



## **DATABASE OF MEASUREMENTS ON THE OFFSHORE WIND FARM EGMOND AAN ZEE**

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**Summary** This paper presents the database of the measurements that have been acquired over the years in the Offshore Wind farm Egmond aan Zee (OWEZ). In addition, two topics are discussed: the analyses on this database that were performed in the past, and the potential for new analyses in the framework of the EU/FP7 project MaRINET. The OWEZ database and the analyses performed on it offer a unique opportunity to study the external conditions of an offshore wind energy site.

### **1 Introduction**

NoordzeeWind carried out an extensive measurement and evaluation program as part of the project Offshore Wind farm Egmond aan Zee (OWEZ) [1]. The technical part of this program considered topics like climate statistics, wind and wave loading, and wind turbine performance monitoring.

Energy Research Centre of the Netherlands (ECN) created on behalf of NoordzeeWind an extensive and accurate database of these data. In addition, ECN performed many analyses on the data.

In this paper an overview is given of the database of measurements on the OWEZ which has been created over the years. The paper starts with descriptions of the facility (section 2) and the content of the database (section 3). Next, the attention goes to the overview of the analyses on the data (section 4). This overview describes the work that was performed in the past, as well as work that can be performed in the future in the framework of the EU/FP7 project MaRINET. Finally, the summary and conclusion are presented (section 5).

### **2 Description of the facility**

The Offshore Wind farm Egmond aan Zee (OWEZ) consists of 36 wind turbines with a hub height of 70 m and a nominal power of 3 MW, plus a 116 m high meteorological mast (figure 1). It is located in the North Sea 10-18 km from the coast near Egmond aan Zee in the Netherlands.

In the period between June 2004 and December 2006, the meteorological mast was used in order to measure the meteorological and hydrological conditions without the presence of the wind farm. Apart from these technical data, environmental data were acquired such as data on birds and fish, and underwater noise.



Figure 1 Photo of wind turbines and the meteo mast in the Offshore Wind farm Egmond aan Zee (left; source: Jos Beurskens), and a sketch of that meteo mast (right; [2])

In the subsequent period, between January 2007 and December 2009, the meteorological mast was used in order to measure the aforementioned data during operation of the wind farm. The data acquired in that period include, among others, the wind conditions in the wake of one or more wind turbines, and the wind data used in order to establish the mechanical load performance and the power performance of some of the wind turbines in the wind farm.

### 3 Content of the database

The database of measurements on the Offshore Wind farm Egmond aan Zee contains [2]:

- A total of 5½ years of measured meteorological and hydrological data, of which 3 years in the presence of the wind farm.
- Continuous time series of 10-minute statistics (mean, standard deviation, minimum, and maximum).
- Six measuring heights (-17 m, -4 m, 20 m, 21 m, 70 m and 116 m above mean sea level).
- Various quantities (wind speed and direction, air and water temperature, relative humidity of the air, air pressure, precipitation, water level, current velocity and direction, tower accelerations, and wave height, period and direction).

The meteorological data are available at [www.noordzeewind.nl](http://www.noordzeewind.nl) and [www.offshorewind.nl](http://www.offshorewind.nl). The other data (hydrological, environmental, higher data rate or originating from wind turbines) are available on request to NoordzeeWind.

### 4 Using the OWEZ database

#### 4.1 Past work

##### 4.1.1 Atmospheric model validation

To accurately predict historic wind conditions and vertical wind profiles is important for an assessment of the wind resource.

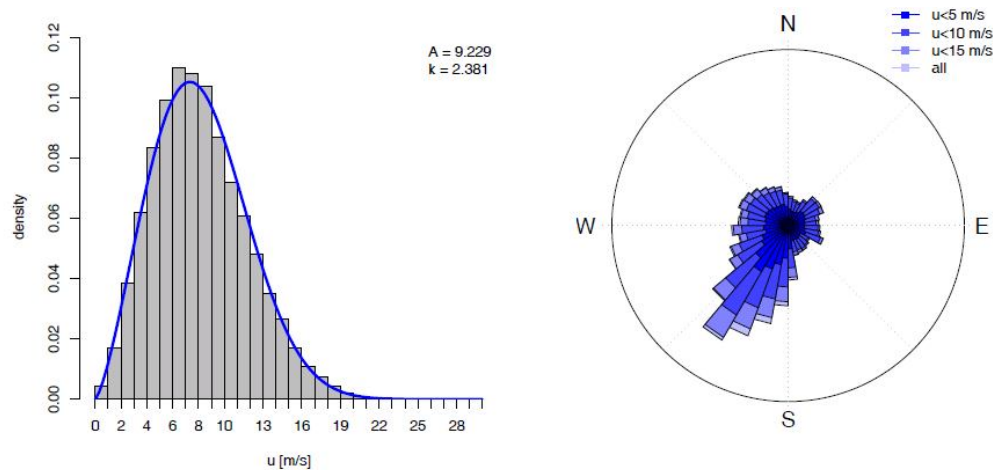


Figure 2 Weibull distribution of the wind speed (left) and sectorwise wind speed distribution (right) at a height of 21 m at the location of the OWEZ [3]

