INGESTING VIIRS SST INTO THE BUREAU OF METEOROLOGY'S OPERATIONAL SST ANALYSES

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Abstract

We describe the method used to ingest Visible Infrared Imaging Radiometer Suite sea surface temperature data into the Australian Bureau of Meteorology's operational daily temperature analyses and demonstrate the effect on accuracy and quality of these analyses.

1. Introduction

Since 2006, the Bureau of Meteorology (BoM) has produced daily optimally interpolated (OI) foundation sea surface temperature (SST) analyses over the Australian region and global domain. The Regional Australian Multi-Sensor SST Analysis (RAMSSA: Beggs et al., 2011) provides boundary conditions for the BoM's regional numerical weather prediction (NWP) models (ACCESS-R2 and ACCESS-C3), while the Global Australian Multi-Sensor SST Analysis (GAMSSA: Zhong and Beggs, 2008) provides boundary conditions for global NWP models (ACCESS-G3 and ACCESS-TC) and initial conditions for seasonal prediction models (POAMAv2 and ACCESS-S2). Both analyses provide SST products to forecasters and the general public (http://www.bom.gov.au/marine/sst.shtml, Figure 1). In addition, GAMSSA contributes to the GHRSST Multi-Product Ensemble (http://ghrsst-pp.metoffice.gov.uk/ostia-website/gmpe-monitoring.html).

The RAMSSA and GAMSSA GHRSST Data Specification v2.0 format level 4 (L4) files (GHRSST Science Team, 2012) from 2006 to present are publicly disseminated via NASA/JPL's PO.DAAC (https://podaac.jpl.nasa.gov) and the Australian Ocean Data Network (AODN: https://portal.aodn.org.au/). The GHRSST-format level 2 pre-processed (L2P) products, used as inputs, are derived from satellite infrared sensors, such as the Advanced Very High Resolution Radiometer (AVHRR), and microwave sensors, such as the Advanced Microwave Scanning Radiometer 2 (AMSR2).

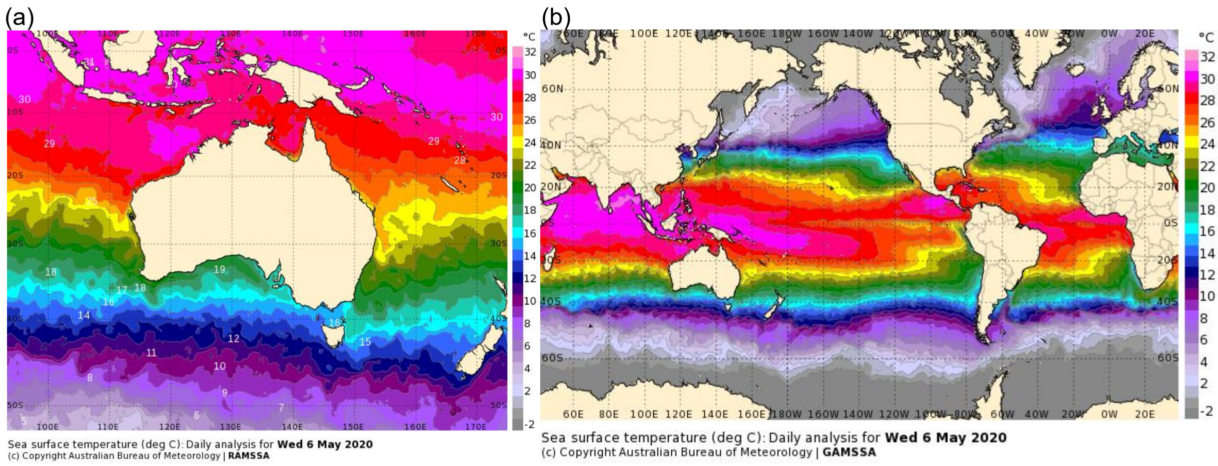

Figure 1: Example of foundation SST for 6th May 2020 from BoM Daily L4 analyses (a) RAMSSA and (b) GAMSSA, formed from NAVOCEANO GAC AVHRR L2P (MetOp-A, MetOp-B), JAXA AMSR-2 L2P, ACSPO VIIRS L3U (Suomi-NPP, NOAA-20) SST and in situ SST (ships, buoys).

From 2018 to early 2020, we experimented with ingesting NOAA's Advanced Clear Sky Processor for Ocean (ACSPO) 0.02° Suomi-NPP and NOAA-20 VIIRS L3U SST data (Petrenko et al., 2010; 2014) into near real-time 1/4° GAMSSA and 1/12° RAMSSA SST analyses. Operational RAMSSA ingested Suomi-NPP and NOAA-20 VIIRS data from 17th November 2019 and operational GAMSSA from 29th April 2020. The VIIRS data from these two afternoon-orbiting satellites complement the Global Area Coverage (GAC) AVHRR L2P SST data from the morning-orbiting MetOp-A and MetOp-B satellites, supplied by the US Naval Oceanographic

Office (NAVO), and the AMSR-2 L2P SST data from the afternoon-orbiting GCOM-W satellite, provided by the Japan Aerospace Exploration Agency (JAXA).

