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Open Access Earth System Science Data Discussions

Sea surface temperature time series from Ballycotton, Ireland

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Abstract. An ongoing and maturing Sea Surface Temperature time-series from Ballycotton in the south of Ireland has been created from deployments of high precision and accuracy sensors and made openly available for download. There is data at the location starting in 2010, with mostly-continuous data since 2016. A data managed process flow, quality control routine and metadata documentation are in place for this sea surface temperature dataset. Alongside this time series is a co-located tide gauge which together allow for a more comprehensive study of the coastal area and the changes occurring there overtime. The sea surface temperature time series is made available through the Marine Institute's ERDDAP server and has been assigned a citation and DOI (doi.org/10.20393/A7545AB4-3F9B-4CF5-97D7-98784B9B8D8C; Marine Institute, 2025a).

1 Introduction

Sea Surface Temperature (SST) is an important variable to monitor in order to better understand the climate of a specific area. Its variability over time can provide knowledge of oceanic processes and change, as well as atmospheric fluctuations and their coupled relationship, due to SST being integral to the exchange of gasses and energy between the ocean and atmosphere (WMO, 2016). Long-term studies of SST allow for separation of different frequencies, from diurnal to decadal scale, of variations which may exist in an area (Kessler et al., 2019; O'Carroll et al., 2019). High-resolution in-situ observations of SST also provide valuable data for validating numerical ocean models and satellite observations, which in turn provide information on SST in areas without in-situ coverage of instrumentation (Lee and Park, 2025; Merchant et al., 2023). Aside from physically characterising the ocean, SST is also useful in understanding the ecology of an area, as the temperature of the water is a significant control for many organisms in where they live (Lai and Zhou, 2025).

Acknowledging the importance of long-term monitoring stations and the usefulness of SST as a variable in studying ocean climate, the Marine Institute set up a sea surface temperature monitoring station in the south of Ireland at Ballycotton, County Cork, in 2010. This station was also a follow on to the successful monitoring station in the north of Ireland at Malin Head (Daves et al., 2025, under peer review). The deployment of the SST station in Ballycotton coincided with the deployment of a tide gauge as part of the Irish National Tide Gauge Network (INTGN). The combined data from these monitoring stations provides a more comprehensive understanding of ocean processes in that area, and in time will help constrain long-term changes.

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1.1 Ballycotton

Ballycotton is a small fishing village in east County Cork in the south of Ireland. The SST data is collected from the eastern end of Ballycotton Pier (yellow dots, Fig. 1). North from the pier lies Ballycotton Bay which is open to the Celtic Sea to the southeast. Prevailing surface currents in the area are westward flowing and bring water from the southeast of Ireland to the southwest (Fernand et al., 2006; Raine and McMahon, 1998). Ballycotton is a site of strong coastal erosion which has formed the bay into what it is today and leads to a high sediment load within the water in the harbour (National Parks and Wildlife Service, 2014).

The location of Ballycotton allows for the temperature data collected there to provide valuable information on the shelf processes in the Celtic Sea. As this region is important for many ecologically and economically valuable fisheries (e.g. *Nephrops norvegicus*, mackerel (*Scomber scombrus*), hake (*Merluccius merluccius*), and whiting (*Merlangius merlangus*)), having a temperature time series dataset can help to investigate changes and variations in population structuring (e.g. Martinez et al., 2013; Sharples et al., 2013).

Figure 1: Map showing the location of Ballycotton (Background map extracted from © 2025 Google: © Landsat / Copernicus, © Airbus, © Data SIO, NOAA, U.S. Navy, NGA, GEBCO)

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2 Dataset

Data acquisition has been occurring at Ballycotton since the 4th of October 2010 and has been collected using a combination of Seabird SBE 39 and SBE 39plus instruments, sampling at 30-minute frequency. The sensors have been secured to the pier wall (51.828133 °N, 8.000802 °W) at 2.85 m below OD Malin, which is the Irish national ordnance datum used to reference Z-height for all such deployments. This fixed vertical height, referenced to OD Malin corresponds to a depth of 3.05 m below Mean Sea Level (MSL) or 0.36 m below Lowest Astronomical Tide (LAT), such that it never dries out. The sensors are secured to the pier by placing them within a pipe which provides protection to the sensors from damage by waves, storms, or human activity. The attachment to the pier has gone through multiple stages of development to find what works best to support the sensors but also to avoid issues caused by the high siltation rate occurring in Ballycotton harbour.

