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300 ans d'hydrographie

QUALITY ASSURANCE AND QUALITY CONTROL OF HRSST DRIFTERS

WMO-IOC, SIXTH MARINE INSTRUMENTATION WORKSHOP FOR ASIA-PACIFIC REGION

MARC LE MENN[1], MARC LUCAS[2], PAUL POLI[3], ARNAUD DAVID[4], ANNE O'CARROLL[5], MATHIEU BELBEOCH[6], KAI HERKLOTZ[7], FRANK DUMAS[1]

[1]SERVICE HYDROGRAPHIQUE ET OCÉANOGRAPHIQUE DE LA MARINE, [2]CLS, [3]MÉTÉO FRANCE/CENTRE DE MÉTÉO MARINE, [4]NKE INSTRUMENTATION, [5]EUMETSAT, [6]OCEANOPS, [7]BSH

16.12.2021

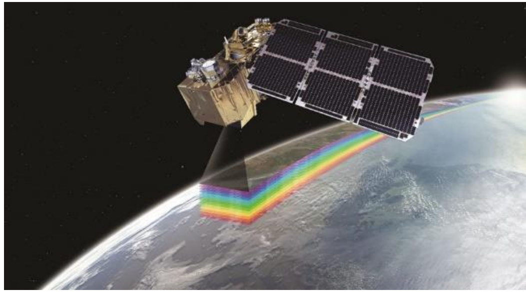
Quality assurance and the TRUSTED project

Quality assurance is widely used in industry, but relatively little in sea surface temperature (SST) measurements.

Paragraph 7.1.5 of ISO-9001 makes the link between quality and metrology. It states in summary that: “*where measurement traceability is a requirement, measuring equipment should be calibrated and/or verified before use against measurement standards that can be linked to international or national measurement standards*.”

The TRUSTED project has been designed to address this paragraph.

Funded by Copernicus, initiated by EUMETSAT and led by CLS, it aimed to build a network of 150 surface drifters for the validation of temperatures measured by the Sentinel satellites of the Copernicus project.



Sentinel-2B satellite launched in March 2017.
Image credit: Copernicus

The drifter design

The buoy developed is called **SVP with Barometer and Reference Sensor for Temperature** (SVP-BRST).

It is a spherical drifter of 40 cm diameter made of high pressure molded polypropylene.

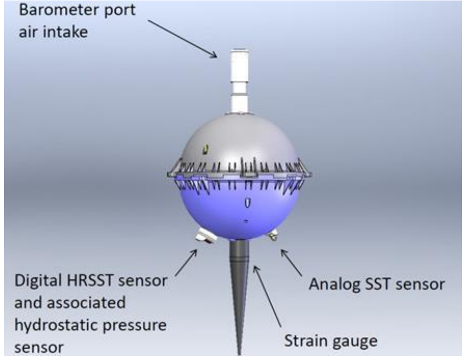
A 12.5 m line (including an elastic section) is attached below the buoy and linked to a stainless bracket.

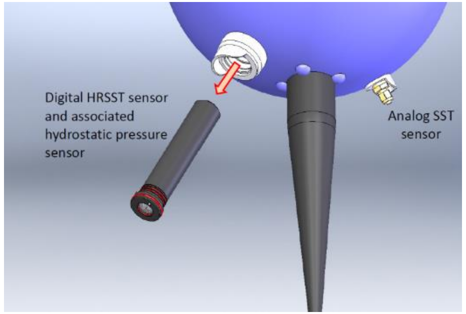
A holey socks drogue centered at 15 m depth is suspended to the line. It is 0.8 m in diameter and 6 m length.

The drogue loss is detected by a strain gauge, instead of a submergence sensor.

More of the usual SST sensor, a **high resolution temperature sensor**, with a resolution of 1 mK, and an hydrostatic pressure sensor are integrated in a module called **MoSens**.

This device is used to assess the measurements depths and the sea states.





