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NORCOWE Reference Wind Farm

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Annual report

norcowe
Norwegian Centre for Offshore Wind Energy

Welcome

Alf Holmelid, Senior advicor, University of Agder

Reducing greenhouse gas emissions is one of the major challenges facing the global society today. Major changes in the energy and industry sector are necessary to avoid a rise in the average global temperature above two degrees. This is a big challenge, but also a big opportunity. A large global market for green technologies is emerging, and the development of environment-friendly energy technologies is taking place at a very rapid pace. The new market represents a major opportunity for Norwegian industry.

The energy sector has played an important role in Norway for a long time, and we have a long history and a strong position in offshore technology and material production. These industrial traditions are a solid base for taking a strong position in the global market for green technology. Over time, the Norwegian industry has shown the ability to adapt to new challenges and stay competitive in demanding markets. Among other factors, the early introduction of environmental regulations led to technology development that gave Norwegian industry a leading international position. Now the industry has the possibility to go a step further and take a leading position within environmental-friendly technology.

Public funding for research and development is essential to take a lead in green technology. The FME scheme is a dedicated, long-term initiative targeted towards solving climate and energy challenges and promoting industrial development. The FME centeres have built up internationally leading research groups in the field of energy research and fostered closer cooperation between the business sector and the research community. There is, however, a potential for even closer and more strategic collaboration between research and industry in this field. Some of the technologies are still immature, and long term investment and industrial ownership are needed to bring the technology to the market. This calls for a strategic cooperation between the industry and the authorities.

To develop environmental-friendly energy solutions we often have to take an inter-disciplinary approach. In NORCOWE we combine engineering disciplines with meteorology and oceanography, and this has shown to be a very fruitful approach. Knowledge about wind and waves combined with knowledge about design for and operation in the actual wind and wave conditions are a key to success in offshore wind energy. This inter-disciplinary approach was a guideline for the research activities in NORCOWE again in 2014. One example is the research activity combining condition monitoring with weather data for maintenance planning. To capture relevant and reliable data, a comprehensive offshore measurement campaign was planned for 2014. Due to unexpected obstacles, the campaign was canceled and a new campaign is scheduled for 2015. However, some of the research goals for the planned campaign were achieved by means of smaller measurement campaigns.

NORCOWE partners now own research facilities and instrumentation needed for meteorological, oceanographic and structural monitoring and investigation, as well as motion compensation. Accurate measurements and flexible test facilities are important infrastructure for developing reliable mathematical models and new technology concepts. These assets are valuable for the offshore wind industry and offshore industry in general. As an example, a number of motion reference units (MRU) have been tested using the motion platforms at University of Agder. The industry continuously asks for a higher technology readiness level (TRL). Therefore, models and test facilities are becoming increasingly important. Mathematical models, instrumentation and labs built up by NORCOWE are valuable assets for further research and innovation in the field of offshore wind energy and offshore operations in general.

Dear reader
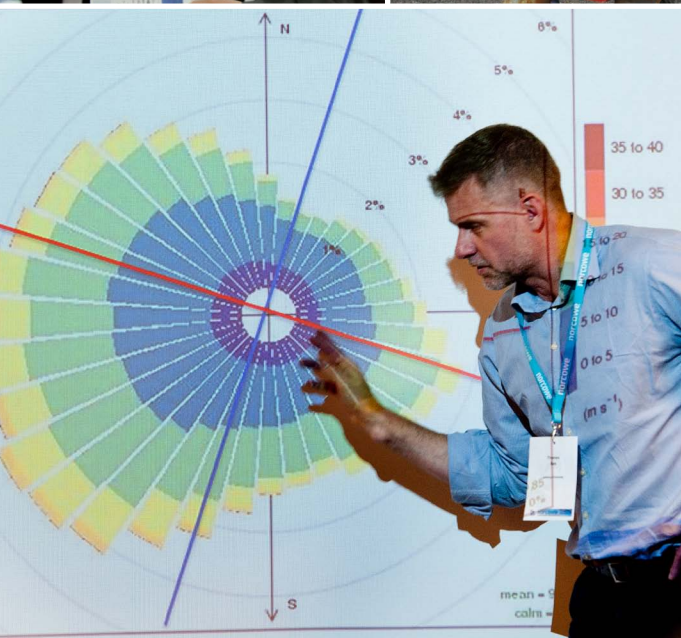
NORCOWE has now been in operation for more than five years. Results have been produced and presented, but it is always an issue to increase the impact of the work performed in NORCOWE.

Joint projects between user partners (industry) and scientific partners are one way of doing so. Workshops and scientific meetings with exchange of knowledge is another tool.
In 2015, there will be a stronger focus on commercialization and utilization of the results, bringing some of the results from NORCOWE into practical application in the industry.

NORCOWE partners have strengthened their international and national cooperation on offshore wind energy during 2014.
NORCOWE also established a new partnership with FLiDAR who joined 1 January 2015.

This annual report presents scientific work and selected results together with the Centre Management Group and the new PhD students.

The second part of the report presents topics like the NORCOWE summer school, international cooperation and public outreach. The list of publications is not included in the report, but it is available at our website.

The current (2015) NORCOWE work packages are:
WP1: *Met/ocean data - Measurements and database*
WP2: *Wind energy estimation - Wind resource assessment, energy yield and layout for offshore wind farms*
WP3: *Design, installation and operation of offshore wind turbines*

This annual report is not a complete overview over NORCOWE, but it is meant to give you a grasp of NORCOWE. Please visit our website for news from NORCOWE or sign up for our newsletter by sending an email to post@norcowe.no . Please feel free to contact us if you want more information.

I hope you will enjoy reading our annual report!
Best regards,

Kristin Guldbrandsen Frøysa
Director NORCOWE

Design and realization of offshore measurement campaigns

Benny Svardal, CMR; Martin Flügge, CMR; Mostafa Bakhoday, University of Bergen and Joachim Reuder, University of Bergen

Reducing the total cost of energy is the primary challenge for the offshore wind industry. The partners in NORCOWE strive to achieve cost and risk reductions along with performance optimization in the whole value chain for offshore wind energy, e.g. through the development of novel tools and models for improving wind resource assessment accuracy, determining turbine and foundation design criteria, planning efficient marine operations, and optimizing wind farm power performance.

The meteorological and oceanographic conditions of an offshore site are key parameters to be taken into account over the whole life cycle of an offshore wind farm. Site assessment, planning and design of the turbines and support structures, wind farm layout, the determination of weather windows for installation and maintenance and the accurate prediction of the power production within the next hours and days are all crucially dependent on a profound understanding of the met-ocean conditions and their appropriate parameterization in our numerical model tools.

While the atmospheric boundary layer over land has been investigated in detail for more than five decades, our understanding of the physical processes within the marine atmospheric boundary layer (MABL) is still very limited. This is highly due to the limited accessibility for meteorological measurements offshore. The new generation of offshore wind turbines creates a demand for detailed characterization of the MABL to an altitude of 200-300 m, matching the increased swept rotor disk area.

Data available from meteorological masts in the North Sea are limited to point-measurements of meteorological parameters such as wind speed and direction, temperature and humidity at a few predetermined altitudes with the highest measurement level at around 100 m above sea level. The development of lidar anemometer technology has enabled remote measurement of wind profiles up to and beyond the altitude of interest. However, simultaneous temperature and humidity profiling to the same altitudes is essential to enable a proper characterisation of the boundary layer stability, and very little data including these measurements are available so far.

In order to address the massive lack of observational meteorological data in key altitude ranges offshore, the acquisition of measurement data with sufficient quality and continuous duration from both the MABL and the OML (oceanic mixed layer) has become a prioritized activity within NORCOWE. The collection and analysis of such datasets are important for an improved understanding of the relevant physical processes. Proper verification data is also essential to validate and improve numerical tools, instruments and method developments related to floating measurement platforms, for example.

FINO1 offshore campaign

Benny Svardal, CMR; Martin Flügge, CMR; Mostafa Bakhoday, University of Bergen and Joachim Reuder, University of Bergen

To close some of the existing gaps between the demand and the observational data availability, NORCOWE aims to perform a field campaign at the German research platform FINO1 from May 2015 to June 2016. The campaign will be carried out by CMR and UiB on behalf of NORCOWE, in cooperation with RAVE, FuE-Zentrum FH Kiel as platform operator, and Fraunhofer IWES and FORWIND as research partners.

One of the key purposes of the campaign is to provide unique datasets for the study of boundary layer stability in undisturbed offshore conditions by simultaneous measurements of wind, temperature and humidity profiles in the MABL up to an altitude of 1000 m enabled by remote sensing technology. Additionally, the campaign focus will cover air-sea interaction, offshore wake propagation, and motion correction techniques for floating instrumentation platforms. Over the duration of the campaign, we seek to cover as many variations in weather and sea-state conditions as possible.

The FINO1 platform is located in close proximity to Alpha Ventus, the first German offshore wind farm, installed in the North Sea 45 km west of the island Borkum.

Meteorological parameters such as wind speed and direction, temperature and humidity have been collected at FINO1 since its operation started in 2003. Wave statistics such as significant wave height and wave speed and direction are recorded by radar from the platform and from a nearby measurement buoy.

NORCOWE plans to install two scanning lidar systems and a microwave-radiometer on the research platform to investigate the atmospheric stability around the wind farm, as well as the interaction of the Alpha Ventus wind turbines with the atmosphere and each other. The lidars will provide data on the wind speed in front of, within and behind the wind farm (up to several kilometers) while the microwave-radiometer will provide temperature and humidity profiles up to a height of 1000 m.

In additions to the meteorological measurements, oceanographic instruments mounted on two bottom frames, a submerged buoy, and the autonomous SailBuoy, will be deployed near FINO1 for a shorter period. This instrumentation will monitor wave statistics, surface currents and turbulence in the upper oceanic mixed layer. The collection of these data is essential for the estimation of turbine tower loads and scour formation. Moreover, these data are crucial for studying air-sea exchange processes, which are known to influence the structure of the wind profile and the atmospheric stability.

The deployed instrumentation will provide a highly versatile data set for investigation of the offshore wind profiles, wind shear and turbulence intensity as a function of atmospheric stability in and around the wind farm. The gathered data allows for the investigation of the structure, extension, dynamics and persistence of single turbine wakes and the near farm wake of Alpha Ventus.

Highlights from the WINTWEX-W campaign

Joachim Reuder, University of Bergen; Valerie Kumer, University of Bergen; Benny Svardal, CMR and Jan Willem Wagenaar, ECN

Purpose

A joint measurement campaign between NORCOWE and the Energy Center of the Netherlands (ECN) was performed in the period October 2013 until November 2014 at the ECN test site Wieringermeer in the Netherlands. The main purpose of this campaign was the characterization of the structure and dynamics of single turbine wakes by the extensive use of static and scanning wind lidar systems. A particular focus was set on the investigation of the effect of atmospheric stability on the strength and extension of the wake downstream the turbine. The experiences related to the long term deployment of lidar systems, the setup of data communication links and the development and test of measurement strategies and appropriate scanning patterns, constitute an important intermediate step in the NORCOWE project towards future offshore measurement campaigns.
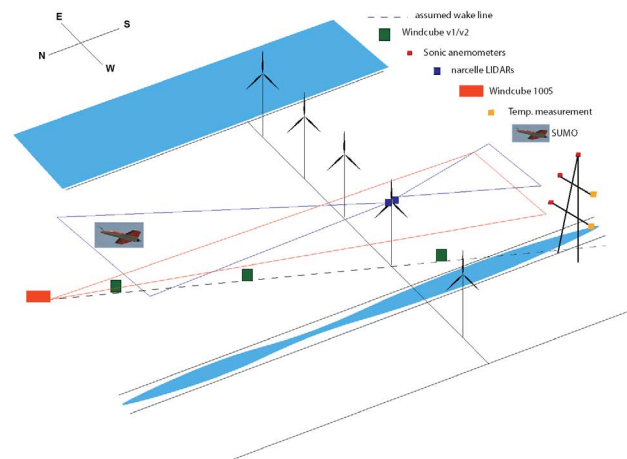

Figure 1: Schematics of the instrumental setup during the WINTWEX-W campaign

Measurement setup

The campaign was mainly based on the extensive use of static and scanning wind lidar technology. The instrumental setup is sketched in Figure 1. In addition to the ECN meteorological 110 m mast, equipped with cup and sonic anemometers, one scanning lidar (Leosphere 100S), four static lidars (Leosphere Windcubes v1 and v2) as well as a downstream looking nacelle lidar (ZephIR 300) were deployed in the period November 2013 until May 2014. The main aim of the campaign was the qualitative and quantitative description of single full-scale

wind turbine wake structure, propagation and persistency under various atmospheric conditions. The scanning wind lidar system (Leosphere WindCube100S) was located ca. 12 rotor diameters downstream of one of the wind turbines in the main wind direction. It was repeating a predefined scan pattern every minute, that consisted of a 60° azimuth sector at three different elevations (2.4°, 4.7°, and 7.1°, corresponding to nacelle height and bottom and top tip height close to the turbines) and three vertical cross-sections at a fixed azimuth angle of 228°. Additional static WindCubes v1 measured wind profiles every second at 2 and 4 rotor diameter downstream distances. Two other static WindCube lidars, a forward-looking nacelle LiDAR (Avent) and three sonic anemometers on
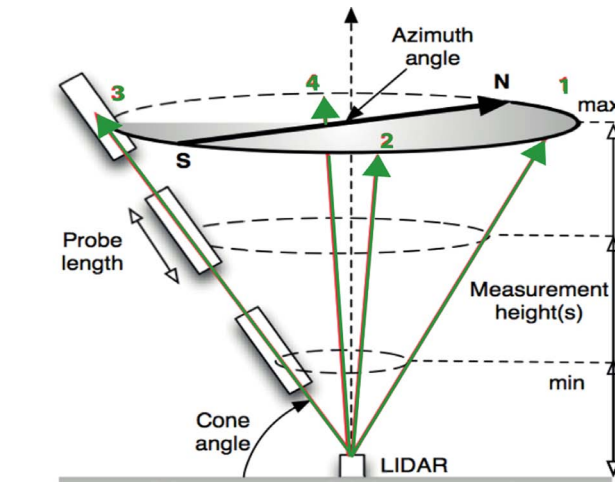

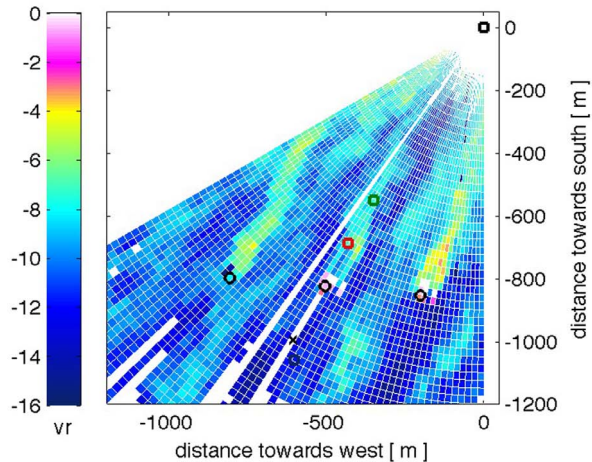Figure 2: Measurement principle of static Doppler LiDAR (WindCube v1) Courtesy Valerie Kumer

Figure 3: 60° PPI scan with 4.7° elevation angle cutting through hub hight of the research turbines. Colors show the radial wind speeds measured by the device while circles, squares and a cross indicate the position of the research turbines, the WindCubes and the metmast respectively. Courtesy Valerie Kumer.

the 110 m mast were placed upstream for a detailed characterization of the flow field approaching the wind turbines.

