Oceanographic Results of Two Years Operation of the First Offshore Wind Research Platform in the German Bight - FINO1

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Introduction

In 2003, the first research platform within the framework of the FINO programme was erected in the North Sea, about 45 km off the island of Borkum. The purpose of the measurements carried out by the BSH (Federal Maritime and Hydrographic Agency of Germany) in co-operation with DEWI (Deutsches WindEnergie Institut) is the determination of physical conditions in the marine environment and of meteorological conditions in the lower atmospheric boundary layer. The oceanographic measurements carried out by the BSH include sea state, currents, and physical properties of sea water. On the basis of the data collected during a 2.5-year period, we report in detail about marine environmental conditions and their seasonal changes, and about the occurrence of extreme events. The observed phenomena are compared to available long-term data series for the North Sea.

The focus of the measurements was on the acquisition of current and sea state data. These data include all parameters that are required as basic input for calculations of the load conditions and forces acting on offshore structures and their foundations, the establishment of maintenance concepts for offshore wind turbines, effective scour protection, and the development of suitable modelling approaches.

Furthermore, the oceanographic data are used as a basis in marine environmental monitoring. In this way, possible impacts of the turbine structures on ocean dynamics and, consequently, on the ecosystem can be identified. To achieve an economically viable and ecologically sound exploitation of offshore wind energy, a thorough analysis of oceanographic conditions in the project areas is indispensable.

Measuring Concept

Oceanographic variables were measured as a contribution to the technical development of offshore wind energy installations. Together with meteorological data, these variables provide a basis for the computation of loads acting on wind turbines and for an appraisal of possible impacts which this technology may have on the marine environment. Figure 1 shows a diagram of the measuring concept, which includes measurements of sea state, currents, oxygen, and physical properties of sea water (temperature, salinity, pressure). A chain of measuring instruments was installed at the centre of the platform jacket consisting of temperature sensors at 3, 10, 15, and 20 metres water depth, and of multifunctional instruments measuring conductivity, temperature and pressure (CTD), as well as oxygen sensors, at 6 and 25 metres depth. The instruments are connected via cable to the power supply and data logger on the platform. An Acoustic Doppler Current Profiler (ADCP) measures the current direction and velocity at 15 depth levels. Probably the most important information comes from a buoy which provides a realistic view of sea state conditions. All data are collected continuously on the platform and are transferred hourly to shore for further processing and presentation on the FINO website.

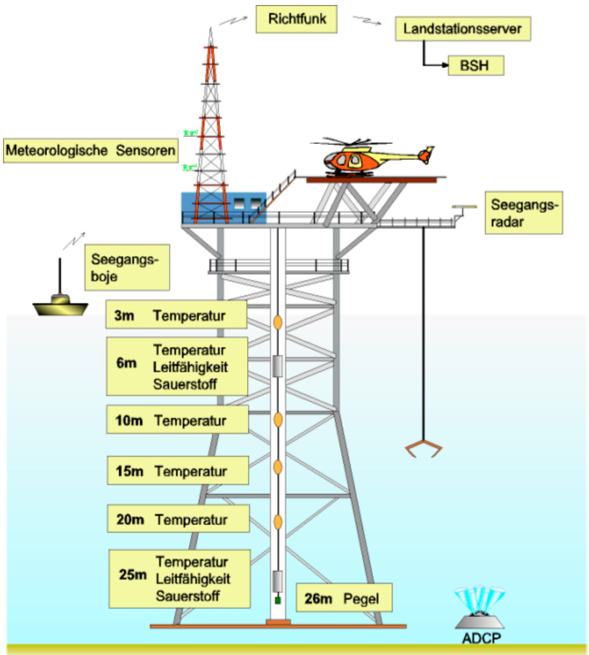

Fig. 1: Measuring concept for oceanographic variables at FINO 1, which includes data on sea state, currents, temperatures, conductivity, pressure, and oxygen.

Temperature Data

The temperature data are used to study interactions between the ocean and atmosphere and environmental monitoring. Temperature measurements were started in October 2003. Owing to the physical forces acting on the measuring instruments in the centre of the platform jacket, data acquisition was interrupted several times. Nevertheless, comprehensive data sets have been obtained during that period.

