Minimizing climate uncertainty for offshore operation decision making

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As offshore wind pushes into deeper, rougher waters, traditional forecasting isn't enough. Miros explores how integrating real-time metocean data with AI-powered models is helping operators stay ahead of changing conditions, boosting safety, efficiency and resilience at sea.

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Of all the key differences between offshore and onshore operations, how different weather impacts decision making is arguably the most crucial. It is intrinsically linked to the sea state, the implementation and behaviour of vessels and, in turn, to the safety and efficiency of actions, be that in offshore exploration and production or offshore wind.

Accurate weather forecasting has long been a cornerstone of offshore operations across the globe and is vital to managing risk and enhancing competence. It is a non-negotiable in the drive to set new standards for safety and efficiency in offshore wind, but it isn't without its limitations.

Weather forecasting has evolved from generalized seven-day predictions to near real-time accuracy, yet for offshore wind operations, traditional forecasts can often fall short. While forecast models provide a broad outlook, they lack the precision, both in location and time resolution, needed for operations that demand reliable, site-specific data. By considering the limitations from traditional weather forecast models, a well-integrated system, consisting of both forecast model and accurate real-time metocean measurements, becomes a clear solution.

Managing offshore wind operations in the face of a changing climate

As areas suitable for fixed-bottom wind are depleted, the offshore wind industry will continue to push into deeper waters further from shore. With that comes increasingly volatile weather and growing wave heights that demand innovative operational strategies, such as service operation vessels (SOVs) with daughter crafts, which have higher wave height operational limits than crew transfer vessels (CTVs). In turn, this demands the need for more accurate weather and wave predictions to maximize site accessibility and ensure safety.

Paradoxically, the key driver behind the world's offshore wind build out, namely the climate crisis, is making the installation and maintenance of wind farms more challenging. Climate change has brought more extreme weather conditions, both in greater magnitudes and frequency. The industry is gradually learning how each factor is impacting day to day operations.

For example, historical data from the Copernicus Marine Environment Monitoring Service (CMEMS) reveals a stark increase in wave heights across the North Sea. Between 2020 and 2022, the percentage of time with wave heights exceeding 1.5 meters nearly doubled compared to 2018–2019.

This trend was particularly evident at the DanTysk wind farm, where 76% of recorded wave heights exceeded 1.5 meters during the 2022–2023 winter season. Such conditions, which significantly impact maintenance schedules, turbine accessibility and operational planning, are only going to worsen while climate change continues.

The solution: AI-enhanced forecasting with real-time data

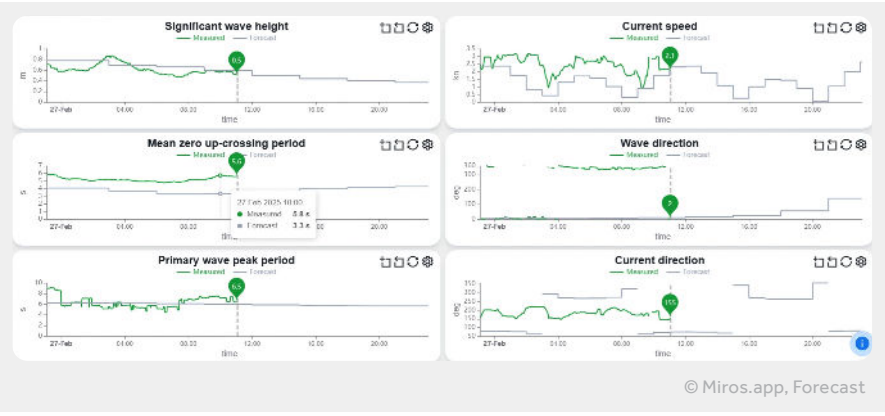
Combatting these challenges requires future-proof thinking and innovative technological solutions. The integration of real-time metocean data with weather forecasting systems is transformative when done well. It enables more accurate predictions, particularly in regions with dynamic and rapidly changing conditions. To achieve this, the integrated system is more sophisticated than simply running both the forecast and real-time measurement campaigns in parallel.

By streaming up-to-the-minute site measurement data into predictive forecasting models, calculations gain valuable, precise benchmark data points to fine-tune forecast data output continuously, enhancing both short-term and medium-term accuracy.

The DanTysk wind farm has been pioneering this approach, commissioning Miros for accurate metocean measurements, with real-time data continuously fed to the forecast provider, i4sea. i4sea has developed a hyperlocal forecasting solution utilizing precise real-time measurements by Miros with AI-driven forecast corrections.

By recalibrating predictions every 20 minutes, this approach surpasses traditional models reliant on broad parameters such as peak direction (Dp), peak period (Tp), and significant wave height (Hs). Instead, it considers the entire sea state, incorporating site-specific obstacles like wind turbines and calibrated wave transmission coefficients.

Integrating real-time sea state data, this refined methodology has led to forecast accuracy improvements of up to 60% over conventional providers, offering offshore wind operators a more reliable decision-making tool. It also improves operational efficiency, as live data helps confirm changes in weather events, such as storm shifts, enabling quicker response times.



