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Editorial: Deep-sea observation equipment and exploration technology

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Editorial on the Research Topic
Deep-sea observation equipment and exploration technology

The increasing interest in deep-sea exploration is a crucial catalyst for driving advancements in deep-sea observation technology research. Numerous sophisticated sensors have been developed to facilitate comprehensive studies of deep-sea physics, chemistry, and geology. For example, cutting-edge small and compact seabed samplers are now employed on various platforms, such as Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs), and Human-Operated Vehicles (HOVs), enabling observation of the hadal zone. Additionally, Micro-electromechanical Systems (MEMS) sensors are routinely utilized for ocean wave observation. This Research Topic aims to foster new insights into ocean exploration and observation technology, including ocean sensor technology, ocean observation platforms, and ocean observation reliability technology.

With respect to ocean sensor technology, the works included in this Research Topic cover communication and navigation technology, opto-electronic MEMS sensors, deep-sea samplers, and specialized equipment for oil and gas exploration. Unlike traditional electromagnetic communication technology, atmospheric evaporation waveguide communication technology facilitates long-distance transmission by utilizing surface water vapor as a transmission medium. Additionally, the dual-axis rotary modulation inertial navigation system (INS) introduces a gravity disturbance compensation method to enhance the positioning accuracy of the INS. With the advancement of MEMS technology, the design of wave sensors and sound velocity profiles has become more miniaturized and modular, allowing marine scientists and engineers to design sensors based on their specific research needs. In the research of specialized instruments for marine geology, the developed deep-sea seabed sampler can directly reach the abyssal zone.

Qiu et al. studied the evaporation duct properties in the East China Sea. The evaporation duct is an abnormal phenomenon that occurs at an extremely high frequency in the marine atmospheric boundary layer and directly affects the propagation of electromagnetic waves. Therefore, it is necessary to investigate the various characteristics of the evaporation duct. Large-scale observations at sea are difficult, so reanalysis data are usually utilized for evaporation duct property studies.

Zhang et al. presented gravity disturbance compensation for a dual-axis rotary modulation INS. The error and frequency characteristics of the INS caused by gravity disturbances is investigated. And the gravity disturbance is introduced into the INS initial alignment and calculation to implement the INS gravity compensation. As INSs are widely employed to establish autonomous navigation systems, this work provides an effective method to enhance the long-endurance positioning capability of underwater or other autonomous passive navigation.

Zhou et al. described the design and application of the miniaturized strap-down inertial wave sensor DWS19-2, which is mainly utilized for ocean air-sea buoys and surface drifting buoys. A 9-axis MEMS inertial module was integrated into an STM32F446 embedded controller to measure buoy pitch angle, roll angle, yaw angle, and 3-axis accelerations.

Zhang et al. designed and calibrated a low-cost underwater sound velocity profiler consisting of three parts: the control unit, the storage module, and the ultrasonic measurement module. This can be integrated into the profilers and platforms or utilized as a sound velocity sensor. The low cost of the sound velocity profiler can enable large-scale deployment.

Chen et al. designed an underwater free-space optical communication module to be used between AUVs and seafloor junction boxes. They characterized underwater optical transmission, established photoelectric signal processing and modulation and demodulation algorithms, and designed a prototype including a free-space optical transmitter and a receiver. They reported that a communication rate of 1 Mbps could be achieved with a transmitter power of 10W.

He et al. presented a submersible-mounted sampler capable of collecting pressure-retained samples at full ocean depth to obtain seabed sediments. The submersible-mounted sampler was fixed on the HOV and coordinated sampling with the manipulator. This sampler has a compact structure, is small in size, and is lightweight, making it convenient to operate with ROVs and HOVs.

Li et al. conducted a sensitivity analysis of seismic attributes and oil reservoir predictions based on jointing wells and seismic data to identify the location of gravelly sandstone. The well analysis and core data were utilized to establish the geological model of mudstone and sandstone and to identify the electrical characteristics of the lithology.

