



The Bureau
of Meteorology

Which IMOS Sea Surface Temperature product should I use?

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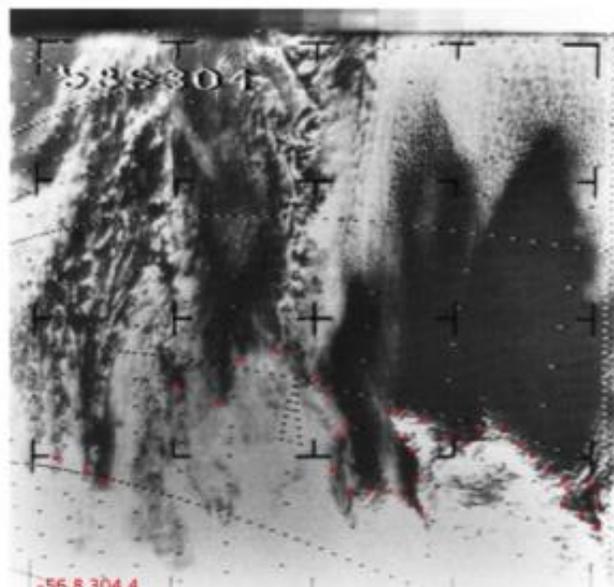
30 October 2025

Where it all began...

1964: Nimbus-1 High Resolution Infrared Radiometer

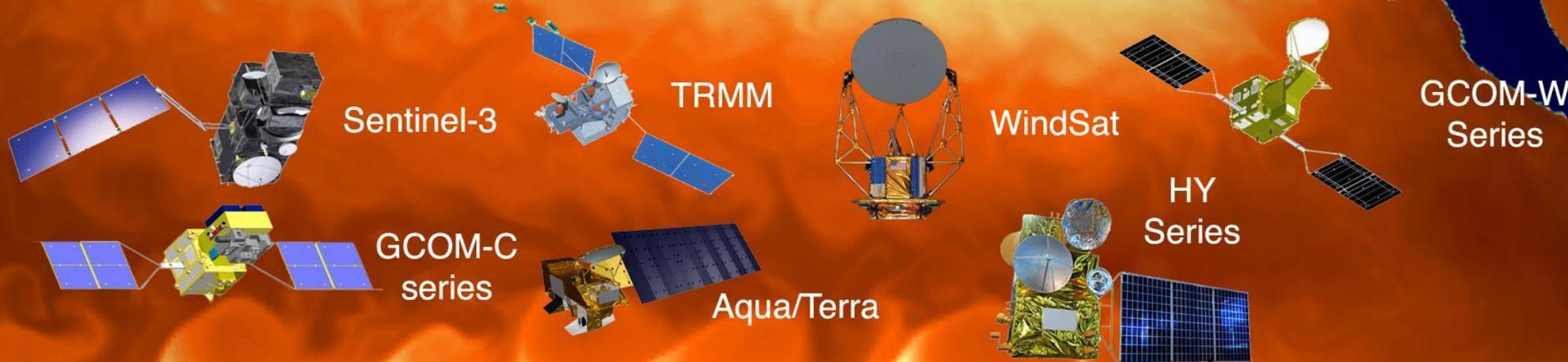
"... limited success in deriving sea surface temperature to within 3° to 6°K of aircraft radiation measurements..."

Alison and Kennedy (1967) NASA Tech. Note.



2023

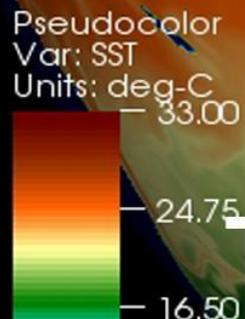
Polar orbiting missions with microwave and optical sensors

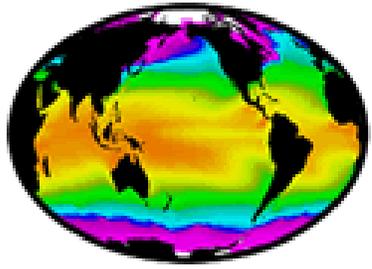


Polar orbiting meteorological missions



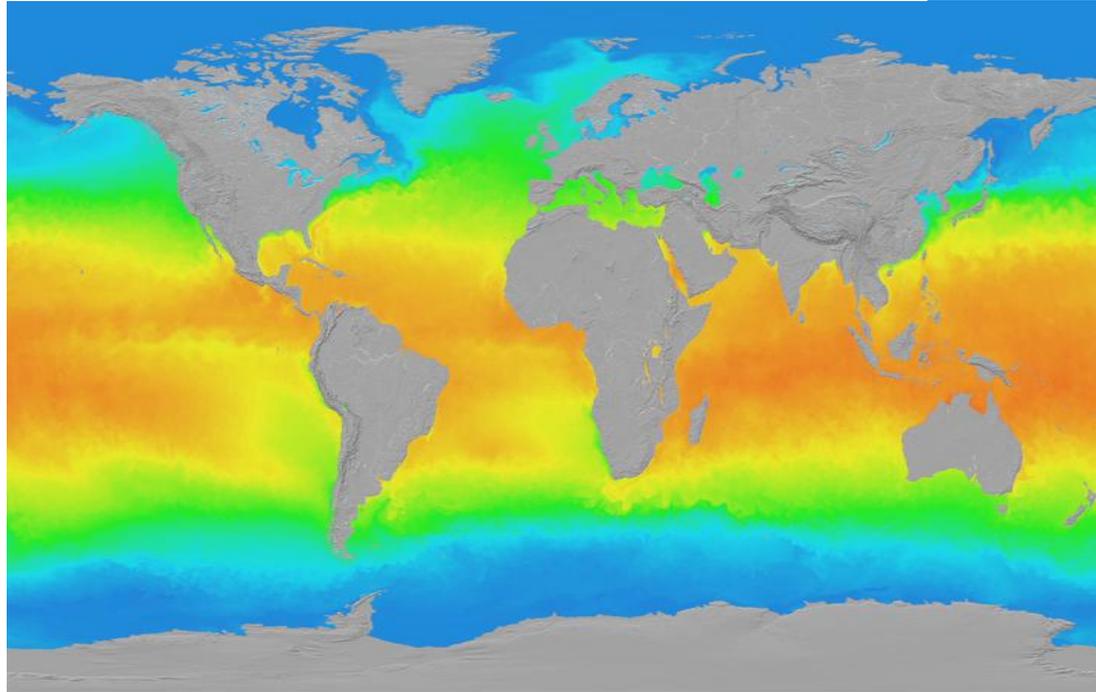
Geostationary meteorological missions





GHRSSST
GROUP FOR HIGH RESOLUTION
SEA SURFACE TEMPERATURE

www.ghrsst.org

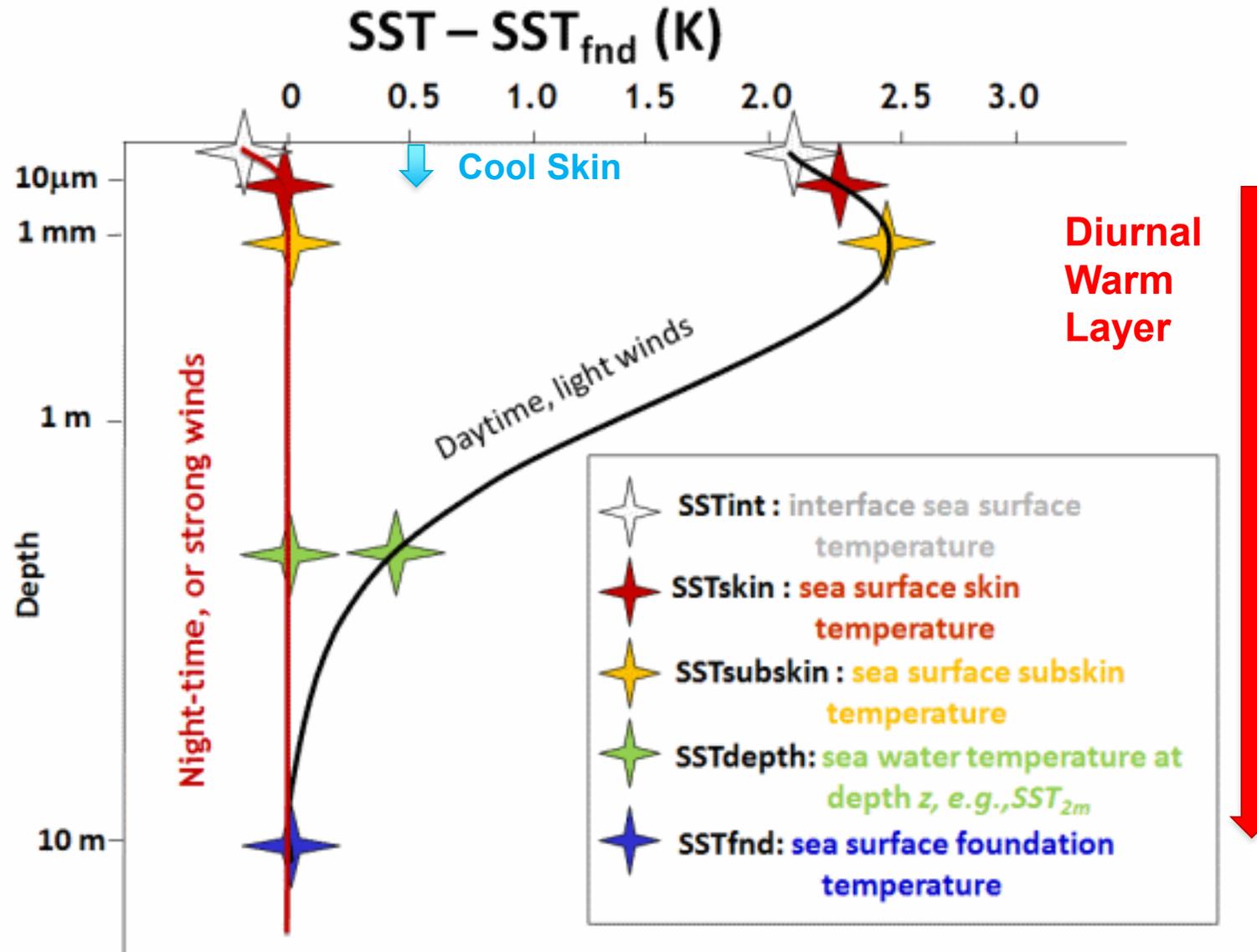


- Framework for SST knowledge and data sharing (inc. data formats)
- Best practices for processing and uncertainties
- Bring SST to operational users and science

GHRSSST mission: To provide operational users and the science community with the SST measured by the satellite constellation

