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An introduction to Calibration & Measurement

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The context

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- In order to understand and manage the complexity of the Marine System, we are needing to rely more and more on **pooled, multivariate, data**.

- These data come **from many sources**, and are acquired employing an ever-increasing variety of measurement technologies **on different spatial and temporal scales**;

- Increasingly, data are coming **from continuously operating, multiparametric, real-time, networked, observing systems** covering wide areas over long time scales.

The context

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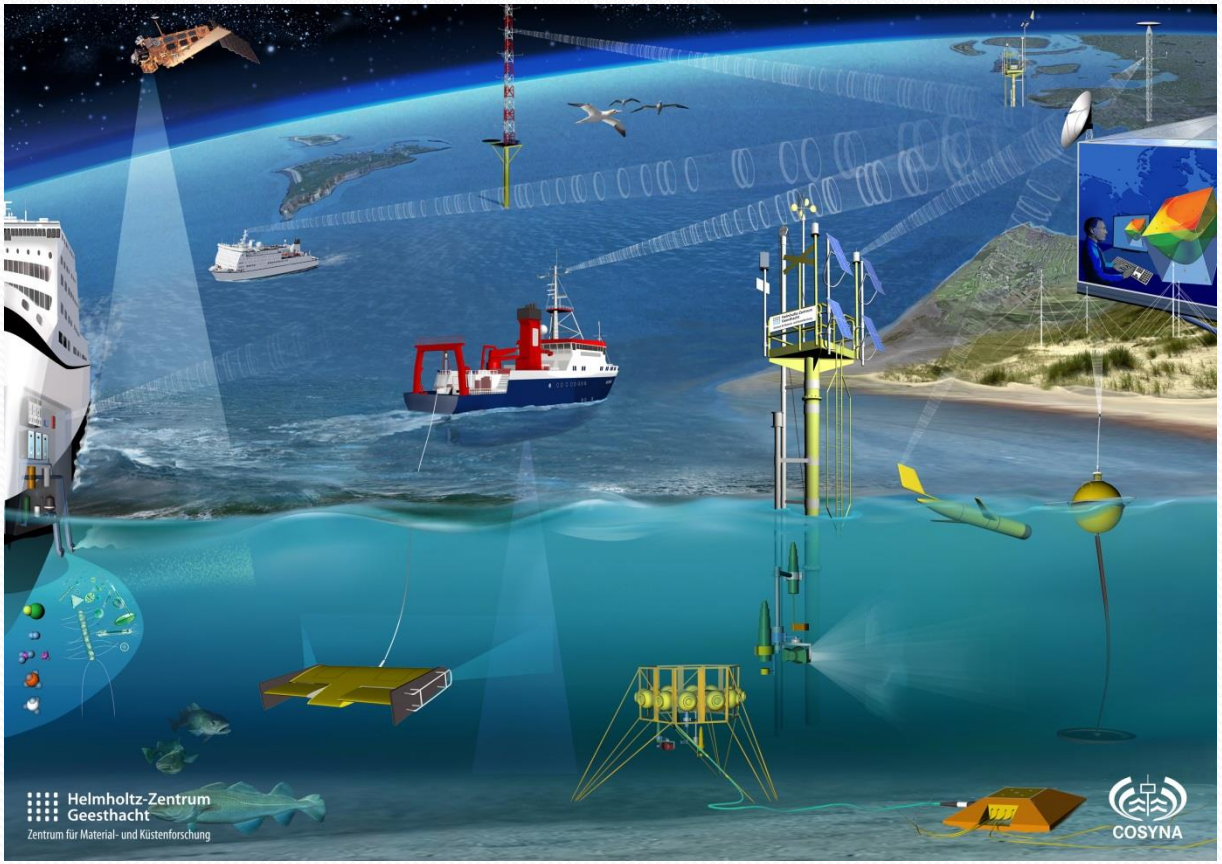

Networked observatories - distributed sensor systems with extensive spatial coverage implementing multiple, variegated, often opportunistic, platforms - are being used more and more to constantly monitor large areas of Europe's marine environment because of their ability to ensure timely, continuous and sustainable delivery of high-quality environmental data and information products for research, industry, and ecosystem health and resource management purposes.

Operationally, however, they are characterized by a striking diversity in the kinds of parameters handled, the frequency and geographical coverage of measurements, equipment maintenance practices, and the quality standards employed for sensors and data exchange.

The context

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Ultimately, all our knowledge, and the effectiveness of any decisions or actions we take regarding the Marine System are going to be determined by the uncertainties and limitations characterizing the MEASUREMENTS that produce the data we use.

Capturing the environmental signal

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Your finger contains receptors (nerve endings) located in and just under the skin that respond to specific stimuli (heat, cold, pain, pressure, etc.).

The receptors provide your body with information concerning its surroundings.

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The sensor in operational Oceanography: an analogy.

Capturing the environmental signal

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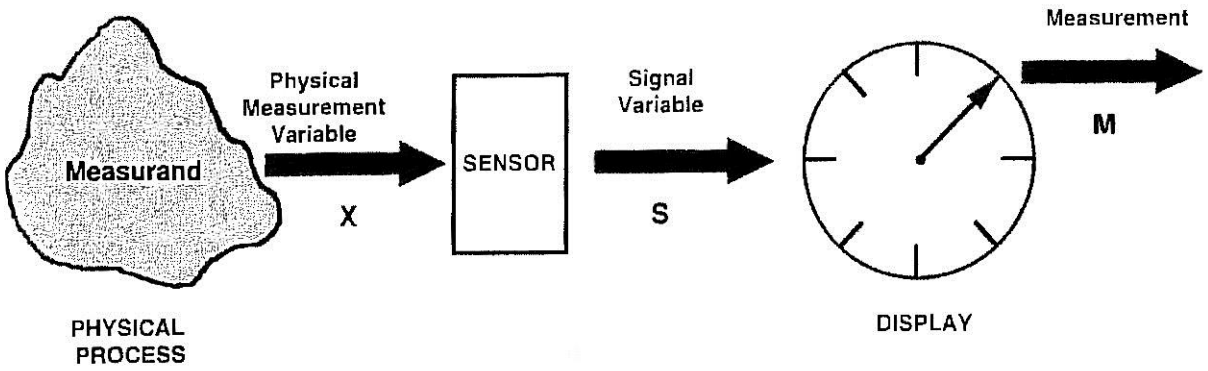
The generalized Simple Instrument Model



Key functional element: the (usually analog) sensor

This element converts the physical variable input into a signal variable output.

