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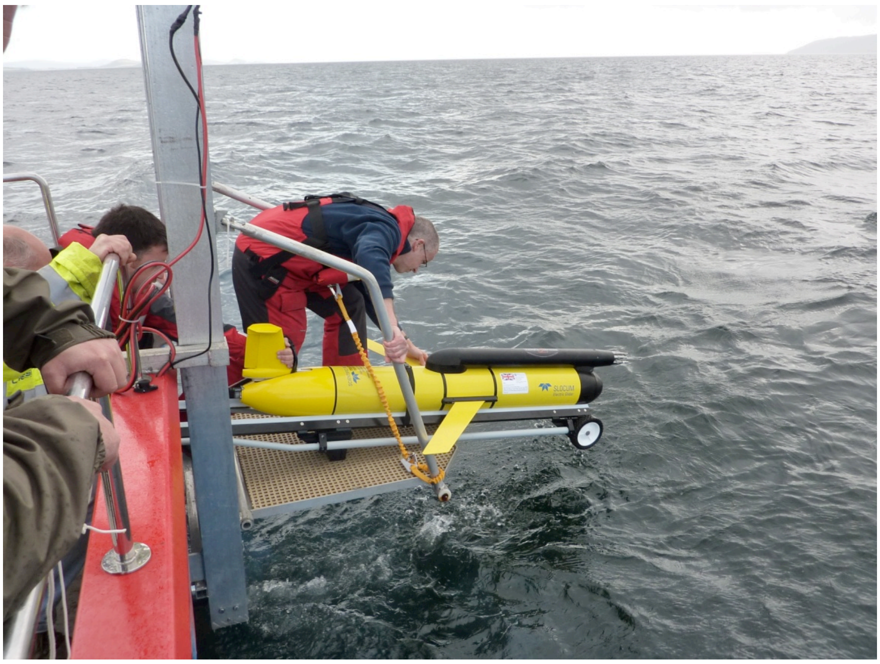
NOC turbulence glider deployment report
for the OSMOSIS Project

C Balfour, P Knight & D McLaughlin

2011



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ABSTRACT

This document summarises the three deployments of the NOC Liverpool Teledyne Webb Research Slocum glider fitted with an external Rockland Scientific International micro-Rider turbulence probe during September 2011. The general aim of these glider deployments was to generate underwater turbulence and glider based CTD measurements for comparison with other sensor systems. This information will be used for evaluation of the performance of other measurement systems that are required for the Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study (OSMOSIS) research project. All of the measurement systems were deployed in close proximity to a series of moorings that had a nominal centre location of 55^{O} 46.92"N, -5^{O} 12.6"W. Turbulence measurements used for comparison with the glider were recorded using a ship based Rockland Scientific International (RSI) Vertical Microstructure Profiler (VMP) and a REMUS 600 AUV with a RSI turbulence measurement package installed. The survey work described in this document was designed to act as a test and rehearsal for the use of the sensor systems that will be required for a Celtic Sea shelf edge based research cruise for the OSMOSIS project. The shelf edge cruise is scheduled to take place during 2012.

An overview of the aims of each glider deployment and the subsequent glider performance is included. The glider deployments in Scotland culminated in co-located survey on Thursday 15^{th} September 2011 that involved all of the OSMOSIS sensors, AUVs, moorings and ship based measurement systems operating in the same general location at the same time. This document concludes with a summary of the glider performance and recommendations are made regarding the scheduling and format for future scientific campaigns that require the use of the NOCL gliders.

KEYWORDS:

ISSUING ORGANISATION

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Terms and Definitions

Turbulence Glider	A 200 metre depth rated Slocum Electric Glider for oceanographic survey work that is manufactured by Teledyne Webb Research, America. The glider has an externally mounted micro-Rider turbulence probe fitted with an internal data recording capability. The micro-Rider is manufactured by Rockland Scientific International, Canada.
OSMOSIS	Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study. This project is led by Reading University and the partners are Southampton, Oxford, Bangor Universities, UEA, National Oceanography Centre, Scottish Association for Marine Science and the UK Met Office.
REMUS 600 AUV	A 600 metre depth rated autonomous underwater vehicle manufactured by Hydroid, LLC, America. This AUV had a turbulence measurement probe installed that included an internal data logging system.
VMP	A ship based Vertical Microstructure Profiler manufactured by Rockland Scientific International, Canada.
FreeWave	Wireless short range radio link based glider communications
Iridium	Wireless data transfer based upon the Iridium low earth orbit satellite constellation.

Abbreviations

NOCL	National Oceanography Centre, Liverpool
ADCP	Acoustic Doppler Current Profiler
AUV	Autonomous Underwater Vehicle
CTD	Conductivity Temperature and Depth sensor
VHF	Very High Frequency
RHIB	Rigid Hull Inflatable Boat
TWR	Teledyne Webb Research
GPS	Global Positioning System
GMT	Greenwich Mean Time

1. Glider Operational and OSMOSIS Project Requirement Overview

This document summarises the deployments that were made with the NOC Liverpool 200 metre depth rated Slocum Electric Glider with a microstructure package installed (turbulence glider). The turbulence glider has an externally mounted Rockland Scientific International micro-Rider turbulence sensor installed that includes an internal data recording capability. The glider also has an externally mounted non pumped seabird CTD, as shown in Fig. 1.

