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GLOBES: the Global Library of Observations from Buoys for Evaluating Sea States

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Abstract. This paper presents GLOBES, the Global Library of Observations from Buoys for Evaluating Sea States, a new dataset of historical wave observations from moored buoys. Wave buoy records are maintained by numerous regional, national, and international observing programs, but differences in data formats, variable definitions, temporal conventions, quality control, and accessibility have limited their combined use. GLOBES addresses these challenges by assembling and harmonizing observations from 27 data providers into a common station-based framework. The first release presented here contains 1,665 buoy records distributed across 41 countries, representing 19,467 station-years of observations spanning the 58-year period from 1969–2026. Records retain their native temporal resolution, ranging from 10 min to 3 h, and include up to seven standardized wave parameters: (1) significant and (2) maximum wave height, (3) peak, (4) zero-crossing, and (5) mean wave period, (6) wave direction, and (7) directional spread. Provider-specific variable definitions, provenance, and quality control information are preserved, while timestamps, units, missing-value conventions, metadata, and quality-control flags are harmonized to support consistent use across observing networks. GLOBES is openly distributed through a versioned archive and can also be accessed through an interactive station interface and programmatic data services. This paper describes the identification and acquisition of source records, variable and quality-control harmonization, temporal processing, standardized file structure, data-use conditions, and access pathways. GLOBES provides a consistent observational resource for investigating wave climate, variability and extremes, and for evaluating numerical model hindcasts and reanalyses, and satellite-derived wave products, while supporting future analyses of long-term changes in sea states and coastal hazards.

1 Introduction

Wind-wave observations are fundamental to a wide range of oceanographic, coastal, and offshore applications, including hazard assessment, engineering design, maritime operations, numerical model development, and climate research. For instance, accurate wave information is critical for predicting coastal hazards, as wave height, period, and direction influence the amount of energy that reaches the coast. These wave characteristics thus affect the severity of overtopping, flooding, and erosion events, which can damage infrastructure, disrupt coastal communities, and degrade

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ecosystems (Almar et al., 2021; Barnard et al., 2017; Storlazzi et al., 2018; Vousdoukas et al., 2018). During vessel transits, navigators rely on timely forecasts of wave conditions and sea state to select safe and efficient routes, minimizing risk to vessels, cargo, and crew (Niclasen et al., 2010; Petersen et al., 2026; Zis et al., 2020). Wave information is also essential for the design and operation of offshore structures (e.g., Feld, Jonathan, et al., 2019; Feld, Randell, et al., 2019; Gouldby et al., 2014; Romans & Vandersohuren, 1995), such as oil and gas platforms, and for renewable wave energy development, where it guides resource assessment, site selection, and the design of wave energy converters (e.g., Behrens et al., 2012; Neary et al., 2020; Saulnier et al., 2011). For recreational activities, wave observations support forecasts that help identify suitable conditions for activities like surfing and sailing (e.g., Berkowitz, 2013; Harless & Dogan, 2023; James et al., 2018). Meeting these diverse needs requires high-quality wave information that is both spatially extensive to support applications across different regions, and recorded over long periods to evaluate and improve numerical models used for wave forecasting, characterize wave climates and rare extreme sea states, and assess changes in wave conditions across multiple temporal scales.

Wave information can be obtained from several sources, including in situ observations, satellite measurements, numerical model hindcasts and reanalyses. Among in situ observing platforms, dedicated wave-measuring buoys emerged during the mid-20th century and have since become a central component of wave monitoring systems. These instruments can provide measurements of wave height, wave period, wave direction, and directional spread, as well as time series of wave spectra at discrete locations. These point observations complement spatially extensive wave information derived from models and satellite measurements. Unlike model-derived products, such as the Global Ocean Waves (GOW) hindcast and ERA5 reanalysis, which provide gridded wave information at the global scale (Hersbach et al., 2020; Perez et al., 2017), buoy observations are not dependent on numerical representations of wave generation and propagation processes but instead provide direct in situ measurements of the sea state at the time and location of observation. Satellite altimeters can also provide direct observations of significant wave height across much of the global ocean (e.g., Cooper & Forristall, 1997; Izaguirre et al., 2011; Meucci et al., 2020; Passaro et al., 2026; Timmermans et al., 2020), but their temporal sampling is limited, with repeat cycles of approximately 10 days for TOPEX/Poseidon, Jason and Sentinel-6 missions. Moreover, other wave characteristics, such as wave period, generally require indirect inference, and some parameters measured by buoys cannot be retrieved from altimetry. Despite their more limited spatial coverage, buoy observations therefore remain essential in situ references for characterizing local wave conditions and for the calibration, validation, and bias assessment of satellite-derived wave products, numerical wave hindcasts, reanalyses, and wave forecasting models (e.g., Chawla et al., 2013; Deb et al., 2026; Jiang & Su, 2026; Perez et al., 2017; Smith et al., 2026).

Wave buoys can be broadly classified as moored platforms, which are tethered to a fixed location on the seafloor and can move within a limited area around it in response to waves, wind, and currents, and drifting platforms, which are not anchored to the seafloor and move with ocean currents across changing locations. Drifting wave buoys can provide observations across large and sparsely sampled ocean regions and have been used, for example, to estimate wind-driven ocean currents and to track the propagation and decay of swell across ocean basins (e.g., Oliveira et al., 2009; Rio & Hernandez, 2003; Young et al., 2026). In contrast, moored buoys repeatedly sample wave conditions at approximately the same location,

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allowing observations to be assembled into station-based time series with consistent spatial reference. Compared to drifting platforms, moored buoys are therefore better suited for characterizing local wave climate, extremes, and long-term variability where sufficiently long records are available (Gemmrich et al., 2011; Jamous & Marsooli, 2023; Morim et al., 2023; Ruggiero et al., 2010; Timmermans et al., 2020). Using these records consistently, however, depends not only on platform characteristics, record length, and quality, but also on how effectively wave observations are stored, documented, quality controlled and made accessible.

Wave buoy observations are collected, coordinated, archived, and distributed through international programs, national agencies, regional observing systems, research institutions, and operational forecasting centers. These organizations support complementary functions, including observing system coordination, operational data exchange, aggregation of observations across networks and platform types, and maintenance of historical archives. At the international level, the World Meteorological Organization (WMO)-Intergovernmental Oceanographic Commission (IOC) Data Buoy Cooperation Panel coordinates drifting- and moored-buoy activities, while WMO-IOC OceanOPS monitors observing-network status and supports standardized platform metadata exchange (Belbéoch et al., 2021; World Meteorological Organization, 2025). These initiatives primarily facilitate observing system coordination and operational data exchange rather than the assembly of complete historical wave records into access-ready station archives. Services such as the Copernicus Marine Service (CMEMS), which provides near-global coverage, and the European Marine Observation and Data Network Physics (EMODnet), which focuses primarily on European waters, aggregate in situ ocean observations from multiple networks and platform types, including wave measurements from moorings, drifting buoys, and other fixed and mobile platforms (de Alfonso et al., 2024; Le Traon et al., 2019; Novellino et al., 2014). These services provide valuable access to observations from many contributing networks, but their distributed datasets are not necessarily direct reproductions of the original provider archives. For example, the CMEMS delayed-mode wave product distributes hourly observations which may include values interpolated over short temporal gaps and applies a centralized quality control framework that can differ from the original provider interpretation. Within CMEMS, the same physical station may also be represented by multiple files or platform codes associated with different deployments, complicating reconstruction of station-based historical records. Another challenge is the uneven availability of wave parameters across records within the same database, which limits the number of stations suitable for regional and global analyses requiring multiple co-located parameters. During 2020-2023, for example, the number of platforms contributing wave height observations to the delayed-mode CMEMS product was approximately 1.3 times that for wave direction and 2.4 times that for wave spectra (de Alfonso et al., 2024). Original provider archives therefore remain important for preserving native temporal resolution, wave variable availability, quality control, and provenance.

Direct access to records from original providers often requires exploring a fragmented landscape of national and regional observing networks and can be time consuming. Historical wave records are maintained by agencies and organizations such as the National Oceanic and Atmospheric Administration National Data Buoy Center (NDBC) in the United States, the Nationwide Ocean Wave Information Network for Ports and Harbours (NOWPHAS) in Japan, and Puertos del Estado (PdE) in Spain (National Data Buoy Center, n.d.; Ministry of Land, Infrastructure, Transport and Tourism, n.d.; Puertos del Estado,

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n.d.). Although these networks provide valuable long-term observations, their archives do not share a common data structure. Records from different providers differ in file formats, temporal resolution, variable definitions and nomenclature, units, missing-value conventions, metadata structure, and quality control procedures. In some cases, the same wave parameter may represent different physical definitions or processing methods across networks, while variable availability can vary across stations within the same provider. For example, a mean wave period represents the spectral mean period T_{m02} in standard NDBC records, whereas NOWPHAS defines its mean period from zero-upcrossing waves. Within PdE, buoys are separated between the coastal REDCOS network and the offshore deep-water REDEXT network, but only REDCOS records provide a zero-crossing mean period in addition to T_{m02}. These inconsistencies limit the combined use of records from multiple networks and require substantial provider-specific interpretation and preprocessing before consistent cross-network analyses can be performed.

