depend on the specific farm layout and meteorological conditions. It is not expected that reliable large-scale farm optimisations can be done with those correction models.

Overdue consideration of CFD in IEC standards
Lastly, CFD methods must be more considered in IEC standards. This is because these models are now standard engineering tools and one must take advantage of their potential for precision wind modelling. It is possible to have well defined technical standards for the CFD models and their application. Additionally, Round-Robin Tests, that are common in many other technical areas, are well applicable to CFD wake modelling techniques.

8. Acknowledgements

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Three Years Operation of Far Offshore Measurements at FINO1

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Summary

The FINO1 platform 45km off the island Borkum is equipped with a 100m met mast. The long term meteorological and oceanographic conditions in the North Sea are recorded. We can now report about more than three years of measurements at this far offshore site. The overall experience with the system is good. The stability of the devices as well as the good data connection made it possible, to operate the long term measurements at a higher data rate as designed in the planning phase. An averaging interval of 1min is realized, most of the sensors are also recorded at their basic sampling rate of 1 sec. The structural dynamic measurements were working without serious damage until the 1. Nov 06, where one single extreme wave event (>15m) destroyed parts of the cable booms. In this report we will summarise the main observations made by the standard measurements.

Introduction

Fig. 1 shows a photo of the FINO1 platform shortly after its erection in 2003. Scientists regularly visit the plat-

The FINO1 platform project is financed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

form to work on technical and biological research projects. Because of the distances to be covered and the difficult boarding manoeuvres from ship to platform, the preferred means of transport is by helicopter. The position of the platform next to the planned German offshore test site is given in Fig. 2, where the approximate travelling times are also given.

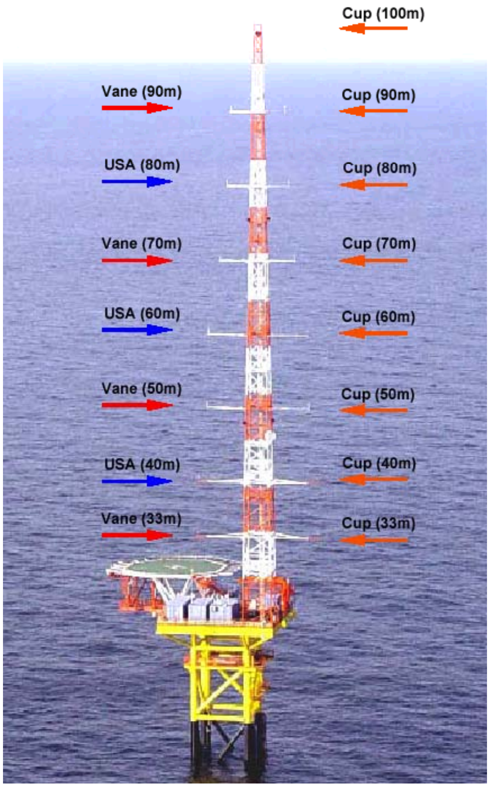

Fig.1: The FINO1 – Platform in the North Sea

In Fig. 1 the positions of the sensors for wind speed and wind direction have been marked with arrows. A series of identical cup anemometers has been arranged on the south-east side facing away from the platform which measures the long-term wind speed at eight different height levels (33.5 to 102.5 m). The platform thus provides one of the most complete continuous wind measurement and meteorological data sets in the offshore area world wide. On the north-west side of the mast, wind vanes are installed at 33, 50, 70 and 90m height to determine the wind direction. High-resolution ultrasonic anemometers (USA) are installed at the intermediate levels (40, 60 and 80m). They not only provide data on short-term fluctuations of the wind flow (turbulence), but by means of the 3-D wind vector are also capable of recording the horizontal wind direction and vertical wind flows. Since they are arranged at a position of 180° to the cup anemometers they can provide an additional measurement of the wind speed at the lower levels when the wind is coming from the north-west and the cup anemometers are therefore lying in the wake of the met mast. Other sensors are measuring the meteorological standard parameters such as temperature and humidity and irradiation at different levels.

