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Open Access Earth System Science Data Discussions

Coastal Ocean Data Analysis Product in North America (Version 2026)

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Abstract. The coastal Ocean Data Analysis Product in North America (CODAP-NA, Version 2026) represents a major expansion of coastal ocean carbonate chemistry synthesis for North American continental margins. Compared to CODAP-NA Version 2021, the updated product integrates newly available cruise observations spanning more than four decades, substantially increasing both the spatial and temporal coverage of coastal biogeochemical measurements across North American continental shelves. Observations from multiple research programs have been harmonized into a unified, internally consistent format through standardized quality control procedures, enabling large-scale analyses of ocean carbon cycling and ocean acidification along the North American margins. This version comprises 446 cruises, 31,864 hydrographic profiles, and 195,489 discrete data records covering continental shelf environments from Alaska to Mexico in the west and from Canada to the Caribbean in the east from 1981 to 2024. Fourteen variables (including temperature, salinity, dissolved oxygen, dissolved inorganic carbon, total alkalinity, pH on the Total Scale, carbonate ion, fugacity of carbon dioxide, silicate, phosphate, nitrate, nitrite, nitrate plus nitrite, and ammonium) were subjected to extensive quality control. CODAP-NA Version 2026 is available as a merged data product in CSV, MATLAB, and NetCDF formats (https://doi.org/10.25921/h2ff-9d66) through the NOAA Ocean Carbon and Acidification Data System (OCADS: https://www.ncei.noaa.gov/data/oceans/ncei/ocads/metadata/0315529.html). The original cruise data were archived and are accessible via a summary table at the NCEI Ocean Acidification Data Stewardship repository (https://www.ncei.noaa.gov/access/ocean-carbon-acidification-data-system/synthesis/CODAP-NAv2.html).

1 Introduction

The global ocean has served as a primary buffer against climate change, sequestering approximately 25% to 30% of total anthropogenic CO_2 emissions since the Industrial Revolution (IPCC, 2022; Gruber et al., 2023; Friedlingstein et al., 2026). While this uptake mitigates atmospheric warming, it drives ocean acidification (OA) which refers to a shift in seawater chemistry that has already resulted in a roughly 30% increase in surface ocean acidity, corresponding to a decline in mean surface ocean pH of more than 0.1 units (Orr et al., 2005; Gattuso et al., 2015; Jiang et al., 2023; Müller and Gruber, 2024). Ongoing CO_2 uptake also reduces carbonate ion concentrations ($[CO_3^{2-}]$) and the saturation state of calcium carbonate minerals such as aragonite and calcite, posing a significant threat to marine ecosystems. This is particularly harmful for calcifying organisms such as corals, mollusks, and pteropods which must use substantially more energy to construct their

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shells and skeleton when carbonate ions decline (Doney et al., 2020; Alter et al., 2024; Findlay et al., 2025). Beyond its effects on calcification, OA impairs a broad spectrum of physiological processes encompassing metabolism, growth, and reproduction across diverse marine taxa, underscoring its status as a widespread and far-reaching stressor on ocean ecosystems (Kroeker et al., 2013; Riebesell and Gattuso, 2015; IPCC, 2022).

Although open-ocean OA trends are well-established and largely follow the trajectory of rising atmospheric CO_2, the dynamics of coastal systems are considerably more complex (Carstensen and Duarte, 2019; Cai et al., 2021). Coastal environments are typically subject to a confluence of additional forcings including freshwater discharge with low salinity and regionally varying alkalinity, riverine nutrient inputs, anthropogenic eutrophication, and regional upwelling, each of which can locally intensify or attenuate OA signals (Cai et al., 2011; Moore-Maley et al., 2018; Waldbusser and Salisbury, 2014). This pronounced natural variability, compounded by a historical scarcity of coordinated and comprehensive observational datasets, has impeded robust characterization of long-term OA trends, their controlling mechanisms, and the associated vulnerabilities of coastal marine ecosystems.

Along the North American continental shelves, the interaction of physical, biological, and terrestrial drivers gives rise to highly heterogeneous acidification patterns that deviate substantially from open-ocean conditions (Jiang et al., 2024). Regional studies have demonstrated that North American continental shelves are among the most vulnerable to accelerating OA: on the West Coast, anthropogenic CO_2 has driven rapid acidification of upwelled waters in the California Current system and connected estuaries, shoaling the aragonite saturation horizon at an unprecedented rate (Feely et al., 2008; Gruber et al., 2012), while along the East Coast and Gulf of America/Gulf of Mexico declining pH and aragonite saturation have been linked to a confluence of riverine inputs, eutrophication, and open-ocean forcing (Wanninkhof et al., 2015; Osborne et al., 2022).

Addressing these challenges requires large-scale, internally consistent, and rigorously quality-controlled data products. The CODAP-NA Version 2021 began to address this gap by assembling discrete carbonate chemistry, oxygen, nutrient, and hydrographic measurements from multiple research cruises conducted along the North American coasts between 2003 and 2018 (Jiang et al., 2021). Although CODAP-NA Version 2021 demonstrated the value of integrated coastal observations, it was exclusively focused on high-quality measurements collected by NOAA laboratories and several academic collaborators. It therefore had limited spatial and temporal coverage, leaving out a significant volume of observational data collected by other institutions.

