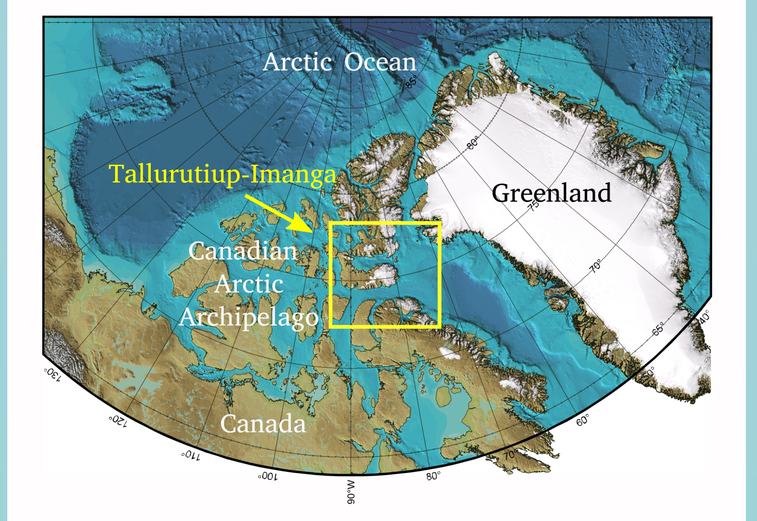
Simulating wave-ocean interactions and coastal impact on the Tallurutiup – Imanga marine protected area (Canadian Arctic Archipelago) over year 2100

Enrico Pochini[1], Paul G. Myers[1]

email: pochini@ualberta.ca 1 Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton (Canada)

Introduction:

The Tallurutiup - Imanga region, located in the Canadian Arctic Archipelago is a critical region for the ecological point of view: it is a regions of high primary productivity and hosts a delicate marine ecosystem which sustains settlements of indigenous populations. Several processes including upwelling, mixing, polynyas formation, retreating glaciers, surface waves and biophysics take place, allowing the thriving of this ecosystem. Climate change is putting this equilibrium at risk[1]. Wave dynamics in particular impact on **coastal erosion** and **flooding**, which are projected to increase in intensity in the future[2,3] putting at risk settlements along the coasts. Changes in primary productivity, caused by changes in ocean, atmosphere, sea ice and meltwater discharges would affect the base of the food web in the whole Arctic. Observational data gaps exists, which makes it unclear how the system will react to on-going and projected climate change in the region. It is therefore necessary to develop techniques to monitor and predict those changes and calibrate remote sensing data. In this planned work we will couple NEMO to a wave propagation model (Wavewatch III), and apply both an already-existing and a new configuration of a regional circulation model to study the evolution of the Tallarutiup-Imanga marine conservation area, including sea ice, tides, surface-waves and biogeochemistry as a robust platform to fill these knowledge gaps.



Objectives:

1) Model development: include wave component (WW3 - NEMO, coupler: OASIS3-MCT)

2) High resolution simulations of ocean circulation, sea ice, wave, biological cycles: historical and projections up to 2100 (forcing CMIP6)

3) Compare with observational network

4) Quantify evolution of risk of coastal erosion and flooding

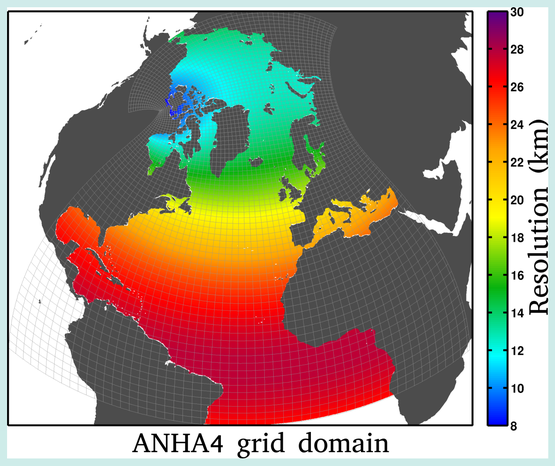
5) Evolution of biophysical processes

Numerical approach:

– NEMO Arctic North Atlantic configuration **ANHA4** (1/4° resolution); mesh 544 x 800 x 50 levels

- Sea ice (LIM2); tides (TPXO9); atm. forcing (CGRS); runoff + freshwater input (Bamber et al., 2018)
- period run 2002 - 2022
- output freq. 5-daily

– Wavewatch III® (WW3) spectral surface-waves model:
- simulates wind & swell waves
- simulate wave spectrum propagation at each grid point
- 32 frequency bins, 24 directions



ANHA4 grid domain

Phase I: historical run

Period: 2002 - 2022
Forcing: CGRF
Boundary conditions: GLORYS2V3

ANHA4 grid (1/4° resolution)
+
AGRIF nest on study area (~1 km resolution)

- Impact of waves on ice dynamics and coastal processes
  ⟹ landfast ice, mixing, upwelling, polynyas
- Model validation (observations: ArcticNET, DFO, Marine Environmental Data Service)
- Quantification of coastal erosion and flooding risks
- Simulate biophysics (BLING)
- Sea ice ⟺ waves coupling (improve parameterisations of land-fast ice and marginal ice zone)


Coastal erosion in Tuktoyaktuk (photo credit: Weronika Murray)

Validated ocean - sea ice - wave - biogeochemistry coupled model of the Tallurutiup-Imanga region

Phase II: future projection 2100 (ANHA4 + AGRIF nest)

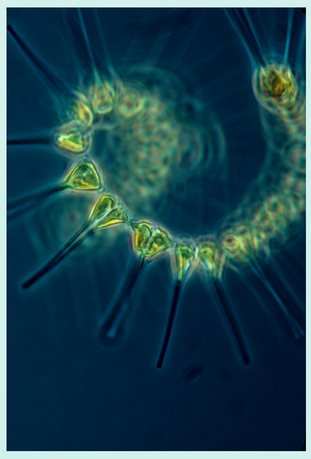
Period: 1970 - 2100
Forcing: CMIP6 downscaled
Boundary conditions: CMIP6 downscaled

Simulate coupled ocean - sea ice - wave state evolution in the Arctic and Imanga Tallurutiup region

⟹ Estimate impact of projected Arctic climate change on sea ice, ocean, waves, biophysics

⟹ Estimate future risk of coastal erosion and flooding (max wave height, periodicity, return period)

⟹ Simulate biophysical changes: primary productivity, acidification


Phytoplankton - The foundation of the oceanic food chain. (photo: NOAA MESA Project)

References:

1) Steiner, N., Azetsu-Scott, K., Hamilton, J., Hedges, et al. (2015). Observed trends and climate projections affecting marine ecosystems in the Canadian Arctic. Environmental Reviews, 23(2), 191-239.

2) Casas-Prat, M., & Wang, X. L. (2020). Projections of extreme ocean waves in the Arctic and potential implications for coastal inundation and erosion. Journal of Geophysical Research: Oceans, 125(8), e2019JC015745.

3) Casas-Prat, M., Hemer, M. A., Dodet, G., Morim, J., et al. (2024). Wind-wave climate changes and their impacts. Nature Reviews Earth & Environment, 1-20.

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