REPORT ON
SECOND ARGO DELAYED-MODE QC WORKSHOP
(DMQC-2)

Carriage House

WHOI

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1) Introduction, Purpose and Aims of DMQC-2

The aims and purpose of the workshop had been circulated in advance of the meeting. The proposal to AST-7 that led to the establishment of the workshop made the following points:

Requirement The driving requirement on DMQC is to ensure a high-quality product by adopting consistently-applied procedures, and ensuring timely data flow from all national programs. Consistency must be achieved across PIs and DM operators.

Background The first DMQC workshop at Scripps (April 2005) provided an opportunity for DMQC operators and PIs to resolve many issues that were at the time holding up progress with DMQC. Attendees at the workshop generally agreed that it was of great benefit to both 'newcomers' and 'old hands'. It also provided a stimulus for groups to press on with DMQC activities. It was immediately recognized that further meetings at appropriate intervals would bring comparable benefits.

The workshop proposal to AST-7 had listed a number of important issues for discussion, which were developed into the workshop agenda. The DMQC-2 attendees were pleased to accept an invitation from Webb Research to tour their facility after the lunch break on Thursday 5 October.

It was noted that the Korean Argo program had been unable to send a representative to the meeting. Kuh Kim had reported that there has been some change of personnel at NFRDI (National Fisheries Research and Development Institute of Korea) who are responsible for DM in Korea, and he hoped that this would lead to some progress.

2) Progress with DMQC of PSAL since DMQC-1

Progress was reviewed for the program as a whole, and each DMQC effort represented at the meeting was invited to comment on their progress so far and identify any specific problems that were holding up progress in their program.

Gilson has parsed the collection of profiles included in the mirror he maintains for the SIO GUI. The following table represents the status of profiles on 7 October 2006. Profiles are grouped by DAC responsible for the float, and not subdivided by national efforts within that DAC. This distinction is significant for aoml (who handle floats from UW, PMEL, SIO, WHOI, …) and coriolis (who handle floats for non-French efforts, notably Germany), and to a certain extent for jma (JAMSTEC, JMA).

The total profiles within the responsibility of the Argo DACs is approximately 240000. King said 80000 new profiles have been added since November 2005. As shown in the table below, 70000 profiles are now held at GDAC in D mode, an increase of 41000 since November 2005. Thus a very considerable number of new D profiles have been submitted in the past year, but the program as a whole is still acquiring new profiles more rapidly than it is delivering D files. A number of national efforts are ready to submit further large batches of D files. The UK has completed DMQC analysis of 40 floats: D files are being prepared at bodc and should be submitted before the end of calendar year 2006. WHOI will submit a large number of floats once the new OW DMQC tool is approved and adopted. csio has completed DMQC analysis of all their active floats; 6 floats requiring adjustment have been submitted; the remaining csio floats require no adjustment and the files will be resubmitted in D mode in the near future.

dac name at GDAC	Total profiles at GDAC	Recent profiles not yet available for DMQC	Profiles available for DMQC	D profiles at GDAC
aoml	118089	47504	70585	34711
bodc	12105	3453	8652	396
coriolis	41661	12664	28997	13121
csio	1202	306	896	338
csiro	6894	3090	3804	1251
incois	9072	3561	5511	340
jma	40970	12927	28043	11187
kma	3442	878	2564	0
meds	11532	2574	8958	8884
Total of above DACS	244967	86957	158010	70228
gts	26454	427	26027	0

Specific comments were made as follows:

meds: Up to date; presently experimenting with applying RT corrections based on DM adjustments and reporting as mode A.

jma: 32k out of 40k are the responsibility of JAMSTEC. The remainder includes a number of pre-Argo profiles which were acquired from floats managed by JMA. Shikama said that JAMSTEC hopes to clear the backlog of these non-JAMSTEC floats when manpower resources are available.

incois: Joseph identified some issues with which extra expertise/advice is required in order to make further progress; these included handling of bad positions (advice was to select a later position from the traj.nc file); handling of PnP4 missions; handling of salinity spikes in the deepest reported level.

csiro: No discussion of csiro under this agendum because Tchen did not arrive until day 2.

csio: Liu Zenghong reported that a non-zero adjustment was decided for 6 out of 24 floats; these have been submitted as D. The remaining floats require zero adjustment. When these are submitted as D files with zero adjustment, csio will be ‘up to date’.

coriolis: V Thierry presented a histogram of adjustments. 3000 out of 6000 N Atlantic profiles had adjustment < 0.01. In the larger adjustments, there was a small positive bias.

bodc: Approx 40 floats had been processed and decisions made over summer 2006. D files would be generated and submitted before end 2006.

aoml: WHOI (Owens) is preparing a large number of floats with the new OW DMQC tool. When that is agreed and stable, a large number of D files will be submitted. SIO (Gilson): 98% complete; thermal lag correction is applied. UW (Wong) 50% done; data sparse areas eg Southern ocean and south Indian remain a problem; have been awaiting new OW tool and new reference database updated since WJO. PMEL (Johnson) Submitted 5000 D files since Oct 2005, compared with acquisition of 4300 new profiles in 2005 and 6400 profiles in 2006. AOML (Molinari) is working on DMQC of pre-Argo profiles as a once-off activity.

