Application of TOMAWAC for wave energy resource assessment: A North Sea wave database

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Abstract – **Wave energy resources as a renewable source of energy, has been constantly appraised in the context of the global green/blue energy transition. To ensure a success development of wave energy projects, one of the first steps is to acquire an accurate assessment of wave energy resources using advanced modelling techniques and long-term reliable databases.**

This study focuses on the wave energy resource assessment of the North Sea region where a significant potential of development is detected. To this, an improved version of TOMAWAC model, a 3rd generation wave-model has been used. More detailed attention was given to the Belgian Part of the North Sea (BPNS) to feed a reliable online wave energy database with a proper resolution. A validated inhouse water level database has been implemented into the model, integrating the variation of water level impact on the wave propagation, especially in shallower areas. These improvements speed up the numerical simulations and presents to be computationally more effective, which proves crucial in terms of large-scale metocean conditions evaluation. The model results have been calibrated and validated against in-situ measurements at both nearshore and offshore positions, and the validated model has been applied to generate a 20-year (2001-2020) hourly metocean condition for North Sea, with a geometric resolution of 500-600 meters near the Belgian coast. The model results have been transformed into an online WEC database for the ocean energy at the North Sea.

Keywords: Wave modelling, Metocean conditions, North Sea, Wave Energy Resources.

I. INTRODUCTION

The ocean is host to a variety of human activities, spanning from tourism, coastal infrastructure, navigation to fisheries and more. In recent years, climate change and sea level rise have increased largely the frequency of coastal flooding and coastal erosion, posing a continuous threat for economic and human life. As such, amongst the efforts to restore the balanced earth environment and seeking a durable development, scientists have been searching for renewable clean energy, such as solar energy, wave energy and ocean energy. New devices and technologies are being developed to generate electricity from waves, tides, as well as offshore wind farms. With an identified resource in the range of 1000 TWh of wave energy and around 150 TWh of tidal energy annually, ocean energy is the largest unknown untapped renewable energy in Europe, and it is expected to provide 10% of the EU's power demand by 2050 [1].

In terms of wave energy exploitation, the North Sea had been long overlooked due to its perceived 'lower' energy resource; however, it has been pointed out in [2] that the wave conditions for North Sea are moderate to high and more importantly, they are more easily accessible thanks to the low distance to coasts. An essential step towards a reliable estimation of the ocean energy is an accurate assessment of the metocean conditions. Three main ways are exploited, include: in-situ measurements, satellite data as well as numerical models. The in-situ measurements are usually for data collection at limited number of locations and cannot be extrapolated to cover a larger domain, moreover, gaps in data are observed, especially during severe weather conditions; the satellite data become more promising in recent years, although they are still limited for the moment by data quality, especially in the near shore region [3]. Large scale numerical models have been widely used: they provide metocean data with high temporal- and spatial-resolution, with the precondition that the model performance has been tested, validated with existing measurements.

In [2], SWAN has been used for generating a 38-year wave database of North Sea, focusing mainly on the Dutch coast. In building up the model, a better parameterization, especially in terms of wind generation and whitecapping, was sought for.

In the current study, a highly-efficient 3rd generation spectral wave model (updated TOMAWAC) has been exploited for simulating the wave conditions on North Sea, with a focus on the Belgian coast. A modelling improvement has been performed, that the water level variations have been incorporated into the wave propagation simulation. Consequently, the influence of tidal variation, the storm surge has been accounted for. This is very relevant for the North sea since the water level remains shallow for a large part near the coast. The tidal level for the North Sea reaches up to more than 4 meters, leading to a non-negligible effect of water level modulation on the wave propagation. This effect is even more pronounced closer to the Belgian coast, where tidal banks with water depth of 15-20 meters are present. As a matter of fact, it has been pointed out in [4] that the wave-current interaction can lead to a variation of wave energy by up to 30%, especially in the shallower zone.

To fully take the wave-current interaction into account, a more comprehensive approach would be exploitation of a full TELEMAC-TOMAWAC coupling, nevertheless, it is too time consuming. In this study, we have incorporated the influence of water level to the wave propagation thanks to a pre-computed reliable database for hydrodynamics in the North Sea. A 20-year metocean conditions for the North sea have been generated. This database can also serve as a useful tool for other offshore and nearshore ocean applications, for example, the extracted wave characteristics can be used to compute the working availability in terms of weather conditions for a certain area. The metocean data has been also translated to an online wave energy database.

