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Data in Brief





Data Article

Tropical western and central Pacific marine heatwave data calculated from gridded sea surface temperature observations and CMIP6



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ABSTRACT

Processed marine heatwave metrics are provided for the tropical western and central Pacific Ocean region (120°E-140°W, 40°S-15°N). The metrics are computed from daily sea surface temperature (SST) data, from both observations and models. The observed marine heatwave data are calculated from NOAA 0.25° daily Optimum Interpolation Sea Surface Temperature (OISST) over the period 1982–2019. The modelled marine heatwave data are from analysis of 18 model simulations as part of the Coupled Model Intercomparison Project, Phase 6 (CMIP6) over the period 1982–2100, where two future scenarios have been analysed. The marine heatwave data are provided on a grid point basis across the domain. Marine heatwave timeseries metrics are also provided for three case study regions: Fiji, Samoa, and Palau.

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Abbreviations: SST, Sea surface temperature; MHW, Marine heatwave; OISST, Optimum interpolation sea surface temperature; CMIP6, Coupled Model Intercomparison Project, Phase 6.

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Specifications Table

Specifications Table				
Subject	Environmental Science			
Specific subject area	Observed, modelled, and projected marine heatwaves in the tropical western and central Pacific Ocean			
Type of data	NetCDF Marine heatwave metrics			
How data were acquired	Daily sea surface temperature (SST) data were sourced from a uniformly gridded observational dataset and model outputs from participating organisations in the Coupled Model Intercomparison Project, Phase 6 (CMIPO Marine heatwave statistics were computed from these data using the marineHeatWaves python module: https://github.com/ecjoliver/marineHeatWaves.			
Data format	Analysed			
Parameters for data collection	A warm water event is typically defined as a marine heatwave if it exceeds a given temperature threshold for five or more days [1]. Daily SST data provide a relevant, robust, and useful measure for the calculation of extreme warm water events in the upper ocean [1,2]. Here, daily SST observations over multiple decades were desired. Model simulations and projections from the latest generation of global climate simulations were favoured.			
Description of data collection	Observed sea surface temperature data analysed were the NOAA 0.25° daily Optimum Interpolation Sea Surface Temperature (OISST), version 2.1 [3]. Observations are available from 1 September 1981 to present day. Coupled Model Intercomparison Project, Phase 6 (CMIP6) daily sea surface temperature data were obtained from the National Computational Infrastructure (NCI) node of the Earth System Grid Federation (ESGF). Marine heatwaves metrics were computed using the marineHeatWaves python module: https://github.com/ecjoliver/marineHeatWaves. All source data are freely and publicly available.			
Data source location	Observed primary data source: Metadata and data access link are available at 10.25921/RE9P-PT57. SST data are provided in a single file per day, but they were analysed from concatenated files (one year of data per file) made available at the National Computational Infrastructure (NCI). Observed data analysis period: 1 January 1982 to 31 December 2019. Model primary data source: Searched for and accessed through the NCI ESGF portal at https://esgf.nci.org.au/search/cmip6-nci. Primary sources and metadata locations provided in the main text. Search for analysed models can be refined with the following selections:			
	 Experiment ID: historical, ssp126, ssp585 Grid Label: gn Frequency: day Variable: tos 			
	Model data analysis period: 1 January 1982 to 31 December 2100. Region analysed: 120°E-140°W, 40°S-15°N (tropical western and central Pacific Ocean). Reference climatology period: 1 January 1995 to 31 December 2014			
Data accessibility	Public repository Repository name: Zenodo Data identification number: 10.5281/zenodo.5069012			
Related research article	Direct URL to data: https://www.doi.org/10.5281/zenodo.5069012 N.J. Holbrook, V. Hernaman, S. Koshiba, J. Lako, J.B. Kajtar, P. Amosa, A. Singh, Impacts of marine heatwaves on tropical western and central Pacific Island nations and their communities, Glob. Planet. Change, 208 (2022) 103,680. https://www.doi.org/10.1016/j.gloplacha.2021.103680 [4].			

