ENHANCING WORKABILITY BY OPERATIONAL WAVE MODELLING

by

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ABSTRACT

When dredging in exposed waters, wave conditions may seriously impact the workability of a dredging project. Especially stationary dredging equipment that makes use of spuds in order to remain in position and transfer the dredging forces to the seabed, like a backhoe dredger or a cutter suction dredger, is vulnerable for harsh wave conditions. The workability of such vessels is not only affected by the wave height, but also the wave period. Other types of marine operations, such as the construction of jetties, installation of wind turbines or the placement of scour protections are affected as well in their workability by the ambient conditions at sea.

Various regions all over the world are known for their problematic wave climate; the African west coast, the French and Spanish Atlantic coast, the Indian coastal waters, etc. are known for their long swell coming with long wave periods. But also less swell-dominated seas such as the North Sea may have severe wind sea systems with typical wave peak periods around 6 to 7 seconds. In extreme cases, even for large cutters, workabilities of less than 50% are not exceptional. Given the large stand-by costs of such specialized vessels, this can have a huge impact on the cost of a dredging project.

There is not only a considerable cost impact. Also the safety of the crew working on board of vessels in harsh conditions is at stake. Usually it is the responsibility of the captain to decide when the works need to be ceased in case of upcoming bad weather conditions. Therefore the captain needs to have a thorough knowledge of the limits of the vessel in terms of metocean conditions, and he/she should also have good insight in the current and upcoming weather conditions. When there is uncertainty in one of those elements, the captain's decision might be subjective and lead to unsafe situations or inefficiency:

- Unsafe working conditions follow from the fact that the equipment is being exposed to conditions beyond its workable limits. This could lead to damage to the equipment, for example damage to the spud, and uncontrollable motions of the vessel. In such case there is a risk for unsafe situations for the crew.

- Loss of efficiency is caused by a captain's decision not to work, while in reality the weather conditions are below the critical limits. This often happens after a period of bad weather, and conditions start to improve again, but the decision to resume the works is dominated by over-conservatism. The quality of the consulted weather forecasts also plays an important role in this process.

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In order to improve this situation, DEME has developed an operational tool in cooperation with BMT Argoss which aims to provide the on-board crew and site staff with information on the present and near-future sea states and whether operational thresholds are expected to be exceeded. The sea state is broken down in systems of common meteorological genesis which are considered to be statistically uncorrelated. With the use of response amplitude operators, key operators are determined and presented via a web application. Whenever the actual wave conditions are getting too rough the system will indicate that the workability limits are being reached and work should be ceased. Real time sea state data can be acquired from buoys that are deployed near the works. Future sea states are provided by a combination of operational atmospheric and wave models that typically deliver a five to eight day forecast window. To be able to further increase the accuracy and skill of these forecasts, the models are calibrated on the measured waves. The wave forecasts make it possible to plan the works more efficiently and to optimally use available workable windows. It generally results in less downtime, less damage and a safer working environment.

The tool has initially been applied for the Wheatstone downstream project, Australia, where a large access channel for a new port had to be dredged. This paper will discuss two other project cases where the tool has been applied; first the dredging works for a new highway at La Reunion island (Indian Ocean) and secondly the dredging and offshore installation works for the offshore wind farm Rentel in Belgium. The focus will be on the quality of the wave forecasts by operational wave models and the continuous calibration efforts which are increasing their reliability during the project.

1. INTRODUCTION

The Workability Tool (WoTo) has been developed to objectify the decision-making process regarding the weather conditions when active in harsh weather conditions. Combining measured and forecasted metocean parameters with the workable limits of vessels, the crew is able to evaluate the workability at any time. The comparison between the measured and forecasted wave parameters gives an appreciation of the confidence one can have in the forecasts.

The deployment of this tool has significantly increased the safety, the awareness, the efficiency and the planning on the different projects where it has been deployed. The reliability of the tool is highly dependent on the quality of the weather forecasts and, depending on the location of a project, the wave modelling can be more or less accurate. The development and improvement of wave models are therefore generally necessary to increase the reliability in the forecasts. These step by step improvements are then validated and/or calibrated using measured metocean data.

After a short introduction of the different hardware and software components, two case studies will be presented and discussed.

2. DESCRIPTION OF THE WOTO

The workability tool needs different entries to compute different outputs. Some inputs and outputs of the tool will be briefly explained below.

2.1 Measured Wave Parameters

To evaluate the current wave conditions, statistical parameters have to be derived from wave energy spectra. These can be obtained from different instruments (radar, buoy, ADCP, etc.). The focus will here be on directional wave rider buoys.

Most wave rider buoys are generally delivering a wave spectrum every 30 minutes. To get closer to a real-time monitoring of the waves, specific software has been developed to reprocess the wave raw displacements data and obtain new wave spectra containing the buoy displacements of the past 30 minutes every 3.75 minutes using a rolling buffer.

To obtain the wave statistical parameters from the spectra, a splitter has been developed by BMT Argoss and integrated in the WoTo. The splitter uses a wind component (from the forecast or measured) to allocate the spectral energy to a swell or a wind system.

A significant wave height (Hs), a mean period (Tm) and a direction (Dm) will thus be obtained for both the sea/wind and swell components. The system will then look at which system is the most impacting the workability of the vessel.

2.2 Forecasted Wave Parameters

The forecasting models are run several times a day by BMT Argoss and the output (Hs, Tm and Dm for both sea/wind and swell components) is imported in the WoTo. Depending on the operations, the frequency of the forecasts is adapted. In the WoTo the forecast is shown next to the measured data (Figure 1) in order to get a feeling on the quality of the forecast.

The model setup will be discussed in more detail in the different cases.

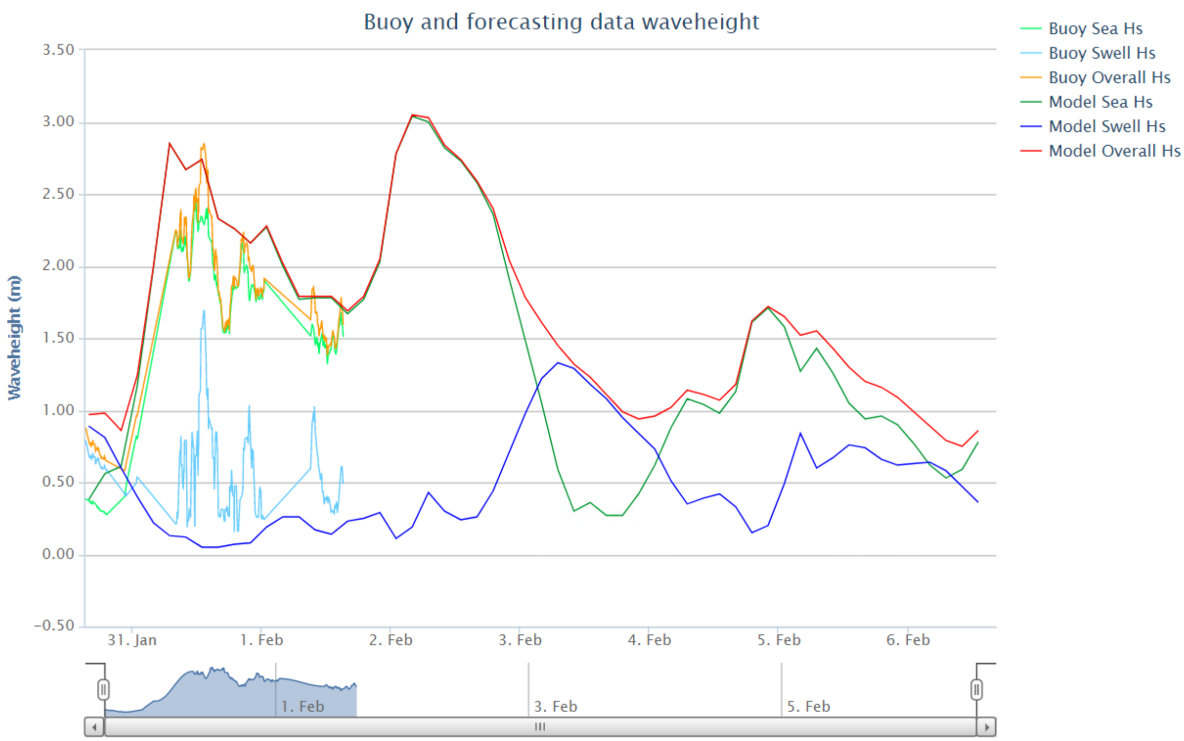
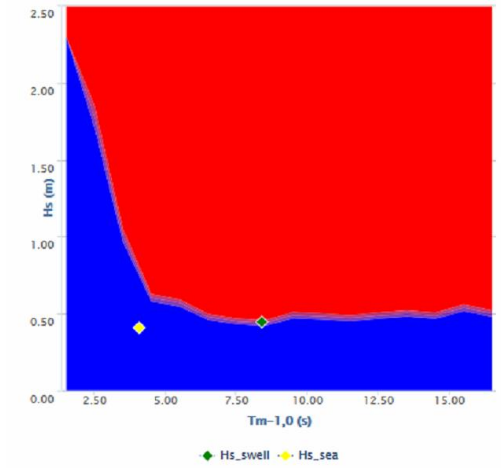