The data collection has not been continuous since 2010. After two yearly sensor deployments (2010 - 2012), there was a pause in consistent operations and a lack of data until the 4th of May 2016 (Fig. 2). There was a sensor deployment between 2014 – 2015, however the sensor became flooded, and no data could be extracted from the instrument. The time series was mostly continuous from 2016. However, due to another sensor failure, there is a final gap in the data from 2023 – 2024. To address the most recent sensor failure, dual sensors have now been deployed and will be maintained together to ensure redundancy in case of issue with one of the units. When two sensors are deployed together, the resultant data is compared for accuracy and only the sensor with the 'best' data, for example the sensor with the fewest outlier points or unnatural spikes in the data, is included into the published time series.

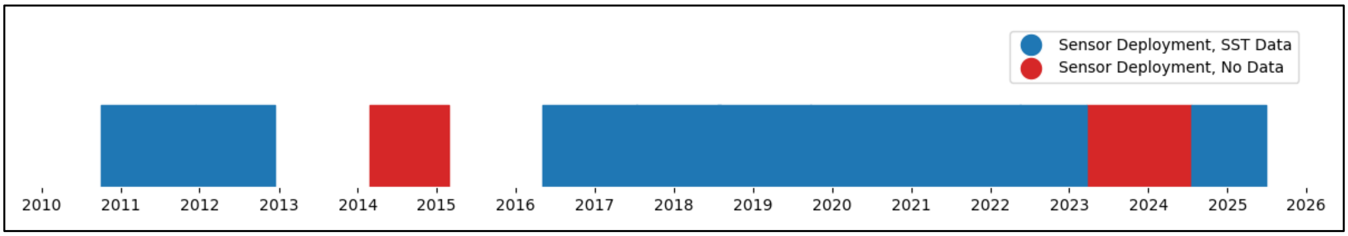

Figure 2: The deployments of sensors on the pier at Ballycotton, which coincide with data (blue) in the time series and the ones with no data (red) due to sensor failure during the deployment.

3 Data Quality

The data for this time series has been collected using high-precision sensors and managed using a standard framework to ensure standardisation of data handling, from collection to publishing. This standardisation ensures that when different operators are working with the data the output is the same across the board. This process is managed through the use of the Marine Institute's Data Management Quality Management Framework (DM-QMF) (Leadbetter et al, 2020), which consists of a 'data pack' of documentation, per dataset, that contains the exact SOPs, process flow diagrams (Fig. 3), and processing code that should be used on data collected as part of a specific project or using a specific sensor.

