Fiducial Reference Measurements for validation of Surface Temperature from Satellites (FRM4STS)

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Fiducial Reference Measurements for validation of Surface Temperature from Satellites (FRM4STS)

TOWARDS SI TRACEABILITY FOR NON-RECOVERABLE SST FRM INSTRUMENTS

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31 May 2018

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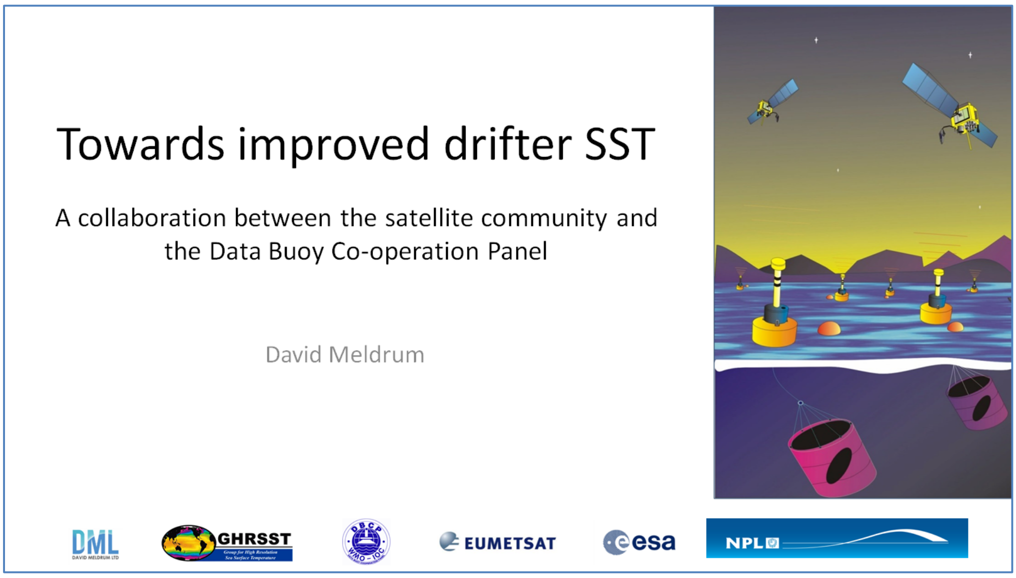
Towards improved drifter SST
A collaboration between the satellite community and the Data Buoy Co-operation Panel
David Meldrum
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EXECUTIVE SUMMARY

FRM4STS Option 1 comprised a body of work to examine every aspect of the reporting and management of SST originating from the global drifter fleet: past, present and future. In addition to two scientific and technical workshops that brought together the drifter SST community to examine the issues around the creation and maintenance of a drifter SST database traceable to SI and agree best practice for the future, and the creation of tools to comb and mine historical databases and platform files for metadata relating to drifter measurement of SST, the work required the production of a technical report that outlines best practice for the future, particularly with regard to SI traceability of drifter SST. This latter activity is the subject of this short report and guide.

The motivation for the study was the increased emphasis being placed by climate scientists and the satellite community on the drifter SST record, and for the need to better quantify the traceability of the measurements to SI, and to elucidate the uncertainty budgets associated with the measurements. Indeed, the quality of satellite SST retrievals currently depends ultimately on the uncertainties associated with drifter observations, and for that reason alone ESA were keen to better quantify and document these uncertainties.

The history of the satellite-tracked drifting buoy, equipped with air pressure and temperature sensors, starts in the late 1970s. However, the main body of this work concentrates on deployments made since the early 1990s, a total of more than 20,000 platforms. At that point a standard design had been evolved, the SVP drifter, offered by several manufacturers: a design that was inexpensive, easy to deploy, and had quantifiable drift characteristics that allowed the same platform to be used by both meteorological and oceanographic users. Since those early days, each manufacturer has adapted the design so that there is now little coherence between drifter A and drifter B. In particular, each manufacturer measures and reports SST in a different way, which creates particular problems for climate scientists who need to understand the finer details of the SST measurement in order to detect and quantify climate signals.

Gathering the historical metadata, including uncertainty estimates, that will assist climate scientists to interpret the drifter SST record is the subject of the first FRM4STS deliverable, ‘OP-10: a web based library of calibration and validation documents for non-recoverable SST instruments’. Developing best practice protocols for the future, in consultation with the entire drifter community, has been the subject of two international workshops, described in a second deliverable, ‘OP-30: Scientific and Technical Meeting Reports: Towards SI Traceability for non-recoverable SST FRM Instruments’.

The future of the metadata library, and the refinement and adoption of best practice protocols, has been assured by the WMO/IOC Data Buoy Co-operation Panel (DBCP) who have committed the necessary resources and re-established a Pilot Project (PP-HRSST) to further develop best practice and fully evaluate the impact of a better SST product, generically known as High Resolution SST (HRSST). In this latter effort, the Pilot Project will be greatly assisted by a new project commissioned by EUMETSAT to fully understand the drifter SST measurement and its impact on satellite SST retrievals.

The promulgation, further development and acceptance of best practice for drifter SST will be achieved by the publication of the bulk of this report as a dynamic document within the JCOMM/DBCP Technical Document series, overseen and maintained by the PP-HRSST.

THE BACKGROUND TO DRIFTER SST

The history of the sensor-equipped, satellite-tracked drifting buoy begins in the late 1970s with the launch of the NIMBUS-F satellite, a precursor of the NOAA polar orbiters which still fly today. NIMBUS-F carried a prototype data collection system (DCS) which allowed the acquisition of sensor data from a wide range of platforms, including data buoys and high altitude balloons. Importantly, the DCS also measured Doppler shifts of the incoming transmissions, which allowed a relatively crude position estimate to be made.

The technology was further developed by the French Centre National d'Études Spatiales (CNES), who have built the DCSs for the subsequent NOAA, European and Indian polar orbiters. Their system was called Argos, and was supplemented by a network of ground stations and reference beacons that allowed near-real-time data acquisition in certain areas and the computation of km-scale or better locations. Argos became the system of choice, indeed almost the only system, for drifting buoy users from the early 1980s until the advent and acceptance of the Iridium satellite system in the last decade or so.

In addition to a number of technical and cost benefits, Iridium allowed almost unlimited amounts of data to be sent from a drifter, whereas the standard Argos message was limited to 32 bytes or less, although messages could be chained to offer the possibility of greater data throughput. This 32-byte limitation, coupled with a general lack of interest in a high quality, high resolution SST measurement at the time, meant that SST was traditionally only reported with a resolution of 0.1K, and with a typical accuracy of 0.2K. Furthermore the near-real-time downstream data distribution to the end-user and to the archives relied on the Global Telecommunication System (GTS) of the World Meteorological Organization (WMO), at that time an archaic system that relied on encoding schemes from the paper-tape and teleprinter era. The coding scheme for buoy data inherently limited the resolution of the SST measurement to 0.1K.

Times have chained, and new GTS coding schemes allow for the transmission of higher resolution data, and accompanying metadata. As a result, drifters that use Iridium for the satellite link now typically report SST with a resolution of 0.01K, although the sensor itself may not be much different in terms of accuracy from the traditional unit.

Of greater concern to the satellite and climate community, is that uncertainty budgets, the multi-component amalgamation of different error contributions, is poorly defined, if at all. On top of this, traceability to SI and national standards is seldom asserted, a major shortfall in an era where the space industry and the climate community are increasingly insisting on a documented traceability path for every measurement that they use.

This study has concentrated on drifter deployments since the early 1990s, when Peter Niiler and colleagues at Scripps developed a ground-breaking standard design for a surface drifter that would answer the needs of both the meteorological and oceanographic communities. This design, the SVP, and its barometer variant, the SVP-B, has become the workhorse design at the basis of every manufacturer's product, and more than 20,000 units have been deployed in the global oceans.

Unfortunately, despite the existence of a detailed construction manual, no two manufacturers' product is the same, except in fundamental properties such as drogue depth and drag-area ratio. Uniformity in these latter two parameters is essential for platform drift data to be assimilated into the global surface current climatology, maintained by the Global Drifter Program (GDP) at NOAA-AOML. Unfortunately, rigorous standards were never specified for the SST data, which means that the historical SST dataset has a heterogeneous parentage which is challenging to assess in detail.

Nonetheless, the satellite community, unknown to the DBCP, have for many years used this dataset as the gold standard for validating satellite-derived SST, in an attempt to recover climate signals and develop a better near-real-time satellite SST product. Now, fortunately, the DBCP and the satellite community have recognised the importance of working together to address, and fund, common aims. In particular, the DBCP have reinstated the DBCP-GHRSST Pilot Project for HRSST (PP-HRSST) to maintain momentum in this area.

