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Decision Support System

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1 Public Summary

Decision support systems for Multi-use Offshore Platforms

The objective of this study was to develop advanced (fit-for-purpose) web based decision support system for the MUP site, supporting all related activities during each phase of the MUP's life cycle. This decision support system is based on a detailed and innovative forecasting system of various relevant parameters (wind, waves, water level, currents etc.) and is based on the three-dimensional numerical flow and wave models. These models are driven by the available meteo forecastings, providing space- and time-varying wind and atmospheric pressure fields for two to seven days in front. The forecasting results are being improved by applying model-data assimilation. This results in the forecast of various relevant parameters, related to wind, water levels, currents, wave heights, wave periods etc. In addition to these parameters, others parameters relevant for the multiple use aspects of the MUP, will be made available and can be depicted in a user-friendly way from the web-site. Regarding the forecast related to aquaculture, the system is able to advice, support and warn operators of aquaculture on low oxygen or food content within a certain period. Depending on the type of vessel, the response of the ship can be calculated by considering the dimensions of the vessel and its degrees of freedom. For specific vessels, used during the project, the responses will be translated from the forecasted parameters during any operations. In this way, the weather windows and forecasted information can be determined and used in much more detail compared to the present state-of-the-art approach during the operations (including transport services). Regarding the forecast related to energy conversion (harvesting), the system will predict the energy to be harvested by wind-, wave- and tide related convergence systems for following days. In addition to the modeling, operator experiences were inventoried, analysed and discussed. From this inventory, new insights in optimisation of constructional, operational, maintenance and decommissioning activities in relation to forecasting is proposed. The decision support system can be applied for the following purposes:

- construction phase due to calculating the responses of ships and e.g. modelling/forecasting dispersion of
- dredging plumes,
- maintenance activities due to calculating hydrodynamic parameters and the responses of applied vessels,
- operational activities including transport services from and towards the MUP,
- predicted harvesting of energy,
- supporting decisions and activities related to aquaculture.

In addition, the system is setup in such a way that it is relatively easy to further optimize its functionalities or adapt to specific wishes of end-users.

2 Meteo Dashboard for multi-use offshore platforms

Introduction to Meteo Dashboard

Installation and maintenance of **offshore wind farms** involve extensive logistics. The key issue is to having all equipment and personnel at the right place and at the right time, while taking into account forecasted meteo- and hydrodynamic conditions. Weather windows - during which marine operations are permissible in view of the wind, wave, water level or current conditions – determine the critical path in an offshore project. Unforeseen weather conditions may lead to a serious delay of offshore operations, at the consequence of high costs as well as risks of safety and damage to equipment.

Accurate forecasts of the meteo (e.g. wind, visibility) and hydrodynamic conditions (e.g. wave, water level and current), and estimates of the accuracy of these forecasts, are therefore considered crucial factors for the planning and decision-making process of offshore operations.

At present, meteo- and hydrodynamic forecasts can be obtained from various public and commercial sources. However, these forecasts are generally coarse, both in time and space, and are known to deliver varying quality: sometimes showing good comparison with in-situ measurements, sometimes poor. In particular for installation or maintenance of high-tech structures, such as offshore wind turbines in relatively shallow-water regions (say <30m), the present hydrodynamic forecasts are considered to be inadequate. This is partly explained by the fact that present forecast modelling systems are mainly calibrated against storm conditions and not specifically for mild weather conditions with wave heights of up to say 1.5m, during which wind farm installations and maintenance typically take place.

Therefore Deltares developed a detailed hydrodynamic forecasting system covering an offshore wind farm in high detail that will provide forecasts of waves, currents and water levels on the basis of meteo- and offshore boundary conditions. The resulting set of forecasts is stored in a database and can be presented together with meteo forecasts (e.g. wind, visibility) and in-situ measurements in a so-called ‘Meteo Dashboard’. The Meteo Dashboard is tailor-made for wind farm operators and includes specific meteo- and hydrodynamic parameters and decision making rules for installation and maintenance activities in the offshore wind farm.

With respect to the **MERMAID** project - the Meteo Dashboard is further improved and extended with modules in order to also support decisions related to **offshore aquaculture**, further referred to as Decision Support System (DSS). As the operational models are site specific, the DSS is specifically setup for the North Sea site (and not for the other three sites). This is in line with the general approach of WP6. The requirements of the system are determined by the combined functions of the North Sea site design, i.e. offshore wind, seaweed and mussels. Therefore the forecast of metocean conditions is relevant, as well as water quality related parameters.

The work is conducted by Deltares in cooperation with WUR (DLO).

3 Objectives

The main objective of the Decision Support System (DSS) is to support the decision making process of the need and ability to go out to the MUP for operation and maintenance (O&M) activities (weather window). “Should we go out” and “could we go out” are the key questions for the system to support decisions about. In addition, the objective of the system is to provide the aquaculture owner the ability to monitor the offshore conditions – related to water quality and metocean conditions - from onshore.

At the start of MERMAID stakeholders - as being possible end-uses of the DSS - were identified to provide input on the requirements of the DSS. The requirements analysis was performed to determine:

1. the target user groups/profiles;
2. user demands regarding the information provided by the DSS;
3. the desired functionality of the tool

The stakeholders and possible users (who) of the DSS were gathered during project meetings. This resulted in the following list of identified stakeholders and users:

- Aquaculture farms; seaweed and (shell) fish;
- Energy farms; wind and hydropower;
- Companies conducting offshore maintenance operations;
- Contractors.

Persons involved in operation and maintenance of wind farms and aquaculture farms were considered to be the main stakeholders. From these meetings the information needed should involve:

1. Operation or maintenance needed;
2. Forecast suitable time window for task;
3. Monitoring.

Several persons from the identified stakeholder and user groups were approached to fill in a questionnaire (by themselves or an interview). The questions target to get more detailed information about:

- Users of the DSS
- Tasks and needed information
- Available information from measurements or model
- Parameters

A total of 7 responses were processed.

From the requirements analysis performed on the results an extensive inventory (questionnaires, meetings and interviews) it was clear that it should be a learning system by capturing choices and gain feedback, and it should support decisions for:

1. Should go out, O&M is needed
    a. Planned
        i. Maintenance schedule (with margins)
        ii. (harvest) forecast
    b. Unplanned
        i. Automatic signaling of acute conditions (e.g. algal bloom)
        ii. Human signaling (e.g. turbine failure)
2. Could go out, O&M is possible.
    a. Suitable time window.
        i. Calm enough sea (wind/wave predictions)
        ii. Time needed for O&M of (combined) function
        iii. acceptable conditions for vessels
    b. Suitable moment
        i. Yield forecast
        ii. Available vessels

To support these functions the architecture of the DSS would consist of a:

- Forecasting system (high resolution – local);
- Database;
- Model application Tool (models: weather windows, knowledge rules);
- Dashboard.

Important for the multi-use offshore wind farms, it should combine the physical phenomena with the biological output and water quality aspects.

