Measuring coastal upwelling using IMOS Himawari-8 and Multi-Sensor SST

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IMOS

1. Introduction

The Australian Bureau of Meteorology (BoM) have since 24th March 2016 produced operational, real-time, sea surface temperatures (SST) from the Himawari-8 geostationary satellite every 10 minutes at ~2 km spatial resolution (at nadir) on the native satellite ("GEO") projection. For ease of use, and to reduce spatial data gaps due to cloud, these native resolution SST data have been composited to hourly and daily night-only mean SST files, projected onto the rectangular Integrated Marine Observing System (IMOS) grid at 0.02° x 0.02°. The compositing of the Himawari-8 data on the IMOS grid presents opportunities for use alongside other IMOS "Multi-Sensor" SST products incorporating data from the Visible Infrared Imaging Radiometer Suite (VIIRS) and Advanced Very High-Resolution Radiometer (AVHRR) satellite sensors, to identify coastal upwelling events. The aim of this study is to determine if these new IMOS satellite products can be used to verify the efficacy of the Bureau's operational version 3.1 Ocean Modelling, Analysis and Prediction System (OceanMAPS) 10 km resolution model (BoM, 2017) in resolving and predicting coastal upwelling around the Australian coast. To assist the study, we also compare with an experimental Ensemble Optimal Interpolation (EnOI) 10 km resolution SST analysis ("GSAS") of the same satellite SST data assimilated into OceanMAPS, using the same Sakov (2014) assimilation system.

2. IMOS Himawari-8 Hourly and Daily L3C products

- Himawari-8 Level 2 Pre-processed (L2P) SSTskin produced by training Himawari-8 brightness temperatures to NOAA's ACSPO Suomi-NPP VIIRS L2P bias corrected SSTsubskin on a single day in 2015, followed by subtracting 0.17°C
- Quality level (QL) derived for each SST value based on proximity to cloud, identified using GEOCAT method (http://cimss.ssec.wisc.edu/csppgeo/geocat.html), and size of estimated error, estimated on "local brightness temperature variability"
- Possible quality levels are 0 to 5, with 5 identifying highest quality
- 10 minute Himawari-8 L2P SSTs composited to hourly Level 3 Collated (L3C) SST by selecting best quality, spatially and temporally consistent value
- Hourly SSTs composited to daily, night-time L3C SST by selecting best quality value, closest in time to local sunrise
- Hourly or daily L3C data on GEO projection mapped to IMOS 0.02° x 0.02° grid using sub-pixel area-weighted averaging of any overlapping pixels (Fig 1a-b)
- Night-time Himawari-8 L3C QL ≥ 4 SST from 1 Nov 2017 to 5 Sep 2018 over IMOS domain biased -0.4°C with 0.9°C standard deviation compared with collocated drifting and tropical moored buoys (BoM fv01 SST Validation Web Page)
- Himawari-8 L3C netCDF files from 1st October 2017 to present available on request

3. IMOS Multi-Sensor L3S products

- Twice-daily, 0.75 km resolution L2P SSTsubskin from Suomi-NPP satellite produced by NOAA OSPO by regressing VIIRS brightness temperatures against collocated drifting buoy SST at ~0.2 m depth, followed by compositing to global L3U files on 0.02° x 0.02° grid (https://coastwatch.noaa.gov/cw_html/sst_viirs.html)
- BoM composite VIIRS L3U SSTsubskin, quality level and error estimate data to daily day/night IMOS VIIRS L3C on IMOS grid and domain (Fig. 1c) (Griffin et al., 2017)
- Twice-daily, 1 - 4 km resolution L2P SSTsubskin from NOAA-18 and NOAA-19 satellites produced by regressing AVHRR brightness temperatures against regional drifting buoy SST at ~0.2 m depth (Griffin et al., 2017)
- SST error estimates obtained using matchups with buoy data, and quality levels defined from proximity to detected cloud (Griffin et al., 2017)
- AVHRR L2P SST mapped to single swath L3U and multiple swath L3C on 0.02° x 0.02° grid using sub-pixel area-weighted averaging of any overlapping pixels
- AVHRR L3C composited, based on quality and uncertainty estimates, with VIIRS L3C data to construct Multi-sensor L3S product (Fig. 1d) (Griffin et al., 2017)
- Night-time Multi-Sensor L3S QL ≥ 3 SST from 1 Nov 2017 to 5 Sep 2018 biased 0.0°C with 0.4°C standard deviation (BoM fv01 SST Validation Web Page)
- IMOS VIIRS L3C and Multi-Sensor L3S netCDF files from 2012 to present available via OPeNDAP on request