HISTORICAL PRACTICE FOR THE MEASUREMENT OF SST BY A DRIFTER

THE ORIGINAL DESIGN FROM THE SVP DESIGN MANUAL

'The thermistor fitting, thermally isolated from the inside of the float, is designed to react quickly to changes in sea surface temperature (SST). Thermal isolation prevents solar heating of the top of the surface float from influencing the SST measurement. The sensor should be accurate to better than 0.1C when the inside of the float is 1C warmer than the sea surface. A thermistor fitting that reacts quickly to temperature changes also speeds up temperature sensor calibration in the lab. We use a Betatherm assembly (part no XP36K53D93) which incorporates a linearised thermistor composite within a stainless steel fitting. Alternatively, an assembly can be made by potting a linearised thermistor composite within a suitable tubing connector. See Figure 1.'

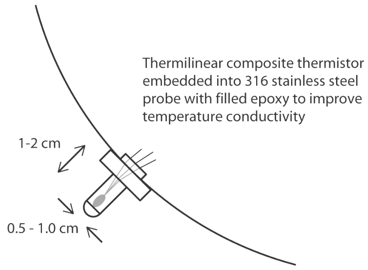


Figure 1*. Detail of the thermistor fitting into the buoy hull.*

Comments: The original design suggestion used a linearised thermistor composite, a common enough approach at the time, which attempted to generate a linear temperature response from a pair of non-linear thermistor beads and a resistor network. This approach avoided the need to linearise the thermistor output in software, but suffered from low absolute accuracy and lack of traceability.

EXAMPLES FROM CURRENT MANUFACTURING PRACTICE

Manufacturer A

An off-the-shelf temperature sensor is used, batch certified to +/-0.1K, and reporting digitally to the main controller. Although the sensor output resolution is only 0.035K, the resolution transmitted is 0.01K. No independent calibration is performed. The manufacturer's published drift studies show that the sensor may drift by 0.1K or more early in its life, but then settles down thereafter. See Figure 2.

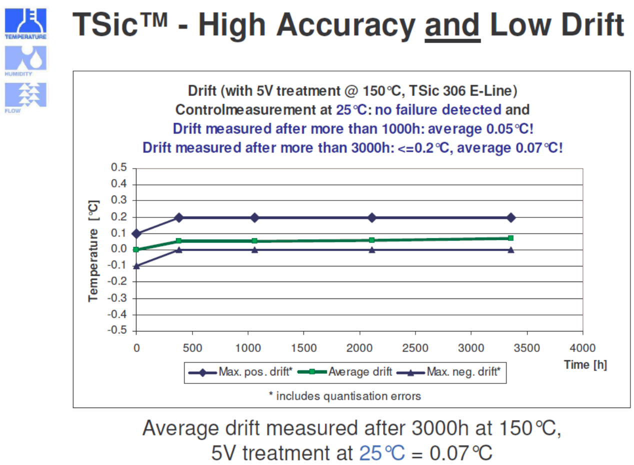


Figure 2*. The drift characteristics of the IST TSic digital temperature sensor.*

Comments:

The approach here is basically an update of the original design suggestion, using a digital output sensor rather than the linearised analogue sensor previously suggested. As such, that is an improvement, although there is no individual calibration or traceability metadata.

Manufacturer B

Verification schedule for temperature sensor

Every temperature sensor is individually calibrated.

Calibration procedure

2.1 Define coefficients of polynomial regression $T(N_T)$, where N_T - output codes of temperature sensor

- *define N_T values at temperatures 0, 5, 10, 15, 20, 25, 30 °C and supply voltage is const;*
- *define coefficients of polynomial regression $T(N_T)$.*

2.2 Evaluating components of error:

- *standard deviation $\tilde{\sigma}$;*
- *ratiometricity error Δ_E - max $T(N_T)$ deviation at a certain input when supply voltage changes from 7 to 15V;*
- *long-term stability Δ_t - max $T(N_T)$ deviation at a certain input during 12 months.*

2.3 Accuracy (worst case error):

$$\Delta_T = 3\tilde{\sigma} + \Delta_E + \Delta_t + \Delta_{ref},$$

where Δ_{ref} - accuracy of reference device.

State primary standard of temperature:
Accuracy ≤ 0.001°C

↓

Comparison standard
Platinum resistance thermometer
accuracy ≤ 0.002°C

↓

Inspection gauge (Marlin-Yug)
Piezoelectric thermometer
accuracy ≤ 0.015°C

↓

Buoy's sensor
MM400 module (SST, Tz channels)
Range minus 5 to 35 °C; accuracy ≤ 0.1°C

Comments:

This manufacturer has made an effort to individually characterise each sensor, and to include an uncertainty term for sensor ageing, but traceability to SI is not explicitly defined. Critically, calibration is performed in the digital domain, using the digital outputs of the custom MM400 processor board. This removes the uncertainty associated with systems where the sensor itself is calibrated but then connected to an uncalibrated downstream signal processing module. It also opens up the possibility for post calibration in the event that the platform is recovered. The specification of the MM400 module is given in Annex A.

Manufacturer C

'Measurement
Thermistor accuracy depends on the precision and uncertainty of the calibration system used. The precision of the measurement, however, is in large part due to the method of the measurement and its approximation and interpolation. To measure the resistance of the thermistor a reference voltage is applied to the voltage divider network consisting of the thermistor and a 0.01% precision resistor. A 24-bit delta-sigma Analogue-To-Digital Converter is used to measure the signal and convert it into digital format which, in turn, is read out by the microcontroller over the SPI bus.

Calibration
The HRSST board consists of analogue and digital sections. The purpose of the analogue section is to condition the input signal, acquire, and convert it into digital format. The analogue section consists of the thermistor, the voltage divider, the Op-Amp buffer, and the analogue part of the ADC. Every component of the measurement circuit contributes its error to the measurement, in addition to the noise inevitably present in any electrical system. Calibration is required to account for the errors. The digital section consists of the digital part of the ADC, the micro-controller and the level translator. Digital and analogue parts function independently. Calibration curves are not required with the HRSST probes. The probes are independently calibrated by the manufacturer (Measurement Specialties Inc, formerly YSI) and the coefficients are stored in the memory of each probe. Calibration certificates are provided with each probe. This certifies that the probe has been calibrated then verified that it is within 0.05 degrees C over the full SST range.

Interchangeability
No component of the analogue section is replaceable or interchangeable without voiding the calibration. Components of the digital section can be replaced with the identical components without compromising the accuracy and precision of the analogue section since they do not directly participate in the measurement process but merely perform the communication between the analogue and digital sections and interface with the host computer.

Calibration process
1. Pot thermistor inside the fitting.
2. Determine the Steinhart-Hart coefficients {a, b, c} with thermistor assembly separated from the electronics board.
3. Enter measured coefficients in the processor NV memory.
4. Attach thermistor assembly to the electronics board.
5. Perform ADC conversion and calculate temperature at set points, using the previously derived coefficients.
6. Determine if the error compared to reference temperature is large enough to warrant applying correction coefficients.
7. If so apply corrections to the coefficients or add offset to measured value
8. If necessary perform measurements in smaller step sizes, 10°C increments over the range.

Post deployment recalibration
If a buoy is recovered, it is possible to perform post-deployment calibration on the probes. The probe assembly, shown can be removed from the buoy hull. Calibration will require a temperature controlled bath at various temperatures and a PC running Hyperterminal to connect to the probe's microcontroller and an external power supply. MetOcean will supply the necessary hardware to allow communication with the probe. The output of the probe can then be verified at different temperatures and an offset curve created.'

Comments:

The full system description and calibration protocol is attached as Annex A. The approach described is similar to that employed by Manufacturer B, except that the sensor is calibrated before connection to the dedicated processing module, which introduces uncertainties as to the unknown accuracy of its analogue to digital conversion, even though the complete assembly is then verified to be within specification at the final stage. The individual calibration certificate supplied is a step forward, although no explicit mention is made of the calibration uncertainties, nor to its traceability to national standards.

A number of SST probes have been serendipitously recovered and recalibrated at the Météo France and at the Scottish Marine Institute. The results showed that the sensors had remained within the +/- 0.05K specification, and that their long term drift was within acceptable climate standards (~10mK per year) – see Figure 3.

