A high-resolution synthesis dataset for multistressor analyses along the U.S. West Coast

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Abstract. The global trends of ocean warming, deoxygenation, and acidification are not easily extrapolated to coastal environments. Local factors, including intricate hydrodynamics, high primary productivity, freshwater inputs, and pollution, can exacerbate or attenuate global trends and produce complex mosaics of physiologically stressful or favorable conditions for organisms. In the California Current System (CCS), coastal oceanographic monitoring programs document some of this complexity; however, data fragmentation and limited data availability constrain our understanding of when and where intersecting stressful temperatures, carbonate system conditions, and reduced oxygen availability manifest. Here, we undertake a large data synthesis to compile, format, and quality-control publicly available oceanographic data from the U.S. West Coast to create an accessible database for coastal CCS climate risk mapping, available at the National Centers for Environmental Information (Accession 0277984) under the DOI 10.25921/2vve-fh39 (Kennedy et al., 2023). With this synthesis, we combine publicly available observations and data contributed by the author team from synoptic oceanographic cruises, autonomous sensors, and shore samples with relevance to coastal ocean acidification and hypoxia (OAH) risk. This large-scale compilation includes 13.7 million observations from 66 sources and spans from 1949 to 2020. Here, we discuss the quality and composition of the synthesized dataset, the spatial and temporal distribution of available data, and examples of potential analyses. This dataset will provide a valuable tool for scientists supporting policy- and management-relevant investigations including assessing regional and local climate risk, evaluating the efficacy and completeness of CCS monitoring efforts, and elucidating spatiotemporal scales of coastal oceanographic variability.

1 Introduction

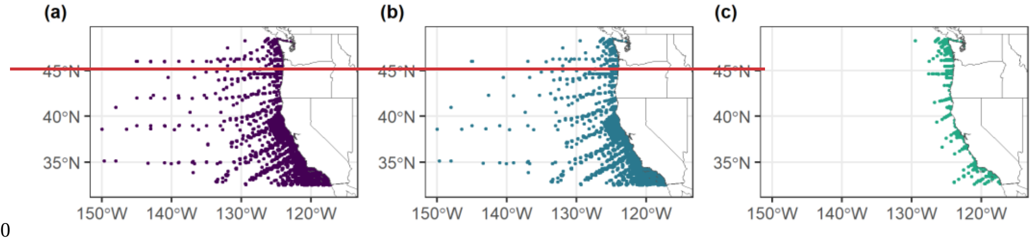
Anthropogenic carbon dioxide (CO_2) emissions are causing dramatic ocean warming, acidification, and deoxygenation (Caldeira and Wickett, 2003; Doney et al., 2009; Doney 2010; Levitus et al., 2012). Interactions among these stressors can compound the severity of each, often synergistically reducing growth, metabolism, and survival of marine organisms across diverse taxa (e.g., Byrne and Przeslawski, 2013; Gobler and Baumann, 2016). Multiparameter extreme events are increasingly common and destructive (Burger et al., 2013; Breitburg et al., 2015). However, global ocean trends may be masked, modified, or overshadowed in coastal ecosystems by combinations of complex local oceanographic processes, terrestrial runoff, freshwater sources, and high local productivity (Borges and Gypens, 2010; Cai et al., 2011; Fassbender et al., 2011; Frieder et al., 2012; Bauer et al., 2013; Takeshita et al., 2015). Despite thorough documentation of global ocean responses to anthropogenic forcing, understanding more localized conditions in coastal environments, such as the California Current System (CCS), remains an active area of research. Improved understanding of spatiotemporal patterns of warming, deoxygenation, and acidification is key to informing climate resilience and adaptation planning for and by the diverse peoples and ecological communities that depend on the coastal CCS (Field and Francis, 2006; Hodgson et al., 2018; IPCC 2019; Weisberg et al., 2020; Ward et al., 2022).

The CCS is an upwelling system where seasonal winds transport cold, low-oxygen, high-CO_2 waters from depth up to nearshore surface environments (e.g,. Hickey, 1979; Huyer, 1983; Chavez and Messié, 2009). Upwelling intensity varies across small spatial and temporal scales and is typically concentrated in the spring and early summer (Hickey, 1979; Marchesiello et al., 2003; Garciá-Reyes and Largier, 2012; Jacox et al., 2018; Cheresh and Fiechter, 2020). During upwelling, extreme values of seasonal dissolved oxygen (DO) and carbonate chemistry parameters such as pH are naturally close to biologically significant thresholds, making organisms in the CCS particularly vulnerable to ocean acidification and hypoxia (OAH) events (e.g., Chan et al., 2008; Connolly et al., 2010; Feely et al., 2008; Gruber et al., 2012; Low et al., 2021; Kekuewa et al., 2022). Local adaptation to high environmental variability may provide some ecological resilience (e.g., Sanford and Kelly, 2011; Kelly and Hofmann., 2013; Donham et al., 2023), but widespread die-offs are already a feature of some OAH events (e.g., Grantham et al., 2004; Barton et al., 2015). The CCS is also vulnerable to warming and heatwaves (Cavole et al., 2016; Frölicher and Laufkötter, 2018; Rogers-Bennett and Catton, 2019; Sanford et al., 2019; Fumo et al., 2020; Cheung and Frölicher, 2020; Free et al., 2023). When extreme temperatures interact with low pH and low oxygen conditions, they can compound the vulnerability of organisms to environmental stressors (e.g., Kroeker et al., 2013; Swiney et al., 2017; Bednaršek et al., 2019; Howard et al., 2020b; Sunday et al., 2021). The balance between local upwelling intensity, warming-induced stratification, and both oceanic and terrestrial influences creates a spatiotemporal mosaic of coastal ocean conditions which, while previously acknowledged and documented (e.g., Feely et al., 2016a, Chan et al., 2017; Cheresh and Fiechter, 2020), remains incompletely described.

As a result of the connections between upwelling, low oxygen, and acidification events, models predict the CCS's vulnerability to extreme events will increase as climate change progresses (Gruber et al., 2012; Bakun et al., 2015). Relative to a preindustrial baseline, anthropogenic forcing has shallowed the depths of perennially corrosive and hypoxic conditions by more than 50 m (Bograd et al., 2008; Feely et al., 2008; Chan et al., 2008; Gruber et al., 2012). Modeled projections of the CCS suggest that pH levels are declining sufficiently swiftly that by 2035, the range of annual variability may no longer overlap with conditions present in the 2010s while the calcium carbonate mineral aragonite could be perennially undersaturated at 100 m depth by 2045 (Hauri et al., 2013; Marshall et al., 2017). Meanwhile, nearshore DO content is expected to decline by 10-20 µmol kg^{-1} by the end of the century (Siedlecki et al., 2021). Upwelling-favorable winds may intensify under future warming (Sydeman et al., 2014; Bakun et al., 2015; Wang et al., 2015); although this effect may be counteracted in some locations by increased stratification of seawater layers (Howard et al., 2020a; Siedlecki et al., 2021) or in areas where wind-driven upwelling is not the dominant process (Garciá-Reyes and Largier, 2010). These competing forces might enhance the disparities between climate hot spots and refugia, underlining the importance of gathering and analyzing climate data with high spatiotemporal resolution.

Despite recognition of the complexity of CCS coastal climate stress, successfully capturing mesoscale, sub-seasonal, and very nearshore patterns of OAH and warming remains challenging. One impediment to unraveling this complexity is the decentralized and non-standardized nature of much OAH monitoring in the CCS, undertaken by governmental, non-profit, and academic centers with varying methodologies and approaches to data accessibility (Taylor-Burns et al., 2020). Further, existing synthesis datasets are not optimized for simultaneous analysis of nearshore warming, deoxygenation, and acidification risks (e.g., Hofmann et al., 2011; Sharp et al., 2022). For chemical oceanographers and modelers, the Surface Ocean CO$_2$ Atlas (SOCAT, Sabine et al., 2013; Bakker et al., 2016) and Coastal Ocean Data Analysis Product in North America (CODAP-NA, Jiang et al., 2021) are also valuable resources. However, the former includes only surface seawater observations of one ~~principle~~ principal parameter of the carbonate system, while the latter includes only discrete bottle observations from oceanographic cruises while excluding autonomous sensor~~s~~ observations and shore samples. SOCAT and CODAP-NA are high-quality and extremely well-curated, but the cost of their selectivity is that many available CCS OAH observations are not available through those compilations. In addition, there are a suite of nearshore ocean acidification, hypoxia, and temperature focused data collection efforts that use a variety of sensors and sampling techniques and have not yet been standardized or integrated. A deliberate synthesis of OAH-relevant datasets with standardized formatting and quality control maximizes our ability to explore, map, and resolve coastal climate stress on sub-regional scales (Bushinsky et al., 2019; Chan et al., 2019). By including both discrete and validated autonomous sensor observations across depths and targeting all carbonate system and OAH-relevant parameters, this synthesis can complement the strengths of tightly focused compilations such as SOCAT (Bakker et al., 2016) and CODAP-NA (Jiang et al., 2021). Additionally, by applying uniform QC standards and formatting to data across the CCS, this compilation builds on the usability, reliability, and spatiotemporal scale of currently available public nearshore compilations (e.g., Ruhl et al., 2021).

Here, we present the Multistressor Observations of Coastal Hypoxia and Acidification (MOCHA) synthesis, the highest resolution OAH-relevant U.S. West Coast dataset to date. MOCHA is a compilation of published nearshore temperature, dissolved oxygen, and carbonate chemistry-relevant datasets for the CCS and is newly archived and available at the National Centers for Environmental Information (NCEI, https://doi.org/10.25921/2vve-fh39; Kennedy et al., 2023) along with associated metadata and quality assurance in adherence with the FAIR data management principles (Wilkinson et al., 2016). We source published data from within U.S. waters from oceanographic cruises, buoys, moorings, and shore samples as well as previously unpublished observations contributed by the author team, and present them in a formatted, quality-controlled, downloadable database for easy access and analysis by scientific teams across disciplines (Fig. 1). While this synthesis ~~dataset~~ is not exhaustive, it highlights real disparities in oceanographic monitoring intensity and provides future investigators the opportunity to compare and integrate their own datasets. This data compilation includes 13.7 million observations from 66 ~~data~~ sources and spans from 1949-2020. To illustrate some of the synthesis product's potential uses, we further include and discuss several "case examples" that ~~focusing on very nearshore, shallow data, as these~~ showcase the largest portion of the MOCHA dataset and its complementary strengths to SOCAT and CODAP-NA. However, we note that the compilation includes records at depth and those extending hundreds of kilometers offshore. It is our hope that this synthesis product supports scientific investigations at a wide range of spatial and temporal scales and allows investigators to link between shallow and nearshore or coastal and oceanic environments. ~~While this dataset is not exhaustive, it highlights real disparities in oceanographic monitoring intensity and provides future investigators the opportunity to compare and integrate their own datasets.~~ We anticipate that this synthesis product will be broadly useful to OAH-focused investigative teams and particularly impactful for coastal scientists investigating policy- and management-relevant projects, such as investigating spatiotemporal variation in marine climate risk from OAH events and warming, evaluating the efficacy and completeness of CCS monitoring efforts, linking oceanographic conditions to coastal social or socio-economic considerations across large geographic ranges (e.g., Ward et al., 2022), evaluating spatial management zones such as aquaculture sites (Clements and Chopin, 2016) and marine protected areas (e.g., Hamilton et al., 2003), and pursuing other questions of interest to coastal communities.



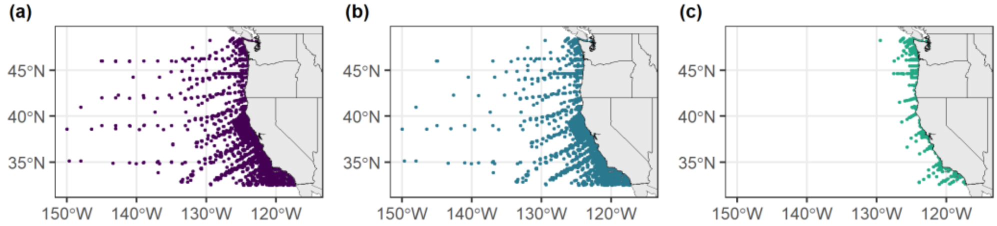


Figure 1: All individual locations for temperature (a), dissolved oxygen (b), and pH (c) observations included in this synthesis along the U.S. West Coast. The pH extent fully captures the extent of all other carbonate system parameters. These figures overstate the useful spatial density of these data, as many individual locations have only been sampled once, but highlight the limited scale of available carbonate system observations relative to more commonly assessed parameters like temperature and dissolved oxygen.

2. Methods

2.1 Data Sources and Types

This project compiled published and publicly available data, as well as previously unpublished data contributed by the author team, including multiparameter OAH-relevant observations from shipboard discrete water samples, *in-situ* autonomous sensors, and shore-collected samples from along the U.S. West Coast. We primarily sourced multiparameter data through existing public data portals, such as NCEI and the Ocean Observing Systems portals, but additionally contacted colleagues to request their assistance in locating additional datasets, presented the project at conferences and management meetings to collect community feedback on included datasets, and scanned published literature that likely included relevant datasets. We prioritized datasets that included carbonate system or dissolved oxygen observations in addition to temperature. When available alongside our target parameters, we also incorporated published chlorophyll and nutrient contents. In all cases, we took the published or publicly hosted data as our starting point, rather than asking for ~~the~~ unprocessed data from the original investigators, then applied additional quality-control measures described in Sect. 2.4. We have limited this publication to data collected before 2020 and ~~data collected~~ within U.S. waters, but we will continue to incorporate new observations according to the methods outlined below, where possible, and will periodically make updated versions of this synthesis dataset publicly available at NCEI (https://doi.org/10.25921/2vve-fh39; Kennedy et al., 2023) as support becomes available.

The data in this synthesis come~~s~~ from a wide array of observational methods and instruments. We screened carbonate system datasets before incorporating them following the discussions of method reliability summarized in Martz et al., (2015). The carbonate system observational methods~~–~~ adhere to one of the following observation methods~~included in this synthesis dataset are~~: (1) discrete seawater samples, preserved at the time of collection and analyzed in a lab with established standards and techniques (e.g., Dickson and Sabine, 2010), of pH, total alkalinity (TA), and dissolved inorganic carbon (DIC); (2) pH measurements from ion-sensitive field-effect transistor-based autonomous sensors (e.g., Honeywell Durafet; Martz et al., 2010) or spectrophotometric sensors (e.g., SAMI-pH; Lai et al., 2018); and (3) pCO_2 measurements from autonomous equilibrium-based infrared gas analyzers (e.g., MAPCO2; Sutton et al., 2014) or spectrophotometric methods (e.g., SAMI-CO2; Schar et al., 2009). We did not include pH measured on glass electrode sensors, due to known issues with precision and calibration (Martz et al., 2010). We discarded any dissolved oxygen and carbonate system datasets that lacked accompanying temperature data. While we preferred carbonate system observations that also included salinity measurements, we retained pH and pCO_2 data without concurrent salinity measurements if they passed all other QC checks (e.g., Chan et al., 2017; Donham et al., 2023). Data collection methods are available for all parameters except temperature and salinity and have been simplified into four groups: 1) “discrete”, for bottle-collected samples analyzed in a laboratory, 2) “CTD” for observations from ship-side profiles with autonomous sensor arrays, 3) “autonomous sensors”, for stationary instruments collecting data at pre-programmed intervals, and 4) “handheld sensors” for observations collected in the field via a glass-electrode probe. The specific instruments associated with each data source are available in the dataset metadata table in the Supplemental Information and archived at NCEI, Accession 0277984 (MOCHA_metadata_table_v2.csv; Kennedy et al., 2023).

2.2 Formatting

After identifying a dataset of interest, we downloaded all available processed data and metadata, including descriptive papers, primary investigator information, project and instrument descriptions, and the original source of the data. Each dataset was assigned a unique identifying number to ensure that every data point could be quickly associated with its parent data source and metadata (Table 1). For all datasets, we retained a copy of the original published data. We manipulated each original dataset into a comma-separated file with minimal alterations - typically limited to eliminating extra header rows and streamlining column names - before transferring datasets into R or Python for further formatting to ensure that all manipulations were trackable.

This synthesis dataset is structured such that each row represents an oceanographic observation from a shared time, depth, location, and data source~~,~~ which may include one or more individual parameter measurements. Parameter measurements are grouped ~~linked~~ with the parameter collection method, such as “discrete” or “autonomous sensor”, and the data quality flag in adjacent columns. Additionally, all observations are also accompanied by “sample scheme” and “habitat” columns to facilitate easy data filtering. The sample scheme column classifies each dataset as one of four types: “cruise” for ship-collected samples, “mooring” for autonomous instruments attached to buoys, “intertidal/subtidal autonomous sensor” for shore- or diver-accessed autonomous sensors, and “intertidal/subtidal discrete collection” for water samples collected by hand from a dock or the shore. The habitat column identifies observations “estuarine” if they were collected within semi-restricted lagoons and bays (e.g., Humboldt Bay). All other observations are labeled as ~~, or~~ “oceanic” ~~otherwise~~. For a full description of included parameters, refer to the submission metadata archived at NCEI (SubmissionForm_carbon_v1_428.csv; Kennedy et al., 2023) and the dataset metadata table in the Supplemental Information.

We retained all directly measured chemical oceanographic observations as we incorporated each dataset, converted observations to standard units if necessary, and mapped them directly to our corresponding synthesis dataset columns. Fortuitously, all pH observations ingested into this compilation were already reported on the total pH scale.~~,~~ When necessary, ~~but w~~we converted discrete pH observations reported at 25°C to *in-situ* conditions using accompanying temperature, salinity, pressure, carbonate-system, and nutrient contents~~conditions~~ using the R package seacarb (Gattuso et al., 2023). We used the following constants for these calculations: K_1 and K_2 from Lueker et al. (2000), K_f from Perez and Fraga (1987), K_S from Dickson (1990), and total boron concentrations from Uppstrom et al., (1974). ~~recommended constants for the temperature and salinity and nutrient data as available (Gattuso et al., 2023).~~ We did not retain published data calculated from algorithms or empirical relationships, such as TA calculated from a TA-salinity relationship or pH derived from temperature, salinity, and DO measurements (e.g., Alin et al., 2012). While we note that published data may have been summarized or filtered by the initial investigators, we did not further summarize or filter data before including it in this compilation except for the Ocean Observatories Initiative (OOI) moorings (dataset 66) discussed below.

