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Accurate Voyage Sea State and Weather Measurements Improve Performance-Based Vessel Management

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Abstract

The latest generation radar-based sensing solutions provide all relevant stakeholders with high-quality information about key vessel voyage parameters such as Speed Through Water (STW), ocean surface currents and wave height, direction and period. This information can now be readily made available both onboard and onshore in real-time. A wide range of vessel performance applications can achieve significant improvements using this information. This paper will describe how the availability of accurate sea state data is of significant value for vessel chartering management. Contractual weather claims can be handled better with more accurate weather data along the vessel route. Furthermore, benchmarking of vessels can be made more accurate when based on high-quality sea state data. In addition, accurate sea state data can unlock cost reductions due to better insights into the physical conditions along the vessel route and therefore better separate effects of weather and actual vessel performance. This can in turn result in significantly reduced vessel fuel consumption. The various use cases will be discussed here together with some examples from testing on vessels.

1. Introduction

Most industrial domains are currently in a process of digital transformation. This holds true also for shipping where a wide set of data from many sources is utilized to gain insight into all aspects of the operation of vessels. Vessel performance optimization has become a hot topic in the area of digitalization, fueled by the fact that shipping contributes to a significant amount of the global air pollution of substances such as sulfur dioxide, nitrogen oxide and particulates as well as to global emissions of carbon dioxide.

The rapid development of new relevant technologies means that new possibilities are made available to support the strong focus on cost reductions and operational efficiency. In order to succeed with digitalization initiatives, there is a need to address significant pain points experienced by the various business stakeholders. These pain points need to be solvable with the use of a combination of high-quality data and data science. Another prerequisite is a suitable platform to both collect the data, process the data, present the results to the users or integrate with external systems. All of this requires a high degree of competence on the various technologies, how to get insight out of vast amounts of data, how vessels are operated and how the various business stakeholders interact.

There is a wide range of data that is relevant for the various use cases and challenges found within vessel performance management. This includes data from a vast array of sensors on a vessel, information about the vessel itself, route information, destination information, weather and sea state information, contractual information and financial figures related to the vessel, charter and fuel.

A crucial data point is the vessel Speed Through Water (STW) which is the vessel speed relative to the water. STW is equal to the Speed Over Ground (SOG) when there is no ocean surface current present. STW can be seen as a measure of the output a vessel produces given a certain input of fuel, loading condition, vessel configuration and sea state. Without accurate data on STW it is not possible to accurately determine the performance of a vessel. Consequently, the lack of accurate STW data is a major obstacle to progress in vessel performance management. Some of the resulting challenges are:

- Difficult to evaluate hull and propeller designs
- Difficult to evaluate the efficiency of hull coatings
- Difficult to evaluate the efficiency of hull and propeller cleaning procedures
- Inaccurate hull performance estimations and resulting suboptimal maintenance planning
- Limited insight into how sea state influences performance at various combinations of vessel speed, trim and draft
- Difficult to accurately determine performance relative to contractual agreements
- Difficult to do accurate and reliable voyage optimizations
- Difficult to do speed optimization

SOG is easily measured by means of a GPS receiver. STW, however, has not been easily measured in an accurate and reliable way until recently, *Gangeskar (2019)*. STW is important since the currents experienced by vessels on the world's oceans are significant and can range up to several knots in magnitude. Models used by weather providers to forecast current patterns are based on coarse grids, they lack input of accurate surface current measurement data and cannot accurately predict conditions in space and time. Thus, there is a need for accurate current and STW data.

There have been significant improvements within radar-based sea state measurements recently *Gangeskar (2017,2018a,2019), Gangeskar et al. (2018)*. The latest solutions in radar-based sea state measurements can measure both ocean waves and ocean currents accurately under widely varying conditions and with high availability, reliability and accuracy.

Both ocean waves and ocean currents have a significant impact on ship performance. The interaction between waves and ship performance is quite complex and requires accounting for factors such as 3D hull properties and loading conditions. The interaction between surface current and ship performance is somewhat simpler. Currents coming against the direction of ship motion means that more water needs to be displaced per time unit compared to a situation with no current. Similarly, currents travelling in the direction of ship motion means that less water needs to be displaced per time unit. Hence, the current component going in the direction parallel or antiparallel to the vessel heading has a major influence on vessel performance. Currents travelling perpendicular to the ship motion might also lead to a need to spend energy to counter the forces inflicted by the currents. Thus, the presence of ocean currents has a profound influence on the performance of the vessel.

Measurements of ocean surface current from moving vessels by traditional underwater (in-situ) instrumentation are associated with challenges. Data is heavily influenced by noise, and systems measuring the speed through water (STW) are influenced by similar disturbances affecting the vessel speed log, *Antola et al. (2017), Baur (2016), Bos (2016), Fritz (2016)*. Wave measurements from fixed underwater instrumentation are scarcely available. The following items are relevant for both acoustic Doppler current profilers (ADCPs), *Flagg et al. (1998), King et al. (1993), New (1992),* and other instruments based on traditional in-situ measurement principles:

- Underwater equipment is exposed to fouling, *Carchen et al. (2017), Goler et al. (2017), Kelling (2017).*
- Measurements are disturbed by air bubbles, turbulence, and inhomogeneous hydrodynamics caused by the vessel motion and propellers, *Bos (2016), Carchen et al. (2017), Brown et al. (2001).*
- Measurements are disturbed by other instruments, for instance acoustic echo sounders and vessel speed logs.
- The surface current measurements are considerably affected by the vessel movement.
- Sensors are frequently inadequately calibrated, *Antola et al. (2017), Bos (2016),* giving systematic errors in certain speed ranges, *Antola et al. (2017).*
- Underwater equipment generally involves installation and maintenance procedures being both time-consuming and expensive.