Probe no.	Date ref1	Tmeasured1 - Tref1 (K) MEAN	Verifi-cation (ref2)	Date ref2	Tmeasured2 - Tref2 (K) MEAN	No. of days elapsed since ref1	Drift (K/year) since ref1
10034	02/10/2012	-0.010					
			MF/SHOM	23/09/2016	-0.063	1452	-0.013
			SAMS	16/08/2017	-0.043	1779	-0.007
10051	16/10/2012	-0.006					
			MF/SHOM	23/09/2016	-0.055	1438	-0.012
			SAMS	16/08/2017	-0.037	1765	-0.006
10067	01/09/2012	0.031					
			MF/SHOM	23/09/2016	-0.007	1483	-0.009
			SAMS	16/08/2017	+0.014	1810	-0.003

SAMS measurement uncertainty: 0.020K

Figure 3*. Results of the post-calibration exercise.*

Manufacturer D

'Calibration Procedure
Calibration procedures for individual sensors vary by type. The manufacturer uses a high accuracy Fluke 7009 calibration bath with stability of 0.0007°C and accuracy of 0.005°C that is used for temperature probe calibration (certified to ISO 9001:2015), or equivalent. A SBE 37 (certified to ISO 9002) temperature reference probe accurate to 0.002 °C, or equivalent, with calibration certified by the manufacturer, is aslo used. The calibration coefficients of the drifter SST module are encoded inside its EEPROM and digital SST data is transferred to the drifter's controller. To facilitate the post-calibration of recovered drifters, the SST data stream is accessible through a wireless link integrated inside the drifter.

Calibration Certificate
Each drifter will be provided with a calibration certificate, traceable to national standards, showing a minimum expected accuracy for each sensor onboard. This calibration certificate will show any calibration coefficients applied onboard the drifter prior to data transmission. If third party sensors have provided manufacturing calibration data, they will be passed along in copy and the original retained at OGS and will be passed along to Dr. Centurioni at the GDP, where they will be permanently stored. This procedure is an integral part of the traceability of the measurements collected by the drifter and the certificates will be stored indefinitely at OGS and on the GDP physical computer servers and on the GDP cloud based archival system. The GDP at SIO operates multiple server racks with overlapping redundancies to ensure data integrity. The GDP at SIO operates two server racks in parallel, one located in the SIO co-location datacenter and one at the San Diego Super Computer Center at UC San Diego. These two racks receive,

process, and relay real-time drifter data for collaborating partners. Further, a third remote system is operated using Amazon Web Services in the Government Cloud data center for a real-time offsite archiving of all incoming data. In the event of a disaster at the San Diego facilities, all computing services can be rolled to the AWS servers for data continuity.'

Comments:

This approaches the ideal situation, with full traceability to SI and a defined SST uncertainty budget. All metadata are also archived indefinitely.

DESIRED BEST PRACTICE

It will be apparent from reading the preceding text that traceability to SI and quantifiable uncertainty budgets are now of paramount importance, both for satellite cal/val and to ensure the usefulness of the drifter SST record for elucidating subtle climate signals. Sensor stability is an important issue, as sensors are seldom recovered for post-calibration. A stable sensor calibrated and certified to SI is the goal. In fact, most thermistor-based sensors are capable of more than adequate stability, especially if they are pre-aged by repeated thermal cycling. The picture with band-gap sensors is less clear, although some products (such as the Maxim 1-wire series) seem to be adequately stable.

It is also increasingly important to understand what the drifter SST sensor is actually measuring, given that the depth of the measurement within the water column is a function of sea state, biofouling accumulation and the presence or absence of the drogue. In this context, it is pleasing to note that the recently-awarded EUMETSAT drifter project will for the first time precisely measure the dynamics of the drifter within the water column. The sampling and averaging protocol also need to be known, as well as the time constant of the sensor, as these all have a bearing on the representativeness of the reported SST.

The main elements of desired best practice may be summarised in Table 1.

Element	**Suggested best practice**
Sensor accuracy	• 0.05K or better
Sensor calibration	• Calibration in the digital domain when attached to drifter controller preferred • Alternatively a stand-alone module reporting digitally, as for Manufacturer C
Sensor traceability	• Individually certified to national standards
Sensor uncertainties	• Metadata should specify total standard uncertainty, including drift
Sensor drift	• Ideally sensors should be pre-aged before characterisation • A sub-set of each sensor batch should be retained for drift characterisation • Recovered sensors should be recalibrated in a suitable lab to quantify drift
Sensor mounting	• Initial depth to be specified in metadata • Sensor time constant to be specified in metadata
Sensor processing	• Sampling and averaging protocol to be specified in metadata
Sensor metadata	• Metadata to include sensor type and reference to calibration file • Metadata to be appended to the BUFR message to the extent possible • Metadata to be archived in perpetuity in a secure manner
Data transmission	• Use of Iridium preferred because of possibility for higher resolution data • DBCP standard coding format preferred (see Annex D) • BUFR to be used for GTS transmission • Metadata to be included to the extent possible
Data archival	• All original data (i.e. prior to GTS insertion) and metadata to be archived, mirrored and freely accessible
Post deployment QC	• Use of Météo France QC tools encouraged (see Annex C)

***Table 1**. Guidelines for best practice for drifter SST.*

THE ROUTE TO A PRACTICAL GUIDE TO BEST PRACTICE FOR DRIFTER SST

This information will be assembled and published within the JCOMM/DBCP Technical Report on Best Practice for Drifter SST after agreement with the drifter community. This Technical Report will conform to the format described in Annex F so that it may be readily updated according to community consensus without having to undergo the multi-year WMO review process.

The report will contain all of the elements in Table 1 on p14, but with additional practical guidance as to particular sensor selection, data processing protocols, etc. To a large extent many of these details will flow from the EUMETSAT study and the work of the newly re-instated DBCP PP-HRSST (see Annex E for details).

In particular, the PP-HRSST, with its Steering Group membership drawn from across the drifter community and chaired by the present author, is mandated to develop a practical guide to future best practice for drifter SST measurement, metadata, traceability, distribution and archival. See Table 2 for its principal Terms of Reference.

The SG will work closely with the GHRSST to:

a. agree and review instrumentation standards and achieve consensus on best practice for drifter SST;
b. identify optimal target ocean areas that will be likely to deliver a high number of matchups and demonstrate the impact of drifter HRSST within the project lifespan;
c. secure sufficient funding to allow the project to proceed expeditiously;
d. work with buoy agencies, the space community and manufacturers to allow a sufficient number of upgraded HRSST drifters to be procured and deployed in the chosen target area(s);
e. ensure that HRSST data flow onto the GTS and are clearly identified as HRSST in associated meta-data and/or bulletin headers;
f. assist in the analysis of the impact of the data on satellite SST retrievals;
g. report to the DBCP at its annual sessions and in the published literature.

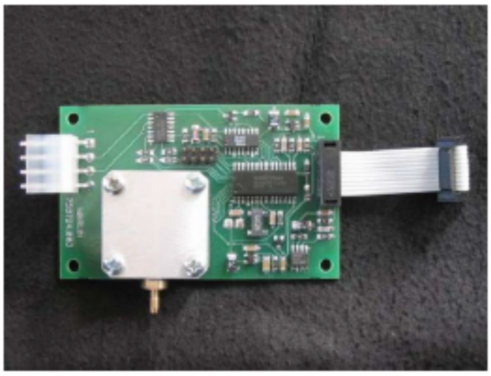
***Table 2**. Terms of Reference for the PP-HRSST*

The PP-HRSST is in the best position to achieve community consensus as to the best way forward: consensus that is vital to ensuring the rapid adoption of best practice, especially for SI traceability, across the global drifter community. As regards the widespread adoption of a higher quality (and more expensive) HRSST sensor, the value or otherwise of this is yet to be fully demonstrated: an uncertainty that will hopefully be resolved by the recently launched EUMETSAT study to equip a small fleet of 100-150 drifters equipped with a high specification SST and other sensors alongside the traditional fit.

ANNEX A - THE MARLIN-YUG SENSOR PROCESSOR MODULE

Air pressure, temperature, temperature profile measurement module MM400

GENERAL



MM400 is an OEM measurement module intended for measurement of air pressure, sea surface temperature, temperature profile and power supply voltage. MM400 module is optimized to be installed in self-powered autonomous systems for environment and industrial monitoring (WOCE style drifters; automatic weather stations, data acquisition systems, etc.). Using 1-Wire® technology to extend measuring possibilities, different sensor attachments are available. By combining a built-in controller with serial interface, MM400 module is a powerful unit, that provides a highly-flexible and cost-effective solution to many applied applications.

