FIVE YEARS OF OPERATION OF THE FIRST OFFSHORE WIND RESEARCH PLATFORM IN THE GERMAN BIGHT – FINO1

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Summary

Since autumn 2003 a technical investigation program operated by DEWI in cooperation with BSH (Federal Maritime and Hydrographic Agency) has been run at the offshore research platform FINO1 in the North Sea, approx.45 km off the island of Borkum. The measurements on the FINO1 platform provide a complete set of maritime data for several years to accompany the German offshore programme. A certain number of research and commercial projects within Germany and the EU ranging from scientific studies on the maritime environment itself, the layout and optimisation of future offshore wind turbines and their support structure as well as economic project optimisation take their benefit on the availability of these data.
In this paper a brief overview of five years' data including availability, long-term wind statistics, vertical wind profile and temperature profile is given.

1. Introduction

One of the main targets of Fino1 is the acquisition of new knowledge about the marine atmospheric boundary layer as well as a better understanding of the meteorological and hydrographical conditions in the offshore area. Because measuring data were already recorded during the test phase from September to December 2003, today scientists and commercial users can access nearly five years of comprehensive record.

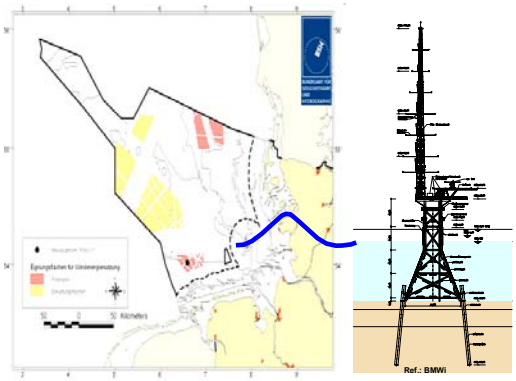

Fig. 1: Position and layout of Fino1 [1]

2. Data availability

The sensors installed as well as the measurement system proved to be extremely stable in the first five years of operation. Through the use of data loggers and a temporary storing of measurements directly on the platform a greater loss of data, such as by a failure of the radio relay connection could be prevented.

The figure below indicates that nearly all parameters show an availability of more than 90%. Looking at the wind speed measured by the Cup-Anemometer, e.g., a value of approx. 96% is reached.

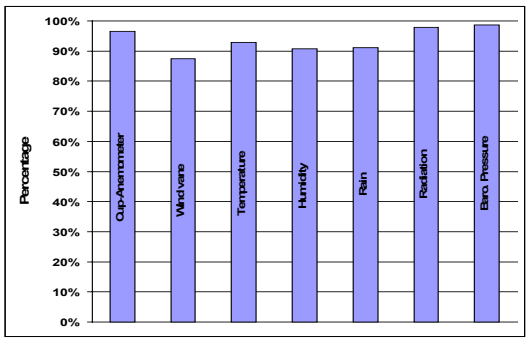

Fig.2: Availability of the main meteorological sensor devices during the period of Jan 2004 – Aug 2008

3. Wind statistics

Particularly with regard to the future offshore wind parks in the immediate vicinity of Fino1, one of the main targets is accurate recording and analysing of the local wind conditions.

3.1 The mean wind profile

Figure 3 shows the Weibull distribution of wind speed at 100 m height during the period from January 2004 to August 2008. The mean wind speed during this period is 10.1 m/s.

On the right hand side one can see that the wind speed distribution shows seasonal differences. During the summer high wind speeds of 15 m/s occur only rarely, and the average wind speed is 8.3 m/s. During the winter months, the mean wind speed increases to 11.4 m/s, and a significantly more frequent occurrence of high wind speeds can be observed.

The wind distribution in spring and autumn (not shown here) differs only slightly from each other and

lies between the values of summer and winter, both in terms of the mean wind speed and of the occurrence of high wind speeds.

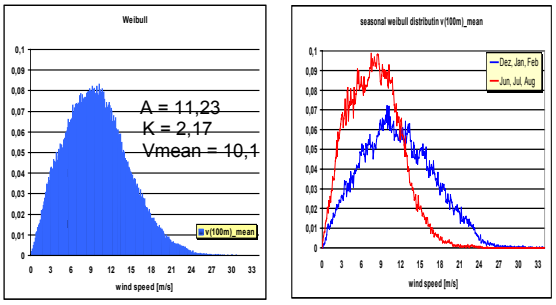

Fig. 3: Mean Weibull distribution and seasonal distribution for wind speed at 100 m height (Jan 2004 – Aug 2008)

In Figure 4 the significant monthly variations from the mean wind speed are represented clearly. But the data also show that there are strong variations concerning the individual years.
For example in 2003 and 2005 the winters were rather wind-weak in comparison to 2006 and 2007.