Why SST depth is important

www.ghrsst.org



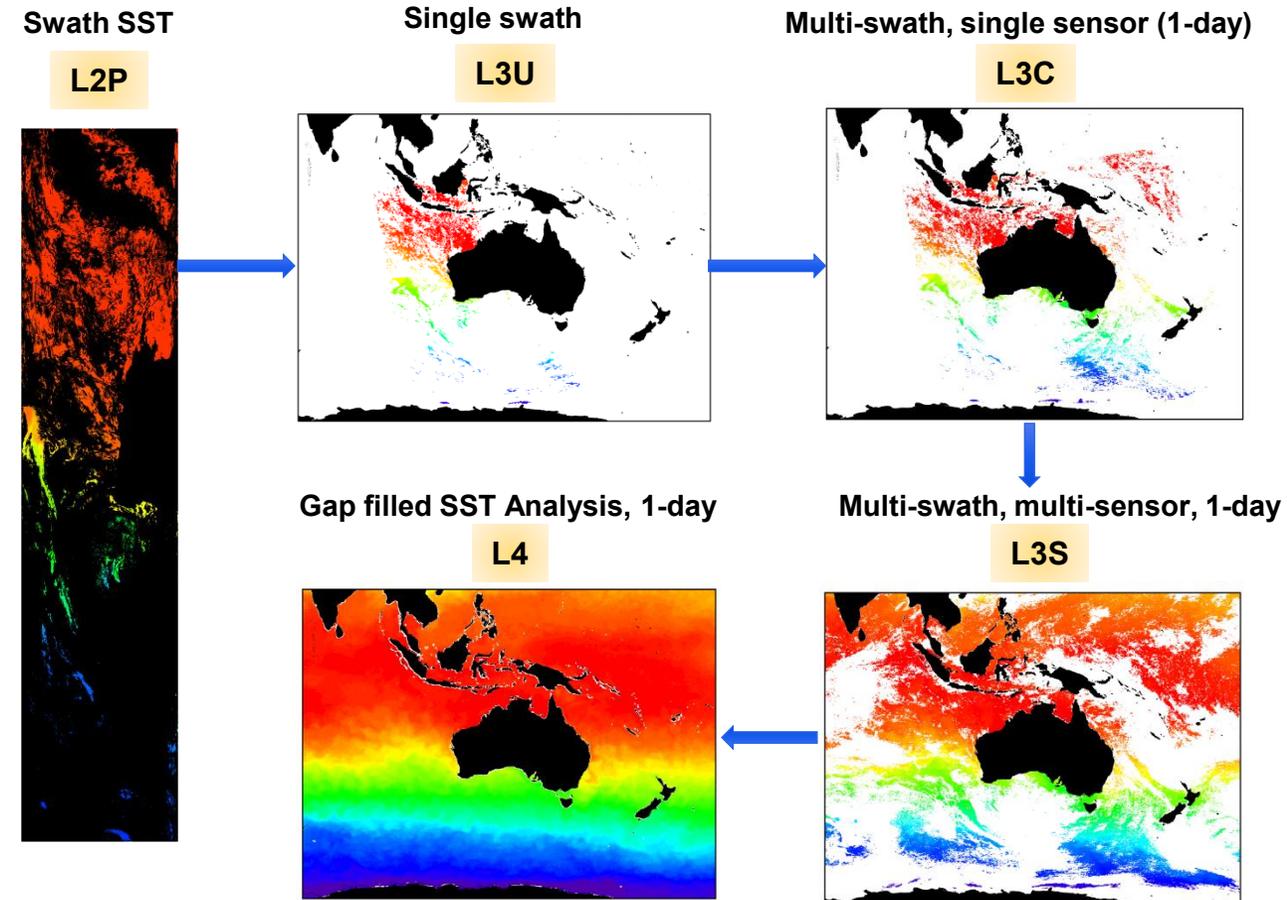
IMOS GHRSSST products

Through the IMOS project, we provide 5 types of GHRSSST GDS2.0 format SST products using IR data from AVHRR, VIIRS and Himawari AHI sensors, and PMW data from AMSR2:

- L2P (geolocated, native resolution of sensor)
- L3U (single swath/scene, gridded)
- L3C (multiple swath/scene, single sensor, gridded)
- L3S (multiple IR sensors, gridded)
- L4 (multiple sensors (IR + MW), optimally interpolated, gridded)

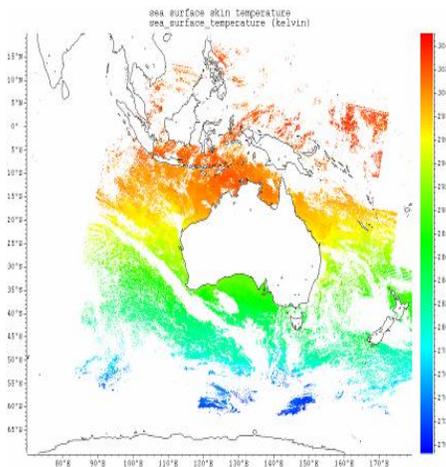
We provide these SST products at 2 depths:

- Skin (SST_{skin}) at ~10 μm depth sensitive to diurnal warming
- Foundation (SST_{fnd}) equivalent to several meters depth and not affected by diurnal warming

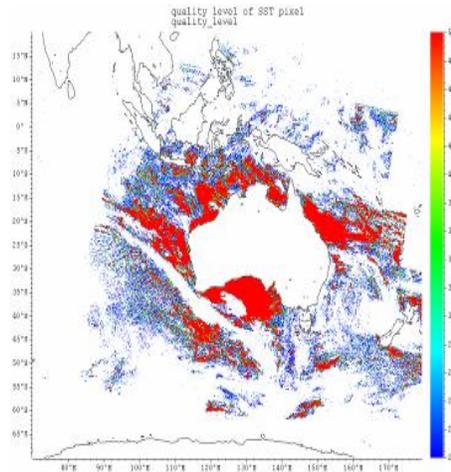


Useful pixel-by-pixel information (following GHRSSST 2.0 format)

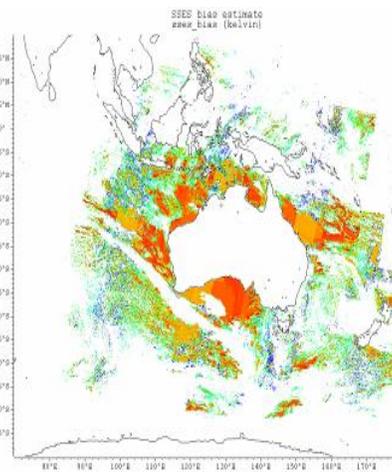
sea_surface_temperature



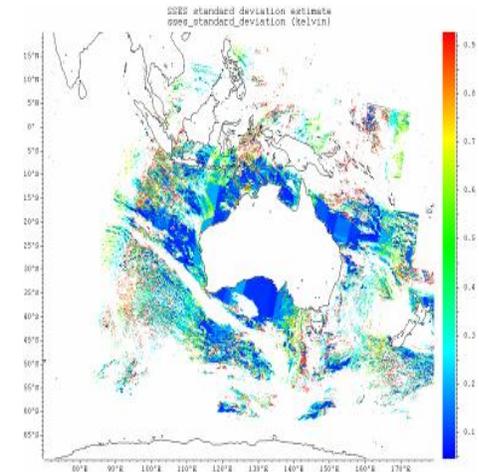
quality_level



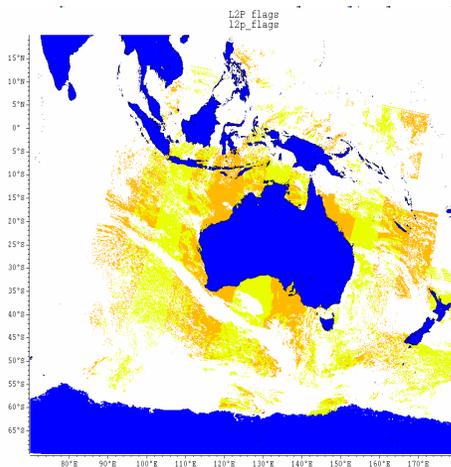
sses_bias



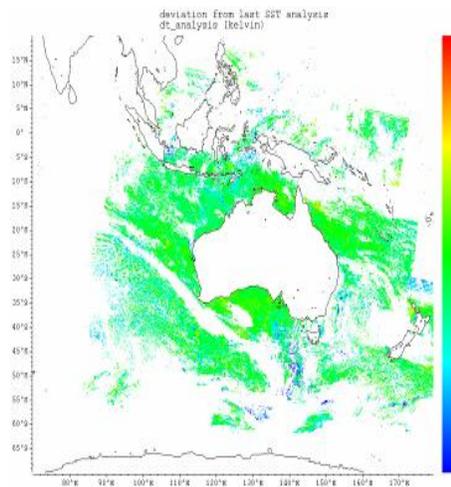
sses_standard_deviation



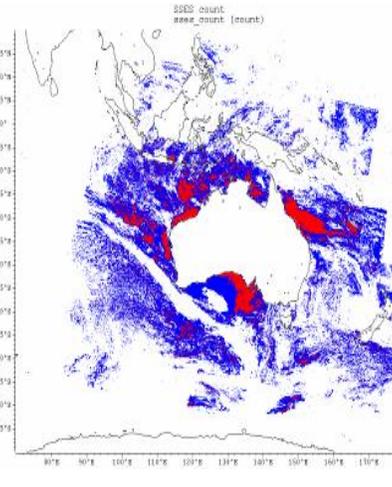
I2p_flags



dt_analysis



sses_count



- + sst_dtime
- + satellite_zenith_angle
- + wind_speed
- + aerosol_dynamic_indicator
- + sea_ice_fraction
- + more

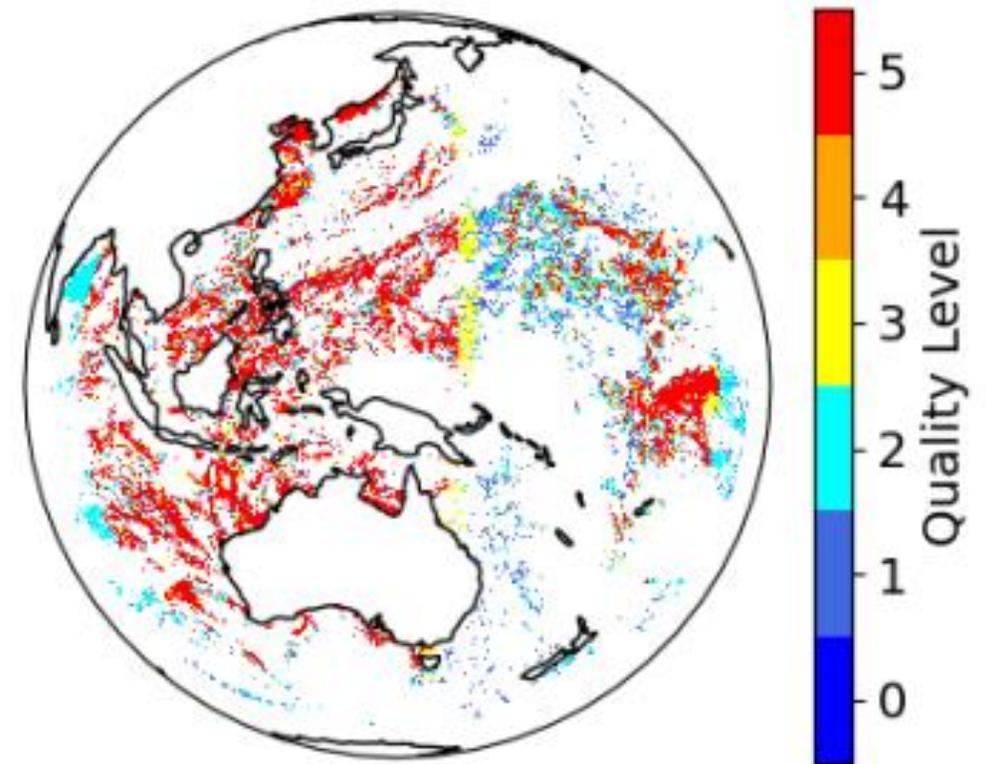
7th Oct 2013 night HRPT AVHRR composite from multiple NPOES satellites "L3S"

Quality Levels in IMOS SST products

For GDS 2.0 format L2P products derived from infra-red radiometer data, quality level (QL) of the data is based on an estimate of degree of cloudiness or other forms of atmospheric interference, such as aerosols.

