The Bureau of Meteorology

IMOS Integrated Marine Observing System

High resolution mapping of thermal stress and marine heatwaves on the Australian coasts using level 3 sea surface temperature data

Pallavi Govekar, Chris Griffin, Claire Spillman , Leon Majewski and Rob Jonson

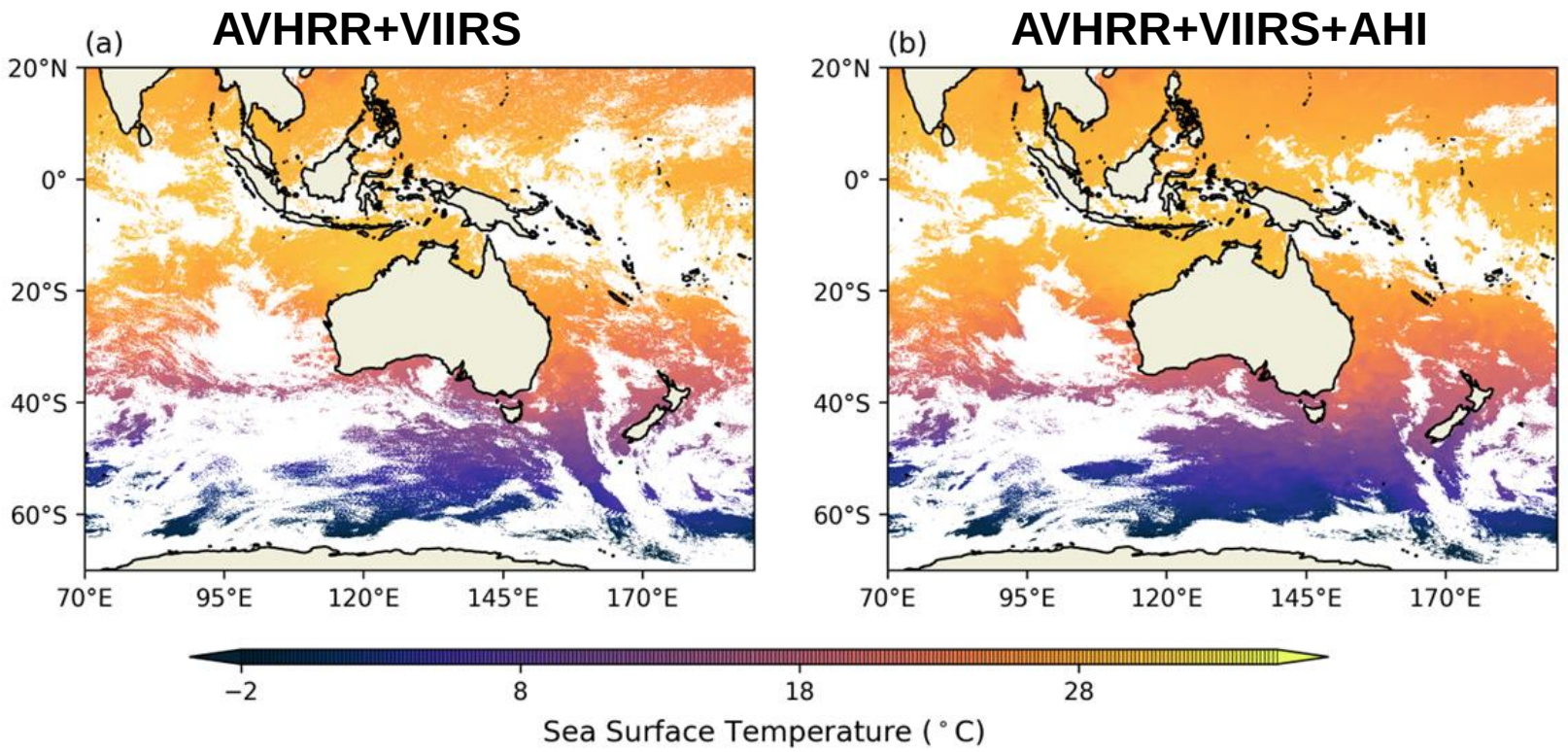
Science & Innovation Group, Bureau of Meteorology, Australia

Pallavi.govekar@bom.gov.au

Acknowledgements : Kat Meletiou and Helen Beggs

GHRSST26 Meeting, Copenhagen, Denmark, 16th – 20th June 2025

Improvements with addition of Himawari 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., 2024) 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 .

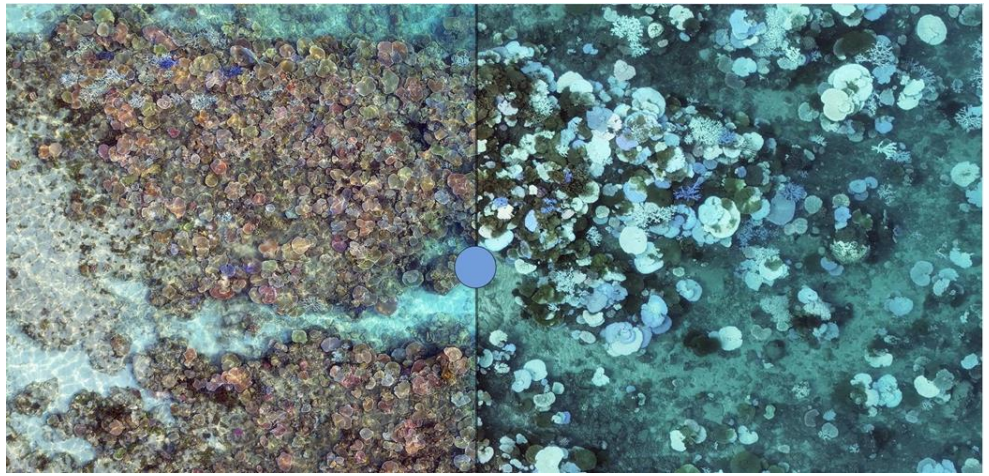
Heat stress monitoring products

❖ The Bureau's ReefTemp Next Generation (ReefTemp) system has provided heat stress monitoring tools for the Great Barrier Reef (GBR) region 2012-2024. The tools have been extensively used by marine managers, government agencies and researchers for managing the GBR Marine Park.

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)

December 2023 20 March 2024



Bleaching extent and coral mortality in the Lizard Island region of the Great Barrier Reef
Photo credit : Dr George Roff from CSIRO

Similar tools for all Australian coasts are essential for understanding extreme events such as marine heatwaves (MHWs) and their potential impacts on marine ecosystems

Heat stress monitoring products

Resources:

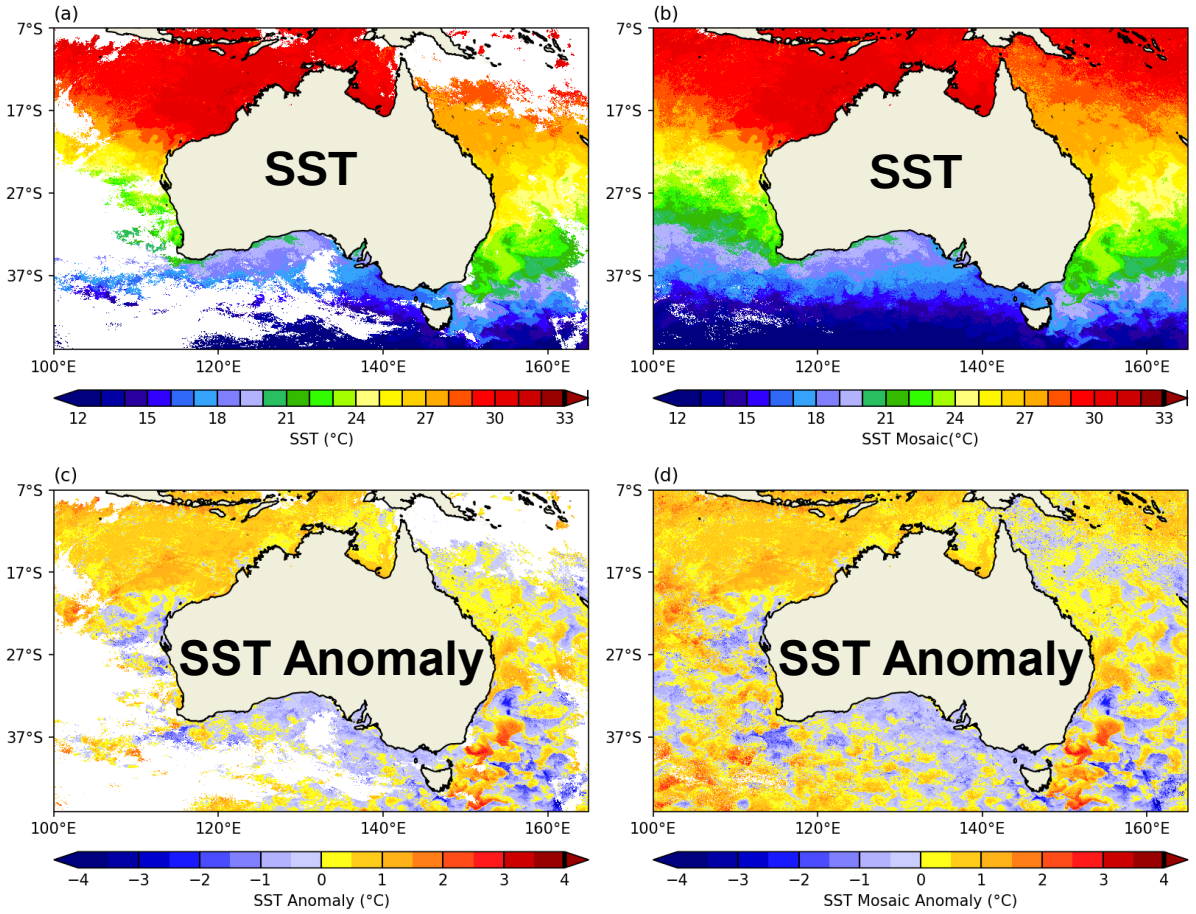
❖ Sea Surface Temperature (SST): Bias corrected (i.e. SST - sses_bias) SST at 0.2 m depth calculated using night-only GeoPolar Multisensor L3S product with quality_level > 2

❖ The SST Atlas of Australian Regional Seas (SSTAARS) climatology constructed using 25 years of night-time daily AVHRR L3S data for the 1992-2016 period was used as a baseline climatology

❖ A mosaic technique where the system fills each pixel that has missing data with the most recent daily SST available for the prior 13 days of the current day for that pixel was used to fill in data gaps.