ID	Dataset	Primary location	Sampling scheme	Habitat	Parameters	Citation
1	Sea-surface water temperature, Santa Barbara Harbor	Santa Barbara LTER, CA	Intertidal/Subtidal discrete collection	Oceanic	T	Carter et al., 2021
2	National Data Buoy Center Station BDXC1	Bodega Head, CA	Mooring	Oceanic	T, S, Chl	National Data Buoy Center, 2023
3	Mid-water SeaFET and CO_2 system chemistry at Alegria (ALE)	Santa Barbara LTER, CA	Mooring	Oceanic	T, S, pH, TA	Santa Barbara Coastal LTER et al., 2018
5	West Coast Ocean Acidification Cruise 2016	West Coast of the U.S.	Cruise	Oceanic	T, S, pH, DIC, TA, DO, Chl, Nuts	Alin et al., 2017
6	National Data Buoy Center	Channel Islands,	Mooring	Oceanic	T, S	National Data Buoy

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	Station 46025	CA				Center, 2023
7	National Data Buoy Center Station 46217	Channel Islands, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
8	National Data Buoy Center Station 46053	Channel Islands, CA	Mooring	Oceanic	T, S	National Data Buoy Center, 2023
9	National Data Buoy Center Station TDPC1	Eureka, CA	Mooring	Oceanic	T, S, DO, Chl	National Data Buoy Center, 2023
10	National Data Buoy Center Station FPXC1	Fort Point, San Francisco Bay, CA	Mooring	Estuarine	T, S Chl	National Data Buoy Center, 2023
11	National Data Buoy Center Station 46221	Santa Monica Bay, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
12	National Data Buoy Center Station 46235	Imperial Beach, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
14	National Data Buoy Center Station 46251	Santa Cruz Basin, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
15	National Data Buoy Center Station ICAC1	Santa Monica, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
16	National Data Buoy Center Station PRYC1	Point Reyes, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
17	National Data Buoy Center Station HBXC1	Humboldt Bay, CA	Intertidal/Subtidal sensor deployment	Estuarine	T, S, DO, Chl	National Data Buoy Center, 2023
18	National Data Buoy Center Station MBXC1	Morro Bay, CA	Mooring	Estuarine	T, S, DO, Chl	National Data Buoy Center, 2023
19	National Data Buoy Center Station MLSC1	Moss Landing, CA	Mooring	Oceanic	T, S, DO	National Data Buoy Center, 2023
20	National Data Buoy Center Station MTYC1	Monterey, CA	Mooring	Oceanic	T, S, DO, Chl	National Data Buoy Center, 2023
21	West Coast Ocean Acidification Cruise 2013	West Coast of the U.S.	Cruise	Oceanic	T, S, pH, DIC, TA, DO, Chl, Nuts	Feely et al., 2015a
22	West Coast Ocean Acidification Cruise 2012	West Coast of the U.S.	Cruise	Oceanic	T, S, DIC, TA, DO, Chl, Nuts	Feely et al., 2016b
23	West Coast Ocean Acidification Cruise 2011	West Coast of the U.S.	Cruise	Oceanic	T, S, pH, DIC, TA, DO, Chl, Nuts	Feely et al., 2015b
24	West Coast Ocean Acidification Cruise 2007	West Coast of the U.S.	Cruise	Oceanic	T, S, DIC, TA, DO, Nuts	Feely et al., 2013

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25	California Cooperative Oceanic Fisheries Investigations (CalCOFI) bottle database (1949 - 2019)	California	Cruise	Oceanic	T, S, DIC, TA, DO, Chl, Nuts	California Cooperative Oceanic Fisheries Investigations (CalCOFI), 2020
26	Applied California Current Ecosystem Studies Partnership cruise observations (2013-2019)	Central California	Cruise	Oceanic	T, S, pH, TA, DO	Davis et al., 2018 *Previously unpublished data contributed by the authors.
27	UC Davis Coastal discrete ocean acidification dataset	West Coast	Intertidal/Subtidal discrete collection	Oceanic	T, S, pH, DIC, TA, DO	Feely et al., 2016a *Previously unpublished data contributed by the authors.
28	Bodega Marine Laboratory ~~weekly~~Weekly Horseshoe Cove discrete shore samples	Bodega Marine Laboratory, CA	Intertidal/Subtidal discrete collection	Oceanic	T, S, pH, DIC, TA, DO	*Previously unpublished data contributed by the authors.
30	Mid-water SeaFET pH and CO_2 system chemistry at Arroyo Quemado Reef (ARQ)	Santa Barbara LTER, CA	Mooring	Oceanic	T, S, pH, TA, DO	Santa Barbara Coastal LTER et al., 2020a
31	Mid-water SeaFET pH and CO2 system chemistry with surface at Mohawk Reef (MKO)	Santa Barbara LTER, CA	Mooring	Oceanic	T, S, pH, TA, DO	Santa Barbara Coastal LTER et al., 2020b
32	Mid-water SeaFET pH and CO2 system chemistry at Santa Barbara Harbor/Stearns Wharf	Santa Barbara LTER, CA	Mooring	Oceanic	T, S, pH, TA, DO	Santa Barbara Coastal LTER et al., 2020c
33	Ocean Margin Ecosystems Group for Acidification Studies (OMEGAS)	West Coast	Intertidal/Subtidal sensor deployment	Oceanic	T, pH	Menge et al., 2015
34	EAGER Project: pH/pCO2-sensing mooring platform on the Oregon coast	Oregon	Mooring	Oceanic	T, pCO_2	Chan et al., 2012

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35	NH10 mooring SAMI-CO$_2$ time-series	Oregon	Mooring	Oceanic	T, S, pH, pCO$_2$	DeGrandpre, 2016
36	SB LTER calibration water-sample pH and CO2 system chemistry	Santa Barbara LTER, CA	Cruise	Oceanic	T, S, pH, DIC, TA	Santa Barbara Coastal LTER et al., 2022
37	Bodega Marine Reserve monthly shore samples	Bodega Marine Reserve, CA	Intertidal/Subtidal discrete collection	Oceanic	T, S, pH, DIC, TA, DO	*Previously unpublished data contributed by the authors.
39	California Coastal seagrass project	California	Intertidal/Subtidal sensor deployment	Varies by site	T, S, pH, TA, DO	Ricart et al., 2021
40	California kelp forest tidal FET sites	California	Intertidal/Subtidal sensor deployment	Oceanic	T, pH, DO	Kroeker et al., 2023
41	NOAA Northwest Pacific harmful algal bloom program cruise SH1709	Washington and Oregon	Cruise	Oceanic	T, S, DIC, TA, DO, Nuts	Alin et al., 2019
42	Oceanographic cruise calibration and validation samples of California Current Ecosystem	Southern California Bight	Cruise	Oceanic	T, S, DIC, TA, DO, Chl, Nuts	Send et al., 2016
43	CCE1 mooring pCO$_2$ time-series	Point Conception, CA	Mooring	Oceanic	T, S, pH, pCO$_2$, fCO$_2$, DO	Sutton et al., 2016b
44	CCE2 mooring pCO$_2$ time series	Point Conception, CA	Mooring	Oceanic	T, S, pH, pCO$_2$, fCO$_2$, DO	Sutton et al., 2012
45	CeNCOOS in situ water monitoring data at Trinidad Head, California	Trinidad, CA	Intertidal/Subtidal sensor deployment	Oceanic	T, S, DO, Chl	Shaughnessy, 2023
46	SFSU Estuary and Ocean Science Department YSI	Tiburon Peninsula, CA	Intertidal/Subtidal sensor	Estuarine	T, S, Chl	Dewitt, 2022
47	CeNCOOS water monitoring data at the Santa Cruz municipal wharf	Santa Cruz, CA	Intertidal/Subtidal sensor deployment	Oceanic	T, S, DO, Chl	Kudela, 2020

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49	San Francisco Estuary Institute and the Aquatic Science Center Regional Monitoring Program	San Francisco Bay, CA	Cruise	Estuarine	T, S, DO, CHl	Bezalel et al., 2021
50	West Coast Estuary Data: Santa Monica Bay	Santa Monica	Mooring	Oceanic	T, S, pH, pCO_2, DO	Rosenau et al., 2021a
51	West Coast Estuary Data: San Francisco Bay	SF Bay	Mooring	Estuarine	T, S, pH, DO, Chl	Rosenau et al., 2021a
52	Validation discrete observations for the Cha Ba mooring	La Push, WA	Cruise	Oceanic	T, S, DIC, TA, Nuts	Alin et al., 2016
53	Morro Bay BM1 T-Pier (NOAA Station MBXC1)	Morro Bay, CA	Mooring	Estuarine	T, S, pH, DO, Chl	Walter, 2023
54	Morro Bay BS1 Station	Morro Bay, CA	Mooring	Estuarine	T, S, pH, DO, Chl	California Polytechnic State University, 2023
55	Cape Elizabeth mooring MAPCO2 time-series	Cape Elizabeth, WA	Mooring	Oceanic	T, S, pH, pCO_2, fCO_2, DO	Sutton et al., 2013
56	Stillwater Cove TidalFET	Carmel, CA	Intertidal/Subtidal sensor deployment	Oceanic	T, S, pH, DO	Donham, 2022a
57	National Data Buoy Center Station 46211	Grays Harbor, WA	Mooring	Oceanic	T	National Data Buoy Center, 2023
58	National Data Buoy Center Station NEAW1	Neah Bay, WA	Mooring	Estuarine	T	National Data Buoy Center, 2023
59	National Data Buoy Center Station CECC1 – 9419750	Crescent City, CA	Intertidal/Subtidal sensor deployment	Oceanic	T	National Data Buoy Center, 2023
60	National Data Buoy Center Station 46237	San Francisco, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
61	National Data Buoy Center Station 46240	Monterey Bay, CA	Mooring	Oceanic	T	National Data Buoy Center, 2023
62	National Data Buoy Center Station PORO3	Port Orford, OR	Mooring	Oceanic	T	National Data Buoy Center, 2023

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63	National Data Buoy Center Station CHAO3	Charleston, OR	Mooring	Estuarine	T	National Data Buoy Center, 2023
64	CB-06 mooring MAPCO2 time-series	Coos Bay, OR	Mooring	Oceanic	T, S, pH, pCO_2, fCO_2, DO, Chl	Sutton et al., 2019
65	NH10 mooring MAPCO2 time-series	Newport, OR	Mooring	Oceanic	T, S, pH, pCO_2, fCO_2, DO, Chl	Sutton et al., 2016a
66	Ocean Observatories Initiative (OOI) Washington and Oregon inshore and shelf moorings	Washington and Oregon	Mooring	Oceanic	T, pH, DO	NSF Ocean Observatories Initiative, 2022
67	Trinidad Head Line CTD Hydrography	Northern California	Cruise	Oceanic	T, S, pH, DO	Bjorkstedt, 2023
68	Newport Hydrographic Line CTD casts 1997–2021	Central Oregon	Cruise	Oceanic	T, S, DO	Risien et al., 2022b
69	Oregon's Marine Reserve mooring	Oregon	Mooring	Oceanic	T, DO	Aylesworth et al., 2022
70	CMOP Saturn-02 mooring	Columbia River Estuary, OR	Mooring	Estuarine	T, S, DO	Columbia River Intertribal Fish Commission Center for Coastal Margin Observation and Prediction, 2023
71	Monthly cross-shore transects of biogeochemical properties in La Jolla, CA	Southern CA	Cruise	Oceanic	T, S, pH, DIC, TA, DO, Nuts	Kekuewa and Andersson, 2022

Table 1: Overview of the included data sources in the MOCHA compilation. Potential measured parameters for each dataset include temperature (T), salinity (S), pH, partial pressure of CO_2 (pCO_2), fugacity of CO_2 (fCO_2), dissolved inorganic carbon (DIC), total alkalinity (TA), dissolved oxygen (DO), chlorophyll-A (Chl), and nutrients (Nuts). Users need to be mindful of the difference between climate-quality and weather-quality datasets and assess the suitability of these datasets for their needs (Newton et al., 2015). The origins of all the included datasets in this compilation are further described in the dataset metadata table available in the paper Supplement and archived at NCEI (https://doi.org/10.25921/2vve-fh39, dataset_metadata_table_v2.csv, Kennedy et al., 2023). Additional, detailed discussions of the following datasets have been previously published: 5 (Feely et al., 2008); 21-24, 26 (Feely et al., 2016a); 25 (Bograd et al., 2003); 26 (Davis et al., 2018); 33 (Chan et al., 2017); 49 (Salop and Herrmann, 2019); 50 and 51 (Rosenau et al., 2021b); 56 (Donham et al., 2022b); 66 (Trowbridge et al., 2019); 67 (Bjorkstedt and Peterson, 2015); 68 (Risien et al., 2022a); 69 (Barth et al., 2021); 70 (Baptista et al., 2015); and 71 (Kekuewa et al., 2022).

2.3 Dataset 66: Ocean Observatories Initiative (OOI) Moorings

The Washington and Oregon OOI mooring data (dataset 66) included millions of observations of temperature, salinity, dissolved oxygen, pH, and pCO_2 at sub-minute resolutions. The size of these datasets required us to aggregate the data to

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daily mean values before incorporation into the larger synthesis dataset. Because many~~uch~~ of these~~is~~ OOI data had not been previously quality controlled, we contacted OOI staff for their guidance on initially filtering the raw data before aggregation. They provided extensive code developed by the sensor manufacturers and OOI staff to identify erroneous pH and DO data from the raw publicly available streams, available at https://github.com/oceanobservatories/ooi-data-explorations/tree/master/python, as well as significant protocol guidance that has since been made public (Palevsky et al., 2022). OOI staff also provided access to discrete sample analyses taken at the sensor moorings to further ground-truth measurements. We only retained data for aggregation if it 1) passed through the provided OOI code's automated checks, 2) had discrete samples associated with the beginning and end of that sensor's deployment, 3) the daily mean sensor values for DO and pH on the day of discrete sampling were within 20 μmol kg^{-1} of the discrete sample dissolved oxygen and/or 0.05 pH units, and 4) displayed reasonable DO content and pH values and variance over time, following OOI's suggested protocols for both automated and "human in the loop" quality control practices (Palevsky et al., 2022). We eliminated all DO data collected prior to 2018 based on advice of OOI staff because the DO sensors prior did not have adequate biofouling control. We then aggregated these data into daily mean values before formatting and quality controlling them further following the practices described for all other incorporated datasets and described in Sect 2.4.

2.4 Quality Control

After formatting individual datasets, we checked all observations to standardize quality across data~~-~~sets and to avoid using questionable data~~ points~~ in future analyses. This quality standardization did not extend to raising all datasets to a "climate-quality" standard (Newton et al., 2015). Users of these data should be aware of the difference between climate-quality versus weather-quality data, as both types of data are included in this synthesis and often coexist within the same datasets. Our quality assurance/quality control (QA/QC) methods drew from a combination of the publishing authors' notes, plots of the data, and expert knowledge of the CCS. The majority of our incorporated datasets had been previously published and subjected to at least automated QA/QC processes, but additional "human in the loop" secondary QC was necessary for almost all datasets, particularly those from autonomous sensors (Pavlevsky et al., 2022). Incoming quality-control notes associated with each data source ranged widely, though most datasets that did include quality information followed the Quality Assurance/Quality Control of Real-Time Oceanographic Data (QARTOD) system, which assigns flags based on internal instrument checks, data reasonableness, and collection method (Bushnell 2018). Given the variability in flagging schemes that incorporated datasets used and the impossibility of accurately assigning detailed QARTOD-style flags to datasets that did not include similarly detailed notes, we opted to create a simpler, three-level quality scheme that could be applied to all datasets~~ could be easily mapped to~~. Using available existing QA/QC information and our further quality control investigations, we categorized each individual parameter measurement~~data point~~ as one of three confidence levels: 1 for "plausible and reasonable" data, 2 for data that we had not assessed, and 3 for "low quality or unreliable" data. We flagged all data the publishing authors had listed as unreliable or suspect with a 3. Regardless of published notes, we assigned all other observations a flag of 2 before further evaluation by our team.

Given the diversity of the datasets and projects this synthesis draws from, we examined each dataset individually using a combination of plots tailored to maximize our ability to identify and evaluate anomalies in that dataset's specific oceanographic and spatiotemporal context. Given that this synthesis primarily sourced published data, we erred towards retaining data as "plausible", rather than following a more stringent flagging philosophy. We recommend that investigators perform additional QC with the MOCHA dataset targeted towards their project requirements. Common quality control plotting techniques included property-property plots of temperature, salinity, DO, pH, TA, and DIC against one another; single-parameter time series from sensor and long-running datasets; and map views and oceanographic cross sections of synoptic cruise data. We examined questionable data through as many different views as possible, such as examining apparent outliers in a temperature-salinity property-property plot individually in their respective time series, to ensure that we were not flagging real or plausible observations. When possible, we further evaluated suspicious observations against other datasets collected nearby. We discussed all data flagging decisions with at least three project members. After this focused quality control, all observations not flagged as "low quality or unreliable" (3) were upgraded to our "plausible and reliable" flag (1) with the exception of 300 surf zone DO measurements taken from shore, which were left as "unevaluated" (2) since they do not reflect oceanic conditions ~~(2)~~. All subsequent mapping and analysis with the observed oceanographic values used only "plausible and reliable" data. For a full example of our formatting and flagging practices, please refer to the Supplemental Information.