Figure 1: visualization of the measured and forecasted statistical wave parameters

2.3 Workable limits of the operation

Depending on the operation of interest, different workable limits are considered. Stationary vessels will generally be modelled in a diffraction model to determine the forces/movements generated under specific wave conditions. Each vessel and activity have their limits and on their basis, workability tables are generated. The WoTo shows the actual wave conditions in a workability plot from which it becomes clear if the conditions are workable or not (Figure 2).



Parameter (Buoys-BUOY2)

	Hs (m)	Tm-1,0 (s)	Direction (deg)
Swell	0.45	8.42	24.1287
Sea	0.41	4.09	58.2697
Overall	0.60	6.45	40.2927

Figure 2: visualization of the comparison between the measured waves and the workable limits of an activity.

3. PROJECT CASES

3.1 Rentel

Project Description

Rentel is developing an offshore wind farm in the Belgian territorial water in a zone designated for offshore energy (Figure 3). The wind farm development is located approximately 32 km offshore from the port entrance of Zeebrugge and 42km from Ostend, in between the Northwind and C-Power concessions. The wind farm will consist of 42 wind turbines generating a nominal power of 309MW.

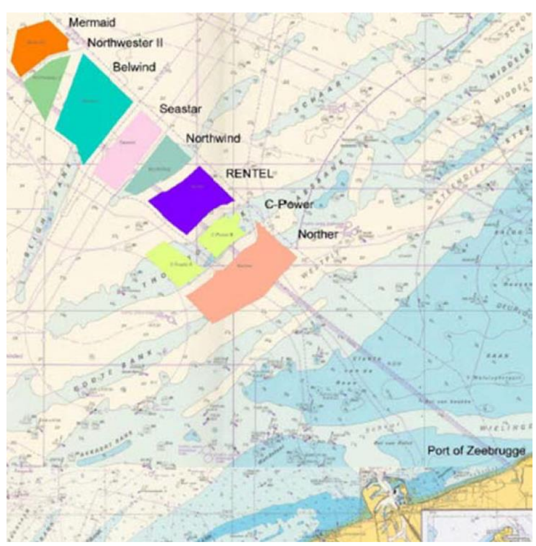


Figure 3: Overview of the Rentel wind farm concession southeast of the Lodewijk Bank and northwest of the Thornton Bank

Dredging International NV (part of the DEME-group) is the main contractor for the works and is further supported by other companies of the DEME-group as shown in Figure 4. The contract involves various operations such as the installation of the foundation and transition pieces, the cable laying and burial, the scour protection, installation of the turbines, etc. Figure 5 shows one of the vessels Geosea is using for the installation of the foundations.

Figure 4: Rentel contractor organisational structure.

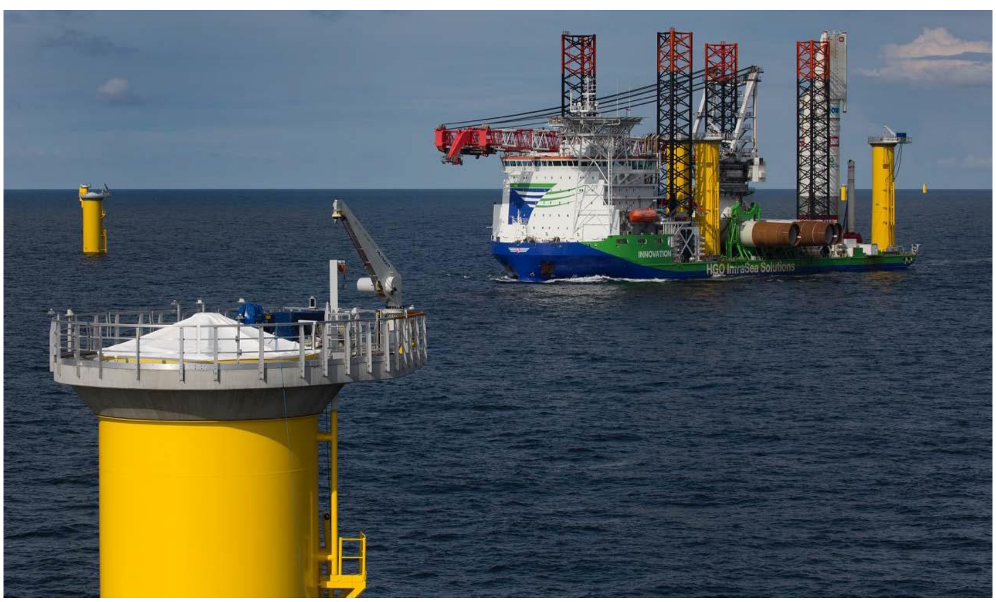


Figure 5: Geosea's vessel Innovation arriving on a windfarm installation site.

Climate

The southern North Sea has a typically moderate climate: unsettled conditions prevail and strong temperature variations do hardly occur. This is caused by the predominant (south-) westerly airflow, which is found in between the semi stationary Azores high pressure area and low pressure areas, which occur frequently over the northern Atlantic Ocean and usually track to the East or North East, close to Iceland towards (northern) Scandinavia.

The activity of the low pressure areas varies throughout the year. Strongest low pressure areas are found in the second half of autumn and during winter, but also in other times of year active low pressure areas may affect the North Sea and cause strong winds and high waves. Strongest winds and highest waves are however often caused by relatively short lived so called ‘secondary lows’, which develop in a frontal system over the British Isles or North Sea and track rapidly to the east or northeast. After the passage of a major low pressure area to the north of the North Sea, associated high swells often enter the North Sea from the NNW. These swells usually reach to the Rentel location. On its way to the south however, wave height usually decreases significantly before arriving at the Rentel location.

At times the Azores high pressure area extends to the east or northeast. Depending on the exact position, this may result in periods of calm conditions over the North Sea. These calm interruptions can vary strongly in duration (between parts of a day till weeks) and occur year round, but are most frequent during spring and summer. The more northerly position of the Azores high pressure area during spring and summer causes the predominant wind direction being more from the W or NW by then. These westerly and north-westerly winds often bring clear skies and good visibility. But as the sea surface temperature is relatively low in spring and early summer (compared to the air over the region), fog fields develop occasionally during warm periods and may cause low visibility, even for several days.

From time to time the Azores high pressure area extends a strong ridge over the British Isles and/or Scandinavia. When positioned over Scandinavia, these high pressure areas cause the wind mainly to blow from easterly directions over the North Sea. These winds can be pretty strong (7-8 Bft) in winter, but wave height at the Rentel locations is most of the time limited due to the sheltering by the Dutch coast. The easterly winds typically bring good visibility since the advected air is usually dry. If the high pressure is located over the British Isles, winds will be predominantly blowing from N-NW directions. Wind speed over the North Sea is often moderate or fresh during these events. High pressure areas over Scandinavia and the British Isles occur most frequently in spring.

Figure 6 shows directional roses of 10 meter wind speed (1-hour sustained) and significant wave height from WaveWatch III Eushelf grid point 51˚40’N, 3˚00’E. The wave rose shows the two major wave systems from the north and from the southwest. Examples of WW3-eushelf model output corresponding to these wave systems are shown in Figure 7 and Figure 8.

