Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories - **JERICO-NEXT**

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Approvals				
	Name	**Organisation**	**Date**	**Visa**
Coordinator				
WP Leaders				

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1. Scope of Document

The scope of this document is drawn from the original Description of Work (DoW) for Task 5.7, Scientific calibration procedures on glider data collection.

The spatial and temporal resolutions of coastal data and their quality are of crucial importance to adequately respond to scientific and societal challenges. Accordingly, to validate these data for analysis, several well-established procedures should be applied before, during, and after every mission.

- Now that multi-platform observations are more and more common, it is essential that calibration and inter-calibration procedures are routinely included in the validation process.
- Also important is the analysis and correction of long-term sensor drifts using a careful comparison with measurements acquired by other platforms and instruments in the same region, during a sensibly common period.

This task particularly focuses on post-mission calibration of glider CTD data (referred to as scientific correction from now on): while the scientific correction procedure is already established for Argo profilers, it still has to be standardized for gliders: information concerning the correction recorded in the metadata file, creation of the corresponding corrected variables and assignment of their associated error. The archival of delayed-mode corrected glider data is another problem to address. The information required in the file metadata has to be precisely defined in order to guarantee the traceability of the processing.

2. Introduction

Gliders are a rapidly maturing class of marine observing vehicles that offer long duration, some operate for several months at a time, autonomous ocean profiling in all weather conditions and sea states, to depths typically up to 1000 m. Gliders operate through using the profiling float principle of controlling buoyancy by pumping oil between reservoirs internal and external to their pressure hull; but unlike profiling floats they balance their buoyancy against lift on a pair of short wings, controlling their centre of gravity and therefore pitch and roll through the movement of weight, conveniently their battery packs, within the pressure hull. In this way glider vehicles glide through the water column, with horizontal and vertical speed components of around 25 cm s^{-1}.

Glider vehicles are typically just over one metre in length and as standard they will have a payload bay equipped with the generic triplet combination of conductivity, temperature and pressure sensors. In addition many will be specified with oxygen sensors and/or a suite of fluorescence and optical backscatter sensors. More unusually they have now been equipped with passive acoustic monitoring equipment and even a vessel mounted ADCP. Some gliders have been externally fitted with UV absorption nitrate sensors, and turbulence/microstructure instruments.

Gliders constitute an essential component of coastal observing systems for a number of reasons. Although flying gliders still has a significant manual component, albeit remote, requiring well trained glider pilots, and deployment and recovery, they are highly cost effective compared to ship based operations. Although slower moving than a research vessel, gliders are capable of acquiring data at a higher temporal and spatial resolution than was previously economically practical, and are able to operate even in rough sea states. The spatial and temporal resolutions of coastal data and their quality are of crucial importance to adequately respond to scientific and societal challenges.

In order to generate data of high scientific quality, calibration/correction has to be applied in two steps after a glider mission. While the first calibration is done routinely using the manufacturer's software, the second is referred to as delayed mode scientific correction. The first calibration is generally applied in real-time and includes a set of specific calibration expressions depending on the sensor type and model with the last manufacturer's calibration coefficients. Whilst instrument manufacturers have significantly improved laboratory calibrations and instrument stability, the effectiveness of gliders as an instrument platform is still limited by the ability to ensure the observations are in-field corrected to a world class standard. This second stage correction requires a careful comparison with measurements acquired by other platforms and instruments in the same region during a sensibly common period. This report focuses on the standards and methods of operation to achieve this.

3. Background and Objectives

The effort carried out by the oceanographic community to monitor the oceans has accelerated significantly since first the introduction of the Argo float and more recently the adoption of glider vehicles. The increased realization that ocean monitoring was critical to understanding climate and global change processes was probably instrumental in driving the new technologies, and it certainly is critically dependent on them. The increase in availability of ocean data over the past 10-20 years has grown exponentially and the quality control of these data is of crucial importance.

The validation of ocean data for scientific analysis has two key components. Firstly the near real-time application of laboratory calibrations and corrections for thermal lag, pressure effects etc. where these are known to exist; and quality control (QC) flagging where data fail to meet sensible criteria and metrics. Secondly the delayed mode scientific field correction to both trusted data and to data where the QC flag has suggested that data recovery could be possible. This report is focused on the second of these, specifically the field correction of ocean glider data, however it is important as a background to examine and remind ourselves of the near real-time procedures. SOCIB has developed a toolbox for the routine real-time and near real-time processing of glider data (Troupin et al., 2015), which includes the thermal lag correction and other routine QC procedures, see Appendix A.

Our overall aim within JERICO-NEXT is to lead the drive for an international world class standard in delayed mode, scientific field corrected, quality controlled glider data. To this end we have the following objectives:

- To respond to scientific and societal challenges by maintaining and enabling world class quality control of glider data at high temporal and spatial resolutions.
- To develop methods and tools to apply well-established procedures before, during, and after every glider mission.
- To incorporate routine multi-platform calibration and inter-calibration procedures in the validation and correction process.
- To monitor and record information concerning the calibration, validation and correction in the metadata file.
- To quantify and clearly describe the achieved accuracy and therefore residual error in the final delayed mode product.
- To guarantee traceability in the data calibration, validation and correction chain.

While a delayed mode field correction, quality control procedure is already established for Argo profilers (argo-quality-control-manual_version2.9.pdf), it still has to be standardized for gliders. What we must avoid in the glider community is work-load driven complacency: the “of course our data is always world class” attitude and the “this is someone else’s problem, I cannot find time and staff to deal with it” attitude. In the end we must ask the question, can we risk not dealing with cross calibration and inter-calibration ?