2.5 Example Subset: Daily Data

High-resolution (sub-daily observations) autonomous sensors are an important component of this synthesis dataset, but the data they produce come~~s~~ with significant computational costs. Furthermore, variability on the scales of hours or minutes captured by such high-resolution records is less comparable to lower-resolution datasets such as those collected over quarterly or annual synoptic oceanographic cruises. To evaluate the spatiotemporal extent of our data coverage, seasonal patterns, and relationships between observed parameters, we created an aggregated summary dataset of daily mean values for each location, depth, and data source. We dropped all questionable individual parameter measurements (i.e., data flagged with a "3" QA/QC code) before creating this summary dataset to ensure that unreliable data did not influence averages. The daily averaging reduced the number of observations (rows) from 13.7 million to 1.2 million as high-resolution sensor datasets, some with observations every 20 minutes, were collapsed into a single row per day. We used this summary dataset in all following example cases that do not explicitly cite "original data." This aggregated summary dataset is available alongside the full MOCHA compilation at NCEI (aggregated_daily_dataset.csv, Kennedy et al., 2023) and we have included the code necessary to recreate it in our public code repository (https://github.com/egkennedy/DSP_public_code).

3 Results and Discussion

3.1 Overall Data Totals

This synthesis dataset includes observations from 66 individual data sources organized across 13.7 million rows ("observations") and 41 columns and spans from 1949-2020. This includes 24.1 million individual parameter measurements, with 13.2 million temperature, 3.6 million salinity, 3.3 million DO, 2.1 million pH, 1.2 million chlorophyll, 561,000 nutrient, 113,000 pCO_2, 9,300 TA, and 8,300 DIC measurements. While we prioritized multiparameter datasets for this effort, our synthesis also includes several temperature-only, high-resolution records to fill specific project needs. The full suite of carbonate system parameters can be directly calculated from 48,000 observations with two reliable carbonate system parameter observations and co-occurring reliable temperature and salinity measurements.

Across sampling schemes, moorings contribute the bulk of the MOCHA observations with 8.9 million rows, followed by intertidal or subtidal autonomous sensors with 3.8 million, oceanographic cruise observations (which include CTD profiles) with 98,000, and finally intertidal and subtidal discrete collections with 24,000. By measurement method, autonomous sensors are the most common, contributing 5 million individual measurements, versus 224,000 individual discrete measurements, 193,000 CTD measurements, and 828 handheld field sensor measurements.

3.2 Aggregated Daily Data Totals

Summarizing the data by day for each dataset, location, and depth provides a clearer picture of the availability of multiparameter data by diminishing the outsized influence of high-resolution temperature sensors. Of the 1.2 million daily averaged observations, just 104,000 are temperature-only. Individual parameter totals are shown in Table 2. Full carbonate system calculations could be performed on 12,000 of the daily observations with measurements of temperature, salinity, and two of the principal~~le~~ carbonate system parameters. As with the disaggregated, full dataset, data totals varied substantially by measurement method and autonomous sensors are still the most common, contributing 643,000 individual daily averaged parameter measurements versus 223,000 discrete, 192,000 CTD, and 816 handheld sensor measurements.

Parameter	**Collection Method**	**Daily Total Observations**	**Overall Reliability Rate**
DO	discrete	199,816	99.7%
	autonomous sensor	563,885	92.4%
	CTD	128,562	99.9%
	handheld sensor	382	93.2%

pH	discrete	4,068	99.6%
	autonomous sensor	78,894	88.7%
	CTD	63,404	100%
DIC	discrete	8,211	99.1%
TA	discrete	8,858	98.2%

Table 2: Overview of dissolved oxygen (DO), pH, dissolved inorganic carbon (DIC), and total alkalinity (TA) observation methods, number of daily observations (grouped by data source, location, and depth), and the overall reliability rates. Autonomous sensors are associated with slightly lower reliability rates due to periods of sensor biofouling or malfunction.

3.3 Flagging and Reliability

The amount of original data flagged as unreliable varied substantially by dataset, parameter, and observation method, but was typically low (Fig. 2). As the bulk of the data in this synthesis product were~~was~~ previously published and had undergone some preliminary QA/QC prior to our incorporation, high reliability rates were expected. Of the dozens of datasets contributing temperature and salinity observations, only one dataset had a parameter flag rate above 5%. Flag rates above 10% were uncommon for all parameters across all datasets, and completely absent for TA and DIC observations. For pH and DO, flag rates within datasets were above 10% for three~~3~~ and eight~~8~~ datasets, respectively. In each case, high rates of "unreliable" data were caused by (1) clear periods of autonomous sensor malfunction, (2) observational methods described by the publishing authors as unreliable, or (3) more rarely, intentionally higher QA/QC standards applied to data which~~that~~ had not been previously screened and published. The vulnerability of autonomous sensors to periods of biofouling or sensor malfunction contributed to higher flag rates relative to other methods, but all four methods were largely reliable (Table 2). Across the entire MOCHA compilation, 99.8% of temperature, 96.8% of salinity, 93.1% of DO, 89.1% of pH, 99.1% of DIC, and 98.2% of TA measurements were considered "reliable or plausible". Across all individual measurements, 97.3% are classified as reliable.

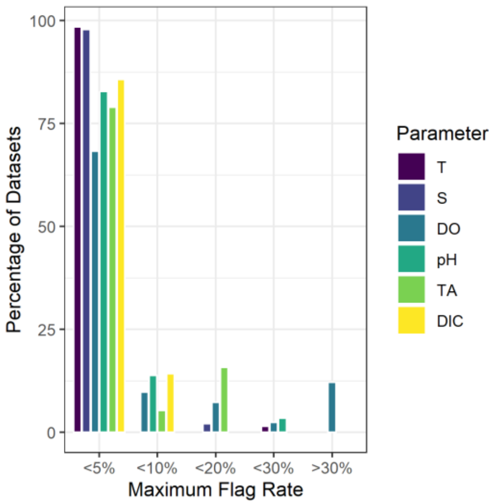

Figure 2: The rate of unreliable ("flagged") observations varied by dataset and parameter measured between temperature (T), salinity (S), dissolved oxygen (DO), pH, total alkalinity (TA), and dissolved inorganic carbon (DIC). Maximum unreliable flag rates were generally low, especially for T and S. All datasets that included measurements with > 30% flag rates used measurement methods described by the original publishers as "not quantitative". Flag rates between 10% and 30% were uncommon but reflected occasional periods of fouling or equipment malfunction in high resolution autonomous sensor datasets or, in rare cases, more stringent standards applied to datasets that had not been previously published and initially quality controlled.

3.4 Spatiotemporal Data Distribution

This dataset spans the U.S. West Coast and reflects the spatiotemporal bias of observational records. Observations are more common in nearshore, near-surface environments and exhibit greater sampling effort in recent years. Fifty-six percent of daily observations were collected within 50 km of shore and 27% within 25 m of the surface. Eighty-six percent of all daily observations were collected after 1990. Carbonate system observations are especially skewed toward recent years, with no measurements of pH, TA, DIC, or pCO_2 in this compilation prior to 2006. By contrast, temperature, salinity, and DO records are common after 1980.

The spatiotemporal coverage of our dataset is highly variable, though generally improves~~ing~~ through time. Mapping the density of observations within 50 km of the coastline and 25 m of the surface through time highlights the influence of dense coastal human populations and major research institutions (Fig. 3). By contrast, the region between 38° N and 44° N is much less densely observed and loses~~t~~ considerable oceanographic monitoring capacity between 2015 and 2020. Temperature and DO measurements have the most extensive coverage but are sparse outside of Southern California before 2000. Salinity measurement density hews closely to the DO distribution and, as such, is not shown here. After 2015, carbonate system observations are limited to a few locations with sporadic coverage north of 39° N which correspond to pH and pCO_2 moorings. Overall, this data compilation demonstrates large spatial and temporal data gaps, which limit our ability to resolve rapid changes in ocean acidification, hypoxia, or warming risk or to contextualize current oceanographic conditions with respect to the recent past.

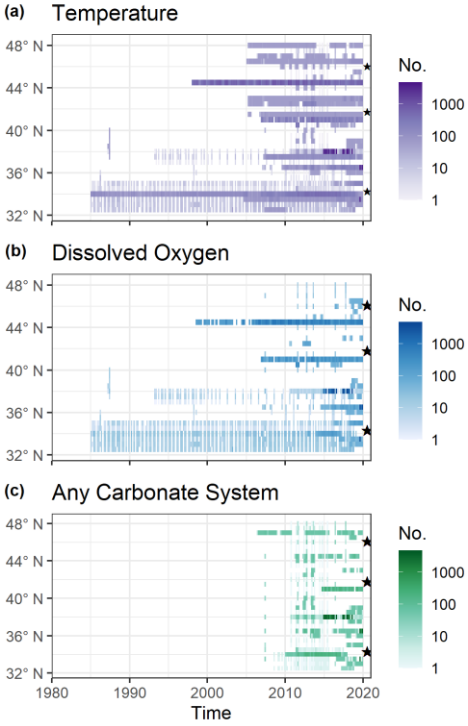

Figure 3: The number of measurements within 50 km of the shore and 25 m of the surface for temperature (a), dissolved oxygen (b), and any carbonate system measurements (c) using two-month, 0.5-degree latitude spatiotemporal blocks. Salinity (not shown) hews closely to the dissolved oxygen distribution. From north to south, stars mark the Washington-Oregon border, the Oregon-California border, and Point Conception (34.5° N). Spatial data coverage was best across all parameters between 2010 and 2015, whereas overall observation quantity was highest between 2015 and 2020. Since 2015, dissolved oxygen and carbonate system measurements have become more concentrated into fewer locations along the coast despite increasing awareness of the risks of nearshore acidification and hypoxia events.

The intra-annual distribution of the daily data is more complex than the interannual distribution (Fig. 4). Temperature, salinity, and DO records are common throughout the year, but have distinct peaks in abundance in April, May, and July through September. Carbonate system records are patchier temporally. Nearly 50% of all TA and DIC observations were taken in May or August, with an additional 19% of observations from September, reflecting the sampling months of the NOAA West Coast Ocean Acidification cruises (Feely et al., 2016a). Between October and April, no single month includes more than 8% of DIC observations or 5% of TA observations. pH observations are more evenly distributed throughout the year, with each~~all~~ month~~s~~ hosting 6-10.5% of the observations except August, which hosts 16%. The concentration of carbonate system observations between May and September is particularly concerning, as upwelling season in Central and Southern California starts in earnest in April (García-Reyes and Largier, 2012; Jacox et al., 2018)~~ and~~ at least two principal carbonate system parameters must be measured to fully constrain the carbonate system (Dickson and Sabine, 2010), so the observational record may be missing significant low pH, low DO events from the early upwelling season.

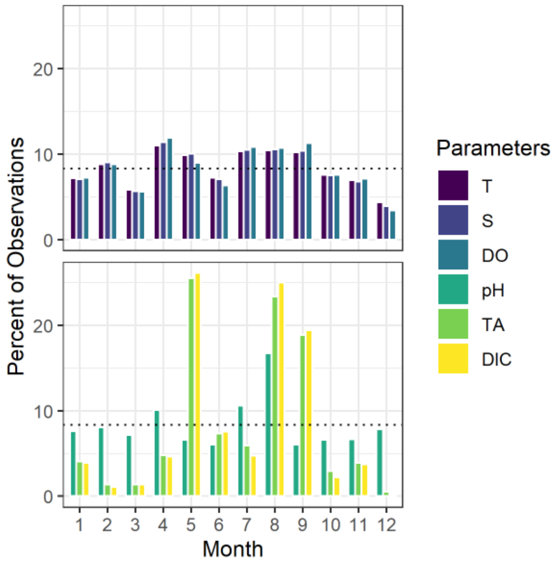

Figure 4: The distribution of daily observations by month varies substantially by parameter relative to an equal split (dashed lines). Temperature (T), salinity (S), and dissolved oxygen (DO) observations are fairly evenly distributed across seasons, with notable observational peaks in April, May, July, August, and September. Carbonate system parameters (pH, total alkalinity or TA, and dissolved inorganic carbon or DIC) are more concentrated in the summer months, with nearly all TA and DIC observations occurring in May, August, or September. Of the carbonate system parameters, only pH observations are nearly equitably distributed throughout the year.

3.6 Oceanographic Analysis Case Examples

3.6.1 Monthly Climatology

This synthesis dataset supports several avenues of investigation of the relationships between OAH parameters. For example, evaluating the variations in monthly climatology across OAH parameters in waters shoreward of the 100 m depth contour shows intriguing differences between regions (Fig. 5). Temperatures rise in all regions during the spring and summer months, peaking between July and September. In Washington and Oregon, peak upwelling occurs between June and August (Bograd et al., 2009; Jacox et al., 2016), which coincides with the period of highest variability and lowest minima for pH and DO observations captured in this synthesis. In both California regions, separated at Point Conception (34.5° N), seasonal surface data are less consistent with the expected upwelling patterns. There, peak upwelling occurs between April and June and is weakest in Southern California (Bograd et al., 2009; García-Reyes and Largier, 2012; Jacox et al., 2016). Somewhat unexpectedly, the lowest median DO and pH observations occur between July and September in both California regions rather than during the months of expected peak upwelling. This trend may reflect intermittent upwelling into the warmer summer months or could be capturing high surface respiration as waters warm; conclusive evidence of either phenomenon requires~~ and invites~~ further investigation. October through March conditions across all West Coast regions are more sparsely~~poorly~~ sampled, but have less variability, cooler mean temperatures, and higher dissolved oxygen content and pH.

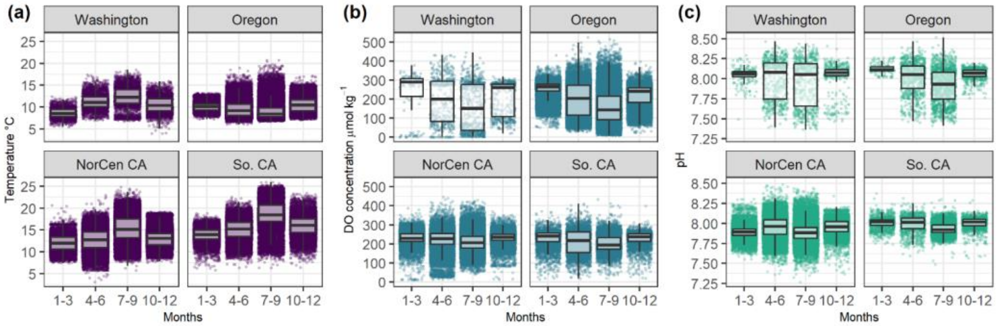

Figure 5: Measurements shoreward of the 100 m bathymetric contour of temperature (a), dissolved oxygen (DO) (b), and pH (c) capture intra-annual and regional variation. The lowest median DO and pH conditions are found with the highest temperatures in late summer, rather than during peak upwelling periods (April – June). Here, California is split into two regions: NorCen CA, spanning the northern border to Point Conception (34.5 N), and So. CA, from Point Conception to the southern border. Ninety-nine percent of the data fall~~s~~ within 30 km of shore and 65% falls within 10 km of shore.

3.6.2 Shallow OAH Events

Nearshore OAH vulnerability information can be particularly important for effective coastal management (Ekstrom et al., 2015; Woodson et al., 2018). Within state waters (< 5 km from shore) in the surface 50 m, there are thousands of co-occurring observations of pH below 7.8 and DO below commonly applied hypoxia thresholds (Fig. 6; e.g., Vaquer-Sunyer and Duarte, 2007; Hoffman et al., 2011). pH conditions below 7.8 can be stressful for many marine organisms (e.g., Byrne and Przeslawski, 2013; Gobler and Baumann, 2016; Bednaršek et al., 2021; Kroeker et al, 2023) and have been observed 8,665 times within 5 km of shore and 50 m of the surface in this data compilation. Of these instances, 65 observations are accompanied by DO contents below the “coastal hypoxia” threshold of 61 µmol kg^{-1} and 400 observations have DO contents below the “mild hypoxia” threshold of 107 µmol kg^{-1} (Hofmann et al., 2011). An additional 220 of these near-surface observations of DO contents below 61 µmol kg^{-1} in state waters have been recorded without accompanying pH information. No simultaneous surface observations of DO and pH record coastal hypoxic conditions with pH levels above 7.8. The low pH, low oxygen observations are most common off the Oregon coast and are typically associated with low temperature upwelling events, but simultaneous mild to moderately hypoxic and low pH conditions are also found occasionally throughout the coast and at a range of temperatures, especially during late summer in semi-restricted estuaries. The few simultaneous observations of DO content and pH suggest that fewer than 1% of observations of low pH (pH < 7.8) in state waters are accompanied by hypoxic water, whereas shallow hypoxic state waters might always be accompanied by low pH conditions. These relationships underscore the importance of multiparameter OAH observations, the clear need for pH monitoring efforts to catch up with DO monitoring efforts, and the potential for even shallow waters to experience extreme conditions.

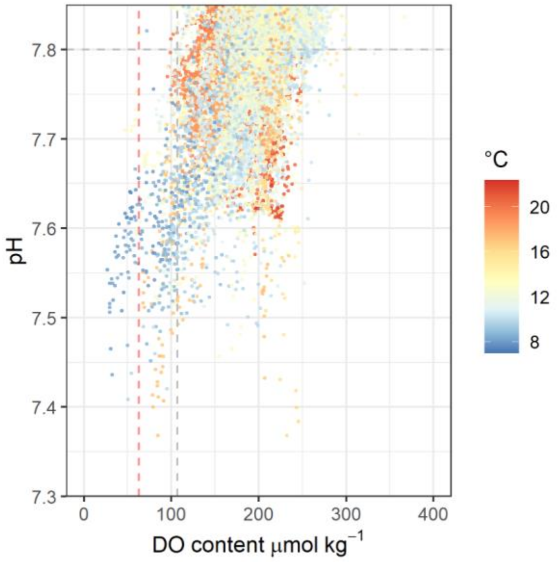

Figure 6: Low dissolved oxygen (DO) and pH conditions are frequently present in state waters (within 5 km of the shore) and 50 m of the surface. pH measurements below 7.8 (grey dashed horizontal line) are common but are more rarely accompanied by mildly hypoxic (< 107 µmol kg^{-1} or 3.5 mg L^{-1} DO, grey dashed vertical line) or hypoxic (< 61 µmol kg^{-1} or 2 mg L^{-1} DO, red dashed vertical line) conditions. Simultaneous low pH, low DO events are typically associated with low temperatures, whereas low pH conditions alone are present across a wide range of temperatures.

