A Sea Surface Temperature product for monitoring Marine Heatwaves in the Northeast Pacific

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A SEA SURFACE TEMPERATURE PRODUCT FOR MONITORING MARINE HEATWAVES IN THE NORTHEAST PACIFIC

by

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ABSTRACT

Hilborn, A., Guan, L., Wan, D., Peña, A. 2025. A Sea Surface Temperature product for monitoring Marine Heatwaves in the Northeast Pacific. Can. Tech. Rep. Hydrogr. Ocean. Sci. 394: v + 23 p.

There is an urgent need to monitor marine heatwaves. Their frequency, extent and magnitude are expected to increase with climate change, negatively impacting marine ecosystems. This report describes acquisition and processing of Optimum Interpolation Sea Surface Temperature, a gap-filled sea-surface temperature dataset at 0.25° spatial resolution, for Marine Heatwave monitoring in the Northeast Pacific. First, to assess the accuracy of this dataset in the Northeast Pacific and the Canadian Pacific Exclusive Economic Zone, its values were compared to observed ocean temperatures measured by buoys maintained by Environment and Climate Change Canada and Fisheries and Oceans Canada. The sea-surface temperature and buoy temperature data sources had good agreement, with the Optimum Interpolation Sea Surface Temperature dataset having an overall cool bias of -0.13 ± 0.44°C, particularly during the summer months. Second, 30-year Optimum Interpolation Sea Surface Temperature climatologies, anomalies, and Marine Heatwave maps were produced for weekly monitoring of Marine Heatwave extent in the Northeast Pacific. Daily statistics showing spatial coverage of the Canadian Pacific Exclusive Economic Zone and Federal Marine Bioregions were also produced. Finally, future improvements and further data sources and monitoring work are detailed. The information provided in this report, along with the code in the R programming language, was made available online and continues to update weekly.

RÉSUMÉ

Hilborn, A., Guan, L., Wan, D., Peña, A. 2025. A Sea Surface Temperature product for monitoring Marine Heatwaves in the Northeast Pacific. Can. Tech. Rep. Hydrogr. Ocean. Sci. 394: v + 23 p.

Il est urgent de surveiller les vagues de chaleur marines. Une augmentation de leur fréquences, étendues et ampleurs est anticipée avec les changements climatiques, ce qui aura un impact négatif sur les écosystèmes marins. Ce rapport décrit l'acquisition et le traitement d’un jeu de données de température de surface de la mer interpolées spatialement. Optimum Interpolation Sea Surface Temperature, ont été utilisés afin de faire du monitorage des vagues de chaleur marines dans le Pacifique Nord-Est. Dans un premier temps, l’exactitude de cet ensemble de données a été évaluée pour l’ensemble du Pacifique Nord-Est et dans la zone économique exclusive du Pacifique canadien, en les comparant aux températures océaniques mesurées par des bouées entretenues par Environnement et Changement climatique Canada et Pêches et Océans Canada. La température des bouées présentaient une bonne concordance avec l'ensemble de données sur la température de la surface de la mer par interpolation optimale. Cette comparaison démontre que les données interpolées présente un biais de froid global de -0,13 ± 0,44 °C, en particulier pendant les mois d'été. Par la suite, des climatologies, des anomalies et des cartes de vagues de chaleur marines ont été produites en utilisant les données d’interpolation optimale sur 30 ans afin de surveiller l'étendue des vagues de chaleur marines dans le Pacifique Nord-Est sur un échelle de temps hebdomadaire. Des statistiques quotidiennes pour la zone économique exclusive du Pacifique canadien et des biorégions marines fédérales ont également été produites. Finalement, le rapport détaille des sources de données additionnelles, ainsi que des améliorations sur les analyses et monitorage possible dans la région. Les renseignements fournis dans ce rapport, ainsi que le code en langage de programmation R, ont été rendus disponibles en ligne et continuent d'être mis à jour chaque semaine.

1 Introduction

Frequent and accurate monitoring of sea-surface temperature (SST) is essential for detecting and understanding changes to surface ocean conditions driven by advancing climate change. Consistent SST monitoring at the large, synoptic scales possible with satellite remote sensing further allows tracking of oceanographic features (e.g., Chen et al. 2019), long-term trends of surface ocean temperature (e.g., Hardy et al. 2021), and calculation of spatial and temporal distributions of marine-heatwaves (MHWs; e.g., Hobday et al. 2016, Oliver et al. 2018). Satellite SST, classified as an Essential Climate Variable (GCOS 2022), is also valuable for monitoring upper ocean layers that impact primary production, and nearshore and shallow-dwelling marine species. Currently, publicly-available, daily-frequency satellite SST records suitable for climate and long-term trend monitoring date back to 1980 (Embury et al. 2024; O'Carroll et al. 2019; see Merchant et al. 2023 for a detailed list of satellite platforms and global SST products). Spatially gap-filled and modelled SST datasets are also integral components of rapid monitoring for developing events, as the ocean surface is obscured by clouds, and thus to satellite-mounted sensors, a large proportion of the time. Current efforts by Fisheries and Oceans Canada (DFO) to monitor ocean surface temperatures in the Pacific Region use SST products from numerous satellite sources. These include:

- Advanced Very High Resolution Radiometer SST (AVHRR, 4 km spatial resolution); see Hardy et al., 2021, Bannar-Martin et al. (*in press*)[1], Boldt et al. 2022 and Boldt et al. 2023
- MODerate-Resolution Imaging Spectroradiometer SST (MODIS-Aqua, 1 km and 4 km spatial resolution); see Boldt et al. 2022, Boldt et al. 2023, and Pacific Region Biophysical and Ecological Overview Reports published on the Canadian Science Advice Secretariat (https://www.isdm-gdsi.gc.ca/csas-sccs/applications/Publications/index-eng.asp) and Technical Report Series (https://science-libraries.canada.ca/) including Bannar-Martin et al. (*in press*)[1] and Liu et al. (*in press*)[2]
- Optimum Interpolation SST (OISST, using interpolated AVHRR SST, 0.25 degree spatial resolution outlined in Huang et al. 2021); outlined here and then integrated into Edwards et al. 2024
- Thermal InfraRed Sensor (TIRS) SST from the Landsat-8 and -9 satellites (30 m spatial resolution); see Liu et al. (*in press*)[2]

Marine heatwaves (MHWs) are of growing global concern as their frequency, duration, and intensity are expected to increase under the continued impacts of climate change (Oliver et al. 2018). Up to 60% of MHWs in the Northeast Pacific (NEP) from 2010 to 2022 have been shown to be more intense or longer-lasting as a result of greenhouse gas emissions (Barkhordarian et al. 2022). MHWs can have devastating impacts on marine ecosystems (see Bond et al. 2015), and abnormally warm water masses may persist for years following MHW events (e.g., Jackson et al. 2018). Even small, short-lived MHWs may have negative ecosystem impacts, as different species have differing thermal tolerances (see Bass et al.

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[1] Bannar-Martin, K., Zahner, S. J. V., Brown, K. H. T., McDougall, C., Robb, C., Burke, L., Du Preez, C., Gartner, H., Hannah, C., Bluteau, C., Hilborn, A., Iacarella, J., Lok, E., Liu, A., Proudfoot, B., Sastri, A., Stacey, C. and Rubidge, E. Biophysical and Ecological Overview of the Offshore Haida Gwaii Network Zones. DFO Can. Sci. Advis. Sec. Res. Doc. *In press.*

[2] Liu, A., Bannar-Martin, K., Bluteau, C., Hilborn, A., Clifton, K., Picard, C., Burke, L., Wright, B., Wray, J., Keen, E., Baer, G., Pilkington, J., Nichol, L., Denley, D., Stacey, C., Herbert, J., Robb, C. and Rubidge, E. Biophysical and Ecological Overview of the Caamaño Sound and Douglas Fjord System Network Zones. Can. Tech. Rep. Fish. Aquat. Sci. *In press.*

2023; Smale et al., 2019) which can decrease when already stressed or sick (Wendling and Wegner 2013). Early warning of MHW events can allow faster mitigation and more effective management (e.g., Hartog et al. 2023, Spillman and Smith 2021). A commonly used definition for MHWs using satellite SST data consists of comparing SSTs to long-term average values from the corresponding time of year. SSTs are classified as a MHW if they exceed the climatological 90th percentile for at least 5 days (provided there are fewer than three below-threshold days; Hobday et al. 2016, Hobday et al. 2018). This definition, with some minor modifications, was adopted for the purposes of this report.

A dataset frequently used for global MHW monitoring is the Optimum Interpolation Sea Surface Temperature (OISST) product processed and distributed by the National Centers for Environmental Information (NCEI; see https://www.ncei.noaa.gov/products/optimum-interpolation-sst). The daily gridded data product integrates ocean surface temperatures from satellites, ships, buoys and Argo floats into a spatially continuous SST dataset, which is very useful for frequent monitoring at large scales (Huang et al. 2021). The input satellite data, which are from the Advanced Very High Resolution Radiometer (AVHRR) sensors, are referenced to the buoy and ship measurements in order to reduce relative biases, particularly as the differing platforms measure different layers of the upper water column. The AVHRR satellite SST, in particular, captures a thin (under 1 millimetre) surface layer, which experiences higher temperature fluctuations from diurnal heating compared to the other input datasets, as the satellite constellation images the globe twice per day. Subsequently, through the bias-correction process, OISST is referenced to represent the temperature at roughly 20 cm depth. A drawback to this process is that erroneous data may be included (e.g. buoy measurements drifting as seen in Hardy et al. 2021), though the input datasets do undergo some quality control steps (see Huang et al. 2021, Freeman et al. 2016). The resulting OISST dataset spans nearly the full length of the AVHRR satellite sensors, dating back to September 1st, 1981, with no spatial gaps.

