Real-Time Quality Control Tests for *In Situ* Ocean Surface Waves

Recommended by the

Quality Assurance of Real-Time Oceanographic Data (QARTOD) Workshops

and

The Waves Technical Workshop

July 2007

IOOS DMAC Standard Submission Information Page

a. Title: *Real-Time Quality Control Tests for In Situ Ocean Surface Waves*

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d. Version # 1.0

e. Recommendation: Adopt the attached standard submission.

f. Authority for standard: This is a new standard. There is presently no IOOS standard for the quality control of ocean surface waves. Existing international standards are outdated. The submission was encouraged by the presentation of the DMAC Steering Team Chair made to the QARTOD IV Workshop.

g. If applicable, statutory requirements for supporting the standard: None

h. Description: Attached are a series of quality control tests developed by the QARTOD workshops and the Waves Technical Workshop and recommended for use by wave data providers. Participants included representatives from government, industry, and academia involved with providing or using wave measurements.

(i) *Purpose or application*: The purpose is to define a minimum standard for the quality control of real-time, *in situ* wave measurements in order to facilitate the exchange of data.

(ii) *Proposed data types to which the standard would apply*: This standard would apply to the Time Series Structured Data Class as the original time series data collection and any transformation from the time domain to the frequency domain. The standard is also relevant to Point Data as the wave time series and spectral records are processed into discrete point data of the bulk parameters (*e.g.*, height, period).

(iii) *Maturity level of the guideline*: Because the guidelines are derived from existing practices and presently used in the operational environments of NOAA's National Data Buoy Center (NDBC) and the Coastal Data Information Program (CDIP), the guidelines should be considered *operational*. Implementation of the eventual real-time in situ quality control procedures would help Regional Associations meet the Ocean.US DMAC requirement for wave data that "… are quality controlled and managed in compliance with Ocean.US DMAC standards and protocols." (Ocean.US, 2006)

i. Rationale/justification: See Section 1.0.

j. References: See Section 4.0.

k. Current Usage: Documented with each test. The tests are generally operational at CDIP and NDBC for their own wave measurements, and NDBC applies the Parameter tests to wave measurements provided by its partner stations. The tests are among those applied to the research data collected by the US Army Corps of Engineers, Field Research Facility at Duck, NC (USACE FRF), see
http://cdip.ucsd.edu/documents/index/product_docs/qc_summaries/waves/waves_table.php?&selected=FRF
. Various manufactures, involved with the QARTOD effort have outlined their QC procedures at the QARTOD Quality Control Test webpage at:
http://cdip.ucsd.edu/documents/index/product_docs/qc_summaries/waves/waves_table.php

NDBC provides a listing of some of its algorithms in Appendix D of NDBC, 2003. However, nearly all of the tests consist of range or limit checks on various measurements and thus are easily implemented with simple coding. The bulk of the work so far has been in reaching consensus on which measurements the checks should be applied to.

Table 1: List of Acronyms and Abbreviations

AODC	Australian Oceanographic Data Center
CDIP	Coastal Data Information Program
DMAC	Data Management and Communications [Steering Committee]
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Date Exchange
IOOS	Integrated Ocean Observing System
NDBC	National Data Buoy Center
NOAA	National Oceanic and Atmospheric Administration
QARTOD	Quality-Assurance of Real-Time Oceanographic Data
RFC	Request for Comment
UNESCO	United Nations Educational, Scientific, Cultural Organization
USACE FRF	US Army Corps of Engineers, Field Research Facility, [Duck, NC]

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1.0 Rationale/Justification

The dawn of the Integrated Ocean Observing Systems (IOOS) brings many challenges related to the distribution and description of real-time ocean data. One of the primary challenges facing the ocean community is the fast and accurate assessment of quality data streaming from the IOOS measurements. Operational data merging and assimilation from multiple data sources will be essential to adequately describe and predict the physical, chemical, and biological state of the coastal ocean. These activities demand simple, accurate, and consistent quality descriptions for every observation distributed as part of IOOS. [1]

The need for standards in wave data was highlighted by the inclusion of an E-mail from David McGehee of 22 August 2002 in Part III, Appendix 4: User Outreach of the *Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems* (Hankin, S. and DMAC Steering Committee, 2005). The Army Corps of Engineers initiated a Wave Analysis Standard under the Field Wave Gaging Program in 1995 (Earle *et al*, 1995) that briefly discussed quality assurance procedures, but no further comprehensive, multi-agency effort had been pursued.