2. RAMSSA/GAMSSA System Configuration Changes

The BoM routinely downloads real-time ACSPO VIIRS L3U files from NOAA's Production Distribution and Access portal. Night-only VIIRS L3U (quality level 5, sses_bias subtracted) SST depth data are collated to daily 1/4° and 1/12° L3C SSTfnd composites for ingestion into the GAMSSA and RAMSSA analyses. Data are further thinned by striding to 1/2° (GAMSSA) and 1/3° (RAMSSA). Thinning the VIIRS data in this manner is necessary, as analysis quality decreases if the density of the observation dataset is too large and the error correlations are neglected (Brasnett and Surcel Colan, 2016). The satellite retrievals (particularly VIIRS) are thinned prior to assimilation into the Canadian Meteorological Centre (CMC) OI analysis so they do not receive undue weight in the analysis (Brasnett and Surcel Colan, 2016). The observation correlation length scale of the VIIRS L3C data ingested into test RAMSSA is longer than either the 9 km AVHRR or 25 km AMSR2 datasets, and it was found that ingesting VIIRS gridded to 9 km caused the RAMSSA OI analysis to produce spurious SST artefacts.

In order to reduce innovation standard deviation compared with drifting and tropical moored buoy SSTfnd, the background correlation length scales were increased from 20 km to 50 km for operational RAMSSA on 17th November 2019, and from 50 km to 80 km for operational GAMSSA on 29th April 2020 (see Table 1). The background field correlation length scale effectively gives the radius of influence of an observation to changes in the background field. Any feature smaller than the observation correlation length scale in extent and within the observation correlation time scale in time is treated by the OI analysis as noise. Observations separated by less than the observation correlation length scale and the observation correlation time scale do not have independent errors.

	Old GAMSSA	**New GAMSSA**	**Old RAMSSA**	**New RAMSSA**
Satellite SST Inputs	NAVO GAC AVHRR (MA, MB) JAXA AMSR-2	NAVO GAC AVHRR (MA, MB) JAXA AMSR-2 ACSPO VIIRS L3U (NPP, N20)	NAVO GAC AVHRR (MA, MB) JAXA AMSR-2 ACSPO VIIRS L3U (NPP, N20)	NAVO GAC AVHRR (MA, MB) JAXA AMSR-2 ACSPO VIIRS L3U (NPP, N20)
In situ SST Inputs	Buoys and Ships (from GTS)	Buoys and Ships (from GTS)	Buoys, ships, Argo, XBT, CTD (GTS)	Buoys, ships, Argo, XBT, CTD (GTS)
Sea-ice Inputs	NCEP 1/12° sea ice analysis (Grumbine, 1996)	NCEP 1/12° sea ice analysis (Grumbine, 1996)	NCEP 1/12° sea ice analysis (Grumbine, 1996)	NCEP 1/12° sea ice analysis (Grumbine, 1996)
10 m Wind speed Inputs	ACCESS-G2 3-hourly 2°	ACCESS-G3 3-hourly 2°	ACCESS-R2 hourly 1°	ACCESS-G3 hourly 1°
Obs. Correlation Length Scale (km)	20	20	12	12
BG Correlation Length Scale (km)	50	80	50	50
Obs Estimated STD (OBSESD)	Calculated from 1-31 Oct 2014 satellite SST vs Buoy statistics	Calculated from 1-31 Dec 2019 satellite SST vs Buoy statistics	Calculated from 16 Mar – 4 Apr 2017 satellite SST vs Buoy statistics	Calculated from 1-31 Dec 2019 satellite SST vs Buoy Statistics
Background Field	Previous day's GAMSSA plus Reynolds and Smith (1994) climatology	Previous day's GAMSSA plus BoM Global Weekly 1° SST (Smith et al., 1999)	Previous day's RAMSSA plus BoM Global Weekly 1° SST (Smith et al., 1999)	Previous day's RAMSSA plus BoM Global Weekly 1° SST (Smith et al., 1999)

Table 1: The configuration of the old and new RAMSSA and GAMSSA systems. Operational RAMSSA and GAMSSA were updated to the new configurations on 29th April 2020. Changes are highlighted in red.

