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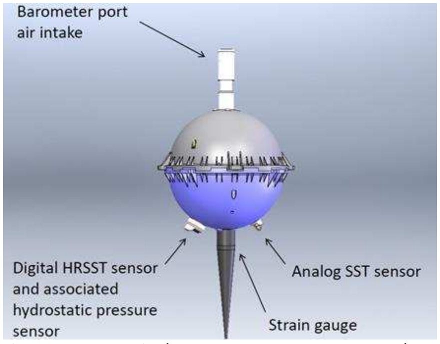
On the role of metrology in oceanography: the example of TRUSTED project

Introduction

Sea Surface Temperatures (SSTs) obtained from satellite-borne instruments, are wildly used in climate and meteorological applications, for the global coverage of ocean they provide. Most of these instruments are well-calibrated and they provide consistent and sufficiently accurate observations, but it is necessary to validate their measurements.
To fill that gap, it was missing a fiducial reference infrastructure.
The Copernicus funded TRUSTED project was initiated by EUMETSAT. Led by CLS, it aims to deploy an independent network of over 100 Data Buoy Cooperation Panel (DBCP) compliant Surface drifter buoys able to make temperature measurements with an uncertainty lower that the uncertainty reached by the Copernicus Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR).
That was not possible without the metrological characterization of the High Resolution SST (HRSST) sensor of the buoys and without insuring the metrological traceability to the SI (International System of Unit) of its measurements. That is where metrology intervene in oceanography.

Buoys conception

The buoy is called SVP (Surface Velocity Program) with Barometer and Reference Sensor for Temperature (SVP-BRST). The baseline SVP-B design is from Sybrandy et al. (2009). It is a spherical drifter of 40 cm diameter made of high pressure molded polypropylene. A 12.5 m line (including an elastic section) is attached below the buoy and linked to a stainless bracket. A holey socks drogue centered at 15 m depth is suspended to the line. It is 0.8 m in diameter and 6 m length. The drogue loss is detected by a strain gauge, instead of a submergence sensor.



Key characteristics:
- Multi-GNSS receiver is included;
- Strain gauge reading and GPS TTFF transmitted as indicators of drogue loss.
- Transmission: 30-bytes iridium SBD message/h.
- HRSST sensor resolution: 1mK. Included in the MoSens device.

- Air pressure : Vaisala PTB 110 BAROCAP (± 0.6 hPa from 0 to 40 °C) traceable to NIST.

- Hydrostatic pressure: measured by MoSens module to 0.05 %, range 0 – 30 dbar.

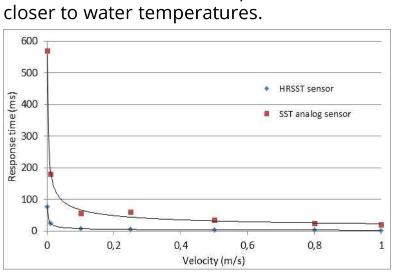
The MoSens device can be calibrated alone before integration in the buoy.

MoSens device with HRSST sensor

The metrology work

The first work was to demonstrate the advantage of using a smaller and lighter temperature sensor. Traditional SST sensors are represented on the opposite photo.

The comparison shows that the effect of heating by radiation is divided by 3.4 to the advantage of HRSST sensor. As demonstrated by De Podesta *et al*. (2018), this effect is proportional to the ratio (*D/V*) where *D* is the diameter of the sensor and *V* the flow speed. The HRSST sensor measures temperatures closer to water temperatures.



The comparison shows also that the theoretical response time τ of the HRSST sensor is divided by 7.4 per comparison to the SST sensor, τ being proportional to the ratio (*m/A*), *m* is the mass of the sensor and *A* its surface of exchange.

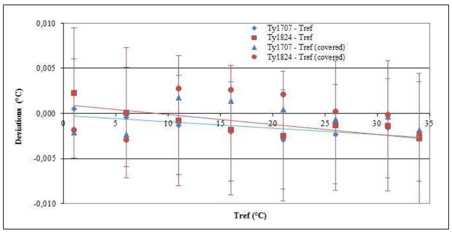
Sybrandy, A. L., Niiler, P.P., Martin, C., Scuba, W., Charpentier, E., Meldrum, D.T.: Global Drifter Programme Barometer Drifter Design Reference, DBCP Rep. 4, rev. 2.2, 2009.
De Podesta, M., S. Bell, R. Underwood, 2018: Air temperature sensors: dependence of radiative errors on sensor diameter in precision metrology and meteorology. Metrologia 55, 229-244.

However, the main contribution of the metrology in the TRUSTED project is in the calibration and the linkage or traceability to the SI of the temperature measurements made by the buoys. A calibration uncertainty budget has been established for two MoSens prototypes.

Uncertainty budget of MoSens calibration	n° 4656 (mK)	n° 4658 (mK)
Reference temperature (u_{tref})	0.9	0.9
Bath stability (u_{Bath})	0.3	0.3
MoSens reproducibility (S)	1.7	0.9
MoSens repeatability (S_{rep})	0.3	0.3
Expanded uncertainty (U_C)	4.0	2.8

Once calibrated, the two MoSens sensors have been integrated in buoys and these buoys have been placed in the calibration bath. A platinum 100 Ω thermometer has been fixed on one of them and protected from the air temperature variations with a piece of foam, in order to measure the external temperature of the buoys and to try to detect its influence on the HRSST and SST measurements.

In order to study this point, a measurement series was made where the buoys were covered with a survival blanket, in order to shield it from radiation with the room and thus to partially insulate the buoy from the room temperature, to enclose the radiations of the bath and to limit the air exchanges.
Results show that with or without the blanket, the deviations are similar in amplitude :



The measurement series realized with the two buoys have been used to assess in details the reproducibility of temperature measurements and the expanded measurement uncertainty of two buoys. It gives 5.5 mK for one and 7.2 mK for the other, with a coverage factor of 2, which is inferior to 0.01 °C as required.

In order to demonstrate that the accuracy estimate still holds, once the buoys are deployed, the two prototype buoys were compared at sea to a CTD profiler (SBE 911+) and a reference thermometer SBE 35, during an oceanographic cruise in Mediterranean Sea.
The results show that the HRSST sensors deviations are of – 7 and - 6 mK for one buoy and 0 and 1 mK for the other.
For completion, it will be necessary to demonstrate that the accuracy holds over the lifetime of a buoy. This will be achieved by recovering a buoy deployed in the North Sea.

Conclusion

The setting up of a fiducial reference network, cannot be dissociated of a complete metrology process in laboratory made of theoretical and/or experimental characterization of sensors and of their environment of measurement.
The TRUSTED project is a perfect example of cooperation between oceanographers, meteorologists, an industry and a metrology laboratory.

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