Schematic of the buoy with its sensors.
Image ® nke Instrumentation.

MoSens calibration and quality control

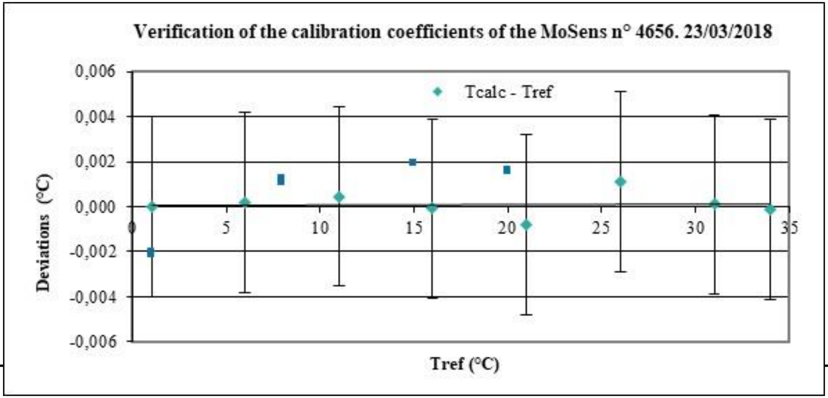
MoSens modules were designed to be able to calibrate the HRSST sensors of the buoys in batches of 10, allowing the **calculation of measurement uncertainties for each sensor** and the detection of manufacturing defects for some of them.

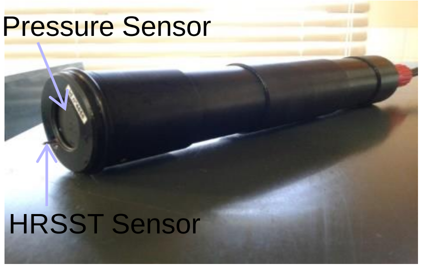
Example of graph made for one MoSens prototype. It shows:

- (light green rhombuses) the residuals of the calibration with the Bennett relation;

- (blue squares) the deviations obtained after the calibration coefficients were applied and verified in the bath;

- the uncertainty bars of this calibration representing the expanded uncertainties (level of confidence 95 %).





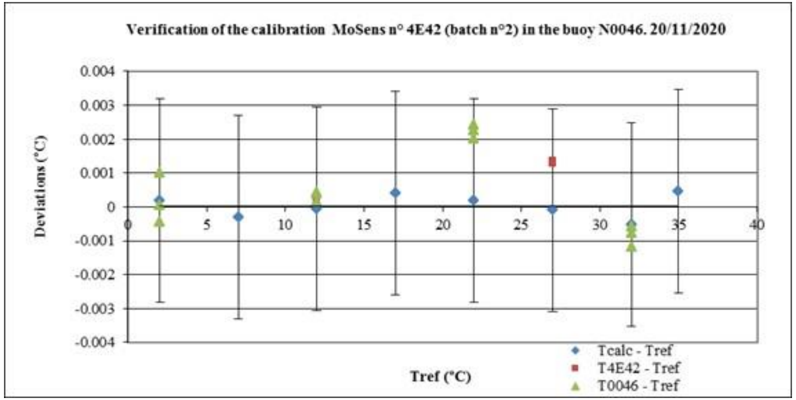
MoSens module

MoSens and buoys quality control

Once calibrated and verified, the MoSens modules are integrated into the buoys and **one buoy per batch of 10 is checked** to ensure the quality of the integration.

Example of graph obtained with one buoy. It shows:

- (light blue rhombuses) the residuals of the calibration of the MoSens module;
- (red square) the deviation obtained after the verification of the MoSens;
- (green rhombuses) the deviations obtained during the verification of the buoy;
- the uncertainty bars of the buoy calibration (at 95 %).