To address these persistent observational gaps and build upon the foundation established by CODAP-NA Version 2021, the synthesis was expanded to incorporate newly available cruise data, extend temporal coverage, and improve regional representation across North American continental shelves. In this paper, we present CODAP-NA Version 2026, a major

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expansion in both scope and scale relative to the previous release. The updated product now incorporates 195,489 discrete samples from 446 research cruises spanning more than four decades (1981–2024) across U.S. waters of the West Coast, Gulf Coast, East Coast, and high-latitude regions. This represents a substantial increase from CODAP-NA Version 2021, which consisted of 3,391 oceanographic profiles from 61 research cruises. All observations have undergone standardized quality-control procedures to ensure internal consistency across cruises and institutions. This foundational data product is a critical record of long-term OA and other biogeochemical trends along North American continental shelves, and can serve as a key resource for carbon cycle research, ecosystem modeling, vulnerability assessments, fisheries management, and future observational programs.

2 Study site

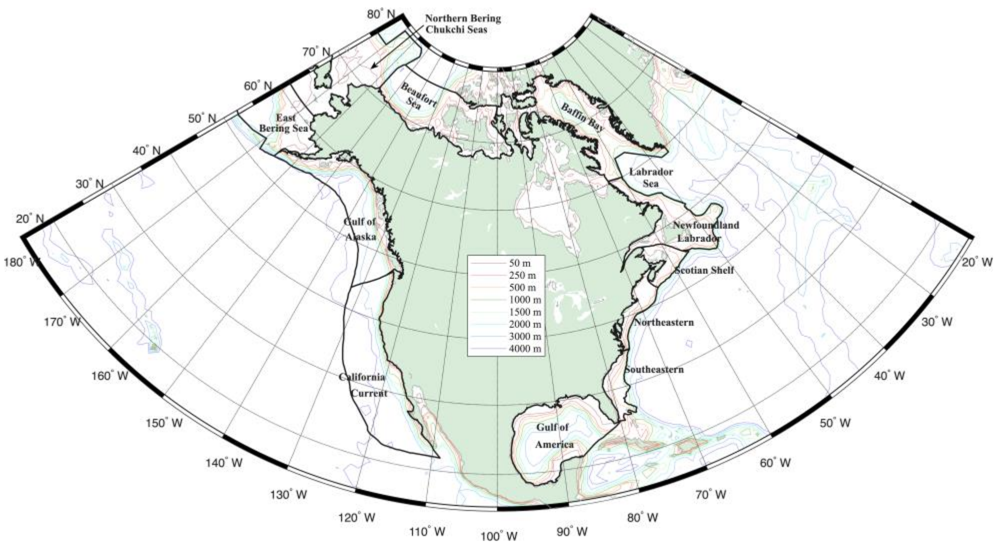

Figure 1. Geographic distribution of defined study regions and regional bathymetric contours across the North American continental margins. Colored contour lines delineate specific seafloor depth thresholds ranging from the inner shelf (50 m) to deep ocean basins (4000 m), as indicated in the central legend. The solid black lines indicate the boundaries of the Large Marine Ecosystems (LMEs).

In contrast to the CODAP-NA Version 2021 release, which was exclusively focused on the continental shelves of the United States, CODAP-NA Version 2026 now aims to be comprehensive with respect to data from U.S. and Canadian continental shelves and large estuaries (Figure 1). Major oceanographic regions, including Beaufort Sea, Northern Bering and Chukchi Seas, East Bering Sea, Gulf of Alaska, California Current, Gulf of America, Southeastern Continental shelf, Northeastern

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Continental Shelf, Scotia Shelf, Newfoundland and Labrador, and Baffin Bay, are explicitly labeled to define the spatial boundaries used throughout this study.

3 Data sources

The CODAP-NA Version 2026 data product was derived from a synthesis of individual cruise datasets collected across the continental shelves and large estuaries of North America (See Supplementary Material). Data from these cruises were mainly sourced from the Ocean Carbon and Acidification Data System (OCADS) at NOAA's National Centers for Environmental Information (Jiang et al., 2023). Although CODAP-NA synthesis primarily targets continental shelf environments, it also includes observations from adjacent large estuaries, continental slopes, and the open-ocean portions of some coastal cruises that extend beyond the shelf break.

4 Methods

The CODAP-NA Version 2026 underwent the same quality control procedures as established in the initial release (Jiang et al., 2021). Experimental Expedition Code (EXPOCODE) is required for all cruises. In instances where an EXPOCODE was unavailable, a 12-digit identifier was generated using the "XXXXYYYYMMDD" format, where "XXXX" substitutes for the four-character ICES ship code, "YYYY", "MM" and "DD" denote the four-digit year, two-digit month and two-digit day on which the cruise departed port, respectively. To facilitate automated data processing, all station and sample identifiers were required to be numerical. Consequently, where original station IDs were provided as strings, a supplementary numerical column was generated. For datasets lacking explicit sample IDs, values were calculated via the methodology established by Jiang et al. (2022), which utilizes a derived relationship between the numerical station ID, cast number, and Niskin ID as shown in Equation (1).

$$\text{Sample\_ID} = \text{Station\_ID} \times 10000 + \text{Cast\_number} \times 100 + \text{Niskin\_ID} \qquad \text{Equation (1)}$$

The following subsections provide a brief overview of some steps that are new in CODAP-NA Version 2026, including references from the World Ocean Atlas (WOA), the application of Empirical Seawater Property Estimation Routines (ESPERs) for consistency validation (Section 4.2), and the treatment of discrepancies between CTD-derived and bottle-based oxygen measurements (Section 4.3). Additionally, negative nutrient values are replaced with zero values. For completeness and ease of reference, the cruise quality flag definitions (Table 1) and primary-level QC flag conventions (Table 2) from the original CODAP product documentation (Jiang et al., 2021) are reproduced here.