The comprehensive data set collected during the campaign is, at the moment, analyzed by the NORCOWE partners UiB and CMR and by our colleagues from ECN. In addition to the modellers in NORCOWE, several international research groups from outside the consortium have already indicated an interest in using the data for model validation purposes. A few results of the campaign are highlighted in the following sections.

4D wake mapping with a scanning lidar

An analysis of first horizontal scans of the scanning Wind-Cube 100 s shows that we could catch some of the meandering motion of the research turbine wakes, which is induced by adapting the yaw of the turbine to the upstream main wind direction. The wakes extended beyond 10 rotor diameter downstream distances, leaving the intended layout of the measurement campaign. On top of the research turbine wakes we could also catch wakes from the 2 kilometre upstream prototype turbines. Therefore, the wake deficit of the research turbines is varying between 4 and 8 m/s, dependent on whether the wakes are interacting or not (Figure 3).

Measurement of wake effects by the SUMO RPAS

During the last years NORCOWE has started to include remotely piloted aircraft systems (RPAS) in its portfolio of instrumentation for the investigation of wake effects. The SUMO system (Small Unmanned Meteorological Observer), a fixed wing aircraft with a length and wingspan of about 80 cm and a total take-off weight of below 700 g, was developed and is owned and operated by GFI/UiB. In the afternoon of May 10, 2014 the system performed several flights around the wind turbines at the test site in rather strong winds of 15 m/s as 10 minute average and slightly above 20 m/s in gusts. The wind direction was from the Southwest.

Figure 4 shows the results gained during the five flights performed. Presented is the East-West component of the horizontal wind speed (u) for flight legs ca. 1 rotor diameter downstream of the turbine row (position B, upper panel), compared to those for the flight legs upstream (position D; lower panel). The grey curves indicate the individual legs (13 for B and 4 for D) and the blue and orange lines represent the corresponding average values. The upstream background wind level in the u component is around 10 m/s (leg D, bottom panel). One rotor diameter behind the turbines the energy extracted by two of the turbines is documented by a clear reduction in wind speed reaching a maximum of around 3 m/s. The wind speed reduction of each of the turbines about 1 rotor diameter downstream covers a distance of about 150-200 m (one tick on the x-axis corresponds to 100 m).

The SUMO operations during the WINTWEX-W campaign have proven the capability of small and lightweight RPAS to measure wake effects in the vicinity of wind turbines. NORCOWE will continue to intensify the use of such small unmanned atmospheric measurement platforms, in particular for the detailed investigation of wake effects.

The effect of atmospheric stability on wakes
Averaging the profiles collected by the WindCubes v1 over a three months period (from November until January) shows similar results as the WindCube 100s with wind speed deficits varying between 4 and 6 m/s. Distinguishing the results between different stability classes reveals that wake deficits and turbulence intensities are strongest during stable atmo-

The opposite is happening during unstable conditions, when vertical motions are accelerated, leading to a vertically expanding wake, which recovers almost to upstream conditions at 4 rotor diameters downstream.

During traditionally modeled neutral conditions, wind resources are highest and turbulence intensities are lowest. However, this leads only to an above average power output for wind speeds below 10 m/s, as for higher wind speeds strong vertical wind shear may be an issue.

Figure 4: East-west wind component (u) for flight legs ca. 1 rotor diameter downstream of two of the five turbines at the ECN test site (position B; upper panel), and for flight legs upstream (position D; lower panel). The grey curves indicate the individual legs of the corresponding SUMO flights (13 for B and 4 for D), the blue and orange curve the corresponding averages.
Courtesy Line Båserud and Joachim Reuder.

Figure 5: Profiles of turbulence intensity (TI, left), wind speed (center) and actual power curve for different stability regimes. The solid lines represent the average, the dots in the left and center row indicate the standard deviation. The colors in the left and central panel correspond to the position of the lidar wind profilers (blue : upstream, red : 1.7 D downstream ; green : 3.5 D downstream), while in the right panel grey and black indicates data from the three months period and blue colors show stability dependent data. Courtesy Valerie Kumer.

Nacelle Lidar wake measurements
Parallel to the ground Lidar measurements, a ZephIR 300 Lidar with conical scan pattern was installed on the turbine nacelle from November 2013 until November 2014, in order to characterize the wake flow. These measurements are being compared with data from the met mast, ground lidars, and an Avent WindIRIS nacelle Lidar mounted in single-beam rear view mode on the same turbine for part of the project period. First results from the nacelle measurements will be presented at the EWEA Offshore Wind 2015 conference in Copenhagen.

spheric conditions. As we saw earlier the research turbines do not face undisturbed upstream flows but are influence by rather far upstream turbines. Therefore, the power output of the research turbine number 6 is altered during stable conditions. Wakes are trapped in a stable atmospheric layer and cannot mix easily with the ambient air as vertical motions are suppressed.

www.norcowe.no

Siri M Kalvig

StormGeo

Jostein Mælan, Head of Renewables, StormGeo

Over the last 3 years, StormGeo has built a strong brand in the North Sea offshore wind industry. Entering 2015, Storm-Geo Renewables provide Metocean decision support to 15 offshore wind projects – most of them in the installation and construction phase, others in the O&M phase.

Combined efforts from onshore wind experience and offshore oil and gas operations support, has been the main fundament in StormGeo's offshore wind market approach. The underlying strengths build on StormGeo's atmospheric and wave model competencies, always with a firm focus on quality, validation and customer feedback. It is fair to say that the close linking to NORCOWE has been vital in this work – especially to secure the full understanding and company commitment of the difference going from oil and gas to offshore wind.

NORCOWE has many exciting activities relating directly to R&D activities in StormGeo. We are a reliable and trustable supplier in this growing industry and the partnership with NORCOWE strengthen us in the important work of continuing this effort and constantly improving it. Examples are atmospheric and wave modelling and efforts on improving the general understanding of wind over ocean. Especially wind characteristics such as turbulence, wind profile variations and wake propagation are important. StormGeo's industry PhDs have always had a close link to NORCOWE: Olav Krogsæter focusing on atmospheric model schemes improving the wind estimates and Siri M Kalvig on the wind wave interactions

and how this influences offshore wind turbines. To secure international success for Norwegian based companies with an ambition in offshore wind, it is crucial to build and strengthen the Norwegian metocean heritage and culture.

Recent wins
StormGeo has been working with all the majors in offshore wind the last three years – RWE, Statoil, Statkraft, Forewind, SSE, Vattenfall and E-ON to mention a few. In 2014 we secured a seven year contact to support RWE at Nordsee Ost – the contract also includes aviation forecasting in addition to metocean forecasting and support. As activities at Dudgeon grow, StormGeo is now monitoring the weather and waves in the project on daily basis. The product portfolio now contains extreme weather alert services, onsite meteorologists, critera based metocean forecasting, aviation support and special purpose vessel response forecasting.

In 2015 and 2016 we look forward to the new NORCOWE offshore wind measurement campaign being established. On the roof of StormGeo's HQ, the lidars will be tested and calibrated before going offshore to the FINO1 platform. We are happy to offer our dedicated and enthusiastic 24/7 meteorologists to real time monitor the lidar performance and reliability over the first couple of months.

Siri M Kalvig, former PhD student at StormGeo and University of Stavanger

When was your PhD defense?
It was the 17th of November 2014 at the University of Stavanger.

Why did you go for a PhD?
I had a strong personal motivation since I am very concerned about climate change and I would like to contribute to the challenge of creating cleaner energy. The winds offshore represent a fantastic potential for clean energy and I wanted to be a part of the solution towards a more sustainable future. My PhD has been an industrial PhD in StormGeo and it is of course also linked to the growing offshore wind business area in StormGeo. StormGeo delivers weather forecast and business support to the wind energy business and my PhD has been a part of StormGeo's R&D effort to ensure better services for this industry.

What is your current position?
I am now working with offshore wind and other renewables in StormGeo.

How do you benefit from your PhD degree today?
In general, I now feel I have a much greater insight in the academic world and that helps in my current work. Specifically I have had the opportunity to develop a new simulation setup for wind turbine performance in the marine atmospheric boundary layer together with Acona Flow Technology and the University of Stavanger. I hope I will be able to still work with some of my findings during my PhD within my position in StormGeo and together with Acona Flow Technology and UiS. I think we have started something very exciting together!

"I have a much greater insight in the academic world and that helps in my current work"

Unexpected vertical wind profiles over the North Sea – on the route of the windjammers

Anthony Kettle, post. doc., University of Bergen

Over the past two decades there has been a number of offshore wind energy projects developed in the Baltic and North Sea areas, in many cases along the sea routes that that were once plied by large sailing vessels between Europe and other parts of the world. These offshore wind energy projects have been spawned by initiatives by European governments to develop sources of clean renewable energy to overcome problems with present energy sources that are based on fossil fuels and nuclear technology. However, the development of offshore wind energy is not without risks.

Offshore wind turbines have hub heights that extend up to 100 m – comparable with large commercial airliners. They have to be carefully designed not only to generate electricity profitably but also stay in operation with little maintenance over a 20 year lifetime in a turbulent wind field whose gust characteristics and short term variability are not completely known. It is important to understand the structure of the wind profile in the lower atmospheric layer not only to assess the available wind resource but also to understand the nature of the fatigue damage that accrues to a wind turbine during operation. Presently, wind turbines are designed and evaluated using simplified parameterizations of vertical wind speed. Decades of land-based tower measurements have built up a paradigm that the wind speed profile should increase approximately exponentially with height with modifications to take account of heating or cooling effects at the land-air interface. The oceanographic measurements that have been conducted from research vessels in the lowest 30 m of the atmosphere over the open ocean have tended to confirm this paradigm. This body of measurements is mathematically formalized within Monin-Obukhov theory, which gives a set of self-consistent rules to understand the structure of the lower atmosphere and the fluxes of heat, water vapour, and momentum from the ocean surface. However, recent measurements at high meteorological towers at offshore wind farm locations in Northern Europe have begun to reveal unexpected features in the vertical wind speed profile. FINO1 is one such mast among several now located around the North Sea (Figure 1a).

FINO1 was constructed in 2003 just north of the island Borkum as part of a German government initiative to construct many wind parks in the far offshore region to meet a request for more renewable energy in the country's future energy mix.

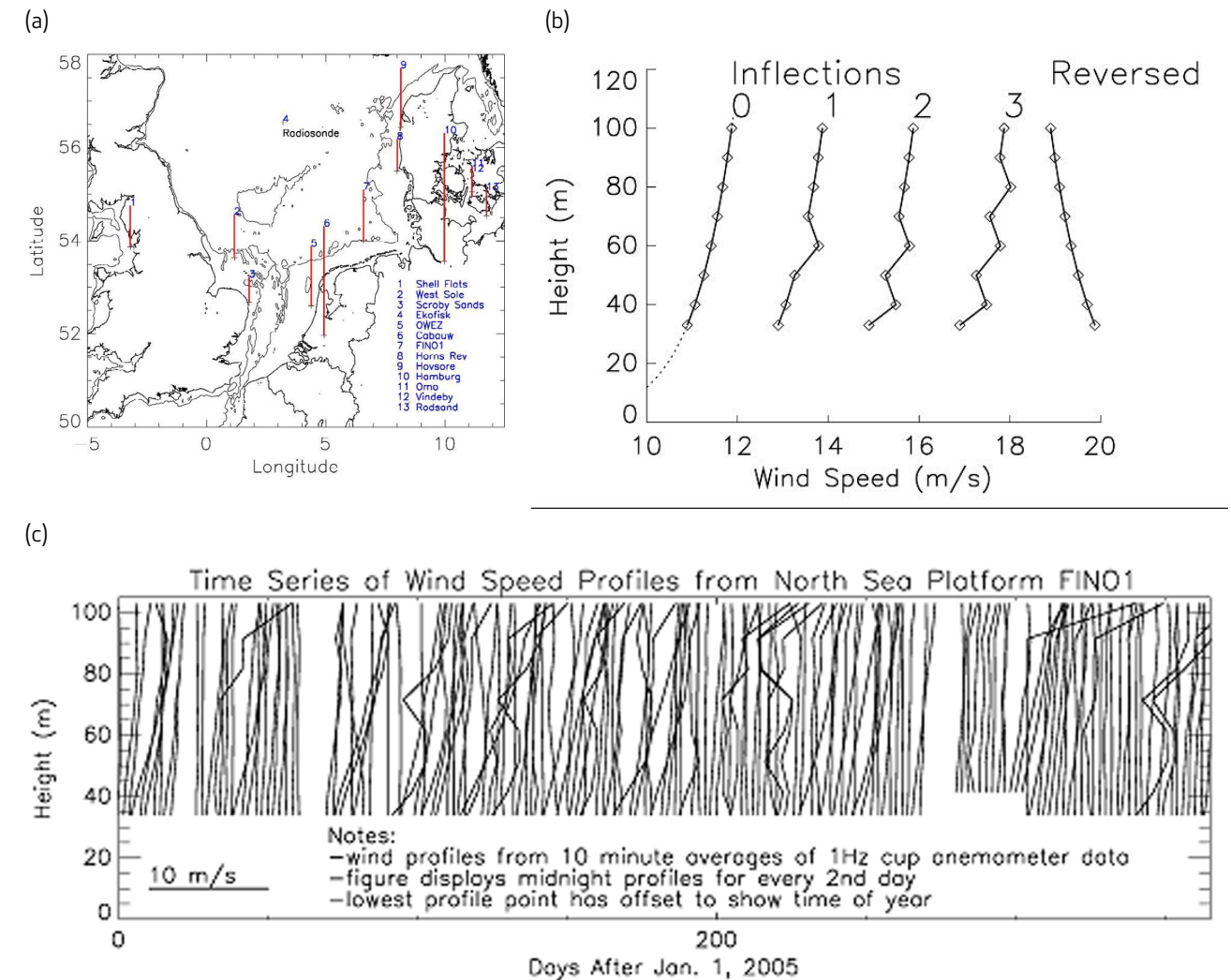*Figure 1 (a). Location of FINO1 in the southern North Sea with other high meteorological masts and installations in Northwest Europe, (b) wind speed vertical profiles (10 minute average of 1 Hz data) at midnight for every second day of 2005, and (c) schematic diagram of the possible number of wind speed inflections and vertical profile configurations from a vertical array of 8 cup anemometers.*

The FINO1 mast has instrumentation that stretches from the seabed up to 100 m into the atmosphere over the sea surface. The measurement project has provided new and important insights into the dynamics of atmospheric and oceanographic processes in the North Sea, as well as wave processes that are important for the design of offshore marine structures. For offshore wind energy, one of the surprises has come from the analysis of the vertical array of cup anemometers that shows the presence of inflections or 'kinks' in the vertical wind profile especially for certain wind speeds and directions. The cascade diagram in Figure 1b illustrates that the measured wind speed profile can sometimes be complicated. The vertical array of 8 cup anemometers on the FINO1 mast can show up to three inflection points and even reversed profiles as shown in the schematic in Figure 1c. Some of the other high offshore meteorological towers in the Baltic Sea and North Sea have revealed similar features. The problem is associated mostly with internal boundary layers that propagate from nearby coastal areas and cause a two-layer or decoupled boundary layer at the location of the offshore mast. The height of the internal boundary layer depends on distance from the coast as well as the turbulent mixing effects of wind speed. Low level offshore jets in offshore regions have also been observed. Internal boundary layers

had previously been recognized for the enclosed Baltic Sea, but the documentation from FINO1 site is unexpected given the prevailing westerly winds and the long distance to the nearest the coastal area. The issue is a potential challenge to offshore wind energy in the construction of larger turbines to take advantage of generally higher winds aloft at the expense of the complicated and potentially damaging turbulent flow patterns.

