A Direct Comparison of the Motion Sensors' Performance from the 2005 Common Dataset

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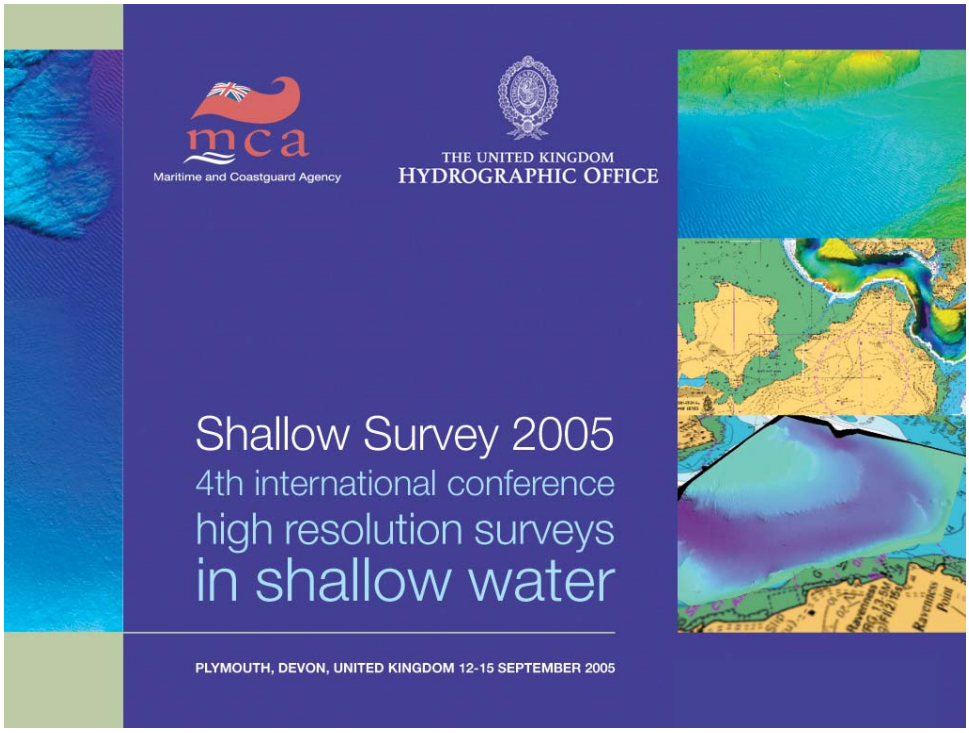
First Presented at



NETSURVEY

THE UNITED KINGDOM
HYDROGRAPHIC OFFICE

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1 Abstract

Integral components of a swathe bathymetry system are the motion and heading sensors. The current trend is to offer a system that combines both of these components in one package, either as an aided inertial sensor or as two sensors linked together by component software. The quality of these inertial sensors has a direct result on the quality of the final survey. Most surveyors when purchasing or specifying a particular inertial system for a project will base their decision on information generated by the manufacturers, which often shows all systems to offer comparable performance but at greatly differing prices. This paper is a direct comparison of five of the leading sensors available.

This paper uses data collected for the 2005 Shallow Survey Conference held in Plymouth as the basis for the comparison. Data was simultaneously acquired from five of the leading motion & heading sensors.

The comparisons are presented in two ways:

- as time varying displays to show the individual sensor performance
- in terms of the actual quality of the acquired bathymetric data when merged with each set of motion sensor data.

2 Introduction

This motion sensor trial was performed in order to produce data that anyone could then take for their own purposes. If a reader is using it to aid their purchase of a multibeam system they should be aware that there are many factors to consider. Some of these factors are the nature of the survey work to be performed, the installation of the equipment on the vessel and in particular the sonar head and IMU. This paper has been written to present one comparison of the data. The authors do not have allegiance to any of the manufacturers and nor do they wish to misrepresent a commercial product. The reader is encouraged to take the data and to produce their own views based on their own requirements.

Without motion sensors or inertial measurement units, it would be impossible to carry out an accurate swathe bathymetric survey. The output from swathe bathymetry systems has been compared before (1996/1997 John Hughes Clarke OMG Multibeam Course) (2001/2003 Duncan Mallace Hydro 2002 and Shallow Survey 2003) but not the motion sensors. To make an empirical comparison it was essential to be able to view the same motion with all the systems. This required logging data from all systems simultaneously.

As well as logging the motion sensor data simultaneously, multibeam data (from a Reson Seabat 8125) and GPS positioning from a Trimble 5700 RTK system was also acquired. In this way the differences between the motion sensors could be observed by looking at the different depth values obtained and hence real world results rather than just graphs.

The authors had hoped to conduct the trials in Plymouth Sound along with the rest of the Shallow Survey data but unfortunately a suitable vessel was not available. The vessel had a very robust mount for the multibeam system, as the smallest amount of movement would have shown up in the data. The vessel also required space and a sturdy surface to install the six different sensors.

The Center for Coastal and Ocean Mapping at University of New Hampshire were kind enough to lend us their vessel 'Coastal Surveyor' for the trials. The trials area was therefore taken from the Shallow Survey 2001 area, being a flat area just North of Newcastle Island.

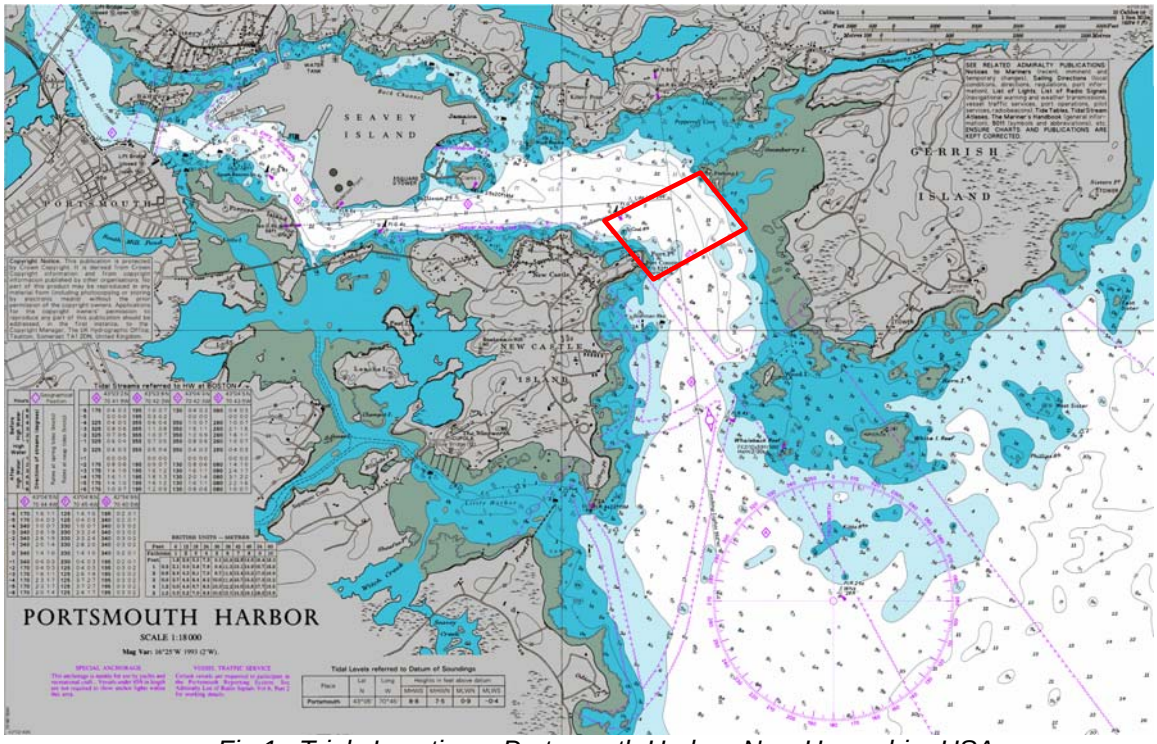


Fig 1: Trials Location – Portsmouth Harbor, New Hampshire USA

The motion sensor systems tested were:

- Applanix POS RS
- Applanix POS MV 320
- CodaOctopus F180
- IXsea Octans
- Kongsberg Seatex Seapath 200
- TSS Marinus