Thus the question arises to what extent the last five years can be accepted as being representative for wind conditions at the location?

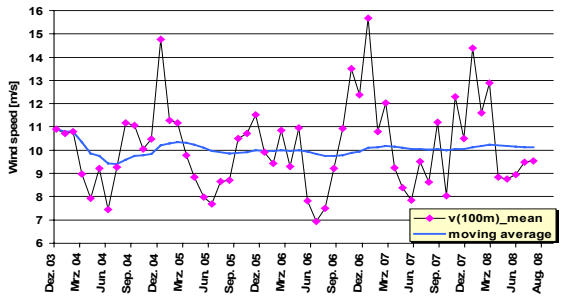

Fig. 4: Monthly mean wind speed at 100 m height (Jan 2004 – Aug 2008)

3.2 Long-term correlation

To decrease the influences of year-to-year wind variations, the data valid for the FINO1 platform for the 5-year period have been corrected to the long-term average by application of the meteorological long-term data of different long-term wind data sets.

Regarding the measured wind speeds at Fino1-platform in the period from September 2003 until August 2008 (Fig. 5), one recognizes that there is a good correlation for the relative course at 91.5 m height.

The comparison of the annual mean wind speed (Fig. 6) also shows good correlation between the different measuring stations and the underlying reanalysis data for the period 09.01.1998 – 31.08.2008 and leads to a scaling factor of 1.00 +/- 0.01.

Therefore they corroborate each other and confirm that the 5-year-period of the FINO1 measurement comprises average conditions in respect to wind speed. The wind direction distribution measured at FINO1 during 2003-09-01 – 2008-08-31 can be regarded as long-term representative.

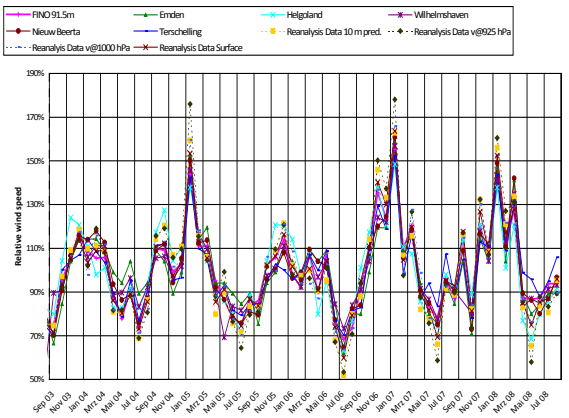

Fig 5: Relative course of monthly mean wind speed at 91.5 m height and long-term data (Sep 2003 – Aug 2008 = 100%)

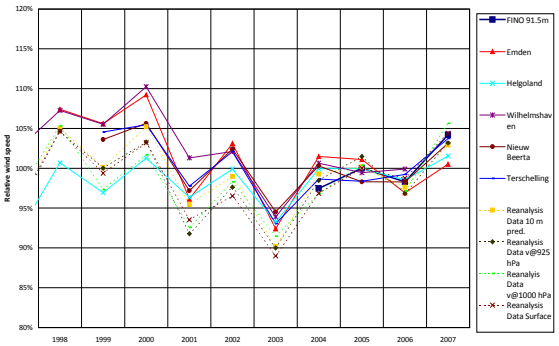

Fig. 6: Relative course of annual mean wind speed at 91.5 m height and long-term data (2004 – 2007 = 100%)

3.3 Wind direction

The mean wind direction distribution at Fino1 during the period January 2004 – August 2008 is shown in the figure below.

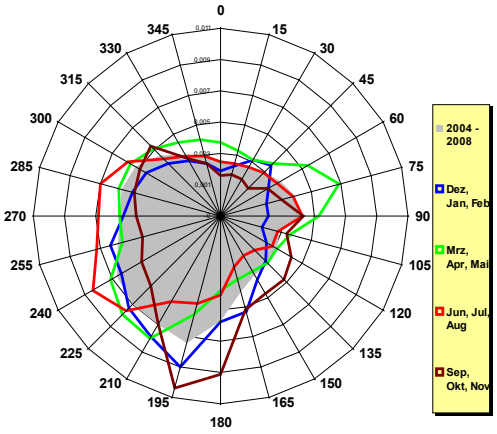

Fig. 7: Wind direction distribution during the period January 2004 – August 2008

Regarding the entire period, one could clearly recognize the dominating flow from western to southwest direction.

A seasonal consideration shows salient differences: Especially during spring, the wind distribution shows a further maximum from east apart from the main wind direction from the west. In autumn and winter the western wind directions, however, occur clearly more frequently than in the annual average.

Contrary to the wind speed, the wind directions measured at the different heights hardly show significant differences.

