QARTOD — QUALITY ASSURANCE OF REAL-TIME OCEANOGRAPHIC DATA

QARTOD IV – Final Report

Fourth Workshop on the QC/QA of Real-Time Data

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TABLE OF CONTENTS

Quality Assurance of Real-Time Oceanographic Data
QARTOD IV – Final Report
Fourth Workshop on the QC/QA of Real-Time Data
June 21 – 23, 2006 – Woods Hole Oceanographic Institution
Woods Hole, MA

INTRODUCTION

QARTOD is a continuing multi-agency effort formed to address the quality assurance and quality control issues of the Integrated Ocean Observing System (IOOS) community. The first workshop was held at the NOAA NDBC office in Bay St. Louis, MS in the winter of 2003. Over 80 participants attended with the primary task of developing minimum standards for calibration, quality assurance (QA) and quality control (QC) methods, and metadata. The workshop resulted in a report that summarized the recommendations on these issues and on future workshops. QARTOD II (second workshop) was held February 28-March 2, 2005 in Norfolk, VA, and focused on QA/QC issues in HF radar measurements and wave and current measurements' unique calibration and metadata requirements. QARTOD III was held on November 2-4, 2005 at the Scripps Institution of Oceanography, La Jolla, CA. It continued the work on waves and current measurements, as well as commencing work on CTD measurements and HF Radar. QARTOD IV was held at the Woods Hole Oceanographic Institution, June 21 - 23, 2006. Related materials are posted on the QARTOD website: http://qartod.org.

QARTOD addresses the challenges related to the collection, distribution and description of real-time oceanographic data. One of the primary challenges facing the oceanographic community will be the fast and accurate assessment of the quality of data streaming from the IOOS partner systems. Operational data aggregation and assembly from distributed data sources will be essential to the ability to adequately describe and predict the physical, chemical and biological state of the coastal ocean. These activities demand a trustworthy and consistent quality description for every observation distributed as part of IOOS. Significant progress was accomplished in previous workshops towards the definition of requirements both for data evaluation and relevant data flags for real-time QC. The intent of QARTOD IV was to report on the recommended quality (QC) descriptions for parameters such as waves and currents and to develop guides for best practices to assure data quality.

WORKSHOP ORGANIZATION & PRESENTATIONS

The QARTOD IV workshop focused participants into the following four areas of interest: waves, *in situ* currents, CTD measurements and dissolved oxygen. The waves and currents groups reported on results from previous workshops on assessing data quality and defining relevant flags for real-time release of data. Efforts to define best practices and shared resources for promoting quality assurance (QA) were begun at QARTOD IV. The CTD group was reorganized and the dissolved oxygen (DO) group was newly formed. All the groups decided to focus on QA at QARTOD IV. The CTD and DO groups plan to work towards the development of QC standards subsequent to the QARTOD IV workshop. Metadata experts from the Oceans.US Data Management and Communications (DMAC) guided each group towards the development of metadata minimum standards within their particular area of focus. The workshop agenda and list of participants can be found in Appendices A and B, respectively.

After the WHOI welcome and a brief history of past QARTOD efforts, a summary of the status of IOOS and DMAC was presented. Efforts of the WMO/JCOMM and international efforts in addressing QA/QC in real-time oceanographic data were addressed by other guest speakers. Presentations provided by the guest speakers are attached in Appendix C. Reports on QC definitions and flags from the In Situ Currents and Waves groups as well as updates and introductory presentations from the CTD and DO groups are also included in Appendix C.

Seven discussion topics were articulated prior to the workshop. These topics were intended to focus discussion during the workshop break-out sessions and to facilitate cross-team discussion during the report out process. Please refer to Appendix D for detailed notes taken during the break-out sessions and spreadsheets addressing the seven discussion topics.

1) Identify existing and emerging standards that should be considered.

2) List the manufacturer's specifications that should be used to evaluate the instrument.

3) Identify, discuss and document processes a user can employ to confirm that a sensor is producing the highest quality data.

4) Identify potential options or partnerships to conduct field verification of the system while deployed.

5) Identify available venues where QA-related issues and information can be exchanged among users.

6) Identify centers where instruments can be sent for calibration. Document sites where users can compare their sensors to established reference sensors.

7) Does the QC standard for this parameter address bio-fouling and fault tolerance?

Appendix D also includes a report from the Metadata Team, which had members sitting in each of the focus areas during the first two days and hosted discussions for a half-day on the last day of QARTOD IV.

CONCLUSIONS

QARTOD was encouraged to continue its effort towards the development of a community dedicated to defining and promoting standards in QA/QC in real-time oceanographic data. Members of the group were encouraged to participate in the Oceans.US DMAC, as they proceed in establishing minimum standards in QA/QC as part of the nascent IOOS implementation.

One point of concern was the adoption by previous QARTOD workshop participants of data quality flag definitions that appear to be inconsistent with some international and national standards. The QARTOD IV body discussed this issue, but determined that the order of the flags is not important, as long as the metadata reflects the definitions (see Knebele, Woodruff in Appendix C).

ACKNOWLEGEMENTS

The workshop was funded by NOAA (Cooperative Agreement No. NA17RJ1223 sub-point 39), with additional support provided by Oceans.US and the WHOI CICOR office. Facilitators from NOAA NOS Special Projects Office provided support in organizing workshop materials and providing notes on proceedings for each breakout group.

ABOVE: QARTOD IV Participants

BELOW: QARTOD IV Organizing Committee

LEFT: Christoph Waldmann (University of Bremen, Germany) briefs the QARTOD IV participants.

APPENDICES

APPENDIX A – WORKSHOP AGENDA

QARTOD IV Agenda
Fourth Workshop on the QC/QA of Real-Time Oceanographic Data
June 21 - 23, 2006
Woods Hole Oceanographic Institution – Clark 507/Quissett Campus

WEDNESDAY - JUNE 21, 2006

7:30 - 8:30	REGISTRATION & CONTINENTAL BREAKFAST
8:30-9:20	INTRODUCTION • WHOI Welcome - Robert Detrick Vice President of WHOI's Marine Facilities and Operations / Chairman ORION Observatory Steering Committee • QARTOD History & Workshop Goals - Bill Burnett, NOAA/ NDBC • DMAC/IOOS & QARTOD - Kurt Schnebele NOAA/NODC
9:20-10:10	GROUP REPORTS on QC • In Situ Currents QC Report - Bill Burnett, NOAA/ NDBC • Waves QC Report - Richard Bouchard, NOAA/NDBC
10:10 - 10:30	BREAK
10:30 - 11:20	GROUP UPDATES on QC • CTD - Jim Boyd NOAA/CSC • Dissolved Oxygen - Tim Koles University of Maryland/ • Center for Environmental Science/Chesapeake Biological Laboratory
11:20 - 11:45	INTERNATIONAL STANDARDS and COORDINATION EFFORTS – • Efforts through the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) - Scott Woodruff - NOAA/Earth System Research • Efforts from Abroad - Christoph Waldmann - Research Center Ocean Margins / University of Bremen
11:45- 1:15	LUNCH / TOURS
1:15 - 1:30	CHARGE to BREAKOUT GROUPS – • Kim Cohen NOAA/NOS/Office of Special Projects
1:30 - 3:00	BREAKOUT GROUPS (Facilitated discussions: In situ Currents, Waves, CTD and DO)
3:00 - 3:20	BREAK
3:20 - 4:40	BREAKOUT GROUPS (as above)
6:30 – 9:00	Cocktails until 7pm followed by New England Clambake at the Jonsson Center

THURSDAY - June 22, 2006

8:00 - 8:30	Continental Breakfast
8:30 - 8:45	Review Day 1 / Day 2 Guidance • Mark Bushnell, NOAA/NOS/Center for Operational Oceanographic Products Services
8:45 - 10:00	Breakout groups (as above)
10:00 - 10:20	BREAK
10:20 - 11:45	Breakout groups (as above)
11:45 - 1:15	LUNCH/Tours
1:15 - 2:45	Groups Develop Materials for Report Out
2:45 - 3:00	BREAK
3:00 - 4:45	Report QA/QC recommendations from each of the four groups • Questions and Open Discussion
4:45 – 6:30	Cocktail Reception in Clark 507

FRIDAY - June 23, 2006

8:00 - 8:30	Continental Breakfast
8:30 - 8:45	Welcome to MetaData Special Session • Julie Bosch, NOAA/National Coastal Data Development Center
8:45 - 10:00 (MSM)	Breakout groups to review & finalize Minimum Standards in Metadata
10:00 - 10:20	BREAK
10:20 - 11:40	Report out on MSM for each group in plenary
11:40 - 12:00	Closing Statements
12:00*	BOX LUNCH provided if requested on registration form

* NOTE if you are trying to catch the NOON bus to Logan/Boston, please let Judy know ASAP.

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Clark 507/Quissett Campus
June 21 - 23, 2006

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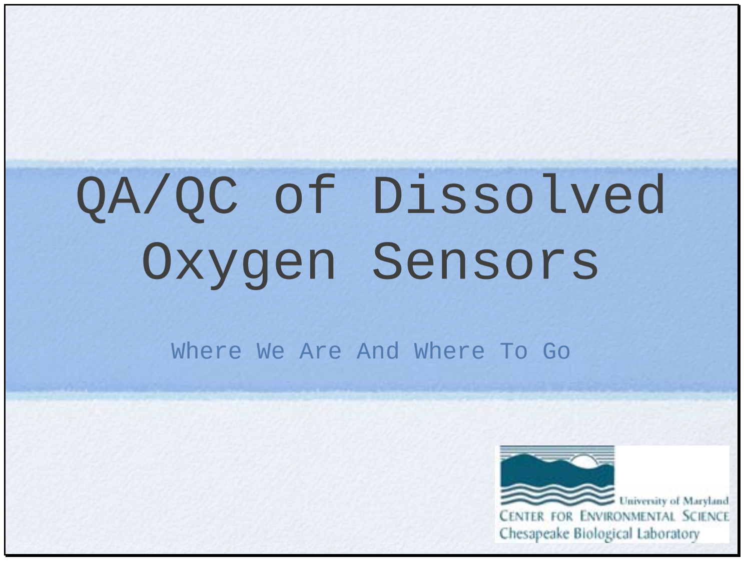
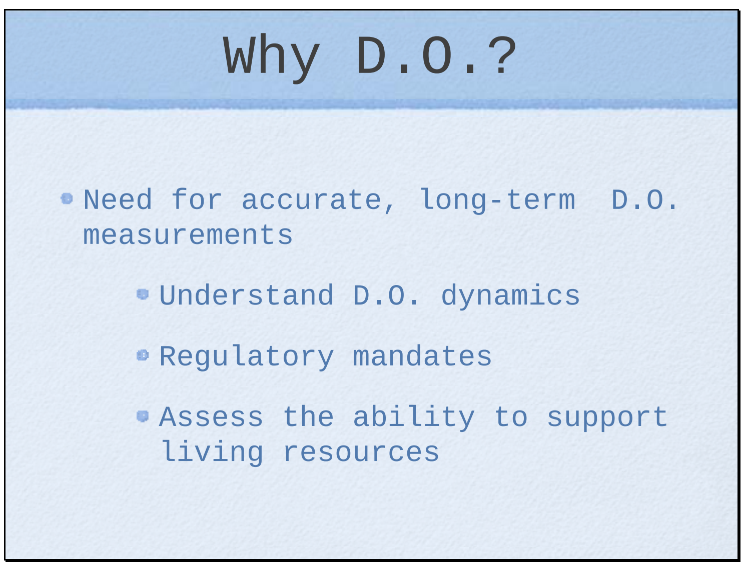
APPENDIX C - PLENARY PRESENTATIONS

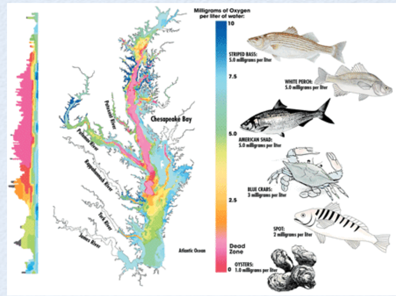
APPENDIX C-1: QA/QC OF DISSOLVED OXYGEN SENSORS





"Dead Zones"

- Due to nutrient over-enrichment
- Occurrence is increasing
- Tied closely to increases in human activities
- Chesapeake Bay, Mississippi River Delta, etc.



Chesapeake Bay Foundation

Why D.O. for QARTOD?

- Sensors viewed as:
  - Unreliable for long-term deployments
  - Expensive to maintain
  - Difficult to calibrate
  - Challenging due to gradual failure/degradation of data

Why D.O. for QARTOD?

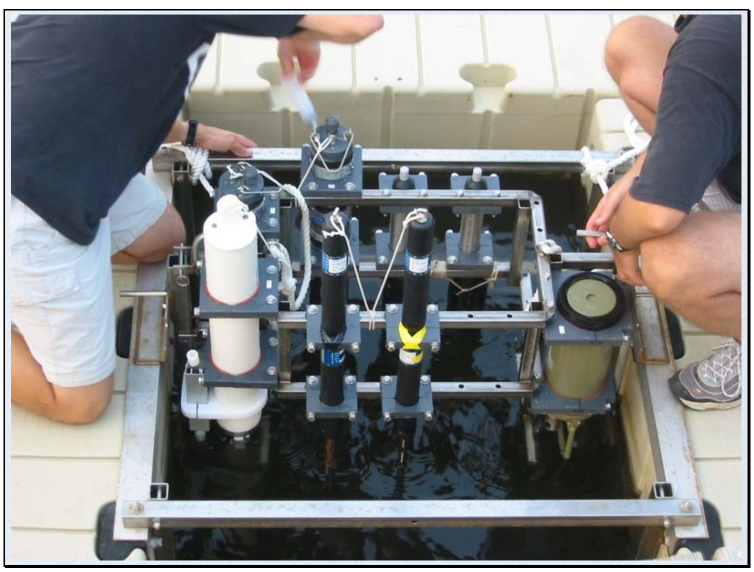
- Some aspects of each issue will need to be addressed through instrument design and newer technologies
- Each issue can benefit significantly from standardized QA/QC protocols
  - Increase the use in real-time applications
  - Improve the quantity and the quality of the data

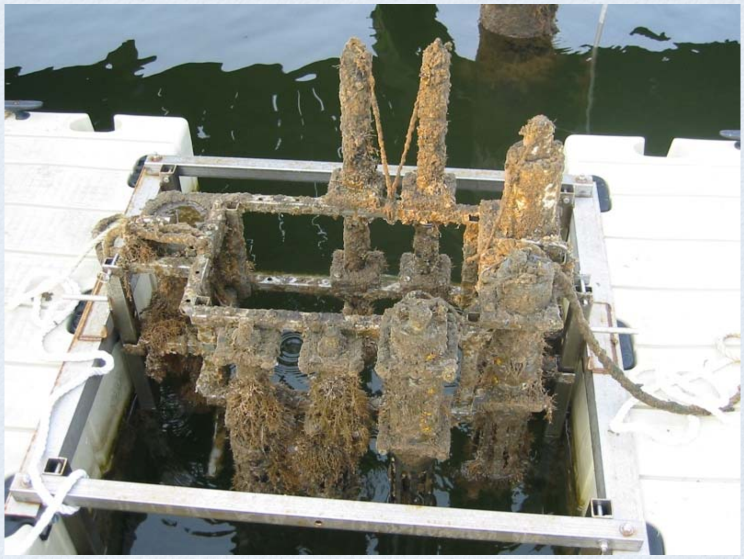
ACT/Orion D.O. Workshop

- "Dissolved Oxygen Probes: Making Oxygen Measurements Routine Like Temperature"
- January 4-6, 2006
- University of South Florida, St. Petersburg
- Call for the standardization of calibration
- procedures
- Establishment of calibration facilities
- Recognized the need for skilled technicians, training opportunities

Issues Surrounding D.O. QA/QC

- BIOFOULING
  - More of a problem in coastal environments
  - Main reason sensors are considered unreliable for long-term deployment
  - Significantly increases the cost of monitoring
  - Elimination of is primarily a hardware issue, but QA/QC issue until that point





Issues Surrounding D.O. QA/QC

- D.O. measurements require the input from both temperature and conductivity sensors
- Scientific vs. Management (Ocean vs. Coastal)
- Moored applications vs. Autonomous Profilers
- High precision/expensive vs. Lower precision/disposable

Issues Surrounding D.O. QA/QC

- Different technologies are available to measure D.O.
  - Galvanic
  - Polarographic, Pulsed and Steady-State
  - Optical (Two different methods)
- Quality of data closely tied to skill of user

Potential QA Solutions

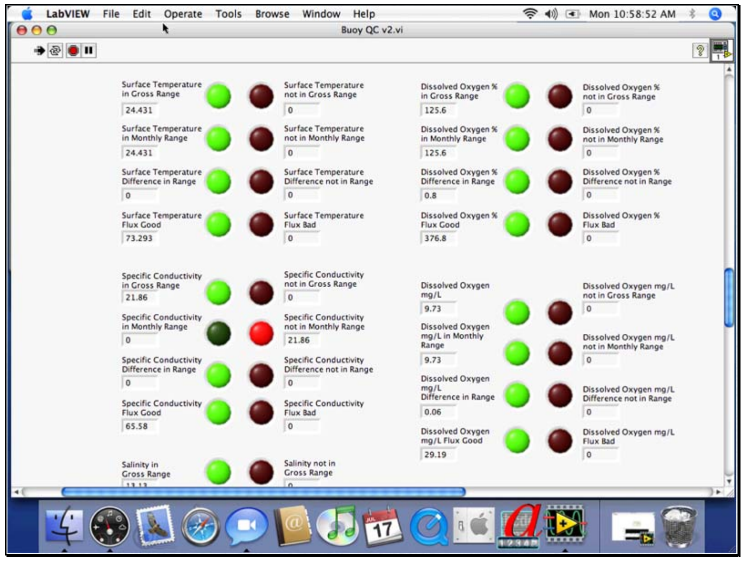
- What are people doing now?
- Identify the best ways to contend with biofouling
- Identify the specific requirements for each of the existing technologies
- Identify coastal zones/areas and define QA requirements
- Identify and suggest training requirements

Potential QC Solutions

- What are people doing now?
- Use of ranges, gradient tests, “stuck” tests, etc - Identify source for limits and how to perform
- Use Winkler titrations to assess the accuracy of the data
- Use linear regression to post correct the data - Standardize the handling of data

MetaData

- What are the metadata requirements needed for DO measurement?
- Date, Time, Position/Location, Instrument Type, Calibration Date and Time, Calibration Values, Length of Deployment, etc......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Buoy QC v2.vi
Surface Temperature in Gross Range
24.431
Surface Temperature not in Gross Range
0
Surface Temperature in Monthly Range
24.431
Surface Temperature not in Monthly Range
0
Surface Temperature Difference in Range
0
Surface Temperature Difference not in Range
0
Surface Temperature Flux Good
73.293
Surface Temperature Flux Bad
0
Dissolved Oxygen % in Gross Range
125.6
Dissolved Oxygen % not in Gross Range
0
Dissolved Oxygen % in Monthly Range
125.6
Dissolved Oxygen % not in Monthly Range
0
Dissolved Oxygen % Difference in Range
0.8
Dissolved Oxygen % Difference not in Range
0
Dissolved Oxygen % Flux Good
376.8
Dissolved Oxygen % Flux Bad
0
Specific Conductivity in Gross Range
21.86
Specific Conductivity not in Gross Range
0
Specific Conductivity in Monthly Range
0
Specific Conductivity not in Monthly Range
21.86
Specific Conductivity Difference in Range
0
Specific Conductivity Difference not in Range
0
Specific Conductivity Flux Good
65.58
Specific Conductivity Flux Bad
0
Dissolved Oxygen mg/L
9.73
Dissolved Oxygen mg/L not in Gross Range
0
Dissolved Oxygen mg/L in Monthly Range
9.73
Dissolved Oxygen mg/L not in Monthly Range
0
Dissolved Oxygen mg/L Difference in Range
0.06
Dissolved Oxygen mg/L Difference not in Range
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Dissolved Oxygen mg/L Flux Bad
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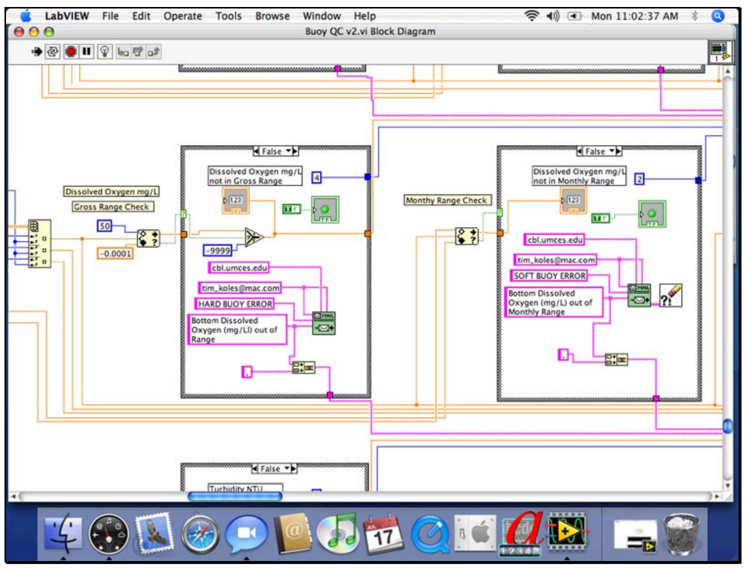
Salinity in Gross Range
Salinity not in Gross Range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Dissolved Oxygen mg/L not in Gross Range
Dissolved Oxygen mg/L
Gross Range Check
50
-0.0001
-9999
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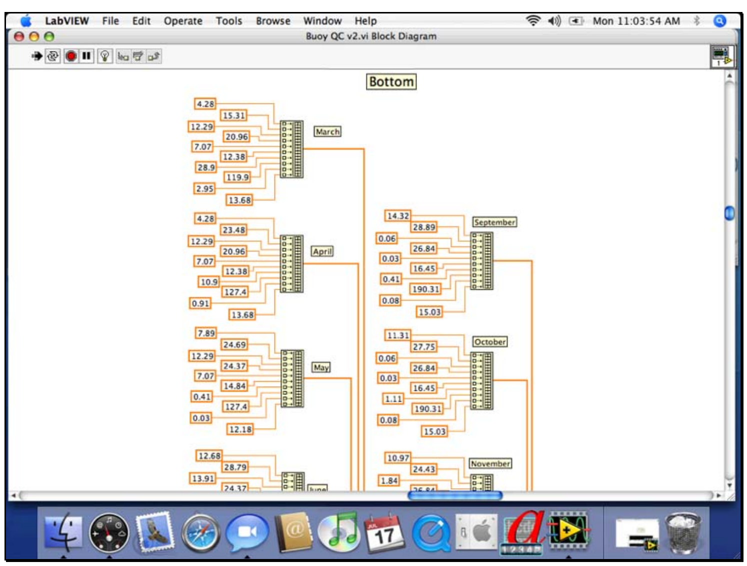
tim_koles@mac.com
HARD BUOY ERROR
Bottom Dissolved Oxygen (mg/L) out of Range
Monthy Range Check
Dissolved Oxygen mg/L not in Monthly Range
SOFT BUOY ERROR
Bottom Dissolved Oxygen (mg/L) out of Monthly Range
Turbidity NTU


LabVIEW File Edit Operate Tools Browse Window Help
Mon 11:03:54 AM
Buoy QC v2.vi Block Diagram
Bottom
4.28
15.31
12.29
20.96
7.07
12.38
28.9
119.9
2.95
13.68
March
4.28
23.48
12.29
20.96
7.07
12.38
10.9
127.4
0.91
13.68
April
7.89
24.69
12.29
24.37
7.07
14.84
0.41
127.4
0.03
12.18
May
12.68
28.79
13.91
June
14.32
28.89
0.06
26.84
0.03
16.45
0.41
190.31
0.08
15.03
September
11.31
27.75
0.06
26.84
0.03
16.45
1.11
190.31
0.08
15.03
October
10.97
24.43
1.84
November

APPENDIX C-2: GUIDANCE TO THE BREAKOUT GROUPS

Guidance to the Breakout Groups

QARTOD IV

June 21 – June 23, 2006

Goals and Objectives

Objective: To raise awareness about the need for QA and to document practices that lead to higher quality data for:

A. *In-situ currents*
B. *Waves*
C. *CTDs*
D. *Dissolved Oxygen*

- *Longer-term goal is the development of a working QA strategy or standard (requires an iterative review)*
- *Breakout sessions are the first step in the process*

Focus Questions ...