International standards for the quality control of wave data were published in Section 2.2., Appendix A: Wave Data of *UNESCO Manuals and Guide 26* (UNESCO, 1993). However, Manual 26 is clearly dated and does not address technological advances in data processing and measuring systems since 1993.

These submitted standards apply only to real-time, *in situ*, surface wave measurements and not to remotely sensed wave measurements (*e.g.*, HF RADAR, SAR).

Through the process of four workshops of the Quality Assurance of Real-Time Oceanographic Data (QARTOD), these guidelines were adapted from existing guidelines of NOAA's National Data Buoy Center (NDBC), the Coastal Data Information Program (CDIP), the US Army Corps of Engineers Field Research Facility (USACE FRF), and participating manufacturers of wave measuring systems – Nortek, SonTek, and Teledyne RDI. Additionally, the individual tests have been mapped to existing tests of UNESCO (1993). NDBC and CDIP apply the QC tests to more than 125 operational stations, and NDBC applies the Parameter tests to another 40 stations of its IOOS partners.

The establishment of IOOS guidelines also encourages the entry of new entities into the realm of wave measurements by removing or reducing the obstacles to making and distributing quality wave measurements in real-time.

[1] Kearns, E. *et al*, 2004, p. 5.

2.0 Background

The recommendations were developed through a series of QARTOD workshops and the Waves Technical Workshop, as follows:

3-5 December 2003	QARTOD I: National Data Buoy Center, Stennis Space Center, MS. Final report available on-line at: http://nautilus.baruch.sc.edu/twiki/pub/Main/WebHome/QARTOD_final_09.pdf
28 Feb-2 Mar 2005	QARTOD II: Norfolk, VA. Web site: http://nautilus.baruch.sc.edu/twiki/bin/view/Main/Qartod2. Waves Breakout Group, chaired by Mr. Kent Hathaway, US Army Corps of Engineers. Breakout groups developed an example set of QC and QC items and established the mechanism for the on-line QC tables hosted by. QARTOD II QC tables at: http://cdip.ucsd.edu/documents/index/product_docs/qc_summaries/waves/waves_table.php
1 November 2005	Waves Technical Workshop, Scripps Institute of Oceanography, La Jolla, CA. Moderated by Dr. William Burnett National Data Buoy Center. Initiated consolidated list of standard QC tests. Results were carried over into subsequent QARTOD III.
2-4 November 2005	QARTOD III: Scripps Institute of Oceanography, La Jolla, CA, Nov 2-5 2005. Web site: http://nautilus.baruch.sc.edu/twiki/bin/view/Main/Qartod3. Waves Breakout Group, Chaired by Dr. Robert Jensen, US Army Corps of Engineers. Continued with results of Waves Technical Workshop and completed first draft of QARTOD standards posted to http://cdip.ucsd.edu/documents/index/product_docs/qc_summaries/waves/waves_table.php?&selected=QARTOD
21-23 June 2006	QARTOD IV, Woods Hole Oceanographic Institution, Woods Hole, MA. Web site: http://nautilus.baruch.sc.edu/twiki/bin/view/Main/Qartod4. Waves Breakout Group Technical Lead: Mr. Richard H. Bouchard, National Data Buoy Center. Request for Comment (RFC) on the QC tables was sent to past participants and other waves-interested parties prior to the workshop. Comments from the RFC were incorporated into the QC standards and briefed at the workshop.
April 2007	Publication of final QARTOD IV Report [available at: http://nautilus.baruch.sc.edu/twiki/pub/Main/WebHome/QARTOD2006_v9.pdf]

3.0 Tests

The tests are applied during the wave data collection and processing – the collected time series, the derived spectral values, and finally the bulk wave parameters of height, period, direction, and spreading.

Each test application is described first with a summary table (Tables 3-1, 3-2, and 3-3), then followed by more detailed description. The tables indicate in which order that the tests should be applied.

Tests result in hard or soft flags. A hard flag indicates that the data should not be released. Distribution and archive of data that are soft flagged are at the discretion of the data provider. If the data transport or archive mechanism and format allow, then soft flags should accompany the real-time data. The test description and flags should be included in the relevant metadata records (example suggested in Appendix A).

