Temperature, salinity, fluorescence, and dissolved O2/Ar ratios measured continuously underway onboard basin-wide transects of the North Pacific from Hong Kong to Long Beach, CA

Website: https://www.bco-dmo.org/dataset/831046
Data Type: Cruise Results
Version: 1
Version Date: 2020-11-20

Project
» North Pacific Surface Carbon, Oxygen and Isotope Measurements from Container Ships (2008-) (NPac Cont Ship)

Contributors	Affiliation	Role
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Abstract
Temperature, salinity, fluorescence, and dissolved O2/Ar ratios were measured continuously from an underway seawater system on board commercial container ships OOCL Tianjin and OOCL Tokyo. Measurements were made from May 2011 to August 2012 during basin-wide transects of the North Pacific Ocean while traversing from Hong Kong to Long Beach, CA

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Coverage

Spatial Extent: **N**:49.56855929 **E**:-120.5016962 **S**:22.68718349 **W**:116.6051464
Temporal Extent: 2011-05-16 - 2012-08-06

Methods & Sampling

Measurements
Measurements for O2/Ar dissolved gas ratios, temperature, salinity, and fluorescence were continuously measured from an underway seawater system (10 m depth) on basin-wide transects of the North Pacific between Hong Kong and Long Beach, California onboard the M/V OOCL Tianjin and the M/V OOCL Tokyo (each individual transect has a unique Cruise ID). Sea surface temperature and salinity at the time of sample collection were determined using a Sea-Bird Electronics SBE45 thermosalinograph (TSG) installed in the ship's seawater intake. Fluorescence was measured using a Seapoint Chlorophyll Fluorometer. This dataset presents uncalibrated data; the discrete calibration data are in https://www.bco-dmo.org/dataset/626855.

Underway measurements of O2/Ar dissolved gas ratios were made using continuous flow equilibrator inlet mass spectrometry (EIMS), following the method of Cassar et al. (2009). Water from the underway seawater system was pumped into an equilibrator cartridge (Membrana MicroModule G569, 0.75" x 1"), the headspace of which was delivered to a quadrupole mass spectrometer (Pfeiffer Prisma QMS) that measured individual ion currents at one-second intervals. To prevent biofouling that could cause respiration in the ship's seawater lines (Juranek et al., 2010), intake lines between the anticorrosive sea chest and the sampling port were purged with bleach and freshwater between every cruise.

NOTE: Since the samples were collected underway on a vessel moving ~24 knots and samples for all parameters were collected by a single shiprider, ship transit from the time that the location coordinates were recorded to the time of actual sampling could reflect a transit distance offset from the recorded location of up to 40 kilometers.

Methods and Calculations
Methods are described in detail in Clayton et al. (in preparation for JGR: Oceans).

To aid in interpretation of the O2/Ar data provided here, we include calculations of the air-sea flux of biological oxygen driven by the biological saturation anomaly (O2Arbiosat), termed "bioflux" by Jonsson et al. [2013]:

Air_sea_flux = k*[O2]eq*(O2Arbiosat/100)

Where k represents the wind speed-dependent air-sea gas transfer velocity and [O2]eq is the oxygen concentration that would be expected in the mixed layer were it in equilibrium with the atmosphere. We calculate k from daily wind speed data from the NOAA National Climatic Data Center's multiple-satellite Blended Sea Winds product (https://www.ncdc.noaa.gov/data-access/marineocean-data/blended-global/blended-sea-winds) following the Nightingale et al. (2000) equation and the 60-day (Reuer et al., 2007) time-dependent weighting scheme. We report k here as "Wkn" representing the weighted k value using the Nightingale algorithm. In conditions with limited influence of physical advection, entrainment, and transient changes due to non-steady state conditions over the dissolved gas residence time in the mixed layer, bioflux is equivalent to net community production. However, there are potential biases in quantifying net community production based on observed O2/Ar in dynamic western boundary current regions where steady state assumptions are likely invalid and strong vertical turbulent dissipation rates have been observed.

The following are additional details for relevant fields in this dataset:

- **TrueO2Ar**: ratio of dissolved O2/dissolved Ar in surface seawater as measured by continuous underway equilibrator inlet mass spec, and calibrated with discrete samples from existing dataset (https://www.bco-dmo.org/dataset/626855).
- **O2Arsat**: O2/Ar ratio expected if both gases were in equilibrium with the atmosphere, which is a function of Salinity and Temperature (Garcia and Gordon, 1992; Hamme and Emerson, 2007)
- **O2Arbiosat**: percent supersaturation of O2 in surface seawater, calculated from the TrueO2Ar and O2Arsat [O2Arbiosat = (TrueO2Ar/O2Arsat – 1)*100]
- **MLD**: climatological mixed layer depth from monthly World Ocean Atlas 2013 (with 1 degree gridded data)
- **Wkn**: air-sea gas transfer velocity in m/day, calculated using a relationship between wind speed and gas transfer from Nightingale et al. (2000) and the NOAA/NCDC Blended Sea Winds satellite wind speed product (Zhang et al. 2006), and using the Reuer et al. (2007) time-dependent weighting scheme and the MLD values given here.

