National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

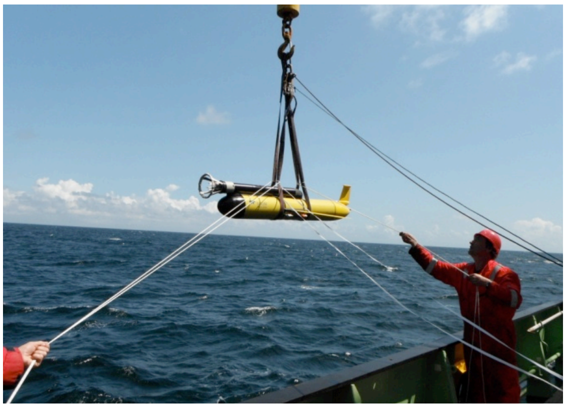
National Oceanography Centre

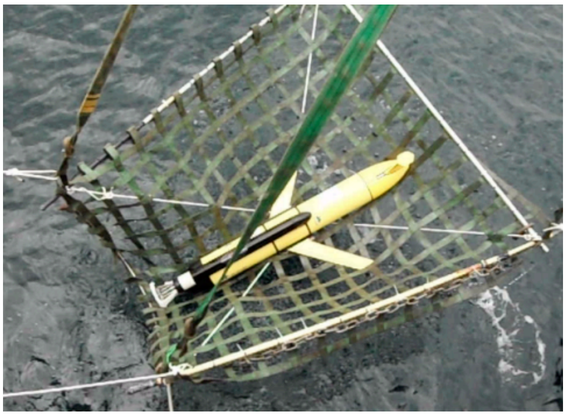
Research & Consultancy Report No. 17

NOC RRS *Discovery* Cruise D376
Glider operations report
June - July 2012

C Balfour

2012



National Oceanography Centre, Liverpool
6 Brownlow Street
Liverpool
L3 5DA
UK

Author contact details:
Tel: +44 (0)151 795 4826
Email: cabal@noc.ac.uk

DOCUMENT DATA SHEET

AUTHOR BALFOUR, C	*PUBLICATION DATE* 2012
TITLE NOC RRS *Discovery* Cruise D376 Glider operations report, June - July 2012.	
REFERENCE Southampton, UK: National Oceanography Centre, 22pp. (National Oceanography Centre Research and Consultancy Report, No. 17)	

ABSTRACT

This document summarises the four Slocum Electric glider deployments during the RRS *Discovery* Based D376 research cruise for the FASTNEt project. The deployments occurred at or close to the Celtic Sea shelf edge. The lack of small boat support for the cruise resulted in a series of procedures for glider ballasting testing, deployment and recovery being developed during the cruise. Towards the end of a cruise a glider that had been deployed with a turbulence sensor was recovered after a nine day deployment. The initial indications after the turbulence glider recovery are that a high quality, novel in water column, high resolution turbulence measurement data set has been recovered.

This report provides details about the glider operational requirements for the D376 cruise and the glider fleet that was used. A series of pictures and supporting text explain the procedures that were applied during the cruise. The report concludes with a summary and details of the initial evaluation of the recovered glider scientific measurements are provided.

KEYWORDS:

ISSUING ORGANISATION **National Oceanography Centre**
University of Southampton Waterfront Campus
European Way
Southampton SO14 3ZH
UK

Terms and Definitions

Turbulence Glider (Unit 175)	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.
Unit 051 and Unit 052	1000m depth capable generation 1 (G1) Slocum Electric Gliders manufactured by Teledyne Webb Research, America.
Unit 194	A 200m depth capable generation 2 (G2) Slocum Electric Glider manufactured by Teledyne Webb Research, America.
FASTNEt	**F**luxes Across **S**loping **T**opography of the **N**orth **E**ast A**t**lantic project. This project combines modelling and observations to enhance the scientific understanding of physical and biogeochemical processes at the ocean to shelf sea transition and associated areas.
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, UK
NOCS	National Oceanography Centre, Southampton, UK
AUV	Autonomous Underwater Vehicle
RSI	Rockland Scientific International
CTD	Conductivity, temperature and depth sensor
RHIB	Rigid Hull Inflatable Boat
TWR	Teledyne Webb Research
GPS	Global Positioning System
GMT	Greenwich Mean Time

Contents

1. Glider Operations Overview and Cruise Requirements

This document summarises the glider operations undertaken during the RRS *Discovery* based D376 research cruise. The work area was close to the Celtic Sea continental shelf edge and formed part of the FASTNEt Ocean Shelf Exchange research project. The schedule required the preparation and potential piloting of four Slocum Electric Gliders by Chris Balfour during the cruise. RRS *Discovery* departed from Swansea, UK on Monday 11th June 2012 and returned to Southampton, UK on Monday 2nd July 2012. The requested RHIB type small boat support for glider operations was not available for the cruise. The cruise work area was close to the Celtic Sea shelf edge approximately 180 miles off the UK Cornish coast. Four gliders were deployed either close to, surveying over or past the shelf edge and into deep water. The intention was to leave three of the four gliders deployed during the cruise surveying after the cruise ended. A glider with a specialist turbulence sensor was deployed and recovered during the cruise and Fig. 1 provides a basic illustration of the deployment location for this glider.