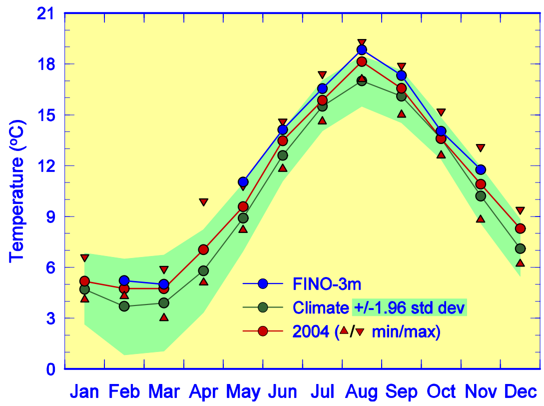

Fig. 2: Temperature data measured at 3 m depth at the FINO 1 platform in 2004 (blue dots) in comparison with the data from "Helgoland Reede" as monthly averages of the years 1970 to 2000 (green dots), the double standard deviation (light green band) and the monthly average of 2004

The winter periods of the three years investigated do not show any major differences. However, the data from the summer periods show a rising peak temperature and a delayed onset of the cooling phase, which led to an exceptionally warm 2006 autumn season. The dimension of the change that is taking place is demonstrated best by a comparison of data from the past 30 years. Figure 2 illustrates the marine climate governing sea surface temperatures from 1970 to 2000, collected at the "Helgoland Reede" roadstead. The monthly averages of the FINO1 data and of the Helgoland data show good correspondence. However, in the autumn of 2004, the near-surface temperatures measured at FINO1 already exceeded the climate value by more than two standard deviations (light green area). With respect to the years 2005 and 2006, this means that the monthly average temperatures were abnormally high for the season.

Current Data

Current measurement data are crucial for the design of wind turbine foundations and, in general, for the computation of load conditions under the influence of changing tidal currents, and for the assessment of potential impacts on sediment dynamics in the area of an offshore wind farm. Figure 3 shows the annual statistics of current measurements at 8 metres depth made in 2005. The main current direction at the FINO 1 platform alternates on the 260 - 80° axis with an average current speed of about 0.55 m/s. Current data have been collected almost continuously since April 2004. Modelling data for the German Bight demonstrate the diversity of current behaviour and underline the importance of these measurements for all wind farm development projects in this sea area.