Thermal stress metrics from night Geo-Polar Multi-sensor L3S SST for 31 March 2020

1-Day **14-Day**



The new metrics covers the whole of the Australian coastal region (100°E – 165°E, 46°S – 7°S)

Heat stress monitoring products

- Sea Surface Temperature Anomaly (SSTA):

$$SSTA_{x,y} = SST_{x,y} - climatology_{today}$$

- Degree Heating Days (DHD):

$$DHD_{x,y} = \sum_{t_0=1^{st}\ Dec}^{t_{1=today}} SSTA_{x,y}\,, where\ SSTA_{x,y} > 0^oC$$

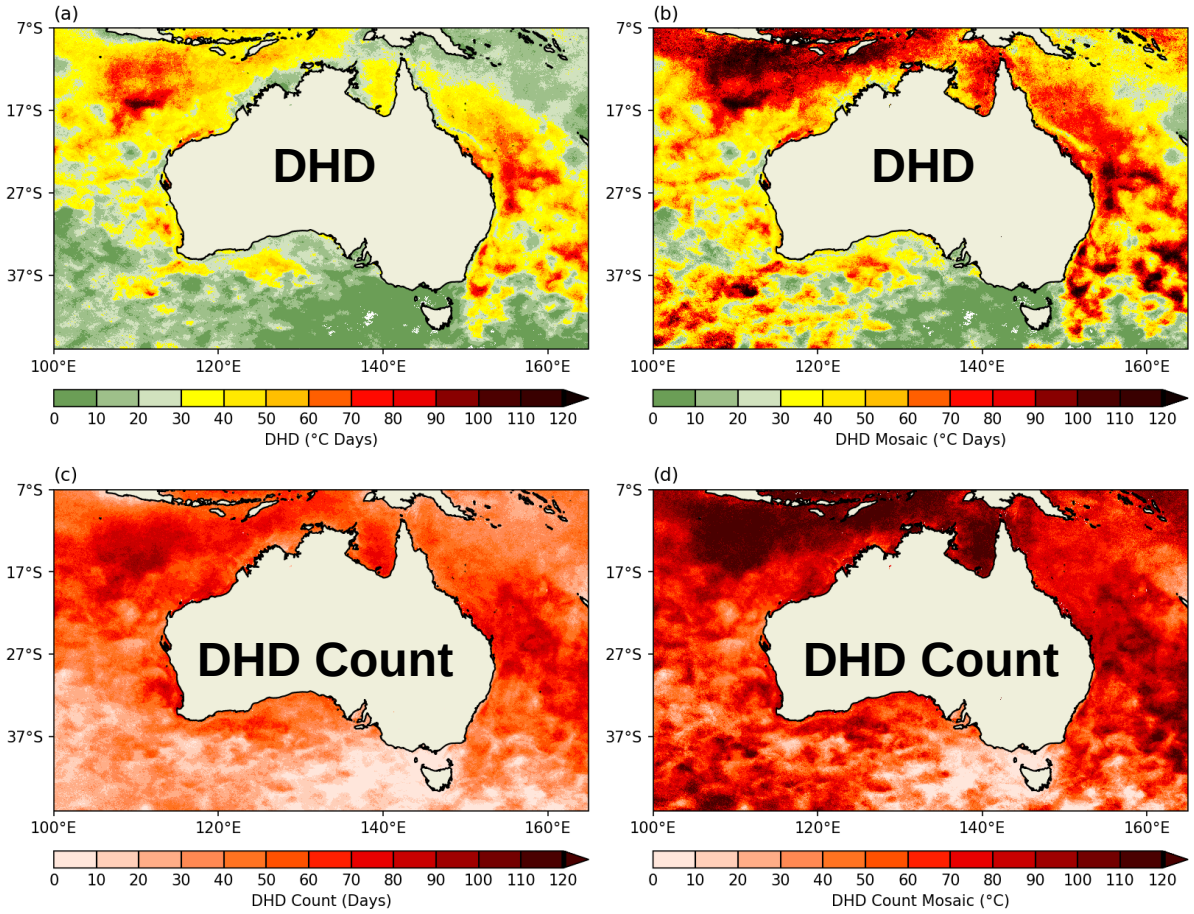
- Degree Heating Day Count (DHD count): This indicates the number of days that contributed to the DHD value reported for the pixel.

- Mean Positive Summer Anomaly (MPSA): The average severity of thermal stress is calculated by dividing the DHD with the DHD count pixel by pixel and is indicated by MPSA values.

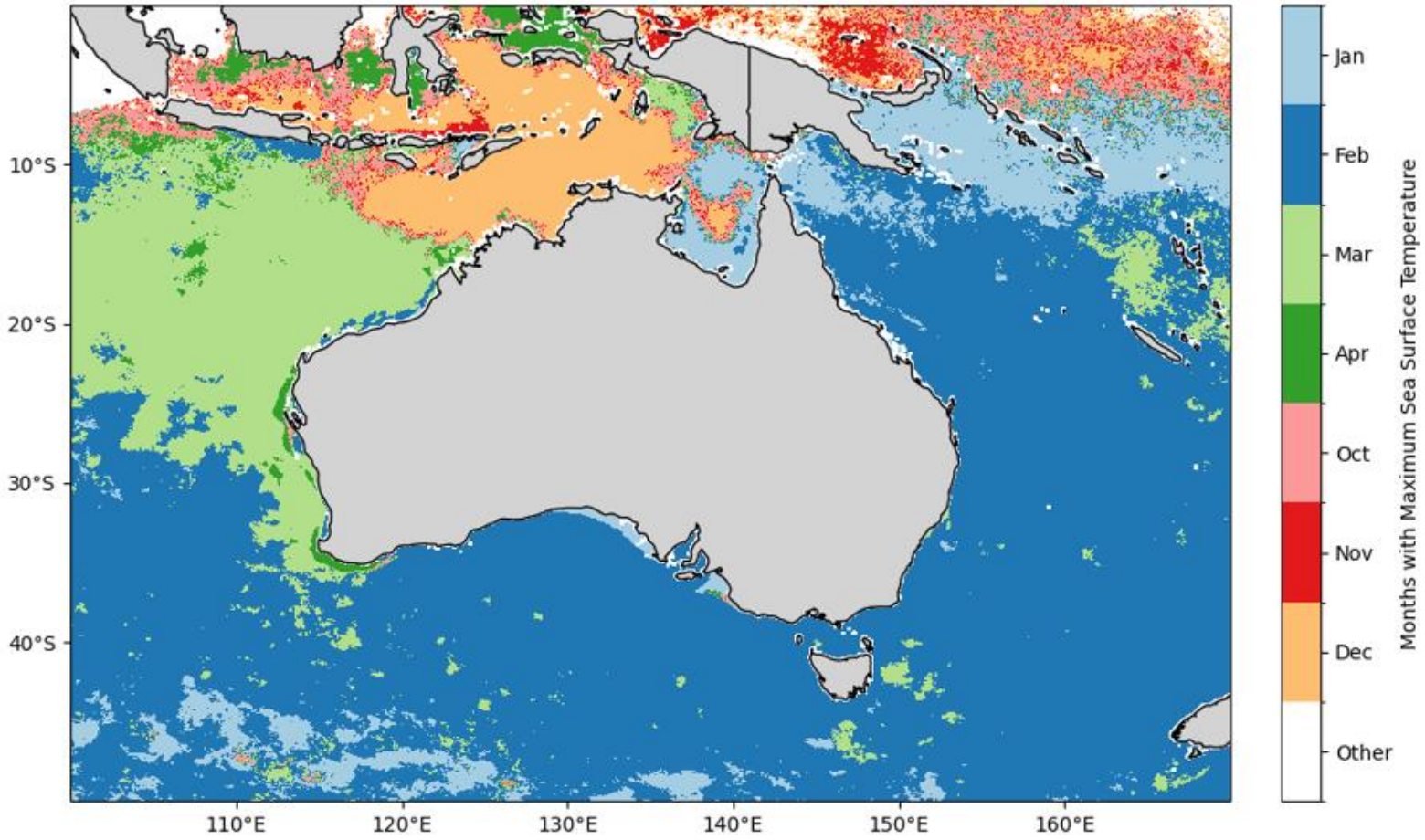
$$MPSA_{x,y} = \frac{DHD_{x,y}}{DHDC_{x,y}}$$

Thermal stress metrics from night Geo-Polar Multi-sensor L3S SST for 31 March 2020

