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Arctic Coastal Erosion: Coupled Modeling System for Coastal Hazards Evaluation

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Accurate forecasting of erosion along Arctic permafrost coastlines is crucial for developing adaptation strategies for Arctic communities and infrastructure.

Permafrost coastline, present along Alaska's North Slope, comprises 34% of the world's coastlines and is rapidly eroding due to heightened wave activity and increased temperatures.

Drew Point, Alaska, Coastline and Permafrost Bluff Erosion

Images courtesy of Ben Jones, University of Alaska, Fairbanks

- Drew Point, Alaska (Figure 1) coastline erosion can exceed 10 m/year and is expected to increase (Figure 2).
- Since 1979, sea ice is down 51% in area and 75% in volume.
- Existing tools for predicting coastal erosion were developed for temperate areas and noncohesive sediments; they are not applicable for permafrost coastlines.
- Integral Consulting has teamed with Sandia National Laboratories, the U.S. Geological Survey, University of Alaska Fairbanks, and University of Texas at Austin to develop monitoring and modeling tools to accurately predict Arctic coastal erosion.

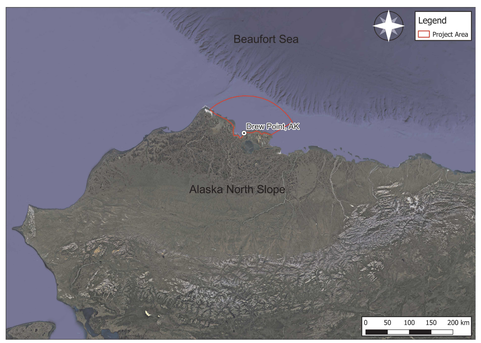

Figure 1. Drew Point, Alaska, Study Site Overview

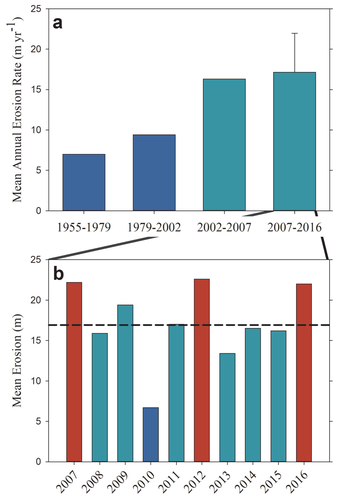

Figure 2. Permafrost Coastal Bluff Erosion Rates at Drew Point from 1955 to 2016 (Jones et al. 2018)

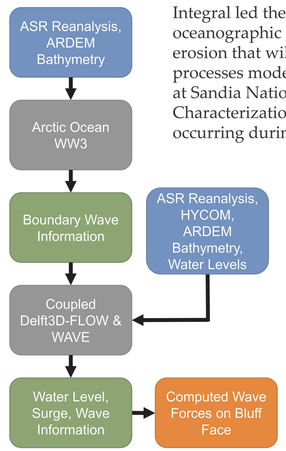

Figure 3. Coupled Modeling System for Drew Point

Integral led the development of a coupled oceanographic modeling system for Arctic erosion that will integrate with a terrestrial processes model currently in development at Sandia National Laboratories (Figure 3). Characterization of discrete coastal erosion events, occurring during storm conditions, requires high temporal fidelity predictions of hydrodynamic and wave parameters along the Alaskan coast through the application of site-specific numerical models.

To predict water levels and wave forces at the bluff face, a three-model system was developed to simulate nearshore conditions around Drew Point on the North Slope of Alaska.

- WAVEWATCH III® (WW3) (Figures 4 and 5)
  - Atmospheric Reanalysis model comparison in WW3 (Figure 6)
- Delft3D-FLOW (Figure 7)
- Simulating Waves Nearshore (SWAN) (Figure 8)

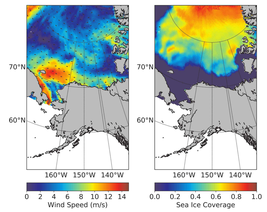

Figure 4. WW3 Boundary Conditions of Wind and Sea Ice Coverage from Arctic System Reanalysis Product

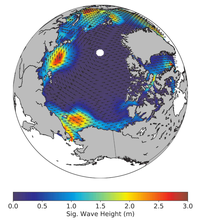

Figure 5. Arctic Ocean WW3 Grid as the Parent Model in the Coupled Modeling System

WW3 grid courtesy of Erick Rogers, Naval Research Lab, and Arun Chawla, NOAA National Centers for Environmental Prediction

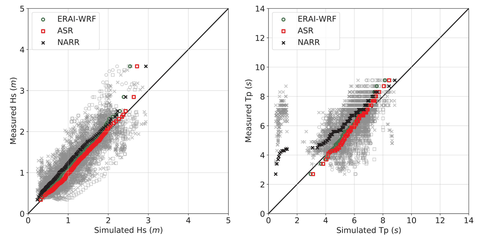

Figure 6. QQ Plot of Simulated and Measured Significant Wave Height (left) and Peak Wave Period (right) for the Arctic WW3 Model Forced by Multiple Atmospheric Reanalysis Products. Gray Symbols Are Raw Data.

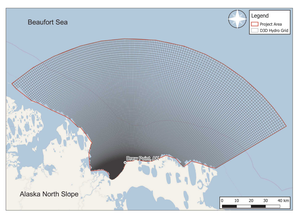

Figure 7. Drew Point Delft3D-FLOW Model Grid Extent and Resolution

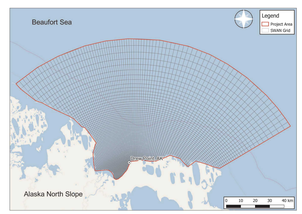

Figure 8. Drew Point Delft3D-WAVE (SWAN) Model Grid Extent and Resolution

The coupled WW3, SWAN, and DELFT3D models incorporate atmospheric and hydrodynamic factors such as sea ice coverage, winds, currents, and regional water levels to predict relevant parameters such as water levels and wave heights along the region of interest (Figure 9).

- 2007–2015 simulations during ice free months

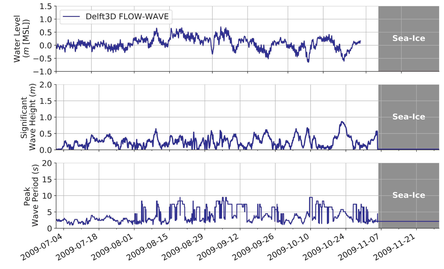

Figure 9. Water Level, Significant Wave Height, and Peak Wave Period Predictions at Drew Point from the Coupled Modeling System

The predicted water level and significant wave height were combined to compute the dynamic pressure forces due to waves at varying heights along a vertical coastal structure, representative of the bluff face.

- Dynamic wave forces passed to micro-scale thermo-chemical-mechanical terrestrial model (Figure 10)
- Thermo-denudation processes simulated
- FY20 expand to mesoscale, tens of kilometers

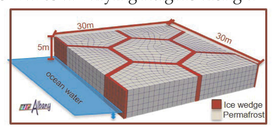

Figure 10. Conceptual Model of Thermo-denudation Terrestrial Model to Be Used to Predict Permafrost Coastal Bluff Erosion

Conclusions

Accurate estimations of Arctic coastal erosion rates will allow for better prediction of coastal hazards, thereby informing management decisions for communities and infrastructure that are built on the permafrost. These innovative tools can be applied to the assessment of coastal hazards worldwide in an effort to protect communities and infrastructure.

References available upon request.

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