3.6.3 Total Alkalinity-Salinity Relationships

As a final example usage, we used the MOCHA synthesis to explore surface (< 25 m depth) TA-salinity relationships along the coast. Developing robust TA-salinity relationships for near-surface, nearshore waters has produced intense interest. Because salinity observations are more readily available in the historical record and relatively cheap to reliably collect, robust TA-salinity relationship or~~ as reliable~~ algorithms allow the full carbonate system to be calculated while only directly measuring one principal~~le~~ parameter;~~,~~ however,~~but~~ these relationships and algorithms can be hampered by nearshore variability (e.g., Fassbender et al., 2017, Davis et al., 2018). We examined surface (< 25 m depth) discrete TA and salinity observations from within 100 km of the shore along the Washington, Oregon, and California coasts and compared the data collected within 2 km of shore to those collected between 2 and 100 km from shore (Fig. 7). Our TA-salinity relationships were very similar when using a 50 km and 100 km cutoff distance and we show the more extensive data here for closer comparisons with previous investigators. Our TA-salinity slopes were not significantly different between any Washington and Oregon regions, though we note that our in our compilation, Washington and Oregon both have very limited discrete TA data within 2 km of shore, which produced~~d~~ large standard errors in the slope terms (4.5 and 3 μmol kg^{-1}, respectively). Our observed offshore Washington TA-salinity relationship of $TA = 42.2 \pm 1.2 \times S + 823$ is more comparable to the Wootton and Pfister (2012) regression, which centered off the Strait of Juan de Fuca, than that from Fassbender et al. (2017). However, we did not correct for seasonal or watershed biases in this example and focus on a more limited stretch of nearshore waters, which may account the differences between our calculated relationships and that of Fassbender et al. (2017).

Each of the two California regions, split at Point Conception (34.5° N), have TA-salinity regressions that are statistically distinct from each other and from both Pacific Northwest regions. The offshore California slope terms are much larger than in the Pacific Northwest region and significantly larger than the Cullison Gray et al. (2011) salinity coefficient of 50.8, particularly our slope for the Northern and Central region (57.4 ± 0.9 μmol kg^{-1}). At a salinity of 33.5, these differences produce an increase in estimated TA of 94.3 μmol kg^{-1} between our calculated Northern and Central California relationship and the Cullison Gray et al. (2011) relationship, which translates to an increase in estimated aragonite saturation of 0.1 at 12℃ and pH = 8.1. The Cullison Gray et al. (2011) relationship was derived from unpublished pCO$_2$ and DIC observations, all taken prior to 2007, so there is limited temporal overlap between our sample sets and any spatial differences in sample area cannot be assessed. The California nearshore region is well-sampled relative to the Pacific Northwest and displays significant variability, potentially reflecting local differences in bedrock or organic alkalinity contributions. The variability in nearshore TA-salinity relationships will continue to present a challenge for coastal communities and state agencies, underscoring the importance of monitoring multiple parameters of the carbonate system in highly nearshore environments.

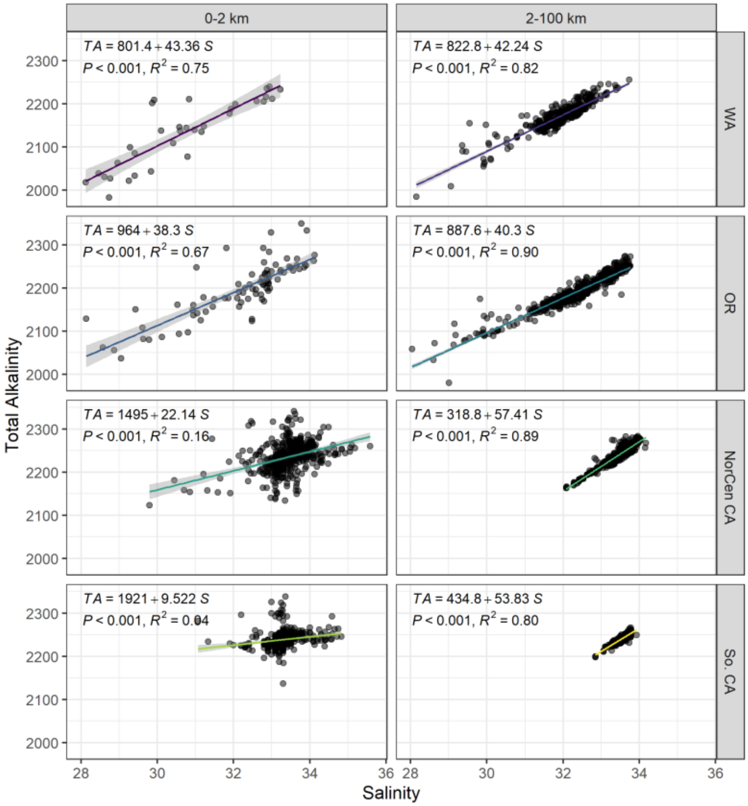

Figure 7: Regional near-surface (< 25 m) total alkalinity (TA)-salinity relationships from 0-2 km from shore and 2-100 km offshore in along the U.S. West Coast. As with Figure 5, the break between northern and southern CA is Point Conception, at 34.5° N. These relationships reflect only direct measurements of salinity and TA on discrete samples with salinity > 28.

3.7 Dataset Limitations

This data compilation reflects reliable, publicly available data, and directly contributes to our ability to map coastal temperature, DO, and carbonate system variation; however, this synthesis also encodes the limitations of the current observational record and the differences in data availability, data scales, and data quality. High resolution autonomous sensors provide excellent temporal resolution for a specific location, but are vulnerable to sensor drift, are not often published with clear calibration records, and are rarely deployed in arrays that fully capture the carbonate system as well as temperature and DO variability. Conversely, discrete samples and CTD profiles from synoptic cruises provide extremely high-precision, multiparameter observations with broad spatial resolution, but are less relatable to high-resolution sensors or hand-collected observations from the surf zone. Carbonate system observation availability has a strong seasonal and spatial bias, with data concentrated in summer months and along coastal population centers. The MOCHA synthesis pulls these distinct data sources into a single synthesis product~~location~~, but we do not claim to have fully resolved the inherent difficulties of combining data of differing quantity, resolution, and quality into a unified picture of the nearshore CCS.

Additional data streams that provide both spatial and temporal resolution could help bridge some of the divides between quality, quantity, and spatial extent in this synthesis and we acknowledge a few such potential data streams here. The temperature and dissolved oxygen records do not include CTD casts from most annual fishery-independent surveys, which could improve spatial resolution at all depths (e.g., Sakuma, 2022). This compilation also excludes some valuable carbonate system data streams, particularly those focused on pCO_2 measurements currently available through SOCAT (Sabine et al., 2013; Bakker et al., 2016). Additional potential carbonate system data sources include pH or pCO_2 records from autonomous gliders (e.g., Chavez et al., 2017) and pCO_2 and DIC records from shore-based monitoring systems (e.g., Burke-o-Lators; Hales et al., 2004; Bandstra et al., 2006). The first would significantly improve the spatial coverage of surface pCO_2 and could improve seasonal bias, but would not have a significant impact on our ability to resolve the full carbonate system or to consider deeper water. Glider datasets would similarly improve our spatial coverage while providing additional information about water column structure. These could represent a valuable expansion to this synthesis, provided calibration records are also available, and will likely be included in updates to this synthesis product (Bushinsky et al., 2019). Shore-based monitoring systems recently deployed by the West Coast OOIs would ~~also~~ be valuable expansions to this synthesis and will also likely be included in an updated product.

4 Conclusions

The CCS is one of the most intensively monitored marine systems in the world, but our ability to accurately resolve the true complexity of coastal climate stress remains limited by data fragmentation, availability, and quality. As interest has shifted from documentation of the global patterns of acidification and hypoxia to more complex coastal environments, the CCS has seen an explosion in monitoring efforts within 50 km of shore in the last 15 years. This expansion has included an increase in both surface and subsurface monitoring efforts, though within 2 km of shore, monitoring efforts below 5 m depth are still much less common than surface observations. While this situation is improving, the continued relative paucity of subsurface nearshore measurements is of particular concern given that mildly hypoxic ($DO < 107$ µmol kg^{-1}) and corrosive conditions have been documented at depths as shallow as 10 m (Kekuewa et al., 2022).

Surprisingly, the U.S. West Coast had especially continuous spatial and temporal coverage of OAH-relevant parameters between 2012 and the beginning of 2015, before a reduction in coverage that lasted through 2020 (Fig. 5). By coincidence, the reduction in DO and carbonate system monitoring in 2015 coincided with the second half of the marine heatwave known as “the Blob”, which stretched from 2014 through 2016 and was associated with higher surface DO and pH (Bond et al., 2015; Siedlecki et al., 2016; Gentemann et al., 2017). Assessing the interactions of an unprecedented marine heatwave with DO and carbonate system conditions lies at the heart of multistressor risk management; however, our ability to resolve both Blob impacts and its recovery was very limited in Northern California and Oregon by the concurrent contraction in oceanographic monitoring. Although the CCS is well monitored compared to many other parts of the world’s oceans, our synthesis here highlights that the patchiness of monitoring projects, often driven by inconsistent funding, has an outsized impact on our ability to utilize those ~~at~~ data to~~–~~ operationally monitor for climate change~~understand how the CCS is changing~~.

While increasing interest in coastal OAH monitoring and the availability of autonomous sensors has markedly enhanced CCS data availability, the frequency and footprints of synoptic oceanographic cruises has decreased in the region. Oceanographic cruises provide highly accurate and spatially broad water column measurements that can bridge the gap between the coastal and open-ocean domains and provide regional contexts for local observations. They also provide some of our only observations near remote portions of the coast. However, nearly all routine oceanographic cruises in the CCS have cut back their footprint, sampling frequency, and depth resolution. The Southern California-based CalCOFI cruises extended throughout the CCS during the 1960s, contracted to Southern and Central California by the 1980s, and now only covers the Southern California Bight while also sampling at significantly fewer depths (Bograd et al., 2003). The loss of CalCOFI cruises in Central California has been offset in part by triannual Applied California Current Ecosystem Studies (ACCESS) cruises near San Francisco Bay, though these cruises are limited to the continental shelf between 37.3° N and 38.4° N. The NOAA West Coast Ocean Acidification (WCOA) cruises took place along the entire CCS five times from 2007 to 2016, but did not occur again until 2021 (Feely et al., 2016a; Feely et al., 2022). The shift towards high-resolution, nearshore monitoring is a significant improvement over a wholesale reduction in oceanographic monitoring, but the concurrent erosion of consistent oceanographic cruises means the ability to resolve large-scale regional patterns is being traded for highly specific understanding of a few select locations.

This synthesis dataset provides one of the largest compilations to date of West Coast nearshore acidification- and deoxygenation-~~–~~related data. This dataset highlights monitoring gaps, but equally provides opportunities for insight into coastal conditions. With the updated spatiotemporal resolution our effort affords, this dataset offers a wealth of opportunities to investigate questions about coastal oceanography and evaluate localized patterns of marine climate stress. We expect the MOCHA synthesis to also be of use for new projects combining temperature and DO records into species metabolic indices (e.g., Howard et al., 2020b), for investigating the frequency and interaction of individual and overlapping ocean acidification and hypoxic events (e.g., Burger et al., 2022), and for developing updated carbonate system algorithms more suited to coastal environments (e.g., Alin et al., 2012; Davis et al., 2018). By archiving this dataset at the National Centers for

Environmental Information (https://doi.org/10.25921/2vve-fh39; Kennedy et al., 2023) in an easily manipulated, consistent format that includes relevant metadata and quality assurance, we provide an important tool for scientists across ecological, oceanographic, and social disciplines as well as coastal decision-makers to address the environmental, economic, and cultural needs of coastal communities.

5 Data Availability

The full Multistressor Observations of Coastal Hypoxia and Acidification dataset, parameter metadata, and dataset metadata tables are publicly available for download at NCEI as Accession 0277984 with the DOI 10.25921/2vve-fh39 (Kennedy et al., 2023). The downloadable content includes the full MOCHA dataset available as a text file, the daily summarized dataset discussed extensively above available as a text file (aggregated_daily_dataset.csv), standard NCEI accession parameter metadata which provides an overview for each variable included in the text files (“SubmissionForm_carbon_v1_428.xlsx”), and a bespoke dataset metadata table describing each included dataset with citations and links to reference papers (MOCHA_dataset_metadata_table_v2.csv). This data package is discoverable via the NOAA Ocean Acidification Portal, NCEI Geoportal (https://www.ncei.noaa.gov/metadata/geoportal/#searchPanel), and other online discovery tools. The dataset metadata table is also available in the Supplemental Information for this paper.

6 Fair Use Data Statement

We request that all users of the MOCHA compilation also fully credit the constituent datasets supporting their work. This helps ensure that the ocean monitoring systems that this, and other, compilations depend on receive trackable citations and continued funding. We also recommend contacting the original principal investigators to discuss collaboration opportunities and to enthusiastically look for opportunities to further include or credit these data providers. Full citation information, dataset DOIs, and reference papers (where available) for each individual dataset in the MOCHA compilation can be found in the References as well as in the MOCHA_dataset_metadata_table.csv available at NCEI (https://www.ncei.noaa.gov/data/oceans/ncei/ocads/data/0277984/).

7 Code Availability

Code for performing carbonate system calculations with the formatted dataset, creating a summarized dataset aggregated by day, and making all included figures is available on GitHub at https://github.com/egkennedy/DSP_public_code.

Competing Interests

The authors declare that they have no conflicts of interest.

Author Contributions

After the first four contributing authors, additional authors are listed alphabetically in two groups: those who contributed significantly to data acquisition, interpretation, and overall project direction and those who contributed to data curation. All authors read, edited and approved of the manuscript. EGK wrote original draft and led data curation and quality control methodology. MZ and SLH provided substantial manuscript reviews, data curation, and methodology insights. TMH led project conceptualization, funding acquisition, and supervision, and provided substantial manuscript review. TMH, KJK, JJ, CF, and ME provided previously unpublished data for inclusion. KJK, AKS, BG, ES, and MW contributed to funding acquisition and project conceptualization. HMP, MW, AMR, GVG, CNR, GC, MD, MIW, EH, and SW provided data curation and sourced new datasets for inclusion.

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Supplement to “A high-resolution synthesis dataset for multistressor analyses along the U.S. West Coast”

Kennedy et al.

2023-10-09

Formatting Example

Here, we provide data formatting and quality flagging examples to illustrate our “human in the loop” QA/QC practices.

We are using a subset of dataset 40 (Kroeker et al., 2023) for both the formatting and flagging example). The full dataset 40 includes temperature, dissolved oxygen, and pH time series from SeapHOx instruments placed at six different sites along the coast. For simplicity, we show only 1 out of 6~~/6~~ sites here.

All datasets pulled into the MOCHA synthesis were converted to a common format and units. While this process was unique for every dataset, the principles were the following: *

1) ~~1)~~ manipulate the minimal amount necessary. *

2) ~~2)~~ retain all directly measured parameters. *

3) ~~3)~~ discard calculated parameters.

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```
library("tidyverse")
library("stringr")
library("viridis")
library("cowplot")

theme_set(theme_bw())

dat <- read_csv("40_subset_BC.csv")
```

Location, Date, Time, and Project Information

All observations need to be accompanied by location, date, time, depth, and project information. Here, we assign a dataset ID number to link it to our metadata spreadsheet; add habitat, sampling scheme, and measurement type (gleaned from individual project metadata), and format temporal and spatial columns.

