12 November 2026

OceanICU
Understanding Ocean Carbon

GLODAPv3: What it is, What's new, What it means for you



MODERATED BY
Siv K. Lauvset
NORCE



Nico Lange
NORCE



Matthew Humphreys
(NIOZ)



Ryan Woosley
(MIT)

Welcome and Thank You for Joining Us Today

Funded by the European Union

UK Research and Innovation

This work was funded by the European Union under grant agreement no. 101083922 (OceanICU) and UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee [grant number 10054454, 10063673, 10064020, 10059241, 10079684, 10059012, 10048179]. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Agenda

About Today's Format

This webinar is being video recorded

- Cameras & Microphones have been disabled.
- Questions posted will not be included in the video recording so your name will not be displayed.

Questions and Answers

- Please use the Q&A function to ask any questions you have.
- Questions will be directed to the appropriate panellist by the moderator during the Q&A session.
- Questions & Answers covered during the session, along with any that we did not have time to respond to, will be posted in text form on the OceanICU website; a link will be sent to you in a post-webinar email communication.

Any problems or comments during or after the session:

Contact: hello@ocean-icu.eu

Today's panelists



Nico will provide an overview of GLODAP and its evolution from version 2



Matthew will present the new quality control methods used for version 3



Ryan will talk about pH in GLODAP, and best practices for carbonate system calculations

OceanICU

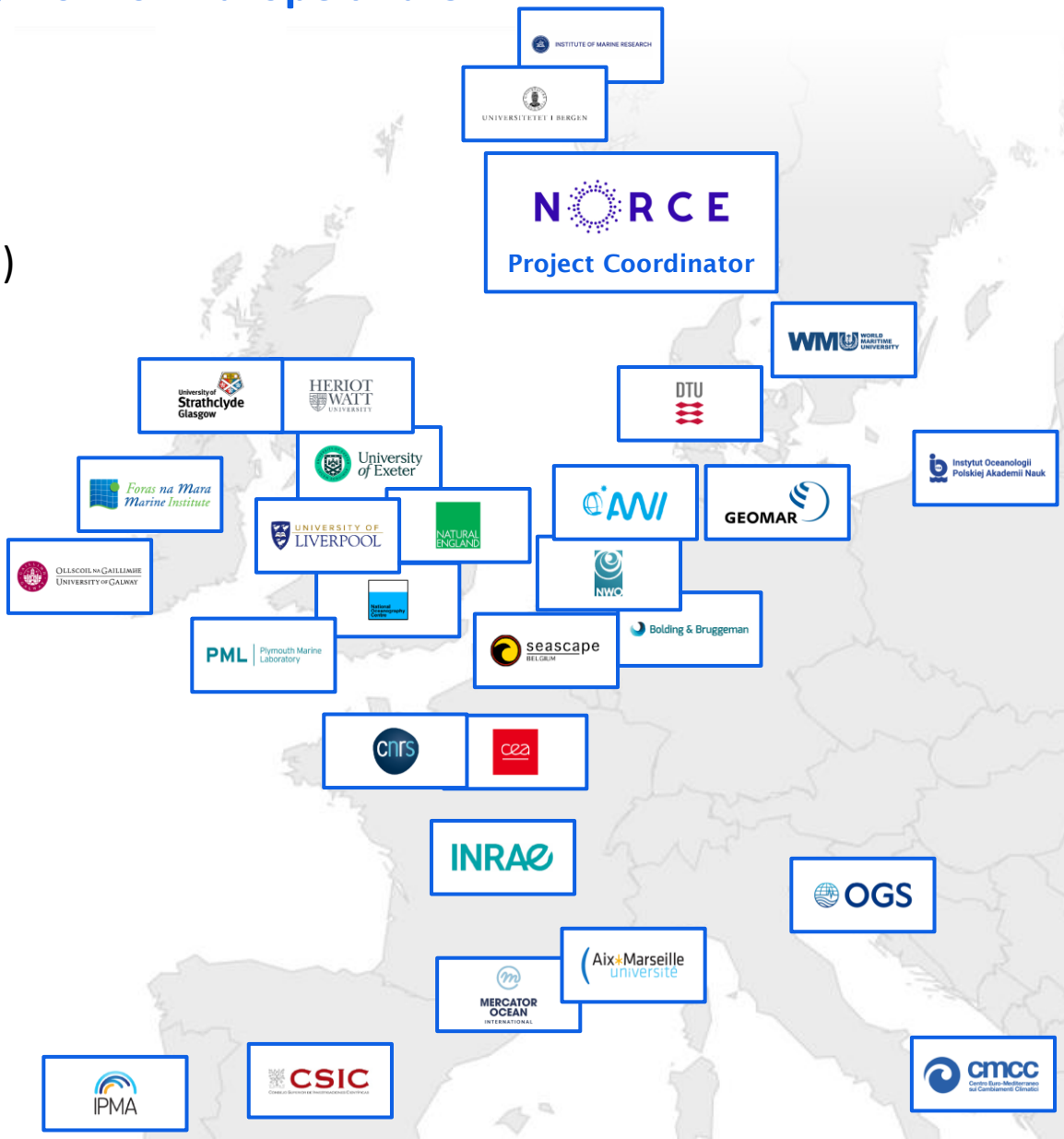
A Pan-European project funded by Horizon Europe and UKRI

Consortium & resources

- 31 Partners, 15 nations
- 60 months (Nov 2022 – Oct 2027)
- Funding: €13 102 052,75
- EU and UKRI Funding

Horizon Europe

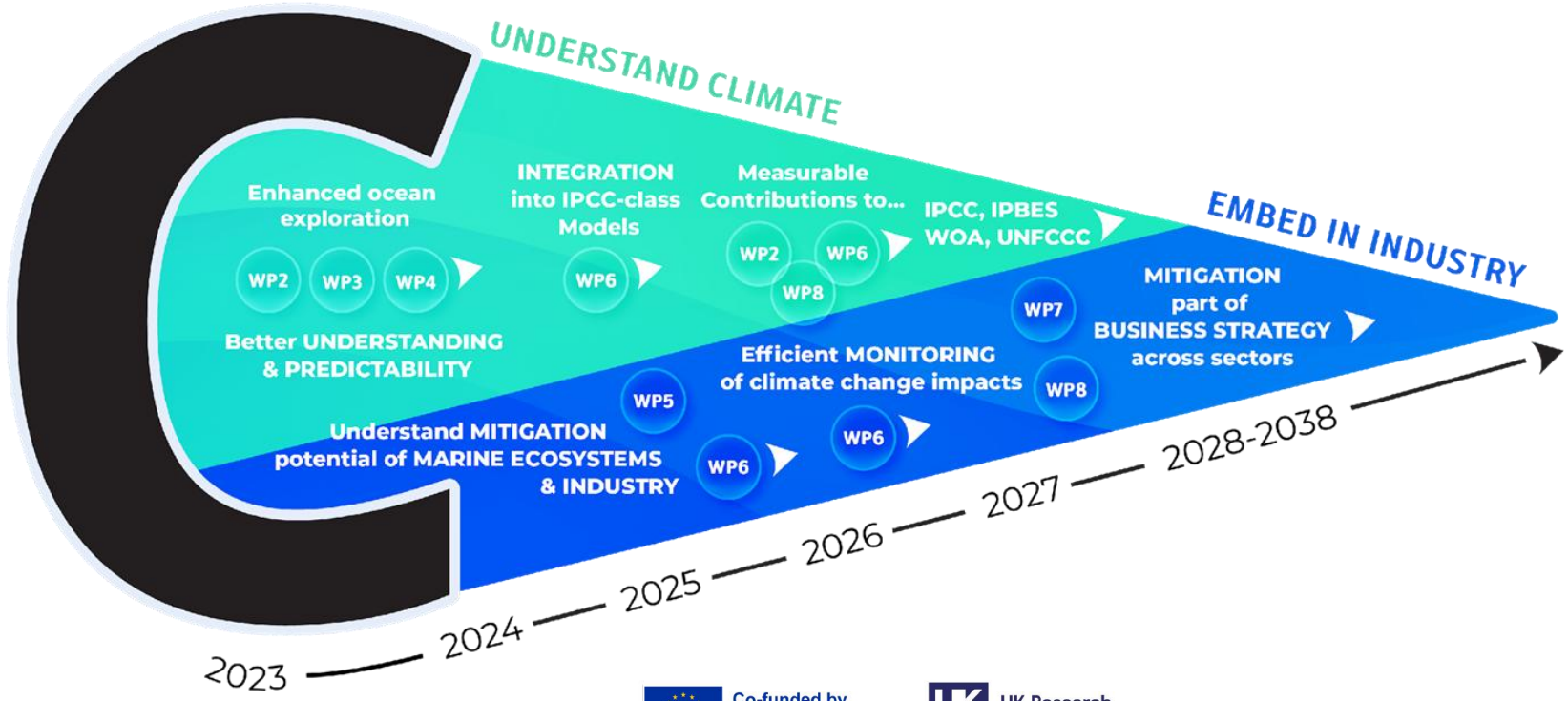
UKRI



Our ambition

OceanICU as a fundamental research-based pathway to impact

1. Define **current state of C cycle** (provide a baseline) and assess future climate driven change to Ocean C cycle
2. Quantify **key processes** relevant to these indirect effects
3. Incorporate key processes into **models** to enable indirect effects to be quantified
4. Translate the improved model skills into **new tools** that allow Ocean users and licencers to estimate C cycle impacts on industrial processes
5. Couple these to **estimates of future industrial processes**, fishing and climate change to estimate industrial impacts on Ocean C cycle



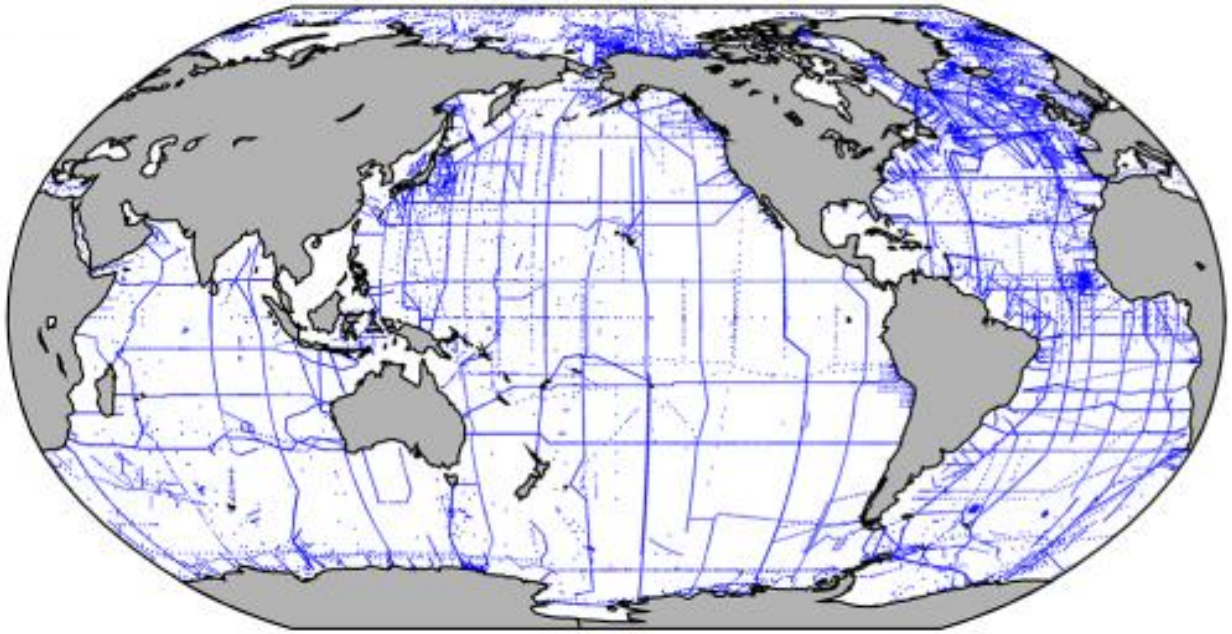
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Global Ocean Data Analysis Project (GLODAP)

GLODAP - A quality controlled, consistent and FAIR data product of hydrographic surface to bottom biogeochemical profiles



www.glodap.info

Original scientific rationale: How much anthropogenic carbon does the interior ocean store?