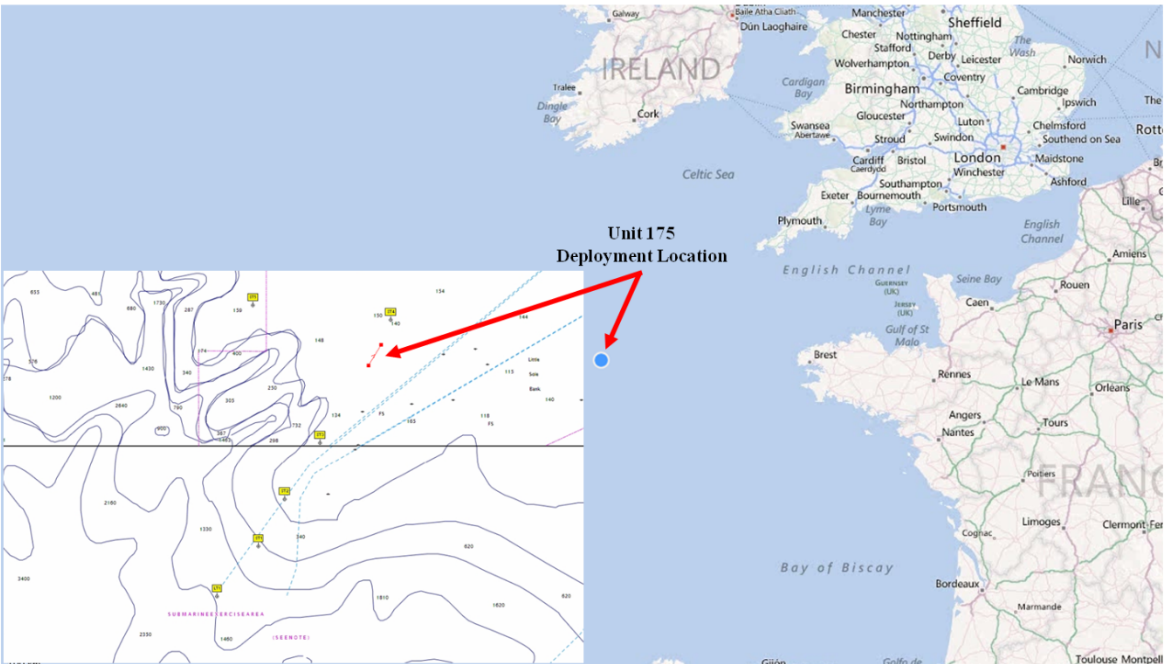


Fig. 1. FASTNEt Project Cruise Work Area

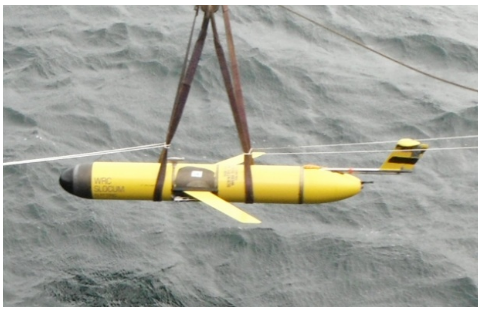
The turbulence glider GPS deployment location of 48^0 28.757'N, 09^0 16.911'W is shown in Fig. 1. The glider was configured to hold station between two waypoints that were approximately 4km apart. The turbulence glider surfaced at 2 hour intervals to attain an updated GPS fix, report vehicle status information and transfer a subset of the internally CTD data in near real time using iridium based satellite communications. During the turbulence glider survey work RRS D*iscovery* was on station several kilometres away from the glider for two separate and approximately day long periods of time. During these cruise stations, surveys were also undertaken using a vertical turbulence profiler (VMP) from the ship. This achieved co-located turbulence measurements during two tidal current cycles for scientific measurement purposes. This survey work also allowed comparison between the novel glider based turbulence measurements and the more established VMP based measurements to be made. The turbulence measurements were also located between two of the cruise mooring sites (ST3 and ST4). The moorings were approximately 5km north east and 18kn south waste of the turbulence glider survey transect. The compliment of sensors that have been used are intended to provide measurements to help study and understand the dissipation rates of turbulent kinetic energy close to the Celtic Sea shelf edge.

2. The RRS *Discovery* Research Cruise D376 Glider Fleet

A summary of the capabilities of the glider fleet that were used during the D376 cruise is shown in Fig. 2. Table 1 summarises the scientific objectives for the glider based survey operations during D376.

The Unit 175 Turbulence Glider 200m depth capable. The science sensors are a non-pumped Seabird CTD and a specialist micro-Rider turbulence probe

Unit 194 a 200m depth capable glider. The science sensors are a pumped Seabird CTD, a WetLabs Triplet (CDOM, Chlorophyll-a and OBS Turbidity) and a Aanderaa dissolved oxygen Optode



Unit 051 – Bellamite is a 1000m depth rated glider with a non-pumped Seabird CTD sensor

Unit 052 – Coprolite is a 1000m depth rated glider with a non-pumped Seabird CTD sensor

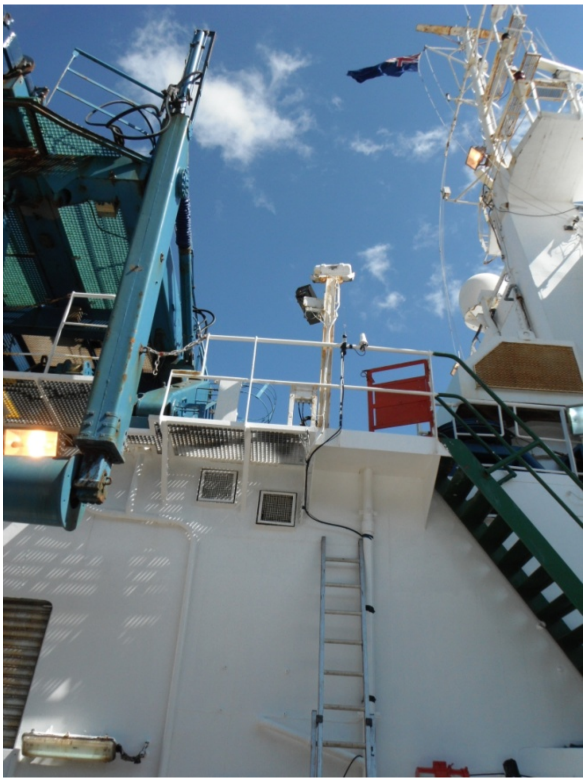
Fig. 2. The D376 Research Cruise Slocum Electric Glider Fleet

Table 1 Initial Glider Survey Transects and Scientific Rationale

Glider	Initial GPS Waypoints	Scientific Rationale for Survey
Unit 175	48^0 28.416'N, 09^0 17.868'W to 48^0 30.642'N, 09^0 15.57'W	To determine the nature of the dissipation rates of kinetic energy for mixing between the ST3 and ST4 moorings. The glider results are validated with vertical profiling (VMP) measurements nearby for a proportion of the time.
Unit 051	47^0 58.00'N, 09^0 53.00'W to 47^0 46.50'N, 10^0 05.00'W	To determine background and intermittent off shelf fluxes by operating in deep waters off the Celtic Sea shelf edge.
Unit 052	47^0 58.00'N, 09^0 53.00'W to 47^0 46.50'N, 10^0 05.00'W	To determine background and intermittent off shelf fluxes by operating in deep waters off the Celtic Sea shelf edge.
Unit 194	48^0 27.00'N, 09^0 20.00'W to 48^0 05.00'N, 09^0 45.00'W	Providing over the Celtic Sea shelf edge CTD measurements to help to determine water mass intrusion, slope currents and stratification. Sensors for Chlorophyll-a, CDOM and dissolved oxygen were used for a limited time to conserve battery energy.

3. Glider Testing, Preparation and Mission Simulation

Following the packing, transportation, mobilisation and unpacking of the four Slocum electric gliders on RRS *Discovery* a programme of testing and deployment preparation was undertaken. This is to verify the integrity of the gliders and identify any deficiencies that may have occurred during the glider preparation operations prior to the D376 research cruise. To facilitate effective glider communications, satellite phone communications and a glider preparatory base a series of work areas were prepared on RRS *Discovery*. Fig. 2 provides some selected photographs of these.