II. STUDY AREA

The Belgian Part of the North Sea covers approximately 3,500 km² and extends up to 87 km offshore from the coast (Figure 1). There are currently several renewable energy projects active in a series of concession areas of in total 225 km² along the Dutch-Belgian maritime border, primarily consisting of offshore wind parks. However, the concessions also contain various pilot projects, notably a planned 5MW wave energy project to be developed by Otary, a major stakeholder in offshore renewables in Belgium. Further concessions are planned for a total additional area of 281 km² to be made available between 2020 and 2026[1]. The further expansion of offshore wind concessions falls into the framework of a planned increase in capacity from approximately 2.3 GW to 4 GW by 2030.

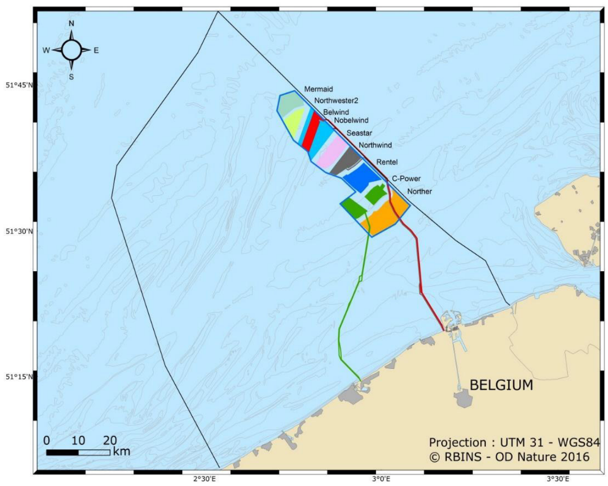

Figure 1 Map of BPNS and current offshore wind concessions.

The possibility of integrating offshore wind and wave power in a combined format allows for maximized power output from the available energy resources. Given the large area currently dedicated to offshore wind which will more than double by 2026 it is key to identify the most suitable technologies available for potential application in new and existing concessions.

III. METHODOLOGY

A. Model description

TOMAWAC (TELEMAC-based Operational Model Addressing Wave Action Computation) is a scientific software which models the changes, both in the time and in the spatial domain, of the power spectrum of wind-driven waves and wave agitation for applications in the oceanic domain, in the intracontinental seas as well as in the coastal zone. The model uses the finite elements formalism for discretizing the sea domain; it is based on the computational subroutines of the TELEMAC system.

TOMAWAC is a 3rd generation spectral wave model, which solves the wave action balance equation:

$$\frac{\partial N(\theta,\sigma)}{\partial t} + \frac{\partial c_j N(\theta,\sigma)}{\partial x_j} = S$$

Where N is the wave action, it is defined as: $N = E/\sigma$, with σ the wave frequency; θ is the wave propagation direction; c_j is the propagation velocity of the wave energy along the four dimensions ($x, y, \theta,$ and σ); S represents all the source and sink terms that parametrize different physical processes accounting for wave energy production and dissipation; in TOMAWAC, the following aspects have been taken into account:

$$S = S_{in} + S_{ds} + S_{nl} + S_{bf} + S_{br} + S_{tr} + S_{ds,cur} + S_{veg}$$

Where: S_{in} is the wind-driven wave generation; S_{ds} is the whitecapping-induced energy dissipation; S_{nl} is the non-linear quadruplet interactions; S_{bf} and S_{br} are the bottom friction-induced and breaking-induced wave energy dissipation, they are more important for shallower near-coastal regions; S_{tr} is the non-linear triad interaction; $S_{ds,cur}$ is the enhanced wave breaking dissipation by currents and S_{veg} is the dissipation due to vegetation. These source and sink terms have been numerically parameterised and integrated in the model (the dissipation due to vegetation has been left out).