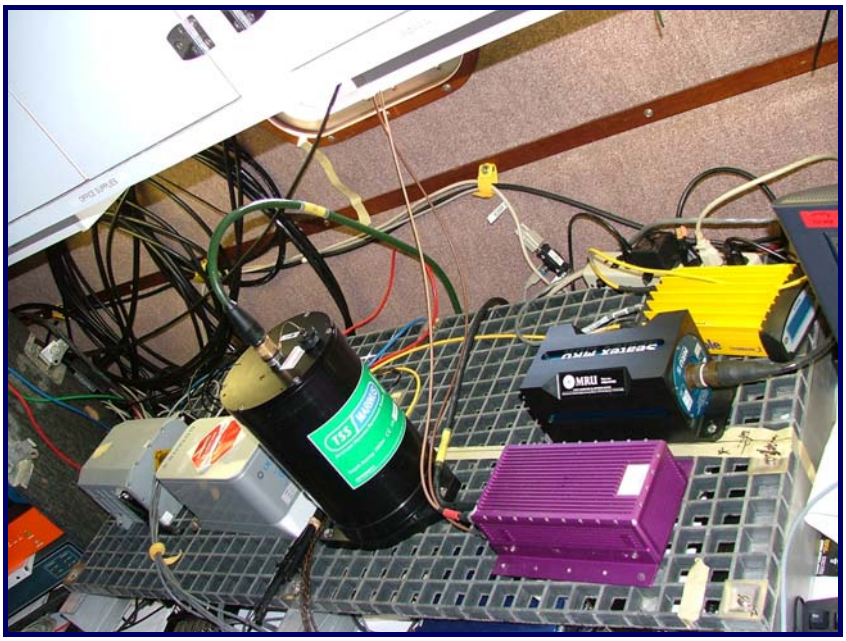


Fig 2: Motion sensor IMU's mounted on platform.

2.1 POS RS

The Applanix POS RS is a Position and Orientation System designed for use as a Reference System. The system provides accurate navigation and attitude data.

POS RS consists of a rack mountable POS Computer System (PCS), a separate Inertial Measurement Unit (IMU) and a GPS Antenna.

POS RS uses two sensor subsystems - the IMU and a Global Positioning System (GPS) receiver. These allow the system to deliver an accurate and comprehensive data set, including:

- Geographic position (latitude, longitude and altitude)
- Heading
- Attitude (roll and pitch)
- Velocity
- Acceleration
- Angular rate of turn
- Performance metrics
- Fault detection and reporting

POS RS generates attitude data in three axes. Measurements of roll and pitch are all accurate to ±0.005 or better. Heading measurements are accurate to .02 or better with GPS aiding (single antenna).

The system includes the POS Display and Controller program, which runs on a PC under Microsoft Windows™. This program is used to configure the system and to monitor its status during operation.

Communication between POS RS and the Controller program is through a 10BaseT Ethernet link

- Messages broadcast by POS RS use the UDP protocol so that other computers attached to the same Ethernet LAN can read them.
- The Controller program uses Transmission Control Protocol (TCP) to issue commands to POS MV. This blocks other computers on the (Local Area Network) LAN from receiving the controlling messages, and prevents POS RS from responding to any other source of controlling message.

Fault Detection, Isolation and Reconfiguration (FDIR) enhances the operating reliability of POS RS. This feature allows the system to monitor the health of its various sensors so that it can reconfigure itself to isolate any that show degraded performance. POS RS also estimates and corrects sensor errors on an ongoing basis using a multi-state Kalman filter that allows it to produce consistent and accurate results.

2.2 Data Acquisition

All data was successfully simultaneously time stamped and acquired using QPS QINSy ver 7.5. Two serial inputs were taken for each system, one for the attitude data and one for heading (with position if applicable).

A 1 Pulse per second (PPS) signal was taken from the POSMV 320 and fed into the acquisition computer via a QPS TTL device attached to COM 1. This pulse is taken from the onboard GPS receiver and is accurate to +/- 100nS with the atomic standard GPS time. The driver for PPS (Pulse-Per-Second) support where the corresponding UTC time is decoded from a NMEA ZDA string. The pulse can be used for exact time tagging. The PPS pulse is generated as a pulse on an output port of a GPS receiver. Within 900 milliseconds after the PPS pulse is received at the COM port, a ZDA output string with the exact UTC time of the pulse should be available at a control port of the receiver.

The data was time stamped upon arrival at the computer. QINSy uses a very sophisticated timing routine based on the PPS option (Pulse Per Second) available on almost all GPS receivers. All incoming and outgoing data was accurately time stamped with a UTC time label. Internally, QINSy uses so-called "observation ring buffers", so that data values may be interpolated for the exact moment of the event or ping.

2.3 Swathe Bathymetry

A Reson SeaBat 8125 was used to acquire simultaneous multibeam data. This system was chosen as it is regarded as the highest resolution system commercially available today. The system operates at 455 kHz and incorporates 240 discrete beams per ping. The Reson Seabat 8125 can resolve depths to 6mm precision and this allowed accurate surface difference computations between bathymetric datasets derived from the different sensors.

2.4 Data Output

During acquisition all the motion sensor, GPS and multibeam data was recorded in one logged file per line. One XTF (eXtendeable Transfer Format – Triton Imaging Inc.) file was created for each motion sensor for each line containing the unique data for that motion sensor together with the common data (Multibeam and GPS). Therefore the only difference between the XTF files was going to be the roll, pitch, heave and heading values within it.

2.5 Motion Sensor Specifications

Whilst the price of the five motion sensors tested vary substantially in price, they all appear to offer identical performance in heave, and the roll/pitch accuracies only vary from 0.01° to 0.025°. This apparent similarity in capability provided the impetus for this study – do all of these motion sensors really have comparable performance?

System	List Price US $	Quoted Heave Accuracy (1 sigma)	Quoted Roll / Pitch Accuracy (1 Sigma)	Quoted Heading Accuracy (1 Sigma)
PosRS	Approx $400,000	n/a	0.0025°	0.008°
F180	$71,000	5cm or 5% heave	0.025°	0.05° (2m baseline)
F180 RTK	$71,000	5cm or 5% heave	0.025°	0.05° (2m baseline)
Marinus	$92,185	5cm or 5% heave	0.025°	<±0.1° RMS secant latitude
Octans III	$67,139	5cm or 5% heave	0.01°	0.1° secant latitude
Pos MV 320	$115,500	5cm or 5% heave	0.02°	0.02° (2m baseline)
Pos MV 320 RTK	$120,295	5cm or 5% heave	0.01°	0.02° (2m baseline)
Seapath 200	$87,220	5cm or 5% heave	0.02° (for ±5° amplitude)	0.05° (2.5m baseline)
Seapath 200 RTK	$105,020	5cm or 5% heave	0.02° (for ±5° amplitude)	0.05° (2.5m baseline)

Table 1: Cost and specification of each unit tested.

2.6 Tests Undertaken

To evaluate the performance of each motion sensor, a series of test survey lines and manoeuvres were undertaken in an effort to simulate the motion experienced by a vessel undertaken a typical harbour survey. A reference surface was also surveyed to allow the bathymetric comparison to take place.

The manoeuvres included;

- 180° turns (normal occurrence during survey at end of line)
- Erratic Manoeuvres (designed to stretch to operating parameters of each system).
- Manoeuvres in a Poor GPS Environment (masking) under the I 95 bridge.
- A straight survey line with a high roll rate and high roll amplitude.

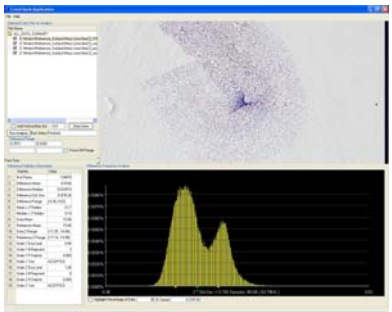
During the two days of the trial the region was subject to high atmospheric pressure, which resulted in very calm weather. Therefore the trials were conducted in very flat water, with no measurable swell or waves. Whilst it would have been useful to have collected some of the data in a moderate sea state, having flat calm conditions did provide one advantage – we knew that any heave recorded was a result of inaccuracies of each motion sensor rather than real vertical displacement of the vessel. The main factor that we would be looking at was heave settlement time.

To gain a baseline for the heave comparison the recorded heave values from the POSMV were post-processed in POSPAC to produce TrueHeave values. It was believed that that this was the closest we could get to establishing the actual heave experienced on the vessel. Heave is not an output of the POSRS, and it would not necessarily be any better than the post-processed POSMV.

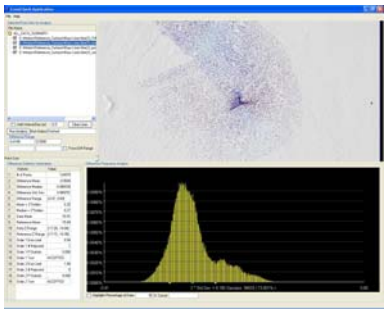
It would of course be possible to examine and compare all of the outputs from each motion sensor; roll, pitch, heave, heading and position (where applicable), but it was decided to focus on the elements of the data that have the largest impact on the measured bathymetry – heave and roll.

