Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 455 (P-5), 2025, pp. 25–27
DOI: 10.25171/InstGeoph_PAS_Publs-2025-073
40th International Polar Symposium – Arctic and Antarctic at the Tipping Point, 4–7 November 2025, Puławy, Poland

Arctic Beach Dynamics under a Changing Climate

Zuzanna ŚWIRAD

Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland

✉ zswirad@igf.edu.pl

1. INTRODUCTION

Elevated water levels at the shore, that result from a combination of sea level rise, tides, storm surges and waves, cause coastal erosion, wave overtopping and flooding, threatening communities and infrastructure (Woodworth et al. 2019). More frequent, longer and more severe storm events observed in the North Atlantic sector of the Arctic (Feser et al. 2015; Wojtysiak et al. 2018) bring more energetic waves to beaches. Decreasing extent and duration of the sea ice cover increases potential fetch, the distance over which wave-generating wind blows, which leads to larger (higher and longer) waves (Overeem et al. 2011). Arctic-wide sea ice extent has been decreasing by 12.8 ± 2.3% per decade (Meredith et al. 2019), while at the shore, the number of ice-free days per year doubled between 1979 and 2012 (Barnhart et al. 2014). Coasts that were protected from waves by ice are becoming exposed perennially or over longer time. Modelling suggests that in future sea ice will continue to decrease while the storminess will further increase (Forbes 2011). Better understanding of the role of sea ice conditions and offshore wave transformations on wave energy delivery to the Arctic shores is needed to predict coastal hazards under changing climate.

2. SEA ICE, WIND WAVES, AND COASTAL EROSION IN HORNSUND, SVALBARD

Analysis of near-daily binary maps of ice/open water at 50 m resolution in Hornsund fjord, Svalbard over 2014–2023 showed a great inter-annual variability in ice timing, extent and coverage with no clear long-term trend. The coldest and iciest seasons were 2019/20 and 2021/22. In the main basin the ice coverage was the highest in March which was ascribed to the presence of pack ice drifting in cold Sørkapp Current from the Barents Sea/Storfjorden area. In the inner bays of Hornsund – Burgerbukta, Brepollen, and Samarinvågen – the ice coverage was highest in April, likely representing fast ice. There was a secondary peak in October which was associated with glacier ice from calving tidewater glaciers (Swirad et al. 2024).

In 2012–2023, 53% of the fjord ice cover was drift ice, 35% was fast ice, 8.5% was glacier ice while the rest was uncertain or masked. Longer sea ice seasons corresponded to lower winter water temperatures, while higher ice coverage was related to lower winter air temperature.

Colder summer temperatures favored glacier ice persistence in the fjord waters (Swirad et al. 2025).

Longer-term analysis suggested that until 2005 pack ice was present outside Hornsund annually over an extended time period, while after 2005 it appeared episodically. This regime shift implies that recently energetic waves from the open Greenland Sea have had an access to the shores over longer time period (Herman et al. 2025). Comparison of a spectral wave model results (Herman et al. 2019) with nearshore wave measurements in Hornsund (Swirad et al. 2023) shows that sea ice attenuates wave energy decreasing wave energy flux and significant wave height, and increasing wave period (Herman et al. 2025).

An increase in the number and duration of storms was observed outside Hornsund for 1979–2015 (Wojtysiak et al. 2018). Moreover, an acceleration in coastal retreat was observed between 1960–1990 and 1990–2011 (Zagórski et al. 2015). It is critical to monitor and model sea ice and wave conditions, and coastal change to better forecast the hazard of coastal flooding and erosion, as well as the risk of infrastructure damage.

Acknowledgments. The study was funded by National Science Centre of Poland SONATINA 5 grant no. 2021/40/C/ST10/00146. Malin Johansson, Agnieszka Herman, and Mateusz Moskalik contributed greatly to the above mentioned publications.