The issues to be addressed by the glider community include: information concerning the calibration recorded in the metadata file, creation of the corresponding adjusted/completely corrected variables and assignment of their associated error. The archival of delayed-mode corrected glider data is another problem to address. The information required in the file metadata has to be precisely defined in order to guarantee the traceability of the processing. This report is constructed to help address these issues and to help harmonise operating procedures by creating a benchmark for the glider community on glider CTD correction and inter-calibration.

Most ocean glider vehicles are fitted with a SeaBird CTD instrument unit. Like all CTD instruments these can exhibit modes of error that require post processing or delayed mode correction. The modes of error typically fall into three categories;

- Spikes and electronic noise,
- Biological fouling,
- Inaccurate or out of date laboratory instrument calibration.

The third of these is the focus of this report, and this requires delayed mode scientific correction, section (5), but it is instructive to discuss the other two categories of error first in (4.1) and (4.2).

4. Spikes, Electronic Noise and Biological Fouling

4.1 Spikes and Electronic Noise

Spikes in salinity data can result from either very sharp vertical gradients in temperature or instrumental 'noise'. By instrumental 'noise' we are referring to problems with the CTD instrument that can result from damaged or loose electronic circuitry, damaged or worn out interconnect cables, or loose connectors either for data or power. Temperature and pressure sensors will not normally suffer from spikes relating to sharp vertical gradients in ocean properties. In the case of pressure sensors this is because they have a rapid response time to pressure changes and their dependence on other ocean properties is minimal; in the case of temperature sensors, they are limited only by their own thermal lag which results in a smoothing of apparent temperature gradients. It is this smoothing that can create spikes in derived salinity however.

Salinity is conventionally derived from the concurrent measurement of conductivity, temperature and pressure. The rate of dependence of conductivity on temperature and salinity is approximately equal. The inherent thermal inertia of temperature sensors and the configuration of the body of the instrument housing them, can introduce a significant lag-time in the accurate measurement of temperature; whereas the measurement of conductivity generally suffers little or no thermal inertia except in very unusual extreme thermal gradients. The effective resulting mis-match in the concurrent measurement of temperature and conductivity creates spikes in salinity values near the beginning and end of even moderately strong temperature gradients such as the seasonal thermocline.

In the case of the early un-pumped CTD instruments fitted to gliders, this lag was complicated by the long path length of the water sampling flow tube to the conductivity sensor. The dimensions of the tube are such that flow through the tube will be more laminar than turbulent, at glider speeds through the water, and this creates a bigger, and difficult to model, effective delay between the measurement of conductivity and temperature (Heslop, 2015). This is then compounded by the order of the sequential polling of environmental sensors for data values by the glider data acquisition electronics. As a result the profile difference minimization thermal lag correction technique of Garau et al. (2011) was developed and is generally applied to data from these vehicles.

In the case of the later pumped CTD instruments, if significant spiking around thermal gradients is observed, a simple thermal lag acceleration of temperature technique, of the form that was developed for towed vehicles such as SeaSoar (Allen et al., 2002), should be tested and applied if successful. The technique accelerates temperature according to

$$T_{corrected} = T_{measured} + \tau.\Delta T \tag{1}$$

where ΔT is the forward temperature difference between successive temperature measurements and τ is typically a small fraction of the sample averaging interval, representing the effective thermal inertial lag. This is an iterative approach, recalculating salinity each time and looking for a minimization of spiking and a general 'cleaning' up of plotted θ/S (potential temperature versus salinity – discussed later) profiles.

Electronic spiking in either temperature, conductivity and/or pressure sensors, where present, is best removed by a combination of automatic and manual filtering of the data **(Figure 1**). An automatic large scale despiking is carried out in the SOCIB toolbox for routine real-time and near real-time QC processing of glider data (Appendix A and Troupin et al., 2015).

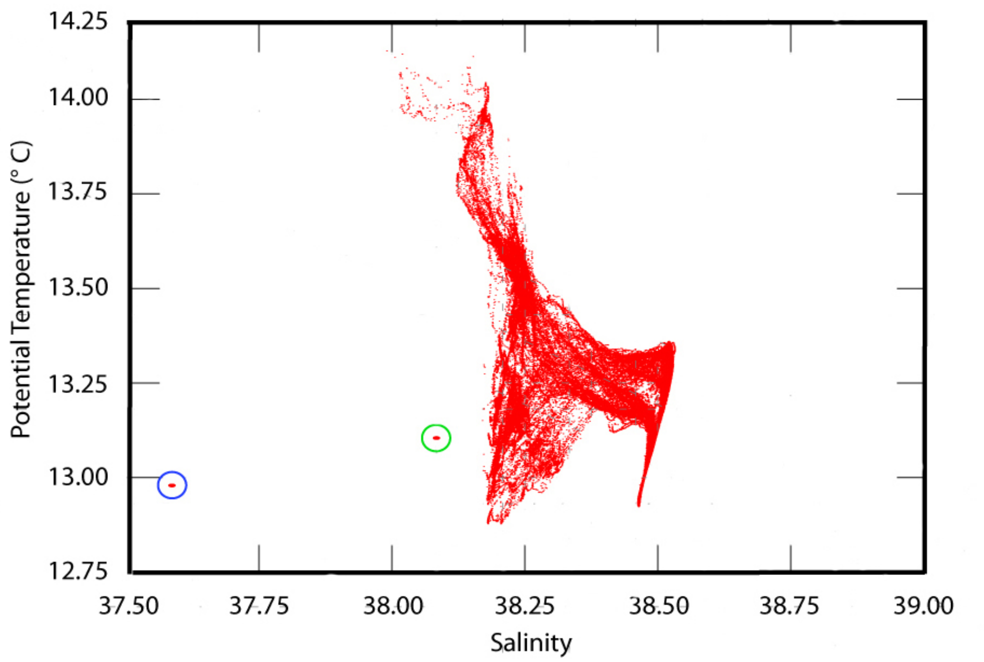


Figure 1: *Two examples of spikes in a θ/S diagram from a SOCIB glider mission. The one circled in blue would be removed by an automatic range test or by gradient test. The one circled in green might require manual removal.*

4.2 Biological Fouling

Fouling offsets occur in conductivity measurement as a result of biological material getting caught in the conductivity measurement cell. This can happen to both resistive and inductive type conductivity measurement cells, but the generally larger dimensions of inductive type conductivity measurement cells renders them less prone to fouling. Encountering a salp bloom can be a typical cause of bad fouling events due to the size and gelatinous nature of salps.