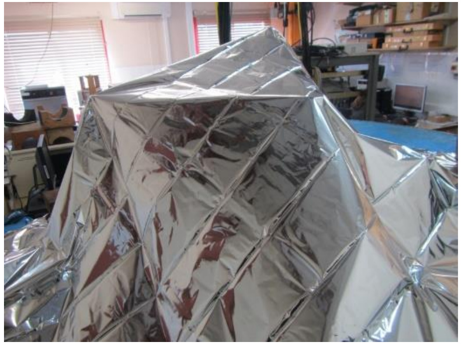
SVP-BRST prototypes before trials at sea.
Image credit: Shom

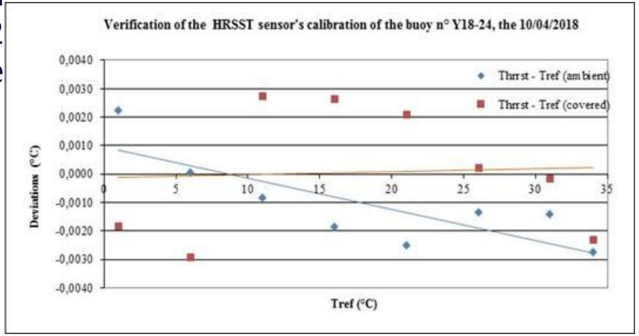
The other contributions from metrology

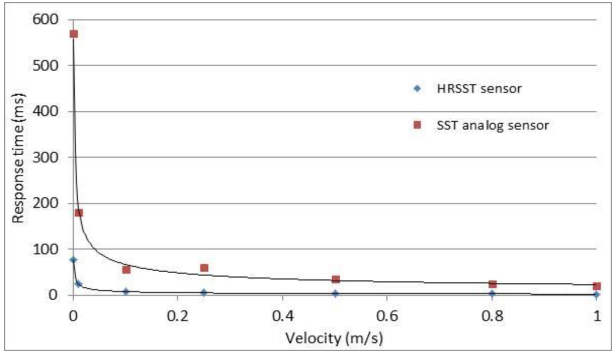
Laboratory measurements allowed to assess **the effect of air temperature on the HRSST measurements** and it allowed to conclude that deviations are more dependent on the cooling or the warming of the water than of the air temperature [1].

A metrological study also led to the conclusion that the error due to solar irradiance is proportional to the square root of the diameter of the cylindrical sensor (all other parameters assumed equal): for the HRSST sensor with D = 0.12 cm compared to the SST sensor with an average diameter of 1.4 cm, the radiative error is divided by 3.4, to the advantage of the HRSST sensor.

The difference in size also has an effect on the response time.

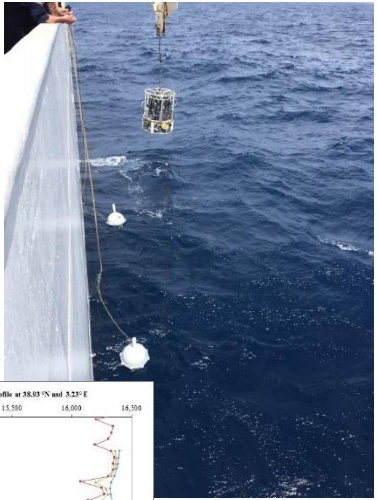






[1] - M. Le Menn *et al.*, 'Development of surface drifting buoys for fiducial reference measurements of sea-surface temperature', *Frontiers in Marine Science*, 6, 578, 2019.

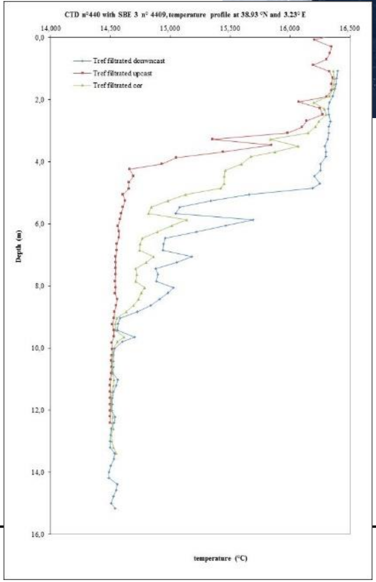
Intercomparisons at sea



During an oceanographic cruise, two buoys have been compared to a CTD profiler and a reference thermometer SBE 35.

