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A simple, relatively inexpensive method of ocean' surface layer temperature profiling

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Abstract

A simple, labour-non-intensive method of temperature profiling of the upper ocean layer is described. A simple set of modern but affordable equipment such as temperature-depth recorder, electric fishing reel, braided fishing line, fishing rod, and a personal computer are necessary. In the experiments described a series of casts to a maximum depth of 481 m were performed onboard a medium sized vessel of 24 m LOA. Detailed list of equipment used, general methodology and advantages of this method are described.

Disclaimer

We decline any responsibility for eventual loss of equipment, data or any other losses or damages involved while using the equipment or methodology described here.

All the brands and trademarks mentioned in the document are examples of equipment used in our experiments and none of them are advertised here. Whatever possible we provided names of other brands/manufacturers developed similar types of tools or devices.

Introduction

During recent years increasing number of research operations in fish biology, fish behaviour and fishery surveys are carried out onboard 'vessels of opportunity': chartered non-specialized fishing or recreational boats. Such kinds of vessels are usually small, lacking specific installations necessary for collecting environmental data (usually CTD[1] or MBT[2] profiling): winches, outrigger beams, sufficient power supplies etc. Installation on board of such equipment on temporary basis are either impossible due to vessel limitations (size, peculiarities of construction) or costly (most available solutions are well above 20,000 Euros). In addition, CTD and MBT probes are usually heavy and need at least two people to be operated in safe conditions. Profiling speed is usually low: from 45 min to 1 hour is necessary to perform one profile down to 400 m depth.

A common alternative is an XBT[3] profiling, which also needs relatively high initial investments (above 10,000 Euros) and further ongoing expenses on expendable probes. Taking into consideration limited budgets of many small-scale field projects, collection of environmental data generally is a non trivial task.

During the first year of the PROSPER project[4] we developed and successfully tested at sea a relatively inexpensive solution (below 4,000 Euros) for temperature profiling of the upper ocean layer down to depth 450 m.

A solution

A simple idea used in our approach is to make use of inexpensive modern technological solutions, readily available on the market. Simple deployment during field operations, time and labour efficient manipulations were important pre-requisites.

[1] CTD – conductivity-temperature-depth probe.
[2] MBT – mechanical bathythermographs.
[3] XBT – expendable bathythermograph.
[4] PROSPER – PROSpection et habitat des grands PElagiques de la ZEE de La Réunion.

TDR[1] is a common small-sized electronic recorder of depth and temperature widely used for analysis of fishing gear behaviour (in particular longlines, purse seines and trawls) (Boggs, 1992; Kim et al., 2007; Gartner et al., 2008; Bach et al., 2009). We considered that TDR used in combination with electric fishing reel as mechanical winch might be a plausible alternative to the expensive equipment mentioned above. A fishing reel was mounted on a fishing rod to compensate the vessel rolling. The reel was equipped with braided fishing line which provides high breaking strength at a minimal diameter. All these components are produced by several companies and are available either in local shops, re-sellers or directly from manufacturers.

Vessels, equipment, system configuration and results

Vessel

We tested our equipment onboard F/V 'Fournaise': a longline fishing boat of 23.9 m LOA, 165 GRT(Fig. 1) based at Le Port, Reunion Island. F/V 'Fournaise' has steel hull and is equipped with roll damping device, which makes her relatively stable at the ocean swells.

Fig. 1. F/V 'Fournaise' used as a platform for equipment testing.

Equipment and pre-installation

Complete list of equipment used is presented in the Table 1. Pre-installation procedures comprised: rigging of the fishing reel with fishing line (approx. 700 m), attachment of fishing reel to fishing rod, electrical load of the battery, placement of the battery into a watertight box and configuration of the TDR. A critical aspect of the setup of the equipment on a small ship is to find the proper place for rod holder and for battery box. Onboard the F/V 'Fournaise', we installed the equipment at the upper deck of the boat (~3.00-3.50 m height over waterline) to protected battery box from saltwater and to minimize the interaction between scientific and fishing equipment (Fig. 2, Appendix I). Steel galvanized tube attached to vessel's guard rails was used as a rod holder (Fig. 2). Transverse stainless pin was fixed at the distance ~320 mm from upper edge of

[1] TDR – temperature-depth recorded

the tube. It was used for latching of gimbal butt cap of the fishing rod to avoid ones rotation during profiling (Fig. 2). To avoid lost motion of the fishing rod its handle was blocked inside the tube by silicone spreaders made from silicon hose.