Other significant changes made to both systems on 29th April 2020 included updating the observation estimated standard deviation (OBSESD) for each input data stream (shown in Table 2) and updating

GAMSSA's background field to relax to the previous week's BoM Global Weekly 1 degree SST analysis (Smith et al., 1999) rather than the Reynolds and Smith (1994) 1961-1990 SST climatology. An additional change to experimental GAMSSA is that the background field is now formed from a weighted combination of the previous day's GAMSSA analysis and the BoM Global Weekly 1° SSTblend analysis.

Sensor	**Matchups**	**Bias (K)**	**STD (K)**	**OBSESD (K)**
AVHRR (MetOp-A)	14315	0.079	0.457	0.54
AVHRR (MetOp-B)	12774	0.052	0.496	0.55
AMSR2 (GCOM-W)	134141	0.162	0.536	0.70
VIIRS (Suomi-NPP)	4113	-0.037	0.363	0.40
VIIRS (NOAA-20)	4276	-0.019	0.362	0.38

Table 2: Matchup bias and standard deviation (STD) statistics for each satellite SSTfnd data stream ingested into RAMSSA compared with drifting and tropical moored buoy SSTfnd observations for 1st to 31st December 2019 over the RAMSSA domain (60°E to 190°E, 70°S to 20°N). Data are matched if within the same 1/12° lat x 1/12° lon RAMSSA grid cell and the same UTC date. The Observation Estimated Standard Deviation (OBSESD) is an estimate of the total expected error and is calculated as STD + | bias | (Beggs et al., 2011). It is used to give a relative weight to each input data stream. OBSESD for buoys is set to 0.4 K, and ships is set to 1.2 K.

3 Impact of ingesting VIIRS data into RAMSSA and GAMSSA

The update to operational RAMSSA on 17th November 2019 to ingest VIIRS data had little positive impact on innovation statistics compared with collocated drifting buoys and moorings, with a reduction in innovation STD cf buoys of 0.002 K in experimental RAMSSA between 17th October and 13th November 2019. However, updating the OBSESD values on 29th April 2020 with low values assigned to VIIRS data, giving them higher weight in the OI analysis (Table 2), reduced the RAMSSA innovation STD by a further 0.016 K (Table 3).

Analysis	**Global Matchups**	**Global Bias (K)**	**Global STD (K)**	**Australian Matchups**	**Australian Bias (K)**	**Australian STD (K)**
Operational RAMSSA (inc NPP/N20 VIIRS and old OBSESDs)				85189	0.127	0.670
Experimental RAMSSA (inc NPP/N20 VIIRS and new OBSESDs)				88782	0.112	0.654
Operational GAMSSA	214165	0.056	0.647			
Experimental GAMSSA (inc NPP/N20 VIIRS)	214082	0.063	0.662			
CMC 0.1deg (inc NPP VIIRS)	343463	0.037	0.627	74826	0.061	0.627

Table 3: Innovation statistics for each Analysis SSTfnd (Date) minus drifting and tropical moored buoy SSTfnd (Date + 1 day) observations for 13th February to 28th April 2020 over the global domain and RAMSSA domain (60°E to 190°E, 70°S to 20°N).

The update to GAMSSA on 29th April 2020 resulted in a reduction of ~0.04 K in robust standard deviation (RSD) compared with independent Argo SST (Figure 2(a)) and ~0.08 K reduction in RSD compared with GMPE (Figure 2(b)). The RSD of 25 km GAMSSA minus GMPE is now comparable to that of 10 km CMC, 5 km UKMO OSTIA or 5 km NOAA Geo-Polar Blend minus GMPE.

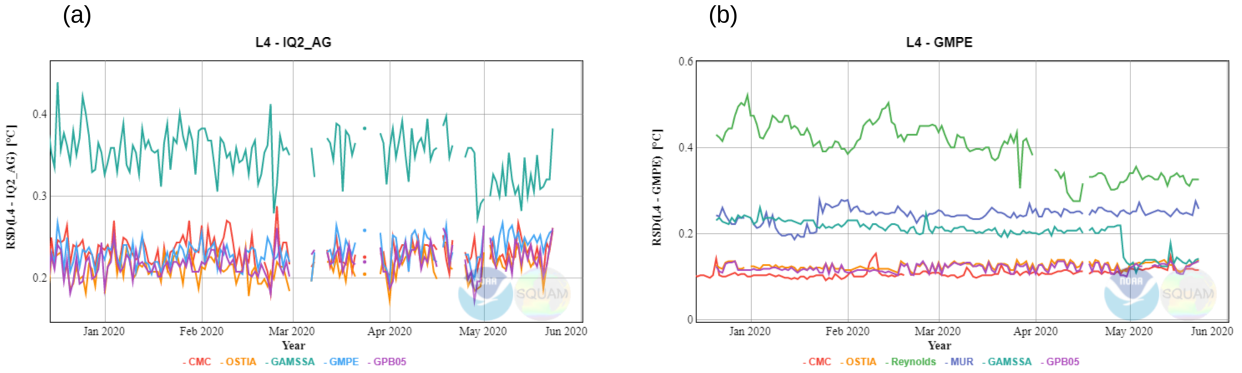

Figure 2: Robust Standard Deviation of various global SST analyses (L4) minus (a) Argo SST, and (b) 25 km GMPE (source https://www.star.nesdis.noaa.gov/socd/sst/squam/analysis/l4/, accessed 27th May 2020).