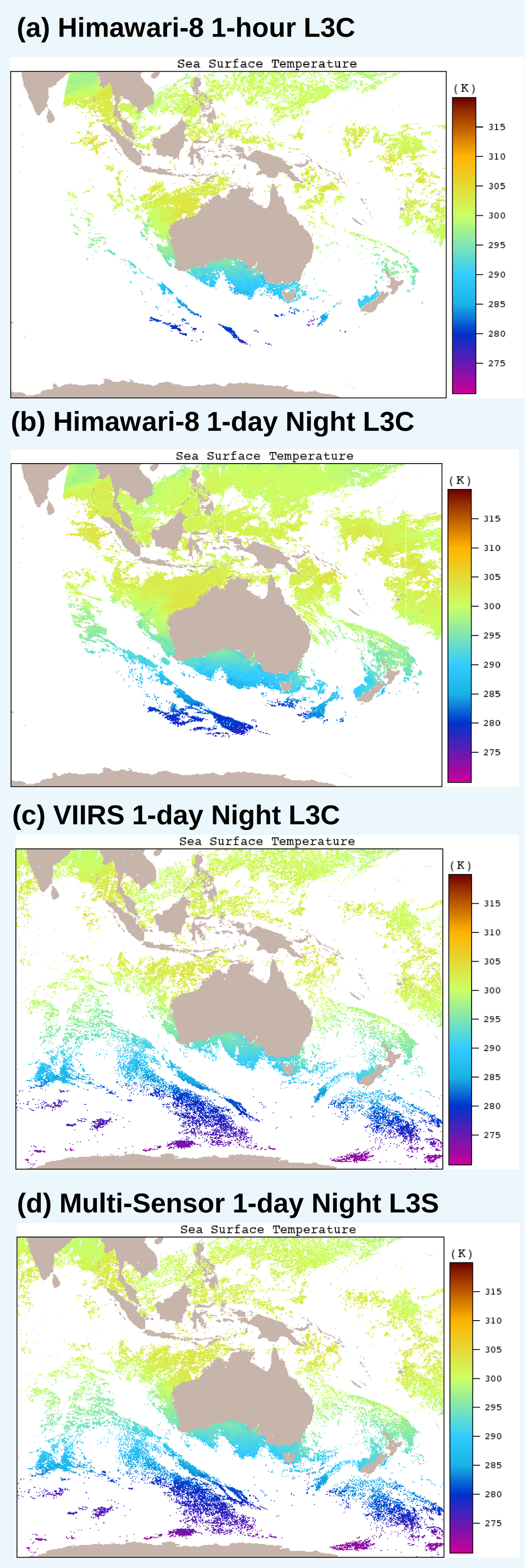


Fig 1. 2 km resolution skin SSTs with quality level 4 and 5 from (a) Himawari-8 Hourly L3C for 15:00 UTC, (b) Himawari-8 1-day night-only L3C, (c) NPP VIIRS 1-day night-only L3C, and (d) Multi-sensor 1-day night-only L3S files for 8th March 2018 over the entire IMOS domain (70°S to 20°N, 70°E to 190°E). Skin SST produced from subskin SST by subtracting 0.17°C.