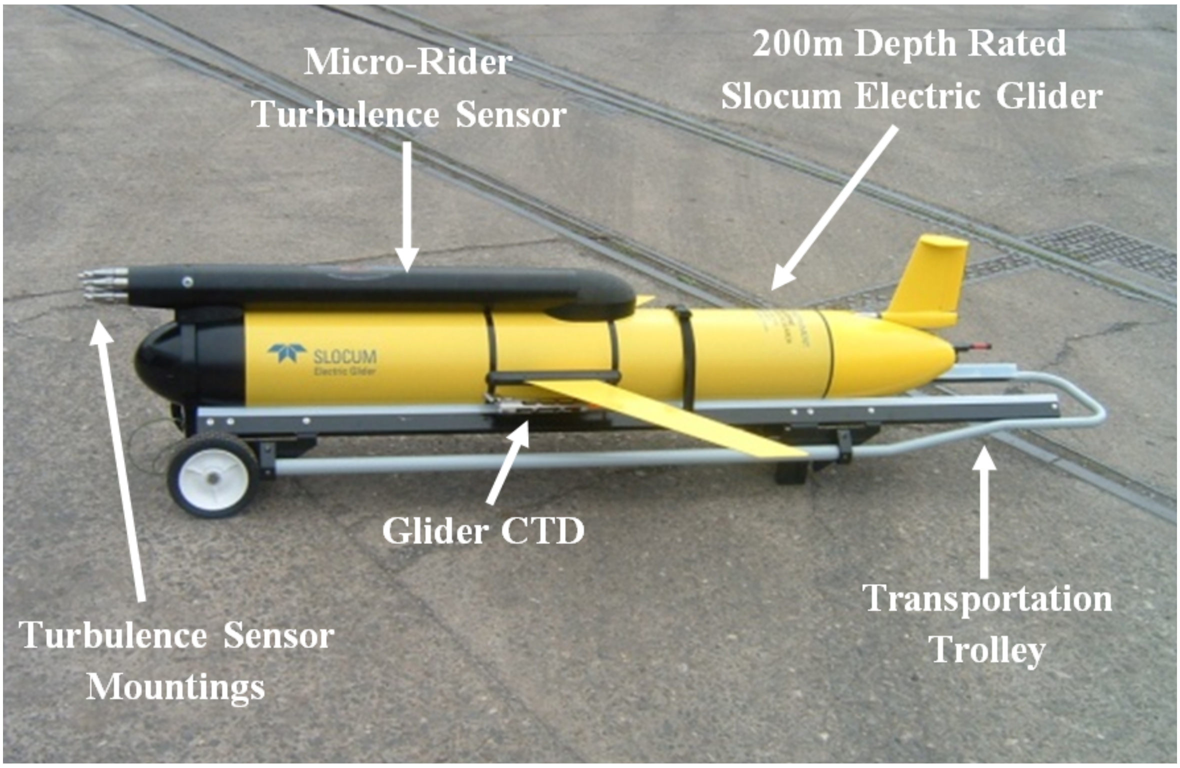

Fig. 1. Turbulence Glider configuration

The turbulence glider deployments occurred approximately 8 nautical miles south of Tarbert Port, Scotland, during September 2011. The general aim of the deployments was to generate comparison turbulence measurements from a ship deployed Vertical Microstructure Profiler (VMP), a REMUS 600 AUV with turbulence probes fitted and the NOCL turbulence glider in conjunction with measurements from a series of deployed moorings. The moorings included buoy mounted meteorological sensors, surface and sea bed mounted internally recoding CTDs, a thermistor chain and ADCPs with a vertical turbulence measurement capability. The moorings had a nominal centre GPS location of 55^{O} 46.92"N, -5^{O} 12.6"W as shown in Fig. 2. This survey work was required as an evaluation of the sensors and systems that will be required by the Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study (OSMOSIS) project. OSMOSIS will aim to use these sensors and systems during a Celtic sea shelf edge scientific research cruise next year. Three deployments and recoveries of the turbulence glider were completed during the glider operations from Tarbert. The following sections of this report provide some key information relating to the purpose of the deployments and the measurements that were made.

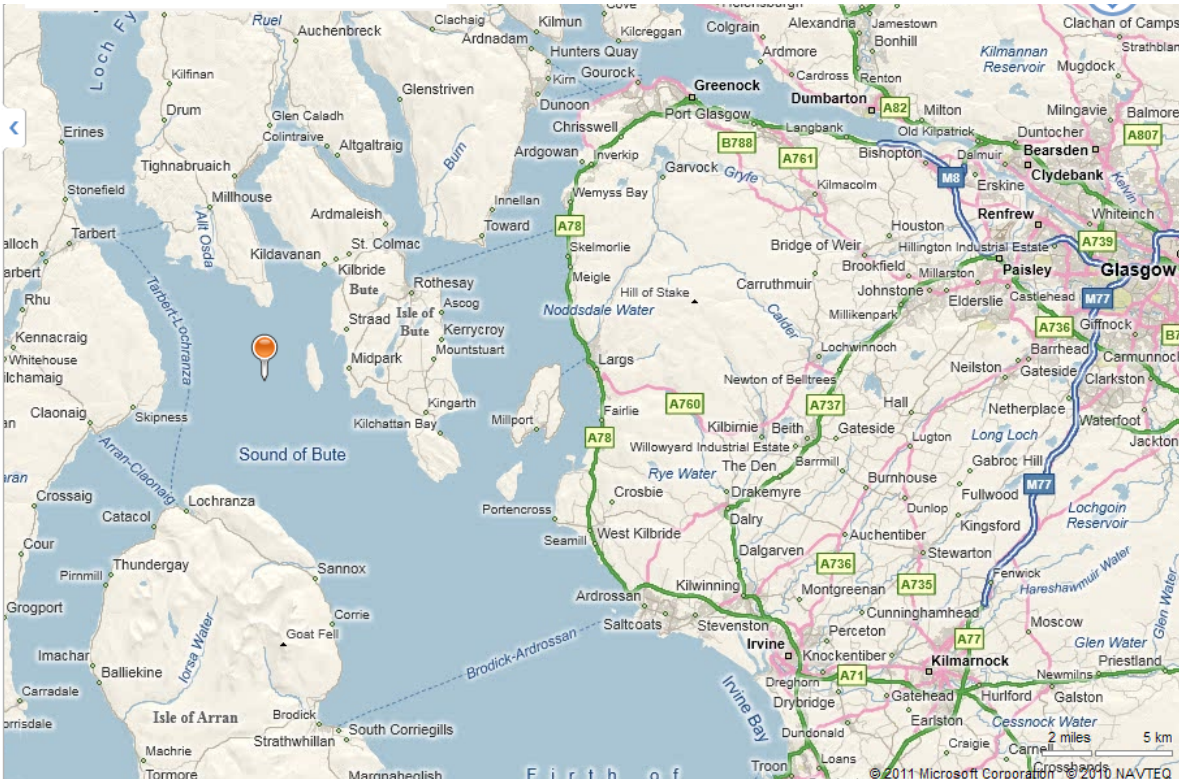

Fig. 2. OSMOSIS Moorings Deployment Location

2. Turbulence Glider Deployment 1 – Thursday 8th September 2011

Participants:

NOCL: Chris Balfour and Danny McLaughlin.

Loch Fyne Dive Charters: Malcolm Goodchild (skipper), Callum Clark and Darren Simpson.

2.1 Deployment 1 Aim (all times in GMT)

The dive boat 'Big Blue' was chartered from Loch Fyne Diver Charters, Tarbert to undertake a turbulence glider deployment and initial operational evaluation. If the glider performed satisfactorily during this deployment then the intention was to consider deploying the glider for an extended period of time of approximately six days. The plan was to navigate the turbulence glider to ~1KM south of the OSMOSIS moorings (55^{O} 46.92"N, -5^{O} 12.6"W) and then leave the glider holding station underwater between two east to west waypoints approximately 2km apart to act as a 'virtual mooring'. The glider was programmed to surface at two hour intervals to provide status information and positional fixes via satellite or short range VHF communications. The glider turbulence probe configuration is shown in Fig. 3.

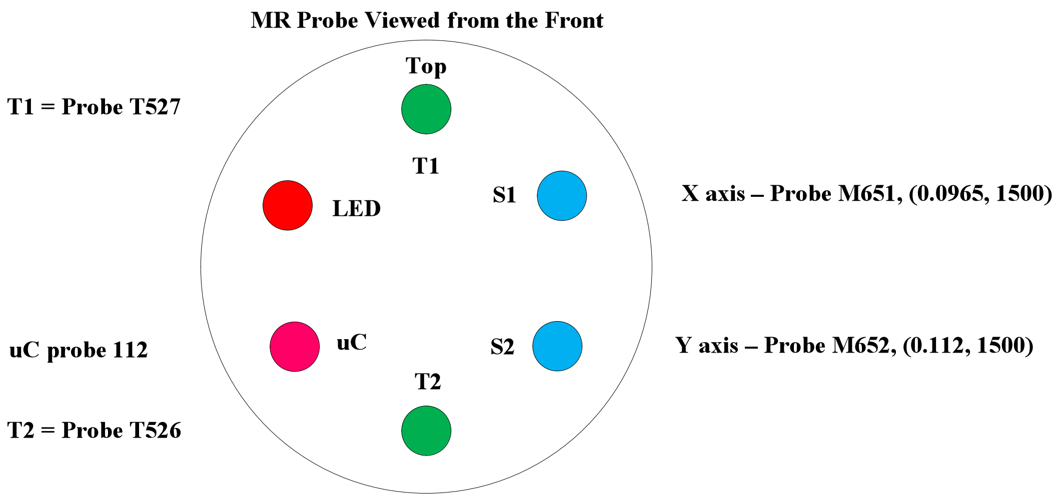

Fig. 3. -Micro-Rider Turbulence Probe Configuration for Deployment 1

2.2 Deployment 1 Overview

During mobilisation for the cruise the skipper advised us of significant trawling activity at our proposed glider deployment location. Additional advice was that westerly winds of more than force 3 tend to result in increased trawling activity in the more sheltered waters close to the study area. Following this advice a series of new glider waypoints were derived to the west of the OSMOSIS moorings. The general intention was operate the glider between new waypoints that aim to navigate from North West to South East. This should operate the glider in line with the anticipated flow of tidal currents and along a contour of deeper water as far away from the anticipated trawling operations as possible. A revised test deployment site was located to the west of the original OSMOSIS deployment site at 55^{o} 46.867" N and -5^{o} 14.604"W to try and avoid trawling activity, as indicated in Fig. 4. A Seabird Microcat CTD and YSI Castaway CTD were then used at the new deployment location and a density in the upper water column of 1024.63kg/m^3 was measured at a depth of ~1.8 metres. There also was evidence of an increasing density with depth in the water column from the YSI Castaway CTD Data. The glider ballasting setup of 1025.66kg/m^3 was considered suitable for these water column conditions. A Sony GPS recorder was used to log the ship position during the trials.

