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A systematic approach to routine data quality assurance in marine monitoring activity

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Abstract - A systematic approach to effective quality assurance of marine monitoring data is presented and discussed briefly. This approach is currently in the preliminary phase of implementation at the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale in Trieste, Italy, for water-column measurements of pressure, temperature and salinity, the fundamental hydrological parameters. The approach is based on classical quality assurance principles, and advocates the development and running of a formal in-house quality assurance programme to ensure measurement quality. First, demonstrable control of all relevant reference measurement systems and in situ measuring equipment is assessed and continually assured, using suitable reference materials, control charts and validated operating protocols. Thereafter, the values of the tolerance limits established for the instrumentation used in the actual monitoring - which then represent the minimum uncertainties that can be expected for any measurements made with them - are employed to evaluate the "goodness" of the field data.

1. Introduction

The success of any monitoring activity essentially depends on whether or not the data collected ensure the fulfilment of the objectives stipulated. This means that at some point during the activity, a decision needs to be made as to what constitutes useful data and what does not. In other words, there is a need to assess the quality of the collected data in some way, so that unreliable elements can be identified and excluded (GESAMP, 1994).

Data qualification is fundamentally a process of categorizing data based on their relative uncertainty when compared to end-use requirements. Obviously, the inherent uncertainty

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associated with the data must be known beforehand. For any particular parameter, this uncertainty can be approximated by the total uncertainty characterizing the underlying measurement process. Hence, a reliable estimation of the latter could, in theory, provide a fairly objective basis for formulating dependable data quality assurance criteria for the specific parameter.

In the present article, a quality assurance scheme for marine monitoring data utilizing the above principle is described and briefly discussed. The scheme was developed (Nair et al., 2000), and is currently being employed, at the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) for the routine processing of water-column temperature, salinity/conductivity and pressure data gathered within the framework of coastal monitoring initiatives.

2. Method

Optimal performances of all reference and field measuring systems for temperature, salinity/conductivity and pressure are ensured continuously by means of an in-house laboratory quality assurance programme employing acknowledged certified reference material and validated standard operating procedures (WOCE, 1994; Turley, 1996); a list of the relevant instrumentation and reference material is provided in Table 1.

For each system measuring a specific parameter, tolerance limits are established and monitored regularly in the laboratory against standard reference material using control charts.

Table 1 - The laboratory instrumentation and reference material used in temperature (a), salinity/conductivity (b), and pressure (c) quality assessment/control.

a)

Test Instrumentation	Reference Material
Hart 1590 Precision Digital Thermometer with Metal-sheath SPRT (Rosemount 162CE / Hart 5699)	Standard Resistors (L&N 4030B / Guildline – 9330)
Hart 7312 TPW Maintenance Bath	Jarrett B13 / Hart 5901 TPW Cell
Hart 923 Gallium Cell Maintenance System	Hart 5943 Melting Point of Gallium Cell

b)

Test Instrumentation	Reference Material
Hart 7052 Seawater Calibration Bath	
Hart 1590 Precision Digital Thermometer With Metal-sheath SPRT (Rosemount 162CE / Hart 5699)	IAPSO Standard Seawater
Laboratory Salinometer (Guildline Autosal 8400B)	

c)

Test Instrumentation	Reference Material
Primary Pressure Standard (Pressure Balance D&H 5400E)	Certified Weights

The same limits, modulated to take into account eventual field sampling errors, are subsequently used as the core quality check for field data relating to the parameter.

Other supplementary checks for data quality include a number of standard visual and automatic measures for the identification and mitigation of inconsistencies of form such as irregular reporting formats, errors introduced during data transcription/transfer, inappropriate ordering of data, incompleteness of observations, etc. Details regarding such procedures and examples of their application are openly available (for eg. CEC/DG XII, MAST and IOC/IODE, 1993; Boyer and Levitus, 1994), and will not be discussed in this article.