```
## Make our target dataframe with correct formatting
target_cols <-
c("dataset_id","latitude","longitude","depth_m","time_utc","t_C",
```

```
"t_flag","sal_pss","sal_flag","pH_total","pH_flag","pH_type",
                 "pCO2_uatm",
"pCO2_flag","pCO2_type","fCO2_uatm","fCO2_flag",

"fCO2_type","tCO2_umolkg","tCO2_flag","tCO2_type","ta_umolkg",

"ta_flag","ta_type","do_umolkg","do_sat","do_flag","do_type",
                 "chl_ugL","chl_flag","chl_type","si_umolkg","nh4_umolkg",

"no3_umolkg","no2_umolkg","po3_umolkg","nutr_flag","nutr_type",
                 "habitat", "sample_scheme")
df40 <- data.frame(matrix(nrow = nrow(dat), ncol = 40))
names(df40) <- target_cols


## Input dataset_id, habitat, and sample scheme
## Copy over coordinates, depth, and datetime if possible.
## Input instrument types
df40 <- df40 %>%
  mutate(dataset_id = 40, sample_scheme = "intertidal/subtidal sensor
deployment",
         habitat = "oceanic") %>%
  mutate(latitude = dat$latitude, longitude = dat$longitude,
         depth_m = dat$depth) %>%
  mutate(pH_type = "autonomous sensor", do_type = "autonomous sensor")

# In this case, the date and time need some formatting before being copied
over
#Format the date and time
dat <- dat %>%
  mutate(day = str_sub(date, start = 1L, end = 2L)) %>%
  mutate(month = str_sub(date, start = 3L, end = 4L)) %>%
  mutate(year = str_sub(date, start = 5L, end = 8L)) %>%
  mutate(date2 = lubridate::make_date(month = month, day = day,
                                      year = year)) %>%
  mutate(time_utc = lubridate::ymd_hms(paste(date2, time, sep = " ")))

# Get the temperature from the DO sensor when the primary temperature
# sensor is not working.
dat <- dat %>%
  mutate(qc_temp = ifelse(is.na(temp) & !is.na(do_temp), 2, qc_temp)) %>%
  mutate(temp = ifelse(is.na(temp), do_temp, temp))

# Copy the datetime over
df40$time_utc <- dat$time_utc
```

Measured parameter data should be accompanied by QA/QC information when possible. Whatever the original publisher's QA/QC system, we mapped all data highlighted by the original investigators as “bad” or “unreliable” to our flag of 3. All other data, regardless of author notes, was mapped to our flag of 2 (unevaluated) until the secondary QC stage demonstrated in part 2 of this supplement. In this example dataset, the columns “qc_temp”, “do_qc”, and “qc_pH” are the quality control notes from primary QC. In the original, raw data, a flag of “4” denotes unreliable observations. We will map all observations marked with a “4” flag to our “unreliable” flag of 3.~~A “4” flag denotes unreliable observations.~~

```r
# Grab temperature, do (umol/kg), and pH observations and quality flags
# Map "bad" flags to 3, all others to 2 (unevaluated)
df40 <- df40 %>%
  mutate(t_C = dat$temp, pH_total = dat$pH, do_umolkg = dat$do_umolkg) %>%
  mutate(t_flag = dat$qc_temp, pH_flag = dat$qc_pH, do_flag = dat$do_qc) %>%
  mutate(across(c(t_flag, pH_flag, do_flag), ~ ifelse(. == 4, 3, 2)))
```

When necessary, measured parameters were converted to our chosen units or adjusted for *in-situ* conditions. In this example dataset, the temperature is already in degrees Celcius and the pH is already *in-situ* and on the total scale, but the dissolved oxygen needs to be converted to saturation.

```r
oxy_saturation <- function(temperature_celsius, do_umolkg, salinity){

  A0 = 5.80818
  A1 = 3.20684
  A2 = 4.11890
  A3 = 4.93845
  A4 = 1.01567
  A5 = 1.41575
  B0 = -7.01211e-3
  B1 = -7.25958e-3
  B2 = -7.93334e-3
  B3 = -5.54491e-3
  C0 = -1.32412e-7

  Temp = log((298.15-temperature_celsius)/(273.15+temperature_celsius))

  #Get the saturation percent
  100 * do_umolkg/exp((A0 + A1*Temp + A2*Temp^2 + A3*Temp^3 + A4*Temp^4 +
                       A5*Temp^5) + salinity*(B0 + B1*Temp + B2*Temp^2 +
                                             B3*Temp^3) + C0*salinity^2)
}


# Convert the DO to %sat using a salinity of 33.5, as recommended by the
Kroeker lab
df40 <- df40 %>%
  mutate(do_sat = oxy_saturation(t_C, do_umolkg, 33.5))
```

The dataset is now formatted and ready for our secondary QC practices.

QA/QC Example: Dataset 40 Subset

For all dataset in this compilation, our flagging principles were the following: * All data identified as unreliable by the original publishers/investigators is assigned an “unreliable” (3) flag. + Retain these flags even if the data looks reasonable during this secondary QC. * All other data is examined through as many lenses as possible and considered in its geographic and temporal context. * Err toward inclusion. If data are reasonable and plausible, do not assign an “unreliable” flag. * For all data that have been examined, upgrade quality flags from 2s (unexamined) to 1s (plausible and reliable) after identifying all unreliable data.

Dataset 40 Considerations

This example will walk through our typical project QA/QC procedures for time series data using a subset of dataset 40 from the Big Creek site and formatted in the example above. These data were generated by a submerged SeapHOx measuring *in-situ* temperature, dissolved oxygen, and pH and are published in full in Kroeker et al. (2023).

For autonomous sensor datasets, QA/QC starts with time series graphs, then moves into property-property plots as appropriate. Here, we show the original time series plots with the original investigator’s initial quality flags. Next, we will identify any additional data that should be assigned an “unreliable” (3) quality flag.

For each of the time series below, we first show all of the data with “unreliable” observations identified by primary QC colored in yellow. Next, we filter out this unreliable data to focus on the data that needs secondary QC. These plots are colored by a second parameter to provide additional context. Additional data identified as “unreliable” during the secondary QC using the time series is circled in red.

Individual Time Series QA/QC

Temperature Time Series

The temperature time series looks plausible. Additional unreliable temperatures may become apparent in property-property plots (next section).

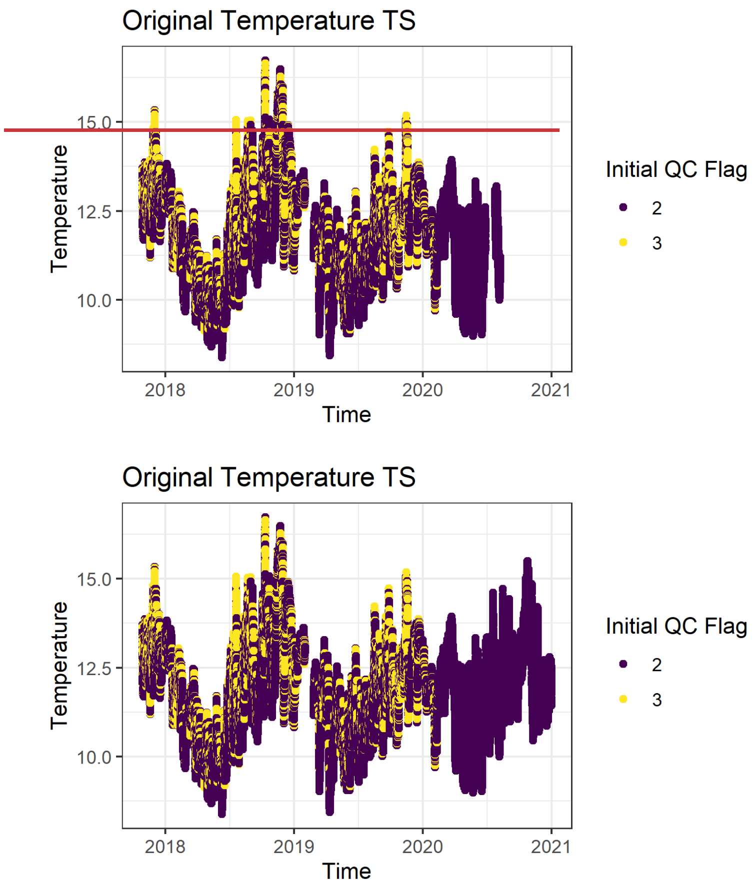
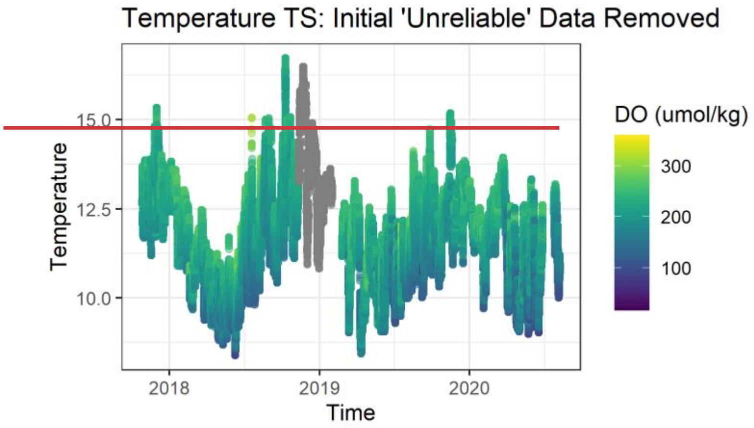


Figure 1: Temperature time series colored by original investigator-applied quality flags.



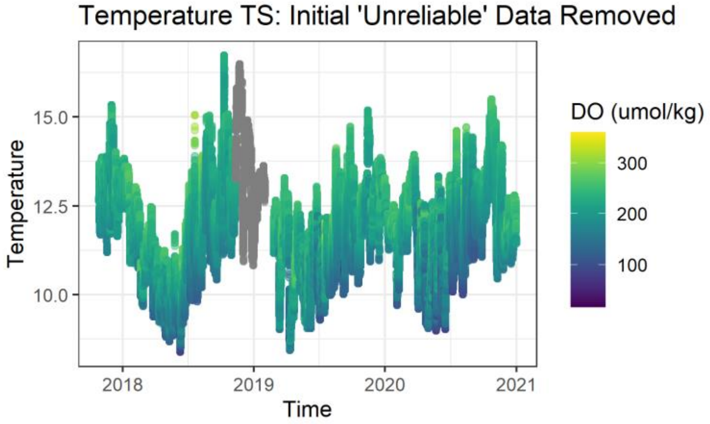


Figure 2: Temperature time series with initial unreliable data removed, colored by dissolved oxygen content.

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Dissolved Oxygen Time Series

The dissolved oxygen time series requires a bit of additional data flagging. After filtering out the data marked as “unreliable” by the original investigator, we find two additional groups of data that should be marked as such. These groups are circled in red in the image below and are flagged in the code section titled, “Apply the additional time series flags.”

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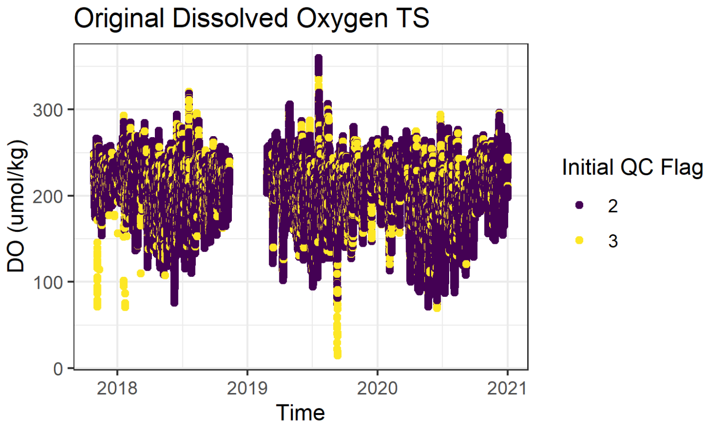

Figure 3: Dissolved oxygen time series colored by original investigator-applied quality flags.

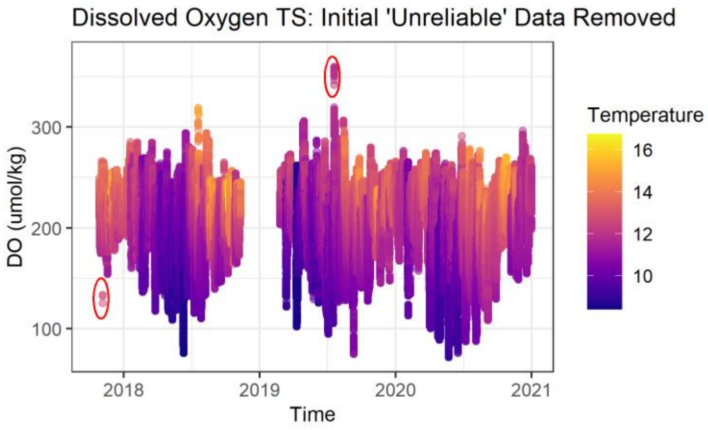

Figure 4: Dissolved oxygen time series with initial unreliable data removed, colored by temperature. We will apply additional unreliable flags to the data circled in red.

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pH Time Series

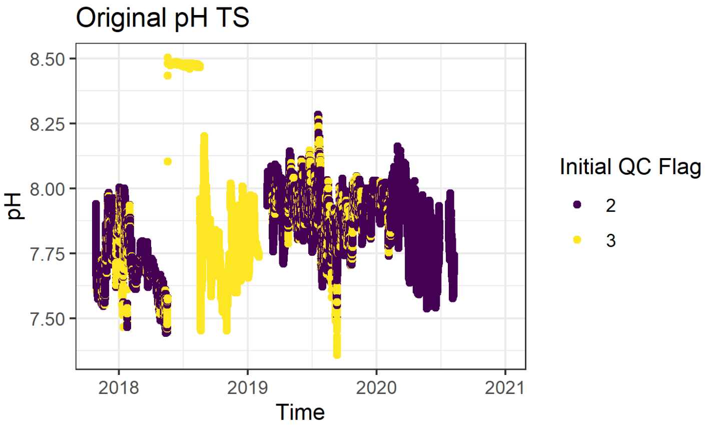

Figure 5: Full pH time series colored by original investigator-applied quality flags.

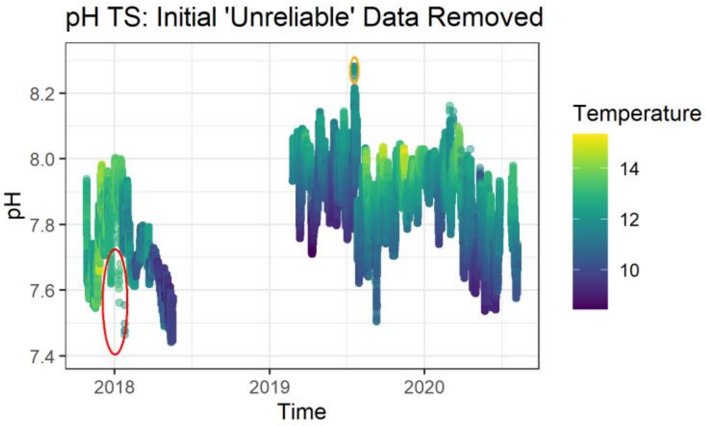

Figure 6: pH time series with initial unreliable data removed, colored by temperature. We apply unreliable flags to the data circled in red around January of 2018 and will more closely examine the data circled in orange.

As necessary, we examined subsets of time series to get a closer look at the data. Here, we're showing the previous time series from 2019 onward. This highlights a few scattered pH observations in 2020 that seem to have unusual temperatures relative to surrounding data and might be unreliable, though they do not have extreme pH values. These points will be better investigated in property-property plots.

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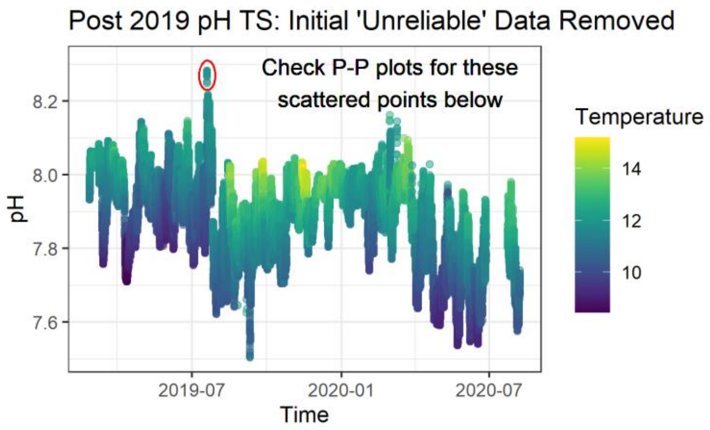

Figure 7: Limited pH time series from 2019 onward with previously identified unreliable data removed. In addition to the anomalously high pH readings in mid-2019, this figure also shows some scatter in the pH readings in 2020. As these data are not anomalous for the time series, we will check to see if they stand out in property-property (P-P) plots.

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Apply the Additional Time Series Flags

Flag the additional unreliable data identified in the time series plots. Retain the 3 flags for all previously identified unreliable data. Eliminate flags for rows with no data.

Note that this flagging code is based on the specific plots and data shown. Each dataset was examined individually, generic flags based on time or parameter values do not apply across datasets (e.g., the code identifying the 2017 unreliable dissolved oxygen observations is not meant to imply that *all* dissolved oxygen observations before 2018 and below 150 umol/kg are considered unreliable).