Examples of the old (operational) and new (experimental) RAMSSA and GAMSSA SST maps are shown in Figure 3(a)-(d). For comparison, the CMC's 0.1° daily foundation SST analysis (Brasnett and Surcel Colan, 2016) is also shown (Figure 3(e)).

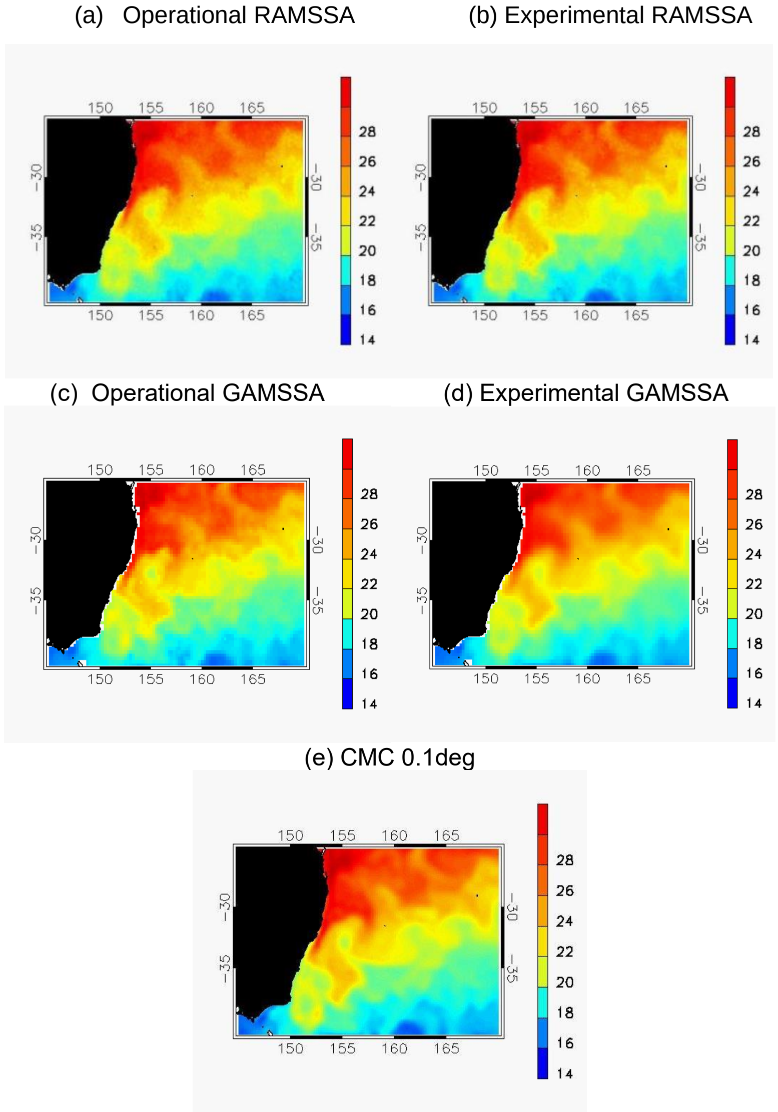

Figure 3: Example of foundation SST in the East Australian Current for 1st April 2020 from daily Multi-sensor L4 analyses (a) operational RAMSSA, (b) experimental RAMSSA (ingesting VIIRS L3U SST), (c) operational GAMSSA, (d) experimental GAMSSA (ingesting VIIRS L3U SST) and (e) CMC0.1deg (ingesting VIIRS L3U SST) (Brasnett and Surcel Colan, 2016).

5. Future work

On 6th July 2020, 4 km resolution NAVO version 2 (v2) MetOp-B GAC AVHRR L2P data replaced 9 km resolution NAVO v1 MetOp-A GAC AVHRR L2P SST in operational RAMSSA and GAMSSA systems. The upgrade resulted in a further decrease in RSD of GAMSSA minus GMPE of around 0.01 K but no change in RSD of GAMSSA minus Argo SST. We plan to ingest NAVO's v2 MetOp-C GAC AVHRR L2P data by the end of 2020.

6. References

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