ENHANCING SHIP OF OPPORTUNITY SEA SURFACE TEMPERATURE OBSERVATIONS IN THE AUSTRALIAN REGION

Helen Beggs[(1)], Ruslan Verein[(1)], Hiski Kippo[(2)], Mark Underwood[(3)], Ian Barton[(3)], Craig Steinberg[(4)], Eric Schulz[(1)], Ross Hibbins[(5)], Alan Thomas[(5)] and Graeme Ball[(5)]

(1) Centre for Australian Weather and Climate Research, Bureau of Meteorology, Melbourne, Australia,
Email: h.beggs@bom.gov.au,
(2) CSIRO Marine and Atmospheric Research, Perth, Australia,
(3) CSIRO Marine and Atmospheric Research, Hobart, Australia,
(4) Australian Institute of Marine Science, Townsville, Australia,
(5) Bureau of Meteorology, Melbourne, Australia.

Submitted to the Proceedings of the GHRSST Data Users Symposium, Santa Rosa, USA, 28-29 May 2009.

1. INTRODUCTION

Remotely sensed sea surface temperature (SST) data are important inputs to ocean, numerical weather prediction, seasonal and climate models. In order to improve calibration and validation of satellite SST in the Australian region, there is a need for high quality in situ SST observations with greater timeliness, spatial and temporal coverage than is currently available. Regions particularly lacking in moored or drifting buoy observations are the Western Pacific Tropical Warm Pool region (Indonesia), close to the Australian coast (including Bass Strait) and the Southern Ocean (e.g. Figure 1).

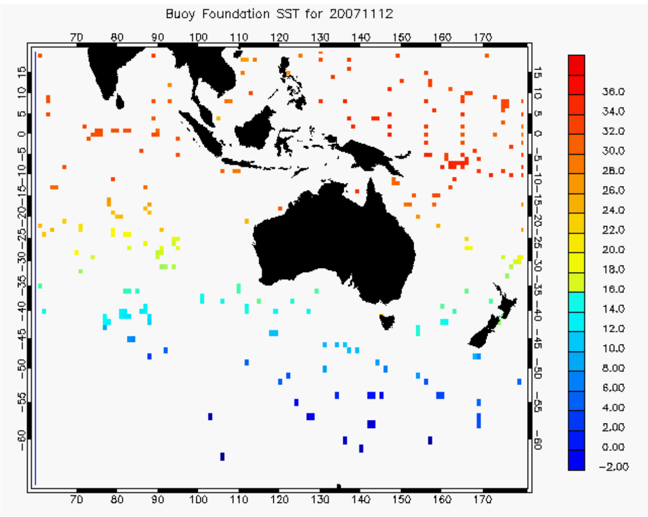

Figure 1. Drifting and moored buoy SST observations from the GTS for 12 November 2007 over the region 20°N to 65°S, 60°E to 180°E.

Typically, SST observations from the ships of opportunity program (SOOP) in the Australian region are either of uncertain accuracy or difficult to access in a timely manner, and have therefore not been used for near real-time validation of satellite SST observations. From 2008, the Integrated Marine Observing System (IMOS: http://www.imos.org.au) Project has enabled accurate, quality controlled, SST data to be supplied in near real-time (within 24 hours) from SOOPs and research vessels in the Australian region.

2. DATA STREAMS

There are eight vessels carrying automatic weather stations (AWS) that participate in the Australian Volunteer Observing Fleet (AVOF) program. Their routes include the Southern Ocean, coastal Australia, Bass Strait, North Pacific Ocean and the Tasman Sea. As part of the IMOS SOOP SST Sensors Sub-Facility, operated by the Bureau of Meteorology (Bureau), these AVOF vessels will be instrumented with hull-mounted temperature sensors (Sea Bird SBE 48), supplying high-quality bulk SST observations every one to three hours. There are also three passenger ferries taking SST measurements for CSIRO Marine and Atmospheric Research (Rottnest Island Ferry), the Australian Institute of Marine Science (AIMS) (Whitsunday Island to Hook Reef and Gladstone to Heron Island ferries in the Great Barrier Reef). In addition, there are near real-time SST data streams available from two Australian research vessels (RV Southern Surveyor and SRV Aurora Australis). In total, thirteen vessels by 2010 will contribute near real-time data to IMOS (see Table 1). All SST data are quality assured (see Section 3), placed in real-time on the Global Telecommunications System (GTS) and fed into the Bureau's near real-time satellite SST data validation system and operational regional and global SST analyses. The QC'd SST data are also available in netCDF SAMOS format (Rolph and Smith, 2005) via the IMOS data portal (http://bluenetdev.its.utas.edu.au). Figure 2 shows the tracks of ships providing IMOS SST data from 4 Feb 2008 to 29 April 2009 to the IMOS data portal and the GTS.