1. Identify existing and emerging standards that should be considered.
2. List manufacturer specifications that should be used to evaluate the instrument.
3. Identify processes that should be used ensure that a sensor is producing the highest quality data.
4. Identify options to collect field verification of the system while deployed

Focus Questions (cont'd) ...

5. Identify available venues where QA-related issues and information can be exchanged among users.
6. Identify centers where instruments can be sent for calibration; Document sites where users can compare their sensors to established reference sensors.
7. * Parameter-specific question (re: biofouling, fault tolerance, and noise)
8. Additional QA topics that should be addressed?

Roles

1. **TECHNICAL LEAD**
   - *Guide discussion; identify key issues*
   - *Clarify technical questions*
   - *Present results in plenary*
2. **FACILITATOR** *(*not subject-matter experts)*
   - *Help to keep the group on task and on time*
   - *Record discussion*
   - *Help prepare report out*
3. **METADATA EXPERT**
   - *Develop draft metadata recommendations*
   - *Present "straw man" to break outs on Day 3*
   - *Lead discussion to edit and refine record*
   - *Present revised metadata records in plenary*
4. **VOLUNTEER NOTETAKER(S)?** – *laptop provided*

Process and Schedule

WEDNESDAY

- *Breakout Groups meet to address pre-defined topics and questions*

THURSDAY

- *Groups work to complete questions and template*
- *Re-convene at 3pm for plenary session to report and discuss results*

FRIDAY

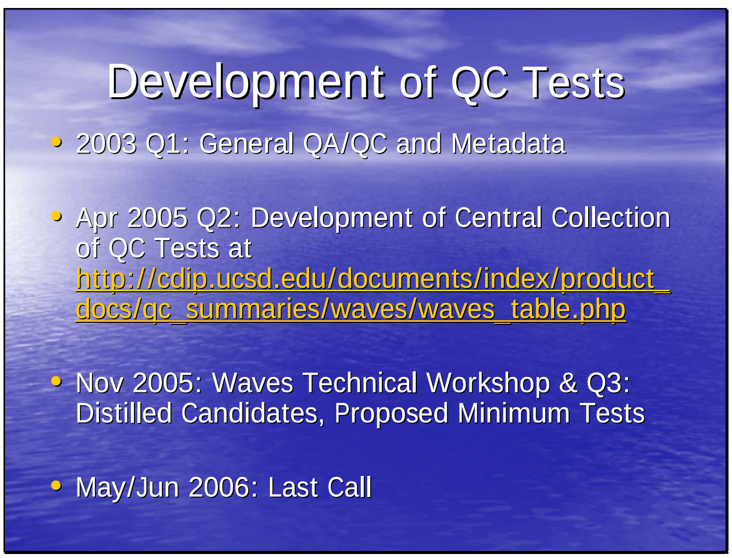
- *Breakout groups meet for metadata session*
- *Metadata expert presents "strawman"*
- *Participants revise/refine metadata fields*
- *Metadata experts present in plenary*

Materials

- Series of QA tables (templates) to address each question in breakouts
- QARTOD IV Metadata Session guidance document
- Metadata Content Worksheet

Questions?

APPENDIX C-3: PROPOSED MINIMUM QUALITY CONTROL TESTS FOR WAVE MEASUREMENTS



Definitions

- ***QC*** – Analyze and verify the data stream to assure the highest quality data possible.
- ***QA*** - Verify that instrumentation is calibrated and tested to assure collection of the highest quality data possible.
- ***Hard flags*** - data rejected.
- ***Soft flags*** - data flagged, but not rejected.

TIME SERIES (Raw Calibrated Data)				
Category	**Criteria**	**Order**	**Flag**	**Action**
Data Gaps	Consecutive N missing data. Maximum number of missing data.	1	Soft	N is user defined. Include in % count.
Spikes	User defined Points >= M*std with P iterations	2	Soft	Interpolate/extrapolate up to N points. N is user defined. M can be user defined, recommended M=4. Include in % count.
Range test	Location, instrument defined.	2		Max/min user defined.
			1. Soft	1. Interpolate/extrapolate up to n points. N is user defined. Include in % count.
			2. Hard	2. Instrument spec exceeded, reject.
Mean shift (segments)	A mean shift "P" occurs in this time series.	3	Hard	Reject entire record. P is user defined.
Acceleration test	User defined (a>M*g)	3	Soft	Recommended M<=1/2. Interpolate/extrapolate up to N points. N is user defined. Include in % count.
Mean test, variance test	User defined, location dependent	4	Soft/Hard	Flag/Reject if exceeds threshold.
Percent points good	Check for M% good data (based on above 6 criteria)	5	Hard	Recommended M>=90%

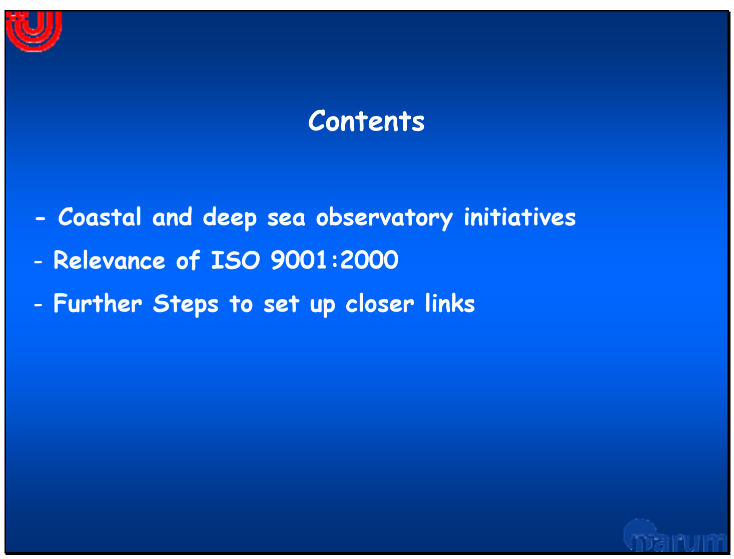
SPECTRAL VALUES				
Category	**Criteria**	**Order**	**Flag**	**Action**
NON-DIRECTIONAL:				
Operational frequency range test	*defined by the environment and instrument	1	1. Soft 2.Hard	1. Max/min user defined. 2. Instrument spec exceeded, reject.
DIRECTIONAL:				
Incident low frequency energy direction	Location defined	1	Soft	User defined
Check factors, ratio	Should be ~ = 1, check over time. Location dependent	1	Soft	User defined

PARAMETER VALUES: Height, Period, Direction, Spreading				
Category	**Criteria**	**Order**	**Flag**	**Action**
Wave parameters max/min/acceptable range (H,T,D,S)	Location dependent	1	1. Hard 2. Soft	User defined limits. 1. Gross or Global Limit(s): Reject entire record if H exceeds limit otherwise reject individual parameter. 2. Narrower Seasonal/Location limits – flag.
Time continuity	Short range history (applied to H)	2	Soft	User defined

Next

- RFC: More documentation for the Table and expand content discussions.
- Complete unfinished parts, Format as a document, Submit as Proposed IOOS Standard/Practices
- QIV:
  - – Quality Assurance
  - – Minimum Metadata for QA

APPENDIX C-4: PERSPECTIVES FROM ABROAD: CURRENT INITIATIVES IN EUROPE



Ongoing and planned Projects

As part of GOOS

EUROGOSS –

Coastal observatories Systems

BOOS, NOOS, MedGOOS,

MERSEA

Need for - QC for Real-time data
- EUROAct as counter part to ACT

Ongoing and planned Projects

Seafloor Observatory initiative ESONET

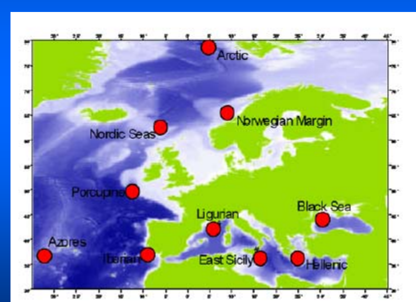
Study phase finished

Networking step

Start 2007
End 2011

Implementation Step

Start 2009
End 2013



Implementation of ESONET

- Find strategic locations
- Evaluate cost efficient solutions, i.e. reuse of decommissioned cables, concurrent use of existing observatory infrastructures
- Stepwise realisation, i.e. establishing testbeds
- Design for interoperability between different instruments and observatory structures

Implementation of ESONET

Work packages of the NoE

- WP 1- Networking
- WP 2- Standardisation: hard- and software, interoperability
- WP 3 - Observatory design related to scientific objectives
- WP 4- Demonstration missions
- WP 5 Implementation Strategies
- WP 6 Socio economic users
- WP 7 Education and outreach
- WP 8 Organisational, management and governance structure

Sensor interoperability and standardisation

General goals

- Interchangeability of instruments
- Standardised integration and operation
- Standardised data quality
- Standardised data access
- Standardised semantics

The possible role of ISO 9001:2000

A coherent quality management system for service providers

Highest Priority → customer satisfaction

The customer view

How do I get access to the data products?

What is the quality of the product?

What value added services are offered?

The possible role of ISO 9001:2000

Highest Priority → customer satisfaction

The service provider view

How can I provide the product in an efficient way?

How can I assure constant quality?

How can I assure a constant improvement in quality and efficiency?

Implementation of ISO 9001:2000

Definition of
- Mission
- Strategies
- Strategic Aims

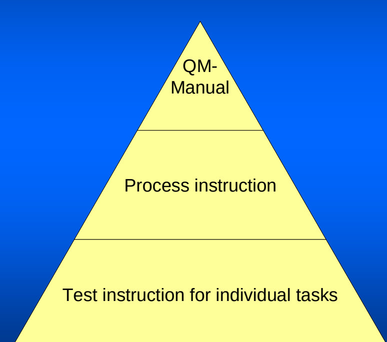
Combination of Strategic aims with processes

→ Need for process oriented organisation

Success will be evaluated by quantifiable parameters

Implementation of ISO 9001:2000

Documentation pyramid



Implementation of ISO 9001:2000

Is this the way to go?

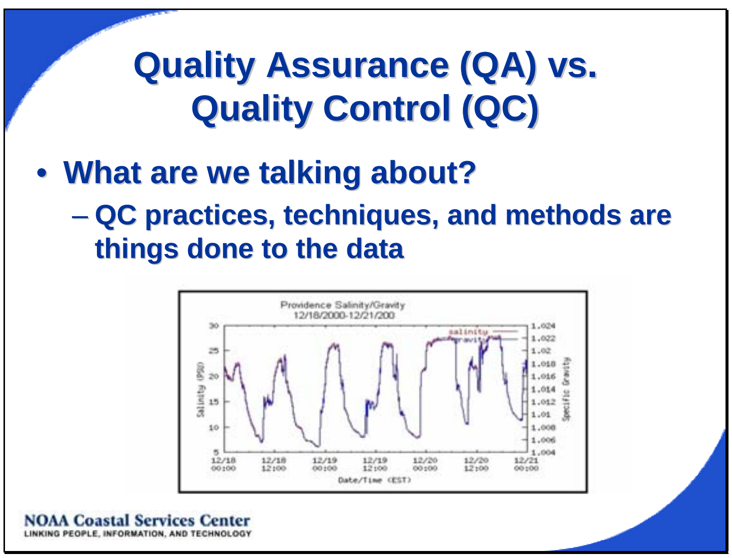
ISO 9000 would allow for

- Transparent quality management procedures
- Better comparison of processes
- Dynamic adaption to future challenges

Further steps

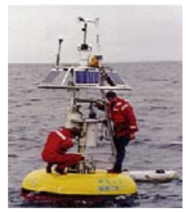
- ESONET will play a role as arbitrator for interoperability and quality management processes
- Define a common vision for cooperation
- Find a common approach by continuous information exchange, common organisation of workshops
- Demonstration of interoperability by exchange of instruments, common data formats, standardised web portals

APPENDIX C-5: QUALITY CONTROL AND ASSURANCE FOR CTD DATA: ENSURING QUALITY DATA



Quality Assurance (QA) vs. Quality Control (QC)

- What are we talking about?
  - QA practices, techniques, and methods are things done to the sensor



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How Did We Get to This Point?

- WOCE WHP Data Reporting Requirements
- CO-OPS Salinity Workshop
- NDBC report: NDBC, 2003: NDBC Technical Document 03-02, Handbook of Automated Data Quality Control Checks and Procedures of the National Data Buoy Center
- Salinity Data Best Practices Workshop Report, NOAA Coastal Services Center, August 2005
- NOAA NODC Global Temperature-Salinity Profile Program
- QARTOD III CTD presentations, breakout notes and report

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And, Where are We?

- Detailed work on salinity variable with required and recommended QC tests and hard or soft flags
- Additional work on the C, T, and P variables that resulted in required and recommended QC tests – no flags associated

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Salinity QC Table

Category	Criteria	Flag	Criteria	Flag
	REQUIRED			
Climatological Range	0 – 50 PSU (practical salinity units)	Hard	Determined by data provider	Soft
Gradient Range	Determined by data provider	Hard	Determined by data provider	Soft
Persistence			Determined by data provider – should be conductivity that is checked	Soft
Message Integrity	No bit or parity errors	Hard		
	RECOMMENDED			
Biofouling	Biofouling measurements exceed threshold for sensor	Hard	Determined by data provider	Soft
Other Derived Variables	Compare to derived data such as speed of sound, specific gradient, etc.	Hard	Determined by data provider	Soft
Nearest Neighbor	Compare salinity observations to nearest neighbor (sensor or platform within 5 km)	Hard	Determined by data provider	Soft
Independent Verification	Compare observations with local expertise, model data, and remotely sensed data for same time period	Hard	Determined by data provider	Soft
Density	Density inversions with depth	Hard	Determined by data provider	Soft
Power	Power reports at 50% potential	Hard	Determined by data provider	Soft

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Conductivity QC Table

Category	Criteria	
REQUIRED		
Range Test (Gross)	Absolute number	
RECOMMENDED (if applicable)		
Range Test (Climatology profile)	+/- (n) SD	
Compare w/ Temperature		
Gradient Tests		
Nearest Neighbors		
Spike Tests	Determined by data provider	
Descent Rate		

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Temperature QC Table

Category	Criteria	Flag	Criteria	Flag
REQUIRED				
Range Tests	Absolute num			
Range Test (Climatology profile)	+/- (n) SD			
Spike Tests				
RECOMMENDED (if applicable)				
Gradient tests				
Compare w/ Conductivity				
Density Inversions				
Freezing Point				
Nearest Neighbor				
TSP relationships (?)				
Dual Sensors				

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Pressure QC Table

Category	Criteria	Notes
REQUIRED		
Range Tests (Gross)	Absolute numbers	
RECOMMENDED (if applicable)		
Range Test (Climatology profile)		
Gradient Test		Required for profile data
Spike Tests		
Compare with surface pressure		QA or QC?
Dual Sensors		
Density Inversions		
Freezing Point		Requires temp, sal, and pressure for calculation

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What Do We Need?

- Cross walk the salinity, C, T, and P tables for the specific QC tests
- Include other derived variables in this suite – depth, density
- Define the criteria for the tests
- Add hard and soft flags
- Stamp as a completed draft version (v1.0)

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Work on QA – Finish QC if Possible

- Focused on QA for this QARTOD
- Have generated solid focus questions for QA
- Will develop a method (madness?) and group to complete the QC if not completed here

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Assumptions and Boundaries

- Real-time and near real-time data – to users within few hours at most
- In-situ (but available RT or NRT)
- Looking at C, T, and P, as well as the derived variables (salinity, depth, density)

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Q-III CTD Group Notes (SIO, Nov 2005)

- began with Salinity Workshop and previous QARTOD reports where temperature was discussed

Discussed:

- CTD methods of collection: profiling from ship, moored, profiling floats, fixed platforms, gliders/AUVs, expendables
- Primary/direct measurements: cond, temp, pres (C,T,P)
- Derived parameters: depth, salinity, density
- Metadata fields

Verification of data collected:

- 'no brainer tests': range, climatology, gradient, spiking routines, comparison with other parameters
- add'l tests: dual and adjacent sensors, expected boundaries, freezing pt., discrete samples, water mass chars, model results
- required vs. recommended criteria; automated vs. human checks

Next steps:

- follow up meeting
- review and cross reference salinity workshop report)

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APPENDIX C-6: IOOS DATA MANAGEMENT AND COMMUNICATIONS (DMAC)

IOOS Update

Int'l: **GEOSS** = Global Earth Observing System of Systems
U.S: **IEOS** = Integrated Earth Observing System

IOOS Update

- IOOS Development Plan approved January 2006
- Moving ahead on 2nd IOOS Development Plan
- Regional Associations – planning grants being issued
- Federal Agencies – more are interested & joining
- Modeling & Analysis – Steering Team to be formed
- NSF ORION – holding joint discussions
- GOOS Regional Alliances – IOOS taking lead for US participation in North American Alliance
- Federal Funding – still tentative, but hopefull

DMAC Update

- 3rd DMAC-ST held May 2006
- Expert Teams working
  - Transport & Access
  - Metadata
  - Archive (on-hold)
- Caucuses working
  - Modeling
  - Regional
  - International
  - Private Sector
- Over 100 'volunteers' participating
- Still have some holes
  - Online Browse
  - IT Security
  - QA/QC, except what QARTOD is doing

DMAC Update

3rd DMAC Steering Team Meeting
- Guideline/Standard Adoption Process
- Guide For IOOS Data Providers
  - New stuff on Transport and Metadata
- Team Work Plans
- Community Information Repository
- Data Transport Laboratory

Read at www.ocean.us

4th DMAC-ST will be Nov 2006

Next Steps

- Ensemble Flag Styles – a comment
- Metadata – need your help
- Adopt QARTOD standards

Ensemble Flag Style

COMMENT – Can we rationalize QARTOD and International styles for descriptive flags?

Flag Value	QARTOD-like Definition	International Style (WOCE Upper Ocean Thermal)
-9	Missing Value	
0	Quality Not Evaluated	No QC Performed
1	Bad	Good Data
2	Questionable/Suspect	Probably Good Data
3	Good	Probably Bad Data
4		Bad Data
5		Changed Values

Addressing Metadata Requirements

General recommendations for minimal metadata content were presented to the DMAC Steering Team (May 06)

Next steps:

Identification of the metadata content for various observations must be done by the data community (collectors and users)

Specific metadata element characteristics also must be defined for machine interoperability

QARTOD Metadata Session established as a forum for this community input

QARTOD IV June 21-23, 2006

Start to Adopt QARTOD Standards

- IOOS needs QA/QC standards and guidance
- "Guidelines/Standards Adoption Process" proposed at DMAC-ST in May 2006
- Process has 3-part sequence:
  - Submitted
  - Proposed
  - Recommended
- Which QARTOD results ready to "submit" now?
- Identify 'priority gaps' needing additional work

QARTOD IV June 21-23, 2006

Questions & Discussion

For More Information

www.ocean.us

k.schnebele@ocean.us

QARTOD IV June 21-23, 2006

APPENDIX C-7: INTERNATIONAL STANDARDS AND COORDINATION EFFORTS THROUGH JCOMM

International Standards and Coordination Efforts through JCOMM

Scott Woodruff
NOAA Earth System Research Laboratory, Boulder CO

Chair, JCOMM Expert Team on Marine Climatology (ETMC)

QARTOD IV
Woods Hole, 21-23 June 2006

Outline

- Intro. JCOMM: objectives & structure
- JCOMM standards & coordination
  - ✓ QA/QC & metadata activities
- META-T project (ocean temperature)
- Connecting QARTOD and JCOMM?
- Conclusions and Next Steps?