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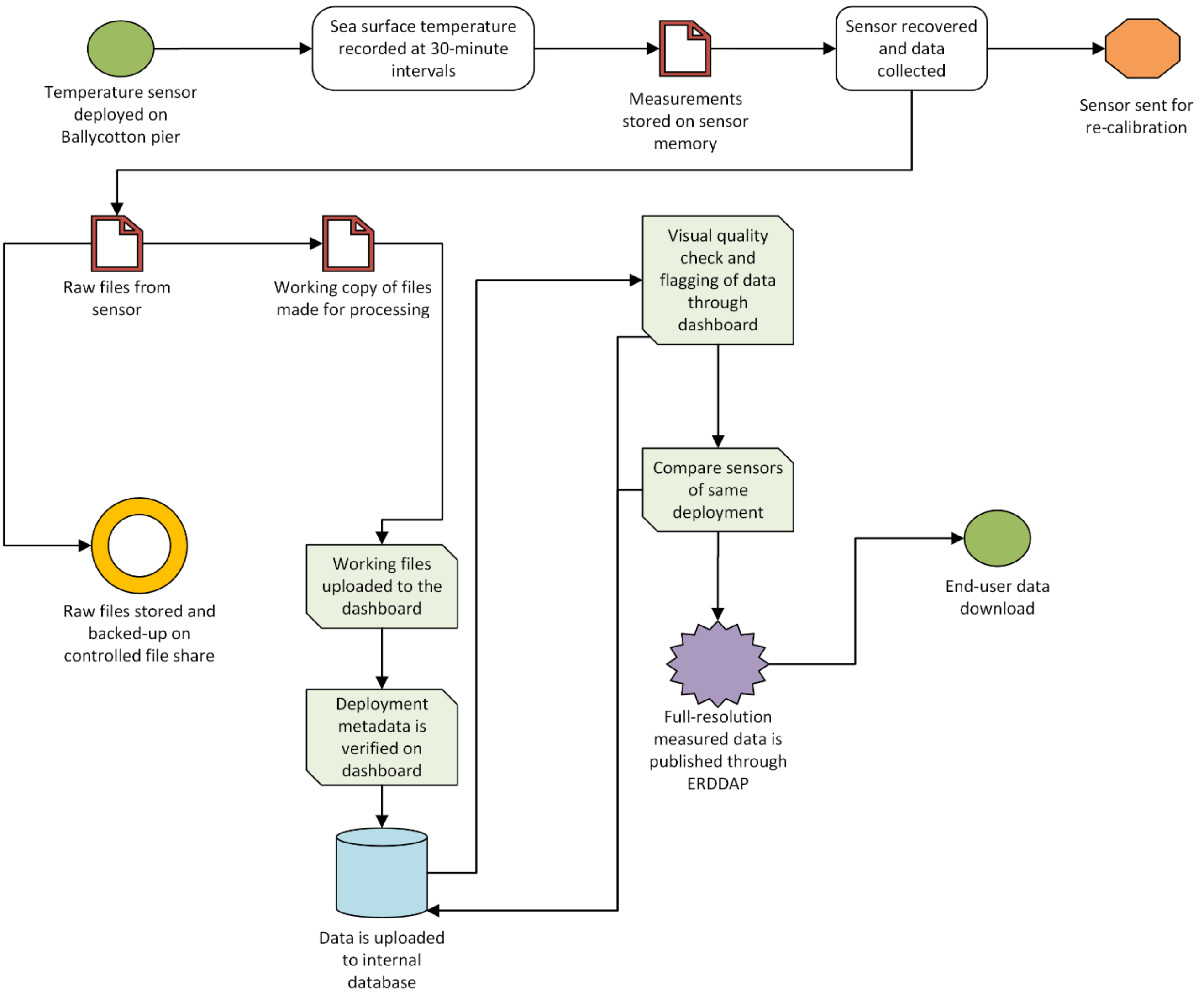

Figure 3: Process flow diagram for Ballycotton. Outlines all the steps undertaken between the sensor deployment and end-user data download. Green boxes denote steps that occur using the in-house dashboard for CTD processing and quality control.

3.1 Automated and Visual Quality Checks

The SST data collected at Ballycotton is actively quality controlled and each data point has a quality flag assigned to it before the data is included in the time series for publication. The quality check procedures for all fixed location CTD-DO instruments used at the Marine Institute have been standardised through an online Python based dashboard to ensure consistency across locations, deployments, and specific sensors. The online dashboard runs automated quality check procedures, such as spike identification and range checking, and it provides a platform to run a visual quality screen to manually flag (Table 1) data points where necessary and confirm the automated flags are correct. This dashboard is connected to an internal SQL database

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that ensures all QC flags are accurately and safely stored alongside the data. The data and QC flags are published to the Marine Institute's data server (https://erddap.marine.ie), an instance of the NOAA ERDDAP data server. No deployment data is deleted or removed; bad data simply gets flagged as so (Table 1). This QC process follows SeaDataNet's data flagging system (SeaDataNet, 2010).

