



# Trends in coastal seawater temperature in Amakusa, southwestern Japan (1940 - present)

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## Abstract

Seawater temperature data spanning over eight decades collected from shallow coastal areas of Amakusa, southwestern Japan, are presented. Our analysis indicates increasing trends in surface seawater temperature, most notably in terms of the yearly minimum temperatures of winter season that has increased by over 2.6°C since the 1940s. In particular, temperatures can be seen to have risen sharply around the 1990s and the recent (2020-) maximum water temperatures tended to exceed 30°C. The importance of continued monitoring effort is stressed and warranted.

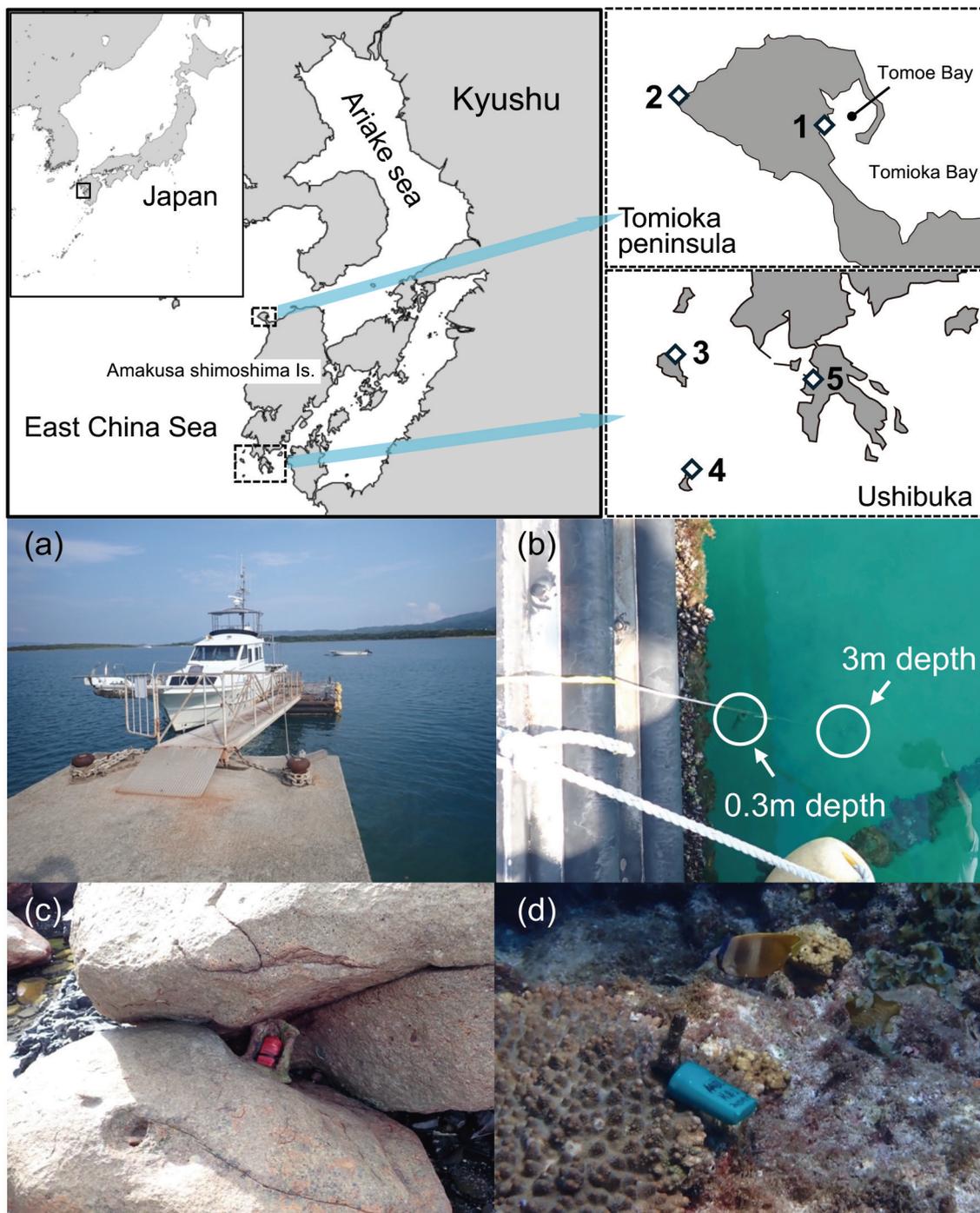
**Keywords:** climate change, global warming, Amakusa-Shimoshima Island, AMBL