MM400 PARTS

MM400 module is a high-integrated device that combines the following parts:

- Precision barometric pressure sensor
- Sea surface temperature sensor (optional)
- Sea subsurface temperature sensors (optional)
- Temperature data-chain for temperature profile measurement (optional)
- Hydrostatic pressure sensor (optional)
- Power supply voltage sensor (optional)
- High-performance microcontroller
- Application software

HARDWARE

- Operation range: -20…+60°C
- Voltage range: +6 to +15 VDC
- Power consumption:
  - Measuring mode < 2 mA;
  - Sleeping mode < 100 mkA
- Serial interface
- Interval between samples: 1 s
- Longterm stability of parameters
- Stability to vibration and shock loads

SOFTWARE

- Fast alteration of configuration
- Adaptation for data transfer through Argos PTTs (e.g. Marlin MT105AM)

AREAS OF APPLICATIONS

- Marine data platforms
- Meteostations (including the boats)
- Control of air and liquid pressure
- Industrial processes control

BRIEF SPECIFICATIONS

Parameters	Range	Resolution	Accuracy
Air pressure, hPa	10 to 1100	0,1	±1,0
Temperature, °C	Minus 20 to +60	0,04	±0,2
Battery voltage, V	6 to 15	0,02	±0,1

Size: 80 × 50 × 20 mm
Weight: less than 70 grams

According to the user's need the application software can be customized and factory installed into MM400 module.

Marlin-Yug Ltd., 2, Kapitanskaya st., 99011, Sevastopol, Ukraine
Tel/fax: +380 692 540450; e-mail: marlin@marlin-yug.com; http://www.marlin-yug.com Revision 3.1. January 2009

ANNEX B - THE METOCEAN DIGITAL HRSST SENSOR

MetOcean

HRSST System Description and Calibration

General	
Model #: SVP-I-BDGZ	**Date:** 8/1/2014
Rev # 2.0	
Description: This document defines the components of the MetOcean HRSST controller critical for the temperature measurement accuracy and the parts interchangeability. It addresses calibration and the ability for post-deployment recalibration.	

Introduction

In 2010, the DBCP and GHRSST established a joint Pilot Project to upgrade elements of the GDP buoy fleet to allow the reporting of higher resolution SST and position. The objective is to operate SVP drifting buoys measuring SST with an accuracy of 0.05 deg C (resolution 0.01 deg C), location with an accuracy of 0.5 km and observation time with an accuracy of 5 minutes. According to the project, the following items are required:

Item	Description	How MetOcean meets this
System accuracy	Measure SST to +/- 0.05 deg C	We use a higher accuracy thermistor.
System accuracy	Calibrate buoy to meet SST	Each probe is calibrated and the coefficients stored. A Certificate of Conformance is supplied with each probe.
System resolution	Report SST to +/-0.01 deg C	We implemented the new DBCP format
Location accuracy	+/- 500 meters	We use Iridium and GPS
Time accuracy	+/- 5 minutes	Our PID defines sampling time within 5 minutes of top of the hour

Page 1

Data collection and communication experts

21 Thornhill Drive - Dartmouth, Nova Scotia B3B 1R9 - CANADA / Tel : +1 902 468 2505 / Fax : +1 902 468 4442 / www.metocean.com

Background

Temperature, on the molecular level, is the average energy of the molecules that compose the substance. If more energy is put into the system, the average speed of the molecules will increase and more thermal energy or heat will be produced. What we measure as the temperature is always related to the average speed of the molecules in a system. Many methods have been developed for measuring temperature. Most of these rely on measuring some physical property of a working material that varies with temperature.

One of the most common devices for measuring temperature electrically is a thermistor.

A thermistor is a type of resistor whose resistance varies significantly with temperature, more so than in standard resistors.

Assuming, as a first-order approximation, that the relationship between resistance and temperature is linear, then:

$$\Delta R = k\Delta T$$

where

ΔR = change in resistance
ΔT = change in temperature
k = first-order temperature coefficient of resistance

In practice, the linear approximation works only over a small temperature range. For accurate temperature measurements, the resistance/temperature curve of the device must be described in more detail. The Steinhart-Hart equation is a widely used third-order approximation:

$$\frac{1}{T} = a + b\ln(R) + c\ln^3(R)$$

where a, b and c are called the Steinhart-Hart parameters, and must be specified for each device. T is the temperature in Kelvin and R is the resistance in Ohms.

MetOcean

To give resistance as a function of temperature, the above can be rearranged into:

$$R = e^{\left(x - \frac{y}{2}\right)^{\frac{1}{3}} - \left(x + \frac{y}{2}\right)^{\frac{1}{3}}}$$

where

$$y = \frac{a - \frac{1}{T}}{c} \quad \text{and} \quad x = \sqrt{\left(\frac{b}{3c}\right)^3 + \frac{y^2}{4}}$$

The error in the Steinhart-Hart equation is generally less than 0.02 °C in the measurement of temperature over a 200 °C range. As an example, typical values for a thermistor with a resistance of 3000 Ω at room temperature (25 °C = 298.15 K) are:

$$a = 1.40 \times 10^{-3}$$
$$b = 2.37 \times 10^{-4}$$
$$c = 9.90 \times 10^{-8}$$

Measurement

Thermistor accuracy depends on the precision and uncertainty of the calibration system used. The precision of the measurement, however, is in large part due to the method of the measurement and its approximation and interpolation.

To measure the resistance of the thermistor a reference voltage is applied to the voltage divider network consisting of the thermistor and a 0.01% precision resistor. A 24-bit delta-sigma Analog-To-Digital Converter is used to measure the signal and convert it into digital format which, in turn, is read out by the microcontroller over the SPI bus.

Data collection and communication experts

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MetOcean

Calibration

The HRSST board consists of analog and digital sections. The purpose of the analog section is to condition the input signal, acquire, and convert it into digital format. The analog section consists of the thermistor, the voltage divider, the Op Amp buffer, and the analog part of the ADC.

Every component of the measurement circuit contributes its error to the measurement, in addition to the noise inevitably present in any electrical system. Calibration is required to account for the errors.

The digital section consists of the digital part of the ADC, the micro-controller and the level translator. Digital and analog parts function independently.

Calibration curves are not required with the HRSST probes. The probes are independently calibrated by the manufacturer (Measurement Specialties Inc, formerly YSI) and the coefficients are stored in the memory of each probe. Calibration certificates are provided with each probe. This certifies that the probe has been calibrated then verified that it is within 0.05 degrees C over the full SST range.

Interchangeability

No component of the analog section is replaceable or interchangeable without voiding the calibration.

Components of the digital section can be replaced with the identical components without compromising the accuracy and precision of the analog section since they do not directly participate in the measurement process but merely perform the communication between the analog and digital sections and interface with the host computer.

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Calibration process

1. Pot thermistor inside the fitting.
2. Determine the Steinhart & Hart coefficients {a, b, c} with thermistor assembly separated from the electronics board.
3. Enter measured coefficients in the processor NV memory.
4. Attach thermistor assembly to the electronics board.
5. Perform ADC conversion and calculate temperature at set points, using the previously derived coefficients.
6. Determine if the error compared to reference temperature is large enough to warrant applying correction coefficients.
7. If so apply corrections to the coefficients or add offset to measured value?
8. If necessary perform measurements in smaller step sizes, 10°C increments over the range.

Post deployment recalibration

If a buoy is recovered, it is possible to perform post-deployment calibration on the probes. The probe assembly, shown in Figure 1 above can be removed from the buoy hull. Calibration will require a temperature controlled bath at various temperatures and a PC running Hyperterminal to connect to the probe's micro-controller and an external power supply. MetOcean will supply the necessary hardware to allow communication with the probe. See Figure 3 below. The output of the probe can then be verified at different temperatures and an offset curve created.