In the data quality assurance procedure just outlined, it is evident that while the context and parameter of interest may vary, the underlying methodology always remains the same.

3. Results

The kind of results that can be obtained with a quality assurance procedure such as the one described above is best illustrated by means of a practical example. The example concerns water temperature data acquired by a profiling CTD probe – henceforth denoted as Probe #2 – currently operating from the MAMBO coastal data buoy in the northern Adriatic Sea (eastern Mediterranean).

The Probe #2 temperature sensor was initially calibrated over its declared operating range in the oceanographic calibration laboratory (CTO) of the OGS using a thermostatic bath and a

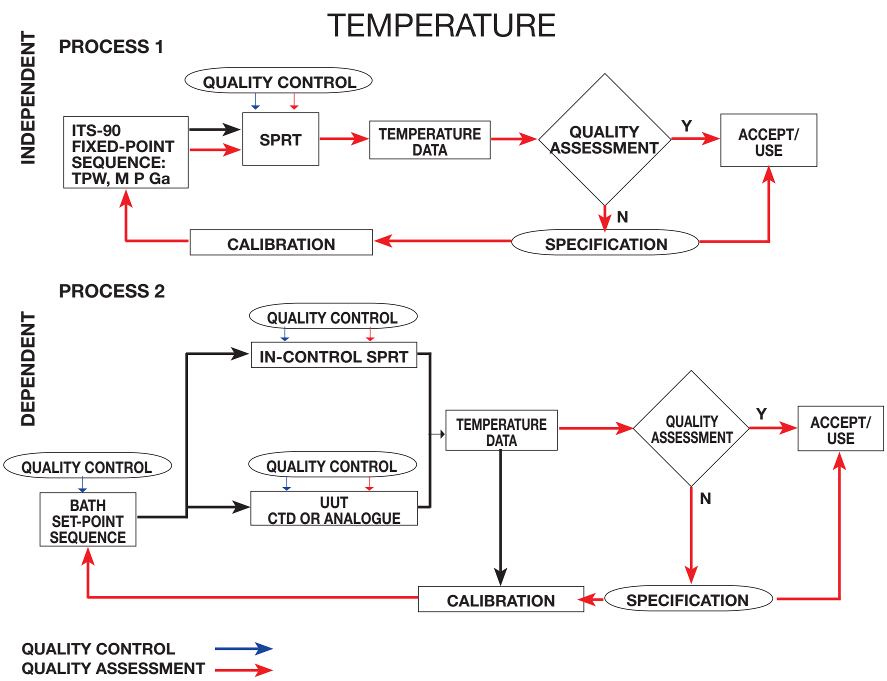

Fig. 1 - The laboratory quality assessment and control procedure for temperature; the Unit Under Test (UUT) can be the temperature sensor of a CTD probe or any similar temperature measuring device.

Standard Platinum Resistance Thermometer (SPRT). The SPRT, which serves as the laboratory temperature transfer standard, is calibrated and regularly controlled against two certified primary temperature standards: a triple point of water cell and a gallium melt cell. The method employed (Fig. 1) is the same one that is used to calibrate and continually control the temperature sensor of the CTD unit elected to function as the "field" reference probe (hereafter designated as Probe #1) for post-deployment evaluations of the Probe #2 temperature sensor.

Examples of the control charts used for assessing the performances of the respective sensors in the laboratory are shown in Fig. 2; for both sensors, control is assumed if scores respect the indicated ±3 control limits, equivalent to tolerance limits of ±0.003 °C. These limits are based on the established precision of the reference SPRT (±0.001 °C).