3.1 Time Series Tests

Data-providers should apply the time series tests to the original measurements assuming that the instruments have been calibrated.

Table 3-1. Time Series Tests

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

3.1.1 DATA GAPS

3.1.1.1 **Scope, Applicability, or Exclusions**

Applies to all *in situ* wave measuring systems.

3.1.1.2 **Description**

When data are received from the field, they are first checked for gaps and missing data. The checks are based on time tags and/or counters that are included in the data stream. A time series will be accepted if there are no more than N gaps, and no single gap lasts longer than M points. The data-provider should perform a best fit to replace missing data. The data-provider defines N and M.

3.1.1.3 **Sources**

CDIP, 2003.
UNESCO ,1993. Check: 2.3.7, *Gaps*
USACE FRF, 2007.

3.1.1.4 **Current Usage**

CDIP, USACE FRF, and Teledyne RDI (discontinuity)

3.1.2 SPIKES

3.1.2.1 **Scope, Applicability, or Exclusions**

Applies to all *in situ* wave measuring systems.

3.1.2.2 **Description**

Check for spikes in a time series. Spikes are defined as points more than M times the standard deviation away from the series mean. A spike is replaced with the average of the previous point and the following point. The algorithm should iterate over the series multiple times. The time series is rejected if it contains too many spikes (generally set to N% of all points), or if spikes remain in the series after P iterations. The data provider defines M, N%, and P iterations.

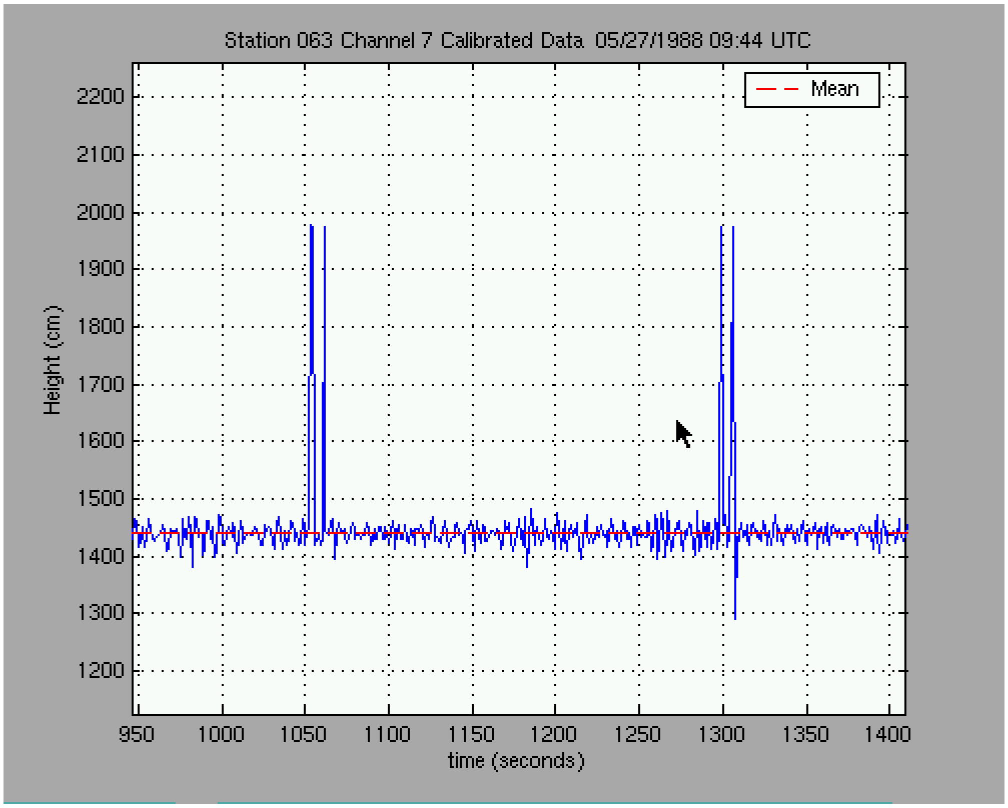

Figure 3-1. Example of spikes in time series data

3.1.2.3 **Sources:**

CDIP, 2003.
UNESCO, 1993. Check 2.1.2.b *Rate of change checks*
USACE FRF, 2007.

