Investigating How Climate Change is Impacting Storm-Induced Erosion in Coastal Alaska

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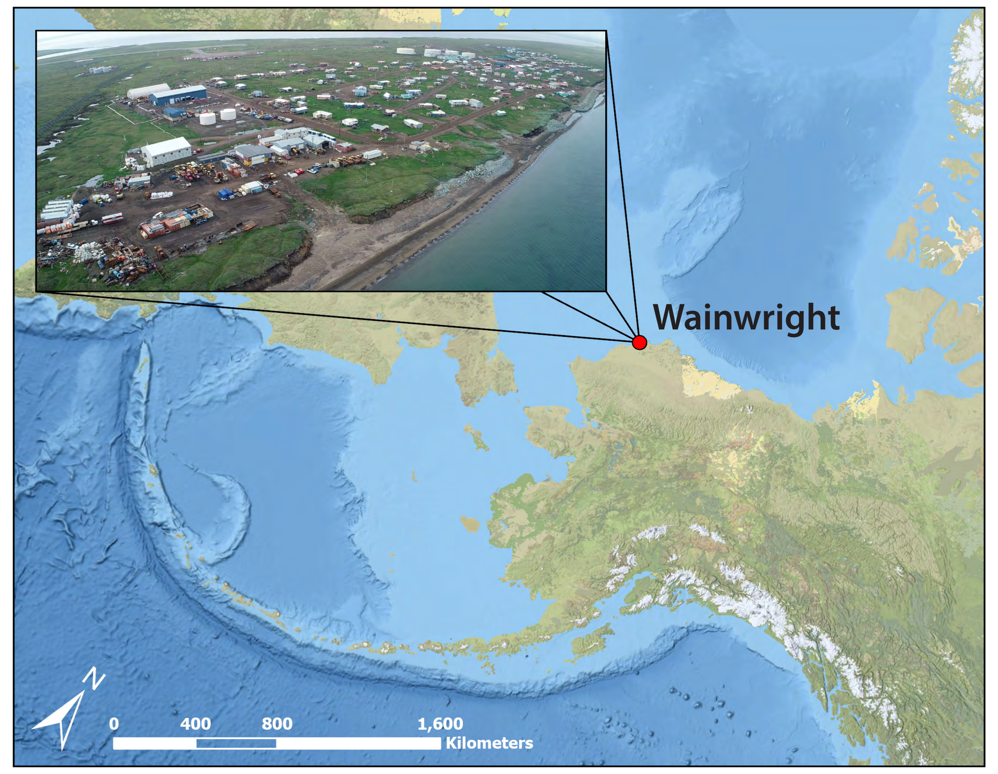
Introduction and Context

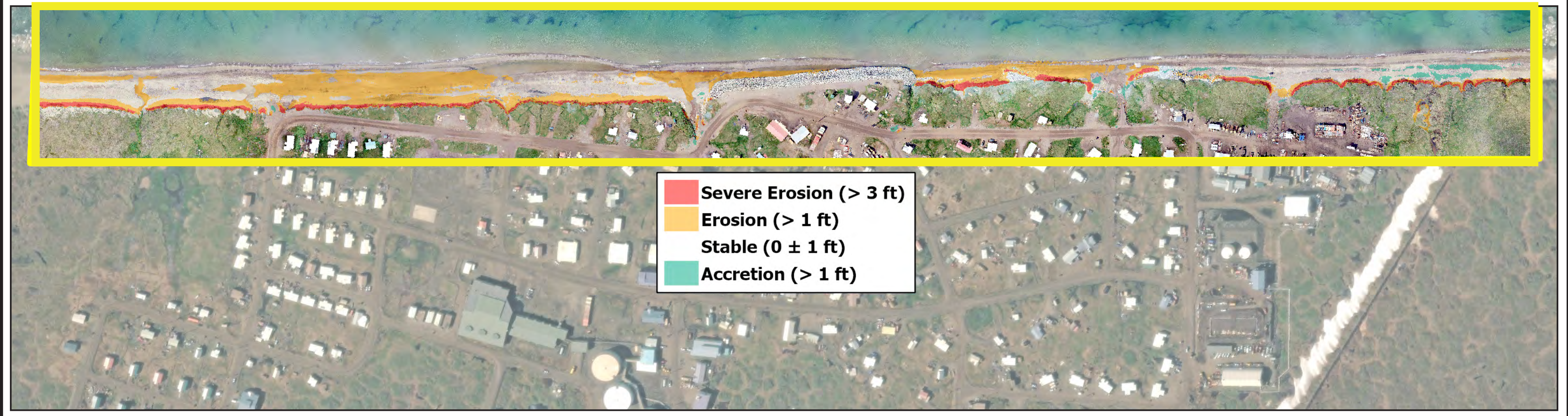
Alaska is experiencing amplified geomorphological hazards due to climate change, yet given its unique and extreme environment, limited data exist that document these increasing threats. Alaska's coastal communities are becoming increasingly more vulnerable to erosion associated with the frequency and severity of storms, compounded by permafrost degradation.