My experience: > data mgmt & marine met

JCOMM Background

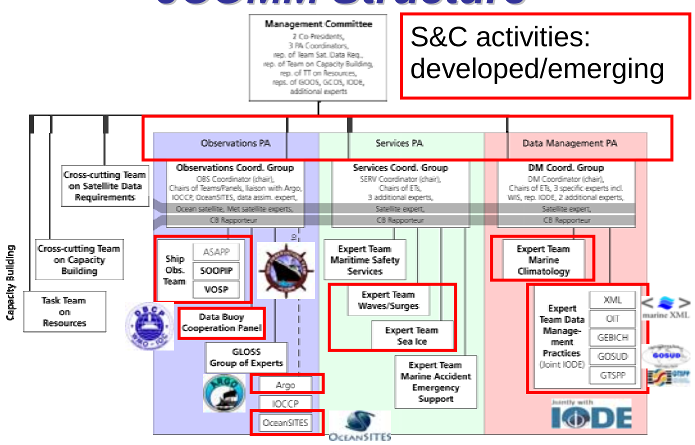
- Joint Technical Commission for Oceanography and Marine Meteorology
  - ✓ World Meteorological Organization (WMO)
  - ✓ Intergovernmental Oceanographic Commission (IOC) of UNESCO
- Former WMO/CMM + IOC/IGOSS
  - ▪ Sessions: 1st (2001, Akureyri)   2nd (2005, Halifax)

http://ioc.unesco.org/jcomm/

JCOMM Background

- Coordinates, regulates and manages a fully integrated marine observing, data management and services system that uses state-of-the-art technologies and capabilities, is responsive to the evolving needs of all users of marine data and products…
- Partners include:
  - ✓ International Oceanographic Data and Information Exchange (IODE)
  - ✓ Global Ocean and Climate Observing Systems (GOOS and GCOS)

JCOMM Structure



Data Mgmt PA (DMPA)

- ET on Marine Climatology
  - ✓ MQCS-V: for VOS (logbook data)
- ET on Data Mgmt Practices, with:
- IODE
  - ▪ Manual for QC (1993): status?
- WMO Commission on Basic Sys. (CBS)
  - ▪ Quality "class" configurations

QC Flags: Ordering?

FM 94 BUFR -- e.g. quality classes:

	0 33 003	0 33 020	0 33 021
0	Not suspect	Good	Within limits
1	Slightly suspect	Inconsistent	Outside limits
2	Highly suspect	Doubtful	Reserved
3	Unfit for use	Wrong	Missing value
4	Reserved	Not checked	--
5	QC info not given	Checked	--
6	--	Reserved	--
7	--	Missing value	--

QARTOD:

0=no eval
1=bad
2=suspect
3=good

Possible user confusion?

META-T Pilot Project

- JCOMM Workshop to establish a Pilot Project for the collection of real-time (RT) metadata re SST and temperature profiles (March 2006, UK)
- Goals:
  - ✓ Facilitate use of ocean temp data
  - ✓ Harmonize ocean & met-ocean practices
  - ✓ Seeking agreed formats & practices

META-T: Draft Plans

- Three categories (metadata & QC)
  - ✓ required for RT distribution w/ data
  - ✓ required for RT applic., but separate
  - ✓ available in delayed mode
- Metadata requirements matrix
  - categories vs. user requirements
  - NWP, SST analysis, ocean models, etc.

QARTOD & JCOMM?

- JCOMM welcomes connection
- DMPA developing JCOMM DM strategy
  - ✓ With IODE (and WMO/CBS)
  - ✓ QC (& metadata) will be key parts
- IODE & CBS practices
  - already not 100% compatible

Adding QARTOD to mix: challenge?

Conclusions and Next Steps

No formal/uniform standards process yet in JCOMM

Relationship to IODE and WMO/CBS practices

JCOMM DM “strategy” draft: by Summer 2006

DMPA Coordination Group meeting: October 2006

Looking forward to learning more about QARTOD!

Thank you - Questions?

APPENDIX D – FOCUS AREA REPORTS

APPENDIX D-1 CTD NOTES & FOCUS QUESTION RESPONSES

CTD Group Leaders		
Metadata Lead	**Process Lead / Facilitator**	**Technical Lead**
Julie Bosch	**Jim Boyd**	**Cyndy Chandler**
NOAA Coastal Data Development Center Stennis Space Center, MS 228-688-3841 julie.bosch@noaa.gov	NOAA Coastal Services Center Charleston, South Carolina 843-740-1278 james.boyd@noaa.gov	WHOI – Marine Chemistry and Geochemistry Woods Hole, MA 02543 508-289-2765 cchandler@whoi.edu

CTD Group Participants				
Name	**Organization**	**Day 1**	**Day 2**	**Day 3**
Dicky Allison	US GLOBEC Data Management Office	x		
Bob Arko	Lamont-Doherty Earth Observatory	x	x	
Brenda Babin	LUMCON	x	x	x
Julie Bosch	NOAA/NCDDC	x	x	x
Janice Boyd	NDBC / SAIC	x	x	
Jim Boyd	NOAA Coastal Services Center	x	x	x
Cyndy Chandler	WHOI	x	x	x
Dale Chayes	LDEO/Columbia University	x	x	
Stephen Diggs	Scripps Institution of Oceanography	x	x	x
Otina Fox	Alaska Ocean Observing System	x	x	x
Bob Groman	US GLOBEC Data Management Office		x	
Mary Carol Johnson	SIO/STS/Oceanographic Data Facility	x	x	x
Monisha Kanoth	University of South Carolina	x	x	x
Chris Paternostro	NOAA / CO-OPS	x	x	
Christoph Waldmann	University of Bremen	x	x	x

GROUP DISCUSSION NOTES

Seven primary questions were made available to the group prior to our meeting in Woods Hole. During the CTD breakout each of the questions was brought up for discussion. Some received more attention than others, based on how well the group felt the specific questions related to CTD quality assurance. The results of these discussions are presented below (grouped by question). Also, responses to the same questions were received via email from Sea-Bird electronics and are included as Appendix A-1.

For purposes of the discussions during QARTOD-IV, we agreed on the following goals and guidelines the latter of which included a working definition of QA and QC terms.

Goal Statement

The goals of the CTD breakout group are as follows:

1. Develop a list of "best practices" organized as requirements and recommendations for sensor quality assurance (QA) for real-time and near-real-time CTD data. Best practices for CTD data management will focus on the minimum information required to manage and make CTD data accessible to any user.
2. Capture the QA best practices in a written format and work towards adoption for use and improvement by the IOOS community.
3. Agree on a list of "best practices" organized as requirements and recommendations for CTD data quality control (QC). This work was started in earlier workshops, including QARTOD III, so much of the work has already taken place.

General Guidance

- For the purposes of QARTOD, quality assurance (QA) includes those practices performed on the sensor, while quality control (QC) includes those practices performed on the data.
- What questions would we need to ask or what topics would we need to discuss to generate a set of operating principles that, if followed during instrument preparation and data collection, would produce data of known and defensible quality for CTD sensors?
- For CTDs, it will be valuable to consider conductivity, temperature, pressure, salinity, depth, and density – both directly measured and derived parameters.

Document convention

The required/recommended designation seen throughout these notes should be a way for the user(s) to assess the value of the data stream. This designation should not prevent someone from contributing data. The thinking was to state whether a particular procedure or method should be required (i.e. essential) to ensure quality assurance, or recommended (i.e. if resources are available). Where "required" or "recommended" has been designated, these are shown in ***BOLD ITALICS***.

Team Leaders Note

The initial list of focus questions was organized as a spreadsheet and we tried initially to record our discussion notes in that format. However, we quickly found this approach to be unsatisfactory after beginning discussion of Question 1, and abandoned that approach in favor of these narrative notes recorded as a text document.

In an effort to self-assess the expertise of our team members, we asked an initial question of the group:

- Of the following job titles, which ones do you feel represent the work you do? (a 2 means that 2 people of our team of 14 raised their hand; many people raised their hand for more than one category)
  - Sensor technician – 2
  - Data collector - 7
  - Data processor - 9
  - Data user - 5
  - Data analyst - 6
  - Data manager - 11
  - System engineer - 3

Question 1 – Documented QA standard(s) used by those in the group.

The group was polled to determine what each individual might be using as a standard during a CTD data collection process. Results varied from using World Ocean Circulation Experiment (WOCE) standards, to manufacturer specifications, to those developed at an organization as the result of experience.

The group identified two sources of QA standards:

- WOCE
- Manufacturer specs (Sea Bird, etc…)

The group also listed "things to consider":

- Pre-deployment calibrations on every sensor for every cruise. ***Required***
- Post-deployment calibrations on every sensor for every cruise. ***Strongly Recommended***
- Periodic calibration of ready to use spares
- Monitor at sea w/ redundant sensors whenever possible.
- Historical and climatological data comparisons.
- On-site fix of problems (cruises) – can't do this for moored sensors.
- *In situ* water samples to compare with the sensor

Question: Does anyone use inductive conductivity sensors? 2 groups

Traceability of the sensors (how, where, when, etc…) calibrations should be tracked and documented. Likely can be handled with metadata.

Question 2 - List the manufacture specifications that should be used to evaluate the instrument

After much discussion, and an initial attempt to list some manufacturer specifications, the group decided against spending valuable time listing specifications. This may have been useful for other groups discussing other instrument types, but not necessarily for CTDs.

- Focus on the sensors that are used by the people in the group
  This was predominantly Sea-Bird sensors for our group:
  SBE 9*plus,* 3*plus*, 3F, 4C, 35RT, 19*plus*, 16*plus*, 35, 49 and 29
  although one person had experience using the RBR XR-620

- Performance of the sensors sometimes matches manufacturer specifications and sometimes not. More real world and context experience of the operator goes into the QA than simply using manufacturer's specifications.

- Accuracy of sensors may not be what is reported by manufacturers, so the real world experience is critical.

- Is this type of info shared? Available online anywhere?

- Has anyone written standard operating procedures (SOPs), based on real world experience? If so, need to gain access and make available to others.

Need to articulate the experience of field people in the know, and figure ways to make best decisions on the fly in the field as data are coming off the sensor.

The line between QA and QC is somewhat arbitrary. We don't want to miss things and shy away from discussion that is important. Need to acknowledge this, but try to focus on QA (pre-deployment).

- QC as doing something about an issue/problem?
- For those things that are in the gray area, let's discuss and not shy away from it too much
- Split between QA and QC is more of an internal QARTOD distinction (NOTE: QARTOD defines QA as "things" done to the instrument to ensure quality, and QC is defined as "things" done to the data to ensure quality.)
- EPA definition of QA vs. QC may be useful as well
  QA/QC terms as defined at EPA Web site (September 2006)
  http://www.epa.gov/quality/glossary.htm#Q
  Quality Assurance (QA) An integrated system of management activities (planning, implementation, assessment, reporting, and quality improvement) that focuses on providing confidence in the data or product by ensuring that it is of the type and worth needed and expected by the client.
  Quality Control (QC) The overall system of technical activities that measures the

attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities that are used to fulfill requirements.

Do we need a list of manufacturers that people are using and can be recommended?

- Group decided that we do not necessarily need to have all the specs listed on a spreadsheet.
- If needed this information is available directly from manufacturers/vendors.
- Recommendations should be based on the need and/or use.
    - If there is a global range that a sensor falls into, then it would be one that is recommended? This might not work because you need different accuracies, etc… based on the task.
    - Match the sensor with the task because of the cost of different sensors. Each has a place, just need to know what the use is.

What are the specs we would want to look at when working on QA…when you are evaluating which instrument to use?

- Manufacturer - Model
- Data Range –
    - lowest and highest possible readings you might get out of the sensor (specific to the instrument, not what is being measured)
- Operating range (i.e., some instruments won't operate at certain temperatures)
    - Could be depth range
    - Could be pressure range
- Resolution – want data at this resolution for this task
- Sampling frequency – how fast sensor can take measurements
- Reporting frequency – how often the sensor reports the data
    - NOTE: There was significant discussion over the sampling, reporting frequency, averaging, etc… and how relevant these pieces of information are for this workshop.
- Response time of the sensor – sensor lag – time response
- Instrument check – visual inspection for defects, biofouling, etc…
- Power check – master clock, battery, etc… – variability in these across sensors –
    - Clock could be compared w/ GPS timing as well?
- Capability to let you know if there was a problem w/ data – can you check if this is working pre-deployment?

Which specifications do you need to meet?

- State what your expected accuracy, etc… is from this data because different people will have different requirements. A different or later user will then know what the original intended use was.
- How did it compare to the design specifications? Did it meet those specifications? Is that good enough?

Are we talking about standards or best practices (common practices)?

- Advise against adopting any particular manufacturer specifications as a standard.
- Look at international community for specific definitions of the specifications/terminology we are looking at above.
    - IEEE, ANSI, ISO…then could document sensor time response per ANSI specs…

Question 3 - Identify, discuss, and document processes a user can employ to confirm that a sensor is producing the highest quality data.

The group spent a significant amount of time on this question, eventually categorizing processes based on what can/should be employed pre-deployment, during deployment, and post-deployment.

Pre-deployment QA checklist:

- Establish, use, and submit (with a reference and version #) a documented sensor prep procedure (protocol). Should include cleaning sensor according to the manufacturer's procedures. ***Required***
- Calibrate sensor against an accepted standard and document (with a reference and version #) ***Required***
- Compare the sensor with another sensor measuring the same thing in the same area (in a calibration lab).
- Need to look at calibration specifications with a critical eye.
- Historical calibration - data can be useful to assess the sensor quality over time…can begin to see drift, etc… - keeping your own database of historical calibrations is a good idea. ***Strongly Recommended***
- Repair history – when, what was the problem, etc…
- Consider storing and shipping information before deploying
    - heat, cold, vibration, etc…
    - document the obvious
    - ask questions of everyone who has handled the sensors
- Should establish and use a formal pre-deployment checklist
- Have well-trained technicians

Deployment: (during the process of deployment and while deployed):

- Should have and use a formal checklist process
- Scrape biofouling off of platform
- Deploy multiple sensors next to each other, but not too close (don't want them to interfere with each other)
- Verify sensor serial numbers
- Visual inspection (Verify position of sensors, fouling, cable problems)
- Verify instrument function at deployment site prior to site departure
- Monitor sensors for issues (freezing, fouling)
    - Any examples of this that can be shared?

- Automate processing so you can monitor the initial deployment and if the sensor is working when you are still on-site
- Specify date/time for all recorded events
- Check software to ensure that the sensor configuration and calibration coefficients are correct
- Visually inspect data stream to make sure you are getting reasonable values
- Compare up and down casts and/or dual sensors

Post-deployment:

- Should have and use a formal checklist process
- Calibrate sensor
- Provide a mechanism for feedback (contact information) on possible data problems
    - This could be part of QC
- Clean and store the sensor properly
- Visually inspect physical state of instrument
- Verify sensor performance by checking
    - Nearby stations
    - Historical data comparisons

General comments regarding QA procedures:

- When possible, note if these tests or processes apply across the method of data collection, or when they do not (i.e., ship board, mooring, etc…)
- A diagram (http://www.ldeo.columbia.edu/~dale/dataflow/), contributed by team member, Dale Chayes (LDEO) provided a visual representation of some of the discussion
  Require serial numbers and model ID from the supplier.
- Do not make the checklist so detailed that it will not be used.
- Don't assume the calibration is perfect…it could be a calibration problem rather than a sensor problem.

Question 4 – Identify potential options or partnerships to conduct field verification of the system while deployed.

This question focused the group on developing lists of potential verification options. A list of climatologies, *in situ*, field, and remotely sensed verification options was compiled.

Methods that can be employed for field verification include:

- Use up and down casts for comparisons
- Nearby stations for ground-truthing your own sensor
- ARGOS float data used for verifying sensor operation (and vice versa)
- Underway systems running when on a cruise…another comparison option
- Other ships of opportunity in the area that are collecting same type of data

Use of Climatologies:

- Navy's GDEM – online
- Levitus
- World Ocean Database
- HydroBase – WHOI - global
- TAO climatology – from PMEL
- Self generated
  - o Monthly or seasonal – how to make this available to others?
  - o A Regional Association or observatory could make its own climatology available for use by others.

In situ:

- Measurements in the vicinity of moorings to make sure the moorings are collecting good data (CTD profile, XBTs, bottle samples, etc…)
- Compare with others in the area
  - o Cooperative programs comparing information/data
  - o Need to be aware of their cycles for collecting data and how available

Field surveys:

- Historical data sets

Remotely sensed observations:

- Could be useful at a coarser resolution
- Use as a reality check, rather than very specific comparisons
- Synthetic BTs
  - o Used by Navy numerical modelers to get sub-surface information from surface data -
  - o Database of regional coefficients that allows you to estimate subsurface properties from remotely sensed surface data (statistical model based on data)

What if both sensors are wrong?

- If two sensors are better than one, it stands to reason that three are better than two. Having multiple backup sensors is not an option for many, however. Also, different types of sensors – not identical – but sensors that make the same type of measurement for which inter-comparison is valid.

Can problems like drift be corrected by the manufacturers?

- Just have to correct it afterwards
- Can be caused by biofouling
- Scouring by currents

Question 5 - Identify available venues where QA-related issues and information can be exchanged among users.

The group listed a number of web sites, research programs, organizations, conferences and meetings where information exchanges could take place. The group also made the recommendation that a forum be established specifically for instrument technicians for observing system sensors.

Web sites:

- Sea Bird FAQs http://www.seabird.com/FAQs/FAQsMainPage.htm
- University-National Oceanographic Laboratory System (UNOLS) Research Vessel Technical Enhancement Committee (RVTEC) http://unols.org/committees/rvtec/
- Alliance for Coastal Technologies http://www.act-us.info/
- CLIVAR and Carbon Hydrographic Data Office http://cchdo.ucsd.edu

Research Programs:

- Marine Metadata Interoperability Project (MMI) http://www.marinemetadata.org/
- World Ocean Circulation Experiment (WOCE) cruise documentation http://www.soc.soton.ac.uk/OTHERS/woceipo/
- US Joint Global Ocean Flux Study (JGOFS) http://usjgofs.whoi.edu/
- US Global Ocean Ecosystem Dynamics (GLOBEC) http://www.usglobec.org/
- Open Geospatial Consortium (OGC) SensorML forum http://vast.nsstc.uah.edu/SensorML/
- EuroGOOS http://www.eurogoos.org/

Conferences and Meetings:

- QARTOD http://www.qartod.org
- American Geophysical Union (AGU) http://www.agu.org/
- American Society of Limnology and Oceanography (ASLO) http://aslo.org/
- IEEE GEOSS http://www.grss-ieee.org/menu.taf?menu=GEOSS&detail=Standards
- IEEE Ocean Conference http://www.oceans06mtsieeeboston.org/ http://www.oceans2007europe.org/
- Marine Technology Society (MTS) http://www.mtsociety.org/
- Ocean Sciences Meeting
- RVTEC Workshops
- International Marine Technician meetings (INMARECH) (every 2-3 years; rotating international sites) http://www.unols.org/meetings/2006/200610inm/inmartech06.html

Need a working group/discussion group/forum for instrument techs for observing systems sensors:

- Could QARTOD sponsor this? On a Wiki? Possibly as part of UNOLS / RVTEC?
  - UNOLS Research Vessel Technical Enhancement Committee (RVTEC) list server. Discussion of ship board technical issues. Send an email to "office@unols.org" and ask to be added to the list.
- Need an umbrella organization… Need to look into how this gets formed/started.
- Discussions for hardware, software, metadata interoperability

Question 6 - Identify centers where instruments can be sent for calibration. Document sites where users can compare their sensors to established reference sensors.

No US Government facilities are known to exist that will calibrate instruments from “outside” independent organizations. Two NOAA offices may potentially provide that capability but further investigation is needed. The French Research Institute for Exploitation of the Sea provides calibration facilities for European Union partners. Scripps Institution of Oceanography Shipboard Technical Support group provides this service for outside organizations. Also, manufacturers provide calibration for their instruments.

Government locations:

- NOAA/NDBC wants to set up a calibration facility (internal or external? need to ask)
- NOAA/CO-OPS – need to ask
- IFREMER http://www.ifremer.fr/anglais/

Manufacture locations:

- Sea-Bird http://www.seabird.com
- OSIL http://www.osil.co.uk/

Universities:

- Scripps shipboard technical support (pressure and temp)

Question 7 - Does the QC standard for this parameter address biofouling and fault tolerance?

The group identified a number of procedures that can be employed to minimize effects of bio-fouling. These procedures and methods include:

- Anti-fouling paint
- Cage around opening to sensor – then have to calibrate the sensor with the plastic mesh covering

- Sensor, location, season dependent
- Optical sensors – manufacturers have wipers on some of these
- Optically clear paints – research stage
    - University of New Hampshire COOA program http://www.cooa.unh.edu/index.jsp
- Flushed out w/ chlorine gas pumped through the system
    - This is power (battery) robbing technique, however
- Frequent changing of the sensors
- Check with calibration facility on which anti-foulants will be handled (allowed) by the calibrators
- Copper plates as shutters which keep the sensor open for limited time
- Put the sensor in the dark
- Mounting of the sensors vertically to minimize sediment buildup – mesh and cone – especially useful for sensors with flow through tubes

For the question of fault tolerance, if a data stream is interrupted the Group identified the following as considerations for addressing the discrepancy (e.g., interpolation, assign "missing data" flag, etc.):

- Recognize data gaps when they happen
    - Metadata should make direct note that the data are not available for a certain time (it is a true gap) – do not want to waste time of others looking for that data
- Is the -99 designation enough to denote there is no data
    - Does this happen if the sensor loses power?
    - Should there be another mechanism to say no data at this time?
    - Record the data acquisition failure somewhere (metadata)
        - Station blown away by hurricane
        - Circuit breaker blown
        - WOCE and U.S GLOBEC Georges Bank program requires you to submit documentation after the cruise (cruise report)
    - Use codes, etc… to denote interpolated data
    - Use a log that records this type of information

One method to address discrepancies was offered:

- Take measurements in the area and then compare and correct the data

Addressing Metadata Related to CTD QA/QC

The approach to addressing metadata for the CTD Group was two-fold. During the breakout sessions, a number of comments were made regarding information that should be captured in metadata. These comments along with other considerations regarding metadata are listed below.