Answering warrants a quality controlled and consistent data product, enabling the study of global phenomena that cannot be robustly investigated from isolated datasets alone

History of GLODAP

- Global Ocean Data Analysis Project (GLODAP, www.glodap.info)
  - First data product (GLODAPv1.1) released in 2004 (https://doi.org/10.1029/2004gb002247)
  - CARINA (2010; https://doi.org/10.5194/essd-2-105-2010) and PACIFICA (2013; https://doi.org/10.3334/CDIAC/OTG.PACIFICA_NDP092) added more recent data in the Atlantic and Pacific Oceans respectively
  - GLODAPv2 initiated in 2011, data product released in 2016 (https://doi.org/10.5194/essd-8-325-2016 and https://doi.org/10.5194/essd-8-297-2016)
  - Annual updates since 2019

- GLODAPv1.1 has more than 1200 citations (according to AGU publication metrics)
- GLODAPv2 and its subsequent annual updates have over 1000 citations combined (according to ESSD publication metrics)

The GLODAP reference group

Since version 2 the GLODAP work has been organised by the reference group

- Nico Lange
- Brendan R. Carter
- Matthew P. Humphreys
- Ryan J. Woosley
- Are Olsen
- Henry C. Bittig
- Alex Kozyr
- Peter J. Brown
- Mario Hoppema
- Masao Ishii
- Siv K. Lauvset
- Marta Álvarez
- Kumiko Azetsu-Scott
- Susan Becker
- Leticia Cotrim da Cunha
- Emil Jeansson
- Akihiko Murata
- Jens Daniel Müller
- Fiz F. Pérez
- Carsten Schirnick
- Reiner Steinfeldt
- Adam Ulfsbo
- Anton Velo
- Toste Tanhua

Do you want to help us improve our gender balance? Please reach out: contact@glodap.info

GLODAP version 3

Why version 3?

- Decadal re-evaluation of all cruises and adjustments is warranted every decade
- Need for more robust uncertainty quantification
- Need to amend known issues in earlier versions/updates
- Dataset was made public on July 7, 2026: https://doi.org/10.25921/m6tp-mj50 (Lange et al., 2026)

Articles / Volume 22, issue 5 / OS, 22, 3403–3414, 2026

https://doi.org/10.5194/os-22-3403-2026
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Article | Assets | Peer review | Metrics | Related articles

Technical note

Furthest-first inversion for internal consistency adjustments in the biogeochemical data product GLODAPv3

Matthew P. Humphreys, Siv K. Lauvset, Nico Lange, Henry C. Bittig, Brendan R. Carter, Mario Hoppe Akihiko Murata, Are Olsen, Toste Tanhua, Adam Ulfsbo, Antón Velo, Ryan J. Woosley, Kumiko Azetsu-S Jens D. Müller, and Fiz F. Pérez

31 Jul 2026

Status: a revised version of this preprint was accepted for the journal ESSD.

The Global Ocean Data Analysis Project version 3 (GLODAPv3) – an internally consistent biogeochemical data product for the world ocean

Nico Lange, Siv K. Lauvset, Brendan R. Carter, Matthew P. Humphreys, Ryan J. Woosley, Are Olsen, Henry C. Bittig, Alex Kozyr, Marta Álvarez, Kumiko Azetsu-Scott, Susan Becker, Peter J. Brown, Leticia Cotrim da Cunha, Larissa Dias, Mario Hoppema, Masao Ishii, Emil Jeansson, Akihiko Murata, Jens Daniel Müller, Fiz F. Pérez, Carsten Schirnick, Reiner Steinfeldt, Adam Ulfsbo, Anton Velo, and Toste Tanhua

Global Ocean Data Analysis Project Version 3

An Introduction to GLODAPv3

Nico Lange, 12.11.2026

Funded by the European Union

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GLODAPv3

At a Glance

1,181
Hydrographic Cruises

~1.5M
Water Samples

Interior Ocean Carbon Focus

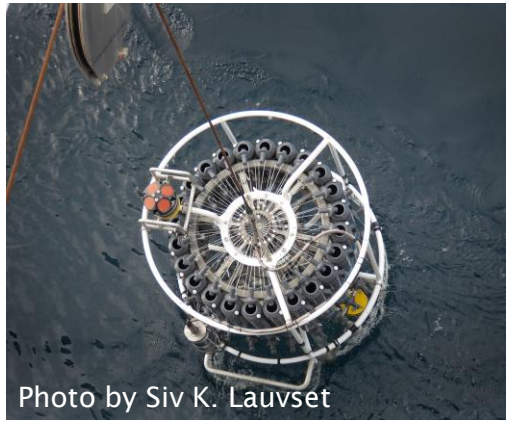
DIC | TA | pH | fCO_2 | CFC-11 | CFC-12 | CFC-113 | SF_6 | CCl_4 | ^{13}C | ^{14}C

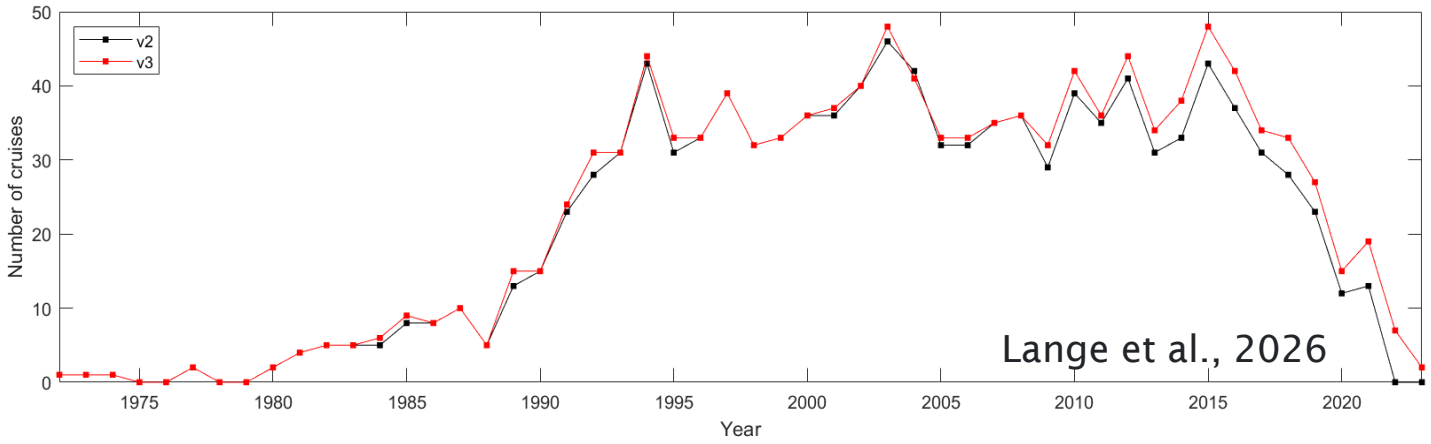
Extensive Quality Control

Ensures high precision and high comparability across multi-decadal global observations.

The most internally consistent ocean biogeochemistry data product out there!