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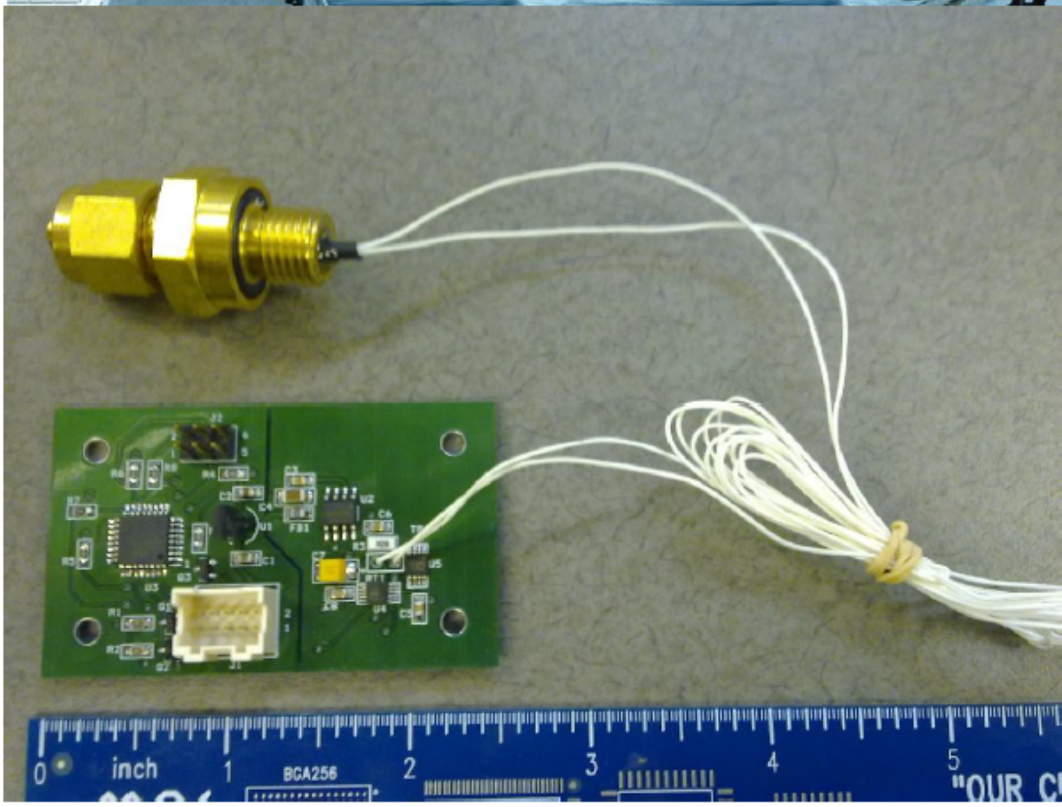

Figure 1 ├ Details of the MetOcean HRSST probe

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measurement SPECIALTIES

Certificate of Calibration

Instrument	: High Precision Temperature Sensor
Serial Number	: 10020
Manufacturer	: Measurement Specialties
Calibration Date	: January 16, 2012

Thermistor assembly manufactured by MetOcean DataSystems was shipped to Measurement Specialties for calibration to assure measurement accuracy of ±0.05°C from 0°C to 40°C. The sensor incorporates the Measurement Specialties 55032 GEM thermistor, potted into a Swagelok style housing with 28AWG Teflon insulated lead wire, approximately 50cm in length. The thermistor assembly was connected to a sensor controller board, powered by the TTL to RS-232 converter via a 9V battery. Controller board calibration and testing was performed using a TTL to RS-232 converter connected to a laptop computer. Logging of data was performed via uConn terminal emulation software. System set-up, thermistor characterization and calibration were performed per MetOcean Data Systems Document #TD-11-043.

The thermistor assembly was calibrated using measurement data at 0.007°C, 25°C and 40°C. Measurement data was collected using temperature standards traceable to NIST. The sensor was powered for a minimum of one minute, followed by repeated measurements for another minute. The resistance values were averaged and entered into a Steinhart-Hart spreadsheet to derive thermistor coefficients. Next, the coefficients were entered into the sensor's controller board and were re-measured to confirm the measurement was within ±0.05°C at 0.007°C, 25°C and 40°C.

Measurement Specialties certifies that at the time of calibration and measurement, using the measurement process described above, the sensor measured within ±0.05°C of actual bath temperature.

Steinhart-Hart Values	Reference Bath Temperature (°C)	Measured Temperature (°C)	Difference (°C)
A=0.000914277	0.007	-0.013	0.020
B=0.000224055	25	24.98	0.020
C=0.000000120	40	39.981	0.019

Phil Metz
Chief Metrologist

Measurement Specialties, Dayton OH

DATE: 01/17/2011

Measurement Specialties
Temperature Products Group

2670 Indian Ripple Road
Dayton, Ohio 45440-3605
USA

937 427-1231   937 427-1640 fax
www.meas-spec.com

Figure 2 – Sample Certificate of Conformance for an HRSST probe.

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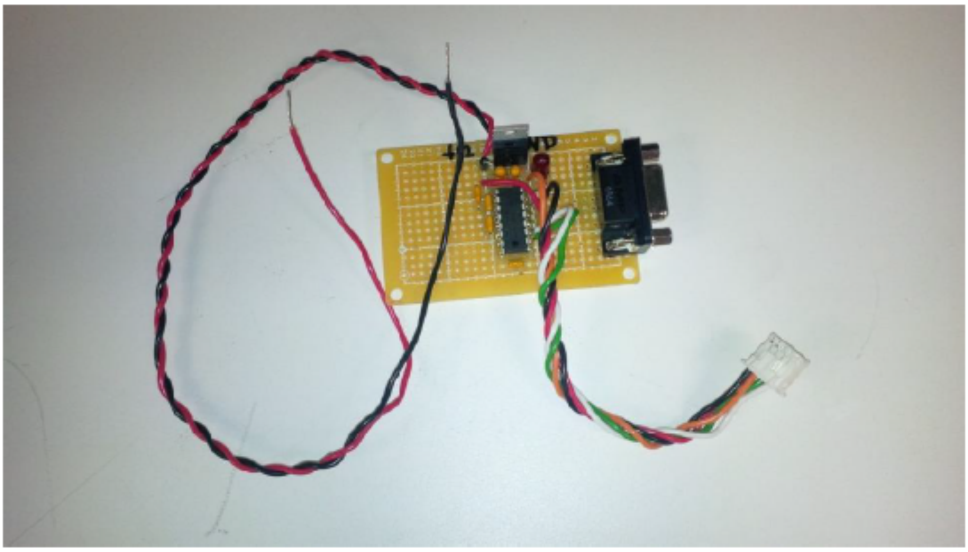

Figure 3- Hardware needed for post-deployment calibration

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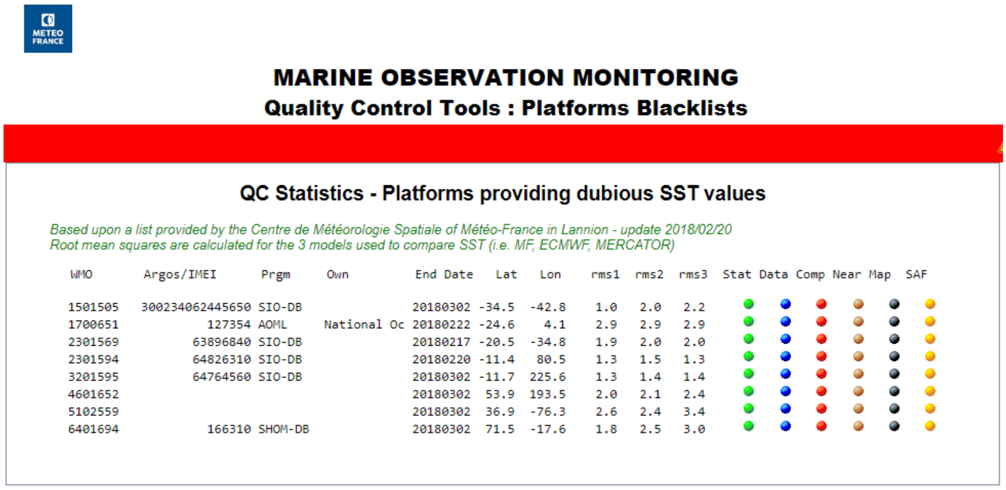
ANNEX C - THE MÉTÉO FRANCE QC TOOLS

The URL for the site is http://esurfmar.meteo.fr/qctools/



METEO FRANCE

MARINE OBSERVATION MONITORING

Quality Control Tools : Platforms Blacklists

QC Statistics - Platforms providing dubious SST values

Based upon a list provided by the Centre de Météorologie Spatiale of Météo-France in Lannion - update 2018/02/20
Root mean squares are calculated for the 3 models used to compare SST (i.e. MF, ECMWF, MERCATOR)

