Post-Doctoral Fellowship: Proposal Outline

Topic	Enhancing Coastal Wave Forecasting for Ireland
Research Theme(s)	1) Wave forecasting 2) Flood forecasting 3) Coastal vulnerability
Background and Rationale (including Strategic Priority)	The Marine Institute has developed a SWAN wave model encompassing Ireland's EEZ, and executed a 30-year Hindcast (1994-2023) to generate a data archive of modelled wave parameters. SWAN (Simulating Waves Nearshore) is a third-generation spectral wave model which was primarily developed for use in coastal regions. The Irish Shelf wave model covers the Irish EEZ at a horizontal resolution of 0.025 degrees. The model has been operationalized in 2024 and replaced the previous SWAN model of the North East Atlantic. It is forced by winds produced by the ECMWF high resolution forecast, and utilizes wave boundary data from the CMEMS 1/12 degree Global Ocean Waves Analysis and Forecast product. The model is run every day to produce a 6-day forecast and a 1-day hindcast, and output includes standard wave parameters such as significant wave height, mean wave period, peak wave period, and mean wave direction. Forecast data and a limited amount of hindcast data is available from the Marine Institute's Thredds and ERDDAP servers. Hindcast data is archived and is available on request. Currently the forecasts are produced on best-endeavours basis, serve general purpose, and are not to be used for safety-critical applications. However, subject to further developments, the operational forecasting capability of the model can be enhanced, including for flood forecasting applications and coastal vulnerability mapping. Met Éireann, as Ireland's National Meteorological Service, plays a critical role in flood forecasting through the National Flood Forecasting and Warning Service (NFFWS). Met Éireann's Flood Forecasting Centre is tasked with delivering high-quality flood forecasts, guidance, and services to key stakeholders as part of a whole-of-government approach to flood emergency response. As climate change increases the frequency of high-impact weather events, Met Éireann continues to enhance its flood forecasting capabilities through research and development of hydrological and oceanographic models tailored to specific local needs. Their mandate includes leveraging advances in model development to improve forecast accuracy, building inter-agency partnerships, and delivering integrated weather and flood information through multiple channels. The enhancement of wave modeling capabilities directly supports Met Éireann's strategic objective to "deliver a high-quality national flood forecasting service" and its commitment to develop impact-based forecasting for flood products and services.

	This work contributes towards Transforming our Knowledge, Advice and Services to better inform policy making, regulation and the sustainable management and growth of Ireland's marine resources. It also aligns with Ireland's Climate Action and Low Carbon Development (Amendment) Act 2021 and other national climate strategies, aiming to provide reliable, evidence-based guidance for climate adaptation in terms of mapping wave climate and coastal vulnerability. The research also aligns with the digital ocean transformation strategic priority and contributes to the development of the Digital Twin of the Ocean for Ireland. This work further supports Met Éireann's strategic goal to enhance impact-based decision making for weather events that promote citizen safety while supporting economic and environmental resilience, as outlined in the "Making Ireland Weather and Climate Prepared" 10-year strategy.
Scope of Research (Scientific/ Technical Challenge)	The overarching aim of this fellowship is to carry out the developments of the MI wave model that would enhance the model's accuracy and operational value, in particular the developments that will strengthen model's flood forecasting capabilities. The fellowship should address key research objectives as follows: • Carry out a comprehensive review of wave models to identify the model that is fit for purpose given the expected outputs from the project. The new/enhanced wave model does not necessarily have to be based on SWAN. • Implement data assimilation techniques to incorporate real-time wave observations from the existing buoy network and satellite data. • Increase the spatial resolution for nearshore areas to better capture coastal processes and local bathymetric effects, particularly in areas prone to flooding and those of high economic importance. • Implement high-resolution atmospheric forcing provided by Met Eireann to improve the representation of local wind fields and their impact on waves • Explore the possibility of integrating ECMWF ensemble prediction system data as model atmospheric forcing to better quantify forecast uncertainty and provide probabilistic wave predictions. Implement in the operational framework if deemed feasible. • Develop automated validation systems against observational data to continuously monitor model performance. • Carry out R&D on coupling the wave model with a hydrodynamic model, preferably one of the existing MI operational models or a newly developed dedicated model, if deemed more appropriate. Operationalize the coupled system, if the predictive skill is improved and time permits.

