Rapid Sound Speed Profiling in Plymouth Sound (Part 1)

by Jim Gardiner Product Manager, Valeport Ltd **and Iain Slade** Survey Trainer, Fugro Academy

Introduction

Over the last decade, rapid improvements in positioning and motion referencing technology have reduced the errors in multibeam echo sounder (MBES) data acquisition considerably. MBES performance has increased mainly due to improved processing power greatly enhancing resolution, accuracy and detection capabilities. However, one of the last remaining unknowns which has a significant and measurable effect on an MBES system is the inherent environmental variability of the water column and the resultant speed of sound field. Significant errors in both depth and positional accuracy of 'ping' locations will occur if an incorrect sound speed profile is applied to correct for refraction effects, which leads to the question: how often should I take a sound speed profile?

This is the first part of a two-part paper in which a dataset gathered during a testing and training exercise will be shared. The demonstrated ability to observe the spatial and temporal variability of sound speed at higher resolution than previously achievable prompted a second question: what is the effect of this variability on my data?

Part 2 of this paper (to be published in **soundings** No. 68) will attempt to answer this via a more focused data gathering exercise and data processing designed to quantify the error budget due to the spatial and temporal sound speed variability both along and across track.

Location

The Barn Pool area of Plymouth Sound has arguably had more pings per square metre than any other area of seabed in the world. Featured on the most recent cover of **soundings**, it was used as one of the Common Dataset collection areas for the Shallow Survey 2015 conference and also, prior to that, for Shallow Survey 2005. Hydrographic training is regularly carried out in this area by Plymouth University, the Royal Navy Hydrographic School and a number of commercial providers.

Barn Pool sits at the mouth of the Hamoaze which is the combined lower tidal reaches of the Tamar and Lynher rivers. A flooded ria, the exchange between the Hamoaze and outer Plymouth Sound occurs through the narrows between Devil's Point and Wilderness Point. Tidal currents through the Narrows can reach up to 3 knots on a spring ebb tide.

Trials Equipment

In November 2015, a week-long deployment was planned, in a collaboration between Valeport and Teledyne OceanScience, to conduct some training on the recently launched rapidCAST winch along with trialling some newly developed profilers from Valeport. Fugro Academy provided waterside facilities in Plymouth Sound.

The rapidCAST underway winch

The rapidCAST winch (Figure 1) was developed by Teledyne OceanScience as an evolution of the Underway SV system that has been in production for a number of years. The rapidCAST adds full automation and the ability to gather vertical profiles up to 500m in depth whilst surveying at speeds up to 8 knots. The winch uses an advanced active line pay-out system with precise tension control, allowing vessel speed and heave effects to be eliminated and the profiler to maintain ±5% depth accuracy.

Figure 1: rapidCAST winch

With a minimal deck footprint, the rapidCAST can easily be installed on most survey vessels. The mobilisation on board Fugro's M/V *Bryn* took ~3 hours. It would take ~1 hour for a repeat installation.

During the trial, which was conducted in water depths up to 40m, the deployment, recovery and download time to gather a profile and be ready to take another took around 60 seconds. Whilst underway at ~4-5 knots, this resulted in a profile spacing of between 100m and 150m.

Valeport profiler

During the trials, two Valeport profilers were used. The SWiFT SVP is the latest sound speed profiler from Valeport with built-in GPS, Bluetooth Comms and a rechargeable battery. It measures sound speed, temperature and depth, and calculates salinity using a new formula developed by Valeport. The second probe was a RapidCTD, which measures conductivity, temperature and pressure to calculate salinity and sound speed.

Figure 2: Valeport SWiFT SVP profiler

M/V Bryn (Fugro Academy)

Fugro Academy, kindly provided access to M/V *Bryn* for the duration of the trial. M/V *Bryn* is a small but well-equipped survey boat used for training Fugro staff in various aspects of marine survey. For the purposes of this trial, the underwater positioning system was removed and the

Figure 3: M/V *Bryn*

deployment mount repurposed to mount the rapidCAST winch. The MBES system remained mobilised and was run alongside the rapidCAST.