1-Day **14-Day**

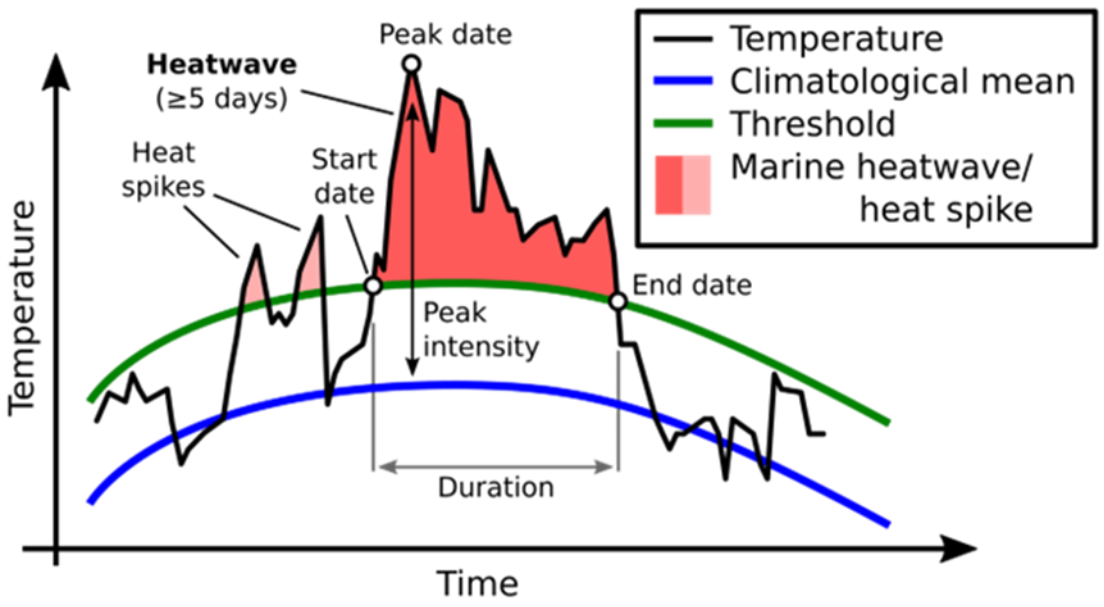


Degree Heating Days calculation - 1st November-30th April

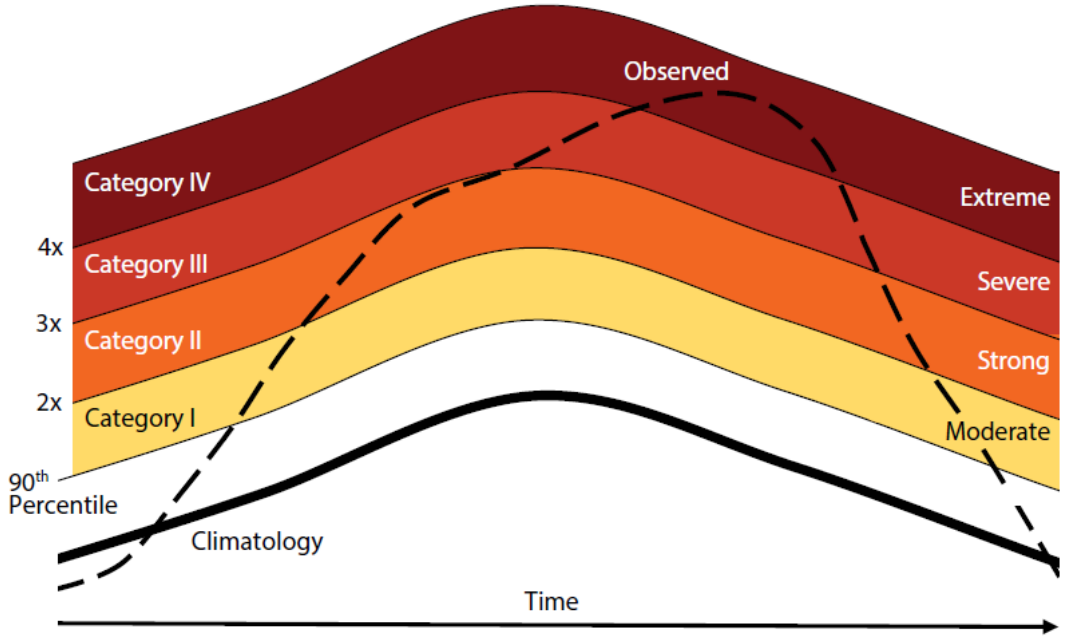


Months of maximum SST using daily mean temperature from SSTAARS climatology (1992-2016)

Marine Heatwave Categories



Hobday et al., 2016



Hobday et al., 2018

- Hobday et al., 2016 - MHWs are defined at locations where an upper locally determined threshold (90th percentile relative to the local long-term climatology) is exceeded for at least a five-day period, with no more than two below- threshold days
- Hobday et al., 2018 - The observed temperature time series (dashed line), the long-term regional climatology (bold line), and the 90th percentile climatology (thin line). Multiples of the 90th percentile difference (2× twice, 3× three times, etc.) from the mean climatology value define each of the categories I–IV, with corresponding descriptors from moderate to extreme. This example peaked as a Category IV (extreme) MHW.

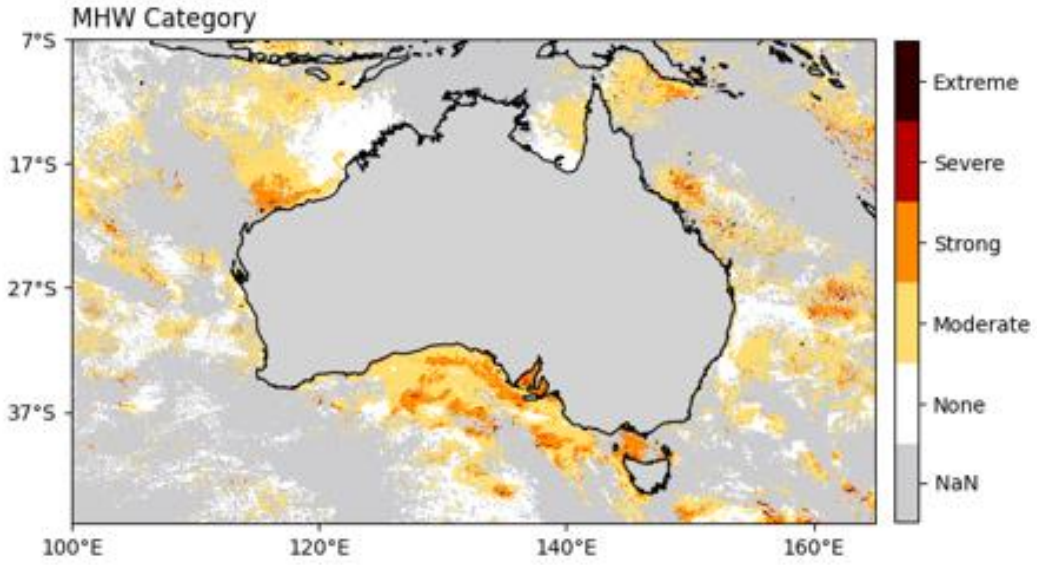
Marine Heatwave Categories

Resources:

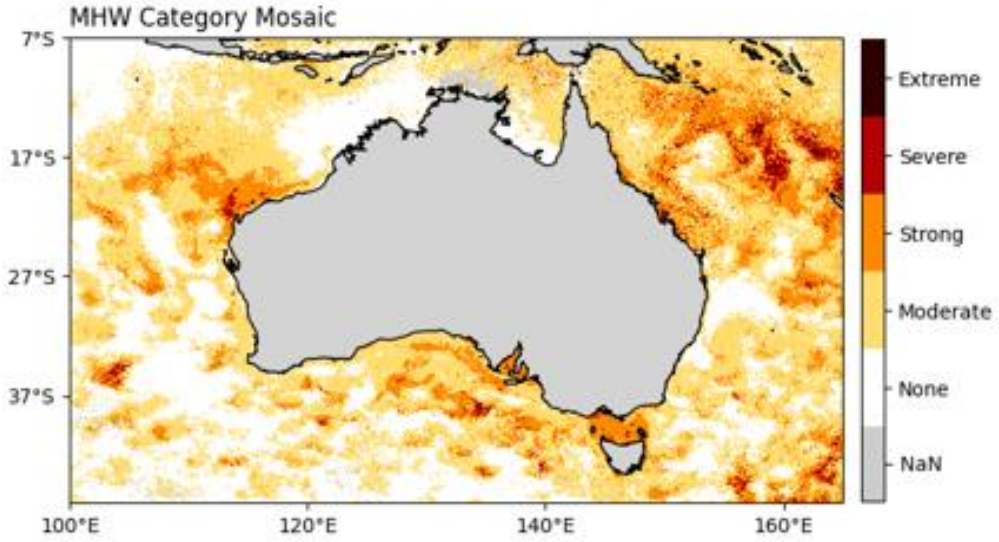
- Sea Surface Temperature (SST): GeoPolar Multisensor L3S product

- Climatology: The SST Atlas of Australian Regional Seas (SSTAARS) climatology (1992-2016)