Despite substantial coordination and data distribution efforts, differences across wave data providers remain a barrier to consistently assembling and using historical, station-based wave records. A unified, multi-provider archive designed specifically for historical observations from moored buoys and organized around station-based records is still missing. Such a resource requires not only aggregation of observations, but also harmonization of wave parameter definitions and explicit documentation of variable availability and provenance. The Free Ocean Wave Dataset provides an important precedent for the standardized processing and dissemination of buoy observations (Häfner et al., 2021). However, its published implementation is derived solely from the U.S. Coastal Data Information Program archive and was developed primarily for data mining and machine learning applications. A complementary precedent is provided by the Global Extreme Sea Level Analysis (GESLA) dataset, which assembles high-frequency sea level observations from tide gauge records across multiple providers into a standardized global archive (Haigh et al., 2026; Haigh et al., 2023). Building on the multi-provider, station-based framework established by GESLA, an analogous approach can be applied to historical wave observations from moored buoys, while adapting it to the challenges associated with wave observations. This framework would enable more consistent use of historical moored buoy records across networks, improve access to long-term wave observations at fixed locations, and support the evaluation and validation of numerical and satellite-derived wave products.

Here, we present GLOBES, the Global Library of Observations from Buoys for Evaluating Sea States, a multi-provider dataset of historical wave observations from moored buoys integrated within a common, standardized structure to support consistent use across networks and applications. GLOBES covers 1,665 buoy records contributed by 27 regional, national, and international providers, with available observations distributed across 41 countries and spanning the period 1969-2026. The dataset contains seven standard wave parameters describing wave height, period, direction, and directional spread, together with station metadata and quality control information. GLOBES is openly accessible, with provider-specific usage and licensing conditions documented alongside the dataset, and is designed in accordance with Findable, Accessible, Interoperable, and Reusable (FAIR) data principles (Wilkinson et al., 2016), facilitating reuse across oceanographic, coastal, climate, remote-sensing, engineering, and machine-learning applications. The dataset is intended to support wave climate characterization and extreme value analysis, as well as the evaluation of numerical models, hindcasts and

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reanalyses, and satellite-derived wave products, with applications to coastal hazard assessment, engineering design, and maritime operations.

This paper describes the development of GLOBES, including the data sources, processing and harmonization procedures, spatial and temporal coverage, licensing, and FAIR data principles (Sect. 2). We then describe the different pathways through which GLOBES data can be accessed (Sect. 3) and the code available to support its use (Sect. 4). Finally, we summarize the main contributions and limitations of GLOBES and discuss opportunities for future development (Sect. 5).

2 Data description and development

In this section, we describe the data sources and spatial and temporal characteristics of the GLOBES records (Sect.2.1), the mapping and harmonization of wave variables (Sect. 2.2), temporal processing and the treatment of duplicate and overlapping timestamps (Sect. 2.3), quality control harmonization (Sect. 2.4), metadata and standardized file structure (Sect. 2.5), data licensing and conditions of use (Sect. 2.6), and the data principles adopted to support FAIR use of the dataset (Sect. 2.7).

2.1 Data sources

The first version of GLOBES, provided here, comprises historical observations from 1,665 moored wave buoy records from 27 international, national, and regional data providers across 41 unique countries, with the earliest records dating back to 1969 and the most recent extending to 2026. Table 1 summarizes the contributing providers, including their full names and abbreviations, data access methods, applicable licenses or terms, and websites. The provider abbreviations are used throughout this article when referring to specific data providers. To identify available wave observations, we first used OpenAI ChatGPT as a discovery aid to compile an initial inventory of potential data providers. The AI-assisted search was used only to identify candidate sources. All candidate providers, observing platforms, data access options, and associated documentation were manually reviewed before determining eligibility for GLOBES. Records were considered eligible when: i) wave observations were obtained from moored wave buoys, with a few exceptions for other fixed-location wave measuring instruments, while data from drifting buoys, satellite altimetry, hindcasts, and reanalyses were excluded; ii) historical observations were available through publicly accessible web portals, APIs, or other data services, or could be obtained directly from the data provider upon request; iii) the record contained at least one measured wave parameter relevant to GLOBES (e.g., height, period, direction); and iv) sufficient information was available to verify the observing platform type, station identity, and data provenance. Although GLOBES primarily focuses on moored wave buoys, an exception was made for NOWPHAS in Japan, where approximately 80% of the historical records originate from bottom-mounted sensors and fixed wave gauges, to preserve the extensive spatial and temporal coverage of this observing network. No minimum record length or completeness thresholds were imposed. As part of this review, we also assessed the applicable data access conditions, license or terms of use, and whether the observations could be obtained and redistributed through GLOBES under documented provider conditions. Only

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datasets for which an appropriate access route and documented basis for inclusion in the archive were retained. We acquired and processed eligible datasets using a common workflow, with provider-specific adaptations where needed to accommodate differences in data access, file formats, variable definitions, metadata, and quality control information.

For each eligible provider, we first compiled a station-level inventory of current and historical moored wave buoy records and associated metadata. Provider documentation and the available source files for retrieving wave observations were then reviewed to identify wave parameters compatible with the seven standardized GLOBES variables described in Sect. 2.2. Where more than one compatible source variable was available for a given parameter, such as spectral- and time-domain estimates of significant wave height, we defined a preferred variable and a fallback variable before processing, with the latter used when the preferred variable was unavailable. Provider quality control procedures, flags, missing-value conventions, time standard, units, and relevant station metadata were also reviewed before obtaining wave observations.

Data were subsequently acquired using one of four main approaches, depending on the provider, namely: (1) direct download from a web portal, (2) automated retrieval through an API or web-service access, (3) direct retrieval from an online archive, or (4) direct data request. Direct download from a web portal refers to datasets obtained through an interactive provider website or download interface. API/web-service access refers to observations retrieved through machine-readable query services such as APIs, ERDDAP, WFS, or similar services. Direct retrieval from an online archive refers to files obtained from structured online repositories, such as HTTP/HTTPS, FTP, or object-storage repositories, without use of an interactive download interface or query service. Direct data request refers to observations supplied, or made available for download, by the provider following a formal request. Providers for which observations were obtained through more than one of these mechanisms are identified as having mixed sources. Of the 27 contributing providers, 9 were accessed through web portals, 8 through APIs or web services, 4 through online archives, 3 through direct data requests, and 3 through mixed sources, the latter comprising BSH, RWS, and KDI (Table 1). BSH observations were obtained through a combination of direct downloads from web portals and direct retrieval from online archives, using the INSITU, SEASTATE, and PINTA source products. RWS observations were obtained through API/web-service access and direct retrieval from online archives, primarily through Waterinfo/WaterWebservices and Waterinfo Extra–Kustgenese 2.0 (KG2). KDI observations were obtained through API/web-service access and direct retrieval from online archives, combining records from the historical wave data archive, the operational web service, and the Rigsarkivet Aflevering 595 historical database.

Although the source datasets differ substantially in file format, temporal resolution, variable nomenclature, units, quality control information, and missing-value conventions, all providers were processed within a common GLOBES workflow, with provider-specific adaptations where necessary. Preprocessing scripts first read the original files, which were retained unchanged, and transformed the relevant information into annual station-level files containing the standardized GLOBES wave variables, timestamps, and quality control fields. In these preprocessing scripts, we harmonized provider-specific observations by converting them to common GLOBES conventions, including mapping provider wave observations to standardized GLOBES variables and units, UTC timestamps, documented missing-value treatment, and translation of provider quality control information into GLOBES flags. The resulting annual files were then processed using methods adapted

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from GESLA, building on experience gained from compiling successive versions across 17 years (Haigh et al., 2026; Haigh et al., 2023; Woodworth et al., 2016). For each station, observations from individual years were combined, ordered chronologically, and checked for duplicate and overlapping timestamps before construction of the final standardized station files and associated metadata and quality control fields. Provider-specific exceptions identified during processing were evaluated individually rather than resolved using general assumptions. The procedures for wave-parameter harmonization, temporal processing, quality control, and metadata and standardized file construction are described in Sects 2.2–2.5, together with the relevant provider-specific procedures.

Table 1. Information on GLOBES data providers, data access methods, applicable licenses or terms, and website.

Provider information				Data access and licensing		
ID	**Provider Acronym**	**Provider Full Name**	**Country**	**Data Access Method**	**License/Terms***	**Website**
1	CCO	Channel Coastal Observatory	United Kingdom	Direct download from web portal	CCO Open Government License (custom)	https://coastalmonitoring.org/realtimedata/
2	CEFAS	Centre for Environment, Fisheries and Aquaculture Science WaveNet	United Kingdom	Direct download from web portal	Open Government License v3.0, CC BY 4.0, or Cefas WaveNet License v1.0 (station-specific)	https://wavenet.cefas.co.uk/
3	NDBC	NOAA National Data Buoy Center	United States	Direct retrieval from online archive	CC0 1.0 (U.S. federal public domain); originator-specific terms apply to some records	https://www.ndbc.noaa.gov/
4	SiMCosta	Sistema de Monitoramento da Costa Brasileira	Brazil	Direct download from web portal	No explicit license identified	https://www.simcosta.furg.br/home
5	MVB	Meetnet Vlaamse Banken	Belgium	API/web service	Provider open-data terms	https://meetnetvlaamsebanken.be/
6	CANDHIS	Centre d'Archivage National de Données de Houle In Situ	France	Direct download from web portal	Etalab Open License 2.0	https://candhis.cerema.fr/
7	ISPRA	Italian Institute for Environmental Protection and Research	Italy	Direct download from web portal	CC BY 4.0	https://www.mareografico.it/en/interactive-map.html
8	NOWPHAS	Nationwide Ocean Wave Information Network for Ports and Harbours	Japan	Direct download from web portal	Government of Japan Standard Terms of Use 2.0 (CC BY 4.0-compatible)	https://nowphas.mlit.go.jp/pastdata/?lng=eng
9	POSEIDON	POSEIDON Monitoring, Forecasting and Information System for the Greek Seas	Greece	API/web service	Direct provider permission	https://poseidon.hcmr.gr/
10	CENDHOC	Centro Nacional de Datos Hidrográficos y Oceanográfico, Servicio Hidrográfico y Oceanográfico de la Armada de Chile	Chile	Direct data request	Direct provider permission	https://www.shoa.cl/php/boyas?idioma=es

