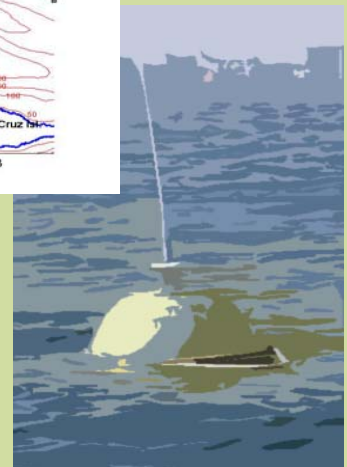
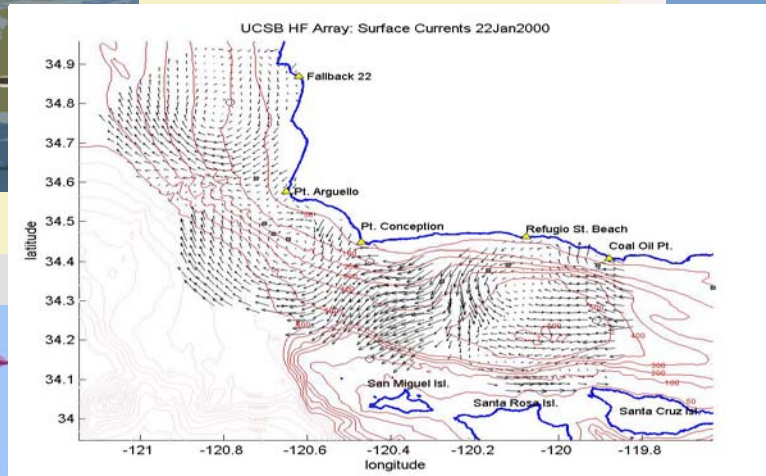
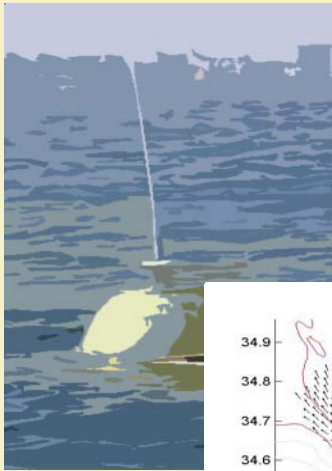


# QARTOD II: Waves and Currents

Second workshop report on Quality Assurance of Real Time Ocean Data

February 28 - March 2, 2005

Nauticus, the National Maritime Center  
Sheraton Norfolk Waterside Hotel  
Norfolk, VA



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# **Second Workshop Report on the Quality Assurance of Real-Time Ocean Data: Waves and Currents (QARTOD–II)**

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Waterside Hotel  
Norfolk, VA

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## Workshop Summary and Next Steps

The Second Workshop on the Quality Assurance of Real-Time Ocean Data (QARTOD-II) took place in Norfolk, Virginia on February 28 - March 2, 2005, sponsored by NOAA/NOS/COOPS and hosted by Old Dominion University's Center for Coastal Physical Oceanography and Nauticus, The National Maritime Center. The meeting was attended by approximately 80 participants from Federal and State governments, academia, and industry. The main goal was to address the specific calibration, metadata and quality assurance/quality control (QA/QC) needs of:

- *In-situ* currents
- Remote currents (high frequency radar)
- Waves

Working groups for *in-situ* currents, remote currents and waves were formed and met during facilitated break-out sessions to answer the following specific questions relevant to their topic:

- QUESTION 1: What real-time quality control tests should be applied?
- QUESTION 2: What categories of real-time quality descriptor flags should be applied?
- QUESTION 3: What real-time metadata descriptors should be applied?
- QUESTION 4: What real-time calibration flags should be applied?
- QUESTION 5: What common data formats should be applied?
- QUESTION 6: Additional requirement associated with the Data Management and Communications (DMAC) Plan?
- QUESTION 7: Next steps and roadblocks to implementation of QA/QC?
- ISSUES FOR FURTHER DISCUSSION

The recommendations from each working group are detailed in pages 10-25 of this report. Here, we present a brief summary of the main points and next steps from each of the three working groups.

### *In Situ* Currents: Main Points

This working group brought together representatives from federal agencies and regional groups involved in the real-time quality control of ADCP data with the goal of publishing approved/standardized quality control checks, data flags and metadata descriptors. During the extremely concise session, participants accomplished the following:

- Reviewed operational ADCP control checks/thresholds performed by (or proposed by) different agencies;
- Proposed quality descriptor flags for each data record;
- Agreed upon a list of metadata descriptors required to capture the minimum information about ADCP sensors;

- Approved various data formats for data delivery.

### In situ Currents: Next Steps

- Continue to meet as a group focused on ADCP quality controls to update recommendations and review new procedures;
- Develop test datasets that can be used to validate a user's quality control procedures/algorithms;
- Publish, in an open source environment, the ADCP quality control tests and thresholds, metadata descriptors and specifications and data formats.

### Remote Currents: Main Points

The Remote Currents working group designed its working QA/QC protocol around HF radar. Given that QA/QC requirements could differ significantly depending on the level of manipulation or processing associated with a given data type, the group defined a hierarchy within which this guidance would apply:

- **Level 1** – Refers to radials (i.e., components of a surface current that flow directly toward or away from a single radar site;)
- **Level 2** – Refers to total vectors (i.e., the vector combination of two or more radials typically measured from two or more radar sites;)
- **Level 3** – Refers to higher order data products (e.g. water parcel trajectory estimates.)

### Remote Currents: Next Steps

The group focused its discussion on the required next steps needed to implement this working QA/QC standard within the community. The Radiowave Operators Working Group (ROWG) provides a useful mechanism to continue these discussions and encourage implementation, having been established to foster collaboration among the HF radar community, develop standards, and provide recommendations to users, developers, and manufacturers. The recommendations defined in QARTOD II will inform these discussions and be integrated into a more comprehensive operators guide.

Need to:

- establish consistency of QA/QC throughout national network;
- develop data dictionary and establish timeline;
- define required data parameters and work with manufacturers to ensure the integration of key recommendations (as developed in QARTOD II and ROWG;)
- develop “best practices” procedures for new operators;
- continue discussion.

### Waves: Main Points



- Sensor selection: Datawell buoy QC chosen as example of a process to establish a QA/QC recipe.
- Background on Waverider buoy characteristics was presented: mooring, operation, data transmission, and data analysis.
- A discussion of Waverider data QA followed – addressing manufactures and additional processing for real-time analysis.
- Simple single-digit data descriptors for QA based on those of QARTOD-I were approved with the modification of labeling “3” as “passed QA” as opposed to classifying as “good.”
- It was suggested that a distinction should be made between real-time flags and post-processing flags, and should be clearly defined in metadata.
- Various output data formats were considered (e.g., ASCII, binary, NetCDF, FM-13, and FM-65). Sharing a common format, along DMAC/FGDC guidelines, is desirable. Translators could deliver other formats.

### Waves: Next Steps

- Recipes for other wave sensors will be compiled.
- Data providers should stay attuned to the IOOS/DMAC evolution. Data providers should prepare to deliver dynamic data service based upon further specifications by DMAC, and provide guidance to DMAC regarding transport protocols and formats for data transfer.
- Data providers need to work with metadata initiative group to define header parameters. They should work towards making headers available in FGDC compliant format on request.
- We need a standardization of XML tags for oceanographic data (waves, currents).
- Work needs to be done on data transport between regional organizations.
- Continue to meet as a group (QARTOD III?) focused on waves quality control to update recommendations and review new procedures.

There were discussions regarding the role of this group in the overall Ocean.US DMAC process. The group felt that it would be worthwhile to become the real-time data group within the DMAC organization.

# Introduction

In the winter of 2003, the first workshop for the Quality Assurance of Real-Time Ocean Data (QARTOD-I) was held at NOAA's National Data Buoy Center in Bay Saint Louis, MS. Over 80 participants attended with the primary task to develop minimum standards for **calibration, QA/QC methods, and metadata**. The workshop resulted in a report which summarized the recommendations on these issues and on future workshops:

[http://nautilus.baruch.sc.edu/twiki/pub/Main/WebHome/QARTOD\\_final\\_09.pdf](http://nautilus.baruch.sc.edu/twiki/pub/Main/WebHome/QARTOD_final_09.pdf).

QARTOD-I participants recommended that wave and current measurements, and their unique calibration, metadata and QA/QC needs be explicitly addressed in the next QARTOD workshop. To this end, **QARTOD-II** was held from February 28 to March 2, 2005 in Norfolk, VA. This report summarizes the workshop proceedings. It can be found as a PDF file in full color here:

<http://nautilus.baruch.sc.edu/twiki/bin/view>.

The dawn of the Integrated Ocean Observing System (IOOS) era brings with it many challenges related to the distribution and description of **real-time ocean data**. One of the primary challenges facing the ocean community will be the fast and accurate assessment of the quality of the data streaming from the IOOS measurement systems. Operational data merging and assimilation from multiple 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 simple, trustworthy, and consistent quality description for every observation distributed as part of IOOS.

The Second Annual IOOS Implementation Conference (3-4 May, 2005) entitled, **Setting National Priorities for the Integrated Ocean Observing System**, adopted the broad goal of bringing together representatives of federal agencies and regional groups involved in the development of IOOS to discuss and agree on priorities for implementing and improving the IOOS. To this end, the conference focused on four related goals:

Identify actions needed to improve IOOS capabilities for more effective:

1. warnings of coastal inundation caused by natural hazards, and;
2. mitigation and management of the impacts of coastal inundation on coastal communities, coastal marine and estuarine ecosystems, and living marine resources.

Initiate processes that will insure:

3. coordinated development of regional coastal ocean observing systems and a national backbone that are interoperable nationwide in terms of data management and communications, and;
4. development of mechanisms that will link IOOS data and information to an emerging national network of educators with the intent of enhancing science education and training and improving public awareness and stewardship of the oceans.

A robust set of recommendations will be presented in this report which will facilitate the IOOS goals stated above.

