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Editorial: Time-series observations of ocean acidification: a key tool for documenting impacts on a changing planet

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Editorial on the Research Topic

Time-series observations of ocean acidification: a key tool for documenting impacts on a changing planet

Ocean acidification (OA) is a pressing global issue characterized by fundamental changes in ocean chemistry, including the reduction of pH levels, due to the absorption of increased atmospheric CO_2. This phenomenon poses significant threats to marine ecosystems, affecting biodiversity, food security, and coastal economies. Time-series observations remain indispensable for documenting these changes, offering insights into the drivers and consequences of OA over temporal and spatial scales. This editorial summarizes the 17 studies in this Research Topic, highlighting the advancements in understanding OA dynamics and their broader implications.

Global and regional trends in ocean acidification

Several studies in this Research Topic provide comprehensive analyses of long-term OA trends and add to the existing evidence of its ongoing process. Bates and Johnson report on four decades of data from Bermuda's Atlantic Time-series Study (BATS) and Hydrostation S, revealing continuous ocean warming, salinification, and CO_2- carbonate shifts. These findings emphasize the region's persistent acidification trends. Similarly, González-Dávila and Santana-Casiano examine 25 years of observations at ESTOC in the Canary Islands, noting increased dissolved inorganic carbon (DIC) and declining pH. In the Mediterranean Sea, Wimart-Rousseau et al. analyze a decade of data from two North Western Mediterranean sites, DYFAMED and ANTARES, demonstrating the role of deep-water convection and biological processes in modulating seasonal carbonate chemistry. Tsiaras et al. integrate model simulations with *in-situ* data, showing how winter mixing and primary production dominate DIC and CO_2 variability across the Mediterranean Sea. While based on Tropical Atlantic observations, Musetti de Assis et al. reconstructed 20 years of carbonate system variability using PIRATA data in the Western Tropical Atlantic. They highlight rainfall and riverine influences on CO_2 solubility. Lefèvre et al. focus on Eastern Tropical Atlantic data, showing significant fCO_2 (fugacity of CO_2) increases over 15 years due to DIC accumulation and SST anomalies. In Polar Oceans, Shadwick et al. document an amplification of seasonal CO_2 cycles in the Southern Ocean Time Series (SOTS), driven by mixed-layer dynamics and biological productivity. Also, Vance et al. analyze the Munida Time Series off New Zealand, finding decadal pCO_2 (partial pressure of CO_2) increases driven by regional circulation changes and anthropogenic CO_2 invasion.

Impacts of ocean acidification on marine ecosystems

Understanding the interplay between chemical changes associated with OA and biology is vital for the understanding of present and future changes in marine biodiversity and ecosystem services. For Coastal Ecosystems, George et al. study the Tanga-Pemba Seascape, suggesting an interplay between upwelling-driven OA and oxygen depletion, with consequences to the vulnerability of resident organisms; additionally, they suggest an important role of seagrass meadows in mitigating OA. Hall et al. connect harmful algal blooms (HABs) in Florida estuaries with changes in carbonate chemistry, showing how these blooms exacerbate acidification. In offshore waters of Columbia, Ricaurte-Villota et al. find that significant seasonal variability of the carbonate system is influenced by annual changes in coastal upwelling, rainfall, and river runoff. Vance et al. describe seasonal DIC patterns across a coastal margin of the Subantarctic Zone, linking them to mixed-layer processes and community production, which maintain the region's status as a net CO sink. Furthermore, studies in the Eastern Mediterranean highlight the unique carbonate system dynamics (Frangoulis et al.), emphasizing the need for sustained observations to assess the impacts of rapid warming and acidification on marine organisms. In Coral Reefs, Knor et al. assess coastal reefs in Honolulu, revealing how freshwater runoff and biological processes buffer OA effects, with implications for coral health.

Innovations in monitoring and modeling

Long-term, ship-based time-series are now joined by new autonomous observing tools with the capability to constrain a broader suite of temporal scales of OA in its impacts. The utilization of time-series data by statistical and predictive models enhances our ability to fill observing gaps and forecast future OA scenarios. By bridging observational data with modeling efforts, researchers can develop more accurate projections of OA progression and its potential impacts on marine ecosystems, thereby informing policy decisions and management strategies. García-Ibáñez et al. showcase new Mediterranean time-series stations for high-resolution CO_2 observations. Tsiaras et al. use sensitivity simulations to identify biological, hydrodynamic, and atmospheric controls on the Mediterranean carbonate system. For long-term data applications, Lefèvre et al. utilized the PIRATA network for tropical Atlantic monitoring, providing crucial insights into regional OA variability, while Wimart-Rousseau et al. highlight the value of sustained multi-decadal data for disentangling natural variability from anthropogenic trends.

Conclusion and future directions

The contributions to this Research Topic emphasize the pivotal role of time-series observations in advancing our understanding of OA. These studies highlight the urgent need for sustained monitoring efforts, the development of standardized methodologies, and the integration of multidisciplinary data to effectively document and address the challenges posed by OA in a rapidly changing global environment. The research presented also underscores the critical importance of interdisciplinary approaches to understand and mitigate OA's impacts, particularly that many of the studies showed the importance of various natural and/or anthropogonic drivers in contributing to OA variability at local and regional scales. High-frequency monitoring, robust modeling frameworks, and collaborative international efforts are essential to deepening our knowledge of OA dynamics and its far-reaching implications for marine ecosystems.

By providing a comprehensive perspective on OA research across diverse ecosystems and timescales, this Research Topic reaffirms the necessity of sustained observations and innovative methodologies in tackling the pressing challenges of a changing ocean. Moving forward, it is imperative to strengthen global cooperation and advance scientific tools to better predict, monitor, and mitigate the impacts of ocean acidification on marine life and human communities.

Author contributions

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