[Data Link download](#)

## Introduction

Climate change has become a major issue attracting global attention (Hansen *et al.* 1988, United Nations 1992, IPCC 2021), with its impacts on marine ecosystems in general being discussed with increasing alarm (Edwards & Richardson 2004; Harley *et al.* 2006; Hoegh-Guldberg & Bruno 2010). In addition, many cases of distributional shifts

in marine organisms have also been reported and attributed to rising seawater temperatures (e.g. Precht & Aronson 2004; Figueira & Booth 2010; Yamano *et al.* 2011; Baird *et al.* 2012; Chaabane *et al.* 2024). Under such circumstances, the importance of basic environmental data has increasingly been recognized and re-evaluated. Pinsky *et al.* (2013) suggested that local variation in climate velocity (the rate and direction that climate shifts across the landscape) could



**Fig. 1** Map of the observation sites: 1, ABL pier; 2, Shikizaki intertidal; 3, Ohshima; 4, Katashima; 5, Haruhae. Photographs: (a) the ABL pier, and the installed water temperature loggers (b) deployed from the ABL pier using a rope, (c) at Shikizaki intertidal, (d) at Katashima 3m depth.

strongly regulate the magnitude and direction of marine species' distributional shifts, highlighting the importance of high-resolution, site-specific environmental observations. While global grid-scale data such as ICOADS (Freeman *et al.* 2017) provided by NOAA PSL and COBE-SST2 provided by JMA (the Japan Meteorological Agency) are becoming widely available, specific local data which are relatively long-term and easily accessible are still limited.

Since its establishment in 1928, the Amakusa Marine Biological Laboratory (AMBL) - Kyushu University has been conducting observations on the biota and the surrounding coastal environments through daily research activities. The AMBL is situated on the northwestern corner of the Amakusa-Shimoshima Island which constitutes part of the Unzen-Amakusa National Park in the middle of the west coast of Kyushu (southernmost of the four main islands of Japan), southwestern Japan (32°31'40"N; 130°02'01"E, Fig. 1). The west of the area faces the East China Sea, under the influence of the Tsushima warm current, a northward-flowing branch of the Kuroshio. In contrast, the northeast side of the area faces the entrance of the Ariake Sea which

is the largest estuarine habitat in Japan. Therefore, the area is also under the influence of water masses from the inner bay with fluctuating temperatures, salinity and currents.

Seawater temperatures have been recorded by the AMBL staff at several fixed coastal sites around the Amakusa Shimoshima. A new project has been started for the centenary (1928-2028) of the AMBL so that these data are sorted and made public to contribute to future studies.

## Materials and Methods

The longest record of seawater temperatures in Amakusa refers to the one observed from 1940 to the present at the pier in front of the AMBL, in Tomoe Bay (Fig. 1, Table 1a). From the 2nd of August 1940 to the 27th of November 1997, seawater was collected every morning at around 9 a.m. (but see below) using a bucket and measured with a thermometer to the nearest 0.1°C ("manual" observation). During the same period, air temperature (°C), atmospheric