15 December 2020, 20:20
Himawari-8 L2P QL

- QL = 0: No data
- QL = 1: Bad (e.g., cloud, rain, close to land, outside valid range)
- QL = 2: Worst quality usable data.
- QL = 3: Low quality
- QL = 4: Acceptable quality
- QL = 5: Best quality



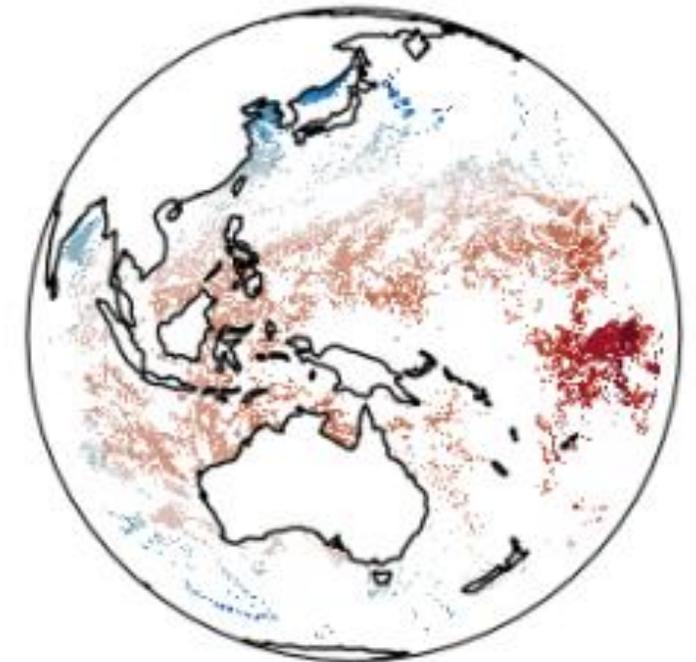
IMOS L2P Sensor Specific Error Statistics (SSES) bias model

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- Empirical model based on matchups with buoy SST data (*Govekar et al., 2024*)
- Rolling 1 month window adjusted every 5 days
- 6-D model based on time of day, satellite zenith angle, quality level, longitude, latitude and age
- Least squares regression to highly correlated components
- SSES bias and SSES Standard Deviation calculated per pixel
- Different models for **GEO** and **LEO** satellite products

15 December 2020, 20:20

Himawari-8 L2P SSES bias



Combining SSES and QL from different producers to form IMOS Multi-sensor L3S Composites

- Bureau uses IMOS 2 km HRPT AVHRR L3U (NOAA-15/18/19), OSISAF 1-4 km FRAC AVHRR L2P (MetOp-A/B/C) (composited to 2 km L3U), and NOAA/STAR 2 km VIIRS L3U (NPP, NOAA-20) GHRSSST products to construct IMOS 2 km Multi-sensor L3S SST products (for 2012 to present).
- To merge data from different satellites, the L3U SSTs are modified such that the "*modified*" quality_level is redefined as the minimum of the original quality_level in the L3U file and an integer value, q_s , calculated using sses_bias (μ_{sses}) and sses_standard_deviation (σ_{sses}) estimates, thus:

$$q_{sses} = \frac{1}{\sqrt{2}} \sqrt{\max \left(\left(\frac{\sigma_{sses}}{\sigma_0} \right)^2 + \left(\frac{\mu_{sses} - \mu_0}{\sigma_{sses}} \right)^2 - 1, 0 \right)}$$

$$q_s = \lfloor 5 \exp^{\eta q_{sses}} \rfloor$$

- Different data sources are then combined using q_s , considering $\eta/\sigma_0 = \text{constant}$

See [Govekar et al. \(2022\) Remote Sensing](https://doi.org/10.3390/rs14153785) <https://doi.org/10.3390/rs14153785> for more details...





Sea Surface Temperature products and their applications from Himawari-9 geostationary satellite

The Sea Surface Temperature (SST) project of the European Space Agency (ESA) Climate Change Initiative (CCI) Programme aims to make climate data records for SST longer, more stable and more accurate, providing data users with different forms of data and documentation.

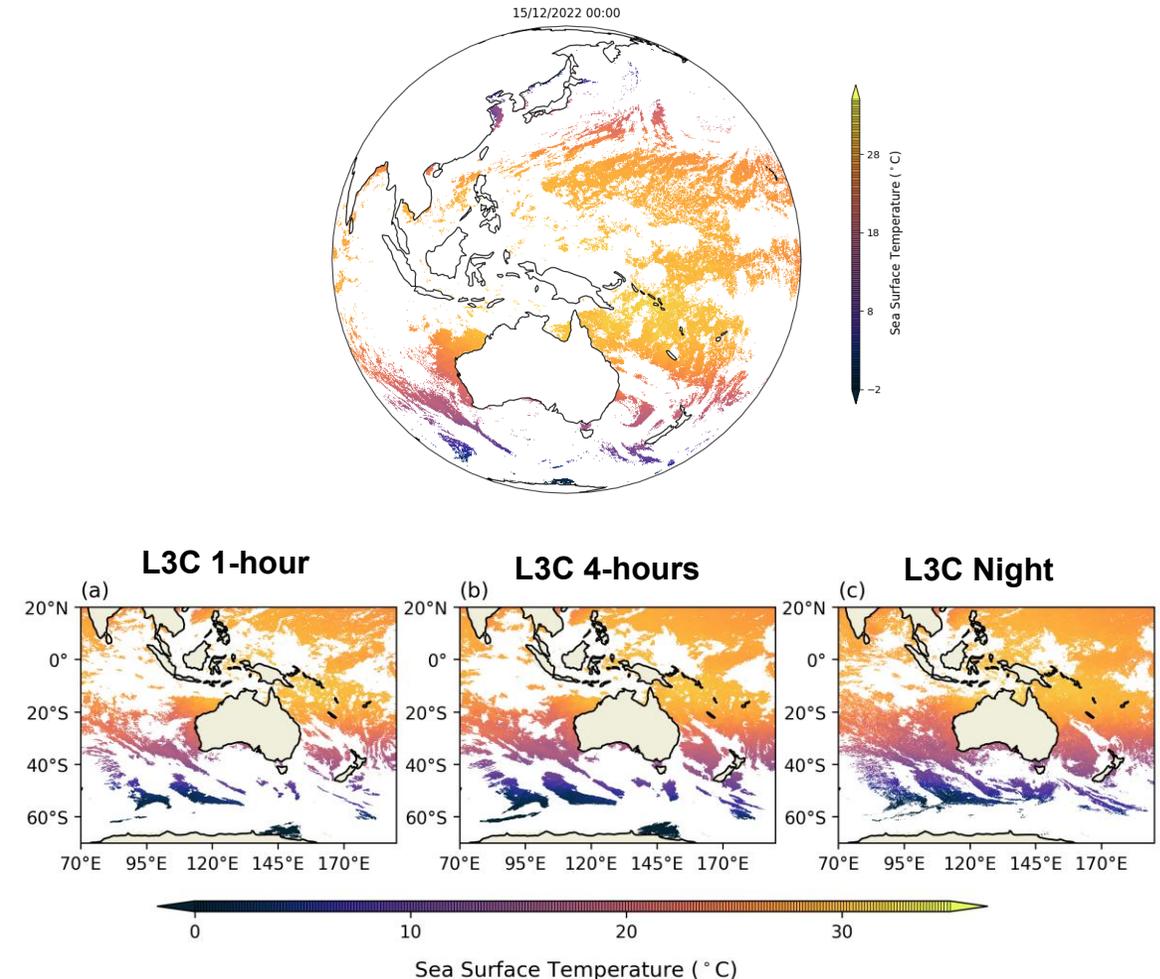
The Bureau is producing Himawari-9 Level 2 SST products every 10 minutes with the newly developed method build in collaboration with the University of Reading.

- ESA CCI SST version 3 processor (Embury et al., 2024)
- Tuned to Bureau's NWP model output
- Empirical bias model developed for Geostationary satellites

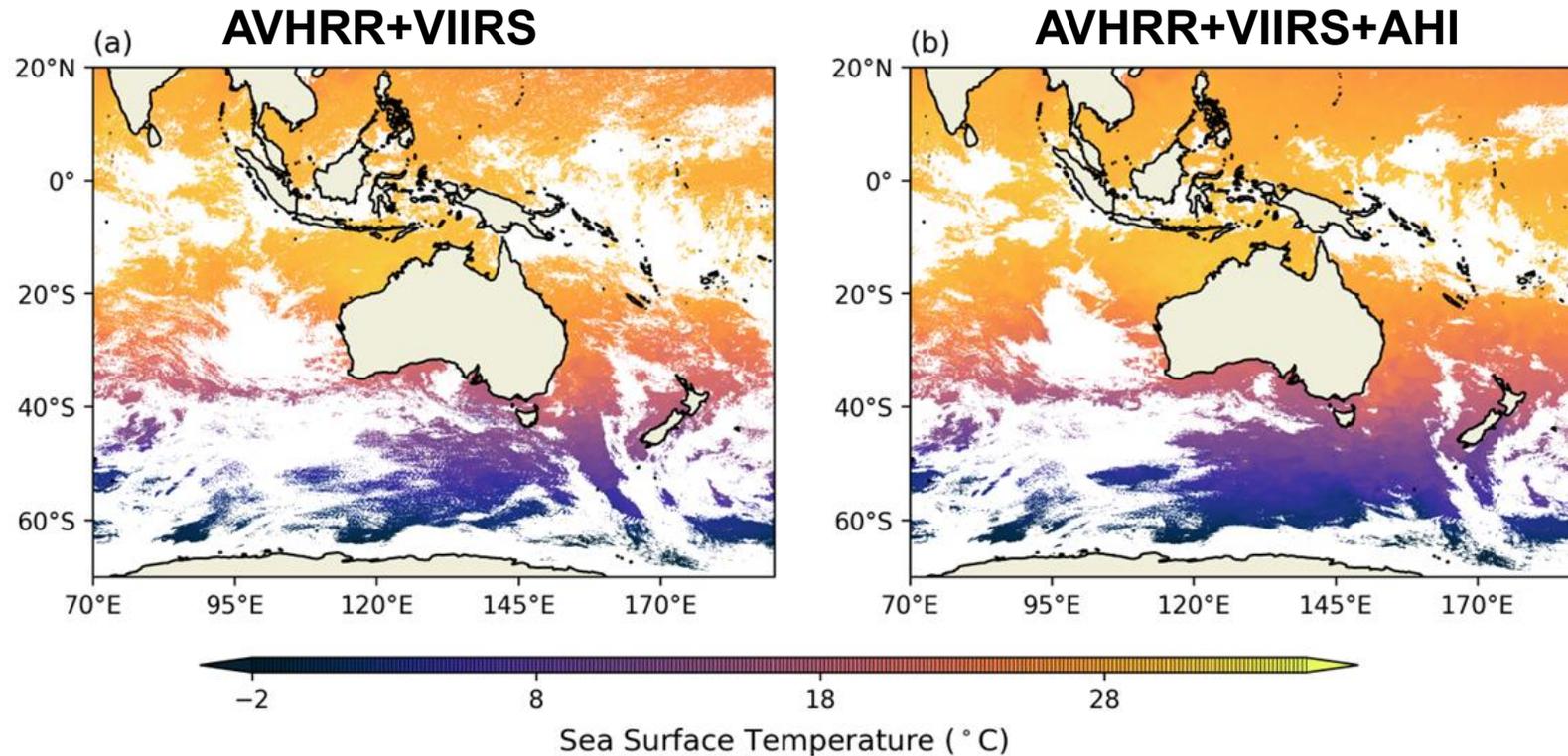
Applications:

- Better input for ocean/NWP coupled models
- Improved composite SST products
- Improved data for applications such as
 - IMOS OceanCurrent
 - Coral Risk Monitoring services
 - Studies of marine heatwaves and ocean upwelling

Himawari-9 Level 2 SSTs



Effect of adding Himawari-8/9 data to composite SST products



- Data from Suomi-NPP, NOAA-20, MetOp-B, MetOp-C and Himawari-8/9 L3C files are composited using an equal weighted averaging method (Govekar et al., 2022) to construct the new GeoPolar MultiSensor L3S SST product.
- The GeoPolar MultiSensor L3S has significantly more data coverage (on average 20%) when compared with the operational MultiSensor L3S SST product .