# Working Group Recommendations

## *In-Situ* Currents Working Group

Breakout Group Topic Definition:

*In-situ currents – the direct measurement of surface and sub-surface ocean currents using instruments that are placed at the location the measurement is to be made.*

### Participants

There were 25 participants in the breakout group.

### Technology Group Selection

Bill Burnett, Technical Lead for the breakout group, briefly described the three most popular in-situ methods to measure ocean currents: electro-mechanical current meters, Acoustic Doppler Current Profilers (ADCP), and drifters.

- Current meters measure the ocean current at a single depth and at a single location. They are usually mounted along a wire that is attached to a mooring.
- ADCPs measure the velocity along a range of depths at a single location. They are usually mounted on a mooring, on the ocean bottom, on the underside of a vessel, or on a pier.
- Drifters are small buoys that measure surface and subsurface ocean currents as they flow with the ocean currents. They are usually located at a certain ocean depth to negate the direct effects of the wind.

The group selected ADCPs as the technology group for breakout discussions. Participants agreed that the discussions should be kept at a general level, with respect to the different vendor models that are commonly used. A minority of the group wanted to focus on current meters.

### Focus Question Discussions

#### **QUESTION 1: What real-time quality control tests should be applied?**

The group agreed upon the following quality control scheme, indicators, and terminology:

Indicator	Level	Flag	Data Release Policy
Green	Level 3	No flag	Pass – data released
Yellow	Level 2	Soft flag	Caution – data released
Red	Level 1	Hard flag	Fail – data not released

### Range Bound Checks

The group agreed upon the following Level 1 real-time quality control checks, if the information is available with the particular instrument in use (as applicable, some apply to the whole profile, while

others apply to individual bins). This list of parameters constitutes the minimum suite of range bound checks associated with real-time data delivery. According to the agreed upon quality control scheme, failure of one of these range bound checks would cause a hard flag and the associated data record would not be released.

- ▲ Pitch/roll
- ▲ UVW – vertical velocity/horizontal velocity
- ▲ Echo amplitude/intensity
- ▲ Percent solutions
- ▲ Percent good pings (PGP)
- ▲ Error velocity
- ▲ Correlation magnitude
- ▲ Surface (or bottom) reflection/detection

The group agreed upon the following Level 2 real-time quality control checks, if the information is available with the particular instrument in use (as applicable, some apply to the whole profile, while others apply to individual bins). This list of parameters represents those range bound checks that should be applied, as resources allow, for real-time data delivery. According to the agreed upon quality control scheme, failure of one of these range bound checks would cause a soft flag to be released with the data record.

- ▲ Heading
- ▲ Bit status (Built In Test) – this should be a hard flag. If BIT test fails, unit generally does not work at all
- ▲ Battery voltage (V1 & V2) two batteries
- ▲ Water temperature
- ▲ Pressure
- ▲ Timestamp – this should be a hard flag. If the time is wrong, the data are not really usable (especially time errors greater than ~10-15 minutes)
- ▲ Standard deviation of speeds
- ▲ Transmit current
- ▲ Correlation coefficient
- ▲ Speed of sound

It was agreed that the next critical step in the development of this quality control recommendation would be the development of thresholds for each range bound check. Example thresholds were suggested in the plenary presentation “Initial Automated Quality Checks for Oil Platform Current Data” by Don Conlee (see Figure 1).

### **Rate of Change Checks**

The group agreed that the “rate of change of echo intensity at a bin” check should be performed as a soft-flag real-time quality control check (due to time series requirements), if the information is available with the particular instrument in use. As time for consideration of Question 1 closed, the group agreed that additional rate of change checks should be considered.

**Figure 1. Initial Quality Check Thresholds for Real-time Current Data**

Parameter	Pass	Soft Flag	Hard Flag
<b>Error Velocity</b> this should vary with the known current regime. Some areas have less than 15 cm/s TOTAL current much of the time	< 15 cm/s	15-30 cm/s	>30 cm/s
<b>Percent Good</b>	38: >25% 75: >10%	38: 22-25% 75: 5-10%	38: <22% 75: <5%
<b>Correlation Magnitude (counts)</b>	38: 3 beams > 110 75: 3 beams > 64	38: 2 beams > 110 75: 2 beams > 64	38: 1 beam >110 75: 1 beam > 64
<b>Echo Intensity (after 15th bin)</b>	No adjacent bin differences >20	Adjacent bin differences 20-30	Adjacent bin differences >30
<b>Vertical Velocity (each bin)</b>	Departure from mean <5 cm/s	Departure from mean 5-10 cm/s	Departure from mean >10 cm/s
<b>Horizontal Velocity</b> this should vary with the known current regime. Many areas have currents greater than 1.25 m/s, and even > 2.5 m/s.	<1.25 m/s	1.25-2.5 m/s	>2.5 m/s

**QUESTION 2: What categories of real-time quality descriptor flags should be applied?**

The group agreed that each real-time data record must go out with a quality descriptor flag. Since there might be multiple bins for each observation, a quality descriptor flag would be required for each bin, where applicable.

The group discussion culminated in the following observations:

- There are two principle customer groups for real-time current data:
  1. Those users that are principally interested in the “velocity at depth” observation for immediate application (e.g., maritime community or general public). The group agreed that this customer group would be best served by an ensemble flag released with each

data record. In most cases, the publication of the observation by a government agency (for example, National Data Buoy Center or Center for Operational Oceanographic Products and Services) would constitute a “pass” quality descriptor flag.

2. Those customers interested in full record (e.g., academia, oil and gas industry). The group agreed that data streams should contain the following quality descriptor flags:

- ▲ Flags for each hard parameter;
- ▲ Ensemble flag linked to release of data;
- ▲ Flags for soft flags, if affordable.

- To meet the needs of these two customer groups, it is probable that two data sets will have to be provided:

1. Real-time observations (only Level 1 and 2 data;)
2. Archived observations (all data.)

- The group agreed the categories of real-time quality descriptor flags should follow the QARTOD I recommendation:

- ▲ -9 = missing value;
- ▲ 0 = quality not evaluated;
- ▲ 1 = bad;
- ▲ 2 = questionable/suspect;
- ▲ 3 = good.

### **QUESTION 3: What real-time metadata descriptors should be applied?**

The group agreed upon the following list of metadata fields as the minimum suite associated with real-time data delivery. With the time allowed for this question during this breakout group session, the group purposefully focused on instrument-level metadata requirements (versus, for example, multi-sensor platforms metadata needs). A more comprehensive recommendation will require additional thought and discussion. The group agreed that these metadata fields should be in the header of the record.

- ▲ Latitude (with a designator: fixed or moving)
- ▲ Longitude (with a designator: fixed or moving)
- ▲ Horizontal datum / reference
- ▲ Depth of water
- ▲ Depth of instrument
- ▲ Vertical datum / reference
- ▲ Time (with a designator for time zone, e.g., UTC)
- ▲ Data collected at beginning, middle, or end of sample
- ▲ Compass reference
- ▲ Serial number
- ▲ Units for data reporting
- ▲ Orientation

The group agreed that the following list of additional metadata fields should be associated with real-time data delivery as resources allow.

- ▲ Sensor type
- ▲ Deployment date
- ▲ Calibration procedures
- ▲ Date of calibration
- ▲ System frequency
- ▲ Bin size
- ▲ Number of bins
- ▲ Sampling interval
- ▲ Bad beam indicator
- ▲ Average interval
- ▲ Pings per ensemble
- ▲ Compass update rate
- ▲ Quality checks descriptions and thresholds
- ▲ Blanking distance
- ▲ Coordinate system for velocity measurements
- ▲ Joyce parameters
- ▲ Platform description, including fixed or moving

It was agreed that the next critical step in the development of this quality control recommendation would be the development of specifications for each metadata descriptor. Further discussion on Joyce parameters was put on hold (i.e., put in the parking lot) due to time constraints during the breakout session.

#### **QUESTION 4: What real-time calibration flags should be applied?**

The group agreed that for real-time delivery of ADCP current data, no calibration flag should be required. The group agreed that the “date of calibration” should be available in the metadata, as resources allow.

#### **QUESTION 5: What common data formats should be applied?**

The group discussion culminated in the following observations:

- ▲ Many data formats are represented in the group at this breakout session;
- ▲ ASCII is universally understood;
- ▲ The future holds the sensor sending data in XML;
- ▲ As a community, we are moving towards automation and interoperability.

First and foremost, the group agreed that the ADCP user community should strive to be DMAC compliant on data formats. Given the expertise and experience represented in this breakout session, it was recognized that the community should actively work with DMAC to develop a solid data formats recommendation.

When pushed to answer Question 5, the group agreed to recommend NetCDF, along with an appropriate data dictionary and convention (e.g., CF).

**QUESTION 6: Additional requirement associated with the Data Management and Communications (DMAC) Plan?**

Due to time constraints the group did not explicitly address this question, although it was agreed that the evolving ADCP QA/QC “recipe” should be DMAC compliant. The group agreed that the ADCP user community should actively work with DMAC to develop robust and practical QA/QC recommendations.

**QUESTION 7: Describe key next steps and current roadblocks to developing & implementing an operational QA/QC capability.**

The group agreed upon the following key next steps:

- ▲ Define thresholds for all recommended quality control tests;
- ▲ Define specifications for all recommended metadata descriptors;
- ▲ Develop an open source environment (e.g., TWiki) for collaboration on all aspects of a QA/QC “recipe” for real-time ADCP current data (recommended quality control tests and thresholds, metadata descriptors and specifications, data formats, etc.). This collaboration would have to include instrument vendors.

The group recognized the following roadblock to developing and implementing an operational QA/QC capability – disparity in requirements for different user groups, as this could lead to two or more required datasets.



# Working Group Recommendations

## Remote Currents Working Group

**Technical Co-Leads:** Libe Washburn, UCSB; Josh Kohut, Rutgers

### SENSOR SELECTION:

The Remote Currents working group designed its working QA/QC protocol around HF radar. Given that QA/QC requirements could differ significantly depending on the level of manipulation or processing associated with a given data type, the group defined a hierarchy within which this guidance would apply:

- **Level 1** – Refers to radials (i.e., components of a surface current that flow directly toward or away from a single radar site;)
- **Level 2** – Refers to total vectors (i.e., the vector combination of two or more radials typically measured from two or more radar sites;)
- **Level 3** – Refers to higher order data products (e.g. water parcel trajectory estimates.)