Iridium (satellite phone) and FreeWave (short range wireless data communications with a glider) Antennas, Starboard – Close to CTD winch to the right of the spotlight mounting

Wet Lab – RRS *Discovery*

External antennas allowed short range (<=2km) wireless glider communications and Iridium Satellite phone calls using an external antenna

Unit 175 testing and mission simulation – RRS *Discovery* Wet Lab

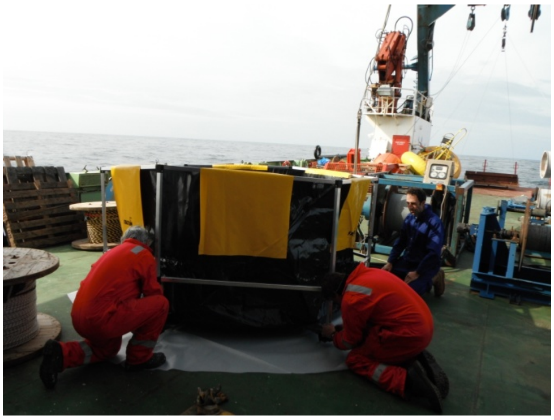
Multiple glider mission simulations in the Wet Lab

Fig. 2. Slocum Electric Glider Communications and Preparation

A key initial objective was to set up a glider testing and evaluation base and the wet lab in RRS *Discovery* proved to be well suited for this purpose. The intended and evolving survey missions for the gliders were simulated inside the gliders to test modifications and help to derive reliable mission configurations. If required, glider hull seals were serviced and internal vacuum monitoring was used as an indication of the effectiveness of the glider hull seals.

4. Deployment Procedure Development, Rehearsals and Ballasting Trials

The absence of small boat support during the D376 cruise resulted in difficulties being encountered in devising a suitable deployment method. This resulted in a series of discussions with the crew during the cruise to devise suitable techniques for Slocum Electric Glider deployment. A distinct possibility was the inability to perform an initial glider dive test with a tether and surface float. This is a manufacturer’s recommended procedure to allow a recovery of a glider if satisfactory ballasting or glider operation does not occur during initial dive testing. As an intermediate step a portable ballasting tank was used for these trials. Fig.3 and 4 show a sequence of pictures of these operations.

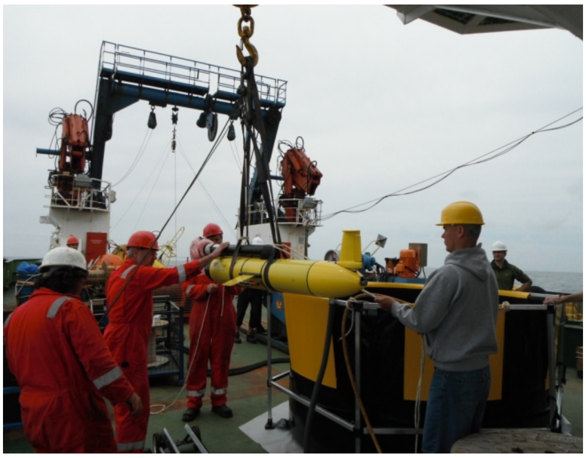


FASTANK 5 – glider ballasting tank assembly

Tank filling with the ships seawater hose

Preparations for glider lifting and release rehearsal

Fig. 3. Slocum Electric Glider Ballasting Tank and Lifting Preparations



Lifting of gliders – double strops – stay lines, release hook and trigger Line

Glider release arrangement testing

Unit 175 turbulence glider ballasting check on RRS *Discovery*. The Seabird Microcat CTD is Visible to the lower right of the picture

Gliders temporarily stored in the ship's hangar after the ballasting tests and subsequent washing down with fresh water

Fig. 4. Slocum Electric Glider Deployment Mechanism and Ballasting Tests

The release mechanism consisted of two strops looped around the fore and aft hull sections of the glider. One side of these strops was coupled to a release hook with a pull line. Two stay lines were looped between each of the strops just above the glider hull to keep tension on the strops around the glider hull. This prevented slippage of the glider during lifting. The release procedure was to loosen and remove the say lines with the glider just above the water. The crane then lowered the glider into the water and the release hook was operated. The crane then lifted the strops away from the glider. This mechanism worked well during tank testing. For the ballasting tests the ship's seawater hose was used to pump near surface seawater with a density and temperature that is representative of the conditions in which the glider will be deployed. A calibrated Seabird Microcat CTD was used to measure the tank water temperature and salinity in order to derive the water density. The most recent ships CTD casts were then consulted to check the water column properties. Any temperature deviations of the seawater while it was used in the test tank were closely monitored. This information was used to compare with readings from historical records for the work area that were used to determine the pre-cruise glider ballasting conditions. These records showed that in a 100m water column ~1027kg/m^3 at ~12.5^{O}C represent reasonable average conditions. For a standard Slocum electric glider the buoyancy pump is capable of compensating for mass variation of between ~± 250g from the neutrally buoyant 'ballasting' condition, or ~± 4 sigma units. Glider ballasting is usually inferred from fresh or salt water test tanks. Internal trim weight adjustments are usually made to ensure that the vehicle is neutrally buoyant for the mean conditions of the deployment water column. In a vehicle that has a typical mass in the order of 60kg there is clearly only a small margin for error. The tank tests were designed to provide assurance of or identify problems with the glider ballasting before a glider deployment is considered. The ships most recent CTD was used as a reference for the tests at a GPS location of 48^{O} 17.90035N, 09^{O} 32.09370W. The CTD values and densities are summarised in Table 2. Considering the turbulence glider required depth of 100m and 140m for the unit 194 glider, these values appeared to be a reasonable ballasting starting point, as verified by the ship's CTD readings in table 2.

Table 2 RRS *Discovery* Ships CTD Results

Depth(m)	Temperature(^{O}C)	Salinity(PSU-78)	Density(kg/m^3)
10	13.20	35.61	1026.87
70	13.08	35.61	1027.16
112	12.05	35.64	1027.58
134.5	11.74	35.64	1027.74

The Teledyne Webb Research (TWR) glider ballasting spreadsheet was used to estimate the ballasting adjustments between the tank (near surface water, taking into account the on deck temperature elevations of the water) and the ships most recent CTD cast. An estimate was that the gliders should be ~40g to 50g too heavy, i.e. slightly heavy in the water. The ship was not moving around significantly and the tank was about 40% full of water. A recently calibrated Seabird Microcat CTD, serial number 5434, was used to determine the tank temperature, conductivity and PSS-78 Salinity. Tank CTD checks were conducted at the beginning, part of the way through and the end of the testing to account for drift, particularly the water temperature. Table 3 summarises the tank CTD measurements during the ballasting trials.

