

An Internally Consistent Dataset of $\delta^{13}\text{C}$ -DIC in the North Atlantic Ocean - NAC13v1

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Abstract.

The stable carbon isotope composition of dissolved inorganic carbon ($\delta^{13}\text{C}$ -DIC) can be used to quantify fluxes within the carbon system. For example, knowing the $\delta^{13}\text{C}$ signature of the inorganic carbon pool can help to describe the amount of anthropogenic carbon in the water column. The measurements can also be used for evaluating modeled carbon fluxes, for making basin wide estimates of anthropogenic carbon and studying seasonal and interannual variability or decadal trends in interior ocean biogeochemistry. For all these purposes, it is not only important to have a sufficient amount of data, but these data must also be internally consistent and of high quality.

In this study, we present a $\delta^{13}\text{C}$ -DIC dataset for the North Atlantic, which has undergone secondary quality control. The data originate from oceanographic research cruises between 1981 and 2014. During a primary quality control step based on simple range tests obviously bad data were flagged. In a second quality control step, biases between measurements from different cruises were quantified through a crossover analysis using nearby data of the respective cruises and values of biased cruises were adjusted in the data product. The crossover analysis was possible for 24 of the 32 cruises in our dataset and adjustments were applied to 11 cruises. The internal accuracy of this dataset is 0.017‰.

The dataset is available via CDIAC at http://cdiac.ornl.gov/oceans/ndp_096/NAC13v1.html, doi:10.3334/CDIAC/OTG.NAC13v1.

1 Introduction

Stable carbon isotope ratios are utilized as a tracer in several applications in marine carbon research. Particularly the stable carbon isotope ratio of dissolved inorganic carbon ($\delta^{13}\text{C}$ -DIC) can be used to enhance the understanding of carbon related processes ranging widely from the estimation of glacial circulation changes (Curry and Oppo, 2005) to testing the performance of ecosystem models

(Schmittner et al., 2013). By observing the temporal development of the lightening of the inorganic
25 carbon pool due to the uptake of CO₂ originating from the burning of ¹³C-depleted fossil fuel carbon,
a phenomenon also known as oceanic ¹³C Suess effect, an estimation of the anthropogenic
carbon fraction of DIC is possible (Gruber et al., 2002; Körtzinger et al., 2003; Olsen et al., 2006;
Olsen and Ninnemann, 2010; Quay et al., 2007; Racapé et al., 2013). Furthermore, δ¹³C can provide
30 information concerning the quantification of biological processes such as net community produc-
tion (Quay et al., 2009). Using the stable carbon isotope signature facilitates the distinction between
anthropogenic, biological and physical drivers of the carbon system (Gruber et al., 1998).

A sample's stable carbon isotope ratio, δ¹³C-DIC, is expressed as per mil deviation from that of
the commonly used standard material Vienna Pee-Dee Belemnite (V-PDB)(Coplen, 1995).

$$\delta^{13}\text{C} = \left(\frac{{}^{13}R}{{}^{13}R_{\text{PDB}}} - 1 \right) \cdot 10^3 \quad (1)$$

35 with ¹³R being the ratio of the two stable carbon isotopes ¹³C and ¹²C in the sample.

For basin-wide estimates of carbon fluxes due to primary production, studies of seasonal varia-
tions, or interannual trends it is important to have a dataset of sufficiently high coverage both in space
and time. Moreover, the dataset should be free of systematic differences between measurements car-
ried out by different laboratories and on different cruises. However, both criteria are not easily met.
40 Since Isotope Ratio Mass Spectroscopy (IRMS), the common method to analyze δ¹³C-DIC data, is
a very time consuming and expensive technique that cannot be performed at sea, data coverage has
remained relatively poor. Therefore, several efforts have been made to assemble a dataset containing
as many cruises as possible.

For oceanic δ¹³C-DIC data this has been done first by Kroopnick (1985) who provided an analysis
45 of the distribution of δ¹³C-DIC in the world's oceans. Over the years more data were accumulated
and different data collections emerged (Gruber et al., 1999; Quay et al., 2003, 2007; Schmittner
et al., 2013). During recent years, databases like GLODAP (Global Ocean Data Analysis Project)
and CARINA (Carbon dioxide in the Atlantic Ocean) were created for carbon-related parameters
(Olsen et al., 2016). These projects did not only assemble the data but also conducted a secondary
50 quality control so that systematic biases between individual cruises could be identified and adjusted
for (Tanhua et al., 2009; Velo et al., 2009; Tanhua et al., 2010a; Pierrot et al., 2010). Relative to
other parameters such as total alkalinity or DIC, however, the dataset for δ¹³C-DIC is still small and
disorganized. Therefore, no secondary quality control, in which deep water samples from different
cruises at nearby locations, so called crossovers, are compared to each other, could be carried out
55 within these collections. Several new cruises have become available for the North Atlantic so that
now the present crossover study could be performed for this area. This crossover analysis features
29 cruises, of which 22 could be compared quantitatively. Cruises without a quantitatively evaluable
crossover were qualitatively related to the corrected dataset.



Figure 1. Map of all stations with $\delta^{13}\text{C-DIC}$ data used in this dataset. Data from deeper than 1500 m was available only for the stations in dark red, so only these stations were used for the crossover analysis.