MHW categories-1 day



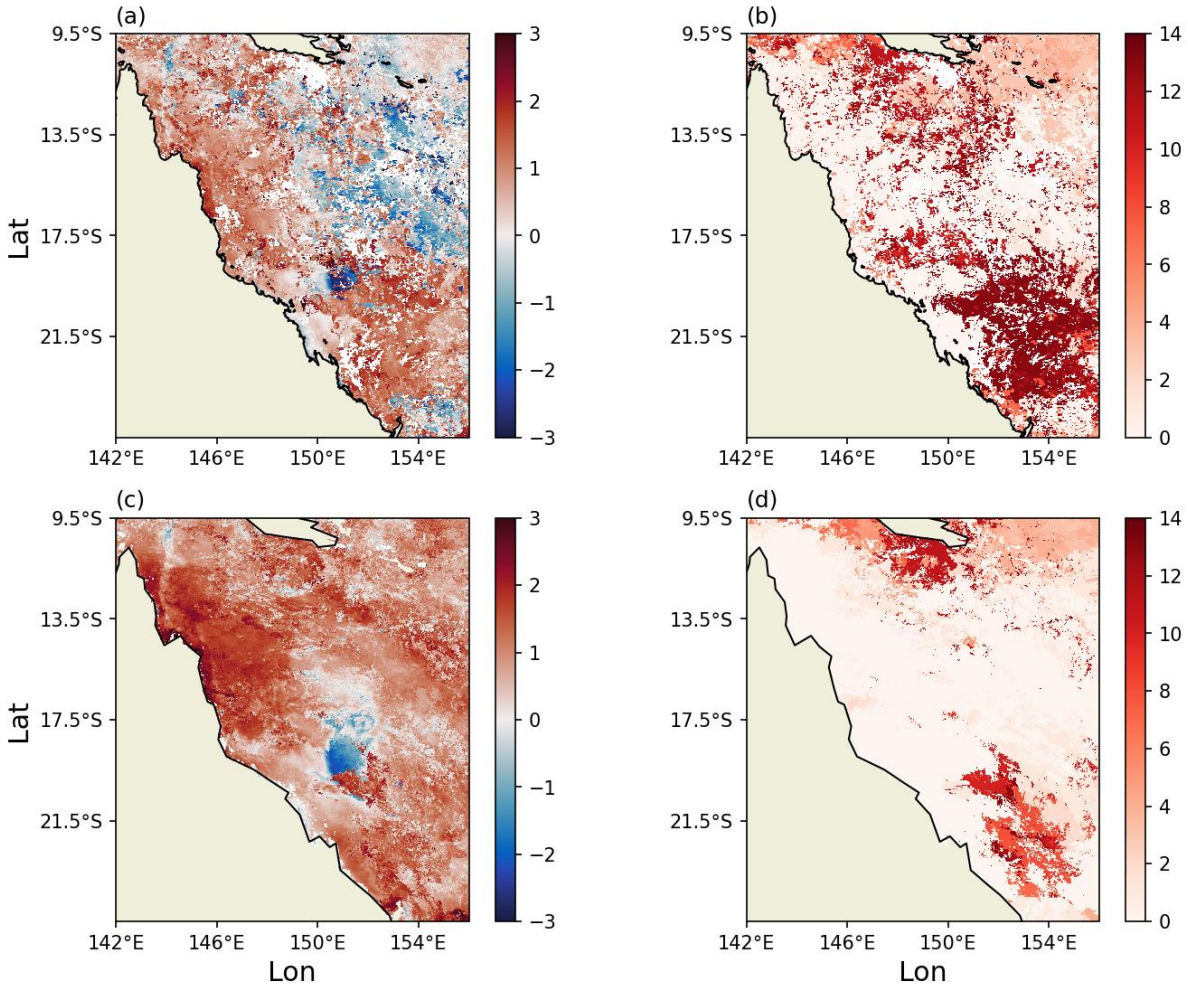
MHW categories-14 days



Marine heatwave categories for 1-day (left panel) and 14-day (right panel) for 4th May 2025

Case study 1:

Cyclone Debbie in March 2017 – arrested coral bleaching due to significant cooling around Townsville.



(a)14-day SST Anomaly Mosaic, (b) mosaic pixel age using current operational MultiSensor L3S SST, (c) 14-day SST Anomaly Mosaic and (d) mosaic pixel age using GeoPolar MultiSensor L3S for 31st March 2017

- Need improvement over gap filling method.

Case study 2

South Australian coast, March-May 2025

- The mysterious brown foam covered South Australia’s beaches contained large numbers of a tiny harmful algal species

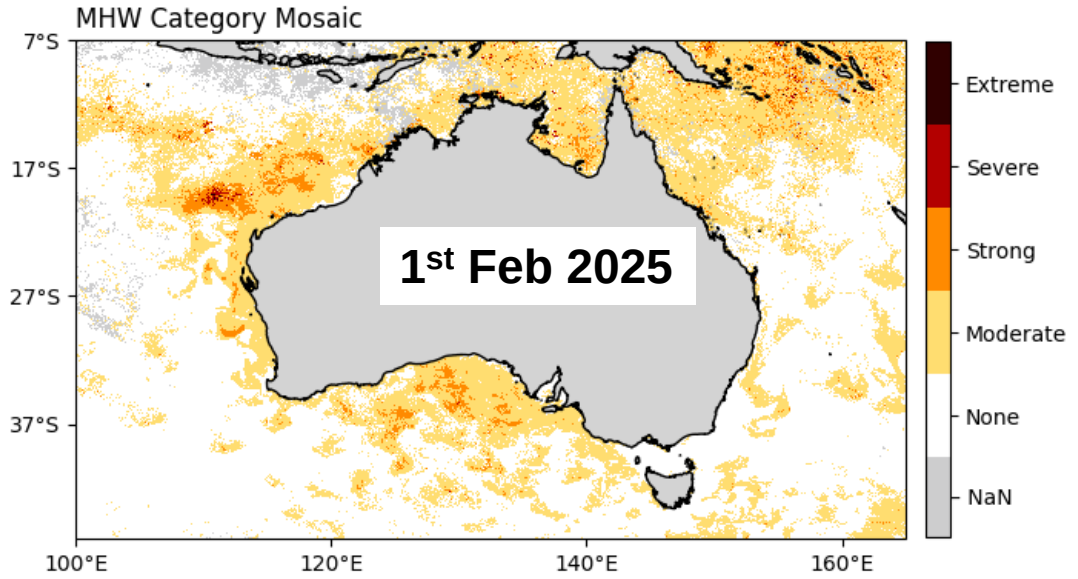
- A toxic algal bloom covered thousands of square kilometres, killing precious sea life, causing flu-like symptoms in humans.