In TOMAWAC, unstructured grid has been exploited, it can be used as a stand-alone wave prediction tool; meanwhile, it offers the possibility to be coupled to TELEMAC for a full wave-current simulation: this method, accounts for more comprehensive physical processes, demonstrates to be computationally expensive. In this study, pre-stored water levels [5], [6] have been read at each time step, integrating the influence of the water levels without largely increasing the computational cost of the wave model.

[1] *https://economie.fgov.be/en/themes/energy/belgian-offshore-wind-energy-4*

B. Numerical scheme

TOMAWAC exploits a fractional time step; for the advection, the method of characteristics is used, which presents to be fast and unconditionally stable, yet it poses issues in forms of the numerical diffusion and loss of energy conservation; for the source terms, a sub-time step has been applied for rapidly varying processes (depth-induced breaking and triad interactions). The method leads to a time-step restriction for accuracy reasons, which substantially increases the computational cost.

To overcome these limitations, a new architecture of TOMAWAC has been introduced [7]. The current numerical scheme has been optimised in the following aspects: (1) A second order spatial advection scheme has been implemented; it decreases the numerical diffusion and presents to be energy-conservative. (2) For the source terms, a separation has been made between the slow and fast physical processes, where different time steps have been applied. As such, the computation time has been reduced substantially. One is referred to [7] for a more comprehensive discussion of the methods and results. In this study, this updated version of TOMAWAC had been applied.

C. Model inputs

1) Geometry and grid

In this study, the computation domain covers largely the North Sea. In the West, it reaches to the intersection point of English Channel and Celtic Sea, comprising of the whole English channel, extending further to the whole east coastline of UK; in the South, it comprises of the Northern coastline of France, Belgium, Netherlands and Germany; the east side covers the West Coastline of Norway and Sweden until Gothenburg and then it extends to the coastline of Denmark.

The whole domain covers roughly 500,000 km^2 area. The bathymetric data come from the EMODNET database, combined with a more refined Belgian coast coming from the Bathymetry of the Belgian Continental Shelf (Flemish Authorities, Agency of Maritime & Coastal Services, Coastal division, Gridding Ghent University, Renard Centre of Marine Geology). The simulated domain and final bathymetry are shown in Figure 2.

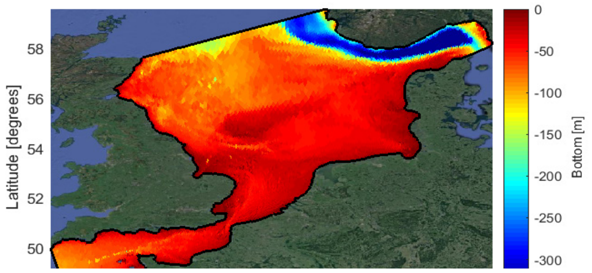

Figure 2 Geometry and coverage of the simulation domain. The mesh is created in latitude and longitude to account for the Earth's curvature.

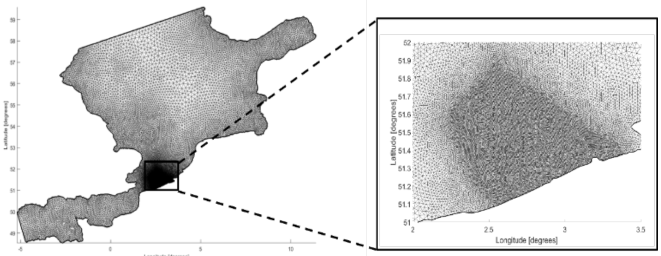

Figure 3 Computational grid for the wave model. The unstructured grid has been refined closer to the Belgian coast.

For the computational grid, a non-homogeneous unstructured triangular grid has been applied: the mesh size presents to be coarser to the northern side open sea, with a rough size of 20km, it is refined for the Belgian coast and the mesh size reduces to 400m. There are in total 30395 nodes and 60615 elements (Figure 3).

2) Wind

Wind is a main driver behind the energy source of locally generated ocean waves. A well-chosen wind source is an essential segment of a highly performant ocean wave models. Wind data are usually provided by institutional or governmental bodies, in which different re-analysis techniques and various atmospheric models have been exploited. In this study, two wind sources, ERA5 and CFSR, have been considered and their performances have been compared.