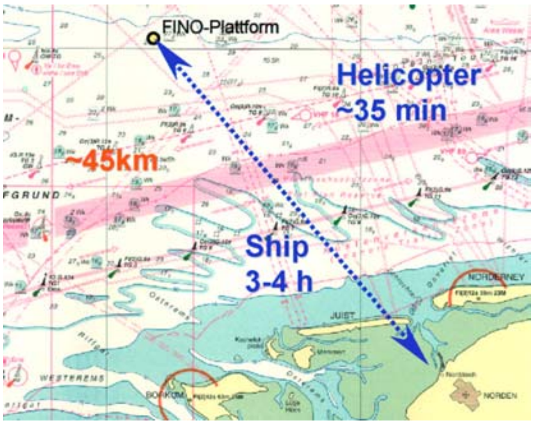

Fig.2: Location of the FINO1 platform 45 km north of the island Borkum

Availability of measurements

Overall data availability for the main meteorological sensor devices lies above 97% for the years 2004-2006. Though the original design would achieve a higher availability the overall data yield with the higher resolution data at 3% sporadic loss outperforms a 100% availability with only 10 minutes averages. Data for the ultrasonic anemometers (USA) at 10Hz is available for about 84% of the three years period. They are connected with the fast measuring system that has higher offline rates due to its design.

Time series of mean conditions

Long Term Wind Speed

For the wind energy use the most important parameter is of course the long term wind speed. Fig. 4 shows the development of the average wind speed from 2004-2006. At each time step of the graph, all dated back data was used to calculate the mean value. As a result you see the stronger variation of the wind speed in the beginning. Starting in the high wind Winter/Spring season the first values are too high. With more data the average value stabilises, the last windy months raise the whole time average again just below 10m/s. The related Weibull distribution has an A value of 11.3 m/s and a shape parameter k=2.2.

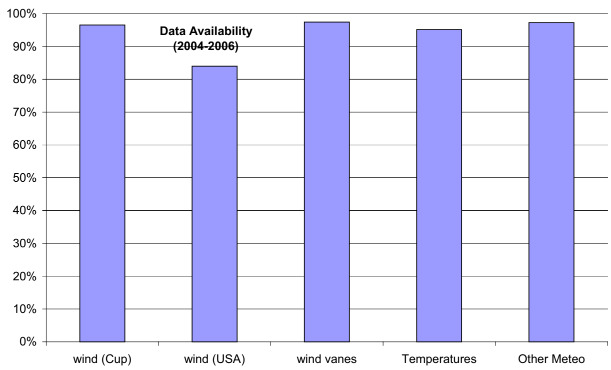

Fig.3: Three years availability of the main meteorological sensor devices.

Long Term Wind Direction

The distribution of wind speeds in Fig. 5 reveals more or less the expected behaviour. The main wind direction is South-West with additionally high contribu-

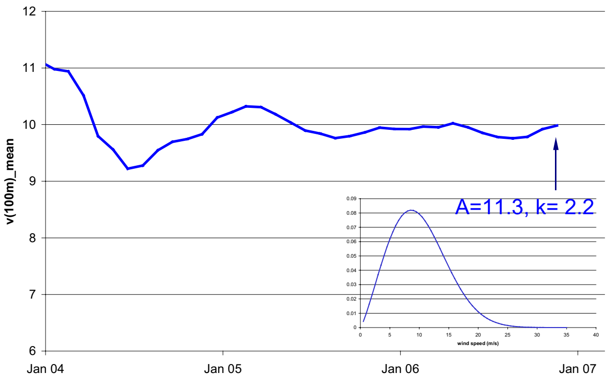

Fig. 4: Long Term wind speed average as it stabilises during the three years period (2004-2006)

tions from North-West. Looking at the averages, not much difference can be seen between the 90m and the 33m level. In contrast to this, a high wind angle difference of more than 30 degrees can be seen for special cases of high atmospheric stability.

Sun Irradiation

The horizontal global irradiation of the sun is measured as an additional parameter. It has an indirect influence on the local atmosphere. For instance by heating up the top water layers. It can also explain some falsified temperature profiles when the sensor shield is heated up, especially at low wind speeds. The warmed up platform deck may cause increased values for the low sensor levels of 33 and 40m. Of course the seasonal variations are strong. No correction for a slight pollution of the sensor glass has been carried out, which means that the measured energy sum of about 1000kWh/year is a value that could correspond to the impact on an unattended photo voltaic solar panel.

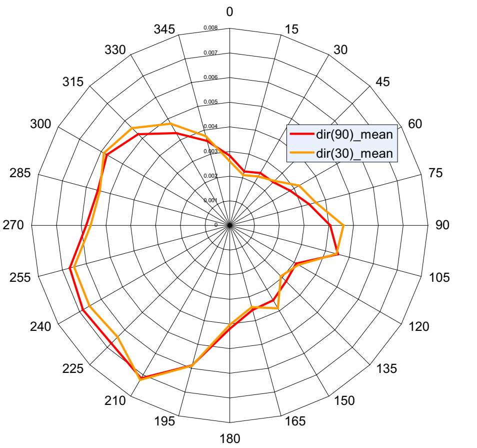

Fig. 5: Distribution of wind speeds as measured at 33m and 90m height (period 2004-2006).