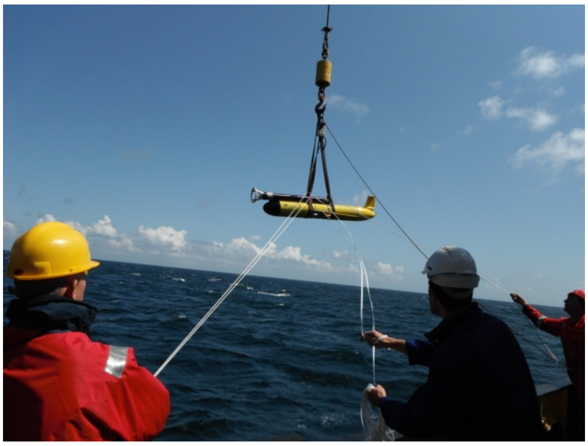
Table 3 RRS Discovery Tank CTD Results, Sunday 17th June 2012

Comment	Temperature(^{O}C)	Salinity (PSU-78)	Density(kg/m^3)
Tank at start 10:02 GMT	15.1563	35.4062	1026.25
Tank during test 12:07 GMT	15.9785	35.6292	1026.24
Tank at end of test at 13:54 GMT	17.0363	35.6524	1026.01

The gliders were placed in the tank one by one and the unit 175 turbulence glider lifting and release method was rehearsed. Units 175, 194 and 051 were tested first and these gliders seemed to be well ballasted. Unit 051 sank and a spring scale attached to the cleat measured (oscillated around) ~50g. Unit 052 also sank and this registered >= 100g on the spring scale, suggesting a potential ballasting problem. If a glider performed in this way in the NOCL tank I would normally consider reducing the ballast weight. An estimate would be to say remove at least 50g, 25g from the front, if this is possible with the oil pump type 1000m depth rated Slocum glider, and 25 g from the rear inside the glider hull. That said, a larger ballasting weight correction of a reduction of in the order of 100g would be recommended in this case. Although the tank on the ship was moving the gliders seemed to not exhibit too much parasitic pitch or roll, with the exception of unit 194. Although this glider was well ballasted the glider exhibited parasitic positive pitch, with the nose section slightly raised. Before the deployment it was noticed that the cleat had been fitted to the aft of the science bay rather than the usual mounting location ahead of the science bay. This problem was corrected before the unit 194 deployment.

5. Deployment Procedure and Refinements

During the unit 175 turbulence glider deployment an attempt was made to tether the glider to perform an initial dive test. The intention was to perform a shallow (~3m) test dive and have the option to keep the glider on station for an emergency recovery if a problem occurred. An initial tethered dive test is in line with the manufacturer guidelines for the early phases of the deployment of Slocum Electric Gliders. This was a difficult problem to solve without small boat support and snagging of the extra line caused the glider to impact with the hull of the ship. A decision was then made to release the glider and risk an un-tethered initial test. A net was also on standby for an emergency recovery, if this was required. It became clear that lightweight fending off poles were required to ensure a deployed glider does not impact with RRS *Discovery* during the initial deployment operations. This was to allow sufficient time for a large research vessel such as RRS *Discovery* to manoeuvre away from the glider after the initial deployment. Fig. 5 shows some picture of the unit 175 turbulence glider deployment.

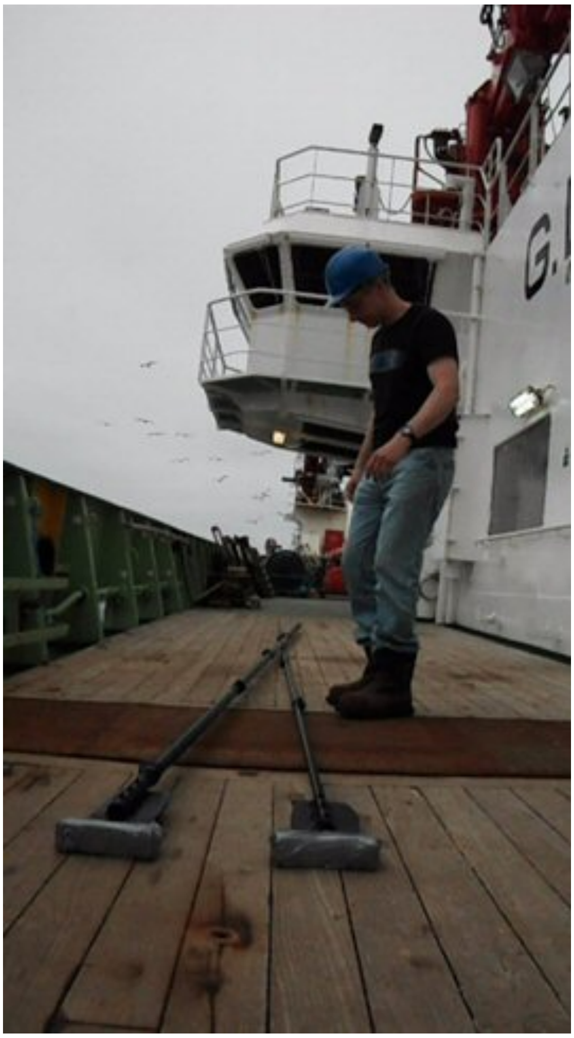


Unit 175 Turbulence glider deployment – Monday 18th June 2012

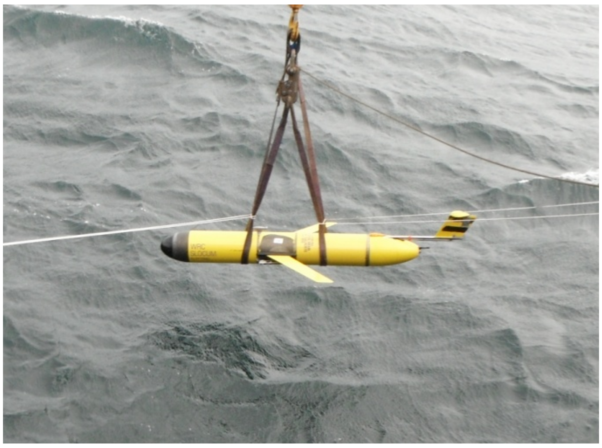
Fending off poles required for Unit 175

Fig. 5. Unit 175 Turbulence Glider Deployment Photographs

Two lightweight fending off poles were then constructed by cutting in half the original long telescopic pole that was supplied by NOC Southampton. The telescopic pole was fully extended and locked in place. Initial testing showed that the telescopic pole could be easily pulled apart by hand in certain sections. In order to prevent this, adhesive tape was used to prevent the pole retracting or sections being pulled apart. The long pole was intended to allow snaring of the upper cleat of a standard Slocum glider. Concerns over the ability or accuracy required to snag a line to a glider upper cleat, the cleat dynamic load bearing ability and the potential excessive movement, snatching and so on that may occur caused this untested recovery system to be abandoned. The cushioned fending off poles that were subsequently constructed proved to be particularly useful for controlling a glider position when it is close to the deployment ship. The micro-Rider turbulence probe mounted on the upper part of the glider hull precludes the easy installation of a load bearing pick up point. Therefore the fending off poles offered a more suitable alternative. Photographs of the fending off poles with curved cushioned ends and the revised deployment method are shown in Fig. 6.