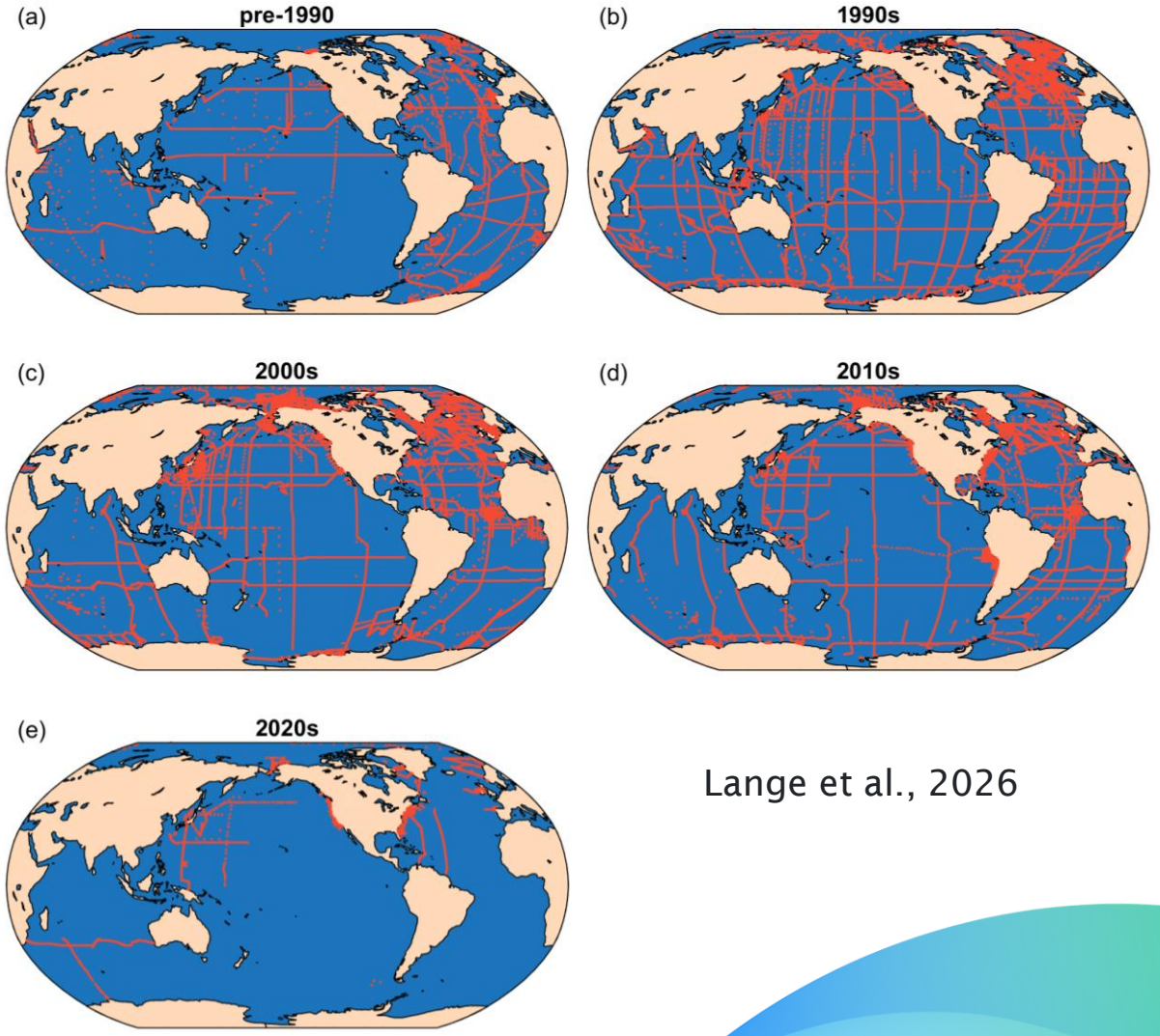






GLODAPv3

At a Glance



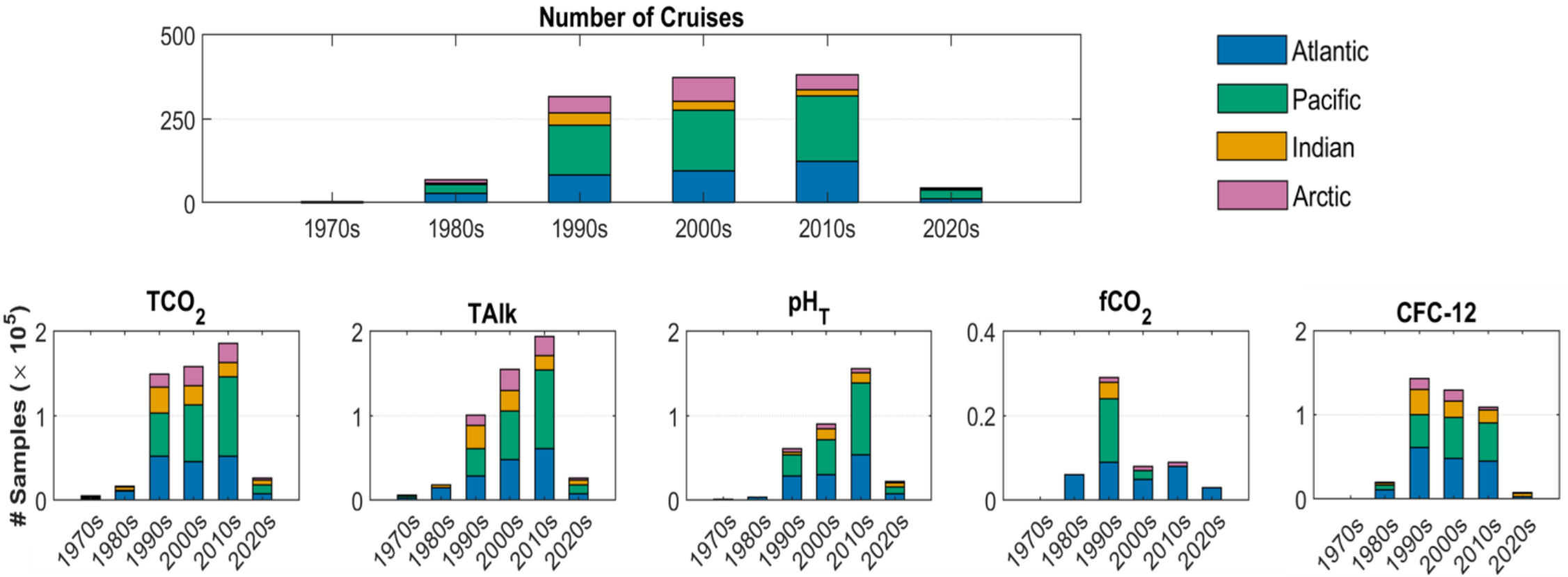
Lange et al., 2026

Observations from large international surveys form the backbone

- Geochemical Ocean Sections Study (**GEOSECS**)
- Transient Traces in the Ocean (**TTO**)
- South Atlantic Ventilation Experiment (**SAVE**)
- World Ocean Circulation Experiment (**WOCE**)
- Joint Global Ocean Flux Study (**JGOFS**)
- Climate Variability and Predictability (**CLIVAR**)
- Global Ocean Ship-based Hydrographic Investigations Program (**GO-SHIP**)

GLODAPv3

At a Glance



Lange et al., 2026

GLODAPv3

Data Quality Control - Definitions

ACCURACY

How close a measured value is to the true value of the seawater property being measured.

We cannot claim to know the accuracy of any ocean data since we do not know the true value.

CONSISTENCY

How well measurements from different cruises agree with one another when measuring under similar conditions.

Quantifies comparability among datasets to allow different datasets to be used together with greater confidence.

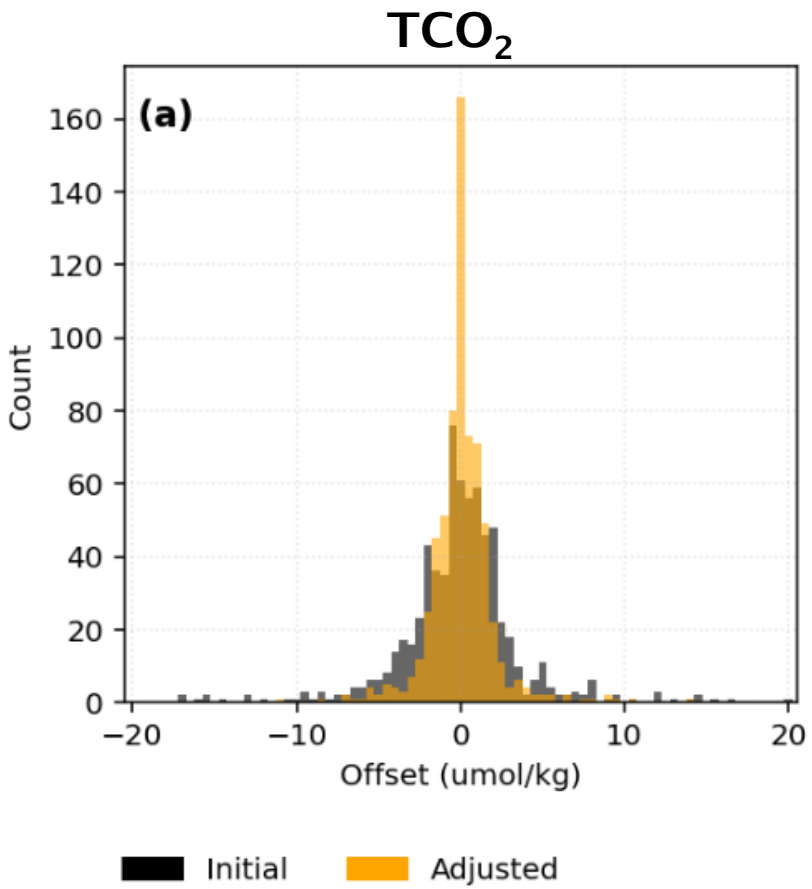
GOAL GLODAP

Whenever needed, apply adjustments to **reduce systematic differences** between cruises to increase overall **consistency**.

GLODAP's secondary QC methods **do not** speak to the true values of the quantities measured.

GLODAPv3

Data Quality Control - Results

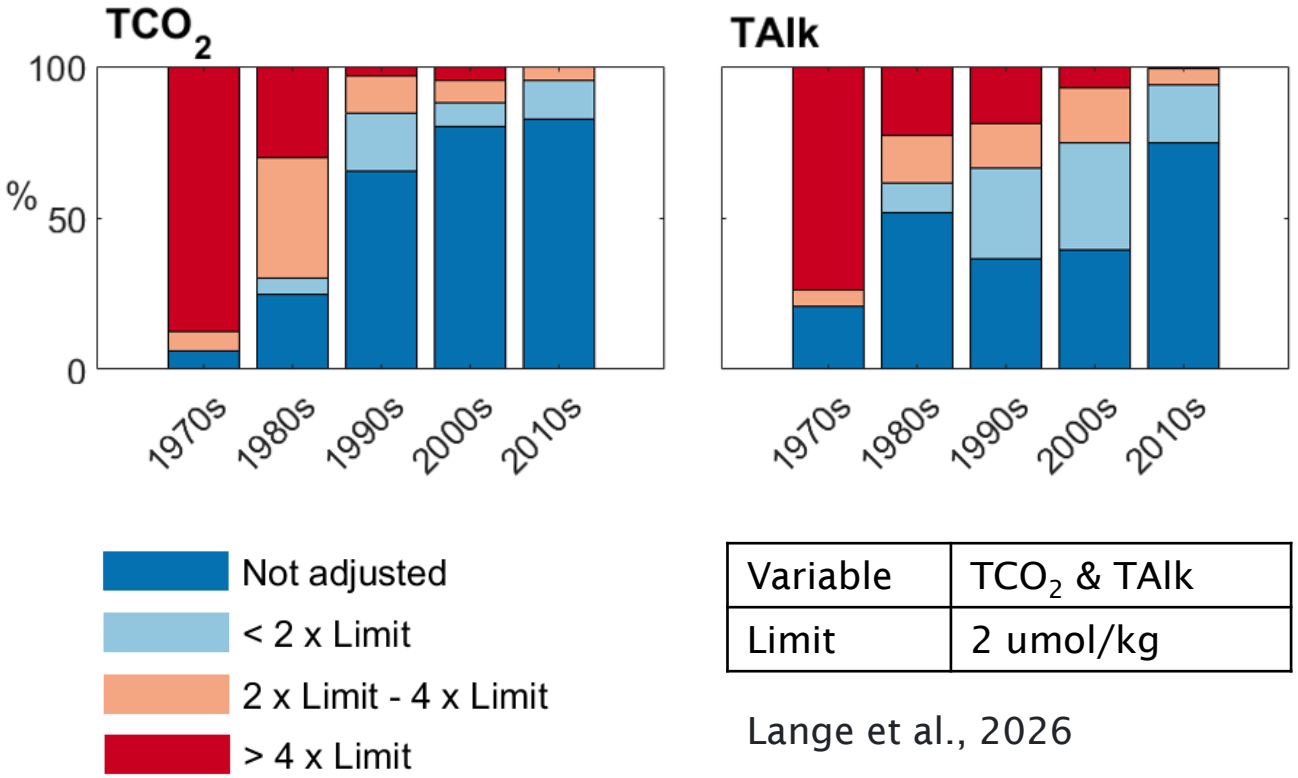


CWMO wRMSE	Initial	Adjusted
SAL (*1000)	1.9	1.3
O_2 (%)	0.7	0.7
NO_3 (%)	0.7	0.4
SIL (%)	1.5	0.5
PO_4 (%)	1.1	0.5
TCO_2 (µmol kg^{-1})	**3.2**	**1.2**
TAlk (µmol kg^{-1})	4.8	1.4