Value of the Data

- Marine heatwaves can have devasting impacts on marine ecosystems, with flow-on effects to
 human society. Such impacts are of particular importance to Pacific Island countries that rely
 heavily on marine resources. The data here provide marine heatwave metrics for the tropical
 western and central Pacific Ocean region, including counts of marine heatwave days, intensities, and durations over the observational period (1982–2019). Counts of marine heatwave
 days are also provided from CMIP6 models, from the historical period, through two possible
 future greenhouse gas emissions scenarios (1982–2100).
- Operators in the coastal and marine sectors in the tropical western and central Pacific Ocean region may have use of these data. Such sectors might include subsistence and commercial fishing, diving, aquaculture, fisheries management, tourism, conservation management and policy development, amongst a host of other sectors dependant on marine heatwave observations and projected changes.
- The data provided can be used to identify historical links between marine heatwaves and
 other observed impacts, including environmental, or societal, such as human health. Further
 evaluation of model performance can be conducted by determining the level of accuracy in
 simulating warm temperature extremes. Projections of marine heatwaves may also be used
 to evaluate levels of future climate change risk to relevant sectors in the region, facilitating
 adaptation planning.

1. Data Description

The primary data are sea surface temperature (SST), which were analysed from both observations and global climate models. In both cases, daily mean SSTs were obtained and processed from 1 January 1982, across a broad region of the Pacific Ocean (120°E-140°W, 40°S-15°N; Fig. 1). Marine heatwave metrics were computed at each grid point within the region. The region spans beyond the tropics, but the descriptor 'tropical western and central Pacific' reflects that the case

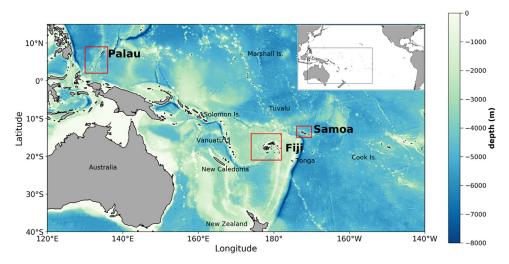


Fig. 1. Domain of the tropical western and central Pacific Ocean region. Case study regions for Palau, Fiji, and Samoa are denoted by red boxes. The inset shows the region in the context of the wider Pacific Ocean. Figure adapted from Fig. 1 of [4].

study island nations of Fiji, Samoa, and Palau all lie within the tropics. Analysis was also conducted on area-weighted mean SST for the three case study regions (Fig. 1):

Fiji: 174°E-178°W, 21°S-14°S
Samoa: 174°W-170°W, 15°S-12°S
Palau: 130°E-136°W, 2°N-9°N

1.1. Observational data

Observational data are from the U.S. National Oceanic and Atmospheric Administration (NOAA) 0.25° daily Optimum Interpolation Sea Surface Temperature (OISST) dataset, version 2.1 [3]. The dataset was generated on a regular global grid from a range of sources, including Advanced Very High Resolution Radiometer (AVHRR) satellite data, ships, buoys, and Argo floats. Gaps in the data are infilled using optimum interpolation, providing a spatially complete dataset. Version 2.1 of the dataset has significant improvements over version 2.0 for January 2016 onward [5].

The data were provided by NOAA in single netCDF files for each calendar day. Australia's National Computational Infrastructure (NCI) provided an extra level of processing, by concatenating and storing the data in single netCDF files for each calendar year. Those annual data files were processed here. They are not publicly available, but equivalent annual data files are available from the NOAA Physical Sciences Laboratory (PSL) at https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html.

The observational data were analysed through to 31 December 2019, thus resulting in 38 complete calendar years. The following data and marine heatwave metrics are provided at every grid point within the region (file: mhw_cats/mhw_cats.pac_is.NOAA_OISST.AVHRR.v2-1_modified.nc):

- Annual mean SST (in °C; variable name: sst_mean).
- The total number of detected marine heatwaves (mhw_total_events).
- Annual counts of detected marine heatwaves (*mhw count*).
- Annual counts of days per year spent in each marine heatwave category (mhw_cats_dpy).
 In this output, lower categories do not include the counts of days spent in more extreme categories. For example, if a marine heatwave is Moderate (Category I) for 5 days, then Strong (Category II) for 10 days, then Moderate for 2 days, it will be recorded as 7 days in Moderate and 10 days in Strong (see Section 2).
- Annual mean of the maximum intensity of each marine heatwave, given as a sea surface temperature anomaly with respect to the seasonal climatology (*mhw_intensity*).
- Annual mean duration of marine heatwaves (in days; mhw_duration).
- Linear temporal trends of the annual counts, intensities, and durations (per year; mhw_count_tr, mhw_intensity_tr, and mhw_duration_tr, respectively).