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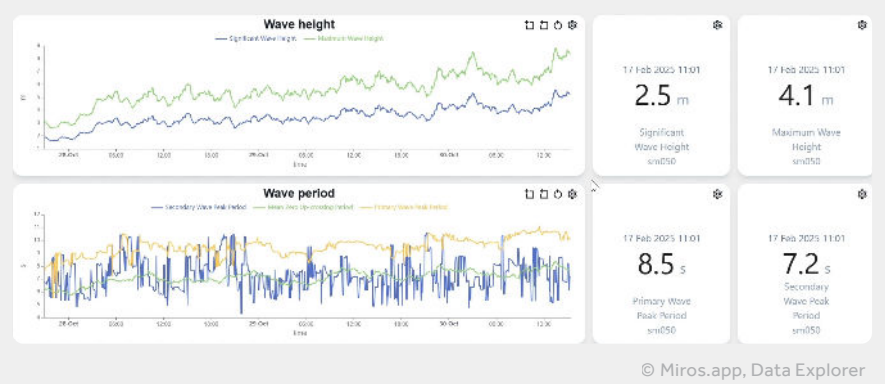

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Additionally, this integration provides local customization, ensuring operations in industries like offshore wind are based on actual conditions rather than generalized predictions.

The benefits to users are multifaceted. Operators can make precise go/no-go decisions, thereby maximizing turbine accessibility and minimizing unnecessary delays. Real-time data allows for better planning, meaning operators can optimize their maintenance windows.

More accurate forecasts mitigate risks associated with rough seas, high winds and thereby improve worker safety, while avoiding unnecessary vessel deployment leads to lower fuel consumption and emissions.

Furthermore, the integration of real-time measurements ensures that even in rapidly changing weather conditions, forecast corrections remain grounded in what's happening onsite. This not only builds confidence among crews and operators but also enhances overall resilience and responsiveness in offshore project planning.

In a sector where safety, efficiency and sustainability intersect, well-integrated solutions like i4sea and Miros demonstrate how next-generation technologies can drive meaningful progress, delivering measurable improvements and future-ready operations.

Tried and tested: seamless integration with existing infrastructure

In offshore wind, adopting innovative solutions means first overcoming the required validation to mitigate uncertainties and risks. Also, in a sea of new industry suppliers, offshore wind operators need reliable options. Suppliers and products not only need to be able to integrate with existing infrastructure but also guarantee they will still be working throughout the rest of a wind farm's lifecycle.

Miros' real-time metocean measurement systems have been rigorously tested across the world's harshest offshore conditions and are ready to be retrofitted to existing infrastructure. Their seamless integration with forecasting and operator platforms ensures compatibility without requiring extensive modifications. This adaptability makes them a reliable and trusted asset for offshore wind operations striving to enhance reliability and efficiency in increasingly unpredictable marine environments.

To make real-time metocean condition monitoring available round the clock, Miros developed a cloud computing-based data access platform, Miros.app, which can be accessed on any browser, on any device. Users can explore live data from sites equipped with Miros sensors, offering a unique window into ocean conditions from a range of wind farms and vessels.

Miros.app provides reliable, real-time access to metocean data that is essential for decision-making in offshore and maritime operations. Built on the Miros Cloud infrastructure, it simplifies how data is collected, accessed remotely and used across different roles and environments, while also providing seamless integration with other third-party platforms and all Miros core sensors, offered as a subscription. Miros Cloud and sensors utilize Microsoft Azure IoT and Cloud infrastructure, the same approach that NASA uses to access live space station sensor data.

The platform includes a range of individually tailorable applications such as Offshore Wind Map, Data Connector, Data Explorer, Forecast, and PredictifAI. Each is designed to meet specific needs across the industry. These tools help users manage, interpret, and predict ocean data more effectively, supporting collaboration and enhancing responsiveness in changing conditions.

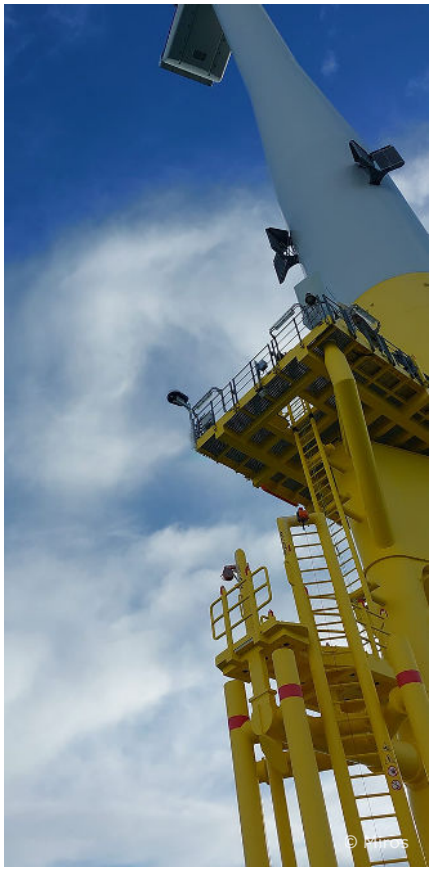
Integrated multi-source monitoring for site oversight

Utilizing multiple data streams supports proactive management and optimizes processes across the entire wind farm. Continuously delivering high-frequency data from connected sensors, Miros Cloud replaces legacy systems and enables scalable, real-time analytics.