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11	SADCO	Southern African Data Centre for Oceanography	South Africa	Direct download from web portal	No explicit license identified	https://sadco.ocean.gov.za/
12	IRCA	Icelandic Road and Coastal Administration (Vegagerðin)	Iceland	Direct data request	Direct provider permission	https://www.vegagerdin.is/
13	IMDBON	Irish Marine Data Buoy Observation Network	Ireland	API/web service	CC BY 4.0	https://www.marine.ie/site-area/data-services/real-time-observations/irish-marine-data-buoy-observation-network
14	IWBN	Irish Wave Buoy Network	Ireland	API/web service	CC BY 4.0	https://www.marine.ie/site-area/infrastructure-facilities/marine-research-infrastructures/wave-buoy-network
15	FMI	Finnish Meteorological Institute	Finland	API/web service	CC BY 4.0	https://en.ilmatieteenlaitos.fi/open-data
16	MEDS	Fisheries and Oceans Canada – Marine Environmental Data Section	Canada	Direct retrieval from online archive	Open Government License – Canada v2.0	https://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/waves-vagues/index-eng.htm
17	KMA	Korea Meteorological Administration	South Korea	Direct download from web portal	Korea Open Government License (KOGL) Type 1	https://data.kma.go.kr/
18	PdE	Puertos del Estado	Spain	Direct data request	Direct provider permission	https://portus.puertos.es/
19	BSH	Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie)	Germany	Mixed sources	Source-specific terms (PINTA, INSITU, SEASTATE)	https://www.bsh.de/EN/DATA/Climate-and-Sea/Sea_state/sea_state_node.html
20	SMHI	Swedish Meteorological and Hydrological Institute	Sweden	API/web service	CC BY 4.0	https://www.smhi.se/en/weather/sea-weather/sea-levels-and-waves
21	RWS	Rijkswaterstaat, Ministry of Infrastructure and Water Management	Netherlands	Mixed sources	CC0 1.0 Universal	https://rijkswaterstaatdata.nl/waterdata/
22	METNOR	Norwegian Meteorological Institute	Norway	API/web service	Norwegian License for Open Government Data (NLOD) 2.0 and CC BY 4.0	https://ocean.met.no/
23	EuskOOS	Basque Coast Operational Oceanography System	Spain (Basque Country)	API/web service	Provider-specific terms	https://euskoos.eus/mapv2/
24	AODN	Australian Ocean Data Network	Australia	Direct retrieval from online archive	CC BY 4.0	https://portal.aodn.org.au/
25	KDI	Kystdirektoratet (Danish Coastal Authority)	Denmark	Mixed sources	Direct provider permission	https://mst.dk/erhverv/kyster-og-klimatilpasning/hav-og-anlaeg/maalinger-og-data/boelgemaalinger/arkiv
26	CWA	Central Weather Administration	Taiwan	Direct download from web portal	Taiwan Open Government Data License 1.0	https://ocean.cwa.gov.tw/
27	MATARA	Wind and wave dataset for Matara, Sri Lanka (Luo et al., 2017)	Sri Lanka	Direct retrieval from online archive	CC BY 4.0	Science Data Bank, DOI 10.11922/sciencedb.447
*Attribution requirements and record-specific conditions are given in the 'USAGE' metadata field of each record file.						

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GLOBES includes 1,665 wave records distributed across 41 countries (Fig.1). Coverage spans the major ocean basins, although station density is strongly heterogeneous, with the largest concentrations of observations occurring in the Northern Hemisphere, especially in North America, Europe, and Japan, as well as in Australia in the Southern Hemisphere. Across latitudes, wave records are concentrated in the northern mid-latitudes, between approximately 30 and 60° N (Fig. 1b), while across longitudes, records are more widely distributed, reflecting the major regional clusters of observing networks (Fig. 1c). Coverage is sparse along much of the South American and African coastlines, across parts of South and Southeast Asia, and across large portions of the tropical and Southern Hemisphere oceans. This spatial heterogeneity reflects differences in the geographical distribution and availability of historical buoy observations among regional and national observing programs.

The contribution of individual data providers to GLOBES varies in both the number and temporal extent of available buoy records (Table 2). Together, GLOBES records represent 19,467 station-years containing wave observations. Individual records contain between 1 and 56 years of observations, reflecting differences in the temporal extent of records available from the contributing observing programs. The overall temporal characteristics of the GLOBES dataset are summarized in Figure 2. Most records contain fewer than 20 years of observations (1,307 records; 78.5%), while 358 records (21.5%) extend for 20 years or more (Figs. 2a-b). Records also differ substantially in when observations began, with 67.5% of the records starting in 2000 or later, and 32.5% beginning before 2000 (Fig. 2c). The geographic distributions of record length and start year are shown in Figures 3 and 4, respectively, revealing that the availability of long-duration and early-starting records is spatially uneven. Long-duration records (i.e., >40 years) are concentrated in Japan, the United States, Australia, and the Netherlands, whereas shorter records are more widely distributed across the global network. Records beginning before 1980 are concentrated in North America, with additional early records in Japan, Australia, and parts of Europe. The longest records occur in Japan, where the Rumoi Port, Tomakomai Port, and Kanazawa Port buoys, all from NOWPHAS, each contain 56 years of observations spanning 1969-2024, followed by Hachinohe Port with 54 years spanning 1970–2024 and Port Kembla, Australia, from AODN with 53 years spanning 1974–2026. Of the 17 records containing 50 years or more of observations, 11 are in Japan, 3 in the United States, and 3 in Australia.

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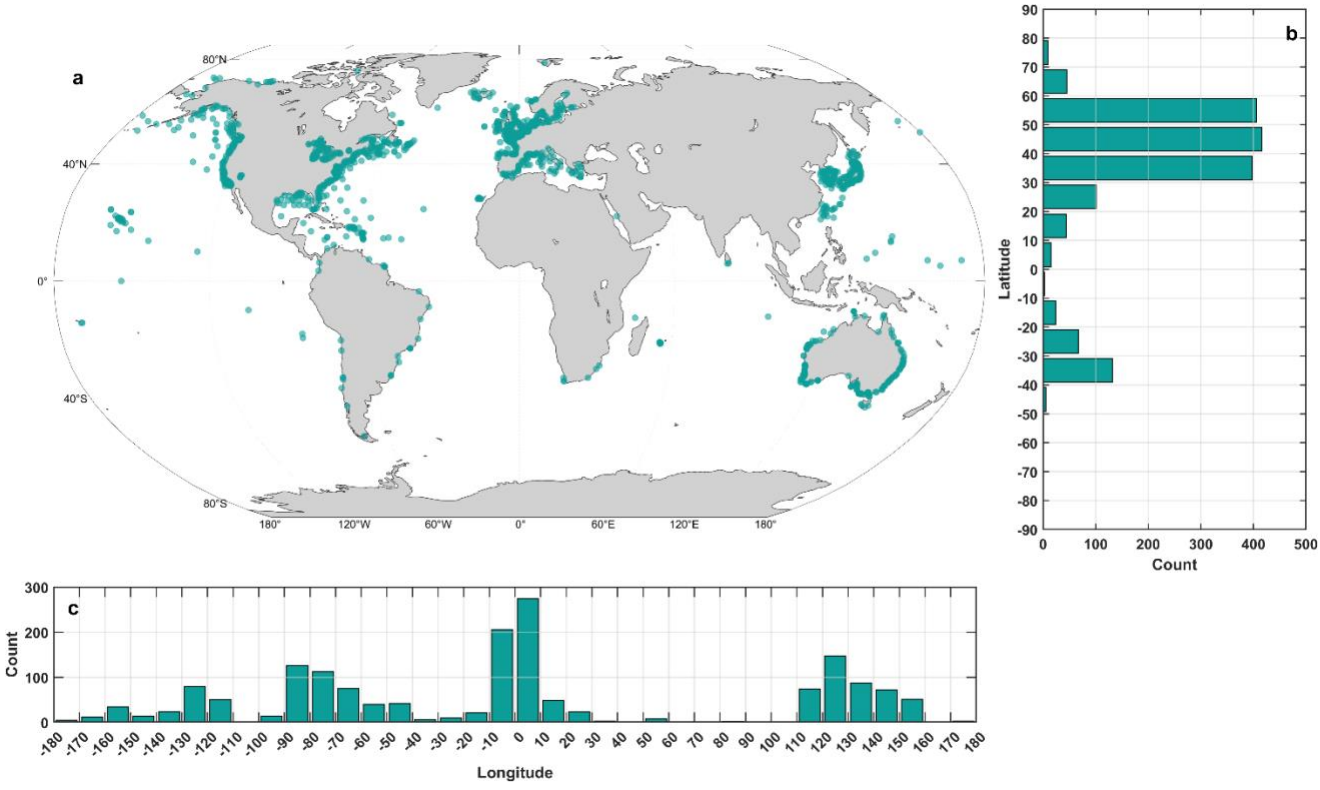


Figure 1. Locations of the moored wave buoys in GLOBES, with histograms of record count by (b) latitude and (c) longitude.

Table 2. Summary of GLOBES buoy records, station years, record-length distribution, and temporal and geographical coverage by data provider.