3.1.2.4 **Current Usage**

CDIP, USACE FRF, NDBC (limited to certain wave sensors), and Teledyne RDI (Delta Max).

3.1.3 RANGE TEST

3.1.3.1 **Scope, Applicability, or Exclusions**

Applies to all *in situ* wave measuring systems.

3.1.3.2 **Description**

Checks that the values of the time series fall within limits defined by the data-provider. The data-provider shall define at least the instrument range and not release wave parameters when the instrument limits have been exceeded.

3.1.3.3 **Sources**

CDIP, 2003
NDBC, 2003, Check 4.1.1, *Range Check*
UNESCO, 1993. Check 2.1.1.a, *Gross error limit*
USACE FRF, 2007.

3.1.3.4 **Current Usage**

CDIP, USACE FRF, NDBC, Nortek.

3.1.4 MEAN SHIFT

3.1.4.1 **Scope, Applicability, or Exclusions**

Applies to all *in situ* wave measuring systems.

3.1.4.2 **Description**

Breaks the time series into N segments of M points each. The segment means are compared to neighboring segments. If the difference in the means of two consecutive segments exceeds P, the data are rejected. The data-provider defines N segments, M points, and P, and shall not release wave parameters when this test fails.

An example of a Mean Shift that should be rejected is provided in Figure 3-2.

UNESCO (1993) recommendations:

N = 8
P = 0.20 m (for displacement)

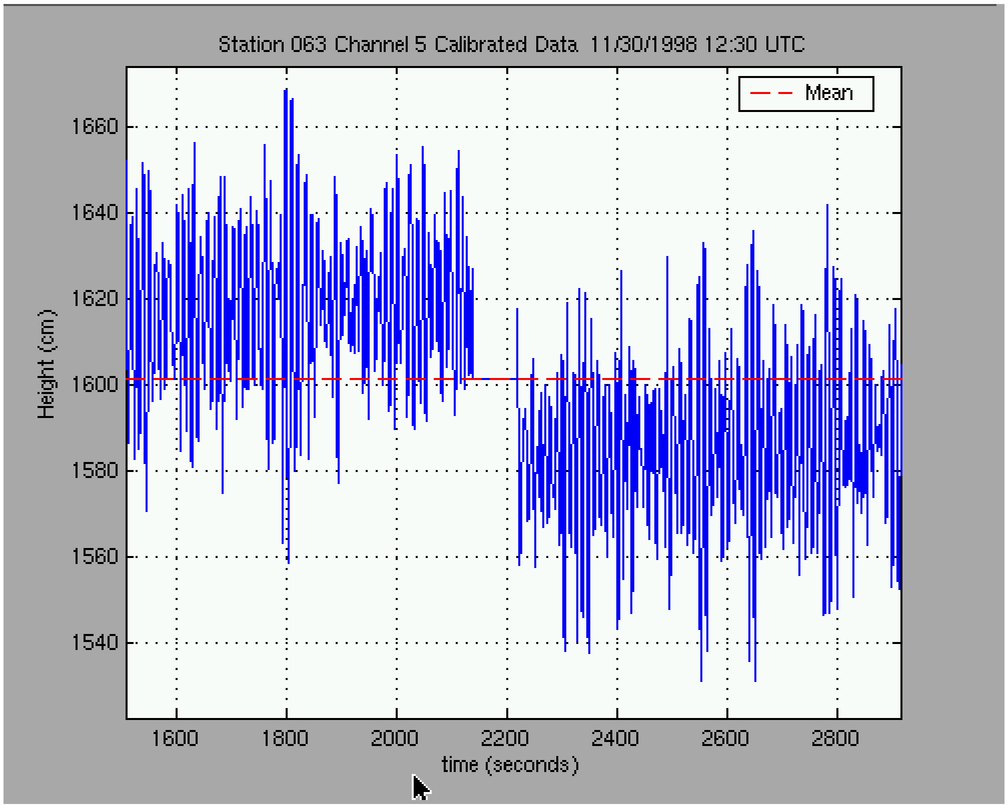

Figure 3-2. Example of Mean Shift

3.1.4.3 **Sources:**

CDIP, 2003
UNESCO, 1993. Check 2.1.3.c, *Data Stability*

3.1.4.4 **Current Usage**

CDIP

3.1.5 ACCELERATION TEST

3.1.5.1 **Scope, Applicability, or Exclusions**

The Acceleration Test applies only to acceleration measuring systems.