Data Collection

Over the course of the week, and whilst training on the rapidCAST winch, the Barn Pool area was used extensively as it offers one of the deepest areas in the Sound (up to 40m) along the flooded river channel. During this period it was shown that the variation of sound speed in Barn Pool was both significant spatially across the pool and also had a distinct temporal variation, most likely due to tidal effects.

Two vertical transects through the Barn Pool area are presented. Both were collected on the same day, ~3 hours apart. The first transect was collected at high tide with the RapidCTD as part of a longer transect from the Breakwater to the upper reaches of the Tamar, above the Tamar Bridge. The second transect was collected on a dropping tide with the SWiFT SVP on the return leg. The tides were neap.

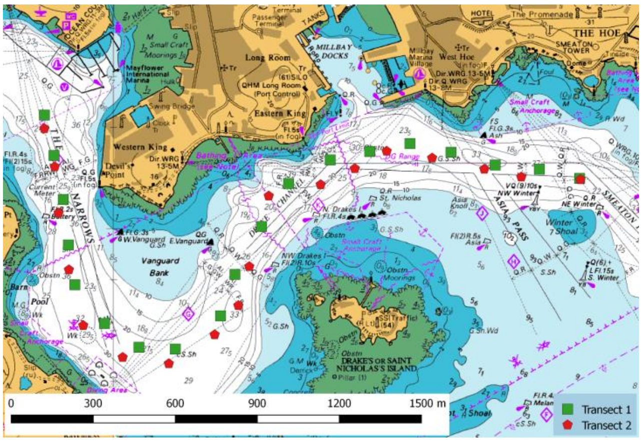

Figure 4: Transect and profile locations

Figure 4 shows the locations of the profiles with Transect 1 (RapidCTD) shown in green and Transect 2 (SWiFT SVP) shown in red. The positions for Transect 2 were recorded using the integral GPS of the instrument whilst the positions recorded for Transect 1 were extracted by matching the timestamp of the instrument with the GPS log from M/V *Bryn*. Both transects took ~15 minutes to complete from end-to-end.

Fortuitously, the first profile on Transect 1 and the last profile on Transect 2 were taken with 5m of each other. This allowed the data to be aligned for relatively easy comparison. All data processing was carried out with Python and the SciPy library.

Data Analysis

The data is presented as a series of vertical transects showing contoured plots of salinity (Figure 5), temperature (Figure 6), sound speed (Figure 7) and finally the difference between sound speed in the two transects (Figure 8). They are plotted with the western end of the transect on the left of the plot and the eastern end to the right.

Below 15m, the salinity, temperature and sound speed can be seen to be relatively stable. In Transect 1, a 5-10m thick layer of colder, fresher water can be seen spread across the transect deepening towards the riverine end. In Transect 2, as the tidal ebb is peaking, the fresher water has been displaced from the eastern end of the transect but the fresh water influence at the western end of the transect has intensified and deepened.

The effect this has on the sound speed field is dramatic (see Figures 6 and 7), with a spatial variation in sound speed along transect in the order of 10-15m/s, and a temporal variation between transects of ±7m/s.

The impact of this variability on the propagation of sound has not been assessed and will be the focus of the second part of this article.