ID	Provider	Records	Station-years	Records by length (years)							Temporal coverage		Countries
				<5	5–10	10–20	20–30	30–40	40–50	50–60	First year	Last year	
1	CCO	42	748	3	0	23	15	1	0	0	1996	2026	1
2	CEFAS	97	617	57	20	14	6	0	0	0	1975	2026	3
3	NDBC	460	5887	181	58	115	48	22	33	3	1974	2025	16
4	SiMCosta	13	62	7	5	1	0	0	0	0	2013	2026	1
5	MVB	16	359	0	2	6	0	8	0	0	1990	2026	1
6	CANDHIS	124	922	60	29	22	13	0	0	0	1985	2026	4
7	ISPRA	16	300	1	2	5	7	1	0	0	1989	2024	1
8	NOWPHAS*	97	2653	2	6	28	25	11	14	11	1969	2024	1
9	POSEIDON	12	139	1	4	6	1	0	0	0	2000	2026	1
10	CENDHOC	8	49	5	1	2	0	0	0	0	2000	2025	1
11	SADCO	6	76	0	3	2	1	0	0	0	1976	1999	1
12	IRCA	13	295	0	2	2	5	4	0	0	1994	2025	1
13	IMDBON	9	134	1	3	0	5	0	0	0	2001	2026	1
14	IWBN	12	81	6	3	3	0	0	0	0	2006	2026	1
15	FMI	8	94	3	0	3	2	0	0	0	2004	2026	1
16	MEDS	145	1014	115	3	2	8	17	0	0	1970	2025	3
17	KMA	124	1248	23	35	61	3	2	0	0	1996	2025	2

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18	PdE	54	1198	4	5	9	23	11	2	0	1981	2026	2
19	BSH	32	332	14	5	7	3	3	0	0	1986	2026	1
20	SMHI	28	174	17	4	4	3	0	0	0	1980	2026	3
21	RWS	117	1330	51	18	28	9	4	7	0	1976	2026	1
22	METNOR	12	65	6	6	0	0	0	0	0	2016	2024	1
23	EuskOOS	5	34	2	1	2	0	0	0	0	2016	2026	1
24	AODN	190	1280	127	33	11	8	5	3	3	1974	2026	1
25	KDI	8	122	3	0	2	0	3	0	0	1988	2026	2
26	CWA	15	250	0	3	7	5	0	0	0	1999	2026	3
27	MATARA	2	4	2	0	0	0	0	0	0	2013	2014	1

*NOWPHAS records and station-years are counted for the 2-h time series only; 80 stations also have 20-min series.

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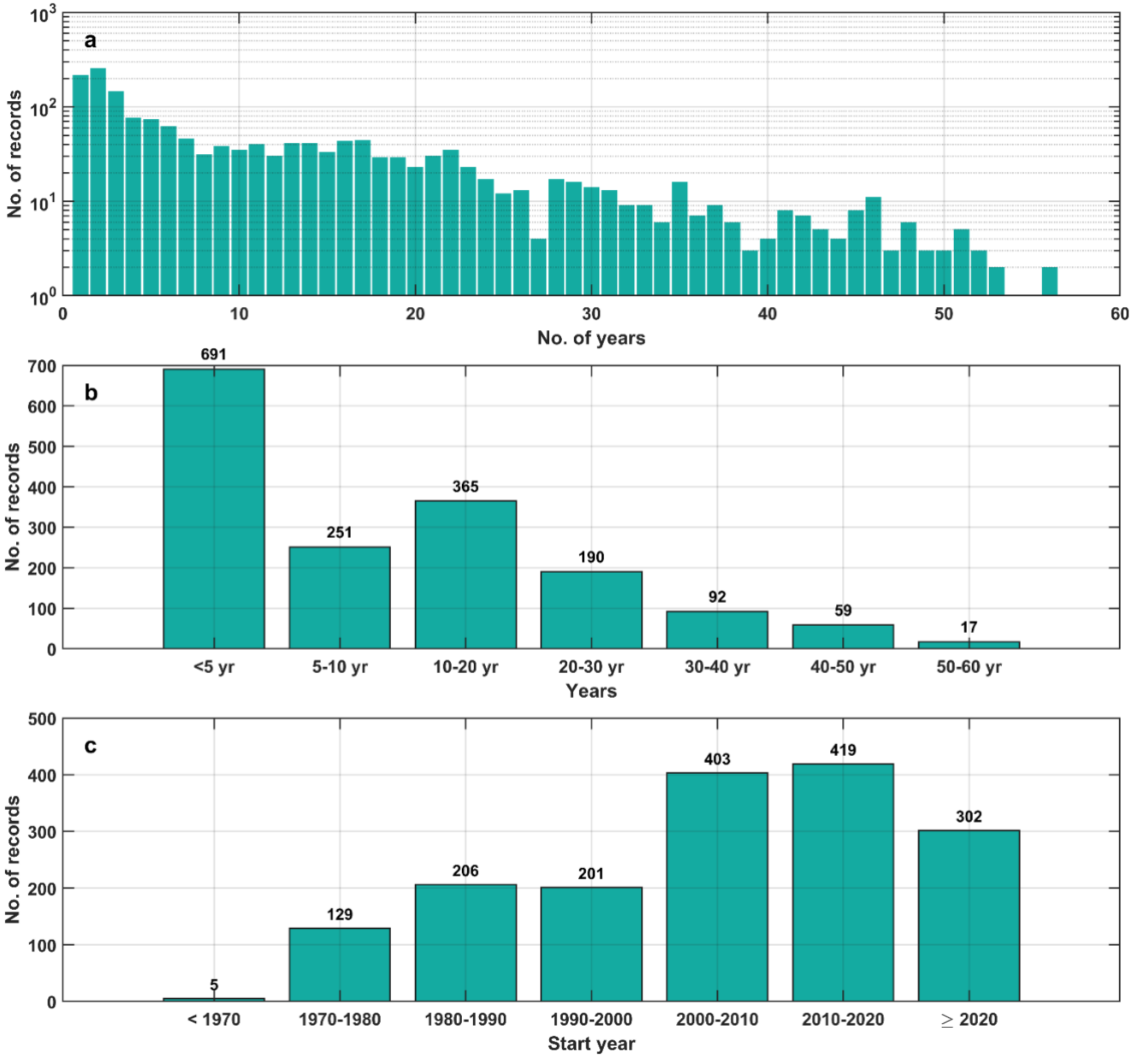


Figure 2. Distribution of buoy records by (a) the number of years of available data, shown on a logarithmic scale, (b) record length, and (c) record start year.

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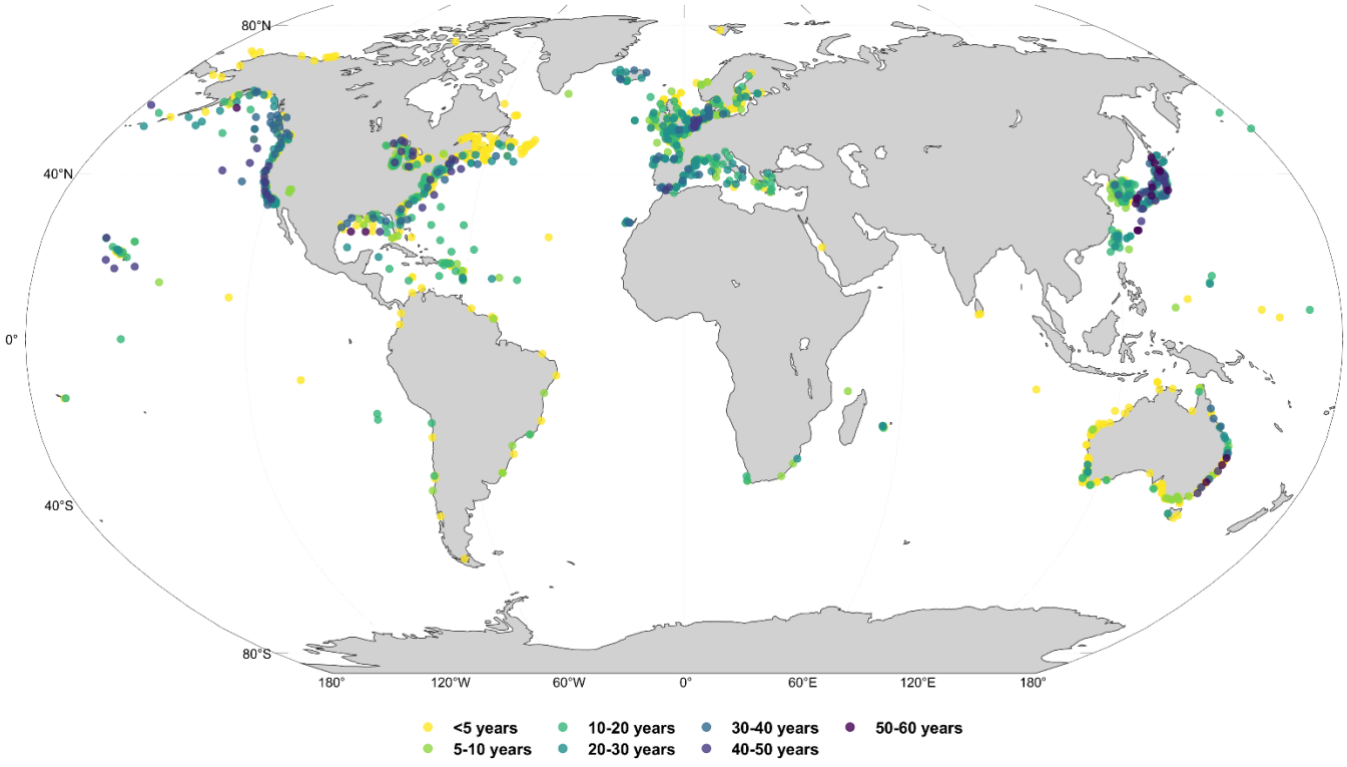


Figure 3. Global distribution of buoy records according to record length. Records are grouped into seven categories, <5 years, 5–10 years, 10–20 years, 20–30 years, 30–40 years, 40–50 years, and 50–60 years, with colors progressing from yellow to dark blue with increasing record length.

