Author's Responses to Reviewer 3

On behalf of the authors, we wish to express our sincere gratitude for the attentive and rigorous review of this manuscript. The suggestions provided were fundamental in elevating the structural clarity and technical precision of our research. The corresponding changes have been integrated into the revised manuscript.

Comment 1: The methodological choice to rely on regional INPE projections (based on CMIP5) is mainly justified by availability and resolution. However, the authors must expand this justification by discussing: the differences in performance between CMIP5-INPE and current CMIP6 ensembles; potential biases introduced by the exclusion of newer models; and whether CORDEX CMIP6 regional products were considered.

Response 1: We appreciate this rigorous scrutiny regarding the climatological baseline. We have explicitly expanded Section 3.2.3 to address these three points:

- **CMIP5-Eta vs. CMIP6:** We argue that for wave operational risk, **spatial resolution is the governing constraint**. While CMIP6 offers updated microphysics, global models typically operate at coarse resolutions (>100 km), which smooth out the wind-sea fetches critical for downtime analysis. The INPE-Eta dataset provides **20 km dynamic downscaling**, offering superior capture of local extremes compared to raw CMIP6 data.
- **Potential Biases:** We acknowledge that older forcing models may contain biases. To mitigate this, we implemented a **Quantile Delta Mapping (QDM)** protocol (Cannon et al., 2015), which corrects distributional biases while preserving the relative climate trends.
- **CORDEX:** We clarified that CORDEX CMIP6 products for the South Atlantic were evaluated but currently lack the extensive validation maturity and specific daily granularity of the "Projeta Brasil" (INPE) dataset for this specific operational application.

Comment 2: The downscaling model reports $R^2 = 0.8885$ and RMSE = 0.1446 m, but the manuscript lacks a spatial breakdown of performance. Please provide: Spatial variability of model skill; skill under extreme conditions; and a comparison with alternative ML algorithms (e.g., Random Forest, SVR, LSTM) or justification for selecting XGBoost alone.

Response 2: We have addressed these technical requests by expanding Section 3.2.2:

- **Spatial Variability:** We explicitly clarified that while the ensemble mean is 0.88, we observed a slight performance degradation in immediate coastal cells due to complex shallow-water bathymetric interactions.
- **Extremes:** We noted that the tree-based ensemble demonstrated robustness in capturing upper quantiles (extremes), avoiding the saturation effects common in linear statistical downscaling.
- **Algorithm Selection:** We justified the choice of **XGBoost over Deep Learning (e.g., LSTM)** by citing Grinsztajn et al. (2022), which demonstrates that tree-based models offer superior efficiency and accuracy for tabular environmental data.

Comment 3: The application of Quantile Delta Mapping is briefly described, but its calibration details are not provided. Please clarify: Calibration period, how extreme waves are treated, and whether trend preservation was tested.

Response 3: We have provided the requested technical details in Section 3.2.3:

- **Calibration Period:** We specified that the bias correction was calibrated using the historical overlap period (1990–2015).
- **Extremes & Trends:** We clarified that the QDM algorithm (Cannon et al., 2015) was selected precisely because it explicitly **preserves the model's projected relative changes (deltas) for all quantiles**. This ensures that future extreme events are not artificially "clamped" to historical distributions.

Comment 4: Uncertainty is addressed only indirectly through scenario contrast (RCP 4.5 vs. 8.5). A more rigorous discussion on uncertainty is expected. Even a qualitative framework can be addressed.

Response 4: We agree that a structured discussion on uncertainty is vital. We have addressed this by rewriting Section 6.1 to establish the requested **"Uncertainty Framework,"** explicitly mapping the sources of risk:

- **Model Driver Uncertainty:** Addressed as "Model Epistemic Uncertainty" (reliance on a single regional driver).
- **Technological Uncertainty:** Quantified via the sensitivity analysis (Figure 5).
- **Scenario Uncertainty:** Addressed by capturing the amplification of variance under RCP 8.5.

Comment 5: Equation (1) assumes daily binary operability based only on SWH and wind speed limits. This simplification must be better justified.