For the three case study regions, area-weighted means of the SST on grid points within the Fiji, Samoa, and Palau regions were computed. The three daily SST index timeseries are provided (file: sst_indices/sst_indices.pac_is.NOAA_OISST.AVHRR.v2-1_modified.nc). Marine heatwave metrics were then computed from these timeseries, and the following output is provided for each case study region (file: mhw_ts/mhw_ts.pac_is.NOAA_OISST.AVHRR.v2-1_modified.nc):

- Annual mean SST (in °C; variable name: sst_mean).
- The total number of detected marine heatwaves (*mhw_total_events*).
- Annual counts of days per year spent in each marine heatwave category (mhw_cats_dpy).
 In this output, lower categories do not include the counts of days spent in more extreme categories (see Section 2).

The 20-year mean of total marine heatwave days per year over the period 1982–2001 is shown in Fig. 2a. Total annual marine heatwave days are computed by summing the days in each category (Moderate, Strong, Severe, and Extreme).

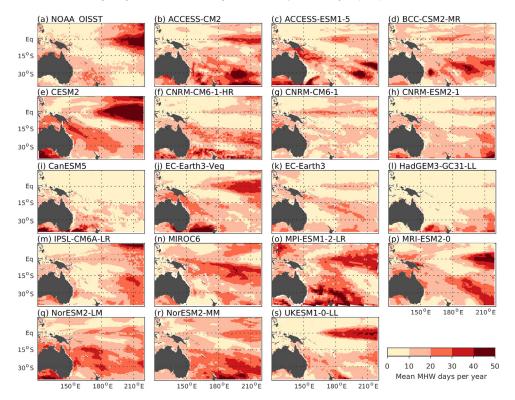


Fig. 2. Mean marine heatwave days over the period 1982–2001, computed from variable <code>mhw_cats_dpy</code>. (a) Observational data (file: <code>mhw_cats/mhw_cats.pac_is.NOAA_OISST.AVHRR.v2-1_modified.nc</code>). (b-s) Individual CMIP6 models (files: <code>mhw_cats/mhw_cats.pac_is.* omodel>. < scenario>. < variant>.nc</code>). Each dataset is plotted on its native grid. Total annual marine heatwave days are obtained by summing the number of days in each marine heatwave category (Moderate, Strong, Severe, and Extreme) at each grid point, and then the 20-year mean is computed. Panel (a) is adapted from Fig. 4a of [4], and the remaining panels show results in each of the models that contributed to the CMIP6 model mean shown in Fig. 8a of [4].

1.2. Model data

Model outputs from those participating in the Coupled Model Intercomparison Project, phase 6 (CMIP6) were analysed. CMIP6 is the current generation of global climate simulations that have informed the 6th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6; https://www.ipcc.ch/assessment-report/ar6/). Daily SST fields (variable name: tos) from native model grids (grid label: gn) were analysed from the historical set of experiments, together with two future shared socioeconomic pathways (SSPs) from the Scenario Model Intercomparison Project (ScenarioMIP) [6]. The future scenarios represent a low greenhouse gas emissions scenario: SSP1-2.6, and a high emissions scenario: SSP5-8.5. One ensemble member from each model and for each experiment was analysed. The historical experiments conclude at the end of year 2014, at which point the future scenarios were appended, thus resulting in two datasets for each model, each spanning the period 1982 to 2100. The requirement of having daily SST from each of the three experiments resulted in a set of 18 models with available data at the time of initial analysis (May 2020; Table 1).

The model data were analysed over the period 1 January 1982 through to 31 December 2100, thus resulting in 119 complete calendar years. The data are provided in two files for each model: historical with SSP1–2.6 extension (historical+ssp126), and historical with SSP5–8.5 extension

Table 1List of CMIP6 model simulated data analysed, along with their global oceanic grid resolutions. For a given model, ensemble members with the same experiment identifiers were used across each of the three experiments. This does not guarantee that the future scenarios are branched from the same common *historical* experiment, but any differences are expected to have little impact on the analysis. The versions analysed for each of the three experiments are given (hist: *historical*, 126: *SSP1*–2.6, 585: *SSP5*–8.5), along with DOI codes. In each case, the full address is: https://doi.org/10.22033/ESGF/CMIP6.