Given the observed and potential impacts of MHWs on the global ocean, more monitoring of SST and its derived products are needed in the Pacific region. For example, with the expanding network of Marine Protected Areas (MPAs; see: https://www.dfo-mpo.gc.ca/oceans/networks-reseaux/development-developpement-eng.html; Canada – British Columbia Marine Protected Area Network Strategy 2014), increased oceanographic monitoring and sampling efforts are underway, with tracking of the presence and proximity of MHWs to these areas set as a high priority. However, as numerous spatial SST products exist, it is important to assess their suitability for monitoring developing events, and their agreement to long-term *in situ* ocean temperature datasets. This report evaluates the accuracy of daily OISST in the Pacific region and outlines the process we developed for calculating SST climatologies, anomalies, and MHW statistics for the NEP, Canadian Pacific Exclusive Economic Zone (CPEEZ), and three federal Marine Bioregions using OISST, version 2.1 (Huang et al. 2021; https://www.ncei.noaa.gov/products/optimum-interpolation-sst). OISST was preferred for MHW monitoring over other satellite SST datasets given that it updates daily, has continuous spatial coverage, and currently spans over 43 years. Daily OISST values are directly compared to quality-controlled temperatures acquired by buoys throughout the CPEEZ, with regression statistics provided. Further, the information presented here (with a weekly update frequency) and R processing code have been made available on Github (see https://github.com/IOS-OSD-DPG/Pacific_SST_Monitoring). Finally, the benefits and drawbacks of using OISST to monitor MHWs are discussed, with recommendations for future work and data sources that should be included for further MHW monitoring in the CPEEZ and NEP.

2 Determining Marine Heatwaves (MHWs) from Optimum Interpolation Sea Surface Temperature (OISST)

Daily and weekly Marine Heatwave (MHW) maps were produced for the NEP, CPEEZ, and three Federal Marine Bioregions using OISST (version 2.1) data. To assess the accuracy of this dataset, their SST values were compared to buoy-acquired ocean temperature measurements in the area of the CPEEZ. R was used to process the data as described in the following sections, with the code available on Github at: https://github.com/IOS-OSD-DPG/Pacific_SST_Monitoring/scripts. The processed OISST and buoy data shown here has also been integrated into the “pacea” R package (https://github.com/pbs-assess/pacea).

2.1 OISST data acquisition

The OISST dataset used consists of daily global spatially-interpolated SST observations at approximately 0.25° x 0.25° spatial resolution. The latest version (v2.1), used here, has significant quality improvements to SST compared to the previous OISST dataset version (Huang et al. 2021). Although this dataset can be accessed from numerous locations, we used the Coastwatch ERDDAP server (https://coastwatch.pfeg.noaa.gov/erddap/index.html) as it consistently updates the global OISST data record with a lag of 2 days or less. Other locations where the data can be accessed include the National Oceanic and Atmospheric Administration (NOAA) ERDDAP server (https://www.ncei.noaa.gov/erddap/info/index.html?page=1&itemsPerPage=1000) or Weather and Climate Toolkit (https://www.ncdc.noaa.gov/wct/batch.php).

Two data products (near real time and final quality) were used to produce OISST climatologies and anomalies, as some ancillary variables used in the processing have a time delay. Final-quality data are provided after two weeks with the gap-filling using all ancillary data, while a near real time (NRT) OISST dataset is available within 48 hours, before all ancillary data sources are available. The NRT OISST product, while having higher errors than the final-quality data, is important for monitoring developing events. However, anomalies and statistics that may have been originally calculated with NRT data must be updated later.

The Coastwatch ERDDAP server was used to access the following records using the “griddap” function from the “rerddap” R package (https://cran.r-project.org/web/packages/rerddap/index.html):

- **ncdcOisst21NrtAgg_LonPM180**: NCDC OISST, version 2.1 NRT product. Daily data span from approximately 4 years to two days prior to the current date.
- **ncdcOisst21Agg_LonPM180**: NCDC OISST, version 2.1 final product. Daily data span from September 1st, 1981, to approximately two weeks prior to the current date.

Daily OISST data were acquired in a region between 30-61.5°N and 120-160°W. For both the NRT and final-quality records, the variables included are SST, SST anomaly, SST error, and sea ice concentration. The “ice” field at each pixel, which provides a value of sea ice concentration fraction, was used to retain only ice-free pixels. Any SST values lower than the freezing temperature of seawater (-1.89°C) were removed. For public data sharing, these data were then saved as rasters in geoTIFF format with the R “terra” package (function “writeRaster”). Open-source software developed for Geographic Information Systems (GIS) and remote sensing that can be used to visualize these files include QGIS (https://www.qgis.org), SeaDAS (https://seadas.gsfc.nasa.gov), and SNAP (https://step.esa.int/main/download/snap-download/).

2.2 OISST validation

OISST values were compared to *in situ* ocean surface temperature measurements in British Columbia (BC) waters, acquired by numerous weather buoys that are jointly maintained by Environment and Climate Change Canada (ECCC) and DFO. Some of this buoy data is also separately ingested into the OISST estimation via the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), which is used as an input *in situ* dataset (Freeman et al. 2016), but such data was not identified as part of this report.

2.2.1 Buoy sea surface temperature (SST) data

ECCC / DFO maintains a network of 16 buoys in BC waters that record hourly ocean surface temperature measurements (see Figure 1A for buoy map). Nine of these buoys have records beginning prior to 1995, with the earliest beginning in September, 1987. These measurements are valuable resources for validating satellite or modelled SST measurements (e.g., Hardy et al. 2021). Likewise, satellite SST can be used to detect buoy instrument failures (see Fig. 7 of Hardy et al. 2021) or provide comparison data for buoy temperature quality control (Kellogg et al. 2021).

SST measurements from ECCC and DFO buoys were acquired from the Canadian Integrated Ocean Observing System (CIOOS) Pacific ERDDAP server, using the “rerddap” R package to retrieve data from the “DFO_MEDS_BUOYS” record (https://data.cioospacific.ca/erddap/info/DFO_MEDS_BUOYS/index.html). Buoys located in Pacific waters were retained (latitude < 60°N and longitude >= 120°W). This dataset was preferred because buoy SST data provided directly by ECCC has very minimal quality control, while data provided by CIOOS have detailed quality flags (“SSTP_flags” field, which ends in 2024). These quality-control steps include removing unrealistic values (≥ 30°C), and comparisons to nearby OISST and AVHRR values. The SST measurements, listed as the “SSTP” field, were retained unless “SSTP_flags” had a value of 1–3, 5–8 or 10 (for the full quality control flag list, see Table 3 of Kellogg et al. 2021).

Daily mean and standard deviation buoy SSTs were calculated for each buoy in their local time zone to reduce the number of samples per day. Climatological daily mean and standard deviation values were calculated over the Canadian Climate Normals climatology period of 1991-2020 (https://climate.weather.gc.ca/climate_normals/) where possible. Seven buoys were installed after January 1st 1991, so their climatologies were computed using all the available data within that 30-year period (see Table 1). The C46303 South Georgia Strait and C46304 Entrance English Bay buoys were excluded from further analysis, as they were installed in 2019.

Table 1. Buoys used in this report, with data beginning later than January, 1991. Rows are ordered chronologically by data record start month and year.

WMO ID	Buoy name	Data start (month, year)
C46145	Central Dixon Entrance	April, 1991
C46183	North Hecate Strait	May, 1991
C46185	South Hecate Strait	August, 1991

WMO ID	Buoy name	Data start (month, year)
C46146	Halibut Bank	March, 1992
C46131	Sentry Shoal	October, 1992
C46147	South Moresby	June, 1993
C46132	South Brooks	May, 1994

The daily mean buoy SST climatologies (Figure 1B) show geographic differences in their annual cycles, with the buoys in the Strait of Georgia and Kitimat Arm (i.e., C46131 Sentry Shoal, C46146 Halibut Bank, and C46181 Nanakwa Shoal) having the warmest summer surface temperatures, exceeding 16°C in August. The C46181 Nakawa Shoal buoy also consistently has the coolest temperatures during the winter months (< 6°C). In comparison, buoys on the shelf, shelf break and further offshore waters reach their peak temperatures later in the year.