3.1.5.2 **Description**

Any acceleration values exceeding M*g (g=gravitational acceleration) are replaced with interpolated/extrapolated values. Up to N points may be replaced. The data provider defines M and N, and the method of replacement.

UNESCO (1993) recommends M >= 0.5.

3.1.5.3 **Sources:**

CDIP, 2003
NDBC, 2003, Check 4.1.1, *Range Check*
UNESCO, 1993. Check 3.1.3, *Gross Error Limits (acceleration)*
USACE FRF, 2007.

3.1.5.4 **Current Usage**

CDIP, USACE FRF, and NDBC.

3.1.6 MEAN TEST

3.1.6.1 **Scope, Applicability, or Exclusions**

Applies to all *in situ* wave measuring systems.

3.1.6.2 **Description**

Check that mean and variance values are within limits defined by the data-provider.

3.1.6.3 **Sources:**

CDIP, 2003.
NDBC, 2003, Check 4.1.1, *Range Check*
UNESCO, 1993. Check 2.1.3.b, *Wandering Mean*.
UNESCO, 1993. Check 2.1.3.d, *Check Limits*.
USACE FRF, 2007.

3.1.6.4 **Current Usage**

CDIP, USACE FRF, and NDBC.

3.1.7 POINTS GOOD

3.1.7.1 **Scope, Applicability, or Exclusions**

Applies to all *in situ* wave measuring systems.

3.1.7.2 **Description**

The data-provider shall keep a summation of the number of points of the time series accepted or rejected by the above six tests. The data provider shall release only wave parameters for which the number of accepted points of the underlying time series shall equal or exceed 90% of all the points in the time series.

3.1.7.3 **Sources:**

Developed by QARTOD as a natural result of the total Time Series tests.

3.1.7.4 **Current Usage**

Teledyne RDI and SonTek.

3.2 Spectral Value Tests

Spectral value tests are applied to frequency domain calculations.

Table 3-2. Spectral Value Tests

SPECTRAL VALUES					
Test #	**Category**	**Criteria**	**Order**	**Flag**	**Action**
NON-DIRECTIONAL:					
3.2.1	Operational frequency range test	**Defined by the environment and instrument**	**1**	**1. Soft 2. Hard**	**1. Max/min provider-defined. 2. Instrument spec exceeded, reject.**
DIRECTIONAL:					
3.2.2	Incident low frequency energy & direction	**Location defined**	**1**	**Soft**	**Provider defined**
3.2.3	Check ratio, or check factor	**Should be approximately 1, check over time. Depth, location dependent**	**1**	**Soft**	**Provider defined**

3.2.1 OPERATIONAL FREQUENCY RANGE TEST

3.2.1.1 Scope, Applicability, or Exclusions

Applies to all *in situ* wave measuring systems.

3.2.1.2 Description

Spectral data should only be reported for the valid range of frequencies. Lowest frequency is usually limited to 0.01Hz. High frequency limits are dependent on the wave field, water depth, and Nyquist frequency. In most cases applicable frequency ranges are provided in manufacturer's specifications.

3.2.1.3 Sources

CDIP, 2003.
Various manufacturers' technical documentation.
Steele, K.E., 1997.

3.2.1.4 **Current Usage**

CDIP and Teledyne RDI. NDBC excludes directional data from 10 and 12-m hull buoys above 0.2 Hz.

3.2.2 INCIDENT LOW FREQUENCY ENERGY & DIRECTION

3.2.2.1 **Scope, Applicability, or Exclusions**

Applies to all *in situ* directional wave measuring systems.

3.2.2.2 **Description**

Checks that the incident energy levels at low frequencies are within expected values as defined by the data-provider, such as consistency between the direction of swell waves and available fetch.

3.2.2.3 **Sources:**

CDIP, 2003.
NDBC, 2003. Check 4.1.6.3, *Swell Direction Check*
USACE FRF, 2007.

3.2.2.4 **Current Usage**

CDIP, USACE FRF, and NDBC.