```
df40 <- df40 %>%
  mutate(t_flag = case_when(t_flag == 3 ~ 3,
                            !is.na(t_C) ~ 2,
                            TRUE ~ NA_real_)) %>%
  mutate(do_flag = case_when(do_flag == 3 ~ 3,
                             time_utc < "2018-01-01" & do_umolkg < 150 ~ 3,
                             do_umolkg > 330 ~ 3,
                             !is.na(do_umolkg) ~ 2,
                             TRUE ~ NA_real_)) %>%
  mutate(pH_flag = case_when(pH_flag == 3 ~ 3,
                             time_utc > "2017-12-20" & time_utc < "2017-12-
25"
                             & pH_total < 7.79 ~ 3,
                             time_utc > "2018-01-01" & time_utc < "2018-01-
15"
```

```
                             & pH_total < 7.81 ~ 3,
                             time_utc > "2018-01-15" & time_utc < "2018-02-
15"
                             & pH_total < 7.6 ~ 3,
                             pH_total > 8.24 ~ 3,
                             !is.na(pH_total) ~ 2,
                             TRUE ~ NA_real_))
```

Property-Property QA/QC for Autonomous Sensor Data

With all multiparameter data sets, we used property-property plots to ensure that data relationships were consistent with biological activity, conservative mixing, and other oceanographic considerations. Here, we will focus on dissolved oxygen and pH data that have not been identified as unreliable either in the original author's quality control or in our time series-based secondary quality control discussed above. All pH and DO data that has already been flagged with a 3 QC value has been excluded. "Unreliable" temperature data is retained in these plots to examine how these temperatures might have affected the pH and DO measurements.

Property-Property Plots for Dataset 40 Subset

We use property-property plots to evaluate the reasonableness of data on the basis of known environmental and oceanographic relationships.

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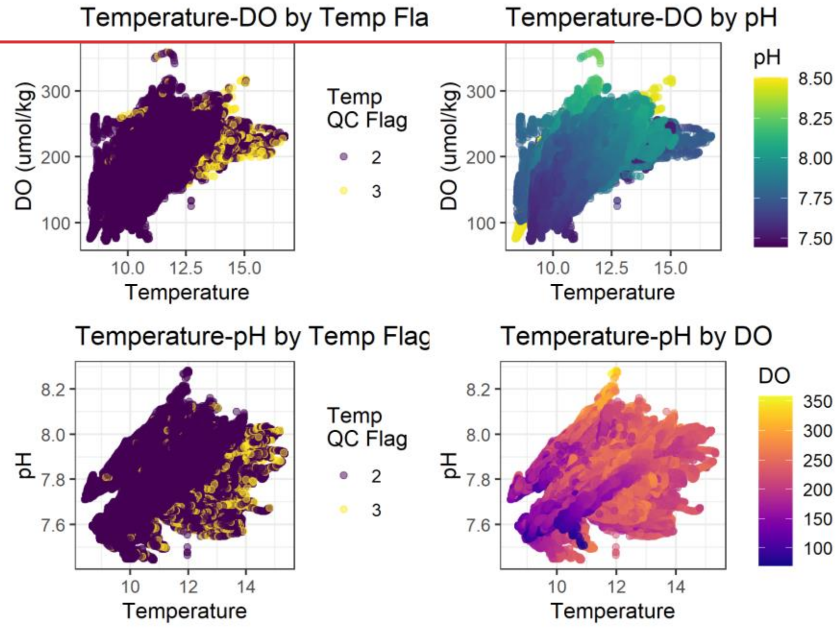

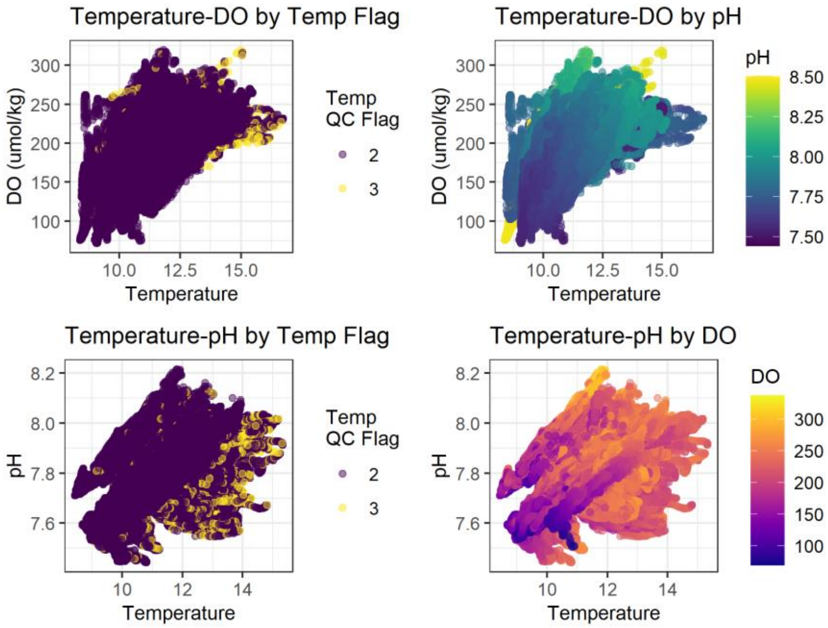

Figure 8: Temperature-dissolved oxygen and temperature-pH property-property plots. Plots colored by temperature flag are an opportunity to evaluate whether unreliable temperatures had an influence on their associated pH and dissolved oxygen measurements. Those colored by a third oceanographic parameter can show the influences of mixing, photosynthesis, respiration, upwelling, or other environmental processes.

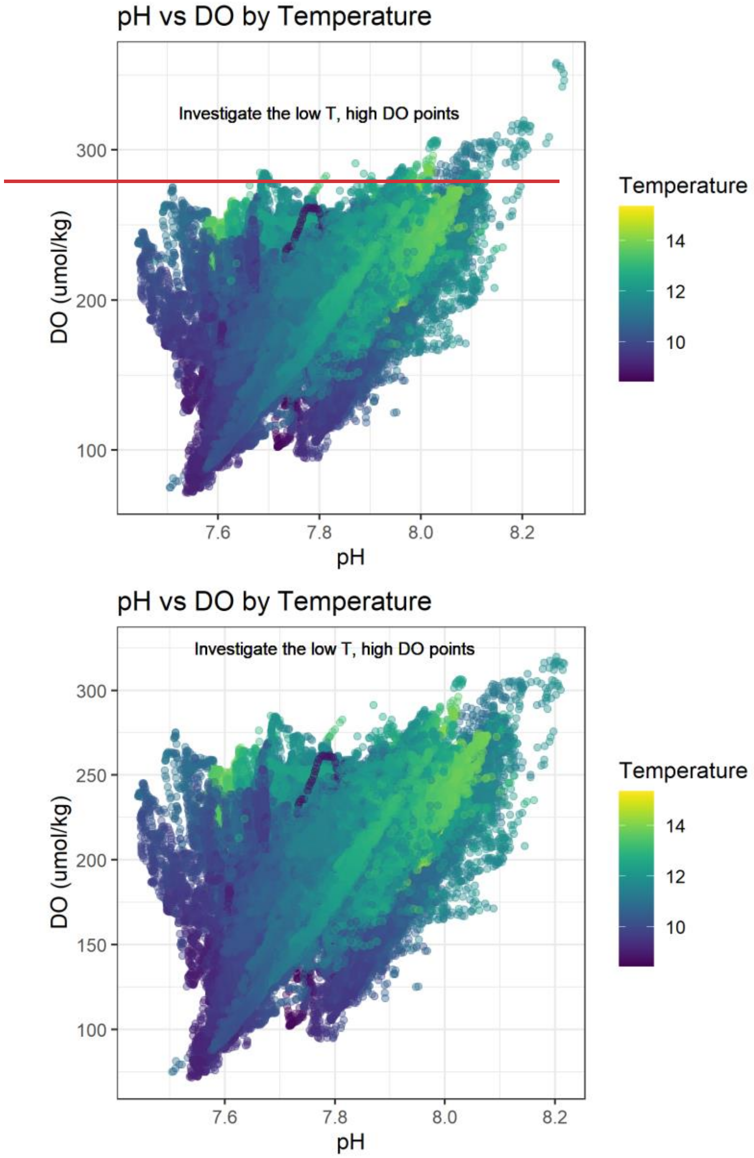

Figure 9: A pH-dissolved oxygen P-P plot colored by temperature. In general in this environment, low temperatures, low dissolved oxygen, and low pH are found together. There is one group of very low temperature, high dissolved oxygen data that warrant further investigation.

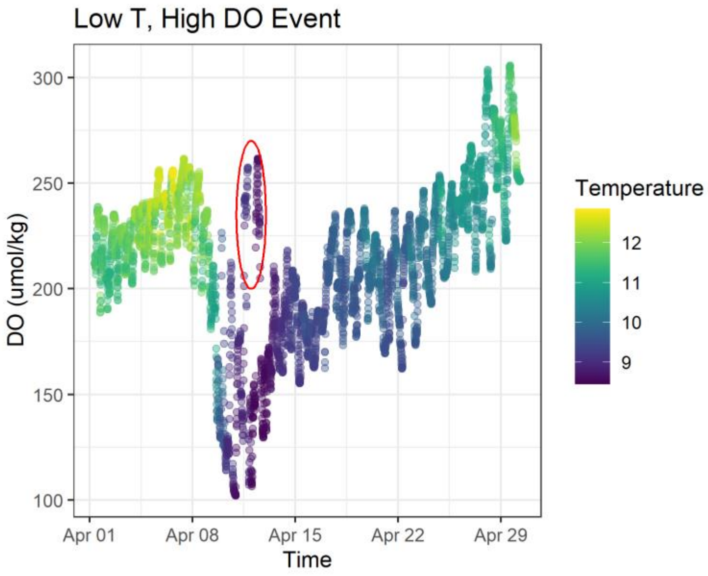

Figure 10: Limited time series of dissolved oxygen colored by temperature focusing on the cold, high dissolved oxygen event. We will flag the dissolved oxygen measurements circled in red as unreliable.

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The property-property plots look plausible in general and don't suggest many additional flags. We will flag the high dissolved oxygen readings associated with the very low temperature event in April of 2019 since these readings are far above what any similar temperature dissolved oxygen values are *and* the sensor data has a large discontinuity between the bulk of the dissolved oxygen readings and the anomalous, higher dissolved oxygen readings.

After marking these high dissolved oxygen readings, we will update all data that hasn't been flagged with a "unreliable" marker (3) to a "reliable or plausible" (1) QC status.

```
## Apply 3 flags to the high DOs in mid April 2019
## Update all flags that aren't 3s to be 1s
df40 <- df40 %>%
  mutate(do_flag = case_when(do_flag == 3 ~ 3,
                             do_umolkg > 225 & t_C < 9 & time_utc > "2019-04-
08"
                              & time_utc < "2019-04-15" ~ 3,
                             do_umolkg > 200 & t_C < 9 & time_utc > "2019-04-
12"
```