WMO	Argos/IMEI	Prgm	Own	End Date	Lat	Lon	rms1	rms2	rms3	Stat	Data	Comp	Near	Map	SAF
1501505	300234062445650	SIO-DB		20180302	-34.5	-42.8	1.0	2.0	2.2						
1700651	127354	AOML	National Oc	20180222	-24.6	4.1	2.9	2.9	2.9						
2301569	63896840	SIO-DB		20180217	-20.5	-34.8	1.9	2.0	2.0						
2301594	64826310	SIO-DB		20180220	-11.4	80.5	1.3	1.5	1.3						
3201595	64764560	SIO-DB		20180302	-11.7	225.6	1.3	1.4	1.4						
4601652				20180302	53.9	193.5	2.0	2.1	2.4						
5102559				20180302	36.9	-76.3	2.6	2.4	3.4						
6401694	166310	SHOM-DB		20180302	71.5	-17.6	1.8	2.5	3.0						

***Figure 4**. The drifter SST blacklist.*

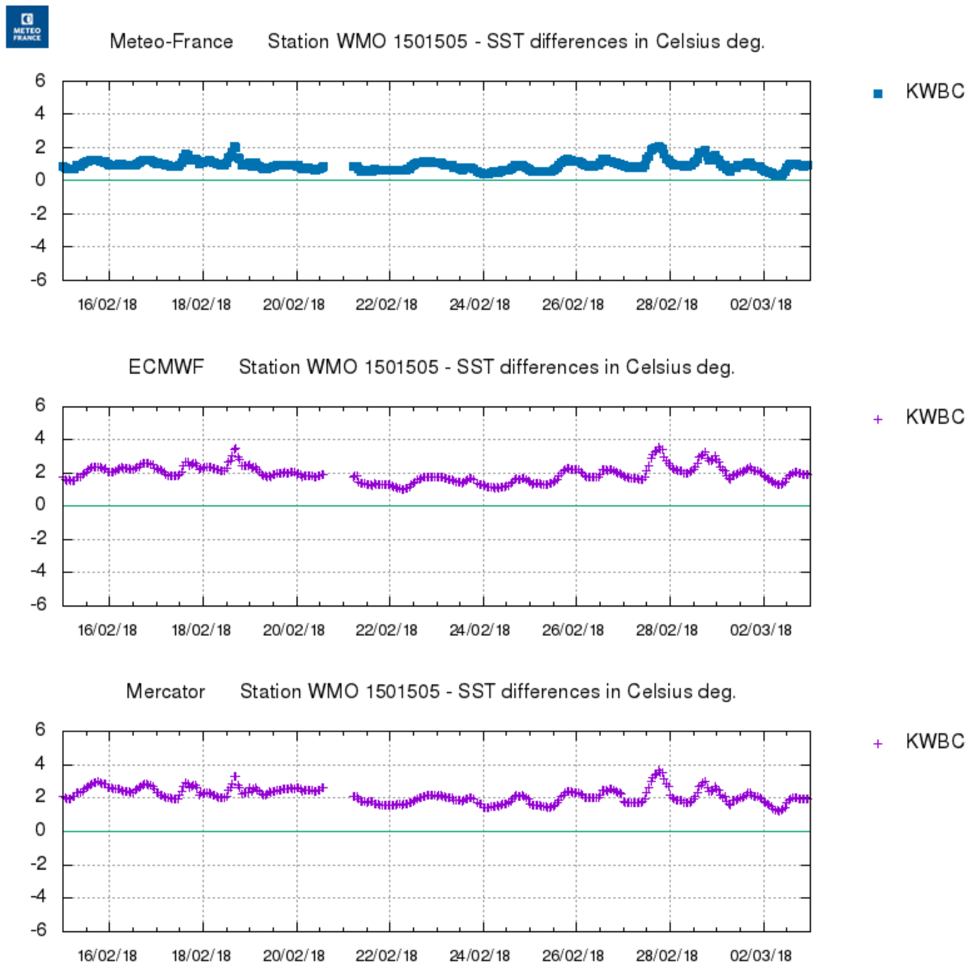


***Figure 5**. An example of how SST from a blacklisted drifter compares with three model outputs.*

ANNEX D - THE SVP-B IRIDIUM MESSAGE FORMAT

Format #000 - SVP-B
(20 bytes)

Parameter	Bits	Pos	Offset	Max	Formula
Format identifier	8	0	0	254	Forced to 0 in present version
Year	7	8	2000	2126	Year = n + 2000
Month	4	15	0	12	Month = n
Day	6	19	0	31	Day = n
Hour	5	25	0	23	Hour = n
Minute	6	30	0	59	Minute = n
Air pressure	11	36	850.0	1054.6	AP (hPa) = n*0.1 + 850
SST	12	47	-5.00	35.94	SST (°C) = n*0.01 - 5
Pressure tendancy	9	59	-25.5	25.5	dP (hPa) = n*0.1 - 25.5
Submergence/gauge count	6	68	0	100	Subm. (%) = n * 1.6129
Battery voltage	6	74	5	17.4	Vbat (V) = n*0.2 + 5
1st Tech. parameter (Iridium)	8	80	0	254	*See § 3*
2nd Tech. parameter	8	88	0	254	*See § 3*
GPS fix time delay	12	96	0	4094	Delay (min) = n
GPS Latitude	20	108	-90	90	Lat (deg) = n*0.0002 - 90
GPS Longitude	21	128	-180	180	Lon (deg) = n*0.0002 - 180
3rd Tech. parameter (GPS)	7	149	0	126	*See § 3*
4th Tech. parameter (GPS)	4	156	0	14	*See § 3*

ANNEX E - PP-HRRST

TERMS OF REFERENCE, WORKPLAN AND INITIAL MEMBERSHIP OF THE STEERING GROUP FOR THE DBCP-GHRSST PILOT PROJECT FOR HIGH RESOLUTION SST DRIFTERS (PP-HRSST)

Background

Following a dialogue between the DBCP and the Group for High Resolution Sea Surface Temperature (GHRSST), the 26th session of the DBCP (Oban, 2010) recognised that drifter SST was critical for the validation of satellite-derived SST, and that the resolution and accuracy of currently reported drifter SST was inadequate. The Panel accordingly decided to establish a Pilot Project for HRSST, overseen by a Steering Group (SG), and with a defined workplan and a three-year duration. Despite considerable investment by the Panel, ESURFMAR and the Met Office, initial deployments of HRSST drifters did not demonstrate a significant improvement in satellite SST retrievals, largely because of the failure of ENVISAT during the evaluation phase. Furthermore, the satellite community proved unable to contribute to the exercise in material terms. Accordingly, with regret, the Panel suspended PP-HRSST's activities at its 30th session (Weihai, 2014).

More recently, the European satellite community has become proactive in supporting the rollout and evaluation of HRSST drifters through specific funded actions by ESA and EUMETSAT. The Panel therefore asked that PP-HRSST be reactivated, and that a revised SG membership and workplan be proposed for consideration by the DBCP EB in advance of its 33rd session (Brest, 2017).

Revised ToRs and Workplan

The Terms of Reference of the SG, its membership, and a workplan are listed below.

Terms of Reference of the SG

1. The SG will work closely with the GHRSST to:

    a. agree and review instrumentation standards and achieve consensus on best practice for drifter SST;
    b. identify optimal target ocean areas that will be likely to deliver a high number of matchups and demonstrate the impact of drifter HRSST within the project lifespan;
    c. secure sufficient funding to allow the project to proceed expeditiously;
    d. work with buoy agencies, the space community and manufacturers to allow a sufficient number of upgraded HRSST drifters to be procured and deployed in the chosen target area(s);
    e. ensure that HRSST data flow onto the GTS and are clearly identified as HRSST in associated meta-data and/or bulletin headers;
    f. assist in the analysis of the impact of the data on satellite SST retrievals;
    g. report to the Panel at its annual sessions and in the published literature.

2. The SG chair and vice chair will be appointed by the Panel, and will recruit other members of the team, drawn from the satellite community, buoy operators, manufacturers, scientists, GHRSST, end-users and other interested parties.

3. The SG chair will convene annual meetings of the SG, will communicate regularly with SG members by e-mail, and will report annually to the Panel.

