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A fine spatial-scale sea surface temperature atlas of the Australian regional seas (SSTAARS): Seasonal variability and trends around Australasia and New Zealand revisited

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ABSTRACT

We use 25 years of Advanced Very High-Resolution Radiometer (AVHRR) data from NOAA Polar Orbiting Environmental Satellites received by six Australian and two Antarctic reception stations to construct a detailed climatology of sea surface temperature (SST) around Australasia. The data have been processed following international GHRSST protocols to help reduce instrument bias using *in situ* data, with only night-time nearly cloud-free data used to reduce diurnal bias and cloud contamination. A pixel-wise climatology (with four annual sinusoids) and linear trend are fit to the data using a robust technique and monthly non-seasonal percentiles derived. The resulting Atlas, known as the SST Atlas of Australian Regional Seas (SSTAARS), has a spatial resolution of ~2 km and thus reveals unprecedented detail of regional oceanographic phenomena, including tidally-driven entrainment cooling over shelves and reef flats, wind-driven upwelling, shelf winter water fronts, cold river plumes, the footprint of the seasonal boundary current flows and standing mesoscale features in the major offshore currents. The Atlas (and associated statistics) will provide a benchmark for high-resolution ocean modelers and be a resource for ecosystem studies where temperatures, and their extremes, impact on ocean chemistry, species ranges and distribution.

1. Introduction

Sea surface temperature (SST) is a vital parameter across a range of marine and climate sciences. SST strongly modulates air-sea fluxes and is thus linked to both ocean and atmospheric dynamics. It also is of great importance to the biodiversity (Tittensor et al., 2010) and biogeochemistry of the oceans as well as marine ecosystem dynamics. For example, on the Australian North West Shelf (NWS), annual and winter minimum SST control calcification rates for coral reefs and SST warming rates are changing the relationship strength between SST and calcification rates (Lough et al., 2016). Also, it is becoming more important to contextualize the spatial extent and severity of marine heatwaves such as the 2011 Ningaloo Niño (Feng et al., 2013), the record breaking warm event in the Tasman Sea during 2015/16 (Oliver et al., 2017), the recent mass coral bleaching event (Hughes et al., 2017), or more generally give insight into the framework proposed by Hobday et al. (2016). Hence there is a growing need to characterize regional climatological temperatures, their non-seasonal variability, and long-term trends.

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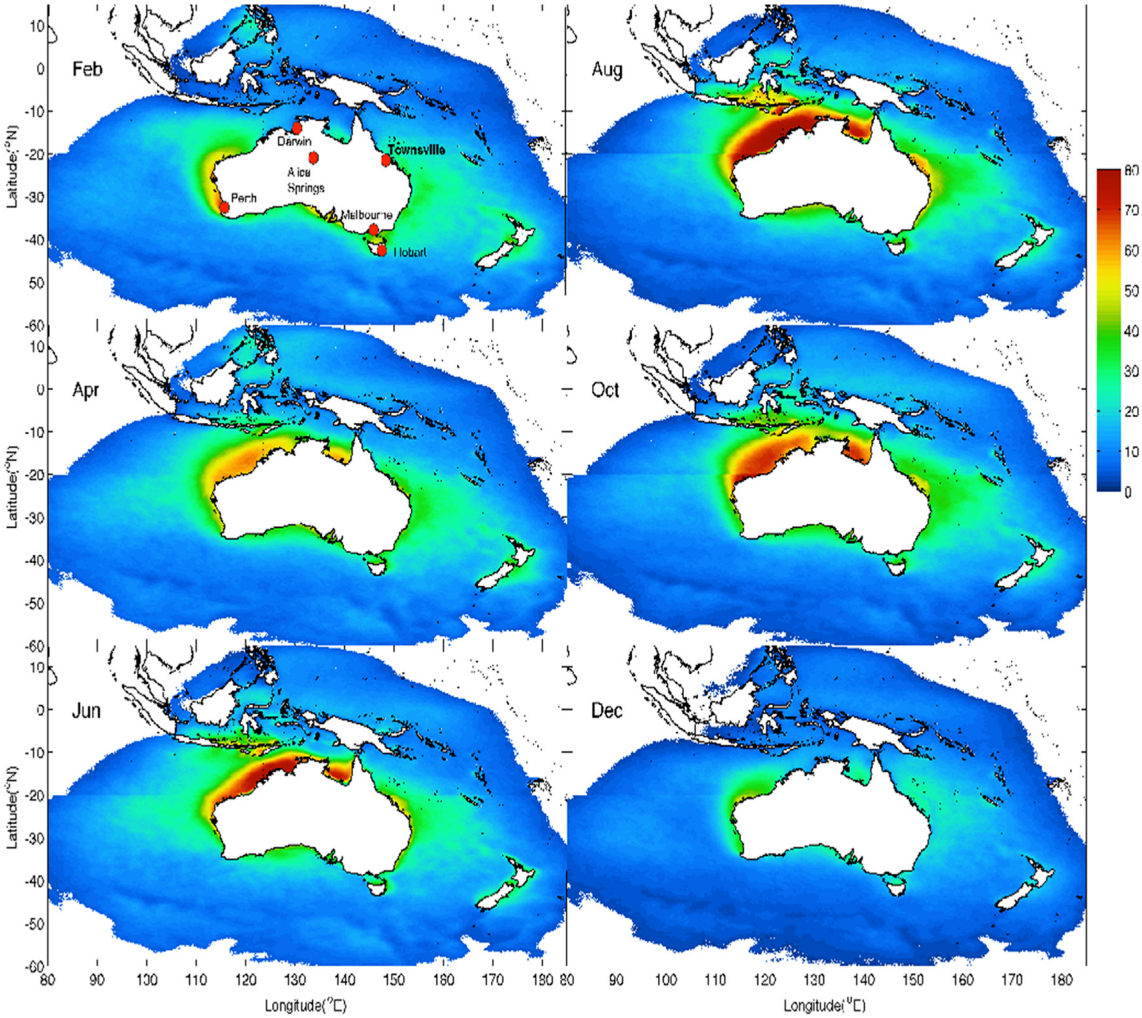