Most vessel performance management applications will benefit from accurate STW measurements. One example is hull (and propeller) performance where the amount of fuel consumed at a given speed is analyzed. Hull fouling will lead to increased friction and consequently increased fuel consumption at the same speed, or, alternatively lower speed at the same fuel consumption. Presently, hull performance estimates are typically based on SOG measurements from a GPS or heavily filtered STW measurements from underwater, hull-mounted sensors. Hull cleaning is an expensive procedure and it is therefore important to estimate the actual hull condition as accurately as possible. Accurate STW measurements can be used to improve hull performance estimations and can lead to improved planning of hull cleaning activities. Similarly, accurate data can be used to investigate the effectiveness of hull cleaning procedures or hull coatings.

There are several vessel performance management use cases related to handling of performance guarantees and weather claims. The charterparty concept is crucial in this context. A charterparty is a maritime contract between a shipowner and a "charterer" for the hire of a ship for the carriage of passengers or cargo.

A charter party normally includes a performance clause, guaranteeing a maximum fuel consumption at one or two speeds in loaded condition. The performance clause is warranted in fair weather conditions, described by a maximum wind force, sea state and no current.

For a ship owner and an operator trading a ship under a charter party, it is crucial to know the ship's actual speed vs. fuel consumption performance. Furthermore, it is important to know the exact wind force, sea state and surface current conditions to determine whether the vessel is operating within or outside the weather conditions defined in the charter party. If the wind force, sea state and surface current conditions are lower than the limits defined in the charter party, for more than 18 hours of a day, the day is deemed a "Good Weather Day". In this case the ship has to meet the warranted speed/fuel consumption described in the charter party. Underperformance in terms of lower speed and/or excess fuel consumption has to be compensated by the ship owner or operator to the charter. If the wind force, sea state and surface current conditions are above the limits defined in the charter party, for more than 18 hours of a day, the day is deemed a "Bad Weather Day" and the ship need not meet the warranted speed/fuel consumption described in the charter party.

In such a setting it becomes crucial to not only have high-performing efficient vessels, but also to be able to accurately monitor the environmental conditions. For both the ship owner or operator and the charterer, it is important to accurately measure the environmental conditions, so that it can be precisely determined when the conditions are within the charterparty limits. Equally important for both parties is to have vessels that are both high-performing and cost-efficient. Therefore, accurate and reliable information about vessel performance makes it easier for charterers to select the best performing vessels for the job. For vessel owners and operators with efficient vessels this represents an additional value that will be attractive to prospective customers.

While wind information has been readily available, it has been more challenging to measure wave and current conditions. With the recent technology development from Miros it is now possible to have access to both wave and STW measurements that are reliable and accurate enough to be used in vessel performance management, *Gangeskar (2018,2019)*. This information can easily be made available both onboard the vessel and onshore in real-time through the usage of modern IoT technologies, Prytz et al. (2019).

This paper presents a description of the system that provides reliable wave and STW measurements, based on an imaging X-band radar, results from a verification study onboard a vessel and how applying onboard measured data could reduce some key challenges associated with determining "good weather".

2. Measurement principle for waves and STW based on imaging X-band radar

Wavex bases its measurements on radar images covering local areas of interest, in a reasonable distance from any disturbing structures, including the vessel hull. Fig.3 shows how measurement areas are extracted from the radar images for current and STW measurements. Measurement areas for waves are extracted in a similar manner. The measurement areas are called Cartesian image sections and are defined during system commissioning through software configuration. Dedicated algorithms process these images to provide the user with real-time wave spectra, as well as integrated wave parameters, surface current vectors and STW data.

Optimum wave and STW measurement performance require radar images with sufficient spatial resolution. The radar's range resolution is determined by the radar pulse width, and the azimuth resolution is determined by the radar antenna beamwidth. For optimal accuracy, the radar should be operated in short pulse mode. (If a solid-state X-band radar, utilizing pulse compression techniques, is used, the spatial resolution in the STW measurement area can be sufficient without compromising the radars navigation performance.) In addition, a wind speed of at least 2 – 3 m/s is required. At this wind speed, the sea surface gets sufficiently rough to create sufficient electromagnetic backscatter, *Skolnik (1980)*. Gravity waves modulate the ocean surface backscatter. A radar image with a clearly visible wave pattern is shown in Fig.2.

Wavex provides current measurements with high accuracy, *Gangeskar (2018a,b,c), PRYTZ et al. (2019)*. Measuring the STW has much in common with measuring currents, and the two measurements are generally based on the same physical principles. The major difference is what the measured water speed is referred to: the vessel when measuring the STW, and a fixed position when measuring currents.

The vessel's velocity through water and current velocity are related through:

$$\vec{\boldsymbol{v}}_{\boldsymbol{STW}} = \vec{\boldsymbol{v}}_{\boldsymbol{SOG}} - \vec{\boldsymbol{U}}, \tag{1}$$

Here $\vec{\boldsymbol{v}}_{\boldsymbol{SOG}}$ is the vessel's velocity over ground. Therefore, obtaining reliable current measurements implies that also STW measurements will be reliable, as they are related to each other (at the same depth) through the speed over ground (SOG), which can easily be extracted from GPS data.