Curved cushioned ends were added to the dual fending off poles. The requirement was to aim for the glider hull fore and aft sections, clear of nose, air bladder cowling, wings and CTD



Poles used to fend off impacts of a glider with the RRS *Discovery* research vessel that was used for the deployments

Deployment of unit 051 – Bellamite without a tether for initial dive testing

Fig. 6. Glider Cushioned Fending Off Poles and Revised Deployment Method

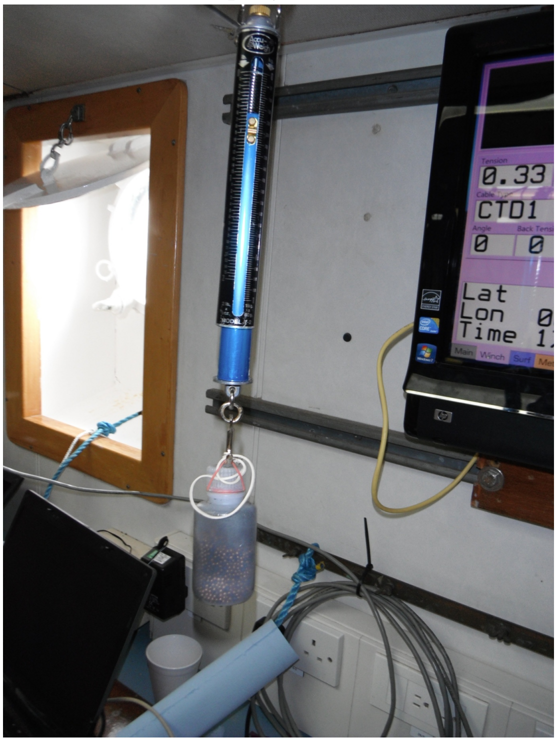
6. Ballasting and Mission Simulations

Following the ballasting tank tests and after encouragement by Chris Balfour a decision by the National Oceanography Centre Southampton (NOCS) was eventually made to re-ballast unit 052 – Coprolite. The proposed deployment day for this glider was postponed for 24 hours to allow these operations to take place in the wet lab of RRS *Discovery*. A series of photographs that illustrate the onboard glider re-ballasting are shown in Fig. 7. The recommended 100g reduction in the glider mass was achieved by removing 50g from a front internal lead ballast trim strip below the glider buoyancy pump oil reservoir. A further 50g reduction in mass was achieved by removing this mass from the central rear tail ballasting bottle inside the glider hull. The glider seals were then cleaned, re-greased and new TWR approved 'O' hull sealing rings were installed. The rear vacuum port showed signs of wear and tear and a new port plus sealing 'O' ring was cleaned, greased and installed. These operations served to illustrate the effectiveness of using a research vessel laboratory and deck space to service, configure and ballast Slocum Electric Gliders. Prior to each glider deployment an 'on_bench' simulation of the intended mission was used. This type of simulation generates test GPS and depth data and runs the glider control software and actuators to check the integrity or identify problems with an intended deployment configuration. Any mission configuration deficiencies detected were corrected before a scheduled deployment. This was usually achieved after detailed consultation with my colleagues at the National Oceanography Centre (NOC) and technical support at TWR.

Unit 052 Coprolite Re-ballasting Sunday 24th June 2012 – wet lab - RRS *Discovery*

Unit 052 coprolite front internal lead ballast trim Strip adjustment

Spring scales proved effective for measuring ballast weights on a moving research vessel



Unit 052 rear ballast bottle adjustments

Fig. 7. Slocum Electric Glider Re-ballasting Aboard RRS *Discovery*

7. **Glider Piloting**

As the gliders were progressively deployed the piloting duties expanded. The unit 051 – Bellamite and 052 – Coprolite glider deployments were coordinated by the use of an onboard satellite phone at a glider control station, as previously shown in Fig. 2. When the initial glider dive testing was complete and the gliders were confirmed as operating satisfactorily control of the gliders was handed over. Pilots based in Southampton (David Smeed and David White) then operated these gliders using Iridium satellite based long range communications. Chris Balfour assumed primary responsibility for piloting the unit 175 turbulence glider with Phil Knight acting as a backup pilot. For unit 194, Chris Balfour and Phil Knight have been operating this glider and implementing a series of progressive power management refinements to the glider setup. Figures 8 and 9 show sample TWR GLMPC software positional plotting outputs for the unit 175 turbulence and the unit 194 G2 gliders.