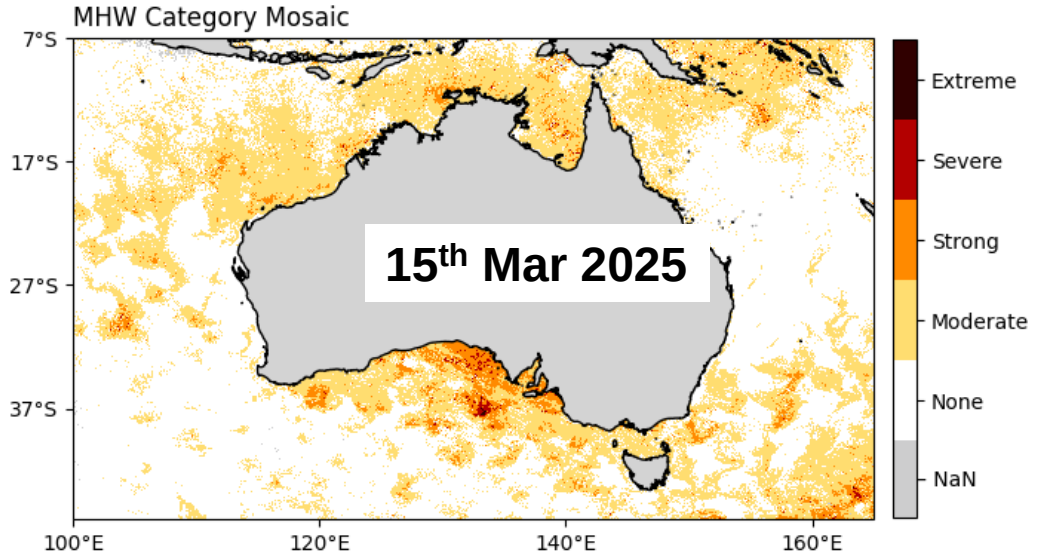
Credit: www.abc.net.au

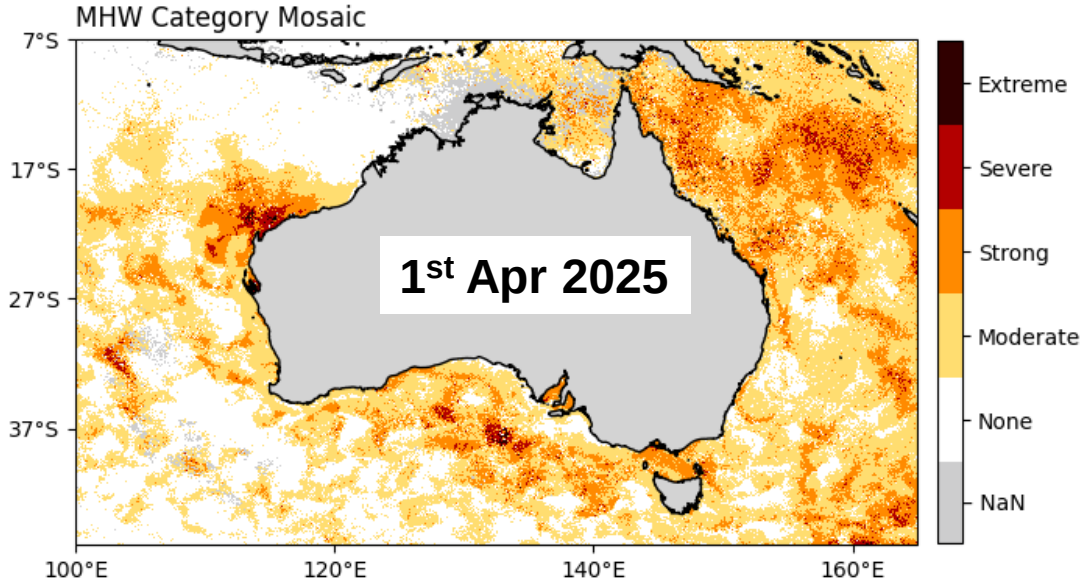
Case study 2

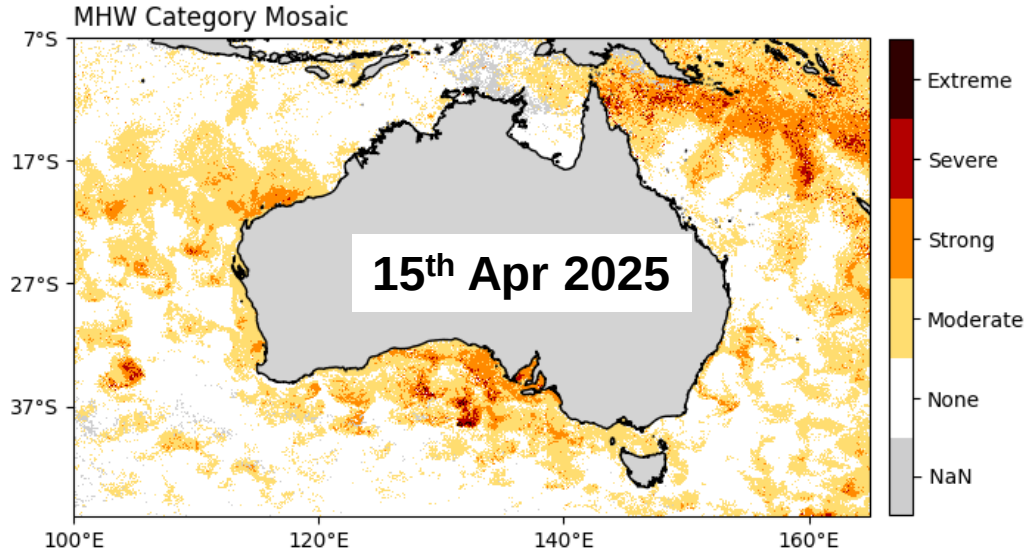
South Australian coast, March-May 2025

MHW categories



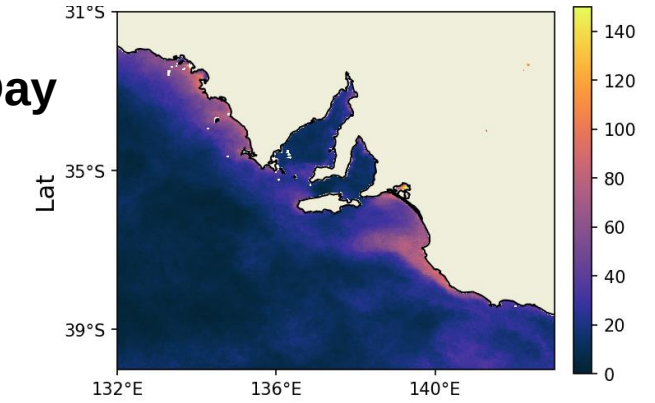


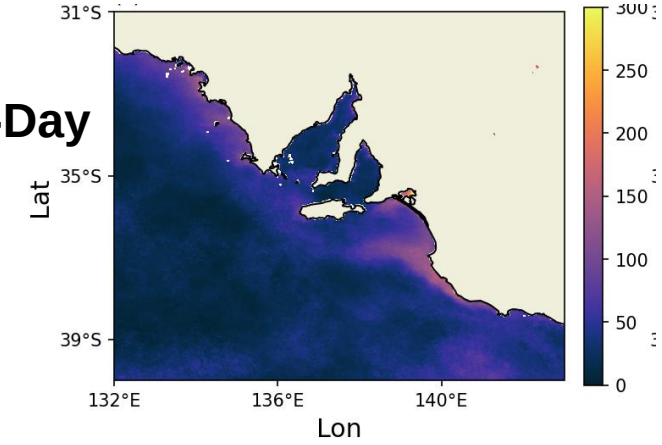


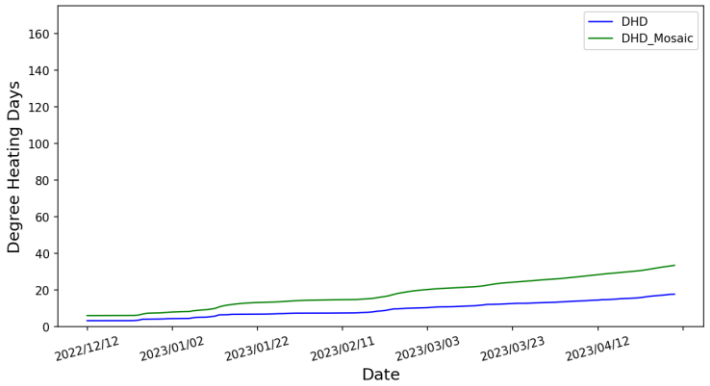


Case study, South Australian coast, DHD 30th April

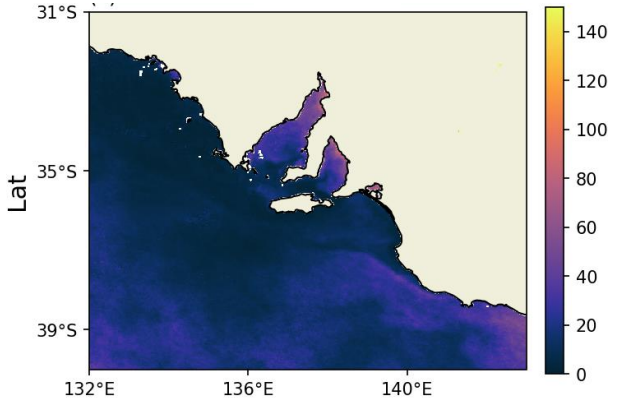
2023

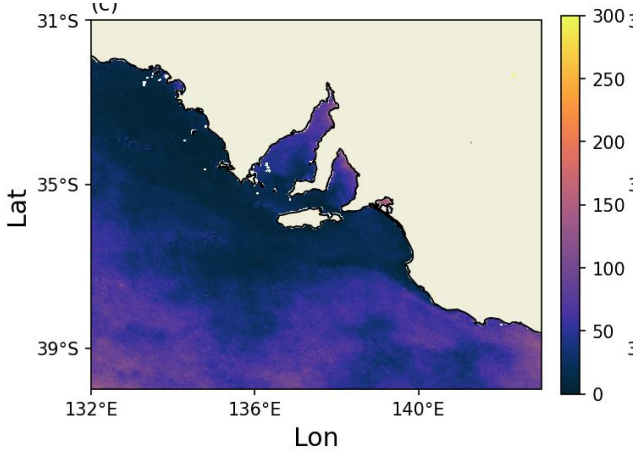


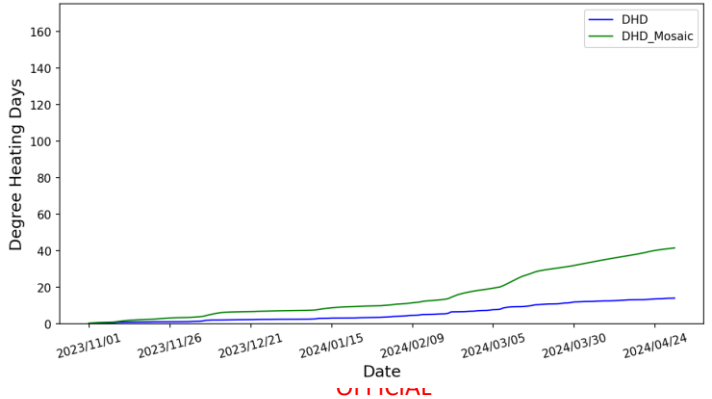




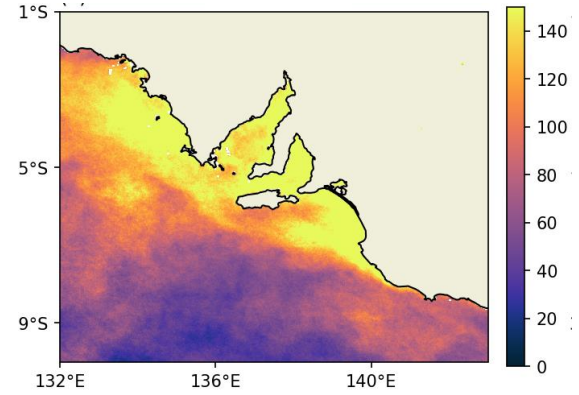
2024

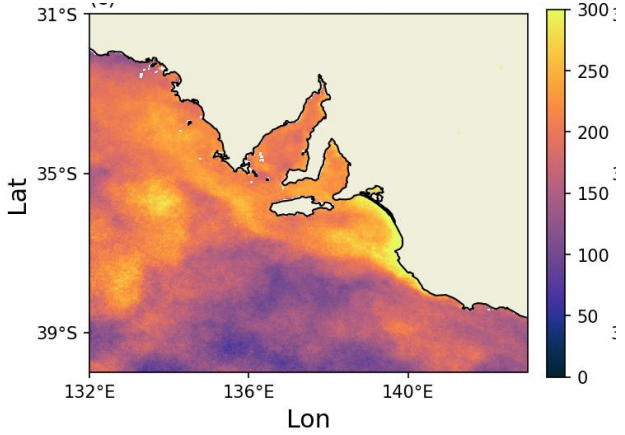


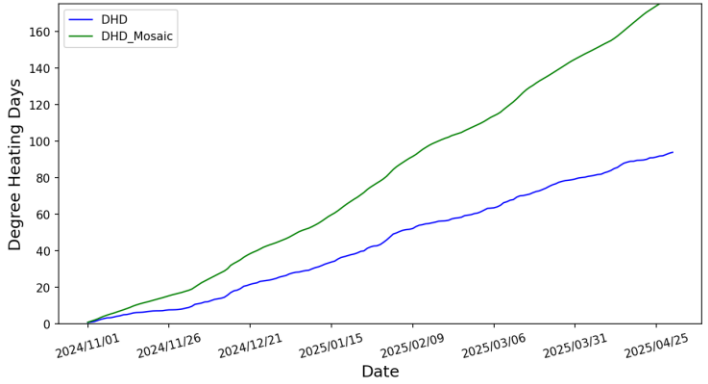




2025





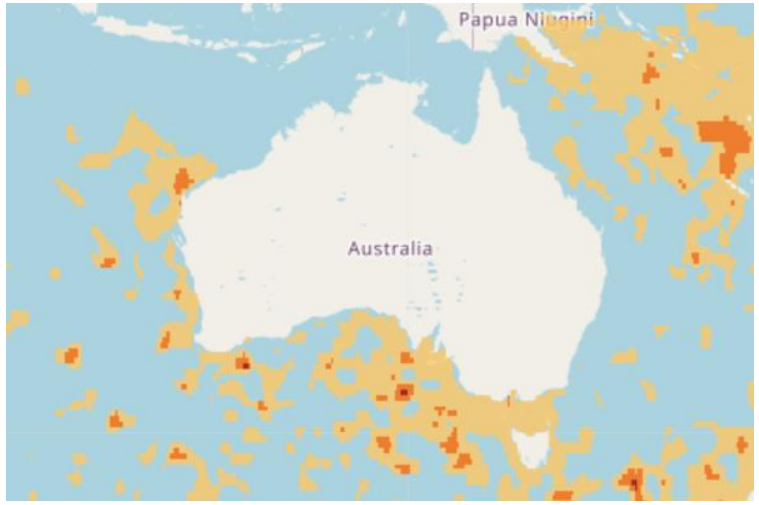


1-Day

14-Day

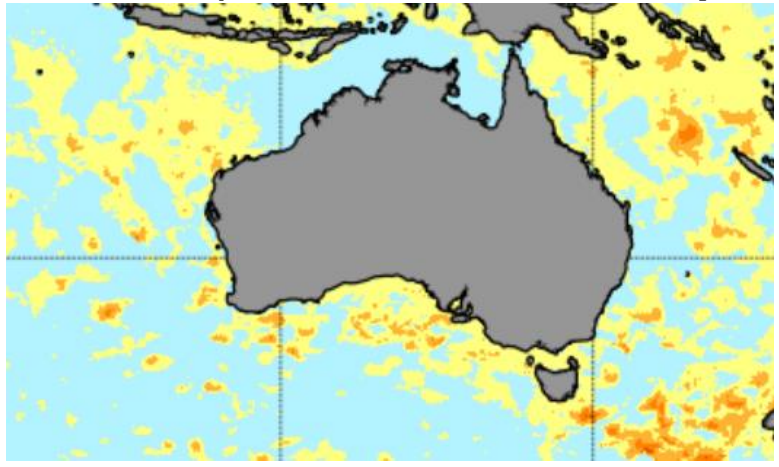
L4 Vs L3 SSTs- Marine Heatwave Categories, 4th May 2025

25 km DOISST v2.1, 1982 – 2011 clim period)



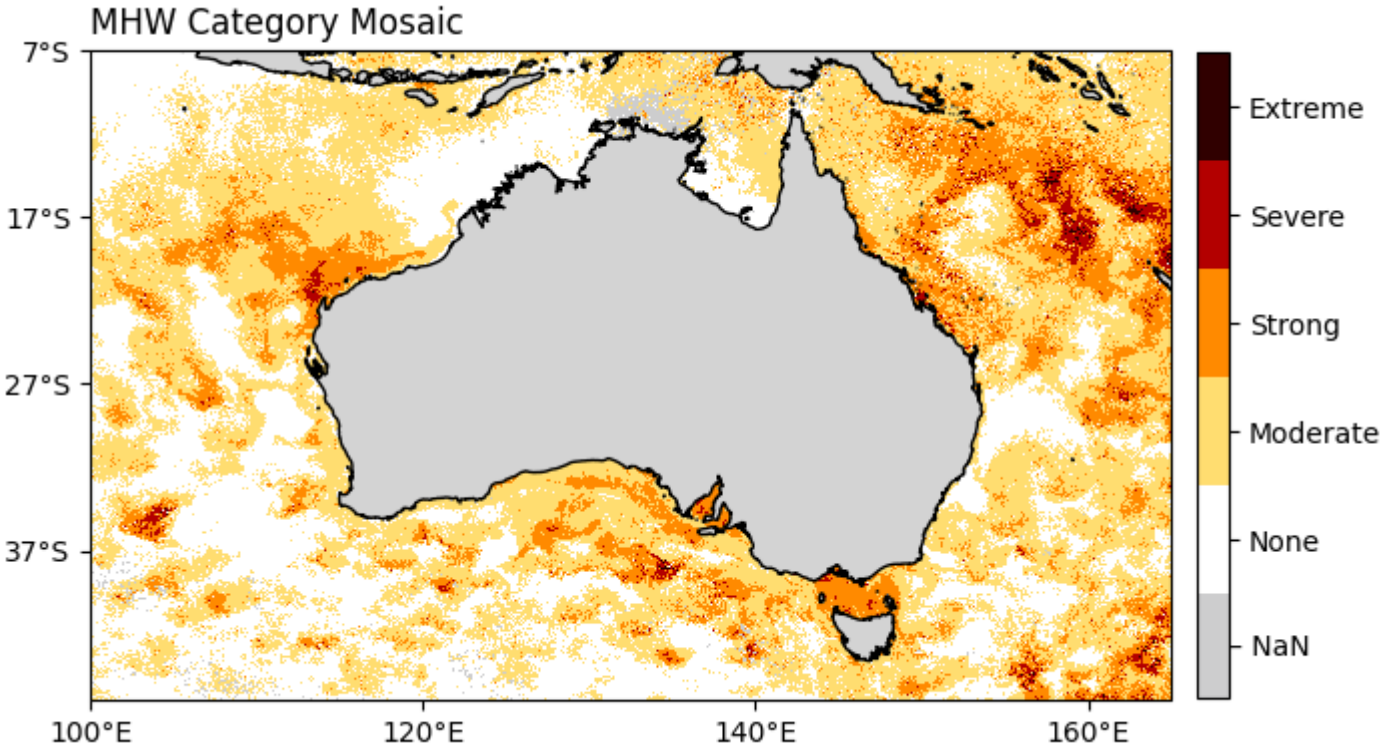
https://www.marineheatwaves.org/tracker.html

5 km Geo-Polar Blend SST Analysis, the baseline time period of **1985 – 1990 plus 1993**