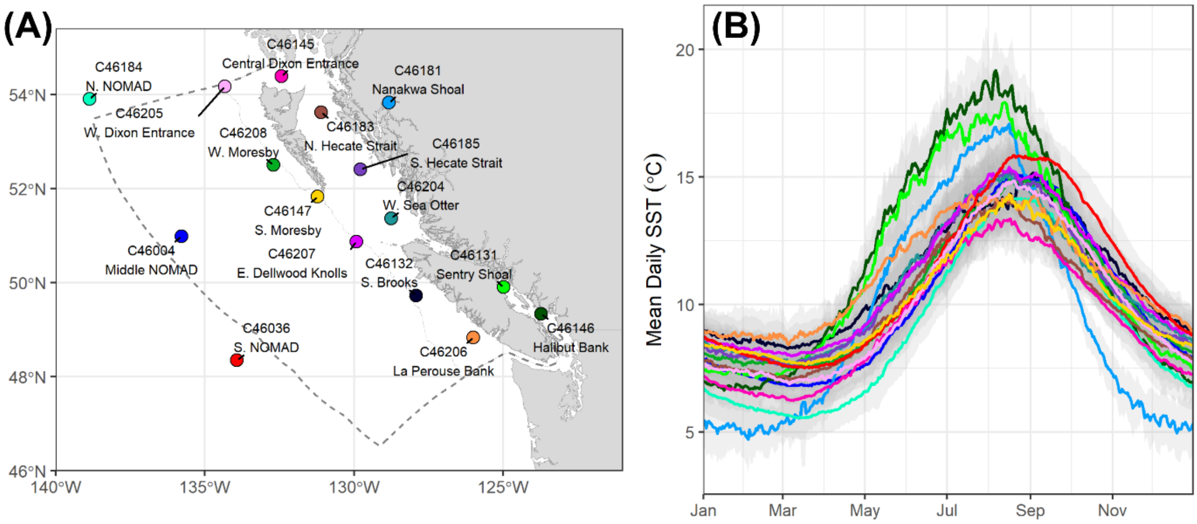

Figure 1. (A) Map of buoy locations and names, with point colours corresponding to the climatologies. (B) Daily mean buoy ocean surface temperature 1991-2020 climatologies with the 10th and 90th percentiles of the buoy measurements shaded. The accompanying OISST 30-year climatologies at these locations are shown in Appendix Figure C1.

2.2.2 OISST and buoy SST comparison

Daily OISST time series were extracted at the closest pixel to each buoy, for comparison between the two data sources. All daily images available from 1991 (i.e., the start of the Canadian Climate Normals period) to the end of 2023 were used. The C46181 Nanakwa Shoal buoy was discarded from the OISST-buoy comparison as it is located in a narrow fjord and does not intersect any OISST pixels. Buoys in the Strait of Georgia were retained, even though the large pixel sizes appear to overlap some islands and land features. However, the original AVHRR data input to the OISST estimation was at higher resolution and should not have included any land areas in its SST calculation.

The daily OISST values at each buoy location were regressed against the daily mean buoy SST values using a Type-2 Standard Major Axis regression. This form of regression assumes both datasets have errors and minimizes it for both axes, rather than minimizing error only for the y-axis. The slope, intercept, r^2, RMSE and bias were calculated for the OISST at each buoy individually, and for all buoys combined using the "lmodel2" R package.

Overall, OISST effectively estimates daily mean buoy SST in the CPEEZ (r^2 = 0.98, RMSE= 0.46, p-value < 0.01; Figure 2), though slightly underestimates SST at higher surface temperatures (e.g., > 10 °C; slope = 0.96). When comparing daily measurements at all buoys combined, the OISST had a mean bias of -0.13 ± 0.44°C, indicating that it is likely to be slightly cooler than the daily mean SST measured by the buoys.

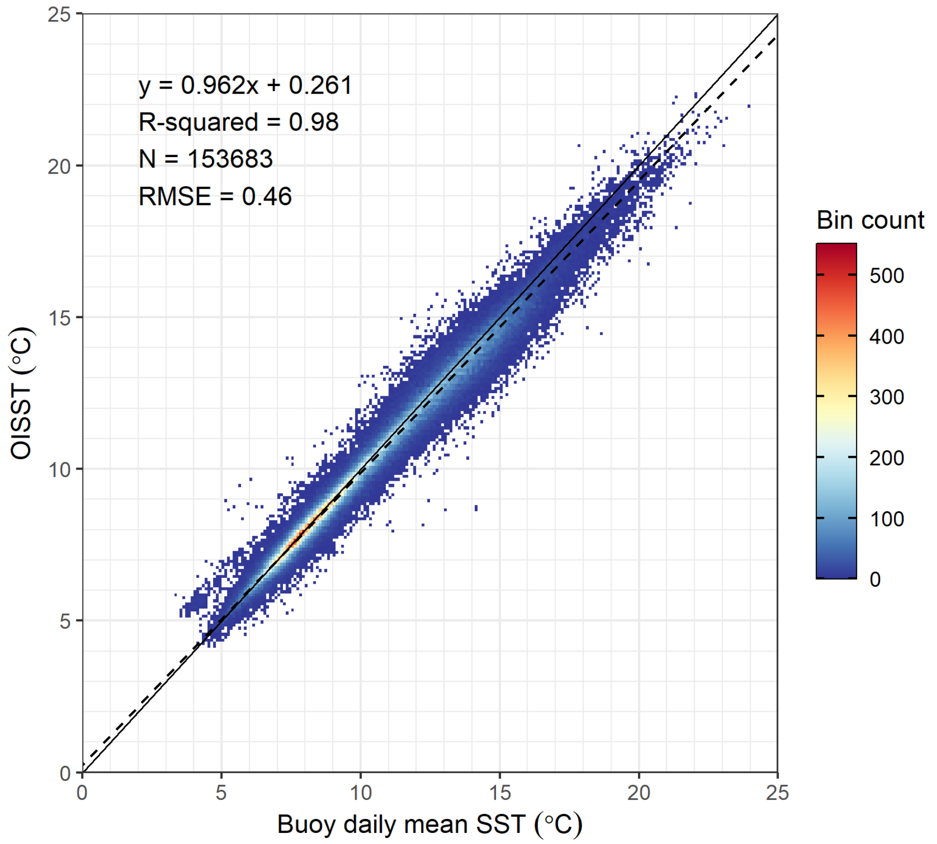

Figure 2. Relationship between the OISST and daily mean buoy SST from 1991 to the end of 2023, plotted as point density in 0.1°C bins, with the count of data points in each bin shown on the right side. The solid black line indicates the 1:1 relationship, and the dashed line indicates the Type-2 Standard Major Axis regression slope. The highest density of measurements lies between approximately 6-10°C.

When examining the regression at individual buoys (Figure 3), the OISST measurements have best agreement to the C46131 Sentry Shoal, C46036 South NOMAD and C46004 Middle NOMAD buoys (lowest RMSE, and highest r^2 values), though all r^2 values were high (≥ 0.95). The C46147 South Moresby buoy was the only location where the OISST was slightly higher than the daily buoy SST (slope of 1.02, intercept of -0.15). The buoy with highest RMSE was C46206 La Perouse Bank (0.57), while the C46204 West Sea Otter buoy had the lowest slope (0.91). The buoys with highest RMSE also had visible outliers (Figure 3), including the C46206 La Perouse Bank and C46204 West Sea Otter buoys, with highest OISST-buoy residuals below 10°C in the OISST dataset. The buoys located in the Strait of Georgia, while having OISST pixels visibly overlapping land due to their large size (see Section 2.2.2), had very good agreement between data sources (r^2 = 0.99 and slopes ≥ 0.96). Overall, all buoys had slopes greater than 0.90 and r^2 values greater than 0.940, with all p-values lower than 0.01. Given that temperature gradients can be strong in the upper few meters of the water column, and that the buoy and OISST datasets represent differing depths, this relationship is effective for our purposes. Further work could examine the differences between buoy and OISST in more detail.

