



Understanding eddy field in the Arctic Ocean from high-resolution satellite observations

Igor Kozlov¹, A. Artamonova¹, L. Petrenko¹, E. Plotnikov¹, G. Manucharyan², A. Kubryakov¹

¹Marine Hydrophysical Institute of RAS, Russia; ²School of Oceanography, University of Washington, USA

- Highlights:** - Eddies are ubiquitous in the Arctic Ocean even in the presence of sea ice;
- Eddies range in size between 0.5 and 100 km and their orbital velocities can reach up to 0.75 m/s.
- High-resolution SAR data resolve complex MIZ dynamics down to submesoscales [O(1 km)].

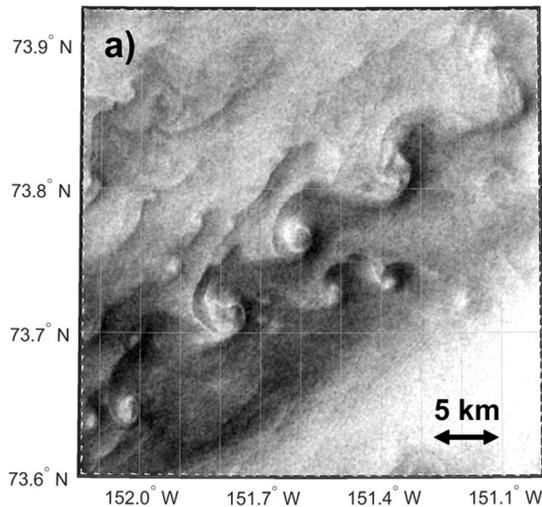


Fig 1. Eddy detection

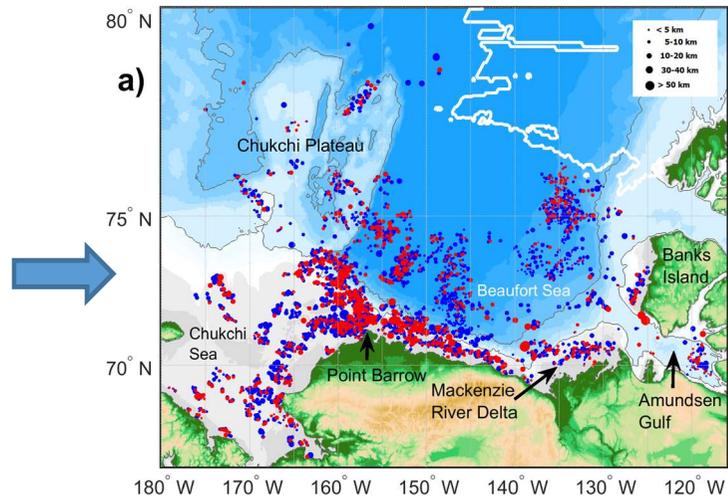


Fig 2. Spatial statistics

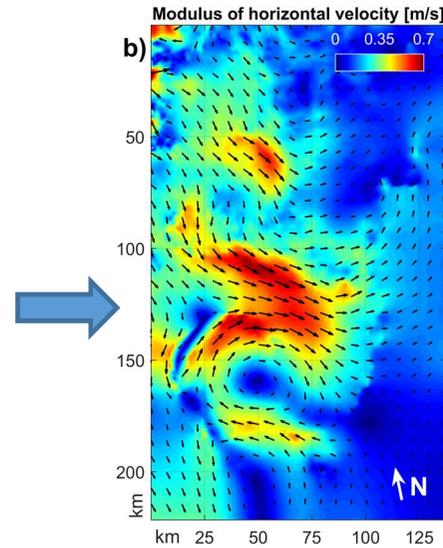


Fig 3. Dynamics





Motivation

- The Arctic Ocean is a host to major ocean circulation systems, many of which generate eddies transporting water masses and tracers over long distances from their formation sites.
- Comprehensive observations of eddy characteristics are currently not available and are limited to spatially and temporally sparse in situ observations.
- Relatively small Rossby radii of just 2-10 km in the Arctic Ocean (Nurser and Bacon, 2014) also mean that most of the state-of-art hydrodynamic models are not eddy-resolving
- The aim of this study is therefore to fill existing gaps in eddy observations in the Arctic Ocean.
- To address it, we use high-resolution spaceborne SAR measurements to detect eddies over the ice-free regions and in the marginal ice zones (MIZ).