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The signal variable output

In the case of most marine sensors, the output signal is one of the following:

- **a voltage;**
- **a current;**
- **a frequency.**

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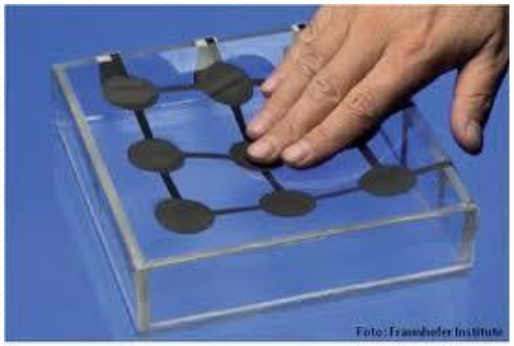
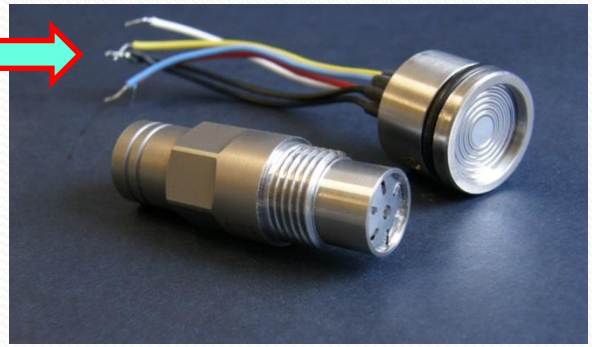
Examples of marine sensors: Physics

Pressure





The strain gauge pressure sensor

Strain gauge pressure sensors generally use a diaphragm or foil with built-in strain gauges as the main sensing element. External pressure causes the deformation (elongation or compression) of the diaphragm, which is converted into a change in resistance.

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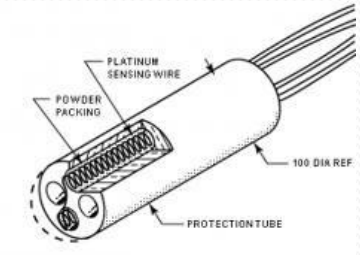
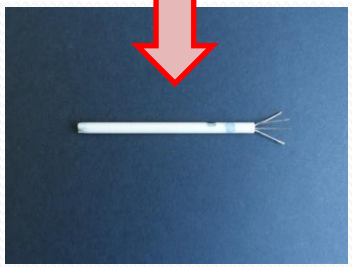
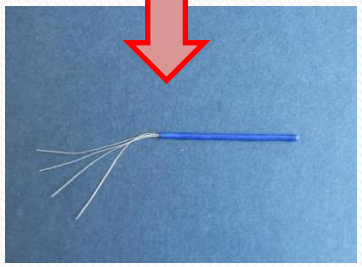
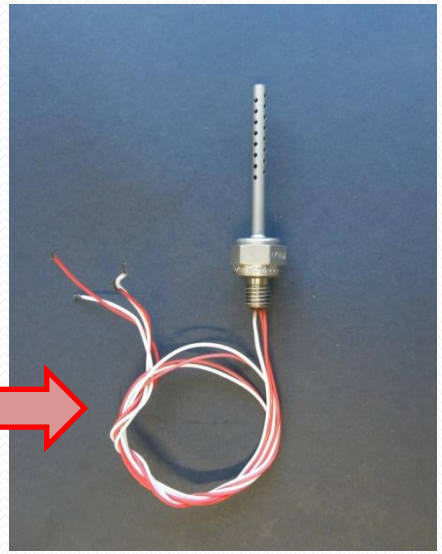
Examples of marine sensors: Physics

Temperature









The Platinum Resistance Thermometer

The Platinum Resistance Thermometer (PRT) uses the electrical resistance of platinum wire to measure temperature.

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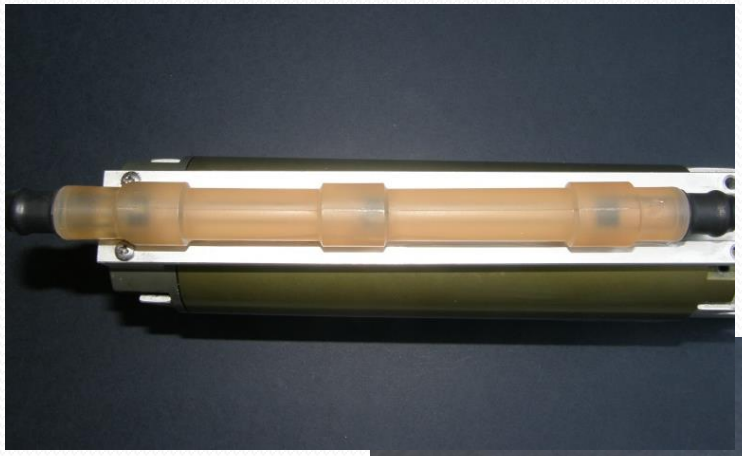
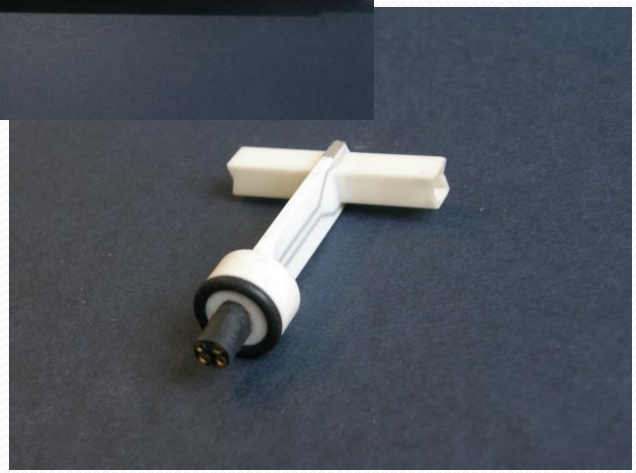
Examples of marine sensors: Physics

Conductivity





The «electrode cell» type conductivity sensor

This type of sensor uses electrodes to measure the conductivity of the seawater in the measuring cell.