> ***QUESTION for DMT:*** *Owens and Gilson reported instances where the translation of files at GDAC to account for format change (profile quality flag) had been undertaken by GDAC, but then 'reverted' to the old value. How did this happen ? How do we ensure it doesn't happen in the future ? Joseph reported experiencing a similar effect for some incois floats.*

> ***Recommendation:*** *DMQC-2 noted that there are now very few profiles being reported as GTS-only and which do not have a responsible DAC. DMT should try to identify a group that would be willing to undertake DMQC for the gts floats that have no other PI. DMQC-2 noted that Molinari's group at AOML was funded to undertake DMQC for pre-Argo floats and suggested that this might be a model for the gts floats.*

2.4) New DMQC tool 'OW'

Owens and Wong described the new statistical tool they have developed in response to discussion at DMQC-1. This will be referred to as 'OW'. The new tool is an evolution of WJO, adopting some features from BS. New features recommended by DMQC-1 include

- 'smart' selection of levels for mapping following ideas of Boehme-Send.
- Code ensures piecewise-linear suggested adjustment.
- Break points kept to a minimum, and introduced automatically where statistically justified.
  - This ensures slowly-varying adjustment, unless operator forces manual selection.
  - Concept of breaking the float into separate 'series', each of which has its own piecewise linear fit, remains from WJO.
- The input format and diagnostics remain unchanged from WJO. The main change is in the central statistical engine, so transition from WJO to OW should be straightforward.
  - Transition from BS to OW is not so trivial.
- Control options are in the config.txt file and the calseries variable.
- OW requires Matlab optimisation toolbox.
- Better selection of levels for mapping leads to smaller PSAL_ADJUSTED_ ERROR than WJO. Careful consideration of number of degrees of freedom (decorrelation scales) concludes BS estimate of PSAL_ADJUSTED_ERROR was too small.

Uptake testing of OW: The following said they would adopt the new tool in the near future: Wong; Owens; Molinari; Gilson on new floats (will retain WJO on existing floats for consistency); Coriolis (not starting before 2007).

3) Implementation of recommendations of DMQC-1

The discussion revolved around the presentation of results from the DMQC intercomparison exercise coordinated by Tchen. A report on the intercomparison exercise will be ready for the next AST.

3.2 and 3.3) sliding window; continuity of adjustment at breakpoints.

King showed examples of floats in which the D files at the GDACs had adjustments which had short-timescale variability, and/or discontinuities in adjustment. These seemed to be contrary to the recommendations of DMQC-1 The discontinuity problem seemed to arise when the proposed adjustment crossed a threshold (eg 2 * error or 0.01) and the adjustment jumped from zero to a non-zero value. It is hoped that the adoption of OW should help/eliminate this problem. A set of 12 test floats was identified by King for running within OW at the workshop.

The results from application of OW to the set of test floats indicated

1) In many cases, OW proposed an adjustment consistent with that chosen by the DMQC operator, with the advantages of piecewise-linear-continuous.
2) The present diagnostics should be improved to assist the operator in identifying cases when a genuine discontinuity occurs in sensor behaviour (see below).

3.6) Extra diagnostic plots.

It was suggested and readily agreed that an extra 'salinity anomaly contour plot' should be produced for PSAL_ADJUSTED as well as the WJO/OW input data. Wong agreed to make the necessary update to the code.

In order to help the operator determine the requirement for break points and cal_series_flags, the new OW tool should produce a diagnostic plot that shows the estimated offset for individual profiles (comparable to running_const = 0 in WJO), as well as the estimated offset after piecewise linear fitting.

The following aspects of PSAL DMQC were reiterated and emphasised:

Adjustment to PSAL should vary slowly with time, unless there is strong evidence for sudden changes. OW will follow this expectation by proposing piecewise-linear adjustment with minimum justified number of breakpoints. Where the DM operator identifies jumps and non-smooth transition cycles, the operator can force extra breakpoints and split the cal_series to allow genuine jumps, eg at cell fouling events.

There should not be a jump in the applied adjustment when the proposed adjustment crosses an agreed size threshold. The threshold will normally be 2*standard error provided by statistical method, or 1* manufacturers instrument accuracy (0.005 is the suggested guideline). By default, the operator should choose the adjustment to ensure smooth and continuous transition from zero adjustment to statistically-significant non-zero adjustment.