Workplan

Year 1:

1. Form SG and agree on working procedures
2. Recruit additional members as required, including key players from within the GHRSST and the satellite community
3. Work closely with ESA and EUMETSAT to ensure that their emerging HRSST drifter activities are properly assimilated within DBCP aims and objectives
4. Ensure that proposed technology solutions adequately address GHRSST requirements

5. Identify the cost of an HRSST upgrade and identify buoy operators and manufacturers willing to participate in the PP
6. Present the PP to the annual GHRSST science meeting and secure GHRSST support, particularly for HRSST data evaluation activities
7. Work closely with JCOMMOPS to establish protocols for the maintenance of the drifter SST meta-data database established within the ESA initiative
8. Establish consensus for best practice for drifter SST for endorsement by the DBCP and GHRSST
9. Draw up a detailed costed implementation plan for approval by DBCP

Year 2:

1. Complete Year 1 work items
2. Work with the satellite community to identify mutually beneficial deployment areas and assist where possible with the deployment of HRSST drifters
3. Oversee calibration/recalibration protocols
4. Ensure that HRSST data are properly identified and distributed on the GTS and are appropriately archived
5. Monitor buoy deployments, data flow and data ingestion by GHRSST
6. Present at GHRSST science meeting
7. Work with the satellite community and GHRSST to identify future activities and funding opportunities
8. Make interim report to DBCP-XXXV

Year 3:

1. Continue with Year 1 and 2 work items
2. Continue deployments as far as possible
3. Attempt recovery of failed or failing buoys for analysis and sensor post-calibration
4. Review technology and data-flow performance and make recommendations as appropriate
5. Work with GHRSST to identify impacts and shortcomings of PP
6. Agree recommendations for future activities, if any
7. Report to GHRSST science meeting
8. Final report to DBCP-XXXVI
9. Work with GHRSST on a journal article
10. Disband

Membership

Chair (DBCP appointee)	(David Meldrum, SAMS, *pro tem*)
Vice chair (DBCP appointee)	(Paul Poli, Météo France)
DBCP chair (*ex officio*)	(Jon Turton, Met Office)
DBCP TC (*ex officio*)	(Long Jiang, JCOMMOPS)
Buoy programme manager(s)	(Sidney Thurston, NOAA; Marc Lucas, CLS)
Representatives from the satellite community	(Anne O'Carroll, EUMETSAT; Craig Donlon, ESA)
Buoy data analyst(s)	(Rick Lumpkin, NOAA-AOML)
Buoy manufacturer(s)	(Andy Sybrandy, Pacific Gyre: Bernie Petolas, Metocean)
WMO CIMO representative(s)	
GHRSST representative(s)	(Gary Corlett, GHRSST-PO)
Oceanographic user(s)	(Luca Centurioni, Scripps)
Secretariat (*ex officio*)	

ANNEX F – PROPOSALS FOR THE JCOMM TECHNICAL DOCUMENT SERIES

World Meteorological Organization

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)

A REVIEW OF SELECTED WMO AND IOC PUBLICATIONS RELATING TO MARINE OBSERVATIONS

RECOMMENDATIONS FOR PROGRESS

CONSULTANT REPORT

WMO SSA ref 1768-11
October 2013

by

David Meldrum
dtm@sams.ac.uk

1. INTRODUCTION

Essentially this report describes a body of work performed under WMO SSA No 1768-11. The object of the work was to examine a number of WMO and IOC Manual and Guides relating to marine observation, and to suggest appropriate revisions, or a strategy for so doing[1]. The impetus for this work had come through the deliberations of The Joint Steering Group (JSG) for the IODE Ocean Data Portal and the WIGOS Pilot Project for JCOMM[2], which had recognised a number of deficiencies in the marine publications of both the WMO and the IOC. These included:

- Inefficient and slow procedures for revision and updating
- Inconsistent and even contradictory treatment of material
- Widespread duplication
- Lack of cross referencing, especially between WMO and IOC
- Non-availability of easily editable document source files
- In some cases the material being significantly out of date

This report examines each of the reports listed in the SSA, as detailed below, and suggests specific actions in regard to each of them. Additionally, and possibly more importantly, the report suggests an entirely new concept for the ownership and updating of the reference material, which takes account of current developments within JCOMM, IODE and WIGOS.

2. THE STATUS OF WMO AND IOC MANUALS AND GUIDES: REGULATORY OR ADVISORY?

It is important to understand the nomenclature, and the different interpretations placed on the words 'Manual' and 'Guide', and even the words 'shall' and 'should', within the two organizations. Within WMO there is a clear hierarchical structure for official documentation:

Technical Regulations impose definite requirements and strong recommendations upon member states, using the words 'shall' and 'should' to express these precise meanings;
Manuals describe detailed technical specifications, using the same language as above, and are considered to be 'dynamic' annexes to the Technical Regulations, with the same regulatory significance;
Guides typically offer implementation guidance, case studies, advice on best practice and the like, and carry no regulatory weight, even if the words 'shall' and 'should' are used.

Thus the WMO documents that fall within the scope of this SSA, comprising both **Manuals** and **Guides**, include both **regulatory** and **guidance** material. The procedure for updating these documents is quite different: changes to Technical Regulations and Manuals typically have to pass through the relevant technical commission and then be endorsed by the governing body, a process that can take many years. While this may be entirely appropriate in allowing member states due time to comply with the 'shall's and 'should's, it is inappropriate in the case of encouraging the implementation of best observing practice, particularly in the rapidly evolving marine field, where new platforms and technologies are emerging at a fast pace.

[1] SSA Description of Duties
[2] WMO/TD-No 1515, JCOMM Technical Report No 48 (2011)

In the case of the IOC Manuals and Guides, the procedure is less clear, although it is plain that they carry no regulatory implications. Additionally many of the documents are seriously out of date.

3. A PROPOSAL TO SEPARATE REGULATORY FROM ADVISORY MATERIAL

It is proposed to introduce a new system for WMO/IOC marine observation documentation that will separate **guidance** from **regulatory** material. The proposal also takes careful account of the fact that two distinct UN bodies are involved, with subtly different ways of working and decidedly different governance mechanisms.

As a result of the above, the principle element of this proposal is to progressively migrate all **guidance** material to two new JCOMM Technical Documents (TDs)[3], and to leave all **regulatory** material within the current framework, currently entirely the province of WMO as noted above. The two proposed JCOMM Technical Documents will gather together current guidance and best practice in Ocean Observation and Marine Meteorology, and will consist essentially of a series of Technical Annexes that are owned and updated by the relevant JCOMM Expert Teams and Programme Areas. In this modern age, there is no longer a requirement that the best-practice annexes be other than links to other documents and to the JCOMM Catalogue of Best Practice, itself simply a series of links. In this way, it is hoped that current best practice can be made available in an efficient manner, that hard-copy paper publications may be superseded, and that the annexes can remain clearly in the ownership of the relevant expert bodies in a way that safeguards the interests, sensitivities and aspirations of both the IOC and the WMO.

The system is envisaged to work as follows:

1. Official manuals and guides will still contain the **regulatory** paragraphs approved by the governing bodies [this currently applies only to WMO], but will also carry a cross reference to the relevant JCOMM Technical Document, either for Oceanographic Observations or for Marine Meteorological Observations.

2. The two JCOMM Technical Documents will consist of background and introductory material (a ‘Wrapper’), followed by technical annexes delineating best practice. Initially best practice will be introduced by platform type: subsequently annexes will also be added by variable (ECV).

3. These annexes will be developed, approved and owned by the relevant expert team(s) within JCOMM. In many cases material for these annexes already exists.

4. The addition of annexes by ECV will be a significant development, and will draw on the considered analysis of GCOS, OOPC, WMO RR and other requirements. This will be a challenging exercise as it will attempt to match aspirations to what is achievable, and to reconcile many competing demands. Ultimately it will depend on executive decision and recommendation by a small expert group, acting in good faith, in order to make progress in a sub-decadal timescale. At present only OOPC is positioned to make these judgements. A much closer link between OOPC and the JCOMM OPA[4]

[3] The designation ‘Technical Document’ (TD) is suggested in preference to ‘Technical Report’ (TR) as the latter acronym is normally associated by the WMO community with Technical Regulations.
[4] First steps towards a much closer collaboration between OOPC and the JCOMM OPA were developed productively during overlapping sessions of both bodies in Washington DC from 3-7 September 2013.

needs to be developed in order to translate visionary aspirations to JCOMM policy and eventual community buy-in.

5. Any updates to the Technical Documents will require to be approved by the co-presidents prior to electronic publication.

6. Suggestions for updates to the regulatory documents (WMO Technical Regulations and Manuals) will from time to time be drafted by the JCOMM Technical Document editor(s) (appointed by the OPA chair) and will be submitted by the Co-Presidents to IOC and WMO through the conventional process in force at the time. This might in due course include the suggestion to move all guidance material to the relevant JCOMM Technical Document, leaving only regulatory material in the official documents.

The significant advantage that this approach confers is that it enables JCOMM to publish and update information and guidance on current best practice without it having to pass through a multi-year vetting filter, and without duplication, and that it will clearly underline the prime responsibility of the JCOMM OPA to take ownership in this area. Importantly, it will also free IOC and WMO to supervene historical demarcations and work together to harmonize their guidance material in an equitable and mutually beneficial way.