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Examples of marine sensors: Chemistry

Dissolved oxygen (DO)

«Beckman» type polarographic oxygen sensor

«Clark» type polarographic oxygen sensor

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Examples of marine sensors: Chemistry

pH

pH sensor with glass electrode

Spectrophotometric pH sensor (reagent-based colorimetry)

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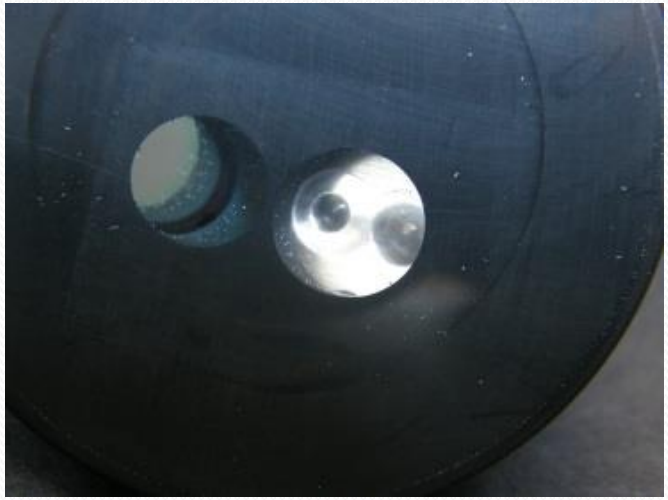
Examples of marine sensors: Biology

Sensors for multiple simultaneous measurements of Turbidity & Fluorescence



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So, you've got the sensor and its output,

SO WHAT?

Is the output a measurement?

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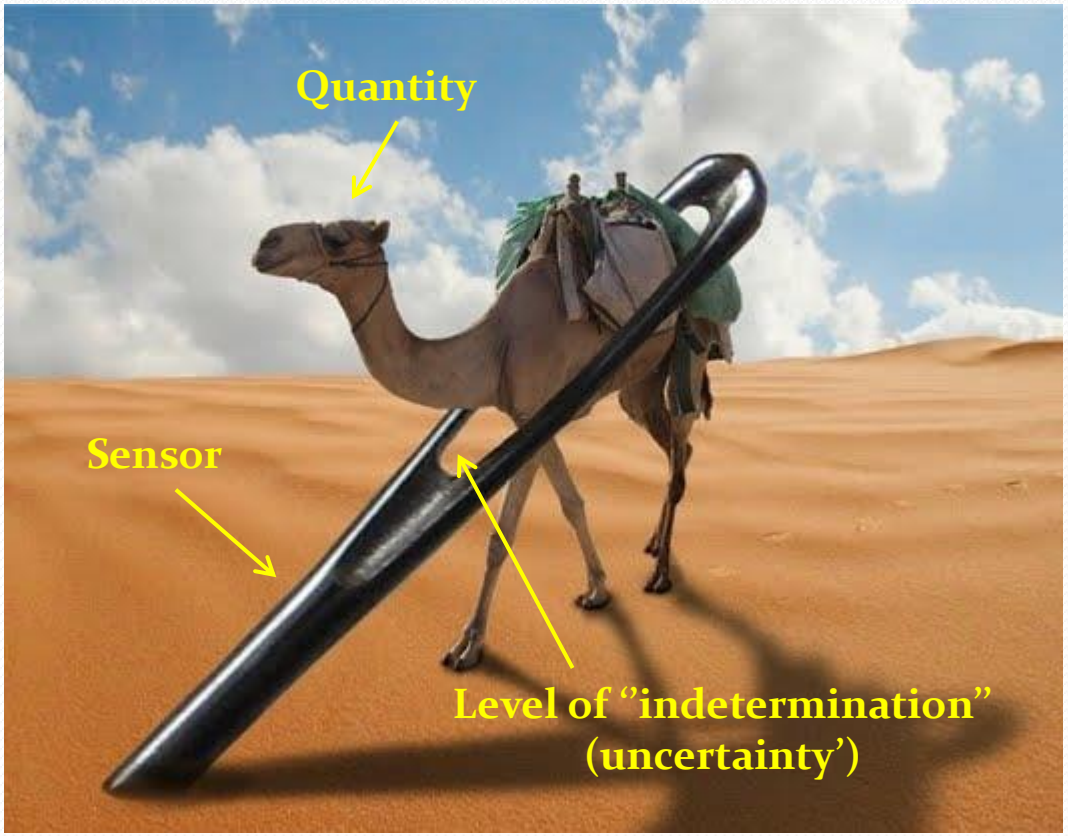
Measurement: giving meaning to the output



MEASUREMENT

The challenge?
The needles are getting better and better, but how much of the camels are we really seeing?

Measurement

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How?

Calibration

(From output to measurement to data)

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Calibration

From the metrological definition:

an operation which establishes a relation between quantity values with measurement uncertainties provided by measurement standards and some equivalent indications with associated measurement uncertainties obtained by other means - an instrument, for example - that, in a second step, can be used obtain a measurement result from the latter (JCGM, 2012).

Calibration

Meaning:

associating the output from a sensor with a reference system (preferably based on the SI) constituted by known values on a recognized scale for the measurand (quantity of interest).