Note also:

When setting QC flags, and especially when considering flag 3 or 4, there should be a tendency to apply higher flags (worse quality data) if the sensor fails soon afterwards. DMQC-2 encourages the use of flag 2 in the circumstances described in the DMQC manual.

4) Reference datasets

Maintaining carefully-prepared reference datasets, suitable for Argo DMQC is a critical activity. It was agreed at ADMT-6 that Coriolis would host and *update* reference datasets, using CCHDO as the route for acquiring new reference data. At present, Coriolis cannot undertake preparing reference datasets from scratch (eg transforming WOD05 into an Argo reference dataset).

Kobayashi summarised the problem of building an Argo reference dataset from published databases. He showed a slide illustrating the point that out of a complete holding of reference profiles (eg WOD05 supplemented by holdings of CCHDO), some profiles must be discarded because their quality is not reliable enough. Others must be discarded because they are not helpful for Argo QC (eg shallow profiles, marginal seas, oversampled regions which dominate the reference dataset).

4.1) Reference datasets in specific regions

Pacific and Indian:

JAMSTEC has prepared SeHYD for the Pacific, but this will not be modified while Kobayashi is away from JAMSTEC (visiting researcher in UK until July 2007). IOHB is an Indian Ocean Hydrobase.

SeHyd and IOHB are available in a form suitable as input files (wmo_boxes) for WJO/OW. IOHB has data formatted in both WJO standard levels and as full profiles. SeHyd is available only at WJO standard levels. A full-profile version could be produced, but not in the near future while Kobayashi is working away from JAMSTEC. Links were:

ftp: //ftp.jamstec.go.jp/pub/argo/data_set/IOHB.zip
ftp: //ftp.jamstec.go.jp/pub/argo/data_set/IOHB_for_WJO.zip
http: //www.jamstec.go.jp/ARGO/product/SeHyD_1.zip

Atlantic:

No activity reported on preparing a new Atlantic reference dataset.

Southern:

Wong has investigated Orsi's WOCE S. Ocean Atlas, but it does not seem to have a significant number of useful profiles that are not already included in WOD05.

S Atlantic:

SARDAC will pursue regional PIs vigorously to secure extra reference data.

Selection of profiles for reference database

Wong showed a list of criteria that had been used to select profiles for inclusion in the reference dataset distributed with WJO. For OW, some criteria had become redundant, and the list was revised to make it appropriate for building a reference dataset for OW. The new list is as follows:

1) Use only data that have passed all NODC quality control tests for observed level data.
2) Use all country codes.
3) Use only profiles that sampled deeper than 900 dbar.
4) Weed out all data points outside these ranges: $24 < S < 41$, $0.01 < P < 9999$, $0°C < T < 40°C$, except for WMO boxes with latitude > 60°N and latitude < 50°S, where $-2°C < T < 40°C$.
5) For WMO boxes that contain more than 10,000 profiles, only select profiles that are post-1995.
6) Eliminate nearby duplicates.
7) Do objective residual analysis using previously qc-d reference data to identify anomalies. Then do visual inspection of anomalies.
8) Identify each reference profile with a unique ID, e.g. under the parameter SOURCE.

When new reference datasets are being compiled or existing datasets are updated, the group compiling the dataset will be responsible for selecting which profiles are included.

> ***Recommendation:*** *DMQC-2 recommends in regions with adequate reference data, the standard run of the DMQC tools should use CTD data only, ie with BTL data disabled. If CTD data are too sparse, BTL data may be included.*

> ***Recommendation:*** *The basis for a complete Argo DMQC reference dataset should be: SeHyd in the Pacific (initially using the reduced-resolution version available on WJO levels, and replaced by the full-vertical-resolution version when JAMSTEC is able to make it available); IOHB (full profiles) in the Indian; Hydrobase in the Atlantic. Hydrobase will need to be translated into the correct input format for OW. WHOI will do this when time permits, but it was hoped this was not a huge task. Hydrobase has missing areas in the Atlantic section of the Southern Ocean. JB Sallee has prepared data from Orsi et al's WOCE Southern Ocean Atlas for use in OW. If any of the agreed baseline datasets has missing areas in the Southern Ocean, it may be possible to fill them in with Sallee's database.*

4.2) Use of float data in reference

DMQC-1 suggested that float data might be used as reference/check data if the DMQC adjustment was zero. Since then Gilson has identified 7 criteria which a float profile should satisfy if it is to be considered useful. This is further discussed in the AST-7 (2005) meeting report. The criteria proposed to AST-7 were:

1) No real-time data.
2) No floats that fail in < 1 year (i.e. available in D-mode but with < 36 cycles).
3) No cycles within 6 months of end of record (i.e. near end of long D-moded record).
4) No cycles which have salinity-drift adjustment (> .001 in bottom data, to distinguish from thermal lag adjustment at shallower levels).
5) No floats whose deepest level is < 800db.
6) No cycles following ones that have significant adjustment.
7) No cycles with < 90% of values (P,T,S) good.