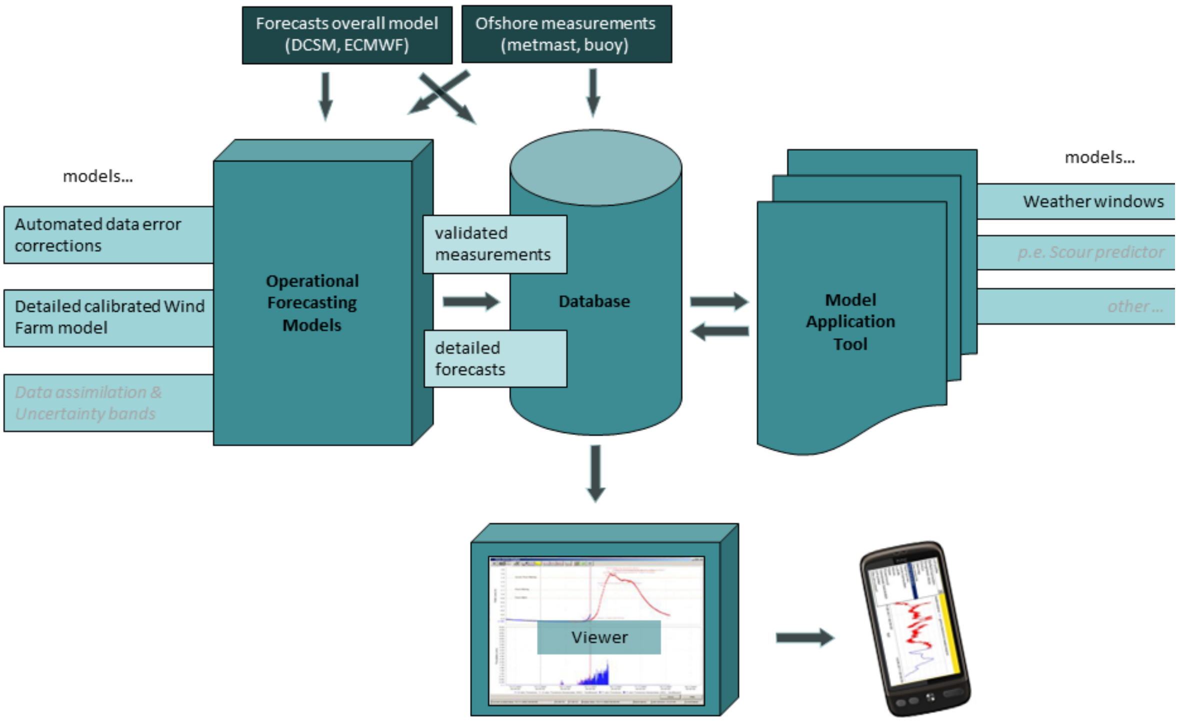


Figure 1. Individual components of the DSS

In order to fulfill these requirements the DSS should be able to:

- Collect, store and present relevant biological and water environment, meteorological and hydrodynamic **measurement** data;
- Collect, generate, store and present relevant biological and water environment, meteorological and hydrodynamic **forecast** data;
- Support the decision making process of installation and maintenance activities at a wind park combined with aquaculture farm based on this information.

The DSS is considered relevant for beforehand planning of Operation and Maintenance activities (O&M) and to less extent also for the installation phase. The weather windows are important for installation as well, but the required characteristics of the installation vessels are not available or too specific. The DSS should focus on wind and aquaculture. It is essential for aquaculture to know what water environment the aquaculture species at the site are experiencing. By providing up-to-date forecasts (or even nowcasts) of the met-ocean conditions for multi-use wind farms of interest, the DSS mainly aims to reduce the costs and risks associated with O&M.

4 Decision Support System: Meteo Dashboard

The Meteo Dashboard is a browser based application (website). The Meteo Dashboard software system consists of three main components:

(1) a back-end based on Delft-FEWS, which runs the
(2) operational forecasting models and a web processing service to evaluate knowledge rules, and
(3) a front-end based on the Delta Data Viewer.

The components (1) and (3), also illustrated in the figure below, are described in more detail in the next sections, and the operational forecasting models are described in section 6.

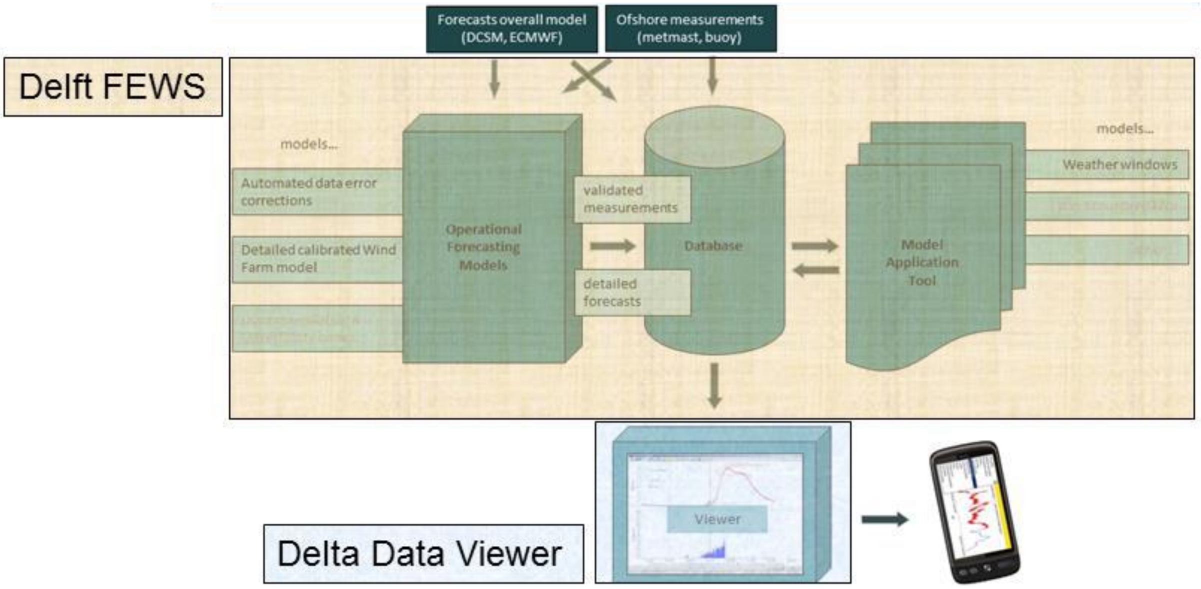


Figure 2. Illustration the Delft FEWS and Delta Data Viewer of the DSS

Back-end: Delft-FEWS

The back-end of Meteo Dashboard applies the Delft-FEWS software. Delft-FEWS is a sophisticated collection of modules designed for building an operational water management system, customised to the specific requirements of an individual organisation. Originally designed for hydrological forecasting and warning, Delft-FEWS is now also being applied for day-to-day operational management, real-time control and forecasting and warning in other disciplines, i.e. water quality and navigation.

The philosophy of the system is to provide an open shell for managing the data handling and forecasting process. Delft-FEWS incorporates a wide range of general data handling utilities, while providing an open interface to any external calculation model. The modular and highly configurable nature of Delft-FEWS allows it to be used effectively both in simple systems and in highly complex systems utilising the full range of available models. Delft-FEWS can either be deployed in a stand-alone, manually driven environment, or in a fully automated distributed client-server environment.

