Testing & Evaluation Report:

Oshen: Persistent Ocean Intelligence for Climate, Security, and Infrastructure

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Oshen C-Star: Preliminary Testing and Performance Evaluation of a Novel Accessible Ocean Sensing Platform

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Abstract

The C-Star platform is a novel, low-cost ocean sensing platform, developed by Oshen, a UK-based company focusing on providing accessible ocean sensing solutions. The platform, 1.2 m in length, is primarily wind-driven using an actuating rigid sail, and can operate autonomously over multiple days. In collaboration with Synchro, a testbed initiative has been carried out to evaluate the navigation and sensing performance of this platform, involving multiple deployments in both California and the United Kingdom. The platform was able to autonomously navigate over a wide range of wind conditions and points of sail, although issues arose at very low wind speeds in the presence of ocean currents. The addition of a small thruster mounted on the stern partially alleviated these issues. Passive acoustic monitoring (PAM) and metocean data were collected, and the latter was compared to reference sources such as weather stations mounted on moored buoys. We examined agreement between atmospheric pressure, air temperature, wind speed, and significant wave height, with discrepancies observed in measurements of wind direction and sea surface temperature. The ease of deployment and usage of the platform was noted.

1 Introduction

The ocean environment is rapidly changing, creating an unprecedented need to better understand ocean conditions at the scales of management need, i.e., over wide areas of place-based policy implementation. Recent advances in ocean technology have increased the offering of methods available for collecting data in the ocean for several different use cases. However, most of these methods are either too expensive to deploy in large quantities (e.g. moored buoys, long endurance autonomous surface vessels), or don't provide the coverage needed (e.g. drifting buoys). There are very limited market-ready technology options that could scale up to provide a low cost, long-duration, wide-coverage network of data capture across the world's oceans. This is thought in part to be due to the high costs of testing new products rigorously in the oceans: firstly, the resulting products that are taken to market are often highly expensive, and not accessible to the wider market of users who wish to better understand our ocean; and secondly, the lengthy testing cycle resulting from difficulties in getting to sea slows both the development and the adoption of new technologies.

The collaboration between Synchro and Oshen presented here works to tackle these problems, combining Synchro's resources and knowledge in the ocean technology testing field with Oshen's rapid development cycle and dynamic team.

Ocean weather data is a foundational part of assessing environmental monitoring and understanding ecosystem change. Metocean data (data at the atmosphere and ocean boundary), forms a key part of ocean weather data informing both maritime operations, ocean and atmospheric weather forecasting, and improving models. Passive acoustic monitoring from the platform is also being tested. Evaluating the performance of this platform and its sensors as a system to deliver metocean data could address such questions as: 1) What changes are occurring in ocean conditions, such as air pressure and sea-surface temperature? 2) Can the system deliver metocean data that is similar to currently used metocean buoy data and improve forecast of oceanic conditions? And 3) can the system simultaneously deliver passive acoustic monitoring of baleen whales?

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1.1 Synchro

Synchro [1] works to address the obstacles that prevent ocean technology from moving beyond the prototype stages to broader practical use. By bringing together technology developers, resource managers, and other end-users for real-world testing, Synchro reduces costs and complexity in the evaluation process. The focus on data quality, usability, and ease of deployment ensures that once tools are validated, they can be rapidly adopted by the research community and broader user base. Through this streamlined approach, Synchro helps deliver reliable, accessible solutions essential for understanding and managing our rapidly changing oceans.

1.2 Oshen

Oshen Ltd. [2] is a UK-based company dedicated to creating low-cost, autonomous ocean-monitoring devices. Since its founding, Oshen has successfully deployed platforms from three continents, where they have demonstrated their ability to navigate autonomously and to survive severe weather events. To date, the company has manufactured nine such platforms, each designed to operate continuously and provide researchers, policymakers, and industry stakeholders with essential data on rapidly changing ocean conditions. By focusing on affordability and scalability, Oshen enables broader access to critical ocean observations without relying on prohibitively expensive infrastructure.

2 C-Star Platform

Oshen's platform, the C-Star, is a wind-driven vessel capable of carrying multiple sensor payloads, powered using a combination of batteries and solar panels. It functions like a controllable buoy, combining the maneuverability needed for targeted data collection with the endurance to remain at sea for multiple months. This small size reduces production and deployment costs, allowing multiple units to be launched in constellations for persistent, wide-area ocean observation. An example of the platform is shown deployed in Monterey Bay in Figure 1.

Figure 1: The C-Star platform deployed in Monterey Bay.
Photo: A. West / MBARI 2024

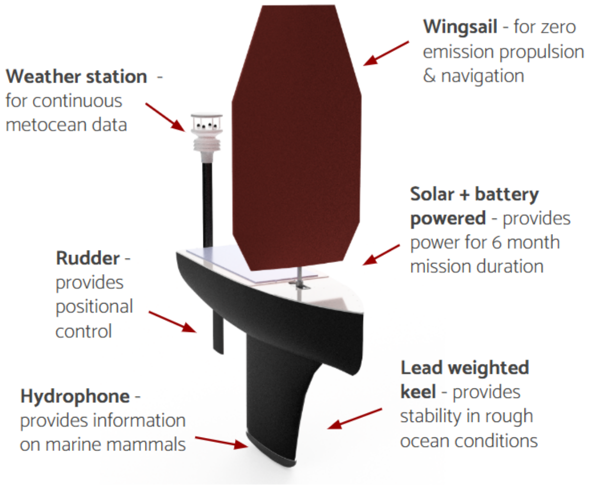


Figure 2: Key features of the C-Star platform

The platform's overall design is shown in Figure 2, which provides an annotated illustration highlighting its key features. The platform's core characteristics, such as dimensions, operational range, and propulsion mechanisms, are summarized in Table 1. Its compact structure and low weight enable straightforward manual deployment and retrieval by 1-2 operators, even in challenging sea conditions. The specific C-Star vessel used by the Synchro team, named *Emperor*, had a 100 Ah battery and no solar panel, as mission durations were short. Other vessels are equipped with a deck-mounted 35 W solar panel and 200 Ah of battery capacity, allowing for extended mission durations.

2.1 Sensor Payload

The sensor payload deployed on *Emperor* for the testing presented in this report is summarized in Table 2. The sensor heights are given relative to the average waterline of the vessel, and as such can be taken as heights above sea level. The payload package includes instruments for passive acoustics, metocean data, and surface temperature measurements. Live readings from the sensors can be accessed during a mission, at a reduced sample rate of one reading per minute, aside from the hydrophone and significant wave height data, which must be retrieved post-mission with the full dataset of sensor readings.

Table 1: C-Star Platform Characteristics

Property	Value
Boat Speed	1–2 knots
Weight	40 kg
Propulsion	Wind (and stern-mounted thruster for low winds)
Power Source	Battery & Solar
Length	1.2 m
Deployment	1-2 people

3 Summary of Testing

The C-Star platform was tested extensively in the USA and the UK to evaluate its functionality, robustness, and user-friendliness. This report is primarily focused on the evaluations conducted in the USA by the Synchro team, but some UK trials are also referred to where relevant for determining critical performance metrics (e.g. upper operational limits).

An overview of the test campaign is provided here, and qualitative descriptions given of the tests carried out. The general test procedure is also described. For reference in subsequent sections, Table 3 lists all relevant tests performed, with a unique identifier assigned to each test.

3.1 USA Missions

The USA missions took place in Monterey Bay with the Synchro team, using the *Emperor* vessel. These missions were used to evaluate the navigation performance of the vessel, as well as evaluate the sensor package through comparisons with the M1 moored buoy.