Section 3.2 of the AST-7 report had encouraged the use of Argo data in reference datasets. Use of good Argo data in sparse areas is attractive, but if Argo has unidentified residual bias errors (too small to be identified and adjusted in DMQC, but non-zero mean), these could accumulate through successive use of Argo profiles as reference and result in a biased Argo dataset. Johnson expressed strong reservation that we do not yet enough experience to be sure that Argo data can be used safely without the risk of bias. DMQC-2 agreed that profiles satisfying 'Gilson's rules' could be used to clarify the probability that a float under inspection required adjustment, but did not recommend that Argo data should be a routine part of DMQC reference.

Gilson's rules were reviewed and agreed as reasonable. No operator had sufficient experience of using float data to propose any modification.

It was noted that OW software is set up so that three sets of reference data can exist in the reference WMO boxes (CTD, bottle, float), with each set enabled or disabled by operator choice. A reference dataset directory consisting of 'acceptable' float profiles in the correct format has not been compiled yet.

Kobayashi presented the results of a simulation exercise in which an idealised basin (which could represent a north pacific basin with decadal variability) was sampled by 'CTD cruises' and 'floats' over an 80-year period. CTD and float ‘observations’ had random error of appropriate size. Although the simulation is only preliminary, its results show that the phase and amplitude of the ocean variation becomes delayed and smaller by using the reference datasets including Argo data.

Joseph showed the results of experiments in the Arabian Sea. Use of good Argo data as reference reduced PSAL_ADJSUTED_ERROR (because of the increased number and more recent reference profiles), but did not significantly change PSAL_ADJUSTED.

> ***Recommendation:*** *At present, DMQC-2 did not endorse the systematic use of Argo data in reference datasets. The use of ‘buddy-checks’ to assist in evaluation of suggested adjustment from DMQC tools was encouraged.*

> ***Requirement:*** *If Argo data are used within DMQC, it is mandatory that this be recorded clearly in the SCIENTIFIC_CALIB_COMMENT.*

4.3) Naming convention

Version codes for the DMQC tool and reference database should be recorded in the HISTORY section and can be recorded in SCIENTIFIC_CALIBRATION_COMMENTS.

> ***Recommendation:*** *Since Coriolis will be the repository for reference datasets, they should develop an unambiguous identification system for reference datasets, which must be more specific than ‘WOD’ or ‘WOD-WJO’.*

5) Miscellaneous issues

5.1, 5.2, 5.3) Fields and format issues

Miscellaneous

Note that <PARAM>_QC should be zero if no DMQC has been performed on <PARAM> (eg when DM has been performed on PSAL, TEMP, PRES, but not on DOXY).

When an adjustment is applied to PSAL, CNDC_ADJUSTED may be fillvalue. If it is not fillvalue, CNDC_ADJUSTED must be recalculated to be consistent with (PRES_ADJSUTED, TEMP_ADJUSTED, PSAL_ADJUSTED).

> *Following email correspondence prior to DMQC-2, Wong will send the GDACS a list of compulsory fields that must be filled in D files. GDACs will use this for checking/rejecting D files submitted by DACs. See also action item under ‘format inconsistencies’.*

Use of ‘scientific_calib’ variables

Float 5900158 (JAMSTEC) was examined as an example. It was noted that the PARAMETER variable had not been completed to show all of PRES, TEMP, PSAL. The complete indexing of variables in PARAMETER is the only way of knowing which elements of the scientific_calib arrays correspond to which adjusted parameter.

The variables for recording calibration information (in particular PARAMETER, SCIENTIFIC_CALIB_COMMENT, CALIBRATION_DATE) have a number of common dimensions, including N_PROF, N_CALIB and N_PARAM.

After DMQC, N_CALIB takes a minimum value of 1. N_PARAM is always the number of <PARAM> variables reported by the float. Thus after DMQC has commenced for any variable, PARAMETER (dimension N_PARAM) must contain the character string for every <PARAM> variable in the file, including DOXY if it is a variable, regardless of whether or not DMQC has been performed for that variable. If no DM has been performed on <PARAM>, or if DM has been performed but the adjustment chosen was zero, then this information must be recorded in the corresponding element of SCIENTIFIC_CALIB_COMMENT.

The present practice at the majority of DM centres is to keep N_CALIB = 1, so that the details of all steps in PSAL adjustment (Thermal lag, WJO adjustment) are described in a single calibration comment. The present practice at JAMSTEC is to record PSAL adjustment in two steps with N_CALIB = 2. In this case the first element in the N_CALIB dimension for PRES, TEMP, DOXY may not be fillvalue – at least one set of calibration information is mandatory. The second element may be fillvalue for <PARAM>s for which there is no second calibration step.