In addition to the offshore meteorological masts, extra information sources about internal boundary layers over the ocean are available from earlier studies of coastal air pollution, radar propagation, and aircraft turbulence that stretch back through the Cold War and before. Even the old-time windjammers have their message for the modern offshore energy industry with practical advice in Maury's classic book on Sailing Directions of 1852 to beware of the wind shadow zones that can extend far over the horizon. Further information about the complicated wind profiles in coastal regions and historical background into their investigation is presented in A.J. Kettle, Unexpected vertical wind profiles in the boundary layer over the southern North Sea, Journal of Wind Engineering and Industrial Aerodynamics, 134, 149-162, 2014.

Line Båserud

What is your scientific background?
I graduated at Geophysical Institute, University of Bergen with a MSc in meteorology in 2013. During my master project I started to work with the characterization and application of the turbulence measurement sensor adapted to the Small Unmanned Meteorological Observer (SUMO). After this I worked for 9 months as a research assistant in the experimental meteorology group at GFI, continuing the activities of my master project in a collaboration project between GFI and Statoil. In addition I gained experience in the quality control and basic data analysis of the FINO3 offshore data set.

What topic is addressed in your PhD?
The topic of my PhD is the investigation of boundary layer turbulence using direct measurements from Remotely Piloted Aircraft Systems (RPAS). I will work with both SUMO and a new quadcopter system that was purchased recently at GFI. The goal will be to improve our understanding of turbulence and turbulent exchange processes under different atmospheric conditions. The main focus areas of my PhD project will be stable and convective boundary layers and the interaction between the atmospheric boundary layer (ABL) and wind turbines, in particular single turbine wake effects.

Why do you address this topic?
With the increasing focus on renewable energy, and in particular the fast development of wind energy, knowledge of the interaction between the ABL (Atmospheric Boundary Layer) and wind turbines become more and more important. The development of small RPAS during the last years has made these highly flexible platforms suitable sensor carriers for measurement of the relevant atmospheric parameters. The goal is to improve our understanding of the transition periods between the different boundary layer regimes, and to capture the downstream extent of wind turbine wakes as a function of synoptic situation and atmospheric stability. This will provide wind turbine producers and wind farm operators with data sets and knowledge that will in the future increase the life time and power output of wind turbines and wind farms.

How is your work linked to NORCOWE?
This PhD project is linked to WP1, and will focus on the further development, qualification and application of novel and promising measurement platforms for wind energy applications such as wind turbine wake studies. The data collected by the RPAS will complement the other measurement platforms already used within NORCOWE, such as wind lidars, microwave temperature profilers, scintillometeres and sodar/RASS.

Local forecasts for winds and waves

Angus Graham, Idar Barstad and Torge Lorenz, Uni Research

A new model that will provide the wind-energy industry with predictions of local winds and waves in the North Sea is being developed by scientists at Uni Research Computing.

The researchers are downscaling from regional to local forecasts, as a more detailed prediction for much smaller areas than in today's regional forecasts is needed. At the same time, it is important to retain a key aspect of these forecasts, the quantification of the uncertainty associated with the prediction, along with the prediction itself. In order to achieve this goal, senior scientist Angus Graham and his colleagues in the Environmental Flow Group are working with a large dataset provided by the European Centre for Medium-Range Weather Forecasts (ECMWF).

The ECMWF forecasts have a low horizontal resolution, on the scale of tens of kilometres. This is suitable for regular weather forecasts, but not for companies conducting offshore wind operations at a specific wind farm, where the effects of coastal or seabed terrain in the locality may be important. The new resolution will be 3 km for the atmosphere and around 300 m for the waves, Graham says. Getting the waves right is particularly important for offshore operations. With better predictions, stay-or-go decisions on maritime operations will be improved, leading to fewer curtailed or unnecessarily postponed missions, and thus a reduction in costs passed onto the energy consumer. Marine safety should also be improved. Everybody involved in offshore wind knows the need for improvements here, says Graham. The methodology is not limited to offshore wind applications, however – it could be used to support decision-making for any site-specific offshore operation.

In modern weather forecasting, the uncertainty of prediction is quantified by perturbing a control or baseline version of the weather model a number of ways, and parameterising the spread in predictions that results. Perturbations reflect uncertainties in the initial state, as a result of partial and statistically noisy observations; amplification of these uncertainties through nonlinearities in the model physics; and uncertainties in the model physics itself. If the perturbations accurately reflect the sum of these uncertainties, their mean – the best single prediction – will lie on average a standard error from the state of the winds and waves that later actually comes to pass. The model prediction system is then wholly consistent with reality.

The research involves an ensemble of perturbed short-term forecasts supplied by the ECMWF at the regional scale being downscaled one by one, using the Weather Research and Forecasting (WRF) mesoscale model of the atmosphere. An example showing the effect of the downscaling is shown in Figure 1. Additional physical processes are simulated at the smaller scales in the downscaling, and additional degrees of freedom are introduced, which validation work with observations has shown increases the sensitivity and reduces the bias, but also increases the spread of values. The results shown are consistent with this. The downscaled winds are then used, along with high-resolution maps of water depth, to downscale the waves with a wave model (WAM).

In the atmospheric downscaling, the researchers are looking to simulate small-scale variations in characteristics of the sea surface, which would otherwise remain smoothed out (these were not taken into account in deriving Figures 1c and 1d). This is the current focus of PhD student Torge Lorenz, who is
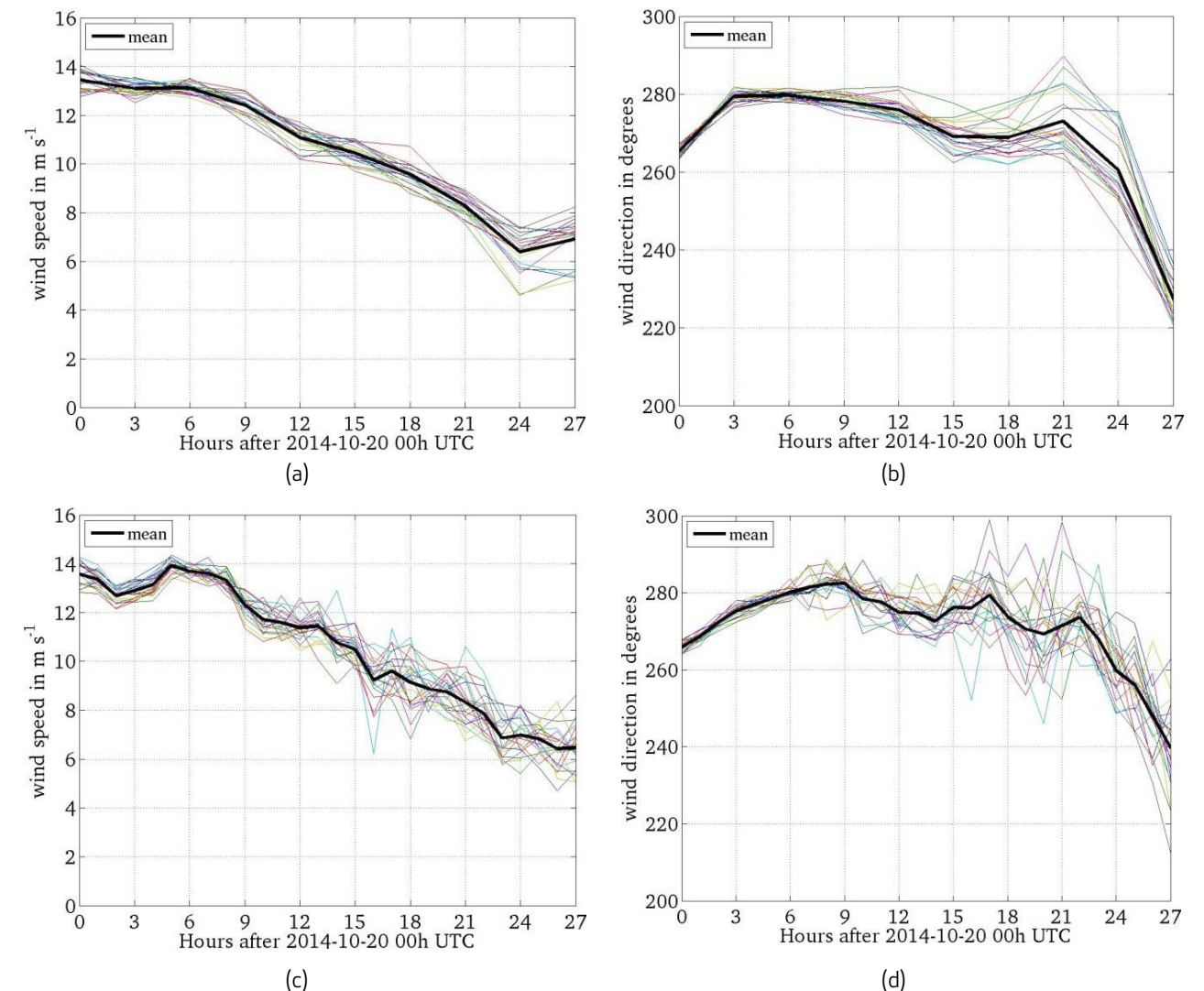

FIG. 1: Ensemble forecast of the wind 10 m above mean sea level at the location of the FINO3 met mast in the German Bight, from midnight 20th October 2014: a) wind speed from 21 runs of the ECMWF model, b) wind direction from the ECMWF runs, c) as per (a) after downscaling using WRF, d) as per (b) after downscaling using WRF.

funded by NORCOWE. Fluctuations in sea-surface temperature (SST) and the associated heat fluxes may be key here, says Lorenz. The fluctuations are partly random in character, and partly related to the SST pattern seen at larger scales – archived satellite infrared measurements show exactly how. When this downscaling has been completed, and some comparison with accurate site measurements of winds and waves has been made, the researchers will be able to assess how far down the road to full consistency with reality the model has come.

The work at Uni Research is also contributing to a three-year project, "Decision Support for Installation of Offshore Wind Turbines", co-financed by the Research Council of Norway and Statoil. The aim of the project is to reduce the cost of installing offshore wind turbines, where waiting for suitable weather windows is a significant cost contributor. Other scientific partners on the project are Marintek, Met.no, Aalborg University, CMR and the Universities of Bergen, Stavanger and Agder. Reinertsen Engineering and Fred Olsen Windcarrier are associated partners.

NORCOWE Met Sailbuoy

Lars Robert Hole, senior scientist, Norwegian Meteorological Institute

In recent years, the Norwegian Meteorological Institute (MET) has utilized miscellaneous autonomous platforms for in situ measurements in ocean and atmosphere. One such platform is the CMR SailBuoy, which is developed by David Peddie and co-workers at CMR Research and is now being produced by Offshore Sensing. The SailBuoy has undertaken several test missions in the North Sea, and near the Canary Islands. It has also been tested for wave measurements near the Lofoten Islands and between the ice floes in the Fram Strait.

Being 100% wind driven and using battery power only for automatic tacking, the CMR SailBuoy system is capable of carrying out long missions for up to 6 months. The sensors and communication system have a separate battery. Typical capacity is 240 Wh, 20 Ah at 12 V. It can both receive navigational instructions and transmit data in real time via 2-way Iridium communication. A full array of sensors can be used for applications in oceanography, meteorology, marine mammal monitoring, algae surveys, oil tracking, and wave measurements. The vessel can be easily deployed and retrieved by untrained personnel, and is not logistically demanding since the operator does not have to travel to the research site.

Another successful mission of the CMR SailBuoy was a 2 month deployment in the northern Gulf of Mexico in March-May 2013 as a collaboration between MET and Florida State University. The experiment was part of the Deep-C project which was funded by BP through the Gulf of Mexico Research Initiative (GoMRI) after the April 2010 Macondo oil spill. The main purpose of the campaign was to monitor surface waters for verification of model output and remote sensing observations, including detection of the Mississippi river plume. During the 62 days of the mission, the SailBuoy covered a cumulative total distance of approximately 2400 km. Averaged over the entire deployment, the vessel speed over ground was 42 ± 30 cm s^{-1} ($\pm$ one standard deviation) with a maximum of 180cm s^{-1}. Three parameters were recorded: sea surface temperature, conductivity, and dissolved oxygen. Observed surface temperature and salinity records were compared with satellite remote sensing data and the salinity fields from a regional ocean modeling system, respectively. The absolute difference between remote sensing data to surface temperature was on an average approximately 0.5 °C.

In 2015, we plan to equip the CMR SailBuoy with a Datawell MOSE G-1000 wave sensor and deploy it during the planned field experiment at the FINO1 platform close to the Alpha Ventus wind park in German waters, starting in June. MOSE G-1000 is GPS based and has an accuracy of 1 cm for motions up to 100 s. It has already been tested successfully for wave measurements on an autonomous boat deployed in the Trondheim farway. We will mainly try to measure significant wave height and wave period, but the sensor is also directional. The measurements will be compared with reference measurements and model output. After the participation in the FINO1 campaign, the SailBuoy will sail to Ekofisk area on its own, for comparison with the operational wave measurements carried out there. Then it will sail back to mainland Norway for recovery.