Lange et al., 2026

GLODAPv3

Data Quality Control - Results



Variable	TCO_2 & TAlk
Limit	2 umol/kg

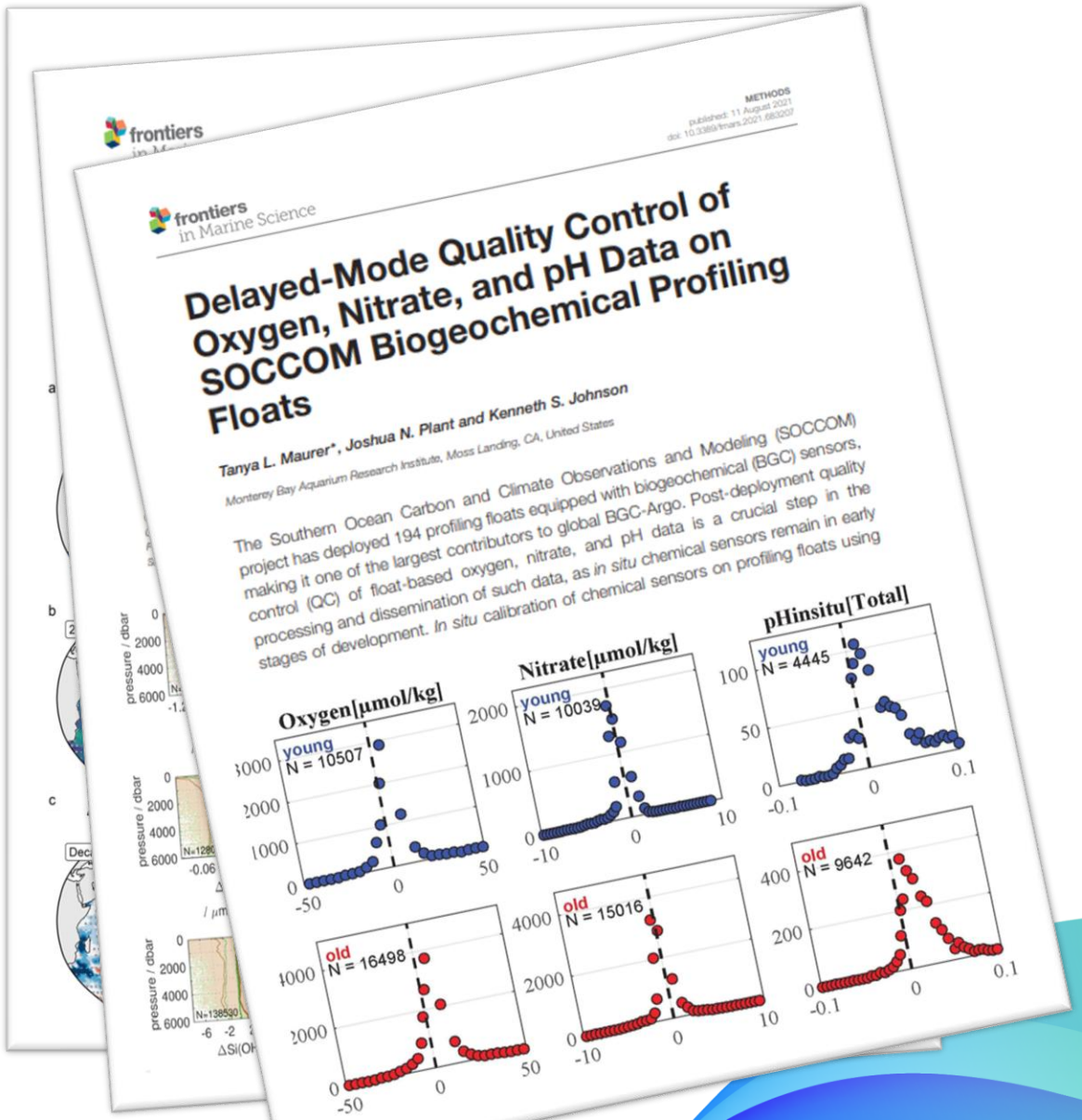
Lange et al., 2026

Fewer adjustments due to widespread adaption of

- Standard Operating Procedures
- Certified Reference Materials

GLODAPv3

Use Cases & Future



What's Next?

- Decadal climatologies to be released by beginning 2028
- EMODnet serving as a data aggregation system for GLODAP
- Annual v3 updates planned but no funding secured yet

GLODAPv3

Data Access & Resources

Webpage	Community webpage, including links to all official GLODAP resources as well as direct access to data.
Ocean Carbon and Acidification Data System (**OCADS**)	Official data repository within the NCEI archive, hosting the GLODAP's metadata landing page and Cruise Summary Table.
Ocean Data Viewer (**ODV**)	GLODAPv3 available in ODV format and explorable through "webODV".
Environmental Research Division's Data Access Program (**ERDDAP**)	Flexible data extraction of GLODAPv3 via ERDDAP.
Adjustment Table	Overview of adjustments as well as related figures and cruise statistics.
GitHub Repository	Repository including all cruise-pair offset tables, codes used, a code to generate an unadjusted version of GLODAPv3, as well as the (living) GLODAPv3 metadata table.

GLODAPv3 OceanICU Resource Directory

OceanICU
Understanding Ocean Carbon

Crossover analysis and furthest-first inversion in GLODAPv3

Matthew P. Humphreys

NIOZ Royal Netherlands Institute for Sea Research

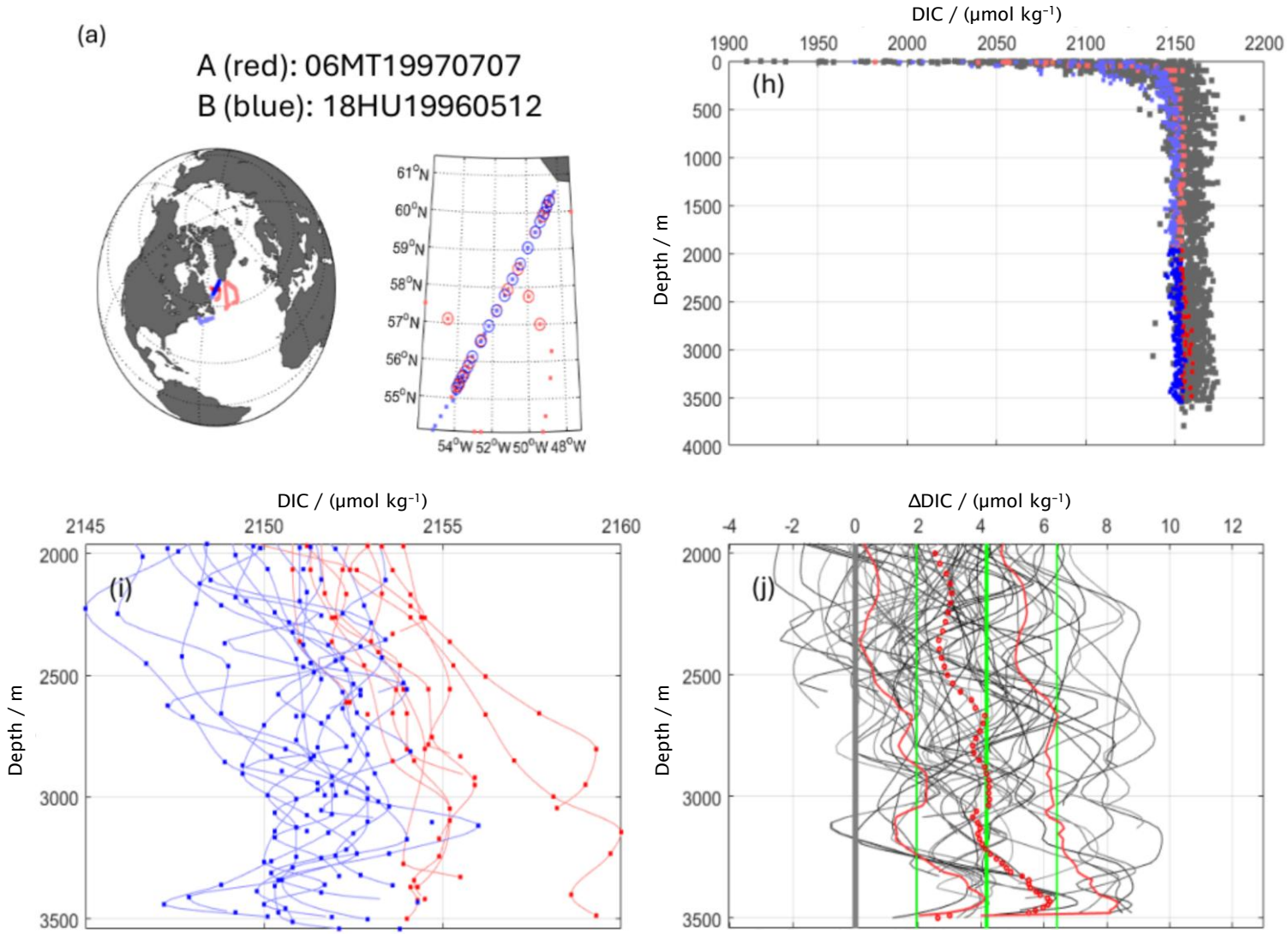
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Crossover analysis

Example from Lange et al. (2026, in press)



This analysis repeated in potential temperature and potential density anomaly space.

Results from all three are combined to calculate the final crossover offset and its uncertainty.

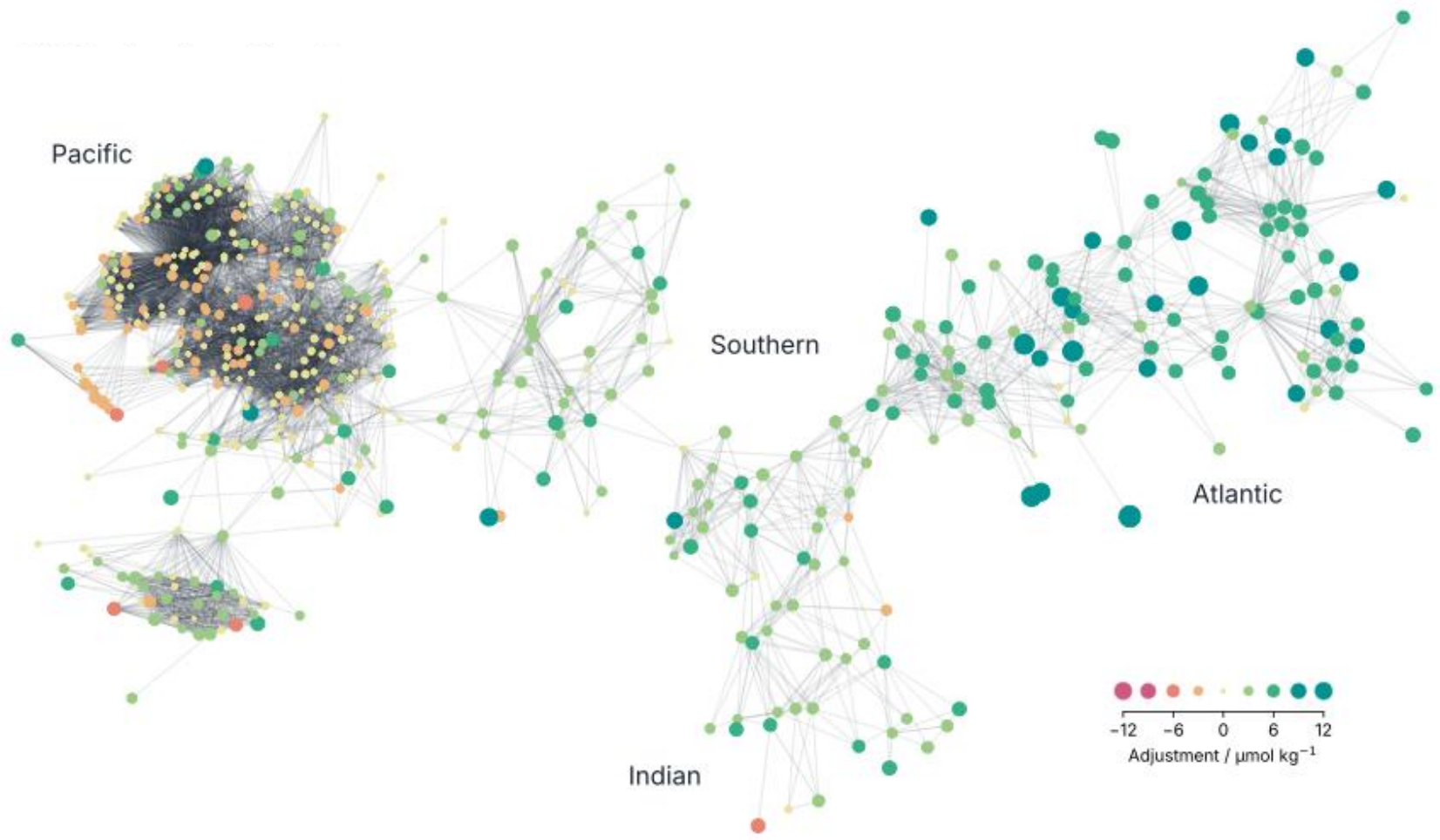
After crossover analysis: inversion

Internal consistency, not absolute accuracy

- Minimise cruise weighted-mean offsets
- Improve internal consistency between cruises
- Make as few adjustments as possible
- Do not eliminate real trends
- Quantify systematic uncertainties at the cruise level
- Pattern of adjustments should generally be random

The problem with global WLSQ

Humphreys et al. (2026, Ocean Sci.)