These instruments make measurements to about 1 m under the surface.

	Value transmitted	sst corrected	Ttrans - Tctd :	Ttrans - Tsbe35	SSTcor - Tsbe35
SST58002 :	16,35	16,382	-0,048	-0,047	-0,014
SST 58019 :	16,35	16,389	-0,048	-0,047	-0,008
HRSST 58002 :	16,391		-0,007	-0,006	
HRSST 58019 :	16,398		0,000	0,001	



The comparison results show that without any correction, **HRSST values are in the standard dispersion range of the SBE 35** and the deviations compared to the CTD and the SBE 35 are inferior to 0.01 °C.

Without corrections, SST deviations are close to – 0.05 °C and with calibration corrections, they are in the calibration expanded uncertainties of these sensors.

Estimate of the drift one year after

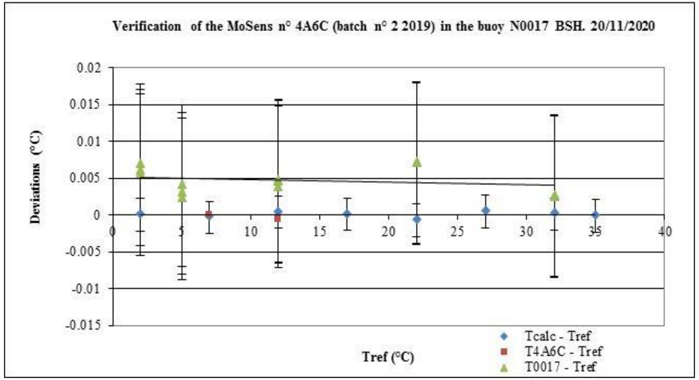
Two buoys have been recovered after one year at sea: one in the Icelandic Sea and another which had been moored at a fixed position by the German Hydrographic Office (BSH).

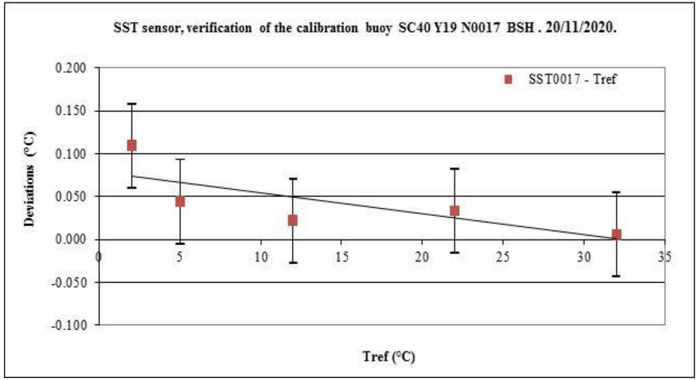
For the BSH buoy, the drift is a shift with values between 3 to 7 mK, 5 mK on average (10 times less than EUMETSAT spec.). That makes a **maximal drift of + 0.0039 °C/year**.

Bars represent the verification expanded uncertainty evaluated to ± 0.011 °C (4.6 times less than EUMETSAT spec.):

Tref standard uncertainty :	0.001	°C
Bath stability standard uncertainty :	0.000	°C
Reproducibility buoy n° 017 :	0.005	°C
Repeatability buoy n° 017 :	0.001	°C
Verification expanded uncertainty:	0.011	°C

Its **SST sensor has been also verified**. Its deviations are close to the limits of EUMETSAT spec. until the temperature of 5 °C, and two times higher at 2 °C.