IMOS GHRSSST products

Designed for different applications...

1 km AVHRR L2P SST_{skin}

2 km AVHRR L3U SST_{skin}

2 km 1-day day/night AVHRR L3C SST_{skin}

2 km 1/3/6-day and 1-month day/night/day+night AVHRR L3S SST_{skin}/SST_{fnd}

2 km VIIRS L3U SST_{skin}

2 km 1-day VIIRS day/night L3C SST_{skin}

2 km 1/3/6-day and 1-month day/night/day+night Multi-sensor (VIIRS+AVHRR) L3S SST_{skin}/SST_{fnd}

2 km 10-min Himawari-8 L2P SST_{skin}

2 km hourly/4-hourly, daily night Himawari-8 L3C SST_{skin}

2 km daily night Geo-Polar Multi-sensor (H-8+VIIRS+AVHRR) L3S SST_{skin}

9 km daily Regional RAMSSA L4 SST_{fnd}

25 km daily Global GAMSSA L4 SST_{fnd}

This is confusing! But we have an NCI web page (<https://opus.nci.org.au> search for "qm43") and book chapter to help you choose.



Bureau GHRSSST products collection on AODN

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<https://portal.aodn.org.au> (search for "SST")



1 Select a Data Collection

2 Create a Subset

3 Download

Register

Sign In

Step 1: Select a Data Collection

Loaded 30 of 36 matching collections

New Search

Parameter

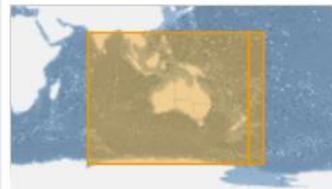
- Physical-Water
 - Temperature
 - Skin temperature of the water body (36)

Organisation

- Commonwealth Departments and Agencies (36)
- Integrated Marine Observing System (IMOS) (36)

Platform

IMOS - SRS - SST - L3S - Multi Sensor - 1 month - day and night time - Australia



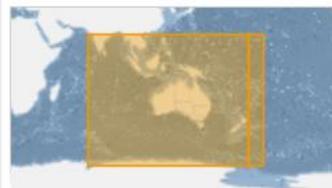
- Temperature
- 2012 - 2024
- Integrated Marine Observing System (IMOS) - Australian Bureau of Meteorology
- Satellite

more

Select >>



IMOS - SRS - SST - L3S - Multi Sensor - 1 day - day time - Australia



- Temperature
- 2012 - 2024
- Integrated Marine Observing System (IMOS) - Australian Bureau of Meteorology
- Satellite

more

Select >>



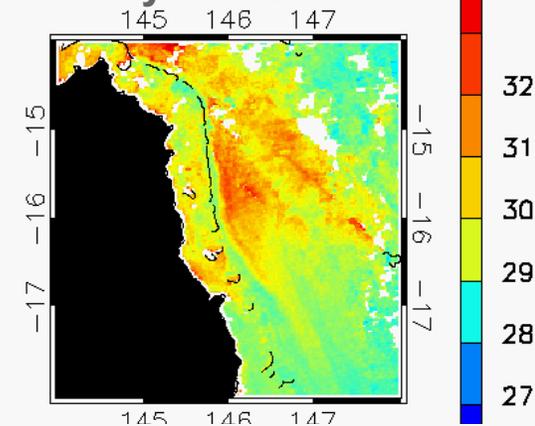


Things to consider when choosing an SST product...

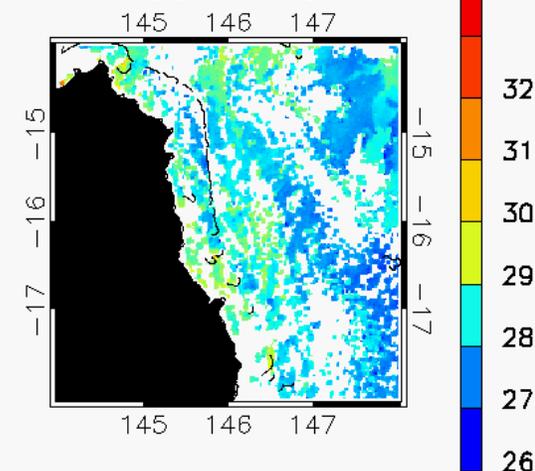
- Depth – skin ($\sim 10\mu\text{m}$), sub-skin or foundation ($\sim 10\text{m}$)?
- Time – length/timeliness, local time of measurement
- Temporal resolution – what is characteristic time period of process?
- Spatial resolution of feature/process
- Spatial coverage – L3 composite vs L4 gap-free?
- Do you need microwave data to measure SST under cloud?
- Geolocation accuracy – native projection or gridded?
- SST accuracy – with respect to what reference?
- Quality level (cloud contamination)

2 km 1-day AVHRR

Daytime skin



Foundation



Applications of IMOS GHR SST Products

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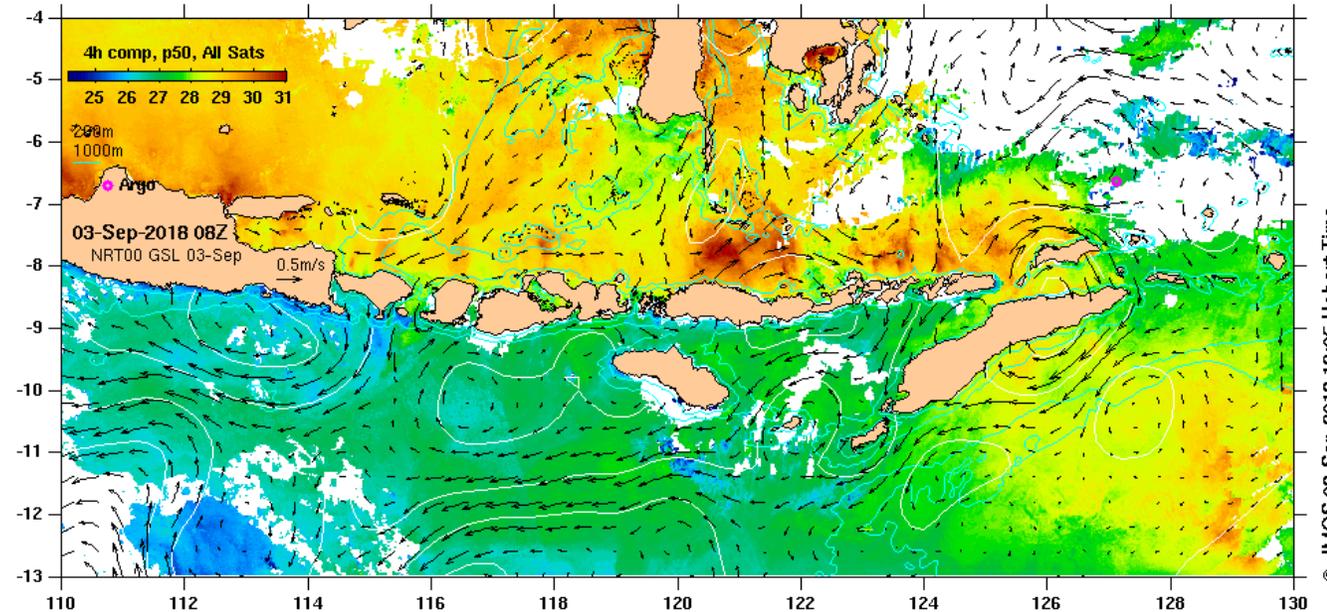
L2P (geolocated swath)

CSIRO's IMOS OceanCurrent 4-hourly 2 km SST maps <http://oceancurrent.imos.org.au>

CSIRO's real-time SST 1 km images for Fishers

<https://mrs-data.csiro.au/myoceancurrent/sst/>

CSIRO 4-hour 2 km L3 SST



Applications of IMOS GHR SST Products

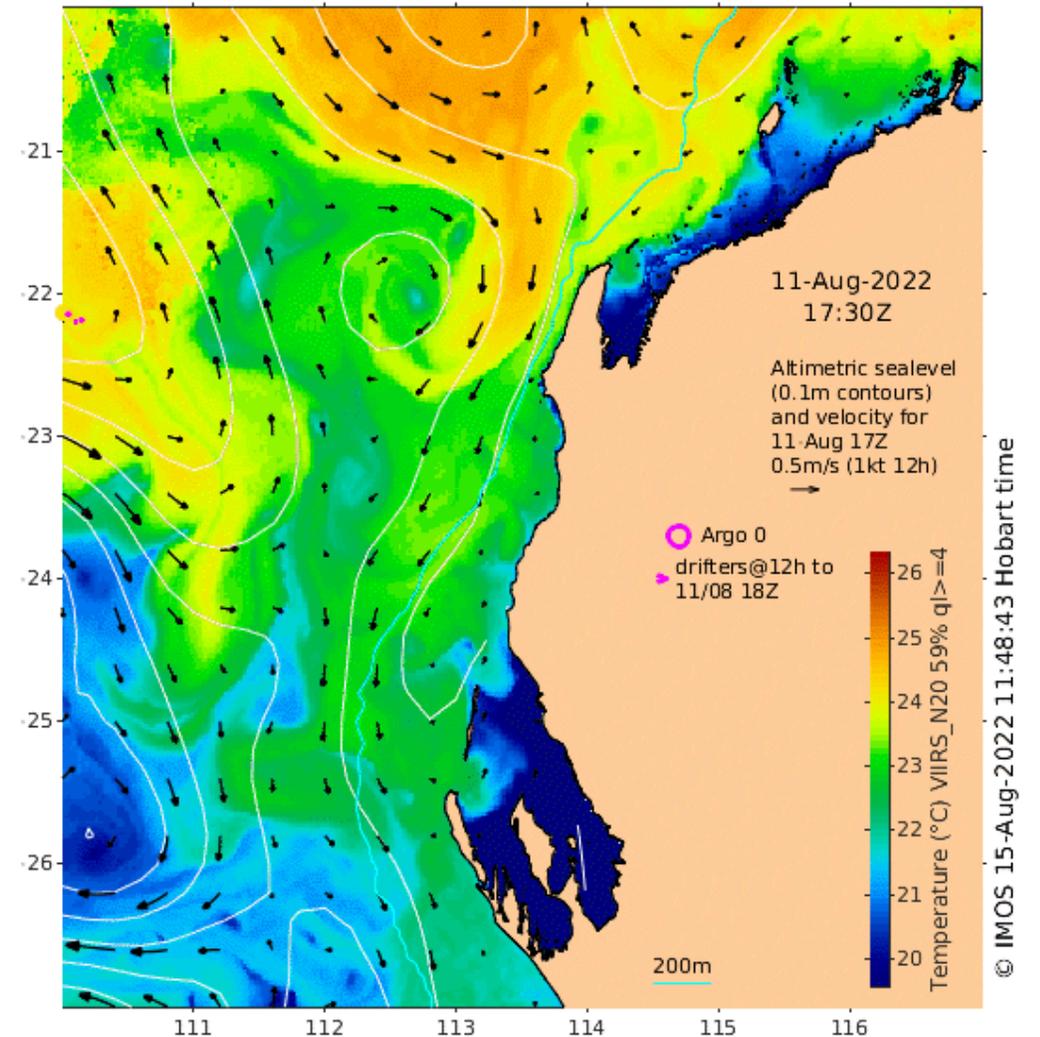
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L3U (2 km gridded, single swath)