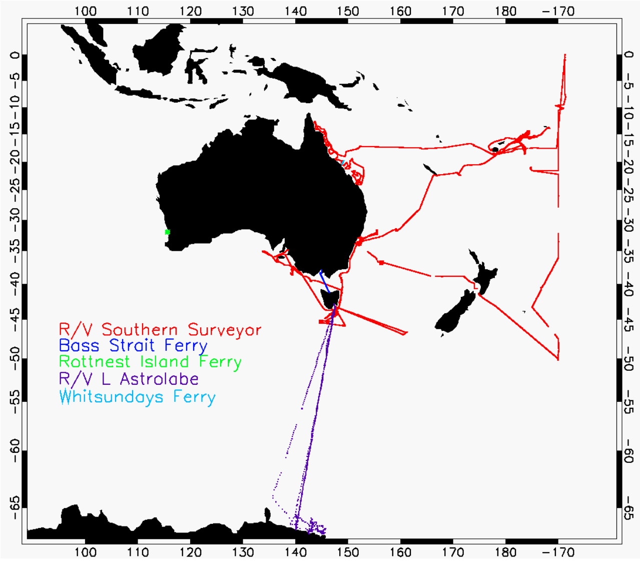

Figure 2. Locations of IMOS ship SST observations to 29 April 2009 from RV Southern Surveyor (red), Spirit of Tasmania II Ferry (indigo), MV SeaFlyte (Rottnest Island Ferry) (green), RV L'Astrolabe (purple) and MV Fantasea Wonder (Whitsundays Ferry) (Aqua).

3. QUALITY CONTROL AND VALIDATION

The IMOS ship SST quality control (QC) procedure is a fully automated process, and is based on the system developed by the Center for Ocean-Atmospheric Prediction Studies (COAPS), Florida State University, for the Shipboard Automated Meteorological and Oceanographic System Initiative (SAMOS: http://samos.coaps.fsu.edu), with small differences due to varying IMOS/Bureau requirements. The QC system flags data that fail to pass the following QC tests, in order of application:

- (i) Verify the existence of time, latitude and longitude data for every record;
- (ii) Flag data that are not within physically possible bounds;
- (iii) Flag non-sequential and/or duplicate times;
- (iv) Flag positions where the vessel is over land;
- (v) Flag vessel speeds that are unrealistic;
- (vi) Flag data that exceeds 3°C above/below the Bureau's most recent operational SST analysis (blended from satellite and in situ SST data either one or two days old).

Once any datum's flag is changed, it will not be altered further by any subsequent test.

In order to assess the accuracy of the largest of the initial IMOS ship SST datasets, the QC'd SBE 3 SST observations from the RV Southern Surveyor were compared against nighttime SST observations from the highly accurate Advanced Along Track Scanning Radiometer (AATSR) on the EnviSat polar-orbiting satellite for the period 1 March to 31 August 2008 (Table 2). For the study, the 10 arcmin averaged, Meteo Product skin (~10 µm depth) SST observations from AATSR were converted to subskin SST using the Donlon et al. (2002) empirical cool skin correction algorithms and the Bureau's operational, 0.375° resolution, Numerical Weather Prediction model surface wind fields. The same night-time, AATSR subskin SST observations were compared with collocated, night-time, subskin SST observations from drifting and moored buoys over a similar region and six month period. The results of the three-way comparison indicated that the RV Southern Surveyor SBE 3 SST observations were an average 0.1°C warmer than buoy SSTs, and the SBE 3 SSTs exhibited 0.1°C lower standard deviation error than buoys when compared with AATSR SSTs. A similar study of the SBE 48 SST from MV Spirit of Tasmania II showed that over the period 10 December 2008 to 29 April 2009 the ship SST measurements were an average 0.14°C warmer than the AATSR subskin SSTs with a standard deviation of 0.30°C. The AATSR subskin SSTs over the same period were 0.02°C cooler than night-time buoy SST with a standard deviation of 0.38°C. Both the RV Southern Surveyor and MV Spirit of Tasmania II SST data streams should therefore prove very useful for validating/calibrating satellite SST.