CFSR wind data exhibiting higher spatial resolution, and it captures well the peak of waves. However, for wider domain, the use of re-analysis CFSR data may lead to higher scatter [2]. Given the primary goal of this study is to yield reliable wave energy estimation, especially for the Belgian coast, both wind source performances were compared with a focus closer to the coast.

3) Spectral wave boundary condition

The boundary condition for waves has been extracted from the ECMWF data (ERA5), which had been reconstructed by the WAve Model (WAM). It had been imposed mainly at the North and West side of the domain boundary. At each boundary node, significant wave height, peak period and wave main propagation direction were used to construct the synthetic JONSWAP spectrum. The spectral wave boundary condition is essential for introducing the swell waves into the wave estimation, which was mainly generated and propagated from the North Atlantic Ocean and the Norwegian sea. This part of the boundary condition has been validated by comparing the modelled 1D spectrum to the measurements.

4) Tide and water level variation

In this study, the influence of hydrodynamics environments has been integrated. Instead of a fully coupled wave-hydrodynamics model, which requires heavy computational cost, results of a pre-constructed hydrodynamics database (North Sea Metocean Database for hydrodynamics: [5]) have been read at each time step of the wave model. The North Sea metocean Database for hydrodynamics has been constructed based on a long-term simulation of in-house iCSM model for 26 years from 1995 to 2020. The iCSM is a tidal surge model developed in TELEMAC-2D, focusing on the continental shelf of the North Sea. The model has been systematically calibrated and validated on water level and velocities for both ordinary and extreme events [5]. The model shows reliable ability to precisely reproduce the hydrodynamics in the North Sea. As such, this pre-stored database has provided valuable hydrodynamical information for this wave model.

IV. MODEL RESULTS

A. *Calibrations and verification of the model*

The model calibration involved two different periods: December 2013 (including Sinterklaas storm event) and in winter 2017. Both periods were marked by significant wave heights that exceeded 3.0 m height. To compare the wave height and wave period between the model results and available measurement over the North Sea, several points were selected, ranging from Belgian nearshore positions (Bol Van Heist) to North Sea offshore positions (Ekofisk) illustrated in Figure 4 and Table I. This approach facilitated a comprehensive evaluation of the model performance across varying distances from the coast.

Table I Points where the measurements and the numerical results have been compared.

	A12	Bol Van Heist	Euro-plat-form	K13	WestH inder	Ekofisk
Lat.	55.38	51.40	51.98	53.22	51.38	56.54
Lon.	3.80	3.22	3.42	3.22	2.43	3.22

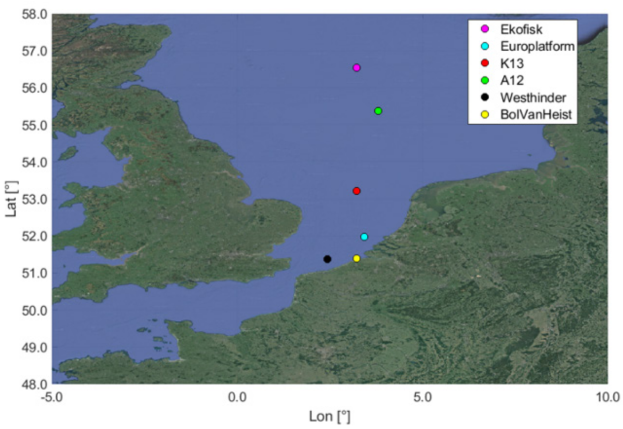

Figure 4 Geographical representation of points where the measurements and the modelling results have been compared.

Bathymetric treatment, wind sources, mesh resolution, wave propagation method, and water level impact were tested and evaluated during the calibration procedure. A summary of model setting has been listed in Table II. Note that the optimal whitecapping dissipation coefficient for CFSR is concluded to be 4.5, while for ERA5, it is found to be a lower value of 3.0.