**Table 1a.** Summary of seawater temperature data at the pier of the AMBL, surface (0.3m depth) (site name, "AMBLs")

start (yy/mm/dd)	end (yy/mm/dd)	interval	method
1940/08/02	1949/12/28	day	manual
1956/01/04	1997/11/26	day	manual
1997/11/26	1999/01/14	2 hours	HOBO water temp pro V2, U22-001
2000/01/26	2000/04/13	16 min	HOBO water temp pro V2, U22-001
2000/04/13	2000/07/22	2 hours	HOBO water temp pro V2, U22-001
2001/11/19	2002/11/22	2 hours	HOBO water temp pro V2, U22-001
2002/11/22	2003/11/19	2 hours	HOBO water temp pro V2, U22-001
2008/03/26	2009/08/18	1 hour	HOBO water temp pro V2, U22-001
2009/08/18	2010/04/22	2 hours	HOBO water temp pro V2, U22-001
2010/04/21	2010/12/01	1 hour	HOBO water temp pro V2, U22-001
2010/11/29	2011/04/15	1 hour	HOBO water temp pro V2, U22-001
2017/08/30	2017/09/02	30 min	HOBO pendant temp/light, UA-002-64
2020/08/26	2021/10/06	15 min	HOBO pendant temp/light, UA-002-64
2021/10/06	2022/09/14	30 min	HOBO pendant temp/light, UA-002-64
2022/09/12	2023/09/15	30 min	HOBO pendant temp, UA-001-64
2023/09/14	2024/10/02	30 min	HOBO pendant temp, UA-001-64

**Table 1b.** Summary of seawater temperature data at the pier of the AMBL, 3m depth (site name, “AMBL3m”)

start (yy/mm/dd)	end (yy/mm/dd)	interval	method
2016/01/31	2017/08/30	30 min	HOBO pendant temp/light, UA-002-64
2017/08/30	2019/05/16	30 min	HOBO pendant temp/light, UA-002-64
2020/08/26	2021/10/06	15 min	HOBO pendant temp/light, UA-002-64
2021/10/06	2022/09/14	30 min	HOBO pendant temp/light, UA-002-64
2022/09/12	2023/09/15	30 min	HOBO pendant temp, UA-001-64
2023/09/14	2024/10/02	30 min	HOBO pendant temp, UA-001-64

**Table 2.** Summary of upper-intertidal temperature data (air temperature at low tide and seawater temperature at high tide) at Shikizaki (site name, “shikizakiIT”)

start (yy/mm/dd)	end (yy/mm/dd)	interval	method
2020/02/10	2020/8/03	1 hour	HOBO pendant temp/light, UA-002-64
2021/01/15	2022/02/02	15 min	HOBO pendant temp/light, UA-002-64
2022/02/01	2023/03/24	15 min	HOBO pendant temp, UA-001-64
2023/03/24	2024/04/10	15 min	HOBO pendant temp, UA-001-64

**Table 3.** Summary of seawater temperature data at Ohshima, (a) 3m depth (site name, “ohshima3m”); (b) 5m depth (site name, “ohshima5m”)

(a)	start (yy/mm/dd)	end (yy/mm/dd)	interval	method
	2011/09/14	2012/06/07	30 min	HOBO pendant temp/light, UA-002-64
	2012/06/12	2013/08/09	30 min	HOBO pendant temp/light, UA-002-64
	2013/08/01	2015/01/26	30 min	HOBO pendant temp/light, UA-002-64
	2015/08/03	2016/12/01	30 min	HOBO pendant temp/light, UA-002-64
	2016/11/30	2018/07/27	30 min	HOBO pendant temp/light, UA-002-64
	2020/09/29	2021/10/01	30 min	HOBO pendant temp/light, UA-002-64
	2021/09/28	2022/10/01	30 min	HOBO pendant temp/light, UA-002-64
	2022/09/28	2023/07/01	30 min	HOBO pendant temp, UA-001-64
	2023/09/19	2024/09/20	30 min	HOBO pendant temp, UA-001-64
(b)	start (yy/mm/dd)	end (yy/mm/dd)	interval	method
	2011/09/14	2012/06/07	30 min	HOBO pendant temp/light, UA-002-64
	2012/06/12	2013/08/09	30 min	HOBO pendant temp/light, UA-002-64
	2013/08/01	2015/01/26	30 min	HOBO pendant temp/light, UA-002-64
	2015/08/03	2016/12/01	30 min	HOBO pendant temp/light, UA-002-64
	2018/06/19	2020/02/13	30 min	HOBO pendant temp/light, UA-002-64
	2020/09/29	2021/10/01	30 min	HOBO pendant temp/light, UA-002-64
	2021/09/28	2022/07/02	30 min	HOBO pendant temp/light, UA-002-64
	2022/09/28	2023/09/28	30 min	HOBO pendant temp, UA-001-64
	2023/09/19	2024/09/20	30 min	HOBO pendant temp, UA-001-64

