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Editorial: Understanding and predicting the Gulf of Mexico ocean dynamics

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Editorial on the Research Topic
Understanding and predicting the Gulf of Mexico ocean dynamics

The Gulf of Mexico circulation has been a focus of oceanographic research for well over a century due to its early importance in maritime transportation and naval interests, expansion of petroleum industry activity since the mid-20th century, and emerging understanding of its importance to regional ecosystems, weather and climate. Over the past several years, a number of research programs have funded significant efforts to advance understanding of and forecasting capabilities for the Gulf of Mexico circulation, including the Loop Current (LC) and its associated eddies (comprising the Loop Current System – LCS), and deep-water dynamics. This research accelerated following the 2010 Deepwater Horizon oil spill with the establishment of the Gulf of Mexico Research Initiative (GOMRI, 2010-2020) and, more recently, of the National Academies of Sciences, Engineering, and Medicine (NASEM) Gulf Research Program (GRP) funded by settlement funds in the aftermath of this disaster. The 2018 consensus study report from the GRP's Committee on Advancing Understanding of Gulf of Mexico Loop Current Dynamics (NASEM, 2018) outlined critical gaps in the understanding and ability to accurately predict the LCS. Although the LCS dominates the upper layer circulation in the Gulf, this report also highlighted the importance of the subsurface and deep layer circulation for the LCS documented by previous investigations that were funded by industry, the Bureau of Ocean Energy Management (BOEM), and its predecessor, the Minerals Management Service (MMS).

This Research Topic was envisioned as a venue in which to collect and highlight advances in understanding and predicting the Gulf of Mexico circulation that have come from recent studies, including collaborative research programs aimed at addressing the gaps identified in the 2018 Consensus Study Report. One such program is the GRP's Understanding Gulf Ocean Systems (UGOS) initiative, which focuses on improving forecasts of the physical dynamics of the open Gulf of Mexico in space and time scales useful for the reduction of risks to offshore energy exploration and production, as well as for other challenges such as forecasting hurricane intensification and managing fisheries. Much of the research published in this Research Topic is the result of collaborative efforts among academic, industry, governmental, and international partners, highlighting the advantages of collaborative team science approaches to understanding complex systems such as Gulf of Mexico dynamics.

The fourteen articles contained within this Research Topic provide new insights into the Gulf of Mexico circulation, including the connectivity between upper and deep circulation and dynamics that impact LC behavior, which can be applied to enhance forecasting through modeling and observational strategies. The articles can generally be grouped into themes that include: characterization of the meso- and submeso-scale upper layer circulation features, upstream conditions in the Yucatan Channel and Caribbean Sea, circulation in the western Gulf and connections to the LCS, subsurface and deep layer circulation and the connection with the upper layer circulation, and impacts of observations on improving long-range forecasts. The results presented in these works can collectively lead to improvements in our understanding and predictive capabilities of the Gulf of Mexico circulation and the ecosystems, climate and weather that it impacts.

Advances in numerical models and satellite observations have led to a more comprehensive characterization of the spatio-temporal variability of the LCS. Satellite altimeters have long provided measurements of the sea level anomalies associated with mesoscale features. The growing suite of satellite observations and the roughly 3-decade record length was used by Zhu and Liang to discover modes of variability, including seasonal signals, in the Loop Current Eddies (LCEs) and smaller cyclonic Loop Current Frontal Eddies. Enhancements in numerical model performance through increased availability of computing power, including the ability to run large numbers of simulations and higher resolution grids, make them well suited for elucidating the role of dynamical processes at scales smaller than the mesoscale that has typically been studied in the Gulf. In this issue, Yang et al. use ensembles of model runs with perturbed initial conditions to show the importance of West Florida cyclonic eddies in governing the LCE separation dynamics. Ernst et al. use a high-resolution (2 km) model reanalysis to characterize the submesoscale eddies and their contribution to the overall eddy kinetic energy, demonstrating potential capabilities of new swath altimeter missions like SWOT (Surface Water Ocean Topography) for observing the Gulf.

A number of studies over the past couple decades have aimed to connect variability upstream in this western boundary current system, namely the Yucatan Current in the Yucatan Channel and eddies in the Caribbean Current, with LCS dynamics including LC extension and eddy separations. Five articles in this issue (Higuera-Parra et al., Manta et al., Le Hénaff et al., Laxenaire et al., and Ntaganou et al.) add to the evidence that understanding the upstream conditions can enhance predictability of the LCS. These studies used numerical models and observations by moored instruments and satellites to show the impacts of eddy-induced vorticity fluxes and shifts in the Yucatan Current position on the Loop Current and eddy detachments, potentially leading to prediction methods and highlighting the importance of accurate representation of these dynamics in model forecasts.

As LCEs migrate westward after detachment, they influence circulation in the western part of the basin. Olvera et al. use numerical model experiments to demonstrate these contributions from LCEs to circulation in the northern, central, and southern Gulf of Mexico, with LCEs contributing to low-frequency modulation of the wind-driven circulation. The LCEs and their high pressure anomalies are similarly shown to induce low-frequency sea level variations along the western boundary of the Gulf of Mexico by Shinoda et al.. Though not directly connected with the LCS, upper and deep layer coupling in the southern Gulf of Mexico is investigated using a numerical model by Moreles.

The LC and a detaching LCE interacted with oil from the Deepwater Horizon spill, transporting the oil over long distances at the surface and within the water column. To better understand the subsurface dispersion in the northern Gulf, Hancock et al. analyze trajectories of 400m floats and numerical model results to characterize subsurface dispersion and the impacts on the dispersion from mesoscale features in the De Soto Canyon region. Exley et al. analyze measurements from an array of 24 current and pressure recording inverted echo sounders (CPIES) in the LC region to provide new understanding of the coupling and energy transfer from the surface to deep Gulf, generating topographic Rossby waves that radiate westward in the basin.

Finally, Dukhovskoy et al. present results from a suite of numerical model experiments to evaluate the impacts of observations from a multitude of platforms, including the CPIES array and satellite measurements, on the model forecast capability. Together, the knowledge contained in these articles combining observational and model results can guide a comprehensive approach to improving prediction of the Gulf of Mexico.

The editors thank all authors that contributed to this Research Topic and the Frontiers editorial staff that made this issue possible. The editors hope that the readers find this collection of articles useful for continued advancement toward a greater understanding and skillful prediction of the Gulf of Mexico system.

Author contributions

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Reference

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