The model performance was assessed using several statistical indicators, including bias, Root Mean Square Error (RMSE), Scatter Index (SI), and the correlation coefficient (R). In the context of wave simulation, a low SI of $\leq 25 - 30\%$ indicating that the general trends have been captured; R is the Pearson correlation coefficient. It is computed as the ratio between the covariance of two variables and the product of their standard deviations; it measures the linear correlation between two sets of data. Therefore, a correlation coefficient of 1 corresponds to data points lying exactly on a line. For wave energy, for a model to be reliable a correlation coefficient higher than 0.9 is required. In Table III, Table IV, Table V and Table VI, model and measurement comparisons for both the December 2013 and the winter 2017 period are summarized.

Our final objective for constructing a wave database is to evaluate the potential of WEC near the Belgian coast, therefore, more weights have been put at points closer to the Belgian coast. Different sources of measurements data have been exploited and they are listed below:

(1) Wave data at BolVanHeist, WestHinder: Monitoring Network Flemish Banks (Meetnet Vlaamse Banken)
(2) Wave data at EuroPlatform, A12, K13: Rijkswaterstaat waterinfo (wave characteristics) Rijkswaterstaat Waterinfo (rws.nl)
(3) Wave data at Ekofisk: FROST : https://frost.met.no/index.html
(4) Wave spectrum at EuroPlatForm: Dutch Rijkswaterstaat.

Table II Final parameters used in setting up the model.

Parameters name	Value
Time step [s]	600
Minimal frequency [Hz]	0.03
Number of frequencies	36
Number of directions	36
Implicitation coefficient for source terms	0.55
Limiter for refraction velocity [7]	Only for directions
Numbers of iterations for small scale processes	10
Number of iterations for advection	1
Linear wave growth	1, Cavaleri & Malanotte-Rizzoli formulation
White capping dissipation	Yes
White capping dissipation coefficient	4.5 for CFSR, 3.0 for ERA5
Depth-induced breaking dissipation	10, see [7]
Number of iterations for the source terms	1
Number of breaking time steps	10

Table III Statistical assessments for significant wave height for December 2013.

	Bol van Heist		Westhinder		Europlatform		A12		Ekofisk	
	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR
Bias [m]	-0.13	-0.08	-0.09	0.11	-0.09	0.08	-	-	-0.02	0.12
RMSE [m]	0.25	0.25	0.29	0.35	0.49	0.41	-	-	0.44	0.90
SI [%]	35%	30%	22%	23%	22%	22%	-	-	13%	24%
R [-]	0.93	0.93	0.92	0.93	0.96	0.95	-	-	0.96	0.89

Table IV Statistical assessments for Tm02 for December 2013.

	Bol van Heist		Westhinder		Europlatform		A12		Ekofisk	
	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR
Bias [m]	0.57	0.47	-0.15	0.06	-0.31	-0.05	-0.05	0.34	-	-
RMSE [m]	0.98	0.76	0.55	0.57	0.61	0.68	0.59	1.19	-	-
SI [%]	20%	23%	14%	13%	14%	14%	12%	18%	-	-
R [-]	0.71	0.78	0.79	0.79	0.74	0.78	0.92	0.79	-	-

Table V Statistical assessments of the significant wave height for winter 2017.

	Bol van Heist		Westhinder		Europlatform		K13		A12	
	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR
Bias [m]	-0.17	-0.12	-0.04	0.04	-0.04	0.06	0.06	0.07	0.32	0.30
RMSE [m]	0.27	0.25	0.23	0.25	0.29	0.33	0.32	0.43	0.67	0.66
SI [%]	32%	28%	17%	17%	15%	18%	16%	21%	24%	24%
R [-]	0.91	0.92	0.94	0.94	0.95	0.92	0.93	0.88	0.84	0.84

Table VI Statistical assessments of Tm02 for winter 2017.

	Bol van Heist		Westhinder		Europlatform		K13		A12	
	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR	ERA5	CFSR
Bias [m]	0.17	0.15	-0.03	0.09	-0.15	0.10	-0.16	0.09	-0.09	0.20
RMSE [m]	0.77	0.75	0.44	0.45	0.47	0.48	0.56	0.52	1.0	1.0
SI [%]	17%	17%	10%	10%	11%	10%	12%	12%	16%	16%
R [-]	0.71	0.72	0.83	0.84	0.80	0.85	0.72	0.80	0.65	0.77

From the model performance shown in these tables, it is seen that overall, the performance of two wind sources is very similar. At offshore points, the CFSR model over-estimate the wave energy (positive bias) while with ERA5 wind, a general underestimation for storm conditions has been observed. At nearshore stations, both wind sources generate a wave energy that slightly underestimate the measured wave height.