Furthermore, Delft-FEWS is applied worldwide to setup forecasting systems in the marine environment. For example, the national flood forecasting systems for the Netherlands, the United Kingdom, the United States and Australia are based on Delft-FEWS.

At Deltares a team of scientists, software developers and ICT experts jointly works on the continuous improvement and expansion of Delft-FEWS. New developments are defined and implemented in close collaboration with the community and all new developments are made available to the whole community by means of bi-annual (i.e. two times a year) releases. Delft-FEWS can be applied free of charge.

Delft-FEWS is a peer reviewed application (Werner et al, 2013). More information can also be found under the following link http://oss.deltares.nl/web/delft-fews.

Front-end: Delta Data Viewer

The Delta Data Viewer is a web viewer (browser based application and portable over different browsers) focusing on presentation of geo-referenced data. It provides a set of generic components to visualize scalar and gridded data and to control processes, which can be customized to provide a unique look, feel and interaction for each application. The Delta Data Viewer is browser based, and ready for touch devises. The Delta Data Viewer supports a series of file formats (KML, GeoJSON, SHP, geo-referenced PNG) and protocols (HTTP, WPS, WMS) commonly used in the marine sciences. The figure below illustrates the Delta Data Viewer related to the Meteo Dashboard. This is the startup screen. Icons are available to represent available buoys. When clicking on these icons a graph will pop up with the time series of the selected 'Parameter'.

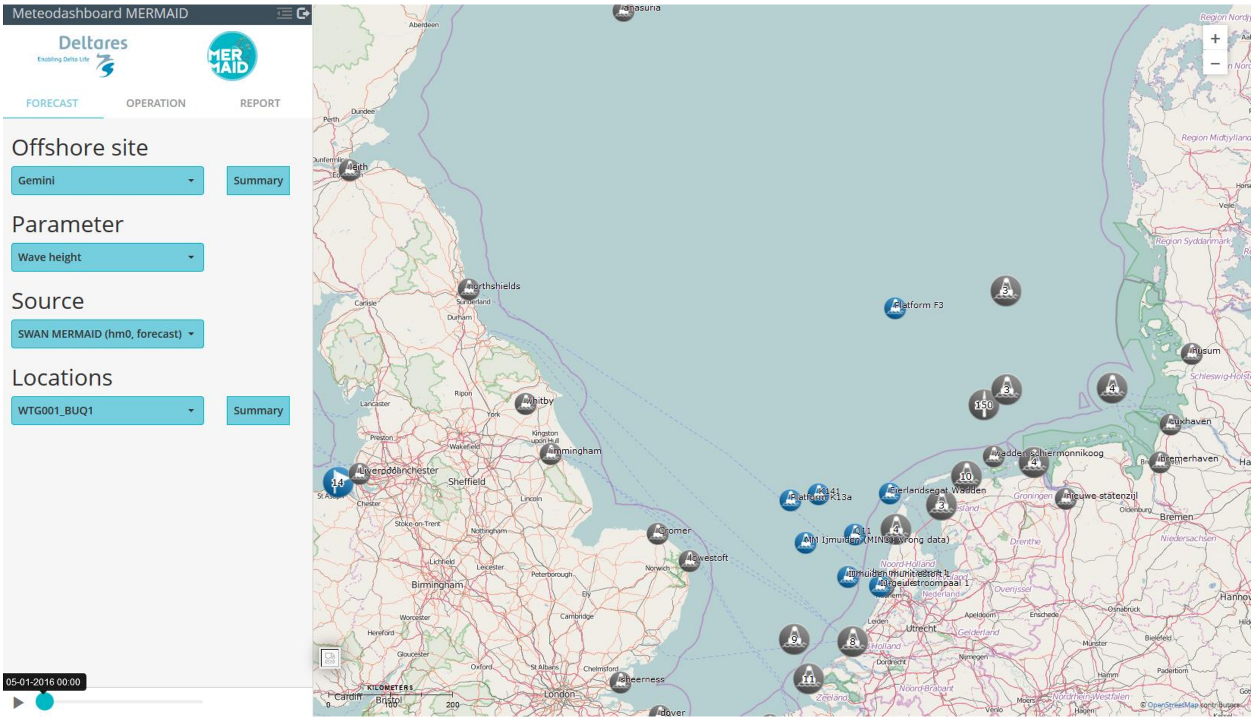


Figure 3. Startup screen of the DSS

The left-hand selection menu presently contains the following tabs (see left pane of Figure 3):

- Forecast: in this menu, the user can select various areas of interest. For this project the North Sea site is the Gemini offshore wind farm site.
- Operation: in this menu, the user can enter threshold values for various parameters (among which wave height). These values are subsequently used to evaluate the model forecast and indicate whether or not the specified threshold value is exceeded at a given turbine.
- Report: in this menu, the user can provide feedback by means of a report on preceding forecasts and how the results were used.

These features will be described in more detail below.

Forecast menu

At this tab the use can select the *Offshore site*. At the tab 'Parameter' one can select the parameter, varying from hydrodynamic to wave to water quality related parameters.