Comments from the Breakout Sessions:

- All calibrations should be tracked and documented
- Identify how, where, and when a sensor is calibrated
- Document any transport (shipping) and storage history (storage pre-deployment) of the sensor
- Identify the standards used against which the sensor is calibrated
- Calibration coefficients must be reported
- Note any differences between pre and post calibration checks
- Note how the actual values compare to manufacturer specification (design specifications)
- Identify specific tests and the values that are applied in the tests
- Document any repairs done to a sensor
- With respect to biofouling:
    - Identify any measures used to minimize biofouling
- With respect to fault tolerances:
    - Data gaps need to be identified
    - Event must be logged
    - Codes for measured vs. interpolated data must be identified
- Metadata must describe how values were determined (eg. How an average is determined when data are averaged over a time period)

Other considerations regarding metadata include:

- The metadata must be captured not only for the primary sensors but for duplicate and spare sensors as well
- Decisions need to be made on how data collectors report which tests are being performed as well as the results from the tests. Guidance needs to be provided for consistency in reporting
- Metadata should capture how the confirmation is made on whether data are "good"
- How do we capture data telemetry issues in metadata?

The second part of addressing metadata took place during the Metadata Special Session on the final day of the workshop. The Group was provided a list of potential metadata fields (Appendix E-2). The goal of the Special Session was to use the worksheet (list) and the comments from the previous days and determine specific metadata fields (elements) that the Group recommends be captured. The results from the session are tabulated below. It should be noted that the layout of the initial worksheet lead to a considerable amount of confusion as to how to approach this task, and the time allotted for the session was too short for completing the task. Never the less, for an initial pass, a number of specific elements were identified as being necessary to capture by the Group. Additionally, a third column of recommendations is provided based on a NDBC reporting template from the Salinity Workshop (August 2005).

Note: highlighted cells in the metadata table indicate clearer definitions are needed for the terms presented.

Metadata Content Areas	CTD Group recommended capture	Req/Rec (Salinity Workshop NDBC Reporting Template)
Sensor Information		Instrument Information
Hardware Info *		
Type	yes	
Manufacturer	yes	required
Model	yes	required
Series/Modification #	yes, if present	
Serial Number	yes	recommended (Instrument ID or serial number)
Deployment Info *		
parent platform		
locality (*in situ*, remote)	yes	
mobility (stationary, mobile)	yes	
deployment Temporal Extent Info *		
date	yes	recommended (Instrument Deployment Date (yyyymmdd))
time	yes	
reference	yes	required (Time Data Reference (GMT required) (time zone))
deployment frequency		recommended (Recovery Time (real-time, bi-annually,…))
Person Info(s) *	yes	
Sensor Quality Assurance		
QA Date/Time Info *	yes	
Method(s) Applied	yes (reference an SOP?)	
Results	yes	
Sensor Quality Characteristics		
precision	yes	
resolution	yes	
Accuracy Info *	yes	
Sensor Calibration		
Calibration Date/Time Info *	yes	required (Date of Last Calibration)
Method Applied	yes	
Individual performing calibration	yes	
Site (where calibration took place)	yes	required (Calibration Facility)
Results	yes (calibration coefficient(s) or calibration report)	recommended (Calibration Coefficient Availability)
Measurements		
Measured Parameters	yes	
measurement depth (nominal depth?)		required (Measurement Depth(s) (meters))

depth reference	yes, if applicable	required (Vertical Datum Reference for measurement depth (sea level at time of instillation, MSL, MLLW,…)
number of sampling periods per hour	yes	required (Number of Sampling Periods per Hour)
sampling unit	yes	
number of samples in sampling period	yes	required (Number of Samples in Sampling Period)
sampling period	yes	required (Sampling Period (minutes, 0=instantaneous))
averaging period	yes	required (Averaging Period)
time stamp representation	yes	required (Time Stamp Represents (middle, beginning, or end of period))
Platform Information		
Deployment Info *		
deployment Temporal Extent Info *		recommended (Platform Deployment Date (last deployed))
Location Info *		
Latitude		required (Latitude (deg min sec))
Longitude		required (Longitude (deg min sec))
Reference		required (Datum Used for Lat/Long)
Bottom Depth		required (Bottom Depth)
Source of Bottom Water Depth		recommended (Source of Bottom Water Depth)
Sensors Present		required (are individual T, S, C, P sensors present)
Name		required (Platform/Station Name)
Station ID		required
Station ID source		required
Station Type		required (Mooring (Subsurface or Surface), Fixed, Bottom Mount, Cast, Drifting)
Mooring Type		recommended (Taut, Catenary, …)
Data Telemetry		
Type (satellite, cabled)		recommended (Telemetry system type)
Update schedule		required (Telemetry frequency)
Processing Specifics		
Pressure corrected for Sea-level Pressure		required

Method of sea-level pressure correction (dynamic from observation or mean sea-level pressure)		required
What correction is applied to this data		required
Data Set Attributes		
Format		
File Content Type (ASCII, binary)		recommended (Data Format (ASCII, CSV, FM64, FM13,…)
QA/QC Flag values (also a code set)		required (flag values)
Applicable QC Flag Reference(s)		recommended (Flag Conventions or References)
Valid Values - Range Domain Info *		
Valid Maximum		required (for each parameter T,S,C,P)
Valid Maximum Definition		required (for each parameter T,S,C,P)
Valid Minimum		required (for each parameter T,S,C,P)
Valid Minimum Definition		required (for each parameter T,S,C,P)
Units of Measure		required (for each parameter T,S,C,P)
Value Temporal Extent Info *	yes (data gaps and start/stop times)	
Value Accuracy Info*		recommended (for each parameter T,S,C,P)
Data precision		recommended (for each parameter T,S,C,P)
Scale convention		required (Salinity Scale Convention (PSS-78)
Parameter Standard Name Info *		recommended (Temperature Standard (ITS90, IPTS-68(75)))
Value type indicator (measured, interpolated,…)	yes (codeset)	
Codeset Domain		(flags)
Codeset Name		(flags)
Codeset Source		(flags)
Date/Time Info	yes	
DateTime	yes, if applicable	
DateTime format	yes, if applicable	
Date	yes, if applicable	
Date format	yes, if applicable	
Time	yes, if	

	applicable	
Time format	yes, if applicable	
DateTime convention	yes	
Person Info		
Name		required (Name of Operator Contact)
Role		
originator		required (Operator (owned and maintained by credit))
Contact Information		
Phone Info		required (Phone Number of Operator Contact)
Email		required (Operator Email)
Web Site		required (Operator URL (a.k.a Data Resource Location))

Next Steps and Recommendations from the CTD Breakout Group

One key recommendation from the CTD Breakout Group is that a Working Group, Discussion Group or Forum be established for instrument technicians for observing system sensors. The group questioned:

- Could QARTOD support this? Possibly on the wiki?
- Could this be done as part of UNOLS/RVTECH?
- Is there an umbrella organization that could be identified?
- How might this get formed or started?

The group recommends that Standard Operating Procedures (SOP) be developed that capture real-world experience and that these SOPs be made available to the data collection community.

Make requests to the Manufacturers to somehow standardize make, model, serial number of sensors.

Guidance should be provided on how to request historical calibrations from a manufacturer.

Appendix A-1.

Post-workshop comments (relevant to CTDs) received from Sea-Bird Electronics

Prior to the QARTOD IV Workshop, I contacted Sea-Bird Electronics and asked them the same focus questions we would be discussing during the workshop. The Sea-Bird response came back to me after the end of our workshop discussion period that ended on 22 June, but I felt it would be useful to include the information in the final CTD group report. Norge Larson graciously agreed to let me share these comments and "incorporate any of my email comments into your workshop material as you see fit". I include them here, copied from the original email. (contributed in August 2006 by Cyndy Chandler, Technical Lead)
The text from the email message below was contributed by:

Nordeen Larson norge@seabird.com
Sea-Bird Electronics, Inc. 425-643-9866 TEL
1808 136th Place NE 425-643-9954 FAX
Bellevue, WA 98005-2398 USA http://www.seabird.com

Subject: Re: QARTOD IV CTD sensors group
From: Norge Larson <norge@seabird.com>
Date: Thu, 22 Jun 2006 19:05:03 -0700
To: Cyndy Chandler <cchandler@whoi.edu>

PROPOSED DISCUSSION TOPICS FOR QARTOD-IV SENSOR QA GROUPS:

1. Identify existing and emerging standards that should be considered.
(Participants should be prepared to provide a very brief [~5 min.] description of their existing QA standards and/or practices.)

Perhaps the most under-used standard is control charting; tracking the drift of sensor calibration. It is a good diagnostic of a healthy sensor.

For pressure you can do a lab & deck test. In the laboratory 6-12 times per year, turn the CTD on, let pressure transducer stabilize for 15 minutes, orient CTD in a standard position and document the pressure and compare it to a local barometer. CTD should read 0.0 dbars at 1 atmosphere pressure (14.696psi or 1013.25 mbar). Chart [P_ctd - (P_barmometer - 1 std atmosphere)]. This should be a relatively smooth trend that exhibits CTD pressure sensor error. Also chart CTD deck pressure before and just after each cast. CTD deck pressure before each cast should look like the lab drift chart. The CTD deck pressure just after a profile contains short-term hysteresis and transient temperature shock error, but should recover to the pre-cast offset in 15-30 minutes. Pressure sensor drift is dominantly offset (versus sensitivity) so the error is the same at all pressures.

For temperature, just track drift reported from calibration labs. SBE temperature sensors drift slowly and are good performers. A calibration once or twice a year is sufficient. Some *in situ* validation of CD temperature is good practice but can be tricky to get right at 0.001C even using the surface mixed layer as the field calibration bath.

For conductivity, track the drift reported from calibration labs. However, conductivity accuracy and sensor problems arise overwhelmingly from coatings in the cell (oils or biology) or a broken cell from mechanical shock or fresh ice. So, a regime of field cleaning and cell assessment is the best QA. SeaBird material on field cleaning of cells is good guidance. to assess a broken cell check the "zero conductivity" frequency. This unique finger-print frequency can be found on its calibration sheet opposite the "bath conductivity" of 0.000000 S/m. a clean dry cell should register this frequency within 0.5 Hz else it is fouled or broken. Rinse the cell well with reliably clean fresh water (DI is always reliable), empty and blow gently by mouth. It should register the "zero conductivity" frequency. repeat rinsing if frequency is high. If the cell frequency stays high by 1 Hz or more something is generally wrong. If fouled, try the procedures in our application notes for cleaning the cell. Never put anything in the cell except fluids (like Kim Wipes or Q-tips, they can alter the electrodes and cell calibration). *In situ* validation of conductivity is wise. A second sensor, salinity samples, or TS are good references.

Of course salinity is the desired quantity and T,P & C have to be right for this. The coordination of the T&C measurements are critical for good salinity. We've implemented a pumped pipe (our TC duct) to ensure coordination of the T&C measurement on the same samples of water. pump rates are important for good data so attention to the pump and good flow is a QA matter for Sea-Bird CTDs. A relatively wide variety of pump flow rates will produce equally good salinity data as long as the pump rate is fixed for a CTD profile (or entire cruise). data processing compensation is usually necessary for each new pump rate to adjust for the time delay in water flowing from the temperature sensor to the conductivity sensor (processing module alignctd). pump rates wash heat out of the conductivity cell wall and data processing corrects this as well (processing module celltm). Guidance for processing is in the software manuals and in CTD Training Course manuals on our website.

2. List the manufacturer specifications that should be used to evaluate
the instrument (e.g., expected accuracy, reporting frequency, etc.).
[fairly simple - we'll rely heavily on the SeaBird documentation for this part]

spec sheets

3. Identify, discuss, and document processes a user can employ to
confirm that a sensor is producing the highest quality data. Indicate
whether this process should be required or recommended.

many methods discussed in 1) above. also CTD deployment methods affect CTD quality. In the CTD Training Course materials look for "shed wakes", "profiling speed", "bottle stops".

4. Identify potential options or partnerships to conduct field verification
of the system while deployed (e.g., ships of opportunity)

your group probably has best ideas here

5. Identify available venues where QA-related issues and information
can be exchanged among users. Provide web sites.

SBE materials. Hawaii HOTS reports and Bermuda BATS reports.

6. Identify centers where instruments can be sent for calibration;

Document sites where users can compare their sensors to established
reference sensors (e.g., PORTS, CMAN, etc.).

Sea-Bird is the best calibration lab and our pricing is set low to make this attractive for tighter budgets. Conductivity is important to get calibrated at regular intervals 2-6 per year depending on field activity and accuracy needs. Temperature is usually extremely reliable and drifts very slowly </= 2mK/yr. Pressure should be calibrated every year but can be monitored closely at atmospheric pressure and the calibration can be done well at several laboratories.

WHOI, SIO, SOC & OSIL in England. Saclant in Italy.

7. Does the QC standard for this parameter address biofouling and fault tolerance? What procedures can be used to minimize effects of bio-fouling (region-specific)? If the data stream is interrupted, what are the preferred methods to address the discrepancy (e.g., interpolation, assign "missing data" flag, etc.)?

For profiling CTDs that come back onto the ship deck, keeping the CTD rinsed with fresh water and an occasional Triton or detergent wash is best practice. See SBE field guides for suggestions and some very important cautions (especially extended exposure of oxygen Teflon membranes to Triton X-100 and possibly other detergents). No *in situ* anti-foulant is practical or beneficial. Bleach (hypochlorite solutions are quite effective as anti-microbial rinses and are not detrimental to conductivity or oxygen sensors. Again please see Sea-Bird documentation for concentrations and duration.

For the special class of moored profilers that remain submerged between profiles, in-situ anti-foulants are absolutely necessary for good low-drift conductivity and oxygen measurements. Sea-bird's TBTO-based anti-foulant is a legal US EPA Registered product, and works very well when used as directed. A key requirement for effective antifouling is holding the flow still inside the cell between profiles so that the slow diffusing TBTO can build to an effective concentration. The pump turned off and the pump plumbing routed in an inertial loop dramatically improves the result. This is the basis for the CTDs used with the ARGO float program and on McLaine Profilers or John Toole's ITP Profilers and calibration stabilities of better than 0.01 PSU for years is being achieved.

APPENDIX D-2 DISSOLVED OXYGEN NOTES/FOCUS QUESTION RESPONSES

Dissolved Oxygen Group Leaders		
Metadata Lead	**Process Lead / Facilitator**	**Technical Lead**
Tom Gulbransen	**John Hayes**	**Timothy Koles**
Batelle Stony Brook, NY (631) 941-3211 gulbran@battell.org	NOAA/NOS Special Projects Office Silver Spring, MD 301-713-3000 X206 john.hayes@noaa.gov	University of MD, Chesapeake Biological Lab Solomons, MD 410-326-7259 koles@cbl.umces.edu

Dissolved Oxygen Group Participants	
Name	**Organization**
Rob Ellison	YSI
Janet Fredericks	Woods Hole Oceanographic Institute/ Martha's Vineyard Coastal Observatory
John Graybeal	Monterey Bay Aquarium Research Institute (MBARI)/ Data Management and Control (DMAC)
Lei Hu	Dauphin Island Sea Lab
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GROUP DISCUSSION NOTES

For the inaugural meeting of the QARTOD Dissolved Oxygen group, seven primary questions were provided to the group to focus discussion during the breakout sessions. An additional thirteen sample discussion questions, focusing on dissolved oxygen-specific topics, were also distributed prior to the breakout group in the meeting notebook (Appendix I: DO Sample Discussion Questions). Each of the primary questions was raised during the breakout session; however, there was not enough time to address all of the additional questions. A subset of these additional questions was discussed, as they pertained to the primary questions and discussion topics.

The DO group felt that the limited number of participants impacted its ability to fully answer the proposed questions. Only a few individuals within the group had experience with field deployment of dissolved oxygen (DO) sensors and the corresponding QA/QC procedures. Also, the group's collective experience was confined to a limited set of DO sensors. In fact, much of the discussion focused on the YSI 6562 Rapid Pulse Dissolved Oxygen Probe incorporated into their 6 series instruments. This limited the discussion, somewhat, to procedures that are most appropriate for pulsed polarographic sensors. However, the group did recognize that other technologies would have different requirements.

Question 1 – Identify existing and emerging standards that should be considered.

The group was unaware of any existing or emerging standards that apply to DO QA. It was noted, however, that there are many common practices among users that could be used as the foundation for a QA standard. Some of these common practices include:

- Pre-deployment calibrations
- Post-deployment calibrations
- In-water, simultaneous readings with freshly calibrated reference sensors
- Water sample collection for analysis (Winkler Titration)
- Utilization of manufacturer recommendations for instruments
- Historical comparisons
- Proper storage of instruments between deployments

Calibration data, as well as other instrument data, should be incorporated into the data stream.

NOTE: DO sensors require input from both the temperature and conductivity sensors to output readings as saturation or concentration. The group felt that it would be appropriate to incorporate the recommendations from the CTD group into future DO QA/QC recommendations.

Question 2 – List the manufacturer specifications that should be used to evaluate the instrument.

Due to unfamiliarity with a few of the DO sensors and their underlying technologies, the group decided not to focus much effort on this question. We did feel though, that manufacturer's specifications can be subjective and evaluation methods are not standardized, nor are they likely to converge anytime soon. Therefore, manufacturer's specifications should not be taken as canon.

Accuracy was noted to be a general term with potentially confusing uses. There can be significant differences between a piece of equipment's specified accuracy, its calibrated accuracy achieved, and its ongoing accuracy during an extended operational deployment. Sensor behavior is highly dependent on the type of sensor and the environment in which it is deployed. Users should take this and their own experience into account and develop their own expected accuracy information.

Question 3 – Identify, discuss, and document processes a user can employ to confirm that a sensor is producing the highest quality data.

To answer this question, the group tried to document processes that could be employed for each of the different technologies, as well as in general. These processes were then characterized as either required or recommended, and participants indicated whether they should be used every time or just in special circumstances.

Many of the suggested processes apply to any DO sensor regardless of underlying technology. To begin, good quality data starts by purchasing the correct instrument for the job. Users can make the whole process easier by considering all the documentation available, knowing their working environment, and considering their skill availability – all while keeping their data quality objectives in mind. The group felt that this was required every time a new site or instrument purchase decision is made.

Maintaining the sensors in good working order is also required all the time to insure proper functioning. Many sensors have consumables, such as membranes and wipers, which need to be replaced regularly. Storage of sensors, when not deployed, needs to happen in accordance with manufacturer recommendations.

After the sensor has been deployed, it was recommended that side-by-side comparisons, using additional sensors or Winkler titrations on collocated water samples, should be performed to insure sensor performance or to evaluate when replacement is needed. This should be done every time, although this may not be feasible for some deployments.

After retrieving your instrument, sensors should be post–calibrated using known saturations to assess the drift due to biofouling and/or electronic drift inherent in the system. We recommend that this check should be conducted every time, although its use in heavily fouled area, where fouling can slough off easily and lead to an under-estimation of drift, needs to considered carefully.

For optical sensors, good maintenance practices are essential, such as keeping the membrane hydrated and monitoring membrane age. A calibration check of the sensor should also be required and a full calibration is recommended if it could be performed on the sensor. A note on calibrations: if a two point calibration is to be performed, the preferred method to obtain a zero point is to use a solution of sodium sulfide in water. This is a significantly more repeatable method to strip oxygen from water than using nitrogen gas.

Once deployed, optical sensors should be inspected and cleaned, if possible, to insure correct operation.

Polarographic sensors, whether pulsed or steady-state, use membranes over an anode and cathode in an electrolyte solution. Membranes on these units need to be inspected all the time and replaced when necessary. Membranes are stretched when applied to the sensor and must be allowed to reach an internal equalization before calibrating the sensors. Failure to do so will cause readings to be incorrect as diffusion rates will be different than when calibrated. Some manufacturers, such as YSI, require that the sensors be "burned in" by running the instrument for fifteen minutes whenever the membranes are changed. Manufacturer recommendations should always be followed to insure proper operation.

Question 4 – Identify potential options or partnerships to conduct field verification of the system while deployed.

The group was able to identify several options and potential partnerships that could be used to verify DO sensors while they are deployed. Some of these options were found to be more useful than others. Most require significant additional work to compare the data and would not be useful for real time applications, but would instead provide verification for archived data. In each case, it is advisable to compare Sampling Plans or Quality Assurance Project Plans to ensure objectives are sufficiently comparable to justify inter-study calibrations.

Ships of Opportunity, Research Programs, and Field Surveys are all considered good sources of verification data, assuming they are present and the data are available. Although no specific group or project was mentioned, the group felt that any additional data available would be useful to help verify data from your sensor. Care should be taken to insure that the data from these groups are of high enough quality and rigor to provide a meaningful comparison. Most likely, there will be a tit-for-tat attitude with this approach in that the data from your system will be used to verify their data. It is also important to appreciate the spatial scale when comparing your data to additional sensors in the field (i.e., nearest neighbor). This is especially true in coastal areas where DO concentrations can vary greatly over a relatively small area.

Climatology was viewed a good way to verify trends in the data with established relationships to other observations. Does the DO value increase during the day when chlorophyll concentrations are high? Do surface DO values increase when wind speed increases? A good understanding of your operating environment is needed to utilize this approach successfully. For instance, wind speed may increase mixing at the surface leading to higher DO values, but if your site is shallow and the bottom topography is right, higher wind speeds from the right direction may cause a turnover in the water leading to lower DO values. Using these surrogate parameters will of course be dependent on their availability, as not all locations will have wind speed and direction, PAR, etc. Also, an investigation of the other parameters QA/QC will be required. While consistency with climatology data is a useful guide to performance, it should not be used as a sole indicator of instrument malfunction.