Fouling always creates a jump to low salinity values on the potential temperature/salinity (θ/S) diagrams that should be used to examine CTD data quality. Fouled conductivity cells can clear suddenly or drift back to normal as the biological material flushes clear. Fouling events can last for a significant time, although generally the turbulence at the sea surface should flush even the most stubborn biological residues.

Fouling events are difficult to identify and correct or discard automatically, although significant work towards this end is on-going. Manually, they are identified by a horizontal (iso-thermal) jump in salinity on the θ/S diagram. A well behaved fouling event will jump low at the start of the fouling and return either in a single reverse jump back to regular salinities or a small number of intermediate reverse jumps summing up to the original offset. In these cases, careful comparison with other θ/S curves will allow the offset value(s) to be identified and applied to the measured conductivity data to correct the dataset. Badly behaved fouling events involve many jumps or slow drifting in conductivity and therefore salinity values. In these cases, data may have to be flagged as bad or discarded from the dataset (**Figure 2 and 3**).

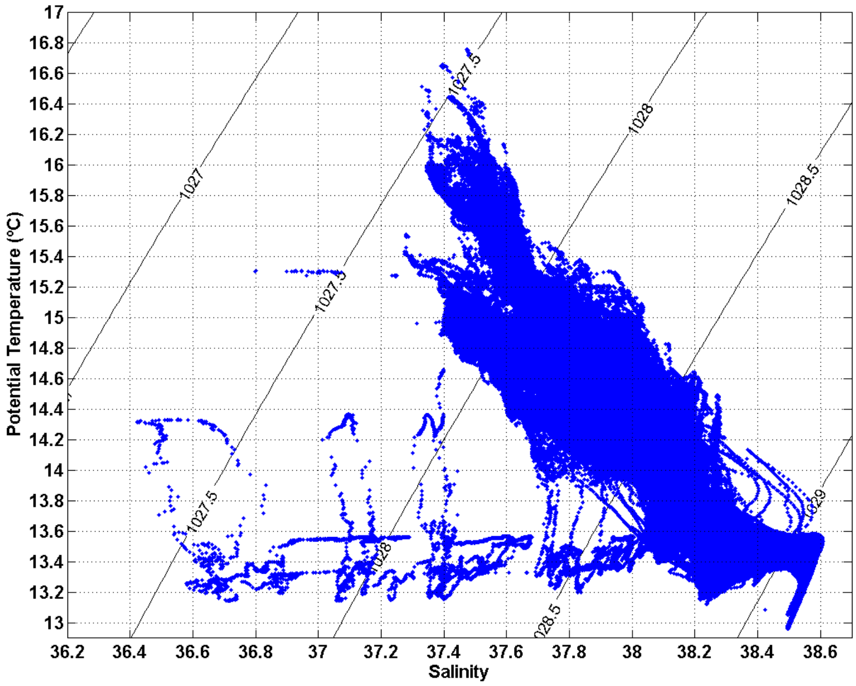


Figure 2: *An example of severe biofouling in a θ/S diagram from a SOCIB glider mission. The correct shape of several of the low salinity offset profiles indicate that some profiles may be carefully examined and recovered with the application of salinity offsets.*

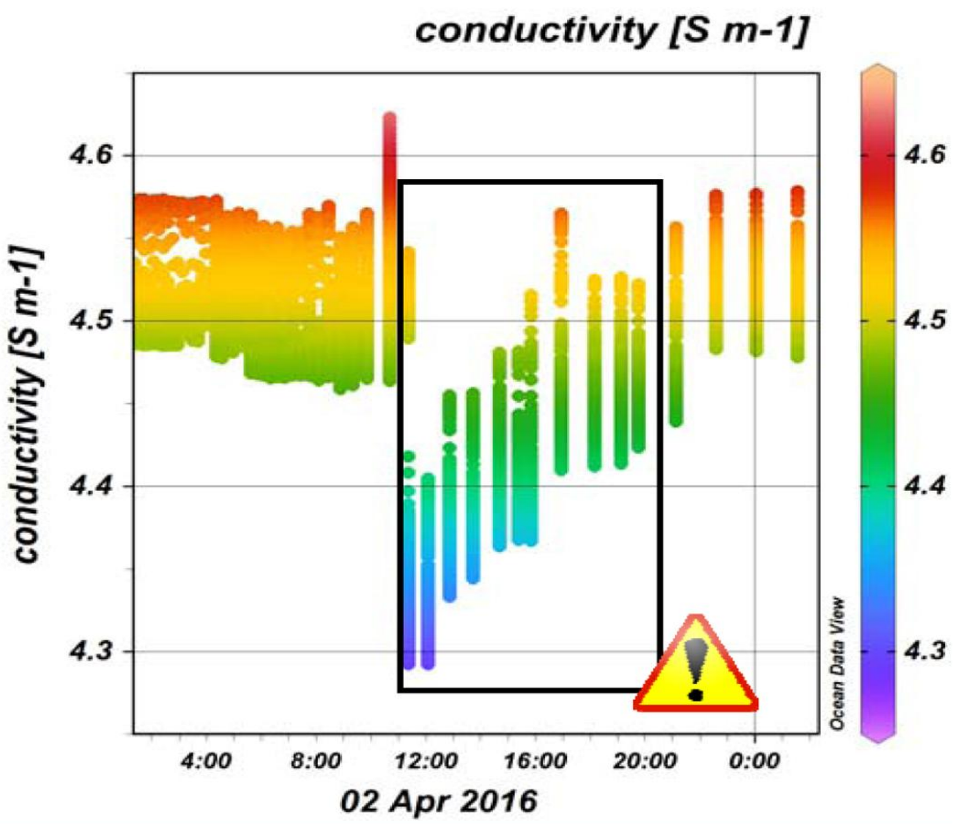


Figure 3: *The effect of the bio-fouling shown in **Figure 2** on the measurement of conductivity as seen in Real Time (RT) display.*