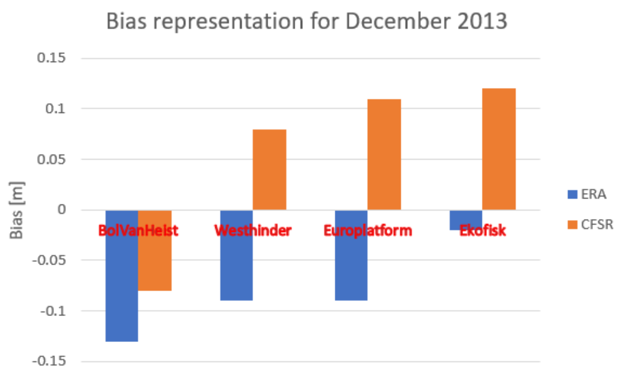

Figure 5 Bias plot for significant wave height for December 2013: from left to right the distance to the shore increases.

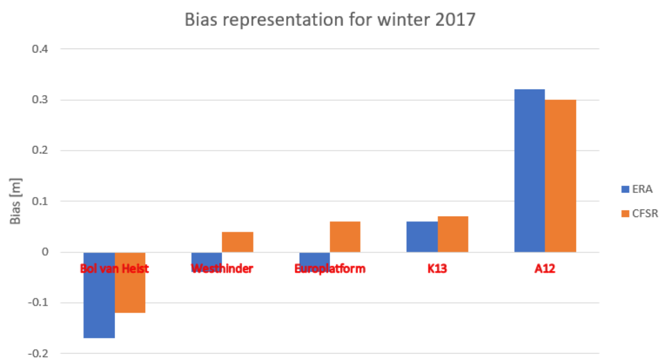

Figure 6 Bias plot for significant wave height for winter 2017: from left to right the distance to the shore increases.

In general, a better performance of ERA5 wind at offshore positions was observed. For instance, at A12 location, for the Sinterklaas storm event, the Tm_{02} has been better captured by ERA5 than the CFSR. At location Ekofisk, a better capture of wave energy has also been represented by ERA5. However, at nearshore point (Bol Van Heist), CFSR outperforms ERA5 wind. The tendency becomes obvious in Figure 5 and Figure 6. In both figures, the bias for significant wave height has been plotted, the distance to shore increases from left to right. It is seen that ERA5 generally performs better at offshore whilst opposite can be concluded for CFSR. For buoy position A12 which is situated the farthest from the coast, each wind generates a bias that reaches roughly 30 cm for winter 2017. Given the main attention of this project focusing more on the nearshore positions, that most of the WEC will be placed near the coastline, thus the quality of nearshore wave energy computation is important. Moreover, CFSR wind performs better for extreme values. For the WEC, it is important to have well-captured extreme values to determine the workability of the device. As such, CFSR wind has been chosen for further construction of the model, bearing in mind that for offshore positions, the results await to be improved.

Apart from the wind sources and the spectral results, other parameters, including time step, wave breaking and whitecapping parameters have also been well calibrated and the highest performance parameters have been chosen. The performance of the final model has been verified not only in terms of the bulk statistical parameters (for an example of wave height and period plot over time at WestHinder, see Figure 8), but also in terms of the spectral results. In Figure 7, measured and simulated 1D spectrum (with CFSR model) has been compared at a nearshore position: Europlatform. Two time instants have been chosen, including the peak of the storm, where wind generated waves are dominant (on top); nearly equally partitioned wind waves and swell for relatively strong wave (below). From these comparisons, it is seen that not only the locally generated wind waves have been well captured, but the sea swell, which are propagated from offshore boundary are also well reproduced, especially its energy partition and distribution over the frequency.