Wainwright, Alaska, is located alongshore the Chukchi Sea and is the third largest community in the North Slope Borough. The present-day village was established in 1904, when a school was first built in its location by the Alaska Native Service. The community was incorporated as a second-class city in 1962. Wainwright is known as Ulġuniq or "Olgoonik" in Iñupiaq, meaning "land that slopes to the sea".

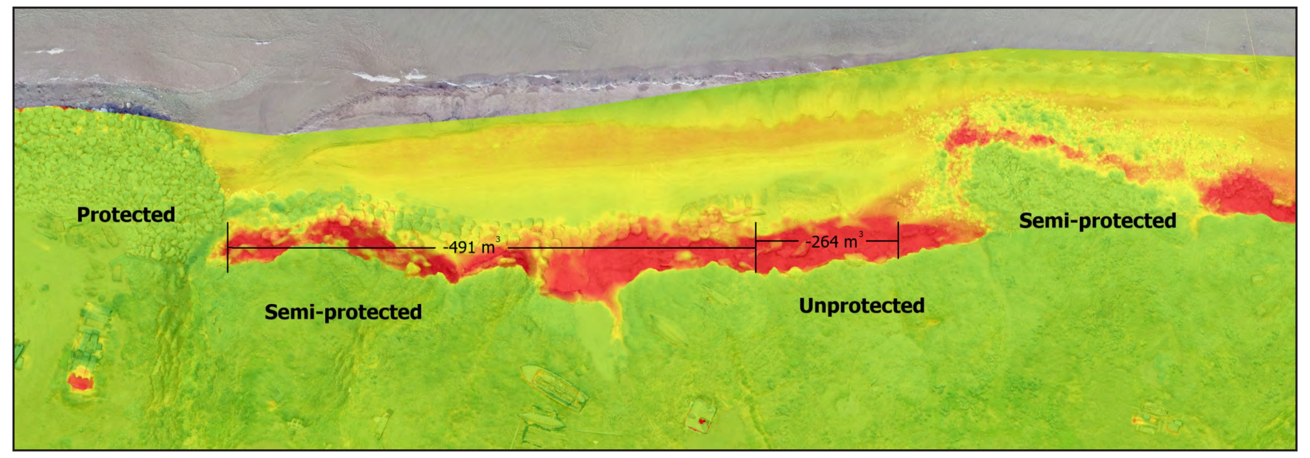
Recent high-resolution elevation data were collected in Wainwright, before and after a significant storm that occurred in northern Alaska on October 6–7, 2022. These data make it possible to quantify the significant amount of erosion that was caused by this single storm event and help evaluate the efficacy of existing erosion mitigation efforts such as a rock revetment and sandbags that have been placed along the community's coastline. Digital surface models created from unmanned aerial vehicle surveys collected in 2021 and 2023 are combined with measured coastal topographic profiles to quantify erosion and volumetric land loss.



Event-Driven Erosion in Wainwright, Alaska



Protected coasts are fronted by permanent, engineered structures (i.e., rock revetments) to mitigate erosion and reduce damage from flooding or wave impacts (USACE, 2008). The purpose of rock revetments like the one employed in Wainwright is to prevent landward erosion by dissipating wave energy (Dean and Dalrymple, 2002). Semi-protected coasts may consist of less permanent mitigation measures like sandbags, gabions, or smaller armor rock such as riprap. While these solutions can be more environmentally friendly, might make use of locally available materials, and may have more affordable upfront costs, they often require maintenance and replenishment (Liew et al., 2022). Whether permanent or transitory, the primary purpose of any protection measure is to attenuate, halt, or deflect incoming waves before they reach the bluff face (Dean and Dalrymple, 2002). Unprotected bluffs are fully exposed and subject to the full force of incoming waves, leaving them especially vulnerable to event-driven erosion. Areas without protection are prone to faster rates of erosion than protected portions of the bluff.