4. HULL-CONTACT SENSOR TESTS

Two SBE 48 hull-contact temperature sensors have been tested in the Bureau's sensor calibration lab and one installed on the RV Southern Surveyor (Figure 3) for comparison tests with the SBE 3 calibrated thermistor installed in the thermosalinograph water intake. The SBE 48 was attached using magnets to the exterior steel hull at a depth of approximately 3 m below the water line and approximately 20 m aft of the bow. The SBE 48 was located approximately 3.5 m to port of the SBE 3 sensor and approximately 2 m higher up on the hull plating. Thermal contact between the SBE 48 heat sink and the ship's hull was achieved by the use of contact grease with a high thermal conductivity. A two dimensional thermal analysis of the installation by CSIRO indicated that the ratio of the face area of the SBE 48 thermal sink in relation to the thickness of the hull affects the conduction of heat to the SBE 48 temperature sensor from the adjacent hull region. It was proposed that the effect of the hull thickness (in this case 0.025 m) can be reduced by placing insulating material around the SBE 48 housing extending to a distance from the sensor element of at least 10 times the hull thickness.

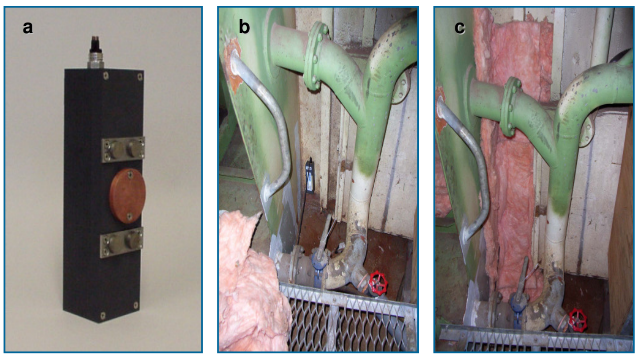

Figure 3. The Sea Bird SBE 48 Hull Contact Temperature Sensor (a) showing the thermal sink (red disk) and four magnets, (b) installed against the exterior hull of the RV Southern Surveyor next to the grey water tank, and (c) covered with "Pink Batt" ceiling insulation.

The SBE 48 sensor housing and surrounding hull was insulated on 27 July 2008 at 0300 UTC using three layers of Bradford "Pink Batt" R2.5 ceiling insulation covering the sensor and surrounding hull to an approximate thickness of 270 mm and a minimum distance of 0.25 m from the sensor (Figure 3(c)). The results presented here are for the cruise commencing 24 July 2008 at 16.6°S, 145.8°E and finishing on 11 August 2008 at 23.8°S, 151.6°E. Prior to insulation (for the period 24 to 27 July 2008), the SBE 48 temperature was on average 0.28°C warmer than the SBE 3 temperature, with a standard deviation of 0.14°C. After insulation (for the period 27 July to 11 August 2008), the average offset was 0.19°C with a standard deviation of 0.12°C. The majority of the error occurred during periods when the water mass exhibited sharp thermal gradients. In water masses with low thermal gradients the average offset was approximately 0.15°C.

An example of the sensor comparison after insulation is presented in Figure 4 for the transect between 2 August 2008 00 UTC, 18.4°S, 147.8°E and 6 August 2008 00 UTC, 21.8°S, 152.9°E. The SBE 48 temperatures exhibited less short term fluctuation compared to the thermosalinograph water intake SBE 3 temperatures, as expected from measurements of SST integrated over a ship's hull.

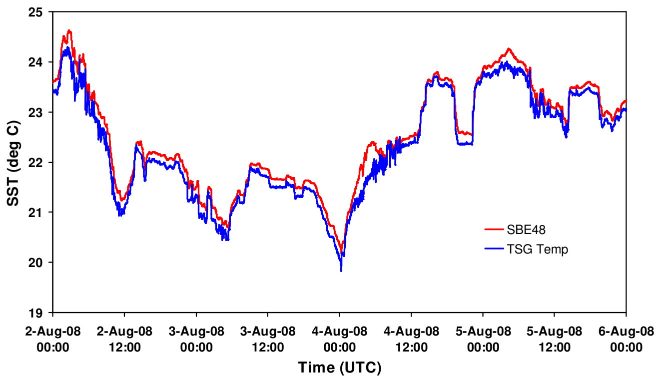

Figure 4. Example of the RV Southern Surveyor SST sensor comparison results after insulation of the hull-contact sensor. The SBE 48 hull-contact temperatures are shown in red and the SBE 3 temperatures in blue.

Although the RV Southern Surveyor has a particularly thick steel hull of 25 mm, and the positioning of the SBE 48 surrounded by black water pipes and hull ribs was far from ideal, this study indicates that the SBE 48 is capable of providing ship SST observations of sufficiently accurate for satellite SST validation and possible calibration. If the SBE 48 has good thermal contact with the hull, is positioned well below the water line away from on-ship heat sources, and the sensor and surrounding hull is sufficiently insulated from the interior ship's atmosphere, the hull-contact sensor should provide a bulk sea surface temperature measurement of comparable accuracy to thermosalinograph water intake temperatures, albeit possibly biased slightly warm. Further comparison tests are planned for the SBE 48 sensor on vessels with thinner hulls and wider spaced hull ribs.