3.2.3 CHECK RATIO

3.2.3.1 **Scope or Applicability: Heave/Slope (pitch, and roll) Buoys.**

3.2.3.2 **Description**

The check ratio or check factor, R, is loosely defined as the ratio of vertical to horizontal wave orbital motions. R is more formally defined by:

$$R = \left\{ \frac{1}{\tanh(kh)} \right\} \bullet \sqrt{\frac{C_{11}}{C_{22} + C_{33}}}$$

where:

C_{11}, C_{22}, and C_{33} are the cross-spectra respectively of heave, pitch, and roll.
k is the wave number,
h is the water depth, and
tanh is the hyperbolic tangent function.

This check ratio is a function of frequency and depth. It should theoretically be 1 for relatively deep water waves, but tends to deviate substantially from that value at periods longer than the peak frequency, and at short periods outside the response range of the buoy.

The data provider may choose any of the following methods of the check ratio test:

> Computed at the peak wave energy period and at a short period (but within the surface-following capability of the buoy) flag values outside the range of 0.9 to 1.1, or
>
> Test at least three frequencies distributed one each in the low, mid, and high frequency ranges, or
>
> Compute the percentage of all frequencies whose check ratio is within acceptable limit of 1.0, and flag if the percentage is outside of an established criterion.

3.2.3.3 **Sources:**

CDIP, 2003.
Krogstad, H.E., 2001.
Steele *et al* 1992.
UNESCO, 1993. Check 3.2.4, *Check Factor*.
USACE FRF, 2007.

3.2.3.4 **Current Usage**

CDIP, USACE FRF, and NDBC.

3.3 Parameter Value Tests

The wave parameters include heights (usually significant wave heights), periods, directions, and spreading parameters.

Table 3-3. Parameter Tests

PARAMETER VALUES					
Test	**Category**	**Criteria**	**Order**	**Flag**	**Action**
3.3.1	Wave parameters max/min/acceptable range (Height, Period, Direction, Spreading)	**Parameter and Location dependent**	**1** **2**	**Soft** **Hard**	**Provider defined** **Reject entire record if H exceeds limit otherwise reject individual parameter.**
3.3.2	Time continuity or Parameter Variability	**Short range history (applied to Height)**	**2**	**Soft**	**Provider defined**

3.3.1 MAXIMUM/MINIMUM RANGE

3.3.1.1 Scope, Applicability, or Exclusions

Applies to all *in situ* wave measuring systems.

3.3.1.2 Description

The data provider should establish maximum and minimum values for the bulk wave parameters – height, period, direction, and spreading.

However, if the wave height fails this test, then no wave parameters should be released.

3.3.1.3 Sources:

CDIP, 2003.
NDBC, 2003. Check 4.1.1, *Range Check.*
UNESCO, 1993. Check 2.3.4, *Check Limits*
USACE FRF, 2007

3.3.1.4 Current Usage

CDIP, USACE FRF, and NDBC.

3.3.2 TIME CONTINUITY or PARAMETER VARIABILITY

3.3.2.1 Scope, Applicability, or Exclusions

Applies to all *in situ* wave measuring systems.

3.3.2.2 Description

The time continuity or parameter variability test evaluates the rate of change of a parameter with time, in other words a maximum limit is placed on the rate of change between successive measurements, or measurements at defined times. It can also be considered a spike test for parameters.

3.3.2.3 Sources

CDIP, 2003.
NDBC, 2003. Check 4.1.2, *Time-Continuity*
USACE FRF, 2007.

3.3.2.4 Current Usage

CDIP, USACE FRF, and NDBC.

4.0 References

CDIP, 2003. *Data QC - data checks and editing*, Available on-line at: http://cdip.ucsd.edu/?nav=documents&sub=index&xitem=proc#quality.

Earle, M. D. ;D. McGehee, and M. Tubman, 1995. *Field Wave Gaging Program, Wave Data Analysis Standard*. US Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, 46pp.

Hankin, S. and DMAC Steering Committee, 2005. *Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems: I. Interoperable Data Discovery, Access, and Archive*, Ocean.US, Arlington, VA, 304 pp. Available on-line at: http://dmac.ocean.us/dacsc/imp_plan.jsp

Kearns, E., C. Woody, and M. Bushnell, 2004. *QARTOD-I Report*, 89 pp. Available on-line at: http://nautilus.baruch.sc.edu/twiki/pub/Main/WebHome/QARTOD_final_09.pdf

Krogstad, H.E., 2001. Second Order Wave Spectra and Heave/Slope Wave Measurements, *Proceedings of the Fourth International Symposium Waves 2000*, Vol. One, ASCE: Alexandria, VA, pp. 288-296.