Extremes and trends in wave climate

Ole Johan Aarnes, scientist, Norwegian Meteorological Institute

Wind generated waves modify a range of processes controlling the exchange of heat, momentum and mass between the atmosphere and ocean, important to weather and climate. The increased roughness imposed by waves is also relevant for offshore wind power production, as it affects the vertical wind profile above the surface. In addition, waves constitute loads on offshore structures that need to be accounted for in design. Site specific wave measurements are however sparse, often requiring the use of numerical models to obtain adequate data coverage in time and space. In this regard, reanalyses constitute powerful proxies of the real climate, as these model-runs are firmly controlled by historical observations (assimilation). However, as most established reanalyses are run globally, with relatively coarse resolution, there is often need for calibration, or better yet, dynamical downscaling of the global model. The PhD work of Ole Johan Aarnes has been focused around limitations and side effects associated with significant wave height (Hs) data obtained from reanalyses, particularly related to their ability to represent extremes and recreate trends. The main motivation has been to overcome these deficiencies by investigating alternative datasets in order to obtain better estimates of return values and trends.

The Norwegian Meteorological Institute (MET) has produced a wind and wave hindcast at 10 km resolution covering the northeast Atlantic – the Norwegian reanalysis 10 km (NORA10). This model-run is a downscale of the global reanalysis ERA-40, covering the period September 1957 through August 2002, but has been prolonged to the present date using operational analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF). NORA10 shows significant improvements in its wave climate representation, especially in terms of extreme events, thus forming a solid foundation for extreme value analysis. Based on different, but commonly applied extreme value models, 100-year return value estimates of Hs have been established within Norwegian waters, illustrated in Figure 1. For the most part, these estimates are within ±5% at any given location.

Like NORA10, most time series of Hs do not extend much further than 50 years implying extremes with a recurrence rate
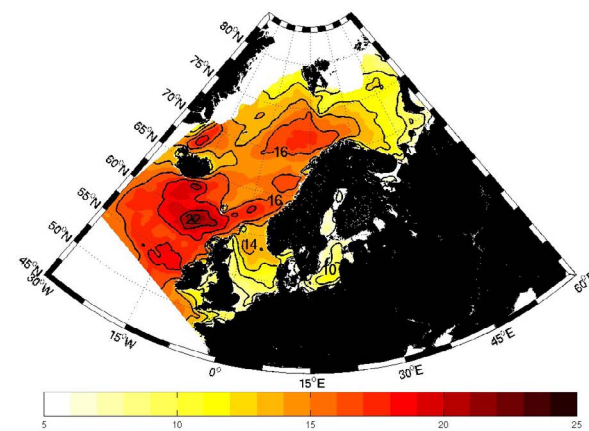

Figure 1: 100-year return value estimate of significant wave height based on NORA10, representative of 1-hour mean sea states.

of 100 years are rarely represented in the data. In an effort to overcome this limitation, this PhD-study investigates the possibility of utilizing archived wave ensemble forecasts (ENS) from ECMWF to obtain vast datasets. By running 50 perturbed versions of the deterministic model at lower spatial resolution, plus a control run initialized from a "best guess" of the atmospheric state, the main purpose of ensemble forecasting is to assign confidence estimates to deterministic forecasts. In general, the spread of the ensemble is increasing with forecast range, reflecting the uncertainty in the forecast. Beyond day 6, the forecast skill is low. At day 10, the 51 ensemble members are sufficiently uncorrelated to be considered independent draws from the model climate. Here, we aggregate historic ENS data, run twice daily, over a period of ~10 years. By assuming each 10-day member being representative of a 6-h mean sea state, the aggregated dataset is equivalent to more than 220 years of data, i.e. the dataset should contain more than 2 events, on average, exceeding the 100-year return value. In this way, 100-year estimates may be obtained directly from the data without resorting to extrapolation of some theoretical extreme value model, presented in Figure 2. This approach is new and should be applicable to other meteorological parameters.
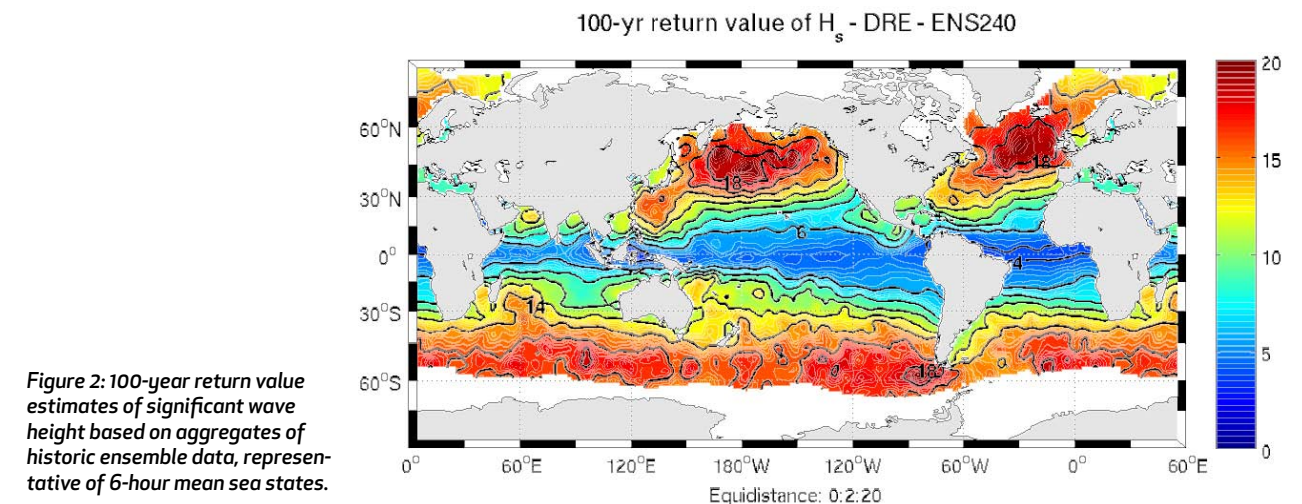

Figure 2: 100-year return value estimates of significant wave height based on aggregates of historic ensemble data, representative of 6-hour mean sea states.

Reanalyses are extensively used for climatic studies and in many cases considered baseline representations of the recent past. It is therefore imperative that a reanalysis is able to recreate realistic trends. An obvious concern is how reanalyses may be affected by the ever growing observational system, especially related to the advent of satellite data. ERA-Interim is a state-of-the-art reanalysis produced at ECMWF, which also comprises prognostic fields, i.e. the model is run as forecasts up to 10 days every 12 hours. This enables the comparison of trends in Hs based on data obtained at the time of analysis against trends obtained at increased forecast range. The purpose of doing such an exercise is to investigate effects of assimilation on trends, an effect that is gradually lost when the model is integrated forward in time. This study reveals that more realistic trends in Hs are obtained from prognostic data, rather than the more often applied reanalyzed data. This applies especially to Hs data, but also seems to have some relevance to wind data. The different Hs-trends obtained with ERA-Interim at the time of analysis and the 48-hour forecast range is presented in Figure 3.
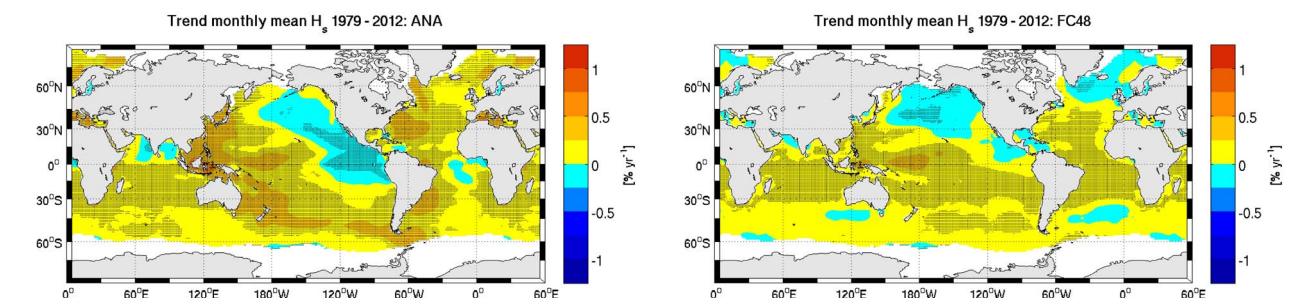

Figure 3: Linear trends in monthly mean Hs obtained from ERA-Interim presented in percentage per year over the period 1979-2012. Left: estimates based on data obtained at analysis: Right: estimates based on data obtained at the 48-hour forecast range.

FLiDAR strengthens body of evidence

Reinhardt Stevens, general manager, FLiDAR

FLiDAR joined NORCOWE January 1, 2015. Here is a brief introduction of FLiDAR.

FLiDAR N.V. is well placed to provide a safe, high quality floating LiDAR solution which delivers highly accurate wind resource data at a reasonable cost.

Over the last five years FLiDAR has designed, developed, deployed, operated and maintained floating lidars on multiple occasions. Most notably, FLiDAR has taken part in three successful third party validations (DTU in the North Sea, Frazer Nash in the Irish Sea, DNV GL in the North Sea) and are involved in five ongoing commercial projects for DONG Energy, Mainstream Renewable Power and EDF.

Validations

Before the FLiDAR company was formally established a prototype floating lidar device was deployed in the North Sea at 1 km distance from a lidar on a fixed offshore platform in order to test the concept. The results were so impressive in terms of data availability and the accuracy of both wind speed and wind direction that a joint venture company was set up to exploit the obvious commercial opportunities. In fact, Risø DTU said "this result would be impressive even for two lidars on land with this separation".
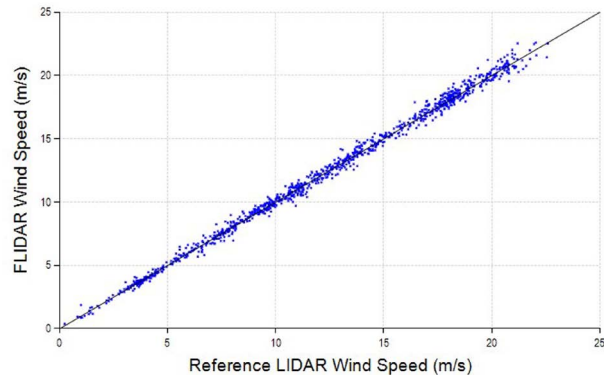

Figure 1: DTU validation results against reference LiDAR
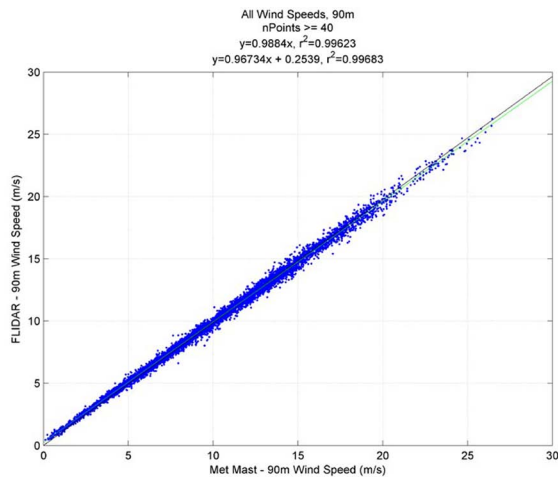
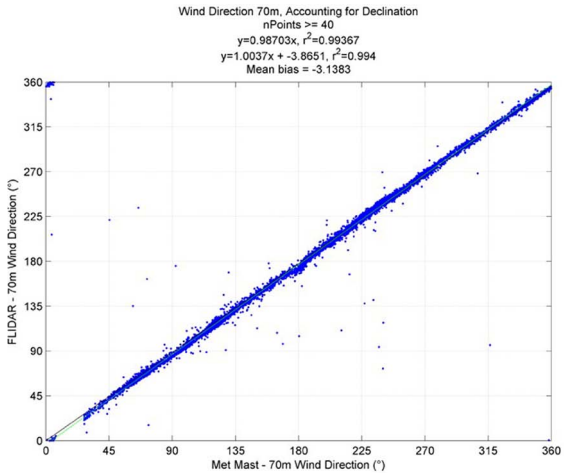

Figure 2: wind speed results from GyM validation

Figure 3: Wind direction results from the GyM trial

A second validation campaign was performed next to the RWE fixed met mast at the Gwynt y Môr (GyM) wind farm. This independent campaign was part of the Carbon Trust OWA floating lidar trials. The report was produced by Frazer Nash and GL Garrad Hassan at the time. Again both wind speed and wind direction were well above the minimum criteria set by the Carbon Trust.

The third independent validation took place at the NAREC met mast as part of the pre-validation for the Mainstream Neart na Goithe wind farm measurements. These measurements have been validated by DNV GL, who also produced the third party report of which the results can be seen below.

Also the availability of the FLiDAR buoy data between the 40 and 200 m altitude surpassed the minimum limit without a problem.

This validation which complements the previous validation within Carbon Trust resulted in the conclusion by DNV GL that the FLiDAR measurement device has demonstrated a strong enough body of evidence to justify reducing the uncertainty associated with the data the FLiDAR buoys measure. FLiDAR has therefore been formally moved along to Stage 2 on the Carbon Trust road map for commercial acceptance floating lidar devices. At this point FLiDAR buoys are the only devices to have reached that stage.
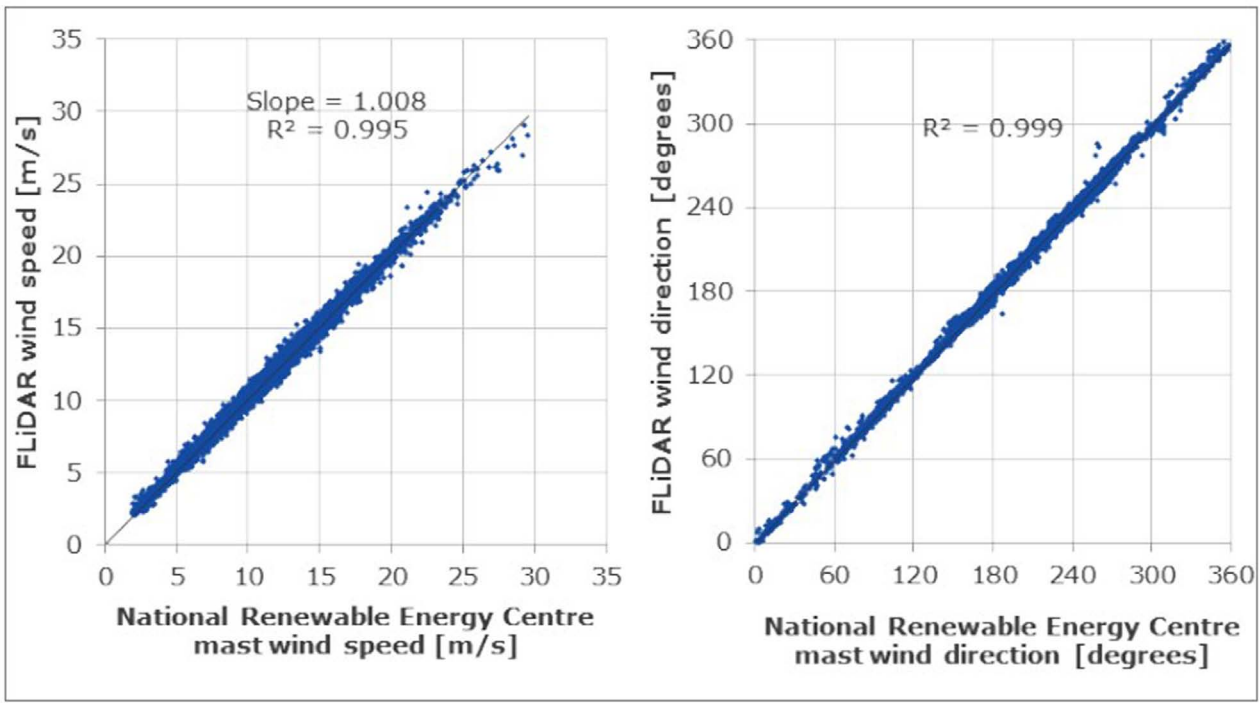
Figure 4: Graphical results of the NAREC validation