	Institute	Model	Ocean grid (lon \times lat)	Variant	Version	DOI code
1	BCC	BCC-CSM2-MR	360 x 232	r1i1p1f1	hist: v20181126	2948
					126: v20190321	3028
					585: v20190325	3050
2	CCCma	CanESM5	361 x 290	r1i1p1f1	hist: v20190429	3610
					126: v20190429	3683
					585: v20190429	3696
3	CNRM-CERFACS	CNRM-CM6-1	362 x 294	r2i1p1f2	hist: v20181126	4066
				•	126: v20190410	4184
					585: v20190410	4224
4	CNRM-CERFACS	CNRM-CM6-1-HR	1442 x 1050	r1i1p1f2	hist: v20191021	4067
				F	126: v20200127	4185
					585: v20191202	4225
5	CNRM-CERFACS	CNRM-ESM2-1	362 x 294	r1i1p1f2	hist: v20181206	4068
,	CIVILIVI CERTITICS	CIVICIVI ESIVIZ I	302 X 234	IIIIpiiz	126: v20190328	4186
					585: v20191021	4226
	CCIDO	ACCECC ECM1 E	260 200	e1;1e1f1		
6	CSIRO	ACCESS-ESM1-5	360 x 300	r1i1p1f1	hist: v20191115	4272
					126: v20191115	4320
7	CCIDO ADCCCC	ACCECC CM2	200 200	1:1164	585: v20191115	4333
	CSIRO-ARCCSS	ACCESS-CM2	360 x 300	r1i1p1f1	hist: v20191108	4271
					126: v20191108	4319
					585: v20191108	4332
3	EC-Earth-Consortium	EC-Earth3	362 x 292	r11i1p1f1		4700
					126: v20200201	4874
					585: v20200201	4912
)	EC-Earth-Consortium	EC-Earth3-Veg	362 x 292	r1i1p1f1	hist: v20200919	4706
					126: v20200919	4876
					585: v20200919	4914
10	IPSL	IPSL-CM6A-LR	362 x 332	r1i1p1f1	hist: v20180803	5195
					126: v20190903	5262
					585: v20190903	5271
1	MIROC	MIROC6	360 x 256	r1i1p1f1	hist: v20191114	5603
				•	126: v20191114	5743
					585: v20191114	5771
12	MOHC	HadGEM3-GC31-LL	360 x 330	r1i1p1f3		6109
					126: v20200114	10849
					585: v20200114	10901
13	MOHC	UKESM1-0-LL	360 x 330	r1i1p1f2	hist: v20190627	6113
		CALDIVIT U-LL	330 X 330	.1117112	126: v20190708	6333
					585: v20190726	6405
14	MPI-M	MPI-ESM1-2-LR	256 x 220	r1i1p1f1	hist: v20190720	6595
	1911 1 -191	IVII I-LJIVII -Z-LK	230 X 220	11114111	126: v20190710	6690
					585: v20190710	6705
15	MRI	MDI ECMO O	360 x 364	-1;1-1f1		
	INIVI	MRI-ESM2-0	JUU X 304	r1i1p1f1	hist: v20210311	6842
					126: v20210329	6909
16	NGAR	CDC) 10	222 224	4:4 46:	585: v20210329	6929
	NCAR	CESM2	320 x 384	r4i1p1f1	hist: v20190308	7627
					126: v20200528	7746
					585: v20200528	7768
17	NCC	NorESM2-LM	360 x 384	r1i1p1f1	hist: v20190815	8036
					126: v20191108	8248
					585: v20191108	8319
18	NCC	NorESM2-MM	360 x 384	r1i1p1f1	hist: v20191108	8040
					126: v20191108	8250
					585: v20191108	8321

sion (historical+ssp585) The following data are provided at every model native grid point within the region (files: mhw_cats/mhw_cats.pac_is.<model>.<scenario>.<variant>.nc; see Table 1 for model, scenario, and variant labels):

- Annual mean SST (in °C) (variable name: sst_mean).
- The total number of detected marine heatwaves (mhw_total_events).
- Annual counts of days per year spent in each marine heatwave category (mhw_cats_dpy).
 In this output, lower categories do not include the counts of days spent in more extreme categories (see Section 2).

The 20-year mean of total marine heatwave days per year over the period 1982–2001 is shown in Fig. 2b-s, for each CMIP6 model on its native grid.

As with the observational data, area-weighted means of the SST on native grid points within the Fiji, Samoa, and Palau regions were computed. The three daily SST index timeseries are provided for each model and scenario (files: sst_indices/sst_indices.pac_is.<model>.<scenario>.<variant>.nc). The data were area-weighted using the cell area data provided by each modelling group (variable name: areacello). The cell area data, trimmed to the tropical western and central Pacific Ocean region are also made available here (files: grid/areacello.pac_is.<model>.<scenario>.<variant>.nc). The scenario and variant labels of the cell area data do not necessarily match those of the SST data, but areacello is the same across all realisations for a single model.