Figure 2. Installation of TDR profiling equipment onboard fishing vessel 'Fournaise'. Arrow shows position of transverse pin for fixation of gimbal butt cap of the fishing rod.

Running end of the braided line was connected with a ball bearing swivel and a snap to 1.5 mm monofilament line. The latter were equipped with lead weight of 0.5 kg and a snap for TDR attachment. Further details of the installation are given in the Appendix I.

A TDR of NKE Instrumentation[1] is a 120 mm length, 25 mm diameter hard plastic tube equipped with depth and temperature sensors (Fig. 3). The temperature sensor is a fine metallic pine, which sticks out of the TDR body. Therefore, use of protection tube is preferable during field operations (Appendix I).

We used NKE TDR model 'SP2T 600' with a 600 m maximum operational depth (breaking depth 1200 m), vertical resolution 18 cm, accuracy 1.8 m. Temperature accuracy of the TDR is 0.05°C in the range 0 +20°C and 0.1°C out of this range. Complete technical specifications are available on NKE website: http://www.nke-instrumentation.com/media/pdf/file3/sp2t-uk-1258631378.pdf .

[1] NKE Instrumentation, Rue Gutenberg, Z.I. Kérandré, 56700, Hennebont, France.

Figure 3. NKE Instrumentation TDR SPT2T600-PI used for temperature profiling during the PROSPER Project. Metallic part visible on the TDR body is the temperature sensor.

Before its first use as a profiler, the TDR should be preconfigured set up using the 'WinMemo': proprietary software of NKE. The principal limitation of NKE software is its incompatibility with the most recent Microsoft operations systems. Computer intended for field operations and NKE software installation should be run with the **Windows XP 32 bit** operation system[1]. Moreover, 'WinMemo' is a 16-bit software, which does not support long file names. A **8.3 file name system** should be used for file manipulations with 'WinMemo'.

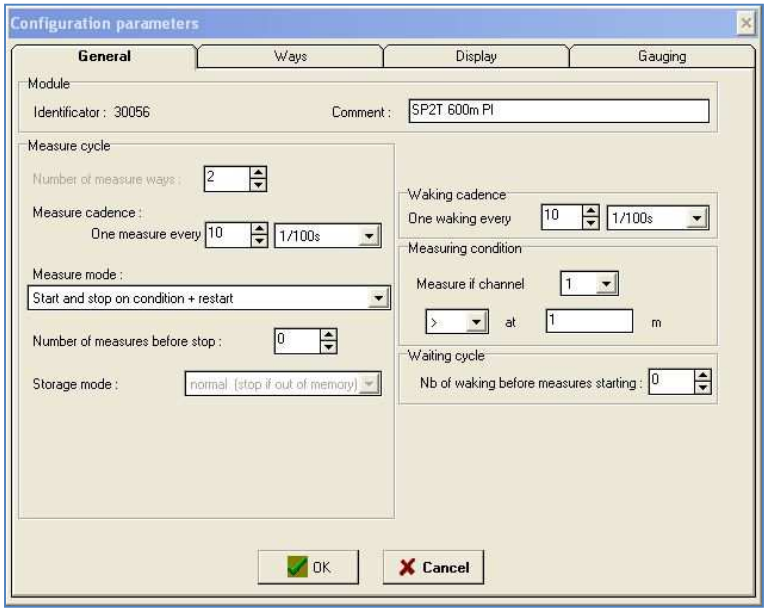

Figure 4. A configuration screen of the 'WinMemo' software.

[1] It should be noted that softwares for most of oceanographic equipment used (CTD by Sea-Bird Electronics, Inc. and XBT by Lockheed Martin Sippican, Inc.) are also incompatible with Microsoft Windows OS higher than XP SP3.