5. Delayed Mode (DM) Scientific Correction

5.1 The Purpose of Inter-Calibration

SeaBird instrument laboratory calibrations are generally considered to set the industry standard which other manufacturers can only strive to achieve, providing service intervals of typically two years are heeded. Nevertheless, even the SeaBird technical manual accepts that an in-field calibration of conductivity to water bottle samples is desirable to approach and maintain a WOCE (World Ocean Circulation Experiment) standard of accuracy for salinity, historically quoted as 0.001-0.003 psu. Indeed SeaBird will only quote their CTD instruments as capable of 0.003 psu. In this section we focus on post-mission, delayed mode correction of glider CTD data, for conductivity, in order to further improve the quality of the measurements by correcting long-term sensor drifts etc. While this task has been established for Argo profilers (Owens and Wong, 2009), the procedure still had to be standardized for gliders: this includes information concerning the calibration recorded in the metadata files, creation of the corresponding corrected variables and declaration of their associated residual error.

The need for a temperature field correction is mercifully rare with SeaBird CTDs, as this can be a difficult problem to deal with. However the principal of correction is the same as that discussed in this section. If a temperature correction is thought to be necessary then this should be applied first and salinity recalculated with the corrected temperature. The need for a conductivity field correction is common, normally manufacturers' calibrations for salinity are in error by the equivalent of a residual offset up to the ± 0.01 psu level; typically depending on the laboratory service/calibration history of the CTD instrument. Although, it is not that unusual to find real-time glider data that are wrong by as much as an apparent residual of 0.03-0.04.

Field correction of CTD data, was traditionally achieved with coincident collection of water bottle samples and subsequent laboratory analyses. However, unlike the traditional CTD frame, glider vehicles have no facility for taking discrete water samples for careful laboratory analysis. Of course this problem is not new, towed undulating vehicles and moorings have been used to carry CTD instruments for many years and generally these too suffered from the limitation of lack of water bottle sampling for in-situ correction. Field correction in these cases has to take the form of an inter-calibration process with other known and trusted datasets for particularly constant or only very slowly varying characteristic water types and water masses. Now that multi-platform observations are more and more common, it is essential that **corrections through inter-calibration procedures** are routinely included in the delayed mode data processing. Inter-comparisons between datasets should always be made by plotting potential temperature against salinity on a θ/S diagram, this is the best way to identify key characteristic water types in the vertical structure of the water; it overcomes the fact that both temporally and geographically, characteristic water types can be found at significantly different depths in the water column.

5.2 SOCIB's DM Scientific Calibration Methodology

For gliders, an inter-calibration methodology has been developed by SOCIB. This methodology follows the following 4 principles:

1. Routine research cruise CTD datasets are post-mission calibrated using salinity samples from Niskin bottles at each CTD station. During a research cruise, Niskin bottles are fired at depths which cover the range of salinities in the cruise survey region. Typically a minimum of between 2 and 4 bottles are fired at each station. Bottle sample salinity values are determined post-cruise using either a Guildline Autosal or Portasal instrument. In delayed mode, the CTD salinities are corrected to bottle sample values in the form of a conductivity gradient, i.e.

   $$\textit{Conductivity\_corrected} = A * \textit{Conductivity\_measured}, \qquad (2)$$

   as recommended by SeaBird (www.seabird.com/application_notes/AN31.htm). The delayed mode corrected data are then added to the SOCIB Data Centre database. These then form the basis for glider inter-calibration.

2. Glider datasets are compared with the most contemporary delayed mode corrected research cruise CTD datasets of missions carried out in the same region. Glider and delayed mode corrected ship CTD data are plotted in the form of potential temperature/salinity (θ/S) diagrams. Particular turning points (water types), and mixing lines (water masses), in the θ/S

diagrams are compared to identify the difference between the uncorrected glider data and the corrected ship CTD data.

3. If the most contemporary delayed mode corrected research cruise CTD datasets and the glider CTD dataset are not quasi-synchronous, a difference in time of more than a few weeks for example, the glider θ/S diagrams are then analyzed from a climatic point of view by paying attention to the seasonal evolution during that year (corrected glider and ship missions before and after the glider mission) and to the inter-annual evolution (corrected ship and glider missions from a similar seasonal time period in previous years). The inter-annual evolution must bear in mind the possibilities of long term water mass changes and decadal scale variability.