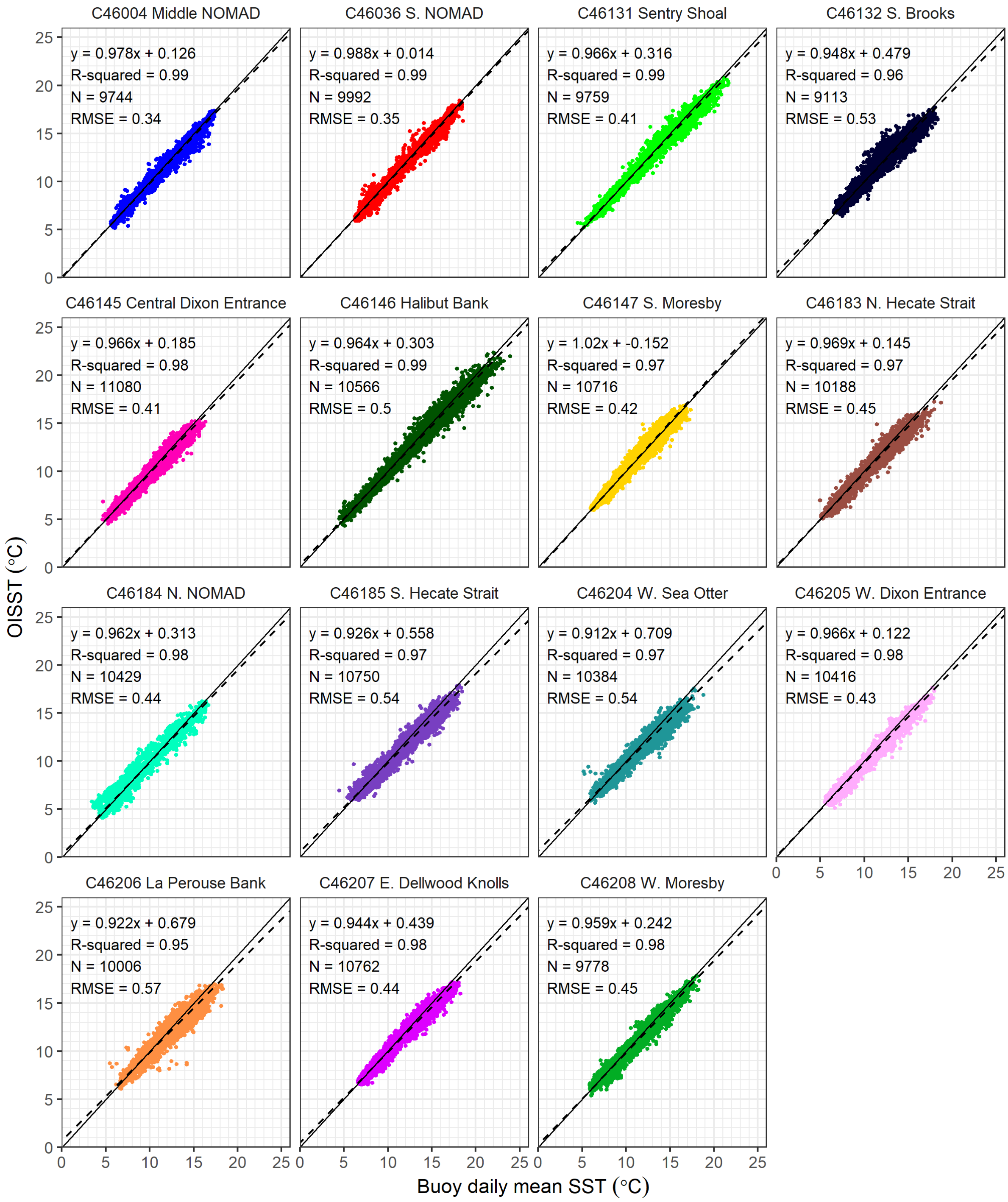

Figure 3. Type-2 Standard Major Axis regressions between daily OISST and daily mean buoy SST, spanning all available records from 1991 to the end of 2023. The black solid line indicates a 1:1 relationship, with the dashed lines indicating the regression slopes.

2.3 OISST climatologies and anomalies

Daily and weekly climatologies were calculated from the OISST data by taking the mean value at each pixel for all images falling into each time interval over the climate normal period of 1991-2020. For example, the January 1st *daily* climatology consisted of the mean of the 30 images from year-day 1 from 1991 to 2020. Similarly, the January 1st *weekly* climatology consisted of the mean of the 210 images from year-day 1 to 7 from 1991 to 2020. Leap-days were ignored when calculating climatologies by excluding year-day 366. Standard deviations for each day and week over this time period were calculated in a similar manner.

For each set of daily and weekly climatologies, the mean and standard deviation maps were saved as geoTIFF files with the R "terra" package. Daily and weekly anomalies were calculated for each year using these climatological layers, by subtracting the daily or weekly climatology from its corresponding day or week in a given year.

2.4 MHW spatio-temporal metrics

To calculate daily and weekly MHW extent maps and time series, the Hobday et al. (2016; 2018) MHW definition and similar implementation on the NOAA California Current Marine Heatwave Tracker (https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker) were followed with some minor modifications. According to Hobday et al., SST values exceeding the 90th percentile of the climatological SST are considered to be in MHW status. Here, the climatological standard deviation maps at each time step were used, with observations exceeding 1.29 standard deviations (corresponding to the 90th percentile in a normal distribution) classified as MHWs. However, in our implementation we avoided setting a minimum MHW duration at each pixel (as is performed in the Hobday et al. definition), in order to directly view zones and spatial extents of MHW-class temperatures.

The surface areas of the CPEEZ and Pacific Federal Marine Bioregions experiencing MHW conditions were calculated using these MHW status maps. Surface area is a straightforward metric for calculating the proportion of surface waters impacted by large MHW events, as well as the length of time that these waters, and thus the species that use them, are exposed to MHW conditions. To determine the proportion of the CPEEZ and Pacific Federal Marine Bioregions in MHW status, the Federal Marine Bioregions shapefile was acquired from the Government of Canada OpenData website (https://open.canada.ca/data/en/dataset/23eb8b56-dac8-4efc-be7c-b8fa11ba62e9). The Offshore Pacific, Northern Shelf and Southern Shelf Bioregions in Pacific waters were used, whereas the Strait of Georgia Bioregion was excluded due to its small, narrow size relative to the OISST spatial resolution (see Figure 5A). A polygon of the CPEEZ was created from this Bioregions dataset by merging the boundaries of all Pacific Bioregion polygons, and was saved in ESRI shapefile format. OISST pixels identified to be in MHW status were intersected with these layers, retaining pixel centers enclosed within the boundaries of the CPEEZ and each Bioregion. The area of each OISST MHW pixel was calculated using the "areaPolygon" function from the "geosphere" R package to account for the curvature of the earth's surface. The percentage of the area covered by MHWs each day was computed by summing the area of all MHW pixels falling within each region of interest, and dividing by the summed area of all pixels that intersect these regions.

3 Monitoring MHWs in the Northeast Pacific and Canadian Pacific Exclusive Economic Zone

Weekly spatial distribution maps of MHWs in the NEP are being produced and updated on a weekly basis. The area of the NEP surface waters in MHW status is extracted daily for the CPEEZ and three marine Bioregions, which can be used to track MHW spatial and temporal extents. These figures and data are stored on a public-facing Github page, with the latest year of maps and data retained online (see: https://github.com/IOS-OSD-DPG/Pacific_SST_Monitoring).

3.1 Weekly MHW spatial distribution

Weekly OISST and OISST anomaly maps were used to track the spatial distribution and development of MHW areas in the NEP and CPEEZ (Figure 4). While the underlying OISST dataset is updated on a daily basis, weekly maps were preferred for tracking the spatial extent and distribution of MHWs to reduce small day-to-day fluctuations that may be introduced in the OISST computation and spatial interpolation process.

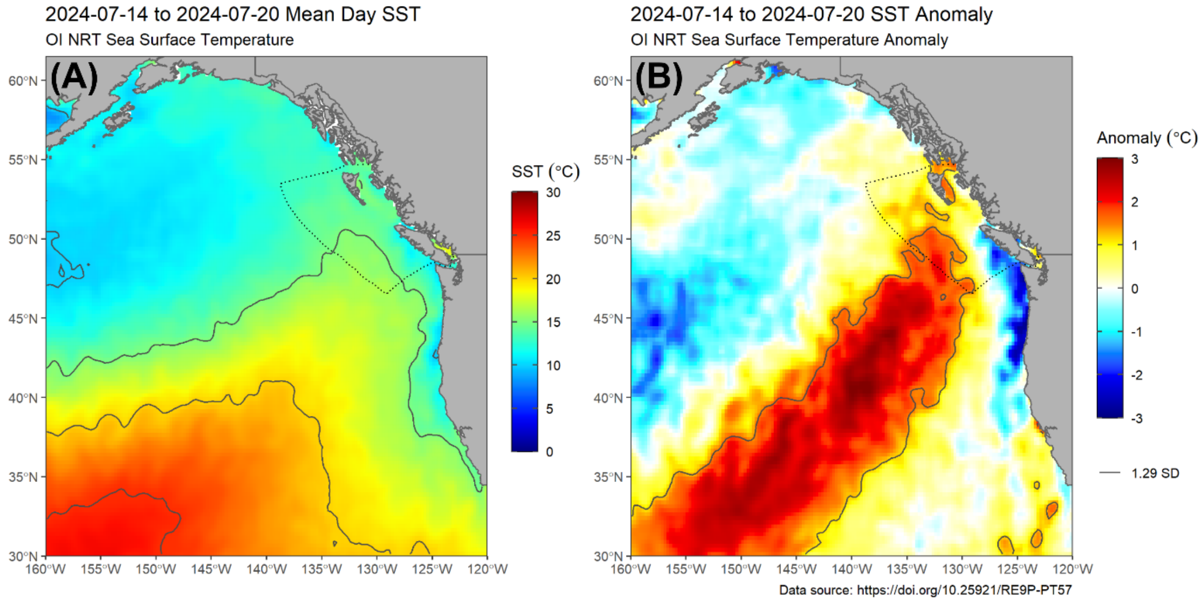

Figure 4. (A) A map of mean OISST and (B) mean OISST anomaly from the week of July 14th-20th, 2024. The CPEEZ is indicated with a black dashed line. SST contours at 5°C intervals are drawn on the weekly mean map OISST. Contours on the SST anomaly map outline 1.29 standard deviations (SD) from the 30-year climatological mean, indicating MHW status (e.g., OISST in the contained area exceeds the 90th percentile).

3.2 Daily MHW area coverage

The area of the CPEEZ in MHW status, expressed as percent of the full area, was calculated from the daily OISST dataset (Figure 5B; Section 2.4). It was similarly calculated for the Offshore Pacific, Southern Shelf and Northern Shelf Bioregions. The percent coverage tends to fluctuate less as the region size grows. However, examination by sub-region shows the spatial differences in duration of MHW events within the CPEEZ. For example, a large MHW that reached the CPEEZ during late July of 2023 (grey area in Figure 5B) persisted longer in the Offshore Pacific Marine Bioregion compared to the other Bioregions located on the continental shelf (NSB and SSB).