### QUESTION 1: What real-time quality control tests should be applied?

A series of parameters were defined to evaluate the quality of Level 1 and Level 2 data. The actions below are proposed to develop QA/QC protocols and should be evaluated for radials and total vectors. However, a high level of uncertainty in a QA/QC test does not always represent an error. The standard deviation in an ensemble of radials, for example, includes both real environmental or oceanographic phenomena and instrument uncertainty, warranting further examination.

#### Level 1

- Establish signal to noise ratio
- Develop criteria to define 1st order peak (for direction finding systems)
- Identify single and dual angle solutions (Applies to direction finding radars only; is not applicable to phased array systems)
- Establish thresholds for sector-to-sector changes in radial speed (A sector is an area over which radials are determined within a range cell.)
- Provide standard deviation and number of vectors in each sector
- Provide percent coverage for each time interval over which radials are computed
- Evaluate eigenvalues for each radial
  - This is a quality parameter used by the MUSIC algorithm.
  - Establish other QA/QC parameters for new algorithms
- Establish parameters and processing methods for new equipment (e.g. new current-measuring radars)
- Evaluate vendor-supplied software outputs for providing additional QA/QC information (e.g. CODAR Ocean Sensors, Ltd. diag.save file)

## Level 2

- Evaluate radial misfit error – root-mean-square difference from back-calculating the radials based on total vectors
- Incorporate geometric dilution of precision (GDOP) into processing
  - GDOP is easily defined if only two sites are contributing radials
  - Need to establish new method if three or more sites are used
- Develop current speed Thresholds for total vectors
  - These values will vary by region
  - They should be defined to provide additional quality checks
- Identify number of radials and sites contributing to total vectors -- it is important to know which (and how many) sites contributed radials to quantify the geometric error). For real-time error assignments this must be a dynamic filter applied to each total vector.
- Provide percent coverage at grid points over time interval for which total vectors are computed.

### **QUESTION 2: What categories of real-time quality descriptor flags should be applied?**

The quality descriptor flags defined in QARTOD I are appropriate; however, an additional flag is required to identify interpolated (radial or total vector) data. “Interpolation” refers to filling values within Doppler spectra or within a range cell (at the radial level). This data quality flag does not apply to interpolations of Level-3 data products. Rather it indicates an interpolation technique was used to create the radial or total vector since this information may influence the utility or application of the data.

- -9 = missing value
- 0 = quality not evaluated
- 1 = bad
- 2 = questionable/suspect
- 3 = good
- 4 = interpolated data

### **QUESTION 3: What real-time metadata descriptors should be applied?**

The following elements should be included in a metadata record for HF radar to enhance the utility of the data.

#### **Level 1**

Site location (Position, elevation and other information about the site such as positions of conductors in the near field of antennas. This information should be updated periodically, as it is likely to change over time.)

- Data units
- Operating institution
- Hardware parameters (e.g. transmit frequency, range resolution, etc.)

- Software parameters (e.g. version no., averaging time, etc.)
- Antenna patterns and time of measurement
  - These patterns are critical to create radials from each site and should be monitored periodically.
  - Time series of these parameters will provide information about antenna pattern stability over time.
- Other equipment and environmental parameters. These include:
  - Internal temperature of the transmitter (This can influence the quality of the data produced by the instrument and should be monitored over time to ensure that the system is working properly.)
  - Reflected versus transmitted power.

## Level 2

- Data units
- Number and identification of sites contributing radials to each total vector
- Parameters used to combine radials for estimating total vector (e.g. averaging time, averaging area)
- Institution responsible for total vector processing
- Grid parameters (e.g. spacing, coverage domain)

### **QUESTION 4: What real-time calibration flags should be applied?**

- Baseline consistency checks (2 sites)
  - Where two radar systems measure radials along a common baseline, operators should compare radial statistics.
  - Along the common baseline, radials should best agree at the baseline midpoint and diverge as distance from the midpoint increases.
- Total/radial consistency checks (3 or more sites)
  - Where three or more sites measure radials over a common area, use total vectors computed from two or more sites to predict radials observed by a third site.
- Antenna amplitude and phase measured between sites
  - Sea echo for phase determination and amplitude
- Forward and reflected power
  - High reflected power could indicate potential problems with the instrumentation (e.g., corrosion)
- System diagnostics (e.g., transmitter temperature sensor)

### **QUESTION 5: What common data formats should be applied?**

NetCDF and ASCII are the preferred data formats for remote currents. Both are used extensively within the HF radar community and, because there are benefits and limitations associated with each, the group found no reason to recommend only one. Data are easily exported from NetCDF to ASCII

and most commercial software packages now offer a number of conversion algorithms; therefore, the level of effort required to complete the transformation is small.

- NetCDF
  - Limitations may exist when transporting data in NetCDF format across the Internet. Future development of an appropriate XML tag (e.g., SensorML and MarineXML) may provide for a more efficient means of transport. Nevertheless, comprehensive data dictionaries and metadata formats must be created before the remote currents community can transition to XML.
  - OpenDAP servers are able to utilize the NetCDF format. Although OpenDAP is currently the preferred transport option, there was general agreement that there may be a need to investigate the “next generation” transfer protocol.
  
- ASCII
  - The ASCII format is equally supported, provided that the file include a consistent description of spatial reference and velocity (e.g., latitude (x), longitude (y), and velocity components (u,v))

#### **QUESTION 6: Additional requirement associated with the Data Management and Communications (DMAC) Plan?**

It is important to ensure consistency between the QA/QC recommendations developed in QARTOD II and those provided in the DMAC Plan for Research and Operational Integrated Ocean Observing Systems. Because DMAC recommends the Federal Geographic Data Committee (FGDC) standard for metadata creation, the working group recommends that operators compare the metadata elements currently provided in a NetCDF header file against FDGC requirements. It is possible that additional information could be included in the header file, if needed.

#### **QUESTION 7: Next steps and roadblocks to implementation of QA/QC?**

The group focused its discussion on the required next steps needed to implement this working QA/QC standard within the community. The Radiowave Operators Working Group (ROWG) provides a useful mechanism to continue these discussions and encourage implementation, having been established to foster collaboration among the HF radar community, develop standards, and provide recommendations to users, developers, and manufacturers. The recommendations defined in QARTOD II will inform these discussions and be integrated into a more comprehensive operators guide.

Need to:

- establish consistency of QA/QC throughout national network;
- develop data dictionary and establish timeline;
- define required data parameters and work with manufacturers to ensure the integration of key recommendations (as developed in QARTOD II and ROWG;)
- develop “best practices” procedures for new operators;
- continue discussion.

## **ISSUES FOR FURTHER DISCUSSION**

1. What level of data should be archived? Should institutions archive cross spectra?
2. Should this group also recommend that operators always back-up or maintain two copies of the data to ensure consistency and data survival?
3. Need to determine global attributes and data attributes for HF radar data

Although QA/QC procedures for Level 3 data were not defined during this exercise, it was suggested that the tidal ellipse could be used as a consistency check to evaluate the quality of Level 2 and 3 data.

# Working Group Recommendations

## Waves Working Group

Technical Coordinator: Kent Hathaway, USACE

Facilitator: Christy Loper, NOAA/NOS Special Projects Office

### ATTENDEES:

1. Torstein Pedersen
2. Jay Austen
3. Jeff French
4. Jennifer Dussault
5. Mark Bushnell
6. Carl Friedrichs
7. Neil Trenneman
8. Xiongping Zhang
9. Peter Stone

10. John Olmer
11. Chris Smith
12. John Brubaker
13. Richard Bouchard
14. Chung-Chu Teng
15. Julie Thomas
16. David Castel
17. Kent Hathaway
18. Frederick Bingham
19. Christy Loper

### SENSOR SELECTION: **Datawell Directional Waverider Buoy**

Comments and questions regarding selection of Datawell included:

- Data dissemination under OpenDAP;
- Issues of proprietary on-board processing data format;
- Datawell provides detailed documentation for decoding formatted data.

What is the Datawell buoy?

The Directional Waverider is a spherical, 0.9m diameter buoy which measures wave height, period and direction as well as sea surface temperature. This surface following buoy calculates wave direction by measuring orthogonal horizontal accelerations. As a consequence, the measurement is independent of buoy roll motions and a relative small spherical buoy can be used. The buoy contains a heave-pitch-roll sensor (Hippy,) three axis fluxgate compass, two fixed “x” and “y” accelerometers, temperature sensor and a micro-processor. A USCG approved flashing light serves as a hazard marker.

A single point vertical mooring, including a 30 m rubber cord, ensures sufficient symmetrical horizontal buoy response for small motions at low frequencies. The low stiffness of the 30 m rubbercord allows the Directional Waverider to follow waves up to 40 m high. The buoy was designed for energetic wave regions and has proven very robust. A protective triangle surrounding the equator protects the buoy from spinning and the effects of ship collisions.

### **QUESTION 1: What real-time quality control tests should be applied?**

Note: These specifications are primarily for Datawell Waverider buoy analysis but much can be applied to other wave instrumentation.

## Quality Assurance

### 1. Time Domain – Time Series

- Wave height test – data are rejected if greater than a preset maximum allowable value (region dependent)
- Flat episode test – data rejected if N consecutive values are unchanged (e.g., N = 5) .
- Spike check – points greater than N standard deviation from the means are considered spikes. Spikes may be linearly interpolated (or spline fit) from adjacent good points. The Standard deviation is recomputed and data is rechecked. Data are rejected if more than M consecutive points are out of range, more than K iterations are required, or the number of points edited exceeds L% of the time series.
- Max and min - site dependent limits. Based on location, water depth and expected extreme wave height.
- Mean test – Time series (detided) should have a near-zero mean. Means exceeding a threshold indicate a possible malfunction.
- Equal peak tests – data are rejected when N consecutive peaks or troughs exhibit the same values.
- Acceleration – rejects data where accelerations exceed one third gravitational acceleration ( $> g/3$ ).
- Mean crossing test – If more than N% of a time series does not cross the mean the data are rejected.
- Period distribution – data are rejected if more than N% of wave periods are greater than 22 seconds (site dependent).

