GLODAPv3: New Methods

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Abstract

For the version releases of the GLobal Ocean Data Analysis Project (GLODAP), the secondary quality control is a two-step approach – crossover analysis followed by an inversion that aims to remove detected crossover differences. When using a global weighted least squares inversion model (WLSQ) on the GLODAPv3 dataset we found a strong spatial pattern in the suggested adjustments not present in cruise weighted mean offsets. Consequently, for GLODAPv3, a new inversion approach called "furthest-first" (FF), a form of coordinate descent optimization, has instead been applied to solve the highly overdetermined linear crossover matrix. This FF method is effective at improving inter-cruise consistency and appropriately tuned, diminishes otherwise exaggerated influences of weak links in the crossover matrix.

Background

The crossover matrix for GLODAPv3 (excluding Arctic and the northernmost Atlantic cruises) is

- A linear system that is highly overdetermined with 20,844 equations for 986 cruises
- A system that is unevenly distributed with strong grouping especially in the Northwestern Pacific
- A sparse bridge network where very few Southern Ocean crossovers represent crucial but weak links between basins

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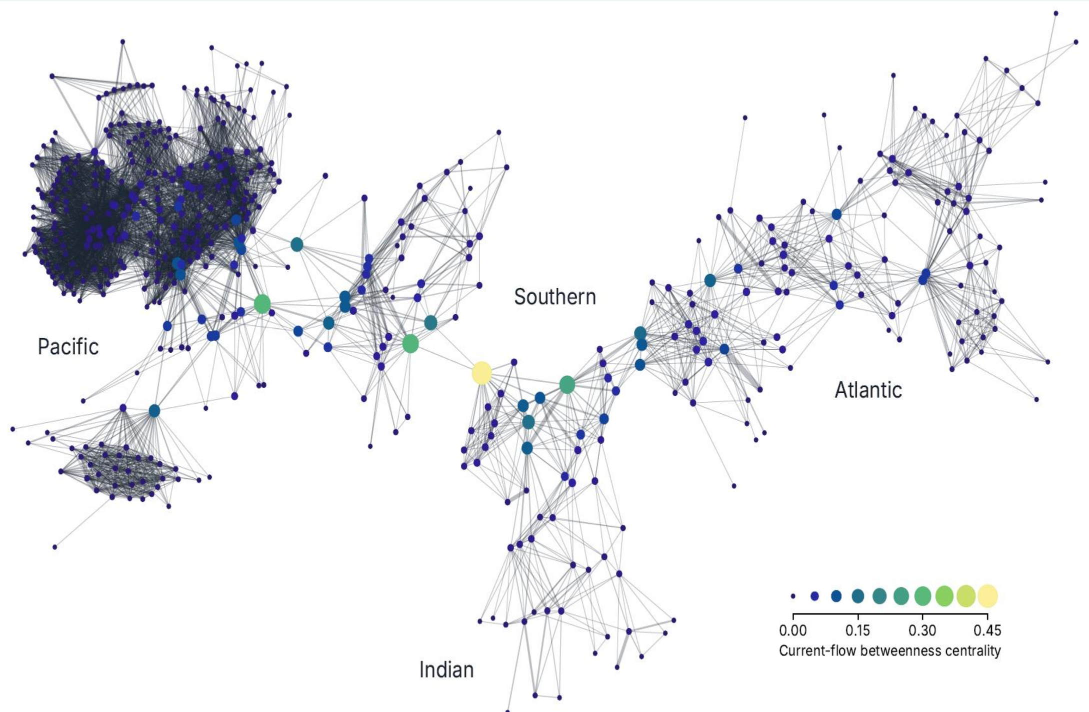
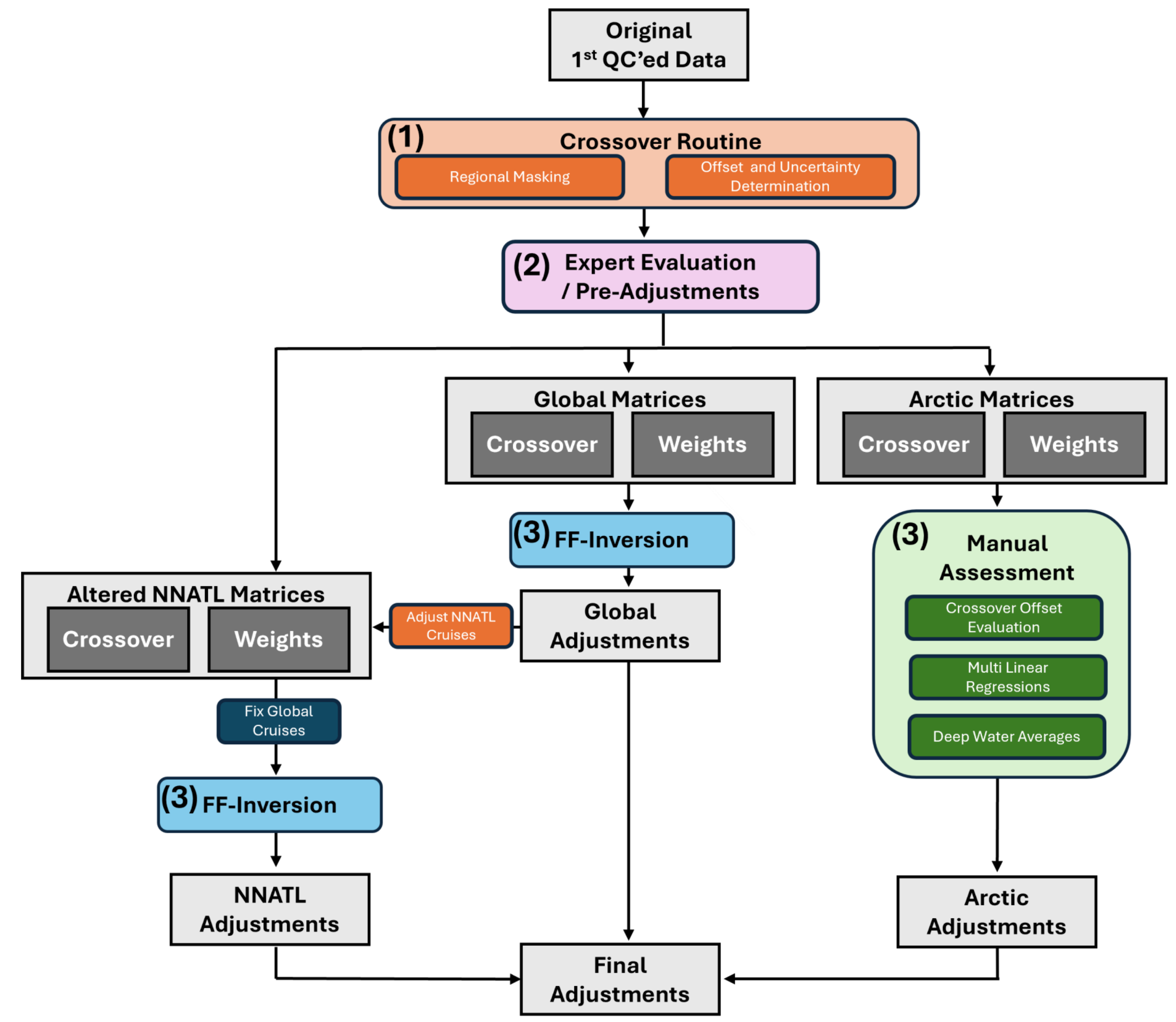
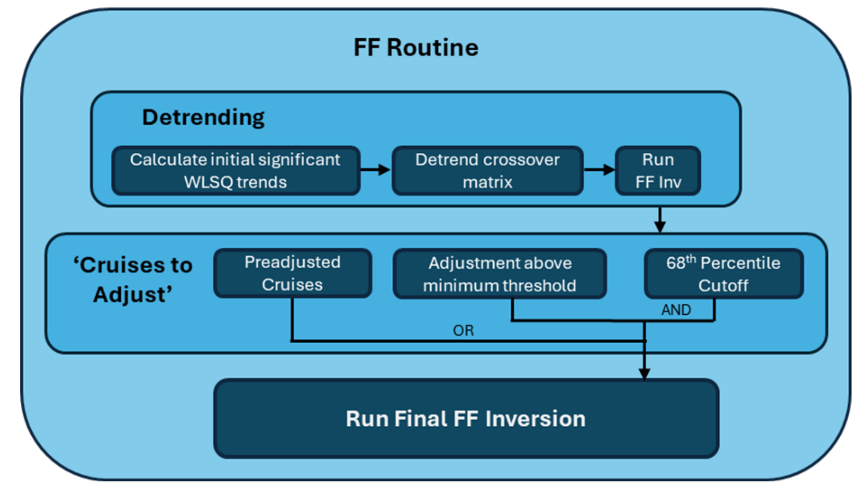


Figure 1. 'Crossover' Network. Dots display individual cruises and lines illustrate connections to other cruises. The colors and size of the dots indicate the importance of a cruise for joining the network together.