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Calibration

Requirements

- **Reference material (certified, recognized or accepted);**
- **An estimation of the calibration uncertainty;**
- **Traceability of the calibration (to the SI);**
- **Specialized equipment and procedures, dedicated staff with expertise and most of all experience (if you lack these resources in-house, don't improvise!**

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Calibration

Objectives

- **Establish veracity (trueness);**
- **Ascertain its limits (uncertainty);**
- **Ensure traceability;**
- **Assure comparability of results.**

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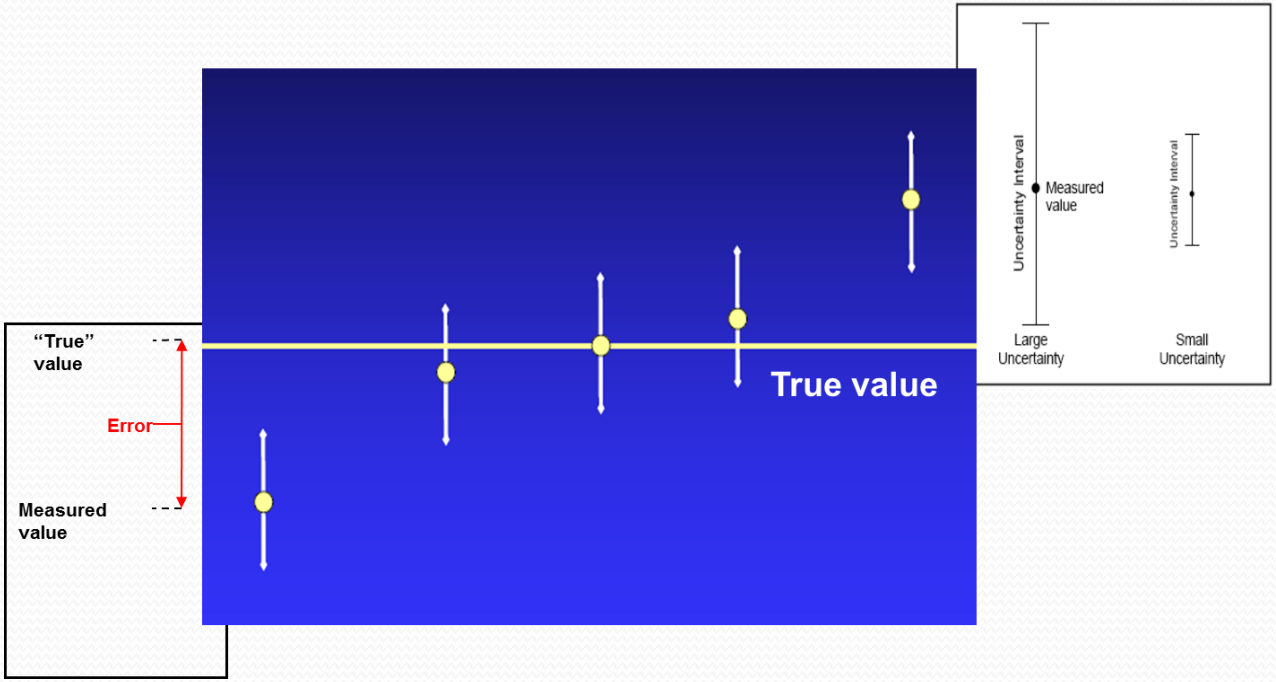
Calibration

Error, accuracy, precision, uncertainty…



Calibration: an example

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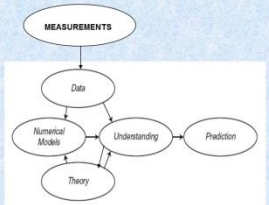
This is why we make measurements!

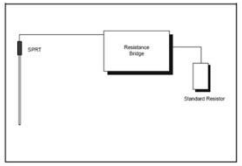


Anchoring theory to reality

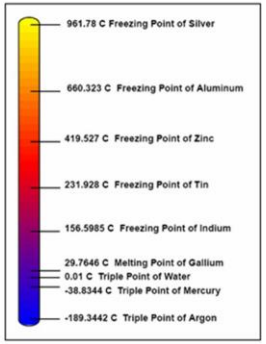
The Reference System for Temperature

Constituted by a high-precision Digital Thermometer (Resistance Bridge), a Standard Platinum Resistance Thermometer (SPRT) and a Standard Resistor.

Resistance Bridge



The principal fixed points of the International Temperature Scale of 1990 (ITS-90) used in Oceanography



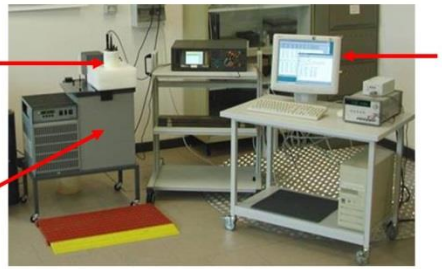
Triple Point of Water (TPW) = 0.01°C

Melting Point of Gallium (MPGa) = 29.7646°C

Overview of a temperature calibration

A temperature calibration is performed by comparing the temperature readings of the instrument being tested with those of a Reference System in a thermostatic bath.

Unit under test



Contemporary acquistion of temperature data from the unit under test and the Reference System

Thermostatic bath

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Uncertainty

Temperature (ITS-90)				
Uncertainty sources	**Manufacturer's specification**	**Assumed probability distribution**	**Observed**	**Standard Uncertainty**
Temperature bath stability	0.002 °C	Triangular	---	0.0008 °C
Temperature bath uniformity	0.002 °C	Triangular	---	0.0008 °C
SPRT stability (at the Triple Point of Water)	---	---	0.0005 °C/year (2003 - 2010)	0.0005 °C
Precision Digital Thermometer accuracy	0.0015 °C	Rectangular	---	0.0009 °C
Combined standard uncertainty				0.0015 °C
Expanded Uncertainty (k = 2)				0.0030 °C

A simple uncertainty budget for reference calibration bath temperature measurements obtained with a Standard Platinum Reference Thermometer (SPRT).