Fig.1 shows the basic components in a Wavex system on a moving vessel. Specialized, DNV type approved hardware is connected to the analog video signal output from a marine navigation X-band radar. This hardware digitizes the analog radar video and outputs a radar image timeseries. Each radar image includes a sector covering the STW measurement area. Digitized images can also be acquired directly from radars with digital data output, commonly known as IP (Internet Protocol) radars. This eliminates the need for additional digitalization hardware.

The Wavex system requires certain radar image meta-data from a GPS and a gyro compass.

To provide STW estimates, all required data are collected, synchronized and processed on the system computer.

For further details on how Wavex measures wave, current and STW, refer to *Gangeskar et al. (2018)* and *Prytz et al. (2019)*.

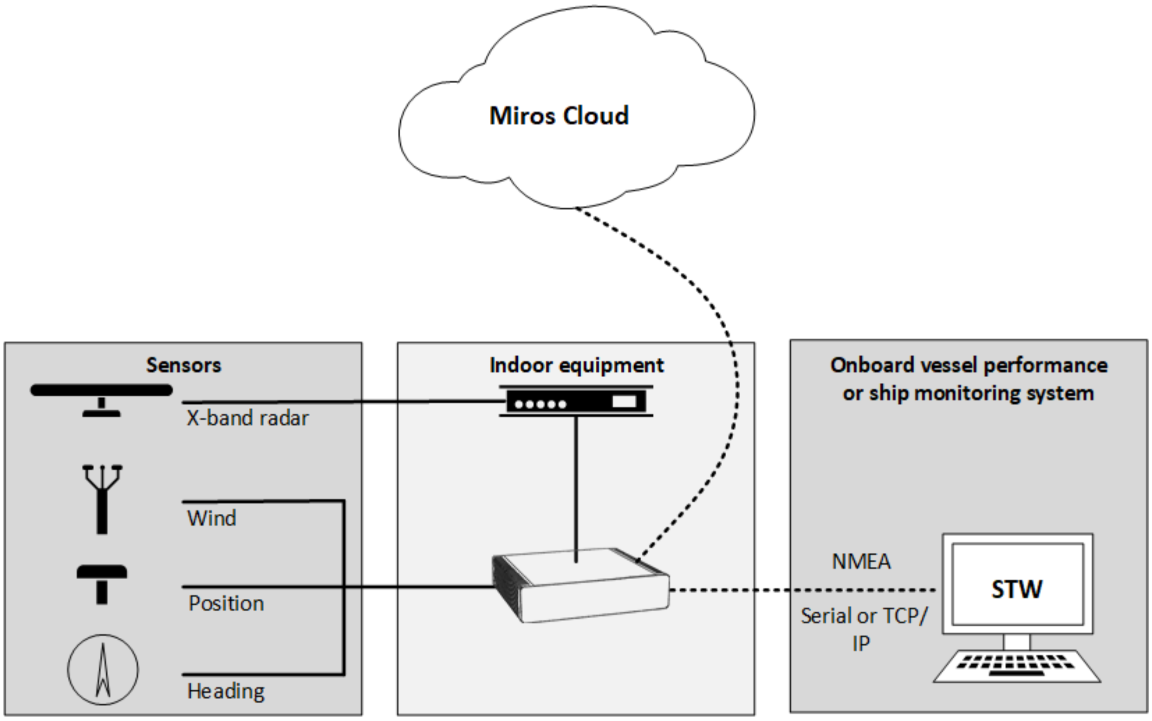

Fig.1: Schematic diagram of system based on imaging X-band radar

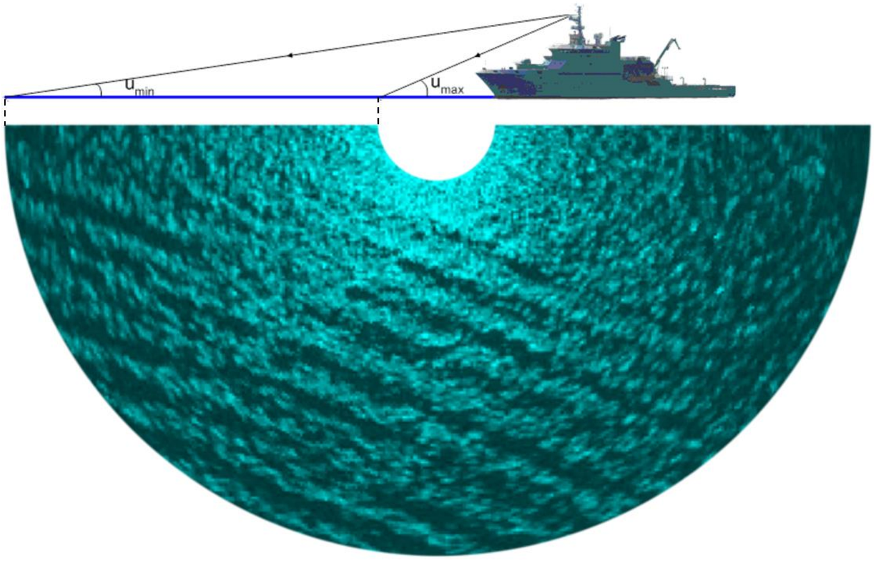
Fig.2: Imaging radar

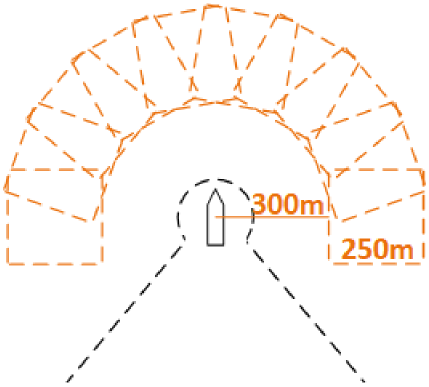

Fig.3: How Cartesian image sections for STW estimates are extracted from a radar image

3. Pilot verification of STW, current and wave measurements at BW Rye

Wavex pilot systems have been installed on various vessels using various types of imaging X-band radars. The system reliability and the accuracy of radar-based STW measurements have been examined and verified by comparing the measurements with theoretical models and standard speed logs over large geographical areas in a wide range of weather conditions and sea states, *Gangeskar (2018a,b,c, 2019)*. Wave measurement accuracy was discussed in *Gangesakr (2017)*. The verifications performed at the dry cargo vessel BW Rye will be presented and discussed here.

