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Editorial

Technological Oceanography

Mikhail Emelianov [1,*] and Georgy I. Shapiro [2]

1 Instituto de Ciencias del Mar, CSIC, Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain
2 School of Biological and Marine Sciences, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK; g.shapiro@plymouth.ac.uk
* Correspondence: mikhail@icm.csic.es

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Advances in our understanding of phenomena in the ocean would not be possible without innovation. Identifying new phenomena, assessing environmental risks, monitoring and forecasting the ocean state, and delivering observational data to modelers are all challenges requiring technological solutions.

This Special Issue of *JMSE*, entitled "Technological Oceanography", aims to present an oceanographic perspective on modern technology, allowing for a better understanding of the ocean in all its diversity and taking into account both societal and scientific needs. This Issue has collected original papers based on applications of novel approaches in the development of new sensors, observational programs, sampling strategies, new ocean modeling techniques and data processing. It is impossible to describe the current state of such a complex and constantly evolving science as technological oceanography in one volume. Thus, the articles presented in this volume are just some examples of modern trends in the development of new technologies in some areas of oceanography.

One of the important aspects of oceanography concerns the long-term measurement of depth profiles of hydrological, biological, chemical, and optical parameters at fixed locations. These in situ measurements are performed with automated tethered profilers, known as Yo-Yo, connected by a flexible cable with bottom anchors or other underwater supports [1]. Autonomous tethered profiling systems that operate in shallow waters often use winches [2]. Alexander G. Ostrovskii et al. (Contribution 1) discusses automated tethered profilers for hydrophysical and bio-optical measurements, advancements which allow researchers to monitor water column parameters from a fixed observational point with high spatial and temporal resolution. These breakthroughs permit the transmission of telematic data in real time, including the results of studies of biogeochemical cycles of carbon transformation throughout the euphotic zone of the sea. The original results of in situ measurements were obtained for the inner continental shelf part of the site using this new tethered profiler. Another innovation is related to marine plankton sampling. Different types and systems have been developed in recent decades to discriminate plankton samples at different strata in water columns [3,4]. Arturo Castellón and Maria Pilar Olivar (Contribution 2) presented a cod-end multisampler design, VERDA. This uses a carrousel-like system, similar to some sediment traps, that works like a revolver with six or eight compartments whose turning mechanism is triggered when the net arrives to a programmed depth level. This device allows research to discriminate plankton samples at different strata in the water column and is useful for all types of ships due to the relatively easy deployment operations.

It is well known that the coastline is susceptible to anthropogenic impact and climate change, particularly the rising sea level and more frequent extreme meteorological events [5]. However, the coastal waters are temporally and spatially undersampled [6] due to the difficulty of establishing oceanographic platforms capable of performing continuous sampling away from the coastline. Another concern is the limited accuracy and spatiotemporal resolution of satellites in the shelf waters. Inmaculada Ortigosa et al. (Contribution 3) described scientific adaptation of a vessel and initial measurements from a "patí a vela", which is a very popular unipersonal catamaran in Barcelona. This versatile sailing vessel has been adapted to contain several low-cost sensors and instruments to measure water properties. Citizen sampling from fully sustainable sailing boats may turn into an effective strategy to monitor the urban coastal waters.

The effectiveness of laboratory experiments continues to improve, allowing researchers to study the physical mechanisms that produce ocean phenomena in detail [7–9]. Andrey G. Zatsepin et al. (Contribution 4) presented the results of a laboratory experiment conducted to quantitatively investigate turbulent exchange between two quasi-homogeneous layers of equal thickness and different density (salinity), as well as the fine structure of the density transition zone (interface) between the layers. It was shown that maximum mixing efficiency was achieved at a critical Richardson number, when the density interface was in a transitional state between the sharpening and diffusive modes.

One of the important tasks of physical oceanography is the assessment of vertical turbulent exchange in the stratified waters of seas and oceans. In particular, the vertical flux of nutrients from deep waters into the photic layer, where most biological production takes place, depends on the intensity of turbulent exchange [10–12]. Oleg I. Podymov et al. (Contribution 5) presented the analysis of the long-term regular time series of current velocity and conductivity, temperature, and depth (CTD) profiles, measured using the moored autonomous profiler Aqualog over the upper part of the continental slope at a fixed geographical location in the Northeastern Black Sea. This study focused on the fine structure of the density profiles to show that the fine-structured Cox number (C) is a power function of the Richardson number (Ri). The original analysis of the obtained data suggests that the estimations of the vertical turbulent mass exchange could be performed using CTD data only.