3 Results

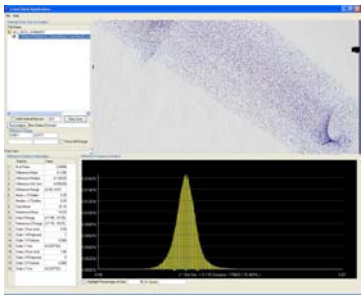
When combined with the multibeam and positioning systems all the motion sensors on test produced bathymetry that was compliant with IHO Order 1 standards for depth accuracy.



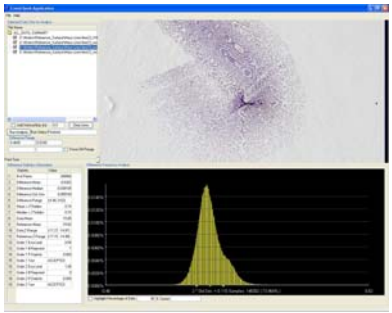
F180 Crosscheck Result



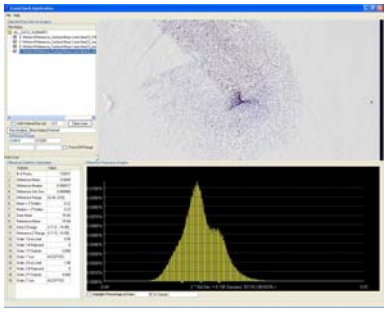
Marinus Crosscheck Result



Octans Crosscheck Result



POS MV Crosscheck Result



Seapath Crosscheck Result

Fig 3: Crosscheck results for each sensor over the Reference Surface

The results were analysed in two different ways:-

- A direct comparison analysis of each component from each motion sensor, represented as a time series to show the individual sensor performance
- An analysis in terms of the vertical accuracy of the acquired bathymetric data when merged with each set of motion sensor data.

The direct comparison uses graphs to show the heave or roll logged simultaneously from each motion sensor. The heave graphs also show the post processed TrueHeave from the POSMV, and the roll graphs show the post processed roll from the POSRS.

To show the vertical accuracy of the acquired bathymetric data the following processing procedure was undertaken;

- Patch test each system to derive the roll, pitch and yaw values for each system.

- Insert the POS RS positions into each of the data files so that there are no discrepancies due to position deviations between systems.
- Take the raw XTF files and apply the same sound velocity, tide and filters, i.e. treat each line in exactly the same way
- For each survey line create a reference line by using the POS RS roll, pitch and heading information and the heave from the True Heave file
- Create a 0.5 metre DTM using the same weighting parameters for each line
- Compute a surface difference computation for each line and apply the same colour map to enable ease of interpretation

Some commentary is included to explain the nature of the manoeuvres undertaken and the achieved results, but in many ways the performance if each system during each stage of the trials is self evident from the plotted data.

3.1 Heave Comparison - Line 23 180° Turn

Line 23 and also Line 29 are really looking at how well the Z acceleration component is 'strapped down' in the motion sensors. The better the delineation of the Z acceleration the less likely the sensor is to be affected by large horizontal accelerations, such as those experienced in a tight turn.

Data logging began at the end of one survey line (point A) as the turn onto the new line commenced (at point B).

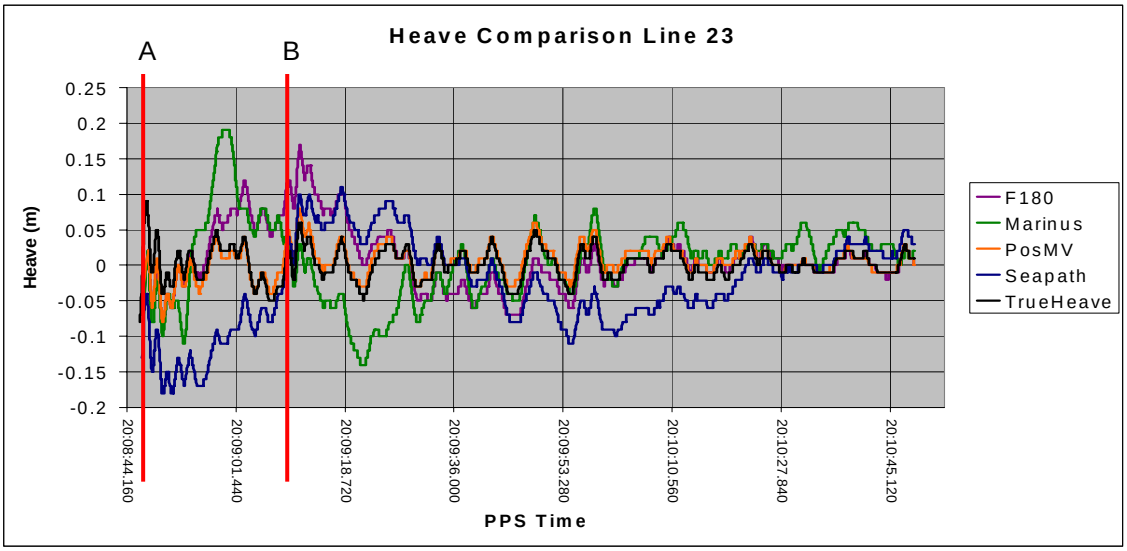
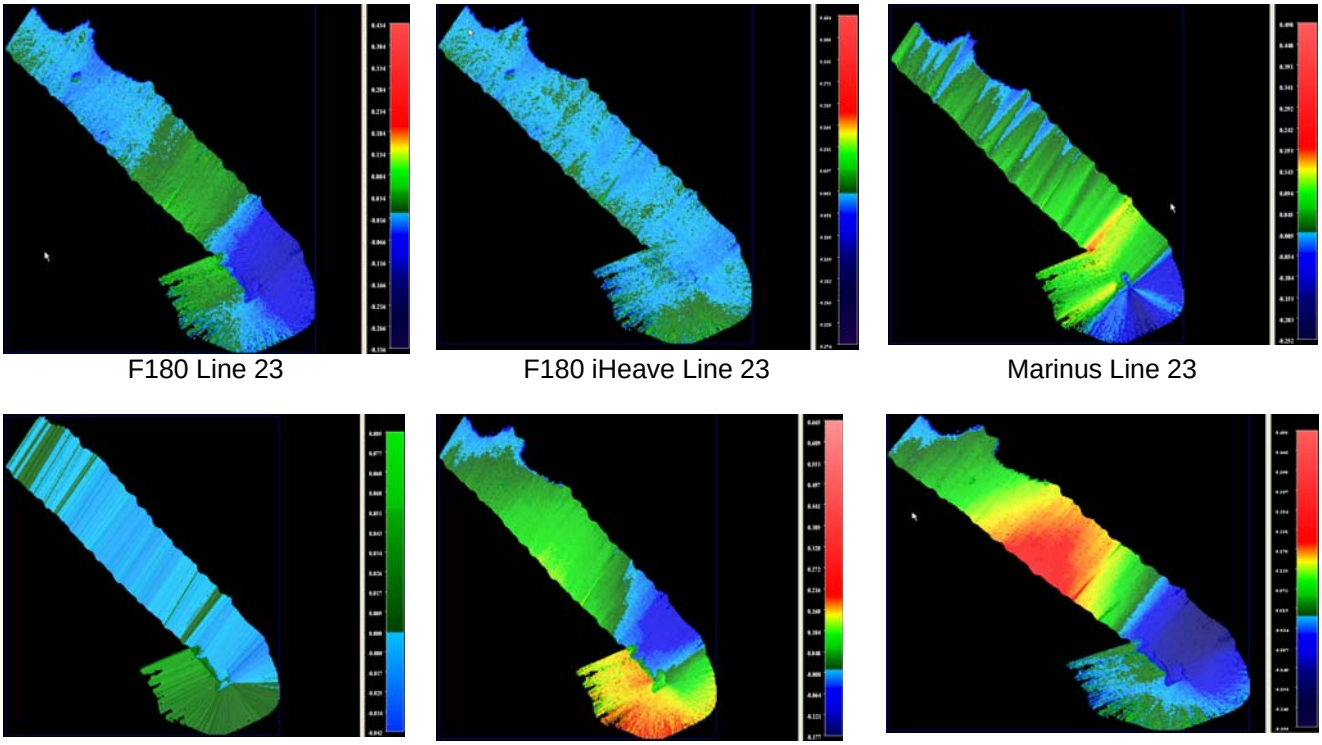


Fig 4: Line 23 direct comparison - heave

F180 and Marinus show deviation of up to 10cm during and immediately after the turn, but settle within 20 seconds of straight running. POSMV shows good agreement with TrueHeave throughout. Seapath shows deviation in heave of up 15cm during the turn, but does not fully settle for 1½ minutes.