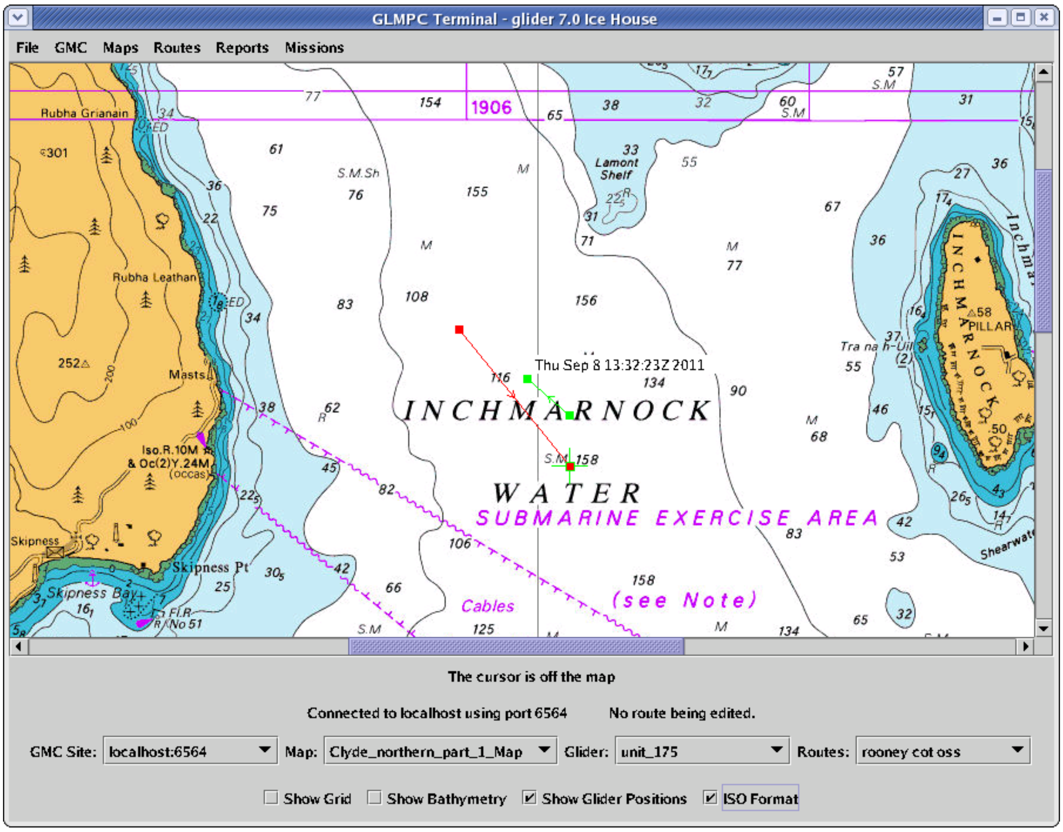

Fig. 4. GLMPS Glider Monitoring Software Screen Capture – Red Dots and Line represent new intended Cyclic Waypoints West of the Original OSMOSIS Intended Deployment Site.
(The Waypoints for a glider 'virtual mooring' are Skewed from North West to South East to follow the anticipated mean tidal current flow path, the green rectangles represent the reported glider positions)

The following glider missions were then completed on Thursday 8th September 2011:

1. The glider science, actuators and operational pre-deployment checks were completed successfully by 09:46.

2. The glider was deployed with a tether and pellet float and a 3 metre 'ini0' dive and climb mission was completed successfully at 10:52. No obvious entanglement of the float line around the microstructure probes occurred.

3. Following this the float was removed and an 'mr_test' mission was completed by 11:53. This involved the glider diving and climbing underwater for 45 minutes to perform a series of dives to 90 metres with automatic pitch motor selection enabled. This was to allow the glider to decide how to trim the glider pitch angle using pitch battery position for the optimal dive and climb angles for the local water column conditions. This mission was completed successfully and the recorded data was downloaded and used to decide what fixed pitch battery position should be used to achieve the ideal dive and climb angles of 26

degrees. Microstructure measurements and glider CTD data had been recorded successfully during climbs as required.

4. The results from the 'mr_test' mission were then used to decide what pitch battery positions should be used for the local deployment site conditions to dive at 26 degrees (ideal) and climb at 35 degrees (steeper to improve the microstructure measurements). A fixed pitch motor position of +0.25 inch was used for dives and –0.1 inch was used for climbs based upon the results from the 'mr_test' mission described in 2 above. Fixed pitch motor positions are used to limit the noise (mechanical and electrical) generated by the glider that is likely to interfere with microstructure measurements. An 'mr_serv1' mission was then run to dive to 90 metres and then climb near the surface for a period of 45 minutes to evaluate the glider performance. This mission was completed successfully at 13:33 and the required dive angle of ~26 degrees and climb angle of ~35 degrees had been achieved, as shown in Fig. 5. Microstructure measurements and glider CTD data had been recorded successfully during climbs as required. During the mr_serv1 mission over the side CTD calibration data was generated by a Seabird Microcat, SN 4966 (with a strain gauge pressure sensor installed). Calibration casts to approximately 10 metres were also undertaken with a Castaway CTD during the glider deployment.

At this stage local fishing boat trawler activity nearly resulted in the loss of the glider and the swift intervention of the skipper, resulted in a trawler changing direction from a heading that would have collided with the glider. The decision was made to terminate the deployment and the glider was successfully recovered without sustaining any damage. Post deployment tests confirmed that the glider and the micro-Rider turbulence probe had successfully recorded the required data during the deployment.