Please note that for applying the crossover **and** inversion routine we assume that the deep water masses (below 1500 m) are only to a negligible amount influenced by changes due to an increasing amount of anthropogenic carbon. Since the detected differences between some cruises were not consistent with a slowly increasing amount of anthropogenic carbon we think that this consistent dataset is an important step for improving the study of carbon isotope dynamics in the upper 1500 m. In regions, for which also the deeper water masses have been shown to contain a high amount of anthropogenic carbon, **we considered crossovers with cruises that took place long before or long after the respective cruise with caution.** We believe that no temporal trends have been removed, or created by the 2nd QC procedures employed here. However, care should be exercised for calculating C_{ant} accumulation in water below 1500 m.

Table 1. Information about dates, PIs and publications of each cruise.

Cruise ID	Expocode	dates	C13 PIs	C13 citation
1	06MT19941012	10/12-11/12/1994	A. Körtzinger, H. Erlenkeuser	
2	06MT1997-M39	05/15-06/06/1997, 07/07-08/09/1997, 08/15-09/09/1997	A. Körtzinger, H. Erlenkeuser	
3	06MT1999-M45	06/10-07/09/1999, 07/11-08/10/1999	A. Körtzinger, H. Erlenkeuser	
4	06MT20010507	05/07-05/31/2001	A. Körtzinger, H. Erlenkeuser	
5	06MT20030723	07/23-08/29/2003	A. Körtzinger, H. Erlenkeuser	
6	06MT20040311	03/11-04/13/2004	D.W.R. Wallace, H. Erlenkeuser	
7	316N19970717	07/17-08/10/1997	R. Key	
8	316N19970815	08/15-09/03/1997	R. Key	
9	316N20030922	09/22-10/23/2003	R. Key, P. Quay	Quay et al. (2007)
10	316N20031023	10/23-11/13/2003	R. Key, P. Quay	Quay et al. (2007)
11	33RO19980123	01/23-02/24/1998	R. Key, P. Quay	Quay et al. (2007)
12	33MW19910711	07/11-09/02/1991	R. Key	Quay et al. (2007)
13	33MW19930704-1	07/04-08/30/1993	R. Key	Quay et al. (2007)
14	35TH20020611	06/11-07/12/2002	H. Mercier	Racapé et al. (2013)
15	5TH20060521	05/21-06/28/2006	H. Mercier	Racapé et al. (2013)
16	58GS20030922	09/22-10/13/2003	A. Olsen	Olsen et al. (2006)
17	58JH19920712	07/12-07/28/1992	R. Nydal	
18	58JH19940723	07/23-08/16/1994	R. Nydal	
19	64TR19900417	04/17-05/31/1990	S. Wijma	
20	74DI20120731	06/11-07/02/2012	A.M. Griffiths, M.P. Humphreys, E.P. Achterberg	Humphreys et al. (2015)
21	74JC20120601	06/01-07/02/2012	A.M. Griffiths, M.P. Humphreys, E.P. Achterberg	
21	74JC20140606	06/06-07/21/2014	E. Tynan, M.P. Humphreys, E.P. Achterberg	Humphreys et al. (2016)
23	OMEX1NA	04/1993-11/1995	R. Keir	Keir et al. (1998)
24	316N19810401	04/01-10/19/1981	C.D. Keeling, P. Guenther	Keeling and Guenther (1994); Gruber et al. (1999)

70 **Table 2.** Information about sample handling and measurements for those cruises where the $\delta^{13}\text{C}$ data have not been published elsewhere.

Cruise ID	Expocode	Laboratory	Analysis period	Sample handling
1	06MT19941012	¹	9/2002 12/2002	- 200 μL $\text{HgCl}_{2\text{sat}}$ / 100 mL sample
2	06MT1997-M39	¹	1/1998 - 2/2000	200 μL $\text{HgCl}_{2\text{sat}}$ / 100 mL sample
3	06MT1999-M45	¹	7/2000 - 6/2002	50 μL $\text{HgCl}_{2\text{sat}}$ / 100 mL sample
4	06MT20010507	¹	12/2001 9/2002	- 50 μL $\text{HgCl}_{2\text{sat}}$ / 100 mL sample
5	06MT20030723	¹	3/2004 10/2004	- 100 μL $\text{HgCl}_{2\text{sat}}$ / 100 mL sample
6	06MT20040311	¹	1/2005 10/2005	- 200 μL $\text{HgCl}_{2\text{sat}}$ / 100 mL sample

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2 Data Provenance and Structure

This dataset comprises data and metadata from 32 research cruises/campaigns from several international research groups, in total 6820 samples. Some of these consist of multiple cruises and one is a time series. For the crossover analysis, some consecutive cruises whose data were analyzed together were treated as one cruise. While the focus is on the North Atlantic, four cruises were included that also have stations in the Nordic Seas, and one cruise extends into the South Atlantic. Thereby, consistency with future extended quality controlled datasets for these regions is ensured. Since only deep (> 1500 m) samples of each cruise are compared in this study, only cruises with at least one deep station could be included in this analysis.