However, we do not expect systematic biases across entire ocean basins

Furthest-first (FF) inversion

Humphreys et al. (2026, Ocean Sci.)

- **Calculate** cruise weighted-mean offsets (WMOs) and their uncertainties
  … accounting for selected trends
- **Normalise** the WMOs by dividing them by their uncertainties
- **Find** the cruise with the largest normalised WMO
  … of the cruises that are permitted to be adjusted
- **Adjust** this cruise such that its WMO is zero
- **Repeat** until convergence

The "furthest" cruise…

… is adjusted "first"

Furthest-first variants

The two-step variant (FF_2) was used for GLODAPv3

One-step: FF_1

- Run FF until convergence

Ultimately, FF_1 generates the same adjustment patterns as WLSQ – including the regional biases

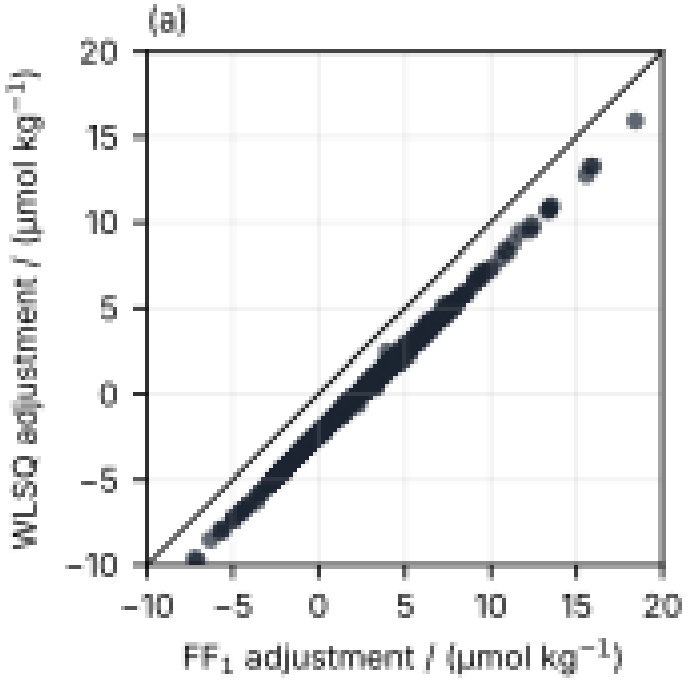
Two-step: FF_2

- Run FF until calculated adjustments fall below some threshold
- Run FF again, allowing only cruises that received an initial adjustment over the threshold to be adjusted

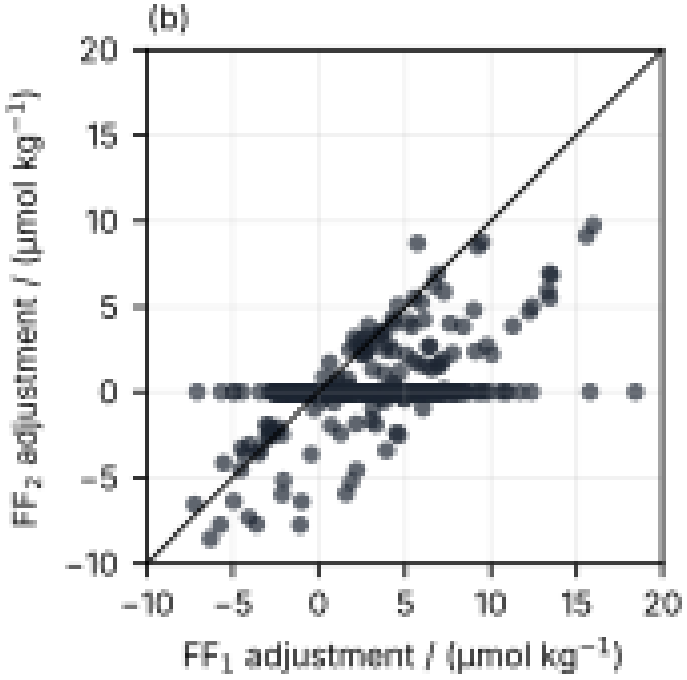
FF_2 stops the adjustment process from introducing regional biases

Comparisons between WLSQ, FF_1 and FF_2

Humphreys et al. (2026, Ocean Sci.)



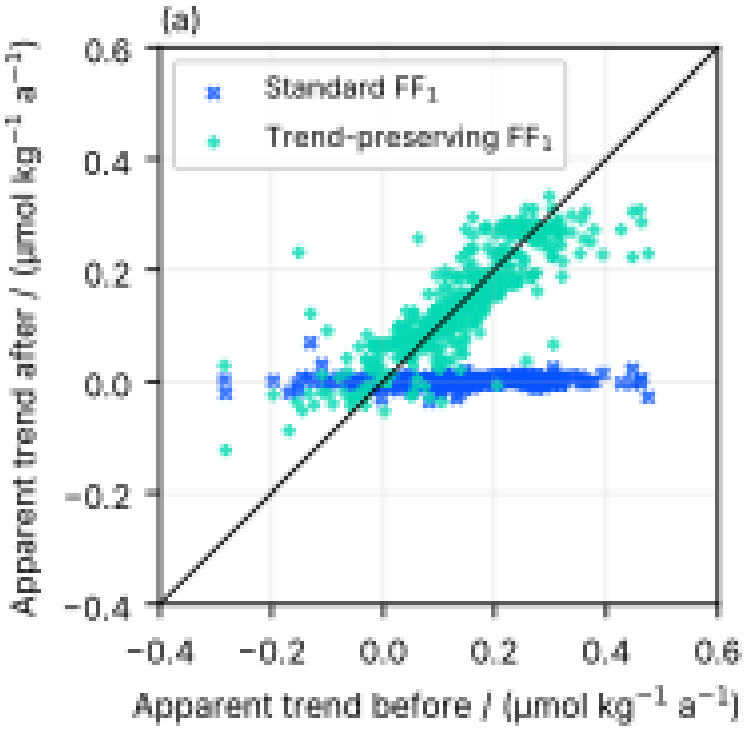
Left to fully converge, FF_1 returns virtually identical results to WLSQ, except for a constant offset



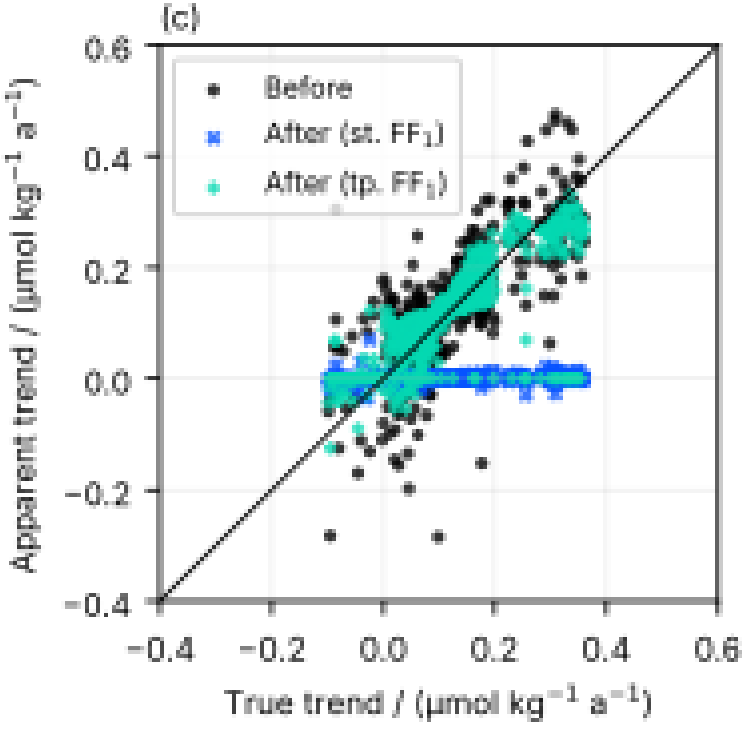
FF_2 adjustments are broadly correlated with FF_1, but individual cruises receive different adjustments

Preserving trends with FF inversion

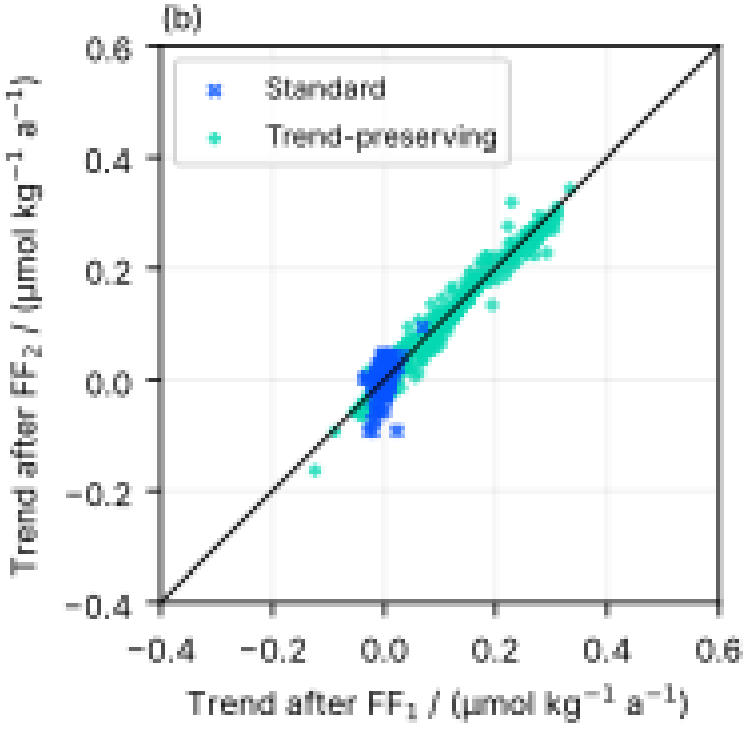
Humphreys et al. (2026, Ocean Sci.)