In-Situ Observations, using collocation of instruments, is probably the most frequently used method to verify data. Using additional DO sensors to collect data at the same time and at the same location as your system provides a quick, although not real time, check of the data. This approach has the added benefit of lessened potential QA/QC issues, since all data are collected in house under your control. Collecting water samples to perform Winkler titrations can also serve the same purpose. Winkler titrations are the de facto standard method to measure DO and, if done properly, can provide very accurate readings of DO. The drawback of Winkler titrations is that they require significant investment in supplies and training to do properly.

If two-way communication is available, the ability to access the sensors remotely could be used to verify sensor operation. Changing sample rates, wiping intervals, updating firmware, resetting defaults, etc could provide insight into questionable data that may otherwise be unavailable. Not all sensors have this ability and not all telemetry systems allow communication of this nature.

The integration of diagnostic data into the data stream is very useful to assess the operation of a sensor. YSI allows the user to select "DO charge" as one of the parameters that can be reported. DO charge is the charge across the anode and the reference cathode on their instrument. Monitoring the charge value can indicate when there might be a potential problem with the instrument. This could be due to bio-fouling or a punctured membrane. Since these data are transmitted with the environmental data, a check of the charge value could be implemented in real time.

Remotely Sensed Observations were not viewed by the group as an appropriate method of data verification since they do not exist as a direct match to DO measurements.

Question 5 – Identify available venues where QA-related issues and information can be exchanged among users.

The group identified several venues where QA-related issues could be exchanged. These included web sites, formal studies, national research programs, and meetings:

- Manufacturer web sites
- QARTOD - nautilus.baruch.sc.edu/twiki/bin/view
- Marine Technology Society (MTS) - www.mtsociety.org/
- Marine Metadata Interoperability Project (MMI) - www.marinemetadata.org/
- EPA's Environmental Technology Verification Program (ETV) - www.epa.gov/etv/
- EPA's Environmental Monitoring and Assessment Program (EMAP) - www.epa.gov/docs/emap/
- National Estuarine Research Reserve System (NERRS) - nerrs.noaa.gov/
- USGS/EPA National Water Quality Monitoring Council Meeting (NWQCM) - acwi.gov/monitoring/
- Buoy Workshop (WHOI) - www.whoi.edu/buoyworkshop/2006/index.html
- DMAC - dmac.ocean.us/index.jsp
- Alliance for Coastal Technologies (ACT) - www.act-us.info

The ACT program was singled out as a good venue for the exchange of information. ACT runs a database of available sensors that allows users to browse through and compare sensor specifications regardless of manufacturer. Second, their evaluations of sensor technology provide insight into real world performance that may not be available through the manufacturer's web site. Lastly, ACT partner locations sponsor workshops where various sensor technologies are discussed in detail with a focus on identifying problems or limitations with current technology and highlighting possible solutions. All of these products are available through the ACT web page.

The most valuable sources of information are the technicians responsible for deploying these instruments in the field. The development of a forum or meeting designed with the technicians in mind; meaning less scientific talks and more hands on, practical applications, would be helpful. CODAR operator meetings and the Buoy Workshop are examples of such a meeting. ACT sponsored a Dissolved Oxygen Training Workshop in 2005 and is looking into the possibility of holding similar meetings.

Question 6 – Identify centers where instruments can be sent for calibration; Document sites where users can compare their sensors to established reference sensors.

The group was not able to identify any calibration center or reference site for dissolved oxygen sensors and more specifically, did not believe that such a location existed. However, this was not looked upon as a pressing concern. Due to the nature of DO sensors, and how most can be calibrated in-house, the group did not feel that a calibration or reference facility was warranted. Instruments that can't be calibrated by the user, such as SeaBird's polarographic sensor and the new optical sensors, need to be sent back to the manufacturer for calibration. Perhaps when optical sensors become the norm, a calibration and reference facility or facilities would be appropriate.

Question 7 – Does the QC standard for this parameter address bio-fouling and fault tolerance? What procedures can be used to minimize effects of bio-fouling? If the data stream is interrupted, what are the preferred methods to address the discrepancy?

Since this was the first meeting of a DO breakout group as part of QARTOD, QC standards for DO sensors have not been developed. The group felt that many common practices that aim to minimize bio-fouling were more closely related to QA rather then QC, since they deal with the sensors themselves and not the data specifically. These would include:

- Anti-fouling paints
- Guards
- Wipers
- Gas generation
- Frequent change over of sensors

In terms of QC, automatic routines can and have been implemented to check the quality of data as it is received. These routines commonly use range limit tests as well as gradient and "stuck" tests to determine if the value appears reasonable or not. The problem with this approach is that bio-fouling affects the sensors gradually and will have an effect on the data before the QC routines will flag the values as suspicious.

It was determined, that post-correcting, using data collected from a freshly calibrated, simultaneously deployed sensor, was the norm for adjusting values that had drifted due to bio-fouling. Winkler titrations on collected water samples could also be used. Once comparison values have been acquired, a linear regression can be implemented to determine a rough rate of drift.

No one in the group was aware of any automated process to adjust the drift caused by bio-fouling and did not think it was possible due to the inability to predict which organisms would cause the fouling and at what rate. Perhaps more complex algorithms that could adjust values on the fly could be developed through future research initiatives. These algorithms would also have to take into consideration the electronic drift inherent in the sensors themselves to be effective. “Smart” sensors, which are just hitting the market, should help with this though it was noted that currently there are software roadblocks that prevent the transmission of the information in these new sensors to the users.

Interruptions in the data stream can be addressed by incorporating time stamp checks or record length checks into any automatic QC routine. Gaps in the data should be marked with distinct values (i.e. -9999 or something similar) and should be noted in the accompanying metadata and log files.

Metadata Recommendations

The DO breakout group’s primary mission was to address Quality Assurance considerations associated with Dissolved Oxygen observations. As such, the group was not necessarily fully equipped to complete discussion of metadata options regarding DO recordings. The group found the initial metadata template material useful, daunting and somewhat confusing. The metadata template contained useful topic areas, such as sensor information, data set quality and positioning. Some of the metadata template entries were obviously not dedicated to DO measurements uniquely and were duplicative with higher-level standards, such as organization identifiers and citation descriptors. The long list of potential metadata attributes in the template underscored the possibly overwhelming nature of metadata encoding. Future DO breakout groups, as well as other QARTOD metadata breakouts, ought to include guidance on how to balance sufficiency with exhaustive content and resource requirements. Finally, the DO breakout group observed often that the metadata template contained some internal inconsistencies. For example, hardware and positioning attributes occurred multiple times. It was fairly obvious that the template had not been fully optimized yet.

There was general support, if not tacit agreement, on the merits of promoting more thorough reporting of metadata. Support was voiced from representatives of distinct perspectives: field scientists, sensor manufacturing, database administrators, and project managers seeking legacy data. The extent of metadata reporting was noted to likely differ depending on the level of “real-time” being achieved, i.e. real-time raw data feeds, real-time feeds with in-stream data processing application software, and real-time via a delayed broadcast pending internal screening. It was also recognized that QARTOD IV’s inaugural convening of a DO breakout group should address the broadest topics and issues first instead of drilling too far into an one topic at the expense of an initial full overview of metadata considerations (this was partially achieved).

The DO breakout group did march down through the metadata template tables as much as possible given the time allotment (Appendix II, Initial characterization of possible metadata attributes associated with Dissolved Oxygen observations). We spent a fair amount of time marking fields as “required” or “required if applicable,” or “valuable.” We focused on parameters that captured the gist of the QA concerns discussed by the group. Further QA discussions will likely expand the number of metadata parameters to be reported, as well as possibly altering their respective level of importance. The group skipped over parameters that were not specific to DO based on the assumption that this information, such as organization contact references, would be addressed by higher level reporting standards. Quite a few QA considerations were truncated by time so a number of parameters are marked as "Needs Further Discussion." The inaugural breakout group felt that a streamlined metadata template would likely need a few more iterations depending on future participants.

Recommendations for the Next DO Breakout Group

This group was able to initiate the discussion of DO QA/QC procedures; however, many more issues will need to be discussed before a comprehensive set of recommendations can be developed. Participants within this group recognized that they did not have expertise with a broad enough range of sensor types and environments to provide QA/QC guidelines that will be appropriate for all users. More experienced users from a variety of backgrounds, as well as manufacturers themselves, should be consulted to review and enhance the output from this group so that it applies to a broader audience. QARTOD leadership should take an active role in identifying and attracting these individuals to participate in future meetings. In addition, the notes from this session and other QARTOD IV breakout groups, should be made available prior to the next meeting to allow these new members to get up to speed.

Many recommendations put forward by this group were generic in nature and not technology specific. The group felt that it was important to keep any final recommendations as general as possible to insure that they will be beneficial in the future when newer technologies become available.

DO Sample Discussion Questions

1. What are the specific QA/QC procedures that apply to:

    a. Polarographic; pulsed and steady state, optical, and galvanic sensors
    b. Moored vs. profiled, AUV, point measurements
    c. Estuarine vs. ocean, scientific vs. management
    d. High end, precise scientific instruments vs. low cost, not as precise monitoring instruments

2. Do different reporting units; %, mg/L, ml/L, M require different QC checks?

3. Is the data from different DO monitoring technologies intercomparable? If not, how should they be differentiated? Are the data from newer technologies, i.e. optical sensors, fully accepted in the community?

4. If one method of automatic QC is to utilize ranges, what should be used for hard ranges (data is bad) and for soft ranges (data is questionable)?

5. Are gradient tests, the difference between two contiguous samples, a good way to test DO values? What about testing for stuck values?

6. Should Winkler titrations be used to verify DO values? If so, what standards in sample collection, processing, and chemical titrating need to be implemented to accomplish this?

7. Is there a way to standardize the post correction of DO data? How would this be used to supplement real-time checks?

8. What training standards should be utilized to improve the skill levels of users which should ultimately improve QA?

9. What metadata requirements are needed for DO? – Time, position, etc

10. DO sensors require conductivity and temperature data to calculate saturation and concentration. What steps are needed to adequately QA/QC these additional sensors?

11. How do you deal with bio-fouling?

12. What roadblocks might prevent the implementation of improved QA/QC methods.

13. Will tests be area specific?

Initial characterization of possible metadata attributes associated with Dissolved Oxygen observations.

Cat.	Attribute	Parameter	Always Required	Required If Applicable	Valuable	Note / Comment
Sensor Information						
	Hardware Info *					
		Type	Y			
		Name			Y	
		Manufacturer	Y			
		Model	Y			
		Series				
		Serial Number	Y			
	Person Info(s) *		Y			
	Sensor Quality Assurance					
		QA Date/Time Info *	Y			
		Method Applied	Y			cite QARTOD DO sensor procedure
		Site (where QA took place)				
		Results			Y	
	Sensor Quality Characteristics					
		Precision				avail elsewhere
		Accuracy Info *				
	Sensor Calibration					
		Calibration Date/Time Info *	Y			
		Method Applied	Y			
		Site (where calibration took place)				
		Results		Y		Y/N versus quantify
		Units		Y		
	Measurements					
		Measured Parameters	Y			
		Measured Phenomena		Y		
		Measurement Record Descriptions				
		Content format details (delimiter, record/field lengths)				
Data Set Attributes						
	Format					
		Standard format name (netCDF, HDF, ODV, ESRI Shapefile, ...)		Y		custom
		File Content Type (ASCII, binary)	Y			needs further discussion
		Record Content Type (ASCII,				needs further discussion

	binary)				
	Content format details (delimiter, record/field lengths,...)				needs further discussion
	Format Description Reference				needs further discussion
Measured/Derived/QCFlag Parameter			Y		needs further discussion
	Parameter Unique ID				needs further discussion
	label/short name				needs further discussion
	long name		Y		needs further discussion
	definition		Y		needs further discussion
	origination (measured, derived, assigned (qcflag))		Y		needs further discussion
	Attribute Domain Values				needs further discussion
	Applicable QC Flag Reference(s)		Y		needs further discussion
	Applicable Parameter Reference(s)				needs further discussion
	Valid Values - Range Domain Info *				needs further discussion
	Units of Measure	Y			needs further discussion
	Value Temporal Extent Info *				needs further discussion
	Value Accuracy Info*				needs further discussion
	Parameter Standard Name Info *				needs further discussion
	Value Resolution				needs further discussion
	Codeset Domain				needs further discussion
	Codeset Name				needs further discussion
	Codeset Source				needs further discussion

Accuracy Info					
Accuracy Specification					needs further discussion
Accuracy Explanation					needs further discussion
Data Set Quality					
Software Quality Checks					
	Data Set Processing (see below)				
	Value Tests				
	sensor range check			Y	needs further discussion
	continuity check			Y	needs further discussion
	reasonable value check			Y	needs further discussion
	stuck value check			Y	needs further discussion
Manual Quality Checks					
	Procedure Info				
	Procedure Name				needs further discussion

		Inspector Person Info *				needs further discussion
		Procedure Performance Date/Time Info *				needs further discussion
		Procedure Results				specific to each data set
	Summary Quality Assessment					
		Value Assessments				needs further discussion
		Data Set Assessment				needs further discussion
	Quality Flag Definitions					
		flag name				same as data set
		flag definition		Y		
	Quality Assurance Project Plan Citation			Y		
	Uncertainty of related observations?				Y	Temp, Pressure for [] saturation
Data Set Processing						
	Process Info					
		name				
		Description		Y		
		Execution Date/Time Info *				did not discuss yet
		Execution Software Version Info *				
		Version ID				did not discuss yet
		Version Date/Time Info *				did not discuss yet
		Repository Resource Info *				did not discuss yet
		Reference Resource Info *				did not discuss yet
		Execution Software Deployment Info *				
		Execution Host Name or ID				did not discuss yet
		Execution Data/Time Info *				did not discuss yet
		Execution Temporal Extent Info *				did not discuss yet
		Execution Resource Info *				did not discuss yet
	Input Resource Info(s) *					
		Resource Name				did not discuss yet
		Resource Person Info *				did not discuss yet
		Resource URL				did not discuss yet
		Resource Temporal Extent Info *				did not discuss yet
		Resource MIME Type				did not discuss yet
		Resource Size				did not discuss yet
	Output Resource Info(s) *					did not discuss yet
	Processing Person Info(s) *			Y		

Data Telemetry				

Type (satellite, cabled)				TBD in general standards
Update schedule				TBD in general standards
Hardware Info				addressed elsewhere?
Type	Y			
Name		Y		
Manufacturer	Y			
Model	Y			
Series				
Serial Number	Y			

Software Version Info				
Version ID				did not discuss yet
Version Date/Time Info *				did not discuss yet
Repository Resource Info *				did not discuss yet
Reference Resource Info *				did not discuss yet

Software Deployment Info				
Execution Host Name or ID				did not discuss yet
Execution Data/Time Info *				did not discuss yet
Execution Temporal Extent Info *				did not discuss yet
Execution Resource Info *				did not discuss yet

Resource Info(s)				
Resource Name				TBD in general standards
Resource Person Info *				TBD in general standards
Resource URL				TBD in general standards
Resource Temporal Extent Info *				TBD in general standards
Resource MIME Type				TBD in general standards
Resource Size				TBD in general standards
Date/Time Info				
DateTime	Y			
DateTime format				TBD in general standards
Date				TBD in general standards
Date format				TBD in general standards
Time				TBD in general standards
Time format				TBD in general standards
DateTime convension				TBD in general standards

Temporal Extent Info				
Beginning Date/Time Info *	Y			
Ending Date/Time Info *	Y			
Composite Interval		Y		
Interval Units		Y		

Location/Orientation Info				
Location Info *				addressed elsewhere
Orientation Info *				addressed elsewhere

Location Info				
Horizontal				
Latitude	Y			
Longitude	Y			
Format (decimal degrees, deg-min-sec,...)	Y			
Reference				
~~Coordinate system used~~				
Latitude Resolution				
Longitude Resolution				
Geographic Coordinate Units				
Vertical				
altitude/depth	Y			
Composite Interval		Y		
unit	Y			
datum				
coordinate system definition				
resolution				

Spatial Extent Info				
Bounding Box				
Northernost Latitude		Y		
Southernmost Latitude		Y		
Westernmost Longitude		Y		
Easternmost Longitude		Y		
Region Info				
Region Name				TBD in general standards
Region Name Source				TBD in general standards
Bounding Polygon				
Bounding Circle				
center Location Info *				
radius				
radius units				

Orientation Info				
Sensor Orientation				
Axes				
X	Y			
Y	Y			
Z	Y			
Azimuth/Elevation				

azimuth				TBD in general standards
elevation				TBD in general standards
Data Set Description				
Title	Y			
Abstract				TBD in general standards
Purpose				TBD in general standards
Keywords				TBD in general standards
region				TBD in general standards
source type				TBD in general standards
parameter				TBD in general standards
phenomena				TBD in general standards
Spatial Extent Info *	Y			
Temporal Extent Info *	Y			
Citation Text				TBD in general standards
Data Set Location (where stored)	Y			
Online Reference (e.g., URL)		Y		
Data Set Person Info(s) *	Y			
Creation Date/Time Info *				TBD in general standards
Expiration Date/Time Info *				TBD in general standards
Data Mode				
real time				TBD in general standards
delayed				TBD in general standards
Modification Date/Time Info *				TBD in general standards
Completion Status (complete, open-active, open-inactive)				TBD in general standards
Related Resource Info *				TBD in general standards

Standard Name Info				
Standard Name				TBD in general standards
Standard Name Definition				TBD in general standards
Standard Name Source				TBD in general standards

Person Info				
Name	Y			
Role				
pointOfContact				TBD in general standards
originator				TBD in general standards
processor				TBD in general standards
principalInvestigator				TBD in general standards
resourceProvider				TBD in general standards
custodian				TBD in general standards
distributors				TBD in general standards
owner				TBD in general standards
Contact Information				
Phone Info (Country Code, Area Code, Phone Number, Phone	Y			

Type)				
Address				TBD in general standards
Organization	Y			
Email	Y			
Web Site		Y		
Platform Information				
Hardware Info *		Y		TBD in general standards
Deployment Info *		Y		TBD in general standards
Location Info *				TBD in general standards
Person Info(s) *				TBD in general standards
Carries				TBD in general standards
Platform Unique ID(s)				TBD in general standards
Sensor Unique ID(s)				TBD in general standards
Name				TBD in general standards
Type				TBD in general standards

Deployment Info				
parent platform Unique ID				
locality (in situ, remote)				TBD in general standards
mobility (stationary, mobile)				TBD in general standards
deployment Temporal Extent				TBD in general standards
nominal deployment Location/Orientation Info *				
relative to parent				TBD in general standards
absolute				TBD in general standards
measured deployment Location/Orientation Info *				
relative to parent				TBD in general standards
absolute				TBD in general standards
deployment frequency				TBD in general standards
Data Set Constraints				
Use constraints			Y	
Access constraints			Y	
Modification constraints				
Other constraints				

~~Sample Attributes~~				
Sample collection method				addressed elsewhere
Sample analysis methods				addressed elsewhere
Sample curation techiques				addressed elsewhere
Sample curation location				addressed elsewhere
Sample Person Info(s) *				addressed elsewhere

Range Domain Info				
Range Domain Minimum				
Range Domain Maximum				
Range Domain Wrap Low				

	Range Domain Wrap High				

APPENDIX D-3 IN SITU CURRENTS NOTES & FOCUS QUESTION RESPONSES

In Situ Currents Group Leaders		
Metadata Lead	**Process Lead/Facilitator**	**Technical Lead**
Nan Galbraith	**Kristen Crossett**	**Bill Burnett**
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Nan Galbraith	WHOI
Leonid I Ivanov	Woods Hole Group
Victor A Levesque	U.S. Geological Survey
Daniel R Martin	NOAA CSC
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Chris Raleigh	CICORE – SFSU
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Jerome R. Wanetick	Integrative Oceanography Division University of California
Lauren M Wetzell	Teledyne RD Instruments

GROUP DISCUSSION NOTES

Attached are the spreadsheets filled out by the In-Situ Quality Assurance (ISQA) working group. While the ISQA tried to answer the initial seven questions posed by the QARTOD Committee – ISQA attendees decided to rearrange/rewrite the questions to best meet the in-situ current's QA needs.

QUESTION 2: List the user/manufacture specifications that should be used to evaluate the instrument. (Question 1 was incorporated into Question 2).