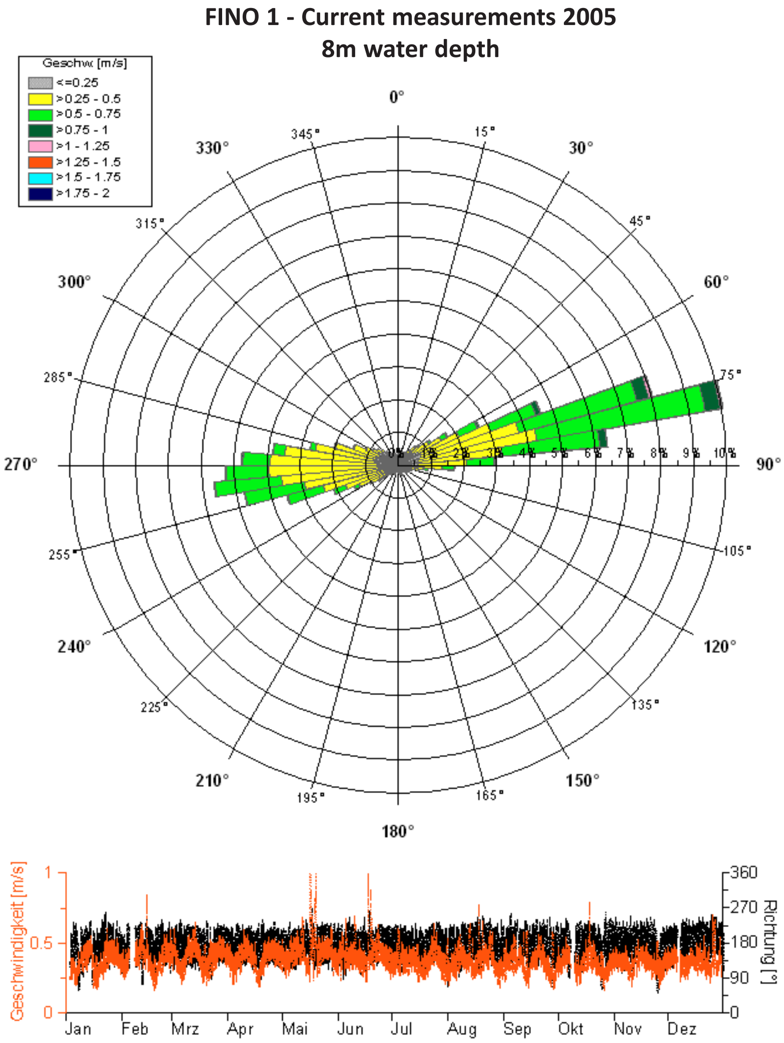

Fig. 3: 2005 current statistics at 8 m depth level at FINO 1. The main direction is on the 260 - 80° axis, and the current speed is mostly between 0.4 and 0.65 m/s. The time series below shows the average over a tide cycle.

Wave Events

Several severe storm events have been observed since the beginning of wave parameter measurements at the FINO 1 platform. In December 2003, the first storm recorded at the platform produced significant wave heights of up to 7 m, with single waves reaching 12.5 m (see figure 4).

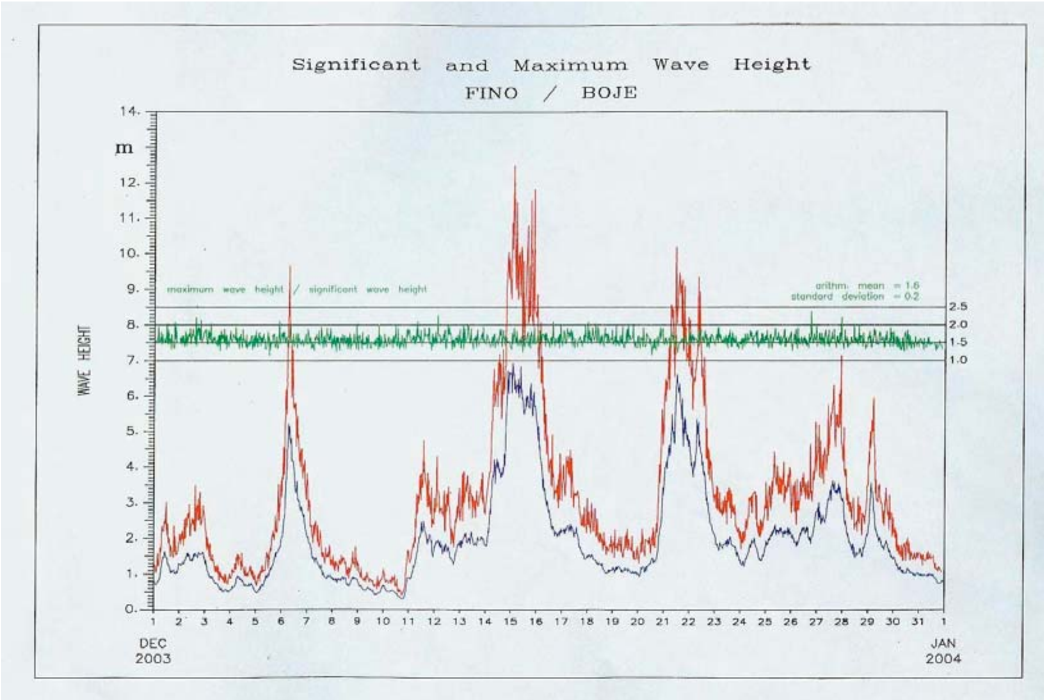

Fig. 4: December 2003, significant wave heights (Hs, blue line), measured maximum wave heights (Hmax, red line) and the relation Hmax/Hs with an average of 1.6.

Using the time series for the whole month of December as a basis, the relation between the two variables maximum wave height and significant wave height (green line) shows an arithmetic mean of 1.6, which is in accordance with the value of 1.7 given in the literature. However, single waves may be twice as high as the significant wave height, which is calculated from the past 30 minutes of sea state measurements.