3.1. Data acquisition

The following results are based on data acquired from the cargo vessel BW Rye. Data from the Miros Wavex and additional on-board sensors have been acquired during four voyages from March 2019 to June 2019, and they are compared with model data from the voyage reports provided by a well-known weather provider. Fig.4 shows the routes during voyage 1, 2, and 3, based on positions acquired from the on-board GPS and stored in the Wavex system. Fig.5 shows the route during voyage 4. Due to the vast amounts of data, the timeseries plots presented are limited to a period in voyage 4.

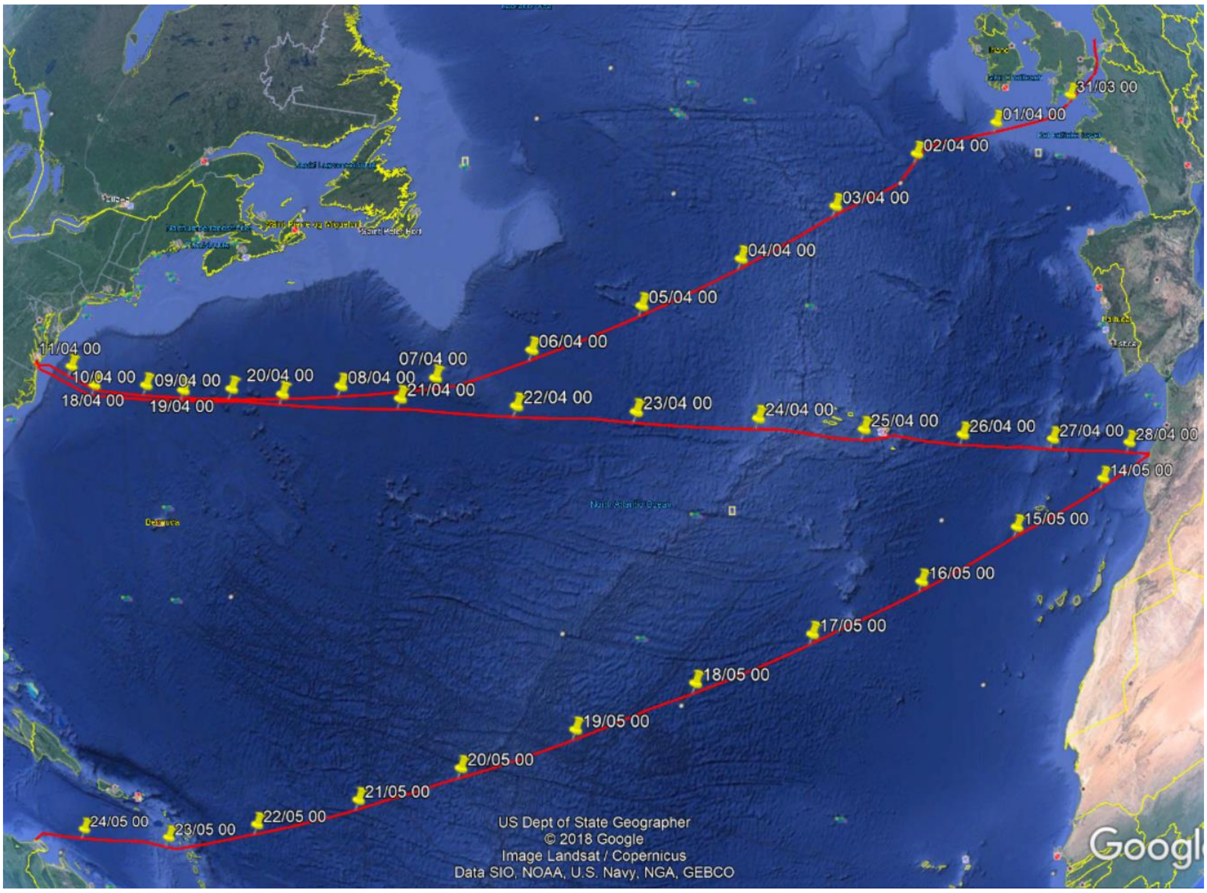

Fig.4: Map exported from Google Earth showing routes during voyage 1, 2, and 3, crossing the Atlantic Ocean westwards, eastwards, and westwards, respectively, indicated by red lines.

The electromagnetic speed log on BW Rye is an EML500-HV1 from Yokogawa Denshikiki Co. Ltd. Speed log data together with data from the onboard GPS and gyro equipment were sampled every 30 and stored to a file for later analysis.

BW Dry Cargo provided voyage reports (PDF files) including model data typically sampled every 6 hours. The directional resolution of current model data was 22.5°, meaning that the specified 10°

accuracy of Wavex current measurements cannot be validated based on these data. In addition, unfortunately, a major part of the model data relates to positions that are from several kilometers to more than twenty kilometers away from the vessel, making comparison with unaveraged measurements less reasonable. The large position deviations are probably caused by coarse data grids in the models.