	ROADMAP KPIS	FLIDAR VALIDATION RESULT
Overall Post-processed Data Availability	>85 %	96%
Mean Wind Speed - Slope	0.98 – 1.02 (Best Practice)	1.008
Mean Wind Speed – Coefficient of Determination (R^2)	>0.98 (Best Practice)	0.995
Mean Wind Direction – Coefficient of Determination (R^2)	>0.97 (Best Practice)	0.999

Figure 5: FLiDAR validation results against Carbon Trust acceptance criteria

Figure 6: Data availability accomplished by FLiDAR

Trends in O&M for offshore wind farms

John Dalsgaard Sørensen, professor, Aalborg University

For offshore wind turbines, costs to Operation and Maintenance (OM) can be up to 25-20% of Levelized Cost Of Energy (LCOE), and can be expected to increase when wind farms are placed at deeper water depths a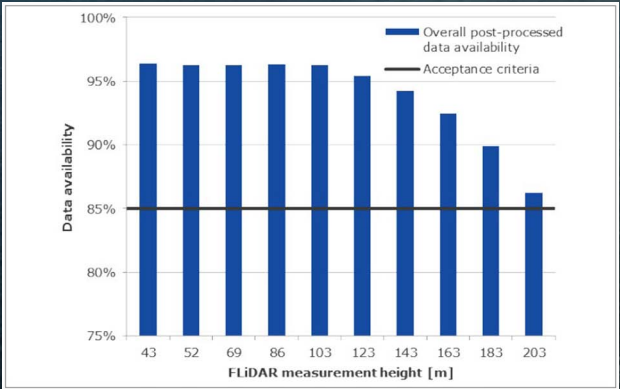nd in more harsh environments. Reducing the cost of OM is therefore an important contributor to fulfilling the goal of lowering the LCOE substantially the next years.

Traditional strategies for OM include corrective and preventive (scheduled and condition-based) maintenance strategies. Most of the maintenance is currently carried out on an ad-hoc, corrective basis when wind turbine components fail. This generally results in large costs especially in case of bad weather conditions, limited availability of vessels, personnel and spare parts. Often some scheduled maintenance is performed including a major annual service supplemented by periodic inspections. The annual services are performed in the summer months to minimize weather downtime and lost production.

There are many possibilities for innovations in OM activities with the potential of making considerable cost savings over the wind farm life cycle. These include optimization of existing OM strategies and procedures especially for far offshore and deep water conditions; reduction of OM costs by improving condition monitoring and by remote presence systems with the objective to minimize the need for on-site and corrective maintenance; application of information from Structural Health Monitoring (SHM) techniques; more detailed analysis of the influence of weather conditions, access criteria and access systems, which could include the use of e.g. floating hotels.

SCADA, CMS and SHM systems provide extremely large amounts of data that are typically only used in a limited way. 'Big Data' tools are able to handle extremely large and complex datasets that are difficult and expensive to handle using traditional database techniques. 'Big Data" tools can be used by wind farm operators in different ways, e.g. for detection of manufacturing defects and for prognosis models.

Improved offshore logistics can be another important contributor to lowering the LCOE. This includes better optimization of the size and number of service vessels and marine as well as onshore logistics. Offshore operations using mother ships, fixed platforms or offshore support vessels are possibilities to be further investigated. As the distance to shore of the wind farms increases and offshore-based access logistics become more important, OM costs will become less sensitive to distance to shore. This again implies that it become more important with efficient and well equipped ports.

Weather forecasting is an area that has a substantial impact on the wind farm OM. Site-specific forecasts of wind speed, wave conditions etc. are used to plan maintenance activities. Improved accuracy of these site specific forecasts seen together with a coupling to the component responses limiting the operations has a significant potential for reducing the OM costs.

Most OM activities are characterized by high uncertainties and large costs. Further, application of condition based methods for OM require that the condition of the wind turbine components can be predicted using models for the development of damages in e.g. blades, bearings and gear boxes. Damage accumulation models used to describe deterioration mechanisms such as fatigue, corrosion, wear and erosion are associated with significant uncertainty and are often the driving mechanisms for failures/faults that need maintenance. Observations of the degree of damage can increase the reliability of predictions and decrease the costs of OM if integrated in a risk based approach. Application of risk based tools has the potential to lower and to improve the predictability of the expected life cycle LCOE.

Surya Teja Kandukuri

What is your scientific background?
I did bachelors in Electrical engineering from Nagarjuna University, India and then a Masters in Systems and Control from Delft University of Technology (TU Delft) in 2006. Since 2007, I have been working in the area of remote prognostics and health monitoring of energy equipment with General Electric company (GE) Global Research, Bangalore until 2011 and then on vehicle health monitoring with Airbus Defense and Space, Bangalore until until I came to University of Agder summer 2014.

What topic is addressed in your PhD?
It is well understood that maintenance for offshore wind turbines is relatively more expensive than that for onshore. A continuous assessment of system health and utilizing that information in planning maintenance has the potential to bring down costs. This ideology is often referred to as health management. Towards this end, my PhD topic deals with diagnostics and prognostics for pitch and yaw systems of offshore wind turbines that help assess their health.

Why do you address this topic?
In order to accomplish a complete system level health management for offshore wind farms, it is necessary to carefully examine each module of the wind turbine and assess whether it could benefit from health monitoring rather than conventional maintenance. Pitch and yaw systems are prone to frequent failures and high associated downtimes but the health monitoring for these systems was so far less focused upon, compared to the drivetrain and generator. In this PhD effort, diagnostics contribution is focused on filling this gap while the prognostics tries to answer a broader question of the impact of corrosion and fatigue on the offshore turbines with focus on these systems. Thereby, we aim to provide a complete health assessment solution for the pitch and yaw systems.

How is your work linked to NORCOWE?
This project fits in well with the WP 3 of NORCOWE towards reduction of cost of energy for offshore wind. The work package WP 3.1 define risk-based maintenance desicision schemes that assume presence of condition monitoring and knowledge of system health, which would be provided (for pitch and yaw systems) through this work. Besides, the health information may be utilized for wind farm control reconfiguration based on system health in WP 3.2 packages.

Lene Eliassen

What is your scientific background?
I have a master degree in Mechanical Engineering from NTNU, Trondheim. After finishing my master I moved to Stavanger, and started working at Subsea 7. My main task there was to do installation analysis of pipelines in the North Sea. After working there for 2.5 years, I started on my PhD in April 2010 at University of Stavanger.

What topic is addressed in your PhD?
The topic addressed in my thesis is aerodynamic loads of a wind turbine rotor. In particular, I have studied the unsteady aerodynamic forces on a rotor moving along- or opposite to the wind direction, due to the fore-aft bending of the tower or the pitch motion of a floating turbine. I have used a vortex code to simulate the aerodynamic loads on the rotor blades. The advantage of using the panel vortex code, relative to other methods is that the vortex theory includes the vorticity of the wake, and can therefore be used to compute the unsteady loads accurately.

At present, the most commonly used method to compute the aerodynamic loads is the Beam Element Momentum (BEM) method, which is based on the assumption of steady state conditions, and the unsteadiness is included using semi-empirical functions. The reason for BEM being more popular is that the computational time is very low. In my thesis, I have investigated the unsteady aerodynamic loads of a wind turbine rotor, and investigated how to reduce the computational time of vortex methods.

What are your main results?
I have developed a vortex code, which is two dimensional and uses panel elements along the airfoil surface and vortex point elements in the wake. Based on the airfoil geometry, wind velocity, relative velocity of the airfoil and the vorticity of the wake, the unsteady aerodynamic loading of the wind turbine airfoil is calculated. The code assumes potential theory, and consequently, stall of the airfoil is not modelled.
Two panel vortex codes are developed, one on the CPU and one on a graphics processing unit, GPU. Based on results of computations, comparing CPU and GPU, I show how one can use the graphic card on a computer to reduce the computational time of the vortex method. The speed-up of the program is largest if there are many vortex particles in the simulation, and for few vortex particles the CPU seems to give the lowest computational time.
Unsteadiness can be measured by the reduced frequency, and if the reduced frequency is above 0.05 the flow is unsteady. In Figure 1 the reduced frequency along a wind turbine blade is shown for two oscillating frequencies. The oscillation motion

is in the axial direction, in-and-out of the wind. From the figure, one can see that the low frequency motion is dominated by steady aerodynamics, while the high frequency is unsteady.
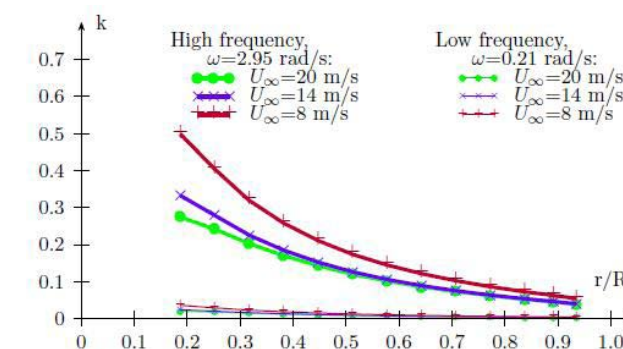

Figure 1: The reduced frequency, k, for a low and a high frequency oscillating motion of the rotor at positions along the blad.
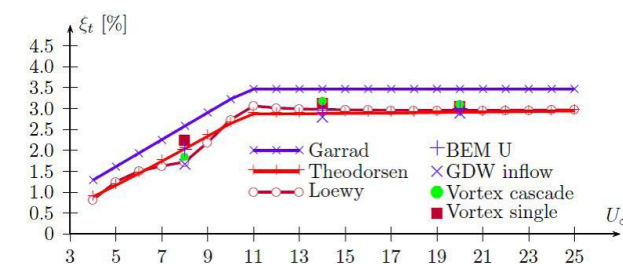

Figure 2: The aerodynamic damping ratio of the first elastic bending mode of the tower.

The frequencies are chosen such that the low frequency motion corresponds to the eigen-frequency of the surge mode of the floating OC3 Hywind, and the high frequency corresponds to the eigen-frequency of the first elastic tower mode of the OC3 Hywind. In Figure 2 the aerodynamic damping ratio for the first elastic tower bending is shown using 7 different estimation methods. Garrad´s method is a simplified method, which only considers steady state aerodynamics, while Theodorsen´s and Loewy´s are both frequency domain theories that consider unsteady aerodynamics of a flat foil. It is seen that these methods predict a lower aerodynamic damping relative to Garrad, which only considers the steady aerodynamics.

However, Theodorsen's theory is based on a single airfoil and a single wake, while Loewy also considers that the airfoil wake will return after one rotation and that the wake from neighboring airfoils will influence the aerodynamic loads. Therefore, there is a difference at a wind speed of 8 m/s, where the blade passing frequency is close to the high oscillating frequency. This same reduction can be seen if comparing a single airfoil modelled with the vortex code to a cascade of airfoils modeled with the vortex code. In the vortex cascade, there are several airfoils in a row modelled to get the effect of the wake from neighboring airfoils and the returning wake.

A consequence of overestimating the aerodynamic damping, is that the calculated fatigue damage is too low. Since the BEM method often uses an unsteady approximation based on Theodorsen's theory, which only considers a single airfoil, the BEM method may underestimate the fatigue damage and not be conservative.

Where are you working now?
I am currently working at NTNU and I am a part of the research project DIMSELO, which aim is to investigate the dimensioning loads of offshore wind turbines. My work will mainly focus on the large rotors, and the turbulent loading.

I will defend my PhD thesis March 13 at University of Stavanger.

Jithin Jose

What is your scientific background?
I completed my graduation from Mahatma Gandhi University, India in Mechanical Engineering. Afterwards I pursued my Master's degree from Indian Institute of Technology Madras, India, where I did my thesis on "Numerical studies on the effect of heave plates on Spar". After my Master's degree, I started working in an offshore consultancy firm, Cybermarine knowledge system. During my tenure with Cybermarine, I worked with their design team for the structural design and analysis of various offshore structures. Currently I am pursuing my studies as a PhD fellow at University of Stavanger.

### What topic is addressed in your PhD?
The title of my PhD is "Offshore structures exposed to large slamming wave loads" which focuses on estimating slamming wave forces acting on truss structures supporting offshore wind turbines in shallow water, for relevant wave conditions. The objective is to design safe and economical foundation structures as slamming loads from breaking waves could lead to failure of the foundation of the support structures. The study is mainly based on experimental studies carried out in Hannover, Germany, during July 2013 (during the Wave Slam project).

Why do you address this topic?
The foundations of offshore wind turbines installed in shallow water are predominantly monopile or truss type structures. The designs of such structures are greatly influenced by the potential slamming loads from the breaking waves. However, little information is available on the slamming forces acting on truss type structures. So far, the information available for the monopile structures is used in the design of such structures. This usually leads to the overdesigning of the truss structure. Therefore, it is necessary to get a better understanding of wave slamming loads on truss type structures installed in shallow water regions with sloping sea bottom.