Figure 5 shows another storm event recorded in the first half of February 2006. Both variables were measured by a directional Waverider buoy moored 100 m north-west of the FINO station. The blue line represents the maximum wave heights computed as a product of the literature value of the arithmetic mean and the significant wave height. A comparison of the measured (red line) and calculated (blue line) maximum wave heights generally shows good correspondence, with the exception of the highest wave phase on 9 and 10 February when the calculated values mostly exceeded the measurements. Nevertheless, the arithmetic mean is an excellent tool for roughly estimating wave heights during a storm event, and it is particularly useful in the case of older buoys which are not capable of storing single wave data, and in case of extreme events which are even beyond the capacity of modern technology. Such an extreme event occurred on 1 November 2006, when storm warnings were issued for the southern German Bight and its coastline. Significant wave heights reaching 10.54 m were recorded at the FINO1 platform at 3:30 a.m. These values were confirmed by the

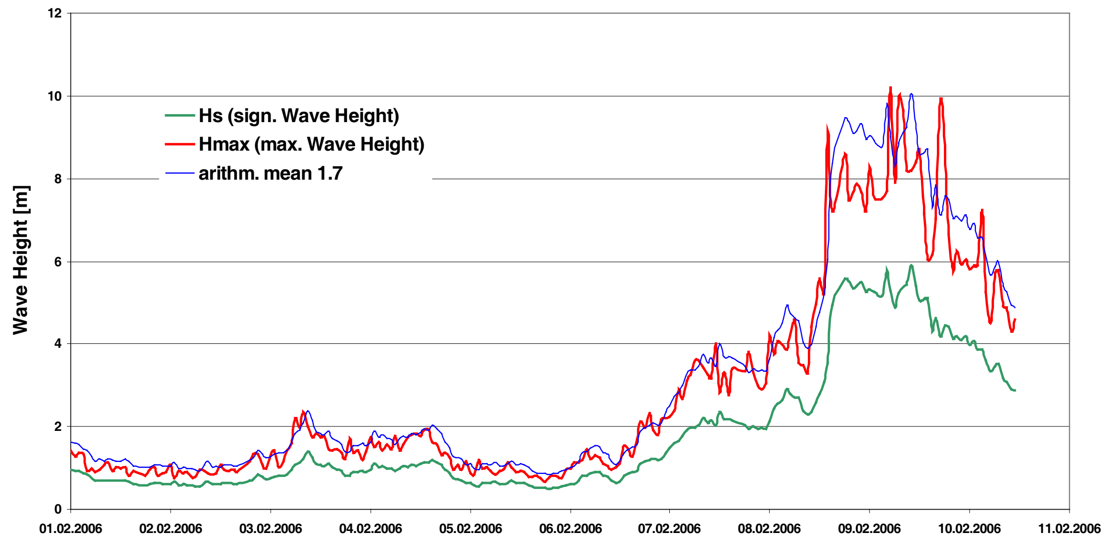

Fig. 5: FINO1 - Storm event on 9 February 2006. The time series shows the significant wave heights (green line), measured maximum wave heights (red line), and the calculated maximum wave heights (blue line, Hs multiplied by the arithmetic mean of 1.7).