Real-time SST maps

- www.fishtrack.com
- IMOS OceanCurrent

OceanCurrent "Snapshot SST" Map



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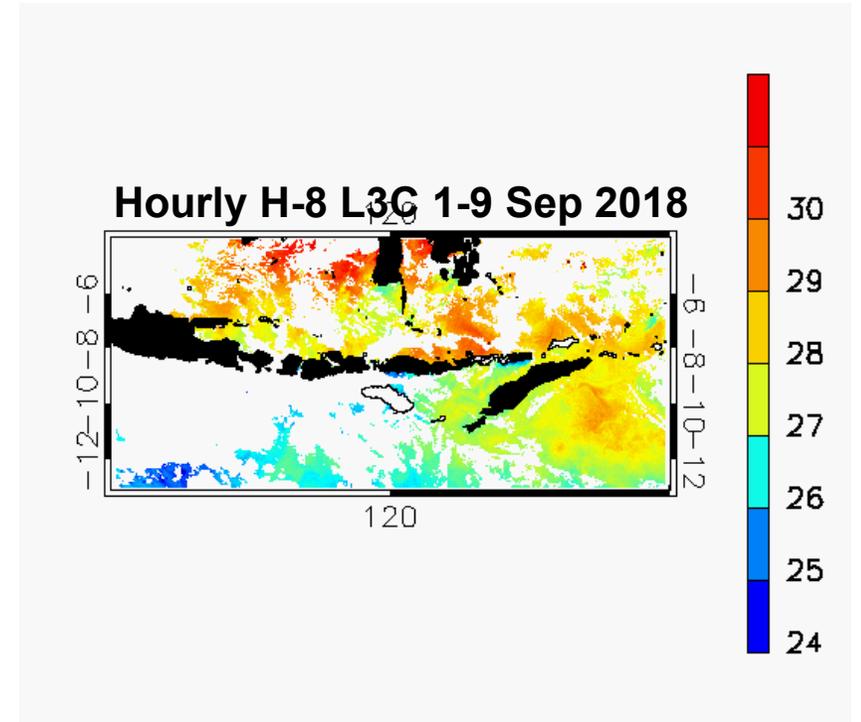
Applications of IMOS GHR SST Products

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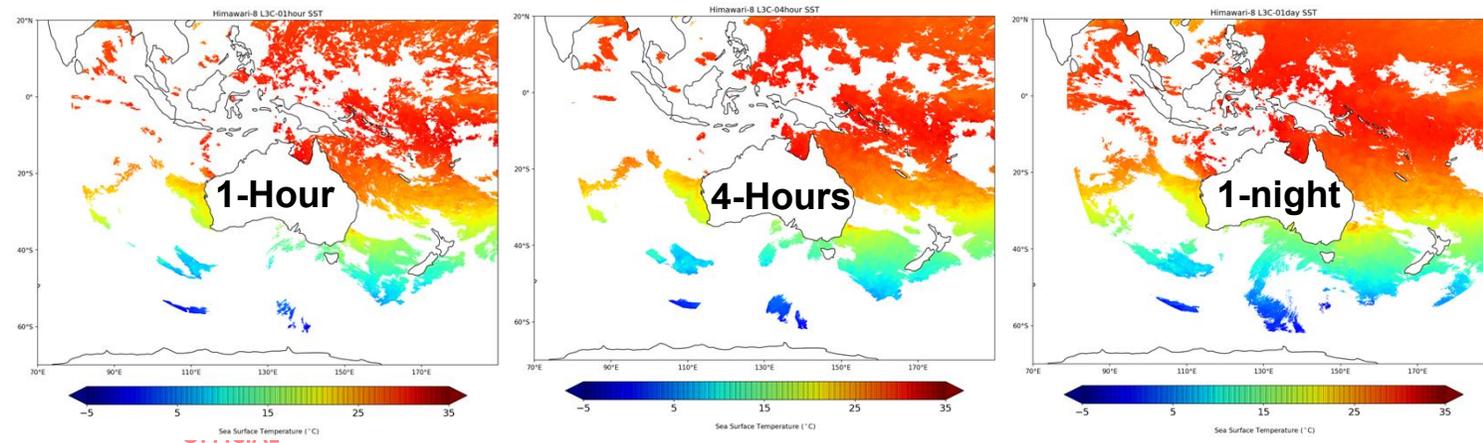
Himawari-8 L3C (Hourly, 4-hourly or daily, 2 km gridded, multiple scene)

Research into:

- diurnal warming ([Hsu et al., 2021](#)) used 1-hour H-8 L3C
- coastal upwelling ([Beggs et al., 2018](#)) used 1-day night H-8 L3C



15 Mar 2020 H-8 L3C SSTskin for QL ≥ 3



Applications of IMOS GHR SST Products OFFICIAL

...requiring high spatial resolution and less gaps than L3C

L3S (0.02° gridded, multiple sensor)

Nowcasting coral bleaching

- [ReefTemp NextGen](#) uses 1-day night L3S

Australian 2 km SST climatologies

- SSTAARS ([Wijffels et al., 2018](#)) used 1-day night AVHRR L3S
- [Roughan et al. \(2022\)](#) used 1-day night Multi-sensor (AVHRR+VIIRS) L3S

Nowcasting Marine Heat Waves

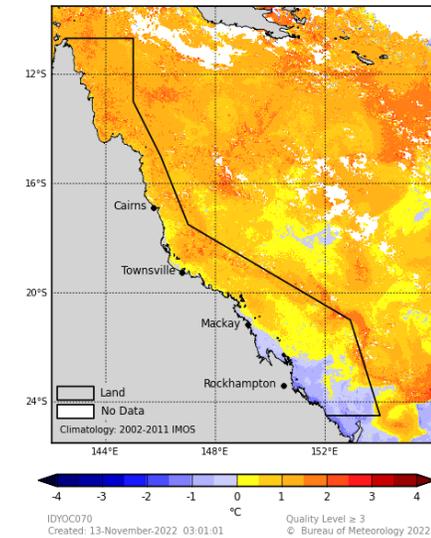
- [IMOS OceanCurrent](#) uses 1/3/6-day and 1-month night Multi-sensor L3S for SST anomaly and percentile maps

Research on marine heatwaves, marine ecology, aquaculture, coastal oceanography and climate change

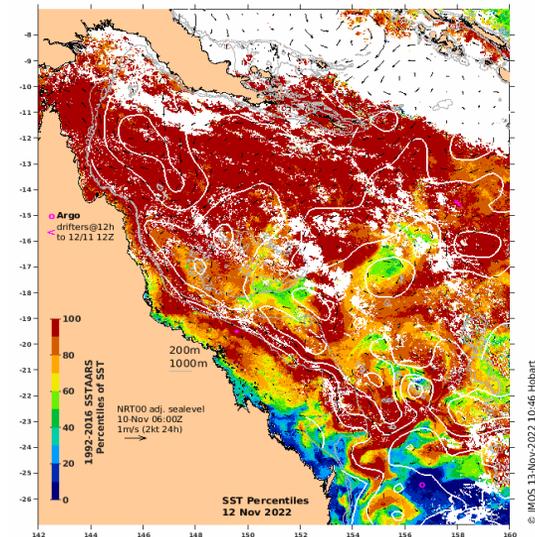
- e.g., [Meng et al., 2022](#); [Rykova et al., 2022](#); [Layton et al., 2022](#); [Hu et al., 2021](#); [Xie et al., 2021](#); [Heidemann & Ribbe, 2019](#); [Ismail et al., 2018](#)

ReefTemp 12 Nov 2022 1-day SST Anomaly

IMOS 1-day: SST Anomaly
12 November 2022 GBR region



OceanCurrent 12 Nov 2022 1-day Percentiles





Heat stress and Marine Heat Wave (MHW) monitoring products

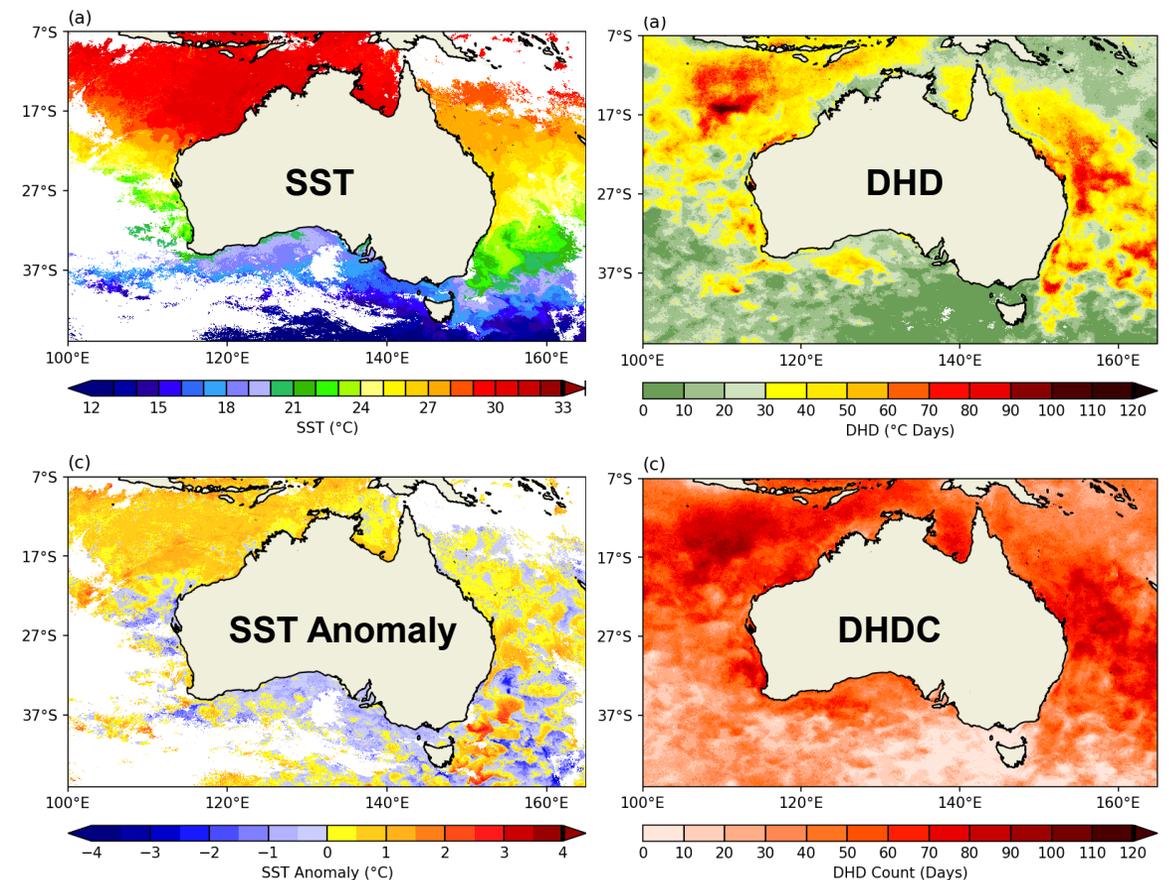
A MHW is defined as a period when seawater temperatures exceed a seasonally-varying threshold (usually the 90th percentile) for at least 5 consecutive days. These extreme warming events can have significant impacts on marine ecosystems as well as human wellbeing and regional economies.