The TDR probe was set up with the following parameters: starting recording depth: 1 m, measuring frequency: 0.1 s (Fig. 4). The maximum TDR descent speed in upper the upper 50 m layer at 'free falling mode' do not exceed 2 $m \cdot s^{-1}$ (1.790±0.067 $m \cdot s^{-1}$). Such a speed allows to obtain at least 5 values per every meter of depth. Actually, more temperature/depth values were obtained since average descent rate was 0.868±0.171 $m \cdot s^{-1}$. Although ascending curve produces more records: retrieving speed of the line usually does not exceed 0.85 $m \cdot s^{-1}$ (most commonly between 0.50 and 0.66 $m \cdot s^{-1}$) we used descending curve for consistency with the other profilers (CTD and XBT). The TDR must be switched on ('Start') mode before launching.

The fishing reel does not need any pre-configuration except adjusting the breaks in accordance with the fishing rod and fishing line strength and setting the depth counter to zero before each cast. Zero depth setting allows automatic stop of the electric reel when the TDR reaches the surface. Fishing reel handling and care instructions are explicitly given in the reel manual. Attention should be paid for lubrication of reel and cable socket contacts with silicon lube. General suggestion is: ample rinsing of the fishing reel, the rod, the line and the TDR with fresh water after each cast.

Intercalibration and measurements precision

Before use of TDR for temperature profiling, two intercalibration casts were performed in order to check the consistency of measurements taken by the TDR and the CTD probe (SeaBird Electronics (http://www.seabird.com/Index.htm) probe 'SeaBird SBE 19+ SEACAT'). The TDR was attached to the frame of the CTD probe and two casts to the maximum possible depth[1] were performed on 02.12.2010 and 16.12.2010 during cruises PROSPER 1 and PROSPER 2 respectively. Both for intercalibration and field data processing, descending t°C/depth (m) curves were used for each probe. Good agreement between the two instruments was obtained in both cases (Fig. 5). No specific analysis of depth and temperature sensors differences were performed as well as intercalibration in laboratory conditions. It was assumed that the accuracy demonstrated in the field casts are sufficient for operational oceanographic works.

Field operations

A total of 74 TDR profiles were performed from May to September 2011 in various sea conditions from calm to relatively rough (max wind speed during profiling was 20 knots and sea state 4). Duration of each station did not exceed 30-35 min. A single person easily operated the whole system for profiling and data retrieving. For reasons of TDR safety, any contact between the braided line and the vessel hull should be avoided by proper positioning of the vessel regarding to wind and currents. Contact of braided line with cutting edges of fouling fauna may cause break of the line and loss of the equipment.

Both temperature-time and depth-time curves were uploaded from TDR memory to the computer either immediately after the cast (Fig. 6) or stored in the TDR memory until suitable moment (attention should be paid to potential memory overload). An example of two consecutive casts uploaded to PC from the TDR memory is presented on Fig. 7.

[1] Maximum depth reached was 417.8 m. It was limited by the cable length which was insufficient to reach 600 m – maximum operational depth of TDR.

Further analysis of the data and their plotting as temperature-depth (T-D) profiles are possible after export of the data into simple text format. The 'Export of measurements' option of the 'WinMemo' software allows data export either into standard text file or RECOPESCA[1] format.