The Octans III was not available at this point in the trials due to the late arrival of the equipment.



F180 Line 23 | F180 iHeave Line 23 | Marinus Line 23

POS MV Line 23 | Seapath Line 23 | Seapath re-processed line 23

Fig 5: Line 23 Surface Difference Computations

The surface difference computations mirror the findings of the graphs. The F180 without a post processed solution varies by approximately +/- 15 cm, but using the iHeave (CodaOctopus's post processed heave data) the difference is nominally about 1 or 2 cm. The Marinus results show what appears to be roll/pitch cross talk in the data. Notably the Marinus was the only sensor that did not have a straight edge with which to align the sensor to the centre line. The Marinus heave values vary by approximately +/- 20 cm. The POSMV realtime heave corresponded very closely with the True Heave varying by approximately 1 – 2 cm but there is an obvious effect in the variation due to the turn compared with the iHeave post processed solution. The Seapath surface difference varies by +30 cm to -12 cm. Kongsberg Seatex thought that there was an error and sent some re-processed data for inclusion in the results. This data improved the initial heave going into the turn but the rest of the of the line was out but up to +40 cm and -20 cm.

3.2 Heave Line 29 180° Turn

This was a 'normal' survey line through the area (typical for an enclosed harbour survey), followed by a 180° turn on to a new line. The data logged begins during the turn onto line, with the start of the survey line (i.e. straight running) at point A. This line took just under two minutes to complete, and then the vessel turned 180° to starboard to commence the next line (at point B).

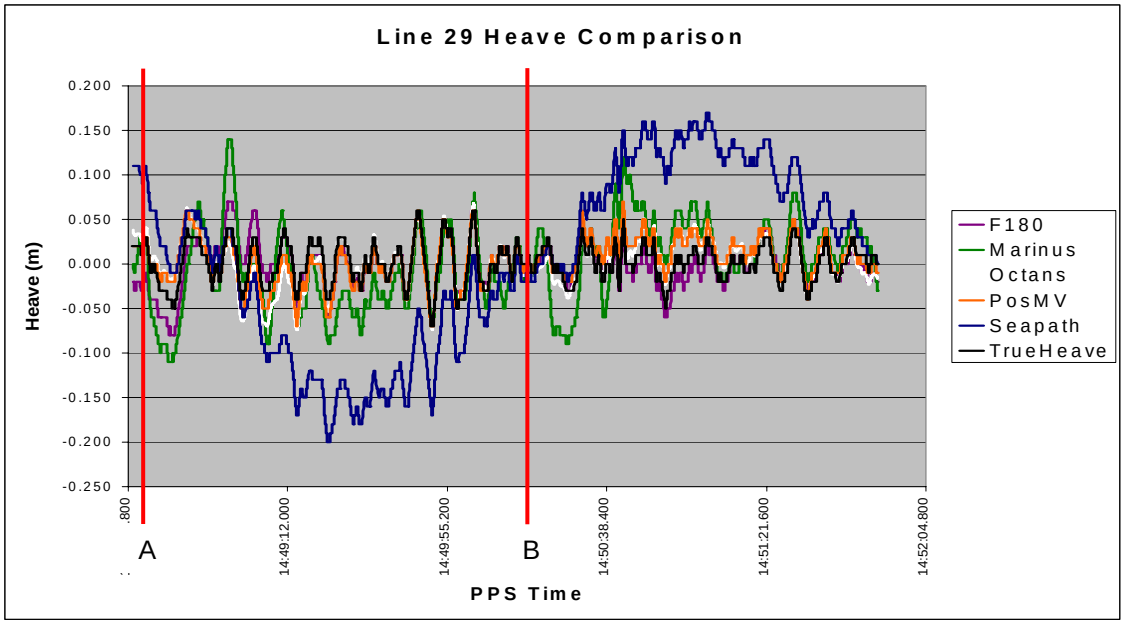


Fig 6: Line 29 direct comparison - heave

Octans, F180 and POSMV show good agreement with TrueHeave whilst on-line. Marinus shows some initial deviation of up to 12cm at the very beginning of each survey line but settles quickly. Seapath shows a maximum deviation of 15cm, and takes more than one minute to come back within specified levels of accuracy. The considerable heave settlement time would mean that the Seapath would measure heave more reliably if the vessel had an extended run-in after each turn before data logging commenced. In the confined waters of the survey area this was not possible.

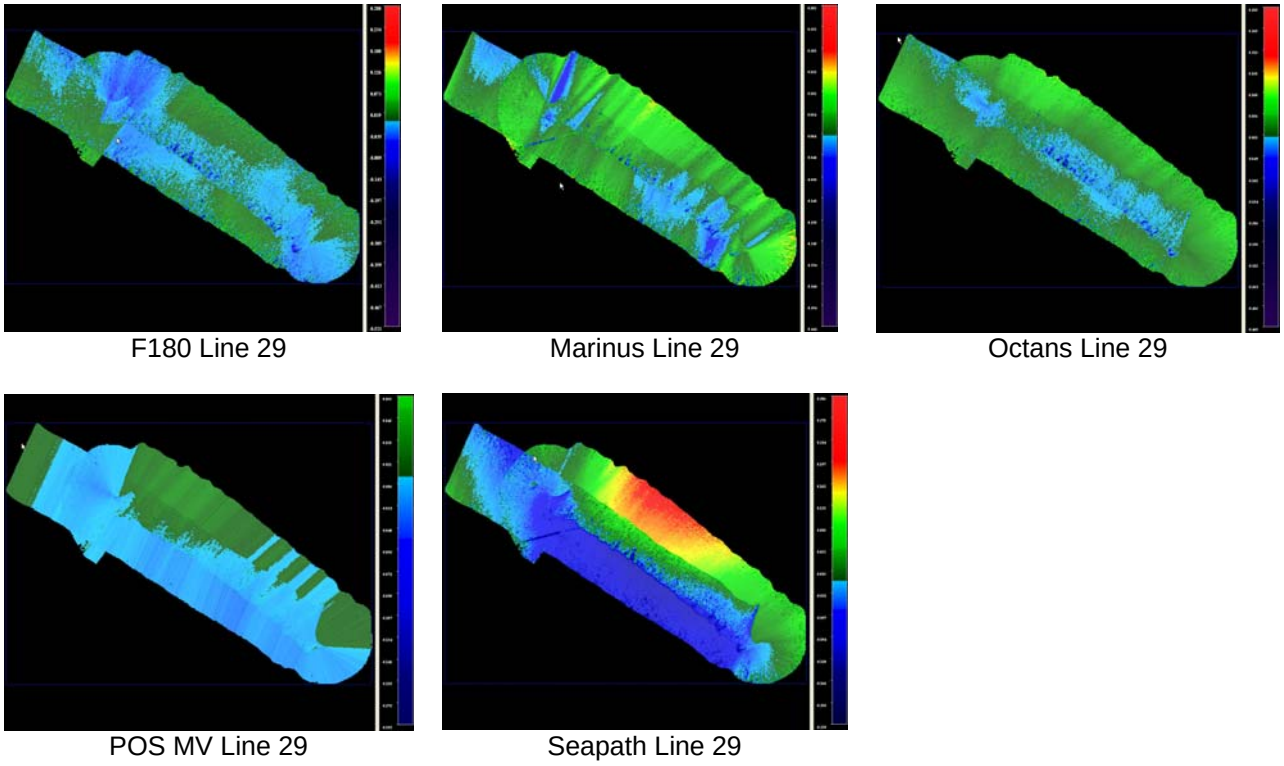


Fig 7: Line 29 Surface Difference Computations

Similarly to Line 23 the surface difference plots show close correlation with the graphs. The Octans and the POS MV show little difference from the reference system (+/- 1 or 2cm). The F180 was not post processed with iHeave for this line but the realtime differences are of the order of +/- 5cm. The Marinus again shows signs of pitch/roll cross talk but the differences are kept to between +/- 10 cm.

The Seapath only really starts to settle at the end of the line and previously to this was varying between +/- 20cm from the reference system.

3.3 Heave Line 26 - Erratic Manoeuvres

A series of erratic manoeuvres were undertaken over the course of 6 minutes, including 180° and 360° spins.