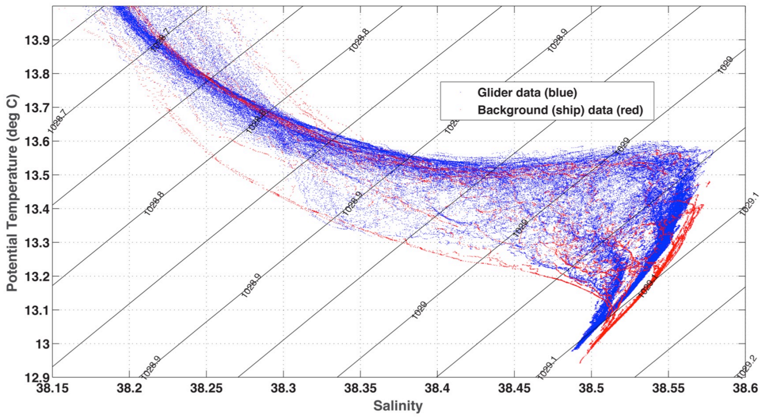
4. Again as SeaBird recommends for their CTD instruments, the glider salinity values are corrected as a conductivity slope, equation (2) (see point 1), although it is worth noting that in ocean regions where salinity and temperature ranges are very small an offset correction can provide equivalent results. Generally the slope correction is iteratively determined (**Figure 4)**, discarding outlier data points in the calculation of slope as required to get a good overlap between glider and ship datasets on the θ/S diagram. Two methods are available for this iteration procedure, firstly a semi-automated procedure of maximising “white space” in overplotted corrected CTD and glider θ/S data, and secondly, the more manual method where a choice of “virtual bottle stop” points in θ/S space can be extracted in comparison with the corrected CTD data. The first method involves the creation of a θ/S diagram of "background" ship data, and "test" glider data. The whitespace maximisation is then carried out, whereby the test data is iteratively moved along the x (salinity) axis by changing the value of coefficient A in equation (2), and a calculation of the whitespace area in the θ/S diagram figure is carried out. The iterative procedure continues adjusting the conductivity correction coefficient (i.e. the coefficient that ultimately leads the shift in the test data to the left or right) until the whitespace area of the figure has reached a maximum. This occurs when the test data is most closely overlying the background data. Generally this first method works well, but there can be exceptions, perhaps where there are a number of distinctly different flavours of particular water masses, where the second method provides a better inspection of the iterations. Confidence in the glider salinity values is then typically significantly better than 0.010 psu assuming the normal confidence in ship CTD calibrated datasets of better than 0.003 psu.

The inter-calibration correction procedure requires several subjective expert decisions, which may influence the outcome of the correction. The appropriate background data needs to be used, where both spatial and temporal separation of the datasets should be as small as possible, whilst respecting the danger of using background data from just one cruise campaign which could result in correcting the glider data to anomalies of a specific cruise campaign and not to the sensor offset. At SOCIB, a dialogue box requests the user preferred method of comparing with cruise datasets, with the options:

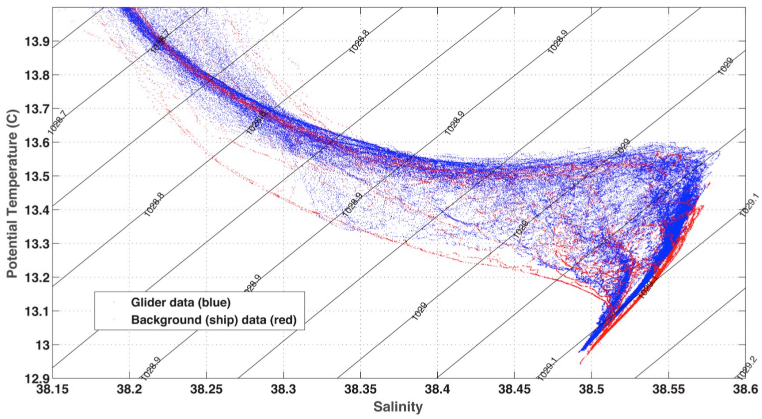
Manual selection of specific cruises
All Cruises of a particular monitoring program
All Cruises of the same season
All Cruises of the same season and cruises directly before and after
Matching Cruise (if one exists) and cruises directly before and after

The results of choosing different options can be compared to investigate the sensitivity to seasonal and interannual variability. The matter of allowing for interannual variability is of great importance as it is becoming increasingly well observed that there may be an increasing salinity trend in intermediate waters of the Mediterranean (Schroeder et al., 2016).

A= 1.000100



A= 1.000200



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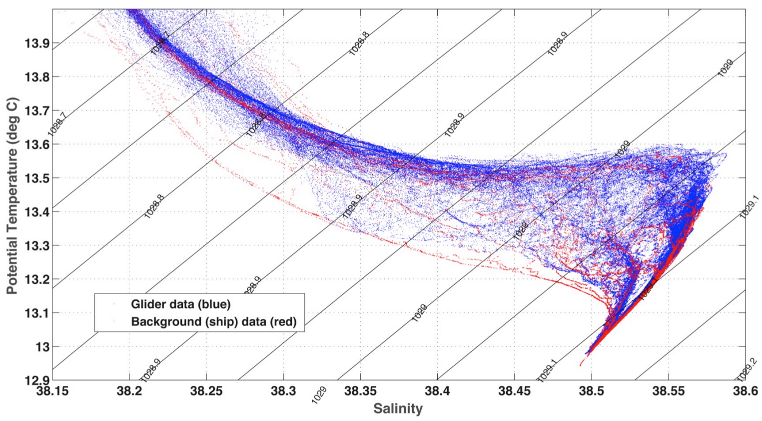

Figure 4: *The iterative selection of gradient A, when field correcting glider data to CTD stations*

The axes used in the θ/S diagrams needs to be appropriate for the inter-calibration correction (e.g. **Figure 4**); for example, excluding highly variable surface data, and avoiding water column regions where the background data points are populated with a wide natural variability in salinity. In other words, the region of θ/S diagram space predominantly used for inter-calibration correction purposes should focus on the most stable parts of the water column; whilst a significant range in salinities overall is required for a reliable correction, this will generally be where the variation in salinity with any given temperature is low, and thus the data points densely overlay each other. This typically describes mode water types, and well defined mixing lines, water masses, in intermediate and deeper waters. Notwithstanding the above discussion, a final examination of the results of correction should be applied to the whole water column to assure the operator that the correction has not caused any oddities in the appearance of the surface waters.