The wind resource in the location of the OWEZ was determined by Barth [3]. To this end he correlated the wind time series of the meteo mast at the OWEZ location and the meteo station Meetpost Noordwijk. The result is shown in figure 2. It was concluded that, compared to the other meteo stations that were considered, Meetpost Noordwijk best represents the wind climate at the OWEZ because of the similar distance to the coast.

Sathe et al. and Loriaux determined the impact of the atmospheric stability on the vertical wind speed profile at the OWEZ location [4, 5]. Sathe et al. concluded that for the prevailing wind directions, i.e. those with a long maritime fetch, unstable and (near) neutral conditions dominate. Under these conditions the measured wind profiles were found to be in agreement with profiles predicted on the basis of the classic Monin-Obukhov theory. For the less frequent stable conditions this theory was found to break down, and a new approach was proposed. Loriaux observed similar anomalies in the measured wind speed profiles, and traced these to changes in the atmospheric stability with height which are not represented in the classic theory.

In a similar way the OWEZ data can be used in order to validate the wind predictions of any atmospheric hindcasting or reanalysis model, or new similarity theory.

#### 4.1.2 Wind prediction model validation

To accurately predict the wind in the near future is of importance for the integration of wind energy in an electricity system.

On the basis of the OWEZ data, Brand validated the ECN wind power forecasting method AVDE and studied the value of wind power forecasting for the operators of a wind farm [6]. It was concluded that the best choice for the wind farm is to accept imbalance payments rather than pay an imbalance fee. With imbalance payments the wind farm settles the imbalance energy with the system operator. This is in contrast to an imbalance fee, where a third party takes care of the imbalance energy. In addition it was concluded that optimized forecasts are the more economic choice over not-optimized forecasts. Optimized forecast were determined by compensating for the systematic error in the wind power forecasting method. To this end the correlation between the predicted and the measured wind was determined (figure 3).

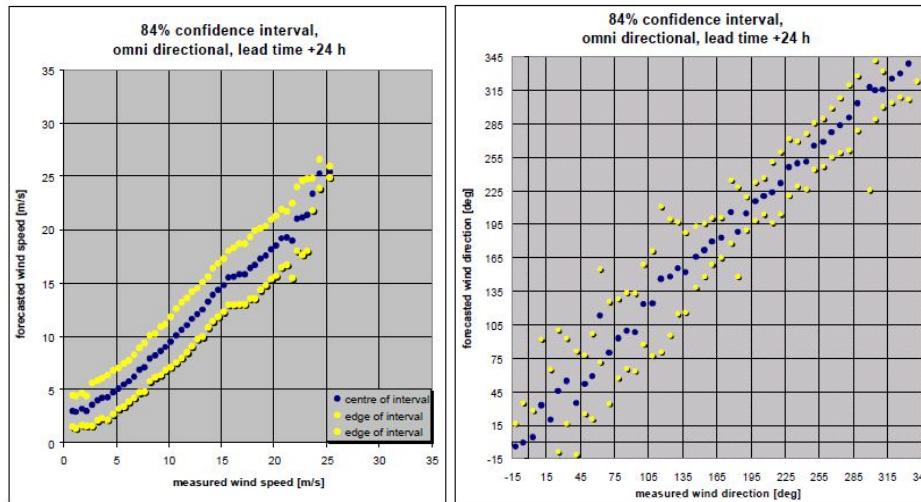


Figure 3 Correlations between the predicted and the measured wind speed (left) and wind direction (right) at the location of the OWEZ [6]

In a similar way the OWEZ data can be used in order to validate the wind forecasts of any short-term wind prediction method.

#### 4.1.3 Wind farm flow model validation

Turbine wakes are responsible for the energy loss and the fatigue increase in wind farms. Therefore accurate descriptions and models of the wind speed deficit and the added turbulence are needed. The OWEZ offers a unique opportunity to evaluate single, double and multiple wakes situations (figure 4).

The effect of the wind turbine wakes on the energy output of the OWEZ was described by Curvers and Van der Werff [7]. In order to determine the sectorwise power curves of the turbines in the OWEZ, they combined SCADA measured electrical powers and nacelle winds, while applying the nacelle transfer function in order to estimate the undisturbed wind speed of a wind turbine. Regarding the modelling, Bot successfully validated the ECN wind farm design tool FarmFlow by using the OWEZ data [8]. FarmFlow is the most advanced wind turbine wake modelling method available, modelling the mean wind as well as the turbulence.