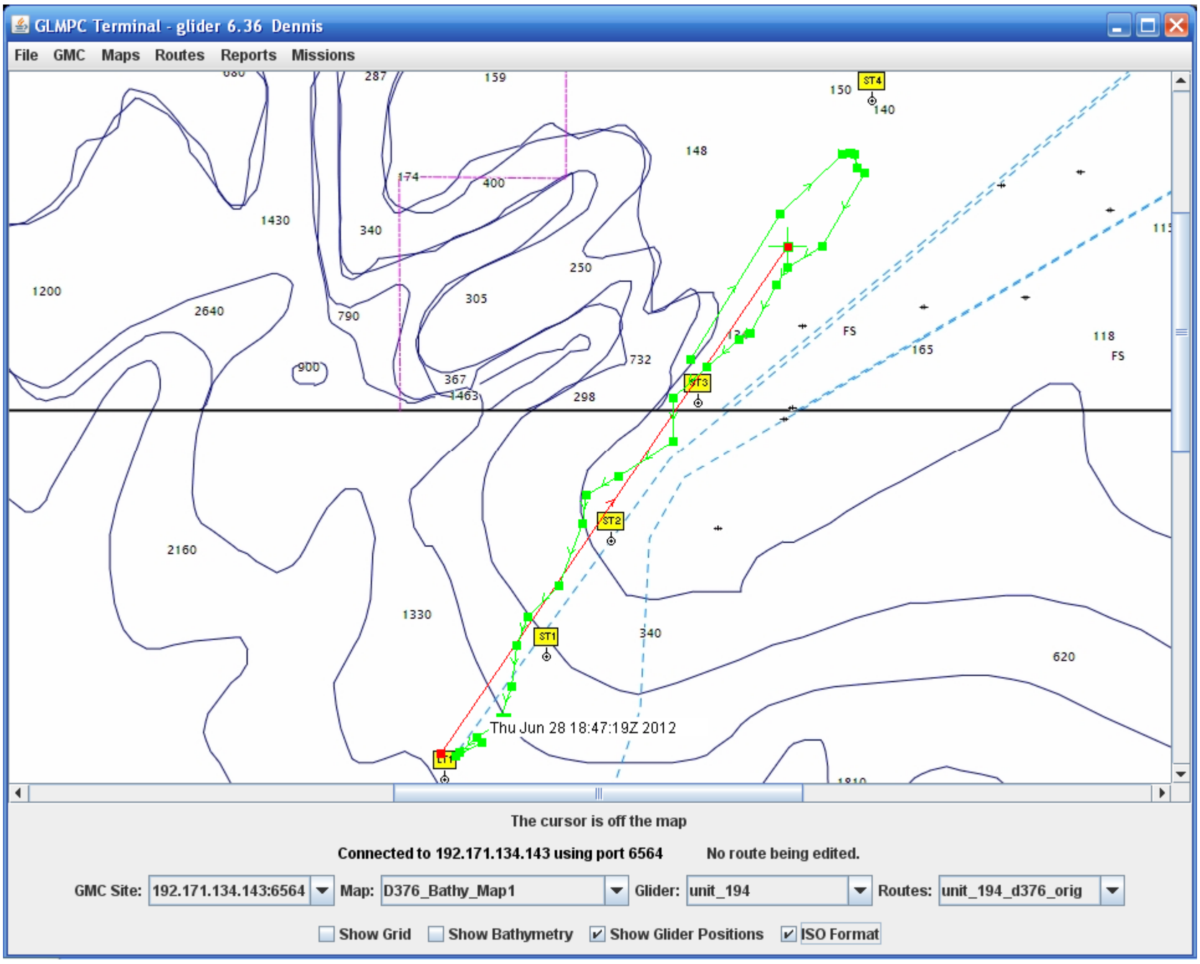


Fig. 8. Unit 194 Slocum Electric Glider GLMPC Positional Plots

Figure 8 shows the unit 194 initial survey close to the cruise mooring stations and across the Celtic Sea shelf edge. The green rectangles represent the reported glider surfacing positions and the red rectangles with a line between, when visible, represent the intended survey area. Figure 9 shows the unit 175 Turbulence glider survey area close to ship based Vertical Microstructure Profiler (VMP) Survey operations and between the ST3 and ST4 moorings. The cluster of green rectangular surface reports obscured the waypoints below on the graphical output. The glider was deployed from 18th to 27th June 2012

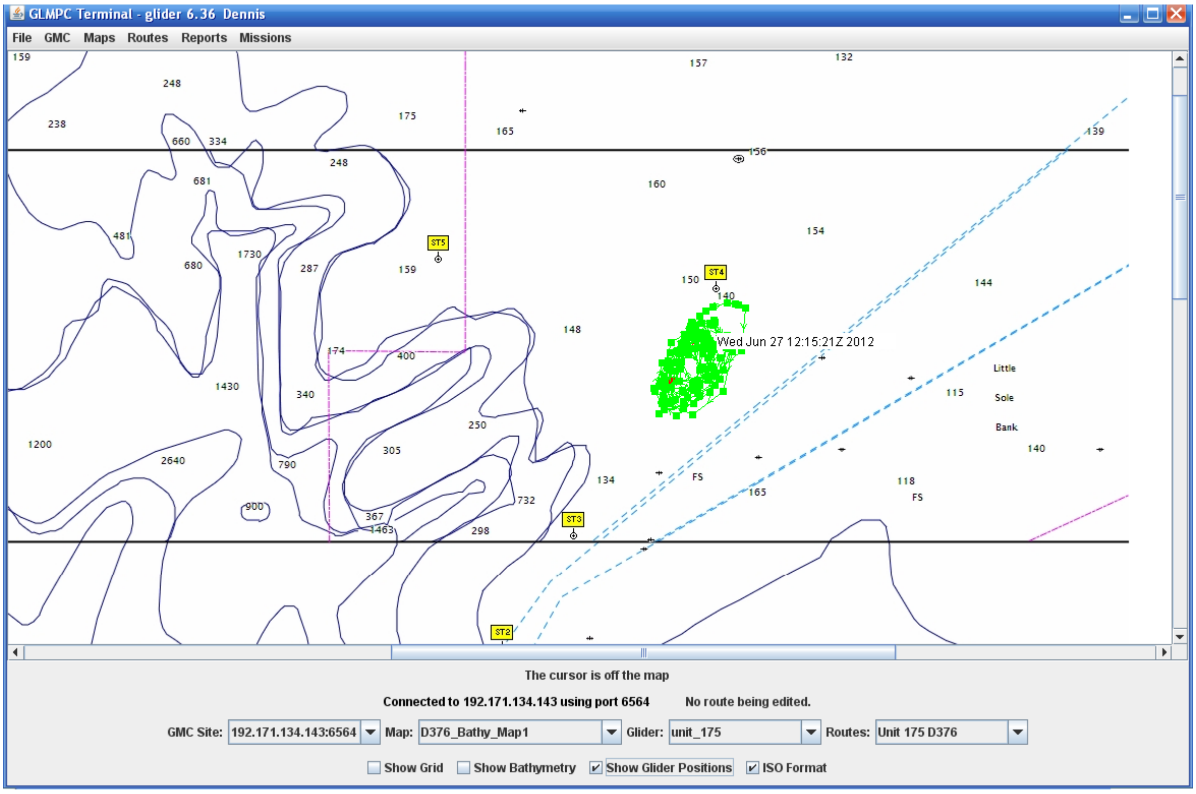


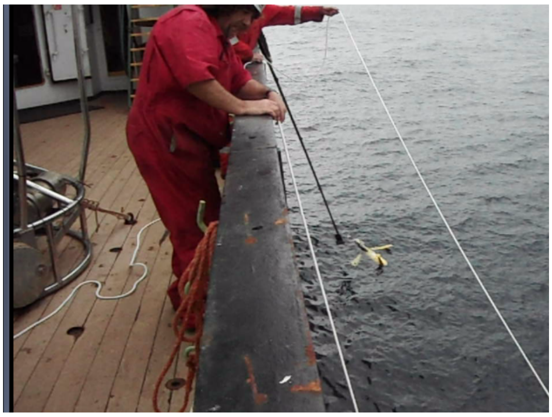
Fig. 9. Unit 175 Slocum Electric Glider GLMPC Positional Plots

8. Recovery System Initial Evaluation

The proposed glider recovery system was used for the first time on Wednesday 27th June and Figures 10 and 11 show a series of photographs to illustrate the method used. The unit 175 turbulence glider was recovered at the first attempt without incurring any damage to the glider.

Preparation of the glider recovery net　　Glider recovery net deployment

Fig.10. Unit 175 Turbulence Glider Recovery Preparations



Unit 175 Turbulence Glider alignment for recovery

Cushioned fending off poles used for the Unit 175 Turbulence Glider recovery

Fig. 11. Unit 175 Turbulence Glider Recovery

9. Summary

The RRS *Discovery* based D376 research cruise for the FASTNEt Ocean Shelf Exchange research project has been very successful in terms of achieving the objectives of four glider deployments and one subsequent glider recovery during the cruise. A particularly rewarding element to this has been the excellent high quality data return that has occurred with the unit 175 turbulence glider. I am confident that a novel and original contribution to physical oceanographic research will be achieved as a result of this work. The glider operations undertaken have served to demonstrate the possibility of using research vessels for complex glider work. The accomplishments of the cruise include such tasks as glider servicing, mission planning and 'on _bench' or in glider mission simulation.