Figure 1 shows the locations of all stations with $\delta^{13}\text{C}$ -DIC data that are part of this compilation. Table 1 shows a summary of the respective cruise dates, the responsible PI and publications in which the data was used. For cruises that have not been published elsewhere, Table 2 shows the sample handling and time periods, during which the samples were analyzed. Some cruises had $\delta^{13}\text{C}$ -DIC measurements over the entire depth range at every station, whereas others just had one or two stations with deep $\delta^{13}\text{C}$ -DIC data. Most of the cruises were conducted in the subpolar North Atlantic, while the tropical region has relative poor coverage. The temporal and latitudinal distributions of the data are displayed in Figure 2. The data were collected in the North Atlantic between 1981 and 2014, with

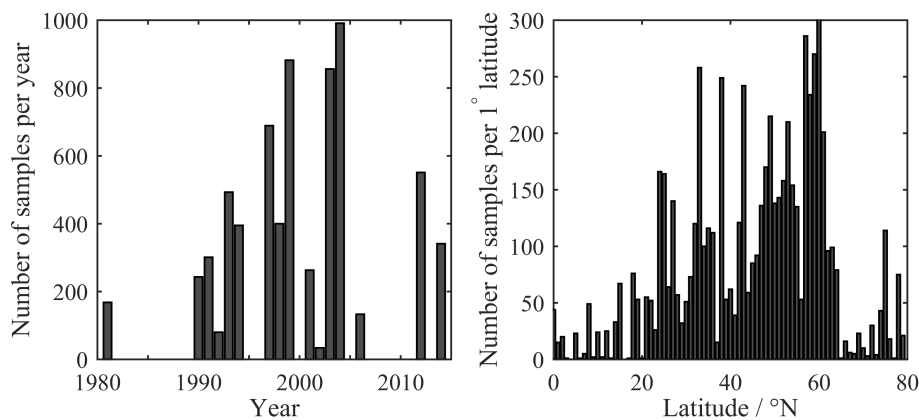


Figure 2. The temporal distribution of the presented dataset ordered by year (left panel) and the sum of all samples at each latitudinal degree (right panel).

90 the majority falling between 1990 and 2005. Considering the seasonal distribution of the data, a bias towards summer time exists, especially towards late summer. The only two cruises that took place between January and March were located south of 42°N. The uncertainty of the $\delta^{13}\text{C}$ -DIC samples analyzed by IRMS is usually reported to be between $\pm 0.12\text{‰}$ (Gruber et al., 1999) and $\pm 0.03\text{‰}$ (Quay et al., 2003).

95 The presented dataset consists of 19 columns, of which the first 16 are cruise number, station, sampling number, day, month, year, latitude, longitude, maximal depth, maximal sampling depth, bottle number, cast number, temperature, salinity, depth, ctd salinity and pressure. Column 17 contains the adjusted $\delta^{13}\text{C}$ -DIC data, column 18 a quality flag (C13f) and column 19 the QC-flag (C13qc, see Table 3). For bad data the quality flag was set to 'not measured' and therefore column 18 has only
 100 two entries (2: good, 9: not measured). Cruises that could be quantitatively compared to each other by the 2nd QC have a '1' in the QC-flag. All others are flagged with '0'.

Additional parameters to most of the cruises can be found in either [GLODAPv2 \(Olsen et al., 2016\)](#) or [CARINA \(Key et al., 2010\)](#). Only the most recent cruises, [35TH20060521](#) and [74DI20120731](#), are not included in these datasets, but the individual cruise files can be found on CDIAC. The
 105 OMEX1NA data are only part of [CARINA](#). The respective cruise numbers in GLODAPv2 and CARINA of the cruises shown in the NAC13v1-dataset can be found in the documentation.

Table 3. NAC13v1 data set parameter list, column names used in the data product and the respective units.

parameter	data product parameter name	data product flag name	unit
NAC13v1 cruise number	cruiseno		
Station	station		
Day	day		
Month	month		
Year	year		
Latitude	latitude		°N
Longitude	longitude		°E
Bottom depth	maxdepth		m
Pressure of the deepest sample	maxsampdepth		dbar
Bottle number	bottle		
Cast number	cast		
Temperature	temperature		°C
Salinity	salinity		
Depth	depth		m
CTD salinity	ctdsal		
Pressure	pressure		dbar
$\delta^{13}\text{C-DIC}$	C13	C13f, C13qc	‰

110 3 Computational Analysis

In order to derive an internally consistent set of $\delta^{13}\text{C-DIC}$ data in the North Atlantic all publicly available data in this area were assembled and quality controlled (QC) in two steps. At first, a primary QC was performed in order to identify obviously erroneous data, such as wrong positions, time stamps and depths. Also outliers were identified and then flagged by comparing the $\delta^{13}\text{C}$ profiles of each cruise internally. After that, the secondary QC procedure was conducted employing a **running** crossover analysis as described by Tanhua et al. (2010b). This MATLAB based software package compares two cruises at a time, searches for nearby stations, so-called 'crossovers', and calculates differences between all crossovers of the two cruises as additive offsets with the unit ‰. As criterion for identifying crossovers a maximum of 180 nm (3° of latitude) distance between stations was used.