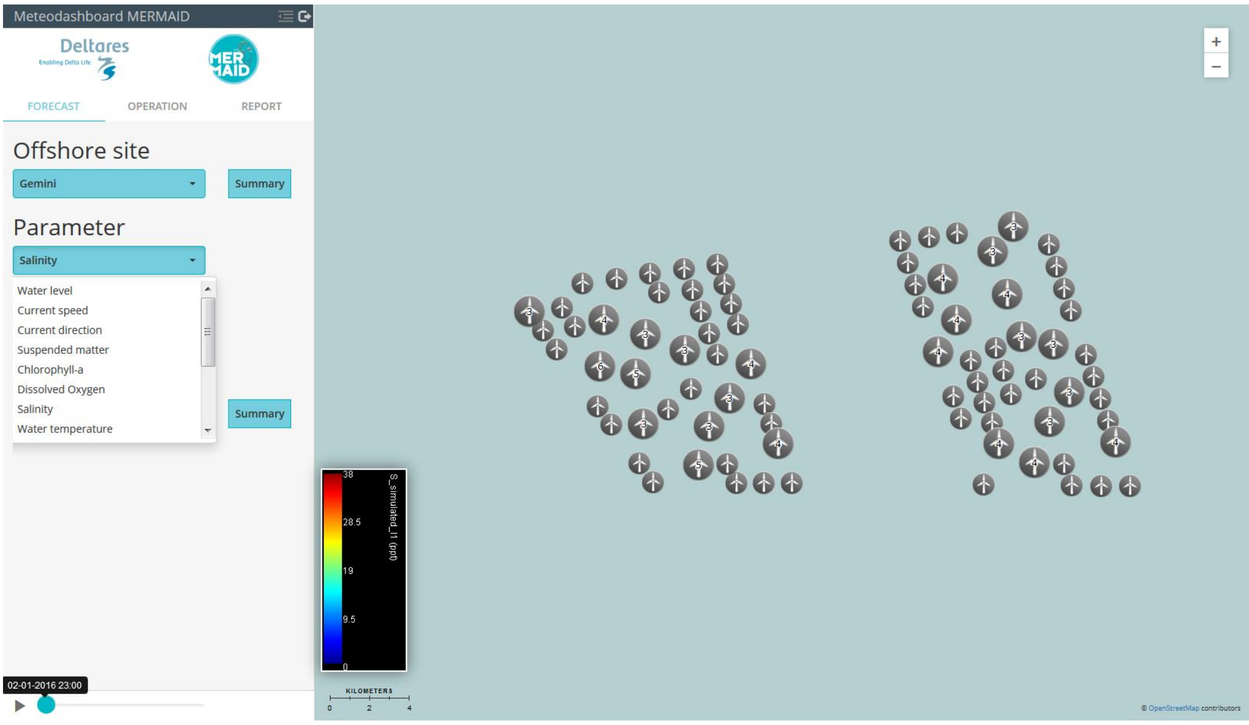
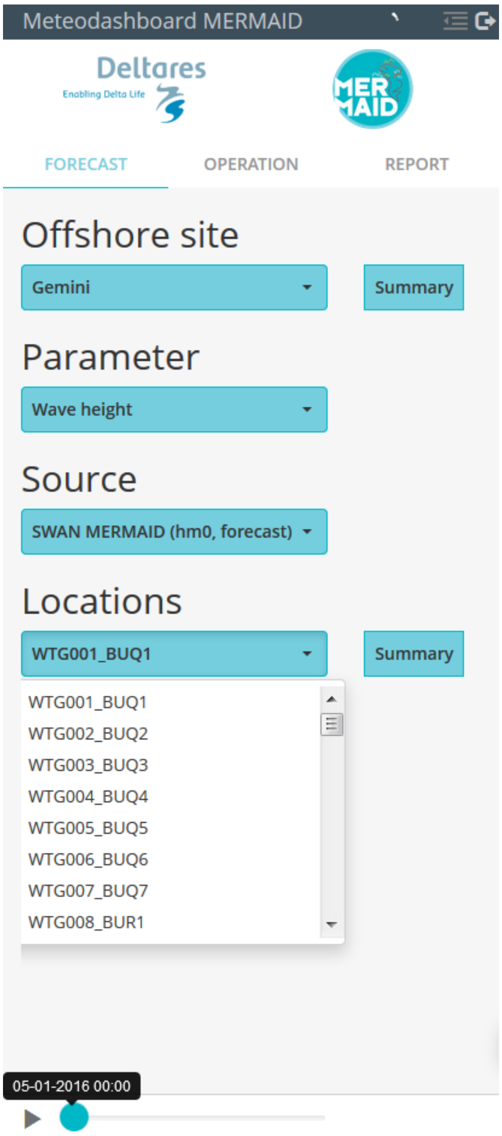


Figure 4. Example screenshot of the DSS, zoomed into the North Sea site, illustrating the options of different parameters to select. The slide bar will lead to more available parameters from the 'Parameter' list.



Furthermore in the tab 'locations' a specific output location can be selected, for instance an offshore wind turbine in the MUP. The 'Summary' button will result in a summary table in pdf format.

Operation menu

In this menu, the user can enter threshold values for various parameters (among which wave height). These values are subsequently used to evaluate the model forecast and indicate whether or not the specified threshold value is exceeded at a given turbine/location during a specific period. Figure 6 shows a screenshot of the Operation menu. After calculating – by pressing the button 'calculate' - the threshold value w.r.t the forecast, red indicates that during the prediction period (here: Tomorrow) no suitable weather window is available. Green indicates that a suitable weather window available. The color ambor indicates it is uncertain whether a suitable weather window is available.

Figure 5. Screenshot of the DSS, illustrating where a specific location can be selected, including the summary button.

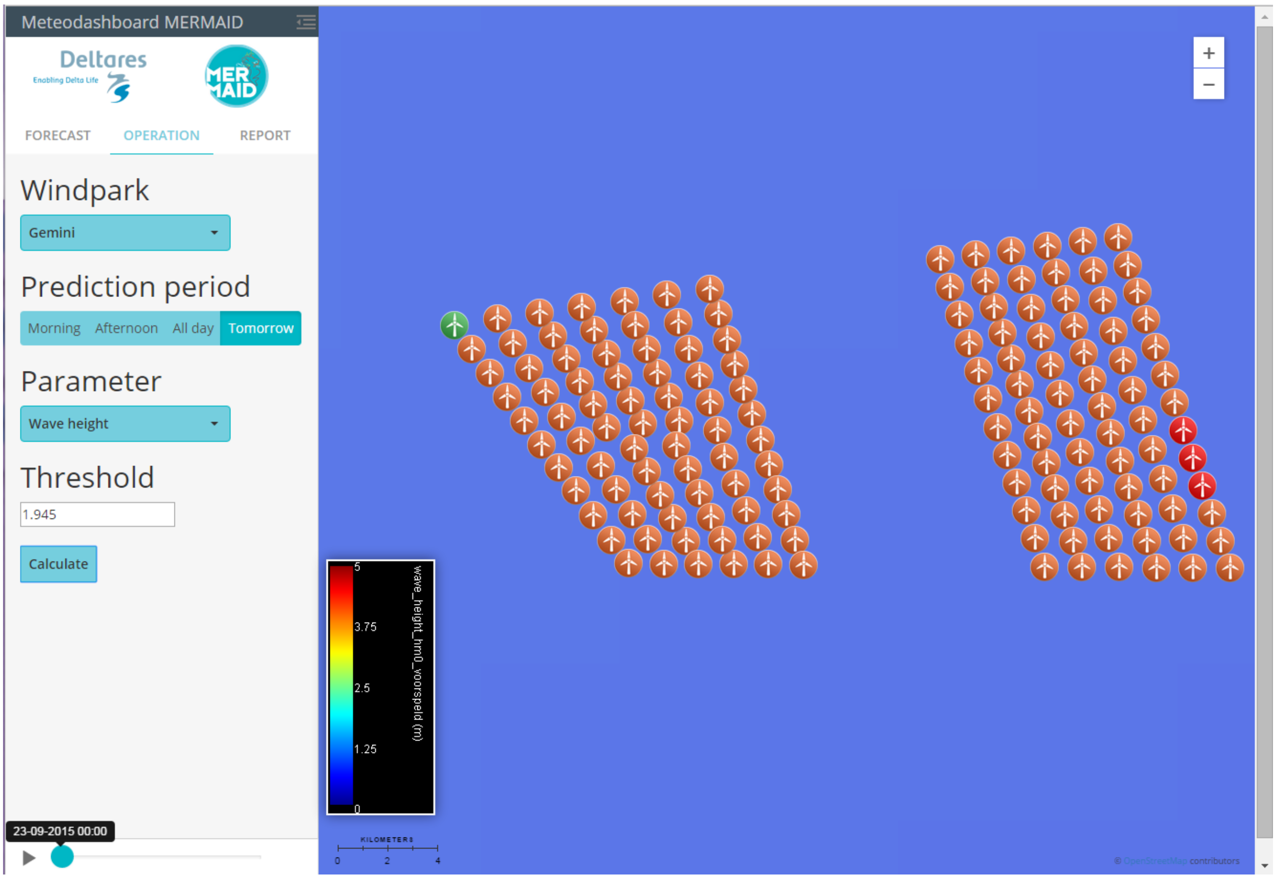


Figure 6. Example screenshot of the DSS under the operation menu.