Like WLSQ, FF eliminates trends unless they are actively preserved



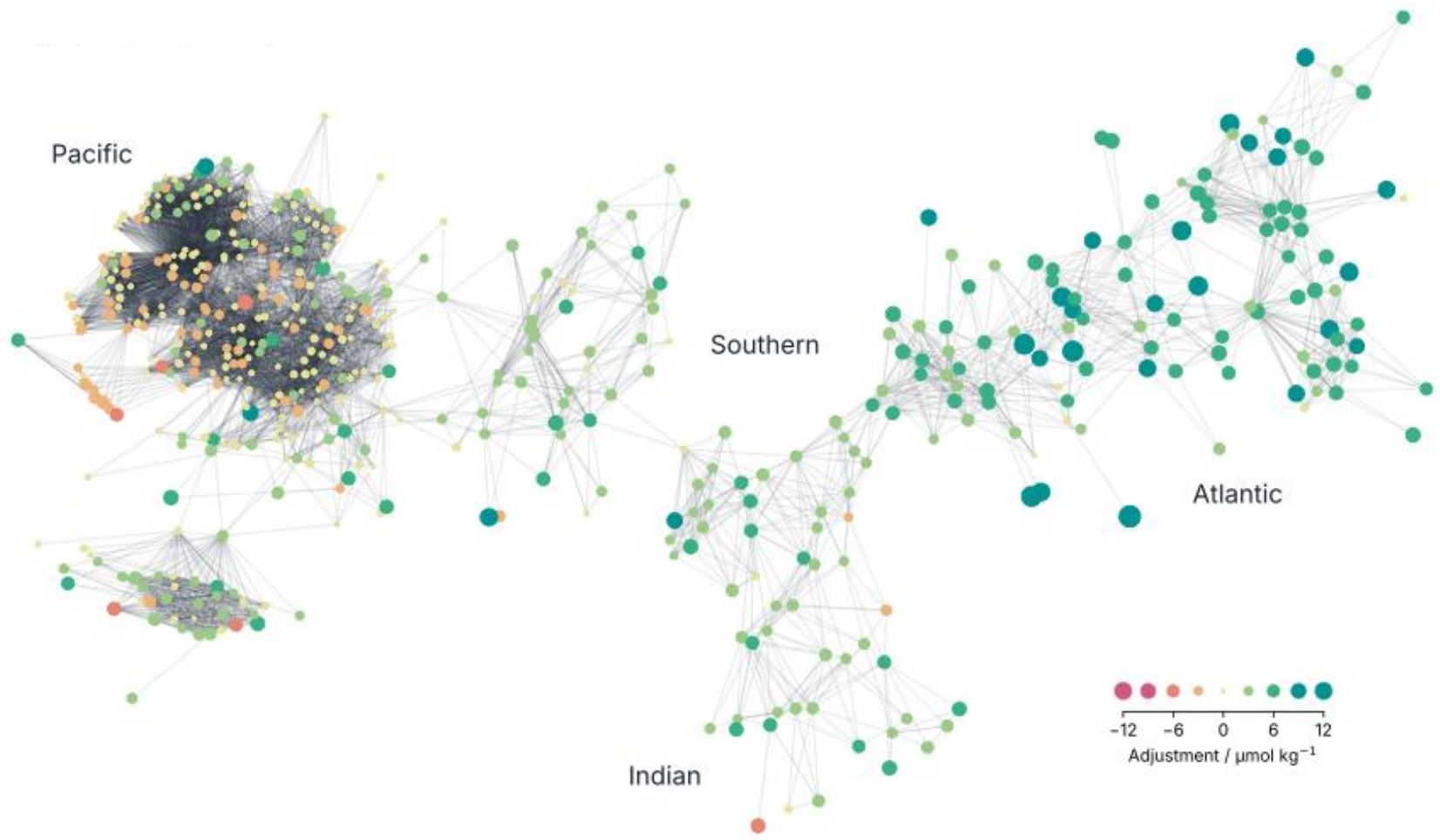
Trends aren't preserved exactly, but nor are they captured exactly in the crossover matrix



FF_2 preserves trends equally well as FF_1

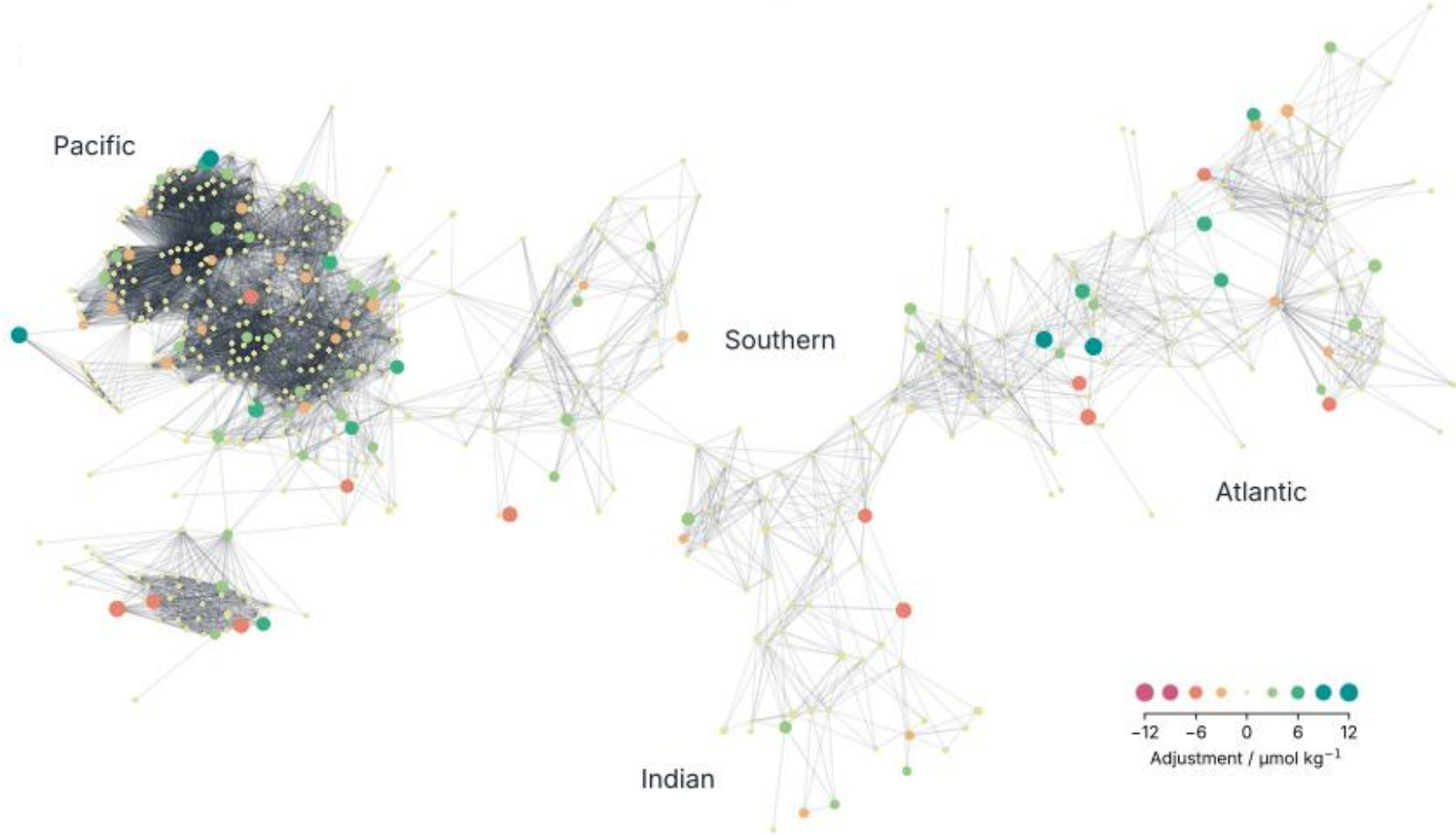
From FF_1 to FF_2

Humphreys et al. (2026, Ocean Sci.)



From FF_1 to FF_2

Humphreys et al. (2026, Ocean Sci.)



Summary

Crossover analysis and furthest-first inversion

- FF inversion produces a set of adjustments plus uncertainties in the adjusted cruises
- These cruise-level uncertainties are separate from sample-level uncertainties
- Selected temporal trends can be approximately preserved
- Selected cruises can be prevented from being adjusted, while still being included
- Regional biases can be avoided using the two-step variant (FF_2)

GLODAPv3 pH_T

Changes and recommended uses

Ryan J. Woosley
Massachusetts Institute of Technology

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Treatment of pH_T

Too few data for full Crossover analysis and Inversion

Version 2

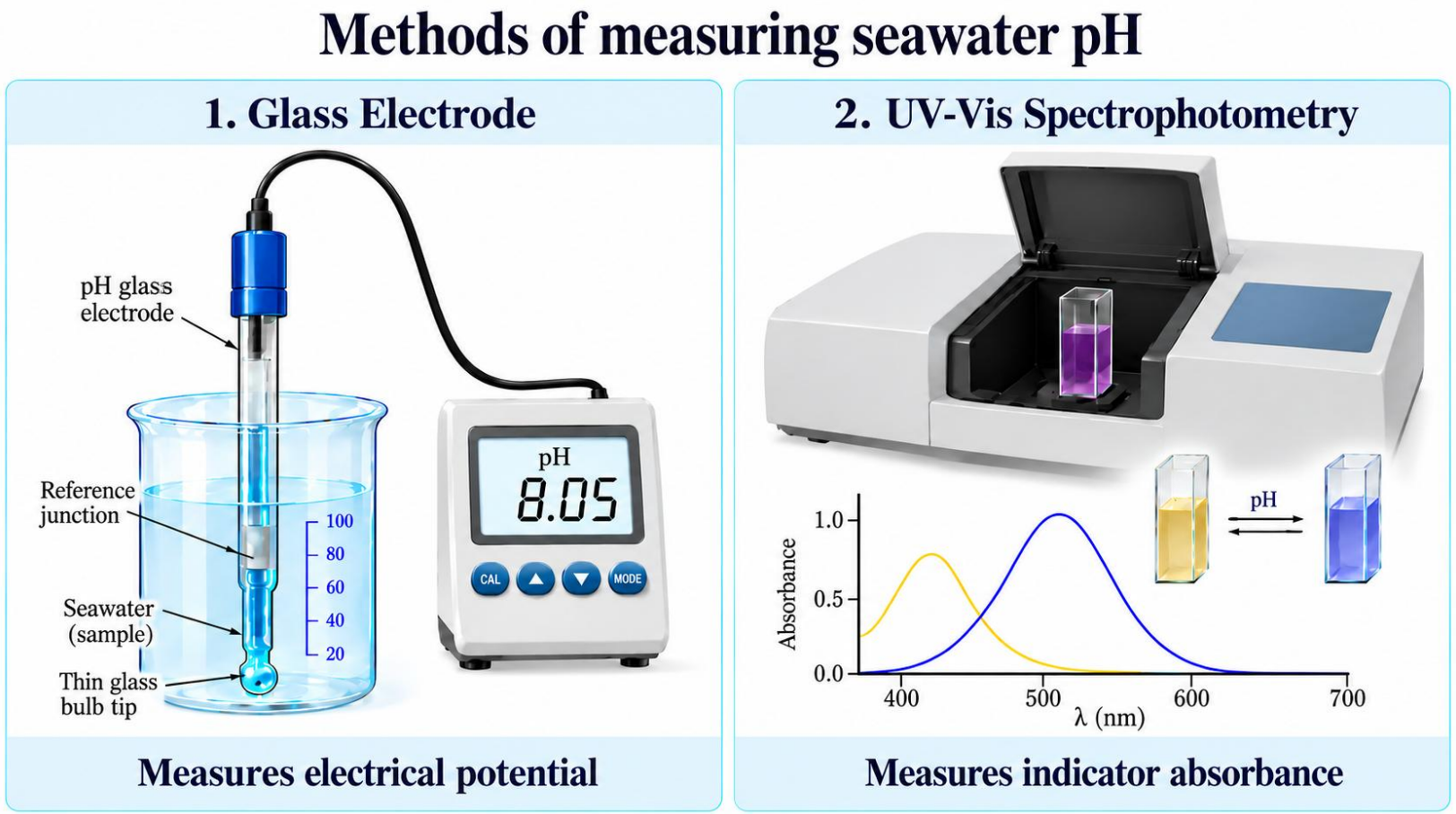
- Constant offset adjustments
- Determination depended on measured carbon variables (pH_T, TA, DIC)
- Combination of crossover and internal consistency
- Measured and Calculated merged into single variable

Version 3

- Primary QC only
- No secondary QC
- Measured values converted to Total Scale and 25˚C
- SEPARATE values calculated from TA and DIC at 25˚C 0 pressure & *in situ* T and P.
- Calculations use same constants as v2, **except total Boron of Lee et al. 2010**

Why the change?