The initially proposed concept of deploying gliders without onboard testing, ballasting verification and a subsequent initial tethered dive test to me is counter intuitive and it remains a cause of great concern. Inferred ballasting conditions and historical records to determine glider ballasting conditions before a deployment combined with possible operator errors, particularly when under time pressure, are potential sources of setup errors. Glider freighting plus mobilisation can also introduce problems such as damage to internal components, weakening of mechanical fastenings or hull seals and so on. To address these concerns the onboard tank tests were very successful and went some way to verify a correct glider setup or identify ballasting deficiencies. While this has been helpful, my preferred option would be a more progressive series of tests of the glider immediately after deployment. A tether and line or surface float offers the chance of a rapid recovery if problems with a glider are evident during or after the initial dive testing. The absence of small boat support for this cruise made this requirement very difficult to accomplish. The ballasting tests, servicing of the gliders, including re-ballasting of a glider during the cruise have also been particularly rewarding. This has verified my recommendation that the mobilisation of sufficient backup materials such as tools, ballast, spares, computers, scales and so on can allow complex glider testing, servicing and corrective operations during a scientific research cruise.

From a personal perspective, while the cruise has been rewarding, I have found that a punishing work schedule was required to meet the objectives of the cruise. Glider problems and piloting requirements often occurred during unsociable hours where I had little or no backup support. My recommendation before the cruise was that at least two experienced Slocum Electric Glider engineers or applied scientists or combination thereof should be onboard to support the volume of work that was required. This requirement would have provided a reasonable level of cover as and when glider related problems occurred. I was very disappointed to find out at short notice before the cruise on May 22nd 2012 that my recommendation of the two Slocum glider personnel on opposite watches would not be implemented. This would have provided almost round the clock technical support and local piloting to increase the data return from the cruise. This would have also reduced the burden on the sole Slocum Electric Glider engineer onboard. This recommendation would be particularly relevant for the times when glider problems occurred during unsociable hours and interruptions in data recording occurred due to the lack of available pilots. It was also disappointing that I was unable to deal with the deployed turbulence glider technical problems in a timely manner that subsequently occurred during unsociable hours. An example of this would be early on Saturday 23rd June at 06:00 am GMT when the unit 051 – Bellamite glider deployment operations started. I could not attend to turbulence glider problems that, when identified, had resulted in surfacing of the glider due to mission aborts. This subsequently interrupted the scientific measurements undertaken by the glider. The reason I could not attend to the turbulence glider problems was primarily due to my glider deployment commitments during the cruise. The unit 051 - Bellamite glider deployment lasted until 09:30am GMT (10:30am UK local time), at which time I then began work on regaining control of the turbulence glider. Phil Knight from NOCL acted as a UK based backup pilot, working from home as and when he could.

A particularly rewarding aspect of the glider operations during the D376 research cruise is the fact that the UK National Oceanography Centre (NOC) are now establishing an enviable track record in achieving difficult glider operations. This work regularly occurs with limited support or backup personnel and under challenging time constraints. My recommendations regarding glider configuration, testing, deployment and recovery were followed during the cruise, albeit with some initial and subsequent ongoing reluctance and scepticism. Despite this I am confident that a significant contribution to NOC glider science related activities has been achieved during the D376 research cruise.

C Balfour

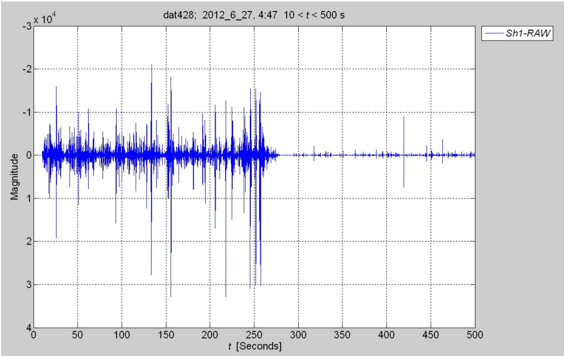
Dr Chris Balfour

10th July 2012

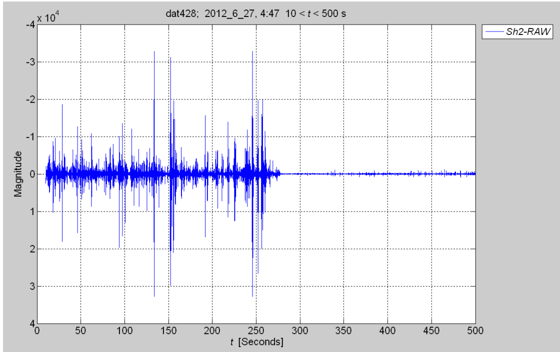
Acknowledgements
The author acknowledges the excellent support provided by the crew of RRS *Discovery*. Their patience, skill, professionalism and excellent support during the difficult glider operations required by the D376 cruise needs to be commended. Once again I owe a big thank you to Ben Allsup at TWR for his continued prompt and detailed technical support that was critical to achieving the requirements of the cruise. Thanks are also due to Chris DeCollibus at TWR for the prompt and very detailed glider altimeter settings and power budget management information that is particularly relevant when operating gliders across the Celtic Sea shelf edge.

Appendix A - Turbulence Glider Data Initial Evaluation

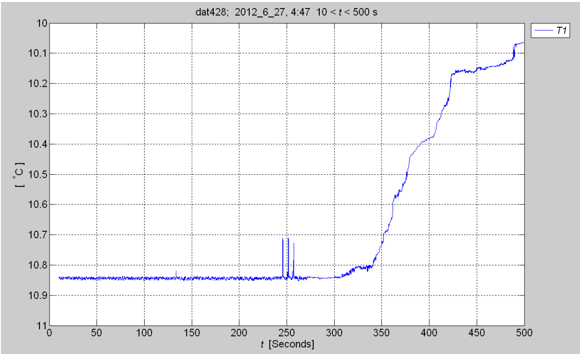
A series of plots of the recorded glider CTD and turbulence data are shown in Figs 10 and 11 for the glider data recorded during deployment 3. These plots indicate that the glider based sensor systems have been operating correctly.



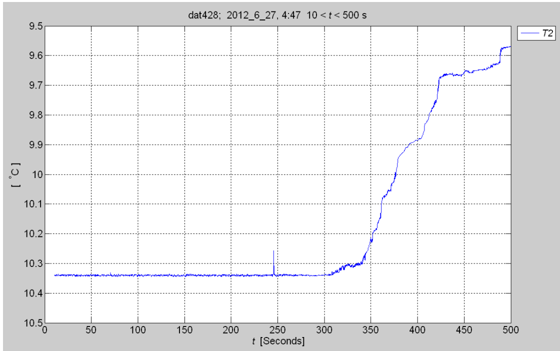
Shear 1 channel – X axis – high and low level signals throughout the data set indicating that the probe is operating correctly