The Bureau is developing MHW products using GeoPolar Multisensor (AVHRR+VIIRS+AHI) SSTs. The metrics will cover the whole of the Australian coastal region (100°E – 165°E, 46°S – 7°S).

Resources:

- ❖ Sea Surface Temperature (SST): GeoPolar Multisensor L3S product
- ❖ Climatology: The SST Atlas of Australian Regional Seas (SSTAARS) climatology
- ❖ Daily Products (for 1 day and 14-day Mosaic):
 - Sea Surface Temperature (SST)
 - Sea Surface Temperature Anomaly (SSTA)
 - Degree Heating Days (DHD)
 - Degree Heating Days Count (DHDC)
 - Mean Positive Summer Anomaly (MPSA)
 - Marine heatwave category (MHW Category)
 - Marine Cold spell category (MCS Category)

31 March 2020

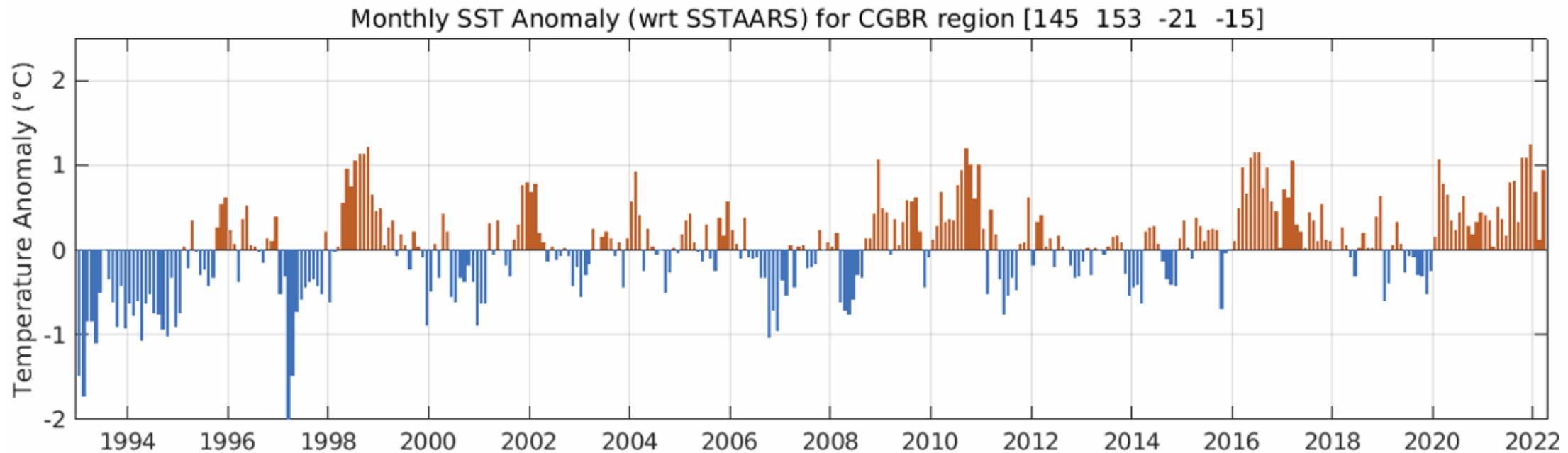


Applications of IMOS GHR SST Products

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L3S (2 km gridded, multiple sensor)

[IMOS OceanCurrent](#) uses 1-month night L3S to provide time series of region-averaged SST anomalies (relative to the SSTAARS 1992-2016 climatology)



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Applications of IMOS GHRSSST Products

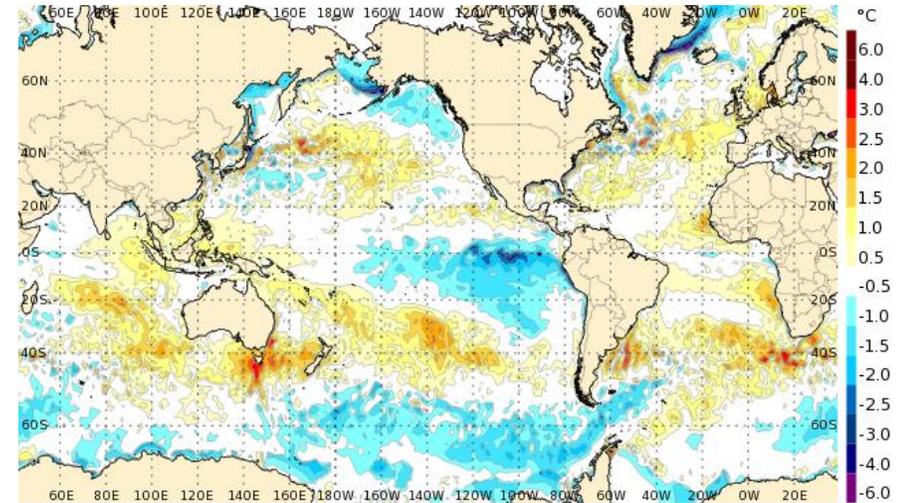
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...requiring SSTs in cloudy regions and smooth SST fields

L4 (1/12° and 1/4° gridded, gap-free, multiple sensor – AVHRR, VIIRS, AMSR2)

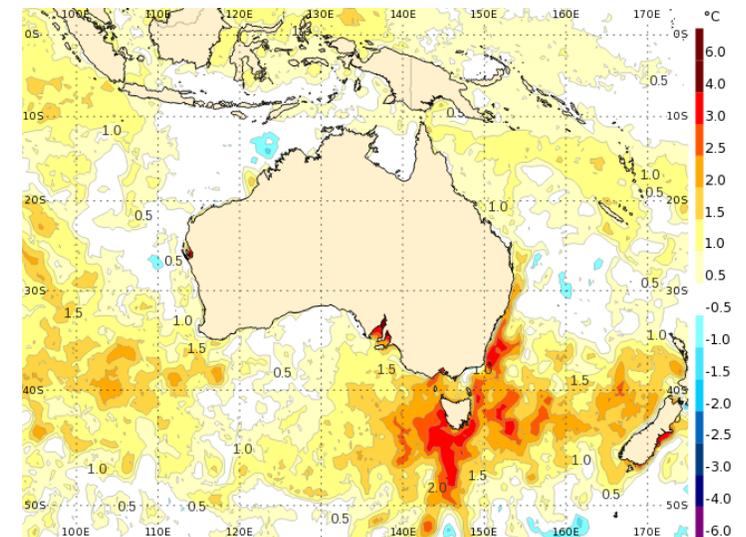
- Boundary condition for BoM Numerical Weather Prediction models
- Initialising BoM Seasonal Prediction Models (ACCESS-S2)
- Nowcasting Marine Heat Waves
- Validating ocean models (e.g. OceanMAPS)
- Research into marine fauna (e.g. [Speakman et al., 2020](#))

28 km GAMSSA SST Anomaly 31 Jan 2022



Sea surface temperature anomaly (deg C): Daily analysis for **Mon 31 Jan 2022**
(c) Copyright Australian Bureau of Meteorology | **GAMSSA** | Climatology 1961-1990

9 km RAMSSA SST Anomaly 31 Jan 2022



Sea surface temperature anomaly (deg C): Daily analysis for **Mon 31 Jan 2022**
(c) Copyright Australian Bureau of Meteorology | **RAMSSA** | Climatology 1961-1990

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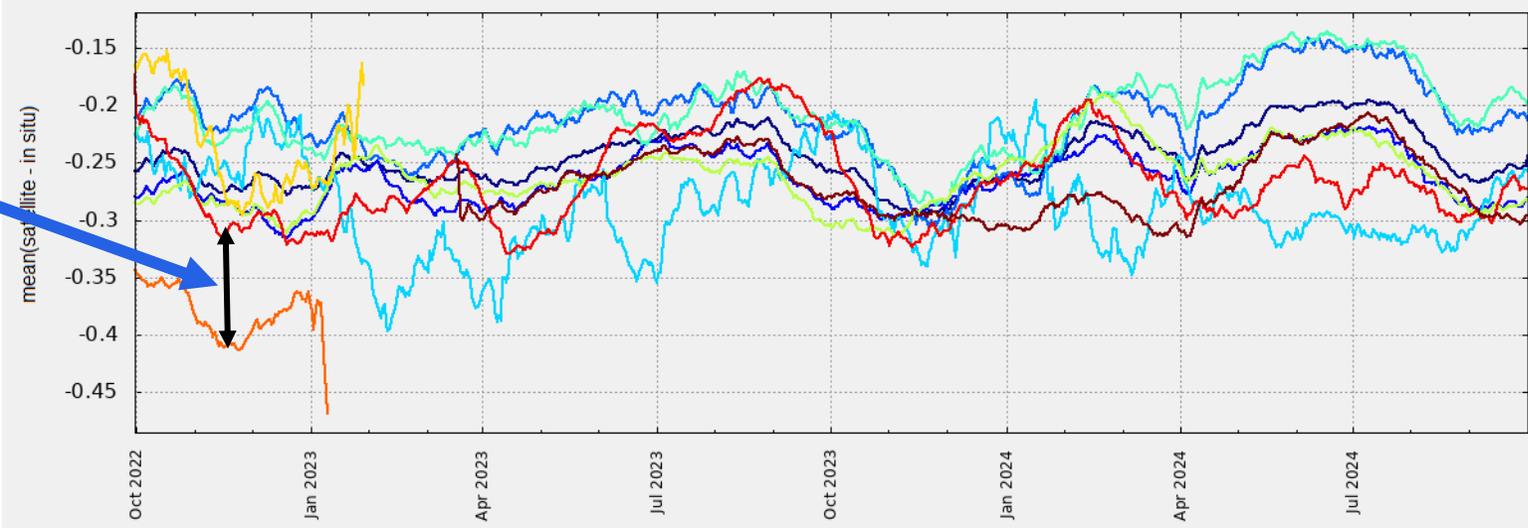
SST performance – with respect to drifting buoys and tropical moorings – platform comparison.