3.1.1 Training and Orientation

An in-person training session at the Synchro base marked the beginning of the evaluation. Two Oshen team members provided an overview of the C-Star's design, deployment protocols, and operational workflows. This training ensured the Synchro team were equipped to handle the platform independently for subsequent missions.

3.1.2 Deployment and Retrieval Process

Each mission adhered to a standardized process:

1. **Mission Planning**: An in-house code developed by Oshen was used to define waypoints, navigation constraints, and objectives.

2. **Deployment**: *Emperor* was transported off-shore on the vessel RV *Paragon*, powered on, checked for GPS connectivity, and deployed manually, as shown in Figure 3.

Figure 3: Deploying *Emperor* from the RV *Paragon*
Photo: A. Laverack / Oshen Ltd. 2024

Figure 4: Manually piloting the C-Star platform from the skiff
Photo: A. Laverack / Oshen Ltd. 2024

3. **Monitoring**: The mission manager dashboard and a redundant tracker provided real-time updates. The waypoints were dynamically adjusted as needed.

4. **Retrieval**: The platform's compact and durable design facilitated safe manual recovery, even in challenging conditions.

3.1.3 Mission Descriptions

MB1: Dockside Test A dockside test followed the training session to demonstrate key functionalities, such as wind propulsion with two sail sizes, waypoint navigation, and data logging. Conducted from a small skiff fitted with an outboard engine, the C-Star was deployed from the dock using a manual launch. During this test, operators utilized the 'full manual control' mode to pilot the platform with a handheld controller, gaining familiarity with its performance, as shown in Figure 4.

Table 2: Specifications of the main sensors.

Main Sensors	Accuracy	Resolution	Range
Barometric Pressure	Absolute ± 0.4 hPa, Relative ± 0.08 hPa	1% RH	1% RH
Sea Surface Temperature (0.7 m depth)	0.1 °C	0.01 °C	0.01 °C
Wind Speed & Direction	0–10 m/s, 0.3 m/s RMSE; 10–40 m/s, 3% RMSE	0.01 m/s	0.01 m/s
Air Temperature	± 0.3 °C	0.1 °C	0.1 °C
Skin Temperature (0.1 m)	0.1 °C	0.01 °C	0.01 °C
Significant Wave Height	Tests validated within 0.05 m of a moored buoy	2 Hz sampling rate	Tests validated 0.5–9 m against a buoy
Passive Acoustics	Signal-to-noise ratio: 63 dB	Sensitivity (dBV/Pa): −41 min, −35 max	Sensitivity (dBV/Pa): −41 min, −35 max

Table 3: Summary of C-Star platform deployments and mission objectives during the testing campaign.

Ident	Location	Vessel	Date	Duration	Summary
MB1	Monterey Bay, USA	*Emperor*			Key functionality + shakedown
MB2	Monterey Bay, USA	*Emperor*	09/27/24	Same day	Short-duration sea trial
MB3	Monterey Bay, USA	*Emperor*	10/15 – 10/16/24	Overnight	Performance evaluations
MB4	Monterey Bay, USA	*Emperor*	10/29/24	Same day	Performance evaluations
MB5	Monterey Bay, USA	*Emperor*	11/14 – 11/15/24	Overnight	Performance evaluations
MB6	Monterey Bay, USA	*Emperor*	01/06 – 01/07/25	Overnight	Updated hardware evaluations
PL1	Plymouth Sound, UK	*Emperor*			Commissioning trial
PL2	Plymouth Sound, UK	*PS1*			Long duration sea trial

MB2: Initial Sea Trial The first sea trial involved a one-day mission conducted approximately 2 nautical miles offshore. The C-Star was sent a set of waypoints, with the target waypoint updated several times to assess upwind performance in the light winds.

MB3-5: Independent Missions Three additional missions were conducted independently by the Synchro team, focusing on specific performance evaluations.

MB6: Hardware Modification Evaluations In January 2025, a final mission involved evaluating the impact of hardware upgrades, including integrating a thruster to augment the propulsion provided by the sail, enabling improved navigation under calm conditions. These data were then plotted against reference sources for comparison.

3.2 Additional UK Missions

The method followed for UK missions was broadly similar to the US tests, with the platform deployed from a rigid inflatable boat (RIB) 3-4 nautical miles offshore from the coast of Cornwall or Devon.

3.2.1 Mission Descriptions

PL1: Commissioning Trial This was the final sea trial carried out using *Emperor* before shipping to the USA - in addition, the vessel sailed close to the E1 moored buoy, allowing metocean data to be compared to supplement the comparisons made in Monterey Bay.

PL2: Long-Duration Sea Trial This was a 6-day mission using a C-Star vessel of similar design to *Emperor*, named *PS1*.

4 Results and Evaluations

The data collected in the tests presented in Section 3 was analyzed by the Synchro and Oshen teams, and is presented here - specifically Section 4.1 focuses on evaluating the navigation performance of the platform as observed in these tests and Section 4.2 on the sensor package performance.

4.1 Navigation Performance

The initial sea trials highlighted several limitations in the platform's navigation performance, particularly in light wind conditions and in the presence of ocean currents. Following these observations, a series of design improvements were implemented and evaluated in subsequent missions. A small stern-mounted thruster was added to provide auxiliary propulsion during periods of low wind, improving the vessel's ability to maintain heading and reach waypoints. A redundant tracking device was also integrated to provide an additional method of monitoring the position of the platform and ensuring reliable recovery in the event of communication loss. In addition, modifications to the sail design were tested to improve propulsion efficiency and overall handling across a wider range of wind conditions. These iterative adjustments formed part of an ongoing process to refine the platform's navigation reliability and operational robustness.

4.2 Sensor Package Performance

The following sections present comparisons between metocean data collected by C-Star vessels and by moored buoys, namely the M1 buoy in Monterey Bay [3], and the E1 buoy in Plymouth Sound [4]. The comparisons were restricted to when the separation distance between the vessel and the moored buoy was 10 nm or less - this limited the comparisons to tests MB3, MB5, MB6 and PL1. The full suite of metocean sensors used could be evaluated in the Monterey Bay tests, but unfortunately the sea surface temperature sensors were not fitted for test PL1, and due to a (since rectified) logging error, wind speed data from the C-Star vessel was not saved, meaning comparisons of these with the E1 buoy's data could not be made.

The C-Star microvessel metocean sensors sample at a nominal rate of 1 Hz, while the moored buoys typically provide data at a much lower rate: the M1 buoy historical data is time-averaged over 10-minute windows, excepting the sea-surface temperature data, which uses a 30-minute window; while the E1 buoy historical data is time averaged over 60-minute windows. To provide a clearer comparison, the C-Star vessel data outputs were resampled and time-averaged to match the corresponding buoy output rate. Error bands have been plotted where available for the C-Star vessel sensors, based on manufacturer specifications. No error bands are provided for the moored buoy data, and this is essentially treated as the ground truth in the comparisons.

4.2.1 Atmospheric Pressure

Figure 6 shows comparisons of atmospheric pressure data collected by *Emperor* and the M1 buoy. It should be noted that a hydrostatic correction has been applied (using a local calculation of air density) to the data from *Emperor* to account for the offset in heights between the two data sources.

In general, agreement is excellent: *Emperor*'s data captures the general trends across all three tests, and differences in absolute value are small, with the M1 buoy reading typically within the error band of *Emperor*'s sensor. Occasionally, *Emperor*'s reading appears to lag that of the M1 buoy, for example during the rise in pressure between 21:00 and 01:00 at the beginning of the data presented in Figure 6a for test MB3, and the later fall between 13:00 and 19:00 in the same test. There are also differences in the peak pressure detected in test MB3 and the lowest pressure detected in MB6. It is possible these discrepancies are a result of local variations in atmospheric pressure, although overall there appears to be little common trend across the three tests in terms of the effect of separation distance on reading agreement.