User	Manufacturer	Instrument	Water Depth	Platform type	Time Stamp Relevant to Ensemble	Orientation	Bin Size	Blanking distance	# of pings	Ping interval	sample duration	data format
	(e.g. Teledyne RD Instruments)	(e.g. 38 kHz BB ADCP										
	NOBSKA	mavs										
WHOI	Sontek	argonaut XR										
USF	RDI	600khz sentinal	20m		start time (of pinging)							
USGS	RDI	1200khz monitor	10m	bottom mount	mid way in ensemble	up-looking	50cm	30cm	60	6 sec	360 sec	binary
VIMS	RDI	1200	10m	bottom mount		up-looking	50cm		60		1 min	binary
USGS	Sontek	argonaut - adv	1m	bottom mount	mid way in ensemble	side-looking	1 cubic cm	n/a fixed			240sec	binary
CO-OPS	Sontek	1mhz	20m	buoy mounted	mid way in ensemble	downward looking	1m	?	300	1sec	360sec	binary to ascii

(Continuation of table provided in Question 2).

best possible standard deviation	water mode #	Expected Accuracy - Speed	Expected Accuracy - Direction	Speed-Resolution	Direction-Resolution	Speed Range	Reporting Frequency	Instrument Check	Compass Type
		0.5-1mm/s (single measurement accuracy)		0.5-1mm/s (single measurement accuracy)			up to 20hz (operator selectable)	test and calibrations routine are built into instrument	
		+/-1% or 0.5 cm/s	+/- 2degrees	.1cm/s	.1degree	+/-6m/s	10sec minimum	built in calibration procedure on compass	
0.8cm/sec	1	1 cm/sec	2 degrees	0.1cm/sec	0.1degree	+/-5m/sec	6min	built in calibration procedure on compass	flux gate
	12	2 cm/sec	3 degrees	0.1cm/sec	0.1degree	+/-5m/sec	10min	built in calibration procedure on compass	flux gate
pretty low	n/a	<1cm/sec	2 degrees	0.1cm/sec	0.1degree	+/-6m/sec	15min	compass calibration, zero velocity check	flux gate
2cm/sec (in tank)	n/a	buoy motion dependent	+/-2 degrees during checkout, +/-15 as deployed	0.5cm/sec	1 degree		6min	in situ compass calibration	nortek flux gate

Attendees from various agencies described their quality assurance / standard process:

Rich Bourgerie (NOAA's National Ocean Service (NOS) Center for Operational Oceanographic Products and Services; CO-OPS) provided a description of their QA standards and practices. CO-OPS manages the Real Time Physical Oceanographic Real-Time System (PORTS) program: http://tidesandcurrents.noaa.gov/ports.html and maintains a 24 hour watch to monitor and QC the observations.. There are thirteen (13) PORTS stations around the nation. CO-OPS has been deploying ADCP sensors (bottomr mounted, upward looking, sidewards looking – either horizontal or buoy mounted) for fifteen (15) years and are operating approximately 25 to 30 sensors nationwide at any given time. Almost all of the systems are maintained in shallow water, no deeper than 100 ft, since their main customers are the shipping industry. The sensors normally operate at 300, 600 and 1200 kHz. CO-OPS visits the Naval Surface Warfare Center's (NSWC) Carderock Division David Taylor calibration facility, a tow tank, that is half-a-mile long, to calibrate their sensors.

Mark Bushnell (NOS, CO-OPS) provided a description of his offices QA standards and practices. Observations are disseminated in PORTS Uniform Flat File (PUFF) format;

http://tidesandcurrents.noaa.gov/publications/pufff4.pdf. For ADCP sensors they use the Nortek compass calibration table.

Jeff Donovan (University of South Florida) provided a description of their QA standards and practice. They use 300, 600 and 1200 kHz RDI ADCPs and calibrate them in the David Taylor calibration facility. Each test costs about $8,500 and one test is made for each frequency. Compass calibrations are performed at the beach and also with a Helmholtz coil to ensure the directions are accurate. They also use the RDI standard deployment tests. Found issues with RDI's 16.28 firmware.

Richard Crout (NOAA National Weather Service's National Data Buoy Center) provided a description of their QA standards and practices. They currently have eleven (11) current meters – Aandera, Sontek and RDI – using battery power from the buoys. The sensors are stored in a cage with a bridle, but NDBC is exploring ways to decouple the ADCP from the buoy – possibly with bottom mounted systems. Some systems are deployed with 78 kHz sensors. NDBC collects data from fifty-eight (58) oil and gas platforms located in the Gulf of Mexico. Most are using 300 kHz or 78 kHz sensors. NDBC operates a Data Assembly Center that is operated 24 hours a day to check observations from the ADCP sensors, oil and gas platforms and partner stations.

Ellyn Montgomery (United States Geological Survey Woods Hole Science Center WHSC) provided a description of their QA standards and practices. They have an assortment of sensors – RDI, Sontek – but do not have many quality assurances applications that are performed in real-time. Most of the sensors are operated in the coastal/near-shore environment – and are upward looking. Calibration is sometimes performed at the David Taylor calibration facility.

Chris Raleigh (Center for Integrative Coastal Observation, Research and Education (CICORE) San Francisco University; SFSU) provided a description of their QA standards and practices. They are using RDI horizontal mounted ADCPs and are looking to maximize the performance of those systems.

This table includes processing that is performed only in real-time. Most of the conversation centered on the fact that users must rely on information from the vendor – for most quality assurance. In some cases this table could be replaced by the manufacturer's specifications – however there might be some users that are interested in how other groups are performing quality assurance. Typical discussions for this question centered on:

a. It could be a very long table.
b. It would be helpful to have vendors fill in the spreadsheet.
c. It could be a "living" document – meaning that the information could change very quickly.
d. Is this table really necessary? Could users just rely on vendor specs?

QUESTION 3: Identify discuss, and document checks that you performed prior to deployment

User	Manufacturer	Instrument	Instrument Check - required	Velocity Check - recommended	Compass Calibration (yes/no) - required	Temperature check (yes/no) - required	pressure check (yes/no) - required	data corrections? (see metadata sheet)	Clock Check (yes/no)
	(e.g. RDI)	(e.g. 38 kHz BB ADCP	predeployment check that rdi has						
USF	RDI	600khz sentinal	standard rdi check with ps= 0	none	standard rdi compass spin	inside lab vs outside lab	no pressure sensor	input magnetic declination from NOAA site	yes
CO-OPS	Nortek	1mhz	standard nortek	david taylor	yes - in situ	yes	yes	none	yes
USGS	RDI	1200khz monitor	internal self test	none but planned	yes	yes in air and at deployment time	yes in air only	magnetic variation	verify through nist

The purpose of this table is to ensure that users perform some type of quality assurance check before the sensor is deployed in the field. Users are strongly recommended to refer to the manufacturer's specifications to ensure the correct calibration is provided. It is also important to remember that these tables refer to the sensor and not the data.

QUESTION 4: Identify potential options or partnerships or centers to conduct field verification of the ADCP while deployed.

In-situ Observations	Remotely-Sensed Observations	Research Programs	Field Surveys	Climatology	Models
(e.g. surface current meters)	surface only				
glider	hf radar	published reports	published reports (journal publication)	historical current measurements	optimal interpolation (OI)
drifter	satellite data (visible, IR SAR)		verify location of instrument		principle (sp?) component analysis
Ships of Opportunity			buoy position in watch circle		tidal constituents

Research vessels					
nearby ADCPs					
nearby current meters					

- Participants felt this question was similar to Question 6
- Keep research programs as a field (e.g. 1-year study could have been performed)
- Use models and climatology fields with caution – there is a high degree of uncertainty here
- Climatology and models don't necessarily mean the same thing; climatology includes "data" as well
- For models, check principle components
- Verify location - require info on position verification (perhaps include this in metadata) position w/in expected watch circle
- Define the platform type in the metadata

QUESTION 5: Identify, discuss, and document checks that you performed prior to deployment.

Web-sites	Formal Studies	Research Programs	Conferences and Meetings	Manufacturer information
	ACT			
GCMD			qartod	RDI
twiki			IEEE/CMTC	Sontek
			MTS Buoy Workshop	Nortek
			Oceans	Aanderraa

			manufacturer users group meetings	
			AGU	
			Ocean Sciences	

QUESTION 6: Identify centers where instruments can be sent for calibration. Document sites where users can compare their sensors to established reference sensors.

Manufacturer	Instrument	Govt. locations	Manufacture locations
rdi		co-ops, any adcp locations to check	rdi (or any lake)

- David Taylor's facilities are also an option.
- Recommendation: develop method for lower frequency QA

QUESTION 7: How do Users Address Biofouling?

User	Manufacturer	Instrument	Procedures to minimize biofouling	Time duration for procedure	Location
	(e.g. Teledyne RD Instruments)	(e.g. 38 kHz BB ADCP)			
CO-OPS		bottom mounted systems	coat w/ red trinidad (3 coats)		chesapeake
USGS	RDI	1200khz monitor	trialex 33 - coopers	1 year w/ 2 coats	tampa bay
	Nortek	awac-ast	heavy duty pantyhose	60 days	tampa bay
	Nobska	mavs	standard procedures	limited	

- USF has the same specifications as the CO-OPS example
- Other examples of procedures to minimize biofouling include pvc tape and plastic bags
- To prevent corrosion, avoid dissimilar metals and coat with red Trinidad
- RDI recommends trilox
- *Practical Sailor* - publication that tests biofouling paints annually
- When cleaning ADCP - don't use pressure washer; simple green works well - removes barnacles

Other Notes:

For QARTOD V

- Present these completed sheets by the next meeting.
- Potential to disband in situ group and move on?
- QC for single point current meters has not been done yet. (NDBC expecting to deploy 40 to 50 and VIMS will be putting out 3, RDI as well)
- QC for current measurements off gliders or buoy platforms (drifters)? Need to address.

Evaluation of In Situ Currents break-out group

- Discussion of instruments was useful
- This is a starting point for someone that will be deploying an instrument, not necessarily recommended set-ups.
- What will be going to IOOS? – Best practices? Show how the users are doing it. It is essentially the user's recommendations are based on how they perform actual setups.
- If I knew we would be focusing on Quality Assurance then we would have brought experts; would have liked to discuss the QC side more.
- More interested in QC of ADCP data (i.e. how we transmit our data.
- Content discussion is better than format discussions (perhaps make format a separate discussion)
- Discussion wandered…could be more efficient; got stuck on questions; overall useful; still unclear if discussion was going to focus on QC vs. QA; TWIKI site very important, simple; perhaps have point person for TWIKI site notify break-out group members of new postings, etc.
- Would like to see one web site…repository; would like QARTOD to keep things open – if in situ currents is not a topic, perhaps devote 1 hour to discuss updates on the topic; national backbone thinking and support; everyone contribute libraries of QA and QC on a web site/repository
- Learned a lot based on other people's experiences
- Interested in real-time QC; learned a lot about ADCP's and will be carrying info back to technical and science staff
- Unclear on distinction of QA and QC as used here; would be more interested in implementation discussions if had long term goals
- In future deal with transfer mechanism to fit data in small enough packet;
- Hoping to hear QC discussions here; looking for QA and QC tools here
- Hoping to hear QC discussions here and developing tools; focused on details
- These discussions cannot take place over email; progress was made in this meeting
- Very informative
- Could we provide well documented code at next QARTOD?
- Hoping to see tools to approach uniformity; last half hour most useful listening and discussing RDI
- Real demand out there for documentation on others experiences (in agreement w/ previous statement)
- Get at least one representative from regions, often an east coast or west coast bias at meetings; last hour most useful listening to vendors; overall the sessions have been great

Observation Type: in-situ current velocity

Method of Collection: adcp

Metadata Content Areas	Example	Additional Information / Notes / Comments
Sensor Information		
Hardware Info *		
Type	acoustic doppler current profiler	
Name	n/a	
Manufacturer	trdi	
Model	sentinal	frequency
Series	work horse	
Serial Number	123456	
firmware vers	16.28	
operating frequency	600khz	
mfgr specs		
Deployment Info *	link to configuration file	other instruments deployed
parent platform	buoy/piling	
locality (in situ, remote)	in situ	
mobility (stationary, mobile)	stationary	
deployment Temporal Extent Info *	start time - end time	
water depth	20m	include range and/or accuracy
nominal deployment Location/Orientation Info *	surface down-looking	
targeted instrument depth/elevation		relative to surface or bottom
relative to parent	surface/bottom	
R absolute		
upfacing, moored, ship-mounted		
measured deployment Location/Orientation Info *		
? relative to a fixed point	2m from buoy deck	definition of fixed point
? absolute		
time of last location info		
quality/accuracy of last location info		
upfacing, moored, ship-mounted		
deployment frequency	3months	turn around frequency
Person* responsible for deployment		contact information
Instrument Prep		
Predeployment checks - details and dates		
		bin size, frequency, ensemble size, depth cell size, p
		minimum acceptable number of samples, lowest acc
		max expected water velocity
		recommended error velelocity setting
Person* responsible for pre-deployment checks		
Sensor Quality Assurance		see question 3
QA Date/Time Info *		
Person* responsible for Sensor QA		
Method Applied		
Site (where QA took place)	WHOI	
Results	pass	pass/fail
Sensor Quality Characteristics		see question 2
Precision		
Accuracy Info *		
Sensor Calibration		calibrated pressure sensors and temperature sensor
Calibration Date/Time Info *		
Person* responsible for Sensor Calibration		
Method Applied		same as quality assurance
Site (where calibration took place)	WHOI	
Results	pass	pass/fail
Measurements		temperature, pressure, currents
Measured Parameters	temperature pressure currents	describe only parameters that are being transmitted

* see expanded list of content fields under the Reusable Fields section

Observation Type: in-situ current velocity

Method of Collection: adcp

Metadata Content Areas	Example	Additional Information / Notes / Comments
Measured Phenomena	tide, rainfall, etc.	
? Measurement Record Descriptions		names of the columns
? depth/height of meausurements		may vary for different parameters
Content format details (delimiter, record/field lengths)		data format

Platform Information		
Hardware Info *		
Deployment Info *		
Location Info *		
Person Info(s) *		
Carries		all instrumentation in the platform
Platform Unique ID(s)		additional instrumentation
Location		targeted depth
Sensor Unique ID(s)		id for additional instrumentation (link to other metada

Data Set Description (fgdc)		
Title		
Abstract		
Purpose		
Keywords		
region		
source type		
parameter		
phenomena		
Spatial Extent Info *		
Temporal Extent Info *		
Citation Text		
Data Set Location (where stored)		
Online Reference (e.g., URL)		
Data Set Person Info(s) *		
Creation Date/Time Info *		
Expiration Date/Time Info *		
Data Mode	real time/delayed	
Modification Date/Time Info *		
Completion Status (complete, open-active, open-inactive)		
Related Resource Info *		

Data Telemetry		
Type	Iridium / Argos / cabled	satellite (type)
Update schedule	hourly	

Data Set Quality		
Software Quality Checks		
Data Set Processing (see below)		yes/no
Value Tests		yes/no
sensor range check	yes/no	yes/no
continuity check	yes/no	time continuity
reasonable value check	yes/no	
stuck value check	yes/no	
time drift	yes/no	
position check	yes/no	quality of position - lat/lon
Manual Quality Checks		
Procedure Info		
Procedure Name		
Inspector Person*		
Procedure Performance Date/Time Info *		
Procedure Results		

* see expanded list of content fields under the Reusable Fields section

Observation Type: in-situ current velocity

Method of Collection: adcp

Metadata Content Areas	Example	Additional Information / Notes / Comments
Summary Quality Assessment		
Value Assessments		
Data Set Assessment		
Quality Flag Definitions		
flag name		
flag definition		

Data Set Processing		
Process Info		
name		
Execution Date/Time Info *		
Execution Software Version Info *		
Version ID		
Version Date/Time Info *		
Repository Resource Info *		
Reference Resource Info *		
Execution Software Deployment Info *		
Execution Host Name or ID		
Execution Data/Time Info *		
Execution Temporal Extent Info *		
Execution Resource Info *		
Input Resource Info(s) *		
Resource Name		
Resource Person Info *		
Resource URL		
Resource Temporal Extent Info *		
Resource MIME Type		
Resource Size		
Output Resource Info(s) *		
Processing Person Info(s) *		

Data Set Attributes		
Format		
Standard format name (netCDF, HDF, ODV, ESRI Shapefile, …)		
File Content Type (ASCII, binary)		
Record Content Type (ASCII, binary)		
Content format details (delimiter, record/field lengths,…)		
Format Description Reference		
Measured/Derived/QCFlag Parameter		
Parameter Unique ID		
label/short name		
long name		
definition		
origination (measured, derived, assigned (qcflag))		
Attribute Domain Values		
Applicable QC Flag Reference(s)		
Applicable Parameter Reference(s)		
Valid Values - Range Domain Info *		
Units of Measure		
Value Temporal Extent Info *		
Value Accuracy Info*		
Parameter Standard Name Info *		
Value Resolution		
Codeset Domain		
Codeset Name		
Codeset Source		

* see expanded list of content fields under the Reusable Fields section

Observation Type: in-situ current velocity

Method of Collection: adcp

Metadata Content Areas	Example	Additional Information / Notes / Comments
Data Set Constraints		
Use constraints		
Access constraints		
Modification constraints		
Other constraints		

Sample Attributes		
Sample collection method		
Sample analysis methods		
Sample curation techiques		
Sample curation location		
Sample Person Info(s) *		

*** Reusable Fields** (apply to multiple content areas)

Date/Time Info		
DateTime		
DateTime format		
Date		
Date format		
Time		
Time format		
DateTime convension		

Temporal Extent Info		
Beginning Date/Time Info *		
Ending Date/Time Info *		

Location/Orientation Info		
Location Info *		
Orientation Info *		

Location Info		
Horizontal		
Latitude		
Longitude		
Format (decimal degrees, deg-min-sec,...)		
Reference		
Coordinate system used		
Latitude Resolution		
Longitude Resolution		
Geographic Coordinate Units		
Vertical		
altitude/depth		
unit		
datum		
coordinate system definition		
resolutior		

Orientation Info		
Sensor Orientation		
Axes		
X		
Y		
Z		
Azimuth/Elevation		
azimuth		
elevation		

Spatial Extent Info		
Bounding Box		
Northernost Coordinate		
Southernmost Coordinate		
Westernmost Cordinate		
Easternmost Coordinate		
Region Info		

* see expanded list of content fields under the Reusable Fields section

Observation Type: in-situ current velocity

Method of Collection: adcp

Metadata Content Areas	Example	Additional Information / Notes / Comments
Region Name		
Region Name Source		
Bounding Polygon		
Bounding Circle		
center Location Info *		
radius		
radius units		

Range Domain Info		
Range Domain Minimum		
Range Domain Maximum		
Range Domain Wrap Low		
Range Domain Wrap High		

Standard Name Info		
Standard Name		
Standard Name Definition		
Standard Name Source		

Deployment Info		
parent platform Unique ID		
locality (in situ, remote)		
mobility (stationary, mobile)		
deplolyment Temporal Extent		
nominal deployment Location/Orientation Info *		
relative to parent		
absolute		
measured deployment Location/Orientation Info *		
relative to parent		
absolute		
deployment frequency		

Person Info		
Name		
Role		
pointOfContact		
originator		
processor		
principalInvestigator		
resourceProvider		
custodian		
distributors		
owner		
Contact Information		
Phone Info (Country Code, Area Code, Phone Number, Phone Type)		
Address		
Organization		
Email		
Web Site		

Accuracy Info		
Accuracy Specification		
Accuracy Explanation		

Hardware Info		
Type		
Name		
Manufacturer		
Model		
Series		
Serial Number		

Software Version Info		
Version ID		
Version Date/Time Info *		
Repository Resource Info *		
Reference Resource Info *		

* see expanded list of content fields under the Reusable Fields section

Observation Type: in-situ current velocity

Method of Collection: adcp

Metadata Content Areas	Example	Additional Information / Notes / Comments
Software Deployment Info		
Execution Host Name or ID		
Execution Data/Time Info *		
Execution Temporal Extent Info *		
Execution Resource Info *		
Resource Info(s)		
Resource Name		
Resource Person Info *		
Resource URL		
Resource Temporal Extent Info *		
Resource MIME Type		
Resource Size		

* see expanded list of content fields under the Reusable Fields section

APPENDIX D-4 WAVES NOTES & FOCUS QUESTION RESPONSES

Waves Group Leaders		
Metadata Lead	**Process Lead / Facilitator**	**Technical Lead**
Anne Ball	**Kim Cohen**	**Richard Bouchard**
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GROUP DISCUSSION NOTES

Seven primary questions were made available to the group prior to our meeting in Woods Hole. During the Waves breakout each of the questions was brought up for discussion. Some received more attention than others, based on how well the group felt the specific questions related to CTD quality assurance. The results of these discussions, as well as the related actions, are summarized below (grouped by question) and in the corresponding spreadsheet (Waves_APPENDIX1).

NEAR-TERM ACTIONS

A. Quality Control

Participants should review the QC Table as a final step before submission to Ocean.US/DMAC. Modifications should be sent to Julie Thomas for report inclusion.
Update: The QC standards will be forwarded to the Data Management and Communications – Steering Group in January 2007 for considerations as a standard. The submission will be posted to: http://nautilus.baruch.sc.edu/twiki/bin/view/Main/WaveQC

B. Quality Assurance

1. Participants will submit summaries of manufacturer specifications for posting on the QARTOD waves quality assurance site. Specifications should be emailed to Julie Thomas.
2. Waves participants should review, edit, and add to each tab of the breakout focus questions spreadsheet (see attached).
3. Participants should identify common elements for inclusion as quality assurance minimum standards. (Important to remember that this is a dynamic document that is subject to change)

QUESTION 1: Existing and Emerging Standards

- Bouchard: NDBC maintains multi-mission buoys – wind, pressure, and waves are currently three of the most critical parameters. QA protocols are largely dictated by the National Weather Service as a whole.
    - QA currently under configuration management. Procedure involves a functional test of the systems themselves prior to deployment. If they pass these tests, they're considered ready for deployment. NDBC completes an integration test on the wave sensors for Datawell Hippy 40 or accelerometers. Once the buoy is integrated, several hours of groundtruthing is completed to validate the data.
- Hathaway: USACE/ Field Research Facility (FRF): Maintains a high-resolution waves system with an 8-meter array. In terms of QA, USACE overlays all of the spectra to ensure that they're consistent. Inconsistencies in this test indicate a potential problem. Waves system is sent to SCRIPPS for calibration. The data comes back in real-time. An RDI ADCP is embedded within the array, which provides waves and currents. There is also an additional pressure sensor included within the system.