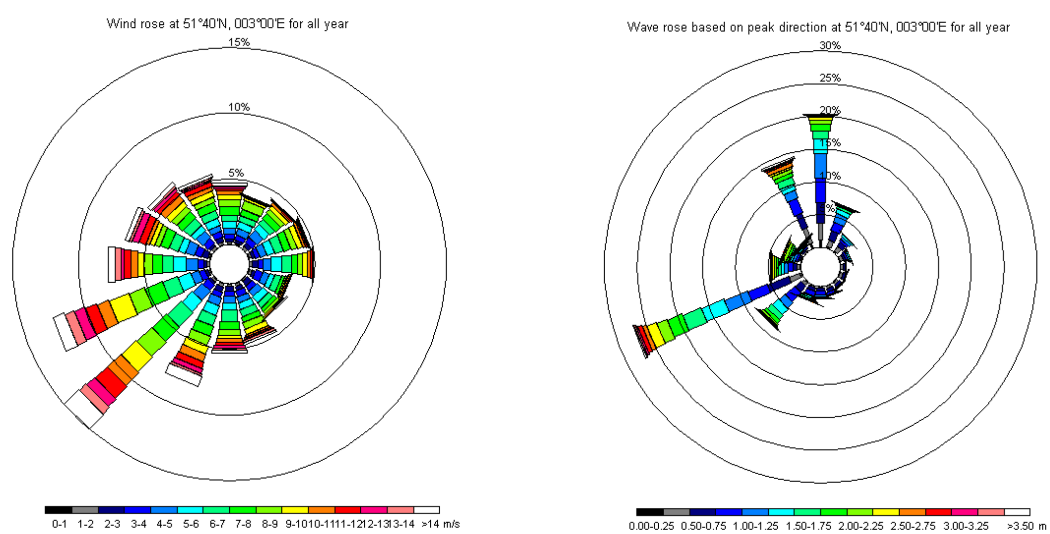


Figure 6: Directional roses of u10 (left) and Hs (right). Data was taken from grid point 51˚40'N, 3˚00’E from regional WW3-eushelf model. Years used 2016-2017.

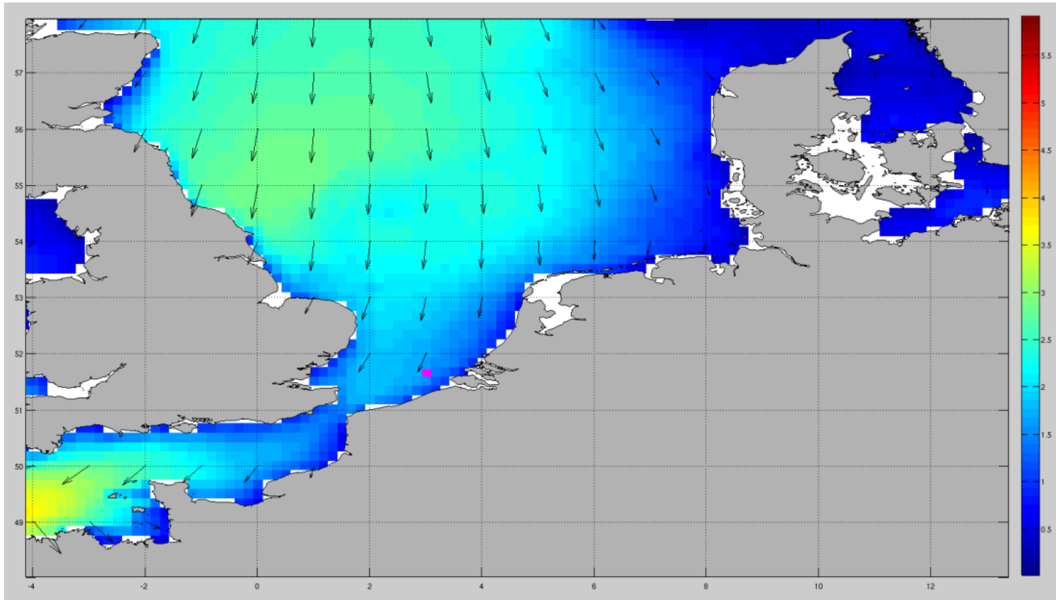


Figure 1: Example of WW3-eushelf waves from northern direction at Rentel (07-jan-2018 03 UTC). project location is shown by the pink square.

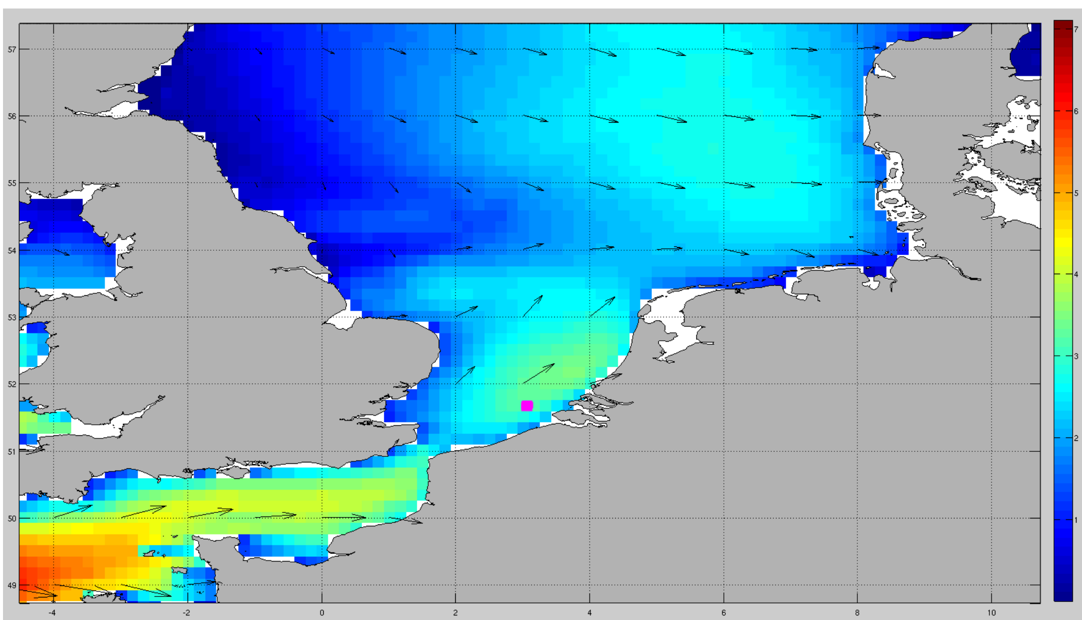


Figure 2: Example of WW3-eushelf waves from southwestern direction at Rentel (18-jan-2018 at 06 UTC). Project location is shown by the pink square.

Model Description

In the southern North Sea, BMT Argoss operates two regional wave model grids. Specifications of these grids are shown in Table 1 and outlines are shown in Figure 9 and Figure 10.

The larger domain covering the European continental shelf (Figure 9) is the regional WaveWatch III EU-Shelf grid with spatial resolution of 10 minutes (~17 km). It is a 3rd generation wave model based on the WaveWatch III code. The WaveWatch model is particularly suitable for propagating offshore waves. The wave model is driven by GFS wind data provided by the marine modelling branch of the National Center of Environmental Prediction (NCEP). It receives boundary conditions from the WaveWatch III Global wave model.

The smaller domain covering the southern North Sea and the English Channel (Figure 10) is the local SWAN DunkA grid with spatial resolution of 6 minutes (~10 km). The SWAN model is a third generation spectral model developed at Delft University of Technology, that computes random, short-crested wind-generated waves in coastal regions and inland waters. The model is based on the wave action balance equation with sources and sinks. SWAN accounts for the following processes:

- Wave propagation in time and space, shoaling, refraction due to current and depth,
- Frequency shifting due to currents and non-stationary depth.
- Wave generation by wind.
- Three- and four-wave interactions.
- Whitecapping, bottom friction and depth-induced breaking.
- Dissipation due to aquatic vegetation, turbulent flow and viscous fluid mud.
- Wave-induced set-up (not applied in this project).
- Transmission through and reflection (specular and diffuse) against obstacles

The wave model is driven by WRF winds obtained from BMT Argoss local WRF nweurope with spatial resolution of 27 km.