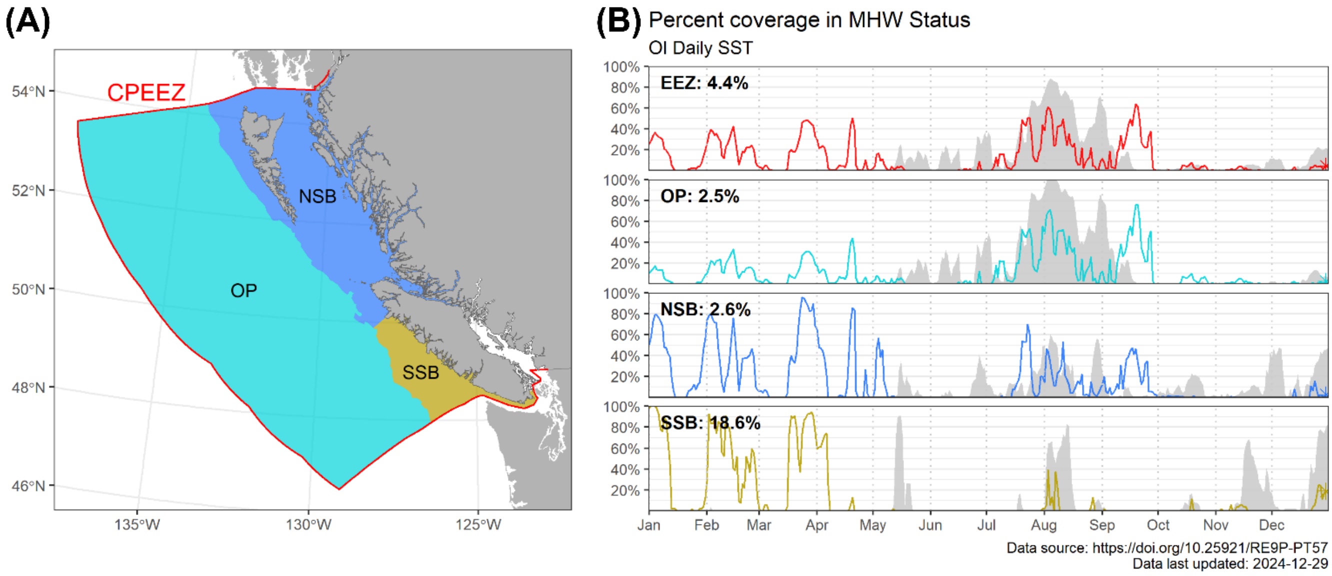

Figure 5. (A) Map of the CPEEZ and Pacific Federal Marine Bioregions. “OP” indicates the Offshore Pacific Bioregion, “NSB” the Northern Shelf Bioregion, and “SSB” the Southern Shelf Bioregion. The Strait of Georgia Bioregion was excluded from this analysis due to its small size relative to the OISST pixel area. (B) MHW percent coverage in the CPEEZ (top), OP (second row), NSB (third row) and SSB (bottom row), derived from OISST. 2024 MHW coverage is indicated in colour, with 2023 shaded in grey for comparison.

4 Discussion

4.1 Current methods and limitations

This technical report describes acquisition, validation, and processing of OISST data for MHW monitoring. The approach used follows the Hobday et al. (2016; 2018) definition, but excludes setting a minimum MHW duration at each pixel in order to directly view zones and spatial extents of anomalously high, MHW-class SSTs. Further, a normal distribution is assumed at each pixel while using standard deviations to calculate the MHW threshold. While this leads to some differences when compared to maps created with the Hobday et al. (2016; 2018) definition, spatial comparisons (see example in Figure A1) had very similar results. Although the Hobday et al. (2016; 2018) definition is widely used in oceanography, it may be less useful for ecological studies that emphasize impacts of differing SST anomalies, magnitudes and heatwave durations among marine species. Further metrics specific to marine species in our region (e.g. cumulative heat stress, number of days exceeding species-specific threshold temperatures, etc.) will help contextualize which events are more harmful than others. Additionally, with increasing global interest in MHWs, a number of tools and data sources using the Hobday definition for monitoring already exist (e.g., maps and pixel time series at the Marine Heatwaves Working Group tracker: https://www.marineheatwaves.org/tracker.html).

Although the OISST data has coarse spatial resolution, it can effectively show where large, anomalously warm water masses are located and raise awareness of approaching MHW events. For example, in August 2023, a large approaching MHW was observed in the OISST data, which engulfed the EEZ (Figure B1) and was then observed in coastal weather buoy data (Figure B2).

Finally, mapping surface MHWs is just one step in monitoring them. Without combining MHW data with long-term measurements acquired throughout the water column, such as ocean temperature time series collected by moorings or gliders, ecosystem-level events and impacts cannot be effectively tracked. Further efforts underway include integrating buoy ocean surface temperature and temperature acquired at multiple depths by moorings into our rapid MHW monitoring. Long-term, daily measurements of temperature are also recorded at 12 coastal lightstations in the BC Shore Station Oceanographic Program (see: https://open.canada.ca/data/en/dataset/719955f2-bf8e-44f7-bc26-6bd623e82884), and are valuable data to include in further comparisons.

4.1.1 Buoy SST and further *in situ* measurements

Buoy SST was compared to the OISST data here, as it is a good data source for long-term reference measurements, and can be used to fill spatial gaps in areas where the satellite data is too coarse (e.g., the Nanakwa Shoal buoy). Further, in much of the global ocean, the ocean surface is obscured by clouds the majority of the time, making it difficult or impossible to monitor SSTs on shorter time scales using satellite data (i.e., daily or weekly) without spatial interpolation. For example, Hardy et al. 2021 showed that AVHRR acquires SST for BC shelf waters on-average 1 out of every 5 days, while further offshore in the NEP, the interval drops to on-average 1 out of every 20 days. The OISST dataset addresses this problem by directly integrating global buoy, Argo and ship measurements with the AVHRR-acquired SST.

However, the buoy SST product distributed by CIOOS, used here, also uses OISST data for its own quality control. As a result, there is existing redundancy in directly comparing these two sources. While separate quality-control steps are applied to the buoy and other *in situ* data ingested to the OISST estimation, the steps are not the same as those applied when directly acquiring the buoy data here, which are more detailed. Further work should detail exactly which buoys and time periods were ingested into OISST, prior to statistically comparing the buoy SST and OISST values, in order to ensure independence of the datasets. Further, as mentioned in section 2.1, NRT OISST data is more likely to have lower quality data input to the SST estimation. This can result in some strange spatial features like "bullseye" patterns, where the OISST values are raised or lowered in a circular pattern at the location of *in situ* input data. However, many of these spatial inconsistencies were observed to disappear in the final-quality OISST product. Therefore, for long-term statistics and other calculations, it is important to use the final-quality OISST product.

A regression was performed to examine the agreement between OISST and the buoy SST sources in the CPEEZ. Overall, OISST had a mean bias of -0.13°C, larger than the global cold bias value found in Huang et al. (2021) of -0.04°C. However, even though the OISST comparison in the CPEEZ represents a much smaller area of the global ocean with fewer *in situ* measurements, these two comparisons similarly show that OISST is slightly cooler than directly measured surface ocean temperatures. Given that the overall comparison between the OISST and buoy SST in BC is good (r^2 = 0.98, slope = 0.96), OISST can more confidently be used to fill gaps in the buoy SST time series here. As numerous buoys have been offline when they are in need of repairs or maintenance in recent years, sometimes for extended periods of time, this demonstrates a potential use for OISST or other satellite data sources to fill those gaps.

The daily mean buoy SST, rather than hourly buoy SST, was used here for the regression to correspond to the daily OISST data. Future efforts should pinpoint the time of day or averaging interval at which it is most appropriate to use the buoy SST for OISST validation, as there is significant diurnal heating visible in the dataset, particularly during the summer months. Further, when examining the buoy SST and OISST climatologies (Figure C1), the climatologies have the largest discrepancies during the summer.

4.2 Future improvements and data sources

OISST is an effective dataset for rapid, large-scale MHW monitoring. This spatially-interpolated SST also has the advantage of using one consistent series of satellite sensors (AVHRR) as an input data source. However, using other higher resolution satellite data sources in the future for monitoring MHWs in the NEP will increase opportunities to compare with sample data, and improve estimates of MHW extent into more constrained coastal areas, including the Strait of Georgia, Barkley Sound, and other large inlets along the BC coast. Additionally, coarse resolution data such as OISST can miss smaller-scale spatial features like SST fronts, eddies or freshwater inputs, which may alter the impacts of MHWs. Further development of this SST and MHW monitoring is ongoing, with the plan to expand these efforts to include the Coral Reef Watch (5 km spatial resolution, January 1985 to present; Liu et al. 2014; Skirving et al. 2020) and Multi-scale Ultra-high Resolution (MUR; 1 km spatial resolution, May 2002 to present; Chin et al. 2017) SST datasets.