4. The vertical wind speed profile

Apart from the meteorologically caused influences on the vertical wind profile, the measuring mast itself has substantial effects on the measured wind velocities. E.g. shading and acceleration effects at the anemometers can arise as a function of the incident-flow direction.

One main target during the evaluation of the measuring data is therefore to obtain a wind profile that is to a large extent independent of mast influences.

In Figure 8 the speed profiles for different incident-flow directions are represented. Only measured values from the speed range between 5 and 12 m/s and for unstable boundary layer conditions (temperature in 30 m height more than 1°C higher than water temperature) were selected.

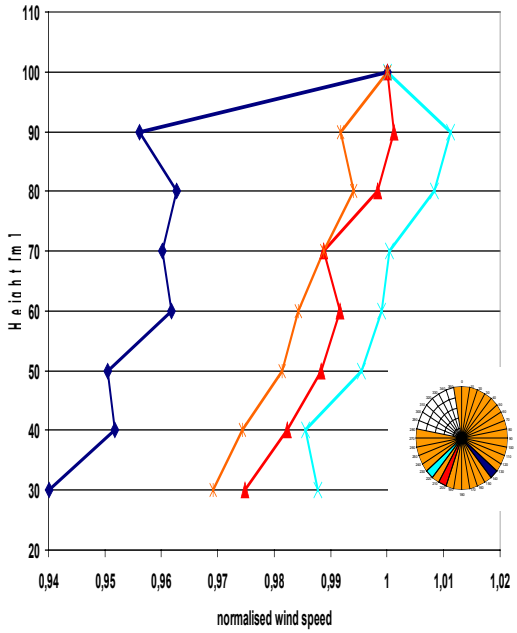

Fig. 8: Vertical wind speed profiles of normalised wind speed for different incident-flow directions

Due to the good mixing of air masses as well as the small turbulence here the wind velocity should be to a large extent identical at all heights.

The partial substantial variations in the profiles must therefore be attributed to the influence of the mast.

During the period 2005-11-15 until 2006-07-12 an additional top-mounted anemometer was installed on the FINO1 platform (see figure 9). The aim of this measurement campaign was to assess in how far the original top anemometer, mounted inside the lightning protector cage, may be influenced by the cage. The results of the measurements are represented in figure 10. The cage causes both shading and acceleration effects.

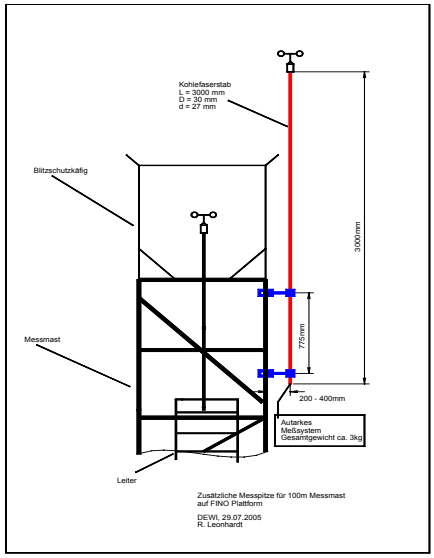

Fig. 9: Sketch of additionally mounted top-anemometer

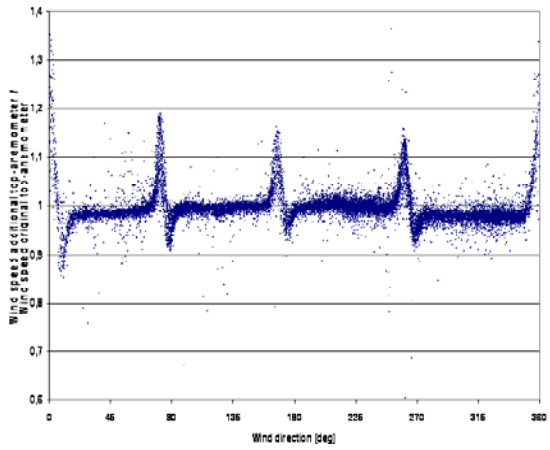

Fig. 10: Ratio of wind speed measured at the additional top anemometer (103.5m) to the wind speed measured at the original top anemometer (102m).

In the next step, in order to eliminate all influences caused by the mast to the original top-anemometer, a correction for each 5° wind direction sector was carried out. Subsequently, from the data record reduced to unstable stratification, the wind sector with the smallest deviations from the expected wind profile (almost identical speed at all heights) was isolated and a correction profile was computed.