Fig.5: Map exported from Google Earth showing route during voyage 4 around the South American coast, indicated by red lines.

3.2. Longitudinal current and speed components

The longitudinal water speed was acquired directly from the speed log data files. Longitudinal speed and current components were easily deduced from Wavex complete STW and current vectors. Comparable model data were calculated based on current speed and direction from the voyage reports, using vessel heading data from the on-board gyro logged in Wavex data files. Current longitudinal components from the speed log were obtained by converting the STW longitudinal component using equation (1) and data available from the speed log data files.

Fig.6 shows longitudinal current and STW components during a part of the voyage around the South American coast. All available data are shown, with no additional averaging in the upper and lower parts of the figures. The middle part of the figures, however, show longitudinal current components after applying an additional centered averaging to Wavex and speed log data, making a total averaging time of 6 hours. The indicated average levels, one measured level for every model data point, make a reasonable way of comparing measured data to model data, as the model data typically have an update period of 6 hours and further analysis typically is based on such 6 hours' values. Hence, the significance of having available measurements rather than model data can be observed, as well as the potentially additional value of getting real-time updates every minute. During periods with rapid changes, as can be seen in the figures, 6 hours update period may be too slow, depending on the application of interest.

As already mentioned, only a part of the model data refers to positions close enough to BW Rye to make comparison of unaveraged current data sensible. Data points within 2 km distance from BW Rye are indicated with black markers in Fig.6, and the remaining points with grey markers. Model data tend to agree more with measurements when considering 6 hours' values during periods with relatively stable currents over large areas, probably because model accuracy becomes better when position and time are less important and when local fluctuations are negligible. Apart from these stable situations, model data often seem to fail to correctly render temporal and spatial variations that are captured by both Wavex and speed log, resulting in only a moderate correlation with measured data. This is also indicated by the statistics in Table 1 and scatter plots in Fig.7, comparing 6 hours' average data from Wavex and speed log with model data. The total averages over all voyages from Wavex and model data agree fairly well, as indicated by the mean deviation in Table 1. Mean deviations based on the speed log are, however, less accurate due to offsets discussed below. Correlations between model data and measured data are moderate, whereas the correlation between the two very different sensors is strong, as discussed below.

When comparing model data with measurements, it should be kept in mind that such model data typically provide rough overviews of environmental data on a large scale in space and time. Measurements, however, can provide representative data for the local area of interest, in real-time or as average values, and with a higher accuracy than model data. Furthermore, measurements are required as input to models to get reasonable output from models.

From the current time series in the upper part of the figure below, it is evident that the radar-based system produces considerably smoother data than the speed log. The reason for the varying amounts of noise observed in speed log data is not known. The speed log data are also influenced by offsets, particularly during voyages 2 – 4, where slowly varying offsets can be observed as negative longitudinal current components (in the opposite direction of the vessel heading) in the typical range of 0.3 to 0.8 m/s. A closer look at any of the voyages tells us that these apparently considerable current contributions are not physically reasonable. For instance, during voyage 2, the speed log measures a considerable current contribution towards west, lasting for more than one week of the voyage, which is not physically reasonable when travelling in these parts of the Atlantic Ocean. One might, however, observe a smaller contribution towards east due to the Gulf Stream and the North Atlantic Drift, though this is probably not measurable unless travelling on a slightly more northern path. Also, note that model data comply well with Wavex data during this last week of voyage 2, when the longitudinal current component is quite stable and close to zero over a large area.

An additional indicator of the speed log offset is the long-term average value of the longitudinal current component, which is expected to approach zero as the amount of considered data increases, provided that there is no systematic offset introduced by for instance always following the larger ocean currents around the world. This average value is -0.39 m/s for the speed log when considering all voyages together, whereas the corresponding value from Wavex is only 0.02 m/s.

Erroneous offsets, like the one observed in the speed log data, can frequently be observed in data from traditional speed logs due to inadequate calibration, as have also been found during previous work on validating STW measurements. The statistics in Table I include the mean deviation (offset) between speed log and Wavex based on all available data (voyage 1 – 4) and no additional averaging, as well as the root-mean-square (RMS) and the standard deviation between the two sensors. The corresponding scatter plot is provided in Fig.7, including a Deming regression (parameters in Table 1), which was preferred to simple linear regression because it accounts for errors in both sensors. As mentioned above, however, the speed log offset is slowly and gradually changing, meaning that the offset is not a constant that can be compensated for when considering all data together. This offset drift can be vaguely seen in the scatter plot in Fig.7 as if the plot consists of several clouds with different offsets.

Despite varying amounts of noise and offsets, the agreement between the speed log and the Wavex is very good when it comes to trends in the time series. This is also supported by correlation coefficients in the range 0.84 – 0.97. By removing the offsets between the two sensors, RMS deviations in the range 0.12 – 0.19 would be obtained for the four voyages, which could be further reduced by noise-filtering the speed log data.