### 2. Frequency domain and processed data

- Datawell Waverider transmits a telemetry quality status flag.
- Wave height min and max thresholds (site specific).
- Wave peak period min and max thresholds (site specific).
- Wave average period min and max thresholds (site specific)
- Wave direction min and max thresholds (site specific and may be a function of height and period).
  - Noise level – average energy level in the tail of the spectrum may not exceed a threshold (value?).
  - Signal to noise ratio (SNR) – ratio of spectral peak to average energy in the spectral tail, threshold is site specific.
  - Datawell “check factor” – ratio of vertical to horizontal displacement.

### 3. Climatological record

- Compare statistics (Hmo, Tp, Dp, Temperature) to previous collections – look for irregularities.

## **QUESTION 2: What categories of real-time quality descriptor flags should be applied?**

The group generally concurred with the descriptor flags suggested by QARTOD I, with one modification (shown in bold):

- -9 = missing value
- 0 = quality not evaluated
- 1 = bad
- 2 = questionable/suspect
- 3 = passed real time QA/QC (*as opposed to the suggested flag of “good”*)

Data with a flag of “3” should not be considered final since it has only passed real time QA/QC. We may need an additional flag for final QA’d data to be included with metadata, although this additional flag would not be considered real time.

It should be noted that Datawell has its own set of descriptor flags, where 0 = good, 1 through 8 are different quality levels. The user can define a further set (e.g. 9+). However, these are not incompatible with Q1 standards and can be mapped to those flags for standardization.

We also discussed the fact that questionable data can be made available upon request (i.e., stored in a non-public domain) with comments included.

## **QUESTION 3: What real-time metadata descriptors should be applied?**

**General discussion:** Metadata requirements should be flexible. The type of calibration performed and calibration date should be included. Headers should be available in FGDC compliant format on request.

**Specific list compiled after breakout group:**

### **Required Metadata**

1. Data set title, who produced it.
2. Instrument information (manufacturer, model, serial number)
3. Location
  - Latitude, Longitude, elevation, coordinate system and datums.
4. Water depth
5. Date, time, time zone (start time, mid-record time. . . .) Are we requiring mid-record time?
6. Data attributes
  - Parameters calculated and terminology
  - Formats
  - Record length, sample rate
  - Analysis technique, software
  - QA flags and additional QA info (thresholds)
  - Spectral parameters from above, and spectral info (frequencies, dof, . . .)
7. Legal restrictions on using the data and disclaimers.

**Optional Metadata** (We need to check FGDC specs – just a start at listing a few)

8. Who processed the data, POC
9. Measurement program description (e.g., CDIP description)



10. Estimates of data accuracy
11. Location accuracy
12. Comments on why the data was collected.
13. Any similar data the user should know about.
14. Formats available, databases

#### **QUESTION 4: What real-time calibration flags should be applied?**

It should be noted that the Datawell buoys are calibrated at the manufacturer prior to purchase. Data provider should include calibration date and method, as defined by manufacturer, in metadata.

Therefore, rather than calibration by the users, data verification is needed. Pre-deployment verification should be conducted prior to each deployment and includes the following tests:

- Bounce test (or vertical wheel test, which is the more sophisticated and more accurate version of the bounce test;)
- compass test;
- inclination test;
- electronic checks (check all electrical components to ensure that they are on and functioning.)

Datawell users should refer to the manufacturer's manual for specifications regarding these tests and inclusion of any other tests that may be needed.

With in situ verification, parameters returned with each data stream, including:

- check factor – ratio of the horizontal and vertical displacement;
- inclination (Datawell checks compass inclination and returns this along with each data stream; since there is a known inclination for each geographic region, data anomalies can be flagged and checked.)

Although not relevant to provision of real-time data, it should be noted that if post-verification reveals problems, data providers should go back and re-flag archived data.

#### **QUESTION 5: What common data formats should be applied?**

Datawell output permits mapping to any desired data format, including:

- ASCII or binary;
- NetCDF;
- Compressed;
- FM-13 and FM-65;
- Others.

Although the group acknowledged that other groups would likely identify NetCDF as the preferred data format, those familiar with Datawell explained that they simply did not receive requests for data in NetCDF format and therefore never had a need to provide data in a NetCDF. The waves group

did not specify a preferred data format. It was also noted that if modelers need data in NetCDF, they can obtain the flat files and reformat the data themselves.

### **QUESTION 6: Additional requirement associated with the Data Management and Communications (DMAC) Plan?**

The group agreed that data providers should:

- keep apprised of DMAC evolution;
- prepare to deliver dynamic data service based upon further specifications by DMAC.

There was discussion over whether data providers should give guidance to DMAC regarding transport protocols and formats for data transfer, or whether it's DMAC who should specify protocols and formats for data transfer? Clarification of how DMAC expects the process to work would be useful.

Also, one group member suggested that development of a DMAC certification would be helpful so that he could ensure compliancy.

### **QUESTION 7: Describe key next steps and current roadblocks to developing & implementing an operational QA/QC capability?**

#### **Roadblocks**

- While several groups have implemented an operational QA/QC system, including SIO and NDBC, these systems have taken much time and experience.
- One problem is the lack of specificity of data format from DMAC. However, as mentioned above, should this group actually be prescribing the formats to DMAC based on our recommendations, or will the DMAC process occur the other way around?
- Standardization of XML tags would be very helpful.
- Data transport between regional organizations may prove problematic(?)

#### **Next steps**

First, circulation of these notes was suggested.

A subset of this waves group should form a working group to undergo this same exercise for other sensors, including accelerometers, pressure sensors, buoys, radar, HF, and video. The output could be framed in a table/matrix and could possibly be posted on the TWIKI.

It was suggested that RDI, NORTEK, and other vendors could compile and submit their QA/QC specifications.

A deadline of one month was suggested.

# Abstracts

## In-Situ Currents

### Quality Assurance and Quality Control Processes for Current Measurements Obtained on USCG Aids-To-Navigation

**Kathryn Thompson Bosley, Ph.D.**

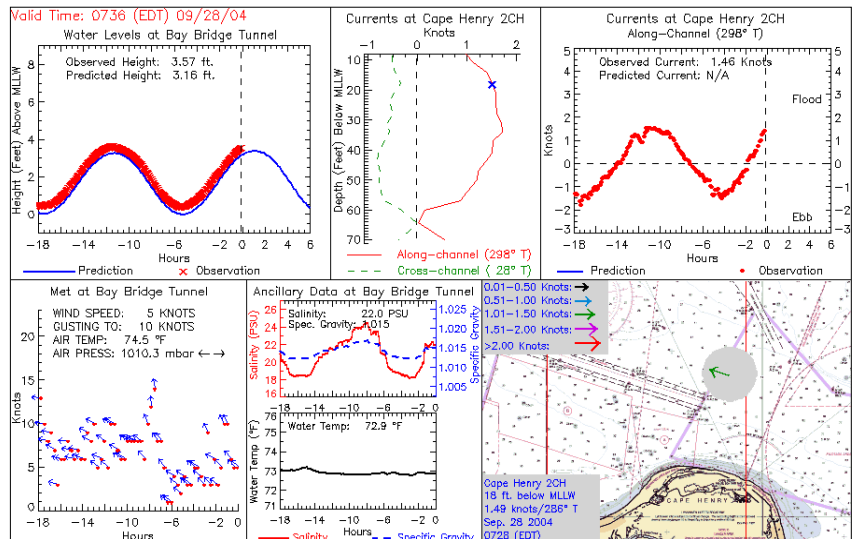
NOAA's Ocean Service

Center for Operational Oceanographic Products and Services

Ocean Systems Test and Evaluation Program

The Physical Oceanographic Real-time System (PORTS®) is a program of the National Ocean Service's Center for Operational Oceanographic Products and Services (NOS/CO-OPS). PORTS® provides real-time marine environmental information to support safe and efficient maritime commerce and informed coastal resource management. In response to user requests for current information near navigation channels, CO-OPS has entered into a partnership with the US Coast Guard to place acoustic Doppler current profilers on existing Coast Guard navigation buoys.

Following a brief description of the measurement and communication technologies used and the design considerations which ensure the PORTS® payload does not interfere with the primary mission of the ATONs, this presentation details the system test and evaluation undertaken, the data flow configuration, and data quality control procedures used to assure that the current information disseminated from these systems meets the quality requirements of the navigation community.



## **Real-Time QA/QC of Current Meter Data in NOAA's National Ocean Service**

**Richard W. Bourgerie**

NOAA/National Ocean Service/ Center for Operational Oceanographic Products and Services

The Continuous Operational Real-Time Monitoring System (CORMS) is a vital component of the real-time QA/QC efforts in NOAA's National Ocean Service (NOS), Center for Operational Oceanographic Products and Services (CO-OPS). The primary mission of CORMS is to perform thorough and robust QA/QC on all real-time data, systems, and products in the CO-OPS domain, to ensure that a reliable source of real-time data is available, while not disseminating data of questionable quality. Data are available to the users in real-time (or near real-time) via various online graphical plots, simple text data, as well as telephone voice response. All data and products are monitored and reviewed on a 24x7 basis, automatically and by experienced CORMS operators working on 12-hour shifts. When a system and/or data problem is detected, CORMS forwards the information to the appropriate field and/or IT personnel to enable corrective action.

The most complex data type that CORMS monitors is current meter data. These data are collected and transmitted at six-minute intervals from a variety of Doppler-type current meters, including RDI, SonTek, and Nortek. Depending on the user needs and site-specific configuration, the current meters are installed in three different orientations: bottom-mounted/upward-looking, pier-mounted/side-looking, and buoy-mounted/downward-looking. Data from the current meters are transmitted using different types of terrestrial communications; armored underwater cable, phone lines, IP modems, and line-of-sight radios are the most common. CO-OPS plans to develop (in the very near future) the ability to utilize the Geostationary Operational Environmental Satellite (GOES) system to more reliably transmit the data from the suite of current meters around the U.S.