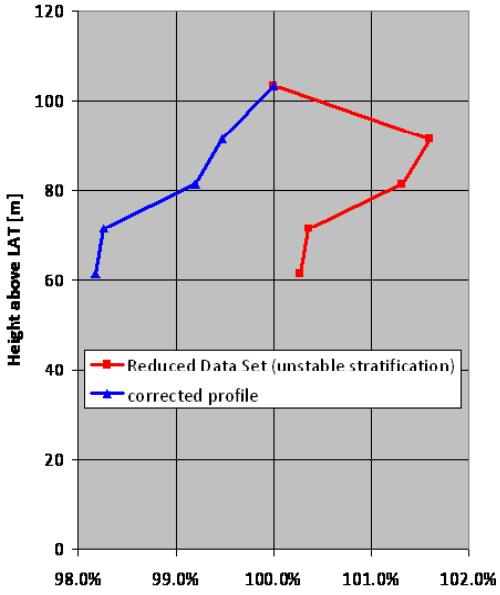

Fig. 11: corrected wind profile for unstable stratification

The computed correction profile is prevailing for the wind speed at the Fino1 platform during unstable conditions. In the last step the original FINO1 wind speed data, reduced to unstable conditions, is compared to the correction profile. The resulting wind direction depending factors are applicable for the entire Fino1 data set.

5. Temperature profile

The thermal stratification in the boundary layer has a decisive influence on the vertical wind profile. Hence, the exact capture of the temperature in the different heights of great importance.
Figure 12 shows the temperature course, based on 6-hour averages for 40 m and 100 m height, as well as the monthly mean temperature of the water surface for the period January 2004 – June 2008.

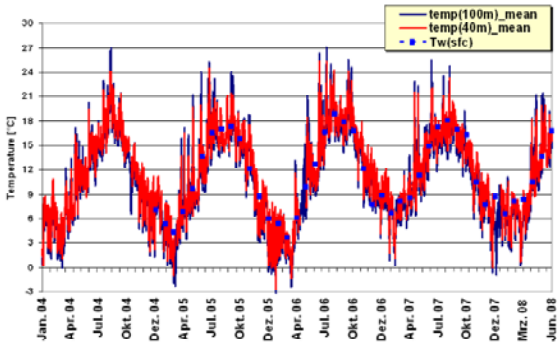

Fig. 12: 6-hour mean temperature in 40 m and 100m height and monthly mean water surface temperature

The mean temperature is 10.7°C (100 m) or 11.9°C (40 m). Only on a few days the mean temperature fell below zero degree and also values greater 24°C were reached rarely during the past five years.
In Figure 13 the ratio of 100 m to 40 m of temperature is shown. The advection of warm air over cold water leads to a stabilisation of the boundary layer. In spring a cumulative appearance of inversion could be observed.

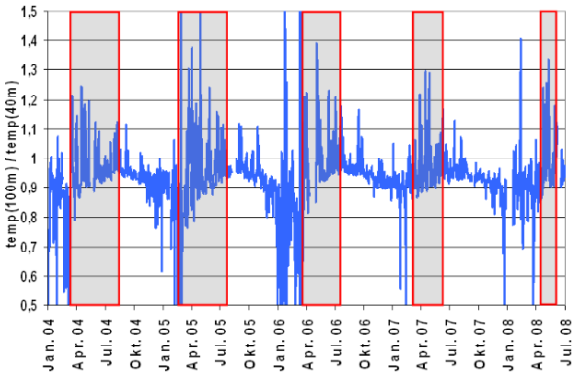

Fig. 13: Ratio of temperature measured at 40 m and 100 m height

The verification of the temperature profile measured at Fino1-platform by comparison with nearby measuring stations [3] indicates a good correlation for the courses.

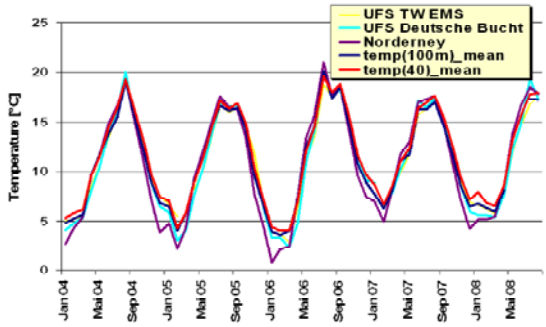

Fig.14: Temperature profile based on monthly mean values

6. Outlook

In the next years in the direct neighbourhood to the Fino1-platform numerous wind parks will be established. The Fino data collected so far already form a good basis for the evaluation of the locations under meteorological and hydrographic criteria. The Fino1-project was extended by another three years, so that also in the future interesting measuring data are to be expected.

References:

[1] Bundesamt für Seeschifffahrt und Hydrographie, Hamburg

[2] NOAA-CIRES Climate Diagnostics Center: NCEP Reanalysis data, Boulder, Colorado, USA, available at the Web site at http://www.cdc.noaa.gov/.

[3] www.wetteronline.de