Food for thought

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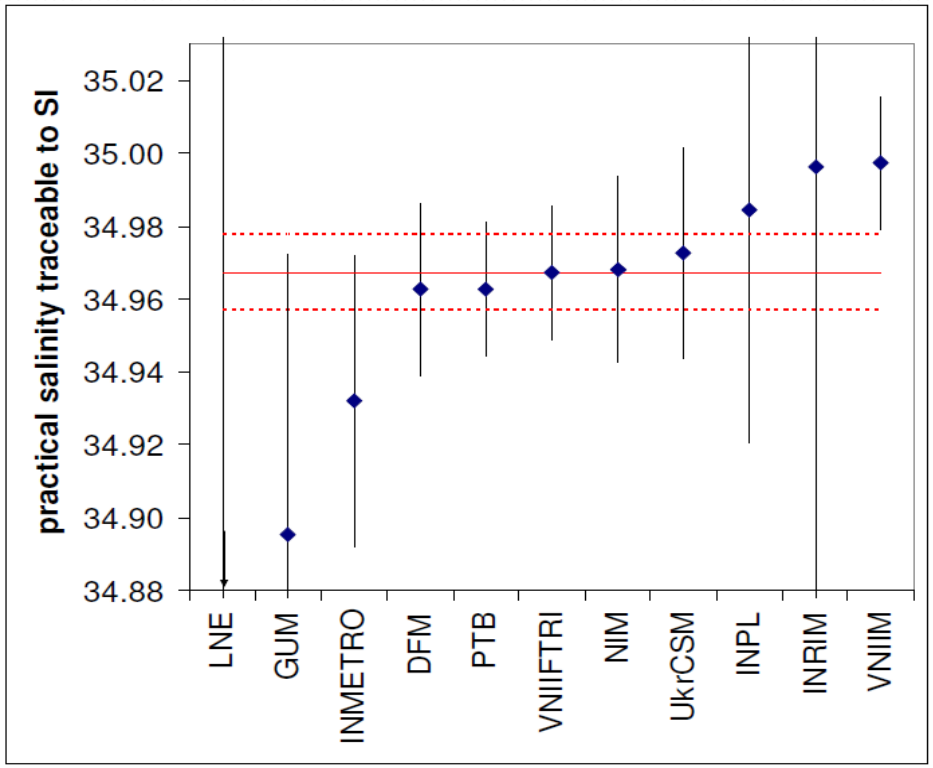
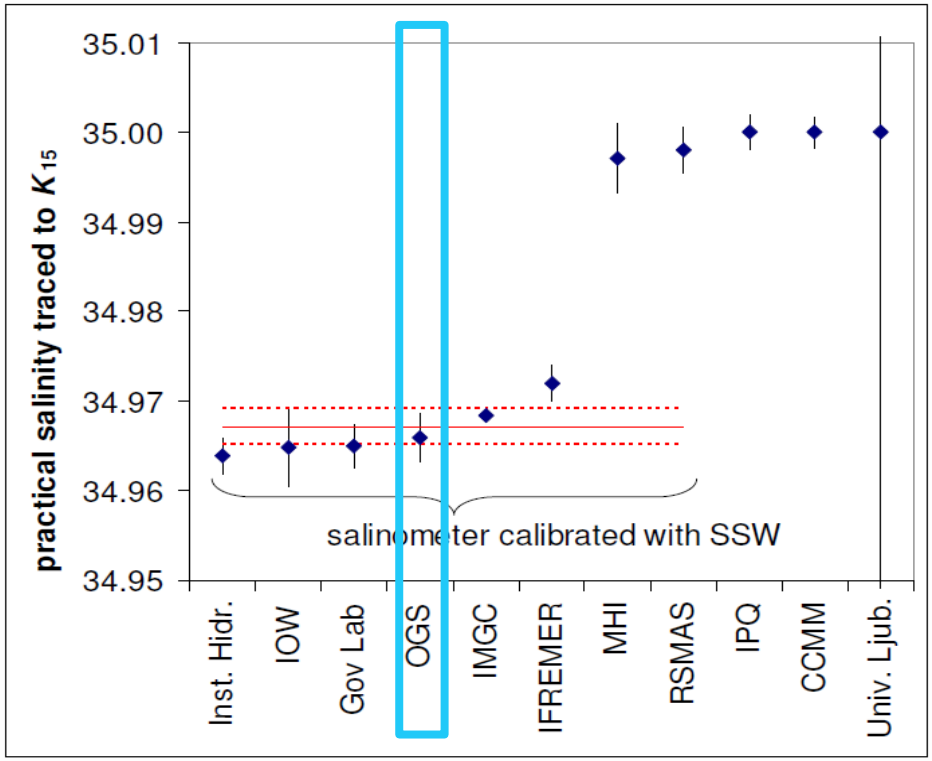


National Metrological Institutes



Marine Research Institutes

Traceable determination of practical salinity and mass fraction of major seawater components