Presently, the real-time data from CO-OPS' current meters undergo basic automated QC checks. These checks are performed on a local data acquisition system (DAS), which is generally a Linux-based PC. Checks include missing data, minima/maxima tolerances such as speed, direction, echo intensity, tilts, heading, percent-good-pings, and vertical velocity. Sample-to-sample tolerances (i.e., deltas) are monitored as well. WARNING flags notify the CORMS operators to be aware of a potentially developing problem, while FAILURE flags automatically shut off dissemination of the data. All flags are archived indefinitely, in case there is a need to investigate a past issue.

The long-term quality assurance of the current meter data is fulfilled by adhering to a standard maintenance schedule that includes routine inspections, cleaning of bio-fouling, and regular sensor replacement. In addition, prior to any deployment, each current meter is tested in a 19 ft. deep towing basin facility located at the David Taylor Model Basin of the Naval Surface Warfare Center in Carderock, MD. The performance of the sensors are verified by towing at incremental speeds, ranging from 5 cm/s to 200 cm/s. If a sensor fails this test, it is not installed in the field.

The "next generation" of CORMS, known as CORMS AI (Artificial Intelligence), is presently in development and testing. It is anticipated that this advanced system will be operational by the middle of 2005. CORMS AI will use a combination of case-based reasoning and rule-based reasoning to more effectively monitor the real-time network, increase the capacity, and reduce the occurrences of operator errors.

## **Initial Automated Quality Checks for Oil Platform Current Data**

**Don Conlee, Dave Gilhousen, Steve Collins and Richard Bouchard**

National Data Buoy Center Stennis Space Center, MS 39529

**Cortis Cooper**

ChevronTexaco

San Ramon, CA 94583

The USGS Minerals Management Service (MMS) has issued a Notice-to-Lessees (NTL) requiring operators in the Gulf of Mexico to monitor and report current measurements on deep platforms and drilling rigs. NDBC will be receiving these observations and making them available via the NDBC website, as well as reformatting and inserting into the GTS. Industry, MMS, and NDBC representatives have established a working group to address QA/QC of these observations. The initial step will be to perform limited range checks via automated algorithms upon data receipt at NDBC. The emerging details of this new reporting system and the initial QA/QC checks will be given.

## Abstracts

### Remotely Sensed Currents

#### Coastal HF Radar and Operational Search and Rescue Modeling

**Paul Hall<sup>1</sup>, Dave Ullman<sup>2</sup>, Josh Kohut<sup>3</sup>**

<sup>1</sup>*Applied Science Associates, Narragansett, RI*

<sup>2</sup>*University of Rhode Island Graduate School of Oceanography, Narragansett, RI*

<sup>3</sup>*Rutgers University Institute of Marine and Coastal Sciences, New Brunswick, NJ*

The effectiveness of search and rescue (SAR) operations in coastal waters depends critically on the ability of responders to accurately predict the motion of drifting objects. At present, SAR responders, such as the US Coast Guard, rely on currents derived from tidal harmonics measured at coastal stations in near-shore regions, or climatological estimates of currents off-shore, to predict the trajectories of drifting SAR objects. The resulting currents are coarsely defined. Networks of High Frequency (HF) radar systems, which provide real-time, spatially dense measurements of surface currents over large swaths of the coastal ocean, have great potential for improving SAR operations by improving predictions of SAR object motions. In light of this potential, the US Coast Guard Research and Development Center has sponsored a series of studies to assess the efficacy of HF radar derived currents for predicting drifter motions and to incorporate real-time HF radar data into an operational SAR model.

We report on the results of a study in which currents derived from HF radar data were used to model the motions of seven Self Locating Datum Marker Buoys (SLDMBs) [Davis-style drifters with onboard GPS, coordinates transmitted via Argos]. The buoys were deployed in three clusters: one in western Block Island Sound (BIS) and the other two in the Mid-Atlantic Bight (MAB), for a 35-day period starting on July 27, 2004. HF radar data for BIS were provided by a three site standard range (25 MHz) CODAR system operated by the University of Rhode Island. Data for the MAB region were provided by a four site long range (5 MHz) CODAR system operated by Rutgers University. SLDMB trajectories were modeled in 24-hour segments, a time scale typical of SAR cases. Results demonstrate that currents derived from HF radar significantly improve drifter trajectory predictions over 24 hr periods relative to tidal harmonic and climatological currents. Furthermore, quality assurance of the HF radar data, and its effect on drifter trajectory predictions, is considered explicitly and several outstanding issues pertaining to the operational use of HF radar data are highlighted.

#### NOS HFR QA/QC Efforts for IOOS: 2005

**Jack Harlan**

NOAA/National Ocean Service

In the effort to establish a national network of HF radars (HFR) for coastal surface current monitoring, the NOAA National Ocean Service FY05 IOOS budget has provided funds for the development of QA/QC algorithms and standards for HFR-derived currents. Some broad areas of interest include: relationship of spectral SNR to rms error, evaluation of methods for creating total vectors from radial velocities, simulation-based evaluation of spectral analysis algorithms.

## **Long-Range HF radar surface current evaluation with in situ observations.**

**Josh Kohut, Hugh Roarty, and Scott Glenn**

Rutgers University, New Brunswick NJ 08901 USA

A network of High Frequency (HF) radars are deployed along the New Jersey coast providing synoptic current maps across the entire shelf. These data serve a variety of user groups from scientific research to Coast Guard search and rescue. In addition, model forecasts have been shown to improve with surface current assimilation. In all applications, there is a need for better definitions and assessment of the measurement uncertainty. During a summer coastal predictive skill experiment in 2001, an array of in situ current profilers were deployed in the vicinity of two HF radar sites, one long range and one standard range system. Comparisons statistics were calculated between different vertical bins on the same current profiler, between different current profilers, and between the current profilers and the different HF radars. The vertical and horizontal shears were then characterized using the observed RMS differences. We further focused on two cases, one with relatively high vertical shear, and a second with relatively low vertical shear. Observed differences between the top bin of the current profiler and the HF radar were influenced by both system accuracy and the environment. Using the in situ current profilers, the environmental variability over scales based on the HF radar sampling was quantified. HF radar comparisons with the current profilers were on the same order as the observed environmental shears, indicating that the environment has a significant influence on the observed differences. Both vertical and horizontal shears contribute to these differences. When the potential effects of the vertical shear could be minimized, the remaining difference between the current profiler and the HF radar was similar to the horizontal shear ( $\sim 2.5$  cm/s) and below the digitization interval of the raw radial data at the time of the deployment.

## **Uncertainty in the Radial Velocity Estimates from Standard Range CODAR SeaSondes in the FRONT Area**

**James O'Donnell<sup>1</sup>, Diane Bennett<sup>1</sup>, Dave Ullman<sup>2</sup>, Adam Houk<sup>1</sup> and Todd Fake<sup>1</sup> and Arthur Allen<sup>3</sup>**

<sup>1</sup>Department of Marine Sciences, University of Connecticut

<sup>2</sup>Graduate School of Oceanography, University of Rhode Island

<sup>3</sup>USCG, Research and Development Center

As part of the FRONT experiment three standard range CODAR sites were established around Block Island Sound. The program conducted nine ADCP surveys of the circulation with the RV Connecticut each of at least three days duration. A subsequent program in the same area made three deployments of surface drifters. We use these data to describe the spatial structure of the operational uncertainty in the CODAR radial velocity components. A careful analysis of the uncertainties expected to arise from the presence of vertical and horizontal shear combined with the spatial and temporal sampling offsets is reported. The distribution of CODAR returns in azimuth is quite different at each of the three sites and provides an opportunity to compare the influences of geometry on uncertainty.

# Abstracts

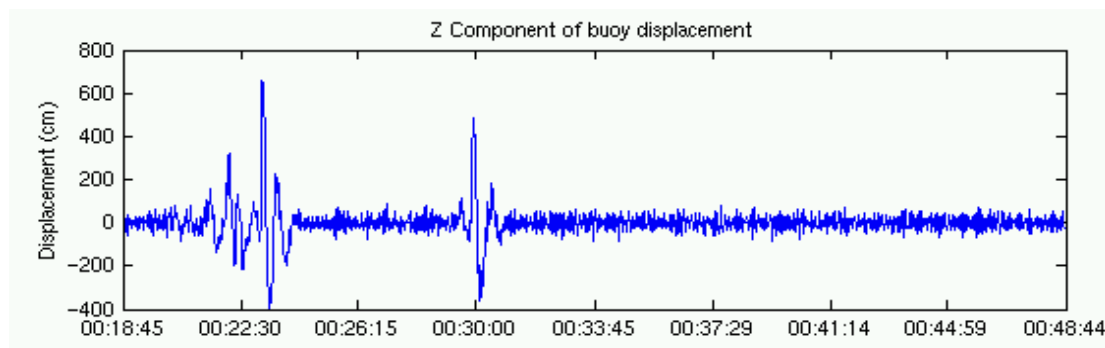
## Waves

### Coastal Data Information Program's QA/QC Methods

**Julie Thomas**

Scripps Institution of Oceanography, Coastal Data Information Program

**Quality Assurance** has always been a prime concern for the Coastal Data Information Program (CDIP). We have noted that good quality instruments are foremost in assuring high quality data. CDIP has developed a suite of pre-deployment diagnostic procedures to identify sensor problems such as Figure 1 & 2.