**Table 4.** Summary of seawater temperature data at Katashima, 3m depth (site name, “katashima3m”)

start (yy/mm/dd)	end (yy/mm/dd)	interval	method
2012/06/11	2013/08/09	1 hour	HOBO pendant temp/light, UA-002-64
2013/08/01	2014/09/05	30 min	HOBO pendant temp/light, UA-002-64
2014/07/29	2015/08/08	1 hour	HOBO pendant temp/light, UA-002-64
2015/08/03	2016/12/04	30 min	HOBO pendant temp/light, UA-002-64
2016/11/30	2017/04/29	30 min	HOBO pendant temp/light, UA-002-64
2018/06/18	2020/02/13	30 min	HOBO pendant temp/light, UA-002-64
2020/09/29	2021/10/09	30 min	HOBO pendant temp/light, UA-002-64
2021/10/07	2022/09/16	30 min	HOBO pendant temp/light, UA-002-64
2022/09/13	2023/09/08	30 min	HOBO pendant temp, UA-001-64
2023/09/08	2024/09/20	30 min	HOBO pendant temp, UA-001-64

**Table 5.** Summary of seawater temperature data at Haruhae (a) near *Acropora muricata* colony (site name, “haruhaeA”); (b) near large *Porites* colony (site name, “haruhaeP”).

(a)	start (yy/mm/dd)	end (yy/mm/dd)	interval	method
	2019/09/02	2020/10/01	30 min	HOBO pendant temp/light, UA-002-64
	2020/09/29	2021/10/01	30 min	HOBO pendant temp/light, UA-002-64
	2021/09/28	2022/09/02	30 min	HOBO pendant temp/light, UA-002-64
	2022/08/28	2023/09/02	15 min	HOBO pendant temp, UA-001-64
	2023/09/02	2024/06/04	30 min	HOBO pendant temp, UA-001-64
(b)	start (yy/mm/dd)	end (yy/mm/dd)	interval	method
	2018/09/02	2020/09/29	30 min	HOBO pendant temp/light, UA-002-64
	2020/09/29	2021/10/01	30 min	HOBO pendant temp/light, UA-002-64
	2021/09/28	2022/05/14	30 min	HOBO pendant temp/light, UA-002-64
	2022/08/28	2023/07/03	15 min	HOBO pendant temp, UA-001-64
	2023/09/02	2024/04/05	30 min	HOBO pendant temp, UA-001-64

pressure (mmHg) and relative density were also measured and recorded. Since the 26th November 1997, water temperature data loggers (HOBO water temp pro2 or HOBO pendant UA-001-64/UA-002-64, Onset computer corp., USA) have been installed on the floating pier at the end of the concrete pier (Fig.1a), recording temperatures at different intervals. In addition to surface water, bottom water temperature has been recorded since 2016 by hanging loggers with a rope from the floating pier: so these refer to the surface layer (at 30cm depth) and the bottom layer (3m depth) (Fig.1b).