Table 1: Overview of the SeaDataNet quality control flags that are used by the Marine Institute

Flag Value	Flag Meaning
0	Data has not been quality controlled. Raw data.
1	Good quality data as verified through quality control procedures.
4	Bad quality data as verified through quality control procedures.
9	Missing data value

3.2 Error

For the entire time series, instrument error on each data point is equivalent to the instrument accuracy margin combined with the drift throughout the deployment and can be taken as stated by the manufacturer's specifications. No drift corrections have been made to the data. Seabird reports the accuracy for the SBE 39 and 39plus instruments to a margin of ± 0.002 °C and a drift of no more than 0.0002 °C monthly (Seabird, 2024). Drift is minimized in the sensors by sending them back to the manufacturer for recalibration between each deployment, which in general get swapped out annually, ensuring drift does not carry on further than an individual deployment. The longest sensor deployment in this time series was 32 months, so the largest error that could be on a data point would be ± 0.0084 °C when the monthly drift for that length of time is combined with the instrument margin, but most data points would have an error value much lower than the extremities within that band.

This anomalous 32-month deployment of an instrument lasted from September 2019 to May 2022. The sensor was deployed for 20 months longer than normal because it got stuck in the pipe and was unable to be retrieved during scheduled maintenance of the station due to COVID pandemic restrictions. Another sensor was deployed alongside, unfortunately however, the data from this co-deployed sensor proved faulty and therefore could not be used to compare collected data with the stuck sensor to ensure the output was good. Using best practices and the knowledge that temperature sensors tend to be quite robust, the data stewards at the Marine Institute have declared the data throughout the length of the deployment to be good data, but when using the dataset this should be kept in mind. Deployment of dual sensors since then will help to negate a similar loss of data quality.

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4 Data Application

4.1 Trend Analysis

One primary objective of maintaining long-term time series such as SST, is that they allow for detailed analysis to be conducted, for example, to understand how ocean climate is changing in a specific area. This dataset is only beginning to mature as a long-term time series; defined as 10+ years of mostly continuous data (Gonzalez-Pola et al., 2020). As the dataset continues to grow, the underlying trends will become more apparent, providing more robust detail on the ongoing changes at the location. However, given the amount of data currently in the dataset, it remains possible to decipher clear trends in SST from the beginning of the time series to more recent years. Preliminary trend analysis has been conducted for the purposes of this paper and to assess, or forecast, what a longer-term trend may look like with continued monitoring. This trend analysis employs inclusion criteria that only includes years that hold at least 11 months of data, of which each must include at least 20 days of data. This ensures that reported yearly averages are accurately representative of the SST conditions throughout the year. Using these criteria, data from 2010, 2016, 2023, and 2025 are excluded from the analysis where yearly averages are created.

Interannual, decadal and longer-term warming can be analysed using a range of techniques and applications; one of the most convenient being to create annual averages from observed data. When SST at Ballycotton is analysed based on these annual averages, an increasing trend of > 0.06 °C (R^2 = 0.665) is calculated in temperature per year (Fig. 4). Over the duration of the data coverage (2011 – 2022), there is a total warming of > 0.7 °C.