Further, though not adopted here, methodologies for defining several MHW categories can applied according to their magnitude above multiples of the 90th percentile threshold, with the lowest being Category 1 (e.g., the SST anomaly exceeds the 90th percentile, but is less than 2x the 90th percentile threshold), and highest being Category 4 (exceeding 4x the 90th percentile threshold; see Hobday et al. 2018). Further, numerous other MHW definitions are used in other studies, such as when SST exceeds the 99th percentiles compared to long-term simulated data (Frölicher et al., 2018, using baseline periods of 500 years or longer), or exceeding 90th percentiles of filtered anomalies compared to seasonal SST measurements (Kohlman et al., 2024). Future efforts may assess MHW categories and definitions alongside biological data, to inform which are most appropriate to use for understanding negative MHW impacts on the wider ecosystems of the NEP.

An additional consideration when examining extreme ocean surface temperatures is the presence of Marine Cold Spells (MCSs). MHWs have captured global attention, with MCSs still being lower concern (Wang et al. 2022). Although the occurrence and intensity of MCSs are globally declining (Schlegel et al. 2021), future reporting could emphasize including MCS metrics, as they can have both positive and negative ecological impacts. For example, MCSs may shift species community structure (Donders et al. 2011), or provide ecosystem benefits and indicate periods of recovery after MHWs (Caputi et al. 2016). As shown in Wang et al. (2022), the number of MCS days annually was either flat or slightly declining in the NEP over 1982-2020. However, the intensity of MCS events was observed to be increasing in some areas of the NEP. In particular, MCS intensities showed increasing trends along the shelf waters of BC north to Alaska, and further offshore in the central North Pacific.

5 Conclusion

This report outlines methodology used in the Pacific Region to monitor large-scale MHWs on a daily and weekly basis. Gridded OISST data is used to calculate spatial and temporal metrics of MHWs in the Northeast Pacific, which are validated using buoy temperature measurements, and provided publicly throughout the year for monitoring the spatial extent of MHWs in the NEP. Continued and expanded monitoring of MHWs in this region is necessary to improve the ability of stakeholders to anticipate, respond, and adapt to future MHW events and their impacts.

The long-term ocean temperature measurements acquired from buoys maintained by DFO and ECCC, used here to validate OISST data, emphasizes the value of maintaining these records in tandem with other long-term monitoring programs (e.g., the BC Shore Station Oceanographic Program). When comparing the buoy SST and OISST data, the latter shows a slight cold bias, particularly during the summer. This suggests that OISST may actually be under-estimating the intensity of some MHWs in the CPEEZ. Therefore, continued long-term temperature records with widespread spatial coverage, like those collected by the ECCC/DFO buoy network, are an integral part of continued MHW monitoring. Further, while it is tempting to fill gaps with OISST values when buoy SST measurements are missing, further analysis is needed to assess OISST accuracy with data sources not integrated into its original estimation.

Further work will continue developing our MHW monitoring capacity, using higher resolution SST products to compare results at different spatial scales, and to improve the ability to map MHW extents in smaller geographic areas like the Strait of Juan de Fuca and Strait of Georgia. These efforts will be added to the material and R code summarized in this report, which can be found online at: https://github.com/IOS-OSD-DPG/Pacific_SST_Monitoring. We also recommend further integration with data sources that acquire temperature data deeper in the water column, including long-term mooring and glider temperature time series, for more holistic monitoring of MHWs and their effects.

6 Acknowledgements

Firstly, we would like to thank Charles Hannah for the motivation and guidance developing and continuing our MHW monitoring work, as well as helpful input and comments during review. We would like to thank the data providers, who make the OISST and buoy SST measurements used here freely and openly available. Further, we would like to thank CIOOS/Hakai Institute for providing the quality-controlled buoy data, and Jonathan Kellogg and Nate Rosenstock for providing input and support on its use, as well as Roy Mendelssohn at NOAA for support accessing CoastWatch data. Finally, we appreciate the detailed and helpful comments from Stephanie Clay, Hauke Blanken, and Cynthia Bluteau.

7 References

Barkhordarian, A., Nielsen, D. M. & Baehr, J., 2022. Recent marine heatwaves in the North Pacific warming pool can be attributed to rising atmospheric levels of greenhouse gases. *Communications Earth & Environment,* June.Volume 3.

Bass, A. V., Smith, K. E. & Smale, D. A., 2023. Marine heatwaves and decreased light availability interact to erode the ecophysiological performance of habitat-forming kelp species. *Journal of Phycology,* April, Volume 59, p. 481–495.

Boldt, J. L., Joyce, E., Tucker, S. & Gauthier, S. eds., 2022. State of the Physical, Biological and Selected Fisheries Resources of Pacific Canadian Marine Ecosystems in 2021. *Can. Tech. Rep. Fish. Aquat. Sci..*

Boldt, J. L., Joyce, E., Tucker, S. & Gauthier, S. eds., 2023. State of the Physical, Biological and Selected Fisheries Resources of Pacific Canadian Marine Ecosystems in 2022. *Can. Tech. Rep. Fish. Aquat. Sci..*

Bond, N. A., Cronin, M. F., Freeland, H. & Mantua, N., 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophysical Research Letters,* May, Volume 42, p. 3414–3420.

Canada - British Columbia, 2014. *Marine Protected Area Network Strategy,* s.l.: s.n.

Caputi, N. et al., 2016. Management adaptation of invertebrate fisheries to an extreme marine heat wave event at a global warming hot spot. *Ecology and Evolution,* April, Volume 6, p. 3583–3593.

Chen, H.-H., Qi, Y., Wang, Y. & Chai, F., 2019. Seasonal variability of SST fronts and winds on the southeastern continental shelf of Brazil. *Ocean Dynamics,* October, Volume 69, p. 1387–1399.

Chin, T. M., Vazquez-Cuervo, J. & Armstrong, E. M., 2017. A multi-scale high-resolution analysis of global sea surface temperature. *Remote Sensing of Environment,* October, Volume 200, p. 154–169.

Cummins, P. F. & Masson, D., 2014. Climatic variability and trends in the surface waters of coastal British Columbia. *Progress in Oceanography,* January, Volume 120, p. 279–290.

Donders, T. H. et al., 2009. Impact of the Atlantic Warm Pool on precipitation and temperature in Florida during North Atlantic cold spells. *Climate Dynamics,* November, Volume 36, p. 109–118.

Edwards, A. M. et al., 2024. *pacea: An R package of Pacific ecosystem information to help facilitate an ecosystem approach to fisheries management,* s.l.: s.n.

Embury, O. et al., 2024. Satellite-based time-series of sea-surface temperature since 1980 for climate applications. *Scientific Data,* March.Volume 11.

Freeman, E. et al., 2016. ICOADS Release 3.0: a major update to the historical marine climate record. *International Journal of Climatology,* June, Volume 37, p. 2211–2232.

Frölicher, T. L., Fischer, E. M. & Gruber, N., 2018. Marine heatwaves under global warming. *Nature,* August, Volume 560, p. 360–364.

Global Climate Observing System, 2022. *The 2022 GCOS Implementation Plan.* GCOS-244 ed. s.l.:s.n.

Hardy, M., Devred, E. & Hannah, C., 2021. Satellite observations of the Northeast Pacific Ocean. *DFO Can. Tech. Rep. Hydrogr. Ocean Sci.,* Volume 335, p. vii + 46 p..

Hartog, J. R., Spillman, C. M., Smith, G. & Hobday, A. J., 2023. Forecasts of marine heatwaves for marine industries: Reducing risk, building resilience and enhancing management responses. *Deep Sea Research Part II: Topical Studies in Oceanography,* June, Volume 209, p. 105276.

Hobday, A. J. et al., 2016. A hierarchical approach to defining marine heatwaves. *Progress in Oceanography,* February, Volume 141, p. 227–238.

Hobday, A. et al., 2018. Categorizing and Naming Marine Heatwaves. *Oceanography,* June.Volume 31.

Huang, B. et al., 2021. Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1. *Journal of Climate,* April, Volume 34, p. 2923–2939.

Jackson, J. M., Johnson, G. C., Dosser, H. V. & Ross, T., 2018. Warming From Recent Marine Heatwave Lingers in Deep British Columbia Fjord. *Geophysical Research Letters,* September, Volume 45, p. 9757–9764.

Kellogg, J. et al., 2021. Quality Control of Weather/Wave Buoy Temperature Data Provided by Environment and Climate Change Canada. *CIOOS Pacific.*

Kohlman, C. et al., 2024. The 2019 Marine Heatwave at Ocean Station Papa: A Multi-Disciplinary Assessment of Ocean Conditions and Impacts on Marine Ecosystems. *Journal of Geophysical Research: Oceans,* June.Volume 129.

Liu, G. et al., 2014. Reef-Scale Thermal Stress Monitoring of Coral Ecosystems: New 5-km Global Products from NOAA Coral Reef Watch. *Remote Sensing,* November, Volume 6, p. 11579–11606.

Merchant, C. J. et al., 2019. Satellite-based time-series of sea-surface temperature since 1981 for climate applications. *Scientific Data,* October.Volume 6.

O'Carroll, A. G. et al., 2019. Observational Needs of Sea Surface Temperature. *Frontiers in Marine Science,* August.Volume 6.