Expected Impact(s)	The expected impact of the project is an improved capability in Ireland in high resolution operational wave forecasting for flood forecasting applications. The proposed improvements to the model, e.g. data assimilation, high resolution atmospheric forcing, will also result in a more accurate wave model for wider applications, e.g. renewable energy resource mapping, safety of operations at sea, tourism, coastal erosion and vulnerability mapping.
Outcomes	Project is expected to deliver the following outputs: 1. **Literature review** – this leads to the identification of the most suitable wave model for the purpose of high-resolution coastal wave forecasting for flood forecasting applications. 2. **Operational wave model** – a fit-for-purpose wave model implemented operationally in the MI operational forecasting framework. The model needs to be of high resolution (i.e. < 100 m) along the coasts of Ireland, computationally efficient, assimilate data and be forced by high resolution Met Éireann's atmospheric forecasts. 3. **Operational validation** – operational validation of the wave model needs to be implemented. 4. **Wave-hydro model coupling researched –** report from R&D on coupling the wave model with a hydrodynamic model will be produced discussing impacts on their respective predictive skills. 5. **Scientific publications –** the fellow is expected to publish in peer-reviewed journals. 6. **Knowledge transfer and operational implementation plan –** Comprehensive documentation of the model setup, validation procedures, and recommendations for long-term operational use to ensure sustainability of the enhanced forecasting system. 7. **Model handover -** the ownership of the model, along with any associated intellectual property (IP), will be transferred to the funding bodies Marine Institute and Met Éireann following the project's completion.
Specific Collaboration	Oceanographic Climate Services section of the Marine Institute, Met Éireann, other operational wave modelling centres in Europe, e.g. through EuroGOOS, IBIROOS, NOOS.
Location of Fellow	Successful Higher Education Institute or Public Research Body (Republic of Ireland or Northern Ireland) **Note:** Also requires occasional research visits to the Marine Institute and Met Éireann.

Duration and Funding Available	4 years €100,000 per annum (i.e. total €400,000 maximum for duration of four years) This fellowship is jointly funded by the Marine Institute (50%) and Met Éireann (50%).
References	Booij, N., Ris, R. C. and L. H. Holthuijsen (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 Calvino, C., Dabrowski, T. and F. Dias (2022). Current interaction in large-scale wave models with an application to Ireland. *Continental Shelf Research*, 245:104798. ISSN 0278-4343. https://doi.org/10.1016/j.csr.2022.104798 Delft University of Technology. SWAN – Scientific and Technical Documentation. Environmental Fluid Mechanics Section, January 2023. URL http://www.swan.tudelft.nl. Version 41.45. Gallagher, S., Tiron, R., Dias, F. (2014). A long-term nearshore wave hindcast for Ireland: Atlantic and Irish Sea coasts (1979–2012): Present wave climate and energy resource assessment. *Ocean Dynamics*, 64(8), 1163-1180. https://doi.org/10.1007/s10236-014-0728-3 Gleeson, E., Clancy, C., Zubiate, L., Janjić, J., Gallagher, S., Dias, F (2019). Teleconnections and Extreme Ocean States in the Northeast Atlantic Ocean, Advances in Science & Research, 16, 11-29. https://doi.org/10.5194/asr-16-11-2019 Komen, G.J., Cavaleri, L., Donelan, M., Hasselmann, K., Hasselmaan, S., Janssen, P.A.E.M. (1994). Dynamics and modelling of ocean waves. Cambridge: Cambridge University Press. Tolman, H.L., Balasubramaniyan, B., Burroughs, L.D., Chalikov, D.V., Chao, Y.Y., Chen, H.S., Gerald, V.M. (2002). Development and implementation of wind-generated ocean surface wave models at NCEP. *Weather Forecast.* 17(2):311–333. doi: 10.1175/1520-0434(2002)017<0311:DAIOWG>2.0.CO;2 O'Brien, L., Renzi, E., Dudley, J.M., Clancy, C., Dias, F. (2018). Catalogue of extreme wave events in Ireland: revised and updated for 14 680 BP to 2017. *Natural Hazards and Earth System Sciences*. 18(3):729-58. https://doi.org/10.5194/nhess-18-729-2018