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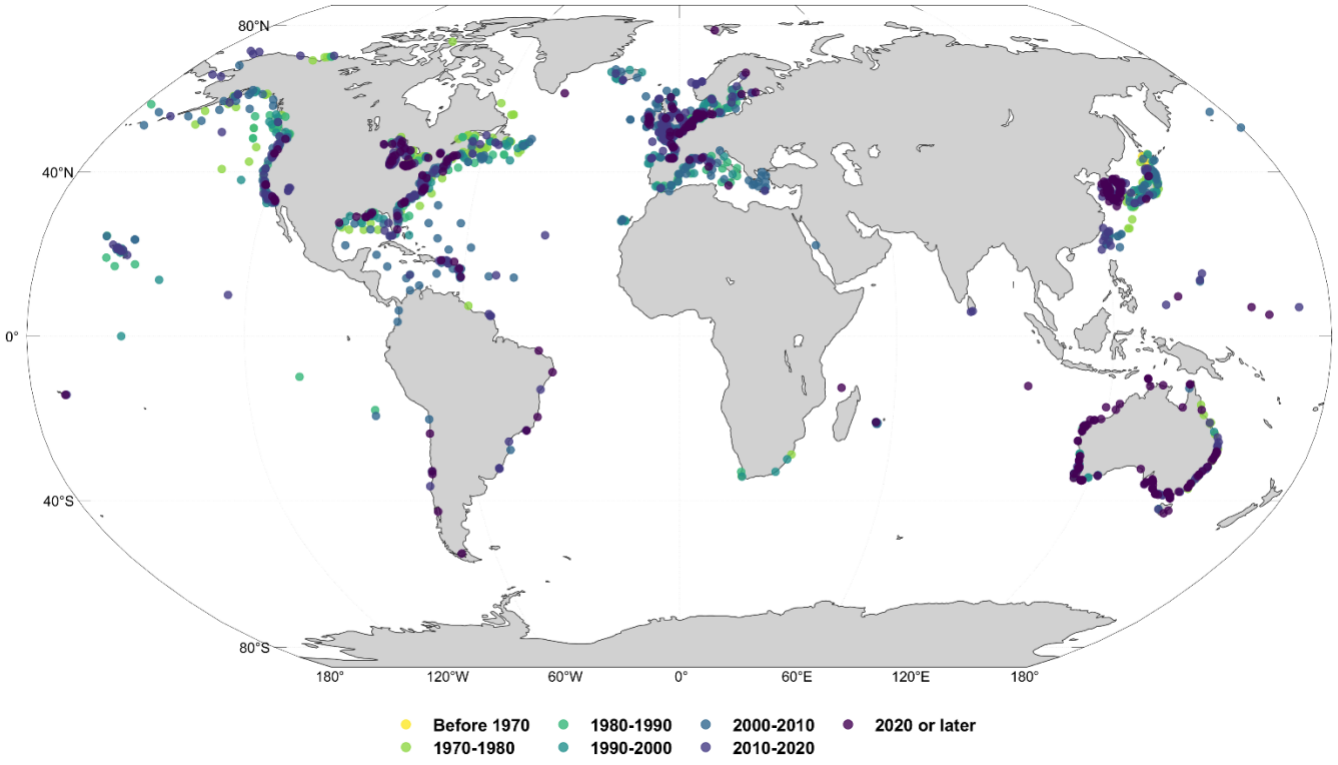


Figure 4. Global distribution of buoy records according to record start year. Records are grouped into seven categories, before 1970, 1970–1980, 1980–1990, 1990–2000, 2000–2010, 2010–2020, and 2020 or later, with colors progressing from yellow to dark blue with increasingly recent record start years.

2.2 Variable mapping and harmonization

GLOBES wave records include seven standardized wave variables: significant wave height (H_S), maximum wave height (H_M), peak wave period (T_P), zero-crossing wave period (T_Z), mean wave period (T_M), wave direction (D_R), and directional spread (S_P). All observations are also assigned a standardized timestamp (TS) in Coordinated Universal Time (UTC). Because providers may define and report these wave quantities differently, harmonization was based on the physical meaning of each source parameter rather than variable name or acronym alone. Variables mapped to the same standardized GLOBES field thus do not necessarily represent identical physical definitions or estimation methods. Provider-specific mappings, including any primary and fallback variables, are documented in Supplementary Table S1. Parameters were converted to common units of meters for H_S and H_M, seconds for T_P, T_Z, and T_M, and degrees for D_R and S_P. Where a standardized GLOBES variable was unavailable from a provider, or where a source value could not be mapped unambiguously to one of the seven variables, the corresponding field was assigned the GLOBES null value of −99.9999.

H_S is generally reported by providers as either a time-domain estimate, commonly expressed as $H_{1/3}$, or a spectral estimate, H_{m0}. Some providers use H_S as a generic variable name for significant wave height, with the underlying definition determined from the accompanying documentation. $H_{1/3}$ corresponds to the mean height of the highest one-third of individual

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waves identified from a wave record, while H_{m0} is calculated from the zeroth spectral moment, m_0, obtained by integrating the wave energy spectrum over frequency, typically as $H_{m0} = 4\sqrt{m_0}$\. For GLOBES, both were treated as compatible representations of significant wave height for harmonization purposes and were therefore mapped to the common H_S field. No conversion between $H_{1/3}$ and H_{m0} was applied. Where both estimates were available, H_{m0} was generally selected as the primary variable because spectral significant wave height was the more commonly available across the contributing providers. The time-domain estimate was retained as a fallback where appropriate. The other wave height variable retained by GLOBES is the maximum wave height (H_M), which represents the maximum individual wave height reported within the measurement record or sampling interval. When available, it was mapped only from provider variables explicitly defined as maximum wave height, including values derived from zero-crossing or other time-domain wave analyses.

GLOBES includes three wave period variables: T_P, T_Z, and T_M. T_P represents the peak or dominant spectral wave period, corresponding to the period associated with the frequency at which the wave spectrum reaches its maximum spectral density. T_Z represents a mean wave period derived from individual waves using zero-crossing analysis. Where providers distinguish between upward and downward zero crossings, the original definition was retained and is reported in Supplementary Table S1. T_M represents a broader mean wave period category distinct from T_Z. In most contributing datasets, T_M corresponds to the spectral mean period T_{m02}, calculated from the zeroth and second spectral moments as $T_{m02} = \sqrt{m_0/m_2}$\, where m_0 is the zeroth spectral moment representing the total variance of sea surface elevation spectrum, and m_2 is the second spectral moment, which weights the spectrum by the square of frequency. Other documented mean period definitions, including T_{m01} and other provider-specific mean-period estimates, were also retained under T_M because providers do not consistently report the same mean-period estimator, whereas T_Z was restricted to quantities explicitly derived from zero-crossing analysis. T_M should therefore be interpreted as a harmonized category of documented mean wave period estimates rather than as a single, universally defined wave period metric. This distinction is important because labels such as mean period, average period, T_Z, and T_{m02} are not used consistently across providers. For example, NDBC standard buoy records report a spectral mean period, which is mapped to T_M, whereas NOWPHAS reports a mean period derived from zero-upcrossing waves and is therefore mapped to T_Z.

The directional variables included in GLOBES are wave direction (D_R) and directional spread (S_P). D_R represents the provider's documented representative wave direction, which may correspond to the direction at the spectral peak or a mean wave direction, depending on the source provider. D_R is generally reported as the direction from which waves propagate and is referenced to true geographic north, increasing clockwise. Because providers may use different directional conventions, and this information is unavailable for some data sources, we retain provider-reported directions as supplied rather than converting them to a common angular convention. The documented angular reference and propagation convention, where available, are reported in Supplementary Table S1. S_P represents the directional spread, a measure of how broadly wave energy is distributed around the representative wave direction, generally at the spectral peak, although mean or spectrum-averaged spread estimates

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were also retained where appropriate (Table S1). Where more than one compatible directional quantity was available, a primary variable was predefined, and a fallback was used only when the primary value was unavailable.

Availability of the seven GLOBES variables varies across providers and individual wave buoy records (Fig.5), with their geographic distribution shown in the Supplementary Fig. S1. H_S is present in almost all buoy records, occurring in 1,664 of 1,665 buoy records (99.9%) and in all 27 contributing providers. After H_S, T_P and D_R are the next most widely available variables, occurring in 79.3% and 66.8% of buoy records, respectively, and in 85.2% and 88.9% of providers. T_M and H_M occur in 58.4% and 47.6% of buoy records, respectively, and in 66.7% and 74.1% of providers. T_Z and S_P are the least commonly reported variables, occurring in 32.1% and 30.7% of buoy records, respectively, and in 63% and 59.3% of providers. Provider-level availability is higher than that of buoy-record availability for every variable, reflecting differences in parameter availability across records within individual provider networks. The geographic distribution also reveals spatial clustering in variable availability. While H_S and T_P are widely available across different regions, T_Z and S_P are generally only available in South America, parts of Europe, Australia, South Africa, and Japan (Fig. S1), likely reflecting differences in buoy instrumentation and the wave parameters reported by individual provider networks.