BIPM-CCQM study (P111) in cooperation with

SCOR/IAPSO WG 127 on Thermodynamics and Equation of State of Seawater

Food for thought

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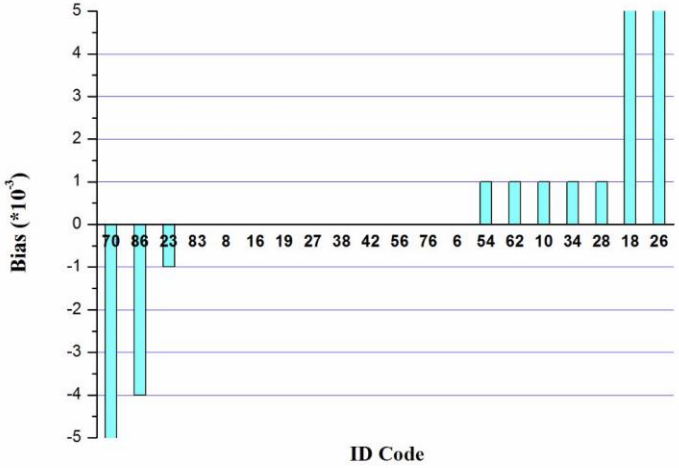
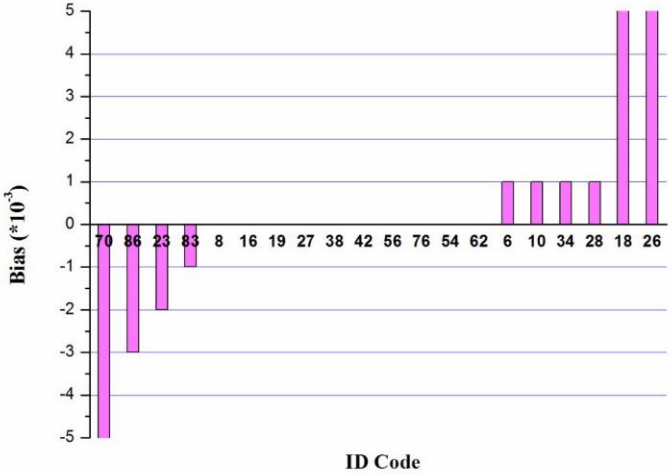
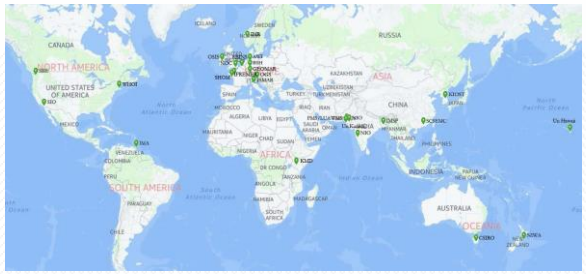




S = 32.530



S = 24.698

Locations of participating laboratories

Final Report, JCOMM Pilot Intercomparison Project For Seawater Salinity Measurements

JCOMM Technical Report No. 84 (WMO, 2015)

Food for thought

What we'd like to receive…

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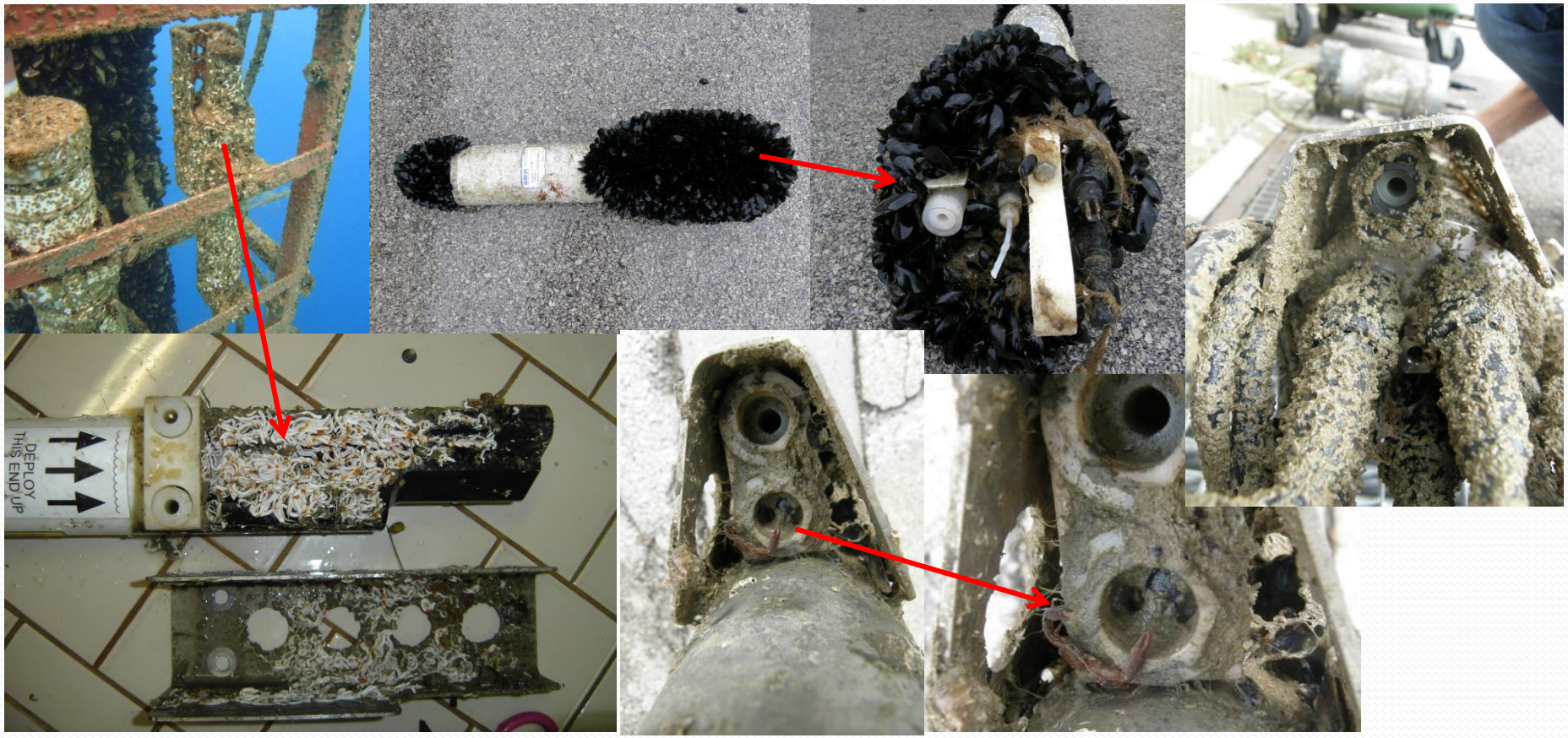
Food for thought