When a calibration is revised/updated, an increase in N_CALIB is not required. The new calibration information overwrites the old information, and describes how to compute the new value of <PARAM>_ADJUSTED in the D file from <PARAM> in the D file.

Format inconsistencies:

Gilson reported that while parsing files at the GDAC for the mirror that is part of the SIO GUI, he had identified approximately 1500 files with some sort of format inconsistency, mainly R files. DMQC-2 welcomed this effort and encouraged him to continue to report inconsistencies to DACs in an effort to resolve them. Following the workshop, and taking into account discussion at the workshop, Gilson undertook further (stricter) format consistency checks and found a significantly larger number of D files that would now be considered to have inconsistent entries. (For example, files in which PSAL_ADJUSTED takes a value but TEMP_ADJUSTED had not been filled.) A final assessment of the number of inconsistencies is not available for including in this report. Wong is working on a list of format criteria that must be met in D files. These will be provided to GDACs with the intention that GDACs will check, and where appropriate reject, D files. Gilson will continue to notify DM centres to help them remove inconsistencies. A list of D file check criteria should be published elsewhere. It could be added as a later Annex to this report when it is agreed and stable.

> ***Action:*** *Wong, Gilson and others will continue to work on preparing a list of D file format checks for implementation at GDAC.*
>
> ***Question for DMT:*** *If a <PARAM> variable has a fillvalue, Reference Table 2 seems to suggest that <PARAM>_QC should take the value 9, indicating missing value, instead of the fillvalue for the <PARAM>_QC variable. Some instances of <PARAM>_QC = fillvalue had been found.*

Further reminder to operators of miscellaneous points:

If PRES_ADJUSTED_QC is bad (4), then all other <PARAM>_ADJUSTED_QC should also be 4.

If <PARAM>_ADJUSTED_QC is 4, then <PARAM>_ADJSUTED must be fillvalue.
Instances of out of range parameters (PSAL, PRES) should have <PARAM>_ADJUSTED_QC flag 4.
Values in netCDF files should not be IEEE NaN.
If <PARAM>_ADJUSTED is a real value <PARAM>_ADJUSTED_ERROR may not be fillvalue.

5.4) Implementation of adjustments determined from DMQC in real-time

RT adjustment of PSAL

There is an approved method for applying offsets to PSAL in RT, based on results of DM. The procedure is that RT DACs calculate the profile offset in the most recent D file available at GDAC, and apply this assuming persistence. RT DACs should be encouraged to adopt this procedure. Extrapolation of trend is not presently approved.

> ***Requirement:*** *DMQC-2 notes that with a growing number of D files available, further experiments should be undertaken to investigate whether the proportion of times when the assumption of persistence of offset provides an RT estimate closer to the final DM estimate than the unadjusted RT value.*

RT adjustment of PRES

DMQC-2 notes that a although RT adjustment of APEX PRES could be performed in a similar manner to PSAL (ie use persistence of most recent available D file), DMQC-2 does not recommend this because of the stated concerns about unknown bias.

5.5) Cell Thermal Mass (discussion led by Johnson)

Johnson reviewed the current status of Argo's ability to adjust PSAL to correct for biases due to cell thermal mass. A paper by Johnson, Toole and Larsen is accepted in JAOTech.

Johnson offers by e-mail a matlab fuction that applies cell thermal sensor lag correction to float data. Input from and output to NetCDF files as well as documentation of this DMQC step in those files are the responsibility of individual DACs.

> ***Note to DMT:*** *The Argo data system must record sensor type (SBE41 or SBE41CP) and if CP then what mode is used. (Continuous pumping with data reported are bin-averages, or 'spot sampling' with minimum 20 seconds pumping of cell before a measurement is recorded.) Also required is an ascent rate algorithm, which can be as simple as 'constant ascent rate in dbar per second after leaving deepest profile pressure' (constant rate is appropriate for APEX; SIO SOLOs have a depth-varying ascent rate).*

The correction is small in deep layers with weak vertical T gradient. It can approach order 0.1 in strong thermoclines and at the base of the mixed layer.

Therefore making cellTM correction should have no impact of DMQC adjustment of whole profiles, because DMQC adjustment tends to avoid parts of the water colum with strong gradients. Therefore there is no requirement to repeat DMQC analysis if cellTM is applied after DMQC.

