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ACCSP Heron Island - Wistari CO2 mooring

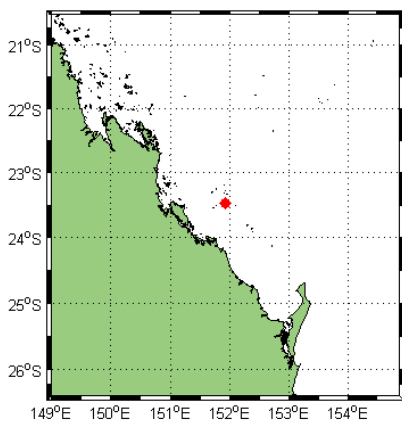
Dataset:

IM05_ANMN-AM_GST_20221102T040000Z_GBRWIS_FV01_GBRWIS-CO2-2211-delayed_END_20230429T220000Z_C-20230710T103610Z.nc

Deployment information

Location:

Heron Island - Wistari Channel, Queensland; -23.4575, 151.927



Water Depth:

16m

Platform:

IM05_ANMN-AM_CO2_GST

Platform code:

GBRWIS

Deployment code:

GBRWIS_25

Expocode:

09F520221102

Start date

20221102T040000Z

End date

20230429T220000Z

Mooring Bounds: North West South East

-23.5305 -23.38453 151.8983 151.9558

Data history

Data report submission:

13-07-2023

Most recent report update:

10-07-2023

Investigators:

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Mooring deployment

Deployed

01/11/2022 22:45

Recovered

20/04/2023 06:00

Vessel

Heron Island Mooring

Moored sensors:

Battelle MApCO2 s/n

0122

Seabird SBE 16pus_V2 s/n

01606552

Aanderaa Optode s/n

1450

Field personel

Abe Passmore, Gary Curtis, Shannon Palmer

Instrumentation

Erik van Ooijen

Quality control

Erik van Ooijen

Data file description:

Variable [Unit] Description =====

TIME [YYYY-MM-DDThh:mm:ssZ] Time and Date, ISO8601

LATITUDE [deg] Latitude

LONGITUDE [deg] Longitude

XCO2_DRY_SW [μmol/mol] Mole fraction of CO2 in the equilibrator head space

XCO2_DRY_AIR [μmol/mol] Mole fraction of CO2 in the atmosphere

fCO2_WET_SW [μatm] Fugacity of carbon dioxide at surface water, corrected for water vapour at surface water salinity and temperature

dFCO2 [μatm] Delta fCO2 = (fCO2_WET_SW - fCO2_WET_AIR)