How It Works





The Math Behind

$$T_{ij} = C_{ij} - r_i D_{ij}$$

$$c_{i,s} = \begin{cases} \dfrac{\sum (T_{ij} + A_{ij}, s) W_{ij}}{\Sigma_j w_{ij}} \\ 0 \quad , where\ abs(c_{i,s}) < lowerlimit/10 \end{cases}$$

$$a_{i,s} = \begin{cases} c_{i,s} \quad , where\ abs\left(\frac{c_{i,s}}{u_{i,s}}\right) = \max\left(abs\left(\frac{c_{i,s}}{u_{i,s}}\right)\right) and\ p_i \\ 0 \end{cases}$$

$$A_{ij,s+1} = A_{ij,s} + a_{i,s} - a_{j,s}$$

With
C_{ij} = Crossover Offset Matrix
D_{ij} = Date Difference Matrix
T_{ij} = Trend-Adjusted Crossover Matrix
W_{ij} = Crossover Weight Matrix
$A_{ij,s}$ = Adjustment Matrix
i = Matrix Row
j = Matrix column
r_i = Slope of Trend Regression
$c_{i,s}$ = Cruise Weighted Mean Offset (WMO)
$a_{i,s}$ = Adjustment per Cruise
$u_{i,s}$ = Standard errors in WMO
p_j = Cruises permitted to be adjusted
s = Iteration Step

The Issue: Weighted Least Square Inversion

- WLSQ are generally acknowledged to solve overdetermined systems poorly
- Global WLSQ produces spatial pattern not visible in Cruise Weighted Mean Offsets (CWMO)
- Damped WLSQ only reduces spatial pattern
- Data 'converge' towards highly consistent NW Pacific
- Issue was minimized in previous versions by regionalizing the WLSQ inversion

The Solution: Furthest-First Inversion

- A form of coordinate descent optimization
- Focuses on minimizing CWMOs instead of individual crossover offsets
- Calculates and adjusts largest normalized CWMO iteratively
- Provides a more flexible solution through a stepwise approach
- Offers additional tuning parameters suited for sparse bridge networks

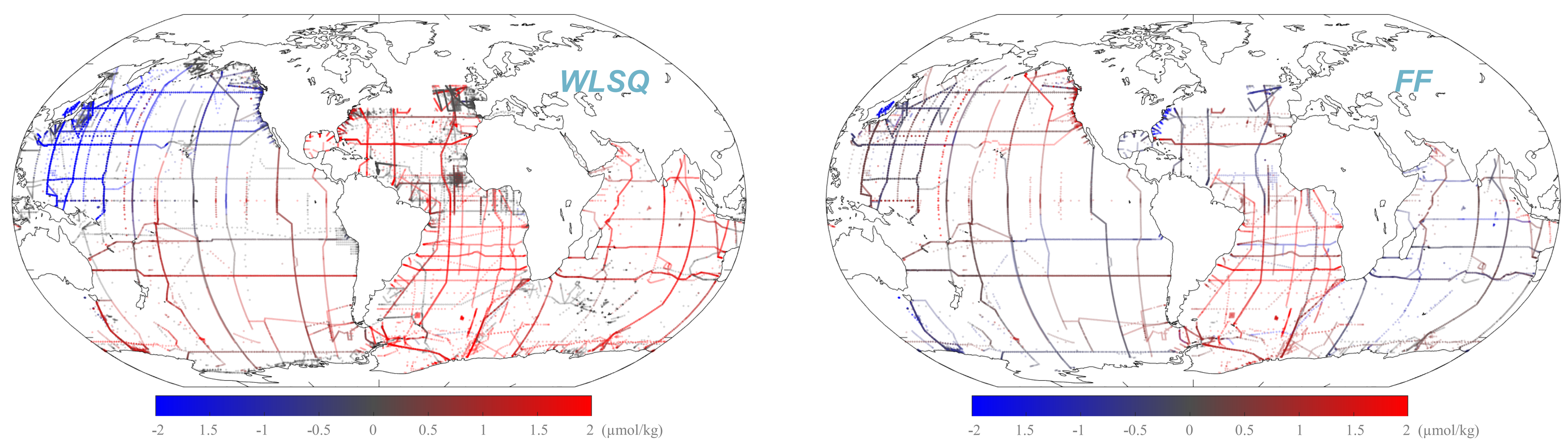


Figure 2. 'Fake DIC Residuals' - The sum of the CWMO and the cruise correction. (Left) Weighted least squares inversion (WLSQ). (Right) Furthest-First inversion (FF).

