

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

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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).

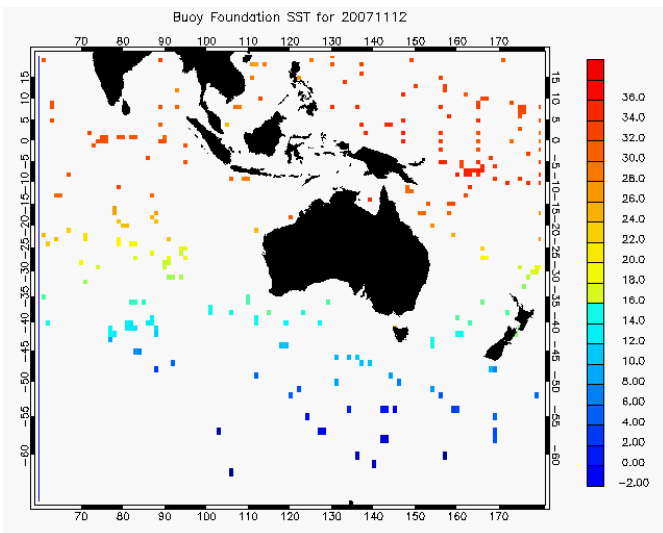


Figure 1. Drifting and moored buoy SST observations from the GTS for 12 November 2007 over the region 20°N to 65°S, 60°E to 180°E.

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.

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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 SBE48), supplying high-quality bulk SST observations every one to three hours. There are also four 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), and Victoria Environmental Protection Authority (Bass Strait Ferry Spirit of Tasmania I). 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, fourteen 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 during 2008 to the IMOS data portal and the GTS.

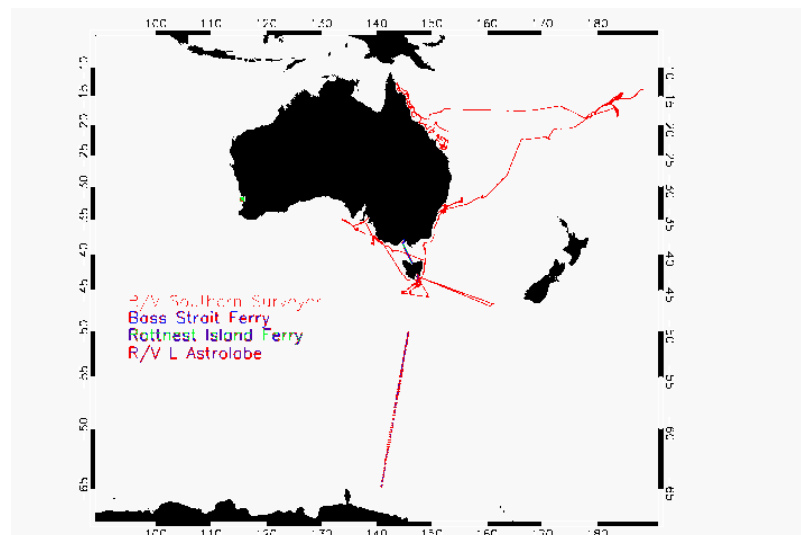


Figure 2. Locations of IMOS ship SST observations for 2008 from RV Southern Surveyor (red), Spirit of Tasmania II Ferry (indigo), Rottnest Island Ferry (green) and RV L'Astrolabe (purple).

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 thermosalinograph 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 nighttime, AATSR subskin SST observations were compared with collocated, nighttime, subskin SST observations from drifting and moored buoys over a similar region and matched within a 1, 3 and 24 hour period. The results of the three-way comparison indicated that the RV Southern Surveyor SBE21 SST observations were an average 0.1°C warmer than buoy SSTs, and the thermosalinograph SSTs exhibited 0.1°C lower standard deviation error than buoys when compared with AATSR SSTs. The RV Southern Surveyor SST data stream should therefore prove very useful for validating/calibrating satellite SST. Once sufficient SST data sets are collected for Spirit of Tasmania II, L'Astrolabe and the other vessels listed in Table 1, the accuracy of these IMOS data streams will be similarly assessed using a three-way intercomparison.

4. HULL-CONTACT SENSOR TESTS

Two SBE48 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 SBE21 calibrated thermistor installed in the thermosalinograph water intake pipe. The SBE48 was attached using magnets to the exterior steel hull at a depth of approximately 2 m below the water line and approximately 20 m aft of the bow. Thermal contact between the SBE48 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 SBE48 thermal sink in relation to the thickness of the hull affects the

conduction of heat to the SBE48 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 SBE48 housing extending to a distance from the sensor element of at least 10 times the hull thickness.