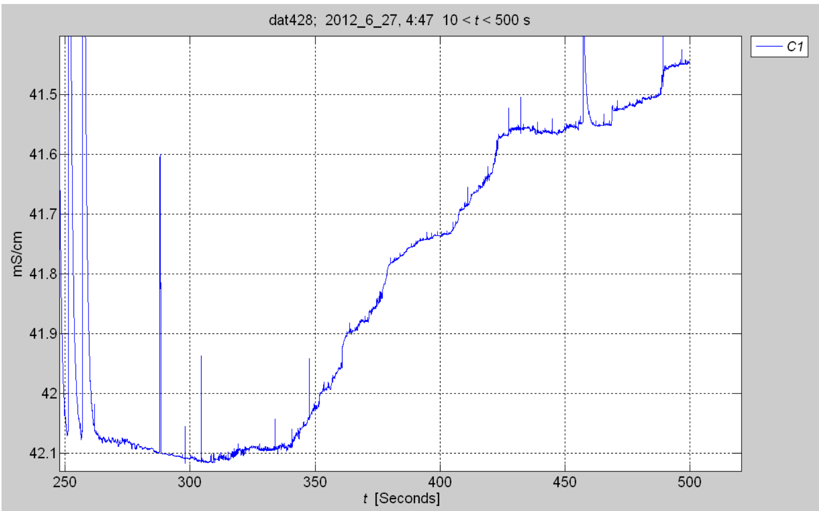
Shear 2 channel – Y axis – high and low level signals throughout the data set indicating that the probe is operating correctly



Temperture probe T1 shows rapid measuremnts of water column temperature changes indicating the probe is operating correctly

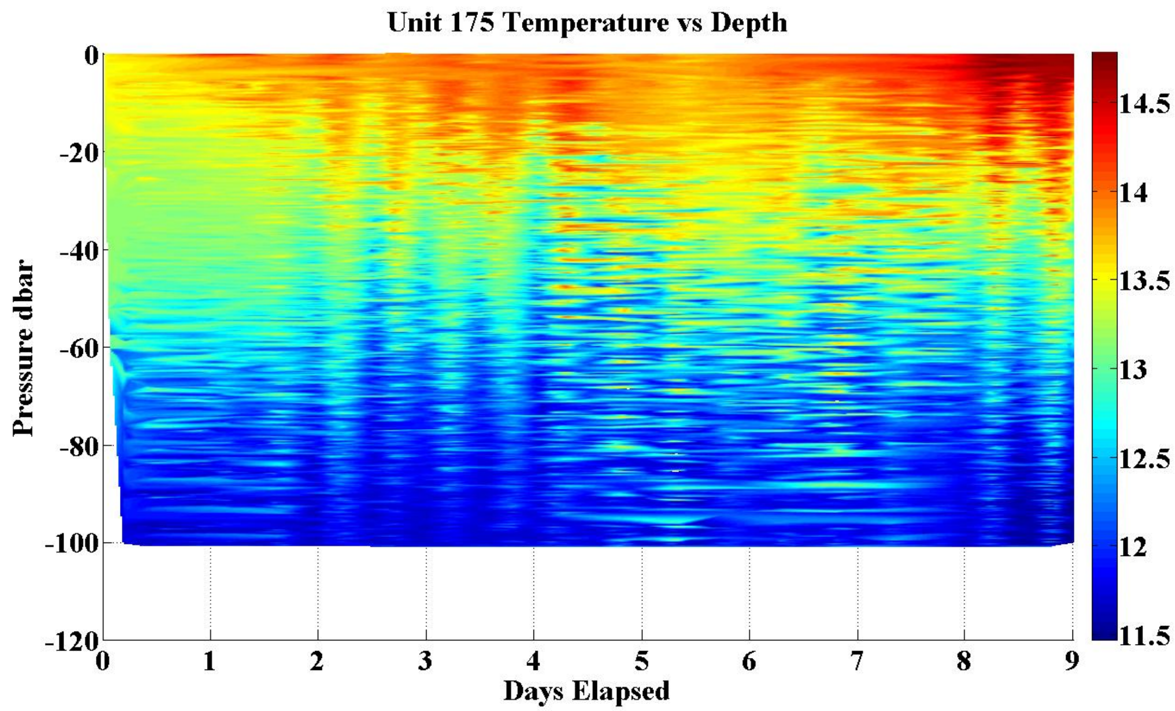


Temperture probe T2 shows rapid measuremnts of water column temperature changes indicating the probe is operating correctly

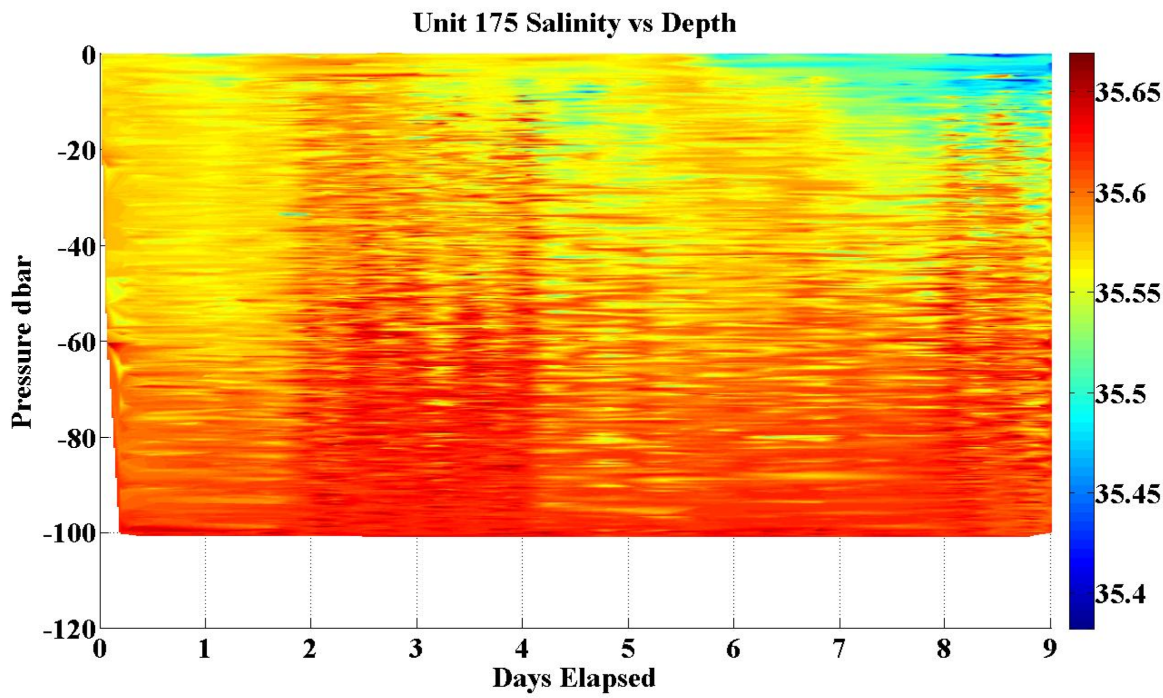


Micro-conductivity measurements demonstrating the probe is still producing rapid measurments in conductivity changes during glider profiling at the end of the deployment. No indication of sustained fouling of the micro-conductivity probes is evident in the recorded data that has been analysed to date

Fig. 10. Recorded Micro-Rider Turbulence Data at a Sample Rate of 512Hz During Profiling at the end of the Glider Deployment indicating sustained correct probe operation



Glider temperature measurements over the 9 day unit 175 turbulence glider deployment



Glider salinity measurements over the 9 day unit 175 turbulence glider deployment

Fig. 11.Glider CTD profiles have been recorded over the full deployment