

Autonomous seawater $p\text{CO}_2$ and pH time series from 40 surface buoys and the emergence of anthropogenic trends

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Abstract. Ship-based time series, some now approaching over three decades long, are critical climate records that have dramatically improved our ability to characterize natural and anthropogenic drivers of ocean CO_2 uptake and biogeochemical processes. Advancements in autonomous ocean carbon observing technology over the last two decades have led to the expansion of fixed time series stations with the added capability of characterizing sub-seasonal variability. Here we present a data product of 40 autonomous moored surface ocean $p\text{CO}_2$ (partial pressure of CO_2) and pH time series established between 2004 and 2013. These time series characterize a wide range of seawater $p\text{CO}_2$ and pH conditions in different oceanic (17 sites) and coastal (12 sites) regimes including coral reefs (11 sites). With well-constrained daily to interannual variability and an estimate of decadal variability, these data suggest the length of time series necessary to detect an anthropogenic trend in seawater $p\text{CO}_2$ and pH varies from 8 to 15 years at the open ocean sites, 16 to 41 years at the coastal sites, and 9 to 22 years at the coral reef sites. Only two open ocean $p\text{CO}_2$ time series, WHOTS in the subtropical North Pacific and Stratus in the South Pacific gyre, are longer than the estimated time of emergence, and deseasoned monthly means show anthropogenic trends of $1.9 \pm 0.3 \mu\text{atm yr}^{-1}$ and $1.6 \pm 0.3 \mu\text{atm yr}^{-1}$, respectively. In the future, it is possible that updates to this product will allow for estimating

anthropogenic trends at more sites; however, the product currently provides a valuable tool in an accessible format for evaluating climatology and natural variability of surface ocean carbonate chemistry in a variety of regions. . Data are available at

<https://www.nodc.noaa.gov/ocads/oceans/Moorings/ndp097.html>

Table 1. Data access to deployment-level archived data files at NCEI and the time series data product for each moored buoy location (decimal degrees of latitude, longitude). The earliest date of seawater $p\text{CO}_2$ trend emergence is calculated by adding the time of emergence (ToE) estimate to the time series start year (see Sutton et al. 2018 for more details). NA denotes sites lacking enough observations for estimating ToE.

Buoy	Location	NCEI archived data files (https:// www.nodc.noaa.gov/...)	Time series data product (https:// www.pmel.noaa.gov/co2/...)	Earliest date of seawater $p\text{CO}_2$ trend emergence
CCE1	33.48, -122.51	ocads/data/0144245.xml	timeseries/CCE1.txt	2020 ± 2
Papa	50.13, -144.84	ocads/data/0100074.xml	timeseries/PAPA.txt	2017 ± 2
KEO	32.28, 144.58	ocads/data/0100071.xml	timeseries/KEO.txt	2018 ± 2
JKEO	37.93, 146.52	ocads/data/0100070.xml	timeseries/JKEO.txt	NA ^a
WHOTS	22.67, -157.98	ocads/data/0100073.xml ^b ocads/data/0100080.xml	timeseries/WHOTS.txt	2013 ± 1
TAO110W	0, -110.00	ocads/data/0112885.xml	timeseries/TAO110W.txt	2024 ± 4
TAO125W	0, -125.00	ocads/data/0100076.xml	timeseries/TAO125W.txt	2017 ± 4
TAO140W	0, -140.00	ocads/data/0100077.xml	timeseries/TAO140W.txt	2018 ± 2
TAO155W	0, -155.00	ocads/data/0100084.xml	timeseries/TAO155W.txt	NA
TAO170W	0, -170.00	ocads/data/0100078.xml	timeseries/TAO170W.txt	2016 ± 4
TAO165E	0, 165.00	ocads/data/0113238.xml	timeseries/TAO165E.txt	NA
TAO8S165E	-8.00, 165.00	ocads/data/0117073.xml	timeseries/TAO8S165E.txt	2021 ± 2
Stratus	-19.70, -85.60	ocads/data/0100075.xml	timeseries/STRATUS.txt	2015 ± 1
BTM	31.50, -64.20	ocads/data/0100065.xml	timeseries/BTM.txt	NA ^a
Iceland	68.00, -12.67	ocads/data/0157396.xml	timeseries/ICELAND.txt	NA
BOBOA	15.00, 90.00	ocads/data/0162473.xml	timeseries/BOBOA.txt	NA
SOFS	-46.80, 142.00	ocads/data/0118546.xml	timeseries/SOFS.txt	NA
GAKOA	59.910, -149.350	ocads/data/0116714.xml	timeseries/GAKOA.txt	2027 ± 3
Kodiak	57.700, -152.310	ocads/data/0157347.xml	timeseries/KODIAK.txt	2028 ± 3 ^a