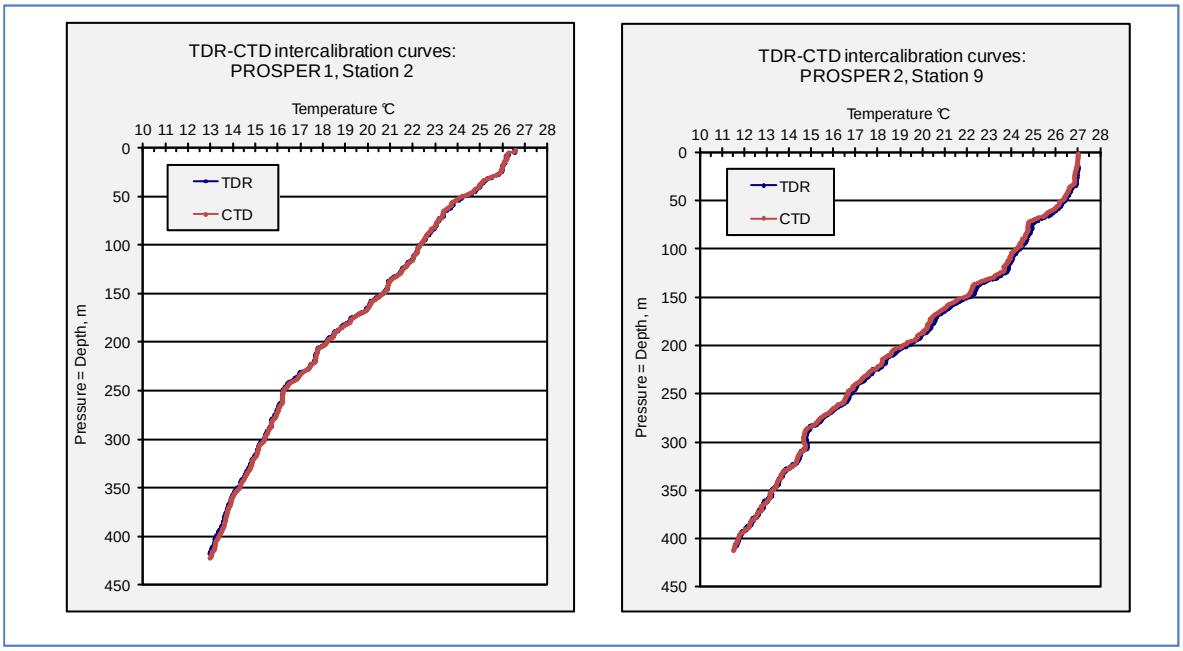

Figure 5. Intercalibration curves of TDR (blue line) and 'SeaBird SBE 19+ SEACAT' profiler (red line).

Standard text files were used in our work. Data transformation implies: selection of the descending part of the profile for each cast and plotting of the temperature-depth (T-D) curves. This can be easily done with any spreadsheet software (in our case Microsoft Excel 2007). MSExcel was used for the extraction of data corresponding to the descending profile and for the export data files. Further manipulations with data: plotting of the profiles, mapping and plotting of temperature sections or surfaces were performed with the Ocean Data View (ODV)[2] oceanographic software.

Examples of TDR casts from a single cruise (PROSPER 6) plotted in ODV are shown in Fig. 8. A surface map of temperature at the depth of 150 m based on the combination of all profiles achieved during the cruise (TDR, CTD,and XBT) is presented in Fig. 9.

Finally, TDR profiling appears to be an extremely effective method of water temperature profiling from small, non-equipped boats. A similar solution was developed independently by I-ATTC scientists and successfully used during their field operations in the Eastern Pacific (Daniel Fuller, 2011 pers. comm.[3]).

[1] NKE format of oceanographic data.
[2] Ocean Data View http://odv.awi.de © 2011 Reiner Schlitzer. Version: 4.4.1
[3] Daniel W. Fuller, Scientist, Biology and Ecosystem Program, Inter-American Tropical Tuna Commission, 8604 La Jolla Shores Drive, La Jolla CA, 92037-1508, USA.

A comparative table shows principal advantages and weaknesses of the method in comparison with other profilers (Table 2). TDR profiling appears to be the cheapest (less than 4,000 Euros) (Appendix III) and the simplest solution for field temperature profiling onboard non-specialised vessels of opportunity.

Further tests onboard smaller boats are planned in forthcoming months to check feasibility of described methodology under higher constraints.

Acknowledgements

We are thankful to captain of F/V 'Fournaise' Frédéric Payet and the crew of the vessel for their assistance during installation onboard and field tests of the equipment.