A volumetric comparison of 2021 and 2023 digital surface models along the 1.77 km of Wainwright's coastline shows that land loss is especially high where no coastal protection is implemented; but the greatest land loss is observed where unprotected sections of coastline lie between discontinuous protected sections.

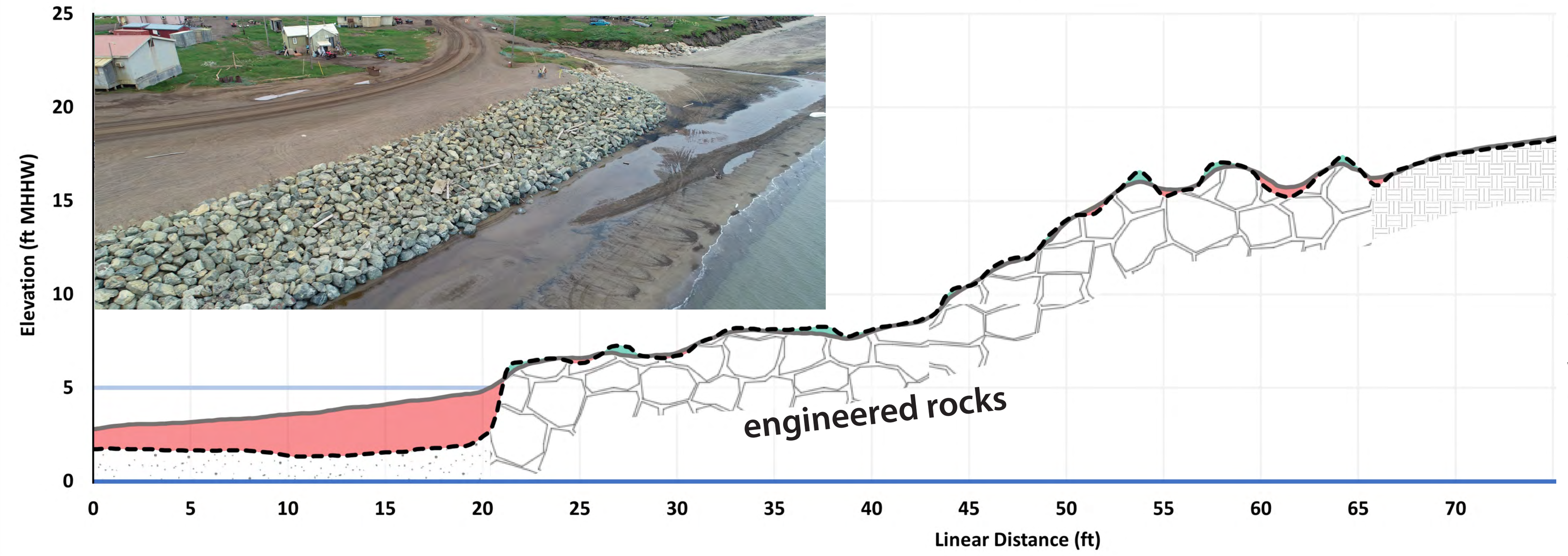
Engineered protections cover approximately 225 m of the 1.77-km-long study area along Wainwright's coastline, with semi-protected bluffs accounting for roughly 400 m, and unprotected bluffs making up the remaining 1.14 km.

Along this entire stretch of coastline, approximately 1.7 acres of unprotected coastline was lost. This included retreat of the bluff edge. Comparatively, approximately 0.25 acres of semi-protected coastline was eroded, and no loss of land was observed behind protected coastline.

