CLIMATE CHANGE IMPACTS ON COASTAL HAZARDS IN NEWFOUNDLAND AND LABRADOR, CANADA

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INTRODUCTION

Newfoundland and Labrador, situated on the eastern coast of Canada, is particularly susceptible to the adverse effects of climate change. Increasing sea levels, intensifying storm events, and shifting weather patterns have led to profound alterations in coastal dynamics, posing significant threats to the region's communities, infrastructure, and natural ecosystems. Coastal erosion, inundation, and storm surge have become pressing concerns, necessitating a comprehensive analysis of these challenges.

Our study employs numerical modeling tools to simulate wave and surge dynamics in the context of climate change. By considering historical data and incorporating climate projections, we assess how changing environmental conditions influence coastal hazards. Robust wave climate projections should consider uncertainties in climate modelling by using a multi-model ensemble (Knutti et al. 2010) and considering different socio-economic pathway scenarios (SSPs). Therefore, we developed a methodology which allows for easily expanding the number ensemble members and climate scenarios using limited computational resources.

The outcomes of this study will provide essential information for coastal planners, engineers, and policymakers. It will enable better-informed decisions regarding infrastructure development, coastal protection, and emergency preparedness. By gaining a deeper understanding of the interactions between climate change, waves, and surge, we can develop more resilient and sustainable solutions to mitigate coastal hazards in Newfoundland and Labrador.

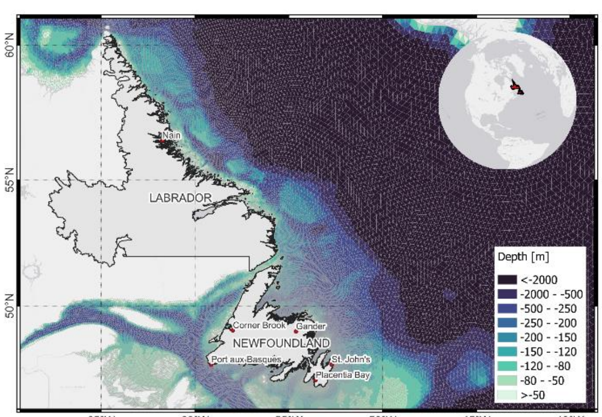

Figure 1 – Study area and model bathymetry

METHODOLOGY

A regional storm surge model was developed using DHI's MIKE 21 FM HD for the North-Atlantic and the Labrador Sea, with higher resolution around the Province of Newfoundland and Labrador. The model water level is static and set to mean sea level (MSL), thereby only producing the storm surge residual of the total coastal water levels. A set of twelve sub-regional wave models were developed using the new DHI's MIKE Metocean Simulator (MIKE MS) covering the entire province's coastline and extending up to 150 km offshore. The models were calibrated and validated against tide gauges and wave buoys in the region.

MIKE MS is based on a hybrid modelling approach that combines process-based models and statistical methods. In brief, it selects discrete events representing offshore wave climate variability, dynamically downscales the events subset while storing the results at desired output points and reconstructs the complete timeseries through statistical interpolation. Details on this novel model is presented in Carvalho et al (2024). This approach allows for increasing the number of ensemble members without excessive computational costs.

For the assessment of historical conditions, the models were forced with wind and pressure fields and offshore wave conditions from the global ECMWF-ERA5 model hindcast. For the future climate assessment, the models were forced with two CMIP6 global climate models (GCM): EC-Earth3 and ACCESS-CM2 for the SSP5.8.5 scenario. Offshore wave conditions were derived from the GCM-forced wind-wave climate models by Meucci et al. (2023).

Historical sea ice cover is based on ice charts from the Canadian Ice Services (CIS) combined with satellite-derived ice concentration from the National Snow and Ice Data Center (NSIDC). For the future projections, ice concentration from the GCMs was used.

RESULTS AND DISCUSSION

The historical period of both GCMs represent the wave and surge climate relatively well in most areas of the region, with EC-Earth3 showing a slightly overestimation of the ice coverage during the historical period, consequently decreasing the median wave height during the winter months (Figure 2). ACCESS-CM2 underestimates wave heights in the west of Newfoundland, while both GCMs overestimates the waves in the southern coast. It should be noted that at this stage no bias-correction has been applied as our primary objective is to evaluate future changes relative to the historical period. Therefore, in this context the GCM-forced models are considered adequate.