#### 4.1.4 Wind turbine design conditions

For predicting wind turbine fatigue loading it is important to accurately model the correlation between the wind, the waves and the currents. The opportunity to do this is offered by the OWEZ data (figure 5).

The simultaneous wind, wave and current climatology at the OWEZ location was evaluated by Barth and Eecen, and Wagenaar and Eecen [9, 10, 11]. They found that the correlation between the wind and the wave directions depends on the atmospheric stability: the two are coupled under unstable conditions but are independent under stable conditions. Nevertheless, the wave direction is mainly determined by the orientation of the coast, as is the tidal driven current direction. As to the wind they confirmed that the scale parameter of the Weibull wind speed distribution increases with height, that the Weibull shape parameters decreases with height, and that the prevailing wind directions increases with height.

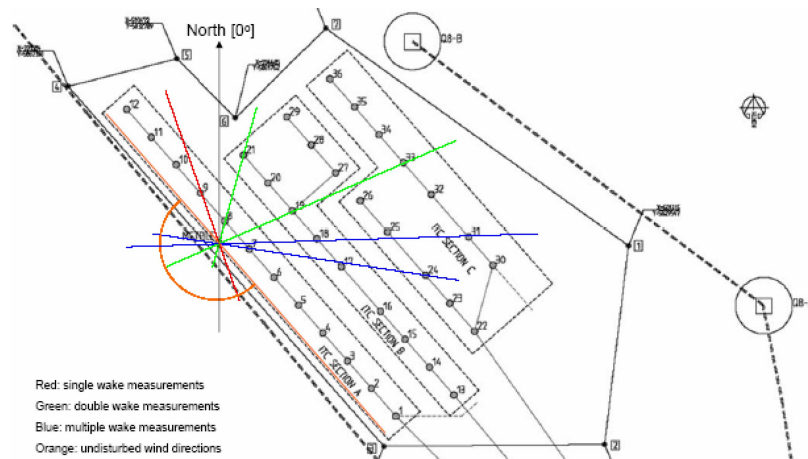


Figure 4 Opportunities to evaluate single, double and multiple wakes situations in the OWEZ [7]

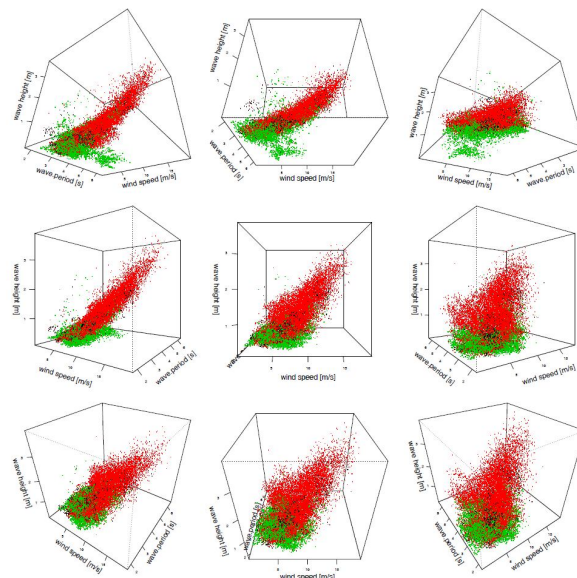


Figure 5 Different oblique views of the 3D scatter plot of wave height, wave period and wind speed at 21 m. The colors black, red and green refer to conditionally unstable, unstable and stable atmospheric conditions, respectively [9]

In a similar way the OWEZ data can be used in order to validate the predictions of any wind-wave model.

#### 4.2 Future work

The EU/FP7 project MaRINET provides the framework for future analyses. The objective of the project MaRINET is to facilitate trans-national access to marine energy test facilities, in this case the database of measurements on the Offshore Wind farm Egmond aan Zee [12]. To this end, late 2011 researchers from the EU25 and the associated countries were invited to submit research proposal in the first of five calls. Another three or four calls are scheduled for the years 2012 - 2014.

In the context of the project MaRINET ECN provides the users of the database additional information on the measured data. The added value of ECN's activities here is to prevent the user an elaborate research of the database, and to provide the user with the information that is required for a successful and an effective use of the data. As a consequence, the analyses on the datasets can be done more effectively. This service can be provided because ECN has performed many analyses on the data in the past.

## 5 Summary and conclusion

The database of the measurements that have been acquired over the years on the Offshore Wind farm Egmond aan Zee (OWEZ) has been presented. In addition, the analyses on this database that were performed in the past, and the potential for new analyses in the framework of the EU/FP7 project MaRINET, have been discussed. It is concluded that the OWEZ database, the analyses performed on it and the experience of ECN offer a unique opportunity to study the external conditions of an offshore wind energy site.

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