5 Accessing the Meteo Dashboard

The Meteo Dashboard is a browser based application (website). This site can be accessed through the following web-links:

http://aw-tc003.xtr.deltares.nl/mermaid/index.php

Although the Meteo Dashboard is setup in such a way that relevant functionality works in all popular browsers, it is best accessed using Mozilla Firefox (which has been the main testing platform during this project).Before accessing the Meteo Dashboard, the user will be prompted for a password. This password can be provided by Deltares on request.

6 Operational forecasting models

One of the main objectives is to set up operational forecasting models for the multi-use offshore wind farm at the North Sea site. The purpose here is two folded:

- Accurate forecasts of the meteo (e.g. wind, visibility) and hydrodynamic conditions (e.g. wave, water level and current), and estimates of the accuracy of these forecasts, are considered crucial factors for the planning and decision-making process of offshore operations. The determining parameter here is wave height (H_s).

- Accurate forecasts of the meteo (e.g. wind, solar radiation) and hydrodynamic conditions (e.g. wave, water level and current) in combination with water quality conditions (concentrations of chlorophyll-a, nutrients (nitrate, ammonium, phosphate, silica), salinity and temperature) are considered crucial factors for a) the onshore monitoring of the aquaculture and subsequently and b) the planning and decision-making process of offshore operations.

The forecasting models interact with each other and are directly coupled. In the following section, the models will be briefly explained separately.

Operational wave modelling

The work reported here is a follow up on five previous studies (Deltares, 2009, 2011, 2012a, 2012c, 2013 and 2015) during which the foundation blocks of the overall model was set up. The operational wave model makes use of HIRLAM wind and pressure fields provided by the KNMI, wave boundary conditions from the operational European shelf wave model WAM of ECMWF (ECMWF-WAM) and water level and current fields from the operational flow model. The prediction horizon will be 48 hours. The different SWAN models that will be used are first listed below:

- SWAN-DCSM (swan-dcsm-j13-v1): This grid covers a large area, including a part of the Atlantic Ocean and the North Sea, and computes boundary conditions for the nested more detailed model domain (SWAN-ZUNO).
- SWAN-ZUNO (swan-zuno-j13-v1): This grid covers a smaller area, including most of the southern North Sea.

Background of SWAN

SWAN has been developed at the Technical University of Delft (lead) as well as at Deltares (see, e.g., Van der Westhuysen, 2010 and Zijlema, 2010). SWAN is the state-of-the-art third generation shallow water phase-averaging wave model. It can account for:

- Wave propagation in time and space, shoaling, refraction due to current and depth, frequency shifting due to currents and non-uniform depth.
- Wave generation by wind.
- Three- and four-wave interactions.
- Whitecapping, bottom friction and depth-induced breaking.
- Dissipation due to vegetation.
- Wave-induced set-up.
- Transmission through and reflection (specular and diffuse) against obstacles.
- Diffraction.

SWAN computations can be made on a regular, a curvi-linear grid and a triangular mesh in a Cartesian or spherical co-ordinate system. Nested runs, using input, namely two-dimensional wave spectra, from other (larger scale) models can be made with SWAN.

The SWAN model has been validated and verified successfully under a variety of field cases and is continually undergoing further development. It sets today's standard for nearshore wave modelling. For more information on SWAN, reference is made to:

http://swanmodel.sourceforge.net/online_doc/online_doc.htm

from where the SWAN scientific/technical documentation and user manual can be downloaded.

Computational grids

The SWAN-DCSM grid is based on the rectangular DCSMv6 grid, but covers a slightly smaller area. The grid has a resolution of 1/20° x 1/30° (which is circa 3.6 km x 3.6 km). The Irish Sea and some Norwegian fjords have been removed from the grid, since these are not expected to be relevant for waves in the area of interest. Excluding these grid cells decreases the computational time of the forecasting simulation. The purpose of the SWAN-DCSM model is to provide boundary conditions for the nested grid SWAN-ZUNO.

The SWAN-ZUNO grid has a higher resolution and has been applied for the shallower areas closer to the Dutch coast to represent the spatial bathymetric variation. It is a curvilinear grid and its resolution varies from 200 m to 2 km.

Bathymetry

The model bathymetry is mostly based on the NOOS gridded bathymetry data set. ETOPO2 bathymetry data is used for areas not covered by this data set. Furthermore, changes have been made to the initial model bathymetry to improve water level representation and in particular tidal propagation. Also, to prevent instabilities, the bathymetry along the open boundaries has been smoothened [Zijl *et al.*, 2013].

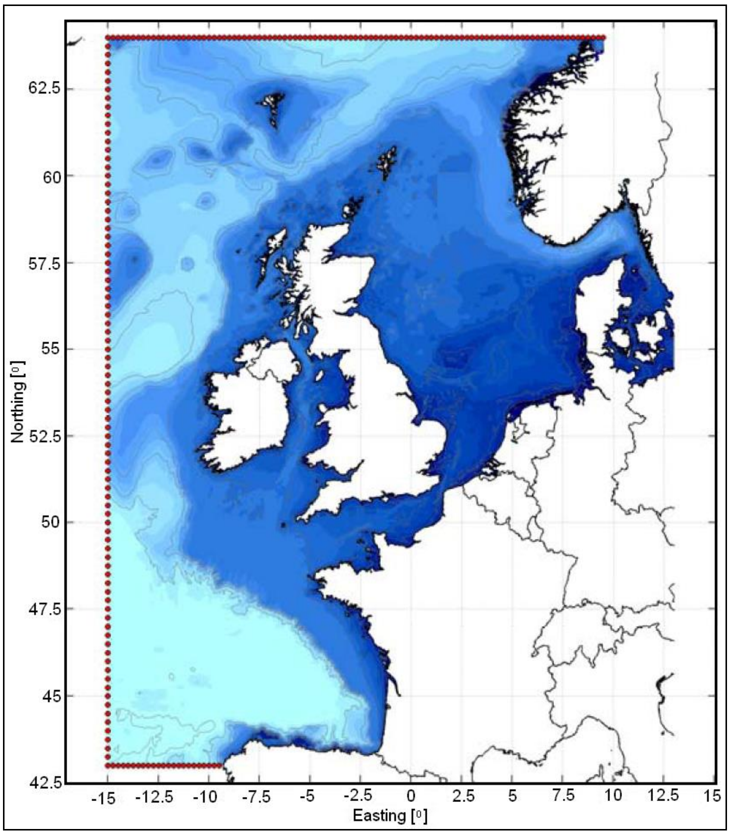


Figure 7: DCSMv6 WAQUA model with bed level (blue) [Zijl et al., 2013].

As can be observed from the bathymetrical map, in the northern parts depths of over 2000 m occur, whereas in the south-western part depths exceed 5000 m. The North Sea is much shallower, with depths of 10 to 100 m, whereas in the English Channel depths are typically around 50 m. In Figure 8 below, the bed level in the North Sea is depicted.