ATMOSPHERIC PRESSURE [kPa] Atmospheric pressure

EQUILIBRATOR PRESSURE [kPa] Equilibrator pressure

SEA SURFACE TEMPERATURE [degC] Sea surface temperature

EQUILIBRATOR TEMPERATURE [degC] Equilibrator temperature

SALINITY [PSS] *Sea surface salinity*

DISSOLVED_OXYGEN [$\mu\text{mol/l}$] *Concentration O₂ in surface sea water*

WOCE QC flag 2=good, 3=questionable, 4=bad

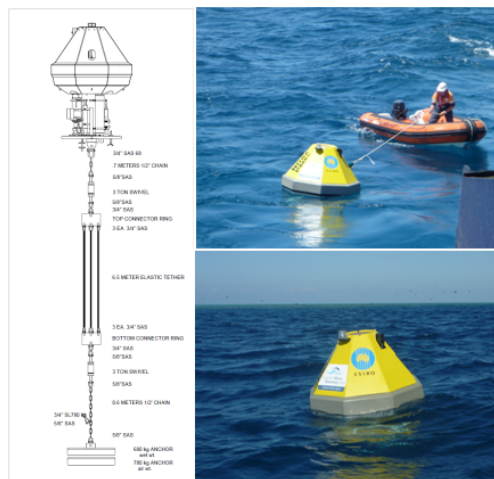
SUB_FLAG 24-bit number, internal QC

General system description and procedures

Instrumentation and methods

Measurements are made with a Battelle Sealogy pCO₂ monitoring system (MapCO₂), a Seabird SBE16plusV2 CTD, mounted on a surface buoy similar to the system described in Sutton et al. (2014), with an Aanderaa optode used to measure dissolved oxygen concentrations. The seawater sensor intakes for the MapCO₂, SBE16Plus V2 and the optode are located at about 1m water depth. The CO₂ measurement uses a bubble equilibrator (Sutton et al., 2014), where the air from the equilibrator headspace is circulated through a LI-COR 820 non-dispersive infrared detector (NDIR) for measurement of CO₂. The system carries out an automated measurement sequence every 2 or 3 hours, depending on the instrumentation setup. At the beginning of each measurement sequence, the NDIR undergoes a two point calibration with a zero CO₂ gas and a high CO₂ standard span gas (typically 450-550 micromol/mol), which bracket the range of CO₂ mole fractions in seawater and air. The zero CO₂ gas is generated by cycling air through a soda lime chamber and silica gel to remove CO₂ and water vapour, respectively. The CO₂ span gas is prepared by the NOAA Earth Systems Research Laboratory in the USA and calibrated on the WMO X2007 scale with a standard deviation of 0.06 micromol/mol (<http://www.esrl.noaa.gov/gmd/cc/airstandard.html>). Each measurement cycle of zero and span gas, equilibrator headspace, and air takes 20 minutes with the equilibrator headspace measurement occurring at about 17 minutes followed by the air measurement. The pressure measurements are considered the same for the equilibrator headspace gas and air measurements due to the design of the MapCO₂ system (Sutton et al., 2014) as are the temperature and salinity of the surface seawater and the equilibrator measured by the Seabird SBE16PlusV2.

Location and mooring design



The Heron Island Wistari mooring is located on the east side of Heron Island in the Wistari Channel in about 16m water depth. A 700kg anchor holds the mooring buoy in position, which is connected to the surface buoy via a 16.5m bungee used to dampen wave action. As part of regular maintenance and to minimise the effects of biofouling, the mooring is recovered every six months, the mooring line checked and replaced if necessary, and a replacement surface buoy and newly calibrated sensors swapped in.

Testing and calibration procedures

The LI-COR 820 sensor response is checked before and after each deployment using a range of CO₂-in-air reference gases (0, 260, 370, 450 micromol/mol) at CSIRO, Hobart. The sensor measurement using factory calibrations for the LI-COR 820 is typically within 1 micromol/mol of the reference gas value. If the LI-COR 820 measurements and the CO₂-in-air reference gas values are different by more than 2 micromol/mol, a correction is applied to LI-COR 820 output based the reference gas values. A seawater bath operated over a range of temperatures and CO₂ expected in the field is then used to check the MapCO₂ system (equilibrator and LI-COR 820 measurement) against a General Oceanics 8050 CO₂ sensor to ensure the systems agree within 2 micromol/mol. Pressure measurements are made using the LI-COR 820 pressure sensor, checked against a Druck DPI142 pressure indicator and verified to agree within 0.5 kPa before and after each deployment. The air CO₂ values are compared to Globalview CO₂ products, although these can result in some variability due to limited data in Globalview to constrain atmospheric boundary layer CO₂ measurements in coastal regions of the Southern Hemisphere.

A SBE16plus V2 CTD is polled for the temperature, salinity, and dissolved oxygen data for each MapCO₂ measurement sequence, with additional measurements made each hour. The SBE16PlusV2 temperature and salinity measurements use either factory calibrations for initial deployments, or annual calibrations performed at a certified National Australian Testing Authority facility at CSIRO, Hobart. The optodes are calibrated before and after deployments at CSIRO, Hobart, using a purpose built calibration system, referenced to dissolved oxygen measurements made using modified Winkler titrations (Culbertson, 1991). The calibrations cover a range of temperatures and oxygen concentrations that occur in the field and new calibration coefficients are generated to fit a Stern-Volmer equation (Uchida et al., 2008).

Data reduction and quality control

Fugacity

After recovery of the instrument the data from the MapCO₂ and the SBE16plus is downloaded. The data are recorded at each 2 or 3 hourly measurement interval as blocks of measurements of equilibrator headspace gas, air, zero and span gas values. The data blocks are checked for size and the MapCO₂ data is checked for outliers and corrected using the Thomson Tau method (Thompson, 1985).