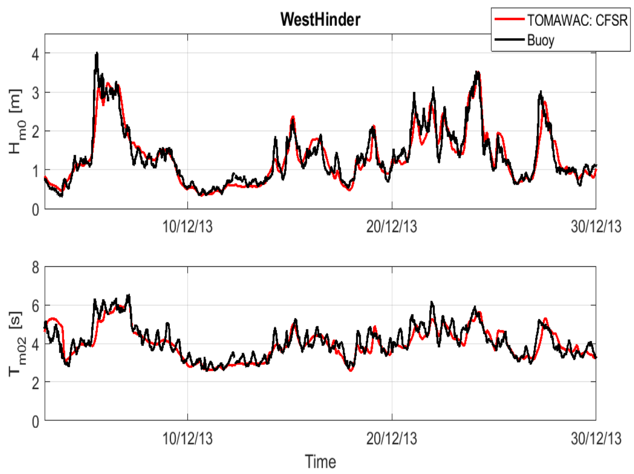

Figure 7 Significant wave height and Tm02 comparison between measurements and modelled results for Sinterklaas storm.

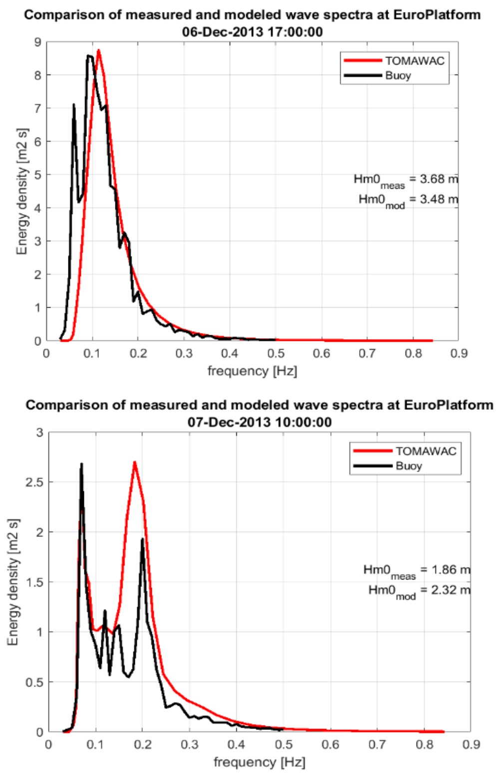

Figure 8 1D spectrum comparison between the Tomawac model and measurements at EuroPlatform.

B. Validation and production runs

With the final parameters being determined, we had used the model for hindcasting another independent period from April to August 2018 for the validation of the model. This period has been chosen for its calmer sea state, with a highest wave reaches at nearshore less than 2 meters. Results at the various locations have been listed in Table VII and Table VIII. It is seen that the bias and RMSE are well bounded, and a lower index of SI has been produced, especially for Tm_{02}. The correlation numbers for R for significant wave height are found to be more than 0.9, it is lower for the wave period. The observation is consistent with beforehand, that using CFSR wind over-estimates the wave energy at offshore points, at its performance improves when approaching the coast.

A general satisfying performance of the model can be concluded. This well-calibrated model has been used to generate a North Sea metocean database for 20 years (2001-2020). A general performance of the models has been evaluated by computing the statistics at nearshore points (WestHinder) for the data availability. The detailed errors for significant wave height have been listed in Table IX. An average bias of -1cm is found, marking the high performance of TOMAWAC model in reproducing the wave energy over a long period of time. It is also noted that the average RMSE is around 20cm, with a high correlation number of > 0.95. These statistical indicators prove the reliability of the constructed database in terms of the wave energy estimation and its potential for offering a first insight into the use of clean ocean energy. This database not only offers a first impression of the local wave and wind conditions for a specific period, but also can provide a general wave condition at specific points for a long period of time. For example, in Figure 9, the wave rose at Bol Van Heist for 20 years has been reproduced. During most of the period, wave energy presents to be in calmer state. The highest waves travel most to East or Southeast direction. Based on this database, it is also possible to extract a seasonal or monthly wave energy and direction fluctuation, providing valuable benchmark for the workability of ocean platforms for the North Sea.

Table VII Statistical assessments for model performance for April to August 2018: significant wave height.