To assess the reproducibility of these results, Figure 7 shows a comparison of data collected in the PL1 test, performed in the UK, against the E1 buoy. Similar agreement is observed in this comparison as to those made against the M1 buoy data.

4.2.2 Air Temperature

Comparisons of measured air temperature over the three tests are plotted in Figure 8. No correction has been made using lapse rate for the difference in height between the two sensors, as this was estimated to be on the order of 0.02 °C and therefore effectively negligible.

While agreement is not as close as for atmospheric pressure, it is still reasonable - in particular, the sudden increases in temperature between 11:00 and 15:00 in test MB3 and between 00:00 and 02:00 in test MB6 recorded by the M1 buoy were both also registered by *Emperor*. Again, as for the atmospheric pressure data, there appears to be little correlation between measurement differences and separation distance - it is likely that local variations in air temperature are sufficiently low over the distances in question that sensor performance is the dominating cause of these differences. The difference in sensor heights (0.5 m for *Emperor* vs. 2.5 m for the M1 buoy) may also be a contributing factor, with *Emperor*'s readings likely much more affected by heat exchange with the sea surface.

Figure 9 shows a similar comparison against the E1 buoy. This shows arguably better agreement than against the M1 buoy - this may be because the sensor heights are in closer agreement, although it is also possible the longer averaging window has smoothed out some discrepancies.

4.2.3 Sea Surface Temperature

Figure 10 presents the SST data collected by *Emperor* during the MB3, MB5, and MB6 tests alongside the SST measurements taken by the M1 Buoy. *Emperor* reproduced the general SST variability observed by the M1 Buoy in tests MB3 and MB6, clearly capturing the diurnal heating and cooling cycle. Correspondence during MB5 was weaker, with *Emperor* showing a systematic cool bias and a reduced diurnal amplitude, although the overall day-night cycle remained evident. Anomalies with the M1 dataset complicate this comparison. The buoy's -10 m temperature sensor frequently fell within the range of *Emperor*'s near-surface SST readings, which is inconsistent with expected vertical stratification. This is possibly indicative of zero-offset errors in the low-cost sensors. *Emperor*'s own measurements show an offset of 0.3-0.5 °C between the hull (-0.1 m) and keel (-0.7 m) sensors. This magnitude is within the physically documented range of the formation of the upper warm water layer [5]. However, the near-constant nature of this offset throughout the diurnal cycle may also imply a sensor error, as enhanced vertical mixing during night-time cooling would be expected to reduce temperature gradients.

4.2.4 Wind Speed and Direction

Wind measurements recorded aboard *Emperor* were corrected to enable comparison with buoy observations. Wind speed was adjusted to account for the difference in sensor height relative to the M1 buoy anemometers, and both wind speed and direction were corrected for the vessel velocity vector in order to estimate true wind conditions.

Wind speed comparisons with the M1 buoy (Figure 11) show good agreement when the vessel is close to the buoy. The observed differences are comparable to the variability between the two wind sensors mounted on the buoy itself. However, agreement decreases with increasing separation distance, suggesting that spatial variability in the wind field is a contributing factor. Wind speed measurements obtained near the buoy can therefore be considered broadly consistent with the buoy observations.

Wind direction comparisons (Figure 12) show larger discrepancies. Agreement during test MB5 is generally acceptable, particularly given the variability between the two M1 buoy sensors. In contrast, tests MB3 and MB6 show substantial differences even when the vessel is near the buoy. During these tests the buoy records relatively stable wind directions, whereas the *Emperor* measurements show greater short-term variability and do not reproduce the buoy-observed trends. To better visualise these differences, the shortest angular difference between the datasets will be included in the analysis, accounting for the circular nature of directional data (0°–360°).

Comparison with the E1 buoy shows a similar level of discrepancy in wind direction. Potential causes being investigated include errors in the vessel heading measurement from the onboard IMU, vessel motion (particularly roll) affecting the vertically mounted sensor, and flow distortion caused by the vessel's sail, within whose wake the wind sensor is located.

4.3 Additional data

In addition to environmental measurements, hydrophones deployed on autonomous surface vessels enable the detection and monitoring of whales through passive acoustic monitoring of their vocalisations.

Significant wave height can be estimated from GPS-derived vertical position measurements (z) by analysing the variance of the vessel's surface elevation over time.

4.4 Hurricane Project with NOAA

In 2025, seven C-Star platforms were deployed during a NOAA-supported project to evaluate the performance of the system in extreme weather conditions. During this emission, the C-Star platform became the first USV to enter and survive the eyewall of a Category 5 hurricane. The platform continued to successfully transmit environmental data throughout the event, demonstrating the robustness of the design and its ability to operate under highly energetic ocean conditions (Figure 5).

During deployment, the platforms encountered significant wave heights of approximately 14 m, with maximum waves estimated at up to 25 m, and wind gusts reaching approximately 140 knots. Throughout the project more than 9,000 nautical miles were sailed, with collected observations ingested directly into operational forecasting models. Individual platform endurance was also evaluated under sustained operational conditions, with the longest continuous deployment lasting up to 100 days. These results highlight the durability of the C-Star platform and its potential to contribute valuable environmental observations in regions where traditional ocean observing systems are sparse or difficult to maintain.

Further details of the project and the mission outcomes are available from the NOAA Atlantic Oceanographic and Meteorological Laboratory project report online [6].

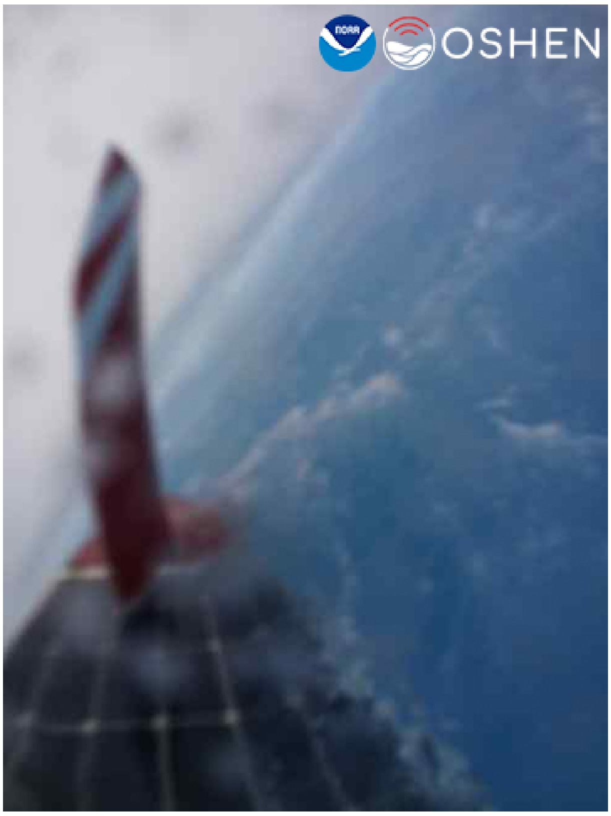


Figure 5: Image captured by a C-Star inside Hurricane Humberto.

5 Conclusions

5.1 High-Level Conclusions

The testing campaign demonstrated that the C-Star platform can autonomously navigate and collect environmental data while carrying a compact sensor payload. Deployments in Monterey Bay and the United Kingdom showed the platform can operate in a range of conditions while collecting metocean and passive acoustic data.

5.2 Navigation Performance

The platform successfully navigated between waypoints under most wind conditions. Early tests showed limitations in very low winds and in the presence of currents. Modifications including the addition of a stern-mounted thruster, improvements to the sail design, and the integration of a redundant tracking device improved navigation reliability and overall mission robustness.