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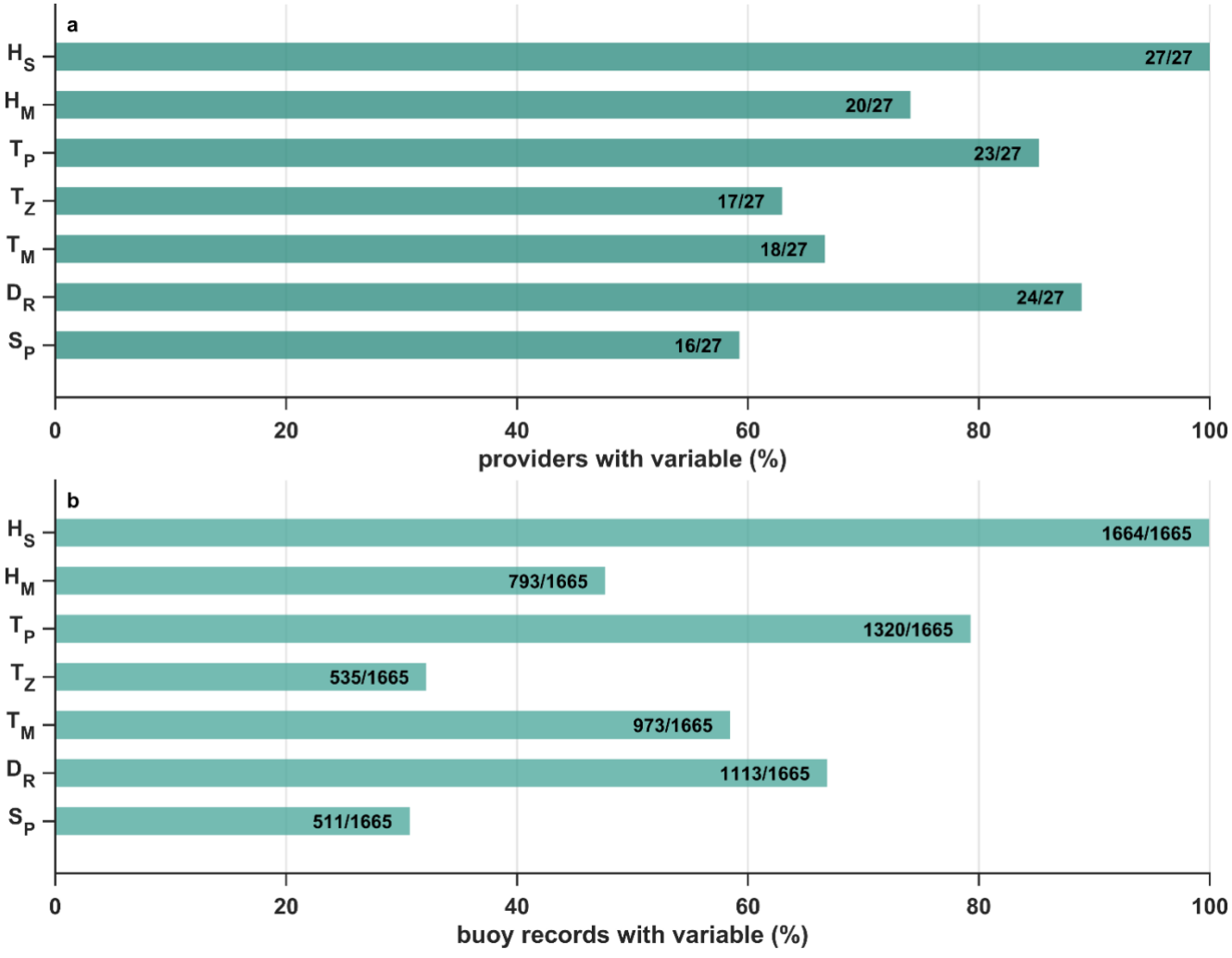


Figure 5. Availability of the seven standardized GLOBES wave variables, significant wave height (H_S), maximum wave height (H_M), peak wave period (T_P), zero-crossing wave period (T_Z), mean wave period (T_M), wave direction (D_R), and directional spread (S_P). Availability is shown for (a) data providers in which at least one buoy record contains the indicated variable and (b) buoy records containing at least one valid observation of the indicated variable. Bars show the percentage of providers or buoy records containing each variable, with the corresponding counts indicated on the bars.

2.3 Temporal processing

Wave buoy records obtained from the 27 contributing providers differed in timestamp conventions and temporal resolution. To ensure consistency across records, all observations in GLOBES were standardized to Coordinated Universal Time (UTC) while preserving the temporal resolution of the original source data. Where provider timestamps were reported in local or fixed-offset time, they were converted to UTC before further processing. This included, for example, NOWPHAS

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and KMA observations reported in Japan Standard Time and Korea Standard Time (UTC+9), respectively, KDI records reported at a fixed UTC+1 offset, and CWA observations reported in local standard time (UTC+8). While the temporal resolution of the original wave buoy records varies from 10 min to 3 h, GLOBES preserves the native temporal resolution of each distributed time series without interpolation or resampling to a common interval, thereby retaining the maximum temporal information available and avoiding assumptions introduced by temporal aggregation. For all providers except NOWPHAS, the source records were distributed at a single temporal resolution. NOWPHAS is the only provider for which two standard temporal products were available, comprising 20-min continuous observations and 2-h historical observations, both of which were retained. The 2-h resolution datasets contribute 97 individual records to the 1,665-record GLOBES inventory, while an additional 80 corresponding records are also provided at 20-min resolution. When the 20-min resolution NOWPHAS records are counted separately from the 2-h records, the distributed GLOBES archive contains 1,745 time series.

After conversion to UTC, observations were ordered chronologically and evaluated for duplicate or overlapping timestamps within each buoy record. Here, duplicate timestamps refer to two or more observations associated with the same nominal timestamp, rather than duplicate buoy records, and they were not removed using a single universal rule. Instead, duplicate timestamps were assessed using provider quality control information, instrument or deployment history, source-product characteristics, and temporal continuity. When multiple entries at the same timestamp represented the same source measurement and contained identical values, they were reduced to a single entry. Where overlapping observations associated with the same station name or identifier represented distinct deployments, spatial positions, or data streams and therefore contained independent observational values, they were retained as separate GLOBES buoy records rather than merged. These records were distinguished using chronological alphabetical suffixes (e.g., a, b, c), with the earliest record assigned “a”, the next “b”, and so forth. When multiple versions of the same observation were encountered within or across source files associated with the same station or identifier, precedence was assigned only where supported by documented processing level, quality control status, or product hierarchy, defined here as a provider-documented priority among different versions or processing streams of the same observation. For example, for AODN, delayed-mode observations were preferred over real-time observations at identical timestamps. Where duplicate conflicting values could not be resolved objectively, the affected wave variable(s) were assigned the GLOBES null value rather than selecting, averaging, interpolating, or otherwise modifying the conflicting observations.

2.4 Quality control harmonization

Quality control procedures and the availability of associated flags vary substantially among providers. Some providers perform documented quality control procedures but do not distribute per-observation quality control flags. For example, Taiwan’s CWA and the U.S. NDBC apply automated and manual quality control procedures to screen observations before public release, but neither provides quality control flags in their publicly available files. Other providers supply quality control flags for each wave variable at a given timestamp, while others provide a single flag representing the quality status of all wave variables at that timestamp. For example, Ireland’s IWBN provides separate quality control flags for individual wave variables

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within the same timestamp, while IMDBON, also from Ireland, provides a single quality control flag applicable to all wave variables at each timestamp. Providers also differ in the meaning and coding of their native flags, including distinctions among data qualifiers, such as good, provisional, questionable, interpolated, rejected, and missing observations.

To provide a consistent interpretation of quality control across providers, each GLOBES timestamp is assigned two standardized quality control flags, FL1 and FL2. These flags harmonize the quality control information supplied by the original providers and do not represent an independent set of quality control tests applied by GLOBES. FL1 is a timestamp-level quality control flag derived from the provider quality control information available for the wave variables present at that timestamp and comprises five quality control categories: unclassified (FL1 = 0), good (FL1 = 1), advisory (FL1 = 2), bad (FL1 = 3), and missing (FL1 = 9) (Table 3). Provider-specific quality control flags were mapped to the GLOBES categories according to their documented meaning rather than their numeric code. FL1 = 0 was assigned when providers performed quality control and released only observations that passed their screening procedures but did not distribute variable-specific or timestamp-wide quality control flags with their individual records. FL1 = 0 was also assigned when provider quality control procedures were undocumented (i.e., SADCO, South Africa) or when observations had not undergone quality control, as is the case for data collected after 2020 from some Chilean CENDHOC buoys, which were distributed as unprocessed near-real-time observations. FL1 = 1 was assigned when all wave variables at a given timestamp were classified as good or passed based on the available provider quality control flag, while FL1 = 2 was assigned when at least one wave variable retained at that timestamp had a provisional, questionable, interpolated, or otherwise advisory status, indicating that the affected variable was retained but may require caution depending on the intended application. Variables explicitly marked bad or rejected by the provider were assigned the GLOBES null value in the main record at that timestamp, while other usable wave variables were retained, with FL1 = 3 assigned only when no usable wave variables remained at that timestamp because all originally available variables were marked bad or rejected. For example, if H_S and D_R are classified as good but T_P is classified as bad by the provider at the same timestamp, the T_P value is replaced with -99.9999, H_S and D_R are retained, and FL1 = 1 is assigned because all remaining wave variables at that timestamp are classified as good. FL1 = 9 was assigned when all wave variables were originally missing at a given timestamp. Missing individual variables did not result in FL1 = 9 when at least one other wave variable remained available and usable. FL2 is a binary flag indicating whether a timestamp contains at least one wave variable that remains available for use after applying the provider quality control information (FL2 = 1), or whether all wave variables are missing or have been rejected (FL2 = 0). We assign FL2 = 1 when FL1 is 0, 1, or 2, and FL2 = 0 when FL1 is 3 or 9. Timestamps with an advisory status (FL1 = 2) are retained (FL2 = 1) because this classification indicates potential quality concerns or processing qualifications rather than necessarily invalid measurements. Excluding observations flagged as FL1 = 2 could discard useful information, while retaining their advisory status in FL1 allows users to apply stricter quality criteria depending on their application.

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Table 3. Standardized quality control flags used in GLOBES. FL1 represents the harmonized timestamp-level quality control status based on the available provider quality control information, while FL2 indicates whether at least one wave variable remains available after excluding values explicitly classified as bad or rejected by the original provider.