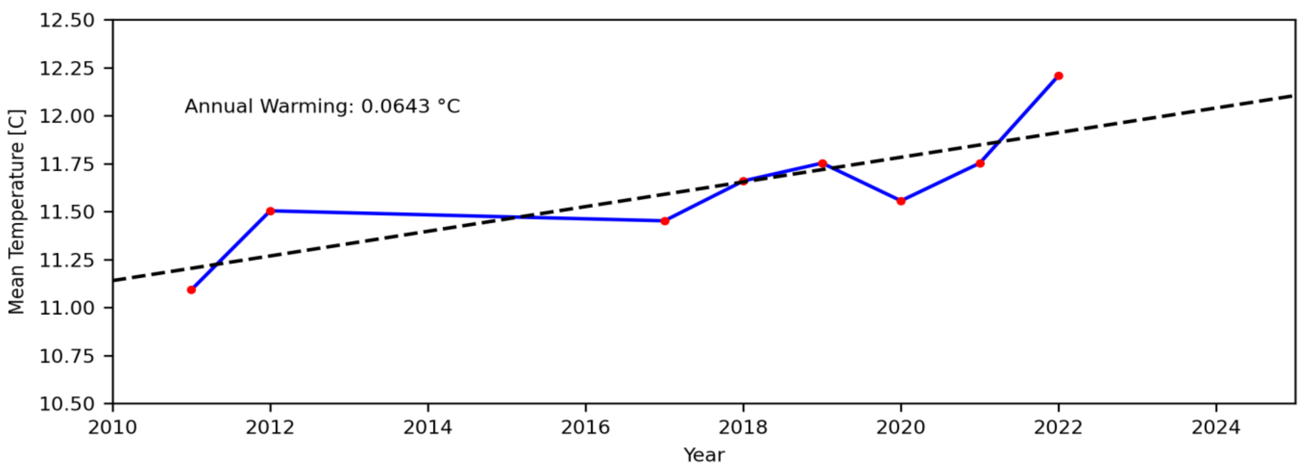

Figure 4: Warming trend analysis at Ballycotton, based on calculated annual averages

A useful metric for investigating change is temperature anomalies, calculated from a long-term climatological mean (e.g. WMO 30-year climate 'normals'). As there is not yet enough data at the location to develop this mean, outputs from an OSTIA sea surface temperature model at 0.05° x 0.05° horizontal grid resolution were used (European Union-Copernicus Marine Service, 2015). First, a comparison was completed between the model data and the collected data to ensure the model data was

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useable. Then the differences between contemporaneous data was averaged to derive an average difference value (0.479 °C). This average difference was then subtracted from the climatological mean (1991 – 2020) that had been developed from the model output. This final climatological mean was used to calculate and visualise yearly temperature anomalies for the length of the deployments at Ballycotton (Fig. 5). Anomalous warming is clearly obvious at Ballycotton over the time series, especially in 2022. This strong warm anomaly in 2022 has been seen in other locations in the northeast Atlantic including in Malin Head on the north of Ireland, which had an anomaly over its 30-year average of 1.17 °C that year (Marine Institute, 2025c).