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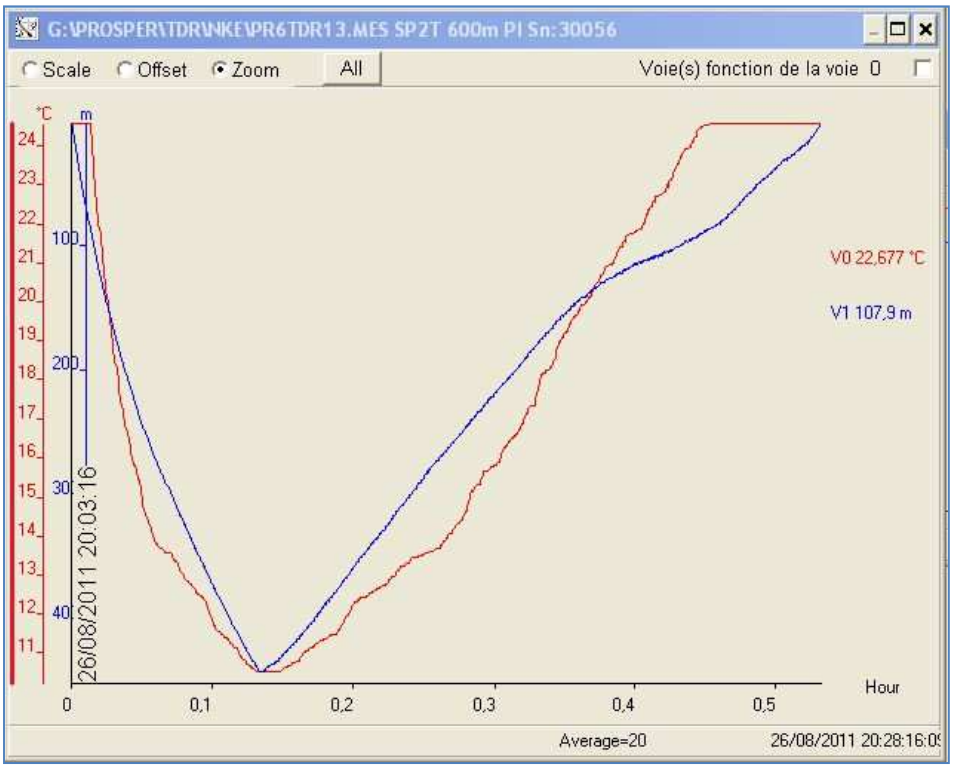

Figure 6. Depth-time (blue line) and temperature-time (red line) curves uploaded from TDR internal memory into PC.

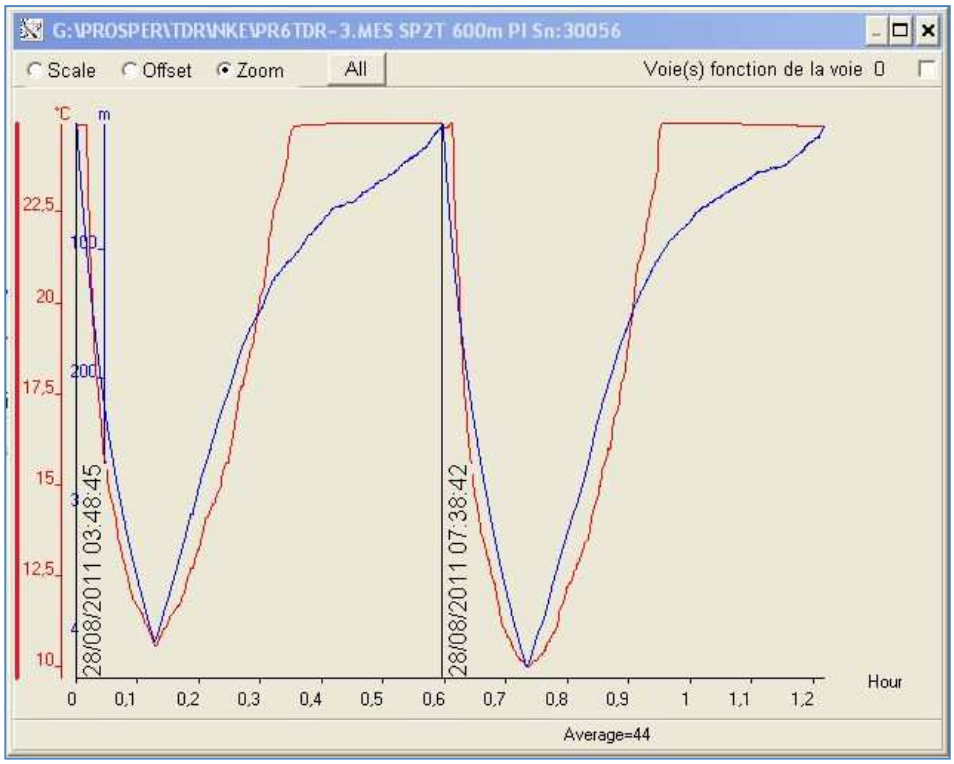

Figure 7. An example of two TDR casts data uploaded to PC. Depth-time (blue line) and temperature-time (red line) curves of each profile are separated by date line (black vertical line).