Grid	Engine	Forcing (resolution)	boundary	Outline ([lon],[lat])	Resolution
WW3-Eushelf	WaveWatchIII	GFS (25 km)	WW3-Global	[-15, 31], [40, 66]	17km
SWAN dunkA	SWAN	WRF nweurope (27 km)	WW3-eushelf	[0.17, 4.46], [49.67,52.10]	10 km

Table 1: Model specification for Rentel

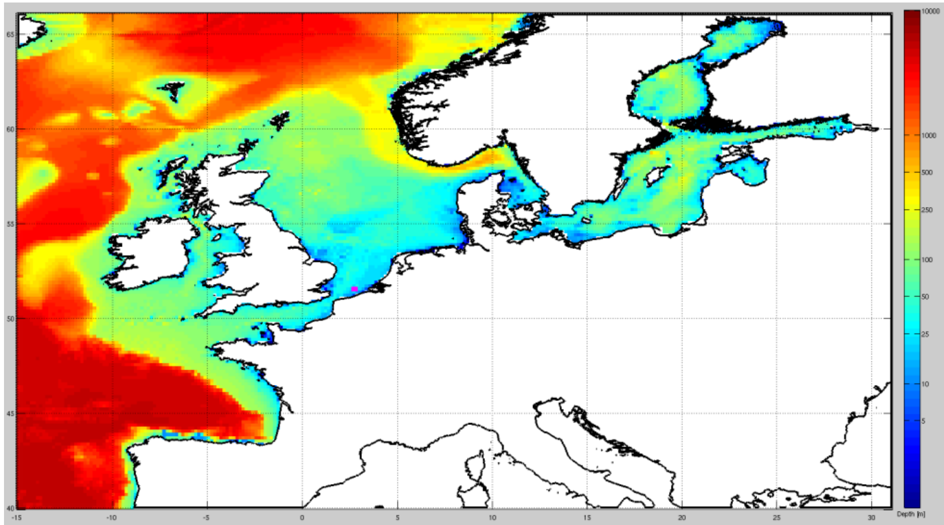


Figure 9: WW3-eushelf model grid outline and depth. Project location is shown by the pink square.

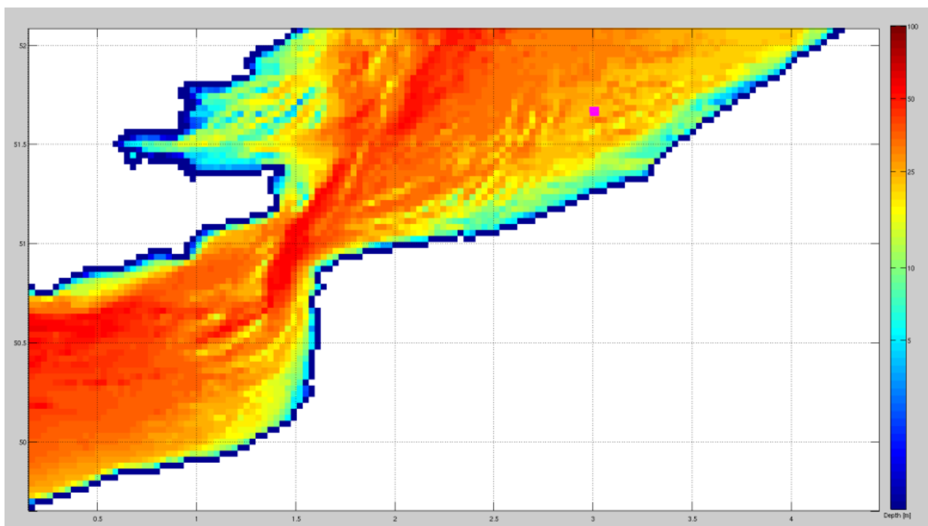


Figure 10: SWAN-dunkA model grid outline and depth. Project location is shown by the pink square.

3.2 La Réunion

Project Description

La Réunion is a French island and department in the Indian Ocean 700km east of Madagascar. On this island a new highway is planned from the capital Saint Denis to La Possession. This 9km long highway will replace the existing cliff road. This road, constructed in 1976, has two lanes in both directions and was designed for 10,000 vehicles per day. Nowadays about 60,000 vehicles make use of the road every day resulting in a lot of accidents and major congestions. Further, the existing road is subject to rock-falls from the steep cliffs adjacent to it and flooding during tropical storms resulting in unacceptable traffic jams. During heavy rain storms the road is even closed for any traffic.

The new highway will be partly constructed as a viaduct and partly as a causeway (see Figure 11) and it is designed to be operational during wind speeds up to 150 km/hr and waves up to 10 m. The project is financed partly by European funds. The main contractor for this project is a joint venture between French companies. SDI (DEME-group) is working in this project as a subcontractor.

Figure 11: Artist impression of the new highway which will be partly constructed as viaduct and partly as causeway.

The work consists of dredging a trench and making the foundation of the revetment for the causeway parts of the highway. Three sections of the highway will be constructed as a causeway. The total length of dredged trench is about 3,070 m. The trench has a width of 25 m at the base and a depth of about 5 m below existing seabed. The total dredging volume amounts about 250,000 m^3. The dredging works are carried out by the backhoe dredger Pinocchio. The dimensions of this dredger are 60x19 m^2. It has three spuds with a length of 40 m and the total installed power is 2,416 kW. Two methods of disposal of the dredger material are used. The first method is to sidecast the material using a pontoon which is moored alongside of the Pinocchio. A second method that has been applied is to use 850 m^3 barges to dispose the material. The dredger material is partly reused in the body of the revetment.

Apart from the dredging works, the work consists of placing of two layers of rock. The first layer is a 2-150mm rock filter of which a total of 170,000 tons must be placed. The second rock layer consists of 0.2-1 ton rock with a total weight of 340,000 tons.

Climate
The volcanic island La Réunion is characterized by a complex orography. High peaks and deep valleys have a strong effect on the atmosphere over and around the island. In winter and spring, the trade winds blow over the region. Strong lee effects can be observed on the west side of the island which are highly correlated to the background wind conditions over the region; small differences in the background wind direction cause significant changes in wind conditions at La Possession. For example: with winds blowing from the E or ENE, the north-easterly wind velocity is higher, up to 20-25 knots, and blows throughout most of the day. Under conditions with a slightly veered background wind (ESE) the enhanced north-easterlies are sparser and weaker. They are then alternated by weak sea breezes. Sea breezes play a very important role in the wind climate on and around La Réunion. A background sea breeze is caused by the difference of surface temperature between land and sea.

Diurnal heating of the island surface by the sun causes, in combination with the high mountains on the island, a strong convection over the island in general and particularly over the mountain tops. This phenomenon occurs virtually every afternoon, especially in summer. The opposite takes place in the evening and early nights. As the convection, triggered by the heating of the sun, stops at the end of the day, the air in the mountains starts to cool. The colder air flows downhill and reaches the coastal areas as a weak to moderate land breeze. When the temperature drop in the mountains is relatively strong in comparison to the one over the coastal areas, the air in the mountains will start to descend rapidly. Like any fluid it will follow the easiest path which is through valleys towards the coast. These so called katabatic winds can reach high speeds and occur very locally. Occasionally, these gusty winds can last for approximately (half) an hour.

Waves do not grow significantly due to the diurnal wind effects at the site of interest as the forcing surface winds are so short lived. Most wave energy consists of swells from the Northern Indian Ocean. During the stronger trade winds in winter waves from the ENE can refract around Saint Denis which results in waves travelling along the shore and reach La Possession. Occasionally, a cross-sea is found with the additional wave system generated between La Réunion and Madagascar. During summer low, variable winds are, as an exception, alternated with severe storms (CEULEMANS & HULST, 2016).

Figure 12 shows directional roses of 10 meter wind speed (1-hour sustained) and significant wave height from WaveWatch III Global grid point 22˚00’N, 3˚00’E. The wave rose shows the two major wave systems from the north and from the southwest. Both wave systems curve around the Island of La Reunion and merge on the northern side of the island. This results in a sea state in which dominant peak switches between both wave systems. This is illustrated by a directional rose of significant wave height and peak direction in Figure 13. The data was taken from the swan reunionD grid using model grid point at the project site 20˚52'21.1S, 55˚24’31.0E. A spatial impression of this process is shown in Figure 14. This shows significant wave height and direction from the reunionC grid. The project site (20˚52'21.1S, 55˚24’31.0E) is shown by the pink square.