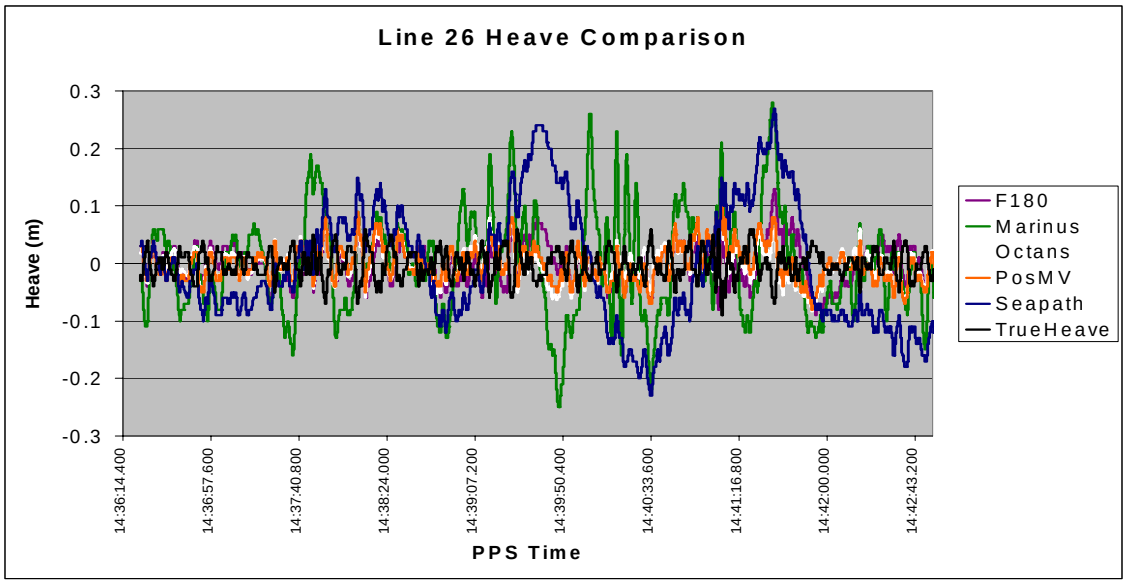


Fig 8: Line 26 direct comparison - heave

The aim here was to unsettle each of the motion sensors as much as possible. Although this does perhaps not represent 'normal' survey operations, a number of surveys have been received at the UKHO where a vessel in confined waters has had to survey very erratically to avoid moorings, structures and other vessels. Such manoeuvres have included 180° spins whilst acquiring data, so whilst the above situation may not be considered as 'normal', it can at least be regarded as 'real world', and it is important that users surveying in such a manor understand the limitations of their systems. These surveys have often had measurable heave artefacts in the data during turns.

F180, Octans and POSMV show good agreement with TrueHeave throughout, with deviations typically less than 5cm. Seapath and Marinus both have heave differences from the post-processed heave in excess of 20cm.

3.4 Heave Line 30 – Intermittent GPS

This data is from a set of short lines and turns under the Interstate 95 road bridge at the upper end of Portsmouth Harbor. The combination of the wide bridge structure and the fairly steep sided river value caused intermittent GPS position drop-outs, and limited the available satellite constellation thus increasing HDOP and GDOP values throughout the data collection period. It was hoped that the poor GPS performance in this area would highlight the importance of the GPS aiding for each motion sensor and any subsequent degradation in motion sensor performance.

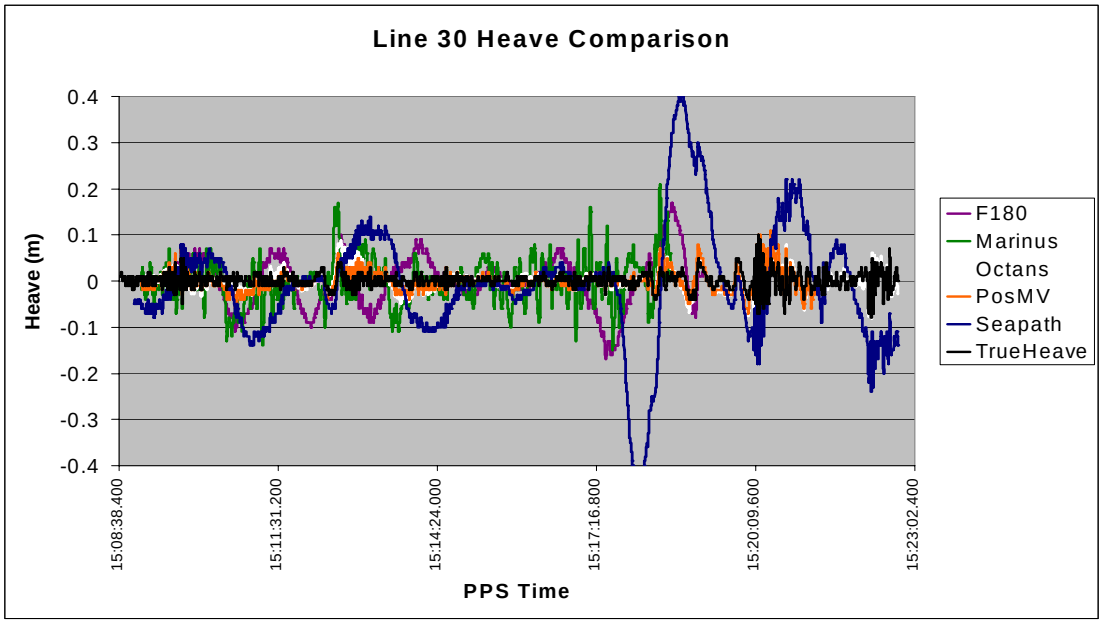


Fig 9: Line 30 direct comparison - heave

Data logging was started as the survey vessel first entered the area under the bridge. Several short lines were run up and downstream in a strong tidal flow with data being continuously logged.

Generally the Octans and POSMV show only a slight degradation in heave performance based upon previous results, with deviation from the TrueHeave values lower than 5cm. The F180 shows a significant decrease in heave performance, with heave deviation of up to 15cm. The Marinus heave is generally in reasonable agreement but is shown to have more 'heave spikes' than on previous lines. The Seapath has the largest heave deviation, with maximum values in excess of 40cm during the longest period of GPS drop-out.

It is also noteworthy that the F180 stopped outputting heave and heading at about 1520h after a prolonged period of GPS drop-out.

3.5 Roll Line 29 180° Turn - POSRS Roll Comparison

As with the heave comparison for line 29, this was regarded as 'normal' conditions for a harbour type survey. The data logged begins during the turn onto line, with the start of the survey line (i.e. straight running) at point A. This line took just under two minutes to complete, and then the vessel turned 180° to starboard to commence the next line (at point B).

The only significant roll experienced was during and immediately after each turn (partly due to travelling through own wake). A small roll bias between each sensor was evident and the roll bias was adjusted to 'calibrate' each motion sensor to the POSRS. As any roll errors would be impossible to see when simply plotting the roll values, therefore it is necessary to subtract the roll values from the benchmark POSRS roll values to produce a difference plot.

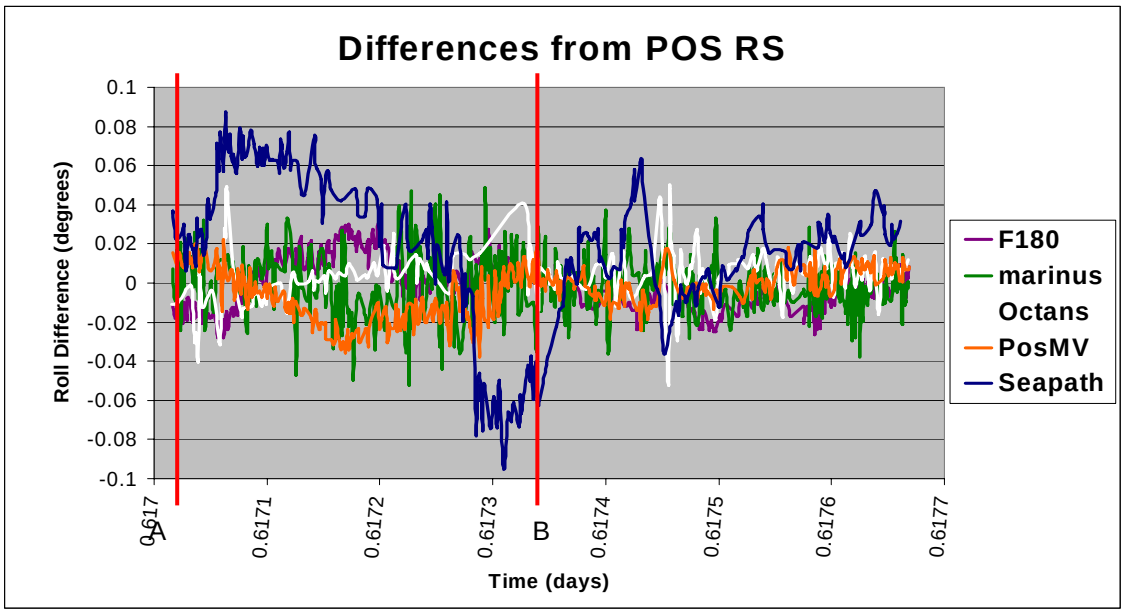


Fig 10: Line 29 direct comparison - roll

To create this plot all co-registered values (i.e. where a roll message from any one motion sensor corresponded with a simultaneous roll message from the POSRS) were subtracted from the POSRS value to calculate the difference. As the POSRS was logged at 200Hz (every 5 milliseconds) and each motion sensor was typically outputting at 50 HZ (every 20 milliseconds) each survey line produced many thousands of simultaneous data points for comparison. It was felt that this offered a more robust comparison than continuous interpolation of the data between roll messages. Table 4.6 shows achieved accuracy values compared to manufacturers quoted accuracy.