Methods

- We use multi-mission high-resolution spaceborne synthetic aperture radar (SAR) data to detect eddies over open ocean and marginal ice zones (MIZ) of Fram Strait and Beaufort Gyre regions.
- Historical Envisat ASAR (the year of 2007) and current Sentinel-1 and ALOS-2 PALSAR-2 data (2016 and 2018) are used in the analysis.
- Every image was visually inspected at full resolution in search of eddy signatures. Then by looking at eddy boundaries outlined due to accumulation of slicks, floating ice, or enhanced wave breaking, their location, diameter, vorticity sign, and manifestation type were defined manually.
- For the analysis of sequential SAR data with time lag below 1h, the maximum cross-correlation was used to obtain horizontal velocity field of mobile ice floes in the MIZ.

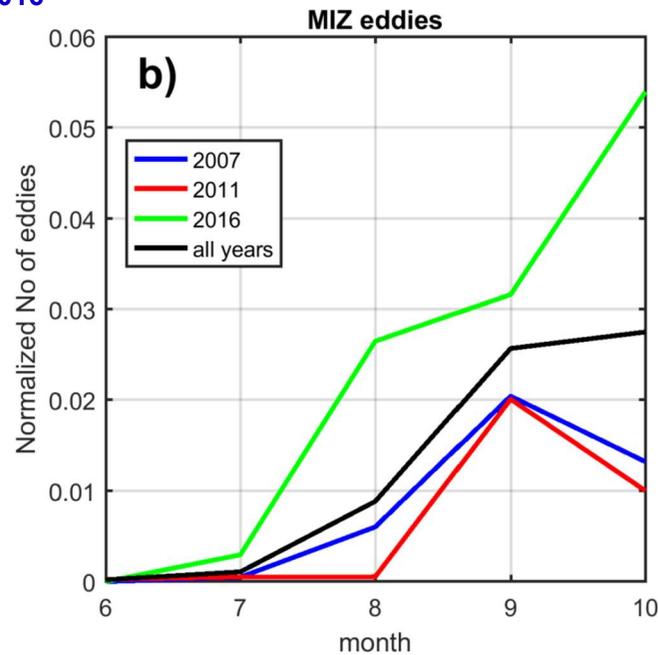
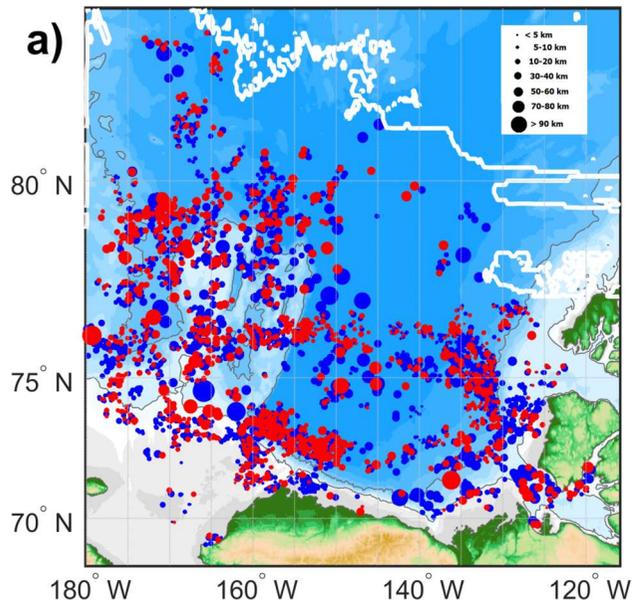