What we get…



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Food for thought

What we get…

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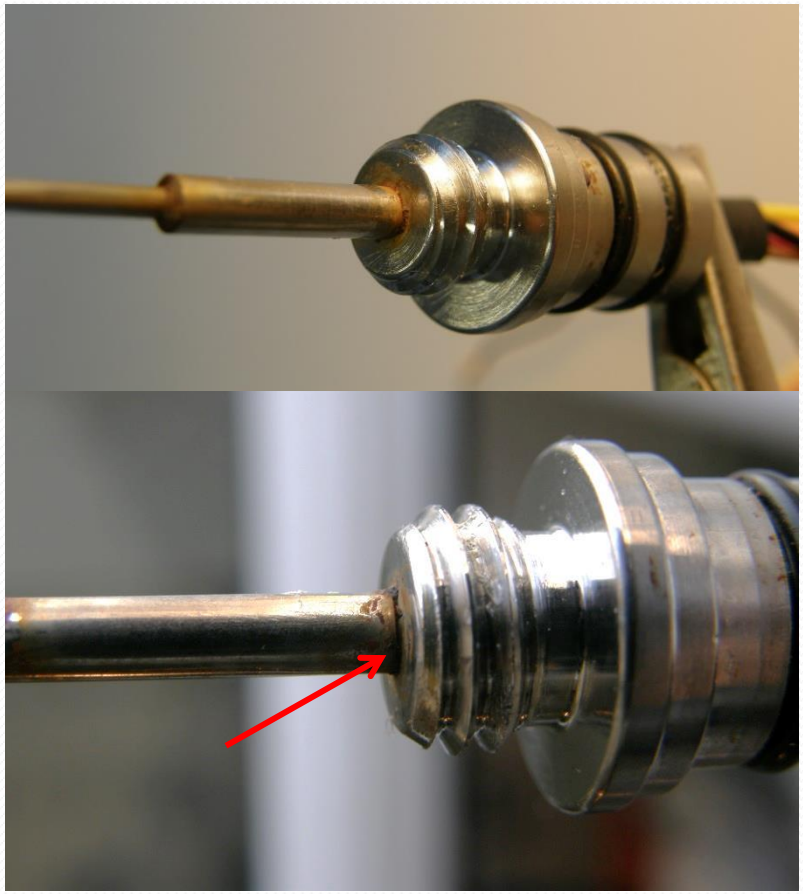
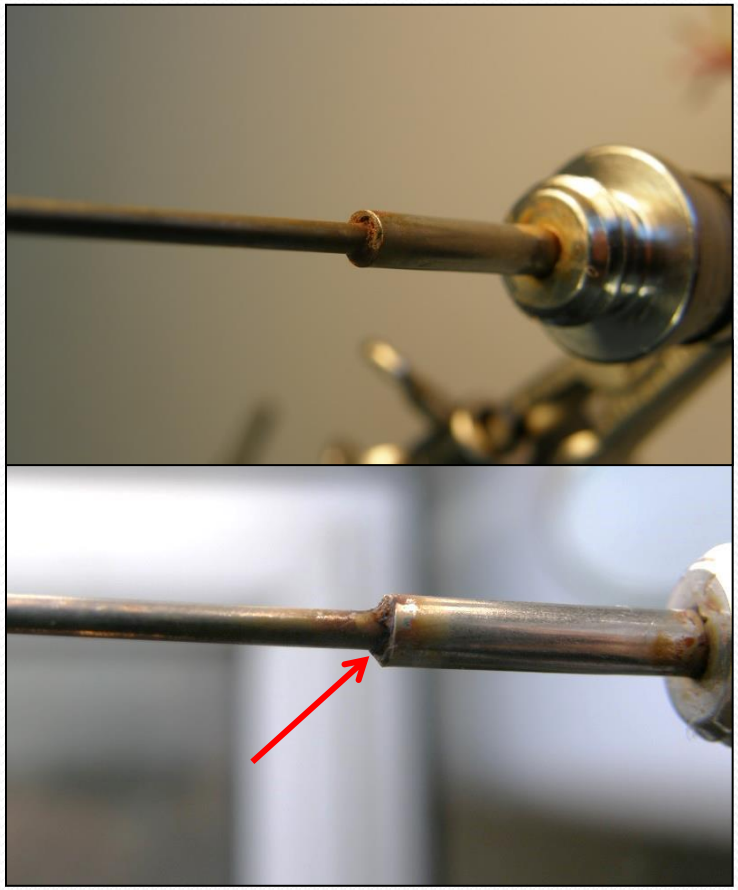
Food for thought