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Table 1. Cruise flags used for this product (reproduced from Jiang et al., 2021).

Flag value	Meaning
A	These were dedicated OA cruises that were executed following Best Practices for global ocean work as outlined in Hood et al. (2011) and other documents as can be found on GO-SHIP site*. Traceable standards and certified reference materials were used, and deep stations (> 2500 m) were sampled to allow using near-constant deep-water concentrations as anchor points. A third inorganic carbon system parameter, such as pH or carbonate ion concentration were often measured, allowing consistency checks.
B	These are dedicated OA cruises that had onboard inorganic carbon measurements performed according to Best Practices (Dickson et al. 2007), and many other parameters to highest accuracy through use of standards and certified reference materials. However, the cruises did not necessarily have all other parameters analyzed to highest standards, such as freezing nutrients for shoreside analyses; not taking oxygen and nutrients samples on most Niskins; not normalizing CTD oxygen trace to Winkler oxygen values, insufficient metadata etc. There often are insufficient deep stations to compare data with open ocean data.
C	These were opportunistic cruises where OA parameters were measured in the water column. They include standard hydrographic, carbon, and OA parameters; T, S, O_2, nutrients, TALK, DIC, pH. Many parameters, including carbon and OA parameters were measured shoreside; CTD oxygen data were not adjusted to Winkler oxygen values. Generally, no dedicated OA personnel were onboard.
D	Underway samples only. These cruises had no CTD casts, and only had samples taken from the seawater supply line, with often a limited variety of other hydrographic parameters. T and S were obtained from thermosalinographs with limited or no salinity check samples.

(*https://www.go-ship.org/HydroMan.html)

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Table 2. World Ocean Circulation Experiment (WOCE) World Hydrographic Program (WHP) QC flags used for this product (reproduced from Jiang et al., 2021).

Flag value	Meaning
2	Acceptable
3	Questionable
6	Average of duplicates
9	Missing value

4.1 WOA reference

Temperature and salinity reference profiles were extracted from the World Ocean Atlas 2023 (WOA23, or WOA henceforth) climatology to provide contextual background fields for each observation (Locarnini et al., 2024; Reagan et al., 2024). For each unique profile, defined by a common Profile_number, a representative geographic location was determined using the first available latitude and longitude. The nearest WOA grid cell was identified by minimizing the absolute difference between the profile location and the WOA longitude and latitude grids. From this grid cell, vertical temperature and salinity climatologies were retrieved and filtered to exclude unmapped grid points and missing data (NaN), in accordance with the standard WOA quality control boundaries (Garcia et al., 2026). When at least three valid depth levels were available, linear interpolation was applied to map the WOA profiles onto the observed sample depths (Depth_meter) for all measurements within the profile. This approach provides a consistent, spatially matched climatological reference for evaluating observed

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hydrographic properties such as temperature and salinity. It enabled, for the first time, the application of QC procedures to variables such as temperature within the community.

4.2 ESPER calculation

The Empirical Seawater Property Estimation Routines (ESPER) represent a suite of estimation tools designed to reconstruct missing seawater biogeochemical properties from more readily available hydrographic parameters (Carter et al., 2021). It utilizes a locally interpolated regression (LIR) or neural network (NN) architecture to relate predictors such as temperature, salinity, oxygen, and geographic coordinates to target variables like DIC, TALK, and nutrients. ESPER-derived values are used for sanity checks to verify that reported values fall within expected ranges. When multiple values are available for a variable, for example directly measured pH on the total scale (henceforth "pH") and pH calculated from DIC and TALK, the ESPER-derived estimate provides an independent reference to help determine which value is more reliable. Such cross-validation protocols are instrumental in identifying statistical outliers and ensuring that the estimated biogeochemical fields remain internally consistent with established thermodynamic relationships. That said, ESPER estimates have inherent limitations in many regions of the ocean and in coastal areas in particular, and should not be used as the sole basis for broadly flagging data values. Discrepancies with ESPER are therefore used herein solely to help call expert attention to anomalous measurements.

4.3 Discrepancy between CTDOXY and OXYGEN

Systematic divergence between CTD-derived and bottle-based oxygen concentrations was identified for several new cruise records (Table 3), necessitating sensor calibration using Winkler titration data as the reference standard during the CODAP QC process. The processing filters the dataset to keep only trustworthy bottle oxygen values (QC flags of 2 or 6) and then computes the average difference between Winkler oxygen and CTDOXY in umol/kg units. Only cruises where the absolute value of the average difference exceeded 2.5 umol/kg or ~10-times the generally accepted accuracy of the Winkler titration method were selected for adjustment (Helm et al., 2012). For each such cruise, a non-linear regression model with calibration coefficients that describe sensor offset, scale, and pressure-dependent behavior was fit to the data. The fitted coefficients were then applied to all CTD casts from the cruise with valid oxygen and pressure data to produce calibrated CTD oxygen concentrations. There were 26 cruises that met the criteria for benefiting from calibration against Winkler data (Table 3). Before calibration the average difference between CTDOXY and Winkler ranged from -15.6 to +8.1 umol/kg with an average of -6.1 umol/kg. After calibration the range in average difference between CTDOXY and Winkler was reduced to -0.4 to +2.2 with an average of 0.4 ± 0.6 umol/kg. The offset correction (Voff) ranged from -17.1 to +24.1 umol/kg. The scaling correction (Soc) ranged from 0.917 to 1.096. The pressure correction coefficient ranged from -1.84×10^{-4} to $+0.37 \times 10^{-4}$.