SEAK	56.260, -134.670	ocads/data/0157601.xml	timeseries/SEAK.txt	NA ^a
M2	56.510, -164.040	ocads/data/0157599.xml	timeseries/M2.txt	NA
Cape Elizabeth	47.353, -124.731	ocads/data/0115322.xml	timeseries/CAPEELIZABETH.txt	2030 ± 4
Chá bã	47.963, -125.958	ocads/data/0100072.xml	timeseries/CHABA.txt	2033 ± 4
CCE2	33.479, -120.814	ocads/data/0084099.xml	timeseries/CCE2.txt	2028 ± 3
Dabob	47.803, -122.803	ocads/data/0116715.xml	NA	2050 ± 6
NH-10	44.904, -124.778	ocads/data/0157247.xml	timeseries/NH10.txt	NA ^a
Twanoh	47.375, -123.008	ocads/data/0157600.xml	NA	2050 ± 6
Ala Wai	21.280, -157.850	ocads/data/0157360.xml	timeseries/ALAWAI.txt	2024 ± 3
Chuuk	7.460, 151.900	ocads/data/0157443.xml	timeseries/CHUUK.txt	2021 ± 2
CRIMP1	21.428, -157.788	ocads/data/0100069.xml	timeseries/CRIMP1.txt	2022 ± 4 ^a
CRIMP2	21.458, -157.798	ocads/data/0157415.xml	timeseries/CRIMP2.txt	2030 ± 3
Kaneohe	21.480, -157.780	ocads/data/0157297.xml	timeseries/KANEOHE.txt	NA
Kilo Nalu	21.288, -157.865	ocads/data/0157251.xml	timeseries/KILONALU.txt	2017 ± 2
Gray's Reef	31.400, -80.870	ocads/data/0109904.xml	timeseries/GRAYSSREEF.txt	2027 ± 3
Gulf of Maine	43.023, -70.542	ocads/data/0115402.xml	timeseries/GULFOFMAINE.txt	2023 ± 3
Crescent Reef	32.400, -64.790	ocads/data/0117059.xml	timeseries/CRESCENTREEF.txt	2020 ± 2
Hog Reef	32.460, -64.830	ocads/data/0117060.xml	timeseries/HOGREEF.txt	2023 ± 3
Coastal MS	30.000, -88.600	ocads/data/0100068.xml	timeseries/COASTALMS.txt	2046 ± 7
Cheeca Rocks	24.910, -80.624	ocads/data/0157417.xml	timeseries/CHEECAROCKS.txt	2020 ± 2
La Parguera	17.954, -67.051	ocads/data/0117354.xml	timeseries/LAPARGUERA.txt	2019 ± 2

Notes: a Discontinued sites where a long-term trend cannot be quantified from this time series data product. b Links to NCEI archived deployment-level data files are provided for both MOSEAN and WHOTS; however, these time series are combined in the time series data product.

