EDITORIAL
published: 11 July 2022
doi: 10.3389/fmars.2022.961282

Editorial: Acoustically Mapping the Ocean

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Keywords: seismic oceanography (SO), diapycnal diffusivity, inversion (seismic), ocean front dynamics, internal wave (IWs)

Editorial on the Research Topic

Acoustically Mapping the Ocean

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Specialty section:
This article was submitted to Ocean Observation, a section of the journal Frontiers in Marine Science

Received: *04 June 2022*
Accepted: *08 June 2022*
Published: *11 July 2022*

Citation:
Gunn KL, Sheen KL and Tang Q (2022) Editorial: Acoustically Mapping the Ocean. Front. Mar. Sci. 9:961282. doi: 10.3389/fmars.2022.961282

Acoustic oceanography can address ocean observing needs, but it is not yet a standard observational tool. Sound remotely senses the ocean, as it travels further and faster than any other signal underwater.

Since this potential was first recognized in the late 20th century, acoustic oceanography has primarily been used to map the ocean floor using frequencies of 10-100 kHz. These high frequencies have also been turned toward investigating physical and biological oceanographic questions. For example, the strong relationship between demersal fish species – those that live close to the seafloor – and seabed depth has been used to map fish distributions, which is not possible with direct observations. In this Research Topic, Landero Figueroa et al. examine the effectiveness of demersal fish species models; they confirm that depth is the primary variable explaining their distribution, whilst the inclusion of depth derivatives has varying effectiveness depending on the species.

More recently, marine seismic reflection data, at lower frequencies of 10-100 Hz, have seen an explosion in their use. This smaller field of acoustic oceanography, so-called seismic oceanography, is a tool that can be used to map the distribution, properties, and dynamics of water masses and it has the potential to overcome significant observational challenges (see review by Dickinson and Gunn). In this Research Topic, the capability of seismic oceanography is demonstrated via a collection of the latest methodological developments and seismic-based advances in our understanding of oceanic processes.

Inversion of marine seismic reflection data yields oceanic temperature, salinity, and density fields in two-, three, and even four-dimensions. Here, two methodological advances expand the capacity for inversion. Azevedo et al. develop a geostatistical inversion that can be used when contemporaneous and collocated hydrographic measurements are not available, instead leveraging common models of large-scale ocean dynamics and existing vertical profiles of the ocean properties measured by ARGO floats. Without any contemporaneous data, this inversion scheme can produce temperature and salinity fields with accuracies of order 1°C and 0.5 psu. In cases where contemporaneous and collocated hydrographic data are available, Xiao et al. develop an established Markov Chain Monte Carlo approach to show that this method can quantify temperature and salinity fields to within 0.16°C and 0.06 psu.

Uniquely, the causes and consequences of short-term water mass variability can be studied using seismic-derived time series of diapycnal mixing alongside its high-resolution imagery. In the South Atlantic, such time series of diapycnal mixing suggest that at 1,000 km and decadal scales the background diffusivity of the thermocline has changed little, whilst temporally intermittent processes, such as storms (Wei et al.) and frontal advection (Gunn et al.), can temporarily alter diapycnal mixing by an order of magnitude. Similarly, in the South Pacific Ocean, observations of daily frontal meandering cause significant changes in water mass thicknesses and temperatures (Cooper et al.).

Internal waves – which drive intense ocean mixing, contribute to ocean-atmosphere interactions, and impact offshore engineering – are particularly difficult to observe with traditional hydrographic methods. Here, their structure as well as their evolution with time is observed and quantified in detail using seismic oceanography. In depths of 300 m, seismic observations of internal wave evolution confirm results from numerical simulations (Song et al.); during shoaling, the degree of waveform change is related to the waves size, and its amplitude and phase velocity increase onshore. In depths shallower than 50 m, which are invisible to seismic oceanography, higher-frequency acoustic methods show internal waves that have amplitudes extending as much at 20% of the water depth (Feng et al.). These observations from the northeastern South China Sea can be generalized to other regions where strong currents impinge on topographic slopes.

The potential of seismic oceanography to solve oceanographic questions, in conjunction with other acoustic and hydrographic measurements, lies with the abundance and resolution of existing measurements plus the continually growing data sets collected by education and industry initiatives. Existing marine seismic reflection data covers every continental shelf and slope in the world's ocean (Figure 4 of Dickinson and Gunn). Using these data, bulk inversion processing can be applied to access physical properties of water masses at unprecedented spatial resolution on a global scale; just as oceanic models with different resolutions are required to investigate the climate, inversion techniques with different limitations and accuracies are necessary. For example, the inversion of Azevedo et al. could be applied in a bulk sense to measure the volume of water masses, whilst the inversion of Xiao et al. (2021) could be applied in a region of significant data coverage to develop high quality time series of small-scale mixing and stirring processes. Oceanic mixing rates are globally limited, yet seismic oceanography can readily be used to expand this valuable data set, an important link connecting mixing to larger scale climate-mediating processes. For example, Wei et al. use seismic data to extend the record of mixing in the South Atlantic Ocean into the late 2010s, whilst Gunn et al. provide rare time series of mixing rates across a front. Meanwhile, seismic imagery alone provides insight into ocean dynamics yielding daily information about water mass position and thickness variability (Cooper et al.). Acoustic data also yield high-resolution information about the evolution of internal waves on the continental shelf (Song et al., Feng et al.).

In this Research Topic, the role of short-lived and rapidly changing processes are highlighted. Acoustic data sets provide a guide for future observational programs as well as an avenue for defining parameterizations that can be included in models, which often do not realistically resolve temporally intermittent oceanic processes. Overall, these studies show how acoustic methods can be used to augment and overcome observational challenges. Through collaborative development, acoustic techniques can become a staple of the new generation of observational tools.

AUTHOR CONTRIBUTIONS

KLG conceived the Research Topic and wrote the editorial with input and advice from KLS and QT. All authors approved this editorial for publication.

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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