When this comparison was first undertaken it was discovered that there was a small time shift in the recorded data which manifested itself as an error strongly associated with rate of change or roll. This error was present for all motion sensors when compared against the POSRS. This was later found to be caused by the difference between internal logging within the POSRS and transmitting data through a serial connection and digiboard into the acquisition computer. Therefore the POSRS data was shifted by 24 milliseconds, which corresponded with the minimum standard deviation of the difference values for each of the motion sensors – once the POSRS time was shifted beyond 24 milliseconds the standard deviation of the difference for each motion sensor began to increase again – thus this was found to be the optimal time shift to minimise the roll error.

It is clear from the graph that there appear to be two types of error present in each of the motion sensors; a high frequency noise (possibly associated with timing jitter) and a longer period drift. With the exception of the Seapath, all units are operating within their own specified accuracies (at the one sigma level). The maximum deviation recorded with the Seapath is 0.08^{o} – 4 times higher than their specified accuracy. However, this also ties in with a settlement period after each end-of-line turn, so it is assumed that longer survey lines would have allowed the Seapath to settle and for roll accuracy to improve.

3.6 Roll Line 27 High Roll Rate - POSRS Roll Comparison

For this line the vessel was rolled substantially by rocking the rudder. This generated roll of up to 12 degrees with a high rate of change of roll (up to 8° per second). It was hoped this would simulate the roll experienced in a small vessel in rough sea conditions although there were no real waves present.

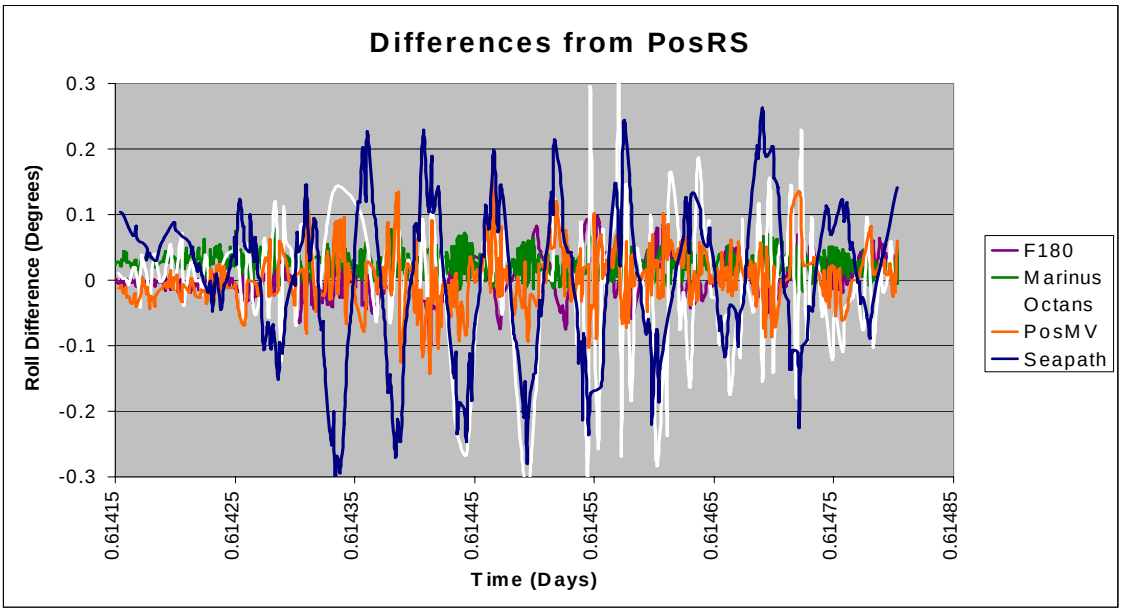


Fig 11: Line 27 direct comparison - roll

It is clear that with the exception of the Marinus none of the motion sensors are operating within their own specified roll accuracy levels (Marinus is only just outside). As with line 29 there appear to be two types of error present in each of the motion sensors; a high frequency noise and a longer period drift. The following table shows the quoted roll accuracy vs. achieved roll accuracy for line 29 and line 27.

Motion Sensor	Quoted Roll / Pitch Accuracy (1 Sigma)	Achieved Roll Accuracy for Line 29 (Low Roll) Based on Difference from POSRS Value (1 Sigma)	Achieved Roll Accuracy for Line 27 (High Roll) Based on Difference from POSRS Value (1 Sigma)
F180 RTK	0.025 °	0.012 ° (48% of Spec)	0.044 ° (176% of Spec)
Marinus	0.025 °	0.015 ° (60% of Spec)	0.029 ° (116% of Spec)
Octans III	0.01 °	0.013 ° (130% of Spec)	0.086 ° (860% of Spec)
POSMV 320 RTK	0.01 °	0.012 ° (120% of Spec)	0.048 ° (480% of Spec)
Seapath 200 RTK	0.02 ° (for ±5° amplitude)	0.038 ° (190% of Spec)	0.066 ° (330% of Spec)

Table 2: Quoted roll accuracy vs. achieved roll accuracy for line 27.

The Octans and Seapath seem most affected by the high roll rate – the Seapath is drifting either side of zero, and whilst the Octans also drifts either side of zero, there are also occasional spikes in the data. It is likely that this is being caused by clock jitter, where the timing is varying around the "true" value, although it is very difficult to prove this.

After presenting these results at Shallow Survey 2005 it was thought that the area of timing should be looked at closely for Line 26, as with 8 degrees of roll per second motion the consequence of a 1 millisecond time error is approximately 0.01° of roll error, a substantial amount. Rather than try to look at the data coming into QINSy we decided to look at data that had been acquired separately and was logged with GPS time stamps internally. This data was the POS RS and POS MV data.

Applanix's POSPac software was used to post process both sets of data. POSPac is modular the following components were used to process the data;

- EXTRACT: Used for extracting, viewing and plotting sensor and navigation data from logged files
- POSGPS: A raw GPS data processing module with multiple base station features. Carrier phase resolution is done within the software for maximum accuracy
- POSProc: Computes the best aided inertial navigation solution from inertial data extracted using POSRT, the differential GPS solution computed using POSGPS, together with other available aiding sensor data. Calculated 200 times per second, the solution includes 3D location, orientation angles, velocity, acceleration and angular rate

Roll and pitch experienced during the time 14:44:18 UTC (398658 seconds of GPS week) and 14:45:44 UTC (398744 seconds of GPS week) are plotted below:

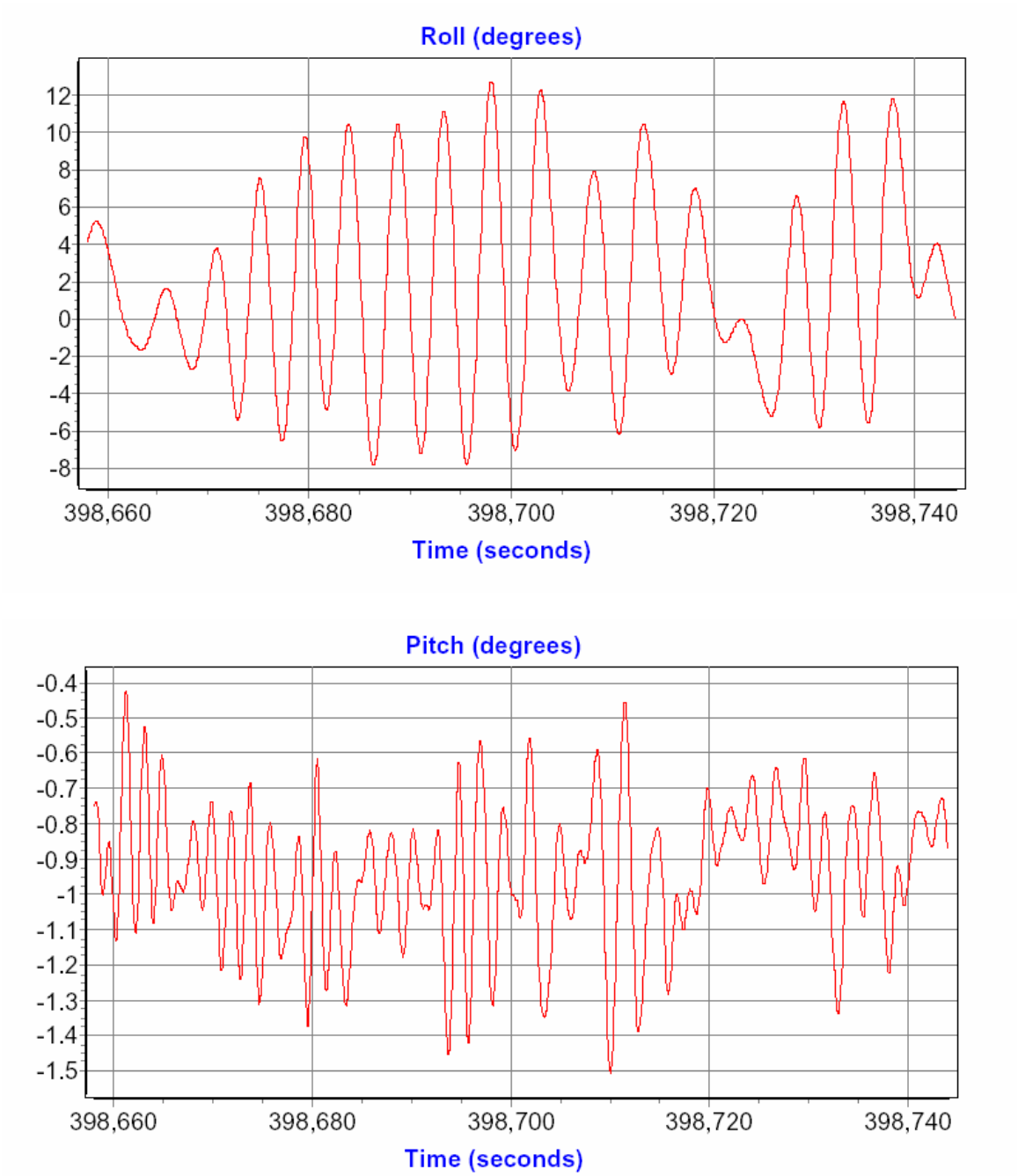


Fig 12: Pitch and Roll values for Line 27 shown as GPS time sequence

3.6.1 Comparisons

Reference System vs. Real Time POS MV320

During the tests, the base station was broadcasting RTK (CMR format) corrections. However, during the actual time period in question (14:44:18 to 14:45:44 UTC) the POS MV real time solution was unable to compute a fixed RTK solution throughout (likely because overheating of the base radio modem was causing intermittent performance). This illustrates one of the limitations of RTK – that of broadcasting the base station data in real time.

By comparing roll and pitch between the POS RS (Reference System) and the real time POS MV 320 solution (using sub-optimal RTK aiding as described above), the following differences were found:

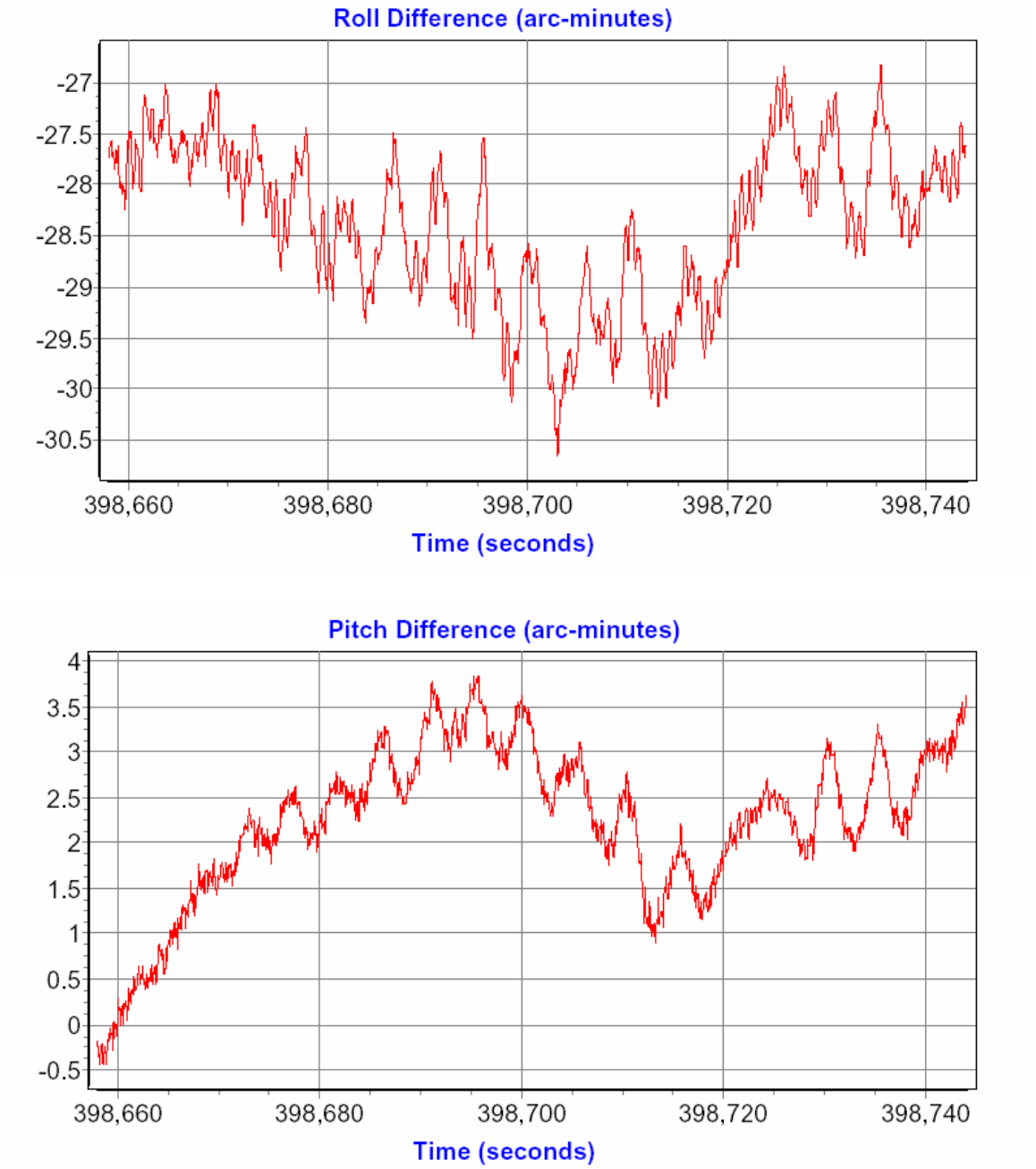


Fig 13: POS RS v POS MV (real time) for Line 27

Note that the differences are plotted in arc-minutes (1 arcmin = 1/60 deg) and also that, since the data has been logged with microsecond accurate time stamping via the POS MV ethernet interface, any timing errors have been minimized.

