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Introduction to the Special Issue on climate change: How the sound of the planet reflects the health of the planet

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ABSTRACT:
Climate change is altering environmental conditions that govern acoustic propagation across oceanic, atmospheric, and terrestrial systems, while also creating new opportunities for acoustic sensing of these changes. This joint Special Issue of the *Journal of the Acoustical Society of America* and *JASA Express Letters* highlights recent advances at the intersection of acoustics and climate science, including studies of ocean acoustic tomography, marine and terrestrial soundscapes, coastal ecosystems such as coral reefs and seagrass meadows, and the impacts of anthropogenic noise. Together, these contributions demonstrate how acoustic methods can provide unique insights into environmental variability, ecosystem response, and long-term climate processes across a range of spatial and temporal scales.
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I. INTRODUCTION

Climate change is transforming the physical and biological environment of the Earth's atmosphere, oceans, and cryosphere. These changes are altering acoustic propagation conditions, reshaping soundscapes, and creating new opportunities for acoustic sensing of environmental processes. As a result, acoustics is increasingly playing a dual role in climate science: both as a discipline affected by environmental change and as a powerful tool for observing and understanding those changes.

In the ocean, climate-driven shifts in temperature, salinity, circulation, and stratification influence sound speed structure and acoustic propagation. Changes in sea ice extent, glacier dynamics, and ocean circulation alter the ambient soundscape and affect the performance of acoustic systems used for communication, navigation, and environmental monitoring. At the same time, passive and active acoustic techniques provide valuable observations of processes relevant to climate science, including ocean temperature variability, ice dynamics, biological activity, and long-term changes in environmental noise.

Acoustics also contributes to climate-related research in the atmosphere and terrestrial environments. Atmospheric temperature and wind structure influence sound propagation over long ranges, while acoustic and infrasonic techniques can be used to monitor natural hazards and environmental processes associated with climate variability. On land and in coastal ecosystems, soundscape monitoring is increasingly used to track ecological responses to changing environmental conditions.

This Special Issue brings together contributions that highlight the diverse ways in which acoustics intersects with climate science. The papers included here address topics spanning ocean acoustics, atmospheric acoustics, ecological acoustics, and architectural acoustics as well as advances in acoustic sensing and signal processing that enable new observations of climate-related processes. Collectively, these studies demonstrate how acoustic methods can provide unique insights into environmental variability across a wide range of spatial and temporal scales.

By assembling this collection, we aim to highlight the growing role of acoustics in climate research and to foster collaboration between the acoustics community and the broader Earth science community. As climate change continues to reshape the environments through which sound propagates, acoustic methods will remain an important tool for observing and understanding these transformations.

II. CONTRIBUTED PAPERS

A. Ocean acoustic propagation and tomography

Underwater acoustic propagation and tomography provide a unique capability for observing large-scale ocean variability relevant to climate processes. Because the speed of sound in seawater depends strongly on temperature and pressure, acoustic travel times and propagation characteristics can be used to infer changes in ocean heat content and

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circulation over basin to regional scales. Using an altimetry-informed gravest empirical mode approach to reconstruct three-dimensional interior water-column properties from two-dimensional altimetry measurements and historical Argo float data, Harris *et al.* (2025) applied acoustic propagation modeling to show that travel times decreased between 2009 and 2023 due to warming of the Gulf Stream. In particular, they found that the core temperature of subtropical mode water in the Sargasso Sea increased by approximately 1 °C.

Dzieciuch *et al.* (2026) demonstrated that long-range acoustic transmissions provide precise, year-round measurements of acoustic travel times beneath Arctic sea ice. This work represents a critical initial step toward applying inverse methods to obtain range-averaged sound-speed (and thus temperature) fields along acoustic paths. Ragland *et al.* (2025) analyzed signals from the Kauai Beacon, which began regular transmissions in March 2023, recorded on Ocean Observatories Initiative hydrophones distributed offshore of the Pacific Northwest. This study demonstrates the potential for leveraging existing passive acoustic monitoring infrastructure for basin-scale ocean observations and provides new insights into single-hydrophone, long-range acoustic propagation that can inform future observing system design.