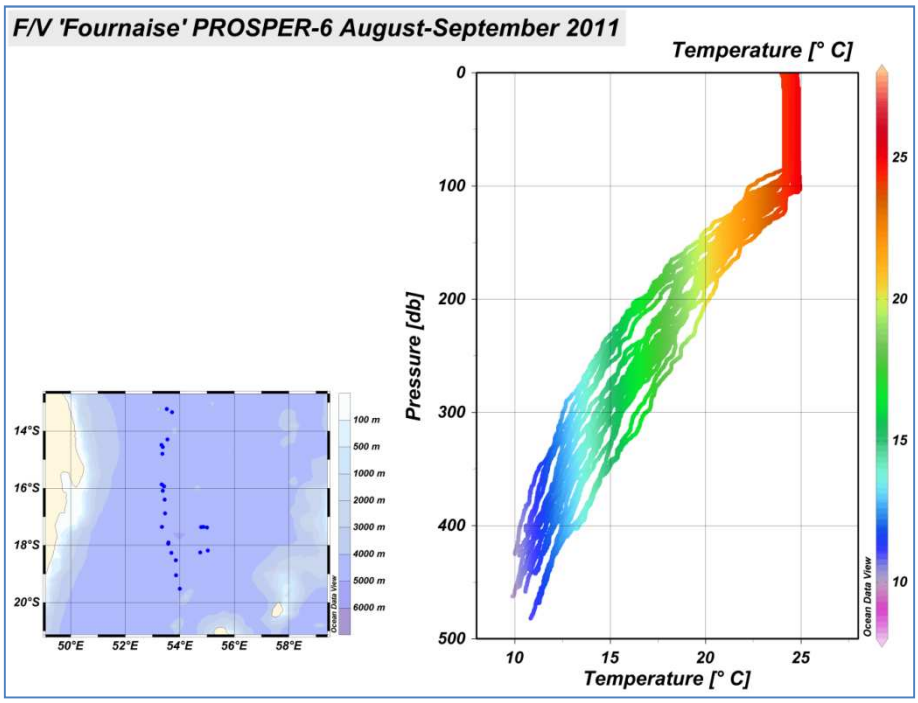

Figure 8. Sample of temperature profiles obtained using TDR profiling during the PROSPER 6 cruise and plotted with ODV software. Map of TDR stations during the cruise is shown in the lower left corner.