Temperatures

In Fig. 6 the time series as mean of all measured temperatures (33-100m) are shown. The dark blue line corresponds to the weekly average, the thermal energy of the water rules out high seasonal changes, as the maximum spread for this average value is only 20°C. Furthermore the weekly averages never fall below 0°C. Minimal and maximal temperatures are given by the blue and the orange line. For only a short period, low negative temperatures can be found. In summertime the warmest periods correspond to a temperature maximum of 27-28 °C.

Looking at the probability distribution of temperatures of the 100m and the 33 m level an overall shift of the temperatures according to the potential temperature law can be seen. It is also obvious that the extreme values of the temperature are more pronounced at the 100m level which is obviously less connected to the water temperature.

The same behaviour can also be seen on Fig. 9, where the 100m and the 70m temperatures are plotted against the 70m temperature value. As long as the temperatures remain under the water value of 19.5 °C a height dependent constant shift of the temperatures can be observed. But when the air temperature exceeds the water temperature level, the temperature layering is inverted. Extreme values of a temperature increase of more than 5°C from the 33m up to the 100m level were measured in August 2005.

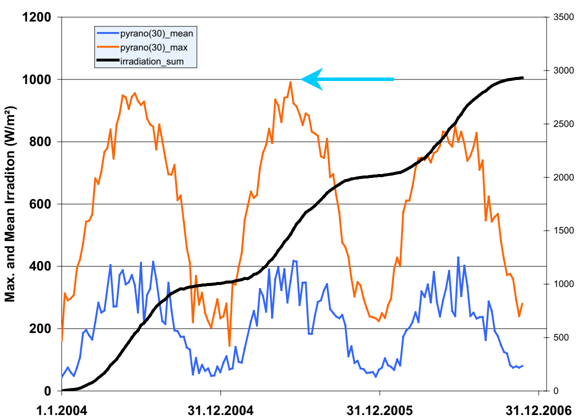

Fig. 6: Mean and maximum global irradiation in the horizontal plane. An average irradiation energy of more than 1000kWh/m² can be found, marking out the FINO1 platform also as a good site for solar energy use.

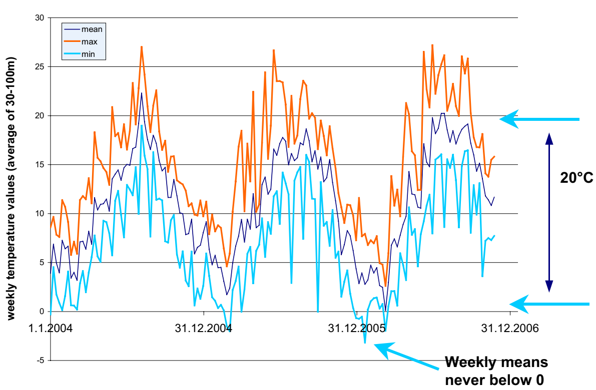

Fig. 7: Time series of the weekly means of the temperatures (mean values from 33-100m) added by the associated minimum and maximum value for each week.

Humidity

The time series for the humidity (average of all heights) does not reveal any seasonal dependence. Maximum values of 100% can be found all over the year and minima lie in between 40-60% relative humidity. The weekly mean values always stay in the range of about 80%

The probability distribution for the humidity on 100m and at 33m height show a similar picture. Saturated conditions of 100% relative humidity are preferred on both levels. A remarkable difference can be found for the lowest relative humidity values. For the 100m level dry periods are more common, which corresponds to warm and dry air layers, that do not reach the sea surface regions.

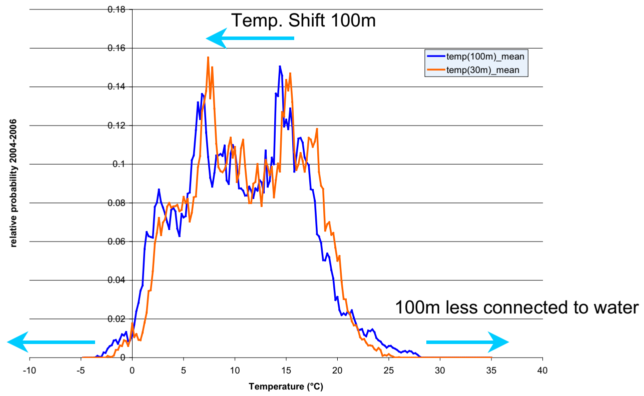

Fig. 8: A probability distribution of the temperatures on 33m (orange line) and 100m (blue line). An overall temperature shift of the 100m level, according to the potential temperature law can be seen