H09 bias correction similar to others - planning to apply to H08

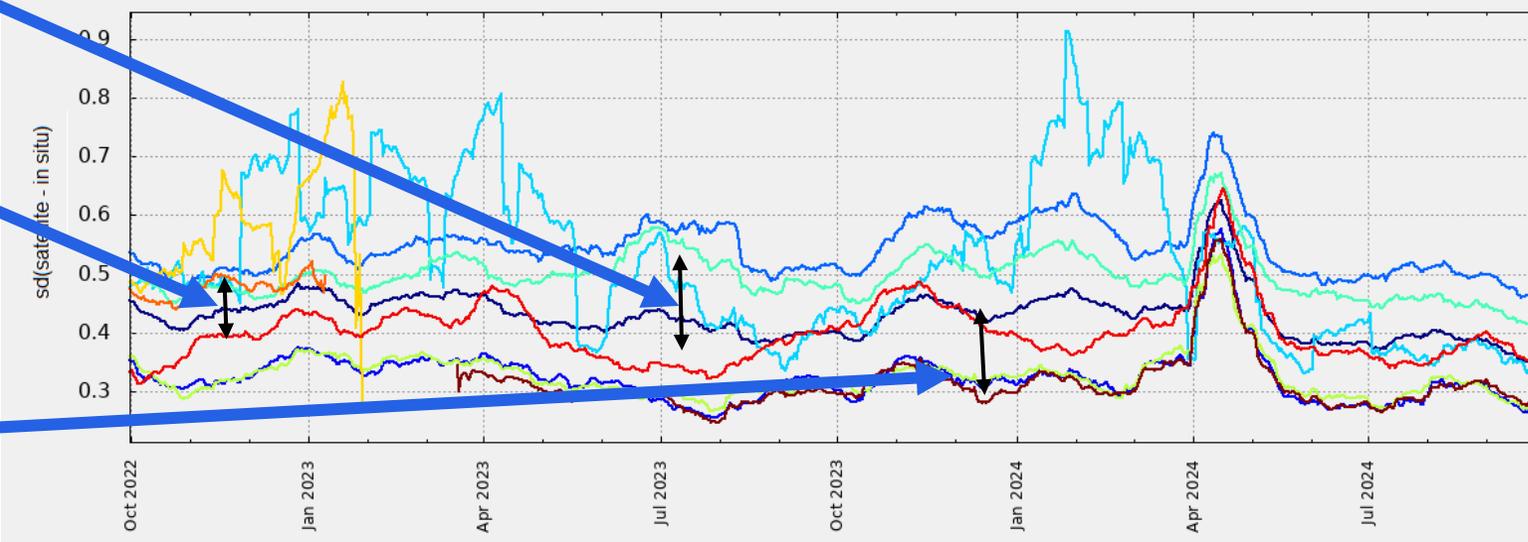
H09 – in situ standard deviation smaller than MetOp derived SST

H09 – in situ standard deviation smaller than H08

H09 – in situ standard deviation in larger than VIIRS



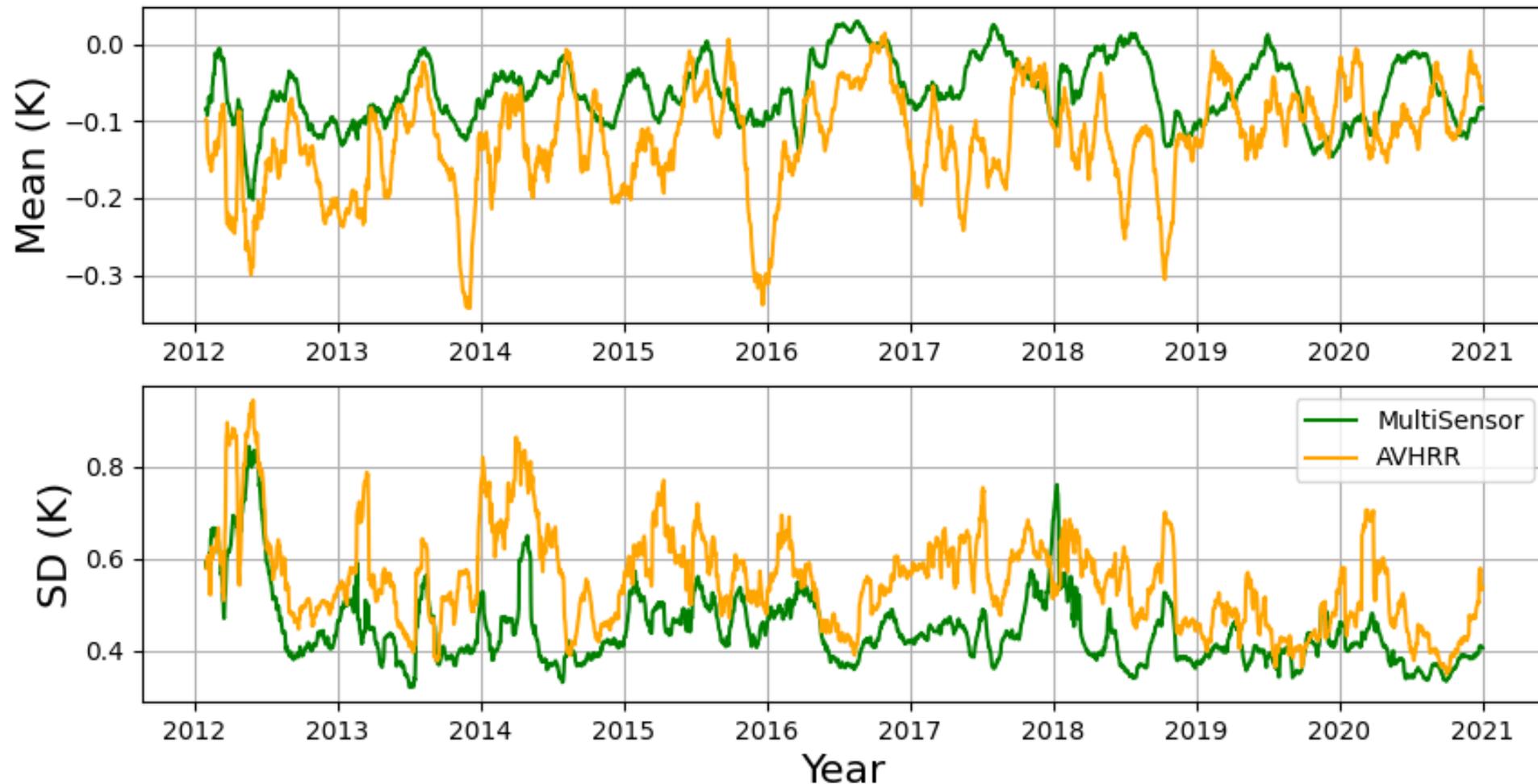
- ALL —
- NPP —
- MetOpC —
- NOAA-18 —
- MetOpB —
- N20 —
- NOAA-19 —
- Himawari-8 —
- Himawari-9 —
- N21 —



- ALL —
- NPP —
- MetOpC —
- NOAA-18 —
- MetOpB —
- N20 —
- NOAA-19 —
- Himawari-8 —
- Himawari-9 —
- N21 —

L3S Validation using moored and drifting buoy SSTs

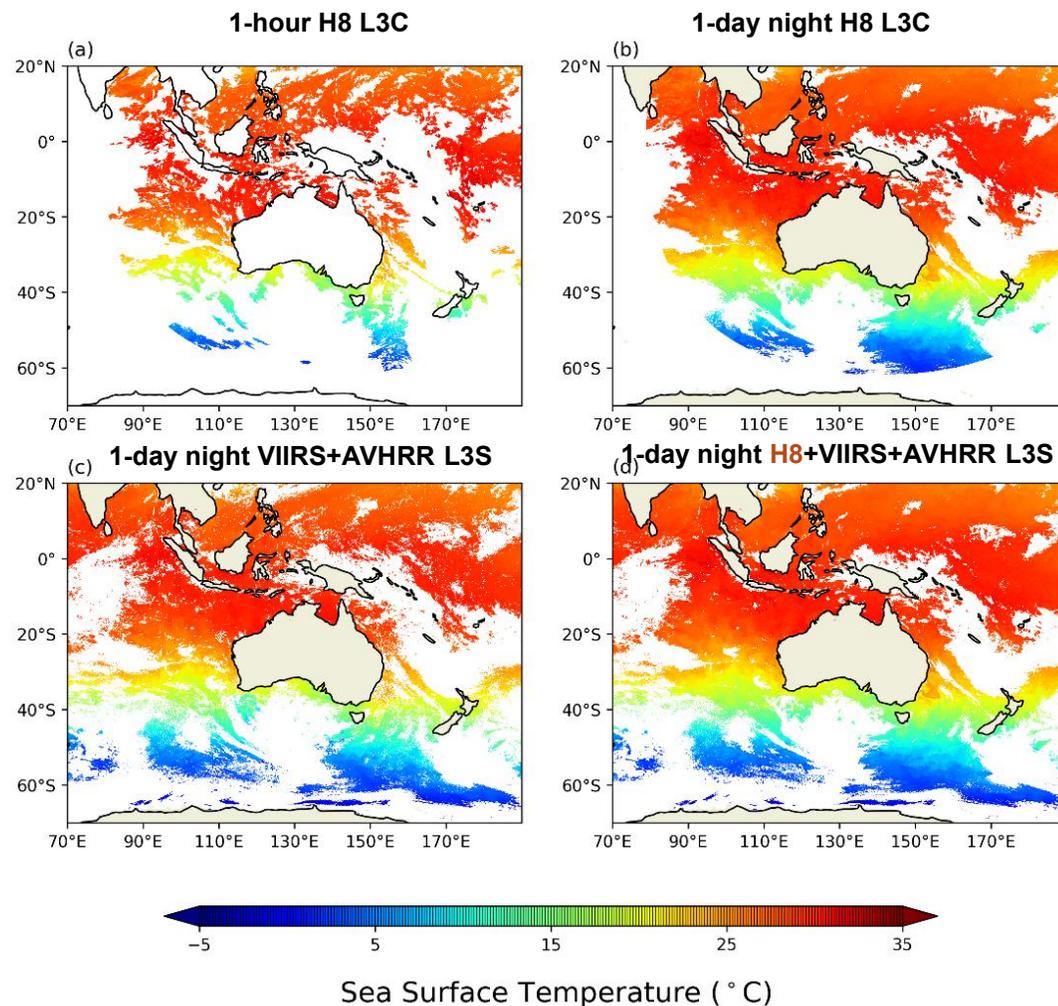
L3S-01day, night only, QL ≥ 4 monthly statistics of L3S SST_{skin} – in situ SST(0.2m) + 0.17K



The pros

- IMOS GHRSSST products easily accessed via Australian Ocean Data Network (<https://portal.aodn.org.au>) and NCI (<https://geonetwork.nci.org.au>)
 - All satellite SST files available on AODN and NCI are GHRSSST GDS2.0 format!
- Common GHRSSST format aids operational model/analysis ingestion and research
 - Bureau uses *only* GHRSSST L2P and L3U files for SST data assimilation into SST analyses and ocean models, and we generally subtract the **sses_bias** from each SST
- Common $0.02^\circ \times 0.02^\circ$ grid projection aids visualization and comparisons
- Quick look maps available from AODN and IMOS OceanCurrent

Some IMOS GHRSSST L3 Products on common $0.02^\circ \times 0.2^\circ$ grid



Summary

- The Bureau produces high-resolution, regional satellite SST products under IMOS useful for monitoring Marine Heat Waves, coastal upwelling, coral heat stress and climate trends over Australasian waters
- IMOS GHRSSST-format L2P, L3U, L3C, L3S and L4 SST products available from:
 - NCI: <https://opus.nci.org.au> (search for "qm43")
 - AODN: <https://portal.aodn.org.au> (search for "SST")
<http://thredds.aodn.org.au/thredds/catalog/IMOS/SRS/SST/ghrsst/catalog.html>
- Bureau Gridded SST Observations Fact Sheet (Aug 2022):
<https://imos.org.au/facilities/srs/sstproducts/sstdata0/sstdata-references>
- Paper in *Remote Sensing* on IMOS Multi-sensor L3S SST products: [Govekar et al. \(2022\)](#)
- Paper in *Remote Sensing* on validation of Himawari-8 L2P SST products [Zhang et al. \(2023\)](#)
- Paper in *Remote Sensing* on Himawari-8 SST products [Govekar et al. \(2024\)](#)
- Chapter on selecting SST products for Australian applications. Search for: "*Researchgate Beggs Ch 14 Temperature, 21 Dec 2021*"