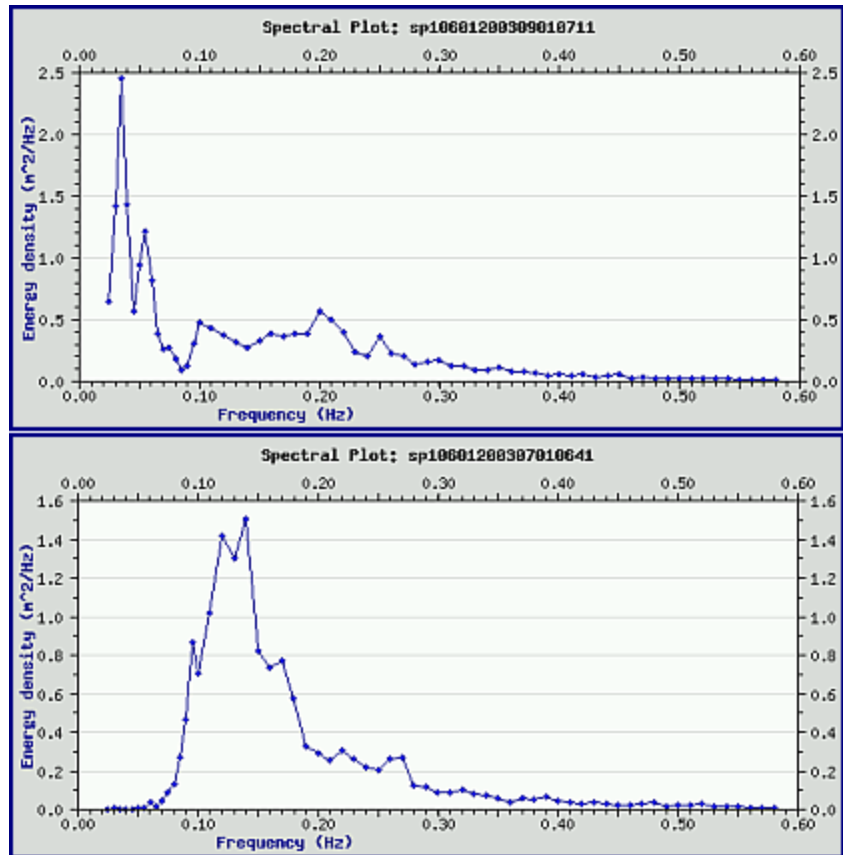


**Figure 1. Time series from a buoy with a bad hippy (heave-pitch-yaw) sensor**



Nonetheless, CDIP's post-processing checks correctly identify the problem with this file, since the resulting spectral distribution and parameter values (in this case  $T_p$ ) are skewed. Here the long-period spikes result in a spectral shift to lower frequencies, and in an unnaturally high  $T_p$  value (approximately 28 seconds).

Two spectral plots. The upper plot shows the shifted distribution of the time series data above; the lower plot shows a more typical spectral distribution



**Figure 2**

**Quality Control:** Measured data are subjected to a series of **Quality Control** tests. A full description of these may be found at: <http://cdip.ucsd.edu> in the Documents section.

The QC Data Summary Table is also available at the CDIP Documentation site:

AR = Array

BS = Basin Energy

DW = Datawell Directional Buoy

NB = Non-Directional Buoy

PR Single Point Pressure

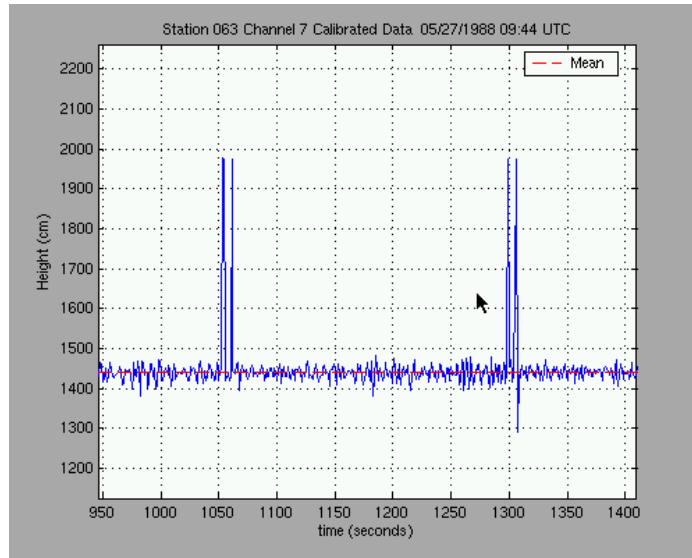
SG = Surge

SPECTRAL PROCESSING						
TEST: description (click name for more details)	AR	BS	DW	NB	PR	SG
DETREND: remove tidal component from long series.		✓				✓
BUOY MEAN: test if non-directional buoy mean is within specs.				✓		
MAX WAVE HEIGHT: check wave height against max in archive.	✓	✓		✓	✓	✓
FLAT EPISODES TEST: test if time series is changing too slowly.	✓			✓	✓	
SPIKE EDIT: replace spikes with average of point and previous.	✓	✓		✓	✓	✓
MAX/MIN VALUE TEST: for water column, check if values are sensible	✓				✓	
MEAN SHIFT TEST: check for a shift in the mean in the series.	✓	✓		✓	✓	✓
EQUAL PEAKS TEST: check for successive peaks with the same value.	✓				✓	✓
ACCELERATION TEST: check if acceleration is greater than 1/3 g	✓	✓			✓	✓
MEAN CROSSING TEST: check if there are too few mean crossings.	✓			✓	✓	
PERIOD DISTRIBUTION TEST: check for excessive long-period waves.	✓			✓	✓	
UNCORRECTED ENERGY COMPARISON: compare time series variance.	✓					
DEPTH COMPARISON: compare time series means.	✓					
SERIES COMPARISON: check correlation of time series.	✓					
CORRECTED ENERGY COMPARISON: compare depth-corrected variance.	✓					
INCIDENT WAVE TEST: check that directions are incident to shore.	✓					
DW STATUS/TRANSMISSION BYTE: discard imperfectly transmitted data.			✓			
BAND DIRECTION MAX/MIN: check Dmean for each band.			✓			
DW CHECK FACTORS: issue warning for bad check factors.			✓			
SUMMARY VALUE MAX/MIN: reject Hs, Tp values outside limits.			✓			
PARAMETER PROCESSING						
TEST: description (click name for more details)	AR	BS	DW	NB	PR	SG
SPIKE TEST: check for abrupt changes in values between records.	✓	✓	✓	✓	✓	✓
RANGE TEST: apply max/min tests to all parameters.	✓	✓	✓	✓	✓	✓
CONSECUTIVE VALUE TEST: check for excessively constant values.	✓	✓	✓	✓	✓	✓
Dp SPREAD TEST: check if Dp values are too spread out.	✓		✓			
Dp RANDOM TEST: check if Dp values are too variable and random.	✓		✓			
VISUAL INSPECTION: review monthly Hs, Tp, Dp plots.	✓	✓	✓	✓	✓	✓

A few examples of the details for each QC test are following.

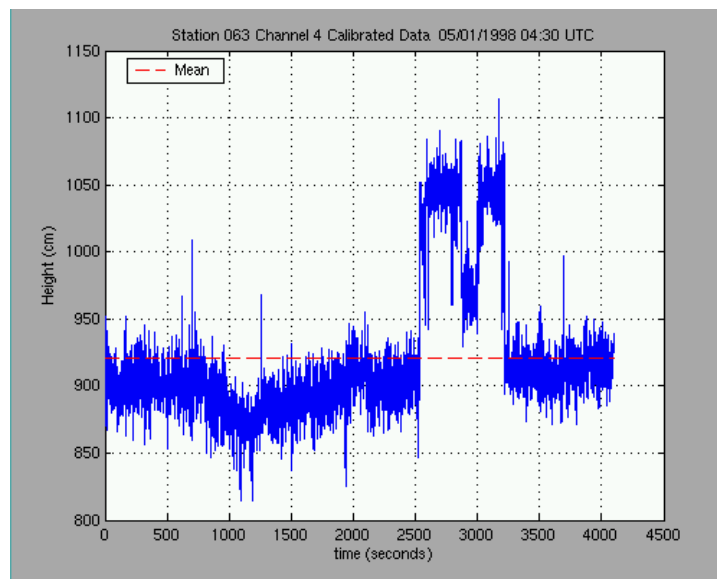
**SPIKE EDIT:** Checks for spikes in a time series. CDIP defines spikes as points more than 4 times the standard deviation from the series mean. A single point spike is corrected by linearly

interpolating between adjacent points. The editing code may loop over the series multiple times; the time series is rejected if it contains too many spikes (generally set to 1% of all points), or if spikes remain in the series after the specified number of loops (generally set to 5).



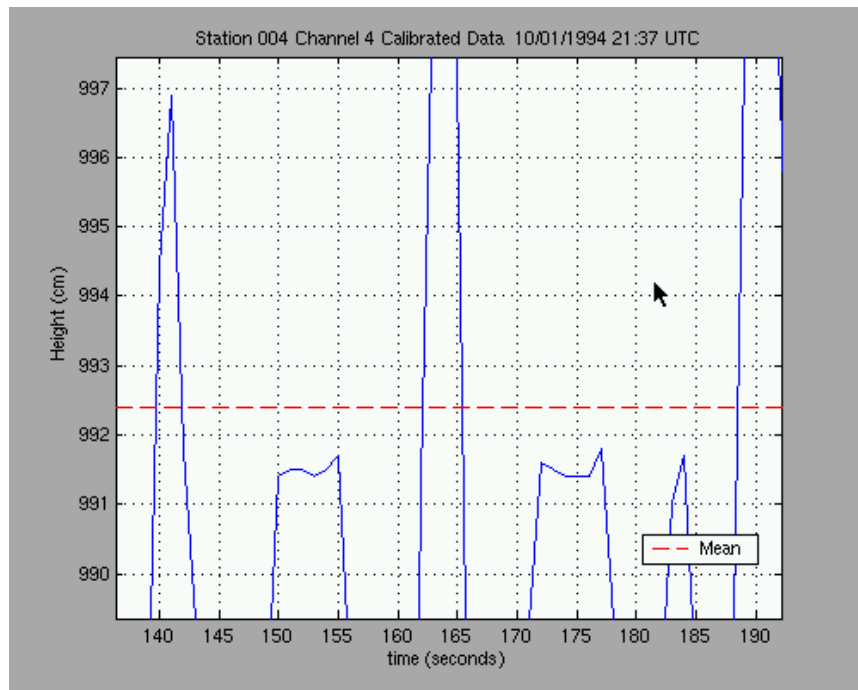
**A sample time series with excessive spikes. Record is rejected.**

**MEAN CROSSING TEST:** A sea surface elevation time series will cross the mean at periodic intervals. This test segments the time series, calculates the mean for each segment, and then checks for mean crossings. If there are no mean crossings within the maximum allowed number of points - 15% of the segment length - then the time series is rejected.