Statistics of MIZ eddies in the Western Arctic Ocean

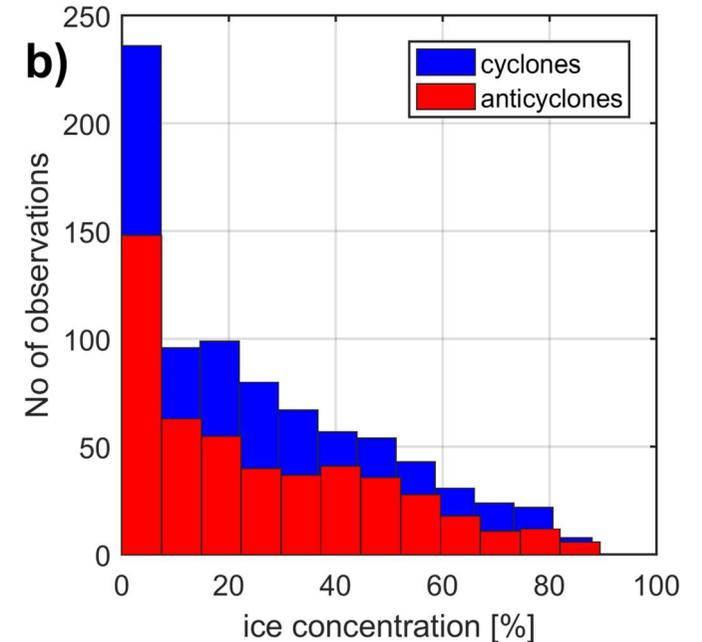


- Analysis of SAR data enabled to reveal key regions of eddy generation and obtain a detailed statistics of their spatial properties.
- For MIZ eddies, the number of eddies clearly depends on sea ice concentration with more eddies detected at the ice edge and over low ice concentration regions.

Locations of 3671 MIZ eddies identified in 2007, 2011, 2016



The number of eddies versus ice concentration in MIZ



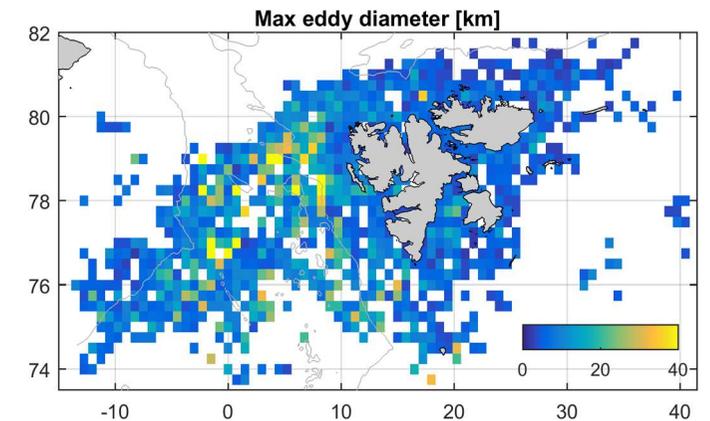
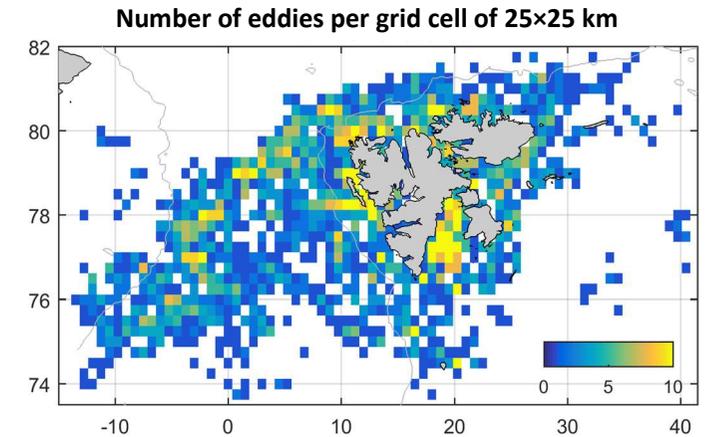
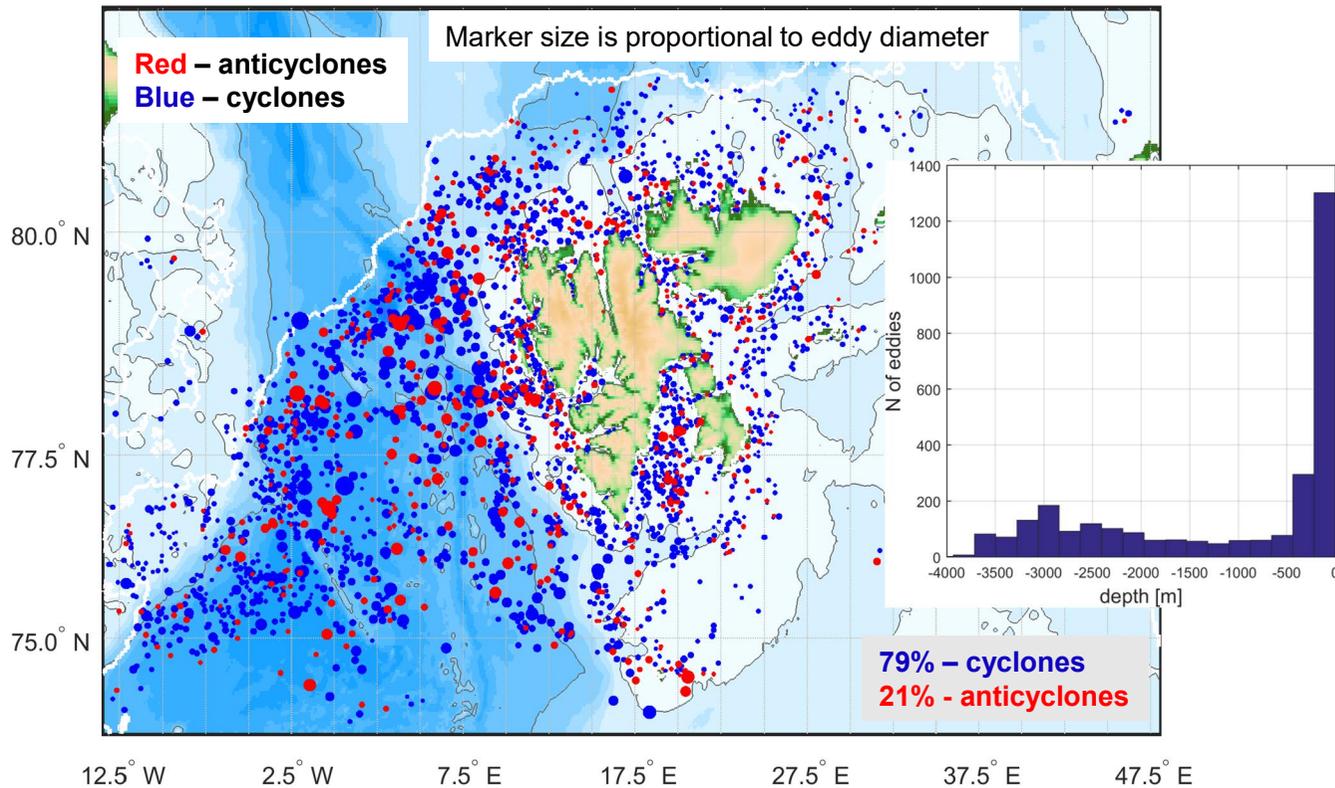
More details can be found in Kozlov et al. (2019), Eddies in the Western Arctic Ocean from spaceborne SAR observations over open ocean and marginal ice zones, *Journal of Geophysical Research: Oceans*, 124 (9), 6601-6616. <https://doi.org/10.1002/2019JC015113>