The purpose of applying the cellTM correction is to achieve the best possible delayed-mode data in all parts of the water column. ***Recommendation:*** *There is no requirement to apply cellTM in real time because by definition the uncertainty in RT files is large because DM has not been performed. The RT uncertainty is already larger than the cellTM adjustment. Application of cellTM in RT is therefore optional.*

Requirement: *DMQC-2 encourages an experiment to be performed in which an adapted float logs 1 Hz data using a SBE41CP and various ascent rates, to enable confirmation of the cell thermal lag coefficients reported by the Johnson et al. JAOTech paper.*

Status of DACs preparation for implementation of cellTM in D mode:

meds: yes / kma: unknown / jma: yes / incois: yes / coriolis: need extra preparation before it could be implemented / csiro: yes (already applying it) / csio: willing to do it; need to acquire source code / bodc: not ready yet; has not compiled comprehensive list of sensor types and operation / aoml: PMEL already applying it; WHOI will get code; SIO apply it in D mode; UW will start if recommended by DMQC-2/

5.6) Pressure adjustment

It was assumed that operators of PROVOR, SIO SOLO and WHOI SOLO knew and understood the treatment of surface pressure offset in their platforms and how to use this information in DMQC. These platforms had been discussed at DMQC-1 and no further information was available.

For APEXs the situation is as follows:

1) A pressure reading is taken immediately before a float starts to descend. (DESCENT_START).
2) In APF8 This is truncated to zero if negative.
3) Add 5.
4) This number is reported in the next cycle as surface_pressure.

So the surface_pressure variable in the tech.nc file takes values of 5.0 or greater for APF8 controllers.

This surface_pressure parameter is used by the float as part of its mission management: it provides a threshold for stopping CTD pumping during ascent to avoid contamination near the surface. In addition this parameter provides the opportunity to infer pressure sensor calibration errors during post processing.

Consider for example a case in which the float had completed a normal surface drift period and the pressure sensor measured a value of +20 dbar immediately before starting a descent cycle. For APF8 controllers, 5 dbar is added and so this value is reported as surface_pressure = +25 during the next surface telemetry period. Since the CTD is switched off at a threshold chosen by the stored ‘surface_pressure’, pressure levels less than 25 will be unfilled in the next cycle ARGOS message.

The non-zero reading could occur because of pressure sensor calibration error (offset). It could also occur because of effects unrelated to sensor calibration error. There is no guarantee that the ‘surface_pressure’ was actually recorded at the surface, for example if grounded and stuck in mud, wave washover, inadequate buoyancy to reach the surface, etc. ‘surface_pressure’ is simply the pressure reading immediately before the clock triggers DESCENT_START.

*Thus **DMQC-2 recommends** that for APEXs, corrections for surface_pressure adjustment are not appropriate for RT. Considering the risk of introducing unknown biases (correcting for positive offsests but not for unknown negative offsets), the decision to adjust PRES in RT should only be taken by AST after consideration of the risks.*

The behaviour of 'surface-pressure' should be examined in DM, and the most likely explanation for values other than zero (ie reported value greater than 5 for APF8) determined. If the behaviour does indicate sensor calibration drift, corrections can be made. The procedure should be: Calculate CNDC(PRES, TEMP, PSAL) / apply adjustment to create PRES_ADJUSTED / calculate PSAL_ADJUSTED(PRES_ADJUSTED, TEMP, CNDC).

Shortly after the workshop, Thierry circulated information concerning the surface pressure offset in 18433 profiles from 633 PROVOR platforms. 12.8% of profiles had a negative pressure offset, but nearly all of these (11.95%) had an offset between -5 and 0 dbar. Therefore there are rather few examples of a significant negative offset. Pending discussion of these results (and possible further breakdown by detailed pressure sensor type if possible) a view can be taken about likely bias due to truncation in APEX floats.

Summary of present practice on pressure adjustment for APEXs:

jma/JAMSTEC: If surface_pressure < 20, adjust PRES and PSAL. If surface_pressure > 20 assume surface_pressure value is misleading and do not adjust PRES.

aoml/UW: If surface_pressure < 5 (reported value < 10 for APF8) do not adjust PRES. Quote PRES uncertainty 5 dbar. If surface_pressure > 5 (reported value >10 for APF8) make adjustment to PRES but not in cases where surface_pressure seems misleading (as discussed above).

aoml/PMEL: adjust PRES and PSAL; threshold not defined; they will review their practice.

incois, csiro, csio, coriolis/ifremer and coriolis/awi do not presently inspect the surface_pressure variable in the tech file.

bodc: surface_pressure is inspected, but no PRES adjustment at present.

Remaining issues on surface pressure offset:

*PROVOR and SOLO users are **requested** to inspect the data in their superior (non-truncated) telemetry and advise on frequency distribution of negative pressure offsets. If APEX users adjust for positive but not negative errors, the dataset will become biased. It is recognised that several types of pressure sensors have been used across the Argo fleet and there is no guarantee that all sensor types will have the same error distribution.*

***Proposal**: APEX users should make correction to PRES and PSAL if surface_pressure is > 5 (ie telemetry value > 10 for APF8). (Note PROVOR make internal adjustment if magnitude > 6 dbar).*

The issue of surface_pressure truncation had come up at the Argo APEX users workshop in 2005, but during the tour of Webb's facility, Webb proposed a formal letter from Argo to request the change and initiate the development.