How is your work linked to NORCOWE?
This PhD research project is a part of WP3 of NORCOWE and is funded by NORCOWE. This PhD project may be linked with other research in NORCOWE for the design of safe and economical support structures.
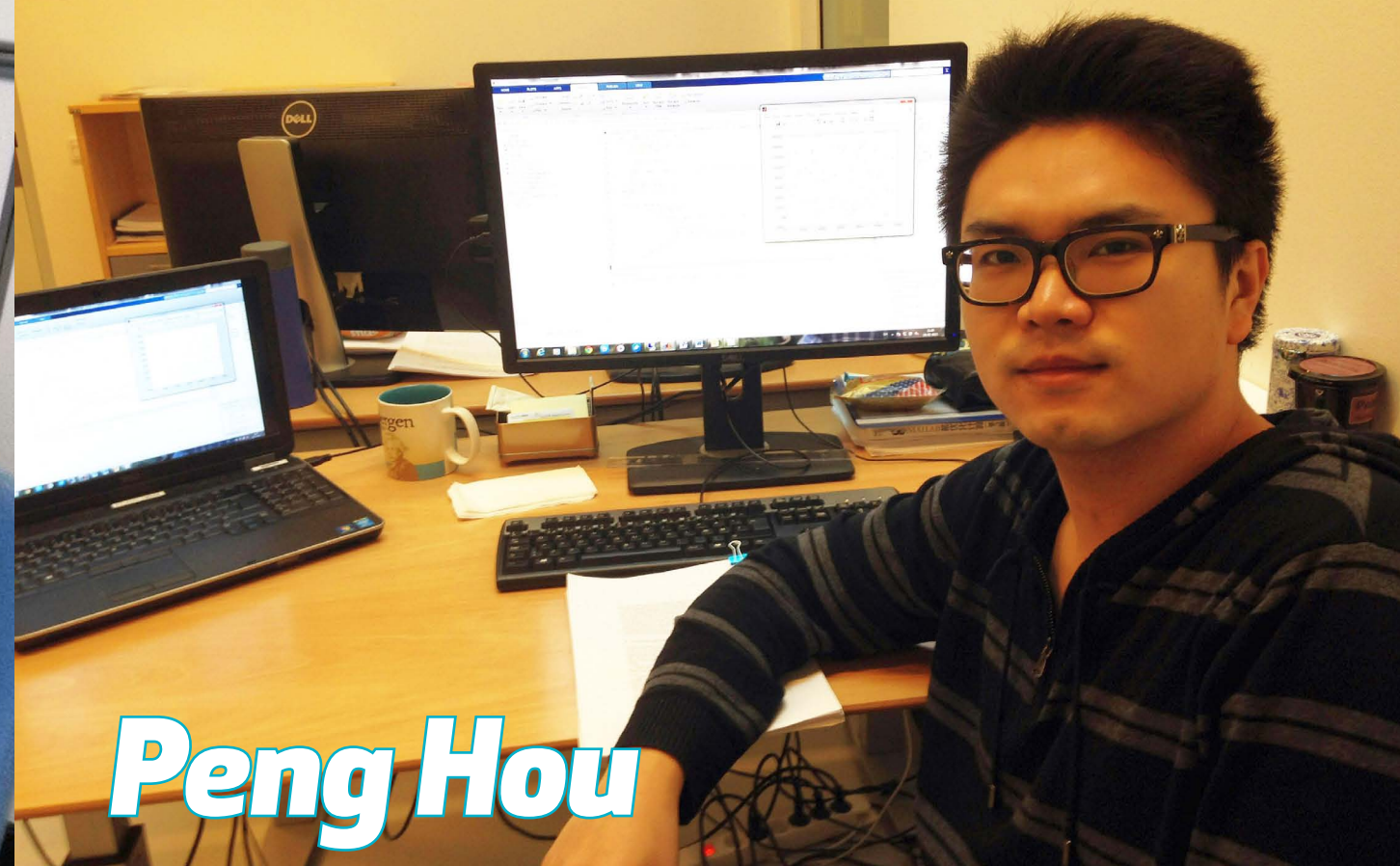
Peng Hou

What is your scientific background?
I graduated from Hebei University of Technology with a degree in eletrical engineering and automation. Afterwards I continued my further education at Chalmers University of Technology in Sweden and got my master degree in electric power engineering in 2010. From 2012 to 2014, I worked in different departments of State Grid, China. Currently, I am continuing my studies as a PhD student at Aalborg University.

What topic is addressed in your PhD?
In my project, a method and procedure to optimize the system topologies and voltage levels for various power levels will be proposed. A design program will be developed; the system costs, power losses of the cable and transformer associated with a wind farm and the connection between wind farms and the electric grid will be evaluated. The topologies and structures will be checked by simulations to assess the technical performance.

Why do you address this topic?
It is known that the offshore wind farm usually consists of a large quantity of wind power clusters and is widespread in the sea, thus a lot of expensive cables and electrical equipment are needed. With the gradual increase of the equipment's voltage level, the proportion of investment on collection system of offshore wind farm construction steps up to 15%-30% which is much higher than in the onshore wind farms. It is desirable to optimize the electrical system layout to make a cost-effective offshore wind farm.

How is your work linked to NORCOWE?
The electrical system has an significant impact on the offshore wind farm performance. In order to get a cost-effective wind farm, the energy yield considering wake effect, investment on electrical equipment and power losses of the wind farm electrical equpment should be considered in layout design phase. The optimization of the electrical power system would be interacted with other NORCOWE projects, such as the lidar measurements for wind energy application (to get the measured wind speed to calculate the energy yield considering wake effects), wind resource assessment, energy yield and layout for offshore wind farms (to obtain the wind turbine locations so that the electrical system layout design can be conducted) to contribute towards an overall optimal design of wind farms.

A previous PhD project, Optimization of electrical system for offshore wind farms by a genetic algorithm, was conducted at ET-AAU, which can provide a solid and valuable background for the proposed work. Furthermore, some previous student projects conducted at ET-AAU in cooperation with NORCOWE partners can also provide valuable inputs to the project, including
- Grid integration of offshore wind farms and offshore Oil/Gas platforms
- Grounding for offshore wind farm electrical system
- Integration of offshore wind farms into Offshore Oil and Gas Platforms as an isolated Power system
- Study of an integration of a wind and wave farm

Tore Bakka

Erik Kostandyan

Tore Bakka, former PhD student at University of Agder

When was your PhD defense?
My PhD defense was 29/11-13.

Why did you go for a PhD?
I guess it is a combination of wanting to learn more and the fact that there were not too many attractive jobs available in the market. During my last semester as a master student, my supervisors said there would be a PhD position available soon and asked if I would like to apply. I thought "why not" and have never regretted it.

What is your current position?
My current position is Project Engineer at National Oilwell Varco, where I mainly work with designing the hydraulic circuits for cranes and winches.

How do you benefit from your PhD degree today?
Modeling and simulation of various system have been very useful. Other good lessons are to be able to work independently, set clear goals, work purposefully towards a goal and schedule my time in a sensible manner.

"Other good lessons are to be able to work independently, set clear goals, work purposefully towards a goal and schedule my time in a sensible manner".

Erik Kostandyan, former PhD student at Aalborg University

When was your PhD defense?
I defended my PhD thesis entitled "Reliability modeling of wind turbines – exemplified by power converter systems as basis for O&M planning" in October 2013.

Why did you go for a PhD?
I was always fascinated by Wind Turbine technologies and associated systems. Attraction came by appreciating and understanding Wind Turbine's generated power capability, its size and weight, and its nature of being environmentally green. It is one of the rare systems which integrates and merges structural, mechanical, electrical and software subsystems into one entity. So, I became interested in learning and building knowledge on such systems, and my ambition was to see them as strong, reliable and safe as possible. By having a chance to do research on Wind Turbines reliability modeling (sponsored by NORCOWE consortium) and being lucky to take this journey under Prof. John Dalsgaard Sørensen's supervision, I started my PhD.

What is your current position?
Currently, I am a Performance Engineer at Vestas Wind Systems A/S. My role and responsibilities include analyzing Wind Turbines' main components reliability by investigating specific failures and building predictive models for them. Also, I am involved in projects for discovering Wind Turbine abnormal behavior in its early stages caused by malfunction or supplier quality issues.

How do you benefit from your PhD degree today?
I am certain that my PhD degree has prepared me well for my current role. There are many situations where solid background in reliability and uncertainty modeling is a fundamental condition or just a necessity to solve the task. Physics of failure based reliability modeling is one of the unique and trustworthy approaches that comes into life currently. Also, in many situations global understanding of Wind Turbine system interactions (gained during NORCOWE organized summer schools, meetings and conferences) helps explaining and seeing outcomes from a broader point of view. I am very glad to have a chance to explore my knowledge and skills gained during the PhD into life, and to work for the company where the motto is "Wind - It means the world to us". All this motivates me and keeps my ambition on supporting Vestas Wind Turbines to be the strongest, the most reliable and the safest one in the world.

Maintenance - in due time

Ole-Erik Vestøl Endrerud, PhD student, University of Stavanger

Motivation

An offshore wind park is very expensive to operate because of high maintenance costs – mainly driven by the marine logistic needed to access wind turbines offshore. New vessels and maintenance strategies are both proposed as measures to lower the maintenance cost, and consequently the levelized cost of energy. However, there does not exist a method to analyse if these new vessels or maintenance strategies will result in increased production and/or lower costs. The purpose of this project is therefore to investigate methods to analyse such measures to provide decision support when designing the operational side of an offshore wind park.

Main results

We landed on simulation modelling being the most appropriate method to analyse marine logistics and operation and maintenance. Mainly because operating an offshore wind park involves many different subsystems, such as marine logistics, spare part management, wind turbines and personnel. The interdependence between these subsystems creates a very dynamic, time-dependent and stochastic system, and analytic models do not capture the behaviour. A simple analogy is a football match: an analytical model will always generate the same final score for the same football match over and over again, and adding stochastic inputs (e.g. Monte Carlo simulation) will generate a distribution of scores based on the randomness of the inputs, but still not an explanation of what produced the final score. A computerised simulation model, however, adds logical relationships (e.g. "shoot IF close to goal") in addition to stochastic input, and is therefore also able to represent what actually caused the final score. The simulation model can then be run several times to generate a distribution of final scores.

An advanced simulation model for offshore wind parks have been developed that takes into account marine logistics, and preventive and corrective maintenance strategies. Special emphasis was given to the marine logistics-part of the model, and we have been able to accurately represent vessel movement and operations in the wind park. This has drastically improved the possibility to analyse how specific vessels perform for maintenance work and the impact of different work processes, vessel fleets and strategies. This was also highlighted when the simulation model was used to analyse marine logistics of Dudgeon Offshore Wind Farm for Statoil. Another interesting part is that this makes it possible to estimate the impact of wind park layout on cost and production.

We are currently working on implementing condition-based maintenance in a detailed way to be able to analyse the impact of such an advanced maintenance strategy for offshore wind parks. The hypothesis is that this will, at least under various circumstances, drastically decrease downtime because of early fault detection and therefore less lost production, in addition to lowering the maintenance cost because of just-in-time spare part management and more efficient use of resources.

Motion lab tests

Geir Hovland, professor, University of Agder

during 2014. A+D develops and sells Motion Reference Units (MRUs) to the offshore wind energy industry and other industries. A typical application for the A+D MRU is monitoring of motions in crew transfer vessels.

One advantage of the A+D's MRUs is the fact that the end-user can modify the filters and algorithms in the unit. For example, the expected frequency contents in wave spectra in different regions vary and hence the low- and highpass filter coefficients in the MRU may be tuned accordingly. However, when the MRUs filters are modified, there is a desire to independently verify the accuracy and the performance of the sensor.

In the Motion Lab the accuracy and performance of A+D's MRUs have been verified using the two Stewart platforms (E-Motion 1500 and 8000) as well as using an independent measurement system: the FARO Xi laser tracker. The tests have included pure sinusoidal motions in heave, roll and pitch with different frequencies and amplitudes, as well as motions containing multiple sinusoidal frequencies and a combination of several degrees of freedom.

December 2014 the Motion Lab was expanded with a new industrial robot from Comau Robotics, Italy. The robot brand is a Smart NJ-110kg-3.0m and it comes with a C5G Open Controller. Most industrial robots come with a closed control system which does not let the end-user modify the low-level algorithms. The C5G Open controller allows researchers associated with the Motion Lab to test out new algorithms and software at the lowest level in the controller (joint torques and angles). The Comau robot is currently in the process of being mounted on top of the E-Motion 8000 Stewart platform. Future research will focus on integration of sensors (such as MRUs and Vision) with the Open C5G controller and using the two Stewart platforms available in the laboratory to do research and experiments with vessel-to-vessel compensation and transfers. Comau Robotics and UiA established their collaboration in the EU FP7 project Hephestos.

Testing Motion Reference Units (MRUs)

Neil Starsmore and Steinar Haga from the company Automasjon og Data AS (A+D) visited the Motion Lab four times

From left: Prof Geir Hovland,, UiA and Doctor engineer Neil Starsmore, A+D

NORCOWE Reference Wind Farm

*Thomas Bak, Aalborg University and
Angus Graham, Uni Research*

Offshore wind farms are complex systems, influenced by both the environment (e.g. wind, waves, current and seabed) and the design characteristics of the equipment available for installation (e.g. turbine type, foundations, cabling and distance to shore). These aspects govern the capital and operating expenditures, which, along with the energy produced, determine the cost of energy. A better system-level understanding of wind farms is hence of critical importance to the wind-energy industry.

The reference wind farm (RWF) has three purposes. It is to serve as a database containing all data needed to represent a wind farm. Researchers can then use data from this database in their research. Second, it is to allow researchers to compare and discuss results, and quantify the benefits of one technological concept or solution over another. Finally, the farm can be used to communicate work to industry, the research community and the general public.

The RWF involves a large-scale offshore installation with multi-megawatt turbines. Driving its definition has been an industry partner consultation on key parameters, aimed at making the turbine spatial densities realistic, while not presupposing an existing layout solution. Avoiding the latter removes the possibility of an unproductive discussion with the designers of an existing farm, and allows focus on key concepts such as the optimal farm shape for a given number of turbines and square area of seabed. Another driver has been the availability of relevant measurement data, for assessment of e.g. met/ocean conditions. Also, the use of a publicly available turbine model has been important, to simplify the use and increase the impact.
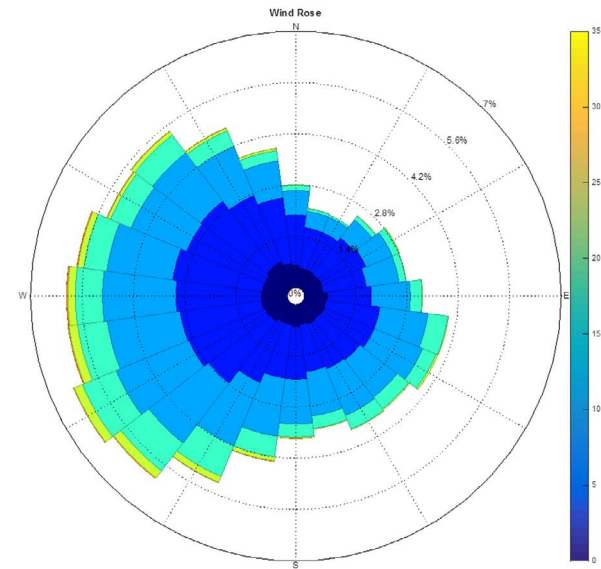

Figure 1: Wind rose for wind speed and direction at hub height, based on wind climatologies at the site of the farm (FINO3) from a decadal simulation. Speeds are in m s−1. Courtesy Angus Graham, Uni Research.

A set of key parameters has already been defined. Values of some of these are given below:
Installed capacity: 800 MW
Number of turbines: 80
Reference zone: Area in vicinity of FINO3[1]
Reference wind turbine: The DTU 10 MW RWT[2], rotor diameter 178 m.
Mean water depth: 23 m
Foundations: Bottom fixed monopile design
Climatologies: Wind and wave climatologies from decadal simulations, with validation to FINO3 measurements in 2010[3]
Electrical design: Cable layout design and energy yields calculation
Operation and maintenance: Operation and maintenance regimes

Farm controller: Basic farm control

To maximize the utility of studies using the RWF and encourage clear and informed communication between experts, a baseline RWF is first being obtained. This takes into account key layout considerations and avoids obviously suboptimal characteristics. So far, a baseline layout and electrical system have been obtained, and baseline loads on turbines have been probed. Assessment of the operation and maintenance regimes and the overall cost of energy are underway.