FL1 Value	Meaning	Definition	FL2 Value
0	Unclassified	All retained wave variables lack provider quality control classifications due to unavailable individual flags despite pre-release quality control, or undocumented quality control procedures, or unprocessed observations	1
1	Good	All retained wave variables were classified as good or passed based on the available provider quality control information	1
2	Advisory	At least one retained wave variable has a provisional, questionable, interpolated, or otherwise advisory quality control status	1
3	Bad	All originally available wave variables were marked bad or rejected by the provider	0
9	Missing	All wave variables were originally missing	0

2.5 Metadata and standardized file format

Following the approach of GESLA, GLOBES records are distributed as standardized ASCII text files, with one main file for each distributed time series. Each file contains a metadata header followed by the wave observations, with one row for each UTC timestamp. The observational component follows a fixed 11-column structure. The first two columns contain the UTC date and time, reported separately in yyyy/mm/dd and hh:mm:ss formats, respectively. These are followed by significant wave height (H_S), maximum wave height (H_M), peak wave period (T_P), zero-crossing wave period (T_Z), mean wave period (T_M), wave direction (D_R), directional spread (S_P), the harmonized quality control flag (FL1), and the binary analysis-use flag (FL2). Wave-height variables are reported in meters, wave-period variables in seconds, and directional variables in degrees,

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following the harmonization described in Sect. 2.2. The standardized structure is retained for all records regardless of which variables are available from the original provider, such that variables unavailable for a particular record remain represented by the common GLOBES null value. The fixed column structure allows records from different observing networks to be read and analyzed using the same processing workflow.

Each main file also contains standardized metadata describing the station, data provenance, temporal coverage, and characteristics of the record (Table 4). These metadata include the station name and code, country, contributor and originator information, geographic coordinates and coordinate system, record start and end times, record length, time-zone information, buoy depth, instrument and measurement precision where available, data-use and attribution requirements, and file creation date. Contributor information identifies the organization through which the observations were obtained, while originator information identifies the organization responsible for the acquisition of the original observations, which may differ from the contributor. This distinction preserves attribution and allows observations obtained through aggregating services or data centers to be traced to their original observing network. This approach was adapted from the station-level metadata structure used for GESLA (Haigh et al., 2026; Haigh et al., 2023; Woodworth et al., 2016), while extending it to accommodate multiple wave parameters.

Table 4. Standardized metadata contained in the header of each GLOBES wave buoy record file.

Metadata Field	Description
FORMAT VERSION	Version of the GLOBES standardized file format
SITE NAME	Standardized name of the buoy station
SITE CODE	Station identifier
COUNTRY	Three-letter ISO 3166-1 alpha-3 country code
CONTRIBUTOR	Organization or data service through which the observations were obtained
CONTRIBUTOR WEBSITE	Website of the contributor
CONTRIBUTOR CONTACT	Contributor contact information
ORIGINATOR	Organization responsible for the acquisition of the original observations
ORIGINATOR WEBSITE	Website of the originator
ORIGINATOR CONTACT	Originator contact information
LATITUDE	Nominal station latitude
LONGITUDE	Nominal station longitude
COORDINATE SYSTEM	Coordinate reference information
START DATE/TIME	First timestamp represented in the standardized record
END DATE/TIME	Last timestamp represented in the standardized record

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NUMBER OF YEARS	Number of distinct calendar years containing at least one non-null wave observation
TIME ZONE HOURS	Time-zone information associated with the record
BUOY DEPTH	Water depth at the buoy location, where available
INSTRUMENT	Wave-measurement instrument, where available
PRECISION	Measurement precision, where documented
NULL VALUE	Standardized value representing unavailable or invalid observations
USAGE	Data-use and attribution requirements associated with the record, based on the provider's applicable license or terms of use
CREATION DATE UTC	Date on which the standardized file was created
COLUMN DEFINITIONS	Names, units, and formats of the 11 standardized data columns
FL1/FL2 DEFINITIONS	Definitions of the standardized GLOBES quality control and use flags

Individual files follow a standardized naming convention combining the station name, station code, three-letter ISO 3166-1 alpha-3 country code, and provider acronym, separated by hyphens. Where observations associated with the same nominal station were retained as distinct records because they represented different deployments, spatial positions, or data streams, an alphabetical suffix (e.g., a, b, c) was added in the filename to distinguish these records. These suffixes were assigned chronologically, with "a" representing the earliest record, "b" the next, and so forth. The standardized filename thus provides a compact identifier for the station and its data source while preserving distinctions among separate records where required.

2.6 Data license and use conditions

The license and use conditions associated with each contributing dataset were assessed individually before inclusion in the publicly distributed GLOBES archive. Information was compiled from provider license statements, terms-of-use pages, open-data policies, dataset documentation, metadata records, and, where necessary, direct correspondence with the data provider. The assessment considered whether commercial and non-commercial reuse and redistribution were permitted, whether use was restricted to specific purposes, and whether additional authorization was required. Where different buoys or data originators within the same provider were subject to different terms, the applicable conditions were evaluated at the record level rather than assigning a single set of terms to the entire provider. The applicable licenses or terms for each provider are summarized in Table 1.

To summarize the use conditions for GLOBES users, we classified individual wave buoy records based on their permitted downstream uses rather than their specific licenses. Four downstream-use categories were defined: all uses permitted, non-commercial use only, non-commercial academic/research use only, and restricted/permission required. The category "all uses permitted" identifies records for which both commercial and non-commercial uses are allowed. "Non-

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commercial use only" identifies records that can be used for any non-commercial purposes, including but not limited to research, while commercial use is restricted. In contrast, "non-commercial academic/research use only" identifies records of which use is specifically limited to non-commercial scientific, academic, or research activities. Finally, "restricted/permission required" identifies records for which additional authorization from the provider is required or other restrictions apply that are not covered by the preceding categories. The geographical distribution of these downstream use categories is shown in Figure 6. Of the 1,665 buoy records included in GLOBES, 93.4% are classified as all uses permitted, 3.4% as non-commercial use only, 3.1% as non-commercial academic/research use only, and one record (0.1%) as restricted/permission required. The non-commercial category includes PdE (Spain) and certain CEFAS (United Kingdom) records, while the non-commercial academic/research-use-only category includes records from CENDHOC (Chile), IRCA (Iceland), POSEIDON (Greece), SADCO (South Africa), and SiMCosta (Brazil). The restricted category consists of a single NOAA NDBC record, station 46044, operated by Monterey Bay Aquarium Research Institute (MBARI), for which reuse and redistribution are permitted, but commercial use requires permission from the principal investigator.

Permission granted to GLOBES to redistribute a dataset does not necessarily grant unrestricted downstream use rights to GLOBES users. Some providers release their observations under open licenses that permit reuse and redistribution for any purpose, whereas others restrict use to non-commercial or academic/research purposes, or grant GLOBES permission to redistribute observations under specific conditions. The inclusion of a record in GLOBES should therefore not be interpreted as transferring ownership of the source observations or superseding the terms established by the original provider. Users are responsible for ensuring that individual records are used in accordance with their applicable license and use conditions. The record-specific use conditions and attribution requirements are provided in the "USAGE" metadata field of each GLOBES record file, and users should consult this information together with the provider-specific license or terms summarized in Table 1 before redistributing observations, incorporating them into commercial products, or otherwise using them beyond the permissions specified for the individual record.

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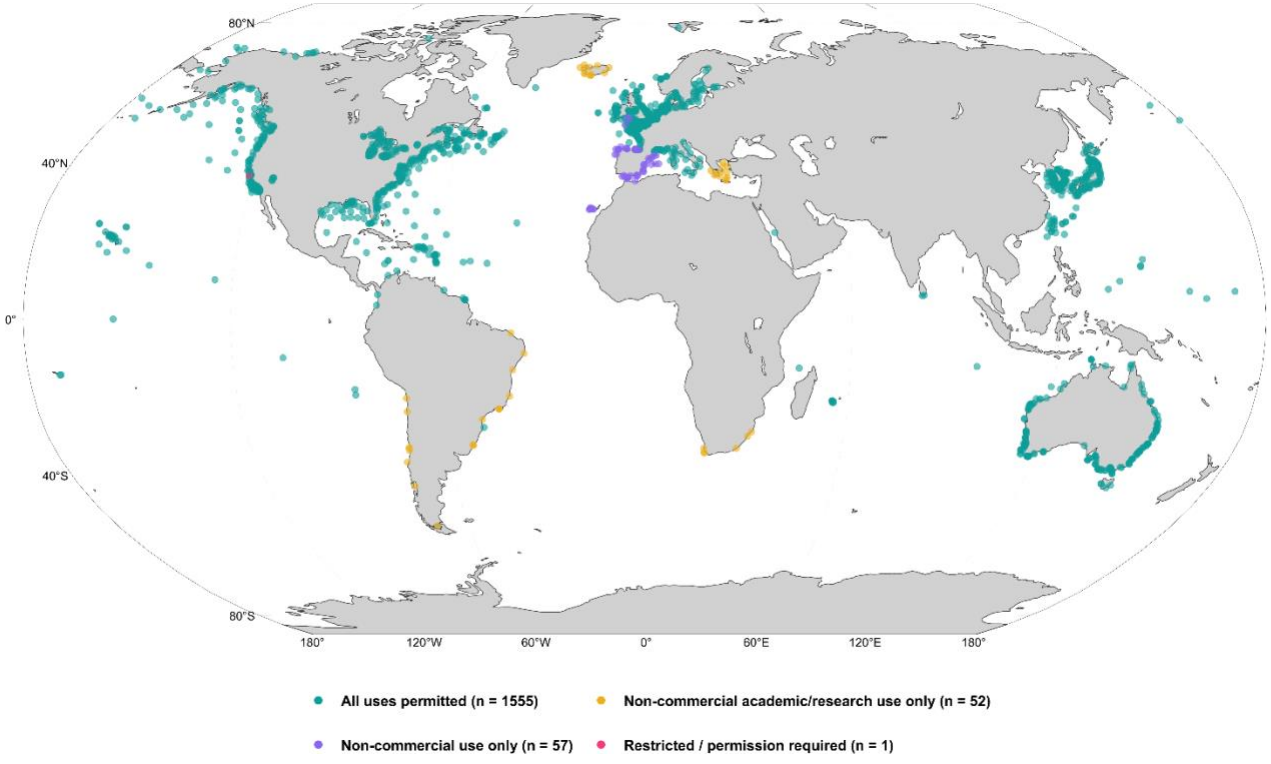


Figure 6. Global distribution of GLOBES buoy records according to permitted downstream use. Records for which all uses are permitted are shown in teal, records limited to non-commercial use are shown in purple, records limited to non-commercial academic or research use only are shown in yellow, and records requiring additional permission or otherwise subject to provider-specific restrictions are shown in pink.