The statistics (in degrees) associated with this time period are as follows:

Element	MEAN	RMS	SIGMA
ROLL	-0.47320	0.47338	0.01290
PITCH	0.03735	0.03998	0.01427
HEADING	-0.33035	0.33068	0.01472

Number of data points: 8600. Time interval: 398658.002 - 398743.990 sec

The large roll error is due to the alignment of the sensor within the POS RS housing and this correlated closely with the Roll Patch Test results of the two systems, which were as follows;

Sensor	Roll
POS RS	-1.93
POS MV	-1.48

Reference System vs. Post Processed POS MV320

By comparing roll and pitch between the POS RS and POS MV (this time post processed with POSPac and using post processed (and therefore robust) kinematic GPS aiding), the following differences were found:

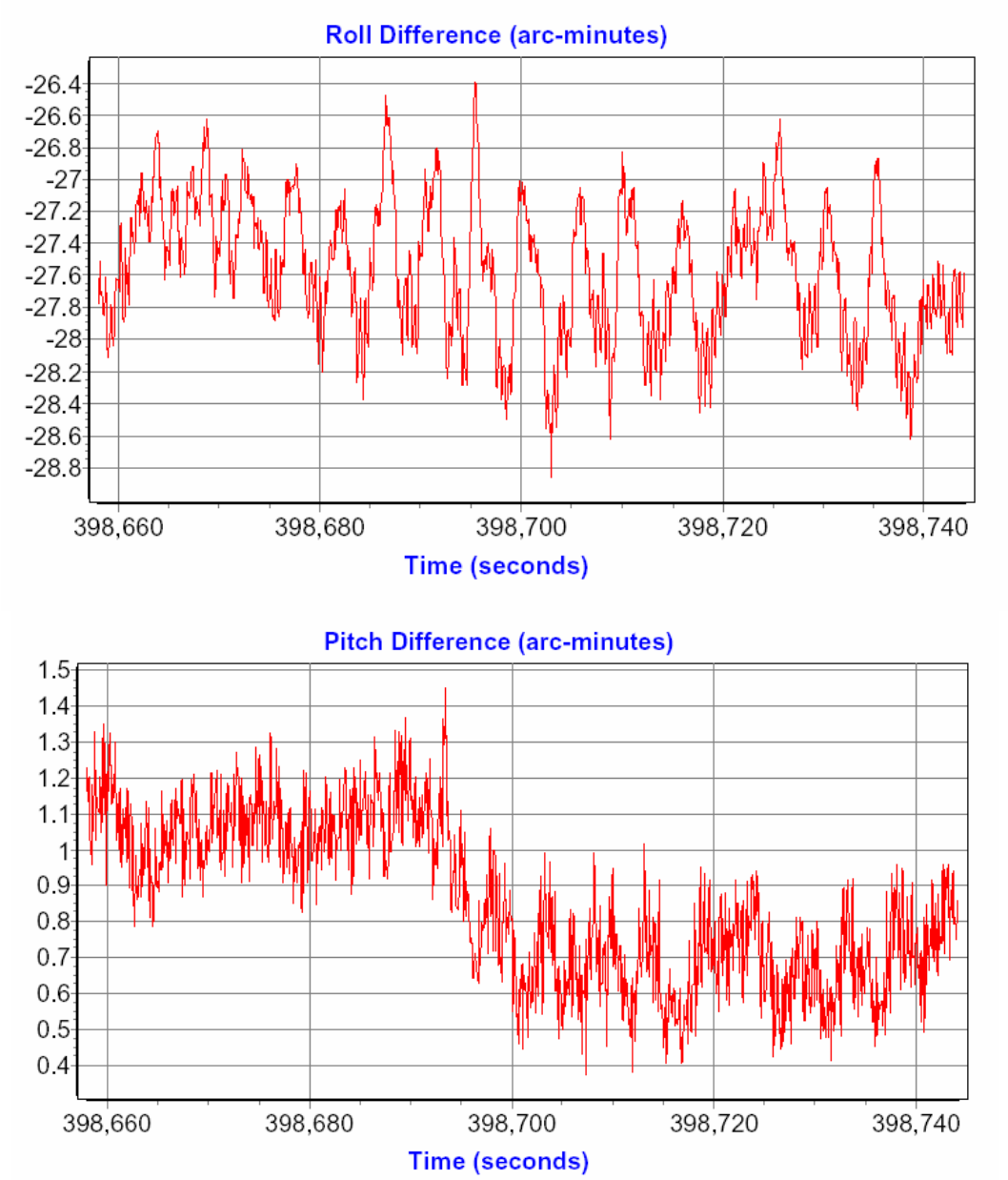


Fig 14: POS RS v POS MV (post processed) for Line 27

The statistics (in degrees) associated with this time period are as follows:

Element	MEAN	RMS	SIGMA
ROLL	-0.45943	0.45949	0.00727
PITCH	0.01431	0.01479	0.00372
HEADING	-0.28204	0.28205	0.00256

Number of data points: 17200. Time interval: 398658.002 - 398743.995 sec

Note that there are twice the number of data points in the post processed solution when compared to the real time data. This is because the real time solution was logged at a 100Hz rate, whereas the post processed solution was created at 200Hz.

3.7 Timing Conclusions

The results show that the POS MV was working within its specifications during the high roll oscillation Line 26. Comparing both post processed sets of data it is clear that timing is the cause of the large roll error variations we saw when taking the motion sensor data in realtime. There was nothing that we could do during the acquisition stage to improve upon the timing accuracy that we achieved. These findings indicate that when large and rapid oscillations are expected then either another means of timing must be found or that the survey swath limit be decreased. Utilising Ethernet logging where the data is time stamped at source could improve timing.

4 Conclusions

Though some of the manoeuvres that were performed could be called ‘extreme’, all these situations have occurred when trying to complete a survey and as such the data should be regarded as likely scenarios. It would be fair to say that the only line where you would have probably stopped surveying was Line 27 with the high roll oscillations. We can therefore make the following conclusions based on our interpretation of the results;

- All systems tested will comply with IHO Order 1 requirements (disregarding other elements of the error budget) under ‘normal’ survey conditions.
- To achieve best performance during survey allow 1 minute after turns for Marinus and F180, 2 minutes for Seapath.
- F180 and Seapath appear to be the most reliant on good GPS to aid the IMU. Performance degrades markedly in poor GPS environment.
- Marketing specifications should make reference to the heave settlement time
- All motion sensors tested, with the exception of Seapath, operated within their specified roll accuracies during low roll amplitude / rate of change conditions. However, when the roll amplitude / rate of change was high, none of the motion sensors met their published roll accuracy specifications (although the Marinus was only 16% beyond manufactures specified accuracy).
- Very accurate time synchronisation for attitude, in particular roll, is critical and for high roll oscillations 1 PPS timing with a serial interface is not sufficient.
- Post processing your IMU data can provide improved accuracy and reliability, especially in heave and will allow you eliminate any run in times.
- Even though the marketing material appears to portray each motion sensor to be of comparable performance, the evidence suggests “you get what you pay for”.

5 Software / Firmware Updates

TSS (International) Ltd have informed us that there was a problem with remote heave in the firmware we used in the sensor trial. The X [athwartships] offset was applied in the opposite sense. They believe this explains the reduced heave performance during the high roll tests.

As previously stated, Kongsberg Seatex believe they also have a software / firmware fault which has degraded the performance of their system. Future upgrades may therefore improve performance.

6 Acknowledgements

These motion sensor trials would not have been able to take place without the assistance of The Joint Hydrographic Center for Coastal and Ocean Mapping at the University of New Hampshire and in particular Capt Andy Armstrong. It would also not have been possible without the cooperation of the motion sensor manufacturers who shipped kit and technicians to UNH to install and operate the equipment. Special thanks should go to Capt Ben Smith for letting us take over his vessel and for fabricating the motion sensor rig to an accuracy of +/- 0.01 degs to the vessel reference frame. Many thanks to Brian Calder for the loan of his computer and serial port card when our ones failed. Reson Inc. and Rick Morton who provided the 8125 to allow us to see the effects on the seabed. Finally thanks to Andy Talbot - Excel Guru at the UKHO – for his assistance with the analysis.

Biography of Duncan Mallace, NetSurvey Limited

Duncan Mallace is the Managing Director of NetSurvey Limited based in Fenny Compton, UK. NetSurvey are a specialist multibeam service company, providing personnel and equipment to a global array of companies and organisations, enabling them to take advantage of multibeam technology without the in-house capability.

Duncan is a graduate of the University of Newcastle Upon Tyne with a B.Sc in Surveying Science. Graduating in 1988 he joined Mason Land Surveys in Scotland for two years before entering the hydrographic community with Oceanscan in 1990. He spent five years with Oceanscan before becoming freelance and then joined Octopus Marine in 1999, where he was Operations Director, running their multibeam services division. In March 2002 he left Octopus and set up NetSurvey.

His hydrographic experience has taken him worldwide and he has been lucky enough to have had a wide range of projects and equipment, however, from no real planning he has ended up specialising in underwater acoustics both for seabed mapping and also for positioning.

Biography of David Parker, UK Hydrographic Office

David Parker is the Bathymetric Advisor at the United Kingdom Hydrographic Office, the world's leading supplier of navigational charts and publications. He is responsible for the UKHO Bathymetric Centre of Expertise, and supplies assistance on surveying issues to other areas within the UKHO as well as to the MCA, Royal Navy and other organisations involved in the collection of bathymetry.

He has a BSc (Hons) in Hydrography and Ocean Science from The University of Plymouth and has worked predominantly in the near shore and port hydrography sector for 10 years since foolishly abandoning a career in yacht sailing. Prior to joining the UKHO, he was Hydrographic Manager at Halcrow Group Ltd based in Reading, UK.