- Devine: Teledyne RDI – Main goal is to be able to provide RDI with specifications for how their operations may need to change in order to ensure compliance with whatever is decided by this group. QA involves an agreement of height spectra calculated from each of the 3 independent measurements types (12x near surface orbital velocity sensors, 4x independent acoustic surface tracking measurements and classic pressure based time series). The near surface array of velocity sensors is used in conjunction with array processing techniques to derive the directional spectra.
- Morrison: Nobska MAVS current meter: Todd intends to determine if there is anything that will need to change, in terms of their existing QA and metadata procedures. QA procedures include frequency response, series of measurements in a tow tank, and pre-and post-deployment calibrations. Unlike ADCPs, MAVs involves single point measurements of flow. QA is relatively straightforward because there is not a gradation of quality -- either the instrument made the measurement or it didn't. However, biofouling could impede flow through the sensor, resulting in a velocity reading that doesn't properly reflect ambient conditions.
- Waves measurements used for aquaculture planning to determine wave forcing measurements and effects. Spectral sense of waves demonstrates limitations of the ADCP; different from wave height and period. One thing that may need to be considered in terms of level of priority for future discussions is "What are the parameters that are robust enough for routine measurement?" There are certain obvious parameters and most have already begun, but there may be a need to define the others (e.g., nitrate, DO, CO2)
- Pederson: NORTEK Wave measurements are taken using a PUV or AWAC. This involves the use of 3 beams, with the center beam used for acoustic tracking. QA procedures involve array processing (max. likelihood); triple point measurement (SUV), acoustic surface tracking, and orbital velocity.
- Steele: Works with both non-directional and directional wave data. A variety of sensors are used for pitch/roll buoy to get quality data out.
- Kim and Gabriel: Attending the session to learn more about quality procedures for waves (ADCP).
- Castel/Thomas: SCRIPPS/CDIP has been measuring waves for 30 years. Various systems have been deployed including wave staffs, ADCPs, pressure gauges, sonic transducers and wave buoys. Currently, pressure sensors and buoys predominate. CDIP checks and verifies manufacturer specifications. Checks include verifying sensor/system (i.e. including cables and hardware) accuracy over extended time, frequency response characteristics, temperature sensitivity, noise floor and sensor resolution. QA for Datawell buoys/through systems includes frequency response, compass swing, inclination, 3 axis (x,y,z) displacement and resolution check. Noise floor is verified by xyz acceleration signal. Field tests are underway for a GPS based wave buoy. Post deployment procedures duplicate pre-deployment procedures. Both real-time and historic data are transmitted to the NWS office, NDBC and disseminated on the web at http://cdip.ucsd.edu. A FGDC and XML compliant metadata record accompanies the spectral information.
- Polonichko: SONTEK: Acoustic Doppler Profiler (ADP) and Acoustic Doppler Velocimeter (ADV) used to measure directional waves. Burst sampling of short-range measurements for waves interspersed with standard current profiles.
- Ulmer: CSC: Beginning to implement data transport labs with OPeNDAP/OGC services. These labs will focus on more on transport protocols; however, to ensure the greatest utility,

they'll need an understanding of how data providers handle waves data what quality control and quality assurance procedures are applied.

Proposed Method to Organize and Distribute Waves QA

Based on input collected during the 2005 Waves Technical Workshop and QARTOD III waves session, a table that depicts necessary QC checks was developed. This table could serve as a model for how to categorize the QA information. Each submission was compiled individually by vendor and/or data provider. All submissions were considered to identify common elements that could be consolidated into a minimum recommended standard. QARTOD IV participants are encouraged to review this information and provide any additional input or feedback. This list is easily extensible and doesn't preclude the addition of other checks or types of sensors, as needed.

The list from QARTOD III represents minimum QC standards based on commonalities among the various submissions. In order to accommodate differences among the various waves systems and sensors, the consolidated list of QARTOD QC recommendations does not define specific limits or numbers of points for each quality control test. Where submissions did not agree or were sensor specific, the table recommends a general range or user-defined value for each test.

The QC Standards will be submitted shortly to Ocean.US/DMAC for review.

There was general consensus from the group that a similar approach would work well for the QA standards development process.

QUESTION 2:	List the manufacturer specifications				
Manufacturer	**Instrument**	**Expected Accuracy**	**Reporting Frequency**	**Instrument Check**	**Data Quality Indicator**
Nobska	MAVS	Single measurement resolution and accuracy are 0.5 to 1.0 mm/s and 1% of reading respectively. Pressure measurement has a resolution of 0.005 decibar or 0.5 cm head and 1% precision.	Generally 2 Hz but up to 20 Hz, operator selectable, averaging and burst sample are also operator selectable	Test and calibration routines are built into the instrument and can be run at the discretion of the operator	A "bad" velocity measurement (generally meaning absent) is automatically flagged by the firmware. Un-flagged measurements have the normal accuracy and resolution of the instrument. A "bad" pressure measurement can result from the pressure port becoming
Teledyne RD Instruments	ADCP waves	See TRDI web site for information on the method of measurement: http://www.rdinstruments.com/pdfs/waves_primer_0504.pdf, and specifications: http://www.rdinstruments.com/waves.html	See TRDI web site for information on waves array specifications: http://www.rdinstruments.com/waves.html	All testing software is included on TRDI web site: http://www.rdinstruments.com/support.html	TRDI quality assurance methods include a 4th acoustic beam to calculate velocity error. TRDI's BroadBand signal processing technique produces a "correlation" data qa parameter for additional quality assurance.

QUESTION 3:	Document recommended QA procedures that confirm a sensor is producing data according to specifications					
Manufacturer/ Collector	**Instrument**	**Measurement Technique**	**Pre-release Process**	**Deployment**	**Post-deployment Procedures**	**Comments**
Nobska	Modular Acoustic Velocity Sensor (MAVS)	Differential travel time and pressure	Calibration procedures are built into the firmware and can be run and recorded by the operator at his/her discretion;	Bad measurements automatically flagged during a deployment; MAVS works in clear water, turbid water, mud, bubbles, etc. Signal can be intermittently blocked by swim bladders - such bad measurements are flagged. Extreme bio-fouling doesn't usually block	Calibration procedures are built into the firmware and can be run and recorded by the operator at his/her discretion	
Nortek	Acoustic Wave and Current (AWAC)	Doppler; surface track (AST), and pressure	Zero pressure sensor and set to atm.; Note atmospheric pressure; Ensure that there is no ferric material near instrument during compass calibration; Identify modes of failure using error codes; Compare spectra (e.g., pressure, velocity, AST); Check tilt	Instrument pointed vertical to surface (diver deployed or use a gimbal); deployed within depth range; beams free of any obstructions;		Recommended
NDBC	Buoy	Heave pitch and roll	Evaluate frequency bands (.03 hz and below) for any unexpected values			
Datawell	Buoy	Displacement/ translational	Compass check; Inclination check -- geographically dependent/ depends on orientation of the buoy; Take a visual sighting; Redundant transmission to ensure that data are not lost; XYZ displacement; Evaluate noise in the low frequency band (usually indicate		When buoy is recovered, same tests are applied to ensure that nothing has changed	
Sontek	Acoustic Doppler Profiler/ Acoustic Doppler Velocimeter	Acoustic doppler and pressure	***SIMPLE:*** Format recorder; Check battery voltage, sensor pressure and temperature (should be similar to ambient conditions), and vent plug for pressure sensor; Zero pressure sensor; Check noise level; Set time to reflect correct time zone; ***DIFFICULT:*** mult	No obstructions; needs to be mounted correctly; be aware of what is above the instrument;	Limit post-deployment checks: signal to noise ratios; verify pressure, temp. and compass readings; verify velocity std. dev.;	recommended
USACE/FRF	Datawell Waverider	Translational/ displacement	Per CDIP			
	PAROS and Sensometric pressure sensor	PAROS - Crystal Oscillator; Sensometric - Strain gauge	Deadweight test (static);	Intergauge comparison; make sure that it's secured;	replace diaphrams, change oil, post-calibration;	Required
	Baylor Wavestaff	Inductive transducer	Complete short test along cable;	periodic cleaning, visual inspection; tightening	Calibration of transducer	required
RDI	Acoustic Doppler Current Profiler (ADCP) and Waves Array	Doppler velocity array, acoustic surface tracking and pressure	Mitigate effects of biofouling by treating with bottom paint (West Marine, Amuron, etc.); Run pre-deployment tests in bucket of water; Zero pressure sensor; Run Plan ADCP to configure ADCP.	Wait to hear the sensor beep prior to deployment, deploy upright on bottom or at top of mooring line.	Screen data post-processing based on established thresholds for error velocity (from 4th beam) + correlation… see TRDI website for more details http://www.rdinstruments.com/learning_center.html.	

QUESTION 3:	Document recommended QA procedures that confirm a sensor is producing data according to specifications					
Manufacturer/ Collector	**Instrument**	**Measurement Technique**	**Pre-release Process**	**Deployment**	**Post-deployment Procedures**	**Comments**
Nobska	MAVS		Calibration and operability assessment tests and procedures are built into the firmware and can be run and recorded by the operator at his/her discretion. We recommend running these procedures and recording the results before and after each deployment.			Measurement quality as described here, is a characteristic of Doppler instruments that depend on backscatter. The differential travel time technique employed by MAVS is not subject to these problems. Any single measurement is either "bad" (generally mea

QUESTION 4:	Identify potential options or partnerships to conduct field verification of the system while deployed						
Manufacturer	**Instrument**	**In-situ Observations**	**Remotely-Sensed Observations**	**Ships of Opportunity**	**Research Programs**	**Field Experiment**	**Climatology**
Nobska	MAVS	MAVS can be and is used in all of these situations. Nobska does not maintain or rent such facilities, but we have access to them.	Data telemetery real-time, as opposed to a remotely-sensed satellite observation (for example)				
Any	Any	USACE/ Field Research Facility (FRF)	ISR X-band	LARC, CRAB	FRF; joint development of instrumentation		
Any	Any	Scripps Institution of Oceanography					
Any	Any	UNCW/ Onslow Bay, NC					
Any	Any	National Marine Sanctuary at Gray's Reef, GA					
Any	Any	Bodega Marine Lab					
		Naval Post-Graduate School, Monterey					
Datawell/Nortek	Buoy/AWAC	CDIP/Nortek (co-located sensors)					
RDI, Nortek, Sontek, Nobska, NDBC, CDIP							
QARTOD Participants							
			ESA/ Synthetic Aperture Radar				
				UNOLS ships for deployment and recovery			

QUESTION 5:	Identify available venues where QA-related issues and information can be exchanged among users.				
Manufacturer	**Instrument**	**Web-sites**	**Formal Studies**	**Research Programs**	**Conferences and Meetings**
NDBC	Datawell Hippy		Steele, K.E., J.C. Lau, and Y.H.L Hsu, 1985. Theory and Application of Calibration Techniques for an NDBC Directional Wave Measurements Buoy, *Jrnl. Ocean. Eng.* , IEEE, vol. OE-10, pp. 382-396.		
Nobska	MAVS	Manuals, documentation, code updates, published papers, applications (see www.nobska.net)	Manuals, documentation, code updates, published papers, applications (see www.nobska.net)		MTS/IEEE/OES OCEANS (see www.oceansconference.org), IEEE/OES Current and Wave Measurement Technology Conference (see www.oceanicengineering.org and follow links under Conferences and Workshops)
All	All	www.qartod.org			QARTOD
		www.ocean.us/cir (Community Information Repository)			
Datawell	Buoy	www.datawell.nl			
RDI	ADCP	www.rdinstruments.com	TRDI web site: http://www.rdinstruments.com/rdi_library.html, http://www.rdinstruments.com/pdfs/WavesBRO2000.pdf	Ocean Observatories: http://mvcodata.whoi.edu/cgi-bin/mvco/mvco.cgi, http://www.frf.usace.army.mil/capefear/realtime.stm, http://www.cormp.org/query_mooring.php?mysta=ILM1, http://wavcis.csi.lsu.edu/station.asp?units=eng&table=WCIS03,	
Nortek	AWAC	www.nortek-as.com			
Sontek	ADP/ ADV	www.sontek.com			

QUESTION 6:	Identify centers where instruments can potentially be sent for calibration/ diagnostic testing.		
Manufacturer/ Collector	**Instrument**	**Facility locations**	**Type of Service**
Nobska	MAVS	Woods Hole, however, full and effective calibration can be accomplished in the field by the user	
NDBC	Buoys	Stennis, MS	Ferris wheel
CDIP	Buoys	SCRIPPS, La Jolla	Ferris wheel
Teledyne/ RDI	ADCP	Support facilities in San Diego, China, France; Signal strength can be measured by customer in field	Beam angle misalignment calibration for <0.5% accuracy in San Diego; calibrate pressure sensors in San Diego and in France;
Nortek	AWAC	Annapolis, MD and Oslo, Norway; Signal strength can be measured by customer in field	Signal strength test
Sontek	ADP/ADV	San Diego; London; Shanghai; Signal strength can be measured by customer in field	SNR test

QUESTION 7:	How are potentially degrading effects of noise and hull frequency response addressed? Other issues?	
Manufacturer	**Instrument**	**Action Taken**
NDBC (User)	Strapped-down Accelerometer	Frequency-dependent empirical function using noise band(s) (< 0.03 Hz) to remove low-frequency noise (<.0.18 Hz) caused by non-vertical motions. See Lang, N., 1987. "The Empirical Determination of A Noise Function for NDBC Buoys with Strapped-Down Accele
NDBC (User)	Magnetometers (azimuth determination and magnetometer-only wave directions)	Corrections for residual and induced magnetism. See 1.Steele, K.E. and J.C. Lau, 1986. Buoy Azimuth Measurements-Corrections for Residual and Induced Magnetism, *Proceedings of Marine Data Systems International Symposium, MDS 86* , MTS, Washington DC, pp 27
	Buoys	Hull frequency response;
	Doppler	Lack of scatters will reduce range and increase noise (issue for Doppler in general, but in areas where one wants to measure waves, lack of scatter is usually not an issue)
Nobska	MAVS	MAVS works in clear water, turbid water, mud, bubbles, etc. The signal can be blocked by swim bladders and this can happen intermittently - such bad measurements are flagged. Extreme bio-fouling will generally not block the signal, but will invalidate t

Considerations for what types of instruments function best in certain locations - Project Design
* Check manufacturer specifications/ recommendations for each of these (Question 2)

Instrument Type
Science and Monitoring Goals
Location
Depth
Directional Limitations
Sampling Frequency
Sampling Duration
Wave Field (low frequency/ high frequency)
Current Velocities
Environmental Considerations/ Biofouling
Analysis Methods

QUESTION 8: Solicited considerations for what types of instruments function best in certain locations

Project Design (* Check manufacturer specifications/ recommendations for each of these (Question 2)). The group developed the following considerations: Instrument Type, Science and Monitoring Goals, Location, Depth, Directional Limitations, Sampling Frequency, Sampling Duration, Wave Field (low frequency/ high frequency), Current Velocities, Environmental Considerations/ Biofouling, and Analysis Methods.

QARTOD metadata for waves

1. Metadata content discussions during the breakout sessions

Throughout the breakout session on waves, a number of comments were made regarding the information or metadata needed to adequately document the quality of the data. The following is a summary of the topics and discussion covered during the session.

Users
There were two types of users mentioned during the sessions. The first were the users of the instruments. The second were the users of the data. Clearly, the different types of users would need different types of information.

Type of platform
Different information is needed based on whether the sensor is on a fixed or moving platform. For fixed platforms, the depth of sensor and the depth to the bottom, as well as the tilt and orientation are needed. For moving (buoy) platforms, metadata needs to include an azimuth check, tilt check, magnetometer check, depth to bottom and hull frequency response.

Instrument choice
The correct choice of instrument affects the quality of waves data. The documentation on the instrument will allow users to determine whether data is valid for a particular use. This includes choosing the correct instrument for the location (inside a bay, low waves, shallow, etc), sampling scheme, directional limitations, depth, sampling duration, sampling frequency, and whether the instrument will be deployed in a low or high frequency wave field.

Procedures
The procedures followed for instrument deployment are also important to the quality of the data. These include pre-release, deployment, and post-recovery procedures.

Flags
There was a fair amount of discussion of flags for data. Issues included the use of international standards, type of flags (hard and soft), the need to be able to crosswalk from one set of flag definitions to another, and the need to document the flagging standards that was used.

Additional effects on accuracy of measurement
The following items were discussed that could potentially affect the accuracy of waves measurements. There was some discussion on the affects of hulls on filtering the data and how as instruments have improved, the hull frequency response becomes more important. Information regarding instrument calibration includes the date, site, and method. Special occasions also need to be noted, such as the change of the battery pack. Environmental factors such as bubbles and currents can also have an affect on data and need to be recorded.

2. Metadata elements identified

The metadata session focused on expanding the existing table of metadata elements created during a previous QARTOD meeting. The attached spreadsheet was created during the metadata session. There was not enough time to complete the list of elements nor fill out all the columns. A longer session will hopefully be held in the future to help complete the required metadata needs. ***(See Table 1)***

3. Acronym list

A list of acronyms needs to be created. The list would include acronyms used for instrumentation, platforms, data values, flags, and other information commonly used in collecting and processing wave data.

4. Conclusions and next steps

Two levels of metadata
A major and important point of discussion was the need for two levels of metadata. One level needs to include a complete record containing all the information needed to document waves to enable users to fully understand the quality and appropriate uses of the wave data. The second needs to be the minimum information needed to transmit with the data from the sensor in order to conserve bandwidth. Future metadata sessions should fully address these needs.

Concurrent sessions for currents and waves metadata
Because wave and current data is collected using the same sensors, it may be beneficial to hold a dual metadata session at a future QARTOD meeting.

Creation of a diagnostic center
Members of the session discussed the need for a diagnostic center to perform tests on the instruments. It was suggested that perhaps IOOS could set up facility to perform these tests. This idea should be shared with the other QARTOD teams for further discussion.

Tag	Value type	Vocabulary or Value range	Definition/Note/ example	Need a contact	Required	Recommended	Lists	Comments
Station Name	text?		Your name for station; ** Cruise ID?				***Sensor types***	
Station Number	number	WMO numbers or user defined	Use WMO if available				AWAC	
							ADCP	
Deployment latitude		degrees minutes tenths (to 4 decimals, if available) or decimal degrees	To precision of 0.1 meters, if available (where the anchor is dropped)				Datawell	
Deployment longitude		degrees minutes tenths (3 decimals)					MAVS	
Precision of lat/long			to 4 decimals, if possible				ADP/ADV	
Location of lat/long reference point			anchor; where buoy is mounted, etc.					
Deployment Datum	text	Horizontal Datums						
Nominal Water Depth	number							
Nominal water depth units	text	Units						
Nominal water depth Datum	text	Vertical Datums	MSL …none or user defined					
User Defined Datum								
How you arrived at the depth?			Chart? Depth gauge					
Sensor type	text	***Sensor types***					***Platform types***	
Sensor depth (variable) meters or N/A							Fixed platform/surface	

Sensor elevation from seafloor							Buoy	
Sensor depth units							Fixed platform/ subsurface	
Sensor elevation units							3 meter disc	
Sample rate	number		Frequency (time between raw data samples)					
Sample rate units	text		seconds or hz?					
Sample Length/ Duration	number		# of points collected at sensor (e.g., "burst")					
Sample length units	text							
Sample interval								
Sample interval units	text							
Data name		height, period, …., significant wave height,						
Data units								
Platform information								
Platform type	text	***Platform types***						
(see Hull frequcncy response for buoys)								
Time reference		UTC, hours since …						
Is clock on instrument stable?								
Direction convention			waves coming from 0 degrees TN, 90 degrees = E					

Tag	Value type	Vocabulary or Value Range	Definition/Note/ example	Need a contact	Required	Recommended	Lists	Comments
							Data gaps	
							Spikes	
QC tests								
Time series (raw calibrated data)								
Test names		***Test names***						
Data gaps test			User defined; to reflect how many missing data points					
Data gaps N value								
Data gaps % count			% data that are good					
Max. gaps test								
Interpolation method			User defined					
Flag		***Flag standards***					Flag standards	
Flag value								
Spikes test							WMO	
Spikes n value							NDBC?	
Spikes m value								
Hull frequency response flag		Y or N	Buoy data only					
Hull frequency response source			Reference					

Calibration/ verification tests								
Calibration test reference								
Calibration test date								
Calibration test site (opt)								
Who did the calibration (opt)								
Massaging down to make data usable/ acceptable								

Future QARTOD Discussion Topics

Recommend the establishment of instrument test facilities
Review scientifically, peer-reviewed literature for intercomparison of co-located instruments

APPENDIX E – METADATA SUPPORT TO QARTOD IV

Metadata Team	
Name	**Focus Area Assignment**
Julie Bosch, Team Lead	CTD
Anne Ball	Waves
Nan Galbraith	In situ Currents
John Graybeal	Floated amongst groups
Tom Gulbransen	Dissolved Oxygen

One of the first steps in standardizing the metadata for certain ocean observations is the identification of the specific elements that must be captured in order to make the data usable, manageable, discoverable, etc. As part of QARTOD IV, a half-day, special session on Metadata was held on Friday, June 23rd. The goal of this session was to develop draft lists of the metadata content needed for wave, in situ current, CTD and dissolved oxygen data. Representatives from the IOOS Data Management and Communication (DMAC) Metadata Expert Team participated in the QARTOD IV breakout sessions to capture items discussed that are relevant to the metadata needs for each particular data type.

Prior to the meeting, an overview document for the workshop's metadata session (Appendix E-1) and a worksheet for identifying metadata content were provided to QARTOD participants (Appendix E-2). These materials were used by some of the breakout groups to help prompt discussions in order to determine necessary metadata content. Along with the list of potential metadata content areas, the worksheet contained columns for checking of the conditionality of the content (whether the information should be required in the metadata), the use of the particular metadata content (either for internal use or to accompany data) and the need for computability (machine-to-machine readability) for each item. Because of time constraints, however, many of these characteristics of the metadata were not completed.

Each breakout group took their own approach to addressing the metadata needs for their particular data type. Each breakout group report integrates the specific metadata content identified along with more general metadata information to be captured. Additionally, the discussion during the plenary part of the metadata special session provided insight into the process for determining metadata requirements. One key response that was echoed by many participants was that the time allotted to work on metadata issues was too limited. When asked if the group were interested in and would attend a workshop solely on dealing with metadata issues, there was a considerable amount of support for this idea. QARTOD participants were given an evaluation form for the Metadata Special Session, the results of which are provided in Appendix E-3.