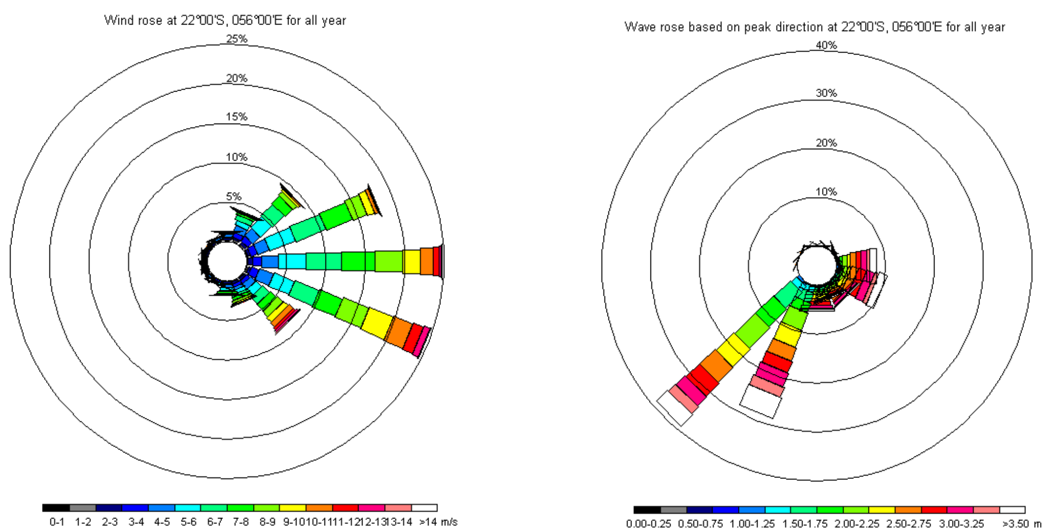


Figure 12: Directional roses of u10 (left) and Hs (right). Data was taken from grid point 22˚00'S, 56˚00’E from WW3-global model. Years used: 2016-2017.

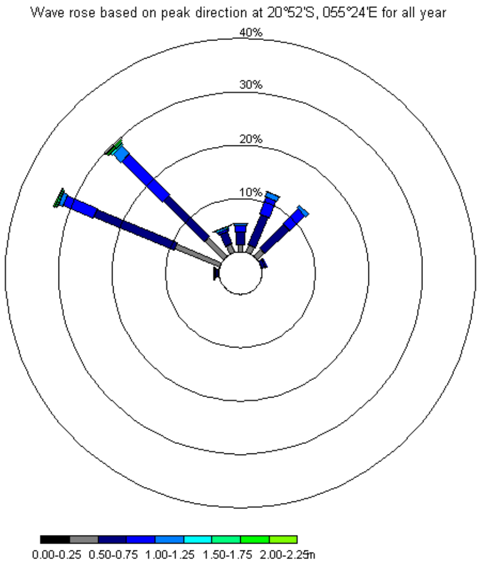


Figure 13: Directional rose Hs. Data was taken from grid point 20˚52'21.1S, 55˚24'31.0E from swan reunion model. Years used: 2015

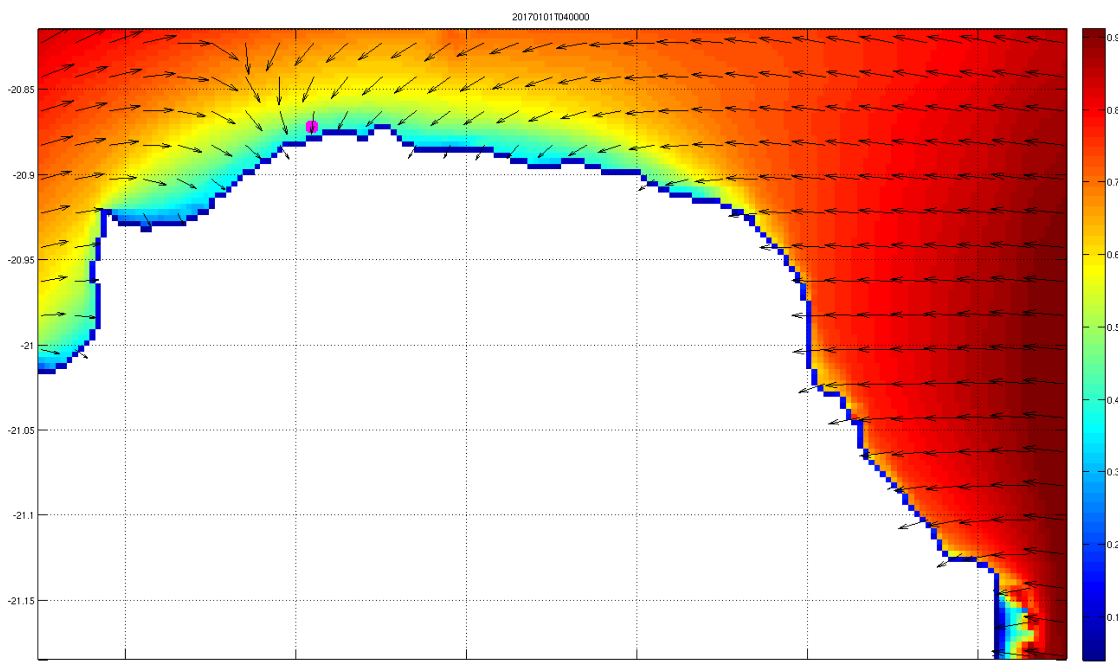


Figure 14: Significant wave height and direction from wave grid reunionC on 01-jan-2017 at 04:00 UTC. The project site is shown by the pink square

Model Description

The BMT Argoss model suite for La Reunion comprises of four nested SWAN grids. Specifications of these grids are shown in Table 2 and outline is shown in Figure 15 (please refer to Rentel model description for description of the SWAN modelling software). The large SWAN domain (reunionA) receives its boundary conditions from the WaveWatchIII Global wave model.

Grid	Engine	Forcing (resolution)	boundary	Outline ([lon],[lat])	Resolution
reunionA	SWAN	WRF-D01 (27 km)	WW3-Global	[55,56], [-21.5,-20.5]	10 km
reunionB	SWAN	WRF-D01 (27 km)	reunionA	[55.17,55.9], [-21.4,-20.8]	2km
reunionC	SWAN	WRF-D02 (9 km)	reunionB	[55.25,55.85], [-21.18,-20.82]	300 m
reunionD	SWAN	WRF-D02 (9 km)	reunionC	[55.34,55.43], [-20.93,-20.85]	80 m

Table 2: Model specification for La Reunion model suite

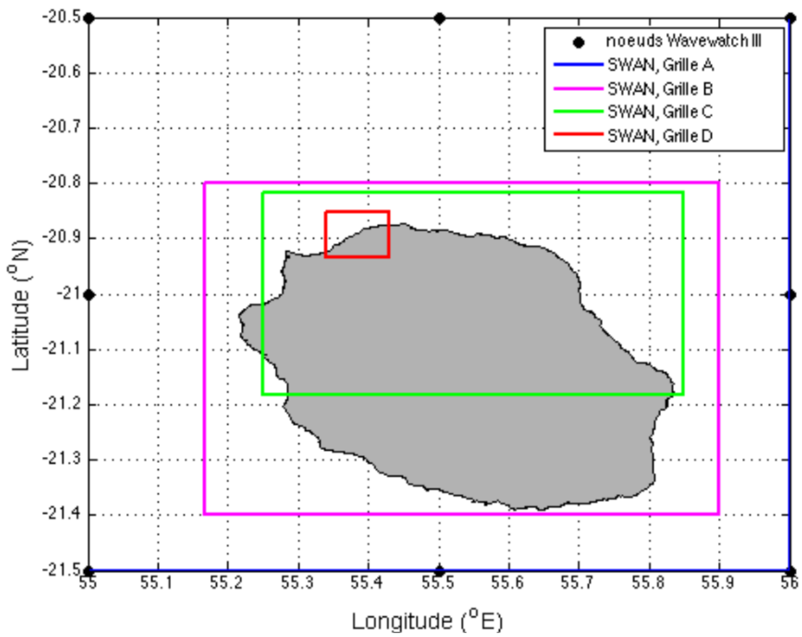


Figure 15: Extend of the swan grids for La Reunion

During the project, several model developments were tested. The developments that lead to improvement of model results are shown in Table 3.