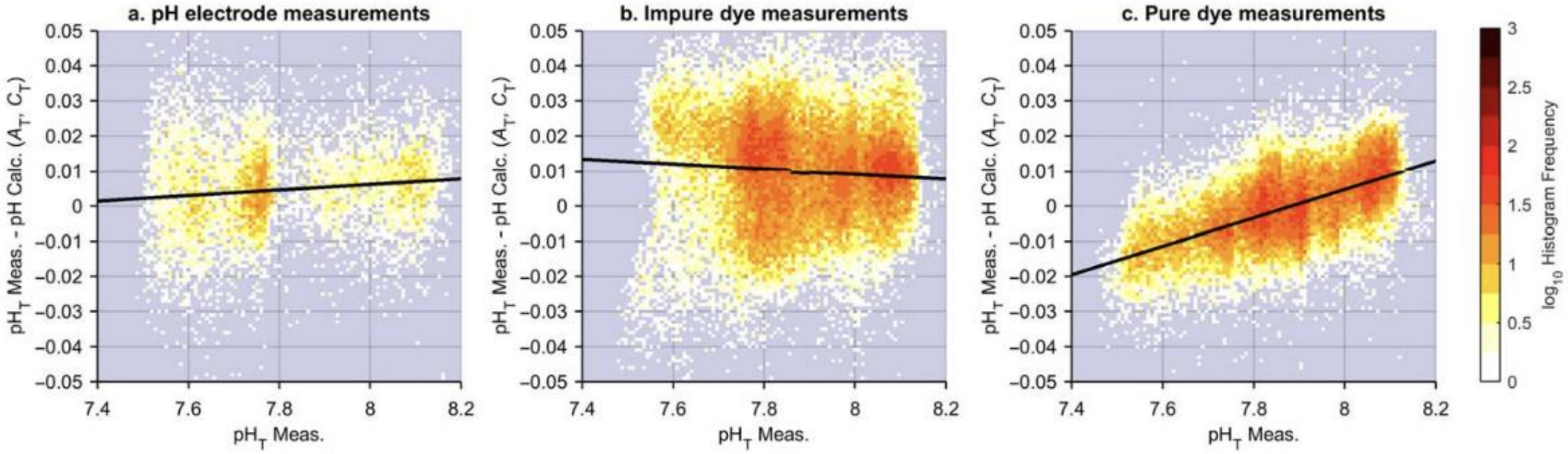
Varied and evolving methods, lack of reference material



AI Generated using GPT-5.6 Terra

Why the change?

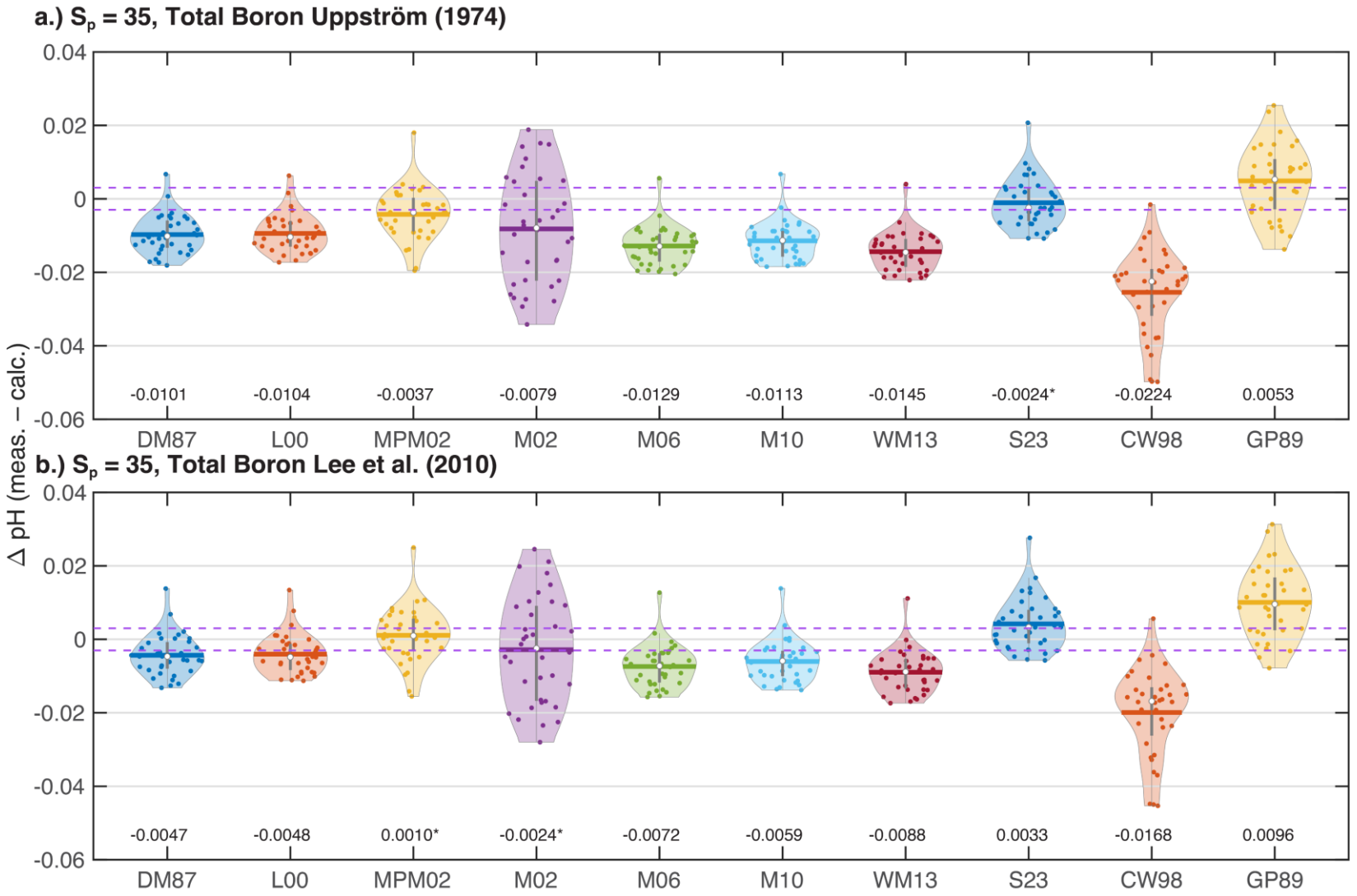
Varied and evolving methods



Carter et al. 2018 L&O:Methods

Why the change?

Internal Consistency Offsets

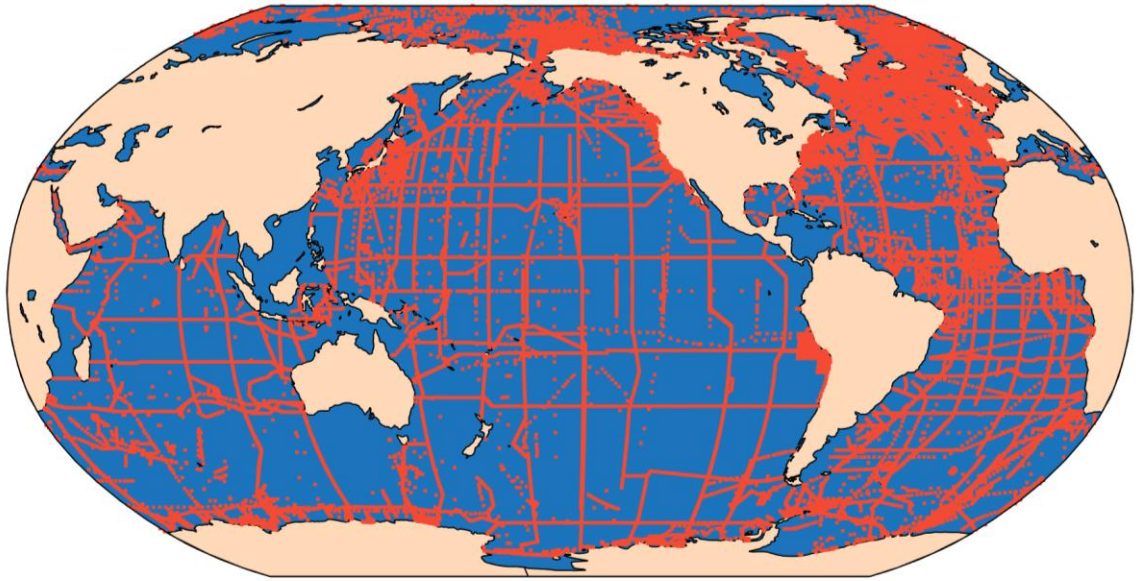


Woosley & Moon 2023 Marine Chemistry

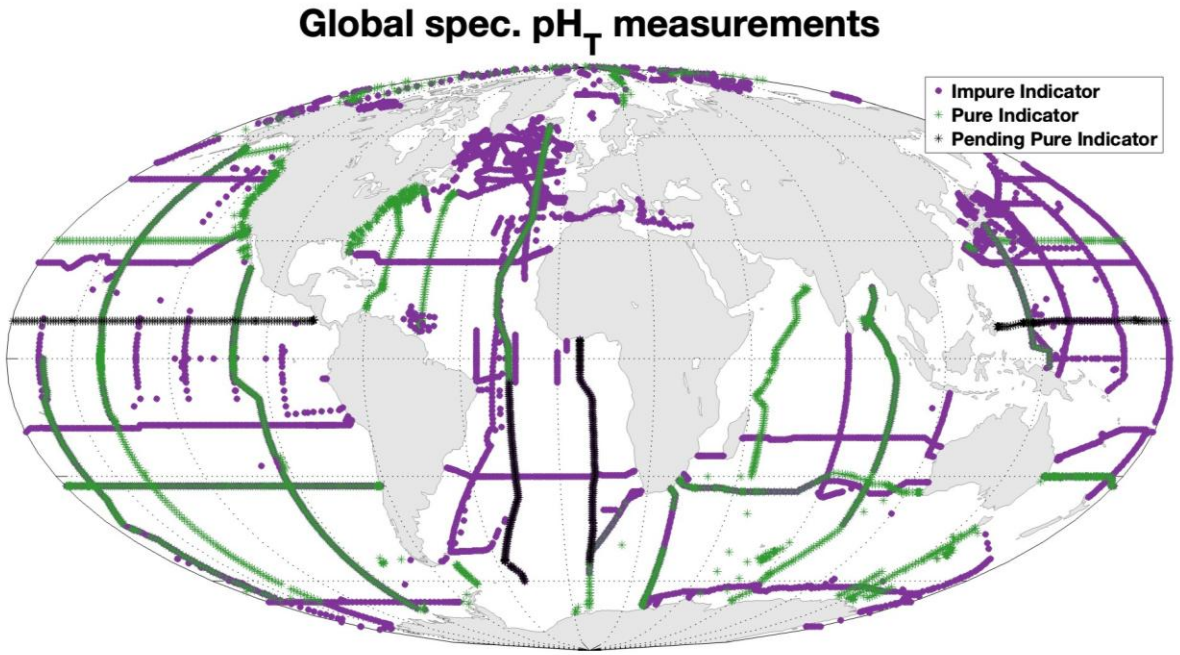
Why the change?