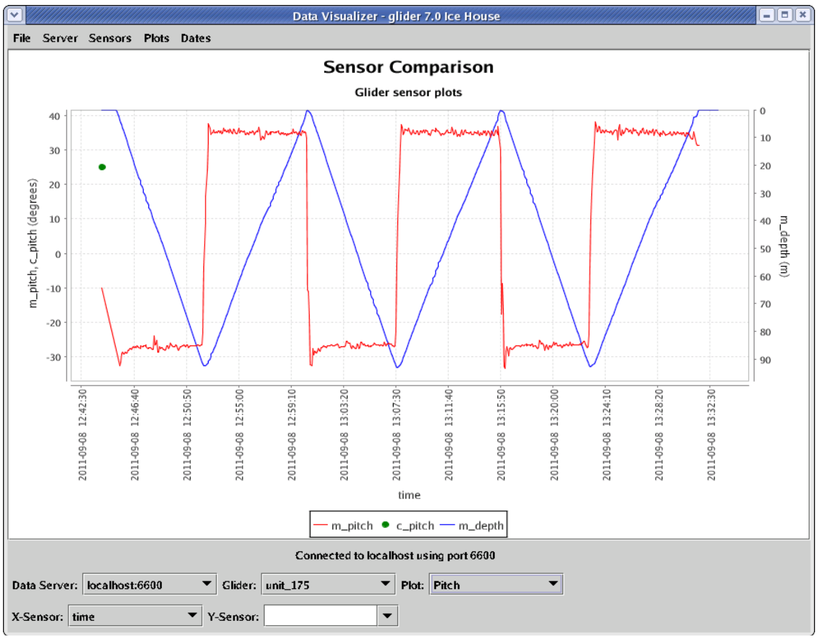

Fig. 5. Data Visalizer Plots of the Glider Dive and Climb profiles

The MR_Serv1 Mission using fixed pitch battery positions produced a 26^{O} dive angle and a 35^{O} climb angle as required

3. Turbulence Glider Deployment 2 – RV Prince Madog Saturday 10th September 2011

Participants:

NOCL: Chris Balfour (CB) and Danny McLaughlin (DM).
PSO: Tom Rippeth

3.1. Deployment 2 Aim (all times in GMT)

A request was made for the NOCL glider team to attempt a turbulence glider deployment from the RV Prince Madog ~1km south of the moorings during the OSMOSIS project cruise. The general schedule was for the Prince Madog to be involved in daylight survey operations close to a series of moorings. The cruise work originated and terminated at Tarbert. While the deployment and particularly the glider recovery is difficult using a larger survey vessel a RHIB was available for glider operations. This was on the proviso that poor weather and particularly the impending Hurricane Katia and subsequent high winds did not result in an unsuitable sea state for RHIB operations. The plan was to deploy the turbulence glider at ~1KM south of the OSMOSIS moorings, which had a nominal GPS location of 55^{O} 46.92"N, -5^{O} 12.6"W, and then leave the glider holding station underwater between two east to west waypoints approximately 2km apart to act as a 'virtual mooring'. The micro-Rider probe configuration shown in Fig. 6 was used for this deployment.

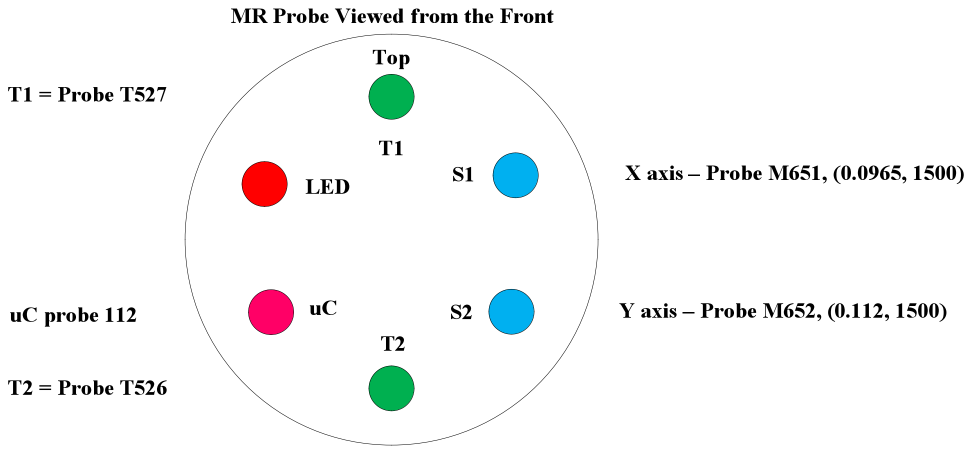

Fig. 6. Micro-Rider Turbulence Probe Configuration for Deployment 2

3.2 Deployment 2 Overview

The NOCL glider team mobilised on the Prince Madog on Saturday 10th September. Initial checks on the ship showed that the glider was operating satisfactorily. Due to REMUS operations it was not possible to attempt a glider deployment until 16:30. This was achieved by placing the glider in the RHIB, which was suspended to the aft of the ship. The RHIB plus a RHIB pilot and the NOCL glider team were then lowered into the water and the glider was launched using its transportation trolley. The delayed deployment and busy cruise schedule meant that there was insufficient time to perform a tether + float test of the glider. This represents a potentially risky strategy as disturbance to the glider setup could have occurred during the mobilisation process. A check of the seawater density profile using a CTD cast from the ship had shown that the mid water column nominal density was approximately

1025kg/m^3. The water column density at the mooring site varied between ~1024kg/m^3 in the upper several metres of the water column and 1026kg/m^3 close to the sea bed. The glider was ballasted for 1025.66kg/m^3, which was considered suitable for this deployment. Requests from the scientists and crew to return to port as soon as possible meant that it was not feasible to recover the glider. This resulted in only limited testing being undertaken on the Prince Madog by the NOCL glider team. At 19:00 the NOCL glider team demobilised at Tarbert with the intention of piloting the glider from the base station (Brenfield Crofts self catering accommodation) approximately 10 miles north of Tarbert port.

After piloting operations started by midnight it became evident that there was a problem with the glider. Aft leak detect mission aborts were occurring although the leak detect signal did not show any signs of a problem when the glider surfaced. If the glider remained on the sea surface due to these mission aborts then the impending high winds were likely to cause the glider to drift off station. This would then probably result in possible damage to or loss of the glider from such hazards as ship collisions, entanglement with fishing or mooring lines, internal electronics failures, glider grounding and/or buffeted in high winds plus shallow waters preventing any effective navigation if missions could be resumed and so on. CB of the NOCL glider team made the decision to pilot the glider through the night to manage the problems that were occurring. At 07:30 GMT on Sunday 11th September the NOCL glider team then mobilised to join the Prince Madog again at Tarbert port. The problem of glider drifting due to mission aborts is illustrated in Fig. 7.

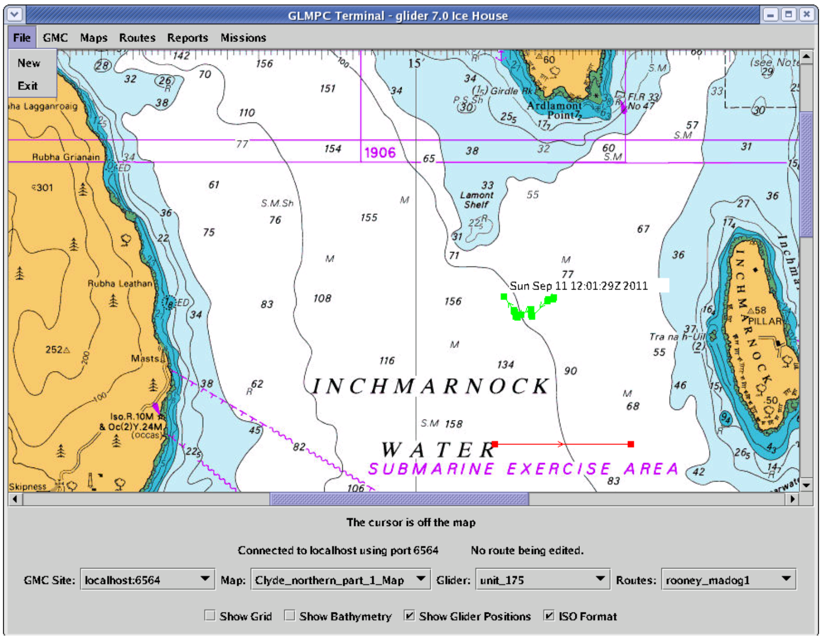

Fig. 7. Plot of the Glider Drifting off Station and North of the Moorings This was due to Repeated Mission Aborts on Sunday 11th September