The NDIR detection is based on the absorption of infrared light by CO₂. For each measurement cycle, the zero and span gas are analysed immediately before equilibrator air or atmospheric gas measurements to calibrate the LI-COR 820 NDIR response and provide a measurement of the CO₂ mole fraction in the gas stream. The gas stream analysed by the NDIR is only partially dried by flowing the gas through silica gel and the same light absorbed by CO₂ is also absorbed by water vapour present in the gas. A dilution correction is applied to account for the presence of water vapour that is measured in the gas using a humidity sensor (LI-COR Application note 129):

$$xCO_2 = \frac{xCO_2^{raw}}{(1 - w/1000)}$$

where w is calculated water vapour mole fraction and xCO_2^{raw} is the raw data value for the CO₂ mole fraction measured in the gas stream by the LI-COR 820 NDIR.

The partial pressure of CO₂ in the water is calculated by applying a water vapour pressure correction:

$$pCO_2 = xCO_2(P - p[H_2O])$$

with,

$$p[H_2O] = \exp(24.4543 - 67.4509 \frac{100}{T} - 4.8489 \ln \frac{T}{100} - 0.000544S)$$

the calculated water vapour pressure of the equilibrator sample at the sea surface temperature, T (K), and Salinity, S (Weiss and Price, 1980) and P is the total pressure in atmospheres.

The partial pressure of CO₂ is converted to fugacity using (Weiss, 1974):

$$fCO_2 = pCO_2 \exp \frac{P(B(CO_2, T) + 2\delta(CO_2, T))}{RT}$$

where, $R = 82.0578 \text{ cm}^3 \text{ mol}^{-1} \text{ K}^{-1}$, $B(CO_2, T) = -1636.75 + 12.0408T - 3.27957 \cdot 10^{-2}T^2 + 3.16528 \cdot 10^{-5}T^3$ and, $\delta(CO_2, T) = 57.7 - 0.118T$

Dissolved oxygen

Two voltage signal ($V0$ and $V1$) related to the bphase (Bp) and the temperature ($Topt$, in degrees Celsius) by:

$$Bp = 12V0 + 10; Topt = 9V1 - 5$$

from the Aanderaa optode are measured and stored by the SBE16plus. From these values a pre- and post-calibrated dissolved oxygen values (DO_{raw}) are calculated using the Stern-Volmer equation (Uchida et al., 2008), and the corresponding pre- and post- calibration coefficients (Appendix 3);

$$DO_{raw} = \frac{(c4 + c5Topt)/(c6 + c7Bp) - 1}{c1 + c2Topt + c3Topt^2}$$

This value for dissolved oxygen applies to use in fresh water and therefore needs to be compensated for seawater salinity using:

$$DO_{sc} = DO_{raw} \exp(S(B0 + B1T_S + B2T_S^2 + B3T_S^3) + C0S^2)$$

With S the salinity obtained by the SBE16plus and

$$T_S = \ln \frac{298.15 - T}{273.15 + T}$$

With T the temperature obtained in Celsius by the SBE16plus, and $B0 = -6.24097e-3$, $B1 = -6.93498e-3$, $B2 = -6.90358e-3$, $B3 = -4.29155e-3$, $C0 = -3.11680e-7$.

Subsequently, a drift correction is calculated and applied from the calibration data for each of the pre- and post-calibrated and salinity compensated values. From these values an average value for the dissolved oxygen (DO) and a standard deviation (SD_DO) is obtained, which is interpolated at the time when the MApCO2 equilibrator pump off cycle ends.

Data report**Automated data quality control report:**

For first order quality control, automated checking of value ranges for a number of diagnostic parameters are checked, and subflags assigned to values outside the accepted ranges listed in Appendix 2. The summary results of the automated data checking procedure were:

Flagged data points:

```
Optode data out of range or interpolation failed
2023/04/22,18:00:00-2023/04/22,20:00:00
2023/04/23,04:00:00-2023/04/23,06:00:00
2023/04/24,00:00:00
XC02 Span pump off or post cal out of range
2023/03/05,22:00:00-2023/03/06,00:00:00
2023/03/11,08:00:00-2023/03/11,10:00:00
2023/03/21,20:00:00-2023/03/21,22:00:00
XC02 Zero pump off or post cal out of range
2023/03/05,22:00:00-2023/03/06,00:00:00
2023/03/21,20:00:00-2023/03/21,22:00:00
```

Delayed mode quality control report:

After automated checking, data are plotted and manually checked in a final delayed mode quality control with WOCE (<http://cchdo.ucsd.edu/formats>) quality flags used, where 2=good, 3=questionable, 4=bad, with the following result:

```
Reason: Mooring broken off-> Action: Manually set to bad:
2023/04/21,18:00:00-2023/04/29,22:00:00
Reason: Possible sample after mooring off position-> Action: Manually set to questionable:
2023/04/21,16:00:00
```

Low salinity values are verified using NRS data at MAI site (<http://www.csiro.au/tasman/nrsweb/>) and BOM flood history data (http://www.bom.gov.au/tas/flood/flood_history/flood_history.shtml).