This constant flow of local, reliable sea state data empowers operations teams with instant insights, enhancing situational awareness for improved and timely decisions. In offshore environments where conditions can shift rapidly, this capability is essential for effective planning and execution.

Site managers can use data from multiple sources to monitor operations and optimize processes, helping ensure project milestones are met across a variety of offshore environments, including vessels, wind farms, ports and platforms.

For data analysts, Miros Cloud provides continuous data streams from connected devices, offering a more flexible and effortless alternative to traditional systems. Forecast providers also gain advantages by working directly with real-time, high-resolution



Miros WaveFusion sensor installed on a turbine. Miros' real-time metocean measurement systems have been rigorously tested across the world's harshest offshore conditions and are ready to be retrofitted to existing infrastructure

datasets, improving the accuracy and reliability of their models in both offshore and coastal applications.

Vessel operators benefit from real-time measurements, as well as upcoming large wave prediction as well as the corresponding vessel motion prediction.

Delivering proven value in the field

Miros.app serves as a practical and accessible tool for turning ocean observations into actionable insights, helping users across different roles better understand and respond to their operational environment. One standout example is Horns Rev 1, the world's first large scale offshore wind farm, which began operations over two decades ago.

Originally kitted out with metocean sensors submerged in water, the site faced high costs in maintaining these sensors. Sensors submerged in water are also prone to damage due to stormy weather, losing months' worth of data each time. As the wind farm evolved, so did its technology. Horns Rev 1 upgraded to Miros' metocean monitoring systems, replacing the existing, traditional metocean sensors with a modern, real-time solution that delivers reliable, remotely accessible wave and weather data.

This shift not only enhanced operational efficiency but also aligned with broader industry goals of transparency, safety and smarter offshore decision making. With Miros technology, operators and now anyone in the world, can monitor conditions such as wave height and surface currents in real time.

The public access to data from Horns Rev 1, DanTysk, and other sites of varying ages showcases how legacy infrastructure can be revitalised with cutting-edge tech, ensuring offshore operations remain safe, efficient and future-ready.

Sustainable maritime operations

Offshore wind is evolving fast. With larger farms, more complex operations, and an ever-growing need for real-time insights, the systems supporting these environments need to keep up, not just today, but for years to come. The reality, though, is that many offshore assets are built to last decades, it is the pace of innovation that moves much faster. This creates a tension between long-term infrastructure and the short-term need for smarter, more adaptable tools.

That's where future-proof systems come in. At Miros, we've spent over 40 years working in maritime technology and we've seen firsthand how quickly operational demands can shift. Our approach is rooted in making it easier for offshore wind operators to adapt without having to overhaul everything when new needs arise.

Instead of static, one-time installations, our systems are designed to evolve. They're built on IoT-enabled hardware, which means updates, whether a new algorithm, sharper data, or a better interface, can be sent remotely, without needing to pause operations or send someone offshore. So, when industry requirements change or new ways of working emerge, the tools you're already using can grow with you.

It's a bit like how self-driving car developers are building today's vehicles to support software updates down the line. The existing hardware can perform future upgrades, while the system gets smarter in the background. We apply the same thinking to metocean monitoring, so your systems stay aligned with the future without the stress of replacements, downtime or compatibility issues.

Ultimately, the goal is to give operators more flexibility and less friction. With future-ready systems in place, you can focus on the bigger picture, whether that's optimizing performance, improving safety or scaling up, knowing that your tech won't hold you back.

Harnessing real-time data: an emerging norm for offshore operations

In offshore wind, the shift from traditional forecasting models to real-time, site-specific measurements and AI-powered predictions is a major step toward more resilient, responsive operations. As climate patterns grow less predictable and offshore conditions become more demanding, access to accurate, real-time data is becoming essential for maintaining safety, efficiency and sustainability.

This is where integrated solutions like i4sea's AI-powered forecasting, working in tandem with Miros' real-time metocean sensors, come into play. By combining predictive intelligence with live onsite measurements, offshore teams gain a clearer, constantly updated picture of their environment. That clarity translates into better decisions, whether it's adjusting operations in response to sudden weather changes, planning more efficient vessel movements or reducing downtime and unnecessary emissions.

This kind of insight also supports long-term performance. Fewer surprises mean fewer delays, less wear on assets and more opportunities to optimize resource use. At the same time, more informed planning helps safeguard people, protect infrastructure and align daily operations with broader environmental and regulatory goals.

Traditional forecasts remain valuable for strategic planning, but when paired with real-time measurements, they offer even greater precision. The result is a smarter, more adaptive way of working, one that's becoming increasingly vital in weather-sensitive sectors like offshore wind.

How do you see this kind of integration being a key element in your operations, especially as metocean data becomes more advanced?

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