In addition to active sources, ambient sound measurements have also been used for ocean acoustic tomography. Recently, a passive approach has been developed that exploits acoustic waves excited by repeating earthquakes, known as T-waves. Zhang *et al.* (2025) examined the influence of ocean eddies on T-wave propagation to improve constraints on deep-ocean temperature estimates.

B. Marine mammals

Marine mammals rely on sound for communication, navigation, and foraging, making acoustic methods particularly valuable for studying their ecology. Long-term acoustic observations are increasingly used to examine how climate-driven changes in ocean conditions influence species distributions, behavior, and marine soundscapes.

The Atlantification of the Arctic is driving a northward shift in suitable habitat for many cetaceans, including sperm whales. Szesciorka *et al.* (2025) assessed the temporal presence of echolocating sperm whales along the continental slope southwest of the Svalbard archipelago. Echolocation rates were higher during summer and fall, indicating seasonal variability in sperm whale presence. In addition, acoustic backscatter and ocean temperature were positively correlated with recorded echolocation activity, suggesting a link between physical oceanographic conditions and foraging behavior. Miksis-Olds *et al.* (2024) examined the acoustic presence of odontocete foraging activity in relation to variability of the central Bering Sea Cold Pool across two distinct climatic regimes. Over a decade of observations, foraging click activity was found to respond differently among beluga, sperm, and killer whales, highlighting species-specific responses to climate-driven environmental change.

The modern Arctic soundscape is increasingly characterized by frequent ice cracking and ridging events resulting from the enhanced mobility and deformation of thinner, first-year sea ice. These broadband, ice-generated sounds overlap spectrally and temporally with marine mammal vocalizations, leading to increased acoustic masking, particularly for bearded seals. Using data from the western Canadian Arctic, Shajahan *et al.* (2025) showed that vocal activity decreased as the contribution of ice-generated noise increased, suggesting a behavioral response to changing soundscape conditions.

The effects of climate change on marine mammal acoustic behavior are also evident at mid-latitudes. Using data from six sites in the Southern California Bight collected over a 15-year period, ZoBell *et al.* (2025) showed that biological sound levels associated with fin and blue whale calls exhibit distinct seasonal and interannual variability. These patterns underscore the sensitivity of whale vocal activity to major climatic events, such as marine heatwaves, as well as to shifts in ocean–atmosphere climate variability, including the Pacific Decadal Oscillation.

C. Reefs and seagrass meadows

Coral reefs and seagrass meadows are dynamic coastal ecosystems whose structure and biological communities are highly sensitive to environmental change. Their soundscapes—shaped by the acoustic activity of fishes, invertebrates, and physical processes—offer a powerful means to monitor ecosystem health and track the impacts of climate-driven stressors. In a survey of six coral reef sites in Hawaii and Bermuda, Freeman *et al.* (2025) found a positive relationship between seawater temperature and overall bioacoustic activity. This work helps constrain the relationship between ocean temperature and reef biophony, an essential step for developing acoustic indicators of ecosystem condition.

Passive acoustic monitoring has been widely adopted for assessing biological activity and reef health. However, a major bottleneck in soundscape analysis remains the substantial human effort required to identify and annotate individual acoustic events, particularly the diverse and abundant sounds produced by fishes. McCammon *et al.* (2025) addressed this challenge by training a convolutional neural network (CNN) to automate the detection of tonal and pulsed fish calls using spectrogram data from five tropical coral reefs in the U.S. Virgin Islands, demonstrating the potential for scalable, data-driven analysis of reef soundscapes.

Amid rapidly changing ocean soundscapes, research continues to unravel how marine animals use sound to communicate, detect predators, locate prey, and identify suitable habitat. Mooney *et al.* (2025) developed the Reef Acoustic Playback System (RAPS), a platform designed to remotely deploy and replay sound cues in order to manipulate soundscapes, enhance larval settlement, and expand experimental studies of acoustic-mediated behavior. RAPS was used to replay reef sounds to promote settlement of *Favia fragum* coral larvae, and in a complementary study, Aoki *et al*. (2024) showed that acoustic enhancement increased settlement in both laboratory and field experiments over the first 24 h.