https://coralreefwatch.noaa.gov/product/marine_heatwave/

Bureau's experimental product, available on NCI
2 km MultiSensor L3S, SSTAARS climatology, 1992-2016



Summary and future plans

- The 10-minute temporal resolution of the newly developed Himawari-8/9 SST data allows for a daily composite with improved spatial coverage, helping downstream thermal stress products. It provides more contemporary data for mosaic SST products, representing closely conditions of the present day.

- Newly developed experimental thermal stress and MHW monitoring metrics are at a very high spatial resolution, exhibiting greater feature resolution.

- Heat stress and MHW monitoring metrics will be made available in netcdf format in near real time by AODN (https://portal.aodn.org.au). Available daily products will be (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)

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Thank you

Pallavi Govekar

Pallavi.govekar@bom.gov.au

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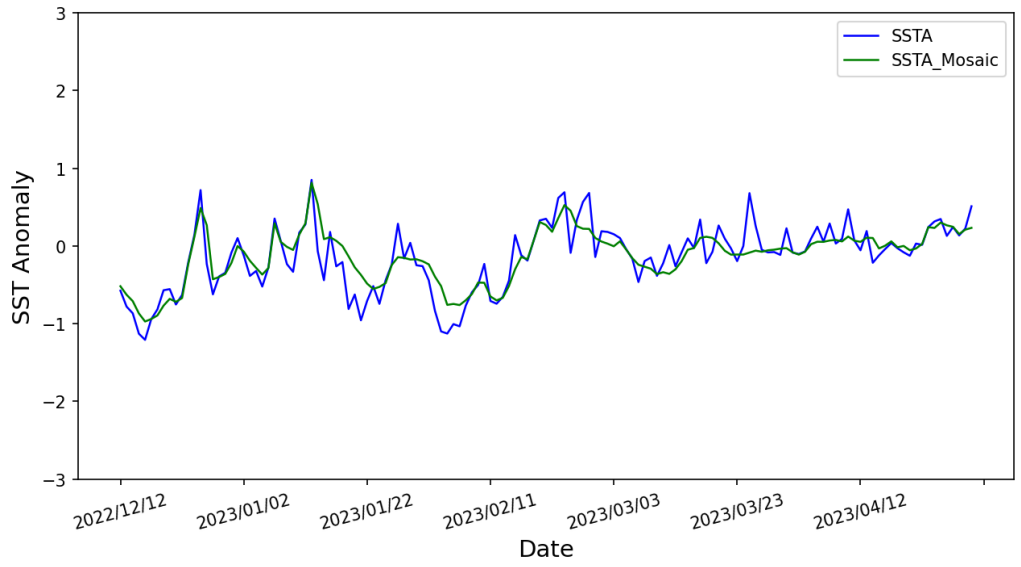
Supplementary slides….