In August 2017 we switched nesting the outer grid (reunionA) from 1D spectra (spectral wave information per frequency) to 2D spectra (spectral information per frequency and per direction). The assumption was that this would improve the wave direction since directional information is better represented in 2D spectra as compared to 1D spectra.

In October 2017 we switched off wave growth due to local wind. The local wind growth over grids reunionC and reunionD is assumed to be marginal, and it showed to effect the wave direction in a negative way.

Development	Description	Used in grid	Date in effect	Effects
Nest in 2d spectra	Nesting of reunionA grid in WW3-Global 2d spectra instead of 1d spectra to allow for better representation of directional information.	A	Aug 2017	wave direction
switch off windgrowth	Local windgrowth results in unrealistic mean wave directions from the N. Windgrowth switched off for grids C and D.	C and D	October 2017	wave direction, wave height

Table 3: Main model developments

4. RESULTS

The results obtained for both Rentel and La Réunion will be presented in a slightly different way. The North Sea being a well-known region where numerous offshore projects have been developed, the wave models are already performing quite well. The focus will thus be on the optimal use of these models by the meteorologists to provide manual forecasts getting as close as possible to the wave measurements.

On the opposite, the La Réunion region is a very particular environment where a lot of local phenomena influence the wave climate. The continuous monitoring of the waves combined with the know-how of BMT Argoss has led to a significant improvement in the accuracy of the forecasting. Being in the middle of the Indian Ocean, the project is greatly benefiting from this increased reliability.

In the sections below, the same type of figure is repeatedly used to indicate the performance of the model against the observations. These figures consist of an upper plot showing both the 0 to 24 hours, 24 to 48 hours and 48 to 72 hours forecasted parameter (blue colours) and the observed parameter (pink). The lower plot shows the bias where pink indicates forecasts higher than the observed data and blue indicates forecasts lower than observed.

4.1 Rentel

As explained in the model description here above, BMT Argoss is using both a SWAN and a WAVEWATCH III regional wave model in the North Sea. Comparing the model results to the observations, one realises that both models are not really accurate. The SWAN model tends to overestimate the wave height (Figure 16) whereas WAVEWATCH III is generally underestimating this parameter (Figure 17).

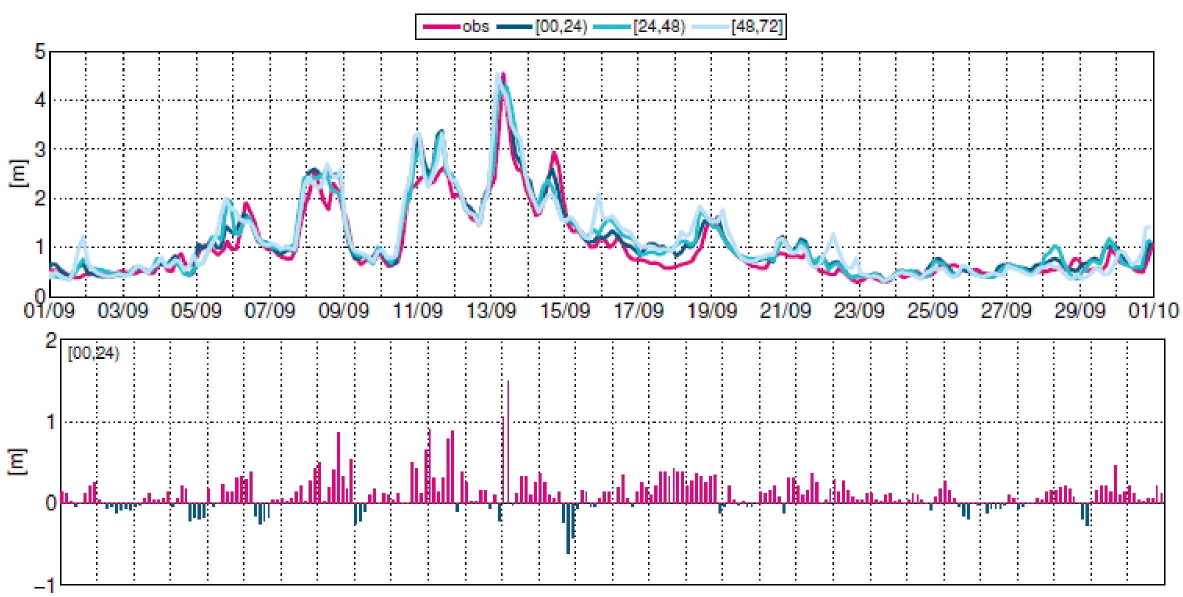


Figure 16: SWAN regional model significant wave height forecast for September 2017 (upper plot) and the bias (lower plot).

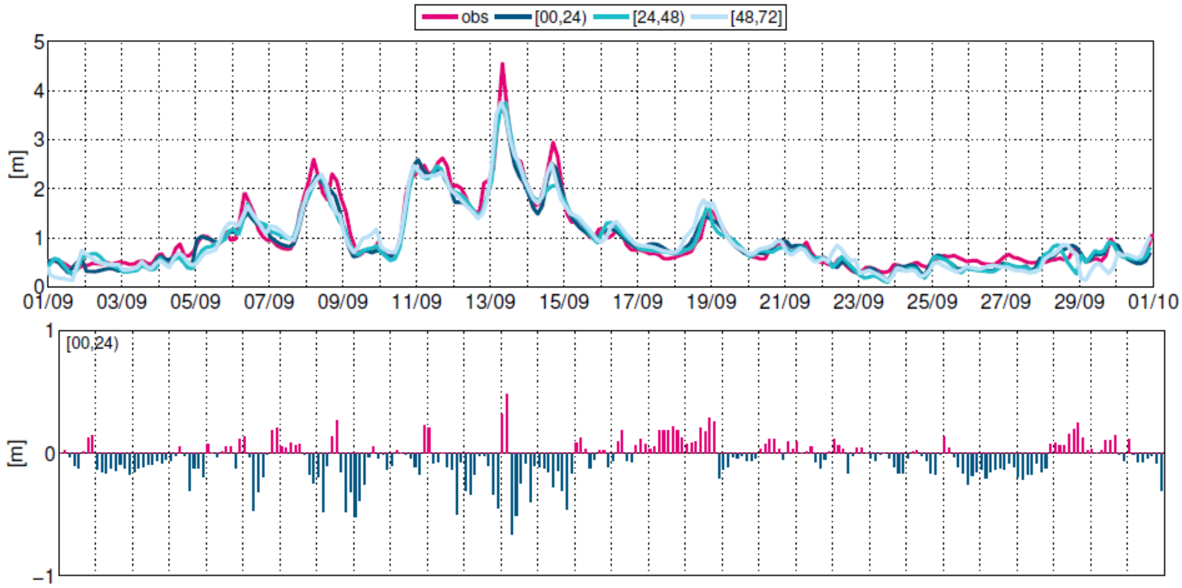


Figure 17: WAVEWATCH III regional model significant wave height prediction for September 2017 (upper plot) and the bias (lower plot).

Thanks to the comparison with the real-time monitoring, the meteorologist can use the output of both models and weigh them properly to offer the project team a constant reliable forecast (Figure 18).