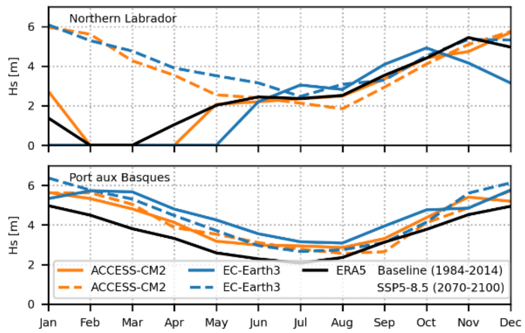

Figure 2 - 99th percentile of significant wave height by month for the baseline period (1984-2014, solid lines) and end-of-century (2070-2100, dashed lines) for SSP5-8.5.

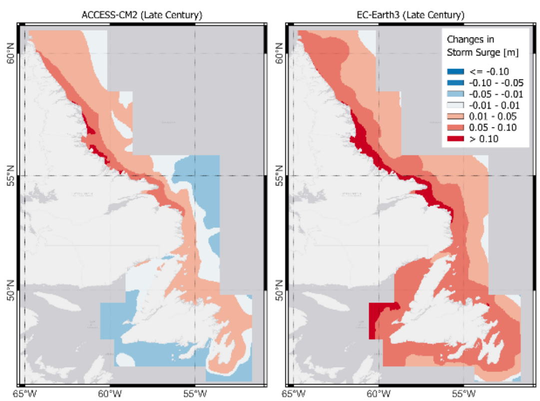

Figure 3 -Projected changes in the 99th percentile of storm surges by end-of-century compared to the baseline (1984-2014 to 2070-2100) for SSP5-8.5.

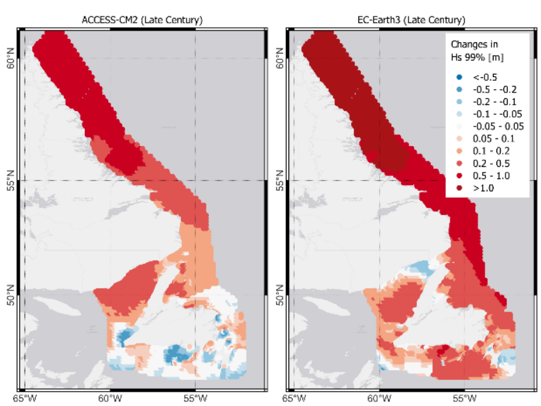

Figure 4 -Projected changes in the 99th percentile of significant wave height by end-of-century compared to the baseline (1984-2014 to 2070-2100) for SSP5-8.5.

Figures 3 and 4 show the projected changes in the 99th percentile of storm surges and wave heights by end-of-century (2070-2100) compared to the historical baseline (1984-2014) for SSP5-8.5 scenario. Overall, the models show limited change in storm surge, with an increase of about 10 cm along the coast of Labrador. Given that the relative mean sea level in this area is expected to decrease due to land uplift, the future risk due to high water levels is expected to be minimal. The average and the 99th percentile of significant wave height is projected to increase in this area, largely due to reduction in ice cover, as observed in other studies (Casas-Prat & Wang, 2020). For Newfoundland, the findings from both models reveal conflicting trends in waves and storm surge. Offshore wave heights in this area are expected to decrease following trends in the North Atlantic wave climate (Lemos et al., 2021); however, local sea level rise and changes to ice cover could have an opposite effect by increasing nearshore wave heights.

CONCLUSIONS

This study is the first step to evaluating impacts of climate change into coastal hazards around the coast of Newfoundland and Labrador. Both climate models consistently predict an increase in average wave conditions and surge levels along the Labrador coast, linked to reduced ice cover. Trends around Newfoundland are less evident with significant differences between the two GCMs simulations, emphasizing the importance of a multi-model ensemble approach to capture the inherent variability in climate change projections.

Our adoption of a computationally efficient hybrid framework for downscaling nearshore wave conditions proves effective, maintaining accuracy compared to traditional dynamical downscaling. The framework developed during this work can be easily implemented to increase the number of ensemble members, leading to a more robust assessment of climate change impacts on wave conditions and providing valuable insights for coastal planning and resilience efforts.

ACKNOWLEDGEMENTS

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