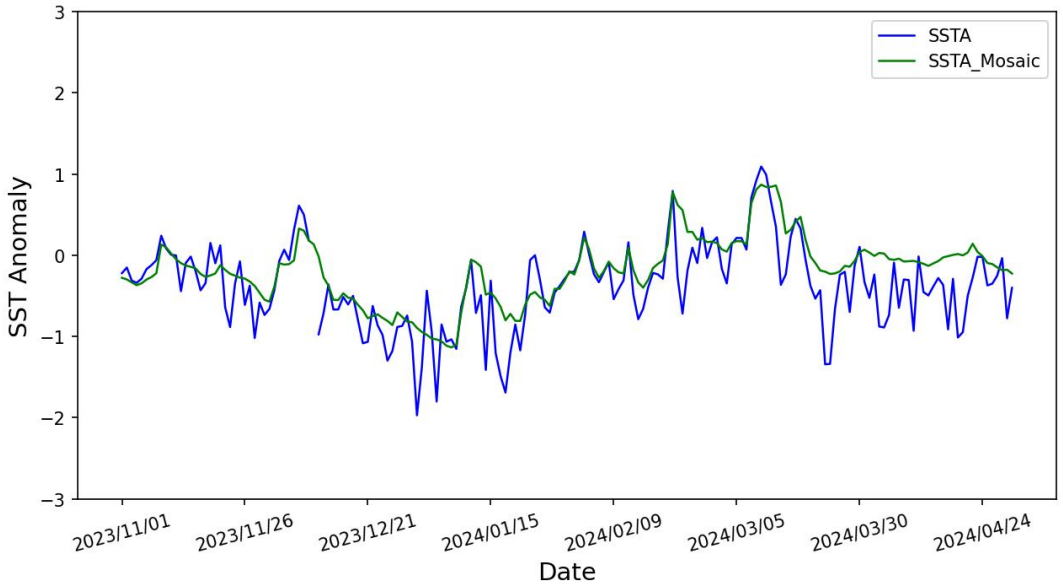
Case study

Degree Heating Days-1 day and 14 days

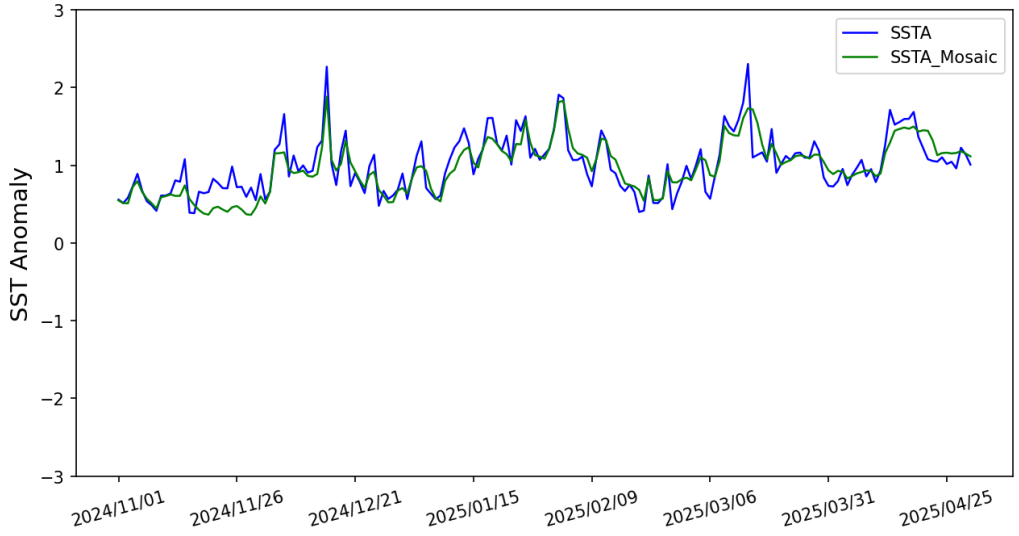
2022-23



2023-24



2024-25



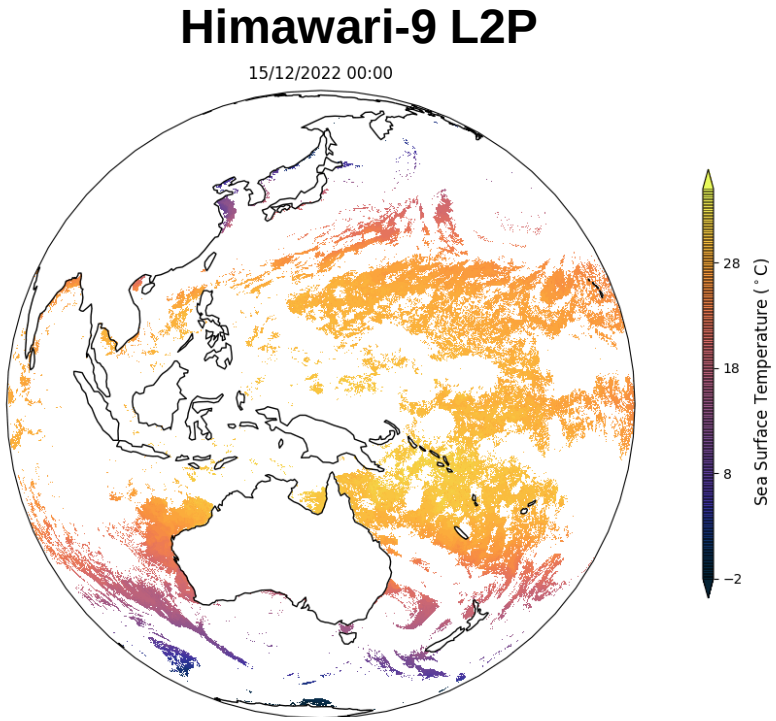
Sea Surface Temperature products and their applications from Himawari-9 geostationary satellite

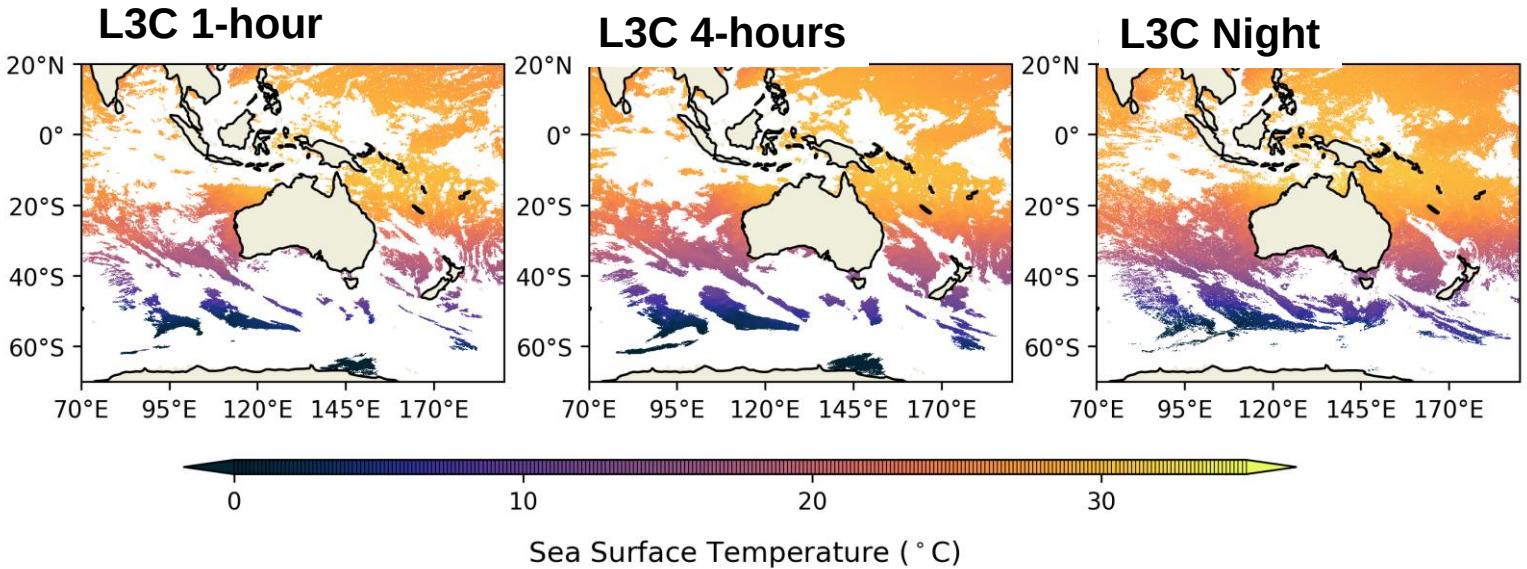
Himawari-9 SSTs:

- 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



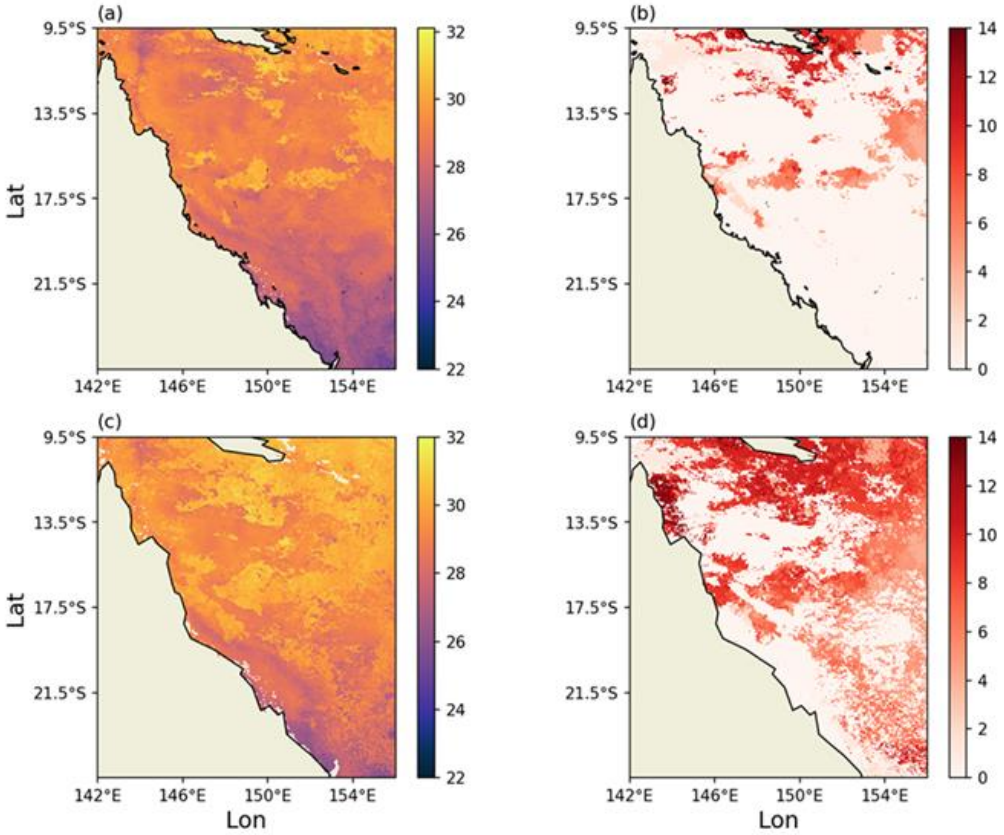


How well do the new heat stress monitoring tools perform?