The wind rose at the site of the RWF is shown in Fig. 1. It is used to derive the baseline layout, shown in Fig. 2. A fundamental directional periodicity in the layout is recognised

1   A German research platform located about 45 nautical miles (80 kilometres) west of the German island of Sylt
2   http://dtu-10mw-rwt.vindenergi.dtu.dk
3   The first full year over which measurements are available

here – a farm constituting a few long rows aligned normally to winds from one compass direction will also appear as a few long rows aligned normally to winds from the opposite direction. In the baseline layout adopted, a perimeter which is periodic about 180° is prescribed. Furthermore, the more energy there is available from winds blowing along a certain orientation on the compass, the fewer and longer should be the rows aligned normally to this. Flow interactions between turbines reduce the energy extracted and increase turbulent loads. In the layout shown, the distance from the farm centroid [at (0, 0)] to the perimeter along a given direction scales with the wind energy available normally to this. Also, in state-of-the-art design, layouts in which large numbers of turbines align in certain directions are avoided. This is achieved within the farm perimeter in Fig. 2 by locating turbines in curvilinear rows that lie on a spiral [centred out of picture to the right at (13.5, −4.9) km]. Finally, it may be noted that spacings in Fig. 2 are lowest along the perimeter, in keeping with state-of-the-art industrial practice.

The loads on turbines in the baseline layout have been examined through effective, wake-enhanced turbulence intensity at hub height according to IEC 61400-1 Ed.4, Dec 2014 draft. Formulas are adjusted to reflect the wind distribution in the wind climatologies (see Fig. 1). The self-generated ambient turbulence inside the wind farm (> 5 turbines to the edge) has been included. Given a hub-height wind speed of 10 m s−1, an ambient turbulence intensity of 15% and a Vöhler exponent of 10 (glass fibre) the effective turbulence intensity for each turbine at hub height, is shown in Fig. 3.

The cabling solution is shown in Fig. 4. The two offshore substations are selected to be installations 61 and 66 in Fig. 2.
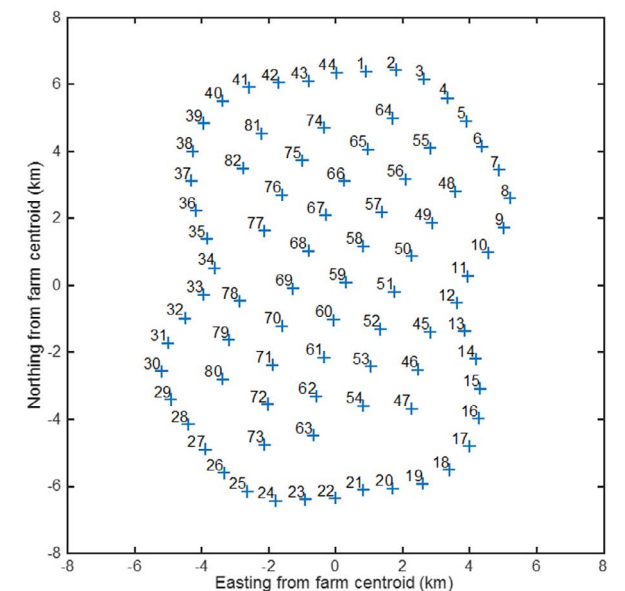

Figure 2: Layout of the 82 installations (80 turbines and 2 substations) in the baseline reference wind farm. Courtesy Angus Graham, Uni Research.

The lines show the cable connection layout and colours cable ratings, as listed in Table 1. Since multiple cables are used between some wind turbines, the number of cables is also indicated in Fig. 4 by line type.

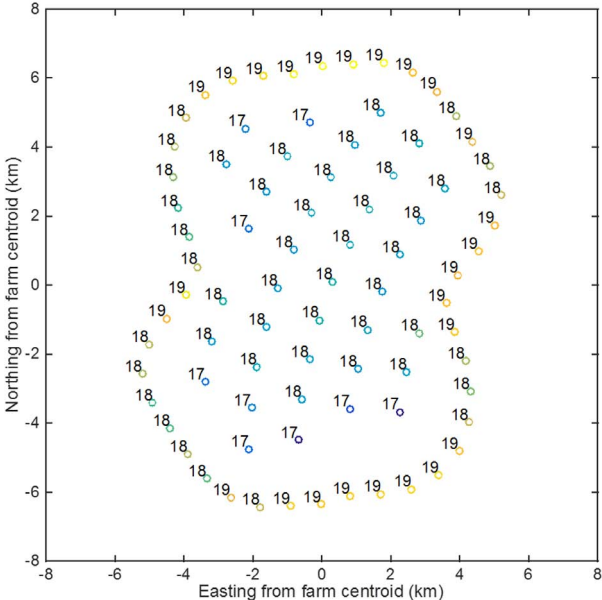The NORCOWE RWF allows users to change designs and parameters in specific areas, while choosing baseline parameters and values elsewhere. For example, the baseline turbine layout can be fixed while different electrical design options are explored. Users can contribute with new inputs and designs, by suggestion to NORCOWE. A variant on the layout shown in Fig. 2 is also being developed, involving the same number of turbines and square area of seabed but a rectilinear grid layout (the longest-established type of layout).

Figure 3: Effective turbulence intensity (%) for each turbine for a hub-height wind speed of 10 m s−1, an ambient turbulence intensity of 15% and a Vöhler exponent of 10 (glass fibre). Courtesy Thomas Bak, Aalborg University.
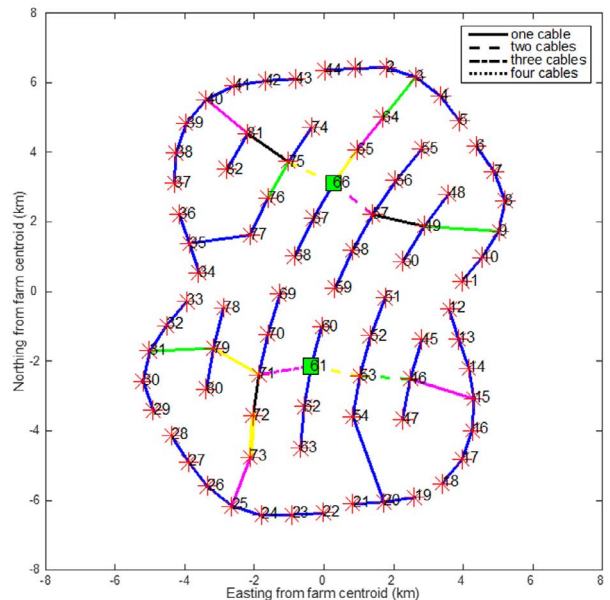

Figure 4: Cabling. Colours are classified in Table 1, line type specifies the number of cables used. Substations are installations 61 and 66.
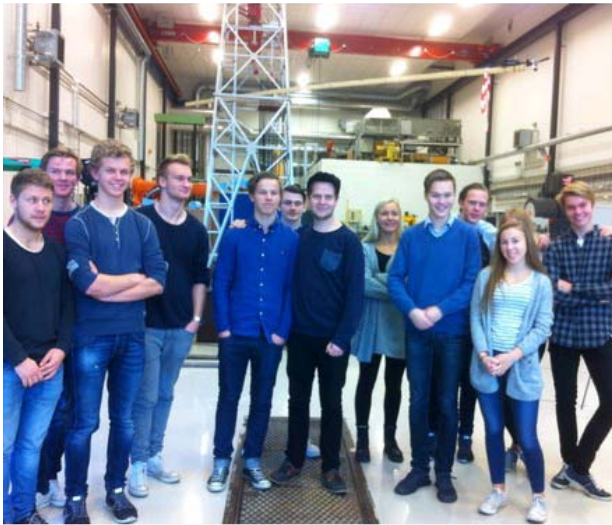Courtesy Zhe Chen, Aalborg University.

Table 1 Cable ratings

	Collection line				
Voltage	66kV				
Type	AC				
Color	blue	green	purple	yellow	black
Cable Sectional area (mm2)	95,150	240,300	400,500	630,800	1000

Public outreach and dissemination

Ingrid Kaurin and Svein Winther, teachers of Technology and Research Methods, KKG

Visit from Kristiansand Katedralskole Gimle (KKG)

14 students and 2 teachers from Kristiansand Kantedralskole Gimle (KKG) visited the Motion Laboratory at UiA Grimstad in November 2014.

The students attend the course Technology and Research Methods at KKG. As part of this course the class visited UiA Grimstad where it was demonstrated how to simulate and compensate for wave motions during offshore operations using a Stewart platform. Typical applications can be found in operation and maintenance of offshore wind turbines in bad weather. The students got an introduction to NORCOWE as well as the mechatronics study program at UiA.

In addition, the Master Mechatronics student Sondre S. Tørdal gave a presentation and demonstration of how to model and control the motions of a hydraulic crane in the laboratory.

On behalf of KKG we would like to thank Geir Hovland and Sondre S. Tørdal for giving us an introduction to the work in NORCOWE and the Motion Laboratory. UiA had created a tailor-made exercise for KKG where all the students could try some basic programming using Matlab. We would like to come back another time.
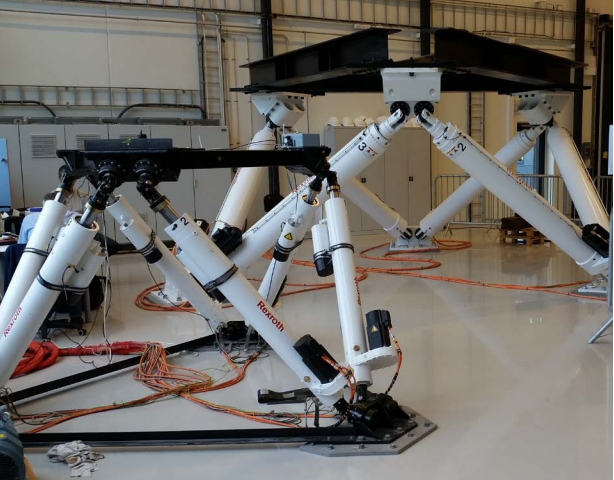

Geir Hovland at UiA hosted the visit and had created an exercise for KKG where the students would analyse a JONSWAP wave spectrum using Matlab, a software tool the students had not used before. The wave spectrum was imported into SimulationX to control the motions of a simulated Stewart platform. Finally, the students were allowed to run their wave spectrum on the E-Motion 1500 Stewart platform in the laboratory.

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Summer school 2014

NORCOWE's summer school has now been arranged five times. It is a five-day in-depth workshop on offshore wind, open for both industry employees and PhD-students. Non-NORCOWE members are also welcome. All courses are in English, opening up for international participation.

The NORCOWE summer school 2014 was hosted by the University of Agder, and took place at Strand Hotel Fevik close to Grimstad at the south coast of Norway.

The chosen topic for the workshop was Innovative Methods and Concepts in Offshore Wind Energy.

From Monday August 11 until Friday August 15, we had seven lecture sessions covering differing topics related to innovation in offshore wind. The participants took part in open discussions, group work and in presenting their results and conclusions. Floating structures, innovation principles in wind energy, heave compensation, multi-use of wind farms and innovative software solutions were the main topics.

This year's lecturers were Kai Christensen, Norwegian Meteorological Institute, Peter Jamieson, University of Strathclyde, Arnfinn Nergaard, University of Stavanger, Wei He, Statoil, Geir Hovland and Magnus B. Kjelland from Norwegian Motion Lab/University of Agder, Finn Gunnar Nielsen, Statoil/University of Bergen and Ove Daae Lampe, Christian Michelsen Research.

On Wednesday, we visited University of Agder to learn about heave compensation. Using Simulation-X the participants got to simulate motions shown by the Stewart platform in the Motion lab. In the afternoon, we were invited to MacGregor in Kristiansand, who have developed a three-axis motion compensated crane. After a short introduction to the company and their crane, we had an interesting guided walk at their industrial site to see what they make.

The NORCOWE Summer School 2015 is to be arranged in cooperation with NOWITECH, August 17 - 21, 2015 (Monday - Friday). Venue: Hardingasete, Hardanger, Norway.
Topic: Harvesting wind energy in a harsh environment

NORCOWE conferences and meetings

NORCOWE has two annual, internal scientific meetings: The 2014 spring meeting was held at University of Agder May 6-7 and NORCOWE day took place in Bergen September 10.

Science meets industry is took place in Stavanger April 2 and in Bergen September 9.These meetings are open to the public. The purpose is to bridge the gap between the industry and the scientific community. There has been a strong industrial presence at these conferences. This year Science meets industry will take place April 16 in Stavanger and September 15 in Bergen.

NORCOWE was well represented at the DeepWind conference in Trondheim.

NORCOWE hosted a FAST course on September 11-12 in Bergen with Jason Jonkman from NREL as lecturer.

An internal NORCOWE Workshop on relevant scales in space and time was hosted by Statoil in February, while workshops on maintenance and operation and the NORCOWE Reference Wind farm were hosted by Aalborg University in October.

There were four issues of the NORCOWE newsletter in 2014. Please send an email to post@norcowe.no to sign up for the newsletter.

International cooperation

NORCOWE has become more visible during 2014. The joint ECN/NORCOWE measument campaign WINTWEX-W at Wieringermeer in 2013/2014 has gotten much attention. The results have been presented at conferences and papers, and there is a great interest in the data and the scientific results. We foresee more international and national cooperation based on this campaign.

The upcoming FINO1 measurement campaign will be conducted in close cooperation with German partners.

NORCOWE partners have a range of international scientific partners and the following list is not complete.

Cooperating international research institutions: University of Strathclyde, DTU Wind, Fraunhofer IWES, NREL, Georgia Institute of Technology (USA), German Wind Energy Institute (DEWI), Universitat Politecnica de Catalunya (UPC) Barcelona, University of Bremen, TU Delft, Lund University, National Centre for Atmospheric Research (NCAR), Hannover Universität, Military University of Technology (Poland), Lodz University of Technology, ECN (The Netherlands), Nelson Mandela University (NMU), Port Elizabeth (South Africa), DHI (Denmark), Swinburne University of Technology (Australia) and University of Cincinnati.
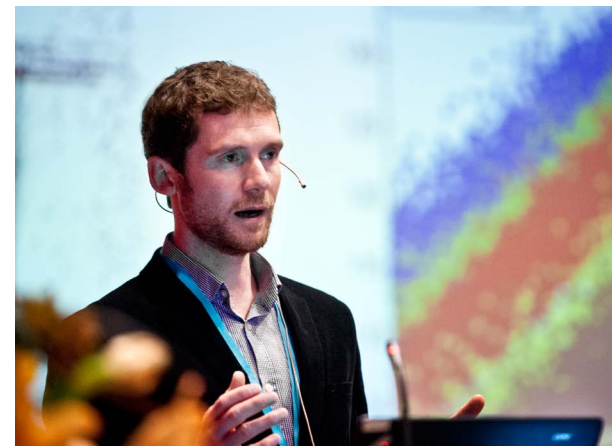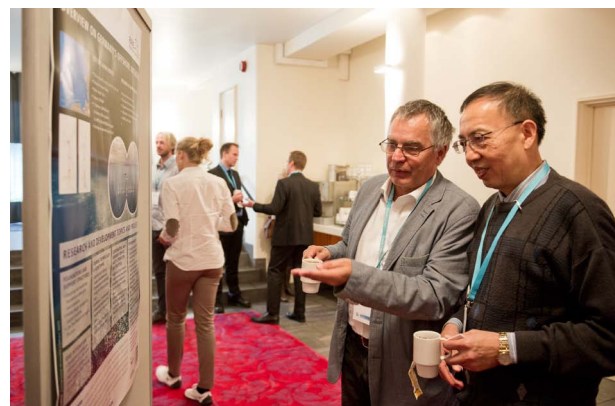
NORCOWE research partners have projects together with e.g. DONG, Vattenfall and Vestas.