5.3 Sensor Performance

Several sensors showed good agreement with reference buoy data, particularly atmospheric pressure, air temperature, significant wave height, and wind speed. Larger discrepancies were observed in wind direction and sea surface temperature measurements, indicating that further calibration and investigation may be required.

5.4 Operational Performance

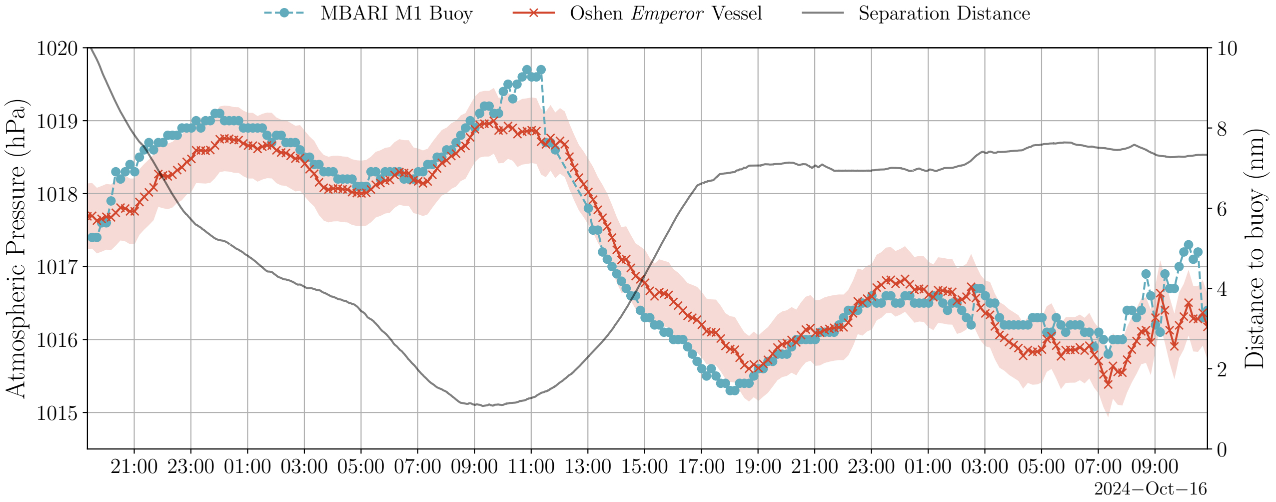
The platform proved relatively easy to deploy and recover due to its small size and low weight. Multiple missions were successfully completed, demonstrating the durability of the platform and the practicality of operating it with a small team.

5.5 Lessons Learned

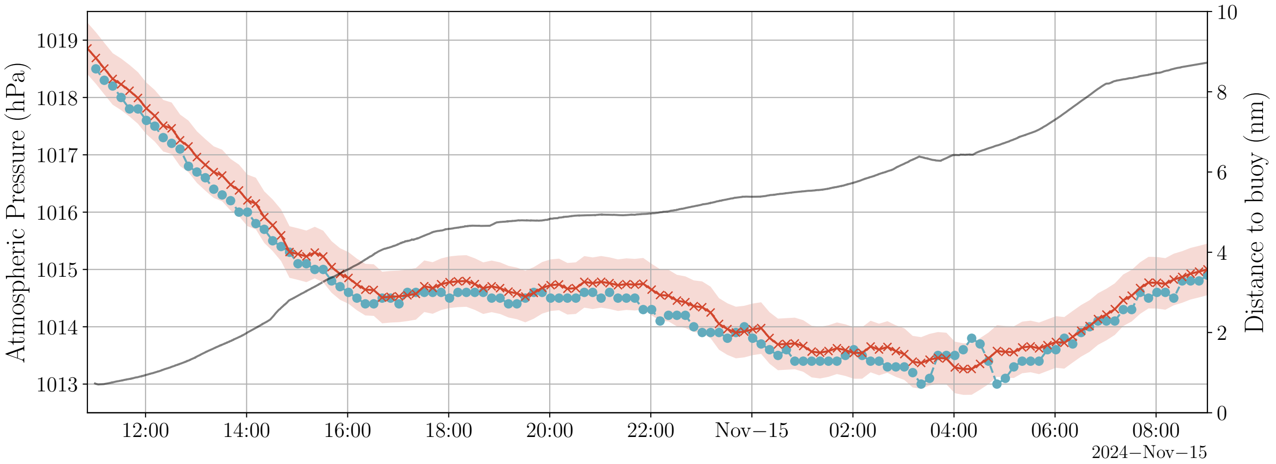
Testing highlighted the importance of operating close to reference sensors when validating measurements and the value of iterative testing to identify and resolve performance limitations.

5.6 Future Development

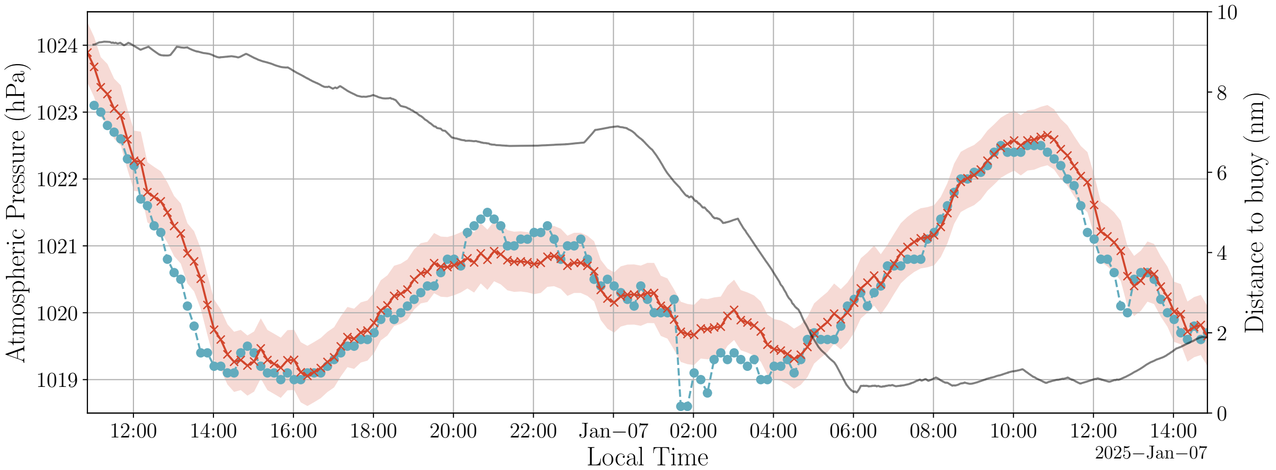
Further work may focus on improving performance in low-wind conditions, refining sensor calibration, and expanding the sensing capabilities of the platform for wider ocean monitoring applications.