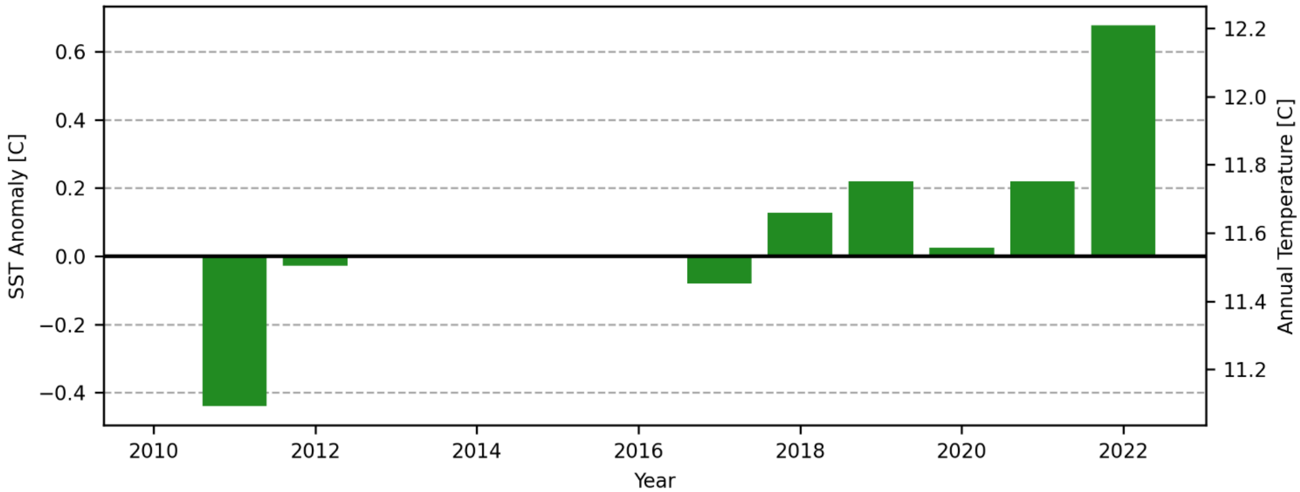

Figure 5: Temperature anomalies at Ballycotton from a 30-year average SST (1991 – 2020) based on an OSTIA model output

4.2 Data Use

As this data has just recently become available for the public to access without having to request the data, there have yet to be published uses of the dataset. However, there are many applications for SST time series datasets, which can be shown in published works that utilise different time series. Some of the uses for such time series are outlined below.

- Understanding changes to ecosystem and organism health (e.g. Wyatt et al., 2023).
- Separating anthropogenic climate change and natural climate variations (e.g. Cannaby and Hüsrevoğlu, 2009).
- Integration into model outputs (e.g. Choo et al., 2025).
- Meteorological applications (e.g. Tokinga et al., 2005).
- Analysis of migration patterns in aquatic organisms (e.g. Friedland et al., 2001).

This diversity in utilisation of other in-situ SST time series show potential ways that this dataset could be employed by various disciplines, including climate science, now that it is openly available.

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5 Data Availability

The Ballycotton SST time series is available through the Marine Institute's ERDDAP data server (https://erddap.marine.ie/erddap/tabledap/climate_ballycotton.html, doi.org/10.20393/A7545AB4-3F9B-4CF5-97D7-98784B9B8D8C; Marine Institute, 2025a). Full metadata surrounding the time series can also be accessed through the Marine Institute's Data Catalogue entry (https://data.marine.ie/geonetwork/srv/eng/catalog.search#/metadata/ie.marine.data:dataset.5324). The data are made available for use under the Creative Commons Attribution 4.0 International (CC-BY-4.0) licence (https://creativecommons.org/licenses/by/4.0/). Associated datasets, such as the Ballycotton tide gauge (https://erddap.marine.ie/erddap/tabledap/IrishNationalTideGaugeNetwork.html; https://data.marine.ie/geonetwork/srv/eng/catalog.search#/metadata/ie.marine.data:dataset.4786) and the Malin Head SST datasets (Marine Institute, 2025b; Marine Institute, 2025c) can also be found on these resources.

6 Conclusion

SST data collection began in 2010 at Ballycotton pier but became consistent in 2016. The data collected at this pier has been fixed in its location, sensor type, and processing throughout, which results in a clean and continuous time series that will continue to mature with sequential sensor deployments. This time series will prove very useful in a range of applications, one of which is analysing the warming trend in the area. The current analysis on the warming in Ballycotton provisionally finds an annual warming rate of 0.064 °C, although the time series is, as yet, immature for robust trend analysis.

This data collection began due to the known importance of long-term continuous time series and as a follow-on and addition to the SST time series in the north of Ireland at Malin Head. This dataset will continue to gain longevity through the continued support from the Marine Institute and in doing so will continue to grow in relevance and usefulness to the scientific community. Furthermore, there is an intention to set up the station to allow for real-time data beginning in May 2026.

Author Contribution

SD: Conceptualization, Formal Analysis, Visualization, Writing – Original Draft, Writing – Review & Editing; **GW:** Data Collection; **GN:** Funding Acquisition, Project Administration; **ED:** Conceptualization, Writing – Review & Editing, Supervision; **RT:** Conceptualization, Software, Dataset Publication, Writing – Review & Editing, Supervision

Competing Interests

The authors declare that they have no conflict of interest.

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