NORCOWE has two international user partners (FLiDAR and Leopshere) and a Danish research partner (Aalborg University).

NORCOWE has good relations to the Japanese offshore wind energy community, and NORCOWE was presented at the Grand Renewable Energy conference in Tokyo in 2014. NORCOWE partners are active in EERA JP Wind, EWEA and EU projects.

NORCOWE has now MoUs with DTU Wind, Fraunhofer IWES, The National Renewable Energy Lab (NREL) in USA, ECN (The Netherlands).

Standardization committees and international bodies
Aalborg University and University of Stavanger take part in three standardization groups:
Maintenance group for revision of IEC 61400-1: 2005: Wind turbines - Part 1: Design requirements
Maintenance group for revision of IEC 61400-3: 2009: Design requirements for offshore wind turbines

Project team for new wind turbine standard IEC 61400-6: Wind Turbines: Tower and foundation design

NORCOWE partners participate in three IEA wind tasks:
IEA Wind Task 31- WakeBench: Benchmarking of wind farm flow models
IEA Wind Task 32 - LIDAR: Wind Lidar Systems for Wind Energy Deployment
IEA Wind Task 33 - Reliability Data - Standardization of data collection for wind turbine reliability and operation & maintenance analyses

List of partners and committees

Jasna Bogunović Jakobsen

Jasna Bogunović Jakobsen is professor in structural engineering at the University of Stavanger. She holds a PhD in structural engineering from the Norwegian Institute of Technology (now NTNU) and a M.Sc. in structural engineering from the University of Novi Sad, Serbia.

Her main research field is structural dynamics, with emphasis on wind loads and wind-induced vibrations of slender structures. In particular, the research has been focused on generation of buffeting loads on long-span bridges and methods to capture the wind-structure interaction responsible for bridge flutter, from ambient vibration data.

At present, she is involved in studies of aerodynamics of bridge stay cables in the critical Reynolds number range, in the full-scale wind and bridge response monitoring, and in various studies on aerodynamics of wind turbine rotors. She is a member of NORCOWE's scientific committee.

Joachim Reuder

Joachim Reuder is professor in experimental meteorology and Deputy Head of Department at the Geophysical Institute at the University of Bergen. He has more than 20 years of experience in atmospheric boundary layer research and is an expert in boundary layer measurements. His experience in a wide range of relevant measurement methods and techniques includes eddy covariance flux measurements, wind profiling by lidar, sodar and radar, temperature profiling by passive microwave radiometers and the development and use of RPAS (Remotely piloted aircraft systems) for atmospheric turbulence measurements.

He is leading WP1 Met-Ocean measurements and database in NORCOWE, managing the national Norwegian infrastructure project OBLO and is also involved internationally in EERA and IEA.

Thomas Bak

Thomas Bak is professor in automatic control at Aalborg University, Denmark. His research is dedicated to improve the use of control methodology within relevant application domains. One important domain is offshore wind energy, with focus on wind farm control.

Thomas Bak has been involved in the NORCOWE summer schools, and is now work package leader of WP3 – Design, installation and operation of offshore wind turbines.

Yngve Heggelund

Yngve Heggelund is a senior scientist at Christian Michelsen Research (CMR), where he has worked since 2001. He has a M.Sc. in industrial mathematics from NTNU and a PhD degree in numerical ocean modelling from the University of Bergen.

At CMR he combines his background in mathematics, physics and programming in many projects including visualization of seismic data, processing and interpretation of marine acoustic data and decision support systems for maritime applications.

In the NORCOWE centre, he is working as a project manager on developing a fast method for computing the flow field and the power production in offshore wind farms.

Nina Winther-Kaland

Nina Winther-Kaland is Research Manager in StormGeo. She holds a PhD in Physical Oceanography, and has broad experience in all aspects of operational oceanography.

Trygve Toft-Eriksen

Trygve Toft-Eriksen is the acting Centre Coordinator at NORCOWE, CMR. The work at Centre Coordinator in NORCOWE is a diverse job. Information flow within the centre and facilitation of meetings, workshops and conferences are amongst his main responsibilities.

His educational background is a Bachelor's degree in Energy Technology (Energy Engineer) and a Master's degree in Innovation & Entrepreneurship at Bergen University College/University of Oslo/Rice University, TX.

Hans Georg Beyer

Hans Georg Beyer is Professor for Renewable Energies in the University of Agder. He holds a PhD in Physics from the University of Oldenburg, Germany. His research areas are renewable energy systems and energy meteorology, covering both wind and solar energy.

Since October 2014 he acts as UiA representative in NORCOWE Centre Management Group. His NORCOWE activity in the next years will be focused in WP1 on meteorological conditions – more specifically on the characterization and modeling of highly time-resolved wind field data.

Kristin Guldbrandsen Frøysa

Kristin Guldbrandsen Frøysa holds a dr. scient. degree in applied mathematics from the University of Bergen. Her first job was at Norsk Hydro, modeling flow in porous media. She has worked with fish stock assessment at the Institute of Marine Research in Bergen and with marketing of instrumentation for current measurement and environmental monitoring at AADI. Her last position before joining Christian Michelsen Research (CMR) was as department manager at Reinertsen. She started as NORCOWE director in January 2010.

Trond Svanes Jensen

Trond Svanes Jensen – R&D Director Aquiloz

Trond Svanes Jensen is the head of R&D at Aquiloz and he is responsible for leading the development of new forecasting models in the company. He has over 18 years of experience from trading, portfolio and risk management in the European energy market, and has through his work experience gained extensive knowledge about applied modelling and forecasting in the energy space. He has a solid theoretical knowledge about statistical methods, time series analysis and machine learning algorithms.

Reinhardt Stevens

Reinhardt is General Manager at FLiDAR NV. He started his career with a strong experience in the offshore industry as an Operational Superintendent and Project Manager at Jan De Nul, an international dredging company. After a switch to the renewables industry he took on the position of Contracts Manager at Electrawinds, an onshore wind developer from Belgium. He combined that period with an Executive MBA education where he gathered a deeper knowledge about the world of business and grew a fond interest in entrepreneurial surroundings. Reinhardt joined FLiDAR as Commercial Manager in the beginning of 2014 and he has assumed the position of General Manager in the beginning of 2015.

Birgitte Rugaard Furevik

Dr. Birgitte Rugaard Furevik received a M.Sc. degree in oceanography from Copenhagen University in 1995 and a PhD from University of Bergen in 2001. Until 2005, she was with Nansen Environmental and Remote Sensing Center in Bergen working mainly with microwave remote sensing. Dr. Furevik has since then been a research scientist at the Norwegian Meteorological Institute. Her main research interests are related to surface waves, the marine boundary layer and model verification, wind profiles, coastal variability and various mesoscale phenomena.

Geir Pedersen

Geir Pedersen is a scientist at Christian Michelsen Research (CMR) and has been a member of the CMG since 2014. His background is from the University of Bergen and the Institute of Marine Research where he specialized in underwater acoustics. At CMR he works mainly with marine measurements and contributes to the NORCOWE offshore measurement campaigns and infrastructure projects.

Angus Graham

Angus Graham leads the Environmental Flow Group at Uni Research in Bergen. He has a degree in physics from the University of Sussex, UK, and a doctorate in applied mathematics from the University of Southampton. He has ten years' research experience in physical oceanography, gained at Southampton Oceanography Centre, and ten years of experience in meteorology and air quality, gained at Manchester Metropolitan University.

At Uni Research he applies his expertise to geophysical boundary layers; air-sea interaction and surface waves; wakes, jets and plumes; remote measurement techniques and image processing; and stochastic simulation.

Finn Gunnar Nielsen

Finn Gunnar Nielsen has a background in engineering from NTNU, with a PhD within Marine Hydrodynamics. He has for more than 30 years worked within R&D related to dynamics of offshore structures. Presently he holds a position as senior advisor in Statoil. His main activities are presently related to R&D within offshore wind. Finn Gunnar has also had a position as adjunct Professor at NTNU, teaching marine operations. Presently he is adjunct professor at University of Bergen teaching at a master programme in energy. Finn Gunnar headed the R&D project that lead to the Hywind floating offshore wind concept. He has also participated in several national and international committees related to offshore wind and marine renewable energy more generally.
He is now chairing NORCOWE's scientific committee.

Eirik Manger

Eirik Manger joined the Centre Management Group in 2014, representing Acona Flow Technology (AFT). He has a MSc in applied mathematics and did his PhD on multiphase flow. Area of expertise is flow modelling, focusing on Computational Fluid Dynamics – or CFD for short. Within NORCOWE the main focus for Eirik and AFT is the impact of waves, especially swell, on the Marine Atmospheric Boundary Layer (MABL). Eirik was a co-supervisor for Siri M Kalvig on her PhD, and has been working closely with UiS and StormGeo establishing methods for investigating this phenomena using CFD.
Acona Flow Technology offers specialized fluid flow competence to its customers. The company employs senior personnel with long experience. AFT joined NORCOWE in 2014 to strengthen its focus and competence on wind simulations.
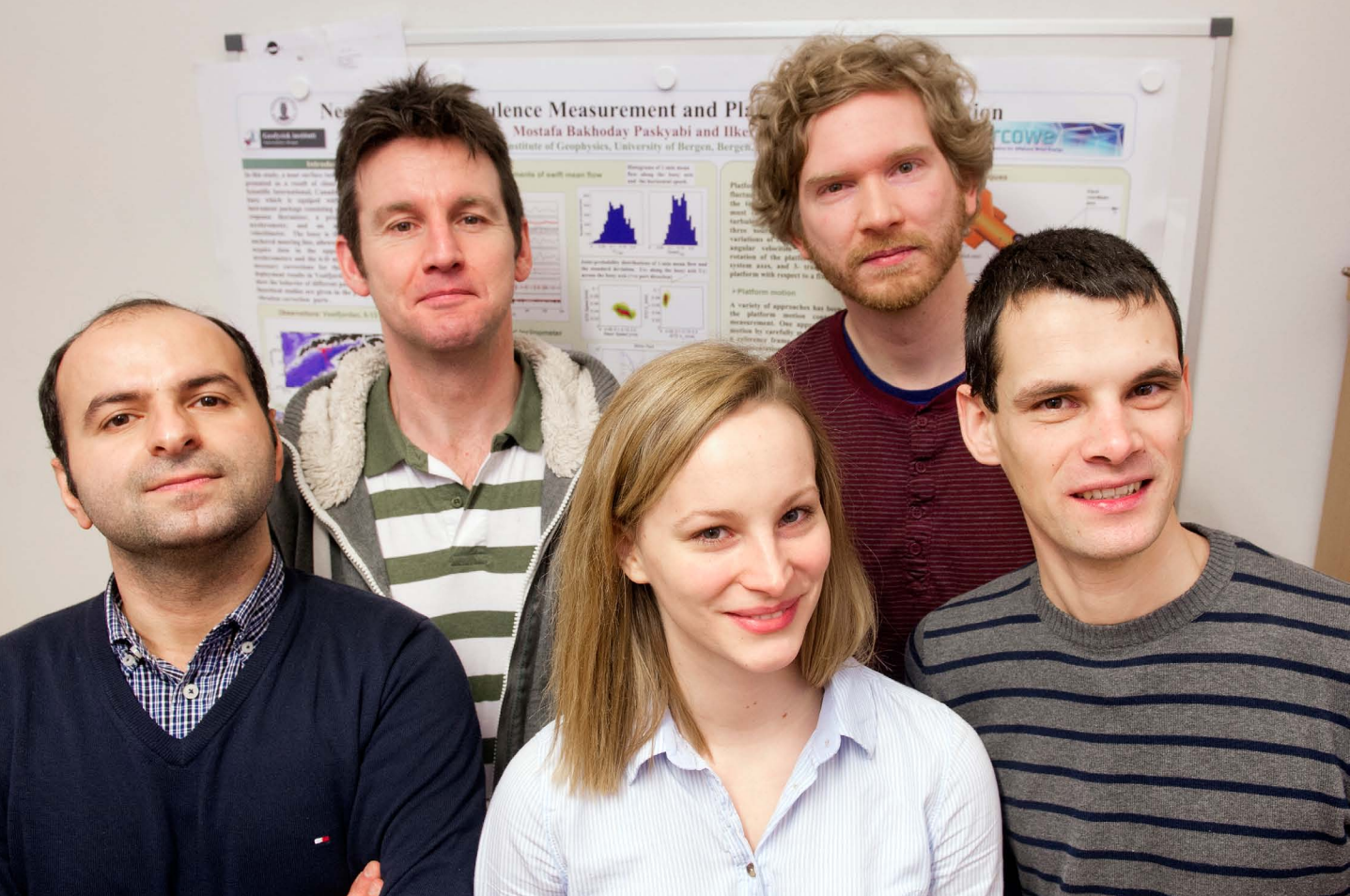
Organization

General assembly
All partners and
EB chairman

Executive Board (EB)
9 representatives
Chair: Alf Holmelid,
University of Agder

Scientific Committee
Lead: Finn Gunnar Nielsen, University of Bergen /
Statoil

International Scientific Advisory Committee
Lead: Finn Gunnar Nielsen, University of Bergen /
Statoil

Centre Administration
Hosted by Christian Michelsen Research AS
Centre Director Kristin Guldbrandsen Frøysa
Acting Centre Coordinator Trygve Toft-Eriksen

Work Package 1
Met-ocean data
Lead: Joachim Reuder, University of Bergen

Work Package 2
Wind energy estimation
Lead: Angus Graham, Uni Research

Work Package 3
Design, installation and operation of offshore wind
turbines
Lead: Thomas Bak, Aalborg University

Key figures 2014

PhD students: 16
Completed PhDs: 5
Post Docs: 1
Master students: 5

Number of publications: 29
Posters and presentations: 49

Contact info

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Trygve Toft-Eriksen, Centre Coordinator

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