Final data quality summary:

Parameter	% flag = 2 good	Number Points
fC02 sea water	95.060578	2040
XC02 atmosphere	99.720410	2140
Sea Surface Temperature	95.340168	2046
Sea Surface Salinity	95.340168	2046
Dissolved Oxygen	95.340168	2046

Data summary:

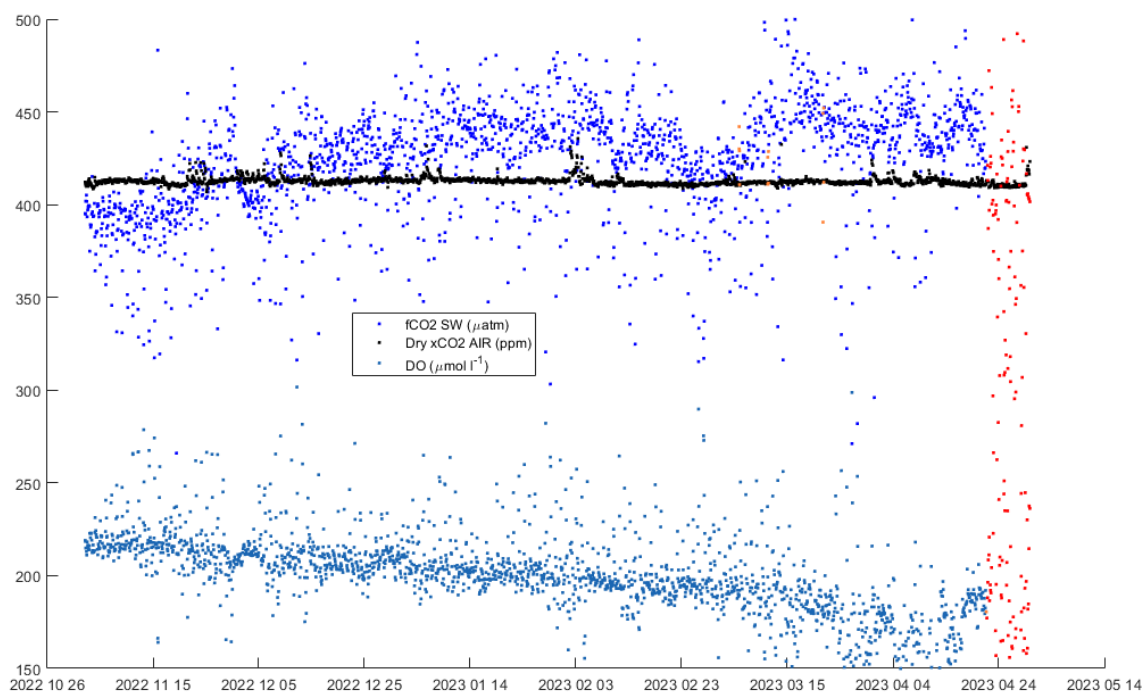


Figure 1: xCO₂ (ppm) for air, fCO₂ (µatm) and Dissolved Oxygen (DO; µmol/l) for sea water. The red and orange data points represent bad (flag =4) and questionable (flag = 3) data, respectively.