Coastal Change in Wainwright, Alaska

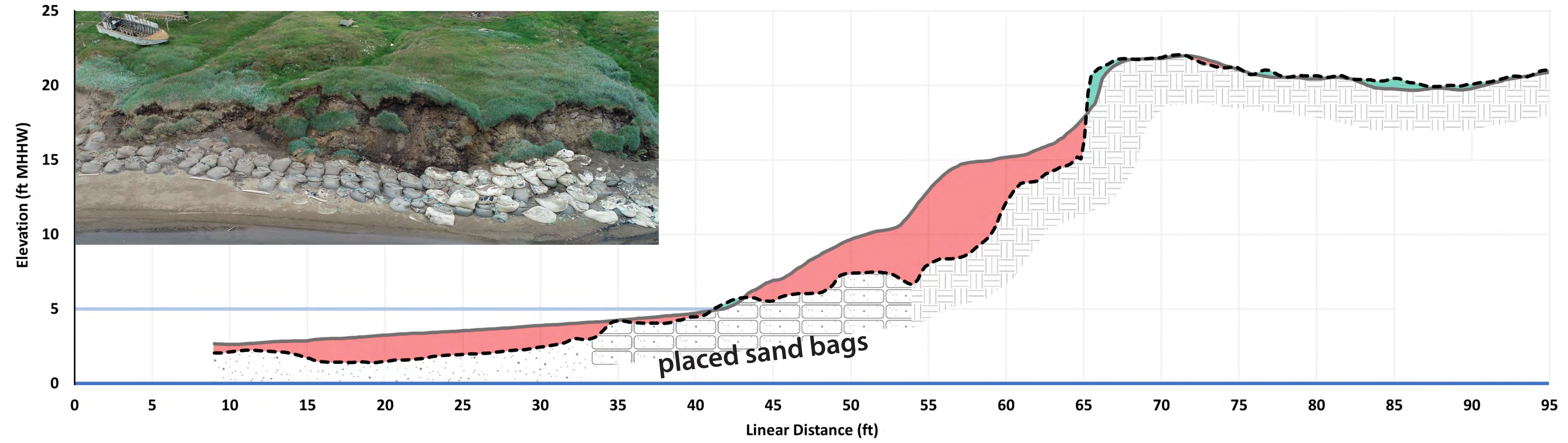
Aerial images below show data that was collected in 2021 (left) and 2023 (right). Coastal elevation profiles were measured along portions of coastline that are (1) protected by a rock revetment, (2) semi-protected by being lined with sand bags, and (3) unprotected.

Profile 1 (protected coastline)

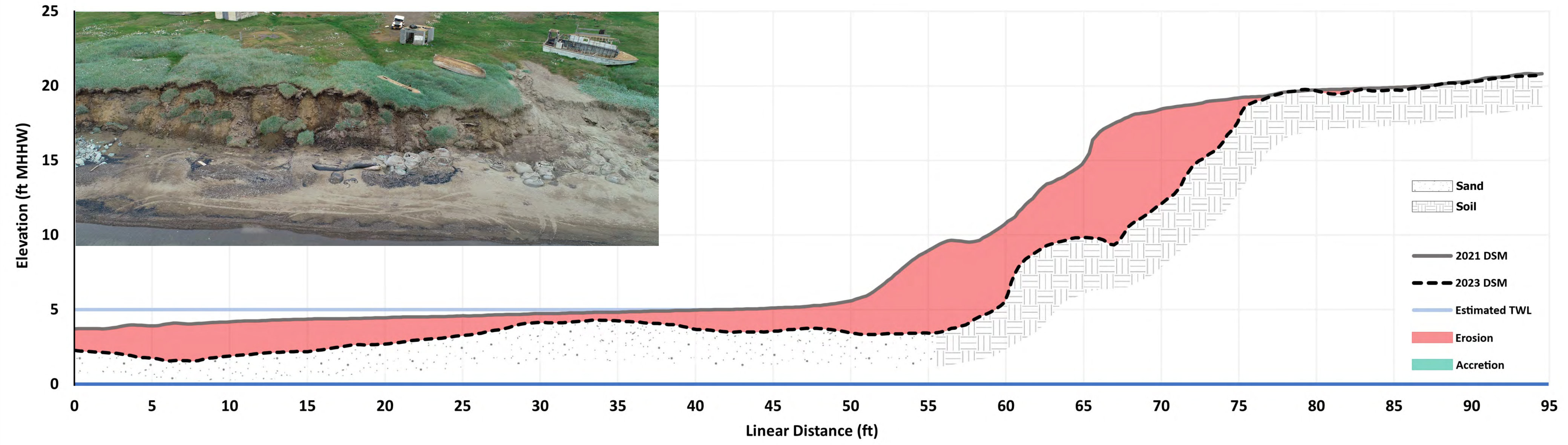


Elevation profile cross-sections were extracted from the 2021 and 2023 digital surface models of coastline (1) lined with an engineered rock revetment, (2) lined with sand bags, and (3) left in its natrual state, in order to compare locations that are illustrative of protected, semi-protected, and unprotected stretches of coastline, respectively. Representative images of each section of coastline are shown in the upper left corner of each profile. Total water level (TWL) for the event is derived from the average reported peak water level in Point Lay and Utqiagvik, Alaska, to the south and north, of Wainwright, respectively.