115 From these crossovers, the $\delta^{13}\text{C-DIC}$ data collected deeper than 1500 m was compared on equal potential density. Based on the resulting offsets and standard deviations determined for each of these crossovers a suggestion for a possible adjustment was made. This suggestion was obtained by an inversion routine using a Weighted Least-Square (WLSQ) and a Weighted Damped Least Square

120

(WDL SQ) model as described by Johnson et al. (2001). The cruise 33MW199930704-1 was analyzed by a reputable laboratory, has relatively low scatter and covers wide distances. Therefore this cruise was selected as core cruise and weighted higher than the other cruises. Unfortunately this was the only cruise meeting these two criteria. Several cruises from different years were in good agreement with the core cruise while the other cruises were adjusted towards it. Choosing the appropriate distance criterion for crossover locations is always a compromise between including as many statistically relevant crossovers as possible by selecting a large enough radius on the one hand and trying to have only crossovers between stations that share similar oceanographic characteristics on the other hand. However, reducing the crossover distance to 120 nm, which is the distance commonly used in CARINA, PACIFICA and GLODAPv2 data products, reduced the amount of crossovers and the number of cruises that could be quantitatively compared to each other but did not significantly change the suggested magnitude of adjustments of the remaining cruises. Therefore, the $3^\circ \times 3^\circ$ criterion was used instead. For some crossovers in highly variable regions with deep water formation, such as the Labrador Sea and the Nordic Seas, the standard deviation of the offset between two cruises was decreased significantly by restricting the comparison depths to >2000 m. Generally, offsets from crossovers in these highly variable regions, from cruises with a relatively poor data precision or with just a few deep samples were considered in the model with less influence, by weighting the offsets with their uncertainty. In Figure 3 all crossovers between the cruises 06MT20030723 and 33MW19930704-1 are shown as an example, both for the uncorrected as well as for the corrected dataset. All crossovers from the adjusted and the unadjusted dataset can be found at: http://cdiac.ornl.gov/oceans/ndp_096/NAC13v1.html.

Whether an adjustment was applied to the data was decided somewhat subjectively in each case based on a combination of the shape and distribution of individual crossover differences and the suggestions given by the inversion routine with knowledge about the sampling region. After applying the adjustments, the inversion was conducted again and it was checked whether or not the adjustment improved the overall consistency within the entire dataset. Temporal changes of the deep water masses were only considered in this step of the routine when comparing the suggested corrections and the corresponding crossover offsets between cruises in areas where also the deep water $\delta^{13}\text{C}$ -DIC was expected to change over time. In order to get a quantitative description of the internal consistency of the final dataset, a weighted mean using the respective offsets of all crossovers and their standard deviation was calculated (Tanhua et al., 2010a).

$$\text{WM} = \frac{\sum_{i=1}^L D(i)/(\sigma(i))^2}{\sum_{i=1}^L 1/(\sigma(i))^2} \quad (2)$$

L refers to the total number of crossover, D to the respective offset of all crossover and σ is their standard deviation.

Another method for revealing systematic deviations between different cruises is a regional multi-linear regression (MLR) (Wanninkhof et al., 2003; Jutterström et al., 2010). In this work, a MLR

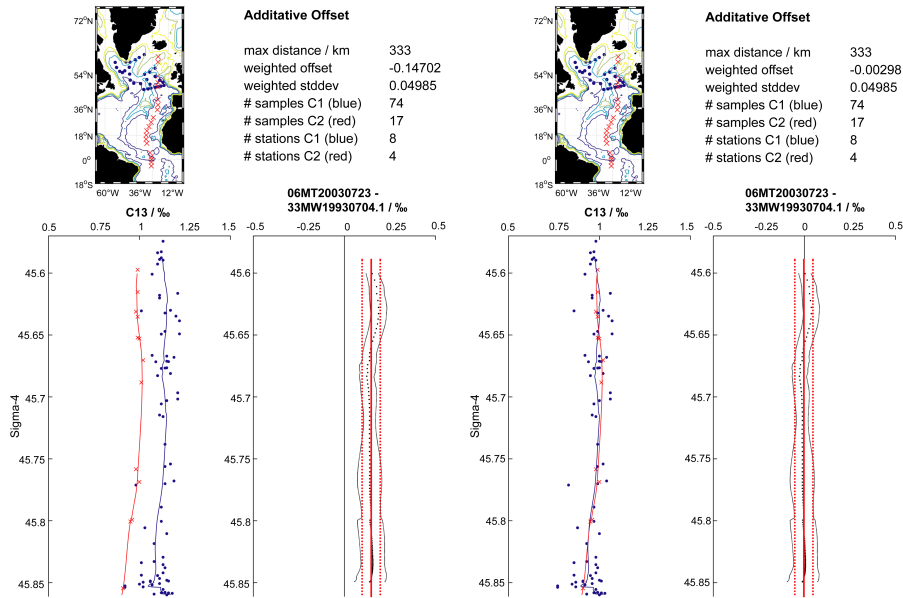


Figure 3. Crossovers between the cruises 06MT20030723 (blue dots and lines) and the core cruise 33MW19930704-1 (red crosses and lines). The C13 plots show the data and mean profiles of each cruise and the difference plots show the difference profiles with its standard deviation (black lines) as well as the crossovers offset with its standard deviation (red lines). The left hand plot shows the original and the right hand plot the adjusted data. In both cases the distribution of the $\delta^{13}\text{C-DIC}$ on equal density surfaces (left hand side) as well as the mean offset between both cruises (right hand side) is shown. The cruise 06MT20030723 was adjusted by -0.15‰ .