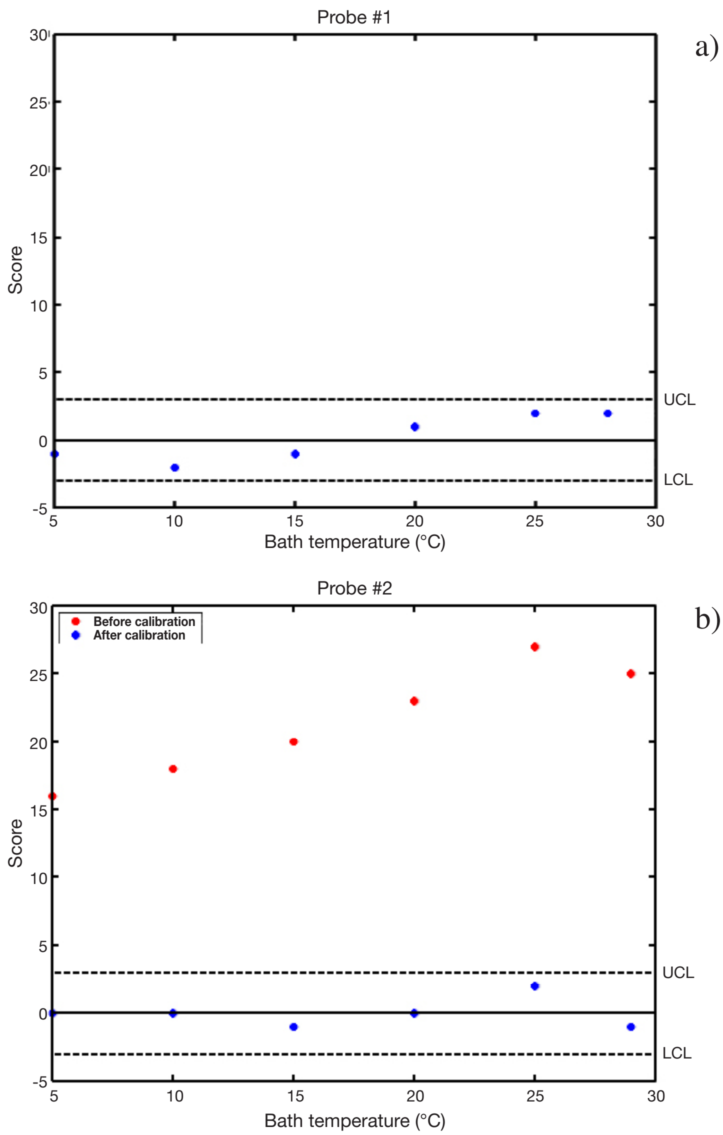

Fig. 2 - Examples of laboratory temperature control charts for Probe #1 (a) and Probe #2 (b); UCL (the Upper Control Limit) and LCL (the Lower Control Limit) indicate the bounds of the established tolerance interval.

When Probe #2 began to operate from the buoy, the performance of its temperature sensor was assessed and controlled in the following way. The mooring site was visited at regular intervals. On each occasion, two temperature profiles were acquired contemporaneously, one with Probe #1 and the other with Probe #2 (if necessary, the procedure was repeated more than once).

The data obtained were used to generate a control chart such as the one shown in Fig. 3. Note that, in this case, tolerance limits of ±0.01 °C are indicated; the larger interval allows for inconsistencies in the data attributable to the sampling operation. In Fig. 3, it can be seen that the deviations of the buoy temperature measurements with respect to the temperature measurements obtained from the hydrological cast are sufficiently well-behaved in relation to the established tolerance limits. Seeing that the last field assessment had produced similar results, the data furnished by the Probe #2 temperature sensor in the intervening period could be assigned an uncertainty of ±0.01 °C with reasonable confidence.

