Numerical Modeling of Tropical Cyclones for Assessing Extreme Coastal Hazards Under Climate Change Scenarios

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The vulnerability of marine renewable energy infrastructure to tropical cyclones is a concern not only along the U.S. Atlantic coast but increasingly for Canadian waters as well. This risk is expected to intensify under future climate change scenarios. Engineering design for offshore projects, such as wind farms, requires accurate site-specific characterization of extreme conditions, including water levels, wave heights, and currents. In many cases, the governing design event is a tropical cyclone.

To address this, Baird has developed and applied high-resolution numerical models to simulate tropical cyclone impacts and extract critical hydrodynamic parameters at project sites. However, estimating the probability of design conditions requires long-term storm records, which are limited for tropical cyclones. To overcome this, Baird has implemented a methodology that generates thousands of synthetic tropical cyclones using a stochastic storm generator informed by global climate model (GCM) outputs. These synthetic events are then simulated in a hydrodynamic model to produce a robust dataset of site-specific conditions.

This approach enables the estimation of return-period-based design conditions under both present-day and future climate scenarios. By incorporating projected global climate conditions for specific timeframes and emissions scenarios, the methodology provides valuable insight into how coastal hazards may evolve over time. This supports more informed, climate-resilient infrastructure planning. The approach was recently applied in a coastal compound flood risk study for the U.S. Navy in Chesapeake Bay, Virginia, and is readily adaptable to other locations along the North American east coast.