Profile 2 (semi-protected coastline)

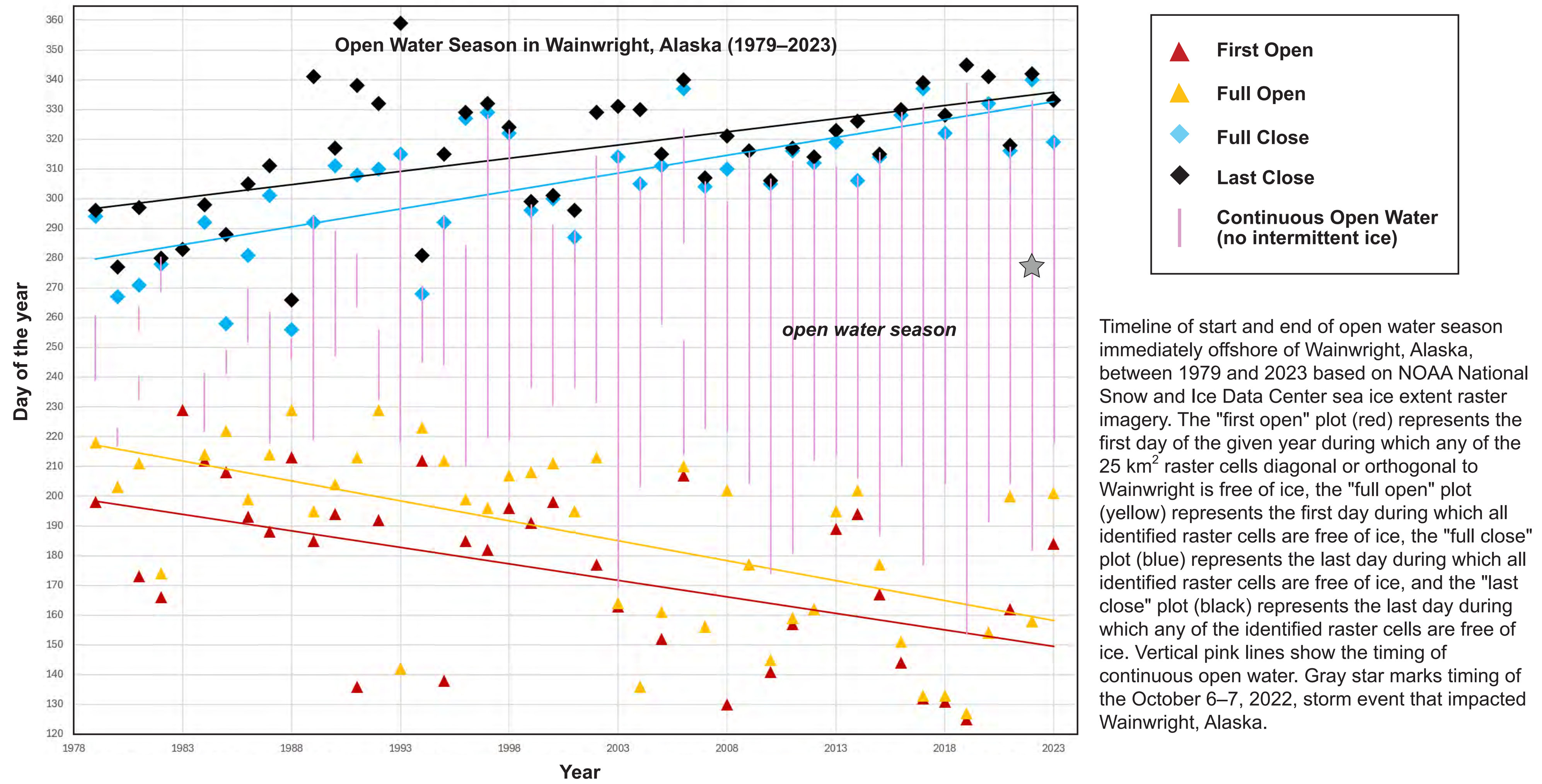


Profile 3 (unprotected coastline)