NDBC, 2003. *NDBC Technical Document 03-02, Handbook of Automated Data Quality Control Checks and Procedures of the National Data Buoy Center*, National Data Buoy Center, Stennis Space Center, MS, 66 pp. Available on-line at: http://www.ndbc.noaa.gov/handbook.pdf

Ocean.US, 2006. *System (IOOS) Development Plan, Ocean.US Publication No. 9*, The National Office for Integrated and Sustained Ocean Observations, 104 pp. Available on-line at http://www.ocean.us/documents/docs/IOOSDevPlan_hi-res.pdf

QARTOD IV Final Report, QARTOD IV Organizing Committee, 2007. Available on-line at http://nautilus.baruch.sc.edu/twiki/pub/Main/WebHome/QARTOD2006_v9.pdf

Steele, K.E., C.C. Teng, and D.W.C. Wang, 1992. Wave direction measurements using pitch and roll buoys, *Ocean Engineering*, **19**(4), pp. 349-375.

Steele, K.E., 1997. Ocean Current Kinematic Effects on Pitch-Roll Buoy Observations of Mean Wave Direction and Nondirectional Spectra, *Journal of Atmospheric and Oceanic Technology*, **14**(2), pp. 278-291. Available on-line at http://ams.allenpress.com/archive/1520-0426/14/2/pdf/i1520-0426-14-2-278.pdf

UNESCO, 1993. *Manual and Guides 26, Manual of Quality Control Procedures for Validation of Oceanographic Data*, Section 2.2, Appendix A1: Wave Data. Prepared by

CEC: DG-XII, MAST and IOC: IODE. 436 pp. Available on-line at:
http://ioc.unesco.org/Oceanteacher/oceanteacher2/06_OcDtaMgtProc/01_DataOps/05_QualControl/02_TechAspects/IOC/mg26.pdf

Appendix A: **Suggested Metadata Terms**

Although not discussed at QARTODs or the Waves Technical Workshop, a natural progression in the standards process would be to address the metadata issues. In doing so, examples of the application to Marine XML as developed by the Australian Oceanographic Data Center (AODC) is used. Marine XML is also supported by the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) of UNESCO (see http://www.iode.org/marinexml/). The schema is documented at:
http://www.metoc.gov.au/products/prod/documentation/marine_xml_schema.html#QCDetailsof marineXML

An example using XBT data has been provided in Figure A-1.

The Suggested Metadata Field Names are adapted from the QC test names and would be used in the <*Test names* = /> fields. To indicate soft or hard flagging the indicators 1 or 2 are used respectively. Note that the name "RangeCheck" is used to apply to several different measurements and its application is understood from the associated measurement.

Table A-1: Suggested Metadata Field Names for QC

QARTOD Test #	Test Title	Suggested Metadata Field Name (<Test Name>)
3.1.1	Data Gaps	DataGapsCheck1
3.1.2	Spikes	SpikeCheck1
3.1.3	Range test, Soft	RangeCheck1
3.1.3	Range test, Hard	RangeCheck2
3.1.4	Mean shift (segments)	MeanShift2
3.1.5	Acceleration test	AccelerationCheck1
3.1.6	Mean test	MeanCheck1
3.1.7	Percent Points Good	PercentPointsGoodCheck2
3.2.1	Operational Frequency Range, Soft	RangeCheck1
3.2.1	Operational Frequency Range, Hard	RangeCheck2
3.2.2	Incident low frequency energy & direction	LimitedFetchDirectionCheck1
3.2.3	Check ratio	RangeCheck1
3.3.1	Max/Min/acceptable Range Check, Soft	RangeCheck1
3.3.1	Max/Min/acceptable Range Check, Hard	RangeCheck2
3.3.2	Time continuity or Parameter Variability	RangeCheck2

