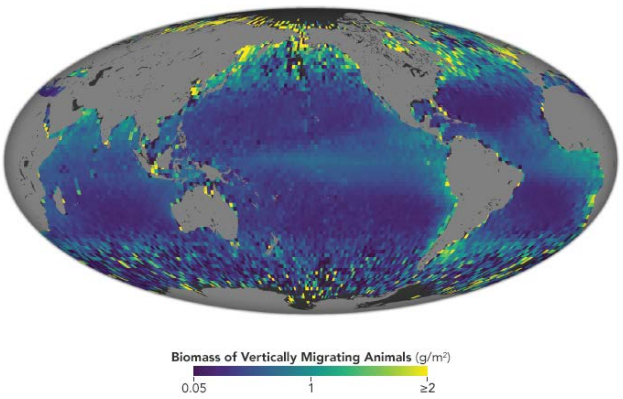
Although CALIPSO was built to study clouds and airborne particles, it has also provided a new perspective on ocean life, allowing researchers to study diel vertical migration (DVM) at a global scale for the first time. The daily movement through the water column of small marine organisms – from planktonic dinoflagellates and crustaceans to fish and squid – has long been studied from ships, but the view from space has yielded insights that improve understanding of the Earth's carbon cycle and can be used to calibrate climate models.

CALIPSO's contribution to marine biological research is rather poignant for those of us old enough to remember that the late Jacques Cousteau's first research vessel in his long-running TV series was named the *Calypso*, after the Greek mythological sea nymph. Two decades before he found fame as a marine explorer and naturalist, Cousteau played a key role in the development of scuba-diving gear, as he co-designed the first safe, twin-hose scuba system, patented in 1945 as the Aqua-Lung. He later co-invented the two-person submarine known as the diving saucer (because it resembled a 'flying saucer' UFO), which allowed him to stay at depths of 350 m for up to five hours.

CALIPSO's laser can only provide remote-sensing data from the upper 20 m of the sea surface, but this is enough to detect the massive migration that takes place on a daily basis. Every night, under the cover of darkness, herbivores that feed on phytoplankton ascend from the depths to the surface layer, where the phytoplankton must remain in order to photosynthesise during the day. Along with the herbivores, which include various kinds of zooplankton and small fish, come the larger animals that prey on them, but just before sunrise they all return to the darker deep water, where they will be harder for predators to see.



CALIPSO's laser pulses are reflected back, or backscattered, by particles and objects in the oceans, influencing the intensity of the signal detected by the satellite's receiver telescope. In this global map of the percentage overnight change in backscattering of light, the red areas had the greatest difference in backscatter between day and night, which indicates a large proportion of animals undertaking DVM.



Joshua Stevens, NASA

Coastal waters have higher nutrient concentrations than open-ocean areas because of river inputs, upwelling and pollution sources, so they are far more productive, supporting an abundance of marine life. This means that even though DVM is most apparent in oceanic waters, the overall biomass of vertically migrating animals is still higher in coastal waters.

This daily movement is the largest migration of animals on Earth in terms of total numbers, and the cumulative effect on global climate is significant. During the day, photosynthesising phytoplankton take up significant amounts of carbon dioxide (CO_2), which contributes to the oceans' ability to absorb this greenhouse gas from the atmosphere. When animals feed on phytoplankton near the surface and then swim back down, they take the phytoplankton carbon with them. Much of this carbon is then defecated at depths where it is effectively trapped, preventing its release back into the atmosphere.

A team of researchers from the United States, France and Canada published their findings on CALIPSO's revelations about this vast animal migration in the journal *Nature* in November 2019.

"What the lidar from space allowed us to do is sample these migrating animals on a global scale every 16 days for 10 years," said lead author Mike Behrenfeld, who is a senior research scientist and professor at Oregon State University. "We've never had anywhere near that kind of global coverage to allow us to look at the behaviour, distribution and abundance of these animals."

The team found that in tropical and subtropical ocean regions – where the water column is nutrient-poor, supporting low phytoplankton concentrations and hence quite clear – there are fewer vertically migrating animals, but they comprise a greater fraction of the total animal population. This is because visual predators have a greater advantage in clear ocean regions, whereas in murkier, nutrient-rich regions relatively more animals can remain near the surface, night and day.

Matt Wilson, Jay Clark, NOAA NMFS AFSC

Zooplankton such as copepods and euphausiids, or krill, undertake DVM to feed on phytoplankton and smaller zooplankton.

The researchers also observed long-term changes in populations of migrating animals that are probably driven by climate variations. During the study period, between 2008 and 2017, CALIPSO data revealed an increase in the biomass of migrating animals in the subtropical waters of the North and South Pacific, North Atlantic and South Indian oceans. In the tropical regions and North Atlantic, biomass decreased. In all but the tropical Atlantic regions, these changes correlated with changes in phytoplankton production.

Recognising that DVM is an important mechanism in Earth's carbon cycle, scientists are taking the phenomenon into account in their modelling of global climate.

"What these modellers haven't had is a global dataset to calibrate these models with, to tell them where these migrators are most important, where they're most abundant, and how they change over time," said Behrenfeld. "The new satellite data give us an opportunity to combine satellite observations with the models and do a better job quantifying the impact of this enormous animal migration on Earth's carbon cycle."

The CALIPSO outputs are also relevant to global food security, because the migrating animals are an important food source for larger predators that are targeted by commercial fisheries. The larger the DVM signal, the larger the population of fish that can live in the deep sea.

"This is the latest study to demonstrate something that came as a surprise to many: that lidars have the sensitivity to provide scientifically useful ocean measurements from space," said Chris Hostetler, a scientist at NASA's Langley Research Centre and a co-author of the paper. "I think we are just scratching the surface of exciting new ocean science that can be accomplished with lidar."

- Behrenfeld, MJ, Gaube, P, Della Penna, A. et al. 2019. Global satellite-observed daily vertical migrations of ocean animals. *Nature* 576**:** 257–261. https://doi.org/10.1038/s41586-019-1796-9

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