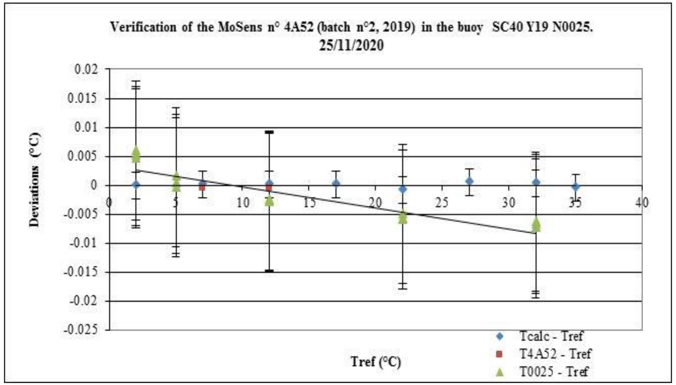


Estimate of the drift one year after

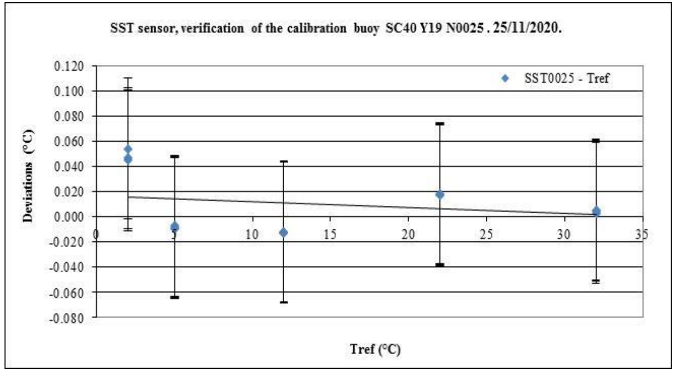
About the buoy recovered at sea, it presents a slope, but the maximal shift is of – 7 mK at 32 °C.

That makes a **maximal drift of - 0.0038 °C/year**.

Verification expanded uncertainty: ± 0.012 °C.



The verification of the SST sensor shows that from 32 °C to 5 °C, the maximum deviation is of 0.019 °C. The point at 2 °C presents also a shift (0.055 °C). This shift is due to the manufacturer's calibration range.



Before to take out the buoy from the water, **measurements have been made with a Sound Velocity Sensor** (SVT) located in the hull of the boat, 6 m under the surface, **and with a Rapid CTD Valeport**.

The two points transmitted by the buoy during the recover and the measurements allow to make a comparison with these instruments.

Estimate of the drift one year after

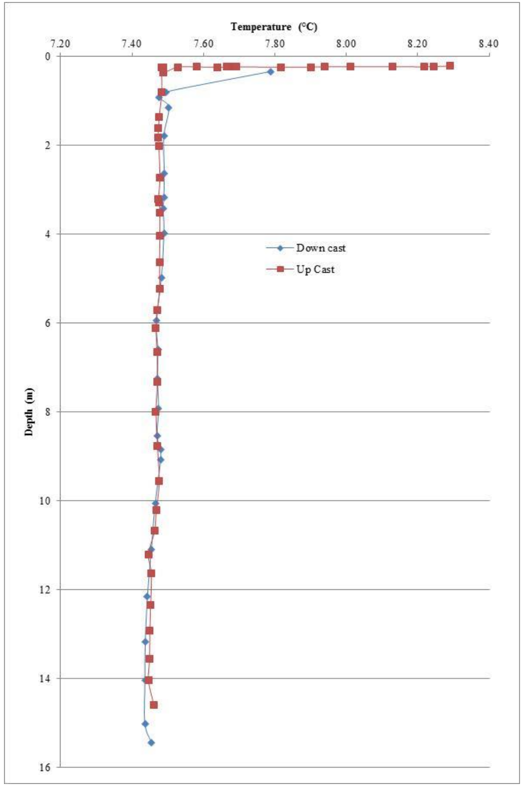
The profile obtained with the CTD shows that the temperature was **very homogenous from 0 to 15 m**, allowing to use the SVT for the comparison.