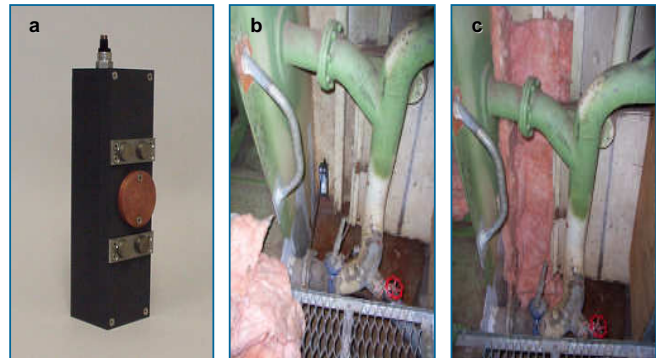


Figure 3. The Sea Bird SBE48 Hull Contact Temperature Sensor (a) showing the thermal sink (red disk) and four magnets, (b) installed against the exterior hull of the RV Southern Surveyor in the bilge adjacent to the water intake to the thermosalinograph, and (c) covered with “Pink Batt” ceiling insulation.

The SBE48 sensor housing and surrounding hull was insulated on 27 July 2008 at 0300 UTC using “Pink Batt” ceiling insulation covering the sensor and surrounding hull to 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 SBE48 temperature was on average 0.28°C warmer than the SBE21 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 SBE48 temperatures exhibited less short term fluctuation compared to the thermosalinograph water intake temperatures, as expected from measurements of SST integrated over a ship's hull.

Although the RV Southern Surveyor has a particularly thick steel hull of 25 mm, and the positioning of the SBE48 surrounded by sewerage pipes and hull ribs was far from ideal, this study indicates that the SBE48 is capable of providing ship SST observations of sufficient accuracy for satellite SST validation and possible calibration. If the SBE48 has good thermal contact with the hull, is positioned well below the water line away from on-ship heat sources, and 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 temperatures, albeit possibly biased slightly warm. Further comparison tests are planned for the SBE48 sensor on vessels with thinner hulls and wider spaced hull ribs.

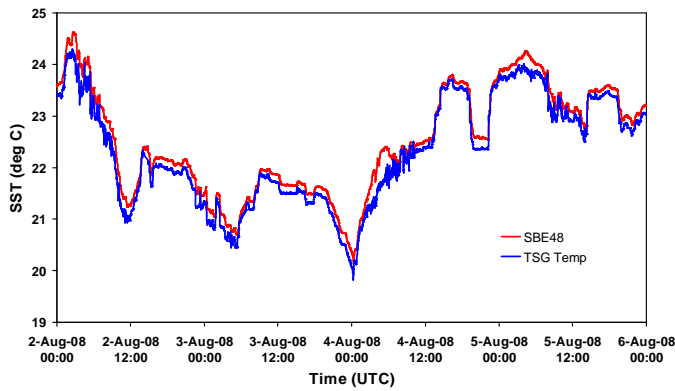


Figure 4. Example of the RV Southern Surveyor SST sensor comparison results after insulation of the hull-contact sensor. The SBE48 hull-contact temperatures are shown in red and the SBE21 temperatures in blue.

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 ten Australian vessels will be added to the project.

Initial assessment of data from two of the temperature sensors (SBE21 and SBE48) 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

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7. REFERENCES

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- Donlon, C. J., P. Minnett, C. Gentemann, T. J. Nightingale, I. J. Barton, B. Ward and J. Murray, 2002: Towards improved validation of satellite sea surface skin temperature measurements for Climate Research, *J. Climate*, **15**, No. 4, 353-369.

<i>Vessel</i>	<i>Callsign</i>	<i>Data Start</i>	<i>SST Sensor</i>	<i>Sensor Depth (m)</i>	<i>Data Interval (minutes)</i>	<i>Data Uploaded to GTS</i>
RV Southern Surveyor	VLHJ	Feb 2008	SBE21	5.5	1 (averaged)	6 hourly (Trackobs)
MV SeaFlyte (Rottnest Is Ferry)	VHW5167	Sep 2008	Pt104	0.1 - 0.5	1 (averaged)	daily (Trackobs)
RV L'Astrolabe	FHZI	Dec 2008	SBE38	4	60 (instantaneous)	hourly
RSV Aurora Australis	VNAA		SBE21	5	1 (averaged)	TBD (Trackobs)
MV Spirit of Tasmania I	VLST	-	SBE38	-	1 (averaged)	TBD (Trackobs)
MV Spirit of Tasmania II	VNSZ	Dec 2008	SBE48	1.5 - 2	60 (instantaneous)	hourly
MV Reef Voyager (Heron Is Ferry)	-		TSG	-	TBD	TBD (Trackobs)
MV Fantasea (Whitsundays Ferry)	VJQ7467		EI4000.4ZL (radiometer)	0	1 (averaged)	TBD
			AD590	1.4	1 (instantaneous)	Daily (Trackobs)
MV Stadacona	C6FS9		SBE48		180 (instantaneous)	3 hourly
MV Portland	VNAH		SBE48		180 (instantaneous)	3 hourly
MV Pacific Sun	MNPJ3		SBE48		180 (instantaneous)	3 hourly
MV Kiribati Chief	VR0B		SBE48		180 (instantaneous)	3 hourly
MV Iron Yandi	VNVR		SBE48		180 (instantaneous)	3 hourly
MV ANL Yarunga	V2BJ5		SBE48		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.

<i>Observations collocated with nighttime AATSR SSTsubskin data</i>	<i>Matchup Period (hours)</i>	<i>Mean (°C)</i>	<i>St. Dev. (°C)</i>	<i>Number Matchups</i>
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).