The forthcoming poor weather caused the scheduled Prince Madog crew change at Troon to be brought forward to Sunday evening. The decision was made for CB to stay on the Prince Madog to pilot the glider and DM to take the works vehicle and drive to Troon (a 3 hour one way drive). Rather than the suggested stay in B&B accommodation at Troon until the scheduled Prince Madog return to Tarbort Port on Tuesday evening (12th September). This strategy provided the NOCL glider team with some level of travel independence. The disadvantage was that CB was the only member of the NOCL glider team now available to manage the glider operations on the Prince Madog. After some discussion and further tests with problematic glider FreeWave and Iridium communications it became evident that there were serious problems with the turbulence glider. A message had been sent to Teledyne Webb Research (TWR) to ask for advice. However that fact that the problem with the glider occurred during a weekend and on a Sunday precluded a fast response to this enquiry. The degraded sea state meant that a RHIB deployment to recover the glider was not possible. A net arrangement was used by the crew to perform an emergency recovery of the glider. While damage to the glider is almost inevitable, particularly the turbulence probes, this represented the only remaining short term glider recovery option. The glider was successfully recovered using a net at approximately 14:00. Inspection of the glider confirmed that the turbulence probes had all been damaged during recovery. There was no other obvious external damage to the glider.

When the Prince Madog arrived at Troon at approximately 16:30 GMT the NOCL glider team demobilised and commenced the long drive back to the base station north of Tarbert port. The general intention was to attempt a repair of the glider and turbulence probes at the NOCL base station, with limited fieldwork resources. If this repair work was successful a further deployment of the glider could be attempted later on during the OSMOSIS cruise, which was scheduled to finish on Saturday 17th September. During the turbulence glider deployment from the Prince Madog a good data return had been achieved despite a series of aft leak detect based mission aborts. The glider flight and science data was successfully recovered. Turbulence data from more than 35 micro-Rider up casts was also recovered. The plot in Fig. 8 illustrates the progressive leak that occurred during this deployment into the aft section of the glider.

Fig. 8. Post Deployment 'Data Visualizer' Plot of a Subset of the glider Data Showing A Progressive Leak Detect Signal During the Deployment from Saturday 10th to Sunday 11th September 2011

(A leak detect Voltage of 2V or Less Triggers a Glider Mission Abort)

Internal inspection of the glider and the micro-Rider turbulence probe confirmed that seawater ingress had occurred into the glider aft section and the front probe connecting enclosure of the micro-Rider. Three days of intensive repair work at the NOCL base station were required to prepare the glider and turbulence probe for another deployment attempt.

4. Turbulence Glider Deployment 3 – Thursday 15th September 2011

Participants:

NOCL:	Chris Balfour and Danny McLaughlin.
Loch Fyne Dive Charters:	Malcolm Goodchild (skipper)

4.1 Deployment 3 Aim (all times in GMT)

The dive boat 'Big Blue' was chartered again from Loch Fyne Diver Charters, Tarbert to undertake a turbulence glider deployment and initial operational evaluation. If the glider performed satisfactorily during this deployment then the intention was to generate as much scientific data as possible during daylight hours in conjunction with and in close proximity to the Prince Madog survey work. The plan was to navigate the turbulence glider to ~1KM south of the OSMOSIS moorings (55^{O} 46.92"N, -5^{O} 12.6"W) and then leave the glider holding station underwater between two east to west waypoints approximately 2km apart to act as a 'virtual mooring' for as long as possible during the day. The replacement micro-Rider probe configuration shown in Fig. 9 was used for this deployment.

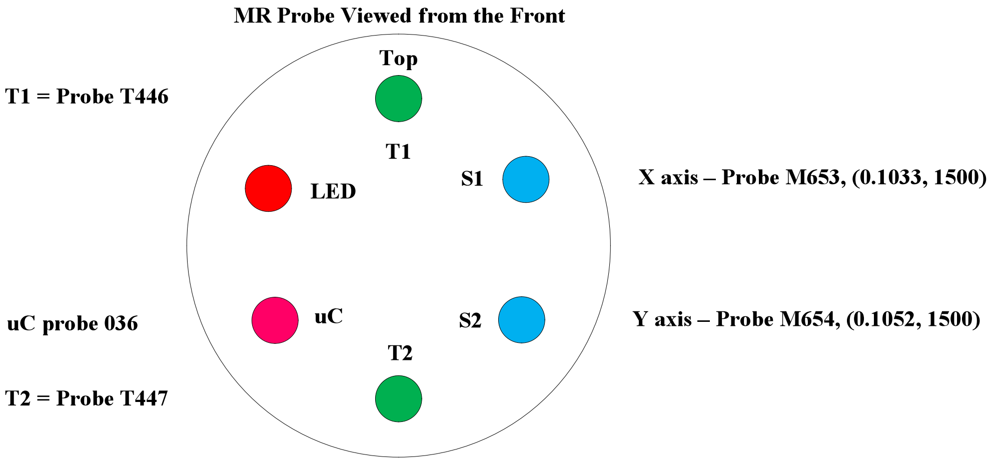

Fig. 9. Microstructure glider probe configuration for deployment 3
The previously damaged probes were replaced

4.2 Deployment 3 Overview

The NOCL glider team mobilised at 05:30 to Tarbert to maximise the time available during daylight for the glider deployment. A similar sequence of operations to that described for deployment 1 occurred. The transit to the deployment site 800 metres south of the OSMOSIS mooring was made and the dive boat was on station by 08:45. After the usual testing of the glider as described in the overview for deployment 1 the glider was launched with a tether at 09:02. An 'ini0' mission dive to 3m and back to the surface was then completed successfully. The glider was then un-tethered without any damage to the micro-Rider probes occurring. The test mission mr_serv1 was started at 09:22. This mission in intended to perform a series of 20 metre dives underwater for a period of 30 minutes with turbulence data and glider CTD data being recorded during glider climbs. During the glider operations a Microcat CTD and a Castaway CTD were used to gather reference CTD data for calibration checking of the glider CTD. The general aim was to incrementally increase the glider dive depth. When the glider surfaced the latest flight and science data would be downloaded, plotted and a check for signs of a leak would be made.

At approximately 09:35 the glider surfaced with a mission abort due to an aft leak detect, as shown in Fig. 10. When the glider was on the surface the leak detect condition was not evident from the glider telemetry.

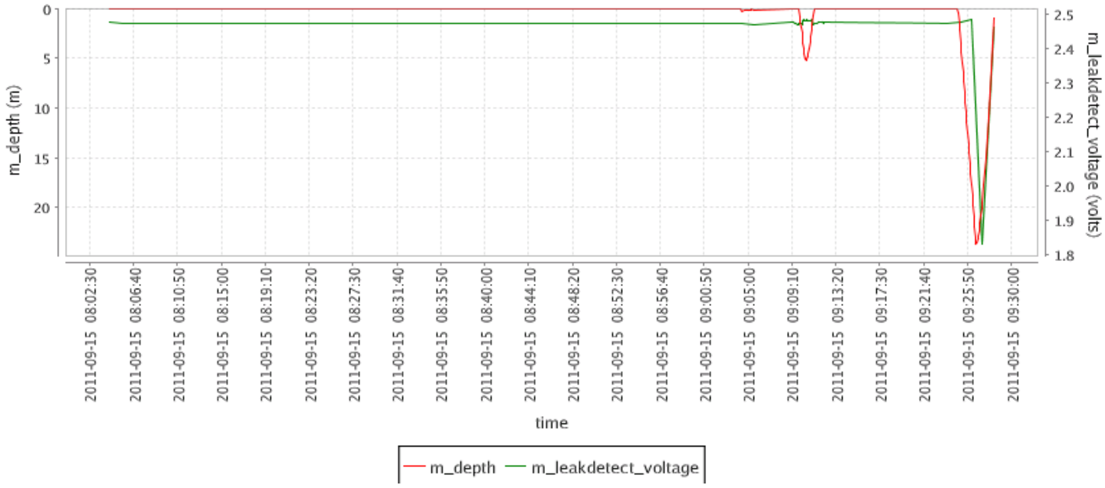

Fig. 10. Evidence of Seawater Leakage in the Aft Glider Section During the Initial 20 metre Un-tethered Test Dive