Figure 5: *The MATLAB GUI for the SOCIB CTD salinity correction pack.*

SOCIB has created both a CTD salinity correction pack (**Figure 5**) and a Glider salinity correction pack (**Figure 6**) written in MATLAB. In these MATLAB packages, at each stage, the option to create two T/S diagrams occurs. In the Glider salinity correction pack user input is required to determine which background data are used, what axis limits to use, and which data are on the topmost layer of the diagram (and are thus most visible). The user is advised to create a plot of all background ship CTD data and the glider data to allow for a sensible decision on which background ship data should be used, first for the whole axis range and then for a "zoomed in" θ/S diagram. In a second stage, the code provides recommendations for the background ship CTD data but still requires user input to determine how closely those recommendations are followed. The user can of course re-run segments of the code if they are not satisfied with the decisions they have made. In a third stage, the automatic whitespace maximisation procedure requires user input to decide on the axis limits, and create final θ/S diagrams of the background and glider data to check the user is happy with the decisions made (**Figure 4**). By default the automatic whitespace iteration procedure is carried out three times with different initial guesses for the correction coefficient. One of these guesses should always be 1 (i.e. no initial movement of the glider data). For the other two initial guesses, the user is advised to use guesses that move the glider data to the left and to the right of the background data. Final θ/S diagrams of the corrected glider data over the background data for all three scenarios are created and the user is then asked to select their preferred scenario solution. The user is also asked to estimate error, which can be done simply by looking at the thickness of the "thinnest" segment of the θ/S diagram and estimating the range of salinity values the glider data could effectively have taken; however the user may have other preferences for estimating error. Finally, in a fourth stage, final θ/S diagrams showing background data, and uncorrected and corrected glider data are created, with user defined axis limits, and a summary file is created detailing the correction coefficient, error estimate, standard deviation of the corrected CTD background data, and a summary of the correction procedure and correction reference dataset; this summary information enters the metadata, for the field corrected data file.

***Figure 6:** The MATLAB GUI for the SOCIB Glider salinity correction pack.*

5.3 DM Metadata

A detailed history of ship and glider slope change values is kept on record from mission to mission. It is important to keep in mind that conductivity sensors tend to drift with time rather than jump about in their calibration correction. It is possible, that for very long missions, the slope constant can change with time; SOCIB has not yet experienced this problem however. Generally SeaBird are correct in their assertion that conductivity correction will simply take the form of a gradient operator, i.e, equation (2). However it should be considered possible that offsets or even higher order operators may be necessary if an instrument is significantly out of calibration

$$Conductivity\_corrected = B + (A * Conductivity\_measured) \tag{3}$$

or,

$$Conductivity\_corrected = B + (A * Conductivity\_measured) + (C*(measured\ conductivity)^2); \tag{4}$$

again we have not yet experienced either of these at SOCIB, and the method for inter-calibration would follow the same procedures just with equation (3) or (4) instead of equation (2).

How to distribute delayed mode calibrated glider data is the final problem to address. What information is required in the metadata files is a question still to be fully answered by the community, since it is necessary to keep a cross reference to the dataset used for the glider correction. We suggest, at a minimum, the following information about the chosen reference dataset should be carried with the corrected glider dataset global attributes; which will enable users to interpret and cross check the resultant corrections at any time in the future if required: Instrument type (e.g. CTD, manufacturer and serial number), mission, platform, time, geographical coordinates, explanatory comments. As discussed above, SOCIB also includes correction coefficient, error estimate, standard deviation of the corrected CTD background data, and a summary of the correction procedure and correction reference dataset, in the final metadata for the corrected variables (**Figures 7 and 8**).

Variable "conductivity_corr"

```
double conductivity_corr(time=1843114);
  :glider_report = "http://www.socib.es/?seccion=gliderPage&facility=gliderReports";
  :_FillValue = NaN; // double
  :sources = "sci_water_cond";
  :coordinates = "time depth latitude longitude";
  :observation_type = "corrected_measurements";
  :long_name = "water conductivity";
  :standard_name = "sea_water_conductivity";
  :conductivity_thermal_corr_used = "NO, unavailable";
  :units = "S m-1";
  :calibration_equation = "COND_CORR=A*COND_01";
  :correction_coefficient_A = 1.000201; // double
  :summary_method = "whitespace area maximisation of a Theta-S diagram comparison, between
      glider data and other nearby (in time and space) cruises was employed";
  :background_data_used_for_correction = "Background comparison Cruises used: 1)
      dep0027_socib-rv_scb-sbe9002_L1_corr_2017-02-14";
```

Figure 7: *An example of the Metadata that accompany the DM scientific corrected conductivity data in SOCIB's Data Centre.*

Variable "salinity_corr"

```
double salinity_corr(time=1843114);
  :_FillValue = NaN; // double
  :sources = "conductivity temperature pressure";
  :coordinates = "time depth latitude longitude";
  :observation_type = "corrected_derived_from_conductivity_corr";
  :long_name = "water salinity";
  :standard_name = "sea_water_salinity";
  :units = "PSU";
  :method = "sw_salt";
  :salinity_error_estimate = 0.007; // double
  :summary_details = "Refer to meta.conductivity_corr.attributes";
  :summary_method_error_estimate = "error estimate is based on a combination of 1) the error in
      the CTD data used for the inter-calibration and 2) the confidence level of the overlap
      between the glider and CTD data at around 13 ºC (i.e. at the tail end of the deepest values
      on the Theta-S diagram)";
  :background_data_used_for_correction = "Background comparison Cruises used: 1)
      dep0027_socib-rv_scb-sbe9002_L1_corr_2017-02-14";
  :residual_salinity_differences_std_background_data: 0.005; // double
```

Figure 8: *An example of the Metadata that accompany the DM derived salinity data in SOCIB's Data Centre.*

6. Collaborations with other WP Tasks

A similar procedure should and will be applied to biogeochemical data. Dissolved oxygen (**Figure 7**), chlorophyll, and turbidity datasets from gliders must be compared, if possible, with delayed mode corrected ship datasets, already calibrated and compared to laboratory analysed Niskin bottle water samples. However, biogeochemical data will be the subject of further future SOCIB reports.