Australian Government

Bureau of Meteorology

Useful sites for information on IMOS SST products

- GHRSSST products: <https://www.ghrsst.org/quick-start-guide/>
- Chapter on how to select an SST product: [Beggs \(2021\)](#)
- Overview of IMOS GHRSSST products: <https://opus.nci.org.au/pages/viewpage.action?pagelId=141492230>
- Access to IMOS GHRSSST products: <https://opus.nci.org.au/pages/viewpage.action?pagelId=141492235> and <http://portal.aodn.org.au>
- AODN Toolbox: <https://help.aodn.org.au/aodn-data-tools/>
- IMOS HRPT AVHRR GHRSSST Products: <http://imos.org.au/facilities/srs/sstproducts/sstdata0/>
- IMOS Multi-sensor GHRSSST Products: Govekar et al. (2022) <https://doi.org/10.3390/rs14153785>
- Maps of BoM L4 SST: <http://www.bom.gov.au/marine/sst.shtml>
- IMOS OceanCurrent maps of IMOS L3U and L3S products: <http://oceancurrent.imos.org.au>
- GHRSSST L4 (inc GAMSSA) Validation/Inter-comparison: <http://www.star.nesdis.noaa.gov/sod/sst/squam>
- Regional SST Maps (inc RAMSSA L4, IMOS L3S and other GHRSSST L2P, L3U, L4 products): <https://www.star.nesdis.noaa.gov/sod/sst/arms/>
- Introduction to users on the set of GHRSSST products: <https://zenodo.org/record/6957658>



The Bureau
of Meteorology

Thank you

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Australian Government
Bureau of Meteorology

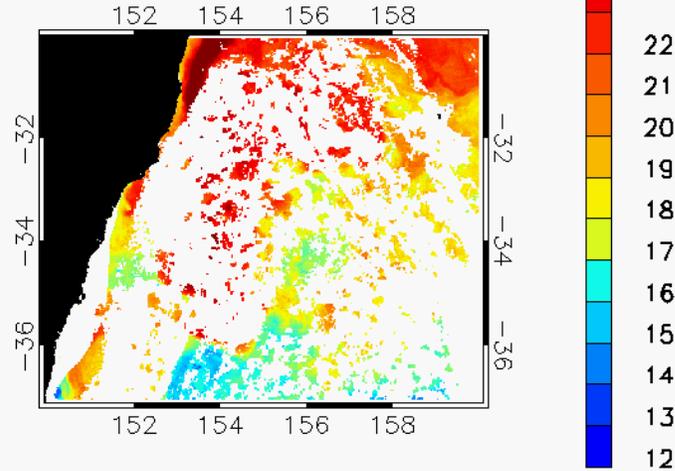
Supplementary Slides

Temporal Averaging vs Spatial Interpolation

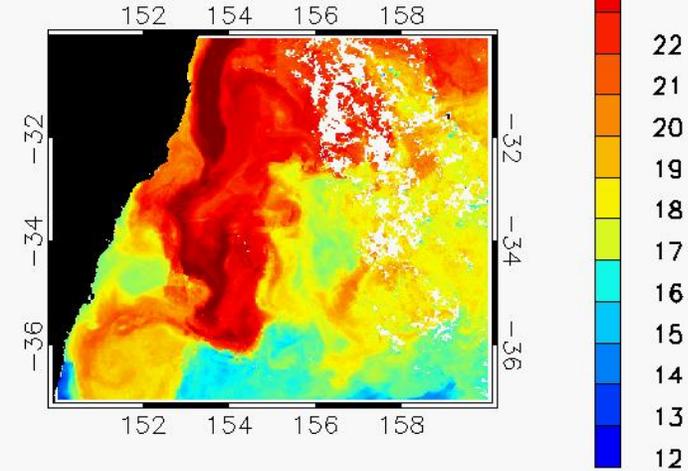
OFFICIAL

E.g. Multi-satellite day+night SSTfnd for 15 Aug 2013

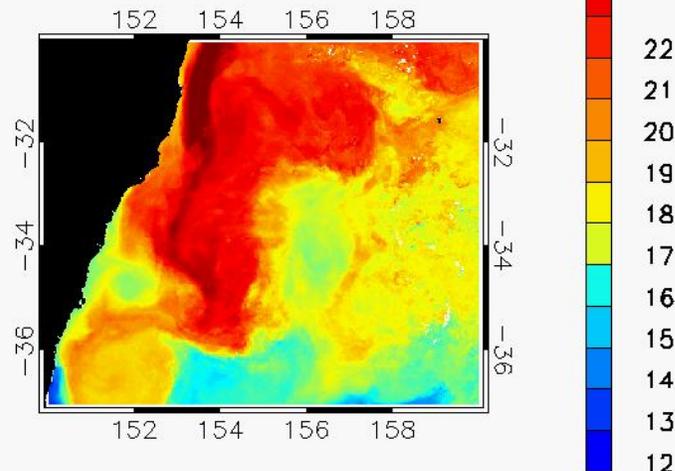
1-day 2 km L3S



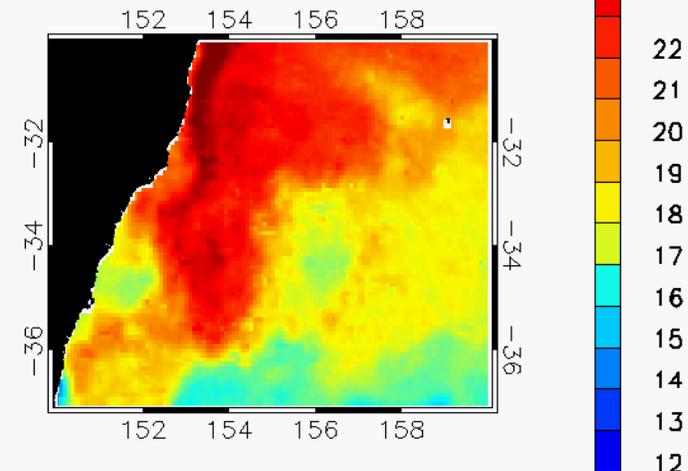
3-day 2 km L3S



6-day 2 km L3S



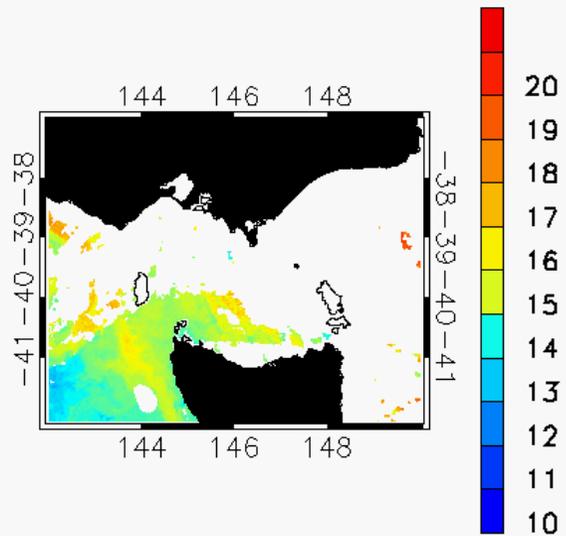
Daily 9 km RAMSSA L4



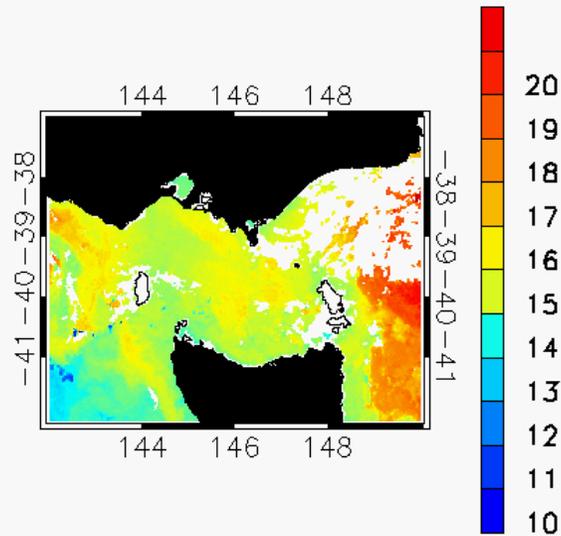
Temporal Averaging vs Spatial Interpolation OFFICIAL

E.g. Multi-satellite day+night SSTfnd for 2 Jun 2014

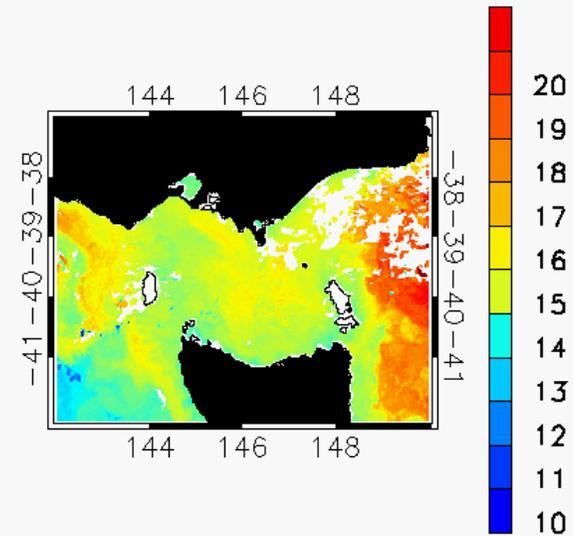
1-day 2 km L3S



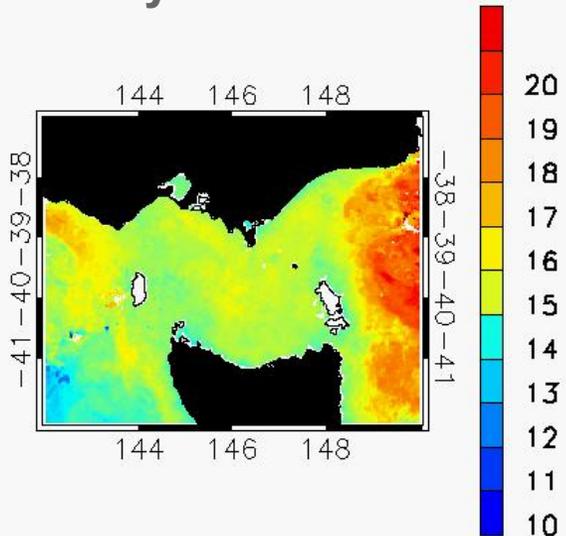
3-day 2 km L3S



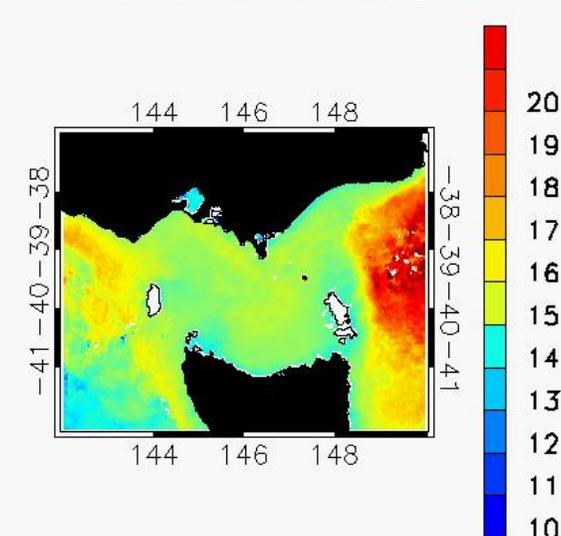
6-day 2 km L3S



14-day 2 km L3S



1-month 2 km L3S



Daily 1 km MUR L4