It subsequently became apparent that the full service and cleaning of the glider at the NOCL base station had not cleared the aft leak problem. The leak appeared to be very small with droplets of seawater only entering the glider when an appreciable depth (10s of metres) was attained. This made the source of the leak difficult to identify. The sea state and weather were relatively favourable during the second dive boat cruise and the decision was made to attempt a glider repair during the cruise. This is an unorthodox approach to glider servicing that would not normally be considered. However this represented the final option to generate the required glider data. That said there is also an inherent risk with this approach. This is primarily due to time constraints and access to the extensive facilities that would normally be available in a lab environment is not possible. The glider was carefully disassembled and opened and a small amount (droplets) of seawater ingress had occurred into the aft section. There was no evidence of seawater ingress into the glider science bay (centre section) or the forward sections (pitch control motor, pitch batteries and buoyancy control diaphragm assembly). The seawater leakage into the aft section of the glider was carefully cleaned with an alcohol based cleaner. The aft section 'O' ring seals and the rear bulkhead vacuum port seal plug were replaced. The glider seals were then carefully cleaned and greased (twice) before the glider was reassembled. The required partial vacuum was then established inside the glider using an external vacuum pump. Trimming of the vacuum value to an appropriate pressure of 6.1 in/Hg and subsequent testing showed that the glider internal vacuum was holding at the required level. The glider tether and pellet float test was then repeated successfully at 12:18.

During removal of the glider tether and pellet float the glider hull, CTD and turbulence probes became entangled with the tether line. After carefully removing the tether there did not appear to be any obvious damage to the glider or turbulence probes. A series of test dives using the custom mission mr_serv1 were repeated for depths of 20m, 40m, 60m, and 90m. After each incremental test depth the glider data was downloaded and plotted to check for any evidence of seawater ingress while the glider was at the sea surface. If no problems were evident an increased depth was attempted until the required 90 metres dive profile was achieved, as shown by the plot in Fig. 11. These test dives were then completed successfully by 15:07. Following this the remainder of the cruise time was used to gather glider CTD and micro-structure up cast data during a series of repeated 90m dives and climbs of the glider underwater. Reference Microcat and Castaway CTD calibration data was generated during the glider operations. Communication with the RV Prince Madog confirmed that VMP and REMUS 600 AUV survey operations had occurred at the same time in the same general location as the glider deployment as required by the OSMOSIS project. A plot of the reported glider locations during this deployment is shown in Fig. 12.

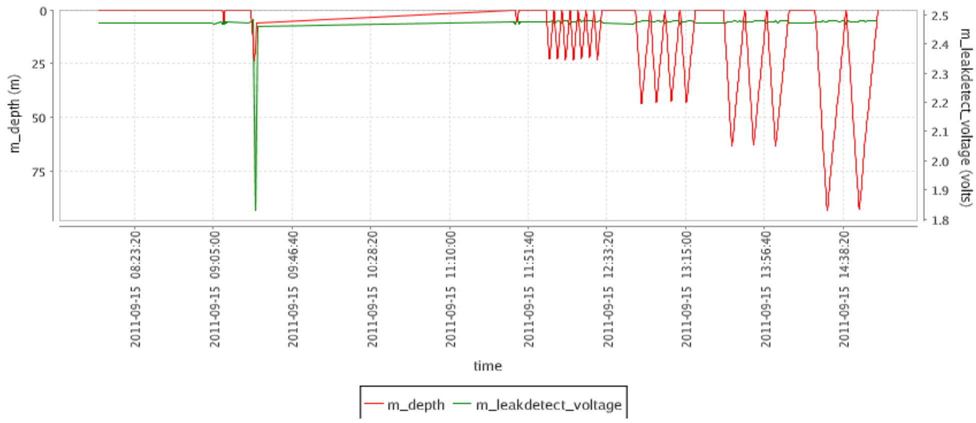

Fig. 11. No Evidence of Seawater Leakage During the Incremental Test Dives of the Repaired and Serviced Glider

(the leak detect to the left of the plot is the initial 20m dive before the glider repair)

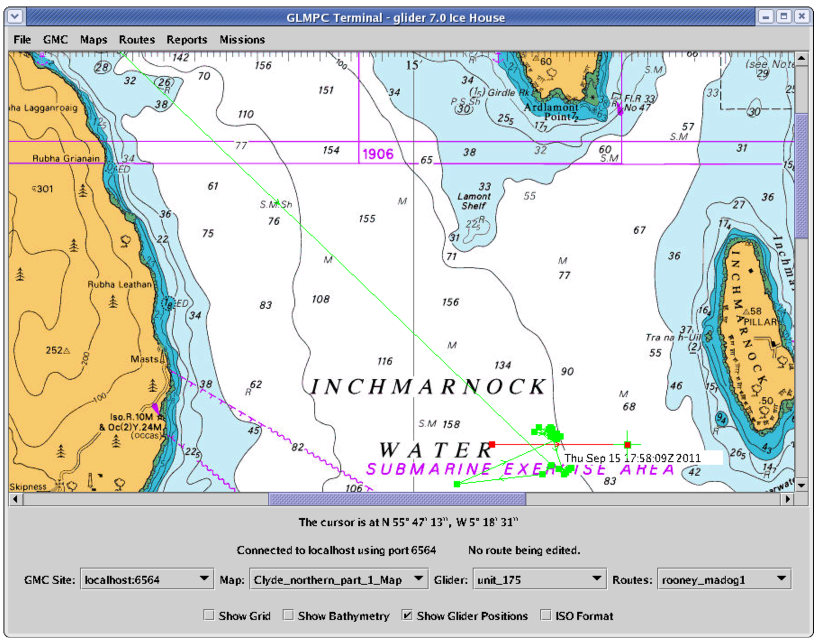

Fig. 12. Glider Reported Positions During OSMOSIS Deployment on Thursday 15th September During Incremental Test Dives to 90m and Subsequent 90m Survey Dives.
The glider remained ~800 metres to 1KM South of the OSMOSIS Moorings, as required at a nominal centre position of 55 deg. 46.471"N and -5 Deg. 12.693" W

Post cruise data downloading and analysis showed that the glider flight, science and the micro-Rider data had been recorded successfully during the cruise. More than 10 full 90m climb microstructure up cast data files had been generated in addition to microstructure data from the 20m, 40m and 60m incremental dives.

5. Summary

A total of three turbulence glider deployments and recoveries were completed successfully in difficult conditions under very tight time constraints. Problems such as trawling and damage to the glider were dealt with effectively with limited fieldwork based resources. Prior deployments of the turbulence glider had not exhibited any seawater leakage problems for dives over several days involving dives to approximately 40 metres. It is most likely that the problems with glider leakage were introduced during the glider transportation and mobilisation or demobilisation processes. The extremely tight initial schedule of the turbulence glider deployment and recovery operations that was suggested for the OSMOSIS project precluded extended testing of the glider after the arrival of the NOCL team at the Tarbert base station. It was fortunate that the self catering accommodation selected had sufficient space indoors to attempt the required glider repair, servicing and testing operations. Despite the difficulties encountered with the turbulence glider deployment schedule, local trawling activities and the less than favourable weather all of these deployments achieved an excellent data return. Where possible, separate Seabird Microcat CTD and YSI Castaway CTD data was generated for monitoring of the glider CTD calibration.