160 based on core cruise data (deeper than 1500 m) was used to verify the suggested corrections, which resulted from the crossover analysis. Moreover, some cruises without a statistically evaluable crossover could now be related to the other cruises. The following equation was used,

$$\delta^{13}\text{C-DIC}_{\text{MLR}} = -16.9 + 0.80 \cdot S - 0.080 \cdot \Theta - 0.0045 \cdot \text{DIC} \quad (3)$$

with $\delta^{13}\text{C-DIC}_{\text{MLR}}$ being the calculated $\delta^{13}\text{C-DIC}$, S the salinity, Θ the potential temperature
 165 in $^{\circ}\text{C}$ and DIC the DIC concentration in μmolkg^{-1} . The DIC concentration was chosen because it is strongly related to changes in the isotope composition and DIC data were available for most cruises. Adding more parameters to the MLR, such as apparent oxygen utilization (AOU) or nutrient concentrations, did not improve the agreement between $\delta^{13}\text{C-DIC}$ and $\delta^{13}\text{C-DIC}_{\text{MLR}}$ of the core cruise and reduced the amount of cruises that could be compared via the MLR analysis. The limitation
 170 of this method is, of course, that the further away in space and time the cruises are from the core cruise, the more likely an observed offset is real. Especially, the cruises reaching into the Nordic seas

show significant deviations, which are most likely real differences between the basins. Therefore, the offsets revealed by the MLR analysis were not taken into account for these cruises.

4 Adjustments

175 The data of all cruises as well as locations are shown in Figure 4. The offsets, as well as the corrections suggested by the WDLSQ inversion routine, the MLR analysis, and the final adjustments are listed in Table 4. In Figure 5 the results of the WDLSQ inversion are shown before and after the adjustments were applied. Some cruises show quite big deviations from the core cruise. However, we do not know the reason for these biases. Besides the actual sample analysis in the laboratory, 180 also different sampling routines on board the ship, insufficient poisoning and the sample storage time can cause these biases. For most cruises that took place in the North Atlantic, the offsets revealed by the MLR analysis were in the same order and magnitude as the suggested correction by the crossover inversion routine. Cruises reaching far into the Nordic Seas or the South Atlantic show huge differences, which are caused by different water mass properties in these areas.

185 A detailed overview of the offset of each crossover in the original as well as the adjusted dataset is given in Table 5 in the supplementary information. Moreover, the evidence for our decision will be presented for each cruise.

4.1 06MT19941012, cruise #1

This cruise on the German R/V Meteor is also known as M30-2. The inversion suggested a correction 190 of -0.07‰ . The mean offset of all crossovers is 0.11‰ too high. The MLR analysis revealed a smaller offset of 0.05‰ and, thus, the cruise was adjusted by -0.07‰ .

4.2 06MT19970515, 06MT19970707 and 6MT19970815, here referred to as 06MT1997-M39, cruise #2

195 These cruises are also known as M39 cruises with three legs of $\delta^{13}\text{C}$ -DIC sampling (M39-2, M39-4, M39-5). Since each leg of this cruise had only a few stations with $\delta^{13}\text{C}$ -DIC samples, and all these samples were analyzed together, these cruises were summarized for the crossover study. Both, the inversion routine and the single crossover with the adjusted cruises show no evidence for an offset.

4.3 06MT19990711 and 06MT19990813, here referred to as 06MT1999-M45, cruise #3

200 These cruises are also known as M45-2 and M45-3. Since both were analyzed together, they were summarized for this crossover study. The inversion suggested a correction of -0.15‰ and the mean offset of all crossovers was 0.16‰ too high. After applying this adjustment and comparing this cruise to the adjusted dataset, the inversion routine still suggested a small correction. Therefore, an adjustment of -0.20‰ was applied.

Table 4. Overview of all cruises in this dataset. The data of some cruises were combined for the analysis. For more information, please see the detailed description in the 'Adjustments' section. The mean offsets of the crossovers and the MLR as well as the corrections suggested by the WDLSQ inversion for the original and the adjusted dataset are shown. In the last column the applied adjustments are displayed. NC indicates that these cruises were not considered in the inversion since they had no statistically significant crossover and the core cruise is marked with C. Cruises with insufficient quality data are denoted 'poor' and not included in the further analysis. **Cruises marked with a * had less than 10 deep samples that were part of the MLR analysis.**

cruise ID	Expocode	Calculated offset		Suggested correction		Final adjustments /‰
		crossover	MLR	WDLSQ	WDLSQ (adj)	
		/‰	/‰	/‰	/‰	
1	06MT19941012	0.11	0.05(±0.07)	-0.07(±0.10)	-0.01(±0.02)	-0.07
2	06MT1997-M39	-0.02	-0.01(±0.05)	0.01(±0.14)	0.00(±0.01)	0
3	06MT1999-M45	0.16	0.15(±0.07)	-0.14(±0.09)	0.00(±0.01)	-0.20
4	06MT20010507	0.16	0.30(±0.09)	-0.24(±0.10)	0.00(±0.01)	-0.30
5	06MT20030723	0.14	0.15(±0.08)	-0.15(±0.09)	0.00(±0.01)	-0.15
6	06MT20040311	-0.14	-0.13(±0.09)	0.10(±0.09)	0.01(±0.01)	0.10
7	316N19970717	0.17	0.03(±0.05)	-0.06(±0.17)	-0.01(±0.01)	-0.05
8	316N19970815		-0.01(±0.05)			NC
9	316N20030922		0.11(±0.02)*			NC
10	316N20031023					NC
11	33RO19980123		-0.03(±0.04)			NC
12	33MW19910711	-0.02	-0.04(±0.11)	0.00(±0.01)	0.00(±0.01)	0
13	33MW19930704 1	-0.05	0.00(±0.04)	0.00(±0.01)	0.00(±0.01)	C
14	35TH20020611		-0.24(±0.07)*			0.25
15	35TH20060521	-0.39	-0.02	0.24(±0.21)	-0.03(±0.05)	0.25
16	58GS20030922		-0.15(±0.07)			NC
17	58JH19920712		-0.11(±0.10)			NC
18	58JH19940723		-0.06(±0.05)*			NC
19	64TR19900417					poor
20	74DI20120731	-0.33	-0.14(±0.13)	0.13(±0.28)	0.12(±0.12)	0
21	74JC20120601		-0.33(±0.11)			NC
22	74DI20140606	-0.11	-0.09(±0.09)	0.07		0
23	OMEX1NA	-0.14	-0.23(±0.15)	0.03(±0.13)	0.02(±0.02)	0
24	316N19810401	-0.06	-0.04(±0.08)	-0.03(±0.10)	-0.01(±0.03)	0