Acoustic techniques have also been applied to ecosystem health assessment in seagrass meadows. Gas bodies within seagrass tissue, along with photosynthetically driven bubble production, contribute to sound attenuation, dispersion, and scattering, leading to increased transmission loss. The detachment of gas bubbles from seagrass blades is itself an important contributor to the ambient soundscape. Daily, seasonal, and interannual variations in transmission loss and ambient sound were examined during a two-year experiment conducted in a shallow, subtropical estuarine seagrass meadow (Ballard *et al*., 2024). Building on this dataset, Jerome *et al*. (2025) applied Bayesian inference to estimate above-ground seagrass biomass, revealing seasonal patterns that compared favorably with direct biomass measurements from cores.

D. Pile driving

Human activities are contributing increasing amounts of sound to the marine environment, including high-intensity impulsive noise generated during pile driving for coastal infrastructure and offshore wind energy development. As offshore wind installations expand as part of global efforts to mitigate climate change, understanding the propagation and ecological consequences of these sounds is essential for balancing renewable energy development with the protection of marine ecosystems.

Controlled *in situ* experiments have been conducted to quantify behavioral and physiological responses of ecologically and commercially important species to pile driving noise. In shallow harbor conditions in Woods Hole, MA, caged animals were exposed to both impact and vibratory hammering. Behavioral responses of black sea bass were assessed using video observations, revealing that initial exposure to impact hammering reduced midwater swimming and induced bottom-associated freezing behaviors consistent with heightened vigilance (Jarriel *et al*., 2025). Behavioral states returned to pre-exposure levels during vibratory hammering and during subsequent impact hammer sequences.

Physiological effects of pile driving noise on sound sensitivity in longfin squid were evaluated using auditory evoked potentials to assess temporary threshold shifts (Jézéquel and Mooney, 2024). Sound detection thresholds were measured in unexposed individuals, as well as following a single 15-min exposure and after five repeated 15-min pile driving sound sequences. Across all exposure conditions, no statistically significant temporary threshold shifts were detected, indicating stable auditory sensitivity under the tested exposure scenarios.

E. Terrestrial environments

While many acoustic applications in climate and environmental research have focused on ocean systems, ecoacoustic approaches are increasingly applied to terrestrial ecosystems. In highly biodiverse environments, such as tropical rain forests, avian vocalizations dominate the biophonic soundscape, and passive acoustic monitoring provides an effective tool for biodiversity assessment and for tracking ecosystem responses to environmental and climate-driven change. Automated methods for characterizing soundscapes include acoustic indices, unsupervised learning approaches such as clustering and embeddings, and supervised deep learning methods. Using data from a Malaysian rain forest, Loo *et al*. (2025) compared conventional acoustic indices with deep ecoacoustic embeddings and found broadly comparable performance in capturing daily and monthly soundscape variability.

Despite their widespread use in ecoacoustic monitoring, CNNs can be sensitive to environmental noise, particularly wind-induced artifacts caused by airflow across microphones. Fradet *et al*. (2025) addressed this limitation by developing a framework to detect high-wind conditions using a custom model built on BirdNET's base architecture, applied to recordings from Adélie penguin colonies along the West Antarctic Peninsula. As climate change alters wind regimes in many regions, such approaches enhance the robustness of long-term passive acoustic monitoring and strengthen inferences about climate-related impacts on terrestrial ecosystems.

F. Architectural acoustics

In addition to natural environments, acoustics plays an important role in the built environment. As societies respond to climate change through new building practices, materials, and urban design strategies, architectural acoustics contributes to the creation of indoor spaces that are both acoustically comfortable and energy efficient. These efforts illustrate how acoustic design can support sustainable buildings and enhance community resilience in a changing climate. Using a residential flooring case study, Murphy and Broyles (2025) presented a practical framework for incorporating life cycle assessment to identify low-carbon floor–ceiling assemblies that satisfy acoustic isolation requirements. Achieving meaningful reductions in building-related emissions will require architectural acousticians to be active participants in broader efforts to decarbonize the built environment.

III. CONCLUSION

The contributions in this Special Issue underscore the expanding role of acoustics in advancing climate science across oceanic, atmospheric, terrestrial, and built environments. Together, these studies highlight the ability of acoustic methods to provide integrative, long-term observations of environmental variability and ecosystem response, often at spatial and temporal scales that are difficult to achieve using other approaches. As climate change continues to reshape the environments through which sound propagates, further advances in acoustic sensing, modeling, and data analysis will be essential.

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