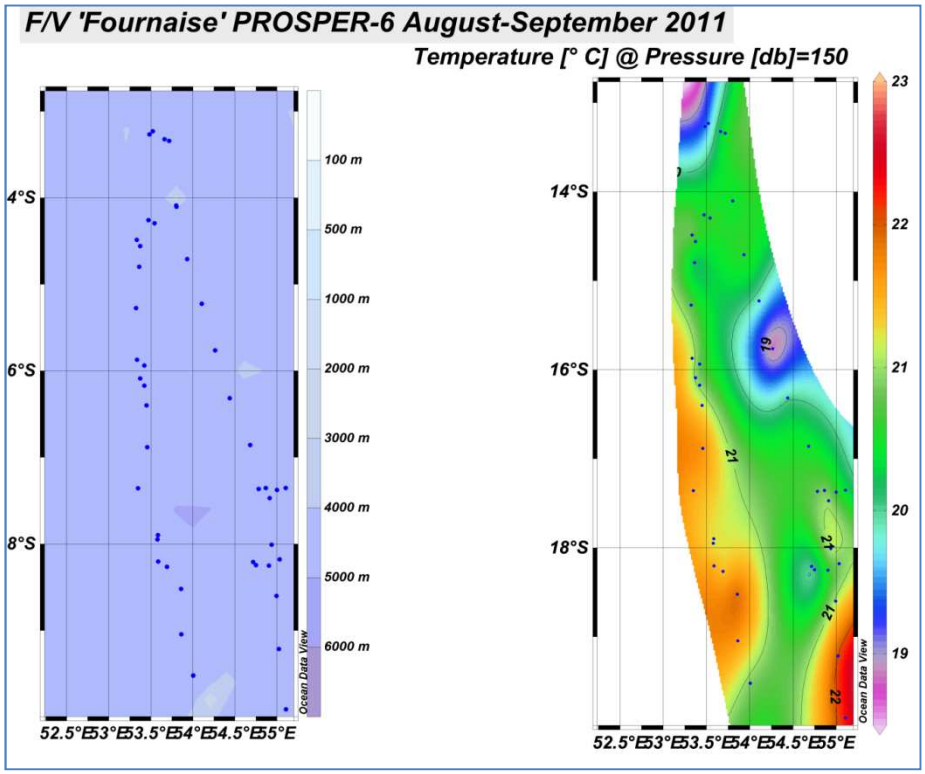

Figure 9. Sample of the surface map of temperature at the depth of 150 m drawn with ODV, based on the combination of all profilers used during the PROSPER 6 cruise (TDR, CTD and XBT).

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Boggs, C.H. (1992) Depth, capture time, and hooked longevity of longline-caught pelagic fish: Timing bites of fish with chips. *Fishery Bulletin*, **90**, 642-658.

Gartner, J.V.Jr., Sulak, K.J., Ross, S.W. &Necaise, A.M. (2008) Persistent near-bottom aggregations of mesopelagic animals along the North Carolina and Virginia continental slopes. *Marine Biology*, **153**, 825-841.

Kim, H.-Y., Lee, C.-W., Shin, J.-K., Kim, H.-S., Cha, B.-J. & Lee, G.-H. (2007) Dynamic simulation of the behavior of purse seine gear and sea-trial verification. *Fisheries Research*, **88**, 109-119.

Table 1.

List of equipment used during PROSPER project for ocean surface layer profiling with TDR

No	Equipment	Model used	Current price at Reunion Island (Euros)	Comments	An examples of other competitive producers (in alphabetic order)
1.	TDR	NKE SP2T600PI	800	http://www.nke-instrumentation.com/media/pdf/file3/sp2t-uk-1258631378.pdf	GEO SCIENTIFIC LTD., Lotec, RBR,Vemco, Wildlife Computers
2.	TDR data retrieving device	NKE data pencil	Free with TDR purchase		
3.	TDR data retrieving software	'WinMemo' v. 1.2.8, update of 17.03.2011	Free with TDR purchase		
4.	Fishing rod	DAIWA Tanacom Boat 210F, 2.10 m, WT 300-800 g	220		PENN, SHIMANO
5.	Electric fishing reel	DAIWA Tanacom Bull 1000	700		SHIMANO, Lindgren-Pitman
6.	Braided fishing line	DAIWA 8 Braid HYPER PE Tournament 0.35 mm, 40 kg (85 lbs test)	155		Berkley, PowerPro/SHIMANO, Stren, Suffix
7.	Battery	YUCEL Y38-12IFR, 12 v, 38 Ah, C20 Pb	50	Dry marine battery of 12V DC. Other brand name: YUASA	NRGZ
8.	Battery box	TREM	25		No data
9.	Battery charger	N/A	50-100		No data
10.	Lead weight 500 g	Local fabrication	8		N/A
11.	Rod holder (stainless or galvanized pipe internal Ø =40 mm)	Local fabrication	Gift from fishing vessel		No data
12.	PC Notebook with Windows XP software[12]	TOSHIBA Tecra M 11	1100		Acer, ASUS, DELL, HP
13.	Silicon lube		20		No data
	Total:		~3200		

[12] Data retrieving software of NKE TDR producer doesn't operate with recent OS of Microsoft (higher than Windows XP SP3).

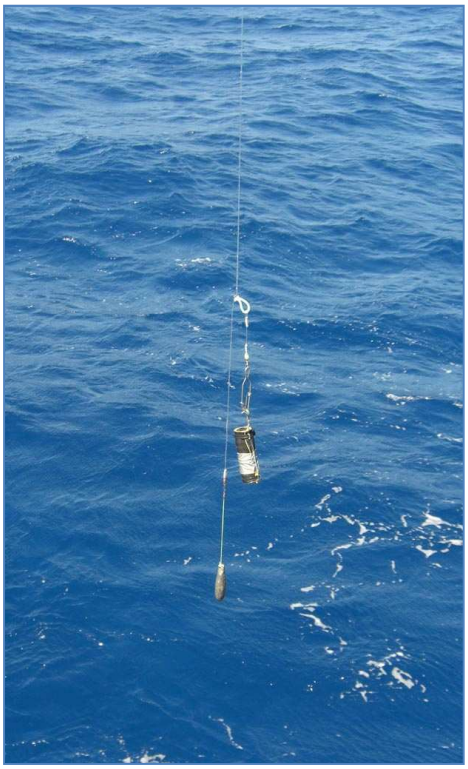
Table 2.