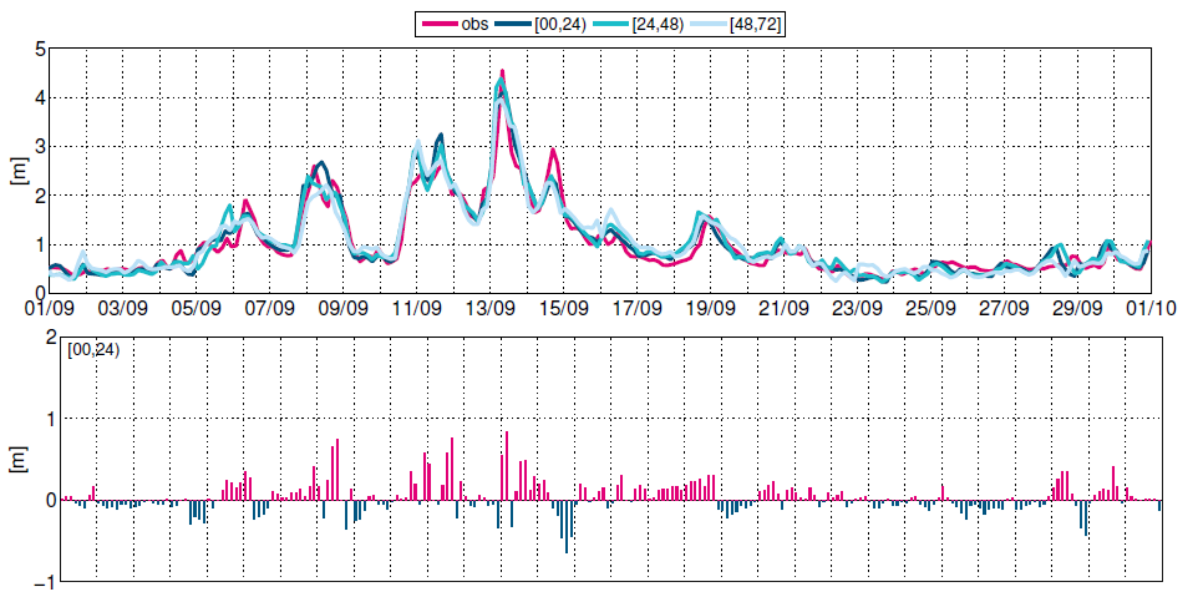


Figure 18: Manual significant wave height forecasts for September 2017 (upper plot) and the bias (lower plot).

Table 4 below compares the performance of both wave models (WaveWatchIII and SWAN) and also the manual forecast. The performance is quantified by the bias of the 0-24hrs predictions compared to the observations. From the table we see results consistent with the results in figures 16 till 18. SWAN overestimates wave height, WaveWatchIII underestimates wave height and the manual forecast is in between both models. Furthermore, the manual forecast shows to be slightly high compared to the observations. Apparently, the relatively high SWAN results affect the manual forecast. Based on this we conclude that giving more weight to WaveWatchIII EU-Shelf and giving less weight to SWAN should improve forecast results.

ME [00,24]	SWAN	WaveWatchIII	Manual forecast
Sig. wave height [m]	0.12	-0.05	0.04

Table 4: Comparison of bias for the forecast of September 2017 between WaveWatchIII model, SWAN model and manual forecast.

4.2 La Réunion

As explained in the section on the climate of La Réunion, the island is prone to very complex refraction as well as local phenomena. The model has thus needed some fine tuning to accurately predict the wave height and direction.

Due to these refraction and local effects, the forecast and measurement locations are of crucial importance. The results presented here will focus on one location to keep it short and clear for the reader. To follow the evolution of the works, the wave rider buoy and forecast locations are modified on a regular basis.

In order to demonstrate the impact of the model performances that have been implemented in August-October 2017 (Table 3), results from a period before the improvements (June 2017) have been compared to a period after the improvements (February 2018).

Note that the mean wave period is not further discussed here. It is not straightforward to compare mean wave periods from models to mean wave periods from buoys. This is due to the fact that the wave model and buoy may use different techniques to compute the mean wave period. Furthermore, the mean wave period is a parameter that on average over the entire globe is useful to help describe sea states, but may be less meaningful and useful in particular situations such as double peaked spectra.

Below, Figure 19 and 20 show comparisons of predicted and observed significant wave height and wave direction for the period of June 2017 (before model improvements). Figure 21 and 22 show the same figures for February 2018 (improved model).

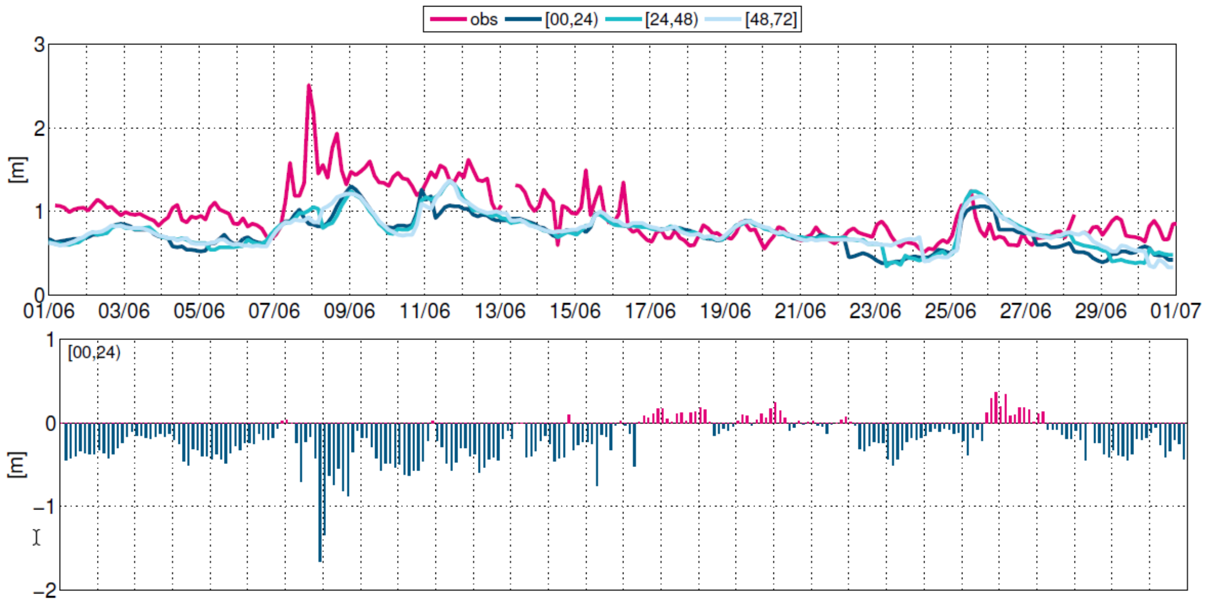


Figure 19: Wave height forecast for June 2017 (upper plot) and the bias (lower plot).

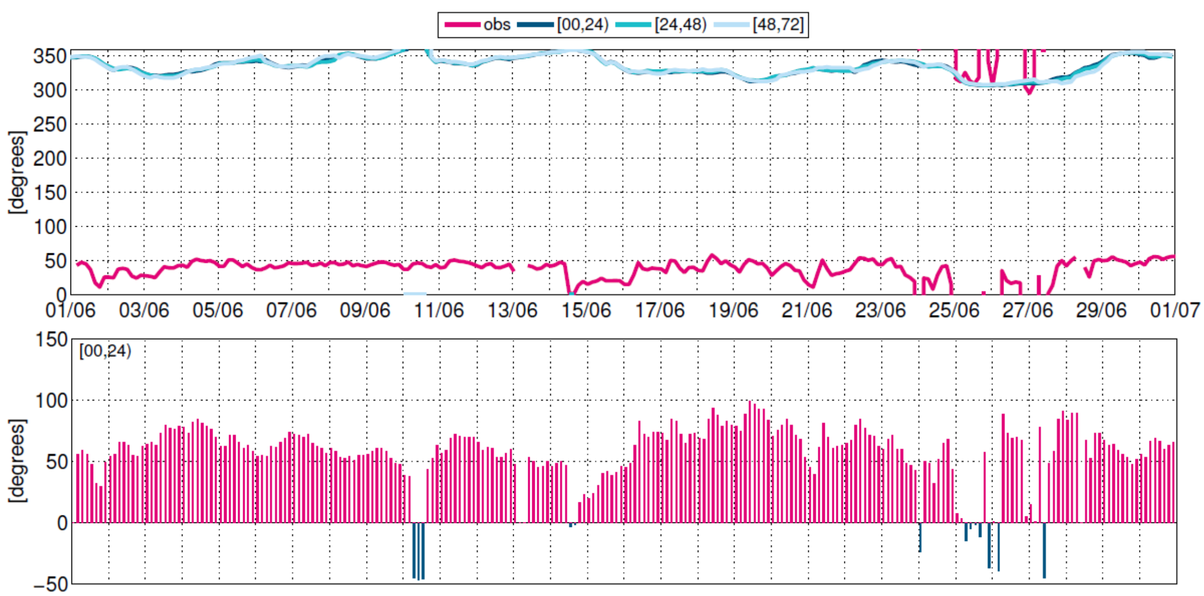


Figure 20: Wave direction forecast for June 2017 (upper plot) and the bias (lower plot).