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Table 3. Cruise data sets meet the criteria for adjustment of the CTDOXY data. Where Voff, Soc and E are the best-fit offset, scale and pressure dependence calibration coefficients. avg.residual.before and avg.residual.after are the average
235 difference between CTDOXY and Winkler before and after calibration. RMSE is the root mean square error of the fitted model.

EXPOCODE	Number of Winklers	Number of Stations	Voff	Soc	E	avg.residual before (µmol/kg)	avg.residual after (µmol/kg)	RMSE
18BP20140422	50	26	2.07	1.0142	-1.83E-04	-2.85	-0.06	10.6
18OL20180605	282	101	2.78	0.9857	-1.34E-04	3.47	0.41	4.1
18NE20150629	236	119	13.16	1.0033	-1.01E-04	-12.61	0.35	5.0
32RC20220812	43	17	7.17	0.9875	-3.70E-05	-4.13	0.16	4.6
33A009072011	122	112	2.29	1.0297	-2.34E-05	-8.34	0.09	8.7
332220170918	385	0	4.82	1.0010	-2.28E-05	-4.76	0.72	9.4
18HU20010530	496	30	-17.12	1.0955	-9.03E-06	-6.03	1.48	2.4
49NZ20000803	329	34	24.14	0.9747	-8.76E-06	-15.63	2.2	9.7
18HU19931105	1520	101	-2.01	1.0435	-4.58E-06	-6.74	0.57	6.2
18HU20060524	719	49	7.3	0.9875	-3.17E-06	-2.53	0.16	1.8
33A009072011	294	18	3.73	0.9952	-7.60E-09	-2.66	0.02	0.0
18HU20110506	851	62	5.7	1.0130	2.16E-06	-10.18	-0.02	2.9
18MF20120601	479	33	7.10	0.9879	2.42E-06	-4.23	0.28	4.7
18HU20130507	674	45	11.31	0.9895	3.25E-06	-9.36	0.22	2.9
18HU20160430	894	55	7.3	1.0230	4.98E-06	-15.48	-0.16	1.6
33AT20220504	524	35	9.65	0.9766	5.04E-06	-3.89	0.28	3.1
18HU20150504	553	37	12.20	0.9895	5.44E-06	-10.85	0.25	3.8
18OL20190409	189	71	15.50	0.9815	6.08E-06	-10.68	-0.38	10.5
322000000000	10301	4447	10.37	0.9785	7.64E-06	-6.03	0.64	15.3
32H120040718	960	60	9.96	1.0009	8.77E-06	-10.72	-0.04	10.9
33RO20070710	1069	89	-4.8	1.0905	1.07E-05	-13.56	0.46	4.7
18HU20140919	178	63	2.93	1.0206	1.25E-05	-9.24	-0.18	2.2
18HU20000520	454	25	-10.46	1.0627	1.29E-05	-11.74	0.68	3.1
18HU20150418	124	51	1.12	0.9814	1.47E-05	3.19	0.21	8.2
33AT20220322	177	78	5.53	0.9421	2.07E-05	8.09	0.22	21.4
29HE19920614	58	11	9.38	0.9170	3.70E-05	3.84	1.71	7.1

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5 CODAP-NA Version 2026

In CODAP-NA Version 2026, there are 31,864 discrete chemical oceanographic profiles, and a total of 196,421 data points. They were collected on 446 cruises in the ocean margins of North America from August 23, 1981, to November 23, 2024. As in the initial release, CODAP-NA Version 2026 includes discrete observational measurements of inorganic carbon system parameters, oxygen, nutrients, and related hydrographic variables (Table 4). It features enhanced data volume for a broad range of oceanographic and biogeochemical parameters, with sample counts varying considerably across variables from as few as 3,186 measurements for fCO_2 measured in-situ to over 194,000 for recommended salinity, reflecting differences in measurement frequency and instrument availability across cruises (Table 5). Notably, the carbonate parameters calculated from TALK and DIC (e.g., fCO_2, pH, carbonate ion) consistently have substantially higher counts (~85,359) than their measured counterparts, highlighting the need to make more direct measurements for variables such as pH and carbonate ions in the future.