Shallow water temperature records from several locations

of the rocky shores of Amakusa, including an intertidal zone, have been taken, as data loggers have made frequent-regular observations possible (Fig. 1c&d). At each site, mounting metal sticks were driven into the seafloor or fixed with underwater glue, and loggers were attached using nylon cable ties. The water depths where the loggers were installed were designated as those at high tide. In the case of the intertidal zone, the logger was placed under a large rock to avoid direct sunlight in the upper intertidal: ca. 200 cm above MLWS (mean low water springs). Further detailed information such as recording intervals and period for each site is summarised in the Tables 1-5.

## Data Explanation

[Data are archived](#) in the csv (Comma-Separated Values) format for each consecutive period or a logger record period and named as “site name\_start day-stop day.csv”. For example, data recorded at the pier in front of the AMBL for surface water between 5 May 1992 and 3 November 1998 would be “AMBLs\_19920505-19981103.csv”. Each data sheet has separate columns for seawater temperature, year, month and day. For the period of manual observation, if any, there are columns for air temperature, atmospheric pressure and relative density of seawater, but no time column, as the observations were made once a day at around 9:00. On the data sheet, days without records are marked as “na”. In the case of logger observations, there were no data periods due to logger loss or malfunction etc. The observation time is recorded in Japan standard time (JST) shown in the time column and combined data for year, month, date and original time information from the logger instruments are also given in a separate column. Note that data logger records include temperatures before installation in the field and after collection from the field, which need to be trimmed accordingly. The data archive will be updated as more data become available, basically annually.

## Results

### Temporal trends in Tomoe Bay

Temporal changes in seawater temperature were examined based on the data from the AMBL pier that have the longest span of all temperature data, covering over 80 years. To avoid bias in yearly averages due to differences in season of observations included in the data set, the minimum water temperature from winter season (January to March) and the maximum water temperature from summer season (July to September) were extracted for each year, and temporal changes in these annual minima and maxima were examined. To eliminate extreme values, the highest and lowest two values were excluded, and the following five values were adopted as data for the daily manual measurement during 1940-1997. In the case of the data from the loggers, after trimming the first two and last five days of each recording period, the highest and lowest 10 values were removed, and the following five values were adopted. Thus, the logger data sets were considered for the period from 28 November 1997 to 27 September 2024 in this analysis. Furthermore, to avoid further biases, the years with less than approximately one month data out of