Results

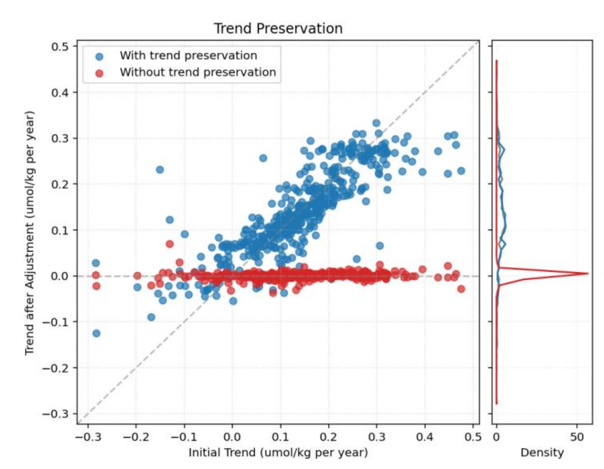


Figure 3. Comparison of significant DIC trends before (grey) and after adjustments applied to simulated data set. The latter for FF runs with trend preservation shown in blue and without in red.

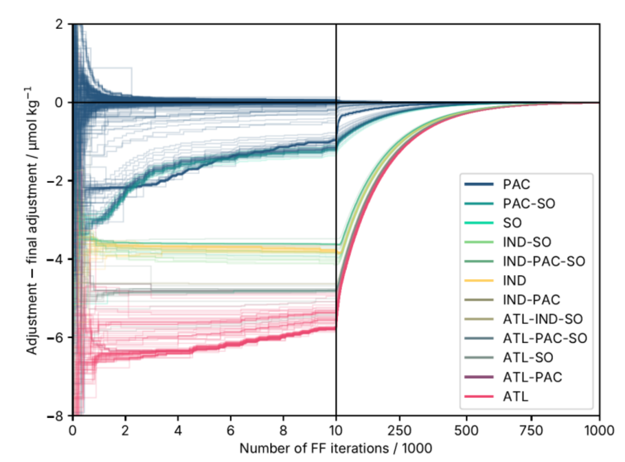


Figure 4. Global convergence owing to DIC corrections. Colors indicate the GLODAP region(s) that each cruise belongs to. Note how regional convergence is achieved prior to global convergence.

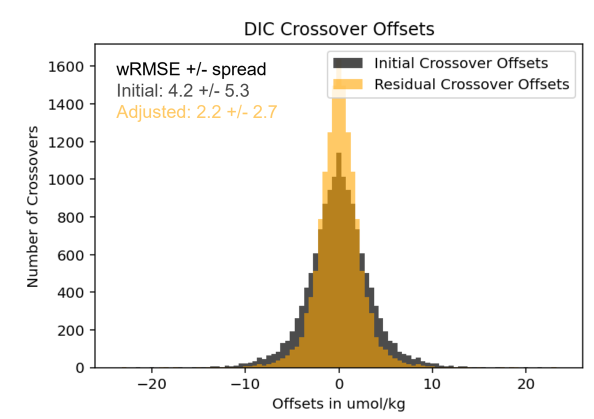


Figure 5. Crossover offsets before (black) and after all adjustments being applied (orange).

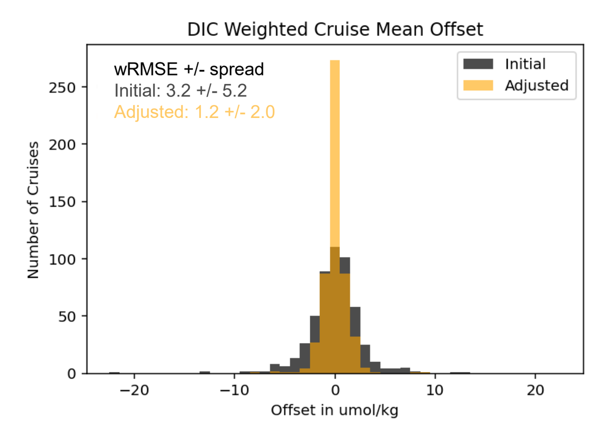


Figure 6. CWMO before (black) and after all adjustments being applied (orange).

The Benefits

- Enhances automation of crossover selection
- Bypasses problematics of weak global crossover connections
- Provides more insight in solutions through step-wise analysis
- Improves overall data product -, as well as inter-cruise consistency
- Accounts for temporal trends
- Implements regionally varying statistical adjustment limits
- Utilizes horizontal density gradients; crossover time-differences; and crossover-ratings
- Propagates uncertainties traceable to variance of crossover analysis

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