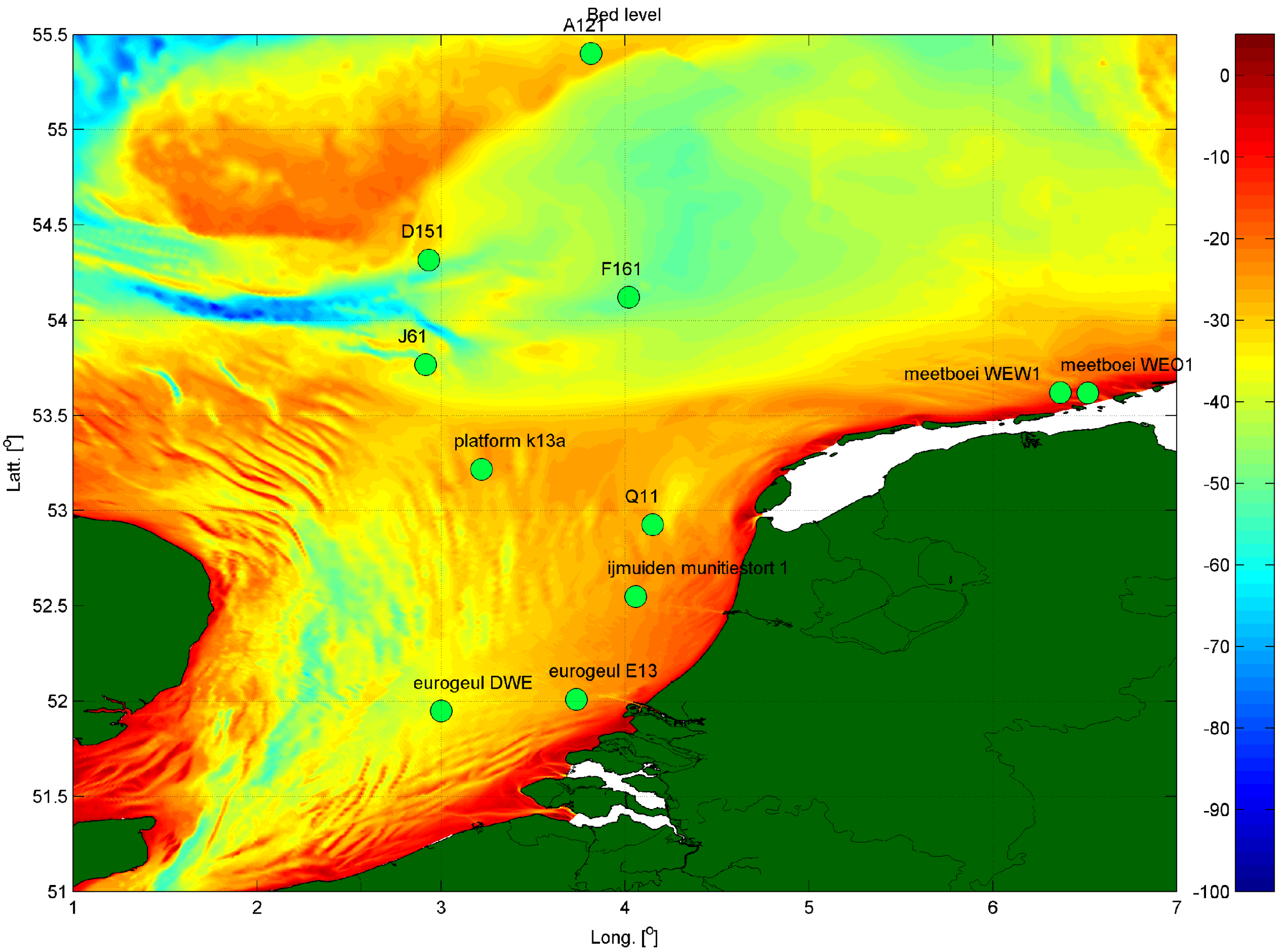


Figure 8. Bed level in the North Sea and the locations of available measurement equipment to validate the operational models.

Validation

The results of the wave forecast are extensively validated for different measurement stations located over the whole North Sea. With respect to the forecast validation, an example has been given in Figure 9. The forecast time series of H_{m0} is presented for Platform k13a for the period 4 – 9 April 2013. In the above figure, the observations together with the first three analyses are given. Below, 17 analyses are given, as can be observed in the legend. Each analysis covers the period from the analysis time till 48 hours after.