Marine heatwave metrics were computed from area-weighted mean SST timeseries, and the following outputs are provided for each case study region (files: mhw_ts/mhw_ts.pac_is.<model>.<scenario>.<variant>.nc):

- Annual mean SST (in °C) (variable name: sst_mean).
- The total number of detected marine heatwaves (*mhw_total_events*).
- Annual counts of days per year spent in each marine heatwave category (mhw_cats_dpy).
 In this output, lower categories do not include the counts of days spent in more extreme categories (see Section 2).

Model and observational data were processed further to simplify the figure generation for [4]. The data were interpolated to the observational grid (i.e., at regular 0.25° resolution), and averaged over four 20-year periods: 1982–2001, 2000–2019, 2020–2039, 2040–2059. One file was generated for each scenario (files: processed/mhw_cats.pac_is.cmip6.<scenario>.nc), and the observational data are present in each. The following outputs are provided:

- Four blocks of 20-year mean SST (in °C) (variable name: sst_mean).
- Four blocks of 20-year means of days per year spent in each marine heatwave category (*mhw_cats*). In this output, the counts of days spent in more extreme categories are included in the counts of days spent in lower categories. For example, the counts of Moderate days include the counts of days spent in the Strong, Severe, or Extreme category (see Section 2).

The case study region data, for models and observations, and both scenarios, were also packaged into a single file (file: processed/mhw_cats.pac_is.cmip6.timeseries.nc). The following output is provided:

- Annual mean SST (in °C) (variable name: sst_idx).
- Annual counts of days per year spent in each marine heatwave category (mhw_cats). As
 above, the counts of days spent in more extreme categories are included in the counts of
 days spent in lower categories (see Section 2).

2. Experimental Design, Materials and Methods

Marine heatwave metrics were computed from the primary source daily sea surface temperature (SST) data using the marineHeatWaves python module (https://github.com/ecjoliver/

marineHeatWaves). The code uses the Hobday et al. definition [1] of a marine heatwave, which is a discrete, prolonged anomalously warm water event that lasts for five or more days, with temperatures warmer than the 90th percentile relative to climatological values. Two excursions above the threshold separated by less than three days are considered a single event. The seasonal climatology and the seasonally varying 90th percentile threshold were uniquely computed for each calendar day and grid point as follows. To increase the number of sample points, the climatology and threshold were computed over an 11-day window centred on a given day, sampling each year within the selected climatological period. After computing the mean and threshold for each calendar day, 31-day moving means were applied to each year-long timeseries in order to give smoother seasonally varying climatologies. This follows the procedure in [2].

Marine heatwaves can be characterised by their duration (number of consecutive days above the 90th percentile threshold), maximum intensity (maximum temperature above the climatological mean during the event), and their categorisation of intensity [7]. Categorisations of marine heatwaves are based on multiples of the marine heatwave intensity threshold, i.e., the temperature difference between the climatological mean and the climatological 90th percentile (see Fig. 2 in [7]). In this way, the category ranges are equally spaced, and temperature anomalies between 1 and 2 \times of the marine heatwave intensity threshold are denoted as Moderate, between 2 and 3 \times as Strong, between 3 and 4 \times as Severe, and \times 4 as Extreme. This dataset is focused on providing counts of days per year recorded in each marine heatwave category.

A 20-year baseline period (1995–2014) was used for the seasonal climatological mean and seasonally varying 90th percentile threshold. This baseline period is the IPCC AR6 recommendation for assessing projected changes relative to the historical period.

The python code for computing marine heatwave metrics, along with the MATLAB code for post-processing are available at https://github.com/jbkajtar/mhw_pacific/. A CSV file containing all CMIP6 model details and references is also available at that location.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

CRediT Author Statement

Jules B. Kajtar: Conceptualization, Methodology, Investigation, Software, Data curation, Writing – original draft, Writing – review & editing; **Vanessa Hernaman:** Conceptualization, Methodology, Investigation, Writing – review & editing; **Neil J. Holbrook:** Conceptualization, Methodology, Investigation, Writing – review & editing; **Paola Petrelli:** Data curation, Validation, Writing – review & editing.

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