Since 2009, a new generation of satellites launched by ESA and NASA have provided radiometric measurements, allowing the retrieval of sea surface salinity [13]. In situ data are crucial for validating and enhancing the quality of satellite products obtained in far oceanic regions, where few such measurements have been taken [14,15]. Marta Umbert et al. (Contribution 6) showed the results of temperature and salinity measurements in the first 60 cm of a water column in the data-scarce areas of the World Ocean. Measurements were obtained during the Vendée Globe, which is the world's most famous solo, non-stop, unassisted sailing race with the CTD MicroCat, installed on the One Ocean One Planet boat. The measurements were performed every 30 s during navigation and this allowed us to obtain data in the sub-Antarctic zone, between the tropical and polar fronts, and it passed through areas of oceanographic interest such as Southern Patagonia (affected by glacier melting), the Brazil–Malvinas confluence, the Southern Pacific Ocean, and the entire Southern Indian Ocean.

Fine-resolution ocean modelling is becoming a ubiquitous practice to resolve important mesoscale and submesoscale features such as eddies, fronts, boundary currents, and localized upwellings, which play important roles in ocean dynamics (e.g., [16,17]). These localized models can be run by relatively small groups due to the availability of excellent ocean models such as ROMS or NEMO to the wider oceanographic community [18,19]. Georgy I. Shapiro and Jose M. Gonzalez-Ondina (Contribution 7) developed a simple and computationally efficient method for creating a high-resolution regional (child) model nested within a coarse-resolution, high-quality data assimilation (parent) model. This method, named Nesting with Downscaling and data Assimilation (NDA), reduces the bias and root-mean-square errors (RMSE) of the child model and does not allow the child model to deviate from reality. The NDA method utilizes data assimilation process in the coarse model as a way to spread information from observation over the whole domain, avoiding the use of simplified and less accurate methods such as spreading via parabolic equation. The NDA method reduces the RMSE, typically by a factor of two to five, but by occasionally more. The method is particularly efficient in areas with sparse observational data.

Due to intrinsic inaccuracies in the model equations and numerical schemes, and due to limitations in the quality of input data streams, even the best ocean models gradually deviate from reality and can only be considered estimates of the true ocean state [20]. The introduction of data assimilation (DA) techniques allows researchers to reduce the deviation of models from the true state, vastly improving the accuracy of ocean forecasting [21]. José M. González-Ondina et al. (Contribution 8) developed a new mathematical method for computing the background and observation error covariance functions and matrices. As data assimilation methods are invaluable tools for operational ocean models, the covariance matrices of background errors (differences between the numerical model and the true values) and the observation errors (differences between true and measured values) are required for correcting ocean model outputs by assimilating observational data using a variational approach. The authors demonstrate that in many cases the new method allows the use of the separable convolution mathematical algorithm to increase the computational speed significantly up to a given order of magnitude.

In recent years, underwater acoustic technology has been widely used to detect underwater targets, describe underwater overviews [22], measure hydrological information, and perform other tasks. Due to the influence of the water surface, water body, water bottom, and other features, sound wave propagation in the ocean presents a complicated distribution state [23]. Xian Ma et al. (Contribution 9) developed a direct solution method for the two-dimensional Helmholtz equation of ocean acoustic propagation without using simplified models. In their study, the authors applied two spectral methods, Chebyshev–Galerkin and Chebyshev–collocation approaches, to correctly solve the two-dimensional Helmholtz model equation. Due to a lack of model constraints, the Chebyshev–collocation method has a wide range of applications and provides results with high accuracy, which is of great significance in the calculation of realistic ocean sound fields.

Ocean acoustic waves propagate over long distances because their energy attenuates to a smaller degree in water than that of electromagnetic waves; consequently, acoustic waves have been widely used in target detection, environmental monitoring, and underwater communication [24]. Wei Liu et al. (Contribution 10) established a vector wavenumber integration (VWI) model to provide benchmark solutions for ocean current study. The depth-separated wave equation was solved using finite difference (FD) methods with second- and fourth-order accuracy, and the sound source singularity in this equation was treated using the matched interface and boundary method. Time-averaged sound intensity (TASI) was calculated using the pressure and particle velocity, and the TASI streamlines were traced to visualize the time-independent energy flow in the acoustic field and better understand the distribution of acoustic transmission loss.

In recent years, dictionary learning [25] has been widely used in the field of sound velocity profile data processing as a feature extraction method. Kaizhuang Yan et al. (Contribution 11) used the dictionary learning method to achieve sparse coding of the high-resolution sound speed profile and used a compressed sparse row method to compress and store the sparse characteristics of the data matrix. Their research revealed how this method significantly reduces the storage capacity of high-resolution sound speed profile data and ensures the accuracy of the data, providing technical support for efficient and convenient access to high-resolution sound speed profiles.

As Guest Editors for this Special Issue, we would like to sincerely thank the authors who have submitted their work to this.

Working with such a bright group of scholars has been an honour and a joy, and we sincerely appreciate their time, energy, and effort. The articles include distinct viewpoints and ideas on the subject matter, encompassing an extensive array of techniques and strategies concerning technological oceanography.

The calibre of the entries as well as the diligence and focus on detail exhibited by every author have impressed us. Because of their contributions, this Special Issue is a special compilation, one that we believe will be of great interest and value to readers in the field.

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List of Contributions

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