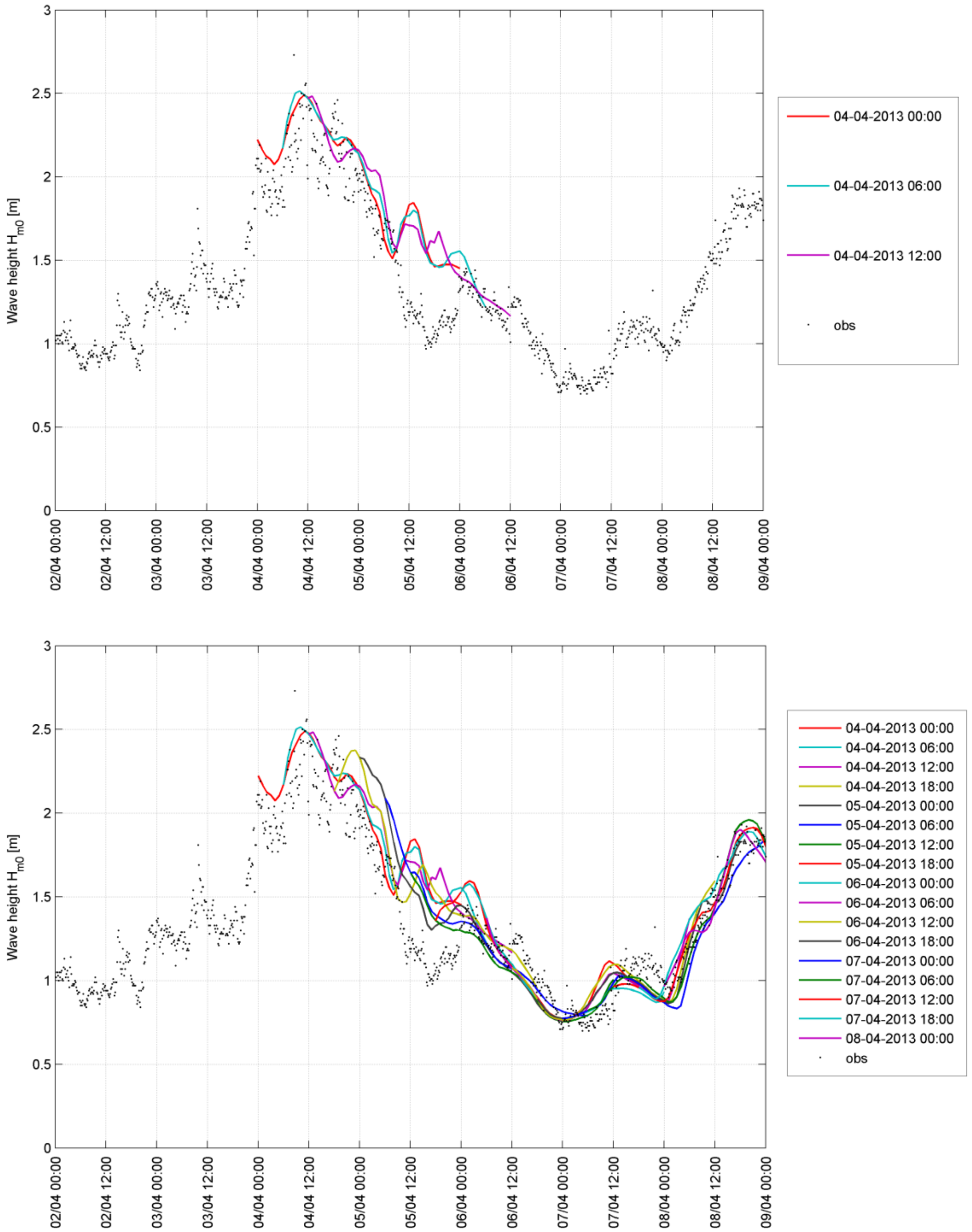


Figure 9. Timeseries H_{m0} [m] Platform k13a; observation and various analyses SWAN-ZUNO.

For further details on the analysis of the wave model validation reference is made to Deltares 2015.

7 Operational water quality modelling

For the operational water quality modelling a connection is made between the MERMAID project and the CoBiOS project. Deltares setup the water quality modelling in operational mode for the North Sea under the CoBiOS project. Below an explanation is provided The CoBiOS project aims to integrate satellite products and ecological models into a really operational and user-relevant information service on high biomass blooms in Europe's coastal waters. To this end CoBiOS will produce a harmonized and validated water transparency product based on satellite images for a large variety of coastal water types which will be used to force ecological models.

While earth observation can provide information on the state of superficial algal blooms, the improved CoBiOS ecological models will make predictions on the fate of blooms, thus allowing assessment of e.g. the risks on hypoxia and dead zones. CoBiOS operates in overlapping model domains in the Northern part of Europe in order to derive uncertainty information from ensemble runs. During two extended trial runs and one operational demonstration phase the combined service will be demonstrated to groups of users and validated by a panel of key users. All facets of post-project sustainable commercial continuation of the services will be analysed in concert with the end-users.

The CoBiOS project is a part of the GMES initiative (Global Monitoring for Environment and Security) and establishes a service network to monitor high biomass events in the coastal marine environment. As such, it contributes to the formulation, implementation and verification of the Community environmental policies, national regulations and international conventions, with specific focus on the WFD, MSFD, Bathing water directive, OSPAR and HELCOM. The project critically reviews and implements the so-called INSPIRE guidelines for data storage and exchange within the project. CoBiOS delivers easily understandable, timely, reliable and relevant information on the state of the environment to all stakeholders, by making information on high biomass development in coastal waters available through an easily accessible Google Ocean Portal. CobiOS intends to reach self-sustainability by providing innovative services, which contributes to improved European competitiveness and sustainable development. As such, it intends to be a showcase example of an operational and autonomous European capability. Deltares provides relevant tools and technologies as well as its knowledge of relevant bio-chemical phenomena in the Dutch coastal waters.

For more background information (computational model setup, validation, etc.) on the CoBiOS project reference is made to the following site. http://cordis.europa.eu/result/rcn/91396_en.html. Under MERMAID these ecological models are incorporated in the DSS.

The Figure 10 below indicates the schematic approach to come from earth observations and measurements to modelling results.

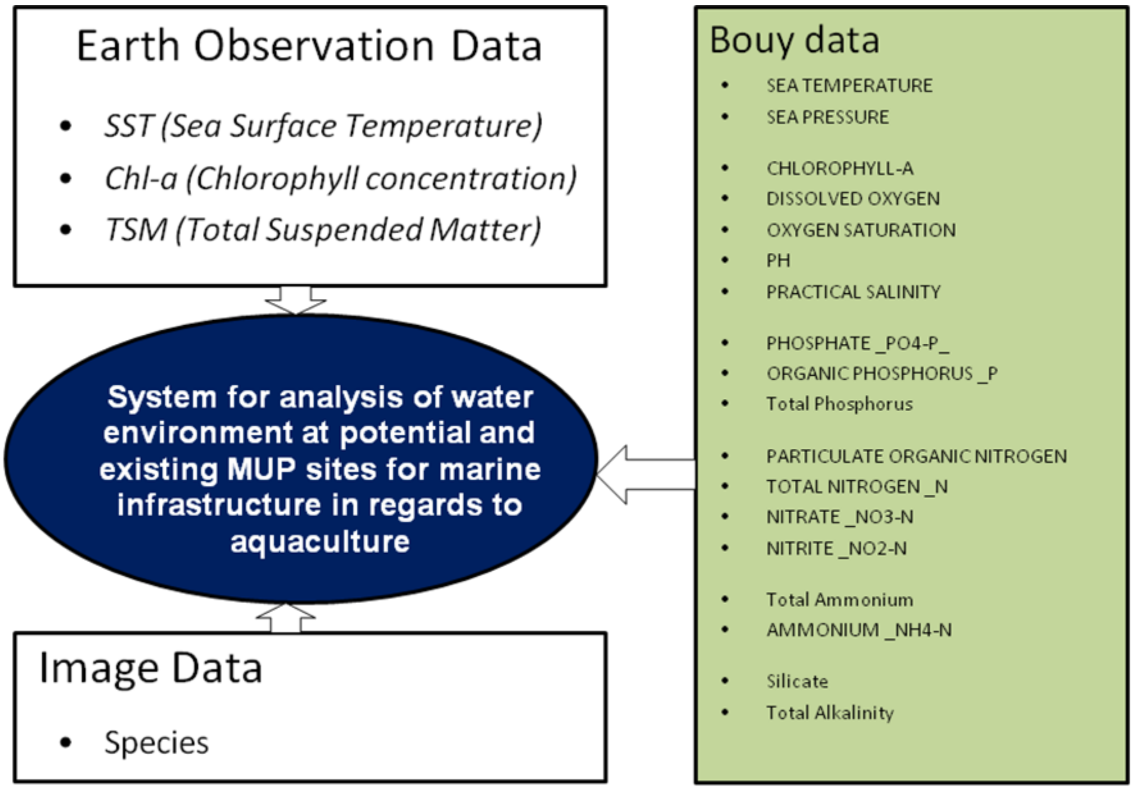


Figure 10. schematic overview of the relation between Earth observation, bouy data and system analysis.