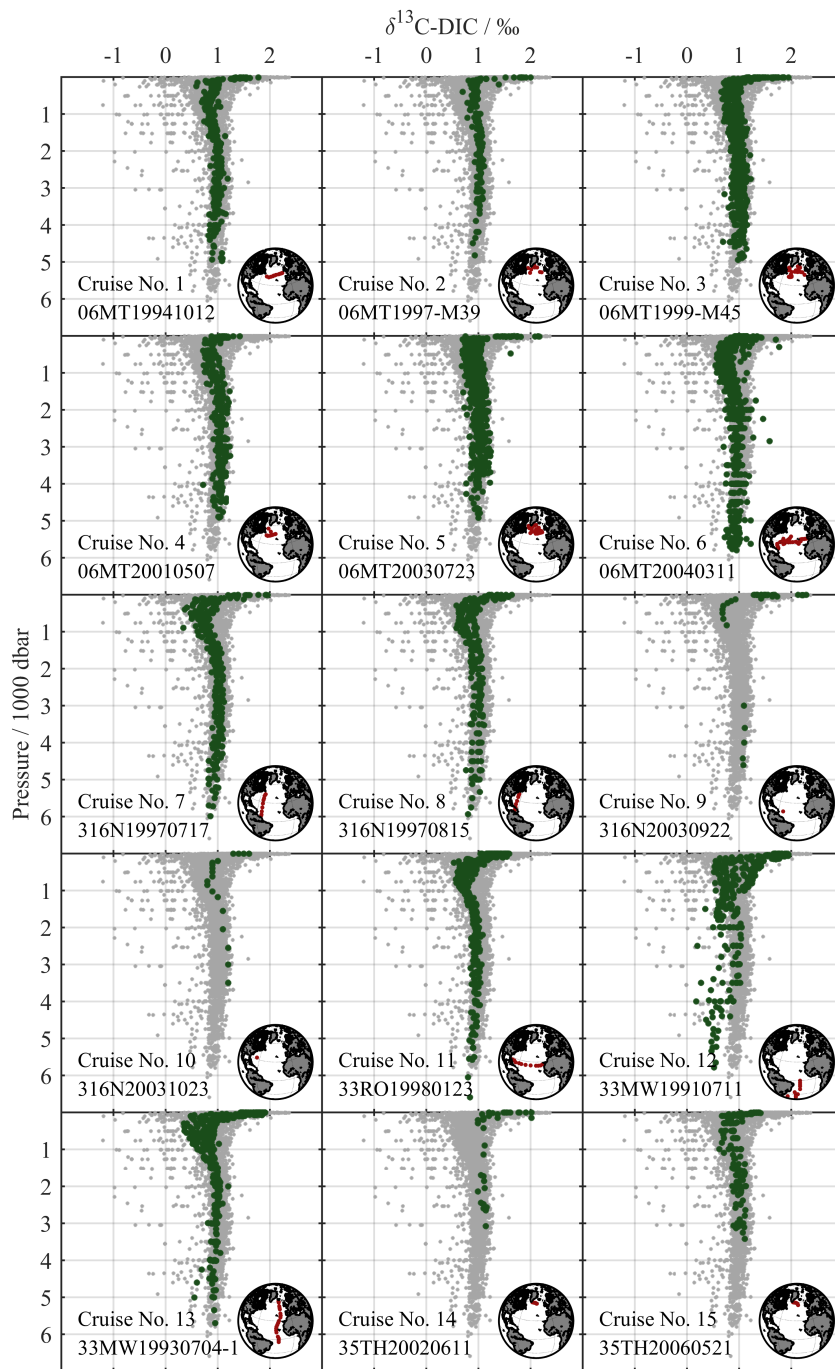


Figure 4. Adjusted $\delta^{13}\text{C-DIC}$ profiles and locations of each cruise. The green profiles represent the data of the specific cruise whereas the gray dots show all profiles in the dataset. *continued on next page*