```
                             & time_utc < "2019-04-13" ~ 3,
                           !is.na(do_umolkg) ~ 1,
                           TRUE ~ NA_real_)) %>%
mutate(pH_flag = case_when(pH_flag == 3 ~ 3,
                           !is.na(pH_total) ~ 1,
                           TRUE ~ NA_real_)) %>%
mutate(t_C = case_when(t_flag == 3 ~ 3,
                       !is.na(t_C) ~ 1,
                       TRUE ~ NA_real_))
```

References

Kroeker, K. J., Donham, E. M., Vylet, K., Warren, J. K., Cheresh, J., Fiechter, J., Freiwald, J., and Takeshita, Y.: Exposure to extremes in multiple global change drivers: Characterizing pH , dissolved oxygen, and temperature variability in a dynamic, upwelling dominated ecosystem, Limnol. Oceanogr., 1–13, https://doi.org/10.1002/lno.12371, 2023.

Dataset Metadata Table

Dataset ID	Dataset Name	Primary location	Latitude range	Longitude range	Depths	Habitat	Date Range	No. Obs.	Sampling scheme	Parameters	Sensors	Comments	Dataset citation
1	SBC LTER: Reference: Sea-surface water temperature, Santa Barbara Harbor, Santa Barbara, CA, USA	Santa Barbara, CA	34.40487	-119.6922	0 m	Oceanic	01/1955 - 12/2018	23373	Intertidal/ Subtidal discrete collection	T			Carter, M. L., Flick, R. E., Terrill, E., Beckhaus, E. C., Martin, K., Fey, C. L., Walker, P. W., Largier, J. L., and McGowan, J. A.: Shore Stations Program Data Archive: Current and historical coastal ocean temperature and salinity measurements from California stations, UC San Diego Library Digital Collections [data set], https://doi.org/10.6075/J06T0K0M, 2021.
2	National Data Buoy Center Station BDXC1 Bodega Head, CA	Bodega Head, CA	38.317	-123.071	0 m	Oceanic	11/2015 - 12/2018	84932	Mooring	T, S, Chl	YSI (6-Series)		National Data Buoy Center: Station BDXC1 - Bodega, CA, National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
3	SBC LTER: Ocean: Time-series: Mid-water SeaFET and CO2 system chemistry at Alegria (ALE)	Santa Barbara, CA	34.4617	-120.29	3 m	Oceanic	06/2011 - 01/2014	67048	Mooring	T, S, pH, TA	Sea-Bird SeaFET; Conductivity and Temperature sensor (SBE 37-SM MicroCAT)		Santa Barbara Coastal LTER, Hofmann, G.E. and Washburn, L.: SBC LTER: Ocean: Time-series: Mid-water SeaFET pH and CO2 system chemistry at Alegria(ALE), ongoing since 2011-06-21, Environmental Data Initiative [data set], https://doi.org/10.6073/pasta/1bd1491475ff6afee4be10d054d1ef0b, 2018
5	Chemical and hydrographic profile measurements during the 2016 West Coast Ocean Acidification Cruise (WCOA2016, May 5 to June 7, 2016)	West Coast of the U.S.	32.77 to 48.49	-126.6 to -117.8	2 m to 2503 m	Oceanic	05/2016 - 06/2016	1371	Cruise	T, S, pH, DIC, TA, DO, Chl, Nutrients	CTD (SBE9+)	Cruise stations have been cropped to U.S. waters.	Alin, S. R., Feely, R. A., Hales, B., Byrne, R. H., Cochlan, W., Liu, X., and Greeley, D.: Dissolved inorganic carbon, total alkalinity, pH on total scale, and other variables collected from profile and discrete sample observations using CTD, Niskin bottle, and other instruments from NOAA Ship Ronald H. Brown in the U.S. West Coast California Current System from 2016-05-08 to 2016-06-06 (NCEI Accession 0169412), NOAA National Centers for Environmental Information [data set], https://doi.org/10.7289/v5v40shg, 2017.
6	National Data Buoy Center Station 46025 Santa Monica Basin, CA	Channel Islands, CA	33.763	-119.053	1 m	Oceanic	12/2007 - 06/2009	12407	Mooring	T, S	YSI; Conductivity and Temperature sensors (SBE 16 SeaCAT, and SBE 37-SM MicroCAT)		National Data Buoy Center: Station 46205 - West Dixon Entrance, CA, National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
7	National Data Buoy Center Station 46217 Anacapa Passage, CA	Channel Islands, CA	34.167	-119.435	0.46 m	Oceanic	09/2004 - 05/2019	214197	Mooring	T	YSI		National Data Buoy Center: Station 46217 - Anacapa Passage, CA (111), National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
8	National Data Buoy Center Station 46053 Channel Islands, CA	Channel Islands, CA	34.252	-119.853	1 m	Oceanic	03/2007 - 09/2008	13302	Mooring	T, S	YSI		National Data Buoy Center: Station 46053 (LLNR 196) - EAST SANTA BARBARA - 12NM Southwest of Santa Barbara, CA, National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
9	National Data Buoy Center Station TDPC1 Trinidad, CA	Eureka, CA	41.055	-124.147	3 m	Oceanic	07/2007 - 09/2011	13564	Mooring	T, S, DO, Chl	YSI	This dataset overlaps with dataset 45 (CenCOOS Humboldt/Trinidad Staion) and is taken from the same shore station over a slightly different timeline. Overlapping observations have been cropped out of this dataset to avoid duplicates.	National Data Buoy Center: Station TDPC1 - Trinidad Pier Trinidad, CA, National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
10	National Data Buoy Center Station FPXC1 Fort Point, CA	Fort Point, San Francisco Bay, CA	37.807	-122.466	0 m	Estuarine	11/2015 - 12/2018	83030	Mooring	T, S, Chl	YSI		National Data Buoy Center: Station FPXC1 - Fort Point, CA, National Oceanic and Atmospheric Administration [data set], [https://www.ndbc.noaa.gov/station_page.php?station=bdxc1, 2023.
11	National Data Buoy Center Station 46221 Santa Monica Bay, CA	Santa Monica Bay, CA	33.855	-118.634	0.46 m	Oceanic	09/2004 - 12/2020	246676	Mooring	T	YSI		National Data Buoy Center: Station 46221 - Santa Monica Bay, CA (028), National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
12	National Data Buoy Center Station 46235 Imperial Beach, CA	Imperial Beach, CA	32.57	-117.169	0.46 m	Oceanic	05/2015 - 12/2018	45470	Mooring	T	YSI		National Data Buoy Center: Station 46235 - Imperial Beach Nearshore, CA (155), National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
14	National Data Buoy Center Station 46251 Santa Cruz Basin, CA	Santa Cruz Basin, CA	33.761	-119.559	0.46 m	Oceanic	10/2013 - 12/2018	69772	Mooring	T	YSI		National Data Buoy Center: Station 46251 - Santa Cruz Basin, CA (203), National Oceanic and Atmospheric Administration [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
15	National Data Buoy Center Station ICAC1 Santa Monica Pier, CA	Santa Monica, CA	34.008	-118.5	10.3 m	Oceanic	01/2010 - 12/2020	941237	Mooring	T	YSI		National Data Buoy Center: Station ICAC1 - 9410840 - Santa Monica Pier, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
16	National Data Buoy Center Station PRYC1 Point Reyes, CA	Point Reyes, CA	37.996	-122.977	1.5 m	Oceanic	04/2005 - 12/2018	984134	Mooring	T	YSI		National Data Buoy Center: Station PRYC1 - 9415020 - Point Reyes, CA, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
17	National Data Buoy Center Station HBXC1 Humboldt Bay Pier, CA	Humboldt Bay, CA	40.777	-124.197	0 m	Estuarine	11/2015 - 12/2018	20766	Intertidal/ Subtidal sensor deployment	T, S, DO, Chl	YSI (6-Series)		National Data Buoy Center: Station HBXC1 - Humboldt, CA, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.

18	National Data Buoy Center Station MBXC1 Morro Bay BM1 T Pier, CA	Morro Bay, CA	35.37	-120.858	0 m	Estuarine	11/2015 - 01/2019	44201	Mooring	T, S, DO, Chl	YSI	This dataset overlaps with dataset 53 (Morro Bay BM1-T Pier) and is taken from the same shore station, though the two datasets have different time ranges. Data from the published NDBC record that overlaps with dataset 53 has been cropped out to avoid duplicates.	National Data Buoy Center: Station MBXC1 - Morro Bay - BM1 T-Pier, CA, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
19	National Data Buoy Center Station MLSC1 Moss Landing, CA	Moss Landing, CA	36.802	-121.791	0 m	Oceanic	08/2009 - 12/2018	162270	Mooring	T, S, DO	pH Electrode (Honeywell DuraFET III); Oxygen Probe (Oxyguard 840)		National Data Buoy Center: Station MLSC1 - Moss Landing, South Harbor, CA, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
20	National Data Buoy Center Station MTYC1 Monterey Bay, CA	Monterey, CA	36.605	-121.889	2.1 m	Oceanic	11/2015 - 12/2018	31449	Mooring	T, S, DO, Chl	YSI		National Data Buoy Center: Station MTYC1 - 9413450 - Monterey, CA, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
21	Chemical and hydrographic profile measurements during the 2013 West Coast Ocean Acidification Cruise (WCOA2013, August 3-29, 2013)	West Coast of the U.S.	36.52 to 48.44	-126.6 to -121.8	2 m to 2530 m	Oceanic	08/2013 - 08/2013	875	Cruise	T, S, pH, DIC, TA, DO, Chl, Nutrients	CTD (Sea-Bird SBE 3+); Dissolved Oxygen sensor (Sea-Bird SBE 43)	Cruise stations have been cropped to U.S. waters.	Feely, R. A., Alin, S. R., Hales, B., Johnson, G. C., Byrne, R. H., Peterson, W. T., Liu, X., and Greeley, D.: Dissolved inorganic carbon, total alkalinity, pH on total scale and other variables collected from profile and discrete sample observations on NOAA Ship Fairweather (EXPOCODE 317W20130803) and R/V Point Sur (EXPOCODE 32P020130821) in the U.S. West Coast California Current System during the 2013 West Coast Ocean Acidification Cruise (WCOA2013) from 2013-08-03 to 2013-08-29 (NCEI Accession 0132082), NOAA National Centers for Environmental Information [data set], https://doi.org/10.7289/v5c53hxp, 2015.
22	Chemical and hydrographic measurements during the 2012 West Coast Ocean Acidification Cruise (WCOA2012, September 4-17, 2012)	West Coast of the U.S.	37.67 to 48.38	-126.1 to -122.9	1.7 m to 2963 m	Oceanic	09/2012 - 09/2012	1056	Cruise	T, S, DIC, TA, DO, Chl, Nutrients	CTD (Sea-Bird SBE 9+); Dissolved oxygen sensor (Sea-Bird SBE 43)	Cruise stations have been cropped to U.S. waters.	Feely, R. A., Alin, S. R., Hales, B., Johnson, G. C., Juranek, L. W., Peterson, W. T., and Greeley, D.: Dissolved inorganic carbon, alkalinity, temperature, salinity and other variables collected from discrete sample and profile observations using Alkalinity titrator, CTD and other instruments from NOAA Ship Bell M. Shimada in the Columbia River estuary - Washington/Oregon, Gulf of the Farallones National Marine Sanctuary and others from 2012-09-04 to 2012-09-17 (NCEI Accession 0157445), NOAA National Centers for Environmental Information [data set], https://doi.org/10.25921/e7m6-gh32, 2016.
23	Chemical and hydrographic profile measurements during the 2011 West Coast Ocean Acidification Cruise (WCOA2011, August 12-30, 2011)	West Coast of the U.S.	33.35 to 48.38	-127.5 to -117.8	1.4 m to 2800 m	Oceanic	08/2011 - 08/2011	1451	Cruise	T, S, pH, DIC, TA, DO, Chl, Nutrients	CTD (Sea-Bird SBE 9+); Dissolved oxygen sensor (Sea-Bird SBE 43)	Cruise stations have been cropped to U.S. waters.	Feely, R. A., Alin, S. R., Hales, B., Johnson, G. C., Juranek, L. W., Byrne, R. H., Peterson, W. T., Goni, M., Liu, X., Greeley, D.: Dissolved inorganic carbon, total alkalinity, pH, temperature, salinity and other variables collected from profile and discrete sample observations using CTD, Niskin bottle, and other instruments from R/V Wecoma in the U.S. West Coast California Current System during the 2011 West Coast Ocean Acidification Cruise (WCOA2011) from 2011-08-12 to 2011-08-30 (NCEI Accession 0123467), NOAA National Centers for Environmental Information [data set], https://doi.org/10.7289/v5jq0xz1, 2015.
24	Dissolved inorganic carbon, alkalinity, temperature, salinity and other variables collected from discrete sample and profile observations using Alkalinity titrator, CTD and other instruments from WECOMA in the U.S. West Coast California Current System from 2007-05-11 to 2007-06-14 (NCEI Accession 0083685)	West Coast of the U.S.	32.6 to 48.28	-129.4 to -118.5	3.2 m to 4199 m	Oceanic	05/2007 - 06/2007	1512	Cruise	T, S, DIC, TA, DO, Nutrients	CTD (Sea-Bird SBE 9+); Dissolved oxygen sensor (Sea-Bird SBE 43)	Cruise stations have been cropped to U.S. waters.	Feely, R. A. and Sabine, C. L.: Dissolved inorganic carbon, alkalinity, temperature, salinity and other variables collected from discrete sample and profile observations using Alkalinity titrator, CTD and other instruments from WECOMA in the U.S. West Coast California Current System from 2007-05-11 to 2007-06-14 (NCEI Accession 0083685), NOAA National Centers for Environmental Information [data set], https://doi.org/10.3334/cdiac/otg.clivar_nacp_west_coast_cruise_2007, 2013.
25	California Cooperative Oceanic Fisheries Investigations (CalCOFI) Bottle Database: Oceanographic data collected from chemical analyses of seawater samples (1949 - present)	California	32.5 to 47.92	-150 to -117.2	0 m to 5165 m	Oceanic	02/1949 - 02/2019	264594	Cruise	T, S, DIC, TA, DO, Chl, Nutrients	CTD (Sea-Bird SBE 911plus)	Cruise stations have been cropped to U.S. waters.	NOAA Southwest Fisheries Science Center, National Marine Fisheries Service, Scripps Institution of Oceanography, UC San Diego, and California Department of Fish & Wildlife (Marine Region): Bottle Database - California Cooperative Oceanic Fisheries Investigations (CalCOFI) [data set], https://calcofi.org/data/oceanographic-data/bottle-database/.
26	Applied California Current Ecosystem Studies Partnership Discrete Carbonate Chemistry Observations (2013-2019)	Central California	36.70 to 38.37	-123.6 to -122.0	2 m to 200 m	Oceanic	05/2013 - 09/2019	170	Cruise	T, S, pH, TA, DO	CTD	Dataset partially published in Davis et al., 2018. This compilation includes previously unpublished observations from 2016 onward.	

27	UC Davis Coastal Ocean Acidification Dataset	West Coast	32.67 to 48.14	-124.5 to -117.2	0 m	Oceanic	09/2010 - 05/2015	452	Intertidal/ Subtidal discrete collection	T, S, pH, DIC, TA, DO	YSI; bottle samples	Dataset partially previously published in Feely et al., 2016. This compilation includes additional previously unpublished shore stations (Hill et al. unpublished). emperature, salinity, and dissolved oxygen taken in-situ with a YSI. All carbonate-system measurements made on preserved samples according to best practices.	
28	Bodega Marine Laboratory Weekly Horseshoe Cove Shore Samples	Bodega Marine Laboratory, CA	38.31627	-123.072	0 m	Oceanic	09/2010 - 12/2020	329	Intertidal/ Subtidal discrete collection	T, S, pH, DIC, TA, DO	YSI	Previously unpublished data (Hill et al. unpublished) from weekly discrete shore samples taken from Horseshoe Cove, Bodega Marine Reserve. Temperature, salinity, and dissolved oxygen taken in-situ with a YSI. All carbonate-system measurements made on preserved samples according to best practices.	
30	SBC LTER: Ocean: Time-series: Mid-water SeaFET pH and CO2 system chemistry with surface and bottom Dissolved Oxygen at Arroyo Quemado Reef (ARQ), 2012-2017	Arroyo Quemado	34.46495	-120.1197	4 m	Oceanic	07/2012 - 03/2017	121265	Mooring	T, S, pH, TA, DO	Sea-Bird SeaFET		Santa Barbara Coastal LTER, Hofmann, G. and Washburn, L.: SBC LTER: Ocean: Time-series: Mid-water SeaFET pH and CO2 system chemistry with surface and bottom Dissolved Oxygen at Arroyo Quemado Reef(ARQ), 2012-2017 ver 5, Environmental Data Initiative [data set], https://doi.org/10.6073/pasta/6a81dcaaa9931c31dfa59132c7c5f829, 2020.
31	SBC LTER: Ocean: Time-series: Mid-water SeaFET pH and CO2 system chemistry with surface and bottom Dissolved Oxygen at Mohawk Reef (MKO), 2012 - 2017	Mohawk Reef	34.39323	-119.7301	4 m	Oceanic	01/2012 - 12/2017	156200	Mooring	T, S, pH, TA, DO	Sea-Bird SeaFET		Santa Barbara Coastal LTER, Hofmann, G., and Washburn, L.: SBC LTER: Ocean: Time-series: Mid-water SeaFET pH and CO2 system chemistry with surface and bottom Dissolved Oxygen at Mohawk Reef(MKO), 2012 - 2017 ver 5, Environmental Data Initiative [data set], https://doi.org/10.6073/pasta/23b8070eb65bae7aedc82fae8ee38b9f, 2020.
32	SBC LTER: Ocean: Time-series: Mid-water SeaFET pH and CO2 system chemistry with surface and bottom Dissolved Oxygen at Santa Barbara Harbor/Stearns Wharf (SBH), 2012-2017	Santa Barbara Harbor/Stearns Wharf	34.40934	-119.6849	4 m	Oceanic	09/2012 - 09/2016	105155	Mooring	T, S, pH, TA, DO	Sea-Bird SeaFET		Santa Barbara Coastal LTER, Hofmann, G., and Washburn, L.: SBC LTER: Ocean: Time-series: Mid-water SeaFET pH and CO2 system chemistry with surface and bottom Dissolved Oxygen at Santa Barbara Harbor/Stearns Wharf(SBH), 2012-2017 ver 4, Environmental Data Initiative [data set], https://doi.org/10.6073/pasta/6322ad40dfbc0bbc037994490218e28e, 2020.
33	Ocean Margin Ecosystems Group for Acidification Studies (OMEGAS) Project: Acclimation and adaptation to ocean acidification of key ecosystem components in the California Current System	West Coast	34.72 to 44.84	-124.6 to -120.6	1 m	Oceanic	04/2011 - 06/2014	381607	Intertidal/ Subtidal sensor deployment	T, pH	Multiparameter sensor (Sea-Bird SeapHOx); Sea-Bird SeaFET; pH sensor (Honeywell DuraFET)		Menge, B. A., Chavez, F., Chan, F., Russell, A. D., Blanchette, C. A., Sanford, E., Friederich, G., McManus, M. A., Raimondi, P. T., Barth, J., Hill, T. M., Nielsen, K. J., Hacker, S. D., Washburn, L., and Gaylord, B.: Moorings temperature and pH from multiple sites in the California Current System starting 2008 (OMEGAS-MaS project, ACIDIC project), May 2015 ver 28, Biological and Chemical Oceanography Data Management Office (BCO-DMO) [data set], http://lod.bco-dmo.org/id/dataset/3650, 2015.
34	EAGER Project: Initiation of a pH/pCO2-sensing mooring platform on the Oregon coast	Oregon	44.25	-124.2	70 m	Oceanic	06/2009 - 10/2010	8976	Mooring	T, pCO2	Sunburst SAMI-CO2		Chan, F. and Menge, B. A.: SH70 SAMI pCO2 from SH70 mooring 2009-MI_LOCO-Lander, 2010-MI_LOCO-Lander in the SH70 mid-shelf time series station (Strawberry Hill): 44.25N, 124.50W from 2009-2010 (EAGER project), December 2012 ver 04, Biological and Chemical Oceanography Data Management Office (BCO-DMO) [data set], http://lod.bco-dmo.org/id/dataset/3812, 2012.
35	pCO2 pH salinity and temperature collected off the coast of Oregon USA by a SAMI-CO2 - Shelf Break and NH10	Oregon	44.641	-124.5	2 m and 120 m	Oceanic	08/2007 - 09/2011	17171	Mooring	T, S, pH, pCO2	Sunburst SAMI-pH; Sunburst SAMI-CO2; Conductivity and Temperature sensor (Sea-Bird SBE 37-SM MicroCAT)		DeGrandpre, M.: pCO2, pH, salinity and temperature data collected off the coast of Oregon, USA by a SAMI-CO2 sensor on the Shelf Break Mooring located below the National Data Buoy Center's meteorological Buoy 46050; 2007-2011 (NH10_ShelfBreak_MLR project), January 2016 ver 12, Biological and Chemical Oceanography Data Management Office (BCO-DMO) [data set], http://lod.bco-dmo.org/id/dataset/632498, 2016.
36	SBC LTER: pH time series: Water-sample pH and CO2 system chemistry	California	34.02 to 35.52	-121.1 to -119.7	0 m to 15 m	Oceanic	06/2011 - 12/2017	588	Cruise	T, S, pH, DIC, TA	Sea-Bird SeaFET; YSI (3100 Conductivity Meter)		Santa Barbara Coastal LTER, Hofmann, G., Blanchette, C., Passow, U., Washburn, L., Lunden, J., Rivest, E., Kapsenberg, L. and Kui, L.: SBC LTER: pH time series: Water-sample pH and CO2 system chemistry, ongoing since 2011, ver 6, Environmental Data Initiative [data set], https://doi.org/10.6073/pasta/8efa600f49c3a171b13d05d70fad1d98, 2022.