4. Coastal upwelling case studies

A case study of three coastal upwelling events (Fig. 2, 3 and 4) indicates that SSTs from the Himawari-8 1-day night-time L3C compare well with IMOS VIIRS L3C and Multi-Sensor L3S, with VIIRS L3C missing some of the cold upwelling, likely due to over-strict cloud masking. OceanMAPS SST analyses and 24-hour forecasts have similar temperatures in the upwelling regions, but these are generally approximately 3°C warmer than the night-time composite SSTs in these cold upwelling regions. The GSAS EnOI SST analyses exhibit slightly colder SSTs in the upwelling regions, and appear to agree closer to the IMOS composite satellite SST data. However, the longer correlation length scales of the GSAS and OceanMAPS analysis systems, and coarser resolution SST inputs, result in smaller SST excursions in upwelling regions.

Fig 2. Maps of IMOS 1-day, night-time, 2 km resolution composite skin SSTs converted to drifting buoy depths (~0.2 m) by adding 0.17°C, from (a) Himawari-8 L3C (QL≥4), (b) VIIRS L3C (QL≥3) and (c) Multi-Sensor L3S (QL≥3), compared with 10 km resolution maps of (d) GSAS EnOI analysis L4 foundation SST, (e) OceanMAPS daily average analysis SST(2.5 m), and (f) OceanMAPS 24-hour daily average forecast SST(2.5 m), for 22nd November 2017 over South-Eastern Australia.

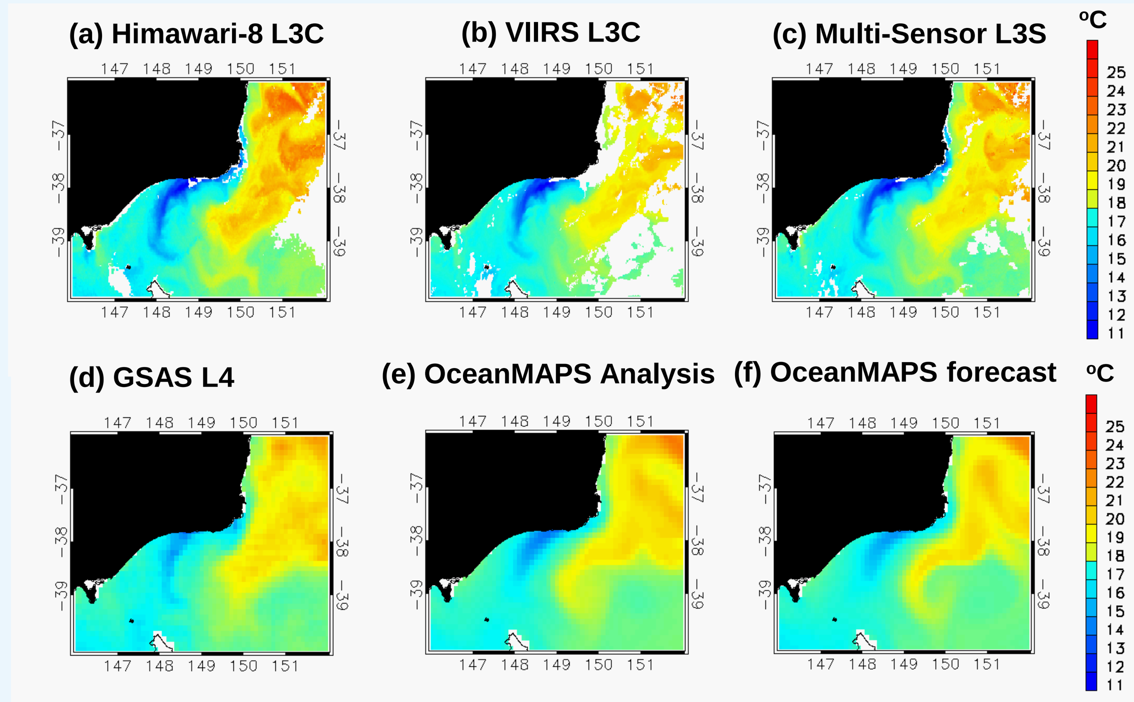


Fig 3. As for Fig. 2 but for 6th December 2017 over Northern New South Wales.