Ocean observation and exploration platforms mainly involve ocean buoys, underwater gliders, AUVs, etc. The profile thermal buoy captures the thermal energy of the ocean and converts it into electrical energy, thus improving the endurance of the profile buoy. Oceanographic buoys are the traditional and mainstream means of observation, while the development of Electro-Optical Mechanical (EOM) mooring cables takes on the role of buoy mooring lines, extending the observation from the sea surface to the sea floor. As a long-range autonomous observation platform, the streamlined design and wing shape of underwater gliders have a crucial impact on their energy consumption. Compared to human-operated ROVs, AUVs' underwater target detection algorithms require strong real-time performance and the ability to cope with issues such as poor underwater light conditions and buried targets.

Chen et al. developed an energy conversion system for ocean thermal profilers that has great potential for application in underwater gliders and profilers. The authors analyzed the performance of the energy conversion system and established an experimental platform to study the system's performance and verify the validity and accuracy of the established mechanical model. They reported that the experiment for mechanical efficiency was close to the simulation, and the energy conversion system can meet the engineering application.

Zhang et al. presented the design of a mooring buoy observation system with a mooring EOM cable. The cable connects the sea surface buoy and the benthic observation node as a transmission link for information and power. The paper also provides detailed design concepts for the buoy nodes and seabed nodes.

The EOM cable plays the role of buoy mooring tether and is also the crucial link to ensure long-term and effective system operation and energy/data transmission. Zhang et al. presented the mooring dynamic characteristics of the EOM cable of the cable-moored buoy observation technology. They analyzed the static mooring loads and dynamic characteristics of the mooring line under different external environments. They also added a rubber snubber to the mooring line to reduce the influence of the sea surface.

Wang et al. reported on a swept-wing strategy to optimize the wing shape and position of underwater gliders. They conducted hydrodynamic numerical simulations of different wing sweep angles and found the optimal sweep angle. They also established a dynamic model of the underwater glider with the hydrodynamic simulation results. This study can improve the optimal capabilities of underwater gliders, such as gliding duration and trajectory accuracy.

Xu et al. described a vision-based real-time underwater target detection method for AUV subsea exploration in poor lighting conditions and deep-sea sediment burial. They integrated the proposed method into the AUV control system for online target detection. They expected this technology to be utilized in the marine archaeological survey field.

Ocean observation is a long-term and sustained effort that requires addressing various issues, such as the overall deployment of the observation system, improving the quality of the observation data, and improving system reliability. This is particularly evident for underwater observation networks and ocean buoy observation networks. Because many of the observations are for the near-shore sea surface, the locations and number of buoys are particularly important in terms of how to cover the observed area with as few buoys as possible. The design life of the seabed observation network is generally more than 20 years, so the watertight connectors should have good reliability and the seabed sensors can self-calibrate and suppress data drift. At the same time, new technologies for seabed observation networks, such as the Internet of Underwater Things, are gradually making underwater observation more intelligent.

Liu et al. optimized buoy deployment in Bohai Bay, China. It was a crucial and core issue to optimize the buoys' effectiveness by using as few of them as possible for the ocean buoy network and to optimize the buoy location to reflect the changing characteristics of the target observation area. The optimization method provides ideas for the selection of buoy deployment locations for regional ocean buoy observation networks.

Skålvik et al. developed measurement strategies to ensure data quality in deep-sea sensors. The paper discusses how sensors can be affected by the specific environment and the correlations between different variables that influence the measurement results. Their research focused on fixed-platform sensors on the ocean floor, which can be deployed for several years in remote deep-sea locations.

Duan et al. developed a non-contact wet-mateable connector for optical communications and power transmission. The inductive coupling for power transmission and optical communication is separated to cope with power transmission and communication issues. They also designed the docking structure of the sockets and plugs to facilitate the operation of the ROVs.

Duan et al. presented the system design of the Xiangshan Internet of Underwater Things (XIoUT). The XIoUT is China's first multi-node constant current cable observation network, which is utilized for collecting and transmitting ocean environmental data. The development of the IoUT has benefited from the rapid development of current intelligent technologies, such as artificial intelligence technology and the Internet of Things technology. In addition, the XIoUT provides a testing system for the research of Internet of Things technologies in the ocean.

The Guest Associate Editors thank all the authors and reviewers for their dedicated work on this Research Topic. We hope that this can inspire further research for deep-sea observation equipment and exploration technology.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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