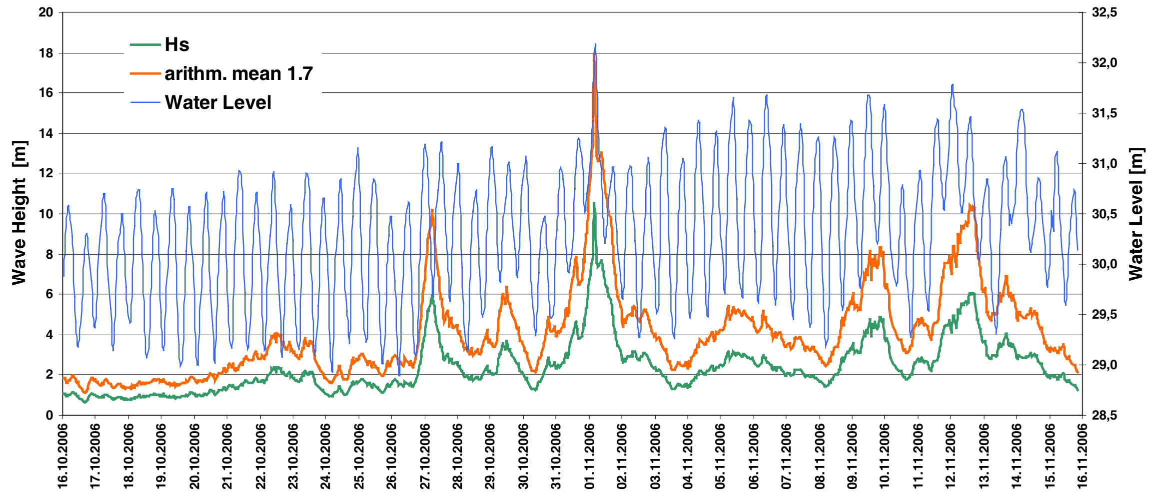

Fig. 6: FINO1 - Storm event on 1 November 2006. The time series shows the measured wave heights (green line), calculated maximum wave heights (yellow line, Hs multiplied by the arithmetic mean of 1.7), and corresponding water levels (blue line) from 16 October to 18 November, including the extreme event of 1 November.

platform's other wave measuring instruments - the Acoustic Doppler Current Profiler (ADCP) and the radar based wave monitoring system WaMoS II. However, both systems are not capable of measuring single waves. Figure 6 shows the time period from 16 October to 16 November, with significant wave heights mostly above 2.0 m, and above 6.0 m (green line) on three occasions. In addition, the water level is indicated as a blue line and shows a remarkable 32.20 m during the storm, which is 2.20 m above normal high water. The cause is the heavy north-westerly gale which led to an extreme water level rise, adding to the impact of the sea state. The yellow line is the estimation of the maximum wave height according to the arithmetic mean of 1.7.

During the time of maximum wave heights, the wave measuring system installed in the buoy was blocked at maximum expansion for several minutes, causing failure of the single-wave recording mechanism. Therefore, the computed significant wave height cannot be considered realistic and has been excluded from the time series. For that reason, we are compelled to use the arithmetic mean in order to estimate the maximum wave height during the storm event of 1 November. Waves of up to 16 m hit the platform, causing damage to the lower working platform. Pictures 1 to 3 provide an impression of the amount of damage caused by this severe storm event. The working platform of FINO 1 is located 15 m above chart datum (CD, 28 m) and thus was 11 m above the water level during the storm. Even structures above the working platform, up to about 15 m above the recorded water level, were damaged in the storm. Floor gratings torn from their mountings and some heavily deformed railings testify to the power of the storm and the dimension of single waves during this extreme event.

Conclusion

In nearly three years of continuous oceanographic measurements, comprehensive, valuable data sets have been obtained at the FINO 1 offshore platform. On the basis of these data, it has been possible to gain an overall impression of the physical power of waves and currents, as well as of the high variability of ocean dynamics in this sea area. The measurement data also provide information about the oceanographic boundary conditions for the construction of offshore wind turbines in the German Bight. However, model data have shown the high spatial variability of ocean physics in the North Sea, which leads to the recommendation to measure the local basic environmental variables wherever larger areas of wind farms are planned to be established.

Pict. 1, right: Lower working platform in August 2006
Pict. 2 and 3, below: damage caused by the storm of 1 November 2006. Several floor gratings had been torn from their mountings, and parts of the railings showed heavy deformation.

Influence of Wave Spreading in Short-term Sea States on the Fatigue of Offshore Support Structures at the Example of the FINO1-Research Platform

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Summary

The distribution of wave directions within a short-term sea state has a relevant influence on the fatigue loading of offshore structures. Measurement data collected at the FINO1 research platform will be used to demonstrate the effect. A better agreement between simulation and measurement can be achieved if wave spreading is taken into account in the simulation of the sea states. The effects of considering wave spreading both in the short-term as well as in the long-term will be studied at the example of a monopile and a tripod.

1. Introduction

Fatigue design of support structures for offshore wind energy converters (OWECS) requires the careful consideration of loads due to the surrounding waves in addition to the fatigue loads due to wind and the operation of the turbine.

It is common practice in the industry to simulate wave loads according to different sea states in the time domain