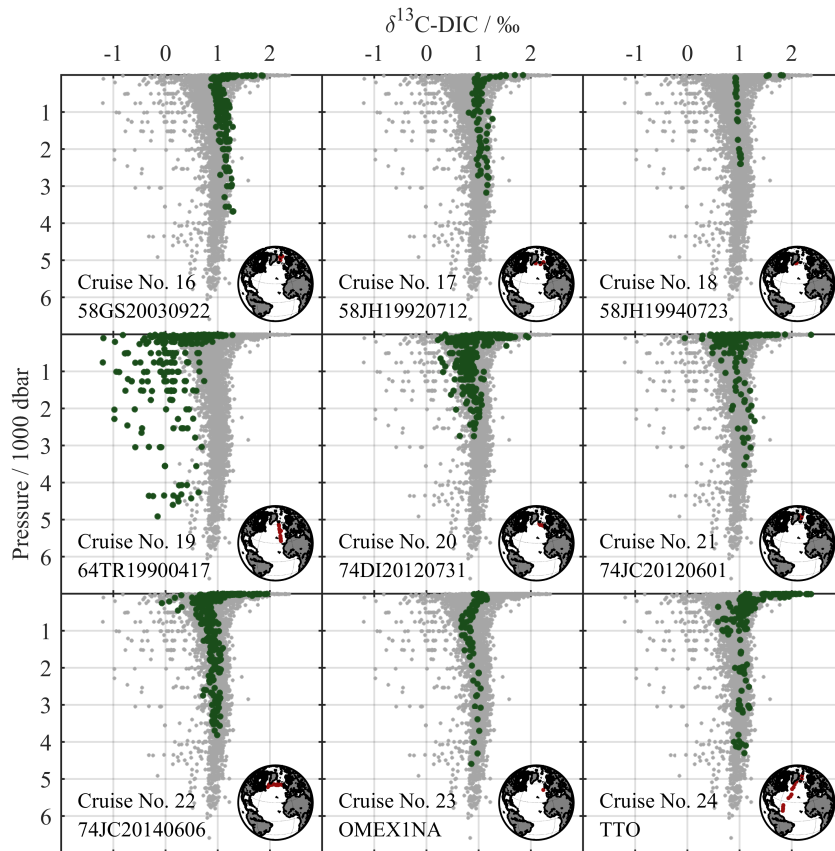


Figure 4.

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Adjusted $\delta^{13}\text{C-DIC}$ profiles and locations of each cruise. The green profiles represent the data of the specific cruise whereas the gray dots show all profiles in the dataset.

4.4 06MT20010507, cruise #4

205 This cruise is also known as M50-1. The inversion routine suggested a correction of -0.24‰ , whereas the mean offset was 0.16‰ too high. **The MLR analysis revealed an offset of 0.30‰ .** Based on the southern crossover with cruise 06MT20040311 and 316N19970717 an adjustment of -0.30‰ was applied.

4.5 06MT20030723, cruise #5

210 This cruise is also known as M59-2 (Friis et al., 2007). The correction suggested by the inversion routine is -0.15‰ , which matches with the positive offsets of the crossovers, except of those with 33TH20060521. Based on the crossover with the core cruise, an adjustment of -0.15‰ was applied.

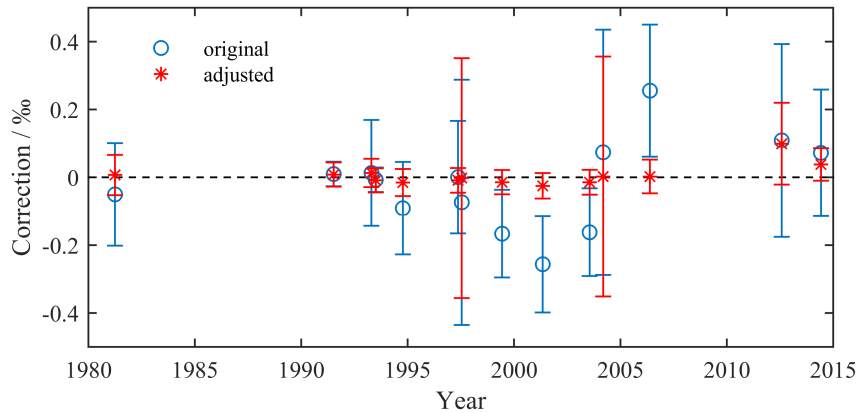


Figure 5. The results of the WDLISQ based inversion routine for the original (blue circles) and the adjusted dataset (red stars). The cruises are plotted at the time the data were collected vs. the suggested correction.

4.6 06MT20040311, cruise #6

This cruise is also known as M60-5. The inversion routine indicates that the $\delta^{13}\text{C}$ -DIC data of this cruise are 0.10 ‰ too low. Additionally, the mean offset as well as the MLR analysis shows that these data are too low. An adjustment of +0.10 ‰ was applied.

4.7 316N19970717, cruise #7 and 316N19970815, cruise #8

These cruises followed the WOCE/GO-Ship standard lines A20 and A22. The inversion suggests a correction of -0.06 ‰ for 316N19970717. It shows one crossover with cruise 06MT2004031, in which a significant positive offset is still visible after cruise 06MT20040311 was corrected. Therefore, an adjustment of -0.05 ‰ was applied for cruise 316N19970717. The cruise 316N19970815 does not show a statistically significant crossover.

4.8 316N20030922, cruise #9, and 316N20031023, cruise #10

These cruises, which took place in the tropical western Atlantic, following the A20 and A22 lines, have only one deep station each. The crossovers of these stations with both, the adjusted data of cruise 06MT20040311 and cruise 316N19970717 show a good agreement, suggesting that no adjustment should be applied.