At this stage this is only a proposal, but it will be presented to the next meetings of the OOPC and the JCOMM OCG, to be held jointly at NOAA in early September 2013 in order to seek comment and endorsement[5].

Meanwhile a draft of the JCOMM Technical Document for Marine Meteorological Observation is attached, with a draft annex that describes current best practice for Sea Surface Temperature observations. This variable is of course relevant also to the parallel JCOMM Technical Document on Oceanographic Observation, and, in the spirit of harmonization and non-duplication, it is envisaged that it would also be cited as an annex to that report.

4. BEST PRACTICE BY PLATFORM TYPE OR BY ESSENTIAL CLIMATE VARIABLE (ECV)?

To date best practice and observing system metrics have proceeded on a platform type basis (e.g. percentage completion of perceived needs for drifting buoys, Argo floats, etc). While this is a worthy metric, it takes no account of the grand picture in terms of which variables need to be observed, at what resolution in time, space and accuracy, and so on. These are more important metrics in terms of our capability to observe, model and predict ocean processes and climate, but they are more difficult to define, implement and measure than platform-based metrics. The definition of the metrics *a priori* is the responsibility of GCOS and the OOPC, the implementation is the responsibility of the JCOMM OPA. A crucial dialogue exists (or should exist) between these bodies in order to match ideals with achievable reality. The importance of dialogue cannot be understated: no ideal is achievable, and debate is essential to identify the make-up of a composite observing system that makes best use of available resources and realistic technology solutions.

[5] The OCG endorsed the concept and proposed methodology during its overlapping session with OOPC in Washington DC from 3 to 7 September 2013

5. THE PATH TO ACCEPTANCE AND ADOPTION OF THE CONCEPT

In practice this may not be as difficult as might be presumed, given that this proposal relates only to non-regulatory **guidance** material. There is no suggestion to propose alterations to **regulatory** material, except through the current channels and protocols. Nonetheless, given the developments taking place within WIGOS and elsewhere, it is expected that these protocols will evolve, and that current best practice as contained within **guidance** material will in due course, and after due reflection, become embodied within **regulatory** provisions. As noted previously, only the WMO requires Member States to abide by Technical Regulations: it is almost conceivable that the same could ever apply in the IOC domain, though the IOC may in due course decide to issue stricter guidelines through GOOS, IODE and particularly through GLOSS, the sea-level observing co-ordination body, whose recommendations and implementation have developed dramatically in response to recent tsunami, storm surge and other coastal inundation episodes, and verge on being **regulatory**.

Given its responsibilities in this area, and their importance with regard to life and to its High Level Objectives (HLOs), the IOC may in due course reflect as to whether it is in the position to seek agreement from Member States to impose minimum standards in sea-level monitoring, and whether these might eventually become **regulatory**.

At this stage, the timeline to acceptance and adoption of the proposal to move all marine observation **guidance** material to a parallel pair of JCOMM Technical Documents might proceed as follows:

1. Presentation to JCOMM OCG-5 and OOPC, Washington DC, Sept 2013, and tabling of draft recommendation;

2. Collection of JCOMM OPA feedback by end Dec 2013;

3. Executive endorsement by JCOMM co-presidents and submission of papers and request for endorsement to WMO EC and IOC GA, May-Jun 2014;

4. Appointment of JCOMM Technical Document editors by JCOMM co-presidents, Jul 2014;

5. Editors identify and communicate with relevant ETs, Sep 2014 (action editors);

6. E-publication of ‘Wrapper’ and available annexes, Dec 2014 (action editors and JCOMM co-pres’s);

7. Identification and solicitation of additional annexes, ongoing (action editors);

8. Evolution of new ECV requirements, metrics and publications, 2014 on (action editors, new JCOMM TTs).

6. SPECIFIC COMMENTS ON DOCUMENTS SPECIFIED IN SSA REF 1768-11

6.1 **WMO No 8** – *Guide to Meteorological Instruments and Methods of Observation (‘CIMO Guide’)*

This guide encompasses a wide range of meteorological practice. In the marine field, in the particular field of ship observations, many important updates have been proposed, particularly by the late Julie Fletcher of the NZ Met Service. These updates still await formal adoption, but otherwise this document is more or less fit for purpose in regard to ship observations. With regard to other marine meteorological observations, the picture is more patchy, with little current input from, for example, any part of the buoy or float community.

6.2 **WMO No 488** – *Guide to the Global Observing System ('GOS Guide')*
This contains many references to marine observations, but the guide is significantly out of date in this regard (latest edition 2007, with much material older and quite irrelevant to current best practice).

6.3 **WMO No 544** – *Manual on the Global Observing System ('GOS Manual')*
This publication embodies the regulatory stipulations with which Member States are required to comply. Despite having been updated in 2010, the marine sections have many omissions, e.g. in regard to the Argo profiling float array, and overall is quite dated.

6.4 **IOC No 4** - *Guide to Oceanographic & Marine Meteorological Instruments & Observing Practices*
This guide was published in 1975 and is largely irrelevant to modern best practice, except that many of the overarching guiding principles remain valid. There is no useable electronic version.

6.5 **IOC No 18** - *User Guide for the Exchange of Measured Wave Data*
As for IOC No 4, this guide is seriously out of date (last revised in 1987) and is not easily editable in its current form, as no electronic version exists.

6.6 **IOC No 26** - *Manual of Quality Control Procedures for Validation of Oceanographic Data*
As with the other IOC guides listed above, the material is in many places seriously out of date. Nonetheless, the basic principles remain valid, and the guide is a good reference in this regard.

7. SPECIFIC COMMENTS ON DOCUMENTS NOT SPECIFIED IN SSA REF 1768-11

7.1 **WMO No 471** – *Guide to Marine Meteorological Services, Chapter 6 – the VOS*
This chapter is up to date and is a useful practical reference for the Voluntary Observing Ship (VOS)

8. CONCLUSIONS

8.1 Conclusion: WMO and IOC Manuals and Guides need significant revision to reflect current best practice in marine observation;

8.2 Conclusion: Neither body is currently able to move swiftly to collect, consider and publish current best practice;

8.3 Conclusion: It is important to separate **regulatory** requirements (currently only relevant in the WMO sphere of influence) from **guidance** material which has no regulatory implication;

8.4 Conclusion: Given the above distinction, there is no reason whereby **guidance** material could not be harmonised and updated on a regular basis without the explicit involvement of either governing body;

8.5 Conclusion: In contrast, **regulatory** material (WMO only) could endure the current multi-year procedure without immediate impact from any review (such as this) of **guidance** material;

8.6 Conclusion: Sensitivities between IOC and WMO are non-negligible, and may impair the fruitful progress of both organizations towards rather similar marine objectives;

8.7 The partition between above-surface (WMO) and below-surface (IOC) responsibilities is ultimately illogical and divisive: a particular area being in tsunami detection and warning, where these artificial boundaries may be inhibiting progress towards **regulatory** implementation of warning and mitigation procedures.

9. RECOMMENDATIONS

9.1 Recommendation: Propose to separate all **regulatory** material from **guidance** material in recognition that **guidance** material needs to be updated more easily and possibly more frequently than **regulatory** material [specific details in attached annex];

9.2 Recommendation: Delegate all marine observation guidance documentation to the JCOMM OPA, with the expectation that all essential and current material will be identified and catalogued by means of two JCOMM Technical Documents explicitly created for the purpose, one to cover oceanographic observations, the other to cover marine meteorological observations;

9.3 Recommendation: Within the JCOMM OPA, currently existing platform groups be tasked with submitting and linking their currently existing best-practice documentation to the proposed new JCOMM Technical Documents;

9.4 Recommendation: The JCOMM OCG move as rapidly as possible to evaluating network performance by ECV, in order that network gaps might be more easily identified and appropriate guidance developed.

ANNEX G - SELECTED REFERENCES AND URLS

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Data Buoy Co-operation Panel http://www.jcommops.org/dbcp/

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Météo France QC tools http://esurfmar.meteo.fr/qctools/

Global Drifter Program Drifter Design Manual http://www.jcommops.org/doc/DBCP/svpb_design_manual.pdf

Quality Assurance for Earth Observation (QA4EO) http://qa4eo.org

CEOS Working Group on Calibration and Validation (WGCV) http://www.ceos.org/wgcv

GHRSST ship borne radiometer validation network https://www.ghrsst.org/products-and-services/product-validation/global-network-of-ship-mounted-irradiometers/

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