Fig. 1. The percentage of days of good observations in each 2 km pixel in each month over the IMOS SST archive used to make the Atlas. In the February panel, the locations of the Australian reception stations which provided data for the archive are marked.

Measurement of SST was revolutionised in 1981 with the launch of the first in the series of National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (NPOES) measuring Earth's emitted long-wave radiance from space using the Advanced Very High-Resolution Radiometer (AVHRR). Once corrected for the radiation emitted by the atmosphere, these space-borne radiometers could be used to map SST on a scale not previously possible.

Due to data transfer and on-satellite data storage limitations, only low spatial resolution (4.4 km at nadir) Global Area Coverage (GAC) AVHRR data were collected globally by these NPOES missions. This resulted in global gap-free (interpolated) SST products, covering years before 2002, being limited at best to 5 km resolution (Merchant et al., 2014, 2016; Roberts-Jones et al., 2012), with AVHRR SST data not available in regions obscured by cloud. To obtain higher resolution data, short duration on-board recording of Local Area Coverage (LAC), or real-time High Resolution Picture Transmission (HRPT) download during a satellite overpass was necessary, allowing data up to 1.1 km resolution at nadir to be acquired.

Based on an earlier lower resolution (4 km) and less comprehensive version of AVHRR data from around Australia (1993–2013), Foster et al. (2014) extracted the seasonal cycle and lower frequency SST variability. While their underpinning statistical model was quite different from that used below, a key difference is the lack of bias-removal in the underpinning AVHRR SST data. This resulted in large biases in the Foster et al. (2014) results compared to *in situ* data – both in the mean and trend fields.

Here we use accurately geo-located, 1.1 km resolution HRPT AVHRR data from reception stations distributed around Australia and Antarctica, which have been stitched together using data from all operational NPOES satellites, consistently reprocessed to SST, bias-corrected and composited over a 2 km × 2 km grid. These data provide a unique and high spatial resolution dataset back to 21 March 1992, made available through the Integrated Marine Observing System from the Australian Ocean Data Network (AODN) portal: https://portal.aodn.org.au/.

Part of the motivation for this work is that the base AVHRR data archive underpinning the SSTAARS is not easily compiled into time series and analysed, due both to their storage in very large single day composites, and the fact that coverage has temporal and spatial gaps due to clouds. This new climatological atlas provides a more accessible form, including percentiles to help quantify extremes, trends, and other