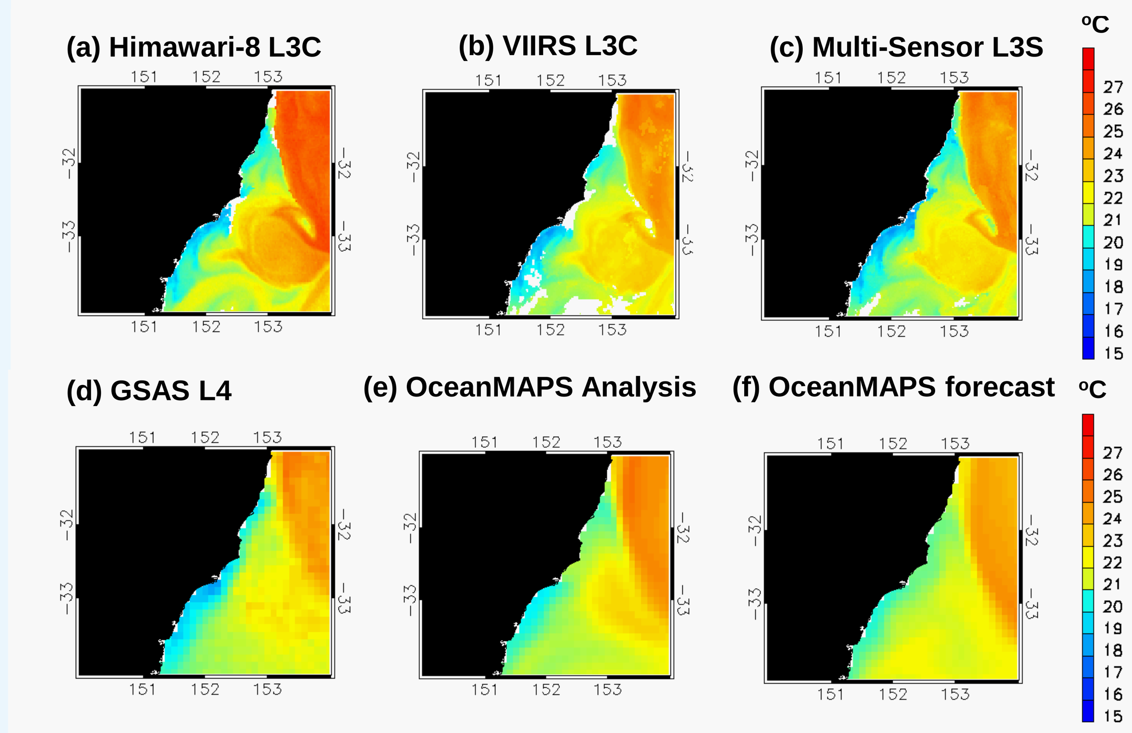
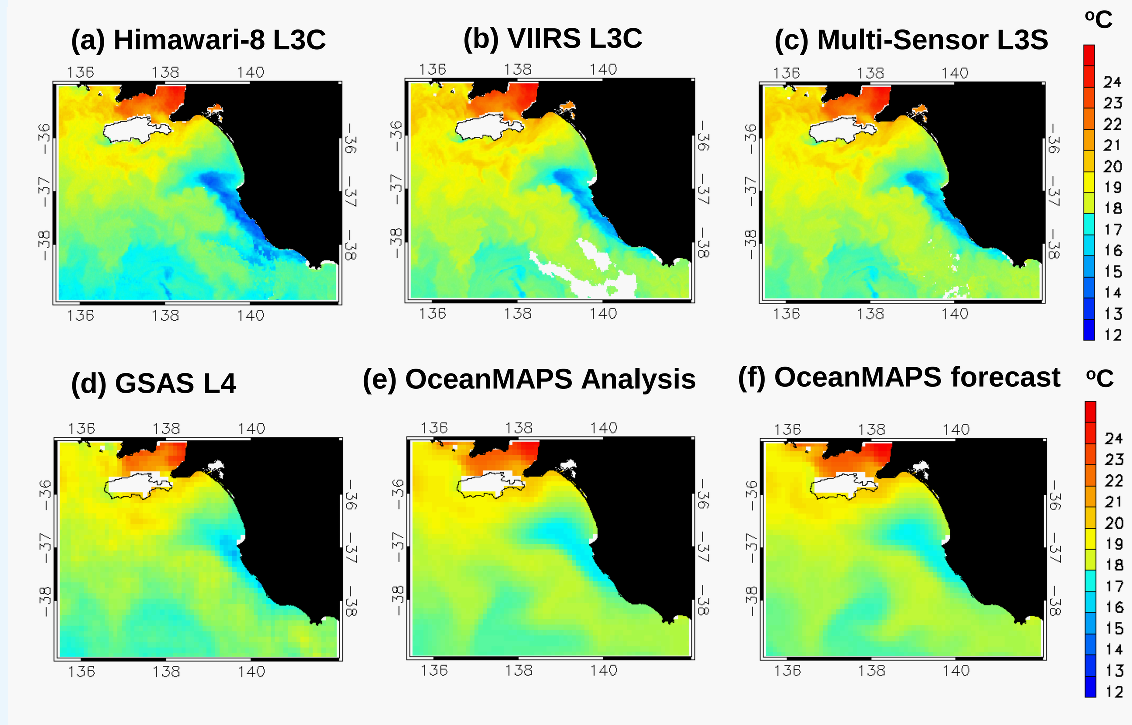