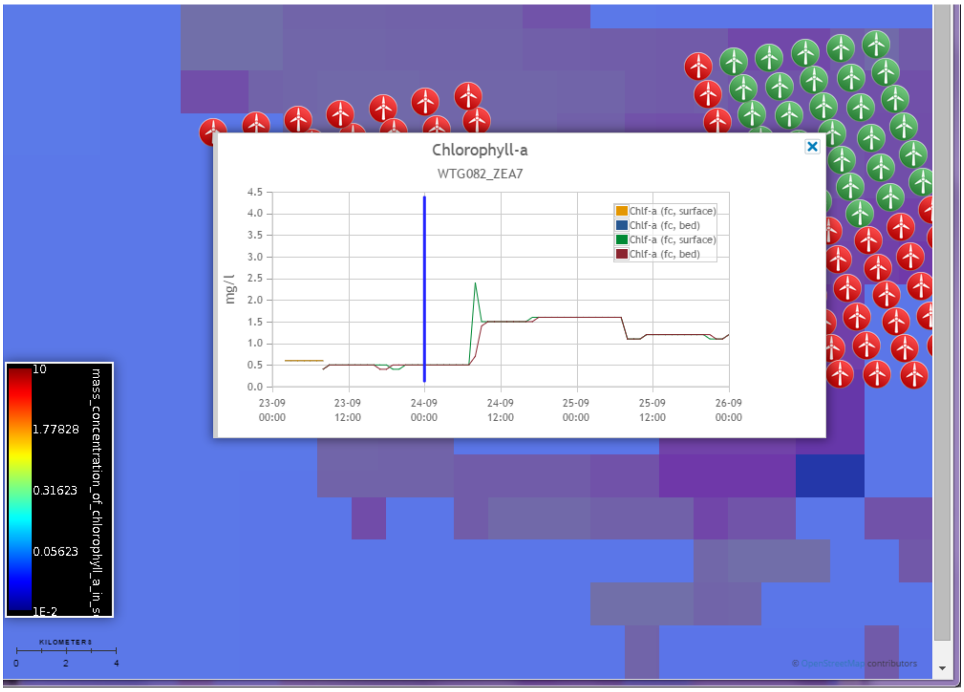


Figure 11. screenshot of the DSS illustrating the time series of Chlorophyll at the North Sea site.

8 Data feeds and available data

The tables below list the data feeds provided to the DSS. These data feeds consist of both measurement data (first table, provider RWS and source MATROOS (Multifunctional Access Tool foR Operational Oceandata Services)) and data from external forecasting models used to drive the operational forecasting models for Meteo Dashboard (second table). The data as described in previous sections is used by the DSS to generate local forecasts of hydrodynamic and wave conditions.

measurement data available in Meteo Dashboard FEWS
Air pressure at 10m above MSL
Wind speed and direction at 10m above MSL
Water level
Salinity
Air and water temperature
Wave height
Wave period (Tm-1.0)
Wave direction

forecast data available in Meteo Dashboard FEWS
HIRLAM v7.2 (from KNMI through RWS / MATROOS)
DCSMv6-ZUNO
CSM8
SWAN-DCSM
SWAN-ZUNO

The data as listed in above tables is imported from the MATROOS database. MATROOS is the operational database and archive maintained by the Dutch Government to store met-ocean data relevant to operational flood forecasting by the Dutch Government. We note that although the forecasts generated by the Meteo Dashboard forecasting models could also be archived in MATROOS, this is not done at present. Also, we note that for the present R&D application of Meteo Dashboard, arrangements have been made with Dutch Government regarding the usage of this data.

Furthermore, the Meteo Dashboard forecasting models use boundary conditions obtained from the DCSMv6(-ZUNO) model as run from RWsOS-Noordzee. RWsOS-Noordzee is the operational flood forecasting system used by Dutch Government for flood forecasting along the Dutch coastline.

9 Conclusions

For this project the Meteo Dashboard system was further improved to incorporate the requirements of aquaculture inside offshore wind farms. The design of the system is based on an inventory of requirements under several possible end-users. This section covers the main conclusions of the study and is followed by a list of recommendations.

The summary and main conclusions of this project are listed below:

- The Meteo Dashboard provides general functionality to collect, store and present relevant meteorological and hydrodynamic **measurement** data available. Although measurement data shown at present is largely obtained from Rijkswaterstaat, the system can easily be extended with additional measurement stations.
- The Meteo Dashboard provides general functionality to collect, generate, store and present relevant meteorological, hydrodynamic and water quality **forecast** data. At present, forecast data included consist of the Meteo Dashboard modelling framework and overall forecasting models from Rijkswaterstaat and KNMI.
- The Meteo Dashboard provides measurement data and model forecasts in support of decision making. In addition, the Meteo Dashboard provides functionality to evaluate this data based on threshold values in order to indicate whether these are exceeded.
- Following the feedback from the possible end-users, interviewed during the project, it is concluded that for the planning of O&M, wave height is the most important parameter, followed by wave direction and, less important, current speed and current direction. Therefore, the most relevant parameters are currently shown in the Meteo Dashboard. For the aquaculture point of view it is most important to have available the parameters **water temperature**, **salinity** and **Chlorofyl**. Also, it was concluded that it is important for the dashboard to compare measurement and model data in one plot.
- The Meteo Dashboard provides functionality to compare measurements and model data in one plot.
- Maintaining historical archives of past forecasts is less essential for O&M, but could be useful in view of discussions with contractors. The focus should be on the most recent forecast. The Meteo Dashboard shows results for the most recent forecast by default. Although the system in technically capable of archiving and retrieving old forecast, this functionality has not been fully implemented for the present application.
- For O&M, conditions along the ship trajectory towards the wind park are less important than condition at the wind park. The most critical phase is the transit from the ship to the wind turbine or aquaculture support structure. Although the Meteo Dashboard can present model output at selected locations along the shipping track to Gemini MUP, this functionality is not critical.
- Showing detailed information for each wind farm and turbine is important, as conditions can differ significantly between turbines in different sectors of the park. The Meteo Dashboard shows relevant forecast information for each turbine, and provides overview displays showing the conditions at each turbine in the wind park. The spatial variation of water quality related parameters over the MUP farms seems less distinct and therefore less relevant.
- An up-to-date forecast should be available at the start of the working day. The forecast scheduling has been tuned to the availability of new HIRLAM and DSCM forecasts in order to reduce latency to the extent possible, thus providing the most up-to-date results at the start of each day.
- If it is useful if information can be presented on portable (mobile) devises. The Meteo Dashboard is browser based on thus fully portable. Although the application is accessible from a mobile phone, the information content included in each display has not been optimized to this end.
- Important information should be accessible in one overview. Excessive scrolling through the dashboard is not desired. Therefore the Meteo Dashboard provides relevant information in a select number of overviews. Excessive scrolling is thus not required.
- The dashboard should show when information was last updated. The Meteo Dashboard shows when relevant information was last updated in the status bar.

10 Recommendations

The following recommendations are identified for future developments and optimisation of Meteo Dashboard for multi-use of offshore wind farms:

- Determine the confidence intervals of the forecast in order to provide this in addition to the forecasted parameters. It is expected to be of added value to the decision making process.
- Further investigate the possibility for data assimilation and error correction.
- The performance of SWAN concerning wave directions has not been assessed yet. Advised is to compare the mean wave direction, and possibly mean wave direction of low frequency waves with observations.
- Continue to monitor the SWAN results and compare them with observations, with the aim for possible model improvements.
- Extend the model validation to a longer period of time, possibly 6 months of calm weather conditions.
- Investigate the added value when forcing the forecasting model with the more detailed and improved meteo forecast called HARMONIE.
- Limit the computational time of the forecast.

11 Literature

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