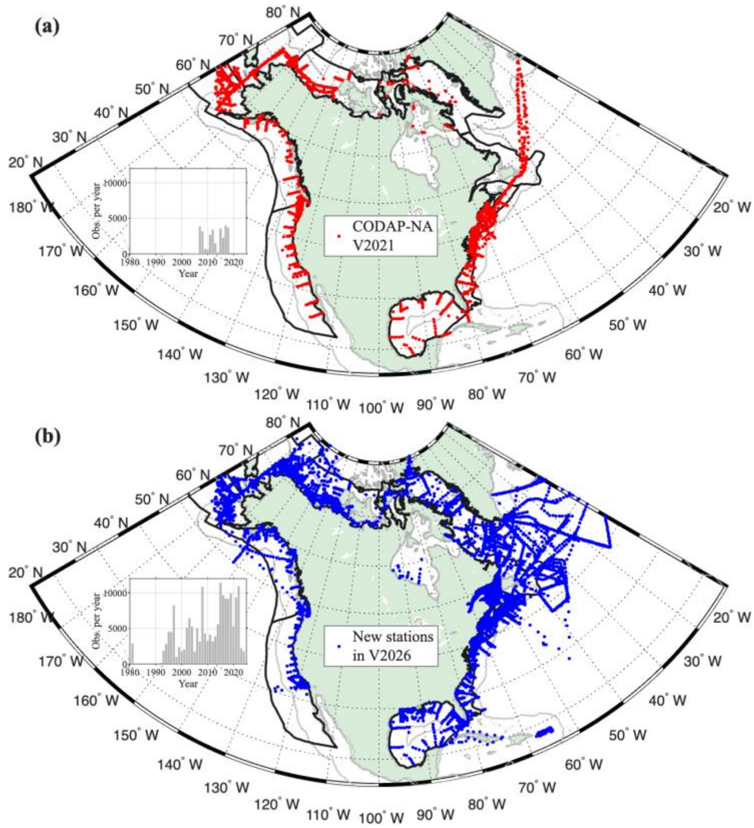

Figure 2. A map showing the spatial distribution of the CODAP-NA data product (Version 2026, featuring a total of 31,864 profiles). Red dots show sampling stations incorporated in the release of CODAP-NA Version 2021 (a), while the blue circles indicate the newly added profiles (b). The gray dotted lines indicate the boundaries of the Exclusive

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Economic Zones (EEZs). The inset bar plots show the historical timeline and total number of observations collected in each year.

Figure 2 illustrates the spatial coverage of the CODAP-NA across all continental margins of North America, filling critical data gaps. Notably, the dataset shows impressive coverage in high-latitude regions, including the Bering Sea, Chukchi Sea, and the Canadian Archipelago. The greatest improvements in spatial coverage occur along the northeastern continental margins of Canada, including the Labrador Sea, Baffin Bay, the Northwest Passage, and the Gulf of St. Lawrence. This is critical for ocean acidification research, as colder waters have higher CO_2 solubility and lower carbonate saturation states, making them "sentinel" regions for climate change.

The bar chart in Figure 2 further illustrates the growth in data volume over time, showing a steady rise in the number of observations per year since the 1980s, with a significant surge in data availability starting in the late 1990s and peaking in recent years (through 2020), underscoring the product's evolving role in comprehensive coastal oceanographic monitoring. Table 1 from Jiang et al. (2021) is reproduced here as Table 4 for the convenience of readers and summarizes the analytical methodologies, associated units, and the distinction between measured and calculated parameters.

Table 4. Parameters that are included in the CODAP-NA (Version 2026) data product.

Abbreviation	Variable name	Unit	Measured/ calculated
CTDPRES	Water pressure recorded from sensors on a CTD rosette. For surface samples collected from an onboard flow-through system, its pressure is equal to the depth of the water inlet. When such info is not available, it is assumed to be 5 dbar.	dbar	measured
CTDTEMP_ITS90	Temperature on the International Temperature Scale of 1990 (ITS-90) from sensors on a CTD rosette. For surface samples collected from an onboard flow-through system, temperature has also been merged into the CTDTEMP_ITS90 variable.	°C	measured
CTDSAL_PSS78	Salinity on the Practical Salinity Scale 1978 (PSS-78) from sensors on a CTD rosette. For surface samples collected from an onboard flow-through system, salinity from the thermosalinograph (TSG) has been merged into the CTDSAL_PSS78 variable.	-	measured
Salinity_PSS78	Salinity on the PSS-78 scale measured as discrete samples	-	measured
recommended_Salinity_PSS78	Discrete salinity with some missing values filled in using CTDSAL	-	measured
CTDOXY	Dissolved oxygen concentration from sensors on a CTD rosette	µmol kg^{-1}	measured
Oxygen	Dissolved oxygen concentration measured as discrete samples from Winkler titration	µmol kg^{-1}	measured
recommended_Oxygen	Discrete dissolved oxygen concentration from Winkler titration with some missing values filled in using CTDOXY	µmol kg^{-1}	measured
AOU	Apparent oxygen utilization	µmol kg^{-1}	calculated
DIC	Dissolved inorganic carbon	µmol kg^{-1}	measured
TALK	Total alkalinity	µmol kg^{-1}	measured
pH_TS_measured	pH on total hydrogen scale (TS) measured as discrete samples at measurement temperature and ambient pressure	-	measured
TEMP_pH	Temperature of pH measurement	°C	measured

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pH_TS_insitu_measured	pH on total hydrogen scale (TS) measured as discrete samples and adjusted to *in-situ* conditions	-	measured
pH_TS_insitu_calculated	pH on total hydrogen scale (TS) at *in-situ* conditions calculated from DIC, TA and other parameters using CO2SYS	-	calculated
Carbonate_measured	Carbonate ion measured as discrete samples at measurement temperature and ambient pressure	µmol kg^{-1}	measured
TEMP_Carbonate	Temperature of carbonate ion measurement	°C	measured
Carbonate_insitu_measured	Carbonate ion measured as discrete samples and adjusted to *in-situ* conditions	µmol kg^{-1}	measured
Carbonate_insitu_calculated	Carbonate ion at *in-situ* conditions calculated from DIC, TA and other parameters using CO2SYS	µmol kg^{-1}	calculated
fCO_2_measured	Fugacity of carbon dioxide measured as discrete samples at measurement temperature and ambient pressure	µatm	measured
TEMP_fCO_2	Temperature of fCO_2 measurement	°C	measured
fCO_2_insitu_measured	Fugacity of carbon dioxide measured as discrete samples and adjusted to *in-situ* conditions	µatm	measured
fCO_2_insitu_calculated	Discrete fugacity of carbon dioxide at *in-situ* conditions calculated from DIC, TA and other parameters using CO2SYS	µatm	calculated
Aragonite	Aragonite saturation state at *in-situ* conditions calculated from DIC, TA and other parameters using CO2SYS	-	calculated
Calcite	Calcite saturation state at *in-situ* conditions calculated from DIC, TA and other parameters using CO2SYS	-	calculated
Revelle_Factor	Revelle Factor calculated from DIC, TA and other parameters using CO2SYS	-	calculated
Silicate	Silicate	µmol kg^{-1}	measured
Phosphate	Phosphate	µmol kg^{-1}	measured
Nitrate	Nitrate	µmol kg^{-1}	measured
Nitrite	Nitrite	µmol kg^{-1}	measured
Nitrate_and_Nitrite	Nitrate and Nitrite combined	µmol kg^{-1}	measured
recommended_Nitrate_and_Nitrite	Nitrate_and_Nitrite, along with Nitrate concentration when Nitrate_and_Nitrite data are not available	µmol kg^{-1}	measured
Ammonium	Ammonium	µmol kg^{-1}	measured