**A sample time series in which long sections remain above or below the mean, failing to cross the mean regularly. Record is rejected.**

**FLAT EPISODES TEST:** Checks for very slowly changing values over a specified number of points. This flat-lining may indicate a sensor problem limiting the response of a pressure sensor. Generally speaking, flat episodes are defined as displacement measurements which change by less than 1 cm over 4 to 10 consecutive points. If more than 5 flat episodes are found, the time series is rejected.



**A couple instances of flat episodes, each showing six consecutive values falling within 1 cm. Record is rejected.**

## SUMMARY

CDIP provides both wave measurements and model output to a variety of organizations and individuals. End users include the military, local and State government agencies, coastal planners and managers, commercial and recreational fishermen and of course surfers! The data are transmitted to the National Weather Service every 30 minutes, in addition to being updated on the web in near real-time.

## ADCP-Based Determination Of Directional Wave Spectra In The York River Estuary

**J. Brubaker, L. Brasseur, C. Friedrichs, T. Nelson and L.D. Wright**

Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA

Several deployments of an acoustic Doppler current profiler (ADCP) in the York River have revealed significant challenges with respect to estimation of wave spectra for the short-period waves typical of the York and similar estuaries. Fundamental to quality assurance are determination of threshold levels for detection of wave height and minimum wave period in order to set limits for initial screening. Just prior to the passage of Hurricane Isabel in September 2003, a 600 kHz ADCP (RD Instruments) was deployed on the bottom at 8 m depth in self-contained mode. The unit performed throughout the harsh conditions and produced apparently reasonable

estimates of wave parameters during the passage of the storm. However, during the less energetic periods, wave estimates did not seem reasonable. Similar results were obtained during a second deployment in which comparison data from a Nortek AWAC were available.

With respect to determination of wave spectra, the trials with the 600 kHz ADCP were somewhat opportunistic and sub-optimally configured. Currently, we are implementing a component of our observing system to facilitate more systematic trials with a 1200 kHz ADCP, cabled to shore. In this mode, working with RD Instruments, we will be able to execute and assess tests of various sampling configurations. Quality assurance considerations can impose associated requirements on support systems, such as power demand and bandwidth for real-time telemetry. Again, the cabled mode will enable convenient testing over a range of configurations, and help determine the minimum requirements for more remote deployments without the luxury of a cable.

## **NDBC Real-time Wave Data Processing and QC/QA**

### **Chung-Chu Teng**

NOAA National Data Buoy Center

The NOAA National Data Buoy Center (NDBC) has a network of 88 data buoys and 54 land-based C-MAN stations. Currently, all NDBC buoys and four C-MAN stations measure non-directional wave data. Among them, 28 buoys also measure directional wave data. Under a long-term plan, NDBC will add directional wave data capability to all of its buoys and most of the C-MAN stations. The wave data measured from NDBC stations are extremely important to marine forecasters, engineers, scientists, planners, mariners, marine operators, etc.

On a fixed C-MAN station, the wave measurements are derived directly from displacements measured by a fixed wave sensor. On a buoy, all of the wave measurements are derived in some way from the estimated energy spectra of time series of buoy motion. Wave information collected from data buoys is probably the most complex measurements made by NDBC because the wave information is converted from buoy motion via spectral analysis and transfer functions. For unidirectional (or nondirectional) wave data, the vertical motion of the buoy is required. For directional waves, NDBC wave buoys use the surface-following principle, i.e., the buoy's pitch and roll angles are used to derive wave direction information. Directional wave processing, which involves cross spectral analysis and phase angle correction, is much more complex than the processing of nondirectional waves.

For a buoy wave system, the wave data formats and processing algorithms have inseparable ties to and direct impact on wave data quality. In this presentation, NDBC wave formats and processing will be briefly described. The formatting and processing issues include:

- Scheme of data acquisition: Sampling rate and total data record length;
- Wave format: Reporting wave frequencies, number of reporting frequency bands, and frequency bandwidth;
- Spectral analysis based on conventional FFT method or other methods (e.g., maximum entropy method, maximum likelihood method, etc.);
- Use of data window and digital filter.

One very important data processing issue is the low frequency noise correction. When buoy acceleration spectra are converted to displacement spectra, acceleration energy density is multiplied by the reciprocal of radian frequency to the fourth power. At low frequencies, this multiplier becomes quite large. As a result, any unwanted signal, or noise, is amplified along with the wave energy. The excess low-frequency energy or noise must be removed before converting the spectra so the noise will not contaminate the wave spectra and the derived wave parameters.

As mentioned, wave data from buoys are not measured directly, but are converted from buoy motion. Thus, wave data quality control (QC) plays an important role for making sure the whole wave-measuring process and buoy system work correctly and the final wave data can truly represent the real sea state. NDBC data QC is based on the following three general principles:

1. Reasonability: Data should be in reasonable ranges and intervals;
2. Continuity: Data should maintain the continuity in time and space;
3. Consistency (or correlation): Data should have proper time correlation, spatial correlation, and correlations with other measurements.

Based on the above principles, NDBC developed many QC algorithms for wave data, such as range check, time continuity, internal consistency, etc. Many other algorithms based on ocean wave theories and characteristics were also developed, such as wind-wave algorithm (which compares the wind to wave energy), swell direction check, high frequency spectral spikes, wave height verses average wave period, etc. In addition, when needed, NDBC also uses data from NCEP's wave models and wave data from other organizations to check its buoy wave data.

# Abstracts

## General Topics

### **TWiki Tutorial: an online demonstration of TWiki use and features**

#### **Jeremy Cothran, Software Developer**

Baruch Institute for Marine and Coastal Sciences at the University of South Carolina

Wiki is the Hawaiian word for “quick” and a wikis are a browser based tool for collaboratively creating and managing online content – one of a variety of content management systems. Wikis are designed to encourage community contribution to an open, flexible and dynamic framework of information (see <http://wikipedia.org> or <http://twiki.org/cgi-bin/view/Main/TWikiInstallation> for example). A TWiki is a kind of wiki with features, installation and support particular to TWiki.

A tutorial is provided to help users become more familiar with the available features presented by the twiki such as registering with the twiki, creating and editing webpages and attachments, page formatting options, review of document revisions and email notification on content change.

### **An Oceanographic Processing Environment: From System Design to Data Quality**

#### **Chris Paternostro, Oceanographer<sup>1</sup>, Roman Semkiw, Systems Analyst<sup>2</sup>**

<sup>1</sup>National Ocean Service/CO-OPS, Silver Spring, MD

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Oceanographic data are increasing by data types and volume making present methods of processing and determining quality a cumbersome task. We are developing an end to end state-of-the-art data management system to ingest, quality control, analyze, and decimate water velocity and related data. This will allow scientists to thoroughly study the physical processes instead of writing and altering computer code to analyze the data. The benefits will include reducing time for preliminary analysis thus allowing more in-depth analysis, increasing consistency of results between users, and improving overall data quality.

During the initial stages of the system development, we are focusing on system quality control. The design of the system architecture follows a planned structured methodology. The Capability Maturity Model level 3 system development process assures the quality of the software developed. Figure 1 shows the sequential steps that should be taken to develop quality software.

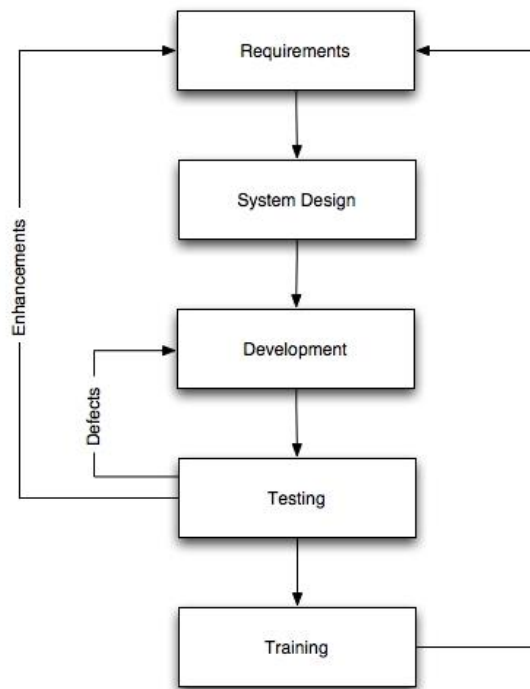


Figure 1. Linear method to develop quality

The initial phase includes documenting detailed functional and system requirements. System users and maintainers are interviewed and their feature requests are included in the requirements and design documents. The quality of the final product is directly correlated to the quality of the system requirement specifications. The second phase is to document the conceptual design of the system using requirements to develop prototypes and to perform market research for commercial off the shelf products.

The third phase is the development stage. Software modules are developed, integrated, and tested. During this phase, preliminary systematic testing is performed and software bugs such as run time errors will be resolved. The fourth phase is quality system testing. Intensive testing of data sets with known results are used to check the integrity of the system. In addition, semantic software bugs such as sign differences, round-off errors, or incorrect results will be revealed requiring modifications to the software modules. If the testing reveals a flaw in the software design, the enhancement process starts by analyzing the missing requirements and then repeats the software development life cycle process (Figure 1). The last phase is training the users of the system. A demonstration of the system is performed and user documentation is written.