(a) MB3



(b) MB5



(c) MB6

Figure 6: Comparisons of atmospheric pressure data collected from *Emperor* and the M1 Buoy

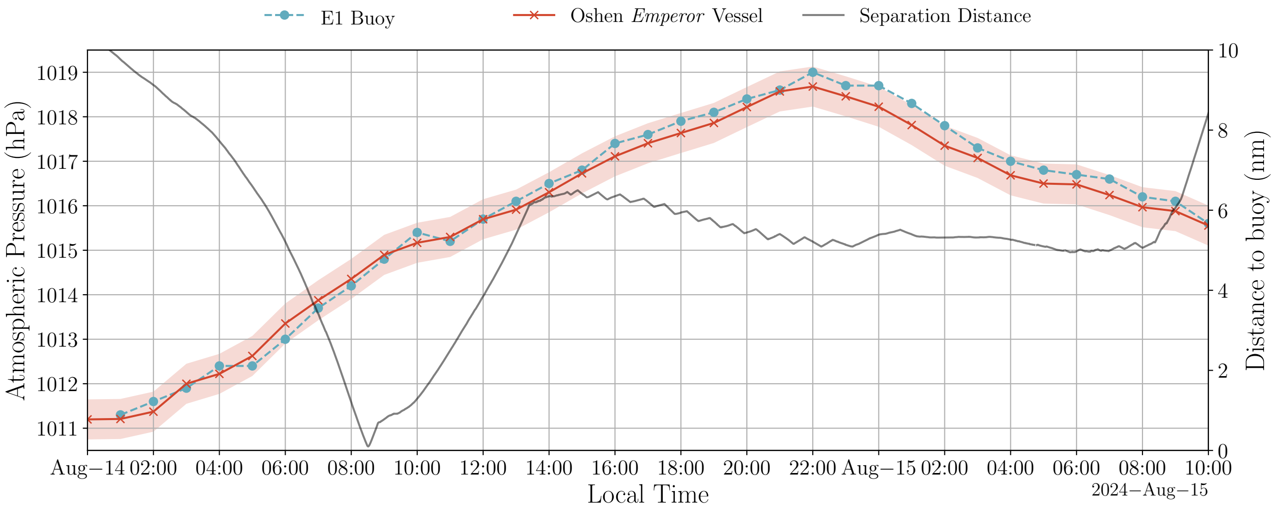
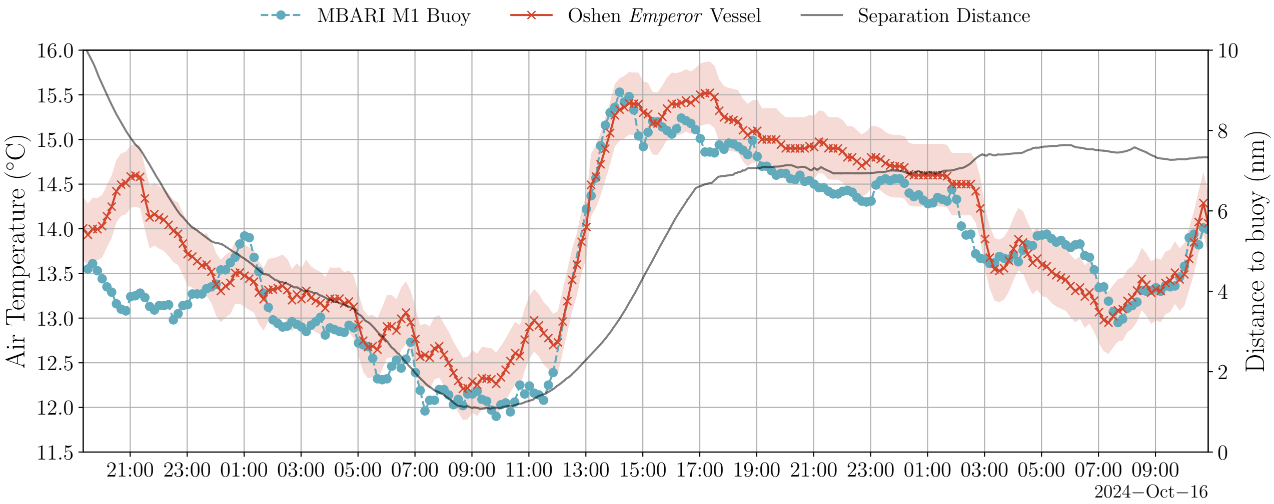
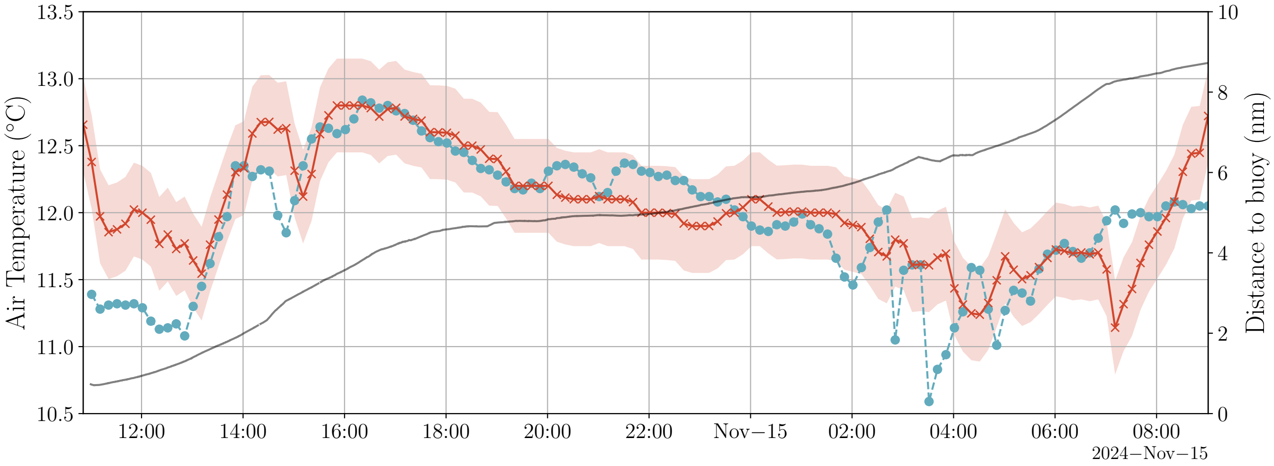


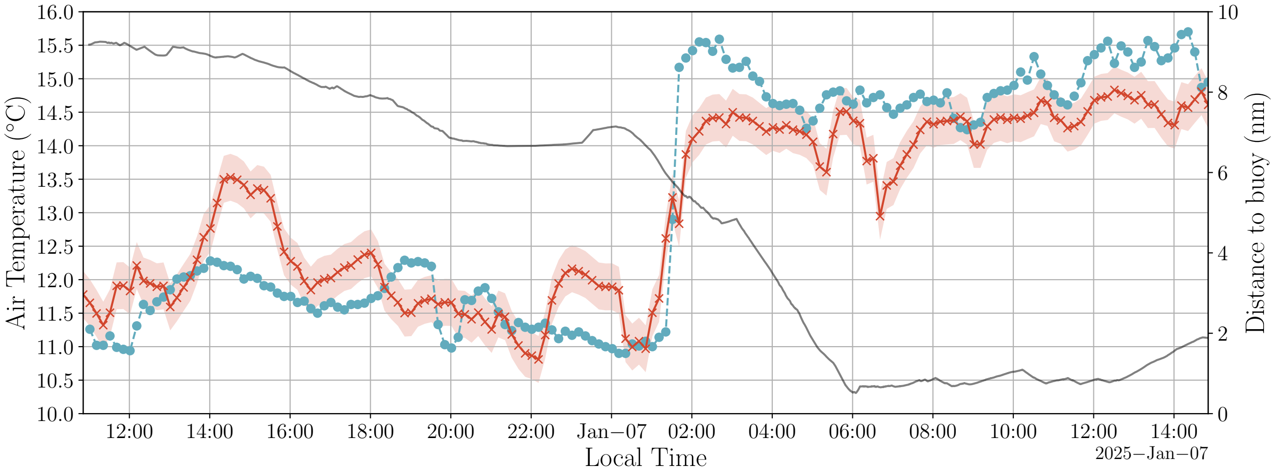
Figure 7: Comparison of atmospheric pressure data collected from *Emperor* and the E1 Buoy in test PL1