Table 5. The minimum, maximum, mean, and data point counts of the parameters that are included in the final product. Refer to Table 4 for their full parameter names and units.

Abbreviation	Units	Min	Max	Mean	Count
CTDTMP_ITS90	°C	-1.792	33.423	6.868	189,692
CTDSAL_PSS78	-	0.04	39.919	32.806	184,480
Salinity_PSS78	-	0.11	43.56	34.006	62,993
recommended_Salinity_PSS78	-	0.04	43.56	32.903	194,838
CTDOXY	µmol/kg	2.8	659.8	252.6	149,954
Oxygen	µmol/kg	1.9	799.6	243.6	98,797
recommended_Oxygen	µmol/kg	1.9	799.6	255.8	171,229
AOU	µmol/kg	-345.3	323.7	49.8	170,298
DIC	µmol/kg	629.3	3113.2	2089.7	104,386
TALK	µmol/kg	561.5	3383.5	2222.7	98,682
pH_TS_insitu_measured	-	7.192	8.479	7.916	25,885
pH_TS_insitu_calculated	-	7.059	8.98	7.939	85,359
Carbonate_insitu_measured	µmol/kg	28.1	298.9	127.4	7,322
Carbonate_insitu_calculated	µmol/kg	10.7	377.6	102.0	85,359
fCO2_insitu_measured	µatm	198.3	1574.1	457.6	3,186

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fCO2_insitu_calculated	µatm	25.7	4094.2	540.3	85,359
Aragonite saturation	-	0.16	6.01	1.48	85,359
Calcite saturation	-	0.26	9.67	2.33	85,359
Revelle_Factor	-	7.19	21.86	14.83	85,359
Silicate	µmol/kg	0	234.4	19.34	122,919
Phosphate	µmol/kg	0	10.46	1.17	131,569
Nitrate	µmol/kg	0	51.06	13.61	119,389
Nitrite	µmol/kg	0	15.65	0.13	90,962
Nitrate_and_Nitrite	µmol/kg	0	51.25	13.21	106,184
recommended_Nitrate_and_Nitrite	µmol/kg	0	51.25	13.07	134,899
Ammonium	µmol/kg^{-1}	0	68.4	0.65	69,014

A comprehensive visualization of the spatial density, seasonal distribution and depth coverage of the CODAP-NA Version 2026 dataset is presented in Figures 3-5. The geographic distribution of oceanographic profile measurements across the North American ocean margins for nine key variables are presented in Figure 3. There is a notable scarcity of discrete measurements for pH, carbonate ion, and fCO_2. The seasonal distribution reveals a bias toward summer and fall and a relative scarcity of observations in winter and spring, similar to the first release (Figure 4, Table 6). This seasonal imbalance, while logistically expected, poses a challenge for accurately characterizing the full annual biogeochemical cycle, as the critical winter-time convective mixing and carbon outgassing processes remain understudied.