Time series of extreme conditions

Extreme values for the wind speeds (10min averages and 1 sec. gusts) are plotted in Fig. 12. As expected, a clear seasonal dependence can be seen. Maximum values 1 sec values of about 80 km/h (22m/s) are quite typical for summer months while in the winter period extremes of 100km/h (28m/s) are typically exceeded. An extreme value for the 1 sec. gust was observed at 8.1.2005 (148km/h or 41m/s) and the three years maximum was detected at 31.12.2006 with 164 km/h or 45 m/s respectively (Fig. 13).

An extreme wind situation, that corresponds to an extreme wave and water level situation took place on 1.11.2006. It was the only storm where noticeable damage was caused to the measuring devices, especially for

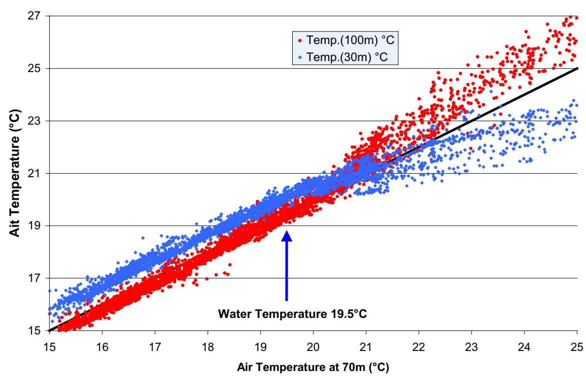

Fig. 9: Plotting the 100m and the 33m temperature values against the 70m temperature reveals an inversion of the temperature layering that is connected to the relation of the air temperature to the water temperature

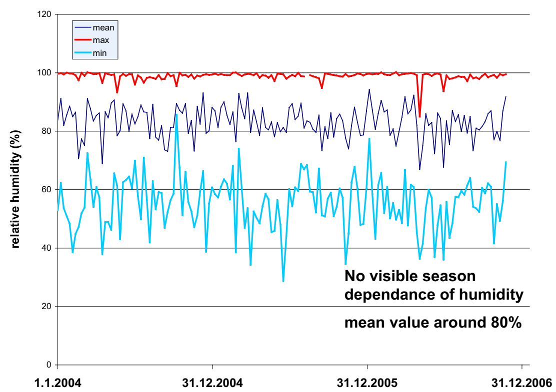

Fig. 10: Time series of the weekly means for the relative humidity (height average). No seasonal dependence can be detected. Mean values stay constantly in the range of about 80%.

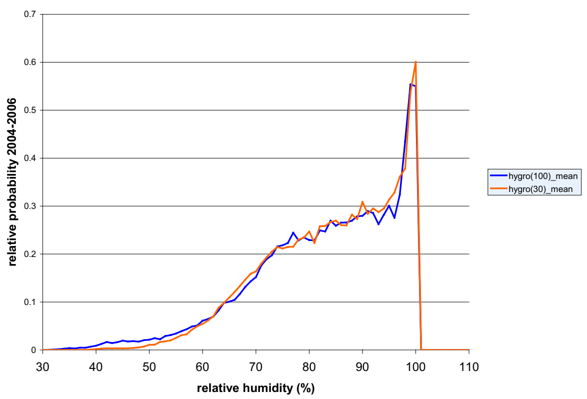

Fig.11: The probability distribution of 100m and 33m level show a preference for saturated conditions of 100% relative humidity

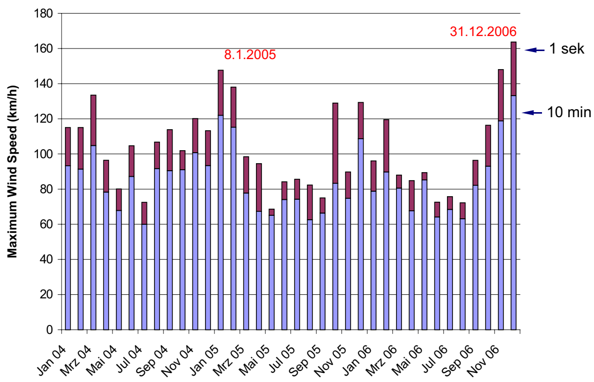

Fig.12: Extreme Values for the 10min average wind speed at 100m level and for the 1 sec. gust. The three years extreme value was detected on 31.12.06 a short term maximum of 165km/h

the strain gauges and acceleration sensors at the support structure of the FINO1 platform. Waves with a maximum height of more than 15m rushed through the walkabout below the main platform deck and destroyed about 50% of the cable booms that were fixed to the railing. The severe water pressure that was caused by extreme orbital speeds of the waves can be seen in Fig 14.