What we get…





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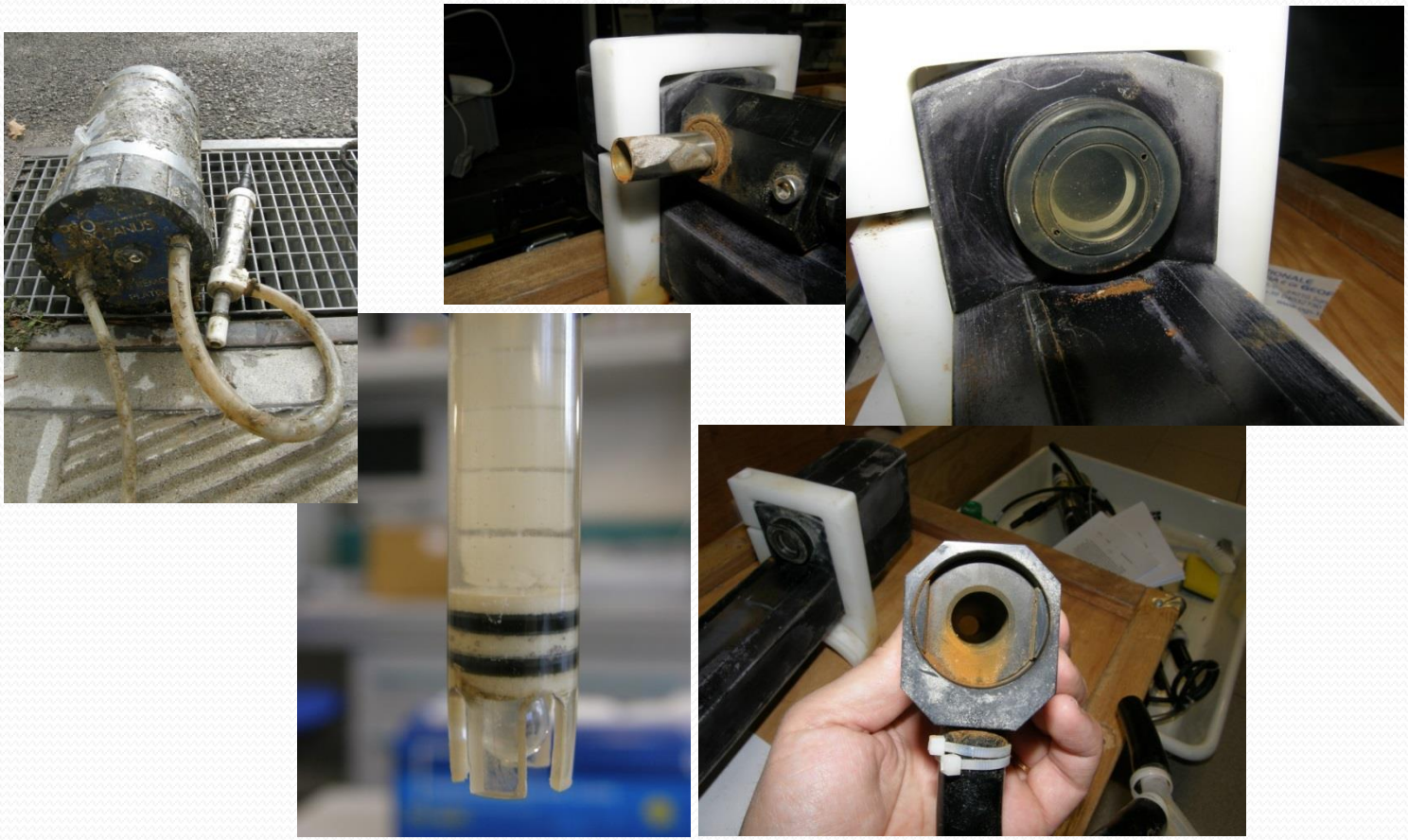
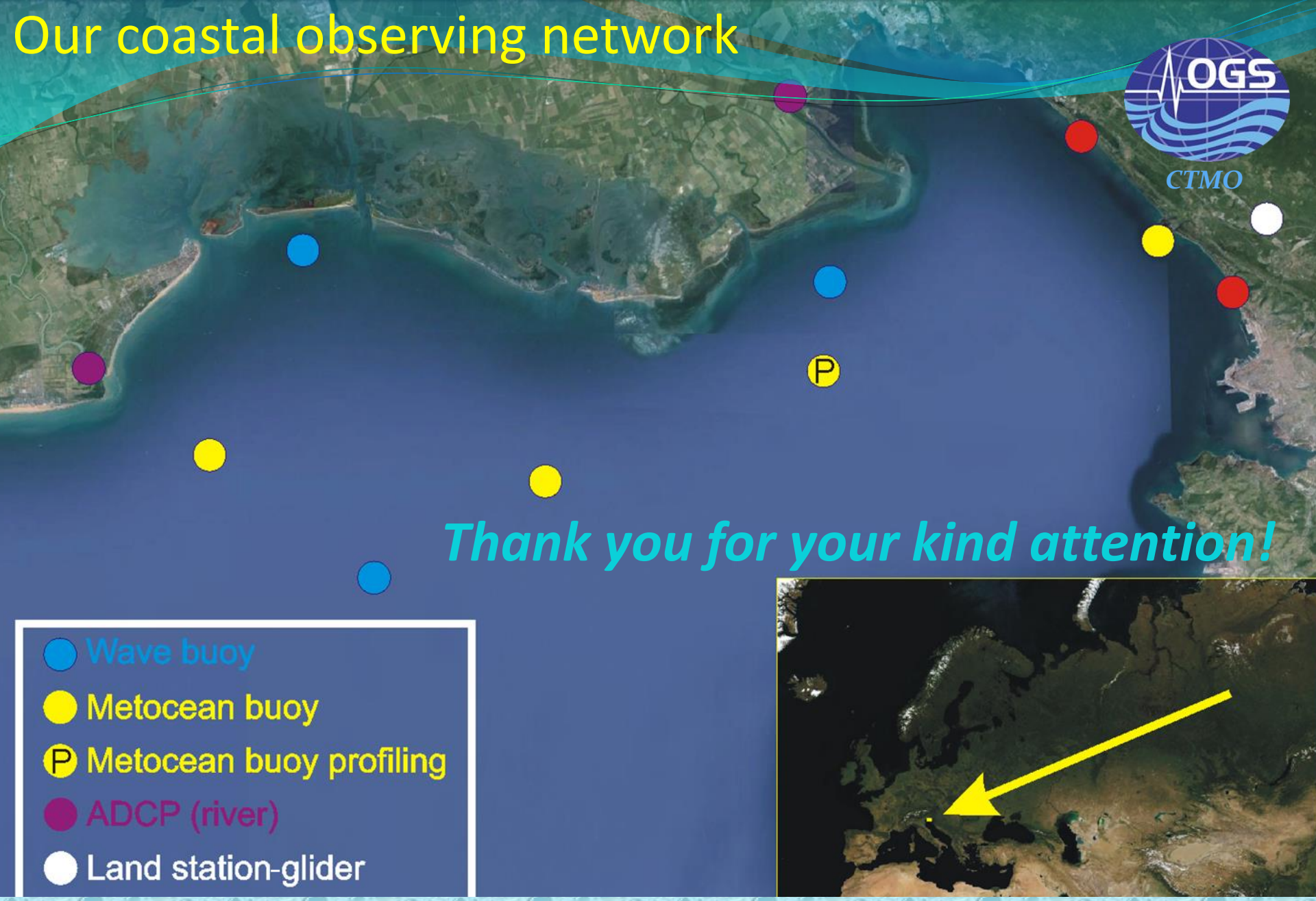
Food for thought

What we get…



Our coastal observing network



Thank you for your kind attention!