Oliver, E. C. J. et al., 2018. Longer and more frequent marine heatwaves over the past century. *Nature Communications,* April.Volume 9.

Piatt, J. F. et al., 2020. Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014-2016. *PLOS ONE,* January, Volume 15, p. e0226087.

Raymond, W. W. et al., 2022. Assessment of the impacts of an unprecedented heatwave on intertidal shellfish of the Salish Sea. *Ecology,* July.Volume 103.

Schlegel, R. W. et al., 2021. Marine cold-spells. *Progress in Oceanography,* November, Volume 198, p. 102684.

Skirving, W. et al., 2020. CoralTemp and the Coral Reef Watch Coral Bleaching Heat Stress Product Suite Version 3.1. *Remote Sensing,* November, Volume 12, p. 3856.

Smale, D. A. et al., 2019. Marine heatwaves threaten global biodiversity and the provision of ecosystem services. *Nature Climate Change,* March, Volume 9, p. 306–312.

Wang, Y. et al., 2022. Understanding the Changing Nature of Marine Cold-Spells. *Geophysical Research Letters,* March.Volume 49.

Wendling, C. C. & Wegner, K. M., 2013. Relative contribution of reproductive investment, thermal stress and Vibrio infection to summer mortality phenomena in Pacific oysters. *Aquaculture,* November, Volume 412–413, p. 88–96.

WMO, 2016. *The Global Observing System for Climate: Implementation Needs,* s.l.: s.n.

APPENDIX A - Contrasting MHW definitions

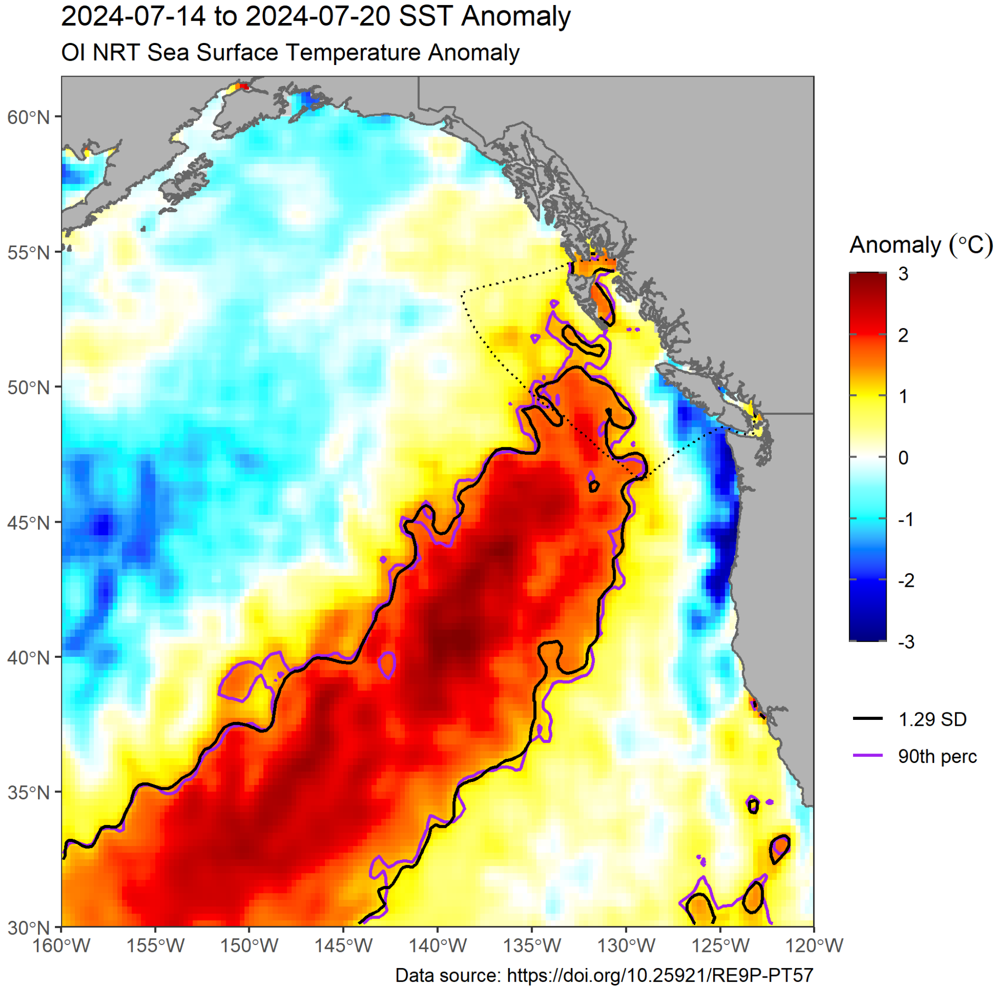

Figure A1. SST anomaly map from the week of July 14-20, 2024, contrasting MHW areas delineated in two ways: first, using the 90th percentile of the 30-year climatological SST (purple line), and secondly, MHW area exceeding 1.29 standard deviations (i.e., approximately the upper 90th percentile in a normal distribution) from the 30-year climatology (black line). The CPEEZ is shown as a dotted black line. Using standard deviations are slightly more conservative in area, while using the 90th percentile returns a slightly larger but generally less contiguous area defined as MHW.

APPENDIX B - Summer 2023 MHW progression

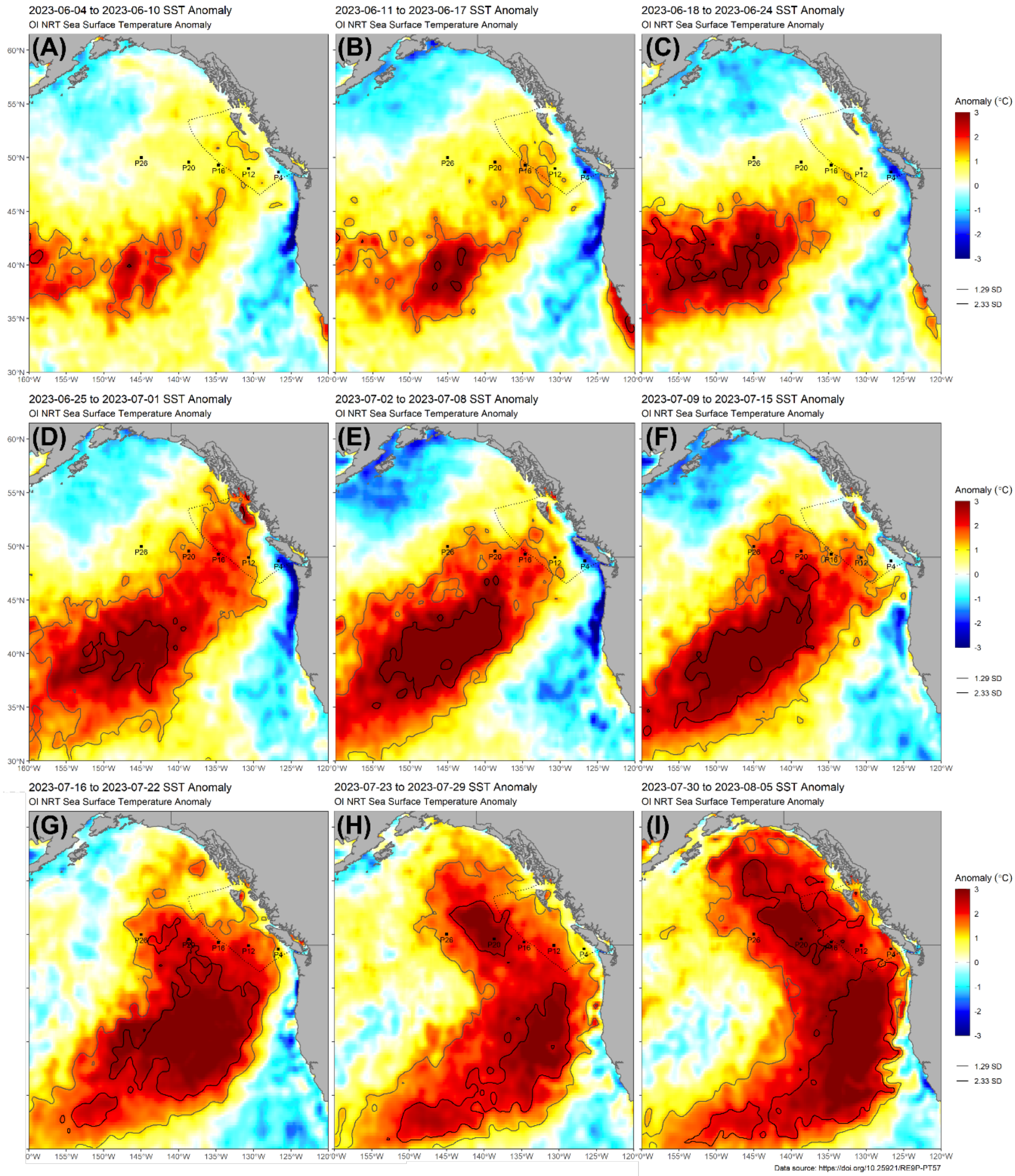

Figure B1. A large MHW observed expanding in the NEP in 2023. Starting at the end of June, it extended eastward across the NEP to the NSB (B-D), while cold anomalies persisted along the west coast of Vancouver Island south to Oregon (B-E). As the summer progressed, the MHW area expanded northeastward to encompass much of the shelf waters of western North America (H-I). The MHW area is delineated here with two lines, 1.29 and 2.33 standard deviations (corresponding to the 90th and 99th percentile of the climatology), with the CPEEZ indicated with a dashed line, and selected stations along Line P shown as labelled points.