(a) MB3



(b) MB5



(c) MB6

Figure 8: Comparisons of air temperature data collected from *Emperor* and the M1 Buoy

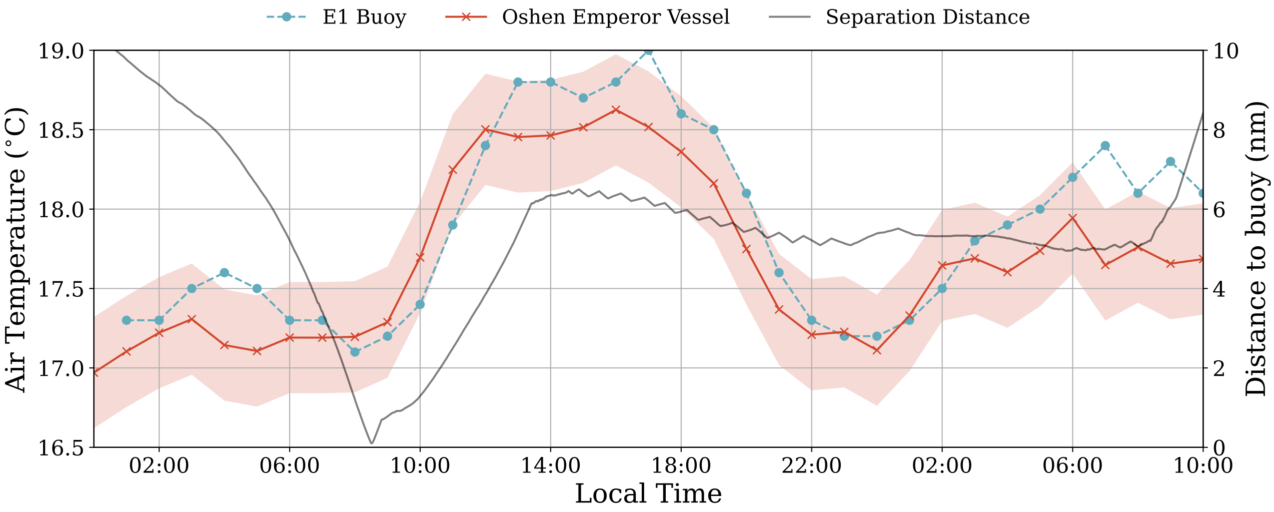
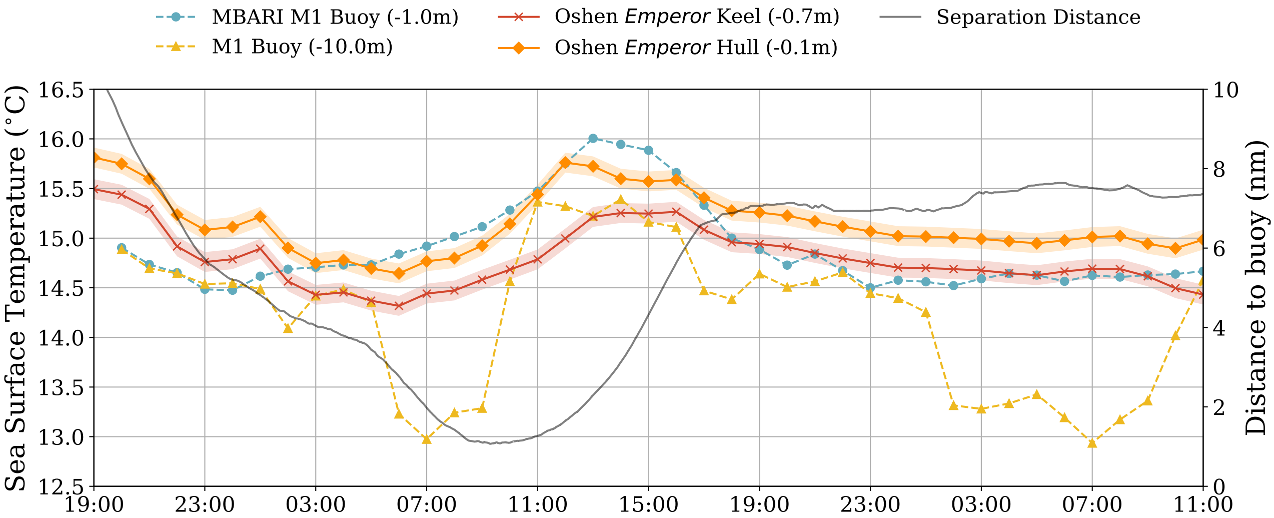
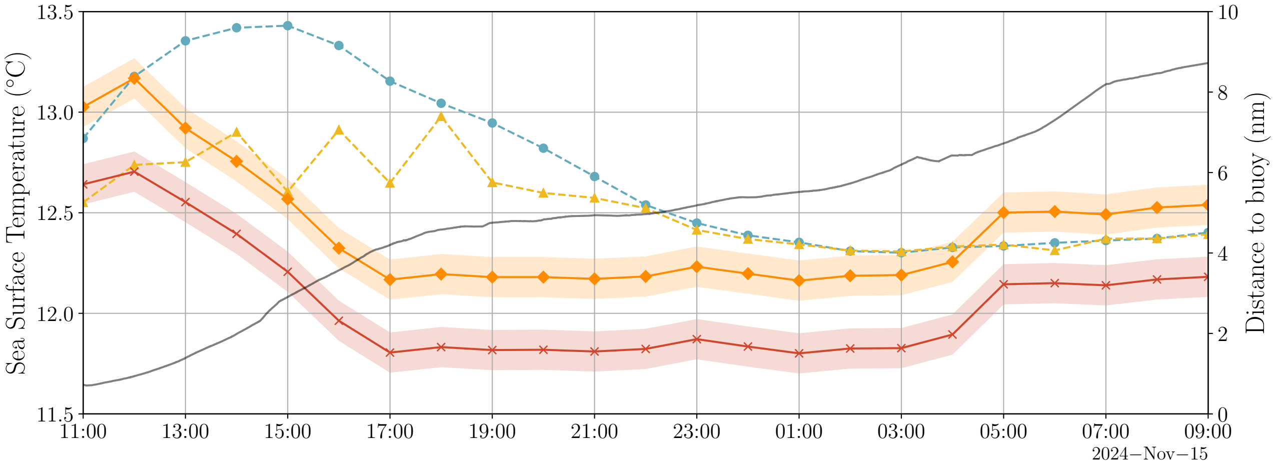


Figure 9: Comparison of air temperature collected from *Emperor* and the E1 Buoy in test PL1