Data Processing Description

Data processing:
Data are reported as the mean over a three-minute measurement period, chosen to match the e-folding response time of O2/Ar ion current ratios for this EIMS setup. This yields a spatial resolution of ~2 km at the average ship speed of ~25 knots. For the Tokyo_3 cruise, a Loess filter with a 30-minute half-span was applied to remove high frequency instrument noise in the EIMS setup, reducing the spatial resolution to ~40 km, giving a marginal sampling for mesoscale fields. This filter was not applied to the May 2011 or July 2012 cruises in order to preserve the spatial resolution of the data.

BCO-DMO processing:
- Data from all cruises were combined into a single dataset with an added column for Cruise ID
- Timestamp converted to ISO DateTime UTC format in additional column
- Longitude converted from a 360 degree scale to +/- 180 scale, and put in separate column

- Parameter names adjusted to comply with database requirements
- Added a conventional header with dataset name, PI name, version date
- Units added to parameter description metadata section
- Missing data identifier of 'nd' (no data) used

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Data Files

File
NPac_underway_data.csv (Comma Separated Values (.csv), 1.44 MB) MD5:dacea01e15125c6bad1e95080f8070a9 Primary data file for dataset ID 831046

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Related Publications

Cassar, N., Barnett, B. A., Bender, M. L., Kaiser, J., Hamme, R. C., & Tilbrook, B. (2009). Continuous High-Frequency Dissolved O2/Ar Measurements by Equilibrator Inlet Mass Spectrometry. Analytical Chemistry, 81(5), 1855–1864. doi:10.1021/ac802300u
Methods

Clayton, S., Palevsky, H. I., Thompson, L., & Quay, P. D. (2021). Synoptic Mesoscale to Basin Scale Variability in Biological Productivity and Chlorophyll in the Kuroshio Extension Region. Journal of Geophysical Research: Oceans, 126(11). Portico. https://doi.org/10.1029/2021jc017782 https://doi.org/10.1029/2021JC017782
Methods

Garcia, H. E., & Gordon, L. I. (1992). Oxygen solubility in seawater: Better fitting equations. Limnology and Oceanography, 37(6), 1307–1312. doi:10.4319/lo.1992.37.6.1307
Methods

Hamme, R. C., & Emerson, S. R. (2004). The solubility of neon, nitrogen and argon in distilled water and seawater. Deep Sea Research Part I: Oceanographic Research Papers, 51(11), 1517–1528. doi:10.1016/j.dsr.2004.06.009
Methods

Jonsson, B. F., Doney, S. C., Dunne, J., & Bender, M. (2013). Evaluation of the Southern Ocean O2/Ar-based NCP estimates in a model framework. Journal of Geophysical Research: Biogeosciences, 118(2), 385–399. https://doi.org/10.1002/jgrg.20032
Methods

Juranek, L. W., Hamme, R. C., Kaiser, J., Wanninkhof, R., & Quay, P. D. (2010). Evidence of O2 consumption in underway seawater lines: Implications for air-sea O2 and CO2 fluxes. Geophysical Research Letters, 37(1), n/a–n/a. doi:10.1029/2009gl040423 https://doi.org/10.1029/2009GL040423
Methods

Nightingale, P. D., Malin, G., Law, C. S., Watson, A. J., Liss, P. S., Liddicoat, M. I., Boutin, J., and Upstill-Goddard, R. C. (2000). In situ evaluation of air-sea gas exchange parameterizations using novel conservative and volatile tracers. Global Biogeochemical Cycles, 14(1), 373–387. doi:10.1029/1999gb900091 https://doi.org/10.1029/1999GB900091
Methods

Reuer, M. K., Barnett, B. A., Bender, M. L., Falkowski, P. G., & Hendricks, M. B. (2007). New estimates of Southern Ocean biological production rates from O2/Ar ratios and the triple isotope composition of O2. Deep Sea Research Part I: Oceanographic Research Papers, 54(6), 951–974. doi:10.1016/j.dsr.2007.02.007
Methods