Between 10h30 and 11h30	SVT	SST	HRSST	SST - SVT	HRSST - SVT	RapidCTD (-0,24 to -6.7 m)	SST - CTD	HRSST - CTD
Average	7.426	7.410	7.445	-0.016	0.019	7.476	-0.066	-0.031
Standard uncertainty	0.015	0.016	0.018	0.022	0.024	0.007	0.017	0.020

Without calibration corrections of the HRSST and of the SST, their average deviations are of 0.019 °C and – 0.016 °C compared to the SVT and – 0.031 °C and – 0.066 °C compared to the CTD.

After applying corrections from the deviations observed during the verification, it is possible to reduce significantly the deviations for the SST to – 0.002 °C and – 0.052 °C but, not for the HRSST (0.02 °C and – 0.03 °C) because its drift at 7 °C was very small.

Between 10h30 and 11h30	SVT	SST cor	HRSST cor	SST - SVT	HRSST - SVT	RapidCTD (-0,24 to -6.7 m)	SST - CTD	HRSST - CTD
Average	7.426	7.424	7.446	-0.002	0.020	7.476	-0.052	-0.030
Standard uncertainty	0.015	0.016	0.018	0.022	0.024	0.007	0.017	0.020
Expanded uncertainty	-	-	-	0.044	0.048	-	0.034	0.039



Conclusion

Measuring SST and providing Fiducial Reference Measurements suitable for the comparison and the validation of satellite SST measurements, is not an easy task.

The TRUSTED project has had the merit of trying to set a frame of reference for these comparisons, through:

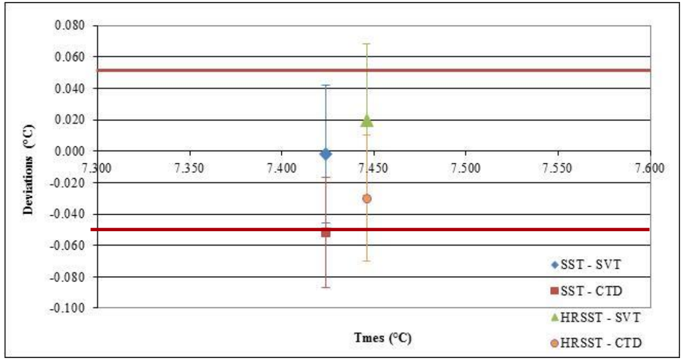
- the development of an innovative network of buoys;

- the development of a new HRSST sensor;

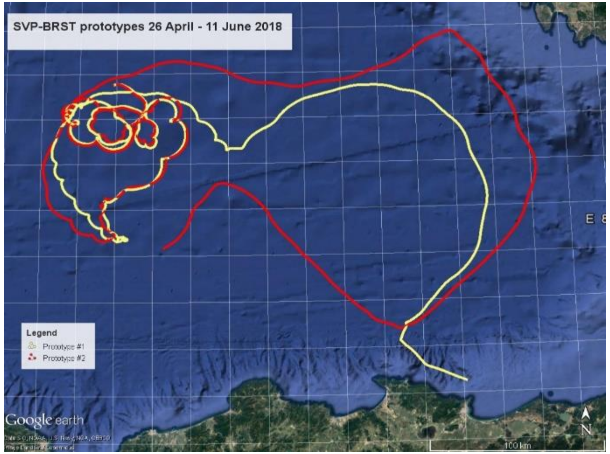
- the call to a metrology laboratory for the sensors calibration and for the comparison of the results.

The graph on the right shows that the application of metrological rules can provides proof that the tolerances of +/- 0.05 °C set by EUMETSAT can be met on the long term with the HRSST sensors of the network that has been set up.

But the natural variability of the environment means that the uncertainties of the comparison may exceed the limits set.



The uncertainty bars represent a level of confidence of approximately 95 %.



Thank you for your attention