frontiers | Frontiers in Marine Science

TYPE Editorial
PUBLISHED 31 October 2023
DOI 10.3389/fmars.2023.1323361

Editorial: Sea ice - ocean interactions

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KEYWORDS

sea ice, ocean, interactions, Arctic, Antarctic, observations, models

OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 17 October 2023
ACCEPTED 23 October 2023
PUBLISHED 31 October 2023

CITATION
Docquier D, Ponsoni L, Simon A and Piola AR (2023) Editorial: Sea ice - ocean interactions.
Front. Mar. Sci. 10:1323361.
doi: 10.3389/fmars.2023.1323361

Editorial on the Research Topic
Sea ice - ocean interactions

Context

Arctic sea ice has been retreating and thinning at a fast pace since the beginning of satellite observations (1979), mainly as a result of the ongoing anthropogenic global warming (Fox-Kemper et al., 2021; Meier and Stroeve, 2022; Rantanen et al., 2022; Sumata et al., 2023). On the opposite side of the globe, Antarctic sea ice slightly expanded from 1979 to 2015, followed by a series of record lows in sea-ice area since 2016 (Fox-Kemper et al., 2021; Fogt et al., 2022; Purich and Doddridge, 2023). Understanding the exact mechanisms that drive these changes in sea ice is crucial in order to improve future projections of not only sea-ice area and volume, but also other climate variables, due to the importance of sea ice in the climate system (Dieckmann and Hellmer, 2009).

The ocean plays a key role in driving changes in sea ice and carries a large amount of energy, potentially melting sea ice from below (Carmack et al., 2015; Polyakov et al., 2017; Purich and Doddridge, 2023). Conversely, changes in sea ice can also affect ocean circulation and heat transport [e.g. Sévellec et al. (2017)]. Despite an overall improvement in the understanding of sea ice-ocean interactions, significant gaps still exist at different time and spatial scales, including the two-way influence between sea ice and ocean heat transport, the effect of model resolution, and teleconnections between sea ice and oceanic climate modes of variability.

The aim of this Research Topic is to raise the visibility and advance our understanding of sea ice-ocean interactions in both the Arctic and Antarctic regions using observational and modeling tools. We present below the main findings from the articles published in our Research Topic, which we divide into the Arctic and Antarctic regions.

Arctic sea ice - ocean interactions

Wang and Danilov explore the main drivers of changes in ocean circulation that have occurred in the Arctic in the past 20 years using model simulations, supported by observations. They find that the decline in Arctic sea ice has had a strong influence on the acceleration of the Beaufort Gyre and the emergence of Arctic Atlantification in the eastern Eurasian Basin, via an increase in surface freshwater flux (for the Beaufort Gyre), as well as modified water mass spatial distribution (for both regions). They conclude that the recent sea-ice decline, together with changes in the wind regime, has been an important controlling factor of the Arctic Ocean circulation variability.

Langehaug et al. use 13 different global climate models, which they rank by performance compared to observations in terms of e.g. ocean temperature and salinity, sea-ice sensitivity to carbon dioxide emissions, and ocean heat transport. Their model selection allows them to better constrain the originally large model spread in future temperature and salinity in the Arctic Ocean, focusing on the near-to-mid term future period (2025-2055). They identify the Eurasian Basin as a source of model uncertainty, as warm water enters the Arctic at this location. Due to the large model spread, they call for caution when using CMIP6 models. Their study provides a way to improve future model projections of ocean temperature and salinity in the Arctic Ocean.

Wang et al. look at recent changes (1979-2020) in winter sea-ice area in the Bering Sea, which is mostly controlled by the competition between northerly winds, pushing sea ice southward, and northward ocean heat transport, which melts sea ice. They show that poleward ocean heat transport has a large influence on the intra-seasonal variability of Bering Sea ice in early winter, based on empirical orthogonal function (EOF) analysis applied to satellite observations. They also find that the maximum sea-ice area in the Bering Sea can potentially be predicted via their EOF analysis.

Yu M. et al. investigate the sensitivity of optical properties of Arctic summer sea ice on ice microstructures (volume fraction, size and vertical distribution of gas bubbles, brine pockets and particulate matter). They show that gas bubbles are major scatterers within sea ice. They also find that microstructures are more important for seasonal compared to multiyear sea ice in partitioning radiation transfer. Their results suggest that these microstructures should be taken into account in numerical models.

Antarctic sea ice - ocean interactions

Heil et al. present a Mini Review of recent observational studies that investigate processes linking sea ice, the ocean and atmosphere in the joint Ross Sea - far East Antarctic Region (RSfEAR). They identify a number of knowledge gaps, including (1) a too small number of observing systems, (2) a lack of connection between the Ross Sea and far East Antarctic sector in terms of studies, (3) a need to connect different disciplines, and (4) a need to understand future trajectories of major components of the sea ice - ocean system. The authors provide suggestions for an observational system design rethink in this region.

Yu L. et al. identify the possible mechanism leading to large interannual fluctuations in summer sea-surface temperature (SST) in the Pine Island Bay (West Antarctica), based on satellite observations and composite analysis. According to this mechanism, during the previous November, northerly winds prevail, which causes sea ice to be pushed offshore, resulting in a decrease in sea-ice concentration. Due to this absence of sea ice, solar radiation heat flux is enhanced and SST increases during the following January, via the positive ice-albedo feedback. Thus, this study could provide important insights for seasonal forecast of summer SST in the Amundsen Sea.

Stevens et al. investigate *in-situ* observations of suspended ice crystals in an ice-shelf water outflow region from the Ross/McMurdo Ice Shelves. They find that relatively large ice crystals have been entrained in a turbulent boundary layer. The existence of such crystals influences the regional variability in Antarctic sea ice, as well as the fate of the ice-shelf water.

Conclusions

All the above studies highlight aspects of the tight links between sea ice and ocean processes in both polar regions. They also show the wide range of spatial scales that need to be investigated, from pan-Arctic or pan-Antarctic, to regional and local, going down to microscopic. With this Research Topic, we also try to highlight the need to combine both observations and models to better understand processes affecting both sea ice and the ocean. We hope the papers presented here will further guide the research on sea ice - ocean interactions.

Author contributions

DD: Conceptualization, Project administration, Supervision, Writing – original draft, Writing – review & editing. LP: Conceptualization, Project administration, Writing – review & editing. AS: Conceptualization, Project administration, Writing – review & editing. AP: Conceptualization, Project administration, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. DD is funded by the Belgian Science Policy Office (BELSPO) under the RESIST project ('REcent Arctic and Antarctic Sea Ice lows: Same causes, same impacTs?'; contract no. RT/23/RESIST). AS is funded by ANR and France 2030 through the project CLIMArcTIC (grant ANR-22-POCE-0005).

Acknowledgments

We thank the Frontiers in Marine Science editorial staff for their support and all of the authors and reviewers who participated in this Research Topic.

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The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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