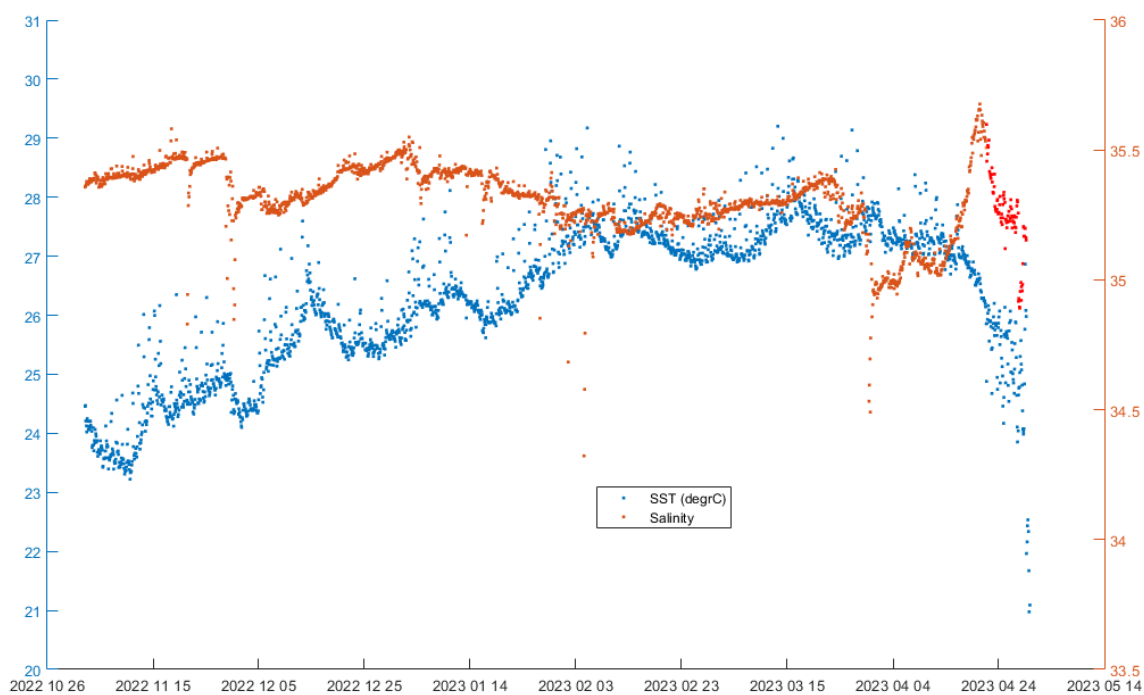


Figure 2: Sea Surface Temperature and Salinity. The red and orange data points represent bad (flag =4) and questionable (flag = 3) data, respectively.

Appendix 1: Instrumentation specifications

Seaology pCO₂

MANUFACTURER: Battelle Memorial Institute, Columbus, Ohio, USA
 WEBSITE: <http://battelle.org/our-work/national-security/maritime-systems>
 MODEL: Seaology
 SERIAL NO: 0122
 FIRMWARE VERSION: 3.18
 EQUILIBRATOR DESIGN: Bubble Equilibrator
 EQUILIBRATOR VOLUME: Less than 100 ml of air equilibrating with an unlimited volume of seawater
 HEADSPACE GAS FLOW RATE: ~600 cc/min
 VENTED: yes
 INTAKE DEPTH: 1m
 MEASUREMENT METHOD: Absolute, non-dispersive infrared (NDIR) gas analyser

CO2 and Equilibrator and Air Pressure Sensor:

MANUFACTURER:LI-COR, Lincoln, Nebraska, USA
WEBSITE: <http://www.licor.com/env/>
MODEL: LI-820
CO2 RESOLUTION: 0.1 $\mu\text{mol/mol}$
CO2 UNCERTAINTY: < 2 $\mu\text{mol/mol}$ based on comparisons in the laboratory
before and after deployment with four WMO X2007 referenced gas standards (0, 260, 370, 450 $\mu\text{mol/mol}$)
and < 2 $\mu\text{mol/mol}$ based on pre-deployment comparison in the laboratory with equilibrator headspace
measurements of seawater made using a General Oceanics model 8050 pCO2 measurement system (General Oceanics, Miami, Florida, USA).
PRESSURE RESOLUTION: 0.01 KPa
PRESSURE UNCERTAINTY: < 0.5 KPa, Based on laboratory comparison against Druck DPI 142 pressure indicator
CALIBRATION DATE: 23/04/2022

Relative Humidity Sensor:

MANUFACTURER:Sensirion Humidity Sensor, USA
WEBSITE: <http://www.sensirion.com>
MODEL: SHT71
MEASUREMENT RANGE: 0-100%
ACCURACY: +/- 3% (20-80% RH)
CALIBRATION: Factory calibration before purchase
RH CORRECTION: yes

CO2 Span Gas:

MANUFACTURER:NOAA Earth Systems Laboratory, USA
CYLINDER NUMBER: JA02239
GAS CYLINDER PRESSURE, PRE-DEPLOYMENT: 1300 psi
GAS CYLINDER PRESSURE, POST-DEPLOYMENT: 800 psi
CO2-IN-AIR CONCENTRATION (WMO X2007): 546.41 PPM
CALIBRATION DATE: 2014-03-31

O2 Sensor:

MANUFACTURER:Aanderaa, Norway
WEBSITE: <http://www.aanderaa.com/>
MODEL: 3585
SERIAL NO: 1450
FOIL BATCH NO: 1023
RESOLUTION: <1 μM
UNCERTAINTY: < 1 $\mu\text{mol/l}$, based on Winkler oxygen titrations at CSIRO, Hobart
CALIBRATION DATE:PRE-DEPLOYMENT: 01-Feb-2021 POST-DEPLOYMENT: 01-Feb-2021
OPTODE USED: SBE optode

CTD Sensor (Equilibrator and Sea Surface):

MANUFACTURER:Sea-Bird Electronics, Bellevue, Washington, USA
WEBSITE: <http://www.seabird.com/>
MODEL: SBE 16plusV2_seacat
SERIAL NO: 01606552
RESOLUTION: 0.0001 $^{\circ}\text{C}$; 0.00005 S/m
UNCERTAINTY: 0.005 $^{\circ}\text{C}$; 0.0005 S/m
CTD DEPTH: 1 m
CALIBRATION DATE: 29-03-2021

pH sensor:

No pH Sensor

Appendix 2: Range limits

Range limits for assigning flags to instrument diagnostic parameters. Values outside the ranges are automatically flagged as bad. Max SD is the maximum standard deviation of all readings at each measurement time.

Variable Min Max

Span Value Deviation	-5	5
Zero Value Deviation	-5	5
Delta pressure Atmosphere	5	9
Delta pressure Equilibrator	5	9
Max SD_XCO2_EQUIL_PUMP_ON		10
Max SD_xCO2/ pCO2/ fCO2	2	
Max SD_PRESS_LICOR_EQUIL_PUMP_OFF		0.05
MAX SD_PRESS_LICOR_AIR_PUMP_OFF		0.1
MAX SD_TEMP_LICOR air/equil/span		0.1
MAX SD_RH_AIR_PUMP_OFF	1	
MAX SD_RH_EQUIL_PUMP_OFF	1	
MAX SD_RH_TEMP_AIR_PUMP_OFF		0.05
MAX SD_RH_TEMP_EQUIL_PUMP_OFF		0.05
MAX SD_RH_SPAN_PUMP_OFF	3	
MAX SD_RH_TEMP_SPAN_PUMP_OFF		0.05
SBE Temperature	-2	40
SBE Salinity	0	42
Optode DO	50	400

Appendix 3: Instrument calibration coefficients

Oxygen optode calibrations coefficients for optode 3585 serial number 1450 foil number 1023:

Coefficient	Pre-deployment	Post-deployment
C1	0.0032285	0.0032285
C2	0.00013427	0.00013427
C3	1.5968e-06	1.5968e-06
C4	217.24	217.24
C5	-0.096931	-0.096931

C6 7.5398 7.5398
C7 4.627 4.627

Seabird SBE16plus V2, serial number 01606552 calibration coefficients:

Temperature	Coefficient
TA0	0.0012965
TA1	0.00025486
TA2	3.7293e-07
TA3	1.2284e-07
TOFFSET	0

Salinity	Coefficient
G	-1.0553
H	0.14219
I	-0.00030566
J	4.0881e-05
CPCOR	-9.57e-08
CTCOR	3.25e-06
CSLOPE	1

Additional information:

The CO₂/acidification mooring at the Heron Island was initially funded through and Ocean Carbon and Acidification project of the Australian Climate Change Science Program awarded to BT. The mooring is now funded through the Integrated Marine Observing System - supported by the Australian Government through the National Collaborative Research Infrastructure Strategy. Users of these data are requested to cite the data source as below and to send copies of manuscripts to the PI prior to submission to ensure data are accurately represented.

Citation:

We rely on users of these data to recognise the effort required to obtain data by citing these data as:

B. Tilbrook, E. van Ooijen, C. Neill, A. Passmore and J. Black (2018) Ocean and atmosphere CO₂ system timeseries measurements from Wistari Channel, Heron Island, Australia. <http://imos.aodn.org.au/imos123/>

References

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Attachments

No attachments