The Bigger Picture

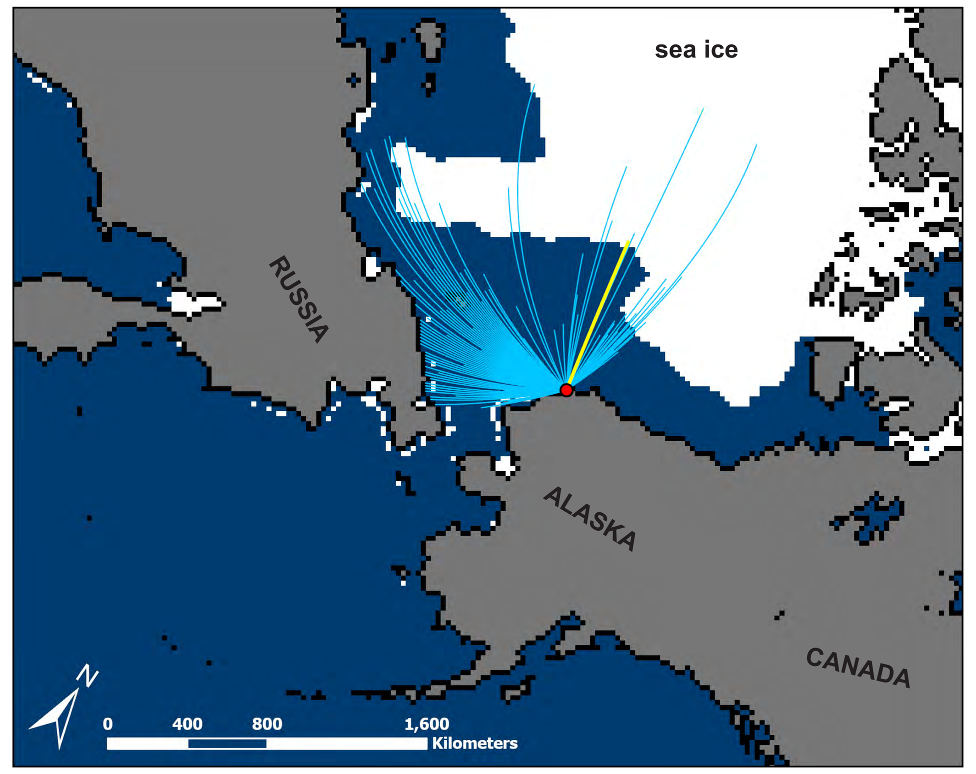
When placed in the context of longer-term temperature, weather, and sea ice data, this work may provide insights into to the possible future impacts of emergent Arctic storm events and may help guide the development of erosion mitigation strategies that can ensure the resilience of Alaska's coastal communities facing a changing climate.



Timeline of start and end of open water season immediately offshore of Wainwright, Alaska, between 1979 and 2023 based on NOAA National Snow and Ice Data Center sea ice extent raster imagery. The "first open" plot (red) represents the first day of the given year during which any of the 25 km^2 raster cells diagonal or orthogonal to Wainwright is free of ice, the "full open" plot (yellow) represents the first day during which all identified raster cells are free of ice, the "full close" plot (blue) represents the last day during which all identified raster cells are free of ice, and the "last close" plot (black) represents the last day during which any of the identified raster cells are free of ice. Vertical pink lines show the timing of continuous open water. Gray star marks timing of the October 6–7, 2022, storm event that impacted Wainwright, Alaska.

Placing the October 2022 storm in a larger context is challenging because of the absence of storm data in Alaska. However, using weather data from a weather station at the Wainwright airstrip (data available on the Iowa Environmental Mesonet) and applying cut-offs for wind speed, direction, and duration allows for historical storm events to be identified.

Future work will include determining storm frequency and severity (using wind speed, duration, and sea ice extent data) and cross referencing with existing storm narratives. These data will be placed in the context of sea ice extent to test the increase of coastal storms making landfall during ice-free seasons and to help validate exisiting projections of this trend (e.g., Vermaire, et al., 2013; Henke et al., 2024; Jahn et al., 2024).



Loxodromic inverse wind vectors (light-blue) for identified high wind events (from wind data compiled from the Iowa Environemntal Mesonet) that impacted Wainwright (red dot) and occurred during periods of open water between August, 1979, and October, 2023. The October 6-7, 2022, event is highlighted (yellow) and overlain on the October 6, 2022, sea ice extent imagery (NOAA National Snow and Ice Data Center).

Acknowledgments

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