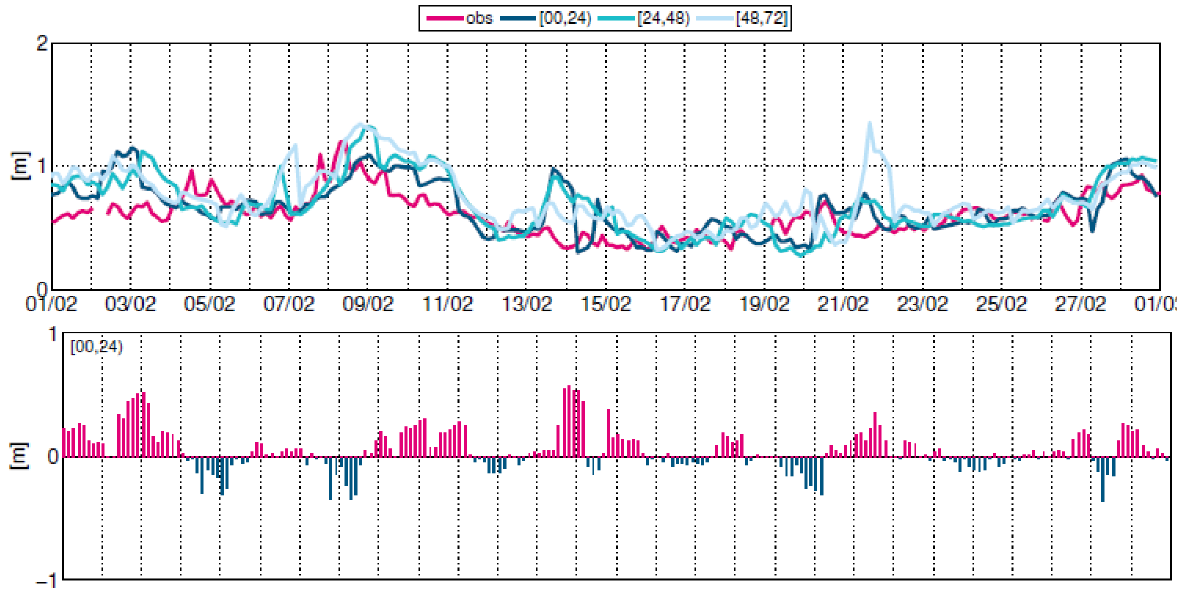


Figure 21: Wave height forecast for February 2018 (upper plot) and the bias (lower plot).

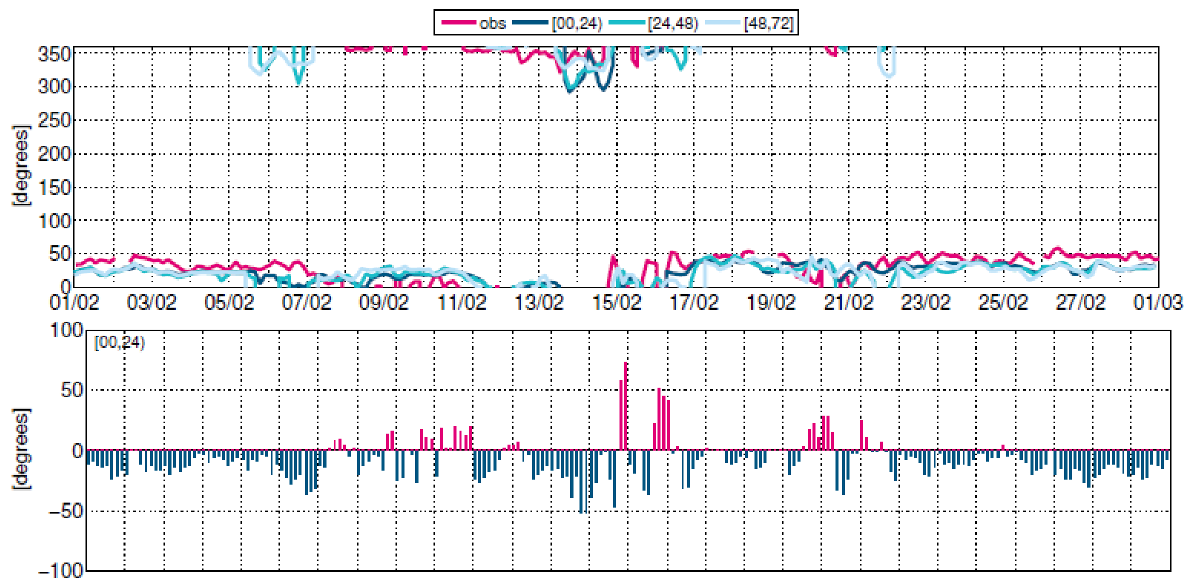


Figure 22: Wave direction forecast for February 2018 (upper plot) and the bias (lower plot).

Table 5 presents the bias of the model performance for a period before model improvements (based on April to June 2017) and after the model improvements (January-February 2018). These numbers and the figures 19 till 22 show that in the old situation, the forecast on average significantly underestimated the wave height at the project location and that the wave direction was systematically off by about 40 degrees (observations: northeast, model: north), while after improvements the wave height on average was only slightly overestimated while the wave direction is pretty much spot on.

ME [00,24]	Before model improvements April-June 2017	With improved model January-February 2018
Sig. wave height [m]	-0.24	0.08
Wave direction [deg]	37	-5

Table 5: Comparison of bias for the forecast before and after model improvements.

5. DISCUSSION

The two project cases above show the efforts being done to improve the predicted metocean conditions on site by using feedback (observations) from the site. There are some restrictions however that have learnt us that it is impossible to let the forecasts exactly match the observations:

- It is hard to find a consistent data set from buoy measurements on a project due to the fact that sometimes the buoy is displaced by the project crew, the buoys are taken out of the water (protection during storms), gaps in the data due to bad signal (remote sites), problems with acquisition software etc.

- It is not always straightforward to compare mean wave periods from models to mean wave periods from buoys. This is caused by the fact that the wave model and buoy may use different techniques to compute the mean wave period. Furthermore, the mean wave period is a parameter that on average over the entire globe is useful to help describe sea states, but may be less meaningful and useful in particular situations such as double peaked spectra.

- Comparing wave model output to buoy data can result in significant improvement of model results. However, there are a few limitations to this. These limitations include

    - Representability of model results for the buoy location

    - Wave model resolution

    - Differences in computation method of integrated parameters (wave height, wave period) between buoy and model

    - The wind data source driving the wave model. Poor quality wind data will in general result in poor quality wave data.

    - Quality of bathymetric data (for nearshore location)

6. CONCLUSIONS

Working in exposed marine environments may seriously affect the workability of the equipment being used in a project. Given the large stand-by costs of specialized offshore equipment, this can have a huge impact on the cost of those projects. There is not only a considerable cost impact. Also the safety of the crew working on board of vessels in harsh conditions is at stake.

The Workability Tool has been deployed to inform the crew and site staff with information on actual and upcoming wave conditions linked to the working limits of the equipment. The tool has proven itself in numerous situations in order to limit the downtime, work more safely and to better plan the works. Besides, the tool makes the bridge personnel aware of the metocean conditions. Based upon an increase of confidence (due to comparison wave forecast and real-time measured waves) the crew can now easily take an objective decision to stop or start or replace the works.

Input to the WOTO are forecasts coming from models. Wave models are developed to represent sea states on a global, regional and local scale. Many processes are included in the wave model, which are used all over the globe. Specific locations require specific tuning of the wave model parameters, such as wind drag, coefficients influencing refraction and others, and for this it is vital to have reliable buoy information. This paper has shown that the quality of the weather forecast can significantly improve during the project by making use of the field observations. The expert meteorologists are able to use the observations in the interpretation of the model forecasts to deliver an improved manual forecast. Besides, at set times they will use the observations to adjust and tune the wave models to better represent the observed conditions. When the quality of the forecast is increasing, the crew will also gain more confidence in the forecast which will help them to better plan the works and take responsible decisions.

References

Ceulemans, C., and Hulst, A.Th.C. (2016). Verification report La Reunion: Possession Monthly report, Amersfoort.