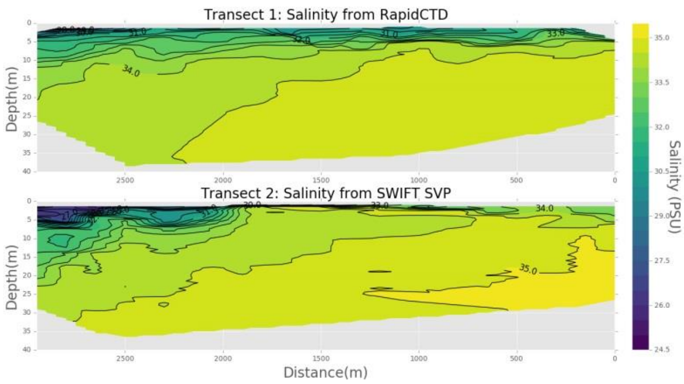

Figure 5: Salinity transects

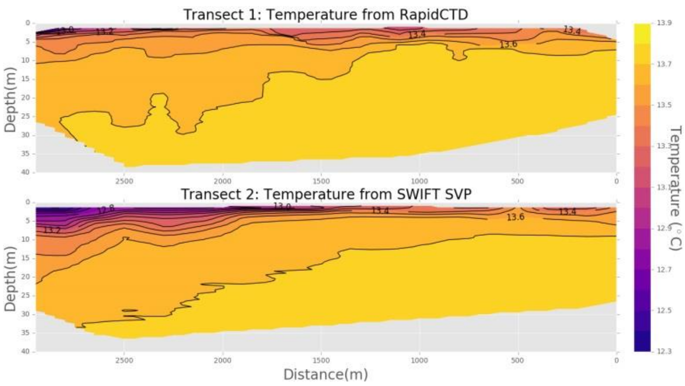

Figure 6: Temperature transects

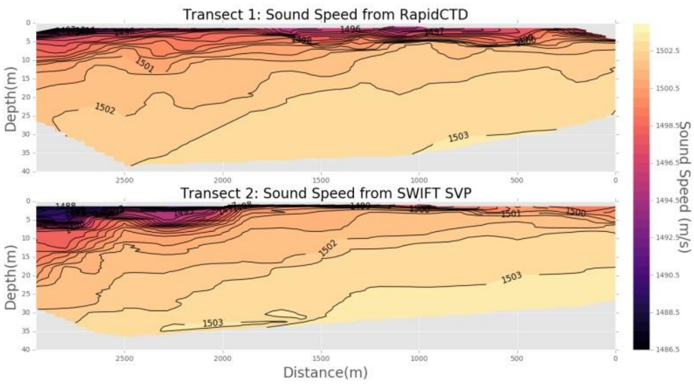

Figure 7: Sound speed transects

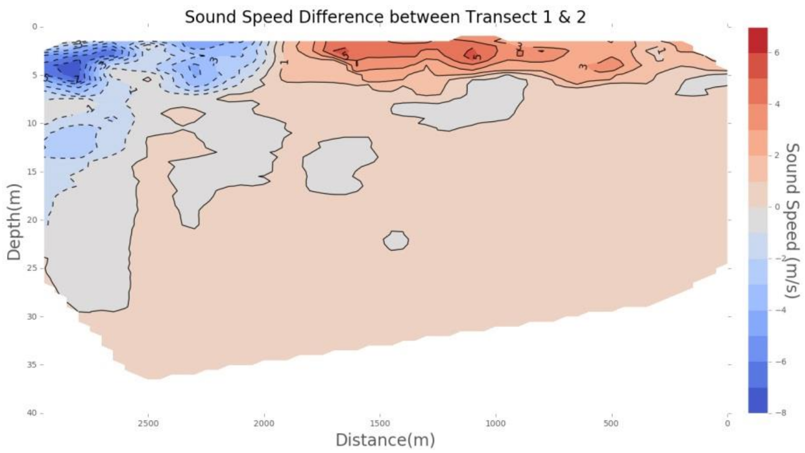

Figure 8: Sound speed difference transect

Further Work

The two questions posed at the start of this paper were:

- How often should I take a sound speed profile?
- What is the effect of this variability on my data?

If you are working in a dynamic coastal environment, the answer to the first question is probably more often than you do now. The data presented clearly shows dramatic and significant differences in the sound speed environment occur both spatially and temporally.

