

Title: Metrology for oceanic salinity and acidification

Abstract

As a result of increasing anthropogenic CO₂ emissions and absorption of CO₂ by the oceans there has already been a noticeable increase in the average oceanic acidity from pre-industrial levels. This global threat requires a global response. Another, closely related quantity is salinity (mass fraction of dissolved material in seawater). To date, salinity is derived from conductivity results using the non SI based scale PSS-78, which is not sufficient to guarantee long-term stability and international comparability. Metrological, traceable references for pH and salinity are needed in order to increase the understating of impacts of the ocean acidification and salinity, and to underpin long-term strategies and political decisions.

Conformity with the Work Programme

The proposed topic is directly related to the Grand Challenge "Environment" as documented in the *EMRP Outline 2008* (I.1.1, page 8), addressing new stable and comparable measurement standards for environmental changes and the environmental performance of new technologies.

Keywords

Oceanic parameters, ocean acidification, seawater, salinity, pH, CO₂ sequestration, global carbon cycle, ocean temperature monitoring

Background to the Metrological Challenges

The ocean acts as the main regulator of the global climate system and as a sink for anthropogenic carbon dioxide. The dynamics of these systems are strongly dependent on the properties of seawater. Absolute salinity of seawater is a key variable for monitoring and modeling ocean circulation. To understand the impact of anthropogenic carbon dioxide on the ocean and to quantify the acidification process in more detail, metrological references for pH and salinity are needed.

In 2010 the Intergovernmental Oceanographic Commission (IOC) endorsed the new Thermodynamic Equation of Seawater – 2010 (TEOS-10) from which accurate algorithms for calculating density and many other thermodynamic properties (e.g. heat capacity) of seawater are available. Part of the new thermodynamic treatment of seawater involves adopting absolute salinity. Absolute salinity is an SI consistent quantity, defined as the mass of dissolved material in a given mass of seawater. From a practical point of view, frequent routine mass fraction measurements of all relevant seawater constituents are impossible to achieve. Hence, in practice, absolute salinity is estimated from practical salinity, given on the Practical Salinity Scale that was endorsed by UNESCO in 1978. Practical salinity is calculated from conductivity measurements, which can easily be performed even under rough oceanic conditions. The measurement results are related to the conductivity of a defined potassium chloride (KCl) solution, but they are not related to the SI. This gives two major problems:

- First, it is not possible to prepare replicates of the potassium chloride solution by weighing unless the same source material is available. Only in that case can reproducibilities of the order of 0.0004 (PSS-78) be achieved. The reproducibility of a KCl solution, and hence the traceability of salinity, is therefore not achievable over the timescale necessary for climate monitoring.
- Second, the SI definition of absolute salinity makes it necessary to link its determination to the kilogramme. So, there is a strong need to link practical salinity, and therefore absolute salinity, to stable SI measurement standards.



SI traceable measurements of the conductivity and density of Baltic Sea samples indicate that the density of seawater can be measured under laboratory conditions with a significantly smaller relative uncertainty (3×10^{-6}) than conductivity (which can be measured traceable to the SI with a relative uncertainty of 3×10^{-4}). Both quantities are sensitive to variations in absolute salinity. Since in practice practical salinity will remain the measurement quantity of choice, those findings suggest that practical salinity measurement instruments could be calibrated via density rather than conductivity measurement standards. This approach would also align with the TEOS-10 formalism. Other measurement quantities like speed of sound and the refractive index are also sensitive to variations in absolute salinity but their applicability as estimates for absolute salinity with respect to SI traceability and the corresponding uncertainty have not been investigated yet.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them, in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP protocol.

The JRP shall aim at the development of methods, standards and tools to establish traceability of oceanic salinity and acidification to underpin climate models. This shall include

1. the development and characterisation of in-situ sensors and methods taking pressure and temperature dependencies into account
2. the development and characterisation of reference sea water.

Appropriate technological approaches shall be explored to reach an uncertainty of better than 10^{-4} for absolute salinity measurements in situ. Special emphasis shall be given to implementation in the framework of GCOS.

Proposers shall give priority to work that meets documented stakeholder needs and may include measures to facilitate the development of European standards and Directives.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

In your JRP submission please detail the impact that your proposed JRP will have on Marine Strategy Framework Directive 2008/56/EC.

You should also detail other Impacts of your proposed JRP as detailed in the document “Guidance for writing a JRP”

You should detail how your JRP results are going to:

- feed into the development of standards through appropriate standards bodies
- transfer knowledge to the marine and climate monitoring community.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards

- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

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3. J. C. Orr, et Al. *Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms*, Nature, 2005, 437, 681.
4. J. T. Wootton, C. A. Pfister, J. D. Forester, *Dynamic patterns and ecological impacts of declining ocean pH in a high-resolution multi-year dataset*, PNAS, 2008, 105, 18848.
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8. Sparasci F., Pitre L., Hermier Y., *Realization of the Triple Point of Water in Metallic Sealed Cells at the LNE-INM/CNAM: a Progress Report*, International Journal of Thermophysics, vol. 29 (3), pp. 825 – 835, 2008, Springer Netherlands