***Action:** King will write to Webb Research on behalf of DMQC-2 and request that they address the problem of truncating negative surface pressure offsets. DMQC-2 suggests the* *use of a median of surface pressure determinations over a typical wave period (eg >= 10 seconds) rather than a single spot value.*

5.7) Manuals and documents

QC manual: *Wong will update the QC manual to reflect the conclusions of DMQC-2, and will specifically include the list of checks that GDACs should be asked to carry out to test for mandatory fields and legal values in D mode files.*

'DMQC cookbook': There has been a request for some time for a DMQC cookbook. DMQC-2 considered that with the introduction of the new OW and consequent planned withdrawal of WJO and BS, it would be inappropriate to prepare a cookbook until the procedures for use of OW have stabilised. The new tool has fundamentally new options to control (eg the piecewise linear algorithm) and more experience is needed in their use. DMQC-2 therefore decided not to progress the preparation of a cookbook at the present time.

Reminder to DMQC operators: Wong reminded those present that when emailing comments/problems/etc about DM issues, we are encouraged to use the argo-dm-dm@jcommops.org mailing list, to which all DM operators should be subscribed. This provides a secure record of comments and replies, and enables operators to benefit from the discussion even if they are not directly contributing. Note that argo-dm is data management; argo-dm-dm is delayed mode; argo-dm-rt is for real time.

5.8) Abnormal PSAL at base of profiles

Joseph and Tchen showed examples in which a 'hook' in PSAL may be observed in T-S diagrams at the bottom of the profile.(eg csiro/5900029; incois/2900552). The hook is usually (but not exclusively) towards higher salinities, so even though the effect is small order(0.002) in the example float, there becomes a possibility of bias. The 'hook' appearance occurs when two measurements are reported at nearly identical pressures (eg 2005 & 2000 dbar). The first measurement is 'bottom of profile' and the second is from the pressure lookup table.

If the bottom of profile is, for example, at 1999, then the first lookup pressure might be 1900, so the appearance of the hook is not pronounced. This does not mean the effect is absent, but it is too small to detect. SBE are aware of the problem and are considering possible explanations. One hypothesis is that the first (deepest) measurement taken after the APEX starts the CTD is subject to a thermal inertia effect that is not being identified and corrected. During the descent to maximum pressure phase of a PnP APEX, the sensor is somewhat shielded from the ambient flow and there is no pumping of the conductivity cell.

5.9) QC for TEMP

There was a brief discussion of DMQC for TEMP. DMQC-2 had no new suggestions on how to identify bad TEMP data. Visual inspection and operator experience remain the main approach.

5.10) Objective analysis in support of QC of floats

Thierry presented results of tests at Coriolis of use of objective mapping to identify suspicious values in float data. Out of 11,500 profiles tested, about 5 anomalous profiles were identified. The anomalies have been notified to the corresponding DACs and have been corrected. In addition, the procedure allows to point out some floats that were not consistent with the reference climatology.

Thierry will work with Perkin on these MEDS floats to identify why MEDS accepted the particular adjustment under investigation. The floats were in a region of strong horizontal gradient, and the MEDS decision had been supported by buddy checks

6) Other parameters

6.1) Oxygen

Kobayashi presented the results of a study of oxygen measurements on 9 Japanese floats. This covered SBE43 and Aanderaa Optode sensors. Sensor performance was evaluated by comparison with research cruise oxygen bottle samples from four different cruises in 2005 and 2006. A manuscript on the results has been submitted in a Japanese domestic journal, but is available with an English Abstract.

Sensor bias: A consistent pattern was observed across both sensor types. In the deeper layers ($T < 4$), there is a mean bias with float oxygen 5 μmol/kg lower than bottle samples. Higher in the water column, the mean bias of float data becomes 20 μmol/kg, with errors as large as 40 μmol/kg. These errors are much larger than the suggested uncertainty provided by the manufacturers.

Sensor drift: The upper ocean had too much variability to assess sensor drift over the deployment period of 7 to 19 months. In deeper layers, the sensors appeared to be stable at order 5 μmol/kg, but this was difficult to confirm with great reliability.

Users of DO floats: Kobayashi identified approximately 75 oxygen floats based on metadata files at the GDAC. These included 33 reporting SBE data, 31 reporting Aanderaa and 10 unknown.

Country	Aanderaa	SBE	Unknown
Norway			2
Canada	12		
Chile			6
Germany	10		2
Japan	6	3	
USA	1	30	
Australia	2		
Total	31	33	10

The USA includes 5 UW floats equipped with both Aanderaa and SBE sensors. The metadata files identify 4 as SBE and 1 as Aanderaa. Each float reports just one DOXY variable in the profile data. According to UW's website, 4 floats are transmitting data from both sensors and the SBE data are reported. The float described as Aanderaa in the metadata measures DO by Aanderaa only.