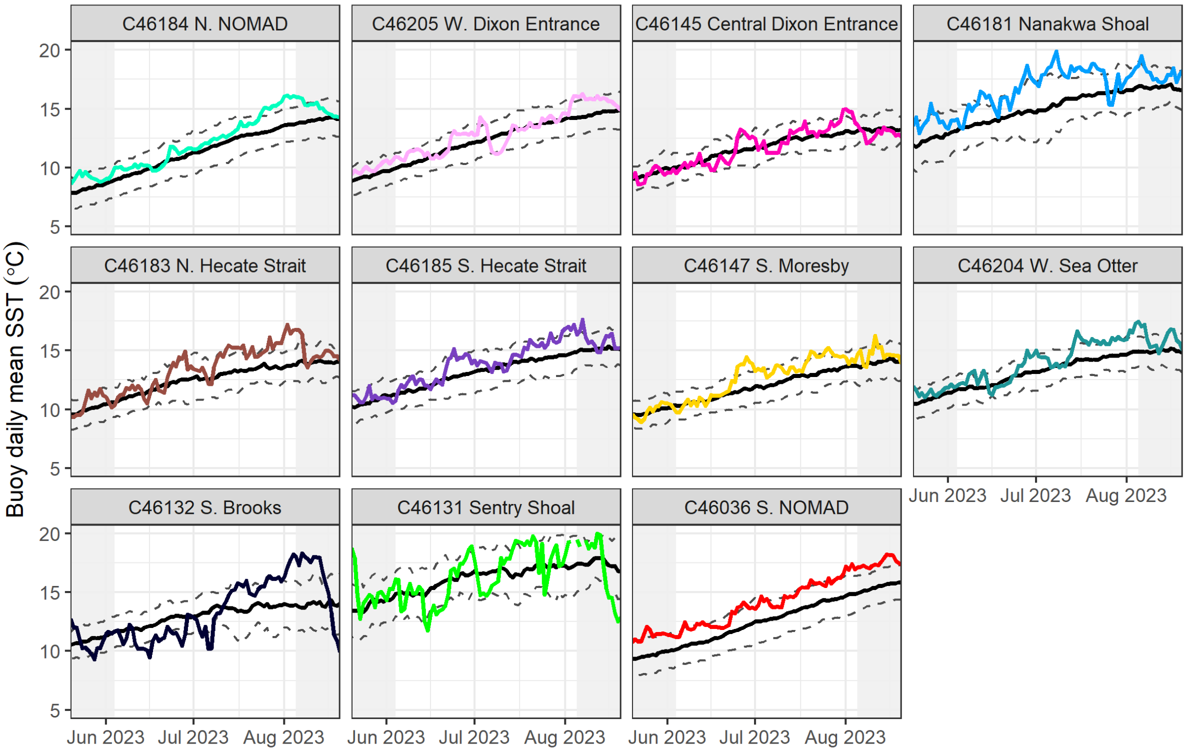

Figure B2. Daily mean buoy temperatures from late May to early September 2023, with the date range corresponding to Figure B1 indicated with a white background. The black line indicates the buoy daily climatology, with the dashed line indicating 1.29 standard deviations above and below those values, while the coloured line shows the 2023 daily mean temperatures (See Figure 1 for buoy map). Corresponding to Figure B1, some locations have warm anomalies throughout the time period (e.g. C46184 North and C46036 South NOMAD buoys). C46132 South Brooks, located off the west coast of Vancouver Island, has cool temperatures relative to its climatology, then warms after July 8th, corresponding to the arrival of the MHW delineated in Figure B1.

APPENDIX C - Buoy SST and OISST climatologies

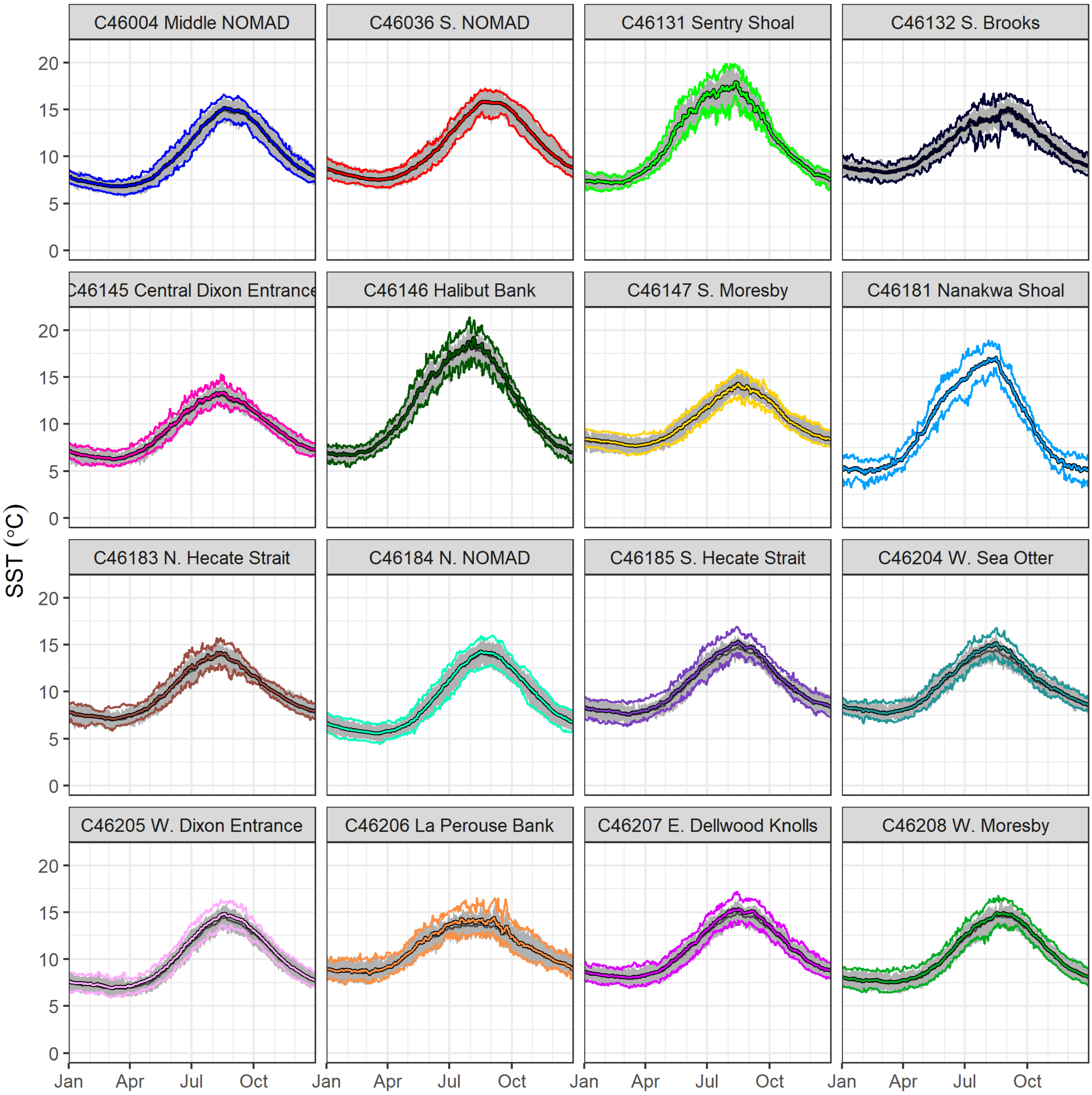

Figure C1. 30-year climatologies from the daily mean buoy SST and OISST datasets are superimposed. OISST climatologies at the buoy locations, with 10th and 90th percentiles shaded, are shown in grey. The buoy mean SST climatologies are indicated with coloured lines outlined in black, and the 10th and 90th percentiles as lines of the same colour above and below the mean. C46181 Nanakwa Shoal is too enclosed to retrieve usable OISST data, so shows only the buoy SST climatology. C46145 Central Dixon Entrance, C46183 North Hecate Strait, C46185 South Hecate Strait, C46146 Halibut Bank, C46131 Sentry Shoal, C46147 South Moresby, and C46132 South Brooks began after 1991.

APPENDIX D - Acronyms

Table D1. Acronyms used throughout the report.

AVHRR	Advanced Very High Resolution Radiometer
CIOOS	Canadian Integrated Ocean Observing System
CPEEZ	Canadian Pacific Exclusive Economic Zone
DFO	Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
MCS	Marine Cold Spell
MHW	Marine Heatwave
MPA	Marine Protected Area
MUR	Multi-scale Ultra-high Resolution
NCDC	National Climatic Data Center
NEP	Northeast Pacific
NOAA	National Oceanic and Atmospheric Administration
NRT	Near real-time
NSB	Northern Shelf Bioregion
OISST	Optimum Interpolation Sea Surface Temperature
OP	Offshore Pacific Bioregion
SSB	Southern Shelf Bioregion
SST	Sea Surface Temperature