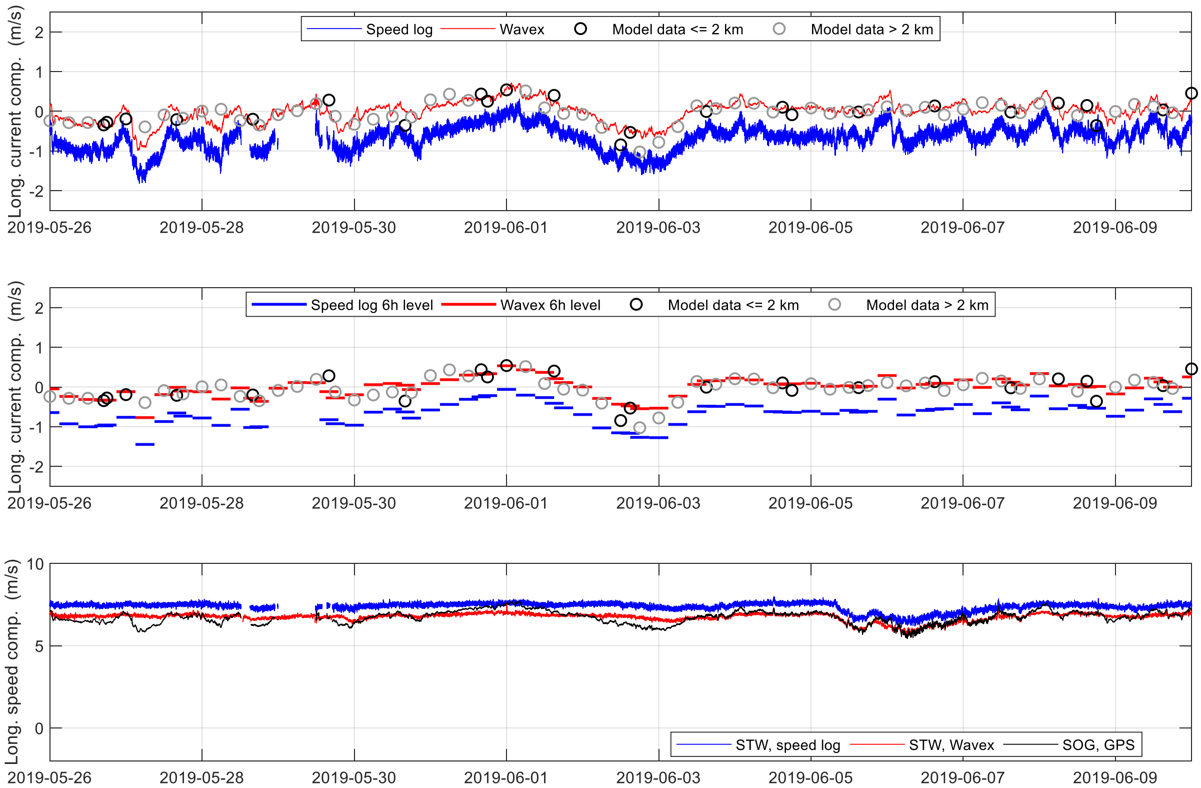

Fig.6: Time series of longitudinal current components and speeds during a voyage around the South American coast (Fig.5).

The data capture during voyage 1 and 2 is complete for both Wavex and speed log. Three hours of data at the end of May 20 (voyage 3) are missing from the Wavex system, in which the system seems to have been turned off. Approximately one day of data around May 16 are missing from the speed log, in addition to one day around June 20. The reason for this is not known. Model data are missing from the voyage report during a longer period from June 14 to June 17. Presumably, this is due to lack of model data for the narrow areas of the Strait of Magellan and for the areas close to the Chilean coast north of the Strait of Magellan (see Fig.5). Except for a period around June 14 due to land and lack of waves in the radar images when BW Rye was passing through a part of the Strait of Magellan, Wavex data have good quality also during voyage 4.

Table I: Correlations, deviations, and Deming regression parameters between longitudinal current components from speed log, Wavex, and model, based on all available data and single voyages

	Voyage	Statistics				Deming regression	
		Correlation	RMS deviation (m/s)	Mean deviation (m/s)	Standard deviation (m/s)	Gain	Offset (m/s)
Radar vs speed log	All	0.85	0.47	-0.43	0.18	0.76	0.34
	1	0.97	0.29	-0.25	0.13	0.85	0.20
	2	0.90	0.48	-0.46	0.12	0.91	0.43
	3	0.87	0.48	-0.44	0.19	0.61	0.28
	4	0.84	0.51	-0.48	0.18	0.67	0.33
Radar vs model	All	0.54	0.26	-0.07	0.25	0.79	0.06
Speed log vs model	All	0.48	0.47	0.36	0.31	1.21	-0.35

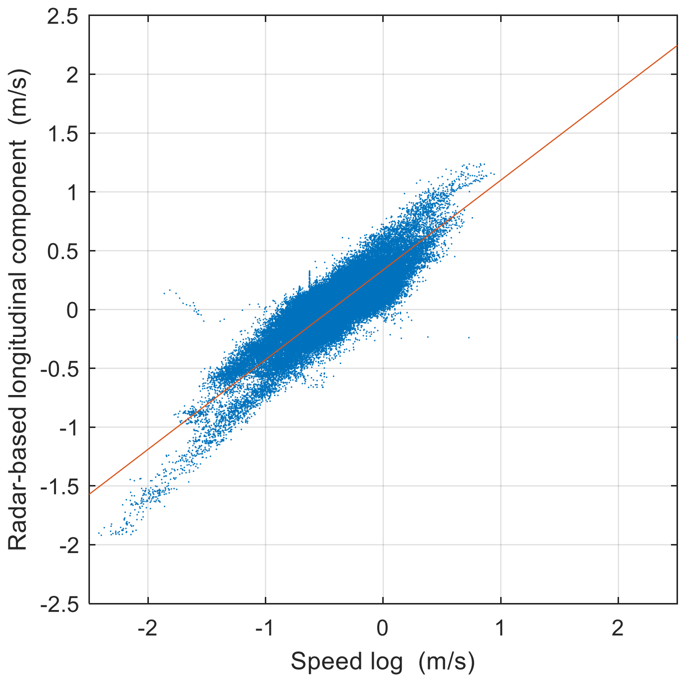

Fig.7: Scatter plot of longitudinal current components from speed log and Wavex, all voyages

