AN EFFICIENT HYBRID DOWNSCALING OF NEARSHORE DIRECTIONAL WAVE SPECTRA FOR LONG-TERM SHORELINE MODELLING

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MOTIVATION

Developing robust methodologies for predicting sandy shoreline changes over the next 10 to 50 years is a significant concern for coastal communities worldwide. Improving these shoreline models necessitates the refinement of the wave time series used to drive these models, as well as the accurate reproduction of the complete directional wave spectra, as opposed to relying on classic bulk parameters. The development of high-quality wave time series can be pursued through full dynamical downscaling of waves, establishing statistical relationships between offshore and nearshore waves, or employing hybrid methods. Hybrid models combine the computational efficiency of statistical models with the precision and detail of dynamical downscaling models, resulting in faster and more cost-effective wave predictions.

While dynamical downscaling is the conventional approach in small geographical areas, hybrid methods are better suited for regional shoreline analyses and for examining long time series under various climate scenarios. In this study, we propose the utilization of BinWaves, an additive hybrid method, to downscale waves along the coastlines of New South Wales (NSW), Australia.

BINWAVES

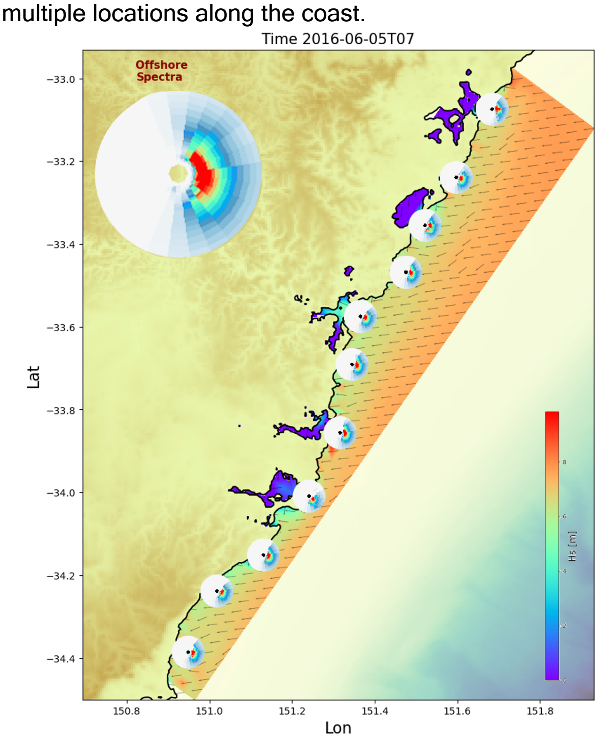
BinWaves is the first additive hybrid model in the literature that addresses wave propagation from deep to intermediate waters while accounting for the full complexity of the directional wave spectra. The method involves splitting the entire spectrum into several individual monochromatic wave systems, each with its own distinct frequency and direction of propagation, thereby creating a library of pre-computed cases. Given the reduced nonlinear effects in deep to intermediate waters, the method relies on linear wave theory, assuming that the propagation of these individual wave systems can be treated as independent during the reconstruction process. Under this assumption, the propagated wave spectra (S_p) at any location within the domain can be reconstructed using Equation (1), where S represents the offshore spectra and K_p represents the propagation coefficient for each of the monochromatic wave systems.

$$S_p(f_i, \theta_j) = \sum_i \sum_j S(f_i, \theta_j) * K_p{}^2 (f_i, \theta_j) \qquad \textbf{(1)}$$

To create the pre-run library of monochromatic wave propagations, 696 cases (29 frequencies and 24 directions) were executed using the numerical model SWAN (Simulating Waves Nearshore, Booij et al., 1999), and spectral information was stored.

WAVES RECONSTRUCTION AND VALIDATION

For the particular task of wave reconstruction in NSW, with a coastline spanning over 2000 km, we have developed a process that involves iterating the methodology over various tiles at a 200-meter resolution. Figure 1 presents the BinWaves results at the Sydney tile with superimposed propagated waves for a specific day, along with the complete directional wave spectra at multiple locations along the coast.



The methodology has been validated using available buoy spectral data across NSW yielding satisfactory results. BinWaves has demonstrated its efficiency in downscaling waves, which will serve as input for a nested high-resolution shoreline model. By using BinWaves relying on the library of pre-executed cases, a 40-year hindcast record can be reconstructed in a question of minutes. This capability will also enable the creation of ensembles for future wave projections, making it a highly suitable tool for long-term assessments across extensive regions.

REFERENCES

Booij, N., Ris, R. C., & Holthuijsen, L. H. (1999). A third-generation wave model for coastal regions 1. Model description and validation. Journal of Geophysical Research: Oceans, 104(C4), 7649-7666. https://doi.org/10.1029/98JC02622