Open ocean eddies in Fram Strait



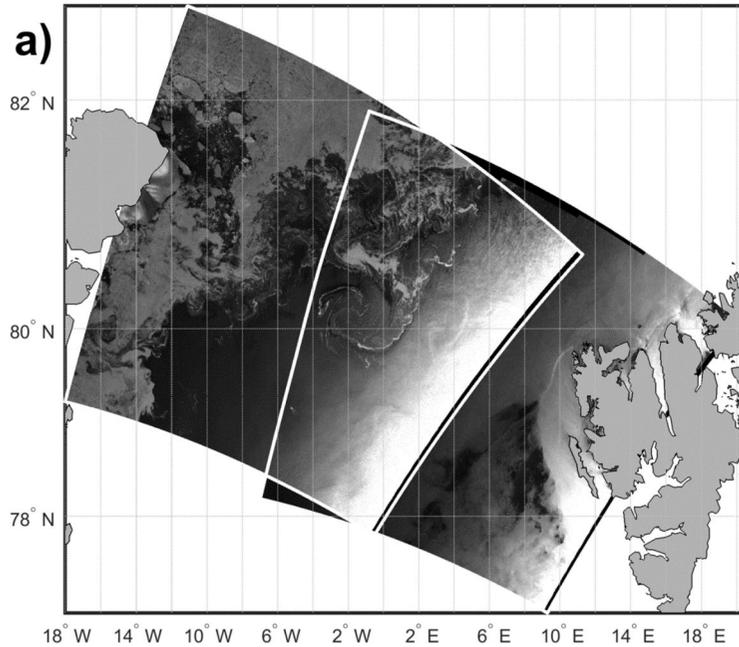
The locations of **2954** eddies detected over open water regions in 258 SAR images in July-September 2007