Designing a quality system will help ensure the final product is maintainable, transferable, and consistent. A logical build has the benefit of being able to transfer quality data and source code algorithms to other users. Figure 2 shows the envisioned design of our data management system. We are using a modular design so new functions can be added in the future. A quality system also ensures separate modules can be upgraded but still give consistent results. We are requiring the design to be platform independent and accessible from various locations around the country. Finally to account for the ever growing nature of oceanographic data, we are requiring the system

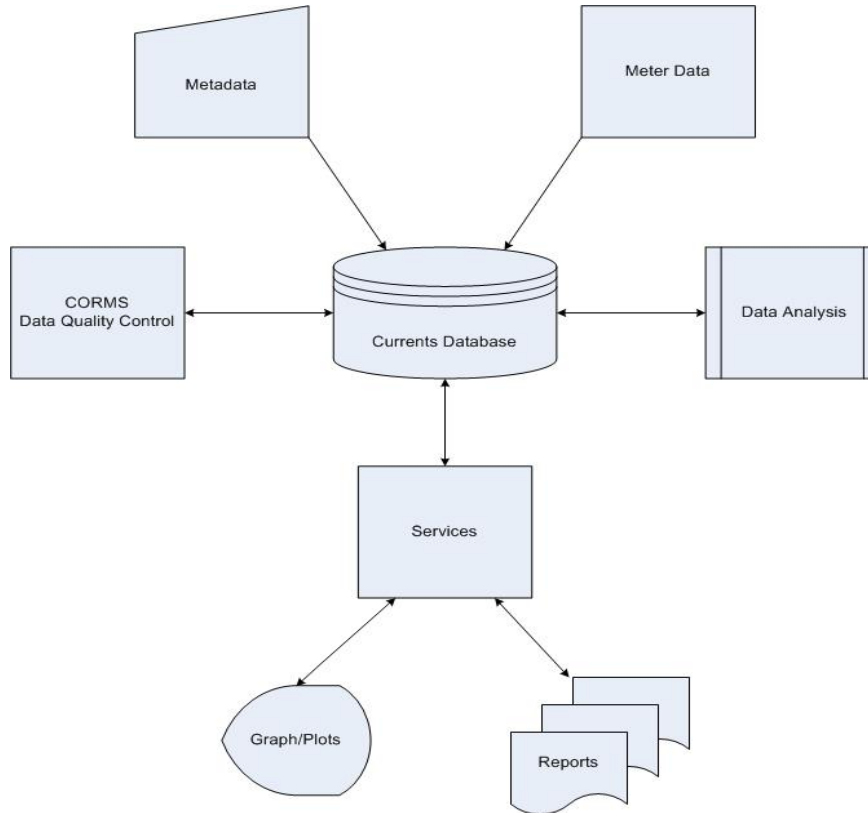


Figure 2. Modular design of the data management system.

to flexibly handle larger data sets that have higher spatial and temporal resolutions.

Well-defined algorithms will be implemented determining the quality of both the data and the analysis results. The data management system will provide oceanographers the means to study water velocity data using a wide suite of mathematical and graphical tools allowing us to create more products rather than spending time altering data sets.

## Data Integration Demonstration

**Julie Thomas**

Scripps Institution of Oceanography

In November 2004, COTS/ONR and the Regional Association held a workshop to enhance coordination, especially data integration, among its partners and other collaborators.

One of the key outcomes of the workshop was to participate on a data integration demonstration. This demo would be amongst the coastal observing systems within and across regions, and have a federal backbone.

Two products were proposed:

1. A product of interest to the weather/ocean television channel;
2. A national display portal (interoperability demo 1 + additional variables).

The additional variables are listed as waves, currents, sea surface temperature, wind and chlorophyll. The topic areas were divided into 6 working groups:

1. Demonstration goal focus;
2. Metadata;
3. QA/QC (Including liability issues;)
4. Data assembly and aggregation;
5. Common interface;
6. Communication facilitation.

It is the intent of the QA/QC group to build upon the framework of the parameters and guidelines proposed by QARTOD.

## **Progress on Metadata Issues for Ocean Observing**

### **Stephanie Watson and Julie Bosch**

Central and Northern California Ocean Observing System (CeNCOOS) and NOAA National Coastal Data Development Center (NCDDC)

The Integrated Ocean Observing System (IOOS) Data Management and Communications (DMAC) plan identifies activities, milestones, and tasks related to issues ranging from data aggregation to archive. The need for effective metadata is prominent in the plan, which emphasizes its role in data discovery. Since the plan has been publicized, several inter-related activities have developed to help implement the metadata aspects of the plan. In this presentation, we will discuss the Marine Metadata Interoperability (MMI) Initiative (<http://marinemetadata.org>), the NOAA Coastal Observation Technology System (COTS)/Office of Naval Research working group on metadata established to help implement a second iteration of the IOOS Interoperability Demonstration (<http://www.openioos.org>), and the metadata issues paper being prepared by the DMAC Organizing Committee. We will address how these activities relate to the scope of the QARTOD II workshop.

# **QARTOD II Workshop Agenda**

**Monday, February 28 – Nauticus Auditorium, 3<sup>rd</sup> floor**

**7:45** Coffee and Continental Breakfast with the Old Dominion University Propeller Club and the ODU Maritime Institute

**9:00** Welcome and Assembly Addresses  
Meeting Manager – Larry Atkinson  
Nauticus Director Welcome – Rich Conti  
NOS CO-OPS – Rich Edwing, Deputy Director of NOS/CO-OPS

**9:30** Review of QARTOD I Findings – Mark Bushnell

**9:50** Challenge and Meeting Goals – Mark Bushnell

- 1) To share information between users, operators, vendors, etc. with existing plans, needs, and operations
- 2) To develop working sensor-based QA/QC standards for:
  - *In-situ* current observations;
  - Remote current observations;
  - *In-situ* (and remote) wave observations.
- 3) Discuss implementation issues: standards, or not?, peer review (Type A) or cooperative efforts (Type B) for:
  - QA/QC;
  - Algorithms;
  - Product delivery;
  - Standardization/metadata balance.
- 4) To develop a framework for QARTOD III

**10:00** Review of Workshop Agenda – Larry Atkinson

**10:15** Break

**\*\*Presentation format is 20 minutes with 10 minutes for questions and discussion.\*\***

**10:30** Presentations: *In-Situ* Currents – Bill Burnett, Moderator  
Richard Bourgerie - Real-Time QA/QC of Current Meter Data in NOAA's Ocean Service  
Don Conlee - Initial Automated Quality Checks for Oil Platform Current Data  
Jennifer Dussault – QA/QC for ATON ADCP

**12:00** Lunch

**13:30** Presentations: *In-situ* Currents, cont'd. – Bill Burnett, Moderator  
Chris Paternostro – An Oceanographic Processing Environment: From System Design to Data Quality

**14:00** Presentations: Remote Currents – Libe Washburn, Moderator  
Jack Harlan – NOS HF Radar QA/QC Efforts for IOOS: 2005  
Paul Hall – Coastal HF Radar and Operational Search and Rescue Modeling

**15:00** Break

**15:15** Presentations: Remote Currents, cont'd. – Libe Washburn, Moderator  
Josh Kohut – Long Range HF Radar surface current evaluation with in-situ observations

Jim O'Donnell – Uncertainty in the Radial Velocity Estimates from Standard Range CODAR Sea Sonde in the FRONT Area

16:15 Adjourn for the day

17:00 Moderators SPO Meeting – Sheraton Waterside Hotel

## Tuesday, March 1 – Sheraton Norfolk Waterside Hotel

8:30 Continental Breakfast – **Promenade, 3<sup>rd</sup> floor**

9:00 Presentations: *In-situ* Waves – Kent Hathaway, Moderator – **York Hall, 3<sup>rd</sup> floor**  
Julie Thomas – Data Integration Demonstration  
Chung-Che Teng – Real-time Wave Data Processing and QA/QC  
J. Brubaker – ADCP-Based Determination of Directional Wave Spectra in the York River

10:30 Break – **Promenade, 3<sup>rd</sup> floor**

10:45 Cross-cutting Presentations – **York Hall, 3<sup>rd</sup> floor**  
Jeremy Cothran – TWiki Tutorial: an online demonstration of TWiki use and features  
Stephanie Watson – DMAC/MMI/Metadata

12:00 Lunch – **Riverwalk, 1<sup>st</sup> floor**  
From 12:30 to 1:30, there will be an open house on *R/V FAY SLOVER* which will be berthed at Waterside Marina, located west of the Sheraton Hotel and directly in front of Waterside.

13:30 Charge to the Breakout Groups – **York Hall, 3<sup>rd</sup> floor**

For sensor specific data:

- What real-time quality control tests should be applied?
- What categories of real-time quality descriptor flags should be required?
- What real-time metadata descriptors should be required?
- What real-time calibration flags should be required?
- What common data formats should be required?
- Additional requirements associated with DMAC?
- Describe key next steps and current roadblocks to developing and implementing an operational QA/QC capability.

14:00 Breakout Groups – Facilitators: Bushnell, Ache, Cohen, and Loper

- *In-situ* (and Remote) Waves – Tech Lead: Hathaway; Facilitator: Loper – **Riverview, 4<sup>th</sup> floor**
- Remote Currents – Tech Lead: Washburn; Facilitator: Cohen – **Montpelier, 4<sup>th</sup> floor**
- *In-situ* Currents – Tech Lead: Burnett; Facilitator: Ache – **Greenway, 4<sup>th</sup> floor**

16:30 Adjourn for the day

18:00 QARTOD II Participant's Reception at Nauticus. There will be a 10 minute presentation by Ken Tenore of the Alliance for Coastal Technology.

## Wednesday, March 2 – Sheraton Norfolk Waterside Hotel

8:30 Continental Breakfast – **Monticello Foyer, 1<sup>st</sup> floor**

9:00 Reports from the Breakout Groups – Moderator, Larry Atkinson – **Monticello, 1<sup>st</sup> floor**

- *In-situ* (and Remote) Waves
- *In-situ* Currents
- Remote Currents

**10:15** Synthesize Workshop Recommendations/Resolutions – Facilitator, Larry Atkinson

**10:45** Break – *Monticello Foyer, 1<sup>st</sup> floor*

**11:00** Designing QARTOD III – Facilitator, Larry Atkinson  
Prospective date, location, lead, and parameters of interest

**11:30** Workshop Follow-up and Action Items –  
Facilitator, Larry Atkinson

**12:00** Adjourn

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