APPENDIX C Example Marine XML File


```
<MarineDataSet caveat="Unclassified" name="Mk12XBT" description="Dataset contains temperature-depth profiles, along
      with bathymetry." creationDate="2002-21-22T17:24:15K">
   <Quality>Good</Quality>
   <Custodian>
     <Property name="Agency">Australian Oceanographic Data Centre</Property>
     <Property name="WebSite">http://www.metoc.gov.au/</Property>
   </Custodian>
   <QCDetails agency="AODC" operator="LT" date="2001-05-22T12:47:17K" status="Complete">
      <Tests>
         <Test name="DuplicateCheck1.0" field="SpatialReference and TemporalReference" />
         <Test name="RepeatObsCheck1.0" field="SpatialReference and TemporalReference" />
         <Test name="RangeCheck1.0" field="SpatialReference and TemporalReference" />
         <Test name="SpeedCheck1.0" field="SpatialReference and TemporalReference">
            <Result recordID="0" details="Average speed to observation 1 is 112 knots. This exceeds the upper speed
                limit of 30 knots." " />
         </Test>
         <Test name="LandCheck1.0" field="SpatialReference" />
      </Tests>
      <Flags>
         <FlagSet name="XBT-Mk12-AODC1.0 Flags"> 0=No Flag(Accept); 1=Hit Bottom(Reject); 2=Wire Break;
              3=Wire Stretch(Accept); 4=Wire Stretch(Reject); 5=Leakage(Accept); 6=Leakage(Reject);
              7=Spikes(Accept); 8=Spikes(Reject); 9=Constant Temperature Profile(Accept); 10=Constant
              Temperature Profile(Reject);11=Insulation Penetration(Accept); 12=Insulation
              Penetration(Reject);13=Temperature Offset(Reject);</FlagSet>
      </Flags>
      <Edits>
         <EditedValue recordID="0" date="2001-05-22T12:47:15K" editedBy="AODC.LT"
              object="SpatialReference.GeoPoint.Coordinates" field="Longitude" previousValue="115.281667"
              reason="Failed SpeedCheck1.0" />
      </Edits>
   </QCDetails>
   <MarineDataRecord ID="0" reject="false">
      <SpatialReference>
         <GeoPoint>
            <Coordinates datum="WGS84">
               <Latitude>-34.553333</Latitude>
               <Longitude>151.281667</Longitude>
            </Coordinates>
         </GeoPoint>
      </SpatialReference>
      <TemporalReference>
         <Instant>
            <Date year="2001" month="3" day="28" hour="5" minute="40" second="13" timeZone="Z" />
         </Instant>
      </TemporalReference>
      <Source isObservedData="true" sourceFileName="T0_00001.RDF" agency="RAN" projectID="01004AN">
         <Platform type="MARINE" name="HMAS ANZAC" identifier="VKNG" />
      </Source>
      <Data numberOfDataObjects="3">
         <DataObject index="0" name="XBT" type="Primary" numberOfParameterSets="1" reject="false">
            <ParameterSet index="0" numberOfParameters="3">
               <Sensor name="XBT" model="Mk12 T-10" />
               <Parameter index="0" name="Water Temperature" units="Degrees Celcius"/>
               <Parameter index="1" name="Water Depth" units="Metres" />
               <Parameter index="2" name="XBT-Mk12-AODC1.0 Flags" units="" />
               <ValueList numberOfValueSets="2">22.874,0.63,0 22.936,1.26,0</ValueList>
            </ParameterSet>
         </DataObject>
         <DataObject index="1" type="Primary" numberOfParameters="1" reject="false">
            <Parameter index="0" name="Sea Surface Temperature" units="Degrees Celcius">
               <Value>21.0</Value>
            </Parameter>
         </DataObject>
         <DataObject index="2" type="Ancillary" numberOfParameters="1" reject="false">
            <Parameter index="0" name="Bathymetry" units="Metres">
               <Value>100.0</Value>
            </Parameter>
         </DataObject>
      </Data>
   </MarineDataRecord>
</MarineDataSet>
```


Figure A-1: AODC QCDetails Example from p. 25 of Roani *et al*, 2002.

Reference:

Ronai, B., Sliogeris, P., De Plater, M., and Jankowska, K., (2002) 'Development and Use of Marine XML within the Australian Oceanographic Data Centre to Encapsulate Marine Data.' *Marine Data Exchange Systems Conference*, Helsinki, Finland. [Available on-line at http://www.iode.org/marinexml/files/AODC.pdf]