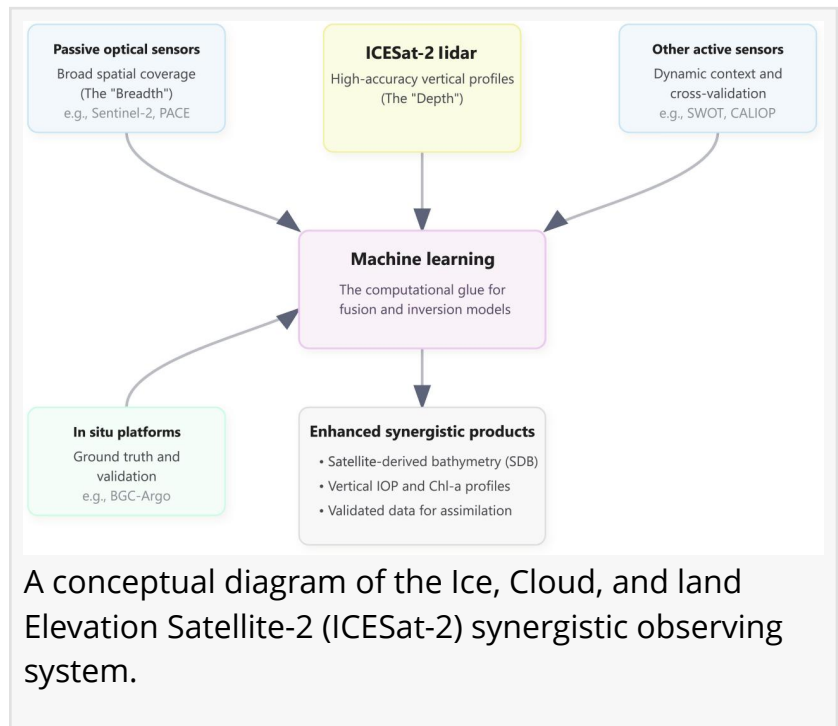


Photon-counting lidar transforms ocean observation

GA, UNITED STATES, June 12, 2026 /EINPresswire.com/ -- A new review shows how ICESat-2, a satellite originally designed for ice monitoring, is reshaping ocean science by adding the missing vertical dimension to space-based observation. Using photon-counting light detection and ranging ([lidar](#)), the system can measure shallow-water depth, profile optical properties through the water column, and support studies of marine ecosystems. By combining precise lidar tracks with imaging satellites and in situ observations, this approach points toward a more complete three-dimensional view of the global ocean.



For decades, passive ocean-color satellites have provided valuable maps of surface chlorophyll and related marine properties, but they mainly capture an integrated signal from the upper ocean and cannot directly resolve vertical structure. Earlier lidar missions showed that active sensing could partly overcome this limitation, yet they were not optimized for ocean science and faced major constraints in spatial resolution and retrieval accuracy. These limitations have restricted scientists' ability to observe subsurface features, polar waters, and dynamic coastal environments. Based on these challenges, deeper research into three-dimensional ocean observation from space is needed.

Researchers from the State Key Laboratory of Satellite Ocean Environment Dynamics at the Second Institute of Oceanography, Ministry of Natural Resources, and the Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou) published (DOI: 10.34133/remotesensing.1040) this review in the Journal of Remote Sensing on March 26, 2026. The article explains how ICESat-2 is helping solve a long-standing problem in marine remote sensing: how to observe not only the ocean surface, but also key structures beneath it that influence navigation, ecosystem dynamics, and climate-related processes.

The review shows that ICESat-2's Advanced Topographic Laser Altimeter System (ATLAS), the first spaceborne photon-counting lidar, has moved ocean remote sensing beyond mainly two-dimensional surface observation toward a more three-dimensional framework. In shallow, clear waters, it can measure depths of up to 40 m, with reported bathymetric accuracy approaching about 0.5 m root mean square error (RMSE) in some studies. It can also retrieve water-column optical properties, including the diffuse attenuation coefficient (K_d), and after correction these results agreed with Biogeochemical-Argo (BGC-Argo) observations with a mean absolute percentage difference of 15.7%. A major advance highlighted in the review is sensor synergy: ICESat-2 becomes far more powerful when combined with Sentinel-2, Moderate Resolution Imaging Spectroradiometer (MODIS), Sentinel-3, Surface Water and Ocean Topography (SWOT), Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), and BGC-Argo data.

ATLAS operates at 532 nm, a water-penetrating wavelength, and fires at 10 kHz, producing dense along-track sampling of about 0.7 m together with centimeter-level vertical precision. Scientists mainly use the Level 2A ATL03 Global Geolocated Photon Data product, while ATL24 now provides an official coastal and nearshore bathymetry product for broader use. Transforming raw photons into useful ocean information requires three major processing steps: photon classification, correction of detector after-pulsing artifacts, and refraction correction based on Snell's law. Machine learning (ML) methods such as PointNet++ and other supervised approaches have improved photon extraction and automation, while physical and ML-based corrections have strengthened the retrieval of depth and optical parameters. The review also describes notable ecological applications, including the first spaceborne observations of Antarctic ice-edge phytoplankton blooms extending roughly 230 km and concentrated within the upper 15 m of the water column.

The authors suggest that ICESat-2's greatest value lies not in functioning as a standalone sensor, but in serving as part of an integrated observing system. In that role, its highly precise vertical profiles can calibrate and strengthen other datasets, helping researchers build a more complete picture of ocean structure, biology, and environmental change from space.

This paper is a comprehensive review rather than a single experimental study. It synthesizes progress in ICESat-2 hardware, data products, retrieval algorithms, validation studies, and multisensor fusion strategies. The authors discuss photon denoising, after-pulsing correction, refraction correction, bathymetric inversion, optical-profile retrieval, and machine-learning fusion with passive satellites and in situ platforms. The review also includes a bibliometric analysis showing rapid growth in this field since the launch of ICESat-2 in 2018.

The review argues that ICESat-2 has laid the foundation for a new generation of ocean-focused Earth observation. Future progress will likely come from stronger integration with hyperspectral missions such as Plankton, Aerosol, Cloud, Ocean Ecosystem (PACE), dynamic mapping systems such as SWOT, and next-generation lidar missions including Earth Clouds, Aerosols and Radiation

Explorer (EarthCARE) and Daqi-1. With effective integration, these systems could help scientists move toward an operational three-dimensional, and eventually four-dimensional, framework for observing the global ocean.

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