APPENDIX E-1 – GUIDE TO METADATA DISCUSSIONS

How to Determine the Information Needed to Understand and Use Data

Guidance for Metadata Capture

June 23, 2006

Purpose of this guide

This guide was developed to help determine the information that is needed for someone to understand how to use data, whether it was collected or processed by themselves or others. It consists of questions to ask and a checklist of potential information fields that may be applicable to the data of interest. The guide focuses on the information that succinctly describes data versus the more general or textual information such as title, summary, and keywords.

Definition of metadata

For the purposes of this guide, metadata is defined as the information needed to identify, understand, access, manage, and use data.

Purpose of metadata

Metadata serves a lot of functions for data users, though the functions often vary according to the user's role. A cursory look (see table 1) at some metadata functionalities and user roles shows the range of needs for a variety of metadata content.

Data Source Creator	Data Provider/ Owner	Data System Developer	Data Manager	Data Tool Developer	Data Analyst	Science User	System Operator User	Educational User	Public User	Metadata Content Areas
Sensor Information										
X					X	X	X			Data source (instrument type, mfg, calibration, etc.)
Platform Information										
		X			X	X				Accuracy of location
Data Set Description										
						X				Title
							X			Unique ID
								X	X	Textual summary or abstract, purpose
								X		Keywords describing data set
			X							Data set location (server, file system, DB name, etc.)
				X	X	X	X	X	X	Spatial extent
				X	X	X	X	X	X	Temporal extent
		X	X							System environment (software, operating system, etc)
Data Set Quality										
				X	X	X		X		Quality assurance / quality control methods
	X				X	X		X	X	Quality assessment results
Data Set Processing										
		X	X	X	X	X				Data processing methods
			X	X	X	X	X			Data set lineage and version history
					X	X				Sample analysis methods (when applicable)
					X	X		X		Sample collection methods in field (if applicable)
Data Set Attributes										
			X	X		X	X	X		Data set format
	X		X	X	X	X	X	X	X	Observation parameters (item name, units, valid values, etc.)
Data Set Constraints										
	X		X			X		X		Access constraints
		X	X	X	X					Expiration date (date data set should be deleted)
	X	X	X							Liability
					X	X	X	X	X	Use constraints

Table 1: Metadata Functions by User Role

Background information

Metadata helps the user discover, evaluate, access, and use the data by answering most reasonable questions (who, what, where, when, why, and how) posed about a data set (figure 1).

Who

Who collected the data?
Who processed the data?
Who wrote the metadata?
Who to contact for questions?
Who to contact to order?
Who owns the data?

Where

Where were the data collected?
Where were the data processed?
Where are the data located?
Where was the instrument mounted?

When

When were the data collected?
When were the data downloaded?
When were the data processed?
When was this data file generated?

How

How were the data collected?
How were the data processed?
How do I access the data?
How do I order the data?
How was the quality assessed?

What

What are the data about?
What project were they collected under?
What are the constraints on their use?
What is the quality?
What are appropriate uses?
What parameters were measured?
What format are the data in?

Why

Why were the data collected?
Why is part of the data set missing?

Figure 1: Metadata Questions

There are a number of content standards for metadata, and these are geared toward broad categories of data, for example geospatial data, remotely sensed data, or biological data. Although there is room in these standards to capture almost everything that is needed, their element definitions are usually too broad or "flexible" to allow for machine (automatable) readability/interoperability of the information. More specific descriptions of the elements, with constrained choices for the content, make the information provided by the metadata much more useful.

But a single, general-purpose metadata content standard is unlikely to meet the needs of all observational data. Much of a standard will apply to data sets across the board; however, individual types of data will have additional content elements with specific methods of collection having possibly even more unique requirements.

So, the BIG question is:

What do you need to know about data to make it useful?

Deciding what's important

Consider the case of in situ current data. To answer the big question requires answering the following questions: How was the data collected? Was it obtained using a current meter or an ADCP and what "kind," make, model, and series? How was the instrument's quality assurance determined prior to deployment? Now, how is the instrument deployed? On a fixed platform? Moored? The answers to these questions may influence what else a user may need to know.

Let's look at what information would be needed about the position of the instrument. You could say that the vertical position (depth/altitude) of the instrument is a critical piece of information regardless of how the instrument is deployed. But, what about horizontal position? Are basic latitude and longitude enough? What if the ADCP is hull mounted? How is the position of the instrument determined? What is applied to quality control the position data? Does the position become part of the data, or something that applies to the complete data set? Are the metadata requirements for positional information for a hull mounted ADCP different than a moored current meter?

As a first step in determining what is important about the data, ask yourself some questions. In addition to the questions listed above, consider:

- What do I need to remember about how I collected or processed my data?
- What do I need to know about how someone else collected or processed the data that I want to use?
- What software might I (or others) need to use to automatically access, view, or process the data?
- How important is it to know the location accuracy of where the data was collected?
- What is important to know about the platform, instrument, or sensor?
- What details of the measured parameters or calculated values is needed? Sampling rates? Valid values? Flag definitions?
- What about the instrument calibration? Is it important to know how often a sensor is calibrated or date of last calibration?
- What processing is done on the raw data? Are values reviewed to see if they fall outside normal data ranges?

As a data collector, processor or user, you need to make sure those questions that are important to you are answered in the metadata.

Metadata content worksheet

In order for metadata to fully address (answer) the user needs, the content of the metadata must be determined. To help facilitate identifying the content requirements for metadata for specific ocean observations, an extensive, but not comprehensive, list of potential metadata content fields is provided in the accompanying worksheet, MetadataContentWorksheet.xls. The worksheet is designed as a checklist to prompt users to identify the information they need to know about a data type.

Along with the list of potential metadata content areas, the worksheet contains columns for checking of the conditionality of the content (whether the information should be required in the metadata), the use of the particular metadata content (either for internal use or to accompanying data) and the need for automatability (machine-to-machine readability) for each item. A column is included for any additional information, notes or comments and this column can be used for defining any specific characteristics that may be needed for a particular content element.

Worksheet instructions

1. Initially, since each observation type and method of collection can potentially require different metadata content, a separate worksheet should be used for each specific observation type. For example, in situ currents by moored ADCP would be separate from in situ currents by hull-mounted ADCP.

2. As you go through the worksheet, consider what information must be captured
   - add things that are missing
   - expand existing items that need to be more specific
   - cross off things that don't apply
   - check off whether things should be required (critical) or included only if applicable
   - identify whether items are just needed for internal data management use, or should accompany the data for other users
   - identify which fields must be "automatable" (machine-to-machine readable).

3. For any item that you think is necessary, please provide specifics about what you need to know about that item such as specific formats, method, or units that apply. Then indicate whether the item is Always Critical/Required or Required only if Applicable by checking the appropriate column.

Note that items listed under Reusable Fields can be used in multiple places. These are essentially repeatable content elements. These are indicated by an asterisk (*) in the worksheet. As these fields can apply to various other content areas (for example Location Info can be apply to the platform or sensor), the additional information column can be used to indicate the specific cases of use.

Next steps

Any information collected on the worksheets will be compiled with metadata notes taken throughout the QARTOD breakout sessions. This compilation will be used as a starting point for the Metadata session of the workshop. During the Metadata session, breakout group participants will work on refining the initial list of metadata contents and evaluate the importance (requirement) of the items. The results from each breakout group will be presented along with any status or next steps to be taken. For each group, an initial template of the metadata content needed to describe each data type will be compiled. The template will be delivered to QARTOD and the breakout team members for review. If acceptable, QARTOD can then work with the workshop participants and members of the IOOS DMAC Metadata Team to prepare and submit these results as a metadata content recommendation into the IOOS DMAC standards process.

APPENDIX E-2 – METADATA FORM FOR FOCUS AREA DISCUSSIONS

Observation Type: ______________________ Individual/Organization Name: ______________

Method of Collection: ______________________ Role: ______________

Metadata Content Areas	Additional Information / Notes / Comments	Conditionality		Use		Automatable
		Always Critical/Required	Required If Applicable	Accompany data	Internal use	
Sensor Information						
Hardware Info *						
Type						
Name						
Manufacturer						
Model						
Series						
Serial Number						
Deployment Info *						
parent platform						
locality (in situ, remote)						
mobility (stationary, mobile)						
deployment Temporal Extent Info *						
nominal deployment Location/Orientation Info *						
relative to parent						
absolute						
measured deployment Location/Orientation Info *						
relative to parent						
absolute						
deployment frequency						
Person Info(s) *						
Sensor Quality Assurance						
QA Date/Time Info *						
Method Applied						
Site (where QA took place)						
Results						
Sensor Quality Characteristics						
precision						
Accuracy Info *						
Sensor Calibration						
Calibration Date/Time Info *						
Method Applied						
Site (where calibration took place)						
Results						
Measurements						
Measured Parameters						
Measured Phenomena						
Measurement Record Descriptions						
Content format details (delimiter, record/field lengths)						
Platform Information						
Hardware Info *						
Deployment Info *						
Location Info *						
Person Info(s) *						
Carries						
Platform Unique ID(s)						
Sensor Unique ID(s)						
Data Set Description						
Title						
Abstract						
Purpose						
Keywords						
region						
source type						
parameter						
phenomena						
Spatial Extent Info *						
Temporal Extent Info *						
Citation Text						
Data Set Location (where stored)						
Online Reference (e.g., URL)						
Data Set Person Info(s) *						
Creation Date/Time Info *						
Expiration Date/Time Info *						

Data Mode						
real time						
delayed						
Modification Date/Time Info *						
Completion Status (complete, open-active, open-inactive)						
Related Resource Info *						

Data Telemetry						
Type (satellite, cabled)						
Update schedule						

Data Set Quality						
Software Quality Checks						
Data Set Processing (see below)						
Value Tests						
sensor range check						
continuity check						
reasonable value check						
stuck value check						
Manual Quality Checks						
Procedure Info						
Procedure Name						
Inspector Person Info *						
Procedure Performance Date/Time Info *						
Procedure Results						
Summary Quality Assessment						
Value Assessments						
Data Set Assessment						
Quality Flag Definitions						
flag name						
flag definition						

Data Set Processing						
Process Info						
name						
Execution Date/Time Info *						
Execution Software Version Info *						
Version ID						
Version Date/Time Info *						
Repository Resource Info *						
Reference Resource Info *						
Execution Software Deployment Info *						
Execution Host Name or ID						
Execution Data/Time Info *						
Execution Temporal Extent Info *						
Execution Resource Info *						
Input Resource Info(s) *						
Resource Name						
Resource Person Info *						
Resource URL						
Resource Temporal Extent Info *						
Resource MIME Type						
Resource Size						
Output Resource Info(s) *						
Processing Person Info(s) *						

Data Set Attributes						
Format						
Standard format name (netCDF, HDF, ODV, ESRI Shapefile, …)						
File Content Type (ASCII, binary)						
Record Content Type (ASCII, binary)						
Content format details (delimiter, record/field lengths,…)						
Format Description Reference						
Measured/Derived/QCFlag Parameter						
Parameter Unique ID						
label/short name						

long name						
definition						
origination (measured, derived, assigned (qcflag))						
Attribute Domain Values						
Applicable QC Flag Reference(s)						
Applicable Parameter Reference(s)						
Valid Values - Range Domain Info *						
Units of Measure						
Value Temporal Extent Info *						
Value Accuracy Info*						
Parameter Standard Name Info *						
Value Resolution						
Codeset Domain						
Codeset Name						
Codeset Source						

Data Set Constraints						
Use constraints						
Access constraints						
Modification constraints						
Other constraints						

Sample Attributes						
Sample collection method						
Sample analysis methods						
Sample curation techiques						
Sample curation location						
Sample Person Info(s) *						

*** Reusable Fields** (apply to multiple content areas)

Date/Time Info						
DateTime						
DateTime format						
Date						
Date format						
Time						
Time format						
DateTime convension						

Temporal Extent Info						
Beginning Date/Time Info *						
Ending Date/Time Info *						

Location/Orientation Info						
Location Info *						
Orientation Info *						

Location Info						
Horizontal						
Latitude						
Longitude						
Format (decimal degrees, deg-min-sec,...)						
Reference						
Coordinate system used						
Latitude Resolution						
Longitude Resolution						
Geographic Coordinate Units						
Vertical						
altitude/depth						
unit						
datum						
coordinate system definition						
resolution						

Orientation Info						
Sensor Orientation						
Axes						
X						
Y						
Z						
Azimuth/Elevation						
azimuth						

elevation						

Spatial Extent Info						
Bounding Box						
Northernost Coordinate						
Southernmost Coordinate						
Westernmost Cordinate						
Easternmost Coordinate						
Region Info						
Region Name						
Region Name Source						
Bounding Polygon						
Bounding Circle						
center Location Info *						
radius						
radius units						

Range Domain Info						
Range Domain Minimum						
Range Domain Maximum						
Range Domain Wrap Low						
Range Domain Wrap High						

Standard Name Info						
Standard Name						
Standard Name Definition						
Standard Name Source						

Deployment Info						
parent platform Unique ID						
locality (in situ, remote)						
mobility (stationary, mobile)						
deplolyment Temporal Extent						
nominal deployment Location/Orientation Info *						
relative to parent						
absolute						
measured deployment Location/Orientation Info *						
relative to parent						
absolute						
deployment frequency						

Person Info						
Name						
Role						
pointOfContact						
originator						
processor						
principalInvestigator						
resourceProvider						
custodian						
distributors						
owner						
Contact Information						
Phone Info (Country Code, Area Code, Phone Number, Phone Type)						
Address						
Organization						
Email						
Web Site						

Accuracy Info						
Accuracy Specification						
Accuracy Explanation						

Hardware Info						
Type						
Name						
Manufacturer						
Model						
Series						
Serial Number						

Software Version Info						
Version ID						
Version Date/Time Info *						
Repository Resource Info *						
Reference Resource Info *						

Software Deployment Info						
Execution Host Name or ID						
Execution Data/Time Info *						
Execution Temporal Extent Info *						
Execution Resource Info *						

Resource Info(s)						
Resource Name						
Resource Person Info *						
Resource URL						
Resource Temporal Extent Info *						
Resource MIME Type						
Resource Size						

APPENDIX E-3 – SURVEY OF METADATA PROCEEDINGS DURING QARTOD IV

QARTOD IV Metadata Special Session Evaluation Results

The following are the results and comments provided on the evaluation forms for the QARTOD IV Metadata Special Session, June 23, 2006.

Who Responded

From the 21 evaluation forms received, respondents categorized themselves as having the following backgrounds:

Data collector	15	(71%)
Data processor	16	(76%)
Data user	11	(52%)
Data analyst	12	(57%)
Data manager	15	(71%)
Other	2	(10%)

The number of respondents participating in QARTOD Breakout Groups is as follows:

CTD	5
DO	2
In situ currents	9
Waves	4
Unidentified	1

Metadata Session Format

Background materials and worksheets
Scale: Detracted from understanding (1) – Enhanced understanding (4)
Evaluation Result: 3.1

The metadata facilitators were
Scale: Poorly prepared (1) – Well prepared (4)
Evaluation Result: 3.5

The metadata facilitators communicated concepts and ideas
Scale: Poorly (1) – Very well (4)
Evaluation Result: 3.3

The breakout groups were facilitated
Scale: Poorly (1) – Very well (4)
Evaluation Result: 3.3

The process used was suitable for capturing the necessary information
Scale: Strongly disagree (1) – Strongly agree (4)
Evaluation Result: 2.6

Session Pace

The pace of the session was
Scale: Too slow (1) – Too fast (5)
Evaluation Result: 3.0

The time allotted for the process was
Scale: Too short (1) – Too long (5)
Evaluation Result: 1.3

Value and Applicability

This session adequately determined the fields that need to be captured for this type of data.
Scale: Strongly disagree (1) – Strongly agree (4)
Evaluation Result: 2.5

Attending this session was good use of my time
Scale: Strongly disagree (1) – Strongly agree (4)
Evaluation Result: 3.4

Other Comments

- need much more time to hash this out
- need to address QC metadata as well
- confusion from spreadsheet
- more time next time, or separate metadata meeting
- more time
- need definitions of terminology
- please publish/email results of breakout sessions
- future focus on minimum metadata requirements
- metadata – several layers; address them separately; identify what is sensor specific and use breakout to address this in detail; address upper levels at a separate time; necessary but too time consuming
- next steps: (1) how or what metadata should be included with data; (2) compile what metadata is being collected and how it is being disseminated; (3) need for combining sensors because if we are talking about groups of instruments as an "observing system" then organizations will report same metadata for all instruments
- very difficult, if not impossible, to create one formula for in-situ currents metadata to fit all current measurements; our group concentrated on ADCP only in this QARTOD IV session.
- far, far too many metadata fields; data takers will ignore them
- amazingly useless start of session spread sheet; each group should do what is needed, then how does it fit globally

- too few definitions; terms unclear or not applicable; time of 1 hour ridiculously short to attempt to "require" or "recommend" anything; this needs several full days
- need to have a better starting document from which to work
- need more than 60 minutes
- must make a distinction between real-time and historic metadata; feel that QARTOD is the right group though to address these fields
- there needs to be a short and easy to understand dictionary for metadata terms
- if we are going to continue to work on metadata at the upcoming QARTOD meeting we need to give the session enough time to get some work done

QARTOD IV Metadata Special Session Evaluation

June 23, 2006

We would appreciate your feedback both positive and negative so that we might improve future sessions. Please complete the following questions.

My background is (check all that apply):

- ❑ Data collector
- ❑ Data processor
- ❑ Data user
- ❑ Data analyst
- ❑ Data manager
- ❑ other____________________

Session

- ❑ CTD
- ❑ DO
- ❑ In situ currents
- ❑ Waves

1) METADATA SESSION FORMAT (circle the appropriate level of response (1 to 4) for each question

Background materials and worksheets	Detracted from understanding	1	2	3	4	Enhanced understanding
The metadata facilitators were	Poorly prepared	1	2	3	4	Well prepared
The metadata facilitators communicated concepts and ideas	Poorly	1	2	3	4	Very well
The breakout groups were facilitated	Poorly	1	2	3	4	Very well
The process used was suitable for capturing the necessary information	Strongly disagree	1	2	3	4	Strongly agree

2) SESSION PACE (circle the most appropriate response)

The pace of the session was	Too slow 1	2	Just right 3	4	Too fast 5
The time allotted for the process was	Too short 1	2	Just right 3	4	Too long 5

3) VALUE AND APPLICABILITY (circle the most appropriate response)

This session adequately determined the fields that need to be captured for this type of data	Strongly disagree 1	2	3	Strongly agree 4	NA
Attending this session was good use of my time	Strongly disagree 1	2	3	Strongly agree 4	NA

4) OTHER COMMENTS

APPENDIX F - 2006 QARTOD IV WORKSHOP SURVEY RESULTS

SHUTTLE:

Good		15
Fair		1
Poor		
N/A		12

VENUE:

Great	A+	3
Good		24
Fair		1
Poor		

FOOD:

Workshop

Excellent	A++	3
Good		21
Fair		2
Poor		

Clambake

Excellent	A++	8
Good		20
Fair		
Poor		

WORKSHOP CONTENT

1st day

Good	24
Fair	4
Poor	

2nd day

Good	24
Fair	4
Poor	

3rd day

Good	18
Fair	4
Poor	4
No answer	3

BREAKOUT GROUP

CTD	6
In-situ Currents	14
Dissolved Oxygen	4
Waves	6

WOULD YOU ATTEND ANOTHER QARTOD

Yes	27
No	1
No answer	1

IF YES, HOW SOON SHOULD WE HOLD THE NEXT WORKSHOP?

6 months	15
1 year	6
No answer	2
Either	2
6-9 months	2

HOW CAN WE IMPROVE?

- Possibly add a met group. Discussion of what items should go into a QA manual and included in SOP's to guide managers of observing systems.
- Additional diversity in attendees (e.g., beyond agencies & academia)
- We need to have a note taker for the plenary session
- The conference room was bright so it was hard to look at the monitor in the beginning. Better later.
- Metadata no fun, but necessary evil. Probably need to spend more time on Metadata.
- Focus on QC – get folks to bring code/scripts willing to share with them
- More focus, less wanderings – more concise direction needed. The questions should have been more thought out, written better. Poorly written questions caused confusion & wasted time. Not too efficient.
- Stay on topic more, more talks needed w/in breakout groups on how things are being done across country, need representatives from ach RA present to foster continuity so there isn't back tracking on issues covered at previous Qartods, more time need on Metadata
- If there is going to be homework, please try to get it out to us sooner
- Force us to prepare better.
- More focus since we can't do it all in 2.5 days. I.e., separate sessions for QA, QC, Metadata (for each component)
- Expand instrument scope (Chl-flurometer/transmissometer-backscatter/nutrients). Publish summary of meeting
- Combine waves and currents at lease for one day to address overlap of issues
- Better leadership in breakout session. Better knowledge of subject matter
- It works well to keep the presentations (general) to a minimum. Breakout groups are good.
- Well organized (schedule, transportation, food, etc.)
- Might be good to have some explicit long term goals

GENERAL COMMENTS:

- Experience level in the groups I attended was, on average, not high enough.
- Staff running this major operation were helpful, friendly and funny (happy). They did an excellent job setting up, dealing with problems & work 'arounds', and should be highly congratulated. Give these people a free massage over the weekend after we're all gone … they deserve it! Thank you so much.
- Well organized meeting – I personally will take a great deal home and hope I contributed as well.
- Super accommodating staff & facilitators & note taking
- I enjoyed the first day party, which was very nice. I enjoyed too much!
- WHOI was a wonderful host!
- Very well put together
- Seems like there needs to be a goal - more clearly defined. Not sure we really completed much these 2 days. The web site needs a shepherd and so we can all use it between Qartod sessions. Separating control from assurance is tough.
- Loved venue for clambake, great facility
- Overall this was very organized and run
- Nautilus didn't have internet
- How to/best practices/cookbooks are in high demand & will increase amount & quality of data/efficiency & cost effectiveness of new users
- Good workshop
- Janet, you did a wonderful job at preparing the workshop! I haven't heard any negative comments. Thanks so much – JT
- Richard, Kim, and Anne did a great job for the waves group