	BVH	West-hinder	Europlat-form	K13	A12	Ekofisk
Bias [m]	-0.09	0.04	0.06	0.09	0.25	0.15
RMSE [m]	0.19	0.21	0.22	0.30	0.39	0.71
SI [-]	28%	24%	24%	28%	35%	22%
R [-]	0.91	0.93	0.96	0.91	0.93	0.91

Table VIII Statistical assessments for model performance for April to August 2018: Tm02.

	BVH	West-hinder	Europlat-form	K13	A12	Ekofisk
Bias [s]	0.41	0.04	-0.23	-0.12	-0.15	0.19
RMSE [s]	0.81	0.51	0.59	0.63	0.78	0.91
SI [-]	20%	13%	14%	14%	16%	31%
R [-]	0.72	0.81	0.77	0.77	0.72	0.75

Table IX Errors calculated for 20 years (2001-2020) for significant wave height at WestHinder.

	2001	2002	2003	2004	2005
Bias [m]	-0.05	-0.07	-0.05	-0.08	0.02
RMSE [m]	0.22	0.22	0.20	0.21	0.21
SI [-]	20%	22%	25%	21%	21%
R [-]	0.97	0.97	0.96	0.97	0.97
	2006	**2007**	**2008**	**2009**	**2010**
Bias [m]	-0.03	-0.06	-0.11	-0.12	-0.04
RMSE [m]	0.22	0.20	0.25	0.22	0.21
SI [-]	20%	22%	22%	23%	22%
R [-]	0.97	0.95	0.96	0.95	0.96
	2011	**2012**	**2013**	**2014**	**2015**
Bias [m]	0.01	0.04	0.02	0.03	0.02
RMSE [m]	0.22	0.23	0.25	0.23	0.22
SI [-]	20%	22%	21%	22%	19%
R [-]	0.97	0.97	0.97	0.97	0.95
	2016	**2017**	**2018**	**2019**	**2020**
Bias [m]	0.09	0.03	0.02	0.03	0.03
RMSE [m]	0.28	0.22	0.21	0.21	0.25
SI [-]	18%	21%	22%	20%	22%
R [-]	0.97	0.97	0.95	0.97	0.97

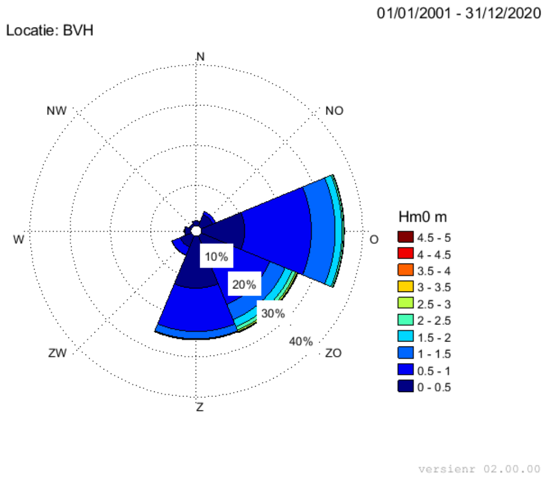

Figure 9 wave rose at BVH for 20 years.

V. CONCLUSIONS

In the current study, we have constructed a semi-coupled (hydrodynamics and waves) model for the North Sea, focusing on Belgian coast. The performance of the model has been evaluated using several reliable statistical parameters. Two wind sources have been compared: ERA5 wind and CFSR wind. The performances of two wind sources are very similar; in general, ERA5 wind has been found to yield a better result regarding wave energy and period at offshore whilst at nearshore, CFSR wind outer-performs ERA. Both winds have been found to underestimate the wave energy at nearshore points, especially at the peak of the storm. Due to the higher performances of CFSR close to the coast, we have constructed the model using this wind source.

The model has been run for 20 years (2001-2020: each year individually for storage and data accessibility reasons). This database offers large potential. It can serve as a basic database for projects that are relevant to the areas and providing a first and fast evaluation of wave energy in terms of seasonal/monthly and yearly changes. It brings valuable insights into the feasibility of WEC at nearshore coastlines, where the wave energy potential has been currently largely overlooked. As a matter of fact, the results of these runs have been converted onto WEC database and presents to be available online (https://sinapps.imdcapps.be/).

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