4.9 33RO19980123, cruise #11

This cruise has one statistically insignificant crossover with the cruise 06MT20040311 and one with cruise 33MW19930704-1. Both seem to be in good agreement, suggesting that no adjustment should be applied.

4.10 33MW19910711, cruise #12, and 33MW19930704-1, cruise #13

The cruise 33MW19930704-1 was considered as core cruise in the present analysis. The cruise 33MW19910711 extends into the south Atlantic and its crossover with cruise 13 shows no need for
235 an adjustment.

4.11 35TH20020611, cruise #14, and 35TH20060521, cruise #15

The latter of these two cruises has a few quantitative crossovers, **which** show a high offset of -0.39‰ . Furthermore, the inversion suggests a correction of 0.24‰ . The high variability of the sampling area south of Iceland, as well as an increasing lightning of the deep water carbon pool over time don't
240 give an adequate explanation for this large deviation and, therefore, an adjustment of -0.25‰ was applied. The cruise 35TH20020611 shows **only** qualitatively analyzable crossovers, which show a lighter carbon pool compared to earlier cruises and a heavier one compared to the original data of cruise 35TH20060521 (Racapé et al., 2013). After adjusting cruise 35TH20060521, both cruises, which were analyzed in the same laboratory, are not in good agreement anymore, which suggests
245 that the earlier cruise also has too low isotope values. **The MLR analysis reveal an offset of the 35TH20020611 cruise of -0.23‰ , which is in the same order as the correction suggested by the crossover routine for cruise 35TH20060521. Since the MLR offset for cruise 35TH20020611 is based only on five samples, we applied an adjustment of -0.25‰ to secure the internal consistency of these two cruises.**

250

4.12 58GS20030922, cruise #16

This cruise has only two very weak crossover, one with the TTO data, which took place 30 years earlier and one with 74JC20120601. When comparing the 58GS20030922 to the latter the offset seems to be consistent with an increasing lightning of the DIC caused by an increasing amount of
255 anthropogenic carbon, that is decreasing with increasing depth. However, the crossover with the TTO data is not consistent with this. Therefore, no adjustment was applied.

4.13 58JH19920712, cruise #17, and 58JH19940723, cruise #18

These two cruises took place in a highly variable area.No statistically relevant crossover exists but the data are in good agreement with the core cruise and the other adjusted cruises in that area.

260 4.14 64TR19900417, cruise #19

This cruise shows extreme scatter compared to all other cruises and, therefore, was not included into the adjusted product. When comparing crossover stations this cruise shows a mean offset to other cruises of about -1.2‰ .

4.15 74DI20120731, cruise #20

265 Both the inversion and the offset mean of the crossover suggest a correction of +0.13 ‰ for the cruise (Humphreys et al., 2015). This most recent cruise took place near the Scotland-Iceland ridge where the deep water masses cannot be assumed to be constant over time. All crossovers indicate a lower $\delta^{13}\text{C-DIC}$ of this cruise when comparing it with the others, which is consistent with an increased amount of anthropogenic carbon. Therefore, no adjustment was applied.

270

4.16 74JC20120601, cruise #21

This cruise has only a few stations with $\delta^{13}\text{C-DIC}$ data in a highly variable region. It has only one crossover with the cruise 58GS20030922. In the MLR analysis, this cruise is too far away from the core cruise to give a reliable outcome. No adjustment was applied.

275

4.17 74JC20140606, cruise #22

This cruise covers the North Atlantic between Canada, Greenland and Scotland. The crossover inversion gives a suggested correction of 0.07 ‰ and the MLR analysis an offset in the same magnitude -0.09 ‰. Since this cruise took place 20 years after the core cruise, anthropogenic influences cannot be neglected in this case. Therefore, no adjustment was applied.

280

4.18 OMEX1NA, cruise #23

During the OMEX1 project in the North Atlantic $\delta^{13}\text{C-DIC}$ samples were taken in January 1994. The MLR analysis revealed an offset of -0.26 ‰. In contrast to that, the crossover inversion did not suggest a correction. No adjustment was applied.

285 4.19 316N19810401, cruise #24

The cruises 316N19810401, 316N19810416, 316N19810516, 316N19810619, 316N19810721, 316N19810821 and 316N19810923 are combined and usually named Transient Tracers in the Oceans North Atlantic Study (TTO-NAS). The inversion does not suggest any correction for this dataset.

5 Conclusions

290 The finalized, quality controlled dataset of $\delta^{13}\text{C-DIC}$ presented here consists of 24 cruises (some of which consists of multiple legs that were grouped) that have been quantitatively compared to each other and form an internally consistent dataset. Nine cruises could not be quantitatively compared to the other cruises due to a lack of crossovers and / or deep $\delta^{13}\text{C-DIC}$ data. The reason of the

295 deviations between single cruises could not be revealed. There was no correlation between a cruises'
bias or its scatter and storage time, analyzing period or volume of HgCl₂ added.

The internal consistency of the adjusted dataset was calculated to be 0.017‰ based on Equation 2.

The database is available at CDIAC via http://cdiac.ornl.gov/oceans/ndp_096/NAC13v1.html, doi:10.3334/CDIAC/OTG.NAC13v1.

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