The waves nearly touched the 20m deck, an impressive example of water forces caused by waves is shown in Fig. 15. The massive steal protection of the ladder from the 20m down to the 15m level was completely compressed along a vertical length of about 3m. A description of the wave situation can be found in the corresponding article of Kai Herklotz in this magazine.

Outlook

Three years of FINO1 measurements show that a long term meteorological measurement can be run with high availabilities. The O&M of the measuring devices is simplified by the easy access with Helicopter. Instruments can be exchanged or repaired more or less all over the year. The stability of the devices as well as the good data connection made it possible, to operate the long term measurements at a higher data rate as designed in the planning phase. An averaging interval of 1min is realised, most of the sensors are also recorded at their basic sampling rate of 1 sec. Therefore long term series of 1 sec. wind speeds can be produced to study turbulence effects on a range from below 1 second up to half a year and more. After repairing the storm damages in spring 2007 it should be possible to operate 100% of the meteorological and about 90% of the structural dynamic devices.

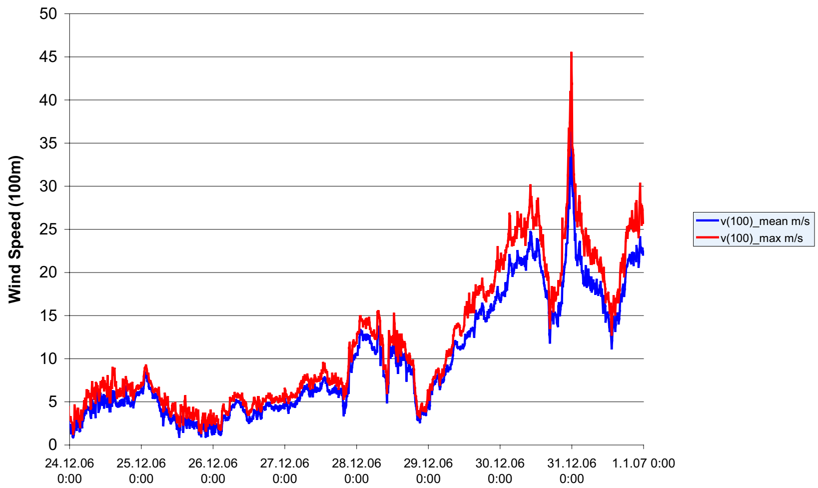

Fig.13: Time series for the three years extreme event on 31.12.06. A short term maximum of the 100m wind speed of about 165km/h was measured.

Fig.14: High orbital speeds of the extreme waves on 1.11. 2006 have torn away the railing of the 15m walkabout and destroyed 50% of the cables which connect the structural dynamic sensors to the platform main deck.

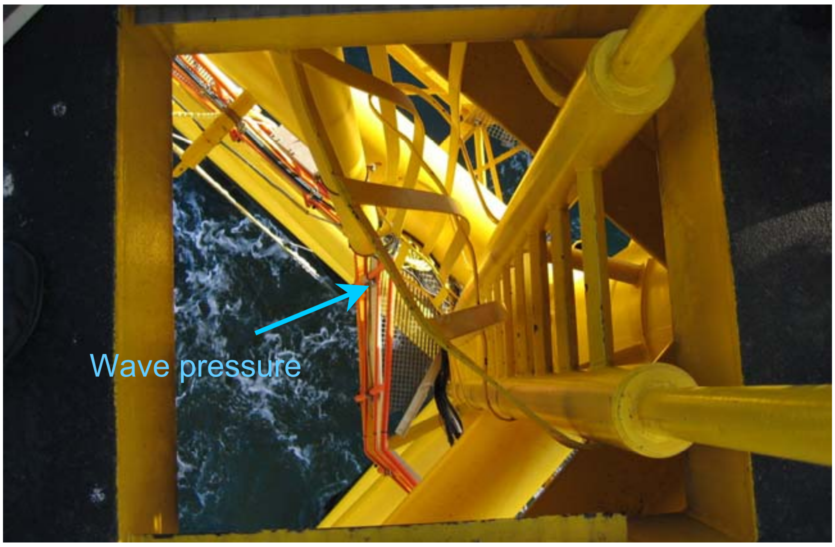

Fig.15: An impressive example of the water forces is seen by the complete compression of the ladder protection just below the 20m level.