Fig 4. As for Fig. 2 but for 8th March 2018 over the Bonney Coast, South Australia, a region where seasonal, wind-induced upwelling generally peaks between January to March.



5. Conclusions

We compared night-time 2 km composites of Himawari-8 and Multi-Sensor (AVHRR and VIIRS) SST data at ~0.2 m depth with the BoM operational OceanMAPS v3.1 SST analyses and forecasts at 2.5 m depth over three Australian coastal regions experiencing upwelling under mainly clear-sky conditions. It would appear from this preliminary case study that the new IMOS Himawari-8 L3C and Multi-Sensor L3S SST products can be used to identify coastal upwelling in cloud-free conditions. It is also demonstrated that the 10 km OceanMAPS ocean model and GSAS EnOI SST analysis can represent coastal upwelling under conditions favourable for upwelling, although not the full magnitude of the excursion in surface temperatures.

The Griffin et al. (2017) method for compositing multiple satellite scenes and/or sensors appears to provide relatively homogeneous and accurate SST fields. The enhanced spatial coverage of the new daily, 2 km resolution IMOS Himawari-8 L3C and Multi-Sensor L3S products provide opportunities to monitor small spatial scale ocean features, with hourly to seasonal time scales, such as coastal upwelling.

6. Plans

By the end of 2018 it is expected that the IMOS VIIRS L3C and Multi-Sensor L3S products will be publicly available from the Australian Ocean Data Network (http:/portal.aodn.org.au). Early in 2019 the 1 – 4 km SST data from the AVHRR sensor on METOP-B will be incorporated into the IMOS suite of Group for High Resolution SST (GHRSST: http://www.ghrsst.org) SST products, including the Multi-Sensor L3S product.

Work is underway to test using the Bayesian clear-sky identification and physical retrieval methods developed by the ESA Climate Change Initiative (CCI) SST Project (Merchant et al., 2017), in collaboration with the SST CCI team at University of Reading, to improve the accuracy and cloud masking in the BoM Himawari-8 SST processing system. These new Himawari-8 retrievals will be tested for incorporation into the IMOS Multi-Sensor L3S products.

7. References

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8. Acknowledgements

We acknowledge the provision of raw AVHRR data from ground-stations operated by the Bureau of Meteorology, Australian Institute of Marine Science, Western Australian Satellite Technology Applications Consortium, Geosciences Australia and Commonwealth Scientific and Industrial Research Organisation (CSIRO).We also acknowledge the provision of NPP VIIRS SSTskin retrievals from the National Oceanic and Atmospheric Administration (NOAA) and the provision of the Himawari-8 AHI L1b data from the Japanese Meteorological Agency (JMA) and Japanese Space Agency (JAXA).