Metrics	New	ReefTemp
SST product	**GeoPolar MultiSensor L3S**	**MultiSensor L3S**
Climatology	SSTAARS (Wijffels et al., 2018)	IMOS (Garde et al., 2014)
Domain	AUS (100ºE-165ºE,46ºS-7ºS)	GBR (142ºE-156ºE,9.5ºS-25.5ºS)
Depth	0.2 m	Surface (skin)

New

Reef Temp



The mosaic generated using GeoPolar MultiSensor SST shows fewer days for mosaic age indicating that it contains more contemporary data, better representing data on the reported date.

Figure:(a)14-day SST Mosaic (ºC) and (b) mosaic pixel age (in days from present) from the new metrics and (c) 14-day SST Mosaic (ºC) and (d) mosaic pixel age (days) from ReefTemp for 15th March 2020.

How well do the new heat stress monitoring tools perform?

With use of high resolution GeoPolar MultiSensor L3S, new thermal stress metrics across the GBR are defined at a very high resolution.

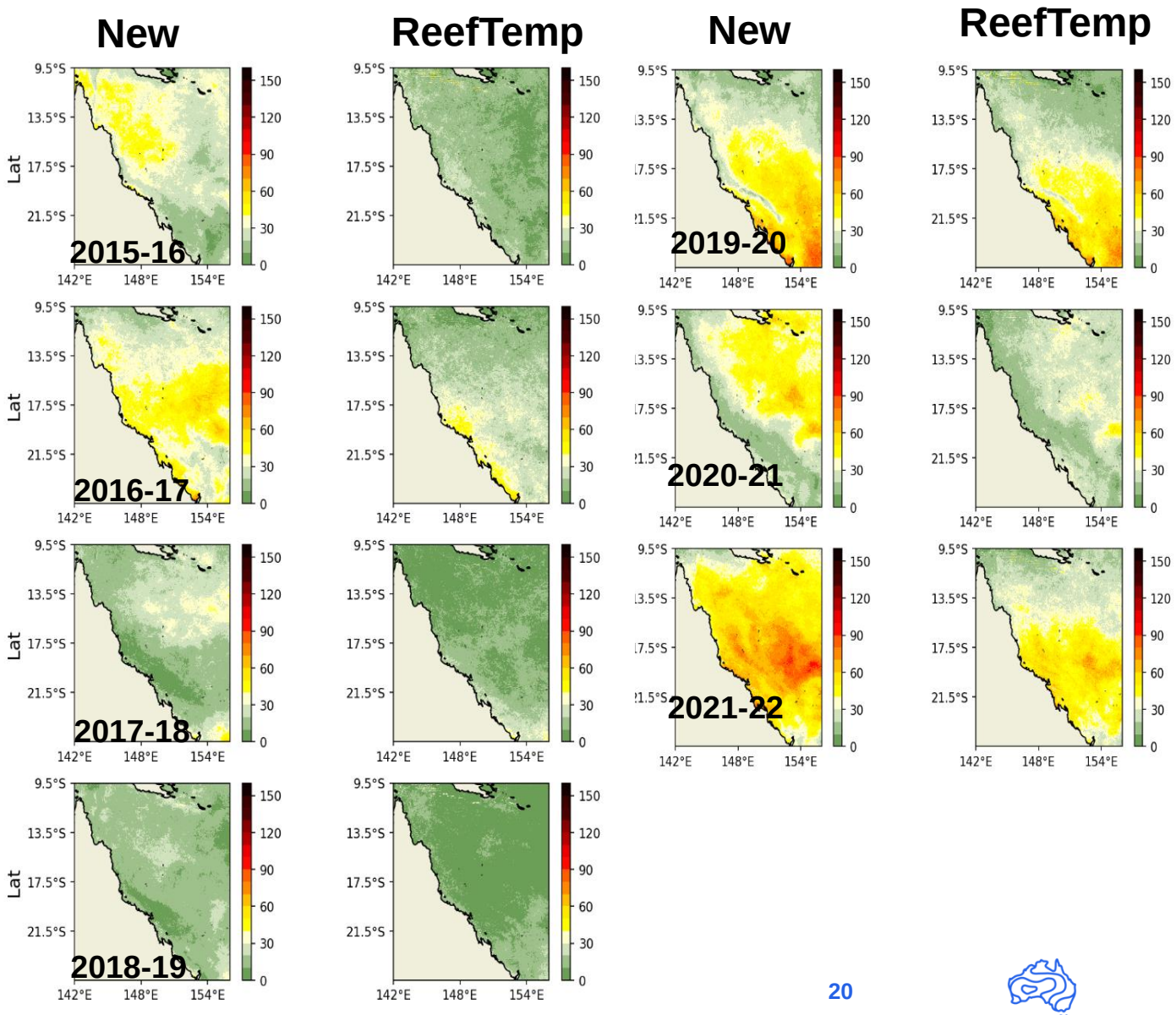
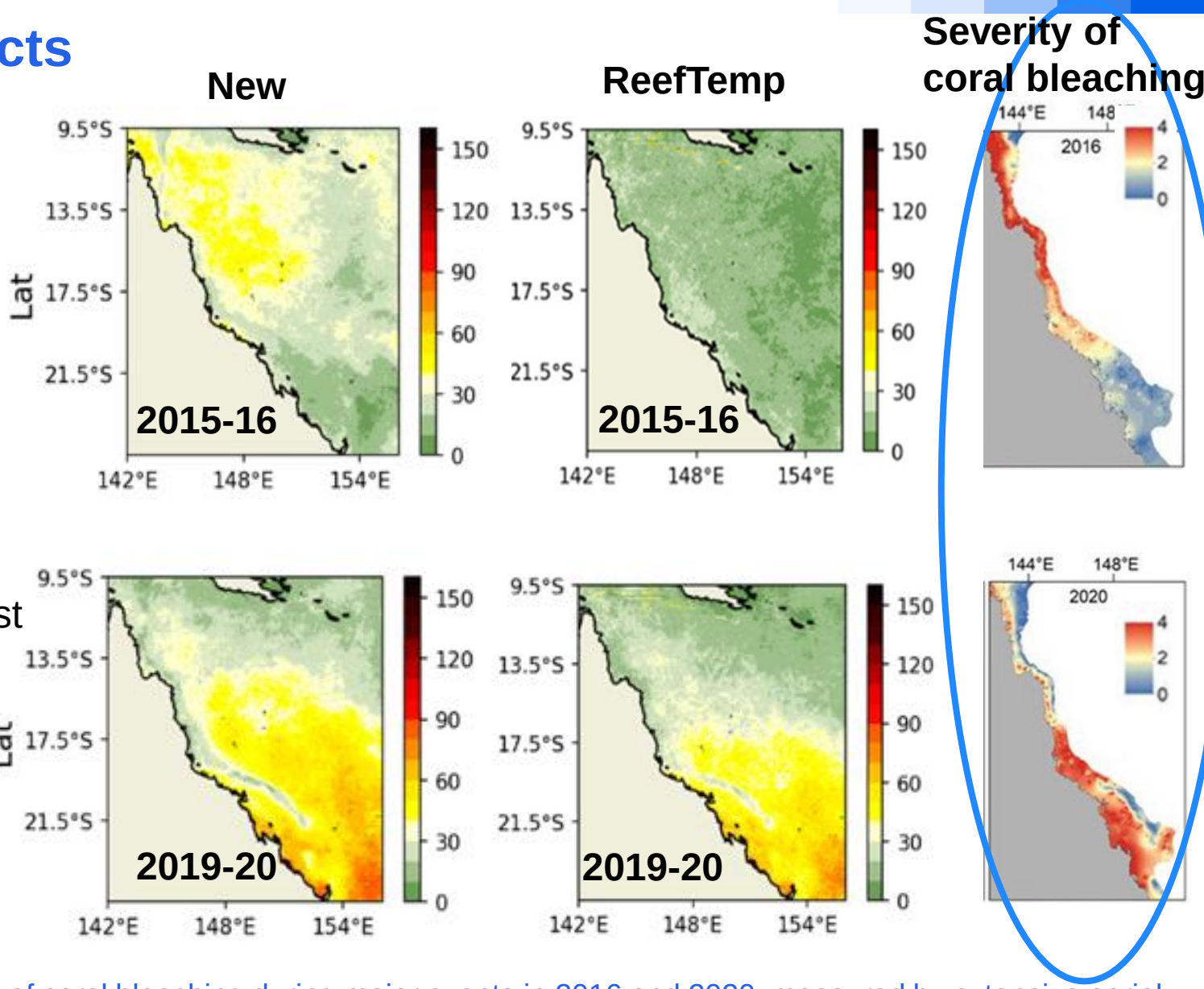


Figure : The DHD (ºC) from new method (left panels) and Reeftemp (right panels) for 2015-16, 2016-17, 2017-18, 2018-19, 2019-20, 2020-21 and 2021-22 summer seasons.

Heat stress monitoring products

❖ During 2015-16, the new system indicates higher DHD values in the northern and central GBR, whereas in 2019-20, it shows elevated DHD values in the central and southern GBR.

❖ These findings align with previous studies that reported the most severe coral bleaching primarily occurring in the northern and central GBR during 2015-16 while in 2019–20, the central and southern GBR experienced the most severe coral bleaching



Hughes et al., 2021: Geographic extent and severity of coral bleaching during major events in 2016 and 2020, measured by extensive aerial scores: 0 (<1% of corals bleached), 1 (1%–10%), 2 (10%–30%), 3 (30%–60%), and 4 (>60%). The number of reefs surveyed was 1,195 (2016) and 1,036 (2020)