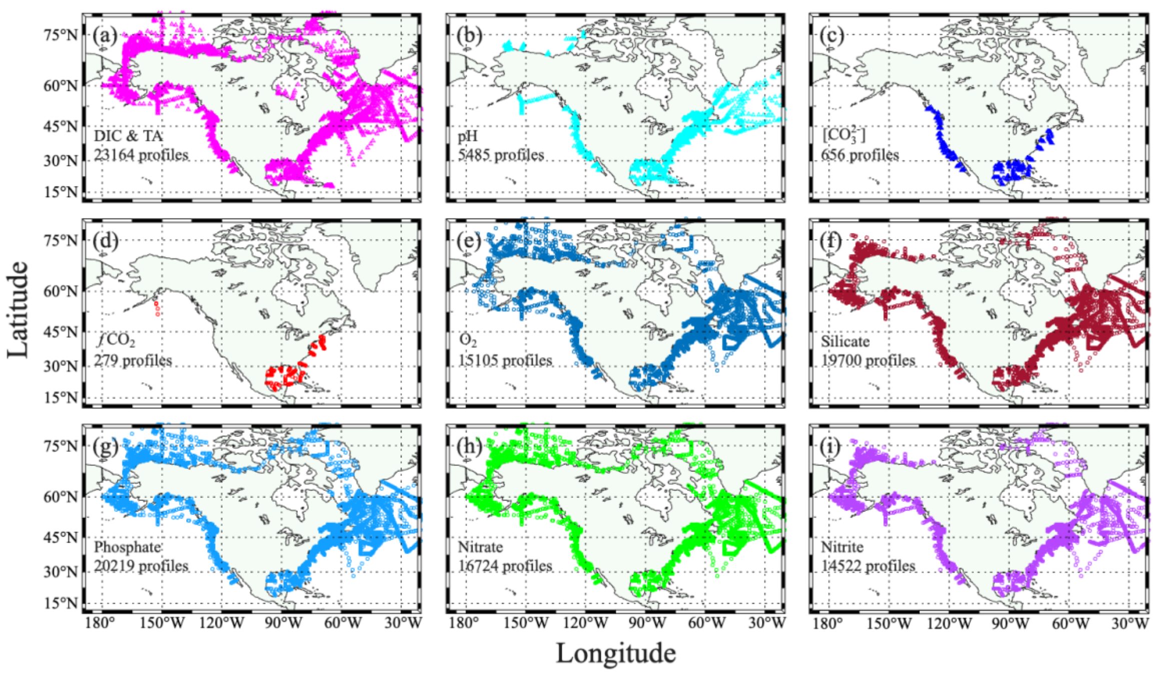

Figure 3. The maps illustrate the geographic extent of data profiles containing at least one measured value for the specified parameters. (a) Profiles containing both dissolved inorganic carbon (DIC) and total alkalinity (TA) (n = 23,255 profiles). (b) Discrete pH measurements obtained via spectrophotometry (n = 5,509 profiles). (c) Discrete carbonate ion ($[CO_3^{2-}]$) measurements (n = 658 profiles). (d) Discrete fugacity of carbon dioxide (fCO_2) sampled via

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flasks (n = 281 profiles). (e) Profiles containing recommended oxygen values (n = 15,108 profiles). Panels (f–i) display the distribution of nutrient profiles: (f) Silicate (n = 20,055 profiles), (g) Phosphate (n = 20,569 profiles), (h) Nitrate (n = 17,081 profiles), and (i) Nitrite (n = 14,847 profiles). Latitude and longitude are provided on the y and x axes, respectively, highlighting extensive coverage across the North American margins and adjacent basins.

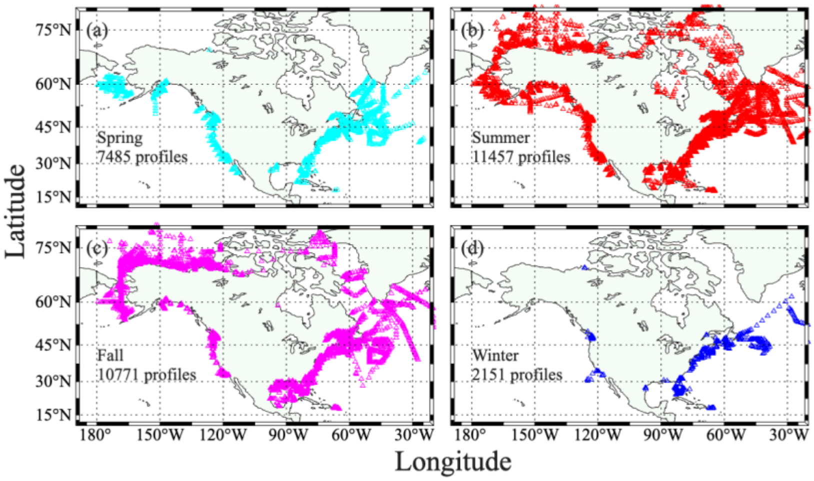

Figure 4. Sampling profiles in each of the four seasons: (a) Spring (March – May), (b) Summer (June – August), (c) Fall (September – November), (d) Winter (December – February).

Table 6. Seasonal distribution of oceanographic profiles and data points by region.

Region	**Spring (Mar-May)**		**Summer (Jun-Aug)**		**Fall (Sep-Nov)**		**Winter (Dec-Feb)**		**Total**	
	profile	**# point**	**profile**	**# point**	**profile**	**# point**	**profile**	**# point**	**profile**	**# point**
Southeastern	316	490	434	2555	587	1586	165	466	1502	5097
Northeastern	458	1738	793	7934	482	3195	135	529	1868	13396
Scotian Shelf	429	2497	902	3187	1200	6024	92	480	2623	12188
Newfoundland_Labrador	467	3107	1235	7453	920	5436	83	398	2705	16394
Canadian Eastern Arctic	89	1261	469	7426	217	2175	0	0	775	10862
Gulf of America/Gulf of Mexico	895	1028	1429	3520	1230	3091	1115	1306	4669	8945
California Current	365	3307	478	5208	313	1784	115	170	1271	10469
Gulf of Alaska	2962	9859	1908	9298	2688	14586	60	808	7618	34551
East Bering Sea	265	1819	325	2118	153	982	0	0	743	4919
Northern Bering Chukchi Seas	35	234	374	3221	568	3192	0	0	977	6647
Beaufort Sea	17	347	575	8020	915	7857	23	424	1530	16648

The temporal and spatial distribution of the consolidated data product from 1996 to 2025 is structured into six distinct time bins to optimize trend analysis (Figure 5). As shown in panels (a-f) the total number of sampling cruises increases dramatically over time, with the vast majority of observations concentrated in the post-2010 operational blocks. When projected across individual coastal margins in panels, this distribution reveals that regions like the California Current and the Northeast Atlantic shelf maintain robust and long-term historical coverage. This temporal-spatial matrix highlights the critical expansion of regional observation density that underpins our analysis of modern ocean acidification trends.