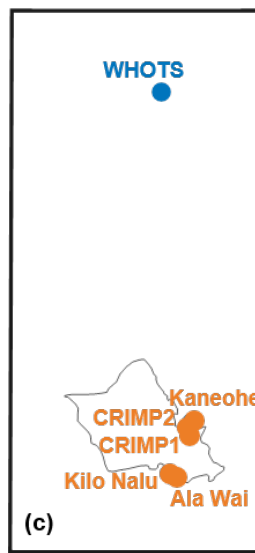
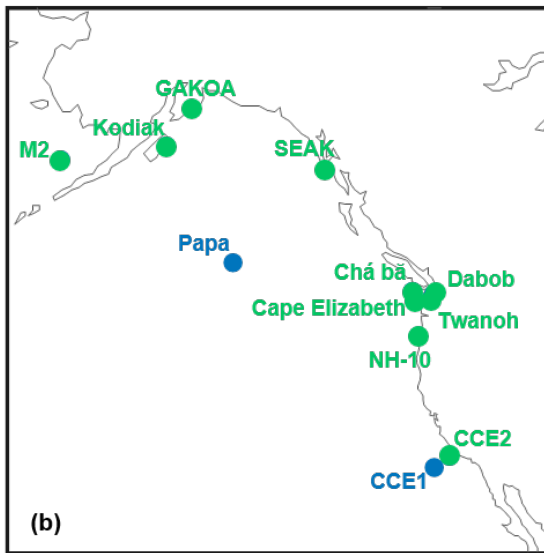
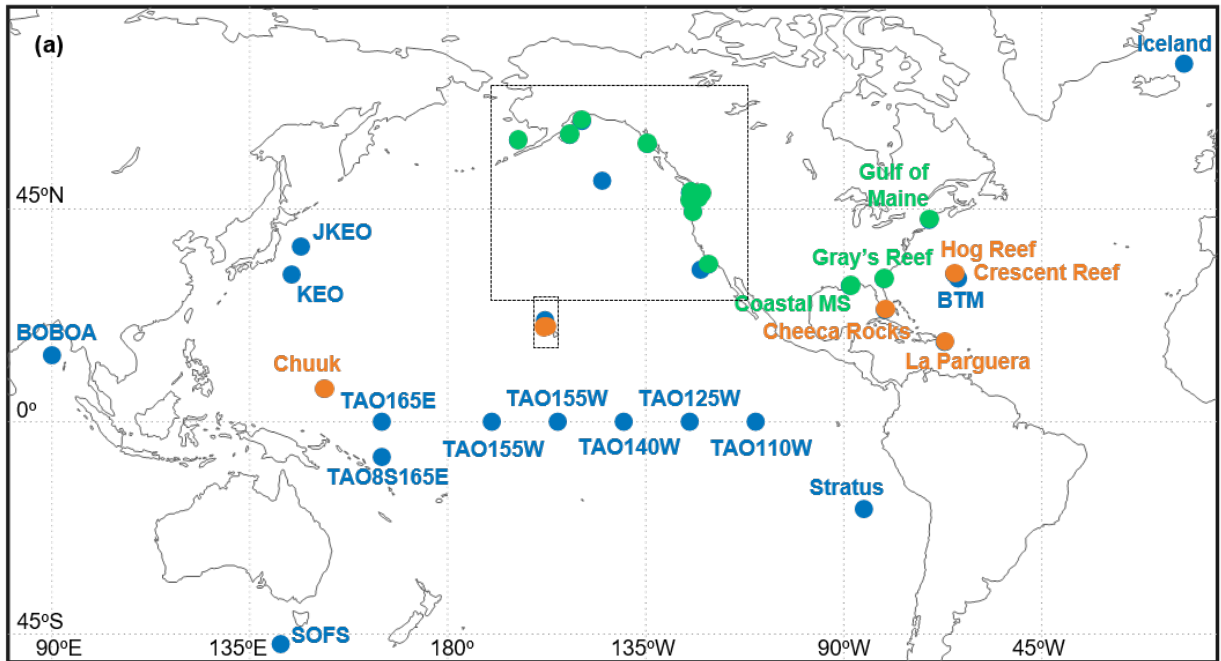


Figure 1. (a) Locations of moored autonomous seawater $p\text{CO}_2$ and pH time series included in Sutton et al. 2018. (b) U.S. West Coast and (c) Hawaii locations. Blue symbols are open ocean sites; green are coastal shelf; and orange are coral reefs.