(a) MB3



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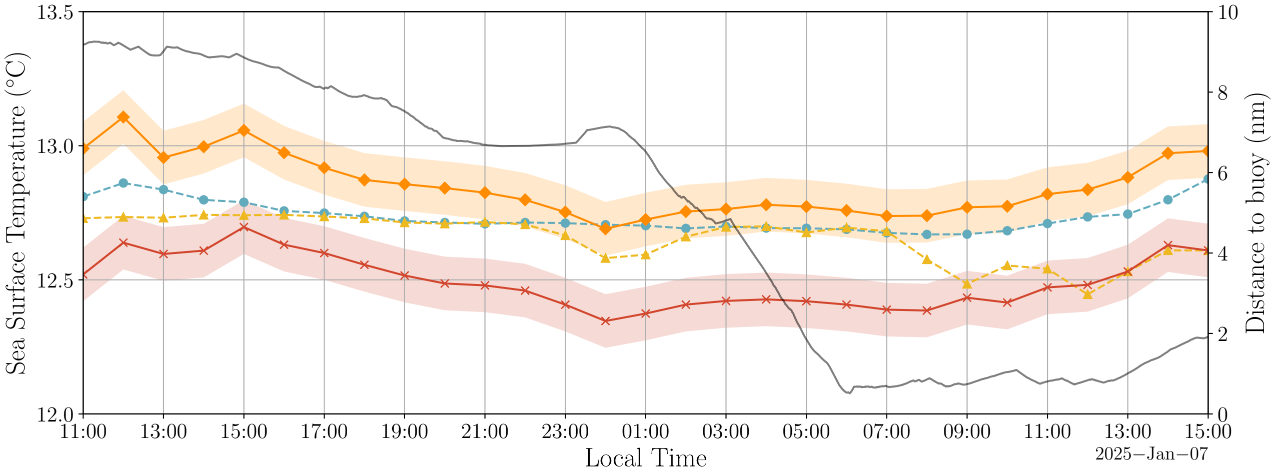
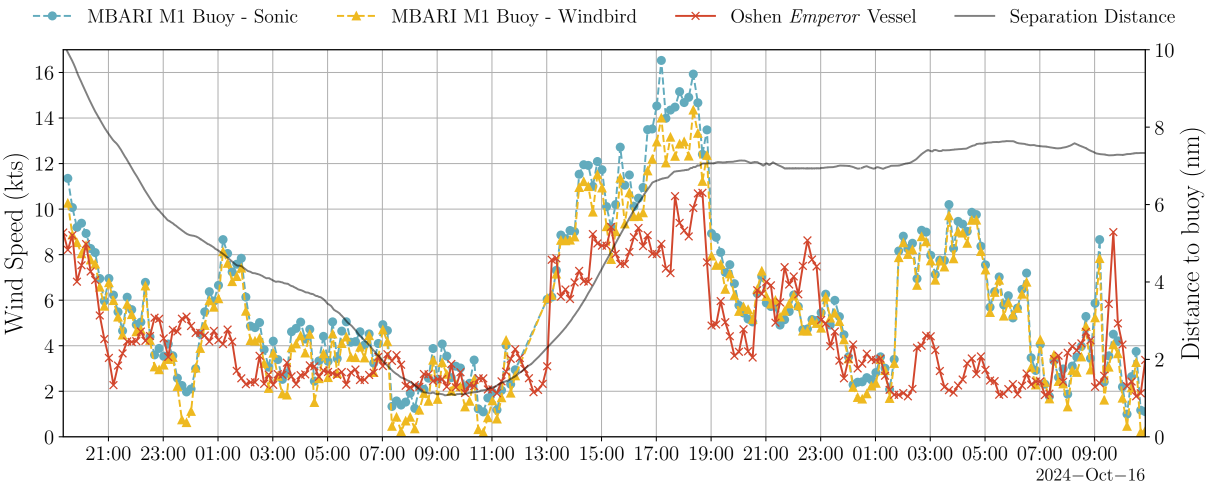
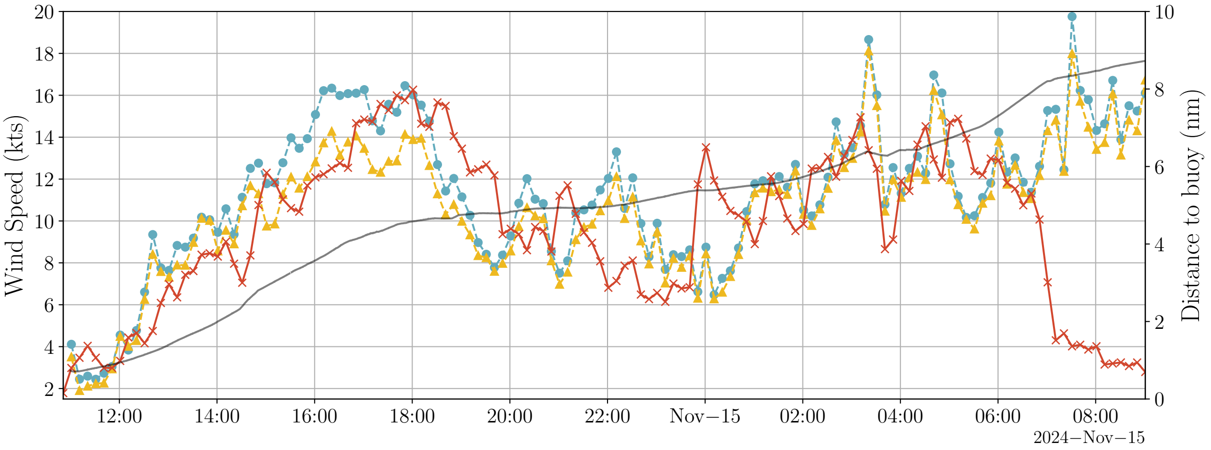


(c) MB6

Figure 10: Comparisons of sea surface temperature data collected from *Emperor* and the M1 Buoy



(a) MB3



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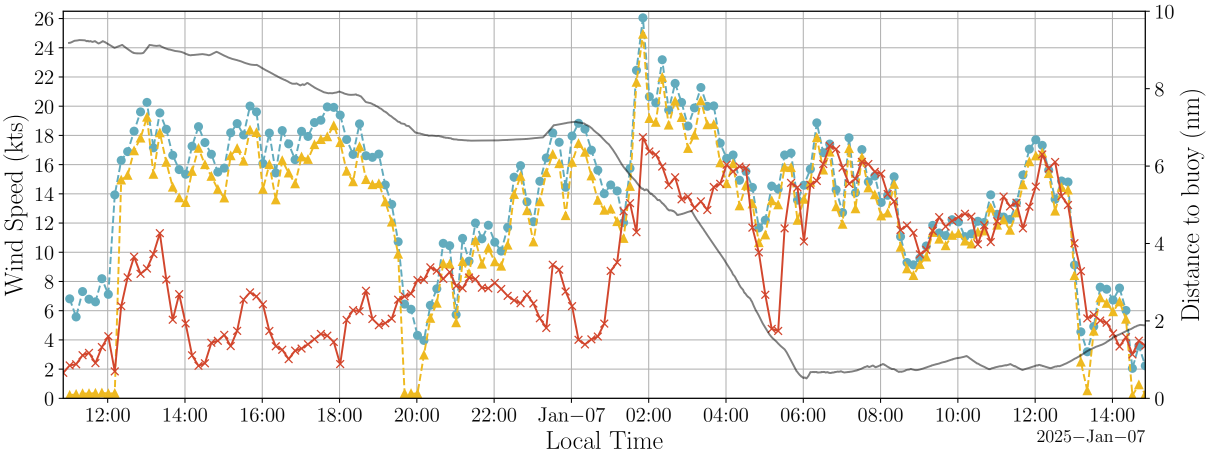
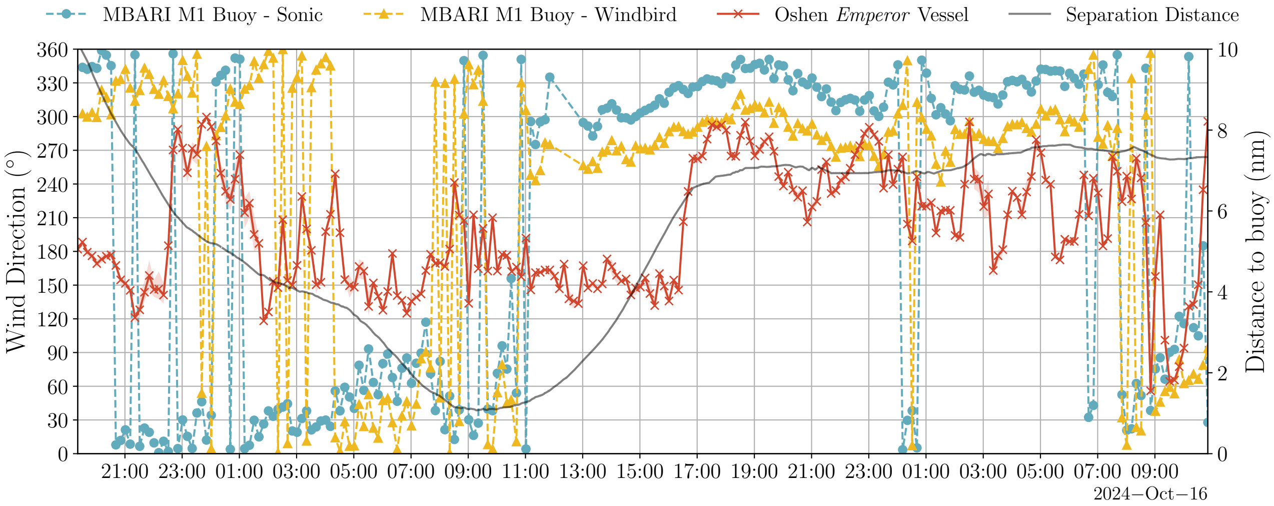