The presentation of scientific inter-calibration correction procedures for delayed mode glider data collection, as presented in this report has clear links with other tasks within work package 5 (WP5). Comparison between the dissolved oxygen measured using a CTD mounted Sea-Bird Electronics, SBE, 43 oxygen instrument, calibrated to Winkler titration determined oxygen concentration of in situ water samples, and the oxygen concentration determined from the glider mounted Aanderaa optodes is a natural extension of the work presented here and has begun in many laboratories including SOCIB (**Figure 9**).

Similarly, cross-calibration correction of glider mounted flourometers and optical backscatter sensors is the subject for further expansion of the work presented here, although we take careful note that these two types of biomass measurement are very dependent on the community species composition of the in-situ plankton. These are subjects that will develop significant links between this Task 5.7 deliverable and the work in progress on Tasks 5.2, concerned with the integration of biological data, and Task 5.5, concerned with the enhancement of quality control procedures for sensor based biochemical data.

The procedures developed in these WP 5 tasks are focussed on adopting, promoting and developing internationally agreed standards for the quality control and inter-calibration of ocean observing networks. This is critical to understanding long term changes in the ocean environment, particularly as the length of the observing history is short compared to the expected timescale of the global and climate changes taking place. WP 5 deliverables, including this Task 5.7 report, are therefore highly relevant to our interactions with European and international ocean observing networks, WP 1, Task 1.4. In addition our support of international standards, and their development, must be a key component of the JERCICO label as presented under our strategy for the future, WP 1, Task 1.6.

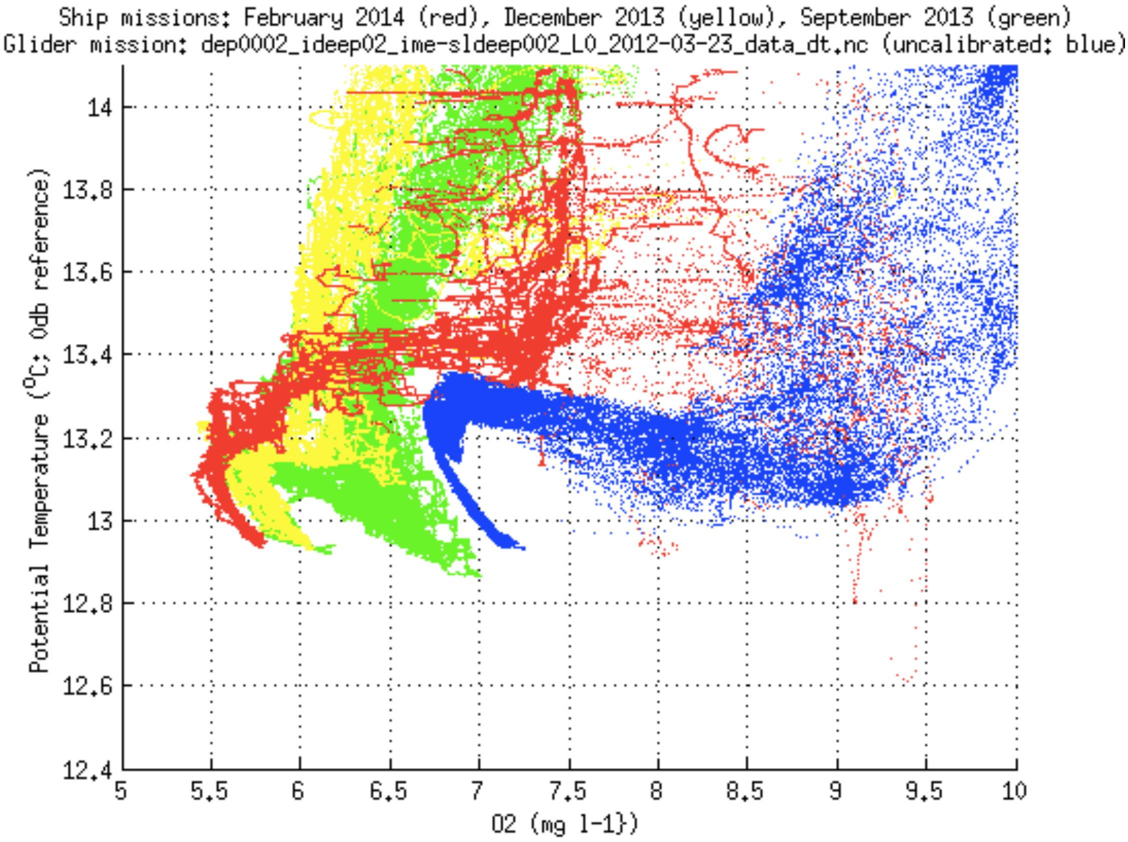

Figure 9: *A potential temperature / oxygen (θ/O) diagram, showing the typical size of corrections necessary from three different glider missions to field correct to bottle calibrated ship CTD survey data (blue).*

As stated in WP 2, task 2.5, the reliability of an observing network, its ability to deliver world class useable information, depends most of all on methodical calibration and assessment activities; which requires close collaboration with WP 5 as a whole, and in particular with Tasks 5.5 and 5.7. Following from this, the Joint Research Activity projects (JRAPS), and in particular JRAP 4, concerned with the 4 dimensional characterisation of trans-boundary hydrography and transport, will need to be fed with world class inter-calibrated and quality controlled data through collaboration with WP 5 in order to determine the impacts of global and climate changes observed in the JERICO data networks. To complete this chain of implicit and explicit collaboration, WP 5 will provide the under-pinning documentation and meta-data to support the added value derived through the JERICO NEXT program and delivered through the Virtual Access and Virtual Services provision under WP 6.