37	Bodega Marine Reserve Monthly Shore Samples	Bodega Marine Reserve, CA	38.31917	-123.0747	0 m	Oceanic	05/2011 - 03/2020	90	Intertidal/ Subtidal discrete collection	T, S, pH, DIC, TA, DO	YSI	Previously unpublished data from monthly discrete shore samples taken on the Bodega Marine Reserve. Temperature, salinity, and dissolved oxygen taken in-situ with a YSI. All carbonate-system measurements made on preserved samples according to best practices. (Hill et al., unpublished).	
39	California Coastal Seagrass Project	California	33.62 to 38.33	-123.0 to -118.1	0 m and 2 m	Estuarine	12/2014 - 12/2019	439769	Intertidal/Subtidal sensor deployment	T, S, pH, TA, DO	Sea-Bird SeaFET; Multiparameter sensor (Sea-Bird SeapHOx); Dissolved Oxygen and Temperature sensor (miniDOT)	Non-seagrass sites only.	Ricart, A. M., Ward, M., Hill, T. M., Sanford, E., Kroeker, K. J., Takeshita, Y., Merolla, S., Shukla, P., Ninokawa, A. T., Elsmore, K., and Gaylord, B.: Coast-wide evidence of low pH amelioration by seagrass ecosystems, Global Change Biology 27, 2580â€“2591, https://doi.org/10.1111/gcb.15594, 2021.
40	California kelp forest tidal FET sites	California	33.42 to 39.27	-123.8 to -117.8	10 m to 13 m	Oceanic	10/2017 - 12/2020	847863	Intertidal/ Subtidal sensor deployment	T, pH, DO	Sea-Bird SeaFET; Dissolved Oxygen and Temperature sensor (miniDOT)		Kroeker, K. J., Donham, E. M., Vylet, K., Warren, J. K., Cheresh, J., Fiechter, J., Freiwald, J., and Takeshita, Y.: Exposure to extremes in multiple global change drivers: Characterizing pH , dissolved oxygen, and temperature variability in a dynamic, upwelling dominated ecosystem, Limnol. Oceanogr., 1–13, https://doi.org/10.1002/lno.12371, 2023.
41	Dissolved inorganic carbon (DIC), total alkalinity (TA), temperature, salinity, oxygen, and nutrient data collected from discrete profile measurements during the National Oceanic and Atmospheric Administration Harmful Algal Blooms (NOAA HABs) program cruise SH1709 (EXPOCODE 332220170918) in Pacific Northwest marine waters on NOAA Ship Bell M. Shimada from 2017-09-18 to 2017-09-28 (NCEI Accession number 0208230)	Washington and Oregon	44.20 to 48.48	-127.0 to -122.5	2 m to 2890 m	Oceanic	09/2017 - 09/2017	462	Cruise	T, S, DIC, TA, DO, Nutrients	CTD		Alin, S. R., Feely, R. A., Newton, J., Trainer, V. L., Adams, N. G., Greeley, D., Curry, B., Herndon, J., and Ostendorf, M. L.: Dissolved inorganic carbon (DIC), total alkalinity (TA), temperature, salinity, oxygen, and nutrient data collected from discrete profile measurements during the National Oceanic and Atmospheric Administration Harmful Algal Blooms (NOAA HABs) program cruise SH1709 (EXPOCODE 332220170918) in Pacific Northwest marine waters on NOAA Ship Bell M. Shimada from 2017-09-18 to 2017-09-28 (NCEI Accession 0208230), NOAA National Centers for Environmental Information [data set], https://doi.org/10.25921/3qa5-v720, 2019.
42	Dissolved inorganic carbon, total alkalinity, nutrients, and other variables collected from profile and discrete observations using CTD, Niskin bottle, and other instruments from R/V New Horizon and R/V Robert Gordon Sproul in the U.S. West Coast for calibration and validation of California Current Ecosystem (CCE) Moorings from 2009-12-15 to 2015-04-29 (NCEI Accession 0146024)	Southern California Bight	32.52 to 34.33	-122.6 to -117.3	2 m to 3038 m	Oceanic	12/2009 - 04/2015	372	Cruise	T, S, DIC, TA, DO, Chl, Nutrients	CTD		Send, U., Ohman, M., Lankhorst, M., and Kim, H-J.: Dissolved inorganic carbon, total alkalinity, nutrients, and other variables collected from profile and discrete observations using CTD, Niskin bottle, and other instruments from R/V New Horizon and R/V Robert Gordon Sproul in the U.S. West Coast for calibration and validation of California Current Ecosystem (CCE) Moorings from 2009-12-15 to 2015-04-29 (NCEI Accession 0146024), NOAA National Centers for Environmental Information [data set], https://doi.org/10.7289/v57d2s6c, 2016.
43	High-resolution ocean and atmosphere pCO2 time series measurements from mooring CCE1_122W_33N in the North Pacific Ocean from 2008-11-11 to 2020-06-11 (NCEI Accession 0144245)	Point Conception, CA	33.456	-122.523	0 m	Oceanic	11/2008 - 11/2017	20583	Mooring	T, S, pH, pCO2, fCO2, DO	Moored Autonomous pCO2 (MAPCO2) system; Sea-Bird SeaFET; WetLabs ECO FLNTU-S Fluorometer and Turbidity sensor; Conductivity and Temperature sensor (Sea-Bird SBE 37-SM MicroCAT, Sea-Bird SBE 16 SeaCAT); Dissolved Oxygen sensor (Sea-Bird SBE 63)		Sutton, A. J., Sabine, C. L., Send, U., Ohman, M., Dietrich, C., Maenner Jones, S., Musielewicz, S., Bott, R., and Osborne, J.: High-resolution ocean and atmosphere pCO2 time-series measurements from mooring CCE1_122W_33N in the North Pacific Ocean from 2008-11-11 to 2020-06-11 (NCEI Accession 0144245), NOAA National Centers for Environmental Information [data set], https://doi.org/10.3334/cdiac/otg.tsm_cce1_122w_33n, 2016.
44	High-resolution ocean and atmosphere pCO2 time series measurements from Mooring CCE2_121W_34N in the North Pacific Ocean from 2010-01-17 to 2021-06-16 (NCEI Accession 0084099)	Point Conception, CA	34.324	-120.831	0 m	Oceanic	01/2010 - 03/2017	19657	Mooring	T, S, pH, pCO2, fCO2, DO	Moored Autonomous pCO2 (MAPCO2) system; Sea-Bird SeaFET; Dissolved Oxygen sensor (Sea-Bird SBE 63)		Sutton, A. J., Sabine, C. L., Send, U., Ohman, M., Musielewicz, S., Maenner Jones, S., Dietrich, C., Bott, R., and Osborne, J.: High-resolution ocean and atmosphere pCO2 time-series measurements from Mooring CCE2_121W_34N in the North Pacific Ocean from 2010-01-17 to 2021-06-16 (NCEI Accession 0084099), NOAA National Centers for Environmental Information [data set], https://doi.org/10.3334/cdiac/otg.tsm_cce2_121w_34n, 2012.
45	CeNCOOS in situ water monitoring data at Trinidad Head, California	Trinidad, CA	41.055	-124.147	0 m	Oceanic	02/2013 - 12/2020	149498	Intertidal/ Subtidal sensor deployment	T, S, DO, Chl	YSI (6-Series)	This dataset overlaps with dataset 9 (NDBC station TDPC1) and is taken from the same shore station over a slightly different timeline. Overlapping observations have been retained in this dataset.	Shaughnessy, F: CeNCOOS in situ water monitoring data at Trinidad Head, California [data set], https://data.cencoos.org/#metadata/48097/station, 2023.
46	SFSU EOS YSI Raw data	Tiburon Peninsula, CA	37.891	-122.447	1 m	Estuarine	12/2020 - 12/2020	5096	Intertidal/ Subtidal sensor deployment	T, S, Chl	YSI (6-Series)		Dewitt, L.: SFSU EOS YSI Raw data [data set], https://oceanview.pfeg.noaa.gov/erddap/tabledap/rtcctdRTCysirt.html, 2022.

47	CeNCOOS in situ Water monitoring data at the Santa Cruz municipal wharf	Santa Cruz, CA	36.9603	-122.0203	1 m	Oceanic	02/2013 - 11/2020	613526	Intertidal/ Subtidal sensor deployment	T, S, DO, Chl	YSI (6-Series)		Kudela, R.: CeNCOOS in situ Water monitoring data at the Santa Cruz municipal wharf [data set], https://data.cencoos.org/#metadata/48323/station, 2020.
49	San Francisco Estuary Institute and the Aquatic Science Center Regional Monitoring Program for Water Quality in San Francisco Bay	San Francisco Bay, CA	37.43 to 38.13	-122.7 to -121.8	0 m to 88 m	Estuarine	03/1993 - 08/2019	1219	Cruise	T, S, DO, Chl	YSI		Bezalel S., Davis, J., Featherston, T., Flores, L., Grosso, C., Hale, T., Shusterman, G., Sutton, R., Weaver, M., Wong, A., and Yee, D.: Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), San Francisco Estuary Institute (SFEI) [data set], https://www.sfei.org/programs/sf-bay-regional-monitoring-program, 2021.
50	West Coast Estuary Data: Santa Monica Bay (15 m) autonomous monitoring coastal acidification data and Santa Monica Bay (60 m) autonomous monitoring coastal acidification data	Santa Monica	33.7	-118.4	15 m and 60 m	Oceanic	07/2016 - 01/2019	18501	Mooring	T, S, pH, pCO2, DO	CTD (Sea-Bird SBE 5P); Multiparameter sensor (SeapHOx); Sunburst SAMI-pCO2		Rosenau, N. A., Galavotti, H., Yates, K. K., Bohlen, C., Hunt, C. W., Liebman, M., Brown, C. A., Pacella, S. R., Largier, J. L., Nielsen, K. J., Hu, X., McCutcheon, M. R., Vasslides, J. M., Poach, M., Ford, T., Johnston, K., and Steele, A.: High-resolution coastal acidification monitoring data collected in seven estuaries along the US East Coast, US West Coast and Gulf of Mexico from 2015-04-23 to 2020-07-29 (NCEI Accession 0225225), NOAA National Centers for Environmental Information [data set], https://doi.org/10.25921/xg33-1n83, 2021.
51	West Coast Estuary Data: San Francisco Bay (surface) autonomous monitoring coastal acidification data and San Francisco Bay (deep water mooring) autonomous monitoring coastal acidification data	SF Bay	37.8928	-122.4469	1 m and 17 m	Estuarine	02/2018-10/2019	38174	Mooring	T, S, pH, DO, Chl	Moored Autonomous pCO2 (MAPCO2) system; Multiparameter sensor (Sea-Bird SeapHOx); Sea-Bird SeaFET		Rosenau, N. A., Galavotti, H., Yates, K. K., Bohlen, C., Hunt, C. W., Liebman, M., Brown, C. A., Pacella, S. R., Largier, J. L., Nielsen, K. J., Hu, X., McCutcheon, M. R., Vasslides, J. M., Poach, M., Ford, T., Johnston, K., and Steele, A.: High-resolution coastal acidification monitoring data collected in seven estuaries along the US East Coast, US West Coast and Gulf of Mexico from 2015-04-23 to 2020-07-29 (NCEI Accession 0225225), NOAA National Centers for Environmental Information [data set], https://doi.org/10.25921/xg33-1n83, 2021.
52	Dissolved inorganic carbon, alkalinity, temperature, salinity, and nutrient data for validation measurements for moored ocean acidification time-series observations of on the Cha Ba mooring off La Push, Washington (May 2011-October 2014)	La Push, WA	47.97	-124.95	1.5 m to 101 m	Oceanic	05/2011 - 10/2014	87	Cruise	T, S, DIC, TA, Nutrients			Alin, S. R., Newton, J., Sutton, A. J., and Mickett, J.: Dissolved inorganic carbon, total alkalinity, phosphate, silicate, and other variables collected from profile and discrete sample observations using CTD, Niskin bottle and other instruments in the northwest coast of the United States near the ChÃ¡ BÃƒ mooring off La Push, Washington from 2011-05-22 to 2014-10-24 (NCEI Accession 0145160), NOAA National Centers for Environmental Information [data set], https://doi.org/10.7289/v5b27sbj, 2016.
53	Morro Bay BM1 T-Pier (NOAA Station MBXC1)	Morro Bay, CA	35.37085	-120.8589	1 m	Estuarine	01/2019 - 10/2020	55197	Mooring	T, S, pH, DO, Chl	Sea-Bird SeaFET; YSI	This dataset overlaps with dataset 18 (NDBC station MBXC1) and is taken from the same shore station, though the two datasets have different time ranges and this dataset features an updated instrument array. Data from the published NDBC record that overlaps with dataset 18 has been retained in this dataset.	Walter, R.: CeNCOOS in situ water quality monitoring at Morro bay [data set], https://data.cencoos.org/#metadata/20679/station, 2023.
54	Morro Bay BS1 Station	Morro Bay, CA	35.33382	-120.8473	1 m	Estuarine	10/2018 - 12/2020	72914	Mooring	T, S, pH, DO, Chl	Sea-Bird SeaFET; YSI		California Polytechnic State University, Center for Coastal Marine Sciences: Morro Bay - BS1 [data set], https://data.cencoos.org/#metadata/100050/station, 2023.
55	High-resolution ocean and atmosphere pCO2 time series measurements from mooring WA_125W_47N in the North Pacific Ocean (NCEI Accession 0115322)	Cape Elizabeth, WA	47.35	-124.73	1 m	Oceanic	06/2006 - 05/2020	32327	Mooring	T, S, pH, pCO2, fCO2, DO	Moored Autonomous pCO2 (MAPCO2) system; non-dispersive infrared (NDIR) gas analyzer; Sunburst SAMI2 pH; Conductivity and Temperature sensor (Sea-Bird SBE 37-SM MicroCAT)		Sutton, A. J., Sabine, C. L., Musielewicz, S., Maenner Jones, S., Dietrich, C., Bott, R., and Osborne, J.: High-resolution ocean and atmosphere pCO2 time-series measurements from mooring WA_125W_47N in the North Pacific Ocean (NCEI Accession 0115322), NOAA National Centers for Environmental Information [data set], https://doi.org/10.3334/cdiac/otg.tsm_wa_125w_47n, 2013.
56	Stillwater Cove TidalFET	Carmel, CA	36.5607	-121.9459	1 m	Oceanic	02/2016 - 10/2020	103515	Intertidal/ Subtidal sensor deployment	T, S, pH, DO	Multiparameter sensor (Sea-Bird SeapHOx)		Donham, E., Strope, L., Hamilton, S., and Kroeker, K.: Coupled changes in pH, temperature and dissolved oxygen impact the physiology and ecology of herbivorous kelp forest grazers, Dryad [data set], https://doi.org/10.5061/dryad.8sf7m0cq7, 2022.
57	National Data Buoy Center Station 46211 Grays Harbor, WA	Grays Harbor, WA	46.857	-124.244	0.46 m	Oceanic	01/2005 - 12/2020	234490	Mooring	T			National Data Buoy Center: Station 46211 - Grays Harbor, WA (036), National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
58	National Data Buoy Center Station NEAW1 - 9443090 Neah Bay, WA	Neah Bay, WA	48.367	-124.614	1.19 m	Estuarine	04/2005 - 12/2020	1077750	Mooring	T			National Data Buoy Center: Station NEAW1 - 9443090 - Neah Bay, WA, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
59	National Data Buoy Center Station CECC1 â€“ 9419750 Crescent City, CA	Crescent City, CA	41.746	-124.184	1.3 m	Oceanic	04/2005 - 12/2020	1212991	Intertidal/ Subtidal sensor deployment	T			National Data Buoy Center: Station CECC1 - 9419750 - Crescent City, CA, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.

60	National Data Buoy Center Station 46237 San Francisco, CA	San Francisco, CA	37.788	-122.632	0.46 m	Oceanic	07/2007 - 12/2020	206800	Mooring	T			National Data Buoy Center: Station 46237 - San Francisco Bar, CA (142), National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
61	National Data Buoy Center Station 46240 Cabrillo Point, Monterey Bay, CA - 158 Monterey Bay, CA	Monterey Bay, CA	36.626	-121.907	1 m	Oceanic	12/2009 - 12/2020	152268	Mooring	T			Coastal Data Information Program (CDIP): Cabrillo Point, Monterey Bay, CA - 158 (46240) [data set], https://data.cencoos.org/#metadata/18373/station, 2023.
62	National Data Buoy Center Station PORO3 Port Orford, OR	Port Orford, OR	42.739	-124.498	1.3 m	Oceanic	04/2005 - 12/2020	1228936	Mooring	T			National Data Buoy Center: Station PORO3 - 9431647 - Port Orford, OR, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
63	National Data Buoy Center Station CHAO3 Charleston, OR	Charleston, OR	43.351	-124.337	2 m	Estuarine	04/2005 - 12/2020	1235698	Mooring	T			National Data Buoy Center: Station CHAO3 - 9432780 - Charleston, OR, National Oceanic and Atmospheric Administratoin [data set], https://www.ndbc.noaa.gov/historical_data.shtml#ocean, 2023.
64	High-resolution ocean and atmosphere pCO2 time series measurements from mooring CB-06_125W_43N in the North Pacific Ocean (NCEI Accession 0190840)	Coos Bay, OR	43.301	-124.535	0 m	Oceanic	06/2017 - 03/2020	4441	Mooring	T, S, pH, pCO2, fCO2, DO, Chl	Moored Autonomous pCO2 (MAPCO2) system; Sunburst SAMI2 pH; Dissolved Oxygen sensor (Xylem/Aanderaa 4175); WetLabs ECO FLNTU-S Fluorometer and Turbidity sensor		Sutton, A. J., Hales, B., Musielewicz, S., Maenner Jones, S., Bott, R., and Osborne, J.: High-resolution ocean and atmosphere pCO2 time-series measurements from mooring CB-06_125W_43N in the North Pacific Ocean (NCEI Accession 0190840), NOAA National Centers for Environmental Information [data set], https://doi.org/10.25921/rr8z-se53, 2019.
65	High-resolution ocean and atmosphere pCO2 time series measurements from mooring NH10_124W_44N in the North Pacific Ocean (NCEI Accession 0157247)	Newport, OR	44.642	-124.3	1.7 m	Oceanic	04/2014 - 04/2017	5929	Mooring	T, S, pH, pCO2, fCO2, DO, Chl	Moored Autonomous pCO2 (MAPCO2) system; Sea-Bird SeaFET; WetLabs ECO FLNTU-S Fluorometer and Turbidity sensor		Sutton, A. J., Sabine, C. L., Hales, B., Musielewicz, S., Maenner Jones, S., Dietrich, C., Bott, R., and Osborne, J.: High-resolution ocean and atmosphere pCO2 time-series measurements from mooring NH10_124W_44N in the North Pacific Ocean (NCEI Accession 0157247), NOAA National Centers for Environmental Information [data set], https://doi.org/10.3334/cdiac/otg.tsm_nh10_124w_44n, 2016.
66	Ocean Observatories Initiative (OOI) Washington and Oregon Inshore and Shelf Moorings	Washington and Oregon	44.38 to 47.13	-125.0 to -124.1	0 m, 7 m, and 87 m	Oceanic	09/2016 - 12/2020	10344	Mooring	T, pH, DO	Sunburst SAMI-pH, Dissolved Oxygen sensor (Xylem/Aanderaa Optode)	This data was aggegated into daily average values before incorporating into this synthesis.	
67	Trinidad Head Line CTD Hydrography	Northern California	40.8641 to 41.081	-125.2 to -125.8	1 m to 545 m	Oceanic	11/2006 - 10/2020	129741	Cruise	T, S, pH, DO	CTD; Sea-Bird SBE 18 pH Sensor		
68	Cross-shelf CTD casts from shipboard survey data collected along the Newport Hydrographic Line, 1997-2021	Central Oregon	44.65	-128.8 to -124.1	0 m to 3000m	Oceanic	01/1998 - 12/2020	577411	Cruise	T, S, DO	CTD (Sea-Bird Scientific 19 SeaCAT, 19plus V2 SeaCAT, SBE 25 Sealogger, or SBE 25plus Sealogger profilers); Dissolved Oxygen sensor (Sea-Bird SBE 43)		Risien, C. M., Fewings, M. R., Fisher, J. L., Peterson, J. O., Morgan, C. A and Peterson, W..: Spatially gridded cross-shelf hydrographic sections and monthly climatologies from shipboard survey data collected along the Newport Hydrographic Line, 1997â€"2021 (1.0), Zenodo [data set], https://doi.org/10.5281/zenodo.5814071, 2022.
69	Oceanographic Data Across Oregon's Marine Reserves	Oregon	42.66 to 45.76	-124.5 to -124.0	15 m	Oceanic	07/2010 - 09/2020	97906	Mooring	T, DO	Onset HOBO Temperature logger, CTD (Sea-Bird), Odyssey Capacitive Water Level Logger		Aylesworth, L., Fields, S. A., Fields, R. T., and Kane, C.: Oceanography Appendix Report, Oregon Department of Fish and WIldlife Marine Resources Program, Newport, OR, https://ecologyreports.oregonmarinereserves.com/Data_Files/6.%20Across%20Reserves/Oceanography/Oceanography_Appendix.html, 2022.
70	CMOP: Physical and biogeochemical observation stations in the Columbia River estuary (Saturn-02)	Columbia River Estuary, OR	46.1735	-124.1272	6 m and 35 m	Estuarine	05/2009 - 11/2019	988113	Mooring	T, S, DO	Honeywell UDA2182 Multiple Input Analyzer	More data is available from this location, but only the Saturn 02 temperature, salinity, and dissolved oxygen observations are included in this compilation.	Columbia River Intertribal Fish Commission Center for Coastal Margin Observation and Prediction.: SATURN Observation Network Endurance Stations: SATURN-02 [data set], https://cmop.critfc.org/datamart/observation-network/fixed-station/?id=saturn02&tab=inventory#anchor_38, 2023.
71	Monthly cross-shore transects of biogeochemical properties in La Jolla, CA	Southern CA	32.87	-117.3	0 m to 40 m	Oceanic	03/2017 - 09/2018	227	Cruise	T, S, pH, DIC, TA, DO, Nutrients	Sunburst SAMI-pH, YSI, Potentiometric Titrator (TA)		Kekuewa, S. and Andersson, A.: Monthly cross-shore transects of biogeochemical properties in La Jolla, CA, Biological and Chemical Oceanography Data Management Office (BCO-DMO) [data set], doi:10.26008/1912/bco-dmo.839175.1, 2022.