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Editorial: Impact of oceans on extreme weather events (tropical cyclones)

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Editorial on the Research Topic
Impact of oceans on extreme weather events (tropical cyclones)

In the last decade, extreme Weather Events (Tropical Cyclones) have caused significant damage to global coastlines as the climate continues to change and both the world population and economic activity near the coasts continue to increase. The World Climate Research Programme's Grand Challenge on Weather and Climate Extremes has highlighted the need for reliable predictions of weather extremes, including Tropical Cyclones in all oceanic basins. The challenge ahead is for the research community to make progress in model improvements, data assimilation, observations, and design of observing systems in light of the most pressing needs from the end user community for improved forecast information on extreme events which impact these coastlines.

This Research Topic highlights some of recent progress made by the research community in model improvements, data assimilation, machine learning methods and use of physical and biogeochemical marine observations for an enhanced understanding of impact of extreme weather events (tropical cyclones, marine heat waves) in oceanic basins across the globe.

Contributing articles have considered observations describing oceanic states influencing extreme events – like warm eddies with a warm deep mixed layer restricting the cooling and contributing to TCs intensification with higher availability of latent heat flux (Kang et al.) or that the presence of a freshwater barrier layer which likely inhibited additional sea surface cooling and enhanced enthalpy flux as factors behind lack of strengthening of developing TC's (Miles et al.) or that the highest surface intensity of a marine heat wave often aligned with low surface salinity anomalies while subsurface temperature and salinity anomaly peaks which often corresponded (Sims et al.).

Other research studies in this Research Topic include modeling studies which describe a new Machine Learning (ML) based ensemble modeling system that produces noteworthy improvements for rapid intensification (RI) predictions in the Western North Pacific basin (Kim et al.). Other studies consider the impact of surface wave assimilation on hurricane track and intensity forecasts (Chen et al.) or that enhancing the regional upper-ocean observing system and improving the fidelity with which the observations are assimilated into ocean data assimilation systems could directly benefit TC intensity forecasts (Chiodi et al.).

As our understanding of the complex interactions between the oceans and extreme weather phenomena, particularly tropical cyclones, advances, it becomes imperative to define rigorous scientific pathways to address the complexities associated with shelf states and coastal inundation/flooding.

Miles et al. highlight the importance of localized ocean features, such as freshwater barrier layers, in influencing tropical cyclone intensity prior to landfall. Their study highlights the utility of novel ocean observing systems in identifying these features and emphasizes the need for careful consideration of upper-ocean metrics during storm events, particularly in regions such as the northern Gulf of Mexico and the associated Mississippi River plume. In addition, Wang et al. highlight the challenges of conducting data reconstruction studies in estuarine coastal zones, particularly in regions such as the Ganges estuary in the northern Bay of Bengal. These areas are characterized by increased dynamic forces in their water bodies. The assessment by Wang et al., which focuses on the absolute values and trends of time series data, provides valuable insights into understanding variability within these regions. Furthermore, Kim et al. emphasize the importance of integrating information about past values in time series data and details about neighboring locations in spatial data. This integration improves the effectiveness of machine learning models in predicting rapid intensification events. By enriching the feature set of models to recognize and exploit these dependencies, significant advances in the robustness and accuracy of rapid intensification prediction models are expected. Such advances are critical for early warning systems and preparedness measures in vulnerable coastal regions.

The main directions for future research and development, based on the findings presented in this Research Topic, are as follows:

Improved numerical modeling: Further refinement and validation of numerical models is essential to accurately simulate the dynamic interactions between tropical cyclones and coastal shelf states. This includes the incorporation of advanced high-resolution coupled (ocean-waves-atmosphere) Earth System modeling systems. Impact of waves and sea spray should be included to improve representation of numerical air-sea fluxes in these coupled models which are critical to permit capture of the nuanced feedback mechanisms that drive coastal inundation and flooding.

Integrated observing networks: The establishment of comprehensive observational networks is essential. These networks should include remote sensing technologies and *in situ* measurements to systematically monitor ocean conditions prior to tropical cyclone landfall. Emphasis will be placed on the integration of physical and biogeochemical observations to elucidate the spatio-temporal variability of coastal processes.

A**dvances in data assimilation techniques:** Innovative data assimilation methods need to be developed. These methods will assimilate diverse observational data sets into prediction systems with increased accuracy, enable coupled data assimilation to provide dynamically balanced initialization fields and allow exploration of multiscale data assimilation algorithms. Exploring the integration of machine learning algorithms can optimize the assimilation of complex oceanic variables and improve forecast accuracy, particularly for rapid intensification events.

Risk-based decision support systems: The development of robust decision support systems underpinned by probabilistic risk assessment frameworks is critical. Incorporating interdisciplinary perspectives will allow quantification of the multifaceted risks posed by tropical cyclones, marine heat waves and coastal inundation/flooding. These systems will facilitate adaptive management strategies and infrastructure planning.

Resilience strategies: Investigate resilience strategies to strengthen coastal ecosystems and mitigate the impacts of extreme weather events.

Stakeholder engagement and knowledge translation: Fostering collaborative partnerships between researchers, policy makers and local communities. Co-develop tailored adaptation strategies and strengthen community resilience.

By charting these scientific trajectories and embracing interdisciplinary approaches, we can catalyze transformative advances in understanding and mitigating the impacts of extreme weather events on shelf states and coastal inundation/flooding. These efforts are critical to protecting vulnerable coastal communities and promoting sustainable coastal development in an era of accelerating climate change.

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Conflict of interest

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