Response 5: We agree that real-world operations involve complex decision-making. However, we have justified this simplification in Section 3.3.2 by citing industry standards. We clarified that for strategic long-term planning, this binary classification serves as the **standard industry proxy for "Waiting on Weather" (WoW)** downtime. We referenced the **DNV-ST-N001** standard to demonstrate that relying on these probabilistic exceedance thresholds is the accepted methodology for estimating fleet availability.

Comment 6: Section 3.3.1 describes a geographic mask yielding 441 grid points. The manuscript must clarify: How these points intersect EPE high-potential zones; whether partial overlap of grid cells was considered; and potential distortions due to the 0.25° ERA5 grid resolution.

Response 6: We have clarified the geospatial processing details in Section 3.3.1:

- **Intersection Method:** We specified that the spatial domain was defined using a "**Centroid Inclusion**" **method**: ERA5 grid cells were selected only if their centroids fell strictly within the high-potential polygons defined by the EPE Roadmap.
- **Resolution & Distortion:** We explicitly acknowledged that the 0.25-degree resolution (~27 km) imposes a limitation for nearshore micro-siting. However, we argued that this resolution is methodologically appropriate for the meso-scale regional risk assessment proposed by FARO.

Comment 7: The manuscript states that the FARO code is available on GitHub. Expand the reproducibility details: Complete list of dependencies and environment file (conda or pip). Computational resources and expected runtime. Instructions for downloading ERA5 and INPE data and replicating pre-processing.

Response 7: We have fully addressed this request to ensure robust reproducibility:

- **Dependencies:** We updated Section 3.5 to explicitly state that the GitHub repository now includes a **requirements.txt** file and a conda environment configuration.
- **Resources:** We added a note regarding computational benchmarks, specifying that the inference pipeline is optimized to run on standard workstations.
- **Data Acquisition:** We clarified that the repository includes a step-by-step README guide for automating the download of ERA5 (via CDS API) and INPE data.

Comment 8: The abstract should explicitly state that the projections are based on INPE regional models derived from CMIP5, not CMIP6.

Response 8: We agree that transparency regarding the data source is essential. We have modified the Abstract to explicitly state that the study utilizes "**INPE-Eta/CMIP5 regional projections,**" avoiding any ambiguity.

Comment 9: There are several formatting errors and broken strings. These must be corrected for editorial quality. Double punctuation (e.g., "potential..") appears in the Conclusions and must be revised.

Response 9: We sincerely apologize for these editorial oversights. We have conducted a thorough proofreading:

- **Broken Links:** We verified and corrected the GitHub URL in Section 3.5.
- **Punctuation:** We eliminated all instances of double punctuation.
- **Formatting:** We reviewed the reference list and in-text citations to ensure consistent formatting strings.

Comment 10: Some links in the reference list appear corrupted. Please verify.

Response 10: A check was performed on every link in the reference list to ensure they are active and correct.

Comment 11: The limitations section is concise but must be expanded to address: The implications of using only one regional climate dataset; absence of multi-model ensembles; lack of probabilistic analysis; effect of not considering multi-dimensional operational thresholds.

Response 11: We agree. As detailed in Response 4, we have completely rewritten Section 6.1 to explicitly cover these points:

- **Single Model/No Ensemble:** We classified this as "Model Epistemic Uncertainty," justifying the trade-off of high resolution vs. ensemble spread.
- **Multi-dimensional Thresholds:** We added a specific discussion acknowledging that the current function (Eq. 1) is uni-dimensional. We

explicitly suggested that future iterations should incorporate multi-dimensional constraints (e.g., Mean Wave Period limits) and "**Window Persistence.**"

Comment 12: The conclusion makes strong claims about FARO as a fully validated framework. Given the methodological restrictions described, consider reflecting: validation within a specific regional and data context.

Response 12: We agree that scientific precision is paramount. We have revised the Conclusions (Section 6) to qualify the scope of our findings:

- **Regional Context:** We explicitly stated that the framework was validated "**within the specific climatic context of Southeastern Brazil.**"
- **Future Scope:** We reinforced that while the framework is a robust "proof-of-concept," its global generalization requires the expansion to CMIP6 multi-model ensembles, which we explicitly listed as a future research step.