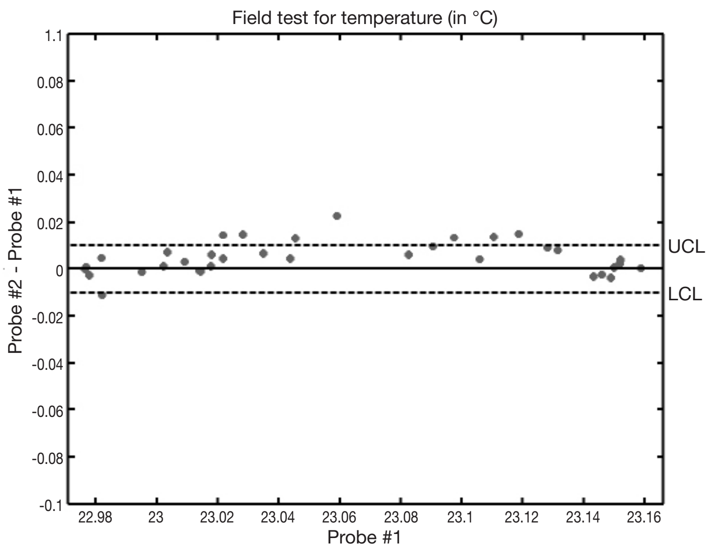

Fig. 3 - An example of the type of control chart used for the quality assessment and control of field instrumentation; UCL (the Upper Control Limit) and LCL (the Lower Control Limit) indicate the bounds of the established tolerance interval (see text for details).

4. Discussion

The data quality assurance scheme presented here offers advantages in every phase of monitoring activity. In the planning phase, it furnishes a priori knowledge of the maximum attainable quality for specific parameters, allowing the formulation of realistic measurement goals. During the operational phase, it facilitates better harmonization of data and aids in verifying that the declared performance standards are being met. In the wind-up phase, it provides records and documentation which help to ensure the traceability of data.

However, the main appeal of the procedure is that it offers flexible and experimentally verifiable quality criteria, unlike similar criteria based on the analysis of historical or climatological data sets. The latter are strongly influenced by the characteristics of the underlying data distributions and, for this reason, impracticable while monitoring systems such as the coastal zone where the observed variability in properties is pronounced.

For instance, in the example recounted earlier, tolerance limits of ±0.01 °C were set for assessing the uncertainty characterizing the buoy temperature data (Fig. 3). Compare these limits with the ±3σ limits that were obtained from the analysis of a historical temperature data set relating to the area of the buoy mooring extracted from the MEDAR/MEDATLAS data base (MEDAR Group, 2002), as shown in Fig. 4.

The latter limits of ±3.5 °C are clearly too large to be really effective as a quality check for poor or spurious data. This is particularly true if the data are to be used subsequently as a baseline for environmental assessments or to evaluate trends.

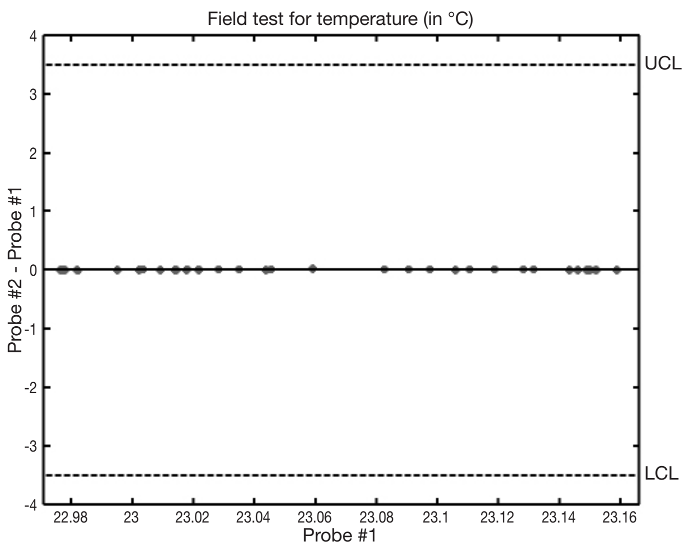

Fig. 4 - Same as Fig. 3, except that UCL (the Upper Control Limit) and LCL (the Lower Control Limit) are established on the basis of an analysis of relevant historical temperature data (see text for details).

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