7. Appendix A

SOCIB has developed a toolbox (**Figure 10**) for the routine real-time and near real-time processing of glider data (Troupin et al., 2015). This toolbox is feely available at http://www.socib.es/users/glider/glider_toolbox/ or at https://github.com/socib/ glider_toolbox.

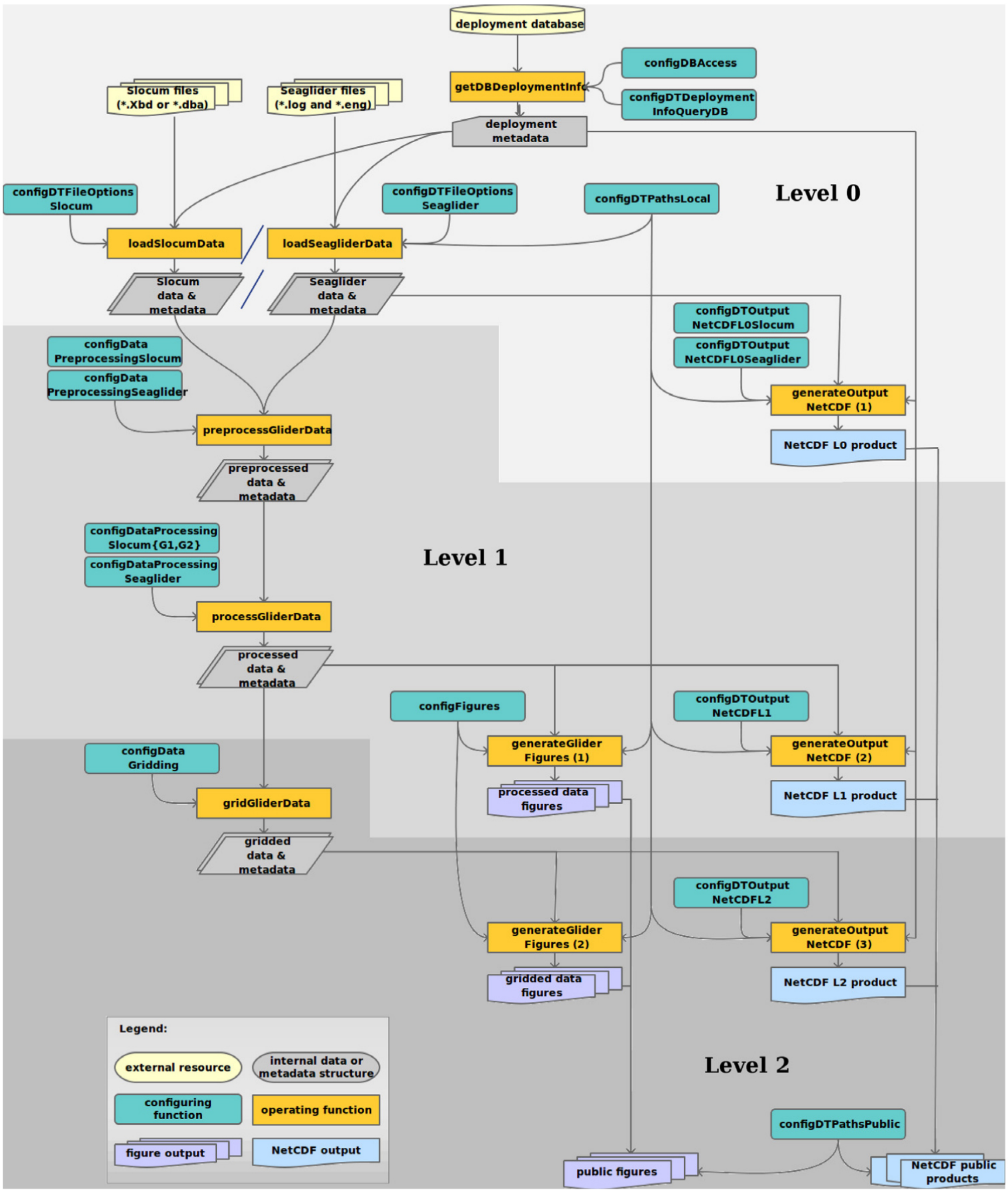

Figure 10: *Glider toolbox diagram: from deployment database to figures (processed data, gridded data and public) and netCDF products (level 0, 1 or 2). The names in the function boxes (rectangles) correspond to the MATLAB/OCTAVE tool functions. (Reproduced from Troupin et al., 2015)*

This toolbox is based on the previous code developed at IMEDEA and SOCIB by B. Garau and E. Heslop. SOCIB has acquired an extensive experience in glider technology, both with Slocum and Seaglider platforms. The development of a glider data processing toolbox therefore evolved naturally from the need to operate and manage these data streams in real-time and delayed mode (Cusi et al., 2013), and to address issues such as thermal-lag (Garau et al., 2011), which can affect glider salinity data depending on the nature of the fitted CTD instrument. With the increasing number of glider users worldwide, a toolbox designed to deal with the specific issues of the glider platform is a timely development. The advantage of the SOCIB toolbox is its support for the rapid processing and consistent organization of data from both Seaglider™ and Slocum and SeaExplorer data types, leading to a well-defined archive of deployments and unified data sets in a self-documented portable format (Network Common Data Form, NetCDF, Rew and Davis, 1990), with user selected processing levels for each deployment. The toolbox is modular and scalable, and incorporates a suite of useful utilities that can be adopted as stand-alone pieces of code.

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