DO data obtained by Aanderaa needs shore-based calibration/adjustment, which modifies by up to 10% of the value at a depth of 2000dbar. The quality of the modified Aanderaa data is comparable to the SBE data (for which routine shore-based-adjustment is not required).

Kobayashi summarised the procedures required for shore-based calibration/adjustment of float oxygen data. This usually involves a requirement for TEMP_DOXY. Where this is not reported or bad, it can be estimated from TEMP with a small resulting error.

Some APEX floats do not send TEMP_DOXY data even if they have an Aanderaa DO sensor. Thus, it is very important that DO sensor type in Meta-data be filled, since it is the only way to identify the sensor type.

Kobayashi reported that he had shown his results concerning sensor bias to D. Gilbert, who agreed that Canadian oxygen floats have a similar behaviour to the Japanese.

> ***Recommendation:*** *Argo is not yet ready to start DMQC for oxygen. The statistical techniques are designed to estimate coefficients in a model for sensor error (in the case of PSAL the model is a simple scaling in CNDC). There is no function form for float oxygen sensor error that explains the offsets reported by Kobayashi, so statistics-based DMQC cannot be performed.*

7) Next meeting

The plenary session closed at 1700 on Friday 6 October 2006, with champagne.

Side meetings and discussions in small groups were held on Saturday 7 October.

Another workshop will be arranged when consensus suggests it will be useful. Until then, issues will be discussed in the argo-dm-dm forum.

Annex – 1 List of workshop participants

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Annex – 2 Final adopted Agenda

Second Argo Delayed-Mode Quality Control Workshop (DMQC-2)

Carriage House

Woods Hole Oceanographic Institution

Wednesday 4 October to Saturday 7 October 2006

Agenda v3 (03 Oct 2006)

Convenors:

Brian King, NOC, Southampton, UK

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Sudheer Joseph, INCOIS, Hyderabad, India

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Convene at 0830 for a prompt 0900 start on day 1. Detailed timing to be agreed at the workshop. (Names in brackets indicate that the person has notified us that they have planned a contribution to the topic, or that we expect they will want to because they have been active in email discussion)

1) Introduction, Purpose and Aims of Workshop

2) Progress with DMQC of PSAL since DMQC-1 (all dmqc operators to contribute)

- 2.1) Review of current status of DMQC effort across the program
- 2.2) Overall status of D files at GDACs
- 2.3) Report on progress/status at each DAC, to include identification of any major reasons for hold-ups and problems that need to be addressed during the workshop if not already on the agenda.
- 2.4) Descriptions and demonstrations of new software and tools available since DMQC-1. (Wong; any others ?)

3) PSAL methods: review and discussion of success of implementation of recommendations from DMQC-1

- 3.1) Review of DMQC intercomparison exercise. (Tchen)
- 3.2) Sliding window and mapping scales
- 3.3) Threshold for adjustment; continuity of adjustment if series is split
- 3.4) With increasing experience, is it becoming easier to recognise generic patterns of PSAL error, or are we observing increasing numbers of 'difficult' floats ?
- 3.5) Discussion of cases requiring 'manual intervention' when the software or reference data is inadequate
- 3.6) Diagnostic plots: do we use the same set as presented at DMQC-1, or are there new diagnostic tools that operators have found helpful ?

4) PSAL methods: reference data

- 4.1) Operators to report on any efforts they have made to enhance reference datasets
  Pacific (Kobayashi)
  Indian (Kobayashi)
  Atlantic (Thierry)
  Southern (Wong)
- 4.2) Report on any experiments with use of float data as reference. Agreement on protocols for doing this.
- 4.3) Managing reference datasets; inclusion of CTD data; version control and naming convention; (Kobayashi, Coriolis ?, Wong)

5) Miscellaneous issues

- 5.1) Requirements for filling fields other than PARAM_ADJUSTED, eg
  - 5.1a) Assignment of PARAM_ADJUSTED_ERROR
  - 5.1b) Tracking of updates, uniform use of CALIBRATION_DATE, etc
  - 5.1c) Consistent use of A and D modes, and review of fields that must be filled in each mode (Gilson, Wong, Tchen)
- 5.2) Review use of HISTORY: any remaining comments or questions ?
- 5.3) Any other unresolved format issues
- 5.4) Implementation of adjustments determined from DMQC in real-time (Coriolis, Perkin)
- 5.5) CTD Sensor response (Johnson)
  - 5.5a) Application in delayed mode
  - 5.5b) Advice to RT centres on application in real time processing
  - 5.5c) Possible inclusion in onboard processing in SBE 41cp
- 5.6) Pressure correction (Wong)
- 5.7) Documentation: Manuals, cookbooks, etc. (Wong)
- 5.8) Abnormal PSAL at base of profiles (Joseph, Tchen)
- 5.9) QC for TEMP

6) Other parameters

- 6.1) Oxygen (Kobayashi)

7) Any other Business