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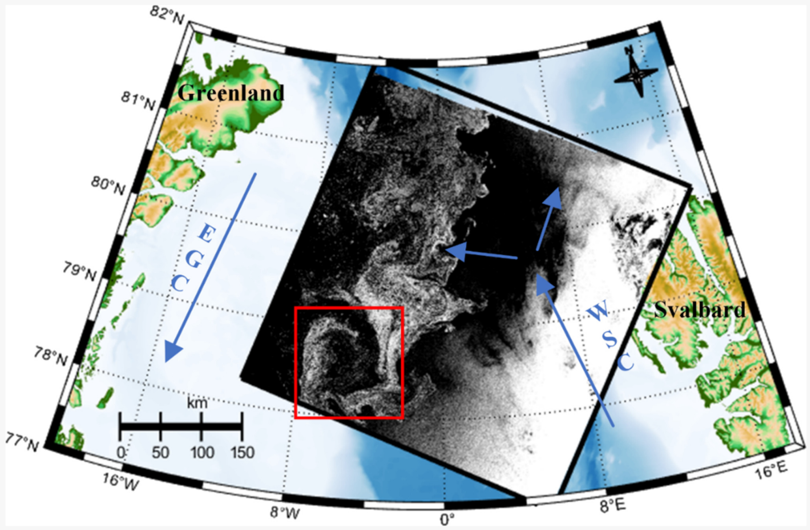
Satellite radar captures hidden dynamics of arctic eddies

GA, UNITED STATES, March 25, 2026 /EINPresswire.com/ -- A research team developed a satellite-based method to analyze the life cycle of ocean eddies forming along Arctic sea-ice edges. By combining sequential synthetic aperture radar (SAR) images with hydrodynamic modeling, the researchers reconstructed surface current fields and retrieved key dynamical parameters of a polar eddy throughout its evolution. The approach provides new insights into ice-edge ocean dynamics and offers a powerful tool for studying interactions between sea ice, ocean circulation, and climate processes.



Map of the study area. The black frame indicates the coverage of the Sentinel-1 SAR image acquired at 07:29:11 UTC on 2021 August 25. The red frame delineates the ROI containing the ice-edge eddy.

The marginal ice zone marks the boundary between open ocean and sea-ice cover and represents one of the most dynamic environments in polar oceans. Ocean eddies generated near ice edges influence sea-ice transport, mixing processes, and energy exchange between the ocean and atmosphere. These rotating structures can redistribute floating sea ice, modify heat transport, and affect regional ecosystems and climate feedback mechanisms. However, direct observations of eddy evolution remain limited because of harsh polar conditions and sparse in-situ measurements. Satellite synthetic aperture radar (SAR) has become an important tool for detecting eddies through sea-ice patterns, yet most previous studies mainly analyzed spatial distributions rather than the dynamic evolution of individual eddies. Because of these challenges, deeper investigation of the spatiotemporal evolution of ice-edge eddies is required.

Researchers from the Aerospace Information Research Institute of the Chinese Academy of Sciences reported a new framework for analyzing the evolution of ice-edge eddies using sequential SAR satellite imagery. Their findings were published on March 2, 2026, in the journal Journal of Remote Sensing. The study focuses on an eddy observed in the Fram Strait, a key passage connecting the Arctic Ocean and the North Atlantic. By integrating sea-ice motion tracking with hydrodynamic vortex modeling, the researchers quantified key physical characteristics of the eddy, including rotational velocity, circulation strength, and radius, providing new insight into polar ocean dynamics.

The study introduces a dynamical parameter inversion framework capable of reconstructing the structure and temporal evolution of ice-edge eddies. Using sequential SAR images, the researchers tracked the displacement of floating sea ice to derive high-resolution surface current fields. These currents were then analyzed using a vortex-based hydrodynamic model to estimate key parameters such as suction intensity, angular velocity, and circulation strength.

Applying the framework to an Arctic eddy revealed a complete life cycle lasting about 22 days. During the early stage, the eddy gradually intensified as both its radius and circulation strength increased. The vortex reached a mature phase when its structure became most coherent and energetic. Afterward, the eddy weakened and gradually dissipated. The results demonstrate how polar ocean eddies evolve dynamically and provide quantitative evidence of their growth, maturity, and decay processes. The research focused on the Fram Strait, where complex interactions between the southward-flowing East Greenland Current and the northward-flowing West Svalbard Current frequently generate ocean eddies. Researchers analyzed time-series SAR images collected by the Sentinel-1A and Sentinel-1B satellites, which provide high-resolution radar observations capable of monitoring sea-ice patterns regardless of cloud cover or lighting conditions. To reconstruct eddy dynamics, the team first tracked the displacement of floating sea ice between consecutive SAR images separated by roughly 50 minutes, allowing them to retrieve the horizontal surface current field associated with the eddy. The retrieved currents were then processed using singular value decomposition to isolate the dominant rotational component while suppressing background currents and noise.

Next, the Burgers–Rott vortex model—derived from the Navier–Stokes equations—was applied to invert the dynamical parameters describing the eddy. Analysis showed that the eddy radius expanded from roughly 28 km to over 35 km, while circulation strength peaked at about 4.5×10^4 m^2/s. The reconstructed current fields closely matched satellite-derived observations, confirming the reliability of the proposed method for capturing real ocean dynamics.

The researchers emphasized that ice-edge eddies are crucial components of polar ocean circulation. “These eddies strongly influence sea-ice redistribution and ocean mixing in Arctic waters,” the team explained. By enabling continuous monitoring of eddy evolution using satellite radar imagery, the new framework provides a valuable observational tool for studying ocean–ice interactions and improving understanding of polar climate dynamics.

The framework integrates satellite remote sensing with physical modeling techniques. Sequential SAR images were first preprocessed through radiometric calibration, filtering, and image registration. The displacement of floating sea ice between image pairs was calculated using a maximum cross-correlation method to retrieve horizontal current vectors. Singular value decomposition was then applied to isolate the dominant eddy structure from the current field.

Finally, a Burgers–Rott vortex model combined with a Levenberg–Marquardt optimization algorithm was used to invert the eddy's key dynamical parameters, enabling quantitative analysis of its evolution.

The proposed approach opens new opportunities for monitoring ocean dynamics in polar environments using satellite observations. As high-resolution SAR datasets continue to expand, researchers will be able to track multiple eddies simultaneously and analyze their interactions with sea ice, ocean currents, and atmospheric forcing. Such insights could improve numerical models of Arctic circulation and enhance understanding of how polar oceans respond to climate change. In the future, combining satellite observations with oceanographic models and in-situ measurements may provide a more comprehensive picture of Arctic marine processes and their global impacts.

References
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