The operations described in this report have demonstrated the difficulties associated with use of a glider that incorporates a turbulence measurement system and its associated fragile probes. Turbulence glider operations require greater care than standard Slocum electric glider work. In addition to this the presence of the micro-Rider turbulence probe on top of the glider obscures the normal lifting point that would be used with the glider. The NOCL turbulence glider can be considered as an experimental survey vehicle that requires very close monitoring by a trained operator in close proximity to the glider. An incremental series of tests with the glider in seawater of an appropriate depth of more than at least 10 metres should be undertaken. To successfully undertake turbulence measurements, calibration dives and subsequent data analysis are required. This allows the optimal parameters for glider flight with fixed pitch motor positions to be determined for an intended deployment location. This represents a significant testing and operational evaluation overhead that must be included in any scheduling of turbulence glider deployments.

The preferred option is to have small boat support for glider operations with a low freeboard or seawater access platform close to the sea surface. This eases the task of glider deployment and recovery and reduces the chances of damaging the glider. Requirements for the support vessel include a sheltered area preferably with a workbench and ac mains power source. This allows portable computers and short range VHF communications to be used to perform the initial close proximity configuration and monitoring of the glider performance before an extended deployment is considered. In addition to this suitable ship based amenities are desired as this type of glider operation is likely to involve at least several hours to one day of intensive work before a glider deployment can be attempted.

Acknowledgements

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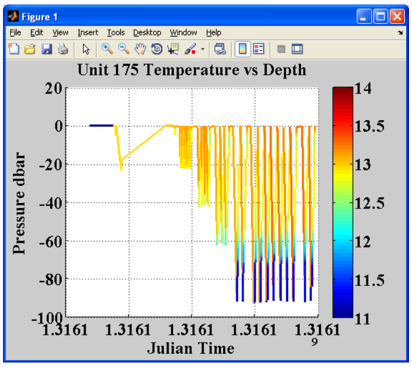
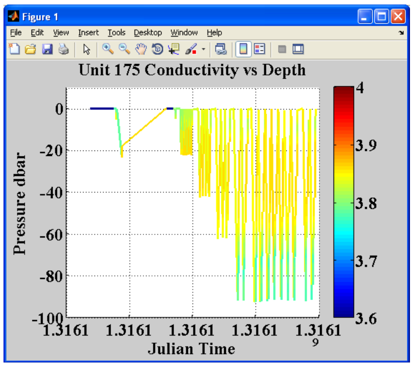
Appendix A - Post Cruise Data Analysis and Plotting

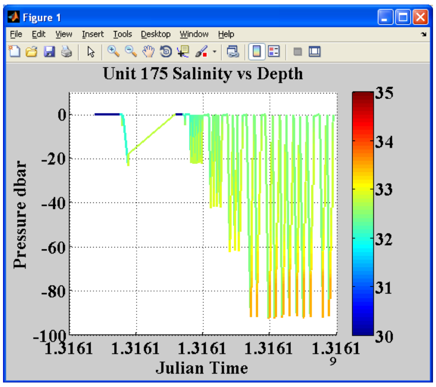
A series of plots of the recorded glider CTD and turbulence data are shown in Figs 13 and 14 for the glider data recorded during deployment 3. These plots indicate that the glider based sensor systems have been operating correctly.



Temperature



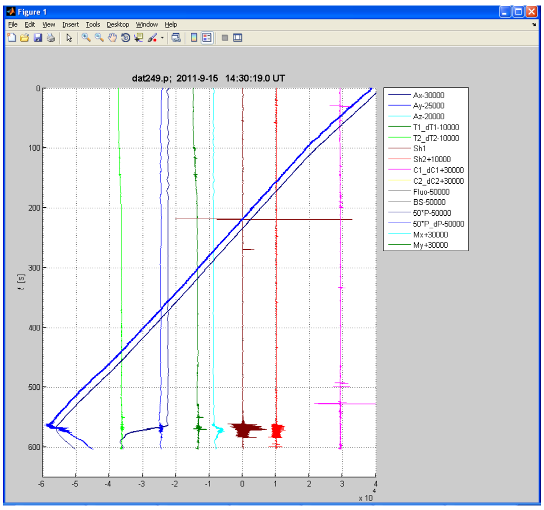
Conductivity



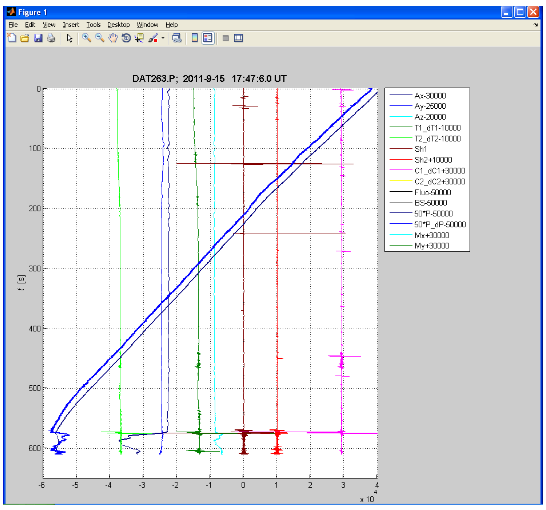
Salinity

Fig. 13. Glider CTD Data from Deployment 3 on Thursday 15th September 2011

(The plots indicate that the glider CTD data recording was successful during the deployment)



14:30 GMT-full 90m Climb

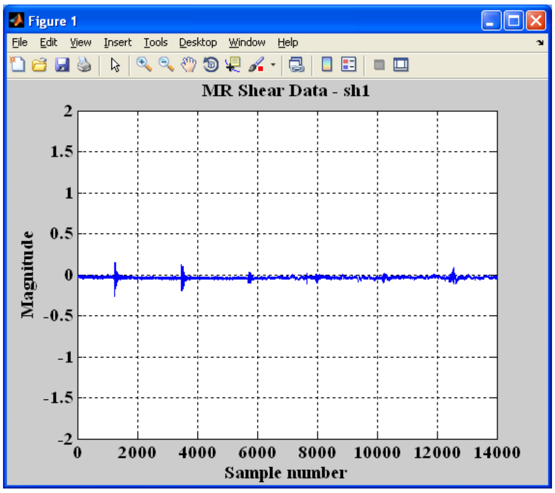


18:55 GMT-full 90m Climb

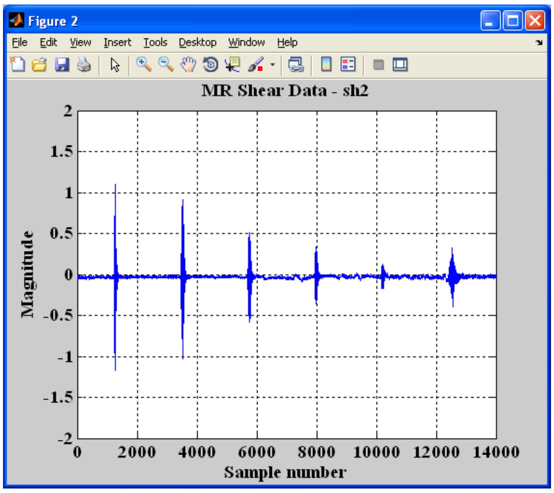
Fig. 14. Sample microstructure Data from the Deployment on Thursday 15th September 2011

The initial thumbnail plots do not show an evidence of obvious problems in the recorded data

Some evidence of what appears to be glider tail fin generated noise appears to have occurred in the raw shear data recorded by the micro-Rider (Fig. 15). In the recorded micro-Rider deployment data during a glider climb there is parasitic spiking in the shear data approximately once every 4 seconds. The spiking is more pronounced on the second shear channel, sh2 (Y axis shear).