3.3. Directional current data

Fig.8 shows wind data and current data from Wavex for the same period, compared with model data. The wind speed varies from 3 to 18 m/s (from 0 to 23 m/s when considering all voyages). Both averaged 6-hour levels and continuous current values from Wavex are shown. An additional centred averaging of 70 minutes is applied to the continuous Wavex data and the wind data, in order to highlight trends and the tidal contribution and to decrease the number of directional wraparounds at low speeds in the visualization. Tidal rotations generated by the tidal current component are often used as indicators of reasonable current measurements. Full clockwise tidal rotations, though somewhat influenced by the vessel's movement and local variations, were observed during several periods, as for instance:

- April 4 – 6 (voyage 1)
- May 18 (voyage 3)
- May 29 – 31 (voyage 4, Fig.8)

In addition, full counterclockwise tidal rotations can be observed during the following periods:

- June 5 – 8 (voyage 4, Fig.8)
- June 9 – 11 (voyage 4)

The reason for the changed direction of rotation is that BW Rye passed the equator around midnight between June 1 and 2; tidal rotations are expected to be clockwise at the northern hemisphere and counterclockwise at the southern hemisphere. This is a very good indicator for reasonable measurements. Also, note how the current direction flattens out for a few days just around equator.

The agreement between model data and measured 6 hours' levels is acceptable for many of the points, for instance when comparing current directions (but not speeds) around equator where the values are relatively stable over large areas. Still, there are also many points for which comparison obviously is less meaningful.

It should be noted that a minor inconsistence occasionally has been observed in the wind speed data when comparing to expected backscatter level in the radar images. In some situations, probably depending on the wind direction, the wind sensor seems to overestimate the wind speed by 1 – 2 m/s during transit when the true wind speed is low. This is probably due to turbulence around the sensor leaving an offset after the vessel motion compensation.

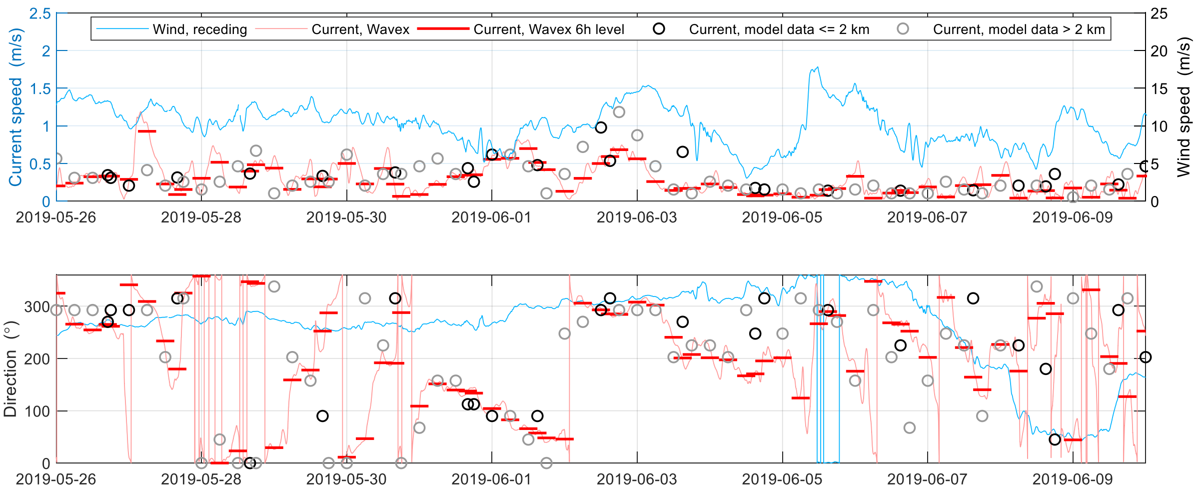

Fig.8: Time series of current and wind data from BW Rye during a voyage around the South American coast (Fig.5), compared to model data. Note how the tidal rotations shift direction from clockwise on the northern hemisphere (May 29-31) to counterclockwise on the southern hemisphere (June 5-8). Equator was crossed approximately at 2019-06-01 22:21.

3.4. Waves

Significant wave heights (H_{m0}) from Wavex for the same period as considered above are shown in Fig.9, together with total wave heights provided by model. Data from the two sources definitively share many of the same trends, and the overall agreement looks reasonable, despite different spatial and temporal premises for the wave height parameters. Statistics are provided in Table II.