5. CONCLUSIONS

During 2008, as part of the IMOS project, new streams of high quality, near real-time, SST observations from four vessels in the Australian region have become available on the GTS and the IMOS data portal. During 2009 and 2010, new data streams from a further nine Australian vessels will be added to the project.

Initial assessment of data from two of the temperature sensors (SBE 3 on RV Southern Surveyor and SBE 48 on MV Spirit of Tasmania II) using a three-way comparison between ship SST, AATSR ATS_MET_2P SST and drifting and moored buoy SST indicates comparable or lower errors than those available from drifting buoys. Although further tests are required, it would appear that the new IMOS ship SST data streams are suitable for calibration and/or validation of satellite SST observations, thereby considerably increasing the spatial and temporal coverage of available validation data.

6. ACKNOWLEDGMENTS

The authors would like to thank Werenfrid Wimmer and Margaret Yelland (National Oceanographic Centre, Southampton) and Bill Emery (University of Colorado) for advice on hull-contact sensors; Shaun Smith (Florida State University) for documentation and software; and Martin Buggellen, Peter Kernabone, Stephen Thomas (CSIRO), Drew Mills (CSIRO) and Michael Mahoney (AIMS) for sensor installations. In particular, the authors acknowledge the support of the owners and crews of the Australian ships of opportunity, who make such an important contribution to operational marine meteorology, oceanography and research. The European Space Agency supplied the AATSR Meteo Product (ATS_MET_2P) files used in this study.

The work was supported by the Integrated Marine Observing System (IMOS) - an initiative of the Australian Government being conducted as part of the National Collaborative Research Infrastructure Strategy.

7. REFERENCES

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Vessel	Callsign	Data Start	SST Sensor	Sensor Depth (m)	Data Interval (minutes)	Data Uploaded to GTS
RV Southern Surveyor	VLHJ	4 Feb 2008	SBE 3	5.5	1 (averaged)	6 hourly (Trackobs)
MV SeaFlyte (Rottnest Is Ferry)	VHW5167	30 Apr 2008	SBE 38	0.1 - 0.5	1 (averaged)	daily (Trackobs)
RV L'Astrolabe	FHZI	30 Dec 2008	SBE 38	4	60 (instantaneous)	hourly
RSV Aurora Australis	VNAA		-	5	1 (averaged)	TBD (Trackobs)
MV Spirit of Tasmania II	VNSZ	10 Dec 2008	SBE 48	1.5 - 2	60 (instantaneous)	hourly
MV Reef Voyager (Heron Is Ferry)	-		TSG	-	TBD	TBD (Trackobs)
MV Fantasea Wonder (Whitsundays Ferry)	VJQ7467	5 Nov 2008	EI4000.4ZL (radiometer)	0	1 (averaged)	TBD
			AD590	1.4	1 (instantaneous)	Daily (Trackobs)
MV Stadacona	C6FS9		SBE 48		180 (instantaneous)	3 hourly
MV Portland	VNAH		SBE 48		180 (instantaneous)	3 hourly
MV Pacific Sun	MNPJ3		SBE 48		180 (instantaneous)	3 hourly
MV Highland Chief	VROB		SBE 48		180 (instantaneous)	3 hourly
MV Iron Yandi	VNVR		SBE 48		180 (instantaneous)	3 hourly
MV ANL Yarunga	V2BJ5		SBE 48		180 (instantaneous)	3 hourly

Table 1. Details of vessels either currently providing or planned to supply QC'd SST data streams to IMOS and the GTS.

Observations collocated with nighttime AATSR SSTsubskin data	Matchup Period (hours)	Mean (°C)	St. Dev. (°C)	Number Matchups
Southern Surveyor SST	1	-0.19	0.15	519
Southern Surveyor SST	3	-0.28	0.19	1651
Southern Surveyor SST	24	-0.19	0.22	7739
Buoy SST	24	-0.08	0.32	2214

Table 2. Mean and standard deviation of satellite observations of nighttime AATSR (ATS_MET_2P) subskin SST minus collocated observations of (a) SST (at ~5.5 m depth) from the RV Southern Surveyor and (b) nighttime subskin SST observations from drifting and moored buoys over the region 60°E – 170°W, 20°N - 80°S for the period 1 March to 31 August 2008. Observations are considered "matched" if measured within same UTC calendar day and matchup period and centres of observations are separated by no more than half the resolution of the AATSR SST observation (1/12° latitude, 1/12° longitude).