References

Barnhart, K.R., I. Overeem, and R.S. Anderson (2014), The effect of changing sea ice on the physical vulnerability of Arctic coasts, *The Cryosphere* **8**, 5, 1777–1799, DOI: 10.5194/tc-8-1777-2014.

Feser, F., M. Barcikowska, O. Krueger, F. Schenk, R. Weisse, and L. Xia (2015), Storminess over the North Atlantic and northwestern Europe – A review, *Q. J. R. Meteorol. Soc.* **141**, 687, 350–382, DOI: 10.1002/qj.2364.

Forbes, D.L. (ed.) (2011), *State of the Arctic Coast 2010 – Scientific Review and Outlook*, Project Report, IASC, Helmholtz-Zentrum, Geesthacht, Germany.

Herman, A., K. Wojtysiak, and M. Moskalik (2019), Wind wave variability in Hornsund fjord, west Spitsbergen, *Estuar. Coast. Shelf Sci.* **217**, 96–109, DOI: 10.1016/j.ecss.2018.11.001.

Herman, A., Z.M. Swirad, and M. Moskalik (2025), Increased exposure of the shores of Hornsund (Svalbard) to wave action due to a rapid shift in sea ice conditions, *Elementa: Sci. Anthropocene* **13**, 1, 00067, DOI: 10.1525/elementa.2024.00067.

Meredith, M., M. Sommerkorn, S. Cassotta, C. Derksen, A. Ekaykin, A. Hollowed, G. Kofinas, A. Mackintosh, J. Melbourne-Thomas, M.M.C. Muelbert, G. Ottersen, H. Pritchard, and E.A.G. Schuur (2019), Polar regions. **In:** *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, Chapter 3, Intergovernmental Panel on Climate Change (IPCC), DOI: 10.1017/9781009157964.005.

Overeem, I., R.S. Anderson, C.W. Wobus, G.D. Clow, F.E. Urban, and N. Matell (2011), Sea ice loss enhances wave action at the Arctic coast, *Geophys. Res. Lett.* **38**, 17, L17503, DOI: 10.1029/2011GL048681.

Swirad, Z.M., M. Moskalik, and A. Herman (2023), Wind wave and water level dataset for Hornsund, Svalbard (2013–2021), *Earth Syst. Sci. Data* **15**, 6, 2623–2633, DOI: 10.5194/essd-15-2623-2023.

Swirad, Z.M., A.M. Johansson, and E. Malnes (2024), Extent, duration and timing of the sea ice cover in Hornsund, Svalbard, from 2014–2023, *The Cryosphere* **18**, 2, 895–910, DOI: 10.5194/tc-18-895-2024.

Swirad, Z.M., A.M. Johansson, and E. Malnes (2025), Distribution of landfast, drift and glacier ice in Hornsund, Svalbard, EGUsphere [preprint], DOI: 10.5194/egusphere-2025-3859

Wojtysiak, K., A. Herman, and M. Moskalik (2018), Wind wave climate of west Spitsbergen: seasonal variability and extreme events, *Oceanologia* **60**, 3, 331–343, DOI: 10.1016/j.oceano.2018.01.002.

Woodworth, P.L., A. Melet, M. Marcos, R.D. Ray, G. Wöppelmann, Y.N. Sasaki, M. Cirano, A. Hibbert, J.M. Huthnance, S. Monserrat, and M.A. Merrifield (2019), Forcing factors affecting sea level changes at the coast, *Surv. Geophys.* **40**, 1351–1397, DOI: 10.1007/s10712-019-09531-1.

Zagórski, P., J. Rodzik, M. Moskalik, M.C. Strzelecki, M. Lim, M. Błaszczyk, A. Promińska, G. Kruszewski, A. Styszyńska, and A. Malczewski (2015), Multidecadal (1960–2011) shoreline changes in Isbjornhamna (Hornsund, Svalbard), *Pol. Polar Res.* **36**, 4, 369–390, DOI: 10.1515/popore−2015−0019.

Received 15 September 2025
Accepted 20 October 2025