More details can be found in Kozlov et al. (2019). Statistical and dynamical properties of ocean eddies in Fram Strait from spaceborne SAR observations. Proc. SPIE 11150, Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions 2019, 111500S (14 October 2019); doi: 10.1117/12.2533317

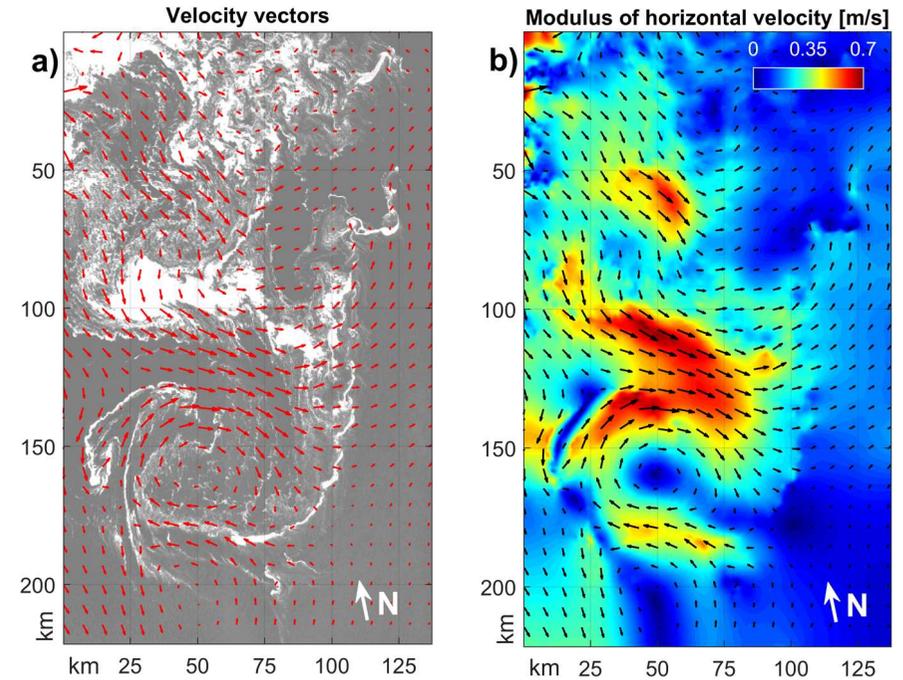


Dynamics of MIZ eddies in Fram Strait



Locations of two sequential Sentinel-1 A/B SAR images acquired on 17 September 2017 over the Fram Strait MIZ with time lag of 48 minutes.

Maximum cross-correlation



- The SAR-based velocity field reveals a large mesoscale anticyclone and numerous submesoscale cyclones and filaments with associated velocities up to **0.75 m s⁻¹**.

More details can be found in Kozlov et al. (2019). Statistical and dynamical properties of ocean eddies in Fram Strait from spaceborne SAR observations. Proc. SPIE 11150, Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions 2019, 111500S (14 October 2019); doi: 10.1117/12.2533317





Conclusions

Detailed statistics of spatial eddy properties was obtained for selected summer seasons of 2007, 2011, 2016, 2018 over the Western Arctic and Fram Strait using spaceborne SAR data.

The most prominent feature of the obtained results is that cyclonic eddies strongly dominate over anticyclones both for open ocean and MIZ eddies.

Eddies are frequently found over the shelf and near continental slopes but also present in the deep basin.

In general, we observe an enhanced eddy generation during 2016-2018 as compared to 2007-2011.

The use of sequential Sentinel-1 SAR images enables to retrieve high-resolution velocity field over MIZ on a daily basis and resolve complex MIZ dynamics down to submesoscales.

This information is critical for better understanding of the key dynamical processes governing the MIZ state, as well as for improving and validation of sea ice and coupled ice-ocean models.

ACKNOWLEDGMENTS

This study was supported by Russian Science Foundation grant #18-77-00082 and Russian Foundation for Basic Research grant # 18-35-20078. This work is also a part of the Arctic Office UK-Russia Bursary project.