(c) MB6

Figure 11: Comparisons of wind speed data collected from *Emperor* and the M1 buoy.



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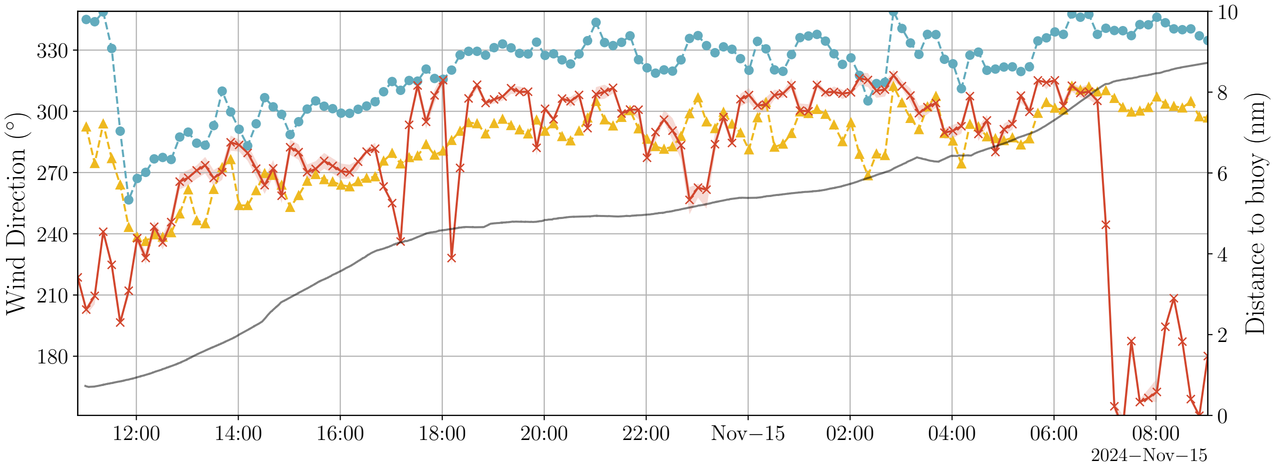
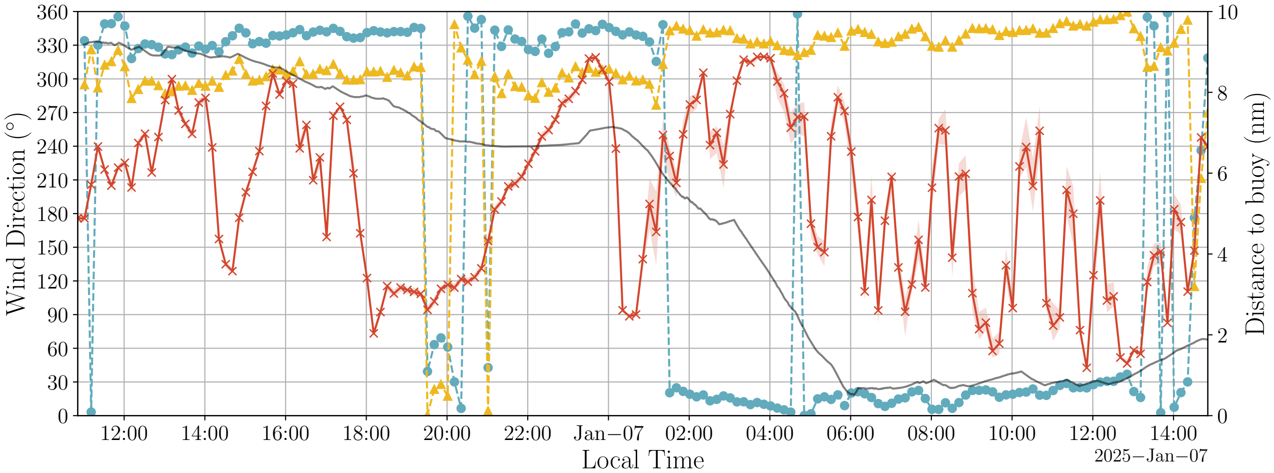


(b) MB5



(c) MB6

Figure 12: Comparisons of wind direction data collected from *Emperor* and the M1 Buoy

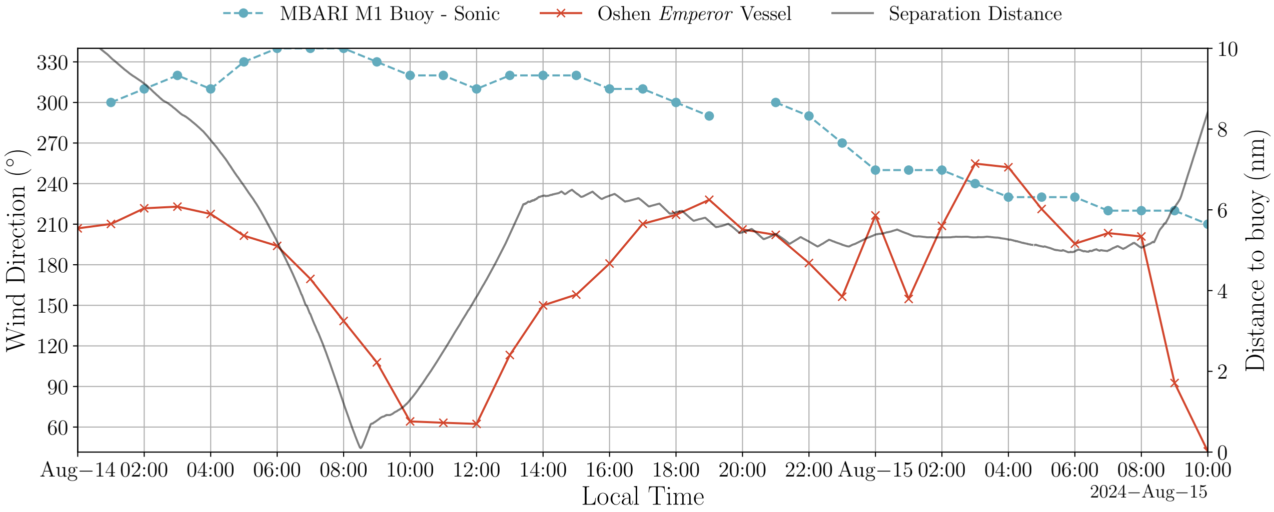


Figure 13: Comparison of wind direction data collected from *Emperor* and the E1 Buoy in test PL1

Acknowledgements

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