Not enough measurements

All GLODAPv3 cruises



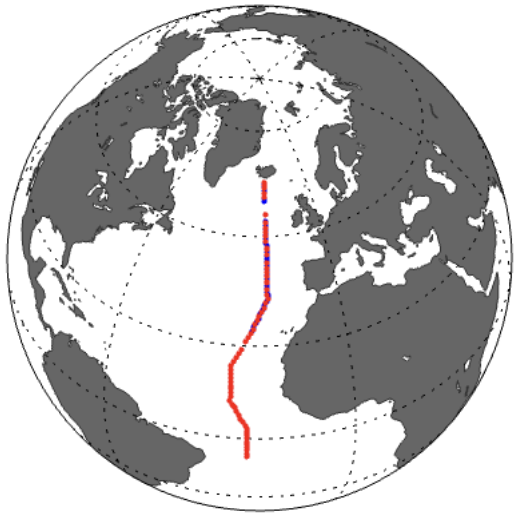
Lange et al. 2026



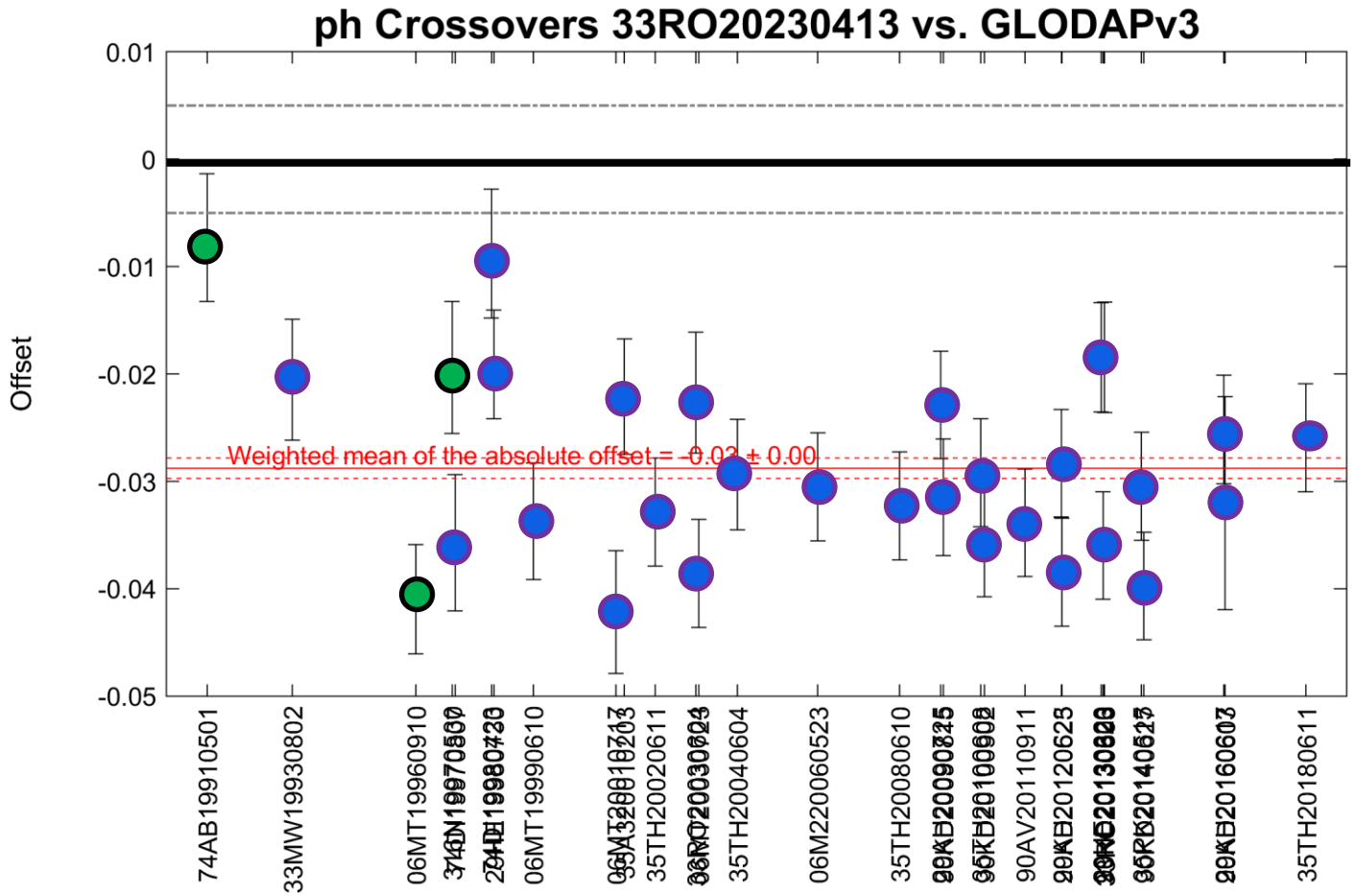
Woosley 2026

Why the change?

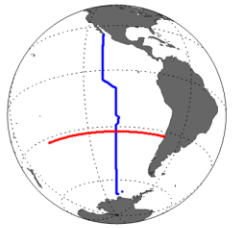
Not enough measurements

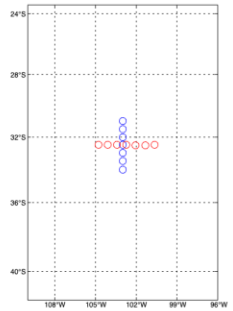


- Purified Dye
- Impurified Dye
- Electrode



Hope for Version 4





Additative offset

max distance [km] 222

weighted offset -0.00019

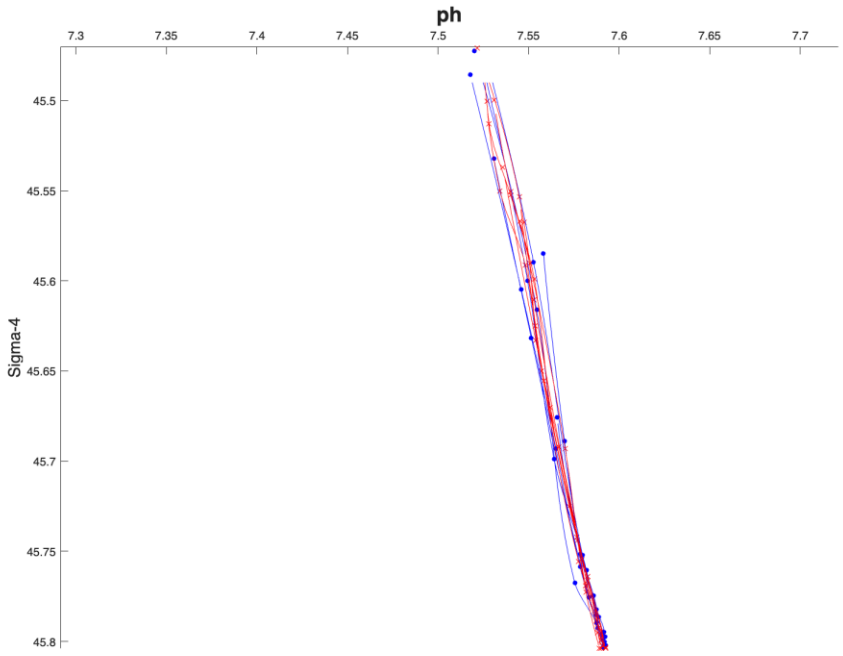
weighted stddev 0.00507

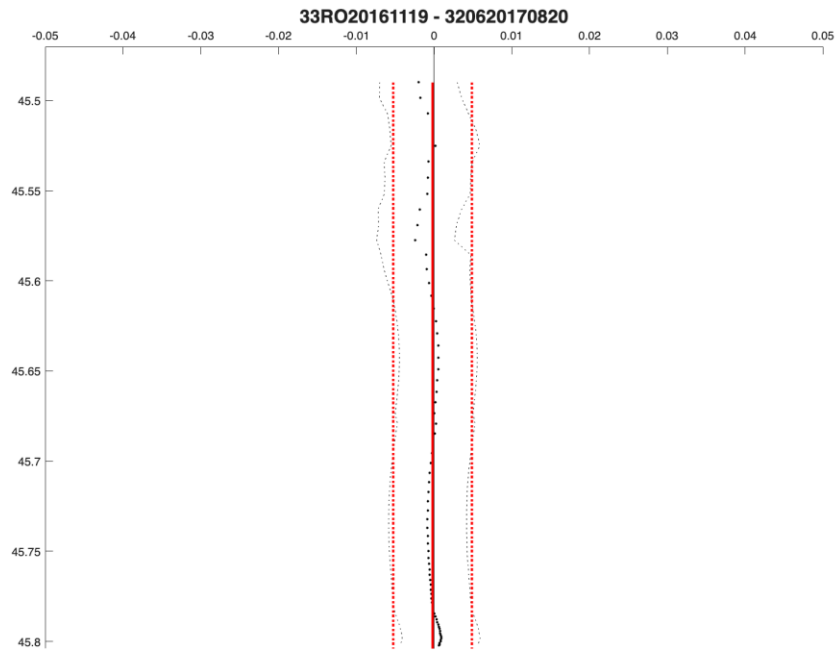
samples C1 (blue) 58

samples C2 (red) 58

stations C1 (blue) 7

stations C2 (red) 7





2ndQC Toolbox

Recommendations for Use

- User must evaluate needs of their use case

- Version 3 generally preferred
  - Reflects improved understanding of pH_T uncertainties

- Measured:
  - Independent of TA, DIC, & Constants
  - Limited coverage
  - Method dependent biases

Calculated:

- Higher global coverage
- Internally consistent by definition
- Ignores organic alkalinity
- Constant choice subjective
- Can recalculate with different constants

- Use care when merging calculated and measured values – **Added uncertainties**
- Uncertainties must be determined on the set being used
- Document all methods clearly!

- **Keep making pH_T measurements!** Make the raw (absorbance) data available!

OceanICU
Understanding Ocean Carbon

Questions & Answers

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GLODAPv3

Data Access & Resources

Webpage	Community webpage, including links to all official GLODAP resources as well as direct access to data.
Ocean Carbon and Acidification Data System (**OCADS**)	Official data repository within the NCEI archive, hosting the GLODAP's metadata landing page and Cruise Summary Table.
Ocean Data Viewer (**ODV**)	GLODAPv3 available in ODV format and explorable through "webODV".
Environmental Research Division's Data Access Program (**ERDDAP**)	Flexible data extraction of GLODAPv3 via ERDDAP.
Adjustment Table	Overview of adjustments as well as related figures and cruise statistics.
GitHub Repository	Repository including all cruise-pair offset tables, codes used, a code to generate an unadjusted version of GLODAPv3, as well as the (living) GLODAPv3 metadata table.

GLODAPv3 OceanICU Resource Directory

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Thank You!

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