Zhang, H.-M., Bates, J. J., & Reynolds, R. W. (2006). Assessment of composite global sampling: Sea surface wind speed. Geophysical Research Letters, 33(17). doi:10.1029/2006gl027086 https://doi.org/10.1029/2006GL027086
Methods

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Related Datasets

References

Quay, P. (2016) **Dissolved gas O2/Ar and triple oxygen isotope discrete samples collected from 16 basin-wide transects of the North Pacific, Hong Kong - Long Beach, CA from the M/V OOCL Tianjin and M/V OOCL Tokyo, 2008-2012 (NPac Cont Ship project).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 2016-02-03) Version Date 2016-02-03 http://lod.bco-dmo.org/id/dataset/626855 [view at BCO-DMO]
Relationship Description: Discrete samples from dataset 626855 (O2/Ar and triple oxygen isotopes) were used to calibrate the TrueO2Ar measurements for dataset 831046 (Continuous underway data)

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Parameters

Parameter	Description	Units
ISO_DateTime_UTC	Mean UTC/GMT time for each time interval in ISO format (yyyy-mm-ddT hh:mm:ssZ)	unitless
Cruise	Cruise ID	unitless
Latitude	Latitude of sample collection, South is negative	decimal degrees
Longitude	Longitude of sample collection, West is negative	decimal degrees
Lon360	Longitude on 360 degree scale with 180 at the Date Line	decimal degrees
Salinity	Sea surface Salinity as measured by shipboard thermosalinograph (TSG)	psu
Temperature	Sea Surface Temperature as measured by shipboard thermosalinograph (TSG)	degrees Celsius
Fluo	Fluorescence measured with underway fluorometer (raw, uncalibrated data)	microgram per liter (ug/L)
TrueO2Ar	Ratio of dissolved O2/dissolved Ar in surface seawater as measured by continuous underway equilibrator inlet mass spectrometry, and calibrated with discrete samples from existing dataset https://www.bco-dmo.org/dataset/626855	unitless
O2Arsat	O2/Ar ratio expected if both gases were in equilibrium with the atmosphere, which is a function of Salinity and Temperature (Garcia and Gordon, 1992; Hamme and Emerson, 2007)	unitless
O2Arbiosat	Percent biological supersaturation of O2 in surface seawater, calculated from the TrueO2Ar and O2Arsat [O2Arbiosat = (TrueO2Ar/O2Arsat – 1)*100].	percent (%)
MLD_WOA13	Climatological mixed layer depth from monthly World Ocean Atlas 2013 (with 1 degree gridded data), used in calculations	meters
Wkn	Air-sea gas transfer velocity in m/day, calculated using a relationship between wind speed and gas transfer from Nightingale et al. (2000) and the NOAA/NCDC Blended Sea Winds satellite wind speed product (Zhang et al. 2006), and using the Reuer et al. (2007) time-dependent weighting scheme and the MLD values given here.	meters per day (m/day)
Air_sea_flux	Exchange of oxygen between the ocean and atmosphere: Airseaflux = (O2Arbiosat/100)*(O2sat)*wkn, where O2sat is calculated from the solubility equation from Garcia and Gordon, 1992.	millimoles O2 per meters squared per day (mmol O2 m-2 d-1)

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Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Equilibrator Inlet Mass Spectrometer
Generic Instrument Description	Cassar N, Barnett BA, Bender ML, Kaiser J, Hamme RC, Tilbrook B., Continuous high-frequency dissolved O2/Ar measurements by equilibrator inlet mass spectrometry. Anal Chem. 2009 Mar 1;81(5):1855-64. doi: 10.1021/ac802300u. Source: Department of Geosciences, Princeton University, Princeton, New Jersey 08544, USA. ncassar@princeton.edu Abstract The oxygen (O(2)) concentration in the surface ocean is influenced by biological and physical processes. With concurrent measurements of argon (Ar), which has similar solubility properties as oxygen, we can remove the physical contribution to O(2) supersaturation and determine the biological oxygen supersaturation. Biological O(2) supersaturation in the surface ocean reflects the net metabolic balance between photosynthesis and respiration, i.e., the net community productivity (NCP). We present a new method for continuous shipboard measurements of O(2)/Ar by equilibrator inlet mass spectrometry (EIMS). From these measurements and an appropriate gas exchange parametrization, NCP can be estimated at high spatial and temporal resolution. In the EIMS configuration, seawater from the ship's continuous intake flows through a cartridge enclosing a gas-permeable microporous membrane contactor. Gases in the headspace of the cartridge equilibrate with dissolved gases in the flowing seawater. A fused-silica capillary continuously samples headspace gases, and the O(2)/Ar ratio is measured by mass spectrometry. The ion current measurements on the mass spectrometer reflect the partial pressures of dissolved gases in the water flowing through the equilibrator. Calibration of the O(2)/Ar ion current ratio (32/40) is performed automatically every 2 h by sampling ambient air through a second capillary. A conceptual model demonstrates that the ratio of gases reaching the mass spectrometer is dependent on several parameters, such as the differences in molecular diffusivities and solubilities of the gases. Laboratory experiments and field observations performed by EIMS are discussed. We also present preliminary evidence that other gas measurements, such as N(2)/Ar and pCO(2) measurements, may potentially be performed with EIMS. Finally, we compare the characteristics of the EIMS with the previously described membrane inlet mass spectrometry (MIMS) approach. PMID: 19193192 [PubMed - indexed for MEDLINE]