2.7 FAIR data principles

We designed GLOBES following the Findable, Accessible, Interoperable, and Reusable (FAIR) principles described in Wilkinson et al. (2016). To support findability, the complete dataset is archived in Zenodo and assigned a globally unique and persistent Digital Object Identifier (DOI), while individual buoy records contain standardized metadata describing their station name and code, geographic coordinates, temporal coverage, contributor, originator, and other record characteristics. GLOBES is also accessible through complementary pathways: the full archived dataset can be downloaded directly from Zenodo, individual records can be discovered and downloaded through an interactive web-based station map with data files hosted on Amazon Web Services (AWS) and programmatically using Python and a metadata CSV file. Additional programmatic access to GLOBES observations and metadata is planned through an ERDDAP-based application programming interface (API) hosted by the University of Hawai‘i Sea Level Center (UHSLC). Together, these access routes are intended to support both direct use by researchers and machine-based discovery and retrieval of the dataset.

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Interoperability and reusability are supported through the common GLOBES data and metadata framework applied across otherwise heterogeneous observing networks. All records use a consistent file structure, standardized wave variable names and units, UTC timestamps, common missing-value and quality control conventions, and standardized metadata fields, including ISO 3166-1 alpha-3 country codes. The API is intended to further facilitate integration of GLOBES observations into automated workflows and other data systems. Reusability is supported by retaining detailed provenance through separate contributor and originator metadata, documenting provider-specific variable mappings and definitions, harmonizing available quality control information into standardized FL1 and FL2 flags, and recording the applicable attribution and use conditions for each record through the "USAGE" metadata field. These features allow users to trace observations to their original sources, evaluate their suitability for different applications, and combine records from multiple observing networks within a consistent global framework.

3 Data availability

GLOBES can be accessed through the project website (https://globes77.wordpress.com/), which provides an interactive global station map through which users can explore buoy locations and associated record information. Selecting an individual station provides access to its metadata and a direct download link to the corresponding standardized buoy record, without requiring users to retrieve the complete dataset archive. These download links are provided through a standalone Keyhole Markup Language (KML) file, with the underlying data hosted on AWS Simple Storage Service (Amazon S3). We also provide a metadata CSV file that enables programmatic access to GLOBES using Python, allowing users to filter buoy records, for example, by geographic location or temporal coverage, and download the corresponding data files directly. The metadata CSV file and example Python code demonstrating how to retrieve buoy records programmatically are available through the GLOBES website. Additional programmatic access is also planned through the ERDDAP platform hosted by the UHSLC. Records distributed through GLOBES remain subject to the provider-specific use and attribution conditions documented in the "USAGE" metadata field and the applicable license or terms summarized in Table 1. Where additional provider attribution is required, users should cite or acknowledge the original data provider in addition to citing GLOBES.

The complete GLOBES dataset is also publicly available through Zenodo at https://doi.org/10.5281/zenodo.23600705 (Quadrado et al., 2026). The repository contains the standardized ASCII files for all publicly distributable buoy records, associated metadata, and supporting documentation. Each published version of GLOBES will be preserved as a versioned release to ensure reproducibility. The dataset should be cited as: Quadrado, G. P., Haigh, I. D., Nagaraj, M., Hague, B. S., Carneiro-Barros, J. E., Wilson, S.T., Thompson, P., and Wahl, T.: GLOBES: the Global Library of Observations from Buoys for Evaluating Sea States, Zenodo, v1.0.0, DOI: 10.5281/zenodo.23600705, 2026. Users of GLOBES should cite this article and the GLOBES dataset when using the standardized observations in analyses, publications, derived products, or other downstream applications.

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Open Access Earth System Science Data Discussions

4 Code availability

MATLAB and Python scripts supporting the use of GLOBES will be available through the project website (https://globes77.wordpress.com/) and archived in a dedicated Zenodo repository associated with a persistent DOI. These scripts will include functions for reading the standardized GLOBES ASCII files. Additional example scripts for retrieving observations and metadata programmatically through the planned GLOBES ERDDAP-based data access service will be provided once the service becomes operational through the UHSLC portal. These scripts aim to facilitate the integration and use of GLOBES records in various applications and user workflows. Access to individual buoy records through the interactive station interface and KML-based links on the GLOBES website does not require users to write or run custom code.

The provider-specific scripts used to acquire, harmonize, and standardize the original observations were developed specifically for the construction of GLOBES, reflecting differences among providers in data formats, access systems, metadata structures, variable definitions, and quality control conventions. These construction workflows are therefore not maintained as reusable or general-purpose software and are not included as part of the GLOBES release. The harmonization procedures and standardized data structure produced by the GLOBES framework are documented in Sect. 2.

5 Discussion and conclusions

GLOBES provides a new global observational resource for investigating wave climate, variability, extremes, and long-term change, bringing together 19,467 station-years of observations from 1,665 buoy records contributed by 27 data providers across 41 countries, spanning 1969–2026. The dataset harmonizes seven wave parameters within a common data and metadata framework while preserving native temporal resolution and documenting provider-specific variable definitions, provenance, and harmonized quality control information. By consolidating historically fragmented wave observations into a consistent and accessible archive, GLOBES facilitates analyses across observing networks and provides an observational reference for evaluating numerical wave models, hindcasts, reanalyses, and satellite-derived wave products. It also provides a centralized resource for discovering historical buoy observations that may otherwise be difficult to locate across regional and national provider archives and fragmented data systems. Nevertheless, spatial and temporal coverage, record length, variable availability, and quality control information remain heterogeneous among records and should be considered when selecting data for individual applications.

Despite including observations across all major ocean basins, GLOBES still exhibits spatial coverage gaps. These gaps primarily reflect three main challenges: (1) the absence of moored wave buoy observations in some regions and/or countries, (2) existing observing networks that have not yet been identified and incorporated into GLOBES, and (3) providers that have either denied requests for data redistribution permission or have not yet responded to our inquiries. These gaps are most evident across the Indian Ocean, including the Gulf of Aden, the Arabian Sea, and the Bay of Bengal, the Indonesian Throughflow region, large portions of the African and the Central and South American coasts, and the waters surrounding New Zealand and Antarctica. To help address these gaps, we aim to continuously expand GLOBES by incorporating

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observations from additional data providers and updating existing records, with new releases planned every one to two years. We also encourage readers and data providers to contact the GLOBES team with information about relevant wave buoy datasets not yet included in the database.

GLOBES was developed primarily to compile observations from moored wave buoys, providing station-based time series at approximately fixed locations. Although wave measurements are also collected using bottom-mounted sensors and fixed coastal or offshore platforms at fixed positions, these systems employ different measurement techniques and processing methods, such as depth-dependent corrections for bottom-mounted pressure sensors, which may introduce platform-specific biases into the wave measurements that complicate comparisons with moored buoy observations. These observing systems were therefore generally excluded from GLOBES, with Japan's NOWPHAS network representing a major exception, retained to preserve its extensive historical and spatial coverage. Future GLOBES efforts may include the development of a separate, complementary database of wave observations from bottom-mounted sensors and fixed platforms, further expanding the global availability of in situ wave measurements.

We envision GLOBES as a foundational resource for research and applications that depend on standardized, quality-documented in situ wave observations, from coastal hazard assessments, engineering and maritime operations to climate research and machine learning. Distributed as a versioned, openly accessible archive in which over 90% of records permit all downstream uses, GLOBES is designed to expand through regular updates and contributions from the wave observing community. By consolidating historical wave observations from multiple providers within a standardized framework, GLOBES provides a common, consistent baseline for advancing wave science and its diverse applications.

Author contributions

GPQ led the study, including conceptualization, methodology, data curation, formal analysis, software, visualization, validation, project administration, and preparation of the original draft of the manuscript. IDH contributed to conceptualization, methodology, data curation, formal analysis, software, and project administration. MN contributed to resources and software through the development and implementation of the AWS-based data-access infrastructure, including the KML-based system supporting access to individual GLOBES buoy records. BSH contributed to the conceptualization of GLOBES, methodology, and identification of relevant data sources. JECB contributed to data curation and methodology. STW contributed to software through the technical development of the ERDDAP-based data-access infrastructure. PRT contributed to resources and project administration through the coordination of UHSLC support for GLOBES data hosting and the development of ERDDAP-based data access. TW contributed to methodology and supervision. All authors contributed to reviewing and editing the

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manuscript and approved the final version. During the development of GLOBES, OpenAI ChatGPT was used as a discovery aid to identify potential wave data providers. All candidate providers, data sources, documentation, and eligibility decisions were subsequently reviewed and verified by the authors. OpenAI ChatGPT was also used for assistive language editing of the manuscript, including improvements to grammar, readability, punctuation, and spelling.

Competing interests

The authors declare that they have no conflict of interest.

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