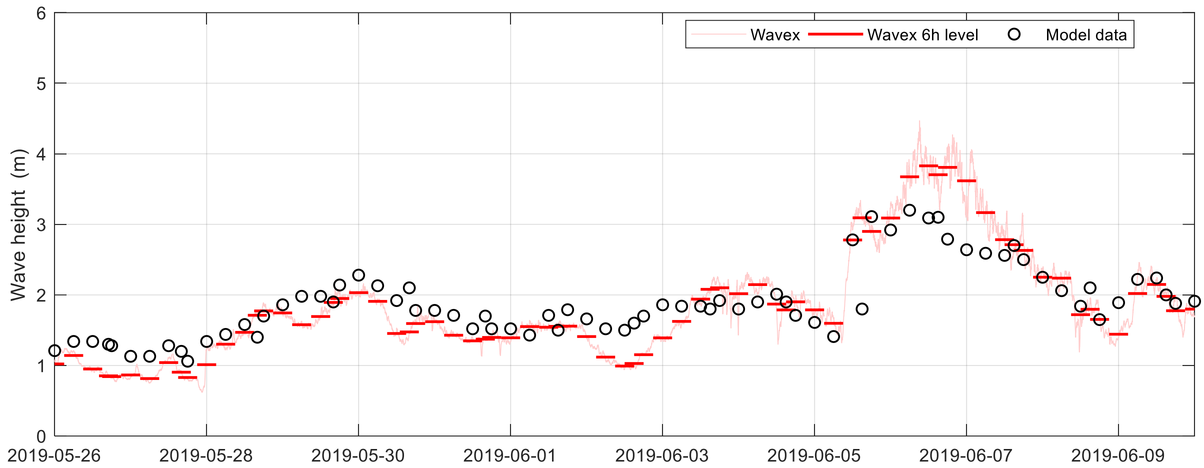

Fig.9: Time series of significant wave heights from BW Rye during a voyage around the South American coast, compared with total wave heights provided by model

Table II: Correlation and deviations between H_{m0} from Wavex and total wave height from model, based on 6 hours levels.

Correlation	RMS deviation	Mean deviation	Standard deviation
0.85	0.47 m	0.17 m	0.44 m

4. Applying onboard measured data as "good weather" decision basis

An important aspect of charterparties is the "good weather" concept, which determines when the contractual claims related to vessel performance are valid. The ship owner or operator provides a performance guarantee specifying a certain fuel consumption that is valid under certain environmental conditions. The conditions are usually specified in terms of wind, wave and current limits. The performance guarantee specifies one or more speed ranges with associated fuel consumption values where the performance guarantee is valid.

Today, good/bad weather assessments are primarily based on model-based data from weather providers and manual observations of weather reported in vessel logbooks. As indicated above and in *Prytz et al. (2019)*, models have significant limitations in providing accurate weather data for a ship at a specific position and time.

Manually assessing the weather is associated with significant uncertainties. Strict and quite time-consuming observation procedures need to be followed to reduce inaccuracies and different kinds of observer bias. Furthermore, the quality of individual observations is questionable, *Tucker et al. (2001)*. Visually observed wave periods are significantly less reliable than instrumentally observed ones, as the eye tends to concentrate on the nearer and steeper short-period waves, thereby ignoring the longer-period and more gently sloping waves, even though the latter may be of greater height and energy, *WMO (1998)*.

In 2017, a vessel performance dispute was considered by the London Court of International Arbitration, *Sigafoose (2017)*, where "good weather" was an important part of the dispute. Among many interesting aspects considered was "evidence of weather". The Court had relative freedom to decide how much evidential weight to attribute to the logs and the reports. Following what they considered was an established view, the Court found that the vessel's logs were generally the best evidence of the conditions experienced. This view could be rebutted with evidence of falsification or exaggeration – but no such evidence was found in this case.

Another aspect of the dispute was the use of the Douglas scale, *Mazarakis (2019),* and differing between sea state, swell and wind sea. With a full directional wave spectrum measured at a vessel's position, a full characterization of the sea state would be available, reducing uncertainty about what conditions a vessel is sailing in, in a time period where its performance is questioned.

The charterer's weather routing report not only sought to exclude periods of adverse current from their performance calculations but went a step further by deducting 0.04 knots from the vessel's speed on the account of an average 0.04 knot boost from following currents, *SOUTHEY (2019)*. The Court concluded that this approach was inappropriate. The reference to 'no adverse current' in the good weather description was intended to ensure the vessel was not affected by current when calculating the performance. To deduct positive current as the weather routing report had sought to do, was considered unacceptable.

Utilizing accurate current data would enable the accurate quantification of the impact of the current on vessel performance, and not only categorize whether there is (adverse) current or not. The Wavex solution measures waves, current and Speed Through Water, and calculates and logs wind data based on input from standard wind sensors. Using accurate onboard-measured data would substantially reduce uncertainty in discussions regarding vessel performance deviations due to:

- Improved weather assessment as the weather affecting the ship at its position at a specific time would be measured accurately.
- Utilizing stable, high-accuracy Speed Through Water measurements would reduce uncertainty in the speed data used for evaluating the charterparty speed-consumption data.

5. Conclusion

The Wavex solution measuring waves, current and STW on BW Rye has been tested and examined. We have observed convincing agreement between Wavex and the speed log when it comes to trends and covariation. However, data from the speed log were influenced by varying offsets, and they were significantly noisier than data from Wavex. The calculated correlation coefficients and standard deviations for the longitudinal current component were in the range 0.84 – 0.97 and in the range 0.12 – 0.19 m/s, respectively. Clockwise (northern hemisphere) and counterclockwise (southern hemisphere) tidal rotations are observed in data from Wavex during the voyages.

Model data comply well with Wavex during some periods with stable currents, when time and position are less important. Beyond that, model data show only a moderate correlation of approximately 0.5 with measured data from Wavex and speed log. A major part of the model data refers to positions too far away from BW Rye to be used for validation of unaveraged data. It should be kept in mind that such models typically provide rough overviews of environmental data on a larger scale in space and time, whereas measurements can provide representative data for local areas of interest, in real-time or as average values, with a higher accuracy than model data. Furthermore, measurements are required as input to models to get reasonable output from models.

An important aspect of charterparties is the "good weather day" concept, which determines when the contractual claims related to vessel performance are valid. Accurate and reliable data for STW, waves and wind for the location of the vessel are of vital importance in order to determine whether the environmental conditions can be categorized as "good weather day" or "bad weather day". It has been shown that the Wavex solution is able to provide high quality data that can be used when analyzing charterparty performance.

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