Dataset-specific Instrument Name	Seapoint Chlorophyll Fluorometer
Generic Instrument Name	Fluorometer
Generic Instrument Description	A fluorometer or fluorimeter is a device used to measure parameters of fluorescence: its intensity and wavelength distribution of emission spectrum after excitation by a certain spectrum of light. The instrument is designed to measure the amount of stimulated electromagnetic radiation produced by pulses of electromagnetic radiation emitted into a water sample or in situ.

Dataset-specific Instrument Name	Pfeiffer Prisma QMS
Generic Instrument Name	Quadrupole Mass Spectrometer
Dataset-specific Description	Quadrupole mass spectrometer (Pfeiffer Prisma QMS) measured individual ion currents at one-second intervals.
Generic Instrument Description	A piece of apparatus that consists of an ion source, a mass-to-charge analyser, a detector and a vacuum system and is used to measure mass spectra. The detector is a quadrupole mass-to-charge analyser, which holds the ions in a stable orbit by an electric field generated by four parallel electrodes.

Dataset-specific Instrument Name	Sea-Bird Electronics SBE45
Generic Instrument Name	Sea-Bird SBE 45 MicroTSG Thermosalinograph
Generic Instrument Description	A small externally powered, high-accuracy instrument, designed for shipboard determination of sea surface (pumped-water) conductivity and temperature. It is constructed of plastic and titanium to ensure long life with minimum maintenance. It may optionally be interfaced to an external SBE 38 hull temperature sensor. Sea Bird SBE 45 MicroTSG (Thermosalinograph)

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Deployments

Tokyo_1

Website	https://www.bco-dmo.org/deployment/626908
Platform	OOCL Tokyo
Start Date	2011-05-16
End Date	2011-05-29
Description	Container ship collected surface salinity, temperature and water samples for carbon and oxygen isotopes measurements.

Tokyo_2

Website	https://www.bco-dmo.org/deployment/626910
Platform	OOCL Tokyo
Start Date	2011-06-27
End Date	2011-07-10
Description	Container ship collected surface salinity, temperature and water samples for carbon and oxygen isotopes measurements.

Tokyo_3

Website	https://www.bco-dmo.org/deployment/626912
Platform	OOCL Tokyo
Start Date	2011-09-20
End Date	2011-10-02
Description	Container ship collected surface salinity, temperature and water samples for carbon and oxygen isotopes measurements.

Tianjin_2

Website	https://www.bco-dmo.org/deployment/626920
Platform	OOCL Tianjin
Start Date	2012-07-24
End Date	2012-08-06
Description	Container ship collected surface salinity, temperature and water samples for carbon and oxygen isotopes measurements.

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Project Information

North Pacific Surface Carbon, Oxygen and Isotope Measurements from Container Ships (2008-) (NPac Cont Ship)

Coverage: Transects across the North Pacific from Hong Kong to Long Beach, California, USA; ~25-50N, 115E-120W

This project is an ongoing time-series beginning in 2008 of measurements relevant to ocean carbon cycling and productivity on basin-wide container ship transects across the North Pacific from Hong Kong to Long Beach, California, with transects made throughout the seasonal cycle beginning in October 2008. The goal of this project is to improve our understanding of the rates and mechanisms of ocean carbon uptake from the atmosphere throughout the seasonal cycle and across spatial gradients across the basin. Sampling includes both discrete samples and continuous underway measurements. Tracers sampled in this program include triple oxygen isotopes (δ17O and δ18O), a tracer of gross primary production, oxygen/argon dissolved gas ratios, a tracer of net community production or carbon export, and carbonate system parameters (pCO2, total alkalinity, DIC, and 13C-DIC) as tracers of ocean carbon uptake and carbon cycling.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0628663
NSF Division of Ocean Sciences (NSF OCE)	OCE-1259055
NOAA Oceanic and Atmospheric Research (OAR) Climate Program Office (NOAA OAR Climate Program)	A10OAR4310088

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