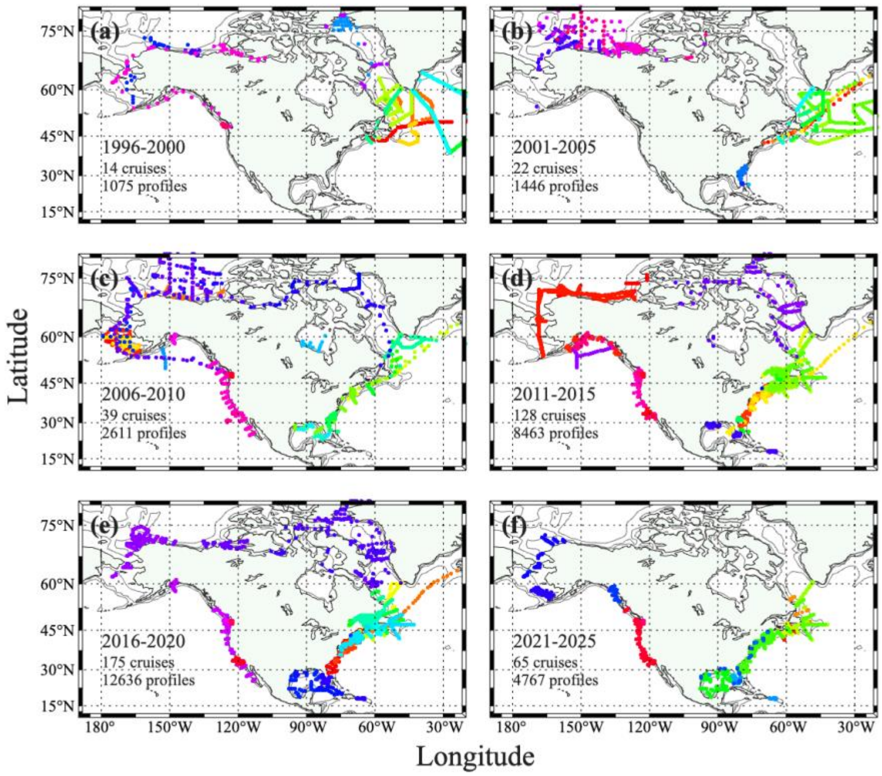

Figure 5. Temporal distribution and data density of observations across defined decade-scale time bins from 1996 to 2025. Panels illustrate the total number of cruises grouped within six distinct multi-year operational blocks, showing a substantial expansion in data volume after 2010. Individual cruises within each time bin are differentiated by color.

6 Data availability

The Coastal Ocean Data Analysis Product for North America Version 2026 is available as a merged data product in the formats of CSV, MATLAB, and NetCDF [https://doi.org/10.25921/h2ff-9d66, NCEI Accession: 0315529], and can be accessed with the link: https://www.ncei.noaa.gov/data/oceans/ncei/ocads/metadata/0315529.html (Yoo et al., 2026). This dataset was produced by NOAA and is not subject to copyright protection in the United States. NOAA waives any potential copyright and related rights in these data worldwide through the Creative Commons Zero 1.0 Universal Public Domain Dedication (CC0-1.0).

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Missing values are encoded as −999 in the CSV and NetCDF files, whereas NaNs are used in the MATLAB file. To reduce file size and facilitate efficient access, data in the NetCDF file are stored in single precision. In both the NetCDF and MAT files, each cruise is assigned a unique Cruise_key, defined as a sequence of consecutive integers starting from 1, with each key corresponding to the associated string identifiers for each cruise: "EXPOCODE", "Cruise_ID", and "Cruise_flag". The original cruise data files are summarized in a web-based table, with links provided for direct access to each dataset: https://www.ncei.noaa.gov/access/ocean-carbon-acidification-data-system/synthesis/CODAP-NAv2.html.

7 Summary and conclusions

This study presents CODAP-NA Version 2026, a substantially expanded synthesis of discrete biogeochemical measurements from North America's coastal oceans, representing a major increase in both geographic coverage and data volume relative to the original release (Jiang et al., 2021). The most notable expansion in spatial coverage occurs along the Canadian Arctic margins, including the Gulf of St. Lawrence, the Labrador Sea, and Baffin Bay. Building on the foundation of Version 2021, this updated product was assembled through rigorous quality-control procedures conducted in close collaboration with data providers, incorporating newly available cruise observations and extending spatial and temporal coverage across all North American continental shelves. The growth in data volume is primarily driven by the inclusion of datasets collected by Canadian scientists, along with a substantial increase in data availability that began in the late 1990s and has continued through 2024. The updated product now contains an extensive archive of 31,864 discrete chemical oceanographic profiles, comprising 196,421 data points collected across 446 research cruises. The temporal coverage was expanded from 2003–2018 to 1981-2024. This evolution underscores the product's role as a comprehensive regional monitoring tool that extends beyond continental shelves into large estuaries, continental slopes, and the adjacent open oceans.

Author contribution:

All authors contributed to the writing of the manuscript. L-QJ secured the funding, coordinated the overall project, and designed and developed the quality control (QC) tools used for the QC process. HY led the data quality control and validation process, and prepared the initial draft together with L-QJ. CL developed and implemented the code for correcting CTD oxygen measurements from Winkler oxygen data and led the quality control of the CTD oxygen observations. RW, DP, LB, CWH, SRA, NMM, IY, NM, EO, BC, KAS, DM, and CL contributed the primary datasets, assisted in developing the QC strategy, and provided technical guidance throughout the product development.

Competing interest

The authors declare that they have no conflict of interest.

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