The second question is one the authors will attempt to answer in Part 2 of this article. A more focused data gathering campaign and processing exercise will attempt to quantify the environmental variability within the study area over a full tidal cycle.

This dataset will then be used to demonstrate the impact on sounding accuracy from a concurrently gathered MBES data set. Processing the MBES dataset with decreasing subsets of the sound speed dataset will simulate more traditional sound speed dipping regimes thereby enabling the expected increase in accuracy to be quantified.

The Authors

Jim Gardiner is the Product Manager at Valeport Ltd.

He holds an MSc Applied Marine Science and a BSc (Hons) in Ocean Science – both from Plymouth University – and he is a Chartered Marine Scientist (IMarEST).

Jim started his career as an Oceanographic Analyst at the UK Hydrographic Office (UKHO). He left that position after eight years to join Valeport as Product Manager in 2008. In this role he focuses on new product development as well as being involved with customer sales, support and training.

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Iain Slade is a Survey Trainer with the Fugro Academy (primarily based at the Training Centre in Plymouth). He is a graduate of Plymouth University – MSc Hydrography and BSc (Hons) Ocean Science – with 12 years' industry experience.

His current training portfolio covers a broad range of topics reflecting his experience, knowledge and skills gained in a wide range of roles across the hydrographic industry.

Iain began his career as a Marine Cartographer at the UKHO, quickly moving into survey data analysis as a Bathymetric Appraisal Officer in the Seabed Data Centre. From there he moved into civil engineering at a number of commercial consultancies mainly in the nearshore/coastal, civil hydrography and port sectors. A move to Fugro expanded his capabilities. Going further offshore exposed him to site surveys, debris surveys, geotechnical investigations, rig moves, ROV construction and IRM work.

Iain recently assisted the Marine Learning Alliance with the delivery of their Advanced Practical Techniques in Hydrography Module.

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news•bulletin

Shell Ocean Discovery XPRIZE

Man has always had a connection with water. It is where we came from, it sustains us and with 70% of our planet being covered by water, it supports one of the largest single ecosystems on the planet.

Historically, access to the deep ocean has been limited by the extraordinary physical challenges of exploring this extreme environment, high cost, limited technological advancements, and lack of investment.

The XPRIZE Foundation's $7 Million Shell Ocean Discovery XPRIZE is a recently launched three-year global competition challenging teams to advance deepsea technologies for autonomous, fast and high-resolution ocean exploration.

It is hoped that this prize will advance the exploration and mapping of the ocean floor, and uncover the planet's greatest wonder and resource for the benefit of humanity. The additional National Oceanographic and Atmospheric Administration (NOAA) $1M Bonus Prize is designed to encourage teams to develop pioneering technology that can detect a biological or chemical signal in the water and track that signal back to its source.

Successful teams will be truly interdisciplinary, and XPRIZE encourages participation from any specialism including hydrographers, robotic engineers, digital imagery experts and software scientists. Teams are encouraged to register to compete by 30th June 2016, with a late registration deadline of 30th September 2016.

Round 1 of the competition take places during the summer of 2017. Competing teams will be required to map at least 20% of the pre-designated 500km^2 seafloor Competition Area at a depth of 2000m, at 5m horizontal resolution (0.5m vertical resolution), within a limited time period. Up to ten teams will share the first $1M from the prize pot and progress to Round 2. Round 2 will take place the following summer, with teams required to map at least 50% of the Competition Area (a different 500km^2) at 4000m depth at 5m horizontal resolution (0.5m vertical resolution) – once again against the clock. The overall winners will be award the $4M grand prize with the runners-up receiving the final $1M.

In both rounds, the technology must be deployed from shore, or air, with no physical human intervention in the Competition Area.

With the recent proliferation in drone and swarm technologies, XPRIZE anticipate a variety of competition entries. Innovators from over 55 countries have already their expressed in competing. XPRIZE invites you to join them in creating the next generation of hydrographic technologies.

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