Comparative table of various profilers

Probe	Cost	Specific equipment installed onboard (winches)	Weight	Ease of deployment/manpower required	Profiling speed	Data acquisition speed	Expendable	Cost of use	Measured parameters	Comment
MBT	Low	Required	Medium	Medium / 2 persons	Fast	Visual-high, manual reading to convert in electronic form	No	Low	T°C	Virtually not present at the market
CTD	High	Required	Medium-high	Low / 2-3 persons	Slow	Medium	No	High	T°C, S, O_2 + additional parameters	
XBT	High	Not-required	Low	High / 1-2 persons	High	High	Yes	High	T°C	
TDR	Low	Not-required	Low	High / 1 person	High	High	No	Low-Medium	T°C	

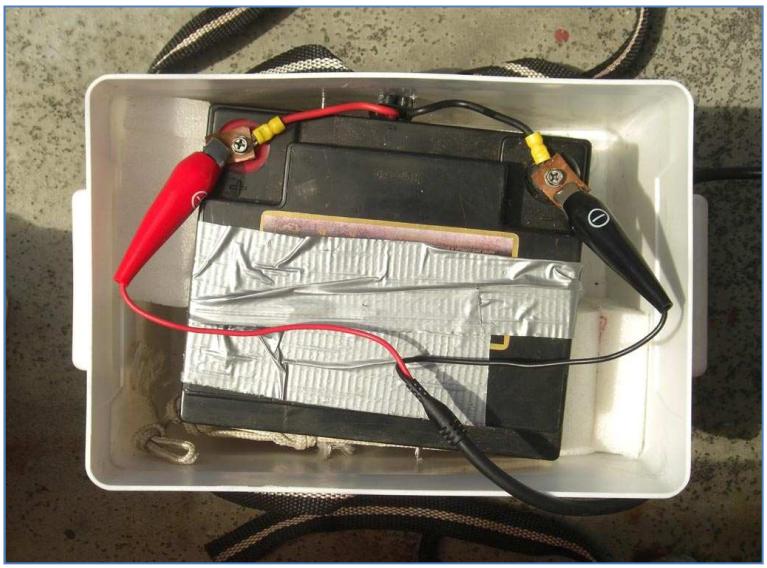
Installation of the equipment for TDR profiling onboard fishing vessel

Colour plates 1, 2. Installation of the fishing rod onboard the vessel



Colour plates 3, 4. Rigging of the equipment. General view (left panel) and detailed view of TDR in the protective tube and lead weight (right panel).

Colour plate 5. Electric power cable socket of the electric reel.



Colour plates 6, 7. Overall view of the battery protection box (left panel) and details of fishing reel power cable connection to the battery (right panel).

Comparative prices for profiling equipment

An example of XBT equipment for 20 launches of XBT probes and associated costs
(PC notebook cost is not included)

No	Equipment	Model used	Current price at Reunion Island (Euros)
1	SippicanXBT USB PC interface	SIPP0112A Mk21 USB Card	10862.00
2	Data retrieving device and software	Free with XBT launching kit purchasing	0.00
3	XBT Launcher	SIPP0017A Hand Launcher Lm3A 50 Ft	1760.51
4	XBT Probes Deep Blue 760 m	SIPP0025A Probe Sippican Deep Blue	103.18
5	XBT Probes T6 460 m	SIPP0006A Probe Sippican XBTT6	72.00
	Total price for equipment and 20 XPT probes T6		14062.51

Prices without VAT, shipping and customs charges.

CTD by Sea-Bird Electronics, Inc.

Initial cost of the CTD probe only: about 15000 Euros (temperature, conductivity, depth) [13]

[13] Low-cost CTD probes could be found at prices as low as 3,500 Euros.