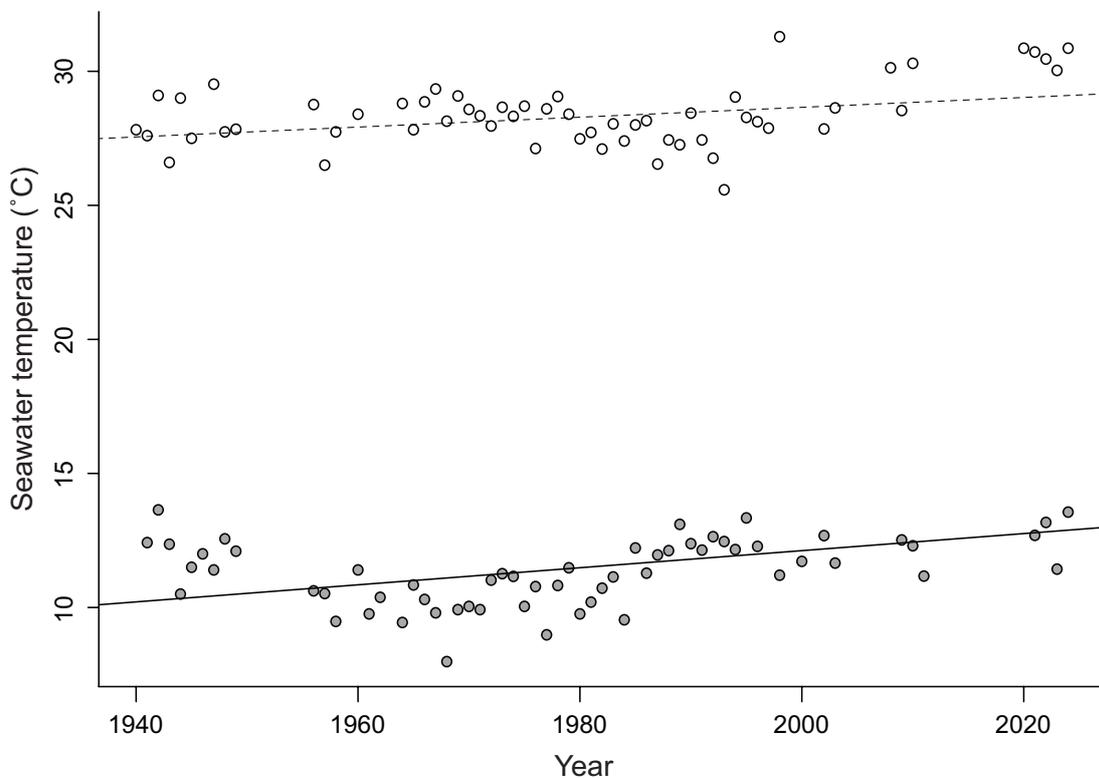


Fig. 2 Temporal trends in the highest (open circle) and lowest (gray circle) surface seawater temperatures in the Tomoe Bay, in front of the AMBL. Sen's slope is shown by the dotted line for maximum summer temperatures (Sen's slope value = 0.018,  $P > 0.05$ ) and the solid line for minimum winter temperatures (0.032,  $P < 0.05$ )

three months (i.e. <20 and <360 records for manual and logger measurement, respectively) were excluded from the analysis. The Mann-Kendall test was applied, and the Sen's slope values were calculated with the R package "trend" in R version 4.4.3 (R Core Team, 2025).

Both the maximum and the minimum temperatures showed slightly increasing trends, with the last few decades appearing to show apparently higher values than in the past (Fig. 2). In particular, temperatures can be seen to have risen sharply around the 1990s and the recent maximum water temperatures tended to exceed 30°C. In the case of the maximum temperature, Sen's slope showed +0.018°C per year, but statistically significant temporal changes were not recognized (M-K test,  $P=0.1$ ). For the minimum temperature, a significant temporal change was detected (M-K test,  $P<0.01$ ), with the Sen's slope value of +0.032. These results suggested that the maximum and the minimum water temperatures have increased by 1.4 and 2.6°C respectively over the 80 years.

It should be noted that the records from 1940 to 1949 consistently show apparently higher values overall than the periods that followed. While this difference could reflect a natural trend, it may also be attributable to artefacts arising from differences in observation times and/or measurement methods. Notably, when this earliest period of the data set is excluded, the increasing trend in water temperature becomes even more pronounced. Specifically, recalculations excluding the early period values (i.e. 1940-1949) yielded a Sen's slope of +0.062 for the minimum water temperatures, which is more than twice the value obtained when the full period is considered and indicates a statistically significant trend (M-K test,  $P<0.01$ ). For the maximum temperatures, although a statistically significant temporal trend was not indicated (M-K test,  $P=0.16$ ), the Sen's slope was also relatively high (+0.024) compared with that obtained for the full period.

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## CONCLUSION

Our brief analysis clearly demonstrated long-term warming trends of the shallow seawater temperatures in the Tomoe Bay, especially in terms of the minimum temperature in winter season. Since winter water temperature has been shown to limit the establishment and distributional expansion of organisms (e.g. Figueira & Booth 2010), rising minimum temperatures may have pronounced ecological consequences, including altered overwintering survival, recruitment timing, and the range expansion of warm-water species into temperate habitats. Continued standardised monitoring of seawater temperatures and associated biological communities in this region will thus be essential for understanding the mechanisms and ecological implications of coastal warming in the broader context of the northwestern Pacific. The open availability of these data will provide a valuable foundation for future academic and scientific works, especially for comparative analyses across Japanese and East Asian coastal ecosystems.

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