SH1 – Showing Spiking at Approximately 4 Second Intervals



SH2 – Y axis Showing More pronounced Spiking at Approximately 4 Second Intervals

Fig. 15. Raw Shear Data Noise Spiking During micro-Rider Deployment on 15th September 2011

(It is suspected that the glider fin motor is causing the spiking)

Discussions with other turbulence glider users and the manufacturers are underway to resolve this. It would appear that this noise can be removed during the shear data post processing and the required microstructure data has been successfully recorded. NOCL are unique in respect of they are the only current user of a coastal Slocum Electric Glider with a turbulence measurement capability. Therefore there are limits to the level of comparisons that can be made between the coastal and deep water Slocum gliders with a turbulence measurement capability.

NOCL have a glider mission profile that employs the ‘comatose’ mode to keep the glider motors, including the tail fin stationary during dives and climbs. Unfortunately this impacts severely on the ability of the glider to navigate underwater. This problem is particularly acute when the comatose mode is used in coastal regions. Tidal currents can severely affect the glider navigation when the comatose mode is used and care is required regarding the usage of this function. There was insufficient time during the NOCL turbulence glider deployment programme for the OSMOSIS project work in September 2011 to experiment with the use of the comatose mode.

Discussions are ongoing with Teledyne Webb Research to derive suitable coastal glider microstructure survey missions with limited or no glider tail fin operation during microstructure measurements. This should allow improved microstructure data quality while impacting less severely than the comatose mode on the navigational ability of the glider.

Appendix B - Selected Photographs from the Loch Fyne Dive Charters Based Turbulence Glider Deployment, Recovery, Testing and Repairs

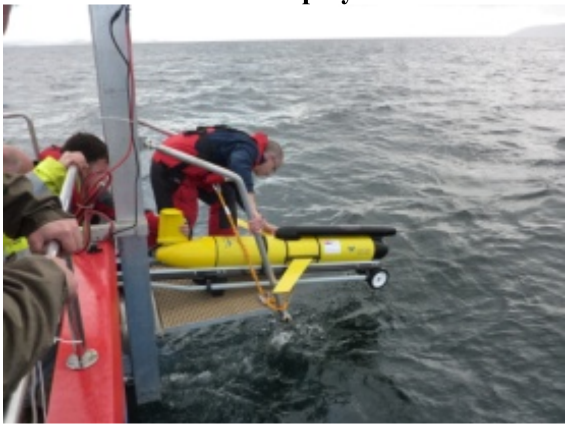
Dive Boat FreeWave Short Range Glider Communications Setup

Glider Deployment Cruise Preparations

Glider Monitoring Station

Transit to the Deployment Site

Pre Deployment Water Density Check

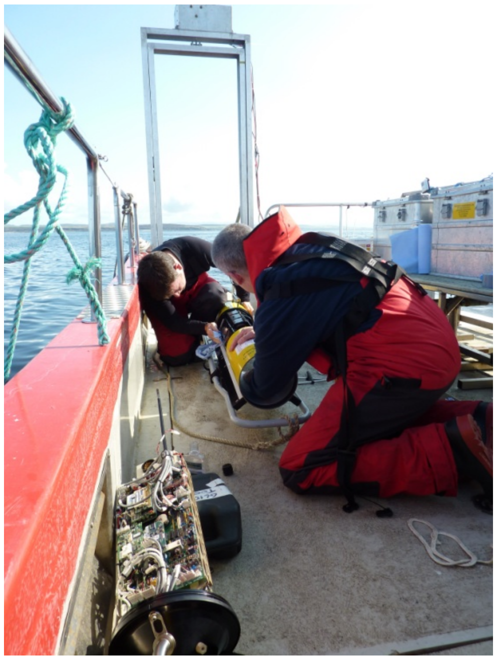


Glider Deployment

Pellet Float and Tether Deployment During Glider Testing

Subsequent Un-tethered Glider Deployment

Trawler Operations Close to the Glider



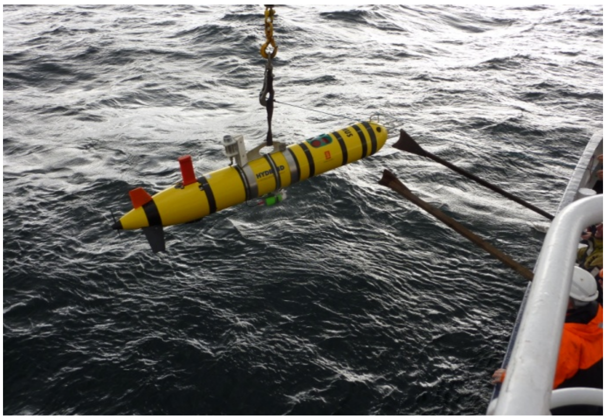
Glider Servicing and Repairs During a Cruise

The RV Prince Madog on Station During the Dive Boat Cruise on 15th September 2011

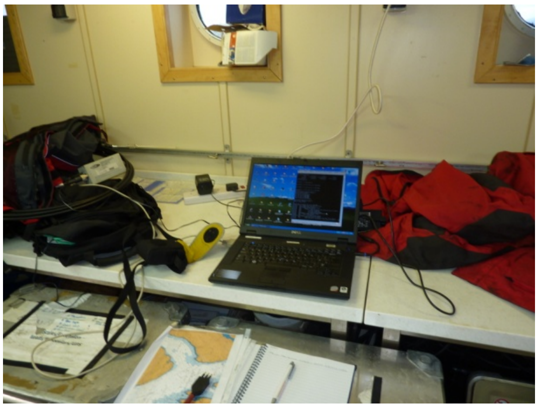
Glider Recovery and Protection of the Turbulence Probes From Damage

Appendix C - Prince Madog Based OSMOSIS Cruise Deployment and Recovery Photographs

FreeWave Short Range Glider to Ship Antenna Installation on the Upper Deck of the RV Prince Madog at Tarbert Port



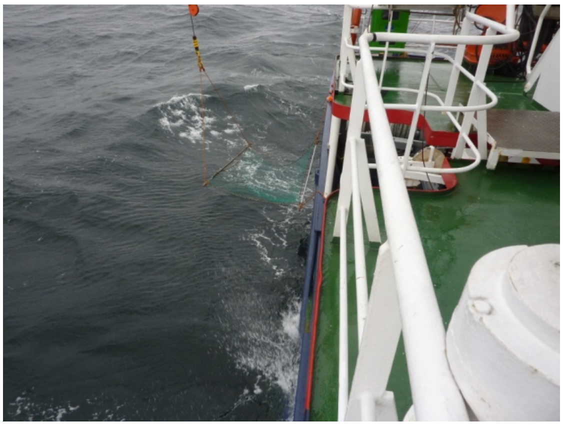
SAMS REMUS 600 AUV Deployment



Arrangement for the Initial Testing of the Glider Using FreeWave

Glider Stored in the RV Prince Madog Wet Lab Prior to Deployment

A Poor Sea State Occurred on Sunday 11th September



Net Preparation for an Emergency Recovery of the Glider

Appendix D - NOCL Tarbert Base Station Glider Work Selected Photographs

Glider and micro-Rider Fault Identification Indoors

Removal of Seawater Ingress from the Glider

Micro-Rider Turbulence Probe Repairs

Testing of the Repaired Glider and micro-Rider Turbulence Sensor

Castaway Calibration CTD Data Downloading and Analysis

Testing of the Repaired Glider and micro-Rider by Running a Mission Simulation with the Glider Connected to an External Power Source